Basic Radar Analysis and Interpretation

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Purpose of this Presentation

• Provide a *basic knowledge of radar interpretation* and *radar limitations*.
• Provide some insight into additional factors which play into NWS warning operations
• Cover basic severe signatures
• Intended audience – EMs, HAMs, Skywarn spotters, etc.
Radar Basics

- WSR 88-D
- Sends out a microwave pulse
- Listens as energy bounces back
- The more returned, the more dense the object is
- Radar is listening much more than transmitting
Doppler Radar measures component of velocity that is **moving toward or away from the radar** by analyzing the Doppler frequency shift from returning echoes.

The WSR-88D uses a pulsed waveform which returns both velocity and range information.
NEXRAD – Why So “Slow”? 

- Rapid update times (< 1 min)
- Continuous monitoring of low levels in storm
- Can continuously sample individual storms
- Smaller dish more prone to attenuation
- Cores of strong storms near radar often not sampled
- Can create 3D views of storms
- Monitor depth of rotation
- Sample storm tops
- Evaluate storm strength trends
- Create derived products
- Minimum sample time of the lowest elevation scan is 4.1 mins
- **SAILS** - for Supplemental Adaptive Intra-Volume Low-Level scans
- **AVSET** – Automated Volume Scan Evaluation and Termination
Basic Radar Limitations
Beam Characteristics

Definition of the 88D beam

The width of the beam is the distance between the two half-power points (where power drops by 50%). For the 88D, this beamwidth is around 1°.
Beam Characteristics
Effects of Beam Spreading

Frederick
112 miles / 11,200 ft

Dyess AFB
25 miles / 1,700 ft

Fort Worth
94 miles / 8,300 ft

Granger
167 miles / 21,000 ft
The farther the radar is from the storm, the higher in the storm it “sees”.
Beam Location

- Radar assumes beam is at certain height based on distance
- Huge implications on hail forecast
NEXRAD CONUS Coverage Map
Base and Derived Products
Introduction to Algorithms
Base and Derived Products

The WSR 88D produces three base products:

- Base Reflectivity — Rain intensity
- Base Velocity — Wind intensity — radial velocity
- BV Spectrum Width — Measure of Variability

ALL other WSR 88D products are derived products. Base data is manipulated by a computer program to produce a new product. This new product is a derived product.
Reflectivity (Z)

- Measures returned power back to the radar from targets
- Units in dBZ (operational scale from about -30 to +80 dBZ)
Velocity (V)

Greens/Cool Winds blowing toward the radar

Reds/Warm Winds blowing away from the radar
Velocity (V)

• Measures the Doppler Velocity* of targets sampled
• Units are in knots. 1 kt = 1.15 mph

Reds/Warm
Winds blowing away from the radar

Greens/Cool
Winds blowing toward the radar
Doppler Radar measures component of velocity that is moving toward or away from the radar (radial velocity).

Just because the radar may indicate low or zero velocity...does not necessarily mean that the wind is not blowing. It may simply mean that the wind is not blowing toward or away from the radar.
February 10, 2009
Reflectivity (left)  Velocity (right)
Let’s Point out the Features

Wind Farms

May 23, 2008
Reflectivity (left)  Velocity (right)
Derived Products

- Composite Reflectivity
  - Highest value of all tilts
- Echo Tops
- VIL
- VAD Wind Profile
- Precipitation Products
- Cross Sections
- 3D Views
Derived Products

Two Other Extensively Used Derived Products

Smoothing –boooooo!

Storm Relative Velocity
Derived Products - Algorithms

- These 3 derived products are most often misused.
- Hail algorithms assume standard atmosphere.
- Algorithms are meant as last resort.
- Decisions should NEVER be based solely on a derived product or algorithm!
The TVS and MESO Indicators

0.5° Reflectivity with TVS/MESO indicators
The TVS and MESO Indicators

• These are all areas of turbulent motion
• Radar will have extreme difficulty in isolating individual circulations within a line
• While tornadoes can form anywhere within a line, the user must focus on favored areas instead of on algorithms
Wait for the Algorithm?

- TVS/MESO algorithm failed due to the extensive range folding in vicinity of the storm.

- Understanding of the near storm environment and subtle radar signatures were key to the successful warning decision.

Bottom line, most tornadoes occur without TVS algorithm and most algorithm TVSs are not associated with tornadoes.
• **GR Level 2 Analyst** and **GR Level 2** processes data at many levels and is more precise.

• This allows for very detailed volume scans (found in the analyst version).

