Project Report
ATC-369

OEP Terminal and CONUS Weather Radar Coverage Gap Identification Analysis for NextGen

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EXECUTIVE SUMMARY

The initial results of a weather radar coverage analysis in support of the Reduce Weather Impacts (RWI) Sensor RightSizing program are presented in this report. The main impetus behind this study is to identify gaps in the radar network relative to the Next Generation Air Transportation System (NextGen) end-state performance requirements. Because detailed performance requirements are currently available only for super-density terminal airspace, we focused on this domain with the 35 Operational Evolution Plan (OEP) airports acting as proxy for the yet-to-be-determined list of super-density terminals. We also analyzed, to a lesser extent, the contiguous United States (CONUS) airspace as an approximation to the en route airspace.

Our major findings are as follows.

1. The current weather radar network (and any future radar network of reasonable cost) will not meet the 4D weather cube single authoritative source (4D Wx SAS) vertical resolution requirements for both super-density terminal and en route airspace domains. This is a simple consequence of basic geometrical and radar antenna beam constraints. Satellite-based sensors and ground-based in situ sensors also cannot fulfill this requirement due to insufficient spatial resolution and/or spatial and temporal coverage. The assimilation of data from ground-based profiling instruments and airborne sensors into numerical weather models may help to partially fill this performance gap. However, a quantitative study is needed to predict the success of this type of approach, and, also more fundamentally, to determine the benefits of instituting such strict vertical resolution requirements for weather observation.
2. Vertical accuracy is also a problem. Accurate determination of the radar beam height is difficult due to the natural variability of the vertical refractivity gradient in the atmosphere. Ducting due to conditions such as an inversion layer can bend an initially upward tilting beam back down to the ground. (Holes in elevation angle coverage can also be produced just above ducts.) Physical modeling can yield estimates of the actual path of the radar beam and correct for height deviations, but it requires knowledge of the atmospheric temperature and humidity fields with fine vertical resolution and spatial coverage over the radar propagation domain, and is computationally intensive. Such height corrections to weather radar data are not currently conducted operationally, and it remains to be shown whether it can be successfully implemented to meet the given vertical accuracy requirements in real time.
3. The update period for convective weather represents another performance gap in both super-density terminal and en route airspace. The current weather radars have volume scan update periods that are substantially longer than the required times. Satellite data refresh rates tend to be even slower. Weather observation data from the aircraft surveillance radars are updated quickly enough, but do not have the requisite spatial resolution and coverage. Phased array radars would be capable of providing such rapid volume scans, but they would not be able to give much better vertical resolution and accuracy than the current weather radars.

4. The horizontal resolution requirement is met in only some parts of the super-density terminal and en route airspaces. Satellite-based sensors and ground-based in situ sensors also cannot fulfill this requirement due to insufficient spatial resolution and/or spatial and temporal coverage.
5. Low-altitude coverage is an overarching problem. The current weather radars are generally spaced too far apart to provide seamless coverage of the boundary layer. For low-altitude super-density terminal airspace, the lack is especially acute for dual-polarization observations, since the Terminal Doppler Weather Radar (TDWR) is not slated for a dual-polarization upgrade. This shortcoming, as well as the horizontal resolution gap, could be overcome by a high-density radar network such as proposed by the Collaborative Adaptive Sensing of the Atmosphere (CASA) program (but not the vertical resolution and accuracy problems as explained earlier).
6. There are two main causal factors for less than complete radar coverage inside specific terminal airspaces—lack of a TDWR and terrain blockage. OEP terminals without a nearby TDWR are HNL, LAX, PDX, SAN, SEA, and SFO, and all of their associated airspaces also experience terrain blockage to some extent. Of airports with TDWRs, DEN, LAS, PHX, and SLC have significant terrain obstruction. Notably poor coverage is observed at PDX, SLC, and LAS with 50% or less mean weather radar coverage of their respective terminal airspaces.

In particular, the vertical resolution requirements (100 ft for super-density terminal airspace below 5000 ft AGL, 500 ft for above 5000 ft AGL and for en route airspace) and the associated accuracy specifications are far from being met by current weather radar systems or other sensors in any comprehensive manner. It is also not expected that a new or supplementary observational network of reasonable cost will be able to fulfill these particular requirements of the 4D Wx SAS. Therefore, we recommend that these requirements be revisited with respect to the value that they provide to the safety and efficiency goals of NextGen.

This study is an initial step towards identifying and analyzing the sensor coverage deficiencies relative to the NextGen 4D Wx SAS performance requirements. The observational gaps exposed here need to be considered in light of coverage provided by other types of sensors on a function by function basis. The 3D gridded digital database of radar coverage generated by this study will be available for future Sensor RightSizing investigations that integrate the contributions from other sensors.

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1. INTRODUCTION

The Next Generation Air Transportation System (NextGen) is a transformation of the current National Airspace System (NAS) to meet increasing future demands in air traffic, while maintaining the high level of safety that has been achieved thus far (JPDO 2007). One of the keys to meeting the efficiency and safety targets set for NextGen is improving the acquisition, dissemination, and use of weather data. In order to accomplish this task, a virtual four-dimensional weather data cube (4D Wx Cube) will be created (JPDO 2006). As a subset of the Cube, a 4D single authoritative source (SAS) of weather data will be defined, so that users will have access to a common set of high-performance weather products anywhere at any time.

The weather data, both observational and forecast, residing in the 4D Wx SAS will need to meet functional (JPDO 2008) and performance (FAA 2009) requirements. As part of the Federal Aviation Administration's (FAA's) NextGen Reduce Weather Impact (RWI) activities, the Sensor RightSizing project was launched to assess the capabilities of the weather observational network in meeting these SAS requirements. An evaluation of the weather sensors for NextGen initial operational capability (IOC) was conducted in 2009 based on only the functional requirements, which exposed qualitative gaps between the expected weather products at IOC and the required weather observation functions at full operational capability (FOC) (FAA 2010). With the performance requirements now becoming available, we can identify gaps in a more quantitative manner.

Although there are over 300 weather observation functions with separate performance requirements associated for each one, there are 4D Wx SAS performance requirements that are common to all functions. These are the spatial resolution and accuracy and update period requirements (Table 1-1) (FAA 2009). Thus, a good starting point for our gap identification activity is determining the extent to which weather sensors satisfy these common requirements.

In this report we focus on the super-density terminal and en route airspaces, and limit the sensors considered to ground-based radars. In general, ground-based radars provide finer spatial resolution data than satellite-based sensors and wider coverage than in situ instruments. Although these other types of sensors also need to be analyzed with respect to the performance requirements, in many cases radars offer the best hope of meeting the spatial resolution and coverage demands (for observation functions that can be satisfied by radar data), so it is a useful first step to concentrate on radars. Clearly, there are many weather observation functions that can only be accomplished by other sensors (or combination of sensors), so a full gap identification study will eventually need to include all instruments.

TABLE 1-1

4D Wx SAS Performance Requirements Above Surface

Location Above Surface		Super-Density Terminal Airspace		En Route Airspace		Global Airspace		Designated En Route Terminal Airspace		Designated Global Terminal Airspace	
Weather Type		**Convective**	**Other**	**Convective**	**Other**	**Convective**	**Other**	**Convective**	**Other**	**Convective**	**Other**
Horizontal Resolution		1/2 km	½ km	1 km	4 km	10 km	10 km	1 km	4 km	10 km	10 km
Horizontal Accuracy		1/4 km	¼ km	1/2 km	2 km	5 km	5 km	1/2 km	2 km	1/2 km	5 km
Vertical Resolution	**≥ 5000 ft AGL**	500 ft	500 ft	500 ft	500 ft	500 ft	500 ft	500 ft	500 ft	500 ft	500 ft
	< 5000 ft AGL	100 ft	100 ft					100 ft	100 ft	100 ft	100 ft
Vertical Accuracy	**≥ 5000 ft AGL**	250 ft	250 ft	250 ft	250 ft	250 ft	250 ft	250 ft	250 ft	250 ft	250 ft
	< 5000 ft AGL	50 ft	50 ft					50 ft	50 ft	50 ft	50 ft
Update Period		1 min	5 min	2 min	5 min	10 min	20 min	1 min	5 min	2 min	20 min

2. METHODOLOGY

To quantify the performance parameters vs. location, we defined three-dimensional (3D) grids over the NAS and computed parameters for each grid cell. For the super-density terminal case, we set a 100-km-radius vertical cylinder over each airport with a horizontal (west-east and south-north) grid spacing of 0.5 km. The vertical grid spacing was set to 100 ft from the height of the airport to 5000 ft above the airport; further up, the grid spacing was set to 500 ft. The top of the cylinder was set to the ceiling of the current terminal airspace. In some cases, the ceiling is variable and delineated by the floor of a nearby terminal airspace, in which case the maximum height was used. For the en route case, the 3D grid was defined over the contiguous United States (CONUS) with 30 arcsec (~0.9 km) of latitudinal and longitudinal grid spacing, and 500-ft vertical grid spacing covering from the surface up to 60,000 ft above mean sea level (MSL), the ceiling for Class A airspace. The definition of the tops of the terminal and en route airspaces are expected to change under NextGen (Souders et al. 2010), but we used the current definitions for lack of better guidance.

A super-density terminal is defined to be an airport with enplanements of at least 1% of all U.S. enplanements (Souders et al. 2010). Statistics from 2008 show 29 airports to fall into this category (FAA 2009a). However, since these rankings fluctuate from year to year, we used the FAA's list of Operational Evolution Plan (OEP) airports as a more stable alternative. The 35 OEP airports (the 29 just mentioned plus six others) are major terminals that were selected in 2000 due to their significant impact on delays over the entirety of the NAS. The list of OEP airports are given in Table 2-1.

To compute the radar beam blockage due to terrain and permanent ground-based structures, we used the Shuttle Radar Tomography Mission (SRTM) Level 1 digital elevation database. The SRTM employed a space-shuttle-borne radar to map the Earth's surface, so the heights of natural and man-made structures are included in addition to the ground altitude. However, there were gaps in the coverage, especially near very tall buildings due to a shadowing effect. Therefore, we filled in the holes with Level 1 Digital Terrain Elevation Data (DTED), which provide more comprehensive coverage. The horizontal resolution of these data sets is 3 arcsec (~90 m) in latitude and longitude. To account for atmospheric refraction, we used the commonly employed 4/3-Earth-radius model (e.g., Skolnik 2008).

Table 2-1

OEP Airports

Airport ID	City, State	Altitude (m MSL)	Latitude (deg)	Longitude (deg)	Terminal Airspace Ceiling (ft MSL)
ATL	Atlanta, GA	312.7	33.640	-84.427	12,500
BOS	Boston, MA	5.8	42.364	-71.005	7,000
BWI	Glen Burnie, MD	44.5	39.176	-76.668	10,000
CLE	Cleveland, OH	241.1	41.412	-81.850	8,000
CLT	Charlotte, NC	228	35.214	-80.943	10,000
CVG	Cincinnati, OH	273.1	39.046	-84.664	10,000
DCA	Arlington, VA	4.6	38.852	-77.038	10,000
DEN	Denver, CO	1655.4	39.862	-104.673	12,000
DFW	Fort Worth, TX	185	32.897	-97.038	11,000
DTW	Detroit, MI	196.9	42.212	-83.353	8,000
EWR	Newark, NJ	5.5	40.693	-74.169	7,000
FLL	Fort Lauderdale, FL	2.7	26.073	-80.153	4,000
HNL	Honolulu, HI	4	21.319	-157.922	9,000
IAD	Dulles, VA	95.4	38.945	-77.456	10,000
IAH	Houston, TX	29.6	29.984	-95.341	10,000
JFK	New York, NY	4	40.640	-73.779	7,000
LAS	Las Vegas, NV	664.8	36.080	-115.152	9,000
LAX	Los Angeles, CA	38.1	33.943	-118.407	10,000
LGA	New York, NY	6.7	40.777	-73.873	7,000
MCO	Orlando, FL	29.3	28.429	-81.309	10,000
MDW	Chicago, IL	189	41.786	-87.752	3,600
MEM	Memphis, TN	103.9	35.042	-89.977	10,000
MIA	Miami, FL	2.4	25.793	-80.291	7,000
MSP	Minneapolis, MN	256.3	44.883	-93.217	10,000
ORD	Chicago, IL	203.6	41.979	-87.905	10,000
PDX	Portland, OR	9.4	45.589	-122.597	4,000
PHL	Philadelphia, PA	11	39.872	-75.241	7,000
PHX	Phoenix, AZ	345.9	33.434	-112.012	9,000
PIT	Pittsburgh, PA	367	40.491	-80.233	8,000
SAN	San Diego, CA	5	32.734	-117.190	10,000
SEA	Seattle, WA	132	47.450	-122.312	10,000
SFO	San Francisco, CA	4	37.619	-122.375	10,000
SLC	Salt Lake City, UT	1288.4	40.788	-111.978	10,000
STL	St. Louis, MO	184.1	38.748	-90.360	8,000
TPA	Tampa, FL	7.9	27.975	-82.533	10,000

The radars that we considered as providing weather data for the 4D Wx Cube at NextGen IOC are the Weather Surveillance Radar 1988-Doppler (WSR-88D, more commonly known as Next Generation Radar or NEXRAD) (Heiss et al. 1990), Terminal Doppler Weather Radar (TDWR) (Michelson et al. 1990), Airport Surveillance Radar-9 (ASR-9) (Taylor and Brunins 1985), Airport Surveillance Radar-11 (ASR-11) (Weber 1999), and Air Route Surveillance Radar-4 (ARSR-4) (Lay et al. 1990). Table 2-2 lists their relevant characteristics. There are other ASRs and ARSRs that yield some weather information but do not generate digital weather data, so we did not include them in this study. Other ground-based weather radars operated by commercial, educational, and research institutions were omitted based on the unlikelihood of their data being made available to public by NextGen IOC; they may, however, be included in future gap mitigation research efforts. Space-based weather radars are research instruments and offer limited coverage, and airborne radars have time- and space-varying coverage and their outputs are only available locally, so they were also excluded. As for lidars, there is one operational system that is used for aviation weather sensing (at Las Vegas, Nevada) and it is deployed specifically for the purpose of low-altitude wind-shear detection. Therefore, we did not include it, either.

Table 2-2

Relevant Radar Characteristics

Parameter	NEXRAD	TDWR	ASR-9	ASR-11	ARSR-4
Minimum Observation Range	~0.5 km	0.5 km	~0.5 km	~0.5 km	9.3 km
Maximum Observation Range (Reflectivity)	460 km	90 km[1]	110 km	110 km	460 km
Maximum Observation Range (Doppler)	300 km	90 km	110 km[2]	N/A	N/A
Range Resolution	0.25 km	0.15 km	0.12 km	0.12 km	0.23 km
Maximum Elevation Angle	19.5°	60°	N/A[3]	N/A[3]	30°[4]
Elevation Beamwidth	0.925°	0.55°	5°	5°	2°
Azimuthal Sample Interval	1°[5]	1°	1.4°	1.4°	1.5°
Minimum Detectable Reflectivity at 20 km	-18 dBZ	-19 dBZ[6]	-1 dBZ	-1 dBZ[7]	6 dBZ
Observation Volume Update Rate	4-10 min	6 min	5 s to 1 min	~1 min	~1 min
Dual Polarization Products	Yes	No	No	No	No

[1] Surface scan has maximum reflectivity range of 460 km.

[2] Doppler data only available on ASR-9s equipped with WSP.

[3] Fixed elevation fan beam.

[4] Two stacks (high and low) of phased array beams (10 total). Only one is available for weather at a given range.

[5] Minimum azimuthal sample interval is 0.5° but wider beamwidth makes effective resolution worse.

[6] STC limits minimum detectable reflectivity to -26 dBZ for range < 9 km.

[7] Sensitivity drops by 17 dB for range < 12 km due to short pulse mode.

Note that these radars have wide-ranging abilities for weather observations. The NEXRAD and TDWR were specifically designed for weather sensing and are, thus, far superior in performance to the others for this purpose. The NEXRAD, in addition, will have dual-polarization capability by NextGen IOC, which is crucial for hydrometeor classification. The reasons why the aircraft surveillance radars are not well suited for weather sensing are their lack of sensitivity, vertical resolution, and sufficient ground clutter rejection performance. To overcome some of these deficiencies, the Weather Systems Processor (WSP) (Weber and Stone 1995) was developed for the ASR-9, which made low-altitude wind-shear detection possible at airports lacking a TDWR or Low-Level Wind-Shear Alert System (LLWAS) (Wilson and Gramzow 1991). Note also the unavailability of Doppler data for the ASR-11, ARSR-4, and the non-WSP ASR-9. The one characteristic of aircraft surveillance radars that is beneficial for weather observation is their rapid update rates (necessary for aircraft separation requirements). Figure 2-1 shows the locations of the radars in the CONUS and Hawaii.

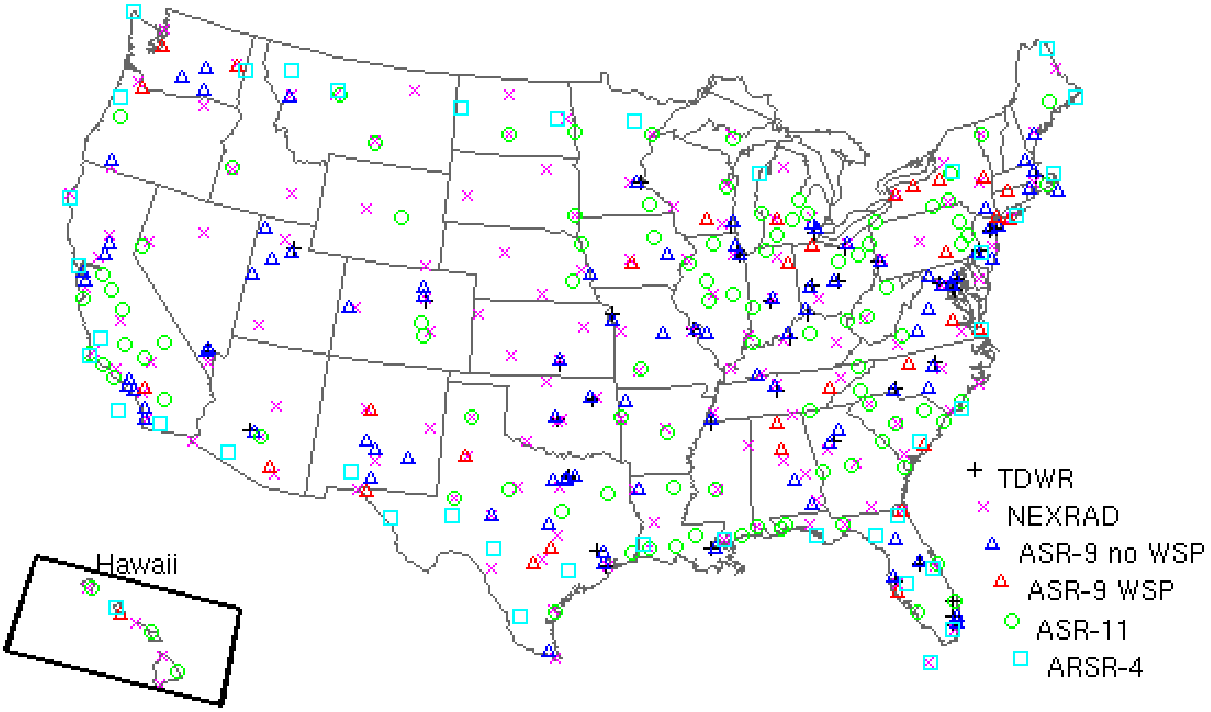


Figure 2-1. Locations of the radars included in this study.

Currently, the real-time availability of the weather data from these radars outside of the local users varies. Historically, the multi-mission, tri-agency NEXRAD has had its data most readily accessible to various users. More recently, TDWR data have been disseminated beyond their local terminal usage via such platforms as the Corridor Integrated Weather System (CIWS) (Evans and Ducot 2006) and Supplemental Product Generator (SPG) (Istok et al. 2009). ASR-9 data have previously been used by CIWS. Prototype SPGs have also been developed for ASR-11 and ARSR-4 data. Therefore, there is a good chance that the data from all of these radars will be available for real-time transfer to the 4D Wx Cube by NextGen IOC.

Let us now return to the topic of the 3D grid cell contents that are the main output products of this analysis. The following parameters were computed for each grid cell: Number of Doppler coverage, number of dual-polarization coverage, preferred radar, minimum detectable weather reflectivity, vertical resolution, worst-case horizontal resolution, and geometric-mean horizontal resolution.

The number of Doppler coverage is the number of radars with visibility to this grid cell that outputs Doppler data for this location. This value has a strong influence on how accurately the wind vector is measured at this point. For example, the Integrated Terminal Weather System (ITWS) Terminal Winds product shows dramatic improvement in wind vector accuracy when coverage is provided by two or more Doppler radars (Cho and Martin 2007). Although the ASR-9 WSP generates Doppler data, because its vertical resolution is poor (and, thus, is not suitable for wind vector estimation) we did not include it in this parameter.

The number of dual-polarization coverage is the number of NEXRADs that are within dual-polarization range with visibility to the grid cell. (The dual-polarization hardware upgrade is expected to be completed at all sites by NextGen IOC, although some of the associated weather products may lag behind, and there have been significant delays in the project so far.) The primary significance of this value is determined by whether it is zero or greater than zero. (There may be some product quality improvement when there is multiple overlap.) Dual-polarization data yield hydrometeor type differentiation capability (as well as improvement in other estimates such as rainfall rate and icing potential) lacking in single-polarization data. Since many of the 4D Wx SAS functional requirements derive directly from hydrometeor classification, this parameter is a very important indicator for requirements coverage.

The minimum detectable weather reflectivity is a measure of the sensitivity of the observing radar at this grid cell. It is based on the reflectivity that would generate a single-pulse signal-to-noise ratio of about unity at the receiver output. Propagation attenuation, clutter, and other potential interference are not considered, so it is an approximate metric.

Although the minimum detectable reflectivity and degrees of Doppler and dual-polarization coverage are not weather observation products and, therefore, do not have specific requirements, they are basic parameters that may become inputs to determining the performance metrics for the observational performance requirements. In that way, they have potential utility as the gap identification and analysis process moves forward.

The spatial resolution quantities, on the other hand, are assigned specific requirements. For radar observations, the resolution parameters are derived as follows. The radar sample volume has these three orthogonal dimensions: Range resolution (Δr), azimuthal resolution ($\Delta\phi$), and elevation resolution ($\Delta\theta$). Δr is given in Table 2-2, and $\Delta\theta$ is range from the radar multiplied by the elevation beamwidth (converted to radians) given in Table 2-2. The effective azimuthal resolution depends on the azimuthal beamwidth, sampling interval, and rotation rate (which varies according to the operational mode for NEXRAD and TDWR). Therefore, we used the nominal azimuthal sampling interval values given in Table 2-2.

The vertical resolution is then given by

$$\Delta z = r_h \Delta\theta + \frac{\Delta r}{r}\sqrt{r^2 - r_h^2} \ , \tag{2-1}$$

where r is slant range and r_h is horizontal range. The horizontal resolution parallel to and perpendicular to the radar beam are given by

$$\Delta h_{\parallel} = \frac{\Delta r}{r} r_h + \Delta\theta\sqrt{r^2 - r_h^2} \ , \tag{2-2}$$

and

$$\Delta h_{\perp} = r\Delta\phi \ . \tag{2-3}$$

Because the 4D Wx SAS horizontal resolution requirement is given as a single value, we needed to distill the asymmetric orthogonal resolution values given by Equations (2-2) and (2-3). We decided to compute the “worst case” horizontal resolution (the maximum of $\Delta h_{\parallel}$ and $\Delta h_{\perp}$) and the geometric-mean horizontal resolution $(\Delta h_{\parallel}\Delta h_{\perp})^{1/2}$.

The minimum detectable reflectivity and horizontal/vertical resolution parameters can have multiple values in a grid cell if there are multiple radars with visibility to that location. The preferred radar parameter selects just one based on the best vertical resolution, since that is the requirement most difficult to meet. The horizontal resolution and the minimum detectable reflectivity also correspond to the values from the selected radar.

Note that we did not attempt to include radio frequency interference (RFI) effects into our radar coverage model. RFI is an ongoing dynamic problem that is being combated via regulatory and technical solutions. Radars and their beam positions affected are changing constantly, so it is not practical to try to forecast specific RFI instances in the future. Likewise, we also did not include wind turbine interference, another dynamic problem (albeit a less rapidly changing one). A fairly minor problem for weather radars at the moment, it may grow with the renewable power generation industry into a more significant hindrance to radar coverage in the future.

3. RESULTS

3.1 OEP AIRPORT RADAR COVERAGE

3.1.1 Overall Results

The overall radar coverage results were averaged over different spatial subsegments and compiled in Table 3-1. (Note that AGL here denotes above the airport ground level.) Individual airport results are given in graphical and tabular forms in Appendix A, in order to maintain the continuity of the text in this chapter.

Table 3-1

OEP Airports Radar Parameter Mean Volume Coverage Percentage

Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
	Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
Doppler	1+	87.47	80.72	67.27	100.00	99.38	96.75	92.36	87.58	78.02
	2+	68.67	63.78	48.25	91.68	91.48	83.04	76.89	73.96	61.26
	3+	31.61	30.94	23.19	59.34	61.64	56.00	43.08	43.32	36.05
Dual Pol.	1+	73.56	69.79	58.31	98.73	99.02	96.39	82.83	80.49	72.24
	2+	11.85	10.87	10.79	56.67	61.14	61.54	29.27	30.25	30.17
Min. dBZ	< -15	81.46	42.23	16.18	86.34	45.37	17.82	82.76	43.30	16.80
	< -5	93.26	80.20	64.02	99.34	95.43	84.63	95.80	85.71	71.43
	< 18	96.25	87.71	75.61	100.00	99.46	97.89	97.61	91.71	83.44
	< 30	96.25	87.74	75.75	100.00	99.46	98.05	97.61	91.73	83.59
H res. ≤ 0.5 km	worst	86.13	37.09	14.82	83.71	37.34	15.11	84.57	37.05	14.91
	mean	91.13	82.45	62.23	87.47	87.00	68.42	89.40	83.45	64.02
V res.	≤ 100 ft	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	≤ 500 ft	31.41	9.92	3.20	22.63	7.78	2.34	28.25	9.11	2.89
Radar	TDWR	72.39	66.46	48.77	80.39	77.51	62.37	74.90	69.86	53.49
	NEXRAD	15.08	14.26	18.51	19.61	21.88	34.39	17.46	17.72	24.54
	ASR-9	8.74	6.55	5.76	0.00	0.03	0.74	5.23	3.88	3.66
	ASR-11	0.00	0.16	1.91	0.00	0.00	0.06	0.00	0.09	1.24
	ARSR-4	0.01	0.26	0.76	0.00	0.02	0.47	0.01	0.14	0.62
	Any	96.22	87.69	75.71	100.00	99.44	98.02	97.60	91.69	83.55

Let us now examine the results in Table 3-1. There is 84% coverage of the OEP terminal airspace by weather radars, with most of the shortfall in the far ranges at low altitude. The TDWR dominates as the radar type selected to cover OEP terminal airspace based on best vertical resolution. This dominance is most pronounced at close range (< 10 km) where the capability for detecting microbursts in the areas noted for attention (ARENAs) is most crucial for operational safety; this is as it should be, since the TDWR was designed and deployed for this purpose. The importance of the NEXRADs increases with range, because unlike the TDWRs their locations are not necessarily tied to airports. The ASR-9s play a small role at low altitudes, with the contributions coming mainly from the deployment of WSPs at HNL, LAX, PDX, and SEA as the primary wind-shear sensor.

Doppler coverage by at least one radar is quite good, except for a noticeable drop off at long-range low altitudes, where the Earth's curvature prevents the TDWR from observing close to the ground and the nearest NEXRAD is also too far for low-altitude sensing. The Earth curvature problem further hinders multi-Doppler coverage at low heights, which leads to more uncertainty in the vector wind measurements at those altitudes.

Dual polarization coverage by at least one NEXRAD is excellent at heights above 5000 ft, but again not so at heights below. This will negatively impact the ability to classify hydrometeors at these lower altitudes. It is interesting to note that low-altitude dual polarization coverage drops off with range, meaning that the locations of NEXRADs and OEP airports actually are somewhat correlated.

The lowest minimum detectable reflectivity threshold used here (-15 dBZ) concerns the ability to measure clear-air winds (relevant at all sites) and to detect dry microbursts (relevant at high plains sites such as DEN, LAS, PHX, and SLC). The capability is high at close range, which is most important for the microburst (safety) aspect. The -5 dBZ threshold encompasses the gust front and wet microburst regimes (Cho and Hallowell 2008). There is utility in detecting gust fronts at further range than microbursts, so that airport operations such as runway configuration changes due to wind shifts behind a gust front can be planned in advance. Thus, it is encouraging to see that the -5 dBZ coverage out to 50 km is fairly good. (A more detailed evaluation of wind-shear detection capability at the OEP airports, which includes location-specific clutter and other effects not considered here, will be presented in a separate report.) The 18 dBZ threshold corresponds to mist or light rain, and the 30 dBZ to moderate rain. We see that there is almost no difference in coverage between these two thresholds, which implies that within the terminal airspaces considered, the radar sensitivity is always good enough to observe down to the light rain level.

The requirement for horizontal resolution is 0.5 km (Table 1-1). As discussed before, radar horizontal resolution is orientation dependent (Equations 2-2 and 2-3). Therefore, we formulated two types of horizontal resolution—the maximum of the two orientations and the geometric mean of the two. The differences between the two are significant as can be seen in Table 3-1. In either case, however, the requirement is not covered well at far range.

The most problematic requirement by far is vertical resolution. The resolution requirement of 100 ft at altitudes below 5000 ft is unmet virtually everywhere within the terminal airspaces. The requirement of 500 ft at heights above 5000 ft is met at only an average of 2%. These are glaring gaps in meeting the NextGen 4D Wx SAS requirements. The problem is even more severe considering that the actual operational volume scan strategies of NEXRAD and TDWR have sparsely spaced elevation tilts—in other words, there are gaps in elevation coverage under the current scans. We computed vertical resolution simply based on the beam dimensions, on the argument that the radars are capable of conducting seamless volume scans.

What other sensors besides radars might fill in this deficiency? Lidars have the required spatial resolution, but the attenuation of their beams by clouds and precipitation means that a high density (i.e., very expensive) network must be formed to cover the airspace, and even then the high altitudes may not be observed due to blockage by weather. Satellite-based sensors are limited by the inherent trade-off between spatial and temporal resolution. For geostationary orbits that provide acceptable temporal resolution, even a hyperspectral sounder is expected to yield no better than about 1-km vertical resolution for humidity and temperature profiles (Wang et al. 2007). Any physically reasonable radar on a geostationary satellite would not possess a beam narrow enough to meet the horizontal resolution requirements. Vertical profiling instruments such as wind-profiling radars, sodars, radio-acoustic sounding systems (RASSs), and millimeter-wave cloud radars can provide fine vertical resolution measurements of specific parameters, but in a very limited horizontal pixel. Sensors mounted on aircraft, balloons, kites, and other airborne platforms could potentially give the required vertical resolution, but they will provide limited spatial and temporal coverage of the terminal airspace. Assimilation of such data into numerical models may help to partially fill the gaps, although these types of sensors do not generate the same weather observations products that radars do.

A higher density of weather radars than currently exists would give finer vertical resolution data. How closely would these radars need to be spaced? Let us investigate the Collaborative Adaptive Sensing of the Atmosphere (CASA) concept of 1.8°-beamwidth X-band radars spaced 30 km apart (Hopf et al. 2009). The furthest that any low-altitude point would be from a radar is 17 km, which translates to a worst-case vertical resolution of 1800 ft. This is still nowhere near the required 100 ft (for altitudes below 5000 ft). In order for this requirement to be met everywhere, the radar spacing would have to be 1.7 km, which corresponds to a 300-fold increase in the number of radars compared to the original CASA concept. This does not appear to be an economically viable option, even with the somewhat decreased cost per unit due to the need for less transmitted power. Narrowing the beamwidth and maintaining the spacing between radars at 30 km would require antennas of diameter ~20 m, which is also not financially feasible and is in complete opposition to the idea of low-cost radars mounted on cell phone towers.

It seems that the vertical resolution requirement will certainly not be met over most of the OEP terminal airspaces in the near future and beyond. This gap calls into question the origins of this requirement, and whether it is absolutely necessary to meet the NextGen goals.

What about the spatial accuracy requirements? Radars have excellent accuracy in range and azimuth, which are the predominant determinants of horizontal accuracy. For example, the specified antenna beam positioning accuracy of the TDWR is 0.05° (Michelson et al. 1990), which translates to an 87-m accuracy at 100 km range for a surface scan, well within the 250-m horizontal accuracy requirement. The range accuracy for the TDWR is even stricter at 50 m (FAA 1989). The NEXRAD positioning accuracy specifications are not quite as stringent as the TDWR's, but the resulting horizontal accuracies are still well within 250 m at moderate ranges. Beam propagation deviations in the horizontal dimension are minor and can be ignored at these distances relative to the antenna positioning accuracy.

Although the same beam positioning accuracy specifications apply to the elevation angle, variations in the vertical refractive index gradients in the atmosphere can dramatically change the beam path in that dimension. Departures from typical refractive gradients are known as anomalous propagation (AP) conditions, and a beam transmitted at an upward angle can eventually bend downward and strike the ground, causing unexpected ground clutter to be observed. (Occasionally, the refractive index gradient can change in the other direction, causing the beam to bend upward.) Since the radar sample heights are typically estimated assuming a standard atmosphere with a corresponding vertical refractivity gradient of $dN/dh = -39\ \mathrm{km}^{-1}$ (the 4/3-Earth-radius approximation) to compensate for beam refraction, and dN/dh can vary locally from -157 to $0\ \mathrm{km}^{-1}$ (Skolnik 2008) via phenomena such as temperature inversion layers, the resulting height errors can be much more than the required vertical accuracies of 50 and 250 ft, especially at low elevation angles. It is therefore difficult for radars to satisfy such strict vertical accuracies under all conditions, except at very short ranges and at very high elevation angles. In principle, it is possible to correct for the fluctuating refraction conditions through physical modeling, but the temperature and humidity fields vs. height must be known at fine resolution and the computational load is extremely high (e.g., Stagliano et al. 2009).

As for the update period requirements, we can see from Table 2-2 that the current volume scan strategies used by NEXRAD and TDWR do not meet the 1-min (convective) requirement. (The exception is the TDWR surface scan, which updates at 1-min intervals during hazard scans. This type of scan was developed specifically for microburst detection.) The aircraft surveillance radars have the required update rates, but do not yield much coverage or vertical resolution. Electronically scanned array radars would be able to conduct volume scans sufficiently fast, an example of which is the multifunction phased array radar (MPAR), a possible long-term replacement for all of the radars considered in this report (Weber et al. 2007).

A final note on the overall OEP airport results: Although we have used a radius of 100 km for the horizontal dimension of super-density terminal airspace as defined in the 4D Wx SAS performance requirements report (FAA 2009), there is a more recent document that states this range will be increased to 180 km for NextGen mid-term operational capability (MOC) (Souders et al. 2010). Therefore, in future gap identification and analyses for MOC and beyond, the super-density terminal airspace dimension definition needs to be expanded, which, of course, implies that the coverage deficiencies noted in this report will be magnified even more.

3.1.2 Individual Airport Results

The comments made above for the mean results also mostly apply to the results for ATL, BOS, CLE, CLT, CVG, DTW, MCO, MEM, MSP, PHL, PIT, STL, and TPA. As for the other airports, there are some departures from the norm that we discuss below.

Better than average overall multiple Doppler coverage is provided at airports where more than one TDWR provide overlapping data. The New York City airports (EWR, JFK, and LGA) are observed by two TDWRs (EWR and JFK), as are the Chicago airports (MDW and ORD, with a TDWR at each). IAH is also covered by two TDWRs (the other one at HOU, which is not an OEP terminal). The same goes for

DFW (the other TDWR located at non-OEP DAL). FLL and MIA each have a TDWR close enough to each other, plus another at PBI, which is not an OEP airport. The metropolitan airports around Washington, DC have the most redundant TDWR coverage with four (BWI, IAD, DCA, plus the one serving Andrews Air Force Base).

DEN (Figure A-8) experiences some terrain blockage, which causes loss of coverage at low altitudes in many directions; overall, the terminal airspace weather radar coverage is 78%. (For all further references to percentage results by airport, see Table A-1.) Increasingly severe blockage is seen at PHX (Figure A-28) (74% mean radar coverage), LAS (Figure A-17) (50% mean radar coverage), and SLC (Figure A-33) (40% mean radar coverage), such that all heights are affected. Note that LAS and SLC are additionally plagued by severe road vehicle and bird clutter, respectively, both of which are hard-to-filter moving targets that degrade the detection of low-altitude wind shear (Cho 2008). A moving clutter spectral filter (Cho 2009), which has been developed to combat these problems, may be implemented on TDWRs by NextGen IOC.

HNL, LAX, PDX, SAN, SEA, and SFO do not have a TDWR. In conjunction with the lack of a nearby NEXRAD, these terminal airspaces have severely curtailed high-resolution Doppler and dual-polarization coverage at low altitudes, with mean volume coverage below 5000 ft AGL of 39% (HNL and SAN), 38% (SEA), 30% (SFO), and 22% (LAX and PDX). (HNL, LAX, PDX, and SEA have ASR-9 WSPs for wind-shear detection, while SFO has an LLWAS. SAN has no ground-based wind-shear detection system.) All of these terminal airspace volumes are also affected by terrain blockage, with PDX having only 29% mean weather radar coverage.

3.1.3 Implications for Individual Weather Observation Functions

The failure to meet the spatial and temporal resolution requirements clearly affects all weather observation functions for which radar data are the primary input. The minimum detectable reflectivity and the degrees of Doppler and dual-polarization coverage, however, impact different subsets of observation functions. In Table 3-2 we list these dependencies. Note that turbulence, which was in the functional requirements set, would have been included under minimum detectable reflectivity and Doppler coverage, but it was not listed under the 4D Wx SAS performance requirements for super-density terminal airspace, so we left it out. Since low-altitude turbulence is a hazard to aircraft (e.g. Bieringer et al. 2004), the omission of the requirement to detect it is puzzling.

The rationale for the categorization of Table 3-2 is as follows. The wind-shear products are obviously dependent on Doppler measurements, but are also listed under minimum detectable reflectivity due to their low radar cross sections under dry conditions. Wind direction and speed are also listed under the same two categories for the same reasons (substitute “dry” with “clear-air”). Drizzle and freezing drizzle, ice crystals, volcanic ash, dust and dust storm, sand storm, thunderstorm initiation, and virga are phenomena composed of very small particles and thus require high radar sensitivity. Mesocyclonic and tornadic events and squalls require Doppler fields for observation. Dual polarization is needed for accurate hydrometeor classification (and precipitation rate) and is expected to contribute to other particle identification (e.g. ash, dust, and sand) if corresponding observational products are to be developed.

Integrating these dependencies with the overall results from Table 3-1 yields potential gaps at the specific observation function level. The functions under minimum detectable reflectivity have coverage deficiencies at far range. The functions under Doppler coverage have gaps at low-altitude long range. The problem is exacerbated for wind direction and speed measurement, which requires multiple-Doppler coverage for accurate vector estimation. The functions under dual-polarization coverage have deficiencies at low altitudes. As an exercise, we computed the 1+ dual-polarization coverage if TDWRs were upgraded with dual-polarization capability. The resulting coverage for altitudes below 5000 ft AGL increased to 87% (range < 10 km), 81% (range < 50 km), and 67% (range < 100 km) from the 74%, 70%, and 58% given in Table 3-1. Thus, if hydrometeor classification at low altitudes in super-density terminal airspace is deemed to be a high priority, equipping TDWRs with dual-polarization capability could be a gap-filling option.

Table 3-2

Weather Observation Function Dependence on Radar Parameters

Minimum Detectable dBZ	Doppler Coverage	Dual-Polarization Coverage
Low-level wind shear	Low-level wind shear[1]	Rain and freezing rain
Gust front	Gust front[1]	Rainfall rate
Microburst	Microburst[1]	Snow
Wind direction and speed	Wind direction and speed	Snow pellets and ice pellets
Drizzle and freezing drizzle	Mesocyclone	Drizzle and freezing drizzle
Ice crystals	Tornado	Ice crystals
Volcanic ash	Funnel cloud	Volcanic ash
Dust and dust storm	Waterspout	Dust and dust storm
Sand storm	Squall	Sand storm
Thunderstorm initiation		Hail and hail stone size
Virga		

[1] Although we did not count the ASR-9 WSP as providing Doppler coverage due to its lack of vertical resolution, for these low-level wind-shear phenomena it provides detection products.

