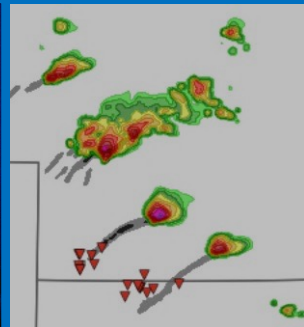




Forecast/Warning Tools and Techniques

Warn-on-Forecast

Patrick C. Burke MS, NSSL WoF Program Lead, FRDD
Lou Wicker PhD, NSSL Chief Scientist for WoF, FRDD



What is Warn-on-Forecast?



- Warning lead time shows no room for growth in a warn-on-detection paradigm
- Forecasts of thunderstorms and their local hazards necessitate a probabilistic approach

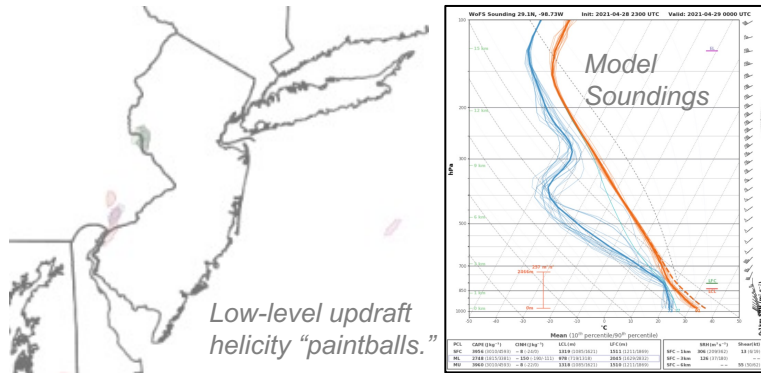
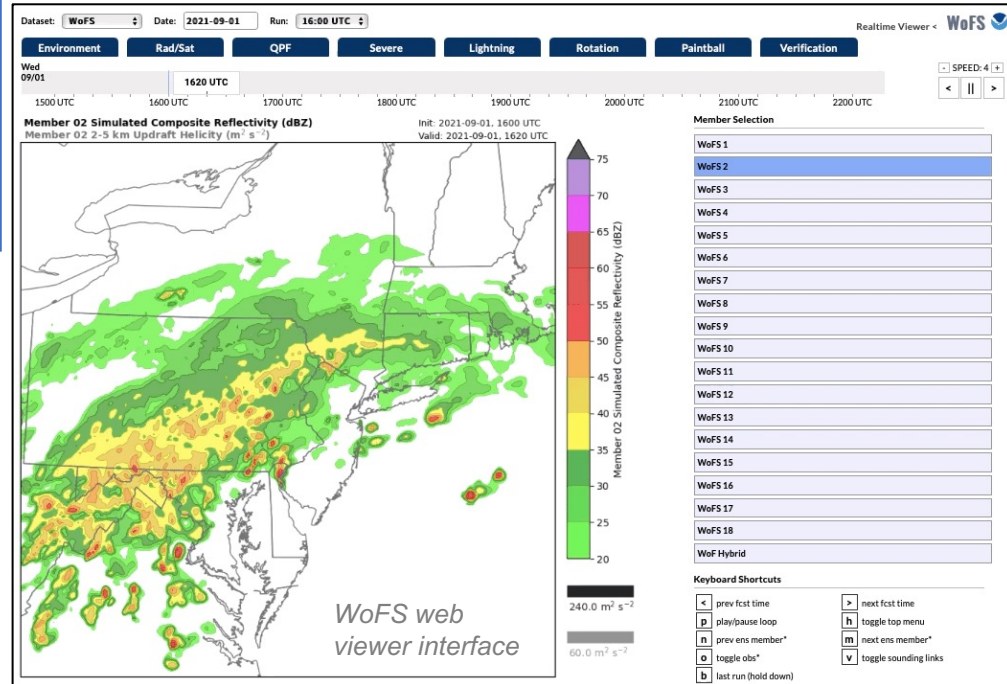
Goal:

Develop and demonstrate with users an ensemble analysis and forecast system that makes probabilistic forecasts of individual thunderstorms and their hazards, 0-6 hours



WoFS is a rapidly updating, storm-scale ensemble predicting individual thunderstorms

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



Low-level updraft helicity "paintballs."

