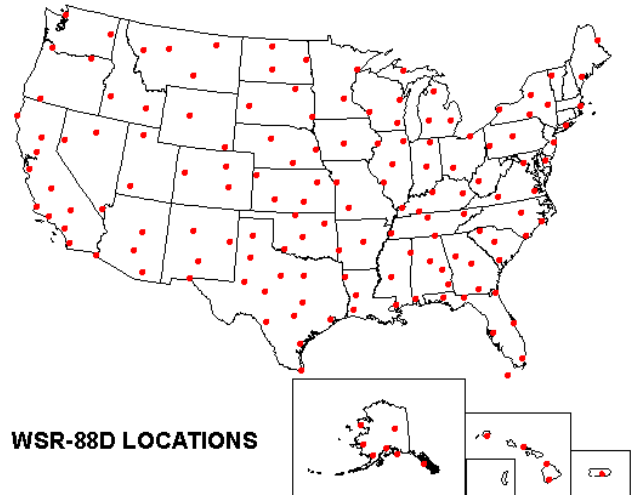


WSR - Weather Surveillance Radar

It was learned during World War II that electromagnetic radiation could be sent out, bounced off an object and returned to a listening device. By measuring the time it took for the energy to travel to the target and back (hence the word *echo*), one could give a location of that object.

Radar is an acronym for **R**adio **D**etection and **R**anging. It was soon learned that raindrops made excellent targets for S-Band radar (~10cm wavelength). A national system of weather radars were set up across the United States in the mid 1960's. Recent advances in technology have resulted in a new system of Doppler radars installed across the US in a program called **NEXRAD**, for **N**ext **G**eneration **W**eather **R**adar. The new radars were to be collocated with modernized weather service offices to help usher in the new millennium with unprecedented radar coverage. The new radars were called WSR-88D's; 1988 technology with Doppler capability. These Doppler radars would replace the conventional non-coherent radars first developed in 1957.

