NOAA TECHNICAL MEMORANDUM NWS SR-168
REPORT ON THE SOUTHEASTERN UNITED STATES WSR-88D USERS' WORKSHOP PATRICK AIR FORCE BASE, FLORIDA FEBRUARY 22-23, 1995

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Introduction

Since their deployment, WSR-88D Doppler radars have become an invaluable tool to the operational meteorologist in Florida. They have been successfully used to evaluate weather conditions during severe events such as Florida's record hail storm in the Orlando area (March 1992); Hurricane Andrew (August 1992); the "Storm of the Century" (March 1993); the Marion County Tornado (January 1995); and Tropical Storms Alberto, Beryl, and Gordon (July, August, and November, 1994, respectively). In addition, the radars have been used to support civil and military aviation operations as well as the nation's space program at Kennedy Space Center.

The experience gained from both operational and research uses of WSR-88D data has also called attention to the need for further enhancements in radar algorithms as various regional biases have become evident. In response to this need and with the intent of focussing on improving radar applications in the Southeast generally, and the Florida area particularly, the 45th Weather Squadron (45WS) at Patrick AFB, together with the Melbourne National Weather Service Office, jointly sponsored the first Southeastern WSR-88D Users' Workshop. Approximately 50 individuals from about 30 organizational units attended representing the NWS, USAF, Navy, NASA, and the academic community (Florida State University).

The workshop was on February 22-23, 1995, at Patrick AFB. It had three major goals. The first goal was to open triagency (Departments of Defense, Transportation, and Commerce) dialogue in the area of concern, sharing among radar users the general experiences and specific problems encountered when applying the radar to the Florida environment. The second goal was to encourage dialogue among WSR-88D users in Florida and the WSR-88D Operational Support Facility (OSF) in Norman, Oklahoma, to address algorithm enhancements. The third major goal was to form relationships that could serve to solve problems, improve coordination, and fulfill training requirements. Overall, the focus of the workshop was to encourage issue-related discussion while setting an example for future WSR-88D workshops which might be held in other regions. The intent of this document is to communicate the experiences gained during the workshop toward these ends.

Day One
Opening Remarks

Lt Col Adang (Commander/45WS) welcomed all participants of the workshop on behalf of the 45th Weather Squadron. Adang shared with the group his vision and theme for the workshop. Agenda items and speakers (Appendix A) were selected to uncover locally-specific issues related to the radar. He recognized that the family of WSR-88D users in Florida is growing with the number of radars now in continual surveillance at Eglin AFB; NWSOs Melbourne, Tallahassee, Jacksonville, and Tampa Bay Area (Ruskin); and NWSFO Miami. Many additional triagency facilities are associated users connected with these radars. He conveyed the significance of the workshop setting an example so that future workshops such as this one might be held at other places.

David Sharp (Science Operations Officer/NWS Melbourne) also greeted the participants. He provided some historical background of the WSR-88D at Melbourne, describing its installation in late 1991 as a Limited Phase Production (LPP) radar. He further described its uniqueness as the first WSR-88D to be deployed in a near tropical environment. Algorithms which were written to accomodate Great Plains weather were now being used in the moisture-rich regime of the humid Southeast. Although utilizing the WSR-88D during severe weather has improved the local forecast and warning decision process, optimization of the radar algorithms for the local environment has not yet been achieved. He stressed that the purpose of the workshop was to serve as a forum for suggesting improvements to current algorithms, assessing operator proficiency and understanding, and nurturing inter-office/agency communication (Biggar, Roeder, and Sharp, 1995). Sharp re-emphasized the issue-related aspect of the workshop in contrast to the "presentation" style of many conferences.

Morning Session

Lt Col Tim Crum (Applications Branch Chief/OSF) was present as representative of the OSF.

His first presentation was divided into two parts:

Upcoming WSR-88D Software Changes. Crum began by explaining the various Software Build definitions and their scheduled release dates. Basically, there are two types of software releases: planned (12 to 18 month cycle) and emergency. Build 6.1 is defined as the NWS commissioning software. Build 7.0 is identical to Build 6.0 but with redundancy capabilities. It is the basis for Builds 7.1 and 8.0. It is the last major government contractor (UNISYS) WSR- 88D software release. Build 7.1 will be installed at only very selected sites to provide spot blanking capability. Build 8.0 is recognized as the first major OSF software release (spring 1995). It will replace Builds 6.0 and 7.0 with several enhancements and many corrections. Build 9.0 is scheduled for release in the summer of 1996 and will be considered the common software baseline.

Crum then reviewed the highlights of Build 8.0 which will be installed on most Florida radars by this summer (1995). Build 8.0 contains 143 approved Configuration Change Requests (CCRs). Among the major fixes are PUP dial-up map correction (RAMTEK hangs), elimination of ghost products, reduced RPG pauses due to unexpected timer expiration, and PUP dialup queue corrections on error conditions. Some new functionality and improvements include software support for the Level II recording jukebox, UCP editable data levels for precipitation products, unambiguous range extension to 94 nm, linear motion estimates, and rotational velocity/shear estimates.

The role of field sites for implementing changes into subsequent builds was also considered. Field sites can submit requests for change through individual agency chain of authority. For NWS Southern Region, changes may be submitted through the Regional NEXRAD Focal Point (W/SR42x1). Military units should submit change requests through their major commands. When submitting, express the relative operational importance of the change request. Communication with the OSF HOTLINE is encouraged. From time to time, field sites will also be asked to participate in a Beta Test of new software builds. Algorithm Enhancement Process/New Algorithms. Crum then spoke concerning the WSR- 88D Technical Needs List.

The current prioritized list (February 1995) is as follows:

(1) WSR-88D Level II Data Archive of Storm Phenomena

(2) Velocity Dealiasing/Range Unfolding

(3) Data Quality Assessment

(4) Severe Weather Detection and Forecasting

(5) Feature Detection, Tracking, and Forecasting Techniques

(6) Precipitation Analysis Techniques

(7) Wind Analysis Techniques

(8) Data Acquisition Rate Needs and Strategies

(9) Interpretive Techniques/Human Interface Techniques

(10) Tropical Cyclone Analysis Techniques

(11) Data Compaction and Transmission Techniques

(12) Icing Analysis Techniques

(13) Turbulence Analysis Techniques

There is much activity in the realm of meteorological algorithm enhancement. An enhanced hail algorithm has already been delivered to the OSF. An enhanced mesocyclone algorithm and Tornadic Vortex Signature (TVS) algorithm are scheduled to be delivered this year (1995). Likewise, progress is being made in the areas of velocity dealiasing and data quality. In addition to enhanced algorithms, several new algorithms are being written. These include algorithms to estimate the liquid equivalent for snow, a damaging downburst algorithm, and improved precipitation preprocessing algorithms accounting for Z/R relationships and bright band detection/mitigation.