3.2 CONUS RADAR COVERAGE

The radar coverage results averaged over the entire CONUS airspace are given in Table 3-3. Results by height are given in graphical and tabular forms in Appendix B, in order to maintain the continuity of the text in this chapter. The area over which the percentages are calculated is marked out in the Appendix B figures as 1°×1° latitude-longitude rectangles that are colored. This is a somewhat arbitrary definition of the horizontal CONUS airspace extent, and, thus, the percentages should be taken as approximations. Note that the CONUS airspace is not equivalent to the en route airspace, since the latter excludes the terminal airspaces.

Table 3-3

CONUS Radar Parameter Mean Coverage Percentage

Doppler			Dual Polarization		Minimum Detectable dBZ				H res. ≤ 1 km		V res. ≤ 500 ft	Radar Type					
1+	2+	3+	1+	2+	< -15	< -5	< 18	< 30	Worst	Mean		TDWR	NEXRAD	ASR-9	ASR-11	ARSR-4	Any
90.22	74.50	54.73	90.06	73.71	2.34	32.23	91.79	92.38	12.35	61.35	0.08	8.26	82.39	0.45	0.45	0.84	92.38

The NEXRAD is the dominant weather radar data provider over the CONUS as expected. Although overall radar coverage is good at 92%, low-altitude coverage by any radar is poor (Figure B-1, top); 90% coverage is not achieved until 8500 ft AGL is reached. (For all further references to results by height, see Table B-1.) This is a well-known problem due to the geometric difficulties in covering a curved surface with a spaced network of radars. (The problem is clearly exacerbated by terrain blockage and lower density of radars in the mountainous West.) Thus, even though the 1+ Doppler and 1+ dual-polarization coverages are excellent overall at 90%, the values fall rapidly from this mean below 10,000 ft AGL. Multi-Doppler coverage is very good at en route flight levels, but much worse at lower heights. The minimum detectable reflectivity threshold results show excellent coverage for precipitation at the higher altitudes and sparse coverage for clear-air measurements. The horizontal resolution requirement of 1 km for convective weather is not met over a wide area, even with the geometric-mean definition. However, as with the terminal case, the biggest gap is seen in comparison with the vertical resolution requirement. Only 0.08% of the CONUS volume meets the 500-ft vertical resolution requirement.

Again, we can look at the CASA concept of creating a dense network of low-cost radars. This type of network is clearly ideal for improving low-altitude coverage, since it defeats the curved-Earth problem. It can also solve the lack in horizontal resolution, because the prototype CASA radar with a 1.8°-beam and 30-km spacing has a worst-case horizontal resolution of ~500 m. The vertical resolution is another matter. To have a worst-case vertical resolution of 500 ft, the radars would have to be 8.4 km apart, which is 28% of the nominal 30-km spacing, resulting in a ten-fold increase in the number of radars needed to cover the CONUS from ~10,000 to ~100,000. Even with some decrease in cost per unit associated with the need for less transmitted power, this is still an economic and logistic problem.

The discussion of the spatial accuracy requirements for the OEP terminal results (Section 3.2.1) applies directly to the CONUS case. That is, the vertical accuracy requirement will be difficult to meet due to the occurrence of AP conditions, even with numerical modeling to compensate for the variations in refractivity. The update period requirement of 2 min for convective weather will also be difficult to meet, given the current mechanically scanned radars, although implementation of a proposed adaptive truncation of NEXRAD volume scans dubbed AVSET (automated volume scan evaluation and termination) (Chrisman 2009) would contribute toward filling this performance gap.

As an exercise, we simulated the extension of TDWR capabilities to include dual polarization (out to a conservative 180 km in range (compared to 300 km for the NEXRAD)) and recovery of Doppler data out to the full 460-km range (Cho 2005). The resulting mean coverage increased slightly to 90.3% (1+ dual polarization) and 76.3% (2+ Doppler) from the 90.1% and 74.5% given in Table 3-3. Thus, from a CONUS-wide perspective, such upgrades to the TDWR would not have a strong effect on the overall coverage.

We will not discuss the implications for individual weather observation functions, because the performance requirements for these functions have not yet been published for the en route airspace domain.

4. CONCLUSIONS

In computing and analyzing the weather radar coverage that we expect to have at NextGen IOC, we uncovered some basic facts. The most glaring gap in meeting the 4D Wx SAS performance requirements is the vertical resolution. The 100-ft vertical resolution requirement for altitudes below 5000 ft in super-density terminal airspace, and the 500-ft requirement for altitudes above 5000 ft in super-density terminal airspace and in en route airspace, cannot be met by radar observations. Even the implementation of a high-density network of low-cost X-band radars á la CASA cannot solve this problem at any reasonable cost. Satellite-based sensors and ground-based in situ sensors also cannot fill this gap due to insufficient spatial resolution and/or spatial and temporal coverage. The assimilation of data from ground-based profiling instruments and airborne sensors into numerical weather models may help to partially fill this performance gap; a quantitative study is needed to predict the success of this type of approach. Given the extreme difficulty in meeting these vertical resolution requirements, we recommend that they be revisited with respect to the value that they provide to the safety and efficiency goals of NextGen.

Another closely linked performance gap concerns the vertical accuracy requirements. (After all, meeting the resolution requirements is useless if the associated accuracy requirements cannot be met.) Accurate determination of the radar beam height is problematic due to the natural variability of the vertical refractivity gradient in the atmosphere. Ducting due to conditions such as an inversion layer can bend an initially upward tilting beam back down to the ground. (Holes in elevation angle coverage can also be produced just above ducts.) Physical modeling can estimate the actual path of the radar beam and correct for height deviations, and programs such as the Advanced Refractive Effects Prediction System (AREPS) (Patterson 2007) were developed for this purpose and are used in the military and homeland protection communities for more accurate detection of remote targets. This type of processing, however, requires knowledge of the atmospheric temperature and humidity fields with fine vertical resolution and spatial coverage over the radar propagation domain, and is computationally intensive. Such height corrections to weather radar data are not currently conducted operationally, and it remains to be shown whether it can be successfully implemented to meet the given vertical accuracy requirements in real time.

There is some ambiguity with the horizontal resolution requirement, because radars yield a resolution volume with two different orthogonal dimensions in the horizontal plane. Thus, we chose to compute and present the results for the worst-case and the geometric-mean of the two resolutions. In either case, there is still difficulty in meeting this requirement in both super-density terminal and en route airspace cases, although not as severe as for vertical resolution.

The update period for convective weather is another performance gap in both super-density terminal and en route airspace. The NEXRAD and TDWR have volume scan update periods that are substantially longer than the required 1 min (terminal) and 2 min (en route) rates. Satellite data refresh rates tend to be even slower. Weather observation data from the aircraft surveillance radars are updated more quickly, but do not have the requisite spatial resolution and coverage. Phased array radars would be capable of providing such rapid volume scans, but they would not be able to give much better vertical resolution and accuracy than the current weather radars. The proposed adaptive volume scan truncation program (AVSET) for NEXRAD would help toward filling this performance gap if implemented.

Low-altitude coverage is also an overarching problem. The current weather radars are generally spaced too far apart to provide seamless coverage of the boundary layer. For low-altitude super-density terminal airspace, the lack is especially acute for dual-polarization observations, since the TDWR is not slated for a dual-polarization upgrade. This shortcoming, as well as the horizontal resolution gap, could be overcome by a high-density radar network such as proposed by the CASA program (but not the vertical resolution and accuracy problems as explained earlier).

As for radar observational gaps at specific airports, there are two main causal factors: Lack of a TDWR and terrain blockage. OEP terminals without a nearby TDWR are HNL, LAX, PDX, SAN, SEA, and SFO, and all of their associated airspaces also experience terrain blockage to some extent. There are valid cost-benefit reasons why TDWRs were not installed at these sites, such as low probability of microbursts (e.g., Hallowell et al. 2009), and other lower-cost wind-shear detection systems are installed at all but one site (SAN). Vis-á-vis the NextGen 4D Wx SAS performance requirements, however, the absence of a TDWR does tend to lower the radar coverage metrics. Of airports with TDWRs, DEN, LAS, PHX, and SLC have significant terrain obstruction. Terminal airspaces with 50% or less coverage by any weather radar are LAS (50%), SLC (40%), and PDX (29%). All others have at least 74% radar coverage.

This study is only an initial step towards identifying and analyzing the sensor coverage deficiencies relative to the NextGen 4D Wx SAS performance requirements. Only radars were included and emphasis was placed on the super-density terminal airspace, since performance requirements have not yet been released for the other airspace domains. The observational gaps exposed here need to be considered in light of coverage provided by other types of sensors on a function by function basis. The 3D gridded digital database of radar coverage generated by this study will be available for future Sensor RightSizing investigations that integrate the contributions from other sensors.

APPENDIX A: RADAR COVERAGE RESULTS BY AIRPORT

The OEP airport radar coverage results are given here in two formats. First, the output parameters are visualized for each airport as four horizontal slices through the airspace at heights of 500, 2000, 3500, and 5000 ft above the terminal altitude (Figures A-1 to A-35). (The exceptions are FLL, MDW, and PDX where the terminal airspace ceiling is below 5000 ft, in which case only the height slices under the ceiling are shown.) Second, the values are averaged over different spatial subsegments and compiled in Table A-1.

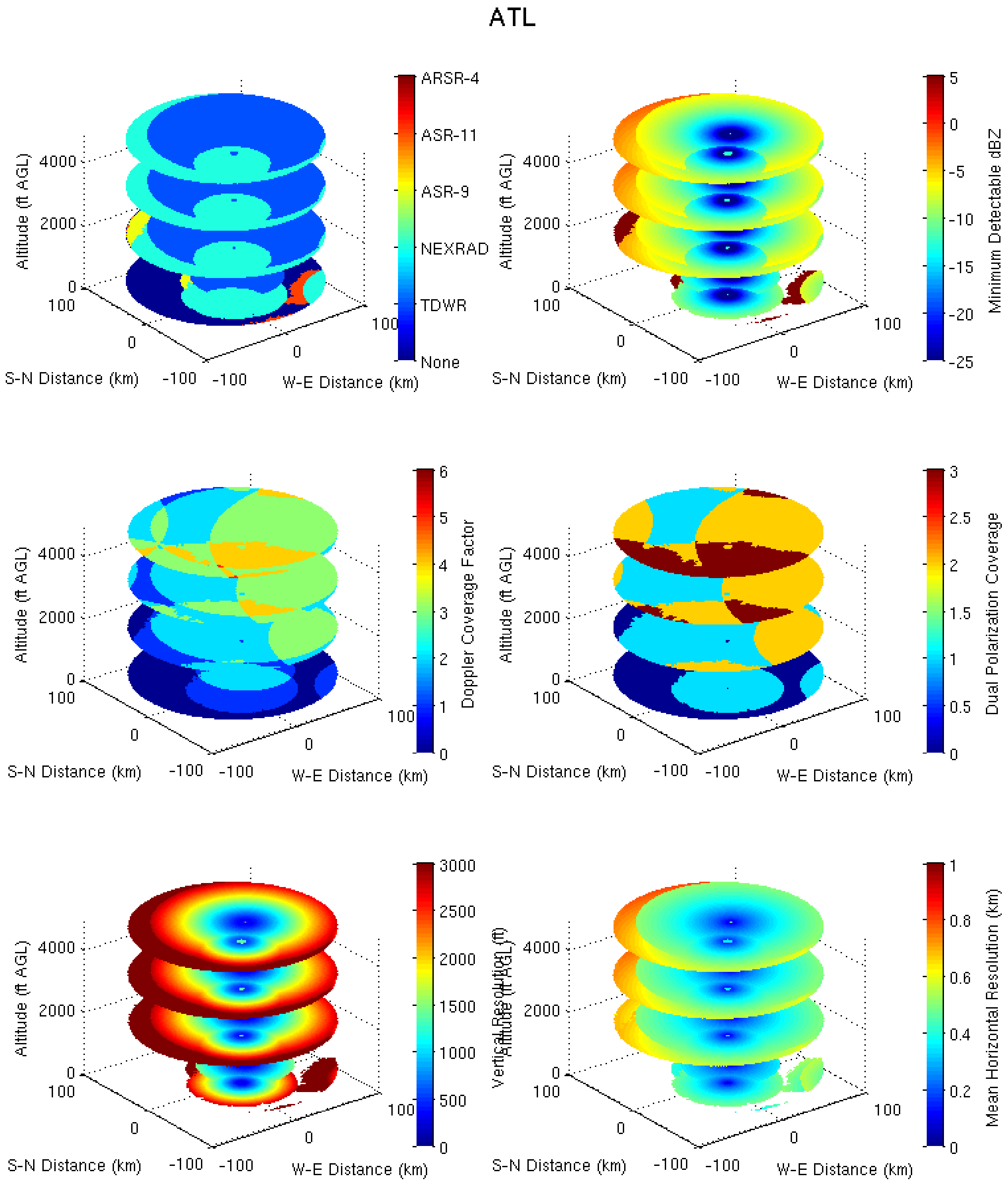


Figure A-1. Radar parameter coverage plots for the ATL terminal airspace.

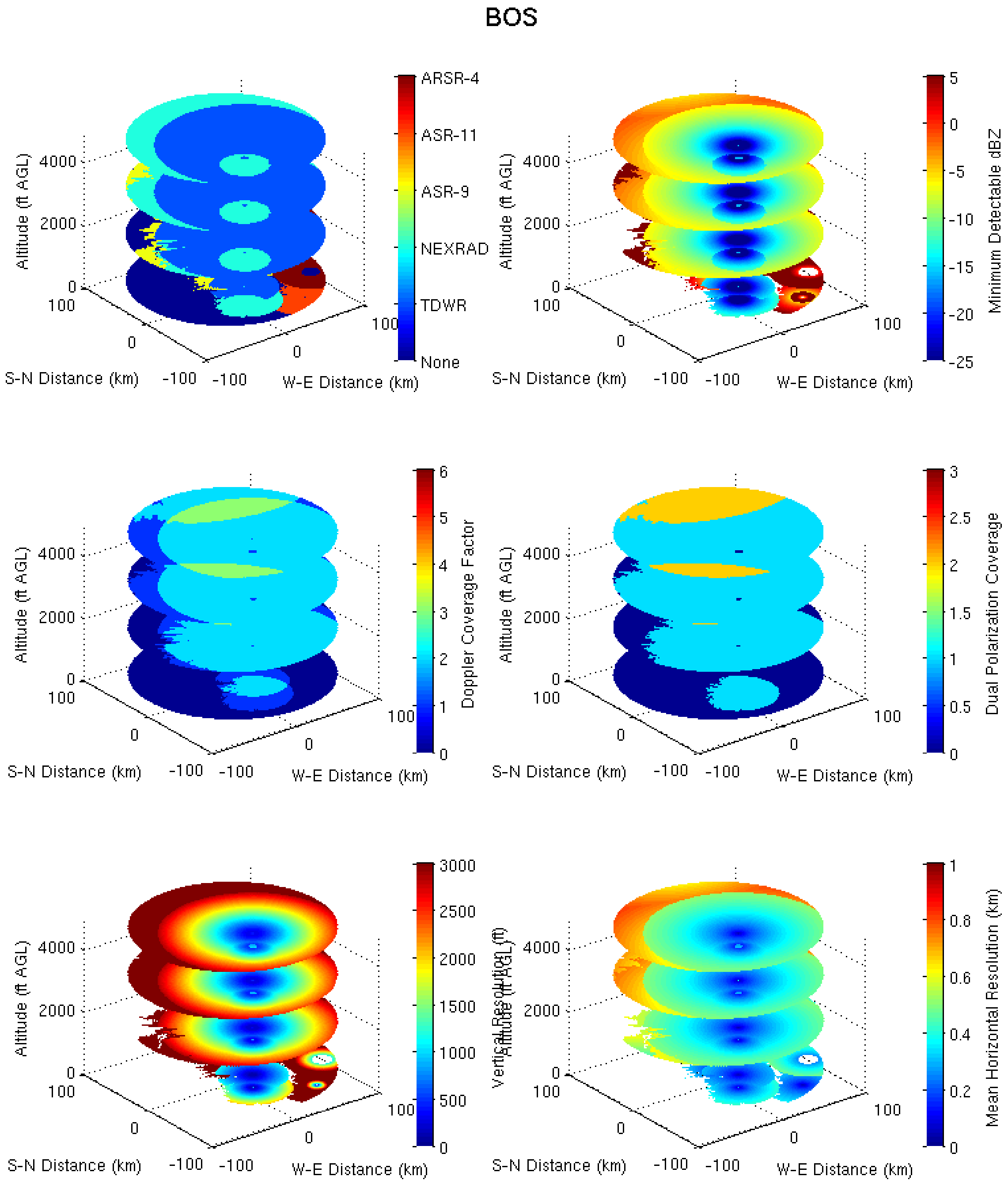


Figure A-2. Radar parameter coverage plots for the BOS terminal airspace.

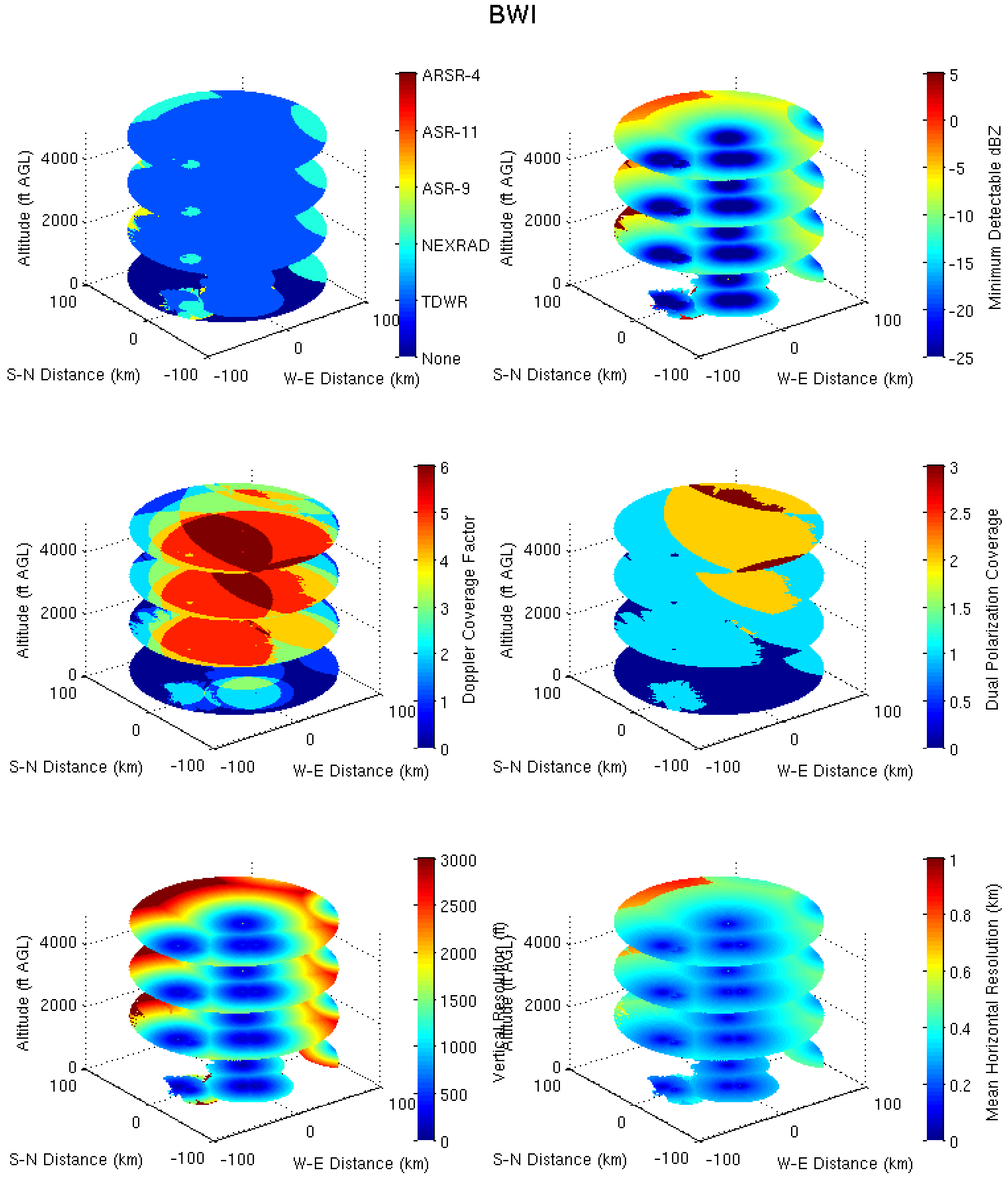


Figure A-3. Radar parameter coverage plots for the BWI terminal airspace.

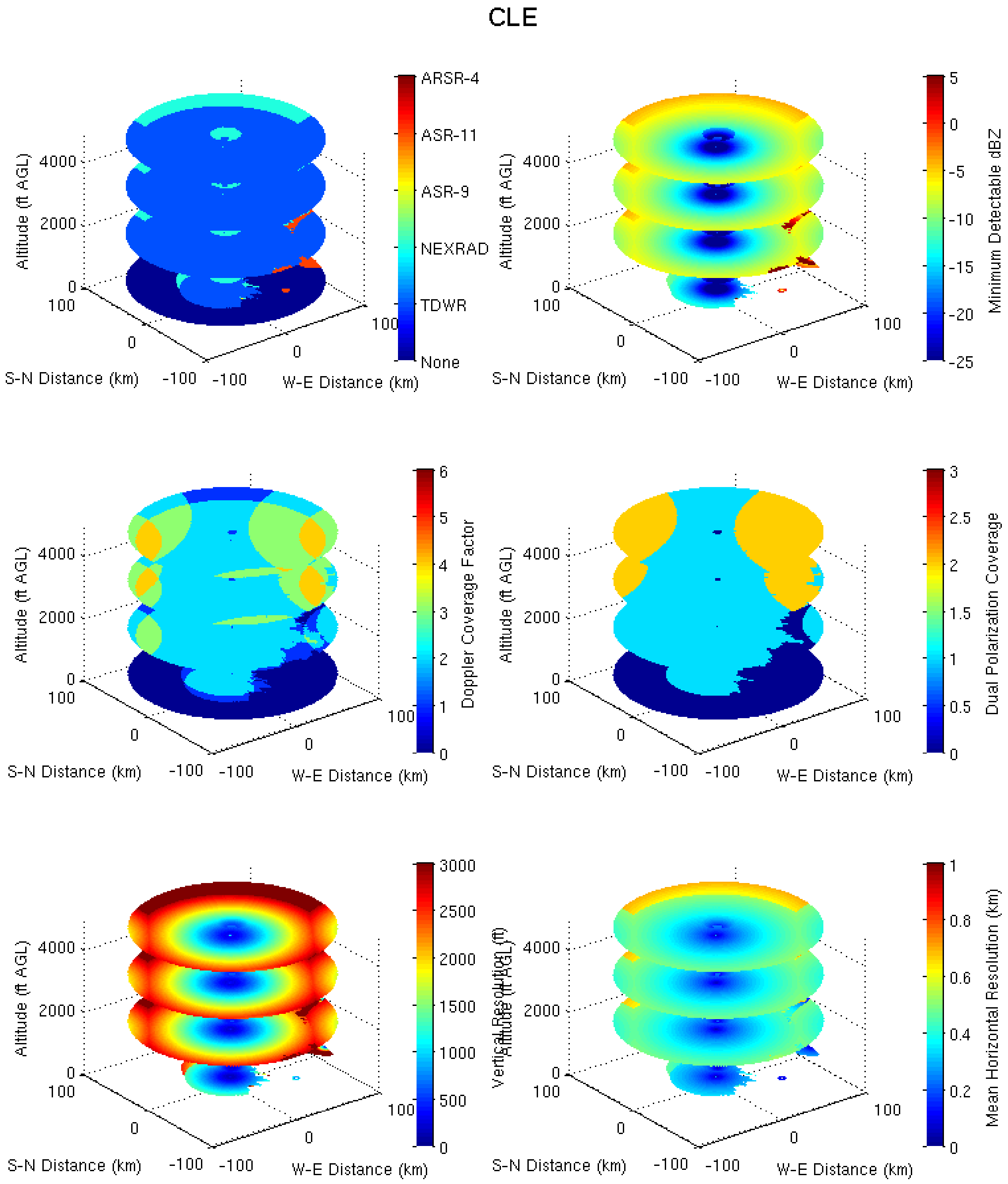


Figure A-4. Radar parameter coverage plots for the CLE terminal airspace.

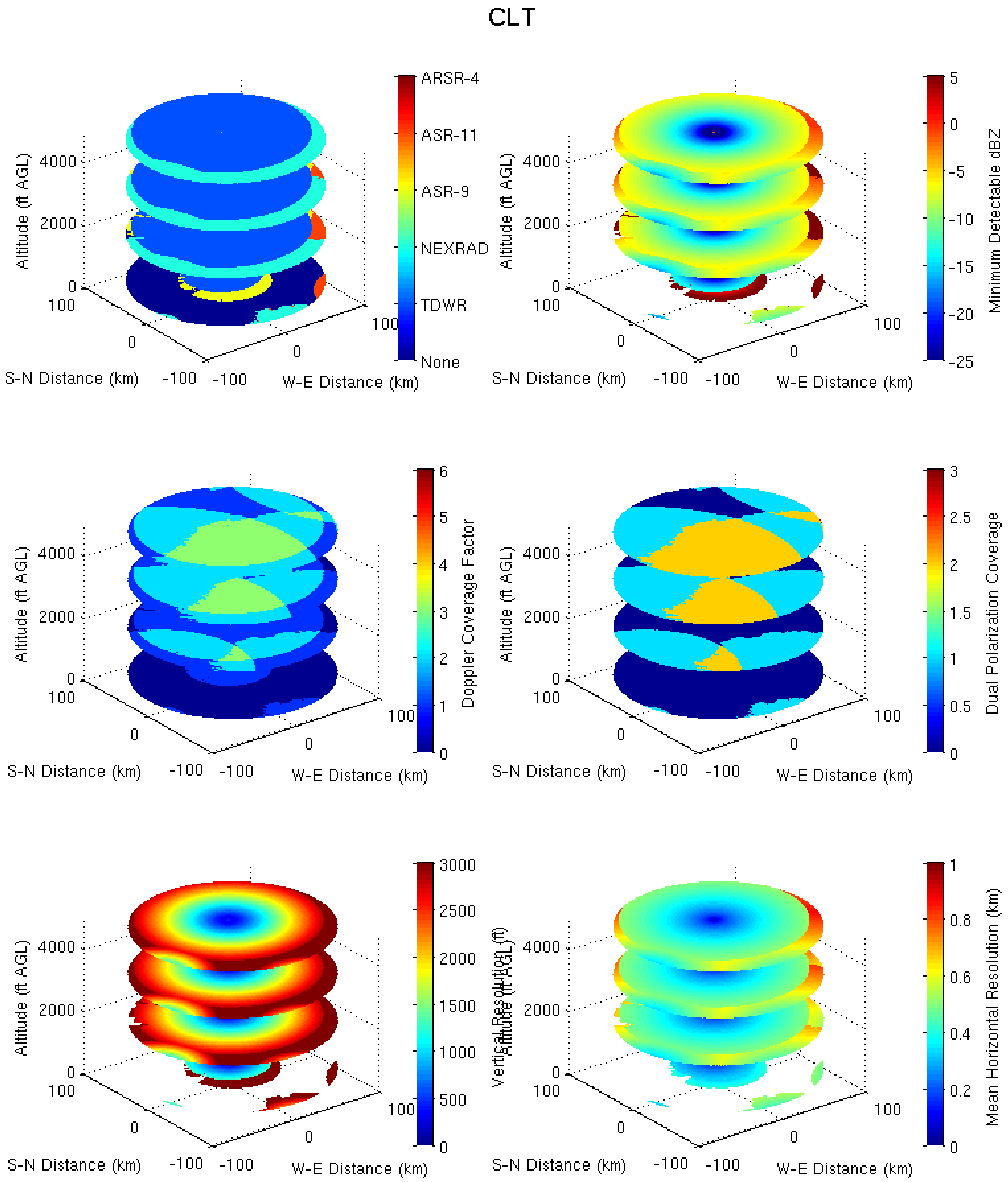


Figure A-5. Radar parameter coverage plots for the CLT terminal airspace.

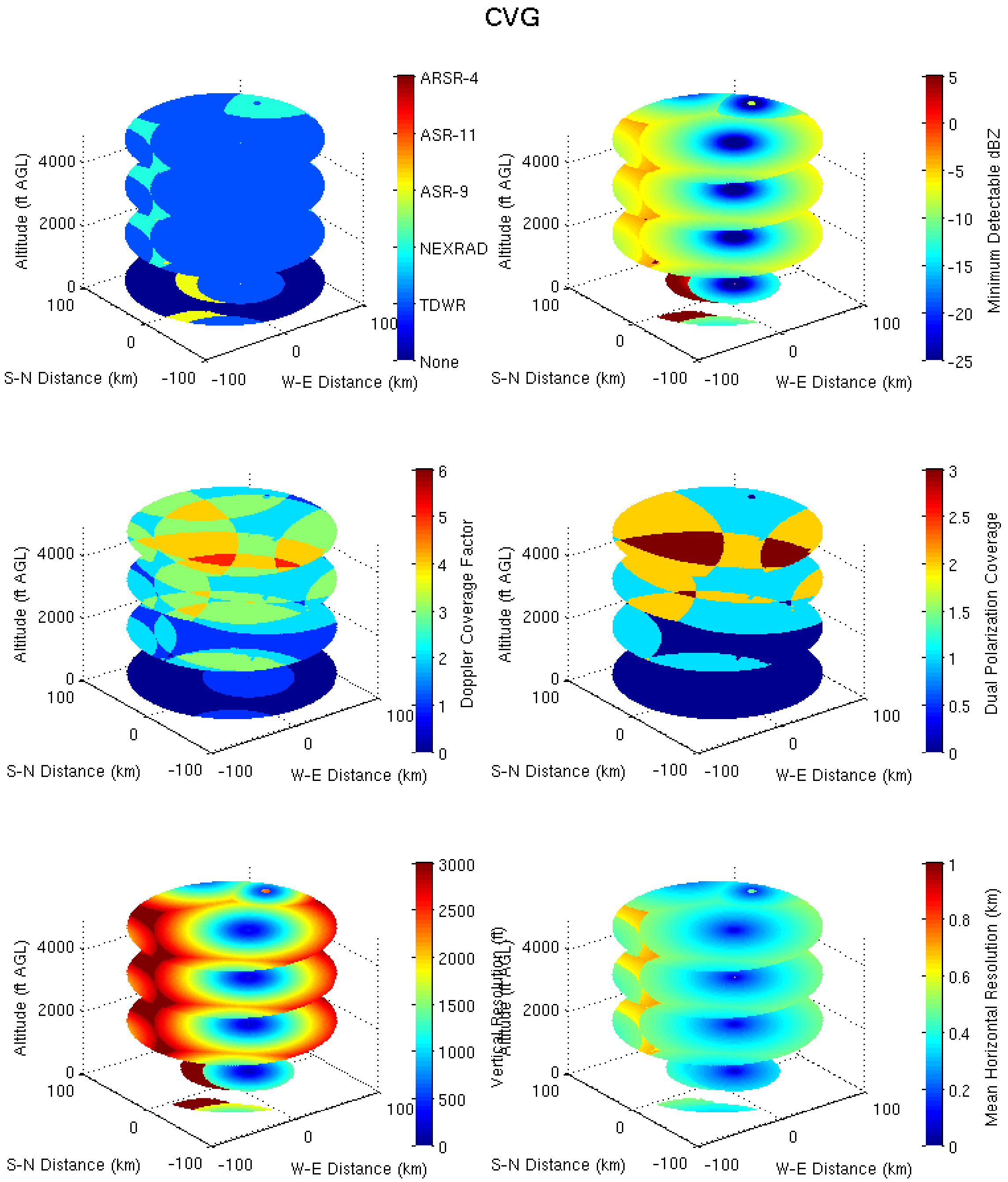


Figure A-6. Radar parameter coverage plots for the CVG terminal airspace.

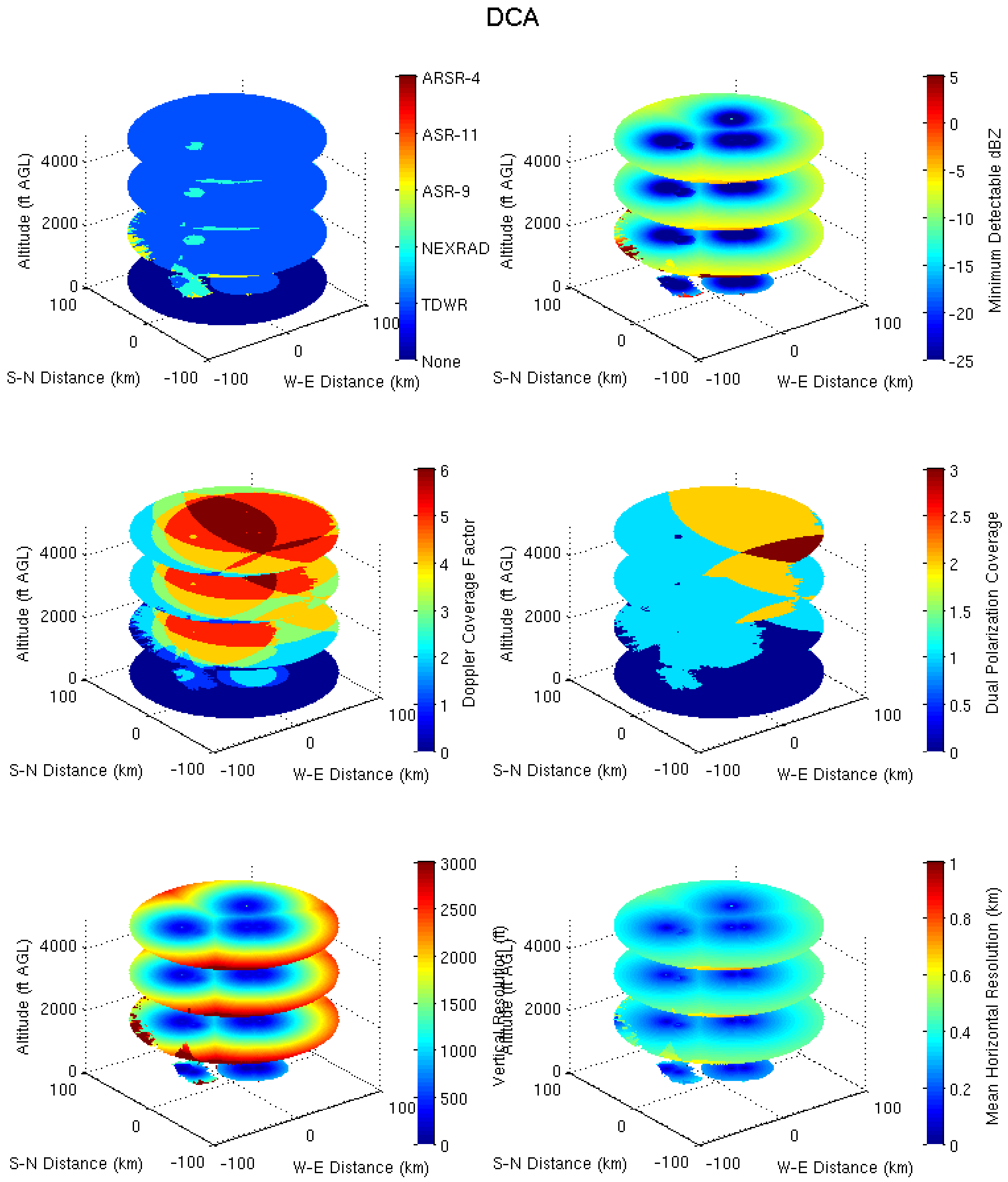


Figure A-7. Radar parameter coverage plots for the DCA terminal airspace.

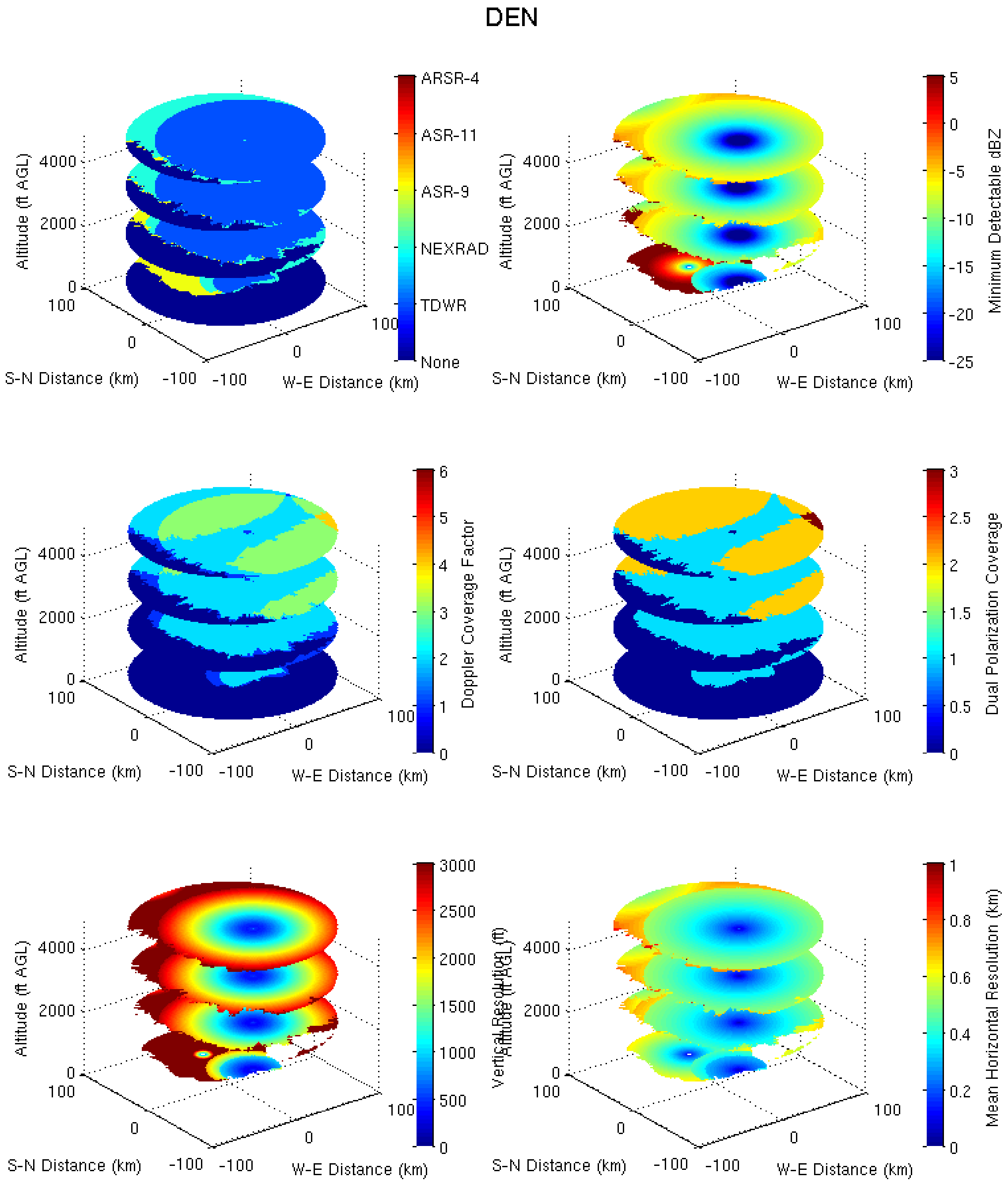


Figure A-8. Radar parameter coverage plots for the DEN terminal airspace.

