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National Severe Storms Laboratory

Welcome and Kickoff to the NSSL 60th Anniversary Symposium

Kurt Hondl, NSSL Deputy Director

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National Severe Storms Laboratory

Welcome and Kickoff to the NSSL 60th Anniversary Symposium

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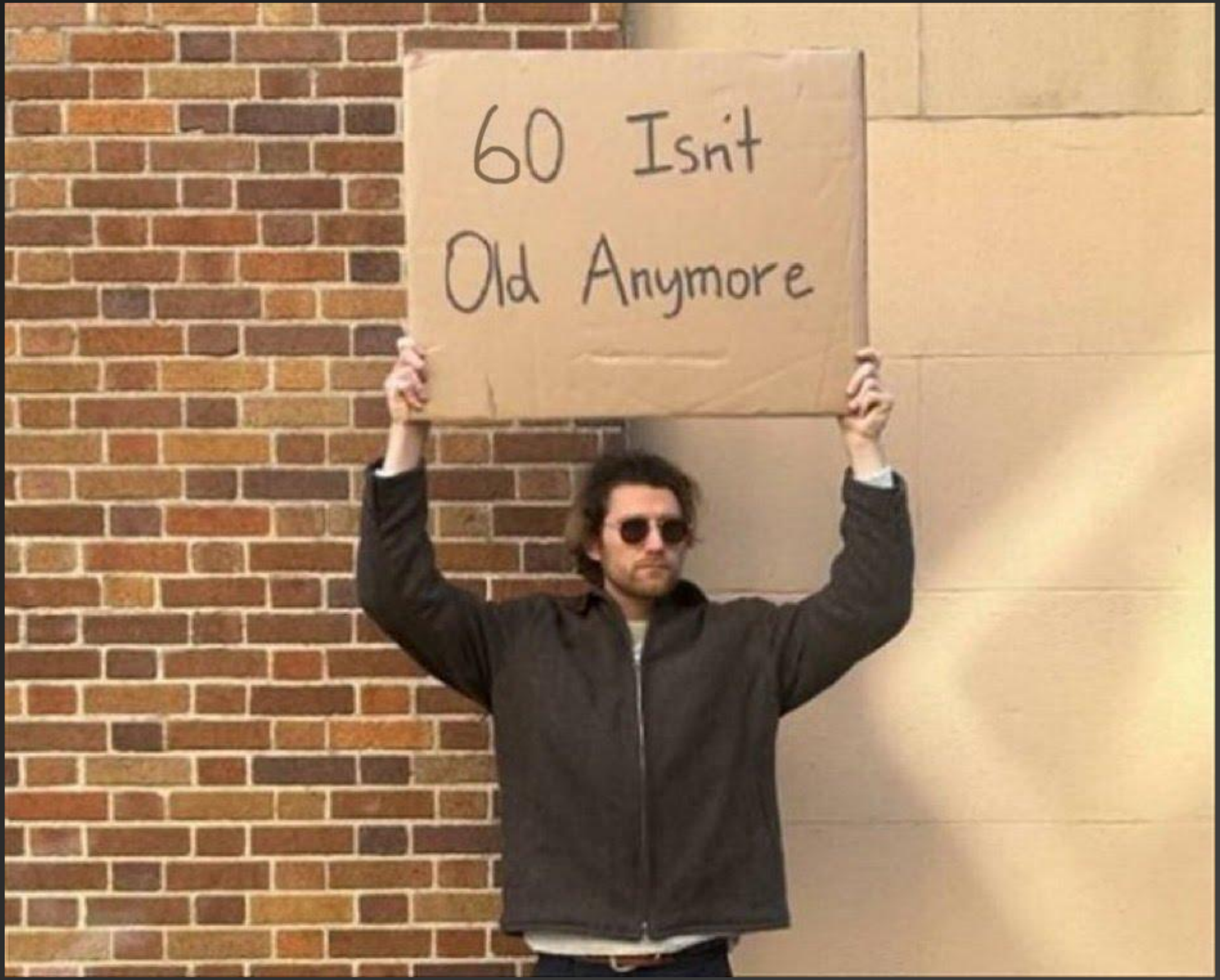

60 Isn't
Old Anymore


NSSL
NATIONAL SEVERE STORMS LABORATORY
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Years
CELEBRATING
60 YEARS OF NSSL

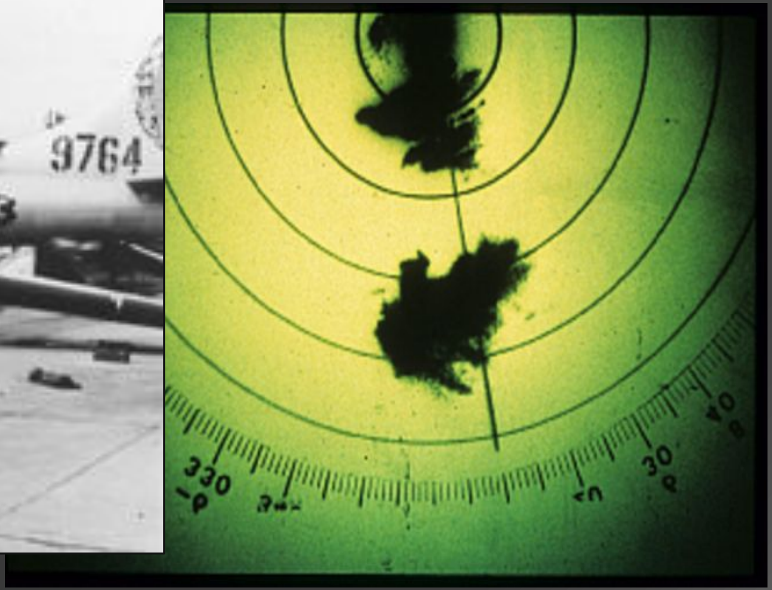
Welcome Everyone!

- In case of severe weather … stay where you are.
- In case of fire or other building emergency … meet at the north end of the parking lot. (★)
- Bathrooms across the hallway and over by the Flying Cow café.
- Let's thank all of those who helped with and conducted the demonstrations this morning!

National Severe Storms Laboratory

Origin Story

- 1948: 1st successful tornado forecast (USAF at Tinker AFB) (March 25th)



- NWS began specialized tornado forecasts in 1952 *(SELS → NSSFC 1966 → SPC 1995)*
- NWS Tornado Warnings were typically issued after visual confirmation of a tornado
- The “Hook Echo” first observed on radar in 1953

SELS → NSSP → NSSL

Dr. Edwin Kessler
1st Director of NSSL

Objectives of NSSL, 1964

Kessler, E., "Purposes and Programs of the NSSL," ***NSSL Report No. 23****, U.S. Weather Bureau, 1964, 18 pp.*

The Laboratory objectives in the national interest are:

1. To gain new knowledge of the morphology and dynamics of severe storms, such as heavy rains, squall lines, thunderstorms and tornadoes, and thereby to contribute to the development of improved forecasting, and understanding.
2. To discover improved methods of collecting, analyzing, and processing severe storm data, and to stimulate development of equipment, especially radar equipment, holing promise of expanded capabilities.
3. To study operating configurations of men and equipment, and thereby to contribute to the design of improved storm observing and reporting systems wherein sensors, processors and communications facilities are efficiently meshed to provide timely, accurate information to the host of users.

The Early Years

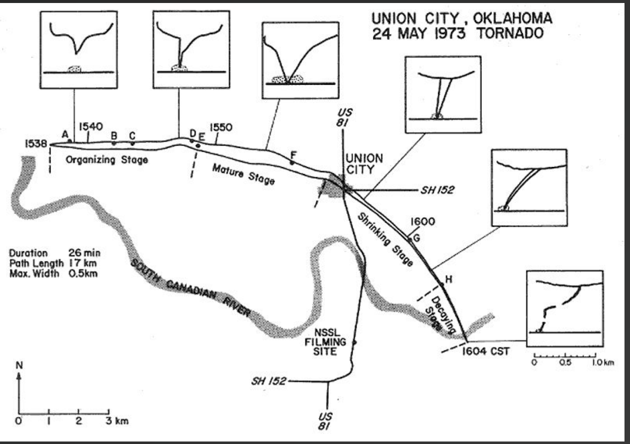
Kathryn Gray

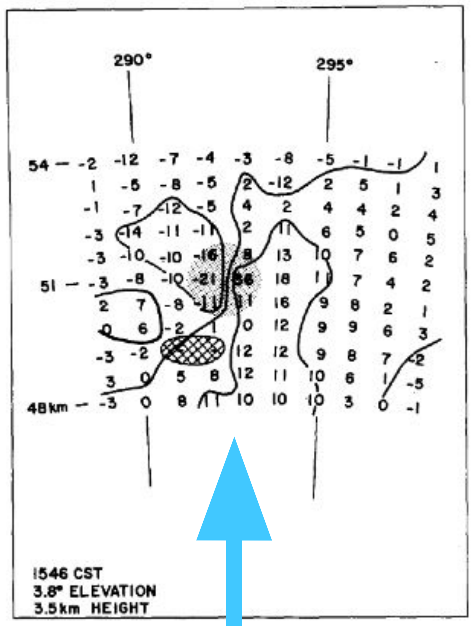
Dr. Kessler

NSSL started in an old barracks building on a former U.S. Navy Base in Norman, OK.

CELEBRATING 60 YEARS OF NSSL

May 24th, 1973 – Union City – Tornadic Vortex Signature





First Observed TVS by Doppler Radar

Rodger A. Brown, Donald W. Burgess, and Leslie R. Lemon (NOAA Special Achievement Award, 1976)

NSSL moved to the NWC in 2006

CELEBRATING 60 YEARS OF NSSL

State

OU
University of Oklahoma

CAGS
College of Atmospheric & Geographic Sciences

SOM
School of Meteorology

OK Meso
Oklahoma Mesonet

OCS
Oklahoma Climatological Survey

SCCASC
South Central Climate Adaptation Science Center

CSA
Center for Spatial Analysis

CIWRO
Cooperative Institute for Severe and High-Impact Weather Research & Operations

ARRC
Advanced Radar Research Center

CAPS
Center for the Analysis & Prediction of Storms

Federal

NOAA
National Oceanic & Atmospheric Administration

OAR

NWS

NSSL
National Severe Storms Laboratory

- Forecast R&D
- Radar R&D
- Warning R&D
- Field Observations

SPC
Storm Prediction Center

ROC
Radar Operations Center

NWSFO
NWS Norman Forecast Office

WDTD
Warning Decision Training Division

NWS offices in the NWC

CELEBRATING
60 YEARS OF NSSL

Meet the NSSL Directors

Edwin Kessler	Robert Maddox	James “Jeff” Kimpel	Steven Koch	John “Jack” Kain	DaNa Carlis
1964 - 1986	1986 - 1996	1997 - 2010	2011 - 2019	2020 - 2022	2023 –

CELEBRATING 60 YEARS OF NSSL

That’s how NSSL went from this


2023 NSSL Advance
Innovating for Tomorrow
October 24-25, 2023

Dr. Steve Thur, OAR Assistant Administrator

Michelle Mainelli, NWS Deputy Director

VADM Nancy Hann
NOAA Deputy Under Secretary of Operations

Panel:
A Legacy of Achievement Through a Continuum of Innovation

Moderator:
Dr. Vanna Chmielewski
Panelist:
- Dr. Pam Heinselman
- Dr. Harold Brooks
- Dr. Ken Howard
- Dr. Dusan Zrnic

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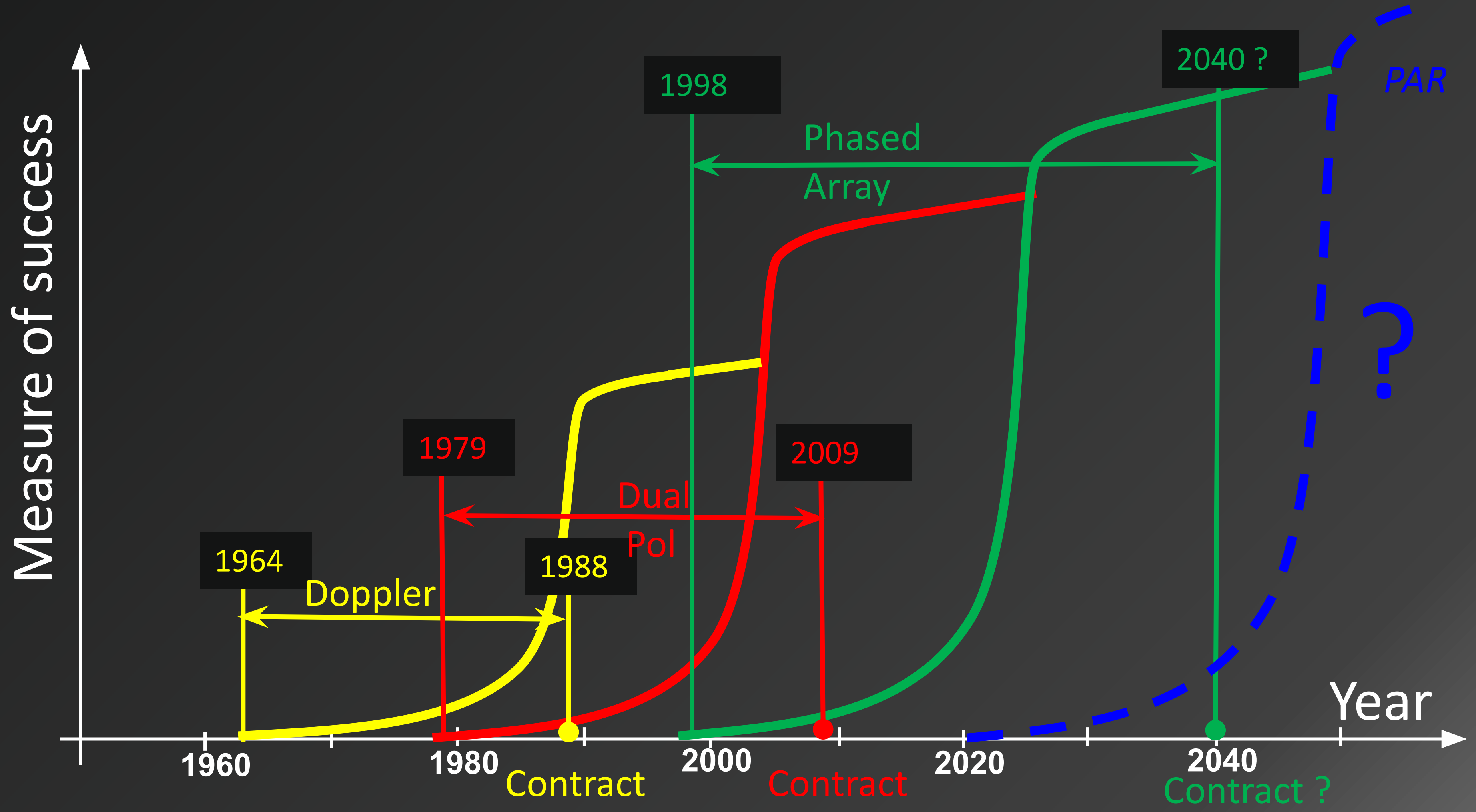
National Severe Storms Laboratory

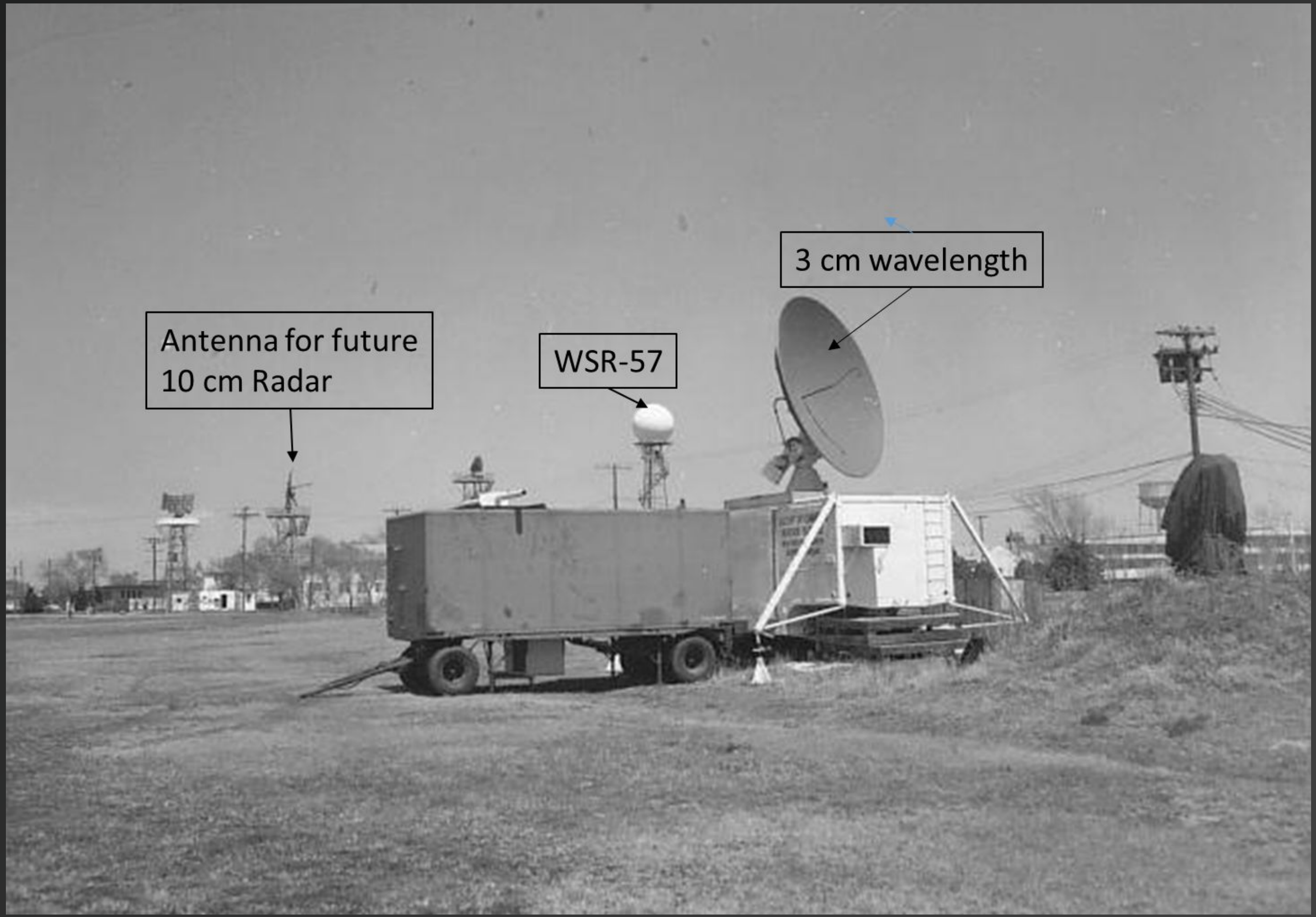
Advancements Impacted by NOAA Administrators

Dusan Zrnic

Radar Technology Development at NSSL & Implementation by NWS



NSSL's 3 cm Doppler Radar (c.a., 1965)



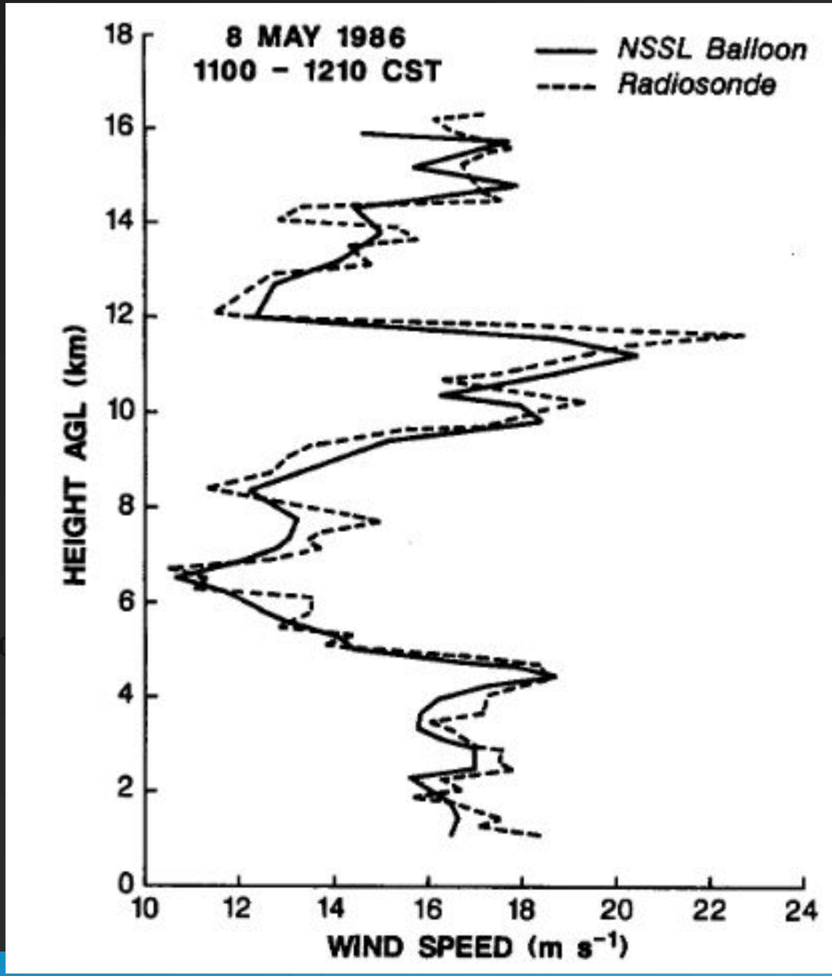
Other Applications

Wind profilers

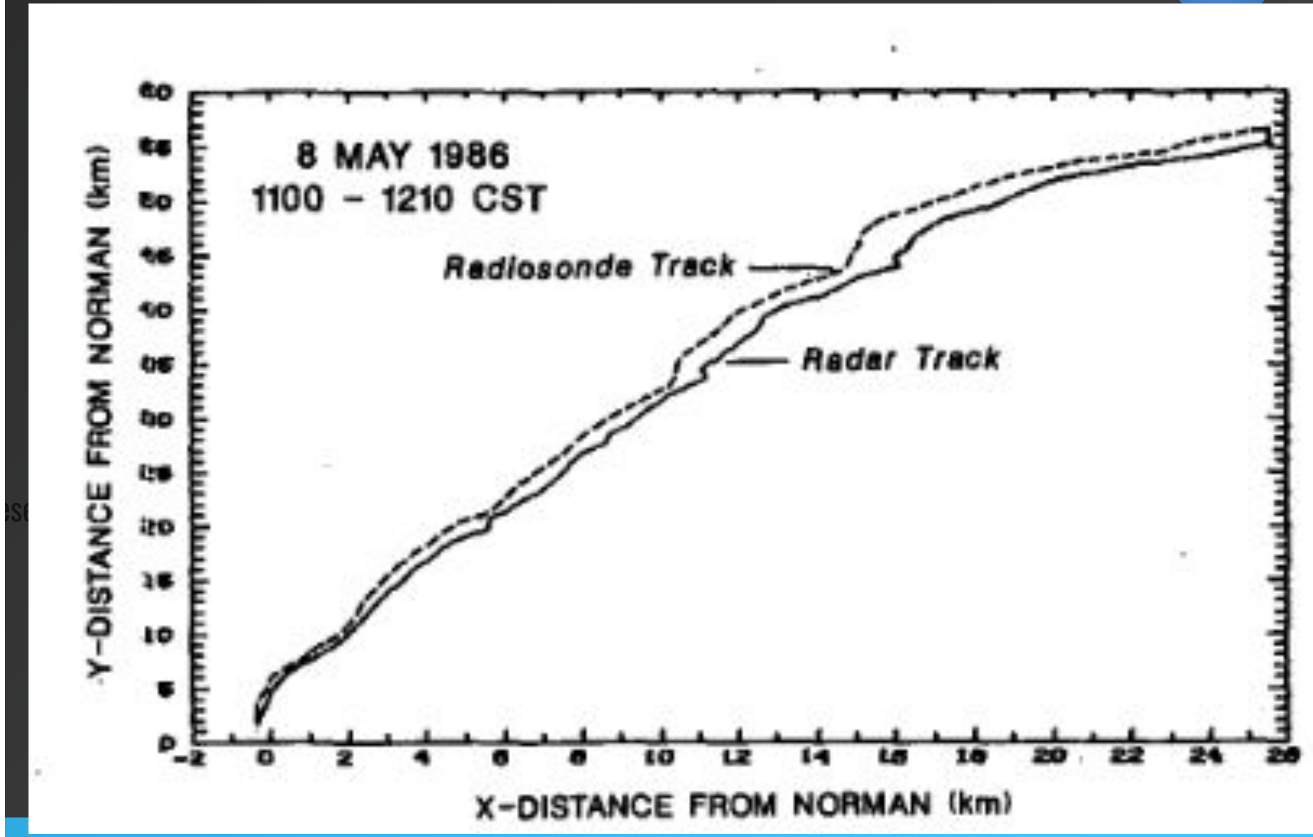
- Installed a 50 MHz profiler on Kessler's farm

Doploon

Use of weather surveillance radars (WSR-88D) for tracking balloons to measure winds



Track in x,y distance projection from Norman



Chronology

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WSR-57 Researc h

1960

1970

Norman 10-cm Doppler 1971

Cimarron 10 cm Doppler 1973

JDOP 1977-79

1980

Cimarron upgraded to dual-pol 1983-84

First
in the World
dual-pol time series (I,Q) 1984

First First Dual Doppler using P3 and Cimarron 1989

1990

First
in the World
dual-pol variables in real-time 1992

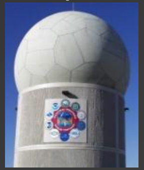
Helped build first Doppler on Wheels 1995

First
WSR-88D research radar (KOUN) 1996

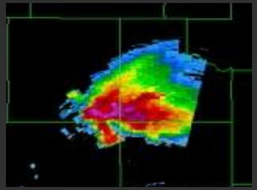
First
WSR-88D (KOUN) Upgraded to open Digital Signal Processing and Dual Pol 1999-2001

2000

Joint POLarization Experiment JPOLE 2002-03



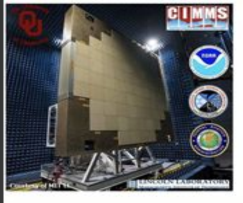
National Weather Radar Testbed PAR 2003



First
tornado detected with PAR 2004

2010

10 Panel Demonstrator PAR 2015



Advanced Technology Demonstrator 2020

2020

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National Severe Storms Laboratory

Innovations Built on a Foundation of Passionate People —*Every Role Matters*

"If I have seen further it is by standing on the shoulders of giants"

Isaac Newton in a letter he wrote to fellow scientist Robert Hooke in 1675

Ken Howard

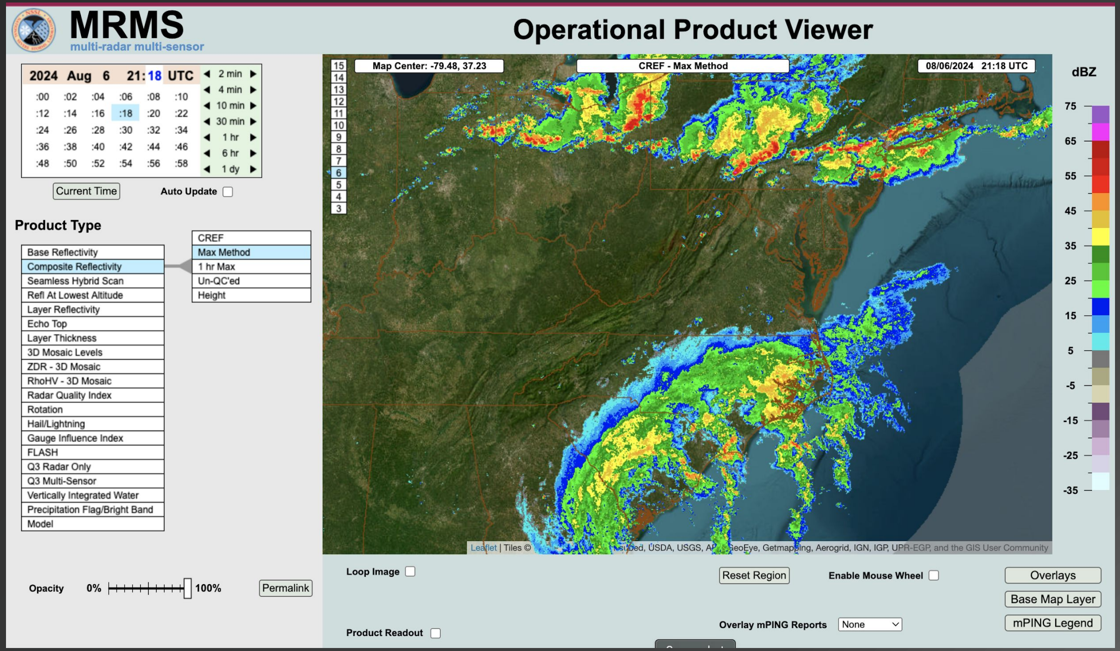
CELEBRATING 60 YEARS OF NSSL

The Foundation of Innovation

Our greatest achievements stem from the collective passion, dedication, and innovation of every individual at NSSL.

Every Role and Idea Matters

Every member of NSSL has played a vital role in advancing our mission. Together, we have transformed how the world understands and responds to severe weather.



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National Severe Storms Laboratory

Innovations Driven by Curiosity

How should high-resolution forecasts be used in forecasting?

Harold Brooks

Innovations Driven by Curiosity

How should high-resolution models be used in forecasting?

STORMTIPE and lessons learned

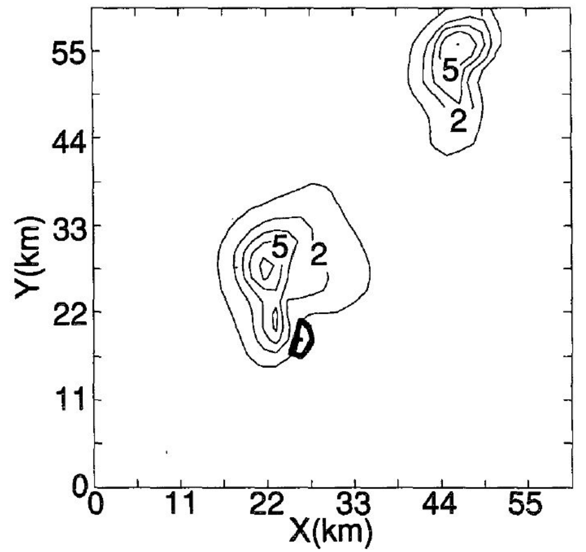


FIG. 6. Rainwater (light) and vorticity (dark) at 100 m at 6600 s of 26 May 1991 STORMTIPE forecast. Tick marks are 5.5 km apart. Contour interval of 1.5 g kg^{-1} for rainwater (lowest contour 0.5 g kg^{-1}) and 0.005 s^{-1} for vorticity with zero contour suppressed.

FORECASTER'S FORUM

On the Use of Mesoscale and Cloud-Scale Models in Operational Forecasting

HAROLD E. BROOKS, CHARLES A. DOSWELL III, AND ROBERT A. MADDOX

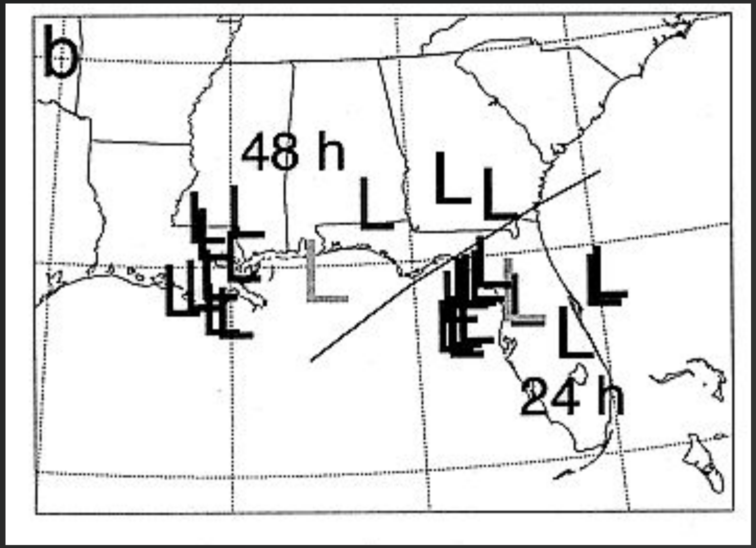
NOAA/National Severe Storms Laboratory, Norman, Oklahoma

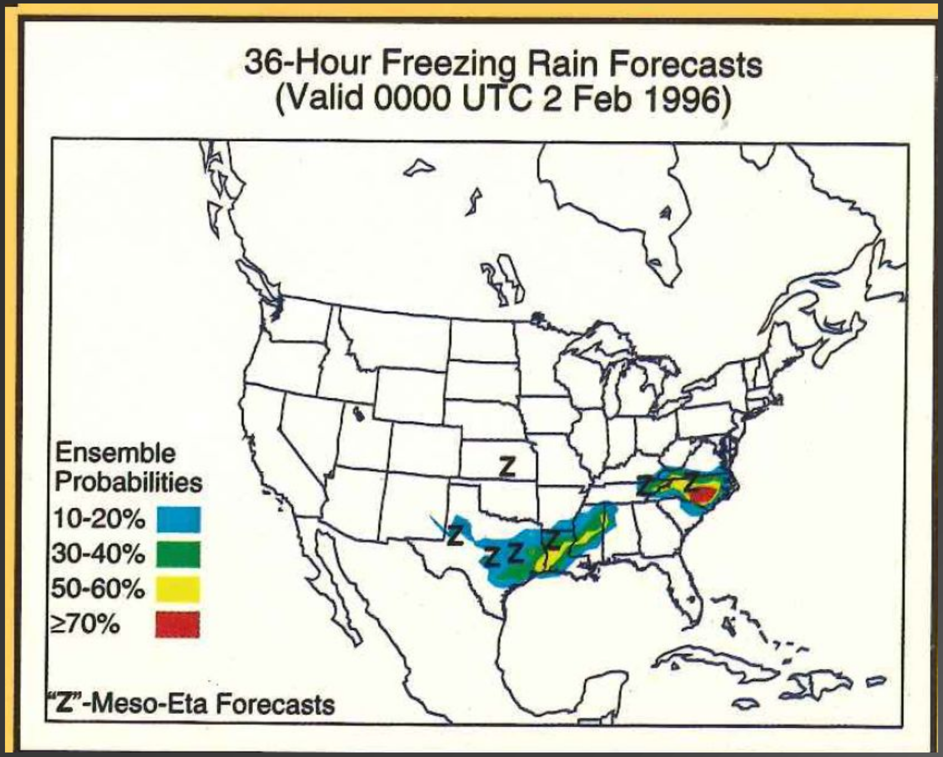
27 August 1991 and 8 November 1991

Innovations Driven by Curiosity

How should high-resolution models be used in forecasting?

Short-range ensemble forecasting





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National Severe Storms Laboratory

Innovations Driven by NOAA's Hazardous Weather Testbed — *Improving Forecast Tools by Including Users*

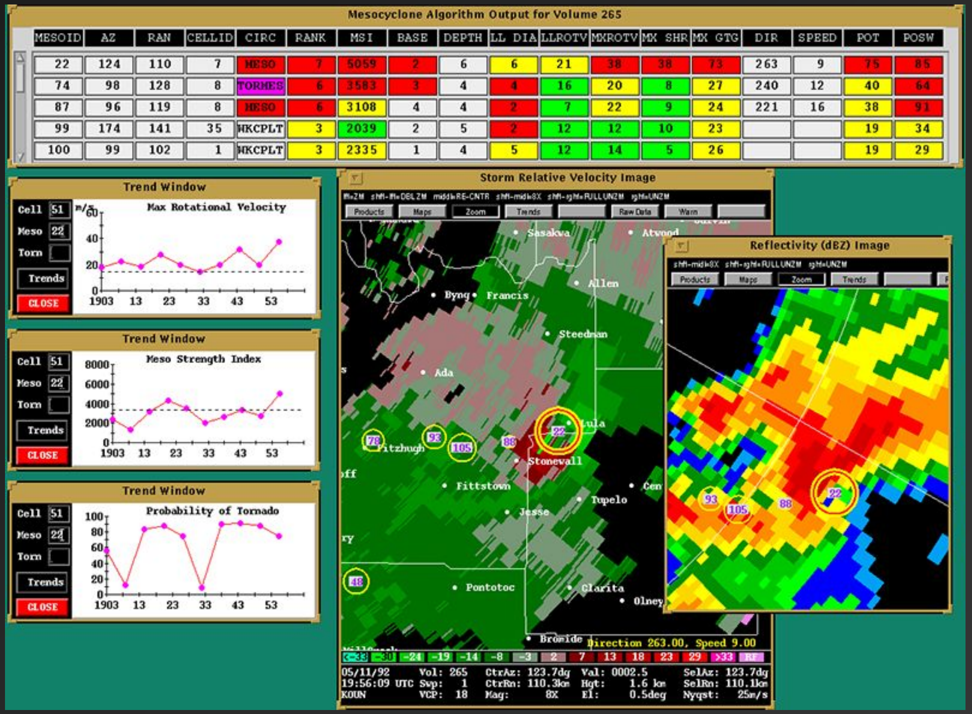
Pam Heinselman

60 Years
CELEBRATING 60 YEARS OF NSSL

Innovations Leading to NOAA's Hazardous Weather Testbed

Improving Forecast Tools by Including Users

Testing Radar-driven technologies



Early R2O successes:

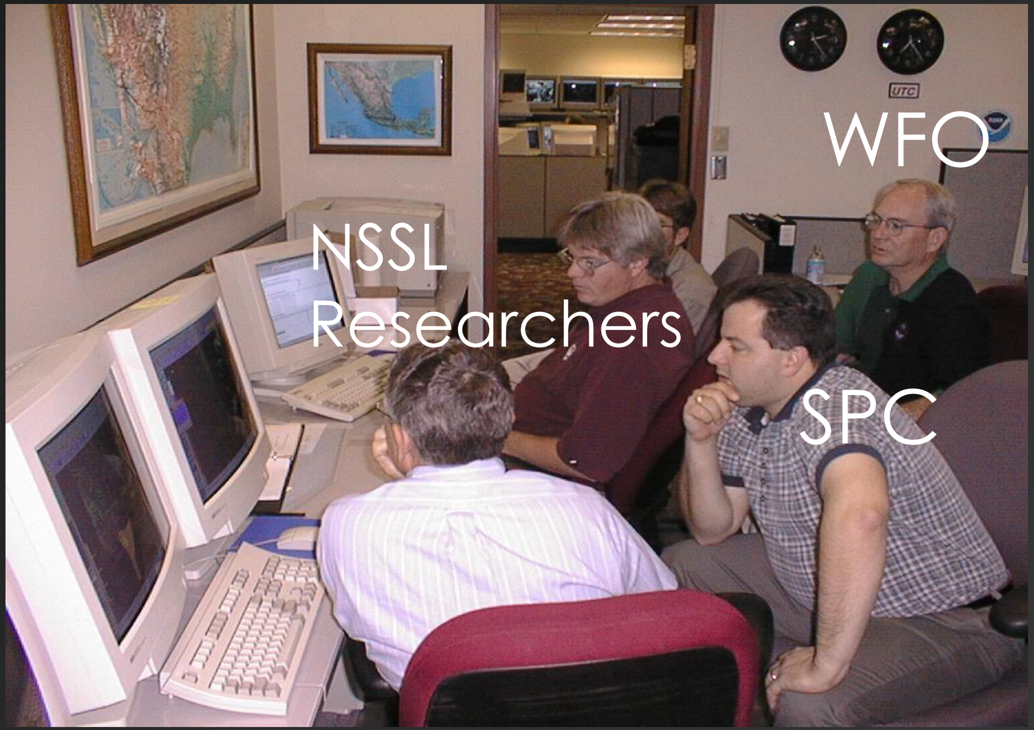
Weather Surveillance Radar - 1988 Doppler Network installed

NSSL's Warning Decision Support System (WDSS) is included in the Advanced Weather Information Processing System (AWIPS) to provide forecasters with the latest severe weather warning technology (1998)

Innovations Leading to NOAA's Hazardous Weather Testbed

Improving Forecast Tools by Including Users

2001 NSSL/SPC "Spring Program"



Since 2000, the Spring Forecasting Experiment, co-led by NSSL and SPC, runs annually during peak severe weather season

Demonstrated and tested "convection-allowing" models, severe storm diagnostics, and visualizations implemented in today's operational models

NOAA's Hazardous Weather Testbed

Gold Standard Testbed serving NOAA, academia, international partners, & industry

Innovations Driven by NOAA's Hazardous Weather Testbed

Improving Forecast Tools by Including Users

<u>Since 2007</u>
Social science expertise increasingly integrated into & improves projects

<u>Since 2016</u>
Integrated Warning Team approach expands users

<u>Since 2020</u>
Implementation of cloud & virtual/hybrid capabilities increases inclusivity

Current innovations shared in the next set of presentations and poster session

A Legacy of Achievement Through a Continuum of Innovation

Drivers of innovation

NOAA Administrators

Passionate People

Scientific Curiosity

End users

What other aspects of innovation have been important to the NSSL legacy?

60 Years
CELEBRATING
60 YEARS OF NSSL

Chasing the Future:
Advanced Research and Development at NSSL


Dr. Anthony Lyza


Dr. Elizabeth Smith


Dr. Robert Clark


Dr. Anthony Reinhart


Dr. Kodi Berry


Patrick Burke


Dr. Makenzie Krocak

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National Severe Storms Laboratory

The Propagation, Evolution, and Rotation in Linear Storms (PERiLS) Field Campaign

Dr. Anthony Lyza

PERiLS Coordinating Scientist and Principal Investigator (PI)

NSSL/CIWRO PIs: Addison Alford, Tyler Bell, Vanna Chmielewski, Mike Coniglio, Kim Elmore, Erik Rasmussen, Anthony Reinhart, Morgan Schneider, Elizabeth Smith, Sean Waugh

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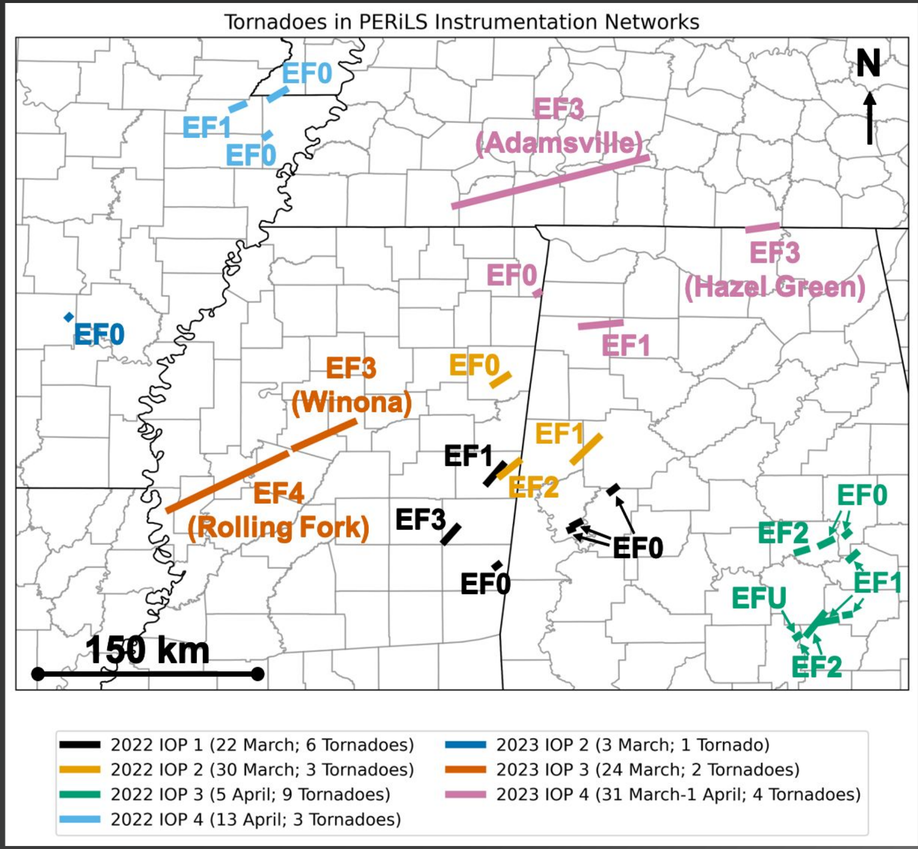
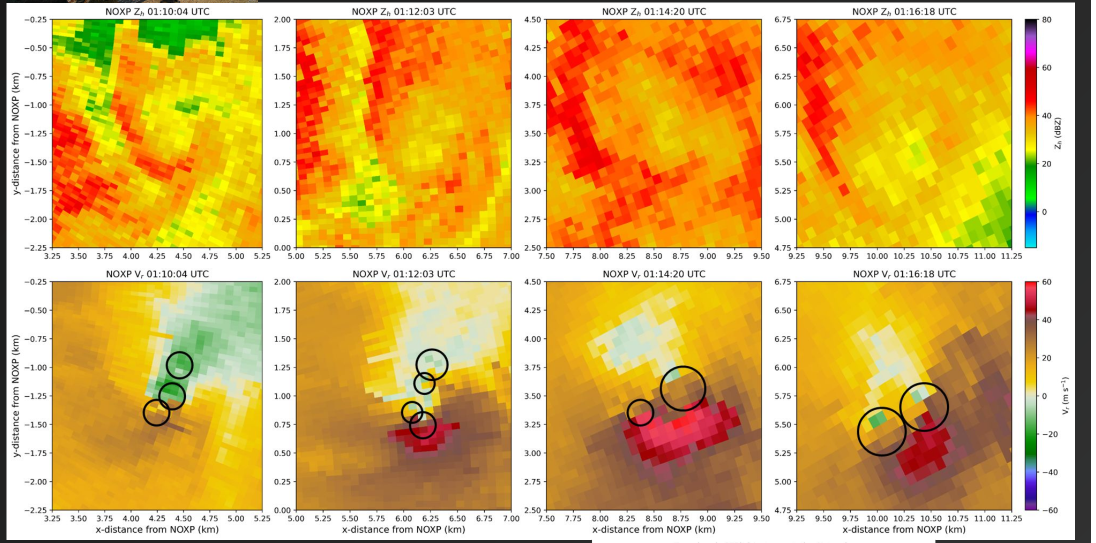
PERiLS Overview

- Operated from 1 March–30 April 2022 and 8 February–8 May 2023 in the Mid-South and Southeast
- Goal: Improve our understanding of tornadoes associated with quasi-linear convective systems (QLCSs) and other "non-classical" tornadic thunderstorms
- Nine total intensive observation periods (IOPs) and 28 total tornadoes

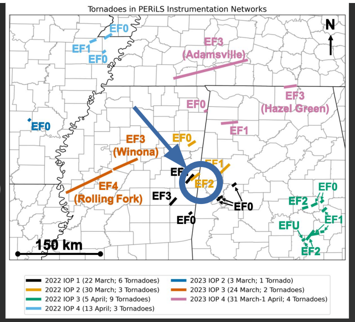


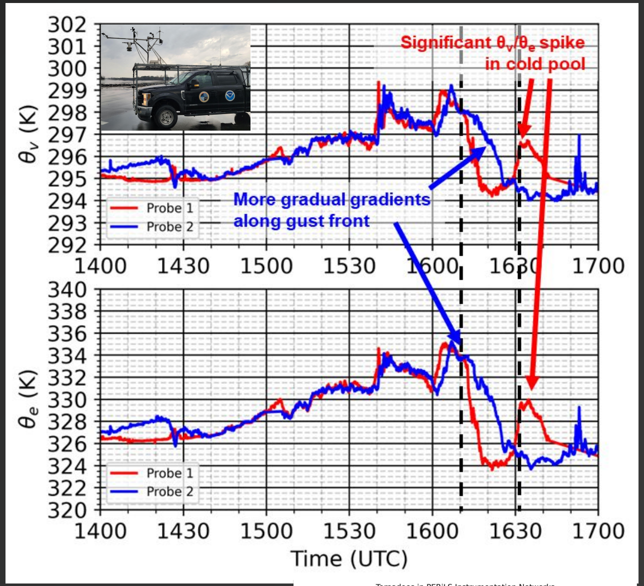
NSF · NOAA · National Weather Service · NSSL · CIWRO · The University of Alabama in Huntsville · OU · ULM · Purdue University · Texas Tech · PennState · Stony Brook University · University of Illinois Urbana-Champaign · NC State University

Examples of Key PERiLS Observations

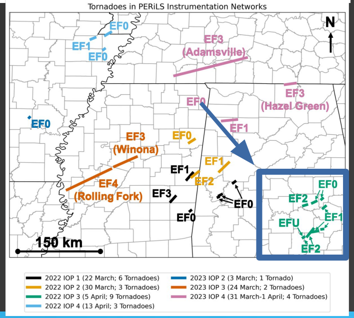


First known mobile radar observations of a multiple-vortex tornado associated with a QLCS (30 March 2022)

