# Weather Radar's Perspective on Wind Farms


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# The Wind Energy Industry and its Benefits

- Renewable and relatively clean energy
- Provides “green collar” jobs
- Low operating costs
- Reliable in windy places such as North Dakota
- Allows nearby land to remain in agricultural use
- Can provide economic benefits in the form of property taxes and annual landowner payments

# The Weather Radar and its Benefits

- It is a key tool of weather forecasters in the preparation of forecasts and severe weather warnings.
- It is designed to detect weather targets and storm scale winds at long ranges.
- It is sensitive enough to depict clear-air (cloud/rain free) boundaries, such as temperature and humidity discontinuities. Example: Fronts

# Common Goals Between the Wind Energy Industry and Meteorological Community

- Enhancing the Nation's economy through cost savings (one through cheap, renewable energy, the other by providing a strategic means to plan operations around the weather).
- Improving the quality of life (one through providing a cleaner source of energy, the other through protecting life and property).

# Wind Farm Impacts to the Weather Radar

- Moving turbine blades, unlike stationary objects like buildings, appear as weather on the radar. Current technology cannot successfully eliminate the “clutter”.
- Potential misinterpretation or masking of thunderstorm and/or winter storm characteristics
- Potential reduction of storm warning effectiveness near and downrange of a wind farm
- False radar-based precipitation estimates, which could impact flash-flood warning effectiveness and contaminate data

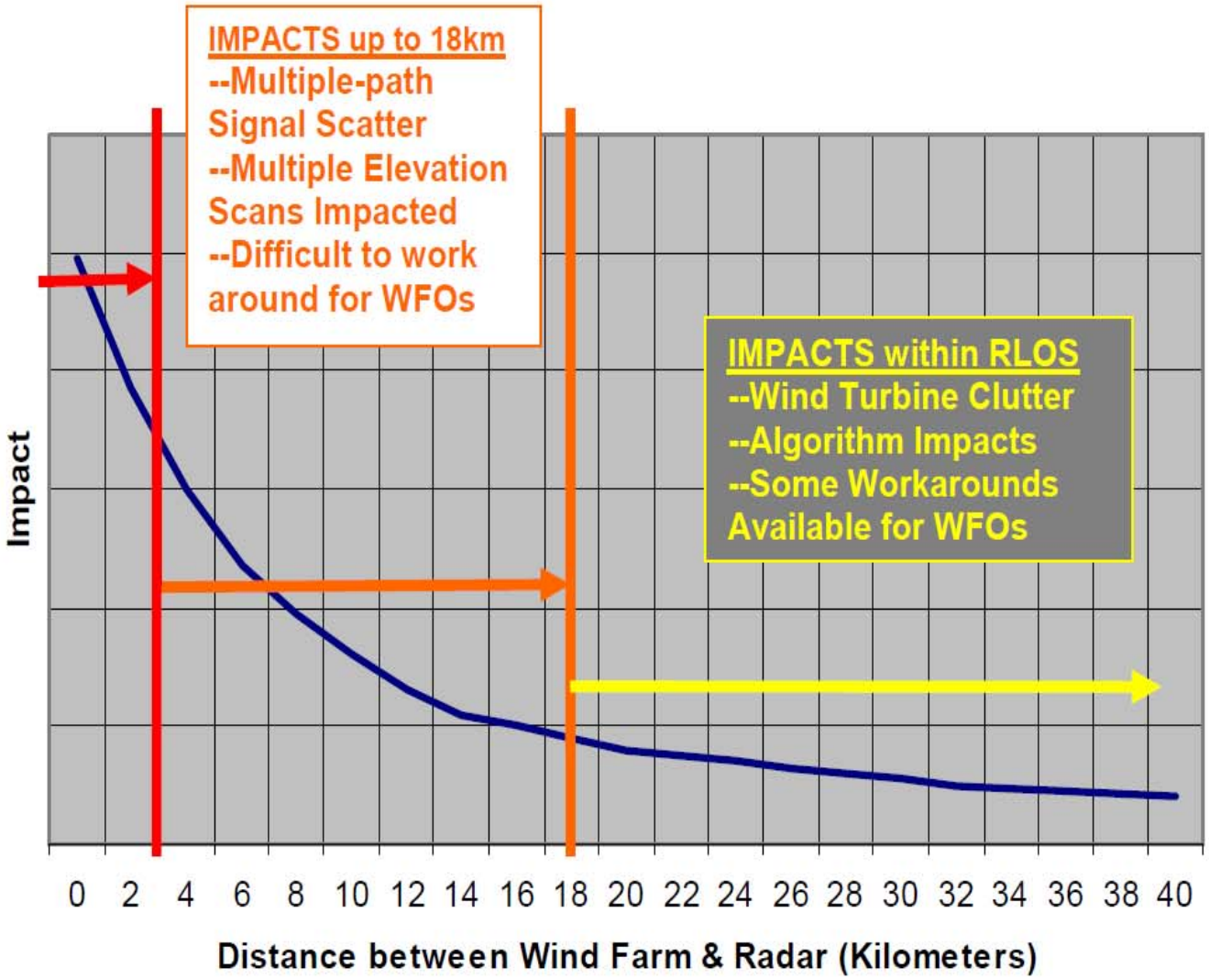
# ESTIMATED WIND TURBINE IMPACT

**IMPACTS up to 3km**
--Radar Receiver Damage (within 200 m)

--Radar Beam Formation (within 1.5 km)

--Partial Attenuation of Radar Beam (within 3 km)

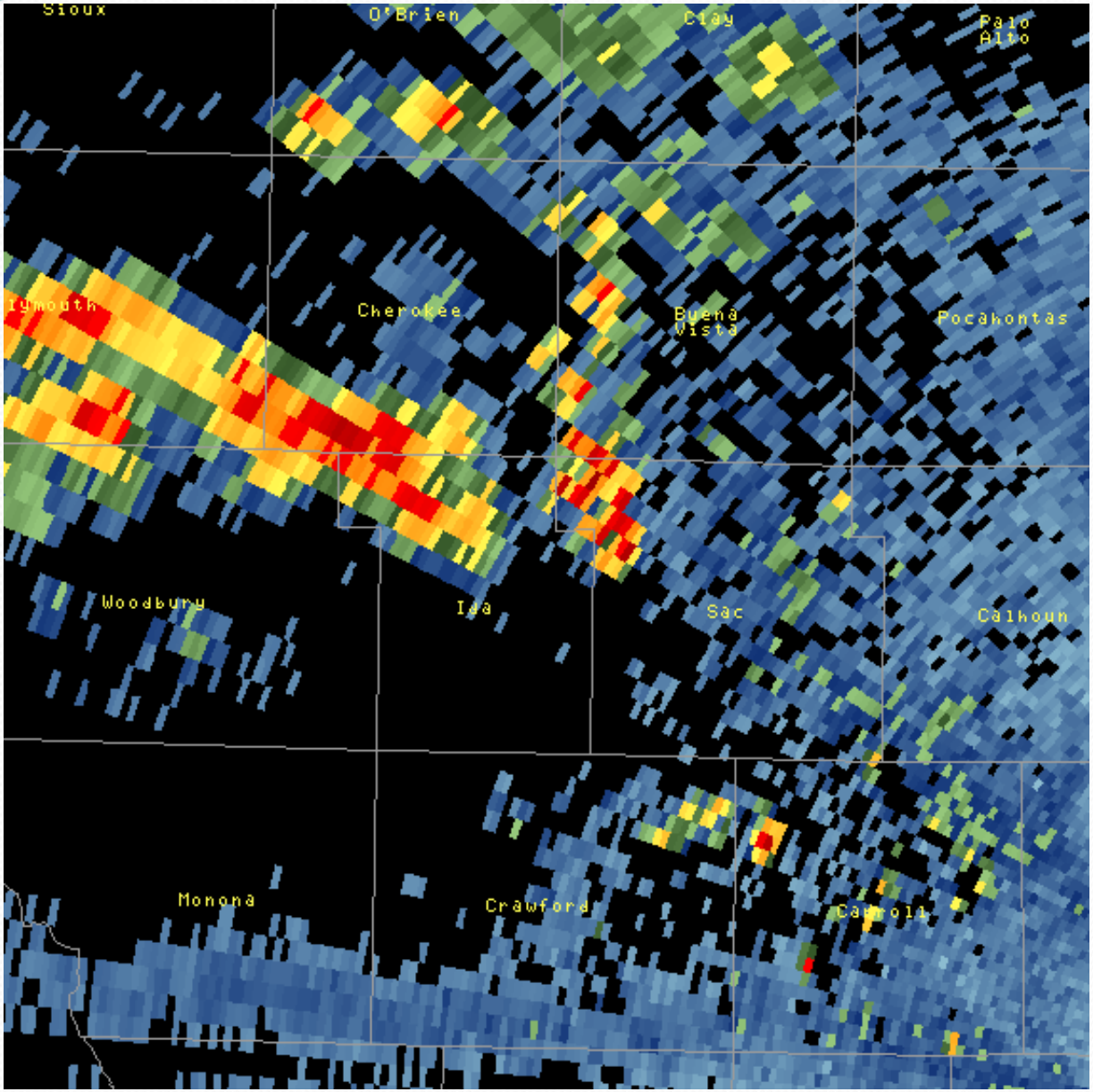
--Limited or No Workarounds for WFOs



# The Impact of the Carroll County, IA Wind Farms on the Des Moines WFO's WSR-88D Doppler Weather Radar
# July 19, 2007

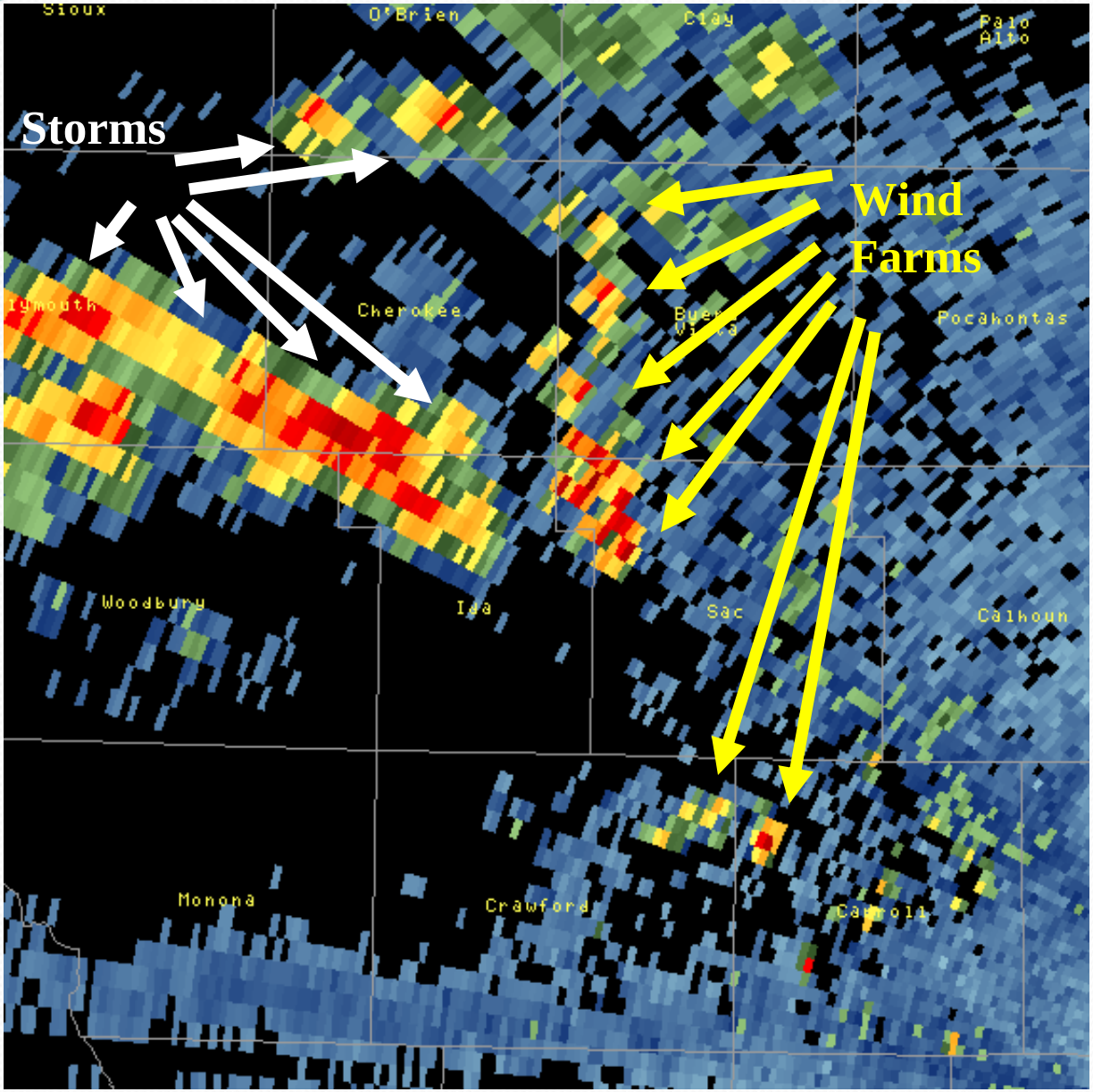
By Karl Jungbluth
Science and Operations Officer (SOO)
National Weather Service, Des Moines, IA