Objects are low-level mesocyclones from all members. Red triangles appear at times/locations of observed tornadoes.





Relevance



WoFS: First ensemble to make *probabilistic forecasts* of individual thunderstorms and their hazards

Congress

Weather Research & Forecast Innovation Act; Tornado Warning Improvement and Extension Program

WoFS integration into operations is a TWIEP goal



OAR

Make forecasts better & Drive innovative science

NSSL

(1) Reliable probabilistic guidance; (6) warning uncertainty information for high-impact events; predict (3) flash flooding, (4) lightning

WoFS advances numerous Grand Science Challenges





Collaborative Approach



NOAA Partners

University Partners



Norman Community

NOAA/NWS



Stakeholder Groups



Quality & Performance



- Dr. Pam Heinselman

NWA Dr. Ted Fujita Research Achievement Award

“outstanding leadership of... NOAA/NSSL Warn-on-Forecast...particularly...in developing collaborations with the operational community...” (2021)

- Dr. Corey Potvin

White House Presidential Early Career Award for Scientists and Engineers (PECASE, 2017)

“significant and innovative contributions to observational analysis of thunderstorms, assimilation... into numerical prediction models, and groundbreaking research to predict thunderstorm-related threats such as tornadoes.”





Publications

- 80+ since 2016

Data Assimilation

Predictability

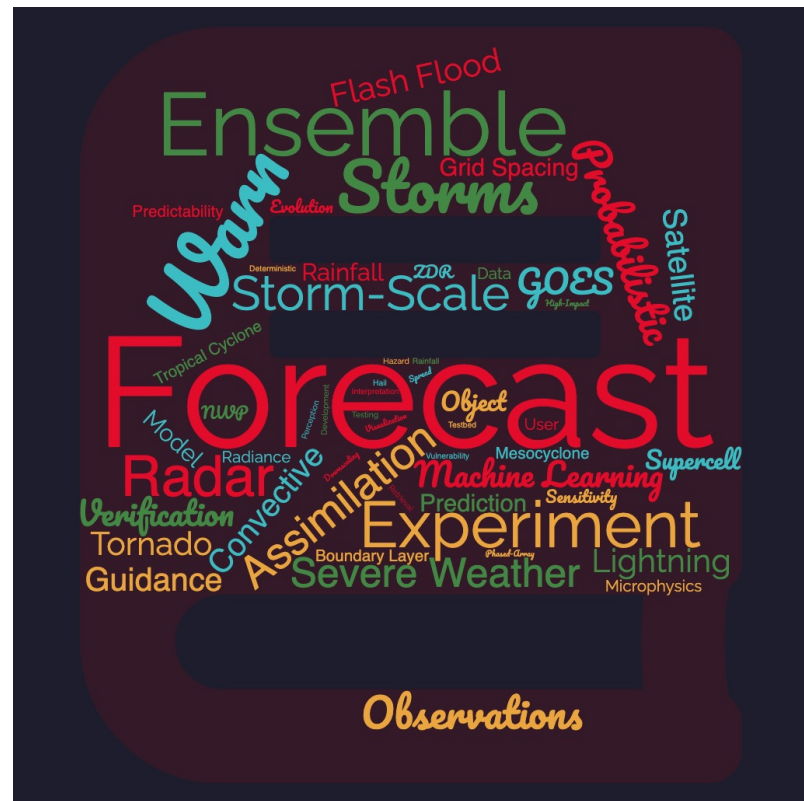
User interpretation

Rainfall / Flash Flooding

Lightning

Machine learning applications

13,000 word, 16-figure chapter,
summarizing WoFS history,
submitted to AGU monograph on prediction
of weather and climate extremes



