# Next Generation Weather Radar Considerations in the Wind Farm Siting Decision Process

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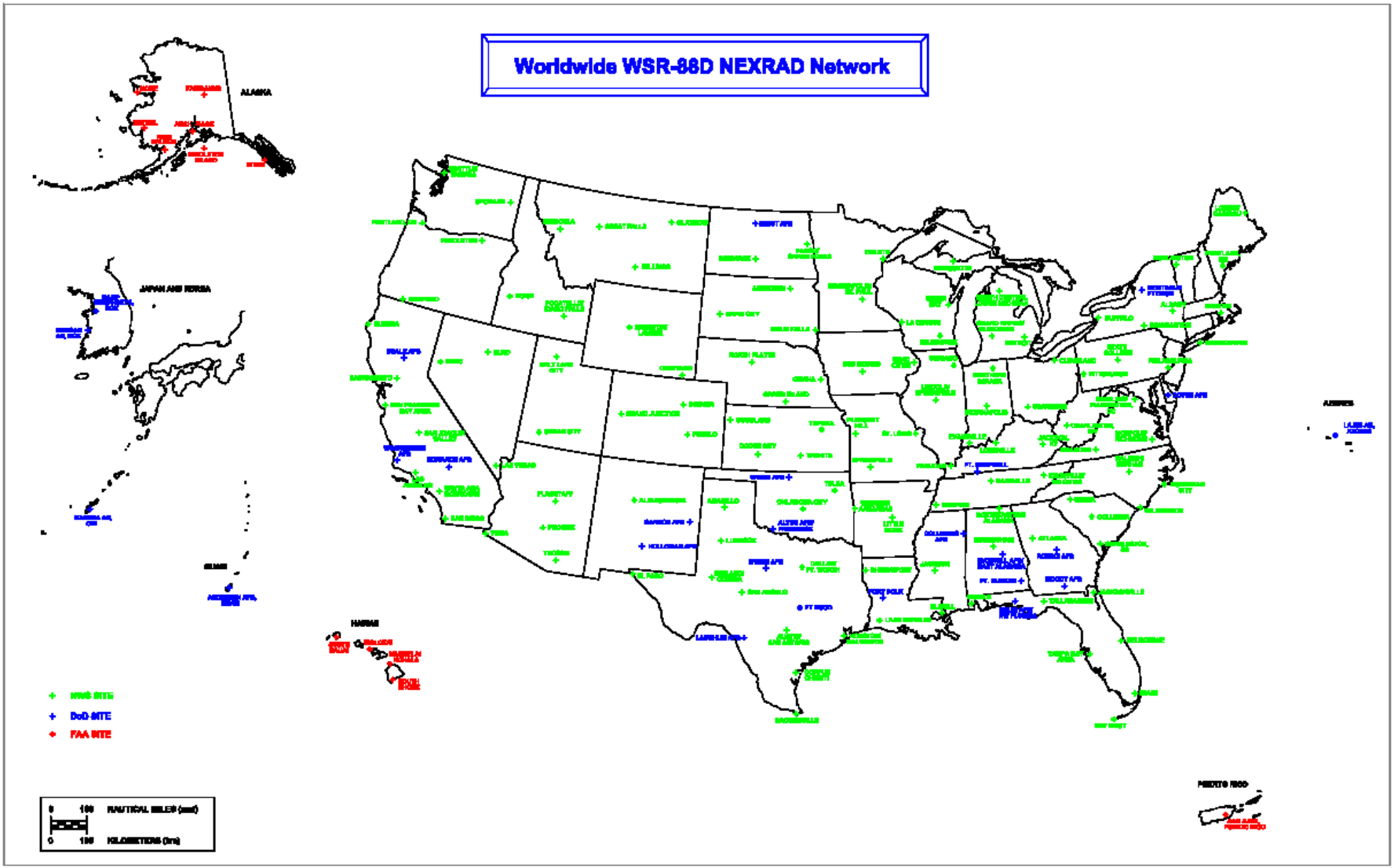
# Overview

- Overview of Next Generation Weather Radar (NEXRAD) mission
- Examples of wind farm/turbine appearance on NEXRAD systems and operational impact
- NEXRAD Program efforts and plans to reach out to wind energy industry and mitigate impacts

