

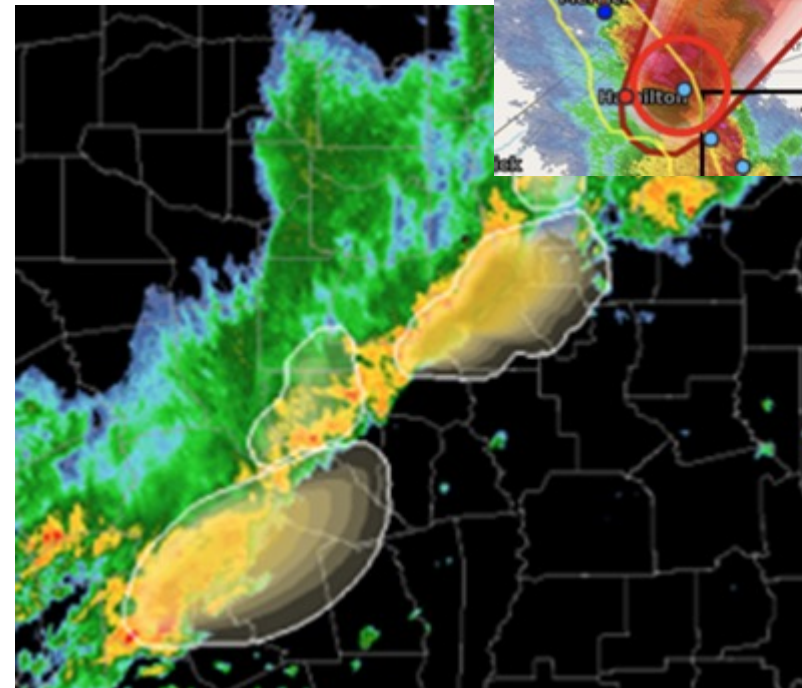
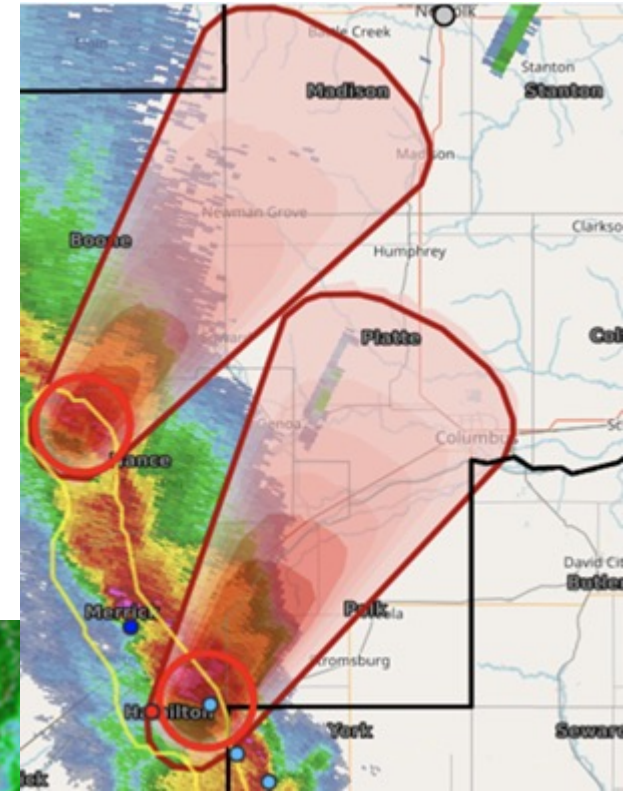


# Advancements in Forecaster-Generated Probabilistic Hazard Information (PHI) for Severe Weather Warnings

CIWRO Workshop  
on Forecast Applications Improvements

Sept. 30, 2022

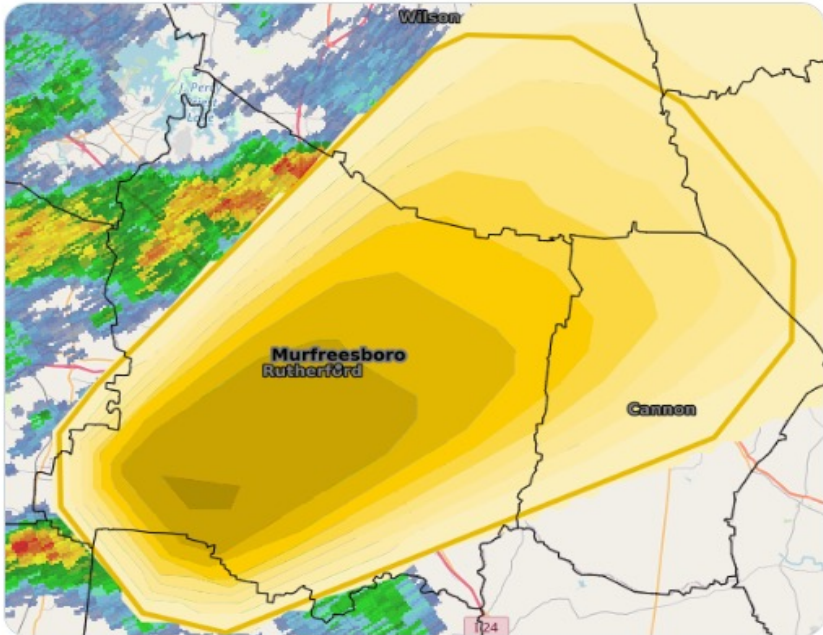
Adrian Campbell, Kristin Calhoun, Thea Sandmael, Clarice Satrio, Rebecca Steeves, Pat Hyland, Justin Monroe, Jonathan Madden, David Hogg, Taylor DeWinter, and Kodi Berry





**HWT\_PHI** @hwt\_phi · 5m

1.5 inch hail and 60 mph winds likely across Rutherford County where a Severe Thunderstorm Warning is in effect until 615 PM. Darker colors indicate higher chances for large hail and damaging winds. #LZK



What is PHI?

# Probabilistic Hazard Information



## More Specific Regarding Time and Location

Provides time of arrival and departure as well spatial coverage of threat.



## Provides defined uncertainty of the threats (temporal, spatial, intensity)

Allows for longer lead-times, though with higher uncertainty.



## Updates continuously as weather changes

Can reflect changes in storm motion, intensity, and evolution immediately.

PHI

# Hazardous Weather Testbed Experiments

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## Developers, Subject-Matter Experts, and Forecasters Together

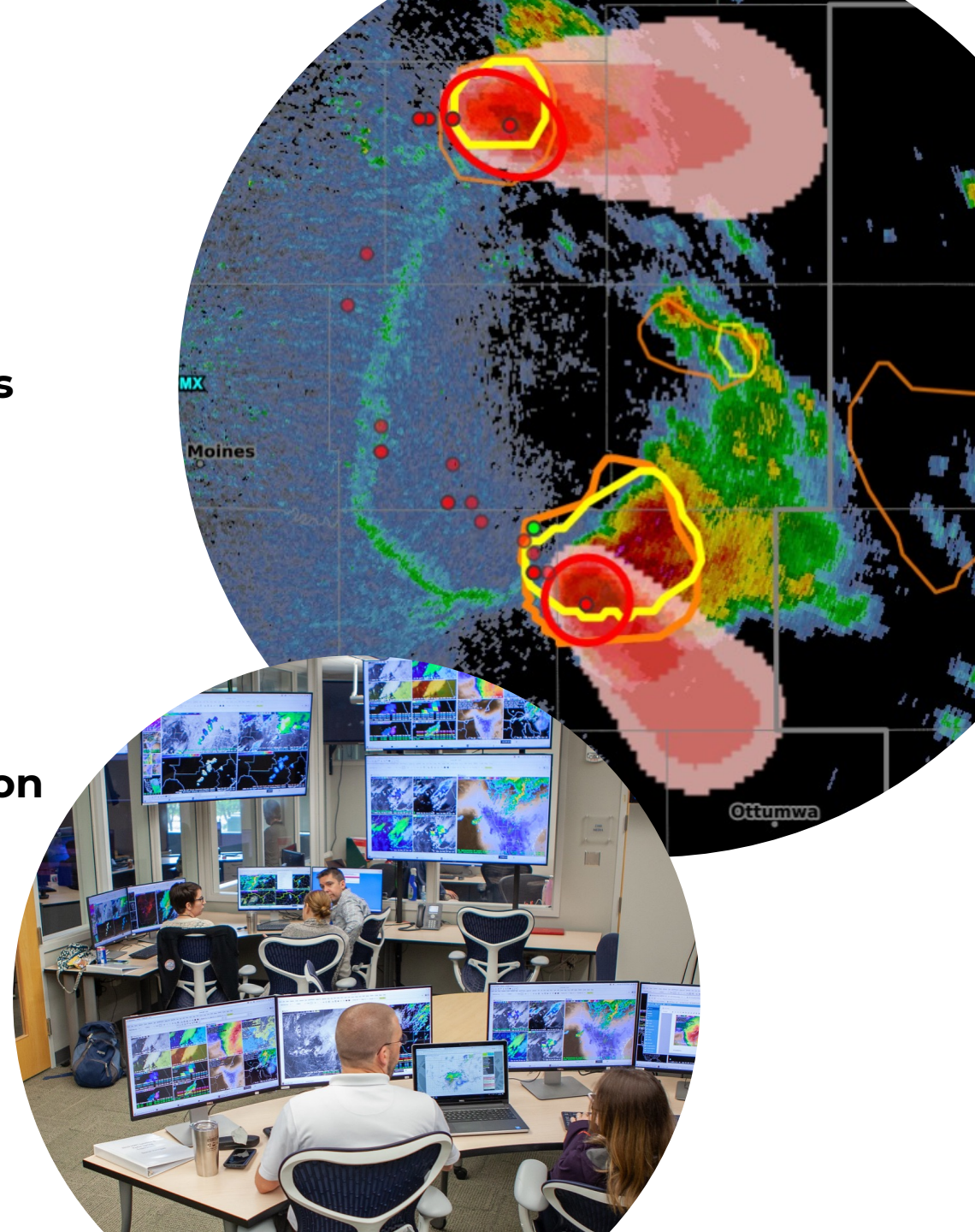
Provide direct feedback on the strengths and limitations of concepts.