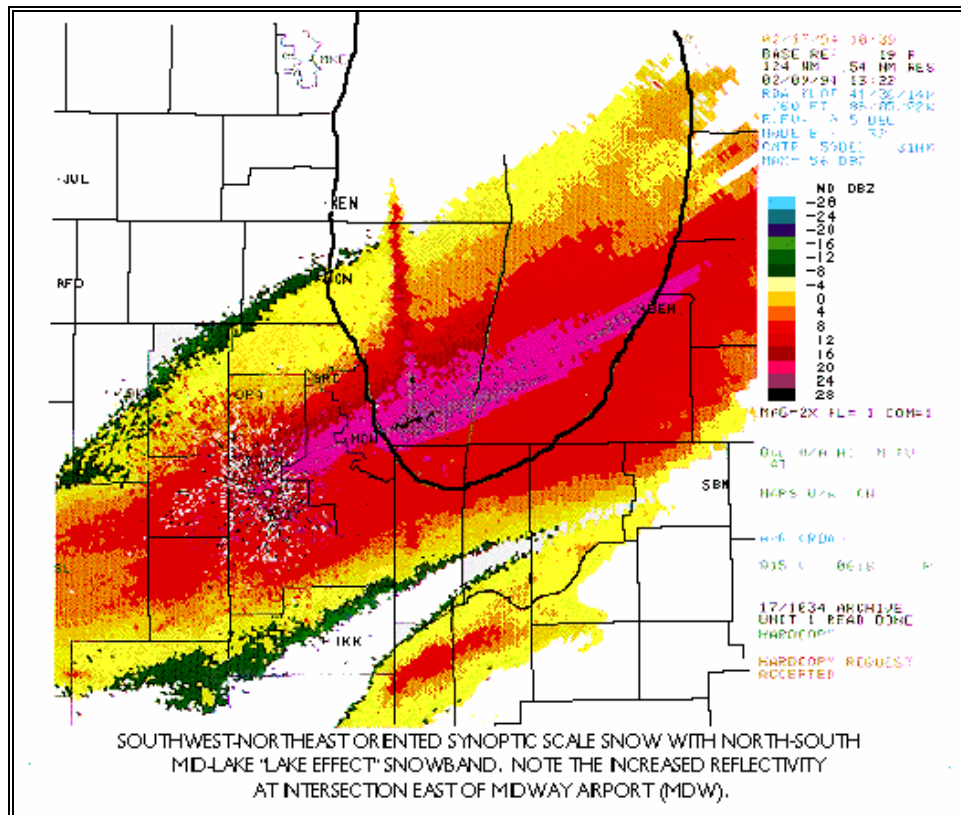


Benefits of the WSR-88D over the WSR-57

- **Improved Sensitivity** - This is basically a result of a greater amount of power transmitted and a greater ability to detect weaker returns. The WSR-88D's ability to detect lighter amounts of precipitation has allowed for the detection of very light precipitation and even subtle clear air boundaries.
- **Improved Resolution** - This is primarily a function of angular beam width. The narrower the beam, the smaller the width at a given distance. This will allow the WSR-88D to differentiate between objects, thereby increasing the resolution.
- **Volume Scanning** - Rather than scanning along varying azimuth angles (PPI) then stopping to scan vertically (RHI), the radar will automatically scan various elevation angles while spinning around 360° of azimuth. Computers will generate products based on this volume scan.
- **Enhanced Capabilities and Algorithms** - Sophisticated computer programs will assist the radar operator to detect various phenomena such as mesocyclones (Mesocyclone Detection Algorithm – MDA), tornadoes (Tornado Detection Algorithm - TDA) and the like. The radar will also have a greater range of reflectivities operating in severe and non-precipitation modes.

The following is a breakdown of reflectivity (in dBZ's) corresponding to various Video Integrator and Processor (VIP) levels of the WSR-57. The WSR-88D's will have fifteen different levels. The minimum detectable reflectivity for the WSR-57 was 18 dBZ whereas the minimum detectable return for the WSR-88D is -28 dBZ.

| VIP Level | Equivalent Reflectivity (Z_e) | $\log Z_e$ | dBZ ($10 \times \log Z_e$) |
|-----------|-----------------------------------|-------------|------------------------------|
| 1 | 0 - (1000) | 0 - (3) | 0 - (30) |
| 2 | 1000 - (12,589) | 3- (4.1) | 30 - (41) |
| 3 | 12,589 - (39,811) | 4.1 - (4.6) | 41 - (46) |
| 4 | 39,811 - (100,000) | 4.6 - (5) | 46 - (50) |
| 5 | 100,000 - (501,187) | 5 - (5.7) | 50 - (57) |
| 6 | 501,187 or more | 5.7 or more | 57 or more |



This radar report shows a lake-enhanced snowfall. Imagine what the image would be like if nothing under 18 dBZ's showed up as echoes! The new WRS-88D's are a great improvement for snowfall observation. Because of the sensitivity of the radar for weak echoes, the non-precipitation mode is often used for snowfall. Heavier rainfall, and especially hail show up well in severe weather mode.

