CHAPTER 2

WSR-88D METEOROLOGICAL PRODUCTS

2.1 Introduction. This chapter provides an operational description of the WSR-88D meteorological products. Table 2-1 provides a listing of those products and their system identifiers. The section covering each product contains its description and its operational characteristics, a brief statement describing its intended operational usage, and a listing of the known operational strengths and limitations.

The description of the product and how it is generated is followed by a brief narrative and by an itemization of the operational characteristics that include:

- System Identifier (ID) - The unique identification for that product within the WSR-88D system.
- Data - The data or information presented in the products.
- Processing - The processing that has been used to prepare the data or information for presentation.
- Availability - The frequency at which, or conditions under which, the product is available.
- Presentation - A description of how the product is presented.
- Resolution and Coverage - The geographical area represented by a single product data value and the geographic area covered by the entire product.
- Data Levels - The parameter resolution or quantization of the data or information in the product. This product level information is available in the Interface Control Document for the Product Specification at: http://www.roc.noaa.gov/ssb/cm/icd_downloads.asp
- Annotations - Additional alphanumeric information included with the product.
- Special Symbols - Where used, special symbols are described.
- Adaptation Data - Those parameters that can be varied to adapt the product to its application.
- Overlays - The following algorithms produce products that can be overlaid on all geographic products to improve operational utility in a given application:

  Hail Index
  Mesocyclone
  Mesocyclone Rapid Update
  Mesocyclone Detection
  Severe Weather Probability
  Storm Tracking Information
  Tornado Vortex Signature
  Tornado Vortex Rapid Update

- Combined Attribute Table - The following elements make up the table:

  Cell-Based Vertically Integrated Liquid Water
  Hail
    Probability of Hail
    Probability of Severe Hail
    Maximum Expected Hail Size
  Mesocyclone
  Storm Characteristics
    Storm Identification
    Storm Location
    Height and Value of Maximum Reflectivity
    Height of 30 dBZ Echo Top
    Forecast Storm Movement
  Tornado Vortex Signature

The usage section describes the potential meteorological applications of the product and lists some of its intended operational uses.

The strengths/applications sections list the strong points of the products which relate to its applications and the limitation sections describes the limiting factors of the product (and its related algorithm). For products based upon the meteorological algorithm processing, the reader should refer to Chapter 3 for additional discussion.

Where available and appropriate, a pictorial or tabular representation of each product is provided. Figure numbers coincide with the product section numbers and, therefore, are not necessarily consecutive.

Table 2-1
WSR-88D Meteorological Products

Product Name	System ID
Clutter Filter Control	CFC
Clutter Likelihood Reflectivity	CLR
Clutter Likelihood Doppler	CLD
Combined Shear	CS
Composite Reflectivity	CR
Composite Reflectivity Edited for Anomalous Propagation	CRE
Cross Section	
Reflectivity	RCS
Mean Radial Velocity	VCS
Echo Tops	ET
High Resolution Enhanced Echo Tops	EET
Free Text Message	FTM
Hail Index	HI
Hybrid Scan Reflectivity	HSR
Digital Hybrid Scan Reflectivity	DHR
Layer Composite Reflectivity	
Average	LRA
Maximum	LRM
User Selectable Layer Composite Reflectivity	ULR
Layer Composite Reflectivity - Anomalous Propagation Removed	APR
Mean Radial Velocity	V
Base Velocity Data Array	DV
Integrated Terminal Weather System Digital Base Velocity	DBV
Mesocyclone	M
Mesocyclone Rapid Update	MRU
Mesocyclone Detection	MD
Digital Mesocyclone Detection Data Array	DMD
One-Hour Rainfall Accumulation	OHP
Hourly Digital Precipitation Array	DPA
One-Hour Snow Depth Accumulation	OSD
One-Hour Snow Water Equivalent Accumulation	OSW
Radar Coded Message	RCM
Reflectivity	R
Base Reflectivity Data Array	DR
Severe Weather Analysis	SWA
Reflectivity	SWR
Mean Radial Velocity	SWV
Spectrum Width	SWW

Table 2-1
WSR-88D Meteorological Products
(Concluded)

Product Name	System ID
Radial Shear	SWS
Severe Weather Probability	SWP
Spectrum Width	SW
Storm Relative Mean Radial Velocity	
Region	SRR
Map	SRM
Storm Structure	SS
Storm Total Rainfall Accumulation	STP
Storm Total Rainfall Accumulation (Digital Storm Product)	DSP
Storm Total Snow Depth Accumulation	SSD
Storm Total Snow Water Equivalent Accumulation	SSW
Storm Tracking Information	STI
SuperOb	SO
Supplemental Precipitation Data	SPD
Three-Hour Rainfall Accumulation	THP
Tornado Vortex Signature	TVS
Tornado Vortex Signature Rapid Update	TRU
User Alert Message	UAM
User Selectable Rainfall Accumulation	USP
User Selectable Snow Depth Accumulation	USD
User Selectable Snow Water Equivalent Accumulation	USW
Velocity Azimuth Display	VAD
Velocity Azimuth Display (VAD) Wind Profile	VWP
Vertically Integrated Liquid Water	VIL
High Resolution Digital Vertically Integrated Liquid	DVL

2.2 <u>Clutter Filter Control</u>. The Clutter Filter Control product (CFC) provides a display of the type and amount of clutter suppression (Notchwidth and Bypass Maps) in effect, for the user selected elevation segment and channel type. Two elevation segments are available for selection; they are "Low" (elevations below 1.65°) and "High" (elevations between 1.65° and 7°) for each channel "Surveillance" or "Doppler."

2.2.1 Operational Characteristics.

System ID: CFC, Product #34.

Data: Active clutter filtering scheme, forced filtering, or no filtering.

Processing: The RDA Status and Control (RDASC) generate the Clutter Filter Notchwidth Map and Bypass Map.

Availability: When Notchwidth and/or Bypass maps are updated or on user request.

Presentation: Polar coordinate image for user selected elevation segment and channel type (Figure 2-2).

Resolution: 1 km (0.54 nm) x 1.4°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 8.

Annotations:

- Standard set*
- Elevation Segment Number
- Channel (Surveillance or Doppler)
- Bypass Map generation date/time
- Notchwidth Map generation date/time.

Adaptation: None.

2.2.2 Usage: Graphically display clutter filter settings.

2.2.3 Strengths/Applications:

- Enables Clutter Filter settings to be graphically displayed.
- Assists in verifying correct clutter settings have been set.

2.2.4 Limitations:

- Only available when RDASC changes in settings occur or when requested.
- Even though clutter filtering can be applied to a range of 460 km (248 nm), this product only displays clutter filter information to 230 km (124 nm).

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

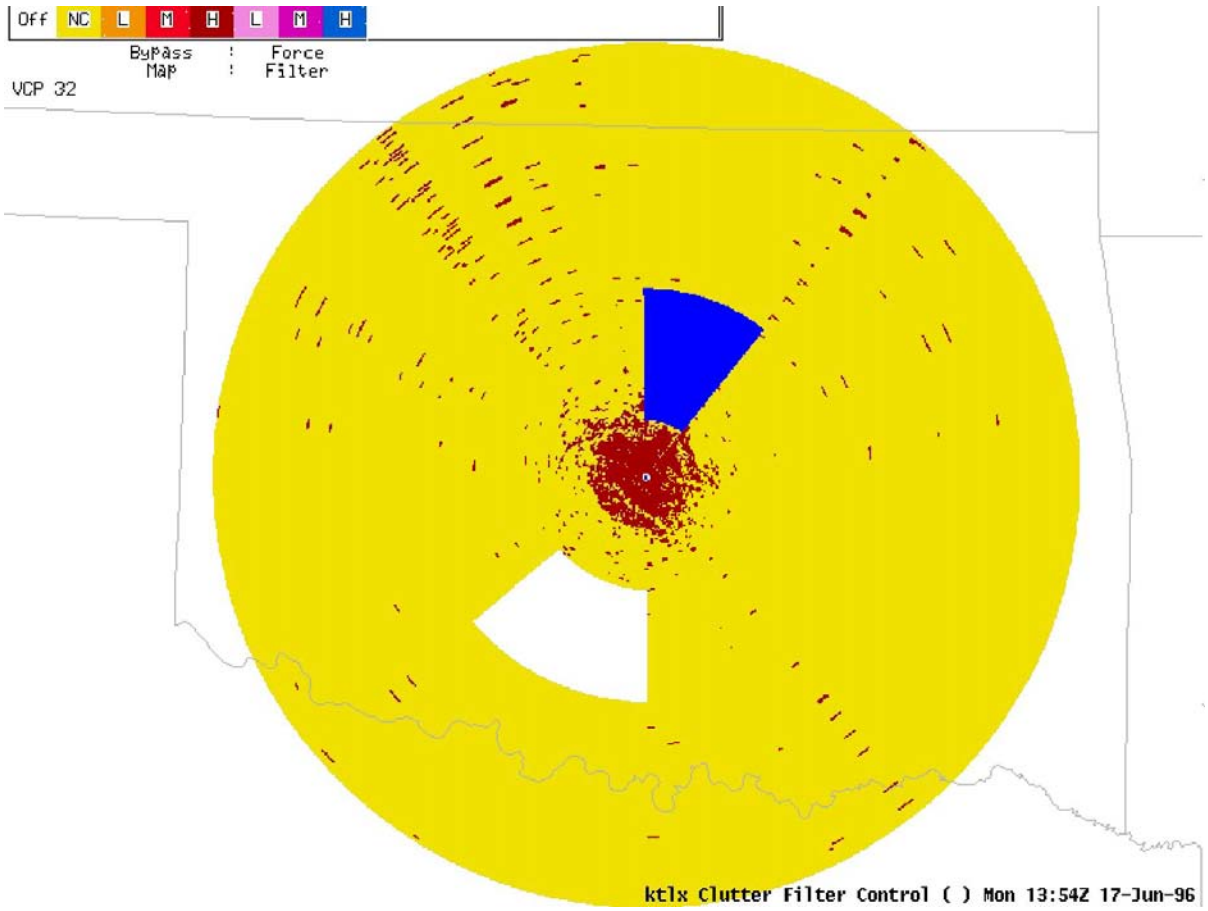

Figure 2-2
Clutter Filter Control Product

An example of operator-generated clutter sensor zones displayed by a CFC product (Advanced Weather Interactive Processing System (AWIPS) graphic). The blue wedge indicates forced filtering is taking place, in all bins contained within the wedge, using maximum suppression. The white wedge indicates an area in which the operator has turned off all clutter suppression. The remainder of the area which is yellow with red pixels is the RDA-generated Clutter Bypass Map. In this case, the map was generated while some type of interference was being detected by the KTLX WSR-88D in Oklahoma City, OK, as indicated by the azimuthal rows of continuous pixels at different azimuths and ranges. In general, if the interference is not constant, a map without the interference is preferable in order to not suppress data unnecessarily.

2.3 <u>Clutter Likelihood Reflectivity</u>. The Clutter Likelihood Reflectivity product (CLR) provides a displayable image of the percentage probability that the radar is detecting ground clutter in the reflectivity radial samples. The product content is based on the output of the Radar Echo Classifier (REC) algorithm using the Anomalous Propagation (AP)/Clutter target logic.

2.3.1 Operational Characteristics.

System ID: CLR, Product #132.

Data: Clutter likelihood (in percent).

Processing: The REC algorithm searches the three base data moments (R, V and SW), within a discrete sampling area, for patterns characteristic of ground clutter and anomalous propagation returns. It combines its results using "fuzzy logic" to produce a likelihood as a percentage, that a given range bin is a return from ground clutter.

Availability: Once per volume scan.

Presentation: Polar coordinate image of probability coded range bins (Figure 2-3).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 11.

Annotations:

- Standard set*
- Data level code
- Site adaptable parameters
- Maximum data value detected.

Adaptation: None.

2.3.2 Usage. The CLR product indicates the likelihood that each range gate is contaminated by clutter return and provides a measure of reflectivity data quality. This assists in reflectivity data interpretation and application of the data. Additionally, output of the REC algorithm is used by the precipitation accumulation function to reject reflectivity range gates that are clutter contaminated.

2.3.3 Strengths/Applications. With availability of all three moments, CLR will indicate probability that each range gate is clutter.

2.3.4 Limitations. The CLR results must be used with caution in areas where there are range overlaid velocity data.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

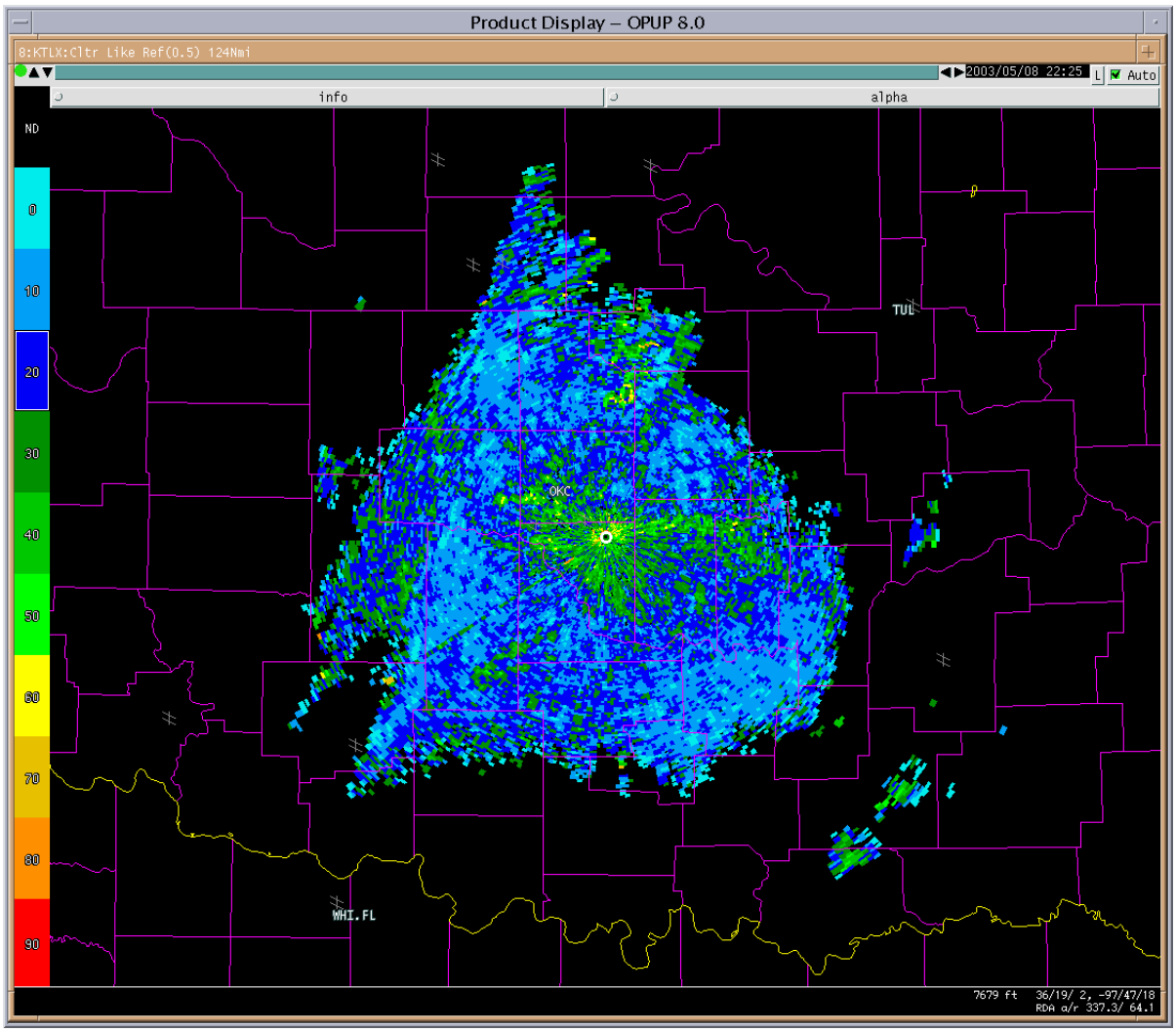

Figure 2-3
Clutter Likelihood Reflectivity Product

A CLR product as displayed on an OPUP from the KTLX WSR-88D in Oklahoma City, OK. Each resolution volume represents the percentage probability that the radar is detecting ground clutter in that reflectivity radial sample. This product was created at the same time as the product shown in Figure 2-4.

2.4 <u>Clutter Likelihood Doppler</u>. The Clutter Likelihood Doppler product (CLD) provides a displayable image of the percentage probability that the radar is detecting ground clutter in the Doppler radial samples. The product is based on the output of the REC algorithm using the AP /Clutter target logic.

2.4.1 Operational Characteristics.

System ID: CLD, Product #133.

Data: Clutter likelihood (in percent).

Processing: The REC algorithm searches the three base data moments (R, V and SW), within a discrete sampling area, for patterns characteristic of ground clutter and anomalous propagation returns. It combines its results using "fuzzy logic" to produce a likelihood as a percentage, that a given range bin is contaminated by return from ground clutter.

Availability: Once per volume scan.

Presentation: Polar coordinate image of probability coded range bins (Figure 2-4).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 12.

Annotations:

- Standard set*
- Data level code
- Site adaptable parameters
- Maximum data values detected.

Special Symbols: None.

Adaptation: None.

2.4.2 Usage. The data are input by the REC and used to reject Doppler gates that are clutter contaminated. The CLD product indicates the likelihood that each range gate is contaminated by return from clutter targets and provides a measure of velocity data quality. This can assist in velocity field interpretation and application of the data. The value displayed for each 1 km (0.54 nm) bin is the maximum of the four corresponding Doppler bins.

2.4.3 Strengths/Applications. With availability of all three moments, the CLD will indicate probability that each range gate is clutter.

2.4.4 Limitations. Probabilities of clutter are not available in range folded areas.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

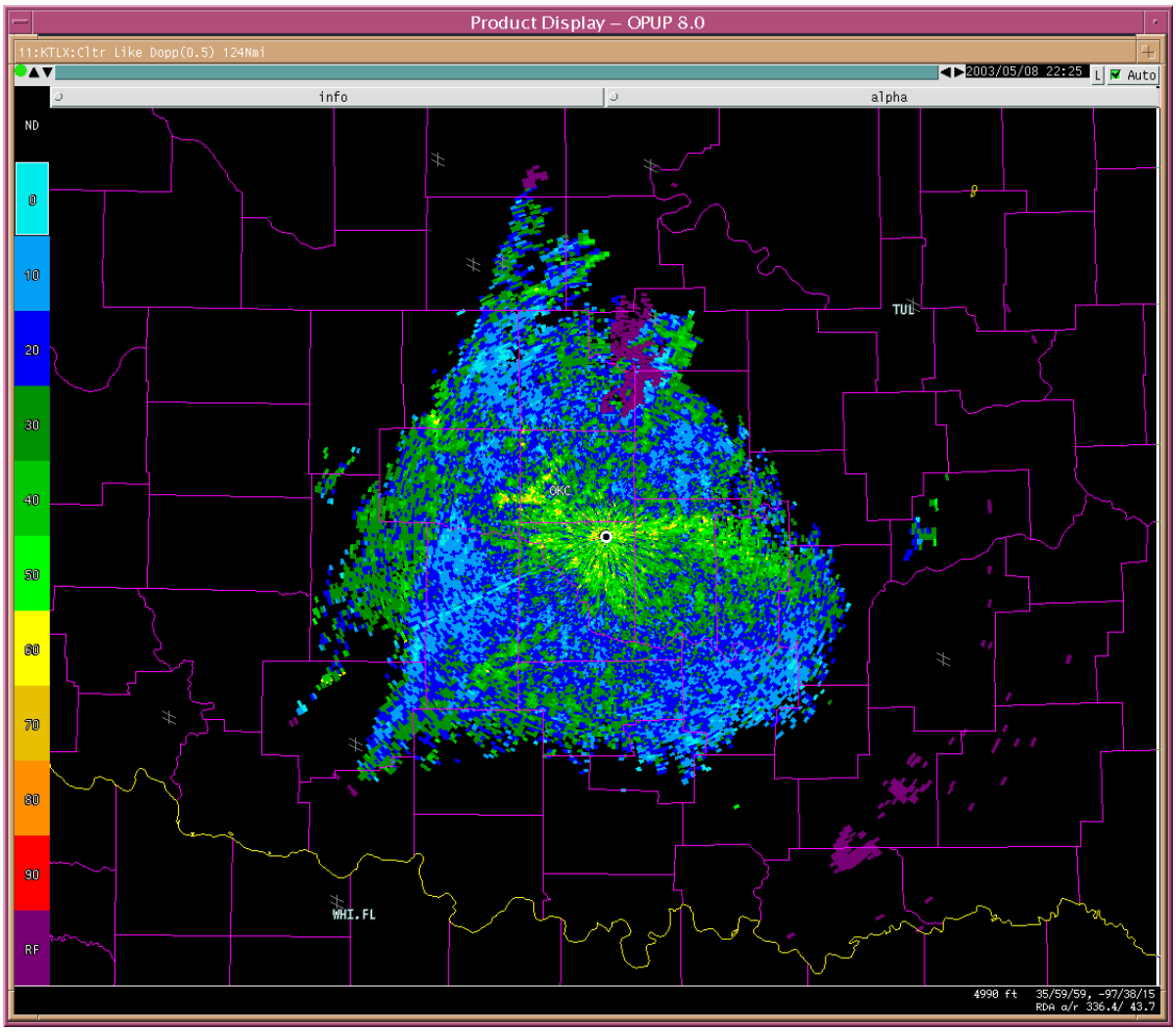

Figure 2-4
Clutter Likelihood Doppler Product

A CLD product as displayed on an OPUP from the KTLX WSR-88D in Oklahoma City, OK. Each resolution volume represents the percentage probability that the radar is detecting ground clutter in that velocity radial sample. This product was created at the same time as the product shown in Figure 2-3.

2.5 Combined Shear. The Combined Shear product (CS) provides the combined radial and azmuthal shear of the mean radial velocity, as calculated by the CS algorithm. It is presented as an image of filtered shear values containing 16 data levels. Upon user request, all site adaptable parameters identified as inputs to the algorithms used to generate data for this product are available in alphanumeric tabular form.

2.5.1 Operational Characteristics.

System ID: CS, Product #87.

Data: Combined azimuthal and radial shear.

Processing: CS Algorithm.

Availability: Once per volume scan at a single elevation angle, as selected at the Master System Control Function (MSCF); lowest elevation is default.

Presentation: Cartesian image of combined shear values (Figure 2-5).

Resolution: 0.5 x 0.5 km (0.27 x 0.27 nm).

Coverage: Radar centered, 230 x 230 km (124 x 124 nm) to 4 x 4 km (2.2 x 2.2 nm).

Data Levels: 16.

Annotations:

- Standard set*
- Data level code
- Elevation angle
- Position and magnitude of maximum shear value
- Site adaptable parameters
- Spatial resolution of product.

Adaptation: None.

2.5.2 Usage. Visual identification of wind shear phenomena associated with gust fronts, downbursts, microbursts, synoptic fronts, and mesoscale/storm scale rotational phenomena.

2.5.3 Strengths/Applications. This product has been used to aid in manual gust front and mesocyclone and misocyclone identification.

2.5.4 Limitations.

- For various reasons this product has not been thoroughly tested in an operational environment.
- Extensive filtering of both velocity data and shear data may remove significant misoscale and mesoscale phenomena (i.e., 40 meters (130 feet) to 4 km (2.2 nm)).
- Critical values have not been established.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

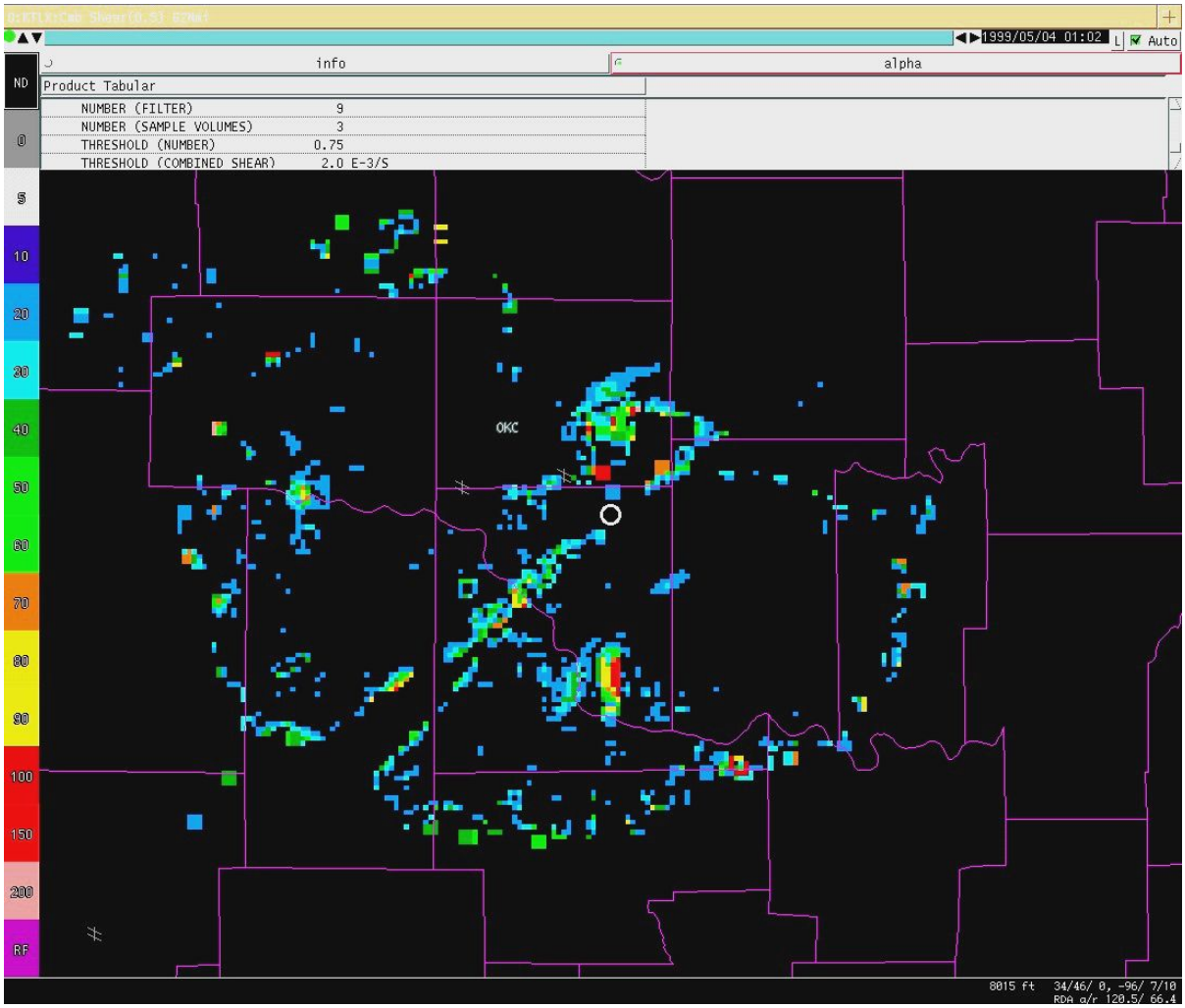

Figure 2-5
Combined Shear Product

A CS product from the KTLX WSR-88D in Oklahoma City, OK. (OPUP display)

2.6 <u>Composite Reflectivity</u>. The Composite Reflectivity products (CR) provide composite reflectivity data displayable as an image. For each geographical resolution element, this product provides the highest reflectivity value above the resolution element available from any elevation angle scan of a volume scan. Thus, the value displayed for a given location within the product could come from any of the elevation scans contained in the current VCP. Storm information generated by the various meteorological algorithms (e.g., Storm Cell Identification and Tracking (SCIT) algorithm, Hail Detection Algorithm (HDA), Mesocyclone Algorithm (MESO), and Tornado Detection Algorithm (TDA)) are included as annotations or graphic overlays, or both, as the user selects. When selected, the algorithm-generated information is provided for all identified storms via the Combined Attribute Table (CAT) .

2.6.1 Operational Characteristics.

System ID: CR, Products: #35, #36, #37, and #38.

Data:

- Composite reflectivity
- Meteorological algorithm output.

Processing:

- Assign highest value of reflectivity from any elevation angle in volume scan.
- Produce combined attribute table.

Availability: Updated once per volume scan.

Presentation: Cartesian image of composite reflectivity values (Figures 2-6, a – d).

Resolution:	**Coverage:**
• 1 x 1 km (0.54 x 0.54 nm) (#35 and 37)	Radar centered, 230 km (124 nm) radius
• 4 x 4 km (2.2 x 2.2 nm) (#36 and 38)	Radar centered, 230 km (248 nm) radius.

Data Levels: 8 (#35 and 36) and 16 (#37 and 38).

Annotations:

- Standard set*
- Combined Attribute Table
- Data level code
- Maximum CR data value detected.

Adaptation: None.

2.6.2 Usage.

- Permits a view of maximum reflectivity levels for the total vertical volume within the range of the radar. As such, it provides a synopsis of the most important reflectivity features in the entire vertical coverage area.
- Allows the user to quickly establish the maximum aerial extent of reflectivity patterns and locate reflectivity maxima with respect to the surface of the Earth. However, information regarding the height above ground or the 3-dimensional structure of the reflectivity pattern must be determined by the use of other products.
- Under favorable reflectivity conditions, a bright band feature may enable the user to identify the presence of the melting level.

2.6.3 Strengths/Applications.

- Provides help selecting vertical cross sections through maximum reflectivity core.
- The CAT is available and provides algorithm established critical storm characteristics at a glance.
- Reveals highest reflectivity in all echoes.
- Determine some storm structural features and intensity trends in storms when compared to base products.
- Reveals the existence of a bright band or other layers by one or more concentric radar-centered circles.

2.6.4 Limitations.

- Low level reflectivity signatures are obscured.
- Height of reflectivity is unknown.
- Echo aloft cannot be distinguished from precipitation reaching the surface.
- Ice crystal clouds aloft, such as altostratus and cirrus, may appear as areas of surface precipitation.
- Non-precipitation echoes (e.g., point clutter, anomalous propagation, biological targets, and particulate matter) may contaminate the product.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

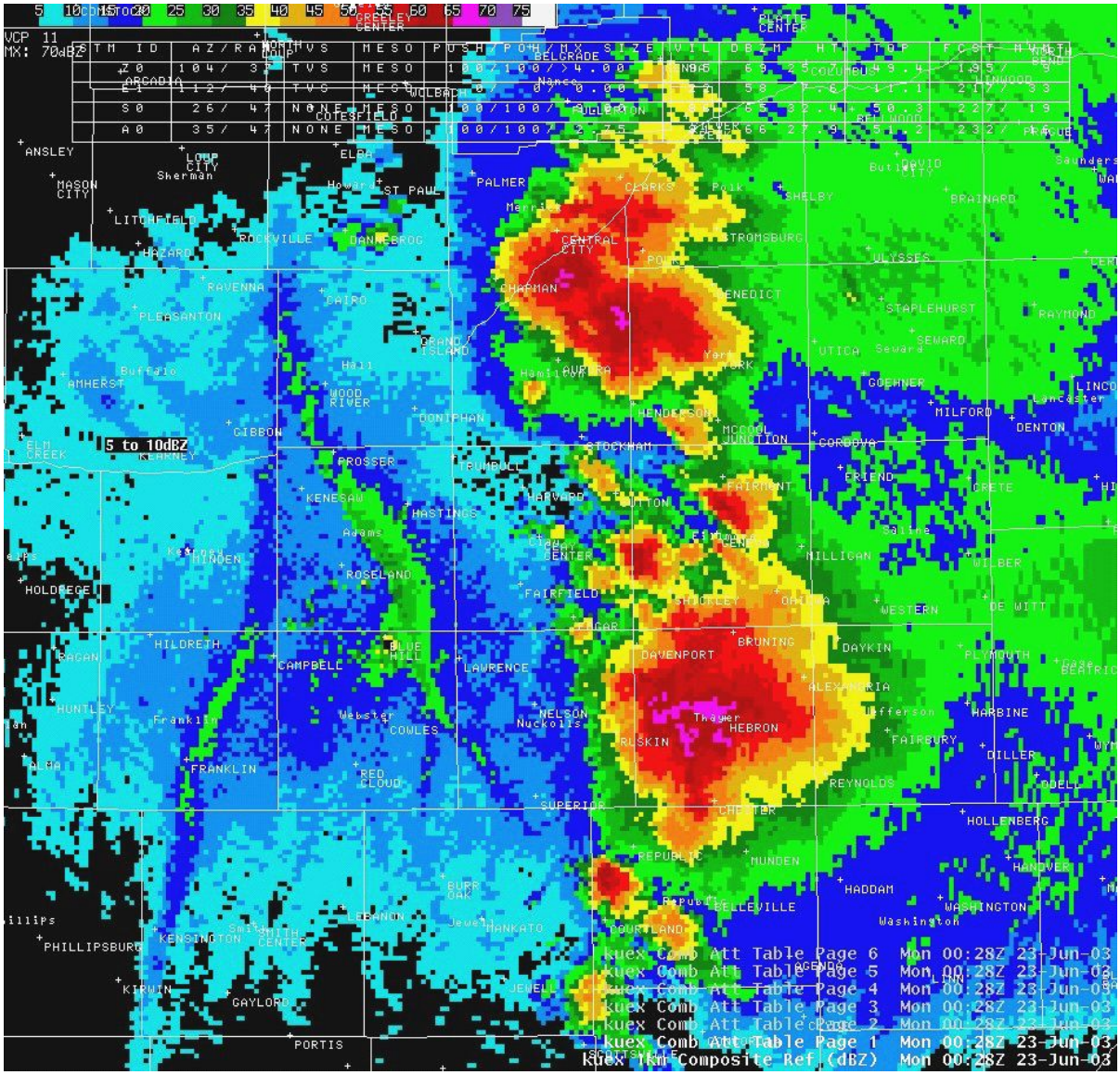

Figure 2-6a
Composite Reflectivity Product

A Grand Island, NE WSR-88D (KUEX) CR product, 1 km x 1 km (0.54 nm x 0.54 nm) resolution and 16 data levels with a Combined Attribute Table at 00:28 UTC on 23 June 2003. (AWIPS display)

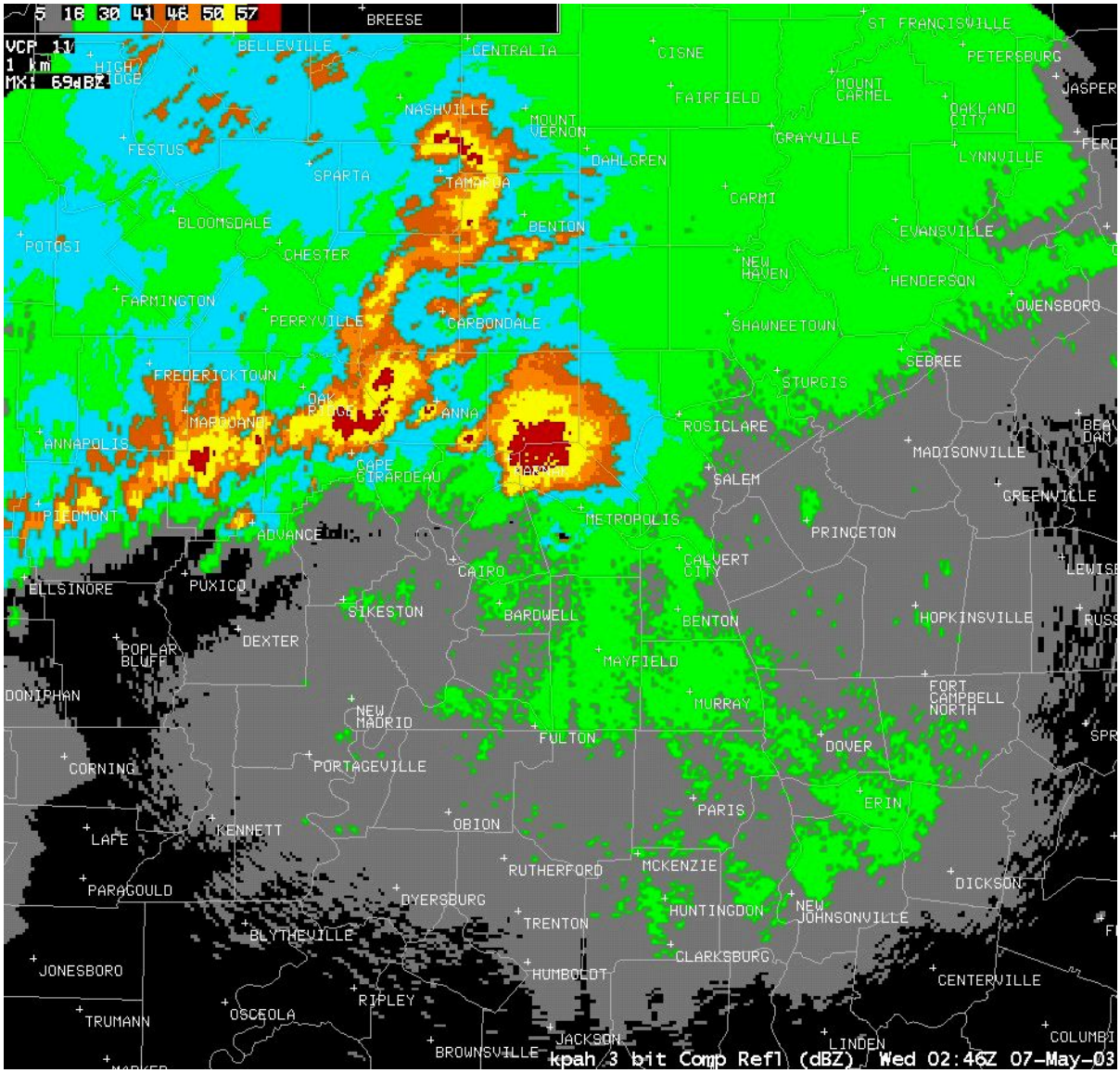

Figure 2-6b
Composite Reflectivity Product

A Paducah, KY (KPAH) WSR-88D CR product, 1 km x 1 km (0.54 nm x 0.54 nm) resolution and 8 data levels at 02:46 UTC on 7 May 2003. (AWIPS display)

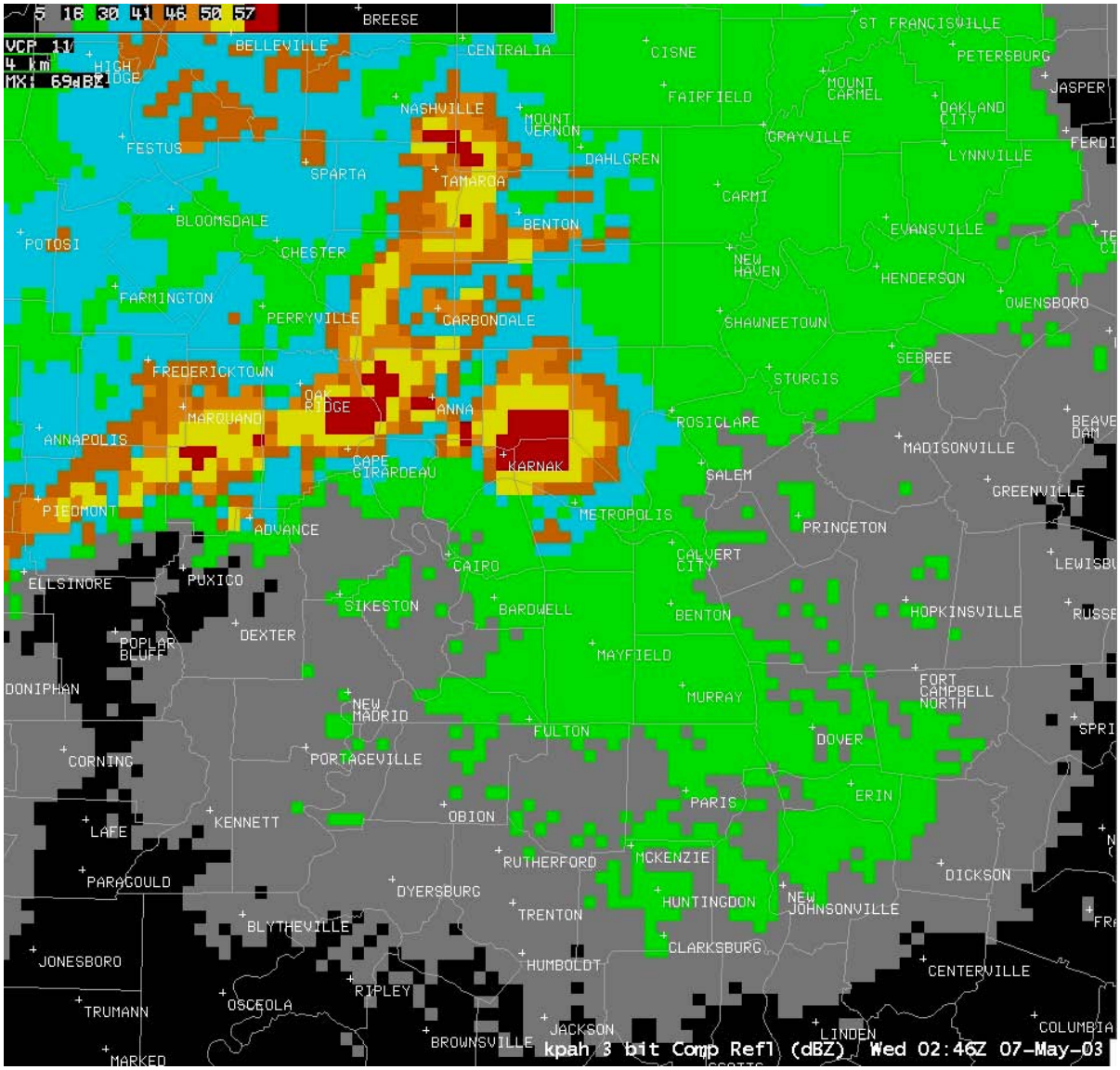

Figure 2-6c
Composite Reflectivity Product

A Paducah, KY (KPAH) WSR-88D CR product, 4 km x 4 km (2.2 nm x 2.2 nm) resolution and 8 data levels at 02:46 UTC on 7 May 2003. (AWIPS display)

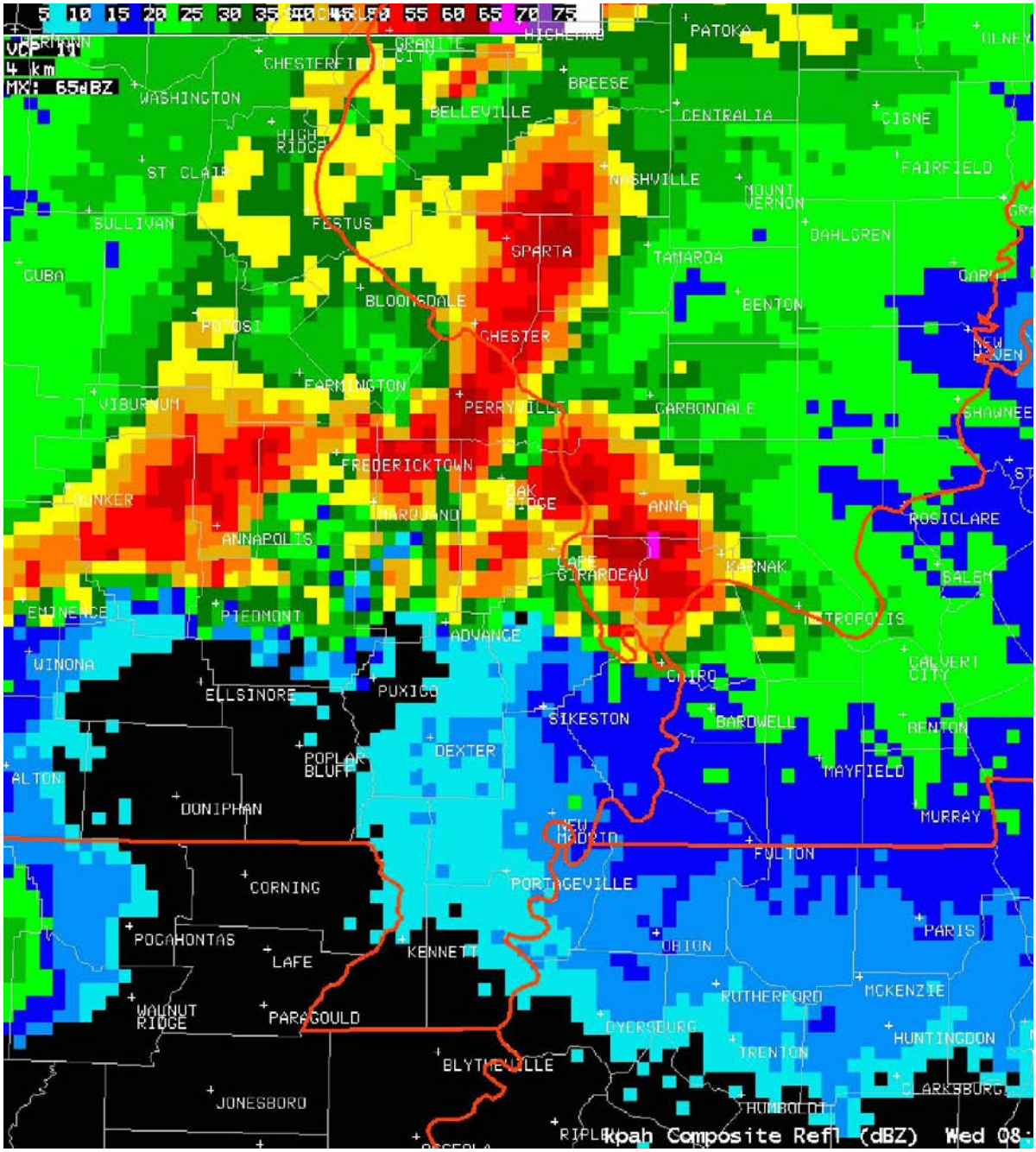

Figure 2-6d
Composite Reflectivity Product

A Paducah, KY MO (KPAH) WSR-88D CR product, 4 km x 4 km (2.2 nm x 2.2 nm) resolution and 16 data levels. (AWIPS display)

2.7 <u>Composite Reflectivity Edited for Anomalous Propagation</u>. The Composite Reflectivity Edited for Anomalous Propagation products (CRE) provide composite reflectivity data displayable as an image. For each geographical resolution element, this product provides the highest reflectivity value above the resolution element available from any elevation angle scan of a volume scan. A clutter editor is applied to the reflectivity image data (using both velocity and spectrum width data as inputs) to remove clutter contaminated data.

2.7.1 Operational Characteristics.

System ID: CRE, Products: #95, #96, #97, and #98.

Data: Composite reflectivity.

Processing:

- Assign highest value of reflectivity from any elevation angle in volume scan
- Algorithm to remove AP
- Produce combined attribute table.

Availability: Once per volume scan.

Presentation: Cartesian image of reflectivity values (Figures 2-7, a – d).

Resolution:	**Coverage:**
• 1 x 1 km (0.54 x 0.54 nm) (#95 and #97)	Radar centered, 230 km (124 nm) radius
• 4 x 4 km (2.2 x 2.2 nm) (#96 and #98)	Radar centered, 460 km (248 nm) radius

Data Levels: 8 (#95 and #96) and 16 (#97 and #98).

Annotations:

- Standard set*
- Combined Attribute Table
- Data level code
- Maximum CRE data value detected.

Adaptation: None.

2.7.2 Usage.

- Permits a view of maximum reflectivity levels for the total volume within the range of the radar. As such, it provides a synopsis of the most important reflectivity features in the entire coverage area but at the same time most AP that might be present in CR is removed with this product.
- Allows the user to quickly establish the maximum aerial extent of reflectivity patterns and locate reflectivity maxima with respect to the surface of the Earth. However, information regarding the height above ground or the 3-dimensional structure of the reflectivity pattern must be determined by the use of other products.
- Under favorable reflectivity conditions, a bright band feature may enable the user to identify the presence of the melting level.