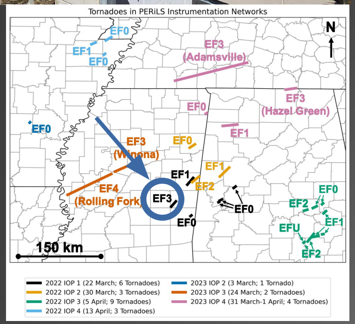




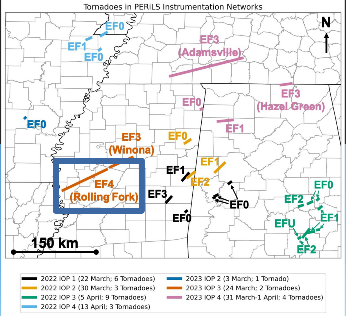
Cold pool of a highly tornadic QLCS (5 April 2022)

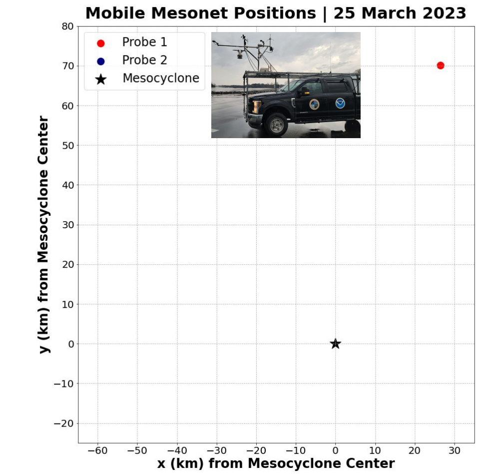


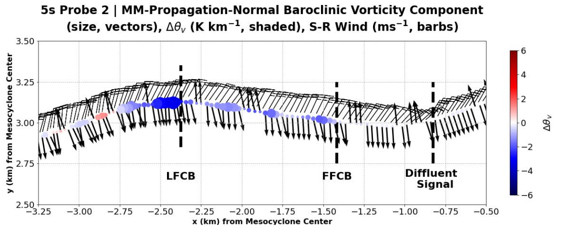
High-resolution ground and aerial surveys from numerous tornadoes



Key PERiLS Observations – Rolling Fork MS EF4

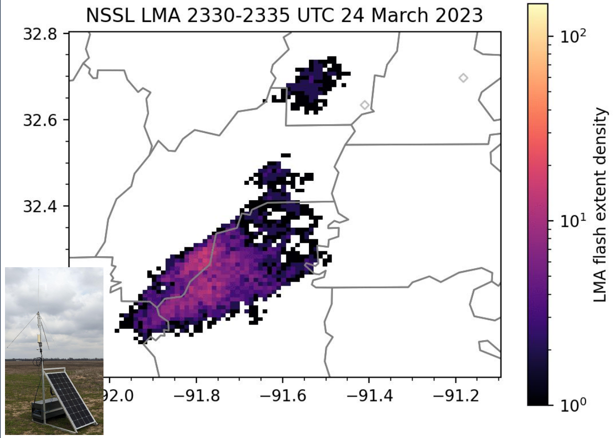






Analysis courtesy Josiah Melke, St. Cloud State Univ. (NSSL Class of 2023 Hollings Scholar)

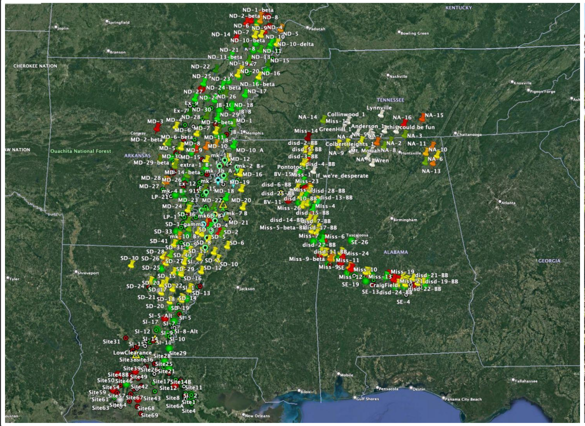
"I want to let you know how we appreciated the help we had with the tornado damage surveying this Saturday from NSSL staff and other team members of the PERiLS Project. The two long track tornadoes would have taken us several days, but with your team's help we were able to get much of it done in one day. They allowed us to focus our attention on the heavy hit areas like Rolling Fork, and they helped fill in the gap in the outskirts of towns. We really appreciated their kindness to assist us." - Bill Parker, Meteorologist-in-Charge, NWS Jackson, MS



Loop courtesy Vanna Chmielewski, NSSL

PERiLS as an Innovative Experiment

- Extensive pre-project planning – hundreds of scouted instrumentation sites
- Integral NWS and local community involvement
- Fundamentally different operations paradigm from tornado field campaigns on the Great Plains
- Service to historically underrepresented and underserved communities



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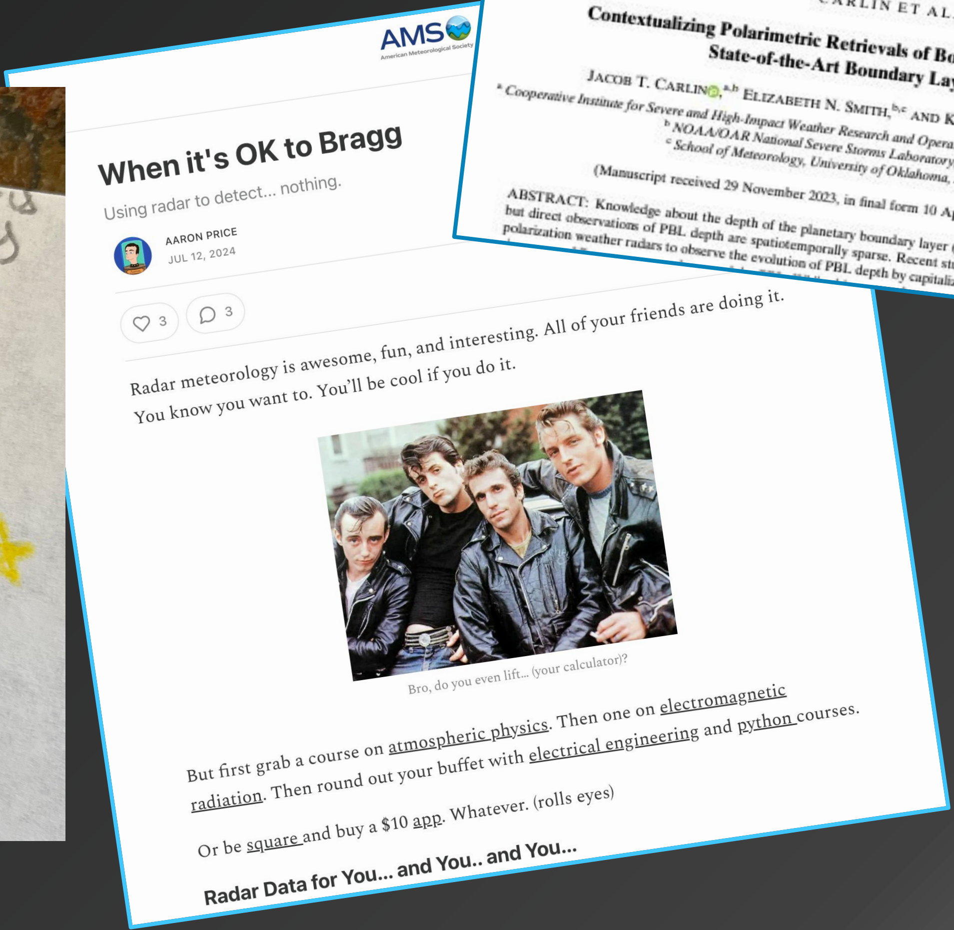
National Severe Storms Laboratory

Chasing the Future, from the Ground Up: Boundary-Layer Observation and Innovation

Dr. Elizabeth Smith, Research Meteorologist, NSSL

Contributions from many NSSL and CIWRO colleagues

Matthew Ammon, Tyler Bell, Jacob Carlin, Lydia Bunting, Mike Coniglio, Josh Gebauer, Bobby Saba, Tony Segales, Jordan Tweedie, Nusrat Yussouf



AMS

When it's OK to Bragg

Using radar to detect... nothing.

AARON PRICE
JUL 12, 2024

3 3

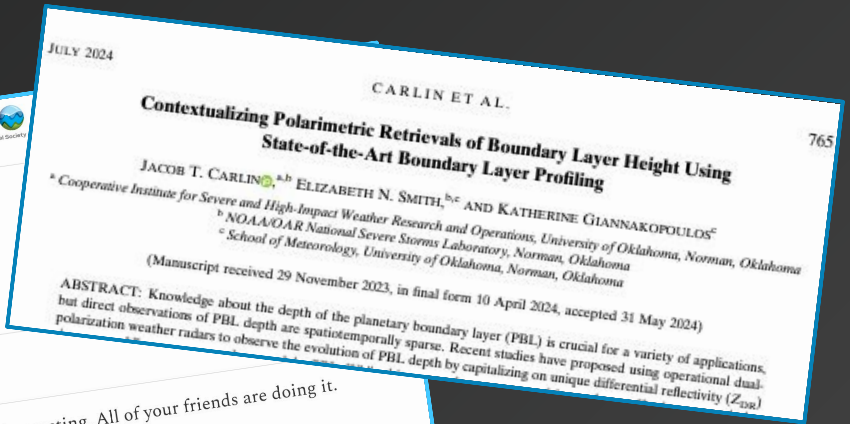
Radar meteorology is awesome, fun, and interesting. All of your friends are doing it. You know you want to. You'll be cool if you do it.

Bro, do you even lift... (your calculator)?

But first grab a course on atmospheric physics. Then one on electromagnetic radiation. Then round out your buffet with electrical engineering and python courses.

Or be square and buy a $10 app. Whatever. (rolls eyes)

Radar Data for You... and You.. and You...



JULY 2024 CARLIN ET AL. 765

Contextualizing Polarimetric Retrievals of Boundary Layer Height Using State-of-the-Art Boundary Layer Profiling

JACOB T. CARLIN,[a,b] ELIZABETH N. SMITH,[b,c] AND KATHERINE GIANNAKOPOULOS[c]

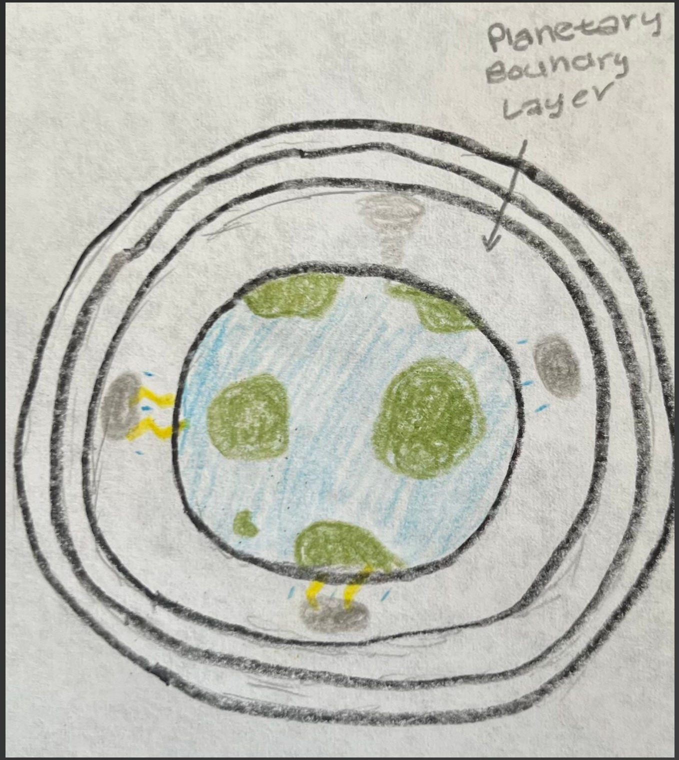
[a] Cooperative Institute for Severe and High-Impact Weather Research and Operations, University of Oklahoma, Norman, Oklahoma
[b] NOAA/OAR National Severe Storms Laboratory, Norman, Oklahoma
[c] School of Meteorology, University of Oklahoma, Norman, Oklahoma

(Manuscript received 29 November 2023, in final form 10 April 2024, accepted 31 May 2024)

ABSTRACT: Knowledge about the depth of the planetary boundary layer (PBL) is crucial for a variety of applications, but direct observations of PBL depth are spatiotemporally sparse. Recent studies have proposed using operational dual-polarization weather radars to observe the evolution of PBL depth by capitalizing on unique differential reflectivity (Z_{DR})

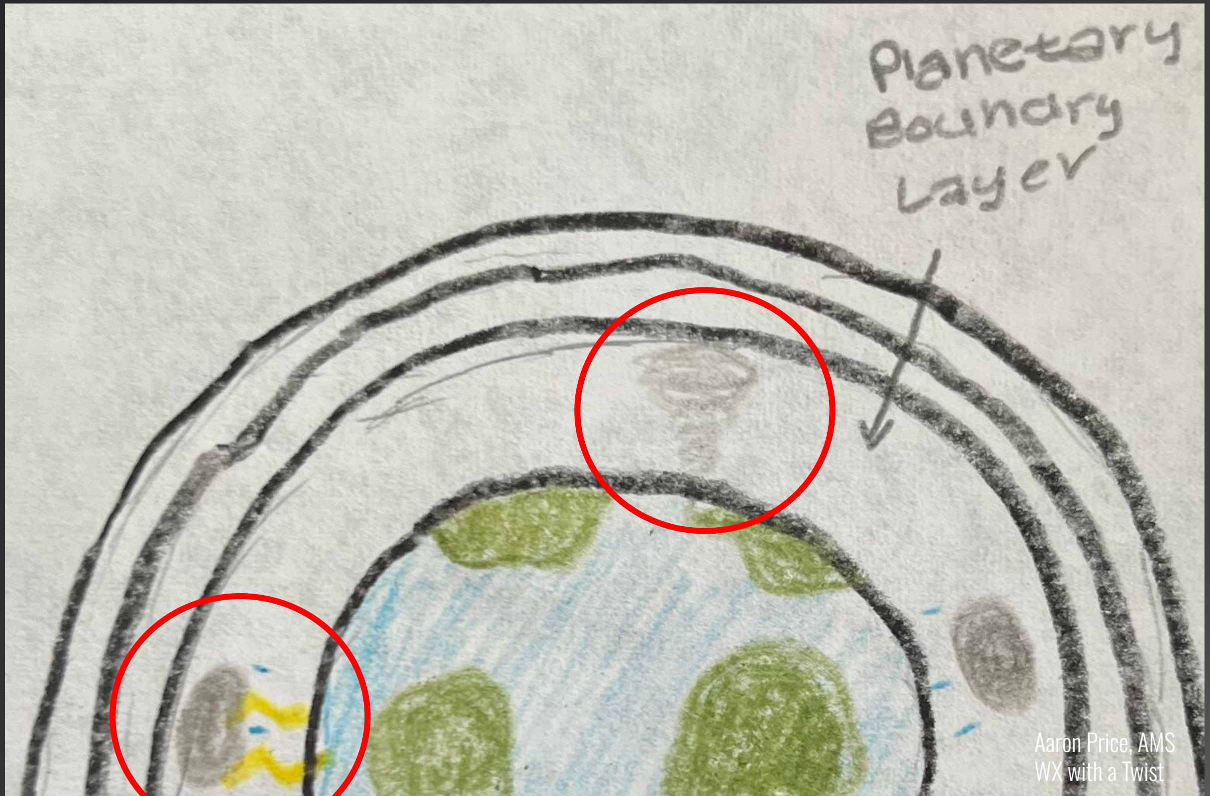
Aaron Price, AMS
WX with a Twist

Technically, his daughter



Aaron Price, AMS
WX with a Twist

Technically, his daughter



Aaron Price, AMS
WX with a Twist

Technically, his daughter

Is the boundary-layer even relevant at NSSL?

Boundary-layer research at NSSL is *not* new

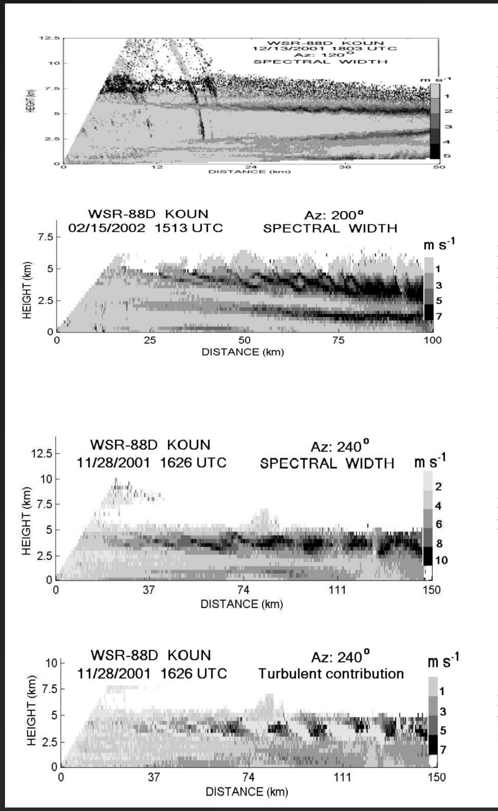


Fig. 4. Stratiform precipitation on Dec.13, 2001. Note a wavy layer at height of 6 km.

Fig. 5. Spectrum width pattern in a form of "cat's eye" structures at heights of 4 to 5 km at ranges of 50 to 80 km

Fig. 6. Spectrum width pattern in a form of patches.

Fig 7. Turbulent contribution to the spectrum width field shown in Fig. 6.

Doviak, R. J., Rabin, R. M., and Koscielny, A. J. **1983**: Doppler Weather Radar for Profiling And Mapping Winds in the Prestorm Environment. IEEE Trans. Geosci and Remote Sens, 21(1), 25-33

Melnivok, V. M., Doviak, R. J., and Fang, M., **2003**: Radar observations of turbulence and wind shear. Preprints, 31st Intl Conf on Radar Meteorol, Seattle, WA, USA, Amer Meteorol Soc, 736–739

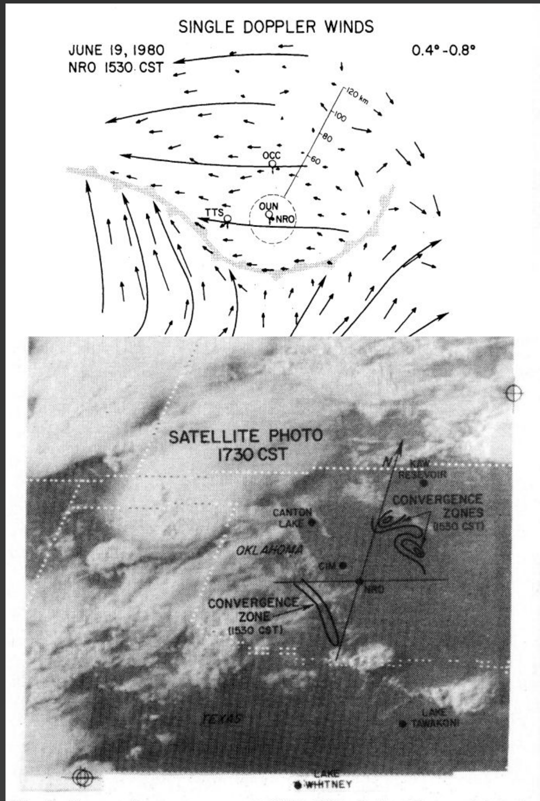
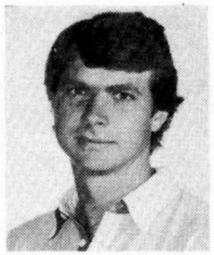


Fig. 6. Zones of convergence at 1530 CST, derived by applying th



But the tools we have are …

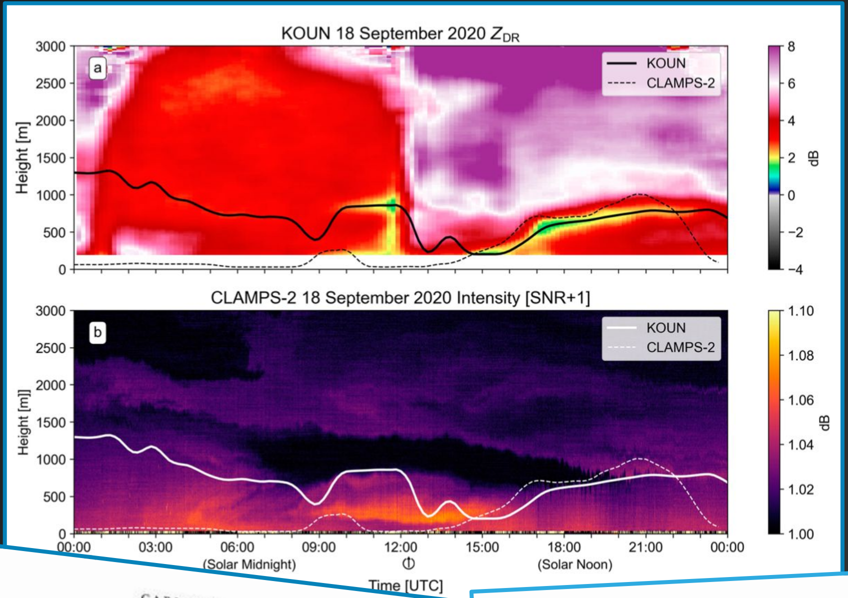
CLAMPS

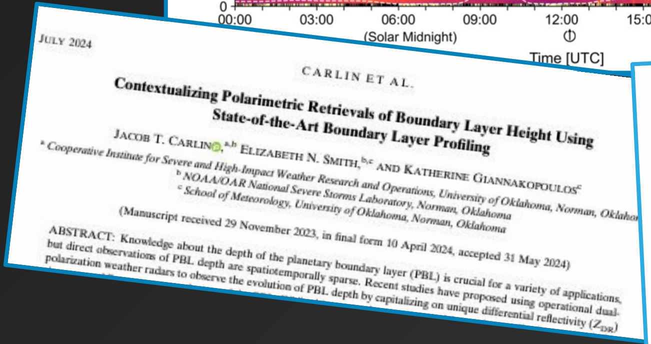
COLLABORATIVE LOWER ATMOSPHERIC MOBILE PROFILING SYSTEM

New tools → New questions?

- All sensor information integrated into automated data system and generate datasets and value-added products (near-real time)
- Doppler lidar provides wind profiles (seconds–minutes | 10s of meters)
- Microwave and infrared sensors provide temperature and moisture profiles (minutes | 10s of meters)

But the tools we have are …





JULY 2024

CARLIN ET AL.

Contextualizing Polarimetric Retrievals of Boundary Layer Height Using State-of-the-Art Boundary Layer Profiling

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[c] School of Meteorology, University of Oklahoma, Norman, Oklahoma

(Manuscript received 29 November 2023, in final form 10 April 2024, accepted 31 May 2024)

ABSTRACT: Knowledge about the depth of the planetary boundary layer (PBL) is crucial for a variety of applications, but direct observations of PBL depth are spatiotemporally sparse. Recent studies have proposed using operational dual-polarization weather radars to observe the evolution of PBL depth by capitalizing on unique differential reflectivity (Z_{DR})

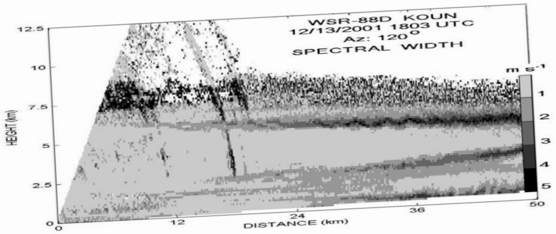
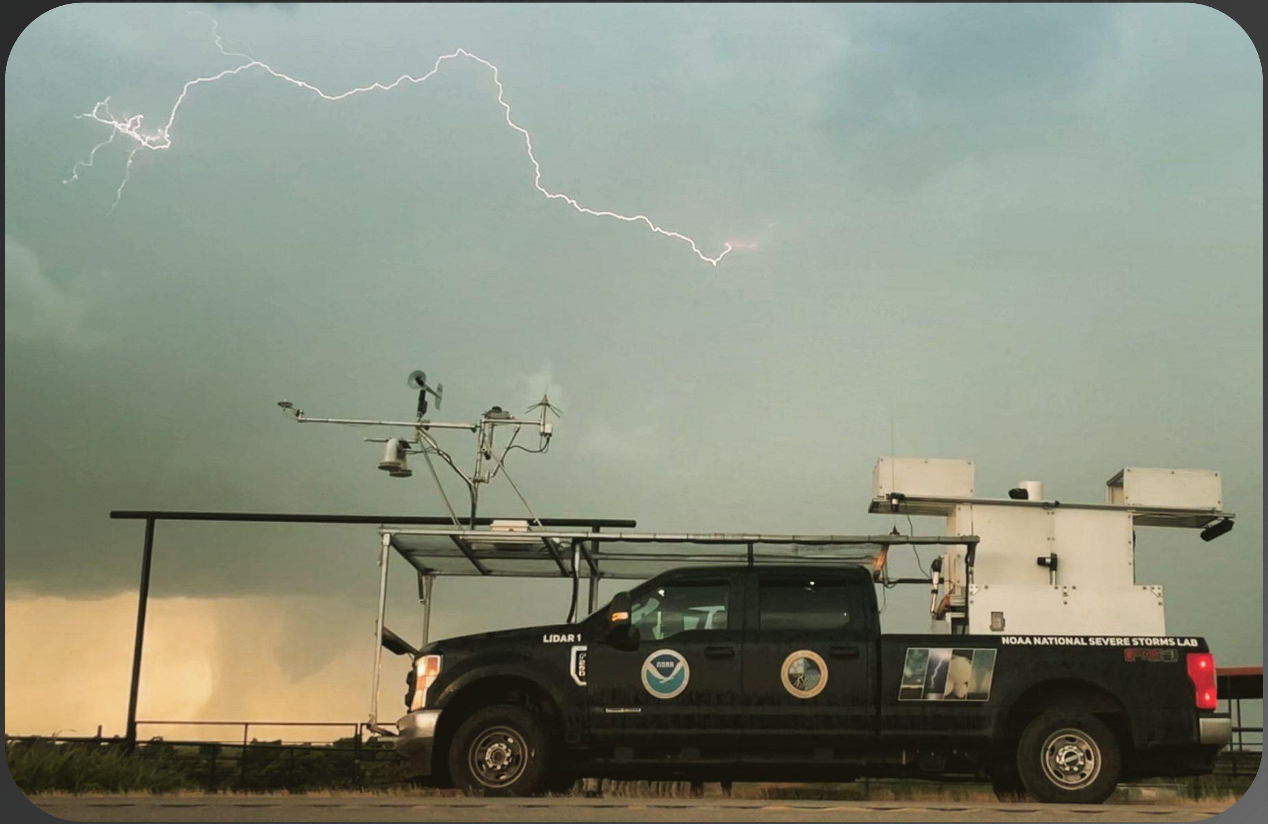


Fig. 4. Stratiform precipitation on Dec.13, 2001. Note a wavy layer at height of 6 km.

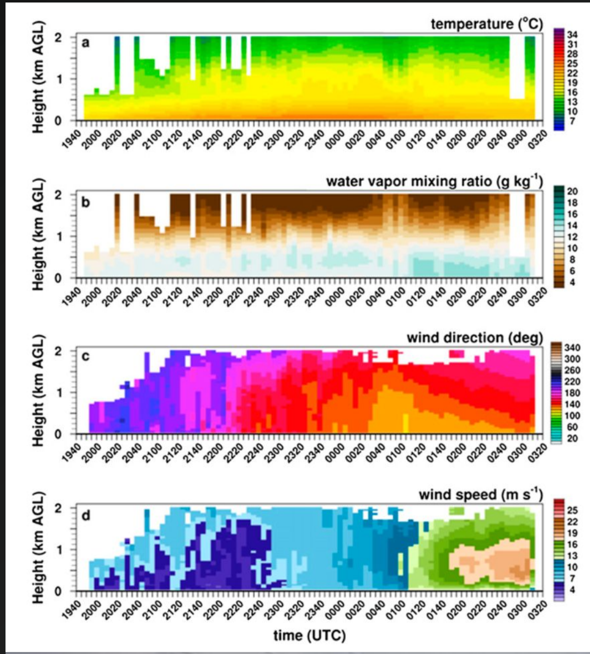
New tools → New questions?

New tools → *Same questions*, but with new perspectives

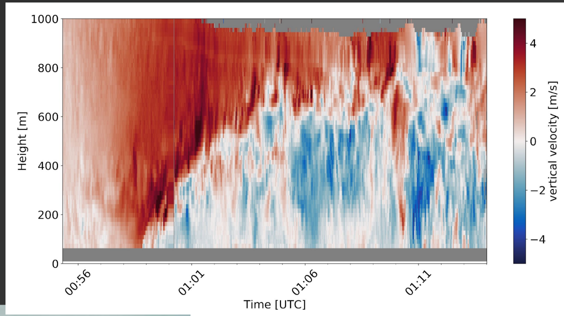
Innovate to meet the mission

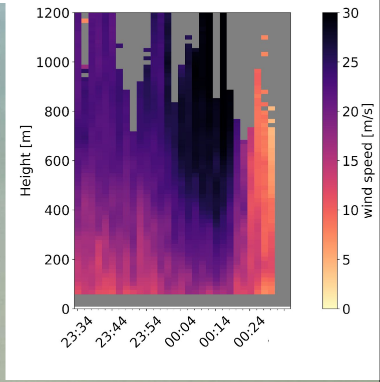


60 Years
CELEBRATING 60 YEARS OF NSSL



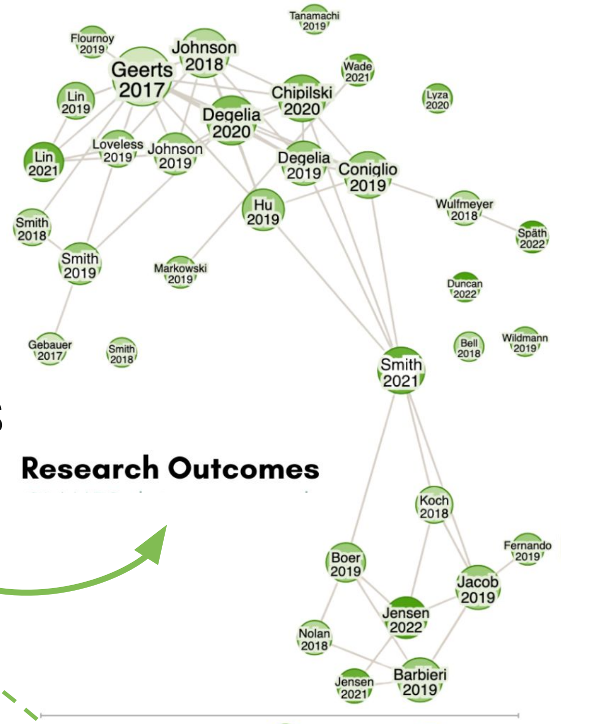
Innovate to meet the mission



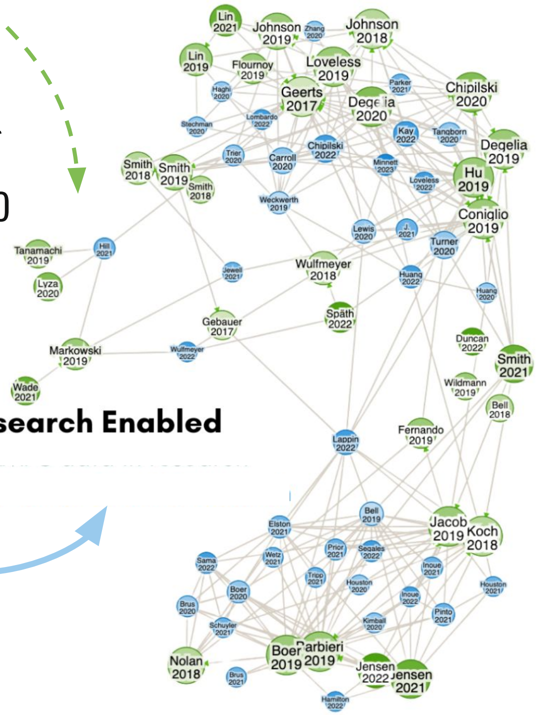


Innovation impacts extend beyond NSSL

Research including CLAMPS observations

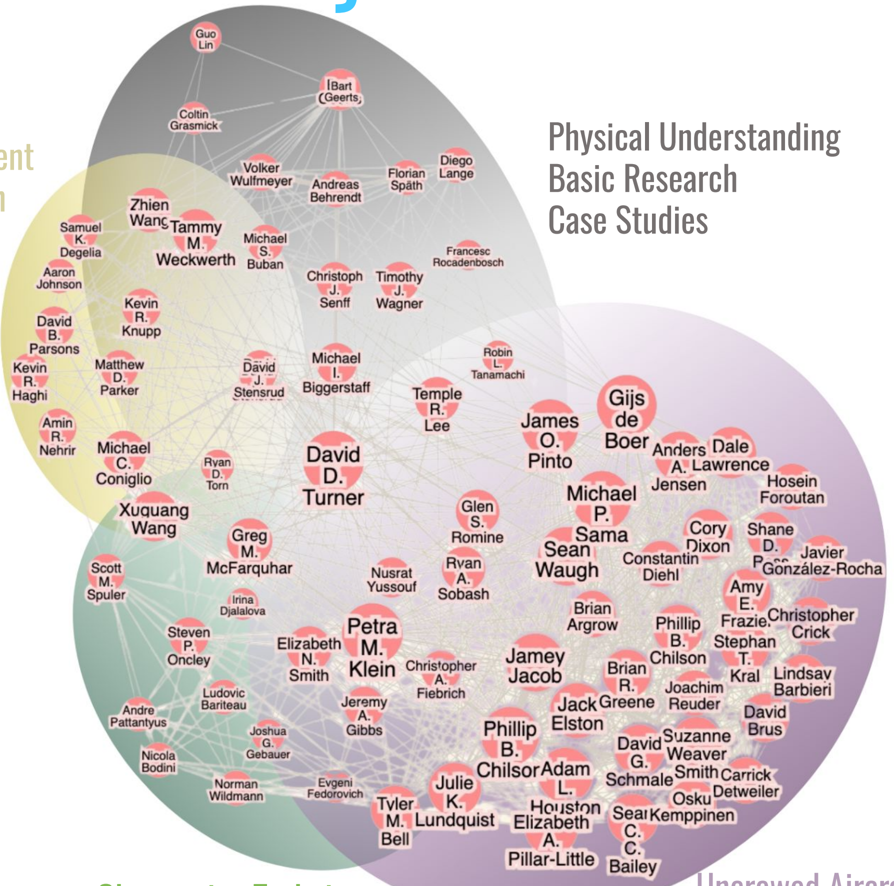


Research directly citing or strongly connected to research including CLAMPS observations



Model Evaluation
Model Development
Data Assimilation

Physical Understanding
Basic Research
Case Studies



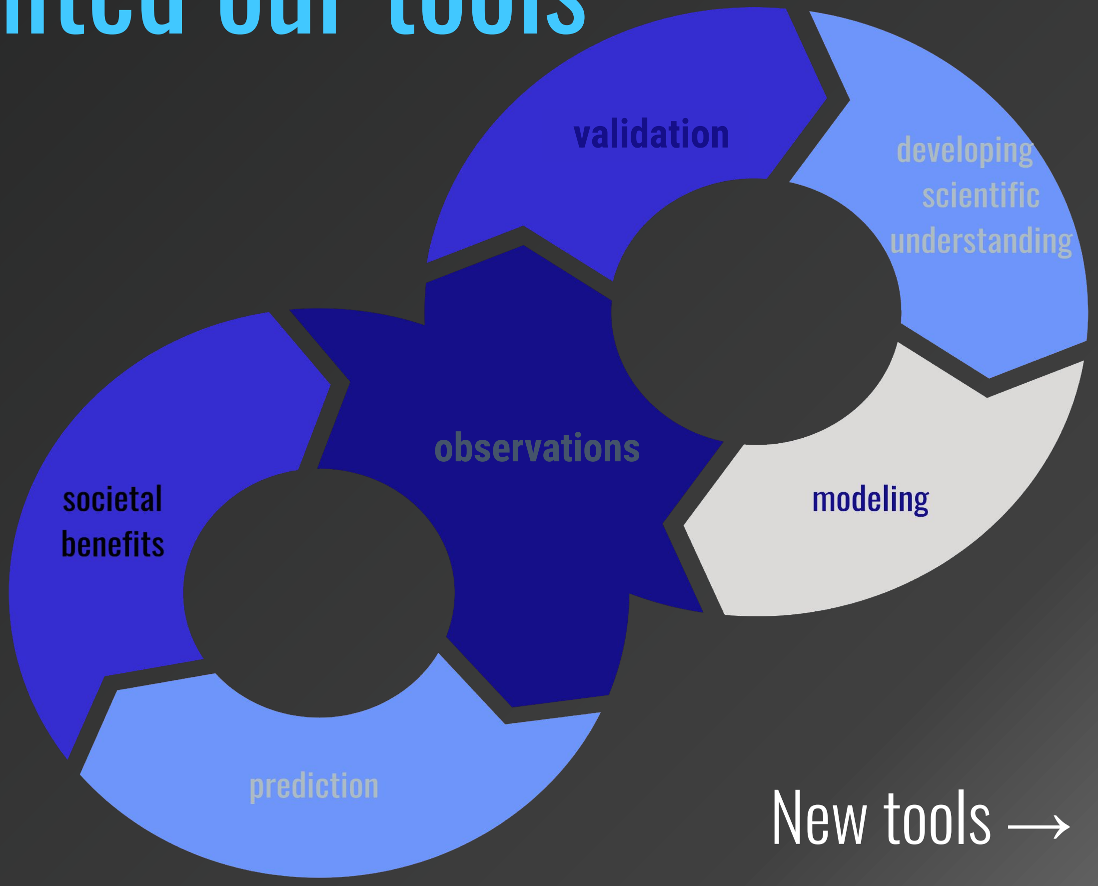
Observation Techniques Research

Uncrewed Aircraft Systems (UAS) research

Innovation isn't limited our tools

Step 1	Ask a question
Step 2	Form a hypothesis
Step 3	Conduct an experiment
Step 4	Form conclusions
Step …	Revisit the question Except publish, measure the success, etc…

?

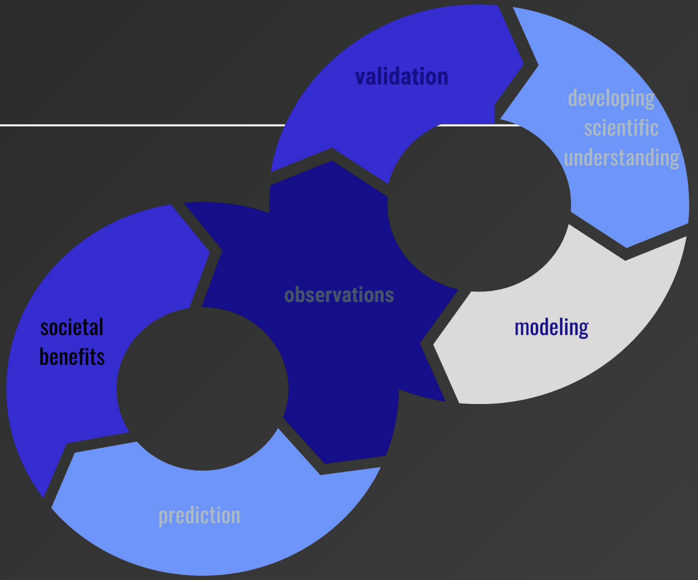


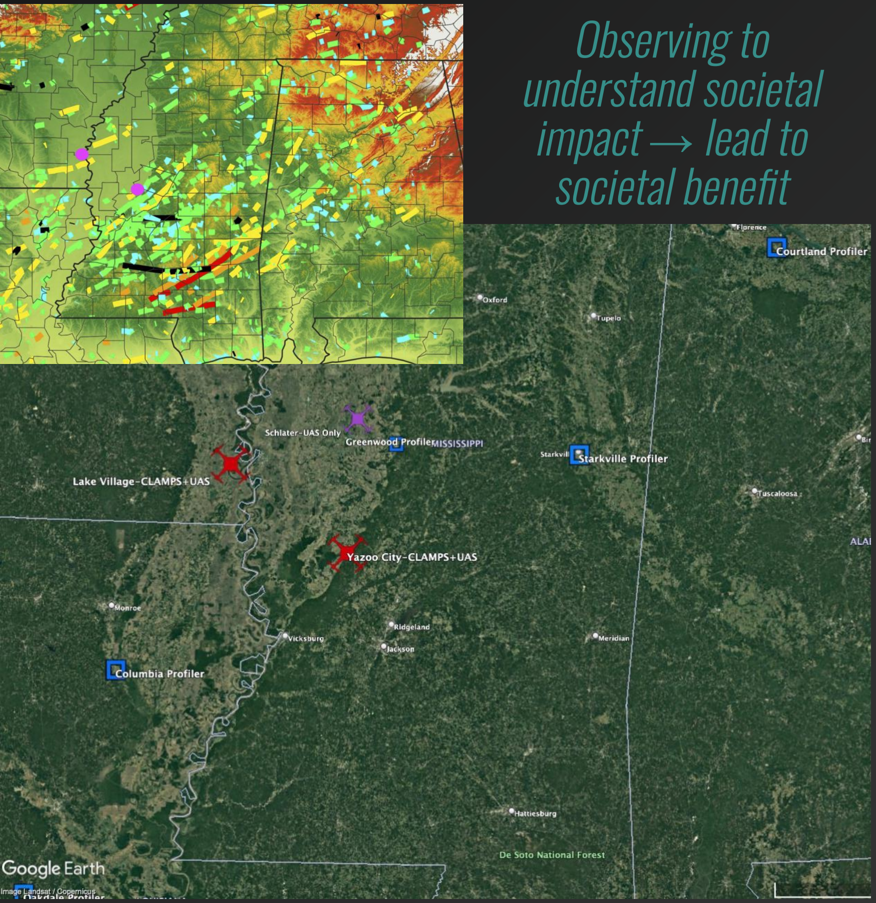
New tools →

New perspectives and new *approaches*

Diverse applications and settings!

PERiLS → The cycle at work



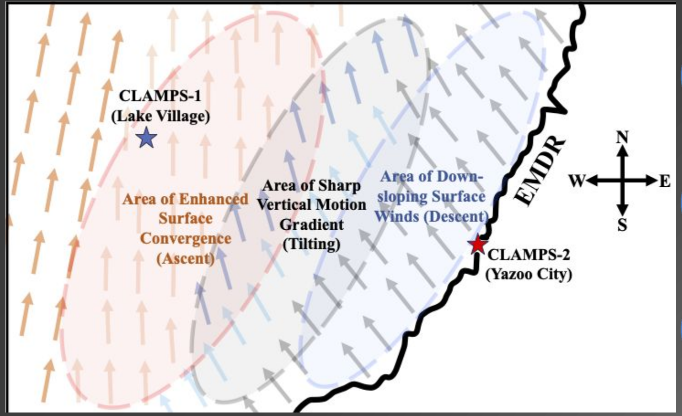


Observing to understand societal impact → lead to societal benefit

Network-in-Network Profiling Deployment

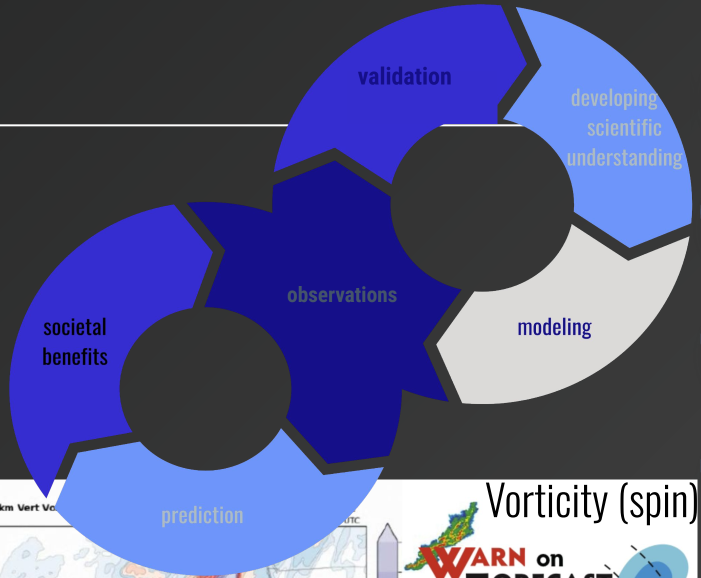
- NOAA's Physical Sciences Laboratory mesoscale network of radar wind profilers (some thermo)
- NSSL's multi-sensor profiler systems (CLAMPS) + uncrewed aircraft systems network deployed *within* mesoscale network
- Multiple seasons of cool-season severe weather data collection
- Long-term datasets enable longitudinal analysis and examination of conceptual models

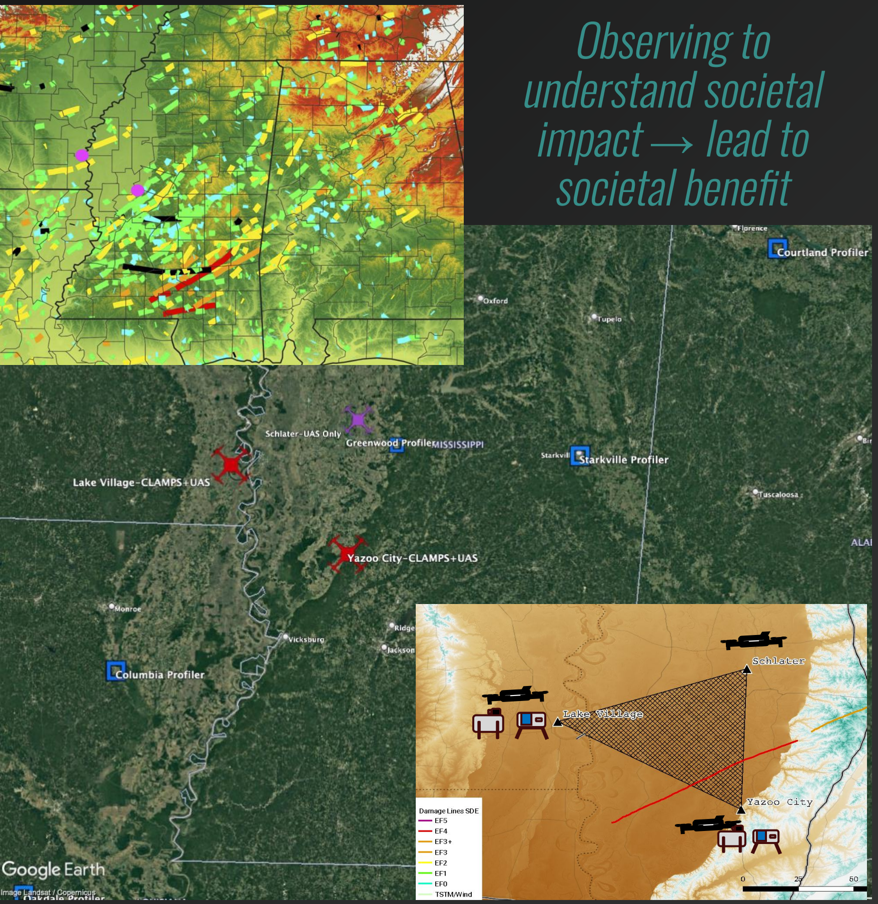
Validating and developing understanding of conceptual models



Relating topography to evolution of convection

PERiLS → The cycle at work

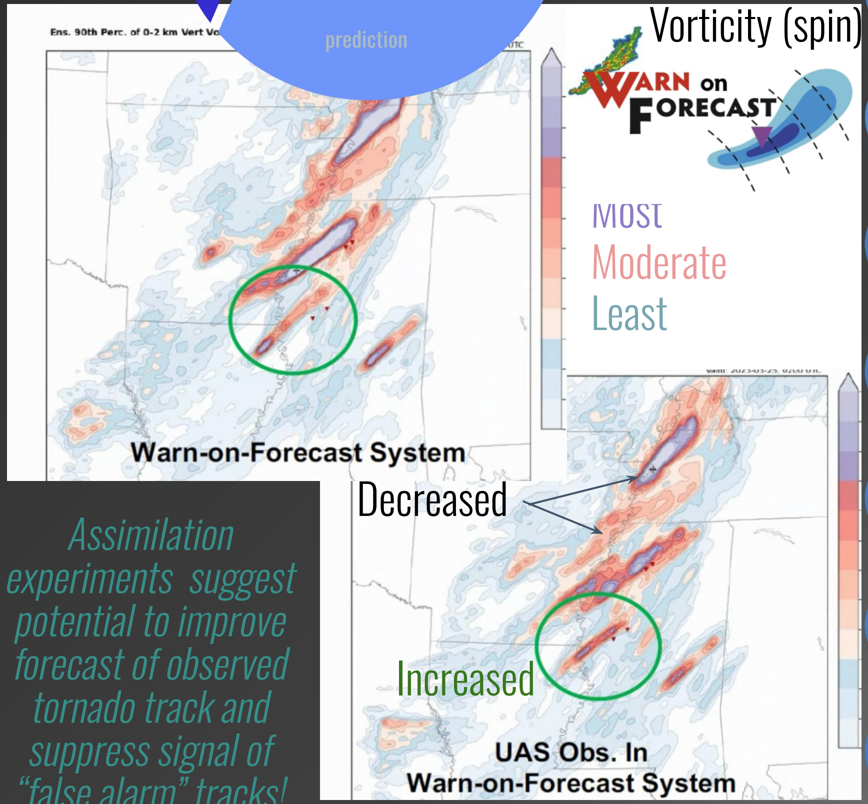




Observing to understand societal impact → lead to societal benefit

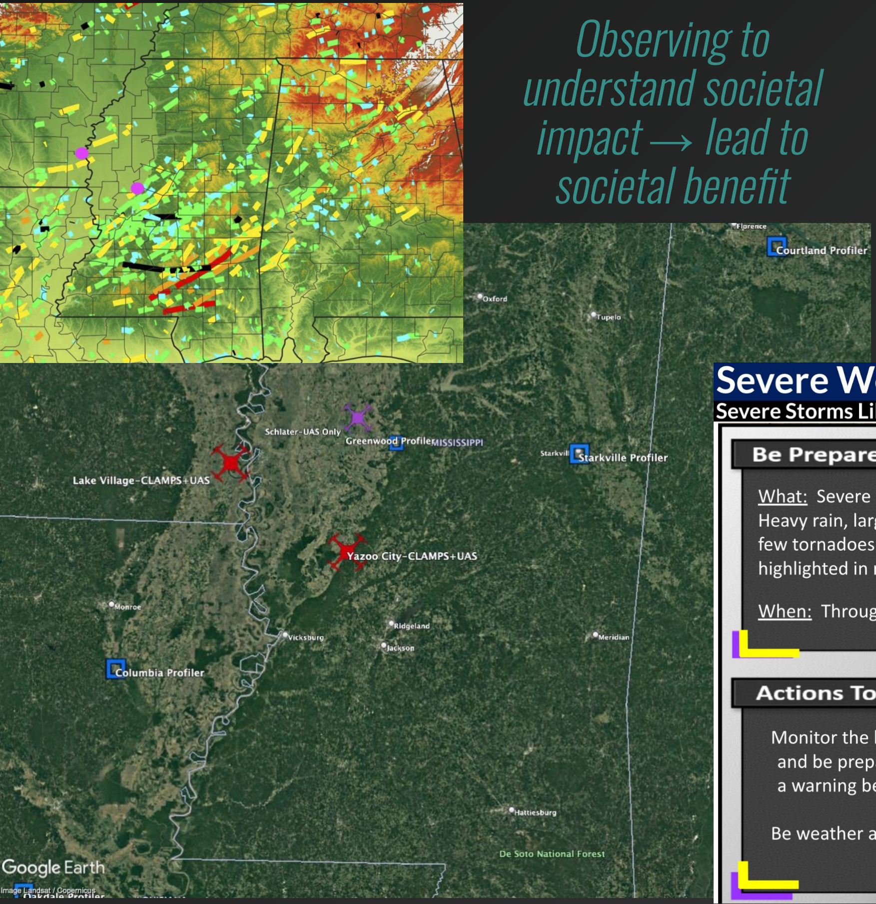
Rolling Fork Tornado

- 23 tornado related fatalities (14 in Rolling Fork)
- Passed through NSSL's fixed PBL profiler network; ***active CopterSonde UAS profiling pre-storm***



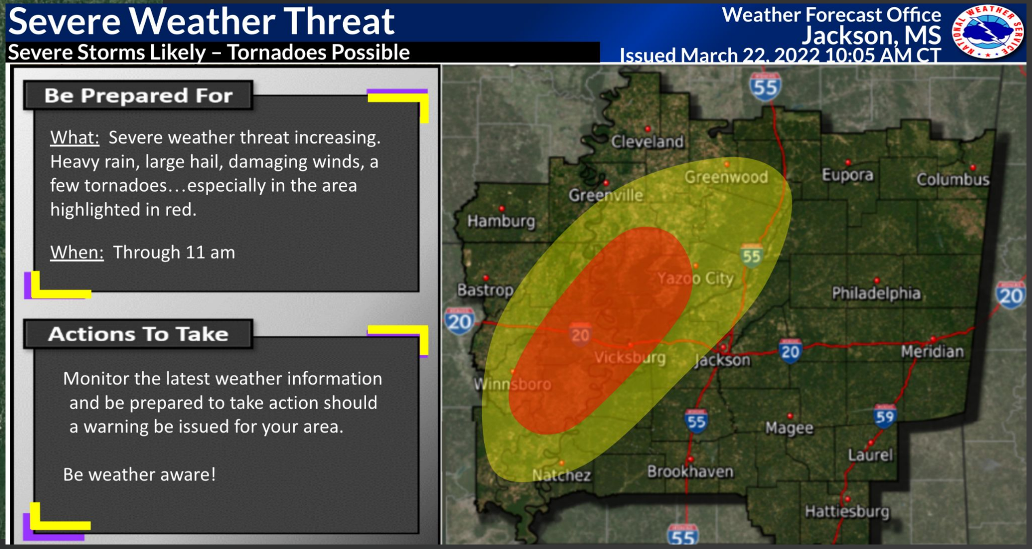
Assimilation experiments suggest potential to improve forecast of observed tornado track and suppress signal of "false alarm" tracks!