Offer insights to better meet needs of operations.

## Test and review automated guidance for PHI Creation

Forecasters were provided various AI-Machine Learning guidance for probability of tornado, severe (hail/wind), and lightning.

Web tools and AWIPS were used for storm interrogation and PHI / warning creation across a variety of storm modes and locations.

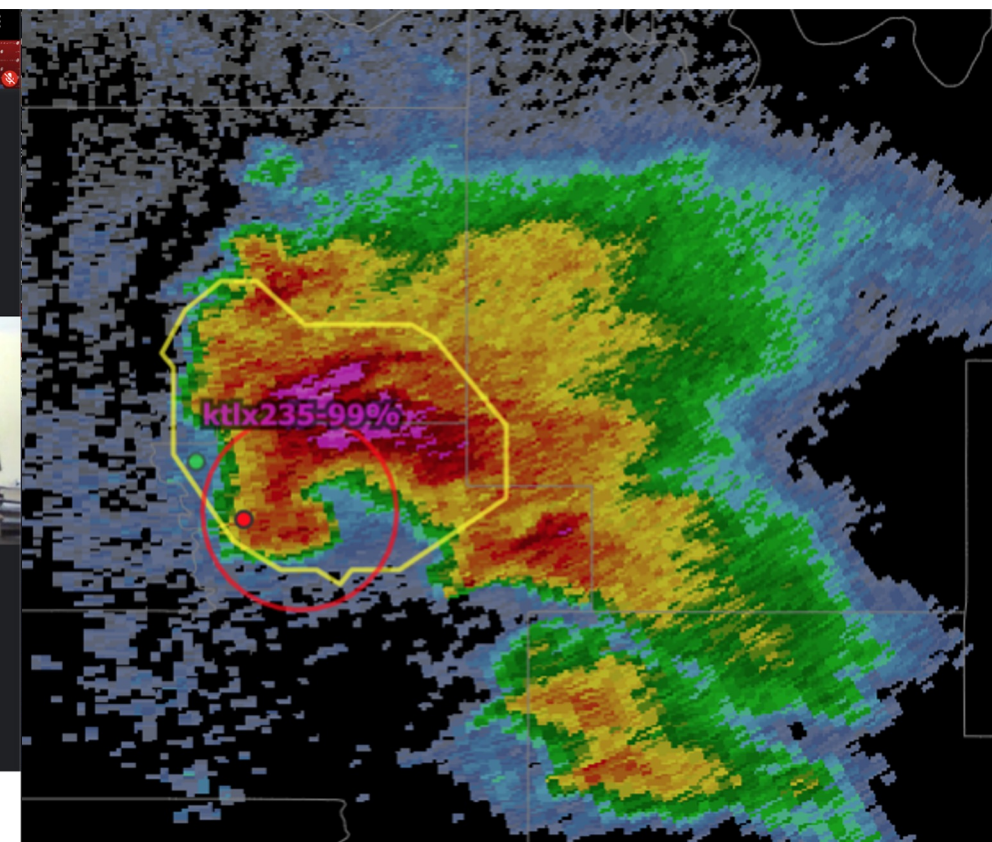
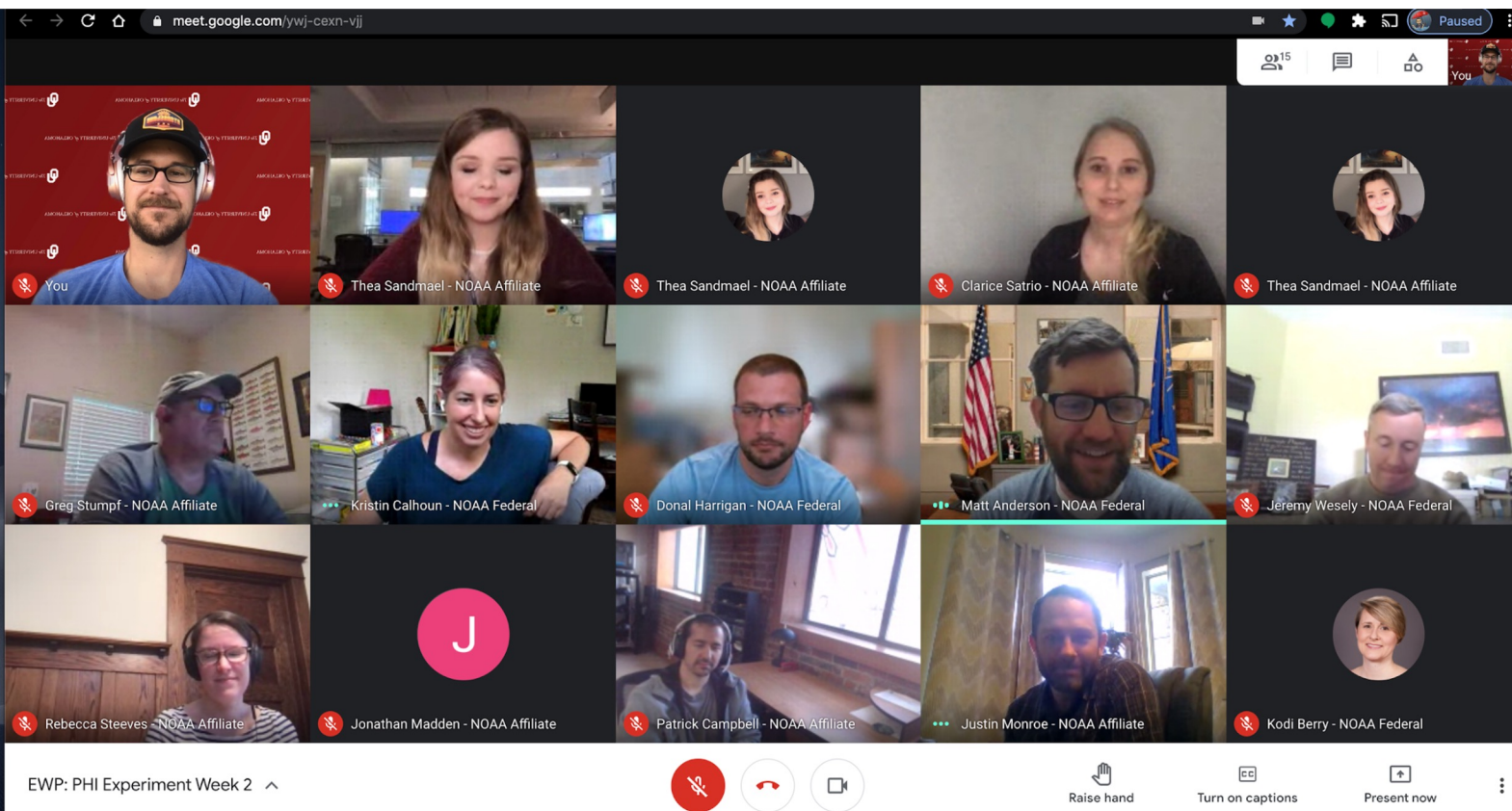


# Virtual Experimental Warning Program: Google Meet(s) + AWIPS and the PHI tool in the cloud... forecasters at home or remote desktop in the office.

**Monday:** Training and hands-on concepts and best practices

**Tues-Thurs:** Morning - archive case; Afternoon - live wx (or if that was a bust - another case)

**Friday:** Discussion



Object characteristics

Hazard-storm object  
(automated or user created)

Hazard Strike Probabilities

**NSSL Prototype Probabilistic Hazard Information (PHI) Tool**

Product: Reflectivity    Opacity: 85% 0% 100%    T: 1/0/0/0    S: 0/12/0/18    L: 0/0/0/0    Site: KTLX

**Hazard Information**

PHI Configuration    Object History    Settings

ID/Start Time: 3 22:58:03 UTC  
 Hazard: Tornado  
 Severity: Radar Indicated Catastrophic

Motion/Duration: 254 @ 24 kts for 60 minutes  
 Direction Uncertainty: 15 °  
 Speed Uncertainty: 8 kts  
 Turning Options

Reset Motion Changes

Guidance: Peak Shear: kts    ProbTor  
 Trend Interpolation: Draw Linear Exp1 Exp2 Bell +5 -5  
 Obs    UNDO REDO    Grid Preview

**Estimated Probability of Tornado Occurrence**

Minutes from Current Time

Storm State:  Steady State     Evolving    Keep Alive  
 Estimated probability graph will not change with the passage of time.

