HOW TO SUCCESSFULLY WORK WITH NOAA ON WIND TURBINE – RADAR INTERFERENCE ISSUES, AN UPDATE

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1. INTRODUCTION

One of the key tools weather forecasters use in preparing forecasts and severe weather warnings is the Nation's network of 160 Doppler weather radars known as the Next Generation Weather Radar (NEXRAD) system, also known as the Weather Surveillance Radar-1988, Doppler (WSR-88D). The NEXRADs are located across the contiguous United States (Fig. 1), Alaska, Hawaii, Puerto Rico, and select overseas sites. The Federal government operates, maintains, and continually upgrades the NEXRAD network to ensure the best possible protection of life and property, and safe aircraft operations. In addition, the National Weather Service (NWS) uses data from the Federal Aviation Administration's (FAA) 45 Terminal Doppler Weather Radars (TDWR) (Fig. 1) to further supplement their forecast and severe weather warning capability.

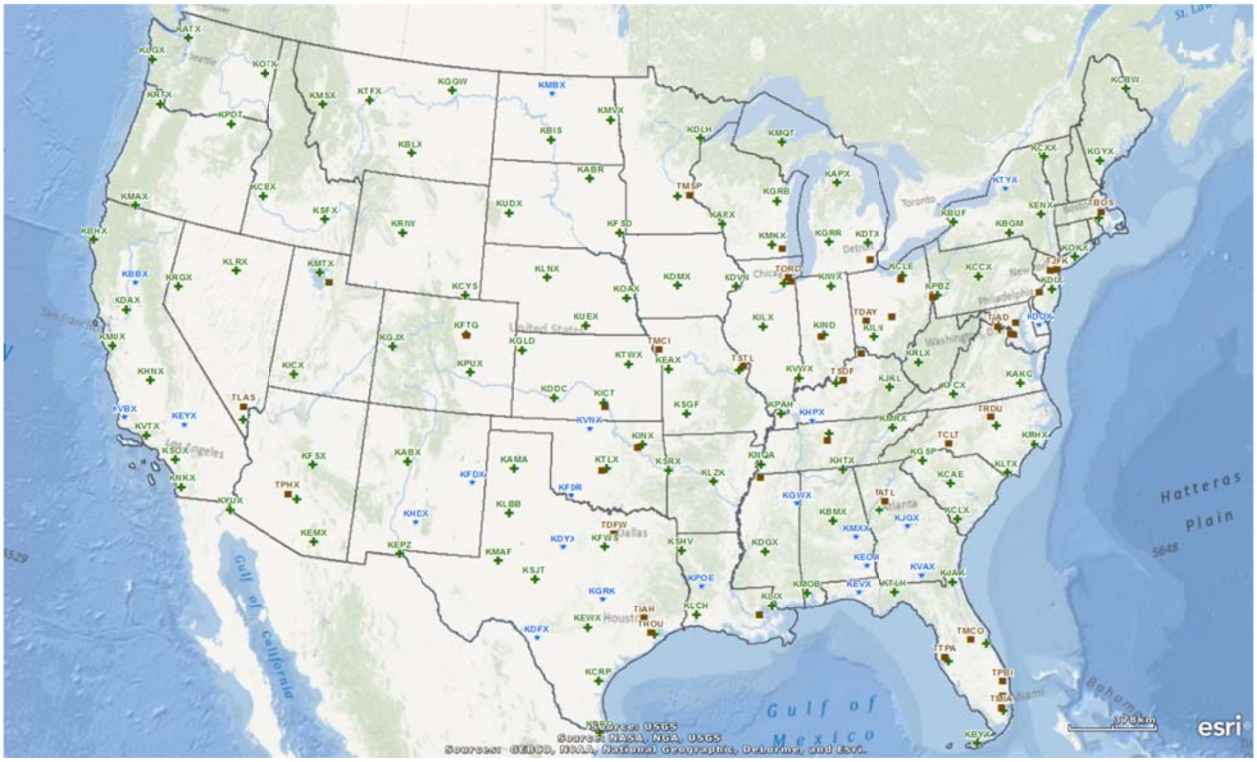

Fig. 1. Map of NEXRAD (green crosses are NWS radars and blue are DOD radars) and TDWR (brown squares) locations in the Continental United States. Twelve additional NEXRADs are located in Alaska (7), Hawaii (4), and Puerto Rico (1).

The Federal government is promoting energy independence through the installation of renewable energy sources, and wind energy is a key resource in many parts of the country. In recent years, NEXRAD operators and data users have noticed an increasing number of wind farms visible in the data, and in derived products such as precipitation estimates. This occurs when wind farms are located in a NEXRAD's radar line of sight (RLOS). Wind

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turbine and weather spectra can span the same Doppler frequencies and share a similar dynamic range, causing conventional radar clutter filtering algorithms, which only filter energy returned from nearly stationary objects (buildings, terrain, etc.), to fail in removing wind turbine clutter from the weather signal. The unfiltered wind turbine clutter can adversely impact radar data quality and the performance of the radar's internal weather detection algorithms.

Over the next couple decades, the potential for wind farms to interfere with the NEXRAD/TDWR radar networks will increase with the anticipated large growth in wind energy projects. This increased interference will result not only from the growth of the number of wind farms, but also from the increasing size of wind farms and the use of taller turbines. NOAA's National Weather Service (NWS) NEXRAD Radar Operations Center (ROC) has evaluated 980 wind farm projects, some with proposed turbine blade tip heights exceeding 152m (500ft) above the ground.

This paper provides an update on NOAA's efforts to improve impact estimates of proposed wind farms and develop options for mitigating wind farm interference issues. Information is presented on:

(1) The NEXRAD system and supplemental FAA TDWR system; how wind farms can impact NEXRAD data and forecast/severe weather warning performance;
(2) How turbines can impact weather radars;
(3) NOAA's new impact evaluation criteria;
(4) How and when wind project developers should contact NOAA; and,
(5) Recent mitigation efforts including education, research, and collaboration with the wind energy industry.

2. OVERVIEW OF NEXRAD and TDWR RADAR SYSTEMS

The NEXRAD (right image) transmits a 10-cm wavelength (S-band), dual-polarized 1° beam at 750 kW peak power, with a range resolution of 250 meters. The maximum detection range is 460 km for reflectivity and 300km for radial velocity. The radar was designed to detect weather targets and storm-scale winds at long ranges. In addition, its receiver is sensitive enough to detect clear-air (without the presence of clouds or rain) boundaries such as temperature and humidity discontinuities. The radar network received a state-of-the-art digital signal processor upgrade in 2006, and is currently being upgraded with dual polarization technology. Operationally, the radar automatically scans the atmosphere in pre-defined coverage patterns from 0.5° to 19.5° elevation above the horizon, then processes and distributes reflectivity, mean radial velocity, and spectrum width (a measure of the variability of radial velocities in the resolution volume) data. From this data, computer algorithms generate a suite of meteorological and hydrological products and alerts used for short-term forecasts, advisories, and warnings for significant weather events such as tornadoes, large hail, wind shear, downbursts, flash floods, and other weather phenomena. National Weather Service and Department of Defense (DoD) weather forecasters use NEXRAD data to provide life- and resource-saving information to support: public, military operations, and inform resource protection decision makers (e.g., emergency managers). The data are also used for the safe and efficient operation of the National Airspace System - NEXRAD data are displayed on FAA air traffic controllers' screens and terminal operations centers. Additionally, the commercial weather industry has experienced rapid growth in the last decade, due in part to the availability of and use of real-time NEXRAD data. Television broadcasters rely on both their own weather surveillance radars and data collected from the NEXRAD network to inform their viewers of evolving weather conditions.

