10B.2

LEVERAGING MULTIPLE FAA RADARS FOR NWS OPERATIONS

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1. INTRODUCTION

The Federal Aviation Administration (FAA) operates hundreds of aircraft surveillance radars around the nation in support of its mission of managing the U.S. air transportation system. The primary responsibility of these radars is to identify and track aircraft. However, a secondary byproduct of the radars' continuous scanning is the capturing of weather information. The National Weather Service (NWS), part of the National Oceanic and Atmospheric Administration (NOAA), has partnered with the FAA to gain access to a number of different radar systems and has shown that their weather data can be a powerful supplementary tool for NWS forecasters for forecast and warning operations.

During the last several years, the NWS Headquarters Systems Engineering Center (SEC) within the Office of Science and Technology (OST), has developed a modification of the Weather Surveillance Radar – 1988 Doppler (WSR-88D) Radar Product Generator (RPG) to enable weather data from FAA radars to be ingested and processed to create products that can be transmitted to and integrated within the NWS Advanced Weather Interactive Processing System (AWIPS). To date, the NWS/SEC has developed such systems, termed Supplemental Product Generators (SPGs), for the Terminal Doppler Weather Radar (TDWR), the Air Route Surveillance Radar, Model 4 (ARSR-4), and the Airport Surveillance Radar, Model 11 (ASR-11).

During 2008, the NWS deployed SPG systems to NWS Weather Forecast Offices (WFOs) that are associated with the 45 TDWR systems. Development of SPGs for the ARSR-4 and ASR-11 radars has been completed, and these units are undergoing system testing with selected FAA radar sites. This paper will provide the latest information on the SPG program, including deployment status and the direction of future development.

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2. BACKGROUND

Around the turn of the century, meteorologists at several research facilities (Saffle et al, 2001, Vasiloff 2001, and Weber 2000) began to investigate if obtaining and integrating weather channel data from FAA radar systems would benefit forecast and warning operations. With the completion and deployment of the NWS Open Systems RPG (Saffle 2002), personnel at the NWS SEC began risk reduction activities to prototype ingesting, processing and displaying data from the TDWR and ARSR-4 (Stern et al, 2002, DiVecchio et al, 2003). In 2003, a web-based prototype was developed for the TDWR (Stern et al, 2004) and deployed to four NWS WFOs for evaluation. Later in 2003, the NWS decided to move forward with the development of a Linux-based processing system based upon the open architecture of the RPG (Istok et al, 2004). The ultimate result of this system would be to provide FAA-based weather radar products to the NWS AWIPS system using native WSR-88D formatting.

In 2004, the NWS established policy on the use of FAA weather radar data within NWS operations (Istok et al, 2005) and a team from the NWS/SEC developed the initial build of the SPG for the TDWR (Stern et al, 2005). In 2005, Build 1 of the SPG was deployed to 10 NWS field offices (Istok et al, 2005). TDWR systems played a part in observing land falling tropical cyclones during the very busy 2005 hurricane season (Istok et al, 2006).

During 2006, Build 2 of the SPG was completed for the TDWR (Istok, 2007). Build 2 provided forecasters with full resolution base products and a subset of WSR-88D algorithm-based products. Design and development of the SPG Build 3 was completed in 2007 and deployment to all eligible WFOs took place during the second half of 2008 (Istok et al, 2008). Figure 1 contains details about TDWR pairings with NWS WFOs.

Also, during 2008, SPGs were developed for the ARSR-4 and ASR-11 systems. Testing and evaluation of the ARSR-4 SPG is currently underway with live data connections to the Watford City, ND ARSR-4 (paired with NWS WFO Bismarck, ND) and to the Makah, WA ARSR-4 (paired with NWS WFO Seattle, WA). Testing and evaluation of the ASR-11 is also underway with a live connection to the Erie, PA ASR-11 (paired with NWS WFO Cleveland, OH).

Additional development of SPG capabilities will be described below in the "Future Activities" section.

3. COMPARING NWS AND FAA RADARS

Stern et al (2003) and Weber (2000) provided capability descriptions and technical comparisons between the NWS WSR-88D and several FAA radars that contained weather channels. Since then, the WSR-88D has undergone several life cycle improvements such as an updated Radar Data Acquisition (RDA) processor as well as the implementation of new scanning strategies.

Figure 1 serves as an update to these graphics, taking into account these improvements. The deployment of the new WSR-88D RDA processor has enabled implementation of improved reflectivity range resolution (down from 1 km to 250 m), increasing the maximum Doppler range from 230 km to 300 km, and improved azimuth resolution (down from 1 degree to 0.5 degrees azimuth) on the low elevation split cuts. The use of new volume coverage patterns has reduced the total processing time of some hazardous weather strategies from 6 minutes down to 4.2 minutes.