With any current, enhanced, or new algorithm, the OSF retains responsibility for its scientific integrity; however, for any meteorological algorithm to reach full maturity, adaptable parameter optimization for a specific location must be achieved. Since the chore of adaptable parameter optimization is too large for the Applications Branch alone, the OSF will be porting algorithms to local sites for evaluation on Scientific Applications Computers (SACs). An algorithm guide with instructions will also be provided. Playback of archived Level II data tapes will be the key ingredient. At certain sites, some algorithms may be tested in real time via an additional wideband connection.

Dr. Peter Ray (Chairman, Meteorology Department, FSU)

Archive II Weather Event Database. From a research perspective, Ray expressed that with the growing network of WSR-88D radars and digital base data recorders (Level II data), there will soon be terabytes of high quality Doppler radar data. More so, both the NWS and the USAF have committed to fitting all radars with Level II recorders. This volume of information will quickly become unmanageable unless appropriate procedures are adopted to document and catalog what is recorded.

Under the Cooperative Institute of Tropical Meteorology (CITM), Ray has been working on creating a Weather Event Database. He stated that identifying and cataloguing "interesting" weather events must occur on-station as they happen. If not, valuable data sets could become irretrievably lost in the volume of recorded data. Once logged, event reports would later be sent at regular intervals to a central location for database storage and access by interested users. Data tapes themselves would be sent to the National Climatic Data Center (NCDC) where a Level II data archive has already been established. Ray envisions that researchers would have interactive access to the database (via Mosaic and the World Wide Web), having the ability to search for specific events by type, location, and/or time. A specific data request could then be submitted to the NCDC. Ray commented that he would like to work with Florida radar stations on this project on a trial basis.

Crum stated that the OSF was exploring the possibility of an Archive II Event Log. He stressed OSF's focus on standardization of policy for the national network of radars. Sharp commented that the Melbourne NWSO was currently testing several variations of an Event Log for efficiency and workload. From this, perhaps, interested parties could begin construction of a national database. Ray noted that one of his graduate students, Charlie Paxton (Science Operations Officer, NWSO Tampa Bay Area), was assessing the potential of automation via the Radar Coded Message (RCM).

Mark Wheeler (Applied Meteorology Unit/NASA/ENSCO)

WSR-88D Exploitation Tasks. Wheeler is a member of the Applied Meteorology Unit (AMU) at NASA/ENSCO. He described the purpose of the AMU as an entity to test, evaluate, and develop new technologies, techniques, and processes resulting in improved weather forecasts by the 45 WS and the Spaceflight Meteorology Group (SMG) at Johnson Space Center in support of NASA's space program. The WSR-88D is part of the new technology available for operational transition. Consequently, an inquiry of proposed WSR-88D exploitation tasks was taken among members of the AMU tasking group (45WS, SMG, and NWS Melbourne).

Wheeler announced that the following two tasks were agreed upon for AMU consideration:

(1) WSR-88D Signatures for the Initiation of Convection

(2) Investigating severe vs. non-severe storm signatures over East Central Florida and adjacent coastal waters

These two exploitation tasks will be written into the AMU"s comprehensive taskings through 1996. The taskings will focus around radar operator techniques with the integration of other data streams. Case study analyses will be supported by the replay of archived Level II data.

Mr. Pinder (45WS/DOR)

WSR-88D Support to Space Shuttle Launch and Ground Processing Operations. Currently, products from two radars are used by Range Weather Operations (RWO) for Space Shuttle Launch and Ground Processing Operations. The WSR-88D at Melbourne is used in conjunction with the WSR-74C/McGill radar at Patrick AFB. Although the McGill radar is based on 25-year old technology and is a "one of a kind" system, it is a highly flexible weather radar controlled and operated by the USAF. Conversely, the WSR-88D at Melbourne represents modern technology with maintenance and operations costs not solely the responsibility of the USAF. The WSR-88D also has improved sensitivity (clear air mode) and Doppler capability, but it supports a variety of other weather-related functions beside NASA/USAF ground and launch operations. This comparison is derived from the cost versus benefit analysis of continuing to maintain and operate the WSR-74C/McGill radar (Taylor, 1994).

Pinder expressed his confidence in the McGill radar and noted it was his primary source of radar information during launch. Radar is one of the tools used to sample the atmosphere in an 85 km radius cylinder from the launch site.

Vertical regions of interest are as follows:

(1) Rain showers and cumulus clouds 1 - 4 km AGL

(2) Thunderstorms and lightning potential 4 - 8 km AGL

(3) Thunderstorm anvils and debris clouds 8 - 12 km AGL

Pinder identified the delay in return of one-time request products from the WSR-88D as one deficiency of the radar in support of launch operations.

Mr. Richard Lafosse (Spaceflight Meteorology Group/Johnson Space Center)

WSR-88D Support to Space Shuttle Landing Operations. LaFosse began by describing the communications configuration of the Spaceflight Meteorology Group (SMG) PUP. The SMG PUP can be associated to either the Melbourne WSR-88D for Shuttle landing operations or to the Houston radar for local JSC applications. This is achieved through the OSF-supplied "switch" software package. The fact that this software exists is little known, and it is apparently used only in certain unique configuration circumstances.

Lafosse commented on the importance of the WSR-88D for SMG operations. The decision to land the Shuttle at Kennedy Space Center or divert the landing to Edwards AFB is based on specific weather constraints at the Shuttle Landing Facility (SLF). The decision to divert to Edwards AFB is very expensive for the taxpayer, since considerable cost (millions of dollars) is involved in ferrying the Shuttle back to KSC. However, attempting to land at the SLF under adverse conditions poses a safety threat for the crew as well as risk of damage to the spacecraft.

He explained the KSC Weather Flight Rule constraints as:

(1) Ceiling at or above 8,000 ft

(2) Visibility greater than or equal to 5 nmi

(3) Winds less than or equal to 25 nts

(4) Cross-wind less than or equal to 15 kts

(5) No Precipitation or thunderstorm anvil within 20 nmi for launch 30 nmi for landing

Lafosse also presented an example from Shuttle flight STS-68 on October 11, 1994, during which the WSR-88D at Melbourne was used to make critical decisions while a major weather system was affecting central Florida.