# NEXRAD Overview

- NEXRAD (Next Generation Weather Radar) - a joint effort of the DOC, DOD, and DOT (aka Weather Surveillance Radar-1988, Doppler (WSR-88D))
- Network of 141 CONUS, 12 OCONUS, and 5 remote DOD NEXRADs
  - Deployed 1991 - 1997
  - S-band (~10 cm/2700 – 3000 MHz)
  - Klystron transmitter; 750 kw peak power
  - Sensitive receiver; Minimum Detectable Signal ~-113 dBm
  - ~0.95 degree beam width (i.e., radar line of sight, between half power points); our benchmark for requesting further consultation with developers
  - 8.5 m reflector antenna
    - Rotates in automated (user selectable) sequence of 360$^{o}$ scans between 0.5$^{o}$ - 19.5$^{o}$ elevation
  - More info at: http://www.roc.noaa.gov/FMH_11/default.asp


Worldwide WSR-88D NEXRAD Network
ALASKA
JAPAN AND KOREA
HAWAII
GUAM
NWS SITE
DoD SITE
FAA SITE

# NEXRAD Overview

(Continued)

- Cornerstone of:
  - Weather forecasts and severe weather warnings
  - Safe and efficient aircraft operations – supports the National Airspace System
  - Enhancement of national economy – public and private sector use the data
- Significant improvements in severe weather and flash flood warnings – saves lives!
  - 70% increase in tornadoes warned; 80% increase in tornado lead time
  - Tornado casualties reduced: 45% fewer fatalities; 40% fewer injuries