2.7.3 Strengths/Applications. Similar to CR except that much of the AP is removed.

2.7.4 Limitations. Similar to CR except that while much of the AP is removed, residual AP will persist under some circumstances.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

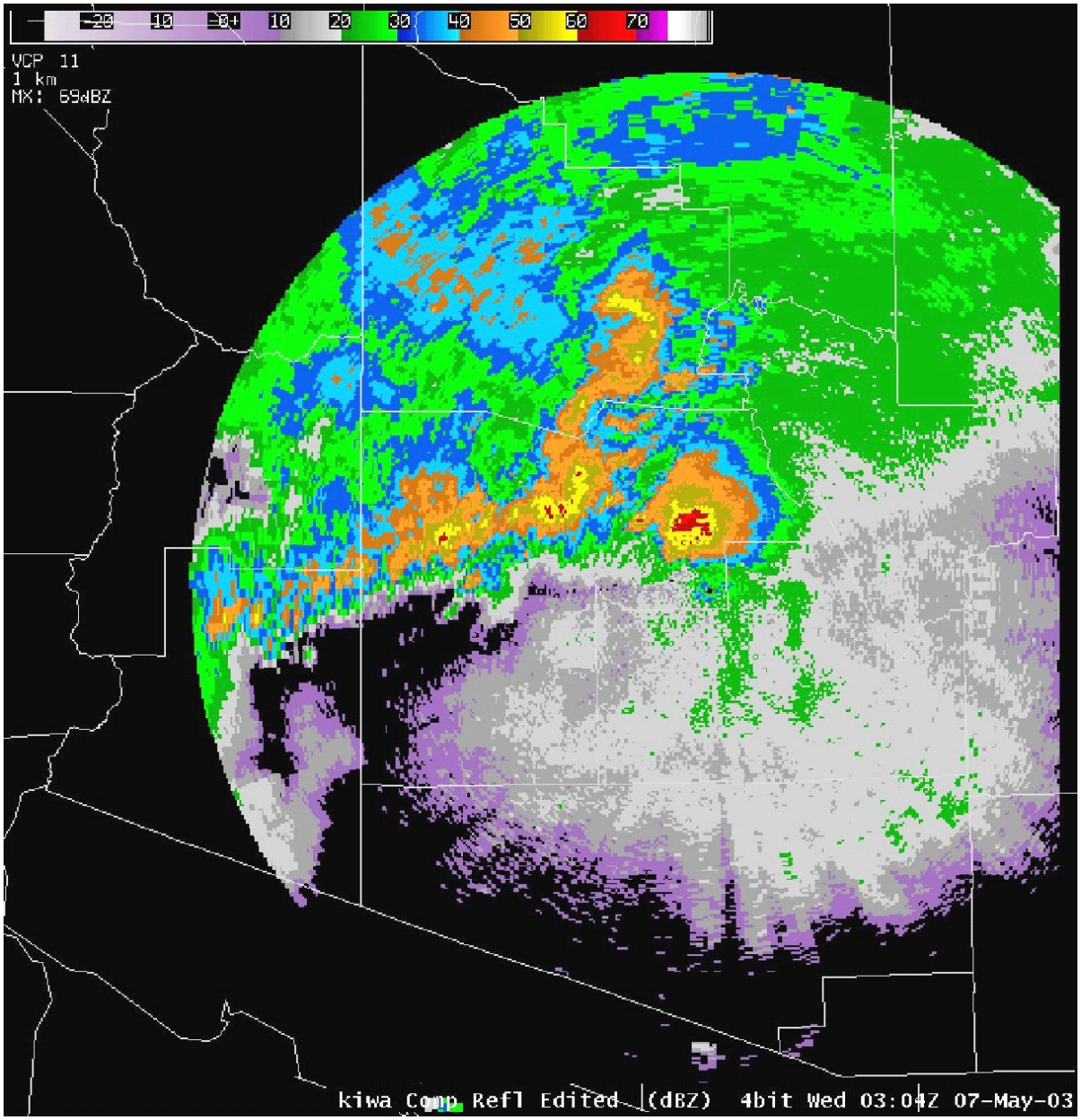

Figure 2-7a
Composite Reflectivity Edited for Anomalous Propagation Product

A Phoenix, AZ (KIWA) WSR-88D CRE product, 1 km X 1 km (0.54 nm x 0.54 nm) resolution and 16 data levels on 7 May 2003 at 03:04 UTC. (AWIPS display)

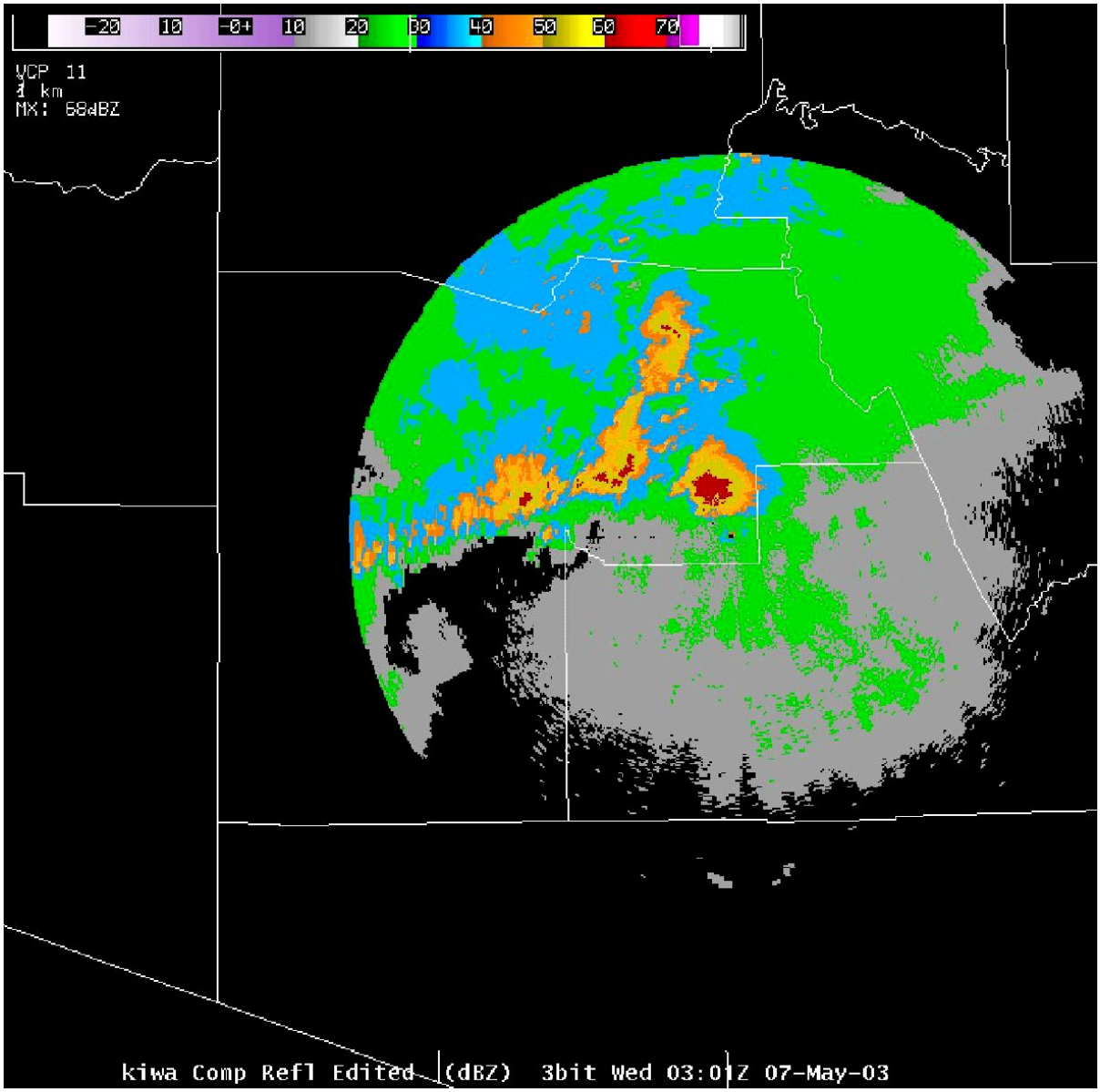

Figure 2-7b
Composite Reflectivity Edited for Anomalous Propagation Product

A Phoenix, AZ (KIWA) WSR-88D CRE product, 1 km X 1 km (0.54 nm x 0.54 nm) resolution and 8 data levels on 7 May 2003 at 03:01 UTC. (AWIPS display)

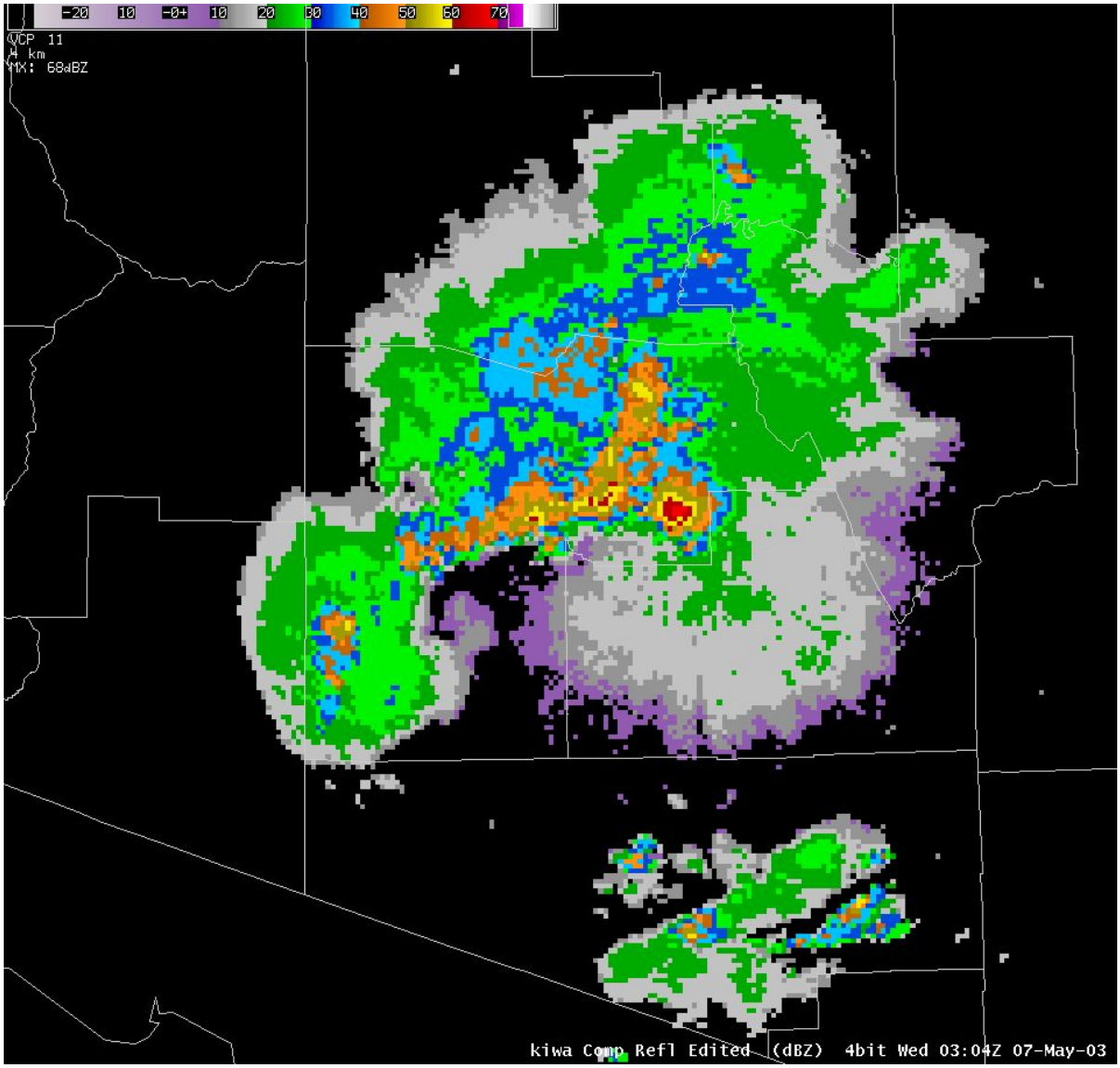

Figure 2-7c
Composite Reflectivity Edited for Anomalous Propagation Product

A Phoenix, AZ (KIWA) WSR-88D CRE product, 4 km X 4 km resolution (2.2 nm x 2.2 nm) and 16 data levels on 7 May 2003 at 03:04 UTC. (AWIPS display)

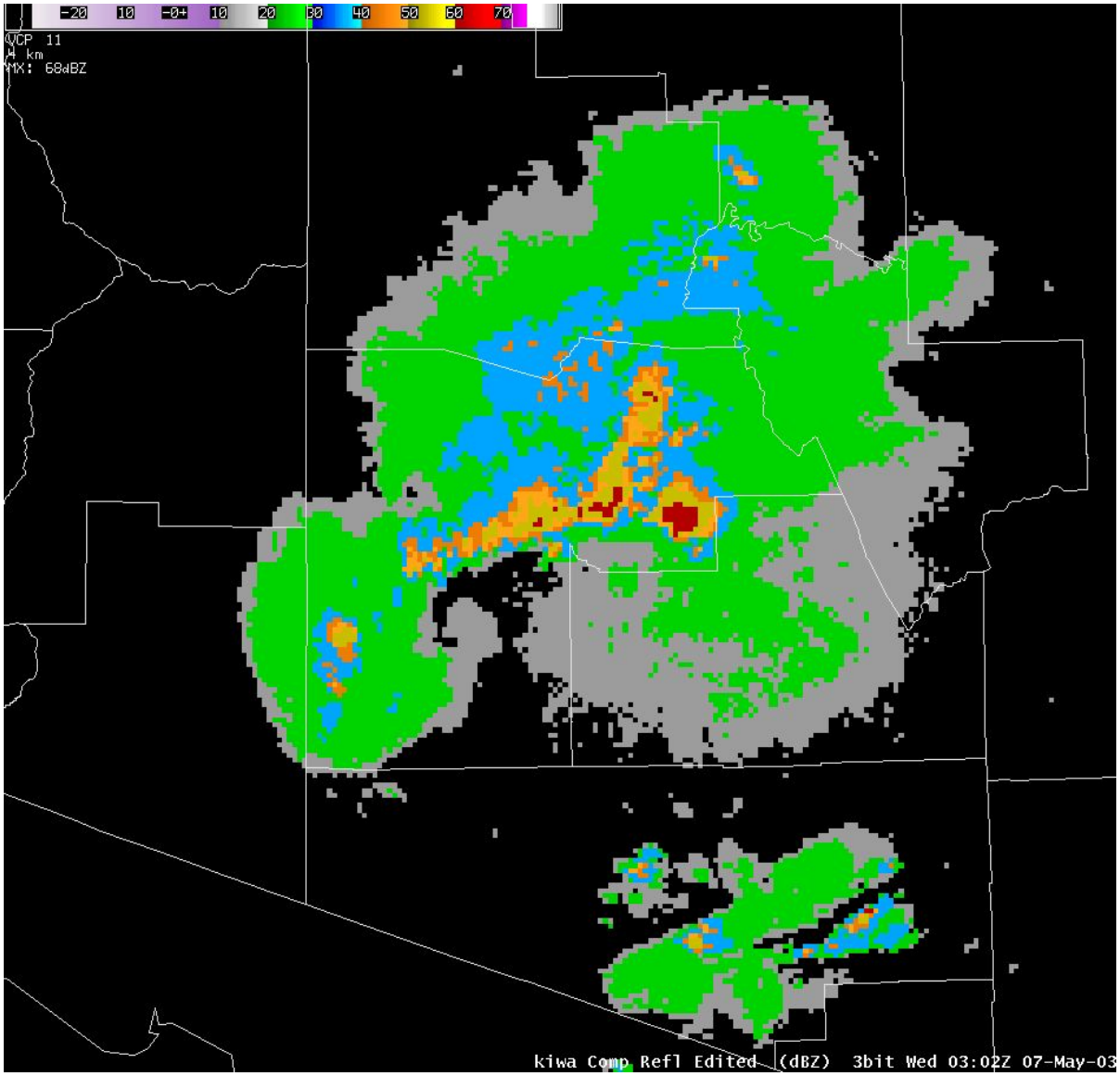

Figure 2-7d
Composite Reflectivity Edited for Anomalous Propagation Product

A Phoenix, AZ (KIWA) WSR-88D CRE product, 4 km X 4 km (2.2 nm x 2.2 nm) resolution and 8 data levels on 7 May 2003 at 03:02 UTC. (AWIPS display)

2.8 <u>Cross Section Reflectivity and Cross Section Mean Radial Velocity</u>. The Cross Section products provide a vertical cross section of either reflectivity or mean radial velocity as an image for a user-selected vector. The operator defines the vector by using two end points, up to 230 km (124 nm) apart, and at any orientation and location within 230 km (124 nm) of the radar. The products are produced by mapping the nearest value in range (within certain limits), to a point in the plane of the vertical cross section. For data gaps, the WSR-88D linearly interpolates between the mapped values, both horizontally and vertically as necessary, for the Cross Section products.

2.8.1 Operational Characteristics.

System ID: RCS (reflectivity), Products # 50 and # 85 and VCS (mean radial velocity), Products #51 and #86.

Data:

- Reflectivity or mean radial velocity
- End points of cross section.

Processing:

- Map nearest data value from volume scan to the point in the plane of the vertical cross section defined by the intersection of the plane and radial.
- Interpolate linearly (both horizontally and vertically) between mapped values, as necessary to fill blank areas.
- When several data values from a volume scan map into a grid box of the plane of the vertical cross section, the maximum data value is selected.
- Vertical interpolation between grid boxes, in which the centers of the beams are located at the radial distances of the cross section.
- The presentation of the display does not account for beam broadening as a function of range.

Availability: Upon user request for one of the data types listed above.

Presentation:

- Cartesian image of requested data; Cartesian data plane of height versus distance (Figures 2-8, a and b).
- Radar located at origin of product display axes for range height indicator (RHI) version of product (one end point at 0, 0). Otherwise end points may be placed any where within 124 nm of the radar as long as the baseline of the product is less than 124 nm.

Resolution: 1 km (0.54 nm) horizontal x 0.5 km (0.27 nm) vertical.

Coverage: Radar centered, 230 km (124 nm) radius x 21.3 km (70,000 ft) (vertical).

Data Levels: 8 (#85 and #86) and 16 (#50 and #51).

Annotations:

- Standard set*
- Data level code
- Data type
- Location of vector center and the end points (azimuth and range)
- Maximum data value detected and location.

Adaptation: Velocity data levels.

2.8.2 Usage.

- Vertical viewing of storms or other radar features along a selected path of interest.
- Reflectivity cross-section useful for estimating echo tops and, to a limited degree, vertical structure of reflectivity.
  - The sensitivity of the WSR-88D allows the detection of cirriform and mid-level clouds. The range of detection is dependent on the ice crystal and snowflake composition.
  - Stratocumulus clouds will often contain precipitation aloft as raindrops or ice crystals and snowflakes, or both, large enough to be detected by the WSR-88D.
  - Precipitation events can be monitored as they evolve and dissipate by observations of descending reflectivity patterns.
  - Moisture or turbulent layers, or both, can be observed from backscatter from refractivity fluctuations.
  - The evolution of the planetary boundary layer can be monitored from the backscatter from refractivity structure, particulates, and biological targets.
  - Horizontal rolls and the evolution of shear oriented convergent bands/cloud streets at the top of the planetary boundary layer can be monitored. The depth of the planetary boundary layer can be monitored during a diurnal cycle.
  - Features such as the bright band may be observed.
- Mean Radial Velocity cross sections can be used to identify boundary layer characteristics, outflow regions, storm summit divergence, jets aloft, descending rear inflow jets, mesocyclone vertical extent, radial convergence aloft, etc.
- Setting of the end points at the radar location will produce a simulation of the more traditional RHI display.

2.8.3 Strengths/Applications.

- Detects vertical extent and placement of precipitation, clouds (containing precipitation sized particulates), insects, smoke plumes, and volcanic ash eruptions.
- Verify existence and location of a bright band.
- Estimate heights of given reflectivity values including echo tops (18 dBZ).
- Evaluate storm structure features such as the WER and Bounded WER (BWER) along the cross section axis.
- Monitor vertical development and dissipation of precipitation.
- Velocity cross sections aid in determining storm top divergence, strength and vertical extent of the convective storm Deep Convergence Zone or the Mid Altitude Radial Convergence region, the mesocyclone, and the TVS.
- Aids in estimating vertical depth and placement of various layers such as cold air, gust fronts, and other types of fronts and regions of convergence and divergence.
- Has proven value in gaining insight into atmospheric kinematic structure in a research setting.

2.8.4 Limitations.

- Mean Radial Velocity cross sections along an arbitrary axis will have mean radial velocity values at unknown orientations to cross section plane.
- Cross section placement may hamper evaluation of storm structure.
- Height estimates are inaccurate due to beam width increases with range, gaps in the VCP, refractive index variations, etc.
- Non-contiguous volume scanning and observations at long range will produce coarse resolution.
- Echo tops and bases are truncated.
- Fast-moving storms may appear to be strongly tilted.
  - The horizontal and vertical extent of echo layers will depend on the beam width, pulse width, and range to the target. Generally, the result is to enlarge the features due to the depth/width of the radar beam.
- Reflectivities of layers may be reduced due to incomplete beam filling.
  - Interpolation between gaps may enlarge or miss features.
- Maxima, minima, and strong gradients of reflectivity will be reduced because of effective beam width and gate-length considerations.
- Reflectivity may be caused by backscatter from birds, insects, particulate matter or precipitation elements, or the refractive index structure.
- Displays have an aspect ratio that exaggerates the vertical scale (21.3 km (70,000 ft) as it relates to the horizontal scale (230 km (124 nm)) causing vertical stretching and relative apparent horizontal shrinking of features.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

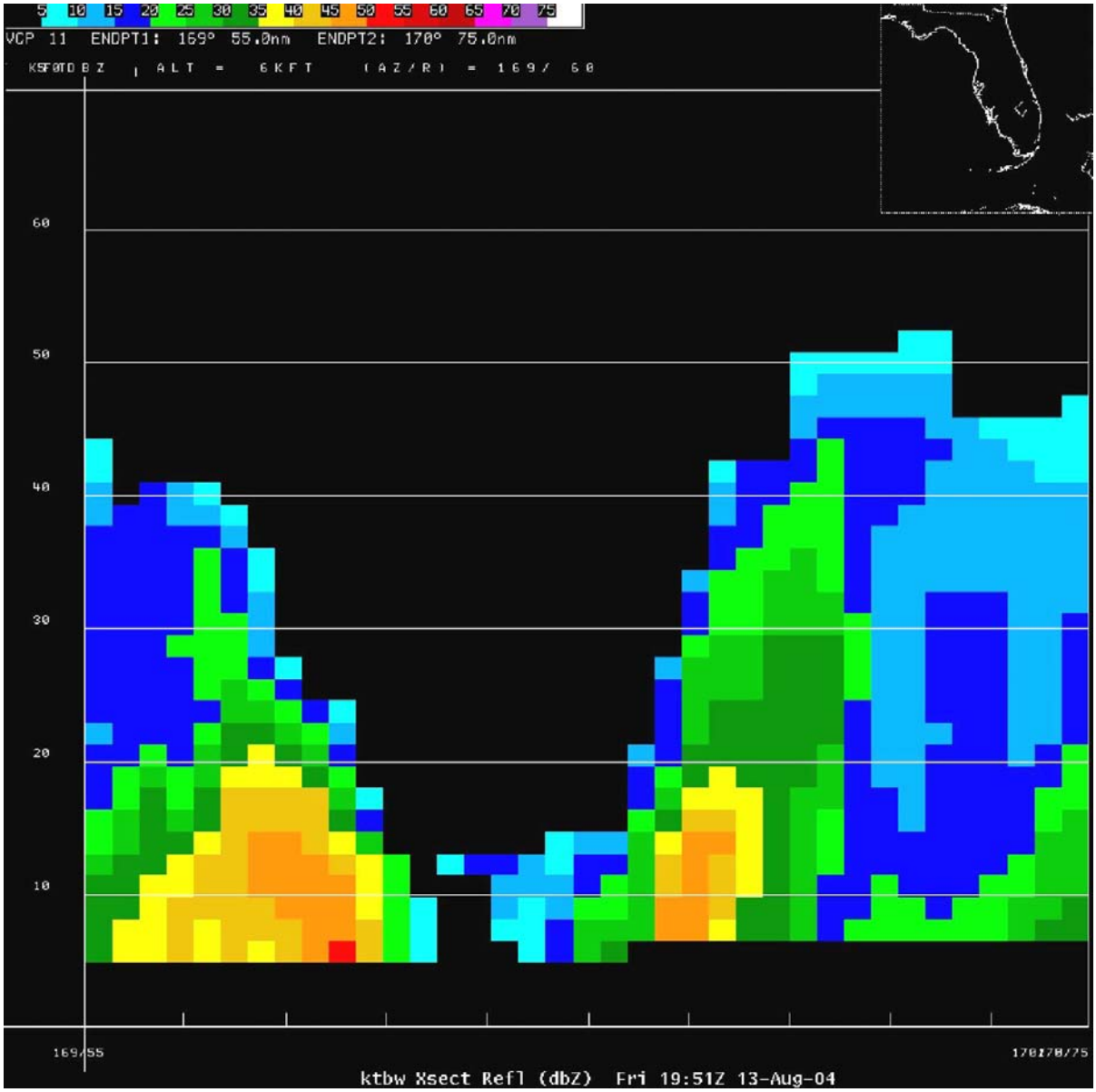

Figure 2-8a
Cross Section – Reflectivity Product

A Tampa Bay, FL (KTBW) WSR-88D RCS product, 16 data levels, on 13 Aug 2004 at 19:51 UTC. (AWIPS display)

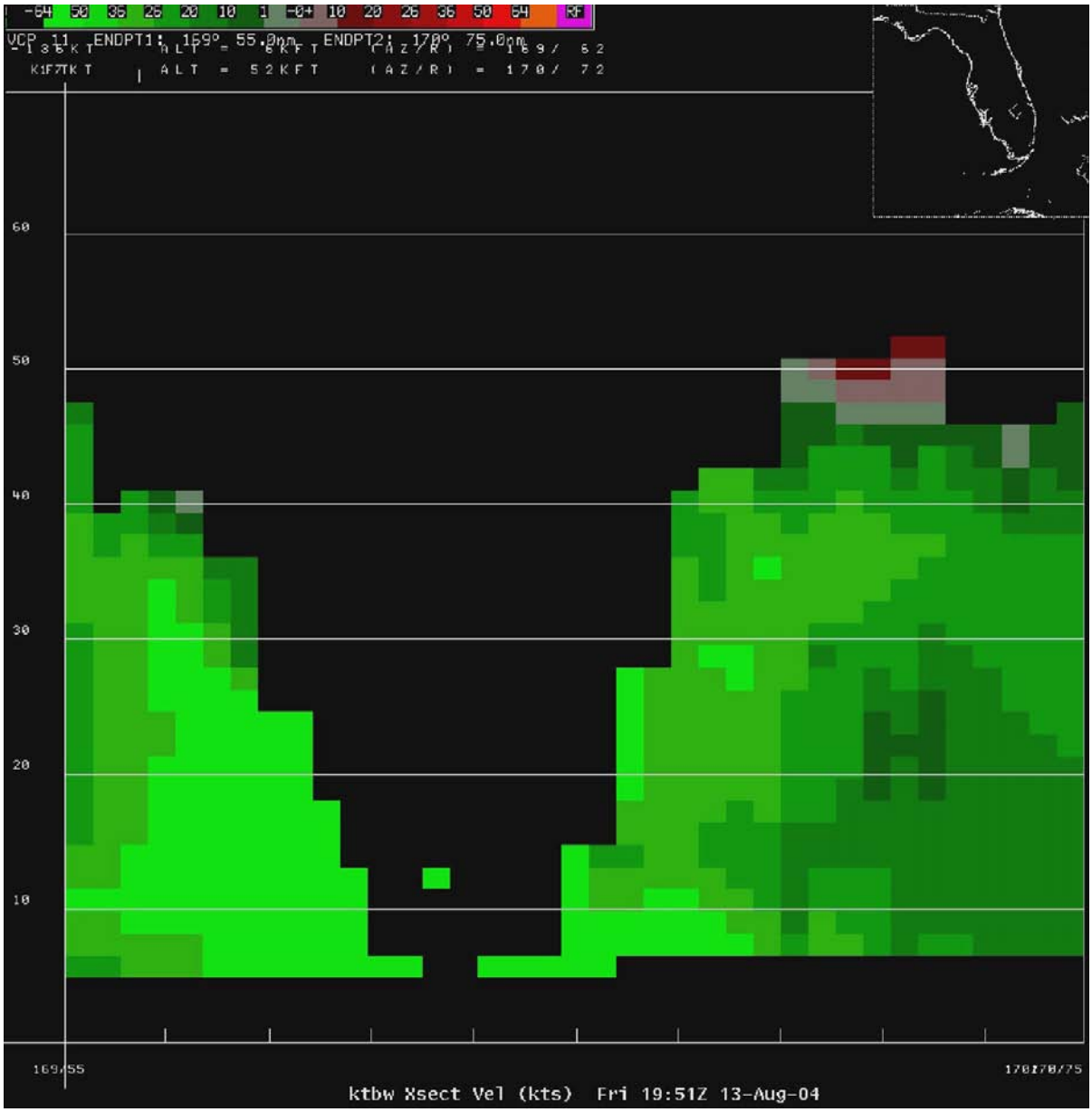

Figure 2-8b
Cross Section – Velocity Product

A Tampa Bay, FL (KTBW) WSR-88D VCS product (16 data levels) on 13 Aug 2004 at 19:51 UTC. (AWIPS display)

2.9 <u>Echo Tops</u>. The Echo Tops product (ET) provides the estimated height of the 18 dBZ (default) return, as estimated by the Echo Tops algorithm, rounded to the nearest 5000 ft MSL for display. The absence of qualifying echoes is reflected in a color graphic product stating "NO ECHOES DETECTED."

2.9.1 Operational Characteristics.

System ID: ET, Product #41.

Data: Height value of highest (in altitude) data-point meeting the minimum reflectivity value of 18.3 dBZ (adaptable parameter).

Processing: Vertically Integrated Liquid/Echo Tops algorithm.

Availability: Once per volume scan.

Presentation: Cartesian image of echo top height information (Figure 2-9).

Resolution:	**Coverage:**
• 4 x 4 km (2.2 x 2.2 nm)	Radar centered, 230 km (124 nm) radius 5,000 to 70,000 ft maximum in 5,000 ft increments in vertical.

Data Levels: 16.

Annotations:

- Standard set*
- Data level code
- Maximum data value detected (height in feet, MSL).

Adaptation: None.

2.9.2 Usage.

- Primary use of the product is to identify those storms with greater vertical development.
- Echo Tops heights are useful as part of briefings prepared for aviation interests and the general public.
- Can aid the user in defining the storm updraft flank, a strong updraft region or the presence of vertical updraft tilt within a storm.
- Observation of collapsing echo tops can aid in timing the onset of a severe weather event.

2.9.3 Strengths/Applications.

- Assist in discriminating AP and other forms of non precipitation echoes from precipitation.
- Aids in identification of storm structural features.
- May indicate elevated echo before any low-level echo is detected.

2.9.4 Limitations.

- There is no correction for data contamination from sidelobes which may result in over estimated tops. There is also no correction for the effects of beam broadening with range; nor for the "stair-step" product appearance due to the echo truncation at radar beam center-line and the use of fixed elevation angle sampling.
- There is no upward extrapolation from the last elevation where echo was detected.
- An echo top height is frequently incorrectly estimated because the VCP sampling is such that the true echo top lies in the vertical gap between successive elevation scans or it is above the highest elevation scan. The latter condition will frequently be true for storms within the cone of silence near the radar.
- Owing to beam broadening with range, discreet elevation angle sampling, and variation in the actual refractive index of the atmosphere, the echo top estimates are inaccurate, often by one or more product data level increments (5000 ft).
- Echo Top heights can differ significantly from visual cloud top heights.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

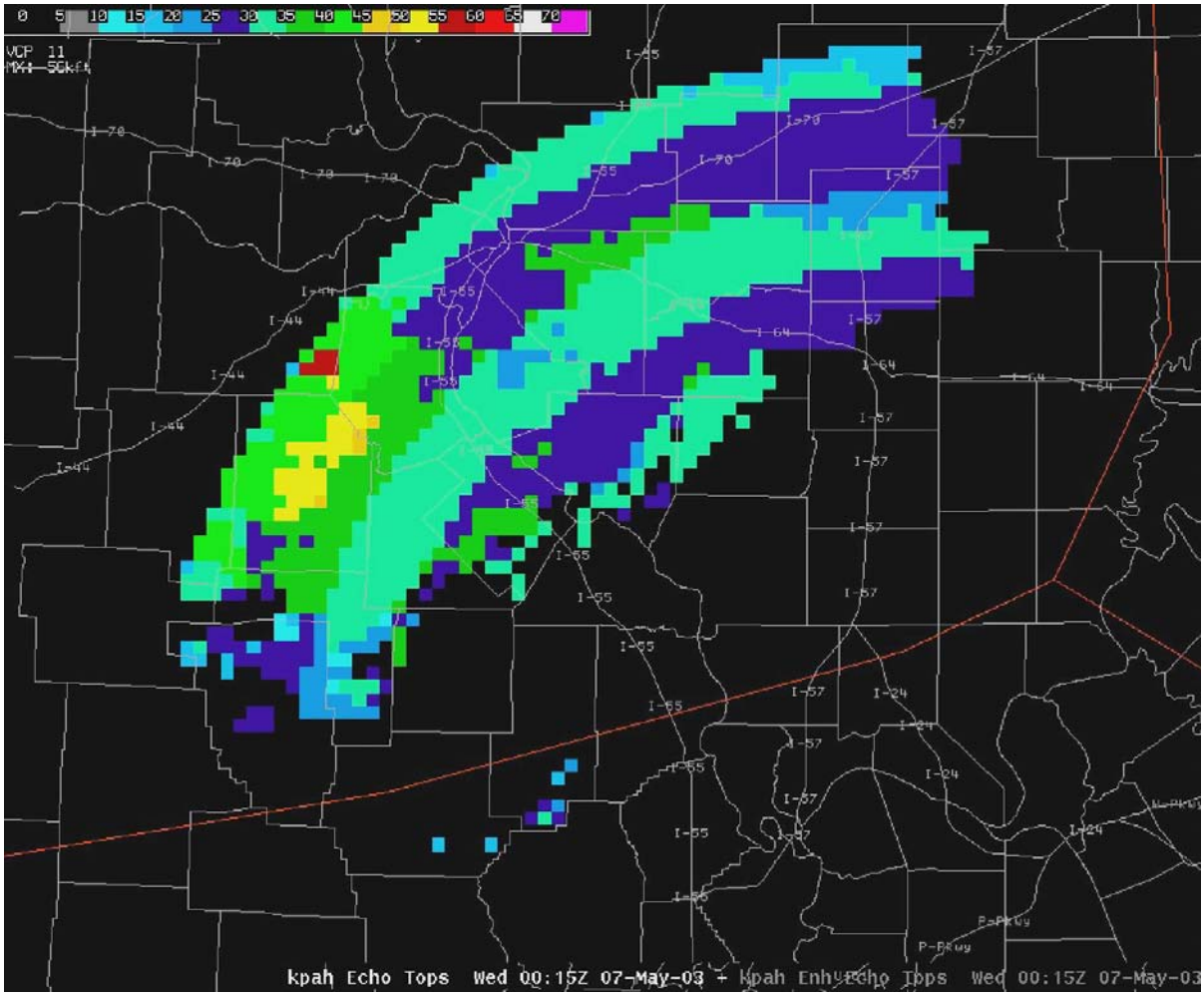

Figure 2-9
Echo Tops Product

A Paducah, KY (KPAH) WSR-88D ET product on 7 May 2003 at 00:15 UTC (AWIPS display). This is at the same time as the EET product in Figure 2-10.

2.10 <u>High Resolution Enhanced Echo Tops</u>. The High Resolution Enhanced Echo Tops product (EET) provides the echo top information, but with linear interpolation providing finer vertical resolution as compared to ET. The result is a product with 1000 ft increments in the vertical. The horizontal resolution is also finer with the use of a polar coordinate instead of a Cartesian coordinate. Data values are referenced to MSL.

2.10.1 Operational Characteristics.

System ID: EET, Product #135.

Data: Height value, reached through linear interpolation, of highest (in altitude) sample volume point meeting the minimum reflectivity value of 18 dBZ (default).

Processing: Horizontal and vertical interpolation of reflectivity, Digital High Resolution Enhanced Echo Tops Algorithm and Data Quality Assurance Algorithm.

Availability: Updated once per volume scan.

Presentation: Polar coordinate image of echo top heights (Figure 2-10).

Resolution:	**Coverage:**
• 1 km (0.54 nm) x 1° at 1,000 ft interval	Radar centered, 345 km (186 nm) radius 1,000 to 70,000 ft in 1,000 ft increments in vertical.

Data Levels: 199.

Annotations:

- Standard set*
- Maximum data value detected (height in feet, MSL)
- Echo top threshold value (in dBZ)
- Number of artifact edited radials in volume
- Digital Data Level to EET conversion information.

Adaptation: Color levels.

2.10.2 Usage. Provides the user with an indication of the upper boundary of significant reflectivity. The product is designed to provide improved vertical estimates of precipitation tops and is superior to the ET product for aviation and other interests.

2.10.3 Strengths/Applications.

- 1,000 ft vertical resolution vs. 5,000 ft vertical resolution for ET**.**
- Finer horizontal resolution (1° x 1 km (0.54 nm)) in the radar framework of polar coordinates vs. the ET product which is on a Cartesian grid and has a resolution of 4 x 4 km (2.2 x 2.2 nm).
- Assist in discriminating AP and other forms of non precipitation echoes from precipitation.
- Aids in identification of storm structural features.
- May indicate elevated echo before any low-level echo is detected.

2.10.4 Limitations.

- There is no correction for data contamination from side lobes; which may result in over estimated tops. There is also no correction for the effects of beam broadening with range.
- An echo top height is frequently incorrectly estimated because the VCP sampling is such that the true echo top lies in the vertical gap between successive elevation scans or it is above the highest elevation scan. The latter condition will frequently be true for storms within the cone of silence near the radar. Vertical interpolation attempts to correct for this, but these errors are still present to some extent.
- Owing to beam broadening with range and variation in the actual refractive index of the atmosphere, echo top estimates are inaccurate, often by 5,000 ft or more.
- Echo Top heights can differ significantly from visual cloud top heights.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

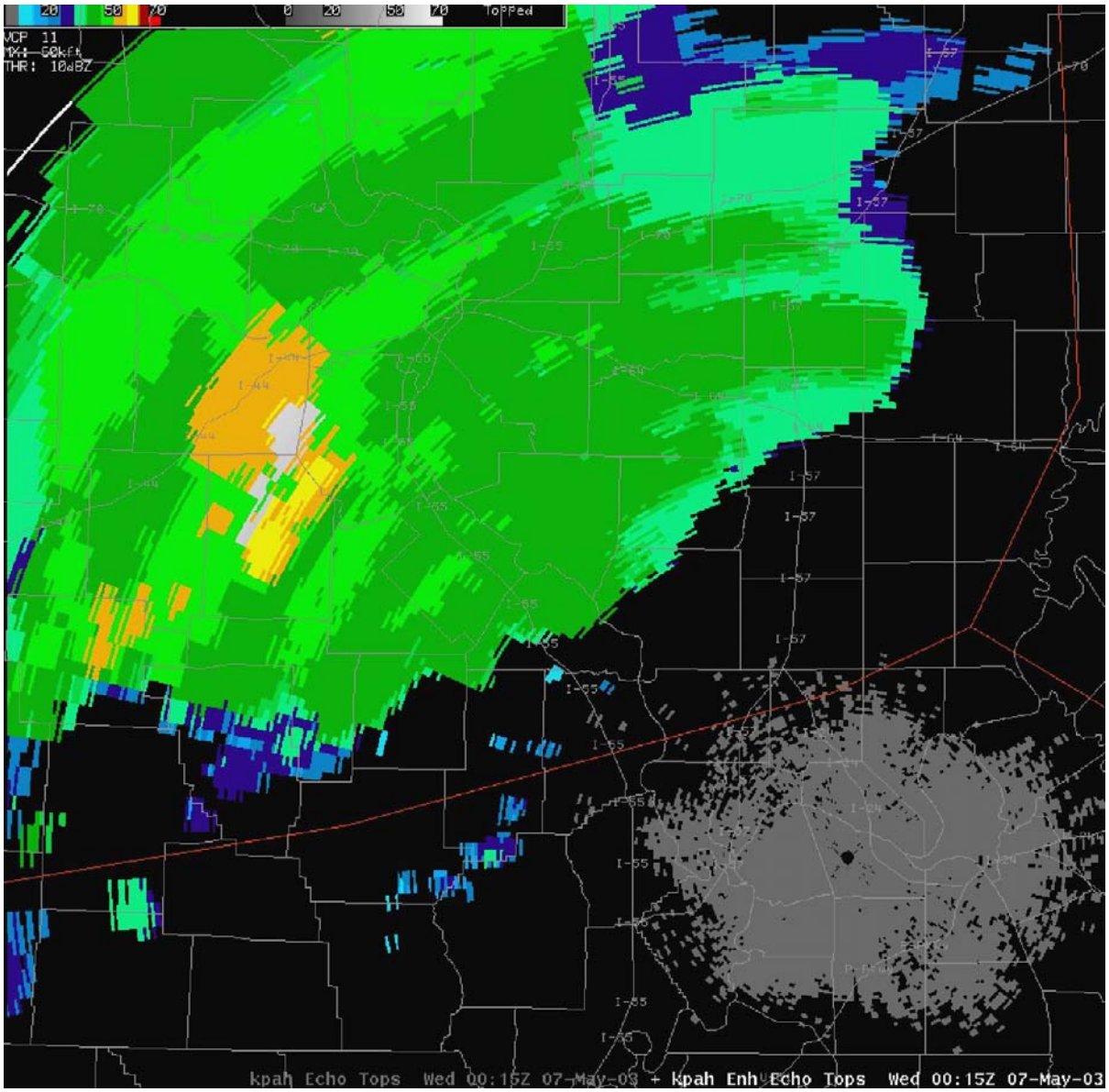

Figure 2-10
High Resolution Enhanced Echo Tops Product

A Paducah, KY (KPAH) WSR-88D EET product on 7 May 2003 at 00:15 UTC (AWIPS display). This is at the same time as the ET product in Figure 2-9.

2.11 <u>Free Text Message</u>. The Free Text Message product (FTM) is an alphanumeric message generated by a radar operator/maintainer at the MSCF HCI for transmission to RPG interfaces. A message may be designated to be transmitted to a specific unit interface or several interfaces. The message format may be a pre-worded message for further user editing.

2.11.1 Operational Characteristics.

System ID: FTM, Product #75.

Availability: When produced by the operator.

Presentation: An alphanumeric message (example below).

Annotations: RPG ID.

Adaptation: Alphanumeric character strings defining the message content, source, and intended destination.

EXAMPLE FTMs:

THE KXXX WSR-88D IS OPERATING WITH A DEGRADED RECEIVER. ECHO PLACEMENT SHOULD BE OKAY BUT EXCESSIVE BACKGROUND NOISE CAN BE NOTED. EL TECHS WILL INVESTIGATE LATER THIS MORNING.

THE KXXX WSR-88D WILL BE DOWN FOR ROUNTINE MAINTENANCE UNTIL 2000Z. WE APOLOGIZE FOR ANY INCONVENIENCE.

THE ECHOES THAT ARE SHOWING UP ON THE KXXX WSR-88D DATA OVER THE GULF OF MEXICO APPEAR TO BE CHAFF.

2.12 <u>Hail Index</u>. For each storm cell identified by the Storm Cell Identification and Tracking (SCIT) algorithm, the Hail Index product (HI) provides: a) the probability the storm will produce severe-sized (1.9 cm (¾ in) or larger) hail (POSH), b) the probability that the storm will produce hail of any size (POH), and b) the maximum expected size of that hail (MEHS). The HI product is produced by the Hail Detection Algorithm (HDA). The HDA uses environmental temperature information and the distribution and magnitude of reflectivity to determine the hail probabilities and size.

2.12.1 Operational Characteristics.

System ID: HI, Product #59.

Data:

- Output of Hail Detection Algorithm
- Meteorological algorithm output.

Processing: Hail Detection Algorithm.

Availability: Hail probabilities and size are computed for each SCIT-identified storm and updated once per volume scan.

Presentation:

- Alphanumeric annotation to other products.
- Formatted table of alphanumeric values (Figure 2-12).
- Special hail symbols overlaid on the identified storm on any geographically-based image product.
- HDA adaptable parameters in a tabular alphanumeric display.

Coverage: Hail probabilities and size will be computed for storms within 230 km (124 nm) of the radar.

Data Levels: 5. Probabilities are provided in increments of 10% with values between 0% and 100%. Hail sizes are provided in increments of 0.6 cm (0.25 in) up to a maximum of 10 cm (4 in); estimated hail sizes over 10 cm (4 in) are displayed as >4.00. Any storm cells beyond the coverage range are given probabilities and a size of "UNKNOWN".

Annotations:

- Standard set*
- Site adaptable parameters
- Storm ID.

Special Symbol: The hail symbol is a large or small green isosceles triangle, filled or unfilled depending on adaptable probabilities of severe hail and probabilities of hail. In addition, the maximum expected hail size rounded to the nearest inch is displayed in the middle of or next to the triangle. If the rounded MEHS is 0, an "*" is displayed.

Adaptation: See Section 3.5.1.

2.12.2 Usage.

- Provides the user with estimated probabilities of hail and severe hail and estimated maximum hail size.
- Selected hail probabilities and sizes can be used to generate alerts.

2.12.3 Strengths/Applications.

- The HI product has shown a very high probability of detection in cells that contain severe hail, especially greater than one-inch diameter hail. A POSH of 50% has the best skill as a warning threshold.
- Storms actually producing very large hail are often correctly indicated as producing such hail by the algorithm.

2.12.4 Limitations.

- For the HDA to perform well, it needs as algorithm input, accurate and timely measurements of the MSL altitudes for the 0° C and -20° C levels.
- Values of POH, POSH, and MEHS will fluctuate at close ranges, especially in Volume Coverage Pattern (VCP) 21, due to gaps in coverage at higher elevations.
- Values of POH, POSH, and MEHS lack accuracy at long ranges due to the broad radar beam and limited elevation angles sampling the storm.
- POSH and MEHS may be overestimated in weak wind and tropical environments.
- For storms beyond 230 km (124 nm), HI will indicate hail as unknown.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

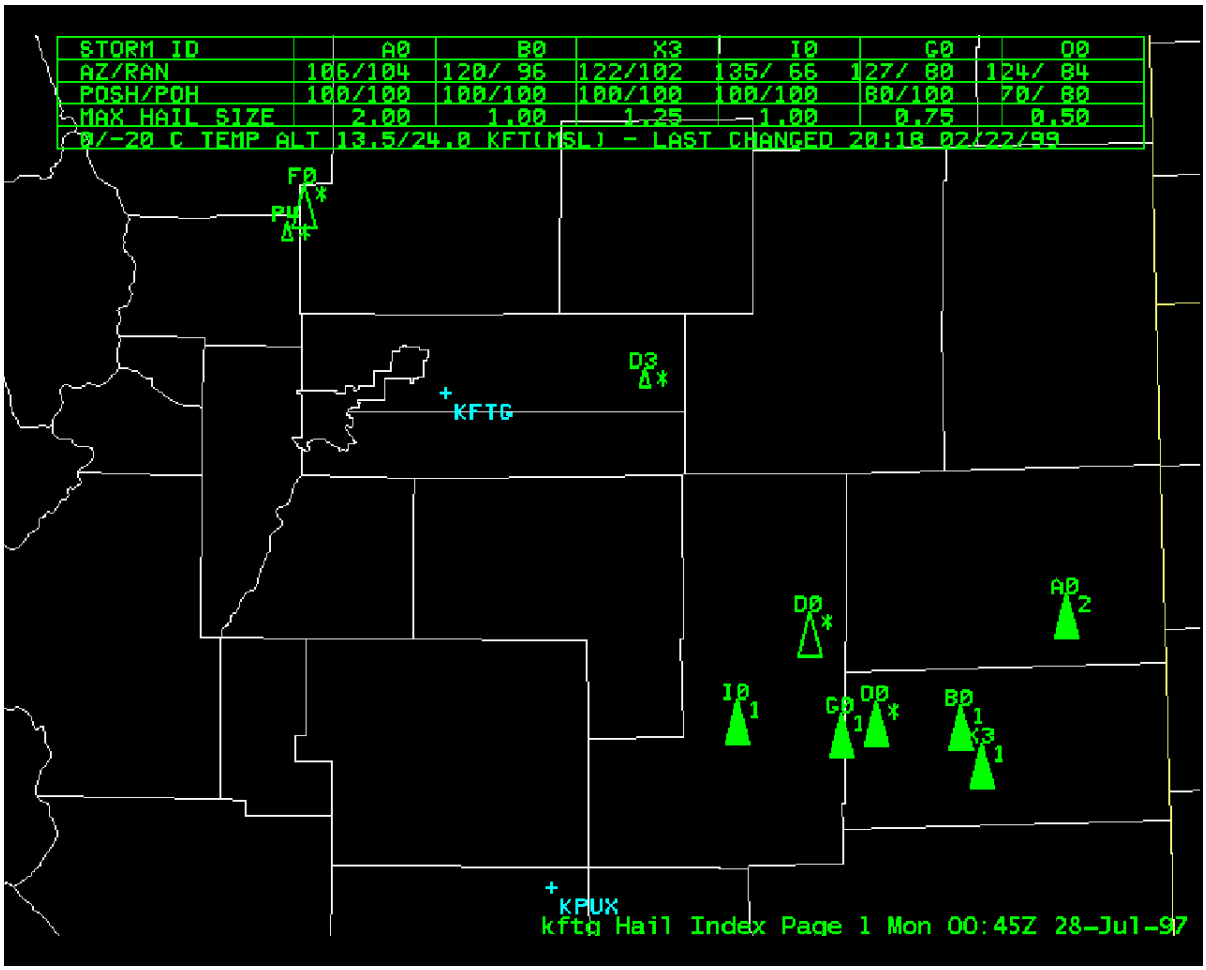

Figure 2-12
Hail Index Product

This HI example from the Denver, CO (KFTG) WSR-88D (AWIPS display) includes identification numbers for identified storms. The hail symbol is a large or small green isosceles triangle, filled or unfilled depending on adaptable probabilities of severe hail and probabilities of hail. In addition, the maximum expected hail size rounded to the nearest inch is displayed nest to the triangle. The Hail Attributes Table provides alphanumeric information.

2.13 Hybrid Scan Reflectivity. The Hybrid Scan Reflectivity product (HSR) is a display of the reflectivity values used in the conversion from reflectivity to rainfall rate (Hybrid Scan). Reflectivity for each azimuth and range is obtained from one of the four lowest tilts. In addition, the data has undergone a series of quality control steps, including corrections for beam blockage, spurious noise, outliers, ground returns, and for the change in beam altitude with range. All precipitation products are derived from the information found in the HSR product.

2.13.1 Operational Characteristics.

System ID: HSR, Product #33.

Data: Reflectivity.

Processing: Enhanced Preprocessing Algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image of reflectivity values, Figure 2-13.

Resolution: 1 km (0.54 nm) x 1°

Coverage: Radar centered, 230 km (124 nm) radius of radar.

Data Levels: 16.

Annotations:

- Standard set*
- Maximum Data Value (dBZ).

Adaptation: Algorithm variables.

2.13.2 Usage. Permits the user the ability to see the graphic product from which precipitation accumulations are calculated.

2.13.3 Strengths/Applications.

- Permits view of reflectivity used in precipitation products.
- Help assess the accuracy of precipitation products.
- Quick view of inconsistencies within the precipitation products.
- Assists in discriminating between precipitation and returns due to AP and clutter residue.

2.13.4 Limitations.

- The bin selected for inclusion in the hybrid scan product is highly dependent upon the output of the REC algorithm and its ability to correctly identify returns from ground clutter. Therefore, limitations listed for the CLR product are applicable to the hybrid scan reflectivity product. The results must be used with caution in areas where there is range folded/overlaid data.

- Ground clutter and AP are sometimes in the product display.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

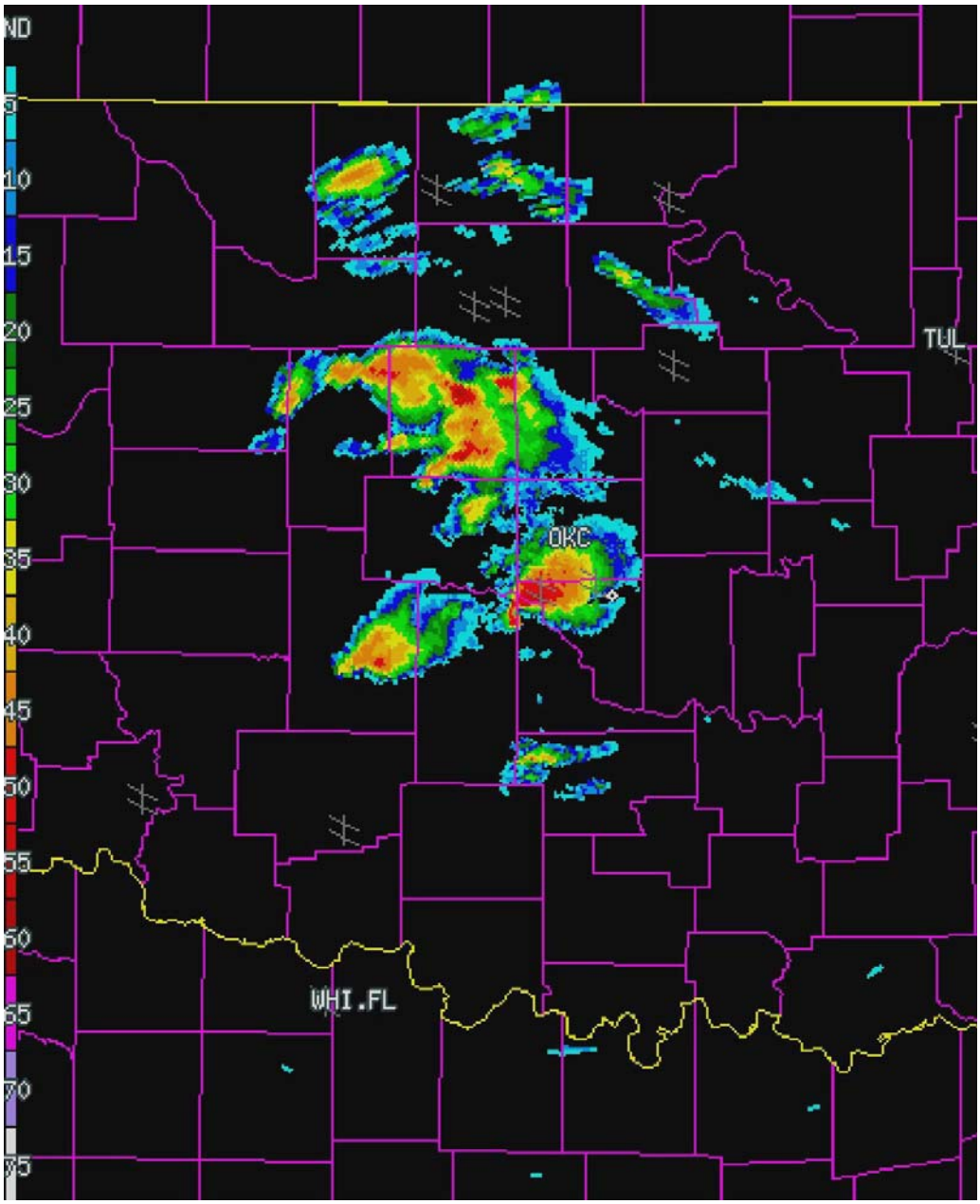

Figure 2-13
Hybrid Scan Reflectivity Product

This HSR example (AWIPS display) is from the Oklahoma City, OK WSR-88D (KTLX).

2.14 Digital Hybrid Scan Reflectivity. The Digital Hybrid Scan Reflectivity product (DHR) provides radar-reflectivity values for the composite Hybrid Scan formatted as a digital data array. The product is assembled from the lowest elevation reflectivity range bins that meet a reflectivity threshold and is not flagged as being from ground clutter and yielding a representative reflectivity value at every sample bin location

2.14.1 Operational Characteristics.

System ID: DHR, Product #32.

Data: Reflectivity.

Processing: Enhanced Preprocessing Algorithm.

Availability: Once per volume scan.

Presentation: A data array product or Polar coordinate image of reflectivity values.

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 256.

Annotations:

- Standard set*
- Spot Blanking Status
- Maximum Data Value (dBZ).

Adaptation: Algorithm variables.

2.14.2 Usage. Provides the hybrid scan digital array for use external to the WSR-88D.

2.14.3 Strengths/Applications.

- High resolution (256 data levels)/ increments of 0.5 dBZ permits detailed record of precipitation accumulation.
- Used in the generation of external products for monitoring flash flood potential, basin estimated precipitation, etc.

2.14.4 Limitations.

- The bin selected for inclusion in the hybrid scan product is highly dependent upon the output of the REC algorithm and its ability to correctly identify returns from ground clutter. Therefore, limitations listed for the CLR product are applicable to the hybrid scan reflectivity product. The results must be used with caution in areas where there is range overlaid data.

- Ground clutter and AP are sometimes in the product display.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

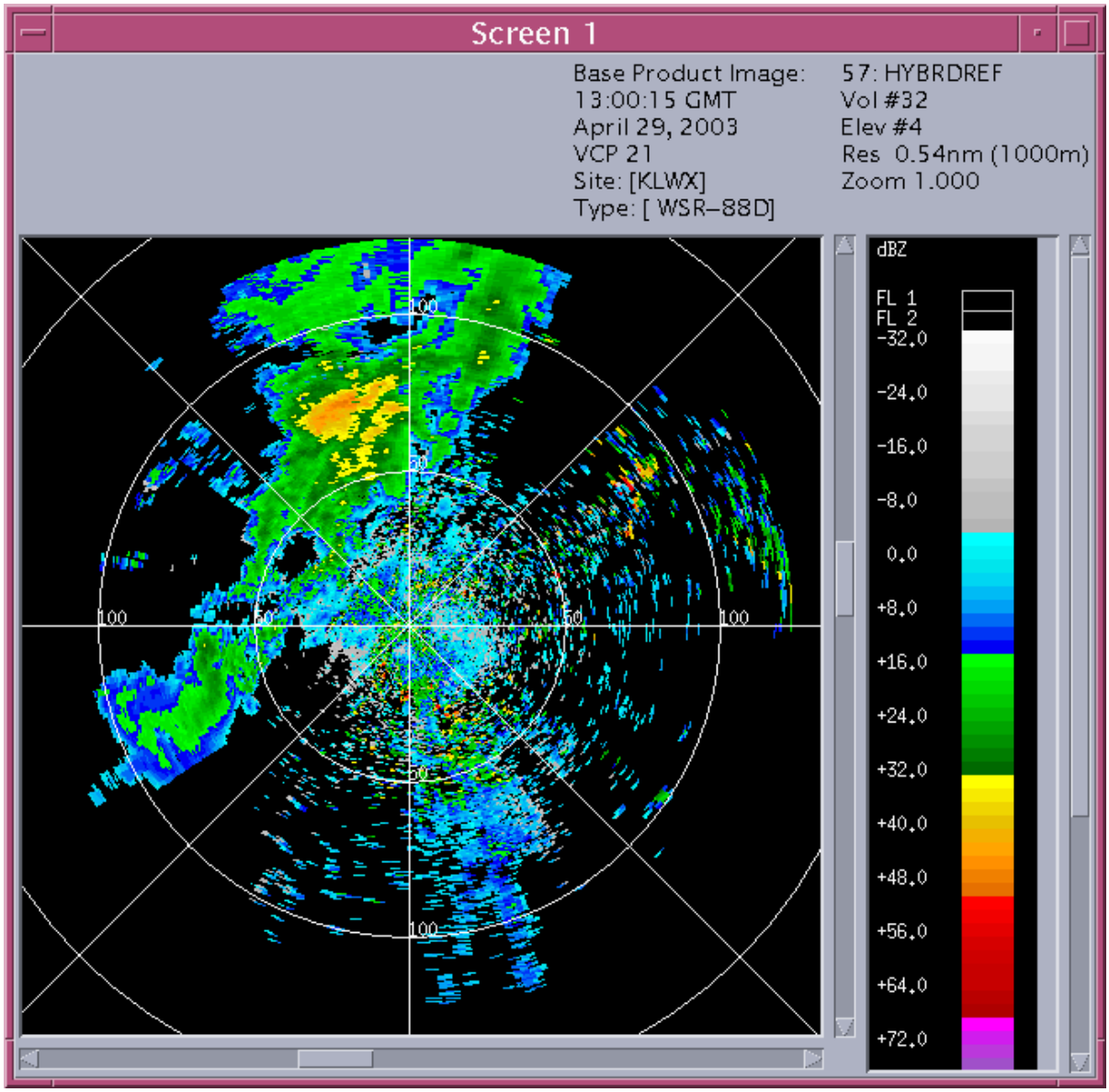

Figure 2-14
Digital Hybrid Scan Reflectivity Product

This DHR product can be compared with the 0.5° Reflectivity product in Figure 3-1 to show how the Radar Echo Classifier removes clutter before processing to produce precipitation products (CODE View graphic display and generated by RPG Build 6 software). Note most of the high reflectivity values to the ENE through E to SW of the radar (KLWX, Sterling, VA) have been removed. The DHR is used by the NWS Flash Flood Monitoring and Prediction (FFMP) program.

2.15 <u>Layer Composite Reflectivity</u>. The Layer Composite Reflectivity products (LRA and LRM) are available for three layers; the depth of each layer is controlled by adaptation data, but must be greater than 6,000 ft. Default values for the layers are surface to 24,000 ft MSL (low), 24,000 ft to 33,000 feet MSL (mid), and 33,000 to 60,000 ft MSL (high). For a layer, the layering algorithm establishes a composite value by either taking the maximum or computing an average of the individual values within the layer grid box.

2.15.1 Operational Characteristics.

System ID: LRA (average), Products: #63, #64 and #89 (low, mid, and high layers respectively).
LRM (maximum), Products #65, #66, and #90 (low, mid, and high layers respectively).

Data: Composite reflectivity.

Processing:

- Averaging algorithm.
- Layer Composite algorithm.

Availability: Three products per volume scan: Low, Middle, and High.

Presentation: Cartesian image of layer composite reflectivity values (Figures 2-15, a and b).