American Meteorological Society (Local Chapter) Luncheon

Guest Speaker, Lt Col Tim Crum (OSF). "Overview of the WSR-88D OSF, or What the OSF Can Do For You."

The February gathering of the local chapter of the AMS was held over lunch at the Non-Commissioned Officers' Club at Patrick AFB. Crum was the featured speaker. He offered area meteorologists and interested guests an overview of the WSR-88D national network and the support role of the OSF. Both attendance and interest were high.

Afternoon Session

Capt Biggar (45WS/SYR). Tour of Range Weather Operations at Cape Canaveral Air Force Station and the Kennedy Space Center

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Day Two

Ssgt Michael (Eglin AFB, FL Weather Flight) Summary of Tropical Storm Alberto Workshop at Eglin AFB, Florida. Shortly following the landfall and subsequent floods associated with Tropical Storm Alberto, NWSO Tallahassee and Eglin AFB co-sponsored a one-day workshop in July 1994 to discuss the performance of WSR-88Ds located in north Florida, central Alabama, and central Georgia. Ssgt Michael shared experiences during the landfall of Alberto across the north Florida Panhandle (Korotky, Michael, and Williford, 1995). He also provided a brief summary of the subsequent workshop.

As Alberto crossed the Florida shoreline on July 3, the WSR-88D at Eglin AFB was in continual surveillance. In addition to the obvious threat due to increased wind and seas, there was an imminent threat of severe weather associated with individual thunderstorms within rain bands. Although cells were discernable in base reflectivity, potential severity of a given thunderstorm was difficult to ascertain. Velocity information was essential for sorting the severe from the non- severe. The Storm Relative Velocity Map (SRM) and the Storm Relative Velocity Region (SRR) proved to be most valuable for this determination. With manual input of observed storm motion, the SRR worked well in determining individual thunderstorm structure.

When assessing the complete field of storms within the radar's Doppler range, the SRM also worked well; but it should be understood that the spiraling nature of rain bands associated with tropical cyclones often results in non-uniform thunderstorm motion. Manual entry of storm motion was therefore required. Oddly, a storm motion of 0 degrees/0 kts revealed the most beneficial velocity information, since bin values of highest magnitude were painted instead of values from every fourth bin when compared to base velocity. This allowed operators to concentrate on those storms with the strongest winds. It was also suggested that manual input of the translational speed of the cyclone itself into the SRM would have likely revealed important characteristics of cyclone symmetry. This information would have been available to associated PUPs, but not to non-associated PUPs due to the manual intervention. Perhaps a future software build would allow for manual input of storm motion using the PARAM1 and PARAM2 options at the Unit Control Position (UCP).

At the time of landfall, Archive Level II or III installation/recording was not supported at USAF facilities. As a consequence, little data were saved during Alberto. Through coordinated efforts, Archive IV data were recorded at NWSO Tallahassee and Eglin AFB during the storm. Recent changes to policy will allow for Level II recording hardware to be installed on all DoD (and NWS) radars. There are no current plans (as of February 1995) for fitting DoD sites with Archive Level III archiving capability, however.

Mr. Muro (Robins AFB, Georgia, Weather Flight)

WSR-88D Estimated Rainfall from Tropical Storm Alberto. Muro followed with a chronology of Tropical Storm Alberto after landfall, with particular attention given to rainfall accumulations across Georgia and Alabama (Muro, 1994).

As Alberto moved inland, associated tropical rains fell for several days over Georgia and Alabama. Observed rainfall broke all-time records across the two-state area. Americus, Georgia, reported 24.48 inches in a 24-hr period. Deaths from the Georgia flood waters tallied 25. The WSR-88D at Robins AFB was in operation during this time and mapped well the location and trend of the heaviest rainfall. In fact, a time-lapse of the One Hour Precipitation (OHP) product proved extremely valuable. Unfortunately, derived accumulations were grossly underestimated when compared to observed readings. Over time, as the radar translated rainfall rates into accumulations, estimates became less and less reliable. Post-analyses showed derived accumulations from the Storm Total Precipitation (STP) product to be underestimated by a factor of 1.5 to 2. It should be noted that real-time rain gauge information was not available to the radar for bias calculations. Furthermore, painted data on the STP product was truncated at 15.0 inches, which further handicapped operator assessment.

Some other precipitation related shortcomings:

(1) There is the genuine need for a 24-hr precipitation accumulation product.

(2) Means to allow for operator defined STP events is needed.

(3) Operators should be able to define precipitation accumulation data levels according to the event. (This is a featured improvement for Build 8.0.)

Peggy Glitto and Leon Mazarowski (NWS Melbourne)

WSR-88D Estimated Rainfall from Tropical Storm Gordon. As with Tropical Storm Albert, Gordon furnished copious amounts of rain. Fortunately for residents of east-central Florida, the heaviest rainfall was just offshore. Many areas did receive over 10 in of rain, however, within a 72-hr period. Much of this rain fell over the St. Johns River Water Management District's rain gauge network. Combined with other gauge readings, a total of 122 gauge totals within 124 nm were compared with derived values from the STP. Glitto and Mazarowski presented preliminary work on their paper concerning the event (Choy, Mazarowski, and Glitto, 1995).

Glitto explained the precipitation processing scheme of the WSR-88D. She reviewed the hybrid scan strategy as well as the concept of bi-scan maximization. She also presented the Z/R relationship employed by the radar (Z=300R1.4) and the range of dBZ values considered as liquid rainfall reaching the ground (18 to 53 DBZ). She further described the computation and application of a multiplicative bias when real-time gauge network information later becomes available to the radar.

Mazarowski then outlined the methodology and results from their study. The OSF (Kelly, 1994) provided systematic procedures for rainfall comparison involving information from the radar's HYPROD.DAT file. Accumulations were compared to an array of STP bins (either 9 bins or 25 bins) centered about a given gauge location. Comparisons were made using the center, best fit, maximum, minimum, and average of bins.

Conclusions point to a significant underestimation of rainfall by about one-third. Applying a uniform bias of 1.35 across the field would have provided more realistic numbers in this case. Bias factors from both Alberto and Gordon should be considered during future tropical events until either the precipitation processing algorithms become more robust or until the rain gauge data acquisition network becomes functional. Closer inspection indicates a greater degree of accuracy could be achieved if more than one bias were to be applied based on range from the radar.

