Project Report
ATC-313

Corridor Integrated Weather System Operational Benefits 2002–2003: Initial Estimates of Convective Weather Delay Reduction

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16. Abstract

The Corridor Integrated Weather System (CIWS) seeks to improve safety and reduce delay by providing accurate, automated, rapidly updated information on storm locations and echo tops along with two-hour high-resolution animated growth and decay convective storm forecasts. An operational benefits assessment was conducted using on-site observations of CIWS usage at major en route control centers in the Northeast and Great Lakes corridors and the Air Traffic Control Systems Command Center (ATCSCC) during six multi-day periods in 2003.

This first phase of the benefit assessment characterizes major safety and delay reduction benefits and quantifies the delay reduction benefits for two key Traffic Flow Management (TFM) user benefits: “keeping air routes open longer/reopening closed routes sooner” and “proactive, efficient reroutes of traffic around storm cells.” The overall CIWS delay reduction for these two benefits is 40,000 to 69,000 hours annually with an equivalent monetary value of $127M to $260M annually. Convective weather delays at most of the major airports in the test domain, normalized by thunderstorm frequency, decreased after new CIWS echo tops and forecast products were introduced.

Recommendations are made for near-term, low-cost improvements to the CIWS demonstration system to further increase the operational benefits.

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EXECUTIVE SUMMARY

This report summarizes the preliminary results of a two-year study to determine if the Corridor Integrated Weather System (CIWS) concept would enable airspace users to increase safety and significantly reduce convective weather delays in the highly congested Great Lakes and Northeast corridors. The CIWS concept being evaluated provides en route and terminal air traffic flow managers with accurate, automated, rapidly updated information on storm locations and echo top heights along with two-hour, high resolution animated growth and decay storm forecasts. The CIWS test region for 2002-03 included five of the eight major metropolitan areas/corridors that are highlighted as focus areas for improving capacity in the recently released FAA Flight Plan 2004-08.

Operational Needs Addressed by CIWS

The FAA Operational Evolution Plan (OEP) identifies *en route severe weather* and *airport weather conditions* as two key problems that must be addressed if the U.S. air transportation system is to alleviate the growing gap between the demand for air transportation and the capacity to meet that demand. Most of the air traffic delay that is so costly to the airlines and the flying public is incurred during severe weather in the congested Great Lakes and Northeast Corridor region shown in Figure ES-1.

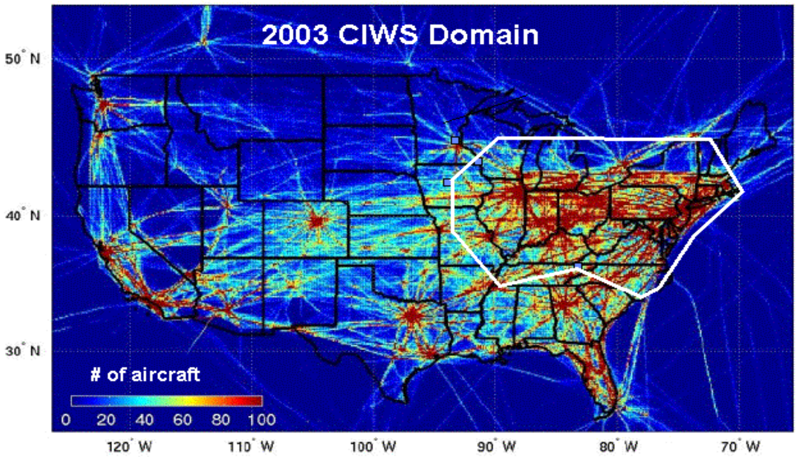

Figure ES-1. National Airspace traffic density on a fair weather day in 2002 with an overlay showing the CIWS spatial coverage for the 2003 testing. Thunderstorm impacts are most significant in areas where there is already significant congestion in fair weather. The CIWS 2003 coverage area includes all the 7 major "bottle necks" identified in the FAA Airport Capacity Enhancement (ACE) Plan (2001). The production CIWS coverage may be larger than the coverage shown above.

It is essential that the National Airspace System (NAS) also maintain safe operations in congested airspace when there is severe convective weather. The major safety objectives listed in the FAA Flight Plan include "reducing cabin injuries due to turbulence." Feedback from major airlines that are leaders in turbulence avoidance have indicated that a main cause of cabin injuries to their flights is encounters with convectively induced turbulence in en route airspace.

Better information on current and forecast weather severity (e.g., heavy rain, storm tops, and regions of storm growth), spatial extent, and future storm locations can help Air Traffic Control (ATC) personnel and airline dispatch assess the safety implications of various alternative plans for dealing with convective weather impacts. Examples of operational decisions that can be facilitated by using CIWS weather information include decisions on whether implementation of a ground stop for specific airports is needed and whether a closed air route could be reopened in the immediate future.

Most en route weather decision support systems show only past or current storm locations, and existing operational forecast products within en route airspace are limited. Two national-scale forecast products are provided by the Aviation Weather Center: the automated National Convective Weather Forecast (NCWF) 1-hour forecast, and the Collaborative Convective Forecast Product (CCFP) 2, 4, and 6-hour forecasts that are updated every two hours. While these products are helpful, the highly congested airspace requires very accurate, current, high-resolution weather information and forecasts to safely improve air traffic flow during thunderstorms.

Additionally, CIWS can provide important enhancements to the precipitation products and forecast capability of terminal areas as shown in Table ES-1. In Figure ES-2, we summarize the relationship of the CIWS products to various weather systems and forecasts in use today.

TABLE ES-1
Operational Domains Impacted by Convective Weather where CIWS can Improve Safety and Efficiency

Domain	Existing Systems[1]	CIWS Role	2002/2003 Test
En route	WARP, ETMS wx, CCFP, NCWF, CWSU	Improve storm severity and tops information plus provide 2-hour automated forecasts Support ATM decision support systems such as ETMS and RAPT	Yes
Major terminals	ITWS, TDWR, ASR-9	Improve long range weather surveillance plus 2-hour forecasts. Support RAPT	Yes
“Important” terminals	WSP	Provide long range weather surveillance plus 0-2 hour forecasts	No
Small airports	MIAWS	Provide basic precipitation with 2-hour forecasts	No
Other		Sensing for forecasts > 2 hours	No

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[1] The existing systems are as follows: WARP is Weather and Radar Processor, ETMS wx is weather displayed on the Enhanced Traffic Management System, CCFP is Collaborative Convective Forecast Product, NCWF is National Convective Weather Forecast, CWSU is Center Weather Service Unit, ITWS is Integrated Terminal Weather System, TDWR is Terminal Doppler Weather Radar, RAPT is Route Availability Planning Tool, ASR-9 is the operational Air Surveillance Radar, WSP is ASR-9 Weather Systems Processor, and MIAWS is Medium Intensity Airport Weather System.

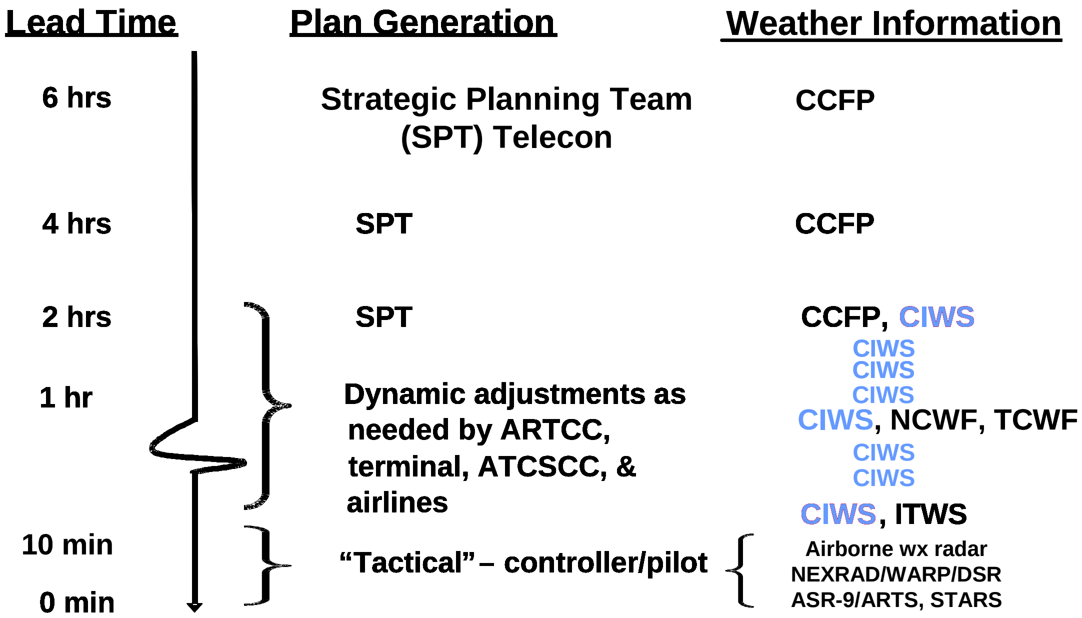

Figure ES-2. Use of various forecasts and weather information as a function of time for convective weather planning in congested airspace. The CIWS products are used to make dynamic adjustments to the strategic plans developed from longer term forecasts. The CIWS provides forecasts every 15 minutes from 15 minutes to 2 hours.

Approach to Meeting the Operational Needs

The solution adopted for the CIWS demonstration system was to take advantage of the high density of existing FAA and NWS weather sensors (Figure ES-3), and the FAA-funded research conducted on thunderstorm evolution, to provide en route and terminal traffic flow managers with accurate, automated, high update rate information on storm locations and echo tops, along with 2-hour animated growth and decay forecasts of storms (Figure ES-4). These state-of-the-art weather products are intended to assist traffic managers to achieve more efficient tactical use of the airspace, reduce controller workload and significantly reduce delay.

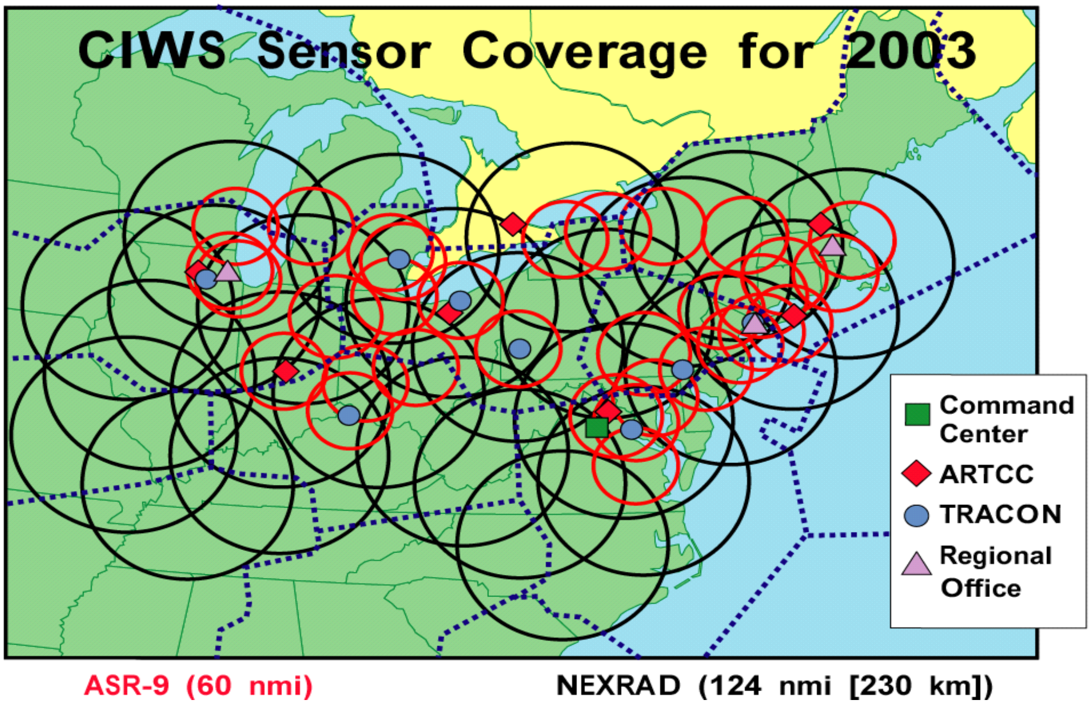

Figure ES-3. Terminal and en route weather sensors used to create the CIWS products for 2002-03 testing. The rapid update rate of the ASR-9 radars (30 seconds) is utilized to detect rapidly growing cells, while the NEXRAD radars provide information on 3-D storm structure and on boundary layer winds. Data from TDWR and Canadian radars will be included in the future. Data from lightning sensors and GOES satellite (not shown) are also integrated with the radar data.

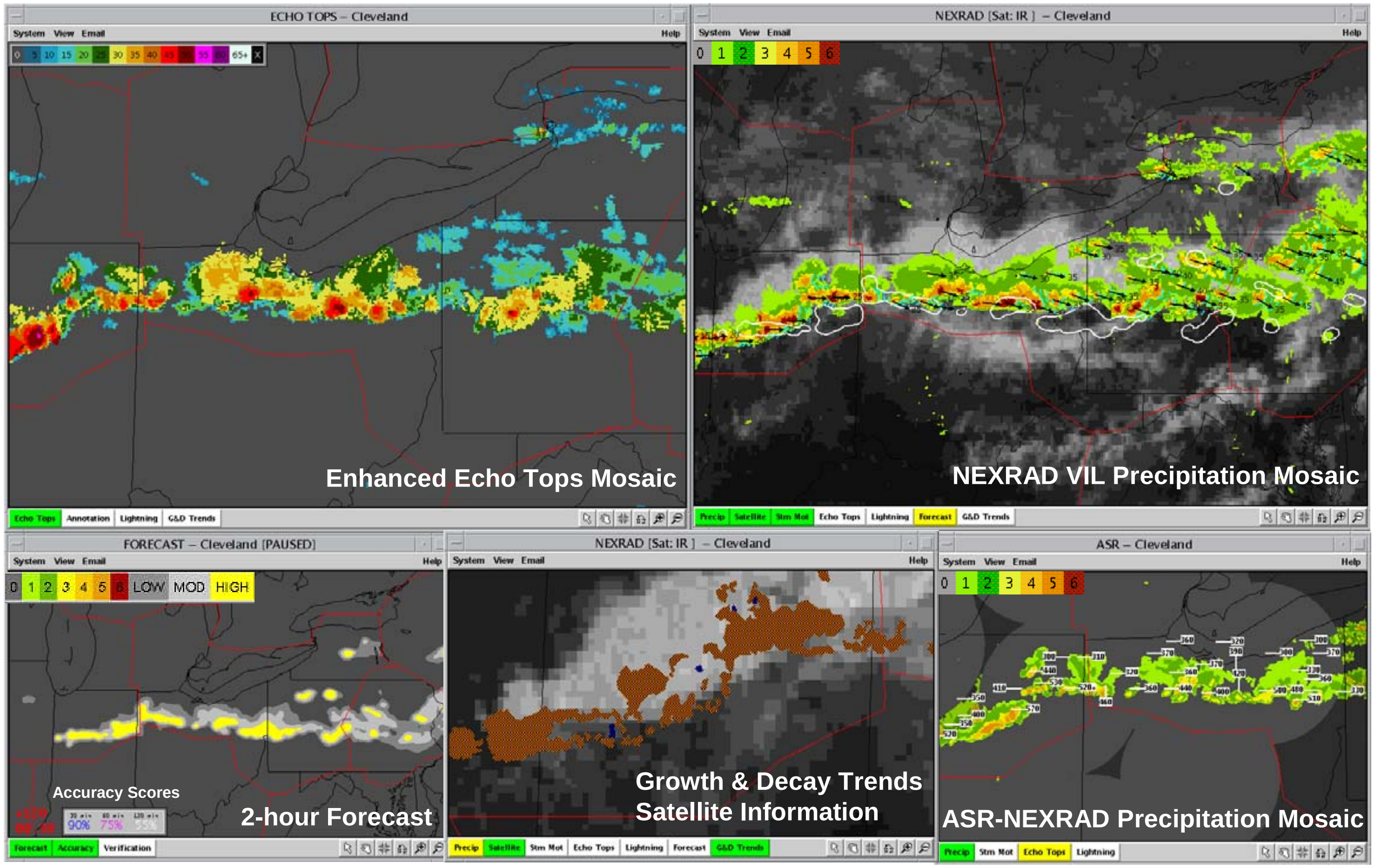

Figure ES-4. Principal CIWS products for 2003 testing. The Echo Tops product (upper left window) shows the height of storms and has been used in conjunction with the radar-based precipitation data to permit aircraft to safely fly over storms, thus significantly reducing aviation delays. The upper right window shows the NEXRAD VIL Precipitation mosaic product displayed with satellite data, storm motion vectors, and two-hour forecast contours. The Regional Convective Weather Forecast (RCWF) provides two-hour animated forecasts in 15-minute intervals (lower left window). Key features of the forecast include the real time indication of forecast accuracy and an explicit depiction of areas of storm growth (orange/black pattern) and decay (blue; see the lower middle window). The lower right window shows the mosaiced ASR and NEXRAD VIL Precipitation product with labels of echo tops.

Results of the Study

Specific objectives of this first phase of the CIWS operational benefits study were to:

- Determine the major operational benefits of the CIWS products when used for real time decision support in the Great Lakes and Northeast corridors

- Quantify the delay reduction for two of the identified principal operational benefits

- Develop a methodology that could be applied to quantifying the delay reduction of other identified operational benefits

- Empirically determine whether changes in gross delay statistics occurred at key facilities that could be attributed to the use of the CIWS products.

All of these specific objectives were met.

Development of a methodology for quantifying delay reduction

The methodology used in this study to quantify CIWS operational benefits (Figure ES-5) is a new approach that utilizes on site observations during "benefits blitz" periods[2], together with studies of individual cases identified from the blitz observations and ongoing post event feedback from the operational users. The analysis of individual cases often involved detailed calculations of queue sizes and durations.

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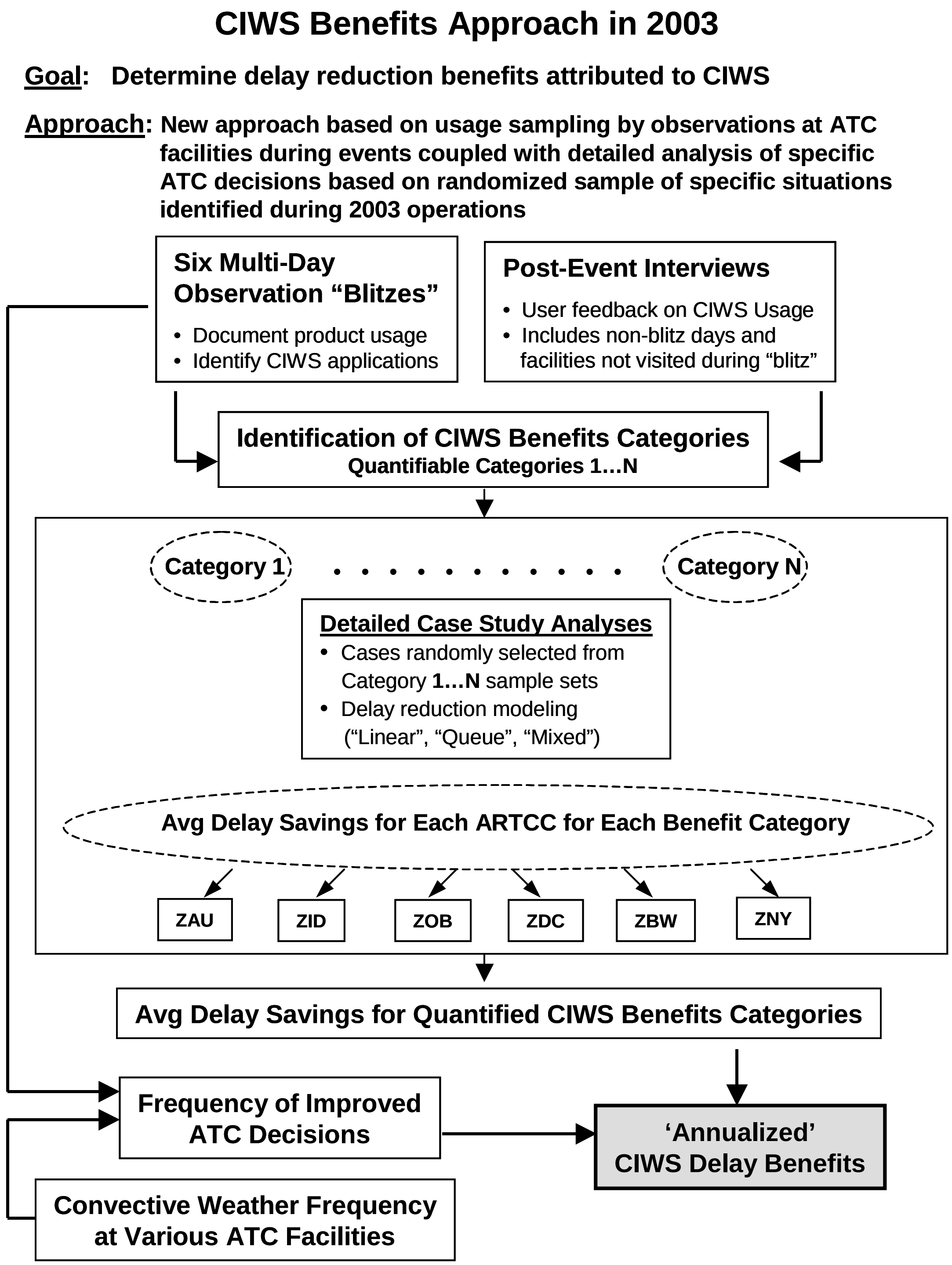
[2] During the "benefits blitz" observation periods, several observers from Lincoln Laboratory were stationed at various ATC facilities to obtain real-time observations of CIWS product usage during convective weather impacts.



CIWS Benefits Approach in 2003

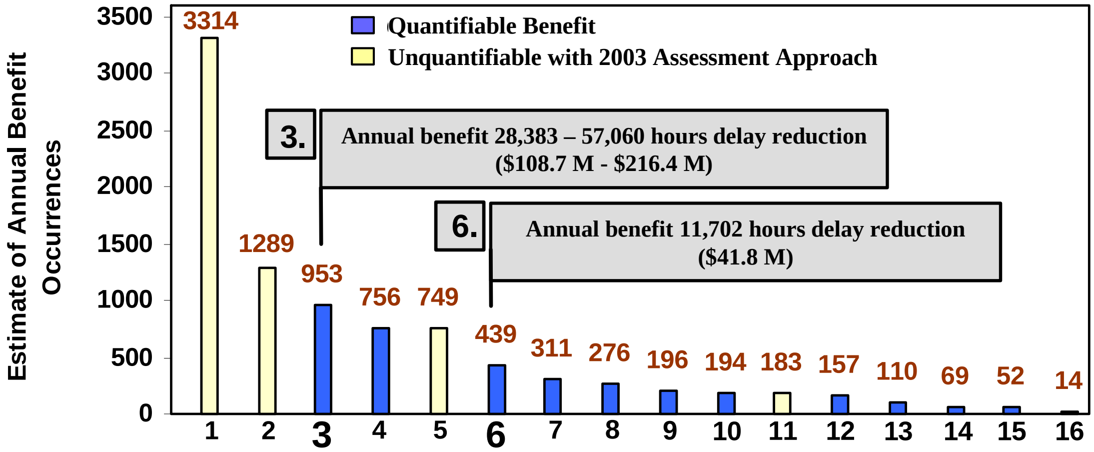
Goal: Determine delay reduction benefits attributed to CIWS

Approach: New approach based on usage sampling by observations at ATC facilities during events coupled with detailed analysis of specific ATC decisions based on randomized sample of specific situations identified during 2003 operations

Figure ES-5. Methodology used to determine CIWS operational benefits.

Identification of major benefits

Major benefits that were identified during the 22 days of simultaneous “benefits blitz” observations at different ARTCCs and the ATCSCC in six different time periods in 2003 are summarized in Figure ES-6.



1	Situational awareness
2	Interfacility coordination
3	Routes open longer
4	Improved Arrival Transition Area (ATA) management
5	Reduce workload
6	Proactive reroutes
7	Directing pathfinders
8	More SWAP departures
9	Shorter/fewer ground stops
10	Directing traffic through gaps
11	Improved safety
12	Close route proactively
13	Optimize runway usage
14	Avoid ground stop
15	Reduced MIT restrictions
16	Improved use of Ground Delay Programs (GDP)

Figure ES-6. Summary of CIWS annual operational benefits identified in 2003 “blitz” observations. Total occurrences of various CIWS benefits categories do not include ATCSCC contributions in order to prevent inflation of benefits occurrences resulting from assigning events to more than one facility. In practice, observed usage benefits (on which these roll-ups are based) were only assigned to the ARTCCs using CIWS to initiate traffic decisions, even if coordination with other facilities was needed or if benefit event occurred along facility boundaries. Exceptions where ATCSCC benefits occurrences were added to the final totals include categories, “Interfacility coordination”, “Reduced workload”, and “Situational awareness”. These specific benefits could not be easily separated by facility and may in fact have proved of more importance at ATCSCC compared to elsewhere in terms of enacting efficient delay mitigation schemes. Benefits 4, 8, 9, 13, and 16 would be shared (to varying degrees) with ITWS.

Note in particular that over 180 cases occurred in 2003 where the CIWS products were used to identify safety concerns associated with a proposed TFM initiative to reduce delays. These safety enhancing situations were typically concerned with the evaluation of alternative traffic flow management initiatives such as:

- Deciding whether an attempt should be made (e.g., with a "pathfinder") to reopen a closed route

- Determining whether a ground stop was warranted at an airport

The most commonly identified benefits -- better situational awareness and better interfacility coordination -- are not easily quantified in terms of hours of delay saved. However, we view both of these as very important because they speak to the issue of improving the overall productivity of the ARTCC TMUs and thereby the NAS.

Coping with rapidly changing convective weather in highly congested airspace is an extremely challenging job. Reducing the amount of time required by the TMU staff to maintain situational awareness and coordinate with other facilities is critical to effectively accomplishing the weather impact mitigation process that is described in Chapter 2 of this report.

We believe that the very high frequency with which increased situational awareness and better inter-facility coordination were observed indicates a significant increase in TMU productivity that may not be fully captured in the analysis of other more readily quantifiable benefits.

The overall CIWS delay reduction benefits for:

- Keeping routes open longer and/or reopening closed routes earlier, and
- Proactive, efficient reroutes

were quantified in this first phase of the CIWS benefits study. **The delay savings for these two categories <u>alone</u> was 40,000 to 69,000 hours annually. The monetary value of this delay reduction assuming airline operations costs are incurred with downstream delay was $ 152 M to $ 260 M per year. The cost savings assuming no airline cost is associated with downstream delay was $ 127 M to $ 214 M per year.**

This range of variation in annual delay estimates reflects the wide range of individual case benefits, which in turn reflects the high sensitivity of delays in congested airspace to issues such as the number of available routes, queues due to excessive demand at multiple locations in the network, and differences in the time duration of storm events. To illustrate, the individual event benefits for "keeping routes open longer and/or reopening routes earlier" ranged from 1 hour to 236 hours.

A number of major delay reduction events were separately analyzed. Of these, several had individual event delay reduction benefits exceeding 800 hours, translating to cost savings of several million dollars. Since these were noted as extreme benefits cases at the time of occurrence and resources available for case analysis were limited, these cases were excluded from the overall annual benefits "roll up" analysis to avoid introducing an upward bias in the results.

We should reemphasize that the quantitative benefits discussed above understate the operational benefits of the CIWS as tested in 2003 for three reasons:

- As noted in Figure ES-6 and in the previous discussions, the available time and resources did not permit us to accomplish quantitative estimates for a number of other high frequency benefits such as better management of ground stops and ground delay programs in support of severe weather avoidance plans (SWAP).

- There were a number of key ATC facilities that did not have CIWS situation displays in 2002-03 (discussed below), which resulted in a number of missed opportunities for delay reduction.

- The benefits of increased departure rates during SWAP events, including the use of the Route Availability Planning Tool (RAPT), have not been considered. RAPT has provided very significant benefits at New York using the ITWS Terminal Convective Weather Forecast (TCWF). RAPT is in the process of being interfaced to the CIWS products to take advantage of the CIWS forecasts, spatial coverage and echo tops products.

Evidence from delay statistics of CIWS operational benefits

Several of the ARTCCs that had significant delay reduction benefits for keeping routes open longer/reopening closed routes earlier and proactive, efficient reroutes (e.g., ZOB and ZID) also showed significant reductions in the delay events at the major airports (CVG, DTW, and PIT) within the ARTCC in 2003 relative to 2002. These reductions in delay events were evident even though the number of convective storm events in the respective ARTCCs was constant or increased from 2002 to 2003.

The overall number of delay events at EWR dropped in 2003 albeit the number of delay events with delays greater than one hour at EWR increased. Since other convective delay reduction systems (specifically RAPT) also commenced operation in 2003, it is unclear to what extent CIWS assisted in reducing the number of overall delay events at EWR.

The significant decrease in delay events (over 66%) at BOS in 2003 relative to 2002 can be attributed in part to ZBW use of CIWS in 2003 and in part due to a 10% drop in overall storm activity.

The number of longer delay events at ORD increased in 2003 while shorter delay events decreased despite constant overall convective activity within ZAU ARTCC and a 12% increase in NWS-identified thunderstorm days at the airport. This unexpected increase in longer delay events may reflect the particular nature of storm events in the two years, procedures issues [e.g., rules governing land and hold short operations (LAHSO) changed in April 2003] as well as other factors. We discuss below options for improving the operational effectiveness of CIWS in reducing delays at ORD.

NEXT STEPS IN QUANTIFYING CIWS DELAY REDUCTION

The results reported here are the results of the first phase of the CIWS operational benefits study.

In the next phase, we will examine additional case studies for the two benefits categories analyzed (so as to reduce the spread in benefits estimates for those two categories). We will also obtain quantitative benefits estimates for several of the other major benefits discussed above including the safety benefits.

During the next phase of the study we plan to include coupled analyses of flight tracks and weather before and after the principal new CIWS products were introduced in late 2002. The motivation is to find additional objective substantiation for the operational user feedback that traffic flow management is evolving towards a new dynamic adjustment paradigm for managing convective weather through use of the CIWS products.

Other important elements of the second phase study include:

- Extrapolating the benefits observations in the Great Lakes and Northeast corridors to other parts of the NAS to assist in determining the appropriate spatial extent of the operational CIWS functional capability
- Estimating the fraction of the overall convective weather delay in the CIWS region that is being reduced by the use of CIWS
- Addressing key aspects of the service being provided to the commercial airlines who are principal “customers” of the FAA’s new Air Traffic Organization (ATO). A key issue for customer impact of delay reduction is improving the model for the “down line” impact of delays. We plan to use more elaborate models for the downstream impacts of initial delays [e.g., using the delay multiplier model of Beatty, et al., (1999)] to better capture the impacts of delay propagation on airline operations resources (crews and aircraft).

Studies also will be carried out to determine if CIWS delay reduction can be estimated by appropriate analysis of FAA delay statistics and the CIWS weather products.

NEAR TERM OPPORTUNITIES FOR INCREASING THE OPERATIONAL BENEFITS PROVIDED BY THE CIWS DEMONSTRATION SYSTEM

The operational feedback provided by the various CIWS users and the benefits analyses reported here have identified some low cost, near term opportunities to significantly increase the operational benefits provided by the CIWS demonstration system. Work proceeds in parallel to provide an operational capability in 2007 or 2008.

These opportunities are as follows:

> ***Improve safety by providing real time access to CIWS products in digital format to airlines and the vendors that provide dispatch decision support systems, so that dispatch can better perform their statutory requirements under the Federal Aviation Regulations (FAR)***

Although the FAA ATC has no responsibility to provide warnings to pilots about possibly hazardous en route weather, airline dispatch does have very explicit responsibilities. Specifically, FAA Regulation (FAR) 121.601 includes the following requirements for dispatchers:

> "Before beginning a flight, the aircraft dispatcher shall provide the pilot in command with all available weather reports and forecasts of weather phenomena that may affect the safety of the flight, including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear, for each route to be flown and each airport to be used.
>
> During a flight, the aircraft dispatcher shall provide the pilot in command any additional information of meteorological conditions (including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear), and irregularities of facilities and services that may affect the safety of the flight."

The CIWS demonstration system has provided real time displays to major airline systems operations centers (SOCs) that are typically used by the airline ATC coordinators and chief dispatchers. However, the responsibility for individual flight safety resides with individual dispatchers who typically have access only to the airline dispatch decision support (DDST) displays. By providing the CIWS products in digital format, the developers of the various airline DDSTs could provide the CIWS products as a user selectable overlay. Requests to provide this information have been received from two DDST vendors already.

> ***Deploy CIWS situation displays at all the TRACONS that manage traffic into major metropolitan areas within the current CIWS domain that were identified in the Flight Plan 2004-08***

Specifically, install situation displays (SDs) at Philadelphia (PHL), the Boston consolidated TRACON, and Washington/Baltimore consolidated TRACON (PCT). There have been several requests from TMUs at both ZDC and ZNY to have CIWS displays installed at PHL and PCT. These displays would significantly improve the ARTCC/TRACON coordination and reduce the ARTCC TMU workload associated with managing internal traffic. This in turn would provide the ARTCC TMUs with more time to handle over flight problems and hence reduce overall NAS congestion.

Deploy CIWS situation displays at all the ARTCCs that border ZAU and the Chicago Tower

The Chicago ARTCC has noted on a number of occasions that there exists a very heavy interfacility coordination workload associated with flights to and from the west, which would be significantly improved if ZKC had a CIWS SD. The Canadian playbook routes that pass north of Toronto are critical for moving east-west traffic when severe convective weather blocks the routes through ZOB and ZID. However, use of the Canadian playbook routes results in a significant increase in traffic from ZAU into

ZMP. Since there often is convective weather near key transitions between ZMP and ZAU, and between ZKC and ZAU, improving common situational awareness would significantly improve the overall capability of the ZAU Traffic Management Unit.

Chicago O'Hare Control Tower has also expressed a strong interest in acquiring a CIWS SD. Today, O'Hare Tower does not have the capability of observing the same weather products as the TRACON (located 30 miles away from the Airport) and Chicago ARTCC, but must deal reactively with severe weather around the airport. Runway configurations play a large part in determining the efficiency for Chicago O'Hare Airport; specifically, dynamic use of the appropriate runways allows for efficient departure and arrival throughput. Since the choice of appropriate runway configuration is heavily dependent on knowledge of the en route weather, the Chicago airport could be much better served were the tower to have a consistent weather product in common with the TRACON and ZAU.

Provide weather radar coverage for the Canadian playbook routes

The CIWS case studies highlighted the importance of having at least one route open at all times between Chicago and New York/Philadelphia/Boston/Washington. When severe convective weather (e.g., a north-south oriented squall line moving slowly eastward) blocks the east-west routes through ZID and ZOB, east-west traffic must either go north or go south around the weather. Rerouting ZID and ZOB traffic to the south causes extreme congestion over Atlanta and along the east coast. The alternative is to use the Canadian playbook routes that pass north of Toronto[3].

If the Canadian playbook routes are to be used effectively, one needs to have reliable information on possible convective impacts within Canada (especially Ontario). It would be necessary to add several Canadian weather radars to the CIWS mosaic (see Figure 9.3 in the full report) to fully cover these routes. NavCanada has offered to fund the real time feed of Canadian weather radar data for the CIWS demonstration system.

Provide Route Availability Planning Tool (RAPT) capability at one of the other major metropolitan areas identified in the FAA Flight Plan

The RAPT system at New York will be interfaced to the CIWS forecasts and echo tops in 2004. The use of RAPT at another major metropolitan area within the current CIWS domain, identified in the Flight Plan 2004-08, is relatively straightforward. Chicago would seem to be a high-priority candidate, considering the level of delays at ORD in 2003 and the local ATC and airline interest.

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[3] The Canadian playbook routes are the most frequently used playbook reroutes during the summer NAS operations.

ACKNOWLEDGMENTS

The FAA CIWS user community at the various ATC facilities that hosted the CIWS observers was a major contributor to this study both in their direct participation in benefits data gathering and, by providing us with invaluable information on the operations of their facilities and the NAS during adverse convective weather. Their ongoing interest and many suggestions for improving CIWS have been most encouraging. We also very much appreciated the benefits observations provided by the airline users and look forward to a much more intensive airline benefits data gathering program in 2004.

Kim Calden, Brian Collins, Darin Meyer, Eric Proseus, Chris Gross, John Oleska, and Tim Rotz from Lincoln Laboratory very ably participated as blitz observers as well as trainers.

Very helpful comments on an earlier draft of this report were made by Dan Citrenbaum of the FAA and Gary Paull of MCR Federal, Inc. Marilyn Wolfson, Beth Ducot, and Steve Bussolari carefully read the entire report and made a number of excellent suggestions that have significantly improved the report.

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1. INTRODUCTION

In this report, we present the results of the first phase of a study to assess the benefits of providing en route and terminal traffic flow managers with high quality, automated, weather products. The products, generated by an experimental Corridor Integrated Weather System (CIWS), were delivered to operational users over a 2-year period. The specific objectives of this phase of the benefits study were to:

- Determine the major operational benefits of CIWS products when used for real time decision support in the Great Lakes and Northeast corridors as characterized by an improved ability of the users to achieve safer, more efficient tactical use of the congested airspace

- Quantify the delay reduction for two of the identified principal operational benefits; specifically, "keeping routes open longer and/or quicker reopening of closed routes," and "proactive, more efficient reroutes of aircraft"

- Develop a methodology that could be applied to quantifying the delay reduction of other identified CIWS operational benefits

In addition to a presentation of the results of the analyses, the study also makes recommendations for near term changes to the experimental CIWS that would be expected to lead to further increases in the safety and delay reduction benefits. Subsequent phases of the benefits study (which will be reported separately) will extend the assessment reported here and will analyze flight tracks of aircraft in convective events before and after the key CIWS products were introduced.

Motivation for the CIWS program

Improved handling of severe en route and terminal convective weather has been identified by the FAA as a major thrust for the National Airspace System (NAS) modernization over the coming decade in both the Operational Evolution Plan (OEP) [FAA, 2000] and the Flight Plan for 2004-2008 [FAA, 2003]. Achieving such improved capabilities is particularly important in highly congested corridors where there is both a high density of over-flights and major terminals.

Delay increases during the months of the year characterized by thunderstorms have dominated the dramatic delay growth in the US aviation system (see Figure 1-1).

In highly congested airspace, such as shown in Figures 1-2 and 1-3, convective weather presents a particularly difficult challenge because:

- It is not possible to accurately forecast operationally significant convective weather far enough in advance to avoid in-flight adjustments of aircraft routes [National Research Council, 2003]

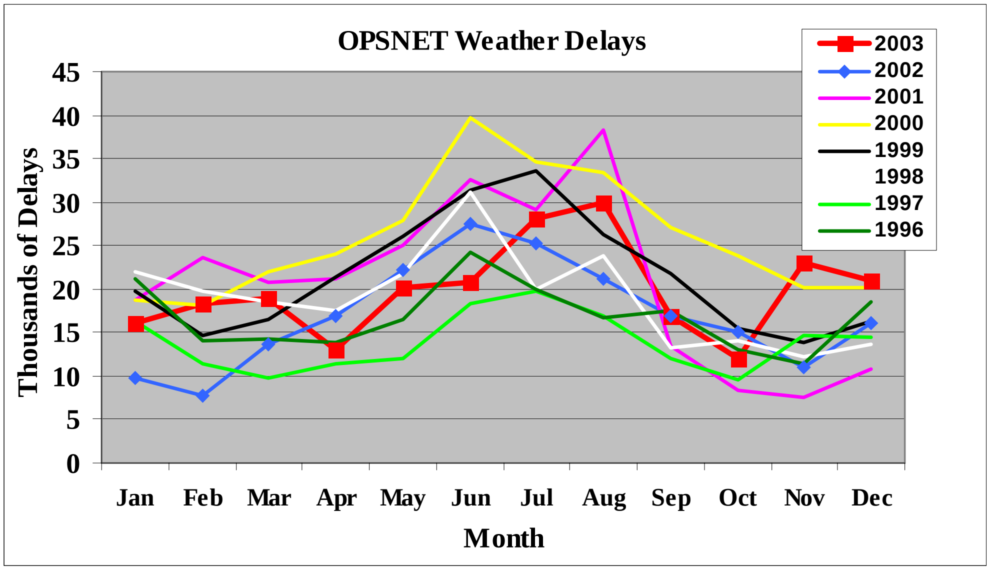

Figure 1-1. U.S. OPSNET weather delays by month for an 8 year period. OPSNET delays are delays of 15 minutes or more that are reported by the FAA's Air Traffic Operations Network. These delays are attributable to single FAA facilities, which assign causality to the event. Typically, approximately 70% of the OPSNET delays are attributed to weather (e.g., wind, rain, snow/ice, low cloud ceilings, low visibility, tornados, hurricanes or thunderstorms). Note that the delay is greatest during the summer months when thunderstorms are most frequent.

- There is often little or no excess capacity available when severe weather occurs. For example, rerouting aircraft around areas of actual or predicted weather can be very difficult when one must be concerned about controller overload in the weather-free sectors.[4]

When major terminals also underlie the en route airspace[5], convective weather has even greater adverse impacts, especially if the convective weather occurs frequently. In Figure 1-4, we show the frequency of convective weather impacts in the Great Lakes and Northeast corridors in 2003. We see that convective weather occurred in this region on approximately 35-55% of the days between April and the end of September.

It is essential that the NAS maintain safe operations in congested airspace when there is severe convective weather. The major safety objectives listed in the FAA Flight Plan include "reducing cabin injuries due to turbulence". Feedback from major airlines that are leaders in turbulence avoidance have indicated that

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[4] A Great Lakes corridor example that dramatically illustrates the need to anticipate weather impacts on route availability in congested airspace is shown on the MITRE Web site (http://www.caasd.org/proj/delay/scenario_a.html). Scenario b at this same web site discusses a case where severe weather in the Great Lakes corridor causes major problems for traffic flows which were quite far removed from the region of severe weather.

[5] A major objective of the FAA Flight Plan (2003) is to increase or improve airspace capacity in the eight major metropolitan areas and corridors that most affect total system delay. Five of the eight metropolitan areas identified in the Flight Plan are within the CIWS domain shown in Figures 1-2 and 1-3, with a sixth metropolitan area (Atlanta) just outside.

a main cause of cabin injuries on their flights is encounters with convectively induced turbulence in en route airspace.

Better information on current and forecast weather severity (e.g., heavy rain, storm top heights, regions of growth), spatial extent, and future locations can help Air Traffic Control (ATC) personnel and airline dispatch assess the safety implications of various alternative plans for dealing with convective weather impacts. Examples of operational decisions that could be facilitated include decisions on whether implementation of a ground stop is needed for specific airports and whether a closed air route could be reopened in the immediate future.

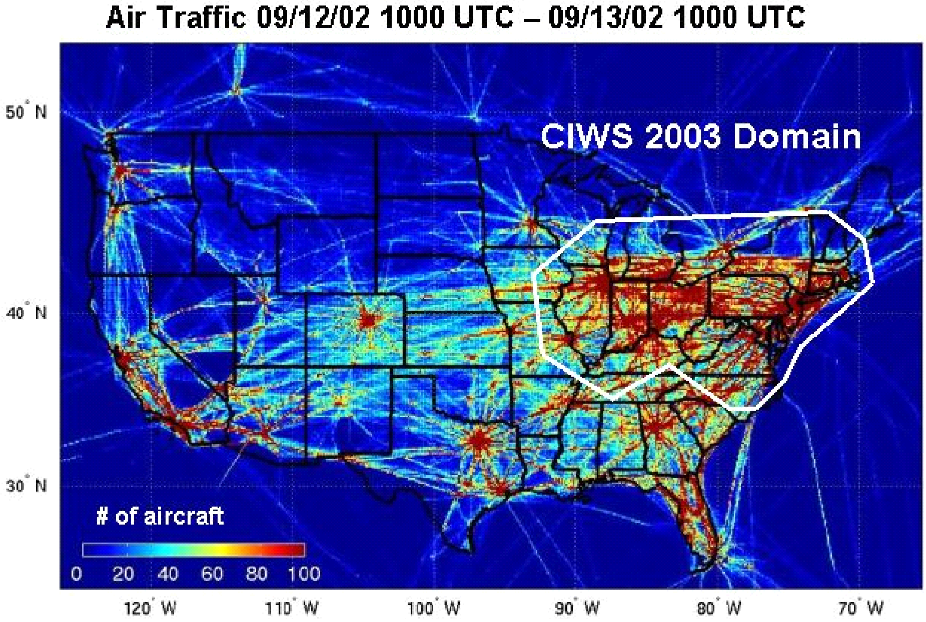
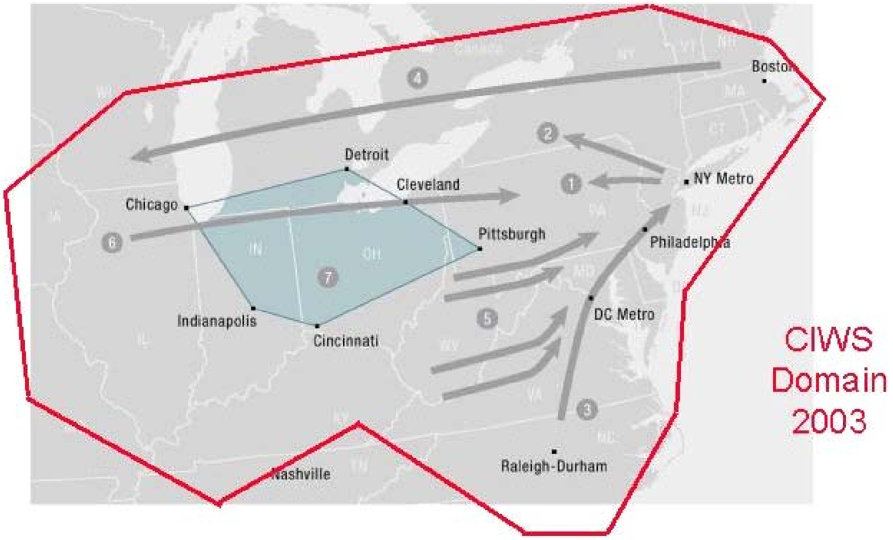


Figure 1-2. Density of traffic in the U.S. with an overlay of the 2003 CIWS demonstration system.



From ACE 2001 Plan

Figure 1-3. Major congestion points in the NAS identified in the FAA Airport Capacity Enhancement (ACE) Plan. The FAA Flight Plan 2004-08 (FAA, 2003) identifies as a major objective improving operations at eight major metropolitan areas, five of which are within the CIWS 2003 domain: New York, Philadelphia, Boston, Chicago and Washington/Baltimore. A sixth major metropolitan area highlighted in the Flight Plan – Atlanta - is immediately south of the CIWS 2003 domain.

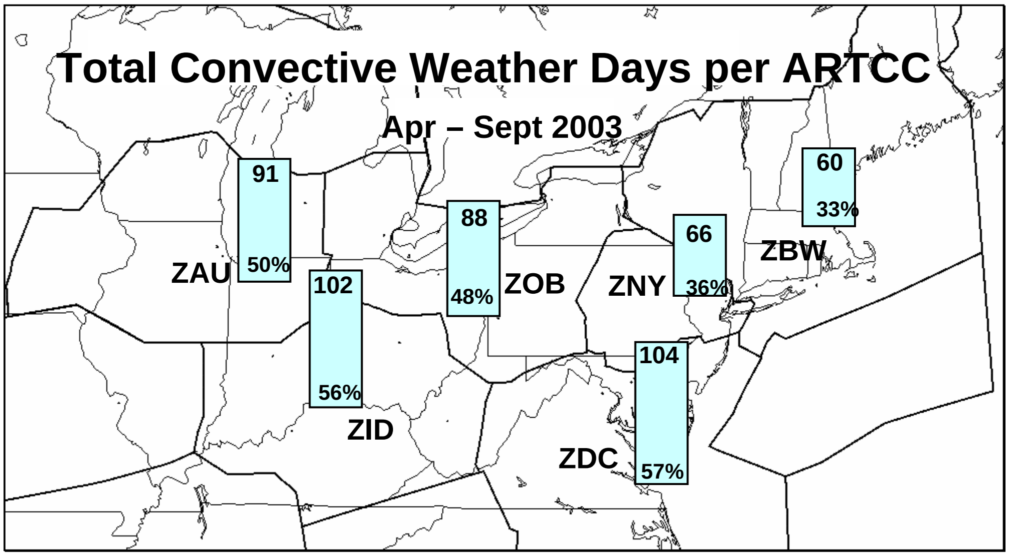


Figure 1-4. Convective weather days per ARTCC during April - September 2003 in the Great Lakes and Northeast corridors. Values at the top of each bar are the number of storm days per ARTCC while the percentages at the bottom of each bar are the percentage of days during the six-month period on which convective weather was present in each ARTCC.

The Corridor Integrated Weather System (CIWS)

In response to the need to enhance both safety and capacity, the FAA is exploring the concept of a Corridor Integrated Weather System (CIWS). CIWS is designed to improve convective weather decision support for congested en route airspace - and the terminals that lie under that airspace - by automatically generating graphical depictions of the current severe weather situation and providing frequently updated forecasts of the future weather locations for forecast times from 0 to 2 hours. Table 1-1 shows the operational domains in which the CIWS could enhance safety and efficiency.

Figure 1-5 shows a vision of the future CIWS architecture as presented at an FAA Acquisition Review in August 2003. According to this vision, CIWS acquires data from FAA terminal weather sensing systems, National Weather Service (NWS) sensors, and forecast products, and automatically generates convective weather products for display on existing systems in both terminal and en route airspace within the CIWS domain. The CIWS products are provided to ATC personnel, pilots, airline systems operations centers (SOCs), and automated air traffic management decision support systems in a form that is directly usable without further meteorological interpretation.

In the terminal airspace with an existing Integrated Terminal Weather System (ITWS) or Weather System Processor (WSP), the CIWS products (displayed on ITWS or WSP screens) can augment the existing convective weather products by providing greater precipitation product integrity and improved forecast capabilities (e.g., extending the current 0-20 minute forecast capability to provide forecasts from 0-2 hours with longer range coverage[6]). At airports that do not have an ITWS or a WSP capability, CIWS can provide very high quality storm severity and 0-2 hour convective forecast products. At en route facilities, the CIWS products would be provided on the Weather and Radar Processor (WARP) display.

TABLE 1-1
Operational Domains Impacted by Convective Weather where Safety and Efficiency can be Improved by CIWS Products

Domain	Existing Systems[7]	CIWS Role	2002/2003 Test
En route	WARP, ETMS wx, CCFP, NCWF, CWSU	Improve storm severity and tops information plus provide 2-hour automated forecasts Support ATM decision support systems such as ETMS and RAPT	Yes
Major terminals	ITWS, TDWR, ASR-9	Improve long range weather surveillance plus provide 2-hour forecasts. Support RAPT	Yes
"Important" terminals	WSP	Provide long range weather surveillance plus 0-2 hour forecasts	No
Small airports	MIAWS	Provide basic precipitation with 2-hour forecasts	No
Other		Improve weather sensing data for forecasts > 2 hours	No

A real time operational demonstration and exploration of the CIWS concept, using dedicated situation displays, began in July 2001 in the Great Lakes corridor, and was extended to the Northeast corridor in April 2002. In August 2002, several key products (including the convective weather forecast and echo tops products) were significantly upgraded. Further enhancements in 2002-2003 reflected feedback from operational users. Additionally, the NavCanada Toronto Area Control Center (ACC) was added as an Internet user in the late spring of 2003.

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[6] The FAA does plan to increase the ITWS forecast capability to one hour, with the addition of the Terminal Convective Weather Forecast Product (TCWF).

[7] The existing systems are as follows: WARP is Weather and Radar Processor, ETMS wx is weather displayed on the Enhanced Traffic Management System, CCFP is Collaborative Convective Forecast Product, NCWF is National Convective Weather Forecast, CWSU is Center Weather Service Unit, ITWS is Integrated Terminal Weather System, TDWR is Terminal Doppler Weather Radar, RAPT is Route Availability Planning Tool, ASR-9 is the operational Air Surveillance Radar, WSP is ASR-9 Weather Systems Processor, and MIAWS is Medium Intensity Airport Weather System.

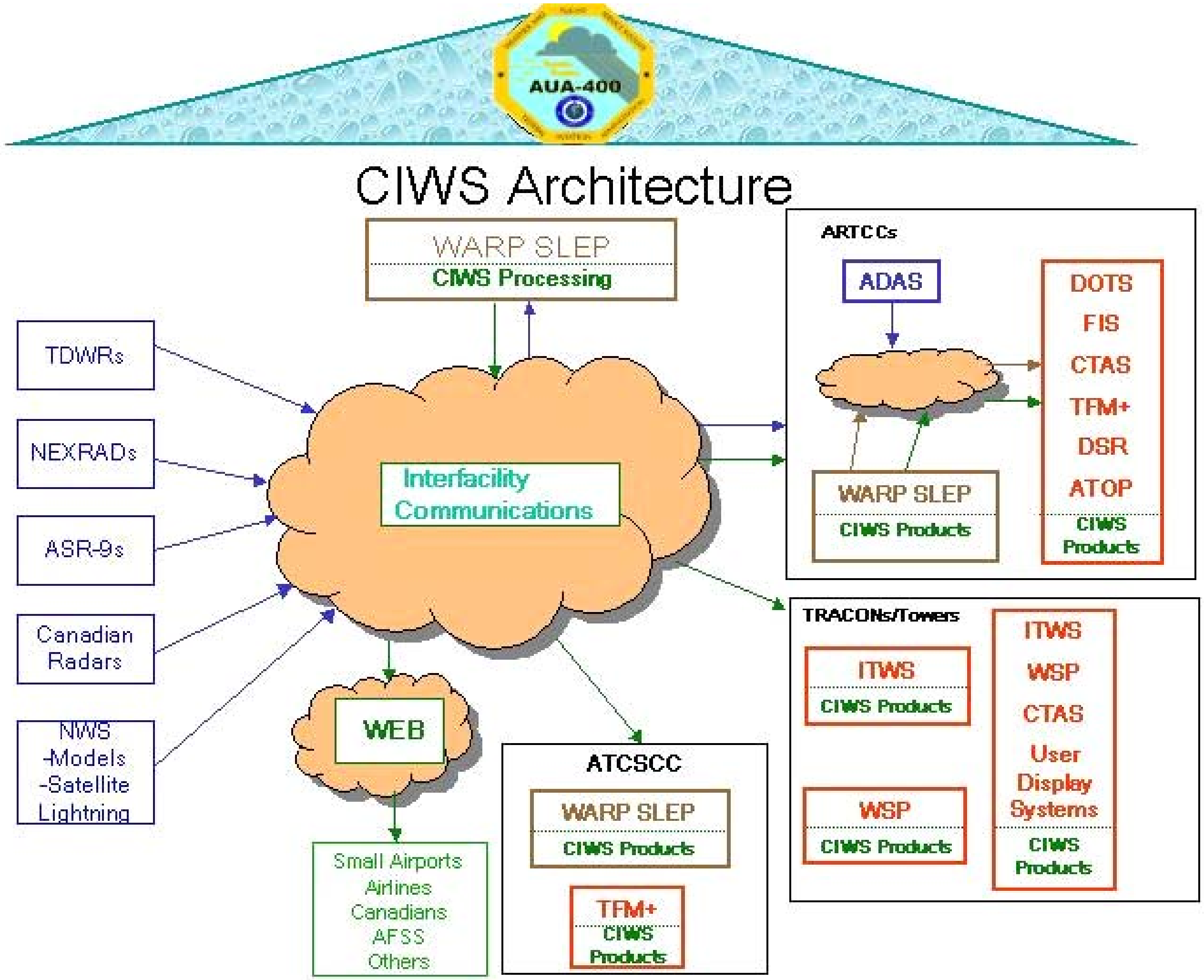

Figure 1-5. Candidate CIWS production system architecture as presented at CIWS Acquisition Review in August 2003 [Moy, 2003].

Suggestions for reading the report

There are two suggestions for reading this report.

Readers who know relatively little about CIWS and are interested in acquiring an in-depth understanding of the operational benefits should proceed through the Chapters in the order presented.

Readers who are knowledgeable about CIWS, and want to quickly get to "the bottom line", will find it sufficient to read:

> Chapter 4.3 (a summary of the weather impacts and delay statistics for the CIWS domain airports in 2002 and 2003 and a discussion of why some airports showed very significant delay reductions in 2003 that we attribute in large part to CIWS usage),
>
> Chapter 5 (a presentation of the methodology for deriving the benefits),
>
> Chapter 7 (the summary of benefits based on intensive observations at ATC facilities),
>
> Chapter 8 (initial results on safety enhancement with CIWS),
>
> Chapter 9 (the summary of results).

Given the interesting, and perhaps counterintuitive results presented in Chapter 7, it is likely that even the readers who sought to quickly read the report will be compelled to look at the detailed case studies in Chapter 6 and Appendices B and C.

The report itself is organized as follows:

Chapter 2 provides background information on the operational needs that motivated the CIWS concept exploration and prior work at estimating operational benefits for systems such as CIWS.

Chapter 3 discusses the salient features of the CIWS system tested in 2003 including the sensors used, real time system architecture, product generation algorithms, and product display concepts. Chapter 4 discusses the system operations and weather impacts during 2002 and 2003.

In Chapter 5, we discuss the new methodology used to assess the CIWS delay reduction. We found in 2002 that simply conducting end-of-season interviews, the approach used successfully to quantify the ITWS benefits, could not yield reliable quantitative delay reduction results when utilized in the very complicated en route/terminal environment of the CIWS demonstration area. Based on feedback from the operational users in late 2002 and at the CIWS user group meeting in 2003, we adopted a new approach that emphasizes:

- Data acquisition by trained observers at ATC facilities during convective weather events

- Analyses of many specific cases so as to handle the very complicated queue interactions that typically occur in en route airspace

Lincoln Laboratory observers were stationed at a number of ATC facilities during six multi-day benefits assessment campaigns ("benefits blitzes") conducted at times when significant convective weather was expected. These intensive observation periods can be viewed as sampling the population of significant convective weather events at a given facility. Each case study required detailed analysis of the traffic flows in the network around the times of the ATC decision under study (e.g., keeping a route open). Via these analyses, we determined which routes were available and how close the various routes and airports were to full capacity. This route/capacity information was then used to quantify the consequences of not using the CIWS product (e.g., what would have happened if a given route was closed).

Chapter 6 analyzes four major delay events from 2002 and 2003 to illustrate the analysis techniques used to determine quantitative benefits, and to provide concrete examples of how one can significantly reduce delay due to convective weather in congested airspace.

Chapter 7 provides quantitative analyses of the delay benefits associated with two principal ATC/airline decisions that are improved from use of the CIWS products:

- Keeping routes open longer and/or reopening closed routes earlier

- More effective rerouting of aircraft around severe convective weather

We show that the delay reduction benefit from these two benefits alone is well in excess of $ 100 M per year.

Chapter 8 discusses initial results of assessing the safety benefits provided by CIWS based on blitz observations. We show that on a number of occasions, CIWS products were used to assess the safety implications of proposed plans for reducing the delays caused by convective weather.

Chapter 9 summarizes the results of the report and discusses the work to be accomplished in a future phase of the CIWS benefits study. This second phase of the study will focus on:

- Quantifying the benefits for additional ATC decisions for which CIWS was observed to be beneficial in the "benefits blitz" observations

- Analyzing additional specific cases for the two ATC decisions identified in this report in order to improve the statistical significance of the final benefits estimates

- Comparing flight tracks during periods when convective weather occurred in 2003 with flight tracks in 2001 (before the majority of enhanced CIWS products were available) to confirm the ATC user claims that their ability to make better air traffic management decisions significantly improved as a result of having the CIWS products available in real time

- Examining data on inflight convective turbulence encounters before and after CIWS commenced operations to see if there had been a change in the (convective weather normalized) frequency of turbulence encounters after CIWS went into operational use

Additionally in Chapter 9, we make a number of recommendations for near term changes to the CIWS demonstration system that that would provide increased safety and capacity enhancements (i.e., delay reduction) in the immediate future.

2. BACKGROUND

In this section, we provide background on recent major FAA initiatives that are addressed by CIWS, the functional domains that CIWS potentially addresses, and how CIWS products are used in the context of the overall ATC convective weather decision-making process. This section concludes with a discussion of previous operational benefits assessments that are germane to the CIWS benefits study reported here.

2.1 OPERATIONAL NEEDS

2.1.1 Needs Identified in the FAA's Operational Evolution Plan (OEP)

The FAA OEP version 5 [FAA, 2000] identifies four problem clusters, or "quadrants" that must be addressed if the U.S. air transportation system is to alleviate the growing gap between the demand for air transportation and the ability of the system to meet that demand. Three of these four problem clusters:

- En route severe weather (EW),
- Airport weather conditions (AW), and
- Arrival/departure rates (AD)

are related to convective weather impacts to varying degrees (en route severe weather is totally convective weather in the OEP discussion, whereas the discussion of arrival/departures rates does not consider convective weather impacts on these rates).

A CIWS operations plan is mentioned in the OEP discussion of the EW quadrant timeline and there is a discussion of the Route Availability Planning Tool (RAPT), which would utilize the CIWS forecasts, in the discussion of integration of weather forecasts into Decision Support Systems (DSSs). Considering that it is currently envisioned by FAA en route services development (AUA-400) that the operational implementation of the CIWS en route functional capability would be as a preplanned product improvement to the WARP (recall Figure 1-5); achieving the CIWS functional capability is discussed in the context of WARP pre-planned product improvements.

2.1.2 Needs Identified in the FAA's Flight Plan 2004-2008

The Flight Plan [FAA, 2003] identifies seven major objectives for increased safety and four major objectives for greater system capacity. CIWS is intended to be responsive to three of the Flight Plan safety objectives:

- Reduce the commercial aircraft fatal accident rate
- Reduce the number of fatal accidents in general aviation
- Reduce cabin injuries caused by turbulence

The objective that CIWS could clearly address in the near term is to reduce the cabin injuries caused by turbulence. A significant number of cabin injuries are caused by convective turbulence (major airline; personal communication). The FAA Initiation Investment Package for Thunderstorm Impact Mitigation [Parker, 2002] states that “thunderstorm convective-induced turbulence, in-cloud and out-of-cloud, account for 60% of all turbulence-related injuries”.

The Flight Plan strategies to achieve this objective include:

> "Develop and evaluate new technologies that will lessen the impact of turbulence and other weather-related issues"

The initiatives proposed in the Flight Plan to implement the strategy include:

> "Improve...timeliness of weather forecasts to identify air turbulence regions" and "Continue to evaluate new airborne weather radar and other technologies"
>
> "Improve dissemination of pilot reports and timeliness of weather forecasts to identify air turbulence areas"

CIWS assists in reducing the likelihood of convective weather encounters by providing very high quality forecast information on future convective storm locations (including which storms are growing) such that traffic can be proactively rerouted away from significant convective weather (see Chapter 8).

It should also be noted that although the FAA ATC has no responsibility to provide warnings to pilots about possibly hazardous en route weather, airline dispatch does have very explicit responsibilities.

Specifically, the FAA Regulation (FAR) 121.601 includes the following requirements for dispatchers:

> “Before beginning a flight, the aircraft dispatcher shall provide the pilot in command (PIC) with all available weather reports and forecasts of weather phenomena that may affect the safety of the flight, including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear, for each route to be flown and each airport to be used.
>
> During a flight, the aircraft dispatcher shall provide the pilot in command any additional information of meteorological conditions (including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear), and irregularities of facilities and services that may affect the safety of the flight.”

Additionally, the FAR states that

> “No PIC may allow a flight to continue toward any airport to which it has been dispatched or released, if in the opinion of the dispatcher, the flight cannot be completed safely.”

To facilitate the airline dispatch exercising their legal responsibility to insure safety of flight, the CIWS demonstration system has installed dedicated full capability displays at virtually all major airline systems operations centers (the only exception is US Air). Also, the major airlines and many smaller airlines can access CIWS products via a server on the Internet.

The National Transportation Safety Board (NTSB) has recommended that the FAA deploy, at all air traffic control facilities, a near-real-time color weather radar display that shows detailed precipitation intensities. CIWS could provide this data for 300 FAA airports (see section 2.2 below). Many General Aviation aircraft that do not have on-board weather radars are being equipped with data link avionics for display of WSR-88D Next Generation Weather Radar (NEXRAD) mosaics. These mosaics have the significant limitation that the data are often tens of minutes old. CIWS can improve the utility of data linked weather by providing an accurate mosaic as well as a detailed forecast of convective weather.

2.1.3 Needs Identified in Recent FAA Documents

The FAA has identified decision-based needs for ARTCC Traffic Management Unit (TMU) personnel in a 1999 study [Browne, 1999] that is intended to serve as a basis for modification of FAA Order 721.38A (CWSU) as well as other related FAA documents such as:

- FAA ORDER 7032.9, TMS Air Traffic Operational Requirements
- FAA ORDER 7210.3, Facility Operations
- FAA ORDER 7032.15, Air Traffic Weather Needs and Requirements: Appendix 2, Paragraph 2.3, High Level Needs
- Operational Concept of the Aviation Weather System (1994): Paragraph 3.2.5, Paragraph 4.2
- A Concept of Operations for the NAS in 2005, DRAFT 3/28/97

The study states that thunderstorm forecasts are needed for 1-8 hours as well as echo tops information to within ± 1 kft below 29,000 feet altitude and to within ± 2 kft at higher altitudes.

A mission need statement (MNS) for aviation weather [Parker, 2002] with an associated investment package for thunderstorm impact mitigation was approved in June 2002. This MNS identifies capability shortfalls in a number of weather related areas and discusses which options offer the greatest benefits in terms of financial worth.

The thunderstorm investment package (IP) portion of the MNS (which was in final review as of January 2004) addresses the need to eliminate avoidable air traffic delays due to thunderstorms and increase safety. The needs (gaps) discussed in the thunderstorm IP are (1) a consistent current-time (state-of-the-atmosphere) product based on improving thunderstorm attribute (e. g., convective induced turbulence, hail, tornados, echo tops, hail, mesocyclones) detection, (2) improved thunderstorm forecast algorithms (0 – 6 hours) based on better detection information, and (3) timely dissemination of current and forecast products to users.

The thunderstorm IP had the highest worth score of the various aviation weather investment packages analyzed in the MNS (albeit with moderate risk due to scientific challenges in developing convective forecasts plus uncertainty in funding for various systems to achieve the benefits).

2.1.4 Needs Recently Identified by the National Transportation Safety Board (NTSB)

The NTSB [2001] has recommended that the FAA incorporate, at all air traffic control facilities, a near-real-time color weather radar display that shows detailed precipitation intensities. The NTSB suggested that the weather radar data might come from TDWR, WSP, a nearby NEXRAD or, regional mosaic images.

2.2 FUNCTIONAL DOMAINS FOR CIWS

In this subsection, we briefly discuss how unmet needs in various functional domains discussed above could be addressed by the CIWS products described in Chapter 3.

En Route Operations

Most en route weather decision support systems show only past or current storm locations, and existing operational forecast products within en route airspace are limited. Two national-scale forecast products are provided by the Aviation Weather Center: the automated National Convective Weather Forecast (NCWF) 1-hour forecast, and the Collaborative Convective Forecast Product (CCFP) 2, 4, and 6-hour forecasts that are updated every two hours. While these products are helpful, highly congested airspace requires very accurate, current, high-resolution weather information and forecasts to safely improve air traffic flow during thunderstorms. Of particular importance is accurate information on the vertical extent of the storms (as will be demonstrated in subsequent Chapters), since there are many occasions where en route jet aircraft can safely fly over high reflectivity storms. Another significant deficiency of the currently available en route products from the viewpoint of both safety and efficiency is the ability to reliably identify regions of short term convective storm growth and decay.

Major Terminal Area Operations (e.g., Pacing Airports)

Many U.S. pacing airports [with the exception of pacing airports on the west coast [see Evans et al., (1999)] are scheduled to receive an Integrated Terminal Weather System (ITWS) [Evans and Ducot, 1994]. ITWS has been demonstrated to be highly cost effective in reducing delays from convective weather near major airports.

The initial operational capability (IOC) ITWS capability could be improved by:

- Extending the convective weather forecast time from the current 20 minutes to the current state of the art which is 2 hours
- Increasing the coverage and data quality of the long range NEXRAD precipitation product
- Improving the storm echo tops information

In FY 2004, the ITWS program will contract for an upgrade to install the 1-hr Terminal Convective Weather Forecast (TCWF). This will significantly improve the ITWS convective weather decision support capability. However, there will still be problems in providing longer lead-time forecasts and in handling convective weather in the transitional en route airspace due to the limited capability and coverage of the long range NEXRAD product used to generate the TCWF. This deficiency in spatial coverage for forecasts and echo tops information is particularly important to consider when seeking to improve departure efficiency out of major airports when there is severe convective weather in the transitional en route airspace [See DeLaura and Allan, 2003, for a description of the Route Availability Planning Tool (RAPT), under test in New York].

At airports served by the Terminal Doppler Weather Radar (TDWR) that do not receive an ITWS and at major pacing airports without a WSP or an ITWS [e.g., San Francisco (SFO)], there is a need to provide improved support for ATC decisions such as:

- Departures from airports during a Severe Weather Avoidance Plan (SWAP) and/or when there is adverse weather in en route airspace near the terminal
- Management of arrival and departure transition area closures
- Departure transition area traffic balancing
- Optimizing traffic flow into the Terminal Radar Approach Control (TRACON) when storms will close or narrowly miss runways
- Anticipating when airports will reopen
- Optimizing holding patterns

Operations at WSP airports

The IOC WSP provides a useful convective weather traffic management capability for a number of important, though less busy airports with 20 minute convective weather forecasts [Rhoda and Weber, 1996].

It would be desirable to extend the functional capability provided by the WSP in three respects:

- Longer lead time forecasts (0 to 2 hours versus the WSP current 20-min forecasts)
- Information on convective weather in the airspace outside the 60 nm range of the Airport Surveillance Radar – Model 9 (ASR-9)
- Storm echo top height information

Additionally, CIWS products could provide a fall back source of real-time information on storm locations and movement if the WSP product generator should fail.

Operations at MIAWS airports

The Medium Intensity Airport Weather System (MIAWS) now in use at three smaller airports provides 20-minute storm forecasts based on data from one or more nearby NEXRAD radars It would be desirable to provide more accurate information on storm severity (through the use of multi-NEXRAD mosaic, such as is described in Chapter 3), echo top heights, and movement, as well as providing longer lead-time forecasts at the MIAWS airports.

Operations at airports that have no weather decision support system

CIWS products could be of assistance in addressing the NTSB recommendation (recall section 2.1.4) that the FAA incorporate, at all air traffic control facilities, a near-real-time color weather radar display that shows detailed precipitation intensities.

The FAA Office of Policy and Plans (APO) Web site associated with forecasts of terminal area activity (http://www.apo.data.faa.gov) shows that there are 474 airports receiving FAA and contract tower services.

The current FAA plans are to provide color displays at approximately 122 airports:

47 airports associated with TDWR/ITWS
35 airports associated with the WSP
40 airports associated with the MIAWS

Hence, there are some 352 airports towered airports that currently would not have a near-real-time color weather radar display that shows detailed precipitation intensities. The NTSB recommendation suggests that the safety of operations at these airports would benefit by having access to high quality information on severe storm location and movement provided that the products could be provided economically.

One approach to economically providing the desired near-real-time convective weather information would be to provide the CIWS products on a PC using a Web browser as the display engine with the CIWS products made available by a server on the FAA intranet (or, the Internet). The principal site-specific cost to provide an operationally useful capability would be incorporating facility specific overlays such as navigation aids, runways, etc into the Web browser software. This type of facility specific overlay capability has been utilized in the CIWS Internet server used for the 2002-03 tests and would be relatively straightforward to extend to additional sites.

2.3 RELATIONSHIP OF CIWS TO EXISTING FAA SYSTEMS AS A PART OF AN OVERALL SYSTEM FOR COPING WITH SEVERE CONVECTIVE WEATHER

In Figure 2-1 we show the key features of the process that is used to mitigate the impacts of convective weather on the system. Put simply, the problems introduced by convective weather are not mitigated unless an appropriate mitigation plan is executed in a timely manner.

The problem in executing the operational decision loop shown in Figure 2-1 is that in the process of determining the ATC impact, developing and choosing an appropriate mitigation plan must be accomplished in a time period commensurate with the ability to accurately forecast the weather impact. This is particularly difficult to do in the congested airspace shown in Figures 1-2 and 1-3 because of the nature of the convective weather (as will be discussed Chapter 4) and due to the very complicated ATC facilities interactions that occur in congested airspace.

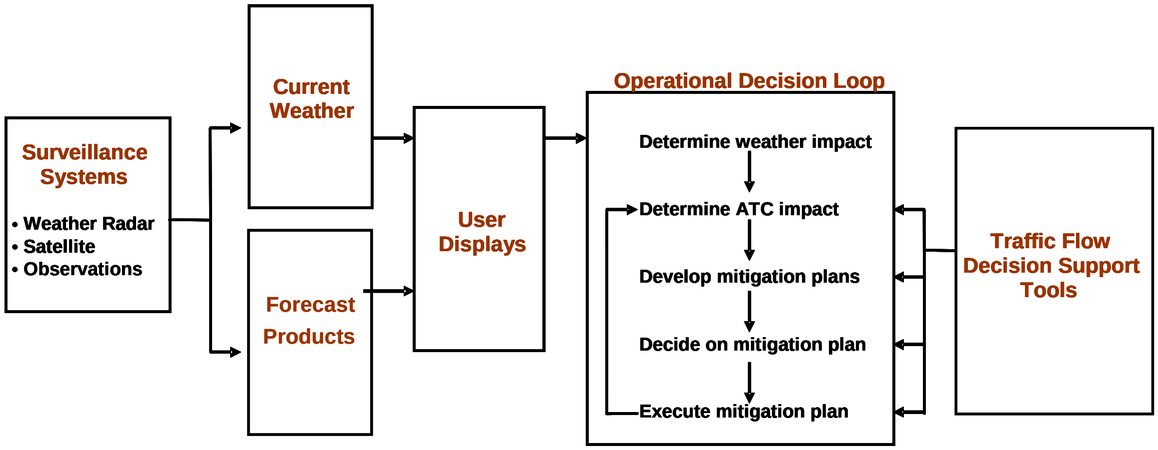

Figure 2-1. Overall convective weather impact mitigation process. It is essential that the Operational Decision Loop shown be executed in a time period commensurate with the time scale over which the weather changes and with the ability to accurately forecast the weather impact. If this cannot be achieved, then the plans that are executed will no longer be an appropriate solution for the weather situation.

In 2000-02, a major focus of the effort to reduce convective weather delays was "strategic" Traffic Flow Management (TFM) through use of the CCFP[8], the Strategic Planning Team (SPT), and collaborative weather mitigation plans. As shown in Figure 2-2, the CCFP forecasts are compared to predetermined "play books" [9] to decide the best strategy for rerouting aircraft to minimize disruptions from the anticipated weather. Note that if the CCFP forecasts could accurately predict the ATC impacts several hours in advance, then there would be a considerable amount of time to spend discussing and executing mitigation plans.

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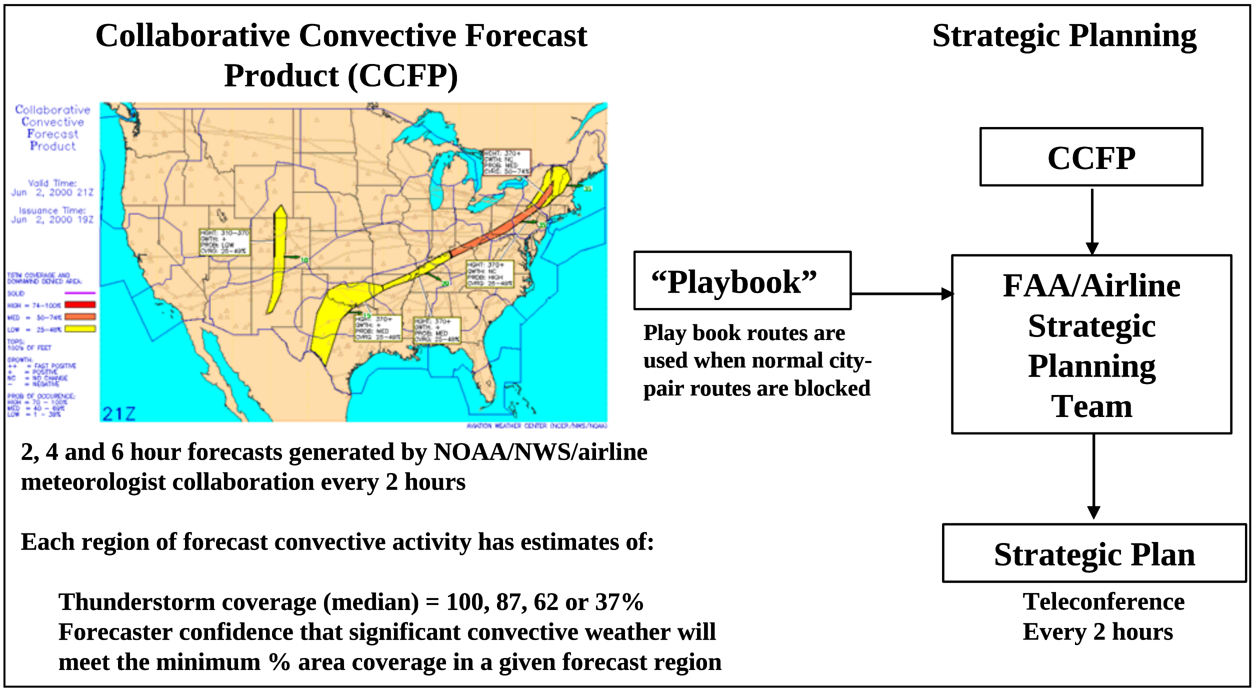
[8] Information on the CCFP performance is available at http://www-ad.fsl.noaa.gov/fvb/rtvs/ccfp/200104-200110/index.html.

[9] The "play book" consists of collaboratively determined routes assuming that there are various hypothetical regions of weather that must be totally avoided by aircraft. Details on all derived playbook routes are available at: http://www.fly.faa.gov/PLAYBOOK/pdindex.html



Play book routes are used when normal city-pair routes are blocked

2, 4 and 6 hour forecasts generated by NOAA/NWS/airline meteorologist collaboration every 2 hours

Each region of forecast convective activity has estimates of:

Thunderstorm coverage (median) = 100, 87, 62 or 37%
Forecaster confidence that significant convective weather will meet the minimum % area coverage in a given forecast region

Teleconference
Every 2 hours

Figure 2-2. Use of CCFP for "strategic planning". The hope was that the forecasts would be accurate enough to support multi-hour weather impact, planning, and execution time window.

This "strategic" approach shown in Figure 2-2 has been successful in improving operations in many cases (especially when the convective weather was due to long lasting fronts or squall lines). However, it was found in 2001 that over 90% of the CCFP forecasts were for regions of "low" predicted coverage (i.e., significant storms were expected to cover between 25 and 50% of the forecast area). In such cases, the strategic plan has generally been to allow a significant fraction of flight plans to be filed through the regions of predicted storm activity with the expectation that there will be tactical rerouting.

A key factor for mitigation planning to address low coverage CCFP forecasts is assessing the ATC impact as shown in Figure 2-1. In particular, one needs to relate weather coverage to the effective tactical capacity for regions that may be partially impacted by convective weather. Based on this tactical capacity, a key strategic decision is made about how many aircraft will be allowed to fly through an area of predicted weather. The estimate of tactical capacity depends critically on the tactical weather products, air traffic management (ATM) decision support tools and the capabilities of the ATC (e.g., traffic flow managers/air traffic controller) and airline (e.g., pilots/dispatch) teams.

Additionally, a large fraction of the significant weather that occurs (over 60%) was outside the CCFP forecast regions [Mahoney et al., 2001]. If the weather that is outside the CCFP forecast regions impacts usage of routes outside the CCFP regions (including the routes used by traffic that was strategically rerouted out of CCFP regions), dynamic adjustments to the strategic plans based on shorter term forecasts and current weather products would clearly be required.

In Figure 2-3, we summarize the key elements of the system that makes dynamic adjustments to the strategic plans. This "dynamic adjustment" system (which will hereafter be referred to as "tactical" planning) is a key factor in determining the effective tactical capacity when adverse convective weather occurs.

In summary, CIWS plays a key role in the tactical planning system by providing 0 to 2 hour decision support that complements the "strategic" weather mitigation system in both en route and terminal airspace. This decision support is achieved in two ways:

- By providing information on current and near term (0-2 hour) storm locations, severity and vertical structure so that ATC users (especially traffic flow managers and supervisors) and airline systems operations centers can make dynamic adjustments to the strategic plans that were developed from longer lead time forecasts such as the CCFP

- By enhancing the effective capacity of airspace when there is convective weather present

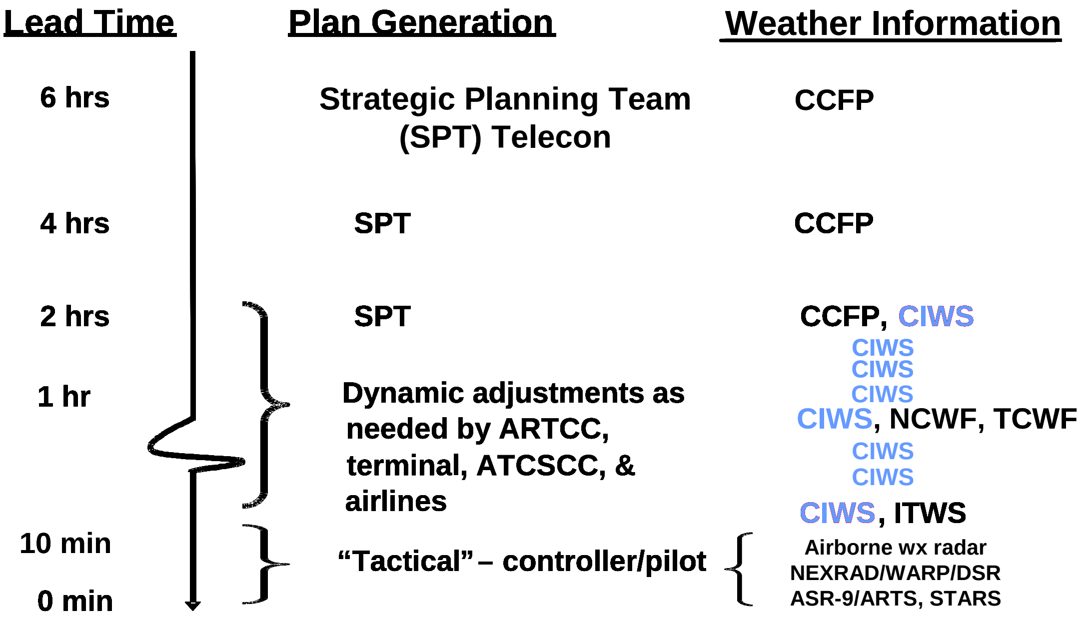


Figure 2-3. Use of various forecasts and weather information as a function of time for convective weather planning in congested airspace. The CIWS products are used to make dynamic adjustments to the strategic plans developed from longer term forecasts.

2.4 PREVIOUS STUDIES OF OPERATIONAL BENEFITS RELATED TO THE CIWS STUDY

The bulk of the previous operational benefits studies considered germane to the current analysis were carried out in the context of an assessment of the delay reduction provided by ITWS [Evans and Ducot, 1994]. The first of these studies, which provided much of the intellectual basis for the subsequent work, was carried out by L. Stevenson of the Volpe Transportation Center and D. Rhoda of Lincoln Laboratory after the ITWS operational demonstrations in 1994. Operational users of ITWS at the various facilities were interviewed at the end of the demonstration period to determine:

- Operational decisions that had been improved by use of ITWS products above and beyond the baseline terminal weather information systems at the airports (TDWR and ASR-9)
- The number of aircraft (or time duration) over which the improvement was typically achieved on a "typical" day with thunderstorm impacts
- The benefit (e.g., minutes of reduced delay time) experienced by the individual aircraft

Based on the interview results, models were developed (see Chapter 5) to quantify the delay savings associated with the various ITWS products above and beyond the baseline weather information systems at the airports. These results were then extrapolated to the other ITWS locations based on the frequency of thunderstorm impacts and the number of operations at the various airports.

It should be noted that in the ITWS study, the greatest operational benefits in terms of improved ATC decision making actually occurred in the traffic management units (TMUs) at the ARTCC that surrounded the terminal areas [Evans and Ducot, 1994]. Key high benefits decisions for ITWS (in order of delay reduction obtained) were as follows:

- Anticipation of arrival and departure transition area closures and reopenings
- Anticipation of runway impacts and shifts due to convective cells to better manage the ARTCC traffic planning to land at the ITWS airport
- Optimization of traffic patterns within the TRACON
- Optimization of airline operations
- Higher effective arrival capacity during thunderstorms

Two subsequent studies of ITWS delay reduction benefits at NY using results from the NY ITWS demonstration system in 2000-2001 are relevant to the present study. These studies were carried out using the same approach as the first ITWS benefits study and are reported in Allan, et al., [2002]. These studies identified a very important benefit for the CIWS domain:

- Increased departure rates when there is a SWAP in effect

that was not discussed in the Stevenson/Rhoda study. On the other hand, at the NY airports, there were relatively fewer benefits associated with anticipating arrival transition area closures and reopenings due to difficulties in holding aircraft outside the TRACON.

A key element of the NY ITWS study was the heavy use of queuing models in determining the benefits. Although it was recognized in the initial ITWS studies that queues could be a factor in delay causality, queues were not a frequent feature of ATC operations at Memphis, Orlando or Dallas. By contrast, situations where the demand exceeded the effective airport/terminal capacity were quite common during adverse weather at the NY airports and hence one had to very carefully analyze the demand and capacity as a function of time to obtain realistic benefits estimates.

Sunderlin and Paull [2002] conducted a study of the delay reduction benefits of the ITWS 60-minute TCWF at Memphis, Dallas and New York. Their approach to benefits quantification and quantitative results were similar to those of Allan, et al. They did note that the benefits of the TCWF (which had no growth/decay capability) were noticeably lower at Orlando (which has a very high frequency of short-lived air mass thunderstorms) than they were at Memphis, Dallas or New York (all of which tended to have somewhat longer lived convective storms).

Mondoloni et al., [2002] carried out an assessment of the delay reduction benefits associated with better routing of aircraft in en route airspace within the CIWS domain. They analyzed a specific date, 25 August 2001, in which there were storms to the southeast of O'Hare International Airport (ORD) using CIWS NEXRAD Vertically Integrated Liquid Water (VIL) mosaic data and the flight paths flown that day. They then compared the actual flight profiles flown with more nearly optimal routes[10] that they considered could have been utilized based on the CIWS products. Specifically, they concluded that:

- "By providing flights with the ability to fly confidently through areas of high convective activity with minimal delay, CIWS will allow operators to file flight plans as they would have on clear-weather days, and
- One hour prior to flying through an area of high convective activity, CIWS allows flights to find gaps in the storms. While still tactical, the longer look-ahead time and precise gap location will reduce delays that result from tactical maneuvers."

Using these assumptions they estimated an upper bound, for the scenario day, of the improved flight trajectory-related time and fuel benefits that can be expected from CIWS. They estimated there would be a distance savings of 228,126 nm, a delay savings of 591 hours, and a fuel savings of 1,317,510 lbs. No effort was made to scale their single scenario results up to a full season.

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[10] Mondoloni et al., [2002], used OPGEN ©, a proprietary software package developed by CSSI to determine the optimized flight paths.