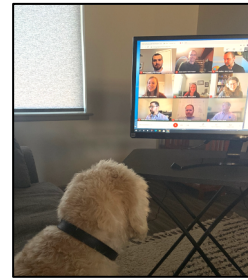


Rich History of User Engagement



Collaboration on Watch-to-Warning graphic

Severe



First WoF testbed experiment conducted involving both national centers and local forecast offices

First real-time demonstration of WoFS use in NWS operations

WoFS becomes a regular in the NOAA Hazardous Weather Testbed

Established a working group with NWS southern region. *Charter developed jointly, NSSL and NWS local and regional offices*



2016

Proof-of-concept demonstration of WoFS for heavy rainfall prediction

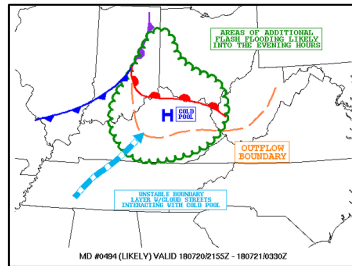


2017

First evaluation at NOAA-HMT Flash Flood and Intense Rainfall & HMT-Hydro experiments



2018



2019

Real-time evaluations with WPC Metwatch Desk for flash flood forecasting



2020

Real-time experiment with NWS WFOs for Southwest monsoon events



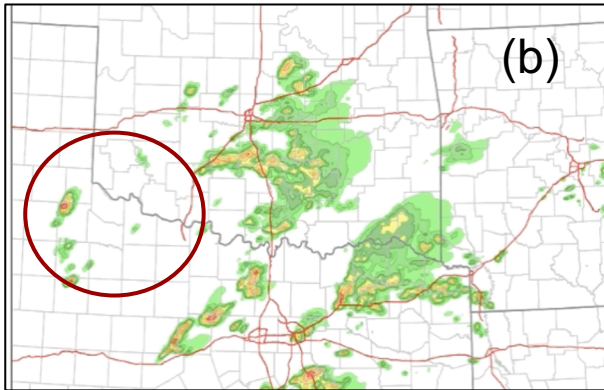
2021



Rainfall



Demonstrated Real-World Influence on Lead Time: Texas Tornado 23 April 2021



Increasing Tornado Threat

Valid **Through 6:00pm**, Friday, April 23, 2021

WHAT

Hail up to baseball size

Damaging winds up to 70 mph

Tornado possible

WHERE

Goodlett, Quanah, Chillicothe, Vernon, Crowell, Frederick

ACTIONS

Be ready to take shelter quickly

NATIONAL WEATHER SERVICE
 WEATHER FORECAST OFFICE - NORMAN, OKLAHOMA
 Issued: 4/23/2021 4:11 PM

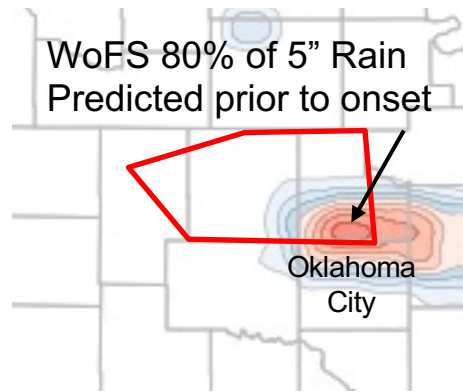
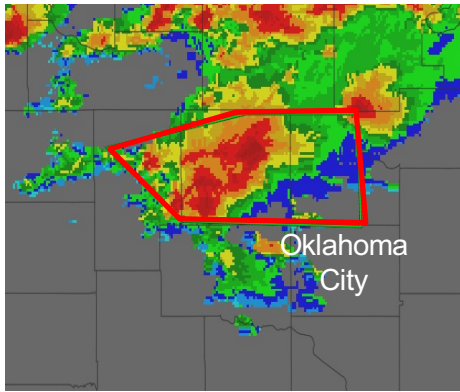
“Mesoscale analysis supported a narrow zone of tornado potential. WoFS resolved a right-moving supercell within that zone.”