Mr. Colin McAdie (National Hurricane Center [NHC])

Hurricane Operations and the WSR-88D. McAdie reviewed a plan for hurricane operations as related to the WSR-88D (McAdie, 1994). Historical background and future expectations for this plan were described. The plan (Appendix B) would serve to define a level of cooperation among offices and agencies, and the NHC, during a tropical cyclone event, with a goal of obtaining the most useful WSR-88D data possible. An agreed upon mode of operation would facilitate use of multiple radars during an event. This would support the common interests of both adjacent offices and national centers such as NHC. The plan offers recommendations for consideration by local Unit Radar Committees (URCs) and the specific UCP commands to accomplish them. The most important items of the plan are the accessibility and proper manipulation of eight-data level velocity products, as well as changing the Velocity Measurement Increment if expected velocities would be in excess of 124 kt.

The following items are particular to the WSR-88D and were discussed individually relating to the plan:

(1) **Operational Mode and Volume Coverage Pattern (VCP)**. The preferred Mode/VCP during a tropical cyclone event is A/21. VCP 21 allows for nine individual elevation slices in a six-minute period. The slower scan rate of the antenna (compared to VCP 11) will result in better velocity estimates (less smearing of velocity data). Also, the potential for loadshedding will be less, since the scan period is six minutes instead of five (compared to VCP 11). It was pointed out that, if necessary, VCP 11 could be used for short-term evaluations of specific features.

(2) **Velocity Data Levels**. It is well understood that the WSR-88D offers base velocity products with either 16 or 8 data levels. The 16-data level products are most commonly used, but field ingenuity has uncovered great utility for the 8-data level products. Since the actual range of values are defined on separate tables at the UCP, the 8-data level products could be used as an extension of the 16-data level products. For example, the maximum displayed velocity for 16-data level products is typically +64 kt. The corresponding 8-data level products could be set up to display higher velocity ranges up to + kt and 100 kt (NHC recommended) to accomodate tropical storm/hurricane force winds. Valuable information could be formatted for display without altering display ranges for the 16-data level products.

(3) **Velocity Measurement Increment**. Routinely, the WSR-88D measures velocities to the accuracy of 0.5 m/s (0.97 kt). This allows for encoded velocities up to +124 kt. Most tropical cyclones will fall within this upper limit; however, Category 4 and 5 hurricanes (such as Andrew and Camille) have winds in excess of 124 kt. When attempting to measure such speeds, it becomes necessary to modify the current VCP, changing the Velocity Measurement Increment from 0.5 m/s to 1.0 m/s (0.97 kt to 1.94 kt). Although the degree of accuracy to which velocities are measured is sacrificed somewhat (degraded from roughly 1 kt to 2 kt), the radar is then able to measure velocities up to +248 kt. Again, these changes must be made at the UCP. It is important to note that changing the Velocity Measurement Increment does not directly affect the way in which velocities are displayed; rather, it directly affects the way in which velocities are measured. Fortunately for the operator, when the change is made, two other unique tables are used to format the velocity data levels for display (again, one for 16-data level and another for 8-data level products). The corresponding 8-data level products could be set up to display velocity ranges up to +115 kt and 135 kt (NHC recommended).

(4) **Non-Associated PUP Access to Needed Products**. Although much has been said concerning the utility of the 8-data level velocity products, it is extremely important to note that currently they are not required to be made available to non-associated PUPs, according to minimum product sets established in Federal Meteorological Handbook No. 11, Part A (FMH, 1991). This means that non- associated PUP operators with area warning responsibility, or national centers, would not have access to these products by default. In fact, NHC would like access to the Composite Reflectivity product (.54 nm) as well. It should be understood that URCs have the power to grant access to these

additional products to non-associated PUPs. This effort will require changes (additions) to the Generation and Distribution Control list (Adaptation version recommended).

Scott Spratt (NWS Melbourne)

Mesocyclone Identification During Tropical Storm Gordon. During the time when Tropical Storm Gordon affected areas of east-central Florida, the WSR-88D at Melbourne indicated the development of numerous mesocyclone circulations within a detached rain band over the Atlantic coastal waters. Five of these circulations prompted the issuance of severe weather warnings. Interestingly, four of these circulations were not initially detected (or were not detected at all) by the current mesocyclone algorithm. One of these landfalling circulations produced the Barefoot Bay (Brevard County) tornado, leaving a damage path three miles long. Another developed into an extremely persistent circulation which moved well inland. This storm produced a short-lived tornado. Neither of these tornadoes were detected by the algorithm, despite their close proximity to the radar.

Spratt described the performance of the current mesocyclone algorithm (and Tornadic Vortex Signature algorithm) as it attempted to interpret mesoscale features associated with Gordon (Spratt, 1995). In general, complete reliance on algorithm output would have been detrimental; manual interpretation was essential, using the mesocyclone/warning criteria established by OSF when considering whether to issue severe thunderstorm warnings. However, if based solely on those criteria, tornado warnings would not have been issued for any of the circulations. This suggests situational adjustments to the criteria, coupled with forecaster knowledge and skill.

Spratt offered several operational recommendations, including the assessment of rotational velocity trends (especially as circulations move closer to shore), examination of rotational diameter (for tighter rotation), and performing volume scan restarts for frequent updates of low and mid-level velocity information. Spratt also suggested that reducing the number of pattern vectors within the mesocyclone algorithm (adaptable parameter - TPV) from 10 to a lower value would increase the likelihood of circulation detection. The parameter TPV defines the minimum number of vectors needed to define a 2-D feature. A word of caution: this could result in more false alarms.

Lt Barry Choy (NOAA Corps, NWS Melbourne)

WSR-88D Approach to Waterspout Forecasting. Choy gave a brief interview of an approach to anticipating waterspout development using the WSR-88D (Choy and Spratt, 1995). These concepts and techniques are currently exercised at NWS Melbourne but might be used at other locations that are prone to waterspouts. Initially, conditions conducive to spout formation should be identified. It has been shown that a high percentage of spouts form within a deep moist layer from near the surface to at least 500 mb, accompanied by weak tropospheric winds. Spouts often form along marine boundaries or at the intersection of boundaries. In either case, recognizing rapid cell intensification becomes important.

Low level, horizontal vortices are inherent features along shear axes and convergence zones. Occasionally the updraft from a developing convective cell becomes collocated with a vortex along the boundary, resulting in upward stretching within the column and subsequent funnel formation (Wakimoto and Wilson, 1989). Mapping cell growth trends and boundaries are strong points for the WSR-88D. Cell growth can be charted by noting increasing trends with the Echo Top (ET) product, the Vertically Integrated Liquid (VIL) product, as well as Composite/Layered Composite Reflectivity products (CR and LRM respectively).