The general public may access the radar data from private companies and the Internet (e.g., http://radar.weather.gov/). Detailed information about the NEXRAD radar is available in (Federal Meteorological Handbook No. 11, Parts A – D; http://www.roc.noaa.gov/FMH_11/default.asp).

The TDWR (left image) has a different mission than the NEXRAD. It was deployed in the early 1990's to detect hazardous wind shear conditions primarily caused by thunderstorm "microbursts" and gust fronts near major airports in the United States. Most of the 45 TDWRs are located east of the Rocky Mountains (Fig 1). TDWR transmits a 5-cm wavelength (C-band), horizontally-polarized ½ degree beam at 250 kW peak power. The TDWR provides higher resolution data (150-m range resolution) than the NEXRAD, but has a shorter range. Its mission is focused on the airport terminal areas and within a 60 km-radius circle.

There are important differences between weather surveillance radars, such as NEXRAD, and air surveillance radars (ASRs), such as those operated by the FAA, Department of Homeland Security (DHS) and DoD. While they both operate on similar principles, their targets of interest and signal processing are significantly different. ASRs look for large, hard, point targets (aircraft) and process the data to mitigate weak environmental returns. In contrast, weather surveillance radars look for very small, widely distributed targets (e.g., water droplets, aerosols, atmospheric particulates) and perform signal processing to remove or mitigate strong, point targets. Therefore, ASR-wind turbine clutter (WTC) mitigation techniques may not be applicable to weather radars. Also, the identification and removal of WTC is likely to be more difficult for weather radars since the many rotating blades of a wind farm return signals that appear very similar to real weather (Fig. 2b).

3. IMPACTS OF WIND FARMS ON THE NEXRAD RADAR

The types and severity of impacts is dependent on distance, intervening terrain, height of the turbines relative to the radar beam, and size of the wind farm. Wind farms can impact NEXRAD radars in three ways:

(1) When the turbine blades are moving and they protrude into the RLOS, they can reflect un-filterable energy back to the radar system and appear as clutter in the base data (reflectivity, velocity, and spectrum width), as shown in Figures 2a and 2b. Unfortunately, this corrupted data is then used by other radar algorithms to detect certain storm characteristics, such as rotation (tornadoes) and storm motion, and to produce a suite of weather products, including precipitation estimates, vertical wind profiles, and severe weather alerts. Turbines sited within 18 km of a NEXRAD begin to impact multiple elevation scanning angles and create multipath scattering returns that show up as spikes of enhanced reflectivity down range of the wind farm.

(2) When turbines are within 3 km of the radar, wind turbines' large nacelles (hubs) can physically block a significant percentage of the radar's narrow beam, attenuating the radar signal and impacting data throughout the entire range of the radar.

(3) If turbines are sited in the radar's near field, which is within 1500 m of the NEXRAD antenna, radar energy reflected from towers and turbine blades can damage the radar receiver and cause other severe impacts.

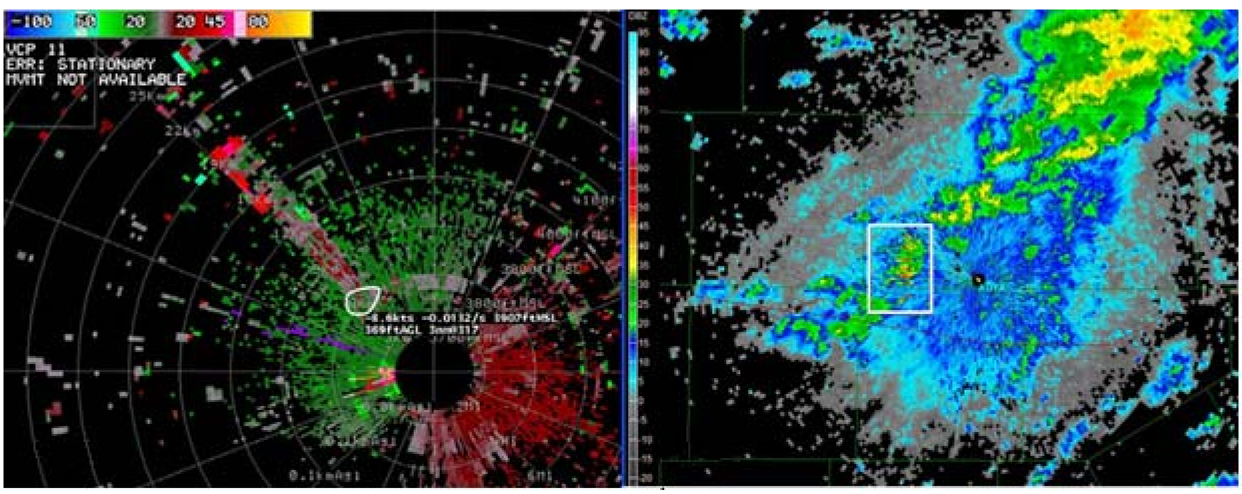

Fig. 2a. This Velocity image (0.5 degree scan) from the Great Falls, MT WSR-88D (KTFX) on February 9, 2006 at 1859 GMT shows how only a few turbines very close to the radar can cause a relatively large impact on radar data. The 6 turbines are approximately 6 km from the WSR-88D and in the RLOS. The velocity data is contaminated in azimuth for 9 degrees and out beyond 20 km due to multi-path and inter-turbine scattering. **Fig. 2b.** This Reflectivity image (0.5 degree scan) from the Dyess AFB, TX WSR-88D (KDYX) on September 9, 2008 at 1044 GMT shows how a large area of wind turbines (west of radar and in the white box annotation) can look similar to weather returns. Note that weather returns down range of the wind farm do not appear to be affected by attenuation due to the wind farm. Potential blockage/attenuation of radar signals by wind farms must be analyzed on a case-by-case basis.

Figure 3 depicts the relative notional impact of wind farms on NEXRAD radars and forecast /warning operations as a function of distance if wind turbines are in the RLOS. Impacts increase exponentially as wind farms are sited closer to the radar, especially within 18 km, and radar operator workarounds become more difficult. Determination of RLOS and impact distance are highly dependent on local terrain, requiring site-by-site analyses. 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, experience gained to date strongly suggests that negative impacts should be anticipated -- some sufficient to compromise the ability of radar data users to perform their missions.