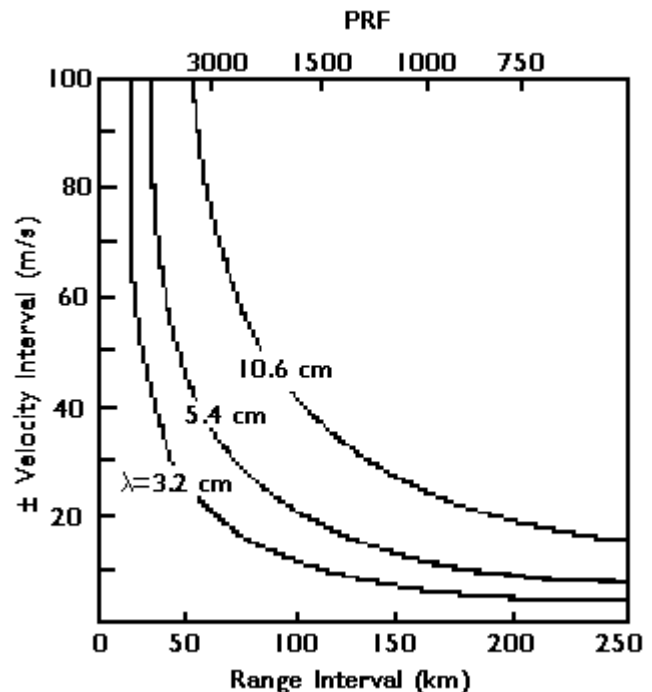
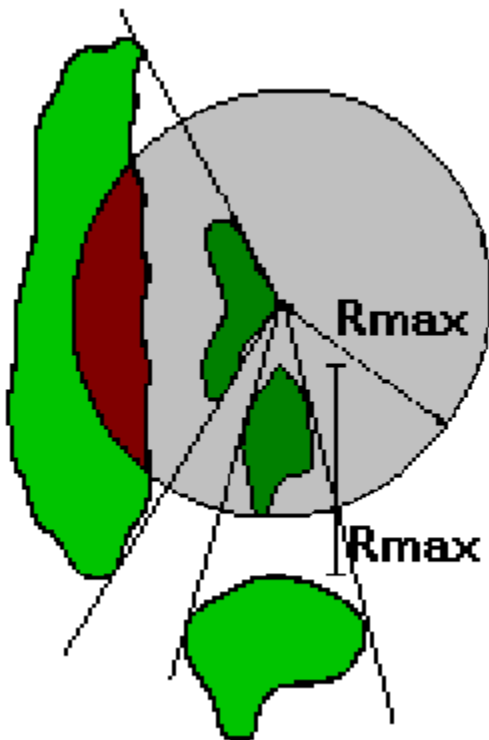
The maximum unambiguous range, R_{\max} , corresponds to half the distance electromagnetic energy can travel between pulses (since the energy needs to travel to the target and back). The pulse repetition frequency (PRF) is a measure of how frequently the pulses are transmitted. If c is the speed of light (taken as $3 \times 10^8 \text{ m}\cdot\text{s}^{-1}$), then

$$R_{\max} = \frac{c}{(2 \times \text{PRF})}$$

In words, the maximum unambiguous range is inversely proportional to the PRF.

| Radar | PRF(pulses per sec) | R_{\max} (km) | R_{\max} (nmi) |
|----------------|---------------------|-----------------|------------------|
| WSR-57 | 164 or 545 | 915 or 275 | 494 or 149 |
| WSR-74C | 259 | 579 | 313 |
| WSR-88D | 318-1304 | 471-115 | 254-62 |

If a second pulse is transmitted before energy from the first pulse has been received, the echo from a target beyond the maximum unambiguous range is displayed at the proper azimuth but at a distance one R_{\max} closer to the radar. This “second-trip echo” exemplifies *range folding*. Echoes may be folded from third and fourth trips if the R_{\max} is small enough to allow for targets to be observed at multiple intervals of R_{\max} .



Average Power Return

A radar is able to detect a small amount of power returned from a target. Obviously, the more sensitive the receiver, the more a radar is able to detect smaller or less efficient scatterers. The radar needs to average returned power from many successive pulses since the power returned from pulse to pulses is highly variable. The WSR-88D will typically average power from 25 pulses to determine a representative value. A radar can increase its ability to detect a target by not only changing its listening ability, but by maximizing the power it transmits. The greater the output, the greater the return.

Maximum Transmitted Power

Whereas the power output of the WSR-57 is 410,000 watts, the output of the WSR-88D is 750,000 watts. The return power is directly proportional to the transmitted power.

Antenna Gain

Gain is a measure of the antenna's ability to focus the radiated energy. The antenna's gain indicates the relative amount that the energy is focused compared to what it would be if it were an isotropic radiator (giving off radiation equally in all directions). The gain of the WSR-88D is 35,481 (compared to the WSR-57 with a gain of 6,460), meaning a target will be struck with over 35,000 times more energy than it would without a dish. Power received from a given target is directly related to the square of antenna gain.