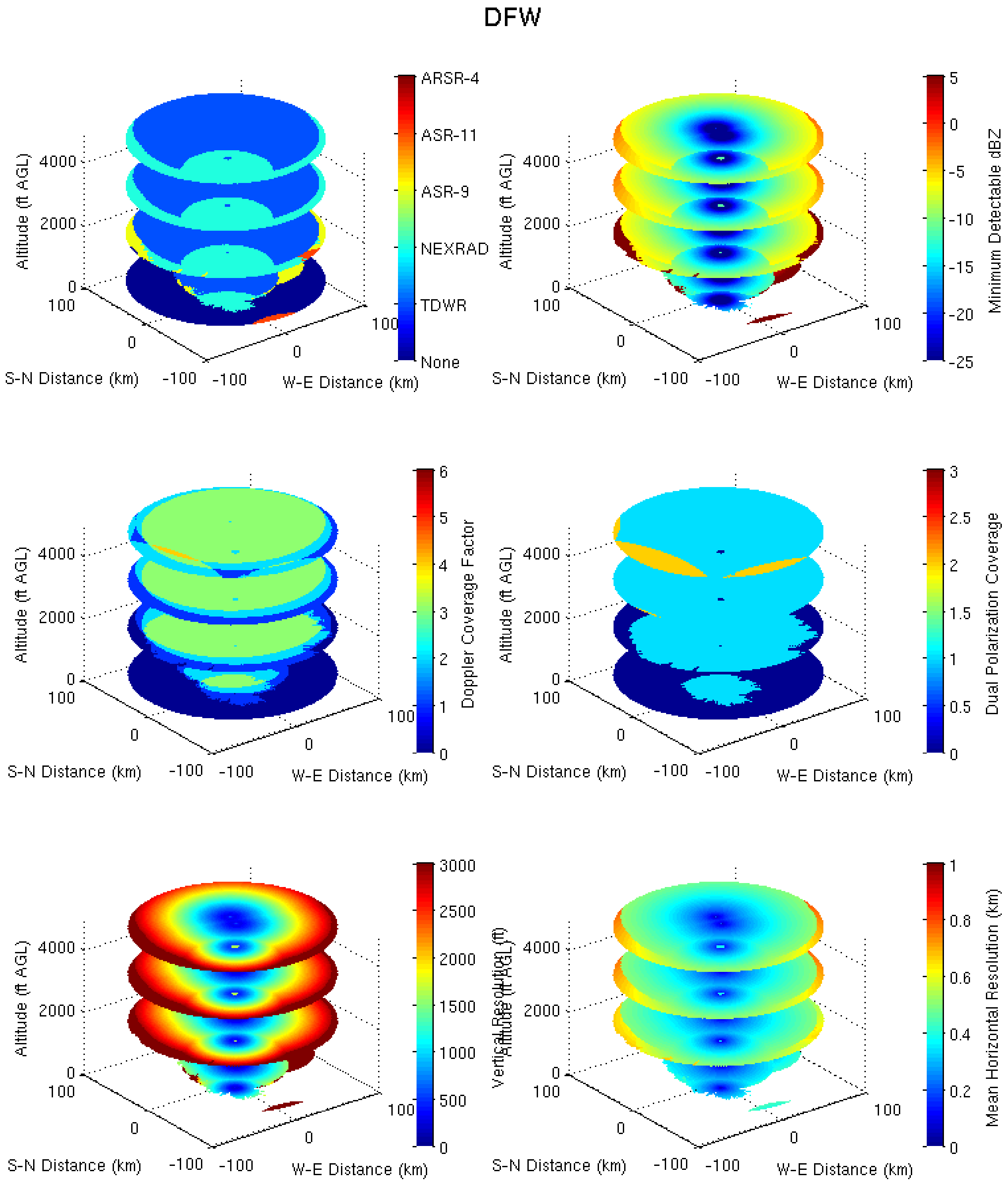


Figure A-9. Radar parameter coverage plots for the DFW terminal airspace.

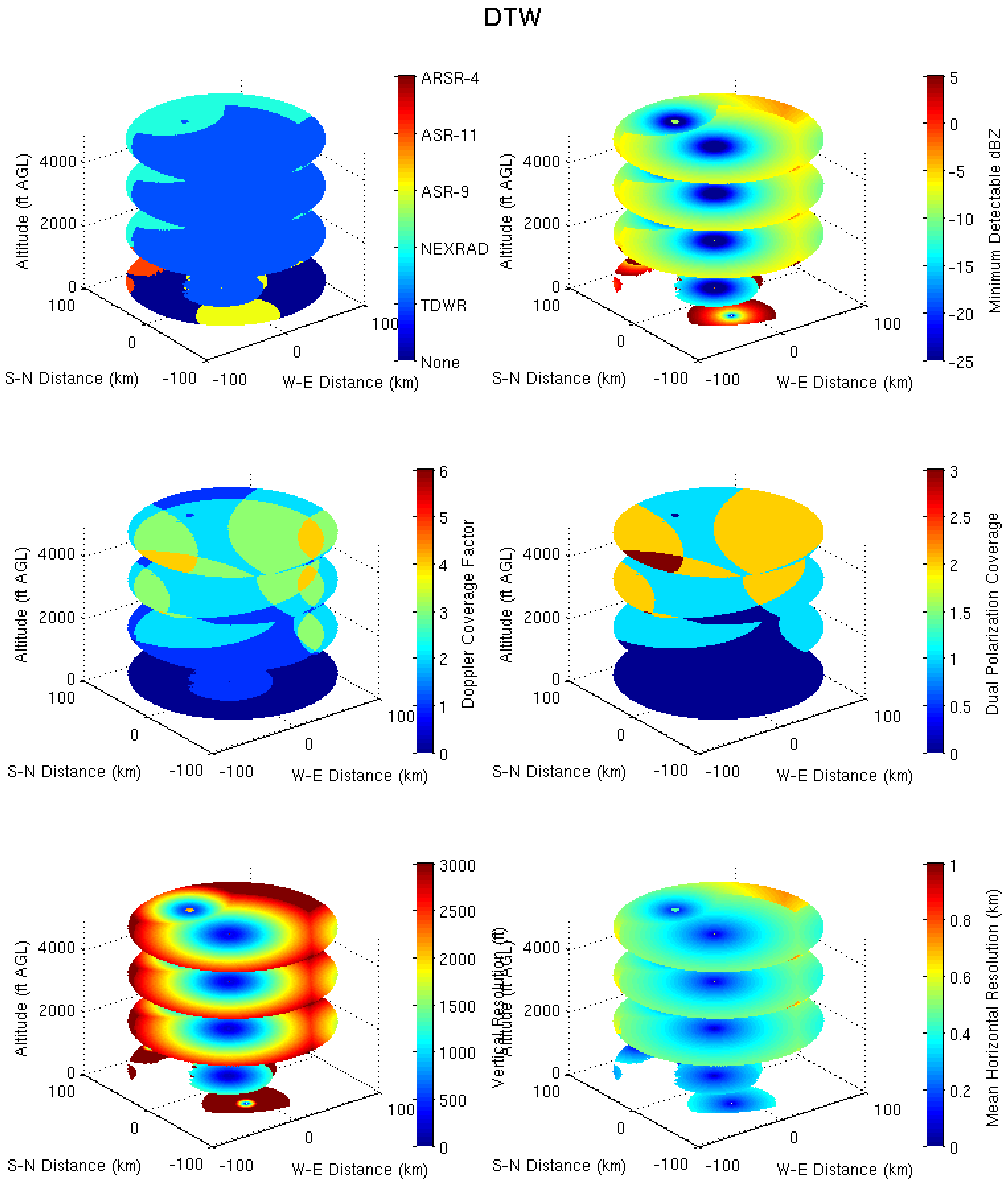


Figure A-10. Radar parameter coverage plots for the DTW terminal airspace.

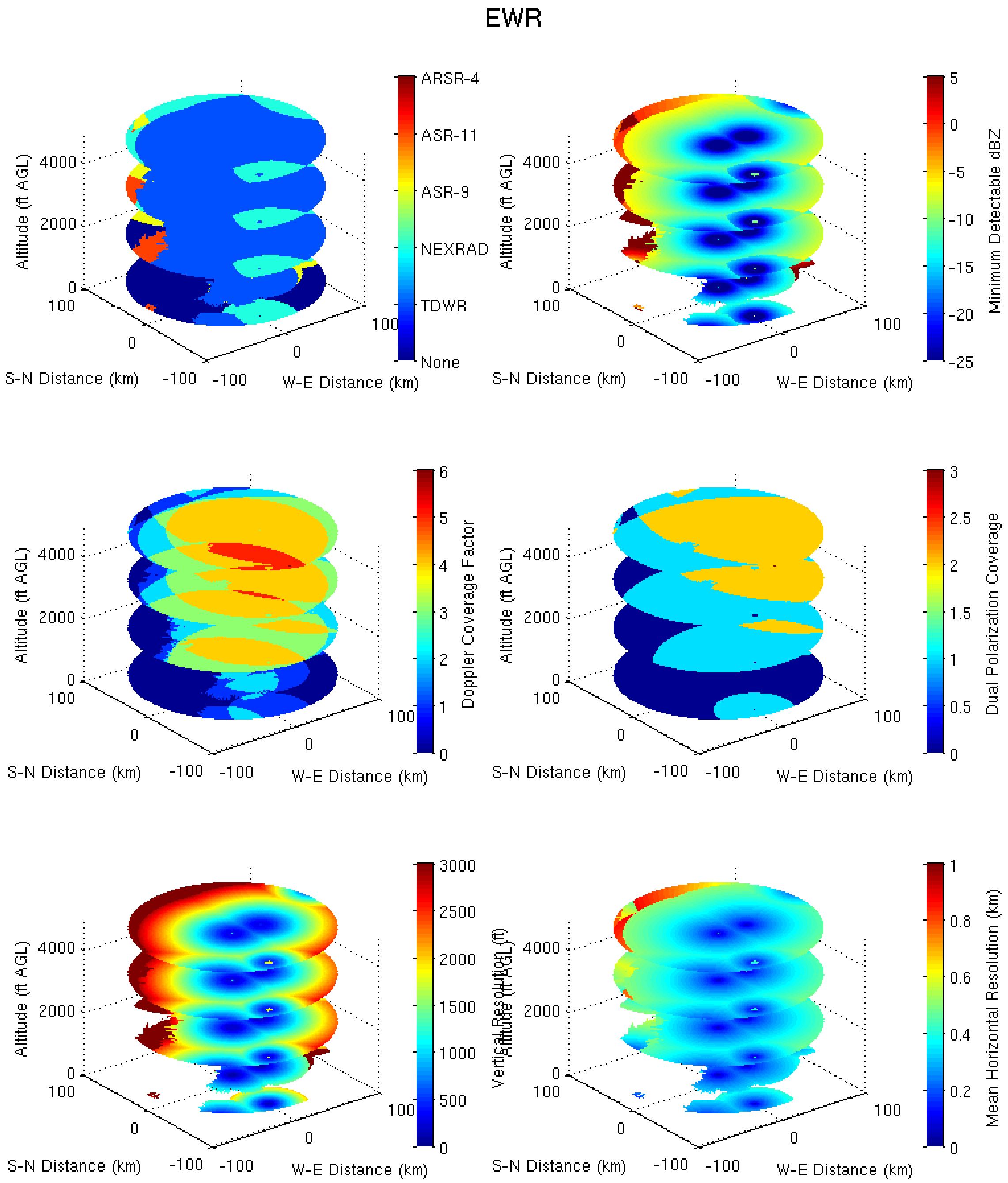


Figure A-11. Radar parameter coverage plots for the EWR terminal airspace.

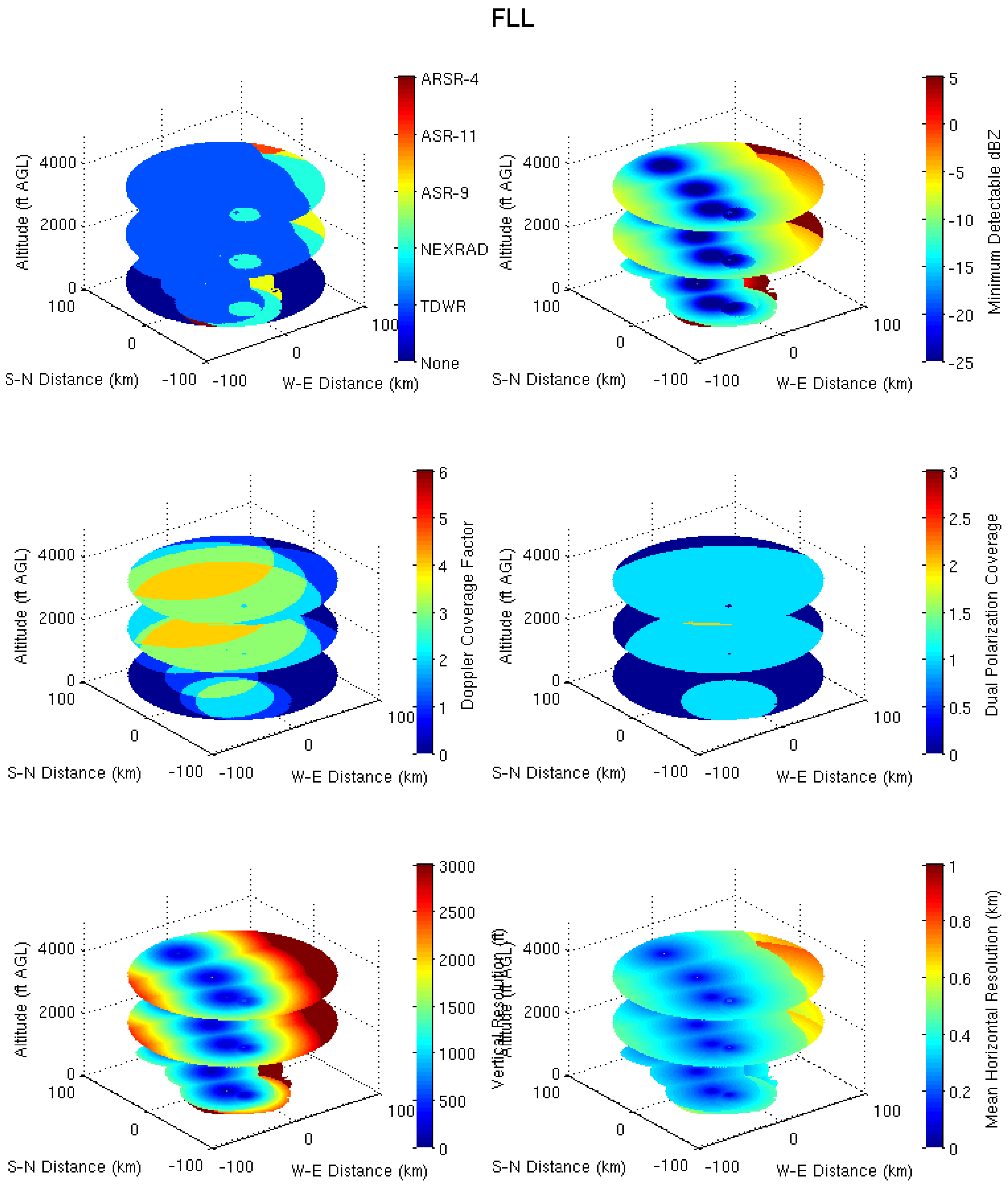


Figure A-12. Radar parameter coverage plots for the FLL terminal airspace.

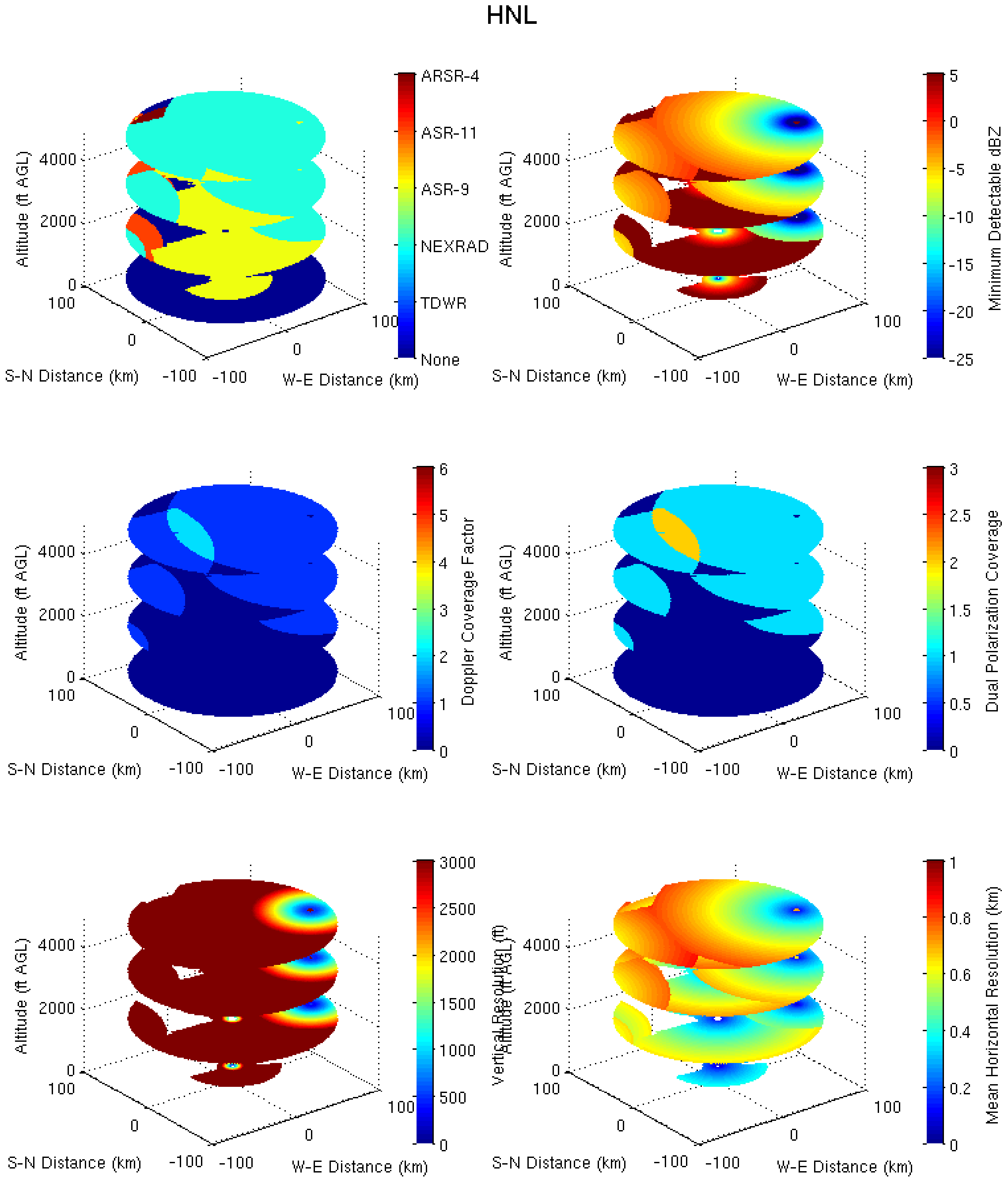


Figure A-13. Radar parameter coverage plots for the HNL terminal airspace.

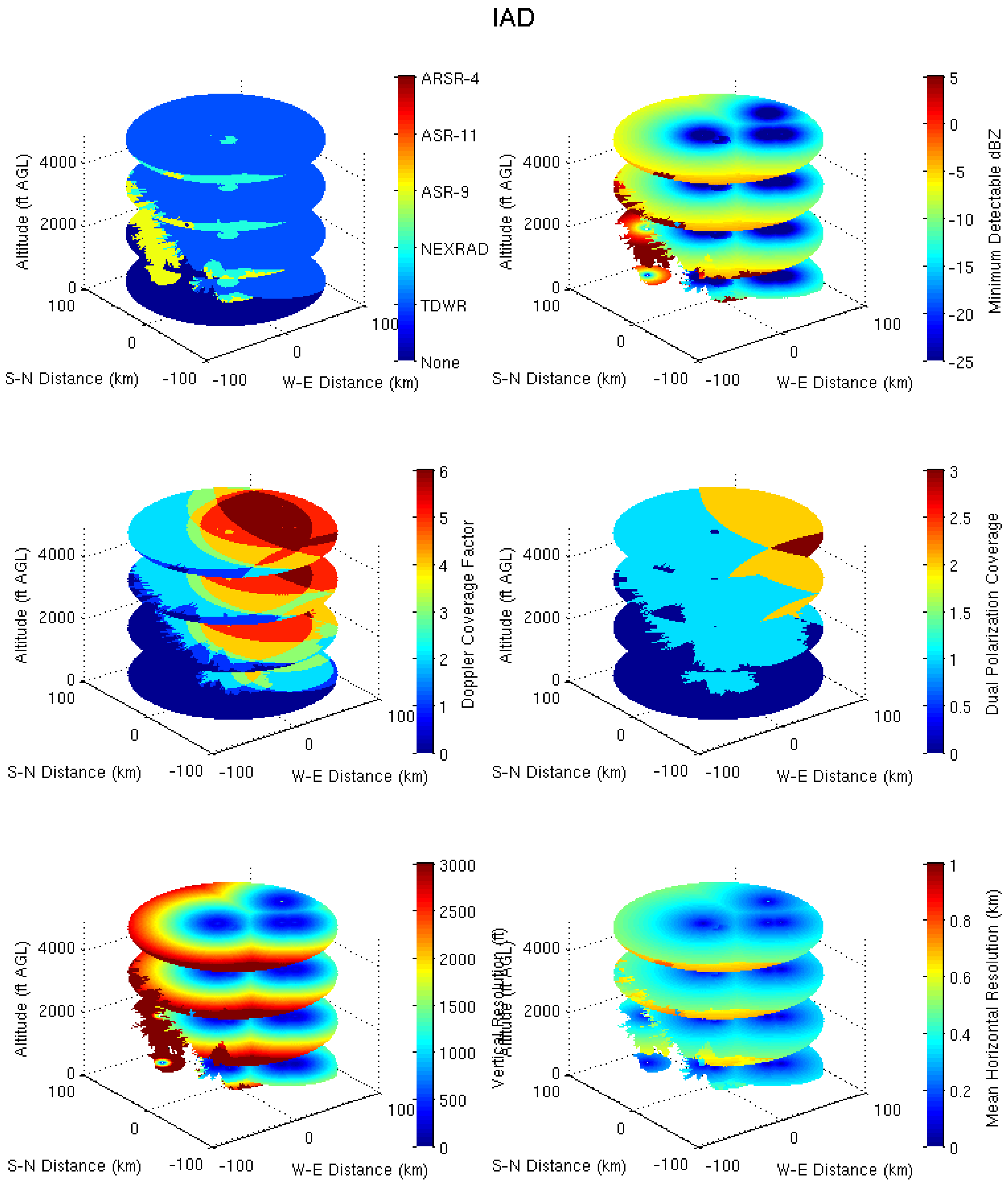


Figure A-14. Radar parameter coverage plots for the IAD terminal airspace.

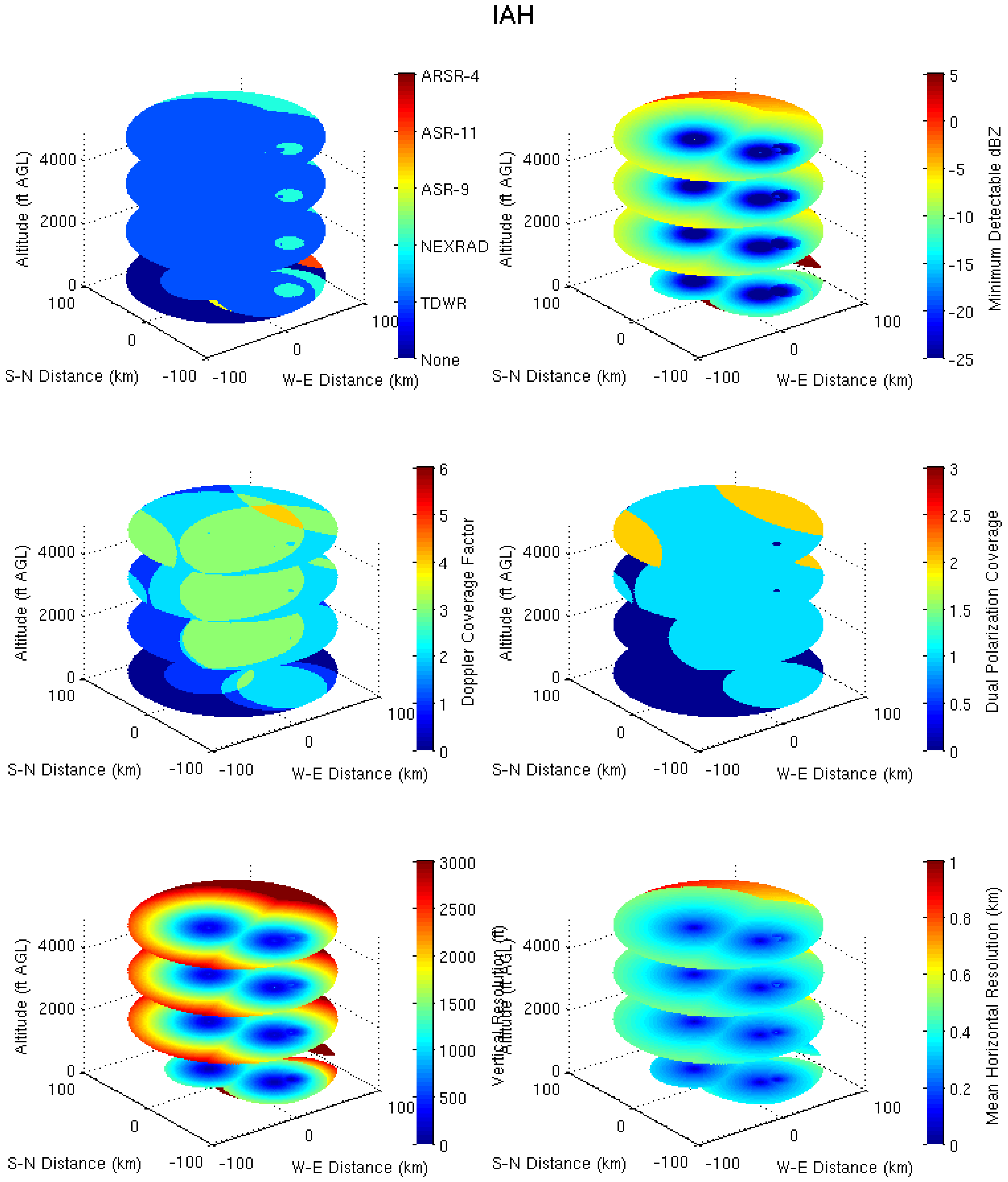


Figure A-15. Radar parameter coverage plots for the IAH terminal airspace.

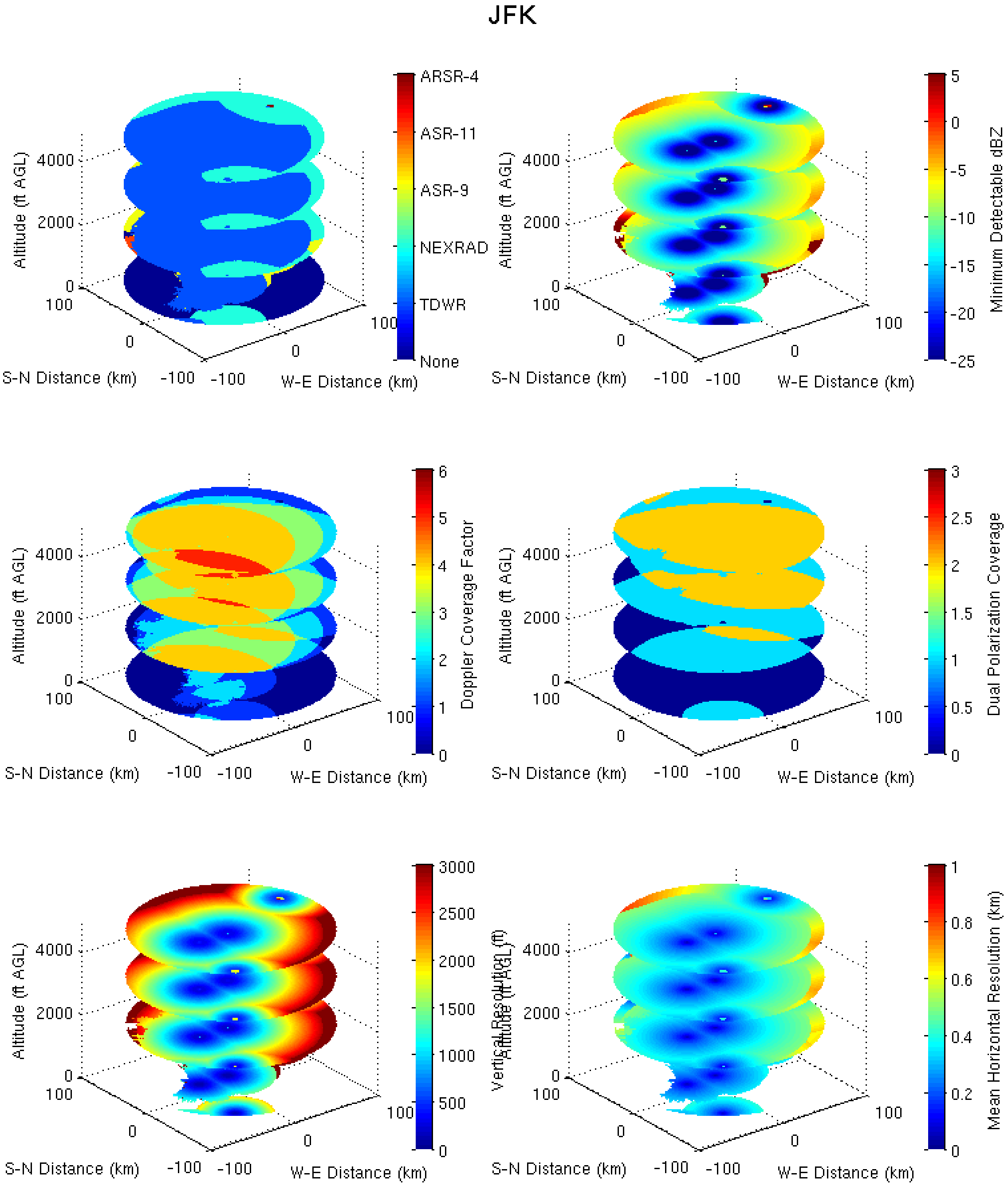


Figure A-16. Radar parameter coverage plots for the JFK terminal airspace.

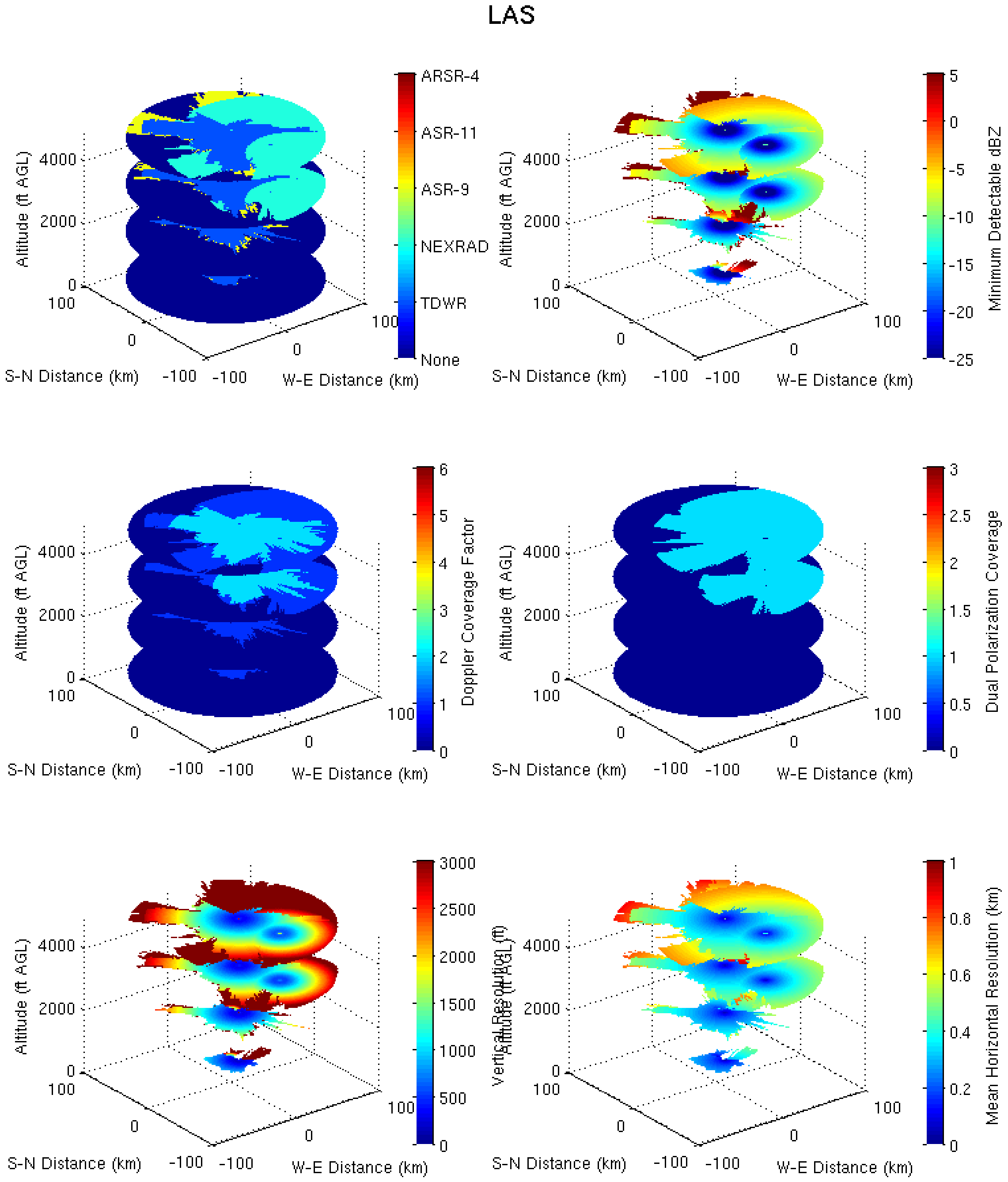


Figure A-17. Radar parameter coverage plots for the LAS terminal airspace.

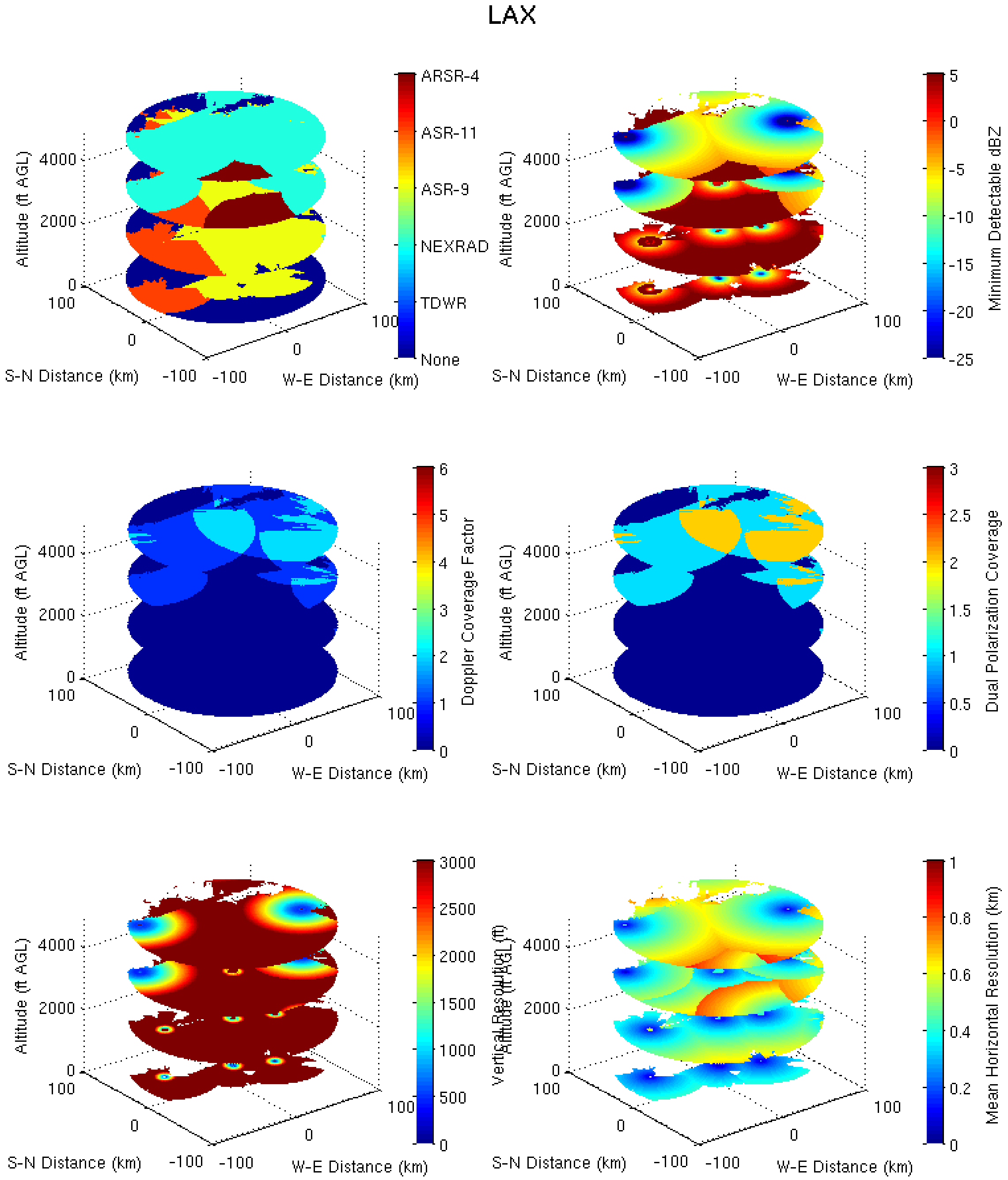


Figure A-18. Radar parameter coverage plots for the LAX terminal airspace.

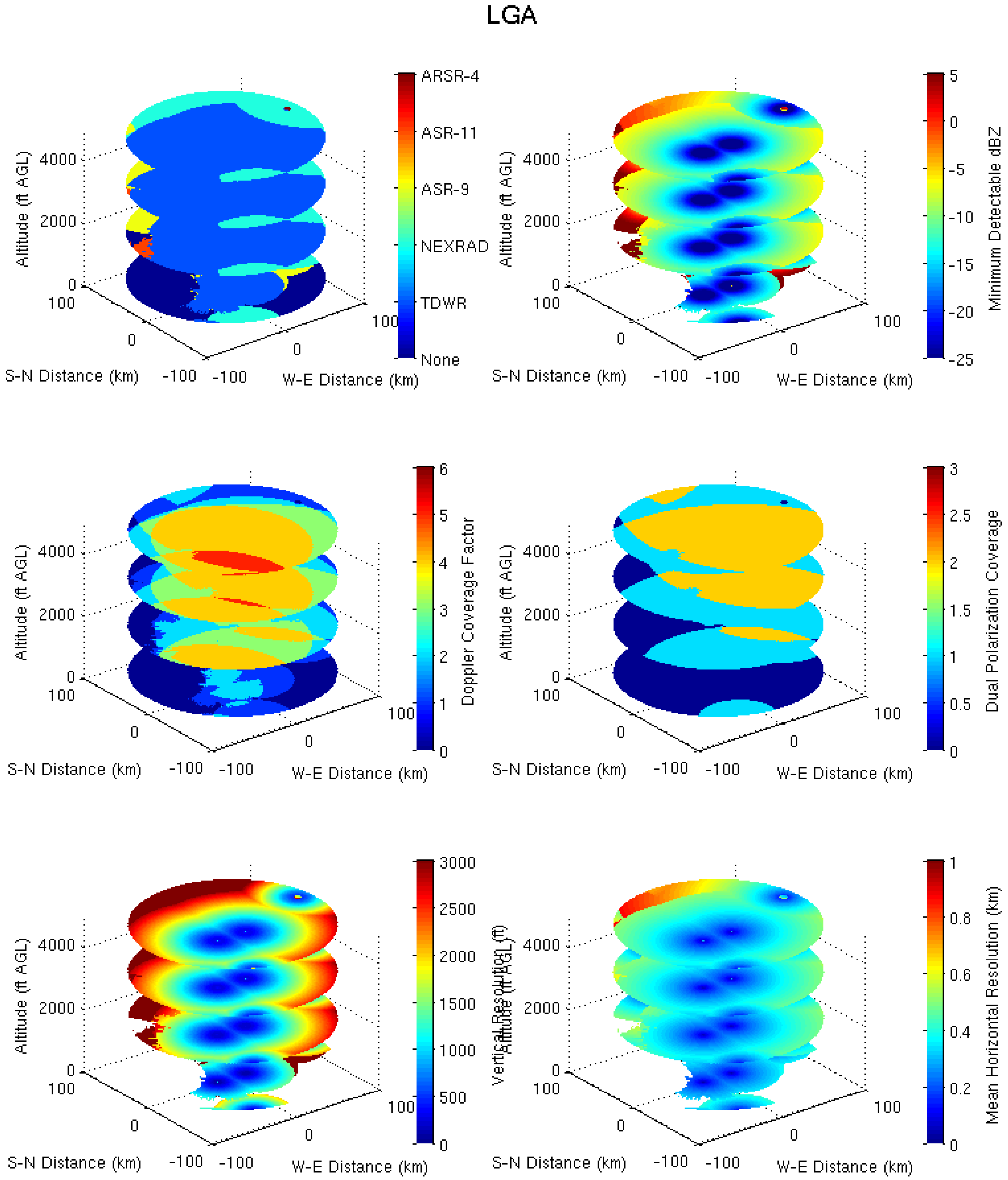


Figure A-19. Radar parameter coverage plots for the LGA terminal airspace.