92 minutes:

Time between this decision support graphic and the first tornado touchdown.

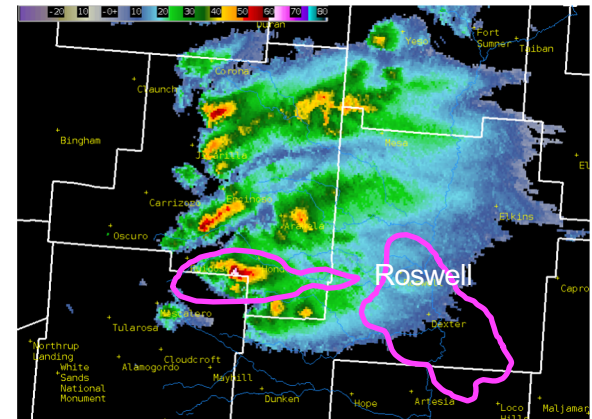
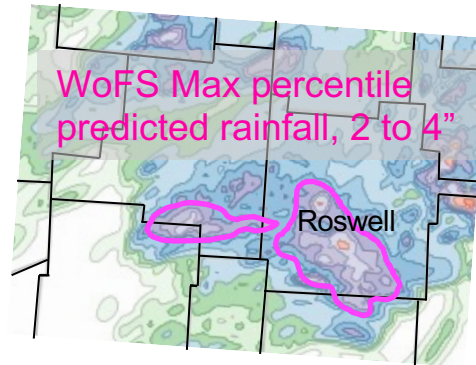


Demonstrated Real-World Lead Time for Flash Flooding



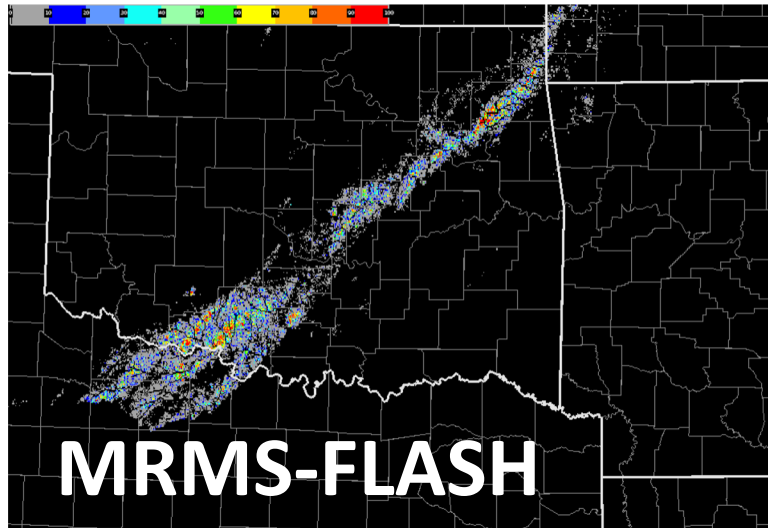
May 27, 2021
Norman, OK Forecast Office:
Average warning lead time 53 minutes
“1-3 hour rain forecasts from WoFS increased confidence for high-end rainfall of 4 to 5 inches, *directly influenced warning decisions.*”

May 30, 2021
Albuquerque, NM Forecast Office:
“*There’s zero doubt we would have had a better handle on the magnitude... and increased lead time” (with WoFS)*”

