Project Report
ATC-433

Report on the 2016 CoSPA and Traffic Flow Impact Operational Demonstration

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16. Abstract

This technical report summarizes the operational observations recorded by MIT Lincoln Laboratory (MIT LL) aviation subject matter experts during the period 1 June to 31 October 2016. The MIT LL observation team visited three Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCC) and the Air Traffic Control System Command Center (ATCSCC) on three separate convective events covering four days during the summer of 2016. Five commercial airlines were also involved in the observations. Specifically noted were the utilization of the deterministic convective weather forecasting model, Storm Prediction for Aviation (CoSPA), and a newly developed decision support application, Traffic Flow Impact (TFI). These field evaluations were supported via the FAA AJM-334 program.

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EXECUTIVE SUMMARY

This technical report summarizes the operational observations recorded by MIT Lincoln Laboratory (MIT LL) aviation subject matter experts during the period 1 June to 31 October 2016. The MIT LL observation team visited three Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCC) and the Air Traffic Control System Command Center (ATCSCC) on three separate convective events covering four days during the summer of 2016. Five commercial airlines were also involved in the observations. Specifically noted were the utilization of the deterministic convective weather forecasting model, Storm Prediction for Aviation (CoSPA), and a newly developed decision support application, Traffic Flow Impact (TFI). These field evaluations were supported via the FAA AJM-334 program.

TFI was developed to leverage long-range strategic weather forecasts and address a current shortfall in strategic planning. TFI provides explicit translation of convective weather forecasts into resource constraints for traffic managers. The display builds upon the CoSPA deterministic decision support tool and is a true multi-model, ensemble forecast that also provides a dynamic measure of forecast confidence.

Without explicit translation there is a lack of an operationally relevant methodology to quantify weather forecast resource impact and overall forecast performance. Successful strategic planning also relies on the experience of traffic managers involved in Traffic Management Initiative (TMI) planning. Uncertainty in decision-making for air traffic managers is inevitable, however managing uncertainty and quantifying the risk of each decision is an area of research where CoSPA and TFI are focused.

The observations, benefits, and comments collected from the air traffic management community during the 2016 convective season are briefly summarized below. A full description, including detailed operational benefit case studies and the results from a season-end survey, are explained in the body of this report.

- The 2016 season was the third convective season that TFI was exhibited at the ATCSCC and the second season to Collaborative Decision Makers (CDM) across the National Airspace System (NAS).
- More than 200 hours of in situ observations were taken and 122 separate overall traffic management benefits (42 attributed to TFI) were documented during the four observation days.
- Feedback from the user community remained positive, with several users providing specific comments in an end of season survey including:
    - Application was easy to use and understand
    - TFI was helpful during operational impacts

- TFI was helpful in facilitating discussion during TMI planning

- Several specific operational benefits were also highlighted during the observations including:
    - Improved Traffic Management Initiative Planning and
    - Improved Airspace Flow Program (AFP) Execution/Management

- Users stressed the importance of further development and the need for continued evaluation of the decision support tool within the operational environment. Most of these requests related to the graphical user interface with graphical changes that would allow more efficient use of the tool during convective events. There were also requests to add TFI Flow Constrained Areas to other regions of the NAS around traditionally challenging sectors of airspace.

ACKNOWLEDGEMENTS

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To Thomas Webster, CoSPA Program Lead during the 2016 observation period, for supporting this program and for his guidance and enthusiasm.

To Anthony Tisdall, Lead of System Operations at Air Traffic Control Systems Command Center, for allowing MIT LL observers access to the operations floor at the ATCSCC and his very knowledgeable staff of traffic management personnel.

To the Traffic Management Officers at Boston, Cleveland, New York, and Washington DC Air Route Traffic Control Centers for allowing access to the facilities and the Traffic Management Unit (TMU) staff.

To the TMU staff at these Centers for giving generously of their time and expertise to help us understand and document the decision-making process.

To the management at Delta, JetBlue, American, United, and Southwest Airlines for allowing MIT LL observers into their facilities and providing access to their staff. Also to the air traffic control staff at these airlines for sharing their insights into the decision-making process.

To the other MIT LL observers (Darin Meyer, Brad Crowe, Richard Ferris, Fulvio Fabrizi, and Peter Erickson) whose many long hours of documentation and analysis made this report possible. Also to Kim Calden, Jim Evans, and the entire Air Traffic Control Systems Group Office, who provided critical managerial advice and program support throughout the entire observation process.

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TABLE OF CONTENTS

TABLE OF CONTENTS
CONTINUED

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
CONTINUED

LIST OF ILLUSTRATIONS
CONTINUED

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LIST OF TABLES

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1. INTRODUCTION

The 2016 Storm Prediction for Aviation (CoSPA) Demonstration was conducted from 1 June to 31 October 2016. As part of the demonstration, Federal Aviation Administration (FAA) facilities and commercial airlines were visited by MIT Lincoln Laboratory (MIT LL) observers, including initial training visits. Targeted field observations were conducted by MIT LL observers to gather information on how the CoSPA weather forecast was used in operations, to obtain feedback on new capabilities, and to collect comments for improvement. During the field demonstration, the 0- to 8-hour CoSPA VIL (Vertically Integrated Liquid Water) and ET (Echo Tops) forecasts were available via web to all registered users through the dedicated website http://cospa.wx.ll.mit.edu and, for the first time since 2011, CoSPA was available on the Corridor Integrated Weather System (CIWS) Situation Displays (SDs). Multiple requests from users over the past four years prompted the return of CoSPA to these dedicated displays.

Given the importance of convective forecasts to air traffic management in the New York Metroplex and across the eastern National Airspace System (NAS) in general, MIT LL subject matter experts conducted field observations on days when storms were forecast to develop across the eastern United States and potentially create an imbalance between demand and the usable capacity for enroute and terminal airspace in the northeast United States. The MIT LL observation team gathered data from three separate convective events covering four days (27–28 June, 14 July and 16 August).

MIT LL observers visited three FAA Air Route Traffic Control Centers (ARTCC) and the Air Traffic Control System Command Center (ATCSCC); all are considered the “main players” in the strategic planning process. The ARTCCs included Boston Center (ZBW), Washington DC Center (ZDC), and Cleveland Center (ZOB). New York Center (ZNY) was initially trained prior to the observations, however the facility was not visited by an observer during the observation days; post-event communications served as a proxy for in situ feedback. Five airlines (Delta, American, United, Southwest, and JetBlue) also participated in the observations.

The main objectives of the 2016 field observation study were to:

- Train and evaluate CoSPA and the Traffic Flow Impact (TFI) [1] decision support application
- Observe and document usage of the TFI application specifically noting:
    - If and how the application is used in strategic planning of Airspace Flow Programs (AFPs);
    - If the addition of Forecast Confidence fulfills the user-requested need for some measure of the accuracy of the 2- to 8-hour deterministic forecast;

- Determine if and how the CoSPA forecast is effectively being used in strategic Traffic Management Initiative (TMI) decision-making;
- Document comments, criticisms, and concerns regarding CoSPA to provide insights on how the application could be improved for decision support;
- Investigate and document user preferences that pertain to current CoSPA capabilities and performance, such as update rate, forecast interval, etc.;
- Document the decision-making process currently employed within traffic management and gain a more in-depth understanding of the process, in order to be able to design and assess potential CoSPA adaptations and improvements;
- Document user suggestions and ideas to help identify unmet needs and define requirements for enhancements to the 2- to 8-hour deterministic forecast.

In addition to the focused observations, refresher training was conducted for existing personnel and training of new FAA traffic managers, as well as airline operations and dispatchers.

1.1 BACKGROUND AND MOTIVATION

The 0- to 8-hour forecast guidance provided by CoSPA addresses key weather impact factors, including intensity of storms, location, scale, permeability[1], and timing (onset, duration, clearing of impact). These factors often determine the type of mitigation needed to offset the adverse effects of weather and can guide planners in the implementation of strategic TMIs such as:

- Playbook reroutes,
- Ground Delay Programs (GDPs), and
- Flow Constrained Areas (FCAs) associated with AFPs.

Before going further, it is necessary to clarify some terminology. An AFP is a TMI that identifies constraints in the enroute system, develops a real-time list of flights that are filed into the constrained area, and distributes Estimated Departure Clearance Times (EDCTs) to meter the demand through the area. FCAs are three-dimensional volumes of airspace, along with flight filters and a time interval, used to

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[1] Permeability is the degree to which airspace that appears to be impacted by convective weather actually is usable by air traffic. Key elements of permeability are the spatial distribution of weather intensity and storm echo tops.

identify flights transitioning the airspace volume. FCAs may be drawn graphically (e.g., around weather), or they may be based on a NAS element such as a Very high frequency Omnidirectional Range/Tactical Aircraft Control (VORTAC) or navigational aid used by pilots. They are used to evaluate demand on a resource. FCAs may be standardized across all facilities for ease of access and to facilitate coordination. FCAs may also be defined in real-time by users.

The FAA has developed several standard or “classic” FCAs (e.g., OB1, A05, A08, etc.) that are used to design AFPs for traffic into the Northeast; these do not change in shape, size, location or filtering criteria. Air traffic users generally refer to these classic FCAs as AFPs, and the same terminology is used in this report to differentiate classic FAA FCAs (now called AFPs) from TFI FCAs. TFI FCAs are static FCAs that are defined within the TFI application and cannot be defined or altered by users. They will be further examined in Sections 3 and 4.

The need for 2- to 8-hour storm forecasts for aviation decision support arises from three key decisions that need to be made: either aircraft must be held on the ground before they depart their origin airport, they must be assigned a different route which entails a longer flight distance, or the aircraft can depart as planned along its filed route. When making these decisions, two important characteristics of flight planning must be considered:

- Airlines are expected to file their flight plans 60 minutes before departure. Airline dispatchers typically begin to plan their flight routes two to four hours prior to departure, especially when weather impacts are expected.

- The overall distribution of domestic flight times for many key airports is such that if significant arrival demand reductions need to be accomplished (e.g., 50% reductions), a number of long duration flights (>4 hours) must be held on the ground.

Most flights are one to two hours in duration (Figure 1), so the weather impact prediction horizon associated with holding flights at their origin airport would be 2.5 to 4 hours, including 1.5 to 2 hours of pre-flight planning. If one assumes a weather impact on airspace capacity duration of about two to four hours, then airline dispatchers and FAA traffic managers need weather forecasts extending out to 4.5 to 8 hours to specify both the start and expected end of a severely constraining TMI.

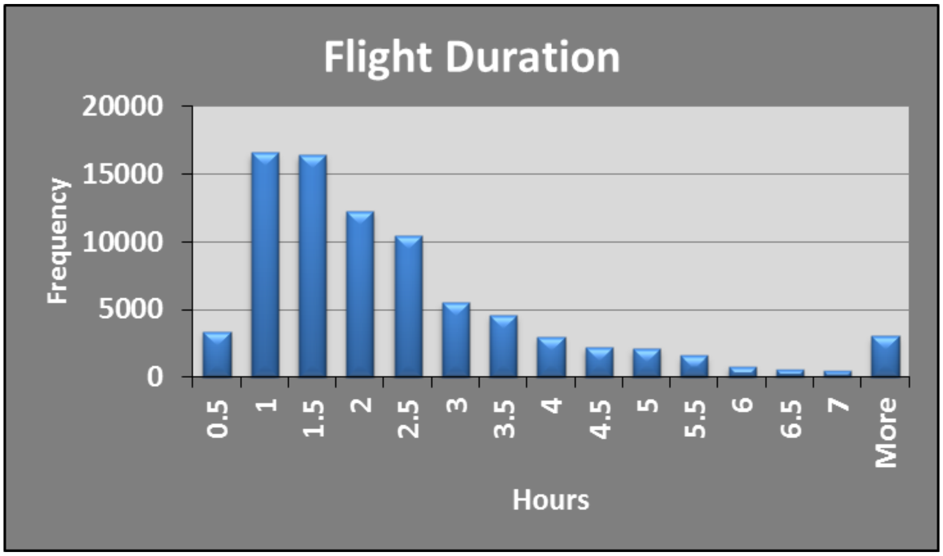

Figure 1. Flight duration (wheels up to wheels down) from five summer days in 2016 (June through August) for all flights (except General Aviation) in the NAS.

The focus for improved strategic convective weather decision support remains in the eastern portion of the NAS, specifically in the "golden triangle" region. This region is defined by the major terminals of New York, Chicago and Atlanta and has a very high density of traffic in enroute airspace (Figure 2), especially centered around New York Terminal Radar Approach Control (TRACON; N90).

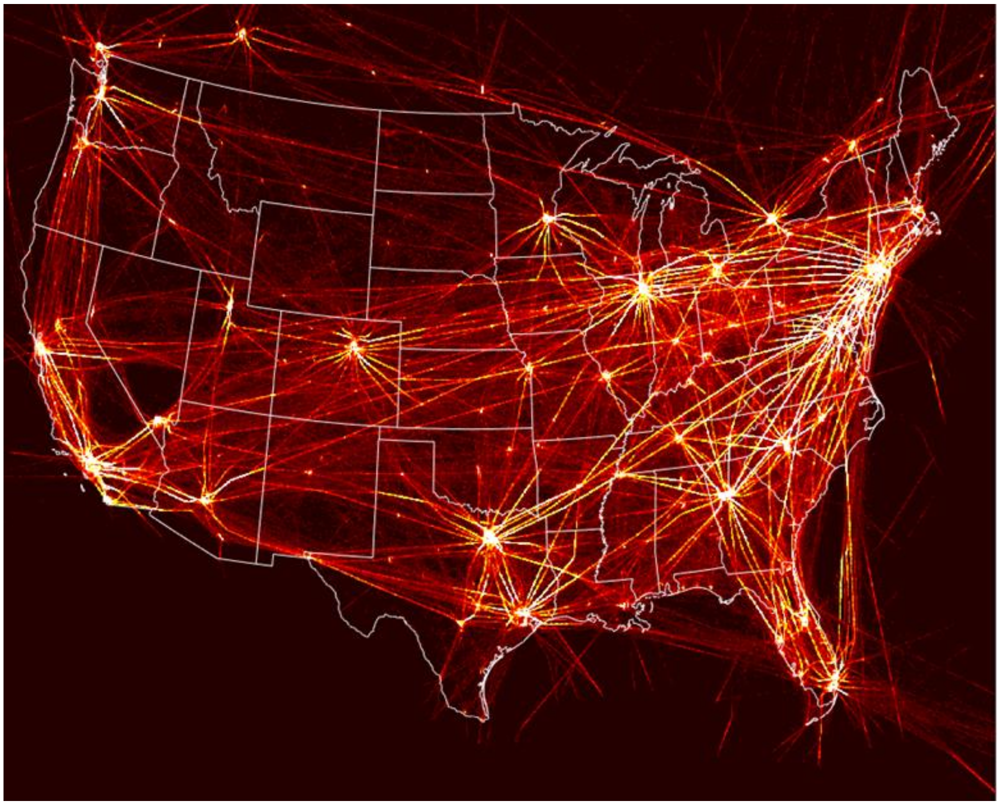

Figure 2. A plot of aircraft density across the NAS spanning the most "active" commercial hours (0900 UTC 18 OCT 2015 through 0400 UTC 19 OCT 2015). There was ***no*** *significant convective weather observed on this example day across the NAS.*

Weather accounts for nearly 70% of all delay in the NAS (Figure 3a). Figure 3b shows the top ten weather-delayed airports for 2016. The EWR, LGA, and JFK airports are combined into the NY3 category; due to airspace constraints, typically when one of these airports is impacted by weather all three suffer delays. The high demand-to-capacity ratio for these major airports, along with the frequency of weather impacts on operations, results in significant weather-related delay in the New York airspace.

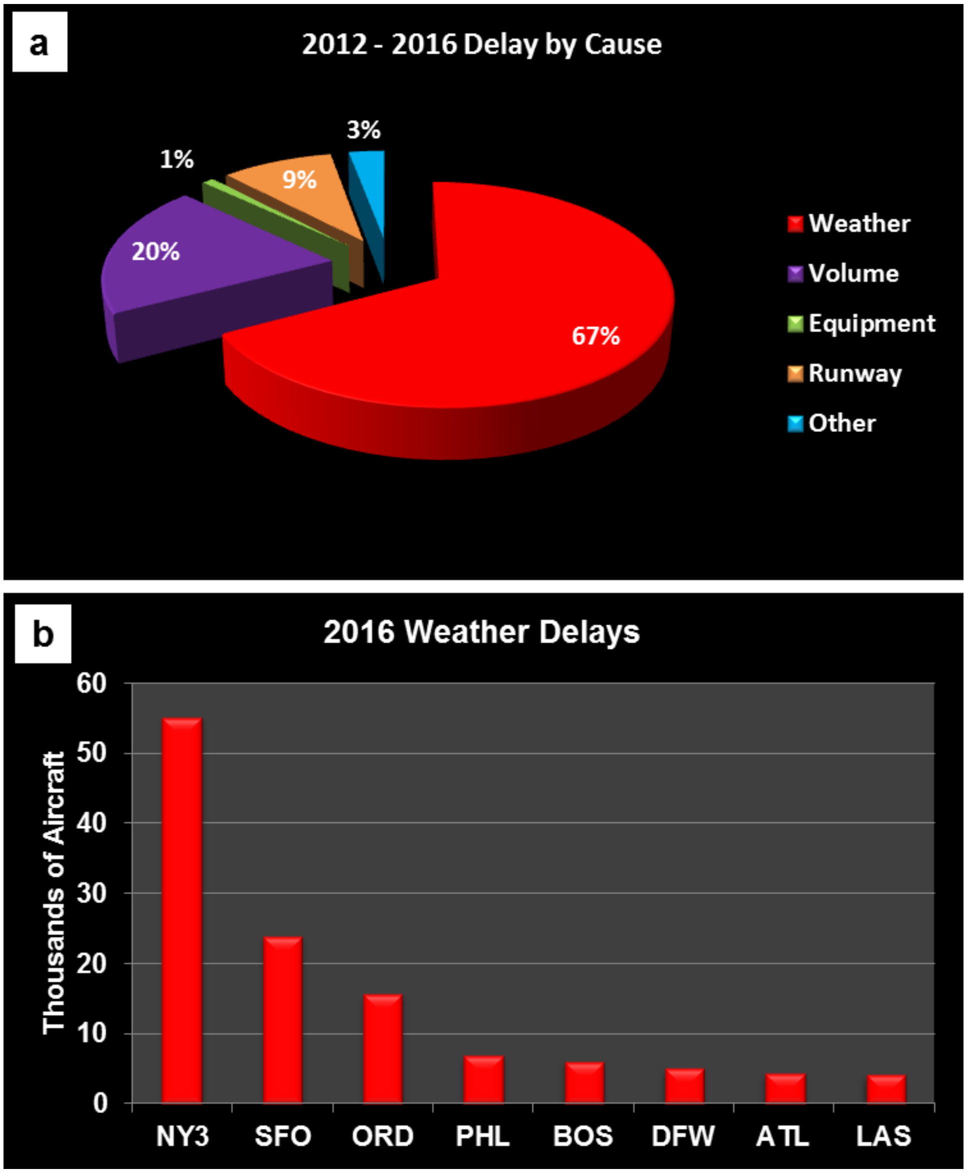

Figure 3. (a) Causes of delayed flights for 2012–2016 and (b) 2016 top weather-delayed airports, derived from the FAA Operations Network (OPSNET) delay data. Note that NY3 is comprised of JFK, LGA and EWR.