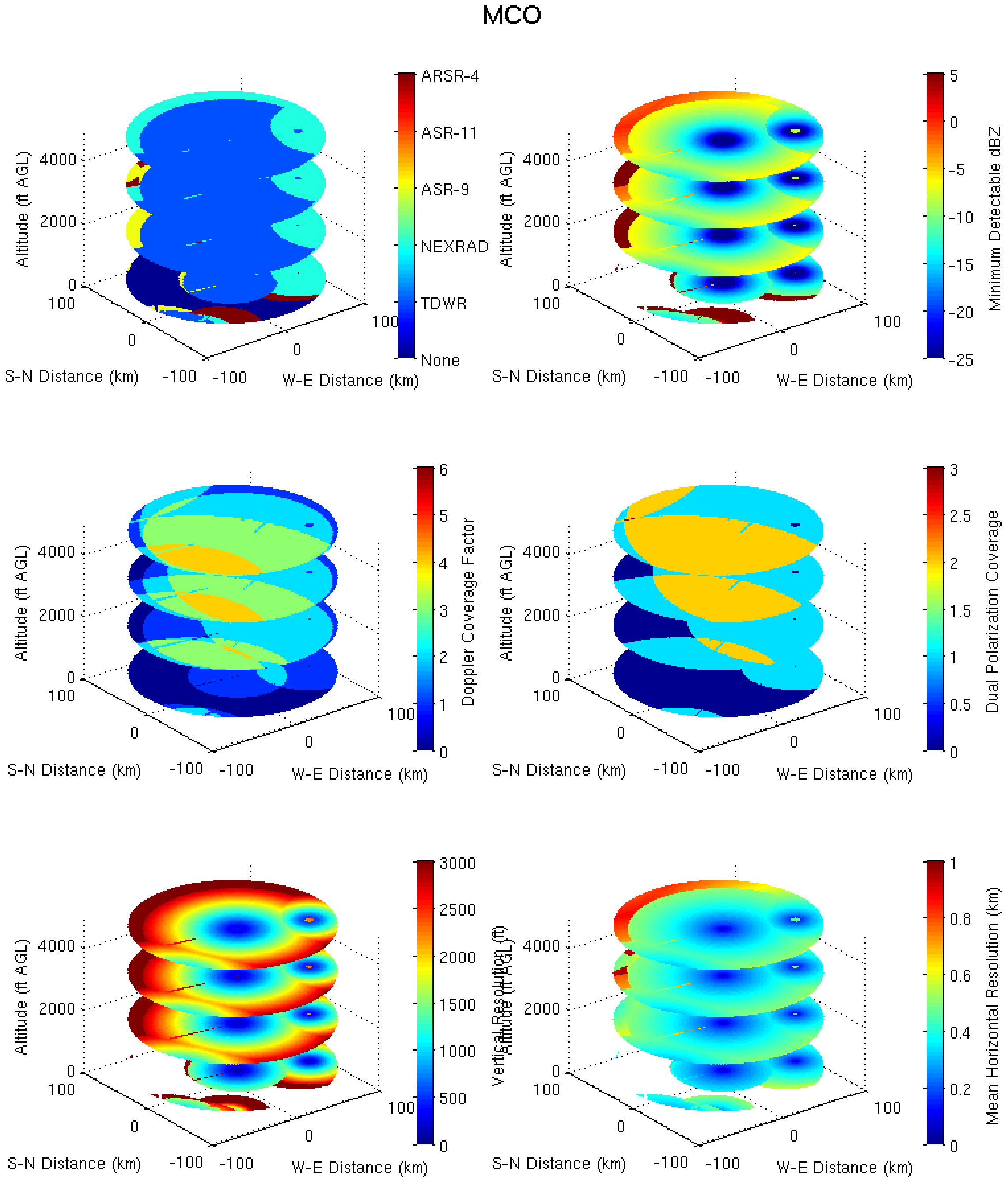


Figure A-20. Radar parameter coverage plots for the MCO terminal airspace.

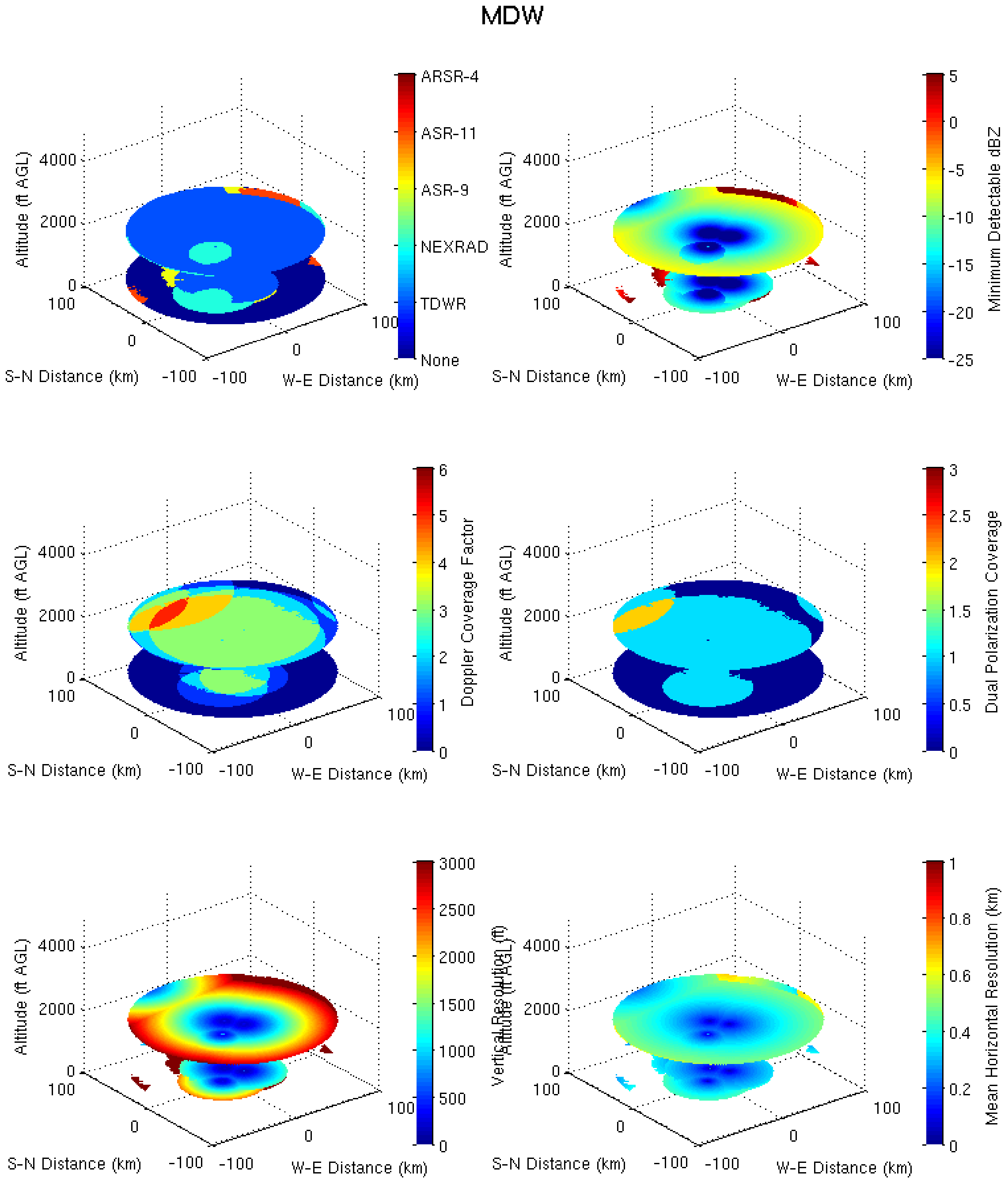


Figure A-21. Radar parameter coverage plots for the MDW terminal airspace.

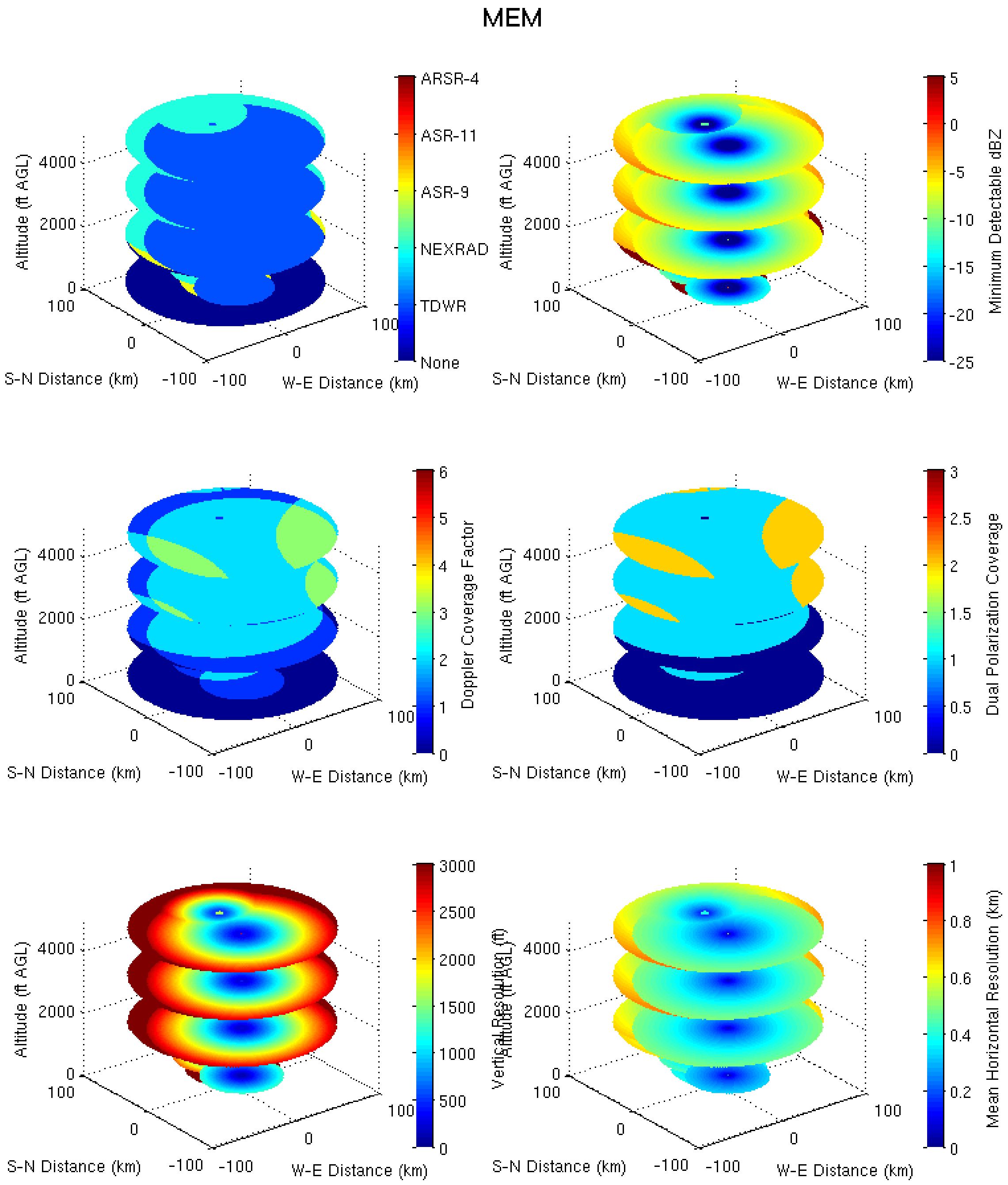


Figure A-22. Radar parameter coverage plots for the MEM terminal airspace.

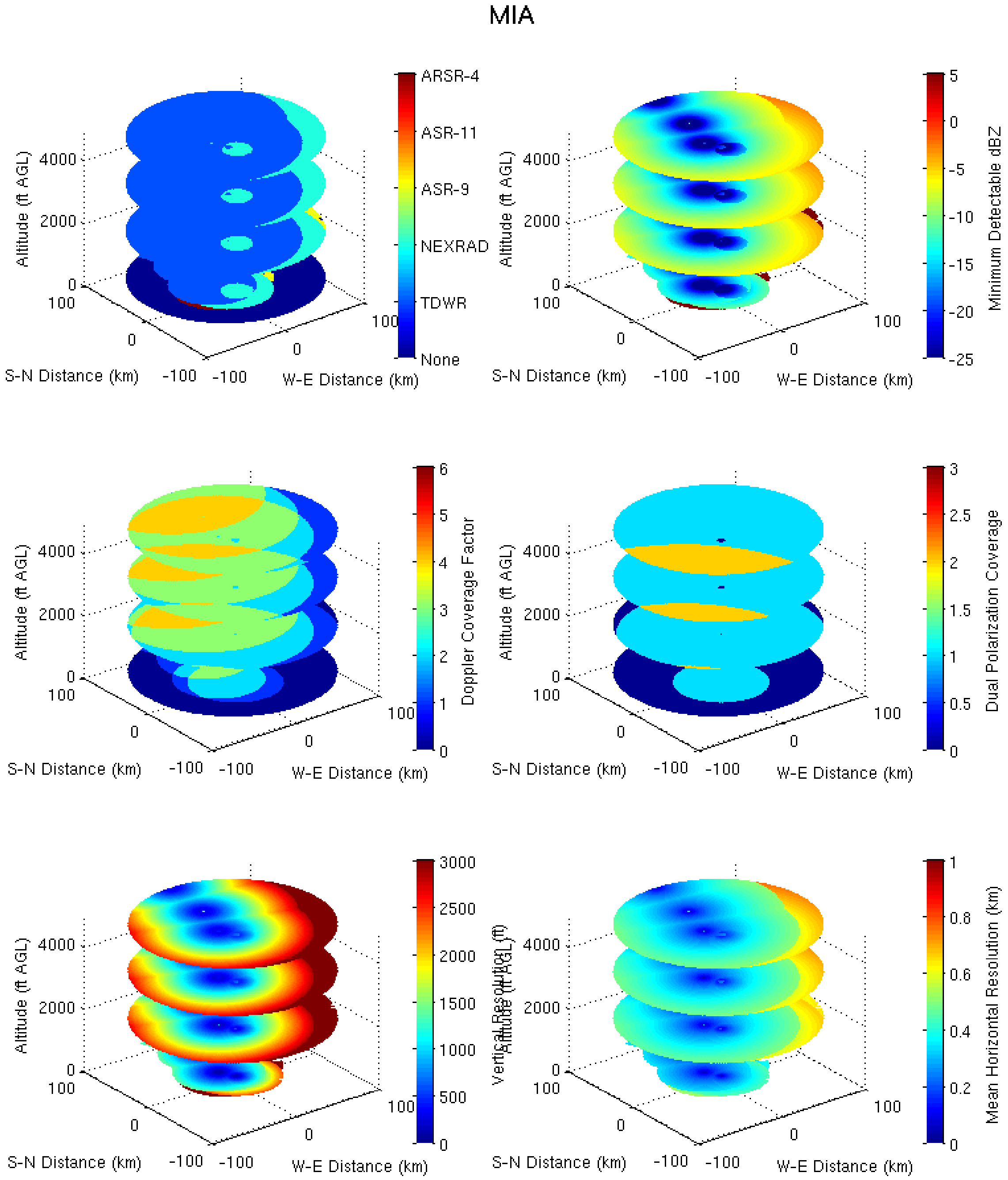


Figure A-23. Radar parameter coverage plots for the MIA terminal airspace.

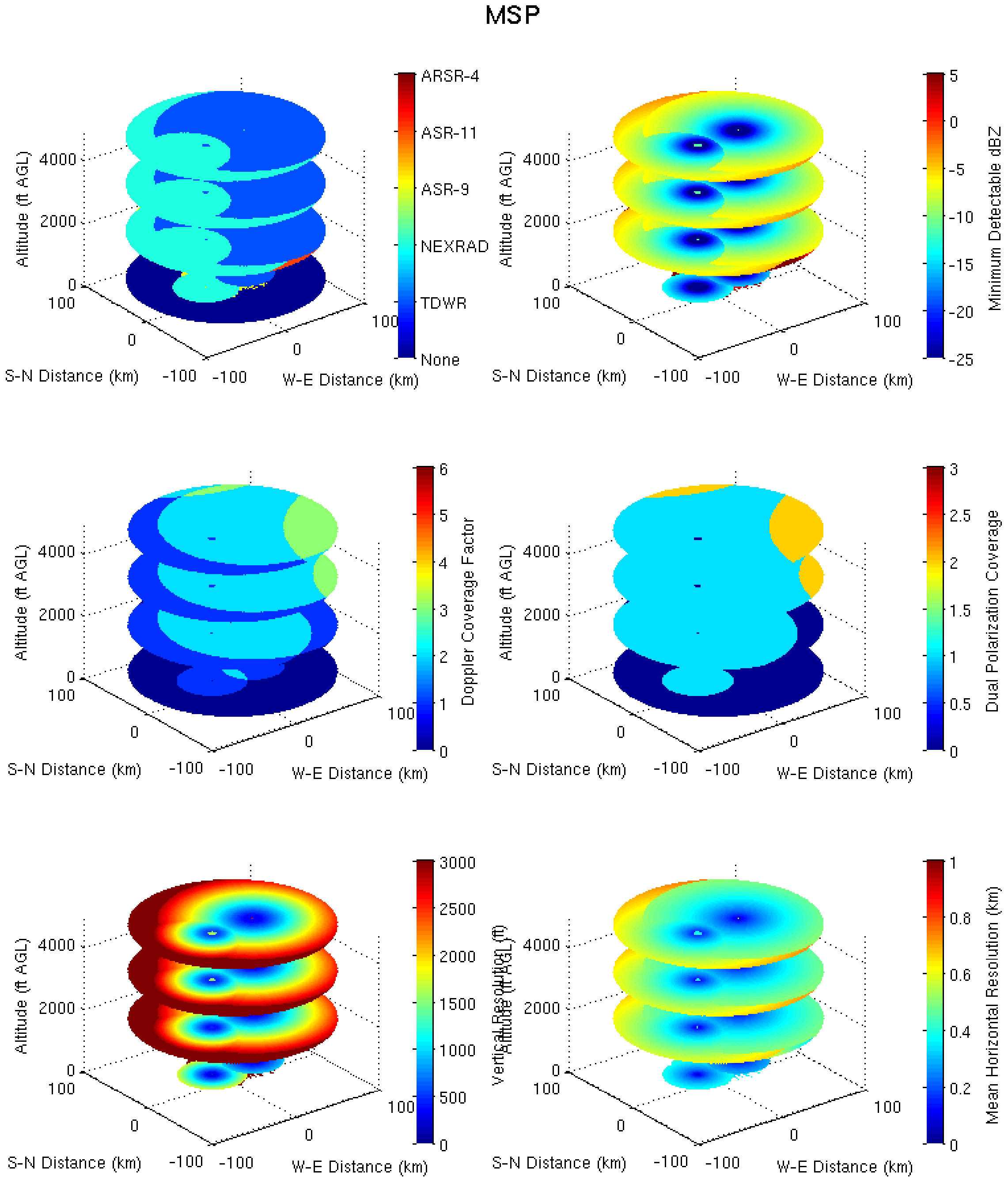


Figure A-24. Radar parameter coverage plots for the MSP terminal airspace.

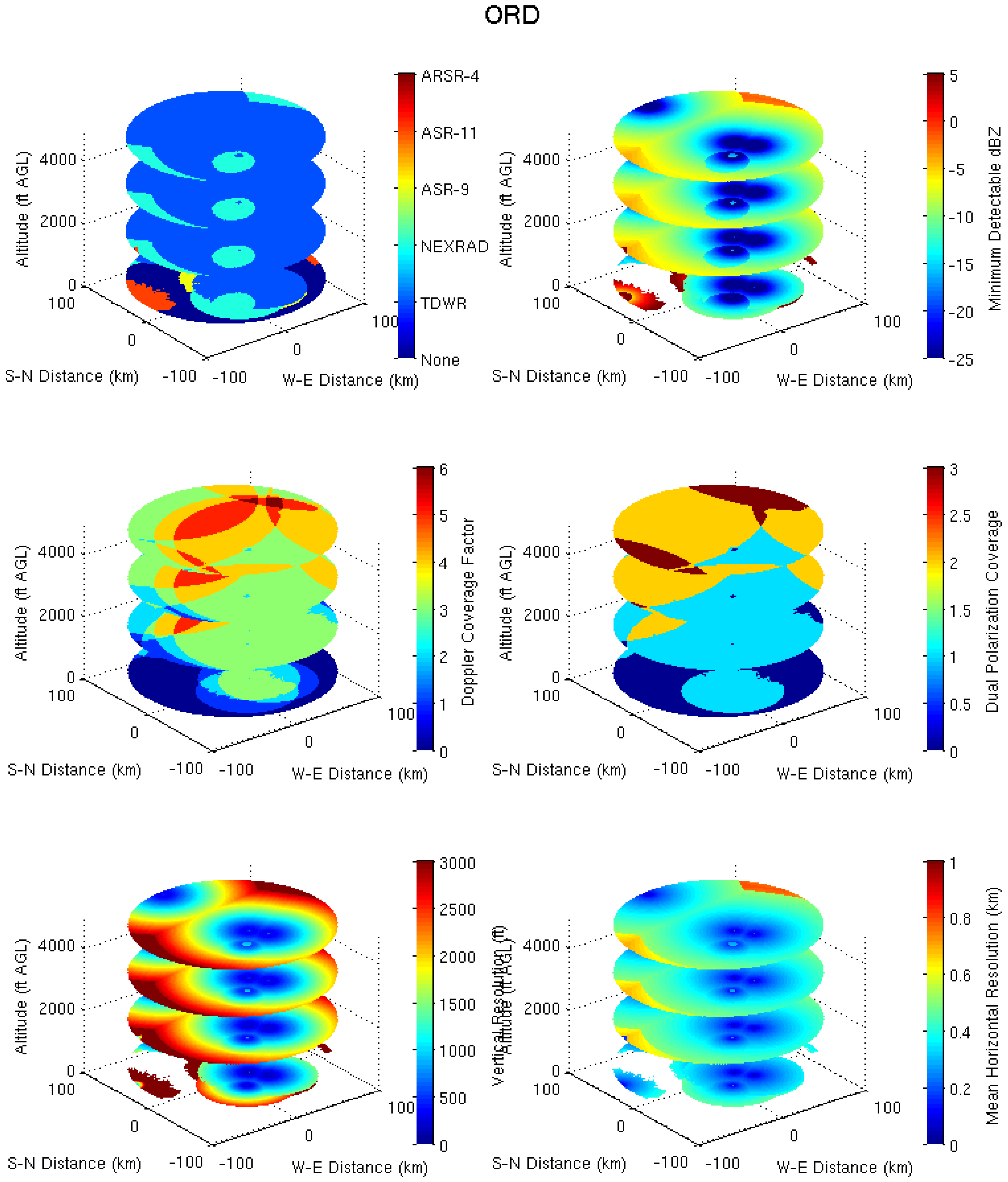


Figure A-25. Radar parameter coverage plots for the ORD terminal airspace.

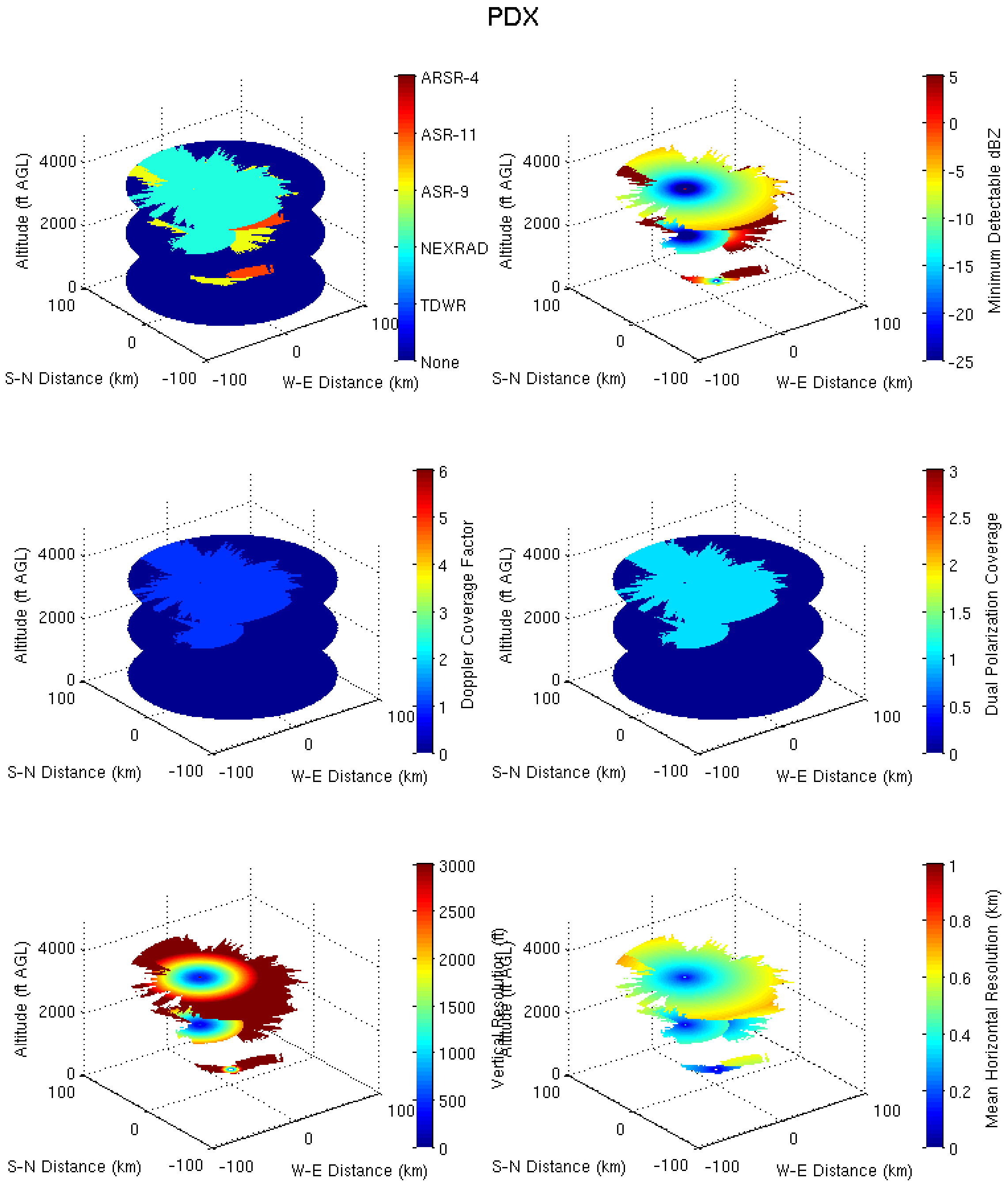


Figure A-26. Radar parameter coverage plots for the PDX terminal airspace.

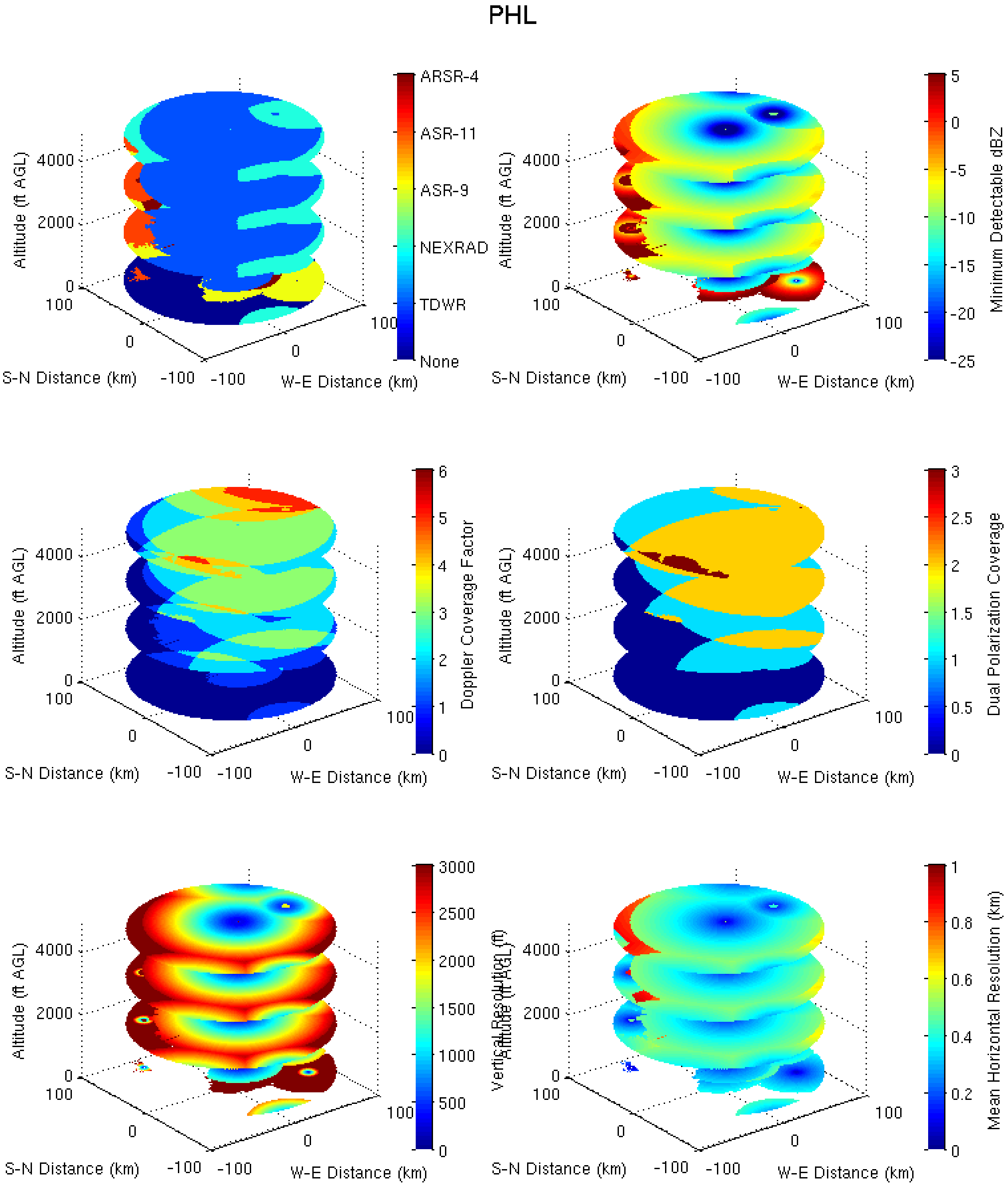


Figure A-27. Radar parameter coverage plots for the PHL terminal airspace.

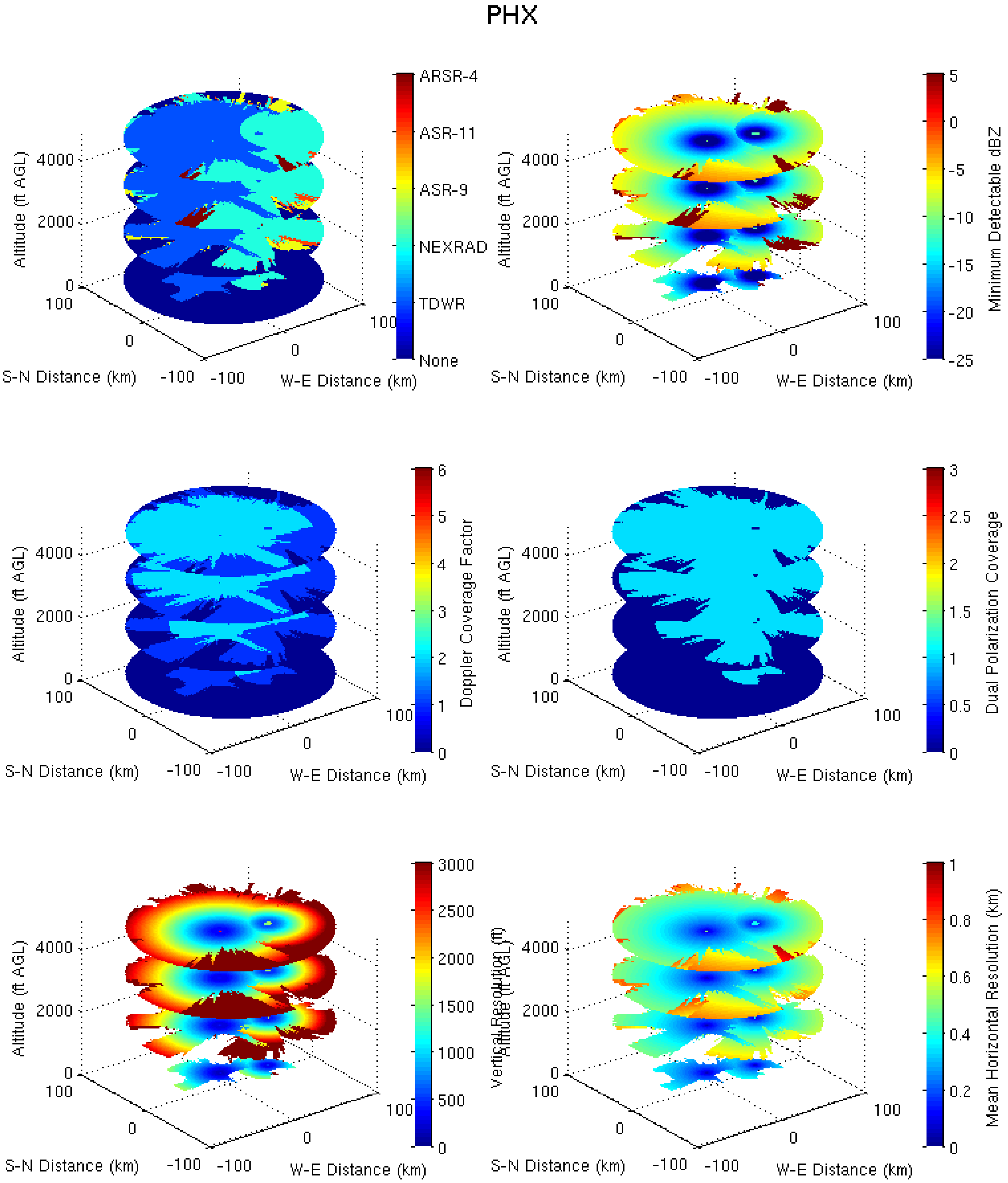


Figure A-28. Radar parameter coverage plots for the PHX terminal airspace.

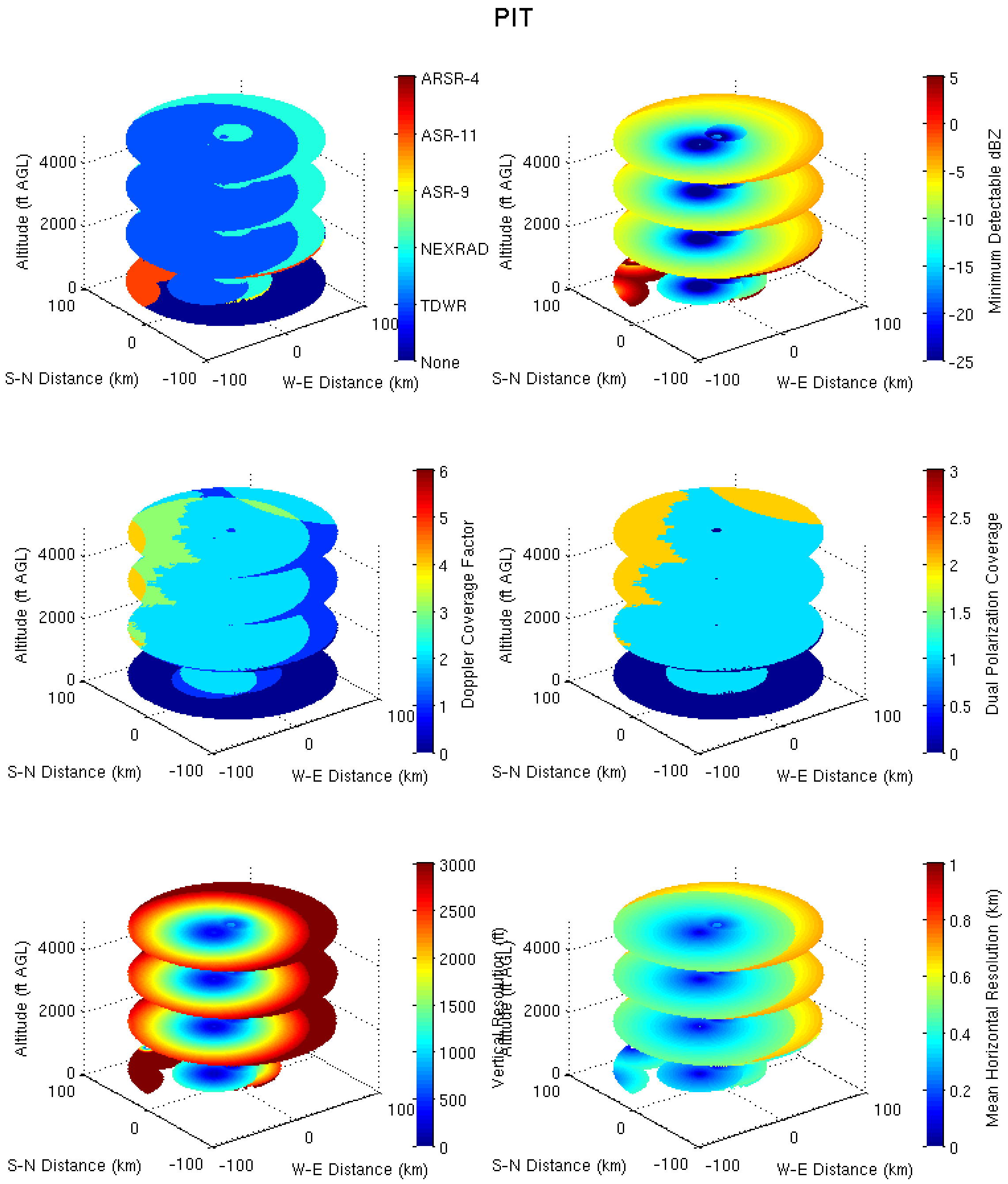


Figure A-29. Radar parameter coverage plots for the PIT terminal airspace.