Angular Beam Width

Power returned to a radar is directly related to the square of the angular beamwidth (assuming a beam narrower than 2° and at a range less than 125nmi). A narrower beam will improve sensitivity by focusing the outgoing power and increase the resolution by decreasing the size of the beam's cross-sectional area.

| <i>Radar</i> | <i>Wavelength (cm)</i> | <i>Dish Diameter (feet)</i> | <i>Angular Beam Width (degrees)</i> |
|----------------|----------------------------|---------------------------------|---|
| WSR-57 | 10.3 | 12 | 2.0 |
| WSR-74C | 5.4 | 8 | 1.6 |
| WSR-88D | 11.1 | 28 | 0.95 |

| <i>Range</i> | | <i>2.0 degree beam</i> | | <i>0.95 degree beam</i> | |
|--------------|------|------------------------|-------|-------------------------|------|
| (nmi) | (km) | (feet) | (m) | (feet) | (m) |
| 50 | 93 | 10613 | 3235 | 5041 | 1536 |
| 100 | 185 | 21227 | 6470 | 10082 | 3073 |
| 150 | 278 | 31840 | 9705 | 15124 | 4609 |
| 200 | 371 | 42454 | 12980 | 20165 | 6165 |
| 250 | 463 | 53067 | 16175 | 25206 | 7683 |

Pulse Length

The radar transmits energy for a given period of time known as the transmission time. When that is multiplied by the speed of light, a train of energy, or pulse, extends outward from the antenna with a pulse length, H. Long pulses are used to determine target locations, while short pulses help determine target intensity and motion characteristics. The power received from a target is directly related to pulse length. The longer the pulse length, the more energy is being transmitted. This will improve the sensitivity of the radar.

| Radar | Transmission Time (microseconds) | Pulse Length (km) |
|----------------|-------------------------------------|-------------------|
| WSR-57 | 0.5 or 4 | 0.15 or 1.2 |
| WSR-74C | 3 | 0.9 |
| WSR-88D | 1.57 or 4.5 | 0.47 or 1.35 |

Contiguous Surveillance

- Reflectivity
- Low Pulse Repetition Frequency (PRF)
- Unambiguous Range of 248nmi (460 km)
- Used at Low Elevation Angles

Contiguous Doppler

- Velocity
- High PRF
- Shorter Unambiguous Range
- Used Primarily at Low and High Elevation Angles

NEXRAD Information Dissemination Service (NIDS)

- Reflectivity(2 tilts) 1x1 km, 16 data levels, 230 km range
- Composite Reflectivity 4x4 km, 16 data levels, 460 km range
- Echo Tops
- Vertical Integrated Liquid (VIL)
- Surface Rainfall Accumulation
 - 1-hr Running Total
 - 3-hr Total (once per hour)
- Storm Total Rainfall
- Hourly Digital Rainfall Array Product
- Radial Velocity (2 tilts) 1x1 km,16 data levels, 230 km range
- Velocity Azimuth Display (VAD) Winds (Time vs Height)
- Layer Composite Reflectivity

(See <http://www.ncdc.noaa.gov/oa/radar/radarproducts.html> for additional information on dual polarization products.)