Resolution:	**Coverage:**
• 4 x 4 km (2.2 x 2.2 nm)	Radar centered, 460 x 460 km (248 x 248 nm) radius (#63, 64, 89) Radar centered, 230 x 230 km (124 x 124 nm) radius (#65, 66, 90).

Data Levels: 8.

Annotations:

- Standard set*
- Calibration constant (scaling constant used by the PSP to calculate reflectivity)
- Layer boundary (vertical depth)
- Maximum reflectivity value detected.

Adaptation:

- Composite method (average or maximum)
- Depth of layers.

2.15.2 Usage.

LRA:

- Intended primarily for distribution to the Air Route Traffic Control Centers (ARTCCs) for use of the Center Weather Service Unit (CWSU) meteorologist and for the development of regional layer composite reflectivity maps.
- Comparison of LRA maps with CR products can provide insight regarding vertical development of both stratiform and cumuliform regimes.
- The high-layer product is useful for identifying those weather systems with extensive vertical development.

LRM:

- Intended primarily for distribution to the ARTCCs for use of the CWSU meteorologist and for the development of regional layer composite reflectivity maps.
- Comparison of layer Composite maps with composite reflectivity can provide insight regarding vertical development of both stratiform and cumuliform regimes.
- The high-layer product is useful for identifying those weather systems with extensive vertical development.
- Useful for monitoring heights of reflectivity maxima.

2.15.3 Strengths/Applications.

LRA: Use the Mid-Level product to help differentiate meteorological echoes from ground clutter.

LRM:

- Mid- and High-Level products are used to estimate the height of the higher reflectivities.
- Comparison of Reflectivity and Mid- or High-Layer LRM products may aid in determining height interval of maximum reflectivity and a storm's intensity trend.
- Use the Mid-Level product to help differentiate meteorological echoes from ground clutter.

2.15.4 Limitations LRA and LRM.

- Altitude limitations on scanning may result in missing significant low-level reflectivity

at longer ranges in the low-layer product and high-level reflectivity at closer ranges in the High-Layer product.

- 8-level products have course resolution.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

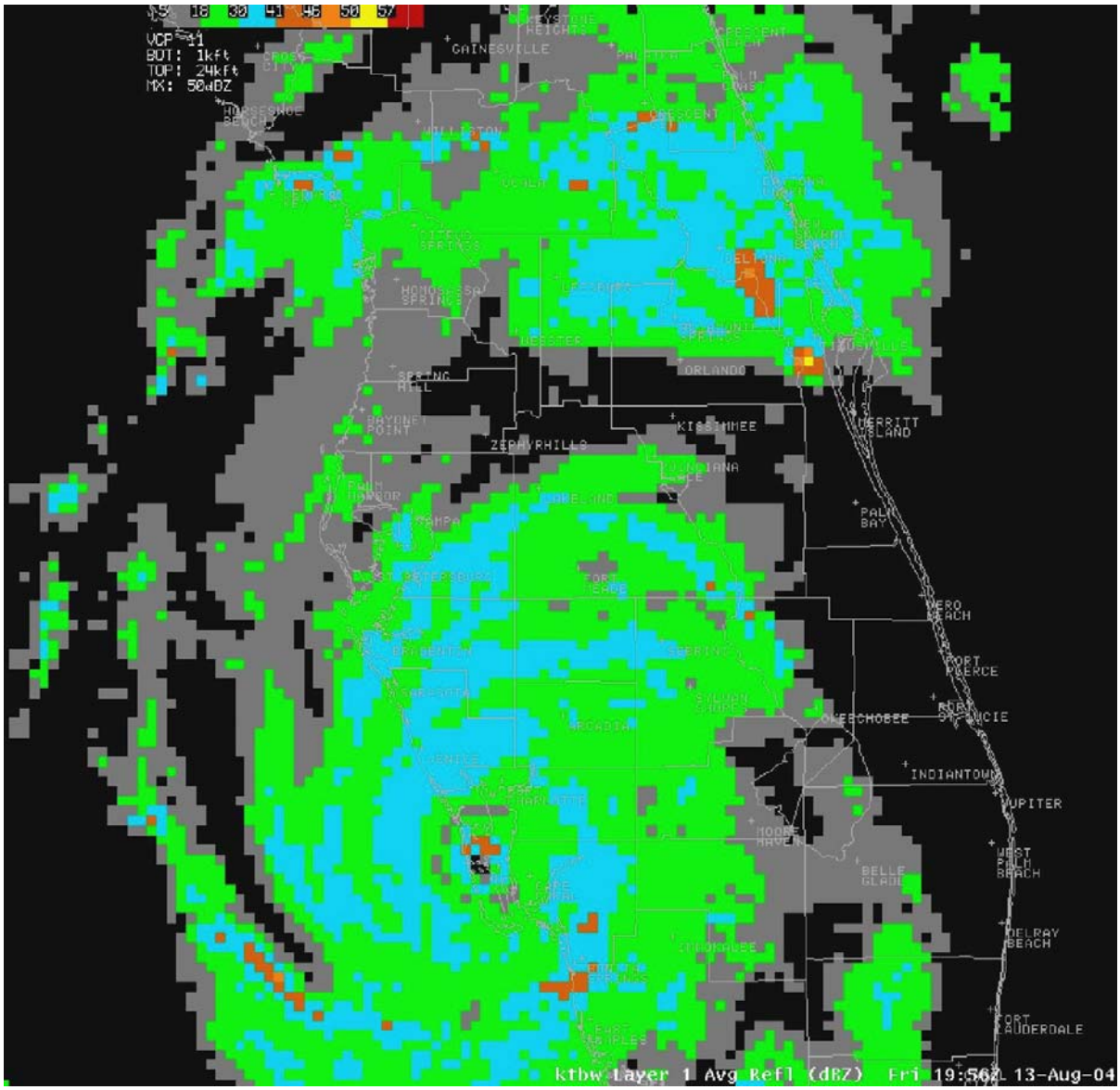

Figure 2-15a
Layer Composite Reflectivity, Low-Level, Product

This LRA example (AWIPS display) is from the Tampa Bay, FL (KTBW) WSR-88D on 13 August 2004 at 19:56 UTC as Hurricane Charley approached the radar. The data time is the same as for Figure 2-15b.

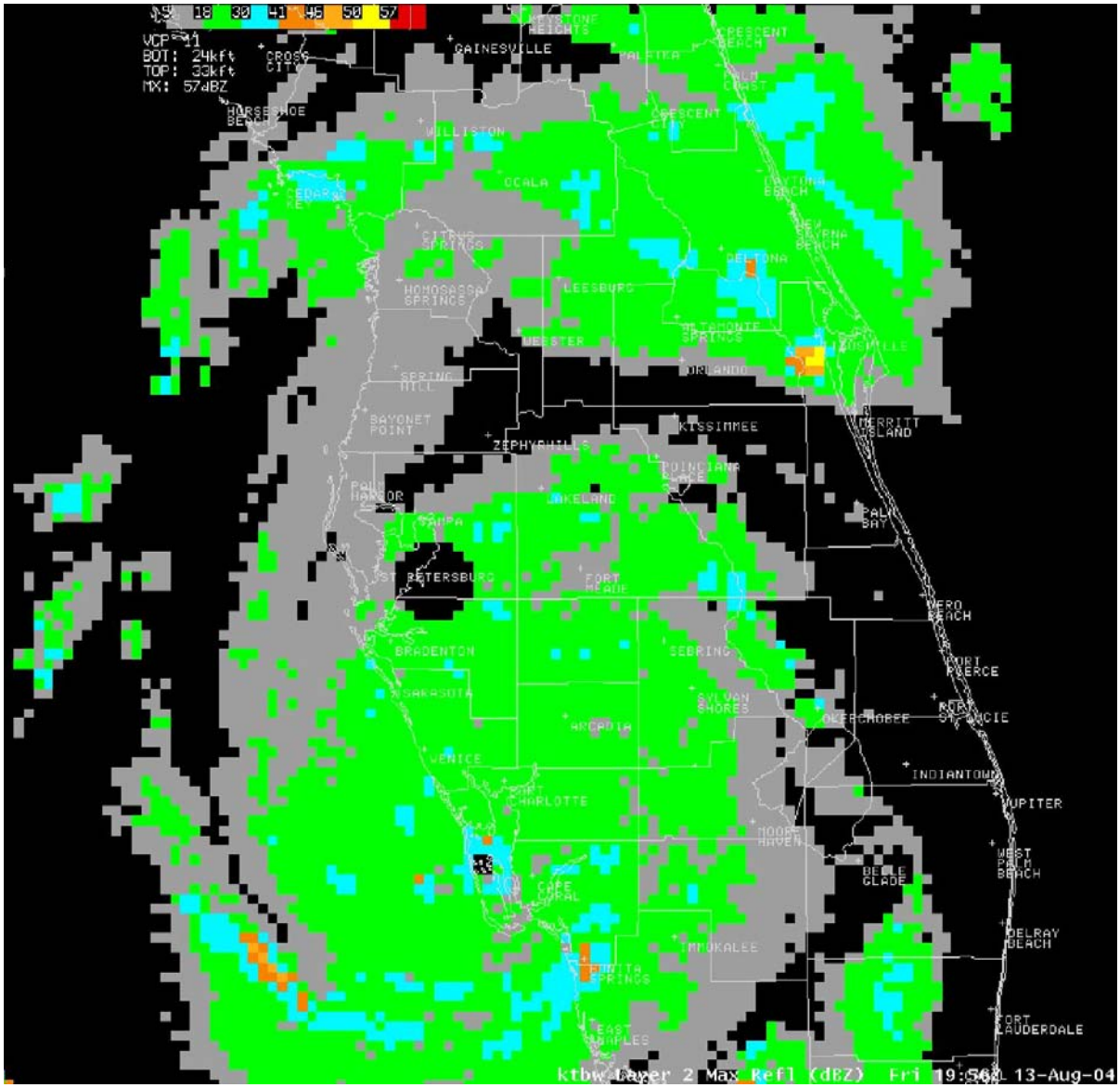

Figure 2-15b
Layer Composite Reflectivity, Mid-Level, Product

This LRM example (AWIPS display) is from the Tampa Bay, FL (KTBW) WSR-88D on 13 August 2004 at 19:56 UTC as Hurricane Charley approached the radar. The data time is the same as for Figure 2-15a.

2.16 User Selectable Layer Composite Reflectivity Maximum. The User Selectable Layer Composite Reflectivity Maximum product (ULR) is polar gridded and allows the operator to choose any layer (1000 ft or more in depth) from the surface to 21.3 km (70,000 ft). The layer is a composite reflectivity maximum.

2.16.1 Operational Characteristics.

System ID: ULR, Product #137.

Data: Composite reflectivity.

Processing:

- Maximum reflectivity selection
- Layer Composite algorithm.

Availability: Updated once per volume scan.

Presentation: Polar coordinate image of layer composite reflectivity values (Figure 2-16).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Calibration constant (scaling constant used by the PSP to calculate reflectivity)
- Composite method (maximum)
- Data level code
- Layer boundary (vertical depth)
- Maximum reflectivity value detected.

Adaptation: Layer Boundaries.

2.16.2 Usage. Similar to the LRM usage, but with the flexibility of the operator specifying the layer heights and thickness. This flexibility enhances monitoring storm growth, severe storm warning operations, and forecasts of aircraft icing and convective storms.

2.16.3 Strengths/Applications.

- The layer can be selected to meet user needs; can be as thin as 1000 ft.
- Has higher resolution by using polar coordinates and more data levels than standard LRM products.
- Can be used to locate and monitor the bright band.
- Can be used to monitor aircraft icing and storm growth.
- Product is a constant altitude layer similar to a Constant Altitude Plan Position Indicator (CAPPI) and can be used to monitor features at a fixed altitude instead of a sloping surface (i.e., base products).
- Can be used to display reflectivity above certain thresholds used by, for example, the Hail Index algorithm.

2.16.4 Limitations. Height of data within selected layer is unavailable.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

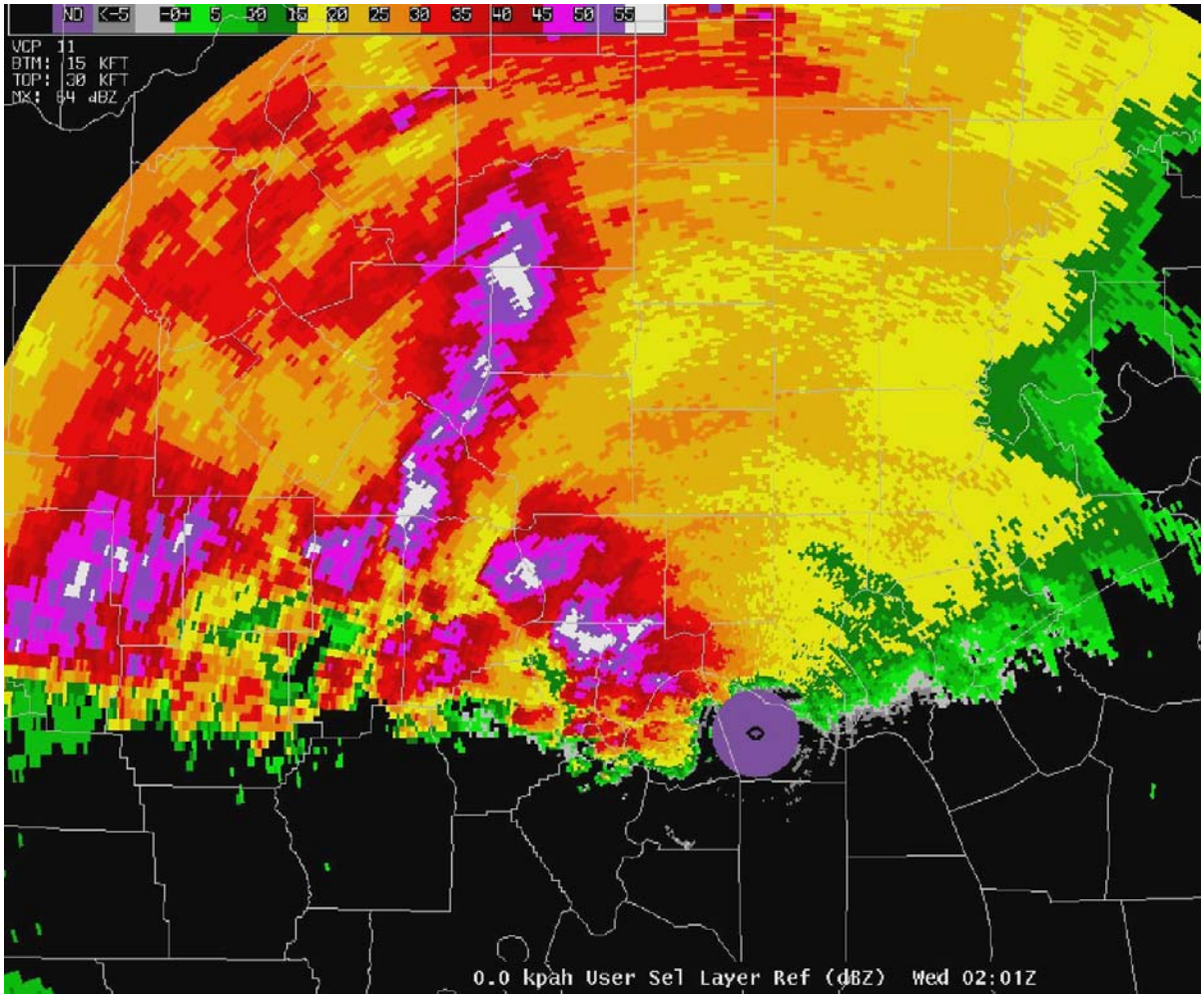

Figure 2-16
User Selectable Layer Reflectivity Maximum Product

A ULR example (AWIPS display) from the Paducah, KY WSR-88D (KPAH).

2.17 <u>Layer Composite Reflectivity – Anomalous Propagation Removed</u>. The Layer Composite Reflectivity – AP Removed product (APR) is an 8-data level reflectivity display similar to the LRM Low Layer 1, product. However, in the lowest defined layer, AP is removed to help prevent misinterpretation. It is derived from the output of an algorithm which processes base reflectivity, velocity, and spectrum width data with the goal of distinguishing between meteorological returns and returns from ground clutter/AP.

2.17.1 Operational Characteristics.

System ID: APR, Product #67.

Data: Composite reflectivity, results of AP Editor.

Processing:

- Maximum selection algorithm.
- Layer Composite algorithm.
- AP checking and removal algorithm.

Availability: One product per volume scan.

Presentation: Cartesian image of layer composite reflectivity values (Figures 2-17, a and b).

Resolution: 4 x 4 km (2.2 x 2.2 nm).

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 8.

Annotations:

- Standard set*
- Calibration constant (scaling constant used by the PSP to calculate reflectivity)
- Composite, maximum
- Data level code
- Lower Layer boundaries (vertical depth)
- Maximum reflectivity value detected.

Adaptation: None.

2.17.2 Usage. Used as the LRM to prevent misinterpretation and applications when AP is detected prior to developing the product.

2.17.3 Strengths/Applications. The APR algorithm attempts to distinguish weather targets from clutter targets.

2.17.4 Limitations.

- The performance of the APR product is reliant on the application of appropriated, traditional clutter filtering.
- Algorithm assumes all low-level data within 45 km (22 nm) of the RDA and below 1 km above the radar level is clutter. This will result in meteorological data being removed at times.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

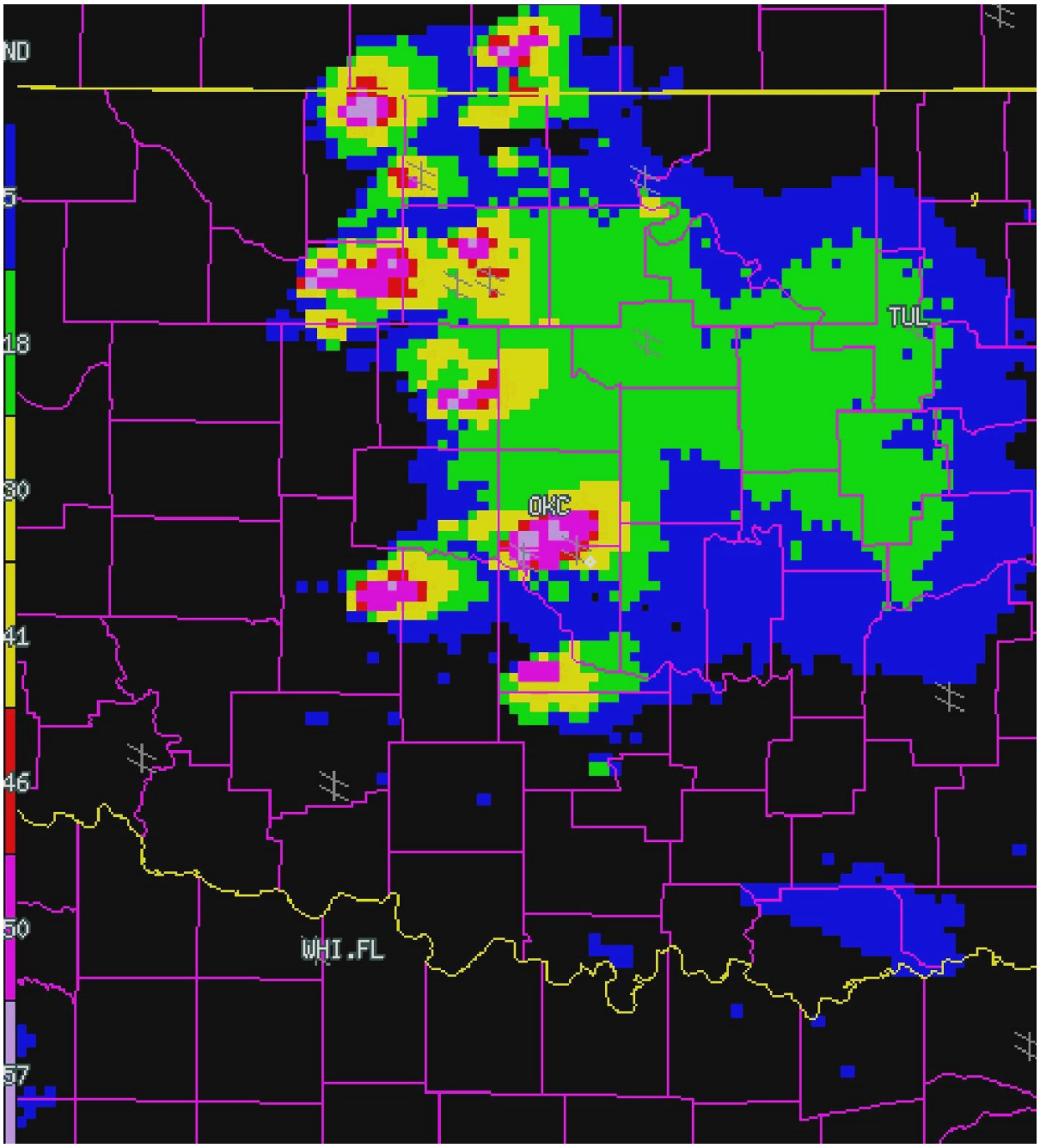

Figure 2-17a
Layer Composite Reflectivity – Anomalous Propagation Removed Product

This APR example (AWIPS display) is from the Oklahoma City, OK WSR-88D.

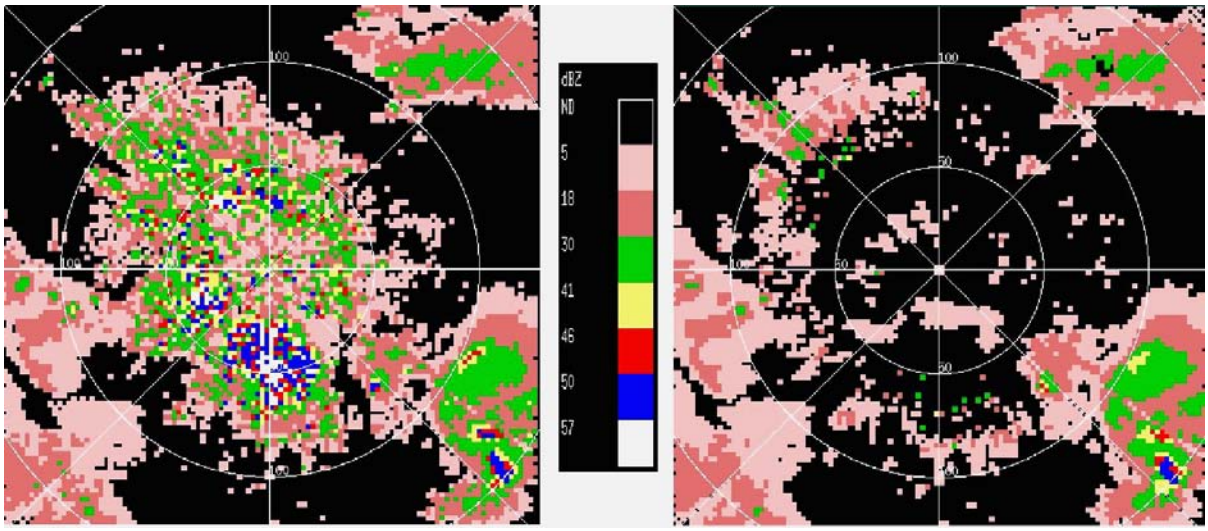

Figure 2-17b
Layer Composite Reflectivity Maximum Comparison with Layer Composite Reflectivity – Anomalous Propagation Removed (Low Level)

A comparison of the Layer Maximum Composite Reflectivity – Product Code 65 (left) – with the AP Removed Layer Composite Reflectivity – AP Removed (right). Both products display 8 data levels on a 4 km x 4 km (2 nm x 2 nm) Cartesian grid. This example is from the Amarillo, TX WSR-88D on 25 May 1994 at 03:22 UTC and depicts areas of weather beyond 187 km (100 nm) of the radar with AP clutter about the radar. This extensive, very strong AP clutter (speckled, high reflectivity factor) is evident in Product 65 (left image) to beyond 92 km (50 nm). The AP editing applied to Product 67 removes much of the strong AP clutter contamination. The AP editing technique used for Product 67 tends to lessen the magnitude of the highest reflectivity factor peaks in areas of weather.

2.18 <u>Mean Radial Velocity</u>. The Mean Radial Velocity products (V) provide displays of radar estimated mean radial velocity, based on the value contained in the first gate of each set of gates (i.e., gate 1 of 1, gate 1 of 2, or gate 1 of 4). They are available for several combinations of coverage and display resolution; each product is available for 8 and 16 data levels. A separate version of each product is available for each antenna scan taken at a constant elevation for each elevation angle in the current VCP.

2.18.1 Operational Characteristics.

System ID: V, Products: #22, #23, #24, #25, #26, and #27.

Data: Mean radial velocity.

Availability: Updated once per volume scan at each elevation angle.

Presentation: Polar coordinate image of mean radial velocity data (Figures 2-18, a-f).

Resolution:	**Coverage:**
• 0.25 km (0.13 nm) x 1° (#22, 25)	Radar centered, 60 km (32 nm) radius
• 0.5 km (0.27 nm) x 1° (#23, 26)	Radar centered, 115 km (62 nm) radius
• 1.0 km (0.54 nm) x 1° (#24, 27)	Radar centered, 230 km (124 nm) radius.

Data Levels: 8 (#22, #23, #24) and 16 (#25, #26, #27).

Annotations:

- Standard set*
- Data level code
- Elevation angle
- Maximum data value detected (both positive and negative).

Adaptation: Data levels.

2.18.2 Usage.

- Aids wind flow structure and shear recognition of the atmosphere on various scales.
- The detection and location of tornadic circulations, mesocyclones, and other atmospheric vortices.
- Determination of local wind field characteristics.
- Can be used to identify boundary layer characteristics or outflow regions.

2.18.3 Strengths/Applications.

- Estimate magnitude of radial velocities. Ground relative wind speeds (and directions, in so far as they can be derived, can be used for use as input into warnings, statements, and forecasts).
- Aid in determining kinematic atmospheric structure via radial velocities. Atmospheric jets and temperature advection can be determined within the local radar coverage area and with adequate reflectors.
- Aid in determining internal convective storm kinematic structure via radial velocity patterns. Vortices such as Tornado Vortex Signatures or mesocyclones and divergence intensity signatures at storm top or in association with microbursts can be identified.
- High temporal and spatial resolution.
- Aid in creating, adjusting, or updating hodographs.

2.18.4 Limitations.

- Range folding may obscure data.
- Velocity aliasing can mask real velocities or shears.
- Velocities may exceed product data levels or even the signal processing specified velocity data levels. The scale is locally adaptable at the MSCF.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

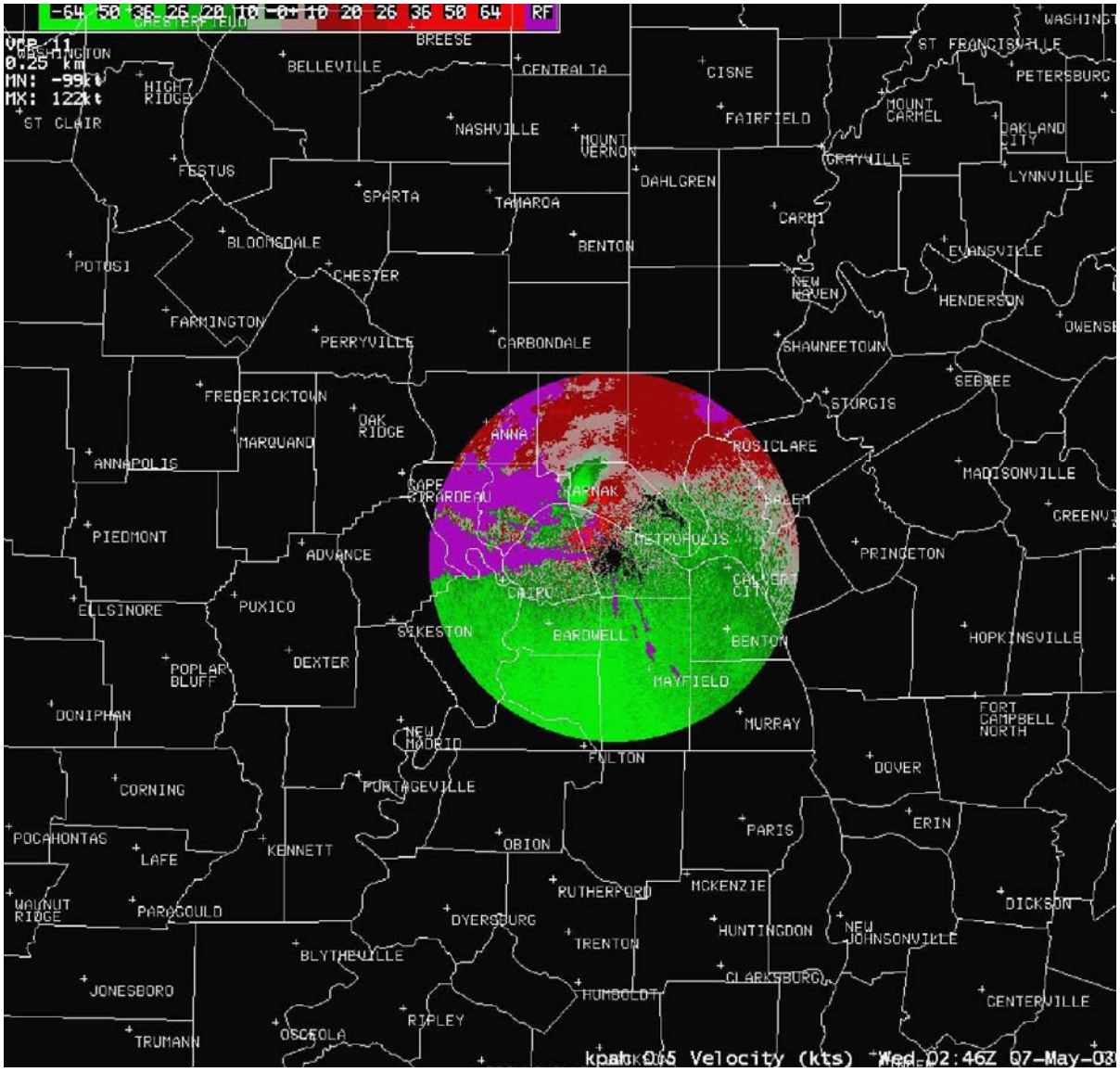

Figure 2-18a
Mean Radial Velocity Product

A Mean Radial Velocity product with a resolution of 1° x 0.13 nm (0.25 km) and 16 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

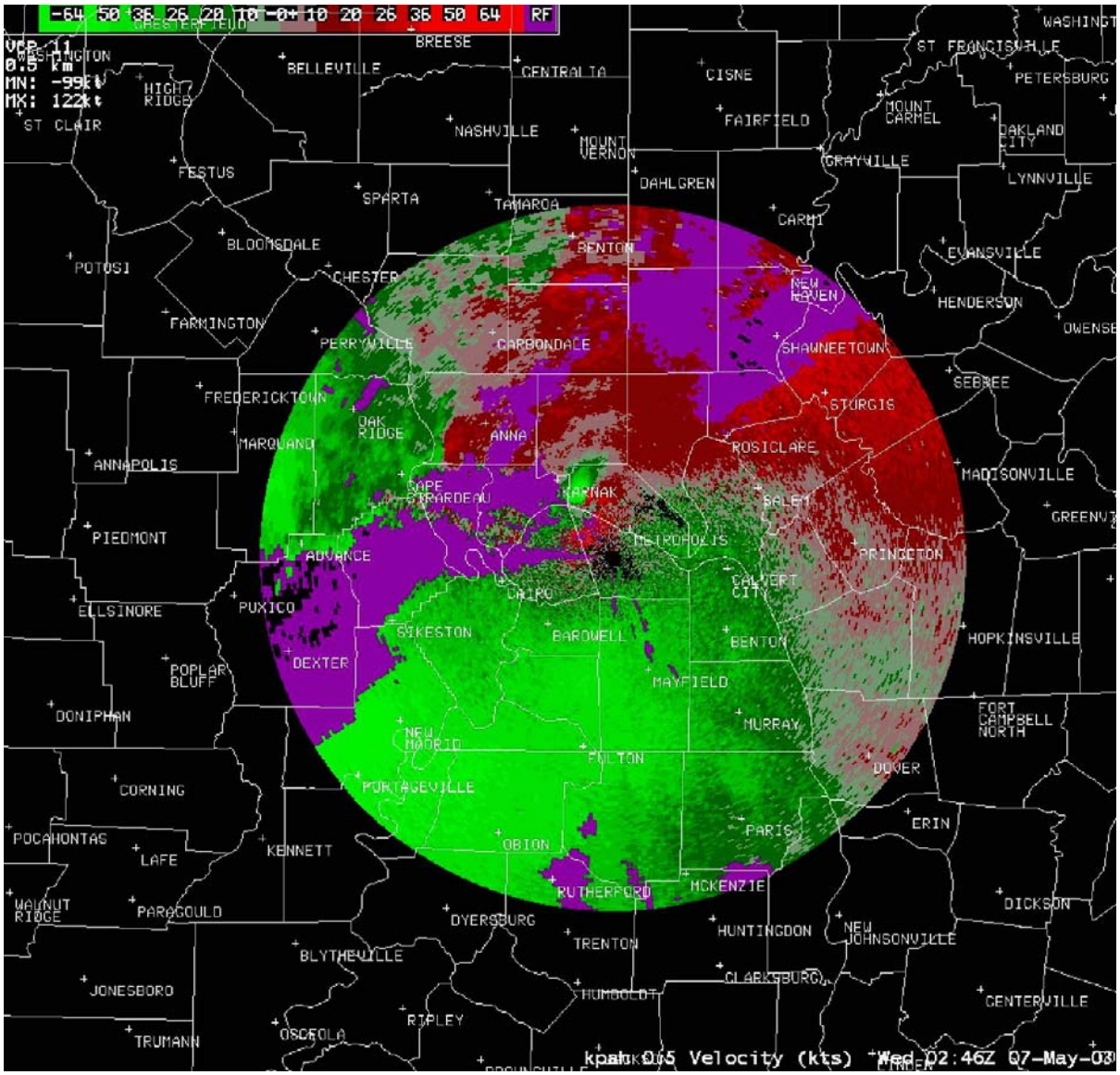

Figure 2-18b
Mean Radial Velocity Product

A Mean Radial Velocity product with a resolution of 1° x 0.27 nm (0.5 km) and 16 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

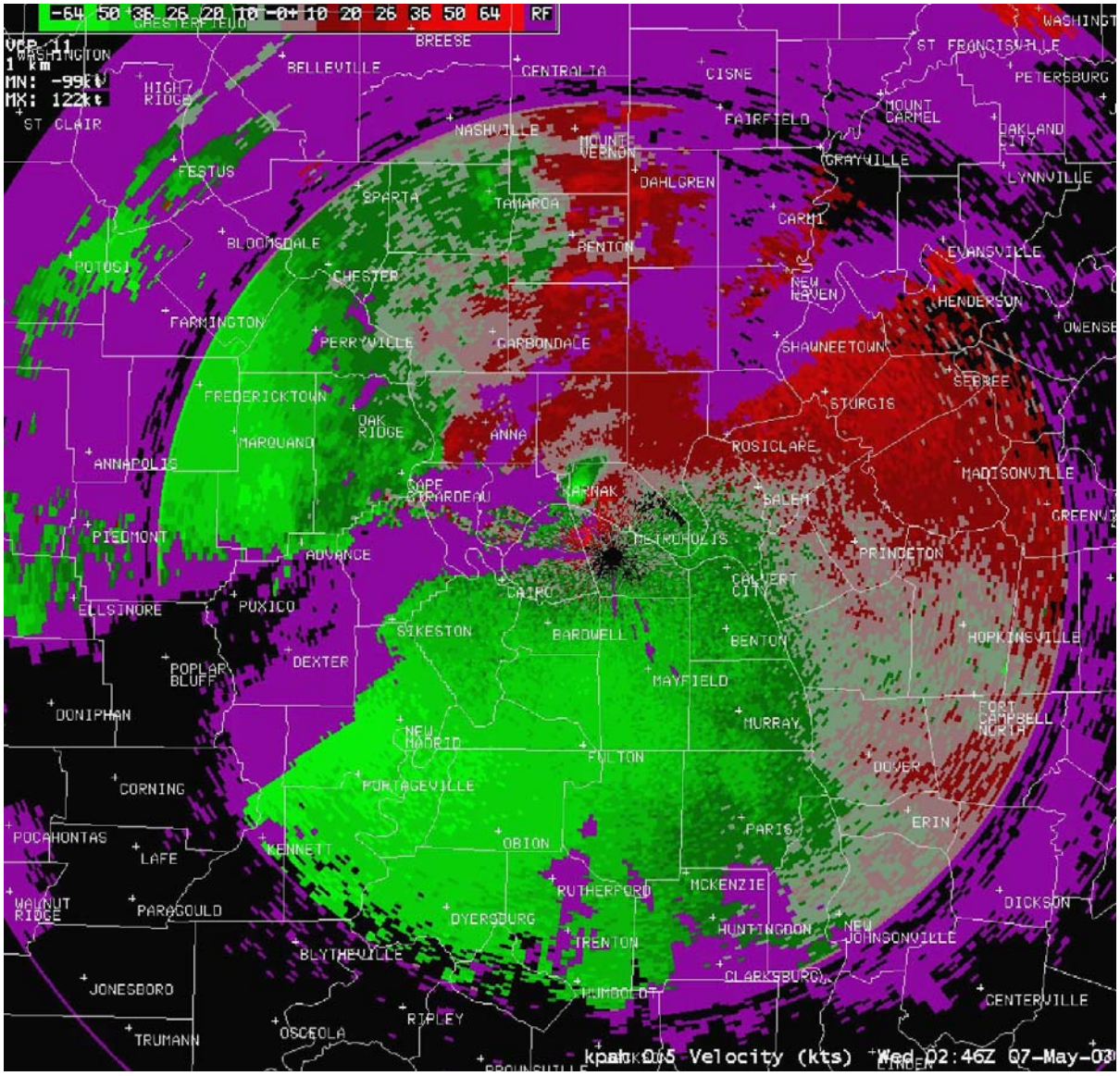

Figure 2-18c
Mean Radial Velocity Product

A Mean Radial Velocity product with a resolution of 1° x 0.54 nm (1 km) and 16 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

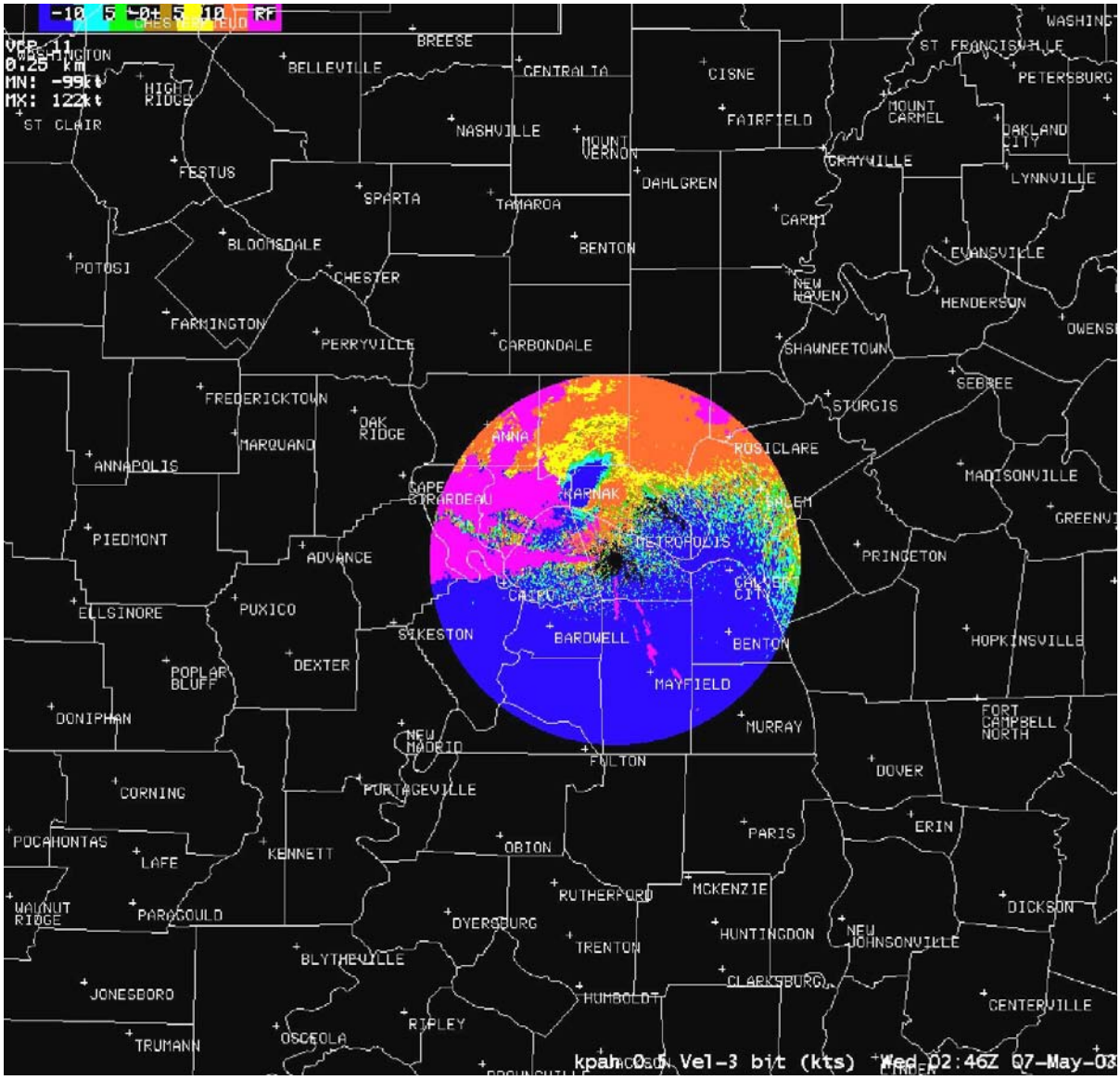

Figure 2-18d
Mean Radial Velocity Product

A Mean Radial Velocity product with a resolution of 1° x 0.13 nm (0.25 km) and 8 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

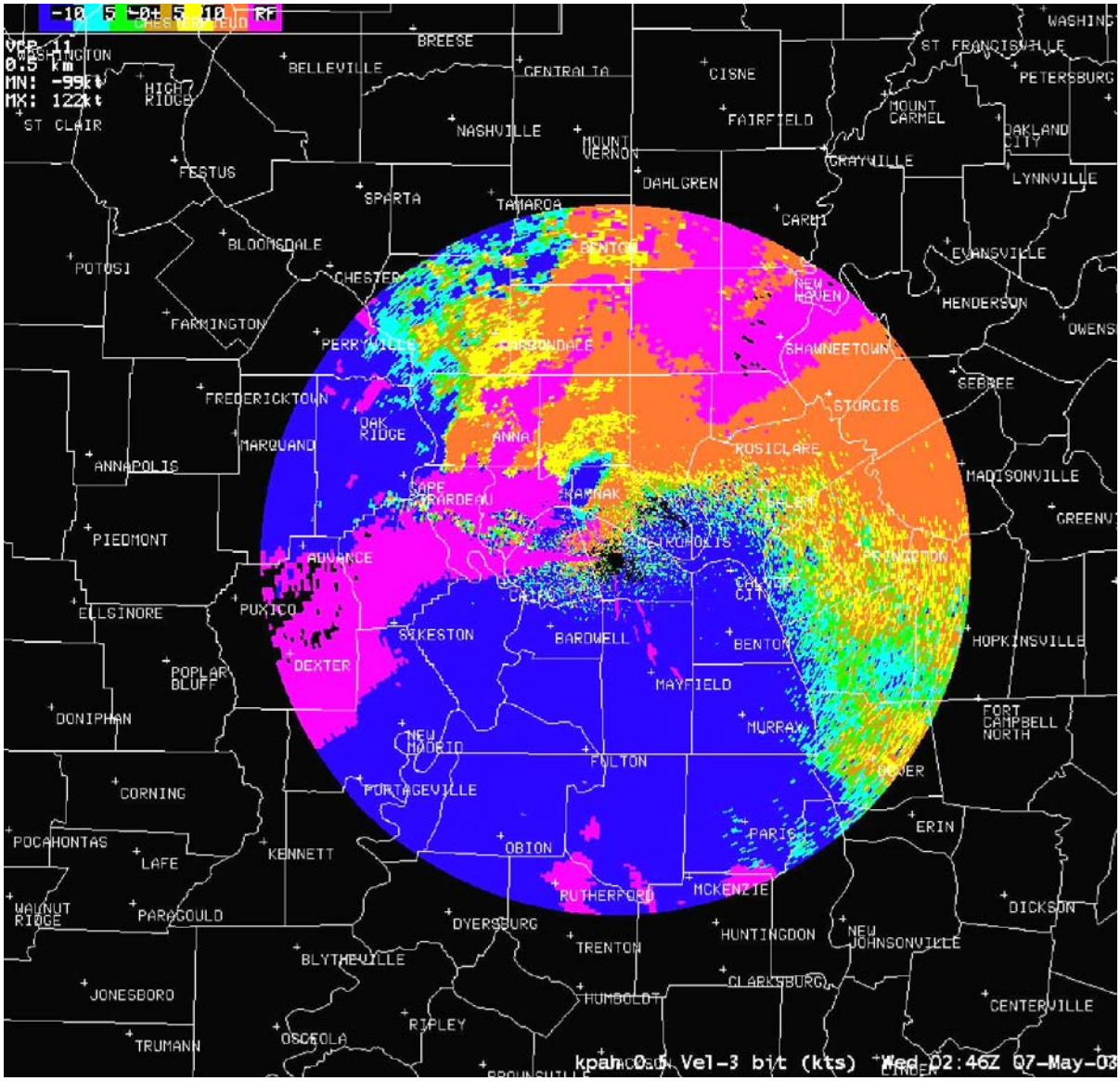

Figure 2-18e
Mean Radial Velocity Product

A Mean Radial Velocity product with a data resolution of 1° x 0.27 nm (0.5 km) and 8 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

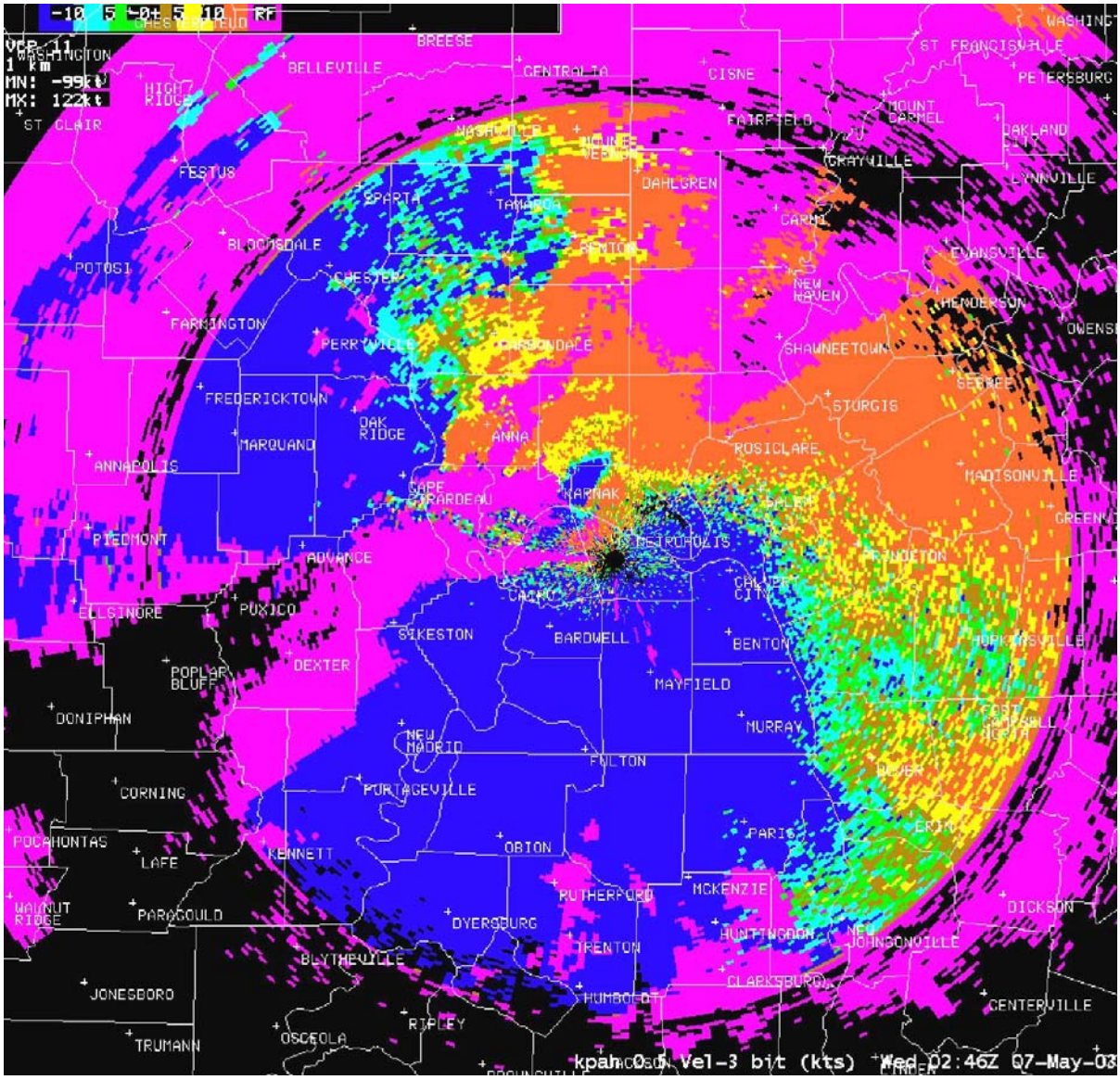

Figure 2-18f
Mean Radial Velocity Product

A Mean Radial Velocity product with a data resolution of 1° x 0.54 nm (1 km) and 8 data levels from the Paducah, KY WSR-88D (KPAH) on 7 May 2003. (AWIPS display)

2.19 <u>Base Velocity Data Array</u>. Unlike the only other velocity product with 0.25 km (0.13 nm) data resolution and a range of 60 km (32 nm), the Base Velocity Data Array product (DV) provides 0.25 km (0.13 nm) resolution to 230 km (124 nm). The product also has 256 data levels. High-resolution data are available to the range limits of measurements. This permits the highest possible resolution in order to detect the maximum velocity detail in mesocyclones and tornado vortex signatures among other features.

2.19.1 Operational Characteristics.

System ID: DV, Product #99.

Data: Mean radial velocity.

Availability: Once per volume scan at each elevation angle.

Presentation: Polar coordinate array of mean radial velocity data (Figure 2-19).

Resolution: 0.25 km (0.13 nm) x l°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 256.

Annotations: None.

- Standard set*
- Data level code
- Elevation angle
- Maximum data value detected (both positive and negative).

Adaptation: Data Levels.

2.19.2 Usage. An aid in the characterization of velocities in meteorological events. The high spatial resolution and largest number of data levels of this product enables high detail detection of:

- TVS/Mesocyclones
- Microbursts
- Storm kinematic structure
- Gust fronts
- Boundaries
- Algorithm validation/quality control
- Non-meteorological returns

2.19.3 Strengths/Applications.

- Array product provides 0.25 km (0.13 nm) resolution out to 230 km (124 nm) giving the best available data resulting in increased spatial/data resolution.
- Largest number of data levels of mean radial velocities.
- Aids in creating, adjusting, or updating hodographs for multiple applications external to the WSR-88D.
- Forecasters have reported being able to issue severe weather and tornado warnings with greater lead time based on the higher-resolution of the product.

2.19.4 Limitations.

- Range folding may obscure data.
- Improper dealiasing may result in erroneous velocity values.
- Product data file size is very large.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

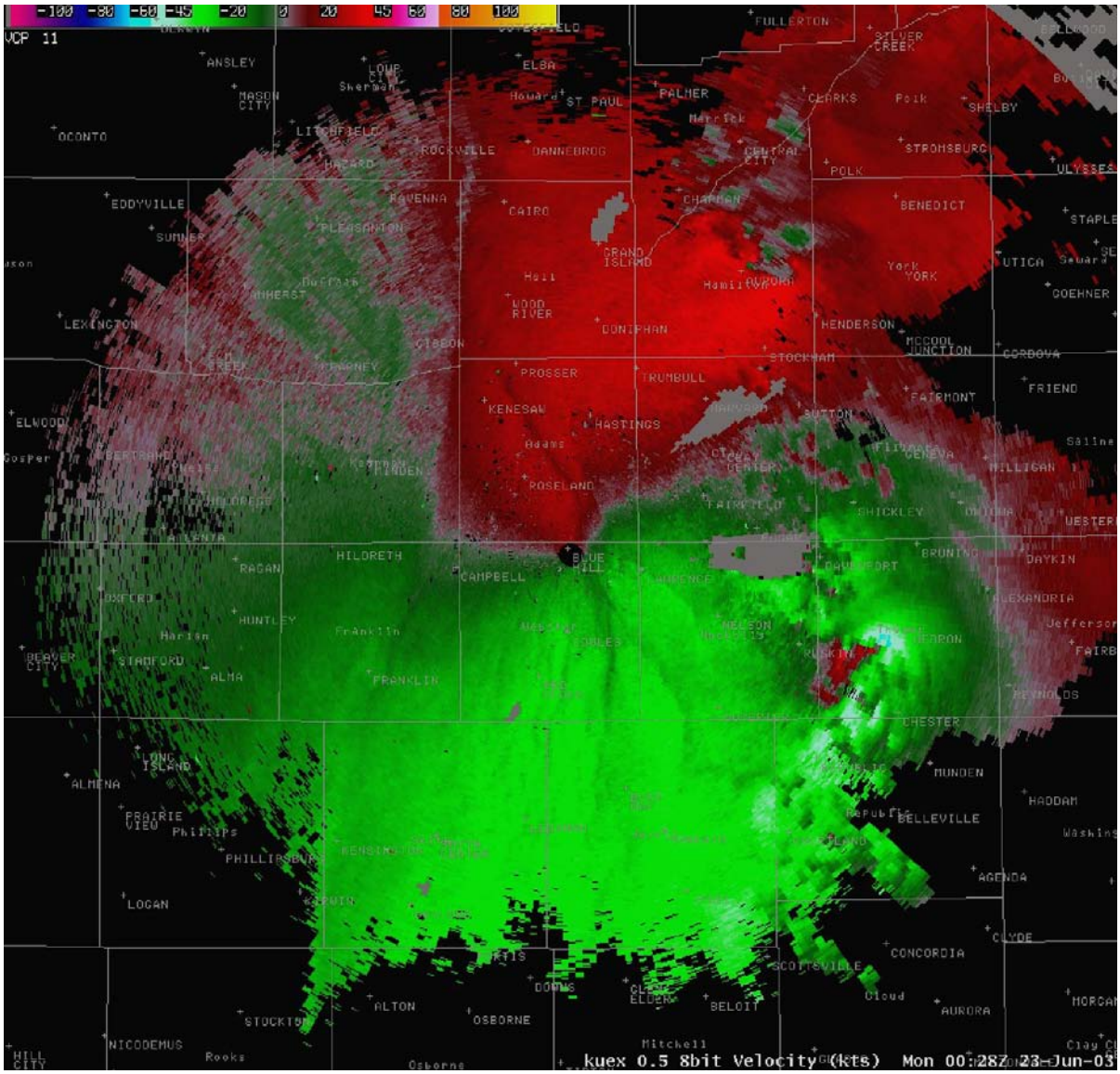

Figure 2-19
Base Velocity Data Array Product

A Grand Island, NE WSR-88D (KUEX) DV product on 23 June 2003 at 00:28 UTC depicting the 256-data levels and 0.25 km (0.13 nm) full resolution of the radar (AWIPS display).

