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Hi Reddit, we're Jessica Schultz, Kurt Hondl, Terry Schuur, and Katie Wilson, NOAA scientists in Norman, Oklahoma. We're here to answer your questions on weather radar research and improvements. Ask us anything!

NOAAgov [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

When severe weather strikes anywhere in the United States, weather radar is one of the most important tools forecasters use to track storms and warn the public. The current system, known as the WSR-88D radar or NEXRAD, provides the best quality data available in the world, and is the most reliable. We are radar specialists and work in at the Radar Operations Center, the support center for the nation's radar system, and at the National Weather Center in Norman, Oklahoma, which houses scientists from a variety of organizations, including NOAA's National Severe Storms Laboratory and the University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies. The NEXRADs were deployed in the early to mid-1990s and were upgraded with new dual-polarization technology a few years ago. To keep them running for another 30 years, a $150 million, seven-year effort is underway to refurbish and replace major system components such as the signal processor, transmitter, pedestal, and equipment shelters. NSSL researchers are developing the next big advancement – phased array radar. It has a unique flat panel antenna made up of a grid of fixed elements, and each can transmit and receive a signal. As a result, the radar beam can be steered electronically, giving users the ability to control how, when and where the radar scans. This will provide forecasters with faster updates. We are ready to answer your questions today from 1-3 p.m. ET about all of it, so ask us anything!

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NOAAGOV R/SCIENCE

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NOAAgov , r/Science , Hi Reddit, we're Jessica Schultz, Kurt Hondl, Terry Schuur, and Katie Wilson, NOAA scientists in Norman, Oklahoma. We're here to answer your questions on weather radar research and improvements. Ask us

Has the radar system ever malfunctioned or stopped working? If so, what is plan B?

eniTTy

Hi! This is Katie. Sometimes the radar system does malfunction during real-time operations. A malfunction could be due to a technical glitch, or sometimes the weather can cause the radar to go down. Thankfully, some NOAA National Weather Service Weather Forecast Offices can use the next-closest radar to track weather, but in instances when they are unable to do so, forecasters can depend on their neighboring offices to provide weather decision support during such events. Hello! This is Jessica. Forecasters can also use other observational systems such as the Federal Aviation Administration's Terminal Doppler Weather Radar (TDWR), satellite, ground instruments, and spotter networks to help overcome the missing radar data. Local technicians work quickly to return the radar to service, and have access to the Radar Operations Center's 24/7 Hotline to receive expert advice and troubleshooting. If the radar issue is unable to be resolved locally, the Radar Operations Center has a staff of radar technicians who can be deployed to any radar within 1 or 2 days.

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Why are wind farms bad for weather radar? Also, what is your favorite weather related song or movie?

focusonsyrup

Hi, this is Jessica. Thanks for the question! Wind turbines impact the radar because the metal structure returns energy back to the radar. Unlike other types of clutter, or non-meteorological data such as buildings, the wind turbine blades move causing contamination in both reflectivity - precipitation- and velocity -wind speed- data. Turbines that are closer to the radar and taller result in greater amounts of contamination, meaning they look like storms when they are not storms. We work with wind project developers to try to reduce the impacts as much as possible.

Our favorite weather-related songs: Jessica - Blown Away by Carrie Underwood Katie - It's Raining Men by The Weather Girls :) Kurt - Rock You Like a Hurricane by the Scorpions Terry - Thunderstruck by AC/DC

How long do you think it will take to get Puerto Rico's Radar running again?

wx_radar

Hi, this is Jessica! Great question! We have a team currently in Puerto Rico working to restore the radar. The old tower has been deconstructed and the new tower is going up! The radar should be back in service by early June. We've posted some pictures of the progress on the Radar Operations Center's Facebook page: https://www.facebook.com/NEXRADROC.

Hi! I am currently a sophomore in college studying meteorology, so if any of my terminology is inaccurate, please correct me.

Dual polarization has been a huge step in terms of being able to identify tornadoes that are on the ground without being able to visually see them, what's the next big technology that will take tornado forecasting to the next level?