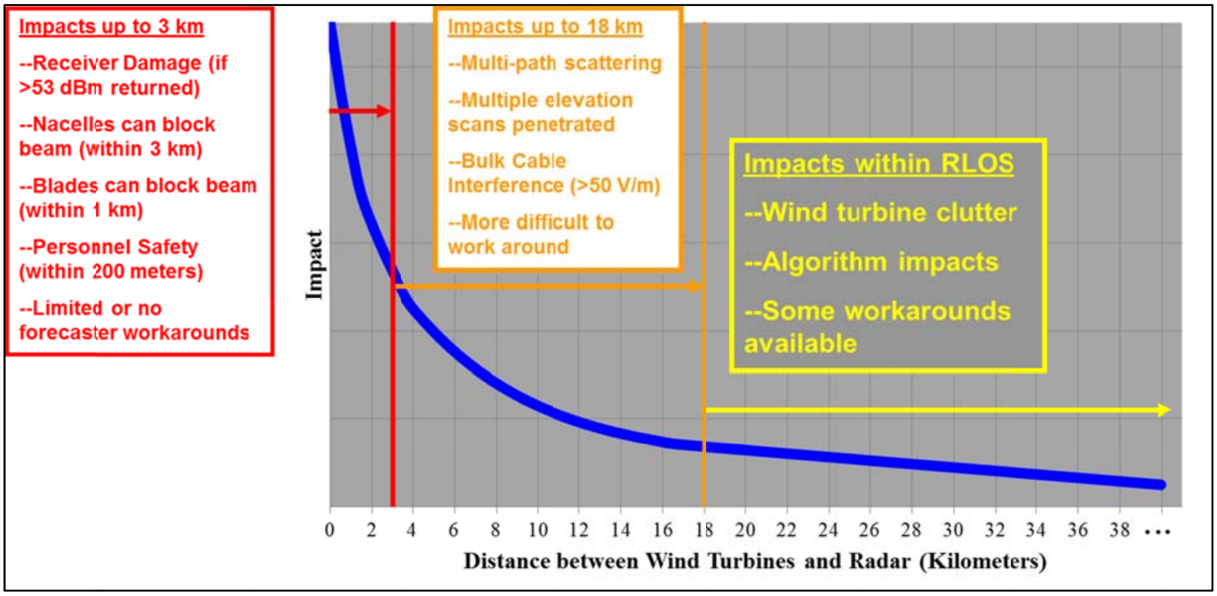

Fig. 3. Notional estimate of impacts of wind farms on NEXRAD radars relative to the separation distance.

Other examples of wind farm impacts are available at: http://www.roc.noaa.gov/windfarm/windfarm_impacts.asp

4. NOAA'S NEW WIND TURBINE EVALUATION CRITERIA

Initially, the ROC established the RLOS as a benchmark for seeking further discussions with developers on mitigation strategies. However, our experience over the past few years is that most wind farms in the RLOS, while a nuisance to radar users, have not proven to significantly impact forecast/warning operations. In order to focus our efforts on wind farm proposals that have a potential for significant impacts, we have limited mitigation discussions to those wind farms that are within about 18 km (10 nm) of a NEXRAD, assuming flat terrain, and whose blades penetrate into the second or higher radar scan angles. Only about 5% of the 980 analyzed wind farm proposals have been projected to be within 18 km (10 nm) of a NEXRAD, and about 1% have been proposed to be sited within 3 km. No wind farm has yet been built within 3 km of a NEXRAD, but there are several wind farms operating within 18 km. Despite this, there have been no missed weather warnings, and only a couple instances of false weather warnings attributable to WTC. Also, when WTC is confined to the first elevation scan, forecasters can generally verify WTC by looking at the next higher scan angles. These findings have allowed us to relax our evaluation criteria. As a result, in the past year, the ROC has settled on new impact criteria and is changing how we communicate the impacts to developers.

Figure 4 below shows the old (left image) and new (right) RLOS model output for the Bismarck, ND NEXRAD. The old output indicates that impacts to radar operations are either "highly likely" or "likely" and that further study is required. Project developers did not find this very helpful. They desired more action-oriented output. Can we, or can't we build there? Are you going to request impact mitigation? The new output communicates our expectations and answers those questions.

The new RLOS model is divided into four zones: No-Build (3 km red circle), Mitigation (orange), Consultation (yellow), and Notification (dark green) Zones. The zones are terrain dependent, except for No-Build, which is a fixed 3 km-radius circle centered on the radar. Also, the Consultation and Mitigation Zones are limited to 36 km unless the turbines penetrate the second elevation angle, in which case the Consultation Zone is extended up to 60 km from the radar. The Notification Zone extends from 36 km to the edge of the radar's line of sight. The intention of this zone is simply to get developers to notify NOAA that they intend to build there. A wind farm built in the Notification Zone will likely be visible in the radar data, so NOAA needs to know it's out there and warn forecasters ahead of time. For wind farms planned in the Consultation Zone, NOAA wants to stay in touch with the developers and track the project to completion. We request that developers keep us informed of any changes to the numbers of turbines, turbine height, or turbine locations. Having this updated information will help us work with WFOs to mitigate WTC impacts. Turbines located in the Mitigation Zone will likely cause significant impacts to the radar data and limit forecaster workarounds. Therefore, we would want to discuss potential options for mitigating impacts. Finally, for projects located in the No-Build Zone, we would want to discourage developers from building in that area. Work-arounds are few and impacts are likely to be great. There are some radars in the mountainous terrain of the Western US where developers may be able to build within 3 km of the radar and still stay out of the RLOS, but they are few.