	WSR-88D	TDWR	ARSR-4	ASR-11
Antenna				
Peak Power	750 kW	250 kW	65 kW	25 kW
Beam Width	0.95 Degrees (on Average)	0.55 Degrees	1.41 Degrees	1.41 Degrees
Power Gain	45.5 dB	50 dB	N/A	34 dB
Minimum Elevation	0.5 Degrees	0 Degrees	Adjustable Phased Array	Fan Beam
Maximum Elevation	19.5 Degrees	60 Degrees		
Maximum Rotation Rate	6 RPM	5 RPM	5 RPM	12 RPM
Transmitter				
Frequency	S Band	C Band	L Band	S Band
Wavelength	10.5 cm	5.3 cm	21.4 – 24.7 cm	10.3 – 11.1 cm
Polarization	Linear Horizontal	Linear Horizontal	Linear & Circular	Linear & Circular
Maximum Reflectivity Range	460 km	460 km	460 km	111 km
Minimum Unambiguous Doppler Range	115 km	90 km	N/A	N/A
Maximum Doppler Range	300 km	90 km	N/A	N/A
Range Resolution (Reflectivity)	250 m	150 m (to 135 km) 300 m (135-460 km)	460 m (0.25 nm)	926 m (0.5 nm)
Range Resolution (Velocity)	250 m	150 m	N/A	N/A
Volume Scan Time				
Clear Air/Monitor Mode	10 min	6 min		
Severe/Hazardous Mode	4.2 min	6 min		
Single Operating Mode		1 min low elevation scans	~ 1 min	~ 1 min

Figure 1 – Comparing technical specifications between the WSR-88D and the TDWR, ARSR-4 and ASR-11 radar systems.

4. TDWR SPG STATUS

Full scale deployment of the TDWR SPG was completed during 2008. Hardware was delivered and installed in 34 NWS WFOs for connections to 45 operational TDWRs. At the time of this writing (December 2008), all TDWR systems had data connections to WFOs except for those at John F. Kennedy International Airport (New York City) and Reagan National Airport (Washington, D.C.). These last two systems were waiting for communications to be finalized. Figure 2 shows a national map indicating the locations of each TDWR along with their paired NWS WFO.

All of the deployed systems contain Build 3.0 of the TDWR SPG. Build 3.0 provides forecasters with not only full resolution base products (reflectivity, velocity and spectrum width) but also a full suite of derived products. Figure 3 shows the storm analysis, derived reflectivity and precipitation products that are being generated within the TDWR SPG and transmitted to AWIPS within NWS offices. During the winter of 2008-2009, TDWR SPG Build 3.1 will be sent to all SPG host sites. This intermediate deployment will provide patches for both system maintenance and upgraded security and should be transparent in terms of operations.

Deployment of the TDWR SPGs has added a valuable supplemental source of radar data for the NWS operational forecasting mission. The high resolution data and fast, 1-minute refresh rate are allowing forecasters to observe and study weather phenomena from multiple viewpoints.

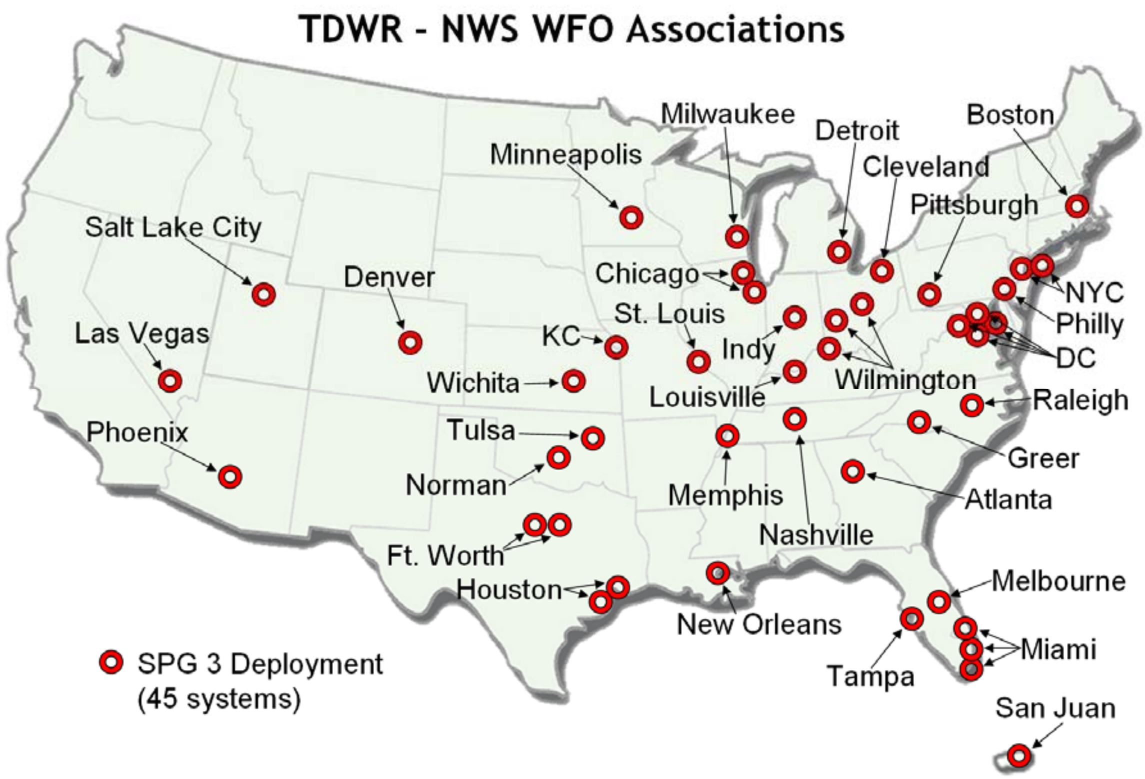

Figure 2 – Locations of the 45 operational TDWR systems and their NWS WFO pairings