Figure 4 provides a breakdown of delays by month for 2016 for each of the three individual major NY terminals, JFK, LGA, and EWR, and for the three combined (NY3).

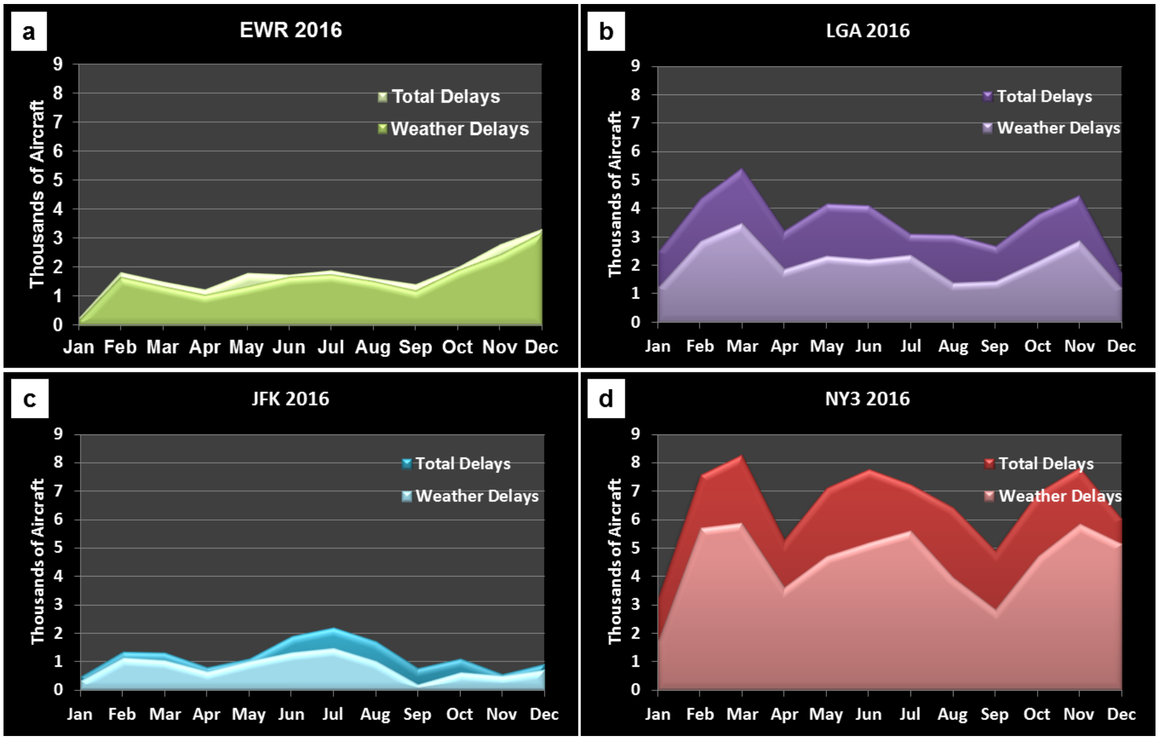

Figure 4. 2016 delay statistics for each of the three major New York terminals, (a) EWR, (b) LGA, and (c) JFK. NY3 (d) represents the combination of the three.

Weather impacts in the Northeast are often handled by traffic initiatives known as Severe Weather Avoidance Planning (SWAP). SWAP requires both strategic and tactical initiatives in order to manage throughput in and around the New York metroplex.

On average, there are 80 SWAP days each convective season (AprilSeptember)[2] during which strategic and tactical traffic management initiatives are issued. During the 2015 and 2016 seasons, an average of about 70 AFPs, 380 GDPs, and 890 ground stops (GSs) were implemented. (Table 1)

[2] Source: FAA 2016 NAS Performance Review/ATCSCC

TABLE 1

Traffic Management Initiative Statistics for 1 April through 30 September[3]

Metric	2015	2016	Average
Total GDPs Issued	375	388	381.5
Total GDP Duration (min)	118,254	134,365	126309.5
Total GSs Issued	865	920	892.5
Total GS Duration (min)	63,573	80,397	71985
Total AFPs Issued	73	61	67
Total AFP Duration (min)	22,297	16,950	19623.5
Arrival Cancellations	41,793	50,525	46159
Departure Cancellations	40,011	47,603	43807

1.2 CURRENT SHORTFALLS IN STRATEGIC PLANNING

Present day air traffic flow management operations use a variety of weather forecast sources to develop the safest and most efficient plan on a daily basis. This weather information consists of both deterministic and probabilistic forecasts that are often interpreted by human forecasters. That interpretation of weather impact in relation to air traffic is then translated into ATC management decisions. However, the explicit and unbiased translation of weather forecasts into capacity resource constraints does not currently exist in today's traffic management arena. There are several consequences of this shortfall. First, without explicit translation there is a lack of an operationally relevant methodology to assess weather forecast resource impact and overall forecast performance. Each participant (e.g., ATCSCC, ARTCC Traffic Management Unit (TMU), and Airline Operations Center) comes to the collaborative strategic planning process with their own set of operational objectives, favorite forecast

[3] Source: 2016 NAS Performance Review-Data includes 1 April through 30 September 2015 and 2016 with 27 airports in CORE.

information, risk tolerance, etc. This wide and often divergent range of opinions and goals must somehow be melded into a plan of action. Without shared objective forecasts of weather impacts and estimates of decision risk, there is little common ground upon which to base discussions about the best plan of action that addresses the different legitimate concerns of stakeholders. Second, the utility of convective weather forecasts is directly related to the quality of decisions and NAS performance outcomes that the forecasts can support. Defining explicit, validated weather translations provides an objective and operationally relevant measure of truth against which forecasts can be compared. Without translation-based forecast evaluations, it is difficult to determine how much of the operational shortfall in convective weather mitigation is due to poor weather forecasts and how much is the result of poor interpretation and application of forecast information.

One of the current strategic TMIs that managers use to mitigate delay is the AFP. The AFP was introduced in the summer of 2006 and marked a new way to manage traffic in enroute airspace during severe weather events. The AFP process was meant to identify constraints in the enroute system using FCAs, and allow for equitable distribution of delay across these FCAs based on historical traffic rate data. Table 2 is an example of the initial rate structure that was developed during the AFP concept release.

TABLE 2

Example of AFP Rates across ZOB ARTCC.

			Throughput Rate for Impact Level:		
AFP Name	Sustained Throughput (No Impact)	Used for Weather Impact on	High	Medium	Low
A05	110	ZOB	65 - 70	70 - 80	85 - 90
A01	115	ZBW/ZNY	70 - 80	80 - 90	90 - 100
OB1	120	ZBW/ZNY/ZDC	80 - 90	90 - 100	100 - 110
BW1	40	ZBW	25	32	35
	OR				
	% Reduction of Actual Traffic		30%	20%	10%

The Flow Evaluation Team (FET), which is a sub-team of the Collaborative Decision Making (CDM) group, was tasked in 2010 to investigate and recommend an FCA capacity estimation[2] which could be applied to the AFP traffic management process. The report identified the top problems within the system. Specifically, the current system:

- Lacks a method to determine practical and achievable capacity and throughput of an FCA;
- Relies on inaccurate historical tables of volume or a simplified averaging calculation;
- Does not take into account any constraints in the system;
- Does not consider airspace complexity; and
- Does not provide an evaluation of risk associated with using different throughput values.

The report further states that "Recent NAS convective weather events and post-event analyses have shown that there is an urgent need to reconsider the guidelines for AFP throughput reductions in the operational concept for setting FCA throughputs." A post convective weather event analysis referenced in the FET report indicated that the estimates used for the major New York metro region traffic flows consistently exceeded the available capacity.

The AFP rates in Table 2 were initially developed in 2006, based on air traffic demand from that period. Only minor modifications to those rates have been made since that time, despite the decrease in total demand over the last ten years. Note that even the "high" impact rates listed in Table 2 only amount to a 30% reduction of the maximum throughput. The FET report concluded that, in order to avoid excessive amounts of unrecoverable delay, throughput rates during high-impact convective events need to be reduced by as much as **50 to 70%** of the sustained throughput rates shown in Table 2. Achieving NAS-wide approval from users (both FAA and airline) for rate reductions of this size is a considerable challenge in the daily collaborative decision making process. The user is being asked to greatly reduce throughput and risk a potentially large amount of unrecoverable capacity based on weather that is not yet impacting operations. Current strategic SWAP requires AFPs to be issued by 14 UTC to 16 UTC, in order to capture enough demand to sufficiently reduce throughput rates. This timeframe is often well in advance of typical thunderstorm development.

1.3 REPORT SCOPE AND OUTLINE

This report provides an overview of the CoSPA and TFI forecast products and documents the results in support of the main objectives stated in Section 1.1. Section 2 describes the field observation process and highlights current operational impacts and recent changes in air traffic management related to the strategic planning process. A detailed explanation of observed CoSPA and TFI benefits is provided in Section 4, along with recorded operational examples. Section 5 details user requests and comments, and presents the findings of a small-scale season-end user evaluation. A final summary and outlook on future CoSPA/TFI work is presented in Section 6.

2. FIELD OBSERVATIONS

2.1 FIELD OBSERVATION PROCESS

Convective multi-day weather forecasts were produced by the MIT LL observation team on a daily basis throughout the summer beginning in April. Each medium range (three- to seven-day) forecast was evaluated in order to determine the potential severity and placement of storms across the NAS, to help plan a field observation. When the forecast indicated the potential for convective weather impact for the northeast United States, the MIT LL observer assigned to a facility reached out to the facility's designated point-of-contact to request permission to visit. MIT LL observers arrived at their respective facility between 1000 UTC (6 AM Eastern) and 1100 UTC (7 AM Eastern) in preparation for, and participation in, the first Strategic Planning Telecon/Webinar (SPT) of the day. They remained at the facility until the end of the weather impact; some nights as late as 0100 UTC (9 PM Eastern). Each observer was at their facility an average of 13 hours per day, totaling approximately 260 hours of in situ observations. Not all airlines and FAA facilities were visited each observation day. Direct communications with FAA and airline operations not visited were made post-event in order to garner feedback on the day's operations and use of the CoSPA and TFI applications.

Observers resided primarily in the TMU or operations area of the facility in order to gather observations on the use of CoSPA and TFI. Observers answered any questions and performed in situ training related to CoSPA, CIWS, and TFI, and answered questions concerning the Integrated Terminal Weather System (ITWS), if requested by Air Traffic personnel and meteorologists. Observers also asked air traffic managers how TMI decisions were made, what information was used to support the decisions, and other questions related to the assessment objectives. Questions were asked only when they did not interfere with the TMU's primary mission of traffic management. To ensure consistency across observers and facilities, each observer used a standardized data-entry sheet to record events in which personnel referred to or otherwise interacted with CoSPA or TFI. Entries included the date, time, user, type of interaction, and notes detailing the context or other stakeholders involved. Benefits results are summarized in Section 4 and are provided in detail in AppendixA. User comments and requests are discussed in Section 5 and shown in more detailed tabular form in Appendix B. Survey results are available in Section 5.3 and Appendix C.

2.2 OBSERVATION DAYS AND MEASURING OPERATIONAL IMPACT

A representative CoSPA VIL image for each of the four 2016 observation days is provided in Figure 5. Thunderstorms were present in various forms and strengths on each day and reduced the throughput across the eastern third of the NAS as a result. Despite differences in size, location, and movement of the storms, the overall synoptic weather pattern featured large scale frontal boundaries that helped to generate the convection each day (Figure 6).

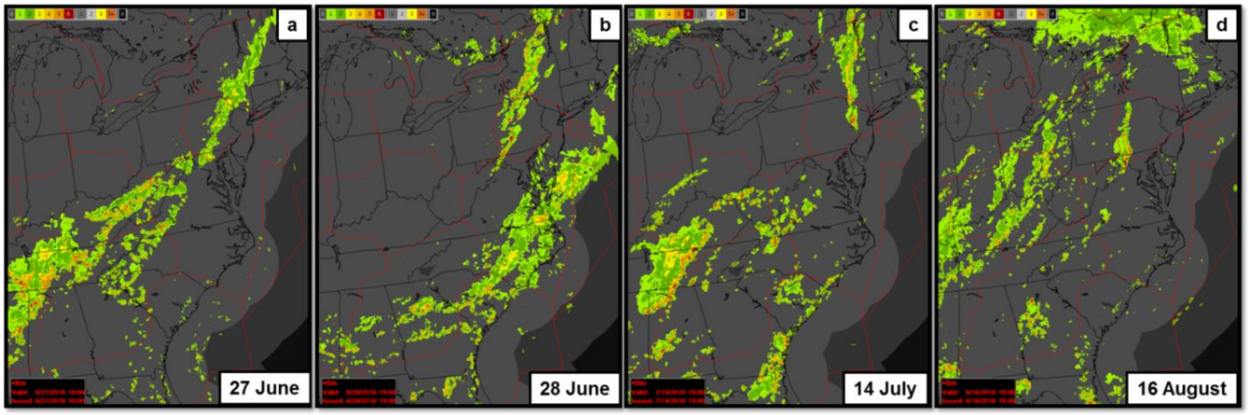

Figure 5. Representative VIL images of each CoSPA observational visit: (a) 27 June, (b) 28 June, (c) 14 July and (d) 16 August 2016.

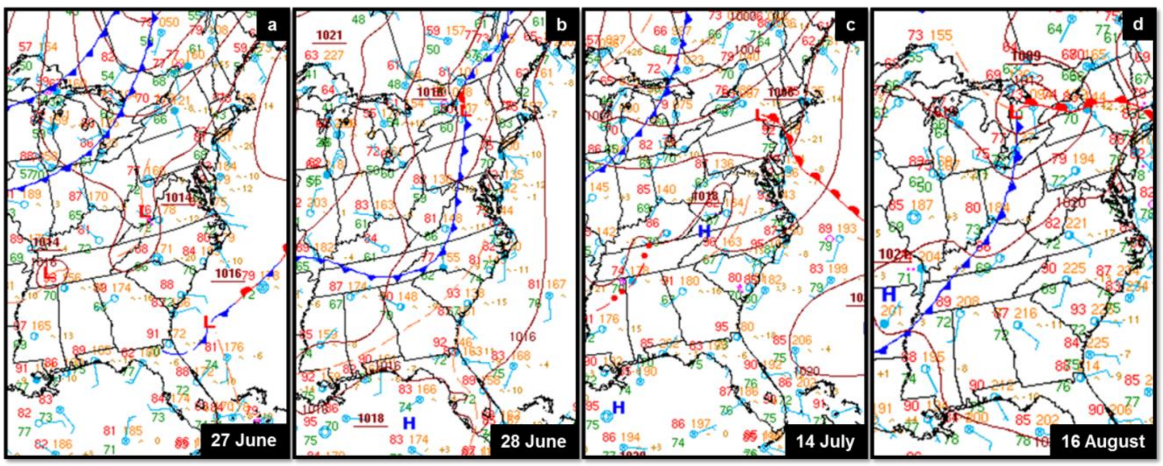

Figure 6. National Weather Service (NWS) 1800 UTC surface pressure and frontal analysis for each observation case day: (a) 27 June, (b) 28 June, (c) 14 July and (d) 16 August 2016.

Meteorologically, each observation day pictured above featured a similar synoptic scale pattern. However, the impact on air traffic and the decisions that were made were very different each day. The complexities of the NAS network along with the unpredictability of individual thunderstorms are the two main contributors to this difference.

TABLE 3 3 provides a brief assessment of each observation day in relation to Air Traffic Control (ATC) impact in the Northeast region of the NAS[4]. Two additional convective weather days are listed in

TABLE 3 3 that were not MIT LL observation case days. The two additional days are provided as a baseline for throughput disruption across the NAS in comparison to the four planned MIT LL observation days. Figure 7 shows the representative VIL images for these two additional days, which are listed among the top most disruptive days during the summer of 2016[5].

TABLE 3

Aviation System Performance Metrics (ASPM)

based on eight core airports in the Northeast NAS

indicating the severity of the impact of thunderstorms on air traffic demand.

Northeast Terminal Operations Delays and Statistics						
Day	Total Ops	Cancellations (Departure/Arrival)	Diversions	Airborne Holding Minutes (hr)	Completion Rate (%)	Airspace Flow Programs (AFP)
23 Jun*	8305	282/275	18	752 (12.5)	94	OB1, A08
27 Jun	8884	32/35	8	673 (11.2)	99	None
28 Jun	8215	249/256	48	2701 (45.0)	94	A01
13 Jul*	8361	323/328	26	1273 (21.2)	92	C08, OB3
14 Jul	8823	250/250	36	4234 (70.6)	94	None
16 Aug	8337	281/276	19	2047 (34.1)	94	OB1, A08

* Additional SWAP day; not a MIT LL observation day

[4] Data gathered using the FAA Aviation System Performance Metrics (ASPM) Air Traffic Organization Efficiency Report Online database.

[5] Based on notes gathered during the End of Season Review on 25-26 Oct 2016; McLean, VA.

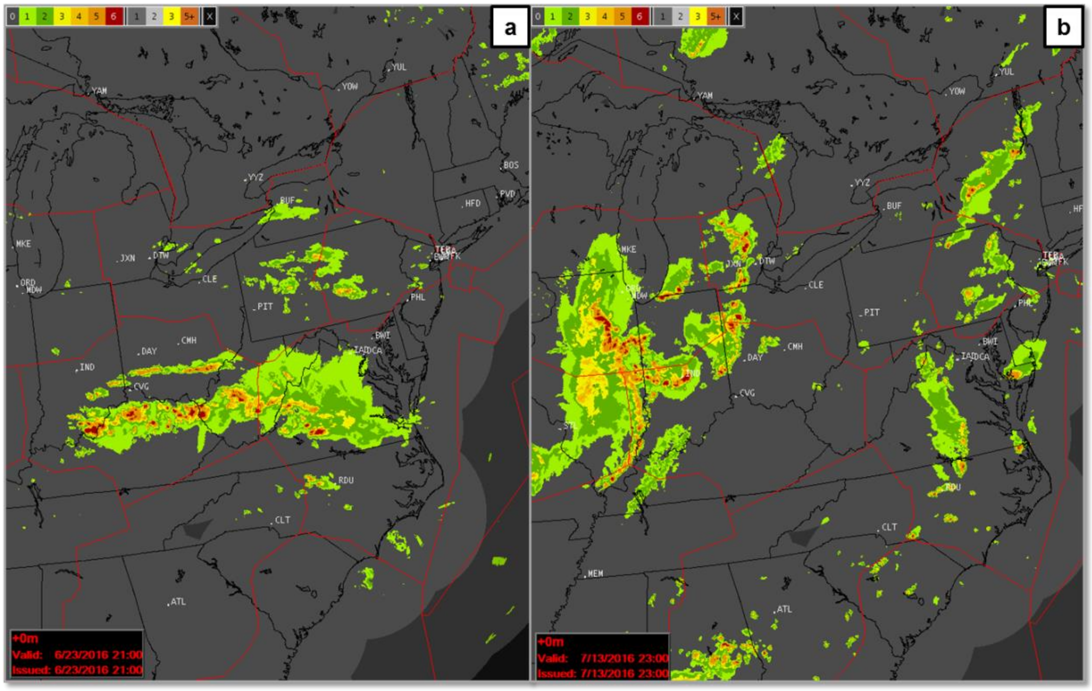

Figure 7. CoSPA VIL images of convective weather days (a) 23 June and (b) 13 July.