# Reflectivity – 02:36 Zulu July 19, 2007



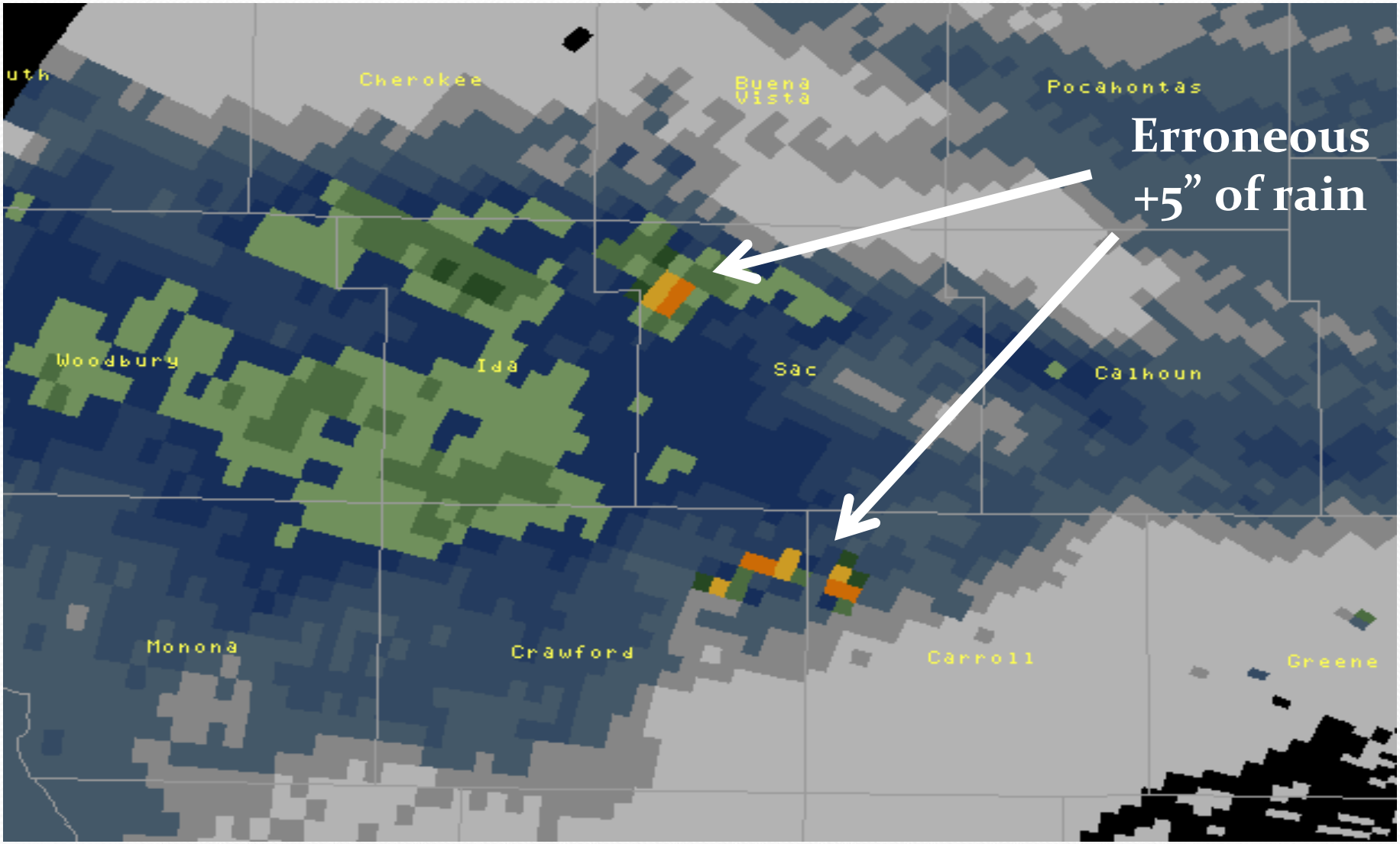

- Real storms or wind farms?
- Caused confusion to an emergency manager
- Question sent to webmaster from a confused user unable who had trouble differentiating between storms and false echoes

# Reflectivity – 02:36 Zulu July 19, 2007

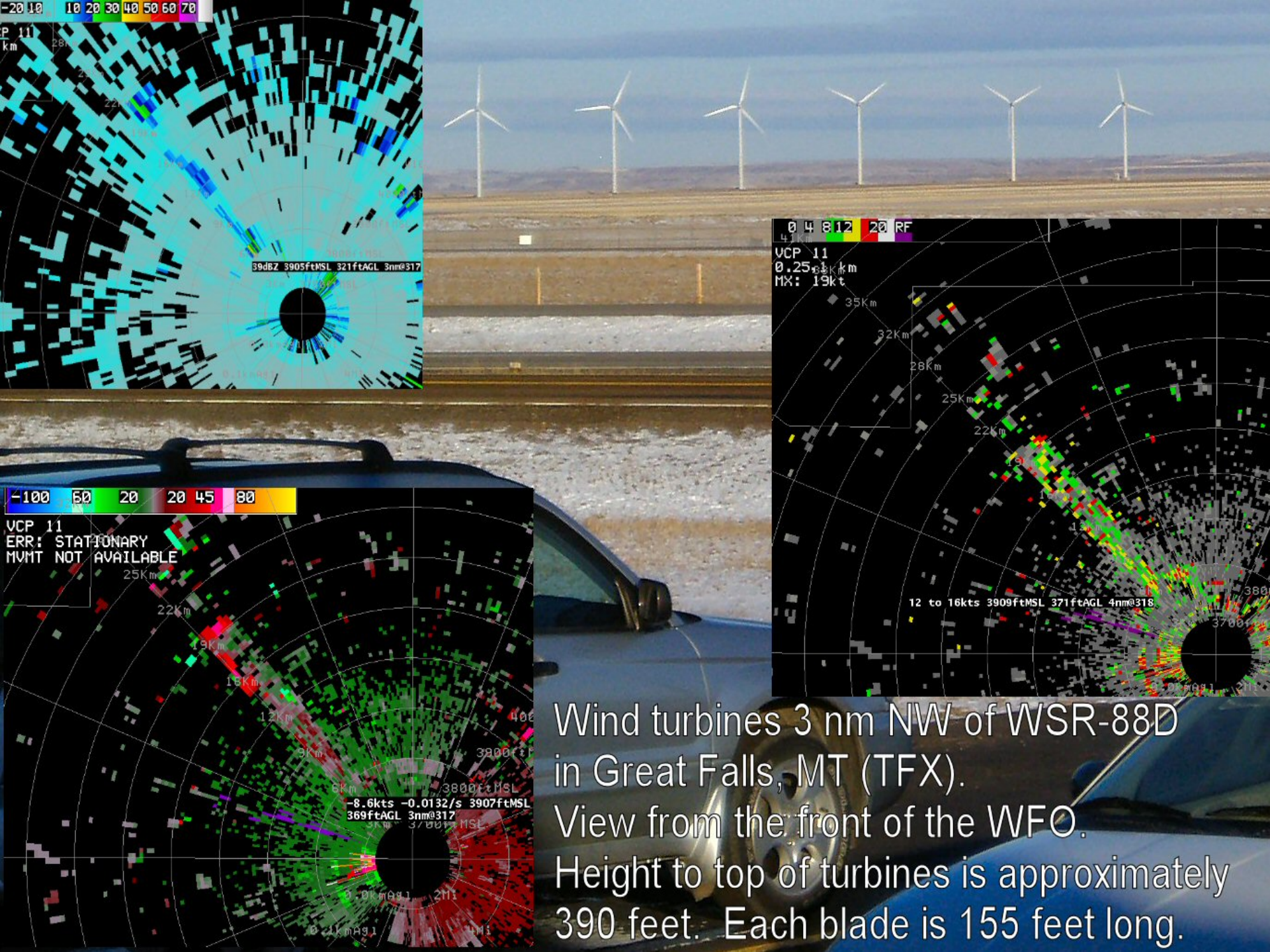



- Untrained eyes having difficulty differentiating between weather and wind farms.
- Trained eyes have difficulty getting accurate echoes near or downrange of medium to high impact wind farms.