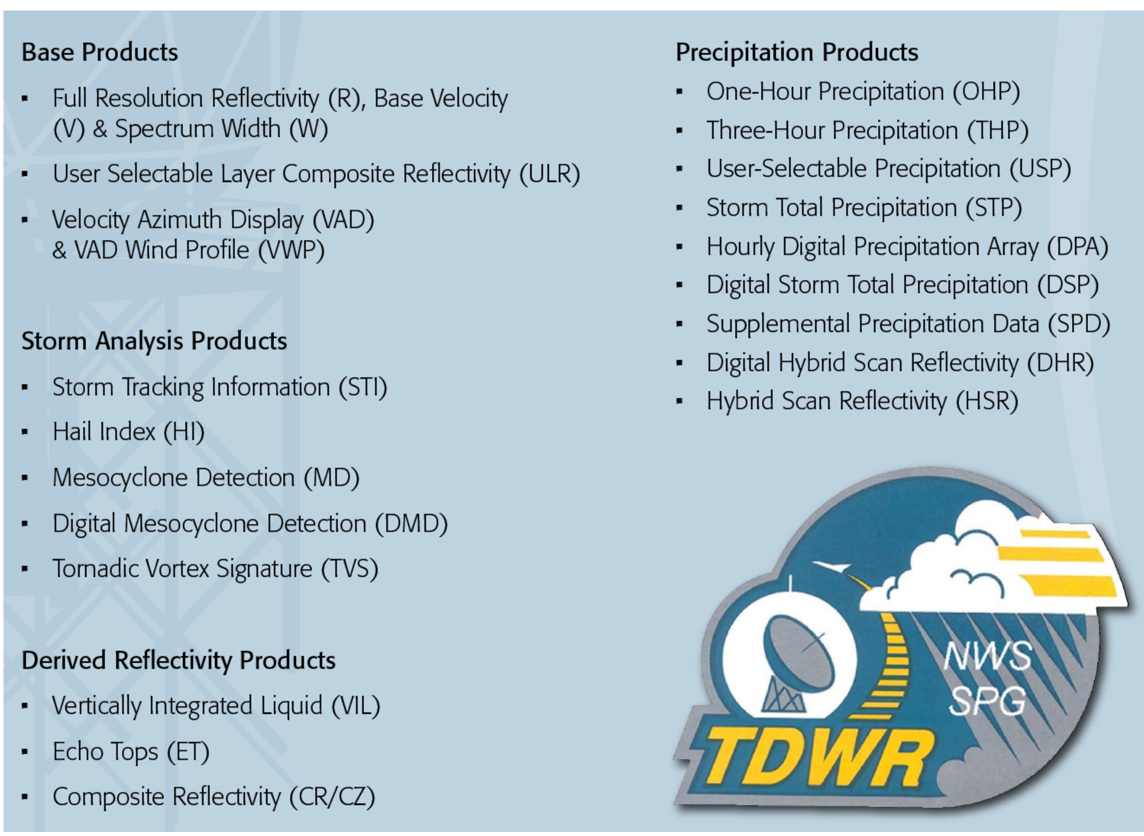

Figure 3 – The full complement of base and derived products available within AWIPS through use of the TDWR SPG Build 3.0

An example of this new capability is shown in Figure 4. During mid August 2008, Tropical Storm Fay moved across the Florida peninsula. At 18:45 UTC on 19 August 2008, as Fay was moving northeastward across Lake Okeechobee, NWS forecasters at the Tampa, Melbourne and Miami forecast offices were able to observe the evolution of Fay and focus on potential weather hazards using SPG-generated products. The fast refresh rate for the velocity products was valuable in assisting forecasters in Miami with issuing tornado warnings for portions of the Gold Coast.

Figure 5 shows how AWIPS can take TDWR base velocity data and create a storm relative velocity (SRM) product for use in warning operations. In this case, the NWS WFO in Miami was able to issue a tornado warning for the community of Wellington, FL with a 28 minute lead time. The tornado produced EF2 damage with estimated winds of 115 mph. Additional details can be found in the NWS preliminary storm report available at: www.srh.noaa.gov/mfl/events/?id=fay_tornadoes.