Detection of actual waterspouts is more difficult. Due to the size of most waterspouts, velocity signatures are often unresolvable, especially at distances greater than 30 nm from the radar. Data from various elevations of SRM and 0.13 nm resolution Base Velocity (V) have proven to be the most useful. Choy noted that Base Spectrum Width (SW) information may also be of benefit.

Marine Experiences and the SWIFT BOAT Experiment. Choy continued his marine-related discussion by sharing recent experiences during the SWIFT BOAT project. Using a "fast boat," NWS Melbourne personnel undertook efforts to verify WSR-88D returns in real time (Choy and Trexler, 1994). On single-day missions during the months of January and August 1994, they set out to observe and document various marine phenomena over the coastal and intracoastal waters of east-central Florida. Communicating by cellular phone, WSR-88D operators navigated mission specialists toward echoes. Manual surface observations were taken and logged. Photographs and video were taken of more interesting features. Instruments mounted on the boat provided wind speed and direction, temperature and pressure measurements. In addition, an optical rain gauge was mounted to capture rainfall from showers which were encountered. Comparisons to WSR-88D data were then made.

Josh Korotky (NWS Tallahassee)

Tracking a Gulf of Mexico Derecho Using the WSR-88D. Korotky presented two contrasting cases of derechos encountered by NWS Tallahassee over the past year. Both events resulted in severe weather and were captured by the WSR-88D. One case (June 25, 1994) involved a long- lived bow echo which developed over the northern Gulf of Mexico and moved onshore at Panama City, Florida. The local environment was highly buoyant and highly sheared. The upright convection showed high reflectivities, tight reflectivity gradients, and high echo tops. Severe weather potential was tracked very easily with the WSR-88D. A contrasting case (February 12, 1995) was also presented. It also consisted of a long-lived bow echo, but with much more subtle features. The local environment was highly sheared, but buoyancy was much lower when compared with the first case. Reflectivities and echo tops were much lower, although the associated severe weather was just as significant. The severe weather threat was better tracked with velocity information. Korotky surmised that resulting pressure perturbations within the system helped to sustain the life of the bow echo while contributing to its severity.

Korotky also embellished on the utility of alternate color schemes for certain products displayed at the PUP. He showed several examples. One more interesting example was an alternate color scheme for base reflectivity products where values less than 15 dBZ (traditionally shades of blue) were changed to grayish. Korotky commented that too many times valuable information in the lower reflectivities is "filtered out" because current low-end colors are visually distracting. The intent is to keep as much cloud and boundary information on the display without it being a nuisance to the operator.

Maj Roeder (45WS/SYR)

Problems with Chaff and the WSR-88D. Roeder summarized how chaff can affect weather radars, and he outlined some identification procedures (Roeder, 1995). Chaff consists of metal foil or highly reflective strands of other material which is dropped (usually at high altitudes) by military aircraft for the purpose of masking aircraft operations. Unfortunately, chaff can also mask meteorological signals, or at least complicate the forecaster's job of interpreting meteorological returns which chaff is present. This is especially important during rapidly changing weather conditions. Numerous chaff events have been observed with the WSR-88Ds over Florida. In fact, chaff may cause the radar to switch from clear-air mode to precipitation mode in the absence of actual precipitation.

The DoD Eastern Area Frequency Coordinator (EAFC) issues "Chaff Deconfliction Messages" to preclude chaff drops that would affect Space Shuttle and other launches. Unfortunately, these messages are not always honored. Roeder then presented the three primary radar signatures used by the 45WS when determining chaff:

(1) Distinctive Banded Structure

Roughly parallel to wind
Moves with the wind

(2) Representative Terminal Velocity

Falls at about 3,000 ft/min
Spreading due to tumbling and turbulence

(3) WSR-74C/McGill returns about 17 dBZ weaker than Melbourne WSR-88D

5 cm vs 10 cm

Frank Alsheimer (NWS Tampa Bay)

Evaluating WSR-88D VIL as a Severe Thunderstorm Signature. Alsheimer presented techniques and considerations for use with the WSR-88D VIL product which have been found to be helpful at NWS Tampa Bay Area for evaluating thunderstorm severity. A VIL-of-the-Day (VOTD) can be calculated from the latest sounding using the following equation:

VOTD = 750 / [(/T500mb/ + T400mb /) x 0.5]

Adjustments can be made using forecast temperatures to account for thermal advection. After deriving the VOTD, the corresponding alert threshold should be set at the PUP (rounded to the nearest 5).

During an event, VIL trends can be useful (Paxton and Shepherd, 1993). Alsheimer said that an increase of 15 kg/m2 (or more), to a value greater than the VOTD in a single scan, points to potential severity. Also, an increase of 20 kg/m2 (or more), to a value greater than the VOTD over two to three scans, has been deemed insignificant. Other tips include looking for larger contiguous areas with values greater than the VOTD and using adjacent radars to cross-check VIL estimations. When dialing up a nearby radar for VIL comparison, one should always consider the VCP in current use with both radars (which affects the resolution in the vertical) and the relative time synchronization between radar volume scans.

Lt Col Tim Crum and David Sharp (Applications Branch/OSF and NWS Melbourne, respectively).

VCP Dependent Reflectivity Discrepancies and Subsequent Investigation. Sharp began by describing the sequence of events that led to an investigation of VCP dependent reflectivity discrepancies concerning the WSR-88D at Melbourne. In preparation for a Tropical Rainfall Measuring Mission (TRMM) Algorithm Intercomparison Workshop, a possible calibration discrepancy between the low-level surveillance tilts and those of the upper tilts were noted (Wolff, 1994). A reduction in dB was observed in areas close to the radar, resulting in rainfall underestimation for those same areas. The problem was linked to the "batch-cut" slices at 2.4 degrees and above. Obvious concern was raised, since the problem is likely to be inherent for all WSR-88D radars. The OSF was asked to investigate.

Crum then presented OSF findings related to this problem (Smith, 1995). Reflectivities associated with near zero velocities were indeed reduced for batch-cut elevation angles. In VCP 21, a reduction of 5 dB was found at 2.4 degrees with a reduction of approximately 1-2 dB at higher slices. In VCP 11, a reduction of 10-15 dB was experienced at 2.4 degrees, with 2-3 dB reduction at higher slices. The cause was linked to unintentional clutter filtering within the Bypass Map. Corrective measures have been identified with an urgent release of corrective information to Melbourne (January 1995). There were no inherent software errors or hardware design flaws, only adjustments to various adaptable parameters at the Radar Data Acquisition (RDA) computer.