3. CIWS 2002-03 DEMONSTRATION SYSTEM FEATURES

In this Chapter, we discuss how the CIWS 2002-03 demonstration system sought to meet the operational needs discussed above by use of:

- Better weather sensing, including an improved update rate for information on storm location and severity
- Improved fully automated algorithms for creating the storm severity products and forecasts
- Common situational awareness between key tactical decision makers

The dramatic recent advances in CIWS infrastructure technologies such as wideband communications capability, workstation computational capability/cost and internet-related software were pivotal in achieving the operational capabilities demonstrated in 2002 and 2003. The bulk of the current tactical convective weather information systems architecture and capability (e.g., NEXRAD, WARP, and to a lesser degree, ITWS), were significantly dictated by the narrow band communications and relatively expensive computer capabilities available in the 1980s and early 1990s. These limitations placed major constraints on the complexity of automatic product generation systems, display product spatial resolution, update rate and features as well as the ability to provide information to a wide variety of users.

We now have the ability to acquire radar data at full resolution, retain that data resolution as much as needed for product generation computations, utilize very sophisticated pattern recognition and image processing techniques in creating the products, and provide the end users with a wide variety of high space/time resolution display products.

3.1 CIWS SENSORS USED IN 2002 AND 2003

NEXRAD

CIWS utilized data from two types of radars to create the majority of the products in 2002 and 2003. The primary CIWS sensor is the National Weather Service WSR-88D or NEXRAD radar, which is an S-band radar with a one-degree pencil beam. This radar creates a volume scan (a full set of tilts from 0.5 degrees to 19.5 degrees about the horizon) every 5 to 10 minutes depending on scan strategy. NEXRADs have been sited so as to provide overlapping coverage across most of the U.S., in turn allowing CIWS to have continuous and in most cases redundant coverage throughout its domain. Access to the full resolution NEXRAD base data was accomplished using a compression server developed under the Collaborative Radar Acquisition Field Test (CRAFT) project [Droegemeier et al., 2002] in conjunction with the Local Data Manager (LDM) software package developed by Unidata.

ASR-9

ASR-9 data was incorporated into the CIWS demonstration system products in 2002. The ASR-9 is an S-band radar with a 5.0 by 1.4 degree fan beam that has a target channel to track aircraft, as well as an independent weather channel that is used to detect six levels of reflectivity. The radar executes a weather volume scan every 12 seconds and the weather data are averaged to produce an update every 30 seconds. Access to the ASR-9 data was accomplished using the ASR-9 Serial Interface System (ASIS) card interface.

Lightning

Lightning data are ingested from the National Lightning Detection Network. This network detects cloud to ground strikes across the U.S.

GOES Satellite

Visual and infrared satellite data from the Geostationary Operational Environmental Satellite (GOES) are obtained via a downlink system located at Lincoln Laboratory. Data from the GOES-East satellite are used in CIWS.

3.2 CIWS SENSOR EVOLUTION DURING 2002 AND 2003

The CIWS NEXRAD network expanded from the initial Midwest sensor suite to the East Coast (Figure 3-1a) in April of 2002 when the three NEXRAD radars used by the NY ITWS prototype, and the NEXRAD in Albany NY, were incorporated into the CIWS products. In early June of 2002, the CIWS domain more than doubled in coverage area with the integration of 11 additional NEXRAD radars (Figure 3-1b). For the summer 2002 CIWS testing period, 21 NEXRAD radars provided coverage. In addition, by June 2002, a 21 radar mosaic of ASR-9s had been deployed for operational use (Figure 3-1d).

Further increases in the CIWS sensor coverage continued through 2002 and 2003. In the fall of 2002, the process of connecting to an additional 10 ASR-9s began. By February of 2003, seven of ten additional ASR-9 connections planned for CIWS had been completed, leaving only three ASR-9 radars from the Potomac TRACON to be accessed. Most of the additional sensors were available by the spring of 2003 with the last three Potomac ASR-9 radars incorporated into the ASR-9 mosaic by August 2003.

Two more NEXRAD radars were accessed in the fall of 2002, one in Roanoke, VA and one in Indianapolis IN. Additionally, two NEXRAD radars were acquired through the CRAFT network bringing the total NEXRAD radars ingested into CIWS for summer 2003 testing to 25. After the three Potomac ASR-9 radars were incorporated into the CIWS ASR-9 mosaic, the total ASR-9s being ingested by the system rose to 31. Figures 3-1c and 3-1e show the sensor coverage during summer 2003 CIWS testing.

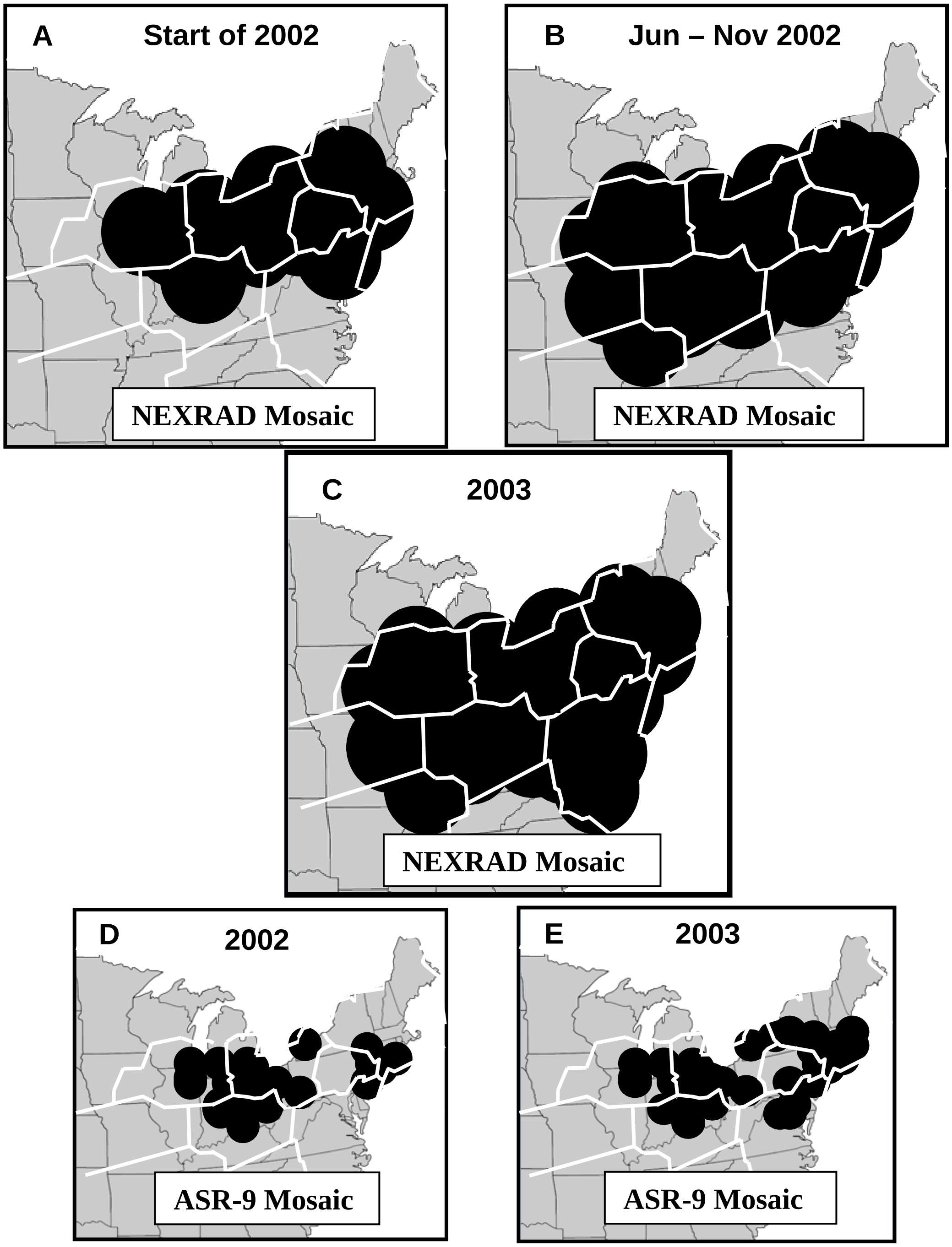

Figure 3-1. CIWS NEXRAD radar coverage (a) at the beginning of 2002, (b) between June and November 2002, (c) for 2003, and ASR-9 radar coverage for (d) 2002 and (e) 2003. The black circles in Figs. (a) – (c) indicate NEXRAD coverage out to 124 nm for each radar site. The black circles in Figs. (d) – (e) indicate ASR-9 coverage out to 60 nm for each radar site. The white lines in each figure represent ARTCC boundaries

3.3 LOCATIONS OF CIWS USERS DISPLAYS

The ATC CIWS user locations for the 2002-03 testing (Figure 3-2) were determined based on feedback from the operational users during the 2001 demonstration period (especially the ATCSCC). Full capability situation displays (described below) were provided for the ARTCCs that control the bulk of the traffic in the Great Lakes and Northeast corridors, including the bottlenecks shown in Figure 1-3. Displays were also provided at the bulk of the major TRACONs in that area (the principal exceptions were the Potomac, Philadelphia and Boston TRACONs). Within the ATCSCC, CIWS displays were provided to the Severe Weather unit, the Weather Unit, and the Chicago/Minneapolis and Cleveland, and New York/Boston sector manager positions. Additionally, real time dedicated displays were provided at the Great Lakes and New England regional offices. The Toronto ACC accessed CIWS products via the CIWS Internet web server.

Two airlines, United and Northwest, had ITWS demonstration displays that could also be used as full capability CIWS situation displays in 2002. During the summer of 2003, Delta, Southwest, and Federal Express (FedEx) added the ability to use a full capability CIWS situation display to their ITWS demonstration displays and in some cases added more displays. During the fall of 2003, United Parcel Service (UPS) purchased a data line allowing them to receive CIWS data at their operations center in Louisville KY. In addition, many airlines have access to products via the CIWS Internet web server; the most active web site users were US Airways, Southwest, FedEx and Delta.

3.4 CIWS REAL TIME SYSTEM ARCHITECTURE

Given the very large number of sensors, the wide area of operation and the need for flexible and rapid system expansion, the communications infrastructure shown in Figure 3-3 is a very important feature of the CIWS demonstration system. In contrast to the ITWS demonstration systems in which dedicated point-to-point links were used, the CIWS demonstration system has successfully used a vendor-supplied frame relay network (Sprint). At each sensor or external user location, there is a local line to the frame relay packet switched network. A DS3 link connects the frame relay network and the real time product generation center at Lexington MA. The frame relay system has provided nearly 100% availability of the communications infrastructure since the system began real time operations in May of 2001.

A network of Commercial Off-the-Shelf (COTS) Unix and Linux workstations, located in Lexington, MA, provided the compute power for data ingest and product generation. To support the development of new algorithms, the system was designed to be modular and flexible. Algorithms can be assigned to individual workstations or sets of workstations to limit resource contention issues. Data are shared between algorithms by means of TCP/IP data streams and shared disks. Additional resources can easily be incorporated into the system by including new workstations in the network. Hardware failures can be easily and quickly resolved using hot spares.

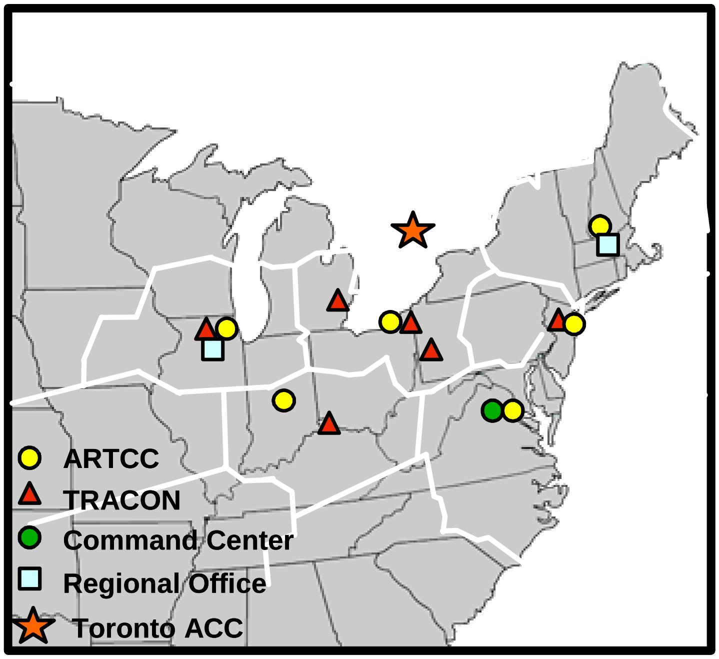

Figure 3-2. ATC facilities currently using CIWS products. Note that Toronto ACC accesses CIWS products via the CIWS Internet web server.

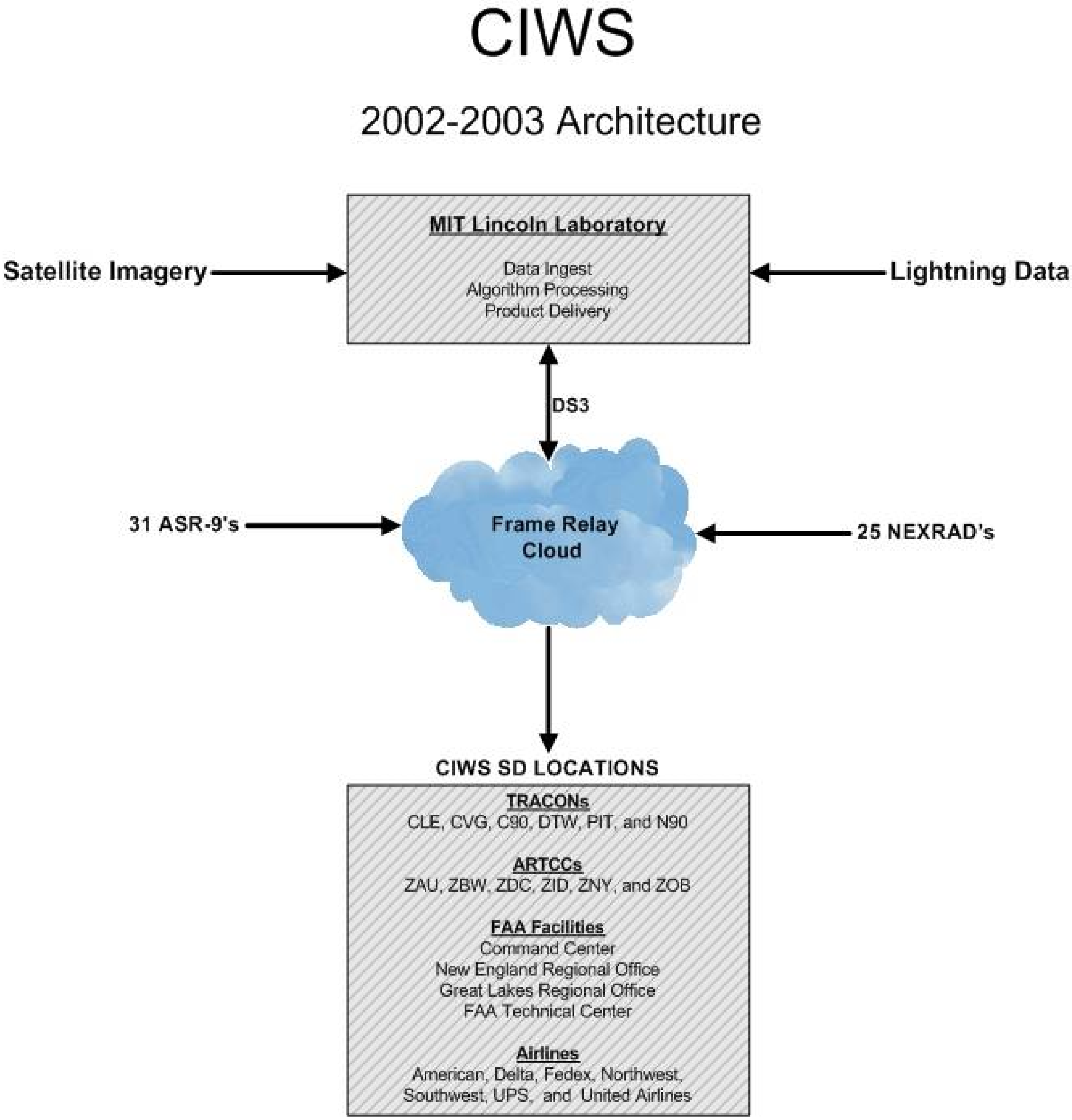

Figure 3-3. Communications architecture for CIWS 2002-03 demonstration system. The product generation and system monitoring was accomplished by workstations located at the Lincoln Laboratory main research complex in Lexington, MA (top). Not shown are Web servers at Lincoln Laboratory providing Web browser viewable products over the Internet.

System monitoring is done at a number of levels. First, each of the input data sources (i.e. NEXRAD base data and ASR-9 data) is monitored using simple scripts to alert personnel to data outages, via audio messages and email pages. Additionally, analysis displays show base data images, as well as intermediate products (e.g., VIL), to allow for human interpretation. Finally, the remote user displays are monitored so that communications failures, hardware, and software failures are detected quickly. The Lincoln site personnel are automatically notified of any such failures.

These design features result in a highly available, flexible system, freeing algorithm developers to concentrate on product concepts and algorithm design.

3.5 CIWS PRODUCTS AND PRODUCT DISPLAY FORMATS

Descriptions of the CIWS products and their display formats are provided in Appendix A. Complete details of the CIWS product suite, including how the products are generated from input data and how the products are displayed are available in Klingle-Wilson and Evans, [2004].

The CIWS product suite for 2001 testing consisted of the NEXRAD VIL Mosaic and the Regional Convective Weather Forecast (RCWF) products. A number of additional products were added to the CIWS suite both before and during the summer 2002 storm season in a series of Builds between April and October 2002. The final major upgrade to the CIWS product suite took place in the spring of 2003. The CIWS products that were tested during the 2003 demonstration period are:

- NEXRAD VIL Mosaic Precipitation
- ASR Mosaic Precipitation
- Storm Motion
- Lightning
- Satellite
- Echo Tops Mosaic
- Echo Tops Annotation
- Regional Convective Weather Forecast
- Forecast Accuracy
- Forecast Contours
- Verification Contours
- Growth and Decay Trends

4. CIWS OPERATIONS, TRAINING AND WEATHER IMPACTS

Discussed in this Chapter are several issues relating to the operational utility of the CIWS, including the availability of the CIWS system during the 2002 and 2003 convective storm seasons, the user training provided, and the degree to which operationally significant convective weather occurred during the test periods. Each of these issues is pertinent when evaluating the significance of the benefits assessment results reported here.

Since real-time use of the CIWS products was optional, and other more familiar alternatives for weather information exist for the FAA ATC users in particular (e.g., the WARP and Center Weather Service Units (CWSU)), CIWS system reliability was a critical element in the users' decision to utilize the equipment on an experimental basis. System reliability is discussed in Section 4.1.

Another key factor in assessing the concept exploration results is the training provided to the users. CIWS provides a number of new products that were never used before, including quantitative real time information on 0-2 hr forecast quality, a new much more accurate depiction of the 3D storm environment (the echo tops map), much faster updates on storm location and severity, and an explicit indication of where storms were growing and decaying. The working hypothesis was that these products would enable the FAA and airlines to accomplish a paradigm shift from reactive dynamic adjustments to the strategic plans to proactive dynamic adjustments. Since the overall test period was relatively short, the nature of the training provided, discussed in Section 4.2, is very important.

Finally, it is always possible that the desired operationally significant weather may not occur and/or the weather that occurs is not particularly stressful operationally. To help quantify this factor, analysis of the weather encountered in 2002-03 and its impact on ATC operations as measured by delays at the major airports in the test region is presented in Section 4.3.

4.1 OPERATIONAL SCHEDULE AND SYSTEM RELIABILITY: 2002 AND 2003

The CIWS demonstration system first operated on a weather conditional basis from its operational inception on 10 July 2001 until 14 April 2002. Products were provided to users when significant weather (level 3 intensity or greater with echo top heights above 18,000 feet) existed anywhere within the CIWS domain. During the February 2002 CIWS Users Group Meeting, users requested that the demonstration system be available continuously. In response to this request, the CIWS began continuous operations on 15 April 2002. The system continues to run live to the users 24 hours a day, seven days a week. During the convective season (April through September), the system was directly monitored between 1100 – 0300 UTC and remotely monitored at all other times. During the off-season, the system still operated continuously but monitoring took place on a weather conditional basis, with on-call monitors available to users at all times.

To illustrate system reliability performance, CIWS down time was noted during the 2002 and 2003 storm seasons (April – September). Total hours of scheduled and unscheduled downtime per month during both seasons are depicted in Figure 4-1. Scheduled down time included routine system recycles, periodic and expected maintenance, and upgrades. Planned CIWS upgrades, released as a series of monthly Builds during 2002 and April 2003, constituted the bulk of scheduled CIWS down time during these periods. All periods of scheduled down time were performed only during benign weather and with advanced notification to CIWS users. CIWS unscheduled down time was primarily due to system hardware problems or temporary network interruptions. As Figure 4-1 indicates, unexpected system-wide outages were rare. In fact, total unscheduled down time during the 2002 (2003) storm season accounted for only 0.3% (0.2%) of the total available operational period. Combined over both storm seasons, total unscheduled down time was only 21.6 hours[11]. In all, achieved operational availability of CIWS exceeded 97% during both the 2002 and 2003 storm seasons (Figure 4-2).

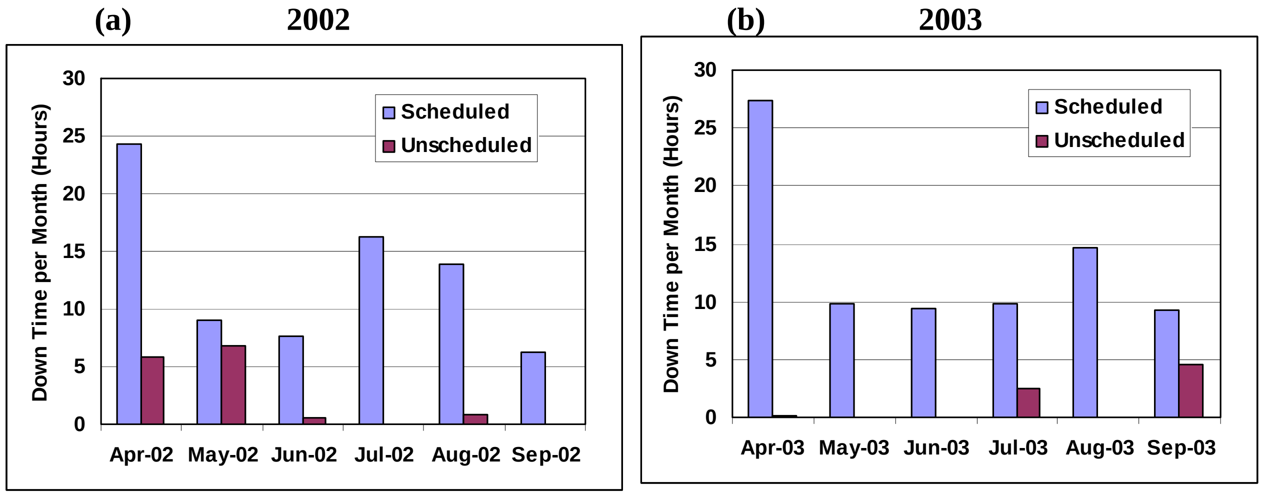

Figure 4-1 .CIWS scheduled and unscheduled down time per month during (a) Apr – Sep 2002 and (b) 2003.

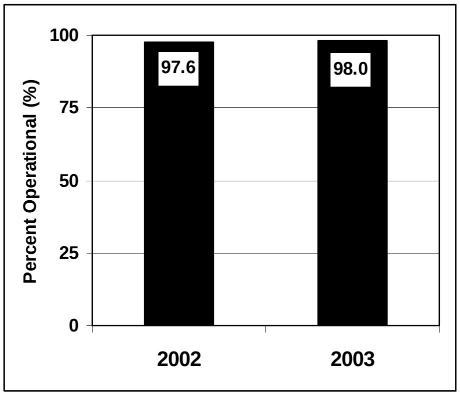

Figure 4-2. Achieved operational availability of CIWS during April-September of 2002 and 2003.

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[11] System reliability statistics do not account for network or hardware problems at individual user locations as these did not affect overall systems performance. System interruptions at individual user locations were nearly always short-lived, isolated events. We are unaware of any user location for which system reliability would be a significant factor in the operational use of CIWS at that facility.

4.2 USER TRAINING

The training provided to the CIWS operational users represents an ongoing process extending over three years, with feedback from the prior year being used to tailor the next training session. The training provided in 2002 and 2003 is of principal interest in evaluating the delay reduction benefits achieved in those years. The training for Builds 1-3 in 2002 was particularly important since many of the most important CIWS products from an operational benefits perspective were introduced at that time.

4.2.1 Training for 2002

A comprehensive training session was conducted for all CIWS users after their systems were installed during the 2001 storm season. However, since some users did not receive their systems until the winter months of 2001 and early 2002, an effort was made to ensure that all new CIWS users were trained before the start of the 2002 storm season. During the 2002 demonstration season, five software releases, or builds, were implemented on the CIWS real time system. The contents of these releases are provided in Table 4-1.

On-site training preceded all major software releases. By agreement with the CIWS Users Group in early 2002, builds containing changes that were deemed primarily cosmetic and easily understood by users did not warrant on-site training. Thus, on-site training was not performed with the Builds 0 and 2 but documentation of the changes was provided to the users with the release notification. Lincoln Laboratory staff was available throughout the summer to provide additional training as requested by any facility. The list of CIWS users trained is provided in Table 4-2.

4.2.2 Training for 2003

During the 2003 season, only one major software release was scheduled (23 April 2003) to provide the users with a stable, unchanging system upon which they could base their assessments. The contents of this release are provided in the last column of Table 4-1. On-site training was provided to most users prior to this software release. Due to scheduling conflicts some users were trained after the software release. The details of the software release were provided in the release notification.

On August 7, 2003, a minor software release was issued with two capabilities that could not be completed in time for the April build. These included the addition of playbook routes, navigational aids and a modified e-mail utility to allow users to send an e-mail without creating a screen image. No on-site training was provided but the details of the release were documented in the release notification.

TABLE 4-1 CIWS Version Release Schedule and System Enhancement Sequence

Version 1.0 3 April 2002	**Version 2.0 10 June 2002**	**Version 2.1 11 July 2002**	**Version 2.2 15 August 2002**	**Version 2.3 1 October 2002**	**Version 3.0 23 April 2003**
Extended coverage from 150 to 250 nm per NEXRAD radar Filtered precipitation levels. Three NYC ITWS NEXRAD radars added to VIL mosaic Capability to turn products off and on in each window Darkened background color VIL mosaic resolution changed from 1km (.5 nm) to 2 km (1 nm) Overlays reorganized	ASR-9 mosaic added Echo Top annotations 11 NEXRAD radars added to VIL mosaic NEXRAD data quality enhancements Product status buttons attached to window Window control buttons location changed Capability to re-center range rings User saved window configurations RCWF Accuracy on/off Storm Cell Info removed including lightning info	RCWF extended from 60 to 120 minute forecast Three levels of forecast probability Multi-scale cell tracker algorithm employed by RCWF Cloud to ground lightning data available on ASR and NEXRAD mosaics	Echo Tops mosaic with annotation Satellite data on NEXRAD mosaic RCWF forecast and verifications contours Enhanced echo tops algorithm incorporated	Zoom-based filtering of Echo Tops annotations on ASR, NEXRAD and Echo Tops mosaic products Zoom-based filtering of Storm Motion vectors on NEXRAD and ASR mosaic products	RCWF Growth and Decay Trends Cloud to ground lightning data added to Echo Tops mosaic 10 ASR-9 radars added to ASR mosaic coverage 4 NEXRAD radars added to VIL mosaic, extending coverage Improved, expanded and reorganized overlays Customized overlays Echo Top filtering by height E-mail capabilities On-line CIWS documentation
Users notified	Users notified; User Training Mid May - early June.	Users notified	Users notified; User Training Mid July - early August.	Users notified	Users notified; User Training Mid April - early June

TABLE 4-2

CIWS Users Trained: 2002

ARTCC	TRACON	Other FAA	Airlines
Washington ARTCC (ZDC)	Chicago TRACON (C90)	Great Lakes Region	United
New York ARTCC (ZNY)	Pittsburgh TRACON (PIT)	New England Region	Delta
Chicago ARTCC (ZAU)	Cleveland TRACON (CLE)	Air Traffic Control System Command Center (ATCSCC)	Federal Express
Indianapolis ARTCC (ZID)	Detroit TRACON (D21)		Continental
Cleveland ARTCC (ZOB)	New York TRACON (N90)		Northwest
Boston ARTCC (ZBW)	Cincinnati TRACON (CVG)		American
			Southwest
			American Trans Air
			United Parcel Service
			Air Canada
			US Airways
			America West

4.2.3 Approach to Training for CIWS

Training was conducted using a slide presentation and a laptop computer that simulates a fully functional situation display running in playback mode. The complete CIWS training details included CIWS background and objectives, characteristics and display concepts for each of the products, and a detailed description of the user interface. The initial training session would last approximately one hour. "Recurrent" training provided the users with a detailed description of the changes that had been made since the prior training visit. The length of this training session depended upon the number of changes. The CIWS point of contact at each facility was provided with a compact disk containing the slide presentation, a hard copy of the slides, and laminated quick reference cards for the situation displays.

The users are introduced to CIWS and given background information that illustrates how weather-related delays have increased over the past years. CIWS as a "tactical" decision support tool is discussed in the context of dynamic adjustments to the plans developed by the SPT. Situations where CIWS information has been useful in improving decision-making and decreasing delays is explicitly discussed with the users. Objectives for the experiment and goals for the upcoming season are also discussed.

Each individual product is introduced and situations in which the product has proven useful are discussed. The product is demonstrated on the laptop and product characteristics (coverage area, update rate, data quality issues) are provided. Product performance is discussed, highlighting situations in which products are very accurate and where the performance may be degraded due to the nature of the convective weather on a given day, site coverage, and/or the ability to remove data artifacts. CIWS products are compared to similar products from other systems (e.g., WARP) so that the users will understand why the depictions of weather and/or forecasts on the various systems may differ[12].

Finally, the situation display user interface is presented. Each button and function is explained fully and suggestions are made to help users customize the display to their individual needs. During the training, users are encouraged to interact with the demonstration laptop to better understand the system and to pose questions as to how the CIWS products might be used to address site-specific issues in handling of convective weather.

The above approach to training differs considerably from the current FAA training method for weather decision support systems such as ITWS or CCFP. In the case of the ITWS, there is computer-based (or slide show) training that emphasizes the operation of the display equipment as opposed to the operational usage implications. Issues of product quality and implications for ATC decision making are not discussed in depth and there generally is no human trainer present who has had first hand experience with the use of the system at other similar user facilities.

We believe that the training accomplished in 2002 and 2003 for CIWS was very important in the overall system acceptance that was achieved. However, this training still was not fully adequate.

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[12] For example, the composite reflectivity products that appear on the WARP and the Enhanced Traffic Management System (ETMS) often indicate much more severe storms in terms of equivalent precipitation level than does the CIWS VIL product. [Robinson et al., (2002) discusses why these differences arise and why the CIWS product is considered to be a better indicator of storm operational significance.]

During “benefits blitz” observations, knowledgeable CIWS observers were present when operational users were solving weather-related traffic management problems in real time. This resulted in informal training on a number of occasions. It became clear that some users do not acquire knowledge well in the “classroom” environment previously used exclusively for CIWS training. Rather, “experiential learning,” where the student is actually trying to solve a real world problem and can ask the instructor for information, appears to be the best approach for many of the professionals that constituted the CIWS user population in 2002-2003.

In some ATC facilities (e.g., ZOB, ZDC, and N90) there are a number of “early adopter” local users that provided the experiential learning instruction on an informal basis for other local users. However, in facilities that did not have a critical mass of early adopter local users, it became clear during the “benefits blitz” observations that we should have provided much more experiential learning based instruction.

4.3 WEATHER AND ITS IMPACT ON ATC OPERATIONS DURING 2002 AND 2003

As noted earlier, one of the important issues in assessing the validity of the CIWS demonstration system results is whether sufficient operationally significant weather occurred in the test period to stress the system. Since the bulk of our quantitative benefits results correspond to 2003, the discussion here will focus more on 2003 than on 2002. However, the delay comparisons between 2002 and 2003 are quite interesting because they qualitatively indicate the benefits from the CIWS products introduced in August 2002.

4.3.1 Convective Weather Impacts

The typical thunderstorm season in the Upper Midwest, Mid-Atlantic, and Northeast United States (the 2002-03 CIWS domain) occurs from April through September, with the peak occurring from late May through August when atmospheric conditions are most conducive for the generation of intense thunderstorms. The 2002 season precipitation was near normal whereas the 2003 storm season produced above-average precipitation throughout much of the CIWS coverage domain (see Figure 4-3). Particularly heavy rainfall regions in 2003 included the Mid-Atlantic, central Pennsylvania, and parts of Indiana and Ohio. This is significant because numerous high-demand jet routes run through each of these regions.

To better differentiate the precipitation events for purposes of air traffic impact studies, the spatial and temporal characteristics of all weather events within the CIWS domain during the 2003 storm season were closely examined. Precipitation events were grouped into two main classes: Organized, including linear storms and clusters of cells, and Unorganized, including cellular and embedded storms. Examples of storms in each of these categories are shown in Figure 4-4.

Storm events were classified as Organized-Linear either when storm cells were spatially aligned in a linear manner, forming a “broken line,” or storms formed a solid line of convection (squall line). Storm events were classified as Organized-Cluster when thunderstorm cells became sufficiently dense for a prolonged period to suggest a larger-scale storm complex organization (e.g., storm mergers resulting in larger complexes that survived for periods generally greater than two hours).

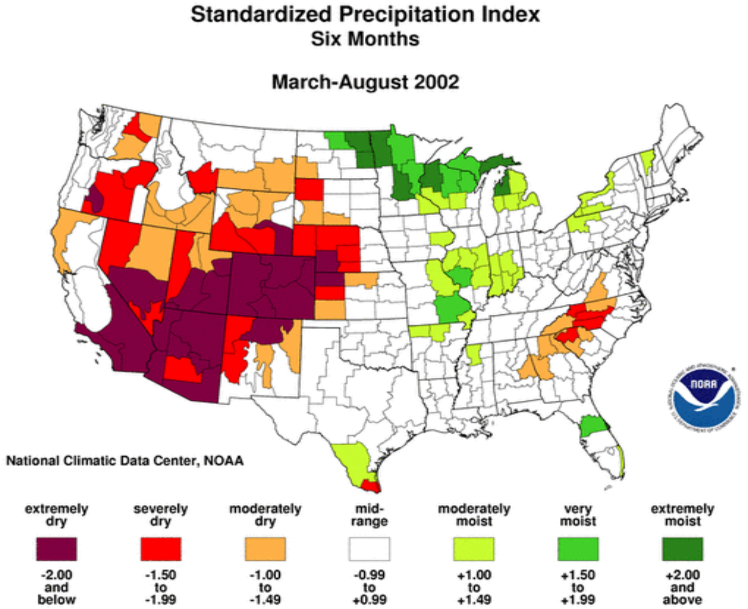
Unorganized-Cellular storms consist of strong isolated thunderstorm cells that remain sufficiently sparse and display no organizational traits (e.g., lines or storm complexes) beyond short-term cell mergers. Unorganized-Embedded thunderstorms were defined as cells embedded in stratiform precipitation demonstrating no larger-scale organizational traits.

The air traffic impact of these various types of storms depends on the storm locations, spatial extent, duration, and extent to which the storms could be accurately forecast and mitigation methods implemented (per Fig. 2-1). Spatially extensive weather with high echo tops that persist for long time periods has a much higher potential for major disruptions, but may be easier to accurately forecast hours in advance. Unorganized-Embedded thunderstorms generally have a small spatial extent and shorter lives and hence would generally be less disruptive unless they unexpectedly occurred in highly sensitive locations (e.g., west of the New York City airports). We would emphasize that the CIWS domain is viewed as a tightly coupled air traffic network for which the impacts of various storms may interact in a highly nonlinear manner. For example, the combination of an unorganized storm in one ARTCC with an organized convective system in another ARTCC may lead to a much greater ATC impact than the impact of the individual storms alone.

Storm events were analyzed every two hours during the summer storm season by visually inspecting the archived CIWS NEXRAD VIL precipitation product, and were tallied for each individual ARTCC within the CIWS coverage area. A breakdown of the number of Organized and Unorganized convective events impacting each of the six ARTCCs covered by CIWS during April – August 2003 is provided in Figure 4-5.

It is interesting to compare the storm event occurrences presented in Figure 4-5 to “days of convection” statistics for a similar period (see Fig. 4-6), the latter of which is analogous to standard NWS “thunderstorm day” statistics for airports. Previous ITWS-related studies [e.g., Bieringer et al., (1999)] have demonstrated that on the terminal scale, conventional statistics of the annual frequency of thunderstorm days at a weather observation station can significantly underestimate the frequency of thunderstorms in a region that contains the weather observation station. Underestimation concerns associated with conventional thunderstorm frequency statistics are exacerbated on the en route scale where the larger spatial and temporal extents render these point observations increasingly unrepresentative. In the CIWS storm tally, multiple storm event occurrences per day per ARTCC were enumerated, and the two event categories were broken out. Care was also taken to tally changes in storm event categories resulting from storm evolution. These allowances, leading to significantly higher storm event totals than the convective weather day statistics, are important in the context of air traffic impacts since multiple daily events and varying degrees of event evolution can have compounding impacts on air traffic operations.

As Figure 4-5 reveals, the number of thunderstorm events throughout the CIWS domain during summer 2003 was significant. Moreover, the frequency of unorganized events greatly exceeded that of organized events in each of the six Centers. This is significant when considering that lifecycles of unorganized cellular convection (typically less than 60 min from initiation to maturity to storm decay) are shorter than the update rate of convective forecast products used for strategic air traffic planning such as the CCFP. The large number of unorganized storm events impacting the heavily traveled Great Lakes and Northeast traffic corridors suggest that improved, near-term tactical planning may assist in managing airspace operations during the peak convective season.



NOTE: Color scale is not the same in both figures

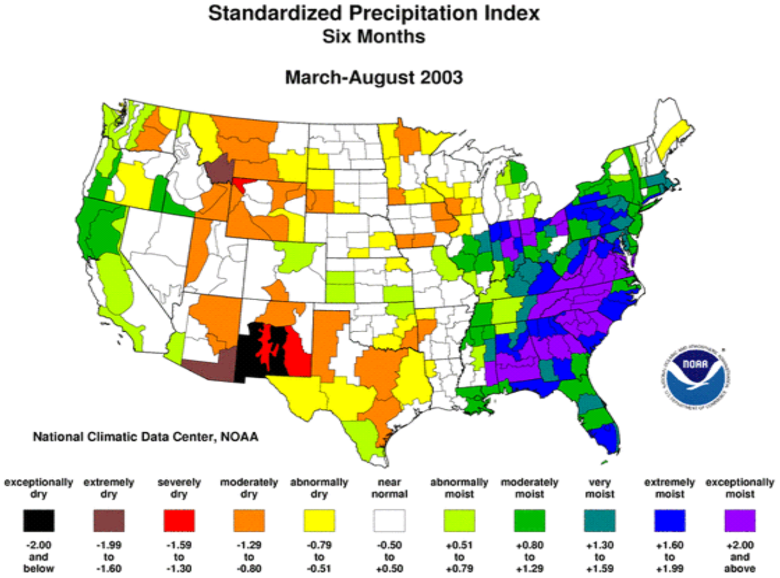
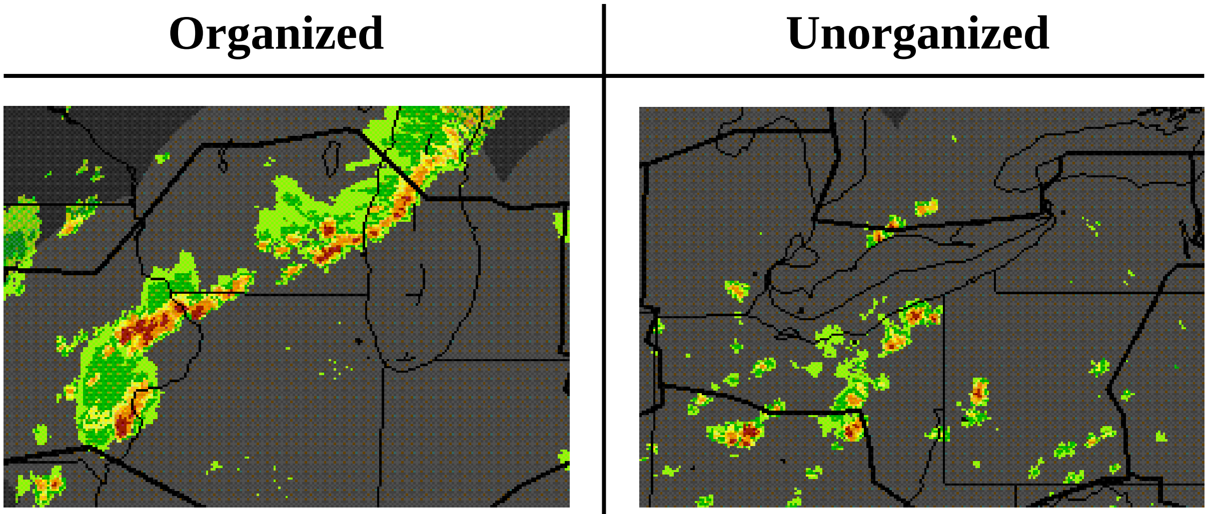
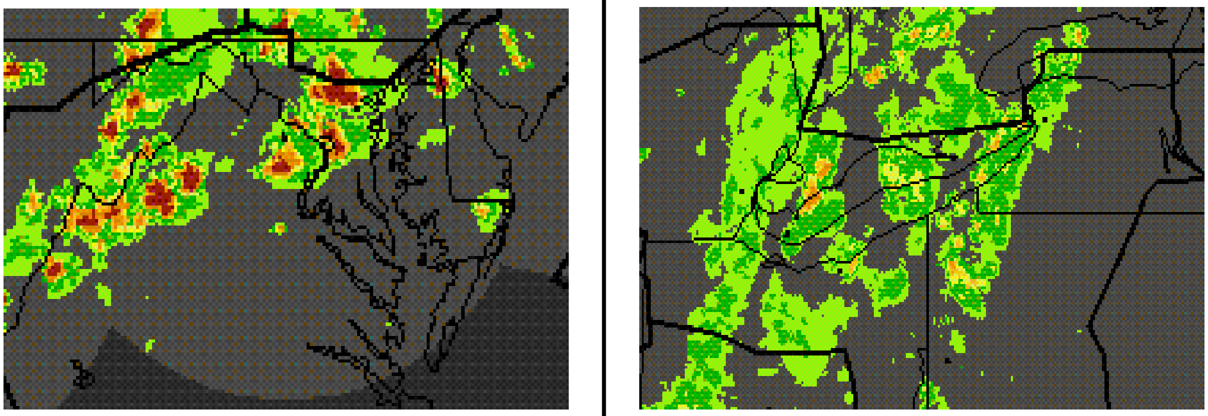


Figure 4-3. Standardized Precipitation Index during the six-month period from March through August for (a) 2002 and (b) 2003.. The Precipitation Index demonstrates the variable degree of above normal precipitation across the Midwest, Mid-Atlantic, and Northeast U.S. (i.e., the Great Lakes and Northeast Corridors of the NAS). These figures were provided by the National Oceanographic and Atmospheric Administration, National Climatic Data Center.



Linear

Cellular



Cluster

Embedded

Figure 4-4. Examples of Organized and Unorganized storm configurations from the CIWS data set.

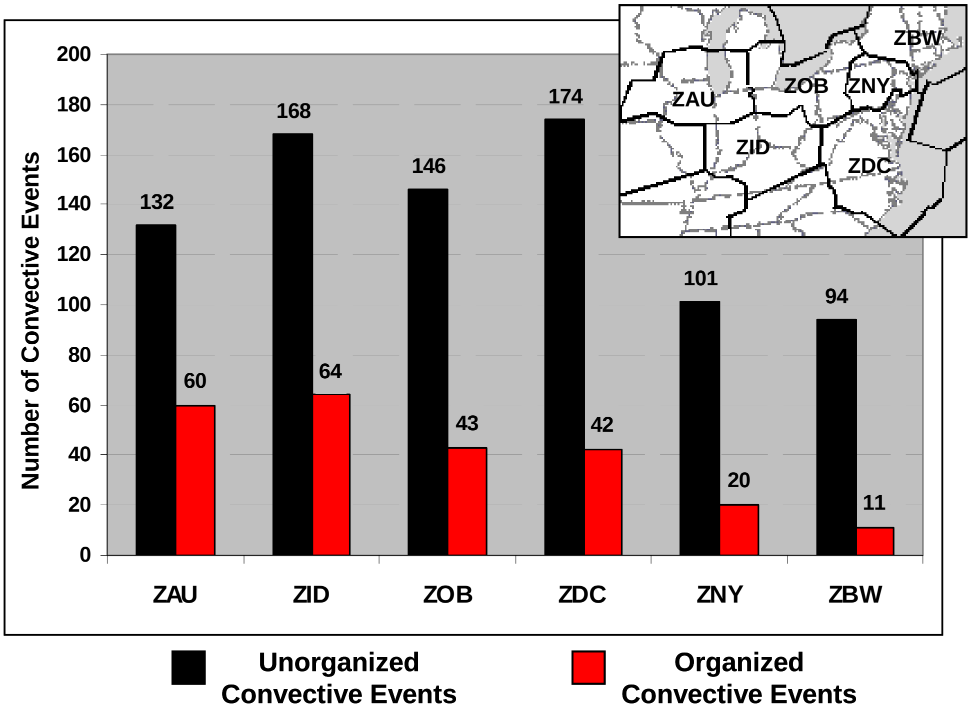


Figure 4-5. Number of Unorganized and Organized convective events per ARTCC during April – August 2003.

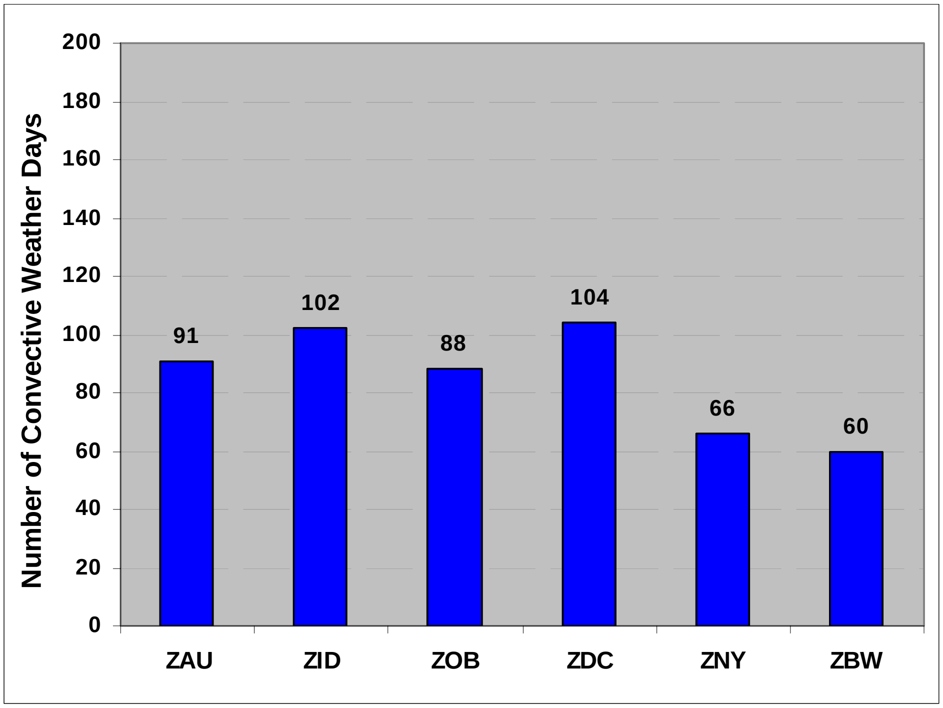


Figure 4-6. Total convective weather days per ARTCC during April-September 2003.

4.3.2 ATC Impacts as Characterized by Airport Delays

In conjunction with thunderstorm frequency statistics, storm-related air traffic impacts at several pacing airports throughout the CIWS coverage area during the 2003 storm season were also identified. Specifically, using the FAA Air Traffic Advisories Database and Operational Information System (OIS), occurrences of ground stop and ground delay programs, and delays less than or greater than one hour related only to thunderstorms, were enumerated for seven airports throughout the CIWS domain (Figure 4-7). It is clear that there were operational impacts, in terms of delays and airport based traffic flow management initiatives, on many days during 2003[13].

Some insights into the relationship between storm frequency and air traffic delay can be gained by also looking at the 2002 storm events and air traffic impacts within the CIWS coverage domain and comparing them to those in 2003 (Figure 4-8). In general, occurrences of unorganized events increased throughout the CIWS domain from 2002 to 2003 (Figure 4-8a) while the relative frequency of organized events varied between 2002 and 2003 (i.e., increased in some ARTCCs and decreased in others). Though overall storm activity (i.e., the sum of organized and unorganized events) were essentially unchanged for most ARTCCs, observed thunderstorm activity in ZDC airspace increased dramatically from 2002 to 2003[14].

We see in Fig. 4-8 that several airports in the Midwest such as Detroit (DTW), Cincinnati (CVG), Pittsburgh (PIT) and Boston's Logan Airport (BOS) exhibited declines in 2003 storm-related delays. The reduced 2003 delays at DTW, CVG and PIT occurred in spite of constant or increased overall storm activity in 2003.

We have not had time to carry out a detailed study of other factors that might be involved in this decline in airport delays at DTW, CVG and PIT. Hence it is not possible to deduce that the delay statistics shown in Figure 4-8 conclusively show a direct correlation between increased CIWS usage by ARTCC traffic managers[15] and decreased thunderstorm delays during a season of increased convective activity. However, in context of the reduced delays at the CIWS airports within ZOB, it is worth noting an unsolicited comment made by personnel at ATCSCC in regards to the performance of traffic managers at ZID and ZOB during a squall line event on 8 June 2003:

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[13] We have not had the resources in this first phase of the CIWS benefits analysis to obtain and analyze the 2003 en route traffic flow initiatives to determine on how many days initiatives such as playbook plans were put into effect in the CIWS domain.

[14] Part of the increase in ZDC thunderstorm activity in Figure 4-8 arises from the greater CIWS coverage area for ZDC in 2003. However, the bulk of the increase is undoubtedly due to increased convective activity in 2003. National Weather Service observation data for Washington D.C. show that the number of thunderstorm days at Reagan Airport (DCA) during May through August increased from 20 in 2002 to 38 in 2003 (i.e., a 90% increase in 2003).

[15] It should be noted that the Boston en route center (ZBW) did not become a significant CIWS user until late in 2002. Hence, 2003 was the first full summer that CIWS products could have significantly impacted the BOS delays.

> "Two years ago, Cleveland [ZOB] would have shut down the airspace and nothing would have moved. Both the Indy [ZID] and Cleveland Centers kept traffic moving through all of the holes. There was never more than one airway closed at a time. There were no departure delays out of O'Hare and traffic kept moving. It was amazing."

During the 8 June 2003 storm event, visitors from Lincoln Laboratory at ZID and ZOB observed numerous applications of CIWS weather products that assisted to minimize both en route and terminal impacts and ultimately reduce delay at the ZOB airports.

The overall number of delay events at EWR dropped in 2003 albeit the number of delay events with delays greater than one hour at EWR increased. Since other convective delay reduction systems [specifically the Route Availability Planning Tool (RAPT)] also commenced operation in 2003, it is unclear to what extent CIWS assisted in reducing the number of overall delay events at EWR.

We attribute the significant decrease in delay events (over 66%) at BOS in 2003 relative to both ZBW use of CIWS in 2003 and a 10 % drop in overall storm activity.

The number of delay events at ORD with delays greater than one hour increased in 2003 while shorter delay events decreased. There was essentially constant overall convective activity within the ARTCC for the two years while the National Weather Service identified a 12% increase in thunderstorm days at ORD from 2002 to 2003. The increase in higher delay events may reflect the particular nature of storm events in the two years as well as airport operations procedures issues [e.g., rules governing the use of land and hold short operations (LAHSO) on wet runways changed in April 2003].

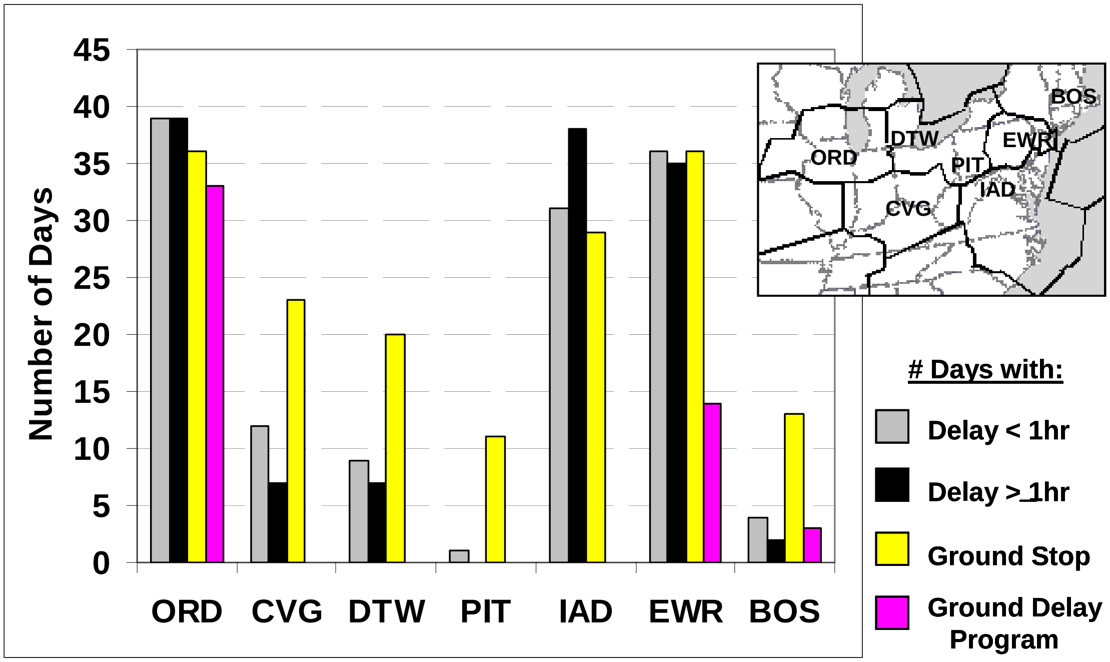


Figure 4-7. Number of days with thunderstorm-related air traffic impacts at airports throughout the CIWS coverage area from April-August 2003.

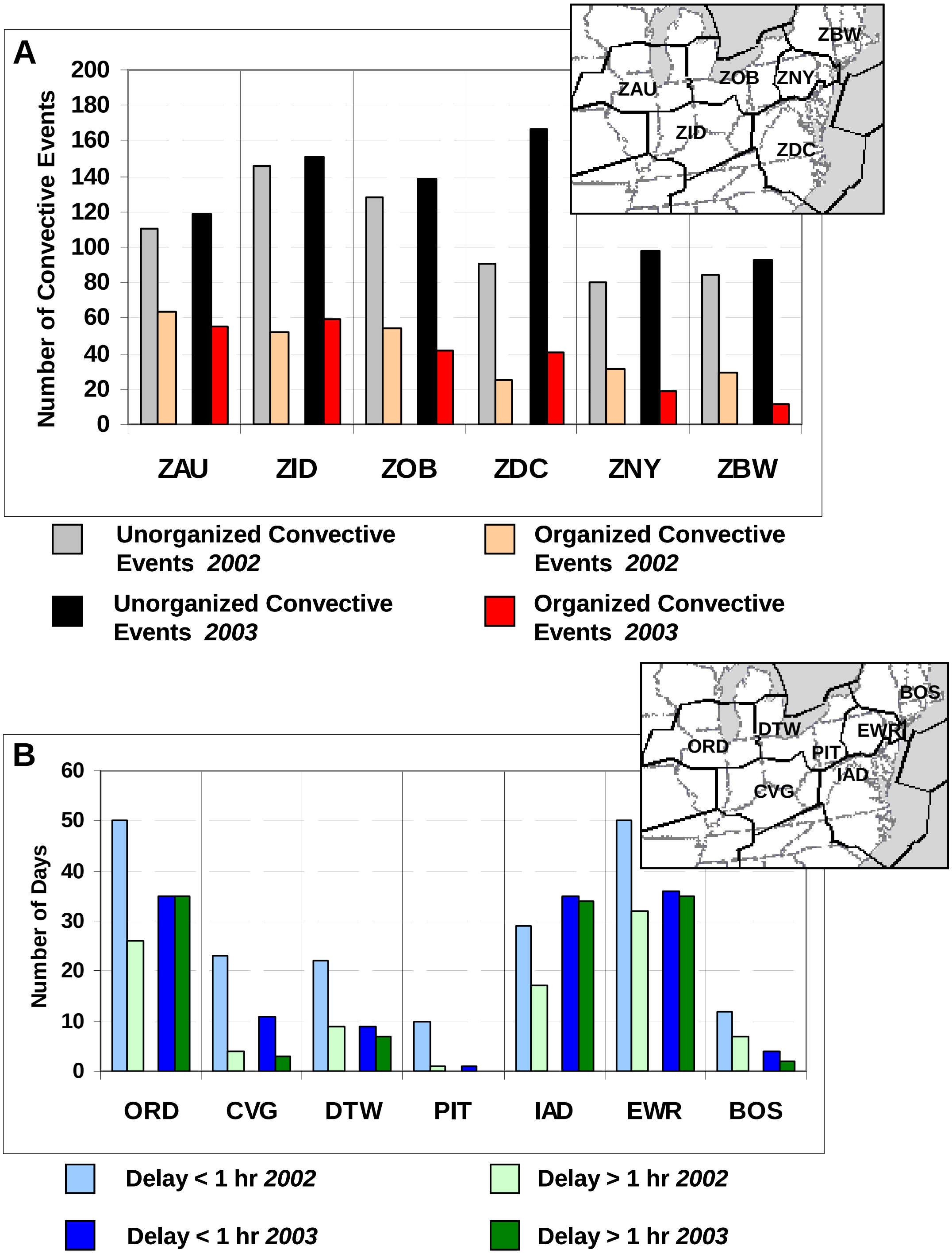


Figure 4-8. 2002 vs. 2003 (a) convective weather events and (b) storm-related airport delays throughout the CIWS coverage area during May through August.

5. APPROACH TO ASSESSING DELAY REDUCTION

The objective of this study was to determine the delay reduction that was achieved with the CIWS demonstration system in 2002-03. Figure 5-1 summarizes the basic approach used to estimate the benefits in 2002, derived from the successful ITWS benefits studies discussed previously. This approach provided useful information on the frequency of various benefits and identified key factors in achieving delay reduction as well as providing quantitative estimates of the delay reduction for terminal operations. However, in response to questionnaires during post-season interviews, the en route users of CIWS could not provide typical estimates for the key parameters (e.g., number of aircraft impacted by a given ATC decision, the average delay savings for each of the aircraft, flow rates through sectors with and without CIWS, etc) either for a given day or as a seasonal average. Rather, they suggested we obtain the benefits by having observers at the facilities during periods of operationally significant convective weather.

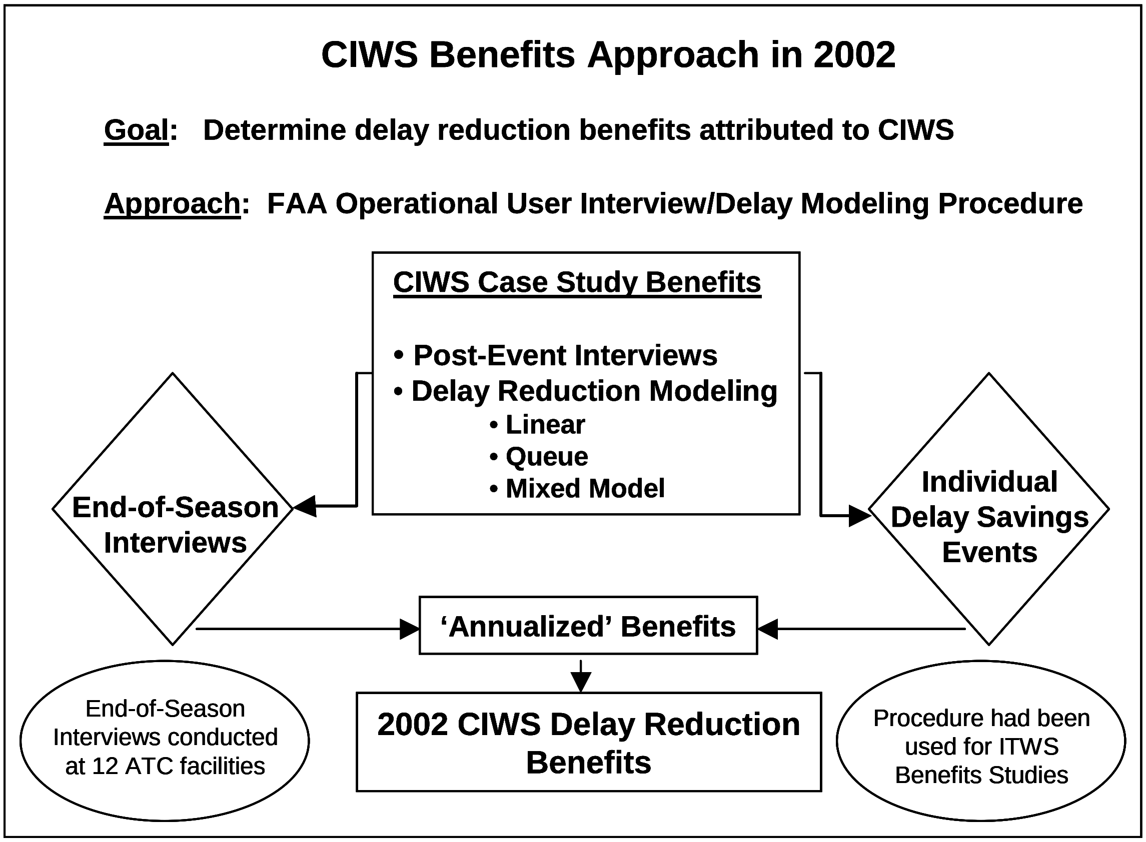
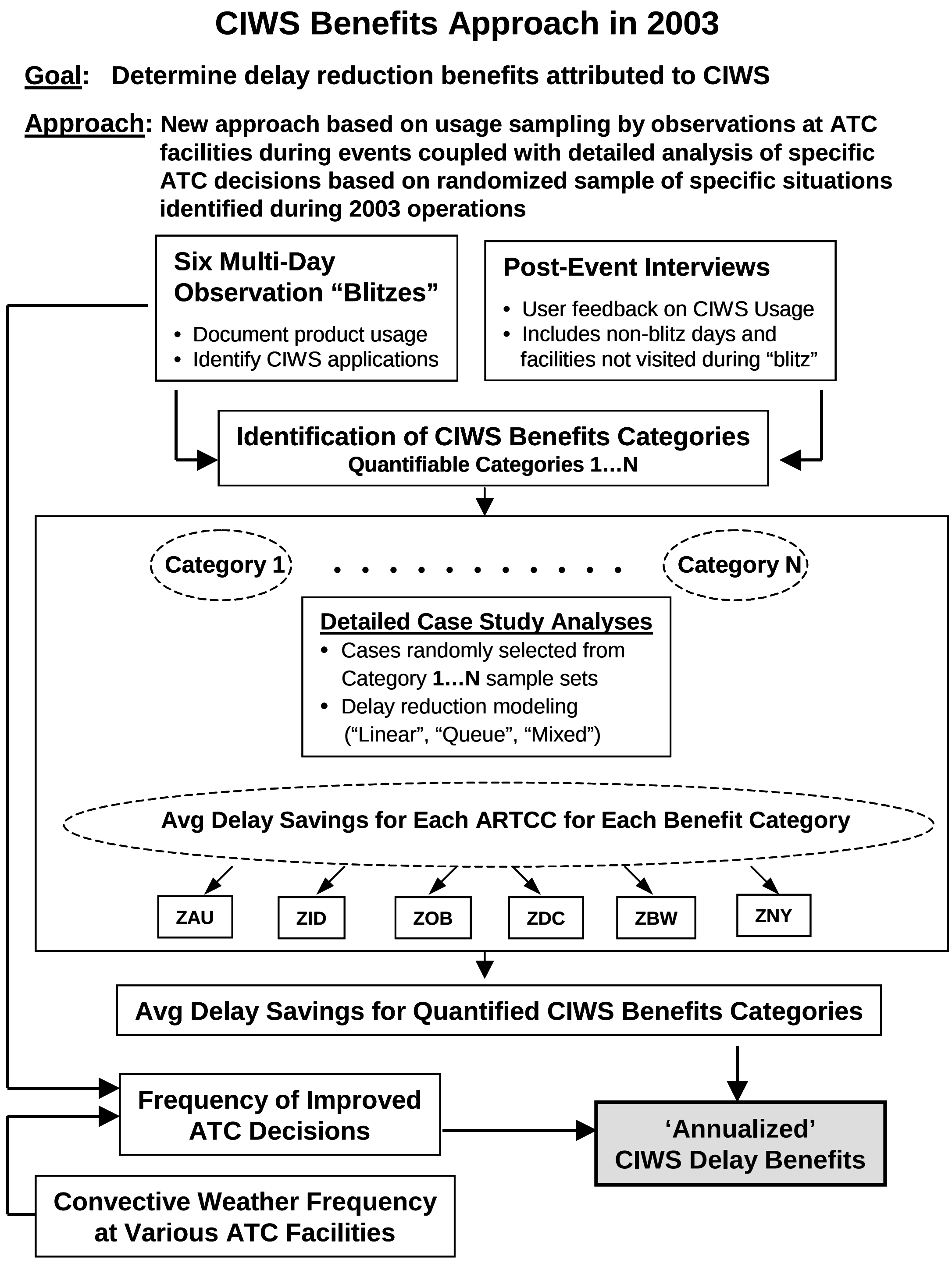


Figure 5-1. Approach taken to determine CIWS operational benefits in 2002.

The 2002 approach was not successful in generating usable quantitative en route delay reduction benefits. Thus, in 2003, we utilized the new approach to benefits quantification shown in Figure 5-2.



CIWS Benefits Approach in 2003

Goal: Determine delay reduction benefits attributed to CIWS

Approach: New approach based on usage sampling by observations at ATC facilities during events coupled with detailed analysis of specific ATC decisions based on randomized sample of specific situations identified during 2003 operations

Figure 5-2. Approach taken in 2003 to estimate the CIWS annual delay reduction benefits.

The new 2003 data collection design would include observers at a number of ATC facilities (and, in some cases airline facilities[16]) during "benefits blitz" time periods in which significant convective weather was expected [Appendix E; Robinson et al., 2004]. These intensive observation periods would be viewed as sampling the population of significant convective weather events at a given facility. Based on both the Lincoln Laboratory personnel observations of users looking at the CIWS displays plus the user statements of ATC decisions they had made using the CIWS products, very detailed statistics could be generated on the frequency with which a given beneficial ATC decision was made using CIWS products per day of significant convective weather.

These statistics could be scaled up to provide an annual frequency of those decisions if one had statistics for the frequency of significant convective weather in a given facility such as were provided in Section 4.3 of this report[17].

Specifically, for a given ATC facility:

# times per day that a particular beneficial ATC decision is made using CIWS products in a certain type of significant convective weather	X	# times per year that type of significant convective weather occurs	=	# times per year (i.e., annual frequency) of a particular beneficial ATC decision

Once one derives an estimate of the average benefit per ATC facility for a particular decision, one can then multiply it by the annual frequency of a given beneficial decision per ATC facility to arrive at an average annual benefit per ATC facility.

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[16] The airline feedback on CIWS benefits will be analyzed in the second phase of the CIWS benefits study and reported in a subsequent report.

[17] The assumption made in this study is that the storm situations "sampled" during the "benefits blitz" events were typical of the population of convective storm events that occurred in the CIWS domain over the summer. On more than one occasion, traffic managers at ZDC informed the CIWS observer during one of several very significant CIWS blitz storm events that it may have been more advantageous, for benefits data collection, for the observer to visit during smaller-scale events. The reason they offered was that during some of the larger storm events at ZDC, impacts were so significant that either (a) the storms completely shut down impacted sections of their airspace with little "wiggle room" for dynamic adjustments using the CIWS products or (b) strong storms in neighboring ARTCCs shut off the flows into ZDC, either reducing traffic so severely that meaningful traffic decisions via CIWS were unnecessary (e.g., demand so low that alternative reroute and/or miles-in-trail decisions carried little meaning and/or offered little in terms of delay reduction) or rendering potential CIWS-derived opportunities moot since no traffic could reach the "benefit zone".

Specifically, for a given ATC facility:

$$\boxed{\text{Average benefit per particular beneficial ATC decision}} \quad \text{X} \quad \text{Annual frequency of a particular beneficial ATC decision} \quad = \quad \text{Average annual benefit for a particular beneficial ATC decision}$$

Summing this average annual benefit (right hand side above) over all the ATC facilities in the Corridor then provides an annual CIWS benefit for that particular beneficial ATC decision.

The challenge, then, is to determine the average benefit for a given ATC decision (boxed term in equation above). This turned out be quite difficult since a critical feature of the highly congested airspace in which CIWS operates is the constrained capacity in <u>both</u> en route and terminal airspace. Hence, one is dealing with multiple queues in a network. As a result of this complexity, each specific case study required detailed analysis of the traffic flows in the network around the times of the ATC decision under study (e.g., keeping a route open), to determine which routes were available and how close the various routes and airports were to full capacity. This information is needed to quantify the consequences of not using the CIWS product (e.g., what would have happened if a given route were closed).

This Chapter proceeds as follows. First, we describe the rationale for the approach taken here as opposed to direct analysis of aviation delay statistics. The major modeling tools used to estimate the hours of delay associated with various situations in which operational benefits were identified are discussed in detail. This is an important section since one of the major challenges in quantifying the CIWS benefits is dealing with the terminal and en route congestion that characterizes convective weather events in the CIWS domain. Finally, we explain how the quantitative results for hours of delay saved were converted to monetary values.

5.1 RATIONALE FOR APPROACH TAKEN TO ESTIMATE DELAY REDUCTION

There are two basic approaches to determining the achieved delay reduction benefits. “Direct” measurement can be used, in which one compares the delays in a baseline time period when CIWS was not in use to delays in a subsequent time period in which CIWS was in use. Alternatively, a “Decision/Modeling” approach can be used, in which user interviews and/or direct observations of decisions made are used to determine the parameters of models that are then used to estimate the delay reduction benefits. The basic assumption is that the weather product is useful only to the extent that it changes user decisions. Thus, one can analyze the various decisions that the users have stated were improved as a result of having access to the weather decision support system under study.

Both of these approaches have been attempted for various past analyses. The pros and cons of the two approaches are shown in Table 5-1. The Lincoln Laboratory experience has been that the Direct method is very hard to carry out in practice even though it appears quite straightforward. Rather, all of the previous analyses of ITWS delay reduction benefits and certain other terminal weather decision support systems (e.g., the TDWR and the ASR-9 Weather System Processor) have proceeded by the modeling approach that was used here.

A very important step in the Decision/Modeling approach is to determine what the key benefits issues will be. First, we determined an initial set of user decisions that were expected to provide significant benefits based on prior studies of operational benefits (see Section 2.2):

- Previous TDWR user interviews by L. Stevenson at the Volpe Transportation Systems Center for the ITWS benefits assessment in 1994-95 at Memphis, Orlando and Dallas
- NY ITWS user interviews by MCR Federal, Inc and Lincoln Laboratory
- Previous discussions with CIWS users including feedback from users at 2001 user group meeting, and the studies of CIWS benefits by CSSI [Modoloni et al., 2001]

The questions asked during the interviews (especially those for the end-of-season interviews in 2002) were closely tied to the models to be used to convert the interview results into quantitative measures of the delay reduction achieved.

Users were interviewed both during and immediately after events, and at the end of the season to determine the parameters associated with the various improved decision making categories (e.g., number of aircraft that might have shorter routes, number of additional aircraft departing per hour, duration of benefit, number of times a benefit typically occurs per day with convective activity, etc). The feedback from operational users modified and extended the set of user decisions to be evaluated as the benefits assessment process proceeded over the summers of 2002 and 2003.

Extremely important results of this process were the realizations that:

- Terminal area operations during convective weather at major terminals such as Chicago, Detroit, and Pittsburgh are very different from the operations at Memphis, Orlando, Dallas and New York

- En route operations in highly congested airspace such as ZOB and ZDC also differ significantly from those analyzed at Fort Worth ARTCC (ZFW), Memphis ARTCC (ZME), and Jacksonville ARTCC (ZJX) as a part of the ITWS benefits studies.

Hence, a number of the delay reduction benefits assessed in this study are new and should be of great interest to researchers of the National Airspace System.

TABLE 5-1

Pros and Cons of Delay Reduction Determination Methodologies

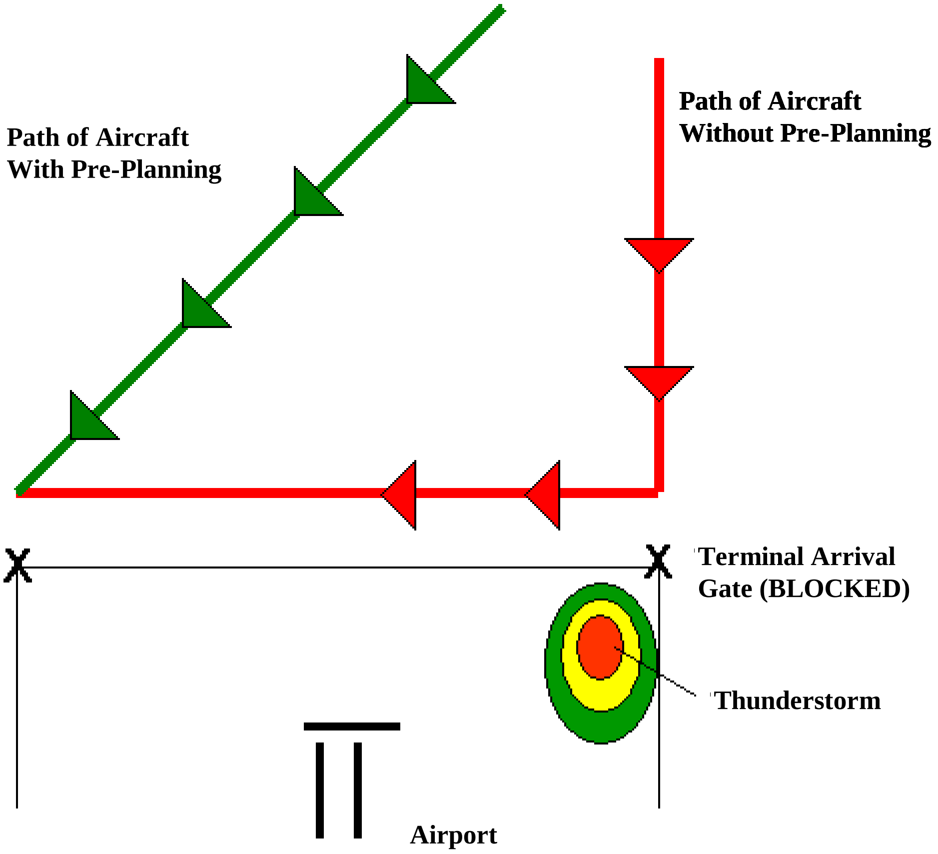
	“Direct” Method	**“Decision/Modeling” Method**
Synopsis	Direct comparison of delay before and after CIWS	FAA operational user interviews and questionnaires + delay modeling
Good features	Actual delay reflects actual cost incurred Easy to explain to recipients of a report	Factors which account for delay reduction are clearly understood Extrapolation to changed circumstances (e.g., operations increases, schedule changes, weather time and duration) is relatively straightforward Only feasible way to assess potential improvement in system products
Problems	Requires very sophisticated knowledge of delay causality to compensate for differences between the “baseline” and “system test” time periods. Factors that must be quantitatively considered are: - Weather (severity, time of day, duration) - Weather in other locations - Traffic changes - Airline operations and scheduling - Air traffic procedures - Traffic flow management changes Not clear which elements of the system account for the delay reduction	May be difficult to validate the approach in some cases Need to make sure that factors considered are independent or that common elements are identified and the impact addressed (e.g., one must make sure one is not counting a factor several times by giving it different names)

5.2 QUANTITATIVE MODELS USED TO DETERMINE DELAY SAVINGS

After the interviews and facility observations, two basic models were used to translate the results into quantitative estimates of the delay reduction benefits. These are described below.

5.2.1 "Linear" Delay Reduction

The first model corresponds to a transient event (e.g., a group of aircraft must fly a longer route) where there is no reduction in the overall average rate of aircraft movement. Figure 5-3 illustrates this for the case of a thunderstorm impacting an entry gate into a terminal area. Other examples of this include optimal rerouting around a region of convective weather, through a gap in a squall line as opposed to flying around the end of the squall line, and flying over a squall line as opposed to flying around the end of the squall line. A key element of this type of delay is that the benefit for improved performance is typically linear in each of the pertinent variables (e.g., traffic density, likelihood of occurrence, ability to realize the benefit in a given situation with an aviation system feature).



$$\text{BENEFIT} = \sum_{\text{Airports}} \underset{\substack{\uparrow \\ \textbf{Scale by Ops/Year}}}{(\text{AIRCRAFT / INCIDENT})} * (\text{SAVINGS / A/C}) * \underset{\substack{\uparrow \\ \textbf{Scale by TSTMS/Year}}}{(\text{INCIDENTS / YEAR})}$$

Figure 5-3. Example of the "fixed" delay linear model as it might be used to analyze a case where a number of aircraft fly a better route due to the use of the CIWS products. Advance planning using CIWS forecasts enables aircraft to fly the direct route shown in green, as opposed to the longer route shown in red.

5.2.2 "Queue" Delay Reduction

Figure 5-4 shows a simple example of the classic queuing situation where the weather reduces the effective capacity of an airspace resource (e.g., a terminal or a route) for some finite time while the demand for the airspace remains constant. This simple queuing model can be used to address both air traffic control/airport reductions in effective terminal capacity and traffic flow management actions by interpreting:

- The effective capacity as the minimum of the air traffic control/airspace constraints on the traffic flow and the flow rate imposed by FAA traffic flow management decisions
- The effective duration as the sum of the actual weather event duration and the time period over which an insufficient number of aircraft are available to utilize the airspace resource due to non-optimal traffic management actions

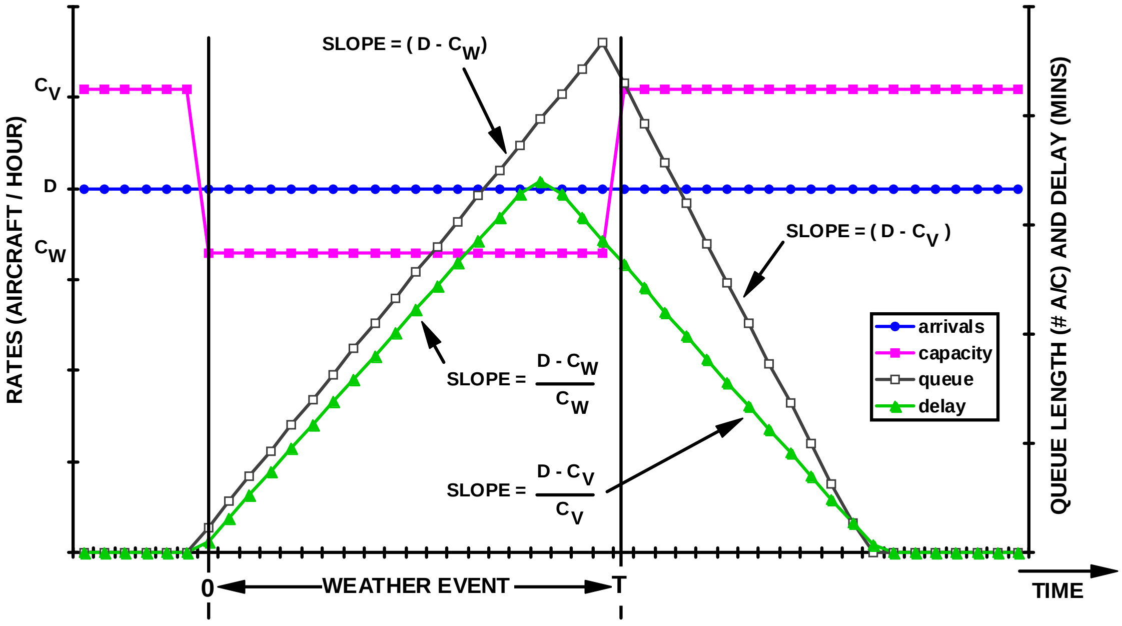


Figure 5-4. Queuing model for delay when adverse weather reduces the effective capacity of an aviation system resource (e.g., a route, an en route sector or a terminal); D = demand, Cw = capacity during adverse weather, Cv = capacity during benign weather, and T = effective event duration (from Evans, 1997).

To illustrate the second bullet above, if an actual weather event at a destination airport lasts for two hours and creates a situation in which a number of aircraft desiring to land at the airport are held on the ground at the respective departure airports, the delay event may be viewed as continuing until the ground hold aircraft are released and land at the destination airport. If forecasts are not used to proactively end the ground hold and the minimum flight time for the aircraft being held on the ground is one hour, then the effective duration is at least three hours.[18]

It is straightforward to show that the accumulated delay for all the aircraft involved in the incident shown in Figure 5-4 is

$$\Sigma(\text{delay to various aircraft}) = 0.5\ T^2\ (D-C_W)\ (C_V-C_W)/(C_V-D) \qquad \text{(Eq. 5-1)}$$

Where again D = demand, C_W = capacity during adverse weather, C_V = capacity during benign weather, and T = effective event duration.

The dependence of delays on the demand and various capacities here is quite nonlinear. For example, we see that small increases in the effective capacity during a weather event, C_W, can produce larger proportional reductions in the accumulated delay because C_W appears in the product of terms.

Since T is squared, reducing the effective duration of a weather event (e.g., by better weather predictions and traffic flow management decision making) can also produce large delay reductions. For example, if a good short-term convective weather prediction enables the ZOB traffic management coordinator to reduce a 3-hour effective duration weather event to 2.5 hours by releasing ground holds, the accumulated delay would be reduced 31 percent.

Equation (5-1) is quite important for understanding the very different delay reduction results that are obtained on the various specific cases in Chapter 6 and Appendices B and C. When the fair weather capacity is close to the demand, one sees major changes in delay for very small changes in C_V. This corresponds to a situation where the airspace resource is highly congested in fair weather. For example, in some cases, a major airport is near capacity at a given time of day in fair weather. In such cases, if convective weather creates a queue of aircraft seeking to use the same airport, the time for an individual flight to get out of the queue can be very long. Similarly, since the equation has differences between the fair weather and bad weather capacities, small fractional changes in the adverse weather capacity can result in large fractional changes in the difference term.

Some of the quantitative queuing results shown in the subsequent sections of this report utilize an enhancement of the very simple queuing model shown in Figure 5-4 in which one allows both the airport (or, en route sector) capacity and the user demand to vary significantly with time. (See Evans et al., 1999 for a description of the model and its validation with measured delay data from Atlanta.) The model is implemented by use of an Excel spreadsheet. Part of the elegance of the model is that it requires only two input fields; demand and capacity as a function of time. Despite the limited input, it was able to model the actual delay fairly well, and was surprisingly accurate in modeling peaks and valleys in the real data.

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[18] The use of holding patterns near the airport (as in the FAA's Managed Arrival Reservoir technique) will result in a more complicated relationship than illustrated in Figure 5-4, but the general principle still remains that ground holds increase the effective duration of a weather event.

To obtain accurate, realistic results from the model, the capacity and demand profiles used to estimate delays were derived from analysis of flight track data for the aviation system resources under study. The demand profile was fairly straightforward. In order to produce a demand that was realistic, we took the demand profile from non-weather days. This profile was assumed to be the actual demand profile on the day in question[19]. An accurate determination of capacity was more difficult. The nominal capacities used for this study varied significantly depending on the scenario. These are discussed with the actual scenarios.

Given the data on capacities and demand, the expected delay can be computed by the model. In this situation, the delay in minutes can be thought of as the minimum delay expected when demand exceeds capacity.

5.2.3 Accounting for Multiple Queues

One of the major complications in the CIWS domain is that capacity may be constrained both at en route sectors and terminals. The en route capacity constraints may be alleviated in some cases by routing traffic through other en route sectors (or, along other routes). However, in doing so, one must be concerned about the possibility of queues developing at the alternative en route resource if the demand with rerouting exceeds the capacity. This is an extremely important issue for actual traffic flow decision making in congested airspace[20] as well as for our offline analysis. We have attempted to address this issue on a case –by-case basis as described in Chapter 6 and in Appendices B and C.

5.2.4 "Mixed" Models

In some cases, a combination of the linear and queue models has been used. An example of this is a situation where flights to a terminal area are rerouted to a different arrival transition area (ATA or "corner post") than the normal (shortest path) corner post, and encounter a queue delay due to the traffic volume at that other ATA. In these cases, there is both an additional distance flown (as illustrated in Figure 5.3) and, there is a queue delay [e.g., given by Equation 5-1]. The need for this type of "mixed" model was fairly apparent when one analyzed specific events as described in Appendix C.

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[19] It would have been desirable to use a number of non-weather days to estimate the demand (e.g., as done in Allan et al., 2001); however, there were relatively few non-weather days in the CIWS domain in 2003 (recall Chapter 4).

[20] In our opinion, many suboptimal traffic flow management decisions are made during convective weather impacts simply because the traffic flow managers cannot readily determine the consequences of various weather mitigation plans for traffic loading on the network. In such cases, very conservative use of the airspace resources generally occurs such that many available airspace resources are not fully utilized which results in far higher delays than needed to occur.

5.2.5 Accounting for Flight Delay Propagation Effects

One of the major factors in both delay modeling and determining delay causality from recorded delay statistics is the "delay ripple" effect which arises when an aircraft is delayed on one leg of a flight (e.g., due to adverse weather) such that the next leg (and subsequent legs) flown by that aircraft that day also are delayed. In cases where the subsequent leg(s) are not weather impacted, the delay on the subsequent legs may not be attributed to terminal weather.

DeArmon [1992] states that "delay ripple is in general pretty strong" and persists over a number of successive legs. Hartman [1993] cites a case where the number of passengers delayed (down line impact) due to delay ripple was 27 times greater than the initial number delayed.

A recent study by a group from American Airlines and Oak Ridge National Laboratory [Beatty et al., 1999] looked at the impact on airline operating resources (specifically aircraft and crews[21]) as a result of an initial delay. They examined the actual impact on the American Airlines operations schedule as a function of both time and amount of delay. They found as the delay on the initial flight increases, the number of flights affected increases as well. The down line impact is shown to be a very nonlinear function of the initial delay and the amount of delay. The end result of their work is a "delay multiplier" table that characterizes the degree of delay propagation as a function of the time of day at which the delay occurs and magnitude of the initial delay encountered.

In our study, we have utilized the approach used in the ITWS delay reduction study conducted by the FAA, the Volpe Transportation Systems Center, and Lincoln Laboratory in 1994-95. Based on the analysis of delays for an aircraft passing through LaGuardia airport, Dr. Steve Boswell of Lincoln Laboratory developed a model in which the amount of delay made up per leg is a random variable [Boswell and Evans, 1997]. This model suggests that the initial delay savings should be multiplied by 1.8 to arrive at the net delay savings (i.e., that the total downstream delay is approximately 80% of the initial delay). It should be noted that this model considers only downstream delays to the aircraft that was initially delayed and ignores the secondary flight impacts that Beatty et al. consider.