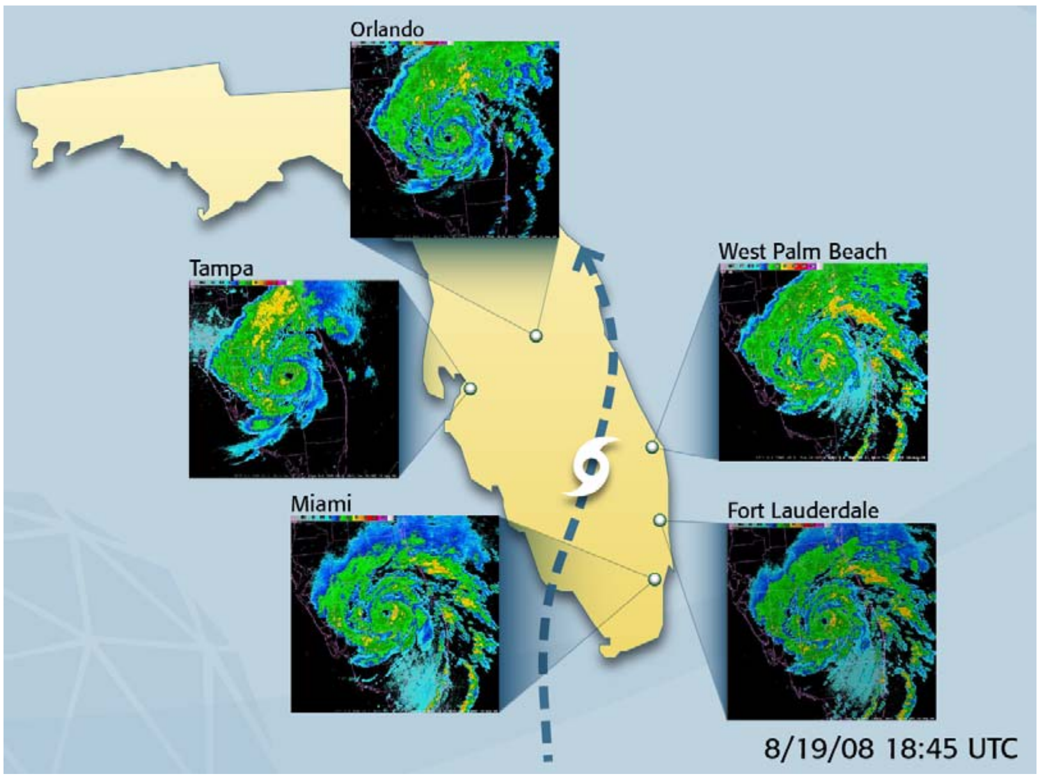

Figure 4 (above) – Simultaneous viewing of Tropical Storm Fay at 18:45 UTC 19 August, 2008 from five TDWR systems. Each image is a TDWR SPG 8-bit long range base reflectivity product.

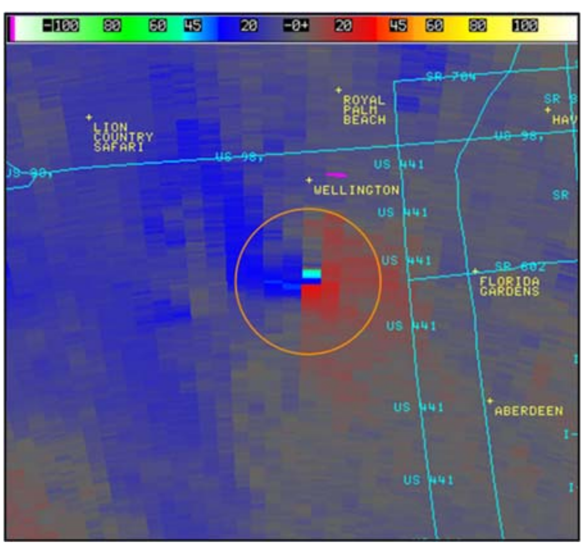

Figure 5 (left) – The Wellington, FL tornado as seen from the Fort Lauderdale (TFLL) TDWR at 05:30 UTC 19 August 2008 during the passage of Tropical Storm Fay. The image is close-up of a.0.3 Degree Storm Relative Motion (SRM) product. The tornado vortex signature is located within the orange circle.

5. ARSR-4 SPG STATUS

The ARSR-4 is a joint FAA and Department of Defense (DoD) program whose mission is to provide aircraft position information to the FAA, Air Force, Navy and Customs Service. As a secondary function, the ARSR-4 also provides weather information to both the FAA and NWS. In mid 2000, the FAA completed deployment of 40 ARSR-4 systems around the periphery of the continental United States (Figure 6).

Different from conical-beam radars, the ARSR-4 uses phased array technology to electronically direct radar beams toward targets or regions of interest. The NWS is able to obtain reflectivity data from a subset of the ARSR-4 systems. The ARSR-4 provides reflectivity values binned according to NWS Video Integrator and Processor (VIP) categories (USDOC, 1981).

The VIP categories are used to group radar reflectivity (in dBZ) into six levels:

- VIP 1 (Level 1, 18-29 dBZ)
- VIP 2 (Level 2, 30-40 dBZ)
- VIP 3 (Level 3, 41-45 dBZ)
- VIP 4 (Level 4, 46-50 dBZ)
- VIP 5 (Level 5, 51-56 dBZ)
- VIP 6 (Level 6, ≥57 dBZ)

Due to processing limitations on the ARSR-4, only five of the six levels are available at any one range. Closest to the radar, VIP levels 1 through 5 are available. However, beyond the “level 1 switch range,” only VIP levels 2 through 6 are reported. The intent of the level 1 switch range is to set it to the range where the radar signal noise approaches the threshold of VIP 2, or 30 dBZ. Thus, the ARSR-4 sends VIP 1 data where radar sensitivity allows, but at the sake of VIP 6 data. This range can vary but is generally about 60 nautical miles (nm) or 111 km.

The reflectivity product generated by the FAA processing of the ARSR-4 data is a hybrid scan, combining higher elevation angle data closer to the radar with the lowest elevation data at farther ranges. This strategy is intended to minimize ground clutter returns. The ranges at which data from one elevation angle stop being used, and data from the next lower elevation angle begin to be used are called “beam switch ranges.” These switch ranges are adaptable data for each ARSR-4. The NWS and FAA will experiment at each ARSR-4 site used by the NWS to establish the best compromise settings for combined NWS and FAA use.