Table 3 consists of traffic data and delay statistics commonly used by the FAA and airline management to gauge daily performance. The eight Northeast Operational Evolution Partnership[6] (OEP) terminals included in the data are Boston International Airport (BOS), EWR, JFK, LGA, Philadelphia International Airport (PHL), Baltimore Washington International Airport (BWI), Washington Dulles International Airport (IAD), and Reagan National Airport (DCA).

The 'Total Operations' count includes all arriving and departing aircraft at each of the eight core terminals. The 'Cancellations' count includes aircraft from originating terminals (arrivals) and aircraft departing the core airports. The 'Diversions' count includes those aircraft that were destined to one of the

[6] OEP airports are commercial U.S. airports with significant activity, which service major metropolitan areas, and also serve as hubs for airline operations. More than 70% of passengers move through these airports.

eight terminals but had to divert to another airport. Airborne holding minutes are characterized in three ways[7]:

1. Flights held within 100 nautical miles (nmi) of the airport when the destination airport arrival rate ***was not*** met;

2. Flights held within 100 nmi of the airport when the destination airport arrival rate ***was*** met;

3. Flights held outside 100 nmi without consideration of the destination airport arrival rate.

The "Completion Rate" is defined by the percentage of scheduled arrivals that were not cancelled, calculated as:

Completion Rate = 100*[1 - Cancelled Arrivals / Number of Scheduled flights]

Cancelled Arrivals are determined on the next day using flight plan cancellation messages for ASPM carriers and all other carriers reporting schedule data, and scheduled flights not flown.

It is often difficult to conclude that traffic was disrupted more on one day than another based solely on individual delay statistics. The operational impact statistics do not necessarily indicate when a day was difficult for air traffic managers. It might be that the weather impact was very severe (e.g., solid squall line) but consistent, accurate forecasts by all the major models helped air traffic managers plan effectively. Conversely, other days might have had significant weather impacts, but unreliable forecasts and/or an overall complicated weather pattern (in space and time) resulted in less effective planning. The fact is that delay can be the result of a multitude of different initiatives that exist to manage air traffic, and the complexity of the airspace involved. Severe weather introduces complexity into air traffic management that at times can be difficult to predict. However, statistics like these are used in many post-analysis discussions and forums by the CDM community. The statistics in

TABLE 3 3 provide a comparison to the most challenging convective days in 2016 for managing air traffic across the NAS while quantifying the level of severity of each MIT LL observation day.

2.3 OBSERVED CONVECTIVE CLIMATOLOGY ANALYSIS

The Air Traffic Control Systems Group at MIT LL has an extensive database archive which includes Enhanced Traffic Management System (ETMS) flight plans, multiple convective weather forecast models, and the corresponding weather truth fields for VIL and ET. This database was used in the development of a new procedure for analyzing the climatology of the entire convective season (April–September). The most recent season (2016) along with the prior three seasons were used in this comparison. For each convective season, the archived VIL fields were used to determine the frequency of

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[7] Source: FAA Operations Network (OPSNET).

occurrence of level 3 or higher VIL (associated with a higher probability of thunderstorms) at each grid point on the map. This frequency is then converted to percentage and the result is shown in Figure 8. (While these percentages may seem low, it is important to remember that level 3+ VIL values are not present all of the time every day. A percentage of 1.5 translates to not quite 7 hours of level 3+ over the entire convective season.) The highest percentage for each of the four convective seasons occurs across the mid-Atlantic and Tennessee Valley regions (Figure 8). Although higher percentages are present in ZNY, the 2016 values are less than the 2015 season, suggesting that 2016 was convectively less active in ZNY than 2015. The climatology shows lower percentages of VIL level 3+ along the spine of the Appalachians from New York State and Pennsylvania into western Virginia.

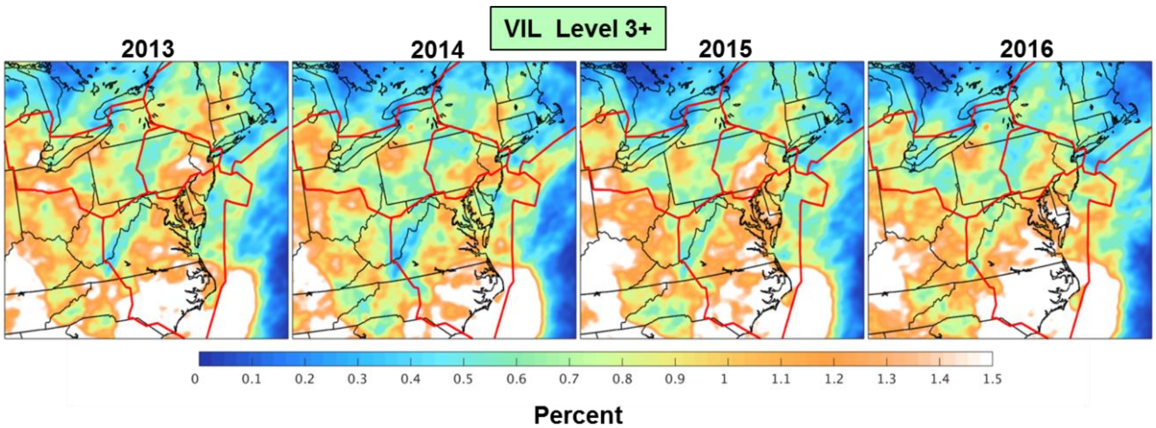

Figure 8. Occurrence of VIL level 3+ in the Northeast U.S. during the convective seasons (April through September) of 2013 through 2016.

The red lines in Figure 8 represent ARTCC boundaries. The Northeast and mid-Atlantic ARTCCs represent some of the busiest airspace across the NAS in terms of total traffic count. The average frequency of occurrence of Level 3+ VIL in these ARTCCs (averaged over every grid point within the ARTCC for the convective season) is shown in Figure 9. While ZBW, ZNY and ZOB have experienced a general decrease in thunderstorm activity since 2013, ZDC has seen an increase, especially since 2014, and is consistently higher than other regions. Figure 10 is a National Weather Service (NWS) map of average thunderstorm days per year which correlates closely with the VIL level 3+ plots in Figure 9 across the Northeast, mid-Atlantic, and Midwest regions.

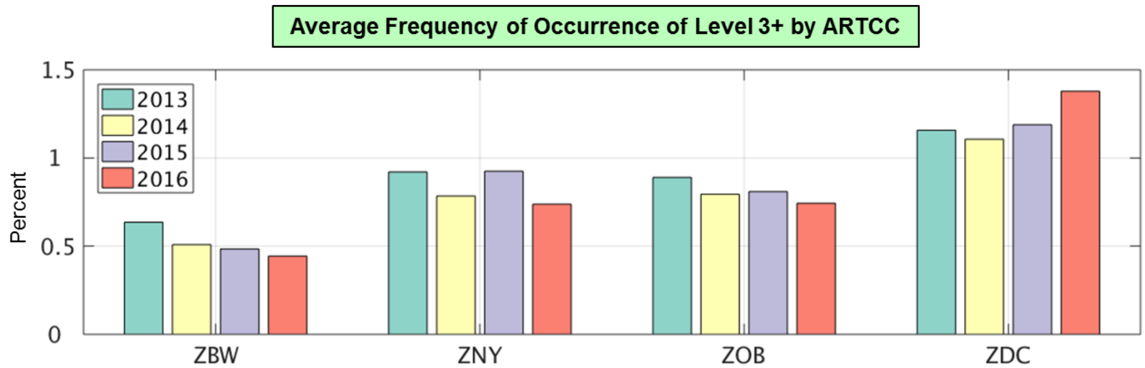

Figure 9. Average frequency of occurrence of Level 3+ VIL within the ARTCC for the convective season (April through September) for 2013 through 2016.

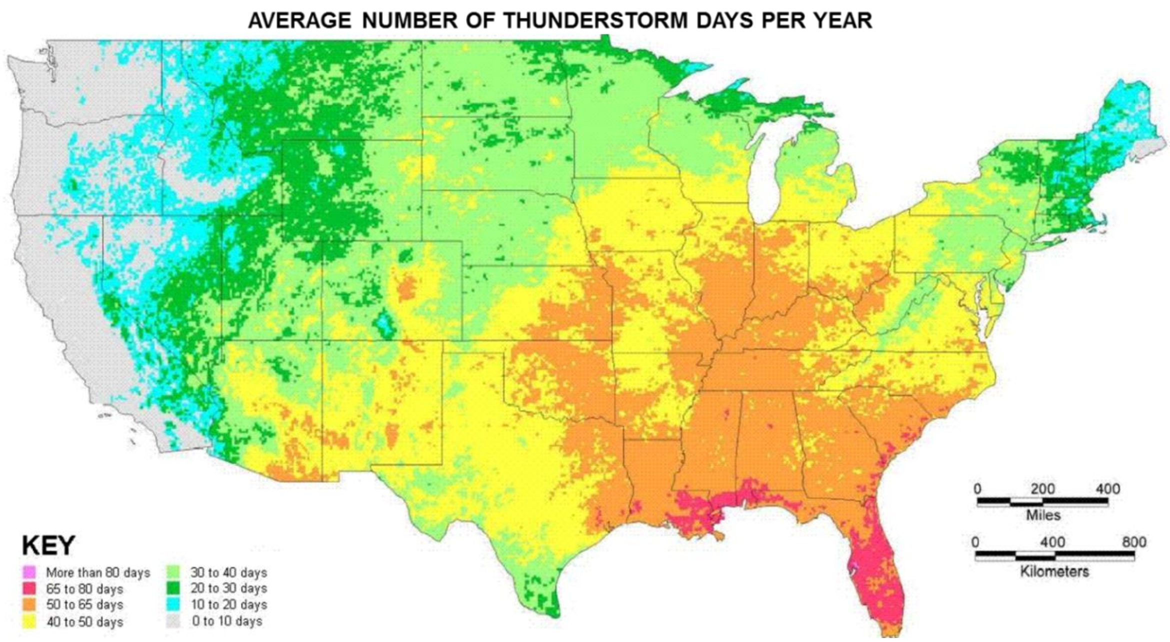

Figure 10. The average number of thunderstorm days per year (2002–2013) released by the National Weather Service.

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3. FORECAST ASSESSMENT

3.1 COSPA

CoSPA produces 0- to 8-hour deterministic forecasts of VIL and ET for air traffic managers [3]. An example of the CoSPA forecast is shown in Figure 11. CoSPA blends short-lead 0-2 hour heuristic forecasts from the Corridor Integrated Weather System (CIWS) with longer-lead forecasts from the National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) numerical model. CoSPA represents a Federal Aviation Administration (FAA)-led collaboration among three laboratories: MIT LL, the National Center for Atmospheric Research (NCAR), and the NOAA Global Systems Division (GSD). NOAA's Earth System Research Laboratory (ESRL) produces an experimental version of the HRRR which was used in CoSPA from 2009 through 2014. NOAA's National Centers for Environmental Prediction (NCEP) began running an operational version of the HRRR in the spring of 2015. CoSPA has been utilizing NCEP's operational version of the HRRR for the past two convective seasons.

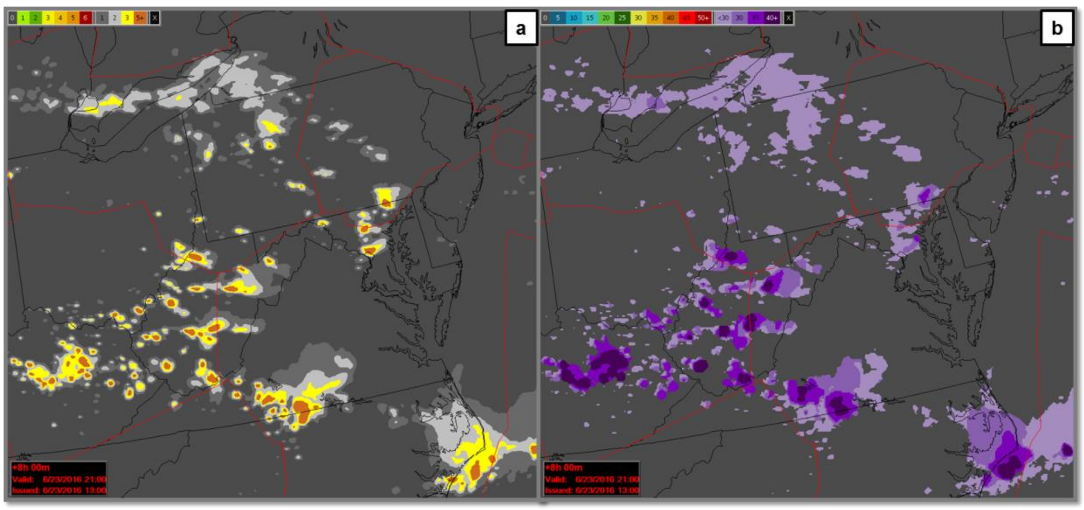

Figure 11. Examples of CoSPA forecast 8 hour products (a) Vertically Integrated Liquid and (b) Echo Top.

CoSPA's ability to predict large-scale events (e.g., cold fronts) more accurately than individual thunderstorms in the 2- to 8-hour range was observed throughout the 2016 convective season. This skill has been noted every season since CoSPA's inception in 2009. CoSPA's use of the HRRR [4] 3km storm resolving model contributes greatly to this accuracy in the longer-lead forecast range (2- to 8-hour). The large-scale forecast accuracy displayed by the CoSPA 8-hour forecast is very useful to air traffic managers at the various facilities. Strategic air traffic planning involves moving large flows of aircraft, many hours in advance of the development of the weather, through the implementation of initiatives such as Playbook reroutes, GDPs and AFPs. The CoSPA 2- to 8-hour forecast allows traffic managers to view how storms may or may not eventually impact large regions of airspace and to assess the need for TMIs. AFP planning, in particular, requires five or more hours of coordination in order to manage West Coast demand expected to traverse impacted airspace in the eastern United States. Key decisions involving weather classification type (line, scattered), timing (onset, duration), scope, and rates of traffic need to be made for aircraft from the West Coast before they depart, since it is easier and more efficient to manage demand from aircraft on the ground rather than in the air.

Figure 12 is an example CoSPA VIL forecast for 1100 UTC 14 July 2016, along with the matching VIL truth. The general weather on this day featured a large scale synoptic cold front moving eastward through the Great Lakes region. Scattered thunderstorms began to form along and ahead of this front by 1500 UTC, stretching from southeastern Canada southward into central Pennsylvania. These scattered storms grew in intensity, moved into eastern NY and New Jersey, and formed several solid lines of convection extending into northern New England. The deterministic forecast on this day captured the initiation of storms along the front as well as the movement and increase in strength of the weather several hours in advance of onset. The skill depicted in this example was typical of what was observed throughout the summer for larger-scale convective events. CoSPA was able to capture onset, duration, and much of the intensity of the storms along with relatively accurate placement of the larger scale lines.

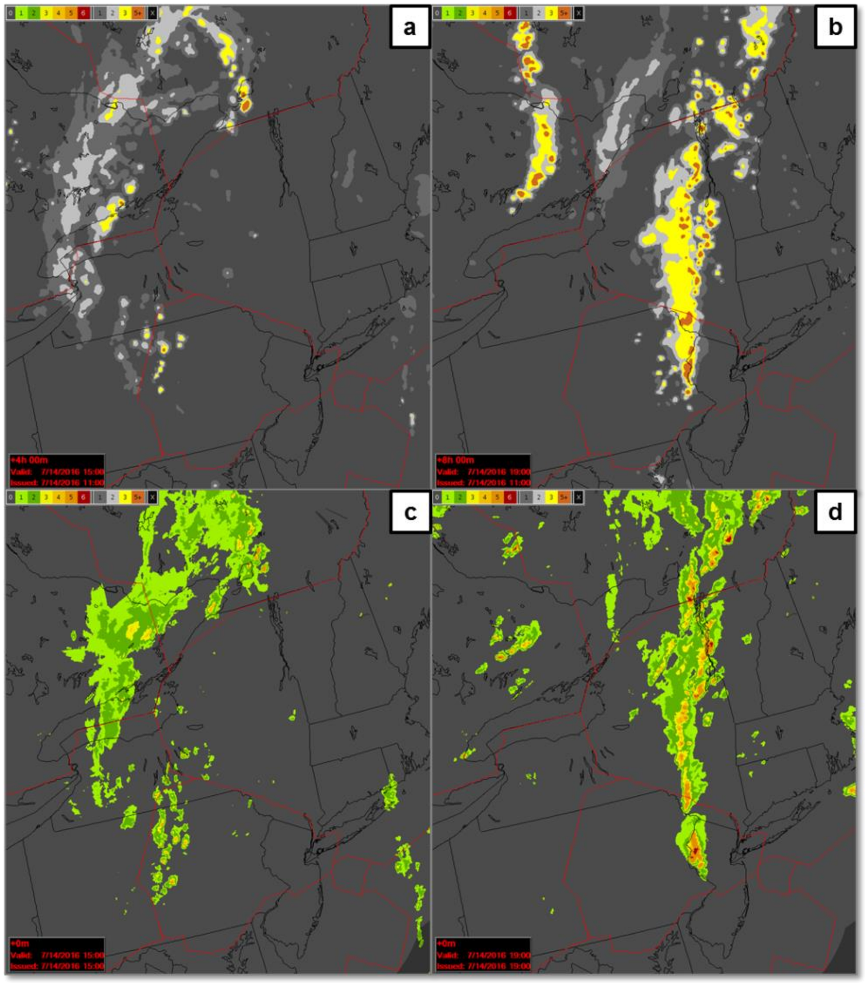

Figure 12. The (a) 4-hour and (b) 8-hour CoSPA VIL forecasts issued at 1100 UTC and valid at 1500 UTC and 1900 UTC, respectively, and the corresponding VIL truth for (c) 1500 UTC and (d) 1900 UTC.

CoSPA continues to be challenged by smaller-scale events and the scattered thunderstorm activity that accompanies this pattern type. The first observation day (27 June) of 2016 was a day that featured a synoptic cold front draped across the Great Lakes. Thunderstorms began to form well ahead and to the south of the front, where more unstable air resided, but far away from the synoptic forcing. As a result, the developing storms were more scattered in nature, but ultimately focused into a large cluster of intense convection that forced air traffic to reroute for several hours that day. Figure13a provides a snapshot of the 4-hour echo top forecast that was produced at 1100 UTC that morning. Although CoSPA had a grasp on the scattered nature of the system, it underestimated the development in storms across southern

Illinois, Indiana and Kentucky. Four key CoSPA deficiencies that have been noted in several similar 2016 cases are:

1. CoSPA forecasts convective initiation later than the actual onset.

2. CoSPA under-forecasts VIL intensities.

3. CoSPA under-forecasts Echo Top heights.

4. CoSPA under-forecasts the event duration (i.e., convection initiates later than forecast and storms decay earlier than forecast).