The delay multiplier table in Beatty et al., shows that a delay multiplier of 1.8 corresponds to the following envelope of delays and time of day:

Delays of 24 minutes at 8 AM local time
Delays of about 1 hour at 1 PM local time
Delays of about 1.5 hours at 5 PM local time, and
Delays of about 3 hours at 7 PM local time

For the delay events shown in Appendices B and C, the local times ranged from 8 am to 10 pm with the mode at about 5 pm.

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[21] They also note that there are impacts on passengers, cargo and gate space caused by delayed flight operations. However, they were not able to quantify the impacts of delays on those other resources and the extent to which impacts on the other resources would further increase the delay impact. As a result of ignoring these other factors in airline operations, Beatty, et al. suggest that their results are very conservative.

In view of the much larger multiplier factors suggested by Hartman and Beatty et al., we feel that the use of the 80% multiplier is a very conservative method of accounting for the delay propagation effect in estimating the CIWS benefits.

In the follow on phase of the CIWS benefits study, we will investigate applications of the Beatty et al., delay multiplier table in conjunction with the time of delay, along with delays associated with the actual events, to estimate average benefits for each ATC decision (per Figure 5-2).

5.3 CONVERTING HOURS TO DELAY TO MONETARY ESTIMATES

Published FAA values for the costs of an hour of delay to the airlines [FAA APO, 2002] and passengers [APO Bulletin, APO-03-01, 2003] were used in the detailed computations in Chapter 6 and Appendices B and C to determine monetary estimates for CIWS delay savings:

Airline direct operating cost (DOC): $2635 per hour for scheduled commercial aircraft
$202 per hour for general aviation aircraft
$616 per hour for scheduled commuters only

Passenger time cost: $28.60 per passenger per hour for commercial flights
$37.20 per passenger per hour for general aviation (GA) flights

Ideally, one would consider the types of aircraft and the number of passengers on each of the flights involved in a given CIWS benefits calculation. It would be possible to determine typical aircraft type distributions and passenger loads for the various air routes and airports. However, time did not permit developing these detailed models in this phase of the study. Given that the New York TRACON was a major origin and destination for the CIWS domain flights, we used the average DOC and passenger time conversion factors used for the Newark International Airport (EWR) in the NY ITWS study [Allan et al., 2001] for this study.

Additional care was taken to differentiate airborne vs. ground delay costs by reducing DOC estimates for the latter by 40% to account for the reduced fuel rate on the ground compared with fuel rate during aircraft climb or cruise. Examination of crew vs. fuel costs for a representative aircraft fleet mix [FAA APO, APO-098-8 – Form 41, 1998 (inflated to 2003)] confirms 0.6DOC for ground delay as an acceptable delay cost conversion factor.

In section 5.2.5, we discussed the very significant impact of reduced flight delay propagation on the overall delay savings provided by a system such as CIWS. There is general agreement that the passenger time associated with the reduction in downstream delay should be included in the monetary value calculations. However, there is no clear agreement as to how airline cost savings should be included. Some recent benefits studies have ignored the airline cost savings associated with downstream delay propagation. On the other hand, Beatty et al., [1999] point out that airlines have appreciable expenses due to impacts on crew times, other aircraft, cargo and gate space. Although Beatty et al., quantify how crew and aircraft constraints that arise out of tight connectivity between operating resources for an airline propagate, resulting in delays to many flights, they do not provide a cost model for converting the "down line" delay to a monetary value.

Since crew time is clearly a significant operations cost factor to airlines, we have had informal discussions with a number of major airlines to determine whether there are crew costs associated with extra duty time that do not involve aircraft operation. We have learned from several major airlines that crews are paid if their duty time is increased even though they are not flying a plane (e.g., waiting for equipment to arrive). A typical feedback (from a major airline) on this topic was as follows:

> "Crews receive duty pay during times that they are scheduled to operate an aircraft, but are not actually doing so. This pay is considerably lower than flight time pay that is earned during the time of brakes release to brakes re-application. The bottom line is, crews are paid for their time, but the rate depends upon whether they are actually operating the aircraft."

The exact amount that the crews are paid varies from airline to airline. There is great sensitivity to the exact amount that crews are paid for duty time that does not involve aircraft operation (apparently because of labor contract differences between the various airlines).

In addition to crew time costs, there are also airline costs associated with ground personnel duty time and the loss of passenger revenue on downstream flights (due to passengers switching to other carriers and missed connection costs[22]). We know of no models that have quantified these costs as a function of the amount of delay and the time of day.

Hence, for this study we have used two different models:

Downstream Model 1 (DM-1): Airline operations costs incurred on downstream delays

The main assumption in the DM-1 approach to determining downstream delay costs is that airline operations costs are incurred due to downstream delays caused by an initial delay. These operations costs include crew time, ground personnel time and costs associated with handling passengers that have been delayed. We have approximated these airline operations costs associated with the downstream delay by the crew costs associated with the DOC.

Operating cost associated with total delay (primary + downstream) using DM-1 can be shown as:

$$\text{DM-1} = [(\text{DOC} * A) + (0.6\text{DOC} * G)] + (0.6\text{DOC} * DS) \qquad \text{(Eq. 5-2)}$$

Where DOC = direct operating cost, A = hours of airborne delay, G = hours of ground delay, and DS = hours of downstream delay.

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[22] e.g., the costs to put the missed-connection passengers up over night and/or transport the passengers to their final destination on a different carrier

Downstream Model (DM-2): No airline operating costs incurred on downstream delays

Based upon recent feedback from MCR Federal, Inc. regarding delay savings estimation procedures, the DM-2 model is included to represent CIWS delay savings results assuming no airline operating costs are incurred with downstream delay.

Operating cost associated with total delay (primary + downstream) using DM-2 can be shown as:

$$\text{DM-2} = [(\text{DOC} * \text{A}) + (0.6\text{DOC} * \text{G})] \qquad \text{(Eq. 5-3)}$$

The difference between equations 5-2 and 5-3 is that with DM-2, the downstream delay operating cost term is zeroed out. Passenger costs are assumed for both primary and downstream delay and added to operating cost estimates from both DM-1 and DM-2.

For completeness, DM-1 and DM-2 operating cost calculations are included with all CIWS delay savings results[23] presented in this report (e.g., Chapters 6 and 7; Appendices B and C).

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[23] The calculated *hours* of delay savings are independent of cost-conversion model.

6. CASE STUDIES OF SIGNIFICANT CIWS DELAY REDUCTION EVENTS

In this section we describe the results of the analysis of four specific delay reduction events during the 2002 and 2003 storm seasons. These events were flagged for study based upon post-event interviews with users[24]. Three case studies were selected for independent analysis to demonstrate that on occasion, CIWS delay savings during convective events can be quite substantial (because of prolonged benefit periods, applications which significantly improved capacity or both). Results from these "Mega-Event" investigations were not included in roll-up statistics used to determine annual CIWS delay reductions for specific benefit categories (see Chapter 7) in order to ensure results from limited sample sets in this Phase of our analysis were conservative. An additional case study involving the use of CIWS to avoid an airport ground stop program is also presented in this section as an example of realized delay savings from other applications not explicitly discussed in this Phase of benefits reporting. Because the significance of these events was recognized in near real-time, it was possible to assemble a substantial amount of information for analysis and wholly investigate optimal modeling approaches suitable for these unique case studies. The analysis of the cases presented here provided very useful practical experience in CIWS domain analyses that enabled us to much more rapidly analyze similar cases, investigated later and described in Appendices B and C.

6.1 10-11 JULY 2003 – ROUTES KEPT OPEN AND IMPROVED REROUTES VIA STORM OVER FLIGHTS

6.1.1 Weather Conditions

A cluster of thunderstorms developed in west-central ZID airspace near 1700 UTC and quickly organized, intensified, and expanded into a solid squall line. The line of convection continued to grow, extending well into ZOB airspace and eventually impacting key routes such as J60 and J64. By 2100 UTC, the solid line of storms impacted airspace from west-central Pennsylvania to Mississippi (Figure 6-1). The squall line tracked steadily eastward with time, slowly weakening and breaking apart as it entered ZDC airspace. Any relief afforded to NAS operations at this time by the decaying squall line was countered by the development of scattered, strong storm cells throughout ZDC airspace between 2300 – 0100 UTC. Convective remnants of the squall line, as well as isolated storm cells, continued to impact ZDC and ZNY airspace through 0500 UTC on 11 July 2003.

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[24] Analysis of 2002 post-event user feedback is presented in Appendix D, demonstrating the contributory importance of this data collection approach to the overall CIWS benefits analysis while at the same time, underscoring the need for the more intensive "blitz" observation approach to identifying CIWS applications.

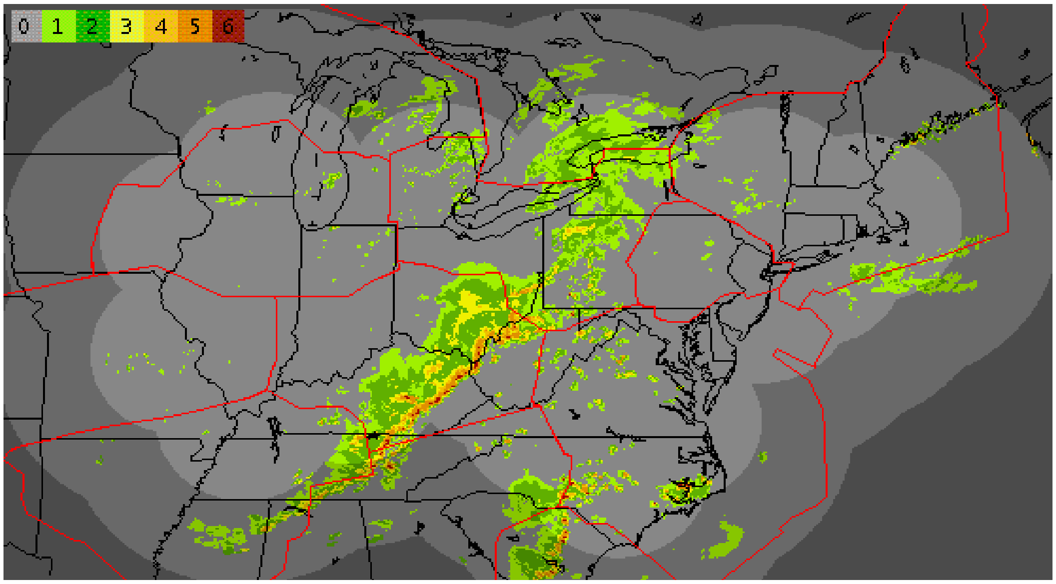

Figure 6-1. Storm coverage at 2100 UTC on 10 July 2003, as depicted by the CIWS NEXRAD VIL Precipitation product. Convection with intensity of level 4 or greater existed in a solid line from west-central Pennsylvania to Mississippi. Reroute options in dealing with the large squall line were further complicated by additional regions of significant convection in ZDC and ZJX airspace.

6.1.2 CIWS Benefits Cited From Interviews with Traffic Facilities

As the squall line intensified and expanded during the afternoon hours, routing options for traffic to and from the major east coast airports became extremely limited. After 1800 UTC, the solid convective line impacted key airways for metro NY traffic, J60 and J64, when demand for these airports is usually most substantial. The squall line located in en route airspace impacted all preferred arrival and departure routes for Philadelphia (PHL) traffic apart from the east coast. Moreover, reroute options for PHL traffic on impacted preferred routes were extremely limited since (a) to the south, the line extended to the Gulf Coast states and additional storms were building in ZDC airspace and (b) less impacted routes to the north of the squall line were being utilized by metro NY traffic flows.

Though storm intensities within the squall line were significant, the CIWS Echo Tops product demonstrated that the northern portion of the line in ZOB airspace possessed echo tops generally less than 30 kft (Figure 6-2). During post-event interviews with personnel at ATCSCC, the National Traffic Management Officer (NTMO) on duty during this weather event informed the CIWS interviewers that CIWS echo tops information was used to identify routes for PHL and NY traffic *over* low-topped convection.

Specifically, in coordination with ZOB and ZNY traffic managers, ATCSCC used CIWS to (a) move metro NY traffic (already over flying low-topped storms on routes J60 and J64) further north on relatively clear routes through northern ZNY/ZBW airspace and then (b) reroute all PHL westbound departures using J60 and J64 (Figure 6-3). Traffic managers at ATCSCC added that without the CIWS Echo Tops product, quick, decisive assessment of the low-topped nature of strong thunderstorms through ZOB airspace would not have been possible, and no reroute options would have existed for PHL traffic beyond the east coast.

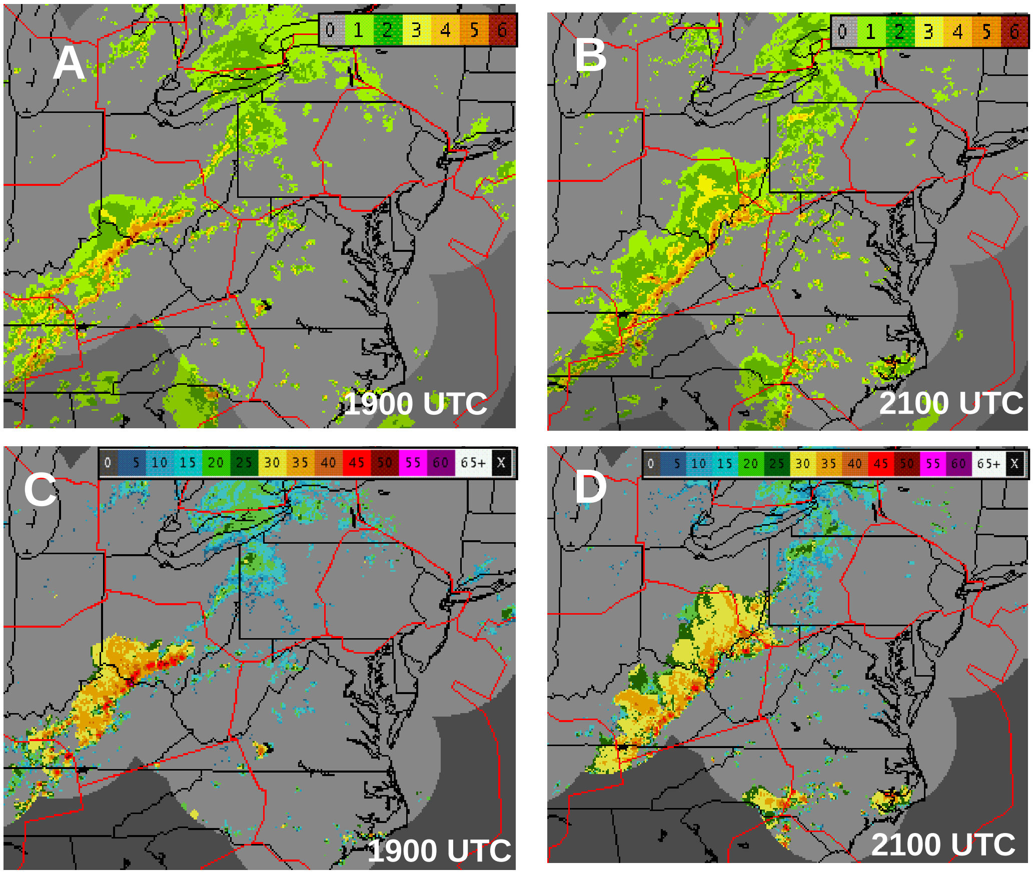

Figure 6-2. CIWS NEXRAD VIL Precipitation and Echo Tops products at 1900 and 2100 UTC on 10 July 2003. By 1900 UTC (a), the squall line was well formed across ZID airspace and filling in across southern ZOB airspace at 2100 UTC (b). The CIWS Echo Tops product (c), (d) informed traffic managers that echo tops associated with level 3-4+ convection comprising the north-end of the line were routinely less than 30Kft. This realization of usable airspace offered significant reroute capabilities for PHL traffic.

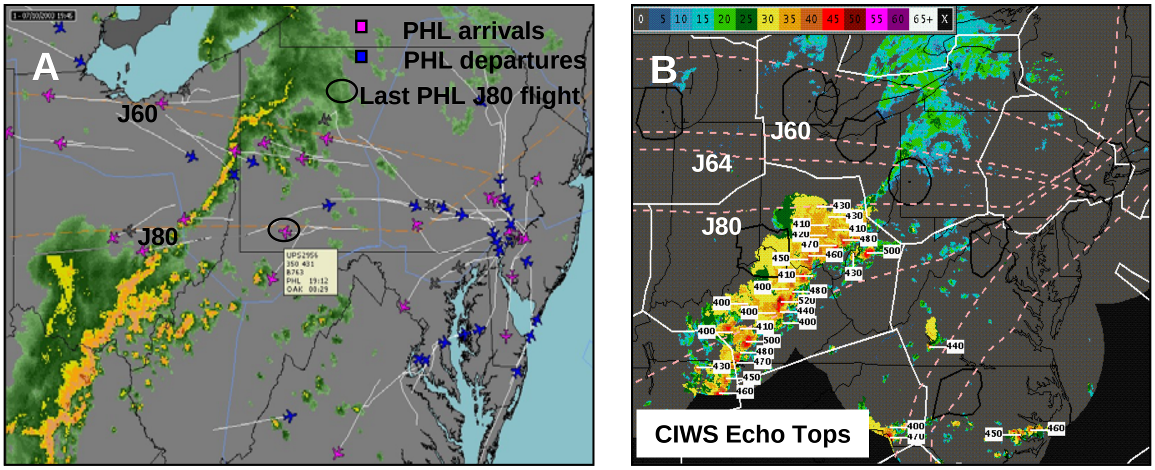

Figure 6-3. (a) Flight Explorer flight track and WSI composite reflectivity data and (b) CIWS Echo Tops products at 1950 UTC on 10 July 2003. PHL westbound departures (shown in pink) were rerouted to J60 and J64 with knowledge that the line of storms in this region possessed low storm top heights. PHL eastbound arrivals through ZOB (shown in blue) were also allowed to fly preferred routes by way of CIWS-derived storm over flights. The circled UPS aircraft was the last flight to utilize its nominal J80 westbound route (before storms closed the airway).

6.1.3 CIWS Delay Reduction Benefits

During the 10 July 2003 storm event, ATCSCC traffic managers informed the CIWS interviewers that recognition of storm over flight opportunities by utilizing CIWS helped to significantly reduce delays at PHL airport. Moreover, before being rerouted to J36/J95 jet routes to allow for the PHL reroute, metro NY traffic was also utilizing J60 and J64 by way of CIWS-derived storm over flights. Without CIWS echo tops information, the reroute of NY traffic to J36/J95, with associated 20 MIT restrictions, would have occurred two hours earlier. A queuing model was used to estimate the CIWS delay savings realized at PHL, EWR, JFK, and LGA airports due to improved reroute planning and allowing key routes to remain open longer.

The periods of CIWS benefits, determined for the PHL airport, were 1745-0300 UTC for eastbound arrivals and 1815-0315 UTC for westbound departures. These time periods were based upon observed storm over flights on preferred routes (arrivals) and implemented reroutes over low-topped convection (departures) enabled by CIWS weather products. During this 9 hr benefit period, over 200 PHL flights were observed flying over strong convection (level 3+ intensity) west of the airport (Table 6-1).

TABLE 6-1

10-11 July 2003 PHL Storm Over Flights

PHL Traffic	Storm Over Flights	Benefit Period (UTC)
Arrivals	96	1745 – 0300
Departures	105	1815 - 0315

ETMS flight track data were used to determine route-based demand and capacity profiles for the purposes of queuing delay calculations. The departure demand profile was based upon actual flight counts on preferred westbound routes (J110, J60, and J64) on the nearest, non-weather, non-delay weekday, with care taken to account for cancellations. Westbound departures on 10-11 July utilizing J60, J64 (implemented reroute assisted by CIWS) and J110 (impacted route) represented the realized PHL departure capacity during the storm event. The calculated delay based on the demand/capacity profile for routes actually used by PHL westbound departures represents the realized delay during the 10-11 July convective event. To determine delay savings attributed to CIWS, the queuing model was run a second time with demand unchanged but capacity during the benefit period reduced to account for only those flights departing via J110 (i.e., no reroutes). Without the CIWS benefit, the lack of routes reduced the expected capacity for PHL westbound departures to zero for several consecutive hours. The difference in calculated queuing delay between the two model runs (with and without westbound routes) constituted the primary CIWS delay savings for PHL departures on 10-11 July 2003.

The same modeling approach was adopted to determine delay savings for PHL eastbound arrivals. Delay savings were modeled based on assumptions that ultimately, weather information provided by CIWS assisted in mitigating restrictions in acceptance rate restrictions for ground delay programs implemented on this day. In other words, without assistance by CIWS in identifying over flight opportunities for arrival and departure streams, a prolonged, imbalance in demand on PHL airport would have required more aggressive ground delay programs allowing fewer arriving flights per hour. The potential decrease in capacity had no CIWS benefit been realized, was based upon the ratio of eastbound arrivals traversing ZOB/ZNY by way of storm over flights to total PHL arrival traffic. Demand profiles were again based upon actual flight counts on the nearest, non-weather, non-delay weekday.

Finally, the queuing model approach was employed to calculate delay savings for EWR, LGA, and JFK departures which utilized J60 and J64 jet routes from 1815-2000 UTC by way of CIWS-derived storm over flights. By 2000 UTC, departures were moved north onto routes J36 and J95 to accommodate the PHL reroute. Delay savings were calculated by adjusting model capacity profiles to estimate the reduced rates, had NY traffic been moved to alternative routes and restricted to 20 miles-in-trail 1.5 hours earlier (i.e., no J60/J64 storm over flights).

Total CIWS delay savings for PHL and metro NY during the 10-11 July 2003 storm event are presented in Table 6-2. In general, departure delay savings were significantly greater than arrival savings, as identification of usable departure routes by way of storm over flights was by far the most important application of CIWS weather products for this event. Accounting for passenger costs and estimated commercial airline direct operating costs (with consideration for reduced fuel costs for delays incurred on the ground), the 800+ hours of total delay saving attributed to CIWS for these airports converts to monetary savings greater than $2,500,000.

TABLE 6-2

10-11 July 2003 CIWS Delay Reduction Benefits

Airport	Arrival Delay Saved (hours)	Departure Delay Saved (hours)	Primary Delay Saved (hours)	Total Delay Saved * (hours)	Savings ** (DM-1) ✦ (DM-2)
PHL †	47.0	244.4	291.4	524.5	$1,969,498 $1,600,966
LGA, EWR, JFK ††	Negligible	167.0	167.0	300.6	$1,128,753 $917,531
TOTAL	47.0	411.4	458.4	**825.1**	**$3,098,251** **$2,518,498**

* Total Delay = Primary + Downstream

** Savings = Operating + Passenger Cost saved

† PHL Benefit Period: 7 hr

†† LGA, EWR, JFK Benefit Period: 1.5 hr

✦ DM-1 and DM-2 are described in section 5.3

6.2 29-30 AUGUST 2003 – PROLONGED USE OF ROUTE THROUGH LINE OF STORMS

6.2.1 Weather Conditions

A persistent broken to solid line of strong thunderstorms moved eastward through the Great Lakes air traffic corridor throughout the day on 29 August 2003. The convective system became more organized during the afternoon hours and by 1800 UTC, a line of storms stretched from Ottawa, Canada southwestward to southern Indiana (Figure 6-4). In addition, smaller, but still formidable, storm clusters and isolated strong cells were present both west and east of the main squall line, further hampering air traffic operations on this day. Storm gaps within the squall line opened on occasion as the system tracked eastward during the evening hours, but coverage and severity of the convective complex remained significant beyond 0200 UTC on 30 August. Air traffic delays were significant throughout the Great Lakes and Northeast corridors, because of both en route and terminal storm impacts.

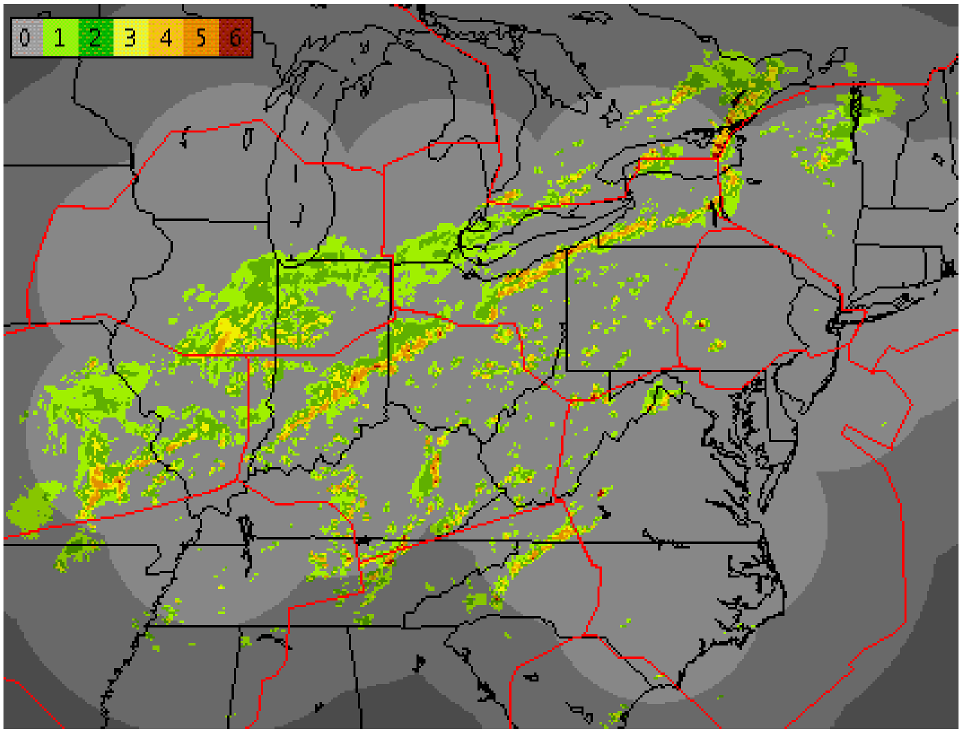

Figure 6-4. Thunderstorm coverage in the Midwest and Northeast U.S. at 1800 UTC on 29 August 2003, as depicted by the CIWS NEXRAD VIL Precipitation product.

6.2.2 CIWS Benefits Cited from Interviews with Traffic Facilities

The intensity and extent of the squall line through the CIWS coverage domain by late afternoon was such that it severely limited routing options for east-west traffic throughout the Midwest, Northeast, and Mid-Atlantic regions. Of particular concern was traffic to and from airports within ZBW airspace, where strong convection threatened to completely block routes beyond the east coast. Based upon the 2 hr CCFP forecast valid at 2100 UTC, conditions were expected to worsen for ZBW operations, as previously forecasted regions of “low-coverage” convection were predicted to fill in and completely block east-west routes through western portions of this en route Center (Figure 6-5).

During post-event interviews, ZBW traffic managers informed the CIWS interviewers that contrary to the CCFP forecast, the CIWS 2-hour convective forecast product predicted an operationally useful storm gap through the convective line near Syracuse (SYR), New York. As the existence of this gap was predicted to persist with each successive 5 min update of the RCWF product, and through each 15-min forecast increment from +15 to +120 min, ZBW traffic managers gained confidence in moving significant streams of eastbound and westbound traffic through the weather opening in upstate New York (Figure 6-6). The traffic managers interviewed pointedly remarked that moving eastbound *and* westbound traffic through a relatively small gap in weather such as existed on 29 August was a rare occurrence in terms of storm gap exploitation.

However, they noted that this gap was their only option for entering and exiting ZBW airspace to the west, so significant traffic was moved through this region over a prolonged period. Additionally, it was revealed by traffic managers during the post-event interview that had the CIWS forecast of a persistent storm gap in the convective line not been available, traffic would have "at best" trickled to/from the west and all airports within ZBW airspace would have been restricted by ground stops. Moreover, since CIWS facilitated high capacity traffic flows on routes through the storm gap in upstate New York, significant ZBW departure backlogs were prevented. As a consequence, the ZBW ARTCC was also able to accept LGA westbound departures via this storm gap, thus helping to alleviate gridlock conditions at this airport due to storms in ZNY airspace.

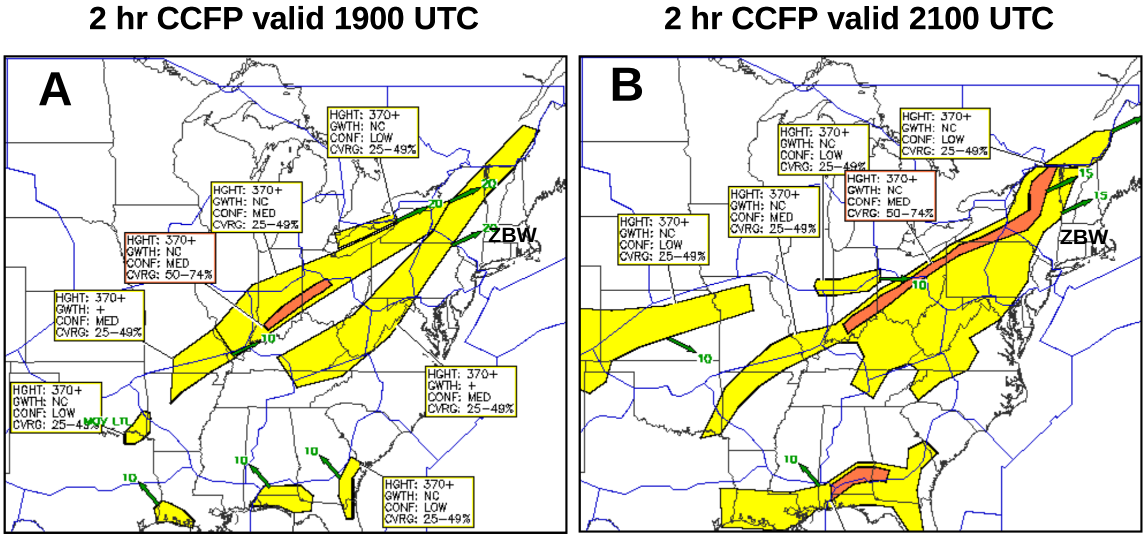

Figure 6-5. 2 hr CCFP forecast valid at (a) 1900 UTC and (b) 2100 UTC on 29 August 2003. By 2100 UTC, this product predicted with "medium" confidence increased coverage of significant convection, forming a solid line completely blocking western ZBW airspace.

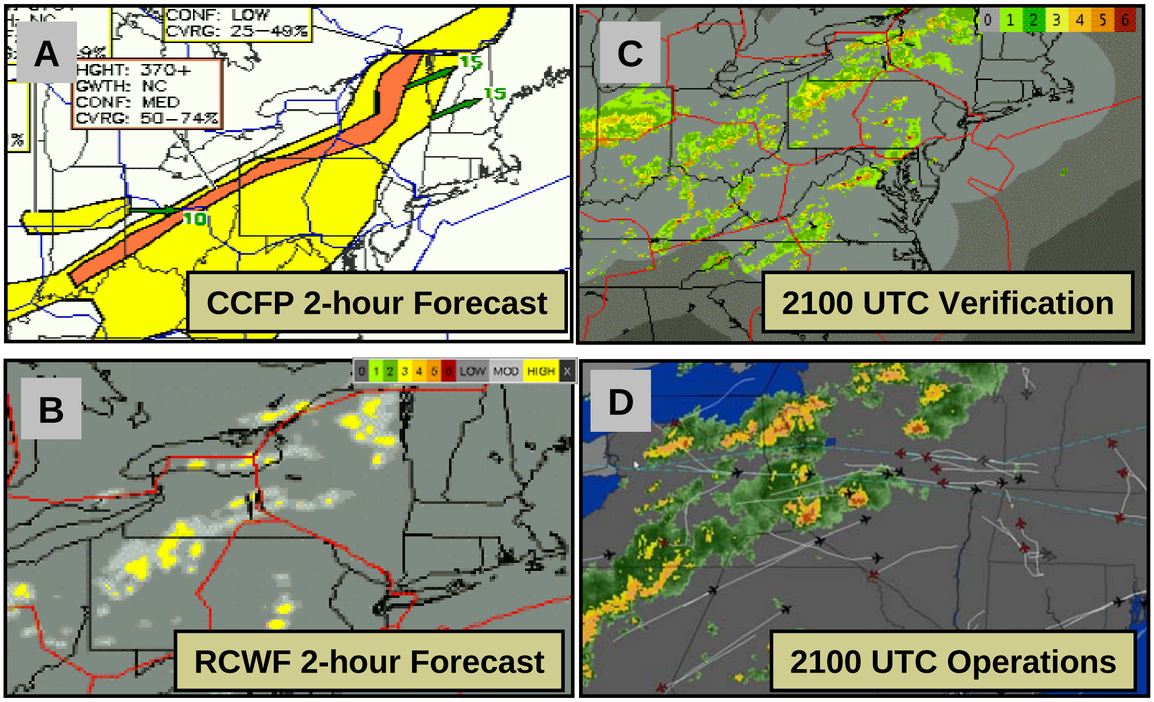

Figure 6-6 (a) 2 hr CCFP forecast valid 2100 UTC, (b) 2 hr CIWS RCWF product valid 2100 UTC, (c) CIWS NEXRAD VIL Precipitation at 2100 UTC, and (d) Flightexplorer flight track and WSI composite reflectivity information at 2100 UTC on 29 August 2003 depicting Boston Logan, Bradley, and Manchester arrivals (black aircraft) and departures (red aircraft) utilizing the storm gap forecasted by CIWS in western ZBW airspace. The accurate forecast of this persistent thunderstorm gap by CIWS allowed ZBW traffic managers to direct a substantial number of aircraft on this east-west route, significantly reducing delay.

6.2.3 CIWS Delay Reduction Benefits

The benefit for this storm event was that westbound departures from ZBW airports were able to avoid ground stop restrictions, once it was determined by using CIWS weather products that the storm gap across Upstate New York would persist. Moreover, traffic managers stated that confidence in the CIWS forecast, based on accurate verifications, allowed them to open routes to eastbound and westbound traffic at significantly greater capacities. A queuing model was utilized to quantify delay savings attributable to CIWS for three ZBW airports: Boston (BOS), Bradley (BDL), and Manchester (MHT).

Demand profiles for arrivals and departures for each airport were determined by enumerating flights on the nearest, non-weather, non-delay weekday. All traffic traveling preferred routes along the east coast, away from the 29 August storm impact region, were removed from all calculations. To model actual delays during the storm event, capacity profiles for these same routes through the storm impact region were determined based upon actual air traffic through western ZBW airspace (i.e., utilizing the persistent storm gap). To model delay for the case without CIWS benefits, arrival and departure capacities at each airport were reduced with the assumptions that an initial 2 hr ground stop for arrivals would have been implemented, followed by reduced traffic rates during the rest of the benefit period. To estimate the traffic flow reduction associated with the ground stop, arrival and departure capacities for each airport were reduced by 50% and 75%, respectively, of the observed flight counts through western ZBW airspace. The benefit period for each airport was based upon the time at which the first and last arrival/departure was observed utilizing routes through the CIWS-forecasted storm gap. Finally, westbound departures from LGA airport, which utilized the ZBW storm gap, were also modeled. Similar logic was used to estimate the capacity had the gap suggested by CIWS not been used. Total delay savings for BOS, BDL, MHT, and LGA on 29-30 August 2003 are presented in Table 6-3. In all, over 1900 hours of delay were saved, resulting in cost savings exceeding $7,000,000; assuming airline crew costs are incurred on downstream delay. Even when assuming no airline cost associated with downstream delay, cost savings attributed to CIWS still exceed $5,900,000. The CIWS delay savings estimated for this storm event are considered conservative since additional ZBW airports such as Providence (PVD) and Portland, ME (PWM) were not included in this study. Arrivals and departures from these airports were also observed entering and exiting ZBW airspace by way of the storm gap across upstate New York.

TABLE 6-3

29-30 August 2003 CIWS Delay Reduction Benefits

Airport	**Benefit Period (hours)**	**Arrival Delay Saved (hours)**	**Departure Delay Saved (hours)**	**Primary Delay Saved (hours)**	**Total Delay Saved * (hours)**	**Savings **** **(DM-1) ✦** **(DM-2)**
BOS	6(A), 7(D)	358.0	326.6	684.6	1232.3	$4,627,287 $3,761,373
BDL	5(A), 8(D)	77.6	137.2	214.8	386.6	$1,451,683 $1,180,067
MHT	7(A), 7(D)	101.7	64.5	166.2	299.1	$1,123,121 $913,006
LGA	2 (D)	-	9.3	9.3	16.7	$62,709 $51,009
TOTAL		537.3	537.6	1074.9	**1934.7**	**$7,264,799** **$5,905,455**

(A) Benefit Period for Arrivals
(B) Benefit Period for Departures
* Total Delay = Primary + Downstream
** Savings = Operating + Passenger Cost saved

✦ DM-1 and DM-2 are described in section 5.3

6.3 18 JULY 2002 – AVOIDING PIT GROUND STOP DURING WIDESPREAD STORM EVENT

6.3.1 Weather Conditions

The atmosphere within the entire Great Lakes and Northeast travel corridors was ripe for convective development, as is typical during mid-Summer months. Widespread, disorganized air-mass thunderstorms developed across Ohio, western Pennsylvania, and West Virginia during the early afternoon. Storms intensified and increased in number over the next several hours and by 2000 UTC, significant level 5-6 convective cells were present throughout the Midwest and Northeast (Figure 6-7). At this time, several level 5-6 storm cells were impacting the Pittsburgh (PIT) TRACON and southern ZOB airspace (Figure 6-8).

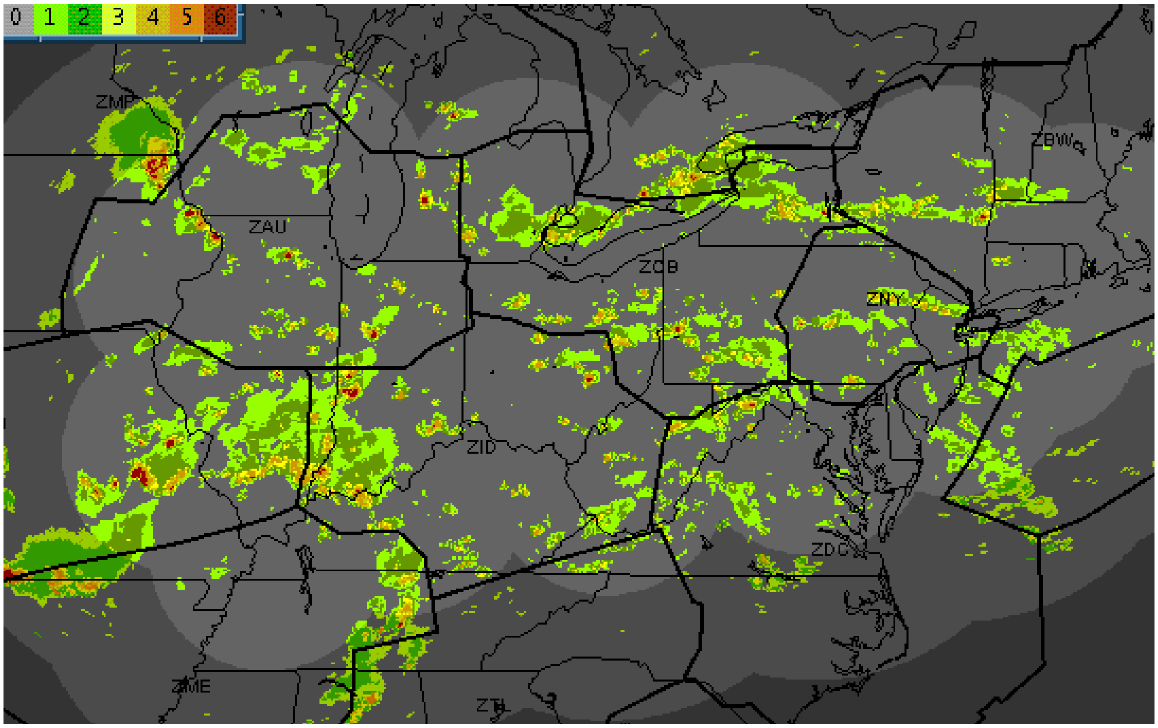

Figure 6-7. Widespread outbreak of disorganized thunderstorms at 2000 UTC on 18 July 2002, as depicted by the CIWS NEXRAD VIL Precipitation product.

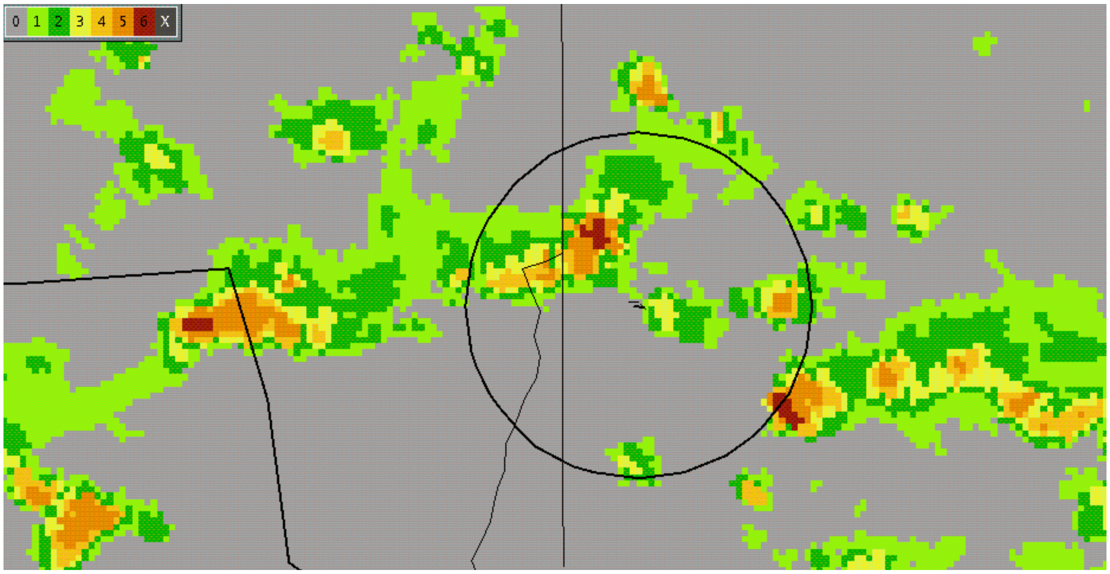

Figure 6-8. Strong thunderstorms (as depicted by CIWS NEXRAD VIL Precipitation) in and around the PIT TRACON (black circle) at 2015 UTC on 18 July 2002.

6.3.2 CIWS Benefits Cited from Interviews with ZOB ARTCC Facility

Despite the direct impact of several strong thunderstorms on PIT air traffic operations during the time of a large arrival bank, a ground stop at the airport was averted. The event had the potential of creating significant delays, but the actual delays were limited. In a post-event interview, traffic managers at the ZOB ARTCC relayed to the CIWS interviewer that CIWS was used to identify that a PIT ground stop would not be needed. Specifically, the CIWS incremental 60-minute[25] convective weather forecast product (Figure 6-9) was utilized to note that although widespread, disorganized storm cells were present throughout Ohio and Pennsylvania, and predicted to move into the TRACON (which they did), convective activity would remain sufficiently scattered to allow arrival approaches to remain open throughout the late afternoon push. Additionally, CIWS echo tops information showed ZOB traffic management that storms near PIT TRACON possessed lower echo top heights and were thus likely weaker than storms impacting other areas of the Great Lakes Corridor (Figure 6-10). CIWS depictions of storm echo tops heights generally less than 30,000 ft in southern ZOB airspace provided traffic management with additional confidence in their initial decision, based upon the convective forecast, to leave the airport open.

ZOB Traffic Managers stated that had CIWS not been available during this storm event, they would have definitely implemented a traffic ground stop at PIT airport. They added that this ground stop would have likely involved all Second-Tier facilities (Figure 6-11).

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[25] The extension of the CIWS forecast product from 60 min to 120 min did not occur until 15 August 2002. Thus, CIWS forecasts beyond 60 min were not available during the 18 July 2002 storm event.

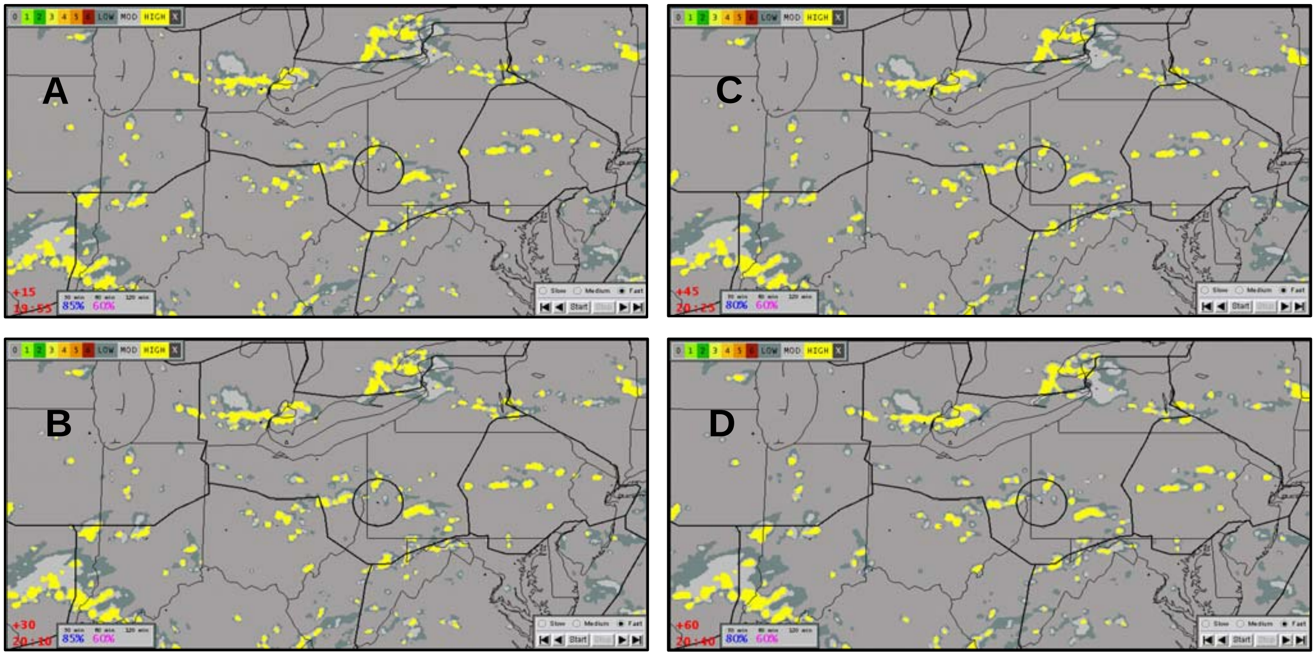

Figure 6-9. CIWS RCWF product issued at 1940 UTC on 18 July 2002. Shown here are forecasts of low, moderate, and high probability of level 3+ precipitation in 15-min increments valid at (a) 1955 UTC, (b) 2010 UTC, (c) 2025 UTC, and (d) 2040 UTC. Real-time forecast accuracy scores at 30-min (blue) and 60-min (magenta) are provided at lower left of each forecast image.

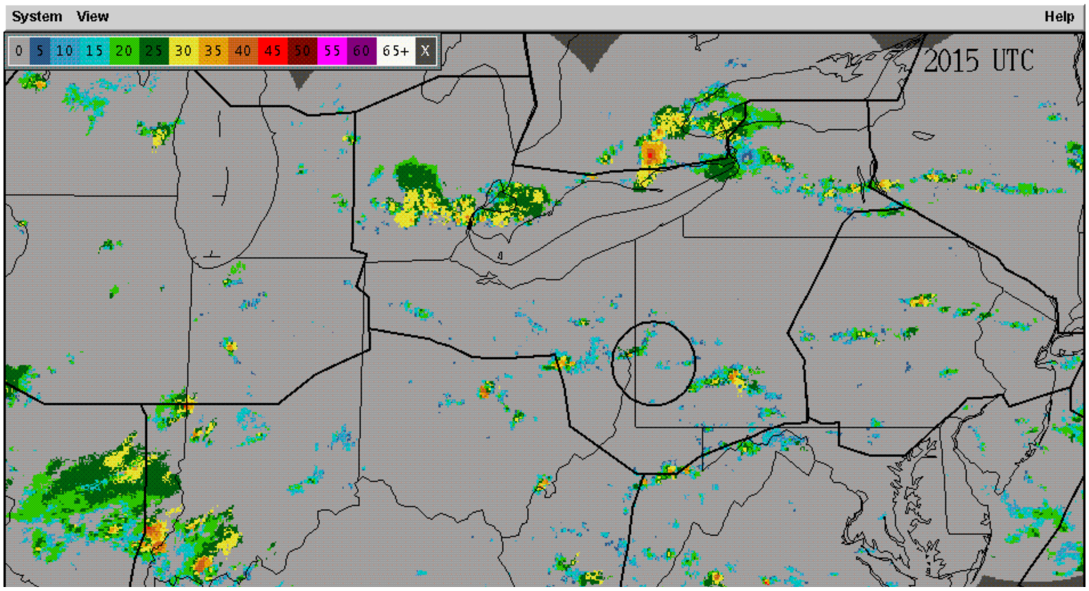

Figure 6-10. CIWS Echo Tops Mosaic at 2015 UTC on 18 July 2002. Though this mosaic was not available until 15 August 2002, traffic managers, using echo tops annotations available at the time via the CIWS NEXRAD VIL product, came to similar conclusions as those evident from the mosaic: scattered storm echo top heights near PIT TRACON were routinely lower than other impacted regions in the Midwest and Great Lakes regions.

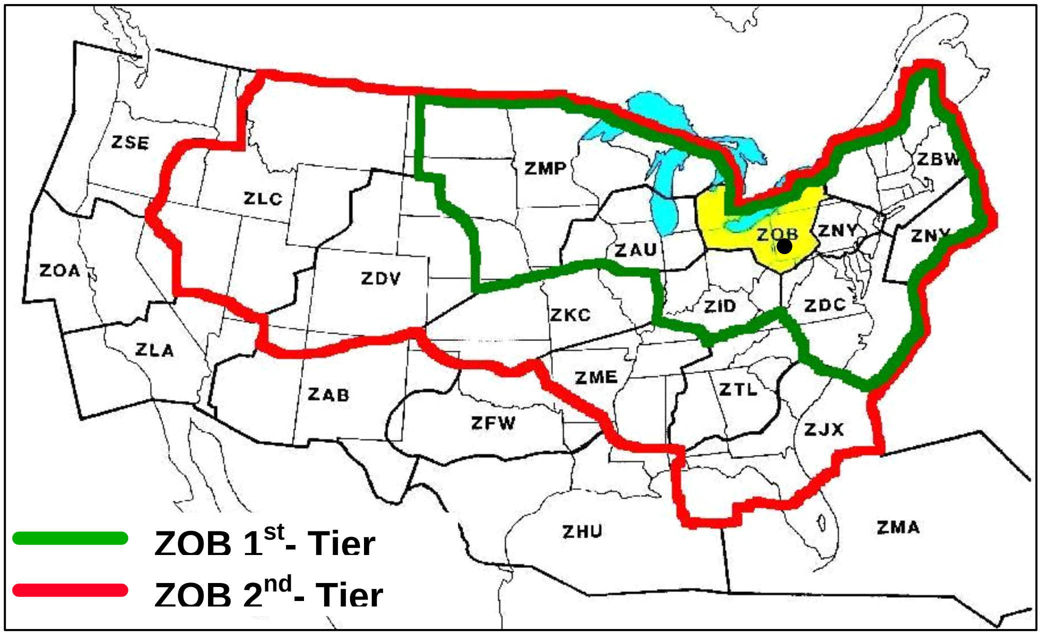

Figure 6-11. Facilities that would have been involved in first and second-tier Pittsburgh ground stops. The black circle in ZOB airspace represents PIT TRACON. ZOB traffic managers stated that CIWS usage on 18 July 2002 allowed them to avoid a second-tier ground stop at PIT.

6.3.3 Delay Reduction Benefits Using Queuing Model

To estimate the delay savings attributed to CIWS for this event, a simple queuing model is employed.

For this case study, the model was run twice in order to determine (a) representative arrival delays that were actually incurred at PIT on 18 July 2002 and (b) arrival delays that would have been incurred at PIT had a second-tier ground stop been in effect from 2015-2115 UTC (the identified impact period). The difference between the two runs in PIT arrival delays was the delay reduction benefit for this particular event. The demand profile for each model run consisted of the daily scheduled arrivals at PIT on the nearest, non-weather, non-delay weekday, with care taken to account for any cancellations. Profiles of PIT arrival capacity in 15-min intervals throughout the day were determined based upon ASPM statistics, interviews with PIT traffic management, and analysis of ETMS flight data.

To model PIT arrival delays had CIWS not been available and a second-tier ground stop been implemented during the impact period in question, capacity was reduced by the number of aircraft departing for PIT from second-tier facilities between 2015-2115 EDT. Moreover, arrival capacity reductions were applied during the 30-min period immediately following the point at which the ground stop would likely have been lifted. These post-impact reductions were based upon the assumption that aircraft departing 20-min or more after the ground stop started would have postponed boarding, resulting in an additional 30-min departure delay after the ground stop ended.[26]

By utilizing CIWS to avoid this PIT ground stop, 24 aircraft (all from airports within first-tier facilities) were able to depart their originating airports and arrive at their destination on time. This resulted in an initial delay savings of 11 hours. Under the assumption that total 'downstream' delay is approximately 80% of initial delay, the total CIWS delay reduction, with additional accounting for delay propagation effects, was 19.8 hours. This translates to delay saving in passenger and operating costs of $74,349, assuming crew costs were incurred on downstream delay. The total cost savings assuming no airline costs associated with downstream delay was $60,436.

It is worth noting that delay savings for this ground stop aversion at PIT are relatively modest in comparison to delay reduction benefits expected at airports within the CIWS coverage region that both have more traffic and are capacity-constrained (e.g., metro NY, ORD, metro DC, PHL, and DTW airports). However this particular CIWS benefit, where the system was used to shorten or completely avoid an airport ground stop, was identified frequently in 2002.[27]

This specific CIWS benefit - avoided ground stop in support of a SWAP - was mentioned a number of times during post-season user interviews conducted at the New York TRACON (N90) facility. During these interviews, traffic managers noted that CIWS had reduced the number of ground stops needed at metro New York airports [Newark, LaGuardia (LGA), Kennedy (JFK), and Teterboro (TEB)] during SWAPs in 2002 by 50%. Though N90 has access to NY ITWS prototype products, they specifically attributed this terminal benefit to CIWS, since its larger spatial domain allowed for more reroute possibilities.

6.4 24 AUGUST 2002 – JET ROUTES KEPT OPEN VIA STORM OVER FLIGHTS

6.4.1 Weather Conditions

A large cluster of rain showers and embedded moderate to strong storms moved eastward through ZDC and ZNY airspace during the morning hours, eventually weakening and moving offshore, out of CIWS coverage. By 1700 UTC, convective storms once again developed across western ZOB and eastern ZNY airspace, west of the major east-coast TRACONS of PHL and N90. Over the next several hours, storms intensified and increased in coverage, eventually organizing into a well-formed broken line of convective cells which moved eastward with time. By 2100 UTC, the broken line of storms was well entrenched across Pennsylvania and into southern Ohio (Figure 6-12). Additional strong storms were also present at this time in central Indiana, as well as further south across ZDC, ZME, and westward into ZKC airspace.

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[26] US Airways traffic management personnel were consulted regarding standard airline ground stop procedures, in order to validate modeling decisions in this delay reduction exercise. PIT airport is a major hub for US Airways and ETMS data confirmed that the majority of aircraft that would have been affected by a potential ground stop belonged to this airline.

[27] Identification of CIWS benefits, such as more efficient ground stop planning, increased in 2003 as traffic management users became more familiar with the complete suite of weather products that were introduced in August of 2002 (as well as the 2003 new products such as Growth and Decay Trends).

The line of storms in ZNY airspace continued to intensify as it moved eastward. The metro New York airports were directly impacted by strong storms at 0100 UTC on 25 August, with convective activity exiting N90 TRACON and moving offshore soon thereafter.

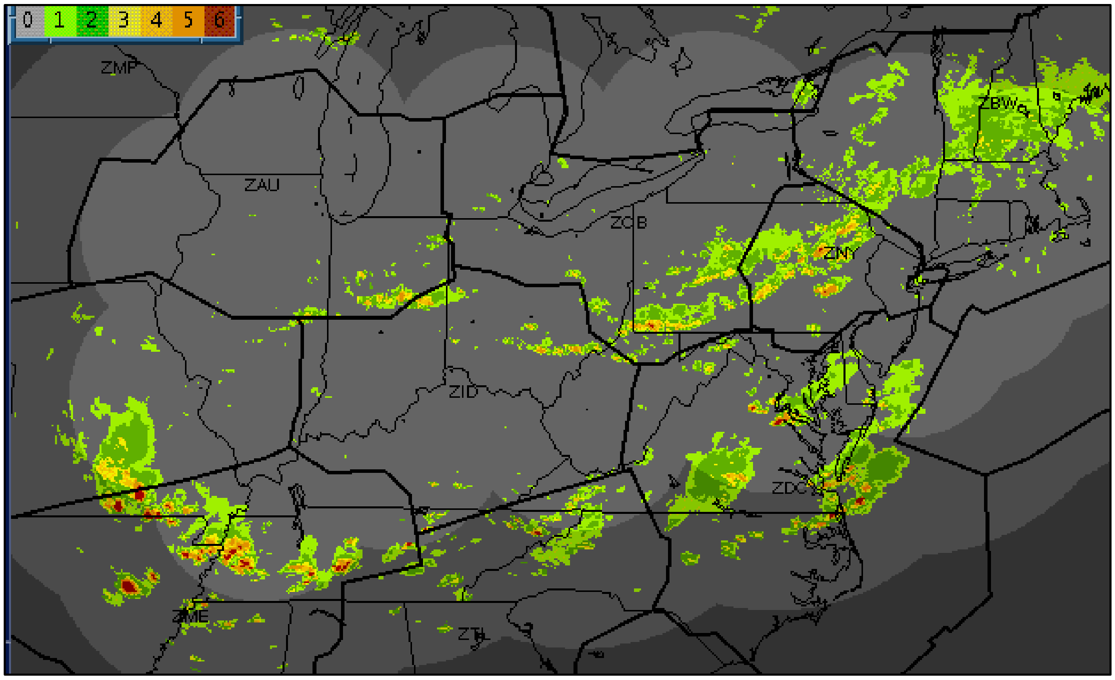

Figure 6-12. Storm coverage at 2100 UTC on 24 August 2002, as depicted by the CIWS NEXRAD VIL Precipitation product. The storms of interest on this day, in terms of user-defined CIWS benefits, coalesced into a broken line of level 4-6 cells across Pennsylvania at this time.

6.4.2 CIWS Benefits Cited in Interviews with Traffic Facilities

With the exception of a brief lull around midday, strong storms impacted the heavily-traveled jet routes comprising the congested airspace over Pennsylvania for approximately 10 hours. Though storm intensity was significant, the CIWS echo tops product demonstrated that the broken line of strong convective cells possessed relatively low storm top heights (Figure 6-13). During post-event interviews at both ZOB and ZNY ARTCC facilities, traffic managers informed the CIWS interviewers that CIWS echo tops information was used to recognize that the strong storms impacting their airspace were indeed ‘low-topped’. This in turn led to their decision to utilize storm over flights to keep en route traffic into, and out of, several large east-coast hubs running close to nominal (Figure 6-14).

ZOB traffic managers stated that they were able to take advantage of the low-topped nature of these storms for the duration of the event. They kept east-west routes along the ZOB/ZNY boundary open with no restrictions other than flight level. They stated that, at times, aircraft passing into and out of ZNY airspace needed only small deviations[28]. Similarly, ZNY personnel managed their en route airspace with no route closures and no MIT restrictions for the majority of the event. By 2330 UTC though, storms had intensified and increased in height as they approached and entered the New York TRACON, rendering storm over flights in this region infeasible as aircraft transitioned from en route to terminal airspace.

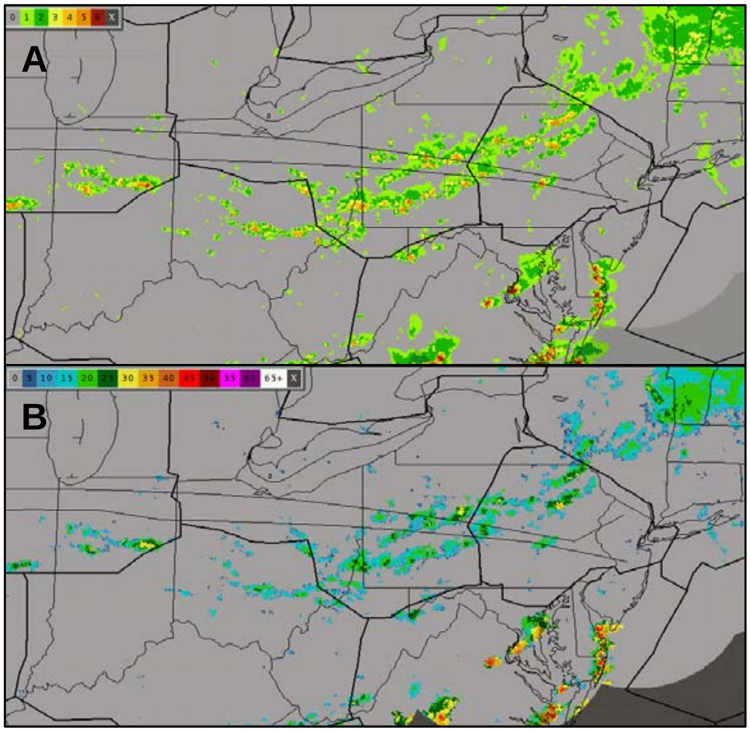

Figure 6-13. (a) Storm intensity as depicted by the CIWS NEXRAD VIL Precipitation product and (b) storm top heights (in kft) as depicted by the CIWS NEXRAD Echo Tops product at 2100 UTC on 24 August 2002. Together, both CIWS products demonstrated that though storms were strong, they possessed low storm top heights suggesting the possibility of en route over flights. The J60 and J64 jet routes are the two horizontal black lines stretching across the corridor from northern Illinois to New Jersey.

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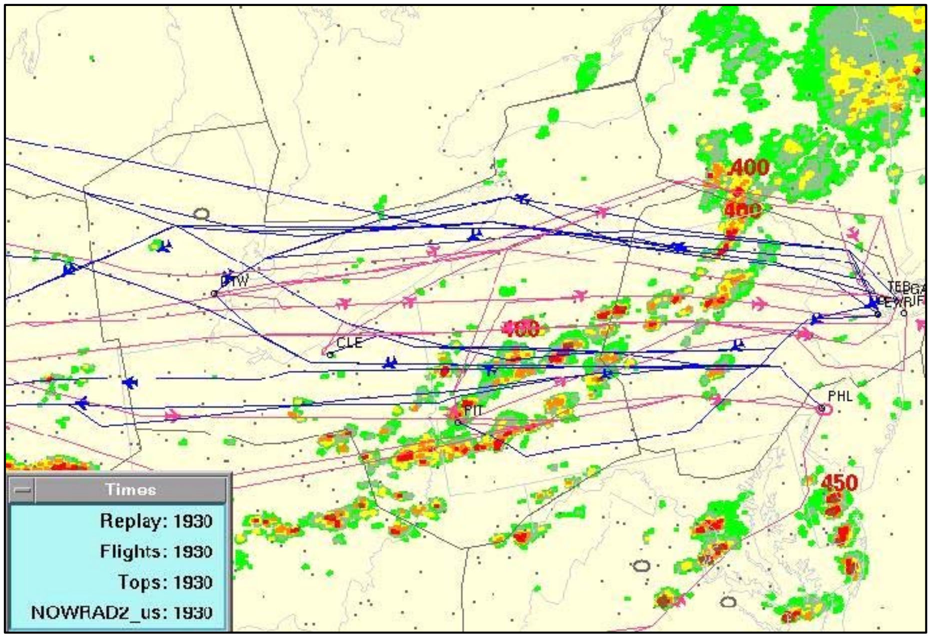
[28] Independent analyses of the flight tracks for the aircraft on 24 August by Lincoln Laboratory personnel showed that approximately 60% of the aircraft traversing the area made small deviations to avoid the high topped storms that were interspersed amongst storms with lower tops. Note in Figure 6-13 that there were several areas of tops in excess of 30 kft in Pennsylvania. Hence, the meteorological conditions in the general region [e.g., the convective available potential energy (CAPE)] were such that forecasters could not have ruled out high topped storms. Pilot reports of high topped storms would not have been surprising.



Replay: 1930
Flights: 1930
Tops: 1930
NOWRAD2_us: 1930

Figure 6-14. ETMS Traffic Situation Display at 1930 UTC on 24 August 2002. Aircraft colored blue are departures from EWR, LGA, JFK, and PHL to several pacing airports across the Midwest and Northern Plains. Aircraft colored pink are arrivals at EWR, LGA, JFK, and PHL from the same select airports. The ETMS weather depiction, based upon composite reflectivity data, illustrates the strong broken line of thunderstorms across New York, Pennsylvania, and Ohio. The storm over flights evident at this time along several key routes were based upon CIWS echo tops information. The large red numbers seen here represent echo tops information available at this time via ETMS. The ETMS indicated tops (40 kft or higher) would not have indicated over flights were possible.

6.4.3 CIWS Delay Reduction

ZOB and ZNY traffic managers informed the CIWS interviewer that by identifying the feasibility of storm over flights with the CIWS products, key jet routes were kept open without the need for spacing restrictions or playbook reroutes. In turn, potentially significant delays at EWR, LGA, JFK, and PHL were spared as arriving and departing aircraft from these airports were the primary benefactors of this day’s traffic planning decision. A queuing model was employed to demonstrate CIWS delay savings based upon assumed arrival and departure capacity profiles variations at each airport.

The determined periods of CIWS benefits, where storm over flights were identified in Pennsylvania and New York, was 1100-1500 UTC and 1700-2300 UTC. ETMS flight track data, in conjunction with weather information, were analyzed to enumerate total EWR, LGA, JFK, and PHL arriving and departing aircraft observed flying over storms during the impact period. A total of 734 storm over flights were observed during the 10-hour impact period (Table 6-4). Arrival and departure over flights for each airport were segregated and used to modify queuing model capacity profiles in this delay savings exercise.

TABLE 6-4

24 August 2002 Storm Over Flights

Airport	Arrivals	Departures	Total Over Flights *
EWR	113	84	197
LGA	82	86	168
JFK	73	103	176
PHL	98	95	193
TOTAL	366	368	**734**

***** Storm over flights in NY and PA observed from approximately 1100-1500 and 1700-2300 UTC

The demand profile for each model run consisted of the scheduled arrivals and departures at each airport on 24 August, with care taken to account for cancellations. Actual arrivals and departures for each airport constituted baseline capacity profile metrics used to model both actual delay as well as hypothesized delay had CIWS not been available to identify alternatives to significant airspace restrictions. It became apparent in our initial queuing model investigations into this case that actual arrivals and departures on 24 August 2002 (a Sunday) were not completely representative of throughput capacities into and out of New York and Philadelphia (by way of the Pennsylvania routes) expected on a weekday with better weather conditions.

Capacity profiles used in modeling CIWS delay reduction benefits were increased by utilizing ETMS flight track data to compare arrival and departure flight counts to and from each airport on 24 August 2002 versus a clear-weather weekday (8 August 2002). Flight count differences between the two days for each airport's arriving and departing flights, through a predetermined airspace zone in southern New York and Pennsylvania, were tallied. Arrival and departure capacity profiles for EWR, LGA, JFK, and PHL were increased by the percent increase in throughput capacity evident on the clear-weather weekday. Flights over storms during the impact period were subtracted from these modified capacity profiles in modeling arrival and departure delays for the comparison case where CIWS was unavailable.

Traffic management decisions during this particular air traffic impact scenario would have had several alternative possibilities, had CIWS echo top information not been available to adequately gauge airspace availability. Three alternate routing decisions are applicable to this case study investigation:

- Routes closed – aircraft held at their originating airports (i.e., no reroutes)
- Routes open, with significant spacing (miles-in-trail) restrictions
- Routes open, with less stringent spacing restrictions

CIWS arrival and departure delay savings at each airport were modeled for each type of alternate routing decision listed above (Table 6-5). It is recognized that Decision A (routes closed, with no reroutes) would have been an unlikely traffic management alternative to combat the impact of a strong line of storms on the airspace in question. However, modeling CIWS delay reduction benefits, given that Decision A was implemented had CIWS not been available, creates an “upper-bound” for the purposes of queuing model sensitivity. In light of the various alternative traffic management approaches that could have been utilized, developing a sensitivity range for potential CIWS delay savings in this particular case study best described potential delay reduction benefits. In this sense, even when assuming the least disruptive alternative approach (Decision C), queuing model results demonstrated combined CIWS delay savings (arrival and departure delay savings for all four airports) of 2800 hours, translating to over $8,500,000 for this 10-hour period.

TABLE 6-5
24 August 2002 Delay Reduction Benefits of CIWS: Queuing Model Results

A. Routes Closed – aircraft held at originating airport (i.e., no reroutes)

Airport	Arrival Delay Saved (hours)	Departure Delay Saved (hours)	Primary Delay Saved (hours)	Total Delay Saved * (hours)	Savings ** (DM-1) ✦ (DM-2)
EWR	834.6	427.9	1262.5	2272.5	$8,533,238 $6,936,428
LGA	501.7	540.0	1041.7	1875.1	$7,041,001 $5,723,395
JFK	601.3	286.7	888.0	1598.4	$6,001,992 $4,878,850
PHL	568.0	578.5	1146.5	2063.7	$7,749,194 $6,299,100
TOTAL	2505.6	1833.1	4338.7	7809.7	**$29,325,424** **$23,837,773**

B. Routes Open, *Significant* Restrictions – 20% more capacity available than A.

Airport	Arrival Delay Saved (hours)	Departure Delay Saved (hours)	Primary Delay Saved (hours)	Total Delay Saved (hours)	Savings (DM-1) (DM-2)
EWR	575.1	314.7	889.8	1601.6	$6,014,008 $4,888,652
LGA	391.1	389.3	780.4	1404.7	$5,274,649 $4,287,630
JFK	457.1	220.2	677.3	1219.1	$4,577,721 $3,721,135
PHL	401.3	371.9	773.2	1391.8	$5,226,209 $4,248,202
TOTAL	1824.6	1296.1	3120.7	5617.2	**$21,092,586** **$17,145,620**

C. Reroutes Open, *Limited* Restrictions – 50% more capacity available than A.

Airport	Arrival Delay Saved (hours)	Departure Delay Saved (hours)	Primary Delay Saved (hours)	Total Delay Saved (hours)	Savings (DM-1) (DM-2)
EWR	320.0	170.4	490.4	882.7	$3,314,539 $2,694,312
LGA	205.6	170.7	376.3	677.3	$2,543,262 $2,067,381
JFK	205.6	119.0	324.6	584.3	$2,194,047 $1,783,461
PHL	197.3	167.3	364.6	656.3	$2,464,407 $2,003,229
TOTAL	928.5	627.4	1555.9	2800.6	**$10,516,253** **$8,548,382**

* Total Delay = Primary + Downstream

✦ DM-1 and DM-2 are described in section 5.3

** Total Savings = Operating +Passenger Cost saved

7. ANNUAL OPERATIONAL BENEFITS OF CIWS IN 2003 SPATIAL DOMAIN

In this section, we "roll up" the various "benefits blitzes" and other operational feedback on situations where the CIWS products enabled the users to make better decisions to arrive at:

- Estimates of the frequency of various CIWS benefits on an annual basis, and
- Quantitative delay reduction estimates for the two major benefits categories ("keeping routes open longer/reopening routes earlier" and "proactive, efficient reroutes") analyzed to date.

First, we summarize and discuss the results of the blitz observations by facility and estimate the frequency of the various benefits categories per year. Next, we summarize the case study results for the two major benefits categories. Finally, we combine these two sets of results to arrive at the annual delay reduction benefits in the 2003 CIWS domain for the two major benefits categories.

7.1 SUMMARY OF "BENEFITS BLITZ" OBSERVATIONS

The dates on which observers from Lincoln Laboratory (LL) were stationed at various ATC facilities to obtain real time observations of CIWS product usage is summarized in Table 7-1[29].

TABLE 7-1
CIWS 2003 "Benefits Blitz" Observation Periods

Blitz Campaign	Dates	Facilities Included
1	8, 10-13 June	ZBW, ZNY, ZDC, ZID, ZOB, ATCSCC, C90, FedEx
2	25-26 June	ZAU, ZID, ZOB
3	8-11 July	ZID, ZDC, ZOB, ZBW, ZNY, ATCSCC
4	20-23 July	ZAU, ZID, ZOB, ZDC, ZNY, ZBW, ATCSCC, C90, FedEx
5	3-6 August	ZID, ZOB, ZDC, ZNY, ZBW
6	2-4 September	ZID, ZOB, ZDC, ZNY, ZBW, ATCSCC, FedEx

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[29] Complete details of the 2003 CIWS Benefits Assessment ("Blitz") Campaign are provided in Robinson et al., [2004].

The detailed results of these observations (see Appendix E) were analyzed to determine when and where the CIWS products were used to make various ATC decisions.

In Table 7-2, we summarize the observations of the principal CIWS benefits by ATC facility and show the number of days that a LL observer was present at that facility in connection with the blitz campaign. Since the number of days that an observer was present at each facility differed, we normalized the “raw” results shown in Table 7-2, yielding the results shown in Table 7-3.

The differences between the various ATC facilities for various benefits decisions shown in Table 7-3 are quite interesting. Note that two facilities, ZOB and ZDC, clearly made many more decisions to keep routes open longer and/or reopen routes earlier using the CIWS products than the other ARTCCs. ZID, ZNY, and ZBW were also quite likely to keep routes open longer and/or reopen routes earlier using the CIWS products. By contrast, ZAU was not as likely to use CIWS to keep routes open longer and/or reopen routes earlier using the CIWS products.

Differences clearly exist between the various ARTCCs in terms of overall usage of CIWS products. For example, we see that the facilities which were most likely to use CIWS to keep routes open longer and/or reopen routes earlier were also generally much more likely to use CIWS to manage reroutes, reduce miles-in-trail restrictions, direct traffic through gaps in the weather, and accomplish interfacility coordination.

However, in comparison to overall high relative usage of CIWS for other ATC management concerns, ZDC’s usage of CIWS to better manage weather impacts on terminal arrival transition areas (ATAs) was low. We attribute this to the fact that although ZDC contains two of the major metropolitan terminals identified in the Flight Plan 2004-08 [PHL and Potomac TRACON (PCT)], neither of those major terminals had a CIWS display.

We note also that ZBW’s use of CIWS to better manage weather impacts on terminal ATAs was low relative to their use of CIWS to keep routes open longer and/or reopen routes earlier. We attribute this to the fact that although ZBW contains one of the major metropolitan terminals identified in the Flight Plan 2004-08 (BOS), there was not a CIWS display at the Boston TRACON in 2003.

At Chicago, the TRACON statistically was more likely to use the CIWS products for a number of the identified benefit categories than the ARTCC. We will seek to provide additional on-site training at ZAU in 2004.

TABLE 7-2

Summary of Observations of Various Operational Benefits by ATC Facility During 2003 Benefits Blitz Observation Period

	Benefit Category	ATC Facility							
		ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	ATCSCC
1	Keeping routes open longer and/or reopening closed routes earlier	5	17	15	24	6	12	1	6
2	Closing routes proactively	0	1	2	6	1	3	0	1
3	Proactive, efficient reroutes	2	10	5	12	4	1	1	3
4	Shorter/fewer ground stops	1	1	5	7	0	2	1	0
5	Ground Stop avoided	0	1	0	0	1	0	3	0
6	Reduced MIT restriction	0	1	2	1	1	0	0	0
7	Traffic directed through gaps in weather	0	6	3	5	0	1	2	0
8	Better management of weather impacts on terminal ATAs	9	18	15	4	2	3	15	2
9	Optimization of runway usage; enhanced runway planning	0	1	1	0	0	1	6	0
10	Improved use of GDPs	0	0	0	0	0	0	1	0
11	Greater departures during SWAP	4	2	2	3	2	2	6	0
12	Directing pathfinders	2	2	4	10	3	2	1	3
13	Interfacility coordination	5	21	29	25	2	14	8	17
14	Improved safety	0	2	4	4	2	3	1	0
15	Reduced workload	2	10	13	19	3	9	6	3
16	Situational awareness	12	45	82	71	8	68	15	19
# Days LL observers present		6	9	14	7	4	7	3	9

TABLE 7-3

Normalized CIWS Benefits Observations by ATC Facility

	Benefit Category	ATC Facility							
		ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	ATCSCC
1	Keeping routes open longer and/or reopening closed routes earlier	0.8	1.9	1.1	3.4	1.5	1.7	0.3	0.7
2	Closing routes proactively	0.0	0.1	0.1	0.9	0.3	0.4	0.0	0.1
3	Proactive, efficient reroutes	0.3	1.1	0.4	1.7	1.0	0.1	0.3	0.3
4	Shorter/fewer ground stops	0.2	0.1	0.4	1.0	0.0	0.3	0.3	0.0
5	Ground Stop avoided	0.0	0.1	0.0	0.0	0.3	0.0	1.0	0.0
6	Reduced MIT restriction	0.0	0.2	0.0	0.1	0.3	0.0	0.0	0.0
7	Traffic directed through gaps in weather	0.0	0.7	0.2	0.7	0.0	0.1	0.7	0.0
8	Better management of weather impacts on terminal ATAs	1.5	2.0	1.1	0.6	0.5	0.4	5.0	0.2
9	Optimization of runway usage; enhanced runway planning	0.0	0.1	0.1	0.0	0.0	0.1	2.0	0.0
10	Improved use of GDPs	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
11	Greater departures during SWAP	0.7	0.2	0.1	0.4	0.5	0.3	2.0	0.0
12	Directing pathfinders	0.3	0.2	0.3	1.4	0.8	0.3	0.3	0.3
13	Interfacility coordination	0.8	2.3	2.1	3.6	0.5	2.0	2.7	1.9
14	Improved safety	0.0	0.2	0.3	0.6	0.5	0.4	0.3	0.0
15	Reduced workload	0.3	1.1	0.9	2.7	0.8	1.3	2.0	0.3
16	Situational awareness	1.2	5.0	5.9	10.1	2.0	9.7	5.0	2.1

Another factor in the ZAU usage of CIWS may be difficulty in coordination with the adjacent facilities. Two ARTCCs immediately adjacent to ZAU [Kansas City ARTCC (ZKC) and Minneapolis ARTCC (ZMP)] do not have CIWS displays. ZKC handles much of the traffic from the southwest and far west into ZAU[30]. ZMP is very important for eastbound Chicago traffic desiring use of the Canadian playbook routes when the normal east-west routes through ZOB and ZID to the east coast are blocked by severe convective activity[31].

The results shown in Table 7-3 can be viewed as a sample mean from randomly sampling the population of situations in which the CIWS products provide operational benefits, since the periods of "blitz" observations were determined only on the basis of a reasonable likelihood of convective weather occurring and all blitz observation days have been treated equally. Taking the sample mean as an estimate of the ensemble average, we can then scale up the normalized usage shown in Table 7-3 by the number of weather events per ATC facility per year to arrive at an annual estimate. Long term statistics for the number of weather events per ARTCC per year do not exist currently[32]. Hence, we have taken as an estimate of the annual frequency of storm events in the various ARTCCs the average frequency of convective weather days observed in 2002 and 2003 (For ZDC and ZBW, we used the frequency observed in 2003 because CIWS did not have adequate coverage of those two ARTCCs in 2002). By multiplying the results in Table 7-3 by this thunderstorm frequency distribution, we arrive at the annual frequency of the various CIWS operational benefits shown in Table 7-4. Limited resources precluded the development of thunderstorm frequency metrics better weighted against climatology. Therefore, it is recognized that extrapolations of annual CIWS benefits at individual ARTCCs based upon thunderstorm frequency distributions heavily disposed towards the above average storm activity in 2003 (particularly in ZDC) may demonstrate an upward bias when compared to roll-ups based upon longer-term storm frequency averages. Historical thunderstorm data will be utilized in the Phase 2 CIWS benefits study to better scale thunderstorm frequency distributions towards longer-term convective activity trends.

Next, we want to convert these annual estimates of the frequency of the various operational benefits to an annual benefit estimate for each operational benefit category. To do this, we need to have an estimate of the average benefit for each of the operational benefits categories. In the next two sections, we discuss how this was done for two of the high frequency operational benefits.

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[30] For example, about 42% of the United traffic from ORD and 37% of the American traffic passes through ZKC.

[31] Severe congestion occurs near and northeast of Atlanta if the Chicago east-bound traffic is rerouted south of ZOB and ZID, so the Canadian playbook routes are critical when ZOB and ZID are blocked.

[32] It is known from ITWS benefits studies (see Bieringer et al., 1999) that the conventional statistics of the annual frequency of thunderstorm days at a weather observation station can significantly underestimate the frequency of thunderstorms in a region that contains the weather observation station.

TABLE 7-4

Annual Frequency of Various CIWS Benefits

	Benefit Category	ATC Facility								
		ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	ATCSCC	ARTCC Total*
1	Keeping routes open longer and/or reopening closed routes earlier	75	173	109	357	104	103	14	53	953
2	Closing routes proactively	0	10	15	89	17	26	0	9	157
3	Proactive, efficient reroutes	30	102	36	178	70	9	14	27	439
4	Shorter/fewer ground stops	15	10	36	104	0	17	14	0	196
5	Ground Stop avoided	0	10	0	0	17	0	42	0	69
6	Reduced MIT restriction	0	20	0	15	17	0	0	0	52
7	Traffic directed through gaps in weather	0	61	22	74	0	9	28	0	194
8	Better management of weather impacts on terminal ATAs	134	183	109	59	35	26	210	18	756
9	Optimization of runway usage; enhanced runway planning	0	10	7	0	0	9	84	0	110
10	Improved use of GDPs	0	0	0	0	0	0	14	0	14
11	Greater departures during SWAP	60	20	15	45	35	17	84	0	276
12	Directing pathfinders	30	20	29	149	52	17	14	27	311
13	Interfacility coordination	75	214	211	371	35	120	112	151	**1289**
14	Improved safety	0	20	29	59	35	26	14	0	183
15	Reduced workload	30	102	95	282	52	77	84	27	**749**
16	Situational awareness	104	458	597	1054	139	583	210	169	**3314**
# Convective Weather Days (based on 2002 and 2003)		89.5	91.5	102	104	69.5	60	42	80	

** Total occurrences of various CIWS benefits categories do <u>not</u> include ATCSCC contributions in order to prevent inflation of benefits occurrences resulting from assigning events to more than one facility. In practice, observed usage benefits (from which these roll-ups are based) were only assigned to the ARTCCs using CIWS to initiate traffic decisions, even if coordination with other facilities was needed or if benefit event occurred along facility boundaries. Exceptions (total benefits occurrences in **bold**), where ATCSCC benefits occurrences were added to the final totals include categories, "Interfacility coordination", "Reduced workload", and "Situational awareness". These specific benefits could not be easily separated by facility and may in fact have proved of more importance at ATCSCC compared to elsewhere in terms of enacting efficient delay mitigation schemes.

7.2 CASE STUDY ANALYSES FOR INDIVIDUAL CIWS BENEFITS CATEGORIES

The computation of the average benefit (in hours of delay and equivalent monetary value) for each such ATC decision in each ARTCC has been accomplished by detailed case analyses. The specific cases to be analyzed were determined by randomly selecting[33] from the specific instances of a given benefit category that had been identified in either the blitz observations or in post event interviews. In this section, we show the number of such cases identified for each ARTCC and then present the results for the two ATC decisions that have been analyzed in this first phase of the CIWS benefits study.

7.2.1 Case Study Results for Benefit: Keeping Routes Open Longer/Reopening Closed Routes Earlier

One of the most frequent benefits of CIWS, either observed during blitz campaigns or identified by users during post-event interviews, was assistance provided by CIWS weather products to delay or prevent route closures and/or reopen closed routes earlier. To model delay savings associated with this particular benefits category, case studies from sample sets for each ARTCC were randomly selected for analysis (Table 7-5). The specific details of each case determined which delay reduction modeling approach was employed in the analysis (i.e., linear reduction, queue reduction, or combination). Complete details for each case study within the ‘Kept Route Open’ CIWS benefit category are provided in Appendix B.

A summary of the CIWS delay savings (hours of delay saved and cost savings) results for each case study under the “Kept Route Open’ benefit category is provided in Table 7-6. We see that there is very wide spread in the hours of delay savings and the equivalent monetary value between the various cases. This wide spread in benefits represents a wide variety of queue situations arising in high congestion airspace. As was noted in Chapter 5, the delay for a queue is very sensitive to demand and capacity. When the bad weather capacity is low and the demand is close to the fair weather capacity, the delays become very sensitive to the bad weather capacity and the duration of the event. Hence, it is not surprising that the benefits for different cases differ by factors of 20 to 100. This is particularly true for keeping routes open since in some of these cases, if a route had not been kept open, major traffic flows would have had no practical available route.

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[33] Random selections of cases for analysis from comprised sample sets were made by employing a standard SUN/PC random number generator utility. A random number between 0 and 1 was created and then multiplied by N_{ij} where N_{ij} is the number of cases in category I for ARTCC J. This was rounded to the nearest integer to determine which case was chosen from the N_{ij} possible cases. This process was repeated for as many cases as time permitted.

TABLE 7-5

CIWS Benefit: Route Open Longer and/or Reopen Closed Route Earlier

Case Study Sample Set

ZAU	Date	Blitz Observance
1	030430	
2	030508	
3	030608	
4	030626	(2) 1530 UTC
5	030626	(2) 1600 UTC
6	030721	(4) 2120 UTC

ZID	Date	Blitz Observance
1	030608	(1) 1630 UTC
2	030610	(1) 2115 UTC
3	030611	(1) 1839 UTC
4	030619	
5	030626	(2) 1515 UTC
6	030709	(3) 2335 UTC
7	030710	(3) 1015 UTC
8	030710	(3) 1645 UTC
9	030721	(4) 1915 UTC
10	030723	(4) 1645 UTC
11	030731	
12	030902	(6) 1945 UTC
13	030902	(6) 2306 UTC

ZBW	Date	Blitz Observance
1	030511	
2	030611	(1) 2124 UTC
3	030611	(1) 2216 UTC
4	030711	(3) 1335 UTC
5	030722	(4) 1928 UTC
6	030723	(4) 0243 UTC
7	030723	(4) 1929 UTC
8	030723	(4) 1935 UTC
9	030805	(5) 2307 UTC
10	030829	(4) 1645 UTC

ZNY	Date	Blitz Observance
1	030507	
2	030509	
3	030612	(1) 2003 UTC
4	030612	(1) 2040 UTC
5	030614	
6	030621	
7	030705	
8	030804	(5) 2125 UTC
9	030805	(5) 2021 UTC
10	030806	(5) 1915 UTC
11	030904	(6) 1500 UTC

ZOB	Date	Blitz Observance
1	030403	
2	030404	
3	030501	
4	030508	
5	030509	
6	030510	
7	030608	(1) 1751 UTC
8	030608	(1) 1825 UTC
9	030610	(1) 2055 UTC
10	030626	(2) 1730 UTC
11	030626	(2) 1750 UTC
12	030626	(2) 1820 UTC
13	030626	(2) 2030 UTC
14	030626	(2) 2320 UTC
15	030626	(2) 0040 UTC
16	030704	
17	030706	
18	030708	
19	030708	
20	030710	(3) 2010 UTC
21	030721	
22	030722	(4) 1548 UTC
23	030722	(4) 2039 UTC
24	030722	(4) 2105 UTC
25	030723	(4) 1847 UTC
26	030731	
27	030801	
28	030803	
29	030804	(5) 2015 UTC
30	030903	(6) 1410 UTC
31	030903	(6) 1515 UTC
32	030903	(6) 1730 UTC
33	030903	(6) 1900 UTC
34	030903	(6) 2100 UTC

Table Notes:

* Entries under Blitz Observance provide Blitz campaign number and time of observance. No Blitz observance means case identified during post-event interviews.