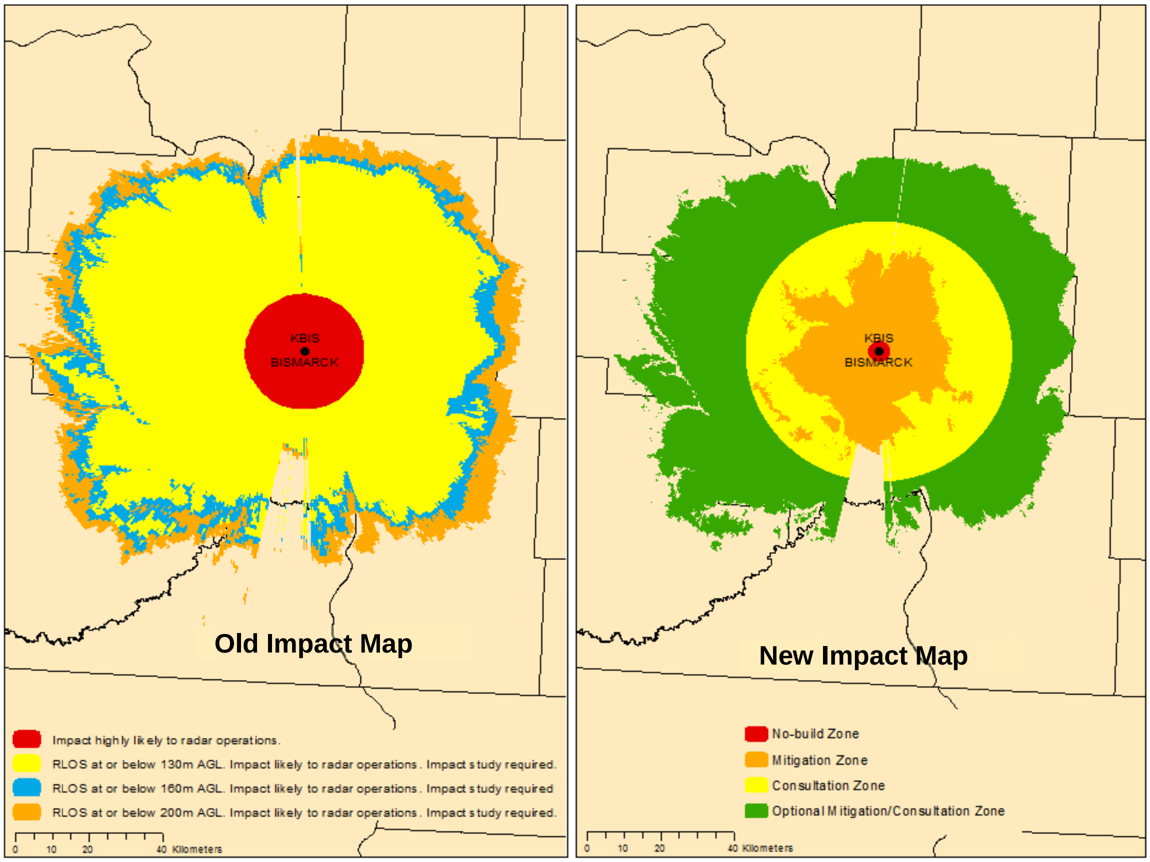

Fig. 4. Example of evaluation criteria changes to RLOS maps for Bismarck, ND NEXRAD. Note reduced areas of red and yellow

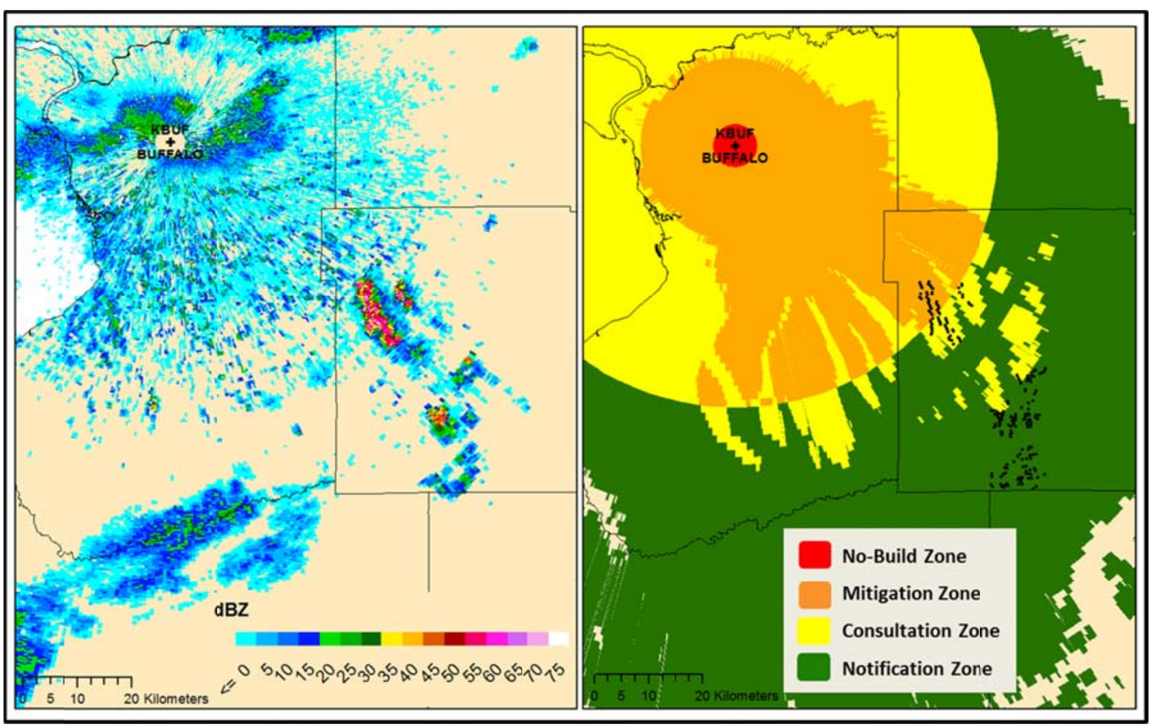

Fig 5: Graphic of new evaluation scheme for Buffalo, NY NEXRAD. Left image is actual radar returns (Reflectivity) and right image has new impact zones with turbines (black dots) overlaid.

Fig 5 above shows actual radar reflectivity returns from the Buffalo, NY NEXRAD on the left side and a schematic of the impact zones with wind turbines (black dots) overlaid on the right side. The wind turbines span three different zones. Note that turbines located within the mitigation and consultation zones create strong false returns (red) equivalent to severe thunderstorms in Reflectivity image. More distant turbines in the green Notification Zone create much weaker returns (blue/green).

5. NOAA'S IMPACT ASSESSMENT PROCESS

NOAA's does a case-by-case analysis of potential wind farm impacts on NEXRAD data and forecast/warning operations. In the last 5 years, NOAA's ROC has analyzed 980 wind energy project proposals. The ROC utilizes terrain data from the Space Shuttle Radar Topography Mission, and the following project and radar system data as input to a geographic information system (GIS) database, to determine if the main radar beam will intersect any tower or turbine blade as it propagates based on the Standard Atmosphere's Refractive Index profile.

(1) Turbine latitude/longitude coordinates, or coordinate pairs describing a polygonal area;
(2) Turbine hub height and maximum blade tip height;
(3) Number of wind turbines:
(4) NEXRAD Impact Zones for the nearest NEXRAD (the zones are terrain-dependent)
(5) Location and elevation of the nearest NEXRAD antenna; and,
(6) Radar beam spread (1.0 degree beam width);

Finally, the ROC estimates the type and amount of severe weather in the counties surrounding the wind farm. The ROC generates a short impact report if the project will be in the RLOS and sends it to the developer.