Where do you radar technology advancing in the next 20 years?

This might be the wrong department to ask, but our current tornado rating based on damage is great for news companies because they can focus on the tornadoes that matter to local areas. However, you can have two identical tornadoes with different ratings based purely off of location and storm track. So wouldn't this rating system hinder tornado research since they were the same tornado yet classified differently?

QuiteAFellow

Hi, this is Kurt. Weather radar technology is always advancing. A lot of the radar technology has been developed for military applications and eventually makes its way to civilian applications. In 2003 we received a "passive" phased array radar from the U.S. Navy and adapted it for weather use. That radar was already more than 30 years old before we received it and eventually retired it in 2016. Meanwhile phased array radar technology has been advancing into what are called "active" arrays and now even into the digital realm. With each new development we see improved capabilities. We are currently researching and developing polarimetric phased array radars specifically for weather applications as a possible replacement for the current WSR-88D — but the WSR-88D is currently the best weather radar out there.

Hi, this is Terry. Research is currently being conducted at NSSL to examine potential improvements offered by phased array radar technology. Unlike conventional WSR-88D radars where the data are collected by a mechanically rotating antenna, phased array radars allow the radar's beam to be

steered electronically. Phased Array Radars allows us to collect data more rapidly -- 1-2 minute updates, while 5-6 minute updates are currently possible on the WSR-88D system. Research into how this "rapid-scan" data might be used to provide improved severe weather warnings is ongoing, as well as how the data might be assimilated to numerical models to improve short-term severe storms forecasts.

Hey there, this is Katie! One of the big steps forward in tornado forecasting that NOAA NSSL has identified is moving from a warn-on-detection approach (i.e., using real-time observations like radar and storm spotter reports) to a Warn-on-Forecast approach (https://www.nssl.noaa.gov/projects/wof/). The goal of the NOAA Warn-on-Forecast Project is to use numerical weather prediction to provide forecast information that allows for earlier anticipation of tornadoes as well as other types of weather including storms that produce severe hail, wind, and flash flooding. Scientists working on WoF are busy developing and testing a prediction system on a more local level that provides uncertainty information for a variety of weather threats from zero to three hours before weather strikes. Researchers at NSSL have already found that the assimilation of improved radar data (e.g., using rapidly-updating phased-array radar) can lead to improvements in model forecasts of storms. Therefore, continuing to advance radar technology while making progress in Warn-on-Forecast is very important! In addition to spending time developing weather models, scientists have also begun investigating how forecasters will use this information to make decisions. For example, through surveys, observations, and collaboration with National Weather Service forecast offices, scientists at NSSL as well as other research institutions across the country are learning about how forecasters understand, apply, and communicate uncertainty information to the public as well as to special end-users such as emergency managers.

What are the causes of abnormal weather? And how often do you think it will occur in the future?

Also... do you think weather related natural disasters can be treated in the future? (Like the movie Geostorm)

Adrian_Ochoa

Hello Adrian! My specialty is in radar meteorology, but let me try to answer your more climate-related question. There are lots of different ways to think of abnormal weather, including how the frequency, intensity, and location of it compares to normal (i.e., climatology). The causes of it highly depend on what type of abnormal weather we are talking about (i.e., hurricane season, winter storms, prolonged droughts), but oftentimes we can tie these events back to large-scale atmospheric patterns. Looking to the future, NOAA scientists and many others are researching how the state of our climate will impact the types of weather patterns we see, including our partners at www.climate.gov, and what that means for the type of weather you and I experience down here on the ground. Most scientists are in strong agreement that we will see an intensity in heat waves, droughts, and flooding, in addition to changes in the activity of hurricane and severe weather seasons. I have not yet watched Geostorm, but I have heard it's a lot of fun like most Hollywood fiction! - Katie

Hi NOAA, thanks for doing this.

What are some of the challenges associated with collecting polarimetric data on the phased array radar?