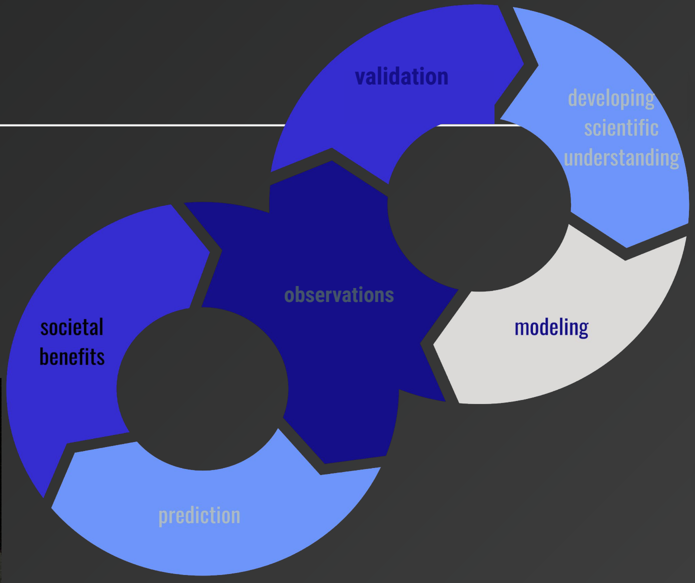
PERiLS → The cycle at work



Observing to understand societal impact → lead to societal benefit

NWS Forecasters in the field

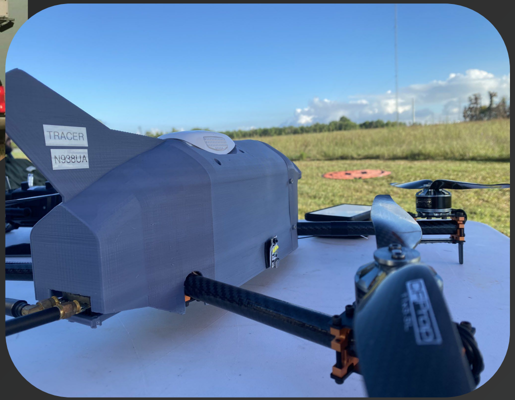




Engaging with Forecasters

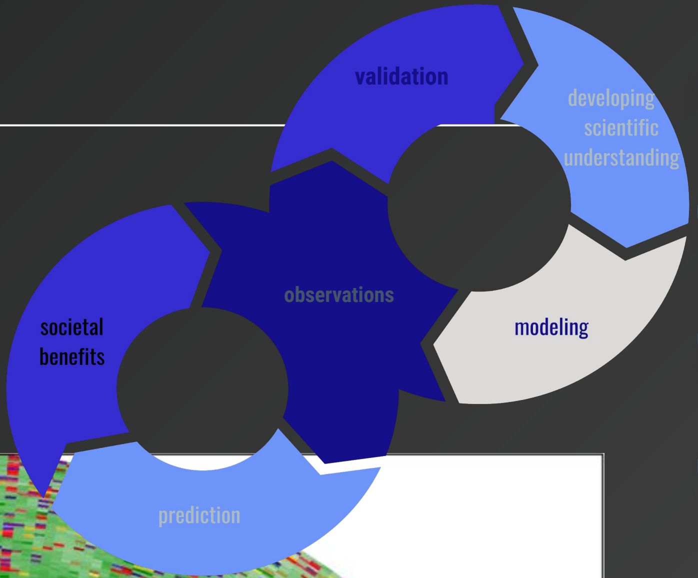
- Understand the use case, barriers, forecast needs
- Include forecaster perspective in R&D
- Directly engage forecasters in development and testing

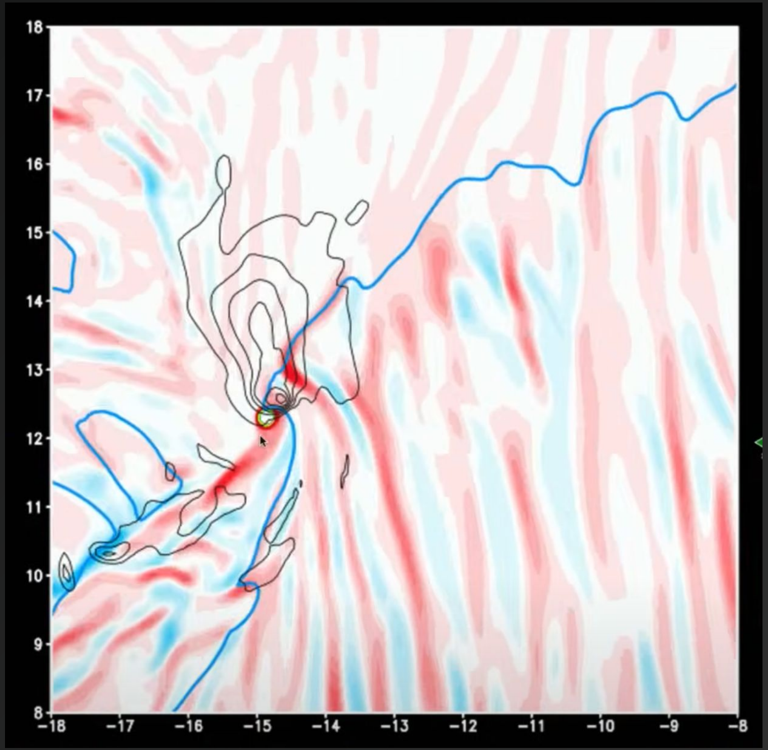
UAS data increased confidence in forecasters' own decisions or in other guidance; more dev. needed to be impactful in isolation



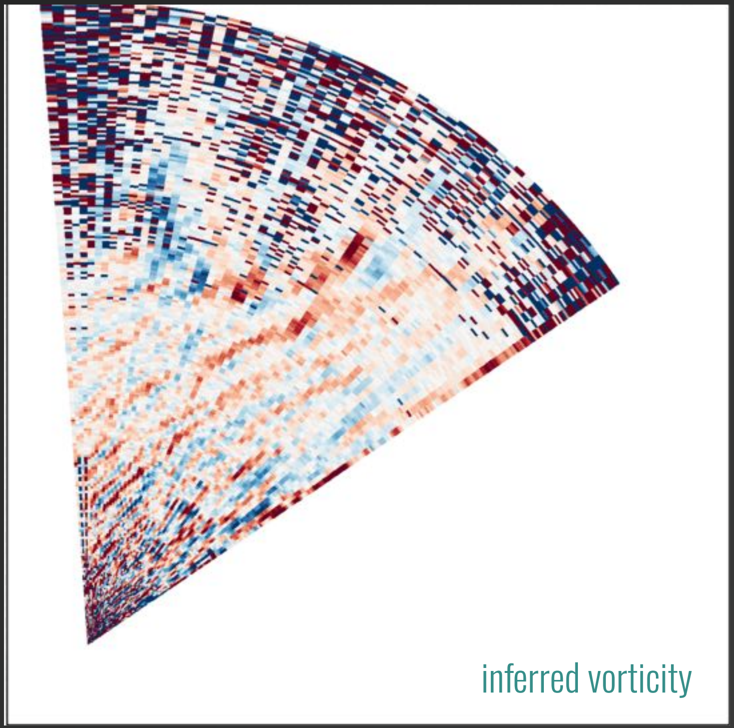
Looking Forward

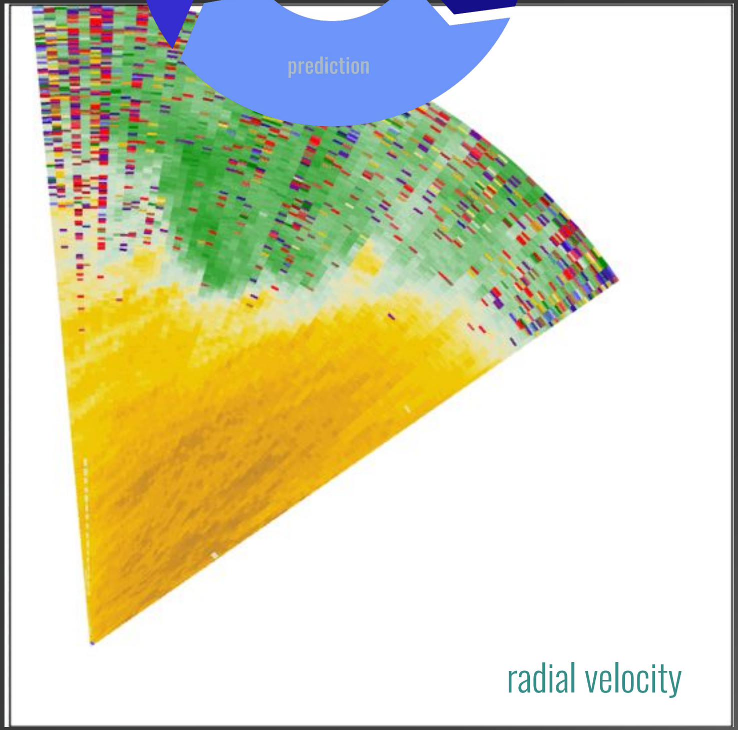
Modeling → Observations





Vorticity -- Markowski, P. 2024: *A New Pathway for Tornadogenesis Exposed by Numerical Simulations of Supercells in Turbulent Environments, J. Atmos. Sci. 81(3), 481-513.*

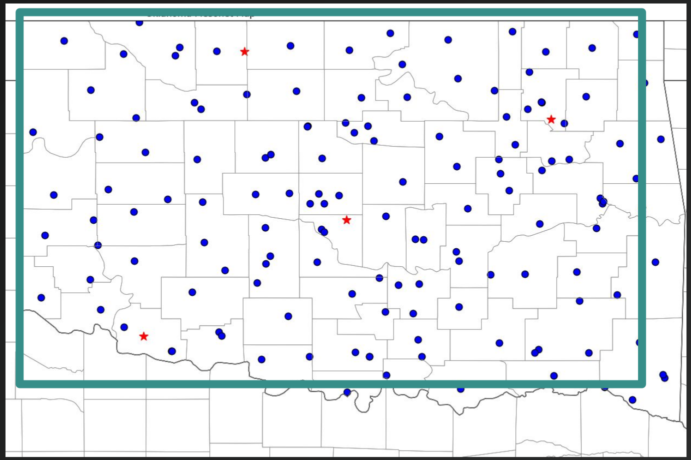




NSSL mobile Doppler lidar observations

Observe something, hypothesize process, simulate it →
Simulate something, go try to observe it

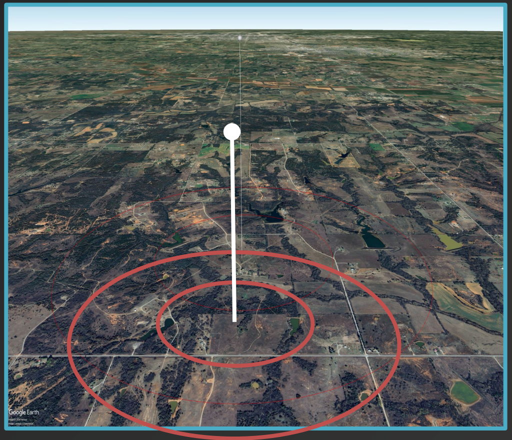
Modeling → Observations → Modeling



Simulating nextgen observation networks

Evaluate network design; impacts for data assimilation and cost effective investments

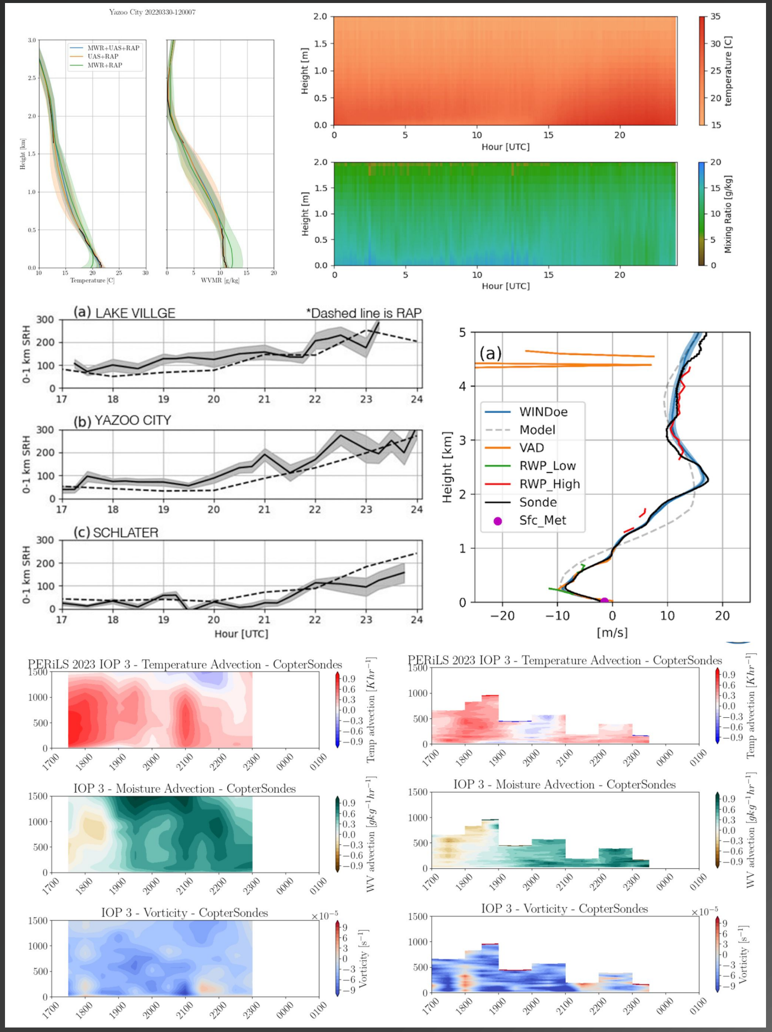
Simulate conditions to evaluate *limitations* of the platforms we use



Algorithm development for higher order product assimilation + uncertainty derivation

Effectively test and plan field deployments/ experiments = cost savings

More effective field planning and targeted R&D goals = cost savings



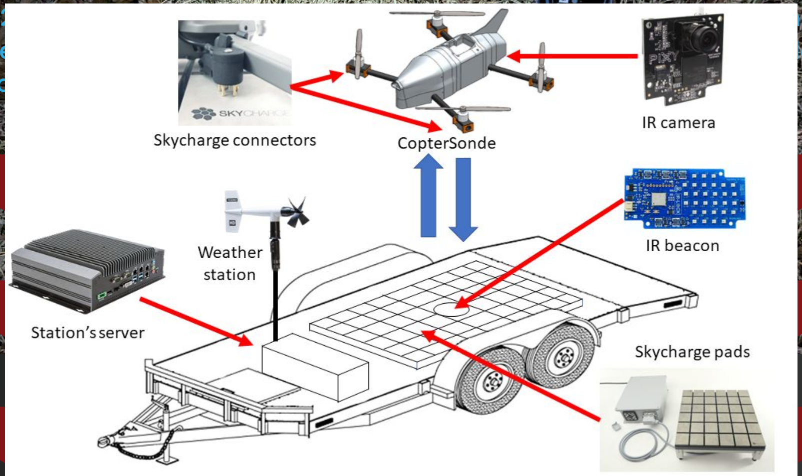
TROPoe

WINDoe

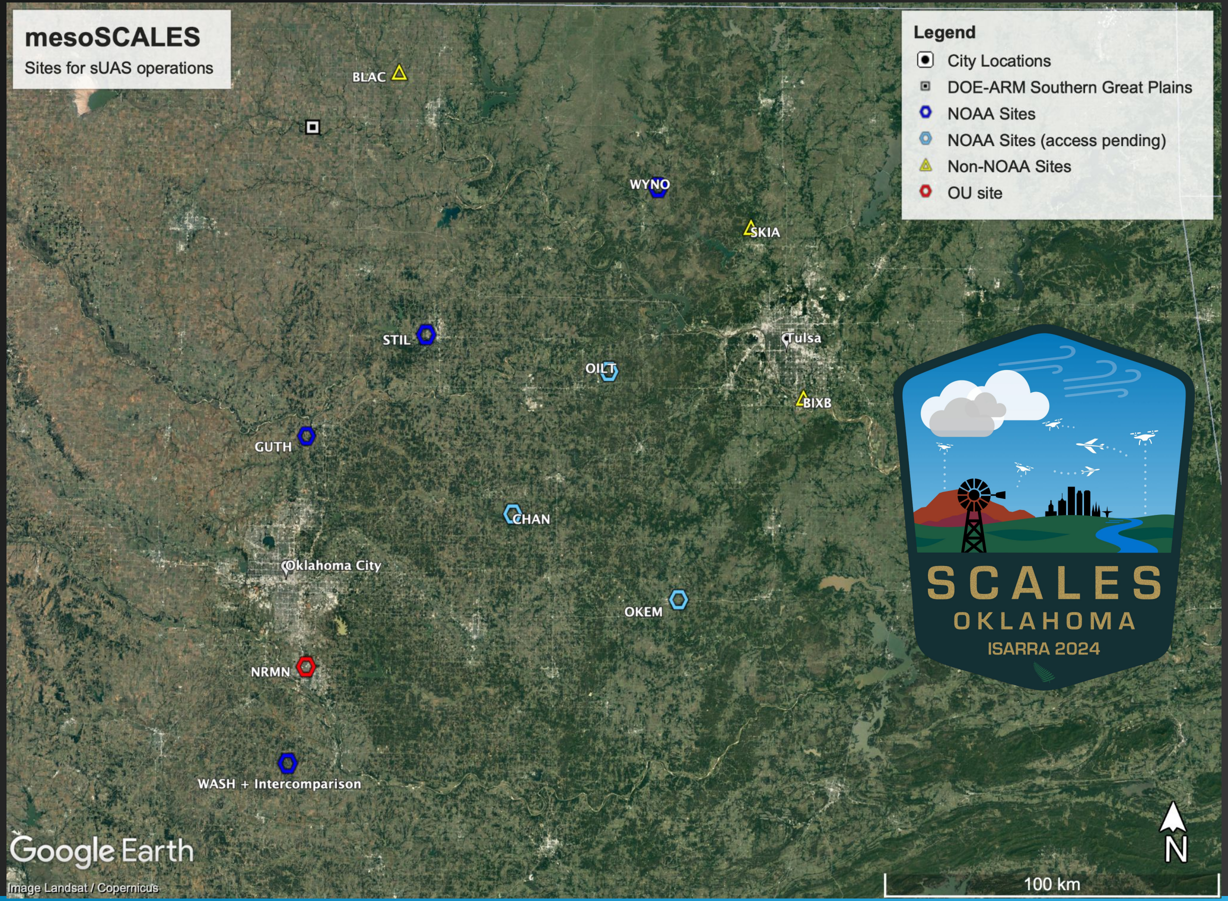
Value Added Products

Targeted R&D Goals

The Coptersonde UAS collects meteorological profiling
multiple projects at NSSL and CIWRO/University of Oklahoma. Since



mesoSCALES: 8-13 Sept



- **NSSL Leading**
  Partnering with PSL and ARL/ATDD
- 10+ site 3D mesonet network
- Supports the World Meteorological Organization's Global UAS Demo. Campaign
- University, International, Commercial partnerships

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DOC / NOAA / OAR
National Severe Storms Laboratory

Phased Array Radar R&D Program

Anthony Reinhart, PhD
PAR R&D Program Lead

The Phased Array Radar Program
at NOAA's National Severe Storms Laboratory

The Phased Array Radar (PAR) R&D program seeks to advance PAR capabilities and demonstrate its benefits to weather observation.

Objectives:

- Engineering research and development
- Meteorological research
- Informing the National Weather Service

Phased Array Radar is an architecture of radar that enables electronic scanning and maximum flexibility.

First Foray into PAR

NSSL used the SPY-1A single-polarimetric PAR system for 13 years 2003 – 2016

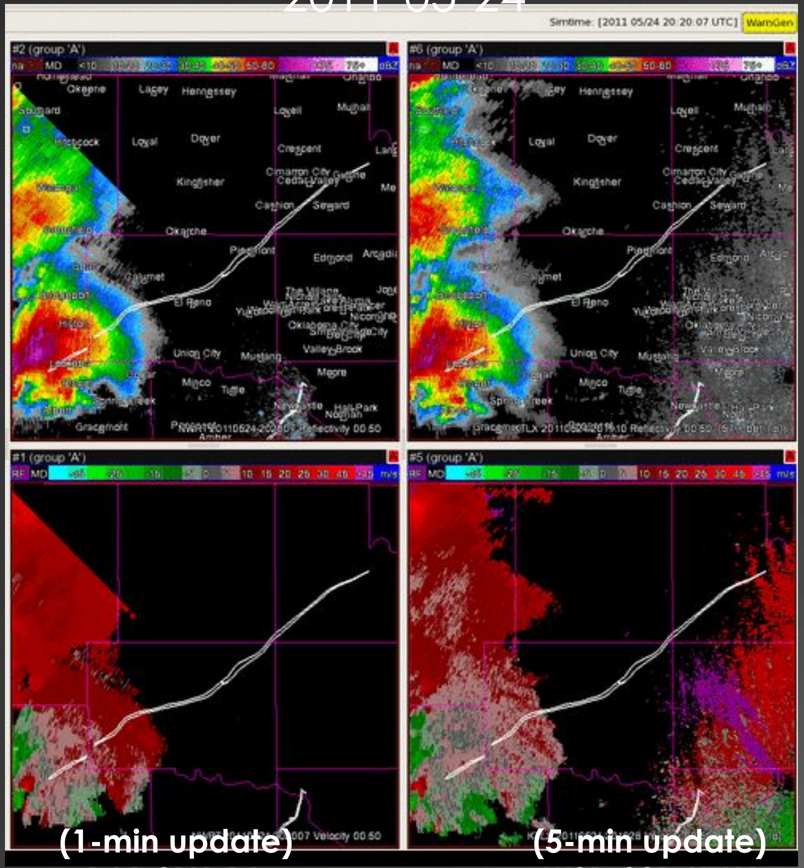
PAR Meteorological Studies of Rapid-Update Data

- Examination of circulation and other severe weather signatures and phenomena
- Integration into Warn-on-Forecast models
- Forecaster evaluations in the Hazardous Weather Testbed

PAR Technology Developments

- Adaptive scanning concepts
- Signal processing and data quality investigations

2011-05-24



(1-min update)
PAR SPY-1A

(5-min update)
WSR-88D KTLX

Advanced Technology Demonstrator

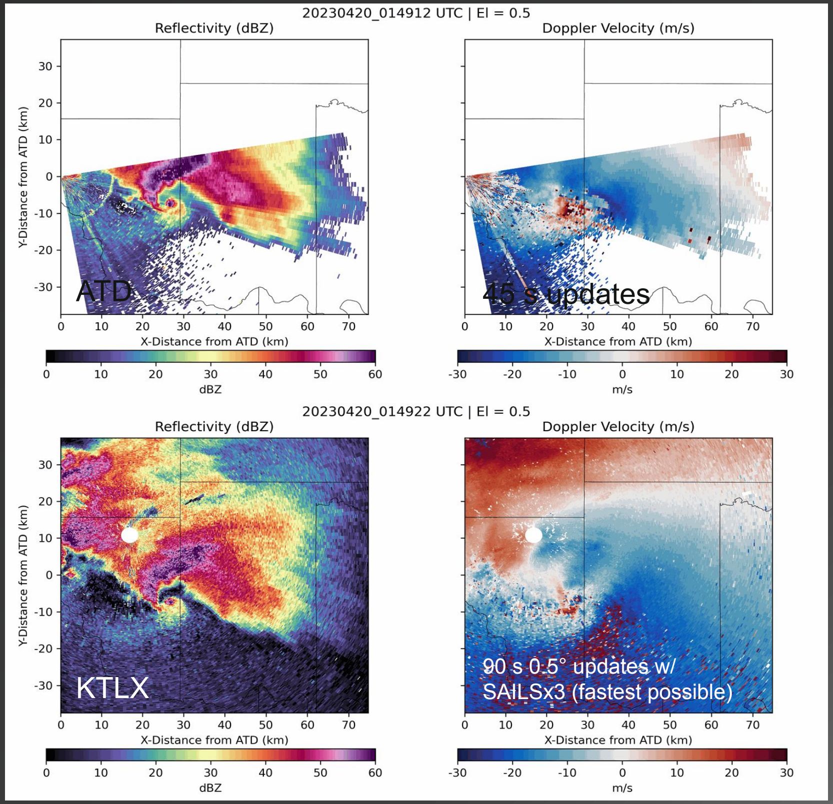
- First large-scale S-band dual-pol PAR built for meteorological applications
- Single face of a multi-face design
- Weather operations began in 2021
- Significant advancement in design and capabilities
- A significant effort to design, build, and now operate a one-of-a-kind system

Demonstrating Benefits of Rapid Low-Level Updates

- Rapid updates allow for earlier detection of features in the algorithms tested
- Precursors of low-level severe convective hazards better identified and tracked
- New and adaptive scanning modes improve our understanding of extreme weather

2023 – 2024 Case Counts (280+ hours)

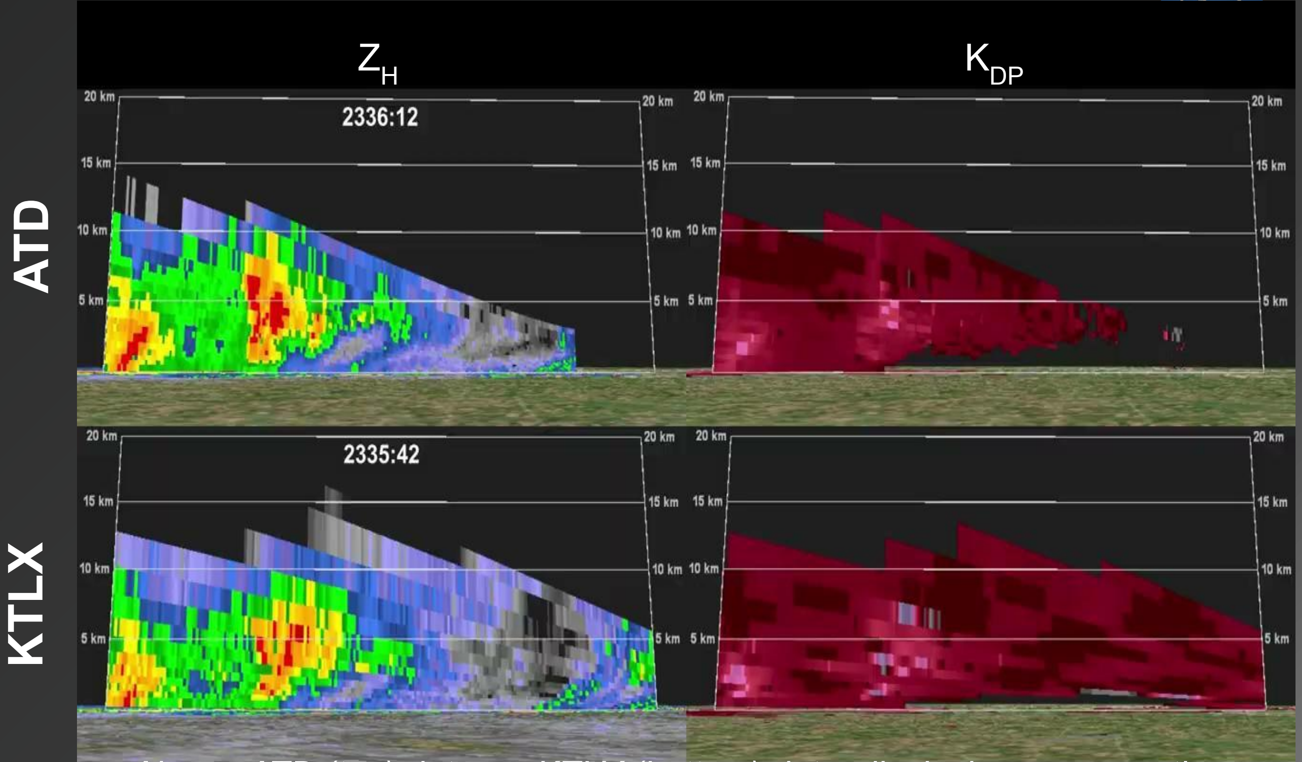
Tornadic Supercells	Severe & Nonsevere MCS	Severe Multicell Convection	Nonsevere Multicell Convection	Downburst	Winter Wx	Clear Air, Fire Wx, & Eng Tests
11	15	16	22	5	6	16



Above: ATD (top) data vs. KTLX (bottom) data, displaying the rapid-updates afforded by PAR.

Demonstrating the Benefits of Improved Volumetric Updates

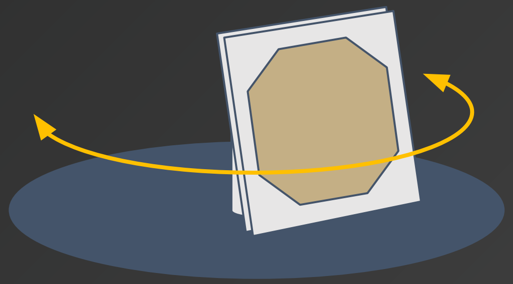
- The fastest update of the 0.5° elevation is ~90-s for WSR-88D
- PARs typically have full volume update of ~60-90-s when operated with same WSR-88D VCP (~30-45-s for 0.5° update)
- When comparing volume updates, PAR is significantly faster. Typically, the WSR-88D volume takes 4-6 minutes to update using convective VCPs



Above: ATD (top) data vs. KTLX (bottom) data, displaying cross-sections through a K_{DP} core associated with a downburst on 9/5/2023.

Rotating PAR Future

- Rotating PAR is an unexplored option for achieving rapid updates with lower cost than a four-faced stationary PAR
- Continue risk reduction with a highly or all-digital system
- Can also continue investigating fixed multi-face PAR design
- NSSL will procure a Rotating PAR Test Article in FY25

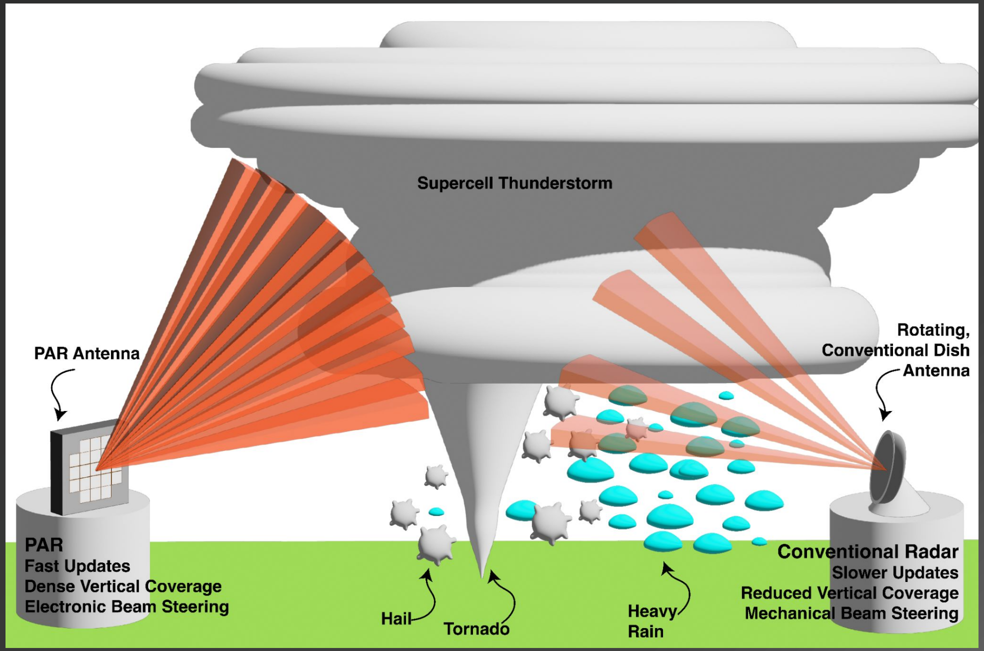


Rotating PAR

- One face operating
- Requires multi-beam modes for the same update rate

Summary of PAR Benefits

Capability	WSR-88D	Rotating PAR	Four- Face PAR
Volume update time	4-5 min (~6 min with SAILS)	~ 1.5 min (pending R&D with proposed PAR Test Article)	~ 1 min
Adaptive scanning	No	Limited	Yes
Frequency Agility	No	Yes	Yes
Adaptive beam shaping	No	Potential	Potential

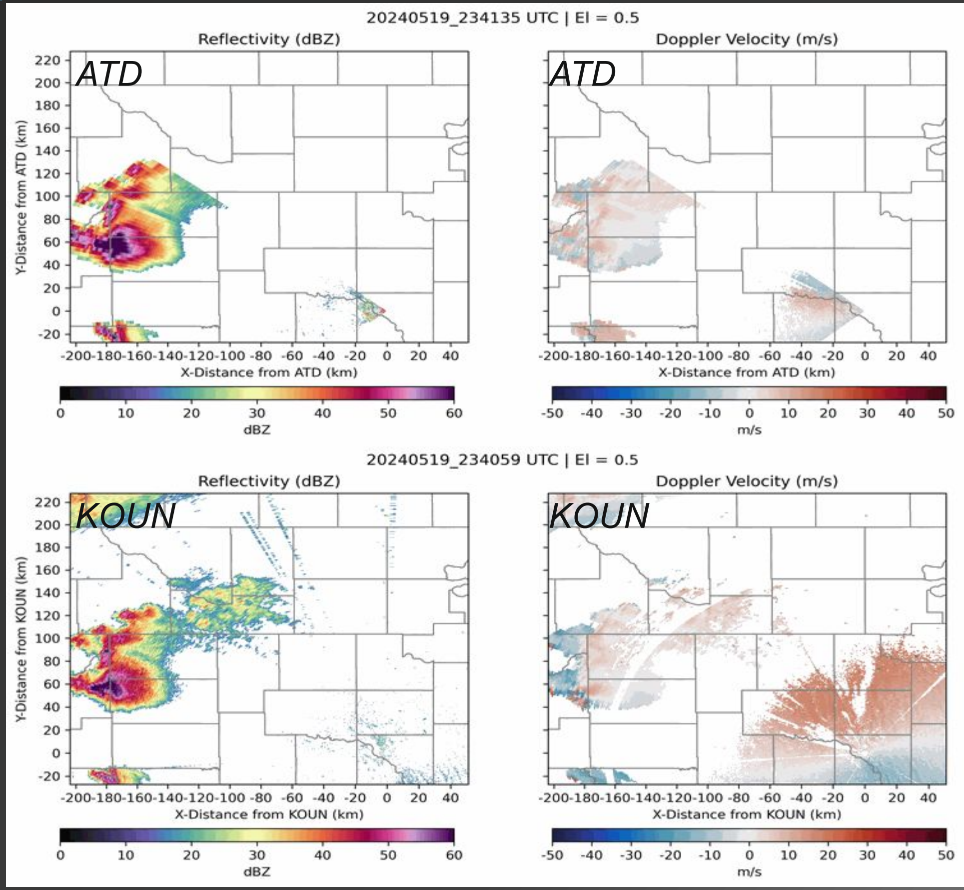


NSSL PAR Research and Development through 2028

Emphasizes meteorological and engineering R&D along with informing the NWS of PAR technology and evaluation using the ATD and the planned Rotating PAR Test Article.

PAR R&D Priorities in the next four years:

- Improved data quality using PAR unique methods
- Exploring PAR capabilities including adaptive scanning and spoiled transmit beams
- Investigation of dual-pol PAR advantages in scan rate on severe and non-severe weather
- Conducting Hazardous Weather Testbed experiments to inform how forecasters are using PAR data
- Evaluating compatibility with other observations
- Helping address PAR's operational viability
- Demonstrating PAR's benefits to operational end-user community



NSSL is providing iterative and continuous feedback to NWS on PAR R&D prior to finalizing next radar network design in 2032

NSSL is doing this by:

- Evaluating compatibility with other observations
- Helping address PAR's operational viability
- Demonstrating PAR's benefits to operational end-user community

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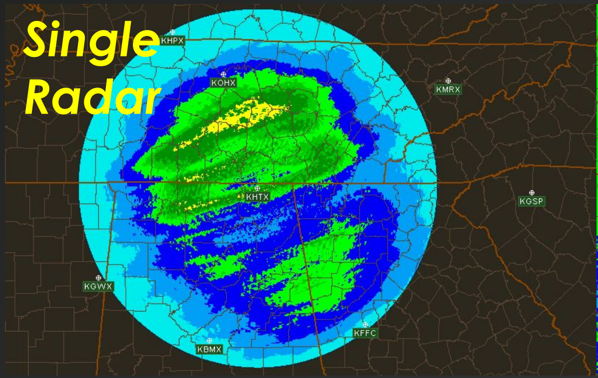
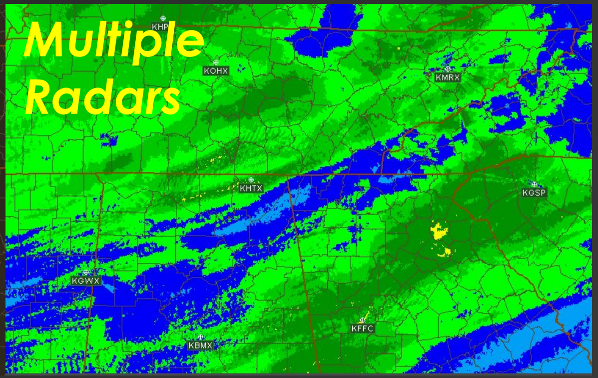
Multi-Radar/Multi-Sensor

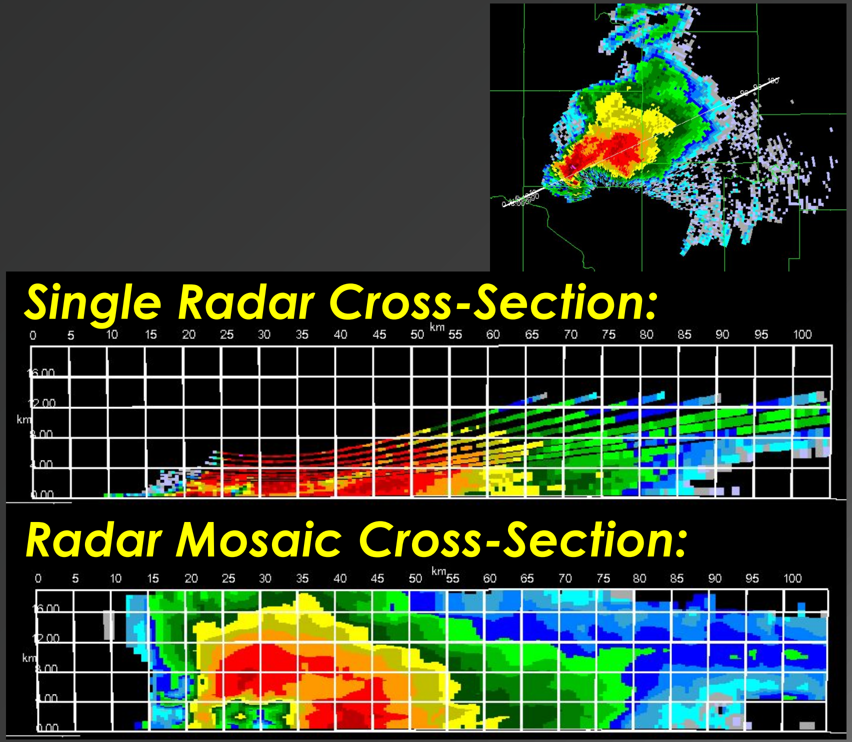
Race Clark
Research Meteorologist (NSSL)

MRMS is an advanced remote sensing processing system.

- We integrate a variety of observations into a seamless atmospheric analysis
  - Radars
  - Surface observations
  - Satellite
  - Model data





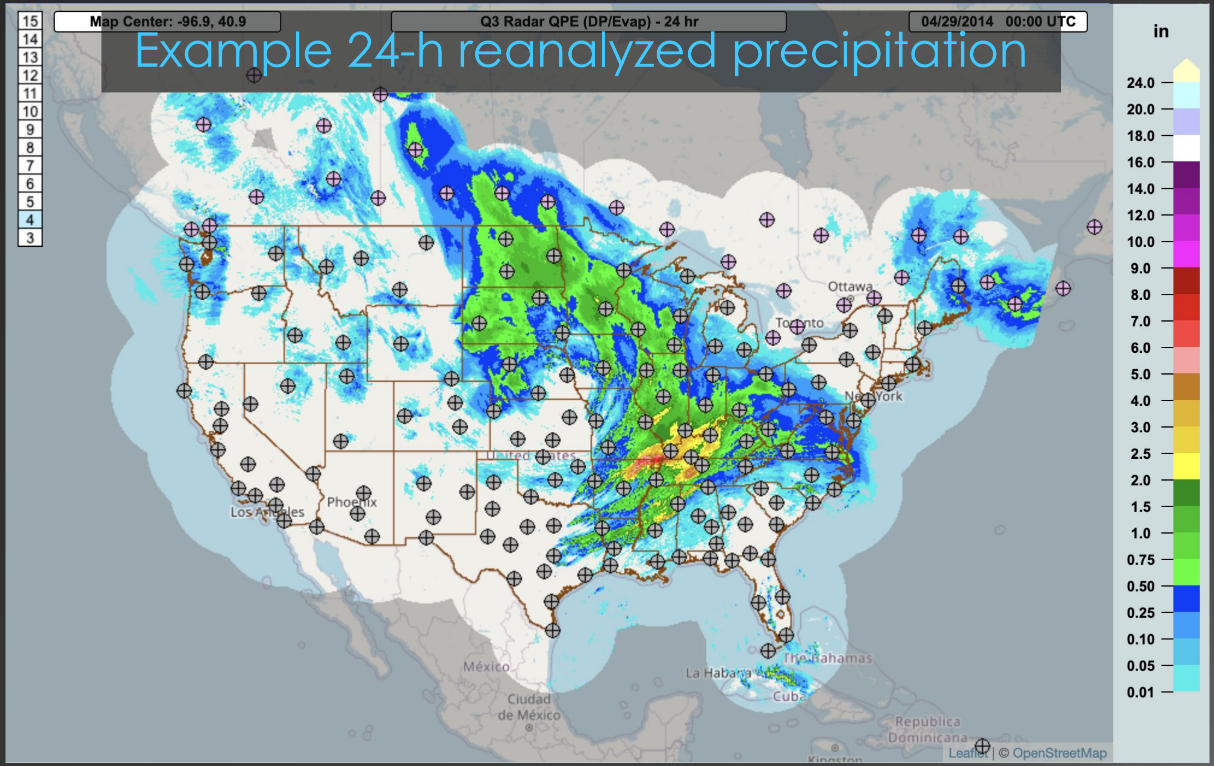


What does MRMS do?

- Clean up and mosaic radar data
- Deliver radar data into forecast models
- Precipitation information to the National Water Model
- Flash flood forecasting models
- Decision support for transportation (aviation and ground)
- Severe convective products

We are generating a decadal reanalysis of MRMS products.

