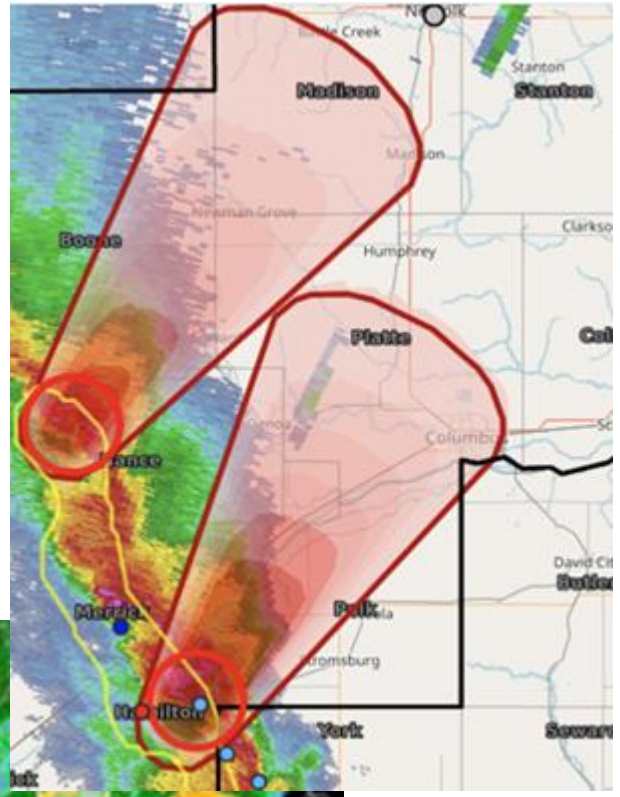
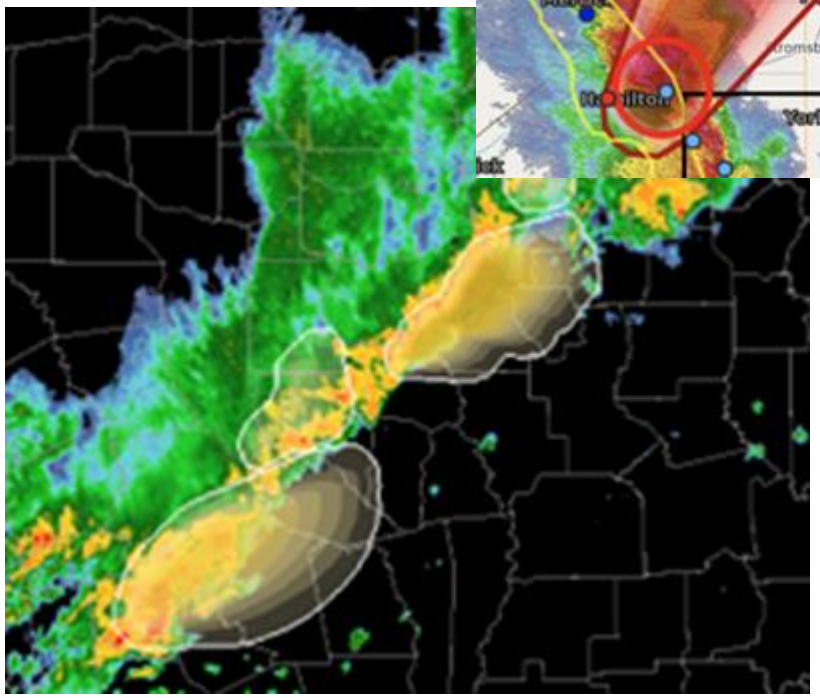
PHI and Related Proposed Advancements in US Severe Weather Warnings





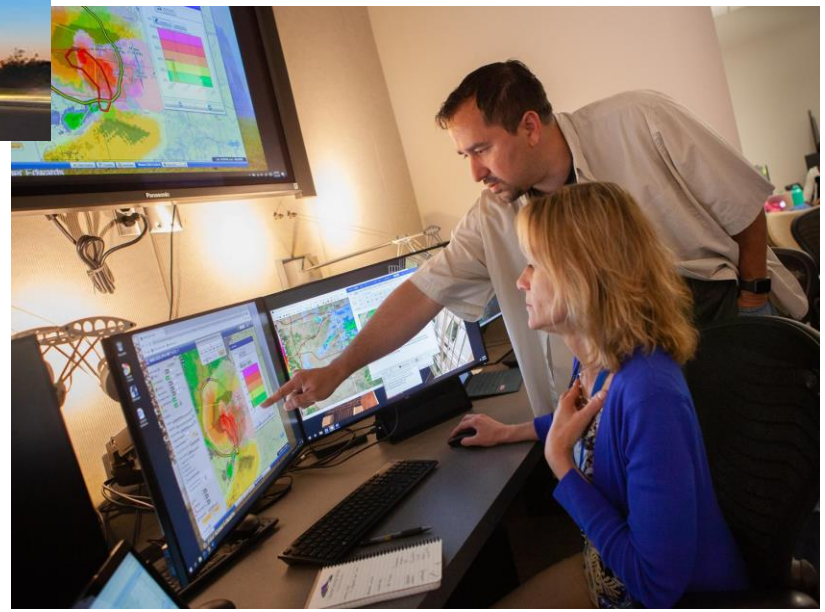
ECMWF UEF 2023

June 7, 2023

Patrick Adrian Campbell, CIWRO/OU/NSSL, Norman, OK;

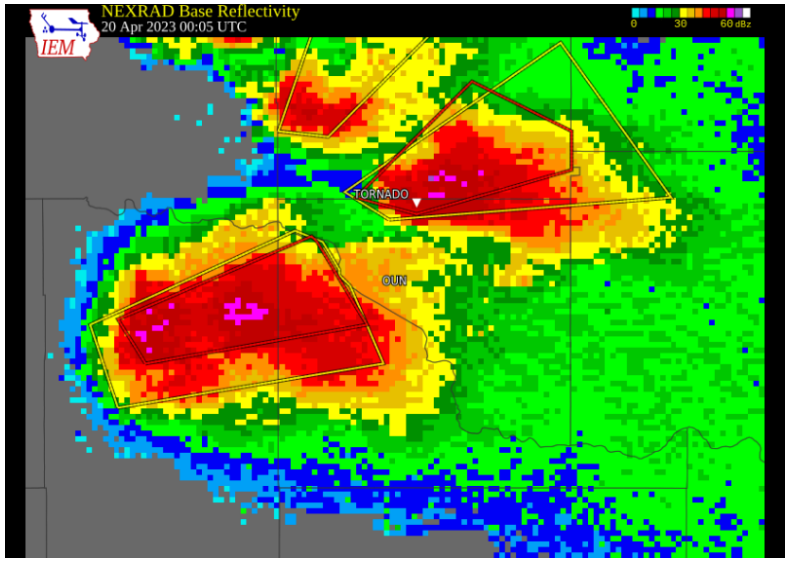
Kristin Calhoun, Thea Sandmael, Clarice Satrio, Pat Hyland, Rebecca Steeves, David Hogg, Taylor DeWinter, Travis Smith, Greg Stumpf, Alyssa Bates, Kevin Manross, and Kodi Berry

Warning Research at National Severe Storms Laboratory (NSSL)



- ❑ Located at US National Weather Center
  - on University of Oklahoma campus in Norman, OK
- ❑ Adjacent to National Weather Service operations
  - Norman Weather Forecast Office
  - Storm Prediction Center
- ❑ Within the NSSL
  - Warning Research and Development Division
  - Hazardous Weather Testbed (HWT)

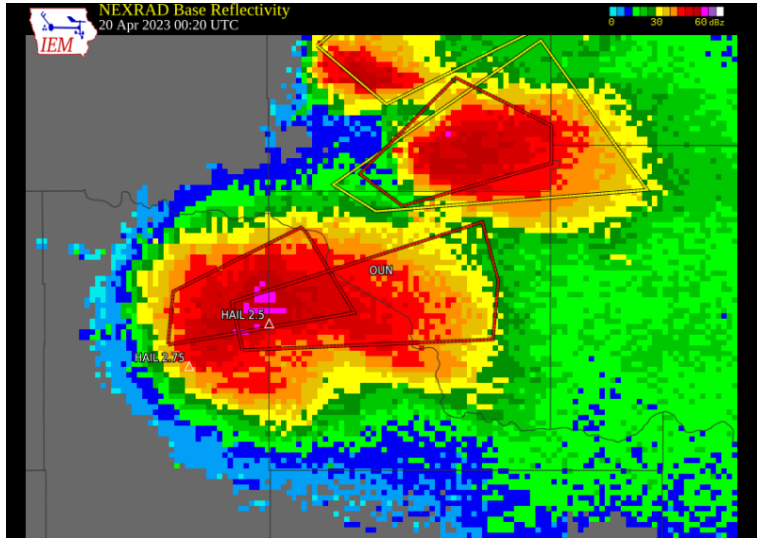
Current Severe Weather Warnings

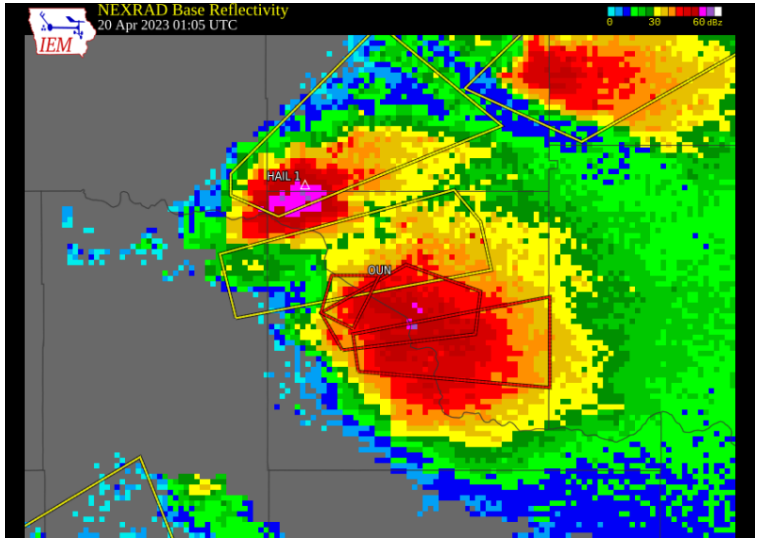


- ❑ Area of threat warnings for hazards
- ❑ Effects of warning:
  - Phone alerts
  - Sirens
  - Event cancellation
  - Weather radio alerts
  - Evacuation
- ❑ Warning benefits:
  - Clear directive to take shelter
  - Leads public, myself included, to take actions that protect lives and property

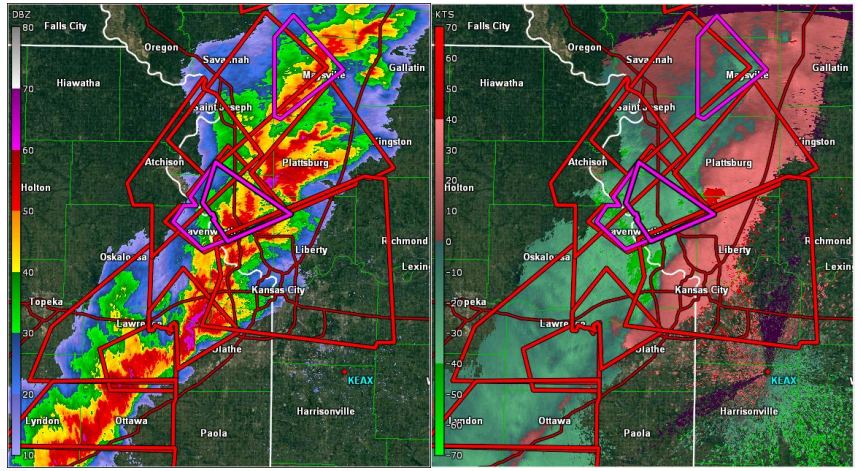
Current Warning Problems

- ❑ Warnings can get messy
- ❑ Why?
  - Warnings defined for area until they expire or are cancelled
  - New warnings placed on top of old
  - Warnings broken up by geographical boundaries