# Radar Estimated Storm Total Precipitation
# 05:12 Zulu July 19, 2007

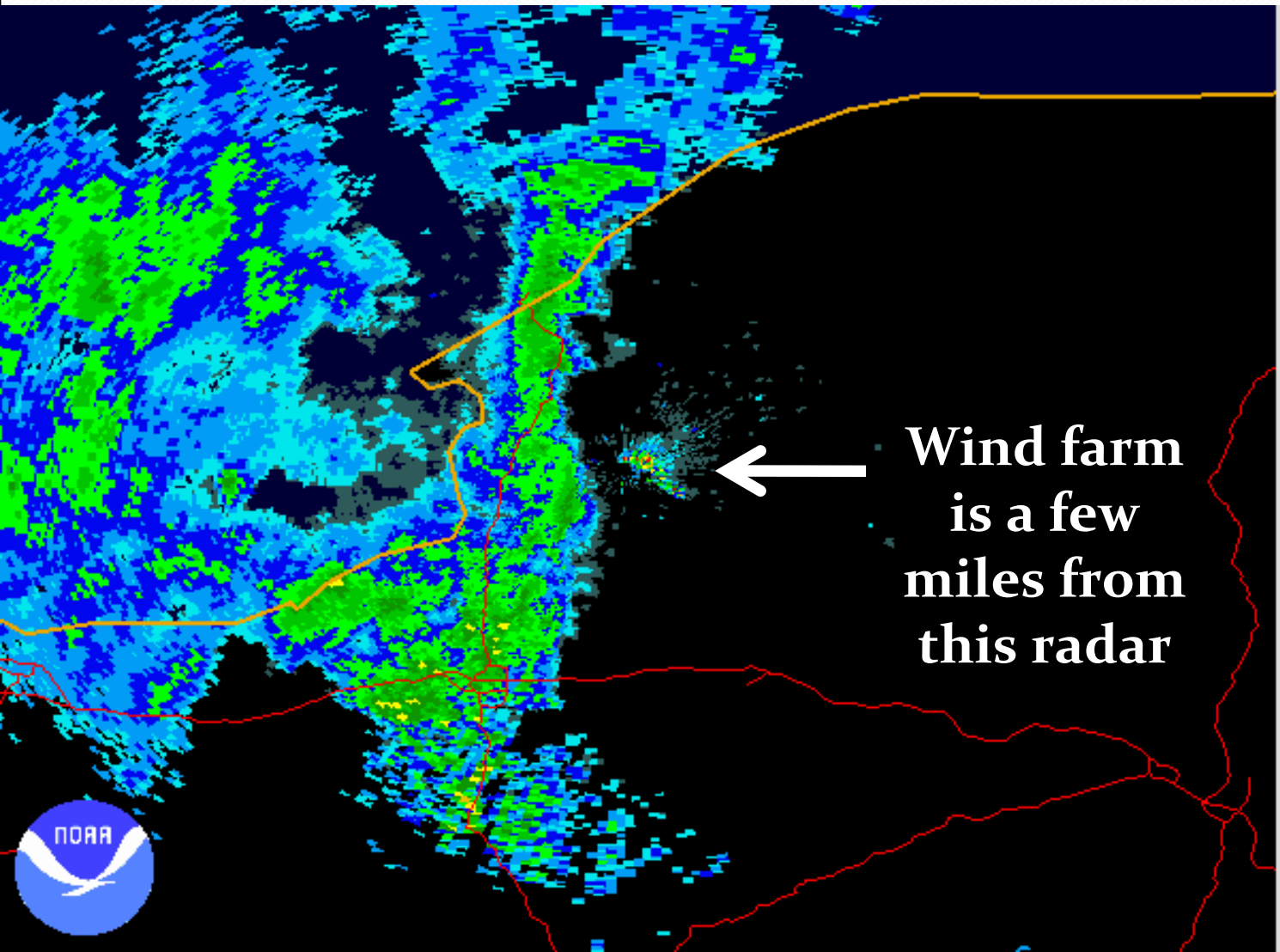


# More Examples




Wind turbines 3 nm NW of WSR-88D in Great Falls, MT (TFX).
View from the front of the WFO.
Height to top of turbines is approximately 390 feet. Each blade is 155 feet long.

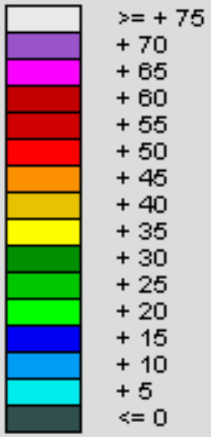
# Reflectivity from the Fort Drum, NY WSR-88D Radar
# 12:34 Zulu March 10, 2007