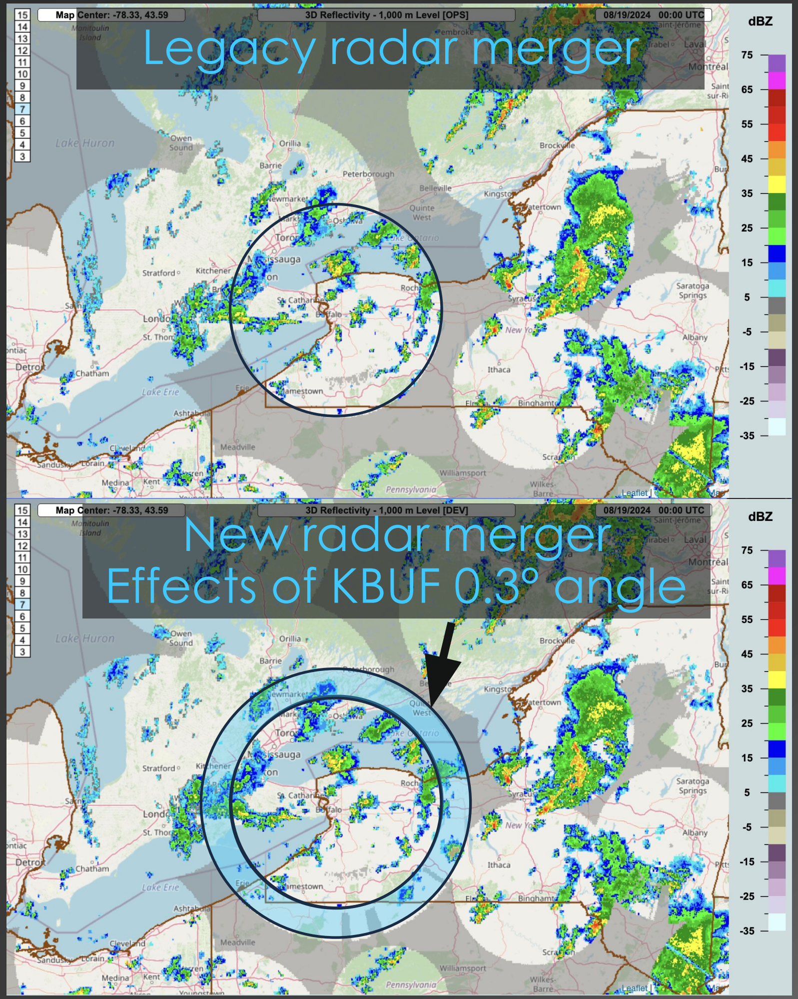
- 2014-Present
- 2 years completed
- Run in AWS cloud
- For scientific community



Reanalyzed 24 radar-only precipitation valid 00z Apr 29, 2014

Volume Coverage Pattern (VCPs) just aren't what they used to be.

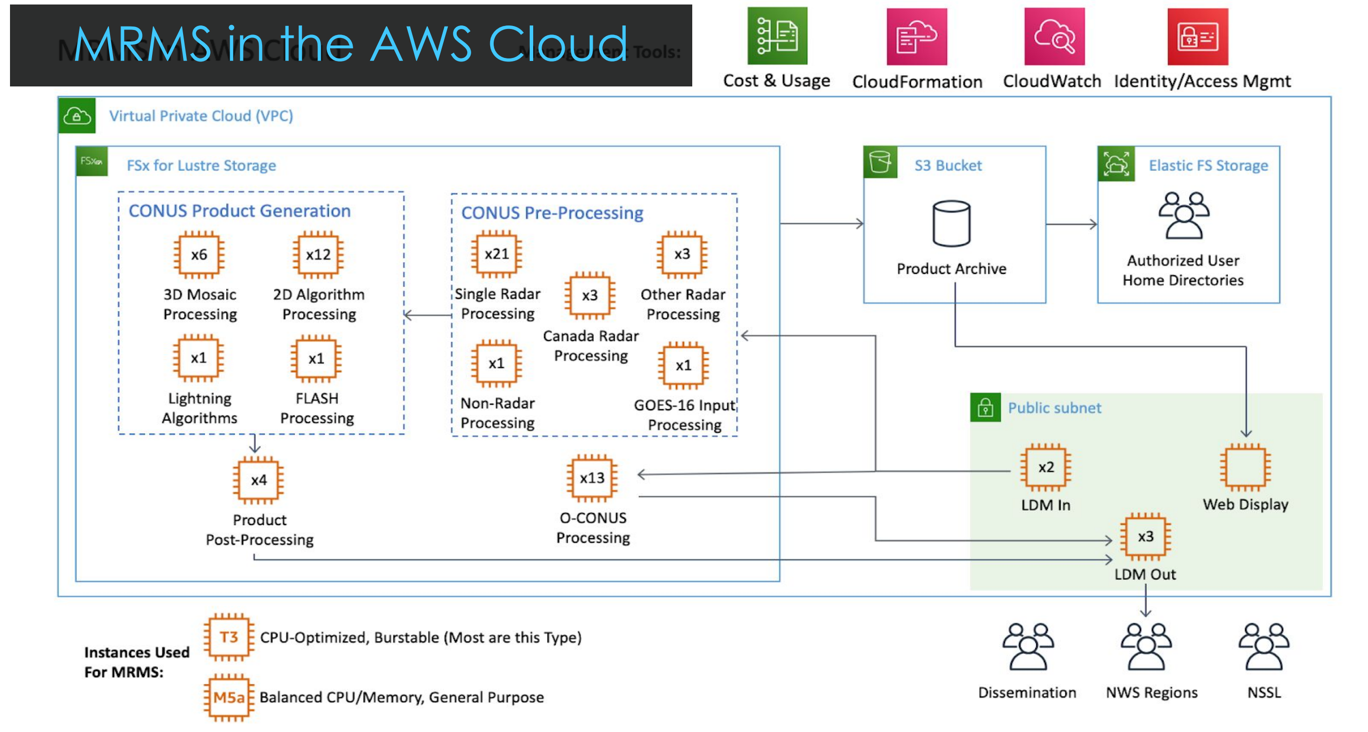
- VCPs getting more complicated
- MRMS wants to use all radar information
- Different networks, different frequencies, and more



(top) constant 1-km altitude PPI of reflectivity valid 00z Aug 19, 2024 [MRMS Operational System]
(bottom) as above [experimental MRMS Cloud System]

We're saying 'farewell' to vMRMS and 'hello' to the AWS cloud.

- Reliable
- Cost-effective
- Future-forward and expandable



Schematic of experimental MRMS Cloud System running on AWS

Supplemental radars show promise for a variety of MRMS-related applications.

- NSSL added the Alamosa, CO C-band radar to the operational MRMS system in February 2021

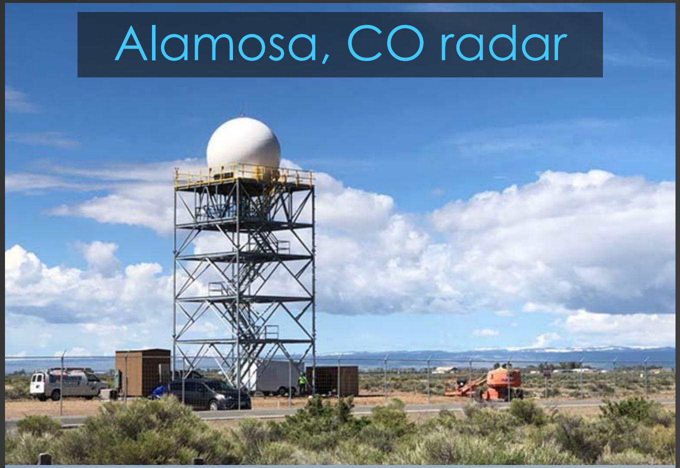
COLORADO
Colorado Water Conservation Board
Department of Natural Resources

EWR RADAR SYSTEMS

- NSSL has an agreement to add the Durango/La Plata County, CO C-band radar to MRMS

La Plata County Colorado
ACCOUNTABILITY · INTEGRITY · RESPECT

BARON WEATHER



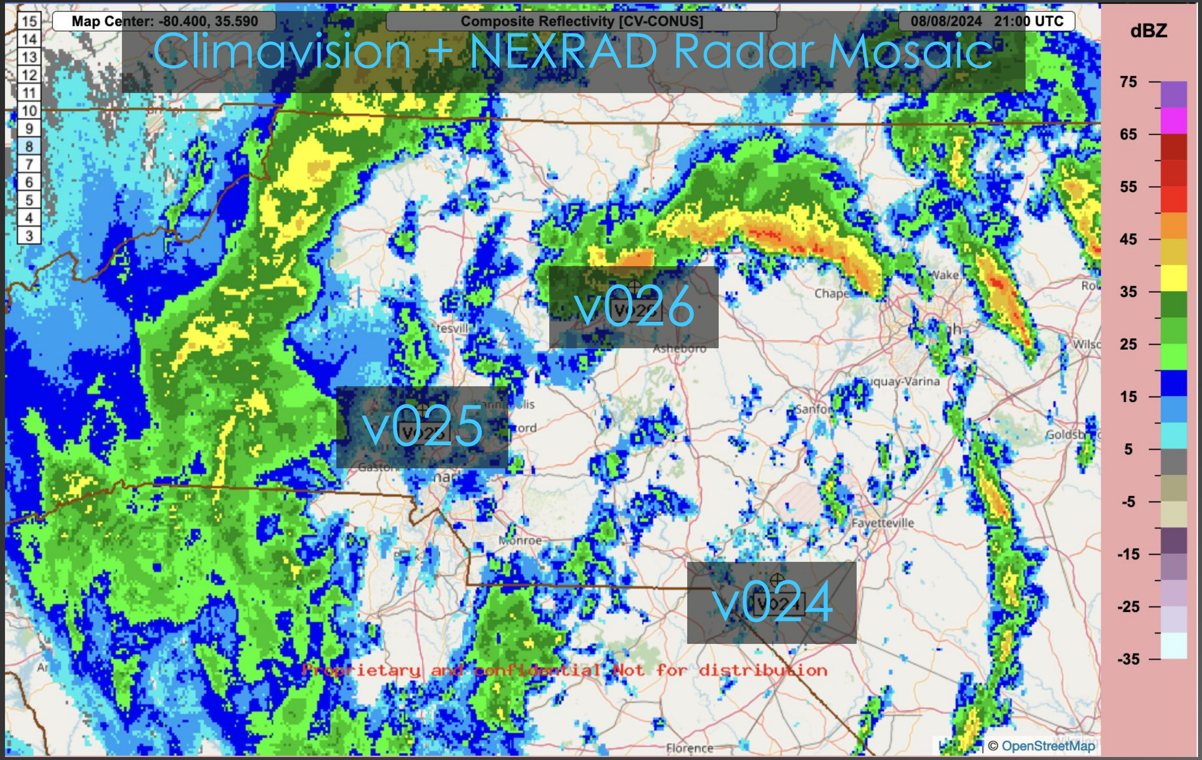
(top) Alamosa, CO [photo via EWR Radar Systems]
(bottom) Installation of radome in La Plata County, CO [photo via Durango Airport]

MRMS works with other partners to identify new sources of weather observations.

Climavision

AQPI
Advanced Quantitative Precipitation Information

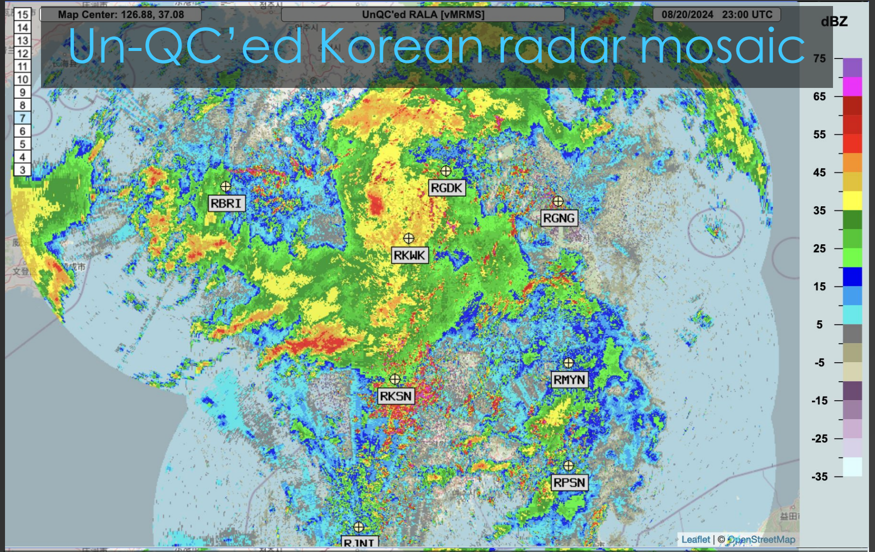
Synoptic.

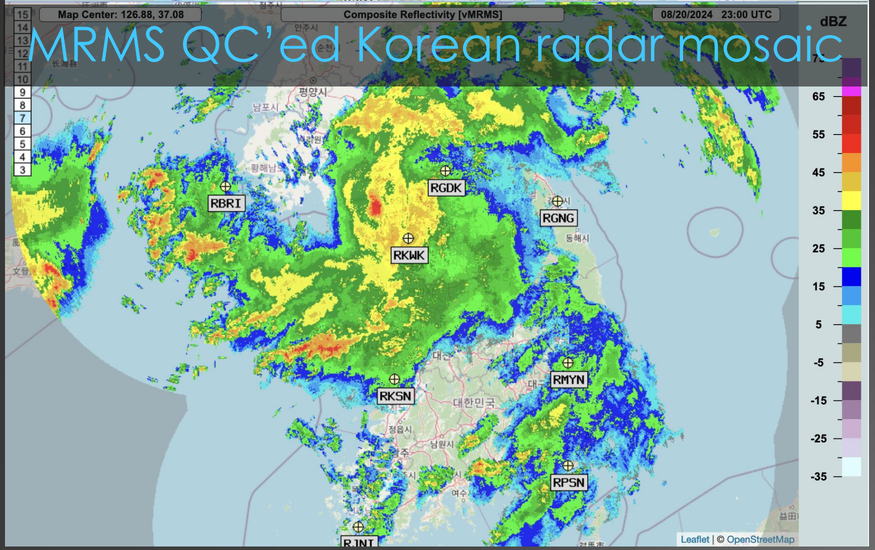


MRMS-Climavision domain Composite Reflectivity valid 21z Aug 8, 2024

MRMS's footprint is international.

- Built and maintaining MRMS for Taiwan
- Interagency agreement with US Air Force, building MRMS for
  - South Korea ->
  - Japan
  - Germany





(top) Korea domain UnQC'ed Reflectivity at Lowest Altitude valid 23z Aug 20, 2024
(bottom) Korea domain Composite Reflectivity valid 23z Aug 20, 2024

MRMS would not be possible without many teams across NSSL and CIWRO.

- Applied Computing for the Meteorological Enterprise (ACME):
  - CIWRO lead: Jeff Brogden / Federal lead: Race Clark
  - Ami Arthur, Karen Cooper, Gabriela Fisher, Nat Indik, Brent Kraninger, Carrie Langston, Timothy Miller, Mike Taylor, Robert Toomey
- Storm-scale Convection and Radar Team (SCRT):
  - Federal lead: Matt Flournoy / CIWRO lead: Ben Schenkel
  - Wenjun Cui, Rachel Miller, Thea Sandmael, Jacob Segall, Brandon Smith
- Storm-scale Hydrometeorology Group (SHMG):
  - Federal lead: Jian Zhang / CIWRO lead: Steve Cocks
  - Ken Howard, Jackson Anthony, Lin Tang, Nana Liu, Dean Meyer, Andrew Osborne, Steve Martinaitis
- Transportation Applications Group (TAG):
  - CIWRO lead: Heather Reeves / Federal lead: JJ Gourley
  - Jorge Duarte, Jillian Dufort, Andrew Rosenow, Daniel Tripp, Adam Werkema
- NSSL Warning Research and Development Division Director: Alan Gerard

Project website:
https://mrms.nssl.noaa.gov/

MRMS is a project of NOAA's National Severe Storms Laboratory and the University of Oklahoma's Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO).

DOC / NOAA / OAR
National Severe Storms Laboratory

FACETs
Forecasting A Continuum of Environmental Threats

Kodi Berry
FACETs Program Lead

What are the Benefits of FACETs?

Modernize the forecast & warning system to provide more actionable information when it's available for:

- Better individual decision making
- More consistent communication
- Advancing NWS probabilistic impact-based decision support services (probIDSS) initiative
- Producing a continuous stream of high-resolution probabilistic information extending from days to within minutes of an event – for all environmental hazards

FACETs Research at NSSL

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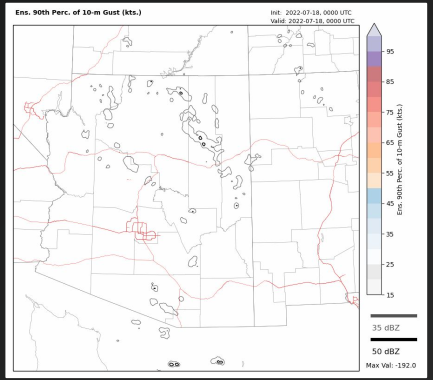
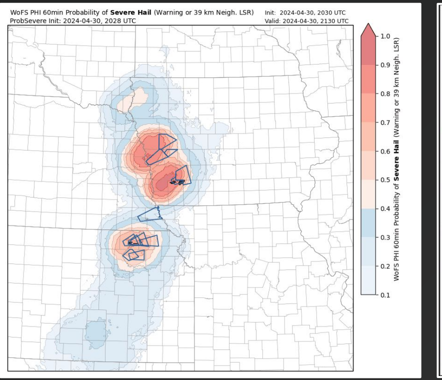
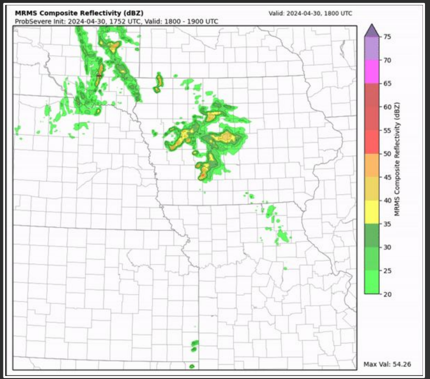
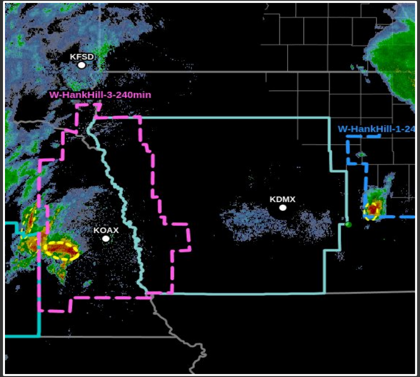
Warn-on-Forecast	Watch-to-Warning	Prob Hazard Info	Threats-in-Motion
0-6 hr	0-4 hr	0-1 hr	0-45 min



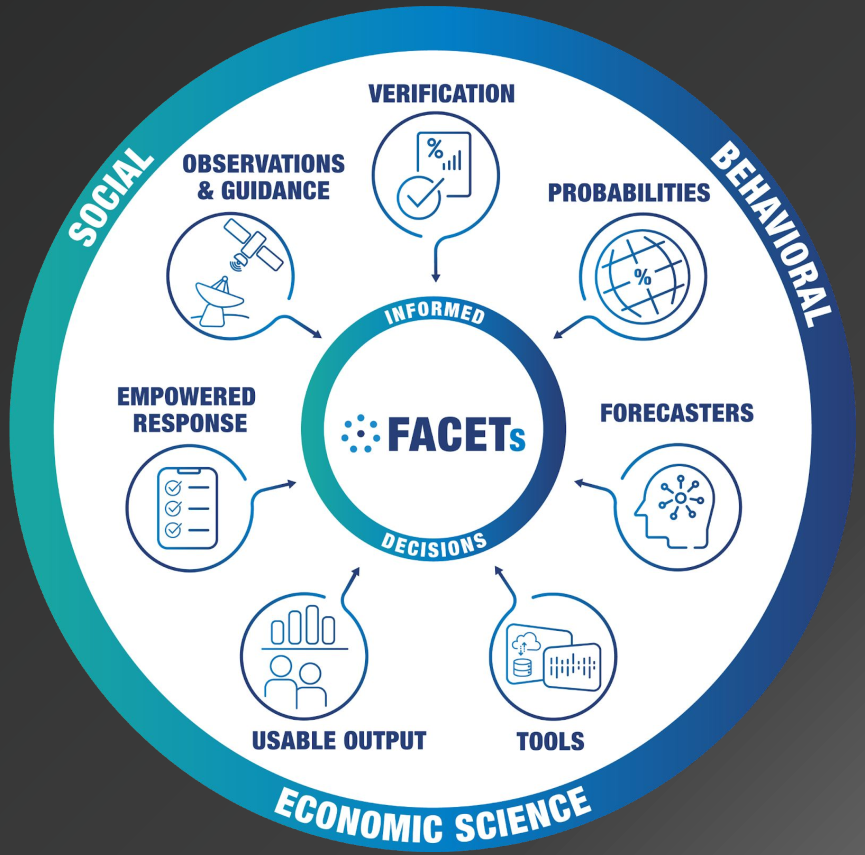






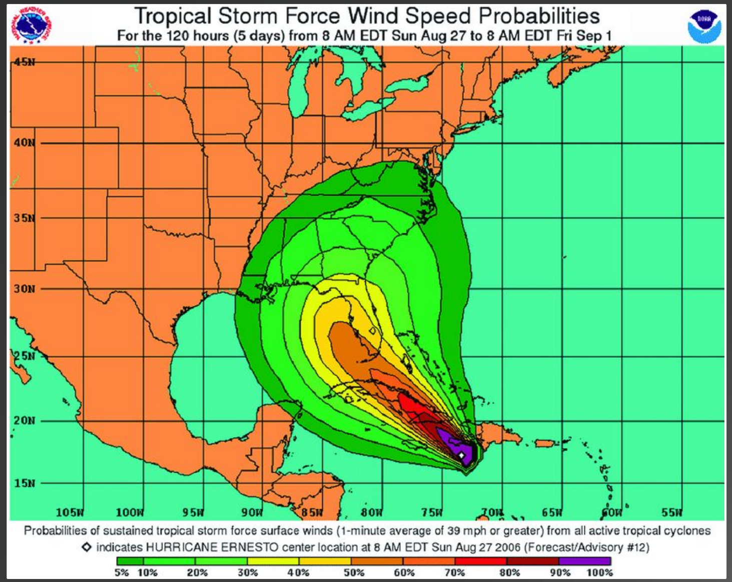
What is FACETs?

FACETs serves as NSSL's research & development framework that guides the co-creation of new probabilistic products & strategies that are user-tested prior to their transition to NWS operations, leading to better forecast information & decision-making



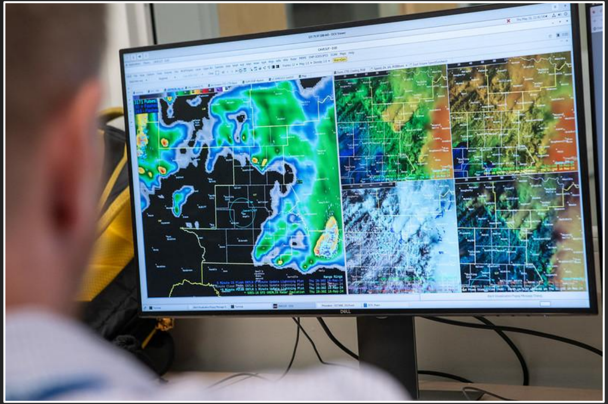
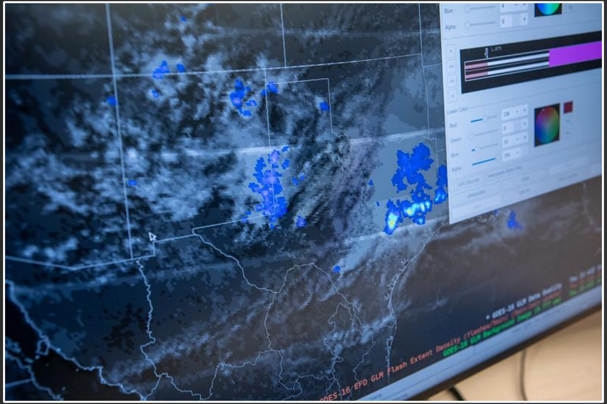
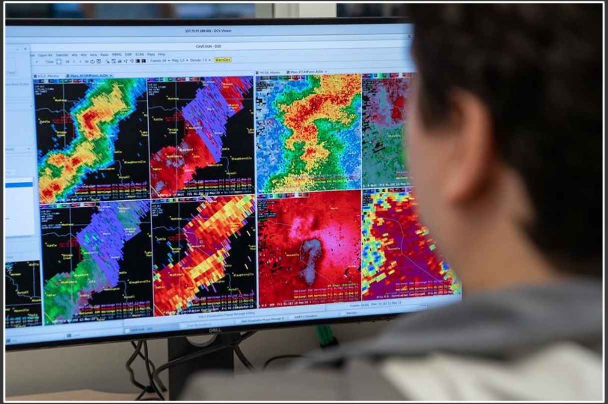
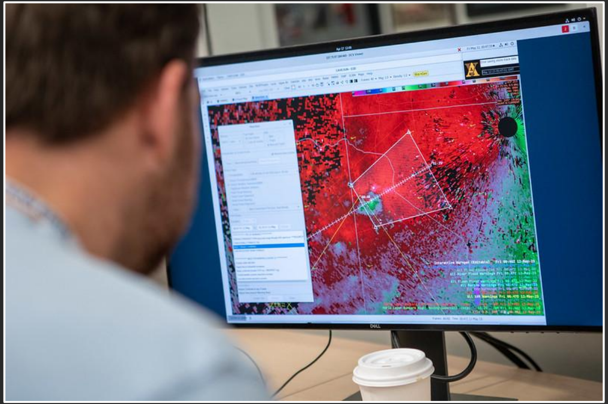
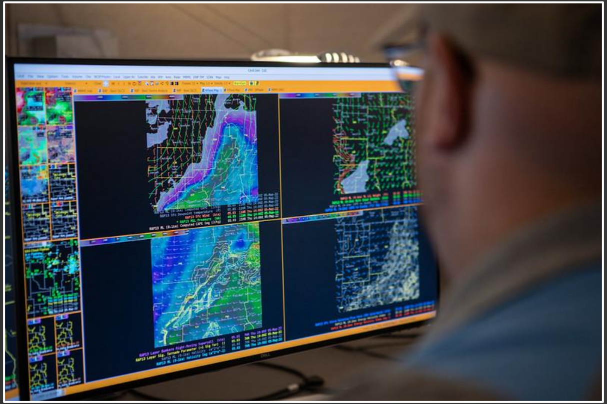
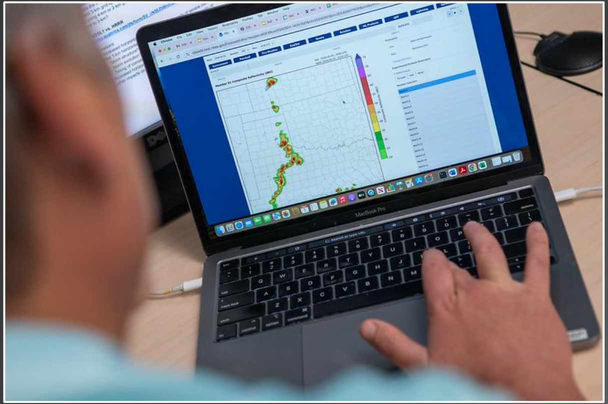
The Journey of Probabilistic Hazard Information (PHI) through the FACETs Framework

- 1995-2004: Forecasters in early HWT experiments expressed that they had more information to share than a warning alone could provide
- NSSL researchers proposed a storm-scale analogue to the NHC's probabilistic hurricane-force wind maps to increase SVR & TOR lead time, at higher uncertainty

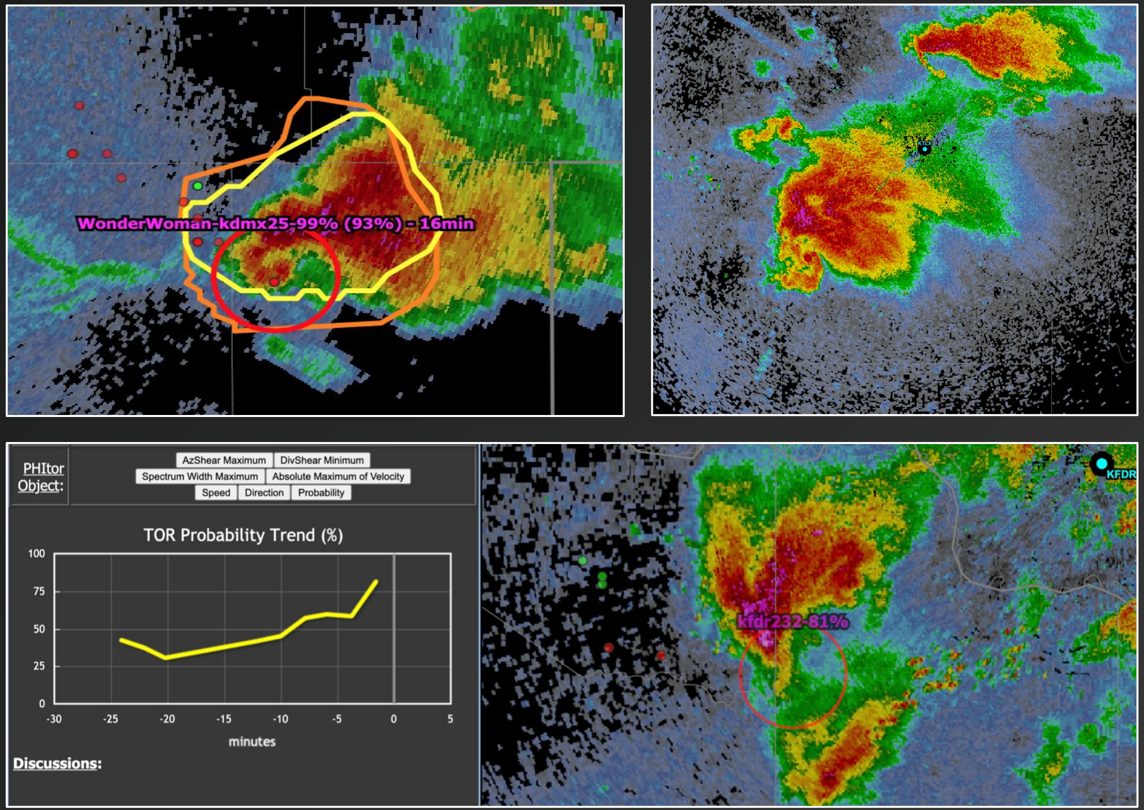


Observations & Guidance

What forecasters use to make decisions

Probabilities



- Object-based storm-scale probabilities & probability plumes to communicate the probability of a severe hazard occurring over the next hour
- Automated guidance from <u>machine learning</u> models
  - Tornado Probability (TORP)
  - ProbSevere v3
  - Lightning Probability

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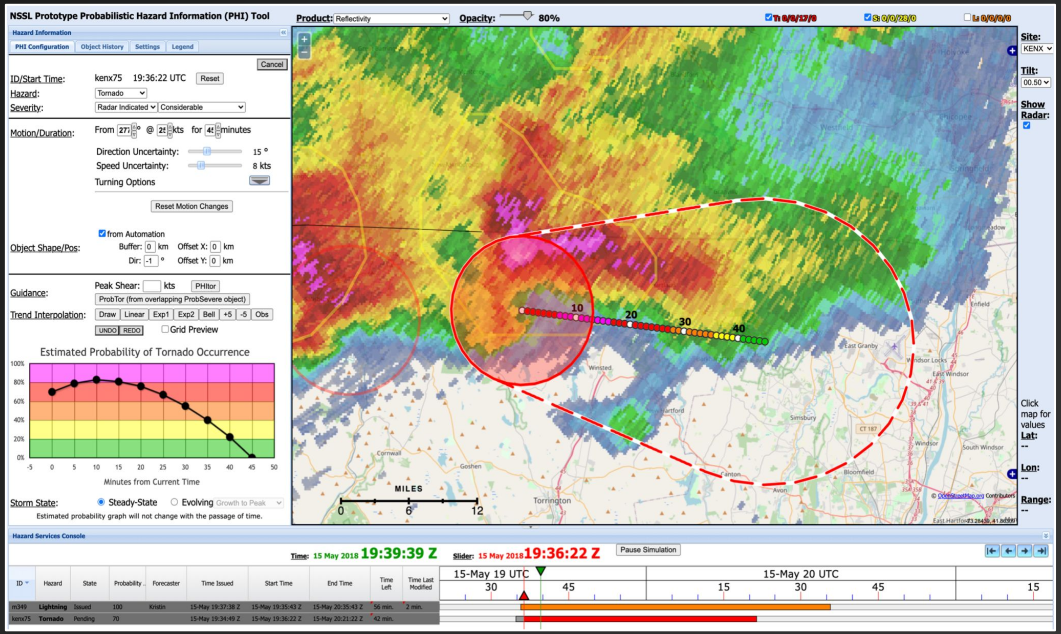
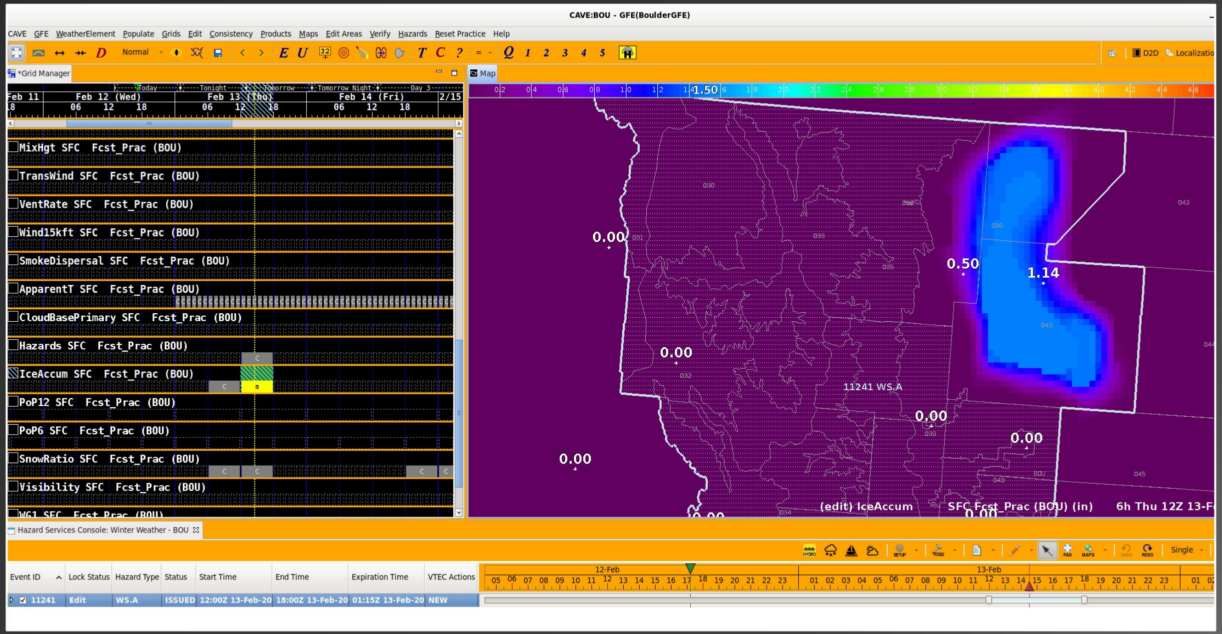
Tools

What forecasters use to issue forecasts & warnings

NSSL: Prototype Web Tool



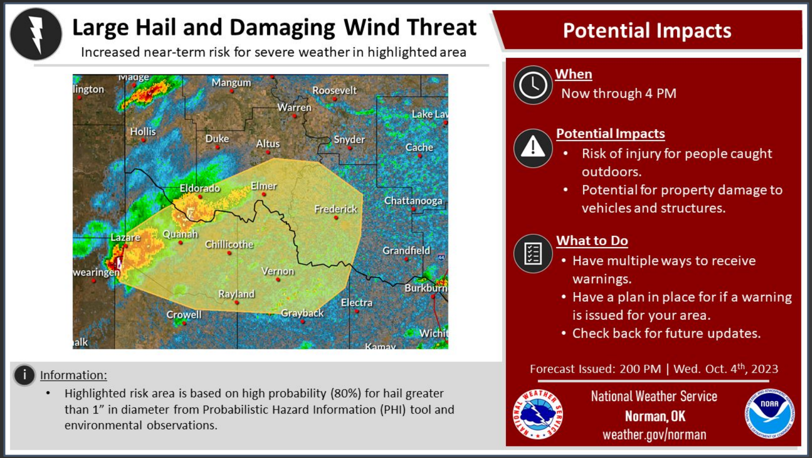
GSL: Hazard Services

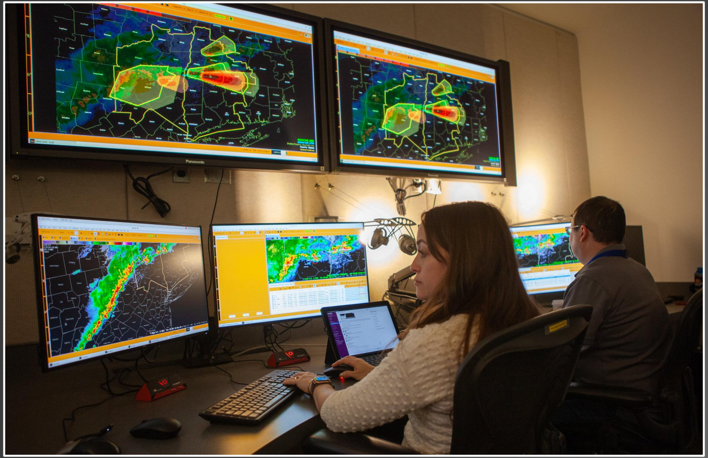


Forecasters

The people making forecast & warning decisions

- HWT experiments & field evaluations with forecasters allow researchers to receive direct feedback, study impacts of PHI on workload & understand how forecasters communicate PHI to the public

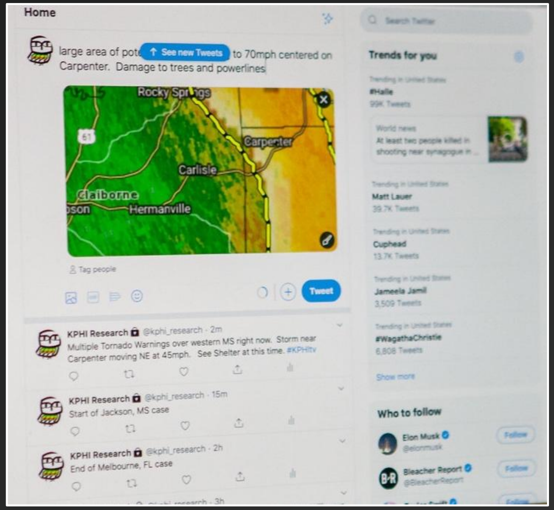


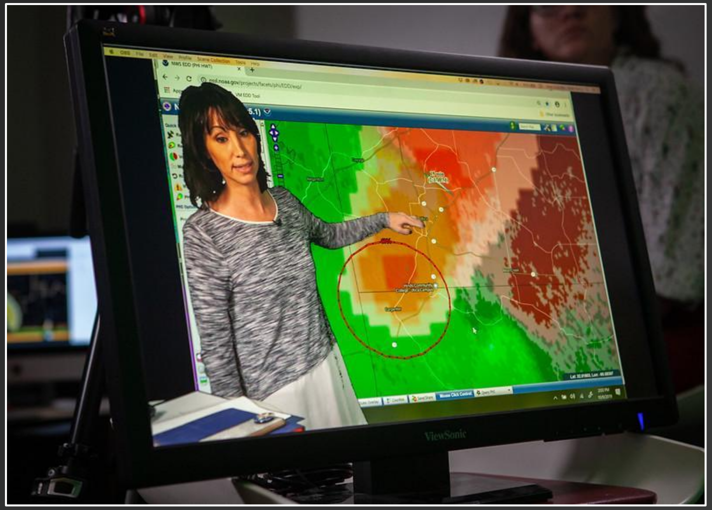


Usable Output

What the end users see (graphics, text, etc)

- HWT experiments with broadcasters & emergency managers allow researchers to evaluate the utility of experimental probabilities in simulated job environments

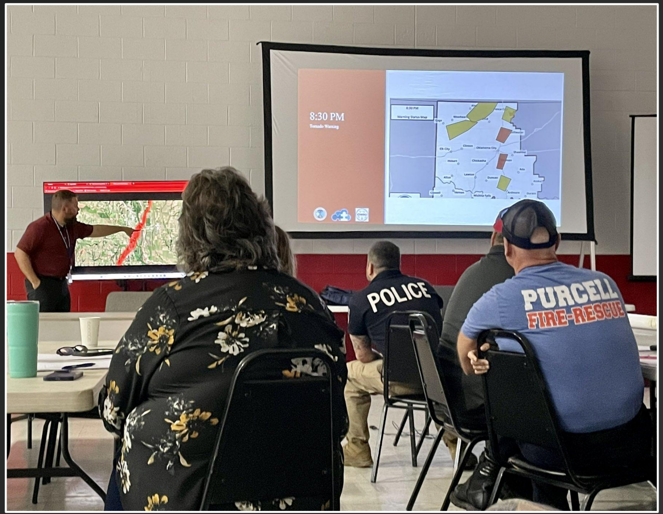


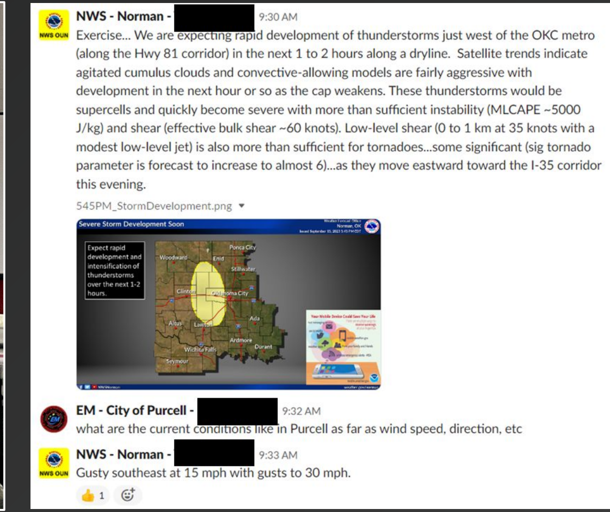


Empowered Response

What the end users do with the usable output

- NSSL-supported experiments & tabletop exercises allow researchers to evaluate community response to experimental products and services





NWS - Norman - [redacted] 9:30 AM

Exercise... We are expecting rapid development of thunderstorms just west of the OKC metro (along the Hwy 81 corridor) in the next 1 to 2 hours along a dryline. Satellite trends indicate agitated cumulus clouds and convective-allowing models are fairly aggressive with development in the next hour or so as the cap weakens. These thunderstorms would be supercells and quickly become severe with more than sufficient instability (MLCAPE ~5000 J/kg) and shear (effective bulk shear ~60 knots). Low-level shear (0 to 1 km at 35 knots with a modest low-level jet) is also more than sufficient for tornadoes...some significant (sig tornado parameter is forecast to increase to almost 6)...as they move eastward toward the I-35 corridor this evening.

545PM_StormDevelopment.png

EM - City of Purcell - [redacted] 9:32 AM

what are the current conditions like in Purcell as far as wind speed, direction, etc

NWS - Norman - [redacted] 9:33 AM

Gusty southeast at 15 mph with gusts to 30 mph.

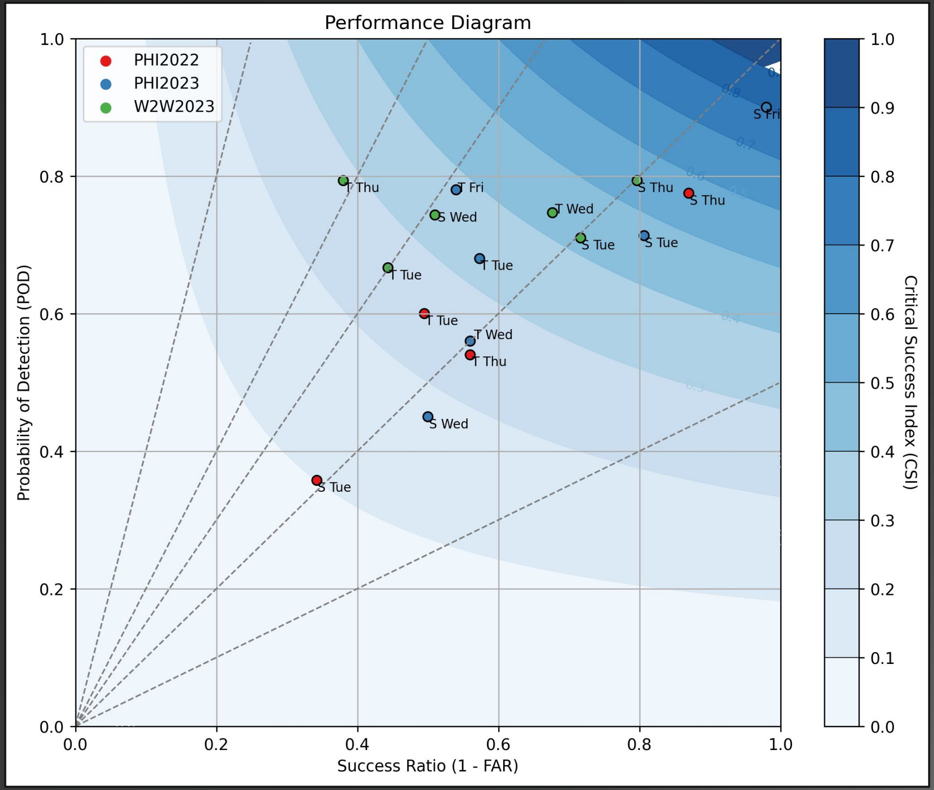
👍 1

Verification

Evaluating system effectiveness

PHI verification is ongoing

- Generally, forecaster skill working with PHI tends to improve quickly even as case complexity increases throughout the week
- More recent experiments show better performance & less variability, likely a reflection of algorithm & tracking improvements



FACETs Grand Challenge: Mentality vs. Reality

- **Forecaster:** No one else understands probabilities
- **Emergency Manager:** The public doesn't understand probabilities
- **Broadcaster:** The public doesn't understand probabilities
- **SBS Research:** "Nearly all of the studies … indicate that people make **<u>better decisions</u>**, have **<u>higher trust</u>** in information, and/or display a **<u>greater understanding</u>** of forecast information when shown a **probabilistic forecast** instead of a deterministic one." Ripberger et al. 2022 (Weather, Climate & Society)

How do we overcome the mentality of "I want it for myself but I don't trust others to understand & use it properly"?