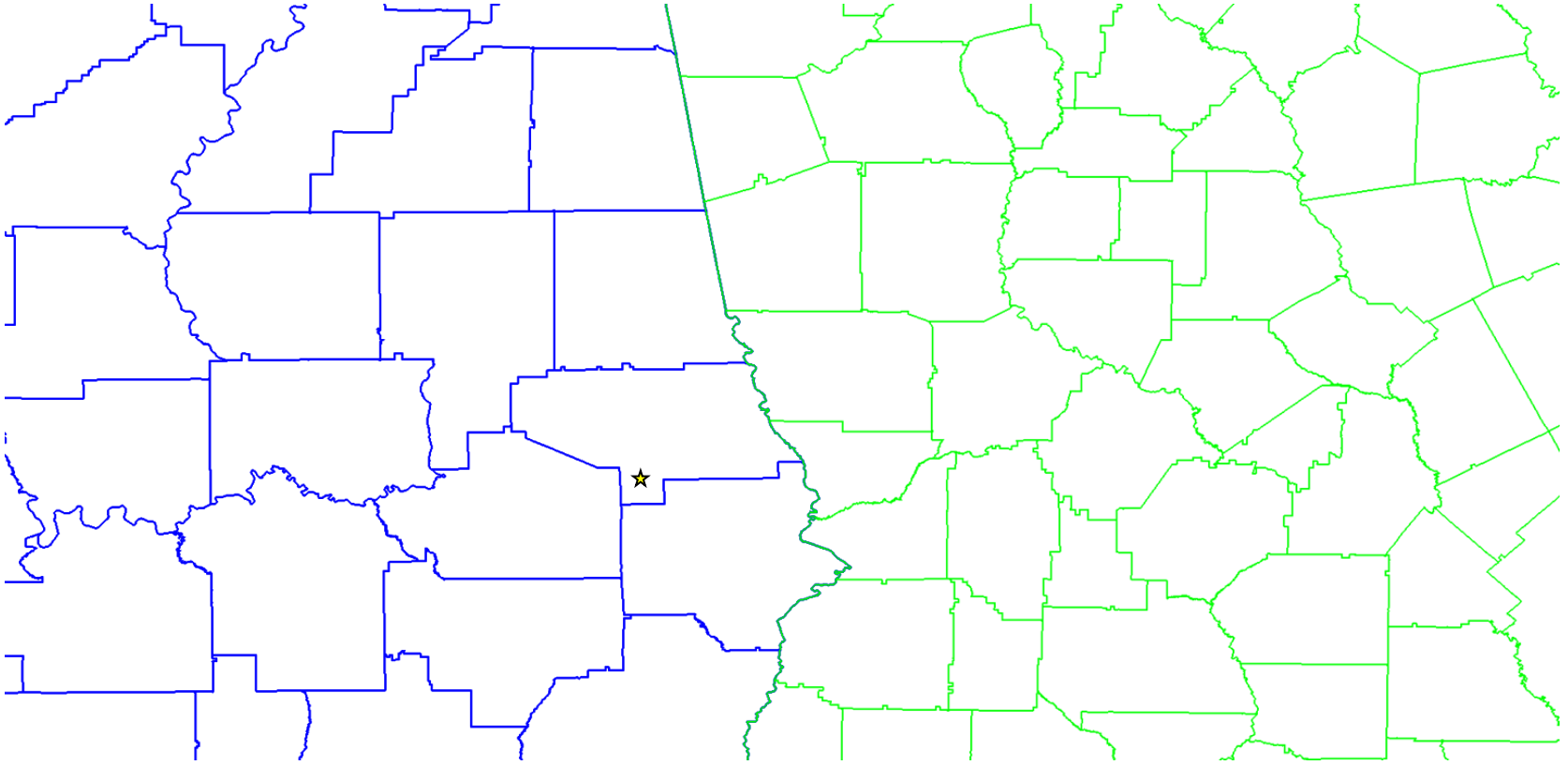


- ❑ Can cause confusion
  - Little information about location and properties of hazard
  - Little effective decision making can occur beyond 'take shelter now'
- ❑ Leads to:
  - Mistrust in information given
  - False alarm fatigue (8 consecutive sirens, Norman, 11 May 2023)
  - Poor decision making (e.g., driving through storms)
  - Variable interpretation of warnings



Inequitable Lead Times

- Warnings broken up by geographical boundaries

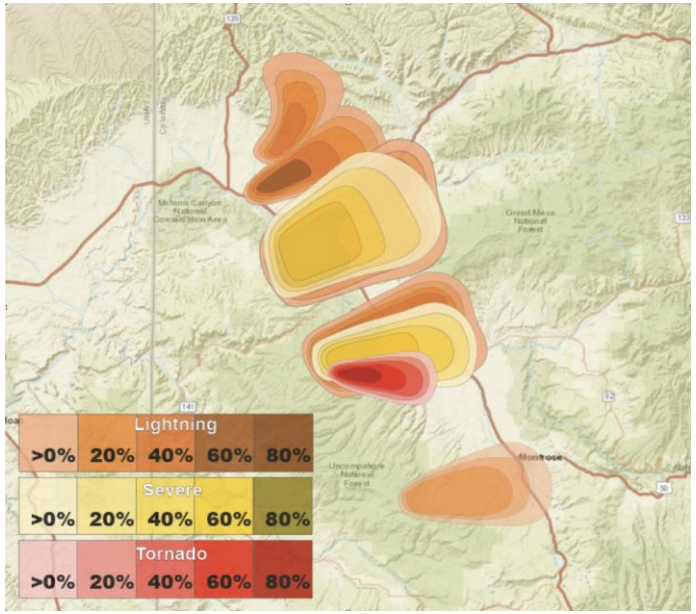


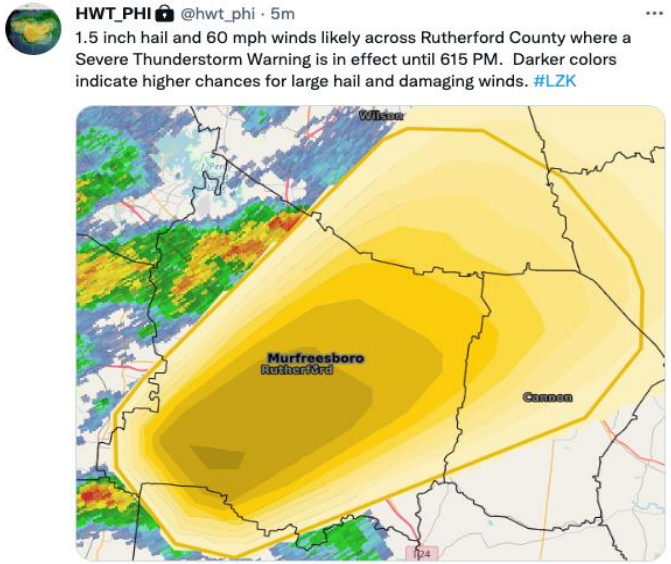
20190303-Lee County AL

(Courtesy G. Stumpf)

Meso Track, NWS Actual Tornado Warnings

Towards Improved Communication of Hazard Information



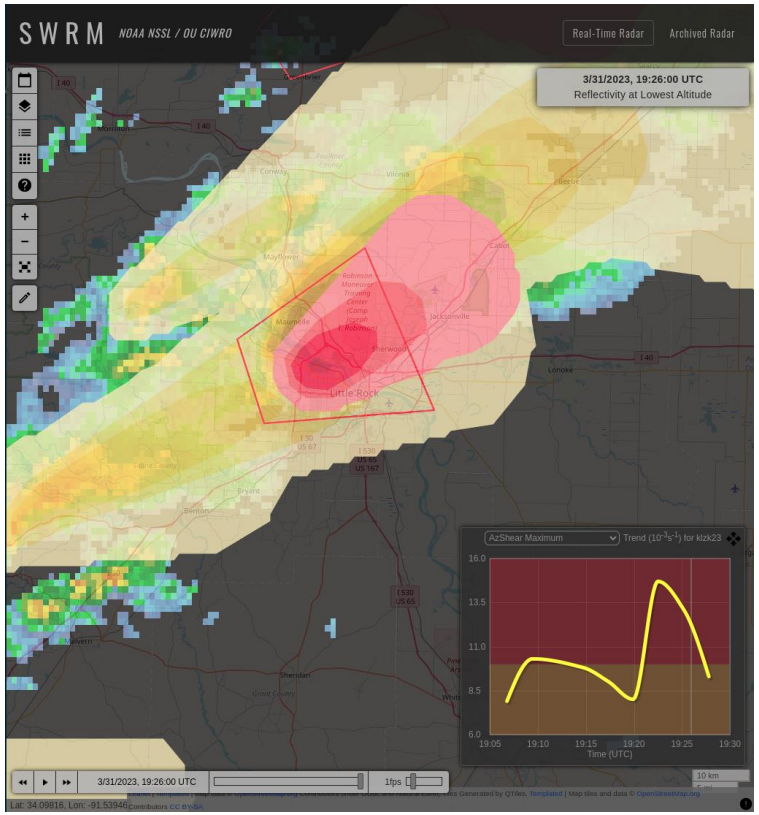


- ❑ Solutions not easy, but
  a promising concept under development is
  Probabilistic Hazard Information (PHI)

- ❑ Similar to hurricane cone of probability, but at warning scale

- ❑ Provides:
  - Defined uncertainty of threats (temporal, spatial, intensity)
  - Spatial coverage of threat
  - Rapid updates: every radar scan (~ 2 minutes)
  - Per hazard information

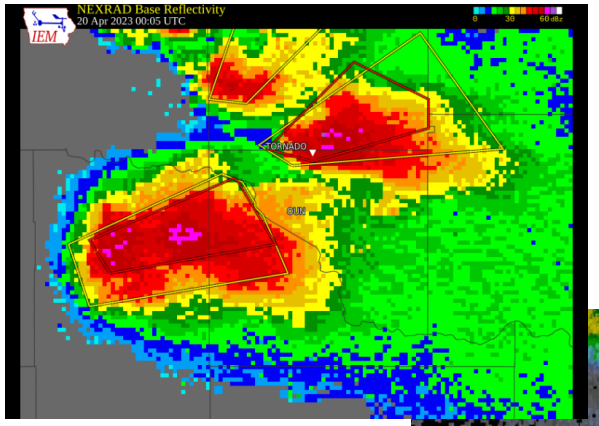
Probabilistic Hazard Information (PHI)

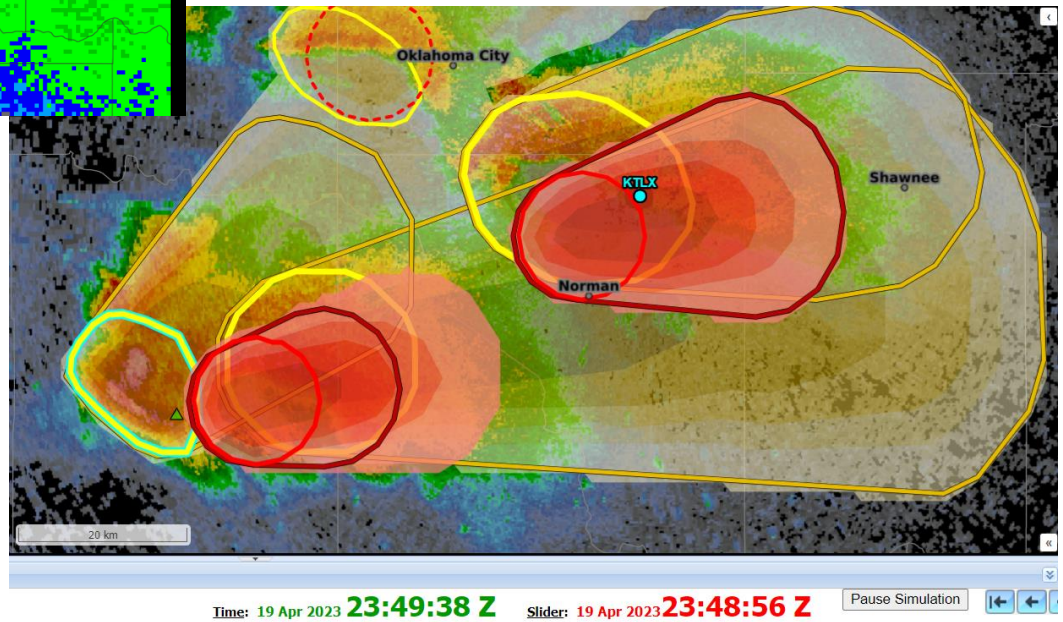


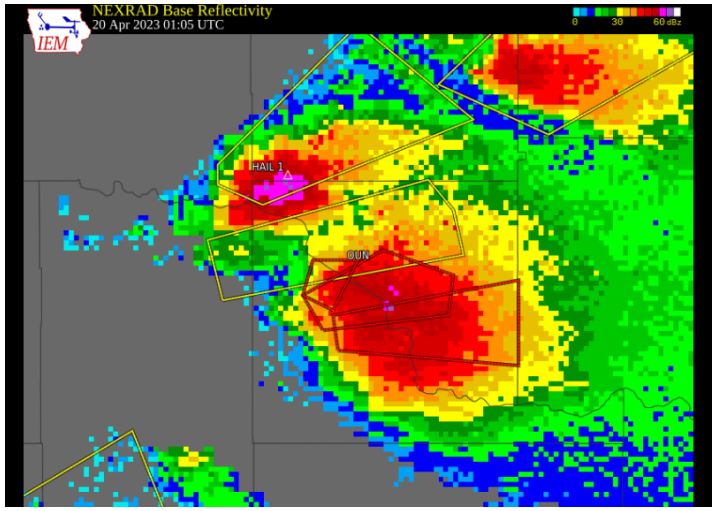
(Courtesy R. Steeves)