ZDC	Date	Blitz Observance
1	030502	
2	030510	
3	030531	
4	030531	
5	030608	
6	030611	(1) 1709 UTC
7	030611	(1) 2302 UTC
8	030612	(1) 2210 UTC
9	030613	
10	030619	
11	030701	
12	030706	
13	030707	
14	030709	(3) 1540 UTC
15	030709	(3) 1635 UTC
16	030709	(3) 1921 UTC
17	030709	
18	030716	
19	030718	
20	030722	(4) 2100 UTC
21	030722	(4) 2111 UTC
22	030722	(4) 2155 UTC
23	030722	(4) 2250 UTC
24	030722	(4) 2330 UTC
25	030723	(4) 1515 UTC
26	030723	(4) 1930 UTC
27	030803	
28	030901	
29	030902	(6) 1815 UTC
30	030902	(6) 1815 UTC
31	030903	(6) 2145 UTC

* Cases randomly selected for analysis are highlighted in gray.

TABLE 7-6
CIWS Benefit: Route Open Longer and/or Reopen Closed Route Earlier
Case Study Delay Savings Results

		DELAY SAVED (hr)			SAVINGS			
ARTCC	**Date**	**Primary**	**Downstream**	**Total**	**Operations (DM-1)✦ (DM-2)**	**Passenger (p)**	**Passenger (d)**	**TOTAL (DM-1) (DM-2)**
ZAU	30 Apr	13.5	10.8	24.3	$50,540 $33,465	$29,349	$23,479	$103,368 $ 86,293
ZAU	26 Jun	106.0	84.8	190.8	$325,581 $191,512	$230,444	$184,355	$740,380 $606,311
ZID	10 Jun	1.4	1.1	2.5	$5,428 $3,689	$3,044	$2,391	$10,863 $ 9,124
ZID	10 Jul	70.4	56.3	126.7	$200,312 $111,302	$153,050	$122,396	$475,758 $386,748
ZID	23 Jul	4.8	3.8	8.6	$18,656 $12,648	$10,435	$8,261	$37,352 $31,344
ZOB	08 May	5.0	4.0	9.0	$14,229 $7,905	$10,870	$8,696	$33,795 $27,471
ZOB	06 Jul	22.0	17.6	39.6	$62,924 $35,098	$47,828	$38,262	$149,014 $121,188
ZOB	03 Aug	236.3	189.0	425.3	$672,399 $373,590	$513,716	$410,886	$1,597,001 $1,298,192
ZDC	22 Jul	10.3	8.2	18.5	$29,248 $16,284	$22,392	$17,827	$69,467 $56,503
ZDC	23 Jul	3.6	2.9	6.5	$14,071 $ 9,486	$7,826	$6,305	$28,202 $23,617
ZDC	03 Sep	36.2	29.0	65.2	$103,081 $57,232	$78,699	$63,046	$244,826 $198,977
ZBW	11 Jun	4.0	3.2	7.2	$11,383 $6,324	$8,696	$6,957	$27,036 $21,977
ZBW	05 Aug	8.9	7.1	16.0	$27,404 $16,179	$19,349	$15,435	$62,188 $50,963
ZNY	12 Jun	1.5	1.2	2.7	$5,850 $3,953	$3,261	$2,609	$11,720 $9,823
ZNY	05 Aug	49.0	39.2	88.2	$139,444 $77,469	$106,526	$85,221	$331,191 $269,216

✦ DM-1 and DM-2 are described in section 5.3

7.2.2 Case Study Results for Benefit: Proactive, Efficient Reroutes

Frequent observations of CIWS usage during the 2003 Blitz campaigns related to improving reroute decision-making during thunderstorm impacts. Moreover, input provided by traffic managers during post-event interviews also indicated that the ability to plan more efficient reroutes was a significant benefit of CIWS. To model delay savings associated with this particular benefits category, case studies from sample sets for each ARTCC were randomly selected for analysis (Table 7-7).

Application of delay savings results from case studies under this benefit category in order to determine annualized CIWS benefits are discussed later in this section. A summary of the CIWS delay savings results (hours of delay saved and cost savings) for each case study under the "Proactive, Efficient Reroutes" benefit category is provided in Table 7-8. Complete details for each case study within the "Proactive, Efficient Reroute" CIWS benefit category are provided in Appendix C.

We note that there is considerable variation in the delay savings for these cases as well. However, the variation is not as great as for keeping routes open longer/opening routes earlier. This is because most of the proactive reroute cases did not involve situations with large queues of aircraft.

TABLE 7-7
CIWS Benefit: Proactive, Efficient Reroutes
Case Study Sample Set

ZAU	Date	Blitz Observance
1	030613	
2	030708	
3	030720	
4	030721	(4) 2045 UTC

ZID	Date	Blitz Observance
1	030420	
2	030619	
3	030804	(5) 2215 UTC
4	030901	

ZBW	Date	Blitz Observance
1	030501	
2	030502	
3	030613	
4	030623	
5	030711	(3) 1153 UTC
6	030723	(4) 1935 UTC

ZNY	Date	Blitz Observance
1	030612	(1) 2003 UTC
2	030612	(1) 2104 UTC
3	030621	
4	030804	(5) 2120 UTC

ZOB	Date	Blitz Observance
1	030403	
2	030404	
3	030420	
4	030613	
5	030619	
6	030620	(2) 1820 UTC
7	030710	(3) 1707 UTC
8	030727	
9	030802	
10	030804	(5) 1851 UTC
11	030805	(5) 2026 UTC
12	030827	
13	030903	(6) 1800 UTC

Table Notes:

* Entries under Blitz Observance provide Blitz campaign number and time of observance. No Blitz observance means case identified during post-event interviews

ZDC	Date	Blitz Observance
1	030509	
2	030531	
3	030701	
4	030704	
5	030707	
6	030716	
7	030722	(4) 1815 UTC
8	030722	(4) 2155 UTC
9	030801	
10	030803	
11	030805	(5) 1920 UTC
12	030805	(5) 1946 UTC
13	030902	(6) 1815 UTC
14	030902	(6) 2330 UTC
15	030903	(6) 1832 UTC

* Cases randomly selected for analysis are highlighted in gray

TABLE 7-8
CIWS Benefit: Proactive, Efficient Reroutes
Case Study Delay Savings Results

		DELAY SAVED (hr)			SAVINGS			
ARTCC	**Date**	**Primary**	**Downstream**	**Total**	**Operations (DM-1)✦ (DM-2)**	**Passenger (p)**	**Passenger (d)**	**TOTAL (DM-1) (DM-2)**
ZAU	20 Jul	1.3	1.0	2.3	$5,007 $3,426	$2,826	$2,174	$10,007 $8,426
ZAU	21 Jul	3.7	3.0	6.7	$14,493 $9,750	$8,044	$6,522	$29,059 $24,316
ZID	19 Jun	1.5	1.2	2.7	$5,850 $3,953	$3,261	$2,609	$11,720 $9,823
ZID	04 Aug	13.3	10.6	23.9	$37,786 $21,027	$28,914	$23,044	$89,744 $72,985
ZOB	04 Apr	41.8	33.4	75.2	$71,885 $71,885	$90,871	$72,699	$235,455 $235,455
ZOB	27 Jul	17.7	14.2	31.9	$59,287 $36,837	$38,480	$30,871	$128,638 $106,188
ZDC	16 Jul	24.9	19.9	44.8	$70,829 $39,367	$54,133	$43,263	$168,225 $136,763
ZDC	22-23 Jul	9.2	7.4	16.6	$26,244 $14,545	$20,000	$16,088	$62,332 $50,633
ZBW	01 May	2.4	1.9	4.3	$9,328 $6,324	$5,218	$4,131	$18,677 $15,673
ZBW	11 Jul	1.9	1.5	3.4	$6,219 $3,847	$4,131	$3,261	$13,611 $11,239
ZNY	12 Jun	1.5	1.2	2. 7	$4,269 $2,372	$3,261	$2,609	$10,139 $8,242
ZNY	04 Aug	7.7	6.2	13.9	$21,976 $12,174	$16,740	$13,479	$52,195 $42,393

✦ DM-1 and DM-2 are described in section 5.3

7.3 ANNUAL BENEFITS FOR ANALYZED CASE STUDY CATEGORIES

Next, we want to combine the annual frequency of the various CIWS benefits categories (Table 7-4) with the results for the two benefits categories analyzed in this first phase of the CIWS benefits study to obtain annual benefits in hours of delay saved and the equivalent monetary value. However, we must decide how to use the various sample case results given that there is a wide spread in the case studies benefits. There are two obvious options:

- Use the mean of the case study results for each ARTCC, or
- Use the median of the case study results for each ARTCC for those cases where three case studies have been accomplished.

In theory, the mean would be the appropriate metric to use. However, where we have a relatively small sample set and the distribution of benefits clearly has very slowly decreasing tails, there may be a high variance to the sample mean. In such cases, the median may be better behaved albeit not necessarily a good estimate of the mean.

In Tables 7-9 and 7-10, we show the annual benefits results for each of the ARTCCs using the mean and median of the case study results for "keeping routes open longer and/or reopening them earlier". Where there were only two case studies analyzed to date, we used only the mean value of the two in the median table.

We see that there is over a factor of two differences between the annual benefit between using the mean and the median of the case study values for "keeping routes open longer and/or reopening them earlier". We are not aware of any standard approach for handling cases such as this given the small number of samples. Rather, it seems that we need to carry out additional case studies emphasizing the high benefit ARTCCs that show the greatest variation between the various case studies. It may be that we will need to fit a probability model to the resulting sample distribution of case study benefits.

In Table 7-11, we show the annual benefits results for each of the ARTCCs using the mean of the case study results for "proactive, efficient, reroutes." Here, we see major differences between the various ARTCCs in terms of benefits generated. Since there was also considerable variability in the sample case benefits, it appears that we need to carry out additional case studies emphasizing the ARTCCs that have the highest mean benefits.

Whether one chooses the median or the mean delay savings results, the overall CIWS delay reduction benefit for these two benefit categories of 40,000-69,000 hours annually is similar in magnitude to what one might expect based on the NY ITWS experience with queue reduction.

TABLE 7-9

Mean Annual Delay Reduction from Keeping Routes Open Longer/Reopening Routes Earlier

Hours				Monetary Value ($)			
ARTCC	**Primary**	**Downstream**	**Total**	**Operations (DM-1) ✦** **(DM-2)**	**Passenger (p)**	**Passenger (d)**	**TOTAL (DM-1)** **(DM-2)**
ZAU	4,485	3,585	8,070	14,104,538 8,436,638	9,742,238	7,793,775	31,640,551 25,972,651
ZID	2,783	2,224	5,007	8,153,055 4,637,550	6,050,554	4,834,077	19,037,686 15,522,181
ZOB	15,184	12,145	27,328	43,224,165 24,023,530	33,009,207	26,402,337	102,635,710 83,435,074
ZDC	5,962	4,772	10,734	17,421,600 9,877,238	12,961,123	10,374,182	40,756,905 33,212,543
ZBW	664	530	1,194	1,997,531 1,158,905	1,444,318	1,153,188	4,595,037 3,756,411
ZNY	2,626	2,101	4,727	7,555,288 4,233,944	5,708,924	4,567,160	17,831,372 14,510,028
TOTAL	31,704	25,357	**57,060**	92,456,177 52,367,805	68,916,364	55,124,719	**216,497,261** **176,408,888**

✦ DM-1 and DM-2 are described in section 5.3

TABLE 7-10
Median Annual Delay Reduction from Keeping Routes Open Longer/Reopening Routes Earlier

Hours				Monetary Value ($)			
ARTCC	**Primary**	**Downstream**	**Total**	**Operations** **(DM-1) ✦** **(DM-2)**	**Passenger (p)**	**Passenger (d)**	**TOTAL** **(DM-1)** **(DM-2)**
ZAU *	4,485	3,585	8,070	14,104,538 8,436,638	9,742,238	7,793,775	31,640,551 25,972,651
ZID	523	414	937	2,033,504 1,378,632	1,137,415	900,449	4,071,368 3,416,496
ZOB	3,806	3,045	6,851	10,885,852 6,071,954	8,274,244	6,619,326	25,779,422 20,965,524
ZDC	3,677	2,927	6,604	10,441,536 5,813,388	7,993,944	6,364,239	24,799,719 20,171,571
ZBW *	664	530	1,194	1,997,531 1,158,905	1,444,318	1,153,188	4,595,037 3,756,411
ZNY *	2,626	2,101	4,727	7,555,288 4,233,944	5,708,924	4,567,160	17,831,372 14,510,028
TOTAL	15,781	12,602	**28,383**	47,018,249 27,093,461	34,301,083	27,398,137	**108,717,469** **88,792,681**

✦ DM-1 and DM-2 are described in section 5.3

*** Mean** CIWS delay reduction results are supplied as a proxy for median benefits results for this category since only two cases were analyzed for ZAU, ZBW, and ZNY.

TABLE 7-11
Mean Annual Delay Reduction from Proactive Reroutes

Hours				Monetary Value ($)			
ARTCC	**Primary**	**Downstream**	**Total**	**Operations (DM-1) ✦ (DM-2)**	**Passenger (p)**	**Passenger (d)**	**TOTAL (DM-1) (DM-2)**
ZAU	75	60	135	292,500 197,640	163,050	130,440	585,990 491,130
ZID	266	212	478	785,448 449,640	579,150	461,754	1,826,352 1,490,544
ZOB	3,034	2,428	5,462	6,689,772 5,544,822	6,596,901	5,282,070	18,568,743 17,423,793
ZDC	3,035	2,430	5,465	8,639,497 4,798,168	6,597,837	5,282,239	20,519,573 16,678,244
ZBW	19	15	34	69,962 45,770	42,071	33,264	145,296 121,105
ZNY	322	259	581	918,575 509,110	700,035	563,080	2,181,690 1,772,225
TOTAL	6,751	5,404	**12,155**	17,395,754 11,545,150	14,679,044	11,752,847	**43,827,644** **37,977,041**

✦ DM-1 and DM-2 are described in section 5.3.

8. PRELIMINARY ASSESSMENT OF SAFETY BENEFITS FROM CIWS

The two principal safety benefits that were identified from the various facility observations in 2003 were associated with en route airspace. In Chapter 7, we note that there were a number of benefits which relate to ATC helping the aircraft avoid encounters with significant convective weather:

• proactive, efficient reroutes (to avoid weather)	439 times per year
• directing pathfinders	311 times per year
• closing routes proactively	157 times per year
• identified safety enhancement situations	183 times per year

The "Improved Safety" benefits category (category 14) was assigned to Blitz observations (Appendix E) that involved using enhanced CIWS weather information to better ascertain the likelihood of safe implementation (or non-implementation) of alternative plans in dealing with convective weather impacts. Typical examples from Appendix E are as follows:

> June 8, 2003 1640Z: ZOB used CIWS to determine that DTW eastbound traffic impacted by weather could not use reroutes south of the weather because of the high echo tops associated with precipitation in that region.
>
> June 11, 2003 0115Z: Weather near Louisville, KY causing problems but UPS hopes any ground stop programs will be minimal. During SPT, ZID TMU Supervisor (STMC) notes that CIWS is showing growth near Louisville Airport (LOU), with no accompanying storm decay regions. Based on CIWS weather information, he states there is no support for avoiding a LOU ground stop.
>
> June 11, 2003 2010Z: ZDC receives a request to open route J48. The ZDC STMC used CIWS to argue that storms with echo tops 41-49 kft were impacting the route and therefore, in deference to safe airspace management, the route open request was denied, despite increasing en route delays.
>
> July 11, 2003 1144Z: ZBW used CIWS to determine potential safe holding areas in western MA if weather impacts BOS traffic.
>
> July 21, 2003 1850Z: ZID STMC called ATCSCC to question the opening of a jet route. The STMC reported CIWS echo tops values for weather in the vicinity and expressed concern that opening the route may be premature.

The common thread between various "Improved Safety" benefits observations from the "benefits blitz" was that CIWS was used to identify situations where alternative, tactical responses to thunderstorm disruptions, though likely to reduce delay, were not safe enough to be utilized.

In other words, by using CIWS, additional reroute options were commonly realized (as discussed in Chapter 7), but conversely, CIWS also performed well in its ability to quickly inform users of safety concerns associated with potential convective weather TFM decisions, thus adequately balancing aggressive delay mitigation tactics with conservative safety counter-checks.

It should also be noted that although the FAA ATC has no responsibility to provide warnings to pilots about possibly hazardous en route weather, airline dispatch does have very explicit responsibilities which were discussed in Chapter 2. Due to the lack of resources to put observers at passenger airline SOCs during the "blitz periods", we were not able to quantify the safety benefits from the airline use of the CIWS products through blitz observations.

With respect to the Flight Plan safety objectives, the current status of detailed benefits assessments is as follows:

1. Reduction of cabin injuries caused by turbulence

   In the next phase of the study, we will seek to obtain statistics on cabin injuries in the CIWS domain before and after the operational inception of CIWS.

2. Reduction of serious operational errors associated with convective weather

   Objective 8 in the FAA Flight Plan, "Enhance the Safety of the FAA Air Traffic System" has as an objective "reduce the number of most serious air traffic control errors by 15% by FY 2008".

   One of the significant causes of air traffic errors is presumably high workload in high complexity airspace. Some of the CIWS domain en route sectors are exceedingly complex and one would imagine that convective weather adds to the complexity and workload.

   As discussed above, we believe quantitative data exist which demonstrate the contributions of CIWS in creating a more orderly, safe traffic flow during convective weather. However, we have no data on operational errors within the CIWS en route domain in the time period 1999-2003. Additionally, the URET system commenced use between 2001 and 2003 which would also help reduce operational errors. We feel it would be very difficult to separate the relative contributions of URET and CIWS under these circumstances. Hence, we do not plan to conduct a detailed analysis of operational errors in the next phase of the CIWS benefits study.

9. SUMMARY

This report summarizes the preliminary results of a two-year study to determine if the Corridor Integrated Weather System (CIWS) concept would enable the users to increase safety and significantly reduce convective weather delays in the highly congested Great Lakes and Northeast corridors. The CIWS concept being evaluated provides en route and terminal traffic flow managers with accurate, automated, rapidly updated information on storm locations and echo top heights along with two hour high resolution animated growth and decay storm forecasts.

9.1 RESULTS OF THE STUDY

Specific objectives of this phase of the study were:

- Determine the major operational benefits of the CIWS products when used for real time decision support in the Great Lakes and Northeast corridors
- Quantify the delay reduction for two of the identified principal operational benefits
- Develop a methodology that could be applied to quantifying the delay reduction of other identified operational benefits
- Determine if there were changes in gross delay statistics at key facilities that could be attributed to the use of the CIWS products.

All of these specific objectives were met.

Development of a methodology for quantifying delay reduction

The methodology used in the study to quantify the benefits is a new approach that utilizes on site observations during "benefits blitz" periods, together with studies of individual cases identified from the "benefits blitz" observations and ongoing post event feedback from the operational users. The analysis of individual cases often involved detailed calculations of queue sizes and durations. To the best of our knowledge, the case studies discussed here in Chapter 6 and Appendices B and C are the most comprehensive quantitative analyses of individual cases carried out to date in the Northeast and Great Lakes corridors and should furnish an excellent background for future in depth studies in this region.

Identification of major benefits

Major benefits that were identified during the six multi-day "benefits blitz" observation periods in 2003 are summarized in Figure 9-1.

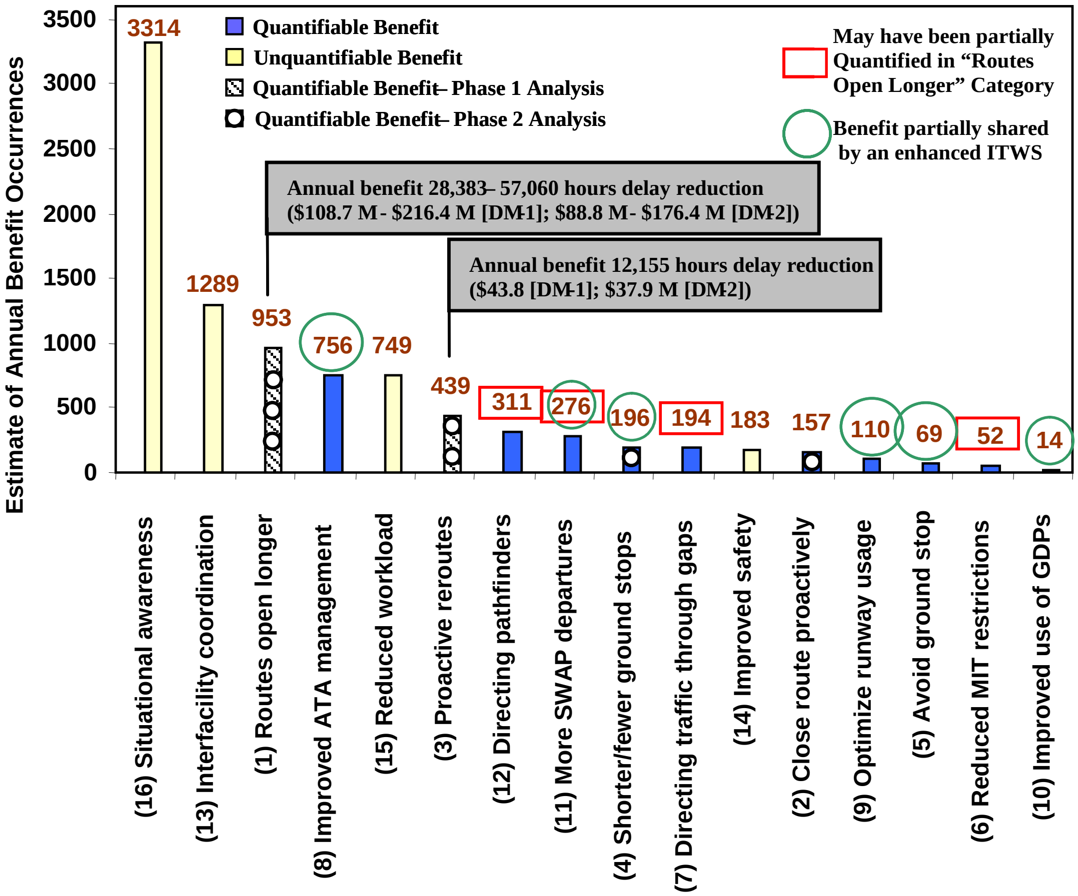

Figure 9-1. Estimated annual occurrences of identified CIWS benefits categories. Numbers (in parentheses) associated with category names correspond to category numbers in previous tables as well as category identifiers in Appendix E. Yellow bars denote benefits that could not be quantified with the approach used in Phase 1. Blue bars denote quantifiable benefits. Striped bars denote benefit categories included in the Phase 1 Benefits Analysis. Bars with open circles denote categories to be included in the Phase 2 Benefits Analysis (The "Kept Routes Open Longer" and "Proactive Reroutes" categories, included in Phase 1, will also be further analyzed in Phase 2 in an attempt to reduce statistical uncertainty). Benefit categories with annual occurrence values boxed in red denote categories that may have been partially quantified in the "Routes open longer" category. Benefit categories with annual occurrence values circled in green denote benefits that would be partially shared with an enhanced ITWS. Annual delay savings estimates associated with the two main categories examined in Phase 1 analyses ("Route kept open longer/reopened closed route earlier" and "Proactive, effective rerouting") are also provided in the figure.

We see that the most commonly identified benefits -- better situational awareness and improved interfacility coordination -- are not easily quantified. However, we view both of these as very important because they speak to the issue of improving the overall productivity of the ARTCC TMUs and thereby the NAS.

Coping with rapidly changing convective weather in highly congested airspace is an extremely challenging job. Reducing the amount of time required by the TMU staff to maintain situational awareness and coordinate with other facilities is critical to effectively accomplishing the weather impact mitigation process that was described in Chapter 2.

We believe that the very high frequency with which these two benefits were observed indicates a significant increase in TMU productivity that may not be fully captured in the analysis of other readily quantifiable benefits.

Quantitative estimates for delay reduction

The overall CIWS delay reduction benefit for the two benefits categories quantified in this first phase of the CIWS benefits study was 40,000 to 69,000 hours annually. The monetary value of this delay reduction estimate, assuming airline operations costs are incurred with downstream delay was $ 152 M to $ 260 M per year. The cost savings assuming no airline cost associated with downstream delay was $ 127 M to $ 214 M.

This range of variation in annual delay estimates reflects the wide range of individual case benefits, which in turn reflects the high sensitivity of delays in congested airspace to issues such as the number of available routes, queues due to excessive demand at multiple locations in the network, and differences in the time duration of storm events.

A number of major delay reduction events were separately analyzed. Of these, several had individual event delay reduction benefits exceeding 800 hours with monetary values exceeding several million dollars. Since these were noted as extreme benefits cases at the time of occurrence and resources available for case analysis were limited, these cases were excluded from the analysis to avoid introducing an upward bias in the results.

We should reemphasize that the quantitative benefits shown above and in Chapter 6 significantly understate the operational benefits of CIWS as tested in 2003 for three reasons:

- As noted in Figure 9-1 and in the previous discussions, the available time and resources did not permit us to accomplish quantitative estimates for a number of other high frequency benefits such as better management of weather impacts on terminal arrival transition areas (ATAs), and closing routes proactively

- There were a number of key ATC facilities that did not have CIWS situation displays in 2002-03 (see Section 9.3), which resulted in a number of missed opportunities for delay reduction

- The benefits [through the use of the Route Availability Planning Tool (RAPT)] of increased departure rates during SWAP events have not been considered. RAPT has provided very significant benefits at New York using the ITWS Terminal Convective Weather Forecast (TCWF). RAPT is in the process of being interfaced to the CIWS products to take advantage of the CIWS forecasts, spatial coverage and echo tops products.

Though understated for reasons listed above, it is recognized that extrapolations of annual CIWS benefits at individual ARTCCs based upon thunderstorm frequency distributions heavily disposed towards the above average storm activity in 2003 (particularly in ZDC) may demonstrate an upward bias when compared to roll-ups based upon longer-term storm frequency averages. Historical thunderstorm data will be utilized in the Phase 2 CIWS benefits study to better scale thunderstorm frequency distributions towards longer-term convective activity trends.

Evidence from delay statistics of CIWS operational benefits

Several of the ARTCCs that had significant delay reduction benefits for keeping routes open longer/reopening closed routes earlier and proactive, efficient reroutes (e.g., ZOB and ZID) also showed significant reductions in the delay events at the major airports (CVG, DTW, and PIT) within the ARTCC in 2003 relative to 2002. These reductions in delay events were evident even though the number of convective storm events in the respective ARTCCs was constant or increased from 2002 to 2003.

The overall number of delay events at EWR dropped in 2003 albeit the number of delay events with delays greater than one hour at EWR increased. Since other convective delay reduction systems [specifically the Route Availability Planning Tool (RAPT)] also commenced operation in 2003, it is unclear to what extent CIWS assisted in reducing the number of overall delay events at EWR.

The significant decrease in delay events (over 66%) at BOS in 2003 relative to 2002 can be attributed in part to ZBW use of CIWS in 2003 and in part due to a 10 % drop in overall storm activity.

The number of longer delay events at ORD increased in 2003 while shorter delay events decreased despite constant overall convective activity within ZAU ARTCC and a 12% increase in NWS-identified thunderstorm days at the airport. This unexpected increase in longer delay events may reflect the particular nature of storm events in the two years, procedures issues [e.g., rules governing land and hold short operations (LAHSO) changed in April 2003] as well as other factors. Discussed in section 9.3 are options for improving the operational effectiveness of CIWS in reducing delays at ORD.

9.2 NEXT STEPS IN QUANTIFYING CIWS DELAY REDUCTION

The results reported here are the results of the first phase of the CIWS operational benefits study.

In the next phase, we will examine additional case studies for the two benefits categories analyzed in Chapter 7 (so as to reduce the spread in benefits estimates for those two categories). We will also obtain quantitative benefits estimates for the other major benefits discussed above.

During the next phase of the study we plan to include analyses of flight tracks and weather before and after the principal new CIWS products were introduced in late 2002. The motivation is to find additional objective substantiation for the operational user feedback that traffic flow management is evolving towards a new dynamic adjustment paradigm for managing convective weather through the use of the CIWS products.

Other important elements of the second phase study include:

- Extrapolating the benefits observations in the Great Lakes and Northeast corridors to other parts of the NAS to assist in determining the appropriate spatial extent of the operational CIWS functional capability

- Estimating the fraction of the overall convective weather delay in the CIWS region that is being reduced by the use of CIWS

- Addressing key aspects of the service being provided to the commercial airlines who are principal “customers” of the FAA’s new Air Traffic Organization (ATO). A key issue for customer impact of delay reduction is improving the model for the “down line” impact of delays. We plan to use more elaborate models for the downstream impacts of initial delays [e.g., using the delay multiplier model of Beatty et al., (1999)] to better capture the impacts of delay propagation on airline operations resources (crews and aircraft).

- Utilization of historical thunderstorm data to better scale the annual storm frequency multiplication factor (used to roll-up observed CIWS benefits to an annual scale) against climatology

Studies also should be carried out to determine if CIWS delay reduction can be estimated by appropriate analysis of FAA delay statistics and the CIWS weather products. This is basically the “direct approach” that was discussed in Section 5.1. As noted there, the “direct approach” has significant problems in handling differences in weather and other factors between the two time periods considered. However, it does have the advantage of possibly capturing the quantitative benefits for some of the high frequency benefits illustrated in Figure 9-1 that could not be readily quantified with the approach to benefits quantification that we have utilized.

9.3 NEAR TERM OPPORTUNITIES FOR INCREASING THE DELAY REDUCTION PROVIDED BY THE CIWS DEMONSTRATION SYSTEM

The operational feedback provided by the various CIWS users and the delay benefits analyses reported here have identified some, low cost, near term opportunities to significantly increase the operational benefits provided by the CIWS demonstration system.[34] Work proceeds in parallel to provide an operational capability in 2007 or 2008.

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[34] The hardware cost for a CIWS situation display (including the communications equipment) is approximately $5K; the annual communications cost for an additional frame relay connection is approximately $ 6 K per year.

These opportunities are as follows:

> ***Improve safety by providing real time access to CIWS products in a digital format to airlines and vendors that provide dispatch decision systems, so that dispatch can better perform their statutory requirements under the Federal Aviation Regulations (FAR).***

Although the FAA ATC has no responsibility to provide warnings to pilots about possibly hazardous en route weather, airline dispatch does have very explicit responsibilities. Specifically, FAA Regulation (FAR) 121.601 includes the following requirements for dispatchers:

> "Before beginning a flight, the aircraft dispatcher shall provide the pilot in command with all available weather reports and forecasts of weather phenomena that may affect the safety of the flight, including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear, for each route to be flown and each airport to be used.
>
> During a flight, the aircraft dispatcher shall provide the pilot in command any additional information of meteorological conditions (including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear), and irregularities of facilities and services that may affect the safety of the flight."

The CIWS demonstration system has provided real time displays to major airline systems operations centers that are typically used by the airline ATC coordinators and chief dispatchers. However, the responsibility for individual flight safety resides with individual dispatchers who typically have access only to the airline dispatch decision support (DDST) displays. By providing the CIWS products in digital format, the developers of the various airline DDSTs could provide the CIWS products as a user selectable overlay. Requests to provide this information have been received from two DDST vendors already.

> ***Deploy CIWS situation displays at all the TRACONS that manage traffic into major metropolitan areas within the current CIWS domain and that were identified in the Flight Plan 2004-08***

Specifically, install situation displays (SDs) at Philadelphia (PHL), the Boston consolidated TRACON, and Washington/Baltimore consolidated TRACON (PCT). There have been several requests from TMUs at both ZDC and ZNY to have CIWS displays installed at PHL and PCT. These displays would significantly improve the ARTCC/TRACON coordination and reduce the ARTCC TMU workload associated with managing internal traffic. This in turn would provide the ARTCC TMUs with more time to handle over flight problems and hence reduce overall NAS congestion.

Deploy CIWS situation displays at all the ARTCCs that border ZAU and the Chicago Tower

The Chicago ARTCC has noted on a number of occasions that there exists a very heavy interfacility coordination workload associated with flights to and from the west, which would be significantly improved if ZKC had a CIWS SD. The Canadian playbook routes that pass north of Toronto are critical for moving east-west traffic when severe convective weather blocks the routes through ZOB and ZID. However, use of the Canadian playbook routes results in a significant increase in traffic from ZAU into

ZMP. Since there often is convective weather near key transitions between ZMP and ZAU, and between ZKC and ZAU, improving common situational awareness would significantly improve the overall capability of the ZAU Traffic Management Unit.

Chicago O'Hare Control Tower has also expressed a strong interest in acquiring a CIWS SD. Today, O'Hare Tower does not have the capability of observing the same weather products as the TRACON (located 30 miles away from the Airport) and Chicago ARTCC, but must deal reactively with severe weather around the airport. Runway configurations play a large part in determining the efficiency for Chicago O'Hare Airport; specifically, dynamic use of the appropriate runways allows for efficient departure and arrival throughput. Since the choice of appropriate runway configuration is heavily dependent on knowledge of the weather, the Chicago airport could be much better served were the tower to have a consistent weather product in common with the other two ATC facilities.

Provide weather radar coverage for the Canadian playbook routes

The CIWS case studies in Chapter 6 and Appendices B and C highlight the importance of having at least one route open at all times between Chicago and New York/Philadelphia/Boston. When severe convective weather (e.g., a north south oriented squall line, moving slowly eastward) blocks the east-west routes through ZID and ZOB, east-west traffic must either go north or go south around the weather. Rerouting to the south results in extreme congestion over Atlanta and up the east coast. The alternative is to use the Canadian playbook routes that pass north of Toronto[35]. Figure 9-2 shows one example of a Canadian playbook route.

If the Canadian playbook routes are to be used effectively, one needs to have reliable information on possible convective impacts within Canada (especially Ontario). As shown in Figure 9-3, it would be necessary to add several Canadian weather radars to the CIWS mosaic to fully cover these routes. NavCanada is very interested in working with the FAA to achieve seamless CIWS coverage and improved situational awareness for the Canadian playbook routes.

Provide Route Availability Planning Tool (RAPT) capability at one of the other major metropolitan areas identified in the FAA Flight Plan

The RAPT system at New York will be interfaced to the CIWS forecasts and echo tops during the winter of 2003-04. The use of RAPT at another major metropolitan area within the current CIWS domain, identified in the Flight Plan 2004-08, is relatively straightforward. Chicago would seem to be a high-priority candidate, considering the level of delays at ORD in 2003 (see Chapter 4) and the local ATC and airline interest.

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[35] The Canadian playbook routes are the most frequently used playbook reroutes.

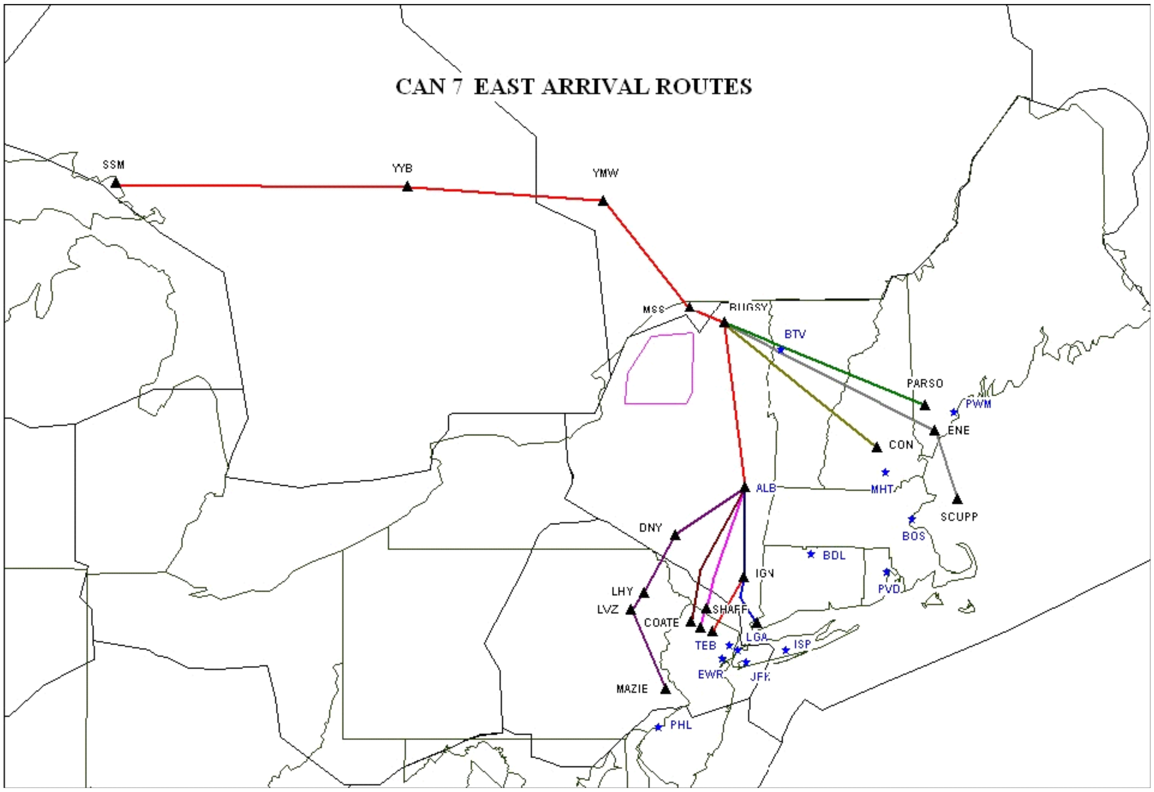

Figure 9-2. Example of a Canadian playbook route that would be used for arrivals into three of the major metropolitan terminals identified in the FAA's Flight Plan 2004-08 when severe convective weather blocks the east-west routes in ZOB and ZID.

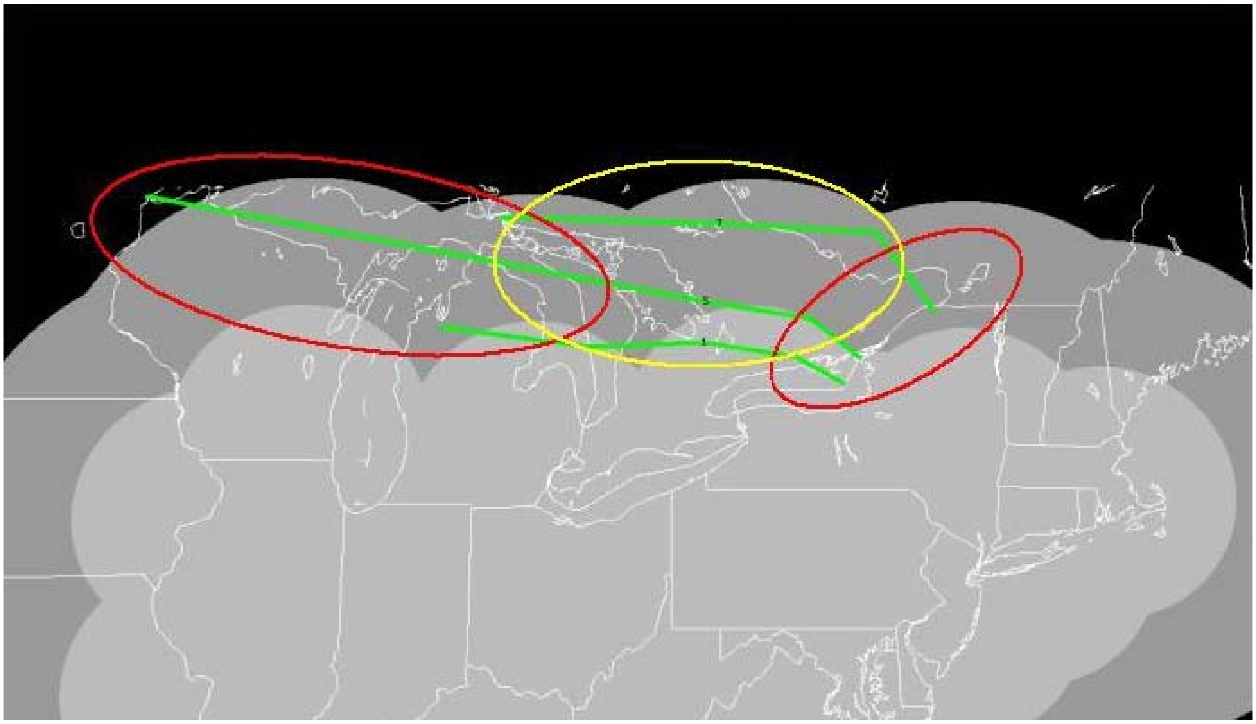

Figure 9-3. Regions where additional NEXRAD (red ellipses) and Canadian weather radars (yellow ellipse) would need to be added to the current CIWS mosaic (light gray is high quality coverage) to provide full coverage of the Canadian playbook routes (green lines). These playbook routes, which are the most frequently used, are critical to NAS operations when the normal east-west routes through ZOB, ZID and ZNY are blocked by severe convective weather.

APPENDIX A
CIWS PRODUCTS AND PRODUCT DISPLAY FORMATS

This appendix provides a brief description of each CIWS weather information product. Graphical examples of the products are included.

A-1 NEXRAD VIL MOSAIC PRECIPITATION

The CIWS NEXRAD VIL Precipitation product provides a high-resolution estimate of vertically integrated liquid water (VIL) based on NEXRAD radar reflectivity data. Because VIL is related to vertically integrated reflectivity, the VIL values are mapped to the corresponding six-level colors used to present radar data. Therefore, the VIL map shows the location and intensity of precipitation as indicated by a mosaic of NEXRAD radars. An example of the product is provided in Figure A-1.

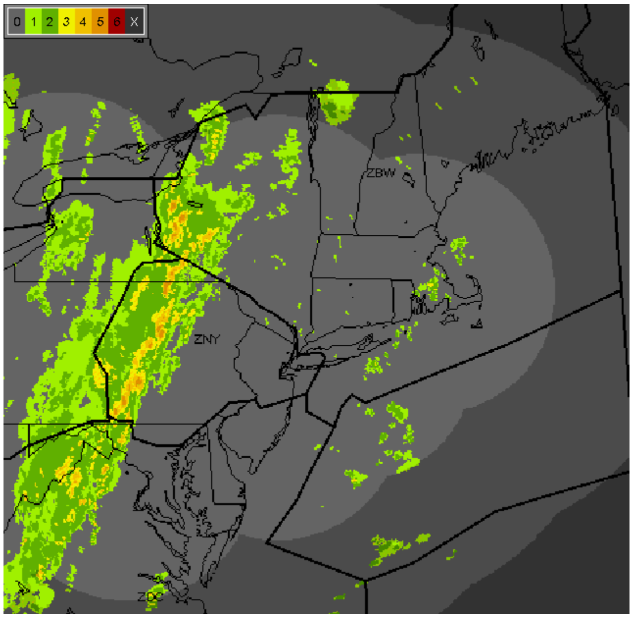

Figure A-1. Example of CIWS NEXRAD VIL Mosaic Precipitation product.

The CIWS NEXRAD VIL mosaic product is displayed in six-level representation. The levels are color-coded as shown in Figure A-1. Weather levels below level one are shown as light gray if within 125 nm of any NEXRAD radar, and as darker gray if further than 125 nm from any NEXRAD radar. The darkest gray level indicates no data regions (areas where there is no coverage by the NEXRAD radars). The resolution of the CIWS NEXRAD VIL Mosaic product is about one nautical mile (two kilometers). All computations are performed at 1-km resolution, but the data are displayed with a 2-km resolution to reduce bandwidth. The maximum range of the product depends upon the number and location of the NEXRAD radars in the mosaic. The update rate is 2.5 minutes.

A-2 ASR-9 MOSAIC PRECIPITATION

The CIWS ASR Mosaic Precipitation product is a representation of the location and intensity of weather from a mosaic of the weather channel data from many ASR-9 radars in the CIWS coverage area. These fan beam surveillance radars have a maximum range of 60 nm, and thus do not completely cover the CIWS domain. For this reason, 1-km (0.5 nm) NEXRAD VIL data are used to fill the mosaic image where ASR coverage does not exist. An example of the product is provided in Figure A-2.

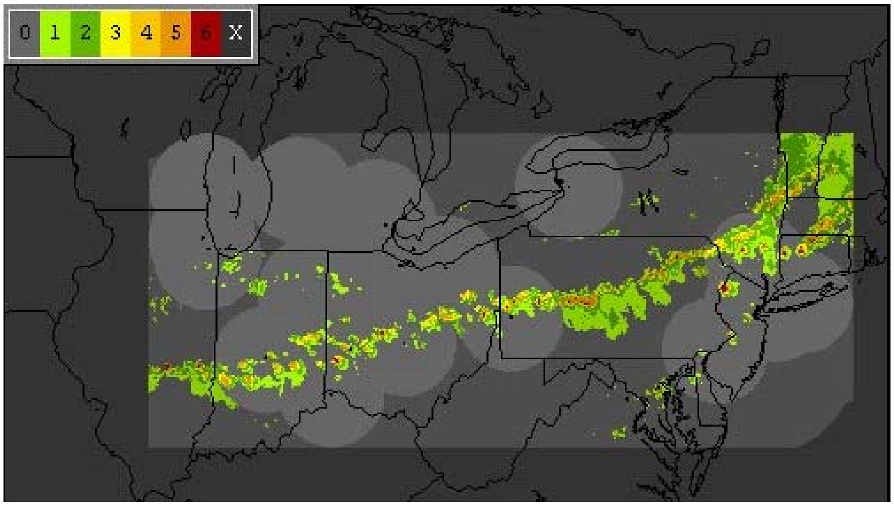

Figure A-2. Example of the CIWS ASR Mosaic Precipitation product.

The CIWS ASR Mosaic Precipitation product is provided in the six-level representation. The levels are color-coded as shown in Figure A-2. Precipitation intensities below level one are represented by light gray where ASR-9 radars contribute to the mosaic. Precipitation intensities below level one are represented by medium gray where NEXRAD radars contribute to the mosaic. The dark gray is used to indicate where there is no coverage by the ASR-9 and beyond 150 nautical miles from the NEXRAD radars.

The resolution of the CIWS ASR Mosaic Precipitation product is 1 km (about 0.5 nm). The maximum range of the ASR-9 contribution to the product is dependent upon the coverage of the individual ASR-9 radars that compose the mosaic (approx. 60 nm). The update rate of the CIWS ASR Mosaic Precipitation product is one minute.

A-3 STORM MOTION

The CIWS Storm Motion product provides an indication of the motion (speed and direction) of storms and a 10- and 20-minute storm extrapolated positions in the terminal and en route areas. An example of the product is provided in Figure A-3. Storm motion is indicated by constant-length, black arrows showing the direction of motion and accompanying text showing the storm speed in knots. Storm speeds are rounded to the nearest five knots. No motion arrows are plotted for storms with speeds of less than five knots; rather a black, unfilled square is used to indicate that the storms are nearly stationary. The update rate of the products depends on the update rate of the underlying precipitation product, 2.5 minutes for NEXRAD and one minute for ASR.

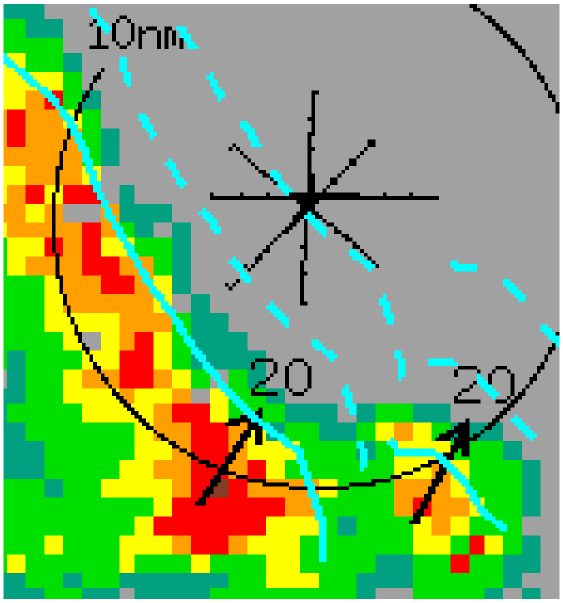

Figure A-3. Example of the CIWS Storm Motion product.

Storm motion estimates are produced for all level three or greater regions and the vectors are assigned to the highest weather levels contained within the level three regions. The maximum range of the Storm Motion product is defined by the underlying precipitation product. The update rate of the products depends on the update rate of the underlying precipitation product. In the NEXRAD window, storm motion arrows are displayed on storms that fall within 125 nm of any NEXRAD radar. In the ASR window, storm motion estimates are plotted only on the ASR-9 contribution to the mosaic.

As shown in Figure A-3, three storm extrapolated position contours are displayed for each storm cell and/or storm cell group. The contours correspond to 0-, 10- and 20-minute extrapolations. A solid blue line indicates the current leading edge of level 3 weather; dashed blue lines indicate the 10- and 20-minute extrapolations. In the NEXRAD window, storm extrapolated position lines are displayed on storms that fall within 125 nm of any NEXRAD radar. In the ASR window, storm extrapolated position lines are plotted only on the ASR-9 contribution to the mosaic.

A-4 LIGHTNING

The CIWS Lightning product provides a map of cloud-to-ground lightning strike locations. An example of the product is provided in Figure A-4.

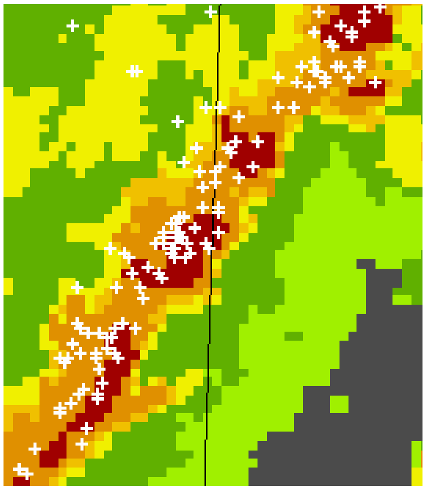

Figure A-4. Example of the Lightning product displayed in the NEXRAD VIL window.

Cloud-to-ground lightning strikes are available for display in the NEXRAD VIL mosaic and ASR mosaic windows. The locations of strikes that have occurred in the past six minutes are indicated by white plus signs (+). The update rate of the product is two minutes.

Lightning strikes are plotted on a grid that is the same size as the grid used for the NEXRAD VIL mosaic. This grid is roughly 1400 nautical miles east/west by 850 nautical miles north/south and centered about 100 miles east of Columbus, OH. Any strikes that fall within this grid are plotted in the windows, even if there is no corresponding precipitation coverage. For example, in the ASR window, the grid containing the ASR mosaic is just large enough to contain all of the ASR-9 radars in the mosaic. The grid containing the lightning data is significantly larger than the grid containing the ASR mosaic. As a result, users will see lightning strikes plotted where there is no corresponding radar coverage in that window. In this case, lightning can be used as an indicator of the locations of storms where no radar coverage is available.

A-5 SATELLITE

The CIWS Satellite product provides satellite images for the CIWS coverage area. Satellite data may be displayed as a background to the NEXRAD VIL mosaic product. An example of the product is shown in Figure A-5. During the day, the visible channel of the satellite data is displayed. Infrared data are displayed from when the sun is roughly 30 degrees above the western horizon until the sun is about 30 degrees above the eastern horizon.

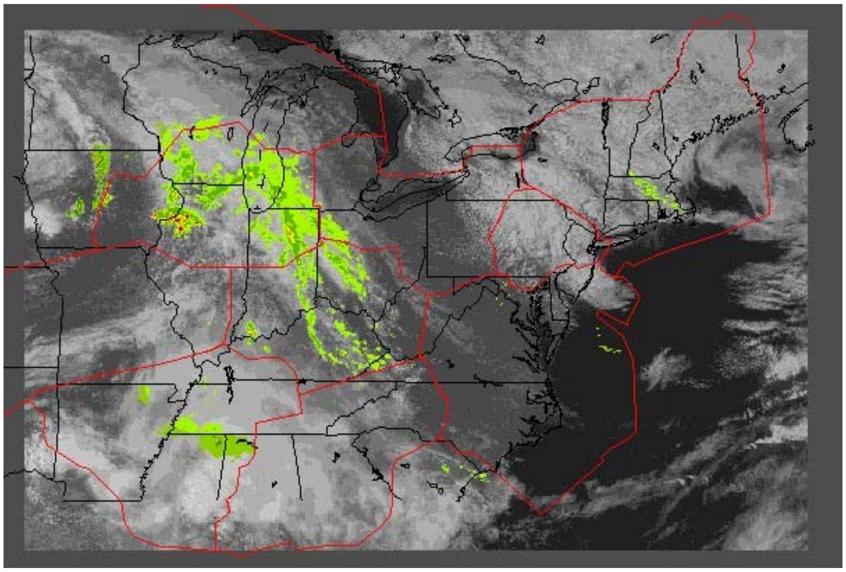

Figure A-5. Example of satellite data in the CIWS NEXRAD Mosaic window.

Satellite data are provided in grey-scale and are displayable only in the NEXRAD window. Satellite data are plotted on a grid that is the same size as the grid used for the NEXRAD VIL mosaic. This grid is roughly 1400 nm east/west by 850 nm north/south and centered about 100 miles east of Columbus, OH. All satellite data within this grid are plotted in the window, even if there is no corresponding precipitation coverage. Therefore, users may see areas in the satellite data typically associated with precipitation, but no precipitation returns may be displayed there because radar coverage does not extend to those areas. When satellite data are displayed, the background grey colors associated with the NEXRAD 230 km and 460 km range radar coverage pattern are not displayed.

A-6 ECHO TOPS MOSAIC

The CIWS Echo Tops Mosaic provides estimates of echo top heights in a gridded format. An example of the product is provided in Figure A-6. Blues and greens represent lower echo top values while yellows and reds indicate higher echo tops values. While the product is computed with a one-kilometer horizontal and 1000-foot vertical resolution, the horizontal resolution of the *displayed* product is one nautical mile to decrease bandwidth. The vertical resolution of the *displayed* product is 5000 feet. The update rate is 2.5 minutes and the coverage is equal to the 125-nautical mile NEXRAD coverage.

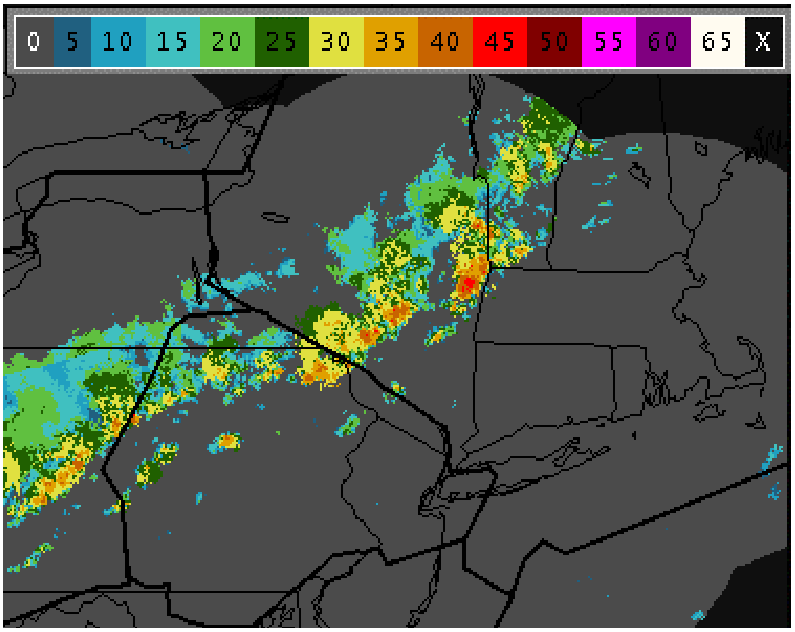

Figure A-6. An example of the Echo Tops Mosaic Map.

A-7 ECHO TOPS ANNOTATION

The CIWS Echo Tops (in the NEXRAD and ASR windows) and Annotation (in the Echo Tops window) products provide echo tops values in label format and in “flight level” nomenclature. For example, an echo top of 54,000 feet is shown as 540. The labels consist of black text in a white box with a white line pointing to the location of the echo top value. An example of Echo Tops in the NEXRAD window is shown in Figure A-7.

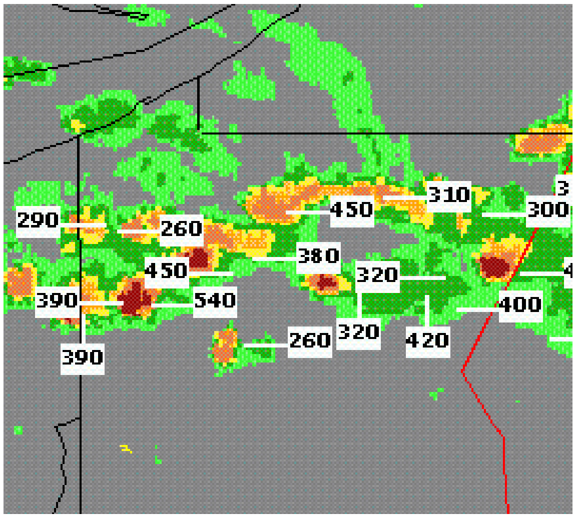

Figure A-7. Echo Tops product in the NEXRAD window.

A-8 REGIONAL CONVECTIVE WEATHER FORECAST (RCWF)

The CIWS Regional Convective Weather Forecast (RCWF) product provides two-hour forecasts (in 15-minute increments) of low, moderate, and high probabilities of level three and greater weather. The product self-scores so that an estimate of its performance over time is always available as a Forecast Accuracy Score (Section A-9). An example of the Forecast product is provided in Figure A-8.

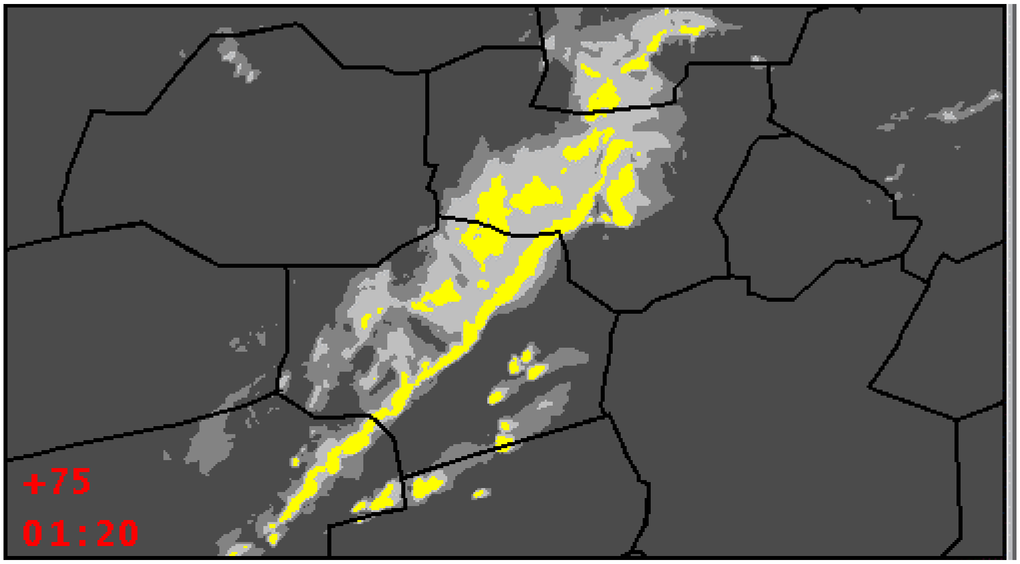

Figure A-8. Example of the Regional Convective Weather Forecast product.

The RCWF provides real-time probability forecasts of level three and greater weather out to two hours. The product uses a three-level probability map showing regions of low (medium gray), moderate (light gray), and high (solid yellow) probabilities of level three and greater weather (Figure A-8). The display animates the forecast from 60 minutes prior to the current time to 120 minutes into the future in 15-minute increments. A loop counter is displayed in the lower left corner of the Forecast window. The top number is the relative forecast time, or the time difference from the current time to the time of the weather shown in the display window. This time is positive for the forecast images and negative for past weather images. Beneath the relative forecast time is the absolute time or forecast time in UTC. The update rate of the RCWF is 5 minutes.

A-9 FORECAST ACCURACY

The RCWF product self-scores and produces the Forecast Accuracy product. The number reported to the users is a Critical Success Index (CSI) score. The CSI is similar to a Probability of Detection but with an additional penalty for false alarms. The Forecast Accuracy product is a measure of how well the past 30-, 60- or 120-minute forecasts performed. It is not a measure of the *current* forecast accuracy. An example of the product is provided in Figure A-9.

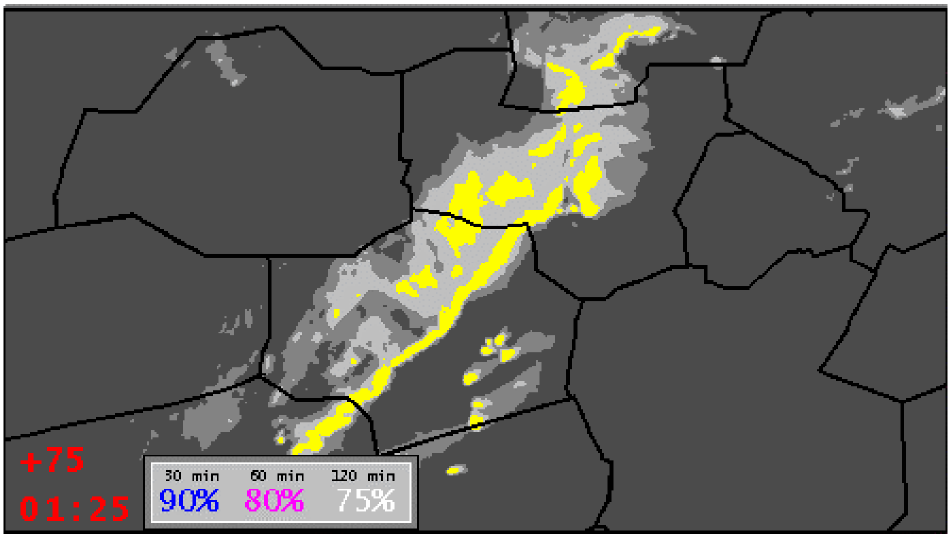

Figure A-9. Example of the Forecast Accuracy product displayed in the Forecast window.

The Forecast Accuracy score is presented in a text box in the lower left corner of the Forecast Window. The 30-minute score is shown in blue; the 60-minute in magenta (pink), and the 120-minute in white. (This color code is maintained in both the Forecast Contours and Verification Contours, discussed in the following sections.) If the forecast is still initializing and not enough time has elapsed to score the forecast, the Forecast Accuracy score display will contain the text “INIT”. If there is not sufficient level

3+ weather to score the forecasts, the Forecast Accuracy scores will contain the text "L3<MIN." Otherwise, Forecast Accuracy scores are presented as percentages.

The Forecast Accuracy scores displayed in the window are for the box centered on the Home of the window. To change the source of the scores, the window Home must be changed.

A-10 FORECAST CONTOURS

The CIWS Forecast Contours product provides forecast contours in the NEXRAD window. These contours represent the 30-, 60-, and 120-minute forecasts of high probability of level three or greater weather. An example of the product is provided in Figure A-10.

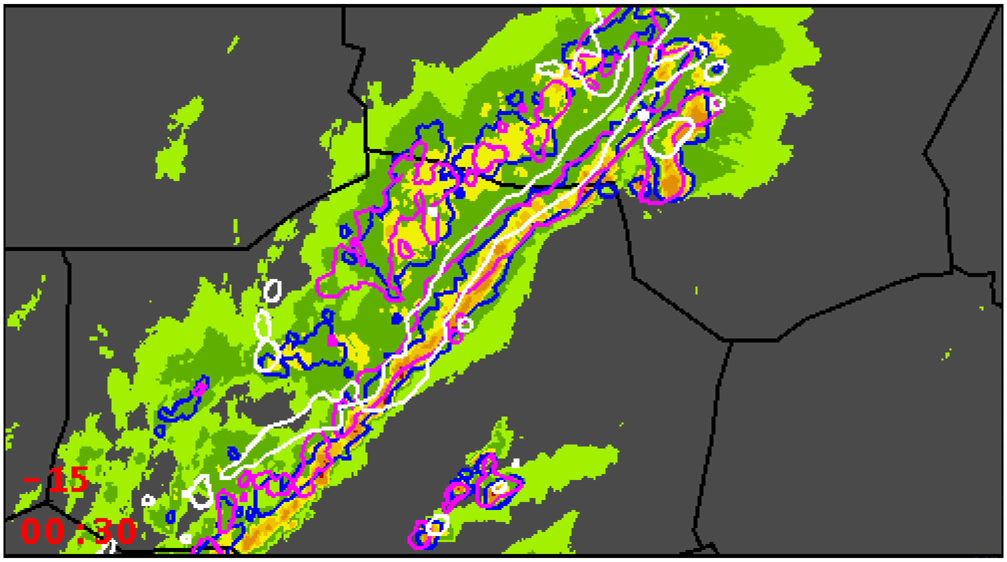

Figure A-10. Example of the CIWS Forecast Contours product.

Contours of forecasted high probability of level three or greater weather are displayed in the NEXRAD window only. In keeping with the color codes introduced in the Forecast Accuracy product, the contours for the 30-minute forecast are displayed in blue, the 60-minute contours in magenta (pink), and the 120-minute in white. In this way, users may view the current weather and the forecasts at-a-glance in the one window.

A-11 VERIFICATION CONTOURS

The CIWS Verification Contours product provides contours of past forecasts on past and current weather images in the Forecast window. These contours represent the forecasts of high probability of level three or greater weather that were made 30, 60, and 120 minutes prior to the weather image upon which they are displayed. An example of the product is provided in Figure A-11.

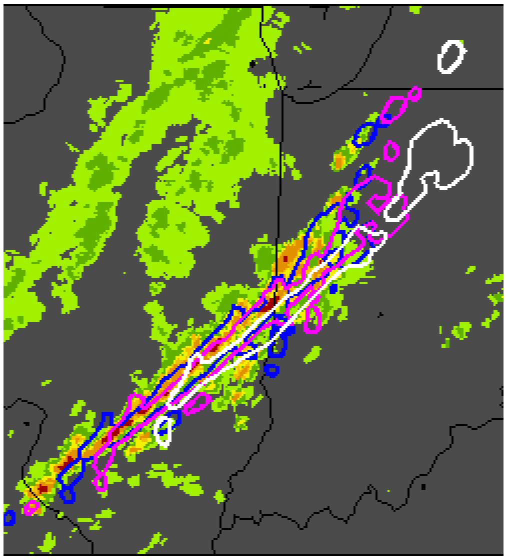

Figure A-11. Example of the CIWS Forecast Verification product.

Verification contours are displayed in the Forecast window only and can only be shown on the past and current weather images. In keeping with the color codes introduced in the Forecast Accuracy product, the 30-minute verification contours are displayed in blue, the 60-minute in magenta (pink), and the 120-minute in white. In this way, users may assess the accuracy of past forecasts by visually comparing them to the weather that was present at the verification time. Verification Contours are better than Forecast Accuracy scores for assessing forecast performance when large scale predictable storm elements (line storms) coexist with smaller scale storms, i.e., when the forecast performance is most variable.

A-12 STORM GROWTH AND DECAY TREND CONTOURS

The CIWS Growth and Decay Trends product shows areas where storm growth or decay has been detected over the past fifteen to eighteen minutes. This product is not a forecast or estimate of future storm evolution, but rather a reliable diagnosis of recent storm behavior. The Growth and Decay Trends product is displayed in the NEXRAD and Echo Tops windows only. Growth trend areas are shown as orange cross-hatched pattern and decay is shown as navy blue regions. An example of the product is provided in Figure A-12.

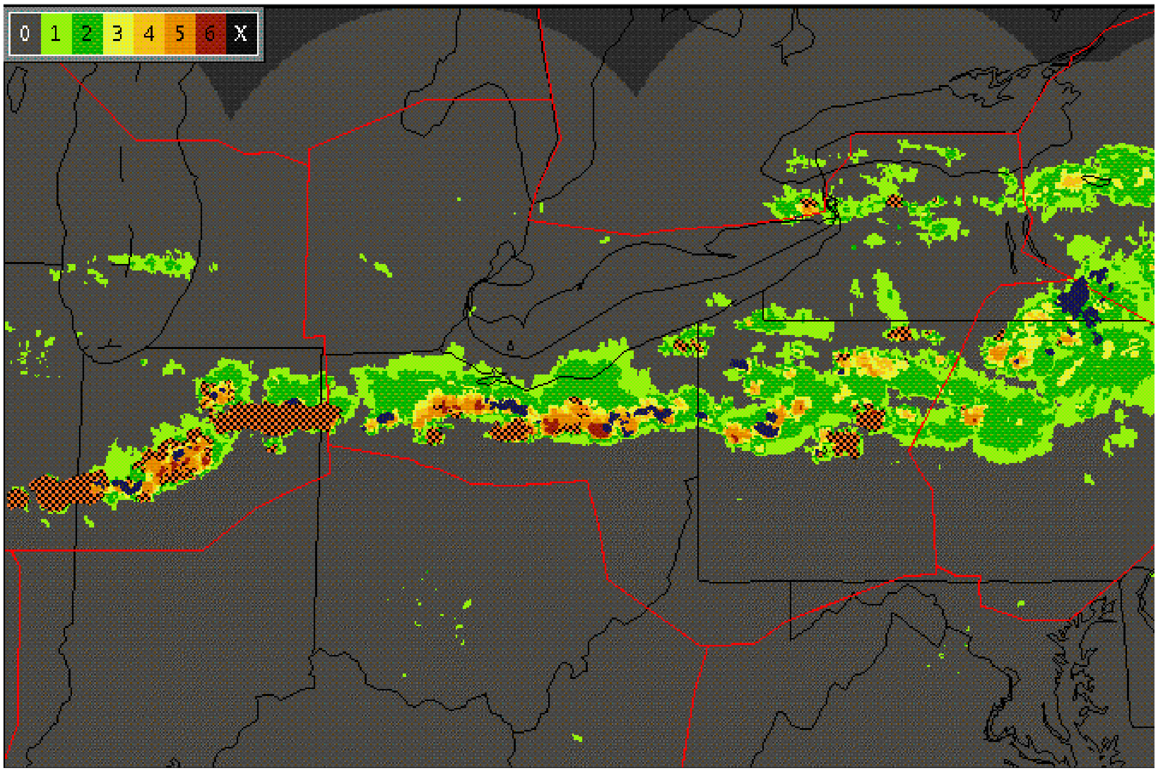

Figure A-12 Example of the CIWS Growth and Decay Trend product.

APPENDIX B
INDIVIDUAL CASE STUDY DESCRIPTIONS

CIWS Benefit: Route Open Longer and/or Reopen Closed Route Earlier

CASE STUDY B-1

ARTCC: ZAU
Date: 30 April 2003
Benefit: Kept J70 route open along with several preferred routes for en route, ZAU over flight traffic; Avoided numerous reroutes

- CIWS Echo Tops information used to identify low-topped nature of widespread level 3+ precipitation
- Routes open by way of storm over flights
- Queue delay avoided on J106 by keeping J70 route open for MSP traffic
- Numerous en route flights avoided reroutes onto either CAN 1 route (to the north) or J80 route (to the south)

CIWS Products Used: Echo tops, NEXRAD VIL, Storm Motion Vectors, RCWF, Growth and Decay Trends

CIWS Delay Savings Calculations:

Benefit Period (J70/J106 Queue): 1.25 hr (1600 – 2100 UTC)
Benefit Period (CAN1/J80 reroute):
Linear Delay Reduction: 11.5 hr
  Flights Avoiding Reroutes 47
  Total Distance Saved 6000
Queue Delay Reduction: 2.0 hr
  J106 capacity with no J70: 20/hr (15 MIT)
  Demand (J70 + J106): 22/hr
Primary Delay Reduction: 13.5 hr
Downstream Delay Reduction: 10.8 hr
Primary Operating Cost Savings: $ 33,465
Downstream Operating Cost Savings (DM-1): $ 17,075
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $ 52,828
Total CIWS Delay Reduction: 24.3 hr
Total CIWS Delay Savings (DM-1): $103,368
Total CIWS Delay Savings (DM-2): $ 86,293

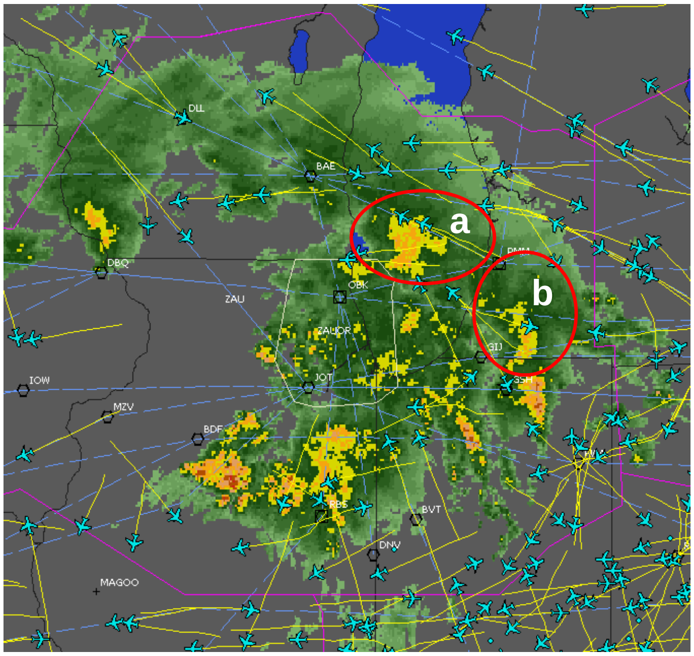

Figure B-1-1. Flightexplorer flight track and WSI composite reflectivity information at 1345 UTC on 30 April 2003. Air traffic above FL 200 not landing at either ORD or MDW is shown. The benefit given by a ZAU TMU during a post weather event interview was that CIWS echo tops information allowed them to route traffic over a number of the storms within their airspace. The two red circles a and b show areas where storm over flights were taking place. Strong intensity but low- topped storms impacted area a between 1345 and 1530 UTC. Aircraft continue to over fly these storms based on CIWS echo tops information, thus avoiding reroutes onto J106. Many over flights also crossed over area b between 1200 and 1530 UTC, another precipitation region with elevated intensities but echo tops at or below FL 300. No air traffic originating or terminating within ZAU airspace (i.e., en route traffic only) were counted in this CIWS delay saving estimate.

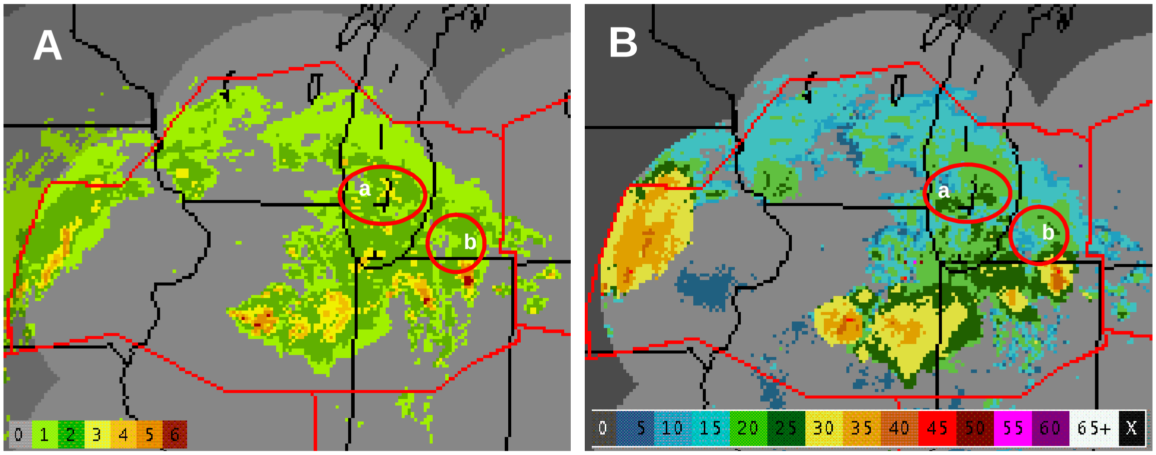

Figure B-1-2. Side by side comparison of CIWS VIL precipitation (Fig. A) and enhanced echo tops (Fig. B) at 1400 UTC on 30 April 2003. Areas a and b from Figure 1 are represented here as well. Areas of VIP level 3 and 4 precipitation in the over flight areas (a and b) were present in the CIWS VIL product, demonstrating the importance of echo tops information in making the decision to keep nominal routes open.

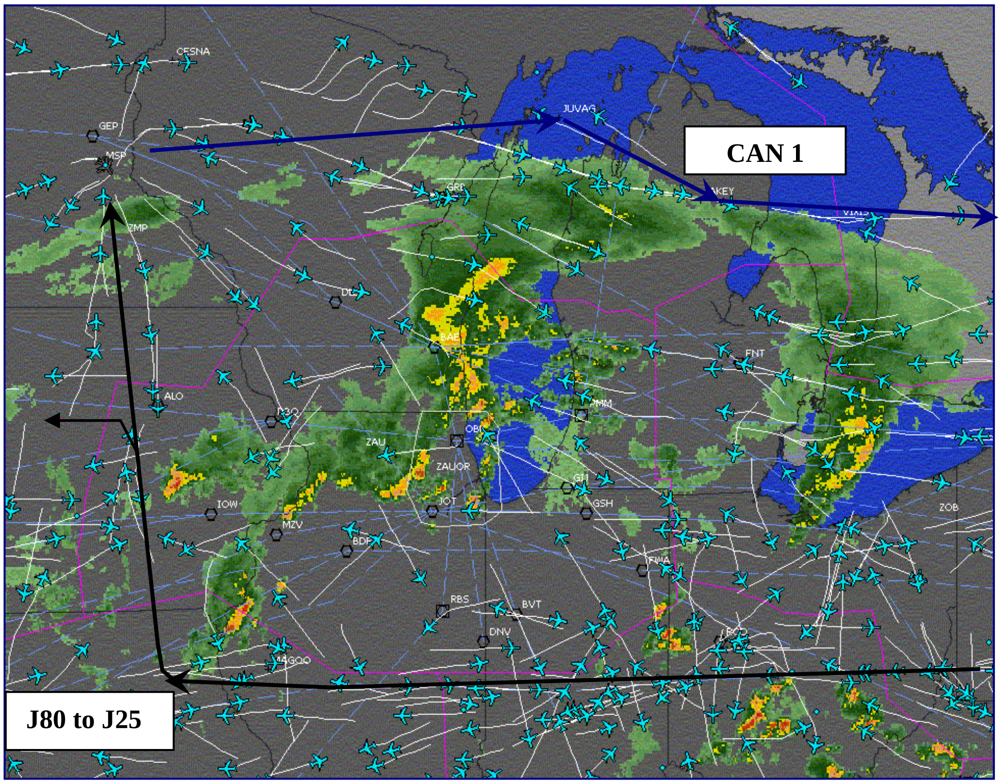

Figure B-1-3. Flightexplorer flight track and WSI composite reflectivity information at 1900 UTC on 30 April 2003. The second convective event to impact ZAU airspace was ongoing at this time. Any eastbound aircraft through ZAU's airspace over flying VIP level 3+ precipitation (courtesy of CIWS echo tops information) flew shorter routes by avoiding the CAN 1 EAST playbook route. Any westbound traffic flying preferred routes through ZAU airspace by way of CIWS-derived storm over flights were able avoid longer flight distances associated with J80 (or J80 to J25) reroutes. Traffic managers at ZAU confirmed that had CIWS not been available, J80 (CAN 1) reroutes would have been the alternative routing decision for westbound (eastbound) en route traffic.

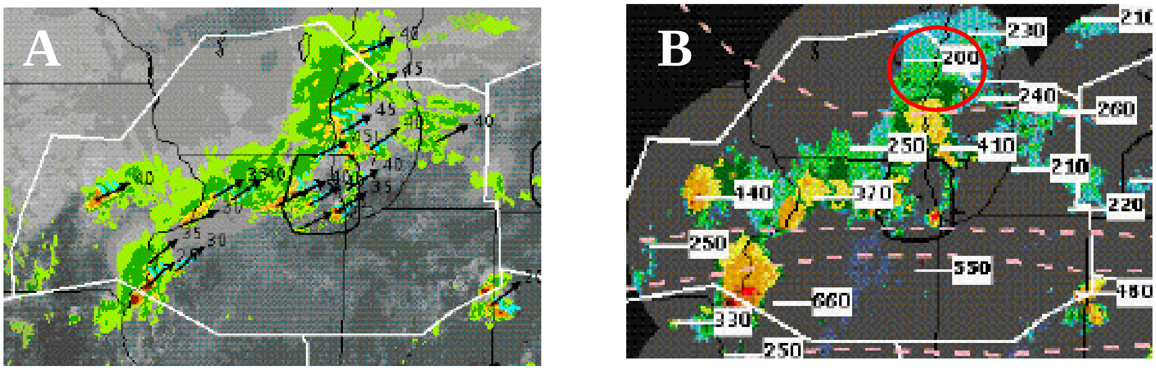

Figure B-1-4. CIWS NEXRAD VIL precipitation (Fig. A) and echo tops (Fig. B) products at 1900 UTC on 30 April 2003. The area of low-topped storm cells (red circle, Fig. B) north of Chicago TRACON identified by CIWS was of particular benefit in terms of avoiding route closures.

CASE STUDY B-2

ARTCC: ZAU
Date: 26 June 2003
Benefit: ORD_FWA2 Playbook route through southeastern ZAU airspace kept open

- CIWS products used to argue against significant reroute
- CIWS Forecast and precipitation products demonstrated that preferred playbook route would be only minimally impacted, and could thus be flown without concern
- 44 aircraft avoided 31 min additional flight time by flying CVG ..IND..OKK..OKK1 route (329 mi) rather than CVG..STL..MAGOO.. BDF3 route (600 mi)

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors

CIWS Delay Savings Calculations:

Benefit Period:	5.0 hr (1600 – 2100 UTC)	
Linear Delay Reduction:	22.7 hr	
Queue Delay Reduction:	83.3 hr	
Capacity, STL reroute	10/hr (30 MIT)	
Demand, including traffic on CVG..IND..OKK:	15/hr (74 planes/5hr)	
Primary Delay Reduction:	106.0 hr	
Downstream Delay Reduction:	84.8 hr	
Primary Operating Cost Savings:		$191,512
Downstream Operating Cost Savings (DM-1):		$134,069
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$414,799
Total CIWS Delay Reduction:		**190.8 hr**
Total CIWS Delay Savings (DM-1):		**$740,380**
Total CIWS Delay Savings (DM-2):		**$606,311**

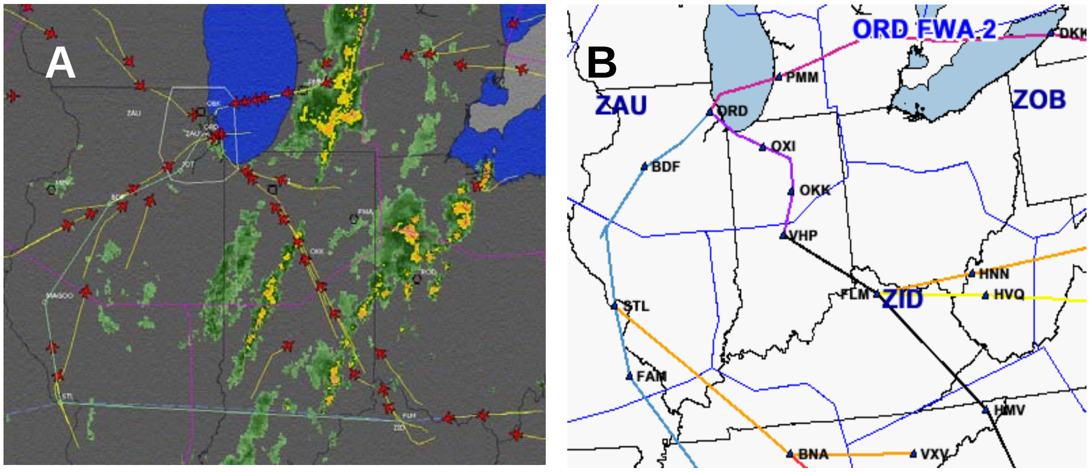

Figure B-2-1. Flightexplorer flight track and WSI composite reflectivity information at 1800 UTC on 26 June 2003, showing ORD arrival flows during an en route convective impact (Fig. A). The CIWS forecast product was used to determine that storm activity southeast of ORD would weaken or remain sufficiently scattered so as not to impede the southeast flow of the FWA 2 Playbook route (Fig. B). Had CIWS not been available, the playbook would have been modified to move all FLM traffic (southeast flow) to STL (southwest flow), with additional MIT restrictions. By avoiding this modification, each flight using the southeast ORD arrival flow saved 260 miles in additional flight distance.

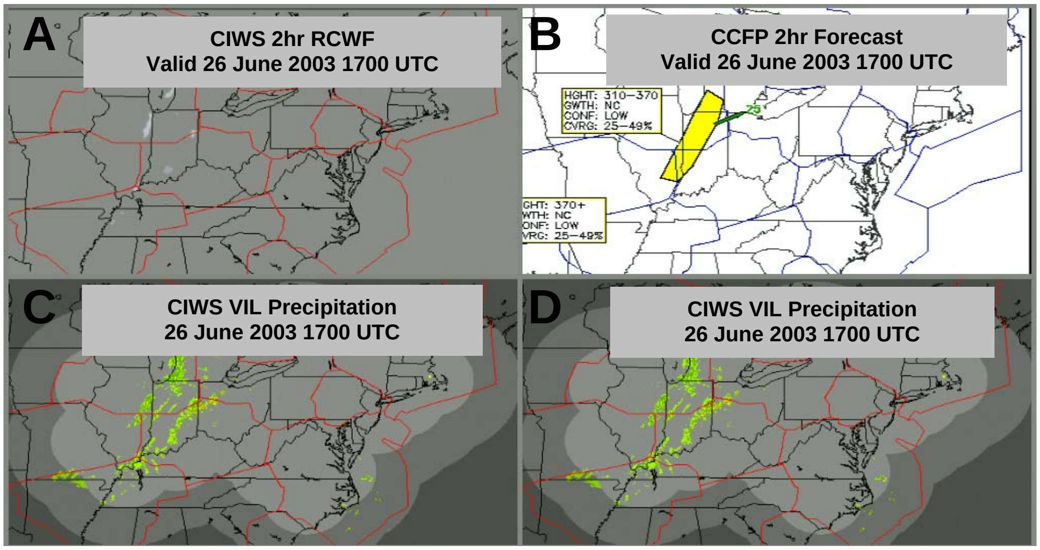

Figure B-2-2. Comparison of CIWS vs. CCFP two-hour forecast products, valid 26 June 2003 at 1700 UTC (Fig A and B, respectively. Each product is compared with CIWS VIL precipitation for forecast verification (Figs C and D). The CIWS forecast product depicts an area of only low to moderate probability of level 3+ precipitation to the south of ORD. The CCFP forecast portrayed a more significant storm impact, predicting a solid area of “low-coverage” convection southeast of ORD with greater potential to disrupt the FWA2 playbook. The ZAU TMC controlling ORD arrivals used the two hour CIWS forecast to determine that no modification was needed to the playbook reroute.