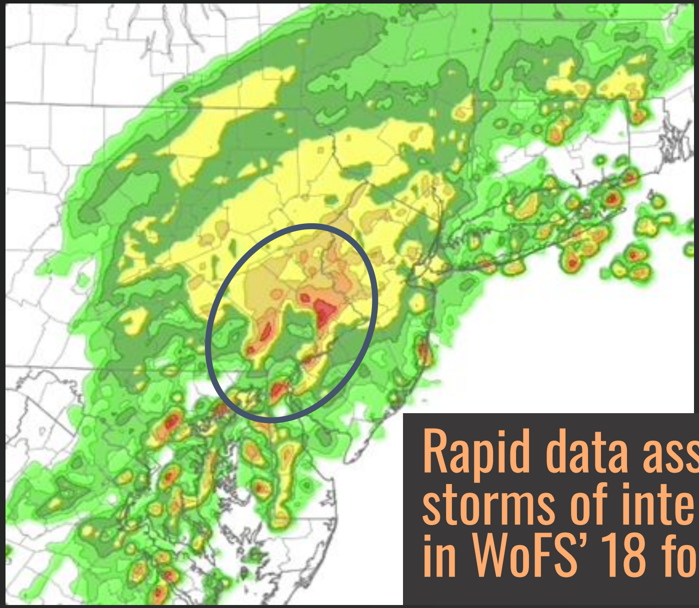
DOC / NOAA / OAR

National Severe Storms Laboratory

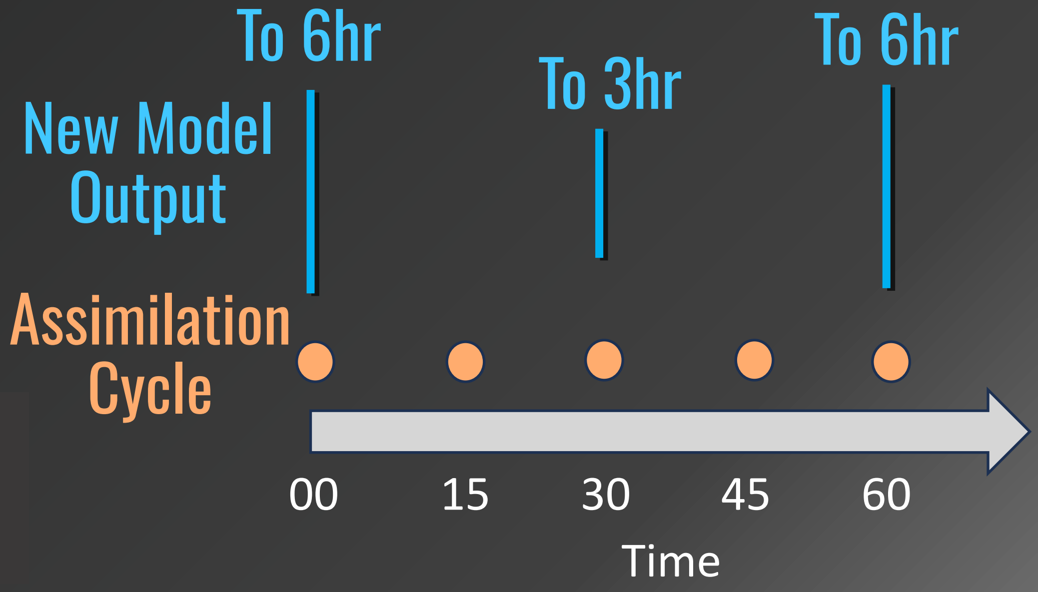
I can see clearly now:
The Warn-on-Forecast System

Probabilistic prediction of individual storms

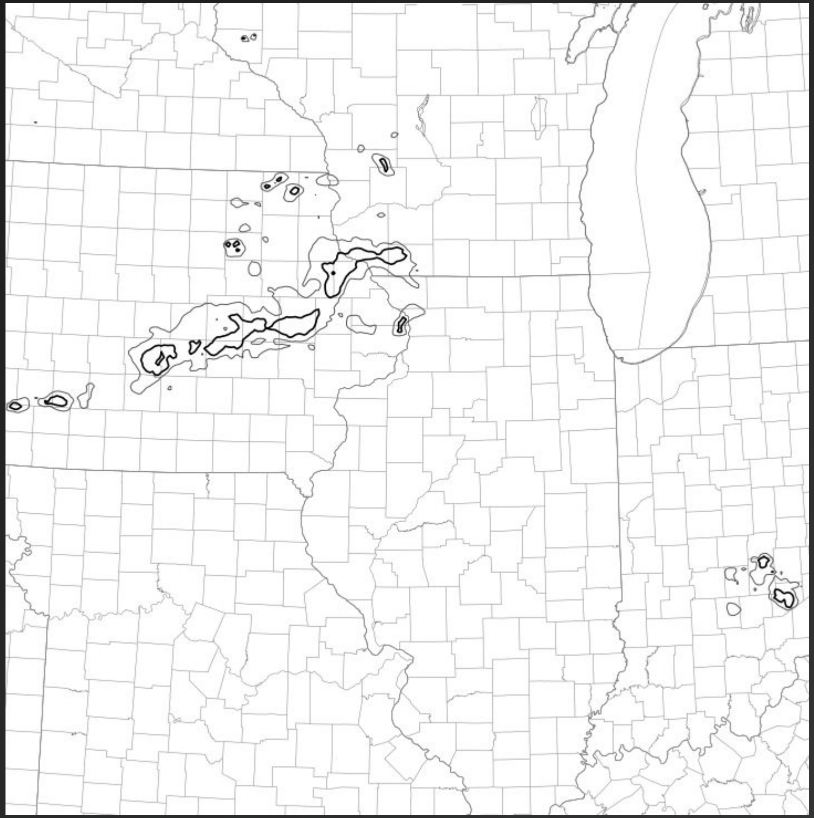
- 36 member analysis, 18 member forecast
- Assimilation w/ radar, satellite, 15 min
- Targeted regional domain, 3 km grid
- New forecast run every 30 min, projected 3–6 hours
- Low latency
- Web viewer informed by users



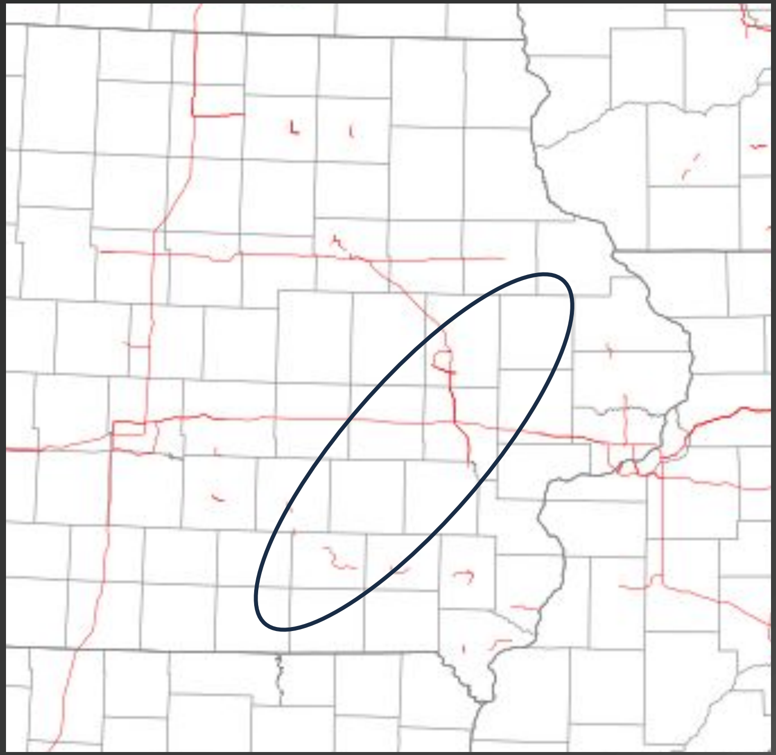
Rapid data assimilation keeps ongoing storms of interest accurately initialized in WoFS' 18 forecast members



What is the probability of severe winds, and where?

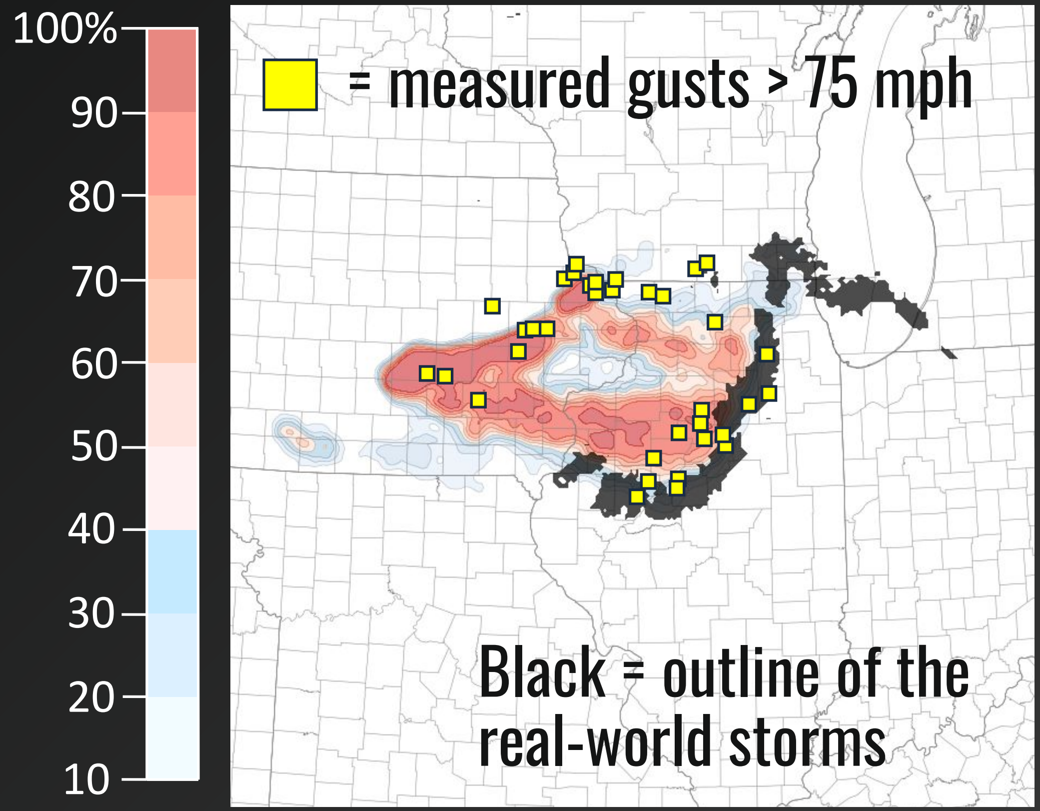


3-hour loops

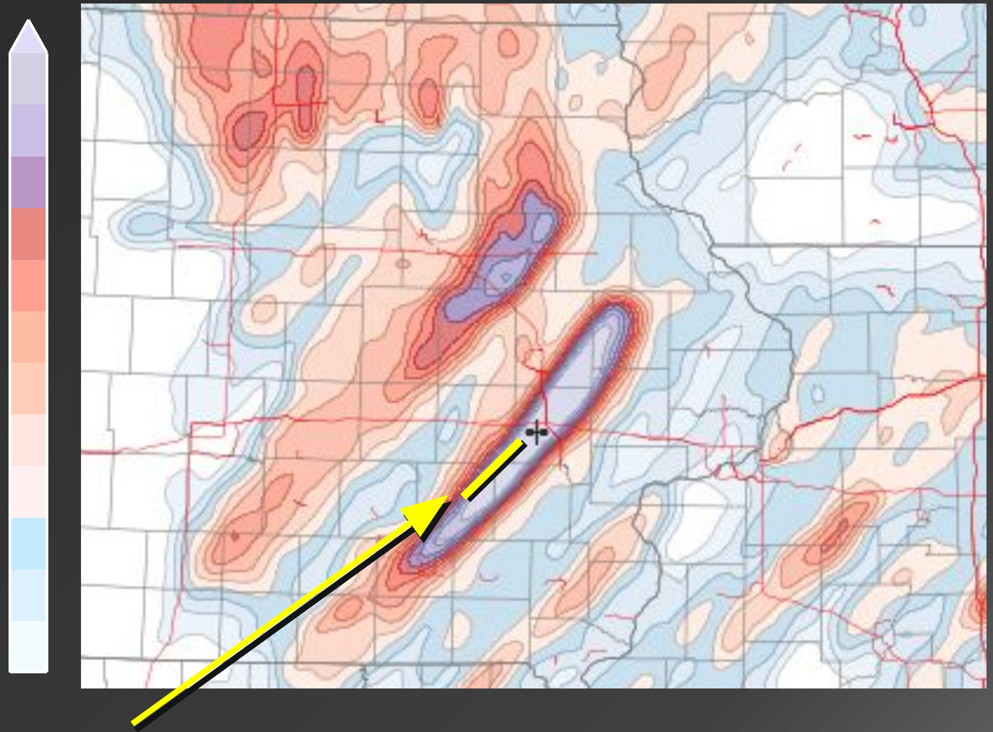


Which storm could produce a destructive, long-lived tornado?

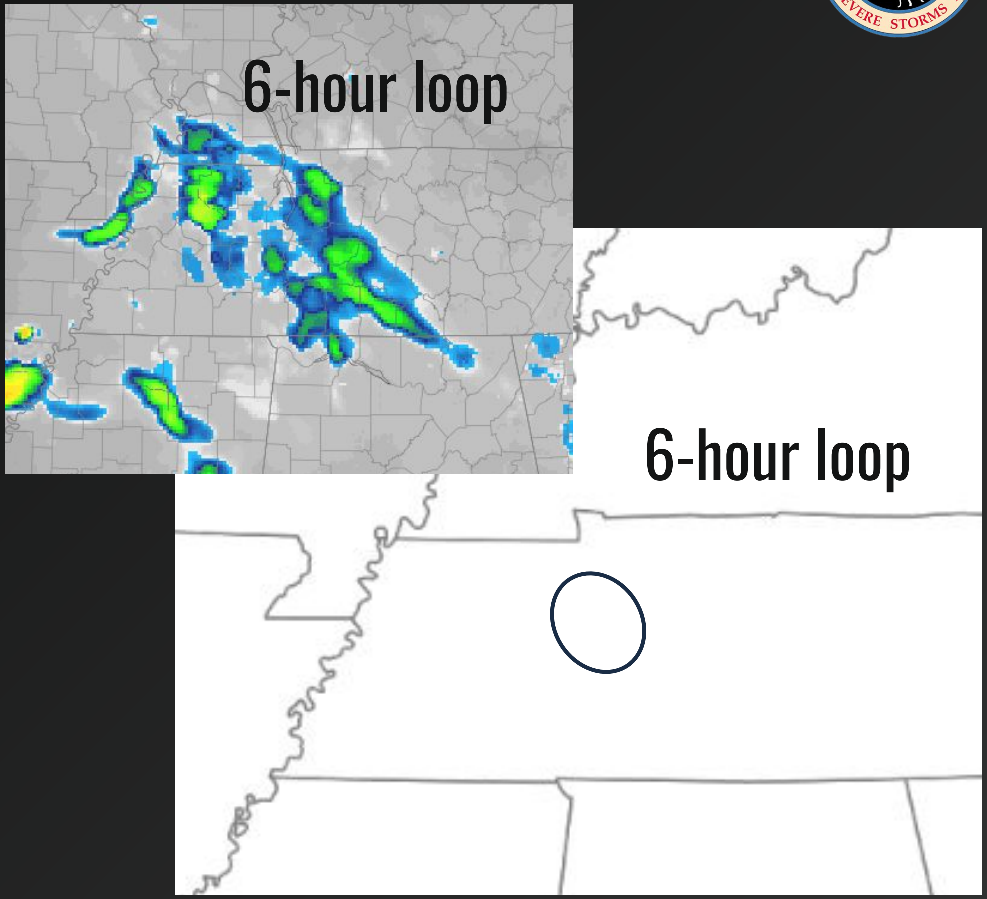
Probability of severe winds across 18 forecast members



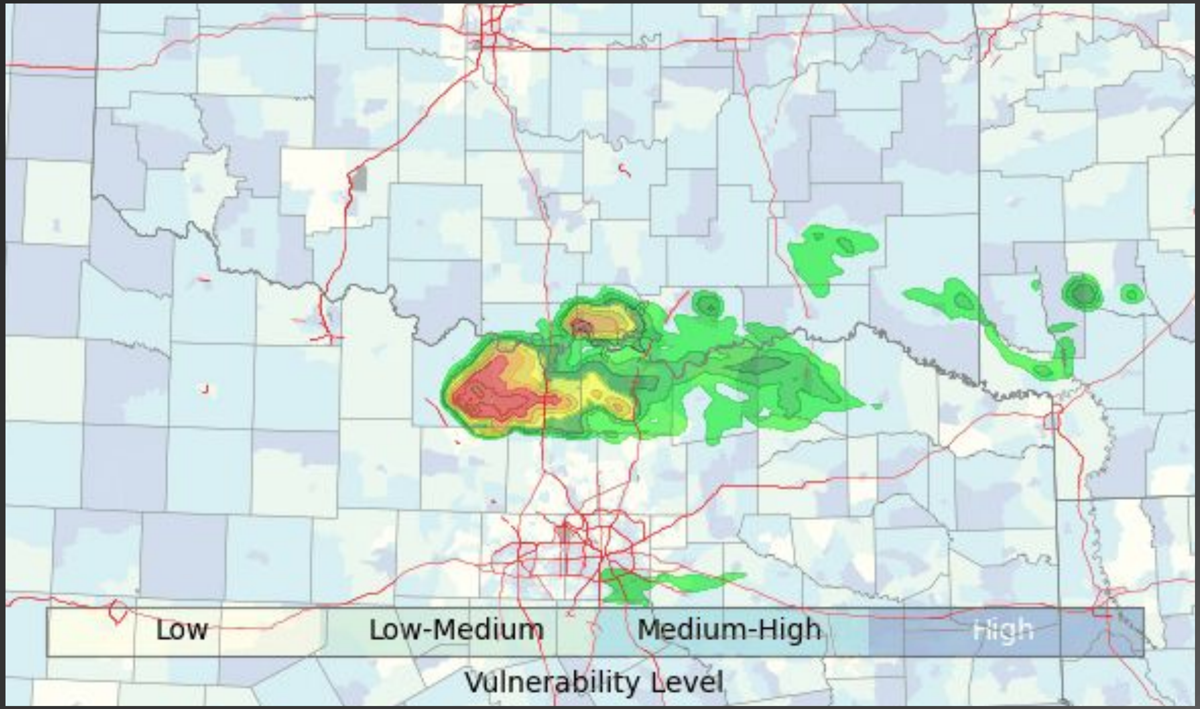
90th percentile magnitude of low-level rotation



Track of the day's only EF-4 tornado

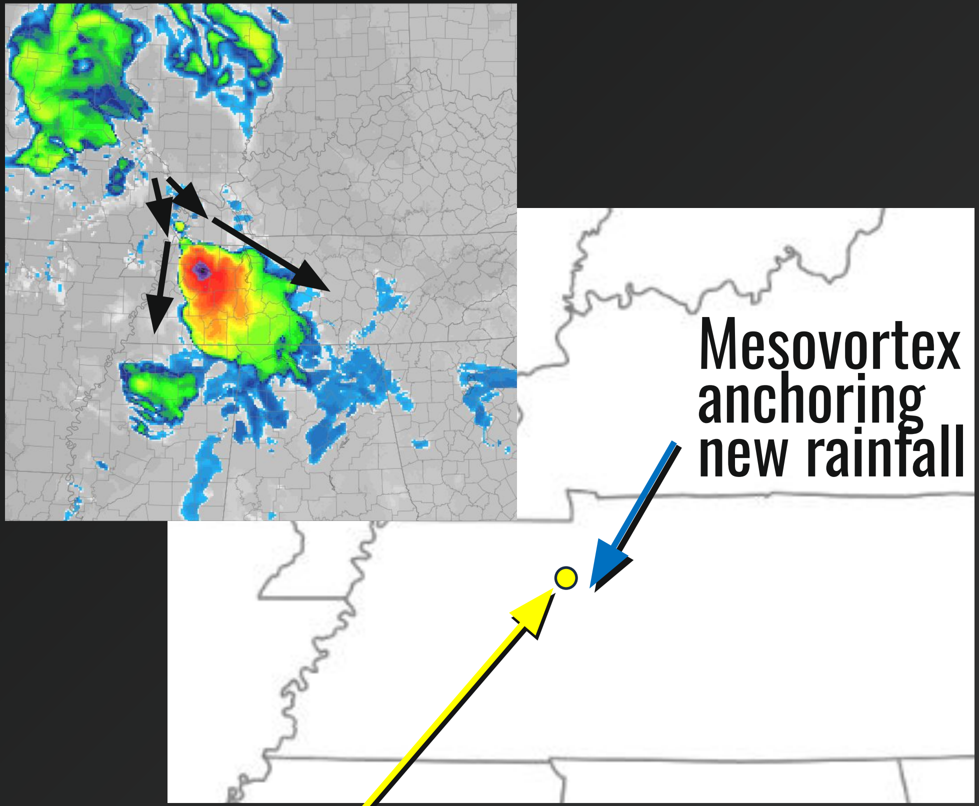


Who are the vulnerable communities in the path?



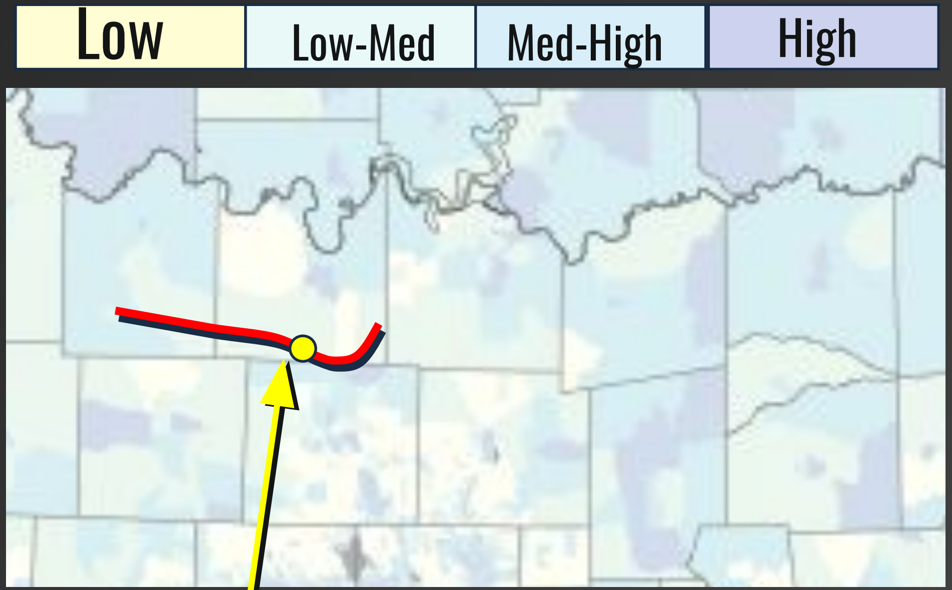
Will the storms move slowly enough to produce flooding rain?

Simulated infrared satellite wedge signature



Site of a catastrophic flash flood

CDC Social Vulnerability Index as an underlay



Site of all 7 fatalities (mobile & manufactured homes) from this 48-mile long tornado path

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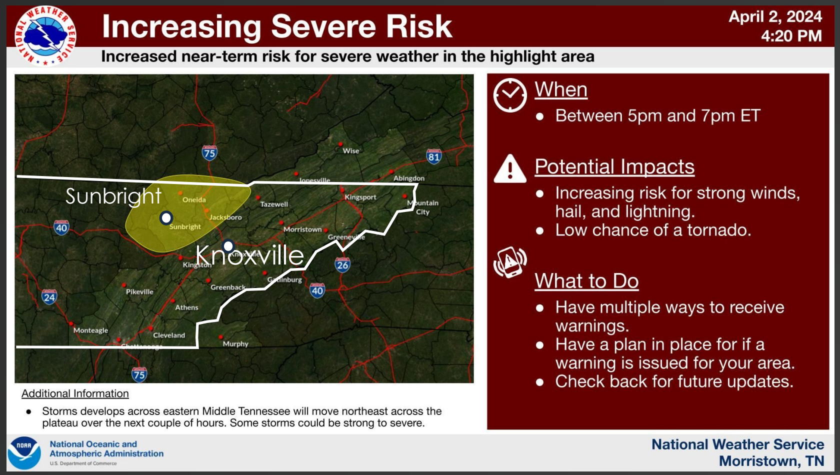
“Yesterday [NWS] WFO Springfield was able to amplify damaging wind messaging with greater specificity because of the data and trends of the WoFS model runs.”

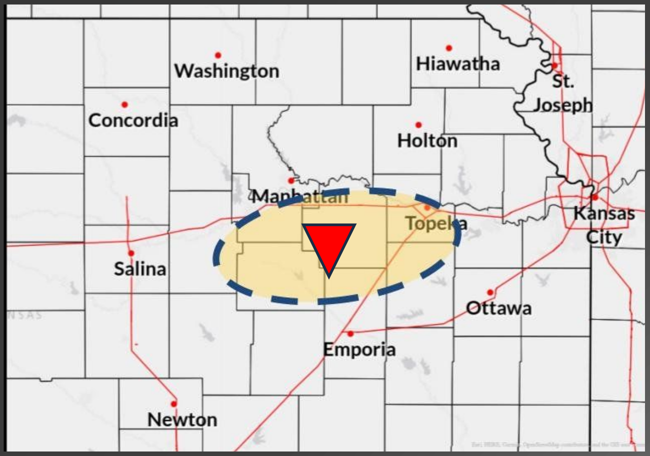
“…we received positive feedback from emergency managers on this additional…data that was available an hour before the tornado”
- NWS Morristown, TN

“We were using cb-WoFS to help anticipate which county the tornado would be [in]…”
-Storm Prediction Center

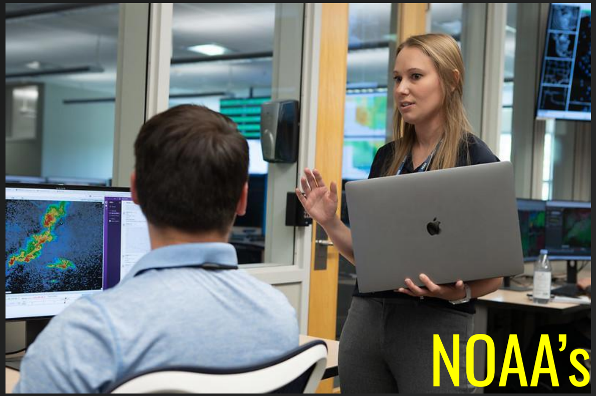
Sure enough, our first tornado (an EF-2…)…occurred almost directly in the center of that circle.”
-NWS Topeka

National Weather Service forecasts issued based on WoFS





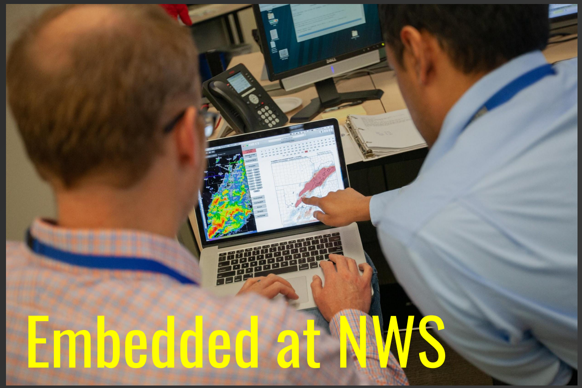
User Engagement



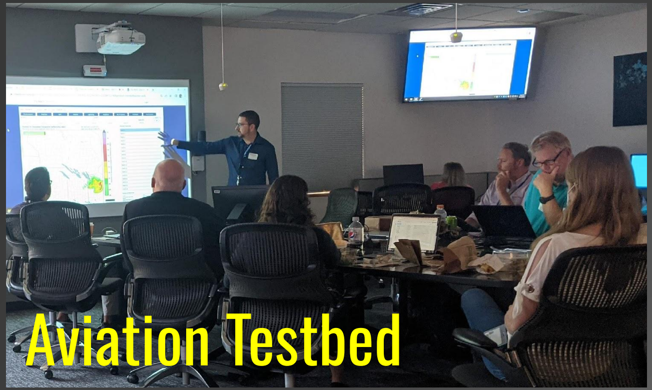
NOAA's Hazardous Weather Testbed

Broadcasters

Emergency Managers



Embedded at NWS



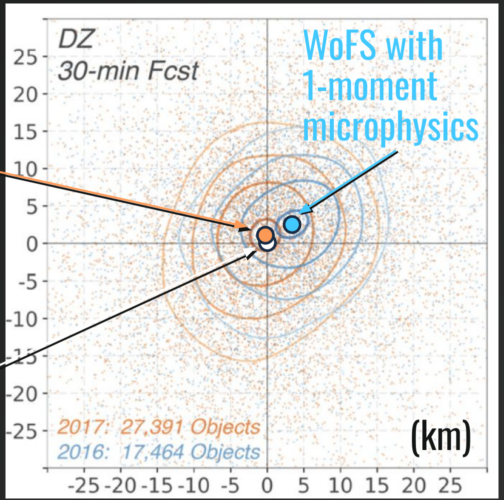
Aviation Testbed

WoFS as a Research Vehicle

- Microphysics
- Model Verification
- Dynamic Core

WoFS with NSSL 2-moment microphysics

Location of storms after 30-min



Storms more accurately projected using 2-moment microphysics

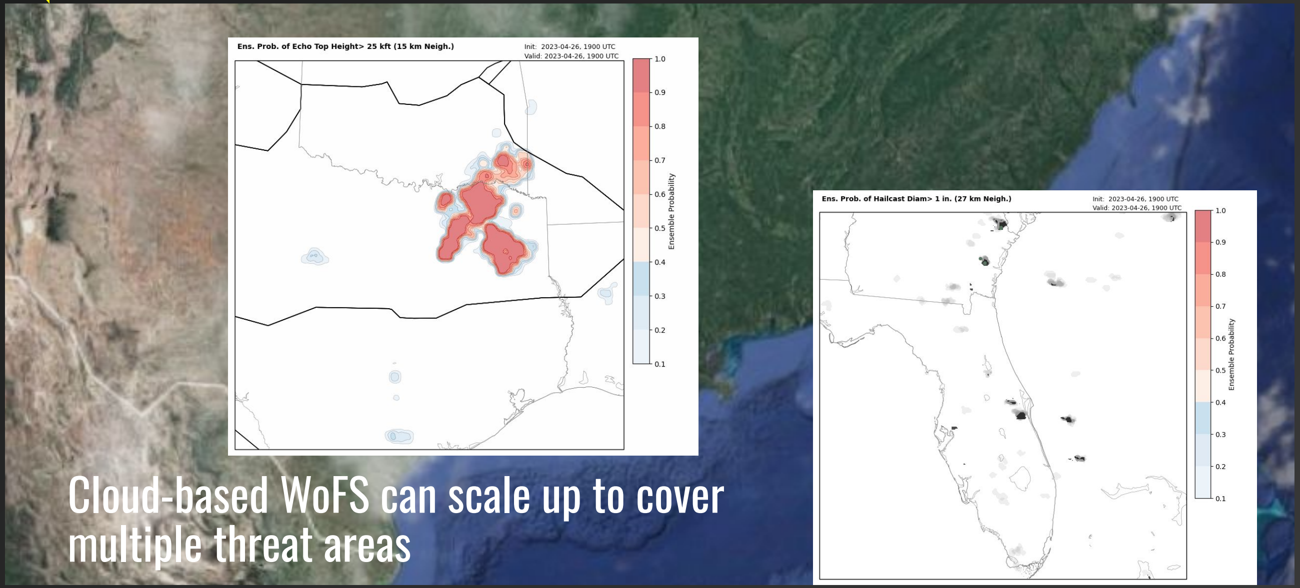
	60	120	180
Critical Success Index			
1-km Reflectivity			
99 percentile	▲	▲	
99.9 percentile	▲	▲	
1-hour Rainfall			
99 percentile	▲	▲	
99.9 percentile	▲	▲	
Frequency Bias			
Updraft Rotation			
99 percentile	▼	▼	
99.9 percentile	▼		

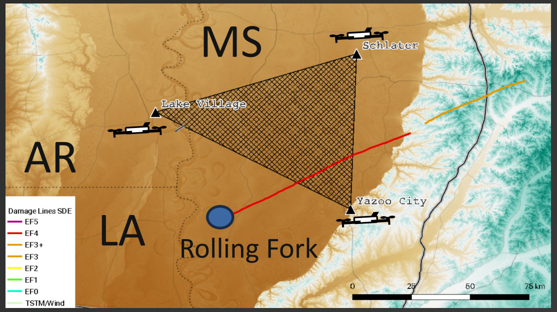
WoFS vs. HRRR time-lagged ensemble (2022) scorecard

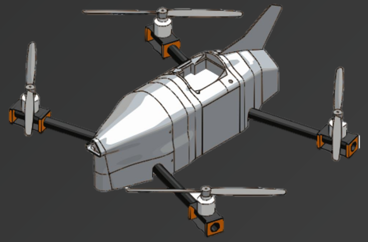
Developing the Model for Prediction Across Scales (MPAS) as the next generation “engine” for WoFS

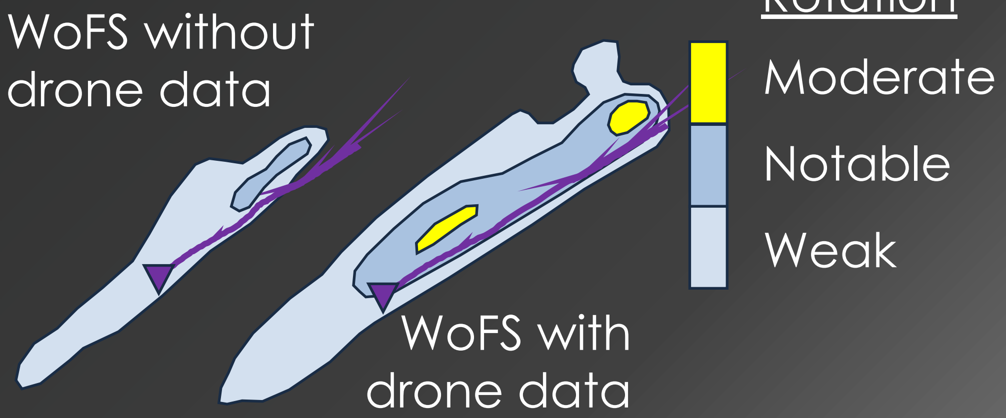
WoFS as a Research Vehicle

- Cloud computing
- Data assimilation
- AI & machine learning





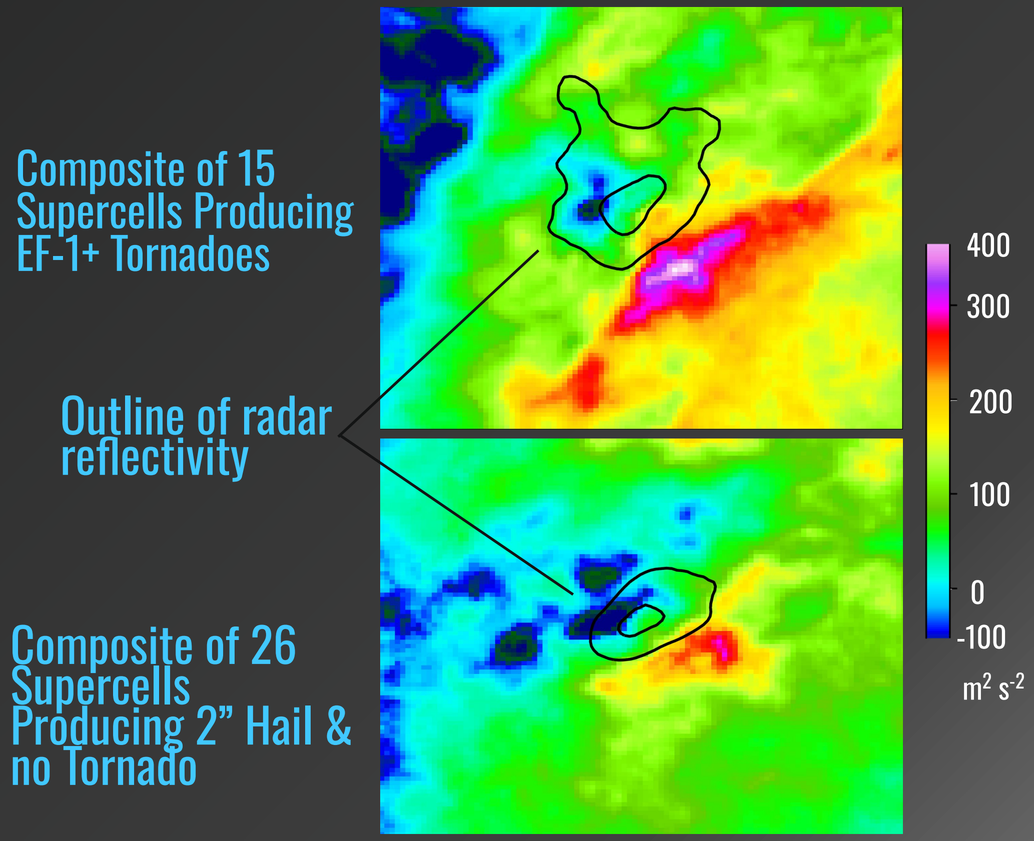




Near-storm Environment

At 1-hour lead time:

- Storms that ended up being tornadic are larger and curved in WoFS
- Broader fetch and greater measure of rotation potential on the inflow side of tornadic supercells in WoFS



Storm-relative Helicity (0–500 m)

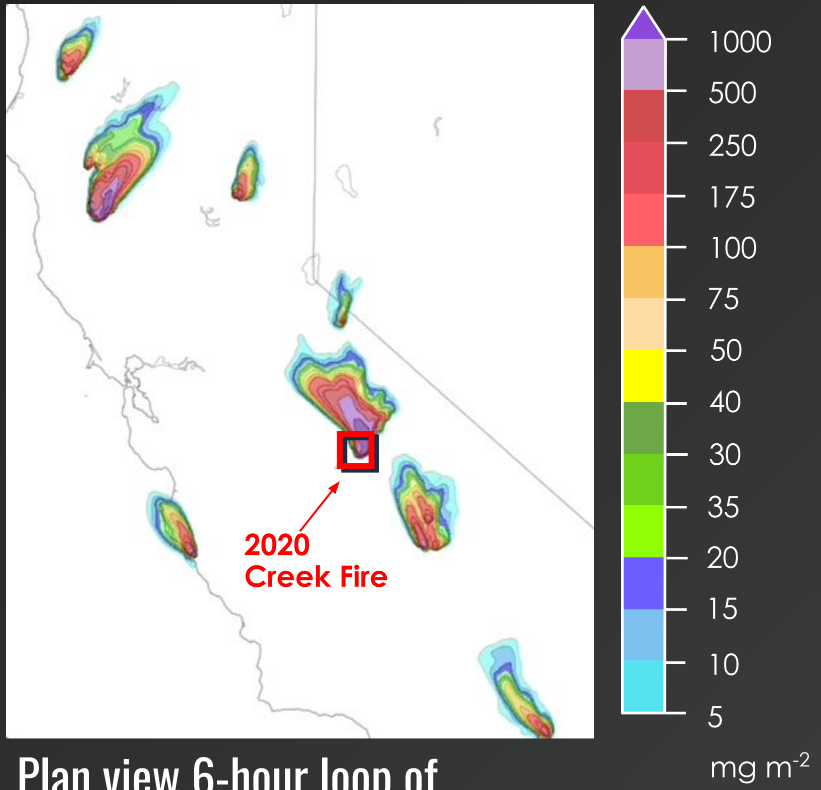
Work by Jerod Kaufman, U. of Kansas

Fire Weather Testbed (2023) report notes:

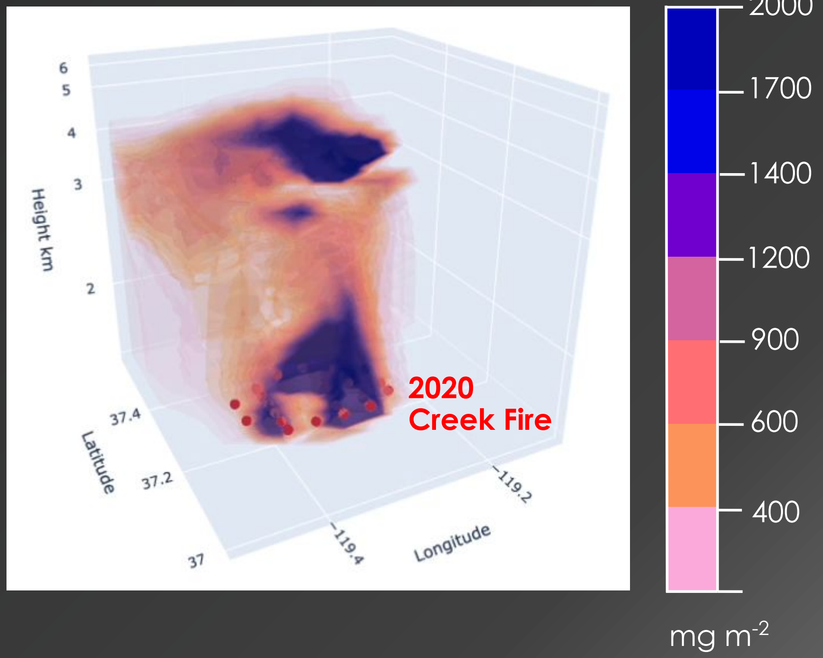
Fire Modeling

"Rapid update...allows for 'on-demand' provision of decision support for potential smoke impacts..."

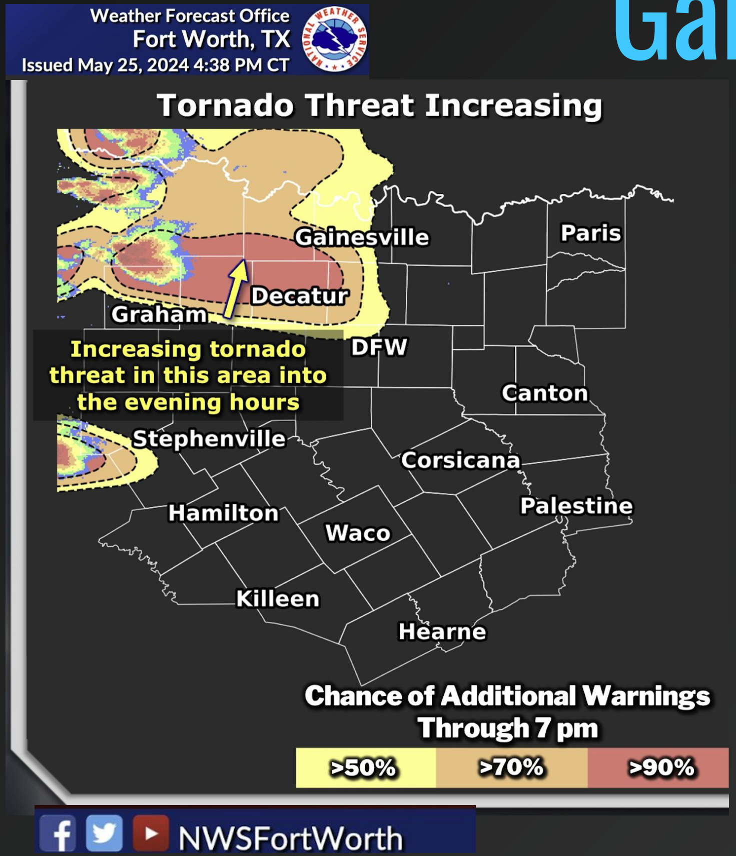
Already seeing operational use to predict fire-effective environmental features in Southern Great Plains Wildfire Outbreaks (Lindley et al. 2023)



Plan view 6-hour loop of vertically integrated smoke



3D view 6-hour loop of smoke density over the fire site



Game-Changing Innovations

- Targeted probabilistic forecasts of individual severe storms
- Rapid data assimilation
- Low latency and custom visuals for fast-paced operations
- Integrated study of guidance usage on watch-to-warning timeline at national & local level NWS offices
- Connection to end users of forecast information

Many NWS offices are beginning to project probabilistic swaths ahead of existing storms for 1 to 2 hours, based on WoFS

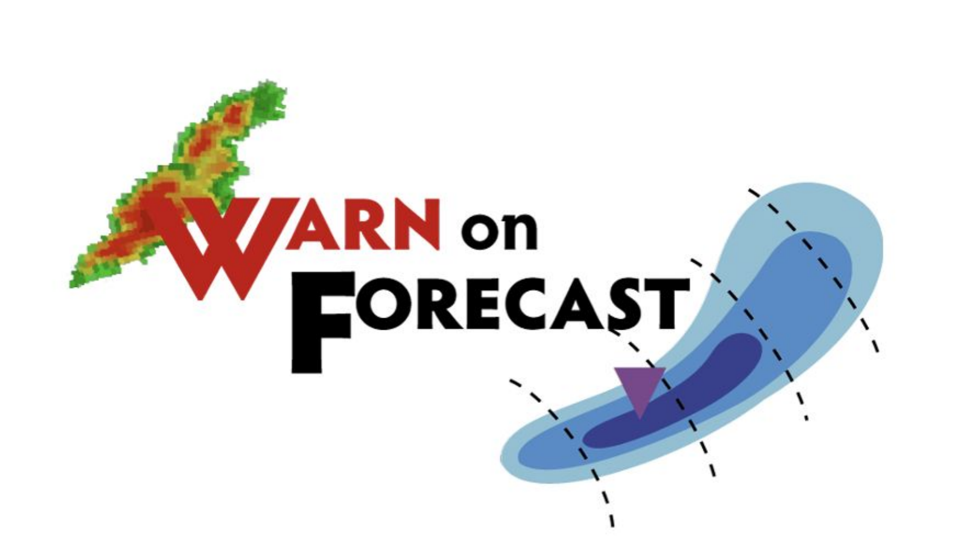
Future

5 years

- Cloud-based 3-km WoFS transitions to NWS operations
  - Using MPAS dynamic core and other NOAA Unified Forecast System parts

10 years

- 1-km WoFS matures, informed by NSSL process studies, with output geared toward user needs via social science



My dream: One hour lead time for individual tornadoes and several hour lead time for the largest flash floods becomes commonplace.

DOC / NOAA / OAR

National Severe Storms Laboratory

Social and Behavioral Science (SBS) at NSSL

Makenzie Krocak
Social Science Team Lead

SBS team overview

Part of NSSL's mission is to help ensure "*forecasters have the knowledge, capabilities, and technologies to remain world leaders in effectively communicating accurate, timely, and actionable forecasts and warnings of extreme weather to the public and commerce.*"

- Social and behavioral science must be incorporated throughout the research and development process
  - When there is still time and opportunity to iterate on tool/product development
  - When user input can drive research questions and outcomes
  - NSSL has established an SBS research group that is fully embedded in lab activities
- Data from users is collected/analyzed from multiple venues
  - Interviews, focus groups, surveys, testbed experiments, etc.
  - Forecasters, emergency managers, broadcast meteorologists, members of the public

Survey analysis

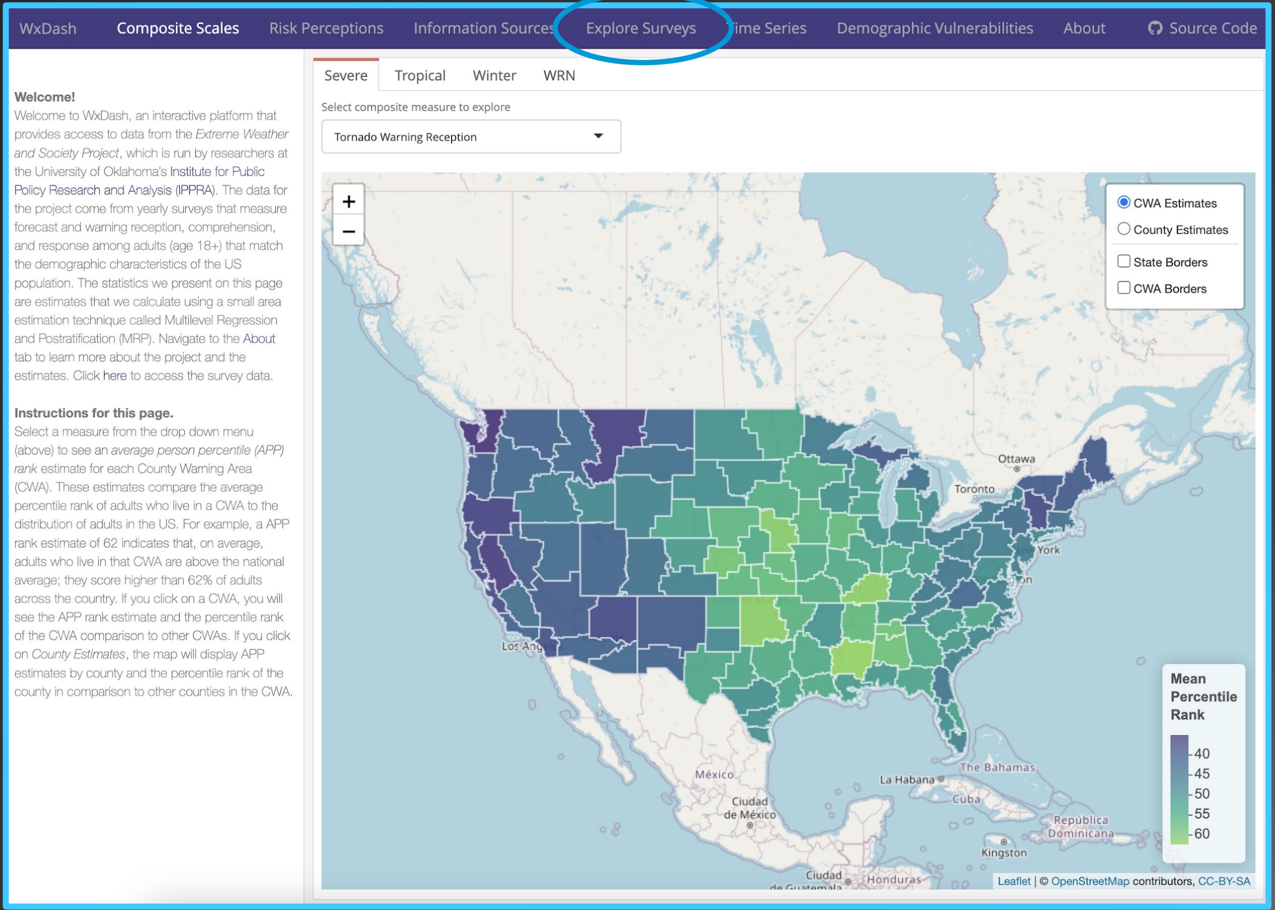
Longitudinal and post-event

Extreme weather and society survey:

- Annual survey that measures forecast and warning reception, comprehension, trust, and response across the country
- Collects vital longitudinal data so we can track measures over time

- Severe Weather (2017)
- Tropical Weather (2020)
- Winter Weather (2021)

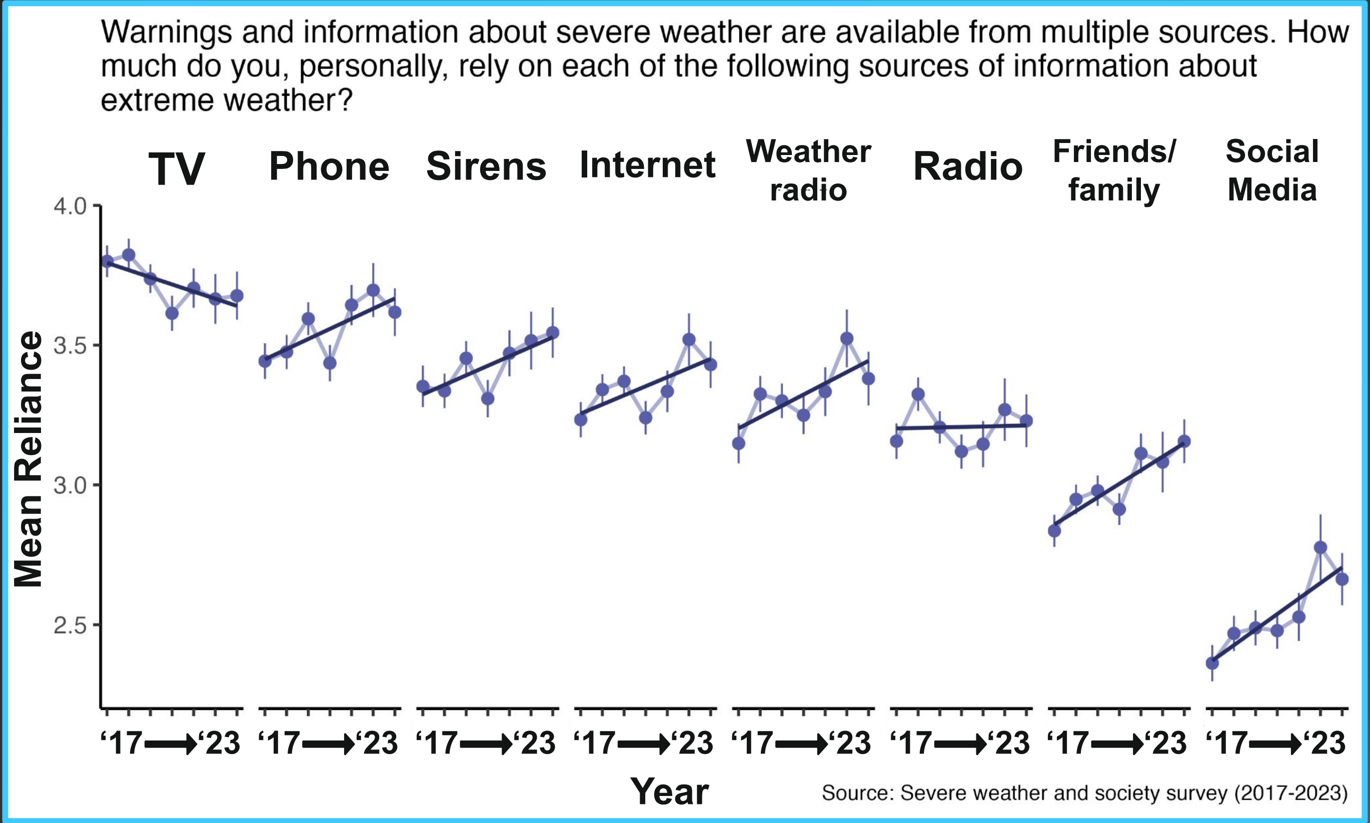
- 1000-3000 respondents every year, for each hazard
- Online survey, representative of the US population



https://crcm.shinyapps.io/WxDash/

What are we learning?