Marie Trabert (Operations Training Branch/OSF)

NWS Centralized WSR-88D Training Program. Trabert was asked to speak on the status of available OSF training. The OSF still supports an 18-day course for all NWS meteorologists and hydrologists who utilize the radar. The primary focus of the course is to train PUP operators. During each month, two classes are taught simultaneously. A reduction to one class per month is expected during fiscal year 1996, since it is projected that the majority of NWS users will have been trained. A three-day UCP course primarily for SOOs and radar focal points is held four times per year. There have been requests for this course to be opened to NWS hydrometeorological technicians (HMTs). Other related training efforts include a short manager's course and a special topics course (engineering); both are available upon request.

An exciting new OSF training effort involves a series of "Regional Concerns" workshops. Each NWS region will have the opportunity to concentrate on regionally-specific weather problems in customized workshops hosted by the OSF. The initial Southern Region workshop will be held in July 1995, including tropical/marine aspects of radar application as a major focus.

In the future, the OSF Training Branch will continue to provide distance learning, computer- based modules for local training. Plans are being drafted for an Advanced Training course for meteorologists as well.

Msgt Kaczmarek (Weather Training School/Keesler AFB)

Air Force Centralized WSR-88D Training Program. The DoD no longer sends students to the OSF for WSR-88D training. The Weather School at Keesler AFB has implemented a complete training course (23-days) for DoD weather personnel. Kaczmarek discussed the curriculum and format. He stated that training was achieved by sending one or two people from each Weather Unit to Keesler. Later, a visiting instructor would train remaining forecasters on- station. It was also noted that some WSR-88D training has been incorporated into the USAF Forecasters School. Kaczmarek said that during the 1994 calendar year nearly 50 DoD Weather Units were trained.

David Sharp (NWS Melbourne)

Training Issues for a Local National Weather Service Office. Sharp spoke briefly about local NWS training related to the WSR-88D. The majority of NWS PUP operator training for meteorologists is achieved at the OSF Training Branch 18-day course. However, conceptual and interpretative skills are improved through experience and follow-on training. At Melbourne, a Level IV archive "training disk" is used to capture products, images, and situations which can be used later for training and familiarization.

In preparation for spring severe weather, for example, the annual (1995) severe weather station drill featured a 2-hr re-enactment of the March 25, 1992, Florida record hail storm (near Orlando). The PUP was placed in "training mode," and recorded products were delivered to the PUP in simulated real-time. Working in teams, forecasters were asked to respond as if the event were actually occurring. The Science and Operations Officer (SOO) monitored the training for proper echo interpretation in the decision process, while the Warning Coordination Meteorologist (WCM) provided oversight on how well office procedures were followed. Providing adequate UCP training for the staff is incumbent upon the SOO and/or WSR-88D focal point. The SOO and focal point receives formal training from the OSF (three-day course); and upon return to the office, they are tasked with training other staff members (including all HMTs).

For HMTs, UCP training and proficiency are based on the OSF supplied in-house course UCP On-site Training Guide. The course addresses many of the checklist items required for radar commissioning. It was noted, however, that in many circumstances the HMTs do not understand the nature of their actions, due to their limited exposure to the complete WSR-88D system. The SOO should work with each HMT individually to achieve comprehensive training. The Data Acquisition Program Manager (DAPM) at Melbourne is exploring the possibility of holding a Florida UCP Workshop in order to share knowledge of handling specific problems, techniques, and procedures with other in-state UCP operators (DAPMs and HMTs).

Finally, Sharp spoke of OSF guidelines available for radar focal points which relate to both the PUP and UCP:

(1) An Operational Guide to Configuring a WSR-88D PUP
(2) An UCP Operational Guide

These guides are available through Regional NEXRAD Program Leader (W/SR42x1) upon request.

Mr. Parks (45WS/DOR)

Training Issues for a Local Air Force Weather Station. Parks began by reviewing the Radar Training and Certification Program (RTCP) requirements instituted at the 45WS. The RTCP outlines a comprehensive list of objectives for forecasters and observers. Radar training incorporates both the McGill and WSR-88D radars. Training consists of orientation, radar principles, severe weather detection, operator proficiency, and certification. Annual recertification is also mandatory. Parks explained that radar training was a never-ending proposition due to the continual rotation of new people versus the amount of exposure required for proficiency.

David Eversole (NWS Mobile)

Recent Experiences Setting Up a New WSR-88D. Eversole commented on his recent experiences with setting up the new WSR-88D at NWS Mobile, Alabama. He explained that although a government accepted radar has been proven sound, that does not necessarily imply the radar is ready for NWS operations. This must be accomplished by on-site personnel. Such documentation as An Operational Guide to Configuring a WSR-88D Principal User Processor (OSF) has been very helpful.

Eversole then proceeded to demonstrate the value of detailed map backgrounds. Although many hours were spent modifying and enhancing original versions which were provided with the radar, locally modified and enhanced map backgrounds now provide greater information to the operator. More detailed map information can be exploited by new forecasters and easily incorporated into statements, warnings, and short-term forecasts.

Conclusion

Open Forum

The following items were discussed in open forum:

(1) The placement of Level II recording between the wideband and the RPG for convenience.

(2) Possibility of implementing an Uninterruptable Power Supply (UPS) for the RDA.

(3) Level II data recording policy.

(4) Common software available for Level II data replay.

(5) Policy regarding dial-in authority for a given RPG.

(6) Dual port configuration of the Applications Terminal on the PUP.

(7) Impact of "On-line Storage Loadshed" at the RPG.

(8) The operational availability of DoD radars vs. spare parts and other factors which influence stability and reliability.

(9) Recap of new algorithms.

(10) Field input into CCRs.

Concluding Remarks

Lt Col Adang (Commander/45WS) and Bart Hagemeyer (MIC/NWS Melbourne) expressed their appreciation to the participants in the workshop. The workshop was considered a success and beneficial for those who attended. It was stated that there is no practical way to measure the total impact the WSR-88D has already made on meteorological operations. With only limited use so far in Florida, there no doubt is much yet to be done to enhance the system so that it is even more valuable for detecting weather hazards that affect the area. With time, users will become even more proficient and algorithms more robust. It is efforts such as this workshop which will help ensure that happens as quickly and efficiently as possible.