6. DO YOUR OWN ANONYMOUS IMPACT ANALYSIS

Developers can do a quick, anonymous impact analysis of a project on NEXRAD and DoD Long Range radars, as well as military operating areas, by using the DoD Preliminary Screening Tool on the FAA's Obstruction Evaluation /Airport Airspace Analysis (OE/AAA) web site at:
https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm

Single-Point Analysis

To perform a single-point analysis, select the "DoD Preliminary Screening" link in left column of web page, select "Single Point" in the Geometry Type drop down menu, then select "NEXRAD" in the Screening Type drop-down menu. Enter a coordinate pair and select submit. Output will appear as in Figure 6.

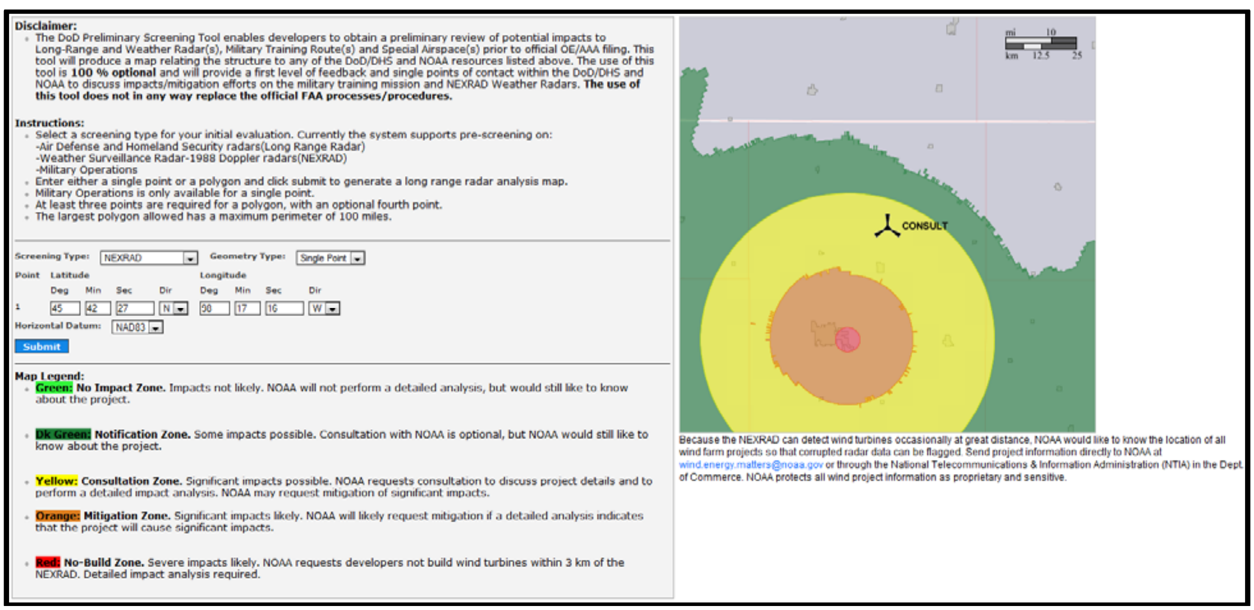

Fig 6: Output map for a Single Point Analysis contains the four Impact Zones, a rotor blade symbol indicating proposed location of turbine, and suggested action by developer.

Polygon Analysis

A polygonal analysis is similar to a single-point analysis except you select “Polygon” in the Geometry Type drop down menu and enter 3 or 4 coordinate pairs designating your development area. An example of the polygonal output is at Figure 7.

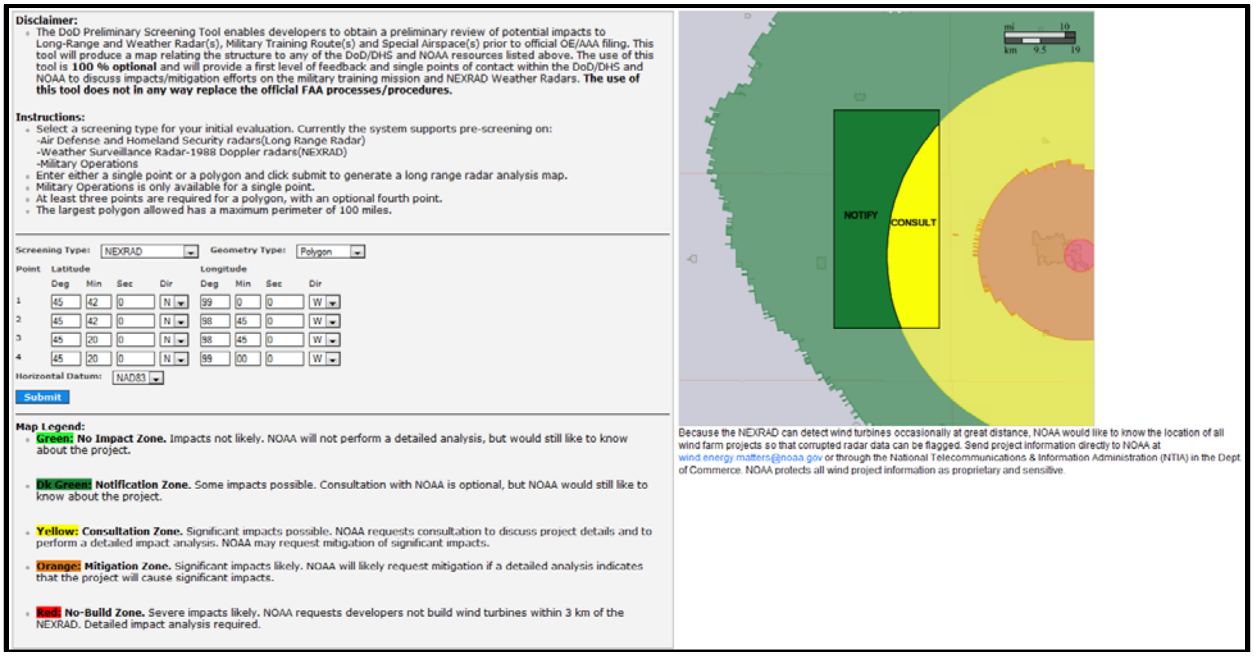

Fig 7: Example output for a Polygonal Analysis (3 or 4 Points).

7. WHEN AND HOW TO CONTACT NOAA

First, we encourage developers to take advantage of the anonymous and quick impact analysis capabilities of the radar screening tools on the FAA’s OE/AAA web site, as discussed above. After getting a feel for general impacts, contact NOAA as early as possible in the planning process and for major project changes, especially if the OE/AAA NEXRAD screening tool indicates a project would be in the red (No-Build), orange(Mitigation) or yellow (Consultation) zones. NOAA has the resources to perform multiple analyses at every stage of project development.