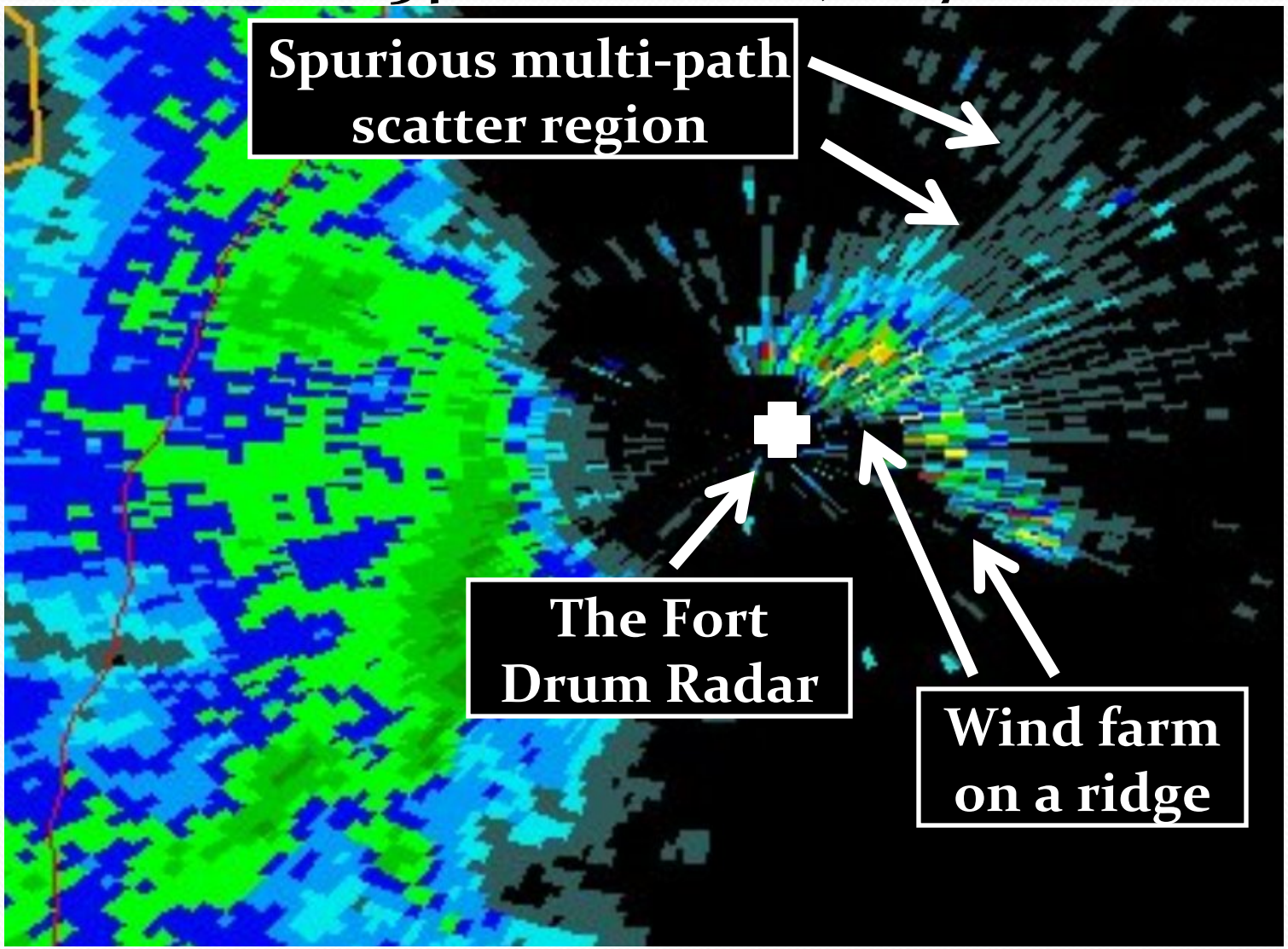

NEXRAD LEVEL-II
KTYX - FORT DRUM, NY
03/10/2007 12:34:53 GMT
LAT: 43/45/21 N
LON: 75/40/48 W
ELEV: 1846.0 FT
VCP: 21

REFLECTIVITY
ELEV ANGLE: 0.48
SCAN TIME: 12:34:52

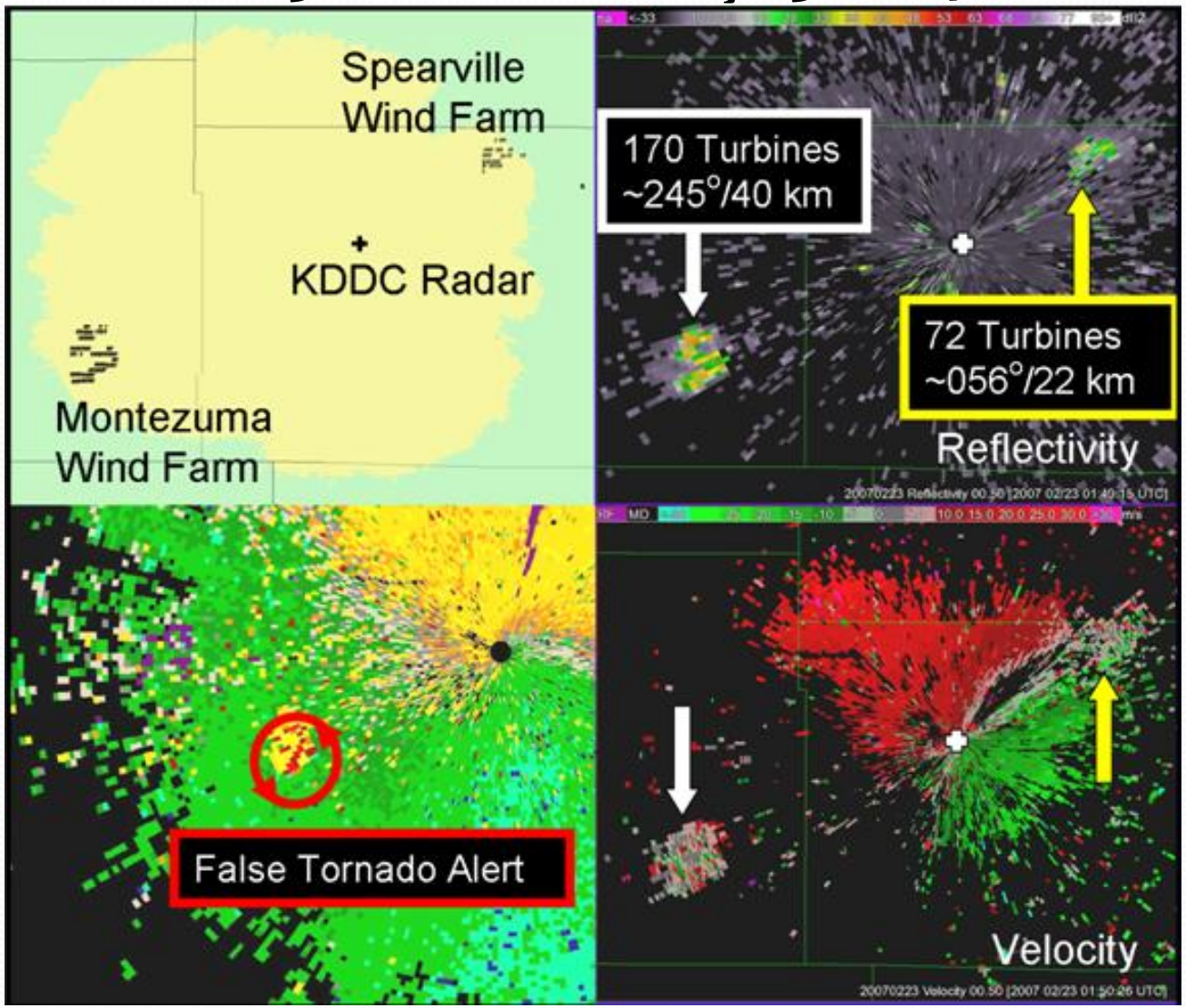
Legend: (Category) dBZ



# Reflectivity from the Fort Drum, NY WSR-88D Radar
## 12:34 Zulu March 10, 2007



# False Tornado Alert on Dodge City, KS WSR-88D Radar 01:50 Zulu February 23, 2007



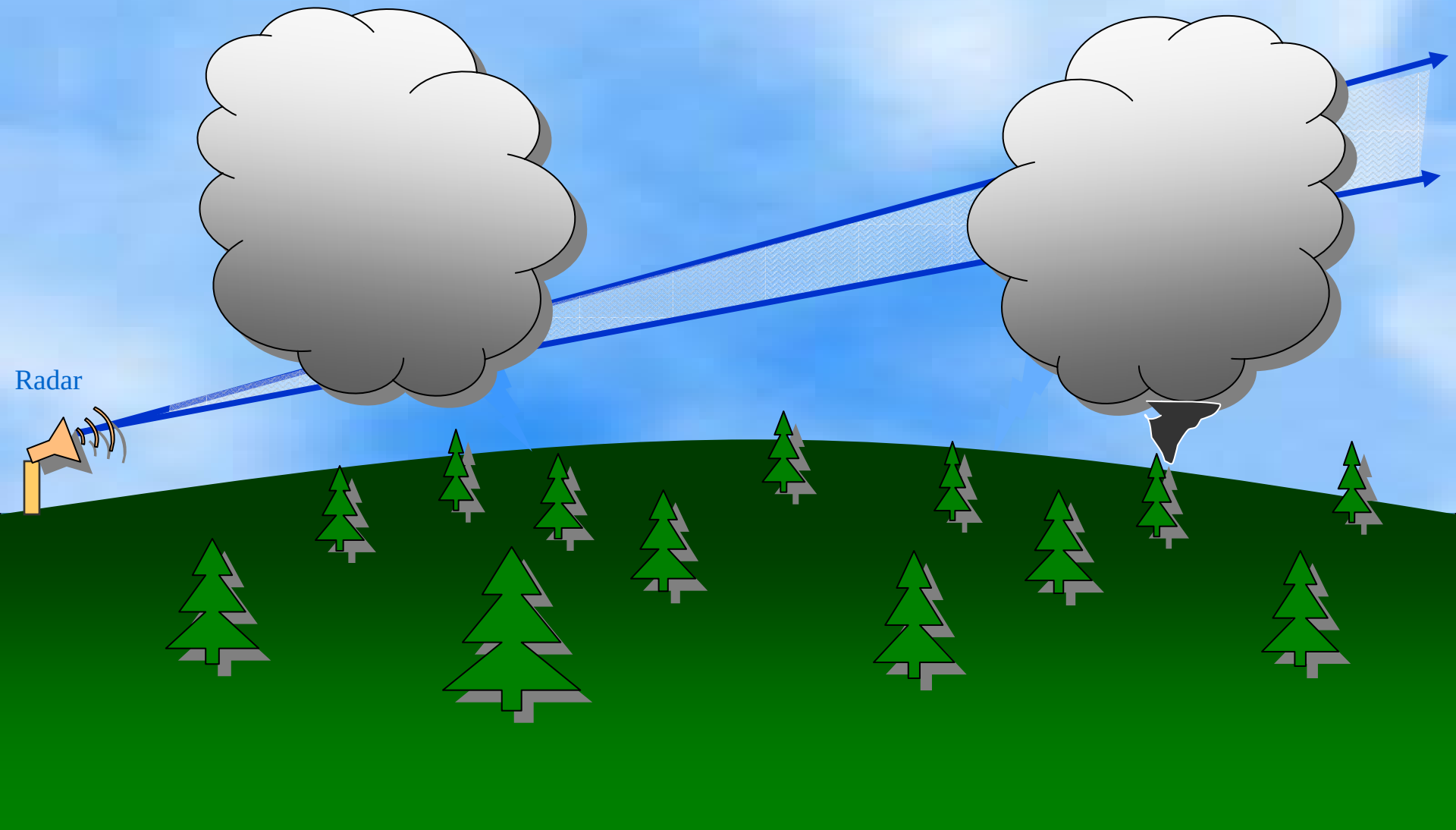
# NWS's Radar Operations Center (ROC)

- A sub-entity within the NWS that provides centralized meteorological, software, maintenance, and engineering support for the network of WSR-88D weather radars.
- It assesses impacts wind farms will have on weather radars.
- It helps to find mutually beneficial solutions for wind farm developers and radar users/operators.
- It educates the public and developers about wind farm and weather radar interaction.

# ROC and Wind Farm Siting Proposals

- **Formal Process:** Developers voluntarily submit wind farm proposals to the Department of Commerce, a process recognized by the American Wind Energy Association's Wind Siting Handbook. The ROC then becomes involved in finding solutions.
- **Informal Process:** Local NWS offices send local news about wind farm development to the ROC. The ROC then contacts the developers.

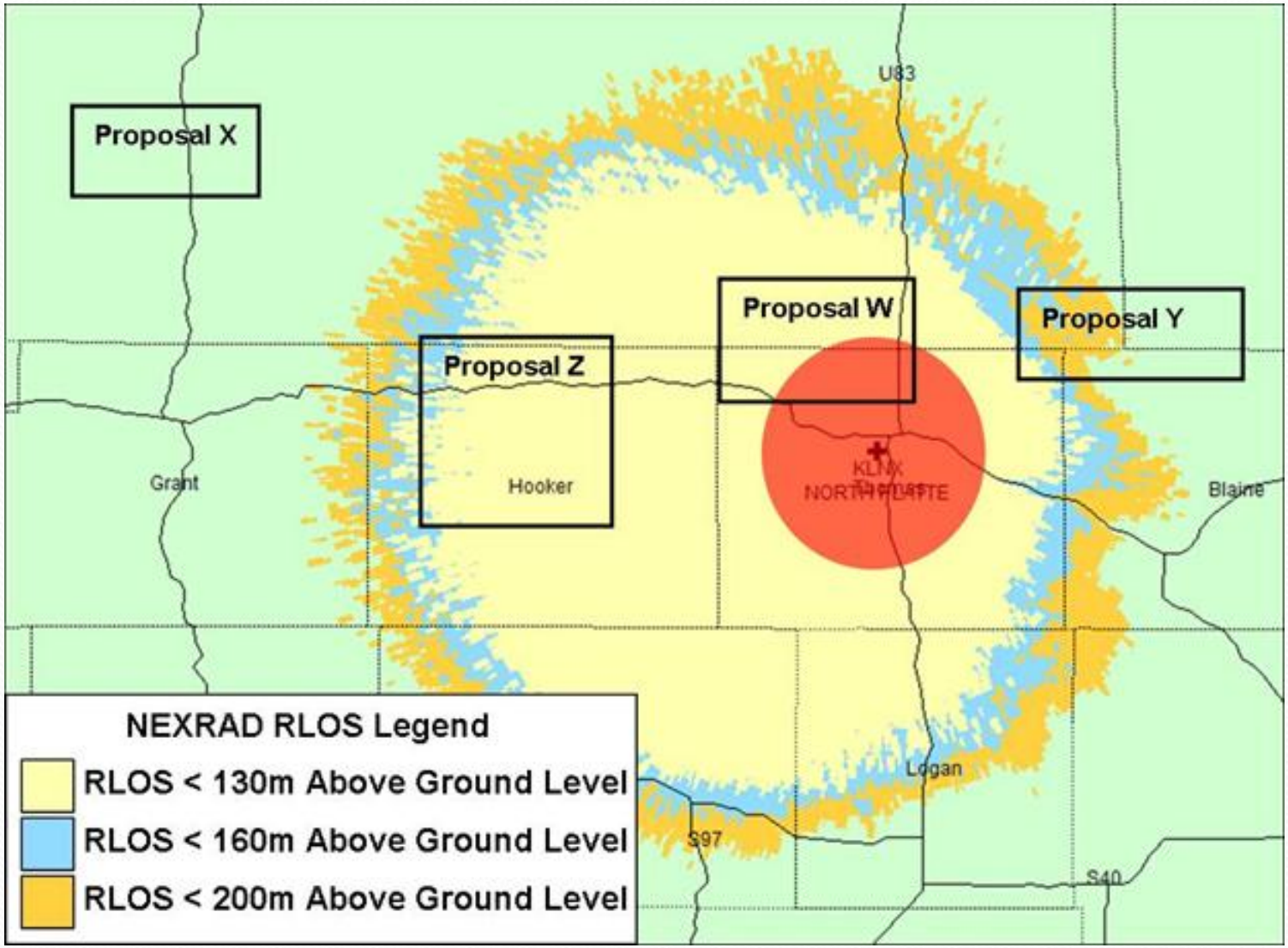
# Radar Horizon



# Radar Line of Sight (RLOS)

- The ROC uses a GIS database (made from the Space Shuttle Radar Topography Mission) to create RLOS maps for weather radars.
- RLOS maps delineate areas corresponding to turbine heights of 130, 160, and 200 meters above ground level (AGL).

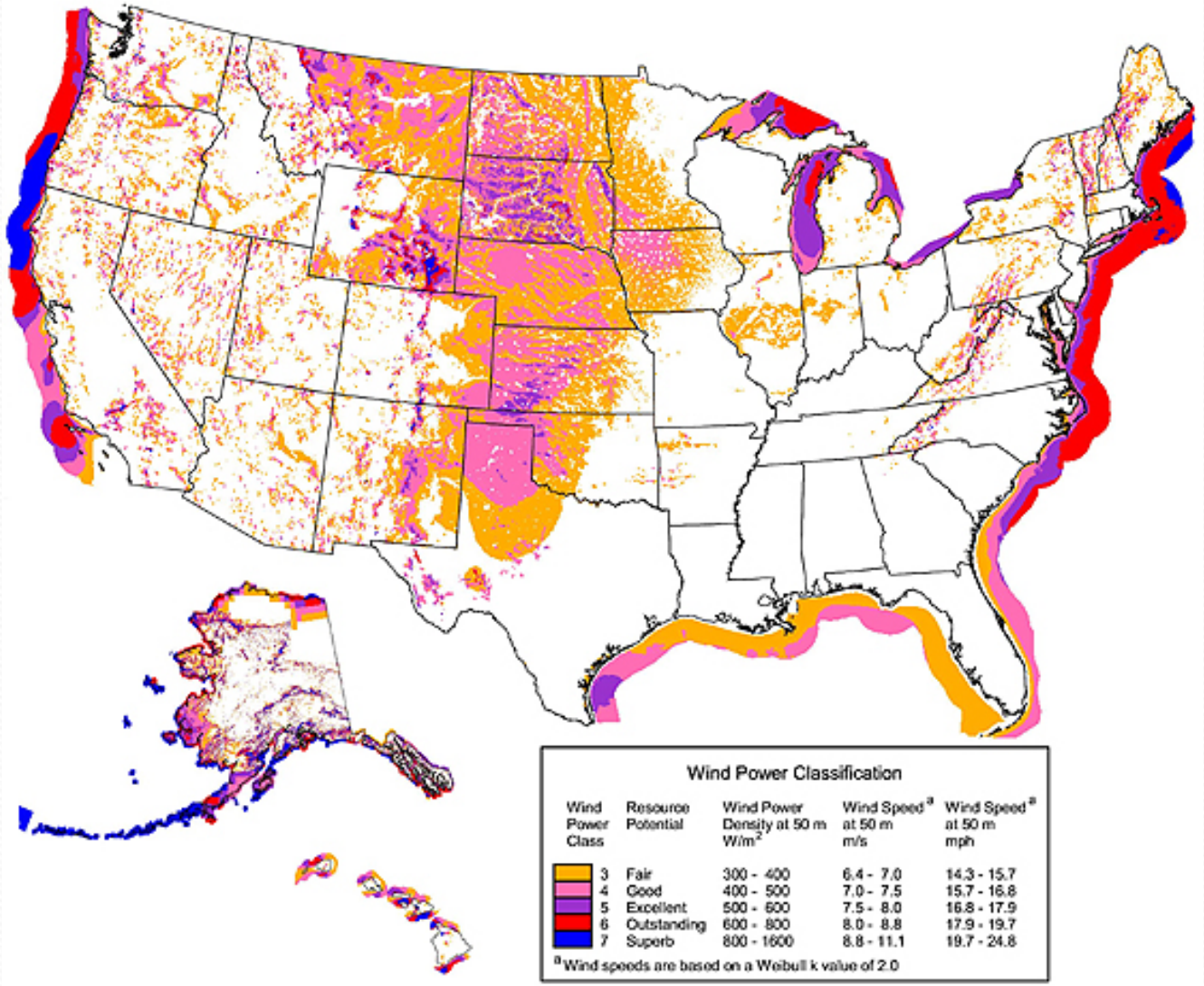
# Typical RLOS Map



# Considerations in ROC Analyses

- Distance of the radar to wind turbines
- Maximum height of wind turbine blades
- Blade intrusion into the RLOS
- Elevation of local WSR-88D radar
- Terrain
- Size of the Wind Farm
- Wind farm orientation to the radar
- Severe weather climatology
- Operational experience of the meteorologists