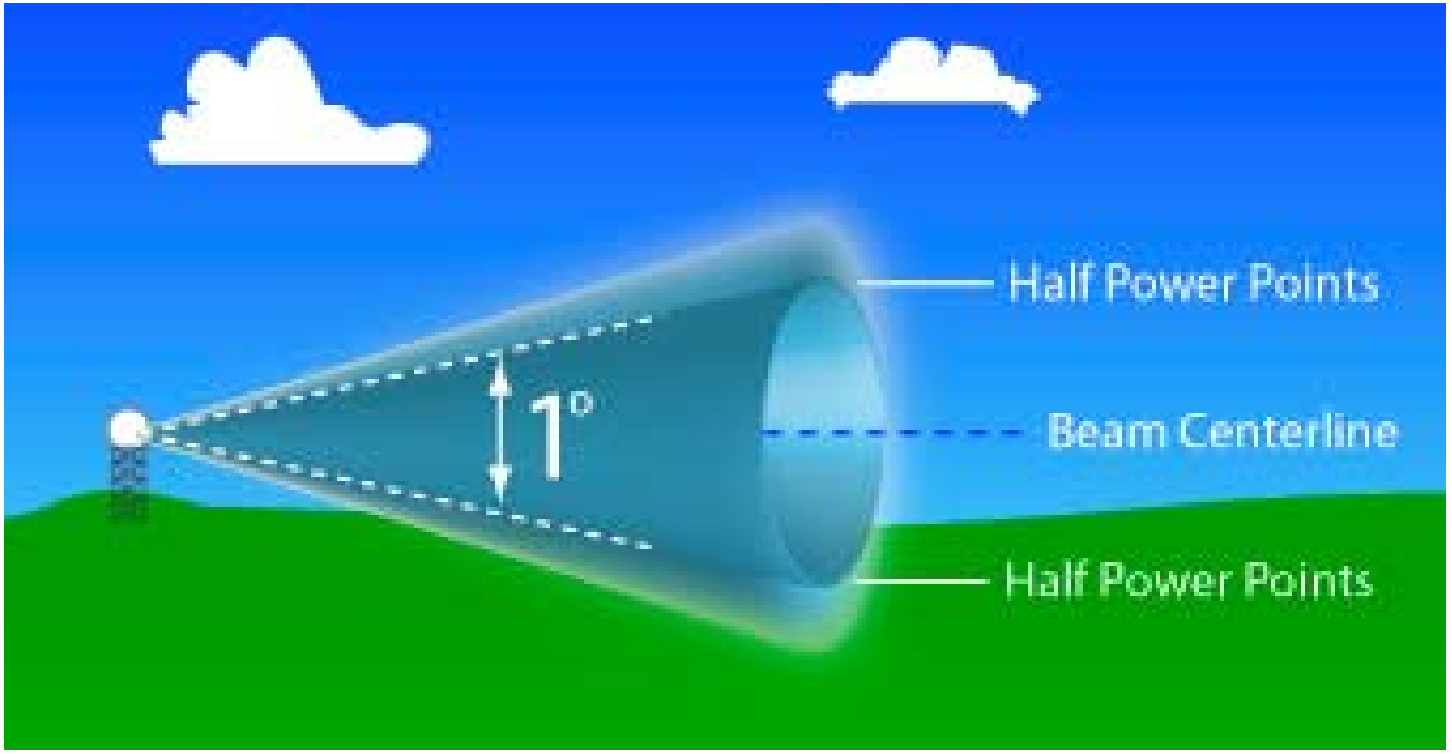
# NEXRAD Overview

## Beam Propagation




# NEXRAD Overview

## Radar Line of Sight

- 

# NEXRAD Overview

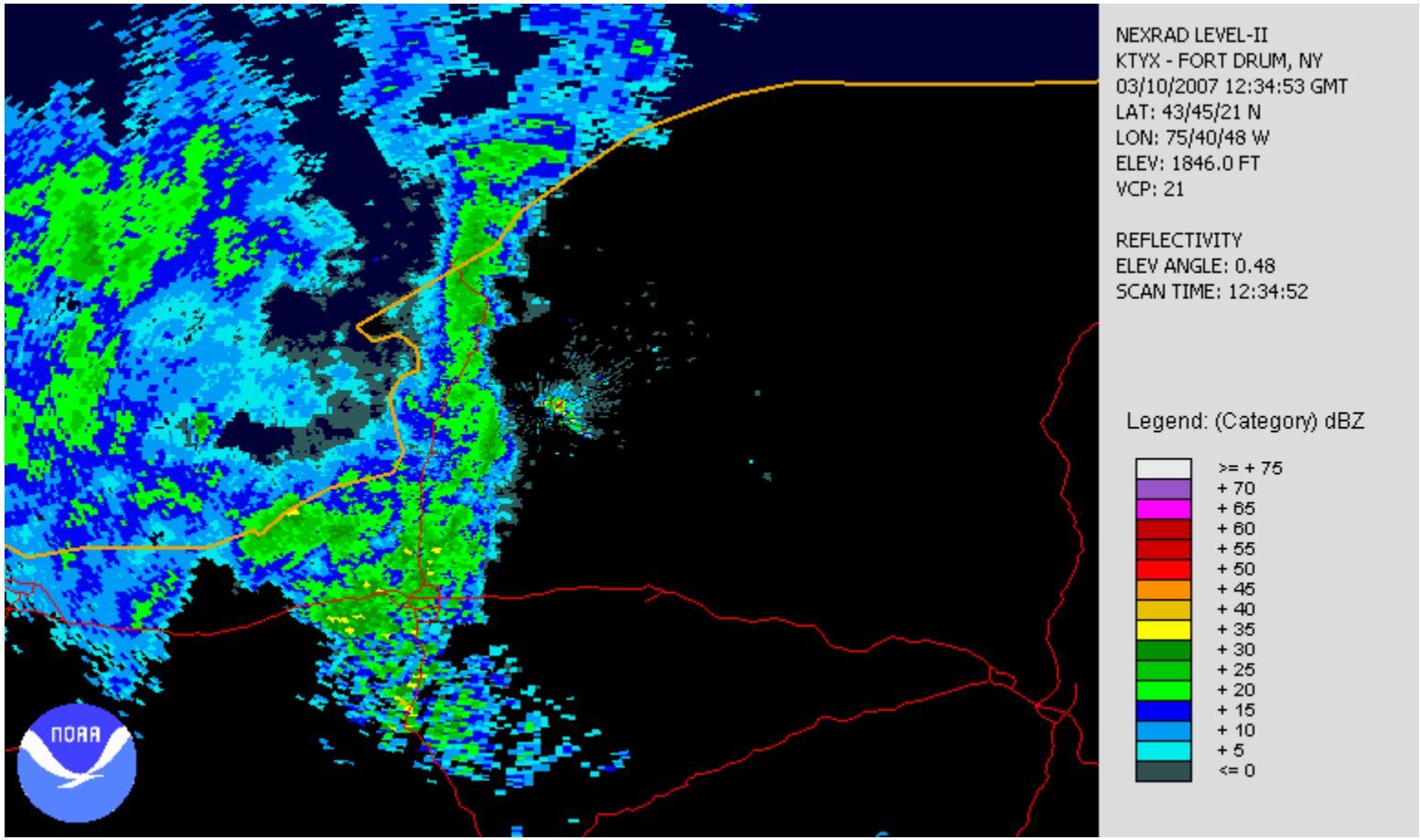
(Continued)