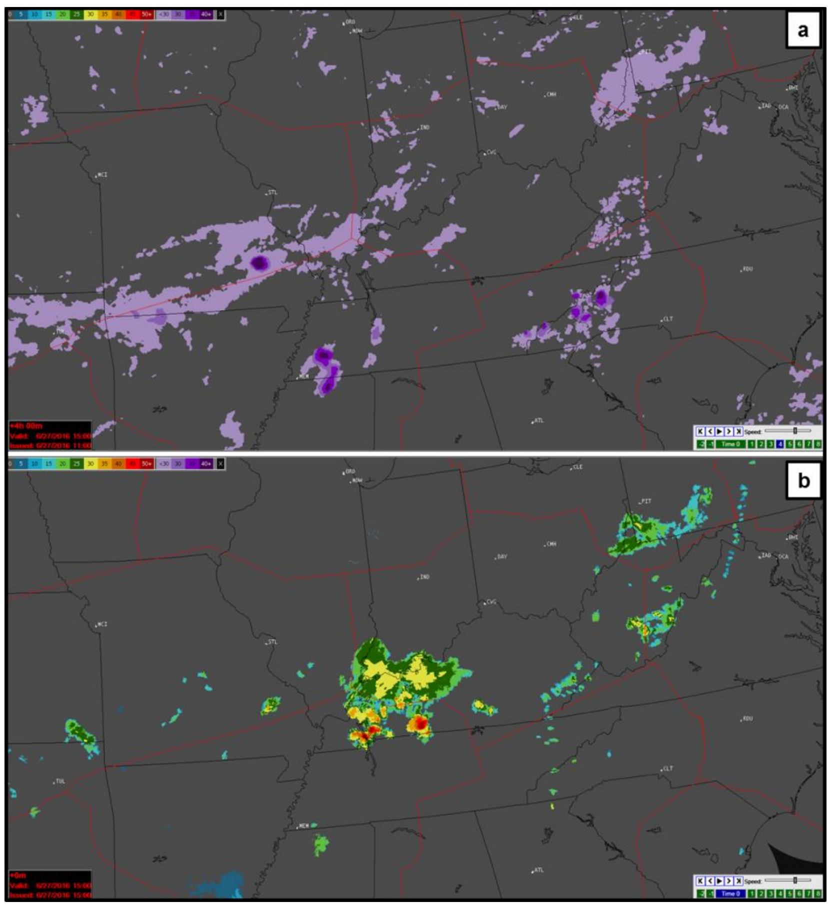

Figure 13. 1100 UTC CoSPA (a) Echo Top forecast and (b) the Echo Top truth from 1500 UTC on 27 June 2016.

A detailed quantitative analysis of the CoSPA VIL forecast was performed using the newly developed MIT LL archive data analysis technique depicted in Figure 8. Figure 14 utilizes the CoSPA VIL forecast of level 3+ and covers the entire convective season (April–September). This analysis reinforces qualitative observations relating to the under-forecast of VIL intensities, particularly in the 2- to 4-hour forecast range. Higher areal coverage of under-forecasting (blue shading) is observed in Figure 14a at the 3-hour mark along with a noticeable bias dip in Figure14b. A similar analysis was performed using the CoSPA Echo Top forecast and is plotted in Figure 15. The under-forecasting of echo tops is also observed and is most pronounced in the six and eight hour time periods.

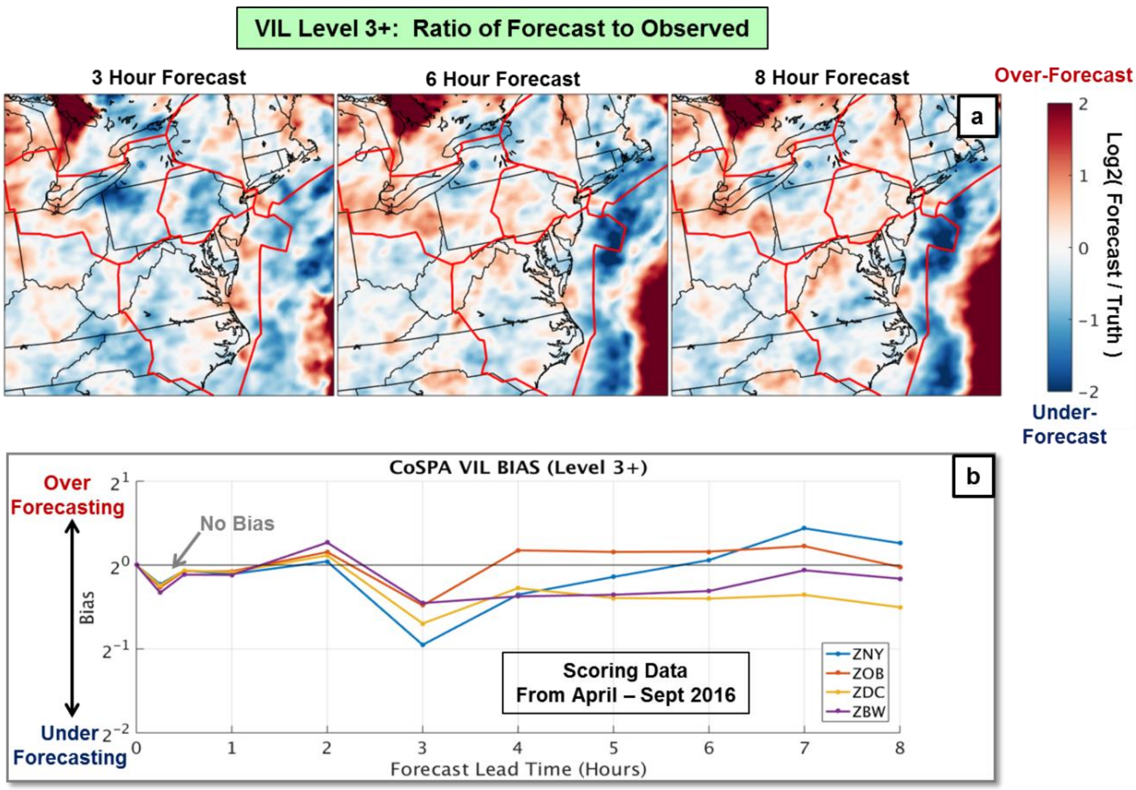

Figure 14. (a) The archive analysis of CoSPA VIL (level 3+) for the 3-, 6-, and 8-hour forecast and (b) the VIL (level 3+) bias over the entire 0- to 8-hour forecast period. Analysis was performed over the convective season (April–September 2016) across ZNY, ZOB, ZDC and ZBW.

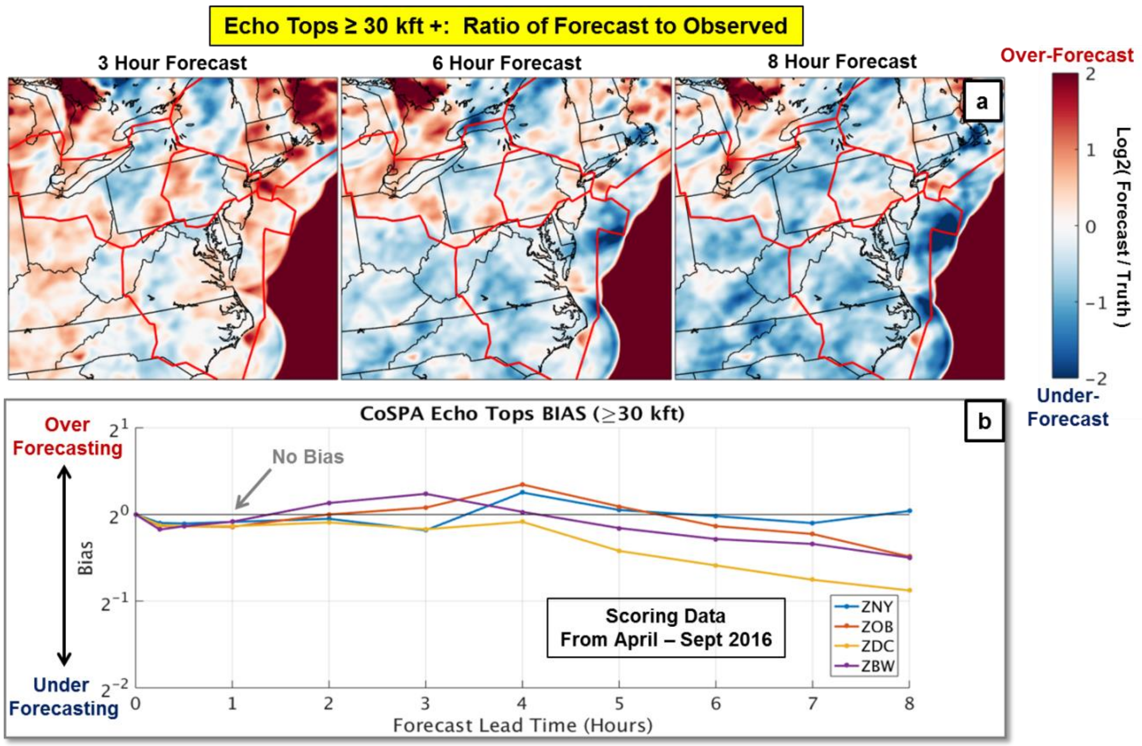

Figure 15. (a) The archive analysis of CoSPA Echo Top (30kft and higher) for the 3-, 6-, and 8-hour forecast and (b) the Echo Top (30kft and higher) bias over the entire 0- to 8-hour forecast period. Analysis was performed over the convective season (April–September 2016) across ZNY, ZOB, ZDC and ZBW.

The under-forecasting signal of both VIL and ET over the same eastern Pennsylvania region in the 3-hour period is a key focus area for improvement. This region falls within the ZNY ARTCC, which is a complex microcosm in the NAS. The FAA Office of Tactical Operations in the Northeast (NE Tactical Operations) performed an airspace density analysis in 2013[8] using seven major markets (New York [LGA, JFK, EWR], Miami, Los Angeles, Seattle-Tacoma, Chicago O'Hare, Dallas-Fort Worth, and Atlanta International Airports). The combination of airspace structure and traffic demand equals airspace density in their example. Each terminal airspace was divided into four quadrants (Figure 16a) and flight tracks (arrivals/departures) were measured at 50 nmi on a typical day without weather factors. Figure 16b is a plot of the NY airspace quadrants which shows that 80% of the traffic in and out of the region is from the west. Therefore, the majority of throughput in N90 uses the airspace where the CoSPA under-

[8] Airspace Density and Distribution by Flight Direction, Leo Prusak-Manager NE Tactical Operations, Dan Bueno-Sr. Analyst.

forecasts (Figure 14 and Figure 15). The location, size, and orientation of severe weather are factors that contribute to delay in and around all terminals across the NAS but particularly in NY where the complex routes are confined to one of the smallest geographical airspaces.

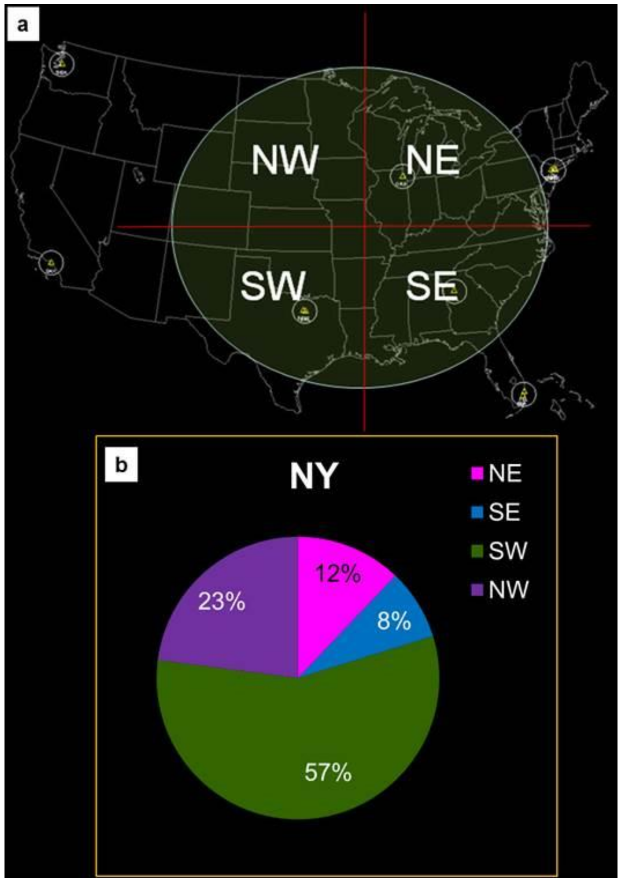

Figure 16. (a) A plot of the seven terminal regions used in the NE Tactical Operations airspace density report and (b) the corresponding NY area density broken out by quadrant.[9]

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[9] Airspace Density and Distribution by Flight Direction, Leo Prusak-Manager NE Tactical Operations, Dan Bueno-Sr. Analyst.

3.2 TRAFFIC FLOW IMPACT (TFI)

The translation of weather forecasts into airspace impact is a key piece of information needed to make efficient traffic management decisions in a time-constrained and often unpredictable environment when thunderstorms limit capacity across the NAS. Translation of a convective weather forecast is also the next step to developing skillful and intelligent strategic decision support for air traffic management. TFI begins by providing an estimate of airspace permeability. In simple terms, permeability is computed from the overlap of forecasted weather with an airspace resource to determine the amount of usable airspace within the resource. The Convective Weather Avoidance Model (CWAM), also used operationally in the Route Availability Planning Tool (RAPT), provides the foundation for TFI's weather impact translation. The airspace permeability is then used to assess the operational impact of convective weather on the air traffic operations (Figure 17).

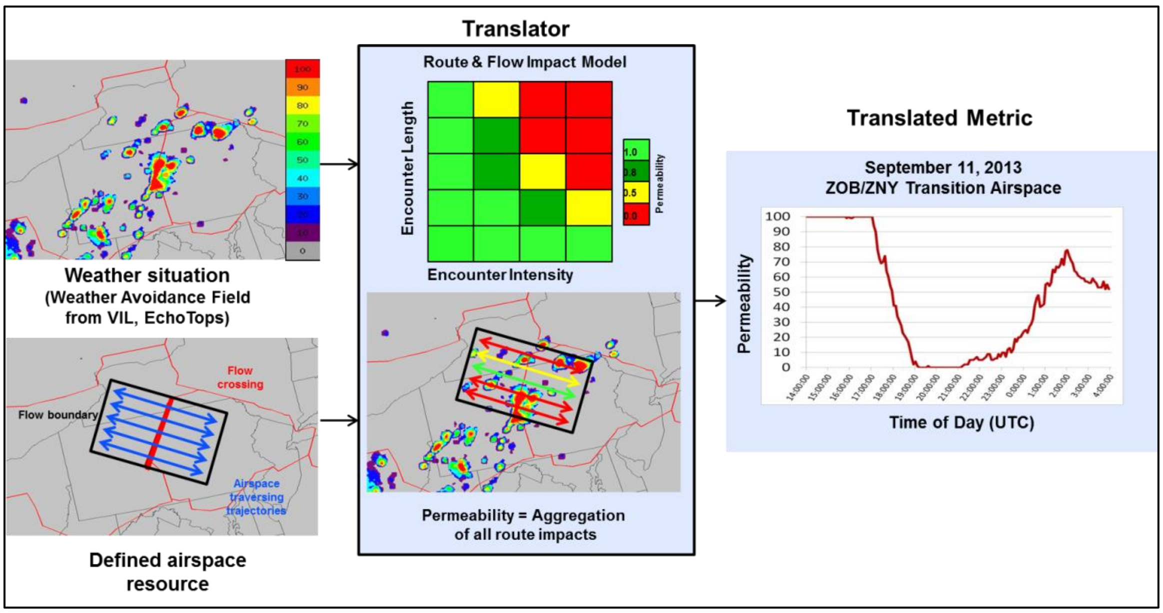

Figure 17. A simplified view of the weather translation process used in TFI.

Figure 18 is a representative example of the TFI interface presented to users during the 2016 convective season. The display builds upon the CoSPA deterministic decision support tool which the users have viewed since its inception in 2009. The added TFI timeline below the forecast picture provides traffic managers a quick-look at each ARTCC and the potential severity of thunderstorms in relation to air traffic flow. Each individual ARTCC contains a listing of several FCA regions in which a traffic manager can “drill-down” to more detail. One of the airspace resources, or TFI regions, is highlighted in this example by the blue shaded region plotted in the New England area. One mouse click on the ARTCC name expands the selection (Figure 19a), providing a list of individual FCA regions. The user has the capability to select individual TFI regions revealing their location and providing further detail on that particular area of airspace in the form of a permeability plot (Figure 19b). The plot maps directly to the color coded timeline (Figure 19a) and provides more detail on how the airspace is forecasted to be impacted in the form of percentage of resource available (y-axis). The solid blue line is the median of expected airspace permeability derived from multiple deterministic and probabilistic forecasts including CoSPA, HRRR, Short-Range Ensemble Forecast (SREF), Localized Aviation Model Output Statistics [MOS] Program (LAMP), and CIWS extrapolation. TFI is a true multi-model, ensemble forecast that also provides a dynamic measure of forecast confidence represented by the blue shaded region. The upper and lower shaded regions make up the prediction intervals of the 20th and 80th percentiles respectively[10].

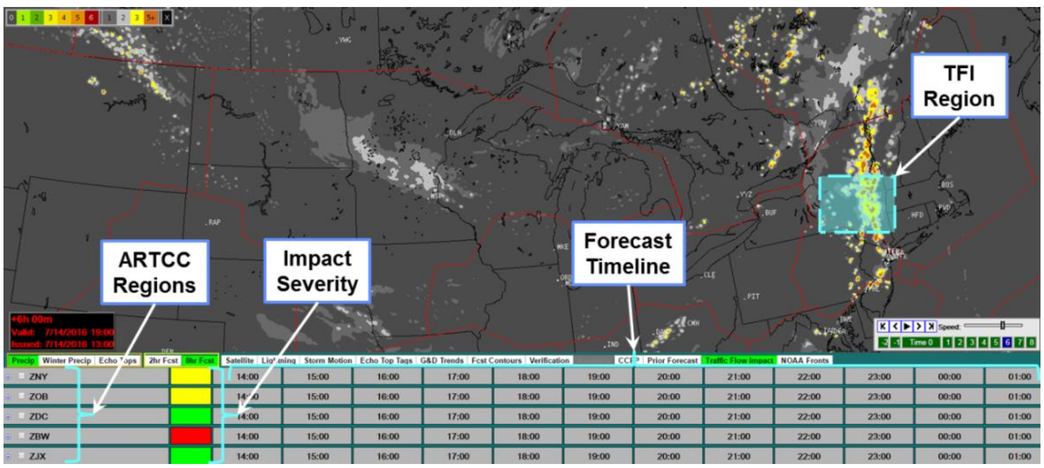

Figure 18. Traffic Flow Impact (TFI) timelines for individual ARTCCs displayed along with the CoSPA deterministic forecast above.