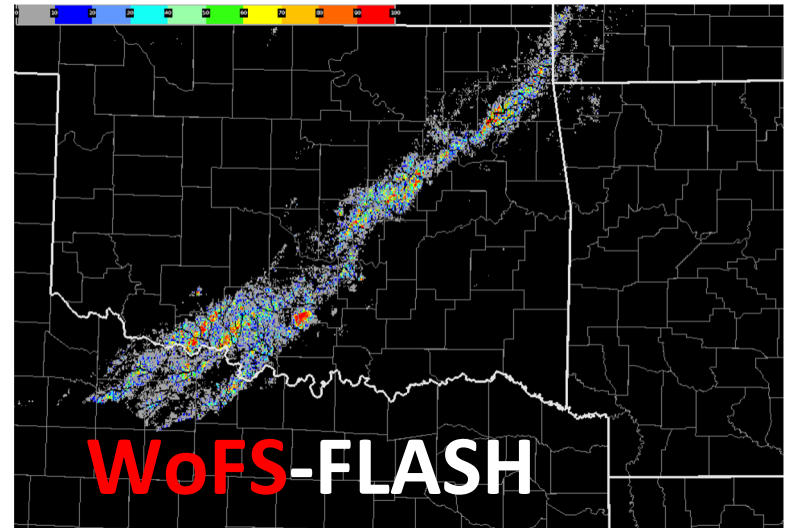


WoFS Unlocks Lead Time for Explicit Water Forecasts

Observations Only



WoFS predicted precipitation as forcing



Probability of Receiving Flash Flood Reports (Yussouf et al., 2020)

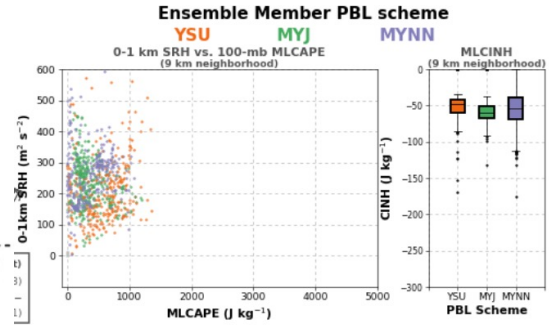
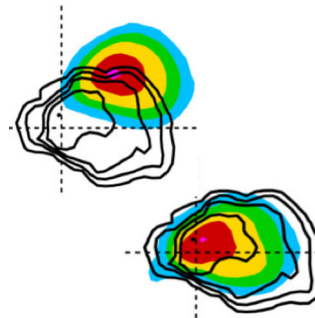
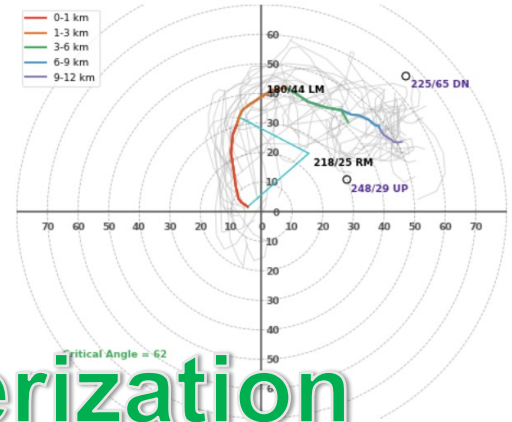


The Quality of the NSSL Approach

Process Studies Inform...

Data Assimilation

& Physical Parameterization



The Quality of the NSSL Approach

Users and Verification inform...

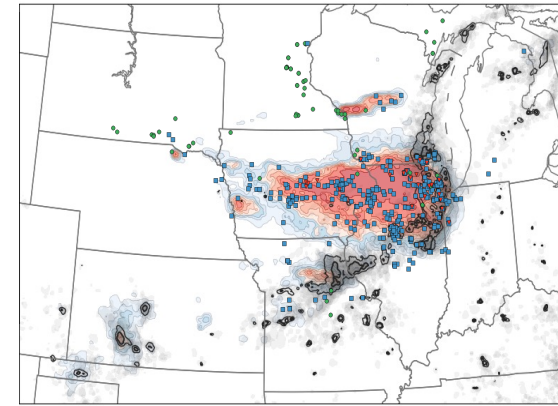
Innovative Products, Strategies

Efficient Operations



Verif. Neighborhood	Threshold (dBZ)	Composite Radar Reflectivity					
		1-Hr	2	3	4	5	6-Hr
3 km	30	▲	▲	▲	▲	▲	▲
	40	▲	▲	▲	▲	▲	▲
	45	▲	▲	▲	▲	▲	▲
	50	▲	▲	▲	▲	▲	▲

