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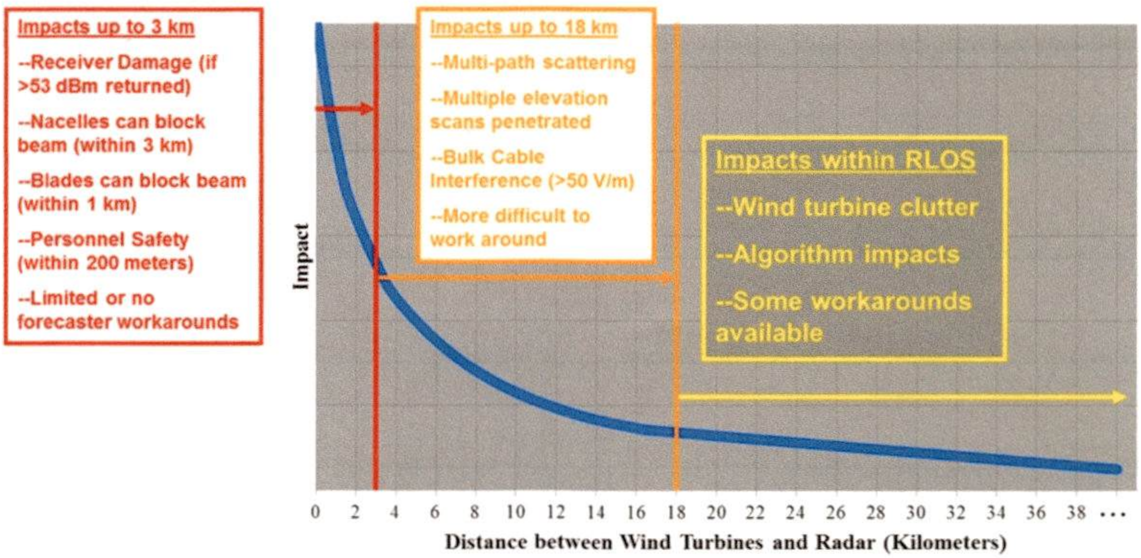
NOAA's National Weather Service
Radar Operations Center
NEXRAD WSR-88D

HOW ROTATING WIND TURBINE BLADES IMPACT THE NEXRAD DOPPLER WEATHER RADAR

Rotating wind turbine blades can impact the radar in several ways. Wind turbines can impact the NEXRAD radar base data, algorithms, and derived products when the turbine blades are moving and in the radar's line of sight (RLOS); and, if turbines are sited very near to the radar their large nacelles and blades can also physically block the radar beam or reflect enough energy back to the radar to damage the radar's receiver hardware.

- **Radar Receiver:** The NEXRAD radar has a very sensitive receiver. The radar's Receiver Protector prevents damage from strong reflected signals; however its upper limit is 53 dBm. Large objects sited very near the radar (< 4 km), such as turbine nacelles, have the potential to return signals that exceed the limit of receiver protector and render the radar inoperable.
- **Beam Blockage:** If sited within a few kilometers of the radar, wind turbines can partially or fully block the radar beam. This beam blockage attenuates the strength of the beam and impacts data beyond the wind farm, causing shadows or spikes in the data through the entire range of the radar (460 km for reflectivity data, and up to 300 km for velocity and spectrum width data).
- **Radar Base Data:** Turbines in RLOS can reflect energy back to the radar and visually contaminate the reflectivity, velocity, and spectrum width data. Forecasters look for certain "signatures" in the data that indicate the severity of the storms. The wind farm clutter can sometimes look just like showers and thunderstorms, or can alter the appearance of a storm (e.g. hook echoes). This visually corrupted data adds uncertainty to the analysis and could cause forecasters to delay/miss a severe weather warning or to warn unnecessarily.
- **Algorithms and Derived Products:** The base reflectivity, velocity, and spectrum-width data are also used by many algorithms in the radar processor to detect certain storm characteristics, such as mesocyclones, relative storm motion, hail, turbulence, etc. Corrupted base data can cause the radar algorithms to generate false alerts or to miss alerts. The radar also generates many additional products using this base data, such as wind profiles and rainfall estimates. Wind turbine clutter can impact the accuracy of these derived products.

The graph below depicts the relative impact of wind turbines (or wind farms) on NEXRAD radars and forecasters as a function of distance (on level terrain) if wind turbines are in the RLOS.