CASE STUDY B-3

ARTCC: ZID
Date: 10 June 2003
Benefit: Early reopening of STL QBALL arrival in ZID en route airspace

- PXV VOR (fix on QBALL route) in ZID reopened early, based upon CIWS convective forecast
- STL QBALL reroute cancelled 1.25 hr early, allowing 4 extra flights to fly preferred routes (and avoid substantial reroute)

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors

CIWS Delay Savings Calculations:

Benefit Period:	1.25 hr (1645-1800 UTC)		
Linear Delay Reduction:	1.4 hr		
Flights Avoiding Reroutes		4	
Total Distance Saved		720 mi	
Queue Delay Reduction:	0		
Primary Delay Reduction:	1.4 hr		
Downstream Delay Reduction:	1.1 hr		
Primary Operating Cost Savings:			$3,689
Downstream Operating Cost Savings (DM-1):			$1,739
Downstream Operating Cost Savings (DM-2):			0
Passenger Cost Savings:			$5,435
Total CIWS Delay Reduction:			**2.5 hr**
Total CIWS Delay Savings (DM-1):			**$10,863**
Total CIWS Delay Savings (DM-2):			**$ 9,124**

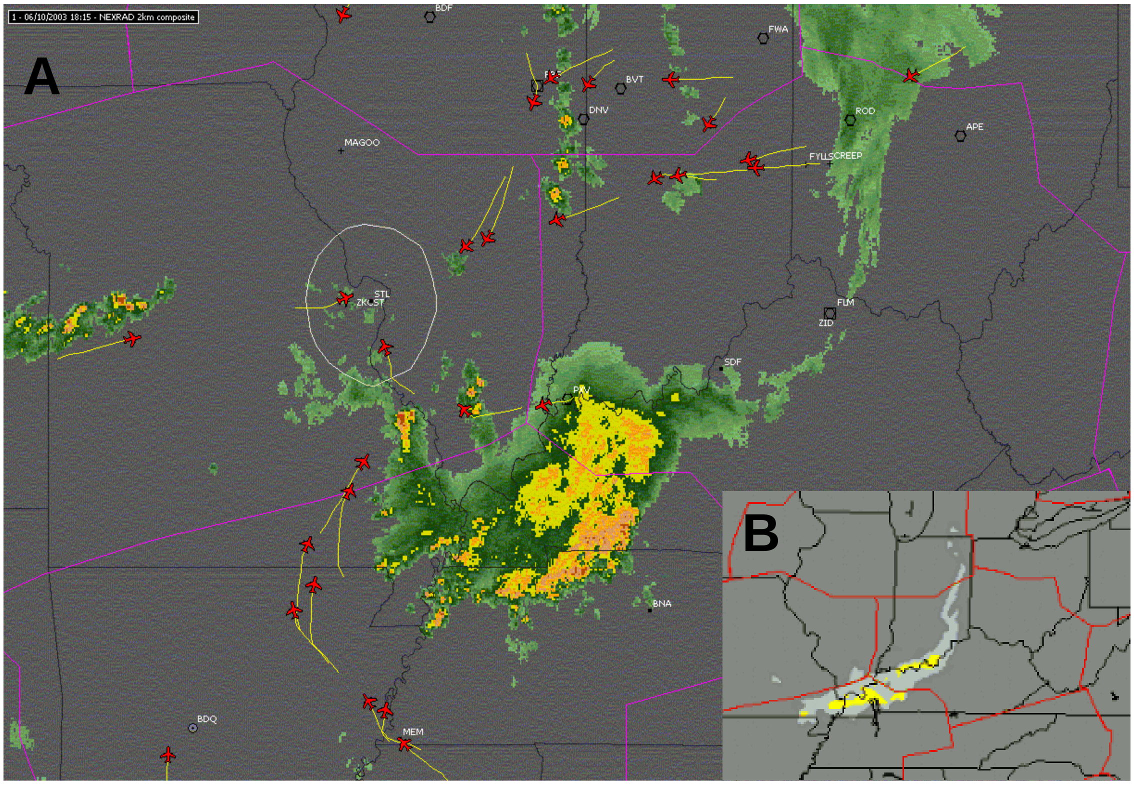

Figure B-3-1. Flightexplorer flight track and WSI composite reflectivity information at 1815 UTC on 10 June 2003, depicting aircraft en route to STL during a convective impact southeast of the TRACON (Figure A). Figure B (lower right corner) is the CIWS forecast valid at 1700 UTC and provides the location of the PXV fix (which is the initial fix for the QBALL standard terminal arrival (STARR) route in ZID airspace) relative to the forecast. On this day, the ZID traffic managers used the CIWS forecast product to determine that the majority of storms would remain south of the PXV fix and thus opened the QBALL STARR early. In Figure A, three aircraft that benefited from the early opening of PXV and QBALL can be seen approaching STL from the southeast, while more aircraft in ZKC and ZME, were turning to use the STARR after being vectored around the weather. The main benefit on this day came from a single aircraft that departed from Richmond, VA and saved almost an hour of flying time.

CASE STUDY B-4

ARTCC: ZID
Date: 10 July 2003
Benefit: Kept APE VOR (J85/J83) open, postponing ORD ground stops for ZTL and ZDC arrivals

- CIWS used to identify that gap in weather would persist long enough to move more ORD traffic
- 16 aircraft avoid prolonged ground stop

CIWS Products Used: Growth and Decay Trend Contours, NEXRAD VIL, RCWF, Storm Motion Vectors, Echo Tops, Lightning

CIWS Delay Savings Calculations:

Benefit Period:	4.3 hr (1650–2100 UTC)	
Linear Delay Reduction:	70.4 hr	
Flights Avoiding Reroutes	21	
Queue Delay Reduction:	0	
Primary Delay Reduction:	70.4 hr	
Downstream Delay Reduction:	56.3 hr	
Primary Operating Cost Savings:		$111,302
Downstream Operating Cost Savings (DM-1):		$ 89,010
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$275,446
Total CIWS Delay Reduction:		**126.7 hr**
Total CIWS Delay Savings (DM-1):		**$475,758**
Total CIWS Delay Savings (DM-2):		**$386,748**

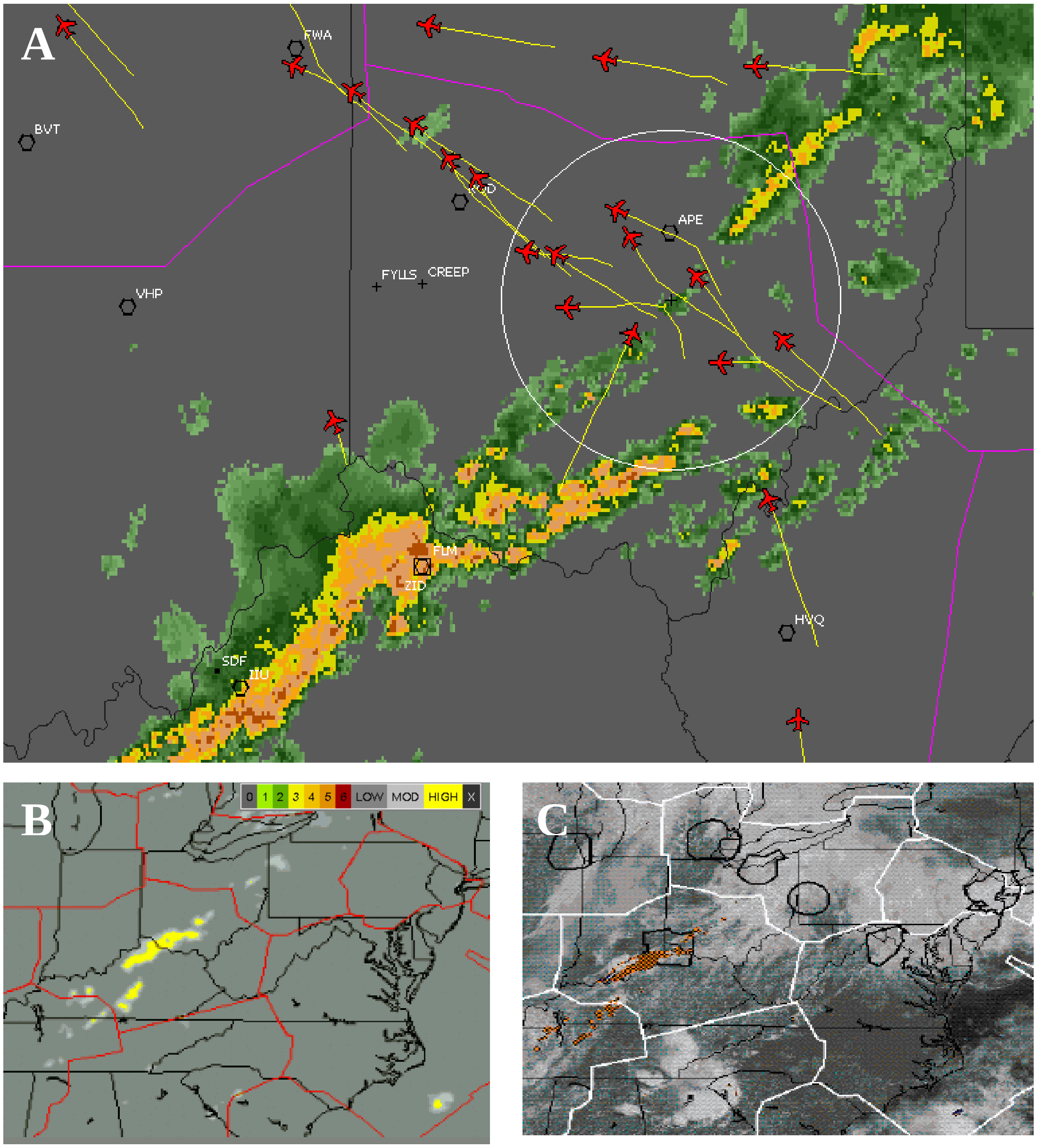

Figure B-4-1. Flightexplorer flight track above and WSI composite reflectivity information at 1800 UTC (Fig. A), CIWS 2-hour forecast product valid at 1900 UTC (Fig. B), and CIWS Growth and Decay Trends and Visible satellite products (Fig C) at 1650 UTC on 10 July 2003. The white circle in Fig. A identifies the benefit area. At 1645, ZID traffic managers decided to allow traffic east of the developing line of thunderstorms in TN, KY and southwestern OH, to continue on to ORD (red aircraft symbols) through a break in the line of storms near the APE VOR (Fig A). ZID kept this route open during most of the ORD ground stop, thereby allowing aircraft in ZDC, ZTL, and ZJX to avoid this program. Traffic managers based this decision on the two hour CIWS forecast (Fig B), which indicated the line of thunderstorms would remain south of APE until after 1900 UTC. Figure C shows the forecast trend product for the time when the decision was made to route ORD arrivals over APE. Note that there is very little indication of growth (hatched orange) in the vicinity of the gap in the line of storms.

CASE STUDY B-5

ARTCC: ZID
Date: 23 July 2003
Benefit: J134 and J6 jet routes kept open to westbound traffic at or above 35 kft an additional 4.5 and 5.5 hours, respectively

- CIWS Echo Tops information informed traffic managers that thunderstorms along routes had relatively low tops, allowing them to keep routes partially open to high-altitude traffic (via storm over flights)
- 48 flights avoided reroutes and saved flight time

CIWS Products Used: Echo Tops, NEXRAD VIL, RCWF, Storm Motion Vectors, Growth and Decay Trends

CIWS Delay Savings Calculations:

Benefit Period (J134):	4.5 hr (1215-1645 UTC)		
Benefit Period (J6):	5.5 hr (1330-1900 UTC)		
Linear Delay Reduction:	4.8 hr		
J6: 38 flights saved 2082mi:		4.0 hr	
J134: 10 flights saved 437mi:		0.8 hr	
Queue Delay Reduction:	0		
Primary Delay Reduction:	4.8 hr		
Downstream Delay Reduction:	3.8 hr		
Primary Operating Cost Savings:			$12,648
Downstream Operating Cost Savings (DM-1):			$ 6,008
Downstream Operating Cost Savings (DM-2):			0
Passenger Cost Savings:			$18,696
Total CIWS Delay Reduction:			**8.6 hr**
Total CIWS Delay Savings (DM-1):			**$37,352**
Total CIWS Delay Savings (DM-2):			**$31,344**

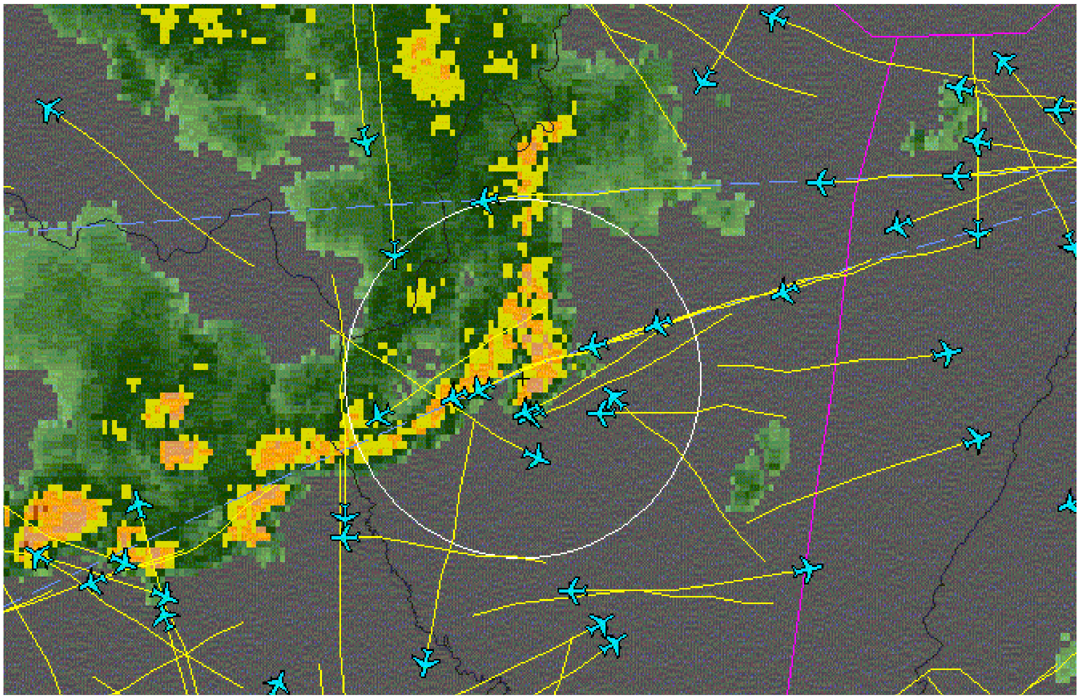

Figure B-5-1. Flightexplorer flight track and WSI composite reflectivity information at 1348 UTC on 23 July 2003. Blue aircraft symbols indicate flights at or above 24 kft. Note that some air traffic is over flying strong thunderstorms along J6 route while other traffic is deviating south of the route. The area of interest is circled in white.

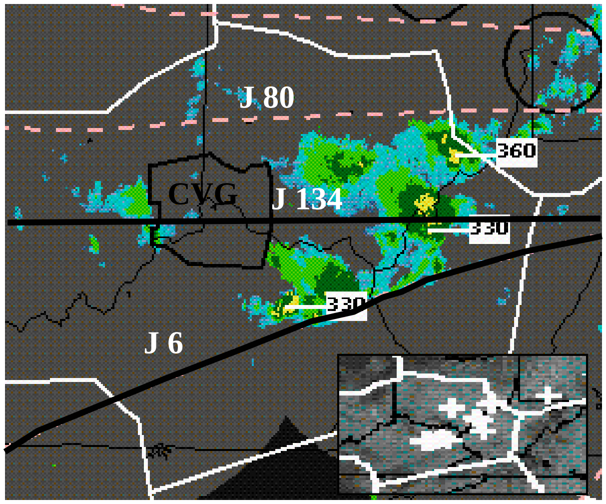

Figure B-5-2. CIWS echo tops product at 1350 UTC on 23 July 2003. The decision to keep J6 and J134 routes (black lines) open above FL 350 was based on these echo tops data. For both Jet routes, ZID kept traffic flying at or above FL 350 avoiding a No-J6 Playbook reroute or reroute of J134 traffic to J80 (dashed pink line). The CIWS cloud-to-ground lightning product (inset) at 1350 UTC demonstrates that these cells were convective.

CASE STUDY B-6

ARTCC: ZOB
Date: 08 May 2003
Benefit: MIT restriction on J80 traffic above 30 kft cancelled early

- Route above 30 kft fully open one hour early
- All J80 traffic entering ZOB via J80 flying above 30 kft
- Queue delay on route reduced

CIWS Products Used: Echo Tops, RCWF

CIWS Delay Savings Calculations:

Benefit Period: 1.0 hr (2115-2215 UTC)
Linear Delay Reduction: 0
Queue Delay Reduction: 5.0 hr
  J80 Capacity without Benefit: 20/hr (15 MIT)
  J80 Demand: 25/hr
Primary Delay Reduction: 5.0 hr
Downstream Delay Reduction: 4.0 hr
Primary Operating Cost Savings: $ 7,905
Downstream Operating Cost Savings (DM-1): $ 6,324
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $19,566
Total CIWS Delay Reduction: 9.0 hr
Total CIWS Delay Savings (DM-1): $33,795
Total CIWS Delay Savings (DM-2): $27,471

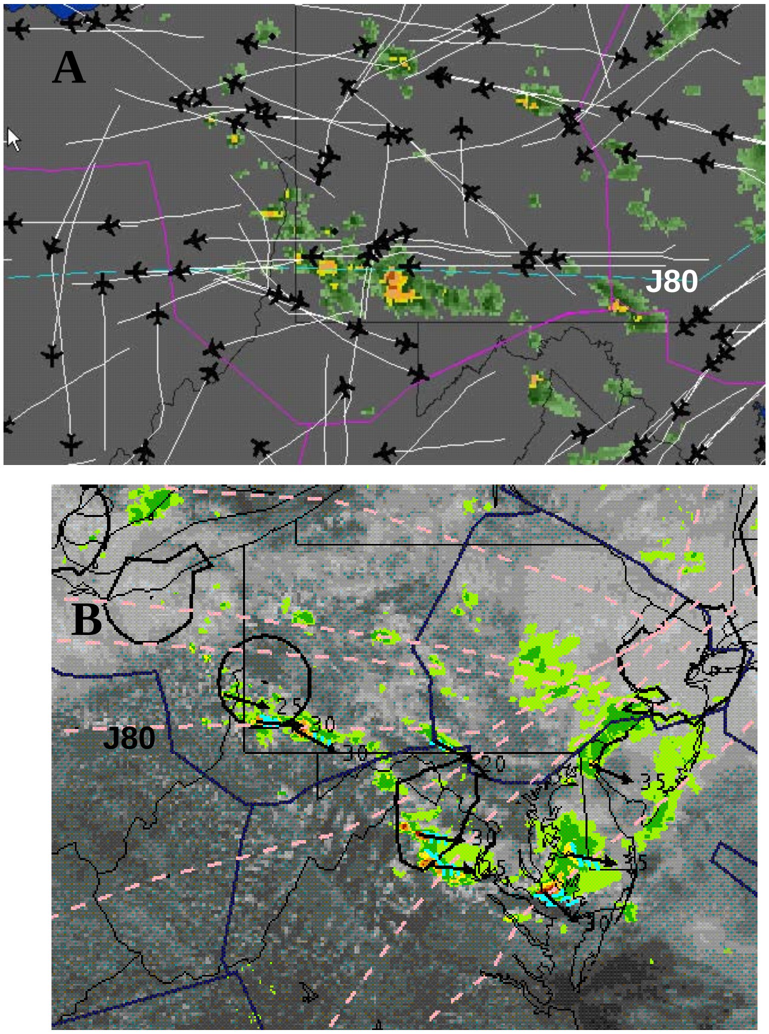

Figure B-6-1. Flightexplorer flight track and WSI composite reflectivity information (Figure A) and CIWS NEXRAD VIL precipitation, visible satellite, and storm motion information (Figure B) at 1730 UTC on 08 May 2003. At this time, a 15 MIT restriction was implemented on J80 traffic because of convection in the vicinity of the route.

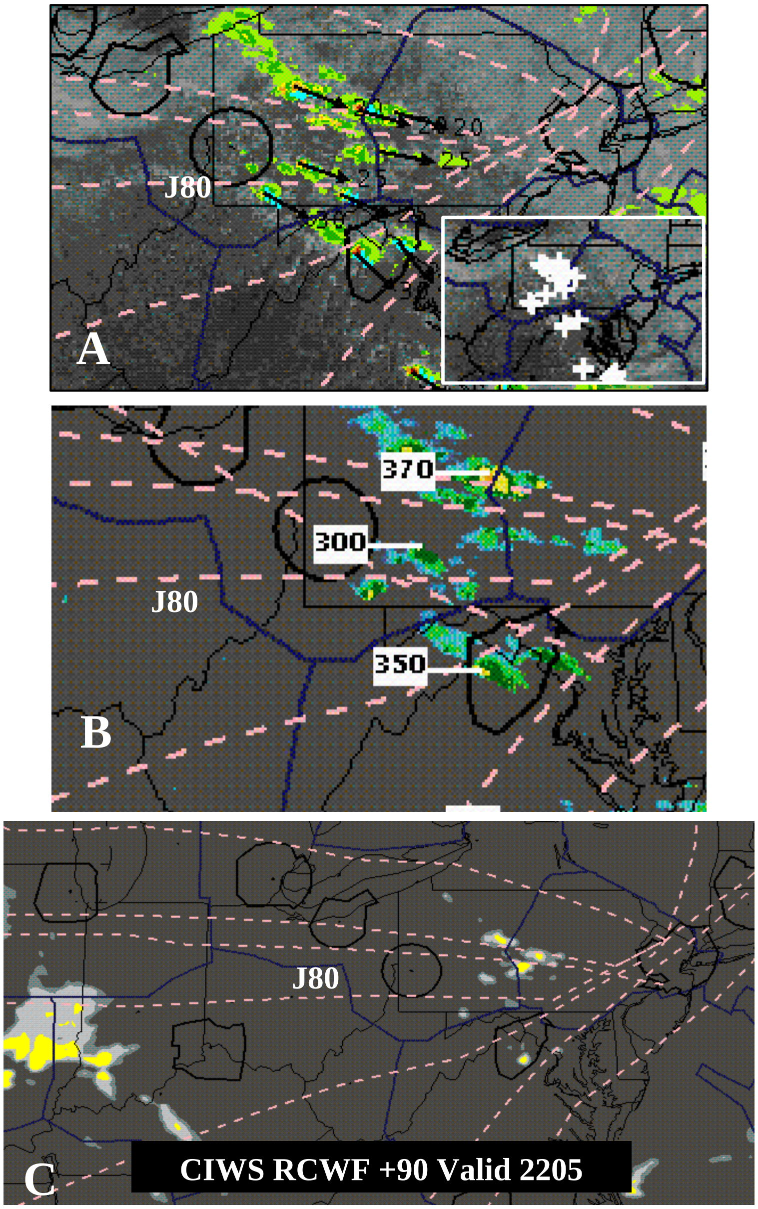

Figure B-6-2. CIWS NEXRAD VIL precipitation, visible satellite, and storm motion information (Figure A), cloud-to-ground lightning (Figure A inset), Echo Tops, with storm height annotations in standard flight levels (Figure B), and C90 minute Convective Forecast at 2040 UTC on 08 May 2003 (Figure C). ZOB Traffic Managers used these products at this time to deduce that despite several electrically active storm cells near J80, echo tops heights were relatively low and improving weather was predicted by the CIWS forecast product. Therefore, the decision was made to remove MIT restrictions on J80 traffic above 30 kft.

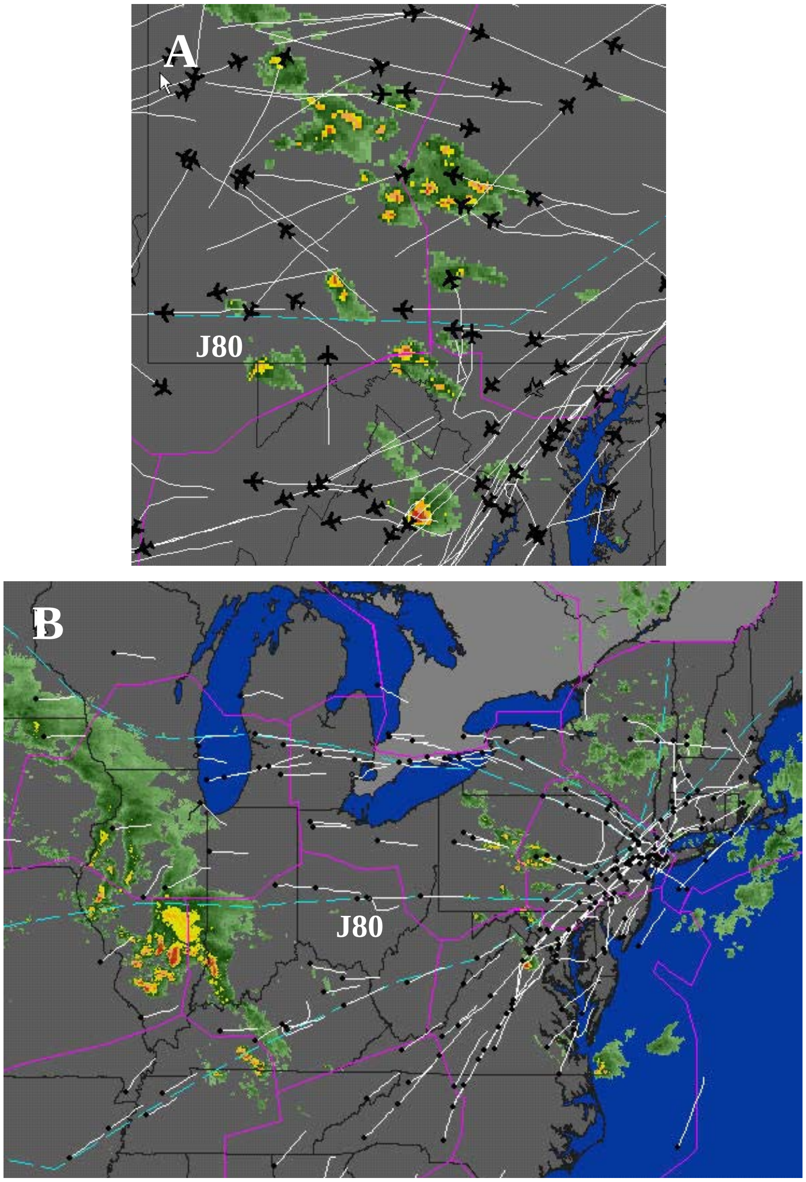

Figure B-6-3. Flightexplorer flight track and WSI composite reflectivity information at 2115 UTC (Figure A) and 2130 UTC (Figure B) on 08 May 2003. At this time, all J80 traffic departing ZNY was flying above 30 kft, with no MIT restrictions. The delay savings for this particular CIWS benefit would have been greater had J80 demand not been significantly reduced because of large convective system in ZKC airspace (Figure B). Because of this weather further west, many J80 flights were rerouted north and south of J80.

CASE STUDY B-7

ARTCC: ZOB
Date: 06 July 2003
Benefit: J80 route kept open with deviations along route, despite heavy weather over/near route

- 11 ZNY departures (6 transcontinental) avoided significant reroutes (J6 or J36/95) with MIT restrictions by flying J80 with tactical deviations

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors

CIWS Delay Savings Calculations:

- Benefit Period: 0.6 hr (2245-2320 UTC)
- Linear Delay Reduction: 0.3 hr
- Queue Delay Reduction: 21.7 hr
    - J6 queue delay increase: 20 hr
        - J6 Demand with Benefit: 20/hr
        - J6 Demand without Benefit: 25/hr
        - J6 capacity with 30 MIT: 10/hr
    - GAYEL queue delay increase: 0.5 hr
        - GAYEL Demand with Benefit: 17/hr
        - GAYEL Demand without Benefit: 21/hr
        - GAYEL capacity with 15 MIT: 20/hr
    - Two flights delayed on ground 1.2 hr without J80 route:
        - EWR to PIT (no other route): 0.8 hr
        - PHL to DAY (no other route): 0.4 hr
- Primary Delay Reduction: 22.0 hr
- Downstream Delay Reduction: 17.6 hr
- Primary Operating Cost Savings: $ 35,098
- Downstream Operating Cost Savings (DM-1): $ 27,826
- Downstream Operating Cost Savings (DM-2): 0
- Passenger Cost Savings: $ 86,090
- **Total CIWS Delay Reduction: 39.6 hr**
- **Total CIWS Delay Savings (DM-1): $149,014**
- **Total CIWS Delay Savings (DM-2): $121,188**

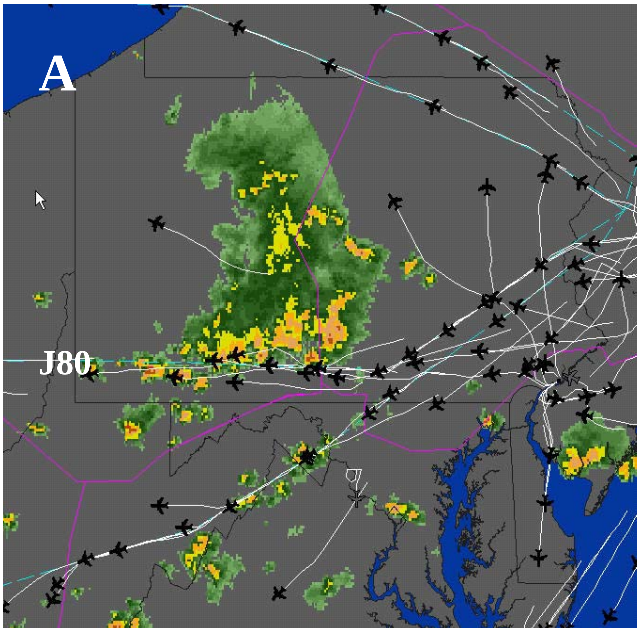

Figure B-7-1. Flightexplorer flight track and WSI composite reflectivity information at 2245 UTC on 06 July 2003. Storm cells began impacting J80 route through ZOB at this time. Minor deviations along the route are observed.

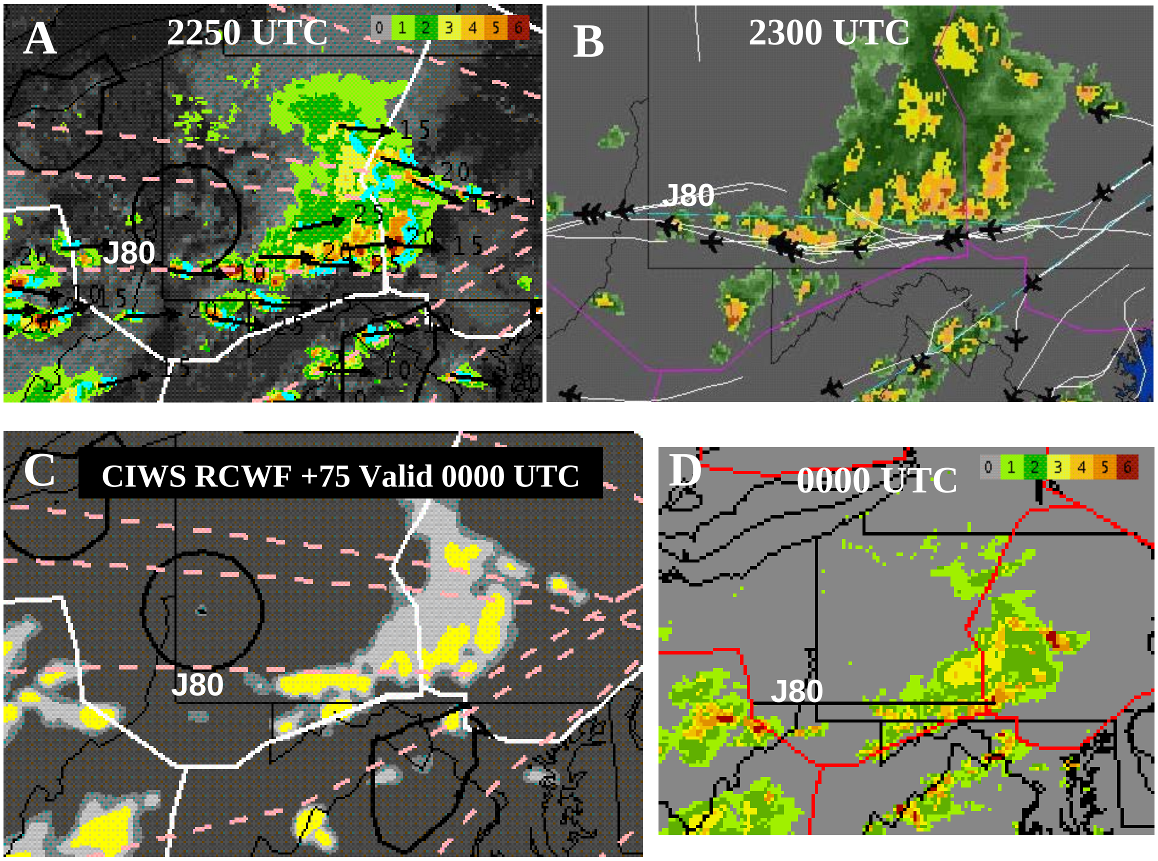

Figure B-7-2. At 2250 UTC on 06 July 2003 (Figure A), CIWS NEXRAD VIL precipitation depicted strong storms directly impacting J80 route. Storm motion vectors indicated that individual cells were moving due east, suggesting a prolonged impact along the route. ZOB traffic managers kept the route open with deviations south of thunderstorms on the route, but still within their airspace (Figure B). This decision was based upon the CIWS forecast product (Figure C), which accurately predicted the southward progression of the storm cluster off of J80 (Figure D). CIWS informed traffic specialists that during the direct impact on J80, there existed enough airspace within ZOB to allow for deviations that did not stray across ARTCC boundaries. As the line was forecasted to move into this deviation zone, it was also predicted to clear J80, allowing traffic to return to J80 rather than being forced out of ZOB airspace.

CASE STUDY B-8

ARTCC: ZOB
Date: 03 August 2003
Benefit: J80 route kept open despite level 3-5 storms along route

- CIWS echo tops demonstrated that storms along J80 in eastern ZOB airspace were mostly less than 30 kft in height; route kept open via storm over flights
- With J80 open, demand on J6 (reroute) greatly reduced
- Substantial reduction in J6 queue delay

CIWS Products Used: Echo Tops, NEXRAD VIL, Storm Motion Vectors, RCWF

CIWS Delay Savings Calculations:

Benefit Period:	4.5 hr (1615-2045 UTC)		
Linear Delay Reduction:	0		
Queue Delay Reduction:	236.3 hr		
With Benefit, J6 Demand less than 10 MIT capacity;			
- J6 Queue Delay with Benefit:		0	
Without Benefit, J80 traffic added to J6:			
- J6 capacity:		20/hr	
- J6 Demand (with J80 flights):		27/hr	
Primary Delay Reduction:	236.3 hr		
Downstream Delay Reduction:	189.0 hr		
Primary Operating Cost Savings:			$ 373,590
Downstream Operating Cost Savings (DM-1):			$ 298,809
Downstream Operating Cost Savings (DM-2):			0
Passenger Cost Savings:			$ 924,602
Total CIWS Delay Reduction:			**425.3 hr**
Total CIWS Delay Savings (DM-1):			**$1,597,001**
Total CIWS Delay Savings (DM-2):			**$1,298,192**

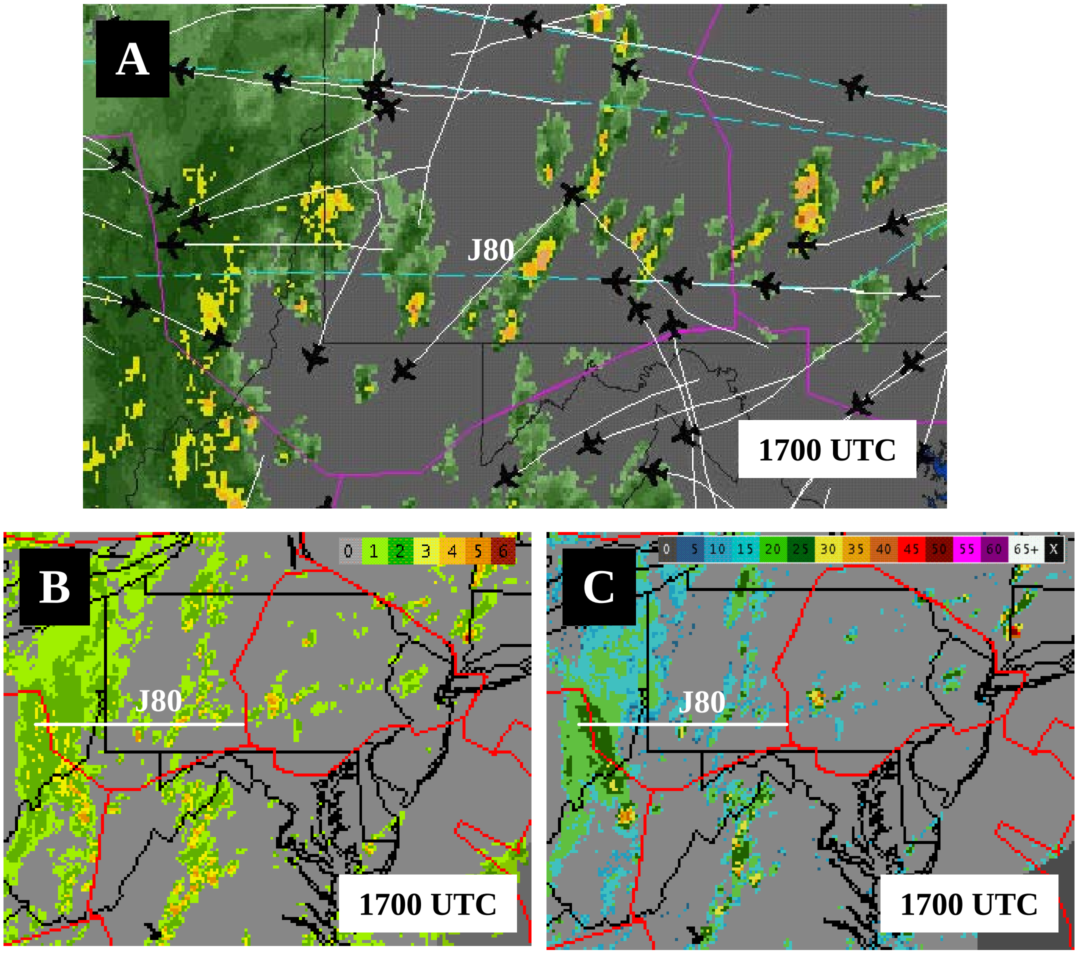

Figure B-8-1. Flightexplorer flight track and WSI composite reflectivity information (Figure A), CIWS NEXRAD VIL precipitation (Figure B), and CIWS Echo Tops (Figure C) at 1700 UTC on 03 August 2003. Strong storm cells were impacting route J80 but ZOB traffic managers, noting the low-topped nature of these storms (as depicted by CIWS), kept the route open to traffic departing ZNY. If J80 had been closed, traffic would have been rerouted to J6, pushing demand on this route above capacity for several hours resulting in considerable queuing delay.

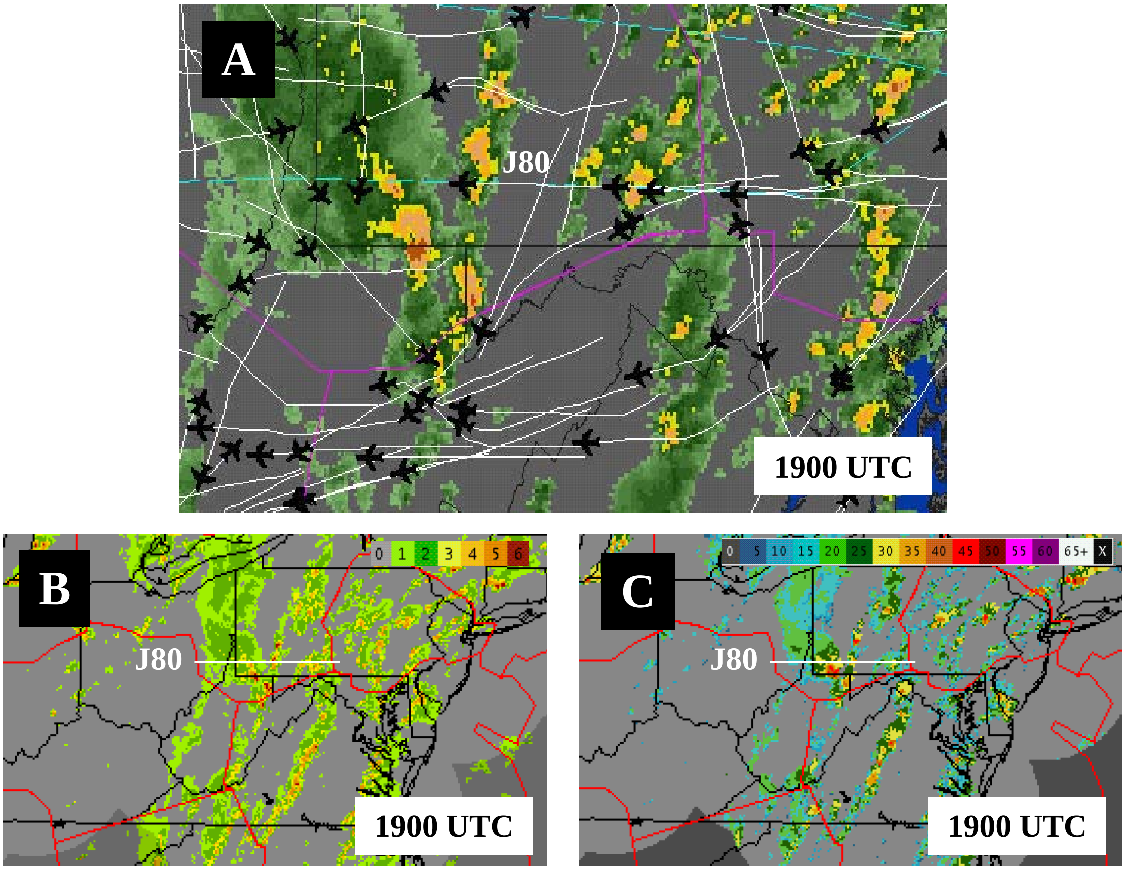

Figure B-8-2. Same as Fig. B-8-1, except at 1900 UTC on 03 August 2003.

CASE STUDY B-9

ARTCC: ZDC
Date: 22 July 2003
Benefit: J6 route kept open (with 20 MIT restriction) despite deviations on route. CIWS consulted to determine that storm echo tops sufficiently low and activity sufficiently scattered at this time to allow route to remain open. ZNY traffic to ZTL was using J6 through ZDC for a reroute.

- CIWS assisted in keeping this route open an additional 1.5 hours
- 11 extra aircraft avoided prolonged ground stop

CIWS Products Used: Echo Tops, NEXRAD VIL, Storm Motion Vectors, RCWF

CIWS Delay Savings Calculations:

Benefit Period: 1.5 hr (2100-2230 UTC)
Linear Delay Reduction: 0
Queue Delay Reduction: 10.3 hr
  Clear-weather capacity: 30/hr
  J6 capacity without CIWS: 0
Primary Delay Reduction: 10.3 hr
Downstream Delay Reduction: 8.2 hr
Primary Operating Cost Savings: $16,284
Downstream Operating Cost Savings (DM-1): $12,964
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $40,219
Total CIWS Delay Reduction: 18.5 hr
Total CIWS Delay Savings (DM-1): $69,467
Total CIWS Delay Savings (DM-2): $56,503

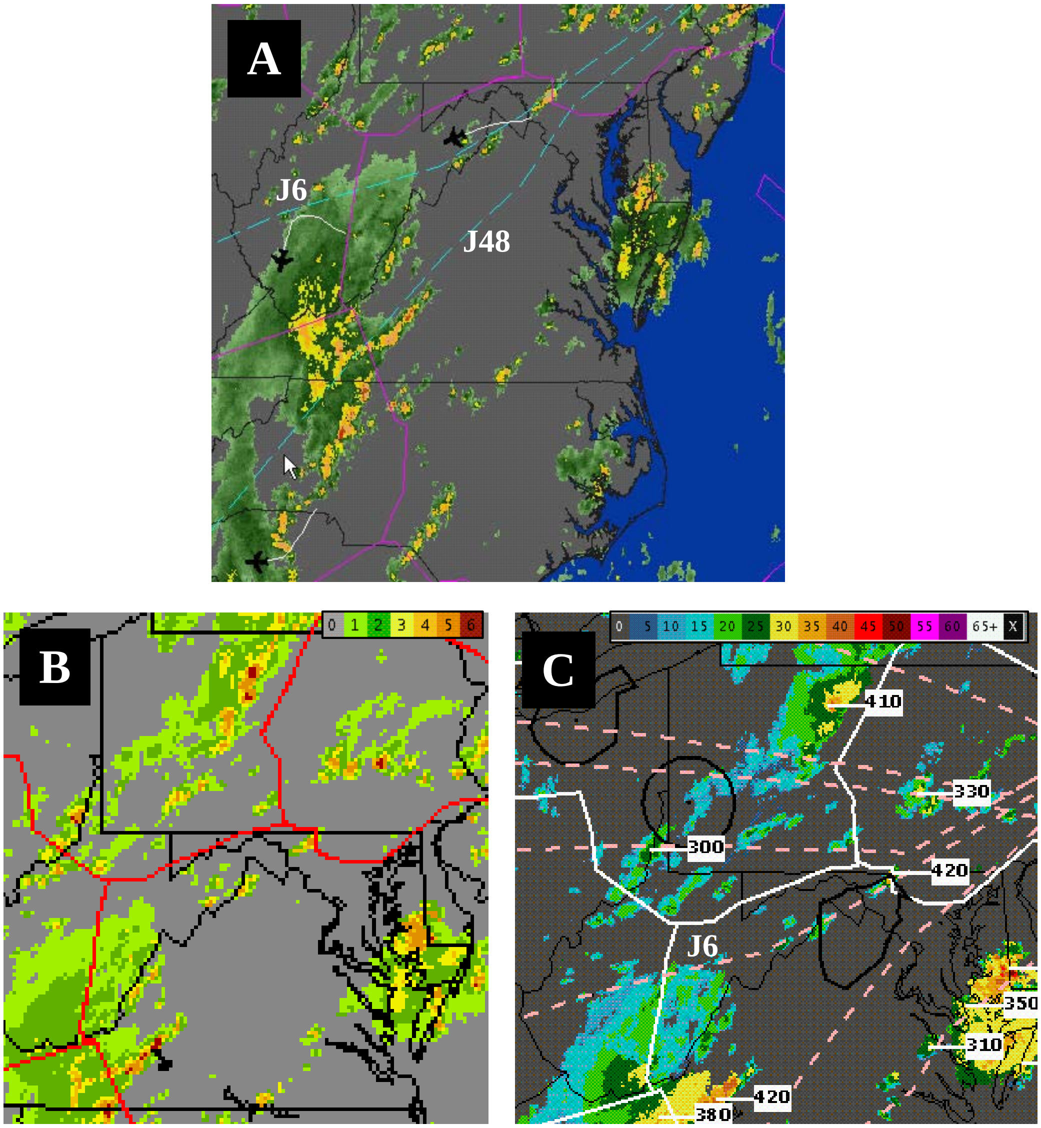

Figure B-9-1. Flightexplorer flight track and WSI composite reflectivity information (Fig. A), CIWS NEXRAD VIL precipitation (Fig. B), and CIWS Echo Tops (Fig. C) at 2100 UTC on 22 July 2003. At this time, ZNY traffic to ATL (black planes) was rerouted off of J48 (preferred route) to J6. At 2100 UTC, a small deviation on J6 because of convection led traffic managers to initially consider stopping this ATL reroute in favor of a ground stop. ZDC used CIWS weather products to determine that though storm cells were strong (level 4-5), echo tops were relatively low and activity sufficiently sparse to allow ZNY to ATL J6 reroute to continue, with deviations along the route when necessary.

CASE STUDY B-10

ARTCC: ZDC
Date: 23 July 2003
Benefit: Early reopening of ZDC Atlantic (AR) routes

- CIWS Echo Tops product used to reopen routes above 330 kft
- Reduced flight distance on 24 flights
- Helped alleviate congestion, reduce sector loads along inland route (CRG..SAV..CHS..ISO route)

CIWS Products Used: Echo Tops, NEXRAD VIL

CIWS Delay Savings Calculations:

Benefit Period:	1.2 hr (1430-1540 UTC)		
Linear Delay Reduction:	3.6 hr		
Avg flight distance saved:		75 mi	
Flight time saved:		9 min	
Number of aircraft:		24	
Queue Delay Reduction:	0		
Primary Delay Reduction:	3.6 hr		
Downstream Delay Reduction:	2.9 hr		
Primary Operating Cost Savings:			$ 9,486
Downstream Operating Cost Savings (DM-1):			$ 4,585
Downstream Operating Cost Savings (DM-2):			0
Passenger Cost Savings:			$14,131
Total CIWS Delay Reduction:			**6.5 hr**
Total CIWS Delay Savings (DM-1):			**$28,202**
Total CIWS Delay Savings (DM-2):			**$23,617**

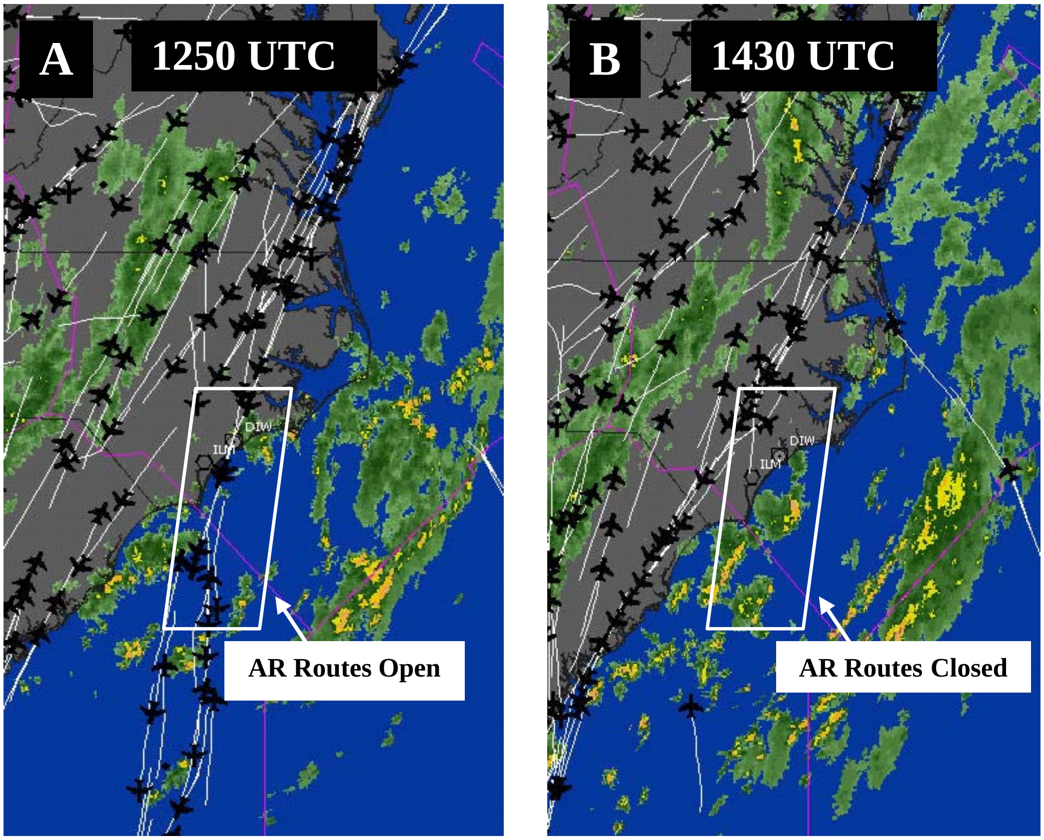

Figure B-10-1. Flightexplorer flight track and WSI composite reflectivity information at 1250 UTC (Fig. A) and 1430 UTC (Fig. B) on 23 July 2003. At 1250 UTC, Atlantic Routes (AR) through ZDC and ZJX airspace were open for both northbound and southbound traffic, alleviating congestion on inland routes. Between 1250 and 1430 UTC, thunderstorms impacted airspace immediately off the Carolina coasts, forcing the closure of AR routes. Traffic was moved to inland routes.

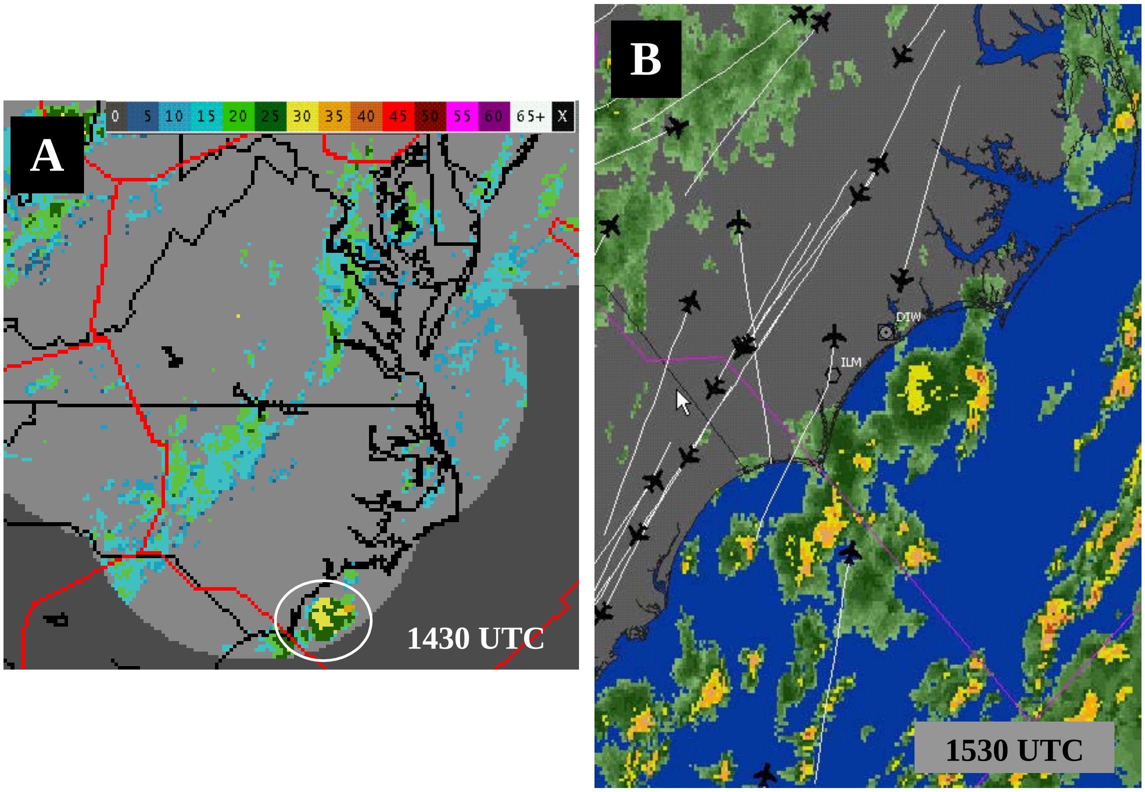

Figure B-10-2. At 1430 UTC on 23 July 2003, ZDC traffic managers used the CIWS echo tops product to determine that the height of storms along the AR routes were generally less than 35 kft (Fig. A, circled echo tops). Based on this information, AR routes were reopened at or above 35 kft. Figure B shows northbound and southbound traffic after AR routes had reopened to high-altitude traffic.

CASE STUDY B-11

ARTCC: ZDC
Date: 03 September 2003
Benefit: Early reopening of ZJX/ZMA/ZTL to PHL, ZJX/ZMA to BOS routes through ZDC airspace

- Resulted in early cancellation of PHL, BOS ground stops
- Reduced arrival queue delay by reducing ground stop period by 1.5 hr
- ZJX/ZMA/ZTL flights to PHL released early: 19
  ZJX/ZMA flights to BOS released early: 3

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors, Echo Tops, Growth and Decay Trend Contours

CIWS Delay Savings Calculations:

Benefit Period:	1.5 hr (2130-2300 UTC)	
Linear Delay Reduction:	0	
Queue Delay Reduction:	36.2 hr	
PHL: 32.4 hr		
BOS: 3.8 hr		
Primary Delay Reduction:	36.2 hr	
Downstream Delay Reduction:	29.0 hr	
Primary Operating Cost Savings:		$ 57,232
Downstream Operating Cost Savings (DM-1):		$ 45,849
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$141,745
Total CIWS Delay Reduction:		**65.2 hr**
Total CIWS Delay Savings (DM-1):		**$244,826**
Total CIWS Delay Savings (DM-2):		**$198,977**

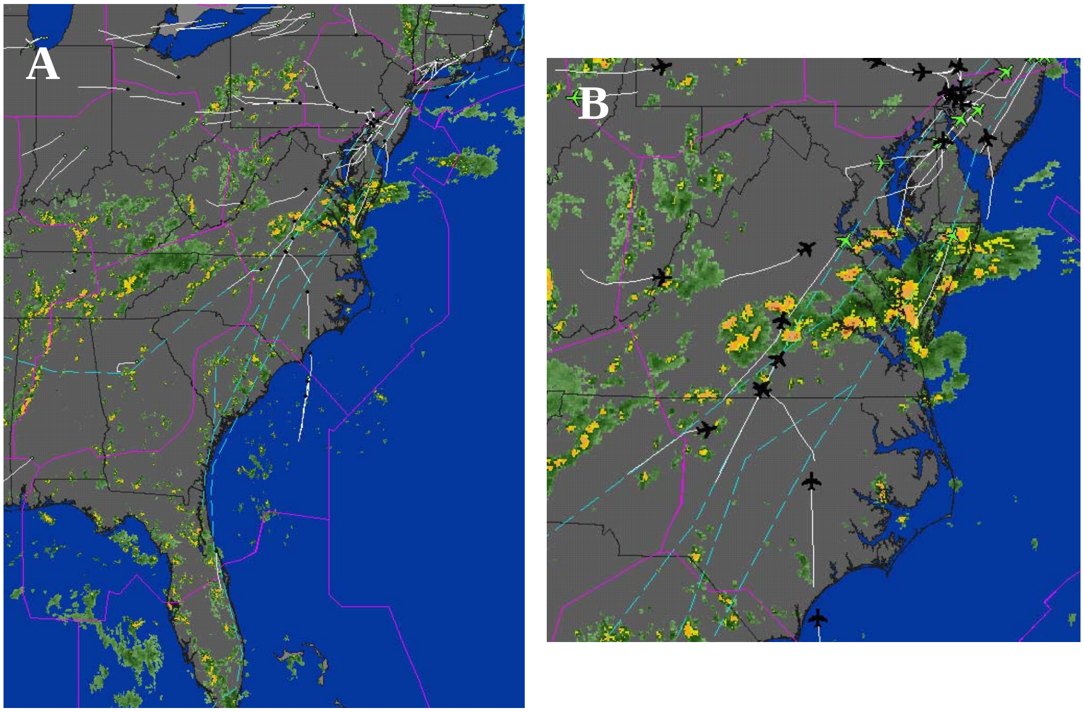

Figure B-11-1. Flightexplorer flight track and WSI composite reflectivity information at 1950 UTC on 03 September 2003. Shown here are PHL (black) and BOS (green) arriving aircraft at the time these airports were issued ground stops for ZJX, ZTL, and ZMA departures. The zoomed out view in Figure A shows the last PHL/BOS departures before ground stop issuance while Figure B provides a closer look at the weather impact within ZDC airspace. ZDC initiated the ground stop as a cluster of strong storm cells impacted preferred flight routes (dashed blue lines).

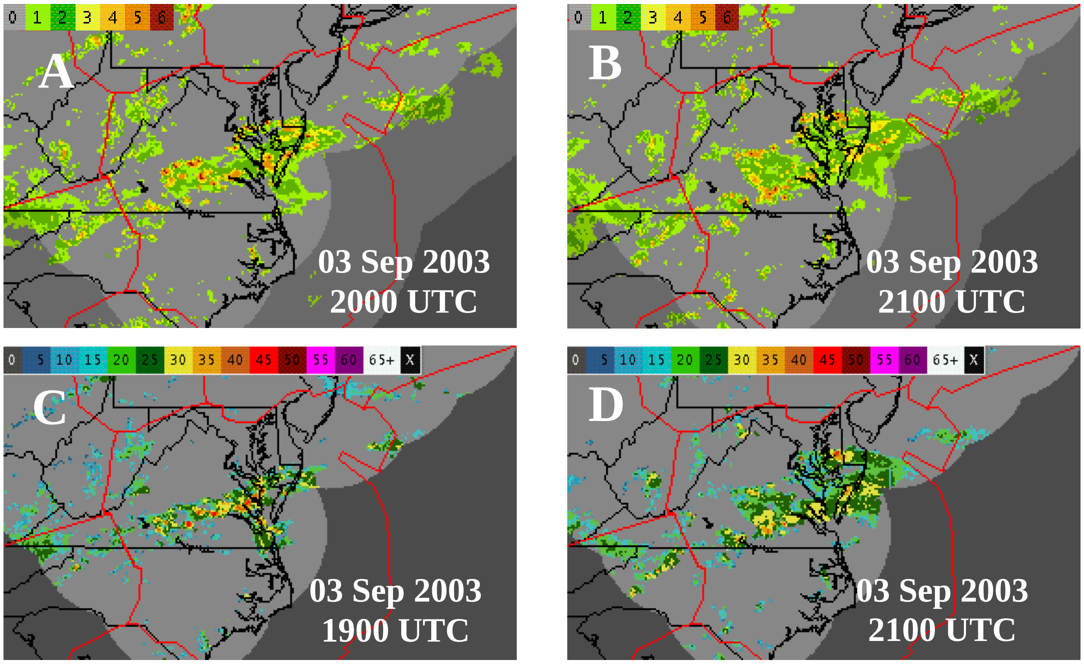

Figure B-11-2. ZDC traffic managers tracked trends in CIWS VIL precipitation (coverage and intensity, Figures A and B) and echo top heights (Figures C and D). Noting weakening trends with time in storm strength and echo top height for convection near the Chesapeake Bay, managers gained confidence that PHL/BOS traffic through this region could be restarted early.

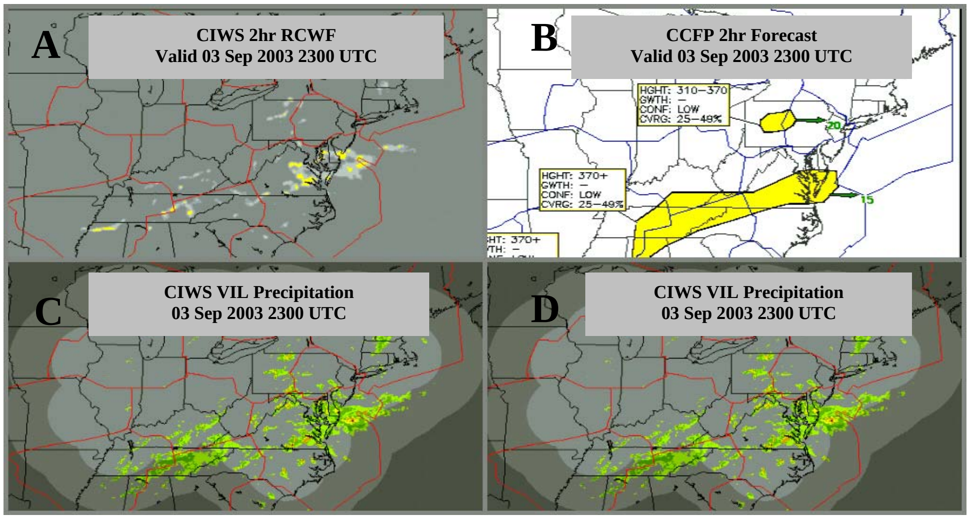

Figure B-11-3. Comparison of CIWS vs. CCFP two-hour forecast products, valid 03 September 2003, 2300 UTC, compared with precipitation verification. In Figure A, areas of yellow represent regions where a high-probability of level 3 or greater intensity precipitation will exist n two hours time. The two-hour CCFP forecast for this period depicts a solid swath of “low-coverage” convection bisecting ZDC airspace. In conjunction with CIWS precipitation and echo top trend information, traffic managers at ZDC utilized the CIWS forecast product to determine that gaps in weather through the Delmarva area would allow PHL/BOS traffic from the southeast to fly along their preferred routes. The two-hour CCFP forecast for this period depicts a solid swath of “low-coverage” convection bisecting ZDC airspace in Figure B. Figures C and D demonstrate that the gap in significant precipitation along the Mid-Atlantic coast predicted by the CIWS forecast product did verify.

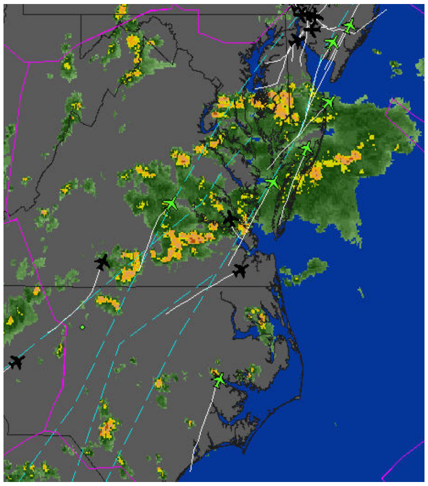

Figure B-11-4. Flightexplorer flight track and WSI composite reflectivity information at 2130 UTC on 03 September 2003. The last of the PHL (black) and BOS (green) flights from the southeast before the ground stop issued at 1950 UTC are traversing ZDC airspace. At this time, ZDC traffic managers decided to reopen these routes and cancel PHL/BOS ground stops approximately 1.5 hours early. Despite heavy weather still on the routes (dashed lines) at this time, confidence in weather trends and convective forecasts provided by CIWS allowed ZDC to be proactive and save delay. 21 aircraft destined for PHL or BOS departed earlier because of this decision.

CASE STUDY B-12

ARTCC: ZBW
Date: 11 June 2003
Benefit: Early reopening of J121 route above 30kft

- CIWS echo tops used to reopen route for storm over flights
- If the route remained closed, 4 BOS departures would have been delayed one hour longer (convection on other routes disallowed reroute options)

CIWS Products Used: Echo Tops

CIWS Delay Savings Calculations:

Benefit Period: 1.0 hr (2130-2230 UTC)
Linear Delay Reduction: 4.0 hr
Queue Delay Reduction: 0
Primary Delay Reduction: 4.0 hr
Downstream Delay Reduction: 3.2 hr
Primary Operating Cost Savings: $ 6,324
Downstream Operating Cost Savings (DM-1): $ 5,059
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $15,653
Total CIWS Delay Reduction: 7.2 hr
Total CIWS Delay Savings (DM-1): $27,036
Total CIWS Delay Savings (DM-2): $21,977

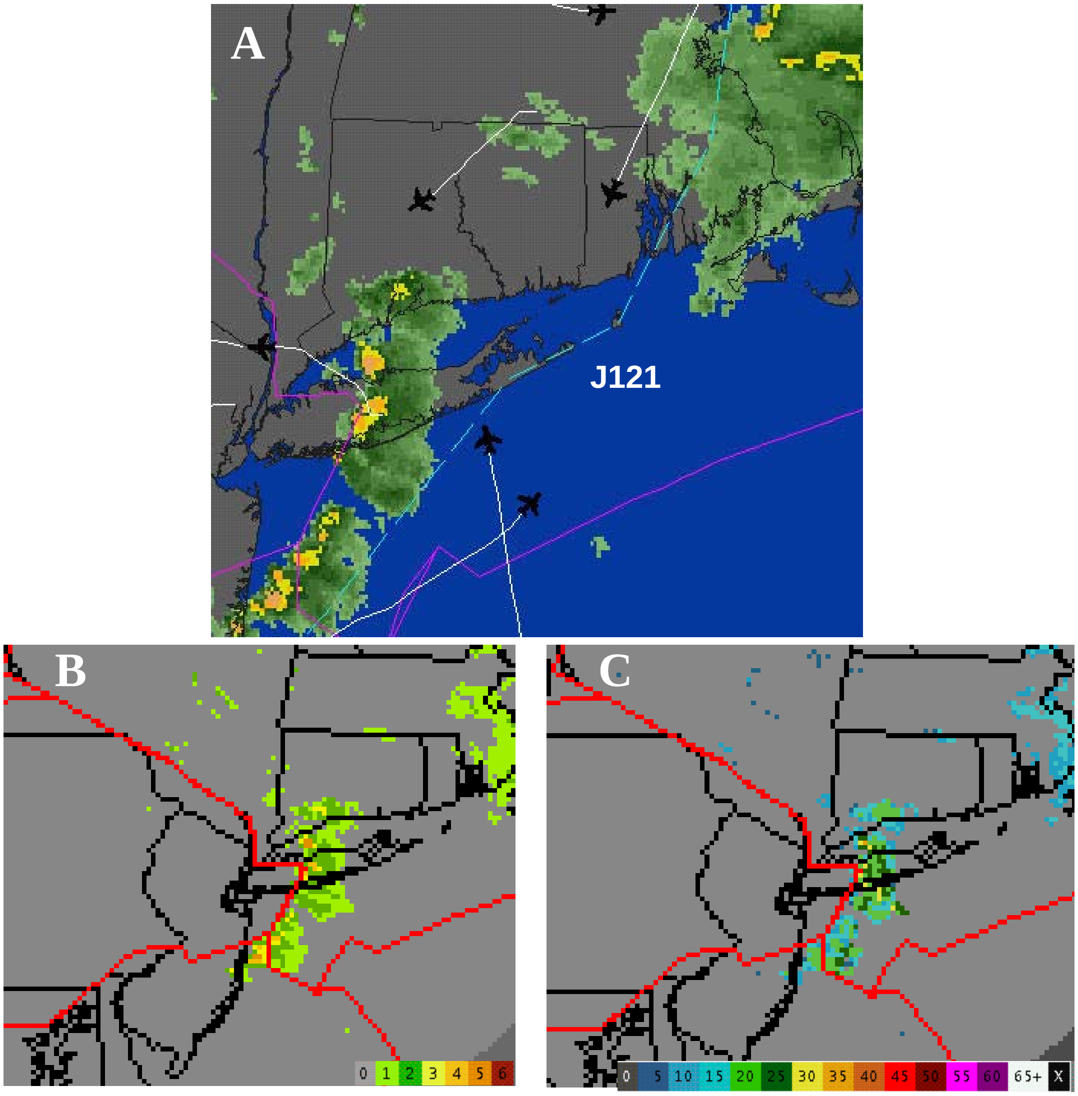

Figure B-12-1. Flightexplorer flight track and WSI composite reflectivity information (Fig. A), CIWS NEXRAD VIL precipitation (Fig. B), and CIWS Echo Tops product (Fig. C) at 2100 UTC on 11 June 2003. A ground stop was implemented at this time for route J121 because of the imminent weather impact in extreme southwest ZBW airspace. Using CIWS to note echo top heights associated with level 3-5 convection were generally less than 30 kft, ZBW traffic managers reopened J121 to traffic above 28 kft soon after initial route closure.

CASE STUDY B-13

ARTCC: ZBW
Date: 05 August 2003
Benefit: CAN 6 Reroute cancelled 45 minutes early, allowing traffic to fly preferred route over SYR VOR earlier.

- CIWS echo tops product showed storm heights peaking in low 30's kft
- CIWS forecast accurately depicted clearing of SYR route
- 8 flights traveled preferred route during benefit period, saving flight time, and avoiding CAN 6 40 MIT restriction

CIWS Products Used: Echo Tops, RCWF, NEXRAD VIL

CIWS Delay Savings Calculations:

Benefit Period: 0.75 hr (2315-0000 UTC)
Linear Delay Reduction: 2.0 hr
Queue Delay Reduction: 6.9 hr
CAN6 Capacity (40 MIT): 8/hr
Demand: 12/hr
Primary Delay Reduction: 8.9 hr
Downstream Delay Reduction: 7.1 hr
Primary Operating Cost Savings: $16,179
Downstream Operating Cost Savings (DM-1): $11,225
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $34,784
Total CIWS Delay Reduction: 16.0 hr
Total CIWS Delay Savings (DM-1): $62,188
Total CIWS Delay Savings (DM-2): $50,963

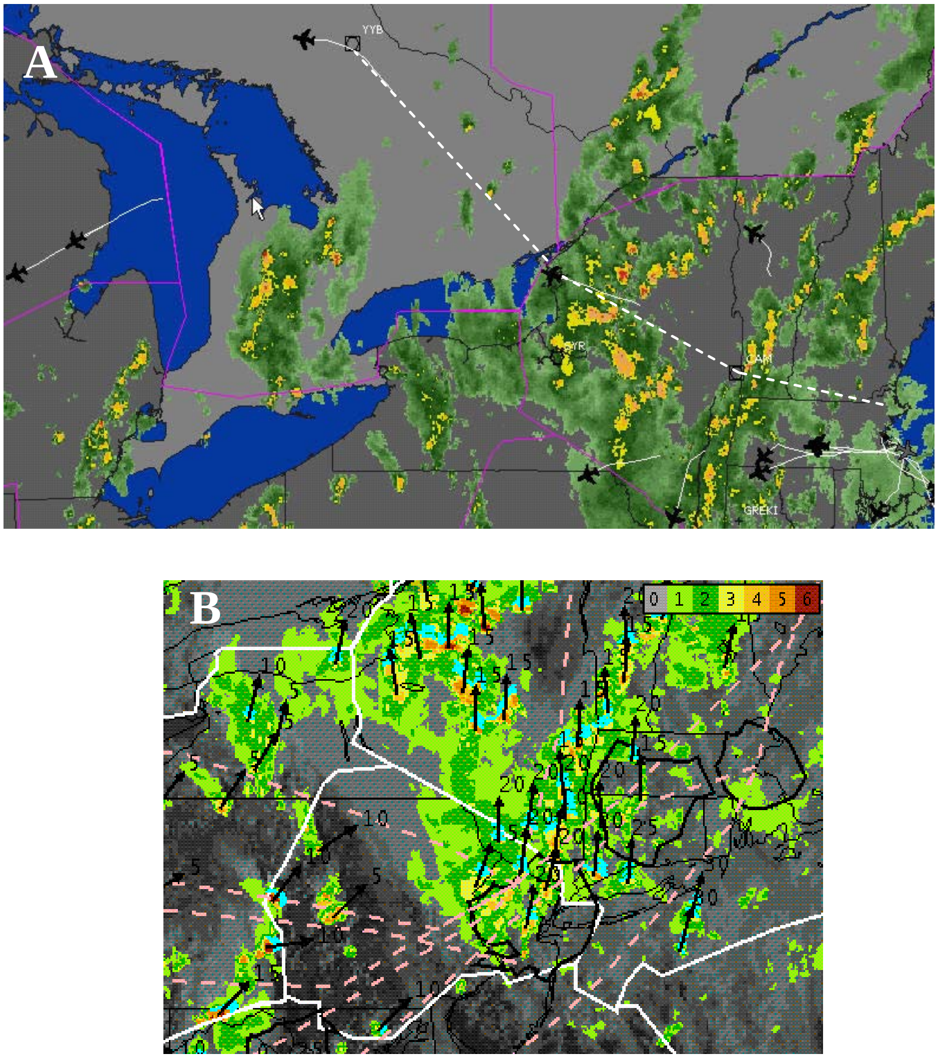

Figure B-13-1. Flightexplorer flight track and WSI composite reflectivity information (Fig. A) and CIWS NEXRAD VIL precipitation, storm motion vectors, and satellite products at 2215 UTC on 05 August 2003. Transcontinental traffic departing BOS airport were routed onto the CAN6 playbook (Fig. A, dashed line) due to strong convection across upstate NY. CIWS NEXRAD VIL precipitation, storm motion vectors, and satellite products at 2215 UTC on 05 August 2003 (Figure B).

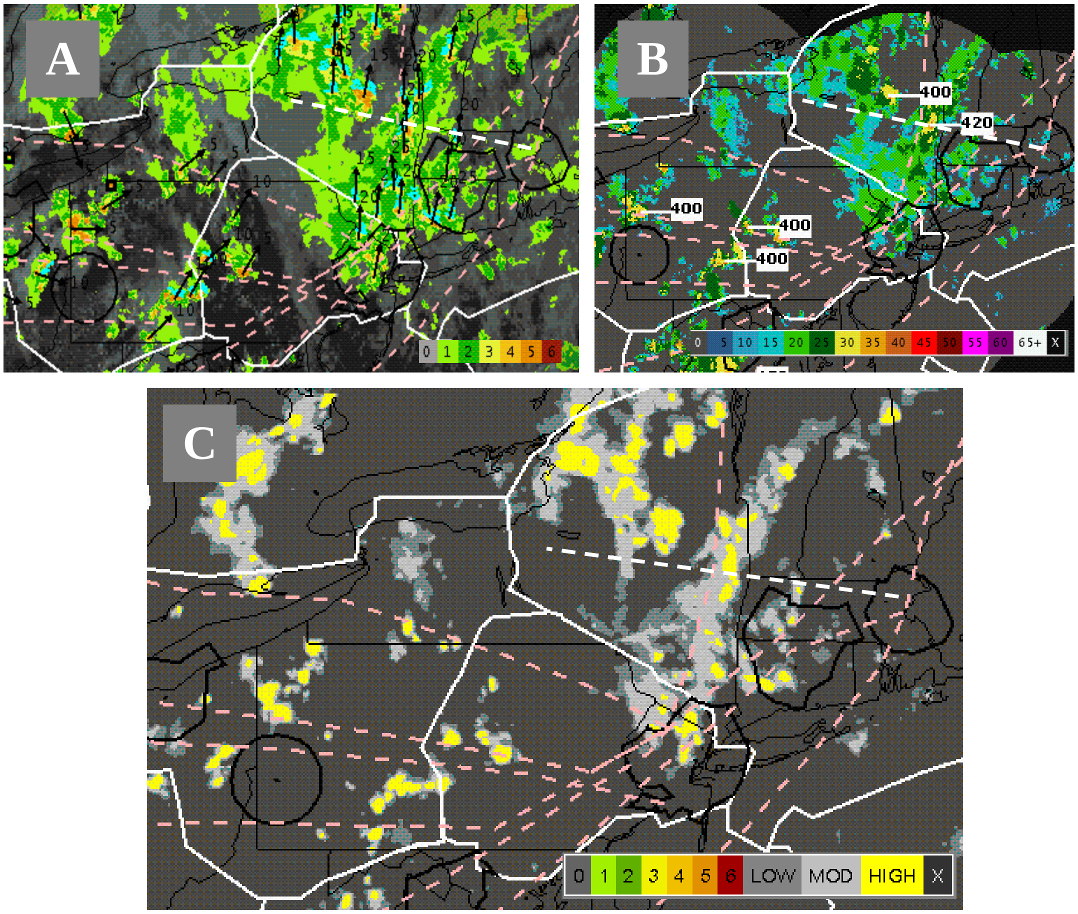

Figure B-13-2. CIWS NEXRAD VIL precipitation (Fig. A), Echo Tops (Fig. B), and 30 minute convective forecast (Fig. C) at 2300 UTC on 05 August 2003. ZBW traffic managers used these products at this time to cancel the CAN6 reroute in favor of reopening the preferred BOS to SYR route for westbound traffic (white dashed line in upstate NY). CIWS storm motion vectors (Fig. A) indicated that level 3-5 cells were moving off of the preferred route. The CIWS echo tops product (Fig. B) indicated that any convection along the routes generally possessed storm top heights less than 30 kft. The CIWS forecast product (Fig. C) indicated that storm cells moving towards the preferred route from the south were predicted to remain scattered, with primarily only modest probabilities of significant impacts. Any convection south of the SYR route also possessed tops less than 30 kft.

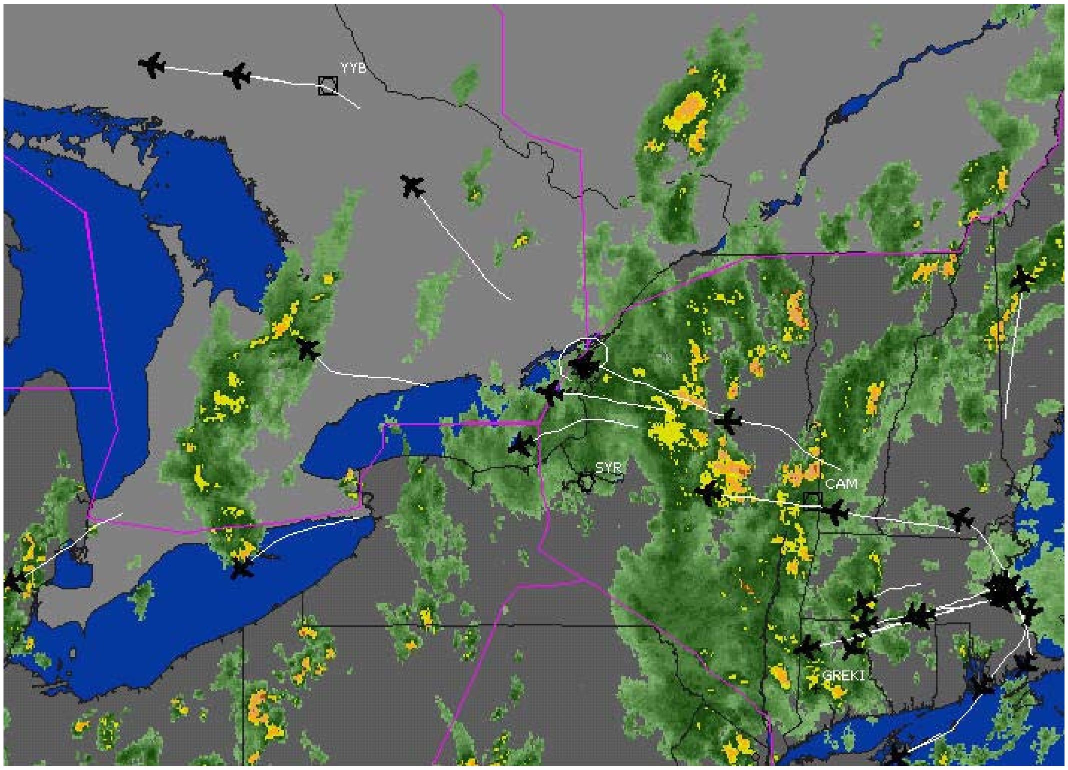

Figure B-13-3. Flightexplorer flight track and WSI composite reflectivity information at 2330 UTC on 05 August 2003. The last CAN6 departures were exiting ZBW airspace and the preferred route via the SYR VOR had been reestablished. The CAN6 reroute was cancelled 45 minutes early.

CASE STUDY B-14

ARTCC: ZNY
Date: 12 June 2003
Benefit: Kept J80 route out of ZNY open longer for westbound departures

- 8 aircraft avoided J60/J64 reroute and saved 11 min flight time
- CIWS forecast and echo tops products consulted to determine impact on route by significant convection would not occur for 60 more minutes

CIWS Products Used: RCWF, Echo Tops

CIWS Delay Savings Calculations:

Benefit Period:	0.9 hr (2015-2108 UTC)	
Linear Delay Reduction:	1.5 hr	
Queue Delay Reduction:	0	
Primary Delay Reduction:	1.5 hr	
Downstream Delay Reduction:	1.2 hr	
Primary Operating Cost Savings:		$ 3,953
Downstream Operating Cost Savings (DM-1):		$ 1,897
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$ 5,870
Total CIWS Delay Reduction:		**2.7 hr**
Total CIWS Delay Savings (DM-1):		**$11,720**
Total CIWS Delay Savings (DM-2):		**$ 9,823**

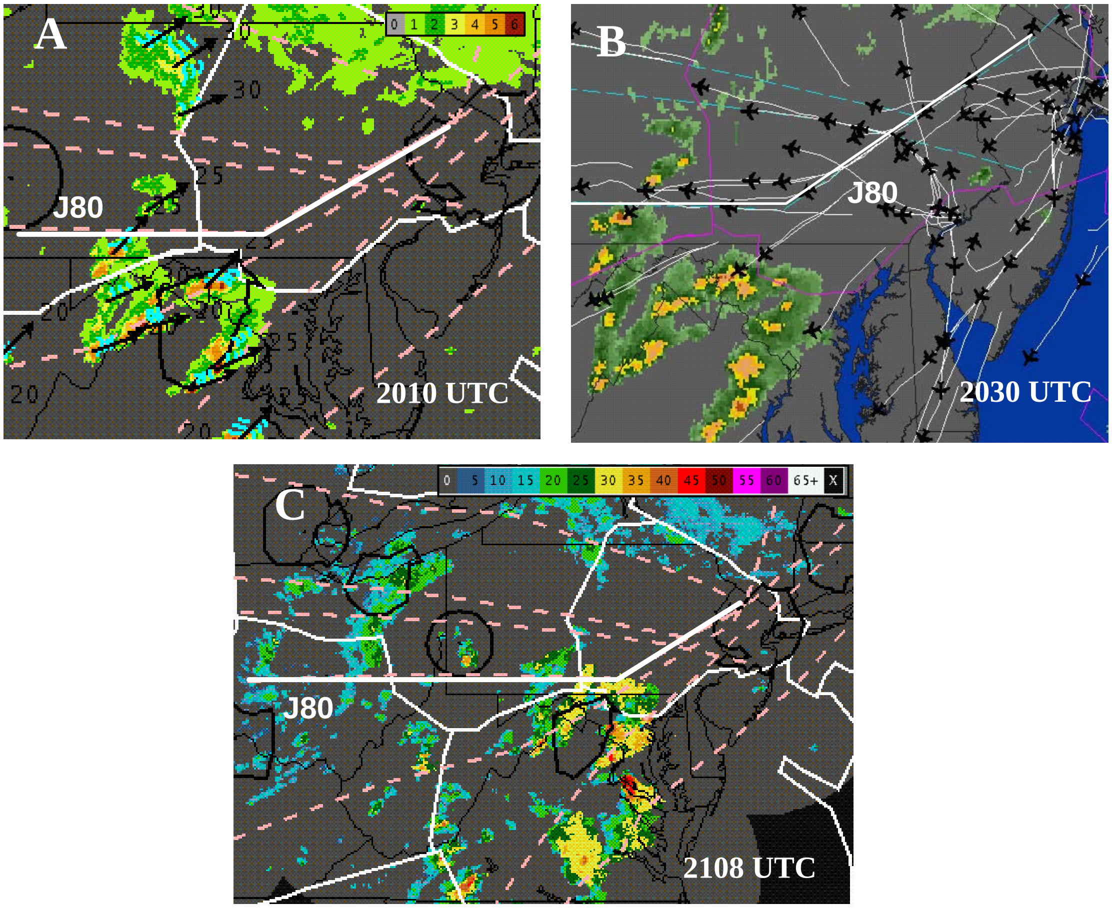

Figure B-14-1. Concerned that an approaching cluster of strong storms would soon impact the route, ZNY traffic managers viewed CIWS NEXRAD VIL precipitation with storm motion vectors (Fig. A) and the CIWS convective forecast product (not shown) around 2000 UTC to determine impacts would be minimal over the next 60 minutes. J80 departures continued without restrictions (Fig. B) until 2108 UTC, when high-topped thunderstorms moved over the route (Fig. C). ZNY said that without explicit knowledge of the speed, direction of movement, and forecast of this storm cluster provided by CIWS, they would have been inclined to reroute traffic to J60/J64 earlier and avoid potential complexity/safety concerns. The decision by ZNY to run not only nominal traffic but also some ZDC reroute traffic on J80 was further facilitated by ZOB's decision to keep J80 open without restrictions in their airspace, despite level 3-5 storm cells along the route.