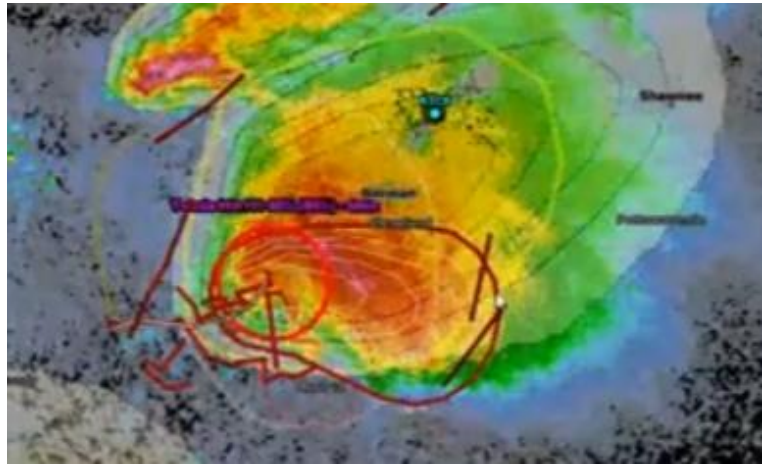
Probabilistic Hazard Information (PHI)

- HWT Experiment Comparisons for April 19, 2023

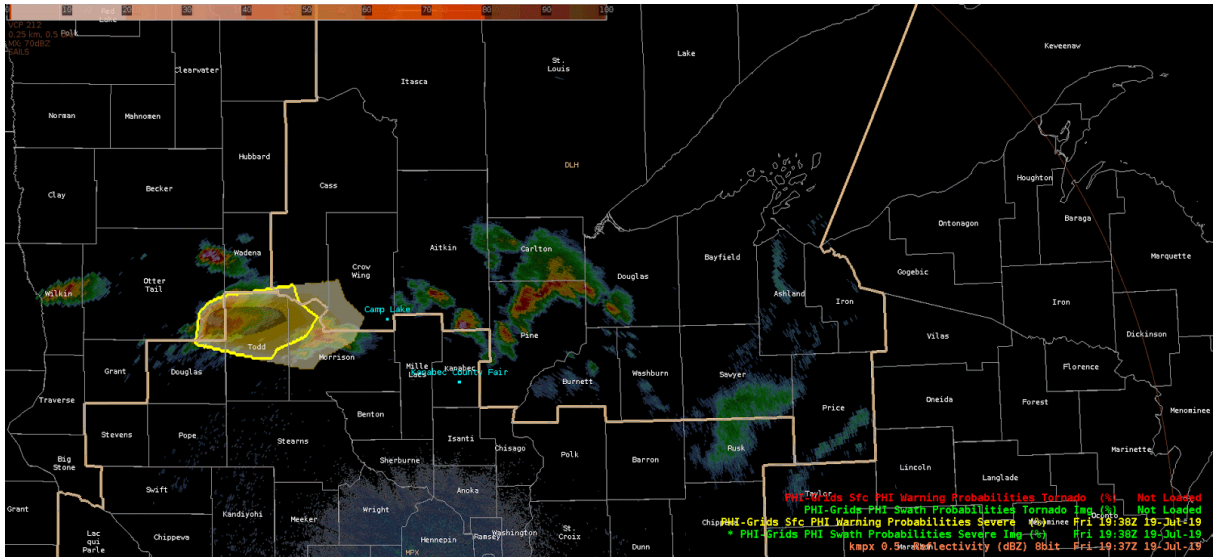








PHI Benefits

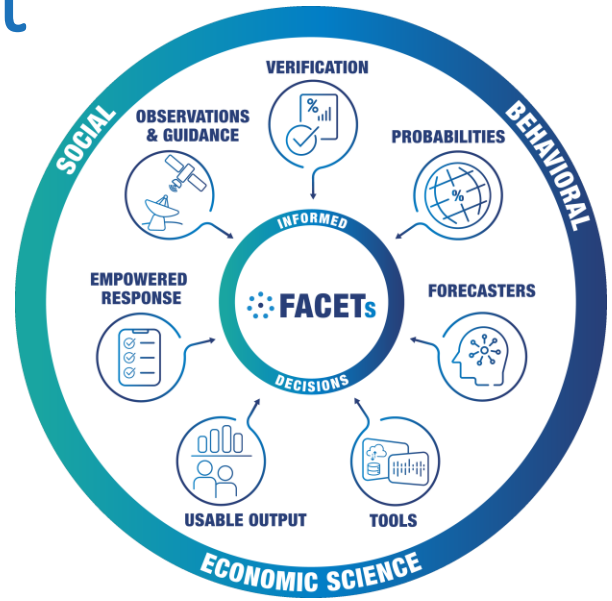


- ❑ Accurate and timely information about location and characteristics of hazard
- ❑ Not interrupted by geographical boundaries
- ❑ Gives information suited to different needs

- ❑ Allows for:
  - Better anticipation of hazard strike, and better protective decisions
  - Longer lead times (at lower likelihood)
  - Immediate all-clear when hazard has passed
  - Greater trust in information & reduction of false alarm fatigue

(Images courtesy P. Hyland, G. Stumpf)

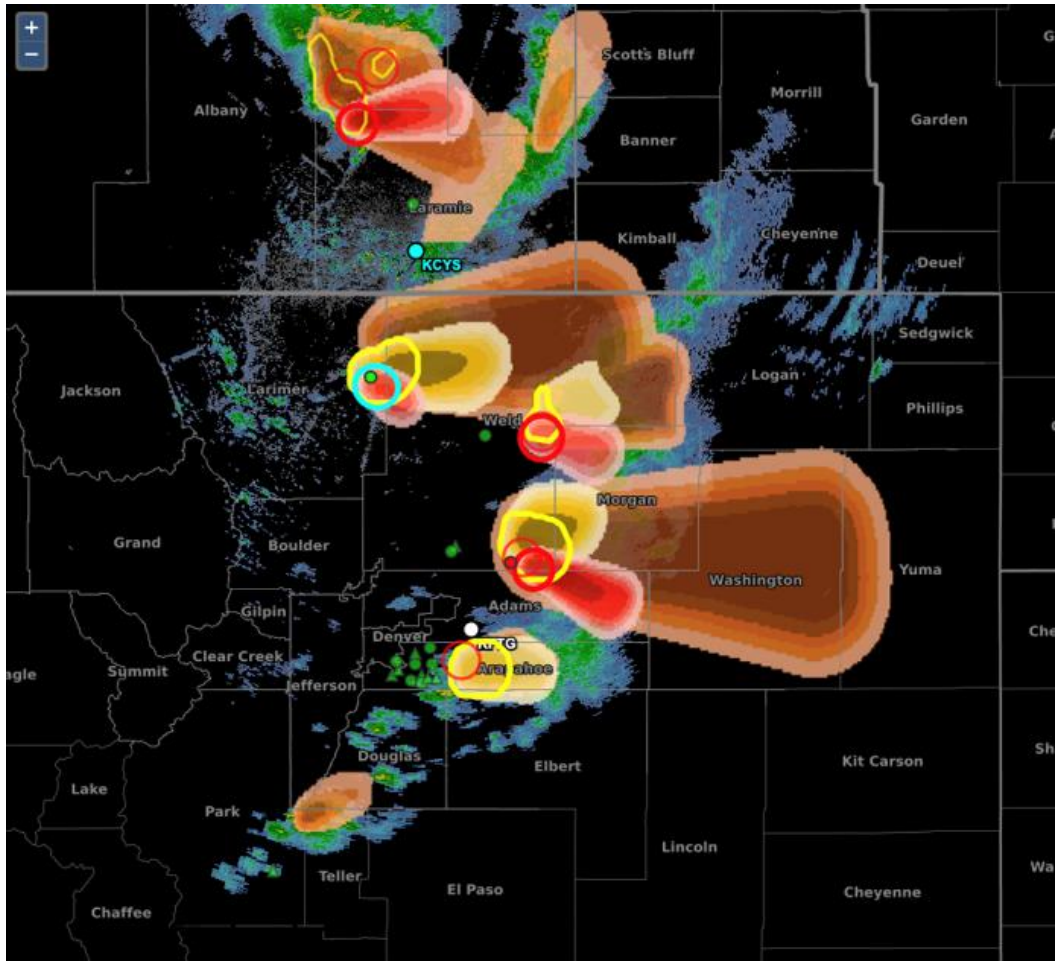
Current State of PHI Development



- ❑ In development for over a decade
- ❑ Important part of Forecasting A Continuum of Environmental Threats (FACETs)
  - Modernization of NOAA's entire forecast & warning process
- ❑ Numerous HWT experiments
  - Bringing developers, subject-matter experts, and forecasters together
  - Providing direct feedback on the strengths and limitations of concepts
- ❑ Ongoing software development
  - ❑ Prototype PHI Tool
  - ❑ HS-PHI module for AWIPS

Model Guidance for PHI

- ❑ One of the most important components in PHI development
- ❑ Hazard-based machine learning/AI algorithms provide the first guess of probability for the forecasters
  - Significantly speeds up PHI creation
  - Addresses the feasibility of PHI
  - Calibrates PHI across forecasters



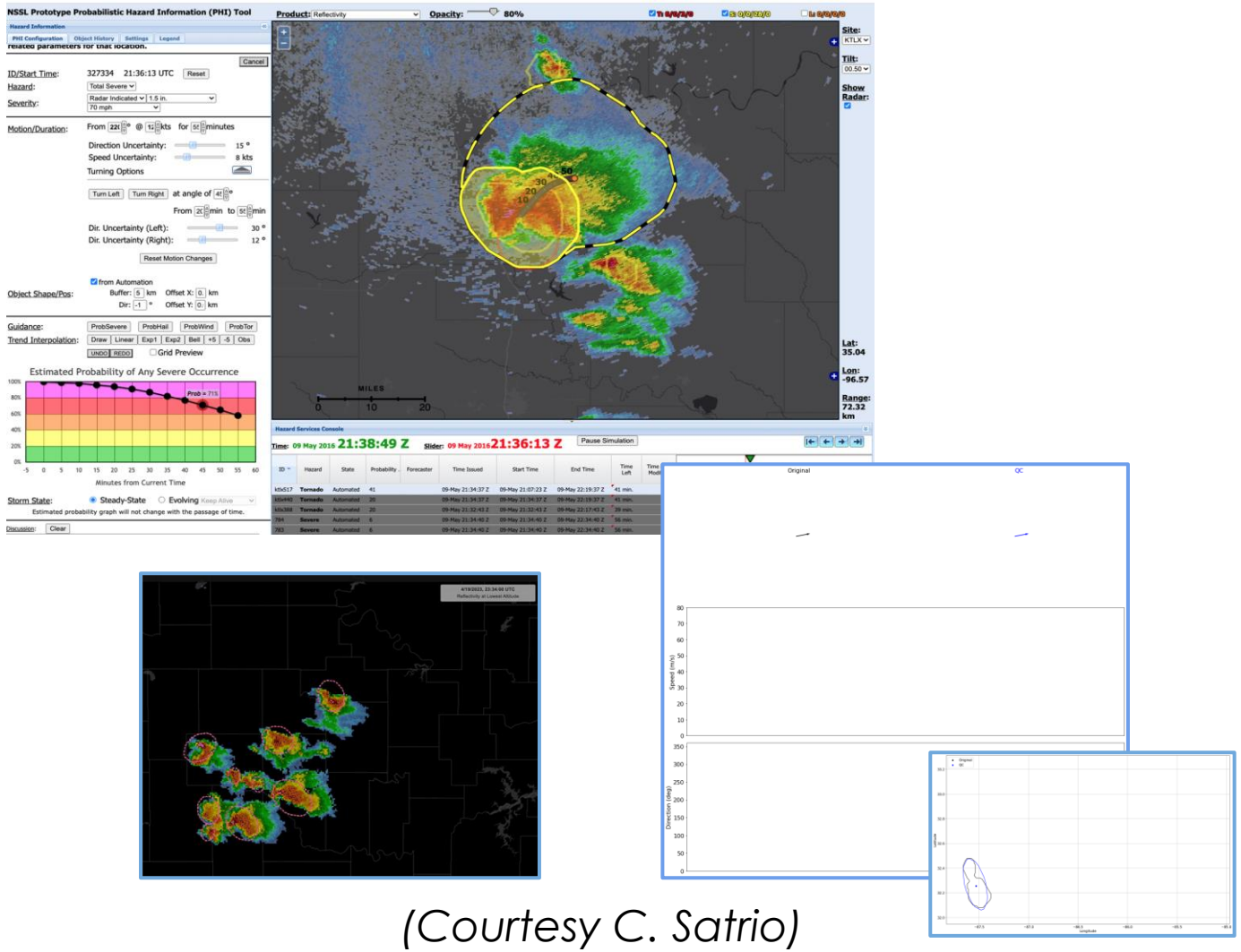
Lightning - ProbLightning (Random Forest)
Severe (wind/hail) – ProbSevere Version 3 (Gradient Boosted Tree)
Tornado - New PHITor Algorithm (Random Forest)