- Typical NEXRAD Site:
  - 10 – 30 m tower
  - 12 m (39 ft) diameter radome
  - 3 equipment shelters

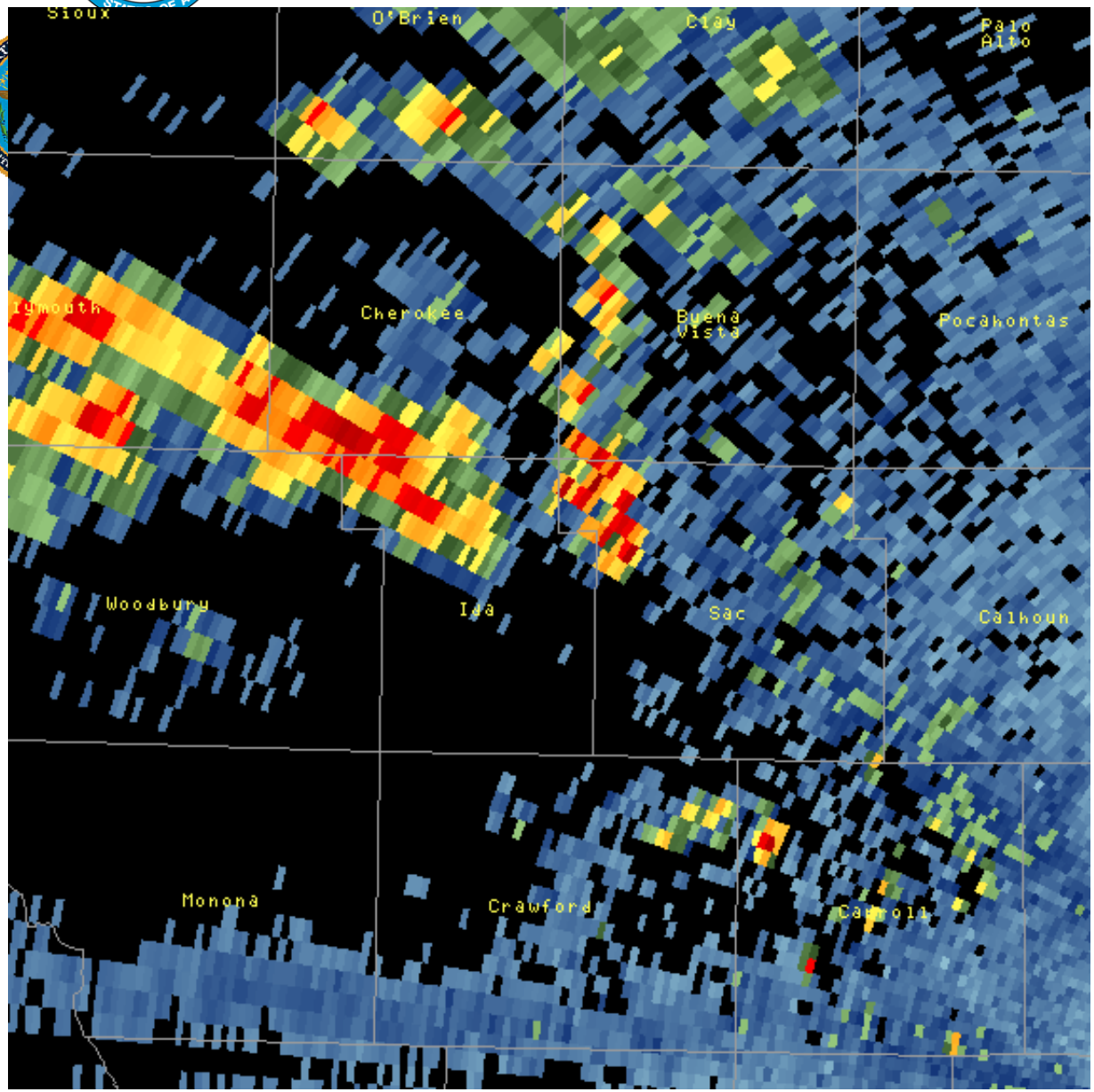
# Potential Wind Farm/Turbine Impacts on NEXRADs