CASE STUDY B-15

ARTCC: ZNY
Date: 05 August 2003
Benefit: Early reopening of J209 route in ZNY airspace

- Resulted in early cancellation of ground stop on WHITE departures from N90
- Increased capacity during high demand period saved significant queuing delay

CIWS Products Used: Echo Tops, NEXRAD VIL

CIWS Delay Savings Calculations:

Benefit Period:	0.50 hr (2054-2125 UTC)	
Linear Delay Reduction:	0	
Queue Delay Reduction:	49.0 hr	
Capacity with Benefit:	17/hr	
Capacity without Benefit:	10/hr	
Primary Delay Reduction:	49.0 hr	
Downstream Delay Reduction:	39.2 hr	
Primary Operating Cost Savings:		$ 77,469
Downstream Operating Cost Savings (DM-1):		$ 61,975
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$191,747
Total CIWS Delay Reduction:		**88.2 hr**
Total CIWS Delay Savings (DM-1):		**$331,191**
Total CIWS Delay Savings (DM-2):		**$269,216**

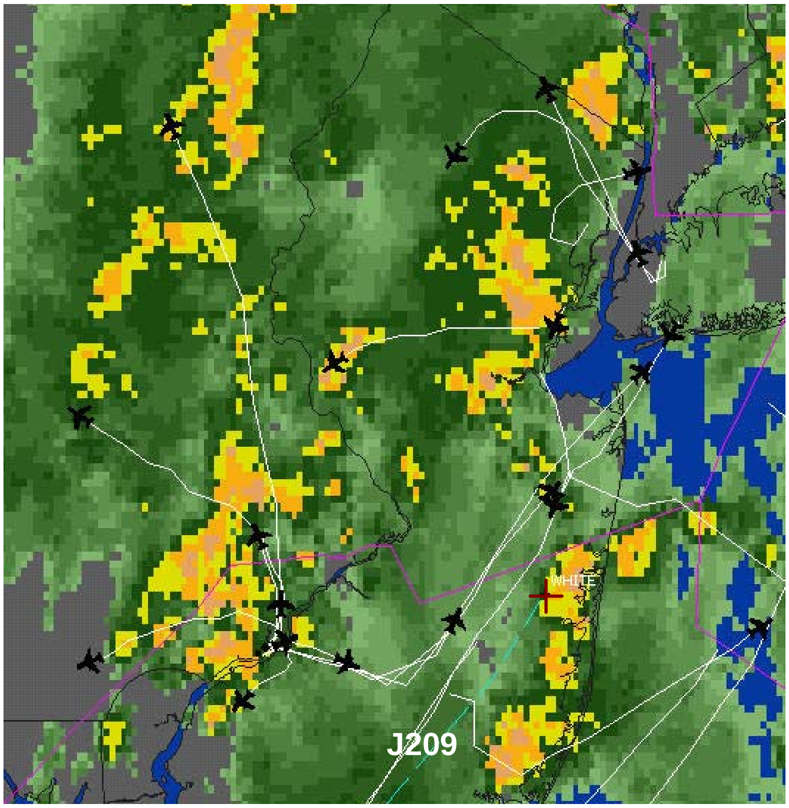

Figure B-15-1. Flightexplorer flight track and WSI composite reflectivity information at 2000 UTC on 05 August 2003. ZNY southbound departures over WHITE fix and J209 were stopped at this time due to thunderstorms.

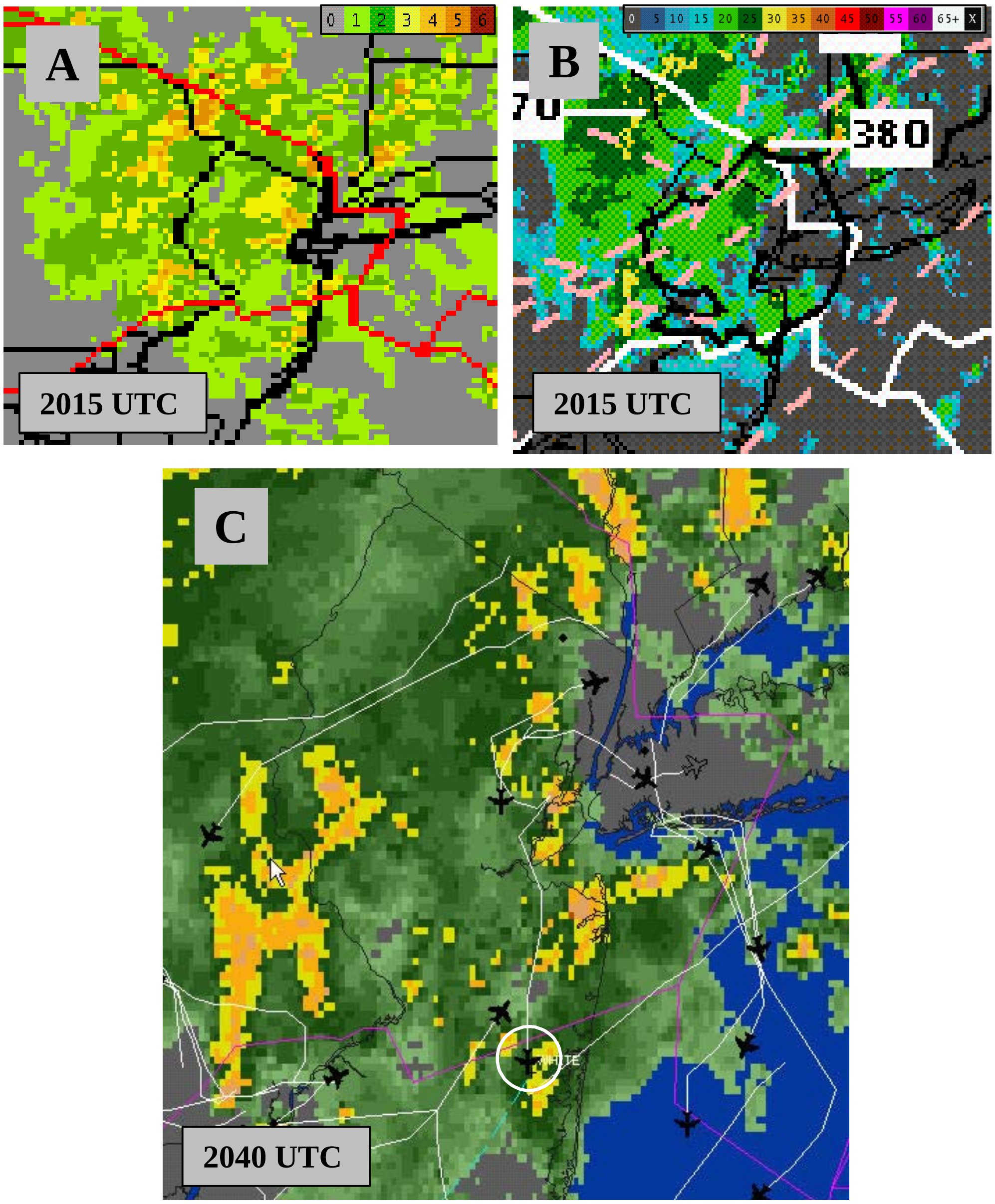

Figure B-15-2. By using CIWS VIL precipitation (Fig. A) and echo tops (Fig. B) to identify the low-topped nature of convection in their airspace, ZNY requested a pathfinder at 2015 UTC (Fig. C, circled plane) in an attempt to reopen WHITE/J209 early. At 2040 UTC, the pathfinder reported that the flight through ZNY was good and the route was reopened at that time. Without CIWS, it is estimated that the route would have remained closed until 2125 UTC.

APPENDIX C
INDIVIDUAL CASE STUDY DESCRIPTIONS

CIWS Benefit: Proactive, Efficient Reroutes

CASE STUDY C-1

ARTCC: ZAU
Date: 20 July 2003
Benefit: Planning for closure of SW ORD arrival fix 30 min prior than it actually closed (using CIWS) resulted in earlier reroute of inbound traffic near Omaha, NE along more efficient path

- Inbound traffic in en route airspace proactively rerouted to arrive at open fix Rather than making turn toward fix closer to terminal airspace

CIWS Products Used: RCWF (+30, +60 min forecasts), NEXRAD VIL, Growth and Decay Trend Contours, Storm Motion Vectors

CIWS Delay Savings Calculations:

Benefit Period:	0.7 hr (2150 -2230 UTC)	
Linear Delay Reduction:	1.3 hr	
Flights Avoiding Longer Route:		7
Total Distance Saved:		98 mi
Queue Delay Reduction:	0	
Primary Delay Reduction:	1.3 hr	
Downstream Delay Reduction:	1.0 hr	
Primary Operating Cost Savings:		$ 3,426
Downstream Operating Cost Savings (DM-1):		$ 1,581
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$ 5,000
Total CIWS Delay Reduction:		**2.3 hr**
Total CIWS Delay Savings (DM-1):		**$10,007**
Total CIWS Delay Savings (DM-2):		**$ 8,426**

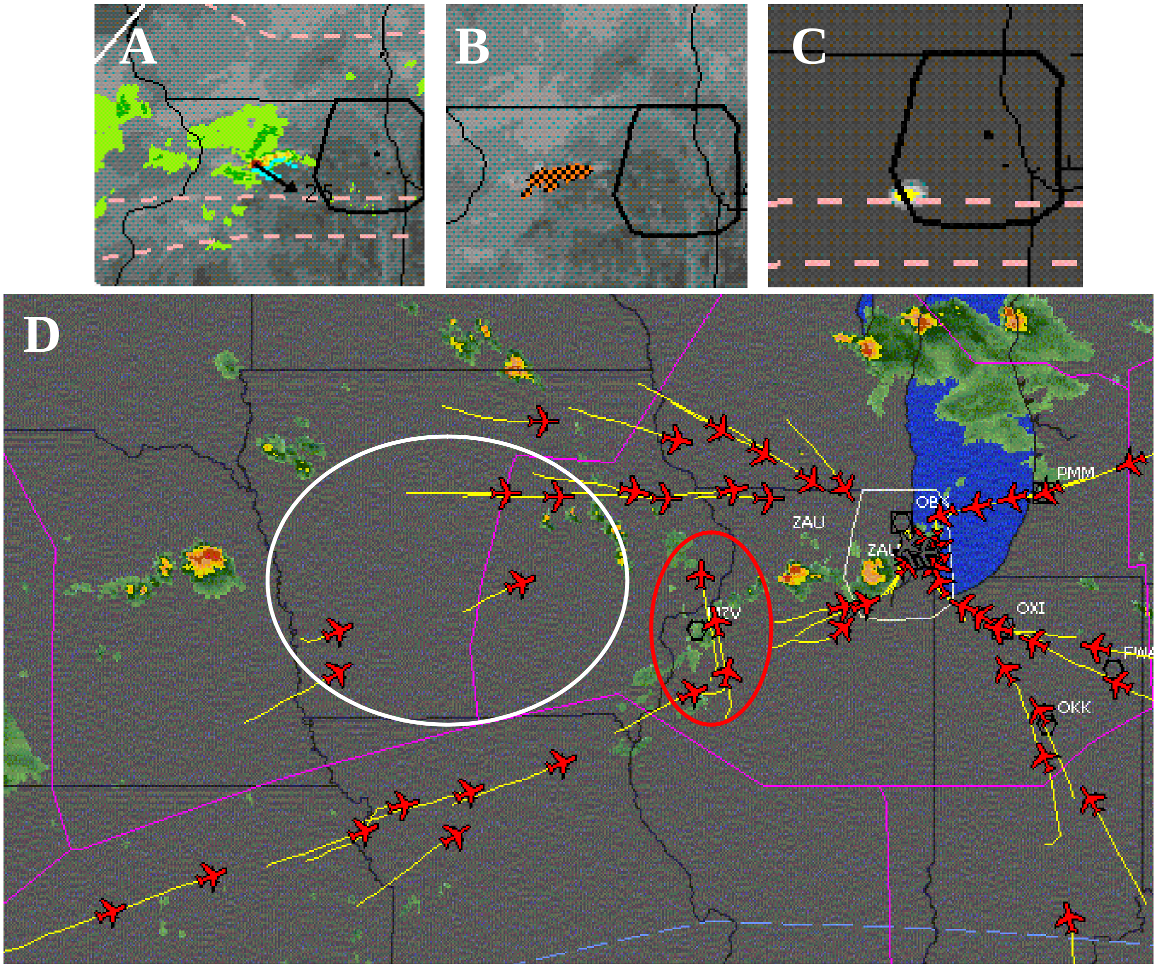

Figure C-1-1. (A) CIWS NEXRAD VIL precipitation at 2110 UTC, (B) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contours at 2110 UTC, (C) CIWS 75 min forecast valid at 2110 UTC, and (D) Flightexplorer flight track and WSI composite reflectivity information at 2230 UTC. The traffic manager working arrivals for ZAU on this day indicated that he used these CIWS products to proactively reroute a few aircraft as far west as Nebraska to the northwest arrival gate (white circle) in order to prevent the need for less efficient reroutes once these flights reached thunderstorms near the southwest arrival fix (red circle). The traffic manager noted that he started rerouting aircraft roughly 30 min before the southeast arrival route was closed.

CASE STUDY C-2

ARTCC: ZAU
Date: 21 July 2003
Benefit: En route, inbound ORD traffic placed on shorter reroute to BAERZ (southeast C90 Arrival fix) rather than PLANO (southwest fix)

- Despite storms near BAERZ, TMC successfully argued for route based upon CIWS forecast and observed storm decay via CIWS Growth and Decay contours

CIWS Products Used: RCWF, Growth and Decay Trend Contours

CIWS Delay Savings Calculations:

Benefit Period:	0.75 hr (2050 – 2135 UTC)	
Linear Delay Reduction:	3.7 hr	
Flights Avoiding Longer Route:		16
Total Distance Saved:		1936 mi
Queue Delay Reduction:	0	
Primary Delay Reduction:	3.7 hr	
Downstream Delay Reduction:	3.0 hr	
Primary Operating Cost Savings:		$ 9,750
Downstream Operating Cost Savings (DM-1):		$ 4,743
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$14,566
Total CIWS Delay Reduction:		**6.7 hr**
Total CIWS Delay Savings (DM-1):		**$29,059**
Total CIWS Delay Savings (DM-2):		**$24,316**

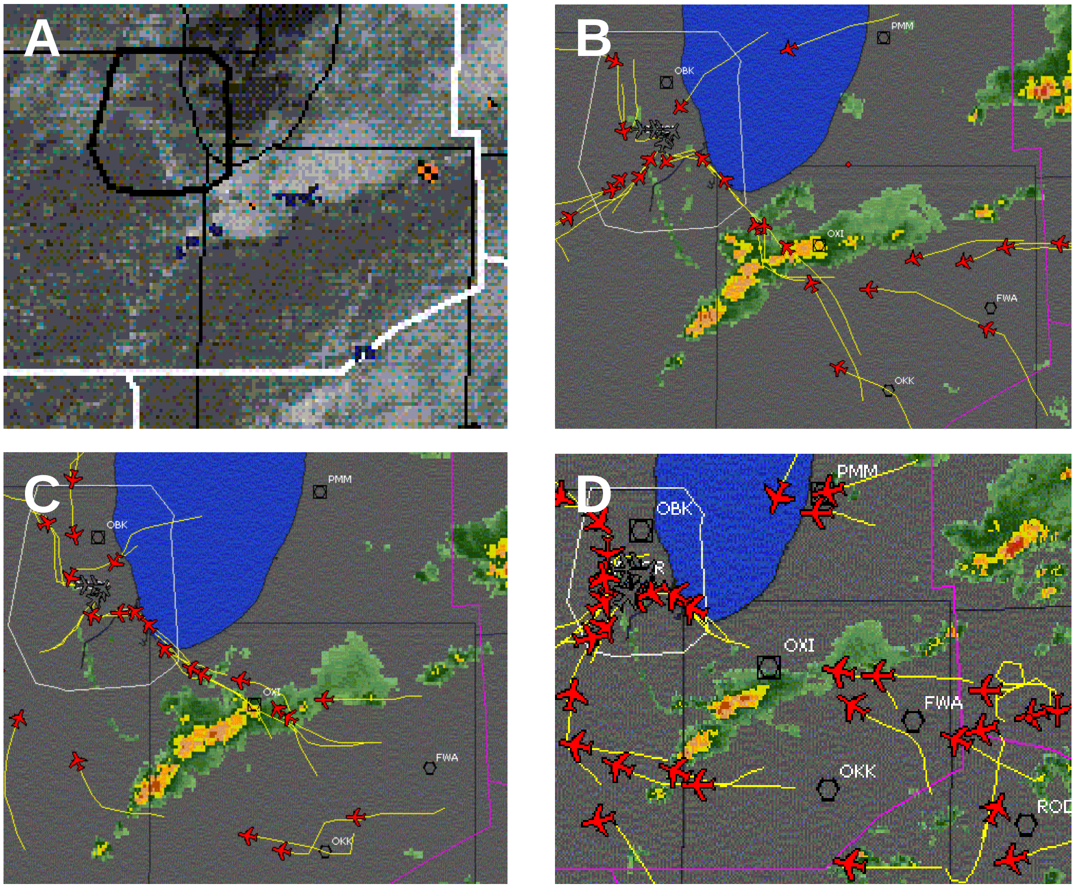

Figure C-2-1. (A) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contours and Satellite products at 2050 UTC, (B) Flightexplorer flight track and WSI composite reflectivity information at 2050 UTC, (C) 2112 UTC, and (D) 2125UTC. ZAU traffic managers used the CIWS growth and decay trend product (Fig. A) to note storms were weakening near the southeast C90 TRACON arrival fix (OXI VOR). Therefore, the decision was made to move traffic back to the more direct OXI reroute (Fig. B to C). This saved 16 en route aircraft an average of 120 miles in delay each.

CASE STUDY C-3

ARTCC: ZID
Date: 19 June 2003
Benefit: CIWS used to determine that a reroute was available for J6 traffic

- Using CIWS forecast products, shorter reroute using J134, then rejoining J6 near BWG, was identified

CIWS Products Used: RCWF, Growth and Decay Trend Contours

CIWS Delay Savings Calculations:

Benefit Period:	2.0 hr (1930 – 2130 UTC)	
Linear Delay Reduction:	1.5 hr	
Flights Avoiding Longer Route:		11
Total Distance Saved:		779 mi
Queue Delay Reduction:	0	
Primary Delay Reduction:	1.5 hr	
Downstream Delay Reduction:	1.2 hr	
Primary Operating Cost Savings:		$ 3,953
Downstream Operating Cost Savings (DM-1):		$ 1,897
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$ 5,870
Total CIWS Delay Reduction:		**2.7 hr**
Total CIWS Delay Savings (DM-1):		**$11,720**
Total CIWS Delay Savings (DM-2):		**$ 9,823**

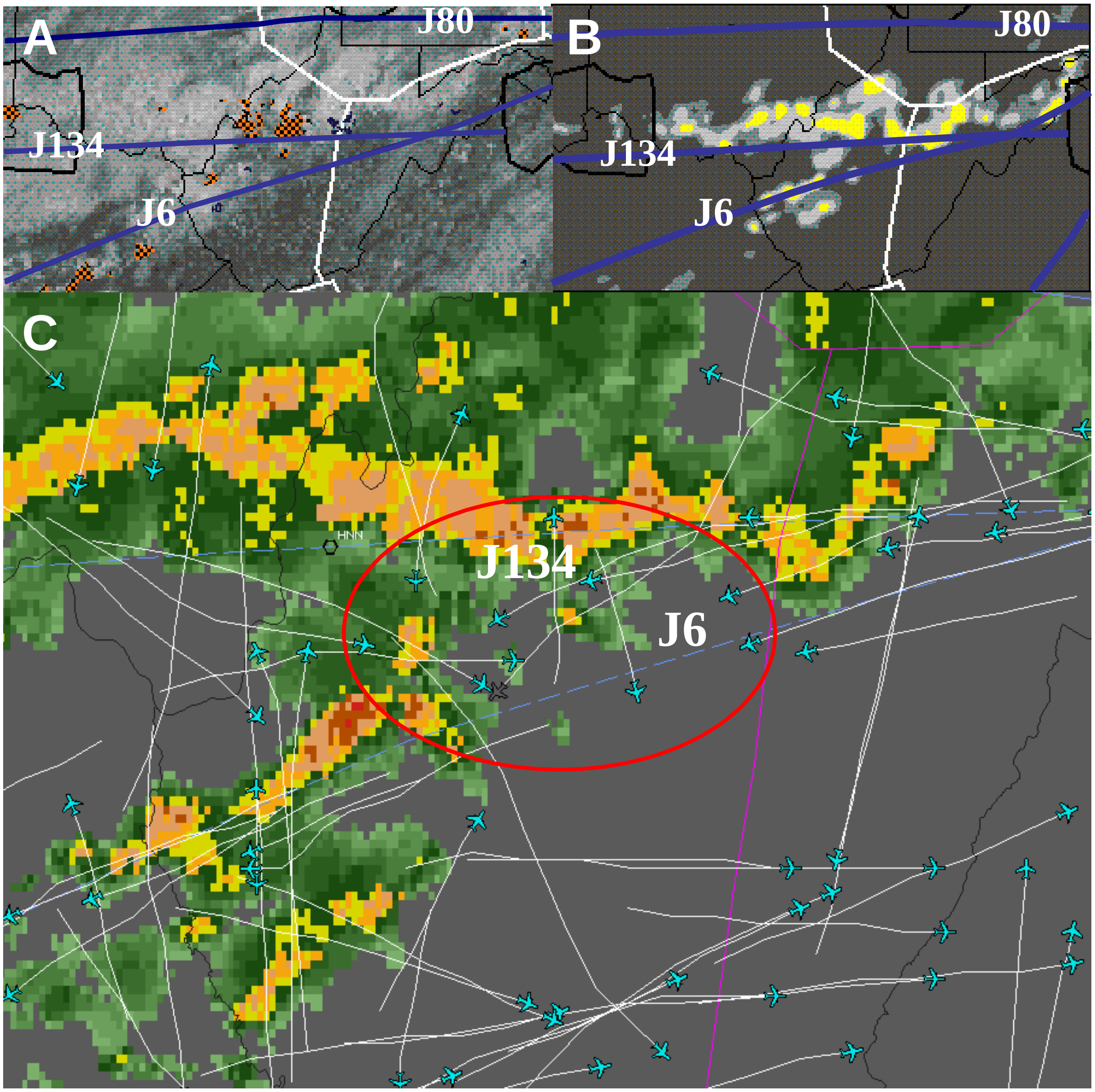

Figure C-3-1. (A) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contours and Satellite products at 2000 UTC, (B) CIWS 1-hr forecast valid at 2100 UTC, (C) Flightexplorer flight track and WSI composite reflectivity information at 2035 UTC. ZID traffic managers used CIWS Growth and Decay Trends (Fig. A) and Forecast (Fig. B) to determine that some J6 traffic could be rerouted on to J134 until clear of the storms on J6 and then directed back towards the south. CIWS depicted this strategy as a worthwhile reroute approach by demonstrating that (1) storms along J134 were not intensifying and (2) forecasted movement of storm on J6 showed the impact to be short-lived, meaning the reroute would only be needed a short while. Figure C shows the area of reroute at around 2035 UTC (red oval between J6 and J134). Aircraft were able to deviate south off of J134 and stay north of weather on J6. These aircraft were able to rejoin J6 once west of the impact region.

CASE STUDY C-4

ARTCC: ZID
Date: 04 August 2003
Benefit: CIWS utilized to determine that reroute was available for en route traffic inbound to CVG from the east.

- Availability of reroute to CVG by way of DJB…APE resulted in early cancellation of ZOB ground stop
- Reroute also assisted additional CVG departures from ZBW, ZNY, and ZDC to release early, saving delay

CIWS Products Used: RCWF, Growth and Decay Trend Contours, NEXRAD VIL, Storm Motion Vectors

CIWS Delay Savings Calculations:

Benefit Period: 1.6 hr (2105 – 2240 UTC)
Linear Delay Reduction: 13.3 hr (20 aircraft exiting ground stop early)
Queue Delay Reduction: 0
Primary Delay Reduction: 13.3 hr
Downstream Delay Reduction: 10.6 hr
Primary Operating Cost Savings: $21,027
Downstream Operating Cost Savings (DM-1): $16,759
Downstream Operating Cost Savings (DM-2) 0
Passenger Cost Savings: $51,959
Total CIWS Delay Reduction: 23.9 hr
Total CIWS Delay Savings (DM-1): $89,745
Total CIWS Delay Savings (DM-2) $72,986

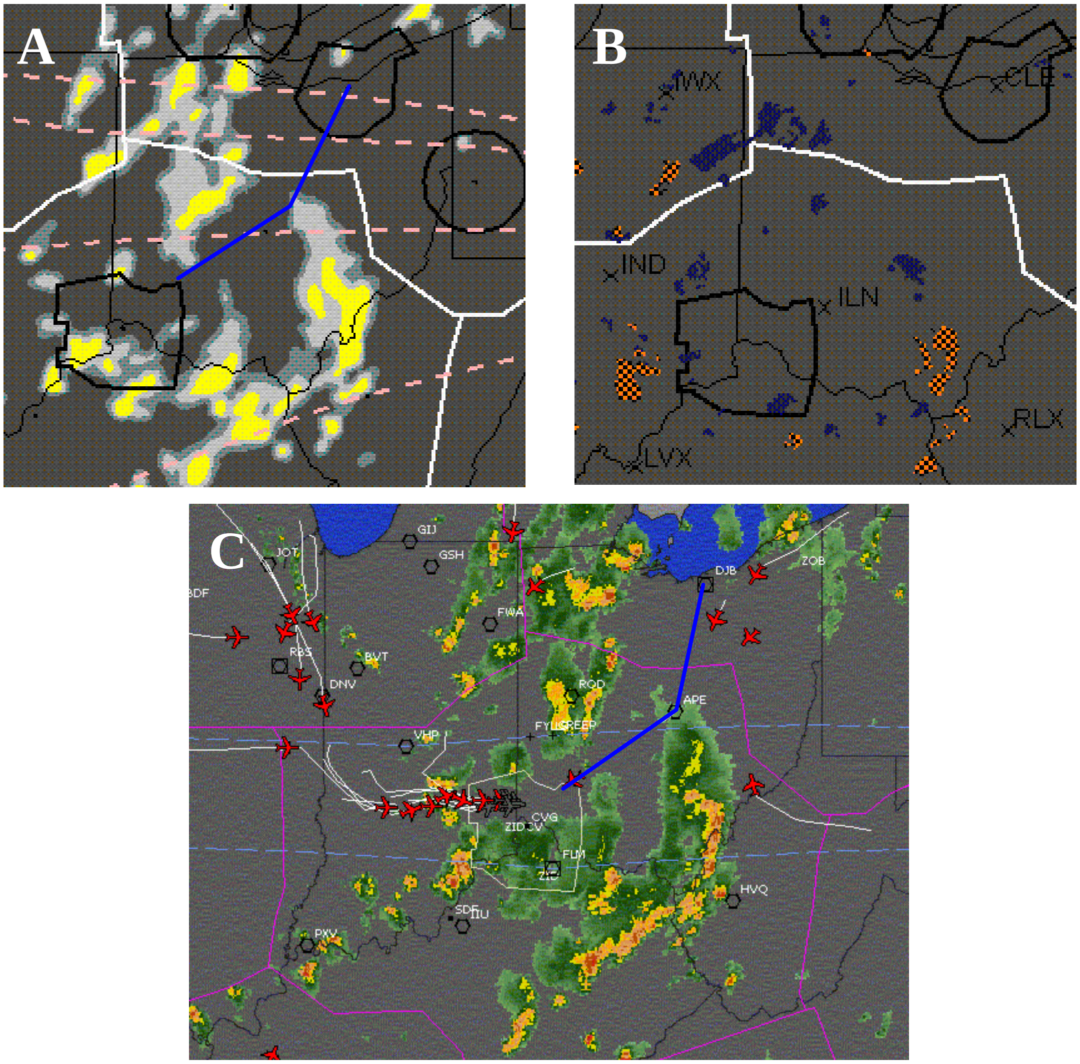

Figure C-4-1. (A) CIWS 90 min forecast valid at 2230 UTC, (B) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contours at 2100 UTC, and (C) Flightexplorer flight track and WSI composite reflectivity information at 2143 UTC. ZID traffic managers used these CIWS products to identify a gap in weather suitable for an arrival reroute for CVG traffic from the east and northeast. The combination of RCWF and growth and decay contours product informed ZID that this reroute (Fig. A,C, blue line) would remain open for an extended period. This reroute allowed for the early removal of ZOB from the CVG ground stop. Several CVG departures from ZNY and ZDC were also able to depart and avoid respective ground stops.

CASE STUDY C-5

ARTCC: ZOB
Date: 04 April 2003
Benefit: Effective reroute through high echo-top convection for ORD arrivals holding ZOB airspace prevented numerous diversions

CIWS Products Used: Echo Tops

CIWS Delay Savings Calculations: **

Benefit Period:	1.0 hr (0230 – 0330 UTC)	
Linear Delay Reduction:	41.8 hr	
Queue Delay Reduction	0	
Primary Delay Reduction:	41.8 hr	
Downstream Delay Reduction:	33.4 hr	
Primary Operating Cost Savings:		$ 71,885
Downstream Operating Cost Savings (DM-1):†		0
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$163,570
Total CIWS Delay Reduction:		**75.2 hr**
Total CIWS Delay Savings:		**$235,455**

****** See Appendix F for description of model used to estimate delay savings associated with avoided diversions

† Due to the unique nature and specific details of this diversion-avoidance case study, neither model DM-1 nor DM-2 yielded downstream operating cost savings. See Appendix F for complete details.

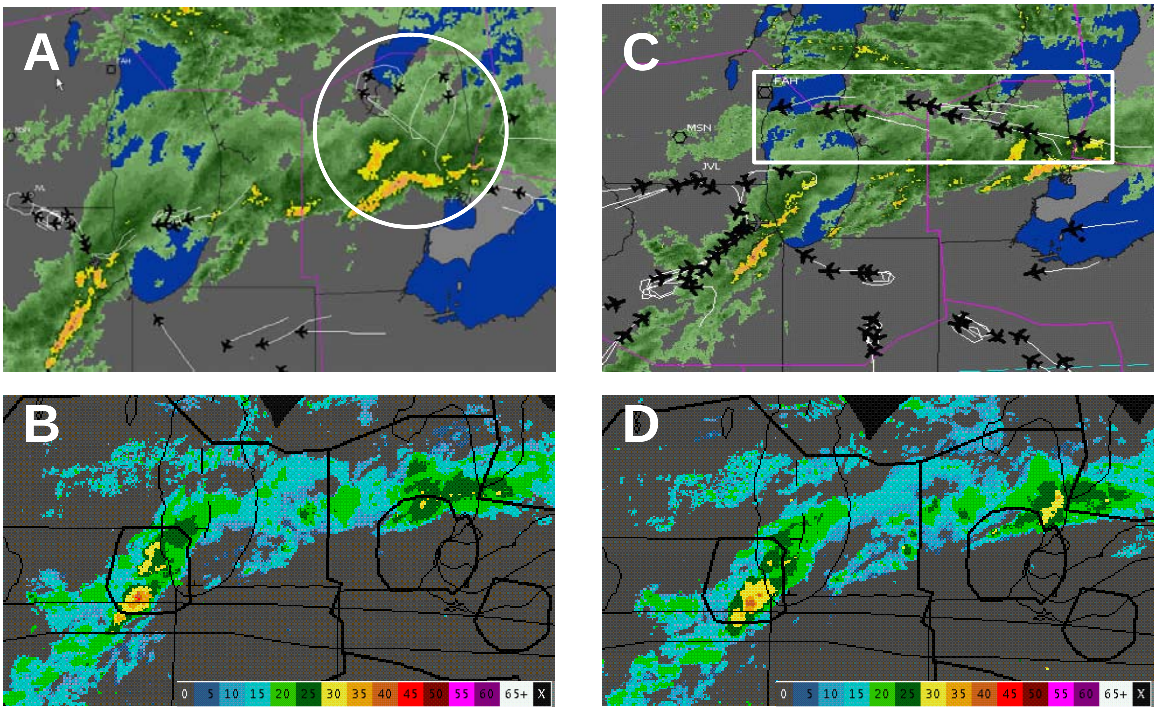

Figure C-5-1. (A) Flightexplorer flight track and WSI composite reflectivity information at 0245 UTC and (C) 0310 UTC, and (B) CIWS enhanced echo tops products at 0245 UTC and (D) 0314 UTC. After 0200 UTC, an area of high echo top storms developed near the ZAU/ZOB boundary in MI. This forced the aircraft arriving at ORD into holding patterns in ZOB airspace (Fig. A, white circle). ZOB traffic managers used CIWS to identify that echo tops were low (Fig. B) and that traffic could be rerouted to the north and arrive safely at ORD via FAH..MSN..JVL route (Fig. C). Without this reroute identified by using CIWS echo tops information, traffic managers informed the authors that 11 aircraft (Fig. C, white rectangle) would have had to divert to alternate airports.

CASE STUDY C-6

ARTCC: ZOB

Date: 27 July 2003

Benefit: Persistent RCWF forecast of storm gap near DJB VOR resulted in shorter flight distances and/or shorter ground stops by way of more efficient reroutes

- Only modeled benefits for DTW arrivals/departures, but additional benefits not included in analysis also realized by ORD, PHL, EWR, LGA traffic

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors

CIWS Delay Savings Calculations:

Benefit Period:	3 hr (1900 – 2200 UTC)	
Linear Delay Reduction:	12.8 hr	
DTW arrivals avoiding longer route:		6
DTW arrivals distance saved:		1820 mi
DTW arrival delay savings:		3.5 hr
ZDC departures to DTW avoiding ground stop:		7 (departing ZDC, PHL)
Delay saved by avoiding ground stop:		9.3 hr
DTW departures avoiding longer route:		22
DTW departure distance saved:		2550 mi
DTW departure delay savings:		4.9 hr
Queue Delay Reduction:	0	
Primary Delay Reduction:	17.7 hr	
Downstream Delay Reduction:	14.2 hr	
Primary Operating Cost Savings:	$ 36,837	
Downstream Operating Cost Savings (DM-1):	$ 22,450	
Downstream Operating Cost Savings (DM-2):	0	
Passenger Cost Savings:	$ 69,351	
Total CIWS Delay Reduction:	**31.9 hr**	
Total CIWS Delay Savings (DM-1):	**$ 128,638**	
Total CIWS Delay Savings (DM-2):	**$ 106,188**	

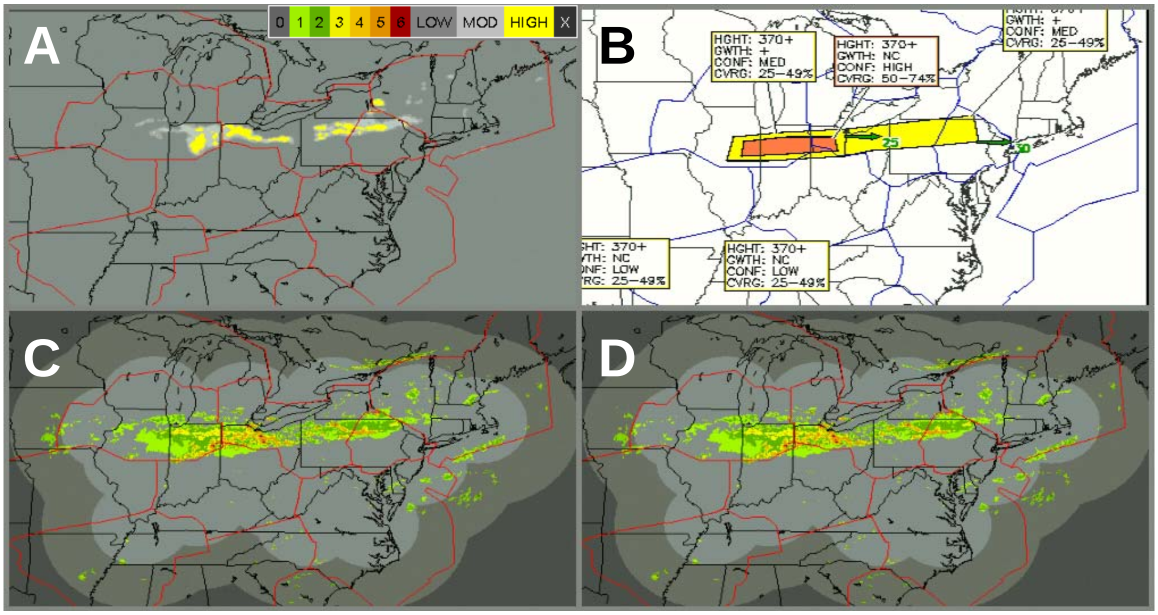

Figure C-6-1. Forecast product comparison between 2-hr CCFP and 2-hr RCWF valid at 2100 UTC on 27 July 2003. While the CCFP showed no break in the line of convection (Fig. B), the 2-hr CIWS forecast showed a large break in E OH and W PA (Fig. A). This forecast verified (Fig. C and D) and ZOB traffic managers used this storm gap to reroute traffic to and from multiple airports.

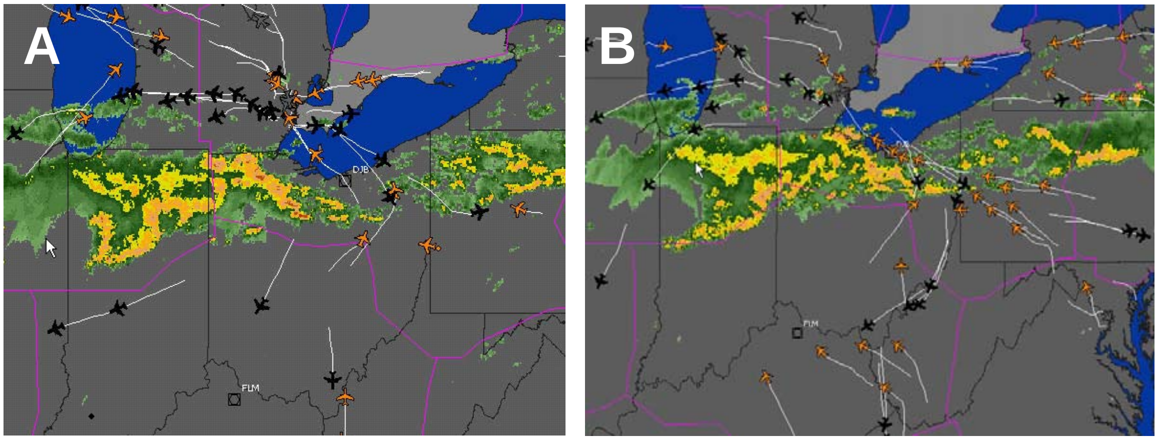

Figure C-6-2. Flightexplorer flight track and WSI composite reflectivity information at 2020 UTC (A) and 2100 UTC (B) on 27 July 2003. Figure A shows the gap over the DJB VOR, being used by southbound DTW departures (black planes), as well as DTW arrivals (orange planes) from the south, to traverse the line of storms. Figure B shows the continued use of this storm gap forty minutes later.

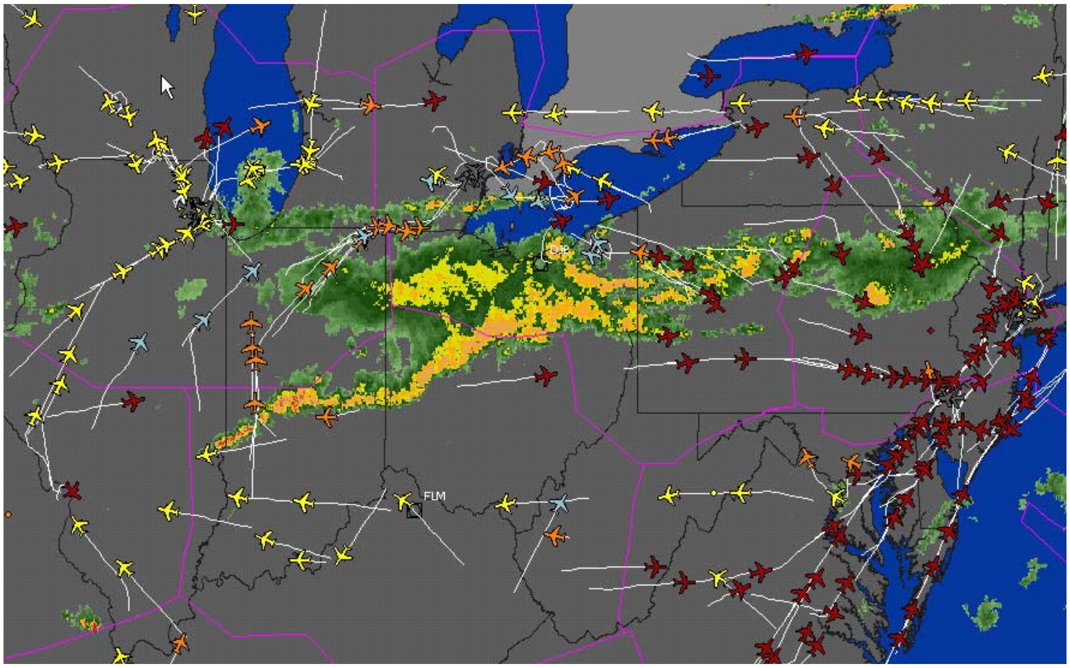

Figure C-6-3. Flightexplorer flight track and WSI composite reflectivity information at 2225 UTC on 27 July 2003. The storm gap in the east-west line near DJB filled in at this time. Flight paths at this time give an indication of longer distance reroutes required earlier had CIWS-enable gap exploitation not occurred. Note DTW arrivals (orange planes) from the south rerouted toward the west end of the line in IN. Without the earlier storm gap, flight distances for metro NY and PHL arrivals (red planes) and ORD arrivals (yellow planes) also increased.

CASE STUDY C-7

ARTCC: ZDC

Date: 16 July 2003

Benefit: CIWS forecast used to determine storm gap would persist rather than fill in and end reroute

- Confidence in RCWF allowed traffic managers to send heavy stream of reroute traffic through storm gap for prolonged period
- ZDC TMU supervisor noted that filtered CIWS NEXRAD VIL precipitation and enhanced echo top product were useful in convincing area supervisors of viability of gap. This, along with RCWF, convinced area supervisors to utilize storm gap for reroutes since their concerns about getting caught in significant holding situation (if gap closed) were eased
- Traffic managers confirmed that without CIWS, ZJX/ZMA to ZNY/BOS would have required a ground stop. Also, active warning and special use areas along the coast limited reroute options east of convection
- Traffic managers added that Potomac TRACON may also have required a ground stop for ZJX/ZMA traffic had the RCWF forecast for the storm gap to persist not been identified. Also, even with ground stops in place, some traffic would still have "trickled" through gap
- Case study conservatively modeled assuming (a) No ground stop for Potomac TRACON and (b) 20% of flights in ZJX/ZMA ground stop to NY/BOS allowed to still move through gap in "no benefit" analysis

CIWS Products Used: RCWF, NEXRAD VIL, Echo Tops, Growth and Decay Trend Contours, Lightning

CIWS Delay Savings Calculations:

Benefit Period:
  ZJX/ZMA to metro NY: 2.7 hr (2020 – 2300 UTC)
  ZJX/ZMA to PHL/TEB/BOS: 1.7 hr (2120 – 2300 UTC)
Linear Delay Reduction: 24.9 hr
  Total flights departing group stop early: 23
  Early departures included in savings calculations: 19
Queue Delay Reduction: 0
Downstream Delay Reduction: 19.9 hr
Primary Operating Cost Savings: $ 39,367
Downstream Operating Cost Savings (DM-1): $ 31,462
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $ 97,395
Total CIWS Delay Reduction: 44.8 hr
Total CIWS Delay Savings (DM-1): $168,224
Total CIWS Delay Savings (DM-2): $136,762

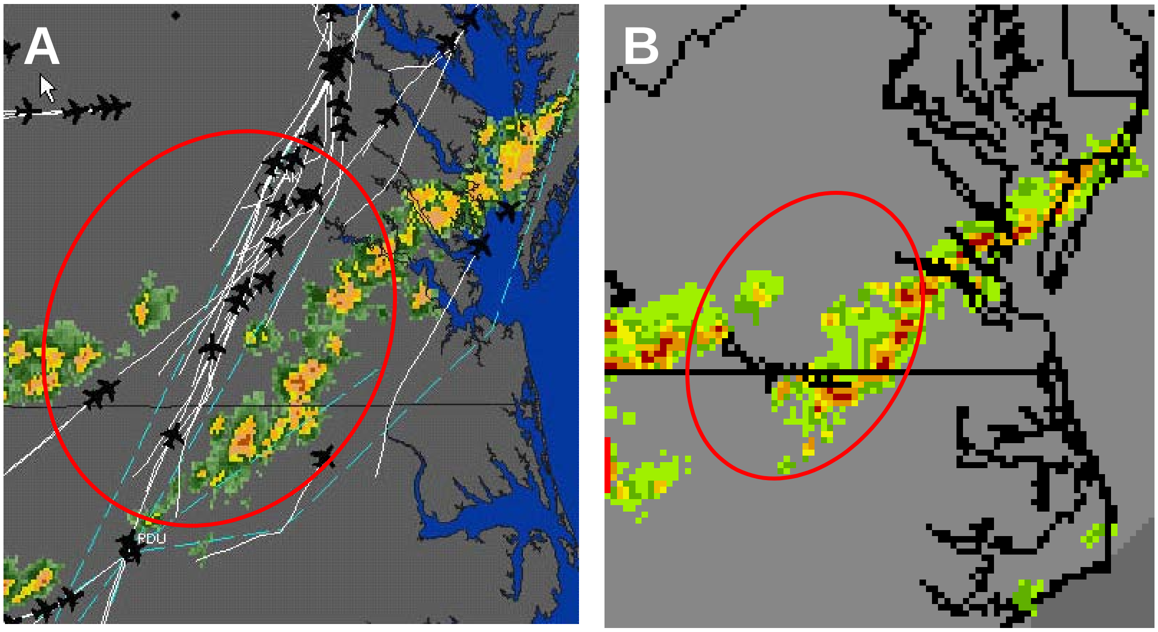

Figure C-7-1. (A) Flightexplorer flight track and WSI composite reflectivity information at 2030 UTC and (B) CIWS NEXRAD VIL precipitation at 2100 UTC on 16 July 2003. ZDC traffic managers used the CIWS forecast product (Not Shown) to determine that a functional gap in convection (red circle) would persist, allowing reroute capabilities for several airports for a prolonged period. In addition to the CIWS forecast product, TMU traffic managers also used the CIWS NEXRAD VIL (Fig. B) to convince the area supervisors that the gap would remain open which in turn gave them confidence to open airspace as their concerns regarding significant holding situations (should the gap close) were eased. Without the CIWS products, the ZDC TMU supervisor would have required ground stops for ZJX and ZMA traffic to metro NY, PHL, and BOS.

CASE STUDY C-8

ARTCC: ZDC
Date: 22-23 July 2003
Benefit: CIWS products to coordinate with ZNY on reroute for ATL to metro NY. Traffic rerouted over GVE VOR then up east coast.

- Traffic managers noted that without CIWS, knowledge on extent of storm weakening trend in central VA would have been limited
- CIWS forecast allowed ZDC to more accurately predict future location of line of storms in NE ZDC/ZNY, better informing them that ATL departures would be able to get eat of weather on the proposed reroute
- ATL departures to JFK, LGA, EWR would have remained on the ground without CIWS

CIWS Products Used: RCWF, NEXRAD VIL, Echo Tops, Growth and Decay Trend Contours, Lightning

CIWS Delay Savings Calculations:

Benefit Period: 2 hr (0000 – 0200 UTC)
Linear Delay Reduction: 9.2 hr (8 ATL flights depart early)
Queue Delay Reduction: 0
Primary Delay Reduction: 9.2 hr
Downstream Delay Reduction: 7.4 hr
Primary Operating Cost Savings: $14,545
Downstream Operating Cost Savings (DM-1): $11,699
Downstream Operating Cost Savings (DM-2): 0
Passenger Cost Savings: $36,088
Total CIWS Delay Reduction: 16.6 hr
Total CIWS Delay Savings (DM-1): $62,332
Total CIWS Delay Savings (DM-2): $50,633

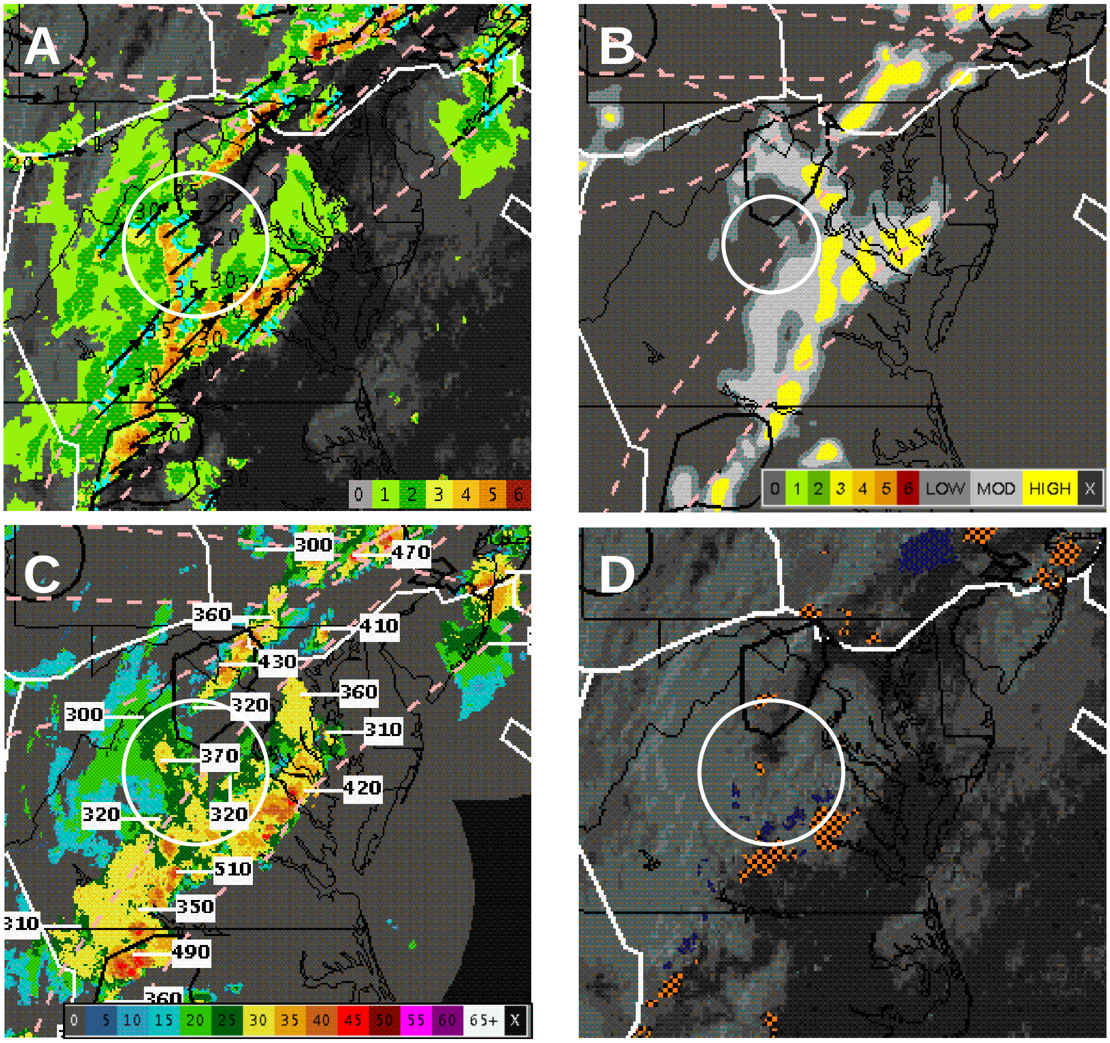

Figure C-8-1. (A) CIWS NEXRAD VIL precipitation (B) CIWS 2-hr forecast product (valid at 0133 UTC), (C) CIWS echo tops product, and (D) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contours at 2333 UTC on 22 July 2003.These four images represent the information the ZDC traffic managers utilized in their reroute decision for ATL departures to metro NY airports. By using these products, traffic managers were able to determine that ATL to NY traffic could be proactively rerouted through the storms in the GVE VOR area (white circle in each image), and then continue north along the east coast with confidence that the approaching line would not shut off traffic flow.

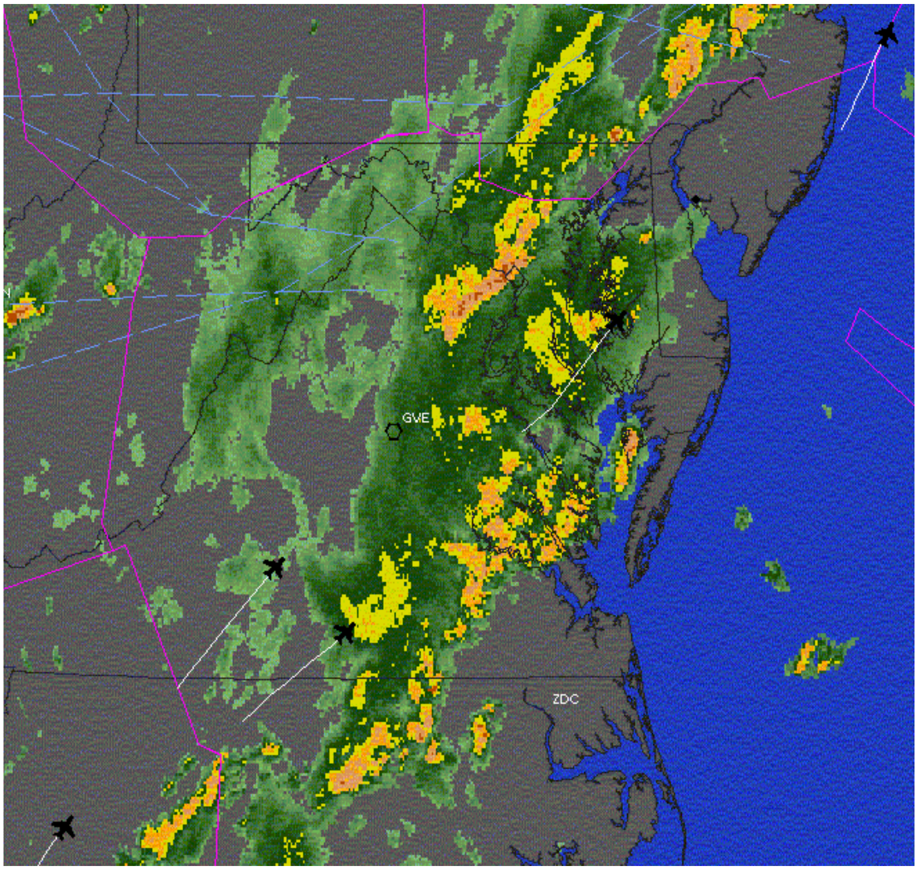

Figure C-8-2. Flightexplorer flight track and WSI composite reflectivity information at 0146 UTC on 23 July 2003. At this time, ATL departures to metro NY airports were traversing ZDC airspace via a CIWS-derived reroute over GVE, then up the east coast. ZDC traffic managers referenced CIWS in discussions with the ZNY to create an option for traffic from ATL to NY. Traffic managers noted that CIWS provided additional information regarding the predicted location of convection in their airspace and the rate of storm decay near the GVE VOR, giving them confidence to issue a reroute through this region, despite significant (but weakening) convection at the time ATL was released on this route.

CASE STUDY C-9

ARTCC: ZBW
Date: 01 May 2003
Benefit: CWSU meteorologists used CIWS Growth and Decay information to inform traffic managers that northern half of squall line through upstate NY was decaying (while southern half was strengthening). BOS departures rerouted on shorter routes towards the north end of the squall line.

- CWSU informed TMU of more direct westbound route (based on CIWS decay trends at 2300 UTC). The first BOS flight on the shorter westbound reroute departed at 2337Z

CIWS Products Used: Growth and Decay Trend Contours, NEXRAD VIL, Echo Tops, Lightning, RCWF

CIWS Delay Savings Calculations:

Benefit Period:	1.9 hr (2337 – 0130 UTC)
Linear Delay Reduction:	2.4 hr
Total flight avoiding longer route:	24
Total distance saved:	1248 mi (52 mi (6 min) per plane)
Queue Delay Reduction:	0
Primary Delay Reduction:	2.4 hr
Downstream Delay Reduction:	1.9 hr
Primary Operating Cost Savings:	$ 6,324
Downstream Operating Cost Savings (DM-1):	$ 3,004
Downstream Operating Cost Savings (DM-2):	0
Passenger Cost Savings:	$9,348
Total CIWS Delay Reduction:	**4.3 hr**
Total CIWS Delay Savings (DM-1):	**$18,676**
Total CIWS Delay Savings (DM-2):	**$15,672**

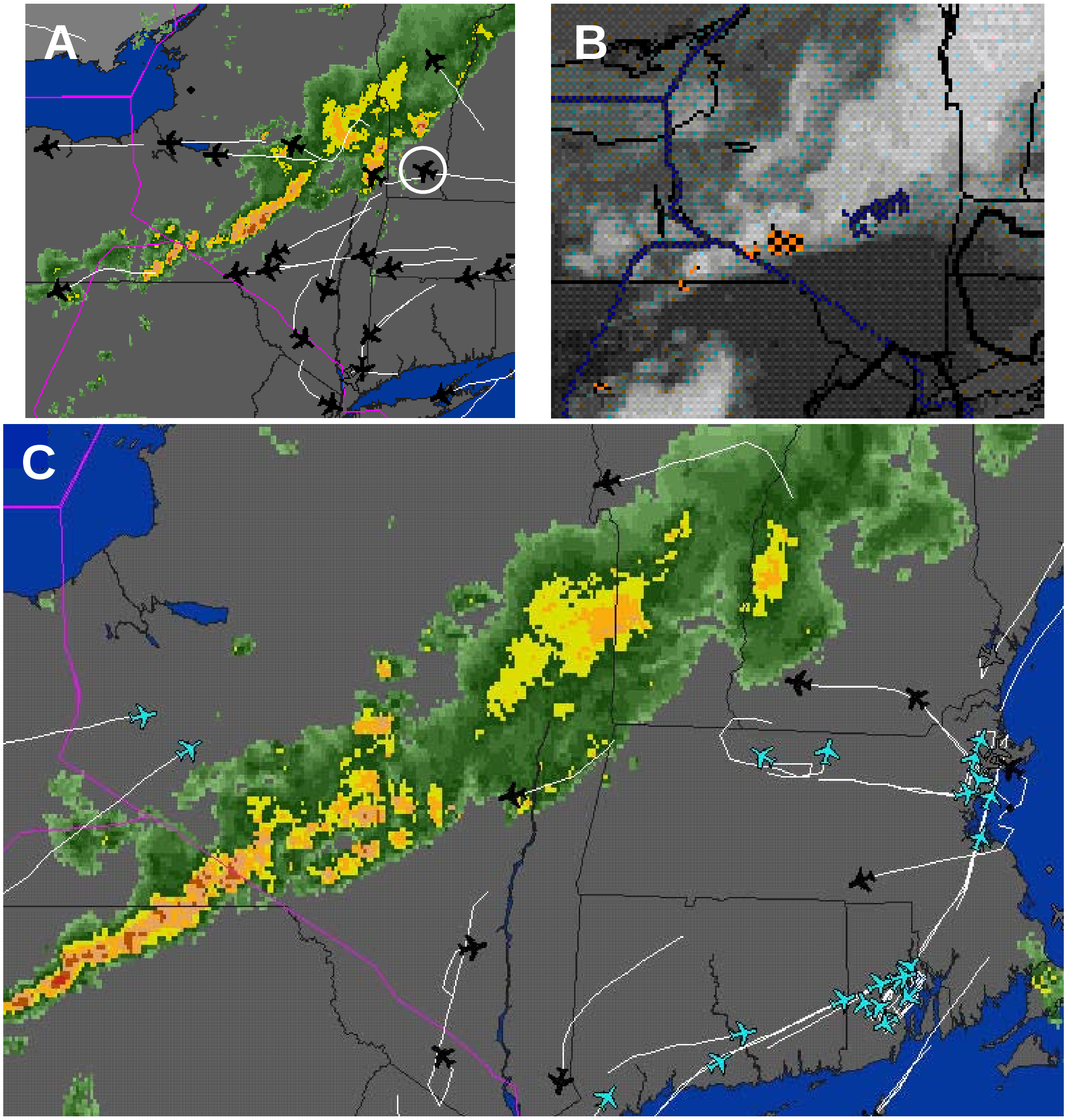

Figure C-9-1. (A) Flightexplorer flight track and WSI composite reflectivity information at 2225 UTC, (B) CIWS Growth and Decay Trend Contours and satellite information at 2300 UTC, and (C) Flightexplorer flight tracks and WSI composite reflectivity information at 2355 UTC on 01 May 2003. Figure A shows conditions as the last westbound aircraft (white circle) departs BOS via the more direct flight plan. By 2300 UTC, the ZBW meteorologists used CIWS growth and decay trends (Fig. B) to see that storms were decaying (blue contours) on the northern end of the line while strengthening (hatched orange) along the southern end. This information was used to convince traffic managers to route traffic towards the north end of the line, despite significant weather still in that vicinity, starting at 2337 UTC. This reroute saved 24 aircraft six minutes in flight time each.

CASE STUDY C-10

ARTCC: ZBW

Date: 11 July 2003

Benefit: CIWS utilized for earlier reroute of BOS traffic around backside of convection, the result of which was the cancellation of a BOS ground stop 20 min earlier.

CIWS Products Used: Echo Tops, NEXRAD VIL, Storm Motion Vectors, Growth and Decay Trend Contours

CIWS Delay Savings Calculations:

Benefit Period:	2 hr (1045 – 1245 UTC)	
Linear Delay Reduction:	1.9 hr	
Delay saved by 3 flights departing early:		1.1 hr
Total flights avoiding longer route:		8
Total delay (distance) saved:		0.8 hr (416 mi)
Queue Delay Reduction:	0	
Primary Delay Reduction:	1.9 hr	
Downstream Delay Reduction:	1.5 hr	
Primary Operating Cost Savings:		$ 3,847
Downstream Operating Cost Savings (DM-1):		$ 2,372
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$ 7,392
Total CIWS Delay Reduction:		**3.4 hr**
Total CIWS Delay Savings (DM-1):		**$13,611**
Total CIWS Delay Savings (DM-2):		**$11,239**

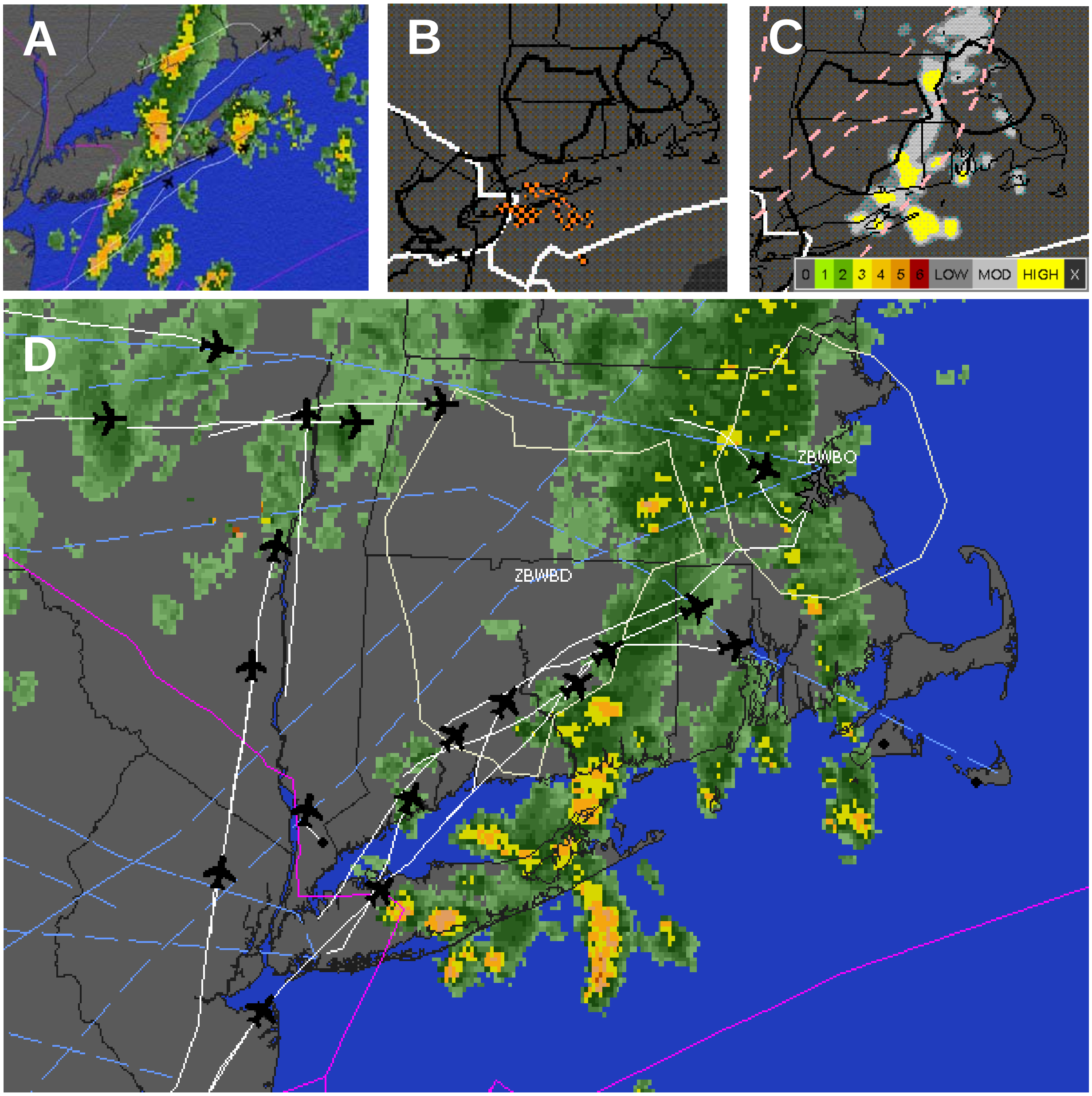

Figure C-10-1. (A) Flightexplorer flight track and WSI composite reflectivity information at 1115 UTC, (B) CIWS Growth (hatched orange) and Decay (blue) Trend Contours at 1200 UTC, (C) CIWS 1-hr forecast valid at 1255 UTC and (D) Flightexplorer flight track and WSI composite reflectivity information at 1200Z on 11 July 2003. ZBW traffic managers initially routed air traffic bound for BOS ahead of the weather (Figure A). TMC consulted CIWS at 1205 UTC to determine that moving traffic behind the line of storms would be more efficient. The TMC used Growth and Decay Trends, (Figure B) and CIWS Forecast (Figure C) to see that proactively reroute traffic behind the line of storms (Figure D) would be possible.

CASE STUDY C-11

ARTCC: ZNY
Date: 12 June 2003

Benefit: CIWS used to proactively reroute J80 traffic to J60/64 and thereby maintain the J80 flow without interruption

- Without CIWS, aircraft that had filed for J80 would have been temporarily halted when weather moved over it at 2145 UTC
- 6 scheduled J80 departures out of NY released between 2145 – 2215 UTC (likely stoppage without CIWS), saving on average 15 min per flight
- Delay saving estimates considered conservative since it is likely there would have been additional delay from holding in the taxi sequence on the runways

CIWS Products Used: RCWF, NEXRAD VIL, Storm Motion Vectors, Echo Tops, Lightning

CIWS Delay Savings Calculations:

Benefit Period:	0.5 hr (2145 – 2215 UTC)	
Linear Delay Reduction:	1.5 hr	
Queue Delay Reduction:	0	
Primary Delay Reduction:	1.5 hr	
Downstream Delay Reduction:	1.2 hr	
Primary Operating Cost Savings:		$ 2,372
Downstream Operating Cost Savings (DM-1):		$ 1,897
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$ 5,870
Total CIWS Delay Reduction:		**2.7 hr**
Total CIWS Delay Savings (DM-1):		**$10,139**
Total CIWS Delay Savings (DM-2):		**$ 8,242**

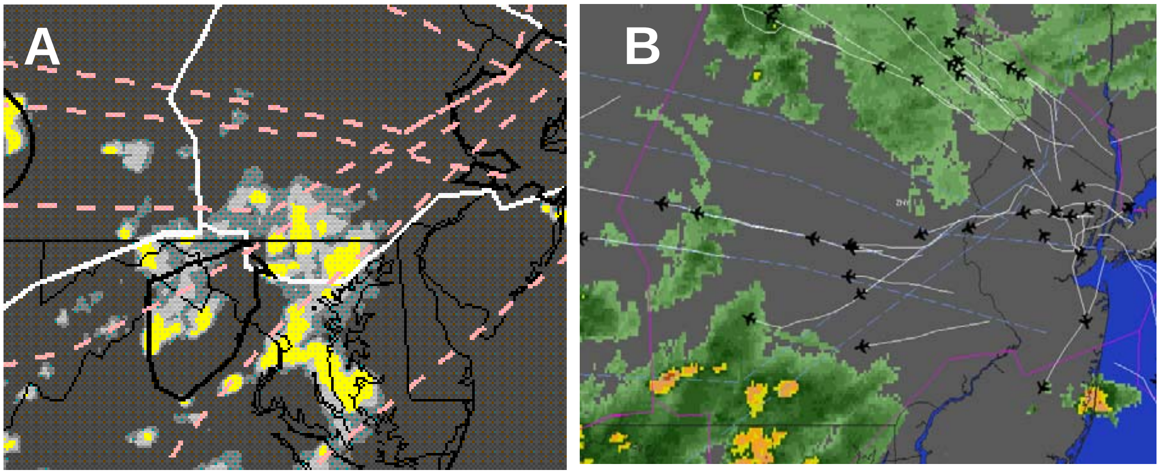

Figure C-11.1. (A) CIWS 30 min forecast valid at 2202 UTC and (B) Flightexplorer flight track and WSI composite reflectivity information at 2202 UTC on 12 June 2003. ZNY traffic managers used the CIWS forecast (Fig. A) to see that J80 would close and proactively rerouted traffic on to J60 and J64. Six aircraft with filed flight plans for J80between 2145 and 2215 UTC were quickly rerouted onto J60 or 64 (Fig. B) saving these flights at least 15 minutes each in flight delay.

CASE STUDY C-12

ARTCC: ZNY
Date: 04 August 2003
Benefit: CIWS depiction of rapid storm growth over J36 route allowed traffic managers to make quick arrangements in rerouting traffic to J95 with almost no interruption in traffic flow

- Deviations of aircraft already on route J36 verified Growth Trend depiction provided just prior by CIWS
- Pre-emptive measure of rerouting to J95 likely saved a 10 min ground stop on N90 north gate departures. Planes in queue on runway would likely have held up departure lineup until J95 reroute was approved.

CIWS Products Used: Growth and Decay Trend Contours, NEXRAD VIL, Echo Tops, Lightning

CIWS Delay Savings Calculations:

Benefit Period:	(2110 – 2210 UTC) 10 min ground stop avoidance, but queue analysis over 1 hr)	
Linear Delay Reduction:	0	
Queue Delay Reduction:	7.7 hr	
Demand on north gate:		10/hr
Capacity with benefit (no ground stop):		12/hr
Capacity without benefit:		10/hr
Primary Delay Reduction:	7.7 hr	
Downstream Delay Reduction:	6.2 hr	
Primary Operating Cost Savings:		$12,174
Downstream Operating Cost Savings (DM-1):		$ 9,802
Downstream Operating Cost Savings (DM-2):		0
Passenger Cost Savings:		$30,219
Total CIWS Delay Reduction:		**13.9 hr**
Total CIWS Delay Savings (DM-1):		**$52,195**
Total CIWS Delay Savings (DM-2):		**$42,393**

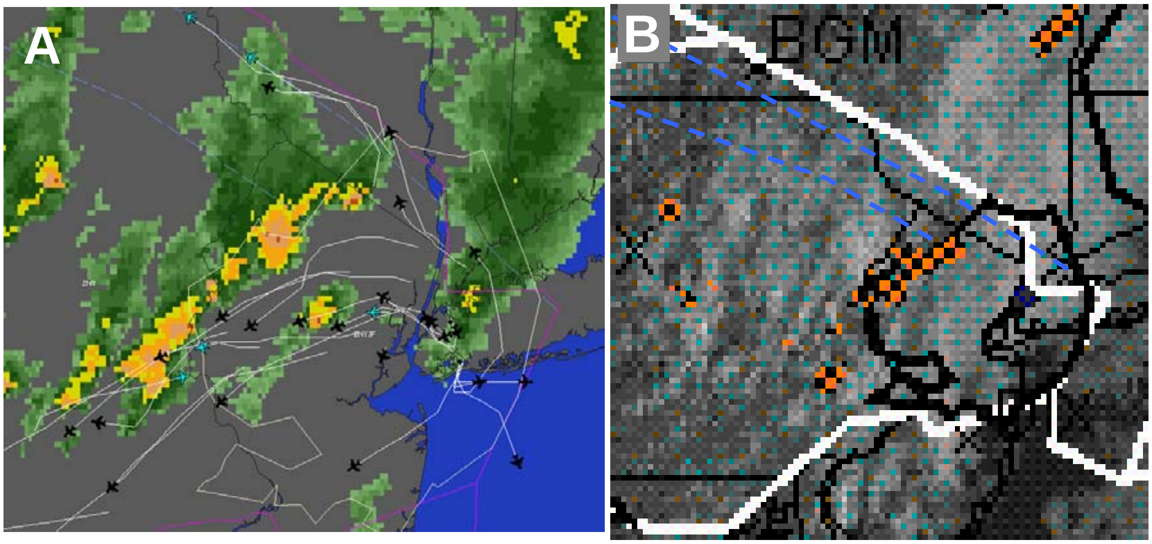

Figure C-12-1. (A) Flightexplorer flight track and WSI composite reflectivity information at 2200 UTC and (B) CIWS Growth (hatched orange) and Decay (dark blue) Trend Contour product at 2117 UTC on 04 August 2003. On this day, traffic managers based a decision to move traffic north from J36 to J95 (dashed blue lines in both images) on CIWS weather information. Both J36 and J95 had been closed for over two hours while storms impacted the routes. At 2110 UTC, both routes were reopened but soon after storms quickly redeveloped near J36. Traffic managers used CIWS to quickly determine that continued storm intensification was expected (Fig. B) at the initial fix for J36, while J95 route would remain unimpeded. Traffic from J36 was proactively rerouted to J95 with little disruption in ATC operations.

APPENDIX D
ANALYSIS OF 2002 POST-EVENT USER FEEDBACK

Interviews during and immediately following convective weather events were conducted with traffic managers (generally by telephone) during the 2002 and 2003 summer storm seasons. Presented here are the results of analyzing the 2002 post-event user feedback. Post-event feedback results from 2003 will be available in Phase 2 of CIWS Benefits Estimates. These results are germane for three reasons:

- The initial quantitative analysis results presented in chapters 6-8 and the Appendices B and C only address a subset of the ATC decisions that were improved by the use of the CIWS products. By looking at the relative frequency of a larger set of ATC decisions one gets a sense of the relative importance of the ATC decisions analyzed,
- Post event interviews cover a much larger set of storm events than occurred during the 2003 "benefits blitz" observation periods,
- Some of the post event user feedback (in particular, the "improved coordination") is hard to convert to a quantitative estimate; but is important for understanding the loss of potential in delay reduction benefits due to inability to put CIWS displays in certain key facilities.

The CIWS users were contacted after 49 storm events from April – September 2002, during which 89 post-event user interviews were conducted. During these interviews, traffic managers from the various facilities with access to CIWS (ARTCC, TRACON, ATCSCC, and airline dispatch) were asked for feedback on whether CIWS was consulted for traffic decision-making assistance during specific storm impact situations that day. If CIWS was utilized, specifics were sought regarding which weather products and traffic decisions were involved for the storm impact in question. Finally, users were asked to cite any problems or shortcomings they may have noted with the system that day. These latter comments were collected throughout the storm season to assist in identifying focus areas for future CIWS improvements.

A compilation of all post-event user feedback from 2002 yielded 105 unique citations of anecdotal CIWS benefits. Unfortunately, only 37% of these user-supplied benefits (39 of 105) were detailed enough to be considered candidates for CIWS delay reduction case studies. Moreover, of the 39 substantive CIWS benefits supplied by users via post-event interviews, only 14 benefit occurrences were documented after 15 August 2002 when the full suite of weather products (e.g., 2-hour convective forecast, NEXRAD echo tops mosaic) first became available. Table A-1 lists all *specific* CIWS benefits cited by users during post-event interviews and Table A-2 summarizes these results.

These post-event interviews proved useful in identifying problems and/or misunderstandings about the CIWS products and enabling us to better understand a wide variety of traffic management applications of CIWS during different types of storm events. Contacting users soon after storm-related air traffic impacts subsided, when usage of CIWS and details of the event were still fresh in their minds, we hoped to provide a useful means of collecting potential CIWS delay reduction information that would nicely complement the end-of-season interviews.

Several factors significantly limited the ability to capture actual CIWS product usage with the post-event interviews during 2002. Some of the limiting factors in the effectiveness post-event user sampling included:

- Availability of CIWS users to discuss CIWS usage during/after the event
- Limited number of Lincoln CIWS operations personnel to conduct interviews – particularly important where numerous users were affected during single large scale events
- Multiple upgrades and training sessions limited the number of facilities (and users at facilities) proficient with CIWS
- Timing of storm events made it difficult to find opportune times to contact users without interrupting their work.

A sampling study was conducted in order to quantify the degree to which the post-event interviews during the 2002 summer storm season covered the space of possible CIWS user feedback opportunities.

The number of significant storm impact days within the dedicated airspace of each CIWS user between 01 April 2002 and 30 September 2002 were enumerated to represent the maximum number of possible post-event user interviews[1]. Specific criteria were assigned to the definition of a 'significant storm impact' based upon spatial and temporal storm characteristics in order to prevent inflation of interview opportunities. Figure A-1 illustrates the monthly and seasonal percentage of user-impact days on which CIWS input was solicited from both ARTCC and TRACON facilities. CIWS users at ARTCC facilities were contacted for constructive CIWS input on 53 of 319 impact days (17%). CIWS users at TRACON facilities were contacted for constructive CIWS input on 36 of 238 impact days (15%). Combined, post-event user interviews (from which CIWS benefits listed in Table 1 were compiled) were conducted on only 16% of all user-impact days during the 2002 summer storm season. Therefore, it is reasonable to assume a potential five-fold increase in documented incidences where CIWS was of benefit to air traffic operations had all possible post-event interviews been conducted.

The breakdown of post-event interview sampling by individual ARTCC facilities with access to CIWS is presented in Figure A-2. It is worth noting that though ZOB was interviewed more than other ARTCC users of CIWS, the percentage of user-impact days on which CIWS input was solicited was low.

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[1] Only ARTCC and TRACON CIWS users were included in the post-event interview sampling study. Even before the sampling study, the authors recognized that the ATCSCC and airline dispatch users were under-utilized in terms of gathering benefits. Only 8 post-event CIWS benefits solicitations were made with airline users in 2002, though when they were contacted, they proved to be some of the more enthusiastic and positive users. Steps were taken in 2003 to ensure that input on CIWS usage from airline and ATCSCC users would be routinely sought on the post-event scale.

TABLE D-1

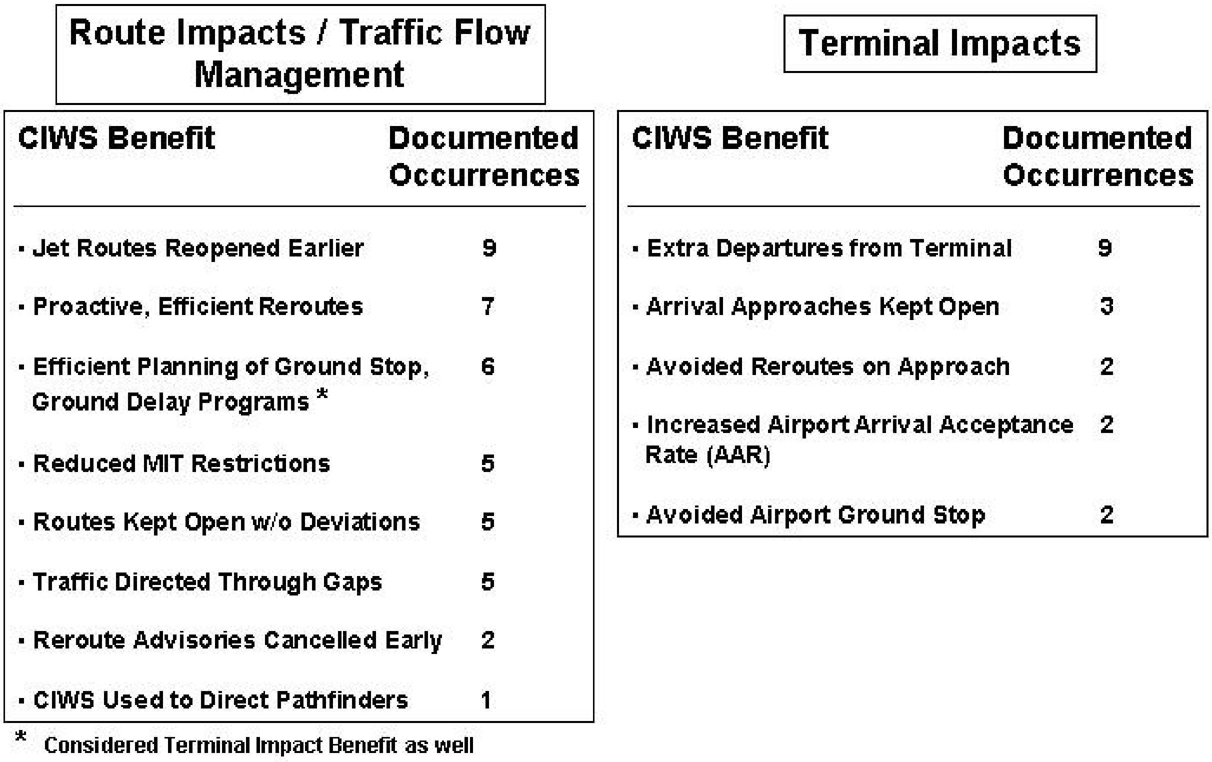
Specific CIWS Benefits Cited by Users during 2002 Post-Event Interviews

Date	Weather Type	User	Impacted Area	CIWS Benefit	Product Used
19 Apr 02	Broken Line	N90	ELIOT, PARKE fixes	Proactively shut fixes 20min early for extra departure	RCWF
01 May 02	Lone, strong cell	CVG	CVG southern departure routes	Kept southbound departures going	Storm Motion Vectors
27 May 02	Widespread cells	ZDC	Dulles Airport	Planned ground stop for eastbound arrivals	RCWF
31 May 02	E-W squall line	ZOB	J60, J64 jet routes	Jet routes opened 55 min earlier	Echo top annotations
05 Jun 02	Widespread linear & cell convection	ZOB	W-NW ZOB airspace	Opened routes 45-60 min early	Echo top annotations
13 Jun 02	Scattered cells	PIT	PIT final approach	Determined storms would not impact approach	RCWF
16 Jun 02	Isolated cells	ZDC	Routes over Chesapeake	Enabled 'normal' ops by flying over cells	Echo top annotations
25 Jun 02	Heavy coverage of strong cells	ATCSCC	CVG	Lifted ground stop 20 min earlier	RCWF
25 Jun 02	Heavy coverage of strong cells	D21	D21 TRACON	Forecasted impact on runways, fixes reduced delay	RCWF
18 Jul 02	Widespread unorganized storms	ZOB	ORD reroutes into ZOB	Reduced '20-as-1' restrictions by 50% 2 hrs earlier; reduced 100% 1 hr earlier	RCWF, Echo top annotations
18 Jul 02	Widespread unorganized storms	ZOB	PIT	Avoided ground stop during large arrival bank	RCWF, Storm Motion
18 Jul 02	Widespread unorganized storms	ZOB	ORD to ZBW route through ZOB	Opened route 30 min earlier	Echo top annotations
18 Jul 02	Widespread unorganized storms	ZID	CVG	Reduced MIT, no reroute on CVG approach	Echo top annotations
19 Jul 02	Widespread cells into squall line	ZOB	J518, J211 from ZDC into ZOB	Opened routes 30-45 min earlier	RCWF, Echo top annotations
19 Jul 02	Widespread cells into squall line	PIT	PIT runways	Opened airport 20 min earlier	Storm-extrapolated position
26 Jul 02	Squall line	Northwest Airlines	D21	CIWS used to convince ATCSCC to shorten ground stop by 30 min & increase AAR (at least 5 planes/hr)	RCWF
29 Jul 02	Broken, loosely-organized line	D21	D21 TRACON	Proactively reroutes 2 arrival fixes; 50-70 planes estimated to reroute earlier	RCWF
01 Aug 02	Scattered unorganized cells	ZOB	J60, J64, J80 jet routes	J80 kept open longer; CIWS used to move traffic from J80 to J60, J64 reducing departure delays from EWR, PHL	RCWF, Echo top annotations, Storm Motion

05 Aug 02	Large cluster unorganized cells	ZID	J80	Reduced MIT from 40 to 30 using CIWS	RCWF
13 Aug 02	Cluster of strong storm cells	ZAU	ORD approached & runways	ORD delay saved by running “tighter, longer”	RCWF
14 Aug 02	Loosely organized storm cells	ZOB	CLE	Ground stop cancelled 16 min earlier	Echo top annotations, Storm Motion
14 Aug 02	Loosely organized storm cells	ZOB	J80	Cancelled 15 per strata MIT restrictions 20 min earlier	Echo Top Mosaic, Storm Motion
14 Aug 02	Loosely organized storm cells	ZOB	J60	Opened route earlier	Echo Top Mosaic, Storm Motion
14 Aug 02	Storm cells	ZOB	PIT	Avoided PIT ground stop	RCWF
16 Aug 02	Broken line of strong storms	ZAU	ORD	Kept ORD flows going longer	RCWF
21 Aug 02	Squall line	C90	ORD, Midway Airport	Used CIWS to keep arrival rates up, departures going longer (& starting them sooner)	RCWF, Storm Motion
22 Aug 02	E-W squall line	ZOB	J60, J64	Planned opening, closing of routes with 30 min lead time	RCWF
22 Aug 02	E-W squall line	ZOB	J80	Used CIWS to direct pathfinders – this helped J80 open earlier	Echo Top Mosaic, Storm Motion
24 Aug 02	N-S broken line of strong cells	ZNY	J36, J584, J146, J60, and J64 in ZNY airspace	These PA routes in and out of ZNY kept open without restrictions	Echo Top Mosaic
24 Aug 02	N-S broken line of strong cells	ZOB	J60, J64, J80 in ZOB airspace	Routes kept open without MIT restrictions	Echo Top Mosaic
24 Aug 02	N-S broken line of strong cells	PIT	PIT TRACON	Reduced departure delay 15-30 min on 10-15 aircraft; CIWS assisted in good coordination with ZOB	RCWF, Echo Top Mosaic, Storm-extrapolated position
02 Sep 02	E-W broken line of storms	C90	ORD	CIWS used for ground delay program (GDP) timing; used to coordinate GDP with ZAU, ATCSCC	RCWF, Storm Motion
03 Sep 02	Broken NE-SW line of storms	PIT	PIT TRACON	Timed closing of runways; timed when to stop taking arrivals – reduced arrival delay	RCWF, Storm-extrapolated position, Echo Top Mosaic
20 Sep 02	Line of strong storms	ZOB	D21	Used CIWS for more efficient arrival reroutes	NEXRAD VIL, Storm-extrapolated position, Echo Top Mosaic
20 Sep 02	Line of strong storms	D21	D21 TRACON	Used CWS to proactively reroute arrivals to other fixes	RCWF
20 Sep 02	Line of strong storms	ZID	J149, J80	CIWS used to note determine when to shut off J149; Kept J80 open longer	Echo Top Mosaic
27 Sep 02	Developing squall line	ZNY	ZNY	CIWS used to direct traffic through storm gap	RCWF, Echo Top Mosaic

TABLE D-2

Summary of 2002 Post-Event Interviews



Route Impacts / Traffic Flow Management

CIWS Benefit	Documented Occurrences
▪ Jet Routes Reopened Earlier	9
▪ Proactive, Efficient Reroutes	7
▪ Efficient Planning of Ground Stop, Ground Delay Programs *	6
▪ Reduced MIT Restrictions	5
▪ Routes Kept Open w/o Deviations	5
▪ Traffic Directed Through Gaps	5
▪ Reroute Advisories Cancelled Early	2
▪ CIWS Used to Direct Pathfinders	1

* Considered Terminal Impact Benefit as well

Terminal Impacts

CIWS Benefit	Documented Occurrences
▪ Extra Departures from Terminal	9
▪ Arrival Approaches Kept Open	3
▪ Avoided Reroutes on Approach	2
▪ Increased Airport Arrival Acceptance Rate (AAR)	2
▪ Avoided Airport Ground Stop	2

As discussed in the text, the relative frequency of these benefit observations is germane, but the absolute number is not a good indication of the overall annual occurrences.