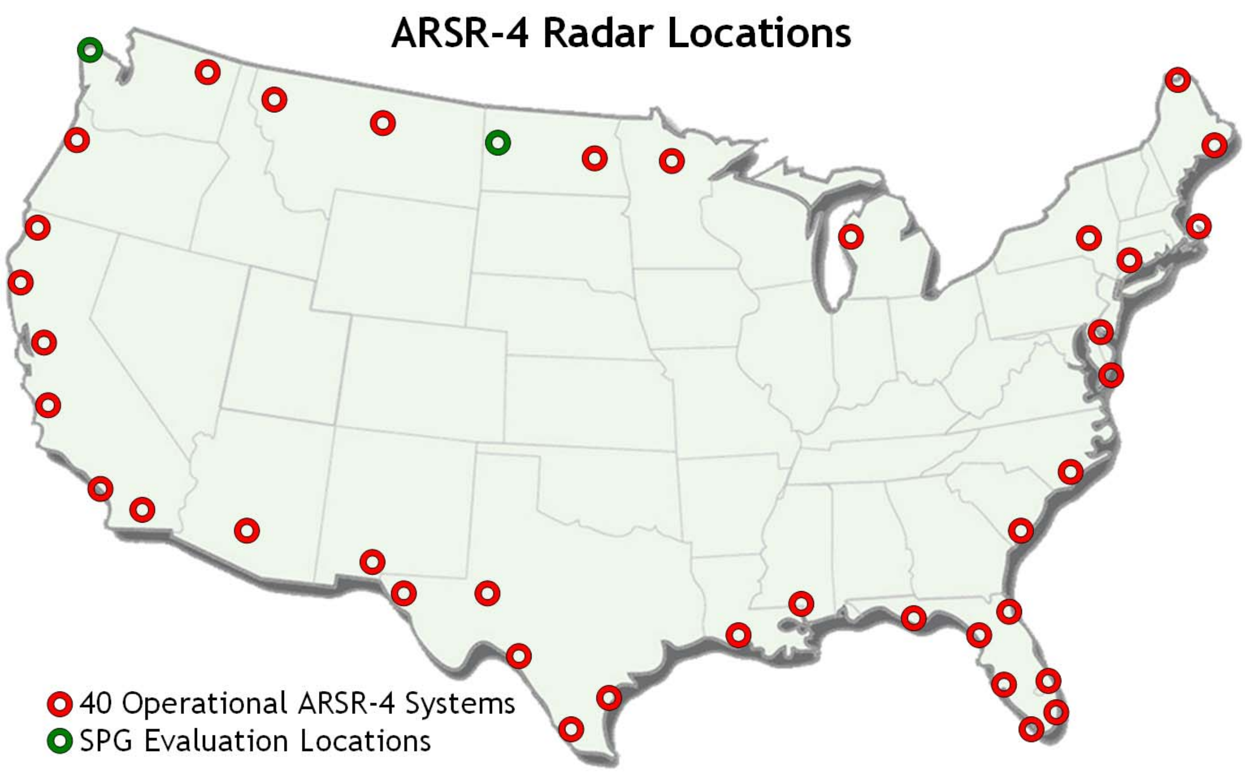

Figure 6 – ARSR-4 radar locations. Sites not shown are Guantanamo Bay, Cuba, Santa Rosa, Guam, and Mount Kaala, HI. The two test and evaluation sites (shown in green) include Watford City, ND and Makah, WA.

Adaptation of the SPG to receive and process data from the ARSR-4 has been completed. For the ARSR-4 prototype SPGs, all data processing and software support are provided by the NWS SEC in Silver Spring, MD. Two ARSR-4 systems supply live data in support of SPG testing and operational evaluation. The ARSR-4 SPG generates a hybrid scan reflectivity product at a rate of approximately one per minute. The products from the Watford City, ND ARSR-4 are forwarded to the Bismarck, ND WFO for inclusion into AWIPS. Products from the Makah, Washington State ARSR-4 are forwarded to the Seattle, WA WFO.

Figure 7 shows an example of how the ARSR-4 is extending radar coverage over the coastal region of Washington State. Data from the Makah Washington ARSR-4 (left image) shows terrain blockage to the north and east of the radar. However the radar coverage over the Pacific Ocean clearly supplements the WSR-88D observations from the system based north of Seattle. The reduced precipitation area within 60 nm (111 km) of the ARSR-4 (as shown by the apparent reduction in echoes close to the radar, Figure 7 left image) is due to the beam switch ranges in effect -- the lowest elevation data start being used at the range of 60 nm (111 km). Evidently, most of the precipitation did not have enough vertical development to reach the higher elevation angles within 60 nm (111 km) of the radar.

Because the ARSR-4 does not utilize the same type of scanning strategies as the WSR-88D and TDWR, and the Doppler velocity data are not available to the NWS, only a limited number of SPG-based products can be generated. Presently, a hybrid scan reflectivity product is being generated. In the future, the NWS Office of Hydrologic Development will be evaluating whether precipitation estimates from the ARSR-4 data would be valuable to NWS operations.

A study will also be performed to determine which other ARSR-4 sites would enhance forecast and warning operations and would warrant connection to a SPG. Also, it has not yet been determined if the ARSR-4 SPG processing will be performed centrally (e.g., NWS Headquarters) or distributed (e.g., at WFOs).