Discussion: Clear

**Hazard Services Console**

Time: 06 May 2015 22:59:10 Z    Slider: 06 May 2015 22:58:03 Z    Resume Simulation

ID	Hazard	State	Probability	Forecaster	Time Issued	Start Time	End Time	Time Left	Time Last Modified
m62143	Severe	Issued	94	pac	06-May 22:45 Z	06-May 22:56 Z	06-May 23:56 Z	57 min. 27 sec.	14 min. 0 sec.
M3	Tornado	Updating	100	pac	06-May 22:58 Z	06-May 22:55 Z	06-May 23:58 Z	56 min. 38 sec.	3 min. 9 sec.
m63661	Severe	Issued	24	PHI	06-May 22:56 Z	06-May 22:56 Z	06-May 23:56 Z	57 min. 27 sec.	
m63535	Severe	Issued	85	PHI	06-May 22:56 Z	06-May 22:56 Z	06-May 23:56 Z	57 min. 27 sec.	
m62759	Severe	Issued	28	PHI	06-May 22:56 Z	06-May 22:56 Z	06-May 23:56 Z	57 min. 27 sec.	

Hazard Strike Probabilities

List of all hazards

Environ/radar controls

## 2021 PHI Experiment

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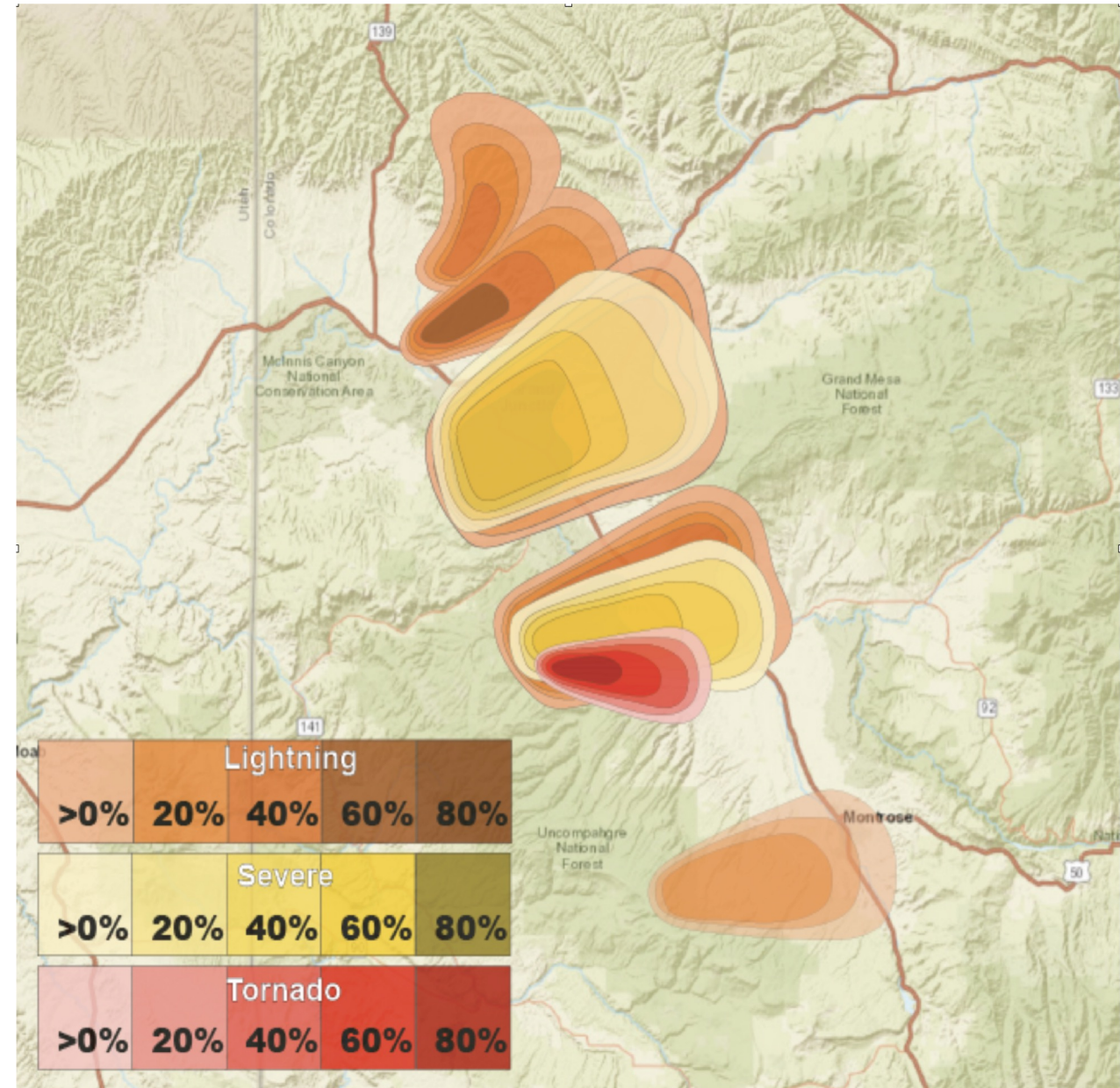
Hazard-based machine learning provides the initial guidance to calibrate PHI for forecasters.

Provides a first guess that the forecaster then manipulates within the PHI tool (web-based) or Hazard Services (AWIPS).

**Lightning** - ProbLightning (Random Forest)

**Severe (wind/hail)** - ProbSevere (Naive Bayesian -Version 2)

**Tornado** - New PHI Tornado Algorithm (PHI-Tor, random forest)



Machine learning/AI algorithms provide the first guess of probability for the forecasters.

- Speeds up object creation
- Calibrates PHI across forecasters

Severe: ProbSevere

Lightning: ProbLightning

Tornado: PHItor

**Estimated Probability of Any Severe Occurrence**

Minutes from Current Time	Estimated Probability (%)
-5	100
0	100
5	100
10	100
15	100
20	100
25	100
30	100
35	100
40	100
45	100
50	100
55	100
60	71

**Hazard Services Console**

ID	Hazard	State	Probability	Forecaster	Time Issued	Start Time	End Time	Time Left	Time Last Modified
ktbx517	Tornado	Automated	41		09-May 21:34:37 Z	09-May 21:07:23 Z	09-May 22:19:37 Z	41 min.	
ktbx440	Tornado	Automated	20		09-May 21:34:37 Z	09-May 21:34:37 Z	09-May 22:19:37 Z	41 min.	
ktbx388	Tornado	Automated	20		09-May 21:32:43 Z	09-May 21:32:43 Z	09-May 22:17:43 Z	39 min.	
784	Severe	Automated	6		09-May 21:34:40 Z	09-May 21:34:40 Z	09-May 22:34:40 Z	56 min.	
783	Severe	Automated	6		09-May 21:34:40 Z	09-May 21:34:40 Z	09-May 22:34:40 Z	56 min.	

ProbSevere (NOAA/CIMSS): Currently Naïve Bayesian (v2) and moving to gradient boosted tree (v3) – more reliable probs for wind and marginal events.

Forecasters typically add buffer for areal coverage, change storm motion, and modify probability depending on local storm reports, storm mode, and environment.