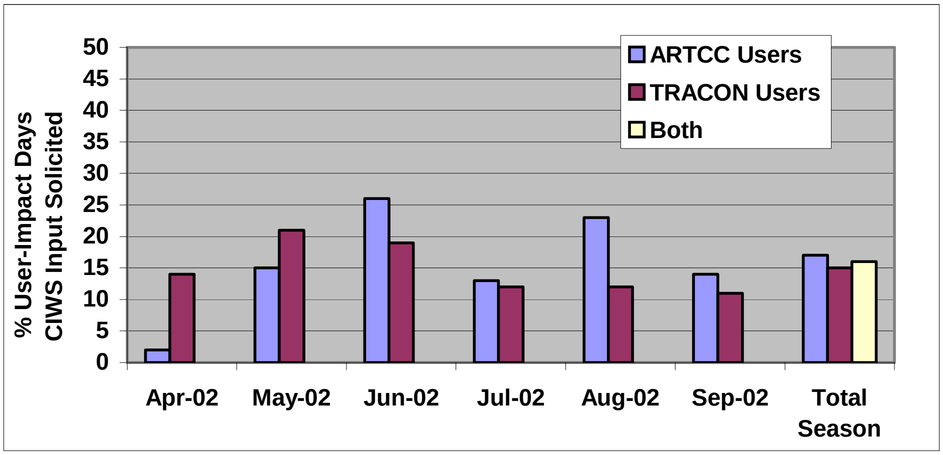


Figure D-1. Monthly and seasonal percentage of user-impact days on which CIWS input was solicited from both ARTCC and TRACON facilities during 2002 summer storm season.

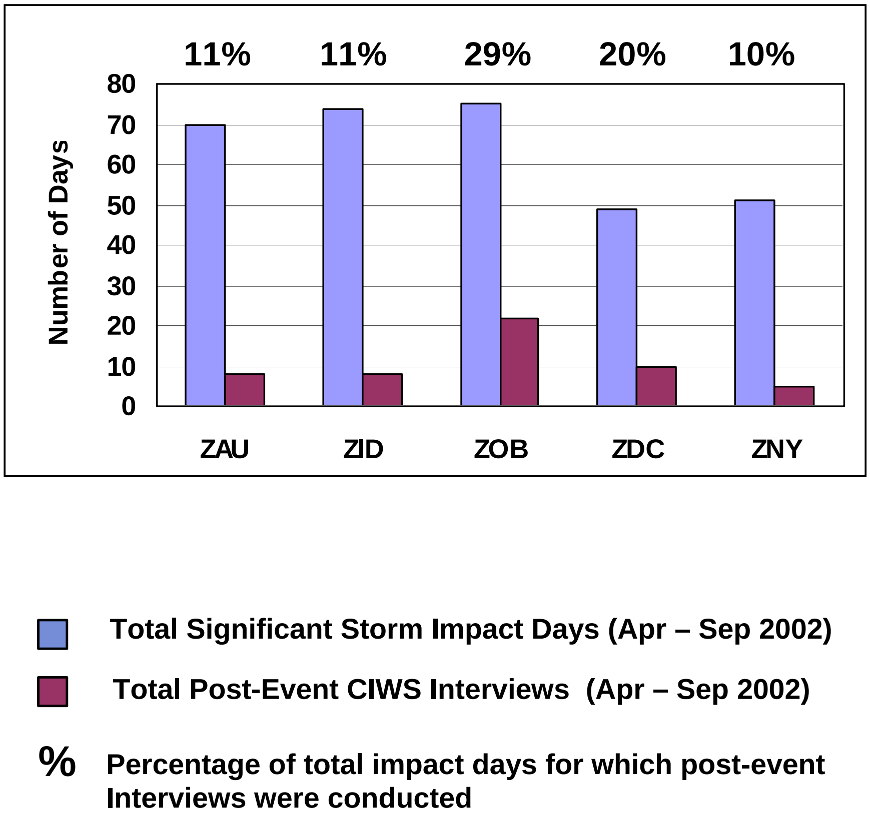


Figure D-2. Post-event CIWS interview sampling frequency per ARTCC for entire 2002 storm season.

APPENDIX E
CIWS BENEFITS ASSESSMENT CAMPAIGNS

OBSERVED CIWS APPLICATIONS: BLITZ 1 – 6

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Index: CIWS Benefits Categories Identified During Blitz Campaigns*

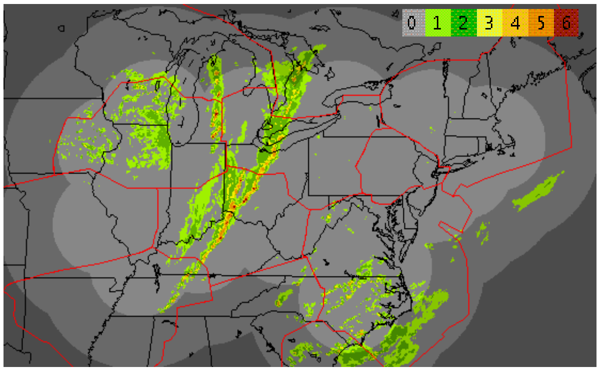
1. Routes open longer and/or reopening closed routes earlier
2. Proactively closed routes
3. Efficient, proactive reroutes
4. Shorter/fewer ground stops
5. Avoid ground stop program
6. Reduced MIT restrictions
7. Traffic directed through gaps in weather
8. Better management of weather impacts on Arrival Transition Areas (ATA)
9. Optimization of runway usage; Enhanced runway planning
10. Improved use of ground delay programs
11. Greater departures during Severe Weather Avoidance Programs (SWAP)
12. Directing pathfinders
13. Interfacility coordination assistance
14. Improved safety
15. Reduced workload
16. Situational awareness

* Applicable benefits categories assigned to each to each observed usage of CIWS during Blitz 1-6

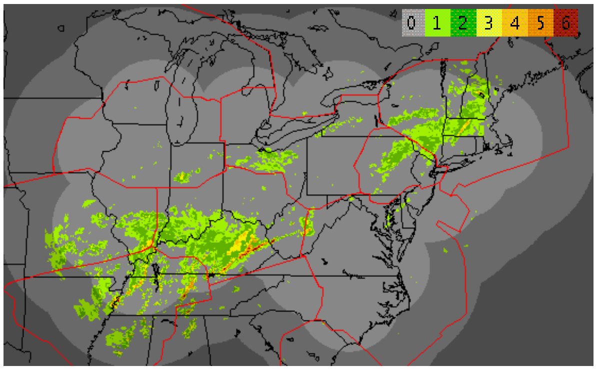
Blitz 1: 8, 10-13 June 2003

Facilities Visited: ZBW, ZNY, ZDC, ZID, ZOB, ATCSCC, C90, FedEx

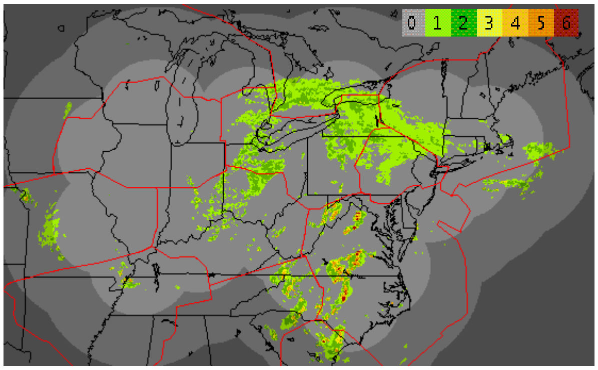
Examples of CIWS NEXRAD VIL Precipitation During Blitz 1:



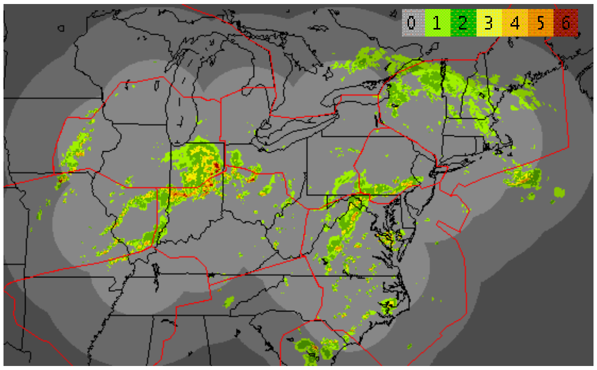
08 June 2003, 1900 UTC



11 June 2003, 1700 UTC



12 June 2003, 1900 UTC



13 June 2003, 2100 UTC

CIWS Benefits Assessment
BLITZ #1
Day 1 - June 8, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1615	ZID	TMC said he tried to use CIWS forecast to assess the time and impact of the filling of the line of N-S weather. However scores were low so he was not confident in the forecast.	RCWF, Forecast Accuracy	16
1630	ZID	Reports of aircraft deviating at WAKEM. STMC used CIWS to assess motion and noted that weather was moving fairly rapidly so that the route may clear. Weather is developing in the CVG area.	Storm Motion, RCWF	1, 8
1637	ZID	STMC used CIWS to assess growth and motion.	Growth and Decay Trends, Storm Motion	16
1627	ZOB	DTW departure fixes WINGS and TYCOB closed due to a line of weather in western ZOB. DTW position consults CIWS.		16
1640	ZOB	DTW eastern routes impacted by weather. CIWS used to determine that eastbound traffic could not go south and top the weather.	Echo Tops	14, 16
1650	ZOB	CIWS was used to support the decision to route DTW southbound departures from APE to ROD. Southeast landing traffic filed over CETUS were moved northwest over Erie, PA to join the SPICA arrival route. TMC recognized that CETUS would be closed for at least three hours, using CIWS as input.	RCWF	3, 9, 11, 13
1700	ZOB	CIWS SD used for hand-off briefing between STMCs.		16
1710	ZID	STMC looked at CIWS to see development. May need to ground stop traffic to CVG. A second line of weather is developing behind the first but STMC says "No one is going to make a 90-degree turn to go through that gap."	Growth and Decay Trends, Storm Motion	16
1723	ZID	CVG TRACON is impacted by a cell at the southern end of the first line. Internal ZID traffic for CVG is ground stopped due to weather (possible microburst). Traffic for CVG is being held in the air. J89 is closing with echo tops 30+kft. ZID can't take traffic bound for DC or NY metros.	Echo Tops, NEXRAD VIL	
1725	ZID	Area 7 reports no holding space. CIWS was consulted for a planned shutdown of J89.		2

BLITZ #1, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1731	ZID	ZID is cut in half by the two lines of weather. The CVG position used CIWS to try to figure out a way to get arrivals to CVG from 1830 to 1930. Arrival rate has dropped to 60 to favor departures but the earlier ground stop has increased the volume. Airborne aircraft are being held. The weather developed earlier than the CWSU forecasted.	Forecast Contours, Growth and Decay Trends, Forecast Accuracy, Verification Contours	13, 16
1747	ZOB	ZOB STMC referenced CIWS on the SPO. Indicated that forecast showed that routes would clear in about one hour.	RCWF	13
1747	ZOB	CIWS used several times to coordinate with surrounding Centers, TRACONs, and SCC.		13
1751	ZOB	Transcon traffic using CAN1 playbook route. ZOB recognized that tops were not very high and kept some traffic on routes that would otherwise have been closed.	Echo Tops, NEXRAD VIL	1, 15
1800	ZID	CWSU reports that the storm tops are dropping and Lightning is going away. STMC confirmed CWSU report by looking at CIWS.	Echo Tops, Lightning	16
1800	ZID	CVG position used CIWS for hand-off briefing. ZOB is moving all airborne traffic to HNN and the first tier ground stop for CVG, due to expire at 1830Z, will probably be extended.	NEXRAD VIL, Forecast Contours	16
1800	ZOB	TMC used CIWS to assess the timing of the impact of weather at CLE and CXR. RCWF predicts weather at the fixes in 1.5 hours.	RCWF, Forecast Contours	8
1825	ZOB	CLE position used CIWS to get four departures out of CLE. Westbound departures were blocked by the weather. Using forecast and echo tops products, the user made provisions for four CLE departures to depart east and turn back west when they were high enough to top the weather.	RCWF, Echo Tops	7, 8, 11, 13
1837	ZID	STMC looked at CIWS to determine echo tops and increasing growth trend. ZID is requesting 15 MIT on CVG departures as soon as CVG can get them out. CVG expects to clear in 15 - 20 minutes. Landing traffic for CVG is ground stopped until 1915.	Echo Tops, NEXRAD VIL, Growth and Decay Trends	9, 11, 13
1900	ZID	TC used 1-hour forecast to determine what would happen to J6 and J42. Noted dissipation at south end of the line. CWSU used SD to brief STMC. CVG ground stop cancelled 10 minutes early, however volume will be low. One user noted that they "could have come out of the hold sooner" but to do that they needed to know when the weather would clear and how long it would take to clear the holds.	Echo Tops, Storm Motion, Forecast Contours	4

BLITZ #1, Day 1 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1907	ZOB	CLE arrivals from the east are being watched closely. Westbound departures over KCLE are stopped except for a few pathfinders testing westbound routes. Echo Tops and RCWF were used to support pathfinders.	RCWF, Echo Tops	12
1915	ZID	In support of SPO, STMC asked about echo tops at the south end of the line in KY. The TSD is showing 45kft while CIWS shows less than 35kt. Traffic is flying over the storms.	Echo Tops	16
1930	ZID	CVG tower thinks they can get departures out through a 15-mile gap. CVG position consulted CIWS for coordination. CVG position doesn't see the gap.	Echo Tops, NEXRAD VIL, ASR	13, 16
1941	ZID	CVG position used CIWS echo tops to assess growth in cells at the southern end of the line in support of setting up CDRs. Wants to see if aircraft can top the storms. Also used echo tops as an indicator of growth and notes that an echo tops loop would be helpful.	Echo Tops	11
1955	ZOB	CIWS used to assess impact of weather near DUNKS (northwest DTW departure fix).	RCWF, NEXRAD VIL	8
2015	ZID	CVG position studying CIWS to try to find an eastbound route for 75 CVG departures. Some departures are going via LEX and then east. Would like a path due east. Even though tops are below 30kft, departing traffic cannot top the weather because they are not above that altitude by the time they reach the weather. Arrivals are using available routes and preference is given to arrivals.	Echo Tops, NEXRAD VIL, Forecast Contours	16
2047	ZID	Traffic is light. Most over-flight traffic has been routed around the Center. ZID mostly concerned with internals. ESP position used CIWS for situational awareness.	Echo Tops, NEXRAD VIL	16
2053	ZOB	Weather is impacting the Polar1 approach to DTW. The TMC used CIWS to determine the re-route strategy.	Forecast Contours, NEXRAD VIL	3, 8, 13
2055	ZID	ESP position noted that weather in ZOB airspace was dissipating and the ZID could open a route to them. Looks like a route will be open for about an hour then ZOB will be impacted.	Echo Tops, Lightning, RCWF	1, 13

BLITZ #1, Day 1 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	SCC	Severe Weather: "Two years ago, Cleveland would have shut down the airspace and nothing would have moved. Both Indy and Cleveland Centers kept traffic moving through all of the holes. There was never more than one airway closed at a time. There were no departure delays out of O'Hare and traffic kept moving. It was amazing." This is an example of how the Centers tactically handle flow internally and between Centers. The problems never made it to the Command Center level.		13, 16
post-event interview	SCC	East position: Used CIWS to monitor what ZOB was doing to keep en route traffic flowing. NYC kept flows moving through the holes in the weather.		13, 16
post-event interview	CVG	CIWS was used to time the arrival of the second line of storms in the CVG TRACON while the storms were 20 to 30 nmi from the TRACON. After that, TDWR was used. CIWS was used for planning holds.	RCWF	8, 11
post-event interview	PIT	CIWS was used to identify opportunities to get westbound departures out during the early afternoon (around 1830Z), but ZOB could not take the aircraft. Around 2330Z, the TMU used CIWS to plan holding, arrivals, and departures. They were able reduce holding times for PIT arrivals by 15 to 30 minutes.	RCWF	8, 11
post-event interview	NWA	Did not use CIWS because DTW was not impacted and echo tops in NY area were low enough that those arrivals and departures were not impacted.		
post-event interview	ZDC	CIWS helped ZDC proactively plan a reroute for J75. Based on CIWS information, a J47 reroute was avoided, saving many aircraft time and fuel. Used CIWS tops information to stop high altitude J6 traffic due to existing SWAPs flying at higher altitudes to get over storms.	RCWF, Forecast Contours, Echo Tops, Growth and Decay Trends	1, 2, 3, 15
post-event interview	ZAU	STMC: CIWS was used for echo tops information. CIWS helped them get a few more departures east over the afternoon line of storms in MI than would have been the case without CIWS. CIWS did a good job depicting and forecasting the isolated development south of C90 during the day. This saved a few (3 to 4) aircraft holding time (15 to 20 minutes each).	Echo Tops, RCWF, Storm Motion	8, 11
post-event interview	ZAU	C90 position: RCWF was used throughout the evening to plan the southbound and eastbound arrivals into C90 and to save holding time. CIWS was helpful in ending a reroute sooner than planned	RCWF	1, 8

BLITZ #1, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	C90	TMC (a new user) felt CIWS depicted the lighter (level 1 and 2) weather better than other systems. Even though weather was light, pilots do not like to go through it. She used the products to get a good fix on the weather to help keep aircraft out of it.	NEXRAD VIL, RCWF	3, 14, 15

CIWS Benefits Assessment

BLITZ #1

Day 2 - June 10, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1445	ZID	TMU attempted to use CIWS RCWF to plan traffic flows from ZFW and ZME into ORD. He wanted to be sure that the traffic would transit ZID in front of the weather. The Forecast Accuracy scores were either L3<MIN or very low. These scores are expected when weather first begins to develop. There must be a sufficient area or level 3 weather present to generate a score and at the beginning of a weather event (when initiation is predominant) the scores will be low. However, he was uncomfortable using the product with these scores.	RCWF, Forecast Accuracy	13, 16
1540	SCC	Weather impacting routes into and out of STL and ORD to the southeast.	Growth and Decay Trends, Echo Tops	16
1639	ZID	TMC used CIWS to open QBALL out of STL even though the forecast accuracy score was only 20%.	RCWF, Forecast Accuracy	1, 8
1830	C90	Showers developing south of ORD/MDW. CIWS shows no impact on the airports in the next two hours, so users are not concerned about the weather.	RCWF, NEXRAD VIL	15, 16
1845	SCC	Weather in the Ohio Valley is impacting routes across the region. SCC is allowing Centers to handle traffic tactically.	Echo Tops	15, 16
1846	ZID	A line of storms is present on the IN-IL border. TMC used CIWS for situational awareness	RCWF	16
1855	C90	More showers developing south and southwest with tops at or below 21kft in the southern part of the TRACON. Users watching weather for potential impacts (situational awareness).	RCWF, NEXRAD VIL, Growth and Decay Trends	16
1900	ZID	STMC requested explanation of Growth and Decay Trends product. He wanted to access the extent and motion of the weather on the IL-IN border. J76 traffic is swapping east due to weather. DFW westbound landing traffic on J6 is swapped south over BNA-MEM-LIT.	Growth and Decay Trends, RCWF, Storm Motion, Verification Contours	16
1915	C90	All southbound departures stopped by ZAU due to weather and volume.		

BLITZ #1, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1915	ZID	SPO: J29 is currently one-way and weather may impact the route. STMC used CIWS to determine when impact would occur.	RCWF	13, 16
1920	C90	TMU turned SD toward controllers so they could see the weather presentation. However, there was too much light from the monitor so the SD was turned away from the controllers. TMU used CIWS to look for signs of growth in the cell south and southwest	NEXRAD VIL, Growth and Decay Trends	8
1925	C90	ZAU resuming departures from ORD but not MDW because they did not get the requested restriction. C90 TMU is using CIWS forecast to monitor the weather situation.	RCWF	16
1940	ZID	STMC asked how long CIWS needed to see weather before it could forecast. User needs to know when the weather will impact J29 and wanted to know how much confidence to place in the forecast. The 2-hr Forecast Accuracy score is 40%, but two hours ago the weather was in the initiation phase. It is likely that the 2-hour forecast is now better than the forecast accuracy score indicates. Due to concerns expressed by Continental Airlines on the SPO, STMC would like to open J29. The weather currently impacting J29 is in ZME and dissipating. STMC expects ZME to call soon to open J29 to two-way traffic. (ZME did NOT open J29.)	RCWF, Forecast Accuracy	16
1945	C90	Primary cause of ORD departure delays - ZAU is having trouble routing all of the traffic between the two clusters.		
1950	SCC	SCC is letting individual Centers handle most of the problems. Turbulence is a problem and is forcing all aircraft down to 26kft or below causing compression.		15, 16
2025	ZID	STMC and ESP position are trying to define a plan for opening J73 using CIWS.	RCWF, Echo Tops, Storm Motion	15, 16
2030	C90	TMU used CIWS to monitor the weather situation. Most of the weather is south of the TRACON and causing no impacts on C90.	RCWF, NEXRAD VIL, Forecast Accuracy	16
2055	ZID	ESP and STMC using CIWS to study weather at BNA.	RCWF, NEXRAD VIL, Storm Motion, Echo Tops	16

BLITZ #1, Day 2 (continued)

Time (UTC)	User	CIWS Applications	CIWS Products Used	Benefits Category
2055	ZOB	An aircraft near FWA at FL350 deviated unexpectedly. CIWS was consulted to determine why. Weather in the vicinity of FWA was not the issue; storms with tops at 37kft near IND were the reason for the deviation.	Echo Tops	16
2100	ZOB	DTW position consulted CIWS to anticipate small area of future DTW impact.	RCWF	8, 15
2115	ZID	STMC used CIWS and an AA "pathfinder" to determine that J6 would be able to open soon. AA flight was "not supposed to be there", but given the weather depiction and opportunity, ZID treated him as a pathfinder. The aircraft did not deviate, so STMC expects the route to open soon. (J6 opened at 2140.)	NEXRAD VIL, Echo Tops	1, 12
2120	C90	Several area controllers looked at the CIWS SD throughout the day for situationa awareness.		16
2225	ZID	User asked about accuracy of echo tops product.		
2245	C90	Weather developing on the west side of the TRACON. CIWS was used to determine if the cells would impact fixes, ORD departures.	NEXRAD VIL, RCWF	8
2300	C90	Broken line of showers developing along the cold front from west central MI southwest across Lake Michigan and into far southeast IA. There is concern that this weather could cause big problems if it were to grow and become a solid line TMU watching the situation via CIWS.	NEXRAD VIL, RCWF, ASR, Forecast Accuracy	16
2325	C90	Line continues to develop. TMU still monitoring the situation.	Growth and Decay Trends	16
2350	C90	A few cells in the line are intensifying to the northwest of ORD. STMC spoke with the tower about the possibility of losing west departures in the near future and then losing runways as the weather passes. Using CIWS to watch weather closely.	RCWF, NEXRAD VIL, ASR, Forecast Accuracy	8, 13, 15
0003	C90	Traffic deviating around cells in the airspace. Worst weather is forecast to go north of ORD. No loss of gates or fixes at this time.	RCWF	8, 15
0047	C90	South end of line is filling in with tops to 30kft. The cell that was forecasted to pass north of ORD did just that. Aircraft are deviating. No restrictions imposed. TMU is using CIWS for situational awareness.	RCWF, NEXRAD VIL	5, 8
0050	ZID	All cells in ZID are showing growth. STMC pointed this out to the TC position who was on the phone with SCC. This information was passed to SCC.	Growth and Decay Trends, NEXRAD VIL	13, 16

BLITZ #1, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
0055	C90	Two departures fixes were closed by ZAU due to weather. A third fix was restricted to 40 MIT.	RCWF, NEXRAD VIL	
0103	ZID	An aircraft heading for CVG is "shooting the gap" between storms whose echo tops are 41kft to 45kft. TMC monitoring his progress.	Echo Tops	16
0115	ZID	SPO: Weather near Louisville, KY is causing problems and ZID expects to institute a ground stop. UPS agrees but hopes to minimize the ground stop. STMC stated that CIWS was showing growth near Louisville, KY and no indication of dissipation. Therefore there is no support for avoiding a ground stop.	Growth and Decay Trends	13, 14
0150	ZID	CIWS forecast shows weather impacting LOU at 0315Z. ZID requested a ground stop from 0200 to 0300 for all first tier Centers and ZMP and ZNY in the second tier.	RCWF	14, 15
0203	ZID	ZNY flights heading for LOU are released with UPS flights having priority. Companies understand that they may have to hold, but holding will occur behind the weather and on the side of the airport that will open first.		
0215	ZID	SPO: UPS meteorologist forecasts weather impacting LOU from 0245 to 0300 with a "clear slot" at 0315. CIWS shows a high probability of level 3+ weather at LOU at 0315 with a clear slot at 0345. STMC says that this timing difference is not crucial. Both forecasts support the first tier and limited second tier ground stop. If necessary, the first tier ground stop can be extended to 0330 to hold back 10 more aircraft.	RCWF	8, 13
0242	ZID	STMC used CIWS to monitor the weather heading for LOU. He really likes Growth and Decay Trends. The line has shown sustained growth throughout which tells the STMC that "this is a force to be reckoned with". TC extends the LOU ground stop to 0330; SCC extends it to 0400.	Growth and Decay Trends, RCWF	8, 14
post-event interview	C90	TMUs use CIWS to determine when runways, gates, and fixes will close and for how long. If CIWS indicates that they will lose something, they call ZAU and ask for a ground stop. The coordination is easier because ZAU also has a CIWS display.		8, 13

BLITZ #1, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	ZID	Early in the morning, storms on the eastern ZKC boundary pushed anvils into ZID airspace. Pilots wanted to deviate around the strong weather. Moderate turbulence was reported at and above FL280. J80 westbound was virtually closed. CVG departures had to go south before going west and then were stopped altogether due to compression caused by turbulence. Traffic was capped at FL270 and turbulence was reported Center-wide. Capping of departures off CVG was instituted to allow some departures to get out. Users consulted CIWS throughout the day, but turbulence was the main problem.		16

CIWS Benefits Assessment
BLITZ #1
Day 3 - June 11, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1220	ZID	CVG is not currently impacted, but south flow into CVG needs a route. The STMC used CIWS to discuss options with the CVG position TMC. They noted that the motion and growth of the storms will likely shut off LEX departures. That opens the airspace to arrivals over SWEDE6.	NEXRAD VIL, Storm Motion, Growth and Decay Trends	2, 8, 13
1315	ZID	SPO: The ZID STMC reported deviations on J6 and expressed a need to reroute traffic.		13, 16
1334	ZID	J6 is now closed to all traffic except ZID internals due to deviations around the weather.		
1525	ZBW	STMC who used to work at SCC commented that the CIWS displays were helpful at SCC where no CWSU was available, but ZBW relies heavily on the CWSU.		
1600	ZDC	Weather is currently in eastern ZID near the ZDC border near routes J6 and J213. TMC used CIWS for situational awareness and noted that cells didn't appear to be dissipating even though the echo tops were decreasing.	Growth and Decay Trends, Echo Tops, NEXRAD VIL	16
1615	ZDC	F-16 reported 45kft tops and aircraft are deviating on J6. STMC consulted CIWS and told area supervisor that the pilot was reporting cloud top, not echo top.	Echo Tops	16
1615	ZID	Weather is propagating along J6. J42 is starting to be impacted and aircraft are deviating. CVG would like to come out of the ground stop with MIT, but weather in the Center is preventing this.		
1626	ZID	CVG position used CIWS to try to determine a way to get inbound traffic from ZTL into CVG. CIWS shows arrival routes will be impacted so there is no way to get the traffic in.	RCWF, NEXRAD VIL, Echo Tops	16
1626	ZID	TC position consulted CIWS to determine how long a hole in the weather in eastern KY/western NC will stay open. The CIWS forecast shows movement into the area and growth. RCWF does not show the hole closing.	RCWF, NEXRAD VIL, Storm Motion, Growth and Decay Trends	7

BLITZ #1, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1630	ZDC	ZDC, ZID and SCC are negotiating to move CVG landing traffic from ZTL around weather. SCC proposed that current airborne inventory be routed through the gap in eastern ZID. CVG landing traffic currently on the ground would be routed east into ZDC airspace east of the existing storm cells, then west into ZID. ZDC STMC quickly referred to the 60-minute Forecast Contours for cells near the ZDC boundary. Cells were forecasted to move east into the airspace where the CVG aircraft would be flying. ZDC did not agree to the plan.	Forecast Contours, Echo Tops, Growth and Decay Trends	13
1655	ZID	STMC used CIWS to check the motion of storms tracking along J42. Deviations continue.	Storm Motion, NEXRAD VIL	16
1700	ZDC	STMC used CIWS 60-min forecast to determine that weather would stay out of sector 37 which carries all DCA, IAD, and BWI arrivals.	RCWF	1, 8, 15
1703	ZBW	STMC asked CWSU if the line of weather is staying together in central MA. Sup is concerned that the line stays to the south. CIWS shows growth at the southern end of the line in CT. CWSU believes weather will remain south, in agreement with CIWS.	RCWF, Forecast Contours, Growth and Decay Trends	16
1705	ZID	ATL departing traffic is tunneling through a hole at Charleston. CIWS shows this hole closing. TMU working out where to put traffic from ORD and ATL when the hole closes.	RCWF, NEXRAD VIL	7, 15
1708	ZID	With respect to the J29/J80, the TC stated that CIWS was really helpful because it showed that J29 will be open.	RCWF	1, 15
1709	ZDC	STMC allowed two aircraft at RDU to depart for CVG via Charleston. Checking CIWS he saw that the aircraft could follow this route and deviate around existing weather.	NEXRAD VIL, Storm Motion, RCWF	3, 15
1710	ZBW	CWSU used CIWS to note that the line was moving east.	Storm Motion, RCWF	16
1740	ZDC	Storms at ZID/ZDC boundary are decaying. STMC and TMC referenced CIWS for information	Echo Tops, NEXRAD VIL	16
1740	ZBW	CWSU used CIWS to monitor the decay of the line of weather in MA.	Echo Tops	16
1742	ZBW	Ops Manager used CIWS to determine that the northern part of the line was decaying.	Echo Tops	16

BLITZ #1, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1755	ZDC	At 1600, a decision was made not to bring CVG landing traffic into ZDC airspace. CIWS indicated growth in cells on the ZDC border at that time. However, CIWS forecast did not verify so CVG traffic will not transit ZDC ahead of the weather.		
1757	ZDC	STMC received a call from an Area reporting pilot requests for possible deviations. He checked CIWS to note that there was only one cell in the area and the echo top was 25kft. He wondered why pilots would request deviations.	Echo Tops	16
1800	ZID	CWSU says that the current weather will dissipate so that J6 will open in two hours. CIWS doesn't dissipate the weather that rapidly. STMC is planning to send traffic down J6.	RCWF	
1800	ZDC	TMC used CIWS to note a large area of growth in southwest VA. This could adversely impact operations later today.	Growth and Decay Trends, Echo Tops	16
1815	ZID	CIWS used for STMC hand-off briefing.		16
1835	ZDC	CIWS used for STMC hand-off briefing.		16
1839	ZID	TC position is trying to determine a SWAP for DTW landing traffic from the south and ATL landing traffic from the north. Normally this traffic flies J89 to J43. J89 is blocked, but a hole exists on J43. The TC TMU used CIWS to see if J43 would stay open.	RCWF, Echo Tops	7
1847	ZDC	Sector 36 has expressed some concern about developing storms. STMC not concerned at this point because echo tops are low and is dealing with reroutes from other Centers.	Echo Tops, Lightning	1, 15
1849	ZBW	STMC used CIWS to determine echo tops values.	Echo Tops	16
1911	ZID	TC position used CIWS to identify that weather over VXV on J43 was growing and that the route would not open soon. There is a big hole near BNA and the hole is getting bigger. Considering this as a possible route.	NEXRAD VIL, RCWF	16
1915	SCC	TMC consulted CIWS to determine movement of storms in ZID airspace.	RCWF	16
1924	ZBW	Level 4/5 weather approaching BOS; echo tops 26 to 28 kft. TRACON called STMC to discuss approaching weather. STMC consulted CIWS and told TRACON that BOS should be impacted around 2025.	Storm Motion, Forecast Contours	13, 16

BLITZ #1, Day 3 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1930	ZDC	STMC referenced CIWS during SPO.	NEXRAD VIL, Echo Tops	13
1936	ZDC	J48 closed as storms move in. CIWS not used for this decision.		
1957	ZBW	STMC and TRACON discussing possible runway change. STMC used CIWS to notify TRACON that the back edge of the weather would pass BOS in 30 minutes; echo tops 22 - 24 kft; no lightning.	Forecast Contours, Echo Tops, Lightning	13, 16
2000	ZID	CVG position asked CWSU about opening a route into CVG. They discussed options over the CIWS SD. TMU would like to bring the traffic in from the south, but CIWS shows that the route will be impacted at 2130. CWSU agrees with the CIWS forecast, so traffic will be routed to approach SWEDE6 from the southwest.		3, 8, 15
2001	ZDC	TMU received request to route NY to ATL traffic via J6. After consulting CIWS, the request was denied.		16
2010	ZDC	STMC received a request to open J48. STMC referenced CIWS to argue that strong storms with echo tops between 41kft and 49kft were present. Route remained closed.	NEXRAD VIL, Echo Tops	13, 14, 15, 16
2015	ZDC	STMC received another request to open J48. STMC reported echo tops values to caller and kept J48 closed.	Echo Tops	13, 14, 15, 16
2018	ZID	SWEED6 arrival to CVG forecasted to be impacted when traffic is due. TMU plans to approach the fix from the southeast and expect deviations.	RCWF	8
2052	ZID	STMC is trying to determine a route for ATL landing traffic from ZDC. CIWS shows that VXV will be open.	NEXRAD VIL, RCWF	
2100	ZDC	STMC referenced CIWS to inform ZNY that J75 was likely to close in 60 to 75 minutes.	RCWF, Forecast Contours	13, 16
2102	ZBW	Area CIC asked CWSU how fast storms were moving over Long Island. CWSU referenced CIWS for information.	Storm Motion	13, 16
2115	SCC	SPT: TMC used CIWS for situational awareness.	Echo Tops, Growth and Decay Trends, RCWF	16

BLITZ #1, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2115	ZBW	SCC asked STMC about weather in ZBW. STMC used CIWS to provide echo tops information.	Echo Tops	13, 16
2120	ZDC	TMC used CIWS to verify timing of weather impact and closing of J75.	Forecast Contours	13, 16
2121	ZBW	TMC used CIWS for situational awareness.		16
2124	ZBW	TMC discussed weather with STMC and Area C CIC. Echo Tops on J121/J174 are below 30kft. Routes were opened to traffic above 30kft. STMC estimated that the route would have remained closed for at least one more hour if CIWS echo tops information had not been available.	Echo Tops	1
2130	ZDC	TMC informed customer that J75 would shut down based on timing of CIWS forecast.	Forecast Contours	2, 13
2135	ZDC	STMC requested that an email be sent to document weather impact on J48/J75.		13, 16
2216	ZBW	TMC suggests to STMC that J121/J174 could be opened to all traffic. Echo Tops of weather impacting J121/J174 are below 26kft. Routes opened. TMC reported that they would never have gotten through the weather without the echo tops product. Ground stop on J121/J174 was cancelled 15 minutes early.	Echo Tops	1, 4
2220	ZDC	Area decided to close J14. Not sure if this was based on CIWS.		
2230	SCC	Severe Weather Unit used CIWS to identify that the echo tops of storms on J149 and J6 were low enough to allow aircraft to start using the routes again. Routes opened for limited use.	NEXRAD VIL, Echo Tops, Growth and Decay Trends	1
2300	ZDC	STMC referred to CIWS to see if a pathfinder could be sent along J134 out of IAD. Currently there is one cell with an echo top of 26kft. However, this may be too high for departing traffic.	NEXRAD VIL, Echo Tops, Lightning	16
2302	ZDC	STMC consults CIWS again. Because J48/J75 are still heavily impacted by weather, STMC decides to send a pathfinder along J134. Pathfinder made it through, but with severe restrictions. Consequently, the cell grew to level 6 with 40kft echo tops at 2323.	NEXRAD VIL, Echo Tops	12

BLITZ #1, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2306	SCC	SCC notes low echo tops in weather impacting ZDC but also growth. Considers this the reason ZDC can't run more traffic. Departure delays for NY and DC airports are growing.	Echo Tops, Growth and Decay Trends	16
2315	SCC	Continuous use of CIWS forecast to monitor weather on J6. Transcon flights are on this route. J6 is impacted by weather now, but it is expected to be clear by the time the transcons arrive.	RCWF	16
2336	ZDC	PCT shut off LDN/AML due to weather and IAD is approaching gridlock.		
2338	SCC	Heavy use of RCWF for J6 and transcons. RCWF indicates the route will remain open (tops are currently low and RCWF keeps L3+ off the route) so the plan is to continue to use the route for transcons.	RCWF, Echo Tops	1
2346	SCC	J6 opening.		
0000	ZDC	STMC consults CIWS to determine that J48 will not clear in the near future.	Forecast Contours	16
0020	ZDC	STMC again consults CIWS to determine a way to open J48. J48 is forecasted to be impacted for at least an hour, but J75 may open. Considering sending pathfinder soon.	NEXRAD VIL, Echo Tops, Forecast Contours	16
0042	ZDC	J48 clearing but remains closed due to another line of incoming weather. IAD coming out of GS; DCA the next to get hit.		
post-event interview	ZDC	The Area 1 Supervisor reported using CIWS all afternoon and evening and directly applied RCWF and echo tops to plan the J48/J75 route closures. CIWS was also used to justify keeping those routes closed.	RCWF, Echo Tops	1, 2, 3, 14, 15
post-event interview	ZID	STMC stated that he really likes the Growth and Decay Trends product. At this point he added the product to the NEXRAD VIL window. He also commented that he likes the Echo Tops product. Growth and Decay Trends is available in the ET window also. Now, when he starts his shift, the first thing he does is add Growth and Decay Trends to the NEXRAD VIL and Echo Tops window. CIWS is his primary weather display now.	Growth and Decay Trends	15, 16

CIWS Benefits Assessment

BLITZ #1

Day 4 - June 12, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1720	ZDC	TMC at SevWx position used CIWS to identify a rapidly growing cell on J6. He formulated a plan for MIT restrictions in the event of deviations on J6.	Echo Tops, Growth and Decay Trends	16
1745	ZDC	TMC continuing to monitor weather on J6. Ten minutes later, the Area notified TMC that aircraft were deviating. Plan formed 30 minutes ago is implemented.	Echo Tops, Growth and Decay Trends	15, 16
1750	ZDC	Strong cluster of storms in southern VA and NC are organizing and filling to form a squall line. STMC monitoring development on CIWS.	Growth and Decay Trends	1
1757	ZDC	Traffic deviating around weather on J6.		16
1833	ZDC	MONTY and GORDD fixes stopped due to volume caused by weather.		
2003	ZNY	STMC used CIWS to determine if J75 traffic could be offloaded onto J6. J6 also impacted but to a lesser extent.	Echo Tops, NEXRAD VIL	16
2005	ZDC	STMC concerned about losing western routes due to developing weather near ZID/ZDC/ZTL boundary. STMC consulted CIWS for growth and echo tops.	Growth and Decay Trends, Echo Tops	16
2020	ZID	CWSU briefed STMC using CIWS SD.		16
2040	ZNY	STMC used CIWS to monitor weather near J80. Weather on the route is mostly low-topped (30kft) and the forecast shows that weather won't block the route for at least another hour. ZNY moved all traffic to J80 to be handed off to ZOB who would then hand off to ZDC west of the weather. Deviations on J80 were encroaching on PHL arrivals, so ZNY moved all PHL landing traffic over upstate NY and kept J80 open.	Echo Tops, RCWF	1
2040	SCC	TCA used CIWS to determine if a pathfinder could be used to get traffic out of DC metro area.	NEXRAD VIL, Storm Motion, Echo Tops	12
2045	ZDC	TMC used CIWS to determine when weather would clear IAD and the LDN fix so that westbound departures can be resumed.	RCWF	11

BLITZ #1, Day 4 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2100	ZDC	STMC requested that the SD be set up with three small VIL windows (one for each DC metro airport) to monitor the weather on each airport. A pathfinder is currently running the LDN/AML route.	NEXRAD VIL, Forecast Contours	8, 12
2104	ZNY	Using CIWS, the STMCs realized that J80 would close soon. They proactively planned to offload all westbound traffic onto J60 and J64. They estimated that these routes would be open for one to two hours. By the time J60/J64 became blocked, J80 would be open.	RCWF, Echo Tops, NEXRAD VIL	2, 3 14, 15
2116	ZDC	BWI departures can't push back because of lightning in the vicinity. TMC requested a pathfinder from Potomac TRACON to test the weather west of IAD. The request was denied. A second request for a pathfinder 15 minutes later was approved.	RCWF	12, 13
2125	ZNY	CIWS used to monitor weather on J80.	NEXRAD VIL, Echo Tops	16
2125	ZDC	A line of weather is impacting J75. STMC used RCWF to determine that J75 would clear in about 45 minutes. This information was used to brief ZNY.	RCWF	13, 16
2151	SCC	During the 2115 SPO, NWA requested that one of its aircraft be used as a pathfinder for J518. The STMC used CIWS Growth and Decay and RCWF to determine that the pathfinder had a chance of making it and advised the Sector to allow it.	RCWF, Growth and Decay Trends	12, 13
2210	ZDC	International flights are schedule to depart IAD in about 10 minutes. TMC used CIWS to determine that cells west of IAD on J134 would stay north of IAD for 60 minutes. A plan was formulated to take the flights south off IAD, then west, then north into ZOB behind the weather. From there the flights could go through ZBW. ZOB refused the plan due to weather and volume.	RCWF	16
2217	ZDC	Discussion of delays but no CIWS usage.		
2246	ZDC	IAD International flights now leaving southbound into weather.		
2258	SCC	DC Metro ground stop lifted but no traffic coming from NY.		
2301	SCC	DC delays 3+ hours. Growth and Decay Trends shows growth in DC area.		16
2305	ZDC	TMC referenced Growth and Decay Trends for storms in IAD area.		16
2322	SCC	IAD hit directly for third time today.		

BLITZ #1, Day 4 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2330	ZNY	STMC used CIWS to determine when PHL would be impacted. He estimated he had about 30 minutes before the airport closed. A ground stop for PHL was implemented and airborne inventory was worked to the airport.	RCWF	1, 8, 13, 15
2340	ZDC	Strong storms again impact IAD. TMC working Potomac position noted weakening in the weather. User told Potomac TRACON that IAD should open in 15 to 30 minutes	RCWF, Growth and Decay Trends, Lightning	13, 16
2343	ZDC	TMC at PCT position referenced CIWS Growth and Decay Trends on a telecon with ZDC and SCC, pointing out why problems continue.	Growth and Decay Trends	13, 16
2350	ZDC	Bow echo approaching PHL, which is already in a second tier ground stop. Bow echo is forecasted to impact PHL in 45 minutes	RCWF	
post-event interview	ZID	There was virtually no weather in ZID today. However, weather in ZDC forced holding of aircraft in ZID airspace. Limited use of CIWS at ZID today.		13
post-event interview	SCC	TCA used CIWS to determine if a pathfinder could be used to get traffic out of DC metro area.		12
post-event interview	ZDC	Area 1 Supervisor reported using CIWS "all the time" for route closing decisions.		1, 2

CIWS Benefits Assessment

BLITZ #1

Day 5 - June 13, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1510	ZID	CVG position used CIWS forecast to time the weather relative to CVG arrivals.	RCWF, NEXRAD VIL	9, 15
1550	ZID	STMC very concerned about losing J42. Weather developing near the route. STMC noted that the weather was growing and told TMC to keep an eye on BKW for deviations. STMC spoke with ZOB about possibility of taking traffic over APE.	Growth and Decay Trends	13, 16
1734	ZID	Weather near FWA causing delays at ORD.		
1912	ZID	STMC talked to ZKC about departures bound for CVG during the 2100 hour. STMC concerned that PXV would close and suggested routing traffic through ZME. STMC used CIWS to determine the time of impact at PXV.		13, 16
1912	ZID	TC position asked CWSU if the hole in the weather to the west would fill. CWSU used CIWS to brief TC.	RCWF	3, 13
1915	ZID	CVG position used CIWS to determine what to do with CVG arrivals at 2130. The forecast was used to determine when MOSEY would be impacted.	NEXRAD VIL	15, 16
2000	ZID	CIWS was used for STMC hand-off briefing.	RCWF	16

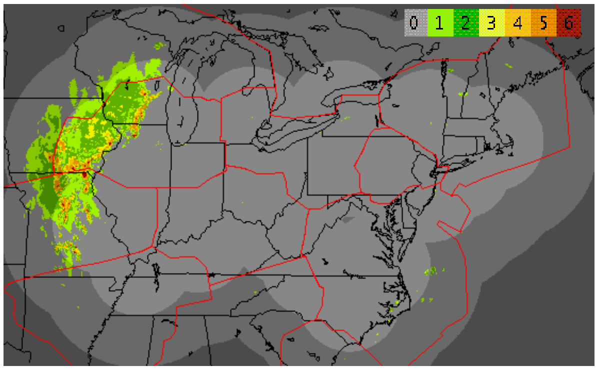
BENEFITS CATEGORY SUMMARY
Blitz 1
6/8/03, 6/10/03 – 6/12/03

	ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	SCC
Keeping routes open longer and/or reopening closed routes earlier	1	1	5	6	2	2	0	2
Closing routes proactively	0	0	2	4	1	0	0	0
Proactive, efficient reroutes	0	2	2	3	1	0	1	0
Shorter/fewer ground stops	0	0	1	0	0	1	0	0
Ground Stop avoided	0	0	0	0	0	0	1	0
Reduced Miles in Trail (MIT) restriction	0	0	0	0	0	0	0	0
Traffic directed through gaps in weather	0	1	3	0	0	0	0	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	2	6	8	2	1	0	6	0
Optimization of runway usage; enhanced runway planning	0	0	1	0	0	0	0	0
Improved use of GDPs	0	0	0	0	0	0	0	0
Greater departures during SWAP	1	2	2	1	0	0	0	0
Directing pathfinders	0	1	1	3	0	0	0	3
Interfacility Coordination	0	5	15	12	1	4	2	3
Improved safety	0	1	3	3	1	0	1	0
Reduced workload	0	2	8	8	2	0	4	2
Situational awareness	0	4	30	24	2	10	7	10
Dates Visited	6/8	6/8 - 10	6/8, 6/10-12	6/8, 6/10-12	6/12	6/11	6/8 - 10	6/8, 6/10-12

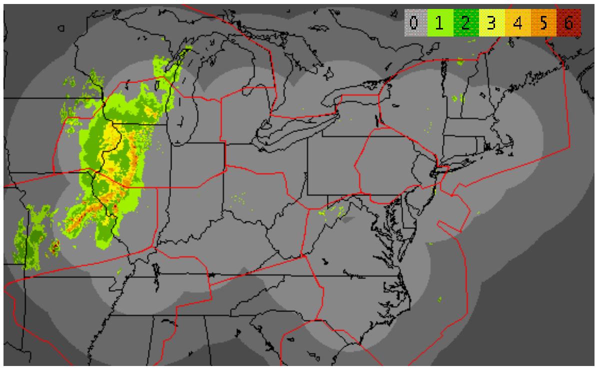
Blitz 2: 25-26 June 2003

Facilities Visited: ZAU, ZID, ZOB

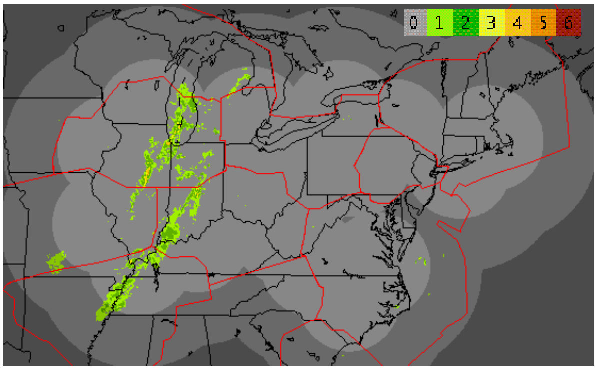
Examples of CIWS NEXRAD VIL Precipitation During Blitz 2:



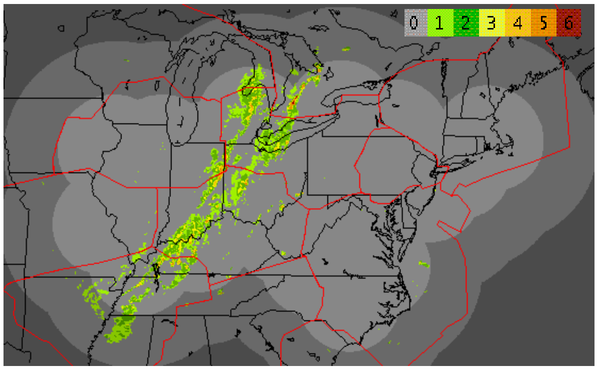
25 June 2003, 2100 UTC



26 June 2003, 0100 UTC



26 June 2003, 1500 UTC



26 June 2003, 2100 UTC

CIWS Benefits Assessment BLITZ #2 Day 1 - June 25, 2003				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
0209	ZAU	CIWS was used to plan when to stop and start arrivals from the northwest over the FARMM fix.	RCWF	8
0311	ZAU	ZAU requested two westbound pathfinders from C90.		12, 13
post-event interview	ZAU	Used CIWS to plan westbound reroutes.		3
post-event interview	ZAU	Used CIWS to SWAP westbound departures out of northbound fixes and around the north end of the weather.		11

CIWS Benefits Assessment

BLITZ #2

Day 2 - June 26, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1030	ZID	TC and STMC discussed the weather and noted that the current weather was dissipating. They confirmed this using the CIWS Growth and Decay Trends product. STMC consulted CIWS SD for some time to acquaint himself with the weather and trends.	Growth and Decay Trends, NEXRAD VIL, Echo Tops	16
1130	ZID	Reports of turbulence at and above 33kft in the eastern half of ZID are causing compression problems.		
1136	ZAU	CWSU feels CCFP develops weather too late in the day, noting development in IL. STMC plans to discuss issue on SPO.		
1150	ZID	TC and STMC used SD to discuss routes for ORD and east-west flow beginning at 16Z. CIWS forecast does not extend to 16Z, but users appeared to be studying the forecast product.	RCWF	16
1515	ZID	Area Sup reports that cell east of VHP is at 35kft and increasing. STMC suggests to TC that ORD-bound traffic be rerouted as soon as possible. TC says CIWS shows no growth in the weather and suggests using the FWA2 route as long as possible.	Growth and Decay Trends	1
1530	ZAU	STMC used CIWS RCWF to support FWA2 playbook route for DC Metro to ORD flow and for ORD traffic from Florida. ZID wants to modify FWA2 to have traffic fly to STL before turning north to C90's southwest arrival fix.	RCWF, Growth and Decay Trends, Echo Tops, NEXRAD VIL	15
1540	ZID	CWSU reports overhearing a PIREP of tops at 38.5kft for the storm east of Indianapolis. The CIWS echo tops estimate for the storm is 35kft while the WARP estimate is 25kft.	Echo Tops	
1600	ZID	TMC at the CVG position used CIWS echo tops for situational awareness.	Echo Tops	16
1600	ZAU	TMC working the ZAU arrival position used CIWS forecast to determine that weather would clear the southeast arrival fix (FWA). ZAU then convinced ZID to run traffic behind storms rather than over St. Louis. ZAU TMC estimates this saved 15 to 20 aircraft 45 to 60 minutes of flying time each.	NEXRAD VIL, RCWF	1, 13

BLITZ #2, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1730	ZOB	TMC used CIWS to plan restrictions on J60 rather than closing the route. J60 is a heavily used NY route and CIWS helped keep the route open longer. Greater restrictions were placed on J64 to reduce volume because J64 carries more internal traffic and was heavily impacted by weather. J64 was subsequently closed due to weather.	Storm Motion, Echo Tops, Forecast Contours	1
1730	ZID	TC used CIWS for situational awareness. He noted growth in the weather and commented that is would impact the FWA2 playbook route.	Growth and Decay Trends	16
1750	ZOB	TMC used CIWS to determine that echo tops were below 31kft and would therefore not impact over-flight traffic.	Echo Tops	1
1800	ZOB	STMC and DTW position consulted CIWS to plan for the DC-to-DTW push. Considered moving traffic south of the weather over MIZAR by the Growth and Decay Trends product showed that the weather was building in that area. Users decided to wait and see.	Storm Motion, Echo Tops, Growth and Decay Trends, NEXRAD VIL	8
1802	ZAU	Storms east of C90 are low and relatively weak but are restricting flow. Restriction of 10 x 1 for eastbound traffic was requested by the Sector.		
1820	ZOB	ZOB is running two DTW southbound streams as one with 20 MIT through holes in the weather. CIWS was used to determine the location of holes and how long they would remain open.	NEXRAD VIL, Storm Motion, Echo Tops	1, 7
1820	ZOB	Note: The TMC indicated that CIWS provides a more accurate representation of the weather than other systems. With this they can keep traffic running longer with fewer restrictions.		
1829	ZOB	TMC indicated that the additional products provided by CIWS help users focus on the more significant weather south and southwest of CLE rather than the benign weather east of Lake Michigan. CIWS is better than other systems because of these additional products.		15
1845	ZID	STMC used CIWS for situational awareness (shift change).	NEXRAD VIL, Echo Tops, Growth and Decay Trends	16
1900	ZOB	Aircraft are deviating on J146. TMC used CIWS to determine why aircraft were deviating. Restrictions were increased from 10-as-1 (10 MIT as one route) to 15-as-1.	NEXRAD VIL, Echo Tops	1

BLITZ #2, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1905	ZOB	STMC used CIWS Echo Tops for situational awareness to assess height of storms (40kft) impacting J584 over Lake Erie.	Echo Tops	16
1930	ZOB	One user requested an Echo Tops Forecast product. He noted that the advances CIWS has made over the past two years have been "tremendous".		
1945	ZOB	TMC, using CIWS, noted that echo tops were lowering and considered easing restrictions on J60 and J64. The STMC consulted the CWSU who said that the convection would regenerate so no changes were made.	Echo Tops, Growth and Decay Trends	16
2009	ZOB	STMC and CLE TMU used CIWS to time the arrival at a cell at CLE. CIWS forecast shows impact in 75+ minutes. CWSU concurs with CIWS forecast so traffic was routed to the west side of the weather rather than try to race to CLE ahead of the storm.	RCWF	8
2030	ZOB	Area Supervisor, TMC, and STMC used CIWS to reduce restrictions on J60 from 20 MIT per strata to 10 MIT per strata.	Echo Tops	6
2110	ZOB	CWSU forecasted that storms would redevelop while CIWS showed the airspace would be usable. No action was taken to open airspace.	Echo Tops	16
2120	ZOB	STMC referenced CIWS to report on SPT that convection was building in ZOB.	Growth and Decay Trends	16
2200	ZOB	Situational Awareness	Growth and Decay Trends, Echo Tops, NEXRAD VIL, Storm Motion	16
2228	ZOB	Observer questioned accuracy of Lightning product.		
2240	ZOB	Planning: TMC viewing CIWS echo tops and contemplating opening J60/J64. TMC thinks opening the routes for all traffic may be premature but at least some ORD traffic could use J64.	Echo Tops, Storm Motion	16
2320	ZOB	J64 (J60?) reopened with 20 MIT per strata	NEXRAD VIL, Echo Tops	1
2340	ZOB	STMC noted that echo tops have dropped considerably over the past 30 minutes and would like to open J60/J64. Area Supervisor reports that aircraft are still deviating at 35kft south of Toledo. J64 was opened to ORD traffic. TMC believes pilots are being conservative about deviating, but wants to see what the ORD traffic does before opening the route to all traffic.	Echo Tops	

<table>
<tr><th colspan="5"><u>BLITZ #2, Day 2 (continued)</u></th></tr>
<tr><th>Time (UTC)</th><th>User</th><th>CIWS Applications</th><th>CIWS Products Used</th><th>Benefits Category</th></tr>
<tr><td>0040</td><td>ZOB</td><td>J60/J64 reopened with most restrictions cancelled based on CIWS.</td><td>Echo Tops, Growth and Decay Trends</td><td>1</td></tr>
<tr><td>0107</td><td>ZOB</td><td>New storm development in eastern OH.</td><td></td><td></td></tr>
<tr><td>Post-event Interview</td><td>NWA</td><td>The NWA ATC Coordinator, in planning for the evening push, used the Echo Tops gridded product to note that almost all tops were below FL300 and elected to leave all aircraft bound for MEM and IND from the NE on their normal routes. This saved them flight time, fuel, and re-routing headaches. A few aircraft would have to deviate slightly from their optimal routes, but no re-routes were necessary.</td><td>Echo Tops</td><td>1</td></tr>
</table>

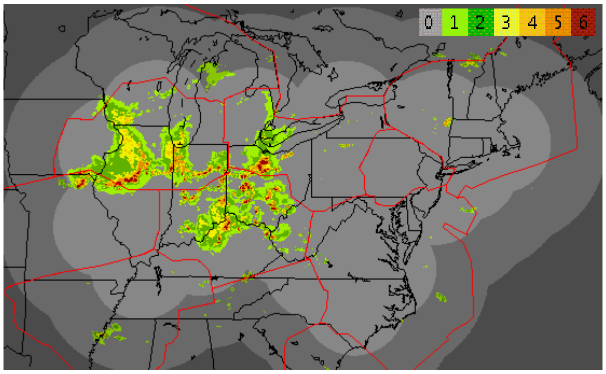
BENEFITS CATEGORY SUMMARY
Blitz 2
6/25/03 and 6/26/03

	ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	SCC
Keeping routes open longer and/or reopening closed routes earlier	1	6	1	0	0	0	0	0
Closing routes proactively	0	0	0	0	0	0	0	0
Proactive, efficient reroutes	1	0	0	0	0	0	0	0
Shorter/fewer ground stops	0	0	0	0	0	0	0	0
Ground Stop avoided	0	0	0	0	0	0	0	0
Reduced Miles in Trail (MIT) restriction	0	1	0	0	0	0	0	0
Traffic directed through gaps in weather	0	1	0	0	0	0	0	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	1	2	0	0	0	0	0	0
Optimization of runway usage; enhanced runway planning	0	0	0	0	0	0	0	0
Improved use of GDPs	0	0	0	0	0	0	0	0
Greater departures during SWAP	1	0	0	0	0	0	0	0
Directing pathfinders	1	0	0	0	0	0	0	0
Interfacility Coordination	2	0	0	0	0	0	0	0
Improved safety	0	0	0	0	0	0	0	0
Reduced workload	1	1	0	0	0	0	0	0
Situational awareness	0	6	5	0	0	0	0	0
Dates Visited	6/25 - 6/26	6/26	6/26					

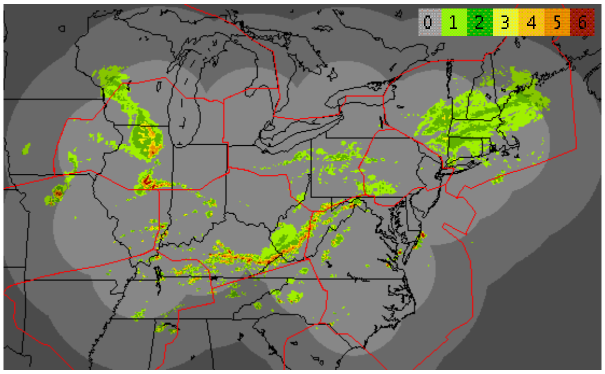
Blitz 3: 8-11 July 2003

Facilities Visited: ZID, ZDC, ZOB, ZBW, ZNY, ATCSCC

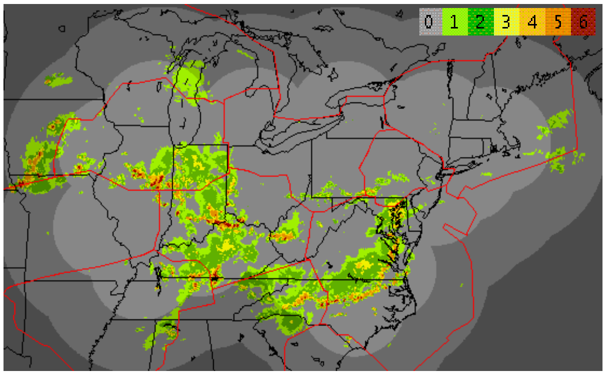
Examples of CIWS NEXRAD VIL Precipitation During Blitz 3:



08 July 2003, 2100 UTC



09 July 2003, 1700 UTC



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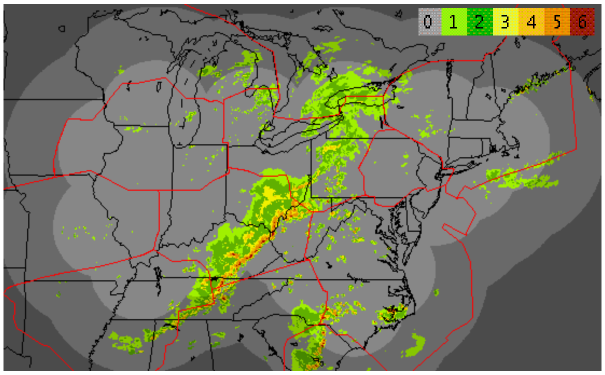
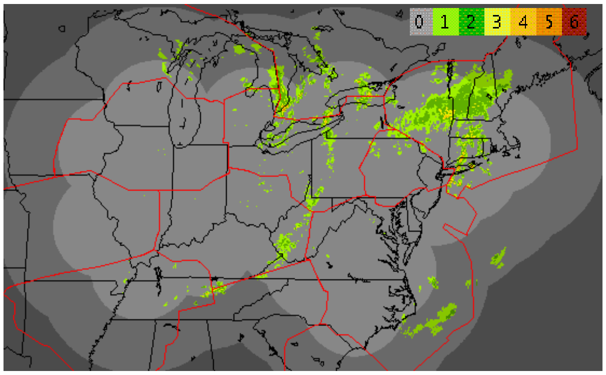


10 July 2003, 2100 UTC



11 July 2003, 1100 UTC

CIWS Benefits Assessment

BLITZ #3

Day 1 – July 8, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1755	ZID	CVG position discussed storm movement from CIWS with TMC at CVG. (Shared situational awareness)	Storm Motion	13, 16
1915	ZID	CVG landing traffic is ground stopped until 1945Z. The CVG position TMC cancelled the ground stop for all Centers at 1925Z based on CIWS. The STMC expressed concern about releasing CVG landing traffic from ZAU. If the airport closes due to weather there is no place to hold this traffic in the ZID airspace. The CVG position TMC showed the STMC that the CIWS Growth and Decay Trends product showed only decay in the area of concern. CIWS indicates that CVG will be impacted by weather for 30 more minutes so it should be clear by the time the first tier traffic arrives. STMC is convinced to allow ZAU traffic to flow.	Growth and Decay Trends, RCWF	4, 8
1940	ZID	Westbound traffic will not use J80. Pilots see overhang from storms and don't want to go there. Eastbound aircraft are picking their way through.		
1952	ZID	CVG landing traffic from ZNY, ZBW, and ZOB (Centers east of the line of weather) is ground stopped until 2100Z due to en route weather between ZOB and ZID. CVG position TMC used CIWS to estimate the time and duration of weather impacts on CVG in order to fine-tune the CVG ground stop. CIWS forecast shows high probability of level 3+ weather at CVG from 2030 to 2115. Current airborne inventory is 18 to 20 aircraft. If CVG closes, the airborne flights may have to be held but if a ground stop is implemented and CVG does not close, there will be no demand. User chose not to restrict flow.	RCWF	1, 4, 8
2030	ZID	CVG position asked about CVG weather impact. CIWS forecast shows that CVG will not be impacted.	RCWF	
2103	ZID	Repeated use of CIWS by CVG position over past 30 minutes to monitor weather impacts at CVG.	RCWF, Echo Tops, Storm Motion, NEXRAD VIL	16
2200	ZID	CVG position used CIWS to investigate routes for CVG landing traffic from ZBW and ZNY. User wanted to see the forecast for FLM and J134. The forecast shows that FLM will be clear in about 45 minutes, when traffic would be arriving at the fix. No changes were made to the plan (i.e. no restrictions were implemented).	RCWF	1

BLITZ #3, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
Post-event interview	DTW	TRACON TMC used CIWS to coordinate with ZOB. The TRACON user pointed out that the MIZAR fix would be closed due to weather around the 3PM push. He expected ZOB to route traffic to other fixes. Instead, ZOB and SCC ground stopped the push traffic. CIWS was used to identify the potential problem.		13
Post-event interview	C90	C90 TMC referenced CIWS when negotiating departure routes with ZAU. Departure delays were threatening to cause gridlock at ORD. The C90 user identified holes in the weather through which they could relieve the departure queue and convinced ZAU to use these opportunities. C90 also used CIWS to time airport closings and changing of arrival fixes.		7, 8, 11, 13

CIWS Benefits Assessment
BLITZ #3
Day 2 – July 9, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1515	ZDC	CIWS is used for situational awareness. Storm location and forecast to assess impact on jet routes and determine when routes will close.	NEXRAD VIL, RCWF, Echo Tops, Growth and Decay Trends	16
1540	ZDC	Weather is impacting the MGM playbook route in ZTL. ZTL asked ZDC to keep the VUC routes open. ZDC TMC used CIWS to determine that the VUC routes would not be impacted by weather and therefore kept the routes open.	RCWF, NEXRAD VIL, Growth and Decay Trends, Echo Tops, Storm Motion	1, 15
1620	ZDC	TMC used CIWS to determine that DC Metro landing traffic from ORD did not need to be routed off normal routes.	NEXRAD VIL, RCWF, Storm Motion, Echo Tops	1, 15
1631	ZDC	J6 being closed. CIWS not used for the decision.		
1640	ZDC	Situational awareness.	NEXRAD VIL, Forecast Contours	16
1700	ZDC	Thunderstorms in ZID airspace have disrupted normal flows. CIWS is used to work out routes and restrictions.	NEXRAD VIL, Forecast Contours	16
1715	ZDC	STMC using CIWS throughout SPO for situational awareness.		16
1720	ZDC	VUC closed.		
1800	ZID	STMC used CIWS frequently prior to 1800Z to check the development and movement of weather on J42. At this time J6 and J42 are closed due to weather.		16
1830	ZDC	CIWS and ITWS are used to track the cell that will soon impact IAD and perform tactical reroutes.	RCWF, NEXRAD VIL, Forecast Contours, Storm Motion, Echo Tops	3, 8
1845	ZDC	STMC, TMC, and Area Supervisors are planning for the eventual impact on DCA and BWI.	Forecast Contours, RCWF, NEXRAD VIL, Echo Tops, Storm Motion, Lightning, and Growth and Decay Trends	16
1905	ZDC	TMC working Potomac position used CIWS to determine when DCA would be impacted and started making plans for the impact.	RCWF, Forecast Accuracy, Storm Motion	8, 15

BLITZ #3, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1921	ZDC	VUC routes impacted by weather. CIWS used to plan new route and tactically reroute two aircraft still on the route.	NEXRAD VIL, Forecast Contours	3, 7
1930	ZDC	CIWS is used to plan evening flows on J45 and J42.	Forecast Contours, RCWF, Storm Motion, Echo Tops	15, 16
2015	ZID	CVG position TMC studied CIWS forecast for situational awareness to determine what would happen to CVG airport by 2200Z. CWSU indicates weather will impact CVG; CIWS shows no impact.	RCWF	16
2115	ZID	CWSU used CIWS SD to brief the CVG position TMC.		16
2134	ZID	STMC uses CIWS to study with weather in the vicinity of CVG. Pop-up thunderstorms are causing CVG to cut off flow. STMC used CIWS to estimate time and duration of impact.	RCWF, Storm Motion, NEXRAD VIL	8, 13
2206	ZID	STMC and CVG position are looking at the forecast to estimate duration of impact at CVG.	RCWF, Storm Motion, NEXRAD VIL	16
2231	ZID	CVG position using CIWS to estimate time and duration of impact at CVG.	RCWF, Storm Motion, NEXRAD VIL	16
2233	ZID	Area Supervisor forecasts that traffic from the east coast coming down J80 will begin to have problems. The TMCs at the TC and ESP positions used CIWS to look at the weather near J80 and estimate the impact. They are considering putting traffic on J22.	RCWF, Storm Motion, Growth and Decay Trends	16
2246	ZID	TC position used CIWS while discussing weather with Severe Weather. Tried to describe weather situation to SCC who apparently did not have access to weather information.		13, 16
2315	ZID	ESP position used CIWS to identify that the BKW fix would close in about 75 minutes. Looking at flow on J42 and planning what to do with the traffic when BKW closes.	RCWF	16
2319	ZID	CVG position used CIWS to identify potential routes into CVG.	RCWF, Growth and Decay Trends, NEXRAD VIL	3, 8
2325	ZID	STMC used CIWS to determine that STL Gateway departures are OK with 20 MIT, thus avoiding unnecessary reroutes or restrictions.	RCWF, Growth and Decay Trends, NEXRAD VIL, Storm Motion	1, 8

BLITZ #3, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	C90	C90 TMC used CIWS to determine that the late morning weather would likely not cause either MDW or ORD to close. Arrivals were not stopped. They are watching CIWS as the next wave of weather approaches to estimate time and duration of impact.		5, 8, 9, 15
post-event interview	C90	CIWS indicated that the worst weather would stay south of the airports and impact arrivals from the south.		8
post-event interview	SCC	Severe Weather position used CIWS for Dulles traffic and impacts on all Washington metro flights.	Storm Motion, Growth and Decay Trends	8, 13
post-event interview	SCC	East position used CIWS heavily for timing weather impacts at Dulles. Also used it as the line of weather moved across the northern ZDC airspace to time start and stop times for EWR and LGA.		1, 8, 15

CIWS Benefits Assessment

BLITZ #3

Day 3 - July 10, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1015	ZID	CIWS was used to examine weather east of London, KY. Reroutes were made based on this information. CVG landing traffic from ZTL is being swapped.	Echo Tops, Growth and Decay Trends, Storm Motion	3
1030	ZID	TC position commented to CWSU during the briefing that the tops had diminished 10kft over the past hour "according to CIWS."	Echo Tops	16
1030	ZID	STMC used SD to check weather in preparation for SPO.	Echo Tops, Growth and Decay Trends	16
1133	ZID	Weather at PVX is causing deviations. ESP position checked CIWS to assess severity of weather (43kft with Lightning).	Echo Tops, Lightning	16
1200	ZID	CWSU briefing indicates that current weather is expected to dissipate. Weather is expected to develop in central KY at 16Z and move to the western ZID boundary by 21Z.		
1640	ZOB	CIWS used for hand-off briefing at the ORD TMC position. TMC continues to study weather focusing on echo tops and Growth and Decay Trends.	Echo Tops, Growth and Decay Trends	16
1645	ZID	TMC used CIWS to estimate when weather would impact APE. ZME does not want ORD traffic, so ZID is trying to find a way to take the traffic over APE along J85 or J83.	RCWF, Echo Tops	16
1653	ZID	ZID TMC asked about Growth and Decay Trends. He wanted a forecast of when the line would fill in. RCWF does not forecast new growth.	RCWF	
1655	ZOB	Possible airborne holding for traffic headed to CVG. CIWS was studied to assess the impact of the hold.	RCWF	13, 16
1735	ZID	STMC looked at CIWS to determine weather impact at CVG. Now coming out of CVG ground stop with 40 MIT, down to one gate.	Storm Motion, RCWF	16
1812	ZOB	Gap between APE and AIR filling and DC Metros are starting to deviate. CIWS referenced for situational awareness.	Growth and Decay Trends, RCWF	7

BLITZ #3, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1815	ZID	Stop all west bound traffic from ZDC and all north and south bound traffic from ZOB, ZAU, and ZTL; nothing transitioning the line of weather. STMC used CIWS to check severity and extent of the weather.	NEXRAD VIL RCWF, Echo Tops, Storm Motion	16
1817	ZOB	Continued use of echo tops as APE-AIR gap fills.	Echo Tops	1, 7
1918	ZOB	J80, J60, J64, and J518 shut. Aircraft routed northward. CIWS referenced.	Echo Tops	16
2010	ZOB	Extensive use of CIWS products and overlays helps open closed jetways at and above FL310.	Growth and Decay Trends, Echo Tops	1
2032	ZID	Very quiet. Not much traffic moving.		
2100	ZOB	CIWS used to reference cells near J60 in an attempt to get it open.	Growth and Decay Trends	16
2300	ZOB	Still trying to open J60. CIWS referenced.	NEXRAD VIL	16
post-event interview	SCC	Severe Weather: Echo Tops was used to coordinate with centers to selectively push traffic. We watched individual routes to determine when to open and close them.		1, 2, 13
post-event interview	SCC	East: CIWS was used extensively as the only source of weather information for J60, J64, and J110. CIWS was used to coordinate with ZNY and ZOB to swap all NYC traffic north and use J60 for PHL departure traffic. User estimated that all of the PHL arrivals and departures benefited using CIWS alone. It was extremely helpful that ZOB had the same weather information for coordination.		1, 3, 13
post-event interview	NWA	NWA used CIWS echo tops information to identify "saddles" in ZID airspace, which may allow NWA to transit the squall line on a limited basis. However, due to deviations in the identified areas, NWA was not permitted to take advantage of the gaps.	Echo Tops	16
post-event interview	ZDC	STMC stated that the closings of J75, J48, and J6 through the ZDC airspace were based on CIWS forecasted movement and echo tops information. CIWS did not assist in keeping these routes open longer, but it did give them specific information on when the routes would be closed, which helped with planning. Management of ZDC internal departures was accomplished based solely on CIWS.	RCWF, Echo Tops, Storm Motion	2, 15

BLITZ #3, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	PIT	The CIWS forecast was used to determine when, where, and if significant weather would impact their operations. The forecast showed them that storms would stay south of the airport so they were able to continue to run traffic without restrictions. The user noted that the forecast was very accurate during this event. Without CIWS, the user would not have been able to accurately predict storm location and would therefore have implemented restrictions.	RCWF	6

CIWS Benefits Assessment
BLITZ #3
Day 4 - July 11, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1144	ZBW	STMC CIWS used to determine when BOS inbounds will have to be rerouted towards western MA.	NEXRAD VIL, Echo Tops, Storm Motion	15, 16
1144	ZBW	CIWS used to determine potential safe holding areas in western MA if weather impacts BOS traffic.		14
1205	ZBW	STMC used CIWS to note that weather heading toward BOS is weakening and that weather growing over Long Island would stay south of the TRACON.	Growth and Decay Trends, Storm Motion, RCWF, Echo Tops	16
1225	ZBW	STMC referenced CIWS in a phone call with BOS TRACON. Noted that heavy weather near Worchester and Long Island may miss BOS. No preventative measures taken.	RCWF, Storm Motion	13, 16
1654	ZBW	Discussion of how satellite data can be useful as a CIWS product.		