Severe Guidance

ProbSevere V3 (NOAA/CIMSS)

- ❑ Object-based probability of severe threat
  - Hail >= 1 inch, Wind >= 50 knots
- ❑ Gradient boosted tree
  - Uses features extracted from GOES, Multi-Radar Multi-Sensor (MRMS), lightning detection networks, and Rapid Refresh (RAP) data

- ❑ Kalman filtering at NSSL for motion stability



(Courtesy C. Satrio)

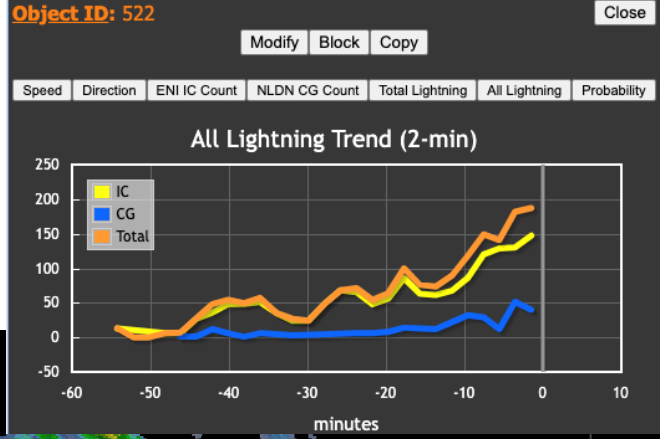
- ❑ Information at: https://cimss.ssec.wisc.edu/severe_conv/psv3.html

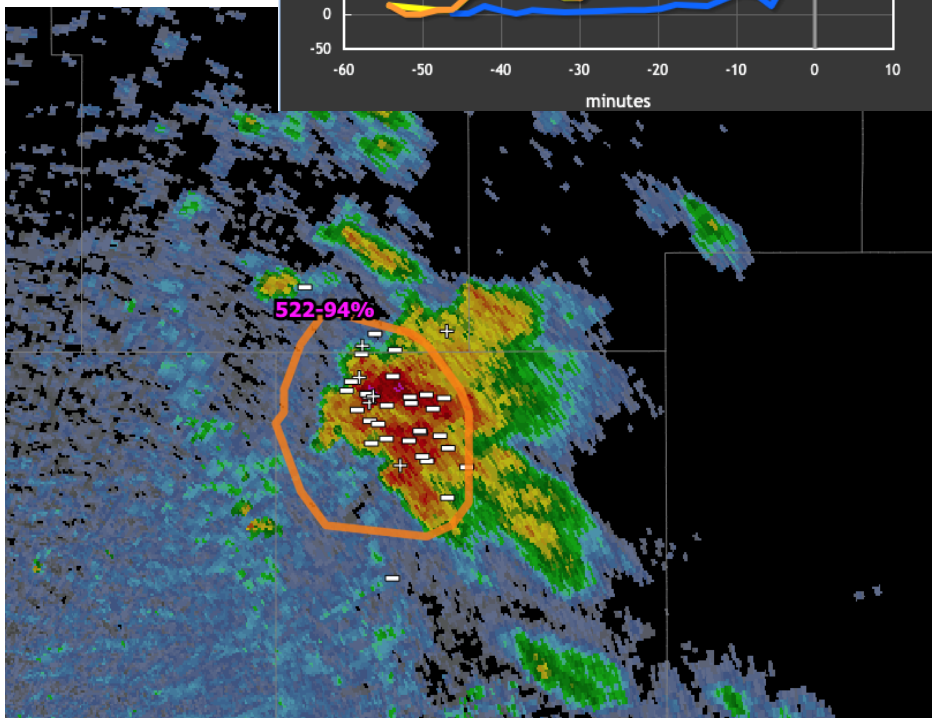
- ❑ Forecasters typically add buffer for areal coverage, change storm motion, and modify probability depending on local storm reports, storm mode, and environment

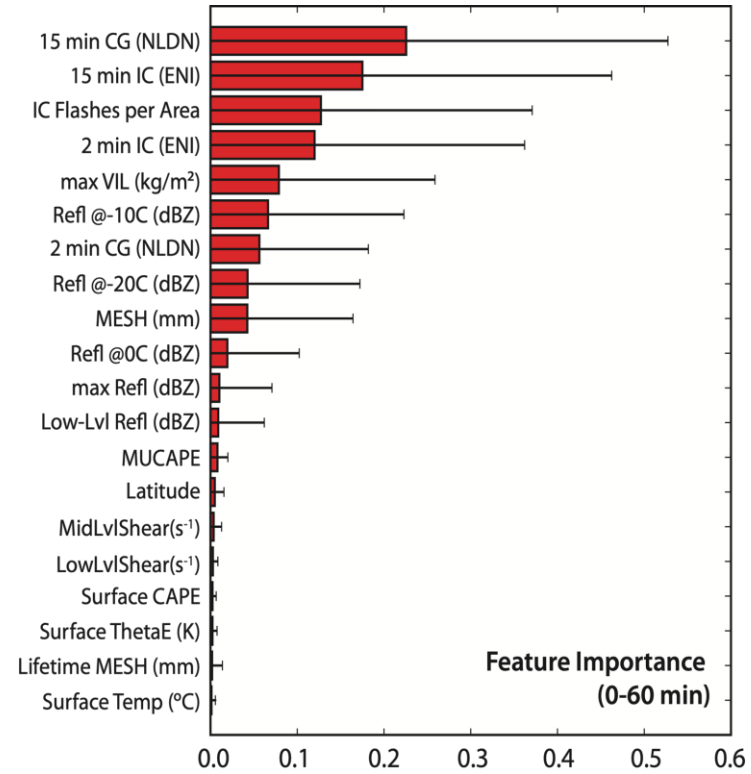
Lightning Guidance

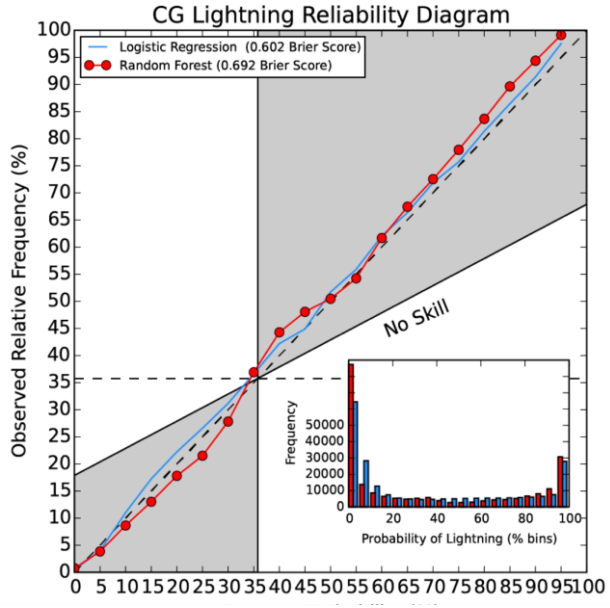
ProbLightning (NSSL)

- Object-based probability of cloud-to-ground lightning
- Random Forest with data from lightning detection networks, MRMS, and Near Storm Environment (NSE)









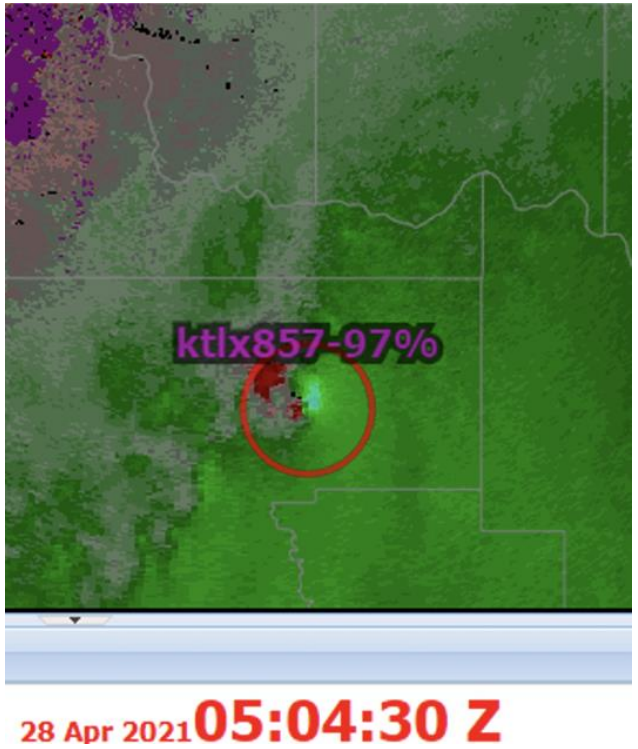
- Tuned for CONUS or individual NWS regions at 15 min intervals out to one hour
- Highly valued by Emergency Managers

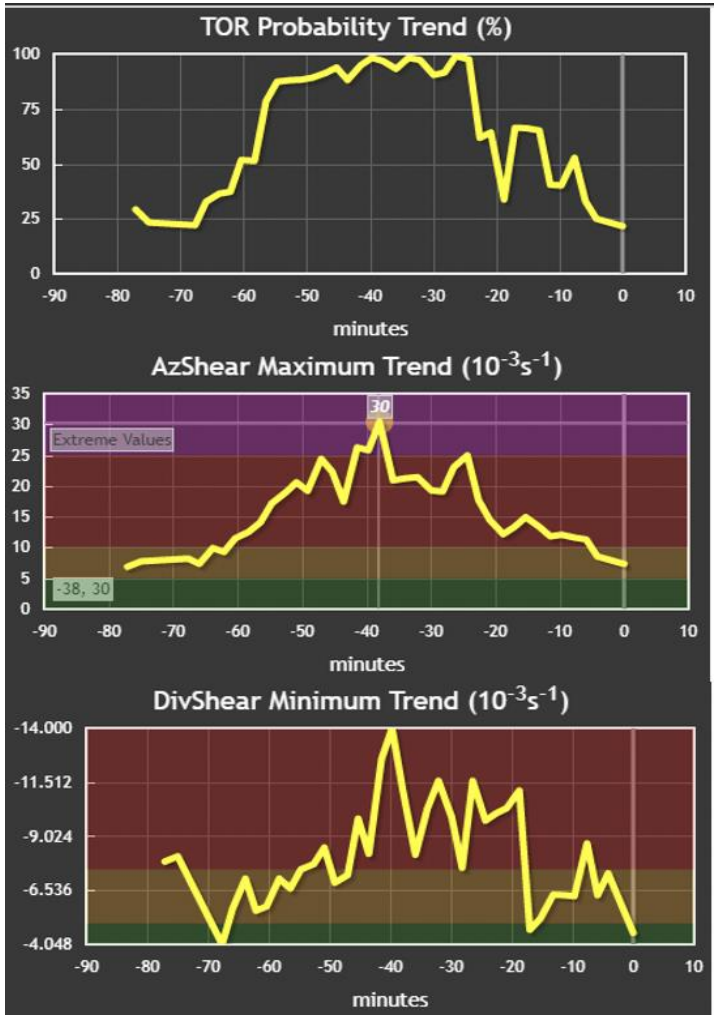
(Courtesy K. Calhoun)