Thousands of hours of field observations by MIT LL subject matter experts over the years have provided valuable insight into the specific strategies used during strategic planning. For successful planning of TMIs, decision makers require weather forecasts of the impacted airspace between 2 and 8 hours in advance of the event to set the critical parameters of the TMI such as start time, duration and maximum flow reduction. Many different weather-only convective forecasts are available to the traffic planner in the strategic time domain, both deterministic and probabilistic. However, these forecasts

[10] Matthews, M., and R. DeLaura, 2015: “Airspace Flow Rate Forecast Algorithms, Validation and Implementation”, Project Report ATC-428, MIT Lincoln Laboratory, Lexington, MA, 2015.

provide little guidance about aviation impact on the air traffic resources and the precise location, severity, scale, and timing of operationally significant storms. The human response to those storms can be notoriously difficult to predict. TFI was developed to target these specific planning components, which were the key characteristics highlighted in training.

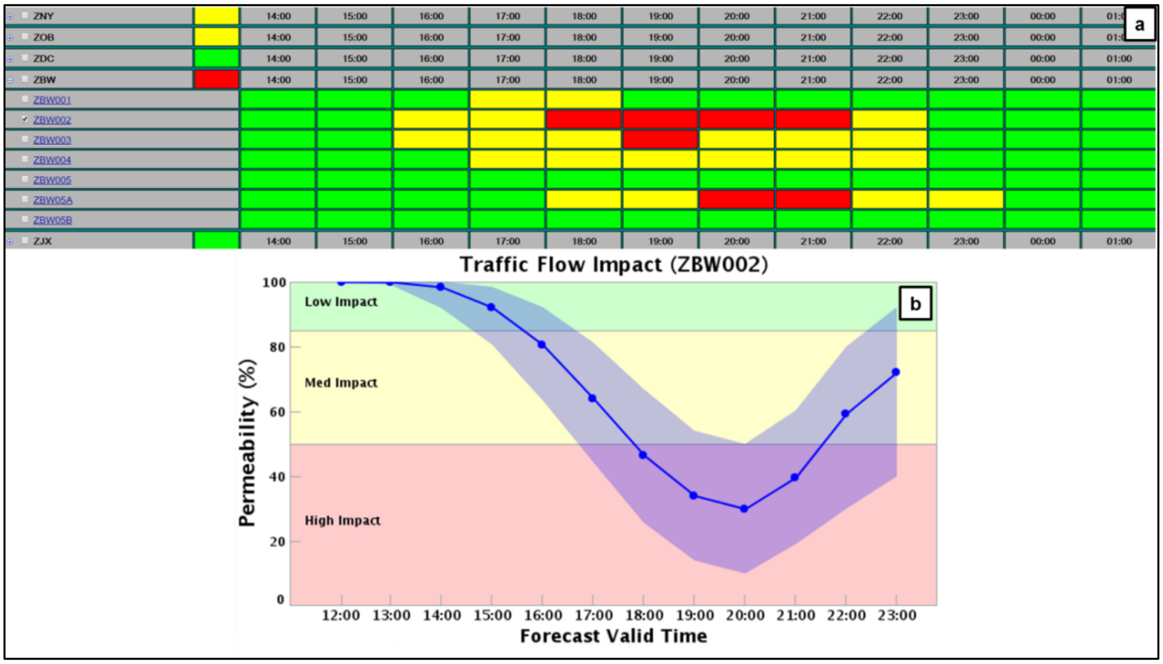

Figure 19. (a) The expanded TFI timeline from the example in Figure 18 highlighting the ZBW ARTCC and (b) the corresponding permeability plot of one TFI FCA region.

Traditional post-event review of a convectively active aviation season typically focuses on the meteorological aspects only. Figure 20 is an example of the general weather overview that was presented by the FAA at the 2016 End of Season Review (EOSR)[11]. EOSR is an annual meeting that takes place at the end of every convective season and is attended by representatives of the CDM community who gather to review best practices and to evaluate potential gaps in technology that could be filled by future research. The example in Figure 20 is typical of the type of meteorological analysis that is presented each year to review the severity of thunderstorms across the NAS.

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[11] 2016 End of Season Review, FAA/CDM, October 2016, Mclean, VA.

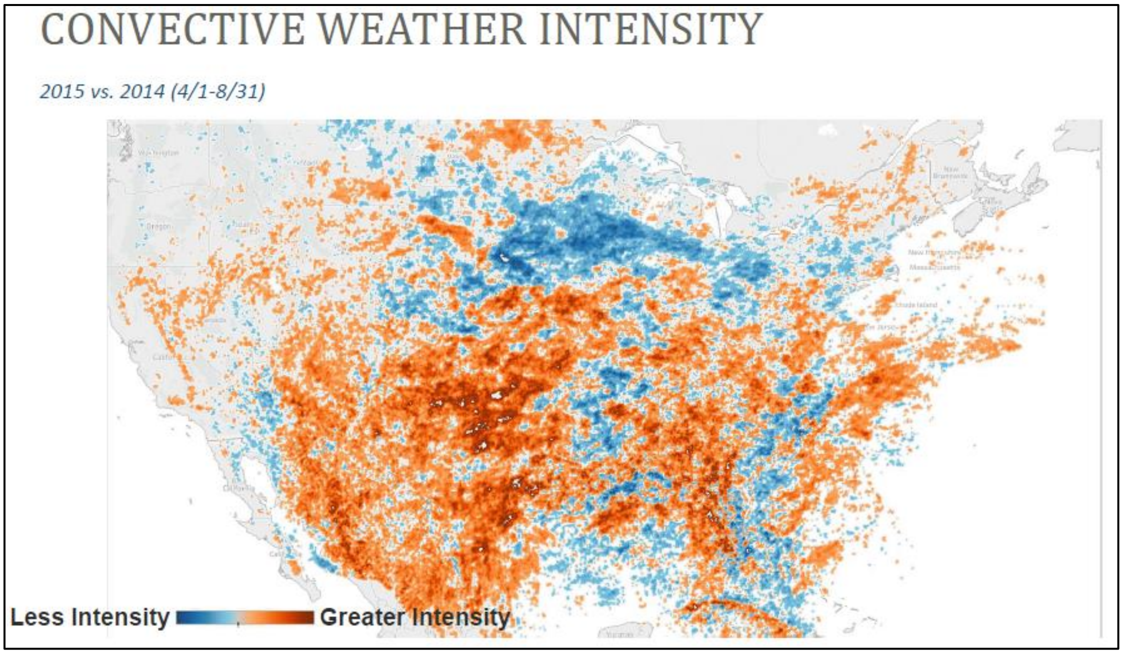

Figure 20: Example weather analysis graphic taken from the 2016 FAA End of Season Review.

MIT LL has approached the post-event analysis of TFIs performance from the same translational perspective that the application is built upon. The analysis blends both the meteorological aspects as well as the implications weather has on managing air traffic during severe weather events. Initial analysis does not group the entire season together, it is broken down on an event-by-event basis. Traffic managers and planners have stated that each SWAP event provides its own unique set of characteristics depending on the timing, severity, and placement of the potential impact.

Each noted convective day from the 2016 season (April–September) was analyzed on an individual basis. The plots in Figure 21 are an example of the TFI analysis on one convective day across ZBW airspace. Figure 21(a) provides a plot of the forecast permeability (blue), the actual truth permeability (black), and the forecast confidence bound (blue shading). In this example, the TFI forecast slightly underestimated the severity of the event but roughly captured the start time and duration of the event.

Figure 21(b) represents the 1300 UTC 6-hour CoSPA VIL forecast and (c) the 1900 UTC VIL truth, one snapshot in time of the entire day. These two plots provide a visual verification of the accuracy in placement and orientation of the storms on this day.

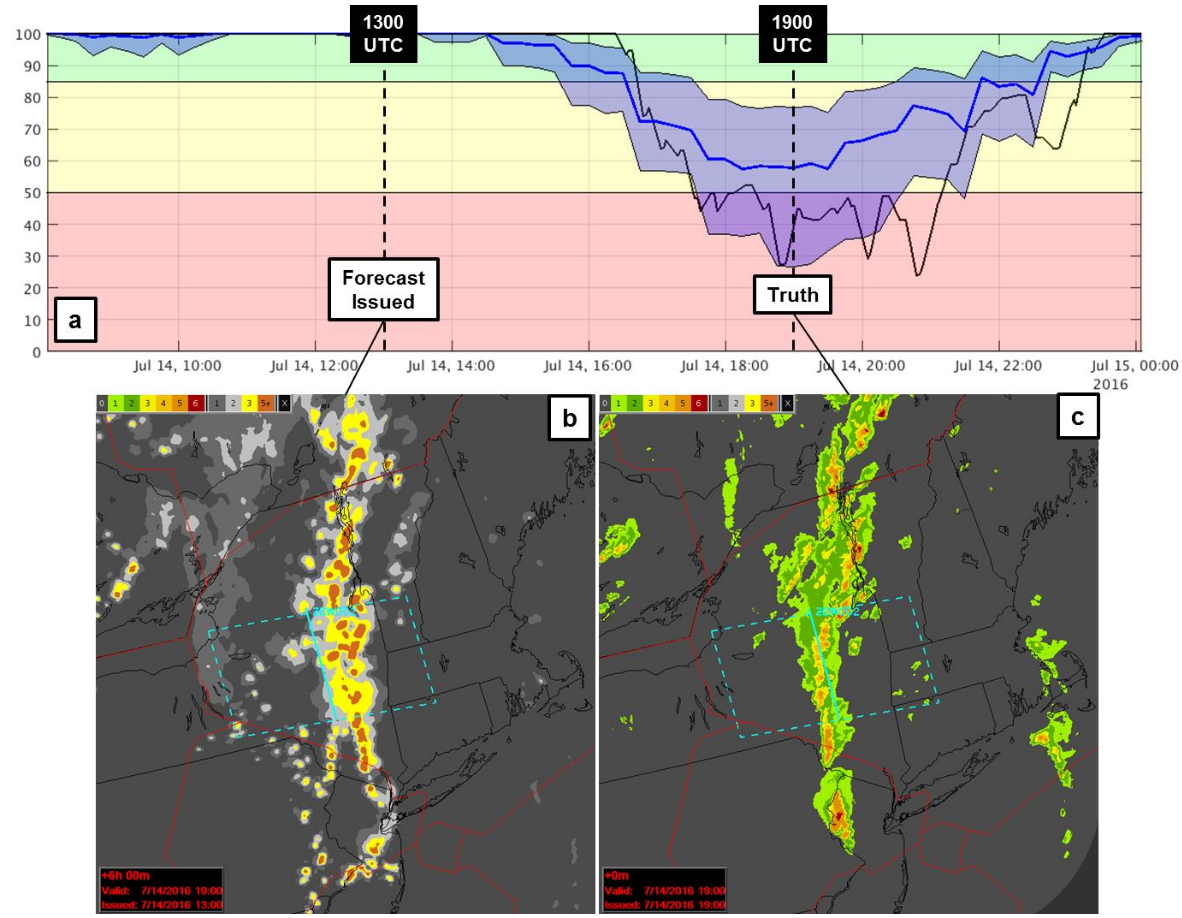

Figure 21: Example of TFI performance on 14 July 2016 across the ZBW airspace (a) along with the 1300 UTC 6-hour CoSPA VIL forecast (b) and the 1900 UTC truth (c).

4. OBSERVED OPERATIONAL BENEFITS

4.1 BENEFITS CLASSIFICATION AND OBSERVED BENEFITS

Observations recorded during field evaluations were analyzed to identify operational decisions where CoSPA and/or TFI provided a benefit to users. These benefits were divided into categories shown in Table 4.

Figure 22 provides the distribution of benefits for each field observation day for all facilities visited on the particular day, and the totals across all days and facilities. The observations from which these statistics are derived are found in Appendix A. Observers documented 122 instances when CoSPA and/or TFI were used operationally, with 42 attributed to TFI. The most common use was for situational awareness, for which there are five categories (SA, SA-AFP, SA-R, SA-T, and SA-TFI), defined in Table 4. There were 97 observations of General Situational Awareness (SA and SA-TFI, 46 and 26 respectively) and 8 observations of support for AFP go/no-go decisions (1 for AFP and 7 for TFI-AFP).

TABLE 4

Benefits Categories

	Key	Benefit Category
Using CoSPA	AFP	**Improved AFP Execution / Management** Assigned when CoSPA used to make AFP Go/No-Go decisions, AFP decisions on start time, stop time, rate, plan modifications, etc.
	C-GDP	**Improved Ground Delay Program Execution / Management** Only assigned when decision aided to explicitly avoid GDP, to implement GDP, to modify rate/scope, or to end GDP, based on CoSPA
	Coord	**Enhanced Inter/Intra-Facility Coordination**
	ERP	**Enhanced Reroute Planning** Includes avoiding reroutes by recognizing viability of nominal routes, proactive reroute implementation, and ending reroutes/returning to nominal routes sooner, etc., based on CoSPA
	SA	**General Situational Awareness**
	SA-AFP	**Enhanced Situational Awareness – AFP** Assigned when FCA forecast confidence estimate plots viewed in reference to AFP rate decision, based on CoSPA
	SA-R	**Enhanced Situational Awareness – Route (Enroute Airspace) Impact Monitoring**
	SA-T	**Enhanced Situational Awareness – Terminal Impact Monitoring (TRACON to Terminal Airspace)**
	Staffing	**Staffing** Assigned when CoSPA used to determine staffing levels.
Using TFI	SA-TFI	**General Situational Awareness**
	TFI-AFP	**Improved AFP Execution / Management** Assigned when TFI used to aid in an AFP Go/No-Go decision, AFP decisions on start time, stop time, rate, plan modifications, etc.
	TFI-GDP	**Improved Ground Delay Program Execution / Management** Only assigned when decision aided to explicitly avoid GDP, to implement GDP, to modify rate/scope, or to end GDP, based on TFI
	TFI-Plan	**Improved Traffic Management Initiative Planning**
	TFI-R	**Enhanced Reroute Planning** Includes aiding in reroute decisions by recognizing viability of nominal routes, proactive reroute implementation, and ending reroutes/returning to nominal routes sooner, etc., based on TFI

Using CoSPA	AFP	Improved AFP Execution / Management
	C-GDP	Improved Ground Delay Program Execution / Management Using CoSPA
	Coord	Enhanced Inter/Intra-Facility Coordination
	ERP	Enhanced Reroute Planning
	SA	General Situational Awareness
	SA-AFP	Enhanced Situational Awareness – AFP
	SA-R	Enhanced Situational Awareness – Route (Enroute Airspace) Impact Monitoring
	SA-T	Enhanced Situational Awareness – Terminal Impact Monitoring (TRACON to Terminal Airspace)
	Staffing	Enhanced Staffing Decisions
Using TFI	SA-TFI	General Situational Awareness
	TFI-AFP	Improved AFP Execution / Management
	TFI-GDP	Improved Ground Delay Program Execution / Management
	TFI-Plan	Improved Traffic Management Initiative Planning
	TFI-R	Enhanced Reroute Planning

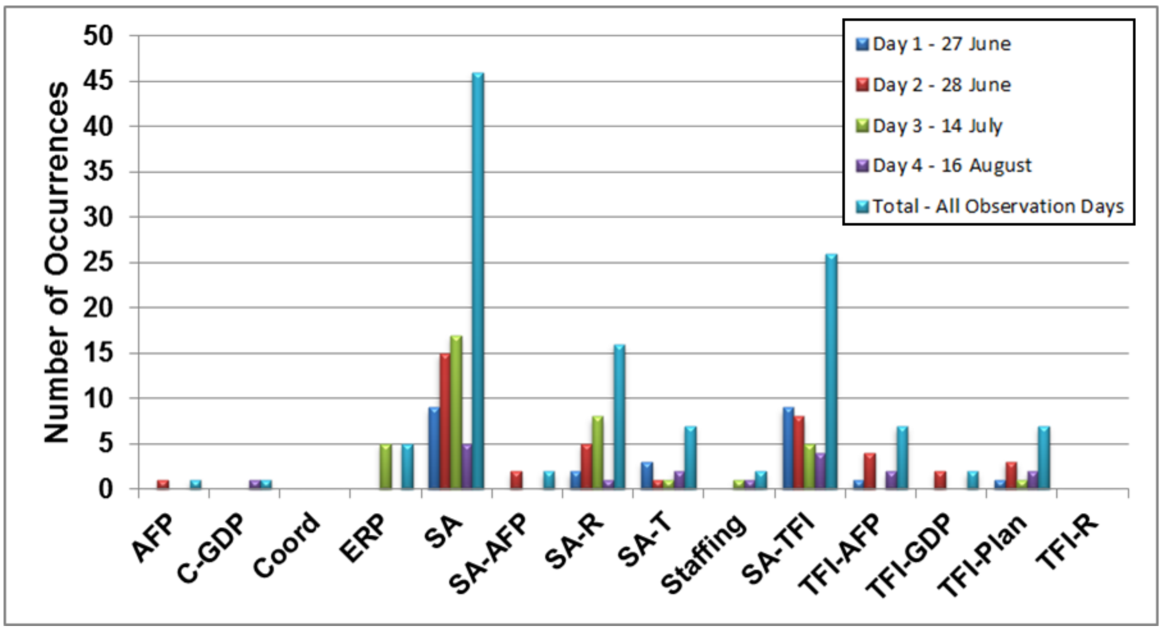

Figure 22. Distribution of benefits by observation day across all facilities in 2016.

4.2 EXAMPLE OF OPERATIONAL USE

Section 4.1 above provides an explanation of the types of operational uses that were observed and a statistical breakdown of each category by day. This section documents specific operational uses of CoSPA and TFI on those days.

4.2.1 Improved Traffic Management Initiative Planning (14 July 2016)

Early morning forecast models (CoSPA/HRRR/SREF) predicted thunderstorms to develop in the Northeast by late morning with potential N90 impact by early evening. There was early discussion from airline users to publish AFPs that morning. Internal comments from terminal managers at ATCSCC supported the use of AFPs as well, to protect direct terminal N90 impact. However, the decision was made for no AFP use on this day based on the forecast for ZDC. A large gap in storms was predicted to persist along the ZNY-ZDC border. A large amount of ZDC airspace was also predicted to remain passable with multiple jet routes available in and out of the region (Figure 23).