Storm-scale ensemble scorecard



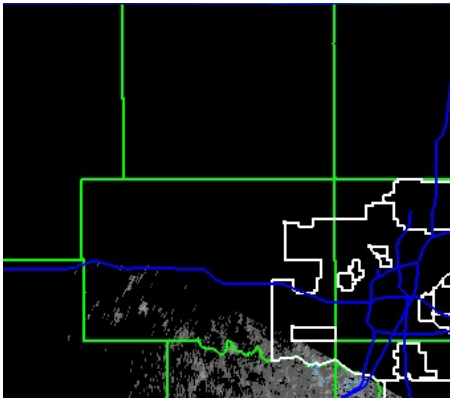
'20 Midwest Derecho – WoFS probability of 50 knot winds, reports overlain



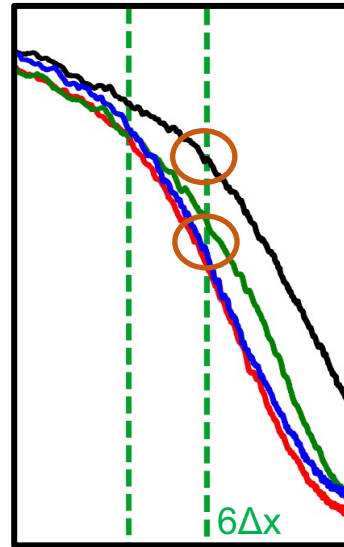
Our Approach Keeps us on the Cutting Edge

Designing and assimilating new data

- Phased Array Radar
- Unoccupied Aircraft Systems
- Boundary Layer Profilers
- Satellites



FV3 model core for storm scale

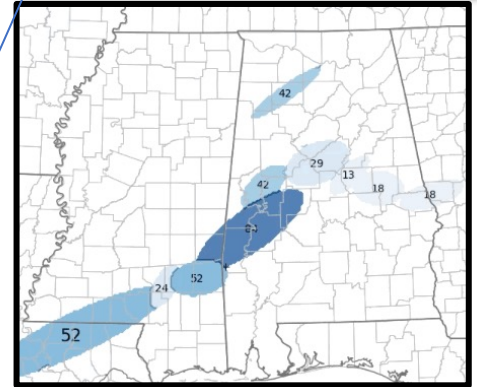
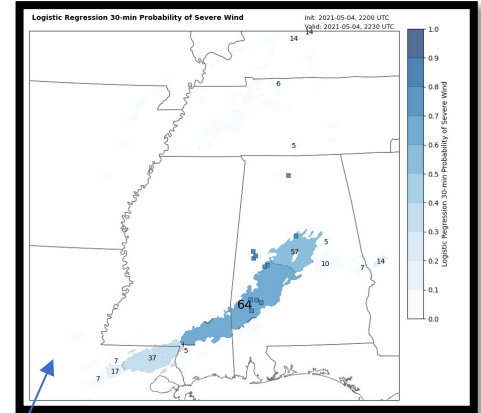
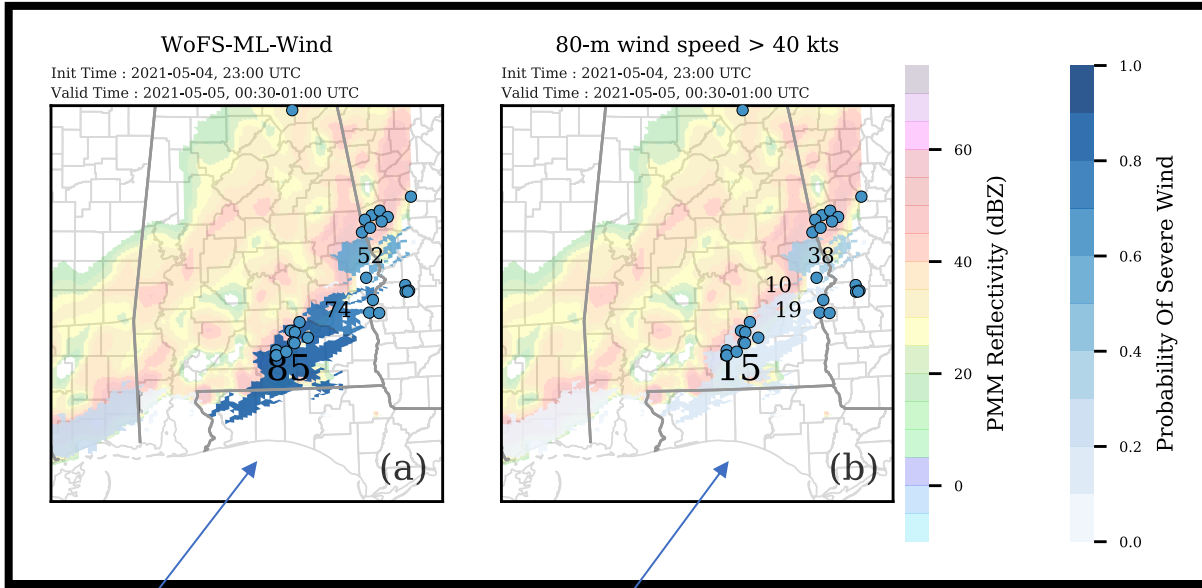