Acknowledgements The author would like to recognize the labors of Capt Biggar (45WS) who was instrumental in organizing the workshop. Sincere gratitude is also extended to Jackie Cartwright and Dan Petersen (NWS Melbourne) for their proofreading skills, and to the Scientific Services Division of NWS Southern Region Headquarters which helped make it possible for so many to participate in the workshop. SSD also edited this manuscript into its final form.

References

The following references are listed for more detailed information concerning certain presentations and corresponding author's work:

Biggar, D., W. Roeder and D. Sharp, 1995: A report on the 1995 Southeastern United States WSR-88D User Workshop, Preprints, 27th Conf. on Radar Meteorology, Vail, CO, Amer. Meteor. Soc., (in preparation).

Choy, B., L. Mazarowski and P. Glitto, 1995: Tropical Storm Gordon - 72hr. Rainfall Totals Over East Central Florida and WSR-88D Comparisons. NOAA Tech. Memo. NWS SR (in preparation).

_____, and S. Spratt, 1995: Using the WSR-88D to Predict East Central Florida Waterspouts. Preprints, 14th Conf. on Weather Analysis and Forecasting, Dallas, Amer. Meteor. Soc., 376-381.

_____, and M. Trexler, 1994: SWIFT BOAT '94 - Using a Fast Chase Boat to Investigate Offshore Weather Features in conjunction with WSR-88D Observations. NOAA Tech. Memo. NWS SR-159. 18 pp.

Federal Meteorological Handbook No. 11 - Part A: Doppler Radar Meteorological Observations - System Concepts, Responsibilities and Procedures. Washington D.C., 1991 (Interim Version)

Kelly, D.S., 1994: Procedures for Forecast Offices to Perform Gage-Radar Comparisons. Operational Support Facility, Applications Branch, Algorithm, Section. (Internal correspondence).

Korotky, J., J. Michael and C. E. Williford, 1995: Tropical Storm Alberto: A WSR-88D Radar Review. Preprints, 14th Conf. on Weather Analysis and Forecasting, Dallas, Amer. Meteor. Soc., 559-564.

McAdie, C., 1994: WSR-88D Operations Plan During Tropical Cyclone Events. (Internal Correspondence.)

Muro, M., 1994: Pictorial Chronology of Tropical Storm Alberto - Part Two. Robins AFB, GA. (Unpublished)

Paxton, C., J. Shepherd, 1993: Radar Diagnostic Parameters as Indicators of Severe Weather in Central Florida. NOAA Tech. Memo. NWS SR-149, 12 pp.

Roeder, W., 1995: Chaff Impacts on Weather Radar. Preprints, 27th Conf. on Radar Meteorology, Vail, Co., Amer. Meteor. Soc., (in preparation).

Smith, S., 1995: Investigation of Reflectivity Discrepancies. Operational Support Facility Investigative Report. (Internal OSF report).

Spratt, S., 1995: A Review of Mesocyclones within a Tropical Storm Gordon Rain Band. NWS Melbourne, FL. (Unpublished).

Taylor, G., 1994: Report on the Comparison of the Scan Strategies Employed by the Patrick Air Force Base WSR-74C/McGill Radar and the NWS Melbourne WSR-88D. Applied Meteorological Unit/ENSCO Memo. for NASA/Kennedy Space Center.

(Internal memo.) Wakimoto, R., and J. Wilson, 1989: Non-Supercell Tornadoes. Mon. Wea. Rev., 117, 1113-1140.

Wolff, D. 1994: Issues Noted Regarding Melbourne, Florida WSR-88D Radar Calibration. (Internal Correspondence.)

APPENDIX A

DAY 1

0800-0830 Registration (Capt Biggar, 45WS/SYR)

0830-0850 Opening Remarks

(Lt Col Adang, 45WS/CC & Mr. Sharp, NWS MLB)

0855-1015 OSF Presentations

(Lt Col Crum, Applications Branch/OSF)
Upcoming WSR-88D Software Changes
Algorithm Enhancement Process/New Algorithms
Plans to Test New Algorithms in Military and
NWS Forecast Offices

1015-1030 = BREAK

1030-1045 Archive II Weather Event Database

(Dr. Ray, FSU)

1050-1105 WSR-88D Exploitation Tasks / Applied Meteorological

Unit (Mr. Wheeler, AMU)

1110-1125 WSR-88D Support to Space Shuttle Launch and Ground

Processing Operations (Mr. Pinder, 45WS/DOR)

1130-1145

WSR-88D Support to Space Shuttle Landing Operations
(Mr. Lafosse, SMG/JSC)

1145-1315 = AMS Luncheon = (Guest Speaker: Lt Col Crum)

1315-1600 = TOUR = Range Weather Operations & Kennedy Space

Center (Capt Biggar, 45WS/SYR)

DAY 2

0800-0815 Summary of Tropical Storm Alberto Workshop

(Ssgt Michael, Eglin AFB, FL Weather Flight)

0820-0835 WSR-88D Estimated Rainfall from Tropical Storm

Alberto (Mr. Muro, Robins AFB, GA Weather Flight)

0840-0855 WSR-88D Estimated Rainfall from Tropical Storm

Gordon (Ms. Glitto & Mr. Mazarowski, NWS MLB)

0855-0905 = BREAK

0905-0920 Hurricane Operations and the WSR-88D

(Mr. McAdie, NHC)

0925-0940 Mesocyclone Identification during Tropical Storm Gordon (Mr. Spratt, NWS MLB)

0945-1000 WSR-88D Marine Experiences

(Lt Choy, NOAA Corps/NWS MLB)
- WSR 88D Approach to Waterspout Forecasting
- SWIFT BOAT Experiment

1010-1025 Tracking a Gulf of Mexico Derecho Using the WSR-88D

Mr. Korotsy, NWS TLH)

1030-1045 Problems with Chaff (Maj Roeder, 45WS/SYR)

1050-1105 Evaluating WSR-88D VIL as a Severe Weather Signature

(Mr. Alsheimer, NWS TBW

1130-1245 = LUNCH

1245-1300 VCP Dependent Reflectivity Discrepancies and Subsequent

Investigation (Lt Col Crum & Mr. Sharp)

1305-1320 NWS Centralized Training

(Ms. Trabert, OSF Training Branch)

1325-1340 USAF Centralized Training (Msgt Kaczmarek, Keesler AFB

Weather Training School) 1340-1350 = BREAK

1350-1405 Training Issues for a Local NWS Office (Mr. Sharp)

1410-1425 Training Issues for a Local USAF Weather Station

(Mr. Parks, 45WS/DOR)

1430-1445 Recent Experiences Setting Up a New WSR-88D

(Mr. Eversole, NWS MOB)

1500-1630 NWS/USAF/USN/OSF Dialogue (Capt Biggar & Mr. Sharp

APPENDIX B

WSR-88D Use During Tropical Cyclone Events, submitted by the National Hurricane Center:

At the Unit Control Position (UCP):

1. Operational mode - normally VCP 21 (precipitation mode), for better velocity measurements.

VCP 11 may also be used for short-term evaluation of specific features.