- Weather information sources are diversifying

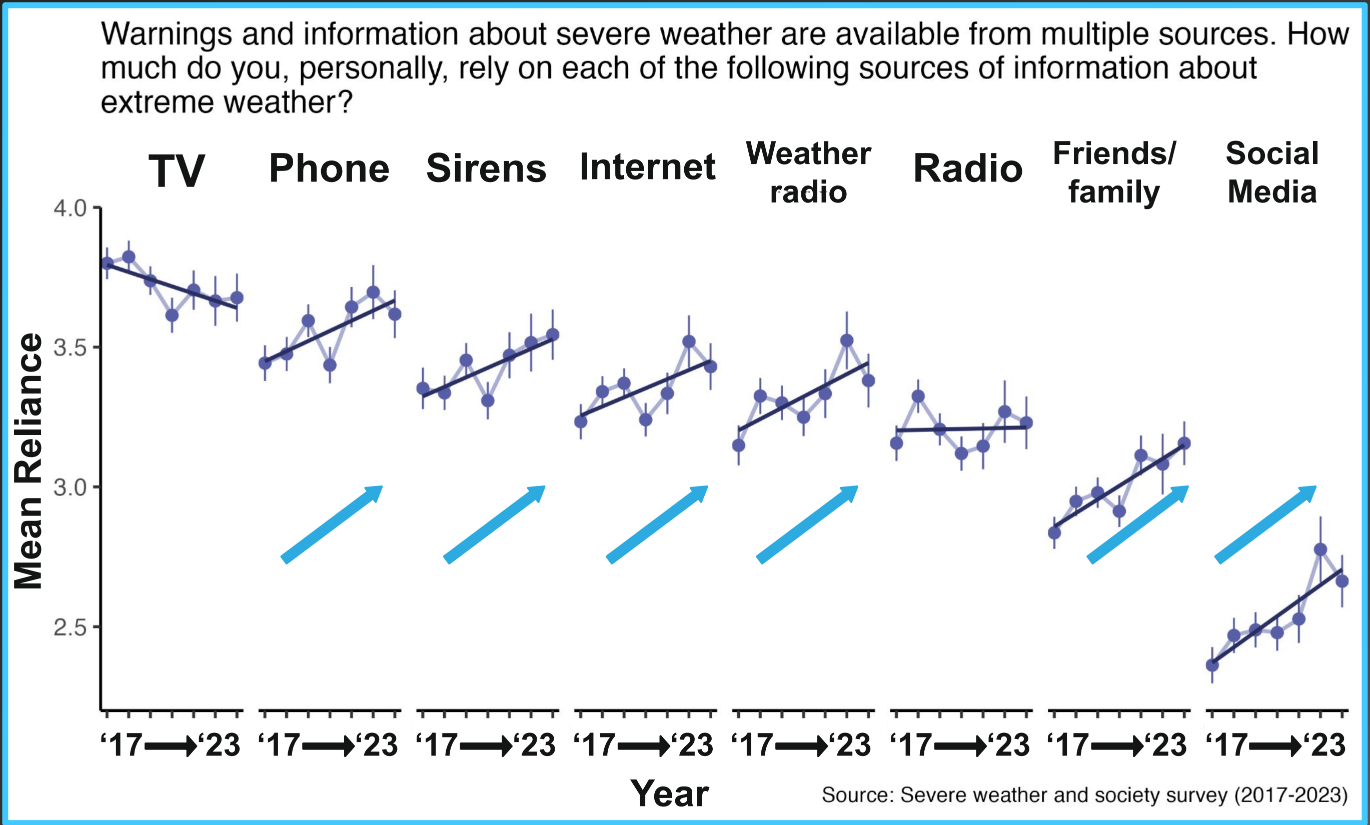


Krocak et al. 2024: The changing weather information landscape: observations, conjectures, and thoughts about the future. Bulletin of the American Meteorological Society, *in press*, https://doi.org/10.1175/BAMS-D-24-0041.1

What are we learning?

- Weather information sources are diversifying
  - 6 of the 8 sources show increasing reliance from 2017-2023

- We need to ensure information is available in quick, easy to understand formats
  - Phones, internet, social media



Krocak et al. 2024: The changing weather information landscape: observations, conjectures, and thoughts about the future. Bulletin of the American Meteorological Society, *in press*, https://doi.org/10.1175/BAMS-D-24-0041.1

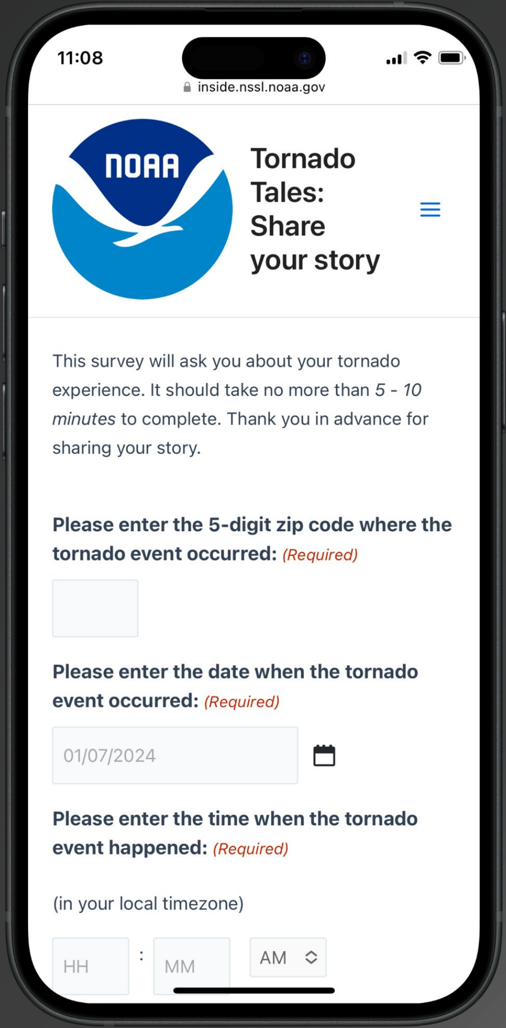
Tornado Tales Post-event Survey

- Data collection tool for people to report actual experiences with tornadoes

- Most tornadoes are not studied
  - Those that are are mostly evaluated from a physical/meteorological perspective
  - We need to understand how people interact with forecast information
  - To ensure it's useful and actionable

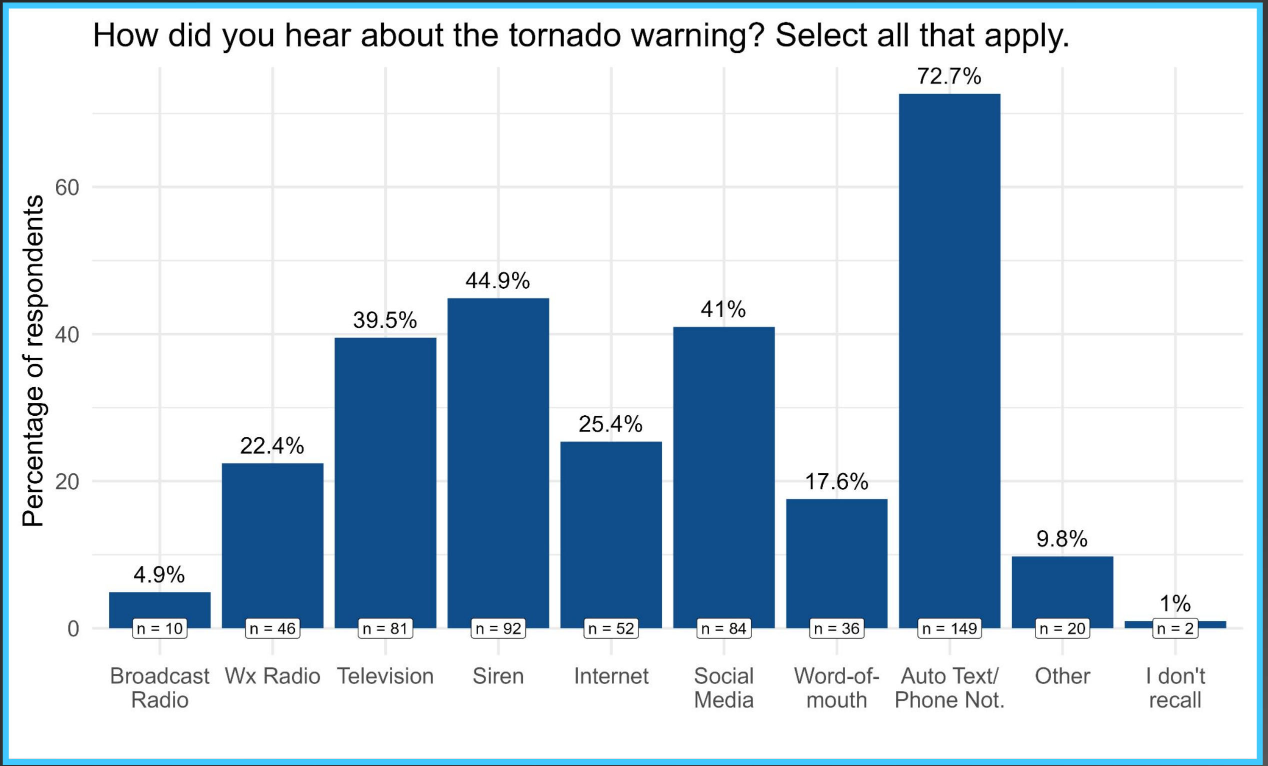
- Social and behavioral science insights will help us understand:
  - How people get information
  - If/how they understand the information
  - If/how they trust and respond to it
  - How these dimensions may vary across different communities and groups of people

https://inside.nssl.noaa.gov/tornado-tales/survey/



What are we learning?

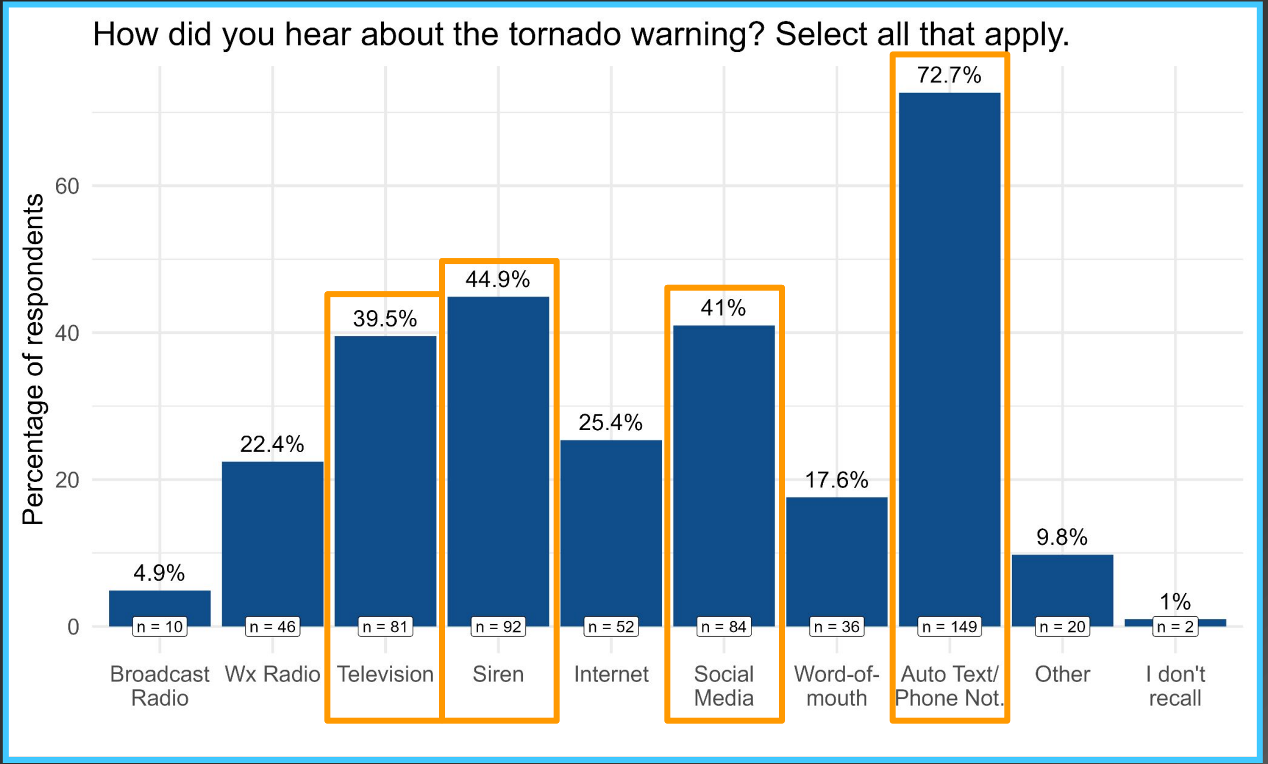
- Pilot data:
    - Mainly from 3 events in 2022/2023
    - About 240 respondents
- Most people were at home during the tornado
    - Most in single-family homes
- Most people received a warning (89%)
    - From phones, sirens, social media, and television



https://www.nssl.noaa.gov/research/social/docs/Tornado%20Tales%20Version%201%20Reference%20Report.pdf

What are we learning?

- Pilot data:
    - Mainly from 3 events in 2022/2023
    - About 240 respondents
- Most people were at home during the tornado
    - Most in single-family homes
- Most people received a warning (89%)
    - From phones, sirens, social media, and television



https://www.nssl.noaa.gov/research/social/docs/Tornado%20Tales%20Version%201%20Reference%20Report.pdf

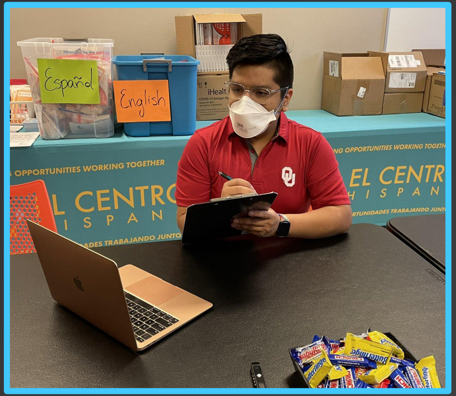
Post-event Interviews

The 24 March 2023 tornado event

- 3 tornadoes struck Rolling Fork/Silver City, Black Hawk/Winona, and Wren/Amory, MS
- 22 deaths and 225 injuries
- Extensive physical science data collection as part of the PERiLS field project

Interviews:

- 11 NWS forecasters
- 13 emergency managers
- 8 broadcast meteorologists
- 26 members of the public



Preliminary Results

- NWS forecasters and broadcast meteorologists knew there was a risk for strong tornadoes
  - They communicated that well in advance of the event
- The storm intensified quickly as it approached Rolling Fork
  - Many residents reported not making it to their preferred shelter location
- There is a huge disparity in resources between neighboring communities
  - NWSChat helped neighboring emergency services respond immediately

Wrapping up

- We need to understand how our forecast information is being used to make decisions
    - Tailor information to help people make actionable, life-saving decisions more efficiently
- If we change the system, how do we know that it was a good change?
    - Longitudinal survey data can help us measure this
- We facilitate the co-creation of tools and strategies with researchers, forecasters, and users
- Partnership with MS/AL Sea Grant helps us return research findings to local communities

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Our Team

Makenzie Krocak
Social Science Team Lead
SBS methods, meteorology

Kodi Berry
FACETs Team Lead
Broadcast met, meteorology

Randy Peppler
CIWRO Associate Director
Geography, risk perceptions

David Hogg
Research Associate
Emergency Management

Taylor Maciag
Research Associate
Geography, SBS methods

Justin Sharpe
Research Scientist
Geography, disaster research

Holly Obermeier
Research Associate
Broadcast met, meteorology

Sean Ernst
Postdoctoral Researcher
SBS methods, meteorology

Partners in Science:
CIWRO Advancing the NOAA and NSSL Mission

Dr. Sebastian Torres

Thea Sandmael

Dr. Montgomery Flora

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National Severe Storms Laboratory

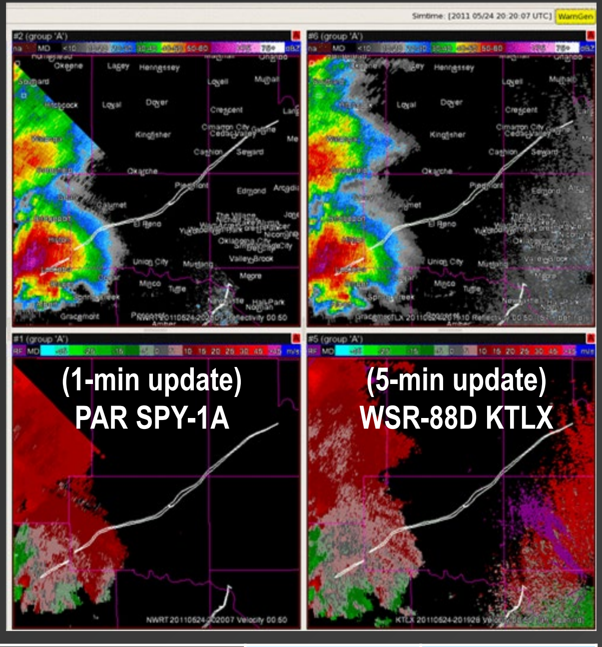
PAR Adaptive Scanning

The radar you need, where and when you need it

Dr. Sebastián Torres
Sr. Research Scientist (CIWRO)

PAR Rapid Updates

- PAR scanning flexibility enables rapid updates
  - Radar beam direction and shape may be changed instantaneously (no mechanical inertia)
  - Advanced techniques not available with conventional radars can dramatically reduce scan times
- Rapid updates lead to more useful weather observations
  - Improved understanding of storm evolution processes
  - Improved performance of NWP models
  - Potential to increase NWS tornado and severe warning lead times (PARISE 2015)

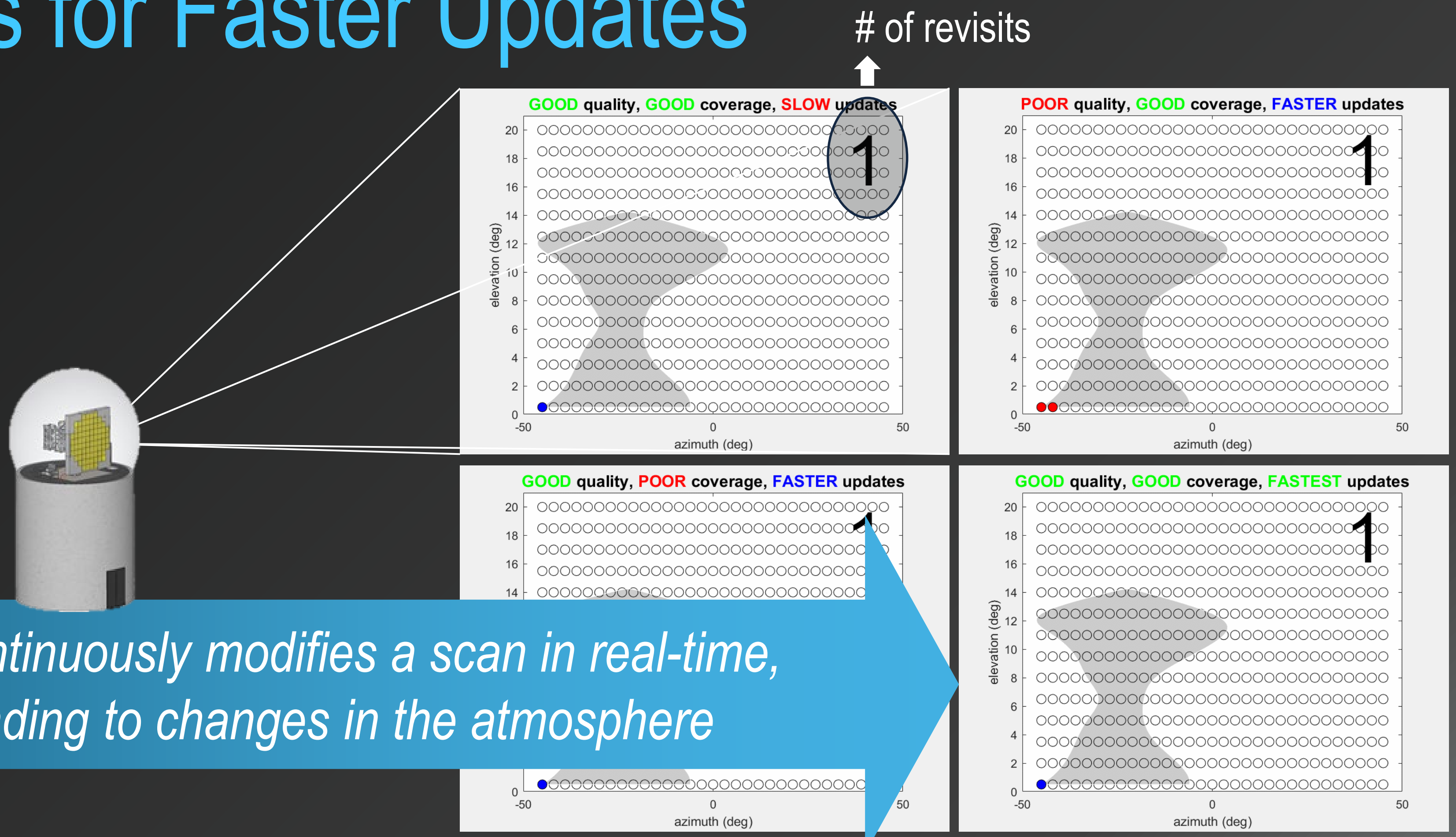


Tornado Warning Metric	1-min Updates	5-min Updates
Lead Time (min)	12.7	9.0
Prob of Detection	0.78	0.62
False Alarm Rate	0.29	0.44

Wilson et al. (2017, WAF)

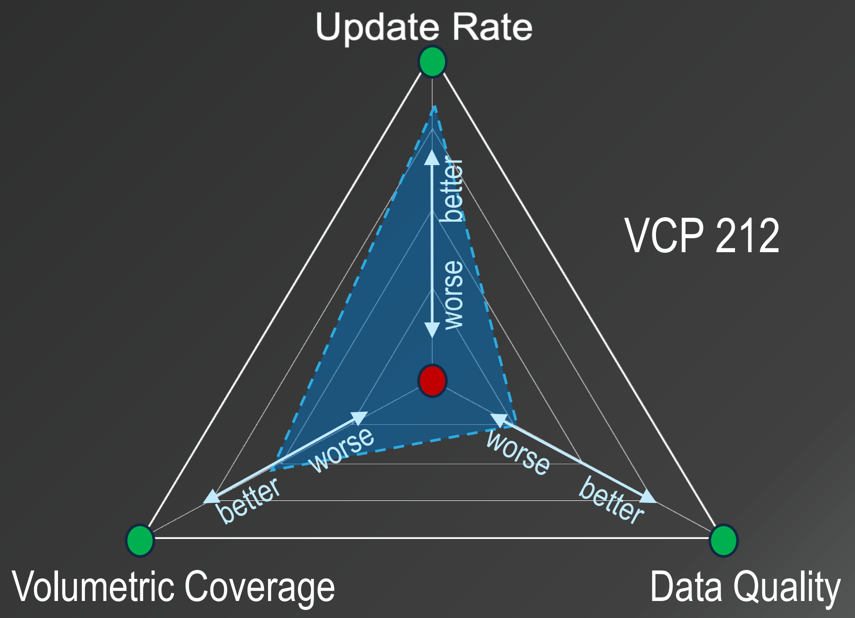
Scan Strategies for Faster Updates

- Reducing Scan Time
  - Shorter dwell times
  - Less coverage
  - Adaptive scanning



***Adaptive scanning** continuously modifies a scan in real-time, automatically responding to changes in the atmosphere*

Adaptive Scanning

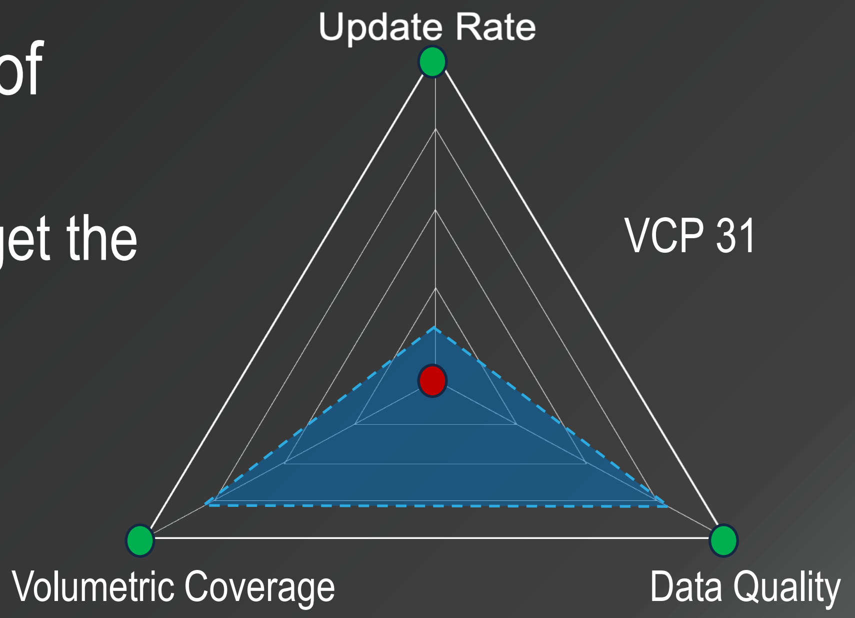


Triangle of radar scanning tradeoffs

Adaptive Scanning

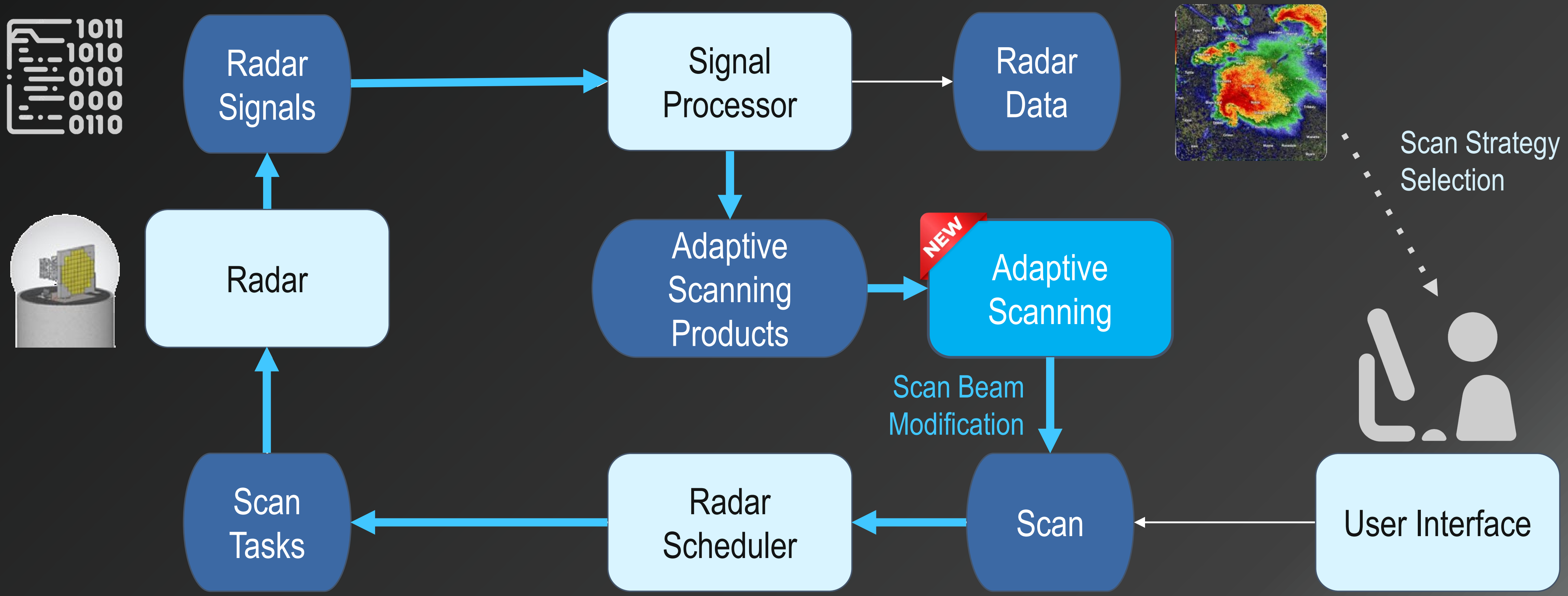
The radar you need, when and where you need it

- PAR's beam agility key to unlocking full potential of adaptive scanning
  - Scans focused on regions of interest and tailored to get the best observations by optimizing tradeoffs
- Adaptive scanning R&D
  - Determine what's best, where, and when
  - Simulations, then demonstrations
  - Use of models, AI, and other observing systems



Triangle of radar scanning tradeoffs

ATD Upgrades for Adaptive Scanning



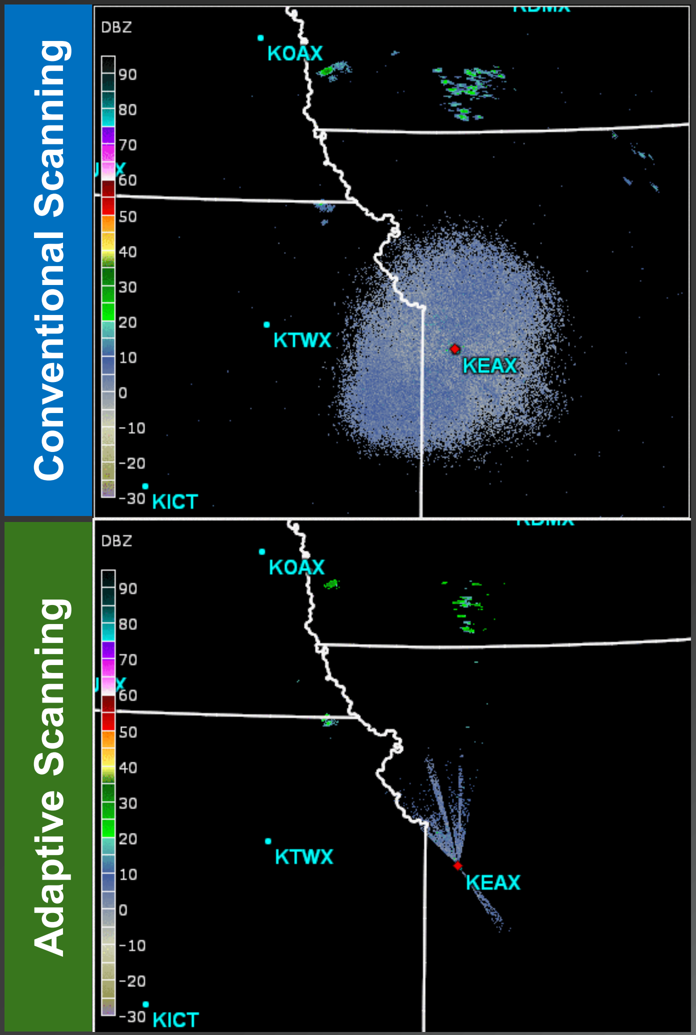
The sky's the limit!

- PAR’s beam agility is key to unlock the full potential of adaptive scanning
    - The radar you need, where and when you need it!

ed to revolutionary

otential to meet

For this simulated case, update times with adaptive scanning are ***~5x faster*** than with conventional scanning



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An Overview of the Machine Learning-Based Tornado Probability Algorithm TORP

HWT collaboration/support:
Brandon Smith, Adrian Campbell, Justin Monroe, Claire Satrio, Jacob Segall, Kristin Calhoun, Tony Lyza, Kodi Berry

Expanded use collaborations:
Charles Kuster, Ryan Martz, Eric Loken

Developer:
Thea Sandmael

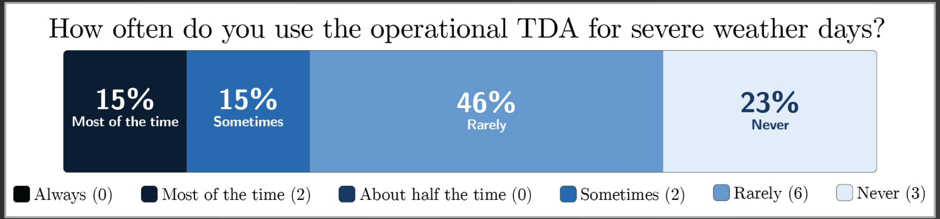
Front-end developers:
Rebecca Steeves, Jonathan Madden

Data preparation (students):
Zachary Fruits, Isaiah Schick, Marcus Ake, Zachary Cooper, Jacob Widanski, Quentin Thomas, Roy Galang, Rosa Mwakyoma, Ben Kassel, Alexa Dringus, Danielle Crutchfield

Tornado Probability Algorithm (TORP)

(Sandmæl et al. 2023)

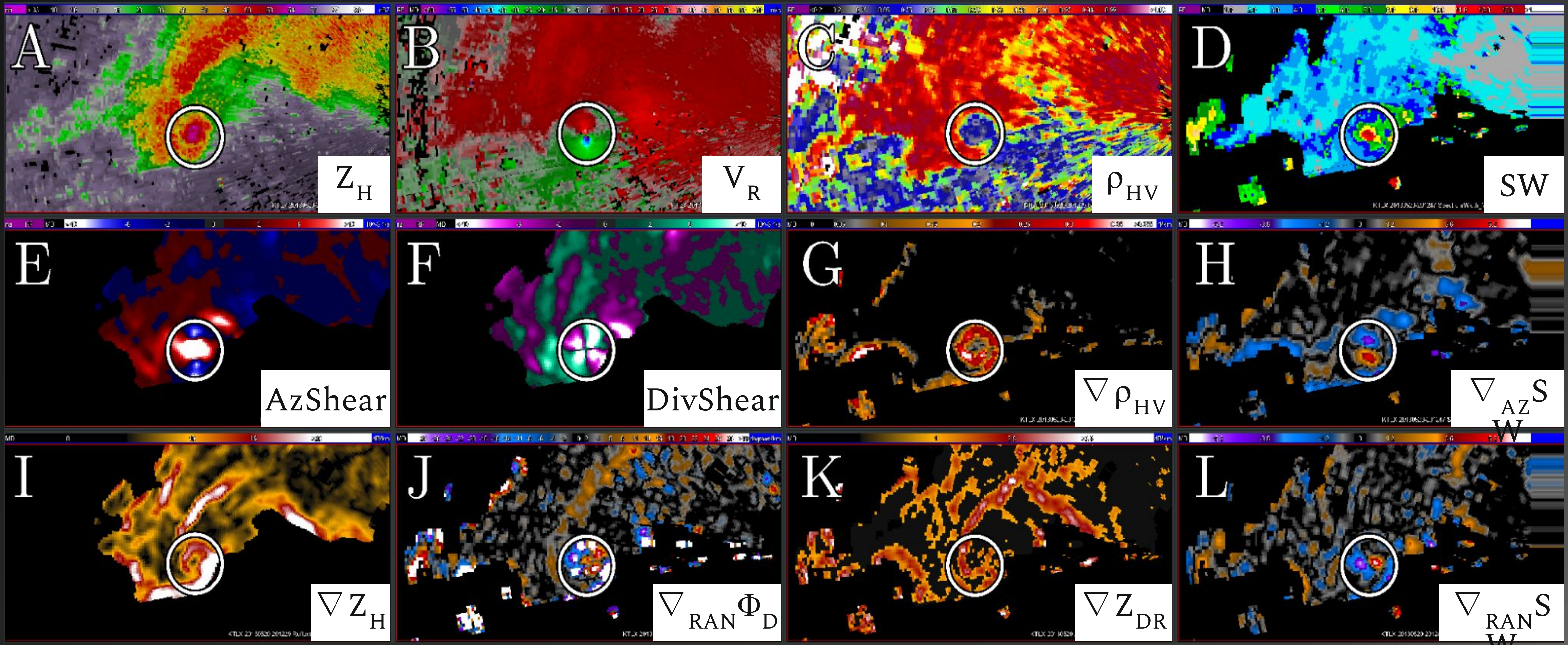
- Replacement for NEXRAD Level 3 Tornado Detection Algorithm (Mitchell et al. 1998)
  - No dual-pol information, binary
- Reads in radar data
  - Single-radar data (default 0.5°)
- Creates objects based on AzShear (Mahalik et al. 2019)
- Extracts radar data to calculate probability using a machine learning random forest model
- Tracks objects
- Outputs a text file



TORP overlaid on low-level MRMS AzShear and Reflectivity fields

Radar Predictors

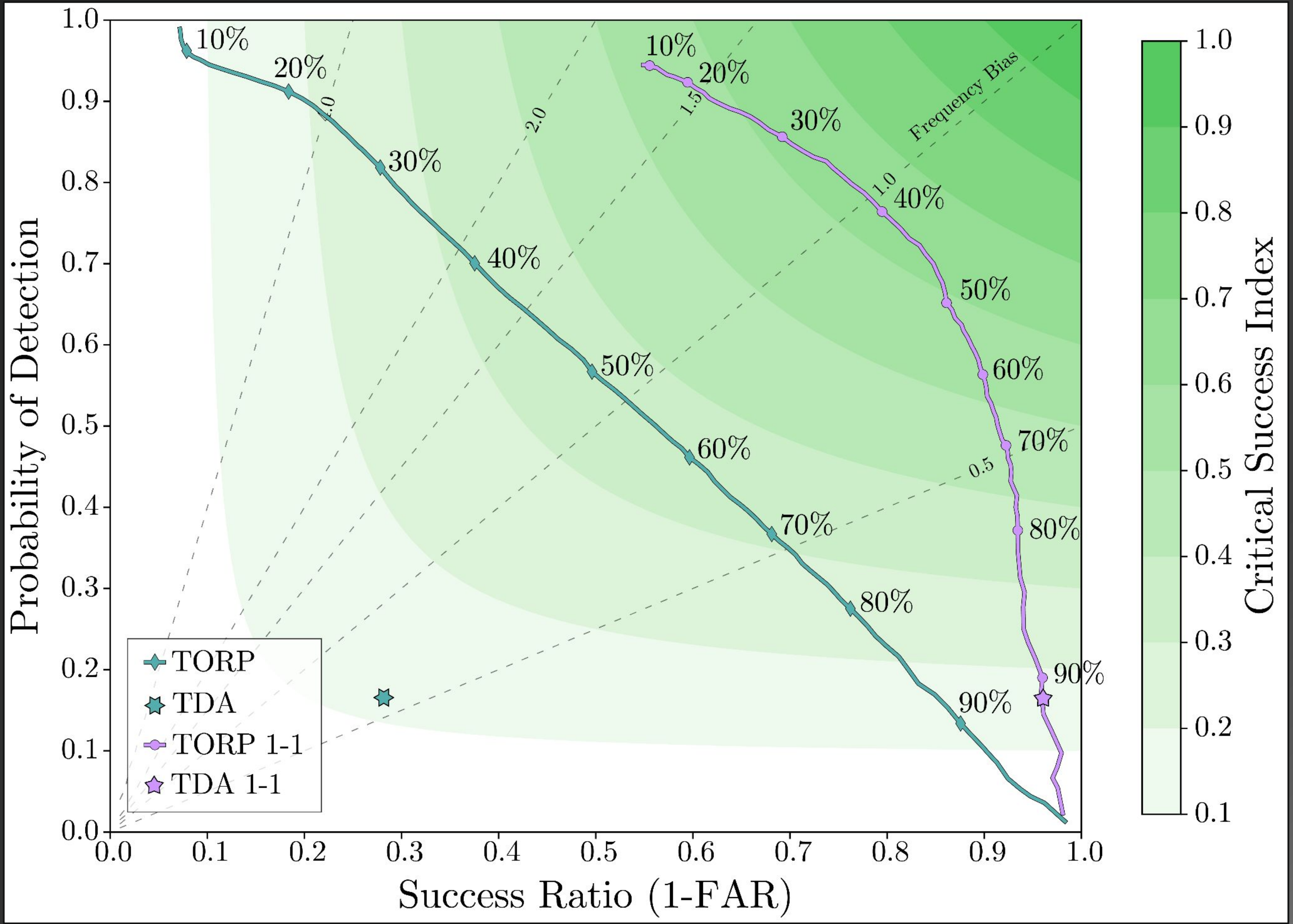
+12 other products



2013 May 20 20:12 UTC - Radar representation of the supercell actively producing an EF5 tornado

Detection Performance Evaluation

- NCEI tornado reports
- Trained on 0.5°-tilt radar data from 2011-2016
  - 166,145 data points, 10.4% tornadic
- Tested on data from 2017-2018
  - 257,097 data points, 6.9% tornadic



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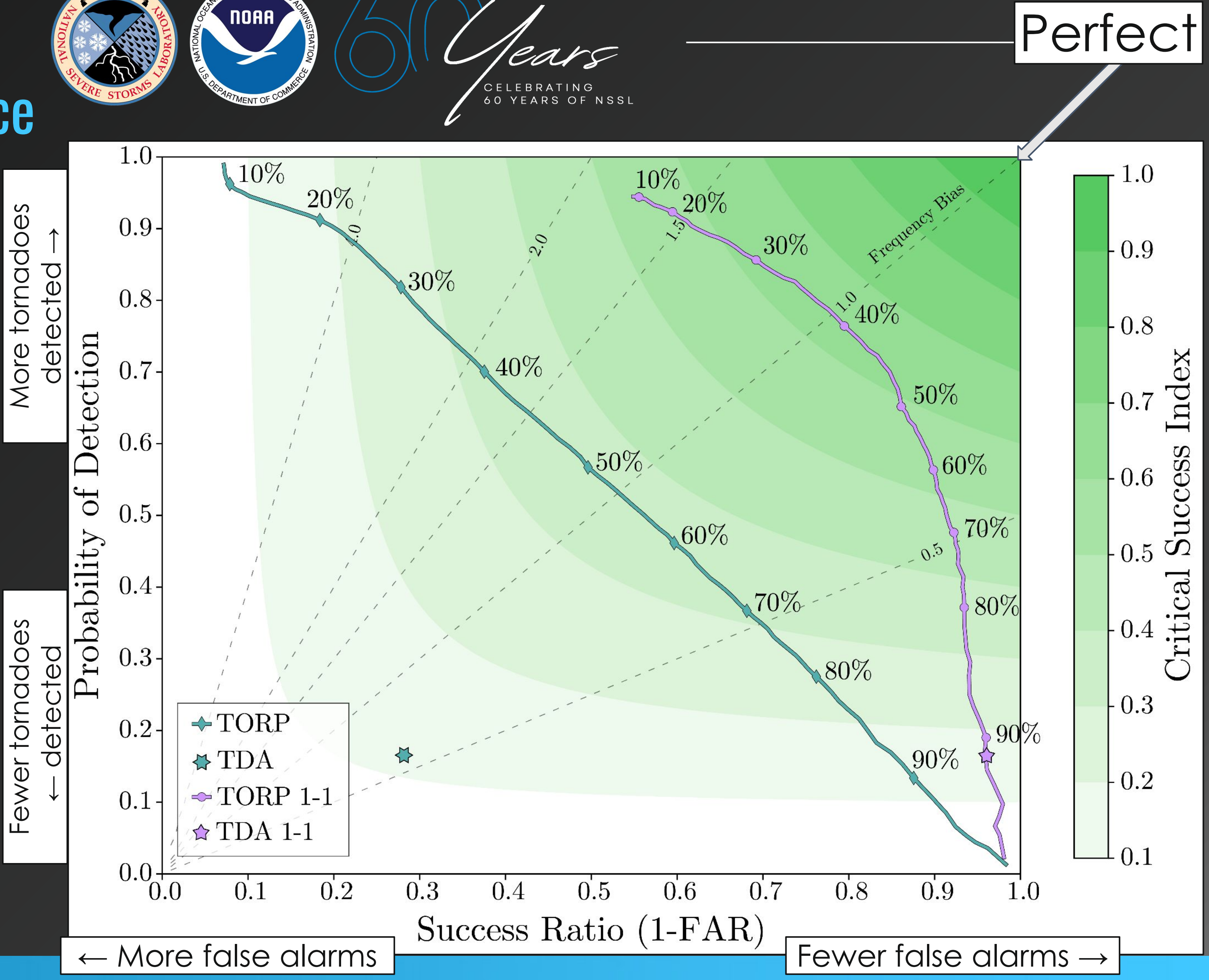

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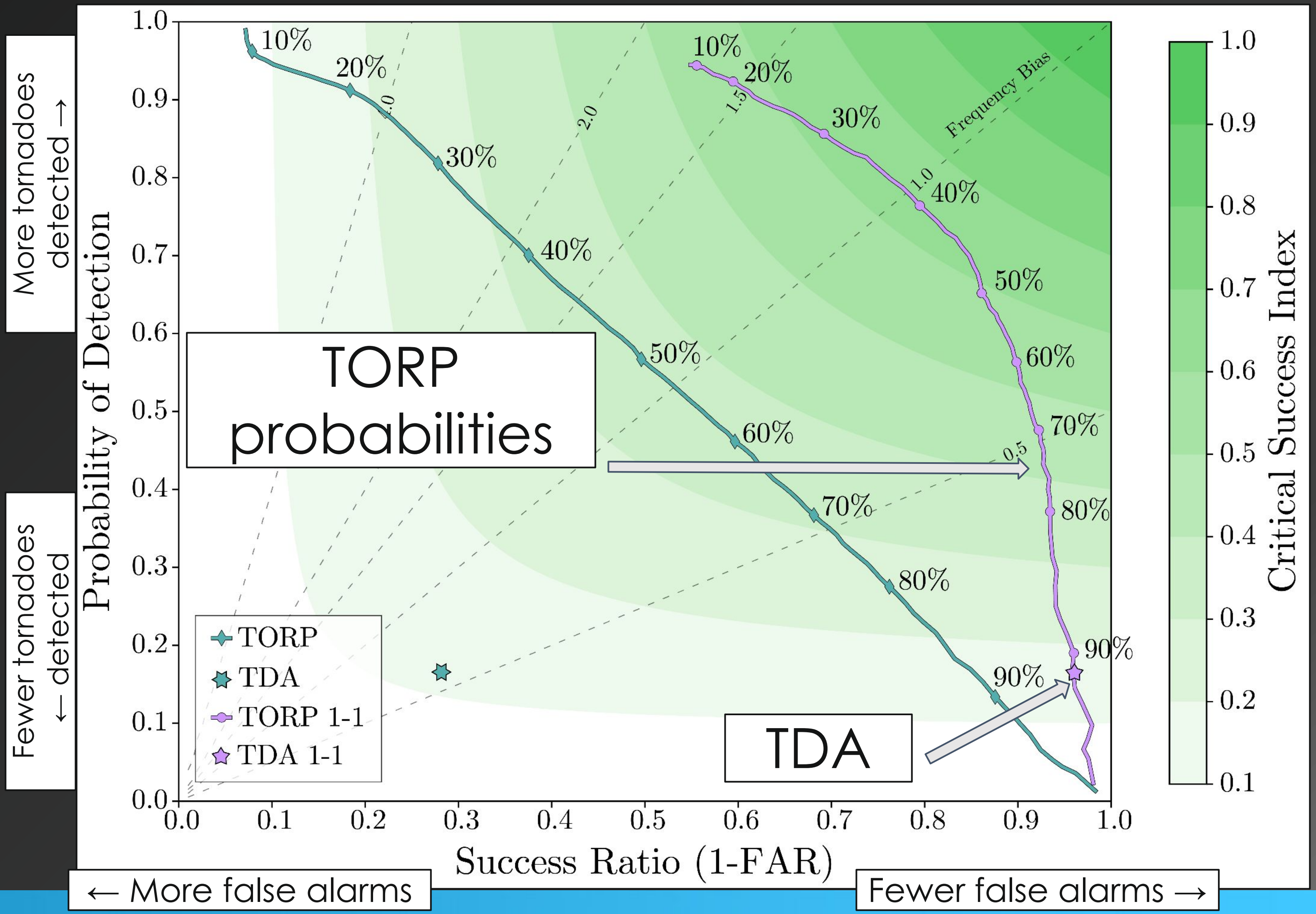