# United States Wind Power Potential

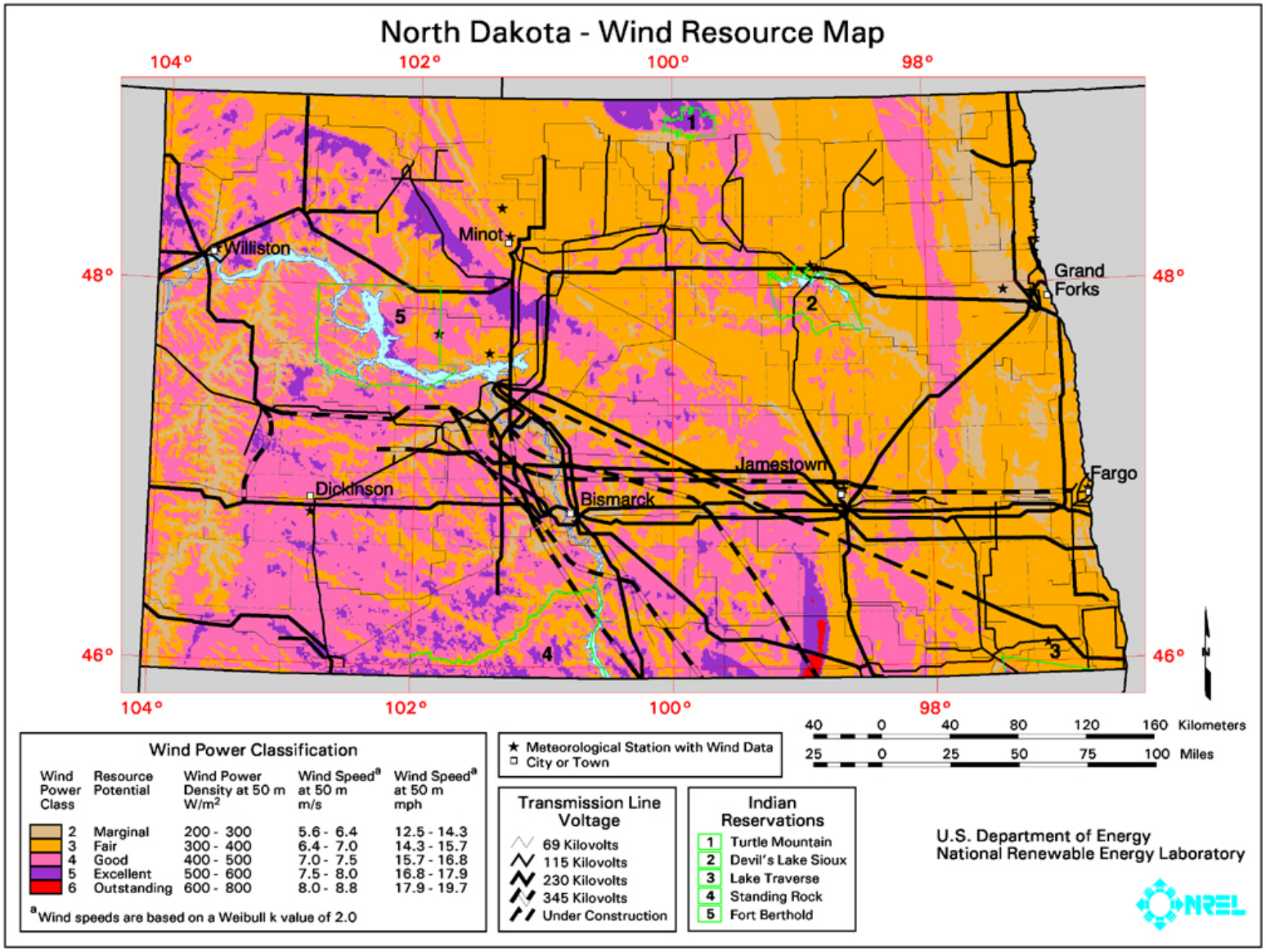


Wind Power Classification

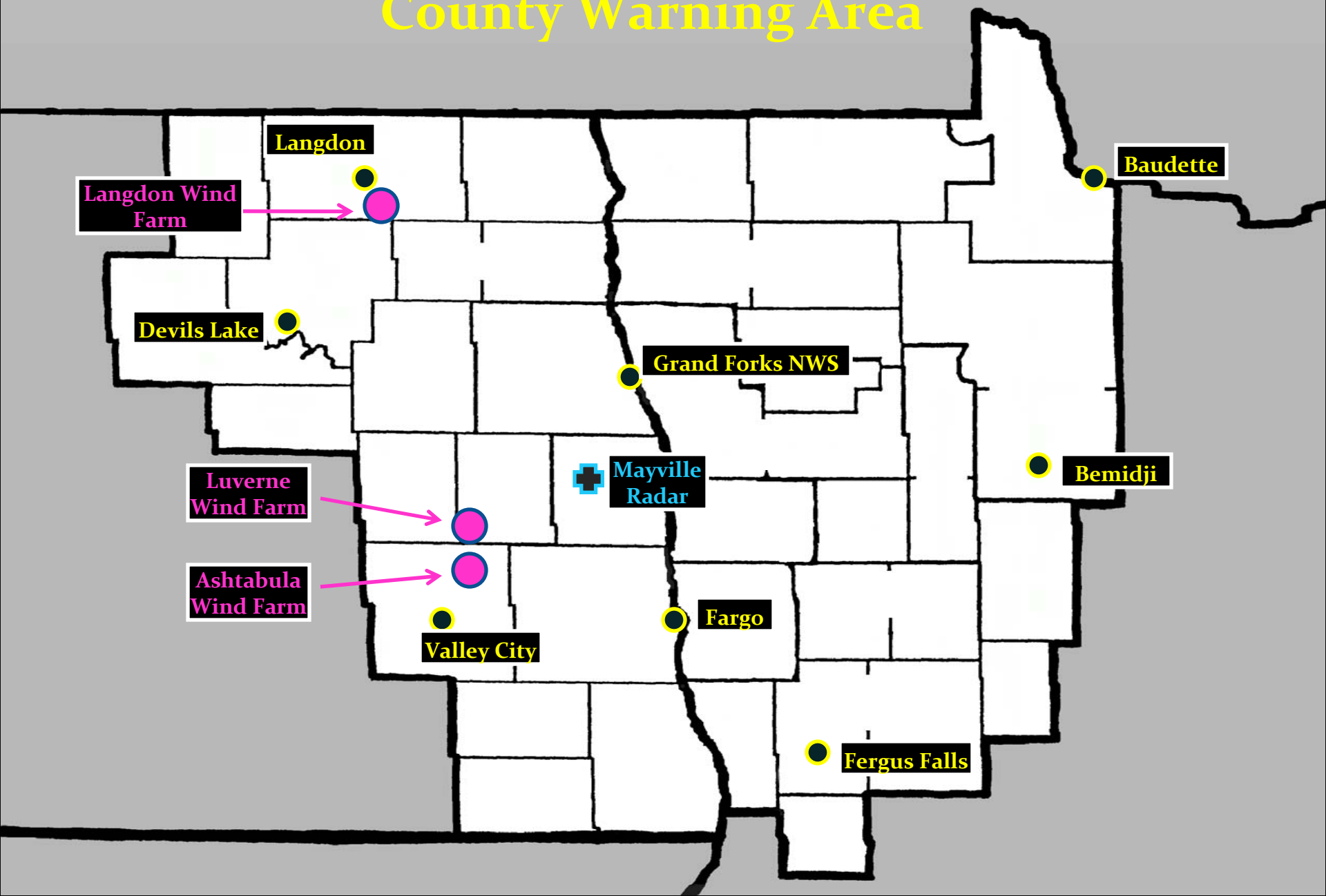
| Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m$^2$ | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph |
|---|---|---|---|---|
| 3 | Fair | 300 - 400 | 6.4 - 7.0 | 14.3 - 15.7 |
| 4 | Good | 400 - 500 | 7.0 - 7.5 | 15.7 - 16.8 |
| 5 | Excellent | 500 - 600 | 7.5 - 8.0 | 16.8 - 17.9 |
| 6 | Outstanding | 600 - 800 | 8.0 - 8.8 | 17.9 - 19.7 |
| 7 | Superb | 800 - 1600 | 8.8 - 11.1 | 19.7 - 24.8 |

[a] Wind speeds are based on a Weibull k value of 2.0

# North Dakota Wind Power Potential



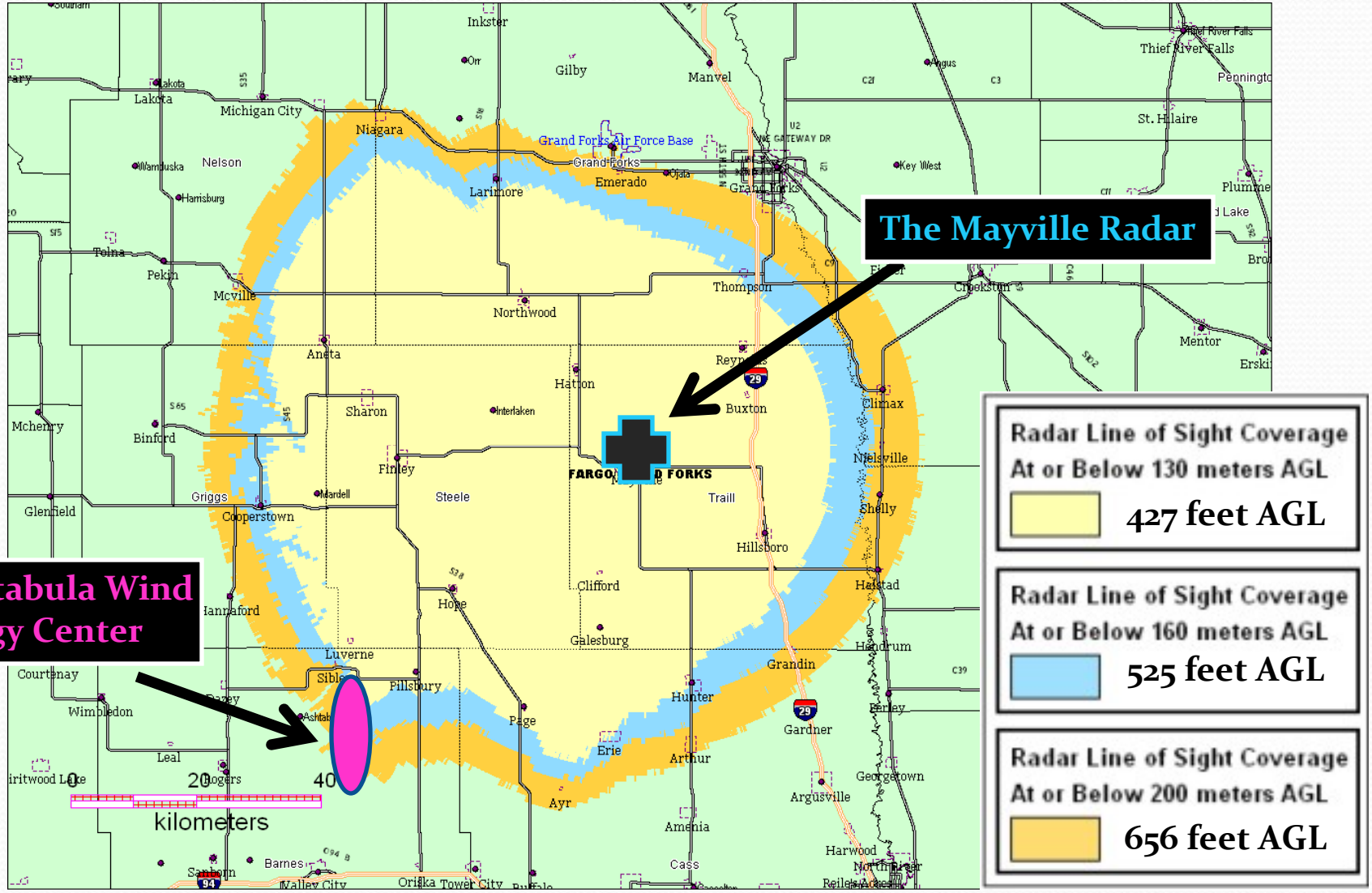
# Wind Farms in the Grand Forks WFO County Warning Area