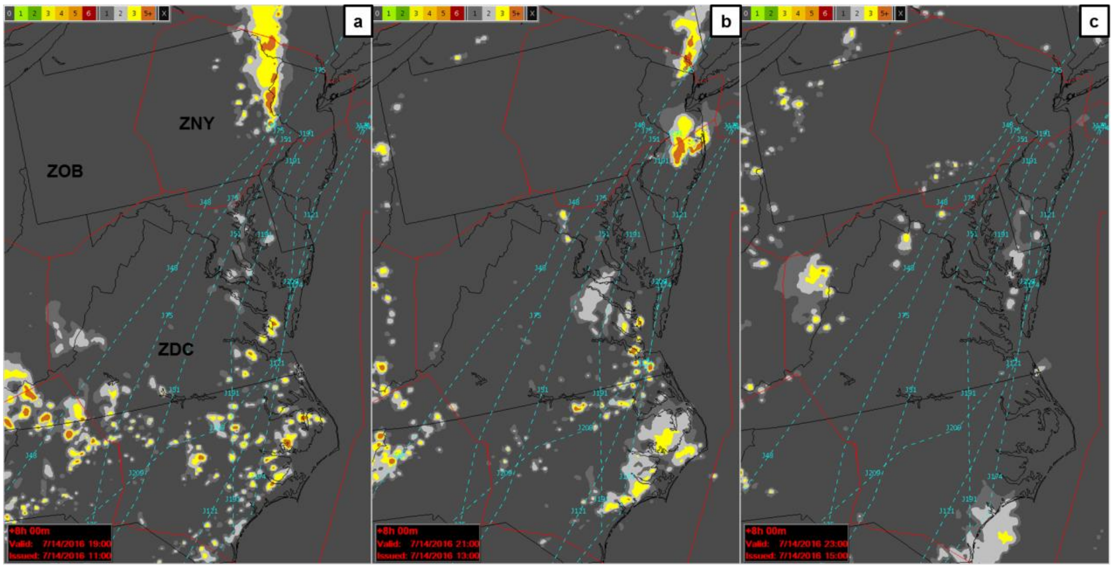

Figure 23. Images of 8-hour CoSPA VIL forecasts issued at (a) 1100 UTC, (b) 1300 UTC, and (c) 1500 UTC on 14 July 2016. ARTCC boundaries are marked in red with arrival and departure jet routes in cyan.

The CoSPA deterministic forecast and TFI plots were reviewed by the National Operations Manager (NOM) and planner upon arrival at the facility that morning. The various TFI plots across the Northeast and mid-Atlantic regions were projected onto the large wall displays at ATCSCC alongside the Flight Schedule Monitor (FSM) which can be seen in Figure 24. In this image, the TFI and CoSPA forecasts are being compared to various arrival demand charts in FSM for terminal and AFP impact due to thunderstorms.

Figure 24. Image of CoSPA and TFI plots projected onto the large ATCSCC displays (left) next to the Flight Schedule Monitor (right).

Discussions centered on the use of AFPs to manage incoming arrivals with the expectation that departure airspace around the NY metros would be disrupted. There was also the potential for direct terminal impact at EWR, JFK and LGA, and this would greatly lower throughput during peak evening volume. Figure 25 shows one TFI region the ATCSCC evaluated during the AFP decision process. In 2015, ATCSCC planners requested TFI-like permeability plots for the forecasts from the individual models that are used as input to TFI, and these were provided for this observation day in Figure 25a. The TFI permeability (solid blue line) and confidence forecast (blue shaded area), and the actual permeability as determined in post-analysis (black line) are shown in Figure 25b; the 8-hr forecast point (valid at 1900 UTC) is highlighted on the TFI permeability plot. Figure 25c shows the 8-hour CoSPA VIL forecast (top) corresponding to the highlighted point in Figure 25b, and the actual 1900 UTC CoSPA VIL truth (bottom); the TFI region is shown by the dashed cyan lines.

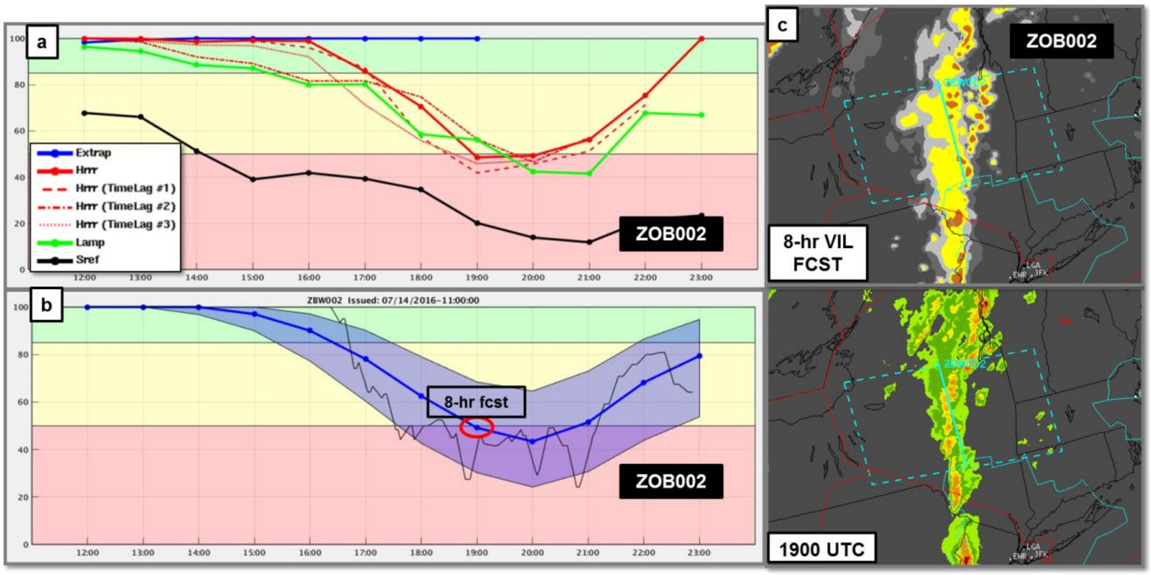

Figure 25. (a) TFI-like permeability plots computed from individual forecast models, (b) TFI plot of forecast (solid blue line) and verification (black line), and (c) VIL truth (top) and CoSPA VIL 8-hour forecast (bottom; valid at 1900 UTC) for the corresponding TFI region ZOB002.

ATCSCC planners used these forecast plots to determine start time, duration, and impact severity while also assessing the confidence in the forecast. Even with early customer and internal suggestions to publish AFPs on this day, no AFPs were issued. Iterative forecast review of CoSPA, TFI, and National Aviation Meteorologist (NAM) consultation allowed ATCSCC planners to decide against AFP use despite the potential high impact in ZNY. Post-event interviews with planners at ATCSCC indicated that similar forecast information from multiple sources, including TFI, gave confidence that specific TMIs could be strategically issued for this event. The consistent outlook that much of the ZDC airspace would not be impacted allowed severe weather planners to enable excess demand in and out of NY through the gaps.

In spite of the accurate deterministic forecast and permeability impact prediction, total delay and diversion counts on this day were in the top five for the summer (TABLE 3). Traffic managers at ATCSCC and ZBW, and airline planners at JetBlue attribute this disparity to the higher-than-normal volume that ZDC handled on this day. When storms block the ZOB-ZNY airspace, reroutes are typically split between northern Canadian routes and jet routes through Atlanta ARTCC (ZTL). Two Canadian routes were being negotiated along the U.S./Canadian border airspace; however, storms were also expected to impact one of Canada’s busiest airports in that region (Toronto-Pearson). Ultimately, Nav

Canada was unable to support the two northern off-load routes. Therefore, most of the rerouted demand had to flow through ZTL to and through ZDC, including inbound and outbound traffic. Average daily operations through ZDC average close to 6,000 planes. Almost twice that amount of operations (11,000) was recorded in ZDC on the 14th, overloading many sectors and bringing the flow to a crawl by late afternoon and evening.

4.2.2 Improved AFP Execution/Management (28 June 2016)

June 28 began with problems early in the morning as late night storms associated with a cold front lingered in the airspace between ZNY and ZDC (Figure 26) with a second cold front on the heels of the first. Proposed GDPs were issued for EWR, JFK and LGA prior to 1400 UTC; PHL was already ground-stopped beginning 1146 UTC.

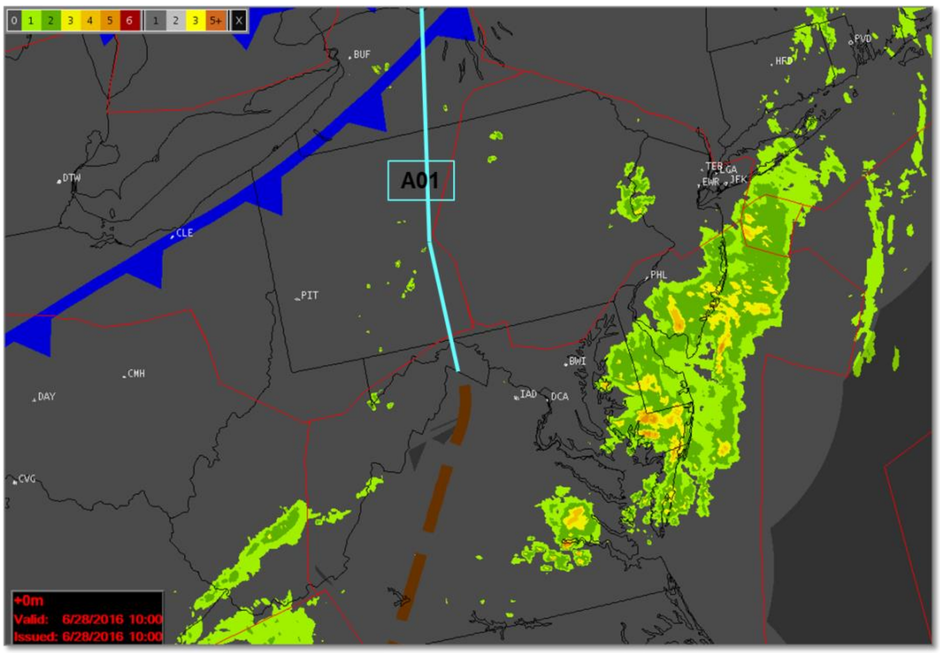

Figure 26. CoSPA VIL image taken at 1000 UTC on 28 June 2016.

The combination of CoSPA, TFI, LAMP and SREF, under the supervision of the NAM, were used to plan and issue the single AFP (A01) used on this day. The model forecasts were consistent from the start of the day with several consecutive runs indicating a similar start time and impact location (Figure 27). Figure 28a provides one of the TFI permeability forecasts (blue line), and associated truth (black line), from the 1300 UTC issue time. Figure 28b clearly shows that models predicted the growth to occur much later in the day and to be less severe than the actual weather. Despite incorrectly forecasting the initial explosive growth of convection, the CoSPA deterministic forecast captured the initiation time and location of the storms.

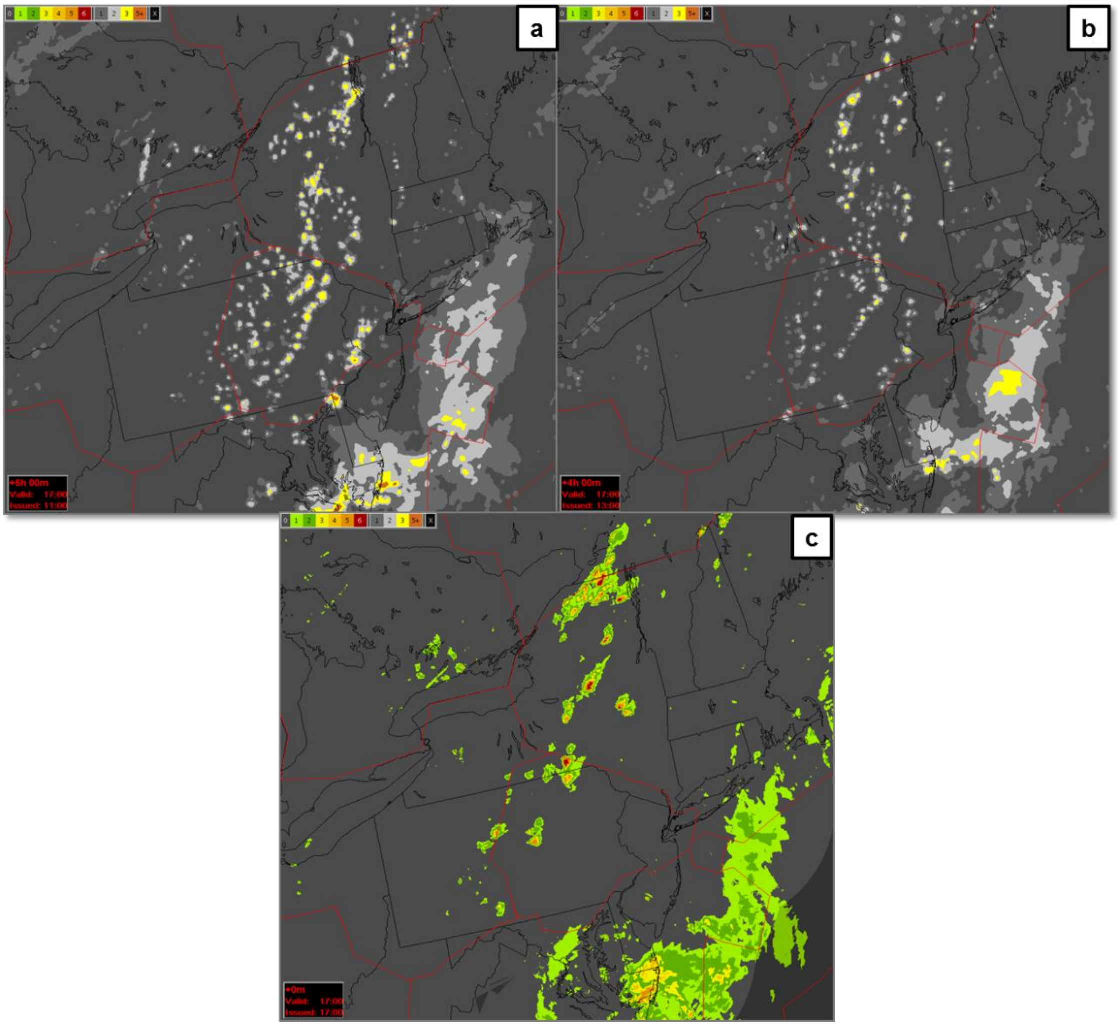

Figure 27. 28 June 2016 CoSPA (a) 6-hr VIL forecast issued at 1100 UTC, (b) the 4-hr VIL forecast issued at 1300 UTC (both valid at 1700 UTC), and (c) the 1700 UTC VIL truth.

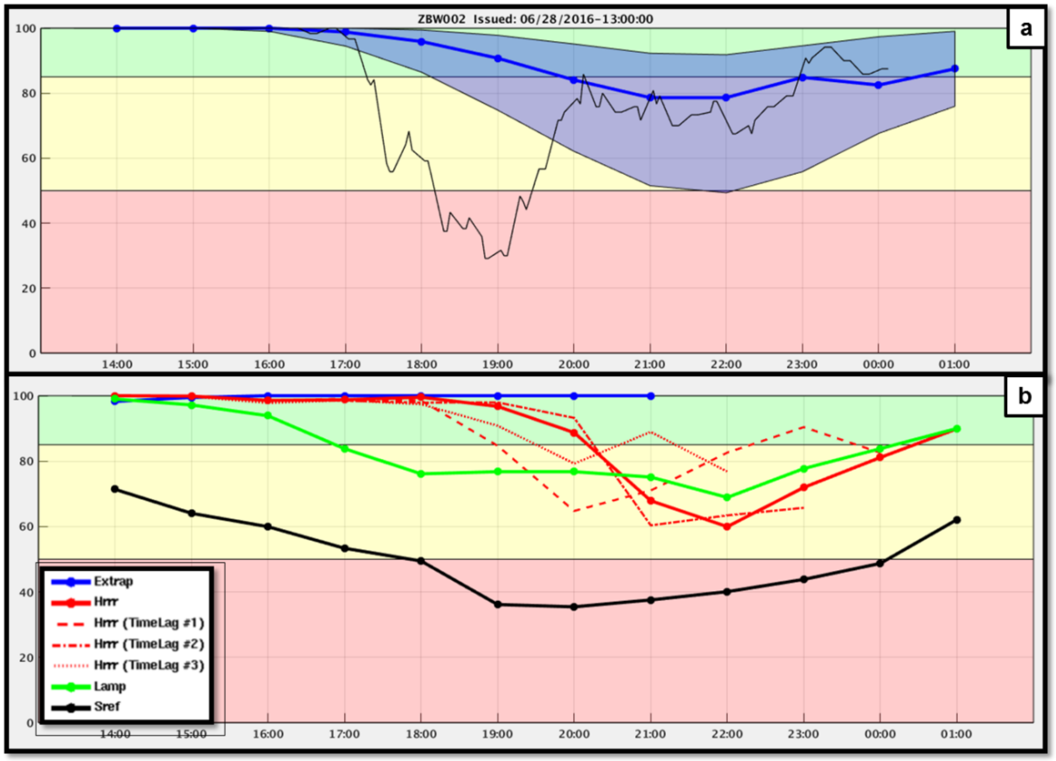

Figure 28. 28 June 2016 (a) 1300 UTC TFI permeability forecast in solid blue along with verified permeability in solid black and (b) the TFI-like permeability forecasts from individual deterministic and probabilistic forecasts for the same time period.

TFI was used by ATCSCC planners to solidify the specifics of the plan, such as when the AFP should start and which specific AFP region to use. The confidence for setting the AFP rate was not high on this day due to the scattered nature of the storms forecasted.[12] This was taken into consideration during the discussion of how severely to restrict flow through A01 (i.e., what impact level to choose to determine the AFP rate as described in Table 2). Traffic managers made the decision by 1545 UTC to issue A01 and implement the restrictions beginning at 1930 UTC. Severe weather planners used TFI and CoSPA to review archived images at 1700 UTC. They used previous CoSPA 8-hour forecasts to verify storm placement and timing. It was determined that forecasts were indeed accurate and therefore the 1930 UTC start time of A01 would remain.

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[12] Based on post-analysis discussion with ATCSCC planner and NOM.

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5. USER COMMENTS, REQUESTS, AND SURVEY RESULTS

5.1 USER COMMENTS

User comments concerning the CoSPA and TFI products were noted for further analysis. These comments are shown in Table 5. The majority of these comments refer to the “slow response” of the SD. In 2016, MIT Lincoln Laboratory was given permission to display CoSPA on the SD, after an absence of five years. The software update to the SD that enabled this display resulted in the SD being slow to respond to user input. Many of these issues have since been resolved.

Users also indicated their approval of the display concept for the various products, and some commented of the accuracy of the CoSPA forecasts. Users indicated their approval of the TFI-like permeability forecasts of forecast model output discussed in Section 4.2.1. Other users commented on the accuracy of the forecasts, such as:

- “The HRRR forecast from 3 to 8 hours is not reliable.”
- The HRRR performance on 26 June was “not good.”
- TFI under-forecasts permeability (2 comments).

TABLE 5

User Comments Documented During Field Observations

Facility	User Comment
FAA ATM	The user stated that ITWS was more accurate than CIWS for DTW weather. It was determined that the user was comparing CIWS echo tops forecast to ITWS Precip forecast. The differences between ITWS and CIWS radar coverage and its impact on the forecasts were discussed.
Stakeholder	The user likes the 8-hr TFI forecast on the SD but is having difficulty displaying it on the website. The user also believes that HRRR reliability from 3 to 8 hours is not "as reliable".
Stakeholder	The user feels current filters for the echo tops products (5,000-foot increments) are too broad.
Stakeholder	The user likes the TFI timeline display of impact.
FAA ATM	The user is pleased to have CoSPA back on the SD.
Stakeholder	The users feel that HRRR performance on June 26 was not good.
Stakeholder	The user told the observer that CoSPA forecasted BNA incorrectly. Two departures were held on the ground because the CoSPA 2-hr forecast indicated impact on the airport. However, when the forecast updated, the airport was no longer forecasted to be impacted.
FAA ATM	The user noted that the SD response was slow, especially during product updates. He further demonstrated a very noticeable lag (not associated with a product update) when dragging a window to a new location.
Stakeholder	The user declares that they have no interest in a 12-hour TFI forecast; four hours is sufficient.