Tornado Guidance

TORP / PHItor (NSSL)

- ❑ Point-based probability of tornado
- ❑ Random forest using data extracted from a 2.5-km radius centered on nearest AzShear max
  - velocity, spectrum width, polarimetric values
  - 0.5°-tilt single-radar
  - Rotation max, min, and percentiles
  - Range from radar





- ❑ Sandmæl et al. 2023 article about TORP at:
  - https://doi.org/10.1175/WAF-D-22-0123.1

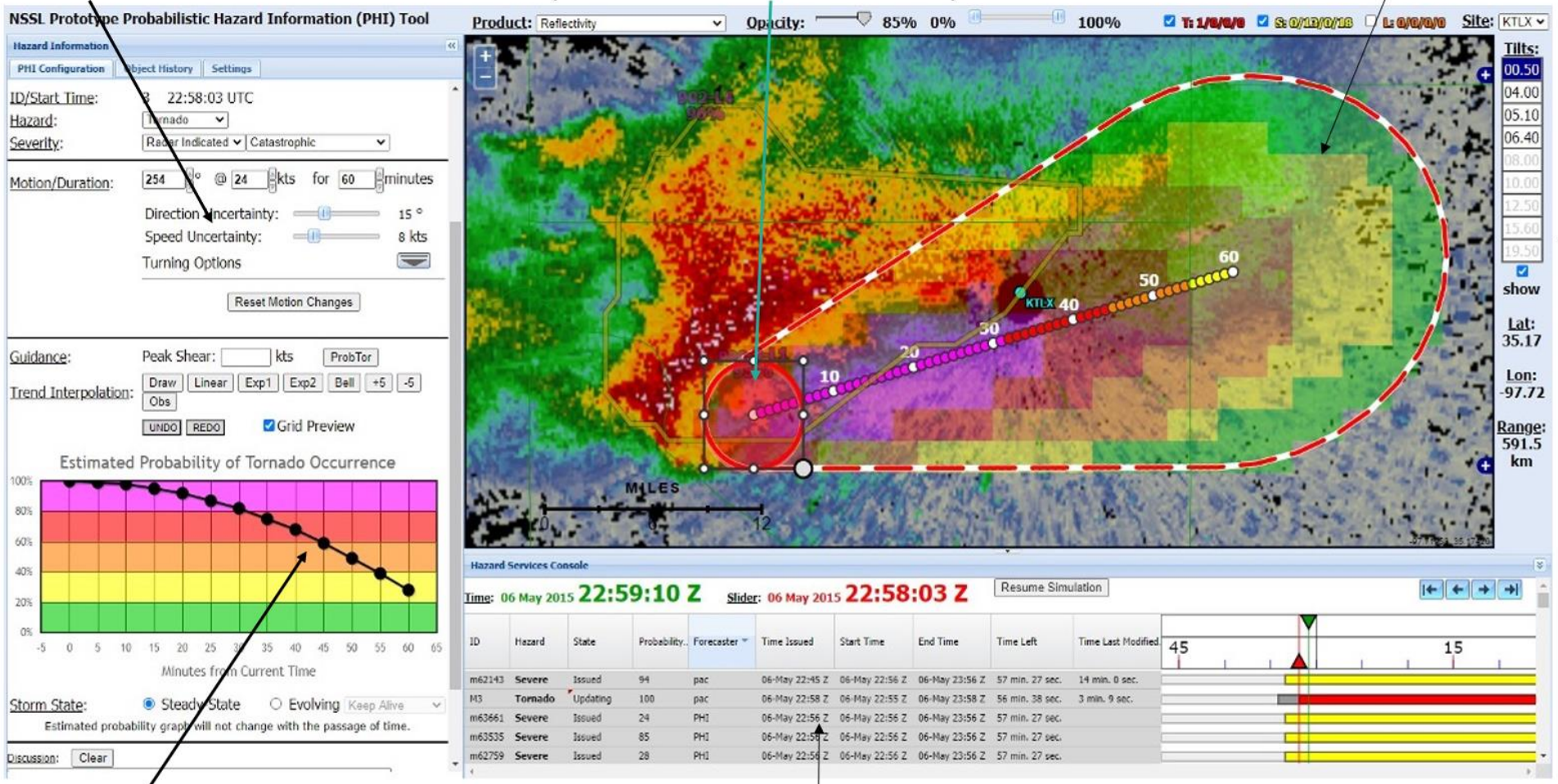
(Courtesy T. Sandmael)

PHI Software

Object characteristics

Hazard-storm object
(automated or user created)

Hazard Strike Probabilities

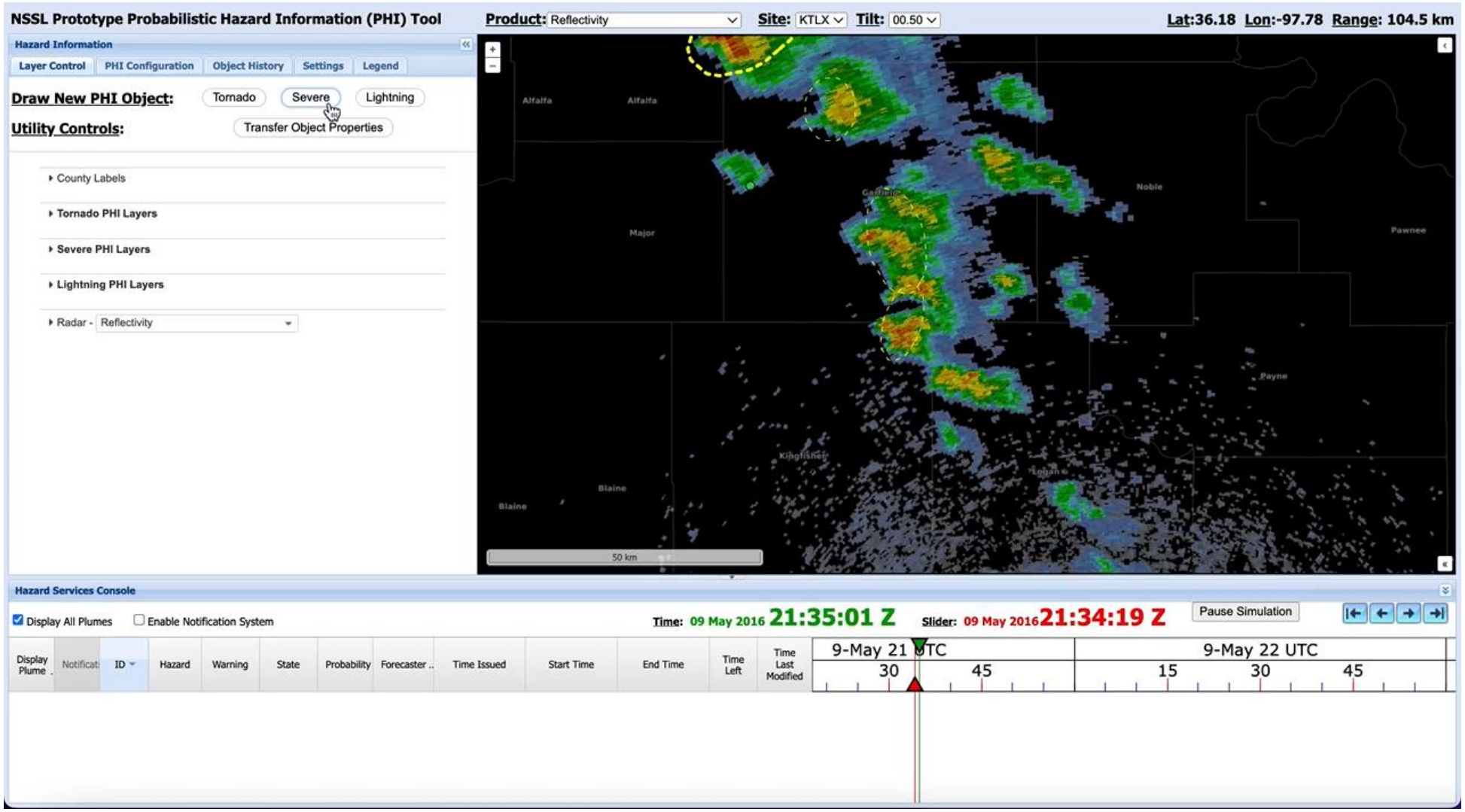


Hazard Strike Probabilities

List of all hazards

Environ/radar controls

PHI Software (Demo)

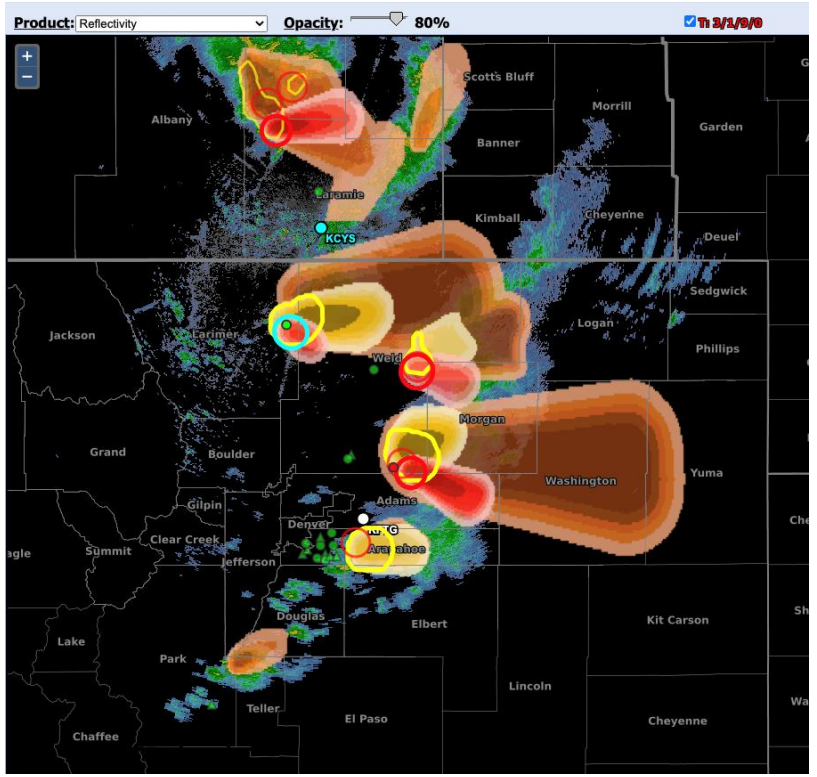


(Courtesy R. Steeves)

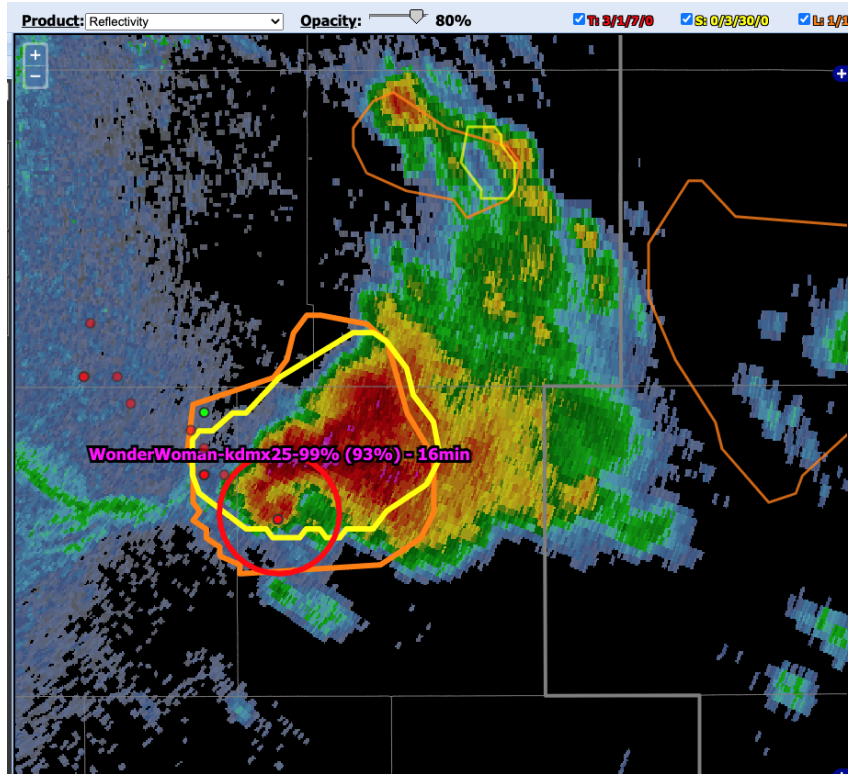
Forecaster Workload and Task Management

- 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)
- Workload could be manageable, but further optimization likely necessary for operationalization of PHI