# Mayville, ND KMVX WSR-88D Weather Radar

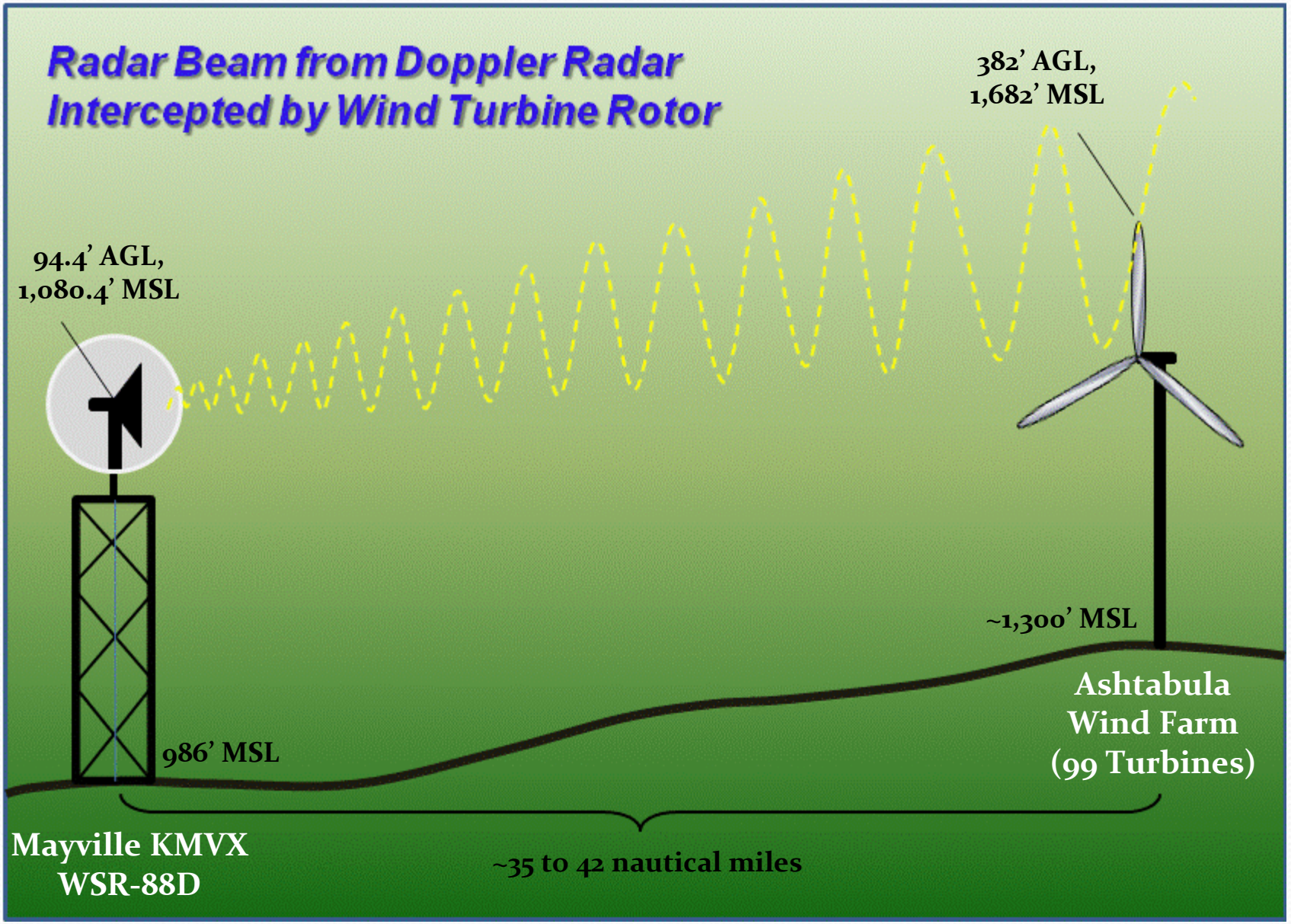
- Our local NOAA Doppler Radar about 30 miles southwest of Grand Forks
- 986 feet above sea level (ASL)
- About 94 feet tower to the center of the radar dome
- Radar beam departs at a height of about 1,080.4 feet

# Mayville KMVX WSR-88D RLOS Map



# Ashtabula Wind Energy Center

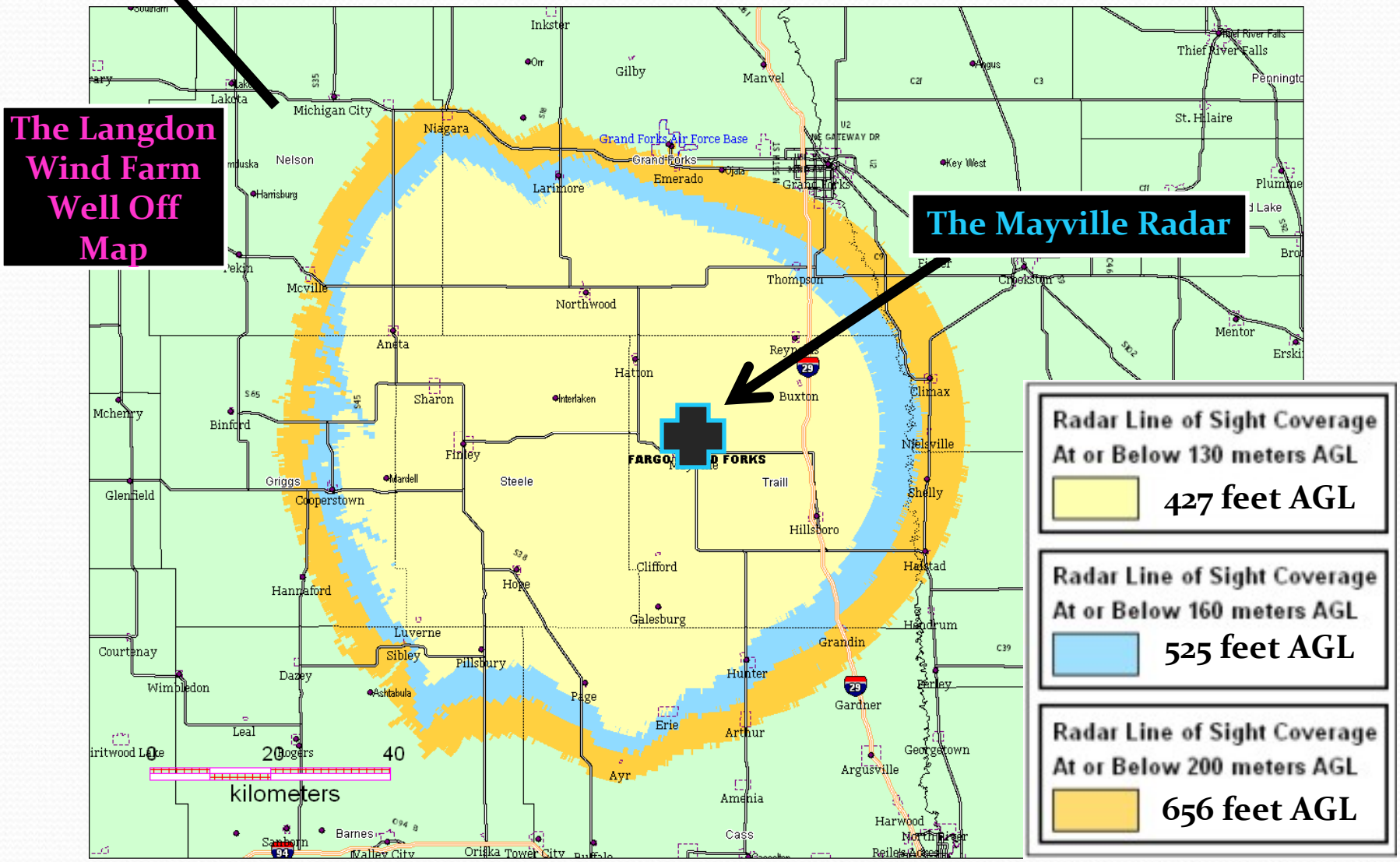
- Low Impact
- 148.5 MW wind farm near Lake Ashtabula
- ~35 to 42 nautical miles from Mayville Radar
- Operational Nov 2008
- 99 turbines (1.5 MW each)
- ~262 feet tall from the ground to the hub
- Shorter blades…~120 feet long
- Blades reach ~382 feet AGL heights


Radar Beam from Doppler Radar
Intercepted by Wind Turbine Rotor
382' AGL,
1,682' MSL
94.4' AGL,
1,080.4' MSL
~1,300' MSL
Ashtabula
Wind Farm
(99 Turbines)
986' MSL
Mayville KMVX
WSR-88D
~35 to 42 nautical miles