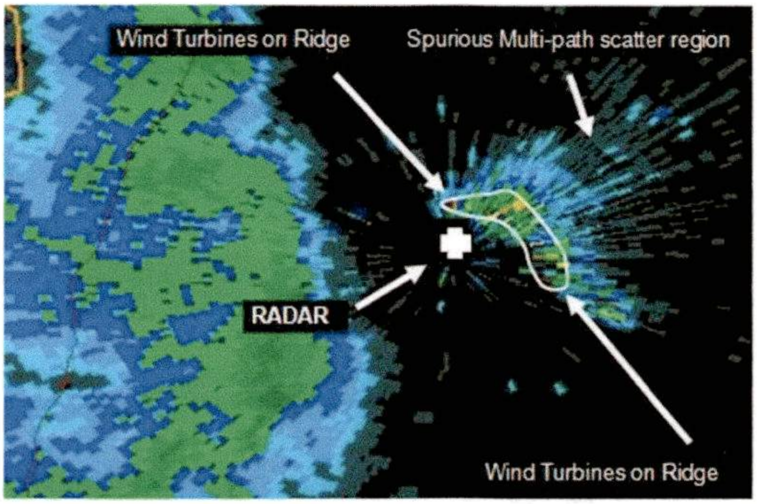
Impacts increase greatly as wind turbines are sited closer to the radar, especially within 18 km (assuming level terrain), as radar operator workarounds become more difficult. Turbines sited at least 18 km from the radar generally only impact the lowest radar scan at 0.5 degrees elevation, and clutter is confined to the wind farm area. Within 18 km wind turbines cause additional impacts including: clutter on multiple elevation scans above 0.5 degrees, multipath clutter down range of the wind turbines, and greater impacts to radar algorithms. Multipath scattering from wind turbines can extend the contaminated data up to 40 km beyond the wind farm. Turbines sited within 4 km of the radar may also cause significant (>10%) attenuation/blockage of the radar beam impacting data throughout the entire range (460 km-reflectivity, 300 km-velocity) of the radar. When turbines are sited within 200 m, construction or maintenance personnel may be exposed to microwave energy exceeding OSHA (Occupational Safety and Health Administration) thresholds. The above distances assume a level terrain and a Standard Atmosphere Index of Refraction profile. Therefore, actual impacts may occur closer or further away from the radar than this chart indicates depending on the terrain and current atmospheric refraction. Accurate determination of the RLOS and impact distances requires a detailed site-by-site analysis.

You may wonder why we can't filter out this clutter since we know where the wind farms are located. The NEXRAD has a sophisticated clutter removal scheme. Since weather is usually in motion, the scheme was designed to filter returns that have essentially no or very low motion. This is effective for removing the returned signals from terrain, buildings, and other non-moving structures. However, the radar sees rotating wind turbine blades as targets having motion, hence processes these returns as weather. At this time there is no filtering scheme available to identify and remove wind turbine clutter while preserving real weather returns.

Wind turbine clutter has not had a major negative impact on forecast or warning operations, yet. However, with more and larger wind turbines coming on line, radars in some parts of the country will have multiple wind farms in their line of sight. Cumulative negative impacts should be anticipated – which, at some point, may become sufficient to compromise the ability of radar data users to perform their missions.