- Non-stationary wind turbine clutter in velocity and reflectivity echoes
  - Conventional radar clutter filters ineffective in mitigating clutter signals from rotating blades
- Clutter (reflectivity) and blockage (all moments); and interference (velocity and spectrum width), can result in:
  - Mis-identification of thunderstorms in/near wind farm reflectivity signature
  - Meteorological algorithm errors
    - False radar estimates of rainfall accumulation
    - False tornado vortex and mesocyclone signatures
    - False storm cell identification and tracking

# Wind Farm Near Ft Drum NEXRAD (Reflectivity Time Lapse)



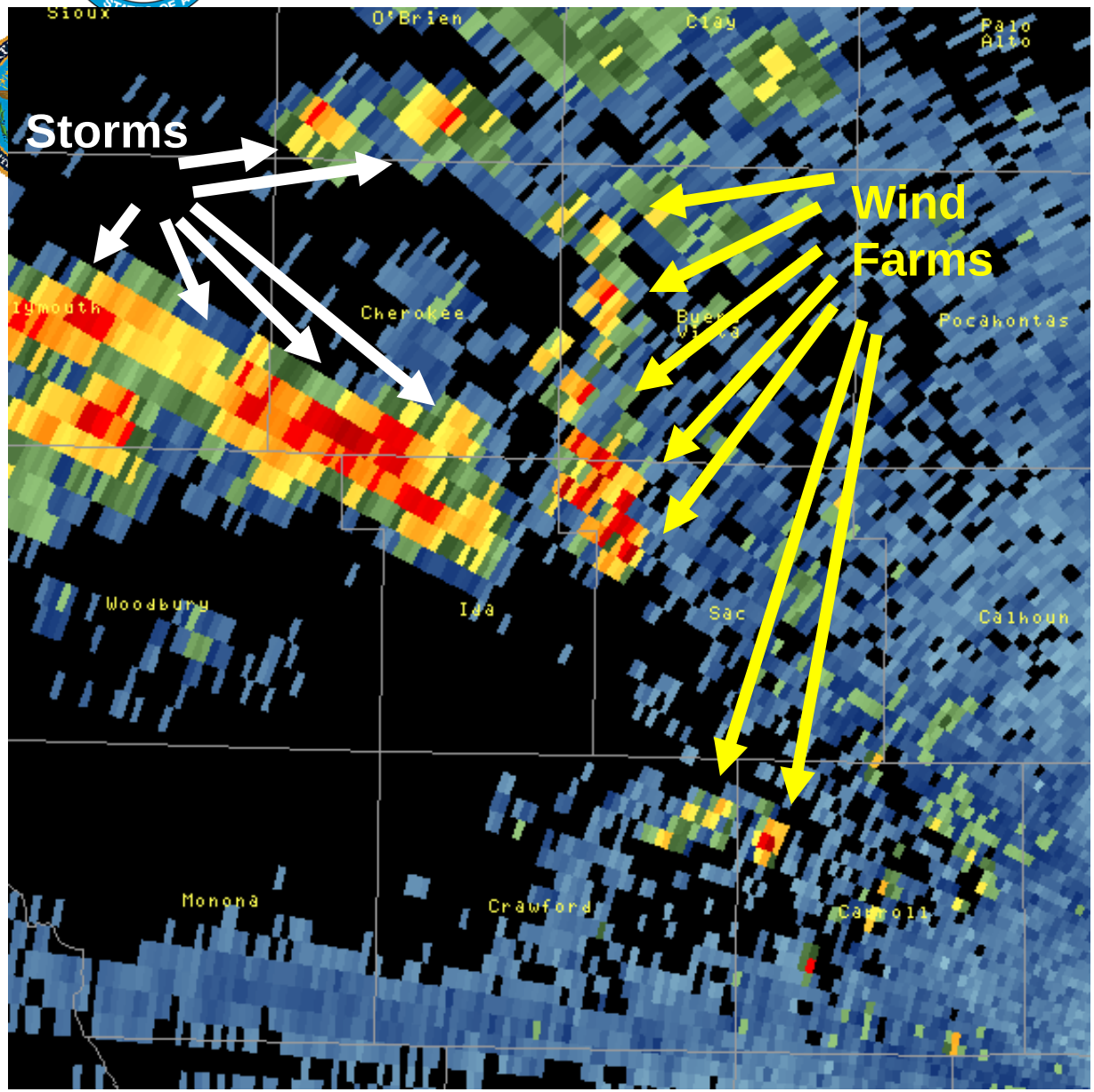
# Wind Farms Can Impact Reflectivity Data Users




Are returns from Wind Farms or real storms???