# Machine learning/AI algorithms provide the first guess of probability for the forecasters.

- Speeds up object creation
- Calibrates PHI across forecasters

Severe: ProbSevere

Lightning: ProbLightning

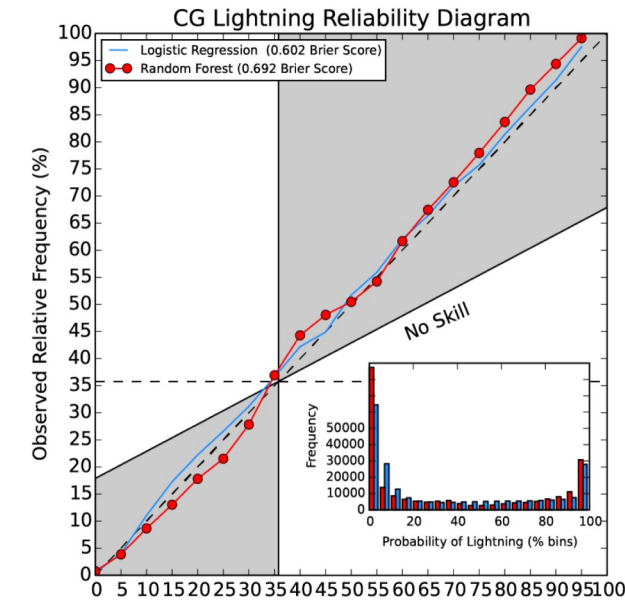
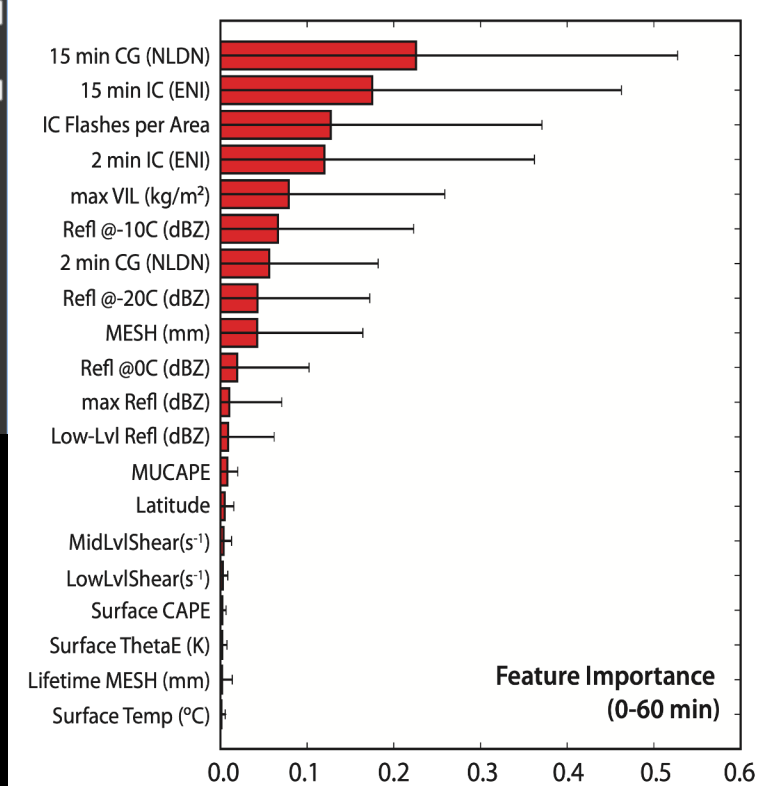
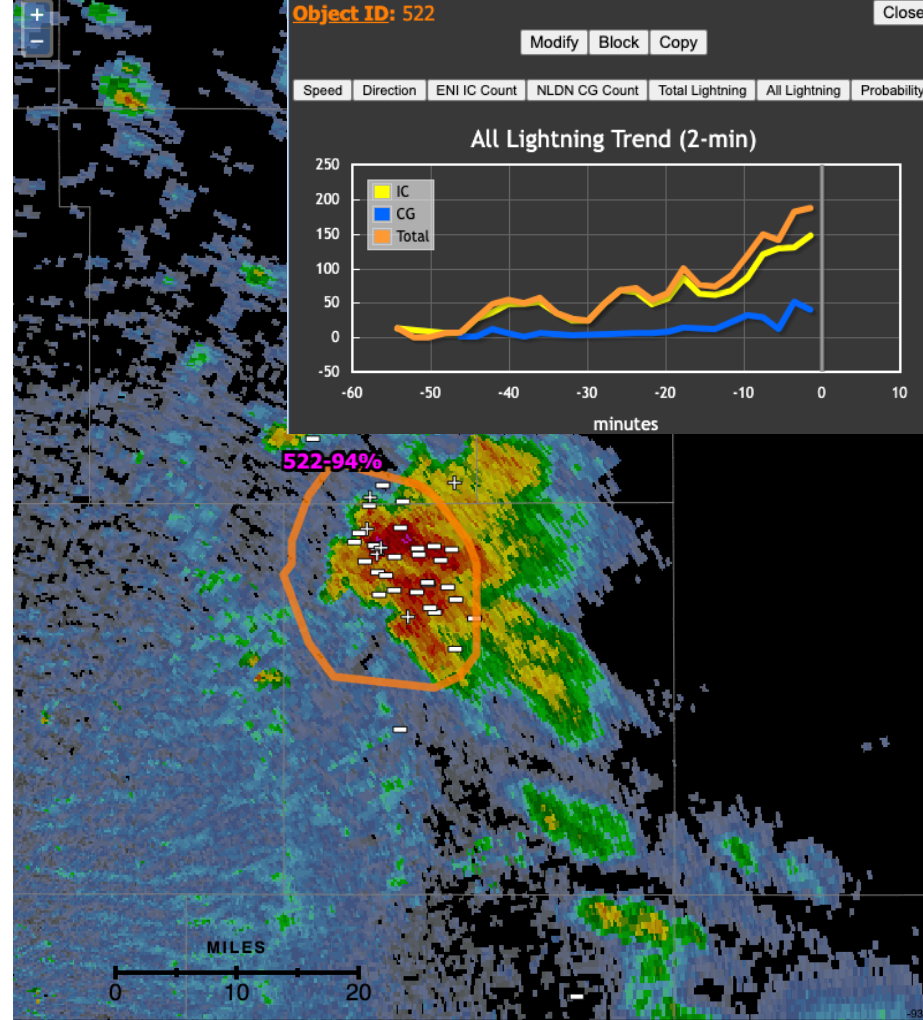
Tornado: PHItor

Storm-based Random Forest with data from lightning detection networks, MRMS, environment.

Tuned for CONUS or individual NWS regions and 15 min intervals out to one hour.

**Emergency Managers loved the new information:**

*“The objects themselves make me feel more confidence. Usually just getting the actual lightning strikes. Everything used to be reactionary, this is more proactive.”*





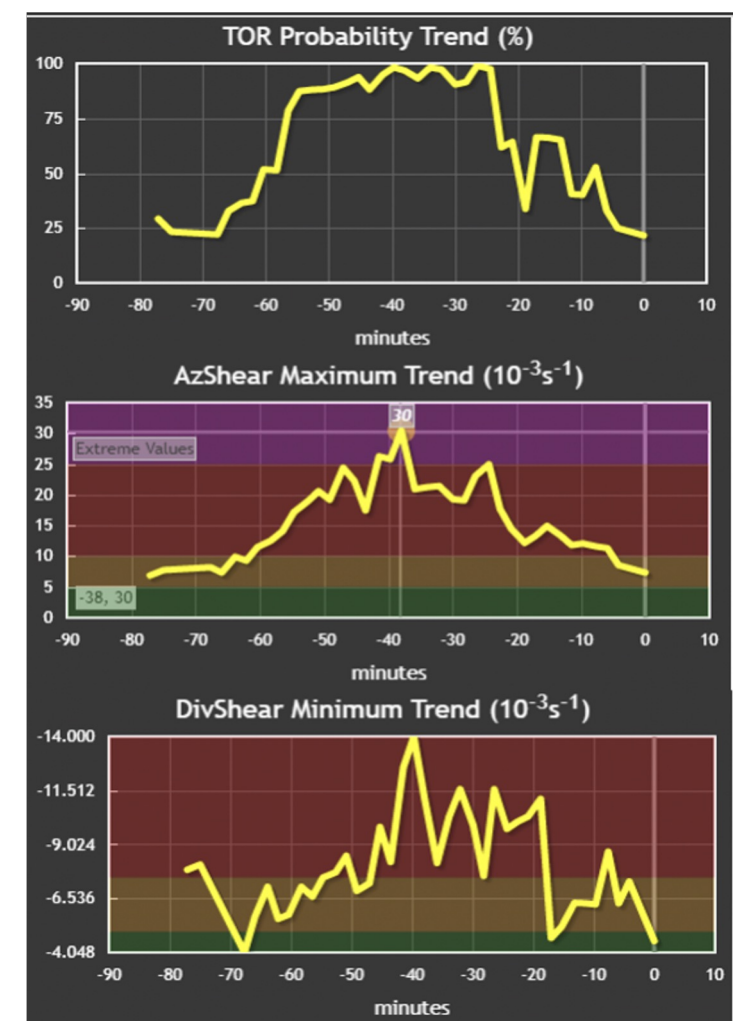
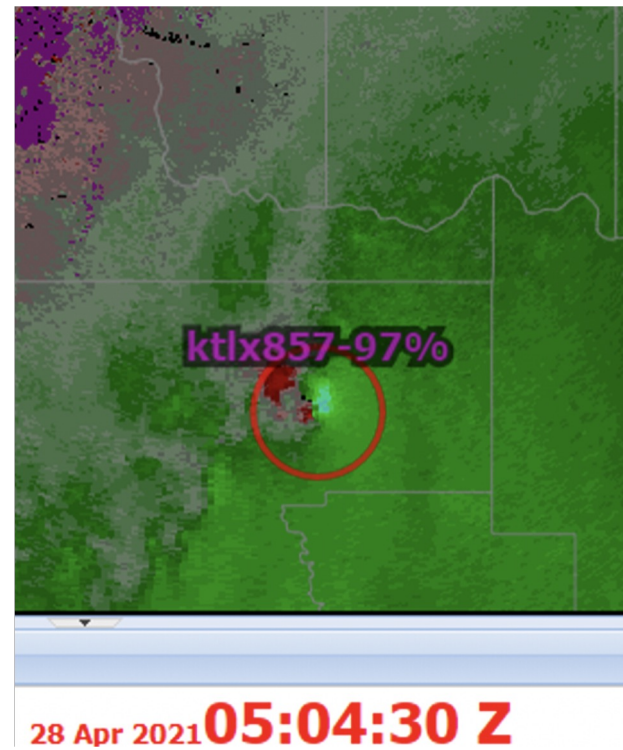
Machine learning/AI algorithms provide the first guess of probability for the forecasters.