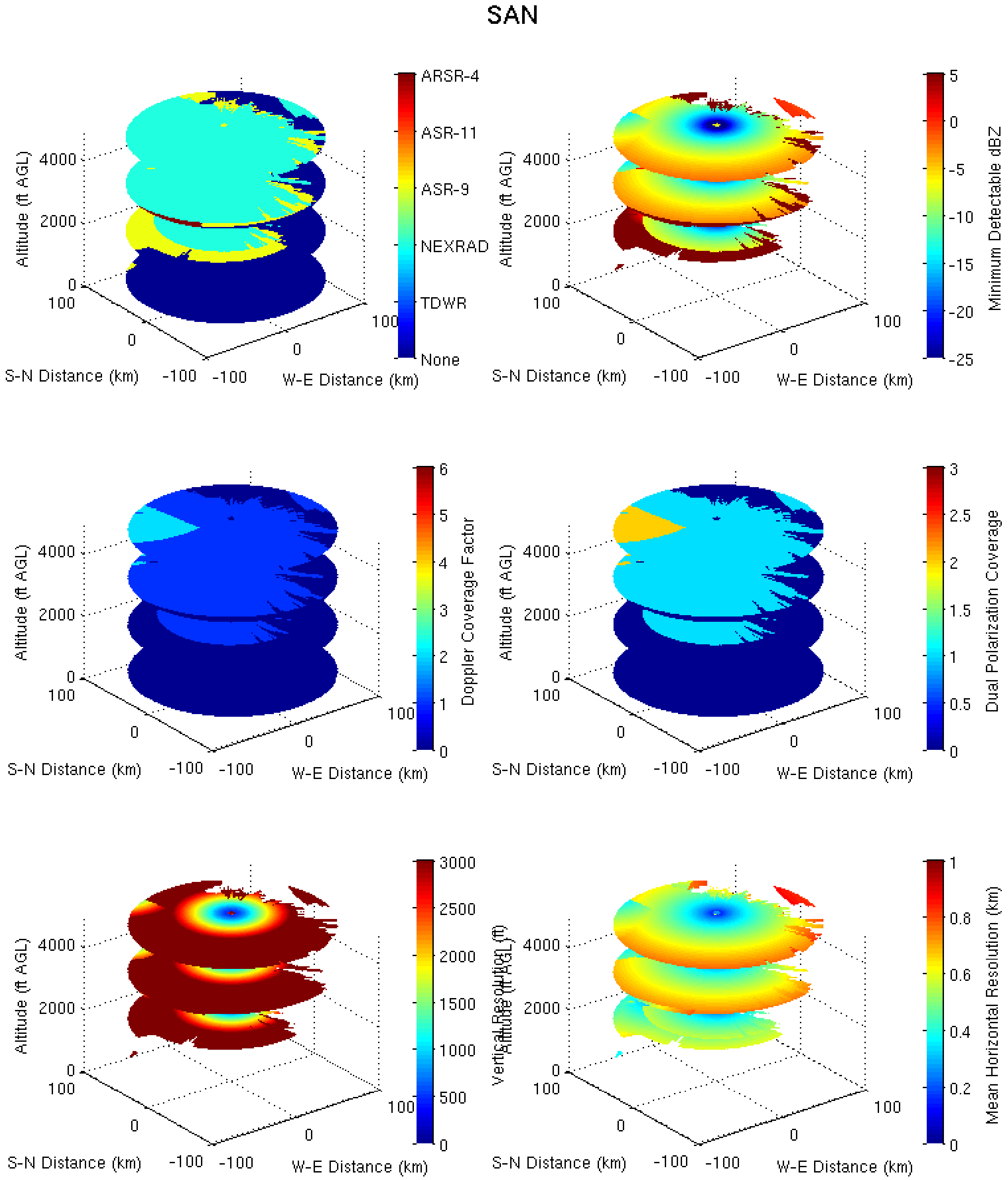


Figure A-30. Radar parameter coverage plots for the SAN terminal airspace.

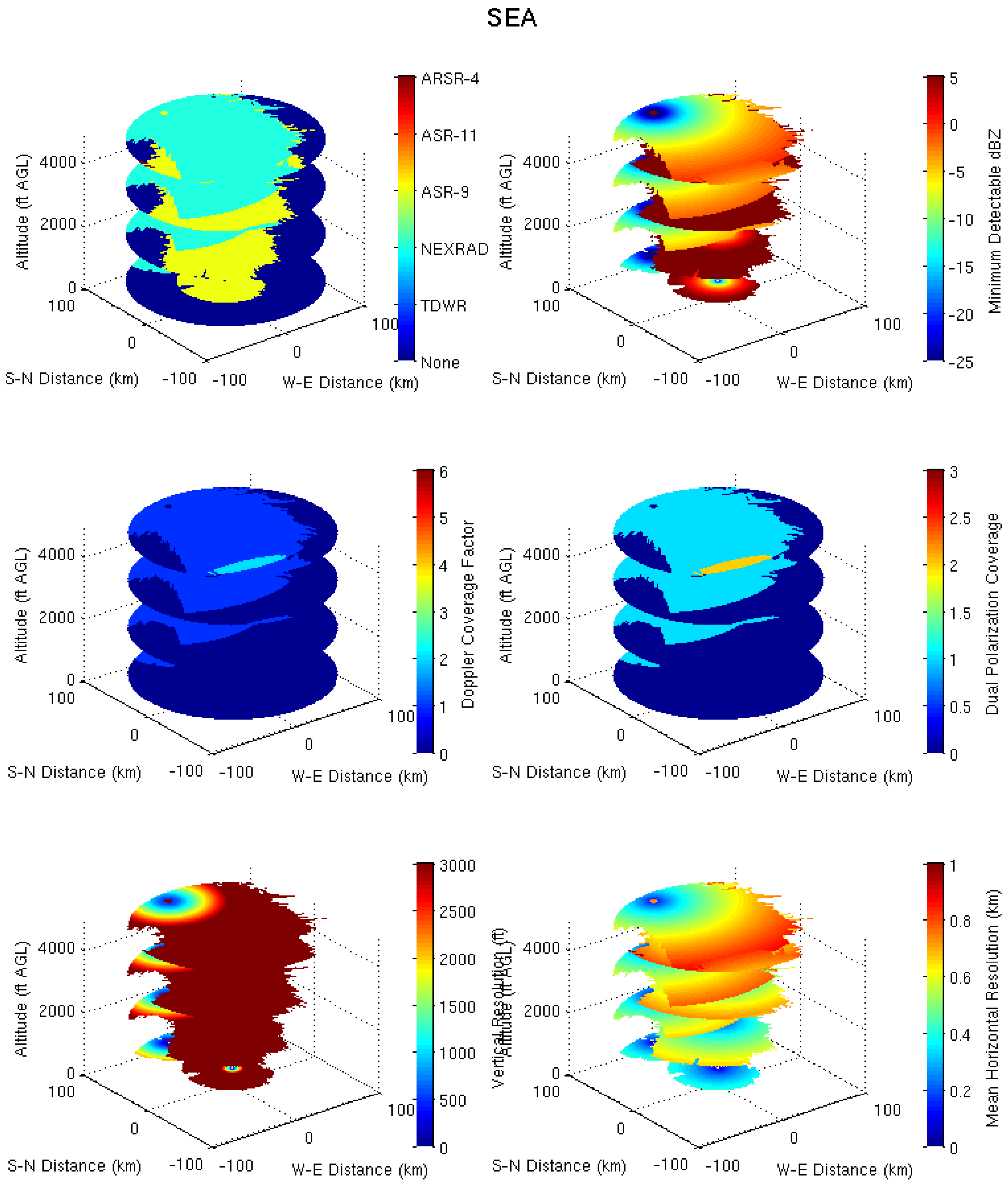


Figure A-31. Radar parameter coverage plots for the SEA terminal airspace.

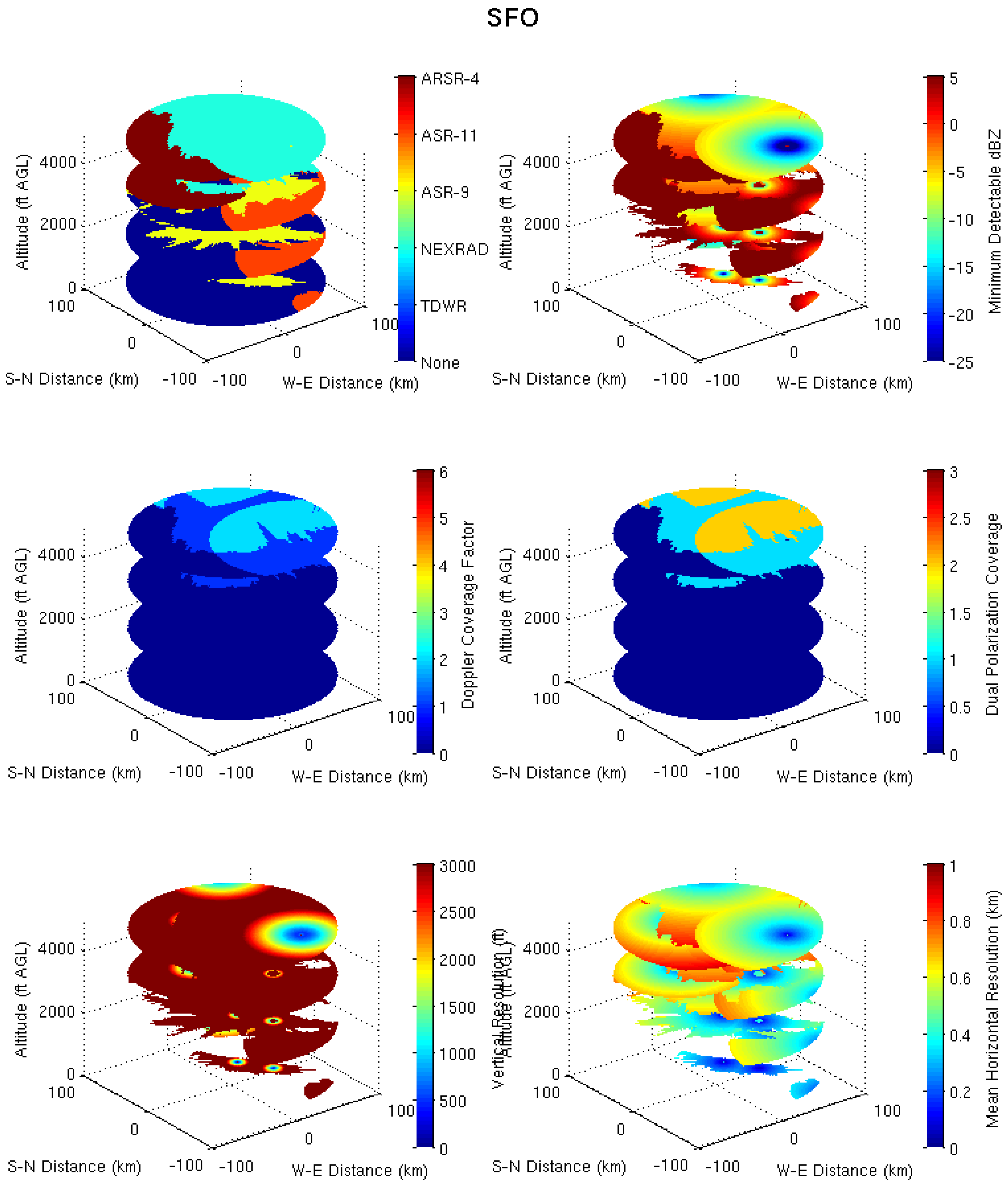


Figure A-32. Radar parameter coverage plots for the SFO terminal airspace.

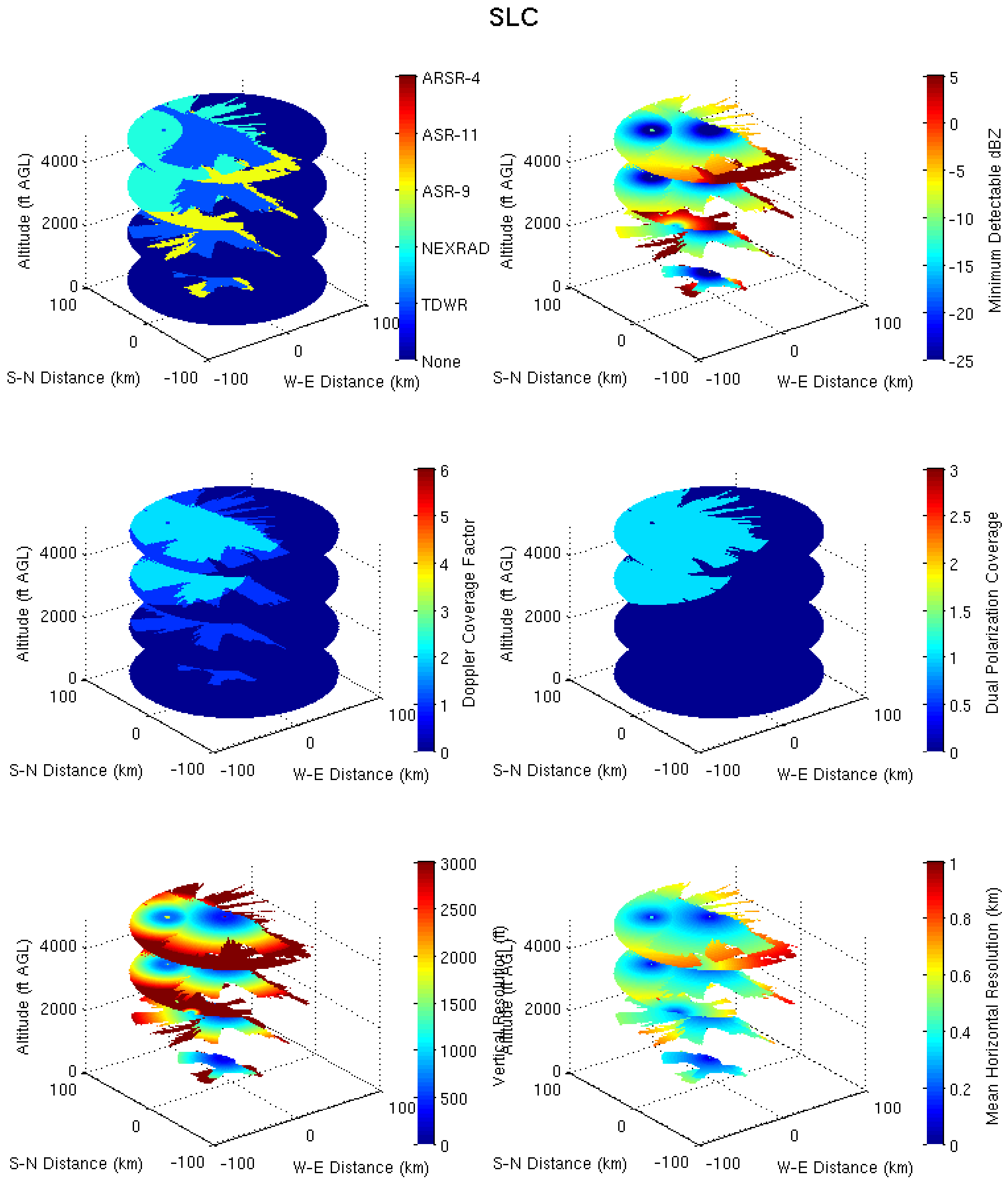


Figure A-33. Radar parameter coverage plots for the SLC terminal airspace.

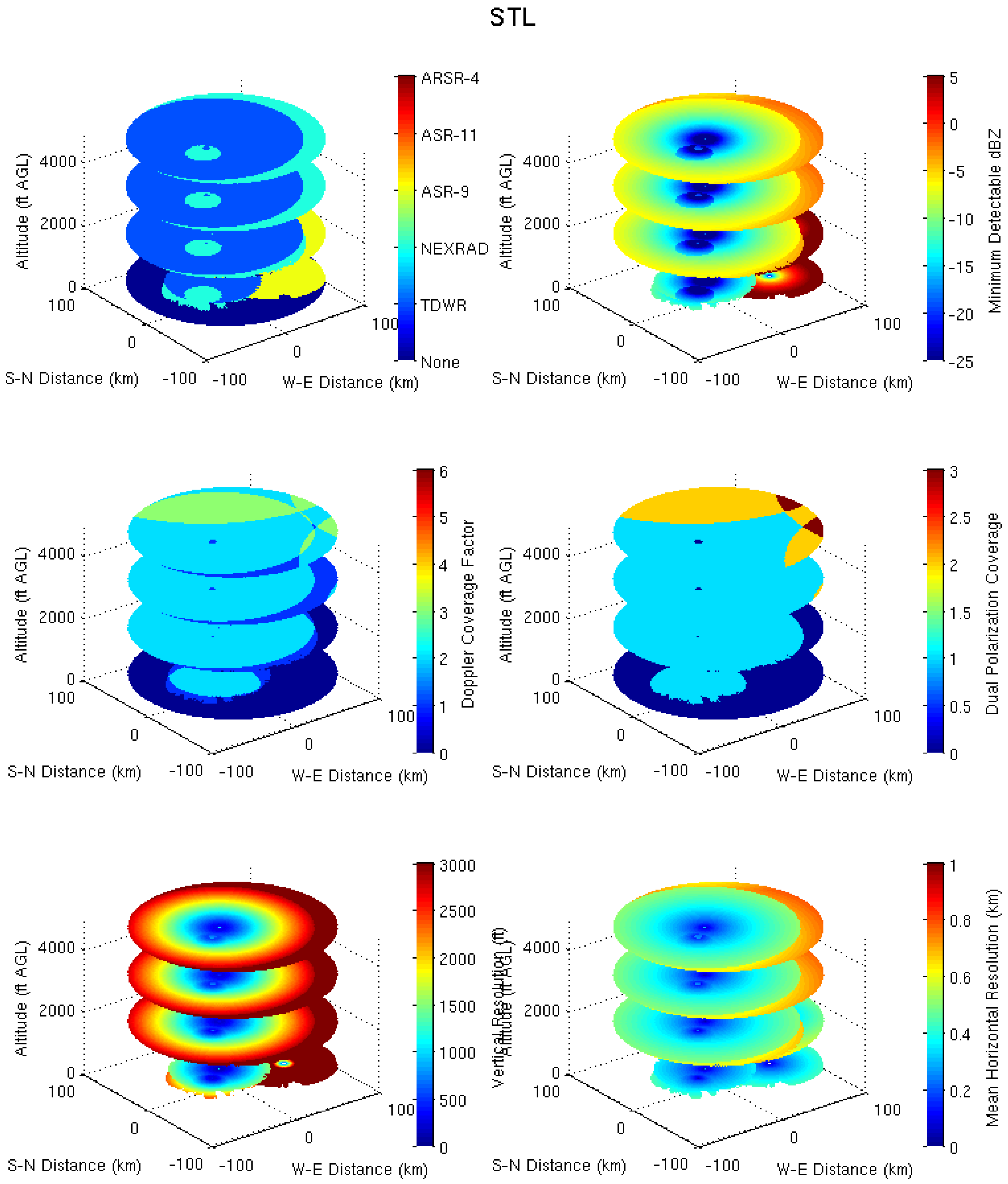


Figure A-34. Radar parameter coverage plots for the STL terminal airspace.

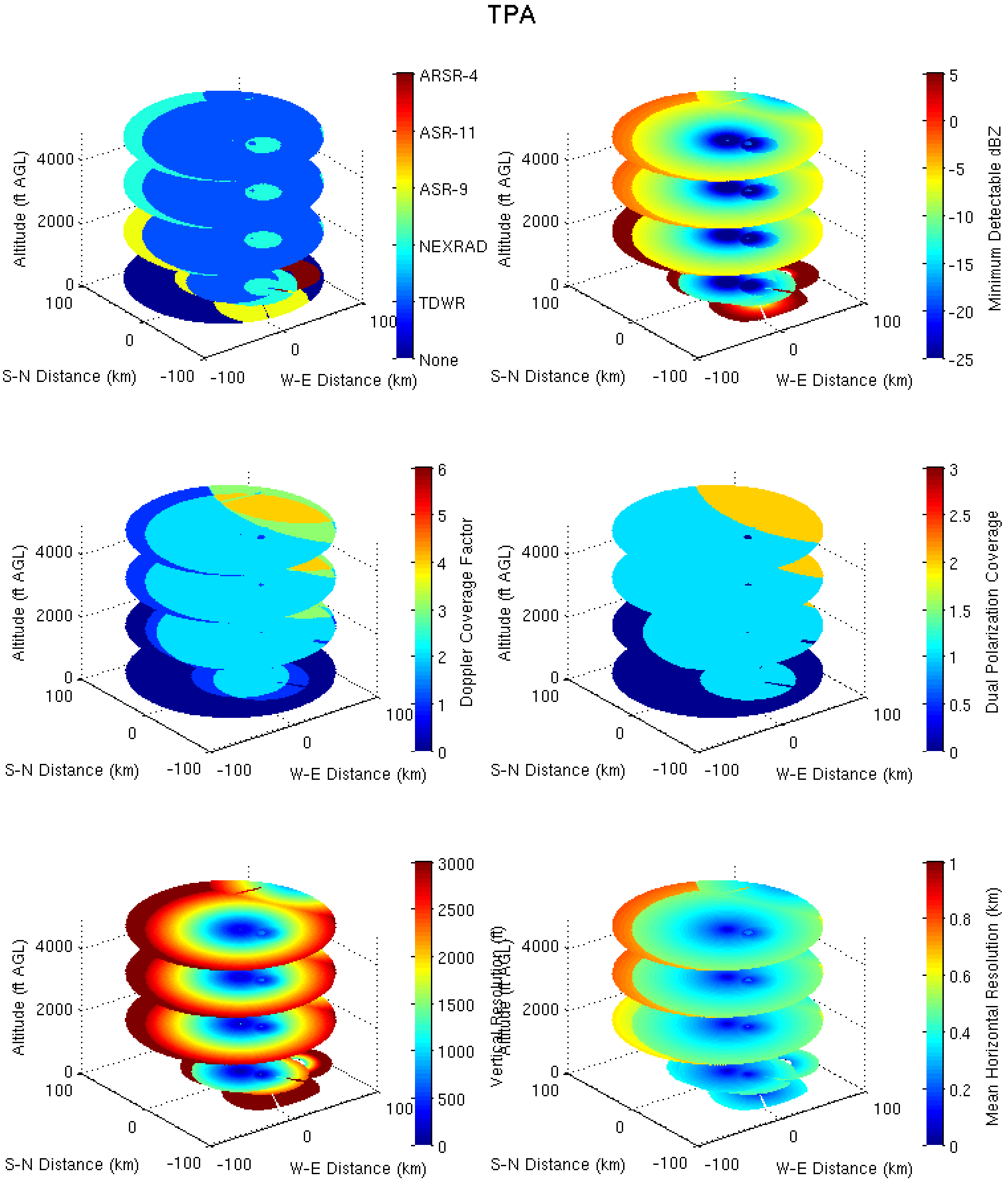


Figure A-35. Radar parameter coverage plots for the TPA terminal airspace.

Table A-1

OEP Airport Radar Parameter Volume Coverage Percentage

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
ATL	**Doppler**	**1+**	96.53	94.59	83.44	100.00	100.00	100.00	98.49	97.65	92.80
		2+	94.48	87.20	66.75	100.00	100.00	99.66	97.60	94.43	85.35
		3+	23.57	24.41	28.39	100.00	96.42	93.38	66.77	65.11	65.12
	Dual Pol.	**1+**	94.61	90.05	76.89	100.00	100.00	100.00	97.66	95.67	89.95
		2+	23.57	24.41	33.71	100.00	96.44	96.41	66.77	65.13	69.15
	Min. dBZ	**< -15**	96.86	58.06	15.96	100.00	57.16	15.76	98.64	57.55	15.85
		< -5	96.93	94.61	79.28	100.00	100.00	91.51	98.67	97.66	86.19
		< 18	96.93	95.05	85.65	100.00	100.00	100.00	98.67	97.85	93.76
		< 30	96.93	95.05	85.65	100.00	100.00	100.00	98.67	97.85	93.76
	H res. ≤ 0.5 km	**worst**	96.93	49.08	13.86	100.00	48.00	13.58	98.67	48.47	13.70
		mean	96.93	95.04	67.95	100.00	100.00	67.73	98.67	97.84	67.83
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	38.38	10.14	2.54	26.15	6.21	1.55	31.46	7.92	1.98
	Radar	**TDWR**	96.41	74.53	54.67	100.00	82.98	67.13	98.44	79.31	61.71
		NEXRAD	0.12	20.06	28.77	0.00	17.02	32.87	0.05	18.34	31.09
		ASR-9	0.40	0.47	1.54	0.00	0.00	0.00	0.17	0.20	0.67
		ASR-11	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.30
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	96.93	95.05	85.65	100.00	100.00	100.00	98.67	97.85	93.76
BOS	**Doppler**	**1+**	91.29	86.71	71.41	100.00	100.00	100.00	93.78	90.51	79.58
		2+	85.32	78.56	56.86	100.00	99.15	92.39	89.51	84.44	67.01
		3+	0.00	1.49	2.98	7.31	29.30	28.71	2.09	9.44	10.33
	Dual Pol.	**1+**	85.32	79.12	66.35	100.00	99.19	99.77	89.51	84.85	75.90
		2+	0.00	1.49	6.14	7.31	29.30	46.39	2.09	9.44	17.64
	Min. dBZ	**< -15**	91.43	37.99	13.11	99.12	41.12	14.11	93.63	38.89	13.40
		< -5	97.56	87.10	62.88	100.00	100.00	78.01	98.25	90.78	67.20
		< 18	97.56	90.57	80.09	100.00	100.00	100.00	98.25	93.27	85.78
		< 30	97.56	90.57	80.61	100.00	100.00	100.00	98.25	93.27	86.15
	H res. ≤ 0.5 km	**worst**	76.88	32.44	12.40	77.03	33.77	11.86	76.92	32.82	12.24
		mean	97.56	90.44	63.48	100.00	100.00	70.19	98.25	93.18	65.40
	V res.	**≤ 100 ft**	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
		≤ 500 ft	2.21	9.96	2.64	0.18	7.66	1.91	1.63	9.30	2.43
	Radar	**TDWR**	91.29	81.78	53.28	100.00	96.09	68.96	93.78	85.87	57.76
		NEXRAD	0.00	4.93	18.13	0.00	3.91	31.04	0.00	4.64	21.82
		ASR-9	6.25	3.84	5.24	0.00	0.00	0.00	4.47	2.74	3.75
		ASR-11	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.46
		ARSR-4	0.00	0.02	3.30	0.00	0.00	0.00	0.00	0.01	2.36
		Any	97.54	90.57	80.61	100.00	100.00	100.00	98.24	93.26	86.15

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
BWI	Doppler	1+	94.13	89.81	81.45	100.00	100.00	100.00	97.07	94.91	90.73
		2+	83.12	79.52	70.50	100.00	100.00	99.16	91.56	89.76	84.83
		3+	81.97	76.27	55.82	100.00	100.00	95.64	90.99	88.14	75.73
	Dual Pol.	1+	65.40	70.41	69.33	100.00	100.00	99.94	82.70	85.21	84.64
		2+	48.27	35.54	19.16	100.00	99.88	91.01	74.13	67.71	55.08
	Min. dBZ	< -15	94.62	51.15	30.52	99.20	54.74	33.08	96.91	52.94	31.80
		< -5	96.85	90.13	79.91	100.00	100.00	93.90	98.43	95.06	86.91
		< 18	96.85	90.83	85.32	100.00	100.00	100.00	98.43	95.41	92.66
		< 30	96.85	90.83	85.61	100.00	100.00	100.00	98.43	95.41	92.81
	H res. ≤ 0.5 km	worst	96.73	41.27	25.51	99.20	43.72	27.04	97.97	42.50	26.27
		mean	96.85	90.83	82.83	100.00	100.00	89.93	98.43	95.41	86.38
	V res.	≤ 100 ft	0.13	0.01	0.01	0.00	0.00	0.00	0.06	0.01	0.00
		≤ 500 ft	69.57	12.36	7.56	60.19	10.09	6.20	64.88	11.23	6.88
	Radar	TDWR	94.13	89.76	72.64	100.00	100.00	87.99	97.07	94.88	80.31
		NEXRAD	0.00	0.05	8.81	0.00	0.00	12.01	0.00	0.02	10.41
		ASR-9	2.72	1.02	3.86	0.00	0.00	0.00	1.36	0.51	1.93
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.14
		Any	96.85	90.83	85.61	100.00	100.00	100.00	98.43	95.41	92.80
CLE	Doppler	1+	97.92	91.66	78.80	100.00	100.00	100.00	98.61	94.44	85.87
		2+	88.99	87.25	64.83	88.77	99.53	95.53	88.92	91.34	75.06
		3+	0.00	4.21	15.32	34.94	63.78	62.53	11.65	24.07	31.06
	Dual Pol.	1+	92.01	90.42	75.03	88.77	99.56	99.89	90.93	93.46	83.32
		2+	0.00	4.21	14.06	34.94	63.80	72.54	11.65	24.07	33.56
	Min. dBZ	< -15	97.93	44.63	11.29	100.00	46.28	11.72	98.62	45.18	11.43
		< -5	97.94	91.67	74.21	100.00	100.00	92.40	98.63	94.45	80.28
		< 18	97.94	92.28	84.69	100.00	100.00	100.00	98.63	94.85	89.79
		< 30	97.94	92.28	84.69	100.00	100.00	100.00	98.63	94.85	89.79
	H res. ≤ 0.5 km	worst	97.94	37.00	10.70	100.00	37.57	9.39	98.63	37.19	10.26
		mean	97.94	92.28	71.13	100.00	100.00	78.37	98.63	94.85	73.54
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	54.57	9.79	2.45	13.57	7.25	1.81	40.91	8.94	2.24
	Radar	TDWR	23.77	79.22	63.62	53.83	92.16	81.86	33.79	83.53	69.70
		NEXRAD	74.15	12.44	15.18	46.17	7.84	18.14	64.82	10.91	16.17
		ASR-9	0.01	0.03	0.31	0.00	0.00	0.00	0.01	0.02	0.21
		ASR-11	0.00	0.58	5.58	0.00	0.00	0.00	0.00	0.38	3.72
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.93	92.27	84.68	100.00	100.00	100.00	98.62	94.84	89.79
CLT	Doppler	1+	94.47	89.80	79.60	100.00	100.00	100.00	97.09	94.63	89.27
		2+	34.63	38.23	32.69	100.00	99.09	94.67	65.59	67.06	62.05
		3+	28.40	17.19	8.59	100.00	92.95	67.56	62.32	53.08	36.53
	Dual Pol.	1+	34.63	38.23	44.04	100.00	99.09	97.21	65.59	67.06	69.23
		2+	28.40	17.19	13.32	100.00	93.02	78.97	62.32	53.11	44.42

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
CLT cont.	**Min. dBZ**	**< -15**	95.08	40.75	10.54	100.00	43.10	11.16	97.41	41.86	10.83
		< -5	97.45	89.96	77.29	100.00	99.94	94.72	98.66	94.69	85.55
		< 18	97.45	92.60	83.77	100.00	100.00	100.00	98.66	96.11	91.46
		< 30	97.45	92.60	83.77	100.00	100.00	100.00	98.66	96.11	91.46
	H res. ≤ 0.5 km	**worst**	97.45	30.93	8.13	100.00	32.45	8.56	98.66	31.65	8.33
		mean	97.45	92.59	69.50	100.00	99.94	74.06	98.66	96.07	71.66
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	41.39	8.35	2.09	32.51	6.78	1.70	37.19	7.61	1.90
	Radar	**TDWR**	94.47	89.79	62.97	100.00	99.94	78.64	97.09	94.60	70.39
		NEXRAD	0.00	0.01	16.63	0.00	0.06	21.36	0.00	0.03	18.87
		ASR-9	2.99	2.80	2.51	0.00	0.00	0.00	1.57	1.47	1.32
		ASR-11	0.00	0.00	1.65	0.00	0.00	0.00	0.00	0.00	0.87
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.45	92.60	83.77	100.00	100.00	100.00	98.66	96.10	91.46
CVG	**Doppler**	**1+**	94.89	90.29	84.24	100.00	100.00	100.00	97.31	94.89	91.71
		2+	66.66	63.27	65.05	100.00	100.00	99.60	82.45	80.67	81.41
		3+	5.28	25.58	31.00	97.97	93.71	91.62	49.18	57.85	59.71
	Dual Pol.	**1+**	66.66	63.28	67.08	100.00	100.00	99.73	82.45	80.68	82.54
		2+	5.28	17.07	18.38	97.97	92.28	89.49	49.18	52.69	52.07
	Min. dBZ	**< -15**	95.34	40.84	17.73	100.00	42.92	18.47	97.55	41.82	18.08
		< -5	97.89	90.50	82.73	100.00	100.00	97.56	98.89	95.00	89.75
		< 18	97.89	93.45	87.08	100.00	100.00	100.00	98.89	96.55	93.20
		< 30	97.89	93.45	87.08	100.00	100.00	100.00	98.89	96.55	93.20
	H res. ≤ 0.5 km	**worst**	97.89	31.36	14.78	100.00	32.46	15.25	98.89	31.88	15.00
		mean	97.89	93.43	81.66	100.00	99.94	88.53	98.89	96.51	84.91
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	23.71	8.36	2.49	15.86	6.78	1.69	19.99	7.61	2.11
	Radar	**TDWR**	94.89	90.20	72.10	100.00	99.94	86.55	97.31	94.81	78.94
		NEXRAD	0.00	0.10	12.15	0.00	0.06	13.45	0.00	0.08	12.76
		ASR-9	3.00	3.15	2.84	0.00	0.00	0.00	1.58	1.66	1.49
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.89	93.45	87.08	100.00	100.00	100.00	98.89	96.55	93.20
DCA	**Doppler**	**1+**	91.48	89.83	81.09	100.00	100.00	100.00	95.74	94.91	90.55
		2+	89.52	87.40	74.67	100.00	100.00	99.96	94.76	93.70	87.31
		3+	85.35	82.77	61.54	100.00	100.00	92.11	92.68	91.39	76.83
	Dual Pol.	**1+**	79.79	76.31	68.39	100.00	99.75	99.94	89.90	88.03	84.16
		2+	21.48	21.36	17.31	100.00	92.67	82.72	60.74	57.02	50.01
	Min. dBZ	**< -15**	92.32	74.52	29.14	100.00	81.94	32.54	96.16	78.23	30.84
		< -5	95.03	90.17	81.01	100.00	100.00	99.34	97.52	95.09	90.17
		< 18	95.05	90.51	83.26	100.00	100.00	100.00	97.53	95.25	91.63
		< 30	95.05	90.51	83.26	100.00	100.00	100.00	97.53	95.25	91.63
	H res. ≤ 0.5 km	**worst**	95.03	64.47	23.74	100.00	69.91	25.71	97.52	67.19	24.73
		mean	95.05	90.51	81.63	100.00	100.00	96.90	97.53	95.25	89.27

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
DCA cont.	V res.	≤ 100 ft	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.00
		≤ 500 ft	55.48	23.20	7.42	48.20	19.72	6.29	51.84	21.46	6.85
	Radar	TDWR	91.48	85.51	78.16	100.00	98.20	98.27	95.74	91.86	88.22
		NEXRAD	0.00	4.32	2.93	0.00	1.80	1.73	0.00	3.06	2.33
		ASR-9	3.56	0.67	2.15	0.00	0.00	0.00	1.78	0.34	1.08
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	95.03	90.50	83.25	100.00	100.00	100.00	97.52	95.25	91.62
DEN	Doppler	1+	94.02	87.84	63.67	100.00	100.00	94.82	95.73	91.31	72.57
		2+	91.22	84.51	57.55	99.82	99.54	91.54	93.68	88.81	67.26
		3+	0.01	7.20	12.49	58.66	71.30	61.49	16.77	25.52	26.49
	Dual Pol.	1+	94.02	87.57	63.37	99.82	99.57	94.67	95.67	91.00	72.31
		2+	0.01	7.20	18.58	58.66	71.31	75.82	16.77	25.52	34.94
	Min. dBZ	< -15	94.26	38.00	9.65	100.00	41.65	10.56	95.90	39.04	9.91
		< -5	95.05	88.77	61.63	100.00	100.00	87.29	96.47	91.98	68.96
		< 18	98.51	93.61	71.31	100.00	100.00	95.47	98.93	95.44	78.22
		< 30	98.51	93.61	71.31	100.00	100.00	95.47	98.93	95.44	78.22
	H res. ≤ 0.5 km	worst	93.03	31.38	8.08	97.75	32.50	8.12	94.38	31.70	8.09
		mean	96.74	91.25	50.13	100.00	100.00	61.44	97.67	93.75	53.36
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	8.36	6.10	1.52	3.96	5.23	1.31	7.11	5.85	1.46
	Radar	TDWR	91.23	84.78	51.76	100.00	99.96	76.98	93.73	89.12	58.96
		NEXRAD	2.80	3.05	11.91	0.00	0.04	17.84	2.00	2.19	13.61
		ASR-9	4.44	5.76	7.40	0.00	0.00	0.32	3.17	4.11	5.38
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	98.46	93.60	71.07	100.00	100.00	95.14	98.90	95.43	77.95
DFW	Doppler	1+	97.97	94.53	81.04	100.00	100.00	100.00	99.03	97.39	90.97
		2+	97.23	91.98	66.86	100.00	100.00	98.52	98.68	96.18	83.44
		3+	88.23	81.29	47.17	98.20	99.32	87.65	93.45	90.73	68.38
	Dual Pol.	1+	88.48	83.03	65.57	100.00	99.47	99.87	94.51	91.64	83.53
		2+	0.00	0.00	1.36	11.51	23.42	47.85	6.03	12.27	25.71
	Min. dBZ	< -15	97.97	65.03	19.71	100.00	65.62	20.18	99.03	65.34	19.95
		< -5	98.00	94.75	79.20	100.00	100.00	95.99	99.05	97.50	88.00
		< 18	98.00	95.28	85.90	100.00	100.00	100.00	99.05	97.75	93.29
		< 30	98.00	95.28	85.90	100.00	100.00	100.00	99.05	97.75	93.29
	H res. ≤ 0.5 km	worst	98.00	55.49	17.10	100.00	55.50	17.30	99.05	55.49	17.20
		mean	98.00	95.28	76.12	100.00	100.00	78.93	99.05	97.75	77.59
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	87.60	16.02	4.03	74.49	11.41	2.85	80.73	13.61	3.41
	Radar	TDWR	97.97	81.60	60.43	100.00	88.21	72.87	99.03	85.06	66.95
		NEXRAD	0.00	12.93	20.60	0.00	11.79	27.13	0.00	12.34	24.02
		ASR-9	0.03	0.76	4.04	0.00	0.00	0.00	0.01	0.36	1.92
		ASR-11	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.39
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	98.00	95.28	85.90	100.00	100.00	100.00	99.05	97.75	93.29

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
DTW	**Doppler**	**1+**	94.23	89.67	79.31	100.00	100.00	100.00	96.15	93.11	86.20
		2+	75.07	70.29	52.69	100.00	99.99	94.84	83.38	80.19	66.74
		3+	4.91	12.48	16.42	95.37	84.65	74.72	35.07	36.54	35.85
	Dual Pol.	**1+**	75.07	70.46	62.99	100.00	100.00	99.92	83.38	80.31	75.30
		2+	4.91	12.48	17.30	95.37	84.68	86.73	35.07	36.55	40.44
	Min. dBZ	**< -15**	94.54	48.57	16.61	100.00	52.59	18.19	96.36	49.91	17.13
		< -5	96.00	89.82	77.55	100.00	100.00	96.02	97.33	93.22	83.71
		< 18	96.00	91.87	85.05	100.00	100.00	100.00	97.33	94.58	90.03
		< 30	96.00	91.87	85.05	100.00	100.00	100.00	97.33	94.58	90.03
	H res. ≤ 0.5 km	**worst**	96.00	39.00	15.38	100.00	41.72	15.63	97.33	39.91	15.46
		mean	96.00	91.86	76.25	100.00	99.96	83.92	97.33	94.56	78.81
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	26.29	8.58	2.49	20.79	7.37	1.84	24.46	8.17	2.27
	Radar	**TDWR**	94.23	80.53	57.51	100.00	89.47	71.56	96.15	83.51	62.19
		NEXRAD	0.00	9.13	21.80	0.00	10.53	28.44	0.00	9.60	24.01
		ASR-9	1.77	2.20	4.03	0.00	0.00	0.00	1.18	1.47	2.68
		ASR-11	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00	1.15
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	96.00	91.87	85.05	100.00	100.00	100.00	97.33	94.58	90.03
EWR	**Doppler**	**1+**	95.33	89.66	76.78	100.00	100.00	99.70	96.67	92.61	83.33
		2+	92.60	84.17	67.32	100.00	100.00	96.16	94.72	88.69	75.56
		3+	66.35	67.07	50.55	100.00	100.00	86.97	75.96	76.48	60.95
	Dual Pol.	**1+**	66.35	67.23	65.68	100.00	100.00	99.70	75.96	76.59	75.40
		2+	38.47	35.18	20.08	100.00	98.43	82.44	56.05	53.25	37.90
	Min. dBZ	**< -15**	95.65	59.87	25.65	100.00	64.16	27.21	96.89	61.09	26.10
		< -5	96.95	89.80	75.63	100.00	100.00	91.60	97.82	92.72	80.20
		< 18	96.95	90.28	83.88	100.00	100.00	100.00	97.82	93.06	88.49
		< 30	96.95	90.28	83.88	100.00	100.00	100.00	97.82	93.06	88.49
	H res. ≤ 0.5 km	**worst**	96.95	49.91	23.20	100.00	52.73	22.71	97.82	50.72	23.06
		mean	96.95	90.27	79.24	100.00	100.00	87.90	97.82	93.05	81.71
	V res.	**≤ 100 ft**	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.03	0.01
		≤ 500 ft	47.68	17.39	4.95	41.87	15.33	3.86	46.02	16.80	4.64
	Radar	**TDWR**	95.33	89.66	63.19	100.00	100.00	79.57	96.67	92.61	67.87
		NEXRAD	0.00	0.00	13.59	0.00	0.00	20.13	0.00	0.00	15.46
		ASR-9	1.61	0.61	4.63	0.00	0.00	0.28	1.15	0.44	3.39
		ASR-11	0.00	0.00	2.46	0.00	0.00	0.02	0.00	0.00	1.76
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	96.94	90.27	83.88	100.00	100.00	100.00	97.81	93.05	88.48
FLL	**Doppler**	**1+**	93.59	89.45	78.98	N/A	N/A	N/A	93.59	89.45	78.98
		2+	84.14	83.66	65.02	N/A	N/A	N/A	84.14	83.66	65.02
		3+	80.33	75.43	43.87	N/A	N/A	N/A	80.33	75.43	43.87
	Dual Pol.	**1+**	80.20	74.38	56.88	N/A	N/A	N/A	80.20	74.38	56.88
		2+	0.00	0.00	0.24	N/A	N/A	N/A	0.00	0.00	0.24