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



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

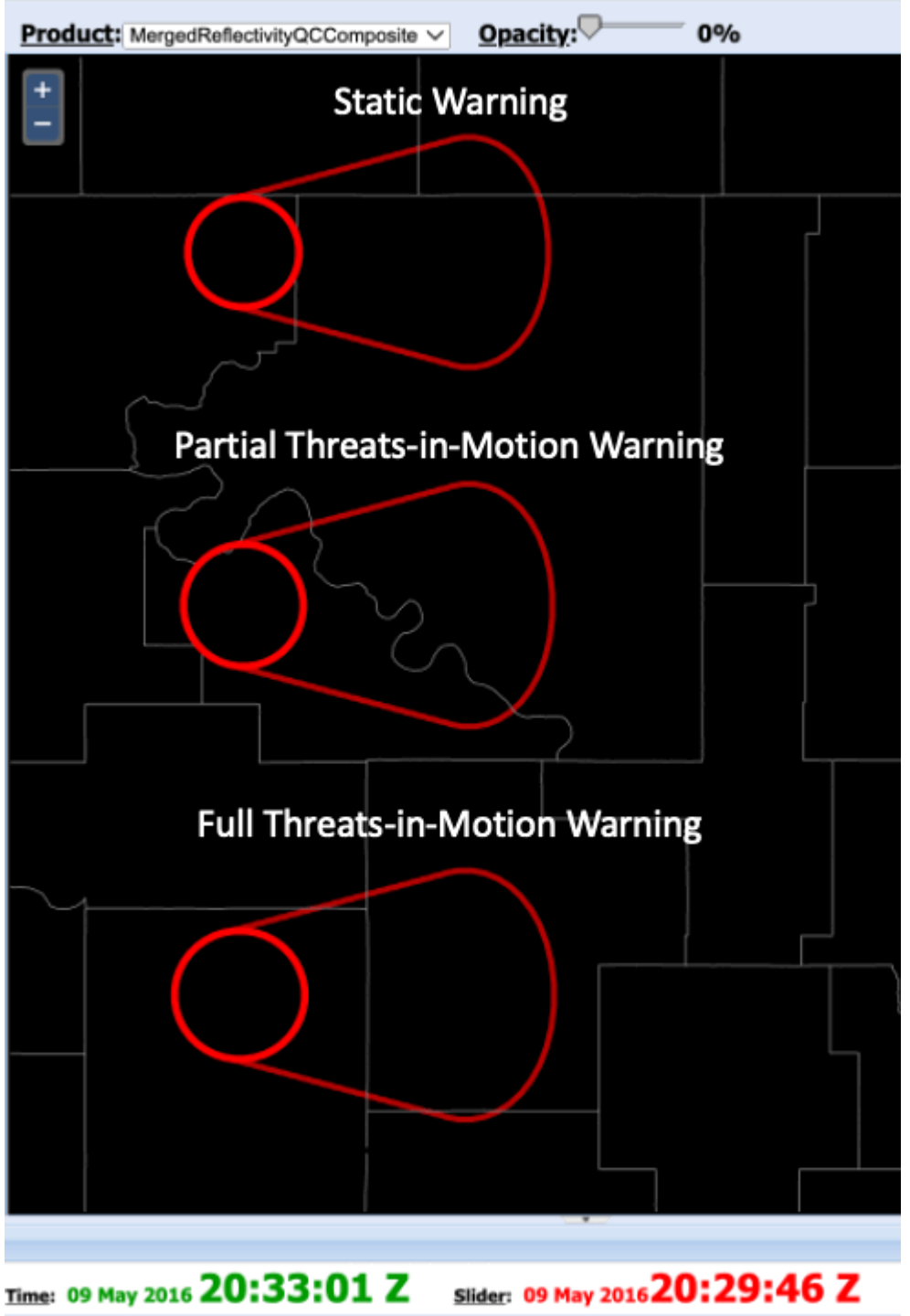


Hazard type	Severe	Tornado	Lightning
No. of objects	8.67 (2.94)	7.75 (4.06)	10.33 (2.62)
No. of updates	14.67 (7.35)	15.75 (10.0)	22.67 (4.69)
Updates per object	1.69 (2.5)	2.03 (2.47)	2.19 (1.79)
Avg time per update (s)	196.64 (105.29)	139.22 (113.39)	105.96 (94.57)
Freq of update (min)	28.34 (18.09)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

Single (All) hazards

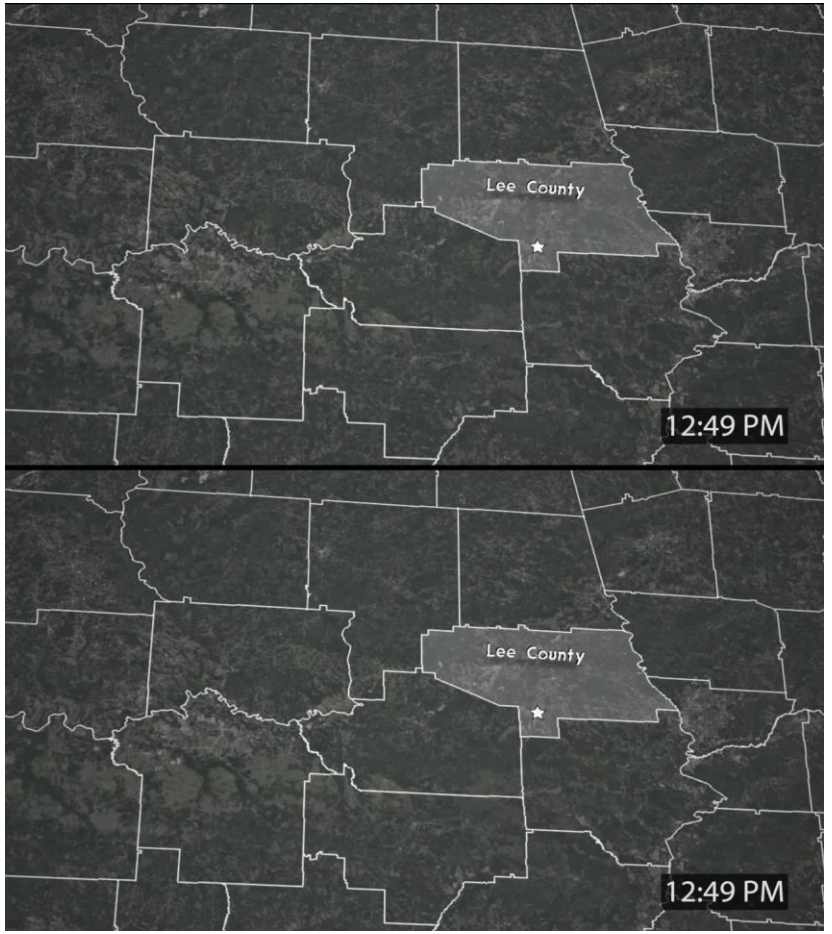
Interactions Between PHI and Warnings

- ❑ Warning area creation is a component of PHI software
- ❑ Warnings still highly desired by decision-makers
  - PHI alone is insufficient trigger for action
- ❑ Static warning creation can be informed by PHI
  - Forecasters may first see PHI as “guidance” for warnings
- ❑ Moving warnings can be tied to PHI hazard objects
  - Referred to as Threats-In-Motion (TIM)
  - Partial or Full TIM options to cover different situations

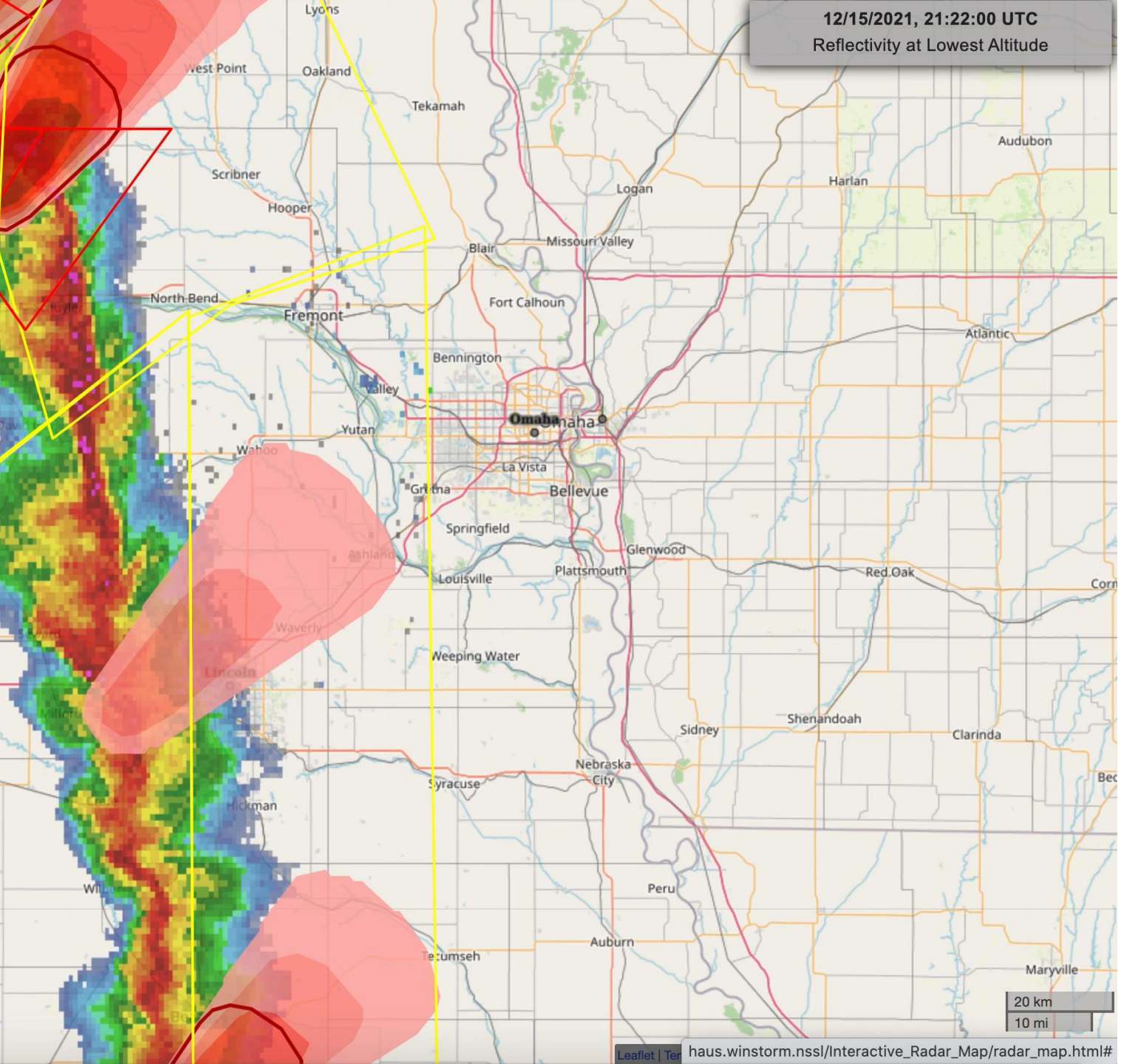


Threats-In-Motion Benefits

- ❑ TIM alone easier to deploy than PHI
- ❑ Accurate and timely information about motion of hazard
- ❑ Can provide more equitable lead times
- ❑ Immediate all-clear when hazard has passed
- ❑ Not interrupted by geographical boundaries



(Courtesy G. Stumpf)