- Speeds up object creation
- Calibrates PHI across forecasters

Severe: ProbSevere

Lightning: ProbLightning

**Tornado: PHItor**



Random forest using data extracted from a 2.5-km radius centered on nearest AzShear max.

- velocity, spectrum width, polarimetric values
- $0.5^\circ$ -tilt single-radar
- Rotation max, min, and percentiles
- Range from radar

Hazard Information

PHI Configuration Object History Settings Legend

related parameters for that location.

ID/Start Time: 327334 21:36:13 UTC

Hazard: Total Severe

Severity: Radar Indicated 1.5 in. 70 mph

Motion/Duration: From 22 @ 12 kts for 5 minutes

Direction Uncertainty: 15°

Speed Uncertainty: 8 kts

Turning Options

Turn Left Turn Right at angle of 45°

From 20 min to 55 min

Dir. Uncertainty (Left): 30°

Dir. Uncertainty (Right): 12°

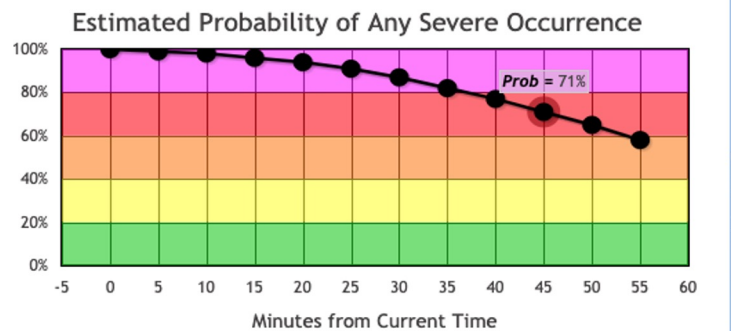
from Automation

Object Shape/Pos: Buffer: 5 km Offset X: 0 km Dir: -1° Offset Y: 0 km

Guidance: ProbSevere ProbHail ProbWind ProbTor

Trend Interpolation: Draw Linear Exp1 Exp2 Bell +5 -5 Obs

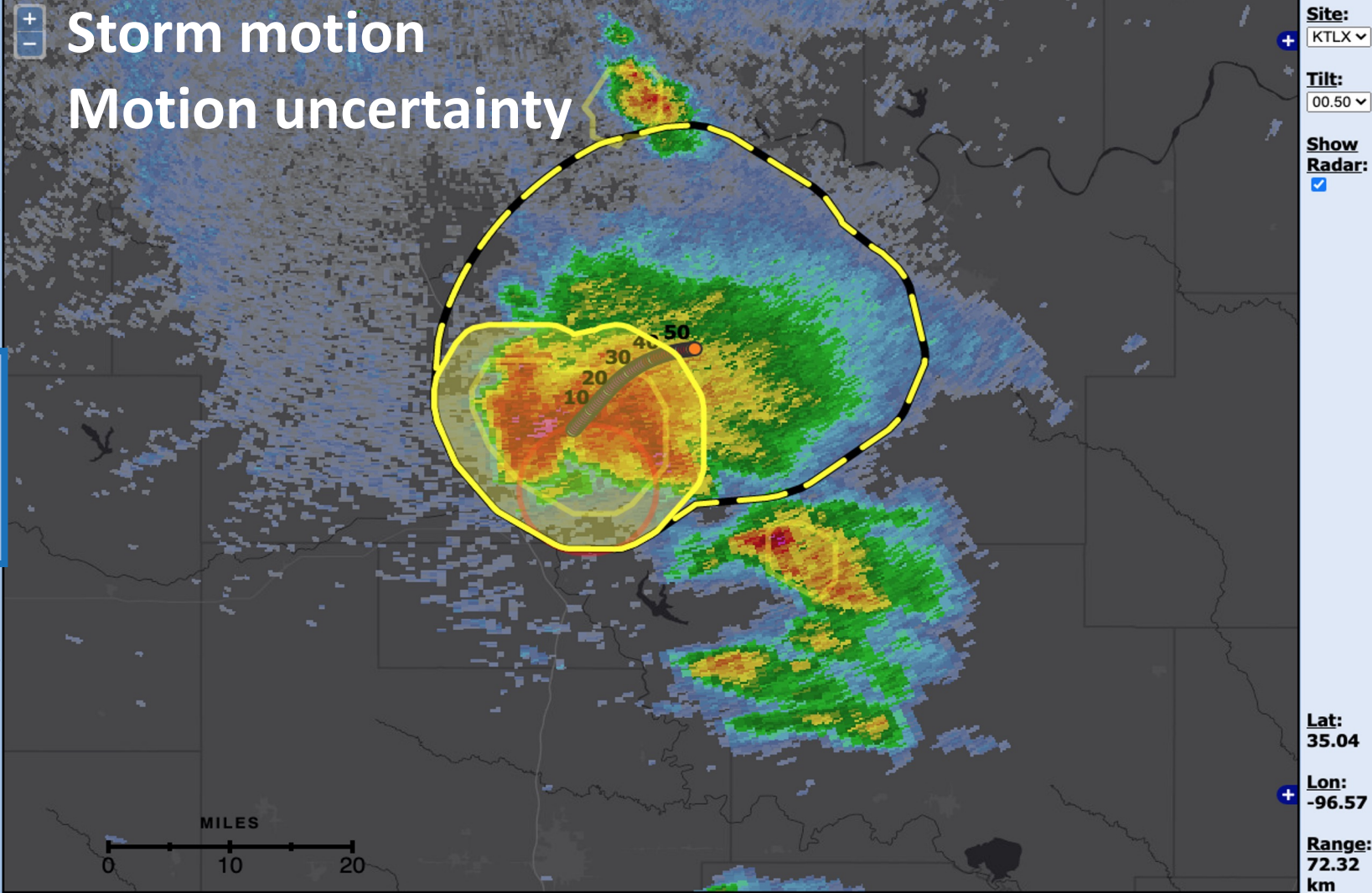
Grid Preview



Storm State:  Steady-State  Evolving

Estimated probability graph will not change with the passage of time.

Discussion:



Hazard Services Console

Time: 09 May 2016 21:38:49 Z Slider: 09 May 2016 21:36:13 Z

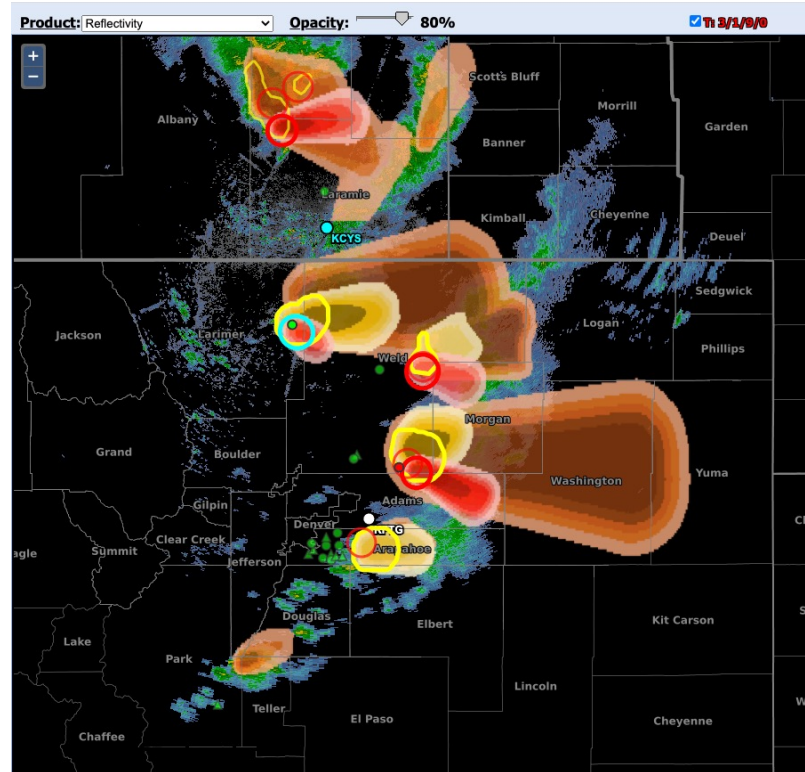
ID	Hazard	State	Probability	Forecaster	Time Issued	Start Time	End Time	Time Left	Time Last Modified
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# Forecaster Workload and Task Management