2.20 <u>Integrated Terminal Weather System Digital Base Velocity</u>. The Integrated Terminal Weather System (ITWS) Digital Base Velocity product (DBV) provides mean radial velocity in a digital array format to support processing external to the WSR-88D (i.e., primarily FAA ITWS). This product is generated for each azimuth scan (elevation based) as requested. Indications for data "below the Signal-to-Noise threshold" and "Range Folding" for each array element is provided.

2.20.1 Operational Characteristics.

System ID: DBV, Product #93.

Data: Mean radial velocity.

Processing: Mean radial velocity generation.

Availability: Updated once per volume scan.

Presentation: Data array in polar coordinates.

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Lesser of 115 km (62 nm) radius or 5.5 km (18 kft) Above Ground Level (AGL).

Data Levels: 256.

Annotations:

- Standard set*
- Minimum data value (in meters per second)
- Increment (in meters per second)
- Number of data levels
- Elevation (in degrees)
- Maximum negative velocity detected (kts)
- Maximum positive velocity detected (kts).

Adaptation: None**.**

2.20.2 Usage. The ITWS will display this data array product according to ITWS requirements.

2.20.3 Strengths/Applications. Provides ITWS system users with high-resolution (256 data levels) mean radial velocity data.

2.20.4 Limitations.

- Range folding may obscure data.
- Improper dealiasing may result in erroneous velocity values.
- Product data file size is very large.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

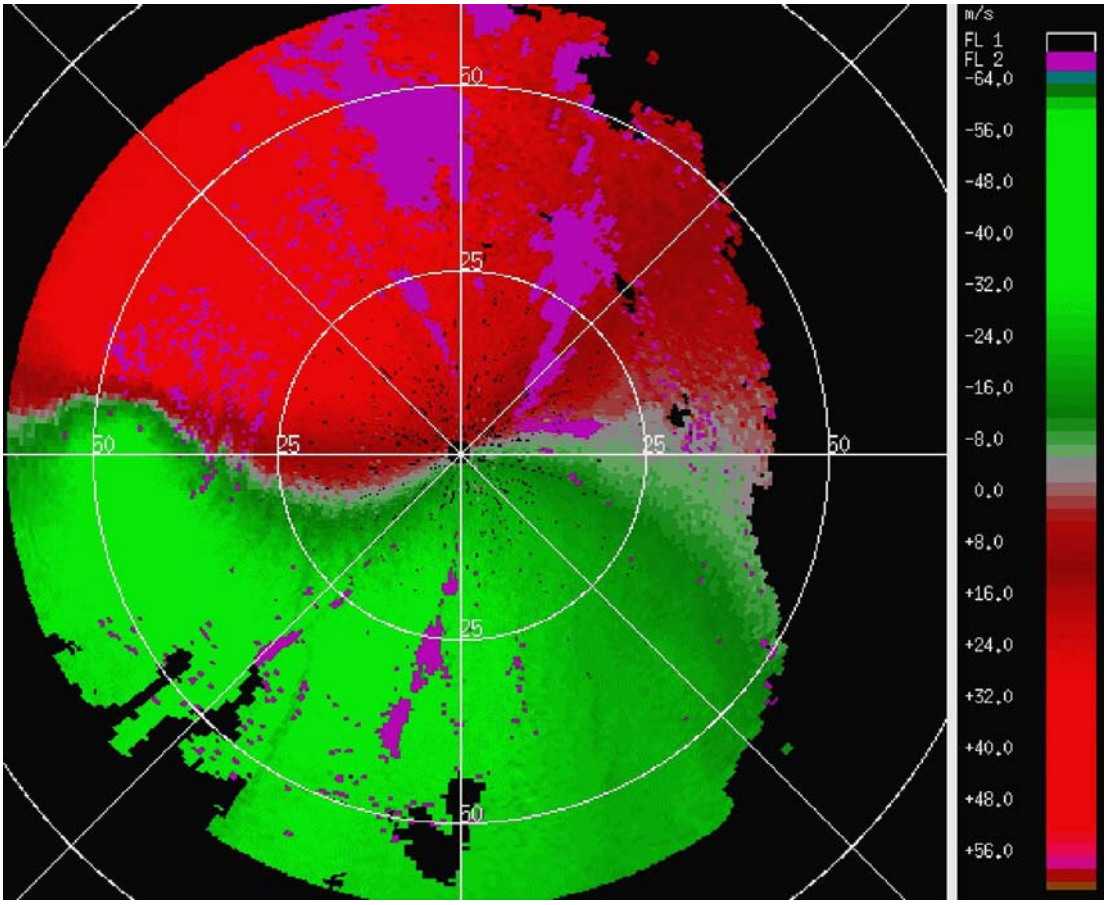

Figure 2-20
Integrated Terminal Weather System Digital Base Velocity Product

An example of the DBV product from the 0.5° tilt of the Melbourne, FL WSR-88D (KMLB) during the passage of Hurricane Charley on August 14, 2004 at 00:35 UTC. Range rings are in nautical miles. Charley's circulation center is near 94 km (50 nm) slightly north of due west of the radar. The product is a polar data array from any single elevation angle tilt in a radar volume with a sample bin for each 0.54 n mi (1 km) slant range and each 1 degree azimuth. The product extends to a range of 62 n mi (115 km) with a data value for each 0.54 n mi (1 km) range bin. This resolution is obtained by sampling every fourth data bin of the mean radial velocity data. The range coverage at higher elevation angle tilts will not include data over 18,000 feet above the radar. The product has 256 data levels for the mean radial velocity range of -63.5 to +63 m/s in 0.5 m/s increments. This data coding is independent of the Doppler velocity resolution of the data provided by the RDA. If the range of velocities produced by the RDA is double the above range (1 m/s resolution), any velocity data exceeding the maximum (-63.5/+63 m/s) will be represented by the maximum. (AWIPS display)

2.21 Mesocyclone. The Mesocyclone product (M) provides information regarding the existence and nature of vortices associated with thunderstorms. This product is generated from the output of the legacy Mesocyclone Algorithm. The product provides information regarding identified shear features within the storm. Features are classified as uncorrelated shear (sufficiently large, symmetrical, but not vertically correlated); 3-dimensional shear regions (vertically correlated, but not symmetrical); and mesocyclones (sufficiently large, vertically correlated, and symmetrical).

Using the Storm Tracking Information, Mesocyclone feature types are related to past feature types and tracked.

2.21.1 Operational Characteristics.

System ID: M, Product #60.

Data:

- Identified shear and mesocyclone features
- Mesocyclone Algorithm output.

Processing: Legacy Mesocyclone Algorithm.

Availability: Updated once per volume scan.

Presentation:

The product is generated in a format that provides an alphanumeric tabular display for all identified features simultaneously, a graphic display, or a graphic overlay to other products. If there is no output from the Mesocyclone Algorithm for a particular volume scan, a version of the product that exhibits the null condition is produced.

- Formatted table of alphanumeric values.
- Graphic display of mesocyclone symbol and feature symbols at computed positions.
- Graphic overlay of mesocyclone symbol at its computed position.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 3

- Mesocyclone
- 3-dimensional correlated shear
- Uncorrelated shear.

Annotations:

- Standard set*
- Combined Attribute Table
- Site adaptable parameters.

Special Symbols: The mesocyclone or 3D correlated shear symbol will be placed directly over the position of the mesocyclone or shear at the lowest elevation scan in which it was detected.

- The mesocyclone symbol on the 230 km (124 nm) radius product is a yellow open circle with a 3/16-inch diameter, whose perimeter is 4 pixels wide. For a window product or a magnified base product, the size is proportional to the average of the radial and azmuthal diameters (if less than 3/16-inch, it defaults to 3/16-inch).
- The 3-dimensional correlated shear symbol on the 230 km (124 nm) radius product is a yellow open circle with a 3/16-inch diameter, whose perimeter is 1 pixel wide. For a window product or a magnified base product, the size is proportional to the average diameter (if less than 3/16-inch, it defaults to 3/16-inch).

Adaptation: See Section 3.6.1

2.21.2 Usage. As an aid in the identification, alerting, and warning for mesocyclones which very often (> 90%) are correlated with severe weather (hail, damaging winds, and tornadoes). It appears that 10% - 15% are associated with tornadoes.

2.21.3 Strengths/Applications.

- Identify mesocyclones. However, because this, like all algorithms, is imperfect the operator must examine reflectivity, velocity, and/or SRM to verify the existence of mesocyclones.
- Identify mid-level mesocyclones that develop downward toward the surface, some that become associated with tornadoes.
- Because of the very frequent severe weather association with mesocyclones, detection of these features often signals at least a severe thunderstorm.
- See Section 3.6.2 for a discussion of the operational strengths/applications of the algorithm.

2.21.4 Limitations.

- Time continuity is not employed. Under most circumstances feature verification requires that it be present for at least two volume scans.
- While the legacy mesocyclone algorithm requires the vertical correlation of only two symmetric and sufficiently strong features, normally a depth of at least 10,000 feet is needed for an operator-determined mesocyclone.

- The algorithm only detects cyclonic rotations even though anticyclonic circulations are sometimes also associated with severe thunderstorms.
- At longer ranges, mesocyclones may not be detected due to poor aspect ratios and the random beam placement during radar sampling.
- Operator does not know which base-data elevation angle to examine for detection verification. Algorithm output is in terms of height and not scan angle.
- Successful detection of mesocyclones depends upon the selection of optimum high and low momentum and other thresholds. Thresholds vary by storm type which itself can vary due to changes in airmass. Those airmasses can themselves change across the radar scanned coverage area.
- Range folding and velocity aliasing may interfere with successful mesocyclone detection. Velocity aliasing can itself induce false algorithm detections.
- See Section 3.6.3 for a discussion of the operational limitations of the algorithm.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

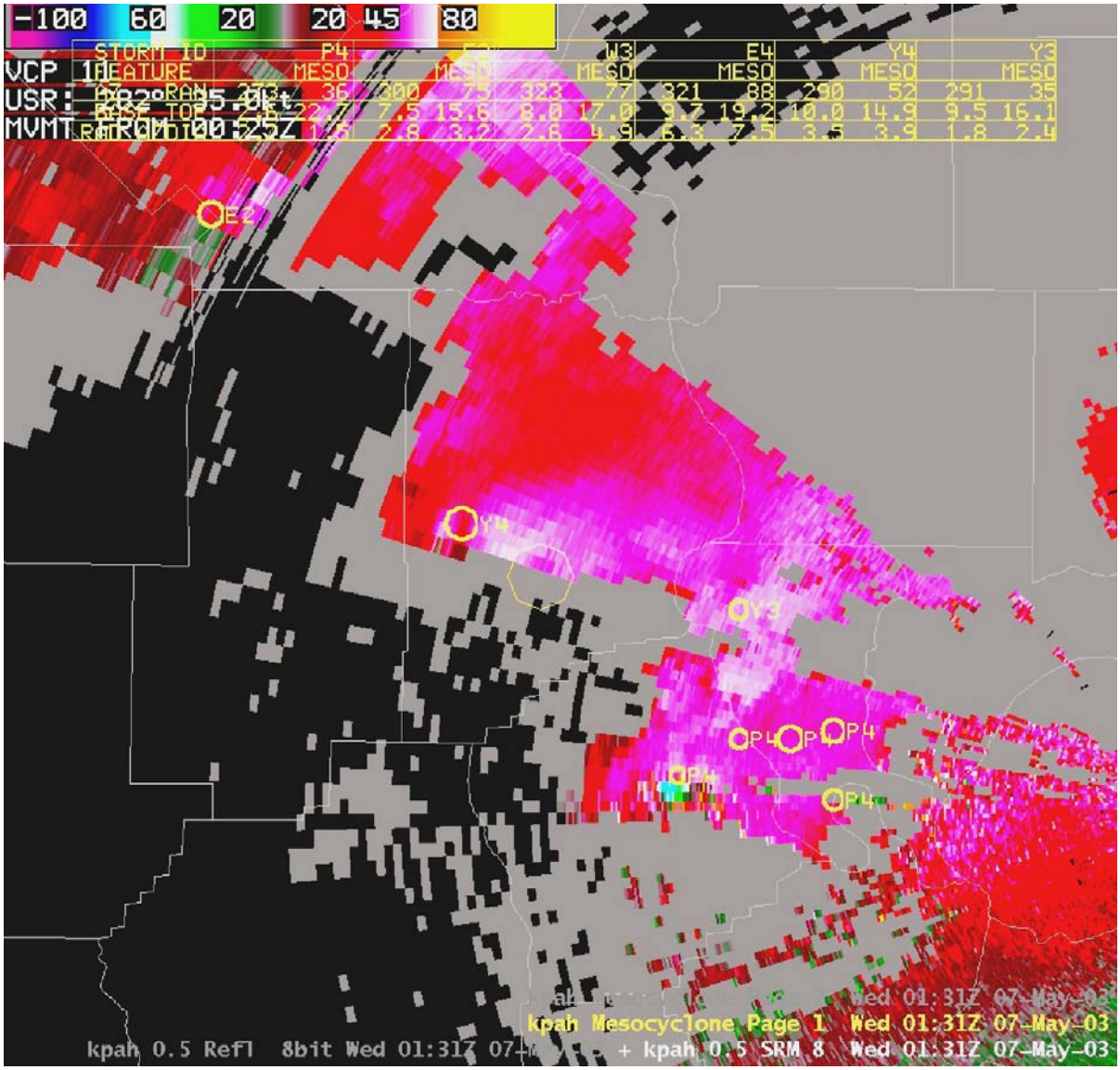

Figure 2-21
Mesocyclone Product Overlaid on an SRM Product

An example of the Mesocyclone (Legacy) product as an overlay on an SRM product from the Paducah, KY WSR-88D (KPAH) (AWIPS display). Mesocyclone features are labeled with the associated storm label (P4, E2, Y3, and Y4). The Combined Attribute Table appears in the upper portion of the screen.

2.22 <u>Mesocyclone Rapid Update</u>. The Mesocyclone Rapid Update product (MRU) is generated to provide legacy Mesocyclone Algorithm information after each elevation scan as opposed to only at the end of a volume scan. The processing is based on data from the elevations that have been completed thus far in the current volume scan. This information is combined with Mesocyclone and Storm Track Algorithm information from the previous volume scan to form the MRU product.

The average motion of all SCIT-identified storm cells from the previous volume scan are used to derive a forecast position at the current volume scan time. In feature type order, the forecast position of each feature from the previous volume is matched to the closest feature from the current volume scan, within a search radius defined by the SCIT algorithm adaptation data. Current 3D features which are not matched to a feature from the previous volume scan are assigned the status of "New". If previous volume scan data are unavailable, all features are reported as New. Current features inherit the attributes of the matched previous feature (associated storm ID, feature type, maximum tangential shear, height of maximum tangential shear, top height, base azimuth, base range, base height, azimuth diameter, range diameter).

The position attributes (base azimuth, range, and height) of a previous feature matched to a current feature are updated to the current detection. If the top height of the matched feature is higher, the feature top height is updated. The position attributes of a previous feature not matched to a current feature is set to the extrapolated forecast position. The statuses of unmatched previous features are assigned to "Extrapolated." Strength attributes are updated if they increase in magnitude.

The strength attributes are feature type and maximum tangential shear. If the maximum tangential shear is updated, the radial and azmuthal diameters and the height of the maximum tangential are also updated. Features with increasing strength attributes are then assigned the status of Increasing. All other matched features are assigned the status of Persistent. Attribute data updated with current volume data are so identified. At the end of the volume scan extrapolated features are removed.

This product is generated in a format that can be used to generate an alphanumeric tabular display, a graphic display, or a graphic overlay to other products. On alphanumeric displays, the status (Persistent, Increasing, New, or Extrapolated) of each feature is reported. In the graphic symbol display, feature status is reported as either Extrapolated or Current. Current features include all features with a status of Increasing, Persistent, or New. If on a particular elevation scan there is no output (i.e., no features of any type are identified), a version of the product is produced that exhibits the null condition.

MRU Feature Status is defined as:

- NEW: A 3D feature detected in the current volume and not time associated with any feature from the previous volume.
- PER: (Persistent) A feature found in both the current and previous volume scans and neither of the two strength attributes have increased in the current volume. The two strength parameters are feature type and maximum tangential shear.

- INC: (Increasing): As PER but with one or both of the strength attributes increasing in intensity in the current volume scan.
- EXT: (Extrapolated): A 3D feature found in the previous volume, but not yet time associated with any feature from the current volume. The extrapolated feature position provided in the product is an estimated position based on the time between the volume scans and the SCIT storm motion from the pervious volume scan.

2.22.1 Operational Characteristics.

System ID: MRU, Product #139.

Data:

- Feature status
- Identified shear and mesocyclone features
- Meteorological detection algorithm output.

Processing: Legacy Mesocyclone Algorithm and Storm Track Algorithm Information.

Availability: Each elevation angle.

Presentation. This product is generated in a format that can be used to generate an alphanumeric tabular display, a graphic display, or a graphic overlay to other products. On alphanumeric displays, the status (Persistent, Increasing, New, or Extrapolated) of each feature status is reported. In the graphic symbol display, features status is reported as either extrapolated or current. Current features include all features with a status of Increasing, Persistent, or New. If on a particular elevation scan there is no output (i.e., no features of any type are identified), a version of the product is produced that exhibits the negative condition. (A caret (^) symbol is used in the MRU's graphic attribute table and tabular alphanumeric product next to feature attributes updated with information from the current volume scan).

- Formatted table of alphanumeric values
- Graphic display of mesocyclone symbol and feature symbols at computed positions
- Graphic overlay of mesocyclone symbol at its computed position.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 3

- Mesocyclone
- 3-dimensional correlated shear

- Feature status including New, Extrapolated, Persistence, or Increasing.

Annotations:

- Standard set*
- Elevation angle
- Site adaptable parameters.

Adaptation: None.

2.22.2 Usage. Provides mesocyclone updates with the completion of each elevation angle scanned thereby enabling the operational meteorologist to make warning and other related decisions before the end of the radar volume scan.

2.22.3 Strengths/Applications.

- Intermediate algorithm output is available before end of volume scan.
- MRU tracks features in order to check time continuity.

2.22.4 Limitations.

- Classification as Increasing or Persistent may be the result of sampling issues versus an actual feature attribute change.
- The MRU graphical attribute table and alphanumeric attribute table contain attributes from both previous and current volume scan information.
- Feature matching ability is dependent on motion supplied by SCIT algorithm which may be in error.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

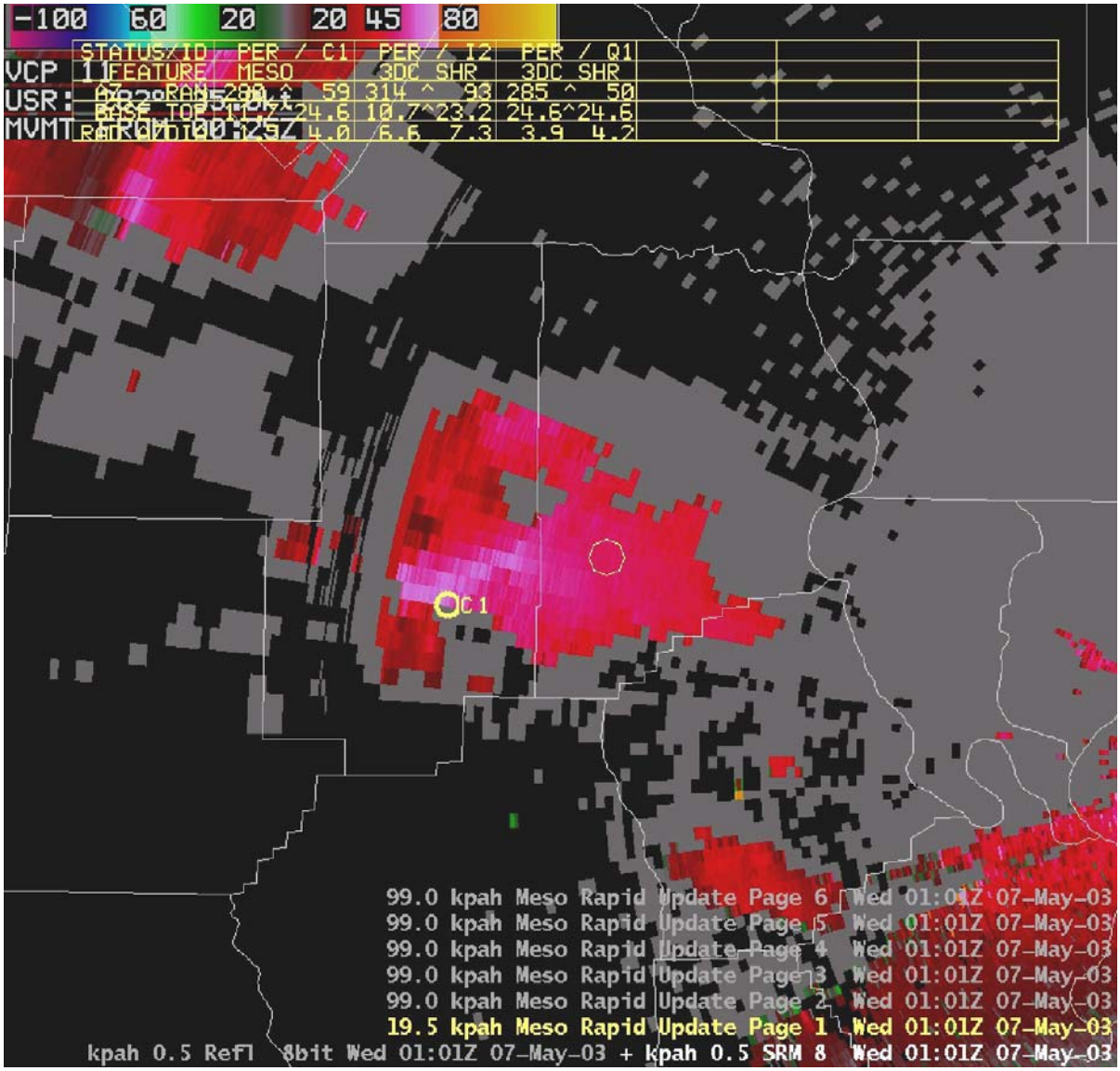


Figure 2-22
Mesocyclone Rapid Update Product Overlaid on an SRM Product

This MRU example (AWIPS display) is from the Paducah, KY WSR-88D (KPAH) on 7 May 2003.

2.23 <u>Mesocyclone Detection</u>. The Mesocyclone Detection product (MD) provides information regarding the existence and nature of vortices associated with thunderstorms. This product is derived from the Mesocyclone Detection Algorithm (MDA) which is separate and independent from the legacy Mesocyclone algorithm although the MD product is analogous to the legacy M product. The MD product provides information regarding identified cyclonic shear circulation features. Circulations are assigned a strength rank number based on the rotational velocity of each of its component 2D features. The strength rank values range from 1 (the weakest) to 25 (the strongest).

The product is generated in a format that provides an alphanumeric tabular display for all identified circulations simultaneously, a graphic display, or a graphic overlay to other products. If there is no output from the MDA for a particular volume scan, a version of the product that exhibiting the null condition is produced.

2.23.1 Operational Characteristics.

System ID: MD, Product #141.

Data: Mesocyclone detections of varying strength, sorted by strength ranks, then by Mesocyclone Strength Index (MSI); Meteorological Algorithm Output.

Processing: MDA Tracking Information.

Availability: Updated once per volume scan.

Presentation:

- Formatted table of alphanumeric values
- Graphic display of circulation symbols at computed positions
- Graphic overlay of circulation symbol at its computed position (Figures 23, a and b).

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 3

- Circulations with strength rank less than 5
- Circulations with strength rank greater than or equal to 5
- Circulations with strength rank greater than or equal to 5 and either detected on the lowest elevation, or with a base height at or below 1 km.

Annotations:

- Standard set*
- Combined Attribute Table.

Special Symbols:

- The symbol for a circulation having a strength rank less than 5 is a thin, yellow, open circle centered at the position of the circulation's base 2D component. The diameter of the circle is based on the diameter of the circulation but with a minimum diameter of 14 pixels. Note that this particular symbol will only be displayed if the default adaptation data setting for the Minimum Display Filter Rank is lowered from its default value of 5.

- The symbol for a circulation having strength rank greater than or equal to 5 is a thick, yellow, open circle centered at the position of the circulation's base 2D component. The diameter of the circle is based on the diameter of the circulation but with a minimum diameter of 14 pixels.

- The symbol for a circulation with a strength rank value greater than or equal to S_n is a thick, yellow circle with spokes that extends to the lowest elevation angle or has a base less than 1 km. The diameter of the circle is based on the diameter of the circulation, but with a minimum diameter of 14 pixels.

- Past position symbols are indicated by solid diamonds. Up to 10 past positions can be included for a given circulation.

- Forecast position symbols are indicated by Xs. Up to 6 forecast positions can be included for a given circulation but the number of forecast positions will never exceed the number of past positions. The forecast position interval is 5 minutes.

Adaptation:

- Minimum Reflectivity, default 0 dBZ.
- Minimum Display Filter Rank, default 5.
- Overlap Display Filter, default Yes (meaning, apply filter that suppresses elevated circulations that overlap lower circulations).

2.23.2 Usage. As an aid in the identification, alerting, and warning for mesocyclones which very often (>90%) are correlated with severe weather (hail, damaging winds, and tornadoes). It appears that ~20% are associated with tornadoes. Research has shown that a strength rank of 5 most closely matches the MESO threshold in the legacy Mesocyclone algorithm.

A summary of a comparison between the MD product and the legacy Mesocyclone (M) product follows:

Both mesocyclone algorithms find different circulations because of algorithm design differences. Only 36% of all algorithm detections are found by both algorithms. The legacy algorithm finds approximately 5.7 times as many circulations as the MDA. The legacy algorithm found an excessive number of non-tornadic circulations compared to MDA. Both algorithms correctly identify a majority of the tornadic circulations, 78%.

As the Minimum Display Filter Rank threshold was lowered below a value of 5, MDA detects more circulations. The newly identified circulations match previous circulations from the legacy algorithm. As the Minimum Display Filter Rank threshold value drops below a value of 3, the number of MDA detections grows very quickly, negating the advantage gained by reducing the number of detections.

As discussed in more detail in Section 3.7.4 and seen in Figure 2-23b, a Mesocyclone Strength Index (MSI) is calculated for each 3D feature. In calculating the MSI, the strength ranks of all 2D feature components are multiplied by 1000, weighted by the average air density in a standard atmosphere, and integrated vertically across the half-power beam width depth at the height of the 2D feature. Integration is done from the feature's base to its top or THRESHOLD (maximum 3D Couplet Core Top), whichever is lower in altitude. The integrated value is divided by the total depth (with half-power beam width added).

2.23.3 Strengths/Applications.

- Identify mesocyclones. Like all algorithms, the MD Algorithm is imperfect, so the operator must examine reflectivity, velocity, and/or SRM to verify the existence of mesocyclones.
- Identify mid-level mesocyclones that develop downward toward the surface sometimes become associated with tornadoes.
- Because of the very frequent severe weather association with mesocyclones, detection of these features often signals the need for at least a severe thunderstorm.

2.23.4 Limitations.

- Time continuity is not required for feature identification. However, the display of past positions easily identifies those circulations with time continuity between two or more volume scans.
- At longer ranges, mesocyclones may not be detected due to poor aspect ratios, random beam placement during radar sampling, and the majority of the 3-D circulations being below the height of the lowest elevation angle.
- The operator does not know which base-data elevation angle to examine for detection verification. Algorithm output is in terms of height and not scan angle. However, circulations detected on the lowest angle are indicated by circles with spikes.
- Range folding and velocity aliasing may interfere with successful mesocyclone detection. Velocity aliasing can itself induce false algorithm detections.

- See Section 3.6 for a discussion of the operational considerations of the MDA.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

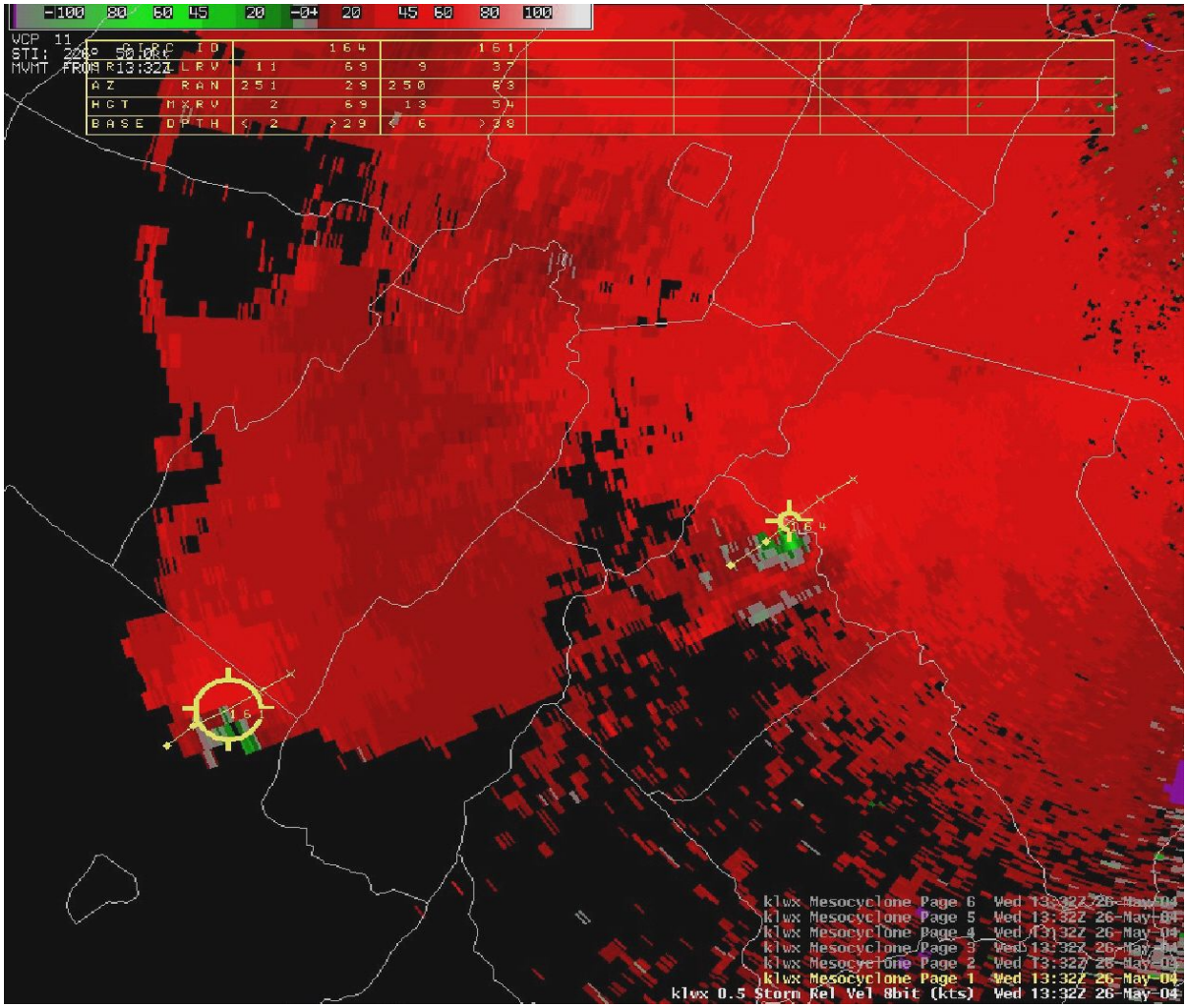
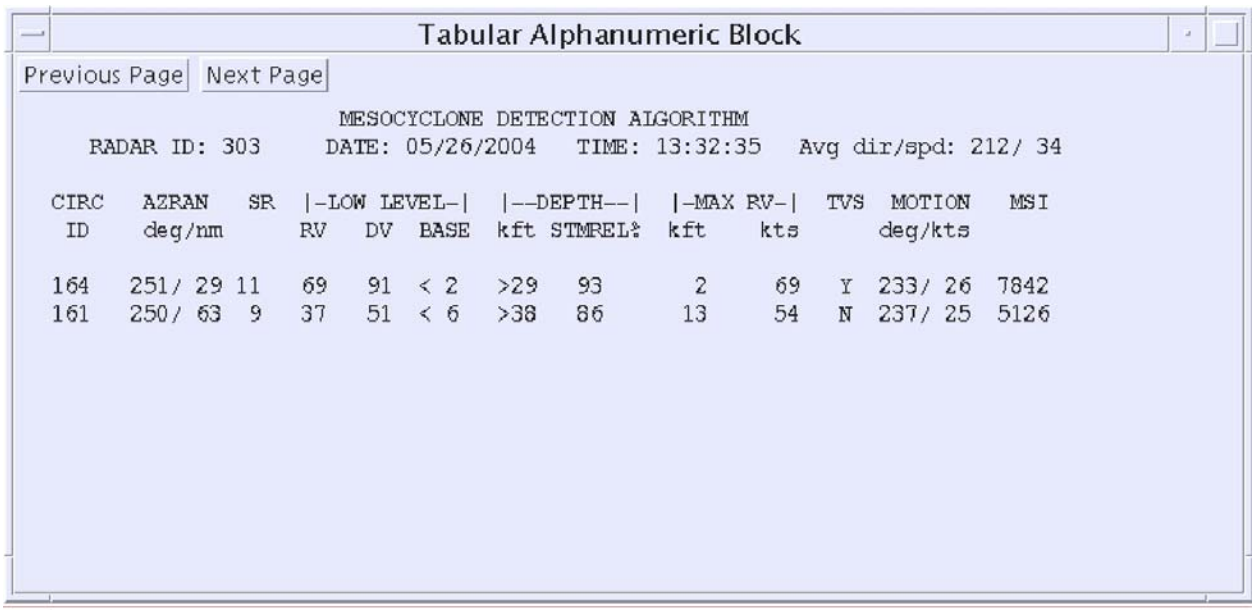


Figure 2-23a
Mesocyclone Detection Product Overlaid on a Mean Radial Velocity Product

This MD example from the Sterling, VA WSR-88D (KLWX) (AWIPS display) includes identification numbers for identified storms. The yellow symbols are related to the circulation strength rank for the cell (less than 5 is a thin, yellow, open circle; greater than or equal to 5 is a thick open circle), the diameter of the circle is based on the diameter of the circulation. Past position symbols are indicated by solid diamonds. Forecast position symbols are indicated by Xs. The Combined Attribute Table provides alphanumeric storm information. Circular symbols with spikes indicate circulations detected on the lowest elevation scan.



Tabular Alphanumeric Block

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MESOCYCLONE DETECTION ALGORITHM

RADAR ID: 303 DATE: 05/26/2004 TIME: 13:32:35 Avg dir/spd: 212/ 34

CIRC ID	AZRAN deg/nm	SR	|-LOW LEVEL-| RV	DV	BASE	|--DEPTH--| kft	STMREL%	|-MAX RV-| kft	kts	TVS	MOTION deg/kts	MSI
164	251/ 29	11	69	91	< 2	>29	93	2	69	Y	233/ 26	7842
161	250/ 63	9	37	51	< 6	>38	86	13	54	N	237/ 25	5126

Figure 2-23b
Mesocyclone Detection Alphanumeric Product

2.24 <u>Digital Mesocyclone Detection Data Array</u>. The Digital Mesocyclone Detection Data Array product (DMD) provides information regarding the existence and nature of all vortices associated with thunderstorms. This product is derived from the MDA which is separate and independent from the legacy Mesocyclone algorithm (M) although the DMD product is analogous to the legacy MRU product. The DMD product provides information regarding identified cyclonic shear circulation features. Circulations are assigned a strength rank number based on the rotational velocity of each of its component 2D features. The strength rank values range from 1 (the weakest) to 25 (the strongest). All detected circulations with a strength rank of 1 or greater are included in the MD product.

DMD "Detection Status":

- TOP: (Topped) When the radar has scanned an elevation over the feature without adding any 2D components to the feature.

- EXT: (Extrapolated) A 3D feature found in the previous volume but not yet time associated with any feature from the current volume. The extrapolated feature position provided in the product is an estimated position based on the time between volume scans and the feature's tracked motion. If no tracked motion for the feature is available, the SCIT storm motion from the previous volume scan is used.

- UPD: (Updated) A 3D feature detected in both the current and previous volume scans but not yet topped.

2.24.1 Operational Characteristics.

System ID: MD, Product #149.

Data: Identified shear and mesocyclone features; Mesocyclone Algorithm output.

Processing: Mesocyclone Detection Algorithm, MD Tracking Information.

Availability: Updated once per elevation scan.

Presentation: The DMD data is presented as a text product, attribute table, or graphic display depending on the display system.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 3

Annotations:

- Standard set*
- Combined Attribute Table
- Circulation ID, Closest Storm ID, Strength Rank, Speed/direction of movement, Base, Depth.

Special Symbols: N/A**.**

Adaptation: None.

2.24.2 Usage. As an aid in the identification, alerting, and warning for mesocyclones which very often (>90%) are correlated with severe weather (hail, damaging winds, and tornadoes). It appears that 10% - 15% are associated with tornadoes. Research has shown that a strength rank of 5 most closely matches the MESO threshold in the legacy Mesocyclone algorithm.

Only on the last elevation of a volume scan, or when a circulation is topped, are all parameters for a feature included in the DMD product. For lower elevation scans, and for features not yet topped, the only parameters included are those that have increased in severity for that same circulation since the previous volume scan. Therefore, in order to gain a complete picture of all current MDA detections before a volume scan is completed, the latest available MD product must be used along with the DMD product from the last elevation of the previous volume scan.

2.24.3 Strengths/Applications.

- Identify mesocyclones. Like all algorithms, the DMD Algorithm is imperfect, so the operator must examine reflectivity, velocity, and/or SRM to verify the existence of mesocyclones.
- Identify mid-level mesocyclones that develop downward toward the surface sometimes become associated with tornadoes.
- Because of the very frequent severe weather association with mesocyclones, detection of these features often signals the need for at least a severe thunderstorm.

2.24.4 Limitations.

- Time continuity is not required for feature identification. However, the parameter named “age” easily identifies those circulations with time continuity between two or more volume scans.
- Occasional time association errors occur, particularly in at the three lowest elevation angles and/or when multiple circulations are detected in relative close proximity of one another. Symptoms of a time association error are changing ID numbers for the same geographically located feature as the volume scan progresses. Generally, these time association errors are corrected as the radar progresses through the volume scan. The

MD products from the lowest elevation angle should be used with caution.

- The algorithm only detects cyclonic rotations even though anticyclonic circulations are sometimes also associated with severe thunderstorms.
- At longer ranges mesocyclones may not be detected due to poor aspect ratios and the random beam placement during radar sampling, and the majority of the 3-D circulation being below the height of the lowest elevation angle.
- The operator does not know which base-data elevation angle to examine for detection verification. Algorithm output is in terms of height and not scan angle. However, circulations extending to the lowest elevation angle are indicated by a circle with spikes.
- Range folding and velocity aliasing may interfere with successful mesocyclone detection. Velocity aliasing can itself induce false algorithm detections.
- See Section 3.7 for a discussion of the operational considerations of the Mesocyclone Detection Algorithm.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

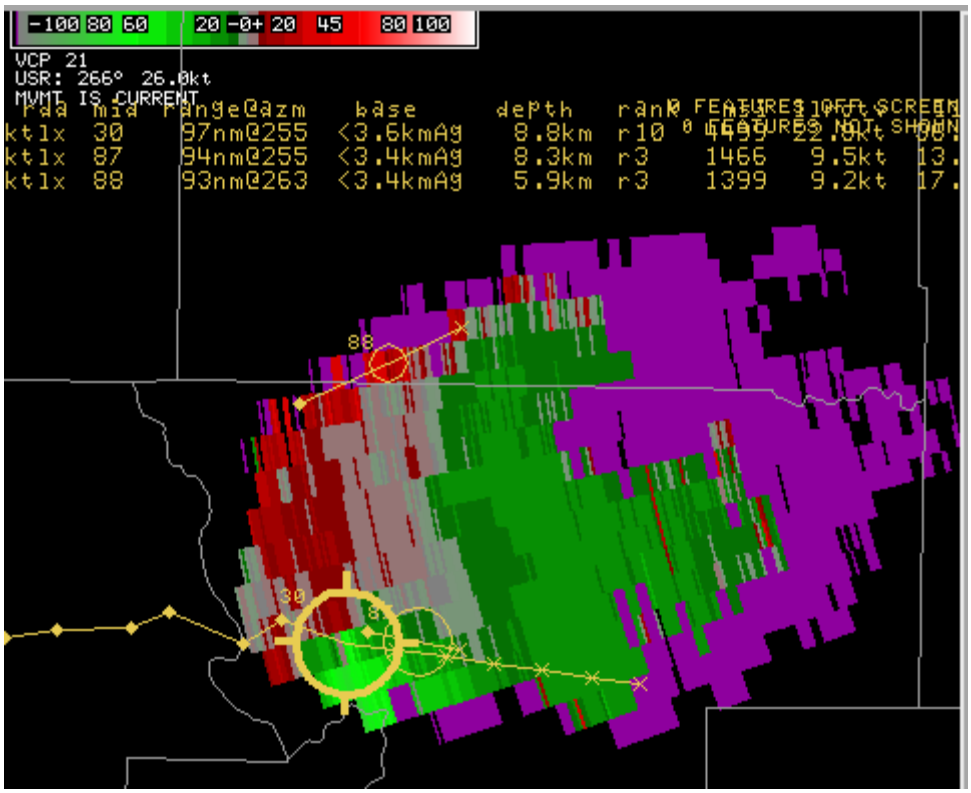

Figure 2-24
Digital Mesocyclone Detection Data Array as an Overlay Product

This DMD example is overlaid on an 8-bit SRM Product collected by the Oklahoma City, OK WSR-88D (KTLX) (AWIPS display). It is zoomed to show the weaker circulations (Circulations 87 and 88).

2.25 <u>One-Hour Rainfall Accumulation</u>. The One-Hour Rainfall Accumulation product (OHP) provides the hourly total rainfall accumulation on a 2 x 2 km (1.1 x 1.1 nm) grid within the 230 km (124 nm) radius of the radar. The product is updated once per volume scan by the Precipitation Series algorithms to provide the precipitation accumulation for the last hour. The total is a running total. If there is too much missing data this product is not generated. The DPA version of this product is produced for use in computers external to the WSR-88D.

2.25.1 Operational Characteristics.

System ID: OHP, Product #78.

Data: Adjusted hourly radar rainfall accumulation estimates.

Processing: Precipitation processing subsystem.

Availability: Once per volume scan.

Presentation: Polar coordinate image of rainfall accumulation values (Figure 2-25).

Resolution: 2 km (1.1 nm) x 1.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Date and End Time of Rainfall Integration
- Maximum Data Value
- Radar Bias Estimate (mean bias for 3-hour product)
- Effective G-R Pair Sample Size (mean for 3-hour product)
- Missing Periods
- Gage Adjustment Bias Flag.

Adaptation: See Section 3.3.

2.25.2 Usage. Assess changes in precipitation intensity in time and space, and for flash flood warnings**.**

2.25.3 Strengths/Applications.

- Assess rainfall accumulations for flash flood watches, warnings, and statements.
- Can be used for Short Term Forecasts and Hazardous Weather Outlooks.
- Time lapse can provide movement and rainfall relative to river basins and other features.
- Other water management applications.

2.25.4 Limitations.

- After extended outages, first product will not be generated for 54 (adaptable) minutes.
- Although every effort has been made to remove non-precipitation reflectivity returns from the calculation of precipitation, residual ground clutter or anomalous propagation may contaminate data.
- The rainfall estimation bias calculation is for the 230 km (124 nm) radius of coverage and may not be representative of one particular area of interest.
- See Section 3.3 for discussions regarding operational considerations of the algorithms.
- The appropriate Z-R relationship may be hard to estimate and vary within the storm.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

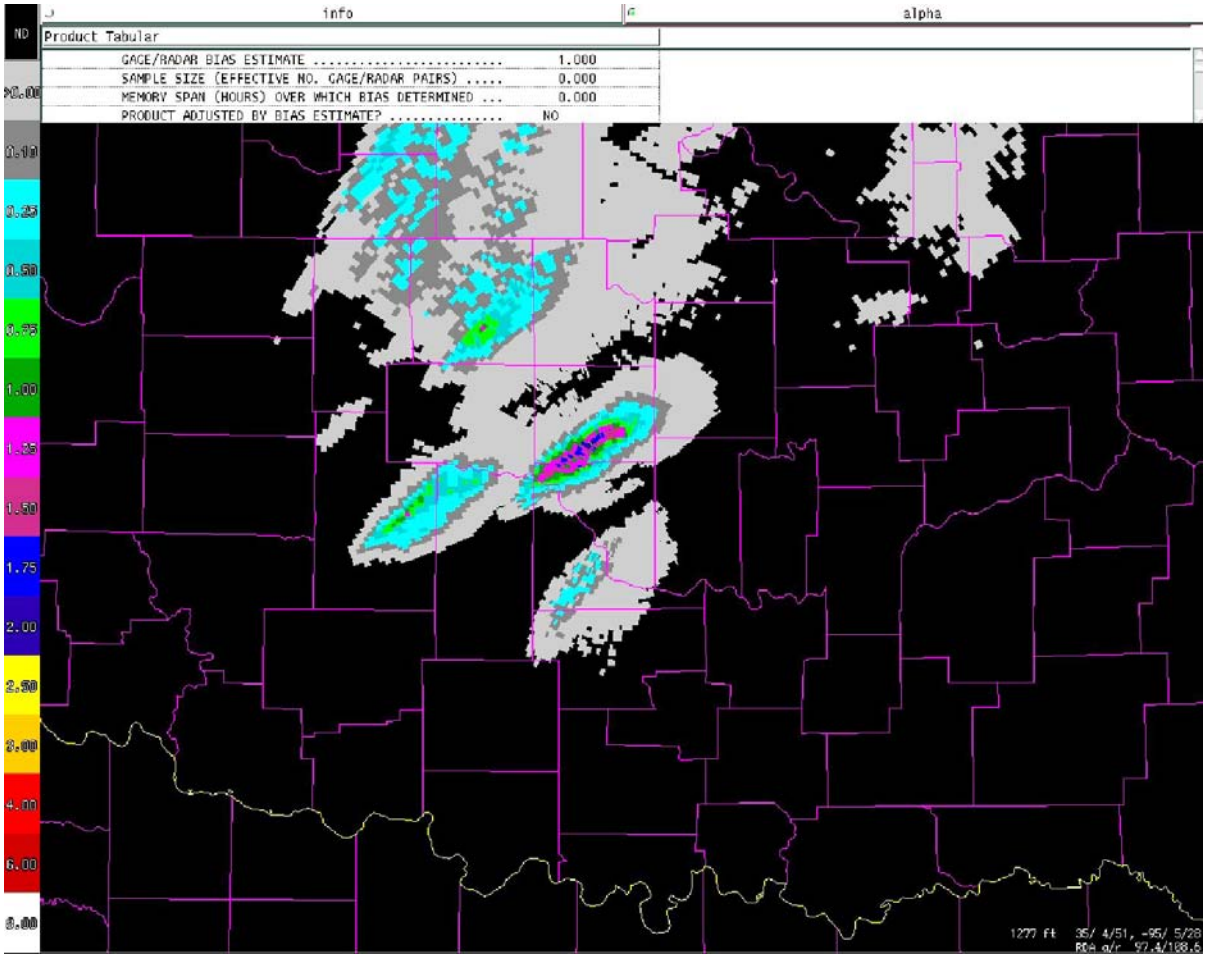

Figure 2-25
One-Hour Rainfall Accumulation Product

An OHP example (AWIPS display) from the Oklahoma City, OK WSR-88D (KTLX).

2.26 <u>Hourly Digital Precipitation Array</u>. The Hourly Digital Precipitation Array product (DPA) provides an hourly running total of radar-rainfall estimates in an array format (not display oriented) to support processing performed external to the WSR-88D. The product is available in 256 data levels for each array element.

2.26.1 Operational Characteristics.

System ID: DPA, Product #81.

Data: Radar precipitation accumulation estimates.

Processing: Precipitation processing subsystem.

Availability: Once per volume scan.

Presentation: Example in Figures 2-26, a and b.

Resolution and Coverage:

- Resolution, 1/40 x 1/40 Limited Fine Mesh (LFM) grid, accumulation data and ¼ LFM grid, rate data
- 131 boxes x 131 boxes
- Radar centered, 230 km (124 nm) radius.

Data Levels: 256 (accumulation); 8 (rate), no color level codes.

Annotations:

- Standard set*
- Supplemental Data, including
- End Date and End Time Hourly Accumulation
- Radar Bias Estimate
- Effective G-R Pair Sample Size
- Memory Span (Hours) used in Bias Estimate
- Total Number of Isolated Sample Volumes
- Total Number of Replaced and Interpolated Outliers
- Mean Percent Area Reduction of all Scans in Accumulation
- Mean Bi-scan Ratio of all Scans during Accumulation Period
- Number of Bad Scans in Current Hour
- Number of Outliers in Current Hour
- Current VCP Number
- Current Operational (Weather) Mode
- Missing Periods (Begin Date; Begin Time; End Date; End Time).

Adaptation Data, including:

- (Preprocessing Algorithm)
- Minimum Reflectivity Threshold
- Maximum Reflectivity Threshold
- Reflectivity Tilt Test
- Inner Range Tilt Test
- Outer Range Tilt Test
- Maximum Range Bi-Scan
- Minimum Echo Area
- Minimum Area-Averaged Reflectivity
- Maximum Area Percent Reduction
- Z-R Multiplicative Coefficient
- Z-R Power Coefficient
- Minimum Reflectivity to convert to Rate
- Maximum Reflectivity to convert to Rate
- Minimum Range Bi-Scan
- (Rate Algorithm)
- Maximum Storm Speed
- Threshold Max Time Difference
- Minimum Area Time Continuity
- Time Continuity Parameter #1
- Time Continuity Parameter #2
- Maximum Rate Echo Area Change
- Range Cut-Off
- Range Effect Coefficient #1
- Range Effect Coefficient #2
- Range Effect Coefficient #3
- Minimum Precip. Rate
- Maximum Precip. Rate
- (Accumulation Algorithm)
- Threshold Elapsed Time to Restart
- Maximum Time for Interpolation
- Minimum Time in Hourly Period
- Threshold Hourly Outlier
- Ending Time Gage Accumulation
- Maximum Period Accumulation Value
- Maximum Hourly Accumulation Value
- (Adjustment Algorithm)
- Time Bias Estimation
- Threshold Number of Gage-Radar Pairs
- Reset Bias Value
- Longest Allowable Lag (Hours)
- Bias Applied Flag.

Adaptation: See Section 3.3.

2.26.2 Usage.

- The DPA supports subjective and objective hydro-meteorological forecast procedures for flash flood watches and warnings, river stage forecasting, water management applications, and other hydrometeorological requirements for numerical use of precipitation data in computers external to the WSR-88D.
- Provides hourly running total digital radar-rainfall estimates in an array format to support processing performed external to the WSR-88D.

2.26.3 Strengths/Applications. Provides high resolution precipitation estimates for generation of external hydrological products such as flash flood assessment and warnings.

2.26.4 Limitations. Product size is very large.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

```
*** ORPG DATABASE PRODUCT LOAD UTILITY ***
-> Number of Products Available=5881
-> Message ID=5750
-> Product Info: LBuffer# 108 MSGLEN 012692 VOLNUM 137 ELEV 04
WARNING: Layer selected exceeds 15 (the current limit), CVT accepts up to 30
WARNING: Number of Layers (16) is out of range (1-15).
CVT will accept up to 30 layers until a new limit is defined.
-> Set Processing ONLY for Layer Number 16
packet code 1 found


Packet 1: Write Text (No Value) Summary Information
Length of Data Block (in bytes) = 3692
I Starting Point: 0
J Starting Point: 0
Message to follow:
ADAP(38) 0.90 50.00 50.00 50.00 99.70 -32.00 20.00 80.00 60.00
300.00 1.40 0.00 70.00 3.00 25.00 15.00 200.00 24.00 13.20
200.00 230.00 0.00 1.00 0.00 0.00 103.80 60.00 30.00 54.00
400.00 0.00 400.00 800.00 50.00 10.00 1.00 168.00 FBIAS(13)
```

Figure 2-26a
Hourly Digital Precipitation Array (Part I)

GAGE-RADAR MEAN FIELD BIAS TABLE
LAST BIAS UPDATE TIME: 08/22/98 16:12 BIAS APPLIED ? NO
MSPAN (HRS) NO. G_R PAIRS AVG. GAGE(MM) AVG. RADAR(MM) MEAN FLD BIAS
0.001 0.000 1.016 1.090 0.932
1.000 0.000 1.863 1.538 1.211
2.000 0.000 2.648 1.933 1.370
3.001 0.000 2.825 2.032 1.391
4.998 0.000 2.908 2.089 1.392
10.004 0.000 2.935 2.118 1.386
168.006 13.494 2.627 2.094 1.255
719.819 126.212 2.417 2.104 1.149
2160.295 212.154 2.381 2.109 1.129
9999044.000 277.982 2.365 2.112 1.120
SUPL(29)RATE SCAN 1 DATE: 12690 TIME:10624
RATE SCAN 2 DATE: 12690 TIME:10880
RATE SCAN 3 DATE: 12690 TIME:11264
RATE SCAN 4 DATE: 12690 TIME:11520
RATE SCAN 5 DATE: 12690 TIME:11904
RATE SCAN 6 DATE: 12690 TIME:12160
RATE SCAN 7 DATE: 12690 TIME:12544
RATE SCAN 8 DATE: 12690 TIME:12800
RATE SCAN 9 DATE: 12690 TIME:13184
RATE SCAN 10 DATE: 12690 TIME:13440
RATE SCAN 11 DATE: 12690 TIME:13824
RATE SCAN 12 DATE: 12690 TIME:14080
RATE SCAN 13 DATE: 12690 TIME:14336
RATE SCAN 14 DATE: 12690 TIME:14720
HOURLY ACCUMULATION END DATE.....: 12690
HOURLY ACCUMULATION END TIME.....: 14400
TOTAL NO. OF BLOCKAGE BINS REJECTED: 0
TOTAL NO. OF CLUTTER BINS REJECTED.: 4707

Figure 2-26b
Hourly Digital Precipitation Array (Part II)

2.27 <u>One-Hour Snow Depth Accumulation</u>. The One-Hour Snow Depth Accumulation product (OSD) provides estimates of the snow depth accumulations during the past running clock hour.

2.27.1 Operational Characteristics.

System ID: OSD, Product #145.

Data: Radar snow depth accumulation estimates.

Processing: Snow Accumulation Algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image of snow depth accumulation estimates (Figure 2-27).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level codes
- SAA adaptable parameters and their values
- Maximum data value detected
- Azimuth and range of the maximum data value
- Range/height correction applied
- Missing periods of accumulations in minutes.

Adaptation: See Section 3.15.

2.27.2 Usage. Provides estimated snow depth accumulation over last hour.

2.27.3 Strengths/Applications.

- Can be used to distinguish areas of high and low snowfall rates and trends and movement of these areas.
- Has adaptable parameters which have been optimized for part of the US which can be changed by the operator
- Snow depth estimates were intended for dry snow (i.e., snow which is not melting).