Operational Modes

I. CLEAR AIR MODE

A. Volume Coverage Patterns

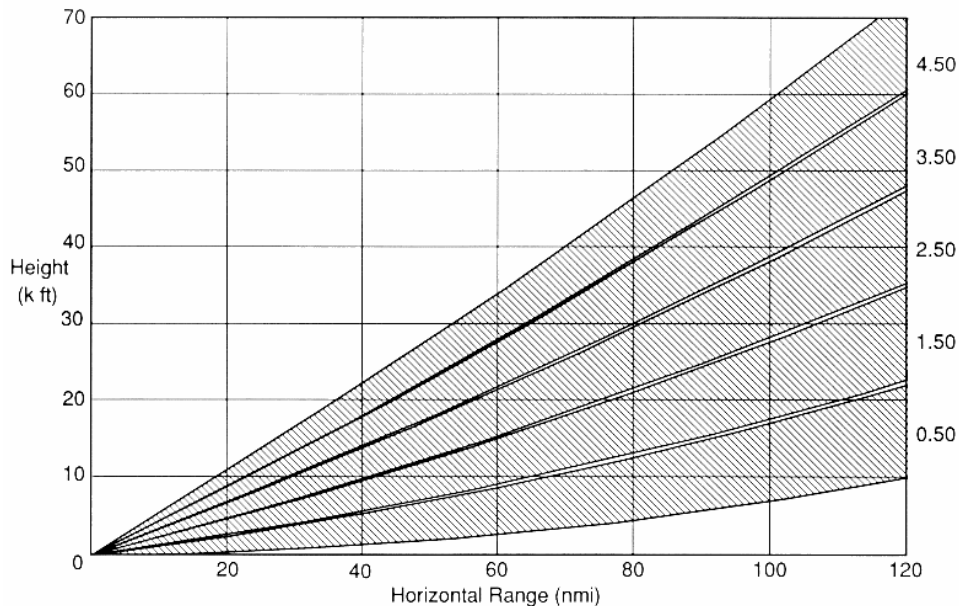
1. VCP 31

- a) 5 Elevation Angles
- b) 10 Minute Volume Scan
- c) Long Pulse (Higher Sensitivity)
- d) Lower PRF (More Velocity Aliasing; Less Range Folding)

2. VCP 32

- a) 5 Elevation Angles
- b) 10 Minute Volume Scan
- c) Short Pulse (Lower Sensitivity)
- d) Higher PRF (Less Velocity Aliasing; More Range Folding)

Number of Scans: 5 Beam Width: 0.95 degrees



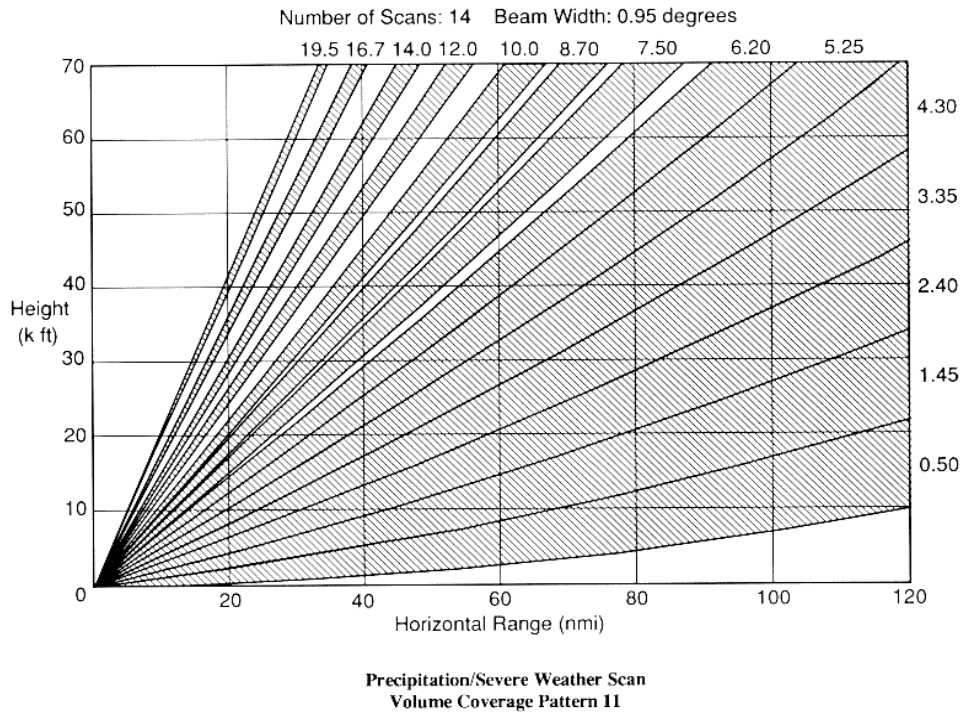
Clear Air Scan
Volume Coverage Patterns 31 and 32

II. PRECIPITATION/SEVERE WEATHER MODE

A. Volume Coverage Patterns

1. VCP 11

- a) 14 Elevation Angles
- b) 5 Minute Volume Scan
- c) Short Pulse (Lower Sensitivity)
- d) Varying PRF's



2. VCP 21

- a) 9 Elevation Angles
- b) 6 Minute Volume Scan
- c) Varying PRF's

3. VCP 121

This VCP implements the multi-pulse repetition frequency detection algorithm (MPDA) which helps mitigate range/velocity aliasing (the Doppler Dilemma). This VCP has the 9 elevation angles and completes 20 azimuthal scans in 5 minutes.

(See <http://www.ncdc.noaa.gov/oa/radar/radarresources.html> for additional resources.)