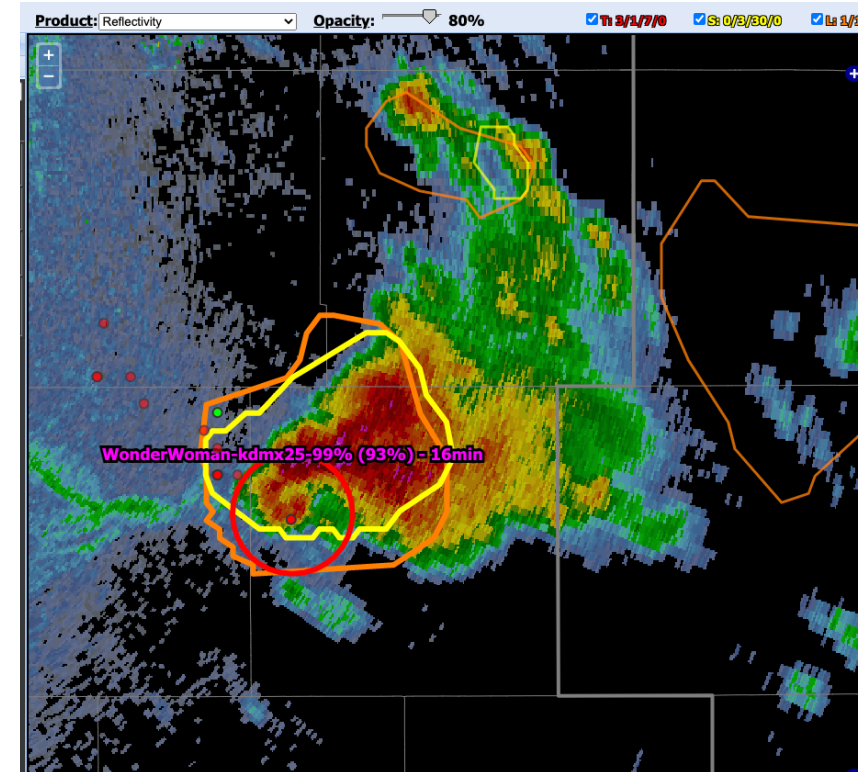
We tested how forecaster workload changed when working multiple hazards over a small area (1-2 storms) vs working a single hazard over a larger domain (e.g., county-warning area).

The choice was sometimes pre-determined (archive cases) and sometimes made via discussion depending on the expected storm mode and coverage (live events).

**Single Hazard (Tor, Svr, or Ltg)**  
(large area, as many storms as necessary)



**Multiple Hazards (Tor, Svr, & Ltg)**  
(small area, 1-2 storms)



Hazard type	Severe	Tornado	Lightning
No. of objects	8.67 (2.94)	7.75 (4.06)	10.33 (2.62)
No. of updates	14.67 (7.35)	15.75 (10.0)	22.67 (4.69)
Updates per object	1.69 (2.5)	2.03 (2.47)	2.19 (1.79)
Avg time per update (s)	196.64 (105.29)	139.22 (113.39)	105.96 (94.57)
Freq of update (min)	28.34 (18.09)	18.15 (10.81)	16.63 (19.12)

Single (All) hazards

## 2022 PHI Experiment Goals



### Test warning creation using PHI

Forecasters may first see PHI as “guidance” for warnings (either automated or forecaster created).



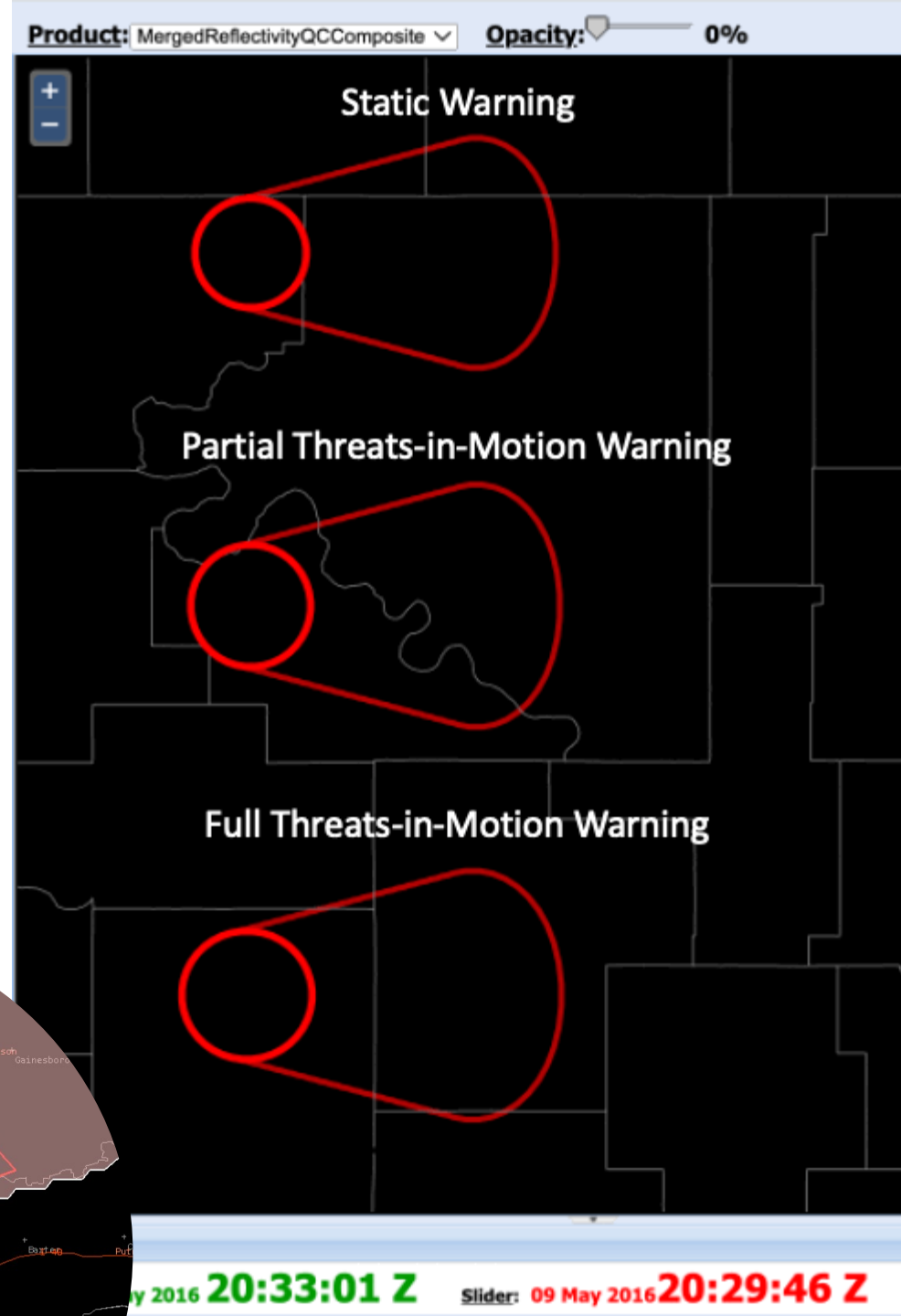
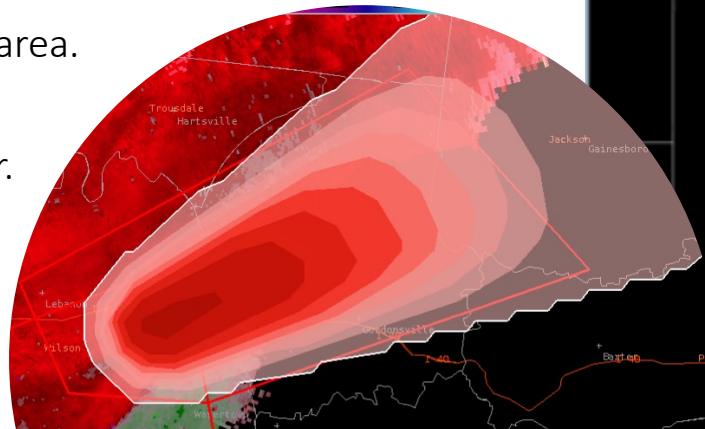
### Test PHI creation with warning generation together