Also how will these beams be steered electronically?

argentgrove

Hi, this is Kurt and Terry. The beam of a phased array radar is steered electronically by changing the

phase -- or timing -- of the transmitters in the array. The thousands of transmit elements in the array work together this way to create a wave front in the desired direction. Unlike the current NEXRAD system that uses a parabolic dish, the beam of a phased array radar changes slightly with each beam pointing angle. So the horizontal and vertical polarized signals can become skewed with respect to each other and to the Earth's surface. This requires fairly extensive calibration and compensation to get usable polarimetric data. This compensation has been shown in theory, but hasn't yet been fully demonstrated in practice. We have a new dual polarized phased array radar coming to the NOAA National Severe Storms Laboratory in Norman this summer that we will be using to collect data and evaluate the polarimetric data. With a parabolic dish antenna (as currently used with the WSR-88D radar system) the beam is always the same no matter what direction the antenna is pointed and the horizontal and vertical polarizations are always orthogonal to each other.

What is the next largest observational gap to fill in severe weather forecasting in the U.S.? Are there regions that do not have enough coverage via radar, satellite, or ground based observations? Do you have a personal "wish list"? Thanks for doing this AMA!

seis-matters

This is Jessica. We're excited to do the AMA! The NEXRAD radars were deployed in the early to mid 1990s across the nation and were sited based on likelihood of hazardous weather, population, and mission requirements of the National Weather Service, Department of Defense, and Federal Aviation Administration. Areas east of the Rockies tend to have overlapping coverage, whereas the western U.S. has limited overlapping coverage due to terrain. Recent developments in technologies, such as the new GOES Satellite, allow forecasters to supplement radar data with other observations.

Do you think that when phased array Radar comes around that we will be able to increase coverage by having multiple small Radars? Out west we have a lot of blank spots on the map with zero Radar coverage.

wx_radar

Hi there! This is Jessica and Kurt. Several government agencies including NOAA, Federal Aviation Administration, and Department of Defense are currently investigating options for a new national radar system, which could include phased array. We'll have to see how those investigations pan out. In the meantime, we are constantly improving the NEXRAD radars to remain viable into the 2030s. Out west, where terrain can complicate the radar coverage, forecasters use other technologies such as the new GOES Satellite, to supplement weather information. There have been research programs looking at the feasibility of smaller, gap-filling, radars to fill in areas blocked by terrain. The smaller radars typically use shorter wavelengths, which suffer signal attenuation in intense rainfall so they may not be suitable for all weather conditions. NSSL is also evaluating the possibility of putting radars on stratospheric balloons to provide better coverage over mountainous terrain.

Hi, NOAA! Thanks for doing this AMA!

What type of research will be done from this mission and how would we benefit from it?

AstroManishKr

Hi, This is Kurt. What mission are you asking about? The next generation of radar? Weather radar is arguably the primary tool used by National Weather Service forecasters when providing warnings for tornadoes and other forms of severe weather. Our mission at NOAA and specifically the National

Severe Storms Laboratory is to improve our understanding of severe weather and to develop better tools for NWS forecasters to provide improved public service warnings. We believe better radars — that provide faster updates, more coverage, and higher data quality — will help NWS forecasters provide better warnings to the public.

Hello! This is Katie here. I wanted to add while there is a lot of research that goes into developing the radar systems used in operations, there is also a lot of work to ensure the new information we provide to forecasters will benefit them. We conduct experiments within the NOAA Hazardous Weather Testbed at NSSL to test how new radar information will impact forecasters' warning decision processes-- such as how they perceive the new information, how forecasters apply what they are seeing to their conceptual models of severe storms, and how the radar information influences the accuracy and timeliness of the warning products they issue. Here at NOAA we work hard to collect important feedback from weather forecasters and to keep them in the research loop so that the most suitable and effective tools are implemented into NWS operations.

Hi, NOAA! Thanks for doing this AMA!

How would we benefit from NOAA satellite's?