Facility	User Comment
FAA ATM	The user commented on the slowness of the SD.
FAA ATM	The planner feels that TFI is slightly under-forecasting impacts.
FAA ATM	The users "love" TFI-like plots for other forecast models (e.g., SREF, LAMP, etc.) that were mocked-up by the observer.
FAA ATM	The users feel TFI is under-forecasting permeability across ZNY001 and ZY006 at 1730 UTC through 1830 UTC and that the impact thresholds (High, Medium, and Low) should be adjusted.
Stakeholder	The user says that CoSPA provides more information about thunderstorms near or on airports and helps when thunderstorms are not forecasted in TAF.
Stakeholder	The user feels the CIWS/CoSPA storm speed for cells west of BWI is too fast.
Stakeholder	The user complained that he was having difficult viewing CoSPA with Internet Explorer and was advised to change to a different browser.
FAA ATM	The user states CoSPA is doing a decent job of forecasting.

5.2 USER REQUESTS

In addition to logging user comments, observers also noted any requests for changes or additions to the CoSPA and TFI product suite. Those requests are provided in Table 6. Many of the requests were for configuration capabilities, such as changes to the way the timelines are displayed. Other requests included the capability to display additional products (e.g., CAWS [Collaborative Aviation Weather Statements], SREF, LAMP, dry lines etc.).

TABLE 6

User Requests Documented During Field Observations

Facility	User Request
Stakeholder	The capability on CoSPA to display CAWS regions (without text) with user-selectable colors.
FAA ATM	TFI FCAs for the southern ZOB/ZNY and the ZOB/ZDC boundaries.
FAA ATM	The capability for the user to display only the TFI timelines of interest rather than displaying all timelines associated with an ARTCC.
Stakeholder	The CoSPA capability to detect and display dry lines.
FAA ATM	The capability to “tear off” TFI timelines so they are in a separate window rather than attached to the weather window.
FAA ATM	The capability to display CAWS on CoSPA.
FAA ATM	A short-cut button that, when selected, changes the home of the window to the location of the Home nearest to the center of the window.
FAA ATM	The Home should be displayed in the Accuracy window.
FAA ATM	The TFI impact windows should be resizable and the FCA name should be in the top left corner instead of the top center of the window.
Stakeholder	TFI windows should not close automatically.

Facility	User Request
FAA ATM	TFI impact thresholds need to be adjusted to more closely match operational impacts.
FAA ATM	Users would like to have TFI-like plots of forecasted impact for other weather models, such as SREF, LAMP, and HRRR, as a display option for TFI. This allows them to make decisions using NAM to verify information in the forecasts.

5.3 POST-SEASON SURVEY RESULTS

Before the observation period commenced, MIT Lincoln Laboratory required all website users to create individual logins. Historically, CIWS and CoSPA websites operated under "shared account" access. This allowed multiple users at the same facility, airline, and institution to log in using the same username/password. Security concerns and the inability to directly contact individual users forced MIT LL to eliminate the "shared account" access and institute individual accounts. Individual account registration allowed MIT LL to promptly notify all registered users individually of any system changes, notifications, or maintenance outages, and to invite users to participate in an online survey.

After the field observation period was completed, users with website accounts were contacted to request that users provide detailed feedback on TFI by completing an online survey; this included users who did not participate in the demonstration. Thirty-two users completed the survey: 19 stakeholders, four meteorologists, and nine FAA/air traffic users. The full results of the survey are presented in Appendix C.

Users were asked to provide feedback on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree) on a variety of questions regarding the ease of use and accuracy of the TFI product. The summary of responses to all questions is provided in Table 7 and the distribution of responses is in Figure 29. Users generally approved of TFI and the timeline display concept. Scores for training were low, relative to many of the other categories. In general, users found the TFI tool useful for understanding operational impacts, easy to use, and worthy of further evaluation.

Survey respondents were provided with the opportunity to include comments with their survey responses and these are available in Appendix C. Many of the respondents were located outside the primary Northeast demonstration area. While CoSPA/TFI is available to any users via the website, budgetary constraints prevented MIT LL from providing training to users outside the demonstration area. Therefore, those who were unhappy with the training were those who did not have the opportunity to receive formal training. Extensive online help is available to all website users, and it may be beneficial to remind all online users of this capability.

One user noted that it seemed that TFI forecasts of low impact were underestimates of the true level of impact; this suggests that the impact level thresholds need to be adjusted. Another stated that timelines for Jacksonville ARTCC (ZJX) were not accurate. Further research is needed to tune the FCAs for ZJX.

Another user indicated that TFI was useful not only for air traffic planning but also for sector staffing purposes. Other users indicated that TFI forecasts should be available for all ARTCCs and not just the northeast, which is the ultimate goal for TFI.

TABLE 7

Summary of Survey Responses

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neutral (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)	Average Score (Scale: 1 – 7)
Easy to Use	0	0	0	5	2	9	16	6.1
Adequately Trained	1	3	2	9	4	4	9	4.9
Continue to Evaluate	0	2	1	3	2	7	17	5.9
Timeline Easy to Understand	0	0	1	4	3	10	14	6.0
Timeline Accurate	0	1	2	5	6	9	9	5.5
Forecast Plot Easy to Understand	0	0	1	8	4	8	11	5.6
"Permeability" Easy to Understand	0	0	4	7	4	7	10	5.4
Impact Categories Helpful	0	1	0	10	2	7	12	5.6
Impact Categories Accurate	0	1	2	8	6	8	7	5.2
Uncertainty Helpful	0	1	1	10	5	6	9	5.3
Tool Helpful for Understanding Operational Impacts	0	0	3	3	0	8	18	6.1
Tool Helpful for Facilitating Discussion	1	0	2	8	4	2	15	5.5

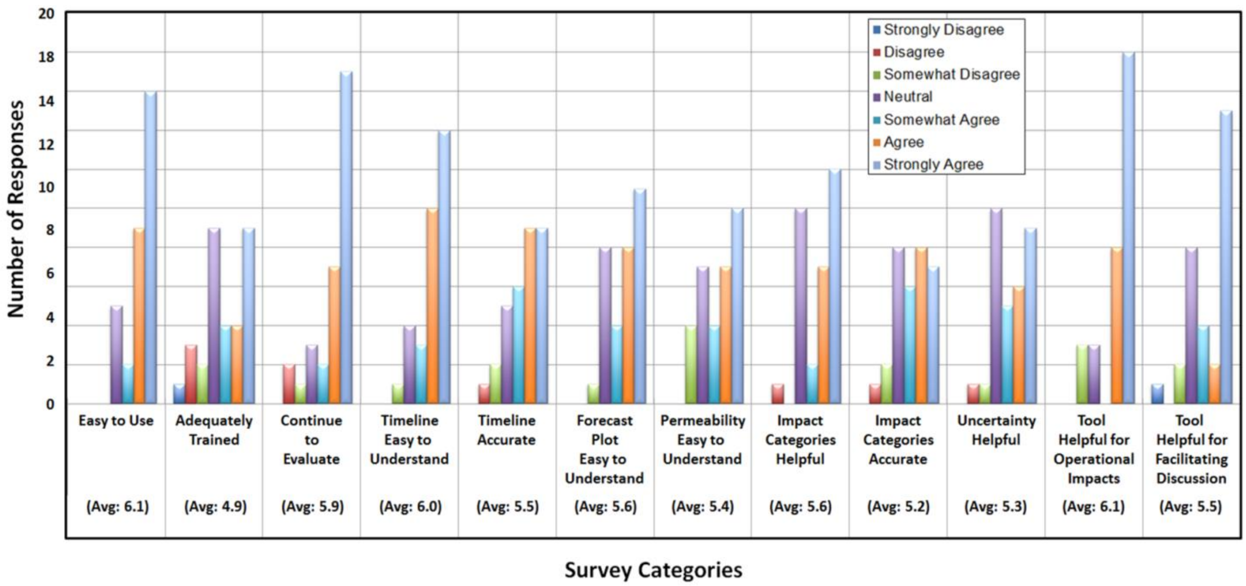

Figure 29. Distribution of user responses to survey questions. The averages beneath each survey category are the average response values on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).

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6. SUMMARY

The CoSPA VIL and ET forecast was provided to all registered users (via web) and, for the first time since 2011, CoSPA was available on the CIWS SDs. Targeted field observations were conducted (1 June through 31 October 2016) by MIT LL observers to gather information on how the CoSPA weather forecast was used in operations, to obtain feedback on the newest TFI capability, and to collect comments for improvement. The MIT LL observation team gathered data from three separate convective events covering four days and collecting almost two-hundred hours of observations. Observers documented 122 instances when CoSPA and/or TFI were used operationally, with 42 attributed to TFI. The most common use was for situational awareness and there were 8 observations of support for AFP go/no-go decisions (1 for AFP and 7 for TFI-AFP).

The 2016 season was the third convective season during which TFI was exhibited at the ATCSCC, and the second season to CDM users across the NAS. TFI was developed to address current shortfalls in strategic planning by providing explicit translation of convective weather forecasts into resource constraints for traffic managers. The display builds upon the CoSPA deterministic decision support tool and is a true multi-model, ensemble forecast that also provides a dynamic measure of forecast confidence. Users have commented year after year that confidence in the weather forecast allows traffic managers greater latitude when making decisions in an environment filled with complexity and uncertainty. The evaluation of TFI in 2016 remained positive with users stating that TFI was helpful with addressing operational impacts. They also strongly agreed that TFI was helpful in facilitating discussion during severe weather events and was easy to use as well. Additionally, users stressed the importance of further development and the need for continued evaluation of the decision support tool within the operational environment. Most of these requests related to the GUI with graphical changes that would allow more efficient use of the tool during convective events. There were also requests to add TFI FCAs to other regions of the NAS around traditionally challenging sectors of airspace.

Air traffic managers will always encounter varying uncertainty when making decisions in a complicated network like the NAS, especially with those decisions that involve convective weather. Uncertainty may never be eliminated from the equation, however, managing uncertainty and quantifying the risk of each decision is an area of research where CoSPA and TFI is focusing. By translating convective weather forecast information into the parameters used in selecting TMIs (e.g., time of onset, level of impact [permeability and flow rates], and duration), more effective and timely TMIs can be formulated and assessed in operations. Additionally, communicating forecast uncertainty using those same decision variables provides an objective, quantitative basis to better understand and communicate the risks and benefits of various levels of TMI strategies.

6.1 FUTURE WORK

Several hundred hours of operational observations in 2016 have provided more insight and ideas to improving the efficiency of TFI. This past year has added another season of convective weather observations and the ETMS flights tracks of hundreds of thousands of planes to the case study research events database. These post-analysis results will be added to the previous two years of observations in the training database set used in the TFI algorithm. Expansion across the NAS of TFI FCAs is one area of focus for future work. Key airport regions such as Chicago, Atlanta, and Dallas-Fort Worth, as well as enroute airspace between each of these terminals, would be included in this expansion. The addition of specific AFP rates to the TFI "drill-down" plots has also been proposed. These rates would appear on the TFI graph along with the measure of permeability and would vary based on each specific TFI region. Research of enroute density and controller workload would contribute to the development of these rates. A follow-on operational observation would then be requested once these proposed developments have been appraised and implemented.

APPENDIX A.
FIELD OBSERVATIONS DURING WHICH BENEFITS WERE DOCUMENTED

TABLE A-1

27 June 2016 Field Observations

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1111	ZOB	No	The STMC displayed TFI prior to the SPT. There is no forecasted impact on ZOB FCAs. CCFP shows weather across ZOB by 19 UTC. The STMC says this is "bad for ZOB" but the worst is impacts on DC routes.		SA-TFI
1230	SWA	Yes	The observer demonstrated both the TFI time lines and graphs to the ATC specialists who really liked the timeline display of impact. The users were concerned with DCA and BWI storm impacts. No AFP is planned for today. TFI currently forecasts green for ZDC and ZOB today.		SA-TFI
1245	SCC	No	The NOM used CoSPA/TFI the previous day to persuade ZOB that AFPs would not be needed.	SA	SA-TFI TFI-AFP TFI-Planning
1300	SCC	No	The user displays CoSPA with CCFP on the website and TFI on the SD. TFI is currently green in ZNY.	SA	SA-TFI
1315	ZOB	No	SPT: An N90 GDP is possible after 22 UTC due to departure impacts. One stakeholder supports the GDP, others want to wait and see. The STMC scrolled through TFI and then back to CIWS.		SA-FTI
1420	SCC	No	CoSPA and TFI were consulted to verify the lack of impact across ZNY/ZOB. ATCSCC feels reroutes alone will be able to manage the anticipated ZDC impact. Per the A4A telecon, stakeholders wanted full GDP/AFP, but ZOB, ZNY, and ZDC did not feel the forecast warranted AFPs.	SA SA-R	SA-TFI

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1500	SWA	No	One user noted that CoSPA shows that the line of storms is forecasted to decay as it approaches the east coast and DC metro airports. Soon after this, a second user suggested reducing traffic to BWI and DCA; he is considering cancelling 28 flights to prevent gate and ramp congestion issues. The second user did not use CoSPA or TFI, but used weather products from another provider, along with TAFs. During the discussion that followed, the first user referenced CoSPA forecasts for 1450 UTC through 1520 UTC. As a result, flights were not cancelled. Had these flights been cancelled, flights between 15 UTC and 08 UTC would have been impacted.	SA SA-T	
1515	SCC	No	The planner uses CoSPA on the SD for the briefing.	SA SA-T	
1529	JBU	No	CoSPA is used to assess impacts on CAN routes and to coordinate with a co-worker.	SA SA-R	
1545	SWA	No	TFI continues to show green for ZDC. The meteorologist tells the user that morning forecasts may have overestimated impact to DC metro airports. Traffic is on normal routes now. The user thinks everything will be OK.		SA-TFI
1915	SWA	No	The user accessed TFI to determine impact; TFI all green.		SA-TFI
2002	JBU	No	The dispatcher uses CoSPA on the web and SD to assess weather in the Northeast and Florida. This user asked if Winter Precip could detect dry line fronts in Texas; the observer responded “possibly".	SA	
2030	JBU	No	CoSPA was used for the stand-up briefing.	SA	
2114	JBU	No	SPT: The stakeholder used CoSPA and TFI for situational awareness during the SPT.	SA SA-R	SA-TFI

APPENDIX B.
USER REQUESTS DOCUMENTED DURING FIELD OBSERVATIONS

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1045	SCC	No	CoSPA is looping at the Planner positions as they focus on the AFP discussion.	SA SA-AFP	
1130	JBU	Yes	The user explained that due to software problems, GDPs must be issued before AFPs, and this is costing stakeholders millions of dollars. CoSPA and TFI were used to examine possible restricted flow through ZBW and ZNY. ZBW002 and ZBW003 show decreasing permeability beginning 1830 UTC.	SA	
1220	JBU	No	The stakeholder used TFI prior to the A4A telecon; ZNY006 is yellow beginning 2015 UTC. ATCSCC is considering AFPs. CAN routes east and west are coordinated and ready to be implemented, and coastal routes are shut down. The stakeholder is unsure of the effectiveness of AFPs and would rather use GDPs and structured routing. Traffic should be slowed enough that AFPs are not needed. ZBW also would rather use GDPs instead of AFPs.		SA-TFI SA-GDP
1230	SCC	No	AFPs are being discussed in SVRWX amongst the NTMO and new trainees, using CoSPA and TFI.	SA	SA-TFI
1300	SWA	Yes	The observer displayed TFI at the ATC desk and noted the 20 UTC yellow impact on ZBW001, ZBW001, and ZNY001. The ATC specialist expects a more difficult day than yesterday.		SA-TFI
1315	JBU	No	SPT: The stakeholder notes that CoSPA shows development after 19 UTC and is concerned that AFP/GDP will delay the traffic into the weather. ATCSCC is waiting for a new model run.	SA SA-AFP SA-R	
1315	SWA	No	SPT: CAWS 1 is issued. GDPs are expected today with CAN route route-outs. Thunderstorms are expected in ZFW after 19 UTC, but CoSPA is not forecasting them. ATCSCC believes the CCFP is doing well today and that DC will not be significantly impacted. More impact is expected in N90. N90 requested that the SERMN routes be mandatory so stakeholders should fuel accordingly. ZBW is impacted with few routes available. The end of the weather line may reach and impact BWI later. OB1 was suggested; the stakeholder would prefer A01 so that DCA and BWI are not included in the AFP.	SA	

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1428	JBU	No	A user examines CoSPA in relation to Atlantic Route tracks across the Gulf to FL.	SA SA-R	
1445	SCC	No	Once GDPs were published, the demand through A02 was reduced sufficiently to avoid issuing A02 altogether. A01 was issued instead. TFI is trending toward greater impact, allowing the planner to be more definitive about this decision.	SA SA-R	TFI-Planning TFI-GDP TFI-AFP
1515	SCC	No	GDPs are published and AFP A01 is being finalized. The Planner feels that TFI is slightly under-forecasting weather impacts.		SA-TFI
1545	SCC	No	A01 begins at 19 UTC. CoSPA is compared to other models (LAMP/SREF) to confirm the 19 UTC start time for the AFP.	AFP SA-R SA	TFI-AFP
1635	SCC	Yes	There is a lot of discussion on the amount of confidence users can put in the models. Prototype TFI-like plots for SREF, LAMP, HRRR, and Extrapolation were made and shown to SVRWX users, who are planning AFPs and routes. The users "love" the plots and would like these as options in the current TFI application. This allows them to make their decisions using NAM to verify information in the forecasts. TFI was used to determine timing of the AFP, but confidence on the rates is not as high due to the nature of the weather.	SA	SA-TFI TFI-AFP TFI-Planning
1715	JBU	No	SPT: Two stakeholder users viewed CoSPA and TFI during the SPT. Several FCAs were yellow so users scrolled through the timeline to determine the onset.	SA SA-R	SA-TFI
1715	SCC	No	The SVRWX Planner asked the observer to help verify the current TFI forecast. The observer used CoSPA/TFI archives to provide a side-by-side comparison of the current 17 UTC VIL forecast with the forecast made five hours previously (at 12 UTC). The forecasts agreed on timing, placement, and severity; even forecasting the initial development of scattered storms across eastern PA/NY and western New England.	SA	SA-TFI TFI-AFP TFI-Planning
1800	SCC	No	The observer discussed TFI-forecasted impact in ZNY with SVRWX Planner and NTMO. The users feel TFI is under-forecasting permeability across ZNY001 and ZNY006 at 1730 UTC. They feel the TFI impact thresholds (Low/Medium/High) need to be adjusted.		SA-TFI
1915	JBU	No	Stakeholder used CoSPA during the SPT to assess the weather as each facility checked in.	SA	

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
194 0	SW A	No	Storms are impacting flows into BWI. CoSPA 3- and 4-hr forecasts were used to assess the impact of storms near Las Vegas. There is not much thunderstorm activity forecast for LAS in the TAFs. The user stated CoSPA provides more information about thunderstorms in and near the area and helps when the TAF forecast misses.	SA SA-T	
201 5	SW A	No	A01 is cancelled. The user assessed CIWS/CoSPA to plan for turbulence on routes.	SA SA-R	
211 5	SW A	No	SPT: Stakeholder meteorologist says storms will impact BWI in 90 minutes. The meteorologist believes that the CIWS/CoSPA forecasts of storm speed are too fast for storms west of BWI.	SA	