We prefer that developers submit their projects through the Department of Commerce’s (DOC) National Telecommunications and Information Administration (NTIA) which acts a as a developer “clearinghouse” for the many federal agencies not covered by the separate FAA Obstruction Evaluation and DoD Clearinghouse processes. The NTIA process is recognized by the wind industry in the American Wind Energy Association’s (AWEA) Wind Siting Handbook (AWEA 2008). The NTIA contact is:

Mr. Edward Davison
U.S Department of Commerce / NTIA
Room 4099A, HCHB
1401 Constitution Ave., NW
Washington, DC 20230
Work Phone: (202) 482-1850 ext. 5526
Fax: (202) 482-4396
Email: edavison@ntia.doc.gov

You can contact NOAA directly via email at wind.energy.matters@noaa.gov .

8. RECENT NOAA/NWS WIND TURBINE CLUTTER MITIGATION INITIATIVES

In 2011, progress was made in our effort to provide training and tools to NWS field offices to mitigate WTC impacts on the radar. First, the NWS Warning Decision Training Branch in Norman, OK developed a 1-hour on-line, publically accessible course to help forecasters identify and mitigate WTC (http://www.wdtb.noaa.gov/). This training has helped raise awareness of the issue within the NWS and has helped forecasters avoid confusion in the forecast/warning process. Second, the National Severe Storms Laboratory (NSSL) and the ROC jointly developed Geographical Information Systems (GIS) "shape" (*shp*) data files showing wind turbine locations. These *shp* files were made available to NWS field offices via a NOAA server download in January 2011 and are also available to FAA and DoD WSR-88D users. The files can be used to create Advanced Weather Interactive Processing System (AWIPS) GIS overlays to help Weather Forecast Office and River Forecast Center staff identify potential areas of WTC. The NSSL and ROC plan to release semi-annual updates of the *shp* files.

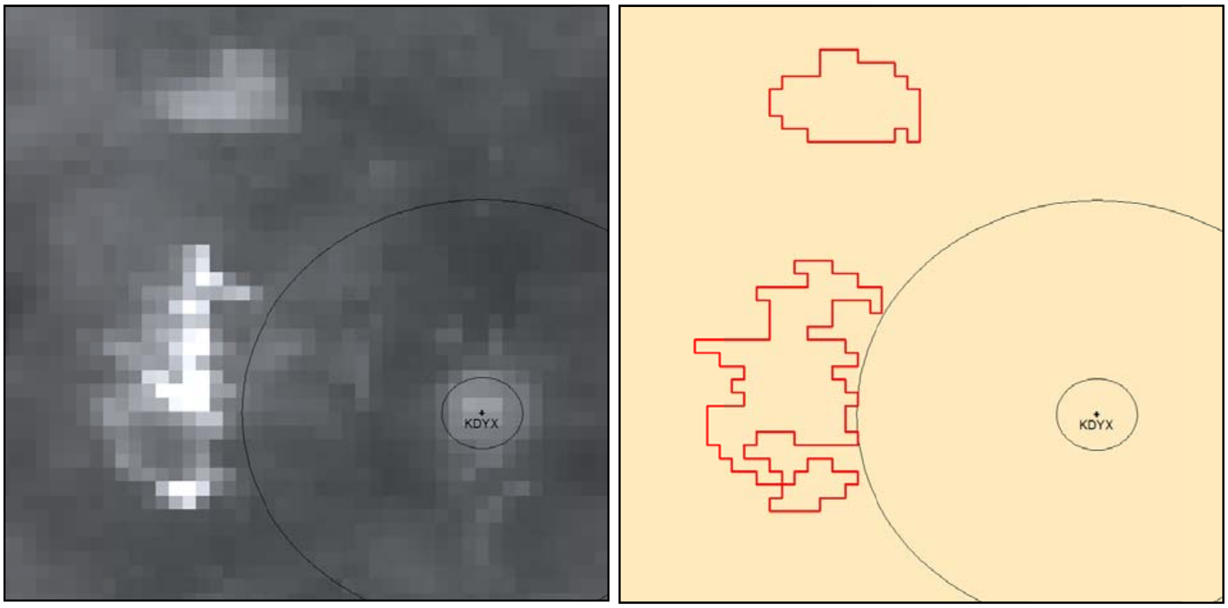

Fig. 8. Left image: 12-month Q2 QPE showing bright "hot spots" west of Dyess AFB WSR-88D (KDYX) near Abilene, TX with 3- and 18-km range rings. Right image: NSSL-generated polygons outlining QPE "hot spots".

The *shp* files included outlines of wind farms, turbine locations from the FAA's "built turbines" database, and turbines identified from digital satellite imagery. The polygon outlines of wind farm locations (Fig. 8, right) were prepared by NSSL using 12 months of accumulated radar Next Generation Qualitative Precipitation Estimation (Q2 QPE) data (visit http://www.nssl.noaa.gov/projects/q2/q2.php for more information). The long-term QPE data show a "hot spot" in precipitation accumulation due to the anomalous high reflectivity associated with WTC and other causes (Fig. 8, left image). Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate precipitation data for the same 12-month period was used to help flag QPE grid cells with unusually high values. Wind turbine point location data were overlaid on the 12-month QPE to determine if the flagged areas were induced by wind turbine clutter. The NSSL then enclosed these wind-farm-induced hotspots with polygons within a *shp* file.

Along with education and awareness, NOAA's Radar Operations Center (ROC) continued to work with some wind energy developers to develop a Letters of Intent for brief (30 to 60 minutes) operational curtailment of turbines in critical weather situations. Operational curtailment is particularly useful in locations with limited or moderate severe weather and where wind farms are located between 3 and 18 km from the radar.

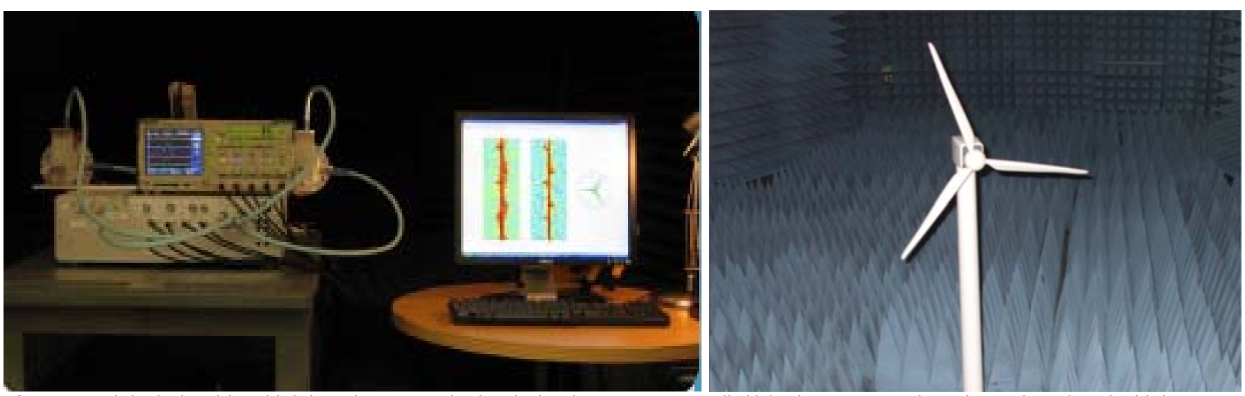

Fig. 9. Model wind turbine (right) and 10 GHz dual-polarized scatterometer (left) in the ARRC Lab at the University of Oklahoma. (Courtesy of the OU ARRC)