2.27.4 Limitations.

- Does not account for blowing or drifting snow.
- The same adaptable parameters are applied to the entire radar coverage, yet actual measured values (such as Z-S relationship and snow ratio) will vary within a storm in time and space.
- The snow depth estimates are not accurate for snow that is melting (in the air or on the ground), but the product/algorithm does not distinguish between dry snow and other precipitation types.
- Accuracy of snow estimates is reduced for small periods of time such as 1 hour.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow while falling.
- Data levels are fixed and only provide a range of estimates (versus a digital estimate).

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

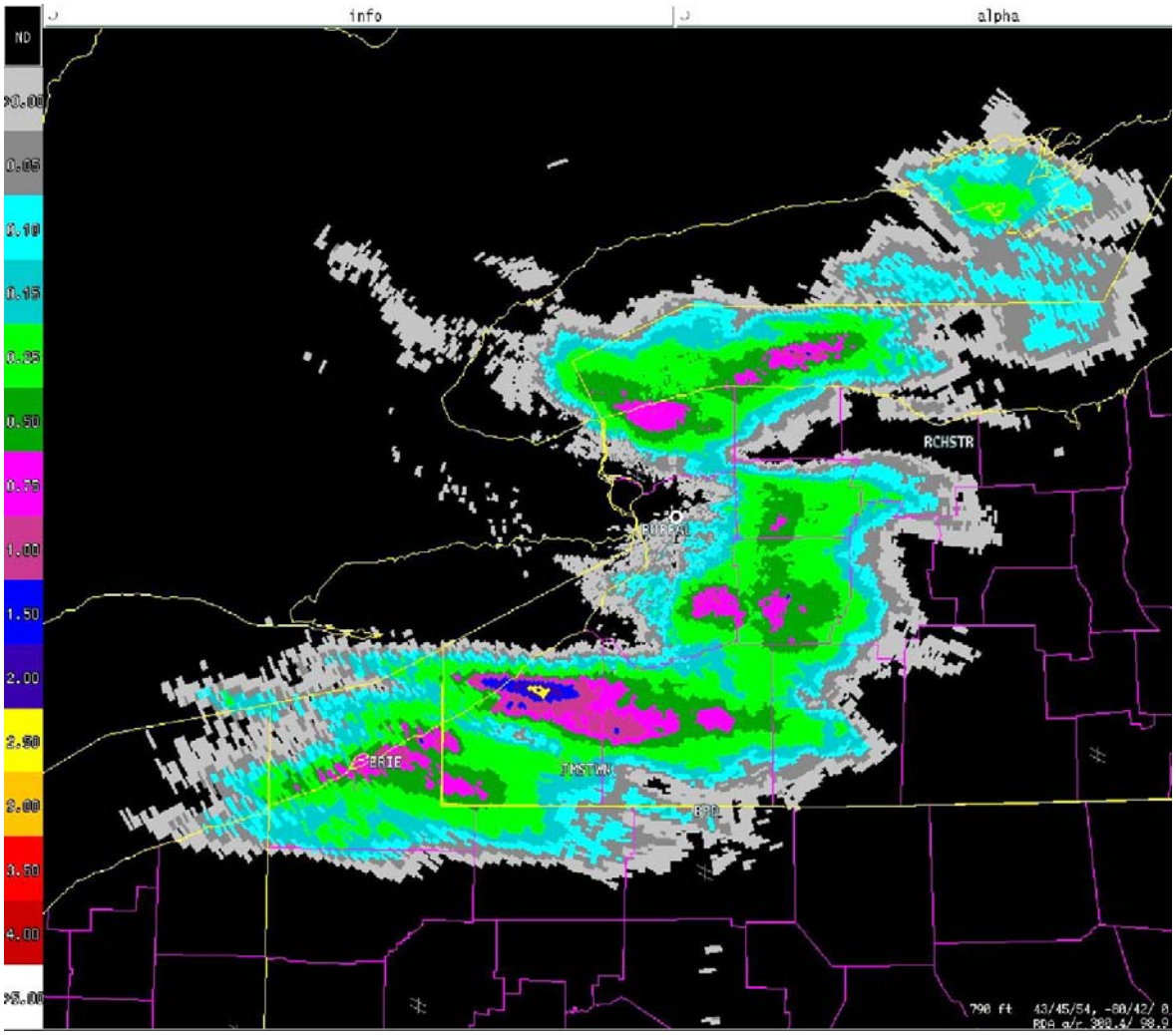

Figure 2-27
One-Hour Snow Depth Accumulation Product

This OSD example (OPUP display) is from the Buffalo, NY WSR-88D (KBUF).

2.28 <u>One-Hour Snow Water Equivalent Accumulation</u>. The One-Hour Snow Water Equivalent Accumulation product (OSW) provides estimates of the water equivalent of the snow that has fallen during the past running clock hour.

2.28.1 Operational Characteristics.

System ID: OSW, Product #144.

Data: Radar snow water equivalent accumulation estimates.

Processing: Snow Accumulation Algorithm.

Availability: Updated once per volume scan.

Presentation: Polar coordinate image of snow water equivalent estimates (Figure 2-28).

Resolution: 1 km (0.54 nm) x 1.

Coverage: Radar centered, 230 km (124 nm radius).

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level codes
- SAA adaptable parameters and their values
- Maximum data value detected
- Azimuth and range of the maximum data value
- Range/height correction applied
- Missing periods of accumulations in minutes.

Adaptation: See Section 3.15.

2.28.2 Usage. Provides estimates of water equivalent of the snow accumulation during the past hour.

2.28.3 Strengths/Applications.

- Can be used to distinguish areas of light and heavy snow rates and trends, and movement of areas.
- Has regionally optimized adaptable parameters which can be changed by the operator.

- Can be used with lower reflectivities than the PPS.
- Has a range/height correction.

2.28.4 Limitations.

- The same adaptable parameters are applied to the entire radar coverage, yet actual measured values (such as Z – S relationship_ will vary in time and space.
- Accuracy of snow estimates is reduced for small periods of time, such as one hour.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow while falling.
- Data levels are fixes and only provide a range of estimates (versus a digital estimate)
- Does not account for blowing or drifting snow.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

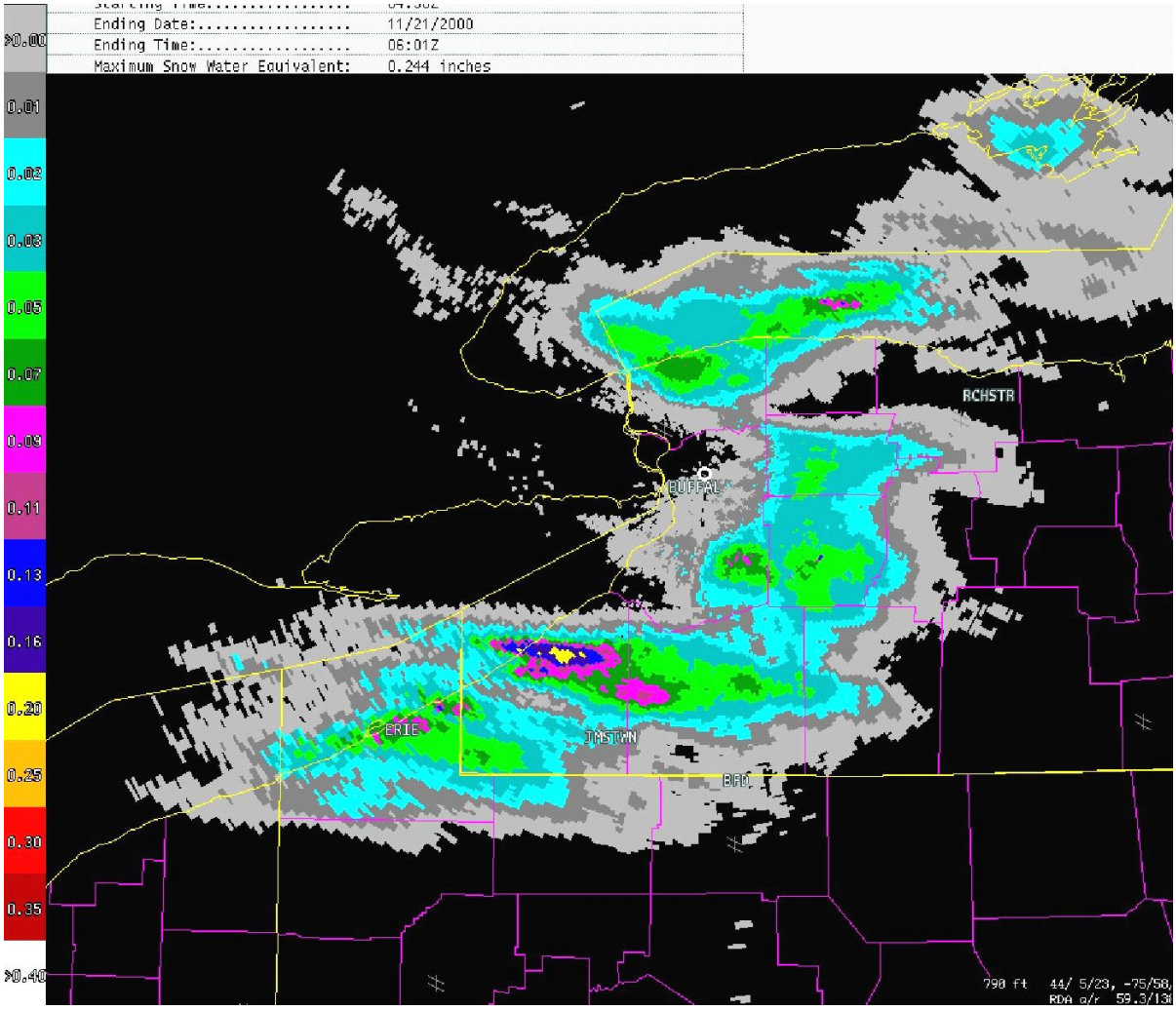

Figure 2-28
One-Hour Snow Water Equivalent Accumulation Product

This OSW example (OPUP display) is from the Buffalo, NY WSR-88D (KBUF).

2.29 <u>Radar Coded Message</u>. The Radar Coded Message product (RCM) is based on grid squares approximately 10 km (5.4 nm) on a side. It is composed of three parts preceded by a communications header. **Part A:** Reflectivity is produced automatically and is presented to the user as a tabular listing of alphanumerics. **Part B:** Velocity Azimuth Display is also produced automatically and is presented to the user as an alphanumeric message. **Part C:** Remarks, consists of automatically provided information that can be augmented at the option of the user. The automatically produced portion of Part C is presented to the user as an alphanumeric message. The RCM is not manually edited.

The **header** is encoded as follows:

ccc	The communications node (PUP site identifier)
sidd	Four letter product source identifier
C/R	Carriage return, line feed.

Part A of the RCM contains a tabular listing of alphanumerics. Data in the RCM are located with respect to a polar stereographic grid. The local grid at each antenna site is designed to be a subset of the national radar grid so that data may be readily composited.

The National Radar Grid has a resolution of 1/4 x 1/4 LFM grid squares, which is 25.7 nm at 60° north. The vertical axis of the grid is parallel to the 105° west longitude meridian and, if the grid extended to the North Pole, the pole would be located at column 41, row 161. For radar observation purposes, however, the grid is limited to 113 columns and 89 rows. Each of these 1/4 x 1/4 LFM grid boxes is further subdivided into 16 grid boxes as shown in Figure 2-19a with the antenna falling into the appropriate 1/16 x 1/16 LFM grid box in the range MMA through MMP.

Rows and columns of the grid boxes are assigned letters A through Y. so that the box containing the antenna site is always box MM. Box AA is at the upper left. As shown in Figure 2-29a each box is further subdivided to form an overall 1/16 x 1/16 LFM grid.

The reflectivity intensity value for each grid box is determined by assigning the maximum value of all Composite Reflectivity boxes whose centers are contained within the 1/16 x 1/16 LFM grid square.

The RCM is based on the 16 level, 4 x 4 km (2.2 x 2.2 nm) CR product (#38), but contains only 9 data level categories; 6 for data, 1 for missing or below threshold data within 230 km (124 nm) and 2 for data beyond 230 km (124 nm). For data beyond 230 km (124 nm), a separate threshold is provided for which: a) all data above that threshold are labeled as level 8, and b) all data below that threshold are labeled as level 9.

Within the tabular listing, a code group is provided for the maximum echo top. The height of the maximum echo top within 230 km (124 nm), and the position where available, is derived from the ET product. The listing also shows the location of the largest mass-ranked centroids within 230 km

(124 nm) of the radar using the 1/16 x 1/16 LFM grid. The maximum number of centroids reported is MSCF adaptable from 1 to 20, with a default value of 12. The forecast centroid speed and direction, as available from the Storm Series algorithms, are also provided.

Part A of the message is encoded as follows:

NEXRAA	Part A indicator.
sidd	Four letter Radar Data Acquisition (RDA) site identifier.
ddmmyytttt	The day (dd) of the month (mm), the year (yy), and the time (tttt), to the Coordinated Universal Time (UTC).
RADNE	No reportable reflectivity intensity values, if appropriate.
RADOM	Radar down for maintenance, if appropriate.
/MDnnnn	Operational mode - Choices are PCPN (Precipitation) and CLAR (Clear Air) (Example: /MDPCPN).
/SCnnnn	Scan strategy - Number of scans per volume over time. Choices are 1405 (14 scans in 5 minutes), 0906, 0510, etc. (Example: /SC1405).
/NInnnn	The total number (nnnn) of intensities (NJ) reported in the following field (Example:/N10144).
gggi	1/16 x 1/16 LFM grid (gag) location of intensity (I) level. Locations and intensities are reported by a series of groups made up of three letters (1/16 x 1/16 LFM) followed by the maximum intensity of the designated grid box. The three letters in order are row, column, and grid box in that row. That is, each 1/16 x 1/16 LFM grid box is reported from west to east starting with the northernmost row with data, followed by the next row south, etc. When succeeding grid boxes contain the same intensity value, the number of succeeding boxes with the same value are designated by a letter of the alpha bet. That is, if four succeeding 1/16 x 1/16 LFM grid boxes (a total of five boxes) are at level 2, they are reported as ggg2D. The 2D may be followed by additional intensity values. Location and intensity groups are separated by a comma (Example: ABF112D331, BCA1211).
/MThh:ggg	The location and height (MSL) of the maximum echo top (MT) within 230 km (124 nm) of the radar using the three letter grid designator (gag) and assigning the height coinciding with the Echo Tops product in hundreds of feet (hhh) (Example:/MT320:NLB).
/NCENnn:	The total number (nn) of centroids (NCEN) reported in this portion of the message. This number corresponds to the corrected centroids (Example: /NCEN04).
Cnnggg dddfff	The centroid (C) number (nn), location (ggg), direction from which it is moving (ddd) and its speed (fff) in knots. Successive groups are separated by a comma. If, during editing data are deleted in a grid box that contains a centroid, this group is corrected by deleting the centroid (Example: CO3QMB 240012).
/ENDAA (C/R)	End of Part A indicator.

The following is a summary of the components of Part A:

/gggiii...i,gggiii...i

/MThhh:ggg

/NCENnn: Cnnggg dddfff,Cnnggg dddfff

/ENDAA (C/R)

Part B of the RCM contains a single profile of the horizontal wind information derived from the output of the Velocity Azimuth Display (VAD) algorithm. Part B of the message is encoded as follows:

/NEXRBB	Part B indicator.
sidd	Four letter product source identifier.
ddmmyytttt	The day (dd) of the month (mm), the year (yy) and the time (tttt), to the nearest minute, in UTC.
VADNA	No VAD data available for the last 15 minutes, if appropriate.
hhhcdddfff	Coded heights (hhh) in hundreds of feet MSL; confidence (c) level, using the Root Mean Square (RMS) error for the coded height; wind direction (ddd) and wind speed (fff), in kts, as derived from the VAD algorithm. The confidence level is given as a single letter in accordance with the following:

A = RMS of 1.9 kts; B = RMS of 3.9 kts;
C = RMS of 5.8 kts; D = RMS of 7.8 kts;
E = RMS of 9.7 kts; F = RMS of 11.7 kts;
G = RMS of >13.6 kts.

Wind direction and speed, as output from the VAD algorithm, shall be reported at up to 19 heights in hundreds of feet MSL. Default heights are:

1,000	6,000	12,000	25,000
2,000	7,000	14,000	30,000
3,000	8,000	16,000	35,000
4,000	9,000	18,000	50,000
5,000	10,000	20,000	

(Example: 080C240060).

/ENDBB (C/R) End of Part B indicator.

The following is a summary of the components of Part B:

/NEXRBB sidd ddmmyytttt (C/R)

hhhcdddfff,hhhcdddfff,hhhcdddfff

/ENDBB (C/R)

Part C of the RCM contains remarks in an alphanumeric format. Automatically generated remarks provide information on the locations of tornadic vortex signatures, mesocyclones, centroids, storm tops, and hail indices. The automated portion of Part C is encoded as follows:

/NEXRCC	Part C indicator.
sidd	Four letter product source identifier.
ddmmyytttt	The day (dd) of the month (mm), the year (yy) and the time (tttt), to the nearest minute, in UTC.

Table 2-2
DEFINITIONS OF RADAR CODED MESSAGE COMPONENTS

BASE	Base of an elevated layer.
CENTROID	The contiguous significant reflectivity (230 dBZ, an adaptable parameter) values collected along the radials (identified as segments) of a volume scan are used to determine the locations of the centroids, or centers of mass, of storms.
CENTER	The circulation of a hurricane or tropical storm is identifiable but no well-defined wall cloud is observed.
ECHO TOP	The Echo Tops algorithm estimates echo (non-zero reflectivity category) top heights for 4 x 4 km (2.2 x 2.2 nm) grid boxes. A grid box represents the area on the Earth where a single value of reflectivity is assigned. The height of the echo top is measured from ground level to the mid-point of the radar radial beam for the highest non-zero reflectivity category per grid box.
EYE	A well-defined central region of a hurricane or tropical storm.
HAIL INDEX	The hail index identifies one of the four following cases: • A given storm is producing or soon will produce hail. • A given storm is probably producing or will probably produce hail. • A given storm is not currently producing hail. • A given storm cannot be analyzed for hail due to lack of data.
LEWP	Line echo wave pattern. A radar pattern formed when a segment of a line of thunderstorms surges forward at an accelerated rate. A mesohigh pressure area is usually present behind the accelerating thunderstorms. A mesolow pressure area is usually present at the crest of the wave.
MALF	Precipitation mostly aloft.
MESOCYCLONE	A 3-dimensional region in a storm that rotates (cyclonically for WSR-88D algorithm usage) and is closely correlated with severe weather.
MLTLVL	Melting level.
PALF	Precipitation partially aloft.

TVS	The radar "signature" of a vortex indicative of a tornadic circulation aloft that may or may not extend to the ground
/NTVSnn:	The total number (nn) of tornadic vortex signatures (NTVS) detected by the TVS algorithm and reported in Part C (Example: /NTVS03:).
TVSnnggg	The location (gag) and number identifier (nn) of each tornadic vortex signature (TVS) (E3xample: TVS02NLB).
NMESnn:	The total number (nn) of mesocyclones and areas of uncorrelated shear (NMES) detected by the Mesocyclone Detection algorithm and reported in Part C (Example: /NMES05:).
Mnnggg	The location (gag) and number identifier (nn) of each mesocyclone or area of uncorrelated shear (M) (Example: M03JLC).
NCENnn:	The total number (nn) of centroids (NCEN) reported in Part C (Example: /NCEN08:).
Cnnggg ShhhHi	The height (hhh) in hundreds of feet (MSL), of the storm top (S), as derived from the Storm Structure algorithm, for each centroid (C) identified in Part A to include location (ggg). The centroid identifier number (nn) is the same as given in Part A. The hail (H) index (I), as provided by the Hail algorithm, is also given as one of the four following data levels: N - no hail; P - probable hail; H - hail; U - unknown (Example: C04QQD S440HP).
PCTRyyyy aa:gg	Precipitation type and intensity trend. Precipitation type (yyyy) may be coded for a representative area of the display. The type is variable and up to four characters in length. The intensity trend (aaa) is also variable in length and up to three characters in length. The location (gg) is reported using the two letter identifier for the 1/4 x 1/4 LFM grid. For convective echo systems, the characteristic type of precipitation is defined as that type associated with the maximum observed intensity. For non convective echo systems, the type of precipitation is defined as that type predominant in horizontal extent. Precipitation types are:
	Type / Symbol / Type / Symbol Rain / R / Drizzle / L Rain Shower / RW / Freezing Drizzle / ZL Freezing Rain / ZR / Ice Pellet / IP Freezing Rain Shower / ZRW / Ice Pellet Shower / IPW Snow / S / Hail / A Snow Shower / SW
	Areas believed to be associated with thunderstorms are designated by the symbol T preceding the precipitation symbol. The intensity trend is evaluated in terms of the net change in the

	characteristic intensity during a period of 1 hour for lines and areas and 15 minutes for cells. The intensity trend is reported as increasing (+) or decreasing (-), if, during the period, the net change in characteristic intensity (dBZ) changes from one intensity level to another. If the net change in the characteristic intensity during the period does not change categories, report the intensity trend as NC (no change). The intensity trends of drizzle, hail, ice pellets, or snow are not reported. Echo systems are reported as NEW (new development) if they originated during the period specified above. The intensity trend of areas or lines that develop from a cell or cells during the hour preceding the report are reported as NEW. For a mixed system, the order of precedence for reporting precipitation type is liquid, freezing, and frozen (Example: PCTRRW,NEW:LO,LP).
/LEWP:gg	A line echo wave pattern (LEWP) may be reported using the two letter 1/4 x 1/4 LFM grid box location (gg) (ExampleLEWP:KJ,LK,MK,NK, OK,PL).
/BASEhhh:gg	The base of an elevated layer (BASE) may be reported in hundreds of feet (hhh) (MSL) using the two letter identifier for the 1/4 x 1/4 LFM grid location (gg) (Example: /BASE090:LO,MO).
/MALFhhh:gg	The occurrence of precipitation which is mostly aloft (MALF) may be reported. The height (hhh) is reported in hundreds of feet (MSL) and the location (gg) is the 1/4 x 1/4 LFM grid identifier Example: / MALF050:KP,KQ).
/PALFhhh:gg	The occurrence of precipitation which is partially aloft (PALE) may be reported. The height (hhh) is reported in hundreds of feet (MSL) and the location (gg) is the 1/4 x 1/4 LFM grid identifier (Example:/PAL FOSO:PM,PN).
/MLTLVLhhh	The height (hhh) of the melting level (MLTLVL) in hundreds of feet (MSL) may be reported Example: /MLTLVL075
/EYEdddfffcc: ggg;	The location (gag) of the eye of a hurricane or tropical storm (EYE), the direction (ddd) from which it is moving and the speed (fff), in knots, of movement shall be encoded. Confidence in the fix (cc) is reported as good (GF), fair (FF), or poor (PF).
LATee.ex, LONeee.ey	Further, the location of the eye shall also be encoded in latitude (LAT) and longitude (LON). The location shall be expressed in whole degrees and tenths (eee.e) specifying north (N), south (S), east (E) or west (W), as appropriate (Example:/EYEI 60010GF :OOA;LAT28.4N,LON178.5W).
/CNTRdddfff: ggg;	The location (ggg) of the center of a hurricane or tropical storm (CNTR), the direction (ddd) from which it is moving and the speed (fff), in knots, of movement shall be encoded
LATee.ex,	Further, the location of the center shall also be encoded in latitude (LAT)

LONeee.ey	and longitude (LON). The location shall be expressed in whole degrees and tenths (eee.e) specifying north (N), south (S), east (E) or west (W), as appropriate (Example: /CNTR160010:00A;LAT28.4N,LON178.5W).
/REM:	This space is for any additional remarks.
/ENDCC (C/R)	End of Part C indicator.

The following is a summary of the components of Part C:

/NEXRCC sidd ddmmyytttt (C/R)

/NTVSnn: TVSnnggg,TVSnnggg,TVSnnggg

/NMESnn: Mnnggg,Mnuggg,Mnnggg

/NCENnn: Cnnggg ShhhHi,Cnnggg ShhhHi,Cnnggg ShhhHi

/PCTRyyyy,aaa:gg

/LE WP:gg,gg,gg,gg

/BASEhhh:gg,gg,gg

/MALFhhh:gg,gg

/PALFhhh:gg,gg

/MLTLVLhhh

/EYEdddfffcc:ggg;LATee.ex,LONeee.ey

/CNTRdddfff:ggg;LATee.ex,LONeee.ey

/REM:

/ENDCC (C/R)
At the end of the message, the following group is sent:

/ENDALL (C/R)

2.29.1 Operational Characteristics.

System ID: RCM, Product #74.

Data:

- Composite reflectivity
- Hail index
- Maximum echo top
- Mesocyclone
- Storm centroid
- Storm structure
- Storm tracking information
- Tornadic vortex signature
- Velocity azimuth display.

Processing: Convert composite reflectivity to 1/16 x 1/16 LFM "gridded" data.

Availability: Up to twice per hour at scheduled time(s).

Presentation:

- Part A: Internal - Pixel Image (Figure 2-29)
  External - Alphanumeric
- Part B: Internal - Alphanumeric
  External - Alphanumeric
- Part C: Internal - Alphanumeric
  External - Alphanumeric.

Resolution:

- Parts A and C: 1/16 x 1/16 LFM grid
- Part B: Up to 19 heights

Coverage:

Radar centered, 460 km (248 nm) radius
Surface to 50,000 feet MSL.

Data Levels: Appendix A.

Annotations:

- Standard set*
- Data level
- Maximum data value for reflectivity
- Maximum echo top.

Adaptation.

- Scheduled production time(s)
- VAD levels.

2.29.2 Usage. Provides summary level radar information. Its primary use is in the preparation National Radar Summary Chart for aviation and other interests. Other uses are derivative.

2.29.3 Strengths/Applications. Provides a national summary of radar echoes.

2.29.4 Limitations.

- Product cannot be edited.
- LFM model and grid no longer used, so grid does not match any numerical model.
- Other federal government, private and universities provide more frequent national and regional mosaics; and provide more sophisticated ways to remove clutter and AP.

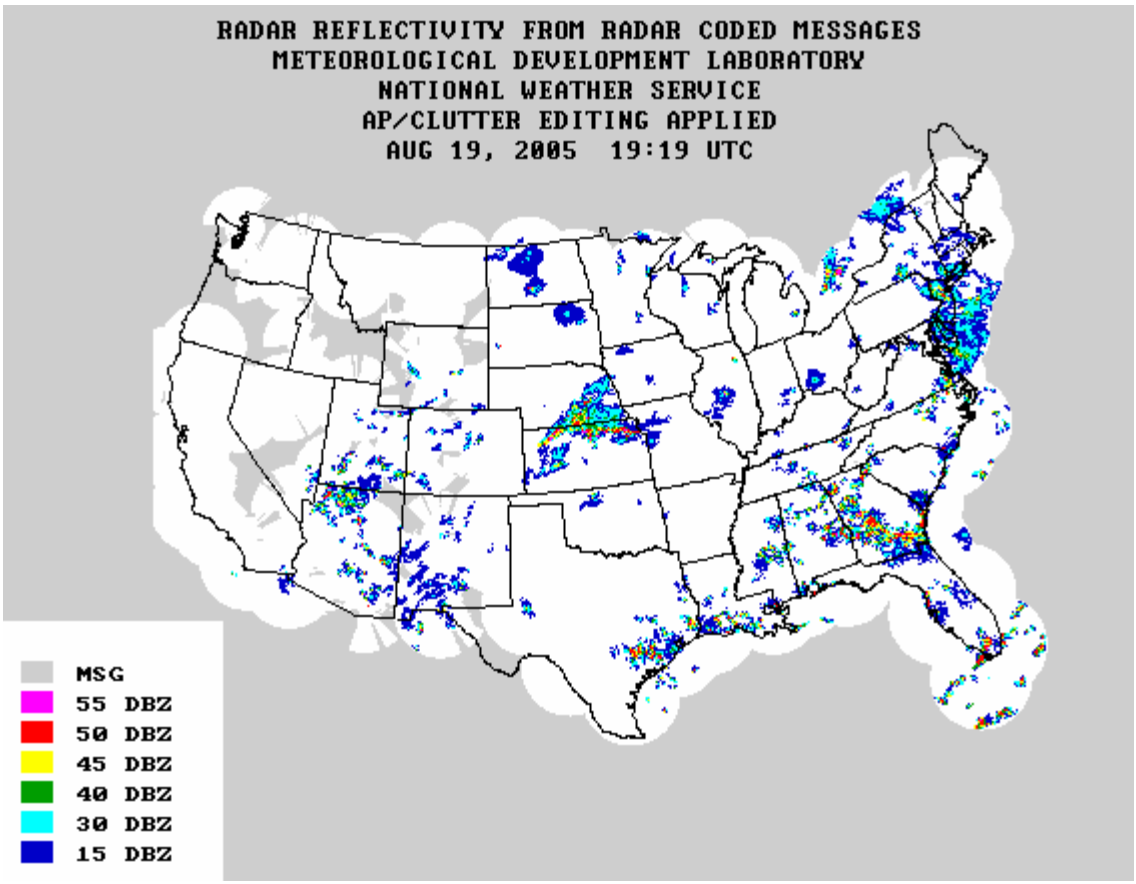

Figure 2-29
Radar Coded Message National Graphic

An example of the National RCM the NWS produces, available at:
http://weather.noaa.gov/radar/mosaic/DS.p19r0/ar.us.conus.shtml.

2.30 <u>Reflectivity</u>. Reflectivity products (R) provide displays of reflectivity data for each elevation angle scan at spatial resolutions up to the maximum capability of the legacy RDA. The products are available for several combinations of display resolution and coverage; each product is available for 8 and 16 data levels. A separate version of each product is available for each antenna scan, depending upon the VCP employed.

2.30.1 Operational Characteristics.

System ID: R, Products: #16, #17, #18, #19, #20, #21.

Data: Reflectivity.

Availability: Updated once per volume scan at each elevation angle.

Presentation: Polar coordinate image of reflectivity data (Figure 2-30, a-f).

Resolution:	**Coverage:**
• 1 km (0.54 nm) x l° (#16 and 19)	Radar centered, 230 km (124 nm) radius
• 2 km (1.1 nm) x l° (#17 and 20)	Radar centered, 460 km (248 nm) radius
• 4 km (2.2 nm) x 1° (#18 and 21)	Radar centered, 460 km (248 nm) radius.

Data Levels: 8 (#16, 17, 18) and 16 (#19, 20, 21).

Annotations:

- Standard set*
- Calibration constant (scaling constant used by the PSP to calculate reflectivity)
- Data level code
- Elevation angle
- Maximum reflectivity value detected.

Adaptation: None.

2.30.2 Usage.

- As an aid in the analysis of meteorological events.
- Primary use is for surveillance as well as a detailed interpretation on a storm-by-storm basis (also see SWA).
- The sensitivity of the WSR-88D allows the detection of ice crystals, some as cirriform and mid-level clouds. The range of detection is dependent on the ice crystal and snowflake composition of the cloud.

- Stratocumulus clouds will often contain precipitation aloft as raindrops or ice crystals and snowflakes, or both, large enough to be detected by the WSR-88D.
- Stratus (and fog) usually will not be detected due to small droplet structure.
- Precipitation events can be monitored as they evolve, develop, and/or dissipate by observations of reflectivity patterns.
- Moisture or turbulent layers, or both, can be observed from backscatter from refractivity fluctuations.
- The evolution of the planetary boundary layer can be monitored from the backscatter from the refractivity structure or particulates (e.g., insects).
- Horizontal rolls and the evolution of cloud streets at the top of the planetary boundary layer can be monitored. The depth of the planetary boundary layer can be monitored during a diurnal cycle.
- Features such as the bright band may be observed.

2.30.3 Strengths/Applications.

- Observe precipitation intensity, movement, and trends.
- Evaluate environmental conditions and meteorological characteristics such as inversions or moisture layers, especially in the Clear Air Mode.
- Identify ice cloud layers and even very light precipitations characteristics.
- Identify and locate the freezing/melting level.
- Observe and at times even track non-precipitation phenomena such as birds, bats, insects, smoke, volcanic ash, chaff, etc.
- Weak returns from refractive index gradients and small particulates such as insects reveal many characteristics of the boundary layer.
- Determine the location and motion of wind shear lines and boundaries such as gust fronts, synoptic fronts, sea breezes, and wind-shifts of all kinds.
- Determine significant convective storm structural features such as WER, BWER, hook echoes, and even evidence for Rear Flank Downdraft (RFD) existence. Line Echo Wave Patterns (LEWP) and squall lines can be identified.

2.30.4 Limitations.

- Data level values cannot be changed.
- Weak returns are not detected in Precipitation Mode.
- Residual ground and point clutter, and AP can contaminate data.
- Discrete elevation sampling of any VCP limits echo sampling only to the scanned elevation angles. Areas between non-contiguous beams and above the highest beam elevation (4.5° or 19.5° depending on VCP) are not sampled at all.
- Chaff echoes are often difficult to distinguish from precipitation echoes.
- Beam broadening with increasing ranges limits detection of features that are small compared to the beam width. This is referred to as “aspect ratio” or the ratio of the beam width to the feature size.

- Beam blocking is possible on lower elevation angles by nearby high-rise buildings or orographic features such as mountains.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

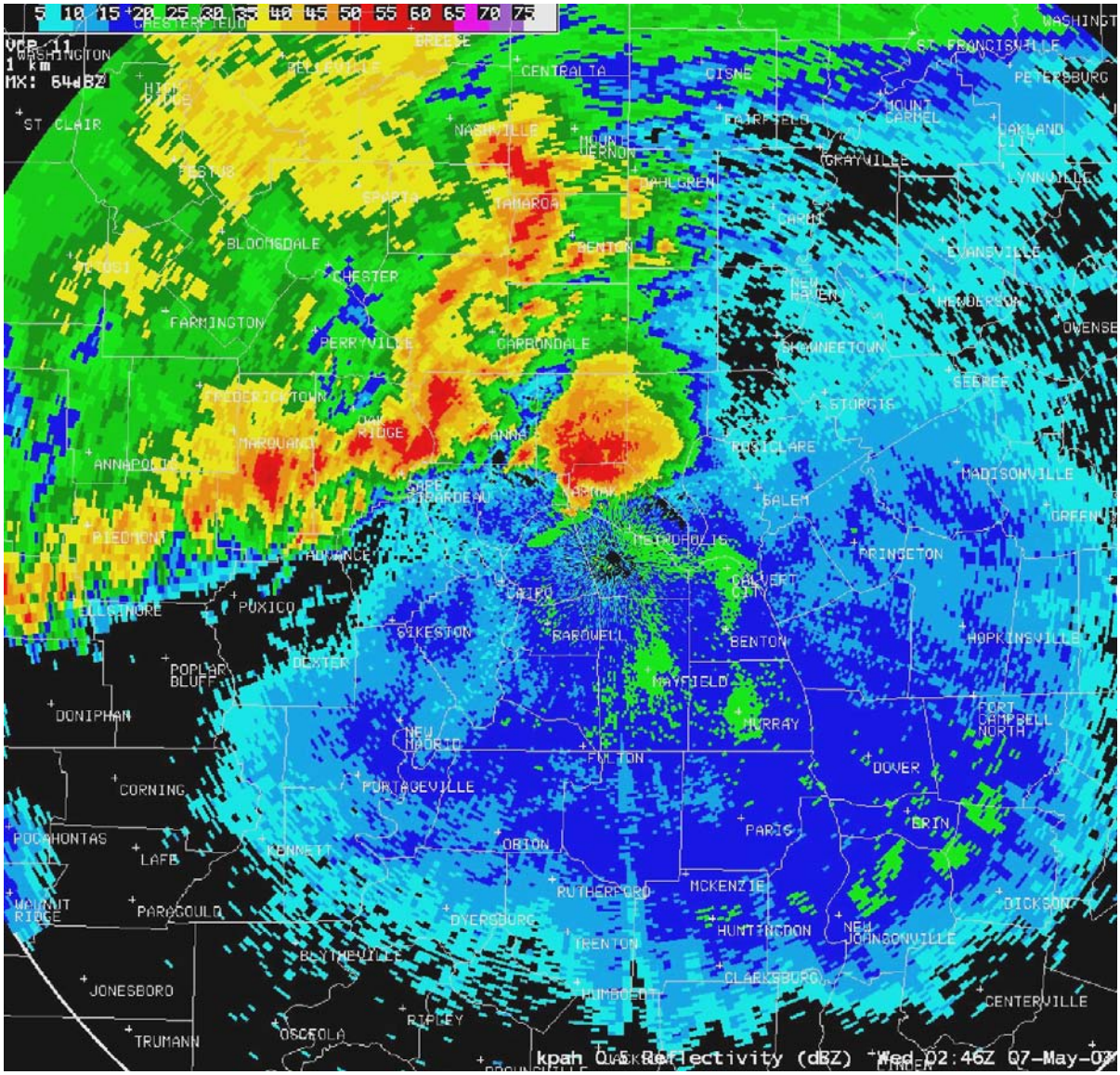

Figure 2-30a
Reflectivity Product

An example of a Reflectivity product (0.5^{o} elevation angle, 16 data levels and 1° x 1 km (0.54 nm) data resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display). Figures 2-30a – 2-30f are at the same time and elevation angle for comparison purposes.

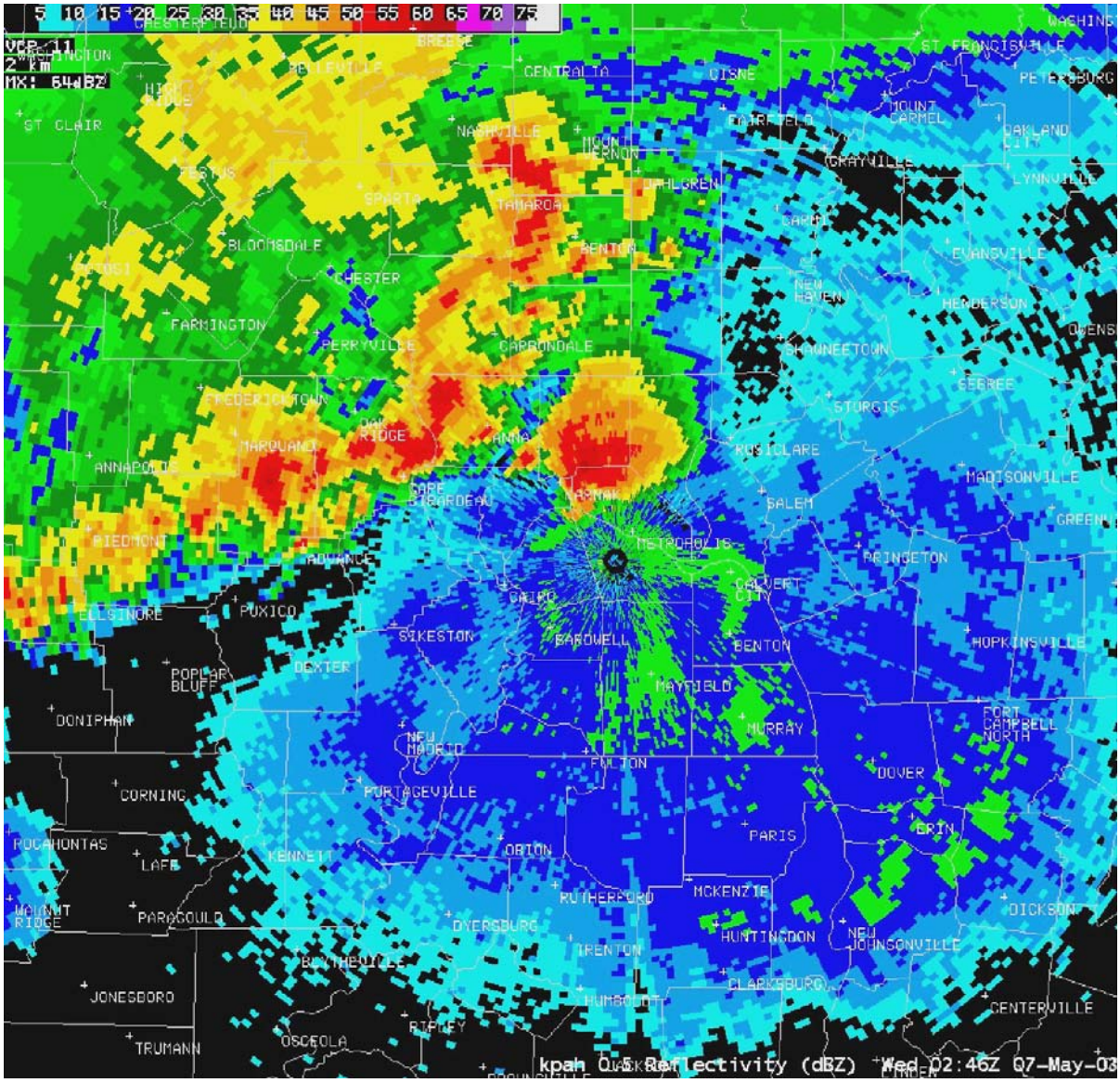

Figure 2-30b
Reflectivity Product

An example of a Reflectivity product (0.5° elevation angle,16 data levels and 1° x 2 km (1.1 nm) resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display).

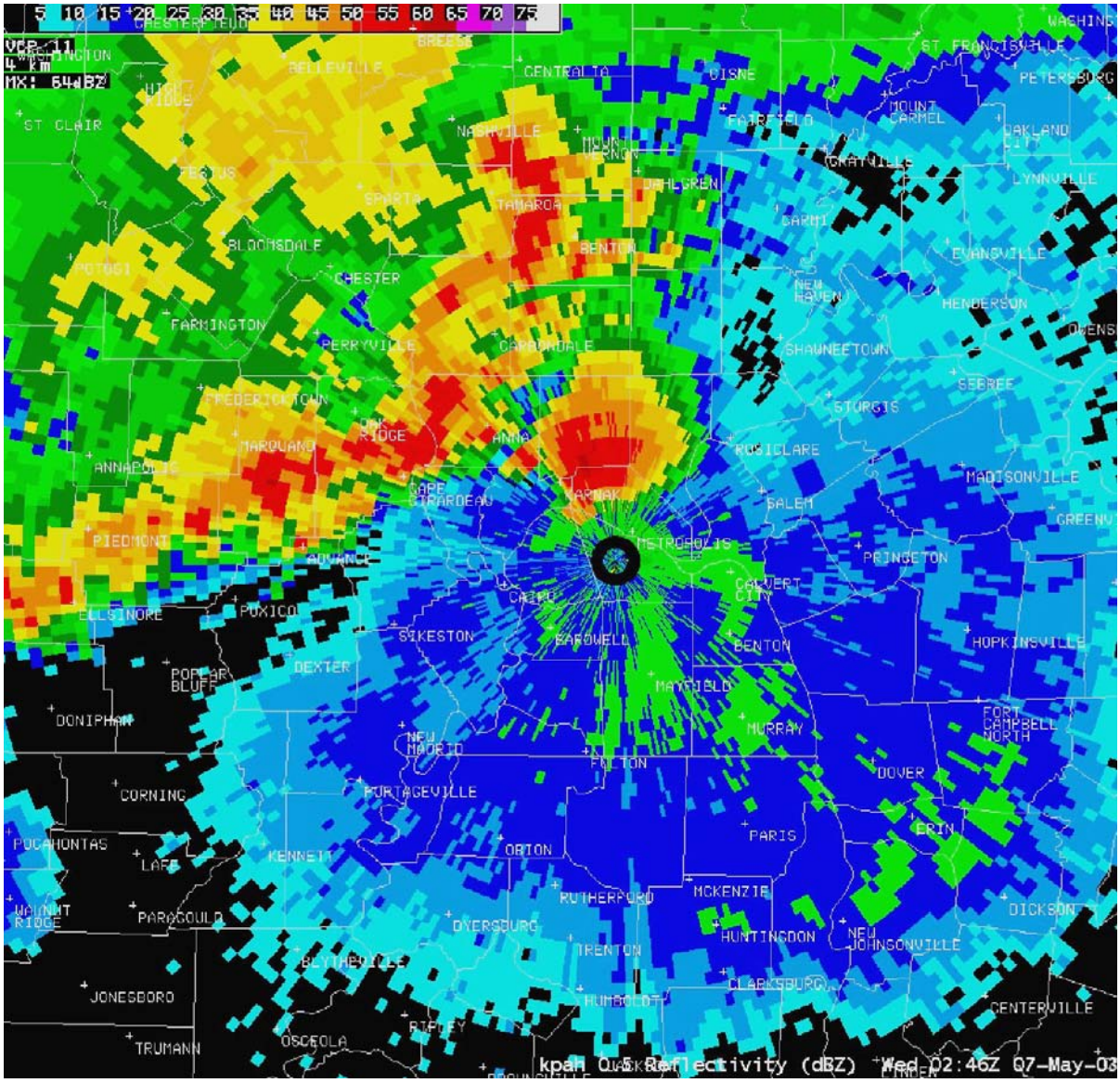

Figure 2-30c
Reflectivity Product

An example of a Reflectivity product (0.5° elevation angle, 16 data levels and 1° x 4 km (2.2 nm) data resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display).

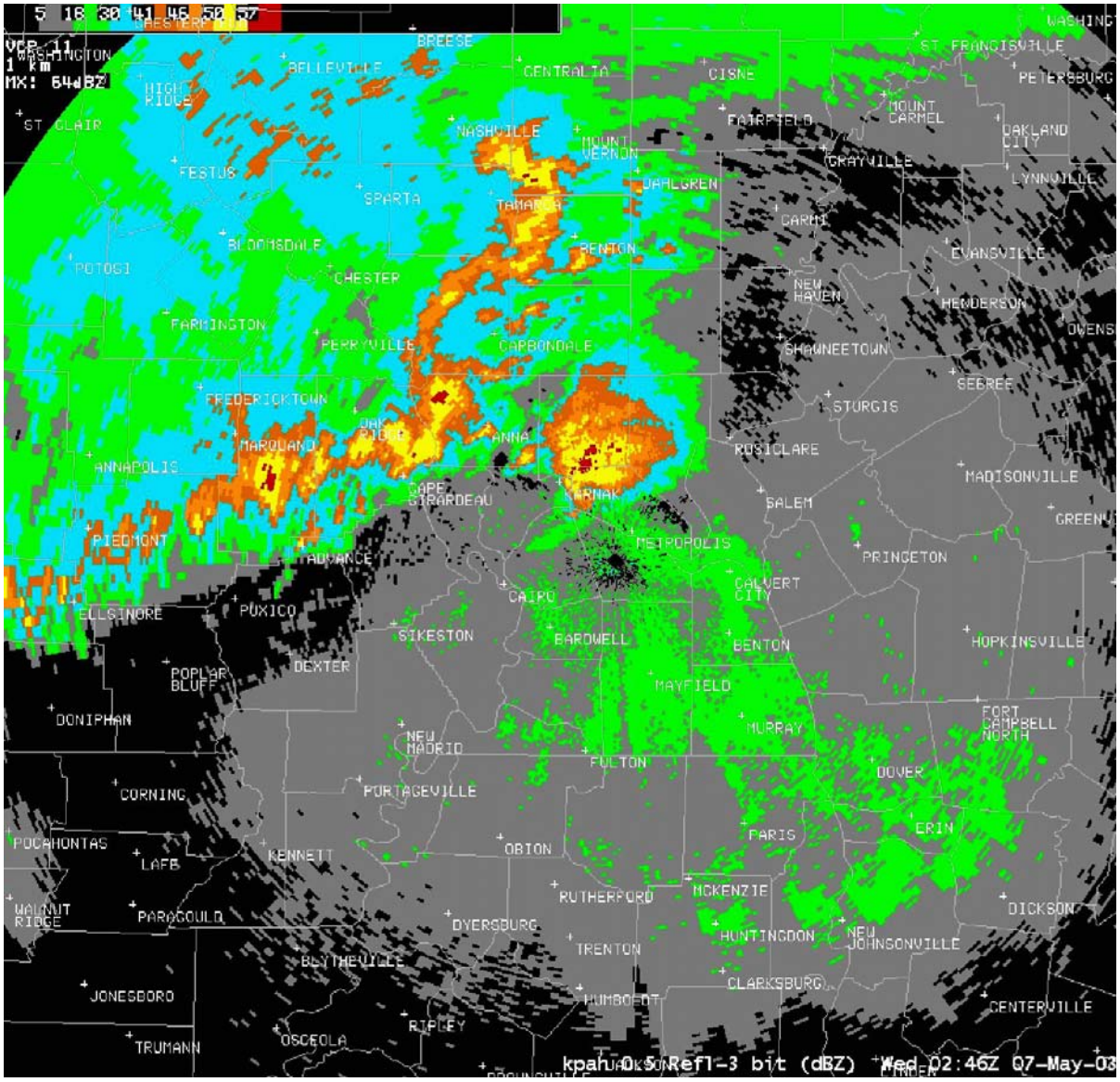

Figure 2-30d
Reflectivity Product

An example of a Reflectivity product (0.5° elevation angle, 8 data levels and 1° x 1 km (0.54 nm) data resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display).

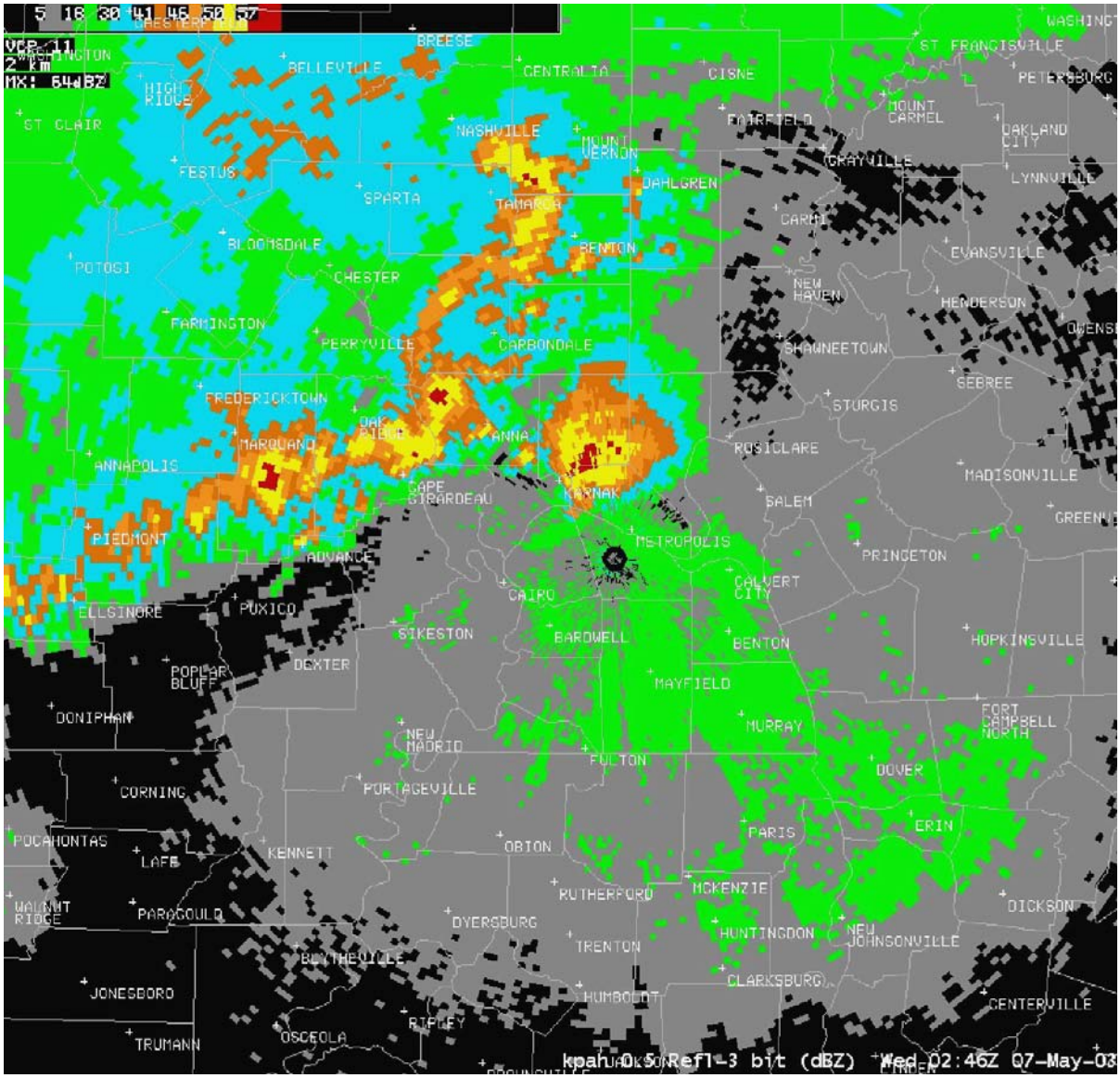

Figure 2-30e
Reflectivity Product

An example of a Reflectivity product (0.5° elevation angle, 8 data levels and 1° x 1.1 nm (2 km) data resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display).

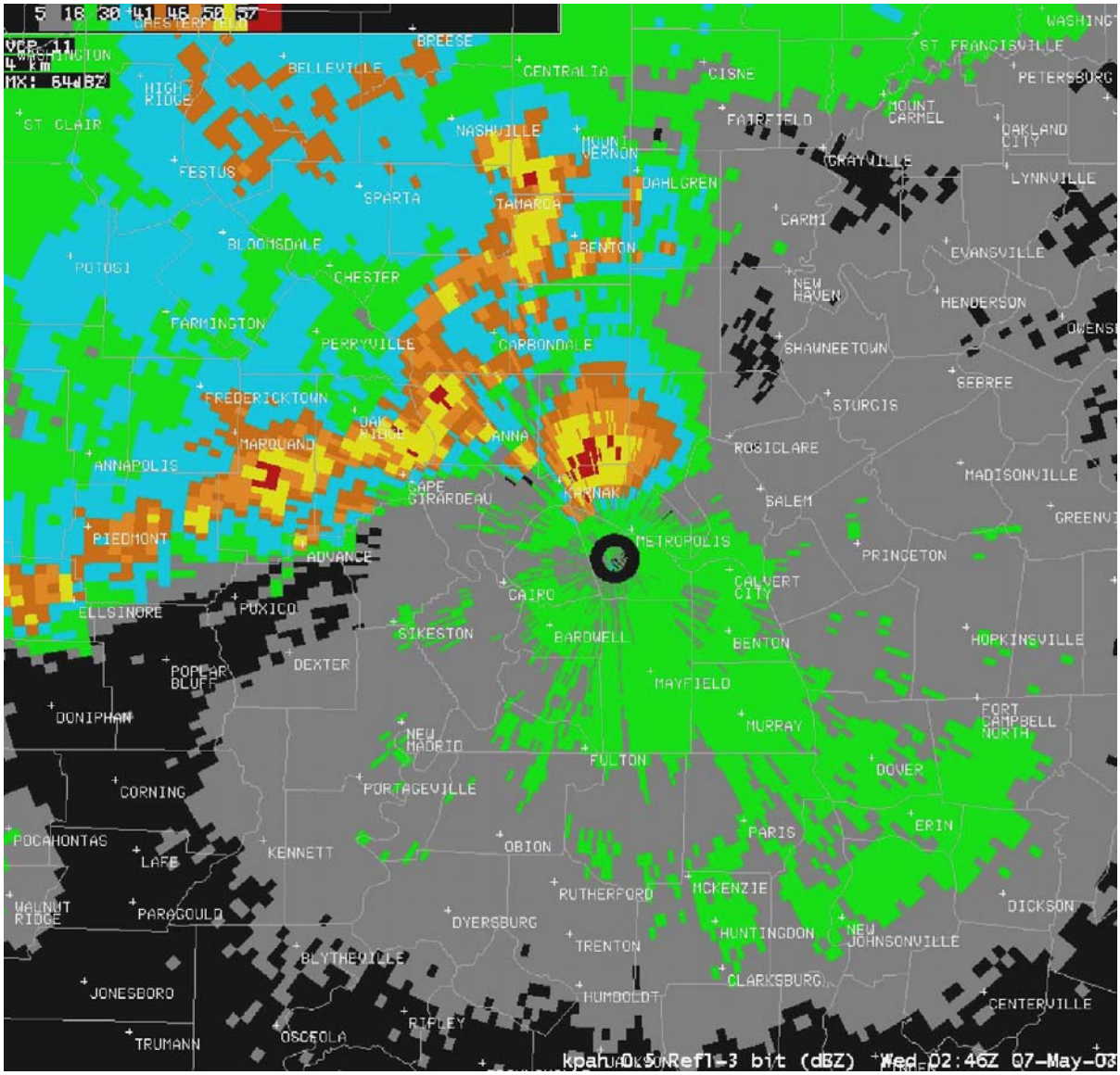

Figure 2-30f
Reflectivity Product

An example of a Reflectivity product (0.5° elevation angle, 8 data levels and 1° x 2.2 nm (4 km) data resolution) from the Paducah, KY (KPAH) WSR-88D at 02:46 UTC on 7 May 2003 (AWIPS display).