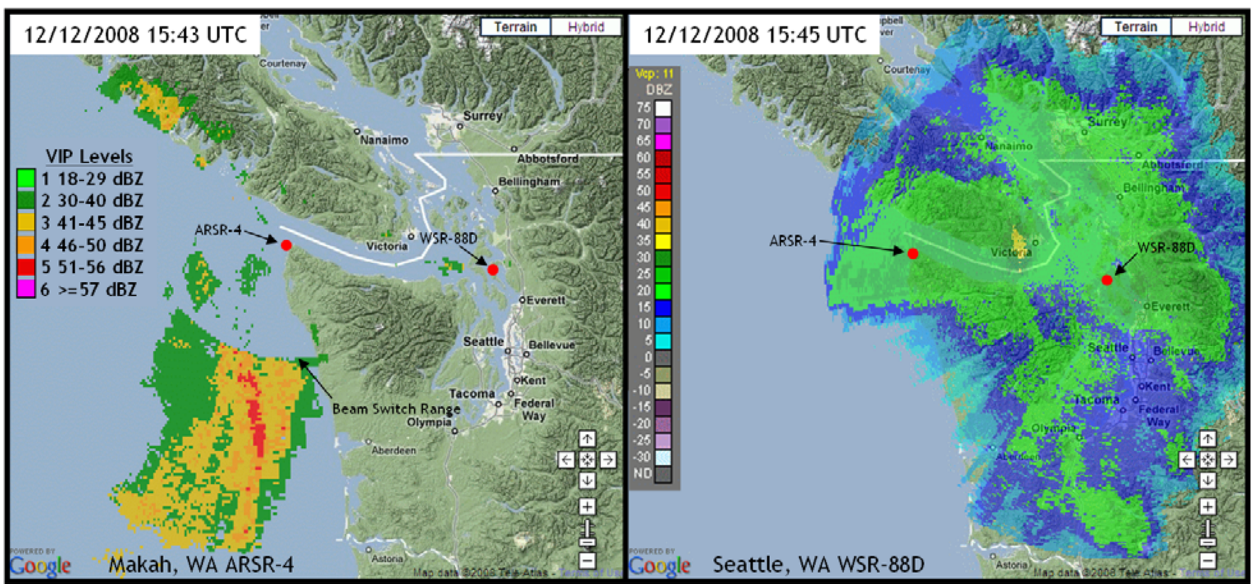

Figure 7 – Precipitation event over Western Washington State in mid December 2008. Left image shows the complementary coverage offered by the Makah ARSR-4. The right image shows precipitation (and terrain blockage to the southwest) of the WSR-88D located just north of Seattle, WA.

6. ASR-11 SPG Status

The Airport Surveillance Radar, Model 11, or ASR-11 is a next-generation solid-state, terminal area air traffic control radar used by both the FAA and DoD. The ASR-11 has been deployed to replace aging analog systems at 65 military and civilian airfields across the country (Figure 8).

Adaptation of the SPG to receive and process data from the ASR-11 has been completed. Similar to the ARSR-4, all processing and software support are currently provided by the NWS/SEC in Silver Spring, MD. At the present time, one ASR-11 system is providing live data in support of testing and evaluation. The ASR-11 SPG generates a reflectivity product at a rate of approximately one per minute. Each product consists of VIP Levels 1 through 6. Since the ASR-11 antenna is a fan-beam in the vertical, the product represents a vertical integration of reflectivity within the beam. Radar products from the Erie, PA ASR-11 are forwarded to the Cleveland, OH WFO for inclusion into AWIPS.

Figure 9 shows an example of data from the Erie, PA ASR-11 during a day with scattered convection along the coastal regions of Lake Erie.

A study will be performed to determine which other ASR-11 sites would enhance forecast and warning operations and would warrant connection to a SPG. Also, it has not yet been determined if the ASR-11 SPG processing will be performed centrally (e.g., NWS Headquarters) or distributed (e.g., WFOs).