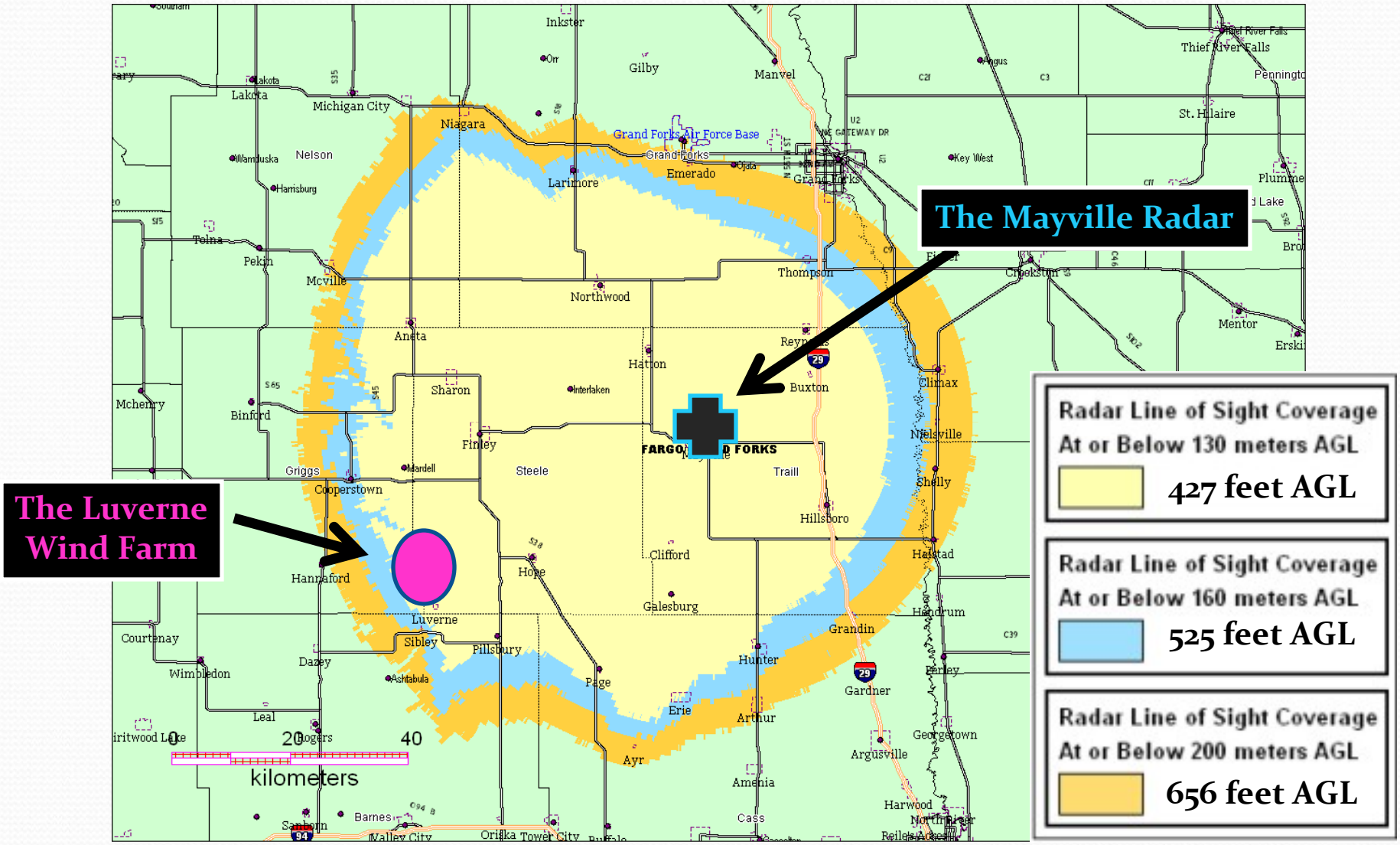
# Langdon Wind Energy Center

- Very Low Impact
- 159 MW wind farm near Langdon, ND
- ~ ? Nautical miles from the Mayville Radar
- Operational Jan 2008
- 106 turbines (1.5 MW each)
- ~262 feet tall from the ground to the hub
- Shorter blades…~120 feet long
- Blades reach ~382 feet AGL heights

# Mayville KMVX WSR-88D RLOS Map

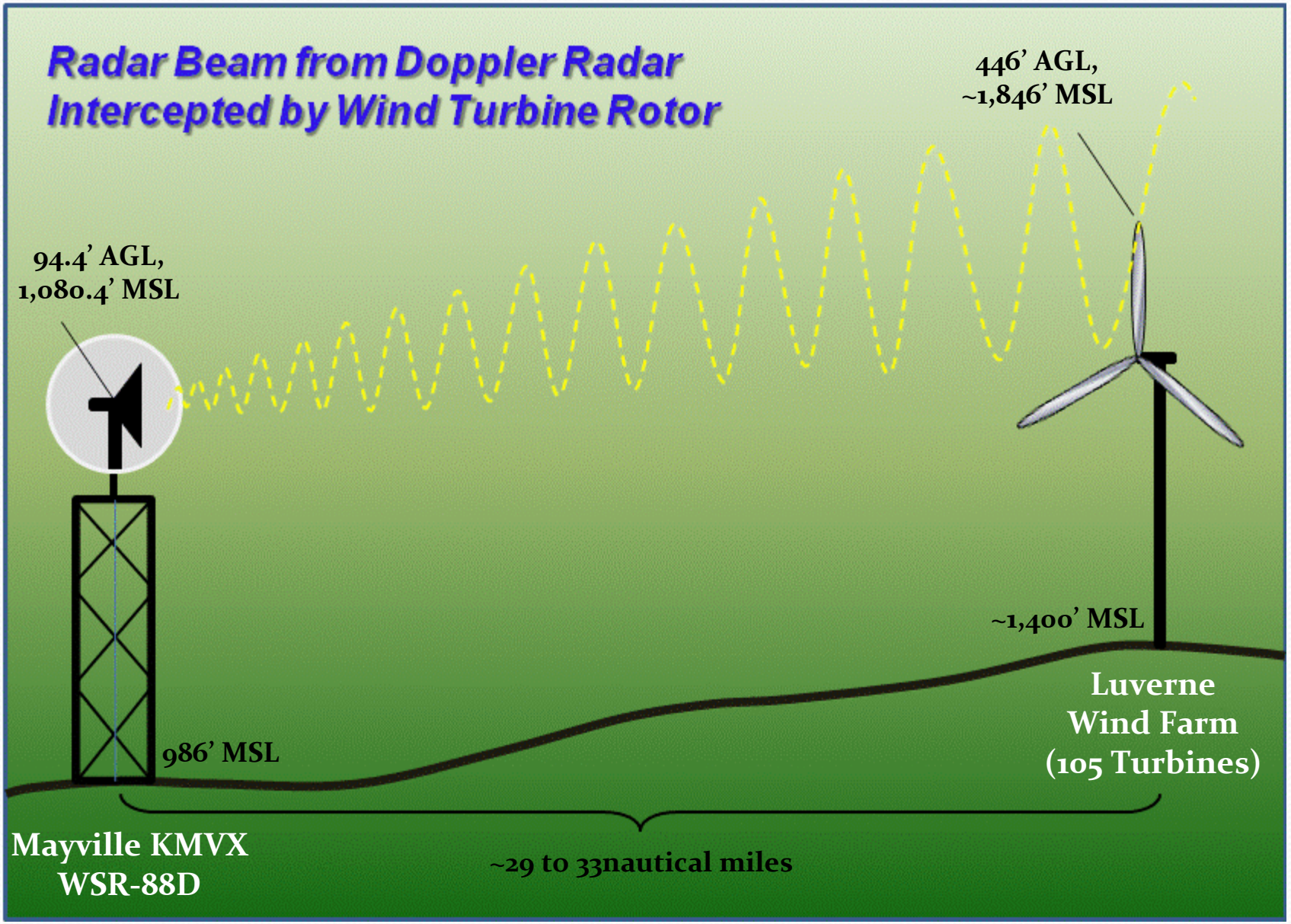


# Mayville KMVX WSR-88D RLOS Map



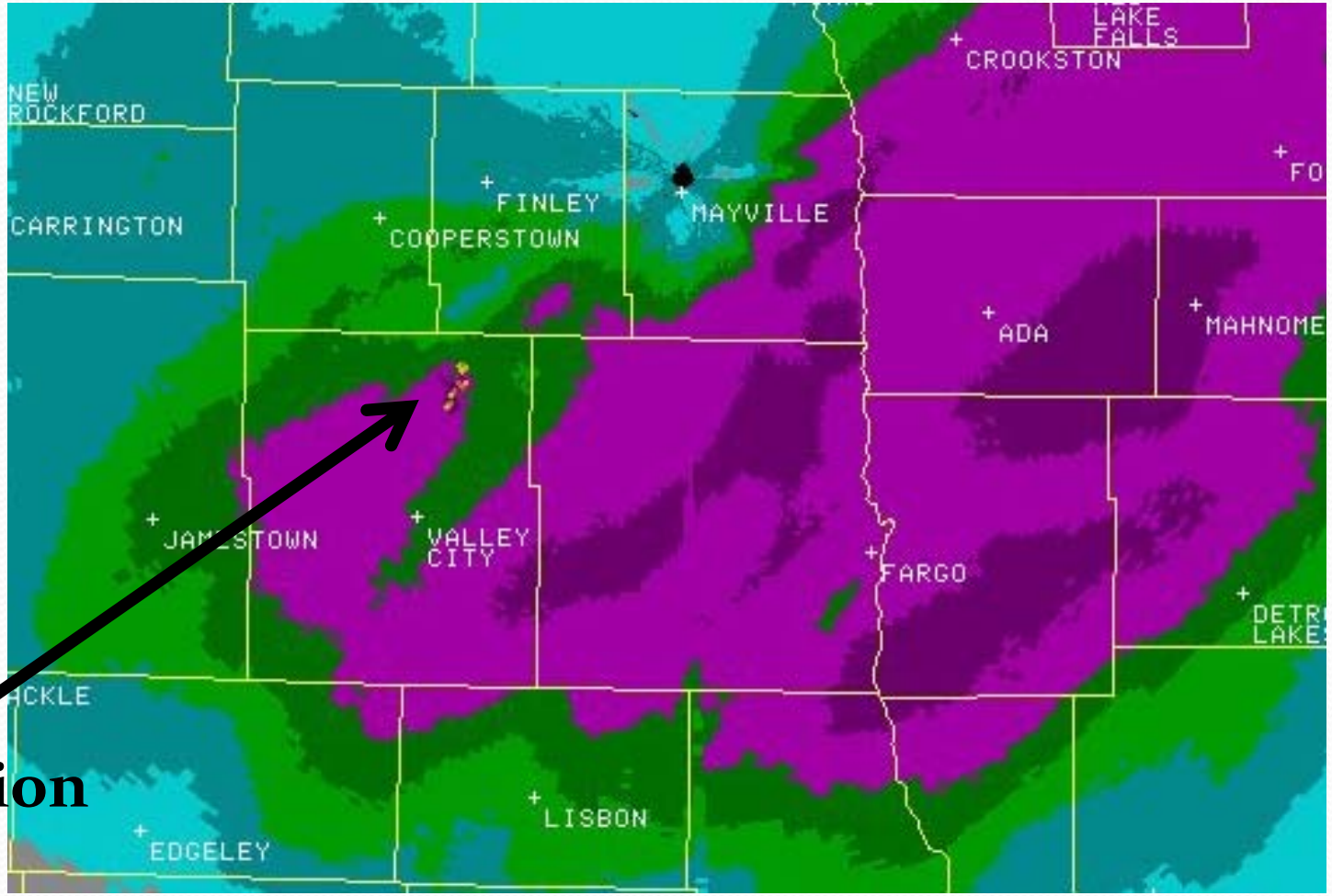
# Luverne Wind Farm

- Low to Medium Impact
- 169.5 MW wind farm near Luverne, ND
- Closest…~29 to 33 nautical miles from Mayville Radar
- Newest to region…Operational Sept 2009
- 105 turbines (1.5 MW each)
- ~262 feet tall from the ground to the hub
- Longest Blades…~184 feet long
- Blades reach ~446 feet AGL heights


Radar Beam from Doppler Radar
Intercepted by Wind Turbine Rotor
446' AGL,
~1,846' MSL
94.4' AGL,
1,080.4' MSL
~1,400' MSL
Luverne
Wind Farm
(105 Turbines)
986' MSL
Mayville KMVX
WSR-88D
~29 to 33nautical miles