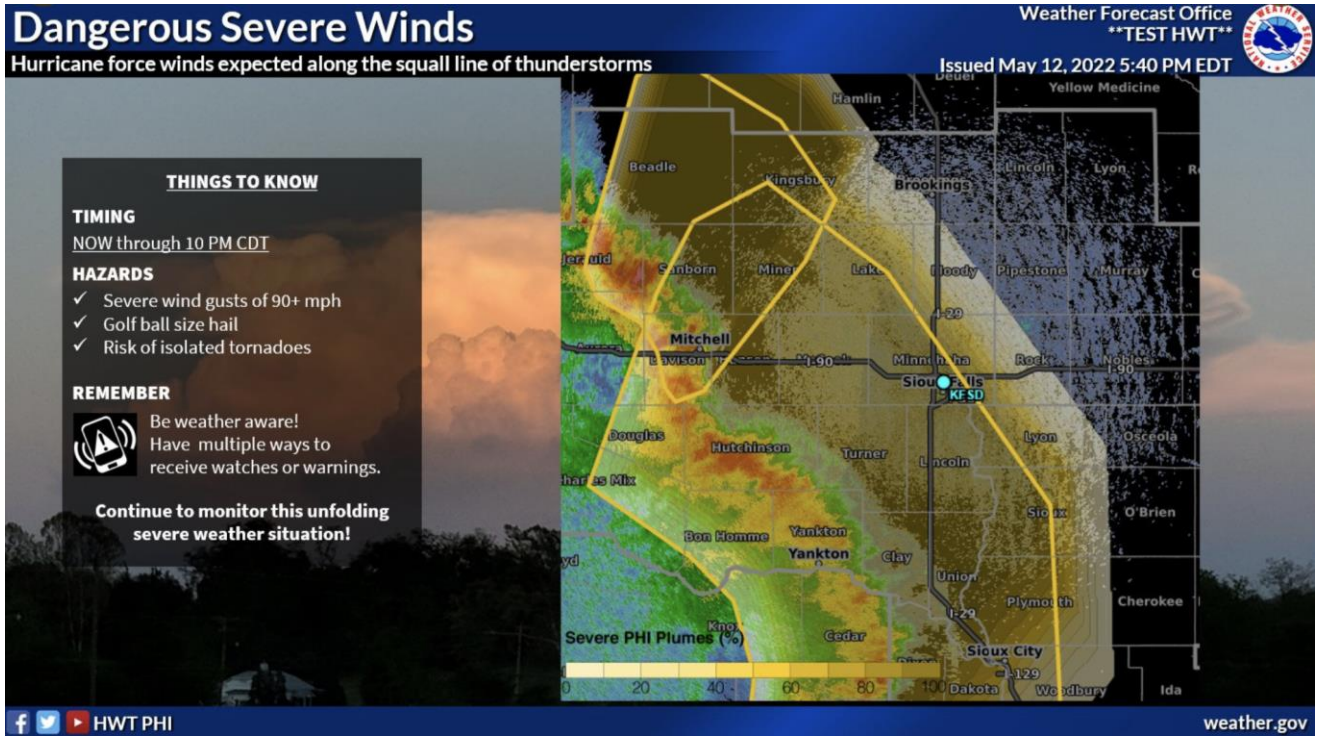


Warnings, PHI, and TIM

- Additional information relative to traditional warnings
- Can assist decision-makers in taking effective actions to protect lives and property

Challenges to Deployment

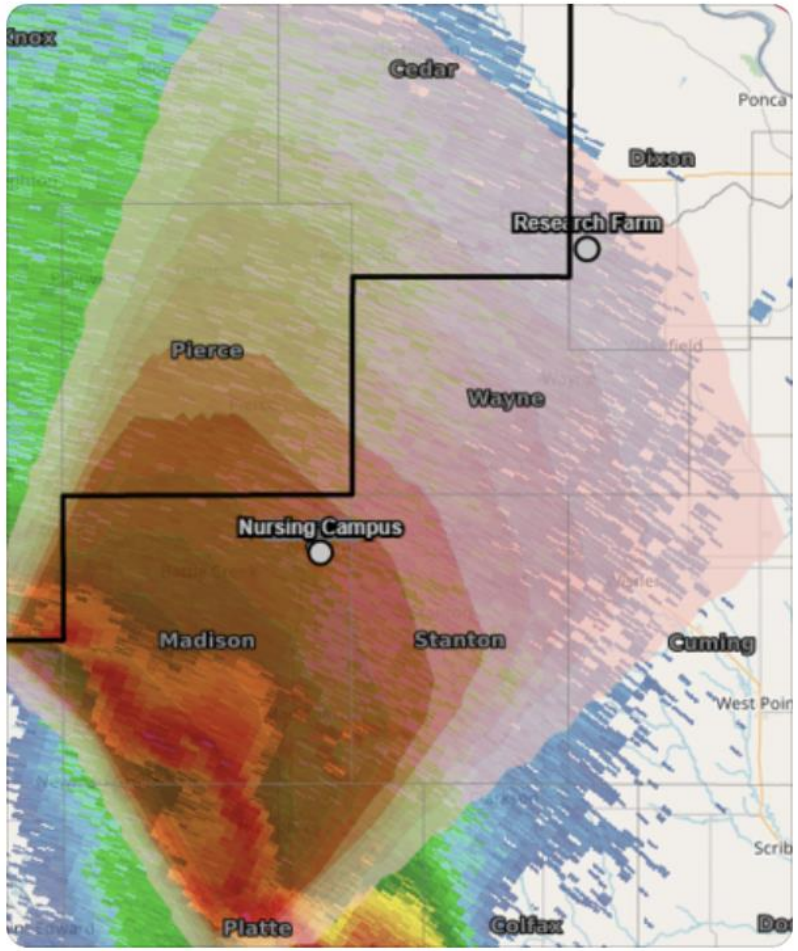
- ❑ Logistics of automated alerts
- ❑ Forecaster workload
- ❑ Effective communication
  - Working towards intuitive and standardized interpretation of PHI for decision makers and the public



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

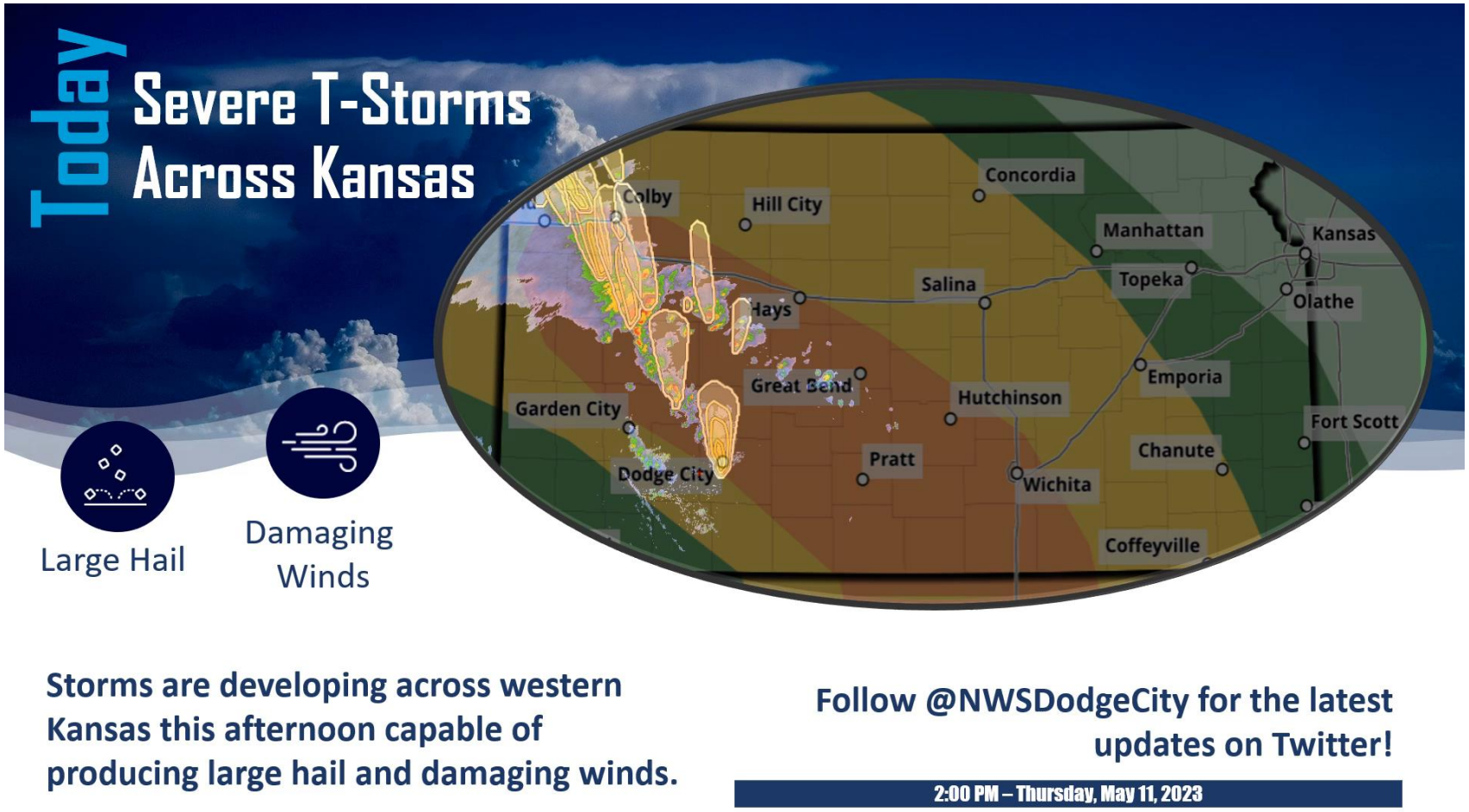
Thanks. We have instructed students/staff/faculty to shelter there. If I receive any damage reports, I'll pass those along to you.

Testing Communication

- ❑ Forecasters always noted they had the highest workload when doing communication
- ❑ Loved the ability to share Tornado PHI
  - Forecasters commented often that it was a visual option for the currently available “tornado possible” tag on a severe warning
- ❑ Forecasters deeply want more social science research to confirm public can understand PHI

New Ideas from the HWT

- Iterative feedback from HWT experiments has driven advances in communications as well as other PHI concepts



Ongoing Work and Steps Towards Deployment

- ❑ Threats-In-Motion
  - First step in warning improvement
  - Possible two to three year timeline

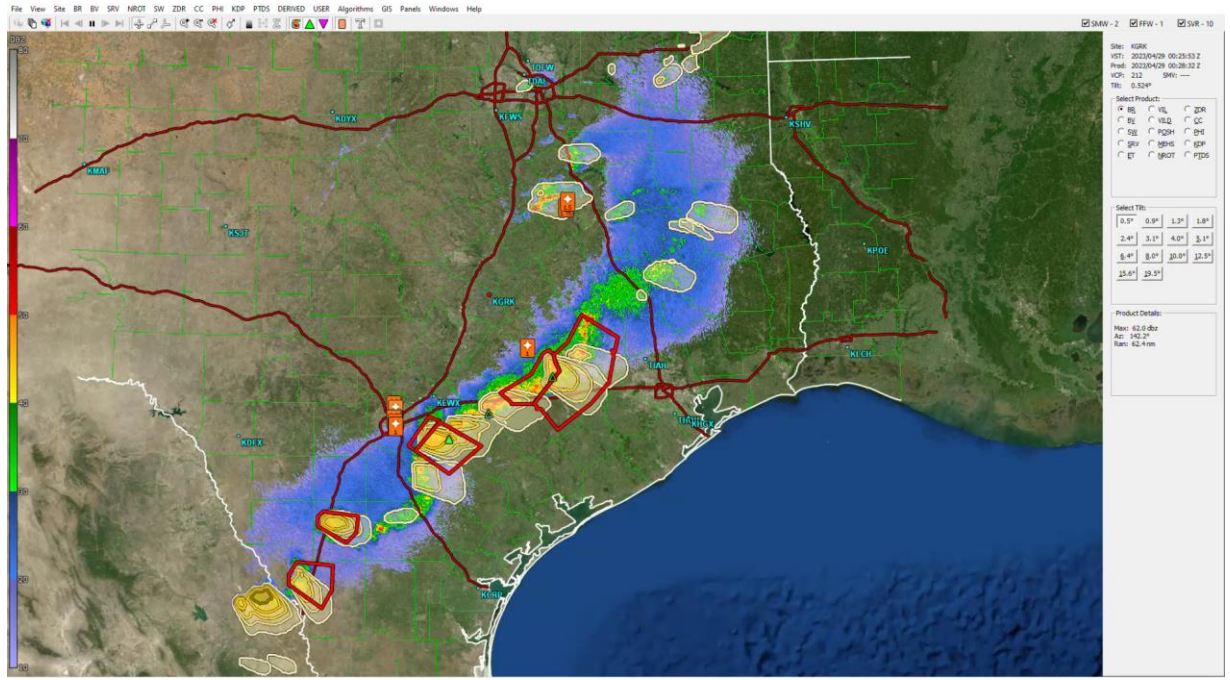
- ❑ Further test end-user (and public) decisions with PHI
  - Additional experiments with Emergency Managers and Broadcast Meteorologists
  - Surveys and focus groups with public