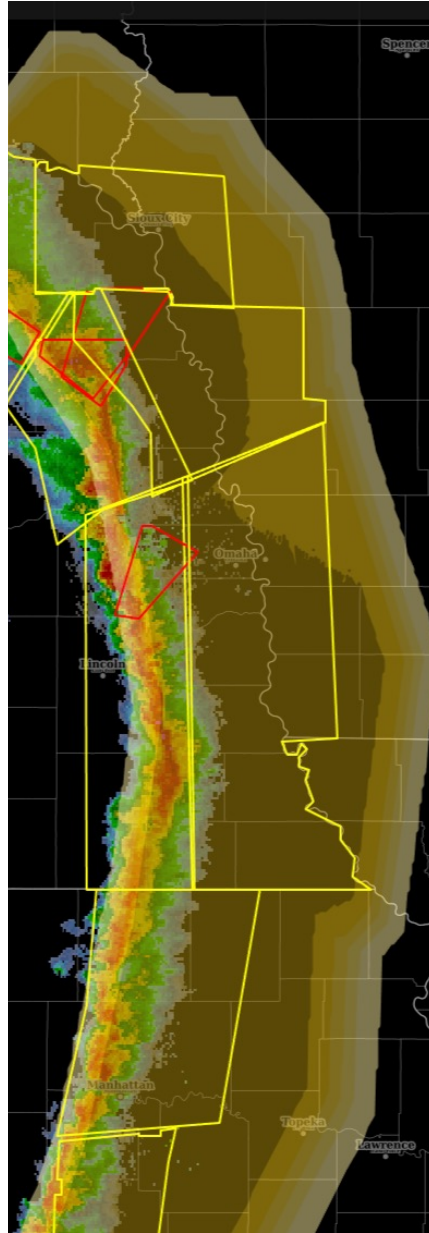
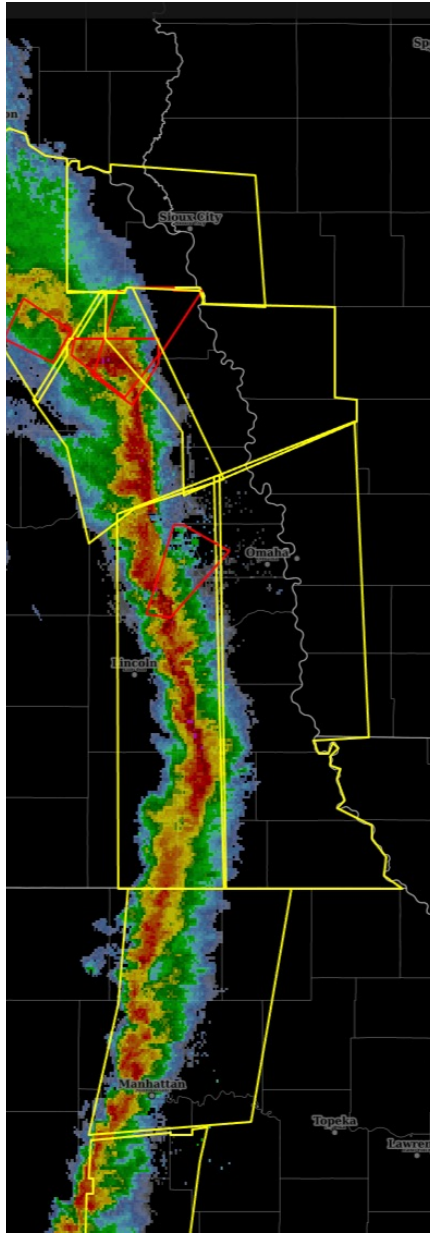
Blending Threats-In-Motion (TIM) concepts with PHI.  
Forecasters could choose conventional (static) warnings or partial TIM or full TIM.



### Test Communication (internally & externally)

Between forecaster pairs in same office area.  
When handing off PHI objects/warnings.  
Externally through NWS chat and Twitter.

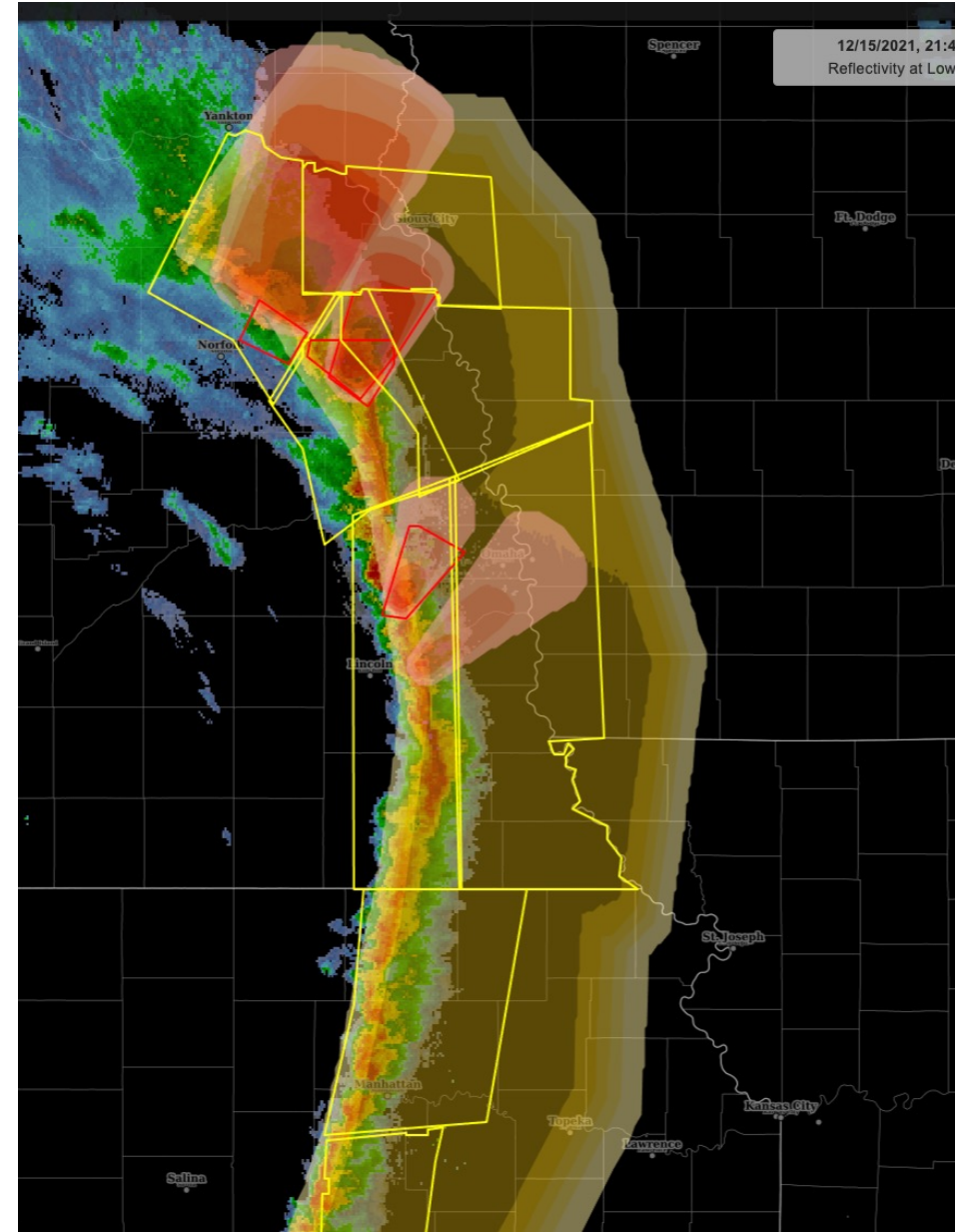


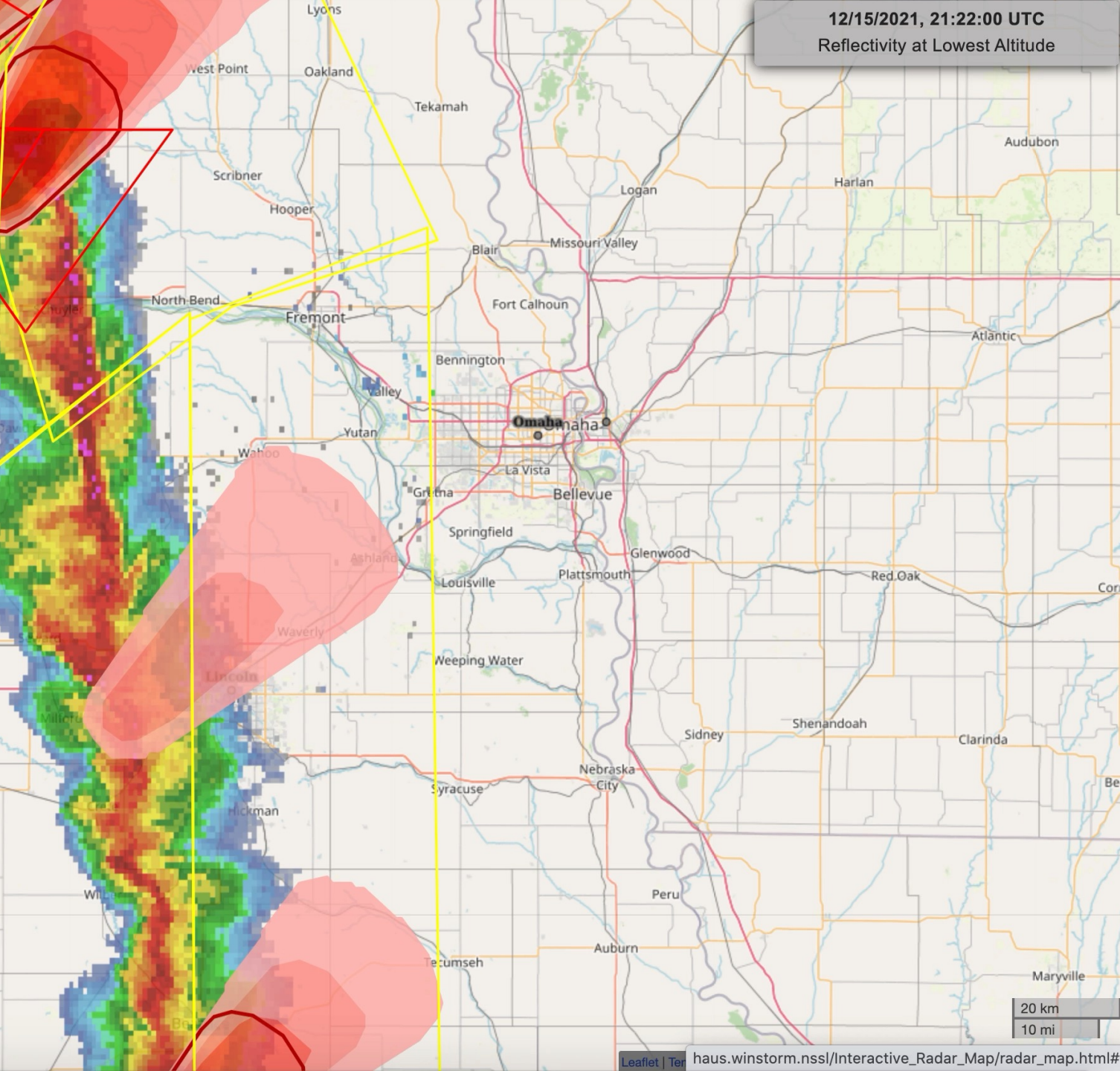


## Warnings and PHI

Warnings are  
necessary decision  
points for a variety  
of end users.