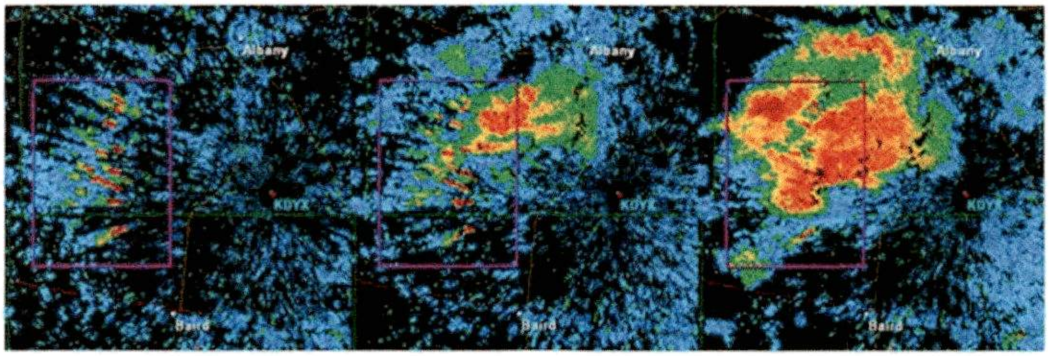
Examples of Wind Turbine Clutter

Zoomed-in Display of WTC-contaminated data from Fort Drum NEXRAD

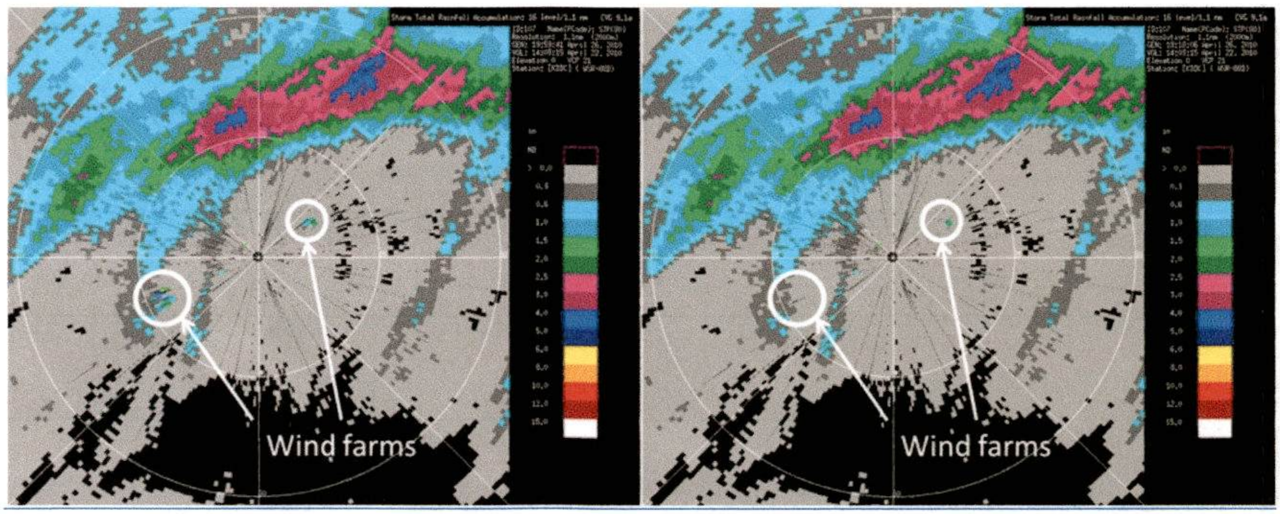


The image above is a zoomed 0.5 degree elevation Reflectivity product from the Ft Drum, NY NEXRAD. There is a large wind farm nearby with turbines oriented from due north through southeast of the radar. The turbines are close enough (within 18 km) to cause spurious multipath scattering that extends well beyond the wind farm and contaminates data at multiple scanning elevation angles.

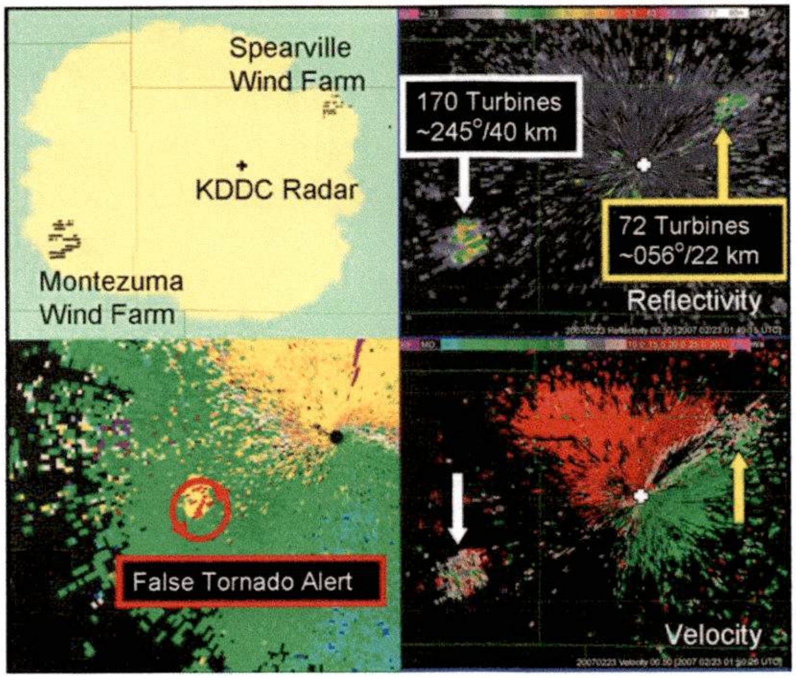
Display of WTC-contaminated data from the Dyess AFB, TX NEXRAD



Sequence (left to right) of 0.5 deg reflectivity images showing thunderstorms developing over a wind farm (purple rectangle) 18–30 km (10-16 nm) west of Dyess AFB, TX WSR-88D. Left: thunderstorms have not yet developed, high reflectivity values due to wind turbines alone. Middle and Right: storm has developed to where in right image a distinct notch structure, indicative of severe weather, formed – note: turbine and weather echoes indistinguishable.