2.31 <u>Base Reflectivity Data Array</u>. Unlike the Reflectivity products, which only display 1 km (0.54 nm) data out to 230 km (124 nm), the Base Reflectivity Data Array product (DR) provides 1 km (0.54) nm resolution (the maximum resolution) Reflectivity data out to 460 km (248 nm). The product also has 256 data levels. This permits a rendition of storms with the highest possible resolution in order to include the maximum structural detail.

2.31.1 Operational Characteristics.

System ID: DR, Product #94.

Data: Reflectivity.

Availability: Once per volume scan at each elevation angle.

Presentation: Polar coordinate data array of reflectivity (Figure 2-31).

Resolution: 1 km (0.54 nm) x l°.

Coverage: Radar centered, 460 km (248 nm) radius.

Data Levels: 256.

Annotations:

- Standard set*
- Calibration constant (scaling constant used by the PSP to calculate reflectivity)
- Data level code
- Elevation angle
- Maximum reflectivity value detected.

Adaptation: None.

2.31.2 Usage. An aid in the analyzing meteorological events in displayable systems external to the WSR-88D. This product delivers the same 1 km (0.54 nm) resolution out to 460 km (248 nm). This provides data for improved analysis within a range of 230 km (124 nm) of:

- Storm structure
- Rainfall rate assessment
- Boundaries
- Algorithm validation/QC
- Non-meteorological returns.

2.31.3 Strengths/Applications.

- Provides the best WSR-88D reflectivity resolution available with the legacy RDA.
- Weak returns in either Clear Air or Precipitation Modes are included. Reflectivity is provided down to -30 dBZ (as a function of range) in both Modes.

2.31.4 Limitations.

- High reflectivities are included in Clear Air Mode. Reflectivities up to >90 dBZ are included in both modes. Receiver saturation occurs with high reflectivity in Clear Air Mode and reflectivity estimates are capped at 28 dBZ.
- Data level values cannot be adjusted.
- Product data file size is very large.
- High detail may be confusing, especially when viewing storms close to the RDA.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

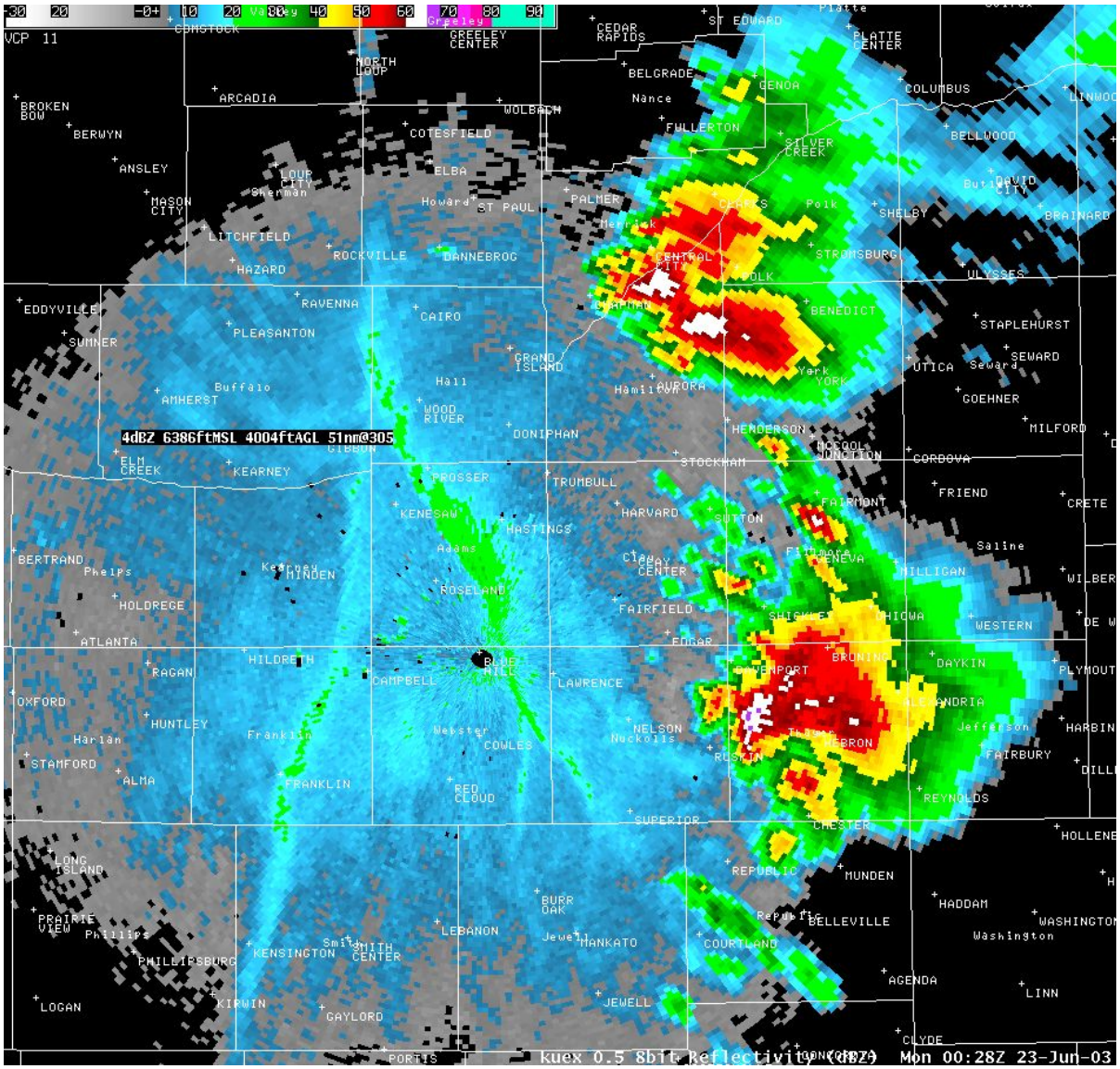

Figure 2-31
Base Reflectivity Data Array Product

An example DR product at 0.5° elevation from the Grand Island, NE (KUEX) WSR-88D on 23 June 2003 (AWIPS display).

2.32 Severe Weather Analysis. The Severe Weather Analysis products (SWA) provide, at the highest product resolution available, separate maps of reflectivity, mean radial velocity, spectrum width, radial shear, or storm relative mean radial velocity for 50 x 50 km (27 x 27 nm) areas. When produced because it has been selected for generation due to the detection of an alert condition, the product is automatically generated for the elevation angle nearest the "critical altitude" for the meteorological phenomenon causing the alert and is centered at the coordinates of that phenomenon. The product can also be generated upon user request for a specified elevation angle and geographic center point.

To aid in the visual interpretation of the mean radial velocity, the storm motion can be removed from the velocity data by manually replacing the mean radial velocity panel with the SRR product.

2.32.1 Operational Characteristics.

System ID: SWA: SWR (reflectivity) #43, SWV (mean radial velocity) #44, SWW (spectrum width) #45, and SWS (radial shear) #46.

Data:

- Mean radial velocity
- Reflectivity
- Spectrum width.

Processing:

- Radial Shear algorithm
- Range-Altitude-Elevation Angle algorithm.

Availability:

- Upon user request
- Automatically upon detection of an alerting phenomenon.

Presentation: Four-quadrant, polar coordinate, image of data values; one data type per quadrant (window) (Figure 2-32). The SWV product requires referencing to the RDA position for correct interpretation. Therefore, azimuths from the RDA with 10° intervals are placed on the image. Range marks at 21 km (11 nm) intervals beginning at 21 km (11 nm) from the RDA are also included.

Resolution:	**Coverage:**
• SWR -1 km (0.54 nm), SWV - 0.25 km (0.13 nm)	50 x 50 km (27 x 27 nm) window within 230 km (124 nm) of the radar
• SWW - 0.25 km (0.13 nm), SWS - 0.5 km (0.27 nm)	

- Product is centered either at location of alerting phenomenon or user-requested coordinates.

Data Levels: 16.

Annotations:

- Standard set*
- Alert category
- Coordinates of product center
- Data level code for each product
- Elevation angle
- Height above ground level of center of window containing meteorological phenomenon
- Maximum data values for each data type.

Adaptation:

- Data levels (velocity only)
- Product center coordinates
- Velocity product type.

2.32.2 Usage.

- Provides the user with the highest resolution radar information available for a severe weather event and allows the user to see all radar moments simultaneously without paging through multiple products. Data are available as a four quadrant product or as individual products.
- Intended primarily for the detailed analysis of severe convective weather.

2.32.3 Strengths/Applications.

- All three base product resolutions are the best available.
- Operator can examine three base products simultaneously allowing direct comparison.
- SRR can be used instead of Mean Radial Velocity
- Effective in investigating convective storms

- Displays product center height
- Provides ability to analyze and evaluate reflectivity, velocity, and spectrum width of a storm at various heights.

2.32.4 Limitations.

- Product data resolution not identical
- Limited viewing area.
- Takes time to request, receive, and view the product.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

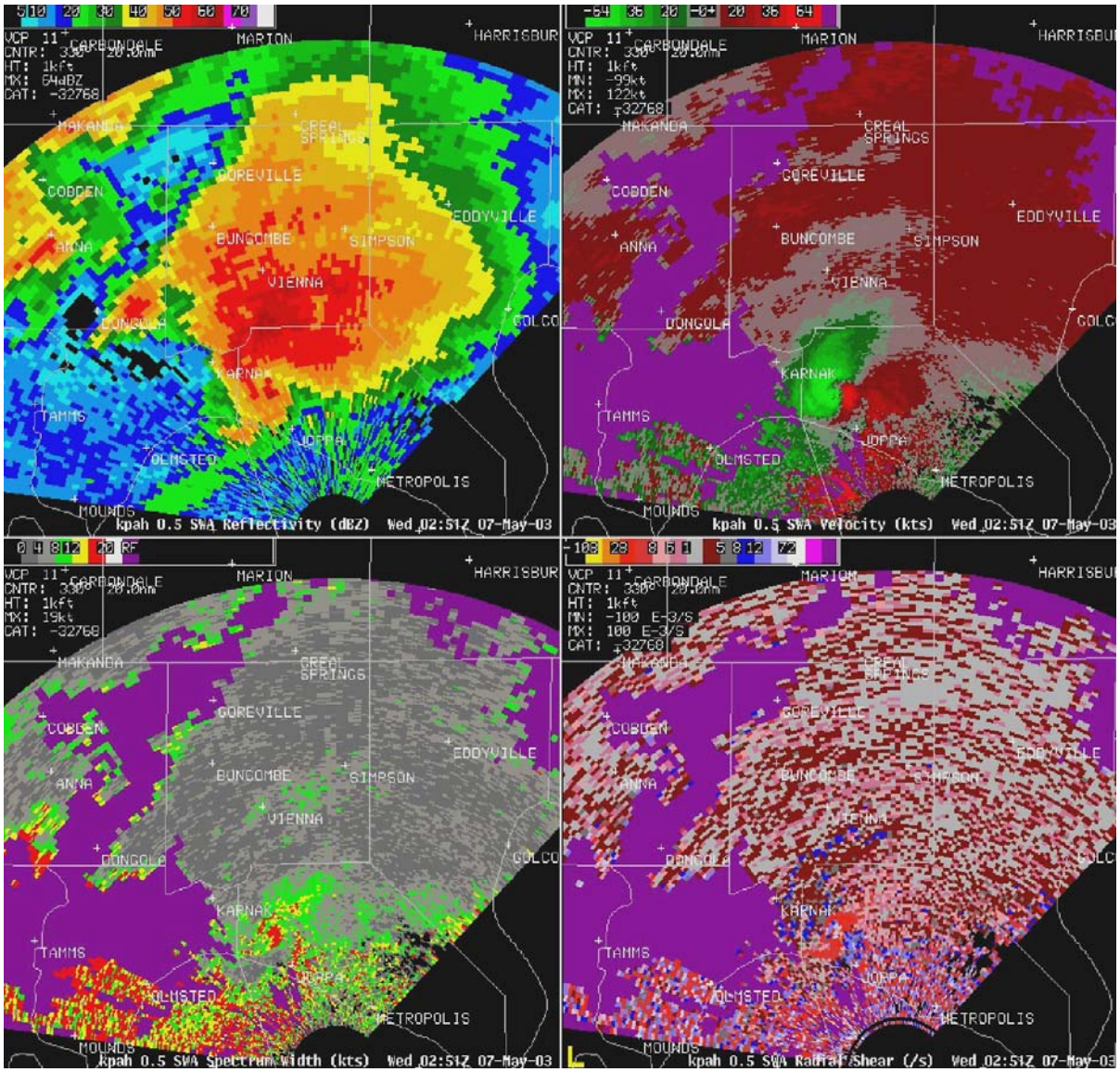

Figure 2-32
Severe Weather Analysis (Quarter Screen Display) Product

SWA product (AWIPS display) from the Paducah, KY (KPAH) WSR-88D on 7b May 2003 composed of the SWR product in the upper left, SWV in the upper right (same as SWR), SWW in lower left, and SWS in the lower right. All product parts of the SWA are in the maximum data resolution, SWR - 0.54 nm (1 km), SWV - 0.13 nm (0.25 km), SWW - 0.13 nm (0.25 km) and SWS - 0.27 nm (0.5 km).

2.33 <u>Severe Weather Probability</u>. The Severe Weather Probability product (SWP) provides a mapped display of the set of probability values calculated by the SWP algorithm for cells that the algorithm defined from the Vertically Integrated Liquid (VIL) array. The SWP value is not a true probability, but rather a measure of relative storm severity. The SWP values are directed related to the horizontal extent of VIL values greater than a specified threshold. The displayed SWP values are assigned to the centers of the defined VIL cells.

2.33.1 Operational Characteristics.

System ID: SWP, Product #47.

Data: SWP values calculated by the SWP algorithm.

Processing:

- Output from VIL algorithm.
- SWP algorithm.
- Algorithm for placing SWP values on corresponding VIL cells.

Availability: Once per volume scan.

Presentation:

- Map of SWP values displayed at the centers of the corresponding VIL cells.
- Overlay of mapped SWP values (Figure 2-33).

Resolution:	**Coverage:**
• 4 x 4 km (2.2 x 2.2 nm)	Radar centered, 230 km (124 nm) radius

- The SWP box size is adaptable and expandable in multiples of a 4 x 4 km (2.2 x 2.2 nm) box. The default presentation 'box' is 28 x 28 km (15.1 x 15.1 nm). At full range, the minimum box size has to be 16 x 16 km (8.8 x 8.8 nm) to accommodate two 7 x 9 pixel integers.

Data Levels: > 0 to < 100%.

Annotations:

- Standard set*
- Data level code
- Maximum data value detected (percent)
- SWP box size.

Adaptation: See Section 3.11.1.

2.33.2 Usage. SWP's main strengths are its ability to automatically extract strong cells from the current radar pattern, to draw a user's attention to those cells, and, if the necessary VIL climatology is available, to provide objective guidance on the likelihood of severe weather associated with those cells.

2.33.3 Strengths/Applications. Quick identification of strongest storms.

2.33.4 Limitations.

- Only incorporates VIL, no environmental conditions considered.
- Since the SWP equation uses VIL calculations as input, inaccuracies in VIL values will affect the SWP output.
- Threshold values for severe storms will vary with differing climatology. Each site will have to establish the long-term climatology of VIL and severe weather.
- May be contaminated with non-precipitation echoes.
- Other considerations arising from the performance of the SWP algorithm are discussed in Section 3.11.2.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

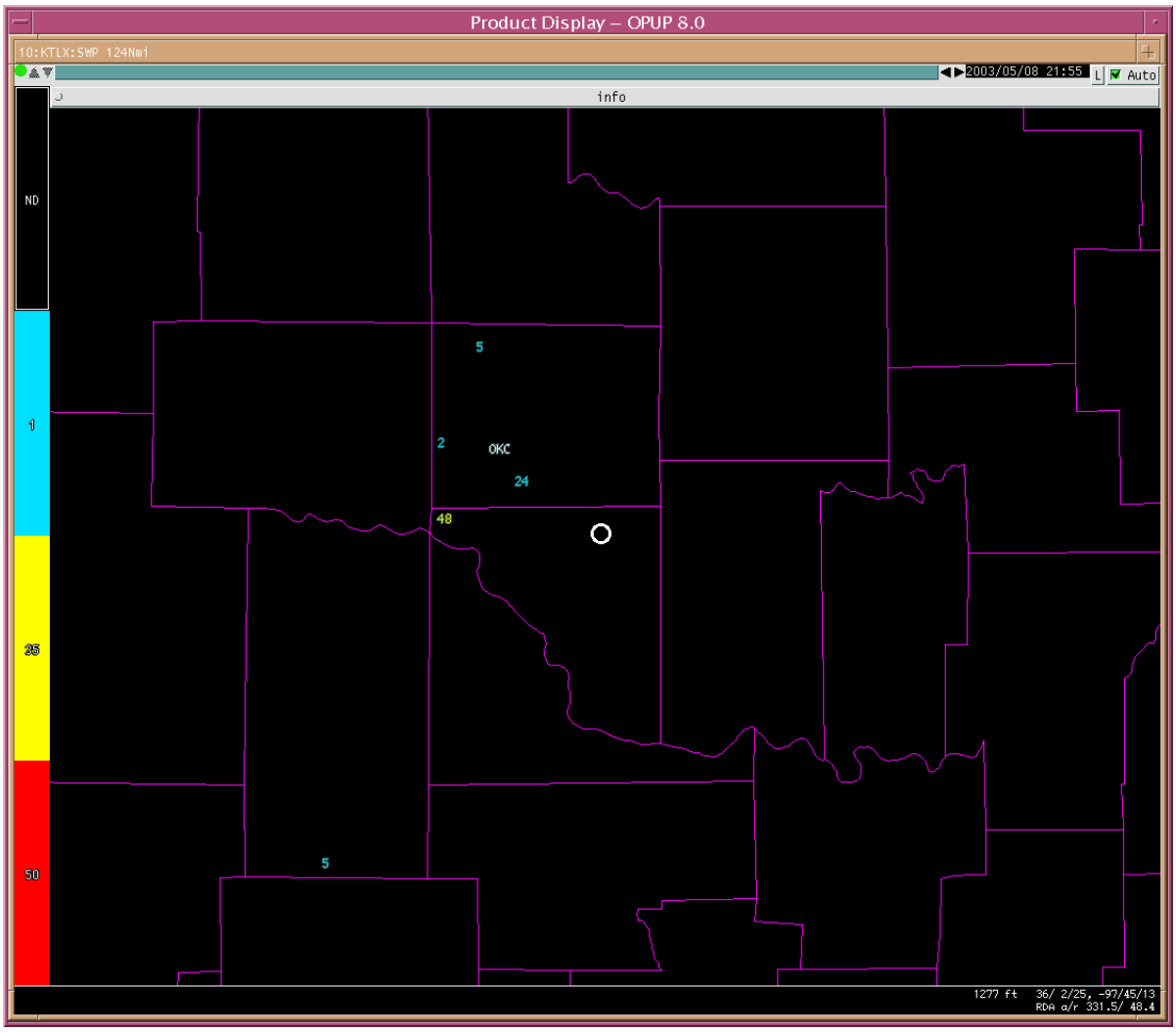

Figure 2-33
Severe Weather Probability Product

An SWP product as displayed on an OPUP from the KTLX, WSR-88D in Oklahoma City, OK. The numbers west and northwest of the radar represent the percentage probability of severe weather based on the SWP Algorithm.

2.34 <u>Spectrum Width</u>. The Spectrum Width products (SW) display mean radial velocity spectrum width estimates as a radial image for each elevation angle scanned, depending on the VCP employed. The estimates are based on the value contained in the first gate of each set of gates (i.e., gate 1 of 1, gate 1 of 2, or gate 1 of 4). The products are available for several combinations of display resolution and coverage; each product is available for eight data levels. A separate version of each product is available for each antenna scan taken at an available constant elevation angle, depending on the volume coverage pattern employed.

2.34.1 Operational Characteristics.

System ID: SW, Products: #28, #29, #30.

Data: Spectrum width.

Availability: Updated once per volume scan at each elevation angle.

Presentation: Polar coordinate image of spectrum width data (Figures 2-34, a-c).

Resolution:	**Coverage:**
• 0.25 km (0.13 nm) x l° (#28)	Radar centered, (62 km) 32 nm radius
• 0.5 km (0.27 nm) x l° (#29)	Radar centered, 115 km (62 nm) radius
• 1 km (0.54 nm) x 1° (#30)	Radar centered, 230 km (124 nm) radius.

Data Levels: 8.

Annotations:

- Standard set*
- Data level code
- Elevation angle
- Maximum spectrum width value detected (kts).

Adaptation: None.

2.34.2 Usage.

- The SW product should be used in conjunction with other products for maximum utility.
- Spectrum width data are related to the turbulence intensity as well as the wind shear across the beam. Beam width and antenna rotation speed also contribute to the width. Primary use of spectrum width is to estimate turbulence associated with:

- Thunderstorms
- Fronts and gust fronts
- Clear air

- Useful for evaluating validity of the mean radial velocity estimates.
- Evidence of convective development will often appear in the spectrum width field before any significant return is detected in the reflectivity field.
- Can be used to determine the structure of the bright band because of increased variance in velocities through the bright band.

2.34.3 Strengths/Applications.

- Can be used to infer weak signal returns near the noise threshold.
- A number of other applications have been suggested for low values. For example they indicate flow acceleration such as with a deepening tropical storm or hurricane, or flow into a strong updraft. Low values within updrafts also indicate unmixed updrafts with characterized by high helicity.
- It has been suggested that broad values can be used to indicate a weakening hurricane, a turbulent updraft becoming mixed with ambient air, a downdraft, or data contamination with three-body scattering.

2.34.4 Limitations.

- As with the Mean Radial Velocity Product, range folding may obscure needed spectrum width data.
- Movement of ground clutter may result in high spectrum width values. For example, cars on the road and blowing leaves on trees in the summer can contribute to high velocity variances in the range bin. Turbulent flow around ground targets such as buildings and water towers may also result in high spectrum widths.
- Weak power returns will cause erratic values near the noise level.
- The legacy RDA SW values may be incorrect due to an error in the processor software.

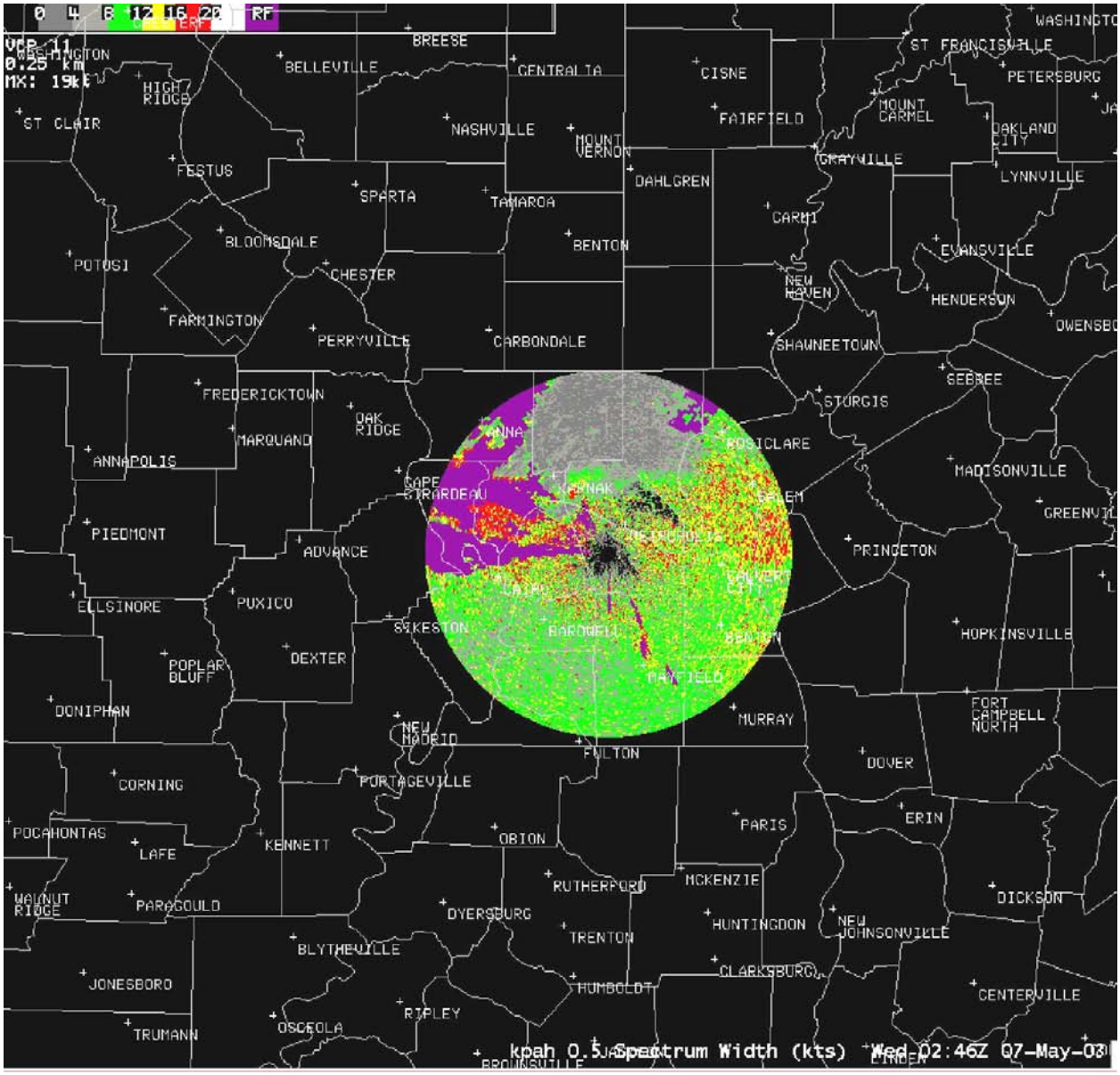

Figure 2-34a
Spectrum Width Product

An SW product (AWIPS display), product resolution of 1° x 0.25 km (0.13 nm) and 8 data levels at an elevation angle of 0.5° from the Paducah, KY (KPAH) WSR-88D on 7 May 2003.

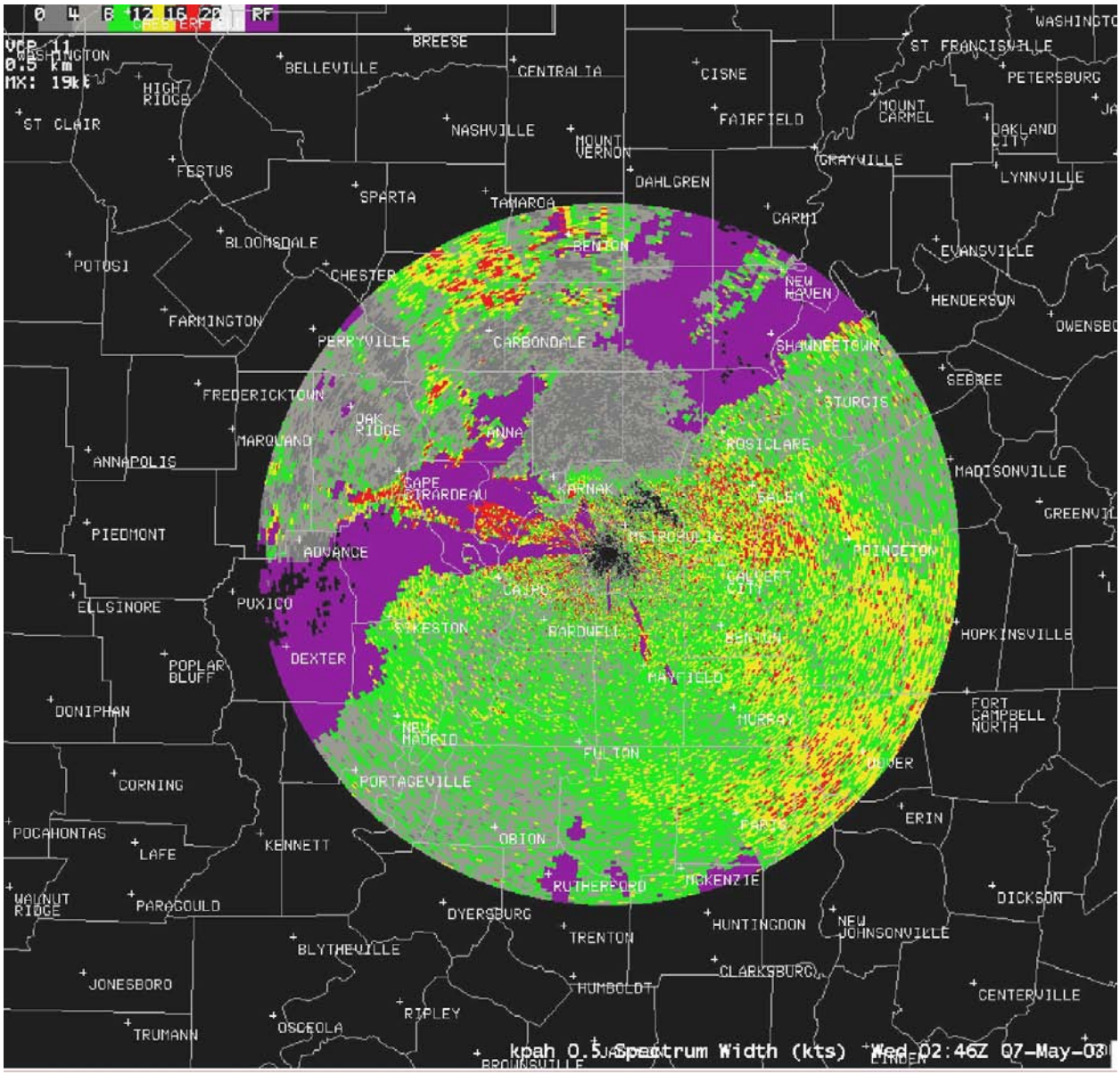

Figure 2-34b
Spectrum Width Product

An SW product (AWIPS display), product resolution of 1° x 0.5 km (0.27 nm) and 8 data levels at an elevation of 0.5° from the Paducah, KY (KPAH) WSR-88D on 7 May 2003.

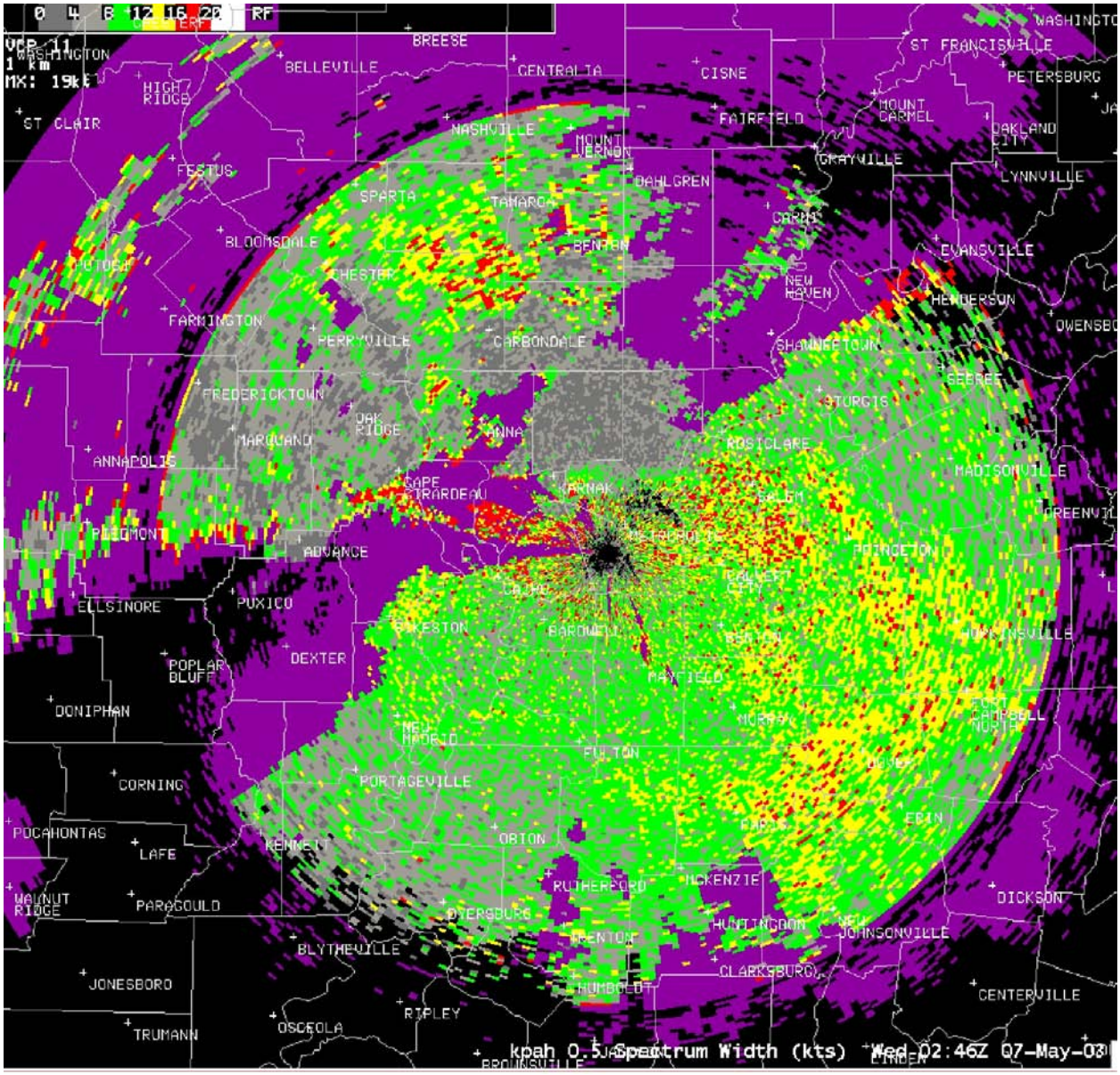

Figure 2-34c
Spectrum Width Product

An SW product (AWIPS display), product resolution of 1° x 1 km (0.54 nm) and 8 data levels at an elevation of 0.5° from the Paducah, KY (KPAH) WSR-88D on 7 May 2003.

2.35 <u>Storm Relative Mean Radial Velocity (Region and Map)</u>. The Storm Relative Mean Radial Velocity products (SRR and SRM) provide an estimate of the mean radial velocity for: (a) a small geographic area centered upon or near an identified storm with the storm motion removed (Region), or (b) the entire area of radar coverage (to 124 nm (230 km)) with the mean storm motion removed (Map). The velocity displayed is based on the maximum value contained in each one of the 0.25 km (0.13 nm) gates of the two or four gates, respectively, contained in the product data resolution. The product is produced upon request for any elevation angle available. The radial component of storm motion used to derive the product is the storm motion value computed for the identified cell by the SCIT Algorithm or a value input by the user. The value of storm motion used to adjust the mean radial velocity values is user-selectable at the time of product request or it defaults to the vector average of all identified storms if not selected. Each product contains 16 data levels for storm-adjusted mean radial velocity.

2.35.1 Operational Characteristics.

System ID: SRR (Region), Product: #55; SRM (Map), Product #56 .

Data:

- Computed motion of a single storm from Storm Cell Identification and Tracking (SCIT) Algorithm
- Storm mean radial velocity.

Processing:

- SCIT Algorithm
- Remove radial component of computed storm motion from the mean radial velocity values.
- Use location for generation when specified (for SRR).

Availability: Upon request for any elevation angle for a window centered at a user-specified location (usually upon a single storm)

Presentation: Polar coordinate image of derived mean radial velocity values (Figures 2-35, a and b).

Resolution:	**Coverage:**
• SRM: 1 km (0.54 nm) x 1°	Radar centered, 230 km (124 nm) radius
• SRR: 0.5 km (0.27 nm) x 1° .	50 x 50 km (27 x 27 nm) window within 230 km (124 nm) of the radar

- Product is centered at the location of the storm center.

Data Levels: 16.

Annotations:

- Standard set*
- Coordinates of product center (window product)
- Data level code
- Elevation angle
- Maximum data value detected (after storm motion removed)
- Vector average of storm motion (all storms for SRM, single storm for SRR, or operator defined).

Adaptation: Storm motion (optional); Center Point (SRR).

2.35.2 Usage.

- As an aid in the visual identification of mesocyclones, TVSs, shear regions, or divergence in the mean radial velocity field when signatures are being confused by addition of storm motion component. Note that a constant is removed from the radial velocity field. Thus, radial velocity shear is not changed.
- The window (SRR) product can be requested as part of the SWA when interested only in a single storm.
- For a line of thunderstorms or a convective system where storm motions are similar, an average storm motion (computed or user input) can be removed (SRM).

2.35.3 Strengths/Applications.

- Provides 3D velocity structure of a storm when used as in a four-panel (or all-tilts) display.
- An aid to human recognition of mesocyclones, TVSs, shear regions, and divergence.
- Most useful with faster moving storms and in radar coverage areas where the storm motion is largely along the radials.
- Operator may input storm motion for both SRM and SRR.
- When using SRR the displayed max and minimum velocities can more easily be located in the product window.
- SRR is a useful alert paired product for the mesocyclone and TVS.
- SRR may be substituted for SWV in the SWA product.
- SRR has better resolution than does the SRM.

2.35.4 Limitations.

- If the computed storm motion is significantly in error, or a vector average of storms moving in a widely divergent pattern is used, storm rotational signatures may still be confused.
- Is inappropriate when ground-relative winds are desired.
- Average storm relative motion will vary from volume scan to volume scan, especially for the SRM product.
- SRR is confined to a limited viewing area.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

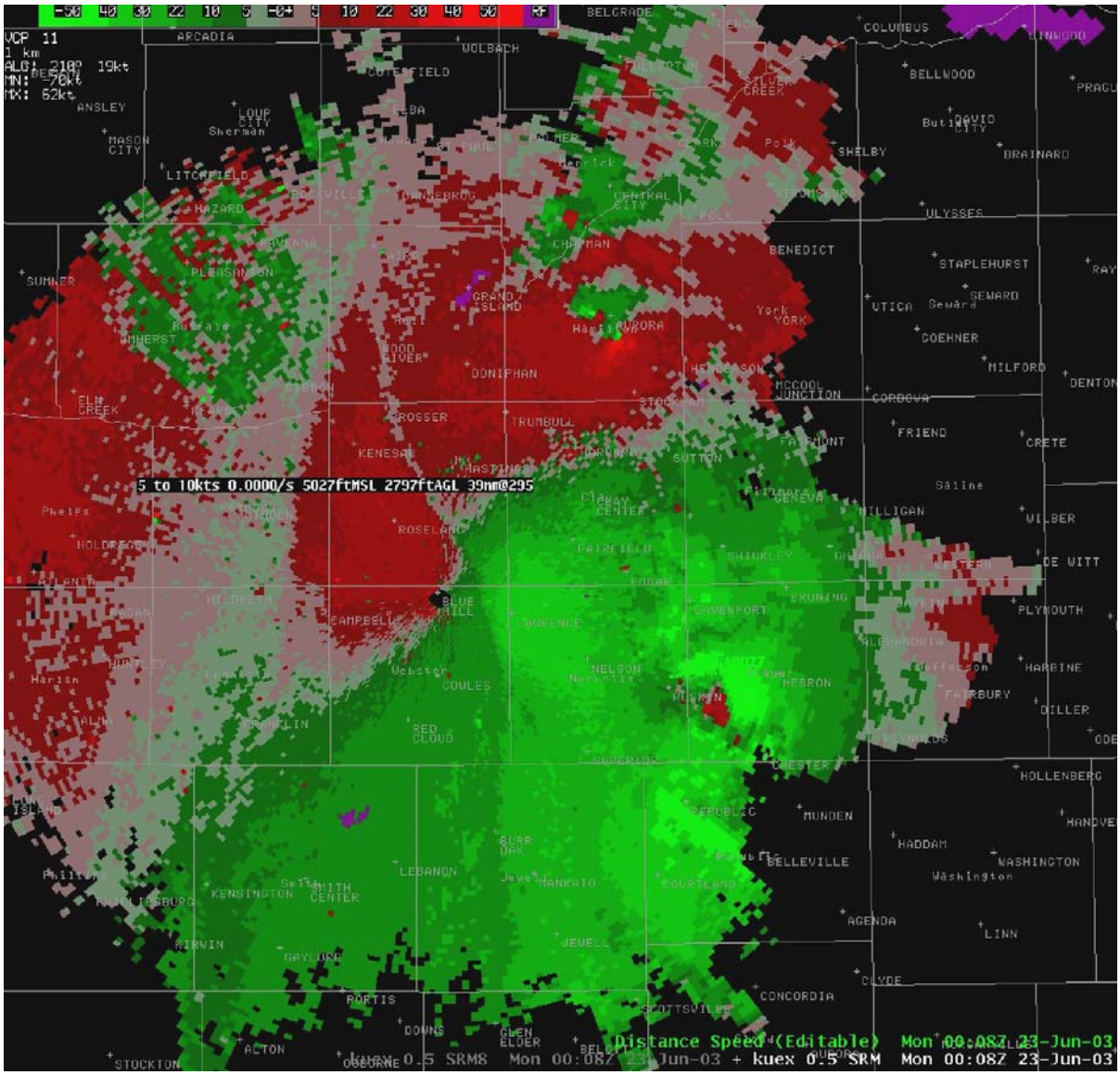

Figure 2-35a
Storm Relative Mean Radial Velocity (Map) Product

An SRM product (AWIPS display), at an elevation of 0.5° from the North Platte, NE (KLNX) WSR-88D on 23 June 2003.

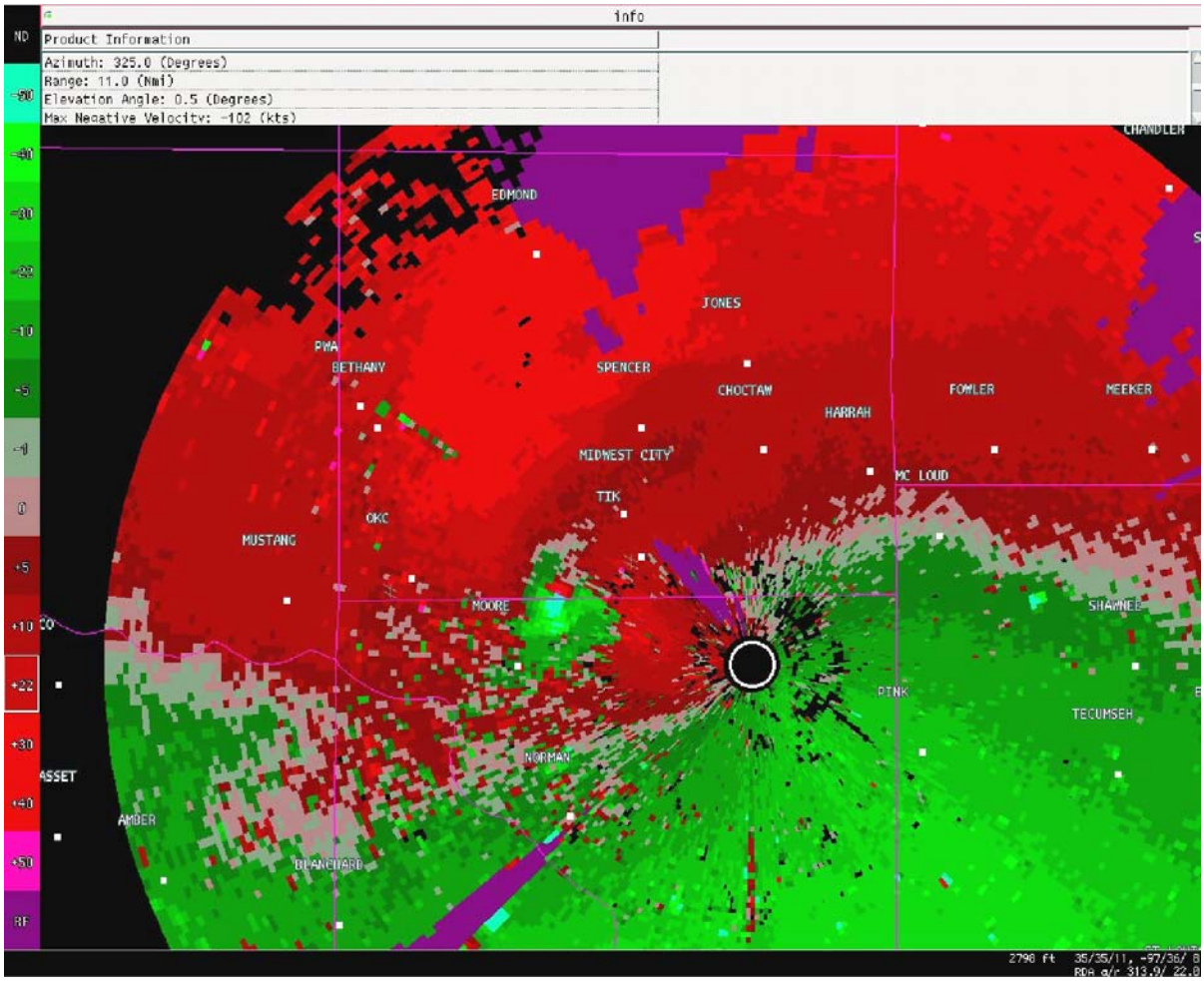

Figure 2-35b
Storm Relative Mean Radial Velocity (Region) Product

An SRR product (AWIPS display), at an elevation of 0.5° from the North Platte, NE (KLNX) WSR-88D on 23 June 2003.

2.36 <u>Storm Structure</u>. The Storm Structure product (SS) provides, for each identified storm cell, information regarding the structure of the storm cell, including trend information. This contains information from the SCIT Algorithm and HDA. Part of this product is in a tabular alphanumeric format; the other part forms the basis of the Trends display. The Trends display consists of time plots of algorithm derived storm cell and hail attributes. The Trends display can be selected for any storm cell identified by SCIT and displays up to the previous 10 volume scans of attributes. For each cell, the attributes in the Trends display are the top height, base height, height of the maximum reflectivity, probability of hail, probability of severe hail, cell-based VIL, maximum reflectivity, and centroid (mass-weighted center) height.

All adaptable parameters used as inputs to the algorithm to generate data for this product are available in an alphanumeric display

2.36.1 Operational Characteristics.

System ID: SS, Product #62.

Data: Output from the SCIT Algorithm and HDA.

Processing: SCIT Algorithm and HDA.

Availability: Updated once per volume scan.

Presentation: The graphics part of the product is the Trends Display. The Trends Display contains four graphs in time of storm cell and hail attributes. The Trends display can be selected for any storm cell identified by the SCIT Algorithm and displays up to the previous 10 volume scans of attributes. For each cell, the attributes in the Trends display are the top height, base height, height of the maximum reflectivity, probability of hail, probability of severe hail, cell-based VIL, maximum reflectivity, and centroid height. (See Figure 2-36b)

- Alphanumeric Display. See Figure 2-36a

This product is displayable only as a table of storm cell attributes containing the following information for up to an adaptable number of storm cells identified by the SCIT Algorithm.

- Storm Cell ID
- Current Storm Position in (AZRAN) degrees and nm to the nearest integer from the RDA
- Storm base in kft
- Storm top in kft
- Cell-Based VIL in kg/m^2
- Maximum Reflectivity in dBZ
- Height of Maximum Reflectivity in kft
- Number of Storm Cells
- Adaptable Parameters for all SCIT algorithms.

By default, all storm cells (entries), up to a maximum of 100, can be displayed in this format. However, the MSCF operator has the capability to limit the number of storm cells included in this format from 10 to 100.

Coverage: Radar centered, 460 km (248 nm) radius of the radar.

Data Levels: Alphanumeric values.

Annotations:

- Standard set*
- Number of storms detected.

Adaptation: Algorithm parameters, see Section 3.4.

2.36.2 Usage.

- Provides user with additional information regarding the character of individually identified thunderstorms.
- Monitoring the time history of storm characteristics may aid in determining when a change in intensity occurs and aid in forecasting the onset of a severe weather event.
- Monitoring the value and altitude of maximum reflectivity may give insight as to where a thunderstorm is in its life cycle. Caution may be exercised in height fluctuations. These can occur due to gaps in the VCP used.
- Maximum reflectivity and storm top may be used to generate alerts.

2.36.3 Strengths/Applications.

- Trends product is generated from SS
- Related data included in CAT.

2.36.4 Limitations.

- Storm tops higher than at the highest elevation angle are identified as "unknown."
- Echo feature heights (e.g., storm top and maximum reflectivity) are subject to errors owing to beam width, placement, and refraction, and gaps in the VCP used.
- When storm cells are in close proximity, portions of cells can become interchanged.
- See Section 3.4.6 for more limitation information.

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal

scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

STORM STRUCTURE

RADAR ID 303 DATE/TIME 09:28:04/13:59:09 NUMBER OF STORM CELLS 74

STORM ID	AZRAN DEG/NM	BASE KFT	TOP KFT	CELL BASED VIL KG/M**2	MAX REF DBZ	HEIGHT KFT
A0	216/ 15	< 1.2	14.1	19	54	6.9
C0	184/ 31	< 2.6	18.4	13	51	2.6
B0	233/ 48	< 4.5	18.2	12	51	9.4
D0	326/ 36	< 2.9	17.7	12	51	10.1
E0	199/ 30	< 2.5	18.3	12	51	11.5
Q2	252/ 12	< 0.7	>13.5	11	54	0.7
V1	315/ 29	< 2.3	13.1	10	50	11.6
Y0	32/ 84	< 9.8	18.8	10	48	9.8
D1	218/ 33	< 2.8	15.4	10	49	6.4
M1	243/ 19	3.6	11.6	9	50	11.6

Figure 2-36a
Storm Structure Alphanumeric Tabular Listing

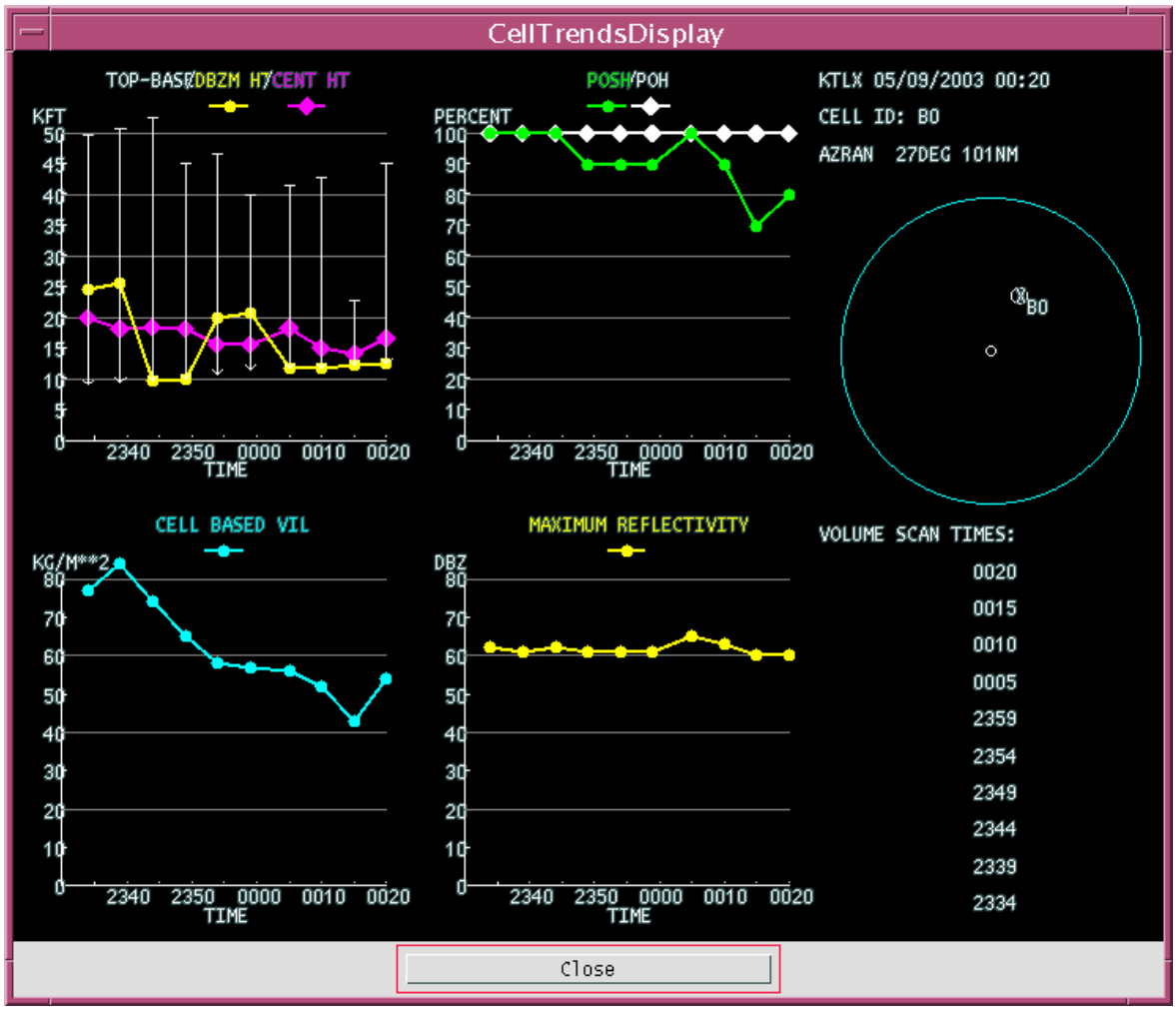

Figure 2-36b
Storm Structure Trend Display

A trend display (OPUP display) for the Storm Structure Product from the Oklahoma City, OK (KTLX) WSR-88D on 9 May 2003 at 0020 UTC. The STI product identified and tracked a very strong storm until it moved beyond 356 km (192 nm).