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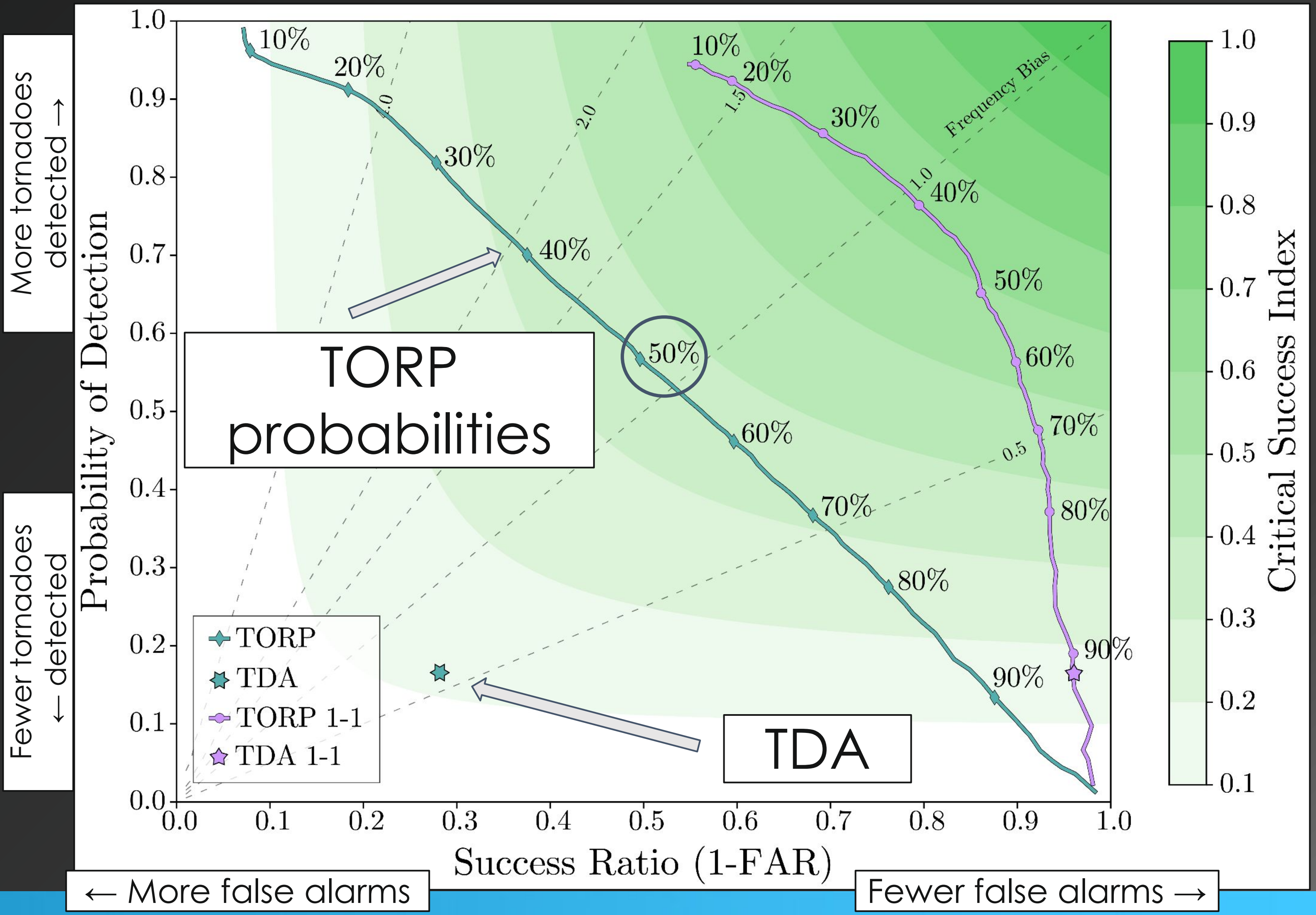
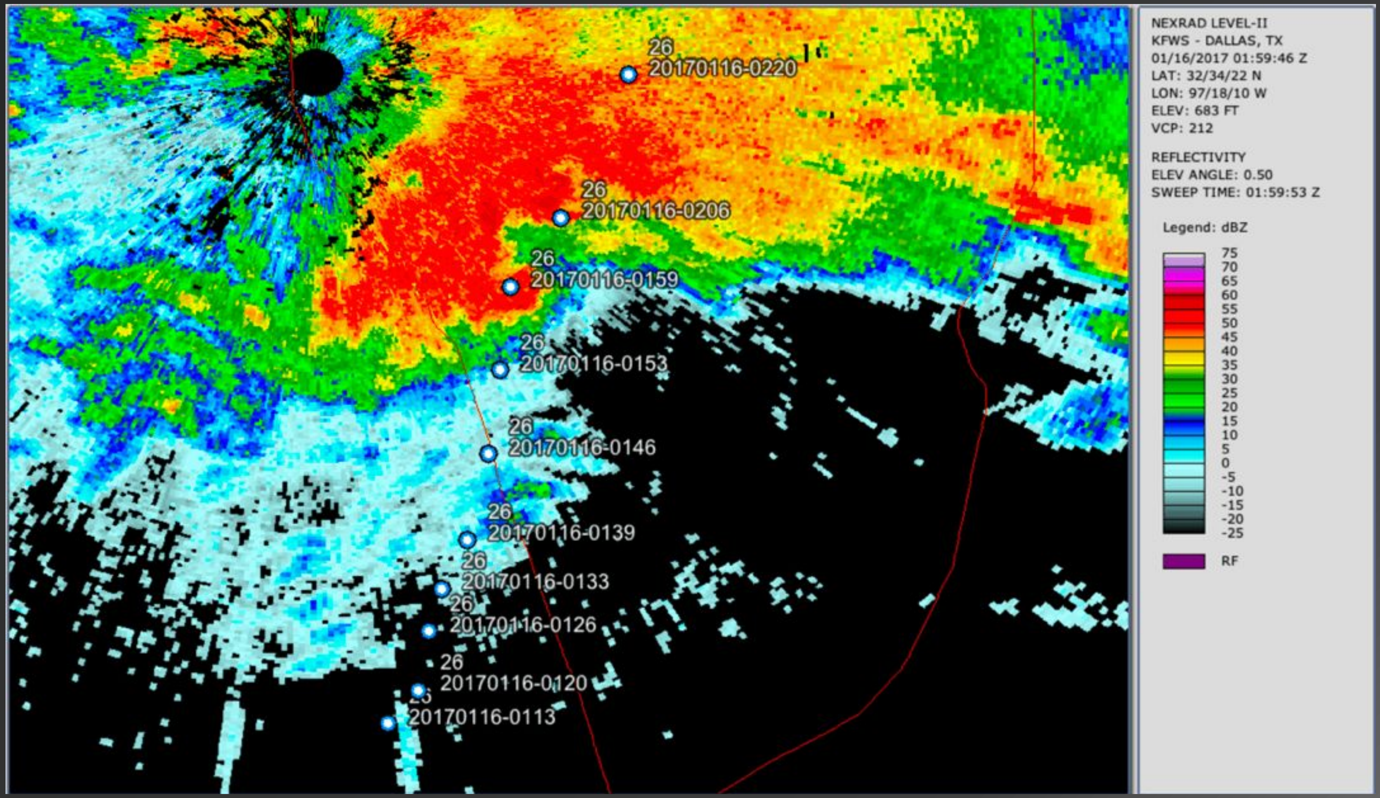


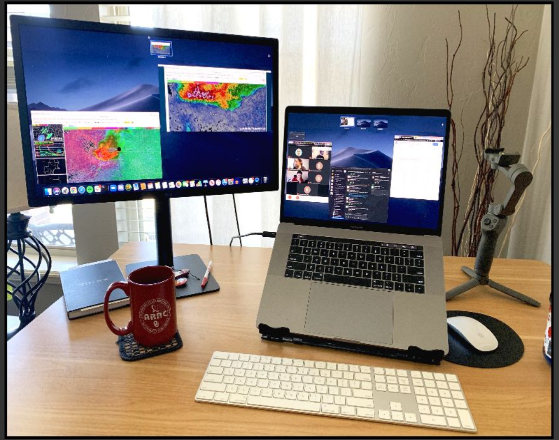
Pre-Tornadic Models

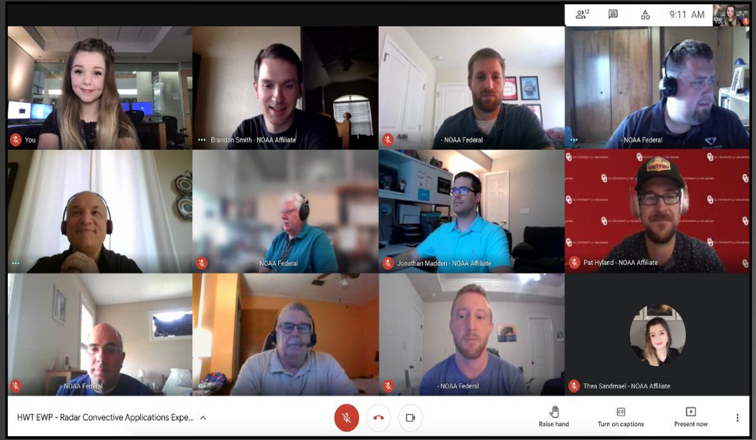
- Trained models for every 5 minutes up to 30 minutes
- 60,000+ data points from tracking thousands of tornadic storms
- Similar performance to detection model



Hazardous Weather Testbed (HWT)

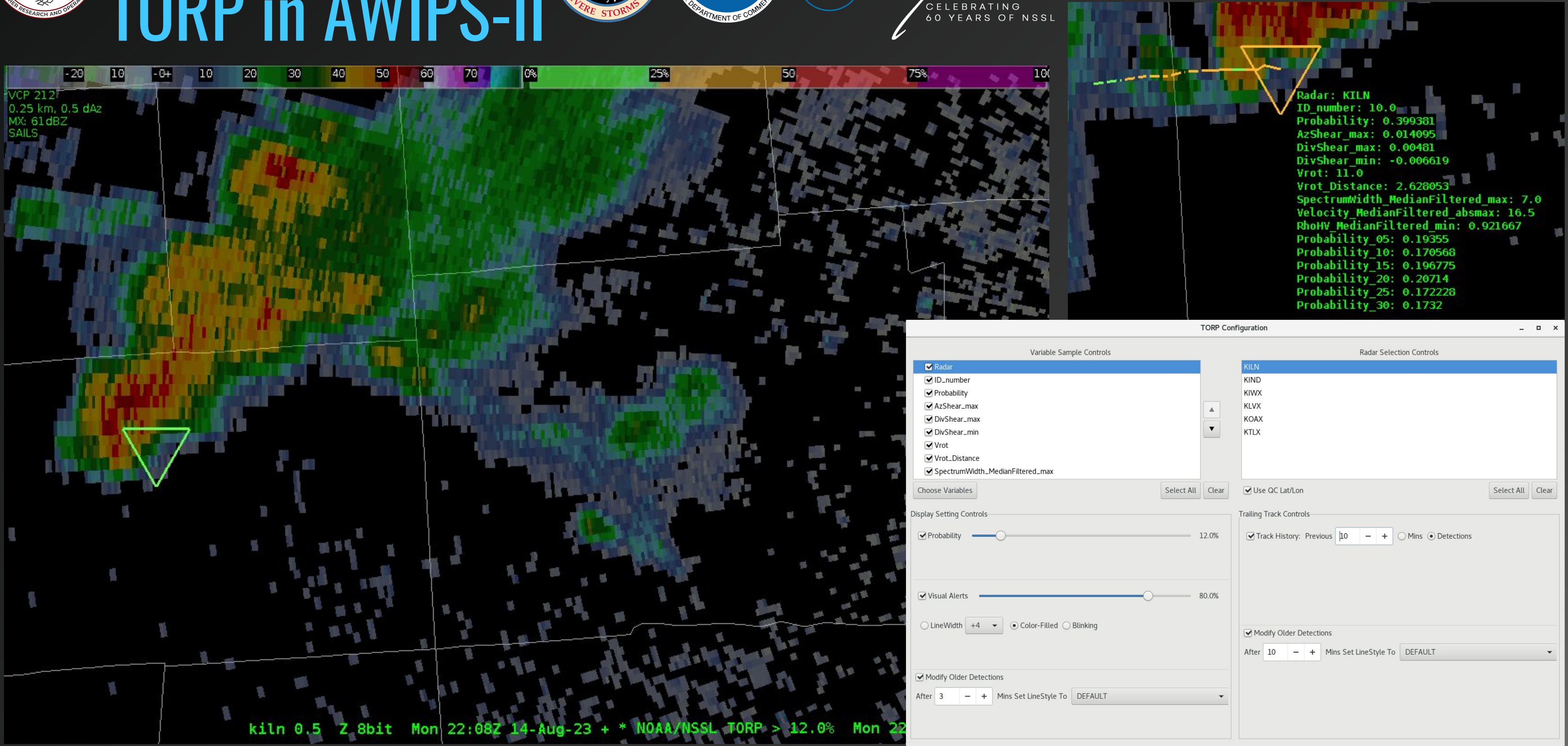
- 2021-2024 Experimental Warning Program
  - Radar Convective Applications
  - Probabilistic Hazards Information (PHI)
  - Watch-to-Warning
- Real-time or displaced real-time severe weather cases
- Tested by over 70 NWS, SPC, and DoD Air Force forecasters



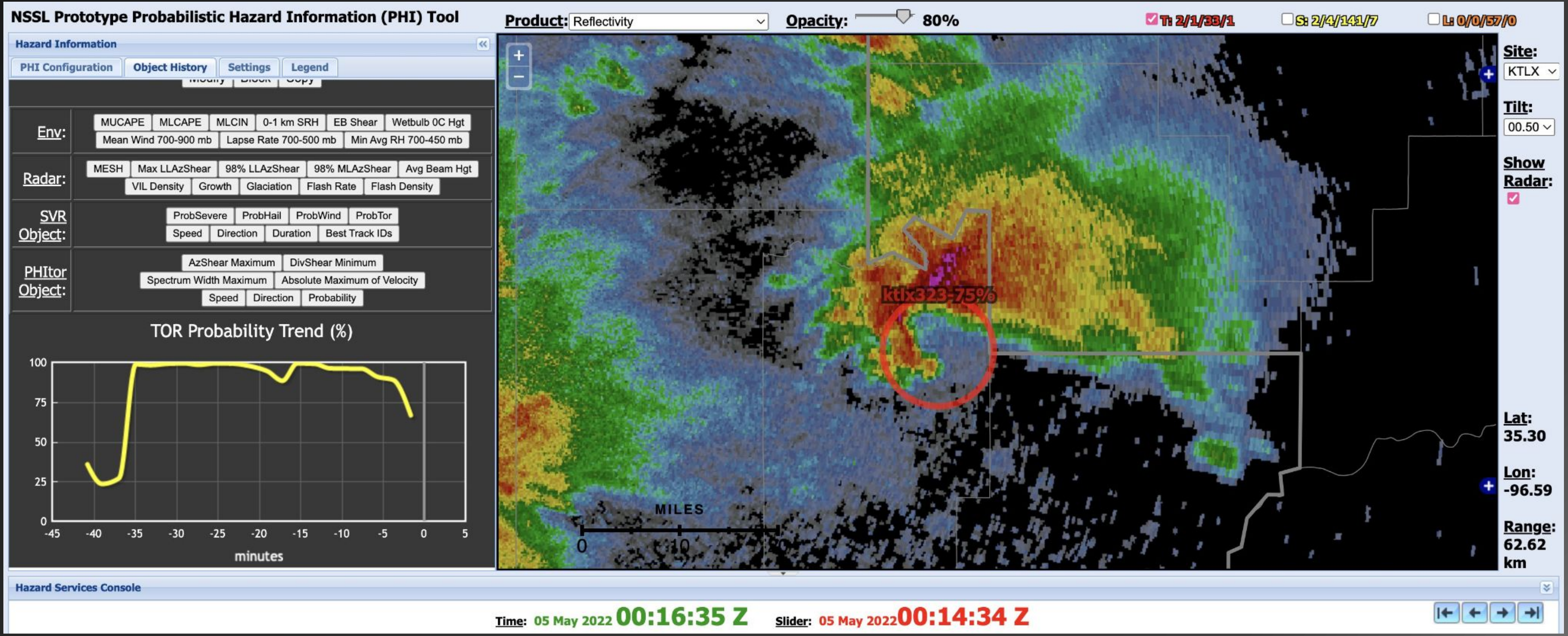


TORP in AWIPS-II

CIWRO · NSSL · NOAA · 60 Years — Celebrating 60 Years of NSSL

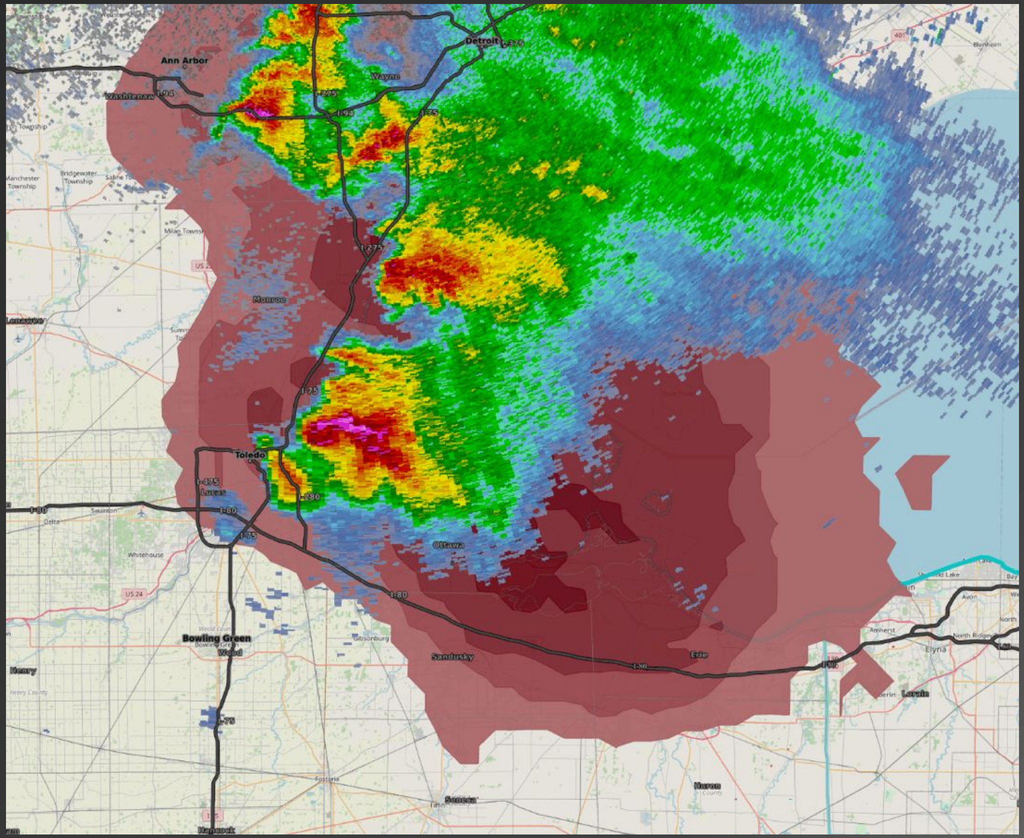


TORP in the PHI Tool



TORP and WoFS Blended Product

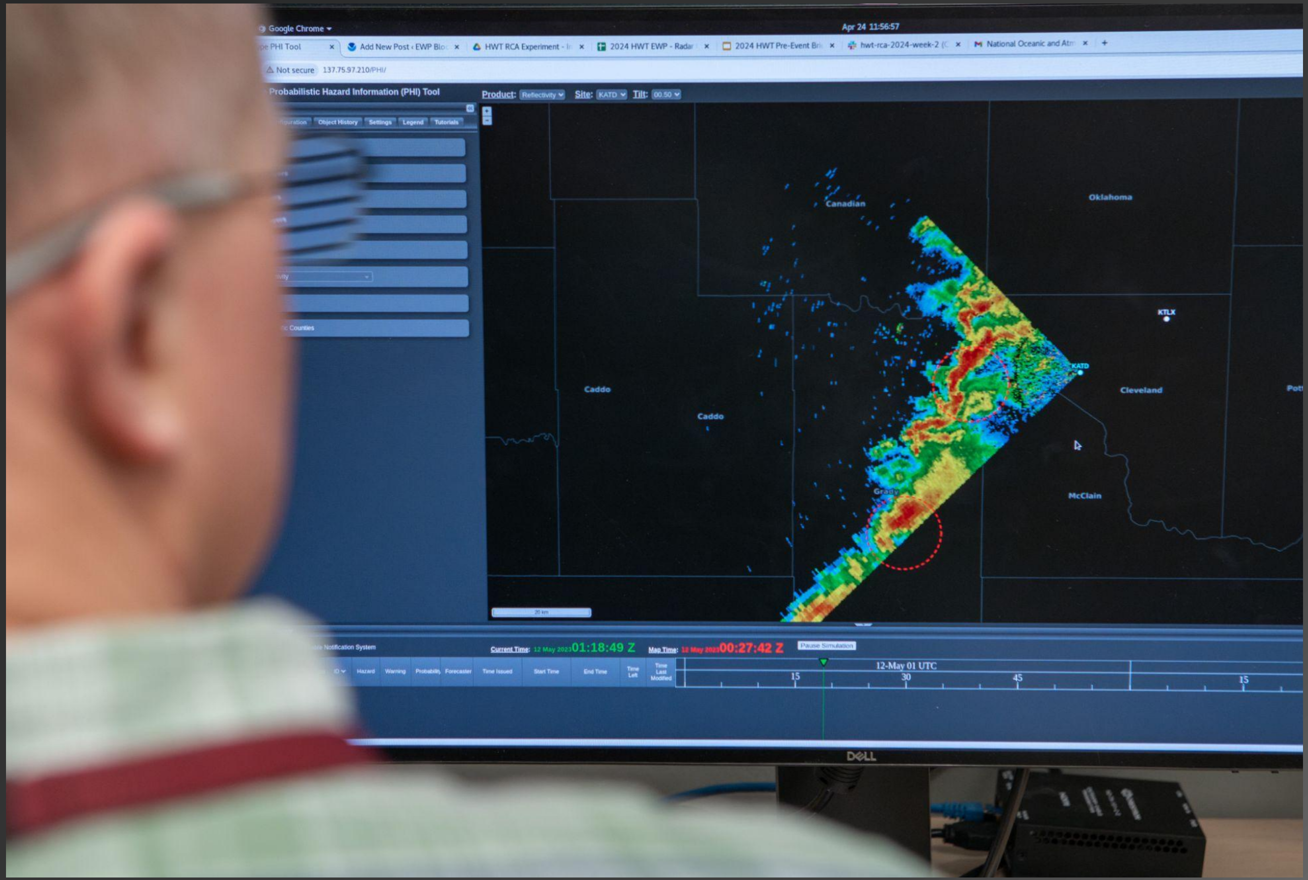
- WoFS-PHI blended tornado product
  - 0-2 hr
  - Machine learning
  - Trained on reports and warnings
- Tested in 2024 Watch-to-Warning experiment
  - Generally provides higher probabilities compared to previous model



2-hour tornado probabilities and current radar reflectivity

TORP with ATD PAR data

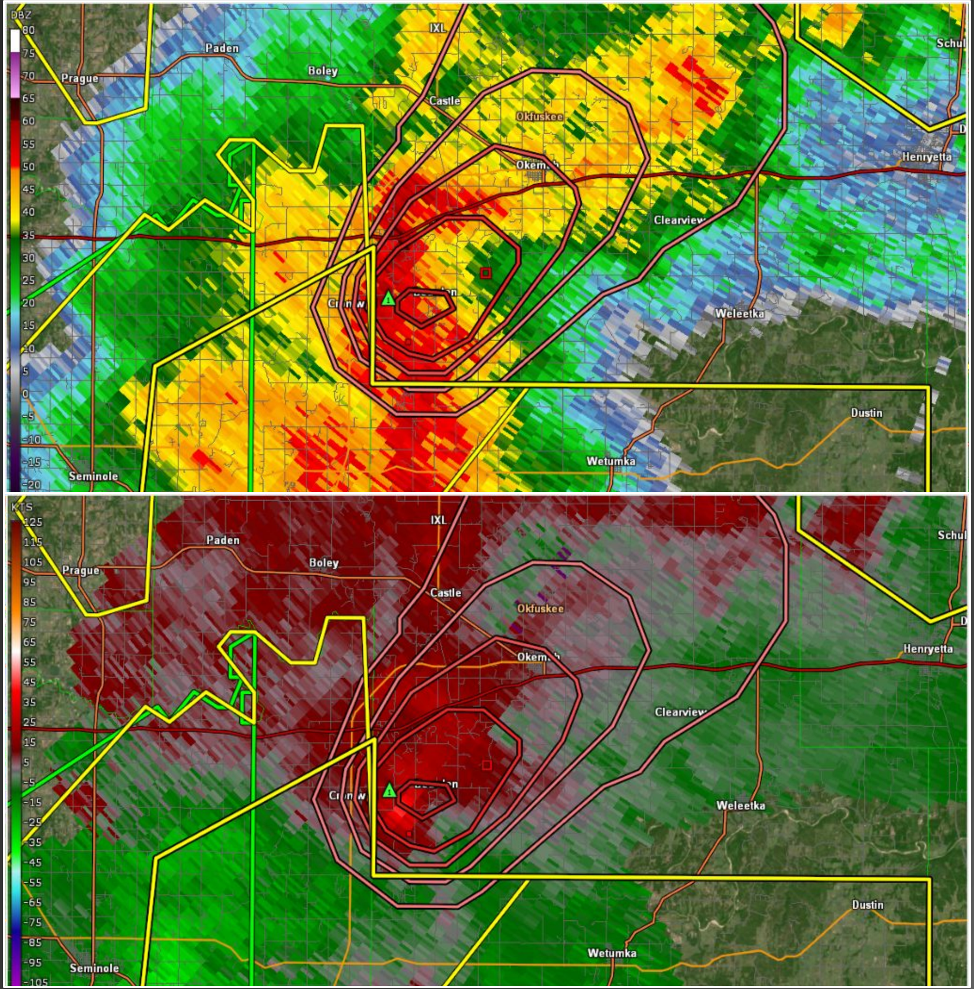
- Part of Radar Convective Applications HWT experiment
- Saw some issues with radial velocity artifacts
- Forecasters reported more stable probability trends
- No notable decrease in (subjective) TORP performance



TORP Real-Time Evaluation at NWS

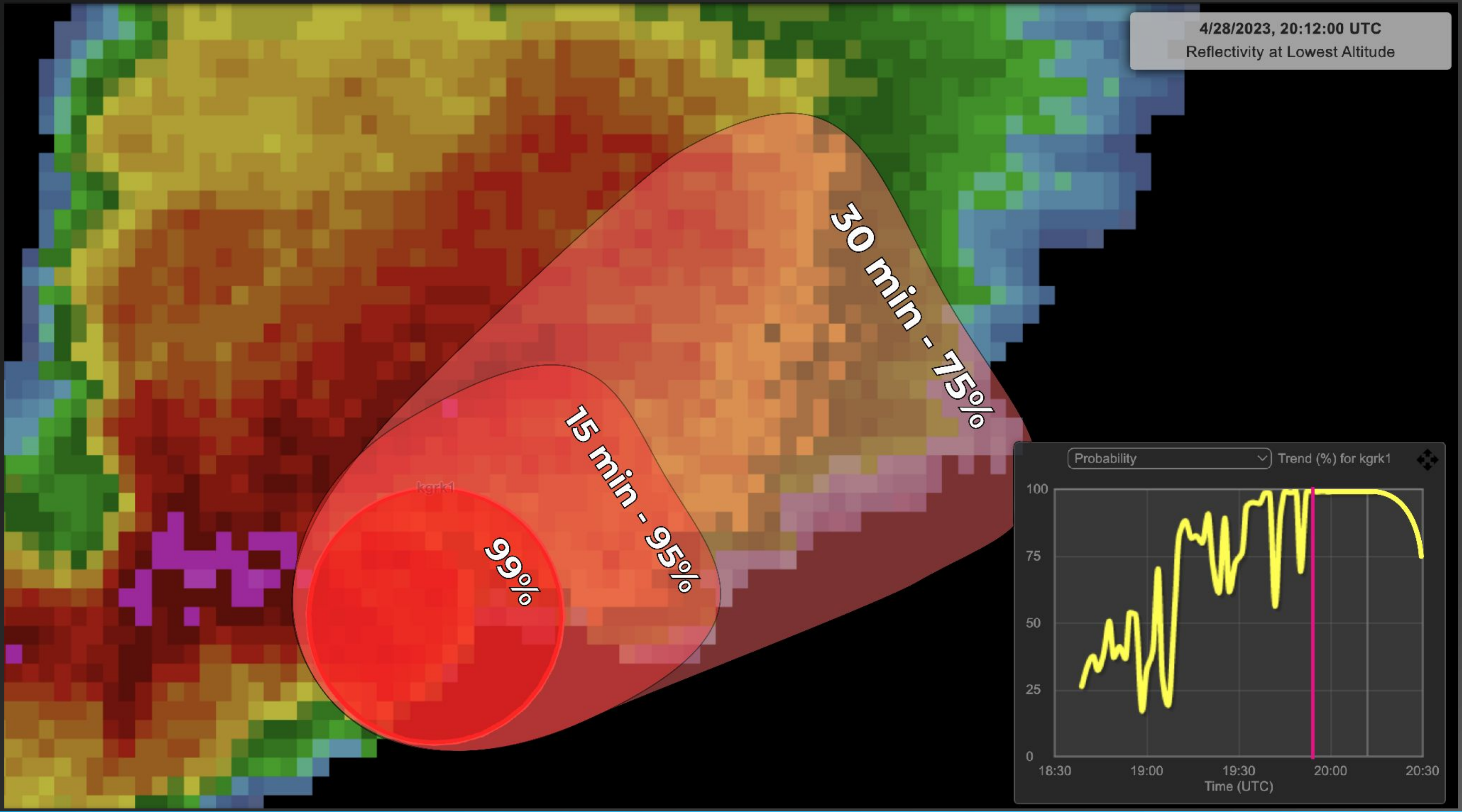
- National Weather Service Southern Region and recently expanded to Eastern
- Tornado PHI plumes based on TORP (less functionality)

"**...PHI Tor started showing a signal with a 20% prob at 1750 UTC then quickly jumped to 80% at 1752.** This **caught our eye** and we **evaluated the circulation more** using KTLX vs KINX and saw the tightening and strengthening meso. **This prompted us to issue a TOR...**"



Screenshot from the forecaster showing the tornado plume

Next Steps


4/28/2023, 20:12:00 UTC
Reflectivity at Lowest Altitude
30 min - 75%
15 min - 95%
99%
kgrk1
Probability
Trend (%) for kgrk1
100
75
50
25
0
18:30
19:00
19:30
20:00
20:30
Time (UTC)

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National Severe Storms Laboratory

AI in the Warn-on-Forecast System: Advancing Severe Weather Guidance

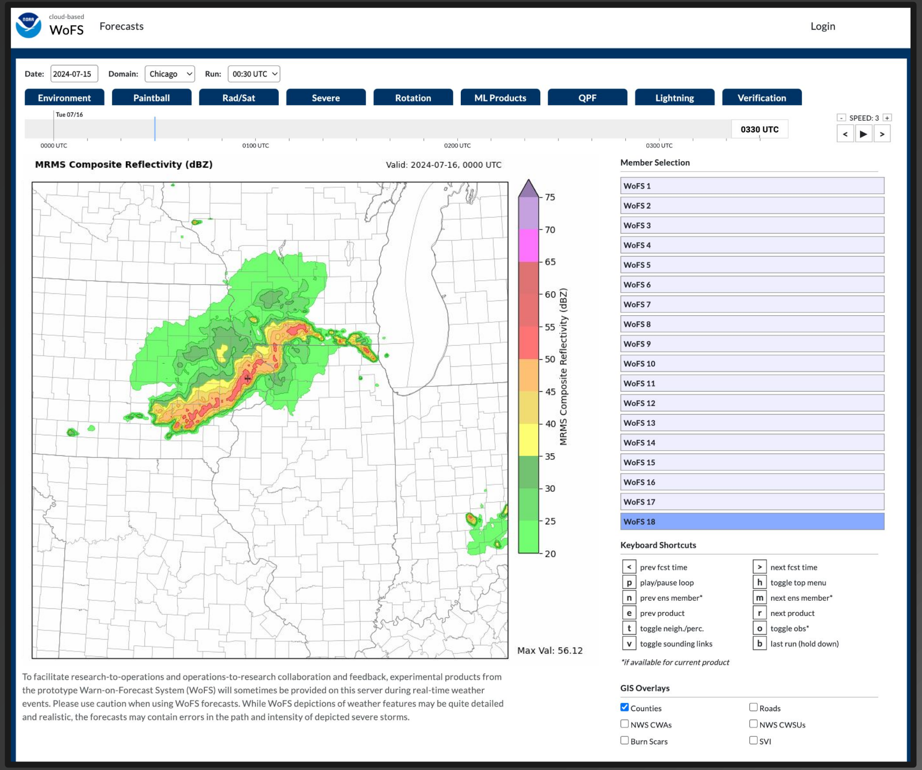
The Warn-on-Forecast System (WoFS) and the need for AI

WoFS is a first-of-its kind ensemble:

- Probabilistic forecasts of individual thunderstorms
- All WoFS output updated every 30 min

WoFS visualizations must be intuitive and trustworthy for users in busy situations where seconds matter

AI can rapidly transform WoFS output into user-friendly, actionable guidance



AI for Watch-to-Warning in the WoFS

Watches
Multiple counties;
hours in advance;
less uncertainty

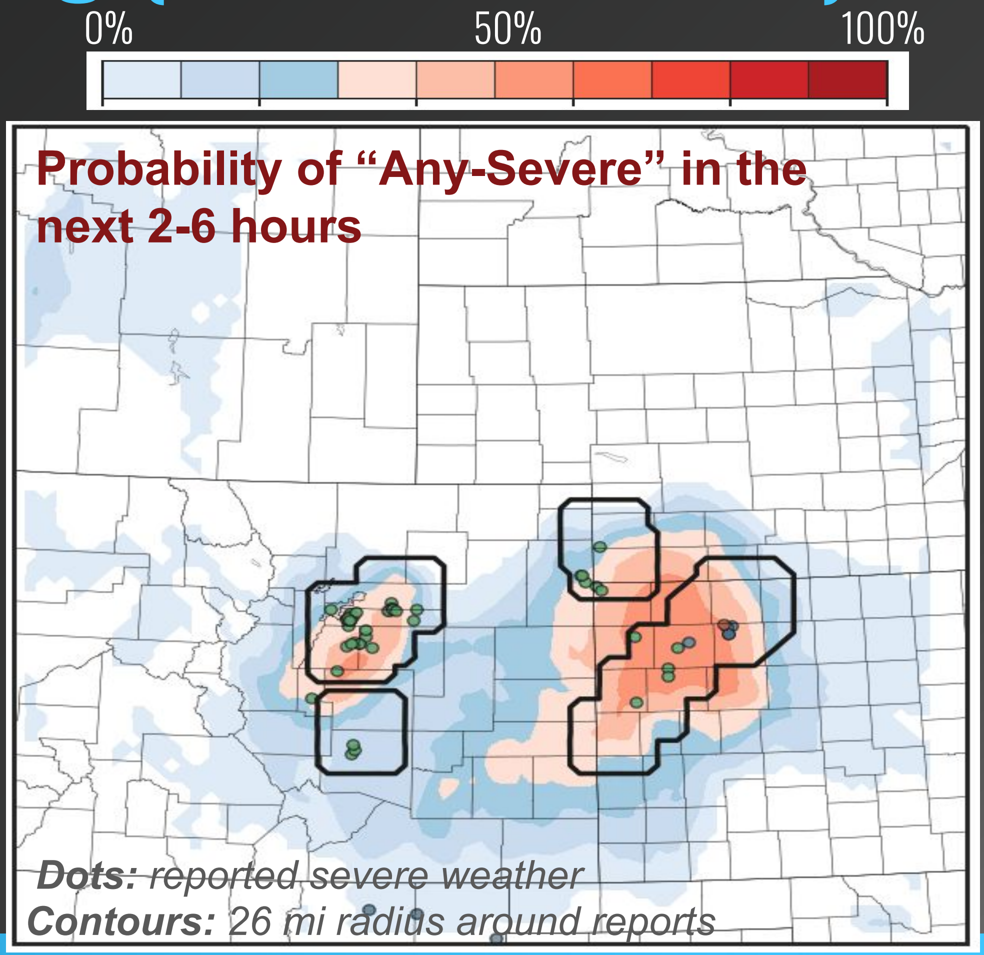
Warnings
Individual storms;
minutes in advance;
more certainty

WoFS-ML-W2W[1] → WoFS-ML-Severe → WoFS-PHI

[1]W2W : Watch-to-Warning

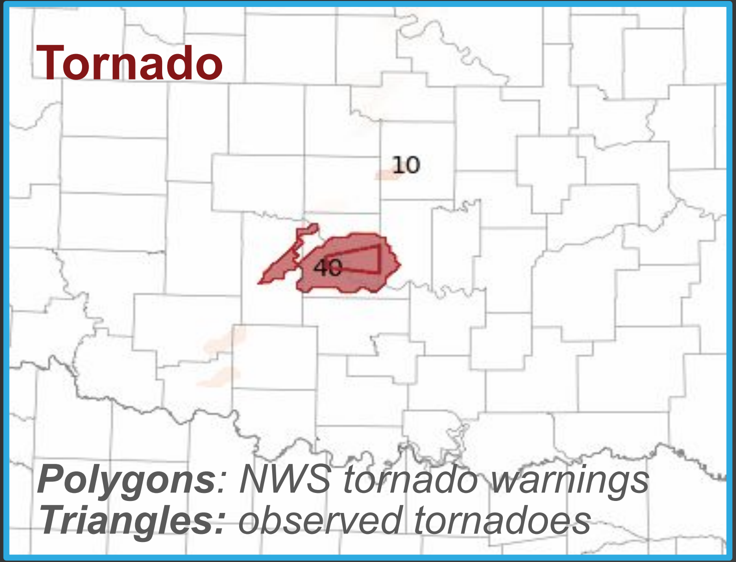
WoFS ML Watch-to-Warning (WoFS-ML-W2W)

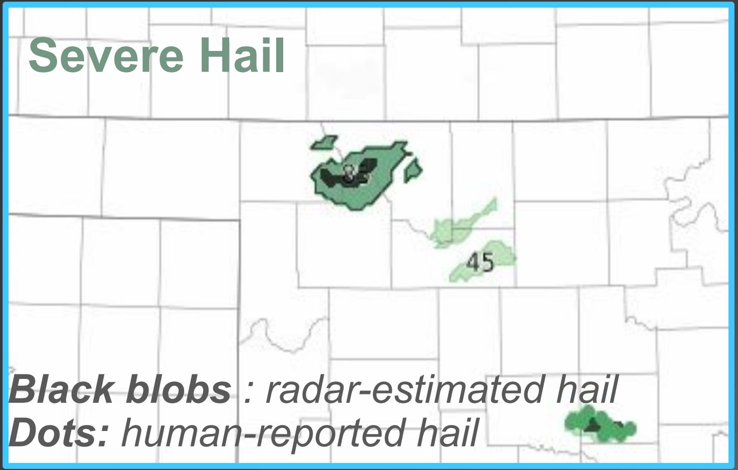
- W2W products serve as a first-guess and allows for a smoother transition to shorter range WoFS-ML-Severe and WoFS-PHI products
- To better reflect higher uncertainty, adopt an "SPC-style" definition of severe weather likelihood
- First deep learning application in the WoFS



WoFS-ML-Severe

- Designed to identify regions of interest in the WoFS output and uses ML[1] to assign probability of different hazards occurring (i.e., large hail, damaging winds, or tornadoes)
- Can highlight specific storms or storm clusters
- Leveraged when available by both NWS WFO forecasters and SPC forecasters during severe weather events





[1]ML : Machine Learning

WoFS-ML-Severe in Action

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Graphic issued 90 mins before storms hit Chicago, IL

27 February, 2024
WFO Chicago, IL

Watch-to-Warning Graphic

Severe Weather Update

February 27, 2024
5:35 PM

Graphic valid through 730 PM CST 2/27/2024

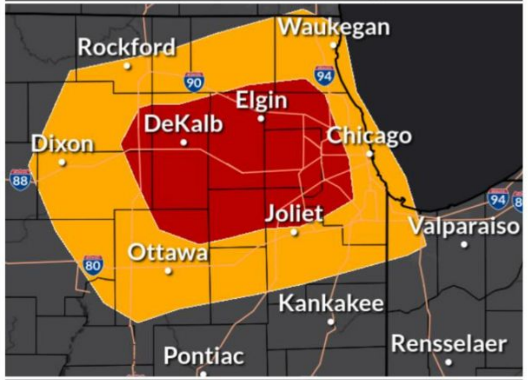
What To Expect

Severe weather threat increasing
Near the I-80 and I-88 corridors, including parts of the W/SW Chicago suburbs

Main Tornado Threat Area
Developing after 600PM
Destructive hail also a threat

Main Destructive Hail & Damaging Wind Area
A few hailstones >= 2" in diameter
Wind gusts over 60 mph

Severe Threat Areas Through 730 PM



Storm Motion: To the ENE at 25 to 35 mph

What You Should Do

- ✔ Have multiple ways to get weather warnings.
- ✔ Move indoors if you hear thunder.

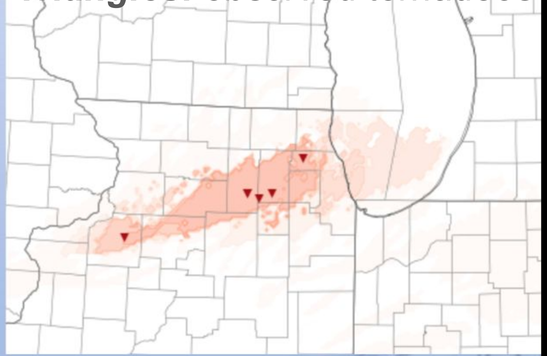
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

National Weather Service
Chicago, IL

This public graphic was " largely based on WoFS output that had lead time for a majority of the tornadoes."

4-hr Tornado Product

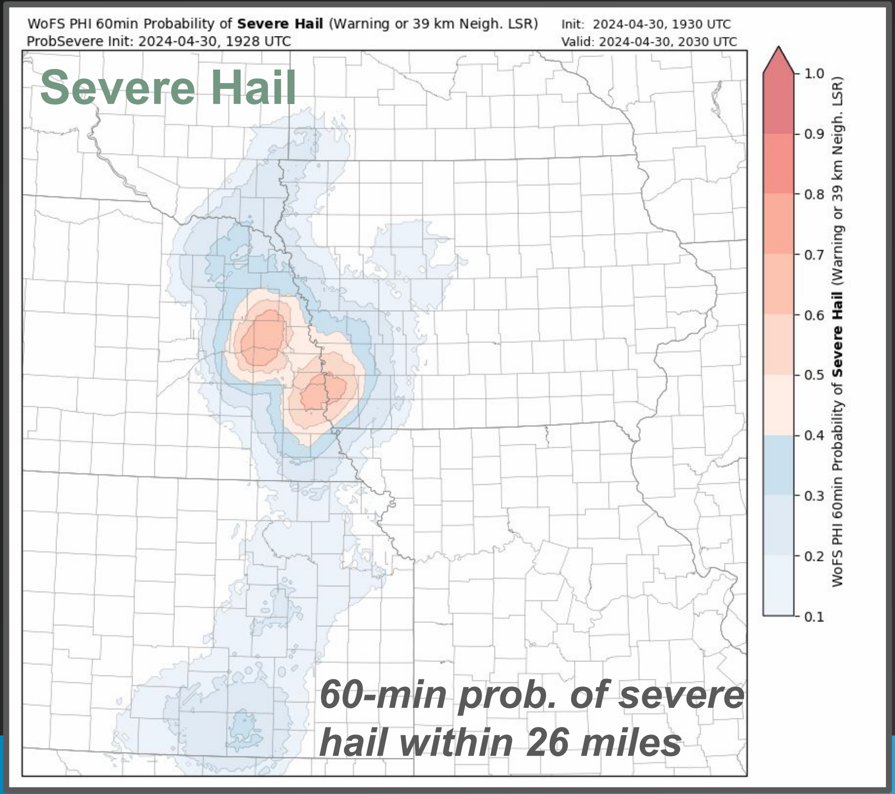
***Triangles:** observed tornadoes*



"…we were particularly impressed with the ability for WoFS to advertise incremental increasing ML tornado probabilties about an hour after CI, maximize in north-central IL, and then decrease into the Chicago metropolitan area."

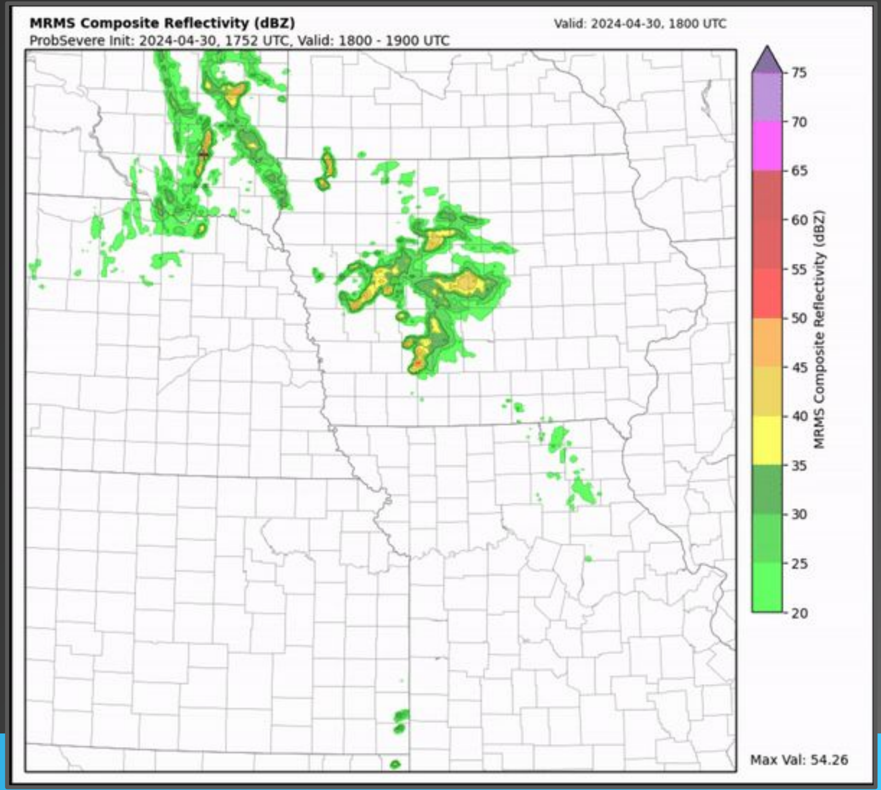
WoFS-PHI: Blending NWP & Observations (WoFS + ProbSevere)

Forecast Mode:
Predicts out to 4-h lead times,
30-min updates (each new WoFS init.)