# Examples of the Mayville Radar's Perspective on Local Wind Farms

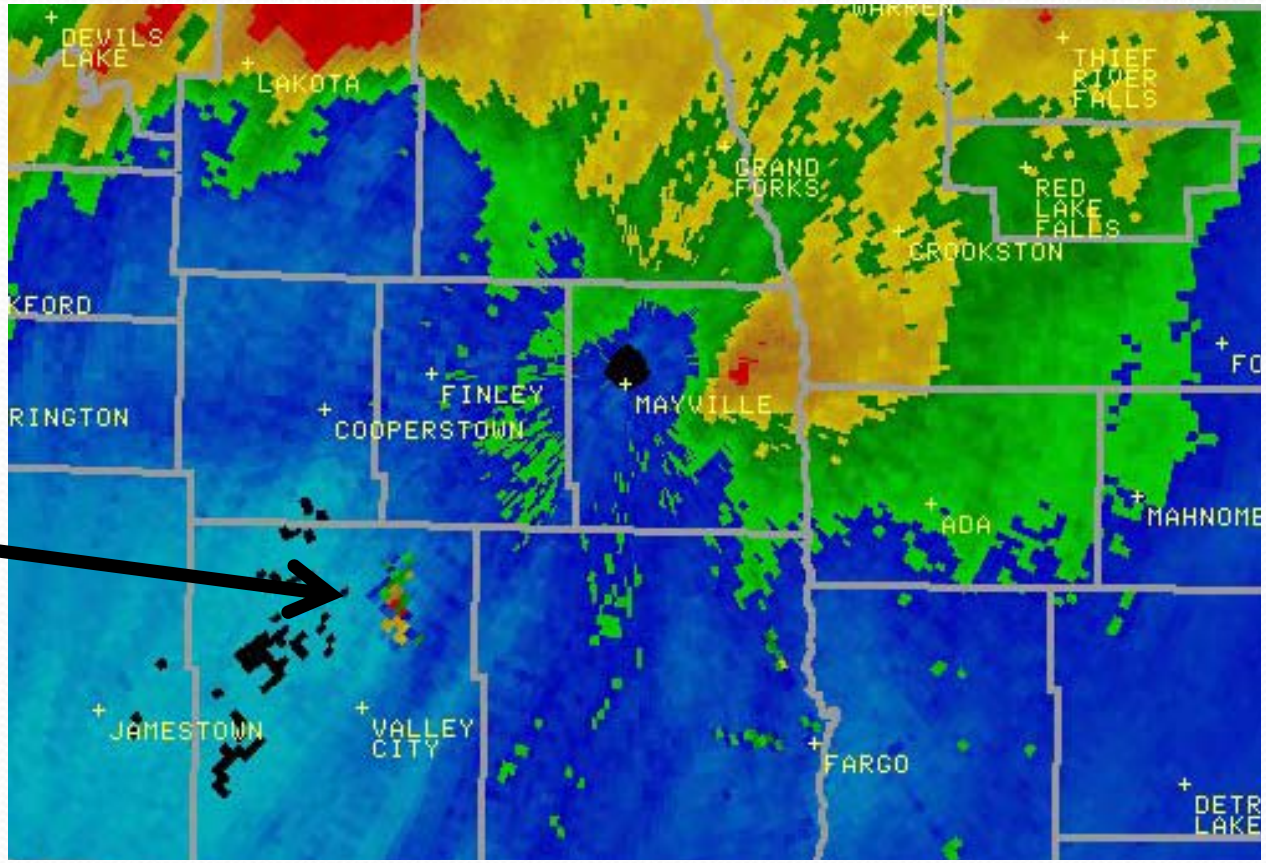
# March 2009 Winter Storm Snowfall Contamination




Contamination

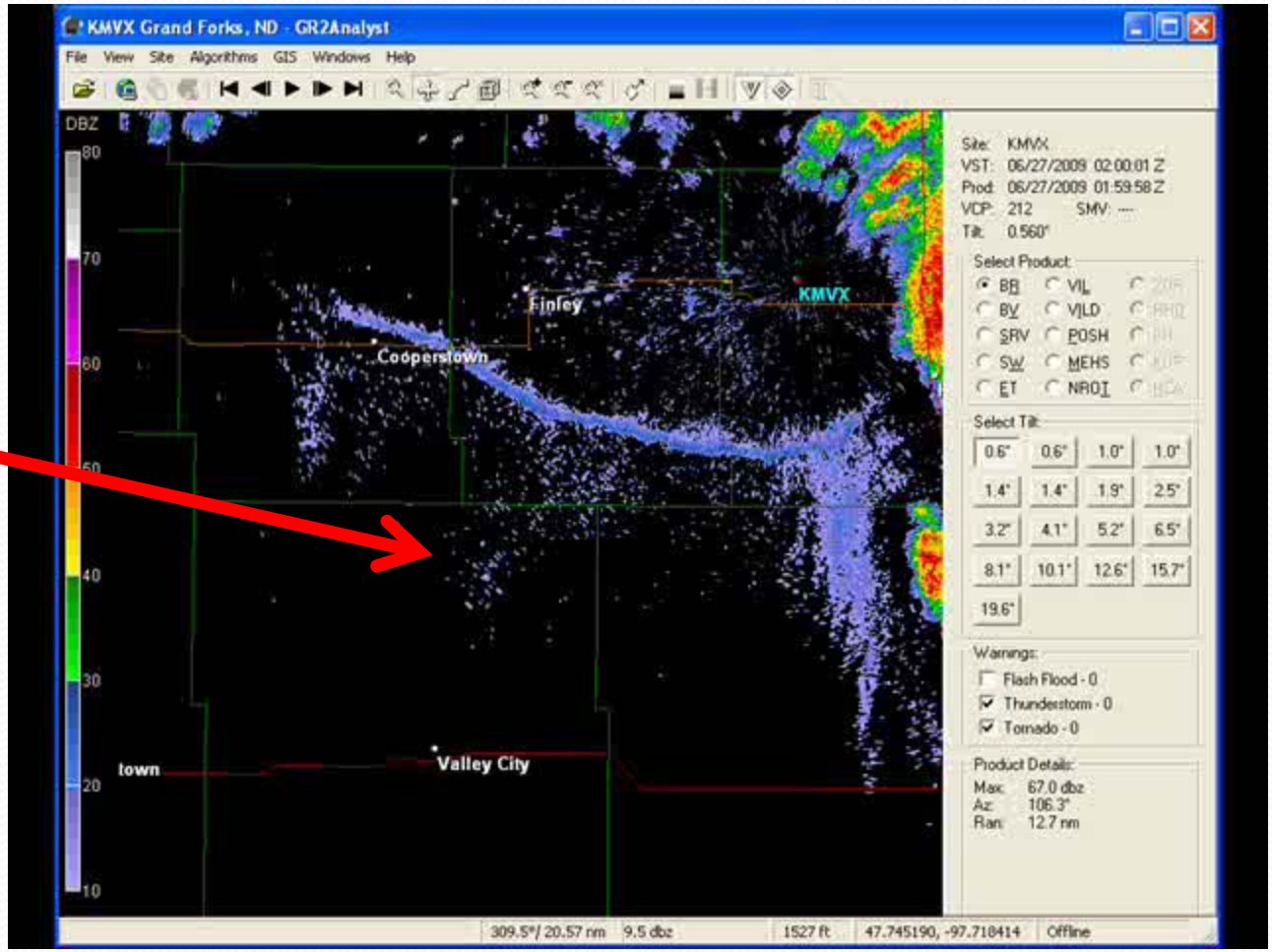
# Radar-Based Rainfall Estimation Contamination

Contamination



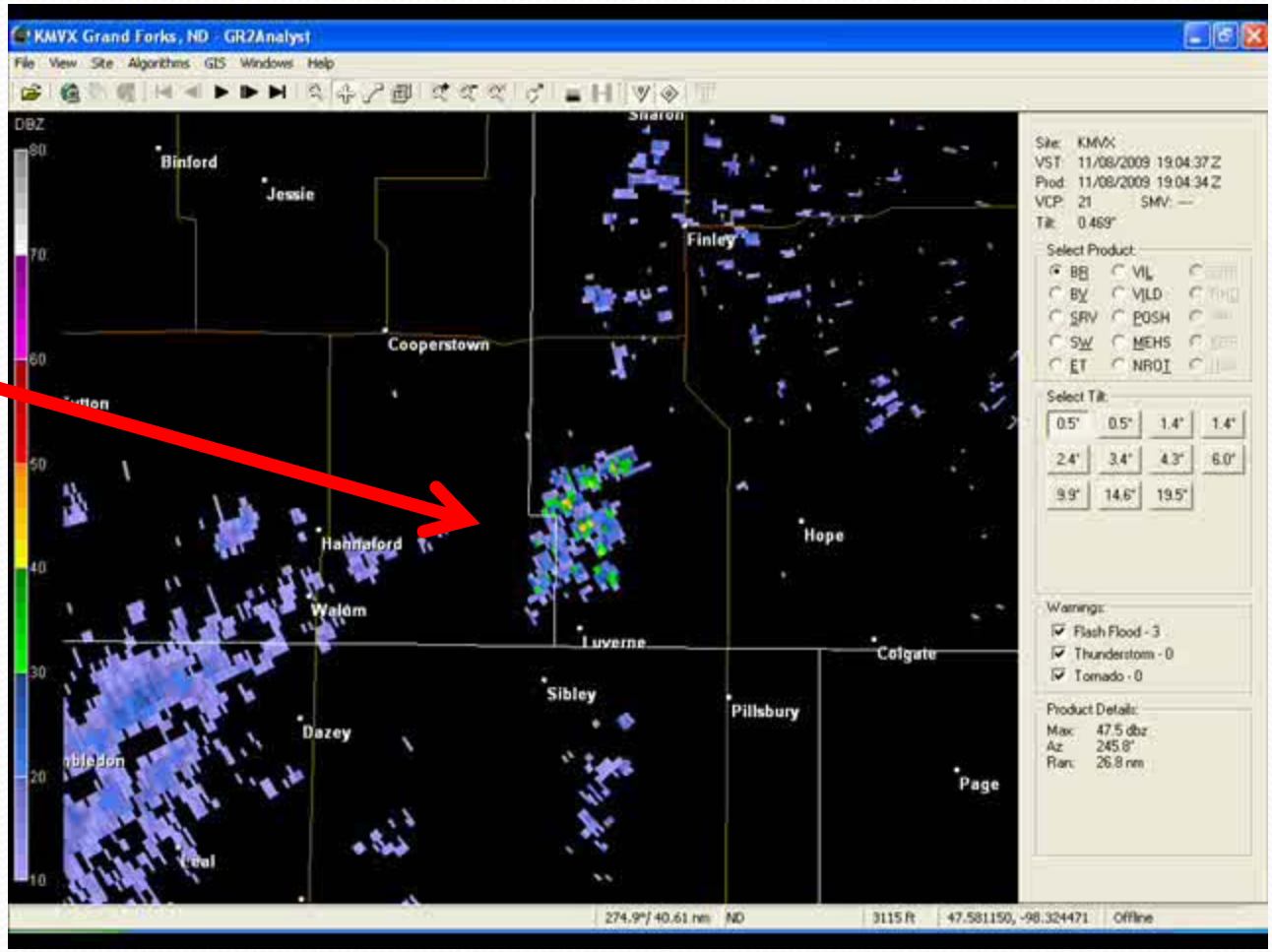
# Base Reflectivity (0.5°) Contamination (Low Impact Situation from Ashtabula Wind Farm)

**Minimal Contamination**



# Base Reflectivity (0.5°) Contamination (Medium Impact Situation from Luverne Wind Farm)

**Medium Contamination**



# ROC Research and Efforts to Find Mutually Beneficial Short-Term Solutions

- Funding studies of signal processing techniques by the Atmospheric Radar Research Center at the University of Oklahoma. One method could be knowledge based, taking in real-time wind turbine data (rotation rate, orientation, etc.)
- Establishing mutually agreed criteria in which wind farms could temporarily cease operations to give WFOs the ability to receive less cluttered radar data, such as in severe weather scenarios.

# OU Research and Efforts to Find Mutually Beneficial Long-Term Solutions

- Oklahoma University's ARCC is investigating the possible use of adaptive null steering with phased array radar.

# For More Information

- The Radar Operations Center's Website: **http://www.roc.noaa.gov/WSR88D/**
- American Wind Energy Association's Wind Siting Handbook