UCP commands: (begin from Main Menu)

RD,CH,21 or **RD,CH,11**

2. Velocity data (display) levels for the 8-data level products should be set to display hurricane force winds. Note that the default settings, which usually display a maximum of 64 kit, will be exceeded by even a minimal Category 1 hurricane.

UCP commands: (begin from Main Menu)

SE,****,VE** (enter appropriate menu)
then **D,5** (display table 5)
then **M** (modify table 5)
suggested values are -100, -80

then **E** (save edits)
then **D,7** (display table 7)
then **M** (modify table 7)
suggested values are -135, -115

then **E** (save edits)

This modifies the 8-level products ONLY. The routine 16-level products are not affected. By entering the negative values above, corresponding positive values are automatically supplied.

Table 5 will be used if the velocity increment is 1 kit (.97 kt or .5 m/s) while Table 7 will be used if the velocity increment is increased to 2 kt (1.94 kt or 1 m/s). Refer to Item 3.

3. If the velocities are expected to exceed 124 kt, increase the velocity measurement increment (VMI) from 1 to 2 kt.

UCP commands: (begin from Main Menu)

RD,PR (Turn off AUTO PRF)
V (display current VCP)
then **V,1.94** (switch VMI of current VCP)
then **E** (save edits)
RD,DO,O (download modified VCP)
RD,PR (turn on AUTO PRF)

Note: If the VMI is 1 kt, Table 5 from above applies.
If the VMI is 2 kt, Table 7 from above applies.

4. Allow Non-associated PUPs (national centers such as NHC) access to:

a.) 8-data level Velocity (V) product (product #24)

b.) 0.54 nm Composite Reflectivity (CR) product (product #37)

These products may be added to the Generation and Distribution Control list, Adaptation List A, with a "Y" in the NAPUP column.

UCP commands: (begin from Main Menu)

AD,****,G,A** (display list A) then **M,9** (modify line 9) AUT AUT STO NA SLICE GEN ARC STO TIM PUP -2.0 1 0 1 60 y then **E** (save edits)

F1 (press F1 key to go to Main Menu)
G (display current list)
then **R,A** (replace current list with changes)
then **E** (save edits) 5. Make certain that the ARCHIVE II device is active.

6. Suggested minimum PUP Routine Product Set (RPS) lists are attached. They were originally developed when RPS lists were confined to only 20 products. However, the fundamental philosophy remains the same as operators interrogate tropical cyclones based on range from the radar and intensity. Also, Storm Relative Velocity products (SRR,SRM) should be generated often via One-Time Request with individual or field motions manually input by the PUP operator. The algorithms may not be able to produce a useful motion on their own due to the rotational aspects of tropical cyclones.

7. It is strongly encouraged that local archival (Archive IV) be initiated. Most important to the plan, for both APUPs and NAPUPS, is the 8-data level velocity product, and, in the event of velocities exceeding 124 kt, changing the velocity measurement increment from 1 to 2 kit.

The advantage of using the 8-level V product is that the location of strong hurricane force winds can be displayed, while leaving the standard 16-level velocity product (-64 kt to +64 kt) alone for routine use.

It is important to note that the key 8-level V product and the 0.54 nm CR product are not available to NAPUPs by current FMH-11 default (5/95). These products can be made available by modifications to the Generation and Distribution Control list. Ideally, this could be done well in advance of a tropical cyclone event. Local Unit Radar Committee (URC) approval should be sought as necessary, in advance, so that changes can be made operationally as the need arises.

For questions or comments, please contact:

Colin McAdie, National Hurricane Center
(305) 229-4447

Acknowledgements:

UCP procedural input provided by Dave Sharp, NWSO Melbourne, Florida

Minimum RPS lists suggested by Stacy Stewart, OSF Training Branch are provided and follow:

Note: Storm Relative Velocity Map (SRM) products may be added to any of the lists, but caution is advised since the rotational aspects of tropical cyclones will result in varied individual thunderstorm motions. Manual one-time requests with operator defined motions are preferred. Great utility has also been shown with the Layered Composite Reflectivity Max-Mid (LRM-M) and the One Hour Precipitation (OHP) products.

Recommended Tropical Cyclone (TC) RPS Lists:

(by range from WSR-88D site)

Center more than 124 nautical miles from radar

Minimum recommended RPS list: Center more than 124 nmi from radar.

Product	Elevation Angle (degrees)	Data Resolution (nautical miles)	Data Levels
Base Reflectivity	0.5	1.1	16
	1.5	1.1	16
	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
Base Velocity	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	0.5	.54	8
Composite Reflectivity		.54	16
Vertically Intergrated Liquid			
Storm Total Precipitation			

Minimum recommended RPS list: Center 62-124 nmi from radar.

Product	Elevation Angle (degrees)	Data Resolution (nautical miles)	Data Levels
Base Reflectivity	0.5	1.1	16
	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	6.0	.54	16
Base Velocity	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	0.5	.54	8
Composite Reflectivity		.54	16
Vertically Integrated Liquid			
Storm Total Precipitation			

Minimum recommended RPS list: Center 32-62 nmi from radar.

Product	Elevation Angle (degrees)	Data Resolution (nautical miles)	Data Levels
Base Reflectivity	0.5	1.1	16
	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	6.0	.54	16
Base Velocity	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	0.5	.27	16
	1.5	.27	16
	0.5	.54	8
Composite Reflectivity		.54	16
Vertically Integrated Liquid			
Storm Total Precipitation			

Minimum recommended RPS list: Center 0-32 nmi from radar.

Product	Elevation Angle (degrees)	Data Resolution (nautical miles)	Data Levels
Base	0.5	1.1	16
Reflectivity	0.5	.54	16
	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	6.0	.54	16
	9.9	.54	16
Base	0.5	.54	16
Velocity	1.5	.54	16
	2.4	.54	16
	3.4	.54	16
	0.5	.27	16
	1.5	.27	16
	0.5	.13	16
	0.5	.54	8
	1.5	.54	8
Composite Reflectivity		.54	16
Vertically Integrated Liquid			
Storm Total Precipitation			