AstroManishKr

Hello, this is Jessica. Thanks for the question! The new GOES satellites are really the next generation. We have access to more detailed and precise data than ever before! There is a lot we will learn about the atmosphere in the coming years. It's an exciting time! For more information, visit NOAA's website on satellites: http://www.noaa.gov/satellites

My question:

Why does Oklahoma have the following four seasons:

Bitter Cold Tornado Season Blazing Hot 8 days of Autumn

?

Thanks!

JakeCooksFood

Hi there! This is Jessica. Due to Oklahoma's location in the south central plains, we experience a wide range of weather. Although some periods of weather might be shorter in Oklahoma, like mild fall days or warm spring days, Oklahoma is a great place for weather research! We have an exciting weather community here studying about all types of weather, and that knowledge can be applied across the country to improve forecasts and warnings.

I've heard phased array radars may be the next big upgrade to NEXRAD. What are science/technological challenges to this and what would need to be done to make this upgrade happen?

saund1pe

Hi! This is Jessica and Kurt. Multiple federal agencies, including NOAA, Federal Aviation Administration, and Departments of Defense and Homeland Security, are currently exploring the feasibility of a national radar network that could include phased array. In the meantime, the National

Weather Service, Federal Aviation Administration, and Department of Defense have invested in a seven-year, $150 million program to keep the NEXRADs, the current network, viable into the 2030s. Here at NSSL, scientists have been studying the technical challenges, including calibration techniques, use of dual polarization, and data quality characteristics of phased array radar technology to determine its readiness to meet operational requirements for a future network deployment. We are developing a polarimetric phased array radar that we will be testing over the next several years. Technology development is only one aspect of the question … the bigger issue will be the cost/budget implications of the Federal budget in determining if and when a phased array radar upgrade is likely to happen.

Is MPAR in operational mode for this storm season?

TacocatAteMyTacos

Hi, this is Terry and Kurt. MPAR -- the Multi-Function Phased Array Radar program at NSSL -- retired our old phased array radar in 2016 so we could make preparations for our new polarimetric phased array radar called the Advanced Technology Demonstrator. The ATD is scheduled to arrive this summer and will be installed over several months before we can begin calibration and checkout of the system. We expect the ATD to be ready for storm season in 2019.

Some parts of the country have poor radar coverage near the surface. Phased array is an exciting advancement in weather radar technology, but is there anything that can be done to increase the coverage (especially in the lower levels)? https://www.roc.noaa.gov/WSR88D/Maps.aspx

WeatherBoy89

Hi there, this is Jessica. In areas where the Federal Aviation Administration's Terminal Doppler Weather Radars, or TDWRs, are available -- those radars provide good very low, low-level coverage. Other options worth exploring include a small, localized network of radars. An experiment in the Dallas-Fort Worth area, called CASA (http://www.casa.umass.edu/main/research/urbantestbed/), has been examining the feasibility of such a network. New technologies available to forecasters, such as NSSL's MRMS Multi-Radar Multi-Sensor project system allow a synthesis of multiple observation networks -- radar, satellite, surface instruments, storm spotters, etc -- to provide a broad view of the environment.

Can predictions of exact timing and exact locations of supercell thunderstorm development be improved through research? What is the biggest challenge to predicting exact time and exact locations, excluding the variability of the atmosphere? What studies are being done to increase the lead time and accuracy a supercell thunderstorms especially those that can produce tornadoes?

wxfreak

Hi Wxfreak! Thanks for the great questions. One of the biggest challenges in the accurate temporal and spatial prediction of thunderstorms is being able to resolve small-scale features within the model. This challenge is linked to the grid spacing; smaller grid spacing in the model requires greater amounts of computing power. The NSSL Warn-on-Forecast project has lots of ongoing research to improve the model predictions of thunderstorms, including studies that improve the ways we represent the atmosphere in the model and studies that test different configurations of the model system (e.g., initial conditions of the atmosphere, grid spacing of the model, and equations to represent a variety of physical processes). The WoF model is being tested in real-time and scientists at NSSL are developing methods to evaluate how well the forecasts are performing. In a qualitative sense, the WoF model has been able to accurately forecast the type of storm that will develop (i.e., supercell versus line) and the mesocyclone (i.e., rotational) intensity of storms. The performance of the WoF model is

variable though, with more accurate forecasts being produced on days when storms are more isolated and convection is already ongoing, and less accurate forecasts being produced on days when storms are more widespread and mixed in terms of their mode. -- Katie

Lots of questions, sorry in advance :)

What would you say has been the most challenging aspect of designing a phased array radar for weather? Also, phased array radars were used in military applications decades ago; why the relative delay in applying this technology to weather radar?