TABLE B-2

14 July 2016 Field Observations

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1030	SCC	No	The Planner is discussing how to manage potential impact on ORD south gates. CIWS/CoSPA are up and being used by the Planner for situational awareness. ORD RAPT is projected overhead. SVRWX also has CoSPA displayed for start-of-shift briefing.	SA SA-T	
1045	None	No	The STMC discusses TFI and MAP (Monitor Alert Parameter) with the observer. He uses weather and flow to reduce the MAP value, and TFI to reduce or increase volume.		SA-TFI TFI-Planning
1100	SCC	No	TFI forecasts red in ZBW and yellow in ZNY/ZOB. The Planner/NOM is viewing TFI.		SA-TFI
1100	JBU	No	CoSPA was displayed with multiple route overlays displayed, but TFI was not displayed. The stakeholder reviewed CoSPA and ADDS TAFs.	SA SA-R	
1100	None	No	The STMC discussed how MAP values work. MAP values are not dynamic; they change only when the user adjusts them. MAP values are adjusted tactically, depending on different variables. CoSPA was used to plan for later in the day.	SA	
1115	SCC	No	The Planner monitors CIWS and CoSPA while training a new planner. CIWS is displayed on the SD and CoSPA on the web.	SA	

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1115	JBU	No	The stakeholder uses CoSPA and CCFP to assess the potential for weather on the ZNY/ZBW border. The 8-hr forecast shows a long line of storms along the Hudson Valley. CCFP and CoSPA match well, but CoSPA forecasts convection farther south into NYC and New Jersey. There was no mention of AFPs during the SPT. The user believes ATCSCC is trying to manage traffic with GDPs.	SA SA-R	
1115	None	No	SPT: ZAU reports weather in all quadrants. ZID expects impacts all day. Traffic on J42 is deviating. If the weather sinks south, ZID will try to find a route around it using J134. (Note: the ZBW CWSU does not expect the weather to extend to PA.) Weather is expected to stay west of KC. The CoSPA 8-hr forecast valid at 1920 UTC shows a solid line of convection on the New England border with a north/south line stretching to NJ. Nav Canada expects Quebec City to be impacted, so no CAN routes will be available.	SA	
1200	JBU	Yes	The observer and stakeholder reviewed CoSPA and TFI to assess potential convection for the afternoon. The stakeholder thinks CAN routes will be needed for BOS departures due to a forecasted line of weather in eastern NY. TFI forecasts red for ZBW002 (45% permeability at 19 UTC.)	SA SA-R	SA-TFI
1215	None	No	The STMC stated that MAP drives other decisions, so they need to work with TFI. ZBW004 is red at 20 UTC. The STMC showed TFI impacts to TMCs.		SA-TFI
1230	JBU	No	A4A telecon: No-J42. No TMI for volume; weather only for BOS. AFPs are not anticipated. The stakeholder considers using Atlantic Routes as long as there are no military operations. Q routes may be impacted by a rocket launch. The stakeholder uses CoSPA to follow a discussion regarding CoSPA.	SA SA-R	
1305	None	No	There are TMA issued at PHL, so MIT is likely. CoSPA is prominently displayed in order for TMCs to monitor the 8-hr forecast. A TMC notes that weather will impact GREKI/MERIT and cause a big problem.	SA	
1315	JBU	No	The stakeholder continues to display CoSPA but not TFI.	SA	
1338	None	No	The TMC is looking at TFI FCA ZBW002 for planning at 1930 UTC and later.		SA-TFI
1341	JBU	No	A dispatcher asked the user about M201, M203, and AZEZU. Neither thinks these routes will be closed, but ATCSCC believes they will be impacted. The user used CoSPA instead of OPC (Offshore Precipitation Capability). The observer believes it would be helpful to have OPC on the SD in addition to the website.	SA	

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1409	JBU	No	CoSPA and FSM were used for a hand-off briefing.	SA	
1515	None	No	SPT: ATCSCC mentioned that CAN routes might be possible starting at 17 UTC but ZBW does not support this. The STMC used CoSPA to argue that if weather develops, they cannot use CAN routes.	SA SA-R ERP	
1530	None	No	The STMC uses CoSPA to determine the viability of CAN routes after 23 UTC. The CWSU says storms will start developing in the next couple of hours. “CoSPA is doing a decent job” so far.	SA SA-R ERP	
1638	None	No	The TMC uses CoSPA to discuss routes with ATCSCC and notes that the forecast calls for weather to move northeast. TMC agrees to “let it ride” until he hears complaints.	SA SA-R ERP	
1702	None	No	The TMO requested a forecast for an Area and used CoSPA to check forecasts. The Area should be OK; not a late night.	SA Staffing	
1715	JBU	No	The user displays CoSPA full screen to monitor the weather.	SA	
2041	SCC	No	Storms are clearing EWR/TEB and approaching LGA and JFK. The SVRWX TMC uses CIWS to tactically plan N90 impacts (using VIL, Storm Motion, and G&D) and then switches to CoSPA to plan the remainder of the evening for International departures at 00 UTC and beyond.	SA SA-R ERP	

TABLE B-3

16 August 2016 Field Observations

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1210	SCC	No	The NAM states that weather is worse than yesterday because storms are further east into ZNY and likely to impact N90, ZBW, and PHL terminal. The NOM is reviewing the CoSPA 8-hr forecast. TFI for ZOB, ZNY, and ZBW was briefly displayed. The Planner states that communication issues in ZOB continue, therefore AFPs are a “given” today.	SA	SA-TFI
1400	SCC	No	TFI is displayed on a large overhead display to monitor weather and review AFP rates before OB1 is published. TFI for ZNY001 is displayed on the screen with FSM. FSM displays both OB1 and A08 rates.		SA-TFI TFI-AFP TFI-Planning

Time (UTC)	Facility	Observer Assist	Observation	CoSPA Benefit	TFI Benefit
1425	SCC	No	A08 rates are being finalized by SVRWX. A FSM “glitch” occurred while AFP A08 was being published, resulting in two versions of A08 on the OIS. SVRWX is using TFI and CoSPA to examine the A08, to check if weather constraints will be present across ZDC.		SA-TFI TFI-AFP TFI-Planning
1515	SCC	No	SPT: CIWS and CoSPA are used by the Planner during the telecon for reference and planning potential GDPs.	SA GDP SA-T	
2025	SCC	No	The SVRWX specialist is planning revisions to GDP/AFPs and adding potential reroutes. CIWS is used to review the forecast for the next two hours to determine when the first line of storms will exit N90, as well as when second line along ZOB/ZNY border will weaken.	SA SA-T SA-R	
2115	ZOB	No	SPT: ZBW reports that all NY departure routes are closed. They are severely restricted to ZOB. ATCSCC says that N90 GDPs have been revised down; OB1 is down to a 50 rate from 01 UTC through 03 UTC. The observer displayed TFI ZNY001, which forecasts red in the first hour going to yellow and green. The next TFI update changed red to yellow.		SA-TFI
2115	SCC	No	VIL and G&D for ZDC were displayed on the SPT webinar. AFP OB1 is revised to 50 from 01 UTC through 03 UTC to allow for work to resolve ZOB frequency issues. More traffic will be routed through ZDC; ZDC should staff appropriately.	SA Staffing	
2315	ZOB	No	SPT: The ZOB STMC displays CoSPA forecast contours for situational awareness. A08 is purged. ZBW reports lots of deviations. ZBW traffic to ZOB was 15 MIT per strat; going to straight 15 MIT. Weather is improving. ZID reports J6 weather is deteriorating but they are doing OK.	SA	
1210	SCC	No	The NAM states that weather is worse than yesterday because storms are further east into ZNY and likely to impact N90, ZBW, and PHL terminal. The NOM is reviewing the CoSPA 8-hr forecast. TFI for ZOB, ZNY, and ZBW was briefly displayed. The Planner states that communication issues in ZOB continue, therefore AFPs are a “given” today.	SA	SA-TFI

APPENDIX C.
POST-SEASON SURVEYS

Air Traffic Management 1	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 1	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.				X			

Stakeholder 1	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
2. I was adequately trained on the use of the tool.		X					
Comment: My training was probably 5 years ago, but overall it is fairly easy to customize settings.							
3. I would like to continue evaluating the tool.		X					
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.					X		
Comment: Timeline feature is very helpful.							
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
Comment: …not quite sure about this….							
7. It was easy to understand the notion of “permeability”.				X			
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.					X		
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X
General Comment: I love using COSPA! Very good product for predicting weather 4–6 hours ahead which helps in determining aircraft routings.							

Stakeholder 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.							X

Stakeholder 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 3	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".				X			

Stakeholder 3	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.					X		
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 4	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
Comment: Easy to use but we could use a little more info on how to apply the tool in events where there is a relatively wide margin of uncertainty.							
2. I was adequately trained on the use of the tool.					X		
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.					X		
Comment: Forecast uncertainty is helpful but a better explanation on how to apply it would help.							
7. It was easy to understand the notion of "permeability".					X		
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.						X	

Stakeholder 4	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
10. The presentation of forecast uncertainty was helpful.					X		
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Air Traffic Management 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.					X		
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.					X		
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.					X		
7. It was easy to understand the notion of “permeability”.					X		
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.					X		
10. The presentation of forecast uncertainty was helpful.					X		
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X

Air Traffic Management 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
12. The tool was helpful in facilitating discussions with other stakeholder.					X		

Stakeholder 5	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.				X			
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.				X			
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.				X			
5. The timeline display color coding accurately portrayed forecasted weather impacts.				X			
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of “permeability”.				X			
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.				X			
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Weather 1	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.				X			
2. I was adequately trained on the use of the tool.		X					
3. I would like to continue evaluating the tool.						X	
Comment: These are not issued for my airspace.							
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.				X			
5. The timeline display color coding accurately portrayed forecasted weather impacts.				X			
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".				X			
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.				X			
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Stakeholder 6	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.				X			

Stakeholder 6	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
3. I would like to continue evaluating the tool.				X			
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of "permeability".						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.					X		
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

I'm hearing that	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.						X	
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X

I'm hearing that	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
5. The timeline display color coding accurately portrayed forecasted weather impacts.				X			
General Comment on Timeline: Some of the mid-range forecast seemed to lack some accuracy, by under representation of actual weather.							
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.					X		
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Air Traffic Management 3	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.					X		
2. I was adequately trained on the use of the tool.		X					
3. I would like to continue evaluating the tool.					X		
General Comment: I would want all ARTCCs to be included in the tool to get a better handle on it (not just a select group of five).							
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.			X				

Air Traffic Management 3	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
5. The timeline display color coding accurately portrayed forecasted weather impacts.			X				
General Comment on Timeline Again, better training material needed to be shown on the web page to make it easier to digest.							
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.			X				
7. It was easy to understand the notion of "permeability".			X				
8. The breakdown of low/med/high impact was helpful.		X					
9. The low/med/high impact cutoffs were accurate.		X					
10. The presentation of forecast uncertainty was helpful.				X			
General Comment on Graph: Again, I would want more areas to be able to understand how it works (or does not work).							
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.			X				
12. The tool was helpful in facilitating discussions with other stakeholder.			X				
General Comment on Summary: Needed to see it for other areas like ZMA and not just a select group of five.							

Stakeholder 8	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X

Stakeholder 8	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Weather 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.				X			
2. I was adequately trained on the use of the tool.	X						
3. I would like to continue evaluating the tool.		X					
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.				X			

Weather 2	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
5. The timeline display color coding accurately portrayed forecasted weather impacts.			X				
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".			X				
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.			X				
10. The presentation of forecast uncertainty was helpful.					X		
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.			X				
12. The tool was helpful in facilitating discussions with other stakeholder.	X						

Stakeholder 9	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X

Stakeholder 9	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Stakeholder 10	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".				X			
8. The breakdown of low/med/high impact was helpful.				X			

Stakeholder 10	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.				X			
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Stakeholder 11	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.					X		
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of “permeability”.							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X

Stakeholder 11	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 12	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.				X			
Comment: Seems like times depicting low impact in the Northeast caused more impact than one would expect.							
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X

Stakeholder 12	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
12. The tool was helpful in facilitating discussions with other stakeholder.				X			
Comment: Not sure how much the FAA used the tool.							

Weather 3	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of “permeability”.						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.						X	

Air Traffic Management 4	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.		X					
Comment: For ZJX it appeared the timelines were always green and never showed any degradation of airspace even during times the airspace was impacted quite heavily with convective activity. I'm not sure if this is due to the location of the FEA lines being used or something else.							
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.			X				
Comment: I would strongly agree if I felt this information was accurate, however based on what I observed it appeared to not capture what was actually taking place within the airspace.							
12. The tool was helpful in facilitating discussions with other stakeholder.			X				

Air Traffic Management 5	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of “permeability”.							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Air Traffic Management 6	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X

Air Traffic Management 6	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of "permeability".						X	
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.					X		
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.						X	

Stakeholder 13	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	

Stakeholder 13	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of “permeability”.						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.					X		
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.					X		

Air Traffic Management 7	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
General Comment: This tool is incredibly useful not only for air traffic planning purposes but also for sector staffing purposes.							
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X

Air Traffic Management 7	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of “permeability”.							X
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.							X
10. The presentation of forecast uncertainty was helpful.							X
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 14	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.			X				
3. I would like to continue evaluating the tool.				X			
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of “permeability”.			X				

Stakeholder 14	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.		X					
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.					X		

Stakeholder 15	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.							X
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.							X
7. It was easy to understand the notion of "permeability".						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	

Stakeholder 15	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.						X	

Air Traffic Management 8	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
General							
1. The tool was easy to use.					X		
2. I was adequately trained on the use of the tool.			X				
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.					X		
7. It was easy to understand the notion of "permeability".				X			
8. The breakdown of low/med/high impact was helpful.					X		
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.			X				
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X

Air Traffic Management 8	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Weather 4	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.						X	
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.					X		
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of “permeability”.					X		
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.					X		

Stakeholder 16	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.						X	
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of "permeability".						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.				X			

Stakeholder 17	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.				X			
2. I was adequately trained on the use of the tool.				X			
3. I would like to continue evaluating the tool.			X				

Stakeholder 17	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.				X			
5. The timeline display color coding accurately portrayed forecasted weather impacts.				X			
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".				X			
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.						X	
12. The tool was helpful in facilitating discussions with other stakeholder.					X		

Stakeholder 18	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.					X		
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.						X	

Stakeholder 18	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
5. The timeline display color coding accurately portrayed forecasted weather impacts.						X	
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	
7. It was easy to understand the notion of “permeability”.						X	
8. The breakdown of low/med/high impact was helpful.						X	
9. The low/med/high impact cutoffs were accurate.						X	
10. The presentation of forecast uncertainty was helpful.						X	
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Stakeholder 19	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.						X	
2. I was adequately trained on the use of the tool.					X		
3. I would like to continue evaluating the tool.						X	
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.					X		
5. The timeline display color coding accurately portrayed forecasted weather impacts.				X			
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.						X	

Stakeholder 19	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
7. It was easy to understand the notion of "permeability".					X		
8. The breakdown of low/med/high impact was helpful.							X
9. The low/med/high impact cutoffs were accurate.			X				
10. The presentation of forecast uncertainty was helpful.					X		
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

Air Traffic Management 9	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
General							
1. The tool was easy to use.							X
2. I was adequately trained on the use of the tool.						X	
3. I would like to continue evaluating the tool.							X
Color-Coded Forecast Timeline							
4. The color-coded timeline display was easy to use and understand.							X
5. The timeline display color coding accurately portrayed forecasted weather impacts.							X
TFI Forecast Graph Questions							
6. The TFI forecast graph was easy to use and understand.				X			
7. It was easy to understand the notion of "permeability".			X				
8. The breakdown of low/med/high impact was helpful.				X			
9. The low/med/high impact cutoffs were accurate.				X			
10. The presentation of forecast uncertainty was helpful.				X			

Air Traffic Management 9	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Summary Questions							
11. The tool was helpful in understanding weather impacts on operations.							X
12. The tool was helpful in facilitating discussions with other stakeholder.							X

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LIST OF ACRONYMS

A4A	Airlines for America
ADDS	Aviation Digital Display Service
AFP	Airspace Flow Program
ARTCC	Air Route Traffic Control Center
ASPM	Aviation Sytem Performance Metrics
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
BOS	Boston International Airport
BWI	Baltimore Washington International Airport
CAWS	Collborative Aviation Weather Statements
CCFP	Collaborative Convective Forecast Product
CDM	Collaborative Decision Making
CIWS	Corridor Integrated Weather System
CoSPA	Storm Predicaton for Aviation
DCA	Reagan National Airport
EDCT	Estimated Departure Clearance Time
EOSR	End of Season Review
ERP	Enhanced Reroute Planning
ESRL	Earth System Research Laboratory
ET	Echo Tops
ETMS	Enhanced Traffic Management System
EWR	Newark International Airport
FAA	Federal Aviation Administration
FCA	Flow Constrained Areas
FEA	Flow Evaluation Area
FET	Flow Evaluation Team
FSM	Flight Schedule Monitor
GDP	Ground Delay Program
GS	Ground Stop
GSD	Global Systems Division
HRRR	High Resolution Rapid Refresh
IAD	Washington Dulles International Airport
JFK	John F. Kennedy International Airport
LAMP	Localized Aviation MOS Program
LGA	LaGuardia International Airport
MAP	Monitor alert Parameter
MIT LL	Massachusetts Institute of Technology Lincoln Laboratory

LIST OF ACRONYMS (CONTINUED)

MOS	Model Output Statistics
N90	New York TRACON
NAM	National Aviation Meteorologist
NAS	National Airspace Sytem
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
nmi	nautical miles
NOAA	National Oceanic and Aviation Administration
NOM	National Operations Manager
NTMO	National Traffic Management Oficer
NWS	National Weather Service
OEP	Operational Evolution Partnership
OIS	Operational Information System
OPC	Offshore Precipitation Capability
OPSNET	Operations Network
ORD	Chicago O'Hare International Airport
PHL	Philadelphia International Airport
PST	Strategic Planning Telecon/Webinar
RAPT	Route Availability Planning Tool
SA-FCA	Situational Awareness – Flow Constrained Area
SA-R	Situational Awareness - Route
SD	Situation Display
SREF	Short-Range Ensemble Forecast
SVRWX	Severe Weather
SWAP	Severe Weather Avoidance Planning
TAF	Terminal Area Forecast
TFI	Traffic Flow Impact
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
UTC	Coordinated Universal Time
VIL	Vertically Integrated Liquid
VORTAC	Very high frequency Omnidirectional Range/Tactical Aircraft Control.
ZBW	Boston Air Route Traffic Control Center
ZDC	Washington DC Air Route Traffic Control Center
ZJX	Jacksonville Air Route Traffic Control Center
ZMA	Miami Air Route Traffic Control Center
ZNY	New York Air Route Traffic Control Center
ZOB	Cleveland Air Route Traffic Control Center
ZTL	Atlanta Air Route Traffic Control Center

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