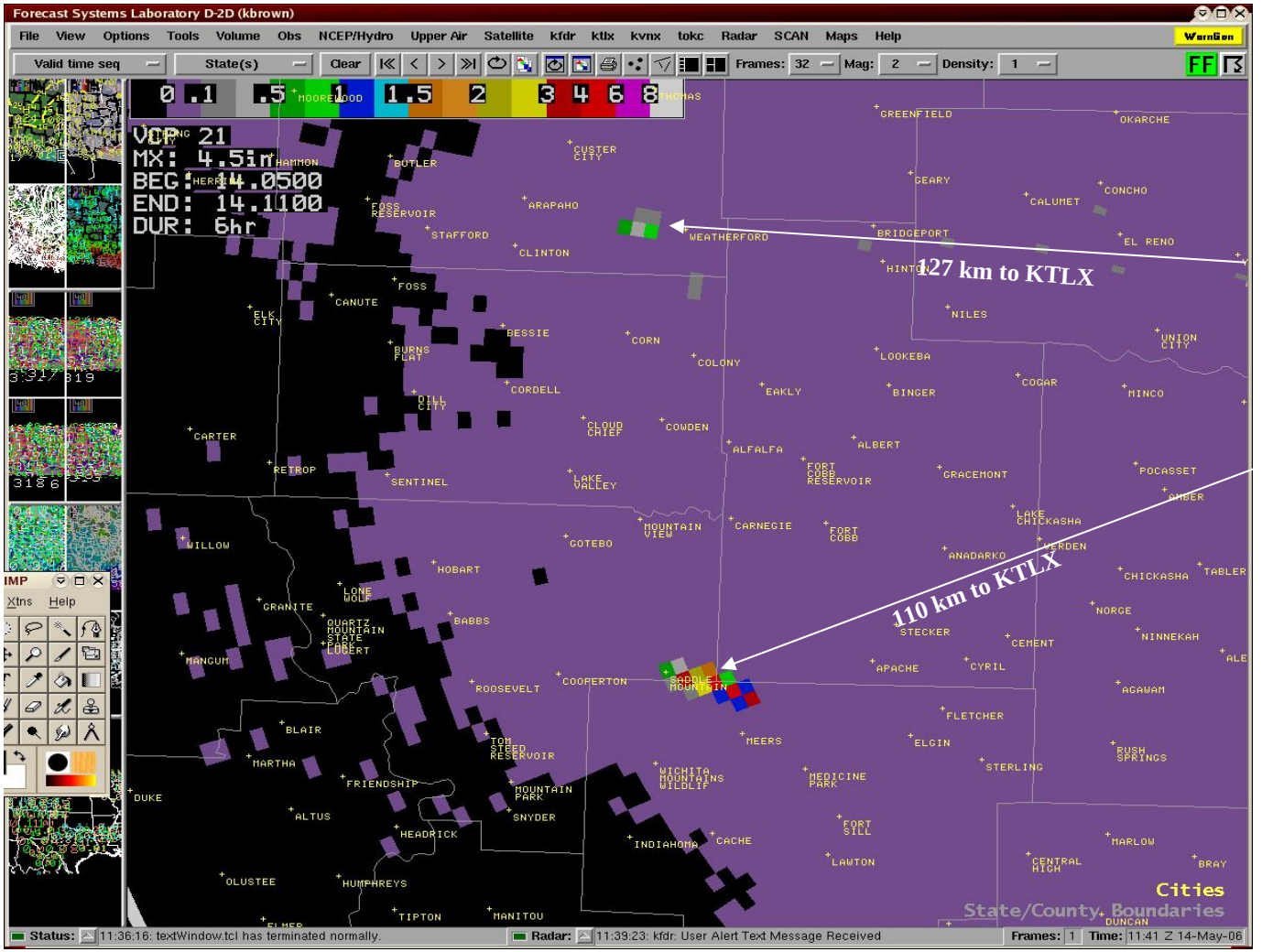
- Emergency manager mentioned some confusion as storms moved in.
- Question sent to webmaster from a user who had trouble differentiating between storms and false echoes.
- Images from 0.5 degree scan on July 19, 2007 at 0236 GMT from Des Moines, IA NEXARD