A recent study by the Atmospheric Radar Research Center ((ARRC): http://arrc.ou.edu) at the University of Oklahoma, with limited funding from the ROC, looked at using base radar data and a fuzzy logic-based algorithm to automatically identify wind turbine clutter in near real time. In addition to detection, the ARRC is currently exploring signal processing methods based on real-time, wind turbine telemetry-based algorithms. These knowledge-based techniques would exploit wind turbine data of blade rotation rate, orientation, etc., and are a good example of the benefits of collaboration with wind farm operators. Studies have also been conducted on the potential mitigation benefits of phased-array radar and other foundational studies are in progress using a controlled laboratory environment with scaled turbine models and dual-polarized scatterometers (Fig. 9).

9. SUMMARY

NEXRAD is a key tool of the NOAA NWS warning and forecast system, providing critical life-saving and resource protection data to multiple Federal agencies and the public. Experience with established wind farms located in NEXRAD RLOS has shown that WTC impacts the radar reflectivity, velocity, and spectrum width data as well as internal algorithms that generate alerts and derived weather products, such as precipitation estimates. The severity of impacts depends on many factors, but in general, wind farm impacts to the NEXRAD exponentially increase as the separation distance between them decreases, especially within 18km. NOAA's NWS supports the responsible development of wind energy and wants to work with the wind energy industry to avoid potential impacts to the NEXRAD radar network and to find technical solutions to the radar interference issue. Based on four years of studying the impacts of wind turbines on the NEXRAD network, the NWS is relaxing its impact criteria and focusing on wind turbines that penetrate into higher elevation scan angles. NWS is also changing how it communicates the impacts to developers by using zones named with the desired action—Mitigation, Consultation, etc. The NWS is collaborating with the wind industry and other Federal agencies to develop both radar-based and wind turbine-based mitigation solutions. On the radar side, the NWS has developed tools and training for radar operators and data users to identify WTC. The NWS has funded studies on radar-based signal processing solutions to initially identify and flag wind farm contaminated data, and eventually filter them from the real weather data. The NWS is also working directly with some wind energy developers on wind turbine-based mitigation, including the possible curtailment of turbine operations during severe weather and the sharing of wind farm met tower data. The NWS believes wind energy and weather radars can coexist through cooperation. Our email is*:* ***wind.energy.matters@noaa.gov***.

10. RELATED WEB SITES

Federal Aviation Administration Obstruction Evaluation / Airport Airspace Analysis (OE/AAA): https://www.oeaaa.faa.gov/oeaaa/external/portal.jsp

National Telecommunications and Information Administration (NTIA) Interdepartmental Radio Advisory Committee (IRAC): http://www.ntia.doc.gov/osmhome/irac.html

University of Oklahoma Atmospheric Radar Research Center: http://arrc.ou.edu/

WSR-88D Radar Operations Center Wind Farm-Radar Interaction Page: http://www.roc.noaa.gov/windfarm/windfarm_index.asp

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How to Successfully Work With NOAA on Wind Turbine – NEXRAD Radar Interference Issues, An Update

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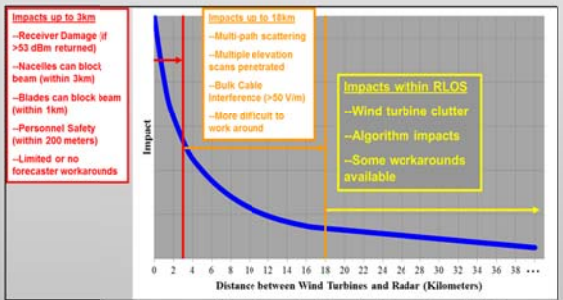
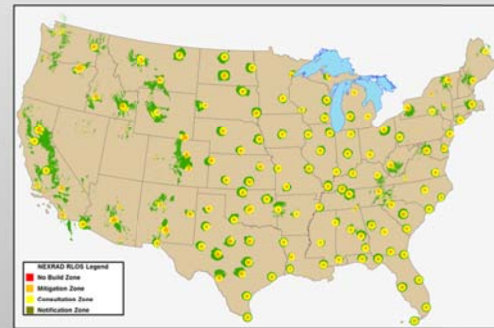
NOAA's New Evaluation Criteria

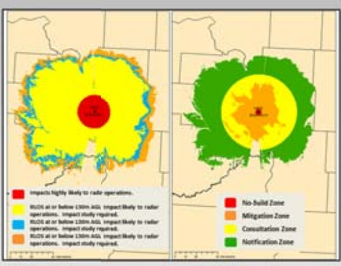


Wind turbine/farm Impact curve versus distance from radar. Operational impacts dramatically increase within 18km (10nm) and become so severe within 3km that no workarounds are available, compromising radar's ability to detect storms over and beyond the wind farm.

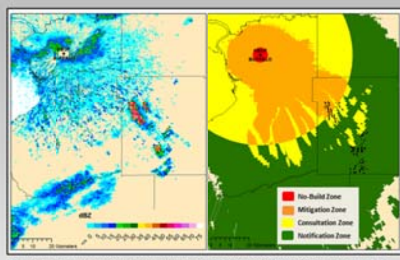
- Industry-friendly changes……decreased area of concern allows turbines closer to NOAA radars
- Based on several years of experience with turbines in radar line-of-sight (RLOS) both near and far from radar
- Original criteria for pursuing mitigation……based on turbines being anywhere in RLOS
- New criteria……focuses on turbines within 18km (10 nm)
    - Beyond 18 km impacts are very low and workarounds are available to overcome wind turbine clutter (WTC).
    - Distant WTC not significantly worse than other types of clutter typically impacting lowest radar scan angle
- New impact zones were based on "inventory" of impacts listed in left figure



National map of wind turbine impact zones for the NEXRAD network. Note that the Mitigation Zones (orange) and No Build zones (red) encompass a very small area of the nation.



Graphic of old versus new Impact Zones for Bismarck, ND NEXRAD. Red and yellow areas have been significantly reduced. New zone names on right communicate NOAA's desired action by developers.



Graphic of new evaluation scheme for Buffalo, NY NEXRAD. Left image is actual radar returns (Reflectivity) and right image has new impact zones with turbines (black dots) overlaid. Turbines located within mitigation and consultation zones create strong false returns (red) equivalent to severe thunderstorms in Reflectivity image.