This radar-estimated Storm Total Precipitation accumulation product from the Dodge City, Kansas NEXRAD on April 22, 2010 at 1403 GMT depicts how wind farms can impact radar-derived products. Erroneous 4+ inch radar-estimated Storm Total Precipitation accumulations (indicated by the arrows) in the image on the left are due to wind farms northeast and southwest of the NEXRAD. The anomalous accumulations make estimates of rainfall over an area/river basin more difficult to determine. However, radar operators can apply exclusion zones to mitigate these anomalous accumulations, as seen on the right. (Radar precipitation algorithms do not use the returns from the exclusion zone to accumulate precipitation.)



Dodge City, KS NEXRAD (KDDC) reflectivity (upper right) and mean radial velocity (lower right) imagery for 0150 UTC on 23 Feb 2007 showing two wind farms within the radar's line of sight. The yellow area in the upper left image depicts areas where the radar line of sight is within 130 m of the ground. The reflectivity and velocity values are anomalous and can confuse users. The lower left panel shows the effects of the wind farm to the southwest whose influence has resulted in a false tornado alert generated by the NEXRAD algorithms. The Weather Forecast Office did not issue a warning because, in this case, other data indicated that there was no severe weather in the wind farm area.

Radar Line of Sight Graphs

The WSR-88D radar performs 360° scans of the atmosphere with elevation angles between 0.5° and 19.5°. The WSR-88D samples up to 14 different elevations angles for each complete scan of the atmosphere. The radar beam increases in height and in diameter as it moves away from the radar, with most of the beams energy at the beam center height. The bottom and top heights of the beam are defined as the points where there is a 50% reduction in the transmitted energy. Below the beam bottom height and above the beam top height the energy drastically decreases. The area between the beam bottom and beam top is referred to as the "beam". There is reduced impact on the radar if the rotating blades are below the beam bottom, especially at "close" distances.

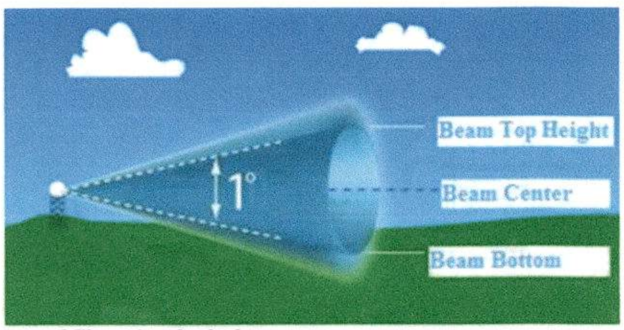


Figure 1 Illustration of radar beam

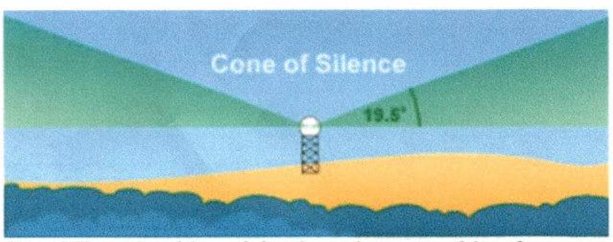


Figure 2 Illustration of the total elevation angle coverage of the radar

Any object within the beam reflects energy back to the radar. The WSR-88D uses a complex algorithm, called a clutter filter, to perform an analysis on the data to determine if the returned energy is from a desirable target (weather) or not (non-weather clutter). One factor used in the clutter filter process is the motion of the return. Clutter mitigation filters within the WSR-88D can not filter rotating wind turbines due to the motion of the blades. When the turbines are close to the radar, they penetrate more of the beam increasing the amount of energy returned to the radar, resulting in higher reflectivity values, potentially at multiple elevation angles.

LINKS

- INTRODUCTION
- HOW ROTATING WIND TURBINE BLADES IMPACT THE NEXRAD DOPPLER WEATHER RADAR
- HOW THE ROC ANALYSES WIND TURBINE SITING PROPOSALS
- RADAR IMAGERY
- FREQUENTLY ASKED QUESTIONS (FAQs)
- ADDITIONAL LINKS AND RESEARCH PAPERS

- FEEDBACK

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