What kind of performance increases can we expect of meteorologists using phased array radars versus the old NEXRAD system? Do the performance increases depend on storm type? Are any new visualization tools or styles being developed for meteorologists (for example, augmented reality could potentially help meteorologists visualize 3D storm structure), or are the standard "slices" of reflectivity, velocity, etc. good enough?

Will phased array radar data have an impact on the accuracy of model outputs? Additionally, do you anticipate any performance increase in the Warn-on-Forecast program from being able to use phased array radar data to help initialize the short-term models?

Raptor112358

What would you say has been the most challenging aspect of designing a phased array radar for weather? Also, phased array radars were used in military applications decades ago; why the relative delay in applying this technology to weather radar?

Hello Raptor (if that is your real name) … this is Kurt. You are correct, phased array radars have been around for about 50 years and were initially developed for military applications. The cost of phased array radar has limited development for civilian applications until the digital age came about and reduced the cost of the electronic components. Military phased array radars were developed for aircraft and missile detection. But weather radars operate differently from aircraft detection radars — we're looking at the combined returns of thousands of individual drops. Additionally, the WSR-88D was recently upgraded with dual polarization capabilities that haven't yet been fully developed on phased array radar technology. Adding dual polarization technology to phased array radar continues to be our greatest technical challenge. We are currently developing a first-of-its-kind dual polarization phased array radar that will be used to evaluate the polarimetric performance and calibration abilities of phased array radar. Our first large-scale polarimetric phased array "weather" radar should be ready for testing during the 2019 storm season.

What kind of performance increases can we expect of meteorologists using phased array radars versus the old NEXRAD system? Do the performance increases depend on storm type?

Raptor, Katie here. This is a great question! This is one I spent years querying for my Ph.D. research. We have put National Weather Service forecasters through different experiments at the NOAA Hazardous Weather Testbed to investigate the impact of rapidly-updating phased-array radar data on their warning decision processes. One aspect we've looked at is forecasters' performance (both accuracy and lead time) during a variety of weather events. In a nutshell, yes we can expect to see performance increases if we provide weather forecasters faster radar updates. In our studies, forecasters using 1-minute radar updates (compared to 5-minute radar updates) issued less false alarms and were able to better discriminate between weather threats. Overall, we saw improvements in lead time too (on average warnings were issued several minutes to ten minutes earlier), with the greatest improvements occurring for isolated supercell tornado events. Forecasters were better able to detect trends in severe weather precursor signatures within the radar data when they were using the faster radar updates. We found these trends improved their abilities to apply their conceptual models

and understanding of storm evolution and make more mastery (i.e., confident and correct) decisions! As a side note, we have also tracked weather forecasters' eye movements during their interaction with phased-array radar data. It was really fascinating to watch how they interrogate the radar data and move around the warning interface. We were able to use these eye-tracking data to provide an objective assessment for differences in how forecasters went about their jobs when using 1-min versus 5-min radar updates. Watch the video here to learn more: https://www.youtube.com/watch?v=EJVjlSDoxXI&t=2s

Are any new visualization tools or styles being developed for meteorologists (for example, augmented reality could potentially help meteorologists visualize 3D storm structure), or are the standard "slices" of reflectivity, velocity, etc. good enough?

Hi Raptor, this is Terry. As part of our research, we are continually working with forecasters in an attempt to better understand how to best present radar data and products in an operational environment. Over the years, a variety of visualization capabilities have been developed and tested, including several packages that have 3D capabilities. When radar data, which are typically collected as a series of "conical scans" at a variety of elevations, are interpolated to a 3D grid, they can then be combined with other environmental parameters, such as environmental temperature with height. An example of such a product is the size of a severe storm "reflectivity core" at the -20C temperature level, which is a product that can be used to gauge severe storm strength. I am currently not aware of any radar visualization tools that implement augmented reality.