• **Advanced user**

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• **GR Level 3** Data processes at only 4 levels, but you get more derived products and rainfall data

• **Basic user**
GR Level 2 Analyst Features

- Base Reflectivity (BR)
- Base Velocity (BV)
- Storm Relative Velocity (SRV)
- Spectrum Width (SW)
- Echo Tops (ET)
- Vertically Integrated Liquid (VIL)
- VIL Density (VILD)
- Probability of Severe Hail (POSH)
- Maximum Hail Size (MEHS)
- Maximum Rotation (NROT)
- Tilt Levels
- Warnings Display
- Placefile Manager – Spotters and Watches
- 3-D Volume Scans
- Smoothing
Base Reflectivity (BR) – this is the intensity of precipitation returned to the radar site. It is measured in decibels. The color scheme used in GRLevel programs can be adjusted by the user.
**Base Velocity (BV)** – this feature is perhaps one of the most characteristic of Doppler radars. It revolutionized our ability to detect internal rotation inside potentially tornadic storms prior to tornadic formation. In addition, it allows the radar operator to detect microbursts within storms. Red is outbound, green is inbound.
Storm Relative Velocity (SRV) – similar to Radial Velocity, but takes into account the motion of the storm. Also referred to as Storm Relative Motion (SRM)
Storm Relative Velocity (SRM)

Base Velocity
- Ground relative wind speed
- Use radar as a reference point
- Includes actual storm motion

Storm Relative Velocity
- Actual storm motion is subtracted out
- Gives a better estimate of the winds relative to the storm (rotation)
Storm Relative Velocity (SRM)

December 31, 2010
0.5° Reflectivity
Storm Relative Velocity (SRM)

Base Velocity (top) Storm Relative Velocity (bottom)
Storm Rotational Tracks & Prelim Damage Paths

http://54.243.139.84/StormDamage/DamageViewer/
Preliminary Damage Paths

http://54.243.139.84/StormDamage/DamageViewer/
Net Rotation – NROT: picks the highest level of wind shear to show the exact location of a Tornado Vortex Signature. Values around 1 or greater are significant.
Echo Tops (ET) – feature that allows the user to quickly calculate the tops of rainfall or thunderstorms (convective activity). Note the scale to the left.
Vertically Integrated Liquid (VIL) – integrates the reflectivity vertically to estimate the liquid water content of a cell. The traditional VIL caps the reflectivity values at 56 dbz in order to reduce the contribution of hail.

Severe hail thresholds are highly dependent on atmosphere temperature profile.

Vil of the day 45 one day, 70 another – based on level of various temperatures.
Probability of Severe Hail (POSH) – indicates in percent the probability of hail ¾” or larger.
Vertically Integrated Liquid Density (VILD) – used to indicate hail size.
Maximum Expected Hail Size (MEHS) – An estimate of the maximum hail size possible in the storm. Does not account for any melting which often occurs.
It is important you check the computer graphic requirements from the GRLLevel website to see if your computer will have the capability to show smoothing.

**Smoothing is EVIL !!!!!!!!!!**
Dual Pol

Differential Reflectivity (ZDR)
Correlation Coefficient (CC)
Hydrometeor Classification (HCA)
Dual-Polarized Radar

Dual-Polarized Radar (upgrade)

- Transmits pulses horizontally and vertically
- Simultaneous
- $225,000/site
Differential Reflectivity (ZDR)

- Differential Reflectivity (ZDR) is the ratio of horizontally returned power to vertically returned power.
  - Helps discriminate large drops from hail
    - Liquid vs. Ice
  - Raindrops become more “oblate”
  - Hailstones “tumble” and appear more spherical
Differential Reflectivity (ZDR)

- Can help distinguish areas of hail or hail cores
  - Certain values indicate ice vs. liquid

Extremely heavy rain or hail?
Differential Reflectivity (ZDR)

- Can help distinguish areas of hail or hail cores
  - Certain values indicate ice vs. liquid

![Differential Reflectivity (ZDR) vs. Reflectivity](image)

- Likely hail core
- Extremely heavy rain or hail?
Differential Reflectivity (ZDR)

Good example of hail core area
Correlation Coefficient (CC)

Correlation Coefficient measures the “uniformity” of the hydrometeors (or non-precipitation elements)

- Values from 0 to 1.00
- Non-meteorological elements are often noisy and diverse (CC less than 0.80)
  - Birds, insects, airborne trees, roofs, etc.
**ALWAYS** look at Base Reflectivity with dual-pol products.
Correlation Coefficient (CC)

What does this reflectivity image trigger in your mind?
- What may be happening?
Correlation Coefficient (CC)

Tornado Debris
- Low values
- Noisy signal
- Tip of “hook echo”

Velocity

Correlation Coefficient (CC)
Hydrometeor Classification (HCA)

Remember...HCA is only where the radar beam intersects a hydrometeor

• It **DOES NOT** tell you what is falling at the ground
• It can give you strong indications based upon assumptions, but ground truth is needed
  ▪ Webcams, spotter reports, surface observations (i.e. temp., weather, etc.)
• HCA can classify hydrometeors incorrectly
Precipitation Classification

Rain Below Melting Level

Heavy Rain Below Melting Level

Dry Snow

Wet Snow

Hail

Graupel

Ground Clutter

Melting Level

New – Giant Hail
Digital Storm-Total Accumulation (DSA)

Expected to produce (and has) more accurate rain amounts
  • Processed to a higher resolution
Digital Precipitation Rate (DPR)

Instantaneous precipitation rate!