2.37 <u>Storm Total Rainfall Accumulation</u>. The Storm Total Rainfall Accumulation Product (STP) provides a display of continuously updated radar-estimated rainfall accumulations within 230 km (124 nm) of the radar. The storm-total rainfall is defined as the total rainfall accumulation since the last one-hour break in significant rainfall over the total area of coverage. This product is generated even when periods of missing data occur.

2.37.1 Operational Characteristics.

System ID: STP, Product #80.

Data: Radar-derived total precipitation accumulation estimates.

Processing: Precipitation processing subsystem.

Availability: Updated once per volume scan.

Presentation: Polar coordinate image of rainfall accumulations (Figure 2-37).

Resolution: 2 km (1.1 nm) x 1°

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of precipitation rate integration
- Current rate bias estimate
- Current error variance of bias estimate
- Maximum data value.

Adaptation: See Section 3.3.

2.37.2 Usage.

- Monitoring of total precipitation accumulation regardless of duration.
- Estimation of total basin run-off due to a single storm.
- Estimation of basin saturation due to previous rainfall events.
- Evaluation of flood reports.

2.37.3 Strengths/Applications.

- Monitor total precipitation accumulation.
- Estimate degree of soil saturation within river basin or area.
- Estimate river basin runoff.
- Post-storm analysis.
- Time lapse used to follow motion of storms relative to river basin location and orientation.

2.37.4 Limitations.

- The radar can stay in Precipitation Mode for extended periods of time owing to high frequency of showers in some areas or due to unaccounted for clutter residue and the STP cannot be reset to zero when appropriate.
- Periods of missing data can be included without the knowledge of the operator, thus compromising data quality.
- Although every effort has been made to remove non-precipitation reflectivity from the calculation of precipitation, residual ground clutter or anomalous propagation may contaminate data.

See Section 3.3 for discussions regarding the algorithm's operational considerations.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

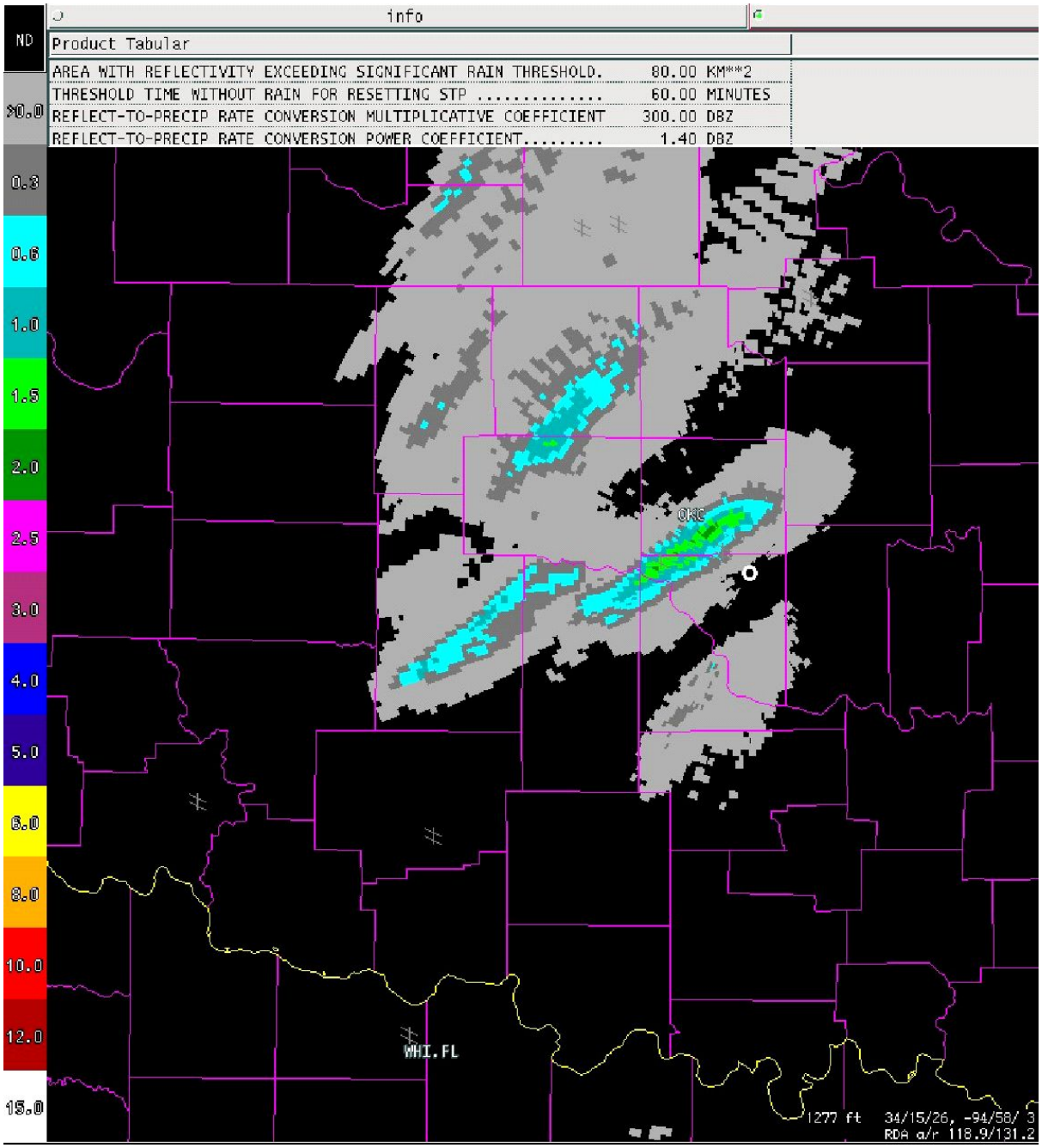

Figure 2-37
Storm Total Rainfall Accumulation Product

An example of an STP product from the Oklahoma City, OK (KTLX) WSR-88D (OPUP display).

2.38 <u>Storm Total Rainfall Accumulation (Digital Storm Product)</u>. The Storm Total Rainfall Accumulation Digital Storm Product (DSP) provides radar-estimated rainfall accumulation data as a digital, high resolution product. The product provides surface rainfall accumulation for a time period that is variable and equals the period of continuous rainfall in the radar area of coverage. The DSP is available for 256 data levels at each sample bin location. The digital product is provided to support processing external to the WSR-88D.

2.38.1 Operational Characteristics.

System ID: DSP, Product #138.

Data: Reflectivity, Hybrid Scan.

Processing: Precipitation processing system.

Availability: Generated once per volume scan.

Presentation: Data array or displayable as a polar coordinate image of rainfall accumulation (Figure 2-38)

Resolution: 2 km (1.1 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 256.

Annotations:

- Standard set*
- Times and date of the beginning and end of the rainfall rate integration
- Mean-field bias in the radar estimate of the precipitation rate
- Effective sample size associated with the bias estimate
- Data level code
- Elevation angle
- Grid display
- Maximum data values detected
- Product center point coordinates.

Adaptation: Algorithm parameters.

2.38.2 Usage. The digital product is provided to support processing external to the WSR-88D.

2.38.3 Strengths/Applications.

- High resolution with 256 data levels.
- Digital and can be used by external users for hydrometeorological models, statements and warnings.

2.38.4 Limitations. Same as the STP product.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

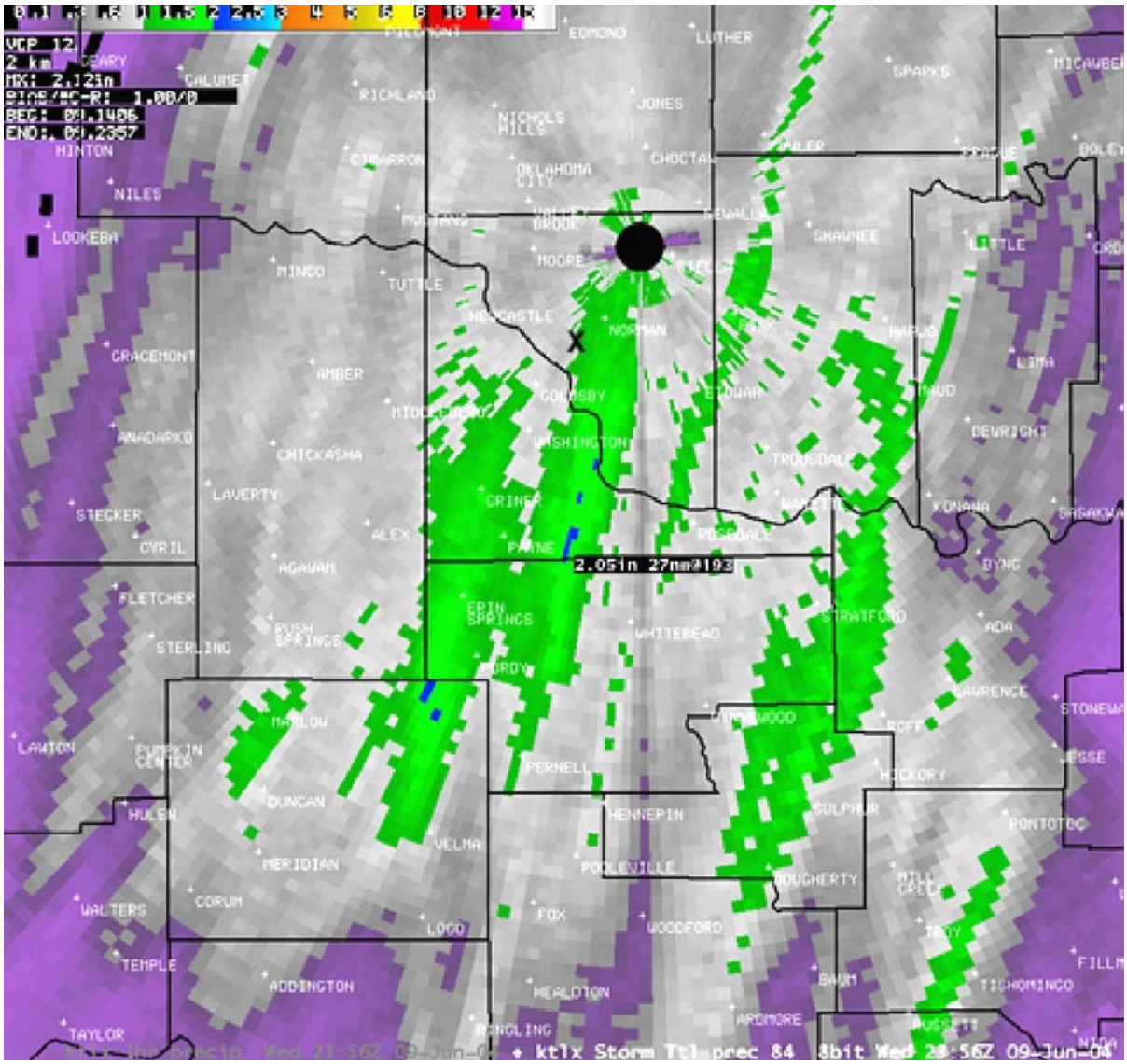

Figure 2-38
Storm Total Rainfall Accumulation (Digital Storm Product)

An example DSP product (AWIPS display) from the Oklahoma City, OK WSR-88D (KTLX).

2.39 <u>Storm Total Snow Depth Accumulation</u>. The Storm Total Snow Depth Accumulation product (SSD) provides a running total of radar-estimated snowfall depth. The product provides estimates since the snow accumulations were last manually reset to zero.

2.39.1 Operational Characteristics.

System ID: SSD, Product #147.

Data: Radar-estimated snow depth accumulation.

Processing: Snow Accumulation Algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image of snow depth estimates (Figure 2-39).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level code
- SAA adaptable parameters and their values
- Maximum data value detected
- Azimuth and range of the maximum data value
- Range/height corrections applied
- Missing periods of accumulations in minutes

Special Symbols: None.

Adaptation: See Section 3.15.

2.39.2 Usage. Provides estimated snow accumulations over storm duration.

2.39.3 Strengths/Applications.

- Can be used to determine the amount of snowfall even when and where no reports are available.

- Has regionally optimized adaptable parameters which can be changed by the operator.
- Can accumulate with lower reflectivies than the PPS.
- Has a range/height correction.

2.39.4 Limitations.

- The same adaptable parameters are applied to the entire radar coverage area, yet actual measured values (such as Z-S relationship and snow ratio) will vary in time and space.
- Snow depth estimates are not accurate for snow that is melting (in the air or on the ground), but the product does not distinguish between dry snow and other precipitation types.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow after being observed by the radar.
- Does not account for blowing or drifting snow.
- Data levels are fixed and only provide a range of estimates (versus a digital estimate).

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

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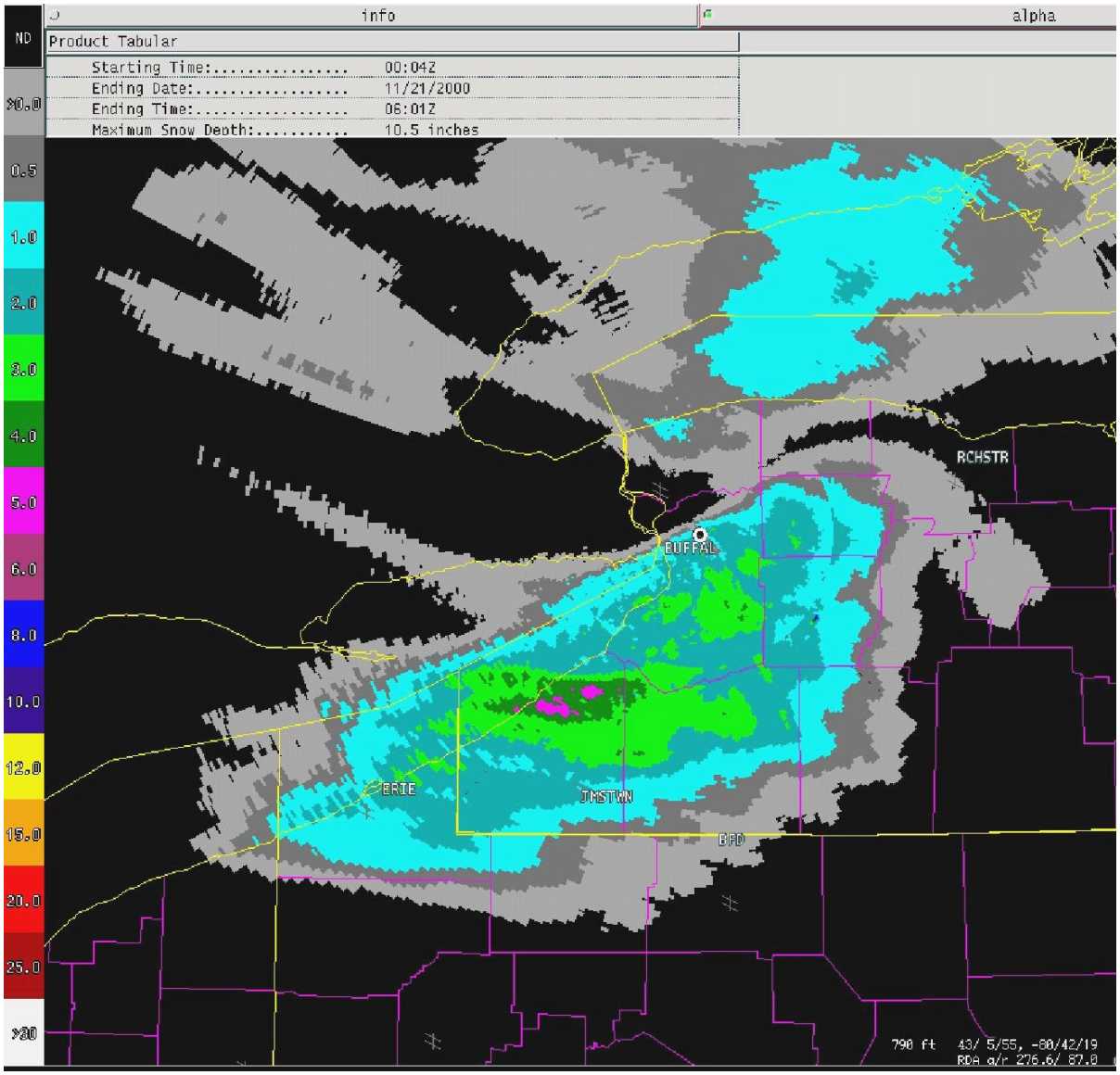

Figure 2-39
Storm Total Snow Depth Accumulation Product

An example SSD product (OPUP display) from the Buffalo, NY (KBUF) WSR-88D.

2.40 <u>Storm Total Snow Water Equivalent Accumulation</u>. The Storm Total Snow Water Equivalent Accumulation product (SSW) provides a running total of radar-estimated snow water equivalent. The product provides estimates since the snow accumulations were last manually reset to zero.

2.40.1 Operational Characteristics.

System ID: SSW, Product #146.

Data: Radar snow water equivalent accumulation estimates.

Processing: Snow Accumulation Algorithm.

Availability: Updated once per volume scan.

Presentation: Polar coordinate image of snow water equivalent estimates (Figure 2-40).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level code
- SAA adaptable parameters and their values
- Maximum data value detected
- Azimuth and range of the maximum data value
- Range/height correction applied
- Missing periods of accumulations in minutes.

Adaptation: See Section 3.15.

2.40.2 Usage. Provides estimates of snow water equivalent over the storm duration.

2.40.3 Strengths/Applications.

- Can be used to determine the amount of snowfall even when and where no reports are available.
- Has regionally optimized adaptable parameters which can be changed by the operator.

- Can accumulate with lower reflectivities than the PPS.
- Has a range/height correction.
- Can also be used to estimate cool stratiform rainfall.

2.40.4 Limitations.

- The same adaptable parameters are applied to the entire radar coverage area, yet actual measured values (such as Z-S relationship and snow ratio) will vary in time and space.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow after being observed by the radar.
- Does not account for blowing or drifting snow.
- Data levels are fixed and only provide a range of estimates (versus a digital estimate).

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

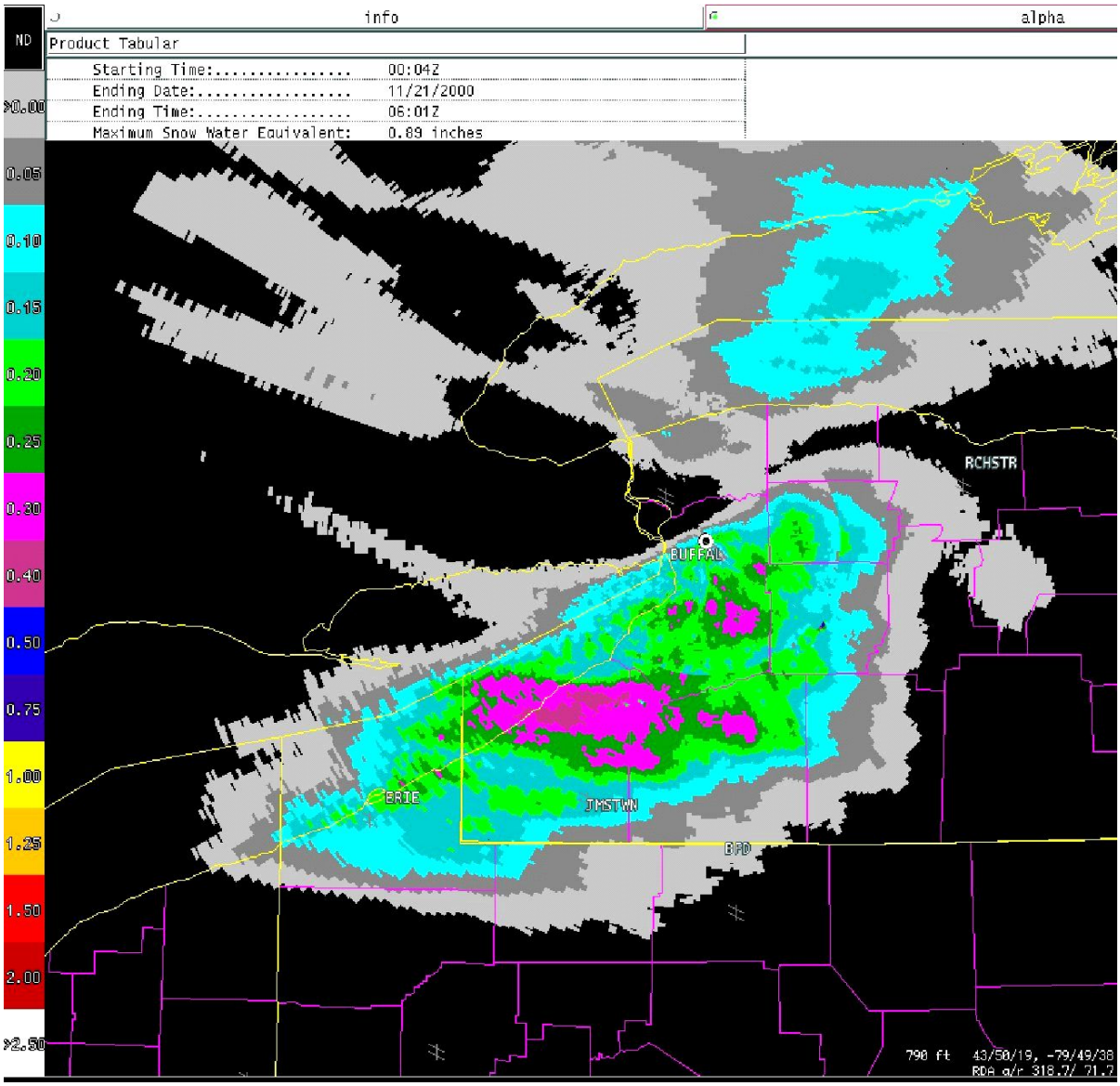

Figure 2-40
Storm Total Snow Water Equivalent Product

An SSW product (OPUP display) from the Buffalo, NY (KBUF) WSR-88D.

2.41 <u>Storm Tracking Information</u>. The Storm Tracking Information product (STI) is the output of the Storm Cell Identification and Tracking (SCIT) Algorithm. It provides the user with information about the past, current, and forecast positions of thunderstorms. It can be produced in a tabular format of alphanumeric values, as a stand alone graphic product, or as a graphic overlay to other products. The algorithm is run each volume scan and correlates the current position of each storm cell with the past history of all storms, thereby updating the track of each storm. A storm for which no past position is found is identified as new and assigned a new unique storm ID. All site adaptable parameters identified as inputs to the algorithms used to generate the data for this product are also available.

2.41.1 Operational Characteristics.

System ID: STI, Product #58.

Data: Storm tracking and trends.

Processing: SCIT Algorithm output.

Availability: Updated once per volume scan.

Presentation:

- Table of storm cell attributes including for each cell the storm ID, storm position (AZ/RAN, in degrees and nm), direction and speed (FCST MVT in degrees and kts), tracking errors (ERR/MEAN in nm and nm), maximum reflectivity (DBZM, in dBZ), and height of the maximum reflectivity (HGT, in kft). This table can be displayed with other products.
- Graphic display of past, current, and forecast storm cell tracks. This graphics display can be overlaid on other products.
- Alphanumeric list of SCIT adaptable parameters.

Coverage: Radar centered, 348 km (186 nm) radius.

Data Levels: N/A.

- Each algorithm identified storm cell is given a unique alphanumeric storm ID. Storm IDs contain three characters, a letter (A to Z) followed by a one digit number (0 to 9). Storm IDs are recycled every 260 storm cells.
- The past and future position interval and number of positions are adaptable parameters and can vary over a range of 5 to 60 minutes (in 5-minute increments). The default interval is 15 minutes.

Annotations:

- Standard set*
- Total number of identified storms.

Special Symbols: For each storm, past positions are shown as small (5-pixel diameter) white filled circles and forecast positions are white plus (+) marks of similar size. The current position is a circle (5-pixel diameter) within which is an "X." If the storm speed is less than an adaptable parameter (default is 2.5 m/s), no past or forecast positions are displayed, and the current location will have a circle around the "X." A white line connects past, current, and forecast positions.

Adaptation: See Section 3.4.

2.41.2 Usage.

- Monitor the position and movement of identified storms.
- Provide an estimate of the future movement of identified storms.
- Forecast movement can be used to generate alerts for storms not currently within an alert box but projected to be (see User Alert Message, Section 2.47).

2.41.3 Strengths/Applications.

- Product works best for well defined and widely separated storm cells.
- Improved performance with VCP 12 due to more sampling at lower elevations.
- A large number of past tracks or future forecast positions for a particular cell indicate a more reliable track.
- The STI product is useful as an overlay on base and volume products.
- Cell motion is used in storm relative velocity products (SRR, SRM).
- Cell attributes are critical inputs to HI and SS products.

2.41.4 Limitations.

- Errors may occur in the identification of cells and in the calculations of attributes especially when cells are located near one another.
- Unrepresentative movements are possible due to irregular development/dissipation of cells.
- The product does not provide movement of areas of showers.
- Actual storm motion exceeding certain thresholds (Section 3.4) will lead to misidentification of storms and very large errors in motion.

- Forecast tracks are always straight lines because they are based on a linear extrapolation of past tracks, therefore storms traveling a curvilinear path or changing direction will not be accurately forecast.
- Intended for application to well defined, isolated thunderstorms; results in other applications will be uncertain.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

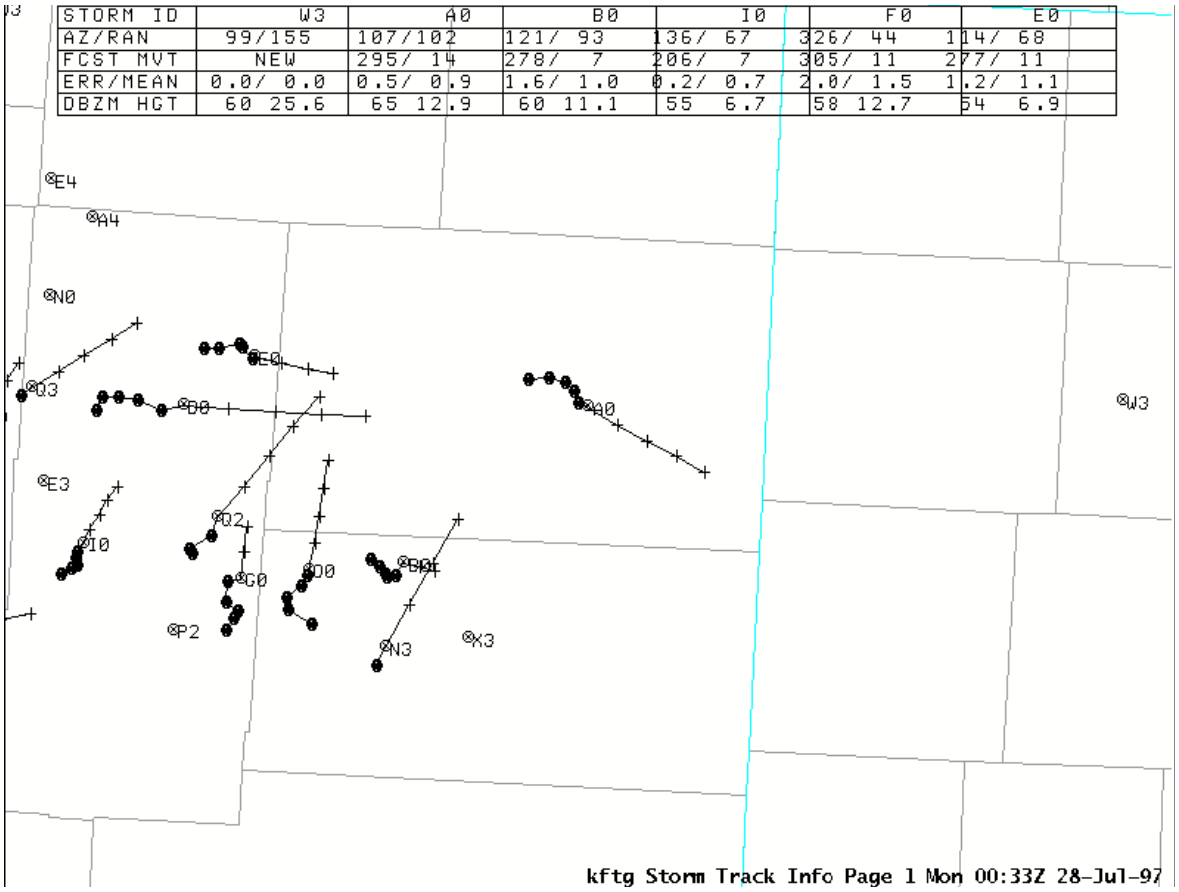

Figure 2-41
Storm Tracking Information Product

An STI product (AWIPS display) from the Denver, CO (KFTG) WSR-88D. The Combined Attribute Table is at the top of the image.

2.42 <u>SuperOb</u>. The SuperOb product (SO) contains 8-bit precision radial velocity data as an average of all base velocity bins within discrete sampling areas for a predetermined time span. Each elevation scan is divided into multiple sampling areas, or SuperOb cells. Velocity data is averaged within these SuperOb cells for each elevation of the VCP. If the VCP changes during the time span, thereby causing a change in elevation angles, a tolerance is established so that elevation differences beyond the tolerance will cause velocity data for the new elevation(s) to be averaged separately. Elevation differences within the tolerance value cause velocity data from the new elevation(s) to be included in the averages for the nearest elevation. If a SuperOb cell does not meet this minimum number of samples within the time span, an average is not computed for that cell.

2.42.1 Operational Characteristics.

System ID: SO, Product #136.

Data:

- Average radial velocity
- Root mean square of the average radial velocities
- Azimuth, latitude, longitude, height, and time deviation.

Processing: Time spans are established as are sample sizes and velocity averages taken.

Availability: The time span over which the velocity data is averaged is adaptable between 10 minutes and 3 hours with the default value being 1 hour. The product is generated at the end of the time span.

Presentation: The product is not displayed in WFOs.

Resolution and Coverage: The resolution and range extent of the SuperOb cells are determined from RPG adaptation data. Adaptation data defines a range size (default 2.7 km (5 km)) and an azimuth size (default 6 degrees). Adaptation data also defines a maximum range for processing (default 100 km (54 nm)).

- Product is contained within 230 km (124 nm) of the radar.

Data Levels: Appendix A.

Annotations:

- Standard set*
- Data level code
- Elevation angle
- Maximum data values detected

- Product center point coordinates.

Adaptation:

- SuperOb cells range size and azimuth size.
- Minimum number of samples
- Time span over which the velocity data is averaged.

2.42.2 Usage. The product is designed for NCEP and use in numerical models.

2.42.3 Strengths/Applications. Permits WSR-88D wind data to be ingested and used in numerical weather prediction models.

2.42.4 Limitations. Velocities are computed for large volumes**.**

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

2.43 <u>Supplemental Precipitation Data</u>. The Supplemental Precipitation Data product (SPD) provides selected supplemental data, generated or collected during the operation of the Precipitation Series algorithms, in a compact array or an alphanumeric format (not a display-compatible format), or both. Up to ten different preselected sets of supplemental data can be requested by computers external to the WSR-88D unit using a single request code. The supplemental data are also appended to the Hourly Digital Precipitation Array (Section 2.26).

2.43.1 Operational Characteristics.

System ID: SPD, Product #82.

Data:

- Number of isolated sample volumes
- Number of replaced and interpolated outliers (reflectivity factor)
- Number of interpolated outliers (hourly accumulation)
- Percent area reduction
- Bi-scan ratio
- Flag (bad scan)
- Missing period indicator (with beginning and ending times if missing period present)
- Computed bias estimate and its error variance, and flag (apply bias)
- GAGE-RADAR SET information
- The number of gage-radar pairs
- For each pair, the gage ID, its azimuth and range (from the radar), the hourly gage accumulation estimate and matching radar accumulation estimate (in inches, to nearest .01 in), and an indicator as to whether the pair used in the BIAS determination
- Data from the RAIN GAGE DATABASE, including the present number of reporting gages, the date and time of last data base update, the ID, latitude, longitude, azimuth, range, gage type (accumulator or incremental) and number of reports for each gage
- For each report, the timestamp, value (in inches, to nearest .01in), and, for incremental-type gages, the duration (in minutes)

Processing: Precipitation processing subsystem algorithm.

Availability: Updated each volume scan (Figure 2-43).

Data Levels: Most supplemental data are a single numeric value with the exception of the 1/4 LFM precipitation rate grid, which is an 8-level data array.

Annotations:

- Standard set*
- Maximum data value.

Adaptation: None.

2.43.2 Usage.

- Provides supplementary information regarding the performance of the Precipitation Series algorithms to computers external to the WSR-88D.
- Primary use is for research and post analysis for system performance checks.

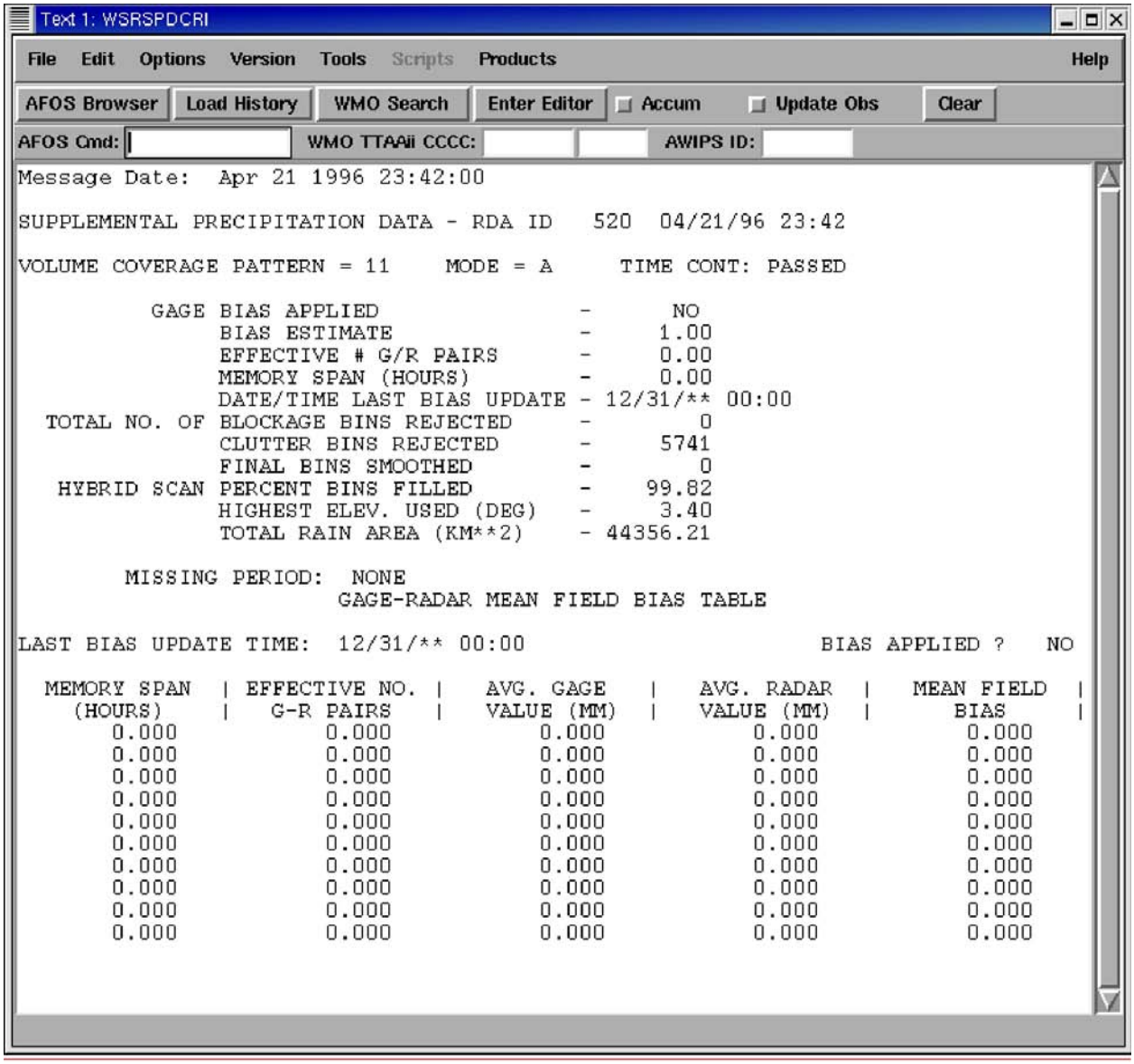
2.43.3 Strengths/Applications.

- Provides information on precipitation correction bias and other information on rain gauge-radar pairs.
- Provides information on the number of isolated bins and outliers.

2.43.4 Limitations. None.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.




```
Message Date:  Apr 21 1996 23:42:00

SUPPLEMENTAL PRECIPITATION DATA - RDA ID   520  04/21/96 23:42

VOLUME COVERAGE PATTERN = 11    MODE = A     TIME CONT: PASSED

          GAGE BIAS APPLIED                -      NO
               BIAS ESTIMATE               -    1.00
               EFFECTIVE # G/R PAIRS       -    0.00
               MEMORY SPAN (HOURS)         -    0.00
               DATE/TIME LAST BIAS UPDATE - 12/31/** 00:00
  TOTAL NO. OF BLOCKAGE BINS REJECTED      -       0
               CLUTTER BINS REJECTED       -    5741
               FINAL BINS SMOOTHED         -       0
   HYBRID SCAN PERCENT BINS FILLED         -   99.82
               HIGHEST ELEV. USED (DEG)    -    3.40
               TOTAL RAIN AREA (KM**2)     - 44356.21

       MISSING PERIOD:  NONE
                        GAGE-RADAR MEAN FIELD BIAS TABLE

LAST BIAS UPDATE TIME:  12/31/** 00:00                    BIAS APPLIED ?   NO

  MEMORY SPAN  | EFFECTIVE NO. |   AVG. GAGE   |   AVG. RADAR  |   MEAN FIELD  |
    (HOURS)    |   G-R PAIRS   |   VALUE (MM)  |   VALUE (MM)  |      BIAS     |
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
      0.000          0.000          0.000          0.000          0.000
```

Figure 2-43
Supplemental Precipitation Data

2.44 <u>Three-Hour Rainfall Accumulation</u>. The Three-Hour Rainfall Accumulation product (THP) provides the sum of the present plus two previous clock hours of rainfall accumulations. It can be produced as often as once per hour for the previous three-hour period. This product is not generated if data for more than one of the clock hours used in computing the totals are missing.

2.44.1 Operational Characteristics.

System ID: THP, Product #79.

Data: Radar-estimated, three-hour total rainfall accumulations.

Processing: Precipitation Series algorithms.

Availability: Up to once per hour.

Presentation: Polar coordinate image of rainfall accumulations (Figure 2-44).

Resolution: 2 km (1.1 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Current rate bias estimate
- Ending date and time of precipitation rate integration
- Maximum three-hour precipitation accumulation detected
- Mean error variance of bias estimate for three-hour period.

Adaptation: See Section 3.3.

2.44.2 Usage.

- Excessive three-hour rainfall accumulations can indicate a potential for flooding.
- Used in conjunction with a later OHP, the THP can delineate areas where basin saturation may have already occurred and thereby provide guidance for estimating changes in the flooding threshold when using the OHP.

2.44.3 Strengths/Applications.

- Provides a longer rainfall accumulation interval than OHP.
- For very long precipitation events, can be used with STP for storm totals analysis.
- Can be used for providing flash flood guidance.

2.44.4 Limitations.

- Product updated only once per hour.
- As a guide to current accumulation amounts, the hourly update rate may not be adequate. Products more than 30 minutes old should be used with caution to estimate current three-hour rainfall amounts.
- Although every effort has been made to remove non-precipitation reflectivity from the calculation of precipitation, residual ground clutter or anomalous propagation may contaminate data.
- See Section 3.3 for discussions of the algorithm's operational considerations.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

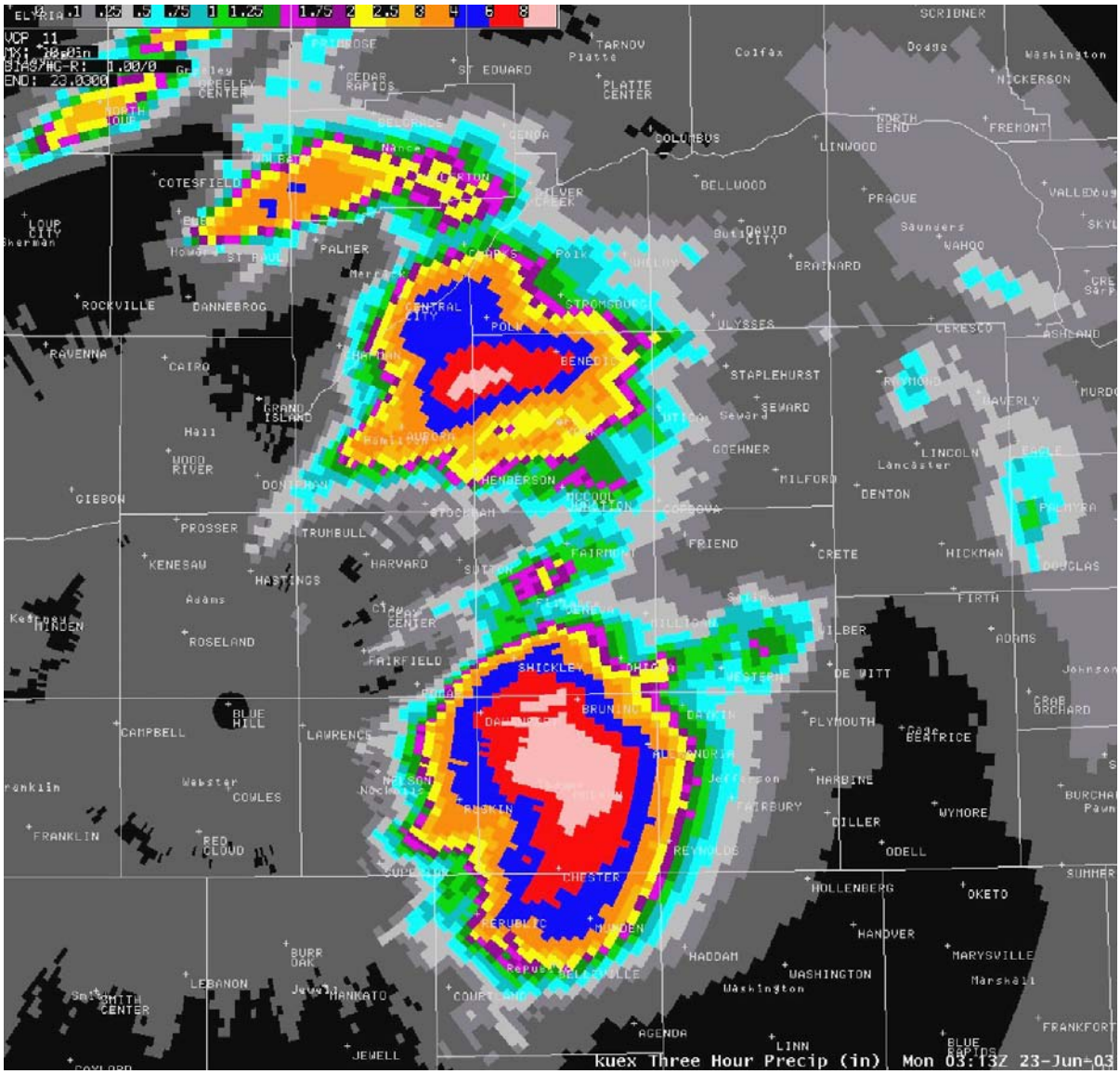

Figure 2-44
Three-Hour Rainfall Accumulation Product

An example of a THP product (AWIPS display) from the North Platte, NE (KUEX) WSR-88D at 03:13 UTC on 23 June 2003.

2.45 <u>Tornado Vortex Signature</u>. The Tornado Vortex Signature product (TVS) provides the TVS ID; TVS location; and maximum shear and its position, orientation, and rotation associated with each detected signature. The product is provided as an overlay to imagery products or as an alphanumeric list of data.

2.45.1 Operational Characteristics.

System ID: TVS, Product #6.1

Data:

- Output of Tornado Detection Algorithm
- TVS attribute table.

Processing: Tornado Detection Algorithm.

Availability: Updated each volume scan.

Presentation:

- Formatted table of alphanumeric values
- Graphic symbol overlay at TVS position (Figure 2-45).

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: TVS and Elevated TVSs (ETVSs).

Annotations:

- Standard set*
- Site adaptable parameters.

Special Symbol: The TVS symbol is an inverted, red-filled isosceles triangle with a 3/16 inch base and a 3/8 inch altitude. The elevated TVS symbol is an open red triangle with similar dimensions.

Adaptation: See Section 3.8.1.

2.45.2 Usage. As an aid in the identification, forecasting, and warning of severe weather associated with tornadoes.

2.45.3 Strengths/Applications.

- Multiple velocity thresholds make it possible to detect peak shear within broader regions of strong shear.
- The TVS product aids in identification of potentially tornadic circulations within or outside of mesocyclones.
- The algorithm, through adaptable parameters, can make it possible to fine-tune the product for differing environments and storm types.

2.45.4 Limitations.

- Adaptable parameters need more research to better fine-tune the algorithm and product performance.
- The algorithm and therefore the product have high false-alarm rates.
- Insufficient research has been done on ETVSs and needs much more work. The ROC recommends leaving the adaptable parameter value for the number of ETVSs displayed at zero.
- Algorithm and product introduce additional uncertainty.
- Detection of a true TVS is range limited due to beam broadening. At longer ranges, most of the signature information is contained in the spectrum width rather than the mean velocity gradient. The maximum range limit on signature detection has been estimated to be about 100 km (55 nm).

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

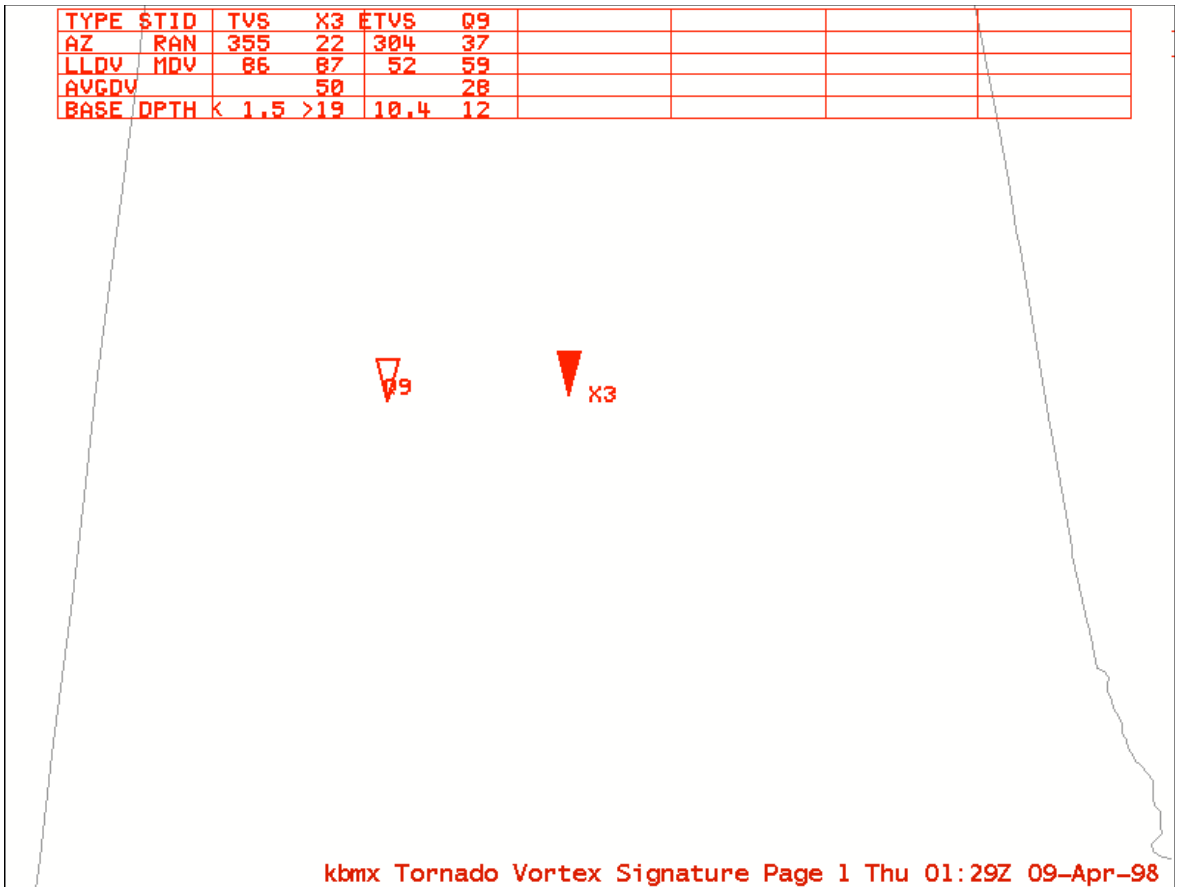

Figure 2-45
Tornado Vortex Signature Product

An example of the TVS product from the Birmingham, AL (KBMX) WSR-88D. The TVS attribute table is at the top of the image.

2.46 <u>Tornado Vortex Signature Rapid Update</u>. The Tornado Vortex Signature Rapid Update product (TRU) is generated to provide updated TDA information. The TDA data for each elevation scan is checked for vertical continuity with data from the elevations that have been completed thus far in the current volume scan. This information is combined with TDA and Storm Track Algorithm information from the previous volume scan to form the TRU product.

2.46.1 Operational Characteristics.

System ID: TRU, Product #143.

Data:

- TRU output
- TRU attribute table.

Processing: TVS and STI Algorithms.

Availability: Updated upon completion of each elevation scan.

Presentation:

- Formatted table of alphanumeric values.
- Graphic display of TVS symbol and feature symbols at computed positions (Figure 2-46).
- Graphic overlay of TVS symbol at its computed position.
- With the following exceptions, the format of the TRU graphic attribute and alphanumeric tabular portions of the product will follow the non-rapid update TVS product: feature status will be reported as EXT, PER, INC, and, NEW to denote extrapolated, persistent, increasing, and new features, respectively; and the character ^ (hexadecimal value 5E) will be placed next to attributes that were computed from current volume scan detections.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels:

- TVS
- ETVS
- Extrapolated features (EXT)
- Persistent (PER)
- Increasing (INC)
- New Feature (NEW).

Annotations: Standard set*.

Adaptation: See Section 3.8.5.

2.46.2 Usage. Provides TVS updates with the completion of each elevation angle scanned thereby enabling the operational meteorologist to make warning and other related decisions before the end of the radar volume scan.

2.46.3 Strengths/Applications.

- Intermediate algorithm output is available before end of volume scan.
- TRU tracks features in order to check time continuity.

2.46.4 Limitations.

- Classification as INC or PER may be the result of sampling issues versus an actual feature attribute change.
- The TRU graphical attribute table and alphanumeric attribute table contain attributes from both previous and current volume scan information.
- Insufficient research has been done on ETVSs and needs much more work. The ROC recommends leaving the adaptable parameter value for the number of ETVSs displayed at zero.
- Feature matching ability dependent on motion supplied by the SCIT algorithm which may not represent the actual movement of the velocity signature.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

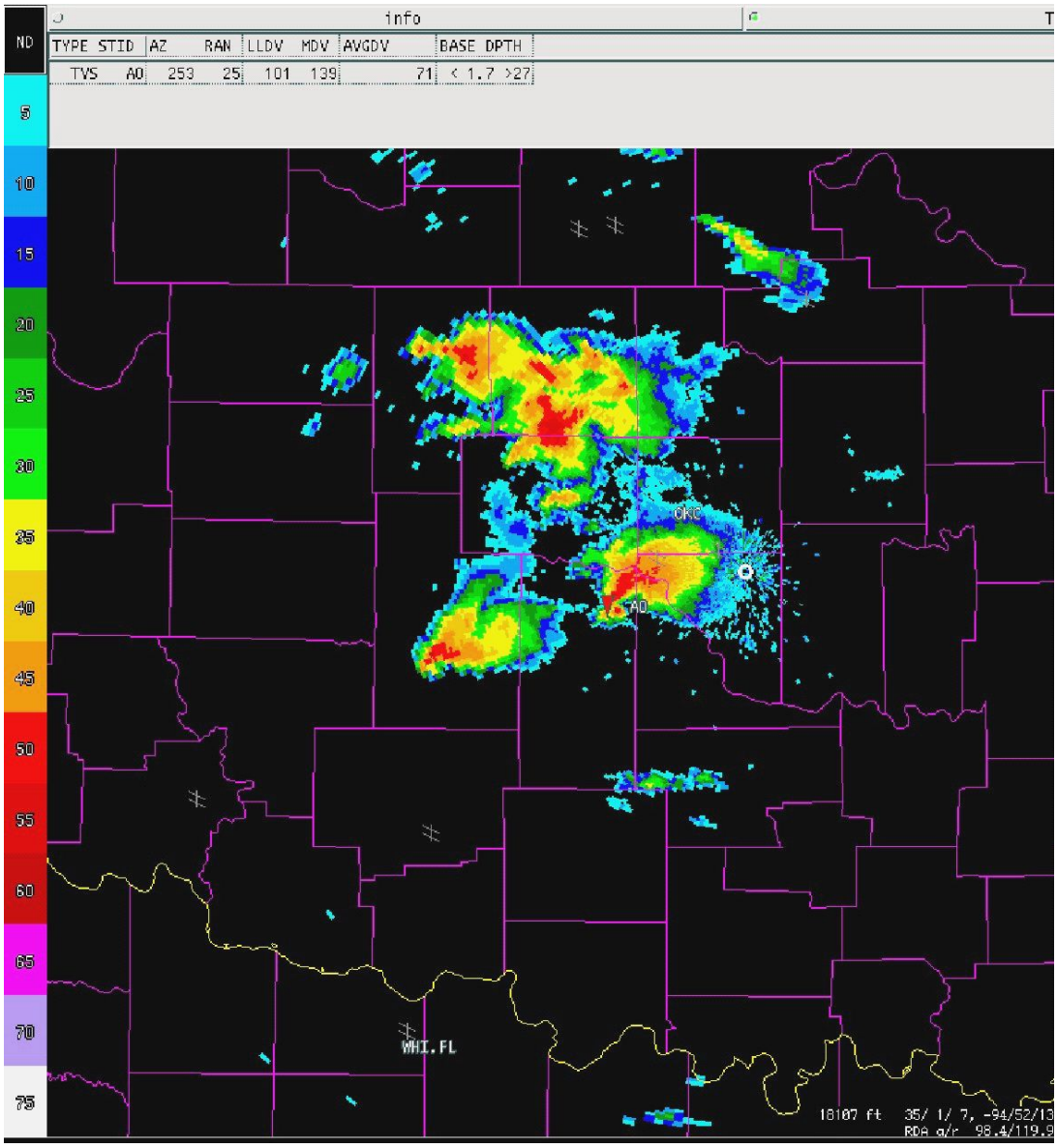

Figure 2-46
Tornado Vortex Signature Rapid Update Product Overlaid on a Reflectivity Product

An example of the TRU product from the Oklahoma City, OK (KTLX) WSR-88D (OPUP display).

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2.47 User Alert Message. The User Alert Message product (UAM) provides a brief message to the user defining an area of indicated severe weather. The message contains the location, type and severity of the weather event, and, if appropriate, storm speed and direction of movement. Alerts are updated once per volume scan. The alert message is issued first when the selected alert condition is initially detected; the alert message is issued only for initial detections of the selected alert condition following periods of non-detection lasting at least one volume scan. Whenever the alert message is issued, it is accompanied by an audio alert if the device has been activated.