Will phased array radar data have an impact on the accuracy of model outputs? Additionally, do you anticipate any performance increase in the Warn-on-Forecast program from being able to use phased array radar data to help initialize the short-term models?

Katie here again… Raptor, yes, scientists here at NSSL do expect phased array radar data to positively impact the accuracy of model outputs. There have been several studies that have assimilated real as well as synthetic rapidly-updating radar observations into numerical models, and the results show more realistic forecasts of convective storms. One of the most recent studies by Supinie et al. (2017) reported the assimilation of phased array radar data led to improved alignment between the model-predicted and radar-derived locations of storm rotation. So, we have high hopes for the ways phased-array radar data can help advance the predictability of the WoF model.

What frequency and ERP does the WSR88D operate at?

wxfreak

Hi, this is Jessica. The WSR-88Ds are S-band radars, so they operate between 2700 and 3000 MHz. Neighboring radars operate on different ends of that band in order to avoid interference between WSR-88Ds, as well as interference with other S-band systems in the vicinity. The WSR-88D produces 700 kw of power. More technical details are available here: https://www.roc.noaa.gov/WSR88D/Engineering/NEXRADTechInfo.aspx

How have improvements in computing technology helped your field of research? Do you partner with academia for your research?

almanac537

Hi Almanac537, This is Kurt. It is hard to have technology advancement without improvements in computer technology. From a radar perspective, computing technology is used in signal processing as well as computational electromagnetic modeling and radiator design. NOAA/NSSL collaborates with many academic partners including The University of Oklahoma. In fact, NSSL is located on the OU

campus and shares a building with the OU School of Meteorology and the Cooperative Institute for Mesoscale Meteorological Studies along with other NOAA and University entities. We also collaborate with industry and other public and private institutions as we conduct our research.

Howdy from an NWS Meteorologist! I wanted to ask yall what the coolest or most spectacular radar signature you've seen was. Mine is a toss up between some fairly strong tornadic couplet and watching biological movements of birds and bats on radar! Thanks for doing this!

tx_BWER

Hi tx_BWER, this is Terry. Wow…..I don't even know where to begin with that question! I spend much of my research life trying to figure out what polarimetric data are telling us. When the WSR-88D network was upgraded to include polarimetry, it seems like we were seeing something almost every day we were trying to make sense of. While my personal interest is primarily in understanding the "ice microphysics" of precipitating clouds, I think many of the intriguing signatures I have seen have been associated with non-meteorological phenomena. An example is the annual migration of Monarch butterflies we see through central Oklahoma in late September every year. Not surprisingly, their radar characteristics seemed to fall somewhere in between what we typically see for insects and birds. And I still remember the large swaths of negative "differential reflectivity" we saw associated with an intense dust storm in Arizona. I'm not sure we ever did figure out what was causing that. There are numerous others.

Hi, this is Jessica. One of the most interesting signatures I've seen is the almost instantaneous flight of birds and other biologicals during a large earthquake near Oklahoma City in 2015. We have a loop of the data on the Radar Operations Center's YouTube: https://www.youtube.com/watch?v=nwveTgmCab8

Hi! Thanks for holding the AMA. Currently a Biology undergrad about to graduate in May. Joining the NOAA Corps is currently my number one goal once I graduate. Any opinions/advice on the Corp and possible joining NOAA afterwards? Thank you!

bluecamoturtle

Hi Bluecamoturtle, Terry here! Thanks for the question! While I don't personally have advice regarding NOAA Corps, I recently worked with them for VORTEX-Southeast. In addition to their well-known marine operations, they also operate the NOAA Aircraft Operations Center, which includes the WP-3D "Hurricane Hunter" aircraft. NSSL has been working with the AOC to collect data to better understand and predict tornadic storms.