# Wind Farms Can Impact Reflectivity Data Users




- Returns are a mixture of real storms and reflected energy from wind farms.
- Wind farms range between ~ 115 to 160 km from Des Moines

# False or Anomalously Large NEXRAD-Estimated Precipitation Accumulations Due To Wind Farms



# NEXRAD Program Efforts to Reach Out to the Wind Energy Industry and Mitigate Impacts

- Respond to voluntary wind farm developer submissions via National Telecommunications Information Administration (NTIA)
  - Completed 140+ analysis requests since summer 2006
  - Provided case-by-case analysis of developer plans on potential impact on nearby NEXRADs
  - Consulted with wind farm developers on how proposed wind farms could impact the nearby NEXRAD; resulting in some alternate siting solutions
- Maintain a wind farm interaction section on ROC web page
  - http://www.roc.noaa.gov/windfarm/windfarm_index.asp
  - Linked to DOE web site: http://www1.eere.energy.gov/windandhydro/federalwindsiting/wind_siting_tools.html

# NEXRAD Program Efforts to Reach Out to the Wind Energy Industry and Mitigate Impacts

(Continued)

- Working with FAA to add NEXRAD tool kit (ala' long-range radar tool kit) to Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) web site
  - Greater NEXRAD visibility for wind farm developers earlier in planning process
  - Developers can perform their own preliminary analysis, anonymously
- In the interim, the Radar Operations Center (ROC) will analyze sites on case-by-case basis upon request and consult with developers to find win-win solutions
  - Recommend developers route plans through the NTIA as early as feasible for multi-agency feedback
  - Send analysis requests to ROC webmaster: http://www.roc.noaa.gov/Feedback/

# NEXRAD Program Efforts to Reach Out to the Wind Energy Industry and Mitigate Impacts

(Continued)

- Funded University of Oklahoma (OU) work to:
  - Characterize the spectral content of wind turbine clutter (WTC)
  - Mitigation through spatial interpolation to mask effects of WTC
  - On-going work into advanced signal processing solutions
  - Limited study on wind farm impacts on NEXRAD and weather forecast/severe weather operations
- Presented and published in papers at:
  - January 2007 American Meteorological Society Annual meeting
  - June 2007 American Wind Energy Association WINDPOWER 2007 conference
  - August 2007 American Meteorological Society International Radar Conference