- Give a good idea of heaviest rain at the moment
More Severe Storm Signatures

And Radar Limitations
Tilt Levels

- Useful with Base Velocity and Storm Relative Velocity to determine the location of rotation
- Useful in locating the hail core.
Tilt Levels

Algorithms take all scans and produce a 3-D image of a storm. The user can zoom and rotate the storm from virtually any angle.
Hail Cores

- Hail growth zone: -10 to -30°C
- Height of 50 and 60 dBZ cores
- Severe hail indications
  - 50 dBZ to -30 C
  - 60 dBZ to -20 C

April 22, 2015
Large Hail?

Composite Ref

Cross Section
Radar Challenges...

The exact same radar signature be severe one time and not the next. True or False

True

What changed?

The Atmosphere

Changes in instability and temperatures high up in the atmosphere (freezing level, etc) impact

• Tornadoes reaching the ground, or not
• Strong winds reaching the surface in squall lines and from downbursts
• Hail formation and size
• This also strongly impacts algorithms!
Storm Circulations and Updrafts
Measuring Updraft Strength

Low Level Convergence / Storm Top Divergence

[Diagram showing radar images with arrows indicating updrafts and outflows at different levels]
Measuring Updraft Strength

Storm Top Divergence

.5 Ref - 5200 ft

3.9 Vel - 29000 ft

45 kts

60 kts
Measuring Updraft Strength

Storm Top Divergence / Low Level Convergence
Measuring Downdraft Strength

Ground Level Divergence – Too Late!

* Severe downburst is hardest element to forecast
Measuring Downdraft Strength

Mid Altitude Radial Convergence (MARC)
Some Lead Time - Not Commonly Seen
Squall Lines
Aug 19, 2015 – 2 am - Reflectivity
August 19, 2015 – Tornado?
Survey Determined this was 90-100 mph Straight-line Winds!
Why Velocities So Low?

Radar only detects component of wind toward or away from radar.
Squall Line (QLCS) Tornadoes
San Antonio, TX  Feb 19 – 956 pm
Squall Line (QLCS) Tornadoes
San Antonio, TX  Feb 19 – 1101 pm
Squall Line (QLCS) Tornadoes
San Antonio, TX  Feb 19 – 1040 pm

Ref  Vel
Squall Line (QLCS) Tornadoes
San Antonio, TX  Feb 19 – 1040 pm

Ref Vel
SRM NROT
Tornado, or No Tornado
Tornado, or No Tornado

Tornado!
Tornado, or No Tornado

No Tornado!
Tornado, or No Tornado

Tornado!
Tornado, or No Tornado

Tornado!
Tornado, or No Tornado

Tornado!
Tornado, or No Tornado

No Tornado!
Tornado, or No Tornado

33 mins later...

Tornado!
Tornado, or No Tornado

Tornado!
When Might a Radar Operator Not Issue Tornado warnings on Strongly Rotating Storm?

Atmosphere not conducive for tornadoes

- Storm bases are high (above 6000 ft) making tornado touchdown unlikely
  - More common issue in plains. Rarely issue for gulf coast.
- Storm is elevated above a stable layer behind a cold front
- Spotters have good view and see no lowering in cloud base
Basic Review - You Tell Me!
Quick Glance – Storm Type

Multi-Cell Cluster
- Downburst Winds
- Hail
- Flash Flooding
- Tornadoes (usually low)

Multi-Cell Bow Echo
- Damaging Winds
- Isolated Tornadoes
- Flash Flooding
- Hail (usually low)

Supercell
- Tornadoes
- Large Hail
- Damaging Winds
- Flash Flooding
Basic Review - You Tell Me!
Most Dangerous?

Caddo Gap, AR
- Catastrophic Flash Flood
- 8”+ Overnight
- 20 Fatalities
- Flow on Little Missouri River went from 30 ft³/sec to 71,000 ft³/sec in a few hours

Dallas, TX
- Squall line merges with supercell
- Catastrophic urban flash flooding
- Rain rates of 6.1”/hr measured
- 16 Fatalities

Kiowa County, KS
- Supercell over open country in SW KS
- Produced multiple tornadoes
- 1 Injury
- 0 Fatalities
Radar Apps and Sources
Conclusions

Radar is just one of many tools used to analyze storm intensity and structure. It has many limitations and the user is responsible for understanding these limitations.

NEVER base a decision solely on a derived product or algorithm!!

What you see is not always what you get. Storm spotters and other information must be utilized in addition to radar data.
Questions ? Comments

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