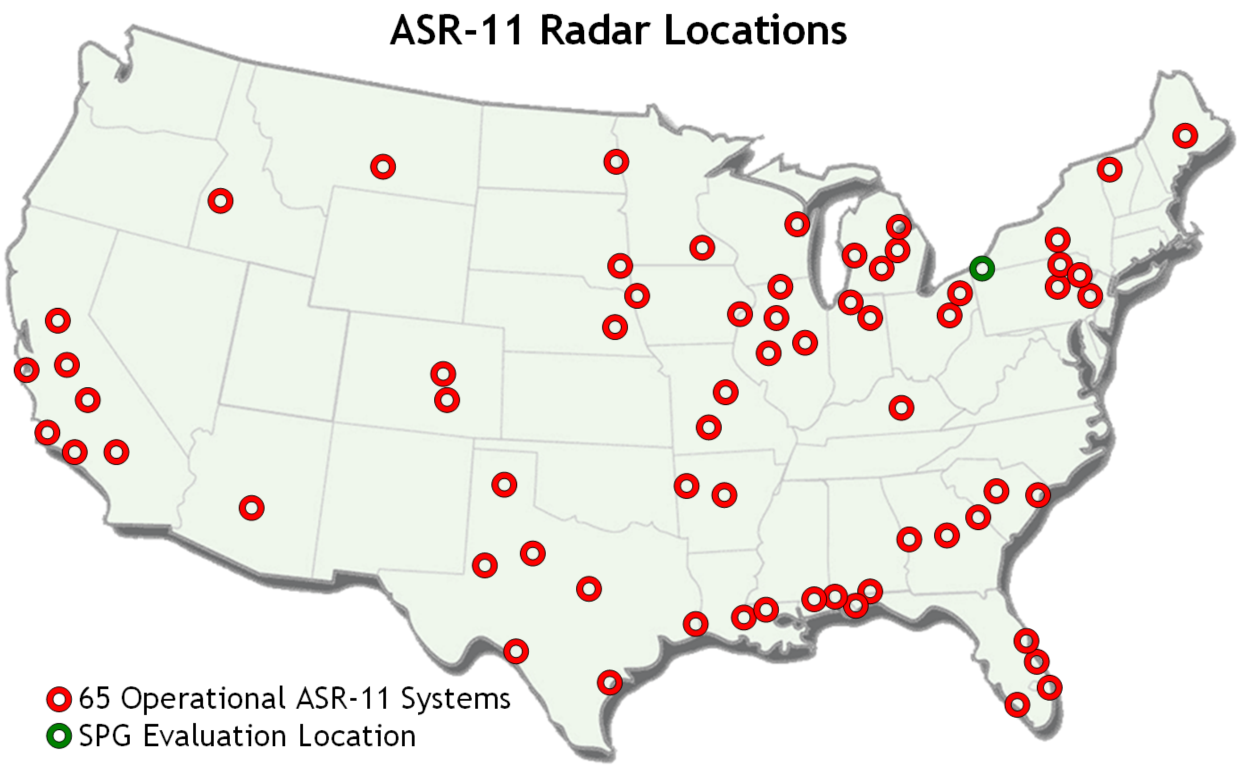

Figure 8 – ASR-11 locations in the Continental U.S. Sites not shown are Fairbanks, AK, Anchorage, AK and Kahului, HI. The location in green (Erie, PA) represents the current SPG test and evaluation system.

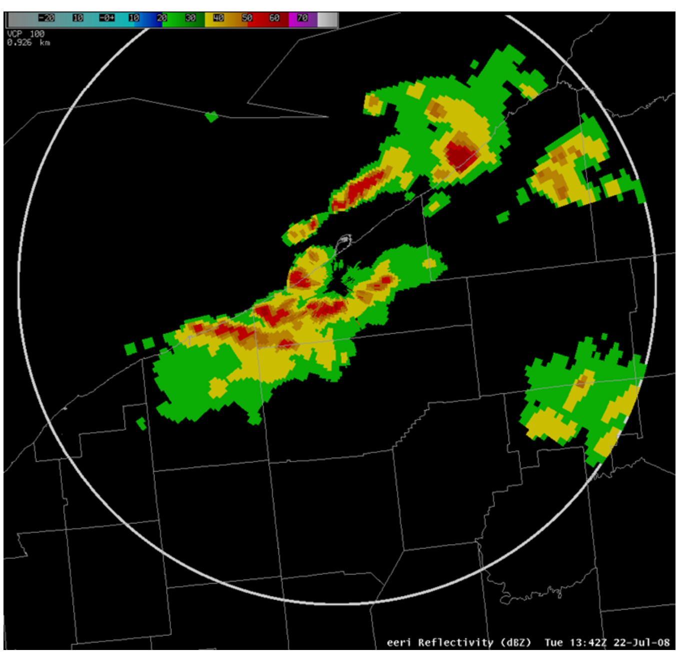

Figure 9 – Scattered convection as captured by the Erie, PA ASR-11 SPG processor prototype from 22 July 2008.

7. CENTRAL DATA COLLECTION AND MONITORING

Similar to the WSR-88D, the NWS has begun to centrally collect and make available Archive Level III products from the TDWR SPGs. Descriptions of available weather radar data files can be found at www.nws.noaa.gov/tg/radfiles.html. The products can be obtained from the NWS Telecommunication Gateway on the server ftp://tgftp.nws.noaa.gov/ via anonymous FTP, NOAAPORT, and from National Climatic Data Center (NCDC) radar product archives. Currently, six locations have their data available on line. The remaining stations will gradually become available during the first half of 2009. As sites are added, status and free text messages will be available from the NWS Level III Radar Site status web page at http://weather.noaa.gov/monitor/radar3/.

The NWS also has plans to provide a display capability for SPG-generated radar products, similar to what is available for the WSR-88D. The next generation of the Radar Integrated Display with Geospatial Elements (RIDGE) will be able to display radar products from the TDWR, ARSR-4 and ASR-11 systems. Beta testing of the new version of RIDGE is planned for early 2009. Figure 10 provides an example of what a TDWR product may look like in the new system.