- NSSL, GSL leading the charge to improve FV3 at convective scales
- NSSL 2-moment microphysics going into the Common Community Physics Package
- Convective scale developmental work to benefit the Unified Forecast System

Vertical kinetic energy spectra reveal current FV3 models have lower effective resolution than HRRR model



Machine learning translated to real-world



Baseline, calibrated probabilities

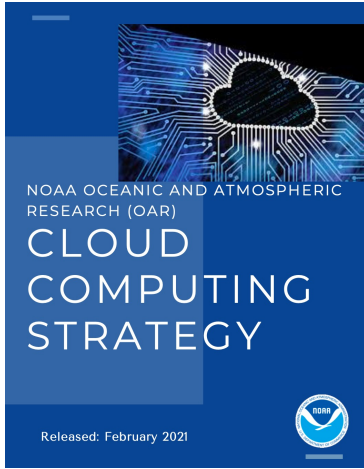
Machine learning-based probabilities

(Flora et al. 2021)

Users helping explore different visualizations of storm objects



Research Priorities through 2025



A WoFS scientist sits with a forecaster during warning operations

- **OAR/NWS Transition Plan**
 - Real-time runs on the cloud
 - Developing workflows, training, HPC logistics
 - WoFS in AWIPS
 - WoFS in teamwork with the Unified Forecast System (UFS)
 - FV3 model core, JEDI data assimilation
- **Calibrated Probabilistic Output**
 - Based on machine learning
 - Bridging across scales to develop verification for probabilistic hazard information in the watch-to-warning time frame
- **Begin Next Generation WoFS**
 - Exploring 1km (or less) grid spacing





Lou Wicker



Katie Wilson



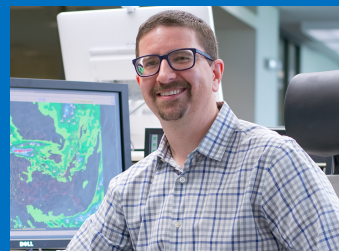
Pat Skinner



Nusrat Yussouf



Joshua Martin



Patrick Burke

And now discussion with the WoF panel



Revolutionizing Severe Storm Warnings

PROGRAM LEADS



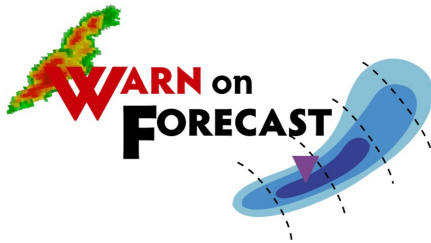
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