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
FLL cont.	**Min. dBZ**	**< -15**	94.20	53.47	28.99	N/A	N/A	N/A	94.20	53.47	28.99
		< -5	97.44	89.95	76.21	N/A	N/A	N/A	97.44	89.95	76.21
		< 18	97.44	93.42	85.41	N/A	N/A	N/A	97.44	93.42	85.41
		< 30	97.44	93.42	85.41	N/A	N/A	N/A	97.44	93.42	85.41
	H res. ≤ 0.5 km	**worst**	91.20	45.16	23.83	N/A	N/A	N/A	91.20	45.16	23.83
		mean	97.44	93.39	77.18	N/A	N/A	N/A	97.44	93.39	77.18
	V res.	**≤ 100 ft**	0.00	0.04	0.02	N/A	N/A	N/A	0.00	0.04	0.02
		≤ 500 ft	13.10	13.45	7.07	N/A	N/A	N/A	13.10	13.45	7.07
	Radar	**TDWR**	93.59	88.89	71.40	N/A	N/A	N/A	93.59	88.89	71.40
		NEXRAD	0.00	0.56	7.58	N/A	N/A	N/A	0.00	0.56	7.58
		ASR-9	3.85	3.65	4.26	N/A	N/A	N/A	3.85	3.65	4.26
		ASR-11	0.00	0.33	2.09	N/A	N/A	N/A	0.00	0.33	2.09
		ARSR-4	0.00	0.00	0.08	N/A	N/A	N/A	0.00	0.00	0.08
		Any	97.44	93.42	85.41	N/A	N/A	N/A	97.44	93.42	85.41
HNL	**Doppler**	**1+**	45.46	41.45	38.92	100.00	100.00	98.69	69.70	67.47	65.48
		2+	0.00	1.38	0.51	53.22	49.18	35.05	23.66	22.63	15.86
		3+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dual Pol.	**1+**	45.46	41.45	38.92	100.00	100.00	98.69	69.70	67.47	65.48
		2+	0.00	1.38	0.51	53.22	49.18	35.05	23.66	22.63	15.86
	Min. dBZ	**< -15**	4.97	0.20	4.92	0.00	0.00	6.88	2.76	0.11	5.79
		< -5	91.40	32.52	25.76	98.96	55.50	43.41	94.76	42.73	33.61
		< 18	91.81	72.81	62.90	100.00	100.00	99.68	95.45	84.90	79.25
		< 30	91.81	72.81	62.90	100.00	100.00	99.85	95.45	84.90	79.32
	H res. ≤ 0.5 km	**worst**	46.35	6.95	6.75	0.00	0.00	7.08	25.75	3.86	6.89
		mean	46.35	39.63	23.20	0.00	10.96	17.58	25.75	26.89	20.71
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	0.26	0.01	0.35	0.00	0.00	0.00	0.14	0.01	0.20
	Radar	**TDWR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NEXRAD	45.46	41.45	38.92	100.00	100.00	98.69	69.70	67.47	65.48
		ASR-9	46.31	31.33	21.50	0.00	0.00	0.40	25.73	17.40	12.13
		ASR-11	0.00	0.00	2.41	0.00	0.00	0.03	0.00	0.00	1.36
		ARSR-4	0.00	0.01	0.06	0.00	0.00	0.72	0.00	0.00	0.35
		Any	91.77	72.78	62.89	100.00	100.00	99.85	95.43	84.88	79.32
IAD	**Doppler**	**1+**	97.60	91.52	77.66	100.00	100.00	99.92	98.80	95.76	88.79
		2+	94.26	88.78	69.59	100.00	100.00	97.44	97.13	94.39	83.51
		3+	89.15	79.58	52.09	100.00	95.88	75.90	94.57	87.73	64.00
	Dual Pol.	**1+**	91.81	88.04	68.01	94.97	99.80	99.87	93.39	93.92	83.94
		2+	0.00	5.47	13.90	48.07	69.47	70.84	24.04	37.47	42.37
	Min. dBZ	**< -15**	97.62	60.13	30.51	100.00	63.93	31.85	98.81	62.03	31.18
		< -5	97.71	91.67	75.91	100.00	100.00	94.83	98.86	95.84	85.37
		< 18	97.71	92.73	84.88	100.00	100.00	100.00	98.86	96.36	92.44
		< 30	97.71	92.73	84.88	100.00	100.00	100.00	98.86	96.36	92.44
	H res. ≤ 0.5 km	**worst**	97.71	47.12	25.93	100.00	49.26	25.62	98.86	48.19	25.77
		mean	97.71	92.73	78.14	100.00	100.00	88.37	98.86	96.36	83.25

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
IAD cont.	**V res.**	**≤ 100 ft**	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	52.41	14.28	7.83	22.30	10.94	6.15	37.36	12.61	6.99
	Radar	**TDWR**	23.13	86.04	72.02	65.17	98.32	93.12	44.15	92.18	82.57
		NEXRAD	74.47	5.48	5.64	34.84	1.68	6.81	54.65	3.58	6.22
		ASR-9	0.10	1.18	7.19	0.00	0.00	0.08	0.05	0.59	3.63
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.70	92.70	84.84	100.00	100.00	100.00	98.85	96.35	92.42
IAH	**Doppler**	**1+**	93.54	92.24	82.67	100.00	100.00	100.00	96.77	96.12	91.33
		2+	87.71	81.98	63.81	100.00	100.00	99.17	93.86	90.99	81.49
		3+	83.87	70.73	34.93	100.00	95.47	83.00	91.93	83.10	58.96
	Dual Pol.	**1+**	83.87	79.23	65.17	100.00	100.00	99.86	91.93	89.61	82.51
		2+	0.00	0.03	5.72	31.48	50.36	64.44	15.74	25.19	35.08
	Min. dBZ	**< -15**	93.35	53.79	21.30	98.87	56.25	21.87	96.11	55.02	21.59
		< -5	95.62	92.36	79.29	100.00	100.00	91.87	97.81	96.18	85.58
		< 18	95.69	93.15	85.14	100.00	100.00	100.00	97.85	96.58	92.57
		< 30	95.69	93.15	85.67	100.00	100.00	100.00	97.85	96.58	92.83
	H res. ≤ 0.5 km	**worst**	75.15	42.51	16.59	77.75	44.27	16.88	76.45	43.39	16.74
		mean	95.69	93.12	79.25	100.00	100.00	85.86	97.85	96.56	82.55
	V res.	**≤ 100 ft**	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
		≤ 500 ft	2.68	11.81	4.73	0.14	9.31	3.46	1.41	10.56	4.10
	Radar	**TDWR**	93.54	92.10	75.70	100.00	100.00	89.39	96.77	96.05	82.55
		NEXRAD	0.00	0.13	6.97	0.00	0.00	10.61	0.00	0.07	8.79
		ASR-9	2.15	0.92	0.37	0.00	0.00	0.00	1.07	0.46	0.19
		ASR-11	0.00	0.00	2.03	0.00	0.00	0.00	0.00	0.00	1.02
		ARSR-4	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.30
		Any	95.69	93.15	85.67	100.00	100.00	100.00	97.85	96.58	92.83
JFK	**Doppler**	**1+**	96.39	92.01	83.10	100.00	100.00	99.94	97.42	94.30	87.92
		2+	81.56	85.73	65.20	100.00	100.00	94.22	86.83	89.81	73.49
		3+	69.25	69.27	46.25	100.00	100.00	82.28	78.03	78.05	56.54
	Dual Pol.	**1+**	69.34	74.09	73.19	100.00	100.00	99.93	78.10	81.49	80.83
		2+	60.36	45.74	23.00	100.00	100.00	88.39	71.69	61.24	41.68
	Min. dBZ	**< -15**	96.68	49.14	27.04	99.76	51.82	28.52	97.56	49.91	27.46
		< -5	97.51	92.23	81.40	100.00	100.00	95.66	98.22	94.45	85.47
		< 18	97.51	93.39	85.67	100.00	100.00	100.00	98.22	95.28	89.77
		< 30	97.51	93.39	85.67	100.00	100.00	100.00	98.22	95.28	89.77
	H res. ≤ 0.5 km	**worst**	97.48	40.98	24.77	99.76	42.52	25.08	98.13	41.42	24.86
		mean	97.51	93.39	78.69	100.00	100.00	87.10	98.22	95.28	81.09
	V res.	**≤ 100 ft**	0.27	0.04	0.01	0.00	0.00	0.00	0.19	0.03	0.01
		≤ 500 ft	70.41	15.70	5.37	64.36	14.02	3.83	68.68	15.22	4.93
	Radar	**TDWR**	96.39	91.30	57.39	100.00	99.45	70.23	97.42	93.63	61.06
		NEXRAD	0.00	0.72	25.71	0.00	0.55	29.71	0.00	0.67	26.85
		ASR-9	1.11	1.38	2.34	0.00	0.00	0.00	0.80	0.98	1.67
		ASR-11	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.13
		ARSR-4	0.00	0.00	0.04	0.00	0.00	0.06	0.00	0.00	0.04
		Any	97.51	93.39	85.67	100.00	100.00	100.00	98.22	95.28	89.77

Airport	**Parameter**	**Height**	**< 5000 ft AGL**			**≥ 5000 ft AGL**			**All Heights**		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
LAS	**Doppler**	**1+**	98.40	52.91	25.68	100.00	98.21	80.11	98.86	65.85	41.23
		2+	35.11	23.71	7.98	100.00	85.52	37.49	53.65	41.37	16.41
		3+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dual Pol.	**1+**	35.11	28.77	17.62	100.00	97.08	77.57	53.65	48.29	34.75
		2+	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.03
	Min. dBZ	**< -15**	98.66	31.77	9.67	100.00	46.72	15.74	99.05	36.04	11.41
		< -5	98.70	54.41	25.45	100.00	98.00	63.78	99.07	66.86	36.40
		< 18	98.81	64.97	35.93	100.00	98.69	85.18	99.15	74.60	50.00
		< 30	98.81	64.97	35.93	100.00	98.69	85.18	99.15	74.60	50.00
	H res. ≤ 0.5 km	**worst**	98.71	29.16	9.08	100.00	38.73	13.90	99.08	31.90	10.46
		mean	98.81	59.55	22.96	100.00	87.06	42.57	99.15	67.41	28.56
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	39.18	6.75	1.69	31.10	6.69	1.67	36.87	6.73	1.68
	Radar	**TDWR**	98.40	44.03	13.66	100.00	76.52	29.75	98.86	53.31	18.26
		NEXRAD	0.00	8.89	12.03	0.00	21.69	50.36	0.00	12.55	22.98
		ASR-9	0.04	11.31	10.03	0.00	0.26	4.95	0.03	8.15	8.58
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	98.45	64.22	35.71	100.00	98.47	85.06	98.89	74.01	49.81
LAX	**Doppler**	**1+**	19.71	24.67	21.74	100.00	99.95	93.96	59.85	62.31	57.85
		2+	13.96	4.72	4.00	100.00	94.58	74.40	56.98	49.65	39.20
		3+	0.00	0.00	0.00	43.28	48.29	36.75	21.64	24.15	18.38
	Dual Pol.	**1+**	19.71	24.67	21.74	100.00	99.95	93.96	59.85	62.31	57.85
		2+	13.96	4.72	4.00	100.00	94.58	74.40	56.98	49.65	39.20
	Min. dBZ	**< -15**	7.79	1.14	4.56	0.00	1.22	12.39	3.89	1.18	8.47
		< -5	89.27	36.32	23.76	100.00	94.70	75.62	94.63	65.51	49.69
		< 18	97.59	83.89	64.90	100.00	99.99	97.70	98.79	91.94	81.30
		< 30	97.59	84.88	65.96	100.00	99.99	97.77	98.79	92.43	81.86
	H res. ≤ 0.5 km	**worst**	69.56	25.73	15.12	0.00	1.40	12.76	34.78	13.56	13.94
		mean	77.88	66.28	44.36	0.00	21.21	31.17	38.94	43.75	37.77
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	0.48	0.04	0.31	0.00	0.00	0.00	0.24	0.02	0.15
	Radar	**TDWR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NEXRAD	19.71	24.67	21.74	100.00	99.95	93.96	59.85	62.31	57.85
		ASR-9	77.87	55.06	25.98	0.00	0.02	1.34	38.94	27.54	13.66
		ASR-11	0.00	2.63	11.26	0.00	0.00	1.27	0.00	1.31	6.26
		ARSR-4	0.00	2.28	6.78	0.00	0.00	1.05	0.00	1.14	3.91
		Any	97.58	84.64	65.76	100.00	99.97	97.62	98.79	92.30	81.69
LGA	**Doppler**	**1+**	94.53	90.20	78.99	100.00	100.00	99.82	96.10	93.00	84.94
		2+	90.10	84.41	61.98	100.00	100.00	92.21	92.93	88.87	70.62
		3+	62.72	66.55	44.23	100.00	100.00	80.15	73.37	76.11	54.49
	Dual Pol.	**1+**	62.72	69.67	68.59	100.00	100.00	99.81	73.37	78.33	77.51
		2+	52.80	40.23	21.02	100.00	100.00	84.12	66.28	57.31	39.05

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
LGA cont.	Min. dBZ	< -15	94.53	49.50	25.04	100.00	52.46	26.51	96.10	50.35	25.46
		< -5	94.54	90.60	76.88	100.00	100.00	91.53	96.10	93.28	81.06
		< 18	95.04	91.98	84.45	100.00	100.00	100.00	96.45	94.27	88.89
		< 30	95.04	91.98	84.45	100.00	100.00	100.00	96.45	94.27	88.89
	H res. ≤ 0.5 km	worst	87.43	42.93	23.56	92.05	44.39	23.04	88.75	43.34	23.41
		mean	95.04	91.98	77.65	100.00	100.00	85.20	96.45	94.27	79.81
	V res.	≤ 100 ft	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.03	0.01
		≤ 500 ft	11.50	16.52	5.04	7.11	14.78	3.84	10.24	16.02	4.70
	Radar	TDWR	94.53	90.05	57.48	100.00	100.00	71.48	96.10	92.89	61.48
		NEXRAD	0.00	0.15	21.51	0.00	0.00	28.34	0.00	0.11	23.46
		ASR-9	0.50	1.78	4.80	0.00	0.00	0.12	0.36	1.27	3.46
		ASR-11	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.44
		ARSR-4	0.00	0.00	0.04	0.00	0.00	0.06	0.00	0.00	0.05
		Any	95.04	91.98	84.45	100.00	100.00	100.00	96.45	94.27	88.89
MCO	Doppler	1+	97.15	92.52	80.40	100.00	100.00	100.00	98.57	96.26	90.20
		2+	78.06	73.80	58.78	100.00	100.00	94.72	89.03	86.90	76.75
		3+	28.54	26.07	23.02	99.04	95.89	78.79	63.79	60.98	50.91
	Dual Pol.	1+	78.13	74.18	69.46	100.00	100.00	99.94	89.07	87.09	84.70
		2+	28.66	26.04	18.70	100.00	95.96	85.53	64.33	61.00	52.12
	Min. dBZ	< -15	96.96	42.12	17.80	99.04	43.71	18.05	98.00	42.91	17.92
		< -5	97.89	92.30	76.54	100.00	99.99	88.51	98.95	96.15	82.53
		< 18	97.93	93.88	87.29	100.00	100.00	100.00	98.97	96.94	93.64
		< 30	97.93	93.92	87.77	100.00	100.00	100.00	98.97	96.96	93.89
	H res. ≤ 0.5 km	worst	97.75	31.97	15.58	99.04	33.04	15.57	98.39	32.51	15.58
		mean	97.75	93.60	76.68	99.04	99.93	78.63	98.39	96.76	77.66
	V res.	≤ 100 ft	0.24	0.02	0.00	0.00	0.00	0.00	0.12	0.01	0.00
		≤ 500 ft	74.46	8.77	2.73	62.80	6.92	1.73	68.63	7.84	2.23
	Radar	TDWR	96.96	91.25	60.70	99.04	99.30	72.98	98.00	95.27	66.84
		NEXRAD	0.19	1.27	19.70	0.96	0.70	27.02	0.58	0.99	23.36
		ASR-9	0.79	1.06	5.03	0.00	0.00	0.00	0.39	0.53	2.52
		ASR-11	0.00	0.10	0.75	0.00	0.00	0.00	0.00	0.05	0.38
		ARSR-4	0.00	0.25	1.59	0.00	0.00	0.00	0.00	0.13	0.80
		Any	97.93	93.92	87.77	100.00	100.00	100.00	98.97	96.96	93.89
MDW	Doppler	1+	93.19	87.81	70.21	N/A	N/A	N/A	93.19	87.81	70.21
		2+	91.11	82.80	58.93	N/A	N/A	N/A	91.11	82.80	58.93
		3+	85.06	74.36	44.92	N/A	N/A	N/A	85.06	74.36	44.92
	Dual Pol.	1+	85.34	76.65	56.63	N/A	N/A	N/A	85.34	76.65	56.63
		2+	0.00	1.05	5.67	N/A	N/A	N/A	0.00	1.05	5.67
	Min. dBZ	< -15	93.19	58.71	17.45	N/A	N/A	N/A	93.19	58.71	17.45
		< -5	93.19	88.06	70.06	N/A	N/A	N/A	93.19	88.06	70.06
		< 18	93.19	89.10	76.73	N/A	N/A	N/A	93.19	89.10	76.73
		< 30	93.19	89.10	76.73	N/A	N/A	N/A	93.19	89.10	76.73
	H res. ≤ 0.5 km	worst	93.19	49.43	14.62	N/A	N/A	N/A	93.19	49.43	14.62
		mean	93.19	89.10	72.58	N/A	N/A	N/A	93.19	89.10	72.58

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
MDW cont.	**V res.**	**≤ 100 ft**	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		≤ 500 ft	85.14	17.56	4.39	N/A	N/A	N/A	85.14	17.56	4.39
	Radar	**TDWR**	93.19	78.24	61.68	N/A	N/A	N/A	93.19	78.24	61.68
		NEXRAD	0.00	9.56	8.53	N/A	N/A	N/A	0.00	9.56	8.53
		ASR-9	0.00	1.30	1.99	N/A	N/A	N/A	0.00	1.30	1.99
		ASR-11	0.00	0.00	4.53	N/A	N/A	N/A	0.00	0.00	4.53
		ARSR-4	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		Any	93.19	89.10	76.73	N/A	N/A	N/A	93.19	89.10	76.73
MEM	**Doppler**	**1+**	94.15	92.55	81.92	100.00	100.00	100.00	97.07	96.28	90.96
		2+	91.64	83.78	55.49	100.00	98.83	95.50	95.82	91.31	75.50
		3+	0.00	0.13	5.71	38.82	55.90	60.86	19.41	28.01	33.29
	Dual Pol.	**1+**	91.75	86.88	72.69	100.00	98.85	99.71	95.88	92.86	86.20
		2+	0.00	0.13	7.39	38.82	55.93	75.81	19.41	28.03	41.60
	Min. dBZ	**< -15**	94.45	59.45	16.49	100.00	61.08	16.99	97.23	60.27	16.74
		< -5	95.99	92.68	79.14	100.00	100.00	94.97	97.99	96.34	87.05
		< 18	96.00	93.38	82.59	100.00	100.00	100.00	98.00	96.69	91.30
		< 30	96.00	93.38	82.59	100.00	100.00	100.00	98.00	96.69	91.30
	H res. ≤ 0.5 km	**worst**	95.99	49.84	14.20	100.00	50.64	14.50	97.99	50.24	14.35
		mean	96.00	93.38	68.09	100.00	99.95	72.98	98.00	96.66	70.54
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	32.91	10.43	2.61	24.32	6.87	1.72	28.61	8.65	2.16
	Radar	**TDWR**	94.04	71.04	53.09	100.00	79.94	66.35	97.02	75.49	59.72
		NEXRAD	0.11	21.52	28.83	0.00	20.06	33.66	0.05	20.79	31.24
		ASR-9	1.85	0.82	0.67	0.00	0.00	0.00	0.92	0.41	0.34
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	96.00	93.38	82.59	100.00	100.00	100.00	98.00	96.69	91.30
MIA	**Doppler**	**1+**	95.12	93.40	84.24	100.00	100.00	100.00	96.52	95.29	88.74
		2+	94.55	89.89	72.19	100.00	100.00	89.23	96.11	92.78	77.06
		3+	90.47	82.78	52.18	100.00	99.57	80.23	93.19	87.58	60.20
	Dual Pol.	**1+**	94.77	89.81	75.54	100.00	99.60	99.90	96.26	92.61	82.50
		2+	0.00	0.54	6.39	0.00	19.46	32.22	0.00	5.95	13.77
	Min. dBZ	**< -15**	95.57	61.68	24.18	100.00	63.97	25.28	96.84	62.34	24.49
		< -5	97.66	93.80	80.62	100.00	100.00	93.47	98.33	95.57	84.29
		< 18	97.66	95.22	87.01	100.00	100.00	100.00	98.33	96.58	90.72
		< 30	97.66	95.22	87.01	100.00	100.00	100.00	98.33	96.58	90.72
	H res. ≤ 0.5 km	**worst**	91.84	54.99	20.03	93.82	55.80	20.52	92.41	55.22	20.17
		mean	97.66	95.16	76.76	100.00	100.00	84.68	98.33	96.54	79.02
	V res.	**≤ 100 ft**	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.03	0.01
		≤ 500 ft	13.22	18.18	5.89	8.57	14.79	4.83	11.89	17.21	5.59
	Radar	**TDWR**	94.90	82.81	72.46	100.00	92.05	85.89	96.35	85.45	76.29
		NEXRAD	0.23	10.59	11.78	0.00	7.96	14.12	0.16	9.84	12.45
		ASR-9	2.53	1.76	2.25	0.00	0.00	0.00	1.81	1.26	1.61
		ASR-11	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.21
		ARSR-4	0.00	0.05	0.22	0.00	0.00	0.00	0.00	0.04	0.16
		Any	97.66	95.22	87.01	100.00	100.00	100.00	98.33	96.58	90.72

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
MSP	Doppler	1+	91.17	89.76	79.22	100.00	100.00	100.00	95.36	94.61	89.06
		2+	89.52	81.36	50.86	100.00	98.60	80.78	94.48	89.53	65.04
		3+	0.00	0.00	3.46	21.79	30.99	41.92	10.32	14.68	21.68
	Dual Pol.	1+	90.15	85.29	71.04	100.00	98.62	99.65	94.82	91.60	84.59
		2+	0.00	0.00	3.66	21.79	31.03	47.49	10.32	14.70	24.42
	Min. dBZ	< -15	92.06	59.03	15.88	100.00	62.86	16.94	95.82	60.85	16.38
		< -5	95.95	90.07	76.68	100.00	100.00	95.22	97.87	94.78	85.46
		< 18	95.95	91.45	81.16	100.00	100.00	100.00	97.87	95.50	90.09
		< 30	95.95	91.45	81.16	100.00	100.00	100.00	97.87	95.50	90.09
	H res. ≤ 0.5 km	worst	81.75	52.45	13.78	83.61	54.96	14.47	82.64	53.64	14.11
		mean	95.95	91.45	64.10	100.00	99.95	70.78	97.87	95.48	67.26
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	4.57	9.65	2.41	0.78	6.77	1.69	2.77	8.29	2.07
	Radar	TDWR	90.11	63.24	49.22	100.00	73.52	63.14	94.79	68.11	55.81
		NEXRAD	1.07	26.52	30.00	0.00	26.48	36.86	0.56	26.50	33.25
		ASR-9	4.77	1.69	0.98	0.00	0.00	0.00	2.51	0.89	0.51
		ASR-11	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.51
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	95.95	91.45	81.16	100.00	100.00	100.00	97.87	95.50	90.09
ORD	Doppler	1+	96.35	92.34	85.13	100.00	100.00	100.00	98.08	95.97	92.17
		2+	91.75	89.06	77.07	100.00	100.00	100.00	95.66	94.24	87.93
		3+	90.30	83.89	64.46	100.00	99.95	99.96	94.89	91.50	81.28
	Dual Pol.	1+	90.37	85.22	76.31	100.00	99.95	99.99	94.93	92.20	87.52
		2+	35.16	31.63	29.88	100.00	98.12	97.56	65.87	63.13	61.94
	Min. dBZ	< -15	96.66	44.09	22.77	100.00	45.05	23.56	98.24	44.55	23.14
		< -5	98.00	92.48	83.24	100.00	100.00	95.78	98.95	96.04	89.18
		< 18	98.00	94.57	89.25	100.00	100.00	100.00	98.95	97.14	94.34
		< 30	98.00	94.57	89.25	100.00	100.00	100.00	98.95	97.14	94.34
	H res. ≤ 0.5 km	worst	92.18	38.23	19.53	93.82	38.25	19.39	92.96	38.24	19.47
		mean	98.00	94.56	82.71	100.00	100.00	87.16	98.95	97.14	84.82
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	12.43	16.07	5.76	5.61	12.18	4.42	9.20	14.23	5.12
	Radar	TDWR	96.35	86.49	74.65	100.00	96.07	88.39	98.08	91.03	81.16
		NEXRAD	0.00	5.84	10.48	0.00	3.93	11.61	0.00	4.94	11.01
		ASR-9	1.65	2.22	1.41	0.00	0.00	0.00	0.87	1.17	0.74
		ASR-11	0.00	0.00	2.71	0.00	0.00	0.00	0.00	0.00	1.43
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	98.00	94.55	89.25	100.00	100.00	100.00	98.95	97.13	94.34
PDX	Doppler	1+	51.90	44.13	21.68	N/A	N/A	N/A	51.90	44.13	21.68
		2+	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		3+	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
	Dual Pol.	1+	51.90	44.13	21.68	N/A	N/A	N/A	51.90	44.13	21.68
		2+	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
PDX cont.	**Min. dBZ**	**< -15**	18.29	14.53	4.14	N/A	N/A	N/A	18.29	14.53	4.14
		< -5	90.46	46.65	21.65	N/A	N/A	N/A	90.46	46.65	21.65
		< 18	90.46	59.27	29.10	N/A	N/A	N/A	90.46	59.27	29.10
		< 30	90.46	59.27	29.10	N/A	N/A	N/A	90.46	59.27	29.10
	H res. ≤ 0.5 km	**worst**	52.59	20.06	5.56	N/A	N/A	N/A	52.59	20.06	5.56
		mean	90.46	48.56	16.42	N/A	N/A	N/A	90.46	48.56	16.42
	V res.	**≤ 100 ft**	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		≤ 500 ft	0.33	1.33	0.33	N/A	N/A	N/A	0.33	1.33	0.33
	Radar	**TDWR**	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		NEXRAD	51.90	44.13	21.68	N/A	N/A	N/A	51.90	44.13	21.68
		ASR-9	38.47	14.93	5.27	N/A	N/A	N/A	38.47	14.93	5.27
		ASR-11	0.00	0.00	2.04	N/A	N/A	N/A	0.00	0.00	2.04
		ARSR-4	0.00	0.00	0.00	N/A	N/A	N/A	0.00	0.00	0.00
		Any	90.38	59.06	28.99	N/A	N/A	N/A	90.38	59.06	28.99
PHL	**Doppler**	**1+**	94.62	88.59	77.33	100.00	100.00	99.78	96.16	91.85	83.74
		2+	74.83	72.01	61.85	100.00	100.00	96.24	82.02	80.00	71.68
		3+	42.54	45.64	39.43	100.00	99.52	83.63	58.95	61.04	52.06
	Dual Pol.	**1+**	74.83	72.02	67.40	100.00	100.00	99.78	82.02	80.01	76.65
		2+	42.54	36.34	24.61	100.00	98.66	83.07	58.95	54.15	41.31
	Min. dBZ	**< -15**	95.25	40.59	19.51	100.00	43.55	20.68	96.61	41.43	19.84
		< -5	97.17	88.76	76.89	100.00	100.00	93.00	97.98	91.97	81.50
		< 18	97.17	90.72	85.93	100.00	100.00	100.00	97.98	93.37	89.95
		< 30	97.17	90.72	86.33	100.00	100.00	100.00	97.98	93.37	90.24
	H res. ≤ 0.5 km	**worst**	97.17	30.86	20.00	100.00	32.47	17.32	97.98	31.32	19.24
		mean	97.17	90.66	82.17	100.00	99.96	87.26	97.98	93.32	83.63
	V res.	**≤ 100 ft**	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
		≤ 500 ft	30.48	8.69	2.71	24.86	7.66	1.92	28.88	8.39	2.48
	Radar	**TDWR**	94.62	88.57	59.60	100.00	99.96	75.71	96.16	91.83	64.20
		NEXRAD	0.00	0.02	17.72	0.00	0.04	24.07	0.00	0.02	19.54
		ASR-9	2.55	1.94	3.23	0.00	0.00	0.04	1.82	1.38	2.32
		ASR-11	0.00	0.00	5.22	0.00	0.00	0.18	0.00	0.00	3.78
		ARSR-4	0.00	0.20	0.55	0.00	0.00	0.00	0.00	0.14	0.39
		Any	97.17	90.72	86.33	100.00	100.00	100.00	97.98	93.37	90.24
PHX	**Doppler**	**1+**	96.53	84.89	55.06	100.00	100.00	94.34	97.83	90.55	69.79
		2+	87.26	61.89	27.18	100.00	98.41	67.61	92.03	75.59	42.34
		3+	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.06
	Dual Pol.	**1+**	87.36	75.74	45.48	100.00	98.91	92.46	92.10	84.43	63.10
		2+	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.49
	Min. dBZ	**< -15**	96.51	53.47	14.90	100.00	60.07	16.88	97.82	55.94	15.64
		< -5	96.77	85.02	52.24	100.00	100.00	86.50	97.98	90.64	65.08
		< 18	96.77	86.15	59.24	100.00	100.00	96.92	97.98	91.34	73.37
		< 30	96.77	86.15	59.60	100.00	100.00	97.66	97.98	91.35	73.87
	H res. ≤ 0.5 km	**worst**	96.66	45.82	13.09	100.00	49.65	14.40	97.92	47.25	13.58
		mean	96.77	84.25	45.09	100.00	99.96	66.43	97.98	90.14	53.09

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
PHX cont.	**V res.**	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	44.93	9.75	2.44	36.56	6.98	1.74	41.79	8.71	2.18
	Radar	**TDWR**	96.43	59.20	31.52	100.00	81.26	57.85	97.77	67.47	41.39
		NEXRAD	0.10	25.68	23.54	0.00	18.74	36.49	0.06	23.08	28.40
		ASR-9	0.13	0.88	2.06	0.00	0.00	1.89	0.08	0.55	2.00
		ASR-11	0.00	0.24	1.10	0.00	0.00	0.44	0.00	0.15	0.85
		ARSR-4	0.00	0.00	1.17	0.00	0.00	0.96	0.00	0.00	1.09
		Any	96.67	86.01	59.39	100.00	100.00	97.63	97.92	91.25	73.73
PIT	**Doppler**	**1+**	97.98	93.44	80.47	100.00	100.00	100.00	98.56	95.32	86.05
		2+	87.57	88.14	61.99	75.88	99.01	91.70	84.23	91.24	70.48
		3+	0.00	0.02	6.13	0.00	12.19	32.73	0.00	3.50	13.73
	Dual Pol.	**1+**	92.19	92.81	78.44	75.88	99.04	99.76	87.53	94.59	84.53
		2+	0.00	0.02	8.53	0.00	12.19	48.13	0.00	3.50	19.85
	Min. dBZ	**< -15**	97.98	48.10	12.49	100.00	50.01	13.00	98.56	48.65	12.63
		< -5	97.99	93.45	73.14	100.00	100.00	88.26	98.56	95.32	77.46
		< 18	97.99	93.59	84.91	100.00	100.00	100.00	98.56	95.42	89.22
		< 30	97.99	93.59	84.91	100.00	100.00	100.00	98.56	95.42	89.22
	H res. ≤ 0.5 km	**worst**	97.99	41.97	11.38	100.00	43.19	10.80	98.56	42.32	11.21
		mean	97.99	93.59	64.90	100.00	100.00	68.93	98.56	95.42	66.05
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	39.64	9.66	2.42	3.65	7.12	1.78	29.36	8.93	2.23
	Radar	**TDWR**	27.50	74.27	57.68	54.56	85.81	72.57	35.23	77.57	61.94
		NEXRAD	70.48	19.17	22.78	45.44	14.19	27.43	63.32	17.75	24.11
		ASR-9	0.01	0.14	0.14	0.00	0.00	0.00	0.01	0.10	0.10
		ASR-11	0.00	0.00	4.30	0.00	0.00	0.00	0.00	0.00	3.07
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.99	93.59	84.91	100.00	100.00	100.00	98.56	95.42	89.22
SAN	**Doppler**	**1+**	75.47	65.27	38.53	100.00	98.77	94.56	87.74	82.02	66.55
		2+	0.00	0.17	1.51	0.00	25.61	32.92	0.00	12.89	17.22
		3+	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.53
	Dual Pol.	**1+**	75.47	65.27	38.53	100.00	98.77	94.56	87.74	82.02	66.55
		2+	0.00	0.17	1.51	0.00	25.61	32.92	0.00	12.89	17.22
	Min. dBZ	**< -15**	50.81	21.30	5.43	66.83	29.31	7.55	58.82	25.30	6.49
		< -5	77.21	65.89	31.61	100.00	98.94	67.70	88.60	82.41	49.65
		< 18	85.64	75.23	51.34	100.00	100.00	97.76	92.82	87.62	74.55
		< 30	85.64	75.23	51.36	100.00	100.00	97.77	92.82	87.62	74.57
	H res. ≤ 0.5 km	**worst**	59.73	23.44	6.84	69.96	30.64	7.96	64.84	27.04	7.40
		mean	85.64	59.28	22.77	100.00	67.98	26.16	92.82	63.63	24.46
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	0.00	1.63	0.41	0.00	0.00	0.00	0.00	0.82	0.21

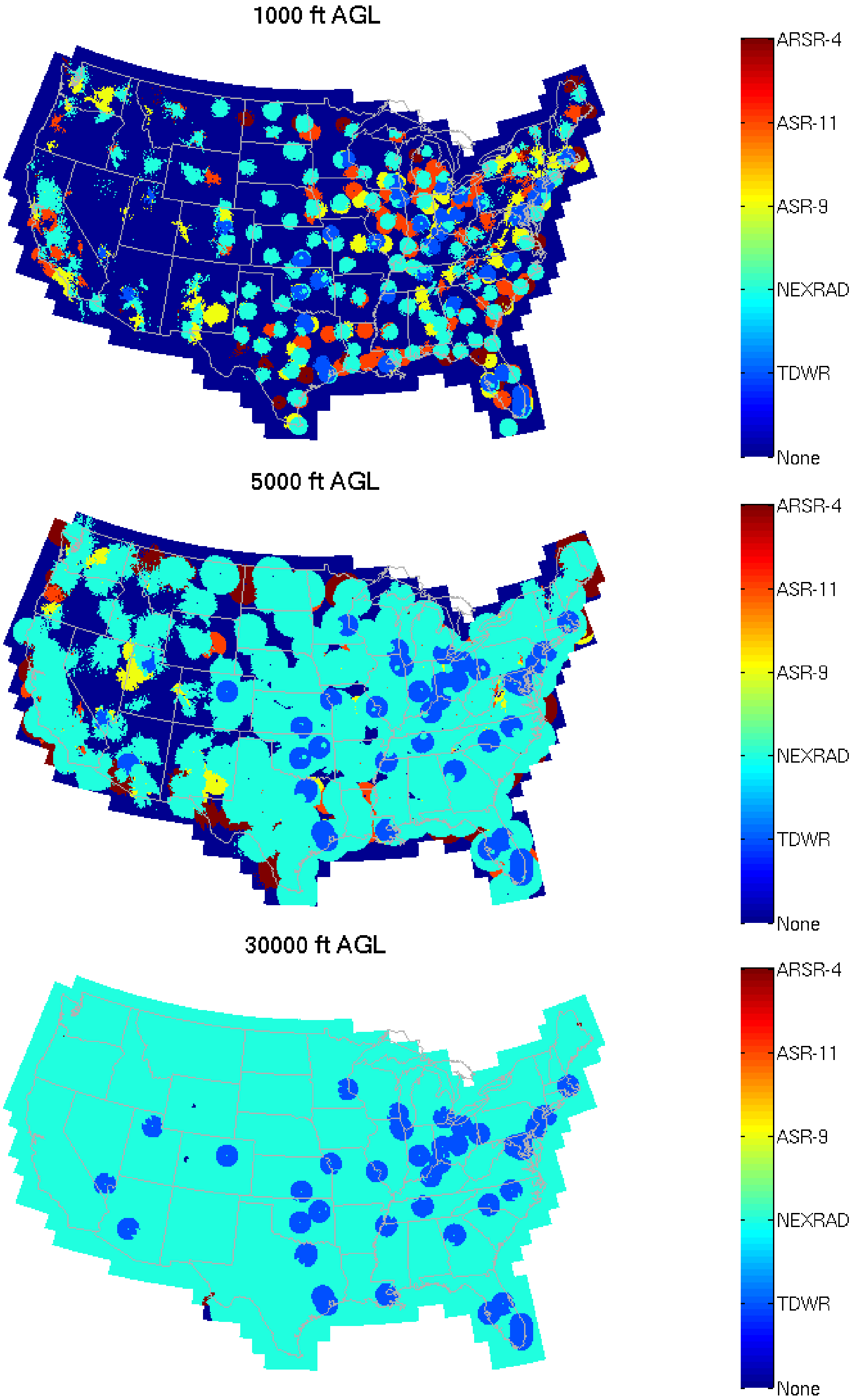
Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
SAN cont.	**Radar**	**TDWR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NEXRAD	75.47	65.27	38.53	100.00	98.77	94.56	87.74	82.02	66.55
		ASR-9	10.17	9.90	11.72	0.00	0.51	2.43	5.08	5.21	7.07
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	1.03	0.00	0.72	0.75	0.00	0.36	0.89
		Any	85.64	75.17	51.28	100.00	100.00	97.74	92.82	87.59	74.51
SEA	**Doppler**	**1+**	67.76	62.41	38.14	100.00	100.00	89.94	83.88	81.20	64.04
		2+	0.00	0.00	0.13	16.13	21.91	23.36	8.06	10.95	11.75
		3+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dual Pol.	**1+**	67.76	62.41	38.14	100.00	100.00	89.94	83.88	81.20	64.04
		2+	0.00	0.00	0.13	16.13	21.91	23.36	8.06	10.95	11.75
	Min. dBZ	**< -15**	4.11	0.16	6.02	0.00	0.00	6.08	2.05	0.08	6.05
		< -5	84.46	40.66	27.36	80.00	50.27	38.91	82.23	45.47	33.13
		< 18	97.07	87.29	57.00	100.00	100.00	92.88	98.54	93.65	74.94
		< 30	97.07	87.29	57.01	100.00	100.00	95.00	98.54	93.65	76.01
	H res. ≤ 0.5 km	**worst**	29.31	4.85	7.37	0.00	0.00	6.27	14.65	2.43	6.82
		mean	29.31	33.72	23.25	0.00	7.33	15.70	14.65	20.53	19.47
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	0.22	0.01	0.48	0.00	0.00	0.00	0.11	0.00	0.24
	Radar	**TDWR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NEXRAD	67.76	62.41	38.14	100.00	100.00	89.94	83.88	81.20	64.04
		ASR-9	29.31	24.81	18.65	0.00	0.00	2.86	14.65	12.40	10.76
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.01	0.00	0.00	2.12	0.00	0.00	1.07
		Any	97.07	87.21	56.80	100.00	100.00	94.92	98.54	93.61	75.86
SFO	**Doppler**	**1+**	43.76	35.65	29.72	100.00	99.92	90.65	71.88	67.78	60.18
		2+	10.96	6.04	3.96	100.00	92.95	71.07	55.48	49.50	37.52
		3+	0.00	0.00	0.00	5.33	11.75	19.38	2.66	5.88	9.69
	Dual Pol.	**1+**	43.76	35.65	29.72	100.00	99.92	90.65	71.88	67.78	60.18
		2+	10.96	6.04	3.96	100.00	92.95	71.07	55.48	49.50	37.52
	Min. dBZ	**< -15**	0.00	1.38	3.32	0.00	3.80	8.91	0.00	2.59	6.11
		< -5	21.91	25.76	25.15	100.00	78.75	68.18	60.95	52.25	46.67
		< 18	92.33	74.49	62.84	100.00	100.00	97.88	96.16	87.25	80.36
		< 30	92.33	74.51	63.76	100.00	100.00	99.92	96.16	87.25	81.84
	H res. ≤ 0.5 km	**worst**	35.08	15.81	8.11	0.00	4.08	9.28	17.54	9.94	8.69
		mean	48.12	36.53	29.62	0.00	22.00	28.47	24.06	29.26	29.04
	V res.	**≤ 100 ft**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.01	0.05
	Radar	**TDWR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NEXRAD	43.76	35.65	29.72	100.00	99.92	90.65	71.88	67.78	60.18
		ASR-9	47.98	30.88	12.98	0.00	0.00	0.01	23.99	15.44	6.49
		ASR-11	0.00	1.71	11.35	0.00	0.00	0.08	0.00	0.85	5.71
		ARSR-4	0.47	6.19	9.60	0.00	0.08	9.19	0.23	3.13	9.40
		Any	92.21	74.42	63.65	100.00	100.00	99.92	96.10	87.21	81.79