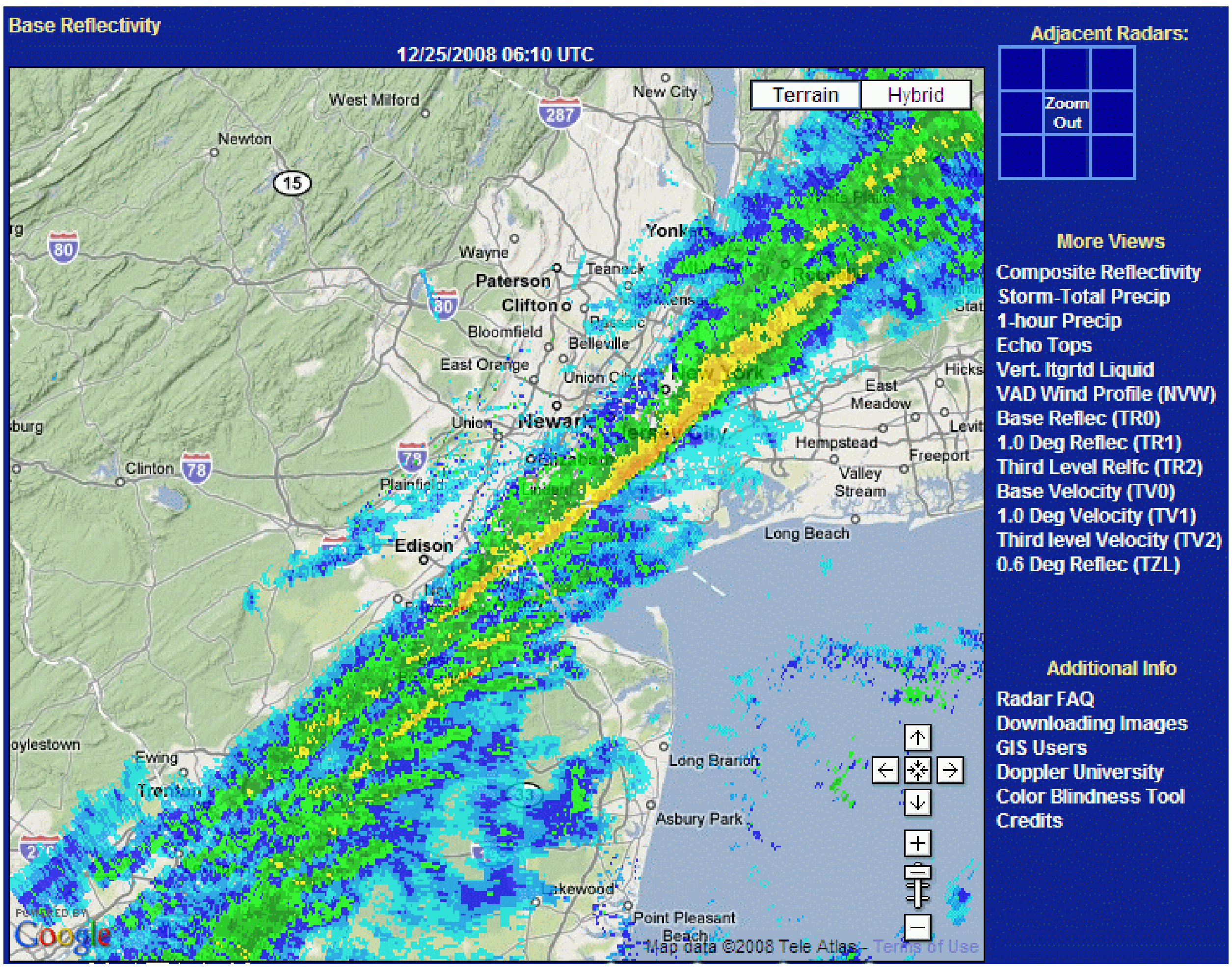

Figure 10 - Example of reflectivity data from the Newark, NJ TDWR as seen on a next generation RIDGE web page.

8. FUTURE ACTIVITIES

During 2009, a number of SPG-related activities are planned.

8.1 *TDWR*

Similar to the current WSR-88D level 2 distribution capability, the NWS/SEC is evaluating whether to make this data set available for the TDWR and what resources might be required. If the decision is made to implement this capability, then it is likely it will be included in a new Build 4 release of the TDWR SPG.

The FAA is working with the Massachusetts Institute of Technology/Lincoln Laboratory to update and enhance the TDWR Radar Data Acquisition (RDA) system. Tests of Build 1 of the rehosted RDA have been underway at Salt Lake City and Las Vegas. This initial build will provide upgraded processing power but no changes for SPG data users. A second build for the TDWR RDA is scheduled for 2010 which would add improved velocity dealiasing, remove one of the redundant low elevation scans near the beginning of each volume and add an additional 1.0 degree scan.

The NWS Warning Decision Training Branch has created training modules to support the use of TDWR SPG Build 3.0. The training modules are open and available to anyone online at www.wdtb.noaa.gov/buildTraining/SPG3/index.html.

8.2 *ARSR-4/ASR-11*

The NWS is working with the FAA to determine if switch range settings in the ARSR-4 can be better optimized for NWS forecast and warning operations. The NWS will also be conducting a study to determine which, if any, additional sites would enhance WFO operations, and therefore should have SPG processing for ARSR-4 or ASR-11 data.

8.3 *Canadian Radars*

The NWS SEC is currently exploring the possibility of developing a SPG for the Canadian C-band weather radars. It is possible that a prototype SPG could be developed for evaluation during calendar year 2009.

9. CONCLUSION

The NWS continues to take advantage of leveraging opportunities with partner government agencies to obtain weather channel data from operational radars. During 2008, the NWS completed fielding SPGs to connect 45 TDWR systems to 34 WFOs. The NWS Warning Decision Training Branch developed online training modules for meteorologists to learn about TDWR SPG Build 3.0. During the winter of 2009, maintenance build 3.1 will be deployed to all TDWR SPG locations.

Prototype SPGs have been developed for the ARSR-4 and ASR-11 aircraft surveillance radars. To evaluate the ARSR-4, live data is being provided from the Watford City, ND and Makah, WA radars to SPGs located at the NWS/SEC in Silver Spring, MD. Radar products are then sent to the associated WFOs at Bismarck and Seattle. To evaluate the ASR-11 SPG, live data is being obtained from the Erie, PA radar with radar products sent to the WFO at Cleveland.

The NWS has begun to centrally collect, distribute, and archive level III radar products from the TDWR SPG. It is expected that products from all 45 TDWR systems will be available for download by mid 2009. The NWS is also working on the next generation of display software for the web. A new version of RIDGE will undergo beta testing in early 2009 and will have the capability to display products from the TDWR, ARSR-4 and ASR-11 radars.

The NWS will continue to evaluate which FAA radar sites would enhance WFO operations and make good candidates for SPG processing. This activity is ongoing. In addition, there will be discussions with Environment Canada about including Canadian radar data into the SPG suite of processing.

The SPG program has already produced many new case studies and has shown to be a valuable supplement to the WSR-88D radar network. It is hoped that these new data sets will assist meteorologists in their forecasting and warning mission.

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