The message is based on the detection of any alerting phenomenon in either of two alert areas. The message is displayed on the color graphic display. The message indicates the radar ID, the date and time, the alert area, the azimuth and range of the 16 x 16 km (8.6 x 8.6 nm) grid box in which the detected phenomenon was found, the user-established phenomenon and threshold, the value meeting or exceeding the threshold, and the storm ID (if the alert is associated with a storm). The message indicates one of the four following conditions:

- Alerts active - at least one alert category has been detected following a volume scan devoid of any alerts.
- Alerts inactive - this is the first volume scan for which there are no alerts for any categories following a volume scan that had at least one alert category for which an alert was detected.
- Alert active for a category - this is the first volume scan for which alerts were detected for a category and area following a volume scan devoid of alerts for that category.
- Alert message update - alerts are detected, however, none of the above conditions hold (i.e., no new alerts were detected).

2.47.1 Operational Characteristics.

System ID: UAM, Product #73.

Data: Alert information containing the location, type, and severity of weather event as derived by the meteorological algorithms (Figure 2-47).

Processing:

- Alert generation.
- Kinematic Series algorithms
- Precipitation Series algorithms
- Storm Series algorithms.

Availability: Automatic, upon detection of each user-selected alert condition at the end of each volume scan.

Presentation: Plain language message accompanied by an audio alert:

UAM NNN (RDA) HH:MM (hour.minute), MM:DD:YY (month:day:year)
Alert Area: (1 or 2)
Alert Box Center Azimuth: XXX.X (tenths of degrees)
Alert Box Center Range: XXX.X (tenths of nm)
Alert Category: (Grid, Volume, or Forecast)
Threshold Value: (user selected value and units)
Exceeding Value: (alert triggering value and units)
Storm ID.

Coverage: Area(s) of coverage are user defined.

Data Levels: Alert thresholds are user defined.

Annotations:

- Standard set*
- Location of alerting phenomenon
- Severe weather information, as appropriate.

Adaptation:

- Alertable phenomena (Table 2-3)
- Alert boxes
- Alert values for each phenomenon are set at the MSCF (Table 2-3)
- Alert value (one per phenomenon) is selected from the values set at the MSCF.

2.47.2 Usage. Notifies user upon detection of alerting phenomenon within a specified alert box.

2.47.3 Strengths/Applications.

- Alerts user of potential severe weather threat when selected**.**
- Alerts user only once until the alert condition no longer exists (for at least one volume scan) and then reappears. This attempts to prevent annoying repeated notification.

2.47.4 Limitations. Anomalous values can trigger an alert.

Table 2-3
Meteorological Phenomena for Alerts

Alert Categories	Coverage Radius (km/nm)	Threshold Criteria
I. Grid Group		
Composite Reflectivity	345/186	dBZ_e: 6 values
Echo Tops	230/124	kft: 6 values
Severe Weather Probability	230/124	Probability (%): 6 values
Velocity (lowest elevation)	115/62	knots: 6 values
Vertically Integrated Liquid	230/124	kgm-2: 6 values
II. Volume Group (non-grid, algorithm outputs)		
Maximum Hail Size	230/124	1 inch up to 4.0 inches in increments of 0.25 inches.
Maximum One-Hour Precipitation Accumulation	230/124	inches: 6 values
Maximum Storm Reflectivity	230/124	dBZ_e: 6 values
Probability of Hail	230/124	%
Probability of Severe Hail	230/124	%
Mesocyclone	230/124	Uncorrelated Shear 3-D Correlated Shear, Mesocyclone
Storm Top	230/124	kft: 6 values
Tornadic Vortex Signature	115/62	Detected
Velocity Azimuth Display Winds (lowest elevation)	NA	kts: 6 values
III. Forecast Group (storm oriented)		
Maximum Hail Size	230/124	1 inch up to 4.0 inches in increments of .25 inches.
Maximum Storm Reflectivity	230/124	dBZ_e: 6 values
Probability of Hail	230/124	%
Probability of Severe Hail	230/124	%
Storm Top	230/124	kft: 6 values
Tornadic Vortex Signature	115/62	Detected

Expansion provisions accommodate additional alert categories as follows:

Group I	1 additional
Group II	9 additional
Group III	10 additional

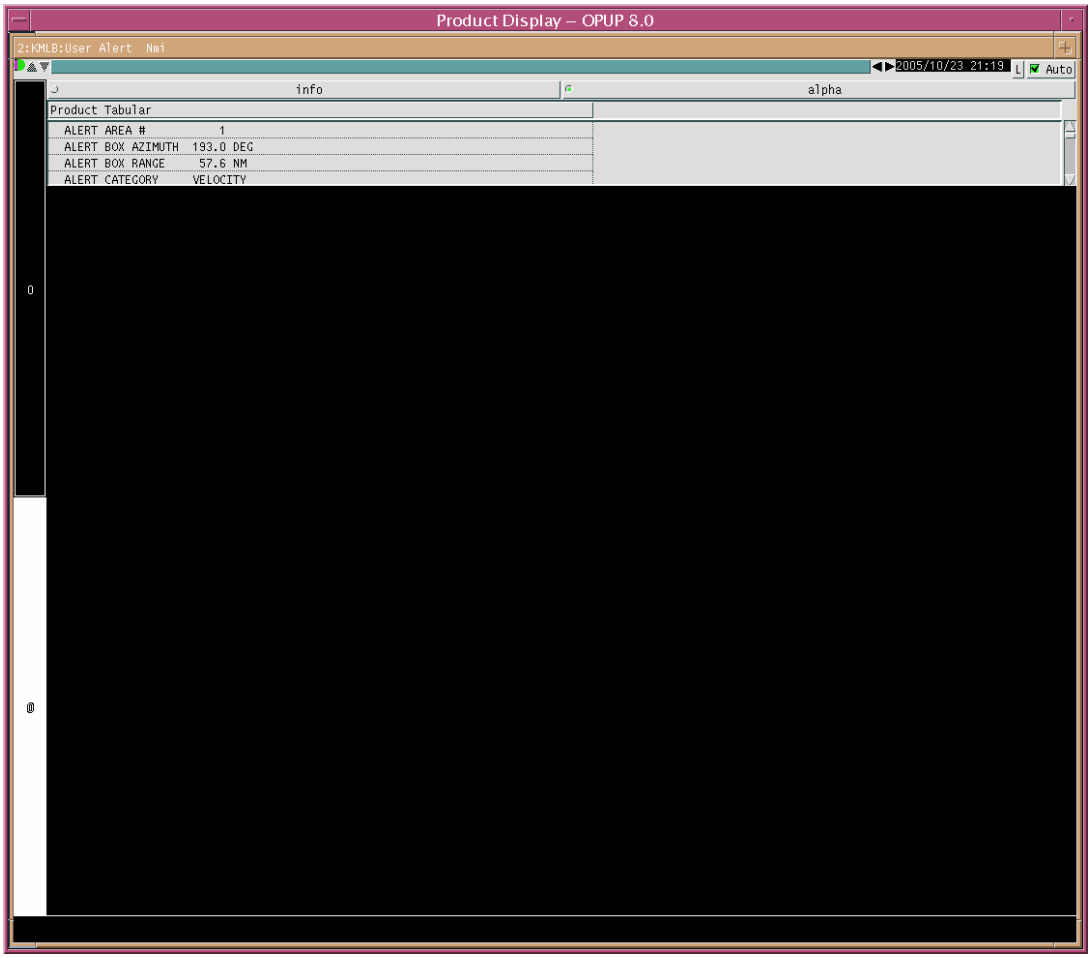

Figure 2-47
User Alert Message

This example of a UAM lists newly identified alerts for the volume scan and the threshold criteria exceeded velocity in the volume scan.

2.48 User Selectable Rainfall Accumulation. The User Selectable Rainfall Accumulation product (USP) provides a radar-estimated rainfall accumulation map displayed as an image, for a user selected accumulation period. The product format and content are the same as the Surface Rainfall Accumulation and Storm Total Rainfall Accumulation products, except the accumulation period is of variable duration (in whole clock hours), ranging from a beginning to an ending time specified by the user.

2.48.1 Operational Characteristics.

System ID: USP, Product #31.

Data: Radar rainfall accumulation estimates.

Processing: Precipitation processing subsystem.

Availability: Once per volume scan.

Presentation: Polar coordinate image of accumulated precipitation (Figure 2-48).

Resolution: 2 km (1.1 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16.

Annotations:

- Standard set*
- Data level code
- Maximum data values detected
- Times and dates of the beginning and end (clock hour) of the rainfall rate integration
- Mean-field bias in the radar estimate of the precipitation rate
- Effective sample size associated with the bias estimate.

Adaptation: Algorithm parameters.

2.48.2 Usage. Used to estimate precipitation accumulation over a user-specified period.

2.48.3 Strengths/Applications.

- Flexible time interval to meet varying weather situations.
- In addition to the 24-hour default USP, any others generated for dedicated users are available by one-time request (OTR) to dial-up users.

2.48.4 Limitations.

- USP accumulations are updated only at the top of the hour.
- Product may contain missing data. At least two-thirds of the specified hourly accumulations must be available for product generation.
- Only 10 products can be generated per volume scan.

---

*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

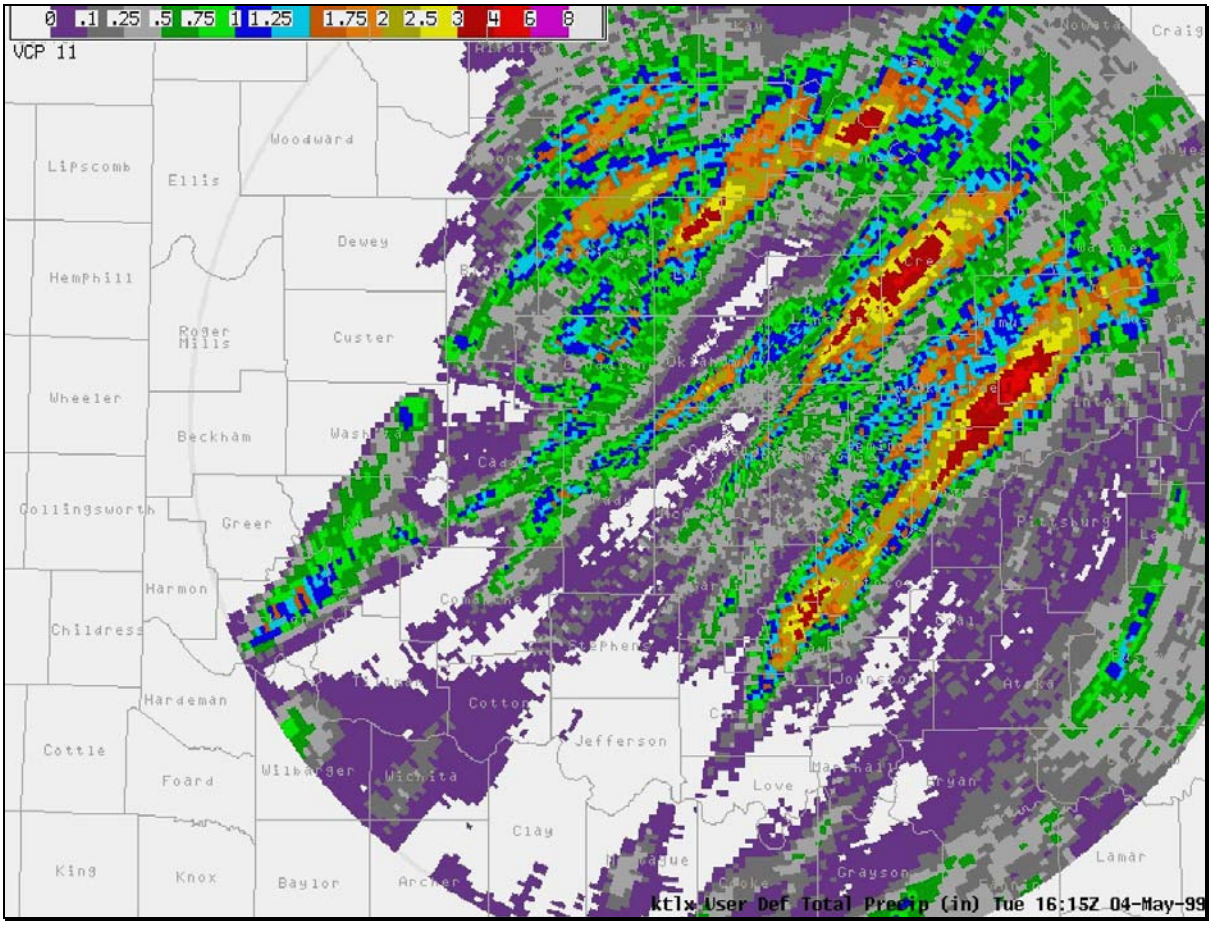

Figure 2-48
User Selectable Rainfall Accumulation Product

An example of the USP product from the Oklahoma City, OK (KTLX) WSR-88D (AWIPS display).

2.49 User Selectable Snow Depth Accumulation. The User Selectable Snow Depth Accumulation product (USD) provides radar-estimates of snow depth accumulations over a user-defined number of whole hours (Time Duration) ending on a user-defined hour (End Hour) of the day (UTC). specified period of time. The accumulations are made up of hourly accumulations updated once per hour near the top of the hour. Products will be blank unless at least two-thirds of the top-of-the-clock hourly accumulations are available.

2.49.1 Operational Characteristics.

System ID: USD, Product #151.

Data: Radar Snow Depth accumulation estimates.

Processing: Snow Accumulation Algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image (Figure 2-49).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 230 km (124 nm) radar radius.

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level code
- Maximum data value detected
- Azimuth and range of the maximum data value
- Range/height correction applied
- End Hour
- Time Duration
- Available Hours.

Special Symbols: None.

Adaptation: See Section 3.15.

2.49.2 Usage. Provides estimated snow accumulations over a user selectable period.

2.49.3 Strengths/Applications.

- Can be used to determine the amount of snowfall even when and where no reports are available.
- Has regionally optimized adaptable parameters which can be changed by the operator.
- Can accumulate with lower reflectivies than the PPS.
- Has a range/height correction.
- Users can select the time period and end hour of accumulations. For example, a user could have a daily (24 hour) accumulation end at 12 UTC.

2.49.4 Limitations.

- The same adaptable parameters are applied to the entire radar coverage area, yet actual measured values (such as Z-S relationship and snow ratio) will vary in time and space.
- Snow depth estimates are not accurate for snow that is melting (in the air or on the ground), but the product does not distinguish between dry snow and other precipitation types.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow after being observed by the radar.
- Does not account for blowing or drifting snow.
- Data levels are fixed and only provide a range of estimates (versus a digital estimate).

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

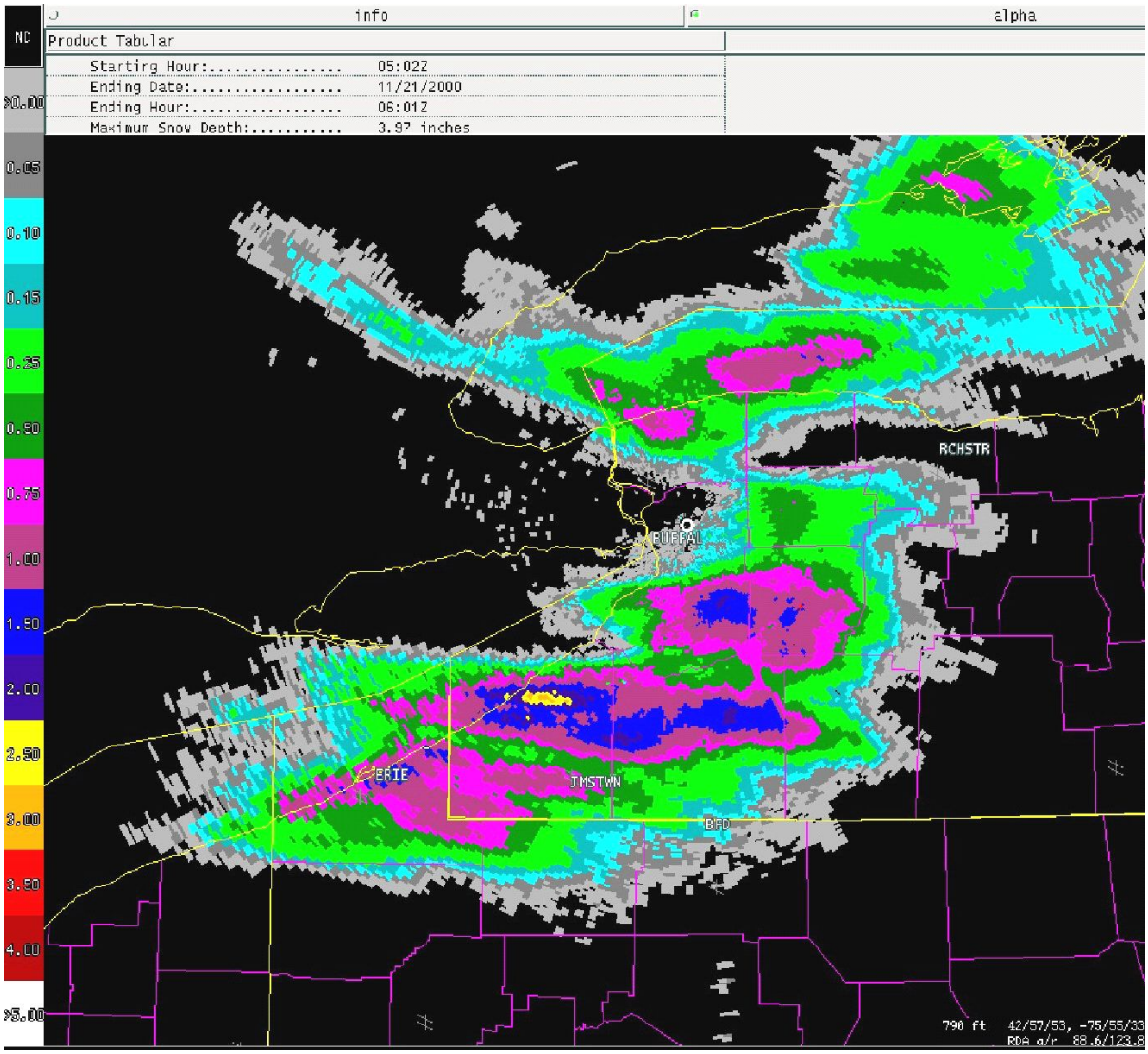

Figure 2-49
User Selectable Snow Depth Accumulation Product

An example of the USD product for a one-hour duration from the Buffalo, NY (KBUF) WSR-88D (OPUP display).

2.50 User Selectable Snow Water Equivalent Accumulation. The User Selectable Snow Water Equivalent Accumulation product (USW) provides a radar estimate of the water equivalent that has resulted from snowfall over a user-specified period of time.

2.50.1 Operational Characteristics.

System ID: USW, Product #150.

Data: Radar estimates of snow water equivalent accumulations.

Processing: Snow Accumulation Algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image of snow water equivalent accumulation estimates (Figure 2-50)

Resolution: 1 km (0.54 nm) x 1°

Coverage: Radar centered, 230 km (124 nm) radar radius.

Data Levels: 16.

Annotations:

- Standard set*
- Beginning and ending dates and times of accumulations
- Data level code
- Maximum data values detected
- Azimuth and range of the maximum data value
- Range/height correction applied
- End Hour
- Time Duration
- Available Hours.

Adaptation: See Section 3.15.

2.50.2 Usage. Provides estimates of snow water equivalent over a user selected number of hours ending at a selected hour.

2.50.3 Strengths/Applications.

- Can be used to determine the amount of snowfall even when and where no reports are

available.

- Has regionally optimized adaptable parameters which can be changed by the operator.
- Can accumulate with lower reflectivies than the PPS.
- Has a range/height correction.
- Users can select the time period and end hour of accumulations. For example, a user could have a daily (24 hour) accumulation end at 12 UTC.

2.50.4 Limitations.

- The same adaptable parameters are applied to the entire radar coverage area, yet actual measured values (such as Z-S relationship and snow ratio) will vary in time and space.
- Snow depth estimates are not accurate for snow that is melting (in the air or on the ground), but the product does not distinguish between dry snow and other precipitation types.
- Range of accurate estimates is at most 150 km, but can be less for very low-topped snow producing clouds such as lake effect snow.
- Does not account for advection of snow after being observed by the radar.
- Does not account for blowing or drifting snow.
- Data levels are fixed and only provide a range of estimates (versus a digital estimate).

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

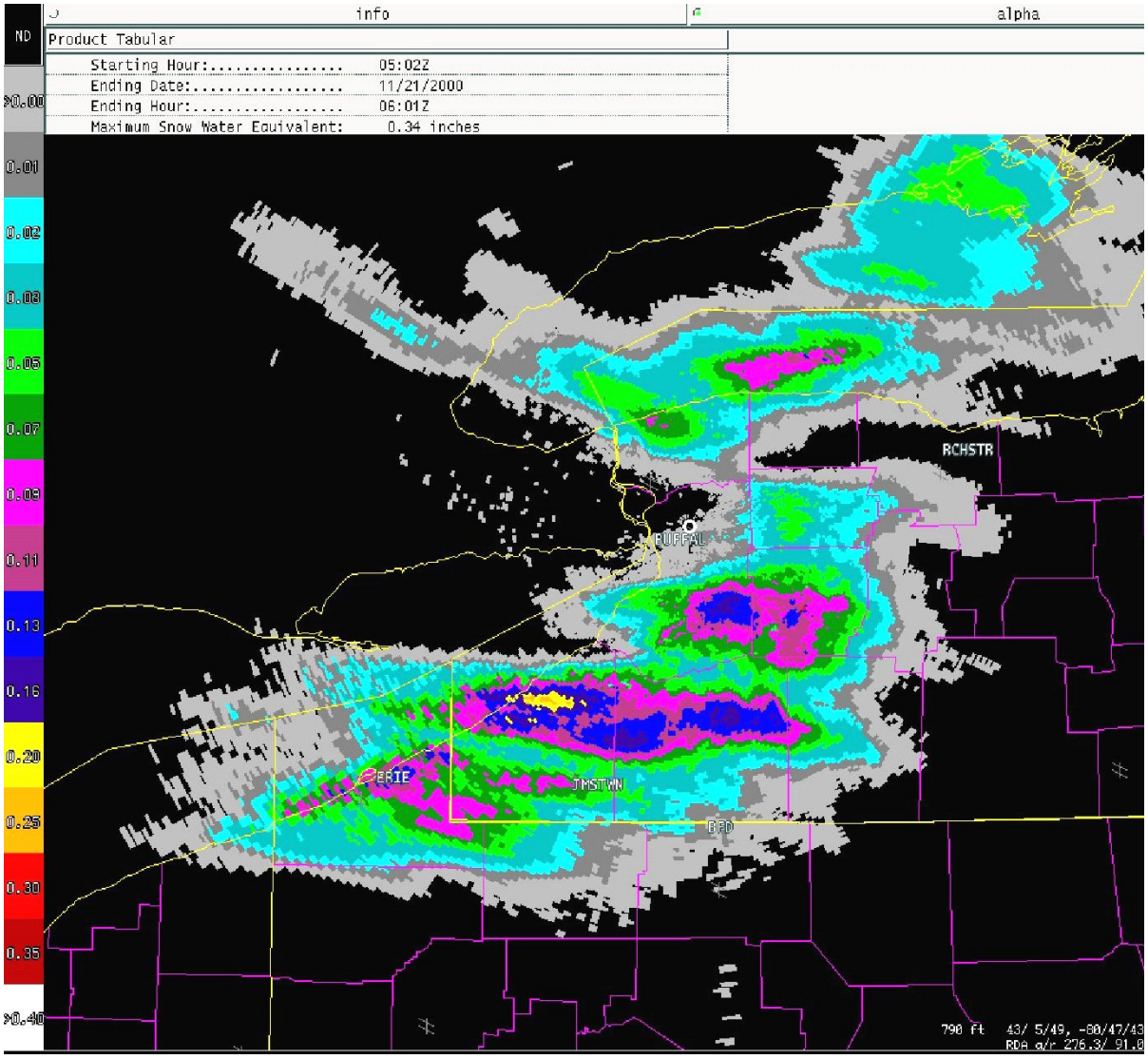

Figure 2-50
User Selectable Snow Water Equivalent Accumulation Product

An example of the USW product for a one-hour duration from the Buffalo, NY WSR-88D (KBUF). (OPUP display).

2.51 <u>Velocity Azimuth Display and Velocity Azimuth Display Wind Profile</u>. The output from the Velocity Azimuth Display (VAD) algorithm is used to create two products; the Velocity Azimuth Display (VAD) and the Velocity Azimuth Display Wind Profile (VWP).

The VAD product is a graphical presentation of the VAD algorithm processing logic for the particular altitude. (Figure 2-51b) This graphical presentation is a data plot of mean radial velocity values versus azimuth angle for one specific reporting altitude along with the best-fit sine wave curve that is used to compute the horizontal wind speed and direction. This horizontal wind speed and direction data is used to build the VWP product.

The VWP product is a graphic display of wind barbs plotted on a height scale in 1,000-foot increments. (Figure 2-51a) The current plot (far right) and up to 10 previous plots may be displayed simultaneously on a time versus height scale. Wind speed and direction for up to 30 altitudes are displayed as wind barbs on a height scale. All altitudes are referenced to mean sea level. Wind speed and direction are reported to the highest altitude with sufficient signal available for processing by the VAD algorithm. If the VAD derived wind estimate at a given height is invalid (i.e., failed threshold for RMS, symmetry, or number of points), winds for that height is reported as “ND”.

The VWP product also includes an alphanumeric (tabular format) portion. This table provides specific information pertaining to each wind entry for up to 52 VAD derived winds. These 52 entries include the selected VWP altitudes (up to 30), an additional one wind per elevation at a constant slant range (up to 20), and the low altitude supplemental winds (2). Wind entries are ordered by increasing altitude. Note: The vertical velocity (W) and divergence (DIV) columns contains valid data only for constant slant range wind estimates. For all other estimates, these fields contain "NA", indicating not applicable.”

2.51.1 Operational Characteristics.

System ID: VAD, Product # 84; and VWP, Product #48.

Data: VAD and VWP.

Processing: VAD Algorithm.

Availability:

- The VAD product is available for any user-specified altitude that is generated by the most current VWP.
- The VWP is generated routinely and updated once per volume scan or it may be generated in response to a one-time request.

Presentation:

- The VAD is a graphic plot of mean radial velocity versus azimuth angle. The best-fit

sine wave is overlaid on the plot of the velocity points (Figure 2-51b).

- The VWP is a graphic display of wind barbs plotted on a height staff. If the wind is calm, i.e., sufficient echoes are present but the speed is less than 5 knots, a circle of 5 pixels in diameter is placed at the appropriate location. The current and up to 10 previous plots may be displayed simultaneously along a time axis (Figure 2-51a).

Resolution: Nearest 5 kts.

Data Levels:

- 30 VWP altitudes, and 8 VAD
- 8 VAD color levels
- 5 RMS levels for VWP.

Annotations:

- For the VWP product:

  - Standard set*
  - Data level code
  - Maximum wind speed and direction for the current plot
  - Nyquist Co-interval
  - Site adaptable parameters.

- For the VAD product:

  - Standard Annotations
  - Slant Range
  - Elevation Angle
  - Wind Speed and Direction
  - Root Mean Square (RMS) Error
  - Computed Altitude of Wind (MSL).

Special Symbols:

- For the VAD product, the velocity data are plotted as single points on a grid of velocity versus azimuth. The best-fit function is plotted over the field of velocity points as a linked vector in a contrasting color.
- For the VWP product, the wind speed and direction are plotted using the standard meteorological wind barb presentation.

Adaptation:

- Beginning and ending azimuth for analysis.
- Reporting altitudes
- Data symmetry threshold
- Root mean square error.

2.51.2 Usage.

- VAD-derived winds are included in the RCM for national distribution. The profiles from multiple radars can then be composited and streamline analysis for large areas can be accomplished.
- The algorithm can diagnose the mean wind using less than 360° azimuth. This allows a determination of winds even when there is no measurable reflectivity through large segments of azimuth. The VAD for a specific computed wind is available if the user suspects the computed value or wishes to analyze the data to a greater level of detail. The VAD can be used to understand qualities of the VWP product.
- The VAD can be used to determine convergence or divergence.
- The VWP product provides a timely determination of the boundary layer wind profile. Time versus height profile plots for periods of one to six hours can be generated allowing the user to keep track of significant changes due to advection or other significant meteorological mechanisms.
- For a VWP reporting altitude for which wind data are missing, VAD can be used to establish why wind data are not being reported. It can also provide the necessary information for adjusting adaptation data, or VAD analysis range and elevation angle, in order to increase the likelihood of obtaining wind data in low reflectivity environments.

2.51.3 Strengths/Applications.

VAD:

- VAD winds are available in Clear Air or Precipitation Mode.
- The VAD algorithm does not require 360 degrees of data.
- Check missing or suspicious wind data on the VWP.
- Update Environmental Winds Table. The VAD winds are fed into the Environmental Winds Table for use in the velocity dealiasing algorithm. This helps minimize dealiasing errors.

VWP:

- The VWP may be of assistance in many operations such as in severe weather, aviation, hydrology, and general forecasting.
- The VWP can be used to create/adjust hodographs.

- Future development may include combining the Storm Tracking Algorithm and VWP to output helicity.

2.51.4 Limitations.

VAD:

- Needs sufficient data points (adaptable)
- May be unreliable in disturbed environments.
- Large flocks of migrating birds may produce anomalous wind data.
- Available for preestablished altitudes only as designated at the RPG HCI for the VWP.

VWP:

- Measurable returns needed - at least 25 data points are required on the individual VAD for data to be encoded at that altitude.
- Winds are not encoded if RMS error or symmetry thresholds are exceeded. ND will be plotted if RMS exceeds 9.7 kts or symmetry exceeds 13.6 kts regardless of data levels.
- Generally only representative of winds within 37 km (20 nm) of the RDA.
- Birds can bias VWP values significantly, especially migratory birds.
- Deformations in the wind field (e.g., fronts, troughs) over the area of analysis can bias the analysis.
- When the area of analysis is reduced by performing the analysis at higher elevation angles and shorter ranges, more care must be taken to account for the vertical component of the Doppler-derived mean radial velocity, especially in areas of precipitation.
- It is necessary to provide the algorithm with symmetry, RMS, and data point thresholds for bounding the data before analysis in order to force the algorithm to disregard spurious data.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

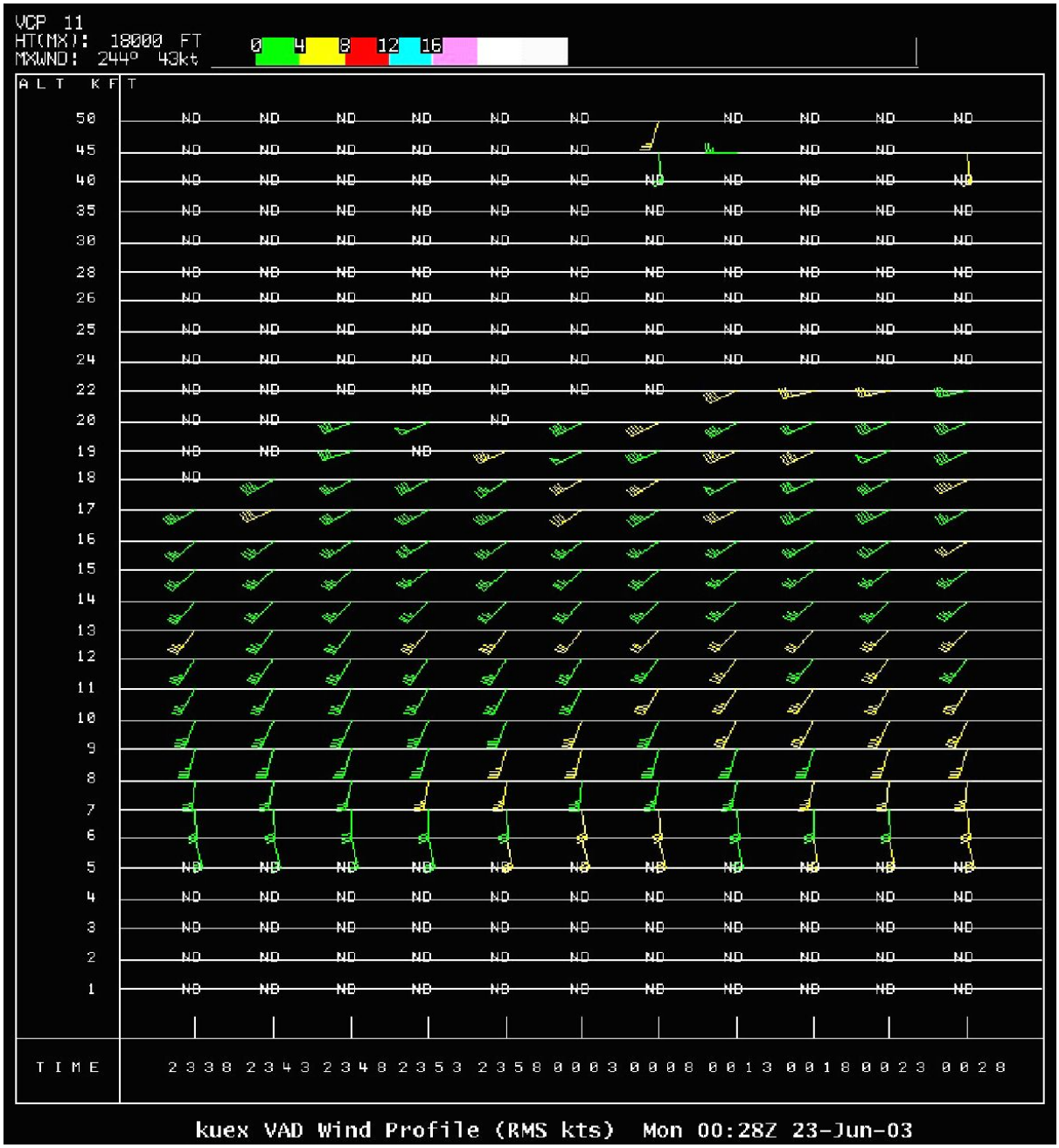

Figure 2-51a
Velocity Azimuth Display Wind Profile Product

This example of a VWP product (AWIPS display) shows the wind estimates produced in the vertical for the last 11 volume scans. “ND” indicates levels where the algorithm was not able to produce a reliable wind estimate.

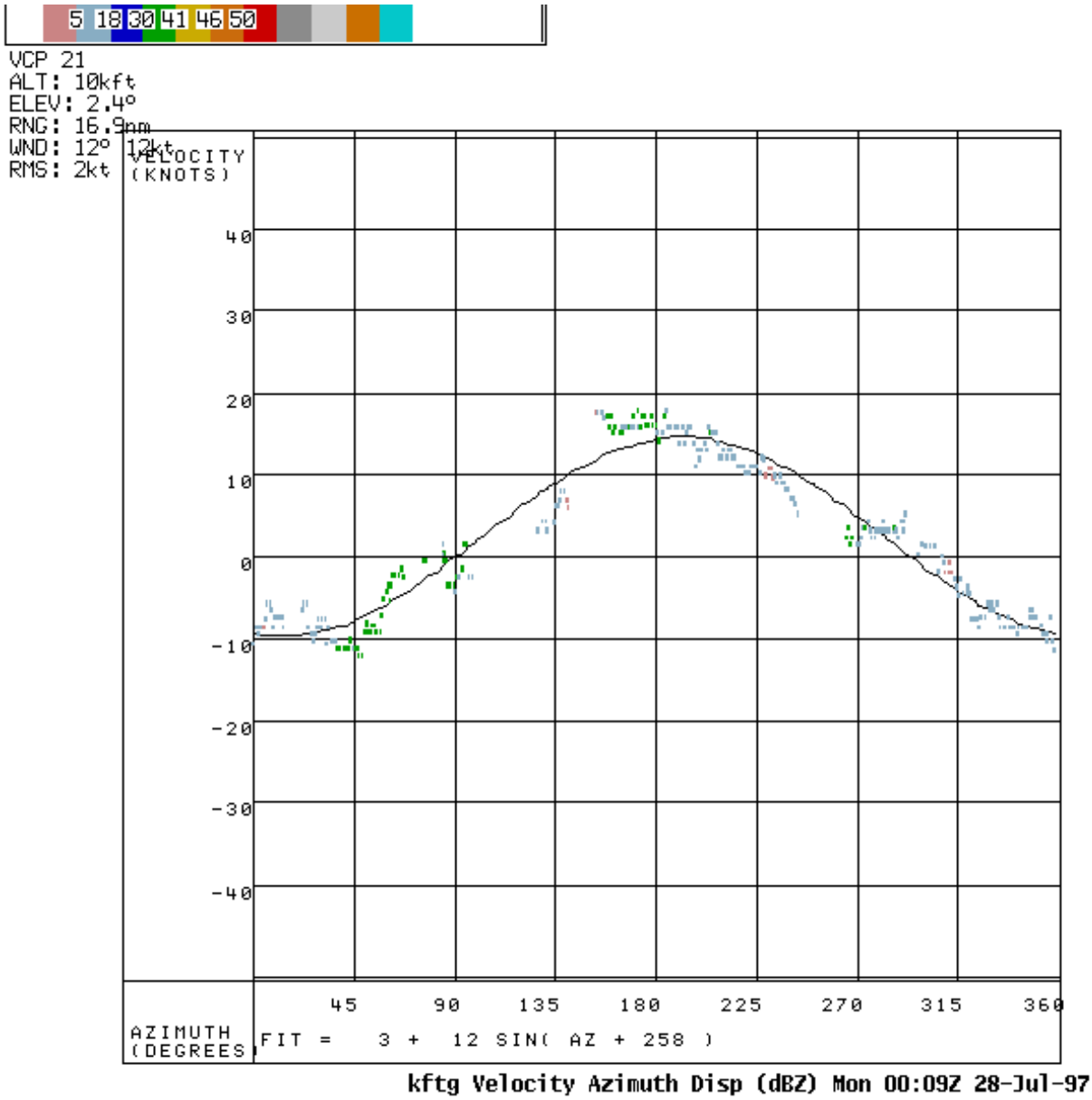

Figure 2-51b
Velocity Azimuth Display Product

This example of a VAD Product (AWIPS display) shows the fit of radial winds measured at a 2.4° scan with respect to the theoretical sine wave curve.

2.52 <u>Vertically Integrated Liquid Water</u>. The Vertically Integrated Liquid Water product (VIL) displays VIL values as an image. The output of the VIL algorithm (Section 3.10) is used to produce the product that is updated once per volume scan.

2.52.1 Operational Characteristics.

System ID: VIL, Product #57.

Data: VIL values.

Processing: VIL Algorithm.

Availability: Routinely generated once per volume scan.

Presentation: Cartesian image of VIL values (Figure 2-52). The product is displayable in full or quarter screen format.

Resolution: 4 x 4 km (2.2 x 2.2 nm).

Coverage: Radar centered, 230 km (124 nm) radius.

Data Levels: 16. Values greater than 70 kg m^{-2} are truncated to 70 kg m^{-2}

Annotations:

- Standard set*
- Data level code
- Maximum VIL value.

Adaptation: Maximum data level code.

2.52.2 Usage.

- VIL is very useful in monitoring the general radar echo pattern for the beginning stages of significant convective development and for helping to distinguish thunderstorms from rain showers. As convective development progresses, relative values of VIL are useful in distinguishing strong, possibly severe, thunderstorms from those not likely to be severe.
- Significantly high ("significantly" will vary with different meteorological conditions) VIL values should be reviewed in conjunction with other severe weather guidance products (e.g., HI, M, SWP, TVS to assess the severe weather likelihood of a given storm).

2.52.3 Strengths/Applications.

- Locate the most significant storms.
- Aids judging storm strength.
- Useful for distinguishing storms producing large hail once the hail thresholds have been established.
- Persistent high VIL values associated with supercells.
- Rapid decrease in VIL values *may* signify the onset of wind damage.

2.52.4 Limitations.

- VIL values are biased by drop size.
- Values for warnings may change daily and across the warning area. Values are airmass dependent.
- Values within 37 km (20 nm) of radar are underestimated due to the cone of silence.
- Grid-Based VIL values will differ from Cell-Based VIL values.
- VIL values for a strongly tilted or a fast moving storm will be lower than if the storm was vertical.
- The presence of hail, beam overshooting of low-level precipitation, beam broadening with range, and non-vertically contiguous VCPs may all affect the accuracy of the VIL estimation for a given storm.
- The relationship of VIL to severe weather needs to be quantified for different meteorological conditions and climatic regimes.
- May be contaminated by non-meteorological echoes.
- VIL fluctuates widely as a storm's range changes, especially with VCP 21.
- Values at distant ranges (> 185 km (100 nm)) may be unreliable.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

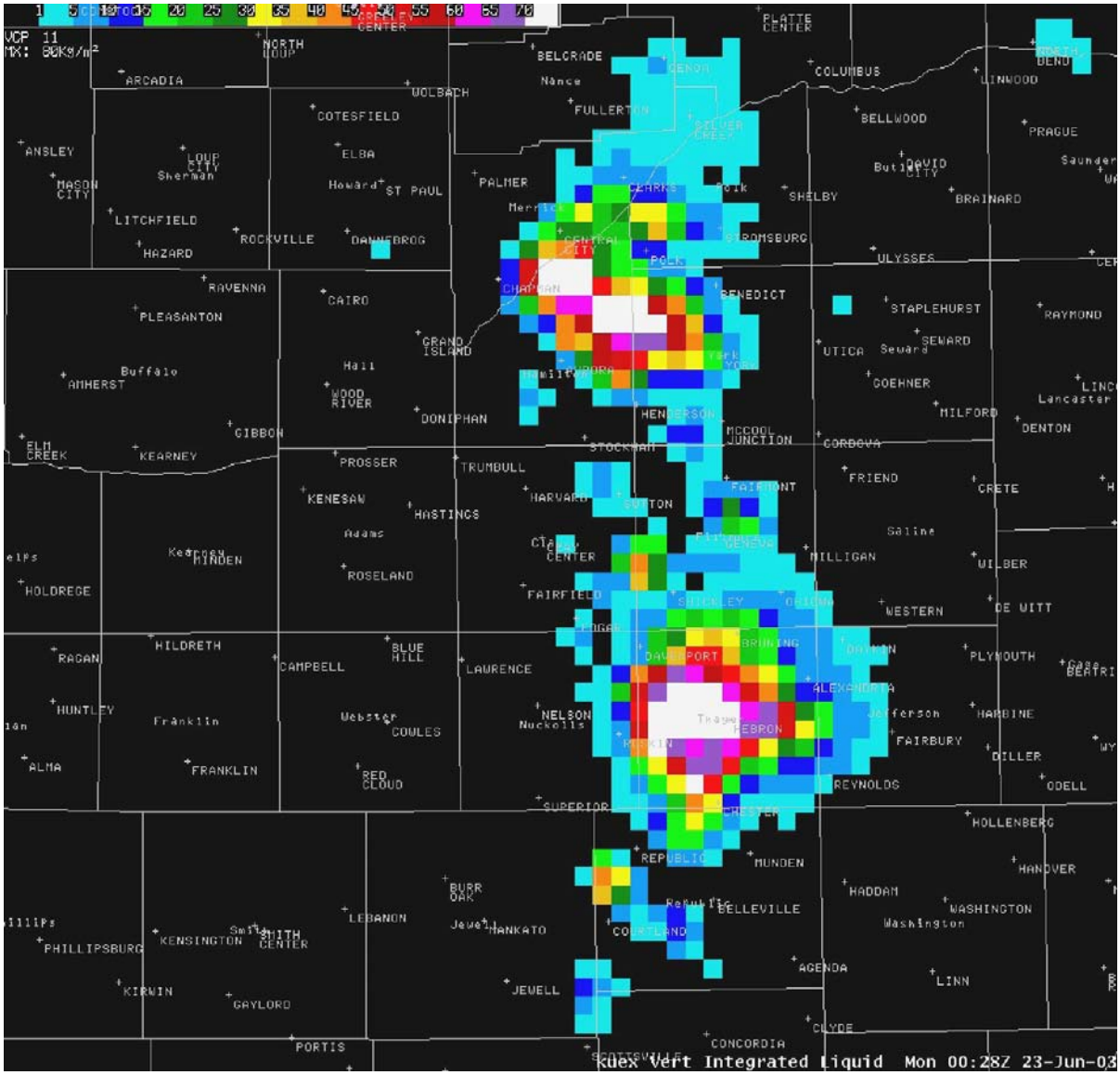

Figure 2-52
Vertically Integrated Liquid Water Product

An example of the VIL product, Image magnified by a factor of 4 (AWIPS display), from the North Platte, NE (KUEX) WSR-88D at 00:28 UTC on 23 June 2003.

2.53 <u>High Resolution Digital Vertically Integrated Liquid</u>. The High Resolution Digital Vertically Integrated Liquid product (DVL) was developed for the FAA in order to show a finer resolution in the lower VIL values rather than higher values. It is intended for display in the FAA ITWS.

2.53.1 Operational Characteristics.

System ID: DVL, Product #134.

Data: VIL values.

Processing: VIL algorithm.

Availability: Once per volume scan.

Presentation: Polar coordinate image of VIL values (Figure 2-53a).

Resolution: 1 km (0.54 nm) x 1°.

Coverage: Radar centered, 460 km (248 nm) radius.

Data Levels: 256.

Annotations:

- Standard set*
- Data level code
- Maximum VIL value.

Adaptation: Data level code.

2.53.2 Usage.

- VIL is very useful in monitoring the general radar echo pattern for the beginning stages of significant convective development and for helping to distinguish thunderstorms from rain showers. As convective development progresses, relative values of VIL are useful in distinguishing strong, possibly severe, thunderstorms from those not likely to be severe.
- Significantly high ("significantly" will vary with different meteorological conditions) VIL values should be reviewed in conjunction with other severe weather guidance products (such as, HI, M, SWP, and TVS to assess the severe weather likelihood of a given storm.

- High data resolution on the lower end of the VIL range will be helpful to the FAA and aviation community.

2.53.3 Strengths/Applications.

- Available out to 460 km (248 nm) from the radar.
- Locate the most significant storms.
- Higher data resolution than that provided by VIL.
- Useful for distinguishing storms producing large hail once the hail thresholds have been established.
- Persistent high VIL values associated with supercells.
- Rapid decrease in VIL values *may* signify the onset of wind damage.

2.53.4 Limitations.

- VIL values are biased by drop size.
- Values for warnings may change daily and across the warning area. Values are airmass dependent.
- Values within 37 km (20 nm) of the radar are underestimated due to the cone of silence.
- High resolution VIL values will differ from the Grid-based VIL values and from Cell-Based VIL values (Figure 2-53b).
- VIL values for a strongly tilted or a fast moving storm will be lower than if the storm was vertical.
- The presence of hail, beam overshooting of low-level precipitation, beam broadening with range, and non-vertically contiguous VCPs may all affect the accuracy of the VIL estimation for a given storm.
- The relationship of VIL to severe weather needs to be quantified for different meteorological conditions and climatic regimes.
- May be contaminated by non-meteorological echoes.
- VIL fluctuates widely with range especially with VCP 21.
- Values at distant ranges (> 185 km (100 nm)) may be unreliable.

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*Standard set includes Product Name; Radar ID; Date and Time of elevation, volume or azimuthal scan; Radar Position; Radar Elevation above MSL (feet); and Operational Mode.

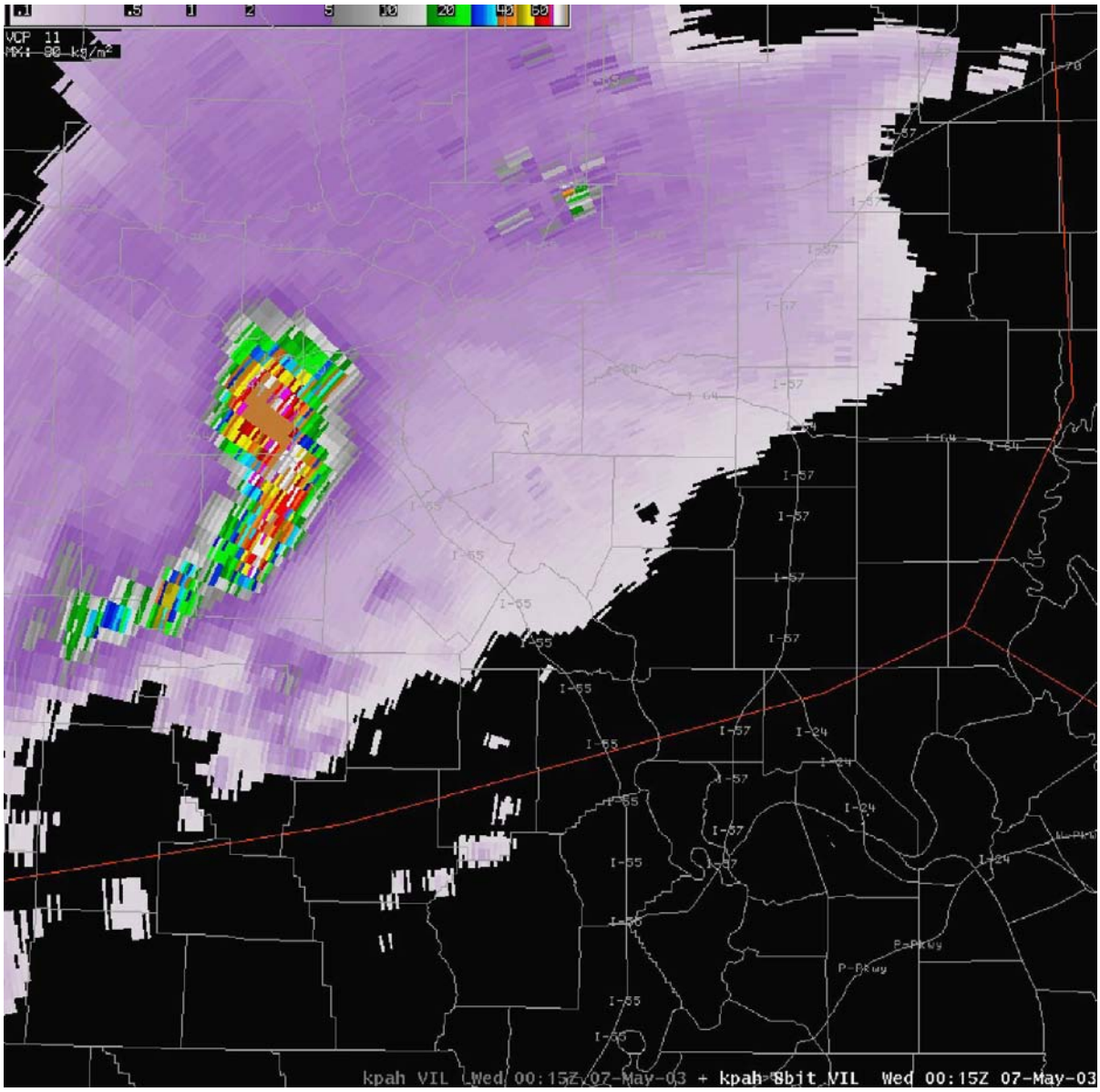

Figure 2-53a
High Resolution Digital Vertically Integrated Liquid Product

An example of a DVL product (AWIPS display) from the Paducah, KY (KPAH) WSR-88D at 00:15 UTC on 7 May 2003.

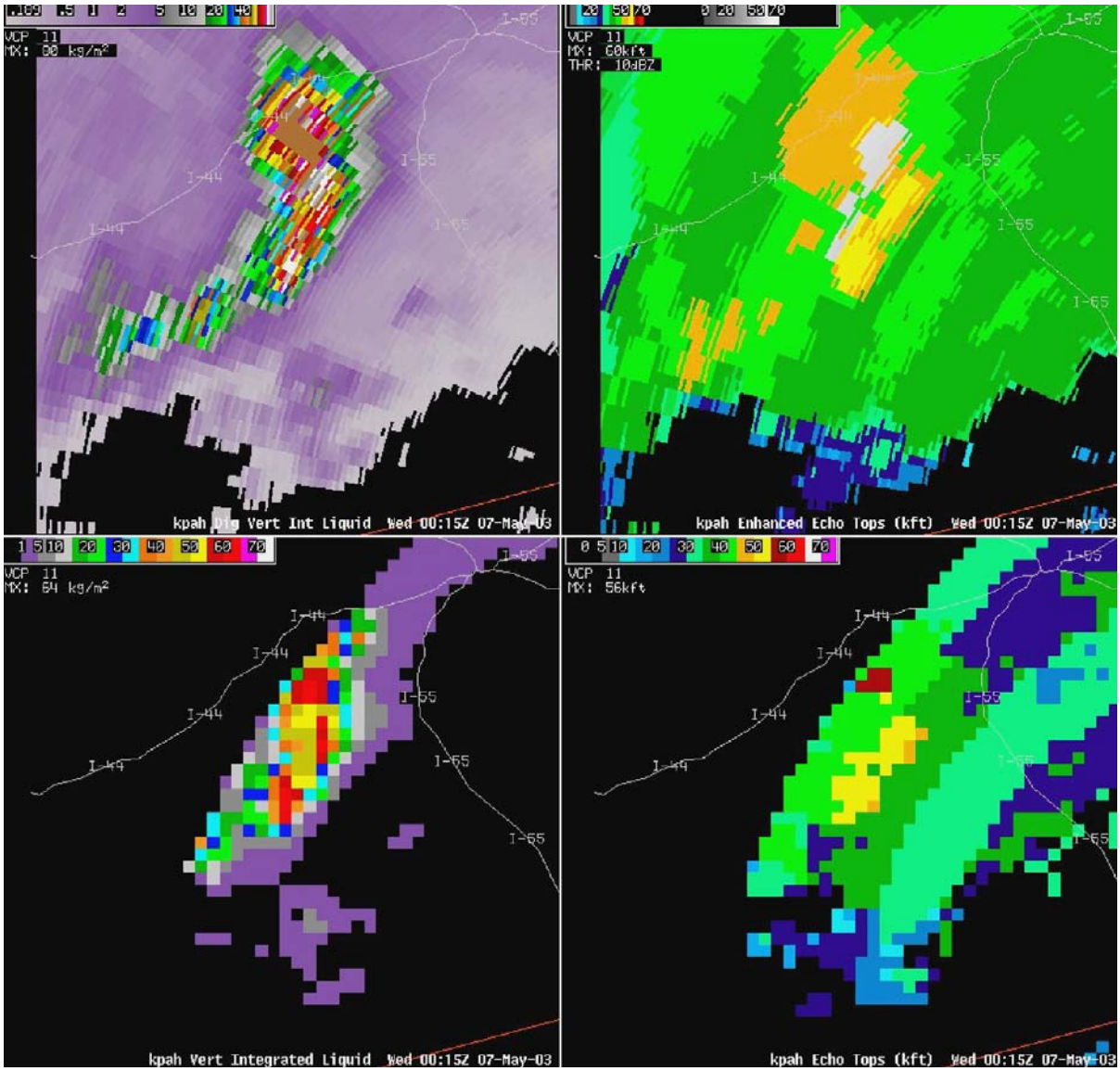

Figure 2-53b
High Resolution Digital and Legacy Product Comparisons (VIL and ET)

A comparison of legacy VIL (lower left) and legacy ET (lower right) with the DVL (upper left) and the EET (upper right). This AWIPS display is based on data from the Paducah, KY (KPAH) WSR-88D.