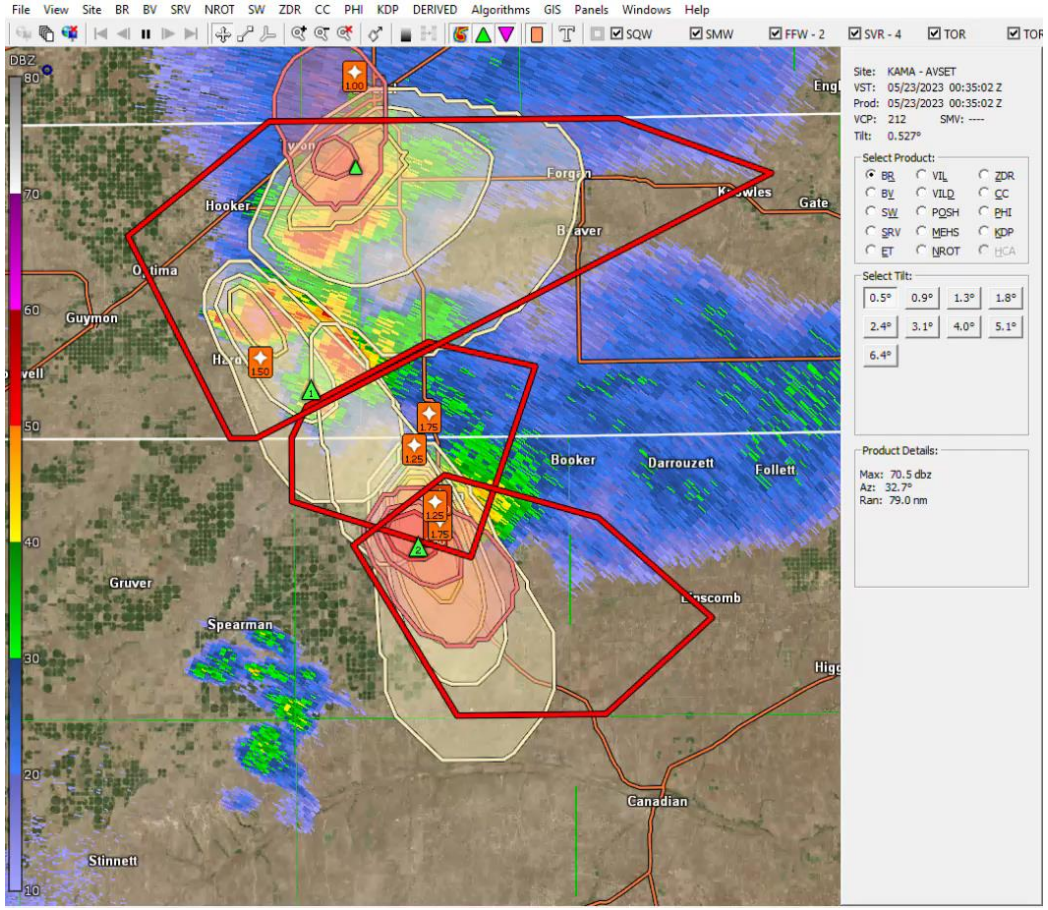
- ❑ Continue testing new concepts for movement towards operations

(Courtesy K. Berry)

Ongoing Work and Steps Towards Deployment (cont.)

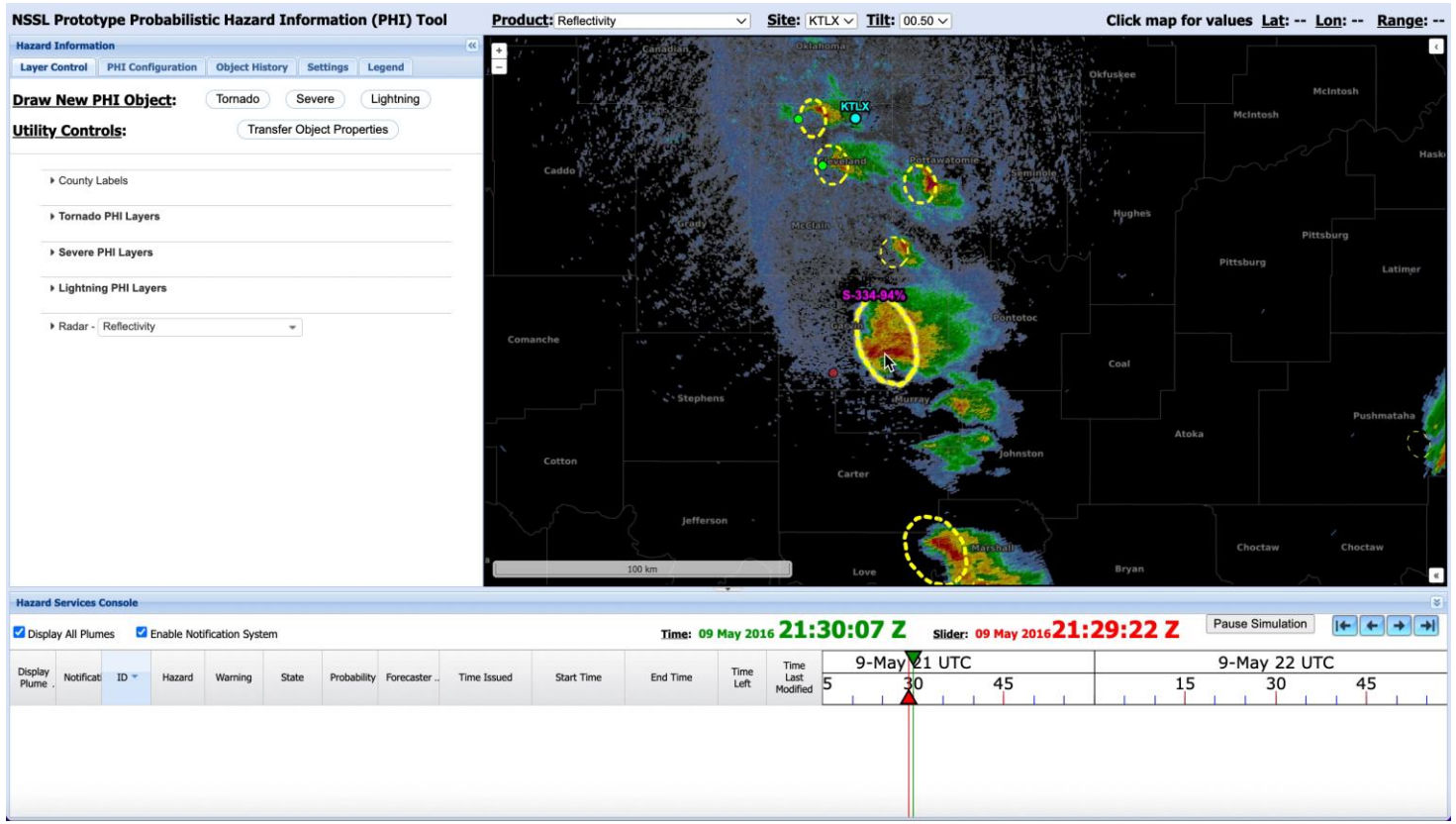
- Current project to provide test feeds to Southern Region Warning Forecast Offices





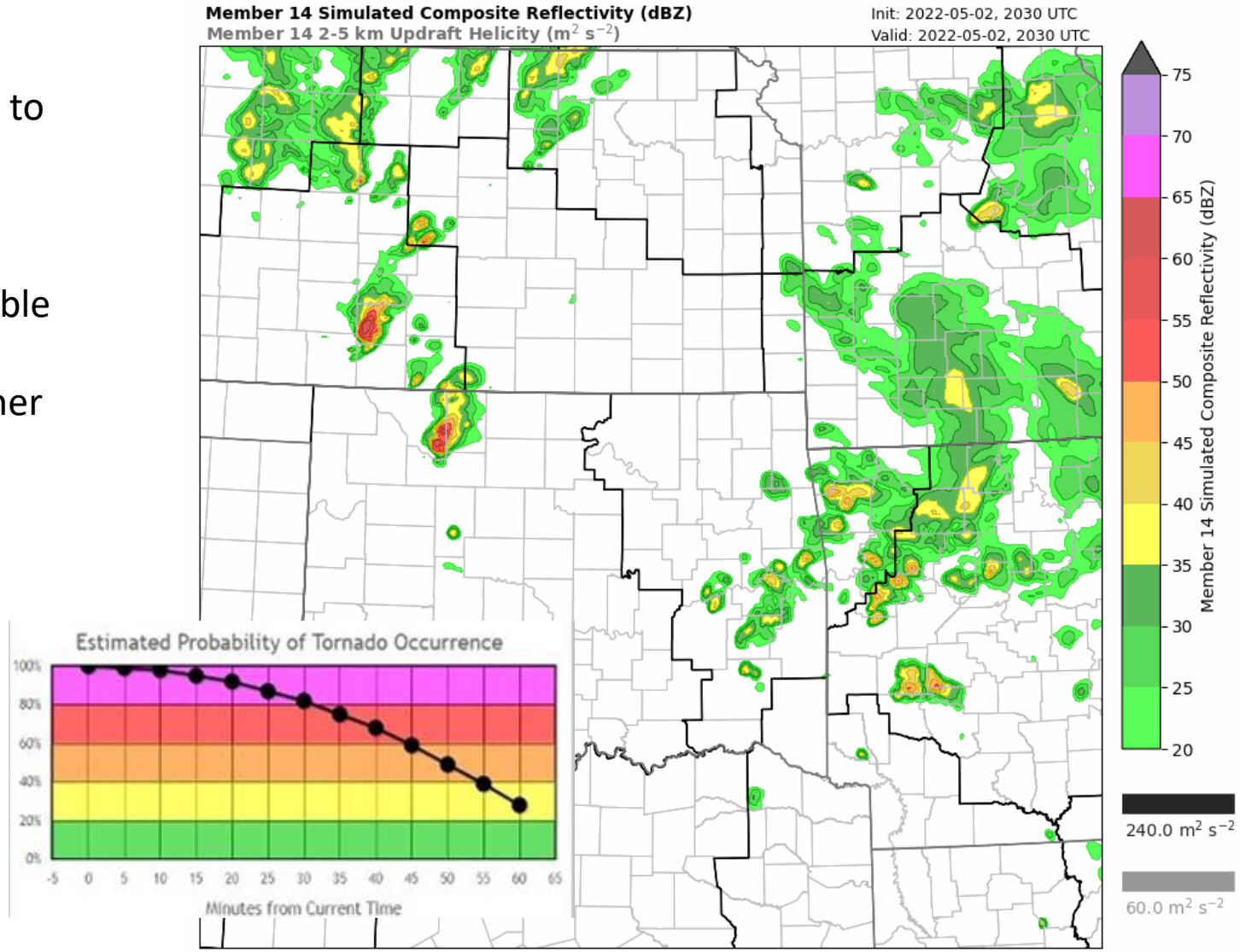
Ongoing Work and Steps Towards Deployment (cont.)

- Ongoing software improvements to address forecaster workload
- Automated notifications to forecaster of storm behavior
  - Such as rapid probability increase



Ongoing Work and Steps Towards Deployment (cont.)

- ❑ Additional guidance at longer lead times
  - Forecasters want “forecast” probabilities to begin to address watch-to-warning gap
- ❑ Integrate Warn-on-Forecast System (WoFS)
  - Rapidly-updating, high-resolution ensemble model system
  - Produces probabilistic high impact weather forecasts
  - WoFS information at: https://wof.nssl.noaa.gov/
- ❑ Watch-to-Warning HWT Experiment in Summer 2023
- ❑ Full PHI deployment likely several years away, but exciting progress is ongoing



Thank you

- Questions?