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km	< 10 km	< 50 km	≤ 100 km
SLC	Doppler	1+	91.51	48.86	27.50	100.00	83.45	59.90	92.92	54.62	32.90
		2+	34.40	21.22	12.64	100.00	66.87	36.84	45.33	28.83	16.67
		3+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dual Pol.	1+	34.40	24.05	17.45	100.00	82.66	58.11	45.33	33.82	24.22
		2+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Min. dBZ	< -15	91.84	24.48	9.43	100.00	31.14	14.39	93.20	25.59	10.26
		< -5	96.10	48.79	27.21	100.00	77.79	51.09	96.75	53.63	31.19
		< 18	96.10	54.19	34.15	100.00	83.90	68.88	96.75	59.15	39.94
		< 30	96.10	54.19	34.15	100.00	83.90	68.88	96.75	59.15	39.94
	H res. ≤ 0.5 km	worst	91.35	20.85	9.18	94.94	25.52	13.11	91.94	21.63	9.84
		mean	96.10	49.59	25.31	100.00	67.74	37.13	96.75	52.62	27.28
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	7.77	5.51	1.38	3.78	5.83	1.46	7.10	5.56	1.39
	Radar	TDWR	91.51	45.45	17.43	100.00	66.57	27.07	92.92	48.97	19.03
		NEXRAD	0.00	3.40	10.07	0.00	16.88	32.84	0.00	5.65	13.87
		ASR-9	4.57	5.16	6.57	0.00	0.25	8.89	3.81	4.34	6.96
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	96.08	54.01	34.07	100.00	83.70	68.79	96.73	58.96	39.86
STL	Doppler	1+	97.30	92.64	77.73	100.00	100.00	100.00	98.20	95.10	85.15
		2+	93.48	88.25	66.29	100.00	98.95	96.54	95.66	91.82	76.37
		3+	0.00	3.04	7.28	38.22	42.28	45.88	12.74	16.12	20.15
	Dual Pol.	1+	93.48	88.49	74.39	100.00	98.98	99.74	95.66	91.98	82.84
		2+	0.00	3.04	10.88	38.22	42.30	54.96	12.74	16.13	25.57
	Min. dBZ	< -15	97.30	46.30	12.05	100.00	47.96	12.42	98.20	46.85	12.17
		< -5	97.96	93.17	70.31	100.00	100.00	84.95	98.64	95.44	75.19
		< 18	97.96	94.96	87.12	100.00	100.00	100.00	98.64	96.64	91.41
		< 30	97.96	94.96	87.12	100.00	100.00	100.00	98.64	96.64	91.41
	H res. ≤ 0.5 km	worst	97.96	38.78	10.64	100.00	38.83	10.16	98.64	38.80	10.48
		mean	97.96	94.96	71.91	100.00	100.00	71.28	98.64	96.64	71.70
	V res.	≤ 100 ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		≤ 500 ft	53.74	10.32	2.58	46.14	7.37	1.84	51.20	9.34	2.33
	Radar	TDWR	97.30	82.35	62.83	100.00	91.04	77.53	98.20	85.25	67.73
		NEXRAD	0.00	10.29	14.90	0.00	8.96	22.47	0.00	9.85	17.43
		ASR-9	0.66	2.31	7.86	0.00	0.00	0.00	0.44	1.54	5.24
		ASR-11	0.00	0.00	1.53	0.00	0.00	0.00	0.00	0.00	1.02
		ARSR-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Any	97.96	94.96	87.12	100.00	100.00	100.00	98.64	96.64	91.41
TPA	Doppler	1+	96.09	91.96	78.66	100.00	100.00	100.00	98.04	95.98	89.33
		2+	92.52	87.27	65.85	100.00	99.75	88.93	96.26	93.51	77.39
		3+	0.00	5.60	13.30	60.09	53.48	46.80	30.04	29.54	30.05
	Dual Pol.	1+	92.52	87.64	73.21	100.00	99.76	99.94	96.26	93.70	86.57
		2+	0.00	1.68	8.44	60.09	53.53	48.17	30.04	27.61	28.31

Airport	Parameter	Height	< 5000 ft AGL			≥ 5000 ft AGL			All Heights		
		Radius	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**	**< 10 km**	**< 50 km**	**≤ 100 km**
TPA cont.	**Min. dBZ**	**< -15**	96.39	44.10	12.53	100.00	45.75	12.91	98.20	44.93	12.72
		< -5	97.68	92.04	72.86	100.00	100.00	86.63	98.84	96.02	79.75
		< 18	97.68	93.66	85.48	100.00	100.00	100.00	98.84	96.83	92.74
		< 30	97.68	93.66	85.86	100.00	100.00	100.00	98.84	96.83	92.93
	H res. ≤ 0.5 km	**worst**	97.68	35.90	10.44	100.00	36.84	10.25	98.84	36.37	10.34
		mean	97.68	93.66	74.42	100.00	100.00	77.97	98.84	96.83	76.19
	V res.	**≤ 100 ft**	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.00
		≤ 500 ft	54.19	10.66	2.67	44.43	7.02	1.75	49.31	8.84	2.21
	Radar	**TDWR**	96.09	83.31	67.99	100.00	93.47	83.88	98.04	88.39	75.94
		NEXRAD	0.00	8.65	10.68	0.00	6.53	16.12	0.00	7.59	13.40
		ASR-9	1.59	1.67	5.94	0.00	0.00	0.00	0.80	0.84	2.97
		ASR-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ARSR-4	0.00	0.03	1.26	0.00	0.00	0.00	0.00	0.02	0.63
		Any	97.68	93.66	85.86	100.00	100.00	100.00	98.84	96.83	92.93

APPENDIX B: CONUS RADAR COVERAGE BY HEIGHT

Here the CONUS radar coverage results are presented by height in two formats. First, the output parameters are visualized as horizontal slices through the airspace at heights of 1000, 5000, and 30,000 ft (AGL) (Figures B-1 to B-7). The AGL height definition was used in order to follow the contour of the land. This is in contrast to the OEP airport figures (Appendix A), which defined the horizontal slices with respect to the airport altitude, a constant. Second, the values are averaged over each height level and compiled in tabular form, with the heights defined as AGL and MSL (Tables B-1 and B-2). The area over which the percentages are calculated is marked out in the figures as 1°×1° latitude-longitude rectangles that are colored. This is a somewhat arbitrary definition of the horizontal CONUS airspace extent, and, thus, the percentages should be taken as approximations. Note that the CONUS airspace is not equivalent to the en route airspace, since the latter excludes the terminal airspaces.



1000 ft AGL

5000 ft AGL

30000 ft AGL

Figure B-1. Coverage by preferred radar type.

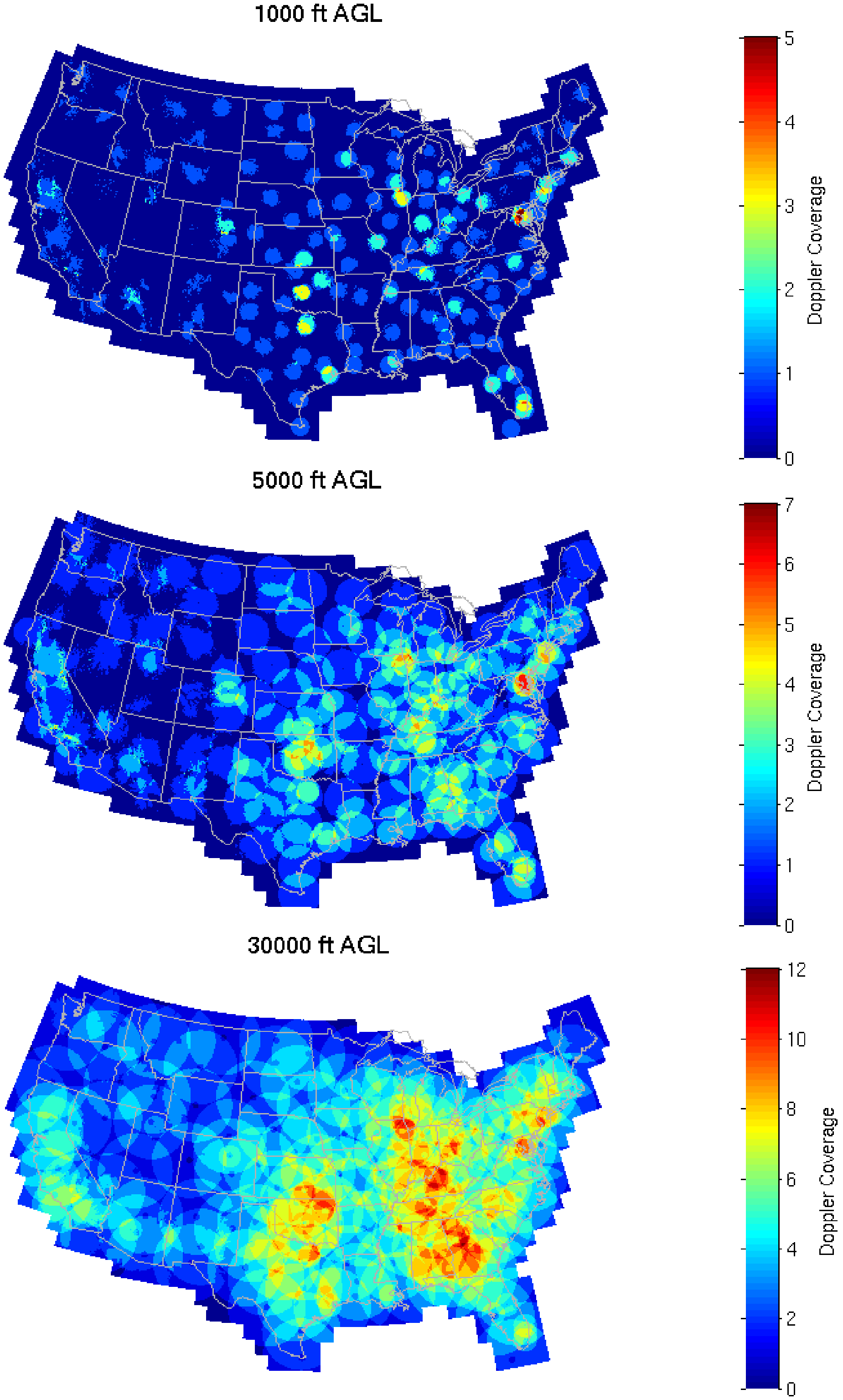


Figure B-2. Degree of Doppler coverage.

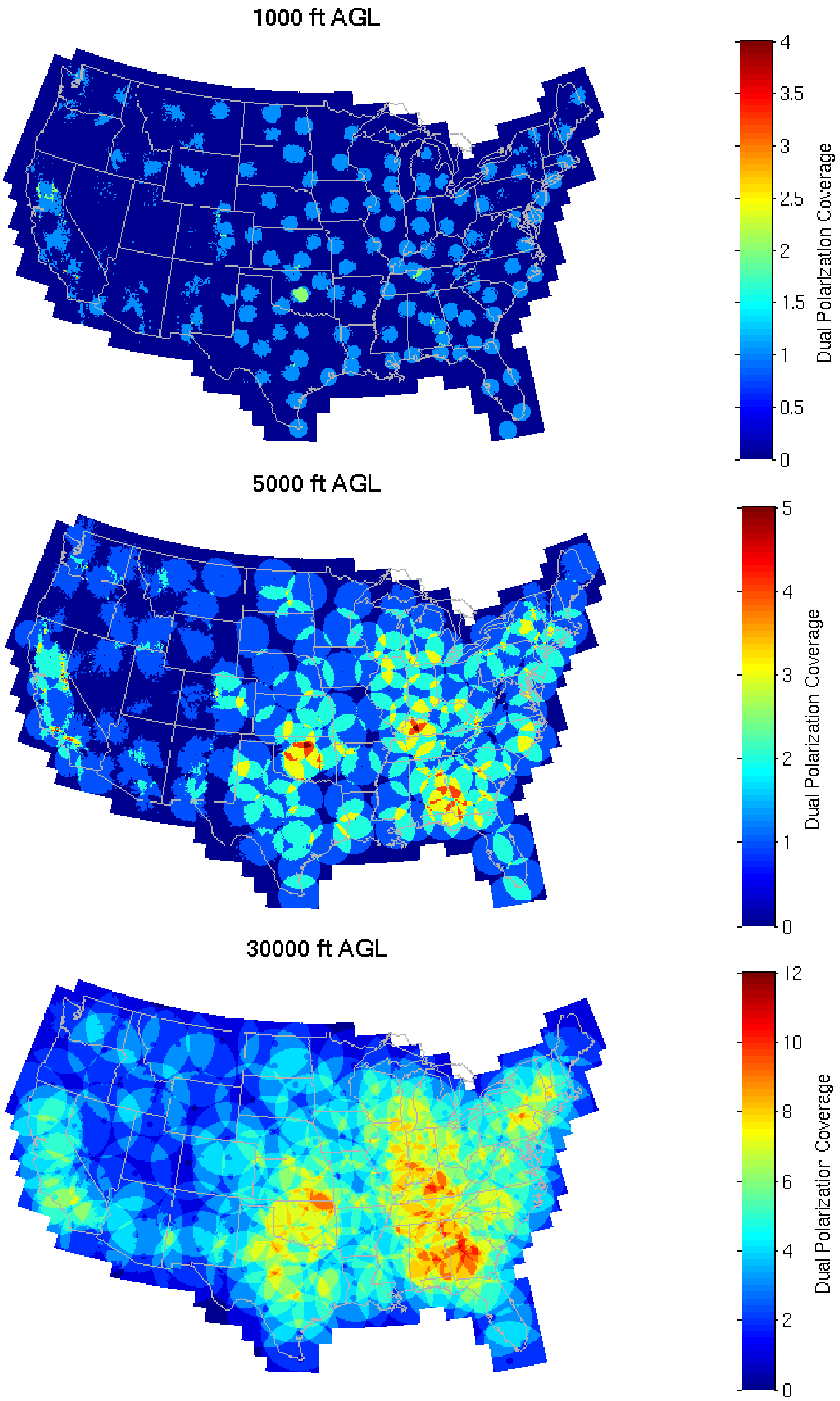
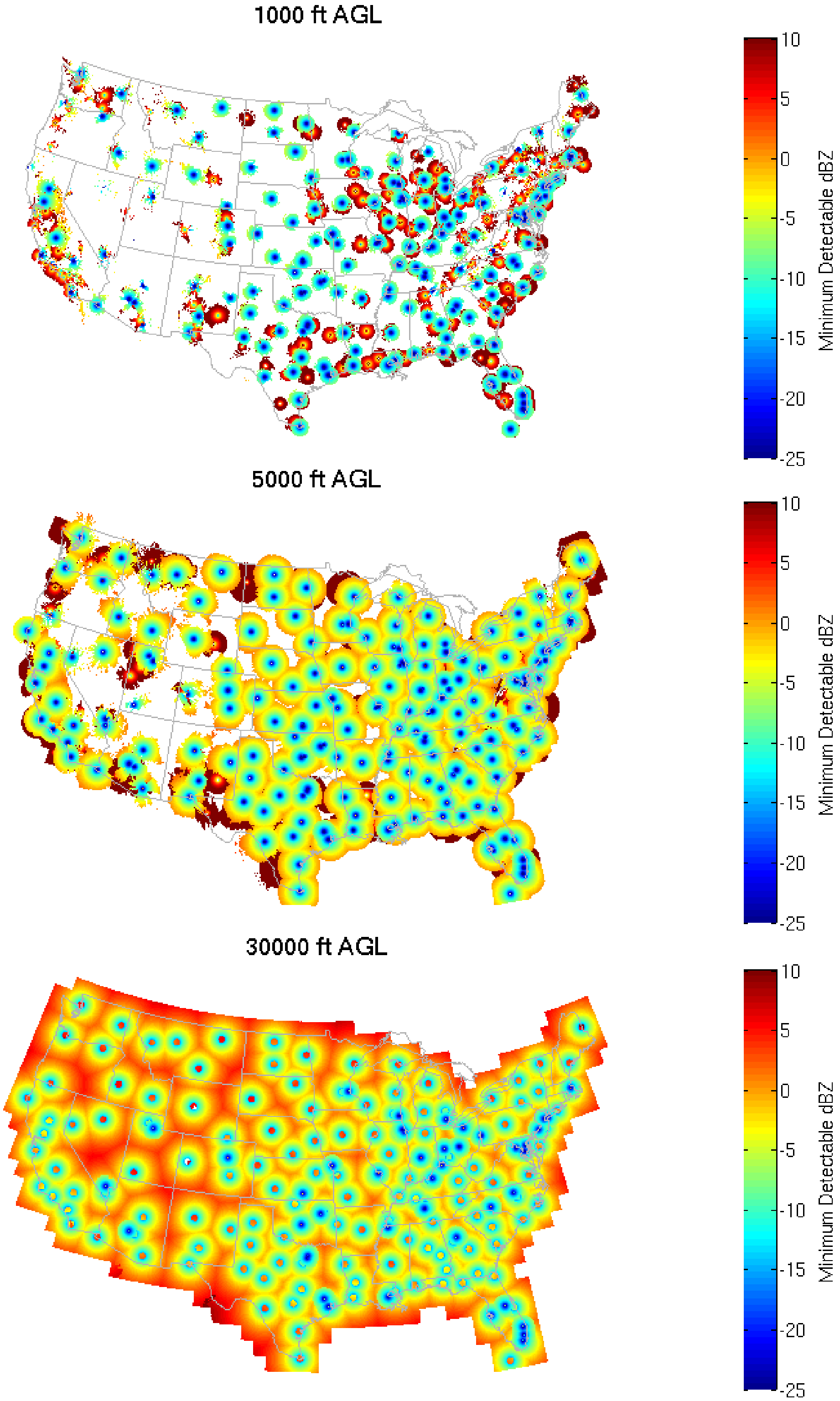


Figure B-3. Degree of dual-polarization coverage.



1000 ft AGL

5000 ft AGL

30000 ft AGL

Figure B-4. Minimum detectable reflectivity.

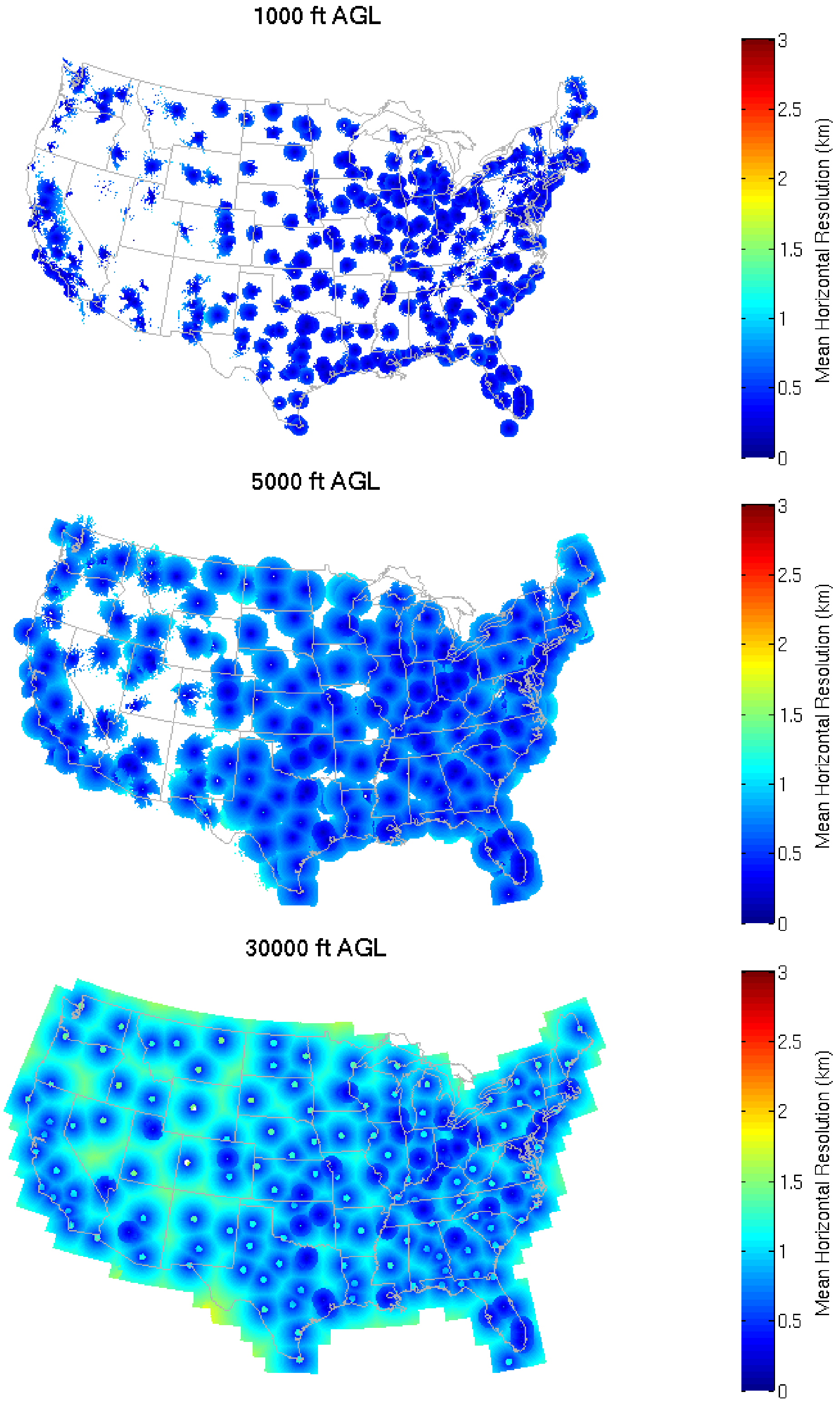


Figure B-5. Geometric-mean horizontal resolution.

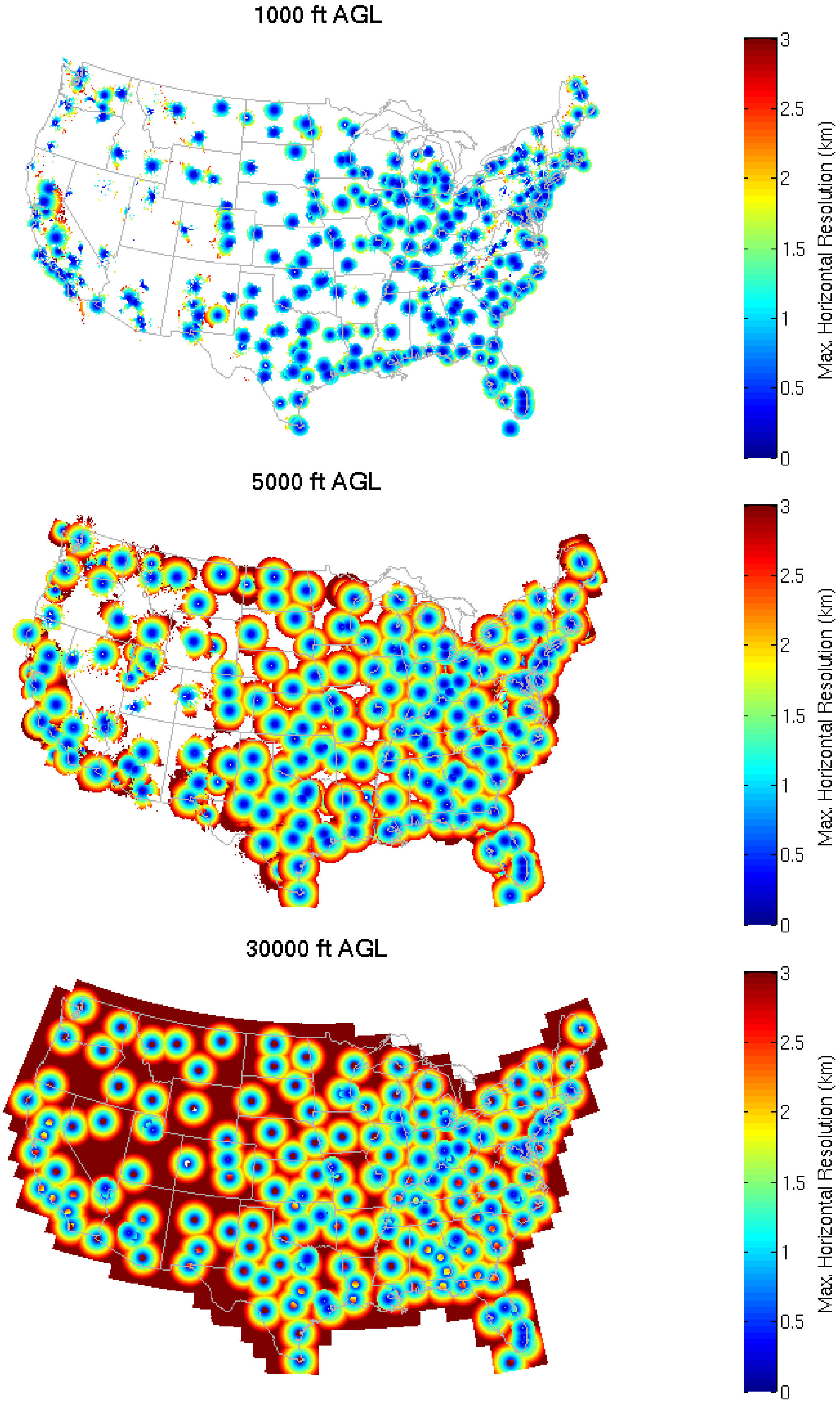


Figure B-6. Worst-case horizontal resolution.

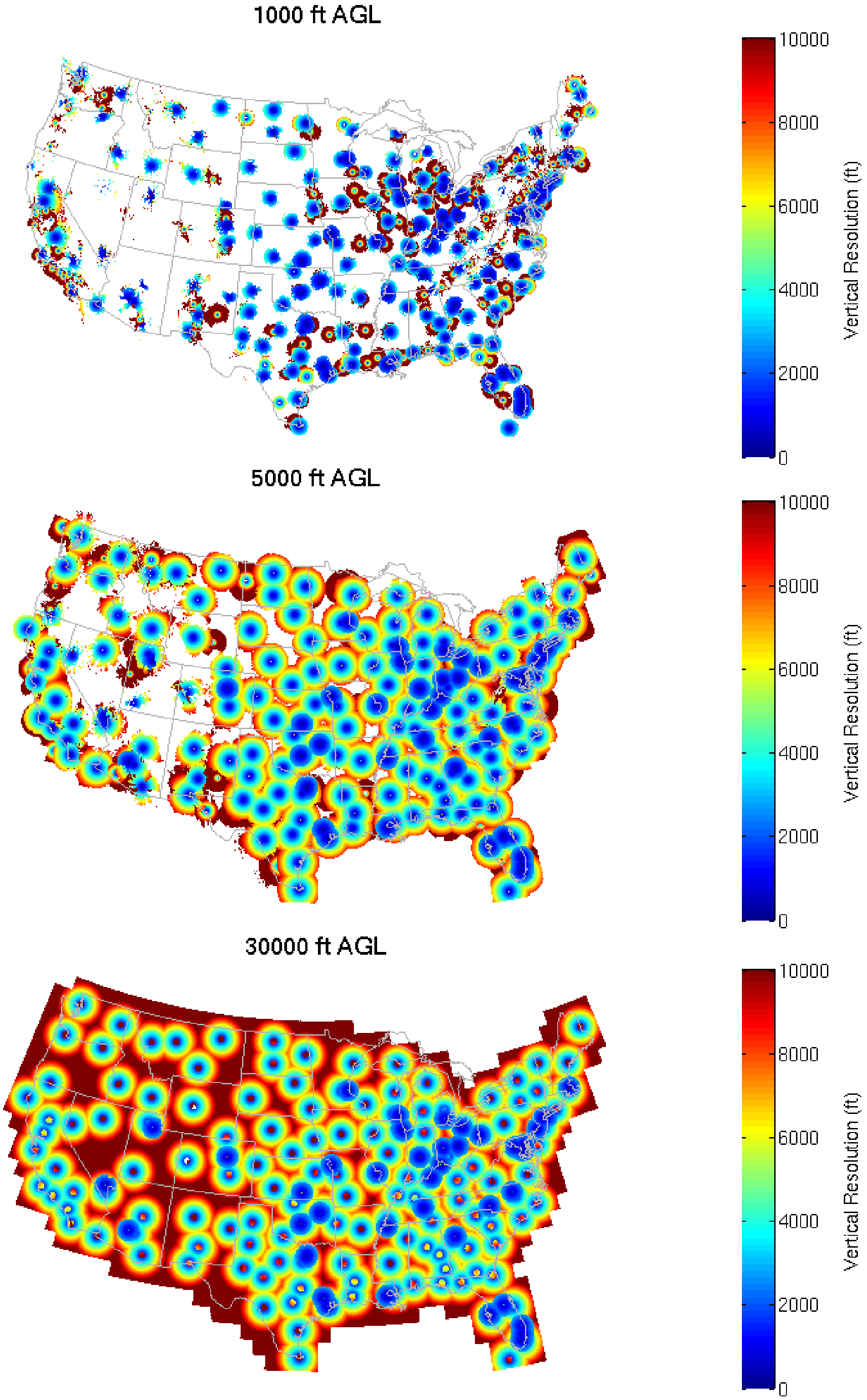


Figure B-7. Vertical resolution.

Table B-1

CONUS Radar Parameter Coverage Percentage by Height AGL

Height (ft AGL)	Doppler			Dual Polarization		Minimum Detectable dBZ				H res. ≤ 1 km		V res. ≤ 500 ft	Radar Type					
	1+	2+	3+	1+	2+	< -15	< -5	< 18	< 30	Worst	Mean		TDWR	NEXRAD	ASR-9	ASR-11	ARSR-4	Any
500	11.33	1.65	0.29	9.77	0.08	3.63	11.23	19.19	19.21	13.57	19.20	0.55	2.70	8.63	3.15	3.58	1.15	19.21
1000	20.86	3.81	0.80	18.66	0.37	4.00	20.34	32.09	32.23	17.02	32.22	0.54	4.96	15.90	4.43	4.99	1.96	32.23
1500	29.69	6.14	1.39	27.39	1.13	4.12	27.40	41.86	42.48	17.18	42.45	0.51	6.71	22.99	4.90	5.24	2.65	42.48
2000	37.49	8.39	1.92	35.69	2.57	4.16	30.93	49.19	50.32	17.01	50.28	0.47	7.41	30.08	4.78	4.90	3.16	50.32
2500	44.45	10.88	2.48	43.26	4.80	4.22	32.50	54.49	56.16	16.81	56.08	0.43	7.58	36.87	4.16	4.02	3.54	56.16
3000	50.78	13.78	3.30	50.04	7.80	4.27	33.44	58.83	60.93	16.62	60.77	0.39	7.65	43.13	3.32	3.02	3.81	60.93
3500	56.40	17.10	4.37	55.97	11.45	4.30	34.13	62.79	65.20	16.41	64.88	0.35	7.69	48.71	2.62	2.19	3.99	65.20
4000	61.29	20.79	5.69	61.03	15.65	4.31	34.63	66.48	69.09	16.19	68.36	0.31	7.73	53.56	2.14	1.58	4.08	69.09
4500	65.60	24.68	7.32	65.45	20.13	4.32	35.00	69.83	72.61	16.01	71.45	0.25	7.75	57.85	1.76	1.14	4.12	72.61
5000	69.40	28.56	9.23	69.31	24.62	4.32	35.28	72.82	75.72	15.89	74.10	0.25	7.78	61.62	1.44	0.82	4.06	75.72
5500	72.76	32.45	11.43	72.71	29.10	4.32	35.51	75.55	78.52	15.82	76.48	0.24	7.80	64.96	1.18	0.62	3.96	78.52
6000	75.76	36.19	13.90	75.73	33.38	4.31	35.66	78.06	81.05	15.73	78.58	0.23	7.82	67.94	0.97	0.49	3.84	81.05
6500	78.47	39.70	16.60	78.46	37.38	4.29	35.75	80.38	83.37	15.65	80.41	0.23	7.84	70.63	0.80	0.39	3.72	83.37
7000	80.91	43.00	19.44	80.90	41.08	4.27	35.83	82.48	85.45	15.58	81.90	0.21	7.86	73.05	0.65	0.31	3.58	85.45
7500	83.05	46.12	22.29	83.03	44.52	4.25	35.87	84.34	87.26	15.52	82.84	0.21	7.88	75.17	0.53	0.26	3.42	87.26
8000	84.91	49.11	25.08	84.90	47.77	4.22	35.89	85.97	88.81	15.47	83.29	0.21	7.89	77.01	0.45	0.21	3.24	88.81
8500	86.53	51.99	27.81	86.52	50.85	4.17	35.89	87.40	90.13	15.42	83.47	0.20	7.91	78.61	0.37	0.18	3.05	90.13
9000	87.99	54.67	30.47	87.98	53.70	4.15	35.89	88.69	91.29	15.37	83.45	0.19	7.93	80.06	0.31	0.15	2.85	91.29
9500	89.29	57.18	33.03	89.29	56.35	4.12	35.88	89.85	92.31	15.32	83.35	0.18	7.94	81.35	0.25	0.12	2.64	92.31
10000	90.47	59.53	35.49	90.46	58.81	4.08	35.87	90.92	93.19	15.28	83.17	0.17	7.96	82.51	0.20	0.10	2.42	93.19
10500	91.54	61.74	37.82	91.53	61.12	4.05	35.84	91.90	93.98	15.25	82.91	0.16	7.97	83.56	0.17	0.08	2.19	93.98
11000	92.49	63.85	40.02	92.49	63.32	4.02	35.82	92.77	94.69	15.22	82.60	0.15	7.99	84.50	0.13	0.07	1.99	94.69
11500	93.35	65.89	42.13	93.35	65.43	3.98	35.80	93.58	95.32	15.19	82.26	0.14	8.00	85.35	0.11	0.06	1.81	95.32
12000	94.17	67.81	44.16	94.17	67.40	3.94	35.76	94.34	95.92	15.15	81.89	0.13	8.01	86.16	0.08	0.04	1.63	95.92
12500	94.93	69.66	46.13	94.92	69.28	3.90	35.73	95.05	96.45	15.12	81.50	0.12	8.03	86.90	0.06	0.03	1.43	96.45
13000	95.58	71.44	47.97	95.58	71.10	3.86	35.69	95.66	96.90	15.08	81.10	0.11	8.04	87.54	0.04	0.02	1.26	96.90
13500	96.15	73.15	49.74	96.15	72.83	3.81	35.65	96.21	97.29	15.04	80.72	0.10	8.05	88.10	0.02	0.02	1.10	97.29
14000	96.65	74.81	51.43	96.65	74.50	3.75	35.61	96.69	97.64	15.00	80.28	0.08	8.07	88.58	0.01	0.01	0.96	97.64
14500	97.08	76.38	53.03	97.08	76.09	3.66	35.57	97.11	97.95	14.96	79.83	0.07	8.08	89.00	0.01	0.01	0.85	97.95
15000	97.44	77.85	54.61	97.44	77.57	3.62	35.53	97.47	98.21	14.92	79.38	0.04	8.09	89.35	0.00	0.01	0.75	98.21
15500	97.75	79.24	56.14	97.75	78.98	3.58	35.48	97.77	98.44	14.88	78.96	0.01	8.10	89.65	0.00	0.01	0.67	98.44
16000	98.01	80.53	57.62	98.01	80.28	3.53	35.42	98.04	98.64	14.83	78.49	0.00	8.11	89.92	0.00	0.01	0.60	98.64
16500	98.24	81.74	58.99	98.24	81.50	3.48	35.35	98.28	98.82	14.78	78.06	0.00	8.13	90.15	0.00	0.00	0.54	98.82
17000	98.44	82.83	60.24	98.44	82.61	3.42	35.26	98.50	98.98	14.73	77.58	0.00	8.14	90.36	0.00	0.00	0.48	98.98
17500	98.60	83.75	61.25	98.60	83.54	3.37	35.12	98.69	99.11	14.68	77.15	0.00	8.16	90.53	0.00	0.00	0.42	99.11
18000	98.71	84.51	62.07	98.71	84.32	3.31	35.08	98.86	99.23	14.62	76.67	0.00	8.17	90.68	0.00	0.00	0.38	99.23
18500	98.80	85.17	62.78	98.80	85.00	3.26	35.04	99.00	99.33	14.57	76.23	0.00	8.18	90.81	0.00	0.00	0.34	99.33
19000	98.88	85.73	63.41	98.88	85.57	3.20	34.99	99.12	99.42	14.51	75.78	0.00	8.19	90.92	0.00	0.00	0.30	99.42
19500	98.94	86.24	63.97	98.94	86.09	3.14	34.95	99.22	99.49	14.45	75.28	0.00	8.20	91.02	0.00	0.00	0.27	99.49
20000	99.00	86.69	64.48	99.00	86.56	3.07	34.91	99.31	99.55	14.39	74.82	0.00	8.22	91.09	0.00	0.00	0.24	99.55
20500	99.05	87.10	64.94	99.05	86.98	2.98	34.85	99.39	99.61	14.30	74.35	0.00	8.23	91.16	0.00	0.00	0.22	99.61
21000	99.09	87.46	65.36	99.09	87.35	2.91	34.80	99.47	99.66	14.19	73.82	0.00	8.24	91.23	0.00	0.00	0.19	99.66
21500	99.12	87.77	65.73	99.12	87.67	2.83	34.75	99.54	99.71	14.03	73.35	0.00	8.25	91.29	0.00	0.00	0.17	99.71
22000	99.15	88.05	66.07	99.15	87.95	2.75	34.68	99.59	99.75	13.97	72.87	0.00	8.22	91.37	0.00	0.00	0.15	99.75
22500	99.18	88.29	66.38	99.18	88.20	2.65	34.61	99.64	99.78	13.92	72.39	0.00	8.20	91.44	0.00	0.00	0.14	99.78