PHI could provide  
additional lead  
time and  
continuity.





# Warnings



What are we communicating with warnings alone?

What additional information does PHI provide for decision-makers?

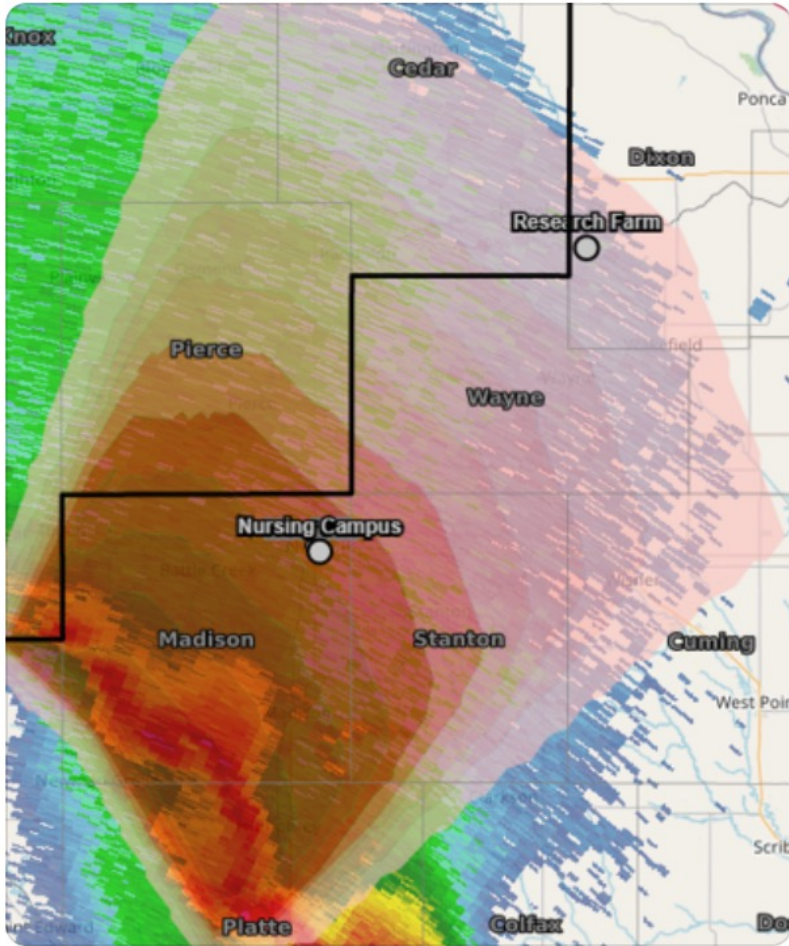
For the public?



**Matthew K** - NOAA Federal 11:20 AM

Storm approaching Nursing Campus in the next 15-25 min poses a high-end severe risk. Strong wind and tornadoes possible

image.png ▾



**David Hogg** 11:21 AM

Thanks. We have instructed students/staff/faculty to shelter there. If I receive any damage reports, I'll pass those along to you.

Testing

# Communication

**Forecasters always noted they had the highest workload when doing communication**

Balancing both specific end-user questions and creating public-facing graphics more demanding than warning decisions and/or PHI creation.

**Loved the ability to share Tornado PHI**

Forecasters commented multiple weeks it was a visual option for the “tornado possible” tag on a severe warning.

**Forecasters deeply want more social science research to confirm people can understand PHI**

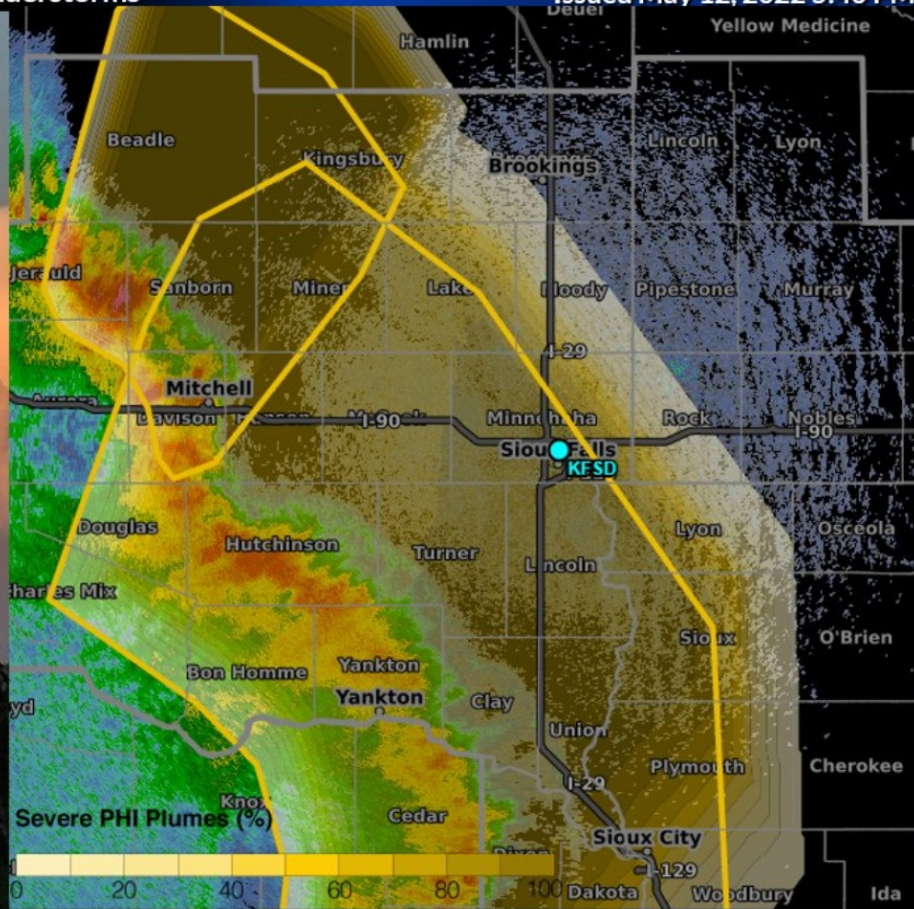
Majority of forecasters were initially hesitant to create public graphics with PHI shown.

# Dangerous Severe Winds

Hurricane force winds expected along the squall line of thunderstorms

Weather Forecast Office  
\*\*TEST HWT\*\*

Issued May 12, 2022 5:40 PM EDT



## THINGS TO KNOW

### TIMING

NOW through 10 PM CDT

### HAZARDS

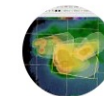
- ✓ Severe wind gusts of 90+ mph
- ✓ Golf ball size hail
- ✓ Risk of isolated tornadoes

### REMEMBER



Be weather aware!  
Have multiple ways to receive watches or warnings.

Continue to monitor this unfolding severe weather situation!



HWT\_PHI  
@hwt\_phi

4:40 pm CDT: Hurricane force winds of 90+ mph are expected along this squall line of thunderstorms as it moves northeast across the area.

Have multiple ways to receive warnings and seek shelter in a sturdy structure if a warning is issued for your location! #fsd

4:44 PM · May 12, 2022 · Twitter Web App

1 Quote Tweet



Tweet your reply

Reply



# Forecaster-driven development

## ⚡ Additional guidance at longer lead times

Forecasters want “forecast” probabilities not just current observational probabilities to begin to address watch-to-warning gap. Need to combine AI/ML with high-resolution convective-allowing models.

## 🔗 Blend Warn-on-Forecast

Initially include WOF into the PHI tool while also developing blended guidance.

## 🐦 Test end-user (and public) decisions with PHI

Additional experiments with Emergency Managers and Broadcast Meteorologists.

Surveys and Focus Groups with Public.

Member 14 Simulated Composite Reflectivity (dBZ)  
Member 14 2-5 km Updraft Helicity ( $m^2 s^{-2}$ )

Init: 2022-05-02, 2030 UTC  
Valid: 2022-05-02, 2030 UTC