New NEXRAD Impact Zones

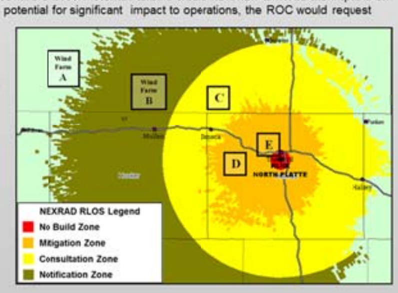
Wind Farm A: Out of the RLOS – Would have no impact on radar data, except in some anomalous propagation conditions, in which case impacts would be minimal.

Wind Farm B: Notification Zone – Dark green areas on map indicate where a 160-meter tall turbine would typically have minimal impacts on radar data and NWS forecast and warning operations. Since impacts are typically minimal and workarounds are available for penetration of only one elevation angle, consultation is optional. However, the ROC would still like to know about the project.

Wind Farm C: Consultation Zone – Yellow area on map indicates where a160-meter tall turbine would have low to moderate impacts on radar data and NWS forecast and warning operations. Due to the potential for significant impact to operations, the ROC would request consultation with the developer to track the project and acquire additional information for a thorough impact analysis.

Wind Farm D: Mitigation Zone – Orange area on map indicates where a 160-meter turbine would have moderate to high impacts on radar data and NWS forecast and warning operations. The ROC would ask to work with developers to get detailed project information, do a thorough impact analysis, and discuss potential mitigation solutions.

Wind Farm E: No-Build Zone – Red area on map indicates where a 160-meter turbine would have high impacts on radar data, NWS forecast and warning operations, and possibly damage the radar. The ROC would ask developers not to build turbines within the red area. In addition, the ROC would consult with developers to ensure they are aware of the likely impact on forecast/warning operations, the NEXRAD system, and turbine Installation and maintenance personnel.



When and How to Contact NOAA

When…..As Soon as Possible and for Major Project Changes

- Especially if a wind project would be located within yellow, orange or red areas (e.g. Wind Farms C,D, and E in image above)
- NOAA can perform multiple analyses, at every stage of development
- NOAA willing to reevaluate your project any time you make significant changes, such as a large increase in number of turbines, in turbine height, or turbine locations
- For additional, detailed information on wind turbine-radar interaction visit the ROC's web page at: http://www.roc.noaa.gov/WSR88D/WindFarm/

How…..Through NTIA or Directly with NOAA

The Department of Commerce's National Telecommunications and Information Administration (NTIA) acts as a "clearinghouse" for developers to voluntarily submit wind farm proposals for review by several federal agencies, including NOAA. This process is recognized by the wind industry in the American Wind Energy Association's (AWEA) Wind Siting Handbook (AWEA 2008). The NTIA contact is:

NTIA Contact
Mr. Edward Davison
Email: edavison@ntia.doc.gov

U.S Department of Commerce/NTIA
Room 4099A, HCHB
1401 Constitution Ave., NW
Washington, DC 20230

NOAA Contacts
Dr. Tim Crum or Ed Ciardi
Email: wind.energy.matters@noaa.gov

NEXRAD Radar Operations Center
1200 Westheimer Drive
Norman, OK 73069

Free, Anonymous Wind Farm Evaluation Tool

NOAA's new wind evaluation criteria have been uploaded to FAA's Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) website at: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm

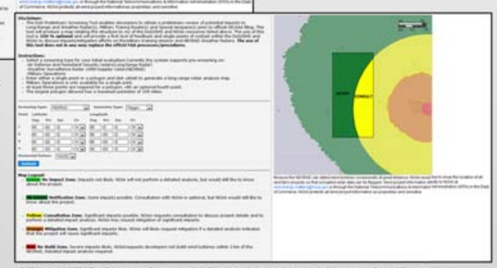
OE/AAA's DoD Preliminary Screening Tool, NEXRAD screening tool results for a single point location.

Single Point Analysis

Select DoD Preliminary Screening Tool in left column of web page, then select NEXRAD in drop-down menu next to Screening Type. Enter Coordinate pair and select submit. Output map is similar to the one at left….contains the four Impact Zones, a rotor blade symbol indicating proposed location of turbine, and suggested action by developer.

Polygonal Analysis (3 or 4 Points)

Similar to Single Point Analysis except you enter 3 or 4 coordinate pairs designating your development area. Example output is in figure at right.

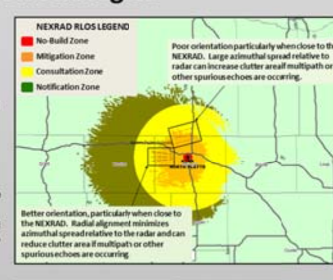


OE/AAA NEXRAD screening results for a polygonal area with associated impact zones.

Available Mitigation Strategies

Create Awareness of NEXRAD Sensitivities

- NOAA is reaching out to wind energy developers to ensure they are aware of NEXRAD locations and potential wind farm impacts
- NOAA's Radar Operations Center (ROC) can provide developers a no-cost site-by-site analysis of proposed wind farms and suggest mitigation options, such as in the figure to the right, or operational curtailment

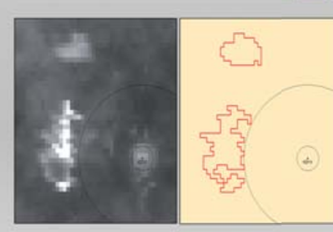


Increase Knowledge

- In absence of predictive impact modeling software, NOAA continues to learn about wind farm impacts on radars and forecast operations where wind farms are already in close proximity to its radars.
- Based on this real-world experience, NOAA's Warning Decision Training Branch (WDTB) developed a training course that introduces forecasters to the appearance of wind turbine clutter (WTC) in radar products and provides information on "work-arounds"
- This course is available on-line at: http://www.wdtb.noaa.gov/modules/windfarms/index.html

Create Wind Farm Identification Tools

- NOAA's National Severe Storms Laboratory (NSSL) and ROC developed GIS overlays indicating wind turbine locations for use by NOAA forecasters
- Overlays created using 12-month accumulated radar estimated precipitation data (http://www.nssl.noaa.gov/projects/q2/q2.php for more info)
- Wind farms create "hot spots" in these data (left side of figure at right). GIS overlays (right side of figure) are added to forecaster data dispay systems to help them identify areas of turbine clutter



Operational Curtailment of Wind Turbines During Severe Weather

- A mitigation option drawing favorable interest from both weather forecasters and wind developers involves limited and rare operational curtailment of turbines during severe weather events (e.g., tornadoes, severe thunderstorms)
- During curtailment, wind farm operators would stop turbine bade rotation for short time periods (on order of 30 to 60 minutes)….allows radar to filter out any WTC signals returned from wind farm
- Turbine clutter significantly reduced or completely eliminated in most circumstances, hence data contamination and algorithm errors are greatly reduced or eliminated
- NOAA already has Letters of Intent for operational curtailment in place with 3 wind farm operators