Height (ft AGL)	**Doppler**			**Dual Polarization**		**Minimum Detectable dBZ**				**H res. ≤ 1 km**		**V res. ≤ 500 ft**	**Radar Type**					
	1+	**2+**	**3+**	**1+**	**2+**	**< -15**	**< -5**	**< 18**	**< 30**	**Worst**	**Mean**		**TDWR**	**NEXRAD**	**ASR-9**	**ASR-11**	**ARSR-4**	**Any**
23000	99.20	88.50	66.66	99.20	88.42	2.58	34.56	99.68	99.80	13.86	71.91	0.00	8.21	91.47	0.00	0.00	0.12	99.80
23500	99.22	88.68	66.91	99.22	88.60	2.51	34.50	99.72	99.83	13.79	71.41	0.00	8.23	91.49	0.00	0.00	0.11	99.83
24000	99.23	88.85	67.14	99.23	88.77	2.43	34.44	99.75	99.85	13.72	70.90	0.00	8.24	91.51	0.00	0.00	0.10	99.85
24500	99.24	88.99	67.34	99.24	88.92	2.36	34.38	99.77	99.86	13.65	70.40	0.00	8.25	91.52	0.00	0.00	0.09	99.86
25000	99.25	89.11	67.52	99.25	89.04	2.28	34.32	99.79	99.87	13.58	69.89	0.00	8.26	91.53	0.00	0.00	0.08	99.87
25500	99.26	89.22	67.68	99.26	89.15	2.21	34.26	99.81	99.88	13.52	69.37	0.00	8.27	91.54	0.00	0.00	0.08	99.88
26000	99.26	89.32	67.83	99.26	89.25	2.14	34.20	99.82	99.89	13.45	68.86	0.00	8.28	91.54	0.00	0.00	0.07	99.89
26500	99.27	89.41	67.95	99.27	89.34	2.06	34.14	99.83	99.90	13.38	68.34	0.00	8.29	91.54	0.00	0.00	0.07	99.90
27000	99.27	89.49	68.07	99.27	89.42	1.95	34.07	99.84	99.90	13.30	67.82	0.00	8.30	91.54	0.00	0.00	0.06	99.90
27500	99.28	89.56	68.18	99.28	89.50	1.83	34.00	99.85	99.91	13.22	67.30	0.00	8.31	91.54	0.00	0.00	0.06	99.91
28000	99.28	89.63	68.28	99.28	89.56	1.70	33.93	99.86	99.91	13.13	66.78	0.00	8.32	91.53	0.00	0.00	0.06	99.91
28500	99.28	89.68	68.37	99.28	89.62	1.62	33.86	99.86	99.92	13.05	66.26	0.00	8.34	91.53	0.00	0.00	0.05	99.92
29000	99.28	89.73	68.45	99.28	89.67	1.54	33.79	99.87	99.92	12.96	65.74	0.00	8.35	91.52	0.00	0.00	0.05	99.92
29500	99.28	89.77	68.52	99.28	89.71	1.46	33.72	99.88	99.93	12.88	65.24	0.00	8.35	91.52	0.00	0.00	0.05	99.93
30000	99.28	89.81	68.59	99.28	89.75	1.37	33.64	99.89	99.93	12.79	64.79	0.00	8.36	91.52	0.00	0.00	0.05	99.93
30500	99.28	89.85	68.66	99.28	89.78	1.29	33.56	99.89	99.93	12.70	64.26	0.00	8.37	91.52	0.00	0.00	0.04	99.93
31000	99.28	89.87	68.72	99.28	89.81	1.24	33.47	99.90	99.94	12.60	63.74	0.00	8.38	91.52	0.00	0.00	0.04	99.94
31500	99.27	89.89	68.77	99.27	89.83	1.23	33.38	99.91	99.94	12.50	63.28	0.00	8.39	91.51	0.00	0.00	0.04	99.94
32000	99.27	89.91	68.82	99.27	89.84	1.21	33.29	99.92	99.95	12.39	62.74	0.00	8.40	91.51	0.00	0.00	0.04	99.95
32500	99.27	89.92	68.87	99.27	89.85	1.19	33.20	99.92	99.95	12.25	62.21	0.00	8.41	91.51	0.00	0.00	0.04	99.95
33000	99.27	89.93	68.91	99.27	89.86	1.16	33.12	99.93	99.96	12.05	61.69	0.00	8.42	91.51	0.00	0.00	0.03	99.96
33500	99.27	89.93	68.94	99.27	89.87	1.16	33.01	99.93	99.96	11.96	61.24	0.00	8.42	91.50	0.00	0.00	0.03	99.96
34000	99.27	89.94	68.98	99.27	89.87	1.16	32.91	99.94	99.97	11.86	60.71	0.00	8.43	91.50	0.00	0.00	0.03	99.97
34500	99.26	89.93	69.01	99.26	89.86	1.16	32.79	99.94	99.97	11.76	60.25	0.00	8.44	91.49	0.00	0.00	0.03	99.97
35000	99.26	89.93	69.03	99.26	89.86	1.15	32.65	99.95	99.97	11.66	59.70	0.00	8.45	91.49	0.00	0.00	0.03	99.97
35500	99.26	89.92	69.05	99.26	89.85	1.15	32.46	99.95	99.98	11.55	59.18	0.00	8.46	91.49	0.00	0.00	0.03	99.98
36000	99.26	89.92	69.06	99.26	89.84	1.15	32.37	99.96	99.98	11.45	58.72	0.00	8.46	91.48	0.00	0.00	0.03	99.98
36500	99.25	89.91	69.08	99.25	89.83	1.15	32.28	99.96	99.99	11.35	58.19	0.00	8.47	91.48	0.00	0.00	0.04	99.99
37000	99.25	89.90	69.09	99.25	89.82	1.13	32.19	99.96	99.99	11.24	57.74	0.00	8.48	91.48	0.00	0.00	0.04	99.99
37500	99.25	89.89	69.10	99.25	89.81	1.11	32.10	99.96	99.99	11.14	57.20	0.00	8.48	91.47	0.00	0.00	0.04	99.99
38000	99.24	89.88	69.10	99.24	89.80	1.11	31.98	99.97	100.00	11.02	56.74	0.00	8.46	91.50	0.00	0.00	0.04	100.00
38500	99.24	89.86	69.11	99.24	89.78	1.11	31.86	99.97	100.00	10.90	56.19	0.00	8.43	91.53	0.00	0.00	0.04	100.00
39000	99.23	89.85	69.10	99.23	89.77	1.10	31.76	99.97	100.00	10.79	55.74	0.00	8.43	91.53	0.00	0.00	0.04	100.00
39500	99.23	89.83	69.09	99.23	89.75	1.10	31.66	99.97	100.00	10.67	55.28	0.00	8.44	91.52	0.00	0.00	0.04	100.00
40000	99.23	89.79	69.05	99.23	89.71	1.10	31.56	99.97	100.00	10.54	54.73	0.00	8.44	91.51	0.00	0.00	0.04	100.00
40500	99.22	89.78	69.05	99.22	89.70	1.10	31.46	99.97	100.00	10.38	54.26	0.00	8.45	91.51	0.00	0.00	0.04	100.00
41000	99.22	89.77	69.05	99.22	89.68	1.10	31.36	99.97	100.00	10.16	53.73	0.00	8.46	91.50	0.00	0.00	0.04	100.00
41500	99.22	89.76	69.05	99.22	89.67	1.08	31.24	99.97	100.00	10.04	53.27	0.00	8.46	91.50	0.00	0.00	0.04	100.00
42000	99.21	89.75	69.04	99.21	89.65	1.06	31.13	99.97	100.00	9.91	52.79	0.00	8.46	91.49	0.00	0.00	0.04	100.00
42500	99.21	89.73	69.04	99.21	89.64	1.06	31.02	99.97	100.00	9.80	52.24	0.00	8.47	91.48	0.00	0.00	0.05	100.00
43000	99.21	89.72	69.03	99.21	89.62	1.06	30.90	99.97	100.00	9.67	51.79	0.00	8.48	91.47	0.00	0.00	0.05	100.00
43500	99.20	89.70	69.03	99.20	89.60	1.06	30.79	99.97	100.00	9.56	51.31	0.00	8.48	91.47	0.00	0.00	0.05	100.00
44000	99.20	89.69	69.02	99.20	89.59	1.05	30.67	99.97	100.00	9.43	50.76	0.00	8.49	91.46	0.00	0.00	0.05	100.00
44500	99.20	89.67	69.01	99.20	89.57	1.05	30.55	99.97	100.00	9.31	50.30	0.00	8.49	91.46	0.00	0.00	0.05	100.00
45000	99.19	89.66	69.00	99.19	89.56	1.04	30.42	99.96	100.00	9.17	49.82	0.00	8.49	91.45	0.00	0.00	0.05	100.00

Table B-2

CONUS Radar Parameter Coverage Percentage by Height MSL

Height (ft MSL)	Doppler			Dual Polarization		Minimum Detectable dBZ				H res. ≤ 1 km		V res. ≤ 500 ft	Radar Type					
	1+	2+	3+	1+	2+	< -15	< -5	< 18	< 30	Worst	Mean		TDWR	NEXRAD	ASR-9	ASR-11	ARSR-4	Any
500	6.78	0.92	0.06	5.12	0.00	3.91	7.20	13.86	13.86	12.77	13.86	0.73	2.20	4.58	2.35	3.21	1.53	13.86
1000	13.67	2.62	0.55	11.36	0.02	4.72	14.15	24.44	24.44	17.81	24.44	0.84	4.04	9.63	3.62	5.09	2.06	24.44
1500	21.63	4.89	1.19	18.44	0.33	5.29	22.01	35.51	35.66	20.84	35.66	0.86	6.65	14.98	4.99	6.68	2.37	35.66
2000	30.28	7.78	1.85	26.92	1.22	5.36	29.41	45.13	45.78	21.70	45.78	0.82	8.87	21.41	5.47	7.11	2.92	45.78
2500	37.61	10.51	2.46	34.75	2.69	5.20	33.77	51.88	52.89	20.64	52.89	0.71	10.06	27.55	5.24	6.68	3.35	52.89
3000	43.40	12.79	3.04	41.48	4.74	5.08	35.55	55.79	57.15	19.72	57.15	0.64	10.04	33.36	4.55	5.56	3.65	57.15
3500	48.83	14.99	3.83	47.62	7.38	5.05	36.19	58.88	60.59	19.10	60.59	0.55	9.69	39.14	3.52	4.34	3.90	60.59
4000	53.65	17.42	4.82	52.92	10.46	4.98	36.57	61.42	63.40	18.58	63.37	0.50	9.36	44.29	2.51	3.21	4.03	63.40
4500	56.90	19.93	5.92	56.43	13.85	4.81	36.28	62.83	65.03	17.73	64.84	0.44	8.96	47.93	1.91	2.24	3.99	65.03
5000	59.52	22.61	7.23	59.20	17.41	4.67	35.79	64.10	66.46	16.97	66.10	0.29	8.64	50.88	1.56	1.55	3.82	66.46
5500	61.77	25.47	8.71	61.55	21.07	4.56	35.28	65.48	67.97	16.56	67.36	0.28	8.38	53.39	1.45	1.10	3.65	67.97
6000	63.80	28.46	10.40	63.63	24.77	4.49	34.96	66.97	69.55	16.28	68.70	0.28	8.21	55.58	1.41	0.83	3.52	69.55
6500	65.55	31.41	12.29	65.41	28.30	4.41	34.74	68.31	70.92	15.94	69.83	0.25	8.11	57.44	1.33	0.65	3.39	70.92
7000	67.15	34.24	14.37	67.07	31.60	4.36	34.55	69.62	72.25	15.74	70.90	0.25	8.00	59.15	1.24	0.56	3.31	72.25
7500	68.86	36.95	16.64	68.81	34.72	4.29	34.46	71.33	73.95	15.73	72.37	0.23	7.95	60.91	1.30	0.51	3.27	73.95
8000	70.75	39.55	19.04	70.72	37.68	4.28	34.57	73.27	75.86	15.74	74.02	0.22	7.90	62.84	1.31	0.49	3.31	75.86
8500	72.71	42.09	21.48	72.68	40.52	4.28	34.82	75.08	77.73	15.71	75.47	0.22	7.89	64.82	1.23	0.46	3.34	77.73
9000	74.68	44.51	23.91	74.66	43.15	4.21	35.11	76.87	79.55	15.68	76.70	0.20	7.89	66.79	1.17	0.40	3.29	79.55
9500	76.55	46.84	26.30	76.53	45.67	4.17	35.28	78.55	81.22	15.56	77.62	0.20	7.90	68.65	1.12	0.36	3.20	81.22
10000	78.26	49.11	28.65	78.25	48.11	4.14	35.33	80.08	82.70	15.45	78.32	0.19	7.90	70.36	1.04	0.32	3.08	82.70
10500	79.96	51.24	30.94	79.95	50.39	4.12	35.37	81.53	84.09	15.38	78.85	0.19	7.91	72.05	0.90	0.29	2.94	84.09
11000	81.63	53.24	33.16	81.62	52.52	4.12	35.47	82.96	85.42	15.36	79.33	0.17	7.92	73.70	0.75	0.26	2.78	85.42
11500	83.23	55.13	35.32	83.22	54.53	4.09	35.60	84.38	86.72	15.36	79.81	0.15	7.94	75.29	0.64	0.24	2.60	86.72
12000	84.72	57.00	37.37	84.72	56.49	4.06	35.68	85.72	87.91	15.31	80.23	0.15	7.95	76.77	0.55	0.22	2.41	87.91
12500	86.14	58.82	39.29	86.13	58.36	4.03	35.73	87.00	89.01	15.27	80.58	0.14	7.97	78.17	0.47	0.20	2.21	89.01
13000	87.46	60.60	41.11	87.46	60.19	4.00	35.72	88.20	90.01	15.22	80.89	0.13	7.98	79.48	0.40	0.18	1.98	90.01
13500	88.68	62.33	42.84	88.68	61.95	3.96	35.72	89.31	90.95	15.18	81.09	0.12	8.00	80.69	0.34	0.16	1.77	90.95
14000	89.80	64.04	44.50	89.80	63.68	3.92	35.71	90.34	91.83	15.14	81.31	0.11	8.01	81.79	0.29	0.14	1.59	91.83
14500	90.84	65.67	46.08	90.83	65.33	3.89	35.70	91.29	92.65	15.10	81.24	0.10	8.02	82.81	0.25	0.12	1.44	92.65
15000	91.80	67.24	47.58	91.80	66.92	3.75	35.68	92.19	93.43	15.07	81.06	0.08	8.04	83.77	0.22	0.10	1.31	93.43
15500	92.70	68.76	49.01	92.69	68.44	3.71	35.66	93.02	94.16	15.03	80.83	0.05	8.05	84.65	0.19	0.08	1.19	94.16
16000	93.53	70.23	50.39	93.53	69.92	3.67	35.63	93.79	94.82	14.99	80.71	0.02	8.06	85.47	0.16	0.06	1.07	94.82
16500	94.31	71.67	51.73	94.30	71.36	3.62	35.60	94.51	95.44	14.94	80.33	0.00	8.08	86.23	0.13	0.05	0.95	95.44
17000	95.02	73.07	53.06	95.02	72.77	3.58	35.57	95.18	96.00	14.90	80.03	0.00	8.09	86.93	0.10	0.04	0.84	96.00
17500	95.66	74.45	54.35	95.66	74.16	3.53	35.53	95.78	96.50	14.85	79.53	0.00	8.10	87.56	0.08	0.03	0.74	96.50
18000	96.23	75.72	55.48	96.23	75.43	3.48	35.19	96.32	96.96	14.80	79.18	0.00	8.12	88.12	0.06	0.02	0.66	96.96
18500	96.74	76.91	56.52	96.74	76.63	3.44	35.16	96.81	97.39	14.76	78.65	0.00	8.13	88.63	0.04	0.01	0.58	97.39
19000	97.18	78.03	57.42	97.18	77.76	3.39	35.13	97.27	97.78	14.72	78.28	0.00	8.14	89.08	0.03	0.01	0.52	97.78
19500	97.55	79.04	58.22	97.55	78.79	3.33	35.08	97.66	98.13	14.67	77.91	0.00	8.16	89.47	0.02	0.00	0.47	98.13
20000	97.86	80.00	58.98	97.86	79.76	3.28	35.04	98.00	98.42	14.62	77.32	0.00	8.17	89.81	0.01	0.00	0.42	98.42
20500	98.12	80.93	59.70	98.12	80.71	3.22	35.00	98.29	98.67	14.57	76.92	0.00	8.18	90.09	0.01	0.00	0.38	98.67
21000	98.34	81.80	60.36	98.34	81.60	3.13	34.95	98.54	98.88	14.51	76.50	0.00	8.19	90.34	0.01	0.00	0.35	98.88
21500	98.53	82.60	60.98	98.53	82.42	3.07	34.90	98.76	99.07	14.46	75.86	0.00	8.21	90.55	0.00	0.00	0.31	99.07
22000	98.68	83.33	61.59	98.68	83.16	3.01	34.86	98.96	99.24	14.15	75.42	0.00	8.22	90.73	0.00	0.00	0.28	99.24
22500	98.82	84.02	62.17	98.82	83.87	2.95	34.80	99.12	99.37	14.10	74.97	0.00	8.21	90.91	0.00	0.00	0.25	99.37

Height (ft MSL)	Doppler			Dual Polarization		Minimum Detectable dBZ				H res. ≤ 1 km		V res. ≤ 500 ft	Radar Type					
	1+	2+	3+	1+	2+	< -15	< -5	< 18	< 30	Worst	Mean		TDWR	NEXRAD	ASR-9	ASR-11	ARSR-4	Any
23000	98.92	84.66	62.70	98.92	84.51	2.79	34.73	99.26	99.48	14.04	74.51	0.00	8.19	91.06	0.00	0.00	0.22	99.48
23500	99.01	85.27	63.21	99.01	85.13	2.73	34.67	99.37	99.57	13.99	74.04	0.00	8.18	91.19	0.00	0.00	0.20	99.57
24000	99.07	85.84	63.70	99.07	85.72	2.66	34.62	99.46	99.64	13.92	73.56	0.00	8.20	91.27	0.00	0.00	0.18	99.64
24500	99.12	86.37	64.15	99.12	86.25	2.59	34.56	99.54	99.70	13.86	73.06	0.00	8.21	91.34	0.00	0.00	0.16	99.70
25000	99.17	86.85	64.60	99.17	86.74	2.52	34.50	99.61	99.75	13.79	72.56	0.00	8.22	91.39	0.00	0.00	0.14	99.75
25500	99.20	87.25	64.99	99.20	87.14	2.45	34.45	99.66	99.79	13.73	72.05	0.00	8.23	91.43	0.00	0.00	0.13	99.79
26000	99.22	87.58	65.35	99.22	87.48	2.39	34.39	99.70	99.82	13.67	71.54	0.00	8.24	91.46	0.00	0.00	0.12	99.82
26500	99.24	87.89	65.68	99.24	87.79	2.33	34.34	99.73	99.84	13.61	71.01	0.00	8.25	91.48	0.00	0.00	0.11	99.84
27000	99.25	88.18	66.00	99.25	88.08	2.26	34.28	99.75	99.85	13.54	70.48	0.00	8.26	91.49	0.00	0.00	0.10	99.85
27500	99.25	88.44	66.29	99.25	88.35	2.18	34.21	99.77	99.86	13.47	69.93	0.00	8.28	91.49	0.00	0.00	0.09	99.86
28000	99.26	88.66	66.57	99.26	88.57	2.06	34.15	99.78	99.87	13.39	69.39	0.00	8.28	91.50	0.00	0.00	0.09	99.87
28500	99.27	88.83	66.80	99.27	88.74	1.88	34.08	99.79	99.88	13.32	68.83	0.00	8.29	91.50	0.00	0.00	0.08	99.88
29000	99.27	88.98	67.01	99.27	88.89	1.81	34.01	99.80	99.88	13.24	68.27	0.00	8.31	91.50	0.00	0.00	0.08	99.88
29500	99.27	89.11	67.20	99.27	89.03	1.73	33.95	99.81	99.88	13.17	67.70	0.00	8.32	91.49	0.00	0.00	0.07	99.88
30000	99.28	89.23	67.38	99.28	89.15	1.66	33.89	99.82	99.89	13.10	67.13	0.00	8.33	91.49	0.00	0.00	0.07	99.89
30500	99.28	89.34	67.54	99.28	89.26	1.58	33.82	99.83	99.89	13.02	66.81	0.00	8.34	91.49	0.00	0.00	0.07	99.89
31000	99.28	89.43	67.69	99.28	89.36	1.49	33.74	99.83	99.90	12.94	66.22	0.00	8.34	91.49	0.00	0.00	0.07	99.90
31500	99.28	89.52	67.84	99.28	89.44	1.43	33.67	99.84	99.90	12.85	65.63	0.00	8.35	91.48	0.00	0.00	0.06	99.90
32000	99.28	89.59	67.98	99.28	89.52	1.38	33.59	99.85	99.90	12.77	65.30	0.00	8.36	91.48	0.00	0.00	0.06	99.90
32500	99.28	89.66	68.10	99.28	89.58	1.34	33.52	99.86	99.91	12.68	64.70	0.00	8.37	91.48	0.00	0.00	0.06	99.91
33000	99.28	89.71	68.21	99.28	89.64	1.32	33.45	99.86	99.91	12.60	64.09	0.00	8.38	91.48	0.00	0.00	0.05	99.91
33500	99.28	89.76	68.32	99.28	89.69	1.24	33.38	99.87	99.92	12.26	63.48	0.00	8.39	91.47	0.00	0.00	0.05	99.92
34000	99.28	89.81	68.41	99.28	89.73	1.22	33.30	99.88	99.92	12.17	63.14	0.00	8.40	91.47	0.00	0.00	0.05	99.92
34500	99.28	89.84	68.49	99.28	89.77	1.21	33.21	99.88	99.92	12.08	62.51	0.00	8.41	91.47	0.00	0.00	0.05	99.92
35000	99.28	89.87	68.56	99.28	89.79	1.20	33.13	99.89	99.93	11.99	62.16	0.00	8.42	91.47	0.00	0.00	0.04	99.93
35500	99.28	89.89	68.63	99.28	89.82	1.19	33.05	99.90	99.93	11.89	61.53	0.00	8.43	91.46	0.00	0.00	0.04	99.93
36000	99.27	89.91	68.70	99.27	89.84	1.18	32.66	99.90	99.94	11.79	60.89	0.00	8.44	91.46	0.00	0.00	0.04	99.94
36500	99.27	89.93	68.76	99.27	89.85	1.17	32.58	99.91	99.94	11.70	60.53	0.00	8.44	91.46	0.00	0.00	0.04	99.94
37000	99.27	89.93	68.81	99.27	89.86	1.17	32.50	99.92	99.95	11.61	59.89	0.00	8.45	91.46	0.00	0.00	0.04	99.95
37500	99.27	89.94	68.86	99.27	89.87	1.16	32.41	99.92	99.95	11.52	59.53	0.00	8.46	91.46	0.00	0.00	0.04	99.95
38000	99.27	89.94	68.90	99.27	89.87	1.12	32.32	99.93	99.96	11.41	58.87	0.00	8.47	91.45	0.00	0.00	0.04	99.96
38500	99.27	89.95	68.94	99.27	89.87	1.12	32.22	99.93	99.96	11.31	58.49	0.00	8.46	91.47	0.00	0.00	0.04	99.96
39000	99.26	89.95	68.98	99.26	89.87	1.11	32.11	99.94	99.97	11.21	57.82	0.00	8.43	91.49	0.00	0.00	0.04	99.97
39500	99.26	89.94	69.02	99.26	89.87	1.11	32.00	99.94	99.97	11.10	57.43	0.00	8.42	91.51	0.00	0.00	0.04	99.97
40000	99.26	89.94	69.05	99.26	89.86	1.11	31.90	99.95	99.98	11.00	57.06	0.00	8.43	91.51	0.00	0.00	0.04	99.98
40500	99.25	89.83	68.90	99.25	89.75	1.11	31.82	99.95	99.98	10.90	56.39	0.00	8.43	91.51	0.00	0.00	0.04	99.98
41000	99.24	89.83	68.92	99.24	89.75	1.11	31.72	99.95	99.98	10.80	56.00	0.00	8.44	91.50	0.00	0.00	0.04	99.98
41500	99.24	89.82	68.95	99.24	89.73	1.10	31.63	99.96	99.99	10.43	55.31	0.00	8.45	91.50	0.00	0.00	0.04	99.99
42000	99.24	89.81	68.97	99.24	89.72	1.10	31.52	99.96	99.99	10.32	54.92	0.00	8.45	91.49	0.00	0.00	0.04	99.99
42500	99.23	89.80	68.98	99.23	89.71	1.06	31.42	99.96	99.99	10.20	54.52	0.00	8.46	91.49	0.00	0.00	0.04	99.99
43000	99.23	89.79	69.00	99.23	89.70	1.06	31.31	99.96	100.00	10.09	53.81	0.00	8.46	91.49	0.00	0.00	0.05	100.00
43500	99.23	89.78	69.00	99.23	89.69	1.06	31.21	99.96	100.00	9.97	53.41	0.00	8.47	91.48	0.00	0.00	0.05	100.00
44000	99.23	89.77	69.01	99.23	89.67	1.06	31.12	99.96	100.00	9.88	53.02	0.00	8.47	91.48	0.00	0.00	0.05	100.00
44500	99.22	89.75	69.01	99.22	89.66	1.06	31.01	99.96	100.00	9.76	52.31	0.00	8.48	91.47	0.00	0.00	0.05	100.00
45000	99.22	89.74	69.01	99.22	89.65	1.06	30.91	99.96	100.00	9.65	51.90	0.00	8.48	91.47	0.00	0.00	0.05	100.00
45500	99.22	89.73	69.01	99.22	89.63	1.05	30.79	99.96	100.00	9.52	51.48	0.00	8.48	91.46	0.00	0.00	0.05	100.00
46000	99.21	89.71	69.00	99.21	89.62	1.02	30.68	99.96	100.00	9.40	50.75	0.00	8.49	91.46	0.00	0.00	0.05	100.00
46500	99.21	89.70	69.00	99.21	89.60	1.02	30.57	99.96	100.00	9.28	50.33	0.00	8.50	91.45	0.00	0.00	0.05	100.00

Height (ft MSL)	**Doppler**			**Dual Polarization**		**Minimum Detectable dBZ**				**H res. ≤ 1 km**		**V res. ≤ 500 ft**	**Radar Type**					
	1+	**2+**	**3+**	**1+**	**2+**	**< -15**	**< -5**	**< 18**	**< 30**	**Worst**	**Mean**		**TDWR**	**NEXRAD**	**ASR-9**	**ASR-11**	**ARSR-4**	**Any**
47000	99.21	89.69	69.00	99.21	89.59	1.02	30.46	99.96	100.00	9.16	49.91	0.00	8.50	91.44	0.00	0.00	0.05	100.00
47500	99.20	89.67	68.99	99.20	89.57	1.01	30.05	99.96	100.00	9.04	49.50	0.00	8.51	91.44	0.00	0.00	0.05	100.00
48000	99.20	89.65	68.99	99.20	89.55	1.01	29.94	99.96	100.00	8.67	48.76	0.00	8.51	91.44	0.00	0.00	0.06	100.00
48500	99.20	89.64	68.98	99.20	89.54	1.01	29.82	99.96	100.00	8.55	48.33	0.00	8.51	91.43	0.00	0.00	0.06	100.00
49000	99.19	89.62	68.96	99.19	89.52	1.01	29.70	99.96	100.00	8.41	47.89	0.00	8.52	91.43	0.00	0.00	0.06	100.00
49500	99.19	89.60	68.95	99.19	89.50	0.97	29.56	99.96	100.00	8.29	47.45	0.00	8.50	91.44	0.00	0.00	0.06	100.00
50000	99.18	89.59	68.94	99.18	89.48	0.97	29.42	99.96	100.00	8.15	47.01	0.00	8.47	91.47	0.00	0.00	0.06	100.00
50500	99.18	89.57	68.93	99.18	89.46	0.97	29.29	99.96	100.00	8.02	46.56	0.00	8.45	91.49	0.00	0.00	0.06	100.00
51000	99.18	89.55	68.92	99.18	89.44	0.96	29.17	99.96	100.00	7.90	45.81	0.00	8.45	91.49	0.00	0.00	0.06	100.00
51500	99.17	89.54	68.90	99.17	89.42	0.96	29.05	99.96	100.00	7.78	45.37	0.00	8.45	91.48	0.00	0.00	0.06	100.00
52000	99.17	89.52	68.89	99.17	89.41	0.96	28.93	99.96	100.00	7.65	44.93	0.00	8.45	91.48	0.00	0.00	0.07	100.00
52500	99.16	89.50	68.87	99.16	89.38	0.93	28.80	99.96	100.00	7.50	44.48	0.00	8.46	91.47	0.00	0.00	0.07	100.00
53000	99.16	89.48	68.86	99.16	89.36	0.92	28.67	99.96	100.00	7.37	44.02	0.00	8.46	91.47	0.00	0.00	0.07	100.00
53500	99.15	89.46	68.84	99.15	89.34	0.92	28.53	99.96	100.00	7.22	43.57	0.00	8.46	91.47	0.00	0.00	0.07	100.00
54000	99.15	89.44	68.82	99.15	89.32	0.92	28.39	99.95	100.00	6.83	43.11	0.00	8.46	91.47	0.00	0.00	0.07	100.00
54500	99.15	89.42	68.80	99.15	89.30	0.92	28.27	99.95	100.00	6.70	42.67	0.00	8.46	91.47	0.00	0.00	0.07	100.00
55000	99.14	89.40	68.79	99.14	89.28	0.92	28.15	99.95	100.00	6.57	41.90	0.00	8.46	91.47	0.00	0.00	0.07	100.00
55500	99.14	89.39	68.77	99.14	89.26	0.88	28.02	99.95	100.00	6.43	41.44	0.00	8.46	91.47	0.00	0.00	0.07	100.00
56000	99.13	89.37	68.75	99.13	89.24	0.88	27.88	99.95	100.00	6.28	40.97	0.00	8.46	91.46	0.00	0.00	0.08	100.00
56500	99.13	89.35	68.73	99.13	89.22	0.87	27.43	99.95	100.00	6.13	40.51	0.00	8.46	91.47	0.00	0.00	0.08	100.00
57000	99.12	89.33	68.71	99.12	89.20	0.87	27.29	99.95	100.00	5.98	40.04	0.00	8.46	91.46	0.00	0.00	0.08	100.00
57500	99.12	89.31	68.69	99.12	89.18	0.87	27.14	99.95	100.00	5.83	39.58	0.00	8.46	91.46	0.00	0.00	0.08	100.00
58000	99.11	89.29	68.67	99.11	89.15	0.84	27.01	99.95	100.00	5.69	39.12	0.00	8.46	91.46	0.00	0.00	0.08	100.00
58500	99.11	89.27	68.65	99.11	89.13	0.83	26.86	99.95	100.00	5.56	38.66	0.00	8.43	91.49	0.00	0.00	0.08	100.00
59000	99.10	89.25	68.63	99.10	89.11	0.83	26.70	99.95	100.00	5.15	38.18	0.00	8.40	91.52	0.00	0.00	0.08	100.00
59500	99.10	89.22	68.60	99.10	89.09	0.83	26.53	99.95	100.00	5.00	37.70	0.00	8.37	91.54	0.00	0.00	0.09	100.00
60000	99.09	89.20	68.58	99.09	89.06	0.82	26.38	99.95	100.00	4.84	37.22	0.00	8.37	91.54	0.00	0.00	0.09	100.00

GLOSSARY

3D	three dimensional
4D Wx Cube	four-dimensional weather data cube
AGL	above ground level
AP	anomalous propagation
ARENA	area noted for attention
AREPS	Advanced Refractive Effects Prediction System
ARSR-4	Air Route Surveillance Radar-4
ASR-11	Airport Surveillance Radar-11
ASR-9	Airport Surveillance Radar-9
ATL	Hartsfield-Jackson Atlanta International Airport
AVSET	automated volume scan evaluation and termination
BOS	Boston Logan International Airport
BWI	Baltimore/Washington International Airport
CASA	Collaborative Adaptive Sensing of the Atmosphere
CIWS	Corridor Integrated Weather System
CLE	Cleveland-Hopkins International Airport

CLT	Charlotte/Douglas International Airport
CONUS	contiguous United States
CVG	Cincinnati/Northern Kentucky International Airport
DAL	Dallas Love Field
DCA	Ronald Reagan Washington National Airport
DEN	Denver International Airport
DFW	Dallas/Fort Worth International Airport
DTED	Digital Terrain Elevation Data
DTW	Detroit Metropolitan Wayne Country International Airport
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FLL	Fort Lauderdale/Hollywood International Airport
FOC	full operational capability
HNL	Honolulu International Airport
HOU	Houston Hobby Airport
IAD	Washington Dulles International Airport
IAH	Houston George Bush Intercontinental Airport

IOC	initial operational capability
ITWS	Integrated Terminal Weather System
JFK	John F. Kennedy International Airport
JPDO	Joint Program Development Office
LAS	Las Vegas McCarran International Airport
LAX	Los Angeles International Airport
LGA	La Guardia Airport
LLWAS	Low-Level Wind-Shear Alert System
MCO	Orlando International Airport
MDW	Chicago Midway International Airport
MEM	Memphis International Airport
MIA	Miami International Airport
MOC	mid-term operational capability
MPAR	multifunction phased array radar
MSL	mean sea level
MSP	Minneapolis-St. Paul International Airport
NAS	National Airspace System

NEXRAD	Next Generation Radar
NextGen	Next Generation Air Transportation System
OEP	Operational Evolution Plan
ORD	Chicago O’Hare International Airport
PBI	Palm Beach International Airport
PDX	Portland International Airport
PHX	Phoenix Sky Harbor International Airport
PIT	Pittsburgh International Airport
RASS	radio-acoustic sounding system
RFI	radio frequency interference
RWI	Reduce Weather Impact
SAN	San Diego International Airport
SAS	single authoritative source
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport
SLC	Salt Lake City International Airport
SPG	Supplemental Product Generator

SRTM	Shuttle Radar Tomography Mission
STC	sensitivity time control
STL	Lambert-St. Louis International Airport
TDWR	Terminal Doppler Weather Radar
TPA	Tampa International Airport
WSP	Weather Systems Processor
WSR-88D	Weather Surveillance Radar 1988-Doppler

REFERENCES

Bieringer, P. E., B. Martin, B. Collins, and J. Shaw, 2004: Commercial aviation encounters with severe low altitude turbulence. Preprints, *11th Conference on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, American Meteorological Society, 11.3.

Cho, J. Y. N., 2005: Extended-range signal recovery using multi-PRI transmission for Doppler weather radars. Project Rep. ATC-322, MIT Lincoln Laboratory, Lexington, MA, 21 pp.

Cho, J. Y. N., 2008: TDWR dry site problem assessment and RDA software Build 3 recommendation. *Project Memorandum 43PM-Wx-0107*, MIT Lincoln Laboratory, Lexington, MA, 32 pp.

Cho, J. Y. N., 2009: Moving clutter spectral filter for Terminal Doppler Weather Radar, Preprints, *34th Conf. on Radar Meteorology*, Williamsburg, VA, American Meteorological Society, P5.2.

Cho, J. Y. N., and B. D. Martin, 2007: Technical assessment of the impact of decommissioning the TDWR on terminal weather services. Project Rep. ATC-331, MIT Lincoln Laboratory, Lexington, MA, 68 pp.

Cho, J. Y. N., and R. G. Hallowell, 2008: Detection probability modeling for airport wind-shear sensors. Project Rep. ATC-340, MIT Lincoln Laboratory, Lexington, MA, 64 pp.

Chrisman, J. N., 2009: Automated volume scan evaluation and termination (AVSET): A simple technique to achieve faster volume scan updates for the WSR-88D. Preprints, *34th Conf. on Radar Meteorology*, Williamsburg, VA, American Meteorological Society, P4.4.

Evans, J. E., and E. R. Ducot, 2006: Corridor Integrated Weather System. *Lincoln Laboratory Journal.*, **16**, 59-80.

FAA, 1989: Specification Terminal Doppler Weather Radar. FAA-E-2806b, Federal Aviation Administration, Washington, DC, 127 pp.

FAA, 2009: Four-Dimensional Weather Data Cube Single Authoritative Source (SAS) Final Performance Requirements (fPR), Version 1.0. Federal Aviation Administration, Washington, DC.

FAA, 2009a: Primary and nonprimary commercial service airports (by rank order). http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/media/cy08_primary_np_comm.pdf.

FAA, 2010: Sensor Network Assessment at NextGen IOC. RightSizing Project Team, AJP-6830, Federal Aviation Administration, Atlantic City, NJ, 64 pp.

Hallowell, R. G., J. Y. N. Cho, S. Huang, M. E. Weber, G. Paull, and T. Murphy, 2009: Wind-shear system cost benefit analysis update. Project Rep. ATC-341, MIT Lincoln Laboratory, Lexington, MA, 186 pp.

Heiss, W. H., D. L. McGrew, and D. Sirmans, 1990: NEXRAD: Next Generation Weather Radar (WSR-88D). *Microwave Journal*, **33**, 79-98.

Hopf, A. P., D. L. Pepyne, and D. J. McLaughlin, 2009: Topological considerations for a CONUS deployment of CASA-type radars. Preprints, *34th Conf. on Radar Meteorology*, Williamsburg, VA, American Meteorological Society, P8.4.

Istok, M. J., A. Cheek, A. D. Stern, R. E. Saffle, W. M. Blanchard, B. R. Klein, and N. Shen, 2009: Leveraging multiple FAA radars for NWS operations. Preprints, *25th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Phoenix, AZ, American Meteorological Society, 10B.2.

JPDO, 2006: Next Generation Air Transportation System Weather Concept of Operations, Version 1.0. Joint Program Development Office, Washington, DC, 60 pp.

JPDO, 2007: Concept of Operations for the Next Generation Air Transportation System, Version 2.0. Joint Program Development Office, Washington, DC, 219 pp.

JPDO, 2008: Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management. Joint Program Development Office, Washington, DC, 180 pp.

Lay, R. J., J. W. Taylor, Jr., and G. Brunins, 1990: ARSR-4: Unique solutions to long-recognized radar problems. *Proc. 1990 Int. Radar Conf.*, Arlington, VA, IEEE, 6-11.

Michelson, M., W. W. Shrader, and J. G. Wieler, 1990: Terminal Doppler Weather Radar. *Microwave Journal*, **33**, 139-148.

Patterson, W. L., 2007: Advanced refractive effects prediction system (AREPS). *Proc. 2007 Radar Conference*, Waltham, MA, IEEE, 891-895.

Skolnik, M., 2008: *Radar Handbook*, 3rd Ed. McGraw Hill, New York.

Souders, C., T. Kays, S. Spincic, F. Bayne, C. Miner, S. Abelman, R. Showalter, J. Tauss, L. Leonard, E. Dash, and J. May, 2010: Next Generation Air Transportation System (NextGen) weather requirements: An update. Preprints, *14th Conf. on Aviation, Range, and Aerospace Meteorology*, Atlanta, GA, American Meteorological Society, J4.1.

Stagliano, J. J., J. C. Kerce, and B. Valant-Spaight, 2009: Prediction and mitigation of anomalous propagation. Preprints, *25th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Phoenix, AZ, American Meteorological Society, 11B.5.

Taylor, J. W., Jr., and G. Brunins, 1985: Design of a new airport surveillance radar (ASR-9). *Proc. IEEE*, **72**, 284-289.

Wang, F., J. Li, T. J. Schmit, and S. A. Ackerman, 2007: Trade-off studies of a hyperspectral infrared sounder on a geostationary satellite. *Applied Optics*, **46**, 200-209.

Weber, M. E., 1999: Wind shear detection using the next generation Airport Surveillance Radar (ASR-11). Project Rep. ATC-266, MIT Lincoln Laboratory, Lexington, MA, 56 pp.

Weber, M. E., and M. L. Stone, 1995: Low altitude wind shear detection using airport surveillance radars. *IEEE Aerospace and. Electronic Systems Magazine*, **10**, 3-9.

Weber, M. E., J. Y. N. Cho, J. S. Herd, J. M. Flavin, W. E. Benner, and G. S. Torok, 2007: The next generation multi-mission U.S. surveillance radar network. *Bulletin American Meteorological Society*, **88**, 1739-1751.

Wilson, F. W., and R. H. Gramzow, 1991: The redesigned Low Level Wind Shear Alert System. Preprints, *4th Int. Conf. on Aviation Weather Systems*, Paris, France, 370.