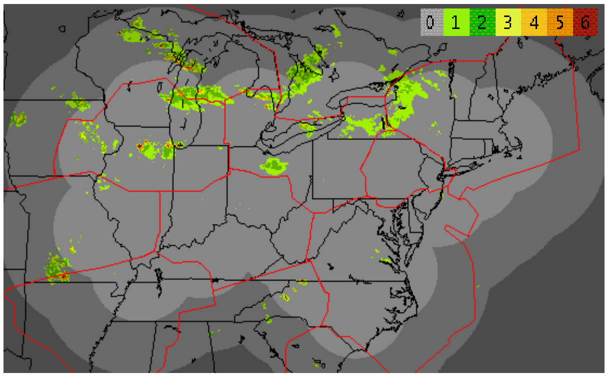
BENEFITS CATEGORY SUMMARY
BLITZ 3:
7/8/03 – 7/11/03

	ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	SCC
Keeping routes open longer and/or reopening closed routes earlier	0	2	3	2	0	0	0	3
Closing routes proactively	0	0	0	1	0	0	0	1
Proactive, efficient reroutes	0	0	2	2	0	0	0	1
Shorter/fewer ground stops	0	0	2	0	0	0	0	0
Ground Stop avoided	0	0	0	0	0	0	1	0
Reduced Miles in Trail (MIT) restriction	0	0	0	0	0	0	0	0
Traffic directed through gaps in weather	0	2	0	1	0	0	1	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	0	0	5	2	0	0	3	2
Optimization of runway usage; enhanced runway planning	0	0	0	0	0	0	1	0
Improved use of GDPs	0	0	0	0	0	0	0	0
Greater departures during SWAP	0	0	0	0	0	0	1	0
Directing pathfinders	0	0	0	0	0	0	0	0
Interfacility Coordination	0	1	3	0	0	1	1	3
Improved safety	0	0	0	0	0	1	0	0
Reduced workload	0	0	0	5	0	1	1	1
Situational awareness	0	5	16	6	0	3	0	0
Dates Visited		7/10	7/8 – 7/10	7/8 – 7/10		7/11	7/8 – 7/9	7/9 – 7/10

Blitz 4: 20-23 July 2003

Facilities Visited: ZAU, ZID, ZOB, ZDC, ZNY, ZBW, ATCSCC, C90, FedEx

Examples of CIWS NEXRAD VIL Precipitation During Blitz 4:



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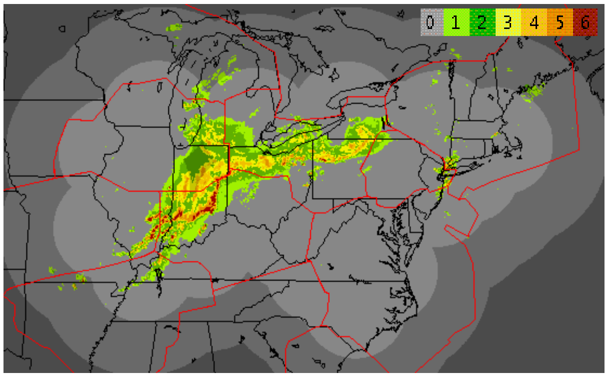
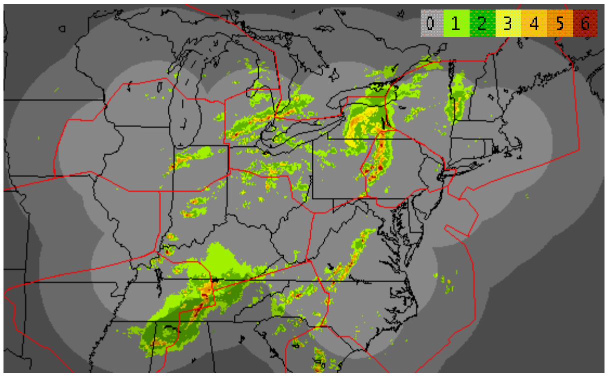


21 July 2003, 1100 UTC



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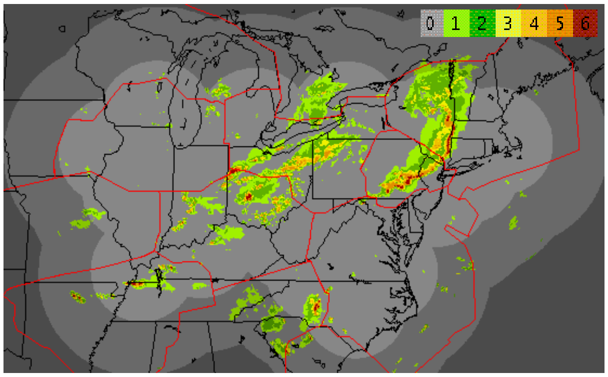

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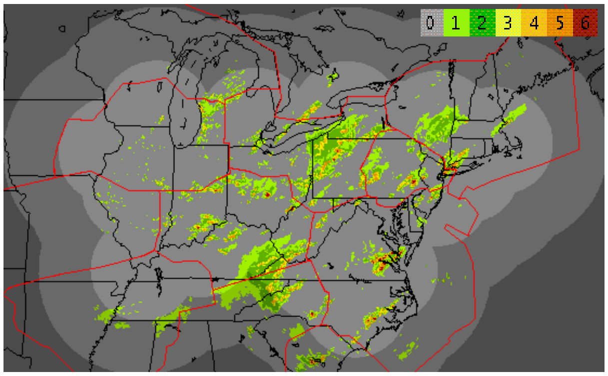
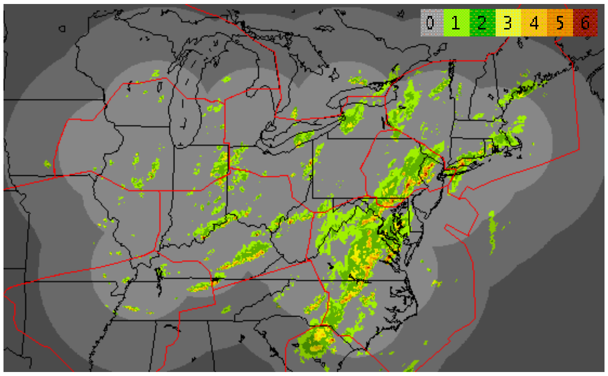


22 July 2003, 1900 UTC



23 July 2003, 0100 UTC

CIWS Benefits Assessment

BLITZ #4

Day 1 - July 20, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
2111	ZAU	STMC used CIWS to determine that the PLANO arrival fix would soon be impacted by storms.	RCWF	16
2120	ZAU	STMC used CIWS during SPT to confirm that opening J60/J64 through ZOB/ZAU is a viable option (CIWS assisted with interfacility coordination).	RCWF, NEXRAD VIL	1, 13
2135	C90	TMC referenced CIWS forecast (RCWF) in discussion with sector supervisor regarding movement and timing of approaching weather. (Watching CIWS for situational awareness and to prevent 'surprises').	RCWF	16
2147	C90	TMC said that based on CIWS, he didn't think ORD would 'get wet' (e.g., storms forecasted by CIWS to miss airport). Based on this forecast, AAR not reduced. Without CIWS, it would have been more difficult to determine that ORD would not be impacted, thus would have likely had to reduce rate to account for wet runways and poor visibility. ZAU concurred with this decision.	RCWF	9, 10, 13
2154	ZAU	Storms developing west of ORD. ZAU expects storms to shut off southbound traffic.		
2208	ZAU	Level 6 storms in C90's southwest arrival gate possessing high echo tops caused gate to be closed. The CIWS forecast provided lead-time notification to TMCs of pending gate closure. TMCs were therefore able to proactively reroute traffic starting as far west as Omaha NE (250 nmi), thus reducing flight times.	RCWF, NEXRAD VIL, Storm Motion, Echo Tops	3, 8
2224	C90	Storm cell 10-15 nmi southwest of ORD lead to stoppage of southbound departure flow. The CIWS forecast was consulted for situational awareness, providing additional information related to pending impact.	RCWF	16

BLITZ #4, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2235	C90	MDW was about to take a direct hit from storms. Various headings were considered for reroutes around the cell just south of ORD and just west of MDW. CIWS was consulted to confirm movement/location of not only this cell, but another large cell further west and following the same path.	RCWF, NEXRAD VIL, Storm Motion	8
2238	ZAU	New storms threatened to shut down the BEARZ (southeast) gate. The STMC and TMC conferenced around CIWS, finally deciding that convection would remain sufficiently scattered to keep BEARZ open and allow traffic to continue flowing. CIWS Storm Motion vectors and Growth and Decay Trends indicated that storms would track to the east and not grow and merge with storms further west (S of ORD).	Storm Motion, NEXRAD VIL, Growth and Decay Trends, Echo Tops	8
2252	C90	Large cell just south of ORD caused a change in runway configuration from 22 R and L to 27 R and L. In this configuration, eastbound traffic must go around to the north, which impacts northbound traffic. The TMC consulted CIWS during his phone conversation with ZAU, discussing the plan for switching eastbounds. Using CIWS, he also informed ZAU that southbound departures may be able to resume in 15-30 minutes.	RCWF, NEXRAD VIL	11, 13
2300	C90	The TMC consulted CIWS with regard to the next cell approaching the ORD area from the west. ZAU wanted to keep using runway 27, but C90 told them they want to eventually switch back to runway 22 to reduce impacts. The TMC consulted the CIWS forecast and estimated that the switch to the more favorable runway configuration may be possible in 30 minutes.	RCWF, NEXRAD VIL	9, 13
2306	C90	A storm cell is located just west of MDW. In planning the best routes for MDW departures, the TMC consulted the CIWS forecast, from which he designed a plan to reroute westbounds using a gap in the convection that was predicted to persist for next hour or so. The TMC took someone over to CIWS to point out RCWF.	RCWF	7, 11

BLITZ #4, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2315	C90	During planning discussions with ZAU, the TMC referenced decay trends overlaid on NEXRAD precipitation. "According to CIWS, it's decaying a little bit too."	NEXRAD VIL, Growth and Decay Trends	13, 16
2325	ZAU	The STMC referenced CIWS on the SPT to confirm that there were no en route issues for ZAU. CIWS information assisted in the decision to cancel the ORD ground stop at 2345Z (75 min early). By using the CIWS forecast, the PLANO arrival fix was opened approximately 10 minutes earlier than was otherwise possible.	RCWF, NEXRAD VIL, ASR, Storm Motion, Growth and Decay Trends	4, 8, 13
2326	C90	One of the large cells west of C90 has greatly diminished and RCWF did an excellent job in representing this evolution. The substantial area of decay (dark blue trend) noted earlier in the NEXRAD window verified.	RCWF, NEXRAD VIL, Growth and Decay Trends	16
2328	C90	The TMC talked with ZAU about storm cells still west of C90. He would like to go back to runway plan that resumes a more normal configuration for eastbound traffic. He referenced the CIWS forecast and offered that this switch may be possible in 30 minutes.	RCWF, NEXRAD VIL	11, 13
2330	C90	CIWS indicated a weakening trend in convection. The next push is west coast push. The TMC noted the decay trends and determined the PLANO departure fix would remain a viable route. When the storms to the west were stronger, the TMC was worried about using this route for this push, but the CIWS depiction of storm decay alleviated his fears. RCWF was consulted to confirm that a return to the normal eastbound configuration would soon be possible.	RCWF, NEXRAD VIL, Growth and Decay Trends	1, 8, 15

BLITZ #4, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
0000	C90	ORD is back to the standard 22 L and R configuration (instead of 27 L and R). The decaying trends noted in CIWS for some time provided additional confidence in this decision.	RCWF, NEXRAD VIL, Growth and Decay Trends	9, 11
0014	C90	RCWF did a good job of forecasting decrease in weather west of C90.		
0040	ZAU	Southbound departures were swapped to west fixes because of level 2 storm on southern C90 TRACON boundary. The storms had no lightning but CIWS was consulted to verify the echo top height and intensity of storms.	Echo Tops, NEXRAD VIL	11
0043	C90	One of the sector supervisors at the TRACON said that he thinks CIWS is the best product they've ever had. He really likes it and said that when weather is approaching, he can actually feel confident that what he's seeing (on CIWS) is going to happen.		
post-event Interview	NWA	A Dispatcher used CIWS forecast to effectively argue against NWA's inclusion in DTW CETUS arrival reroute, thus saving them flight time and fuel. The forecast verified ("The forecast was certainly accurate tonight"). Dispatcher quote: "I know Cleveland [ZOB] has CIWS so I was able to talk about the forecast with them and better present our position."	RCWF	1, 13
post-event Interview	ZOB	The STMC used CIWS RCWF to assist with DTW arrival planning. The forecast correctly predicted that DTW would not take a direct hit so a ground stop was never implemented (despite broken line of strong storms dropping southeastward towards airport). Quote: "The forecast was accurate for us, like it usually is."	RCWF	5, 8

CIWS Benefits Assessment

BLITZ #4

Day 2 - July 21, 2003

Time (UTC)	User	CIWS Applications	CIWS Products Used	Benefits Category
1130	ZAU	STMC consulted CIWS display repeatedly during SPO.	RCWF, NEXRAD VIL, Growth and Decay Trends	16
1208	C90	Weather is well east of C90, but TMCs use CIWS to monitor the weather and plan routes.		16
1407	C90	Showers developing over south central WI possibly associated with a cold front. TMC monitoring CIWS for growth along the front.	RCWF, NEXRAD VIL, Growth and Decay Trends	16
1425	ZAU	While weather in Ohio is decaying, there is development north of C90. This may impact northbound departing traffic. STMC monitored CIWS to assess growth and forecasted location of weather to help determine if a SWAP will be needed.	RCWF, NEXRAD VIL, Growth and Decay Trends, Storm Motion	16
1510	C90	A cell in southern WI is growing, The CIWS forecast shows it staying north of the TRACON.	RCWF, NEXRAD VIL, Growth and Decay Trends	16
1515	SCC	SPO: Biggest concern at this time is the CCFP six-hour forecast which shows a large red area covering west and central PA. SCC is negotiating with Canada to use the CAN1 and CAN7 playbook routes. To complicate matters, military airspace south of NY is in use causing delays into and out of those airports. The ORD arrival rate was dropped to 80 due to unfavorable winds. ZDC is heavily loaded with overhead traffic and is having trouble releasing departures. East-west traffic is moving but with deviations. CIWS was used for situational awareness.		16
1615	ZID	STMC studying weather situation. He stated that a lot of decisions had been made with respect to routing traffic around the weather and he wanted to look at the weather situation in the face of these decisions to determine how the plans would work.		15, 16
1624	ZID	The CVG position TMC routed three aircraft from Area 6 direct to FLM. TMC noted that echo tops were low and the weather was decaying so he decided to use the aircraft as pathfinders to attempt to open a route to CVG. The STMC discussed this possibility with the CVG TMC using the SD for coordination.	Echo Tops, Growth and Decay Trends	1, 12

BLITZ #4, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1715	SCC	SPO: SCC concern is still 2+ hours. Weather has split: one area in eastern PA/western NY another in KY-TN.		
1745	C90	C90 had planned to switch configurations to WEIRD to take advantage of the wind shift associated with the passage of the cold front. Even though the winds had shifted, the configuration change was timed to take place after the noon push was finished. However, just as the switch was about to occur, a cell popped up east of ORD. The TMC used CIWS to determine the time of the switch.	RCWF, NEXRAD VIL, Growth and Decay Trends, Storm Motion	9
1750	ZAU	The bulk of the weather problems are outside ZAU airspace, but weather to the north of C90 is causing SWAPs. The Departure TMC consulted CIWS for situational awareness.	NEXRAD VIL, Storm Motion	16
1800	ZID	CVG position used CIWS for hand-off briefing.	NEXRAD VIL, Storm Motion, Echo Tops	16
1830	C90	A cell developed southeast of MDW and eastbound departures were having trouble getting out. The TMC used CIWS to determine that the storms were moving rapidly and that the departure routes would be clear soon. Departures were halted temporarily.	RCWF, NEXRAD VIL, Storm Motion	4
1830	ZID	STMC used CIWS for hand-off briefing	NEXRAD VIL, Storm Motion, Echo Tops	16
1844	SCC	Users crowded around CIWS to monitor the growth of a new line of weather forming in ZDC and IN/OH.	Growth and Decay Trends, NEXRAD VIL	16
1845	ZAU	Storms have developed south and southeast of C90 and along the ZID/ZAU boundary. The Arrival TMC is concerned about losing the BEARZ fix and is using CIWS as the primary planning tool. The STMCs from ZID and ZAU are coordinating a plan to get ORD arrivals in from the south and southeast.	RCWF, ASR, Growth and Decay Trends, Storm Motion	8, 13
1846	C90	MDW eastbound departures restarted after a pathfinder successfully departed. CIWS was used to determine that the weather would not impact departures.	RCWF, NEXRAD VIL, Storm Motion	11, 12
1850	ZID	STMC called SCC to question the opening of J89/J99. The STMC reported echo tops values of the weather in the vicinity and expressed concern that opening the route may be premature.	Echo Tops	13, 14, 16

BLITZ #4, Day 2 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1859	C90	An area of weather from southeast to southwest of MDW is beginning to fill. TMC used CIWS to monitor the development of the weather and determine how the southeast arrival fix (BEARZ) would be impacted.	RCWF, NEXRAD VIL	16
1911	ZID	STMC used CIWS for SPO preparation.	RCWF, Echo Tops, NEXRAD VIL, Storm Motion	16
1915	ZID	TMC is trying to open a route for traffic departing ORD. CIWS was used to determine an appropriate route. Suggested Muncie-ROD at low altitude and advising pilots to request higher on the hand-off. ZAU does not support this plan.	NEXRAD VIL, Storm Motion, Echo Tops	13, 16
1926	C90	BEARZ continues to be impacted by weather over the southeast TRACON. BEARZ arrivals are being vectored over KUBBS. TMC used CIWS to monitor the BEARZ impact and estimate how long the fix will be impacted.	RCWF, NEXRAD VIL	8
1933	C90	Continued development of weather in the BEARZ area has forced TMC to close BEARZ entirely. TMC used CIWS to monitor the weather development.	RCWF, NEXRAD VIL, Growth and Decay Trends	16
1945	ZAU	Storms continue to develop southeast of C90 and cause deviations over the BEARZ fix. The C90 arrival TMC used CIWS to monitor the development of the weather to the southeast.	RCWF, NEXRAD VIL, Growth and Decay Trends, Echo Tops	16
1945	ZID	ZID is holding ORD landing traffic due to weather at C90. In addition, weather is impacting J80 and there is a lot of activity in the unit to plan an alternative.	RCWF, NEXRAD VIL, Echo Tops, Growth and Decay Trends, Lightning	16
1952	ZAU	ZAU ESP used CIWS to plan DTW departures to be ready at 20Z when GS ends.		11
2015	C90	Weather is moving out of the southeast TRACON and decaying. TMC is planning to open BEARZ soon.	RCWF, Growth and Decay Trends	8

BLITZ #4, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2015	ZID	ZID is nearly clear of weather and traffic is almost back to normal.		
2035	ZAU	Weather southeast of C90 is impacting ORD landing traffic. The arrival TMC used CIWS to keep traffic flowing.	RCWF, NEXRAD VIL, Growth and Decay Trends, Storm Motion, Echo Tops, ASR	8
2045	ZAU	Continued concern that the southeast sector is becoming overloaded due to deviations over BEARZ. TMC closely monitoring CIWS. TMC continues to warn areas that arrivals may have to be rerouted, but is keeping the fix open based on CIWS.	RCWF, NEXRAD VIL, Growth and Decay Trends, Storm Motion, Echo Tops	1
2110	ZAU	Storms southeast of C90 decayed. BEARZ remained open throughout with restrictions. TMC estimated that about 20 aircraft avoided reroutes to the southwest arrival fix.		1, 8, 15
2113	ZID	Weather is developing along the cold front. STMC and CWSU checked CIWS echo tops (FL340).	Echo Tops	16
2200	SCC	A line of weather exists in PA/NY and more in IN and OH. Users are trying to open an ORD/BOS route. All of SevWx is looking at CIWS to attempt to determine a route.	NEXRAD VIL, Echo Tops, Growth and Decay Trends, RCWF	16
2300	ZID	STMC checked CIWS for situational awareness.	NEXRAD VIL, Storm Motion, Echo Tops, RCWF	16
2302	SCC	CIWS referenced often to monitor weather situation.		16
2315	ZAU	Weather in ZOB, ZNY, and ZBW is causing holding in all three Centers. The Arrival TMC used CIWS for situational awareness.	NEXRAD VIL, Storm Motion, Growth and Decay Trends	16
2316	SCC	Eastbound west coast traffic is back to normal routes. NY is expected to be clear in 1 hour and 20 minutes. SCC user referenced CIWS storm speeds on the telecon.	NEXRAD VIL, Storm Motion, RCWF	13, 16
2353	ZID	STMC used CIWS to note that weather to the south was diminishing and suggested going back to normal routes for ORD/ATL. TC position checked CIWS prior to calling SevWx to coordinate. Back to normal routes at 00Z.	Growth and Decay Trends, Echo Tops, NEXRAD VIL	1, 13

BLITZ #4, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
0015	ZID	TMC returning from break used CIWS for situational awareness. Noted growth south of IND.	NEXRAD VIL, Storm Motion, Echo Tops, RCWF	16
0100	ZAU	ZBW passed a 70 MIT restriction to ZAU, which has reduced the departure rate to ZBW to eight aircraft per hour. TMC used CIWS for situational awareness.	RCWF, NEXRAD VIL	16
0115	ZID	N90 reported on the SPO that they expected to be shut down in 30 minutes for two hours. This sounds like RCWF.	RCWF?	16
post-event interview	C90	TMC stated that CIWS is a lifesaver for them when weather that can be tracked is approaching. However, when weather develops in the TRACON or for air mass storms, CIWS is not as effective.		
post-event interview	ZID	TMC indicated that CIWS was "pretty accurate" all morning. He used RCWF, Echo Tops, and Growth and Decay Trends to pick routes into CVG. TMC said that as Growth and Decay Trends began to show growth, the CWSU visited the unit to confirm the growth.	RCWF, Echo Tops, NEXRAD VIL, Growth and Decay Trends	8
post-event interview	ZID	One TMC who uses CIWS often believes it is a great tool. He wonders why more TMCs don't use it.		
post-event interview	ZBW	Echo Tops and Storm Motion all helped give the users an idea of where the weather would be in an hour, but they were too busy to make use of the information.	Echo Tops, NEXRAD VIL, Storm Motion	16
post-event interview	ZBW	ZBW TMC stated that the forecast product helped controllers.	RCWF	15, 16
post-event interview	ZBW	The ZBW TMC used CIWS around 0300Z to determine if weather near EWR was convective. The relatively high VIL values were not associated with lightning, so the user was able to get more planes through to EWR.	NEXRAD VIL, Lightning	1, 9

BLITZ #4, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	ZOB	TMC used CIWS to keep traffic flowing tactically around storms in ZOB even though he was unable to open J60 and J64 simultaneously. CIWS showed that echo tops were too high to keep both routes open, so only one was used. In addition CIWS was used to estimate the time of impact at CLE. As a result, fewer aircraft were held and CLE was opened sooner. CIWS echo tops were also instrumental in opening J80.	NEXRAD VIL, Storm Motion, Echo Tops, RCWF,	1, 4, 8, 13
post-event interview	N90	ITWS/CIWS played an important part in keeping a constant arrival flow into the NY Metro airports. The users advised ATCSCC to keep traffic coming to east coast airports and to institute more aggressive arrival rates of LGA and EWR. Later, CIWS showed that the NY airports would be impacted but that windows of opportunity existed. These windows were utilized well.	RCWF, NEXRAD VIL, Storm Motion	8,10,13
post-event interview	United	The United user stated that they used CIWS more today than any other time this storm season. They were especially impressed with the accuracy of the movement (both for individual cells and RCWF). They noted that the echo tops estimate for a cell southeast of ORD was exactly right. They used CIWS all day.	RCWF, NEXRAD VIL, Storm Motion, Echo Tops	

CIWS Benefits Assessment

BLITZ #4

Day 3 - July 22, 2003

Time (UTC)	User	CIWS Applications	CIWS Products Used	Benefits Category
1230	ZBW	A solid line of level 4 weather is located in central MA and stretches into CT. Users consulted CIWS to determine echo tops. They expressed a preference for CIWS echo tops estimates over other existing products.	Echo Tops	16
1511	ZBW	TMC used CIWS to watch the weather build across MA. Anticipating the need to handle NY Metro departing traffic.	NEXRAD VIL, RCWF	16
1520	ZID	In preparation for a CVG push, the STMC and CVG position TMC used CIWS to determine if CVG would be impacted in the near future. Currently there is no weather in the vicinity.	RCWF, NEXRAD VIL, Storm Motion	16
1522	ZBW	STMC used CIWS to plan for future impacts.	Echo Tops	16
1548	ZOB	Weather in ZNY is forecasted to impact NY arrivals. East/west routes through ZNY are shut off except for JFK. STMC used CIWS to determine the possible loss of J60 through ZOB due to deviations. Currently, J60 and J64 are combined as one route.	Echo Tops	15, 16
1610	ZBW	A neighboring facility requested routing traffic over Hampton. The ZBW STMC refused the request because he believed the weather would not impact the route for another three hours and he didn't want to reroute unnecessarily.	All products	1, 13
1623	ZID	CVG position used CIWS to assess potential impact of weather on CVG operations. User noted that Storm Motion vectors and weather loop indicated motion to the southeast while RCWF carried the weather to the east.	RCWF	16
1647	ZOB	CIWS was used for an STMC hand-off briefing.		16
1654	ZOB	J60/J64 closed below FL370 due to excessive deviations.	Echo Tops	1
1656	ZBW	CWSU used CIWS to brief STMC about a line of thunderstorms.	Growth and Decay Trends, RCWF	16
1702	ZBW	The Operations Manager used CIWS for situational awareness.	Echo Tops, RCWF	16
1710	ZBW	TMC used CIWS to determine echo tops.	Echo Tops	16
1720	ZOB	J60/J64 closed completely.	Echo Tops, NEXRAD VIL, Growth and Decay Trends	

BLITZ #4, Day 3 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1748	ZOB	Interfacility coordination using CIWS regarding storm speed.	Storm Motion	13
1800	ZDC	Scattered convection is building everywhere on the east coast. The Area 5 SUP has the CIWS SD set up to support Area 4 because they currently need it more. Sup asked for more displays.		16
1808	ZOB	DTW TMC conducted hand-off briefing using CIWS.	All products	16
1812	ZBW	CIC used CIWS to monitor the progression of the weather in PA toward the ZBW boundary.	RCWF	16
1813	ZOB	PIT TMC used CIWS to determine when PIT would close and began to formulate a plan.	ASR, Storm Motion	15, 16
1815	ZDC	One area is holding LGA landing traffic for 15 minutes. TMC consulted CIWS to help find a reroute. Aircraft are being routed toward WAVEY temporarily even though weather is moving toward that fix.	NEXRAD VIL, Storm Motion, Echo Tops	3
1817	ZBW	TMC used CIWS to assess progress of the weather.	Echo Tops, Growth and Decay Trends, RCWF	16
1842	ZOB	PIT TMC monitored the weather impact at PIT using CIWS.	ASR, Storm Motion	16
1849	ZBW	STMC used CIWS to close routes.	RCWF, Echo Tops	2
1850	ZDC	STMC consulted CIWS to determine when convection would impact J209. STMC also set up SD to monitor the impact at LGA.	NEXRAD VIL, Storm Motion, Forecast Contours	16
1851	ZOB	PIT TMC continued to monitor weather impact at PIT.	ASR, Storm Motion	16
1900	ZDC	STMC used CIWS to estimate the time of impact on Whiskey.	Forecast Contours	16
1905	ZBW	STMC used CIWS to preplan possible BOS impact at 21Z.	Echo Tops, Growth and Decay Trends, RCWF	15, 16
1910	ZOB	ORD TMC used CIWS for a hand-off briefing.		16
1913	ZBW	CWSU briefed TMU on storms in central CT. This coupled with growth trends and 2hr forecast shows potential impact at BOS at 21Z.	RCWF, Growth and Decay Trends	16
1915	ZID	STMC studied CIWS to determine if and when CVG would be impacted by weather. Planning for a possible ground stop at 2100. STMC referred to CIWS on the SPO to warn of a potential CVG ground stop around 2130.	RCWF, NEXRAD VIL, Storm Motion	13, 15, 16

BLITZ #4, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1920	ZDC	STMC consulted CIWS to determine if BKW would remain open for EWR traffic. Also planning a reroute for EWR arrivals.	NEXRAD VIL, Storm Motion, Forecast Contours	3
1928	ZBW	Area Sup concerned about weather near BUF and what would happen to reroutes if the weather moves in. CIWS was used to estimate that the impact shouldn't occur for another 60 to 90 minutes.	RCWF, Growth and Decay Trends	16
1930	ZOB	ORD TMC used CIWS to determine the impact of weather on the Pullman arrival route.	RCWF	16
1935	ZBW	CWSU used CIWS to brief STMC about weather near JFK.	Echo Tops, NEXRAD VIL	16
1938	ZBW	CIWS was used to estimate the time of impact of weather at BOS. Some cells may impact BOS, but weather may pass to the west.	RCWF, Echo Tops, Growth and Decay Trends	16
2000	ZDC	TMC at the SevWx position used CIWS to time the potential impact of weather on the DC metro airports.	RCWF, Growth and Decay Trends	16
2024	ZBW	STMC noted that everything coming from the south has been ground stopped. Users are attempting to establish a route for BOS departures over MHT. ZNY internals filed through ZBW airspace were ground stopped early as a result of CIWS.	RCWF, Echo Tops, Growth and Decay Trends	15, 16
2026	ZOB	Three pathfinders were sent out of NY westbound on J60 and J64.	Echo Tops	12, 13
2039	ZOB	TMCU used CIWS to determine that the Pullman arrival route into ORD would not be impacted by weather.	RCWF	8
2045	ZDC	Area Supervisor used CIWS forecast to predict the closure of J75 in about 1.5 hours. Area Sup notified TMC to expect loss of route.	Forecast Contours	15, 16
2048	ZBW	STMC used CIWS to coordinate with other facilities.	All products	13
2055	ZOB	The pathfinders sent along J60 and J64 successfully navigated the routes. J60 and J64 are opened cautiously.	NEXRAD VIL, Echo Tops	1
2100	ZDC	At 2030, ATL landing traffic from NY was rerouted to J6 with 20 MIT. Traffic is now deviating on J6. CIWS was used to determine the coverage, severity, and echo tops of the weather on J6. TMC decided that weather was scattered and with low tops so the route remained open with MIT.	NEXRAD VIL, Echo Tops	1, 13
2105	ZOB	J60/J64 opened at all altitudes.		

BLITZ #4, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2111	ZDC	TMU used CIWS to keep J209 open, allowing traffic to pick their way through. With CIWS, they could easily see "saddle" in weather using filtered VIL and echo tops. Forecast Contours showed that the route might close in an hour, but they continued to use it as long as possible.	NEXRAD VIL, Echo Tops, Forecast Contours	1, 7
2120	ZDC	STMC referred to CIWS to determine the fate of storms in southern PA.	Forecast Contours, Growth and Decay Trends	16
2135	ZDC	J75 closed by Area Sup.		
2150	ZDC	At 2105, the LDN/AML route was closed for IAD/DCA departures. PCT complained that this closure was killing them and requested that the route be opened. STMC is concerned about deviations. STMC consulted CIWS to confirm that cells were isolated enough to attempt to open the route with 20 MIT restriction.	NEXRAD VIL, Echo Tops	1, 7, 11, 13
2155	ZDC	STMC used CIWS to confirm that OOD (Woodstown) traffic would be able to go south along the west side of the convection. A pathfinder is being sent from PHL to test the route. However, volume issue in sector 2 may prevent implementation of the plan.	NEXRAD VIL, Storm Motion	12
2210	ZDC	In an attempt to open a route for ZBW traffic, the STMC used CIWS and ITWS to determine if the Robbinsville-Nantucket route could be used.	NEXRAD VIL, Growth and Decay Trends, RCWF	13, 16
2220	ZDC	A gap over BKW is being used by ZOB and ZJX traffic landing at DC metro. TMC and STMC studied CIWS to determine if the gap would remain open. In addition, the users are still trying to find a route to NY but the gaps are not forecasted to last long enough to use as a viable route.	NEXRAD VIL, Storm Motion, Forecast Contours, Growth and Decay Trends	7
2225	ZDC	STMC coordinated with another facility using CIWS. CIWS indicated that ZDC could take traffic, but the sectors are experiencing volume issues.	ALL Products	13, 16
2235	ZDC	Sending some JFK traffic via OOD. TMC used CIWS to confirm that the cell currently impacting the route will have moved off when the traffic reaches the area. The use of CIWS allowed the TMC to open the route 15 to 30 minutes earlier and gave the user confidence in the decision.	NEXRAD VIL, Storm Motion	1, 4

BLITZ #4, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2250	ZDC	STMCs at ZNY and ZDC used CIWS to decide on reroute for NY arrivals from Atlanta. Noting CIWS VIL, Echo Tops, Growth and Decay Trends, and Lightning (all referenced on phone conversation), users decided to bring traffic through weakening storms over Gordonsville (in west-central VA) then northeast through a gap in eastern MD and western NJ; hoping the gap will persist long enough for traffic to make this run. Traffic would have sat on the ground without this decision. ZDC STMC visited the Area Sup to explain the decision and request a pathfinder be sent along the proposed route.	NEXRAD VIL, Echo Tops, Growth and Decay Trends, and Lightning	3, 4, 7, 12, 13
2252	ZBW	STMC used CIWS to determine if more weather would impact BOS.	RCWF, Growth and Decay Trends	16
2330	ZID	STMC used CIWS to estimate when DC Metro airports would be shut off due to weather. RCWF shows impact in two hours, but the forecast accuracy is only 30%. ZID has lots of traffic routed over BKW and the STMC is concerned that ZDC will close the door and ZID will have to hold.	RCWF, Forecast Accuracy	16
0000	ZDC	IAD is shut off even though CIWS shows that weather is not directly impacting the airport. STMC used CIWS to confirm that the airport was not impacted.	NEXRAD VIL, Storm Motion	16
0030	ZDC	CIWS was used continuously to assess the weather situation. However, multiple squall lines in ZDC and ZNY are severely impacting flows. Volume constraints preclude efforts to use CIWS to reduce delays.		16
0037	ZDC	Area Supervisor visited STMC to confirm that the weather situation was improving. STMC used CIWS products and noted some decay but an area of growth and Lightning that needs to be monitored.	NEXRAD VIL, Growth and Decay Trends, Lightning	16
0037	ZOB	CIWS was used to monitor the weather at the NY metro airports.	Growth and Decay Trends	16
0108	ZDC	IAD runways directly impacted by weather for over an hour.		16
0157	ZBW	TMC asked STMC to check the CIWS forecast to determine if the Center could accept traffic from TEB. STMC decided that TEB traffic could not be handled.	RCWF	15
0243	ZBW	TMC used CIWS to plan for reroutes around the backside of the weather. One aircraft was released.	RCWF	1, 11
0320	ZBW	Departure delays for BWI landing traffic at MHT and BOS have reached 2.5 hours. TMC used CIWS and then called SCC to determine if traffic could be rerouted and departures allowed.	RCWF, Echo Tops	13, 16

BLITZ #4, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	N90	TMC used CIWS to determine how long LGA arrivals would be shut out. He also referenced the RCWF in a telecon when he commented that he estimated that EWR would be impacted for about one hour.	RCWF, Echo Tops	13, 16
post-event interview	SCC	CIWS was used for storm motion, looping forecast, and echo tops. With so much weather everywhere, "We were just trying to survive."		

CIWS Benefits Assessment

BLITZ #4

Day 4 - July 23, 2003

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1237	ZBW	A Level 5 thunderstorm with tops to 45kft is approaching BOS. The TMC used CIWS to estimate the time and duration of the impact at BOS.	Storm Motion, RCWF	16
1400	ZID	Aircraft have been deviating around weather on J6 and near CVG. CVG TMC consulted CIWS for situational awareness.	All products	16
1515	ZDC	Storms building along the southeast North Carolina coast are causing deviations. Because of this, the STMC is considering putting MIT restrictions on the traffic on the Atlantic route. CIWS was used to determine that the Atlantic route could stay open at and above FL350 and to send pathfinders to test the route at FL310.	Echo Tops	1, 12
1515	ZID	During the SPO, the STMC commented that weather around CVG was expected to continue all day and that the tops were starting to build. The STMC used CIWS to identify areas of growth.	Growth and Decay Trends, Echo Tops	13, 16
1540	ZDC	STMC used CIWS echo tops to convince Area to keep Atlantic Route traffic in and out over the ocean at FL350 and above.		1
1640	ZDC	Short line of storms is developing in ZNY airspace in southeast PA. One ZDC area is holding LGA landing traffic due to weather. The TMC consulted CIWS and noted that the weather impacting LGA was not the line in PA but a small cell south-southwest of EWR.	NEXRAD VIL	16
1645	ZID	Using CIWS echo tops and the CWSU, the STMC determine to run J134 and J6 westbound traffic above 35kft.	Echo Tops	1
1710	ZID	PIREP of moderate to severe turbulence at FL260 at AZQ.		
1715	ZID	Noting that the echo tops were below 33kft, the STMC suggested running the normal J6 route at and above 35kft, with deviations as needed, and using the No_J6 playbook route below. SCC decided to use No-J6 throughout.	Echo Tops	13
1720	ZOB	Users noted CIWS underestimation of echo tops near BUF. CIWS reports upper 20's; PIREPS for 32kft.	'Zoom-Filtered' Echo Top Annotations	

BLITZ #4, Day 4 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1727	ZBW	TMC used CIWS to determine development and movement of weather near the Hancock fix.	Storm Motion, RCWF, Echo Tops	16
1730	ZDC	Weather with 30+ kft tops is moving east and off of the southbound Atlantic route. CIWS was used to confirm the echo tops in eastern NC.	Echo Tops	16
1740	ZOB	STMC used CIWS to locate development.	NEXRAD VIL, Growth and Decay Trends	16
1750	ZOB	Due to severely restricted arrival routes into ZNY, ZOB was forced to route much of its traffic over BUF. The STMC and TMCs used CIWS to monitor the weather development near BUF.	Growth and Decay Trends	16
1809	ZBW	The CWSU used CIWS to brief the STMC.	NEXRAD VIL, Echo Tops	16
1815	ZBW	TMC used CIWS to investigate the weather in PA and NY. STMC and TMC decided to extend the CLE reroute until 1930. This allowed four more aircraft to get through the weather.	Echo Tops	1
1818	ZBW	TMC used CIWS to monitor the weather in eastern PA.	RCWF, Storm Motion	16
1847	ZOB	With all LGA and EWR arrivals being routed through ZBW, ZOB works to keep J60/J64 open as long as possible. STMC used CIWS to monitor the weather situation on J60/J64	Echo Tops, Storm Motion, Growth and Decay Trends, NEXRAD VIL	16
1850	ZID	CIWS used for STMC hand-off briefing.	All products	16
1900	ZBW	The CWSU used CIWS to brief the STMC.	Echo Tops	16
1929	ZBW	TMC used CIWS to determine the motion of storms near Syracuse. Since storms are slow-moving and the tops are low, it is likely the westbound traffic can deviate around it.	RCWF, Storm Motion, Echo Tops	1
1930	ZDC	J75 is open with no MIT restrictions. However, aircraft are deviating. Restrictions for DC metro traffic over Gordonsville and Montebello have reduced the traffic so J75 restrictions are not needed. The STMC used CIWS to determine the echo tops and movement of weather near J75. The STMC indicated on the SPO that J75 is still a viable route at this time.	Echo Tops, NEXRAD VIL, Storm Motion, RCWF	1, 13
1935	ZBW	ZNY is coordinating with ZBW for ZBW to take ZNY traffic landing ORD and going to the Pacific Northwest starting at 2030. The ZBW TMC consulted CIWS and the CWSU to determine if the route would remain open. ZBW agreed to take ZNY traffic. ZBW TMU also noted echo tops below 30 kft.	RCWF	3,

BLITZ #4, Day 4 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1940	ZID	ZID area 6 is holding DC metro landing traffic. Traffic is backing up into area 5. The STMC studied CIWS for situational awareness.	Echo Tops, Growth and Decay Trends	16
2005	ZDC	A squall line is building in eastern NC. J121/J174 is being run single stream due to deviations. The STMC consulted CIWS to determine the motion of the line and consider how it would impact flow.	NEXRAD VIL, Storm Motion, Forecast Contours	16
2011	ZDC	Echo Tops product used by ZDC to assess weather on J48, J75, J134, and J149	Echo Tops	16
2108	ZBW	CWSU used CIWS information to issue a Center Weather Advisory for weather near Albany.	Echo Tops, Growth and Decay Trends	16
2113	ZOB	STMC, considering lifting restrictions on J80, used CIWS to assess echo tops.	Echo Tops	16
2158	ZBW	The WARP mosaic is missing many of the Northeast radars. ZBW users used CIWS for weather information.	NEXRAD VIL, Past weather loop	16
2202	ZBW	Sector 39 is suffering volume problems due to weather near Albany. STMC used CIWS to determine echo top heights and decides to slow down traffic headed for sector 39. However as soon as the decision was made, the area reported that no flights were going over Albany anymore.	NEXRAD VIL, Echo Tops	16
2210	ZID	CVG position consulted CIWS to consider what might happen to CVG departures over the southwest fix. CIWS indicates that the route will be clear so there is no need to implement any changes.	RCWF	15, 16
2210	ZBW	STMC used CIWS to monitor weather in sector 39.	All products	16
2240	ZBW	CWSU defined an SD configuration that optimized the overlays so that he could provide better service to the TMU.		
2315	ZBW	CWSU provided briefing to Operations Manager using CIWS.	NEXRAD VIL, Echo Tops	16
2345	ZNY	TMC asked MIT/LL observer with help interpreting the forecast product and discussed echo tops of weather stretching from just west of DC to 100 miles west of PHL.	RCWF, Echo Tops	16
0020	ZNY	TMC used CIWS to determine that PHL airspace would not be impacted for several hours.	RCWF, Echo Tops	16

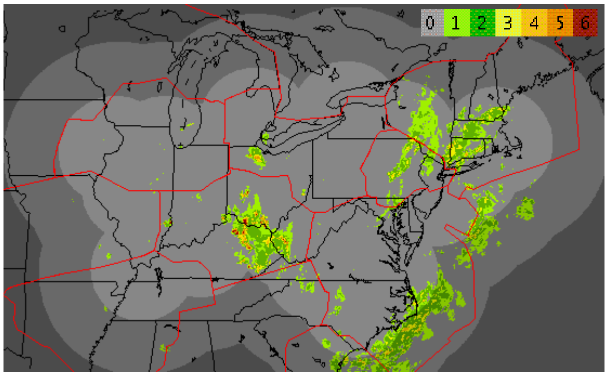
BLITZ #4, Day 4 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	Delta	{ATC Desk] "We have been referencing CIWS constantly now that you set it up for us the way we like it. I've sent multiple messages to TCA and they look at CIWS with me. An excellent tool. Today I really used echo tops and it showed that we could top the cells I was concerned about at the time."	Echo Tops	13
post-event interview	United	[Meteorology Office] "We've been using it [CIWS] to monitor Storm Motions and speeds. An excellent source of information."	NEXRAD VIL, Storm Motion	16
post-event interview	Delta	From the customer comments in the SCC logs: "CIWS indicates that tops should not be an impediment."	Echo Tops	

BENEFITS CATEGORY SUMMARY BLITZ 4: 7/20/03 – 7/23/03								
	ZAU	**ZOB**	**ZID**	**ZDC**	**ZNY**	**ZBW**	**C90**	**SCC**
Keeping routes open longer and/or reopening closed routes earlier	3	3	3	7	0	5	1	0
Closing routes proactively	0	0	0	0	0	1	0	0
Proactive, efficient reroutes	1	0	0	3	0	1	0	0
Shorter/fewer ground stops	1	1	0	2	0	0	1	0
Ground Stop avoided	0	1	0	0	0	0	0	0
Reduced Miles in Trail (MIT) restriction	0	0	0	0	0	0	0	0
Traffic directed through gaps in weather	0	0	0	4	0	0	1	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	6	3	1	0	0	0	4	0
Optimization of runway usage; enhanced runway planning	0	0	0	0	0	1	4	0
Improved use of GDPs	0	0	0	0	0	0	1	0
Greater departures during SWAP	2	0	0	1	0	1	5	0
Directing pathfinders	0	1	1	3	0	0	1	0
Interfacility Coordination	3	3	6	6	0	3	5	1
Improved safety	0	0	1	0	0	0	0	0
Reduced workload	1	2	3	1	0	4	1	0
Situational awareness	7	13	20	16	2	28	8	5
Dates Visited	7/20 – 7/21	7/20 – 7/23	7/21 – 7/23	7/22 – 7/23	7/23	7/21 – 7/23	7/20 – 7/21	7/21 – 7/22

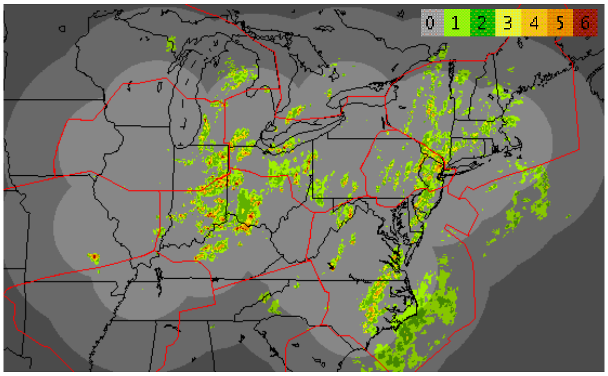
Blitz 5: 3-6 August 2003

Facilities Visited: ZID, ZOB, ZDC, ZNY, ZBW

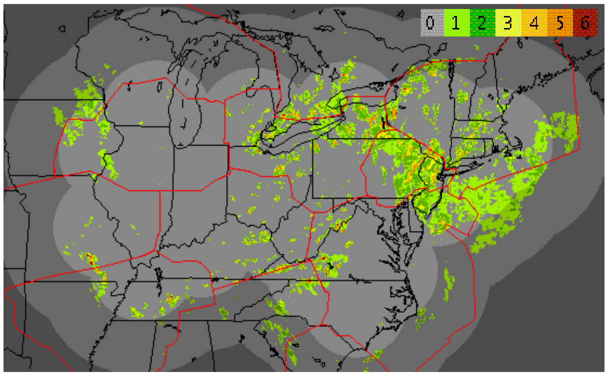
Examples of CIWS NEXRAD VIL Precipitation During Blitz 5:



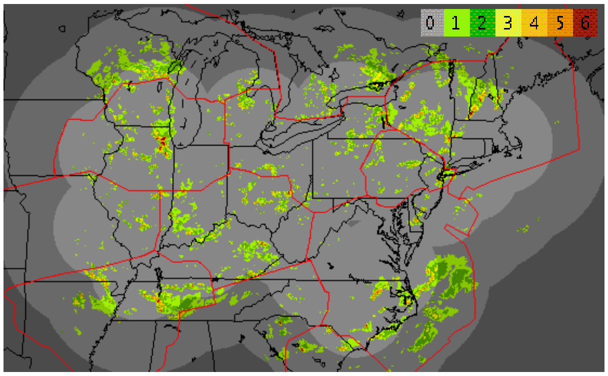
04 August 2003, 1300 UTC



04 August 2003, 1900 UTC



05 August 2003, 1900 UTC



06 August 2003, 2100 UTC

CIWS Benefits Assessment

BLITZ #5

Day 1 - August 3, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1715	SCC	On the SPO, ZAU stated that the CIWS forecast kept the weather south of the airport and that they were planning flows based on that information. SCC agreed with the ZAU plan after consulting CIWS.	RCWF	13
1900	SCC	SCC used CIWS Storm Motion to insure that CAN1 remained free of weather for eastbound traffic to EWR and JFK. SCC projected the CIWS on the big screens.		16
1915	SCC	CIWS was used to monitor the weather near J36 because of the heavy volume on the route. Some traffic was off-loaded to J16 and CAN1 eastbound.	RCWF, Storm Motion, Echo Tops	1, 3
2045	SCC	SevWx used CIWS while coordinating with ZDC. Both facilities agreed that echo tops were too high for north-south flow. Traffic was moved to the backside of the weather.	Echo Tops	3, 13
post-event interview	ZBW	ZBW was able to get planes to BWI and DCA using the forecast and precipitation products. The STMC estimates that approximately nine planes were able to get out that otherwise would not have been able to depart at all. Cells developed over Hancock later in the evening. The forecast showed the cells passing east of the fix. The TMC was able to take approximately 20 aircraft from the West Coast landing NY metro over the fix because RCWF showed that the fix would be clear by the time the aircraft arrived.	RCWF	1, 4, 13
post-event interview	C90	One TMC stated that it was another rough day with rapid development occurring before they could get set up to deal with it. In addition, different areas of weather moved differently. Arrival fixes at each corner were impacted at different times during the day. Once CIWS had a good motion forecast, the TMC was able to use CIWS to determine when fixes would open. Due to low scores, the user was unable to use the CIWS forecast effectively.	RCWF	8

BLITZ #5, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
post-event interview	ZBW	The TMC said that by using CIWS he could identify gaps in the weather that could be exploited by traffic.	NEXRAD VIL, RCWF	7
post-event interview	ZDC	The STMC stated that he used CIWS to plan reroutes for J75, J48, J121, and J174. He used CIWS exclusively to plan reroutes and when the route would be reopened. CIWS provided the forecast information they needed and the result was a better overall traffic plan and better reroute planning. He used RCWF and pathfinders to open routes earlier.	NEXRAD VIL, RCWF	1, 3, 12
post-event interview	ZAU	RCWF and Storm Motion were used to plan when BEARZ would open.	RCWF, Storm Motion	12
post-event interview	ZOB	CIWS was used to find holes in the line of weather along the eastern border. ZOB was able to keep traffic moving until weather developed in ZNY. CIWS was instrumental in opening routes after storms started to decay. CIWS and RCWF were used to plan when J60/J64 would be open. ZOB was able to keep J80 running all night and this helped reduce delays. CIWS was used to help plan SWAPs and plan for the weather impact on DTW.	NEXRAD VIL, Echo Tops, Storm Motion, RCWF, Growth and Decay Trends	1, 7, 8, 13
post-event interview	ZNY	The primary concern for ZNY was terminal operations; getting traffic out to the open fixes with deviations in the terminal environment. Eventually flow into and out of NY was reduced to single stream for all airports. Even though the accuracy of RCWF was high, the spacing did not allow the users to take advantage of gaps in the weather.	RCWF	16
post-event interview	DTW	CIWS was used to time storm impacts on the western gates. They were able to plan for the closure of the gates using RCWF and Storm Motion. The TMC stated that they were able to keep traffic flowing to the northwest arrival fix for some time. The departures had to be swapped south and CIWS was used to coordinate the SWAP with ZOB.	RCWF, Storm Motion	8, 13

CIWS Benefits Assessment

BLITZ #5

Day 2 - August 4, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1400	ZBW	The TMC used CIWS to assess BOS impacts. Echo Tops were used to determine the intensity of the cells and alternative routes to the airport.	Echo Tops	8, 13
1524	ZBW	TMC coordinated with BOS tower concerning landing traffic. CIWS was used to assess the intensity of the weather near the airport. The cells are not currently a problem because the demand is low. However, if demand increases, the weather could cause delays.	NEXRAD VIL, RCWF	13, 16
1556	ZBW	BOS landing traffic is being held due to weather on final approach. Due to low demand, holding does not cause volume problems.		
1604	ZBW	TMC used CIWS to discuss weather situation with CWSU.	Echo Tops	16
1644	ZBW	The CWSU used CIWS to brief the TMU. CWSU pointed out areas of growth in the NY region, which is expected to start causing delays. TMC commented that the RCWF product indicates that the weather is intensifying.	RCWF, Growth and Decay Trends	16
1657	ZBW	TMCs used CIWS to assess weather situation. One user noted 36kft echo tops. Another user briefed the TMU concerning the intensification of the line and the forecast for the weather near EWR.	RCWF, Growth and Decay Trends, Echo Tops	16
1659	ZBW	TMC, during coordination with another Center, referenced the weather situation and indicated that running a stream of traffic through ZBW would not be a good idea due to growth of cells that are already at 36kft.	RCWF, Growth and Decay Trends, Echo Tops	13, 14, 15, 16
1739	ZBW	CWSU used CIWS to advise STMC that BOS could be impacted in 45 minutes.	NEXRAD VIL, ASR, RCWF	16
1745 - 1800	ZOB	DTW ESP used CIWS to proactively reroute 25 DTW landing aircraft heading for the southwest arrival fix. The weather was forecasted to impact the southwest arrival fix at 1900Z. Half of the planes were sent to the northwest fix and half to the southeast fix.	RCWF	3, 8, 13
1822	ZBW	CWSU issued CWA for a convective SIGMET covering NY and thunderstorms in VT and NH. Used CIWS for echo tops information.	Echo Tops	16
1823	ZBW	STMC used CIWS to monitor the weather over Gardner. EWR and LGA are in GDP. Traffic for EWR is being held. STMC decided to meter BOS landing traffic.	NEXRAD VIL	8, 15

BLITZ #5, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1836	ZBW	Over the past few minutes, the STMC has added various overlays to the CIWS windows to help monitor the weather in critical areas. An EWR window was created to monitor impacts there. Now, STMC is using Growth and Decay to assess the weather on J75.	ASR, Growth and Decay Trends, NEXRAD VIL	16
1840	ZOB	STMC and TMC discussed ZAU plan for DC metro landing traffic. ZAU suggested taking the traffic north of Muskegon and then to Flint and DC. ZOB noted that CIWS showed weather building southwest of CLE, which would impact the proposed routing. ZOB suggested taking the traffic south of the weather. CIWS was the primary tool for this discussion.	Growth and Decay Trends, Echo Tops	3, 13, 14
1851	ZOB	DTW TMU used CIWS to prepare for the closing of CETUS (the SE DTW arrival fix). The user planned to move traffic north of CLE and onto the northeast arrival fix.	RCWF	8
1855	ZBW	Weather near EWR is very intense (lvl 5/6; tops 49kft) and there is severe weather along the NY/NJ border. A PIREP of a funnel cloud near EWR was received. The CWSU briefed the Areas on the weather and tops.	Echo Tops	16
1900	ZID	STMC used CIWS to get acquainted with the weather situation prior to the SPO. At this time all 1st tier and many 2nd tier Centers are ground stopped for CVG (exceptions are ZAB, ZDV, ZLC). CVG position used CIWS to determine that CVG would be ground stopped until 2130.	Growth and Decay Trends, Echo Tops, Storm Motion, NEXRAD VIL	15, 16
1915	ZID	SPO: ZID STMC stated "according to CCFP and CIWS, customers can expect problems at CVG for the next four hours."	RCWF	13, 16
1920	ZID	Observer showed TMC how to re-center a CIWS window to see ZID and the east coast. He is concerned about weather impacting the east coast and how that will affect ZID traffic.	NEXRAD Product Window	16
1922	ZBW	STMC considering ground stopping all ZBW traffic. Used CIWS to look at weather in central MA.		16
1923	ZOB	TMC used Storm Motion to time impact of weather on DTW east departure fixes.	Storm Motion	16

BLITZ #5, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1932	ZOB	CLE ESP used Forecast Contours.	Forecast Contours	16
1936	ZBW	BOS westbound traffic stopped because ZNY shut off ZBW.		
1940	ZID	CVG position used CIWS for a hand-off briefing (handed-off to trainee). The SD was used to discuss the weather situation and the current traffic plan. TMCs talked about how to get east coast CVG landing traffic in from the south during the 2200Z hour.	RCWF, Storm Motion, NEXRAD VIL	16
1940	ZNY	Departure coordinator used CIWS to determine if cells just west of ELIOT would cause problems. Decided they would not.	NEXRAD VIL, Storm Motion, Echo Tops	16
1950	ZBW	TMC used CIWS to get echo tops for weather near NY/NJ routes.	Echo Tops	16
2000	ZID	Customer called ZID to discuss trying to get flights into/out of CVG. TMC told customer that if CVG landing traffic gets into ZID airspace and CVG closes, there is no place to hold the traffic outside of weather. TMC informed customer that CVG ground stop would likely be extended until 2100Z.	CIWS SD	13, 16
2000	ZID	The weather appears to be moving south and east and decaying. CVG TMC thinks it might be possible to open CVG to ZKC and ZAU. TMC called CVG TRACON to confer. CVG TRACON suggested sending 2 pathfinders from ORD. If they made it, then release ZAU, then ZKC and ZME. ZID coordinated with ZAU to release CVG landing traffic from ZAU over DAN, 40 MIT high and 40 MIT low. The large MIT restriction was to guard against having to hold in ZID airspace, which is heavily impacted with weather.	Growth and Decay Trends, NEXRAD VIL, RCWF	4, 12, 13
2004	ZOB	In preparation for the NY westbound departures, the TMC used CIWS to determine how long J60 and J64 would remain open. CIWS shows that the route will be impacted soon. TMC planned alternate routes.	Echo Tops, Growth and Decay Trends	3, 15
2015	ZOB	TMC called SCC and requested that traffic on J60/J64 be routed onto J80, J95, and J36. TMC used CIWS extensively throughout the call.		2, 3, 13
2024	ZOB	CLE ESP used CIWS to time the impact of weather on WAKEM arrival fix.	Forecast Contours	8

BLITZ #5, Day 2 (continued)

Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2050	ZID	CVG TMC is very busy trying to open CVG to landing traffic. ZAU is released with 30 MIT regardless of altitude; ZOB is released single stream; ZDC is released without restrictions.	Growth and Decay Trends, NEXRAD VIL, RCWF, Storm Motion, Echo Tops	
2115	ZID	SPO: COMAIR reports 80+ cancellations and crews are beginning to time out. Looking for some relief. ZID reported that the CVG ground stop for the remaining Centers (ZBW, ZNY, ZME, ZTL, ZDC) would be extended to 2200. Deviations are occurring throughout ZID airspace.		
2123	ZBW	BOS position TMC used CIWS to determine when BOS would close.	RCWF, NEXRAD VIL	16
2125	ZNY	TMC warns to expect deviations on north gates, which were just opened. Deviations were reported a few minutes later. Flow was moved to J95. This 5 to 10 minute heads-up helped avoid a ground stop or holding.	Growth and Decay Trends	3, 5, 14, 15
2132	ZID	CVG TMC used CIWS to determine timing and location of weather to work out a SWAP.	RCWF, Growth and Decay Trends, Storm Motion	15, 16
2140	ZID	Pressure on ZID to end CVG ground stop. CVG TMC used CIWS to decide that APE-TIGRR would stay open for 60 to 90 minutes at least. J80 would be impacted, so traffic should go over DJB, APE 30 MIT single stream. CVG TMC used CIWS to cancel the CVG ground stop for all but ZDC and ZTL - 20 minutes early. ZDC remained stopped due to weather on J134.	RCWF, Growth and Decay Trends, Storm Motion, Forecast Contours	3, 4, 8
2152	ZBW	STMC used CIWS to assess the weather on the PA/NJ border.	RCWF, Growth and Decay Trends, Echo Tops	16
2215	ZID	CVG TMC used SD to monitor CVG arrival route. Concerned about losing the APE-TIGRR route. Also watching a cell near TARNE that appears to be headed for CVG. Hoping to open a route for ZTL traffic, but traffic in ZID continues to deviate.	RCWF, Storm Motion, NEXRAD VIL	16

BLITZ #5, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2229	ZID	Opening ZTL and ZME for CVG with 40 MIT restrictions.		
2234	ZID	CVG departures are 15 MIT per route.		
2246	ZOB	CLE ESP used Forecast Contours.	Forecast Contours	16
2250	ZNY	CIWS was used to determine that the north gates would remain closed for the next hour.	RCWF	16
2253	ZBW	STMC used CIWS to route aircraft over BOSOX fix.	NEXRAD VIL, Echo Tops	8
post-event interview	ZBW	A TMC commented that he has been using CIWS "quite a bit lately." He used it Saturday night (August 2, 2003) for information on echo tops and to identify gaps in the weather that could be used to keep traffic moving.		
post-event interview	ZID	ESP position reported using CIWS to open the ORD-to-IND route.		1

CIWS Benefits Assessment
BLITZ #5
Day 3 - August 5, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1635	ZOB	TC used CIWS to examine NYC airport impacts	All Products	16
1645	ZOB	TMU and SCC discussed status of NY metro airports. ZOB had combined the streams for all three airports into one stream with 20 MIT.	NEXRAD VIL	13
1736	ZBW	ZBW traffic to ZNY shut off due to weather over Islip. LGA is clear. TMC used CIWS to monitor weather in NY area and help release traffic to LGA.	NEXRAD VIL, Storm Motion	11
1743	ZOB	The DTW ESP used all four CIWS windows to examine the quasi-stationary cells and determine that DTW would most likely have to hold at one or two arrival fixes.	All Products	16
1745	ZNY	STMC stated that CIWS enabled them to keep departure flows going unrestricted since echo tops were below 30kft.	Echo Tops	1, 11
1755	ZOB	Zoomed-in VIL window was used to monitor the NY metro airports.	NEXRAD VIL	16
1800	ZNY	CIWS was used to keep flows into PHL on J48/J6/J75 unrestricted. Weather was just east of PHL and the echo tops were low. Without the information, a 10 to 15 MIT restriction would have been implemented.	Echo Tops	1, 6, 8
1801	ZBW	STMC used CIWS to assess weather north of LGA and along NY/NJ border.	NEXRAD VIL, Growth and Decay Trends	16
1802	ZBW	STMC used CIWS to determine why ZNY is continuing to take ZBW traffic.	Echo Tops, Growth and Decay Trends, Storm Motion	13, 16
1809	ZBW	STMC asked observer about CIWS forecast product; trying to understand ZNY decisions.	NEXRAD VIL, Growth and Decay Trends, RCWF	
1813	ZBW	CIWS was used to monitor weather around NY metro airports and to coordinate with ZNY.		16
1830	ZOB	The DTW ESP used VIL and Storm Motion to prepare to open the second runway at DTW. (This runway was closed due to microburst activity.)	NEXRAD VIL, Storm Motion, ASR	9

BLITZ #5, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1848	ZOB	CIWS was used to monitor DTW weather.	NEXRAD VIL, RCWF, Echo Tops, Storm Motion, Lightning, Growth and Decay Trends	16
1920	ZDC	Storms are impacting J48 and are west of J75. CIWS was used to assess how much longer traffic might flow on J75 (estimated 30 to 45 minutes). The STMC began to plan to offload J75 based on CIWS information.	NEXRAD VIL, Echo Tops, RCWF	1, 15
1932	ZBW	TMC used CIWS to assess weather situation and to discuss echo tops with a fellow TMC.	NEXRAD VIL, Echo Tops, Storm Motion	16
1934	ZBW	STMC asked CWSU about thunderstorms near BOS. CIWS display was used during the briefing.	NEXRAD VIL	16
1940	ZDC	Aircraft beginning to deviate on J75, causing the STMC to close the route. Traffic moved to J59.	NEXRAD VIL, Echo Tops, RCWF	3, 15
1946	ZDC	TC developed a plan to use J121 to support a SWAP of NY metro airports west for south.	RCWF	11, 13
1954	ZDC	Area supervisor visited the TMU to work out a plan for storms tracking off NY metro departure routes.	RCWF	16
2016	ZNY	Two pathfinders over WHITE were requested based on CIWS.	Echo Tops, NEXRAD VIL	12
2020	ZBW	Weather in ZBW airspace is beginning to impact routes. ZBW wants 8 minutes between all aircraft on all streams until 2230. Area A is overloaded. MHT westbound traffic is stopped to reduce sector load. TMC used CIWS to determine if ZBW airspace would close.	NEXRAD VIL, RCWF	16
2021	ZNY	CIWS was used to determine if a pathfinder would be able to fly over the storms on J36. CIWS shows that echo tops are 25kft. The aircraft topped the weather at FL270.	Echo Tops	12
2026	ZOB	The CLE ESP used CIWS extensively. Seven aircraft were proactively rerouted from the southern arrival fix (KEATN) to the western fix (WAKEM).	Echo Tops, Growth and Decay Trends, Storm Motion	3, 8
2040	ZNY	Pathfinders sent at 2016Z reported a good ride and the route over WHITE was reopened with a 15 MIT restriction approximately 30 to 45 minutes earlier than expected.		1

BLITZ #5, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2042	ZBW	STMC use CIWS to determine if westbound routes over Gardner, MA are clear. Sending six pathfinders.	All Products	1, 12
2100	ZOB	A 40 MIT restriction was placed on PHL landing traffic due to the possibility of losing an arrival route to weather. CIWS was used to plan the restriction.	NEXRAD VIL, Echo Tops	15
2130	ZDC	STMC used CIWS to monitor the impact of weather at EWR.	ASR, NEXRAD VIL, RCWF	16
2140	ZDC	TMC getting concerned about possible need to hold NY metro traffic in ZDC airspace. Used CIWS for situational awareness.		16
2215	ZBW	TMC used CIWS for situational awareness.	Growth and Decay Trends, NEXRAD VIL	16
2220	ZDC	STMC used CIWS to determine when he would have to close J75 and started to plan for reroutes.	NEXRAD VIL, RCWF	2, 15
2238	ZDC	STMC used CIWS to plan flow into EWR.	NEXRAD VIL, RCWF	16
2252	ZBW	TMC used CIWS to assess storms near SYR.	NEXRAD VIL, Echo Tops, Storm Motion	16
2256	ZDC	STMC used CIWS to assess impact of storms on J75.	RCWF	1
2307	ZBW	TMC canceling reroute for CAN6 45 minutes earlier than expected. Used CIWS to note low tops.	NEXRAD VIL, Echo Tops, Storm Motion	1, 13
2315	ZDC	Storms are blocking arrival routes into DC metro airports from ZOB. ZOB called ZDC to ask about alternative routes. TMC used CIWS to assess route availability, but CIWS showed growth and the forecast showed the route would be blocked.	NEXRAD VIL, Growth and Decay Trends, RCWF	13, 16
2328	ZDC	CIWS was used to plan a removal of the MIT restriction on J75 from 20/30 MIT back to normal flow.	NEXRAD VIL, RCWF	1
0005	ZDC	CIWS was used to plan a ground stop for DCA and BWI.	NEXRAD VIL, RCWF, Storm Motion	16
0010	ZDC	STMC used CIWS to plan to open flows between ZDC and ZTL.	NEXRAD VIL, RCWF	1
0110	ZDC	About one hour ago, a ground stop was implemented for the DC metro airports but the storms did not impact the runways.	NEXRAD VIL, RCWF, Storm Motion	

<table>
<tr><th colspan="5"><u>BLITZ #5, Day 3 (continued)</u></th></tr>
<tr><th>Time (UTC)</th><th>User</th><th>CIWS Applications</th><th>CIWS Products Used</th><th>Benefits Category</th></tr>
<tr><td>0115</td><td>ZDC</td><td>Growing storms in NC will cut off north-south routes. Area supervisor visited TMU to discuss a plan to move aircraft west behind the storms rather than pushing more traffic off shore where an active MOA exists.</td><td>NEXRAD VIL, RCWF</td><td>16</td></tr>
<tr><td>0120</td><td>ZDC</td><td>Planning to open DCA, which is currently being impacted by storms. STMC asked that the ground stop be lifted because CIWS showed that the airport would be clear in an hour.</td><td>RCWF, Growth and Decay Trends</td><td>4</td></tr>
<tr><td>0135</td><td>ZDC</td><td>DCA traffic is currently stopped due to weather at the airport.</td><td>RCWF, Growth and Decay Trends</td><td>16</td></tr>
<tr><td>0137</td><td>ZDC</td><td>ZNY called ZDC to request that traffic be allowed to use J48. STMC used CIWS to note that echo tops were below 35kft. ZDC offered J48 to ZNY as long as the traffic was at or above FL350 before reaching ZDC airspace.</td><td>Echo Tops</td><td>1, 4, 13</td></tr>
</table>

CIWS Benefits Assessment

BLITZ #5

Day 4 - August 6, 2003

Time (UTC)	User	CIWS Applications	CIWS Products Used	Benefits Category
post-event interview	C90	TMC reported that while most of the weather today was of the air mass variety, there was a larger cluster that formed over southern Wisconsin and tracked into C90. RCWF tracked this very well and the users at C90 watched this closely. They expected to have to implement a ground stop for ORD. The users monitored the situation and noted that RCWF forecasted the weather to stay off ORD. As a result, ORD was switched to a configuration that utilized runway 27, allowing them to keep arrivals flowing as the weather passed nearby. The TMC said CIWS helped them keep arrivals going much longer than they would have otherwise. While the AAR did drop, the arrivals were never stopped completely.		5, 8, 9
post-event interview	ZOB	The TMU used CIWS extensively to manage reroutes and restrictions. All SDs at all locations in the Center were used heavily throughout the day.		3
post-event interview	N90	At 1915, it was noted that there was no growth on a cell west of COATE/J36. This route was closed due to thunderstorms. Noting the Storm Motion of only 15kts and the fact there was no growth trend, N90 called ZNY and requested a pathfinder for that route. About 45 minutes later, ZNY approved the pathfinder, which went out over GAYEL around 1950--an adjacent route. It is estimated that the request for the pathfinder would have been made one hour later if CIWS had not been consulted.		1, 12, 13

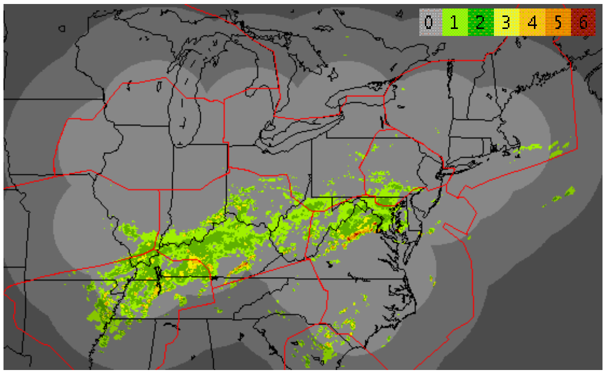
BENEFITS CATEGORY SUMMARY
BLITZ 5:
8/3 /03 – 8/6/03

	ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	SCC
Keeping routes open longer and/or reopening closed routes earlier	0	1	1	6	3	3	0	1
Closing routes proactively	0	1	0	1	0	0	0	0
Proactive, efficient reroutes	0	6	1	2	1	0	0	2
Shorter/fewer ground stops	0	0	2	2	0	1	0	0
Ground Stop avoided	0	0	0	0	1	0	1	0
Reduced Miles in Trail (MIT) restriction	0	0	0	0	1	0	0	0
Traffic directed through gaps in weather	0	1	0	0	0	1	0	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	0	5	1	0	1	3	2	0
Optimization of runway usage; enhanced runway planning	0	1	0	0	0	0	1	0
Improved use of GDPs	0	0	0	0	0	0	0	0
Greater departures during SWAP	0	0	0	1	1	1	0	0
Directing pathfinders	1	0	1	1	2	1	0	0
Interfacility Coordination	0	5	3	3	0	6	0	2
Improved safety	0	1	0	0	1	1	0	0
Reduced workload	0	2	2	3	1	2	0	0
Situational awareness	0	7	7	8	3	21	0	1
Dates Visited	8/3	8/3 – 8/6	8/4	8/5	8/4 – 8/5	8/3 – 8/5	8/3 – 8/6	8/3

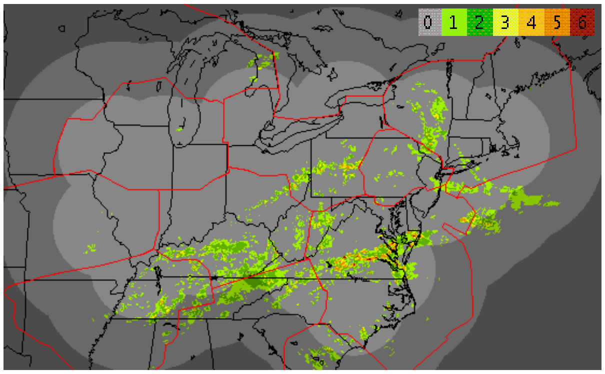
Blitz 6: 2-4 September 2003

Facilities Visited: ZID, ZOB, ZDC, ZNY, ZBW, ATCSCC, FedEx

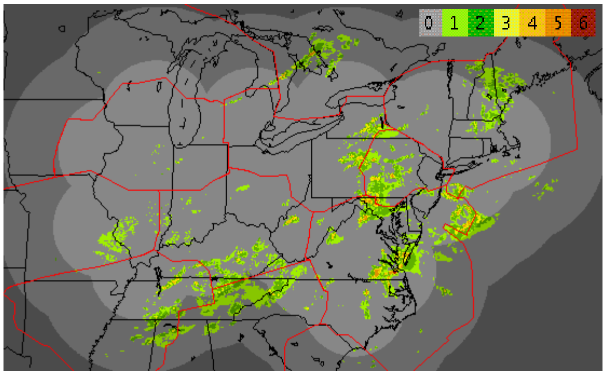
Examples of CIWS NEXRAD VIL Precipitation During Blitz 6:



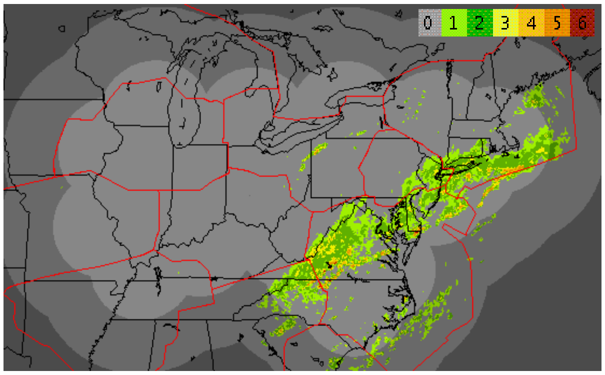
02 September 2003, 2100 UTC



03 September 2003, 1900 UTC



04 September 2003, 0100 UTC



04 September 2003, 1700 UTC

CIWS Benefits Assessment
BLITZ #6
Day 1 - September 2, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1400	ZID	A line of weather stretches east-west along and south of the Ohio River. Echo Tops are below 35kft and mostly below 30kft. Weather is moving northeast at 25 to 30 knots. Aircraft are deviating at 33kft and below but no major reroute is in effect. CIWS was used for situational awareness.	Echo Tops, NEXRAD VIL, Storm Motion	16
1510	ZID	STMC used CIWS to prepare for SPO.	Echo Tops, NEXRAD VIL, Storm Motion, RCWF	16
1515	ZID	STMC repeatedly consulted CIWS throughout the SPO to assess echo tops on J6/J42 and movement of weather onto J42.	Echo Tops, NEXRAD VIL, Storm Motion, RCWF	13, 16
1515	SCC	User consulted CIWS during SPO when ZME expressed concerns about about weather forecasted by CCFP around 19Z and when ZID talked about keeping flow moving because echo tops were low.	Echo Tops, Storm Motion, RCWF	13, 16
1655	ZID	Aircraft deviating on J6 and J89. TMC is trying to work out a north-south route around the weather. STMC contacted ZME to suggest taking traffic down J29 but ZME declined.	Echo Tops	
1715	ZID	Weather in ZME (BNA shows tops to 40kft and growth). Weather in ZID not as severe. ZME may have trouble delivering traffic to ZID. STMC trying to figure out where to take traffic.	Echo Tops, NEXRAD VIL, Storm Motion, RCWF, Growth and Decay Trends	16
1715	SCC	ZID referenced echo tops on SPO.	Echo Tops	13
1730	ZOB	Weather impacting J34 and J162 inbound to ZDC and J518/J211 outbound. CCFP did not forecast this impact.	NEXRAD VIL, Echo Tops, Storm Motion, RCWF.	16
1810	ZOB	STMC used CIWS for hand-off briefing.	All products	16

BLITZ #6, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1815	ZDC	Low-topped level 3 weather is near J149. Some aircraft are deviating. The STMC consulted CIWS to assess echo tops and cell strength. STMC decided not to implement restrictions on traffic.	NEXRAD VIL, Echo Tops, Storm Motion	6
1815	ZDC	Strong storms building along J48. STMC consulted CIWS and determined that a SWAP was needed. Traffic was swapped to J75 up to Montebello.	RCWF, NEXRAD VIL, Echo Tops, Storm Motion	3, 15
1900	ZOB	Storms in ZDC are remaining south of the DC metro airports, allowing ZOB traffic to flow. STMC monitoring weather situation. If J34/J162 are closed, ZOB will have to hold in their airspace.	NEXRAD VIL	16
1915	SCC	ZID again referenced echo tops on SPO and indicated that the current plan looks good.	Echo Tops	13
1930	ZDC	Weather now building on J75 and traffic needs to be moved. STMC used CIWS to decide to move traffic onto J48 and then west of the weather.	RCWF, NEXRAD VIL, Echo Tops, Storm Motion	3
1940	ZOB	TMC used CIWS to determine where storms would be over the next hour. ZID is moving ZDC inbound traffic into ZOB. If IAD closes, ZOB will have to hold.	NEXRAD VIL, RCWF	13, 16
1945	ZID	Weather sinking south. ZID is trying to open J134 to offload J80. STMC quoted CIWS to ZME STMC to convince ZME to open J134/FLM. ZME asked for a pathfinder to confirm that the route is open. ZID passed request for pathfinder to SCC SevWx and ZDC. It was decided that ZID internals would act as pathfinders.	Echo Tops, NEXRAD VIL, Storm Motion, RCWF	12, 13
1950	ZDC	An east-west line of weather is building in central ZDC. Problems are occurring with IAD arrivals from the south. STMC is contemplating bringing traffic along J213, but is cautious due to building weather in that area.	NEXRAD VIL, Echo Tops, Storm Motion, Growth and Decay Trends	13, 16
2020	ZID	Pathfinders report that route is open. With J134 open, J80 may be opened to traffic being routed through ZOB and ZAU.		1

BLITZ #6, Day 1 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2032	ZOB	J60 and J64 closed for ZNY inbound/outbound traffic.		
2115	SCC	ZDC referenced Storm Motion and Echo Tops products on SPO. ZID referenced echo tops.	Echo Tops, Storm Motion	13
2140	ZDC	East-west line persists across ZDC. TMU is considering a reroute further east along the coast but weather is moving into that area. TMC used CIWS for situational awareness.	All products	16
2220	ZDC	NY traffic currently deviating to the east off J209 and into MOA. MOA is currently free and RCWF indicates that weather will not impact the MOA for 60 minutes, but MOA will become unavailable due to military activity in 15 minutes. STMC called SCC to see if SCC could work out something with the military to allow ZDC to use the MOA airspace.	RCWF, NEXRAD VIL	16
2306	ZID	J6 opened as a direct result of using CIWS products. All tops are below 35 kft.	Echo Tops	1
2310	ZDC	A gap in the weather has formed on J75 and traffic is starting to flow there. CIWS was used for situational awareness.	All products	16
2320	ZDC	MOA no longer being used by the military so ZDC is using the airspace for offshore reroutes. STMC used CIWS to determine when normal routes could be reopened.	NEXRAD VIL, Growth and Decay Trends	16

CIWS Benefits Assessment

BLITZ #6

Day 2 - September 3, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1240	ZOB	Storms are developing along the ZOB/ZNY border with tops to FL320. TMU using CIWS to monitor the weather.	RCWF, NEXRAD VIL, Growth and Decay Trends, Storm Motion	16
1310	ZDC	STMC used CIWS to monitor weather impacting FLUKY and HAFNR fixes.	NEXRAD VIL, Growth and Decay Trends, Storm Motion, Echo Tops	16
1315	ZOB	SPO: STMC requested CAN1 be added to the plan for EWR inbound traffic based on CIWS information.	RCWF, NEXRAD VIL	13, 15
1400	ZDC	ESP TMC used CIWS to monitor NY arrivals.		16
1400	ZOB	TMU concerned about PHL arrivals. CCFP shows weather clearing by 15Z; CIWS shows weather present until 16Z.	RCWF, NEXRAD VIL, Echo Tops, Storm Motion	16
1425	ZDC	ESP TMC used CIWS to monitor northeast ZDC/SPA	RCWF	16
1430	ZOB	Aircraft are starting to deviate on J152. STMC consulted CIWS to determine that traffic could continue to use the route. Without CIWS, the STMC stated that all PHL traffic would have been moved off the route resulting in 30 to 60 minute delays.	RCWF, NEXRAD VIL, Storm Motion, Echo Tops	1, 15
1510	ZOB	Aircraft on J80 are beginning to deviate. CIWS was used to keep J80 open.	NEXRAD VIL, Storm Motion	1
1545	FedEx	FedEx used CIWS for situational awareness.	Echo Tops, NEXRAD VIL, RCWF	16
1700	ZOB	ZNY/N90 requested that ZOB stagger traffic on NY inbound routes so aircraft are not side-by-side. CIWS was used to determine if the request could be supported.	NEXRAD VIL, Echo Tops	13, 16

BLITZ #6, Day 2 (continued)

Time (UTC)	User	CIWS Applications	CIWS Products Used	Benefits Category
1715	ZDC	STMC used CIWS to assess growth areas and determine a plan. Large area of growth limiting options. STMC offered an option for a northeast playbook route, but widespread growth is limiting options. STMC referenced CIWS Growth and Decay on the SPO. SCC offered BKW as a solution and STMC assessed this suggestion using CIWS.	NEXRAD VIL, Growth and Decay Trends, Storm Motion, Echo Tops, Lightning	13, 16
1715	SCC	SPO: Storms are beginning to grow in VA. ZDC is running out of room to run north-south traffic and thinking of implementing a ground stop for DC metro airports. SCC users consulted CIWS frequently throughout the conversation.	Echo Tops, Storm Motion	13, 16
1725	ZDC	TMC and STMC used CIWS for situational awareness. ZJX, ZTL, and ZMA are ground stopped for the DC metro airports.	NEXRAD VIL, Growth and Decay Trends	16
1735	ZDC	TMC at NY position wanted to be more aggressive about moving traffic but CIWS showed widespread growth and training of weather. Flow was not changed. In this case, CIWS may have avoided future reroutes that may have resulted from a more aggressive plan.	NEXRAD VIL, Growth and Decay Trends	15, 16
1800	ZOB	ZDC worked with ZOB to move northbound traffic over BKW and between the lines of storms in VA and PA. CIWS was used to examine Storm Motion and Forecast.	NEXRAD VIL, RCWF	7, 13
1820	ZOB	ZNY asked ZOB to put EWR and LGA traffic in a single stream. ZOB STMC used CIWS to convince ZNY to accept two streams with 20 to 30 MIT restrictions.	NEXRAD VIL, RCWF, Echo Tops, Growth and Decay Trends	6, 13
1826	ZOB	Weather impacting PIT arrivals and CUTTA closed. CIWS was used to determine which fix PIT traffic would use.	NEXRAD VIL, Storm Motion	8, 13

BLITZ #6, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1828	ZOB	TMC working Route Control position is trying to keep J60 open but is concerned about increasing echo tops. TMC used CIWS to devise a plan to move NYC departures to J36 and J6 but keep J60/J64 open as one route as long as NY would send them.	Echo Tops, Storm Motion, RCWF, NEXRAD VIL	1, 3, 13
1830	ZDC	DAILY departures are stopped for DCA because planes are deviating into restricted airspace. STMC used CIWS to determine if MOL swap is feasible and takes aircraft west of the weather.	NEXRAD VIL, Growth and Decay Trends	16
1910	ZOB	TMC using CIWS products to keep traffic on J152 moving longer.	Storm Motion, Echo Tops, RCWF, NEXRAD VIL	1
1915	SCC	SPO: Northwest Airlines referenced CIWS during the SPO because of concern about route overload.		13, 16
1915	ZOB	SPO: SCC asked if J60/J64 would close. ZOB STMC suggested the route remain open with expanded MIT. However, ZNY stopped sending traffic on the route due to deviations in ZNY airspace.		
1920	ZDC	J75 closed and traffic swapped. STMC used CIWS to determine how long J75 would be closed.	NEXRAD VIL, Forecast Contours	16
1920	ZOB	TMC at PIT ESP position used CIWS to plan a reroute into PIT.	RCWF, Storm Motion	3, 8
1924	ZDC	J6 closed due to weather. CIWS was used to determine if J6 can be opened earlier.	NEXRAD VIL, Echo Tops, Growth and Decay Trends	16
1945	ZDC	CLT stopped for DC metros. STMC requested and directed 4 CLT pathfinders using CIWS. ZTL agreed. It is unlikely pathfinders would have been sent without CIWS.	NEXRAD VIL, RCWF, Growth and Decay Trends, Echo Tops	4, 12
1950	SCC	CIWS weather is displayed on SCC "big screen".		
2000	ZOB	CIWS used to help determine when routes will open.	RCWF	15, 16

BLITZ #6, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2015	ZDC	In an effort to open WHITE/WAVEY/OOD, the Area Sup sends six pathfinders to each fix. STMC consulted CIWS to assess the weather at those fixes.	Echo Tops, Lightning	1, 12
2030	SCC	Stand-up briefing in the weather unit. Very high praise given to ZDC for "aggressive" traffic movement. CIWS was used frequently in the Areas.	Echo Tops, Storm Motion	
2030	FedEx	Thunderstorms are present in the DC area. FEDEX GOC used CIWS to monitor the movement and growth of the weather in the DC area.	Growth and Decay Trends, RCWF	16
2030	ZOB	TMC used CIWS to plan what to do to keep traffic flowing into NY metro airports.	NEXRAD VIL, Storm Motion, RCWF, Echo Tops	16
2032	ZOB	ZOB having difficulties. J60 and J64 closed by weather.		
2040	ZOB	Storms continue to decay as they track into ZNY airspace. STMC and RC position continue to monitor the storms to open J60/J64.	RCWF	16
2105	ZDC	Area requested 20 MIT on J6 for EWR. STMC checked CIWS to assess weather situation. Level 3-4 and echo tops 33Kft with growth confirmed the need for the restriction.	NEXRAD VIL, Echo Tops, Growth and Decay Trends	14, 16
2105	ZOB	J60 opened with 15 MIT.	RCWF, Storm Motion, Echo Tops.	
2110	ZDC	STMC used CIWS and warned departure TMC to start planning for the loss of J211/J518. STMC then warned other TMCs that ZOB departures to PCT would soon be impacted.	NEXRAD VIL, RCWF, Growth and Decay Trends, Echo Tops	16
2115	ZDC	Storms are near J6 in northwest ZDC. ZDC STMC called ZOB to warn of impending ground stop. STMC used RCWF contours to suggest the impact should last only 60 minutes.	RCWF	13, 16

BLITZ #6, Day 2 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
2133	ZDC	Area Sup used CIWS to determine if it would be feasible to request a pathfinder from ZNY on J75. ZNY agreed to the request.	NEXRAD VIL, Storm Motion, RCWF, Growth and Decay Trends, Echo Tops.	12
2145	ZDC	STMC used CIWS to note that weather was breaking up and more airspace was poised to open. STMC told TMC to release ZJX and ZMA for BOS up the east coast. Even though weather still existed along the proposed route, the STMC was confident in the CIWS forecast that the route would be clear.	RCWF, Growth and Decay Trends, Echo Tops, NEXRAD VIL, Storm Motion	1, 4
2155	ZDC	In last 15-25 minutes, the ZDC STMC used CIWS for early release of ZJX/ZMA/ZTL traffic to PHL/ZBW (3-4 different decisions). The STMC estimated that by the time the traffic reached central ZDC, the route would be clear. He stated that without CIWS, the PHL ground stop would have remained in effect longer.	RCWF, Growth and Decay Trends	4
2200	ZDC	A small line of weak cells is located near the ZID/ZDC border in WV. ZID called ZDC to request a reroute. The TMC used CIWS to note that cells were dissipating. The reroute was denied in anticipation that the deviations would soon stop.	NEXRAD VIL, Echo Tops, Growth and Decay Trends	1, 13

CIWS Benefits Assessment

BLITZ #6

Day 3 - September 4, 2003

Time (UTC)	*User*	*CIWS Applications*	*CIWS Products Used*	*Benefits Category*
1220	ZBW	TMC used CIWS for situational awareness. Weather impacting all routes through NY and VA.	Echo Tops	16
1307	ZBW	TMC and STMC referenced CIWS to assess the weather situation for BOS, which is experiencing delays. BOS is currently clear.	ASR	16
1336	ZBW	TMC asked CWSU to explain weather approaching BOS using CIWS.	NEXRAD VIL, RCWF	16
1414	ZBW	STMC used CIWS for general awareness.	NEXRAD VIL, RCWF, Echo Tops	16
1430	ZNY	Showers and storms from NYC west and south through Trenton down to DC. CIWS was used to estimates when weather would clear affected routes.	RCWF	16
1453	ZBW	STMC used CIWS to close a route. Tops along the route were 48kft and there was not room to deviate.	Echo Tops, NEXRAD VIL	2, 14, 15
1500	ZNY	ZNY used CIWS to work out a route to insure that aircraft were on J80 before they entered ZOB airspace. ZNY rerouted traffic off J64 and back onto J80. ZNY sent 2 pathfinders to Harrisburg-Indian Head to see if the route is viable.	Echo Tops, RCWF	1, 3, 12
1501	ZBW	Used CIWS to determine if aircraft can get above weather.	Echo Tops	16
1502	ZBW	STMC and TMC using CIWS to monitor weather on J121/J174. Watching tops closely on storms impacting J121/174. Tops currently at 42kft. Hoping to use echo tops to reopen route, but concerned that high tops to west will impact route soon.	Echo Tops	16
1510	ZNY	Used CIWS to determine that J230 is an alternate route for WAVEY.	Echo Tops, RCWF	3

BLITZ #6, Day 3 (continued)				
Time (UTC)	***User***	***CIWS Applications***	***CIWS Products Used***	***Benefits Category***
1530	ZBW	J121/J147 open now.	Echo Tops, NEXRAD VIL, Storm Motion	1
1540	ZNY	Used CIWS to open GREKI for LGA westbound long-haul reroute. Departure delays decreasing.	Echo Tops, RCWF	11, 13
1556	ZBW	STMC used CIWS to assess weather west of J121. Closing the route based on CIWS information.	NEXRAD VIL, Echo Tops, Storm Motion, RCWF	2, 15
1617	ZBW	Used CIWS to determine if an aircraft that was already on the route would be able to pick a way through. (Pathfinder)	NEXRAD VIL, Echo Tops, Storm Motion	12
1625	ZBW	STMC used CIWS to assess echo tops on the route navigated by the pathfinder. Decided to open the route to aircraft at and above FL350. Route was expected to be closed until 1800Z.	Echo Tops	1
1715	SCC	SPO: ZID reported CIWS echo tops during telecon. North-south traffic is OK; east-west is having problems.	Echo Tops	13
2115	SCC	SPO: ZOB referenced CIWS echo tops during telecon. NWA referenced weather on J584/J184.	Echo Tops	13

BENEFITS CATEGORY SUMMARY
BLITZ 6:
9/2/03 – 9/4/03

	ZAU	ZOB	ZID	ZDC	ZNY	ZBW	C90	SCC
Keeping routes open longer and/or reopening closed routes earlier	0	4	2	3	1	2	0	0
Closing routes proactively	0	0	0	0	0	2	0	0
Proactive, efficient reroutes	0	2	0	2	2	0	0	0
Shorter/fewer ground stops	0	0	0	3	0	0	0	0
Ground Stop avoided	0	0	0	0	0	0	0	0
Reduced Miles in Trail (MIT) restriction	0	1	0	1	0	0	0	0
Traffic directed through gaps in weather	0	1	0	0	0	0	0	0
Better management of weather impacts on terminal arrival transition areas (ATAs)	0	2	0	0	0	0	0	0
Optimization of runway usage; enhanced runway planning	0	0	0	0	0	0	0	0
Improved use of GDPs	0	0	0	0	0	0	0	0
Greater departures during SWAP	0	0	0	0	1	0	0	0
Directing pathfinders	0	0	1	3	1	1	0	0
Interfacility Coordination	0	7	2	4	1	0	0	8
Improved safety	0	0	0	1	0	1	0	0
Reduced workload	0	3	0	2	0	2	0	0
Situational awareness	0	10	4	17	1	6	0	3
Dates Visited		9/2 – 9/3	9/2	9/2 – 9/3	9/4	9/4		9/2 – 9/4

APPENDIX F

MODEL FOR BENEFITS OF AVOIDED DIVERSIONS IN CIWS DOMAIN

The modeling of diversions has not been treated extensively in the literature. The FAA office of policy and plans [APO, 1983] suggested using 1.5 hours of delay for diversions. The addendum in Jenkins and Cotton [2002] contains the following diversion cost calculation for narrow-body aircraft:

Passenger Cost: 100 passengers @ $82 per person = $8,200

* Hotel room:	$65
* Meals:	$15
* Phone:	$ 2

Airline Operating Cost per Hour: $2,635

Lost Opportunity Cost - Revenue Lost: $10,000

Revenue Lost from Diverted Flight to other airlines: $1,500

So, using these metrics for statistical input, the Jenkins/Cotton models yield a cost per diversion (narrow-body) of $22,335.

A key difference between these two models is the assumption in Jenkins/Cotton that the diverted flight cannot get to the intended destination that day. As a result, passengers must be put in a hotel that night and, some of the passengers would continue on other airlines at the expense of the airline whose plane was diverted.

Since neither of these models directly speak to the situation encountered in the CIWS domain in 2003 where there is significant congestion such that a diverted flight might not be able to take off as soon as it were refueled despite concerted efforts within the CDM program to improve the handling of diversions.

Hence, we opted to develop a specific model to address the particular situation on the 4 April 2003 where 11 aircraft avoided diversions through ATC use of the CIWS products.

The model is as follows:

a. travel time associated with landing and taking off plus taxi in and taxi out at diversion airport: 30 minutes

   This based on a study of the difference between Southwest travel times for one stop versus nonstop flights and, arrival/departure times at the intermediate airport. A similar value was found for a United Airlines nonstop from SFO to BOS compared to a one stop through DEN. Comparison of an American nonstop from SFO to BOS compared to a one stop through STL suggested 1 hour additional flying/taxi in/taxi out time. In the case of the American flights, the nonstop was a 757 and the one stop was a M83, so the flight time difference may reflect aircraft performance. Since the Southwest flights were the same aircraft type, we have chosen to use the Southwest derived estimate.

b. ground time at diversion airport: 60 minutes

This depends on the availability of a gate and refueling capability at an airport. We obtained estimates from a number of airlines. Since a diversion would be an irregular operation, handling in general would not be as rapid as with a scheduled arrival and departure. The times could be as short as 30 minutes in highly favorable conditions; however, 60 minutes was much closer to the median answer.

a. ground time at diversion airport due to congestion on 4 April near the time of adverted diversions: 138 minutes

The flights that avoided diversions were east coast flights to ORD. We looked at the delays to ORD for scheduled flights departing between 7 pm and midnight from CLE and CMH. The average delay for the 5 flights was 138 minutes and the median delay was 170 minutes. We used the average delay to be conservative.

Adding these three contributions, we obtain a total direct delay of 228 minutes. Applying the economic values of airline and passenger cost used elsewhere in the study, we obtain

total direct delay=	**228**	**minutes =**		**3.8**	**hours**
downstream delay				**3.04**	**hours**
DOC for additional air time			**$**	**1,318**	
DOC for ground time at diversion airport				**5,217**	
Total DOC				**6,535**	
passenger (p)=			**$**	**8,261**	
passenger (d)=			**$**	**6,609**	
Total per flight			**$**	**21,405**	
Total for 11 flights			**$**	**235,455**	

In the calculations of airline direct operating cost, we assume that the 30 minutes of additional flight time has a cost of $ 2635 per hour. However, the time spent on the ground at the diversion airport refueling and waiting until a departure slot was available was assigned an economic value that is 60% of the airborne cost.

GLOSSARY

ACC	Area Control Center
ACE	Airport Capacity Enhancement
AD	Arrival/Departure rates
ADAS	Automated Weather Data Acquisition System
AFSS	Automated Flight Service Station
AP	anomalous propagation
ARTCC	Air Route Traffic Control Center
AR	Atlantic Routes
ASIS	ASR-9 Serial Interface System
ASR-9	Airport Surveillance Radar -Model 9
ATA	arrival transition areas
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATM	air traffic management
ATO	Air Traffic Organization
ATOP	Advanced Technologies & Oceanic Procedures
AW	Airport weather conditions
BDL	Bradley, CT Airport
BOS	Boston, MA Logan International Airport
C90	Chicago TRACON
CAPE	Convective available potential energy
CCFP	Collaborative Convective Forecast Product
CDM	Collaborative Decision Making
CIWS	Corridor Integrated Weather System
CLE	Cleveland TRACON
CMR	Composite Maximum Reflectivity
COTS	Commercial Off-the-Shelf
CRAFT	Collaborative Radar Acquisition Field Test
CTAS	Center-TRACON Automation System
CVG	Cincinnati TRACON
CWSU	Center Weather Service Unit
DDST	Dispatch Decision Support Tool
DOC	direct operating cost
DOTS	Dynamic Ocean Tracking System
DSR	Display System Replacement
DSS	Decision Support System

DTW	Detroit, MI Metropolitan Airport
ETMS	Enhanced Traffic Management System
EW	En route severe weather
EWR	Newark, NJ International Airport
FAA	Federal Aviation Administration
FedEx	Federal Express
FIS	Flight Information Services
FL	Flight level
GA	General Aviation
GDP	Ground Delay Program
GOES	Geostationary Operational Environmental Satellite
IOC	Initial Operational Capability
ITWS	Integrated Terminal Weather System
JFK	John F. Kennedy International Airport
LAHSO	Land and Hold Short Operations
LDM	Local Data Manager
LGA	LaGuardia, NY International Airport
LL	Lincoln Laboratory
LOU	Louisville Airport (Bowman Field)
MHT	Manchester, NH Airport
MIAWS	Medium Intensity Airport Weather System
MIT	Miles-in-trail
MSP	Minneapolis, St. Paul International Airport
N90	New York TRACON
NAS	National Airspace System
NCWF	National Convective Weather Forecast
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
NWS	National Weather Service
OEP	Operational Evolution Plan
OIS	Operational Information System
ORD	Chicago O’Hare International Airport
PCT	Potomac TRACON
PHL	Philadelphia TRACON
PIC	Pilot In Command
PIT	Pittsburgh TRACON
PVD	Providence, RI Airport
PWM	Portland, ME International Jetport
RAPT	Route Availability Planning Tool

RCWF	Regional Convective Weather Forecast
SD	situation display
SFO	San Francisco International Airport
SLEP	Service Life Extension Program
SOC	Systems Operations Center
SPT	Strategic Planning Team
STMC	Supervising Traffic Management Coordinator
SWAP	Severe Weather Avoidance Plan
TCWF	Terminal Convective Weather Forecast
TDWR	Terminal Doppler Weather Radar
TEB	Teterboro, NJ Airport
TFM	Traffic Flow Management
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
UPS	United Parcel Service
UTC	Coordinated Universal Time
VIL	Vertically Integrated Liquid Water
WARP	Weather and Radar Processor
WSI	Weather Services, Inc.
WSP	Weather Systems Processor
ZAU	Chicago ARTCC
ZBW	Boston ARTCC
ZDC	Washington ARTCC
ZFW	Fort Worth ARTCC
ZID	Indianapolis ARTCC
ZJX	Jacksonville ARTCC
ZKC	Kansas City ARTCC
ZME	Memphis ARTCC
ZMP	Minneapolis ARTCC
ZNY	New York ARTCC
ZOB	Cleveland ARTCC
ZTL	Atlanta ARTCC

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