Updating graphical overlay with new observations

Warning Mode:
Predicts <u>next</u> 60 minutes,
5-min updates (every ProbSevere forecast)



WoFSCast : AI emulation of the WoFS

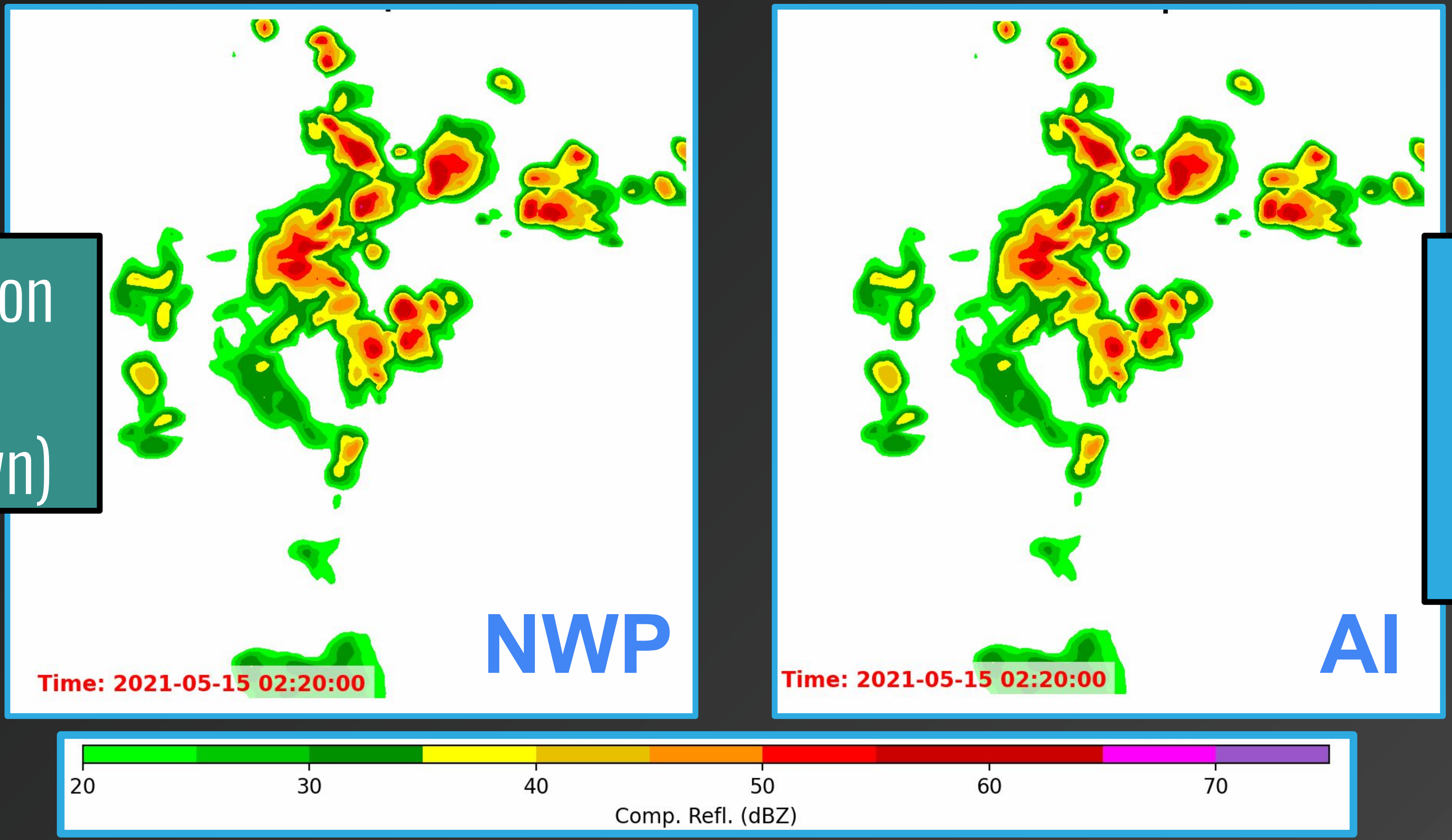
AI-based NWP is quickly challenging traditional global NWP skill, and NOAA is focused on developing AI-NWP for regional predictions

We've refactored Google's GraphCast code and begun training AI-NWP on WoFS data → ***WoFSCast***

Courtesy of Tensorflow GNN Blog

AI-NWP emulation of 3D storm-scale processes

Accurate evolution up to 6 hrs (only 2 hrs shown)

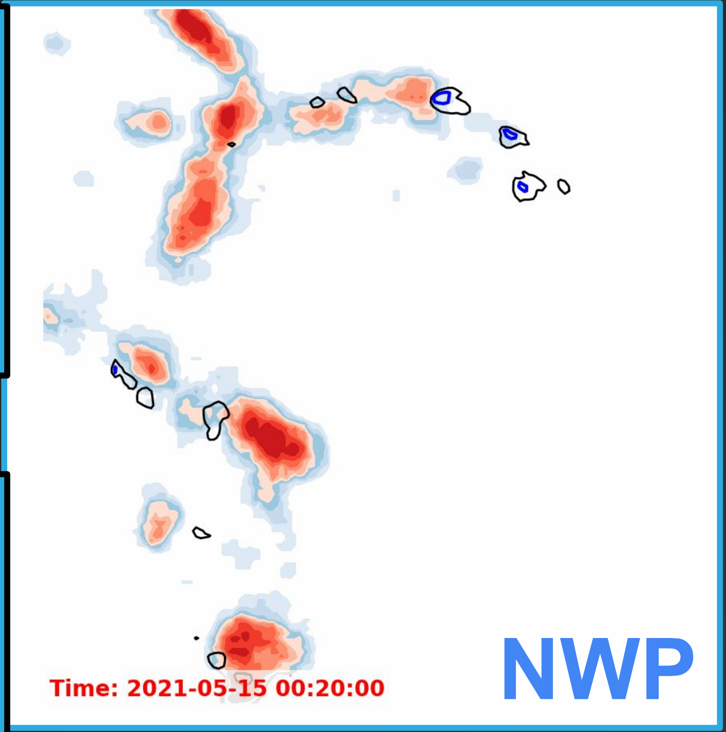


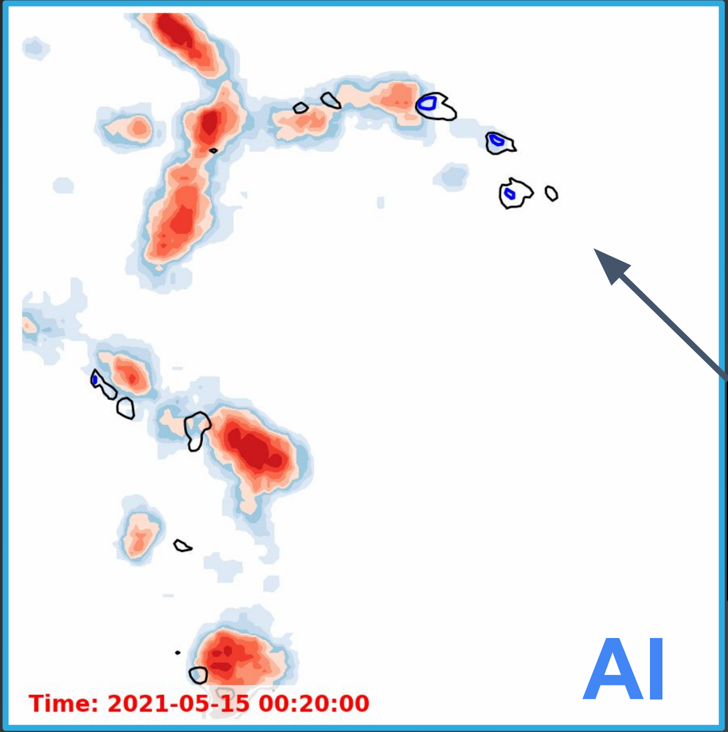
One of the first AI-NWP models trained on NOAA data

Pushing the Frontier of Storm-Scale Prediction

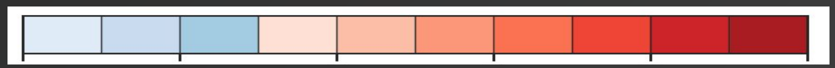
Current WoFS: 8-12 mins with 60+ CPUs (single 6-h forecast)

WoFSCast: 30-45 secs with 1 GPU





Blue/Black: MRMS storms



Probability of Reflectivity > 40 dBZ

Peering into the Future of Storm-Scale AI

- Generating large ensembles (100+ members) in a matter of seconds
  - Improves post-processing calibration and data assimilation
- Running at higher resolution (<= 1km) in real-time
  - NSSL/CIWRO has a growing catalogue of 1-km data to train on
- Running more frequently; closer to the cadence of incoming radar data (if needed)
- WoFSCast is one of the largest AI-NWP models ever created, so expanding its areal footprint will require additional computing and data capabilities

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National Severe Storms Laboratory

NSSL's R&D Future: The Art of the Possible

DaNa L. Carlis, Ph.D.
Director, National Severe Storms Laboratory

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Thank you!

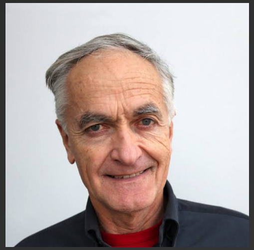
60th Anniversary Planning and Organizing Team


Wes Moody


Daniel Tripp


Vicki Farmer


Kurt Hondl


Dusan Zrnic


Lou Wicker


James Murnan


Jeff Horn


Brandy Griffis


Kim Hoogewind

CIWRO and OU AG&S

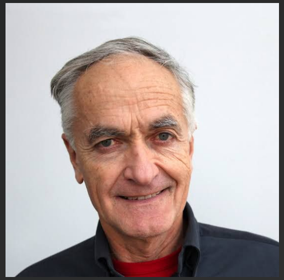
CELEBRATING 60 YEARS OF NSSL

Thank you to our featured speakers!


Pam Heinselman


Harold Brooks


Ken Howard


Dusan Zrnic


Vanna Chmielewski


Thea Sandmael


Sebastian Torres


Monte Flora


Kodi Berry


Elizabeth Smith


Tony Reinhart


Tony Lyza


Kenzie Krocak

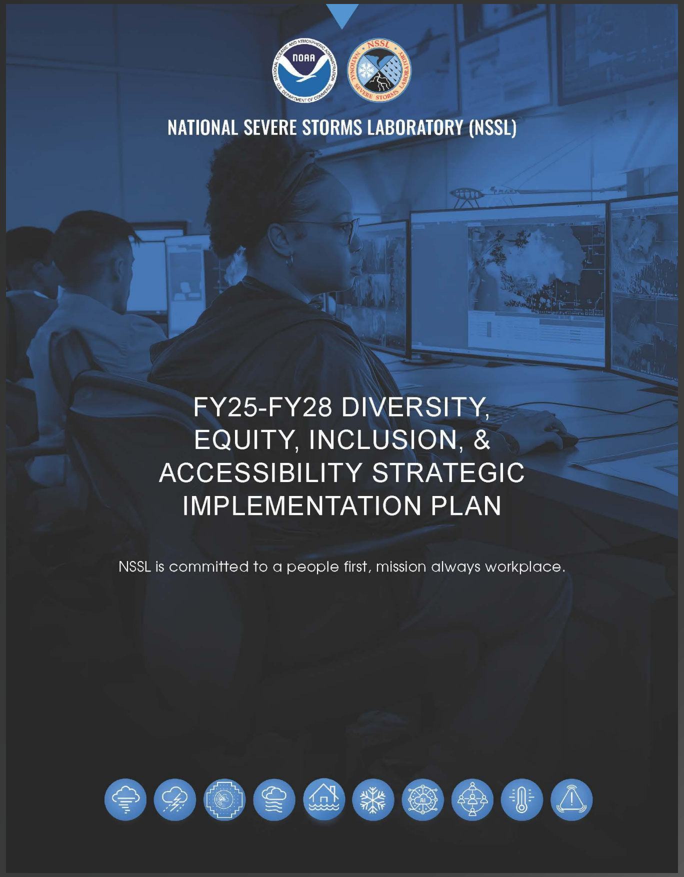

Patrick Burke


Robert Clark

Science for Societal Challenges

People First, Mission Always

1. Recruit and attract a diverse, highly capable workforce,
2. Build a work environment that promotes inclusion,
3. Build a work environment that is equitable and accessible,
4. Foster and sustain a diverse, equitable, and inclusive organization.



Radar Next

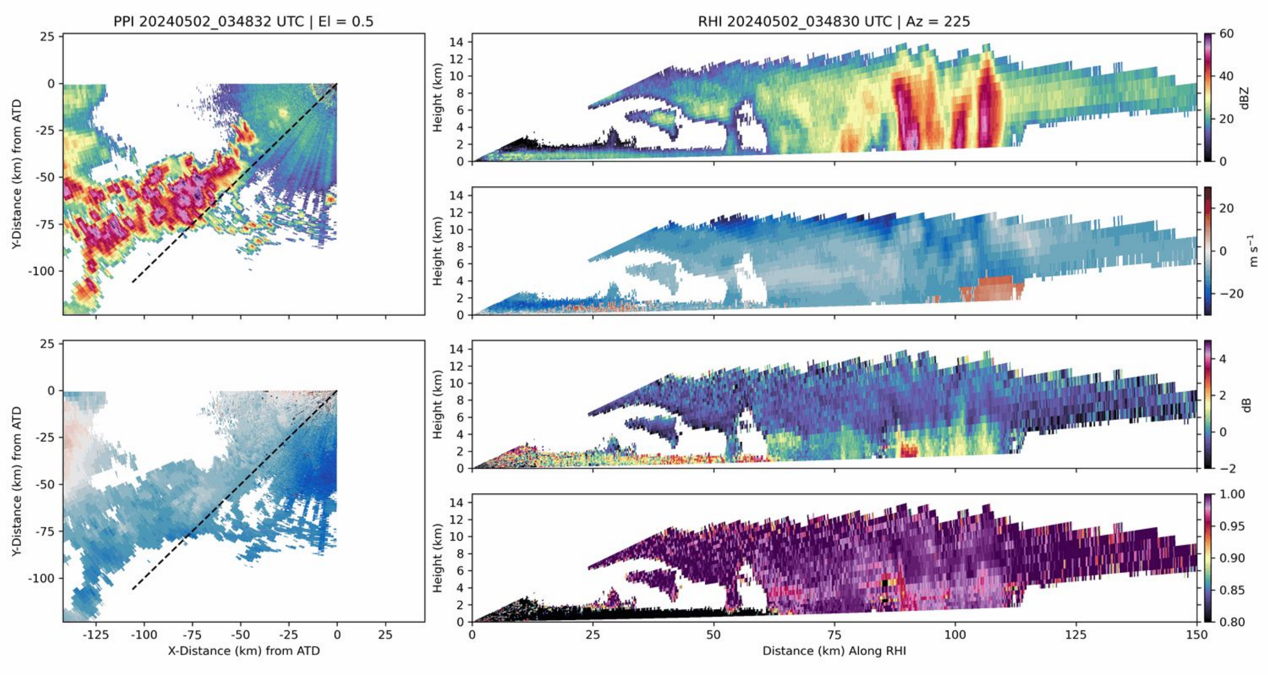

NATIONAL WEATHER SERVICE
Transformation Roadmap
In 2033, the nation and our workforce will have a National Weather Service to address the last critical mile of Impact-based Decision Support Services and to support core partners and the public with high-end, probabilistic hazard information, and the world's best weather, water, and climate community-centric products and warnings. This will be realized through a:
• nimble forecasting process that harnesses cutting-edge technology
• mobile suite of capabilities untethered from traditional infrastructure
• flexible operating model that enables our workforce to meet partners where they make decisions
Read the Roadmap
weather.gov/2033roadmap
PEOPLE
INFRASTRUCTURE
FUTURE
2033


Targeted milestones necessary to achieve a nimble, mobile, and flexible NWS in 2033.
Each step is crucial to enhancing our ability to provide critical life-saving weather, water, and climate information to all NWS partners in all communities across the country, meeting decision-makers where they are and providing decision support services eye-to-eye.
Reaching these milestones in a timely and efficient manner will enable the NWS to achieve our vision for 2033 and will establish a Weather- and Climate-Ready Nation along the way.
Begin Implementation of New Ops Model FY25
Operational AWIPS in the Cloud FY28
Probabilistic IDSS FY29
Full Implementation of Ops Model FY30
Finalize Next Radar Design FY32
Nimble, Mobile, Flexible National Weather Service FY33
DO NOT ENTER
No offices closing
No changes to using local expertise
There will be a place for everyone!
✓ NWSChat 2.0
✓ CMU Transition
✓ Radar Lite

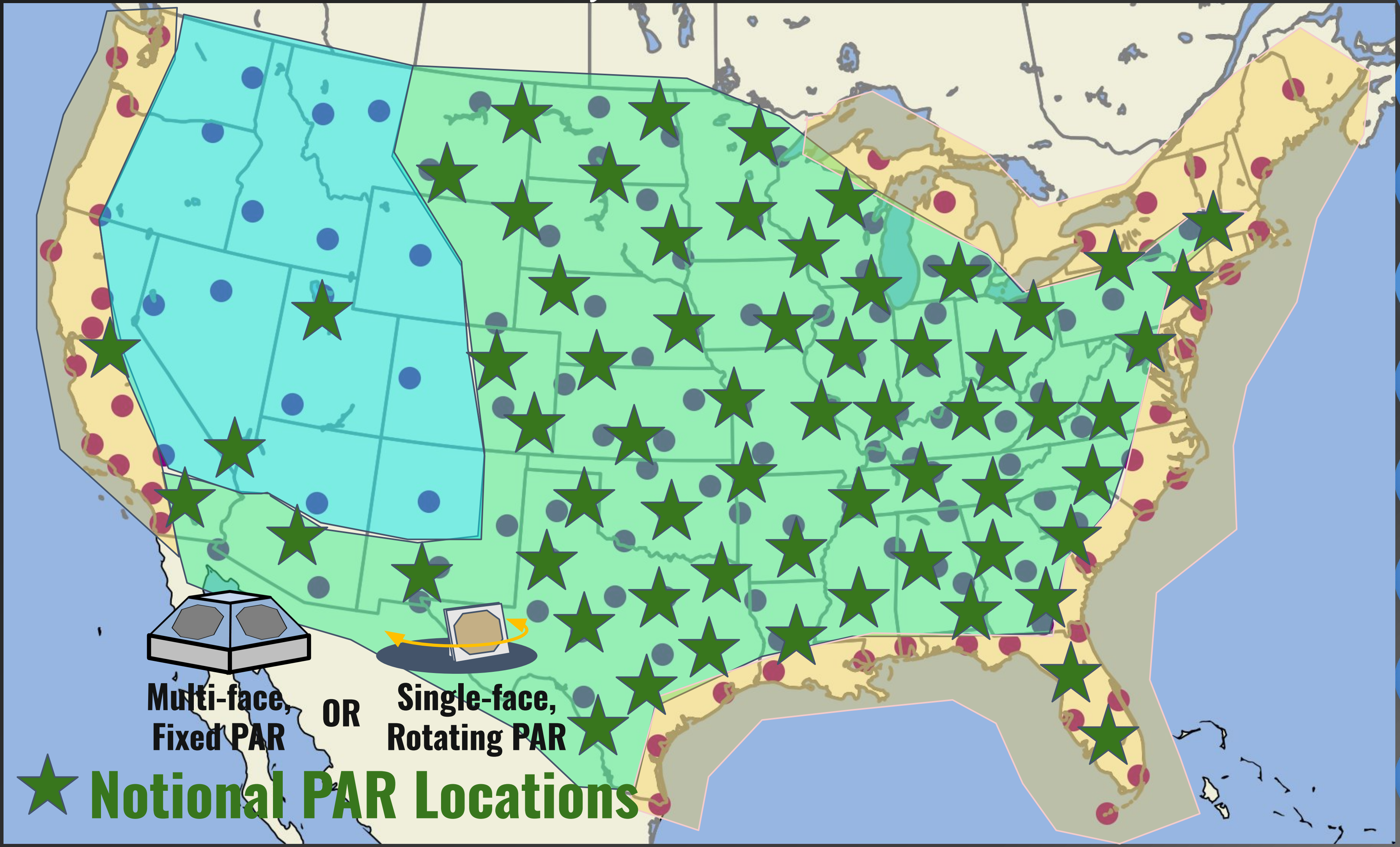
PAR: The radar we need when and where we need it

- Phased Array Radars (PARs) are flexible and customizable to fit many needs
- PARs will be part of the backbone of a hybrid network that involves multiple technologies and public partnerships
- NSSL research is refining technology that will continue to result in high quality data for detection of severe weather, accurate rainfall in important watersheds, and other personal and economic impacts

ATD PPI and RHI



- *This does not assume current NEXRAD sites (in dots) will be used
- Green: S-band PAR backbone with X- or C-band supplemental dish radars
- Yellow: S-band dish radar backbone (Most PARs & supplemental radars ~50+ mi inland)
- Blue: X- or C-band dish radar backbone in most impactful areas with supplemental PARs & satellite radar



VORTEX-USA

- VORTEX started as a field study program in 1990s
- Now: interdisciplinary program to comprehensively attack the tornado problem
  - Full community approach to understand all facets (e.g., physical, social, engineering) - and use research to build societal capacity to better inform, prepare and mitigate

60 Years
CELEBRATING
60 YEARS OF NSSL

Future of Tornado R&D

Storm environment

- Deep profiles from CLAMPS, coptersonde
- Swarms of UAS for variability
- Crowdsourced (chasers) surface weather obs with NSSL-designed systems

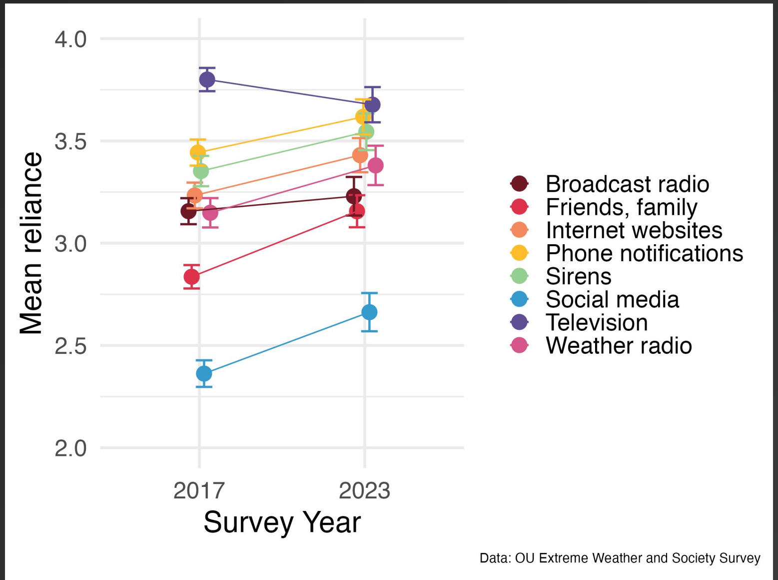
Storm internal processes

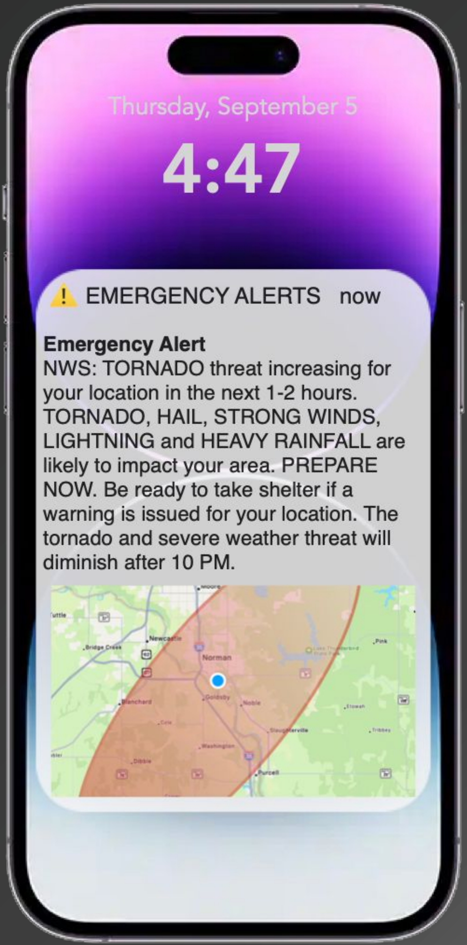
- Storm-capable drones
- Hail cam and next-generation precip imagers
- Close-range dual-pol radar
- In situ mobile mesonet observations

- ML analysis of velocity from crowdsourced video, NSSL in situ imagery, UAS
- Close-range mobile Doppler and lidar measurements from trucks, UAS
- High-resolution computer simulations validated by in situ measurements
- UAS and ground-based studies of damage to structures and the natural environment

Social Behavioral Science
Community Centric Alerts

Cell phone growing importance to alerting individuals of pending hazards

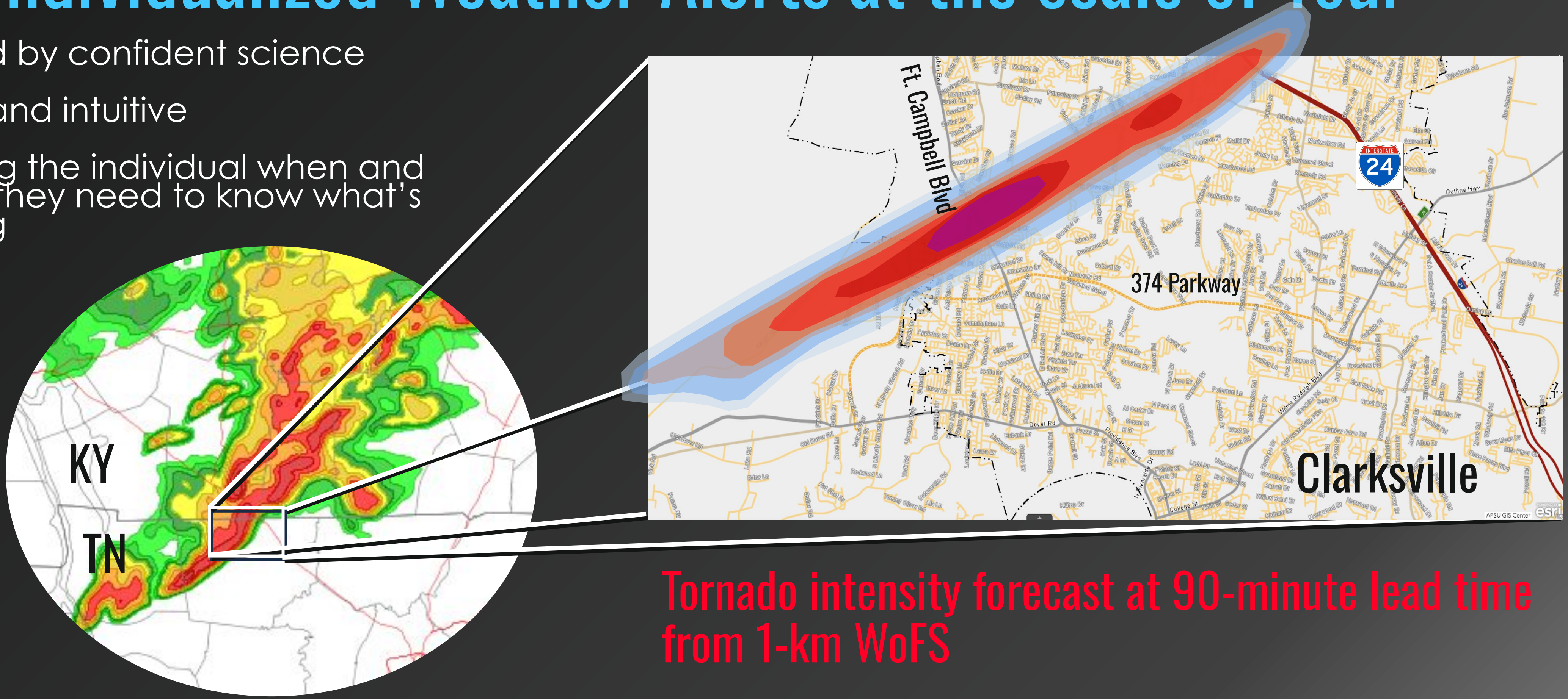




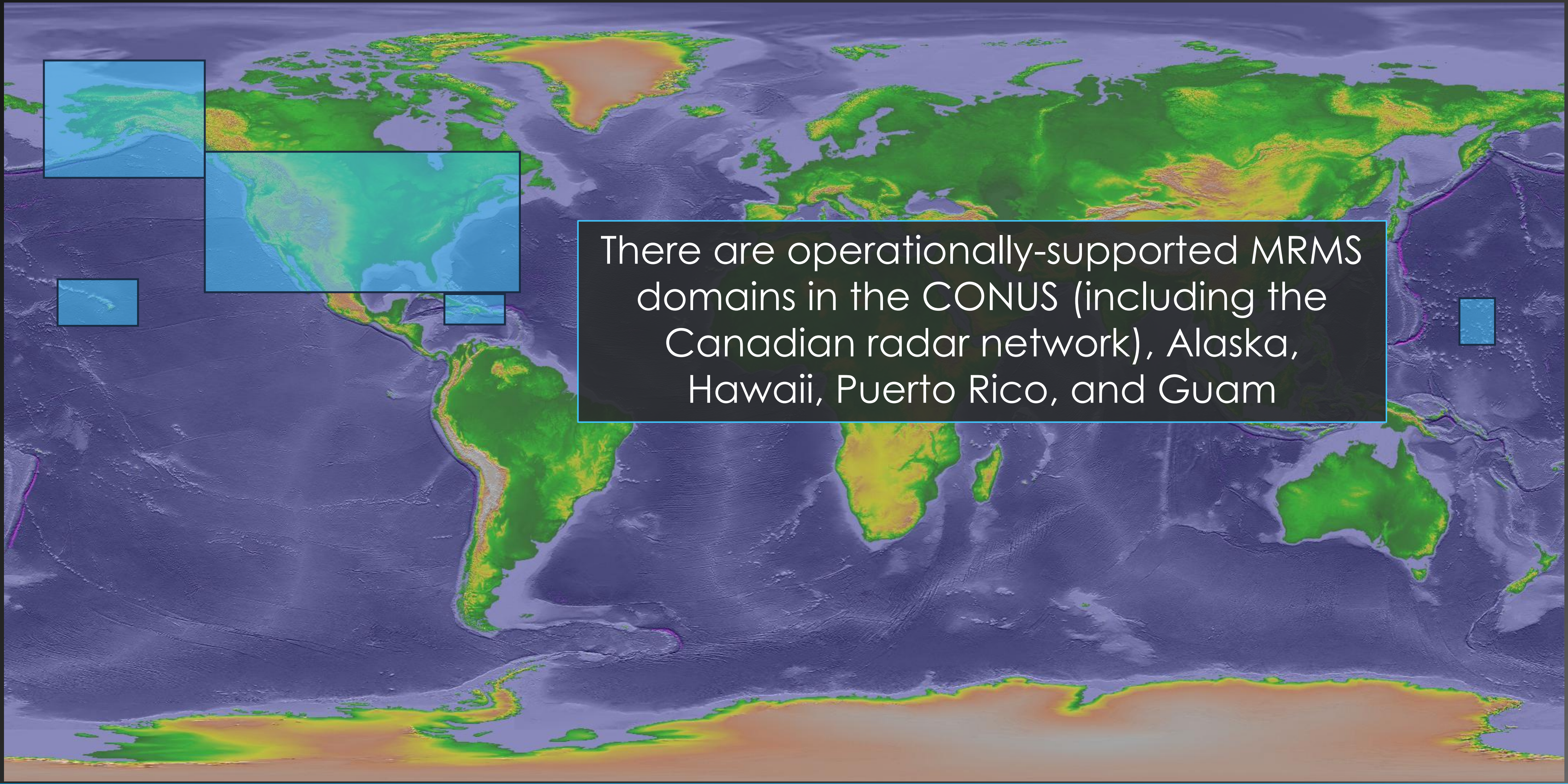
60 Years CELEBRATING 60 YEARS OF NSSL

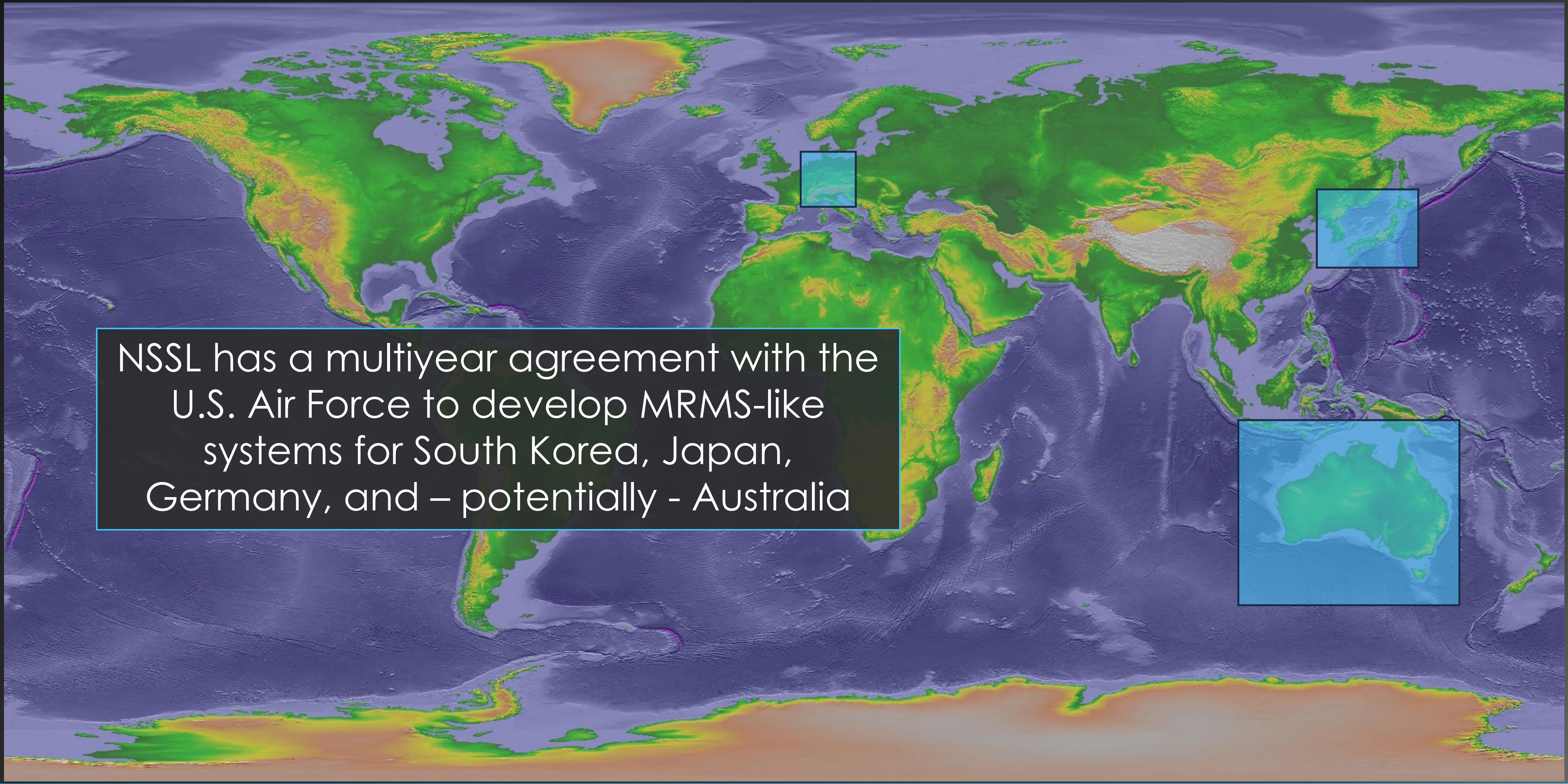
Individualized Weather Alerts at the scale of You!

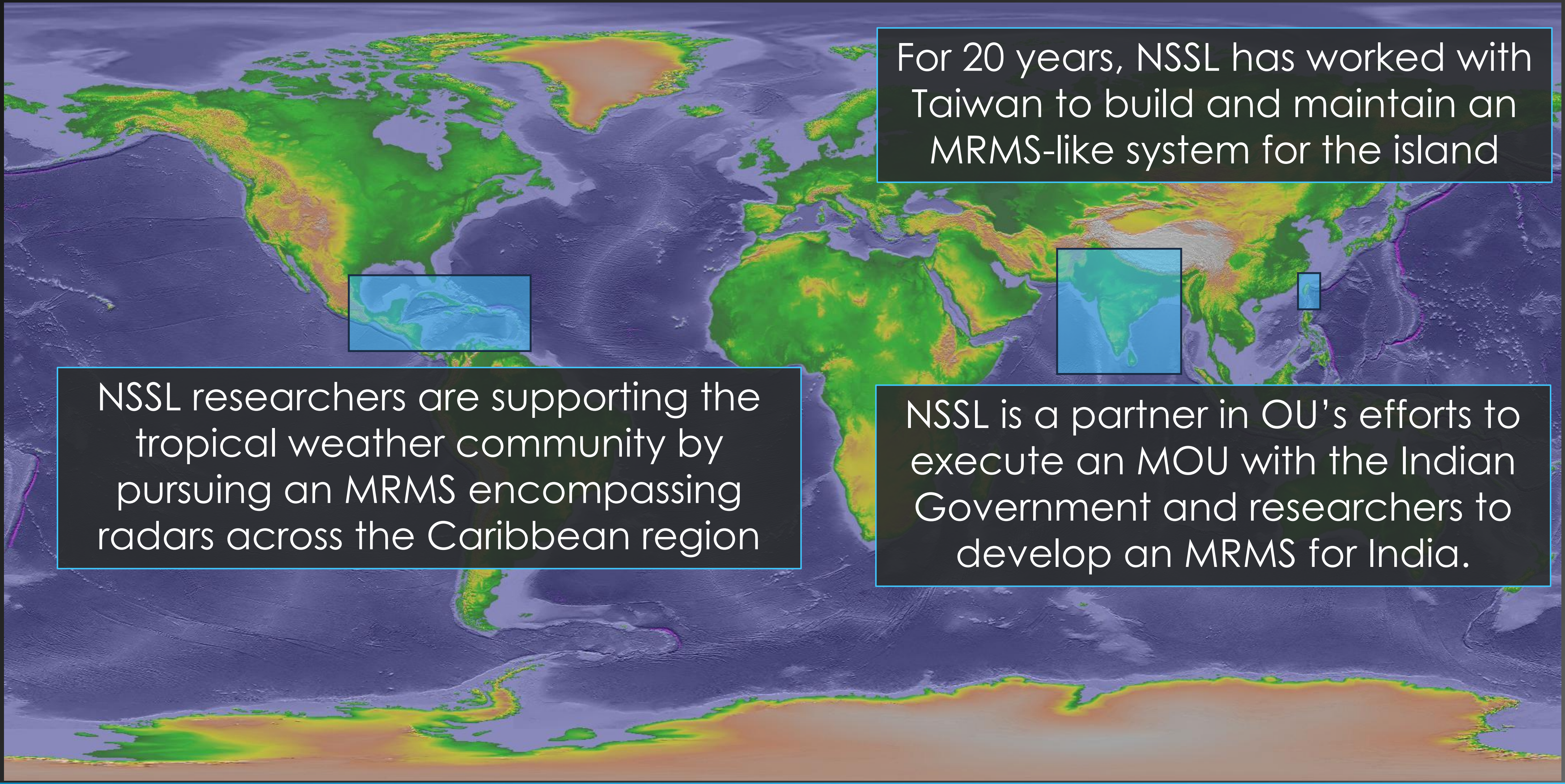
- Backed by confident science
- Quick and intuitive
- Meeting the individual when and where they need to know what's coming



Tornado intensity forecast at 90-minute lead time from 1-km WoFS


There are operationally-supported MRMS domains in the CONUS (including the Canadian radar network), Alaska, Hawaii, Puerto Rico, and Guam

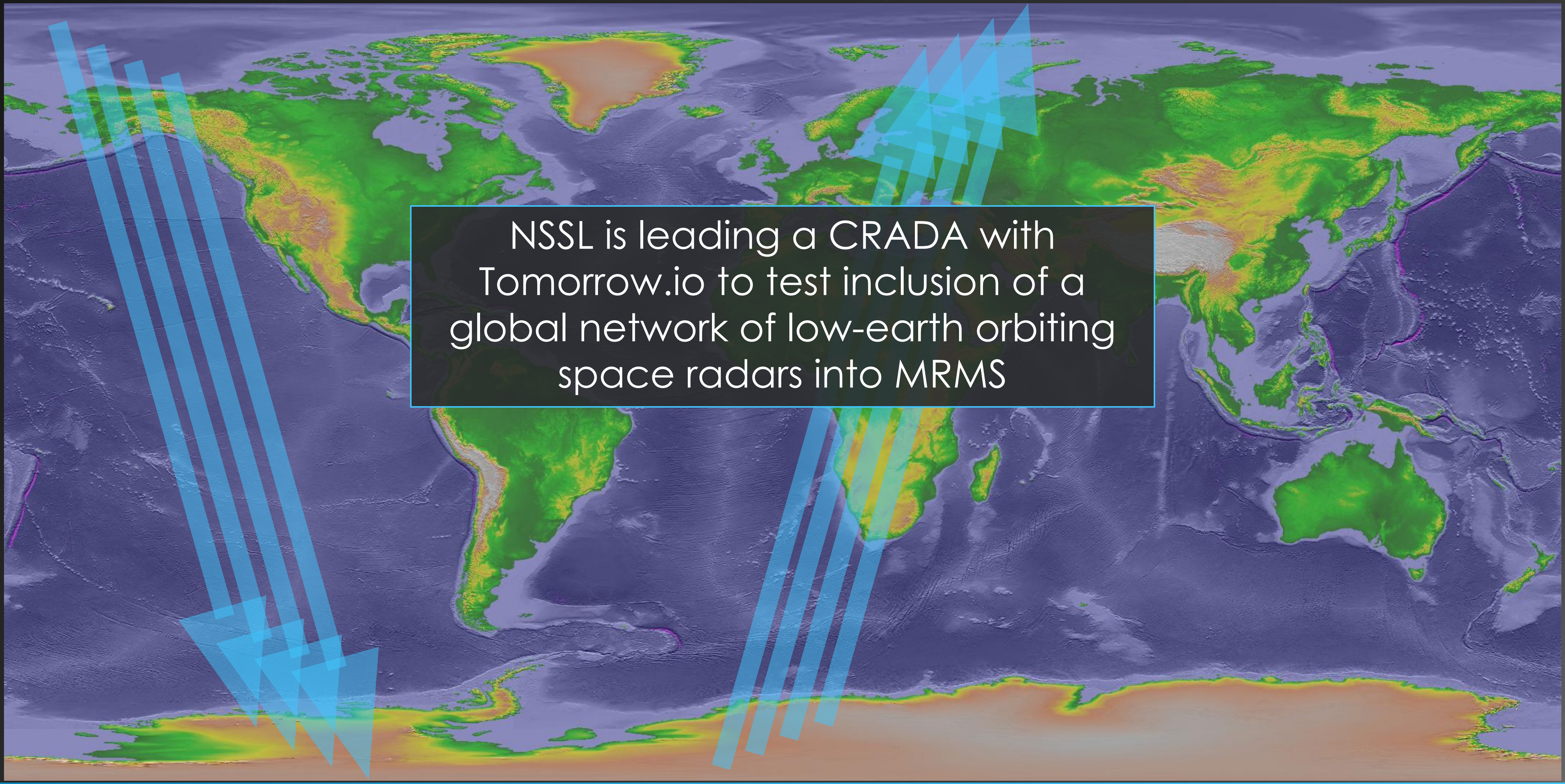

NSSL has a multiyear agreement with the U.S. Air Force to develop MRMS-like systems for South Korea, Japan, Germany, and – potentially - Australia



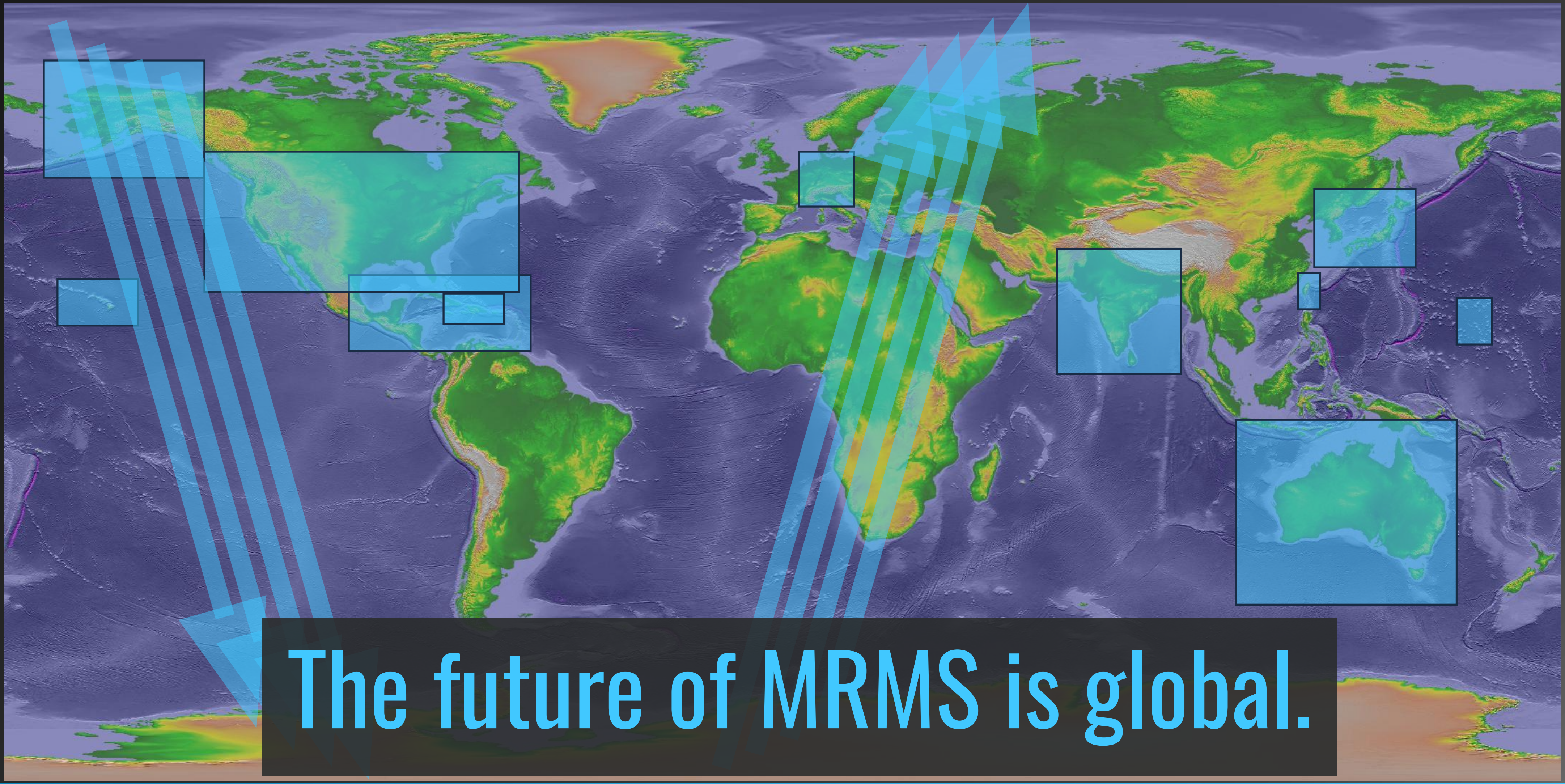
For 20 years, NSSL has worked with Taiwan to build and maintain an MRMS-like system for the island

NSSL researchers are supporting the tropical weather community by pursuing an MRMS encompassing radars across the Caribbean region

NSSL is a partner in OU's efforts to execute an MOU with the Indian Government and researchers to develop an MRMS for India.



NSSL is leading a CRADA with Tomorrow.io to test inclusion of a global network of low-earth orbiting space radars into MRMS



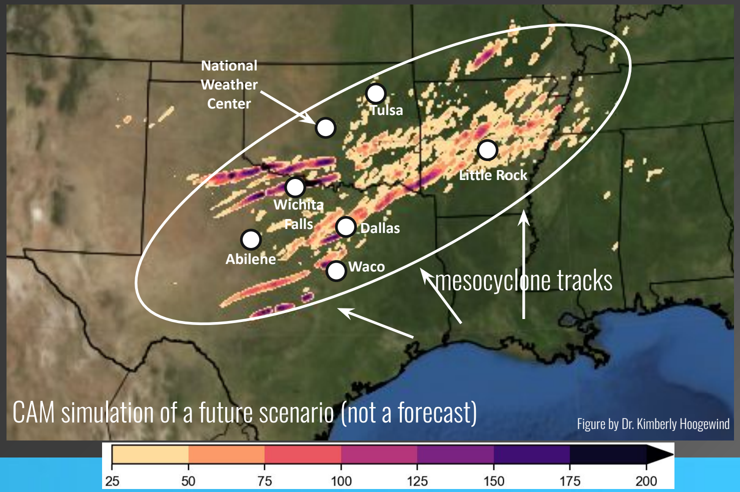
The future of MRMS is global.

What is the Impact of Climate Change on Severe Weather?

- The most consequential science question for the next 60 years due to the socioeconomic impacts
- NSSL and partners uniquely positioned with expertise observing and modeling severe storms
  - Severe Weather Weeks 2-4 Tiger Team: NSSL, AOML, GFDL, GSL, PSL, ARL, WPO, NWS SPC and CPC
- Grand challenge #1: How will the frequency, location, and intensity of severe storms change in future climate scenarios?
- Grand Challenge #2: How will predictability of severe storms change in future climate scenarios?

EF4 tornado – Greenfield, IA – 21 May 2024

Daily Max 2-5 km Updraft Helicity – A Day 60 years from now



Closing

- What's missing and what's next for the art of the possible R&D at NSSL?

Acknowledgements: Kurt Hondl, Larry Hopper, Alan Gerard, Kenzie Krocak, Kodi Berry, Tony Reinhart, Patrick Burke, Erik Rasmussen, Sean Waugh, Race Clark, Ken Howard, and Tom Galarneau

But Wait … There's More

Please join us in the atrium for a reception and poster viewing from 5-6pm.

We didn't have time to show you everything we're doing. You'll get a chance to talk to some of the amazing young (and old) scientists.

Dinner (for those that purchased tickets) will begin at 6pm.

Thank you for attending!