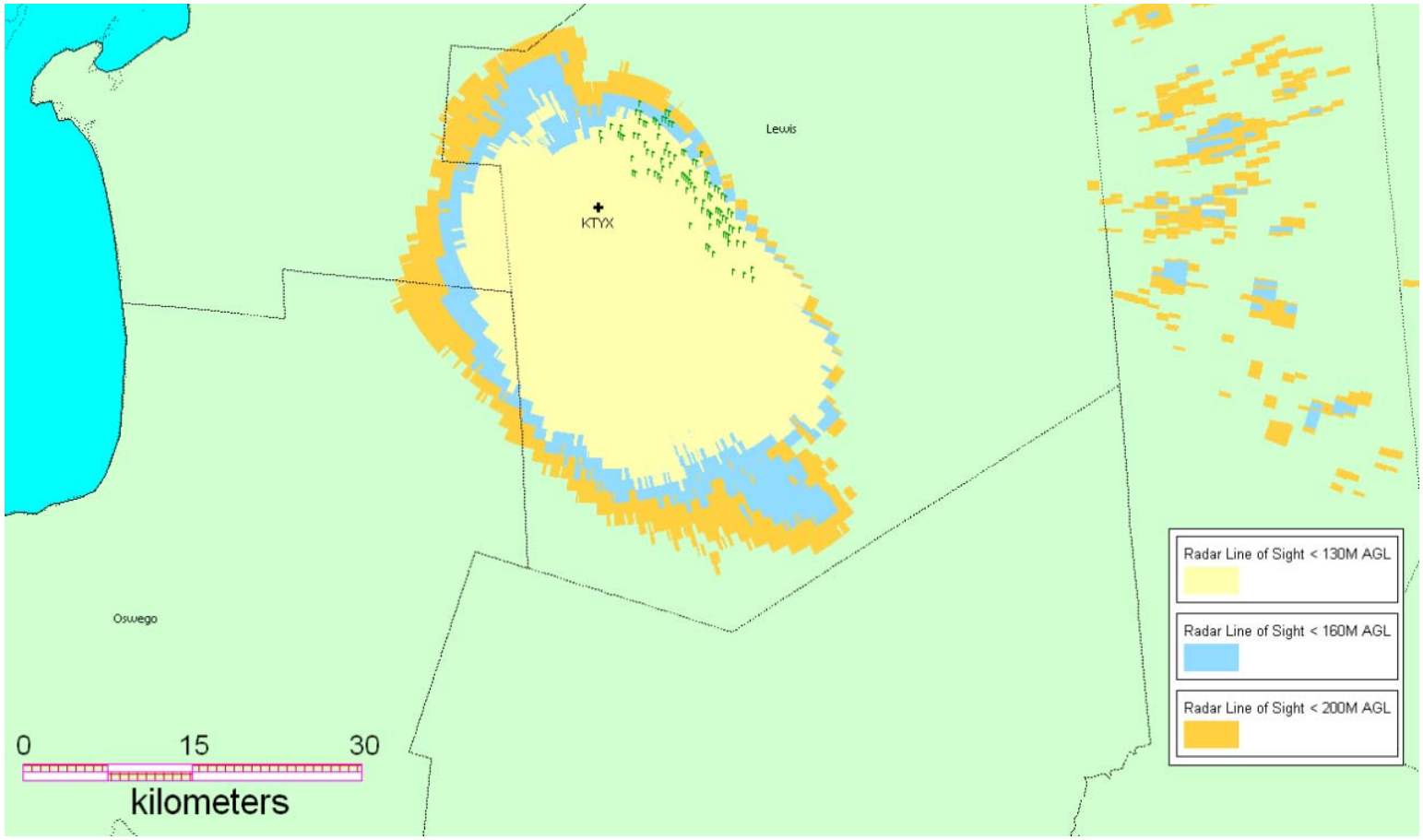
# Highlights NEXRAD Program Of 2008 Mitigation Plans

- Presented an update on wind farm-related activities at January 2008 American Meteorological Society annual meeting
- Participated in January 2008 JASON Winter Study: Wind Farms & Radar
- Continue outreach to wind energy industry
  - Requested to present a poster/paper at AWEA WINDPOWER 2008 annual meeting
    - Goal - reach developers early in planning and siting process
- Continue to fund (limited) OU wind-turbine efforts to develop better analysis and mitigation tools/techniques; many other new ideas yet to explore
- Collaborate with other federal agencies to work with wind energy industry

# NEXRAD Program Evaluation Analysis Tools

- Radar-Line-of-Sight Maps (RLOS)
  - Depicts areas of RLOS within 130 m, 160 m, and 200 m of ground (AGL)
  - Use Space Shuttle Radar Topography Mission database
  - Consider multiple radar elevation angles

# Example of Radar-Line-of-Site Map



# NEXRAR Program Evaluation Analysis Tools

(Continued)

- Prepare engineering analysis and reports on a site-by-site basis; use
  - Use:
    - Distance to turbines
    - Height of turbine blades
    - Height of NEXRAD antenna
    - Average 1.0$^{o}$ beam width, with standard atmosphere beam propagation
    - Terrain
  - For very nearby turbines, determine personnel/equipment safety considerations
  - Determine if beam will intersect any tower or turbine blade
  - Estimate operational impacts based on amount of blockage, location of wind farm, weather climatology, and operational experience

# Summary

- NEXRAD saves lives, reduces injuries!
- Wind farms can effect NEXRAD data quality which can impact forecast/warning performance
  - More opportunity for impacts as more wind farms are installed

# Summary

(Continued)

- NEXRAD Program continuing to:
  - Reach out to wind energy industry to inform them of NEXRAD locations and potential impacts
  - Evaluate proposed wind farms for potential impacts on case-by-case basis
  - Support OU work related to wind turbine radar interference mitigation and assessment of operational impacts
- Radar Operations Center wind farm interaction URL: http://www.roc.noaa.gov/windfarm/windfarm_index.asp