The NOAA Hazardous Weather Testbed: A Summary of Activities Supporting Successful R2O Transitions

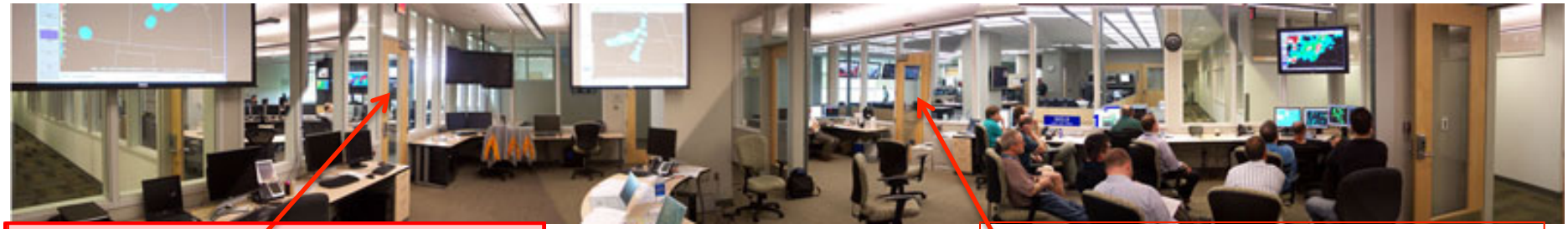
S. Weiss[1], L. Rothfusz[2], A. Clark[2,3], M. Coniglio[2], J. Correia[1,3], G. Garfield[6], P. Heinselman[2], I. Jirak[1], J. Kain[2], C. Karstens[2,3], D. Kingfield[2,3], K. Knopfmeier[2,3], F. Kong[4], K. Kuhlman[2,3], C. Melick[1,3], K. Ortega[2,3], R. Schneider[1], T. Smith[2,3], G. Stump[2,3,5], K. Thomas[4], and M. Xue[4]

[1]NOAA/NWS/NCEP Storm Prediction Center, Norman, OK
[2]NOAA/OAR National Severe Storms Laboratory, Norman, OK
[3]OU/Cooperative Institute for Mesoscale Meteorological Studies, Norman, OK
[4]OU/Center for Analysis and Prediction of Storms, Norman, OK
[5]NOAA/NWS/Meteorological Development Laboratory Norman, OK
[6]NOAA/NWS/Weather Forecast Office, Norman, OK

6th NOAA Testbed and Operational Proving Ground Workshop
April 14-16, 2015
Boulder, CO

NOAA Hazardous Weather Testbed

Where practitioners and researchers work together to enhance community collaboration and accelerate the transfer of research to operations…



Local NWS Forecast Office (OUN): Regional responsibility

Experimental
Warning
Program

Detection/prediction of hazardous weather events ***up to several hours in advance***

Warning Research

Forecasting Research

Satellite-based Research

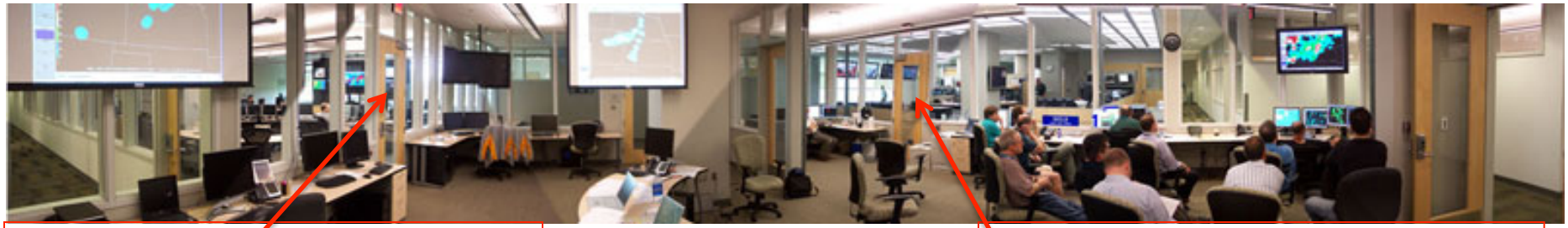
Storm Prediction Center (SPC): Nationwide Responsibility

Experimental
Forecast
Program

Prediction of hazardous weather events from ***a few hours to a week in advance***

NOAA Hazardous Weather Testbed

Where practitioners and researchers work together to enhance community collaboration and accelerate the transfer of research to operations…



Local NWS Forecast Office (OUN): Regional responsibility

Storm Prediction Center (SPC): Nationwide Responsibility

Warning Research

Forecasting Research

Satellite-based Research

Experimental
Warning
Program

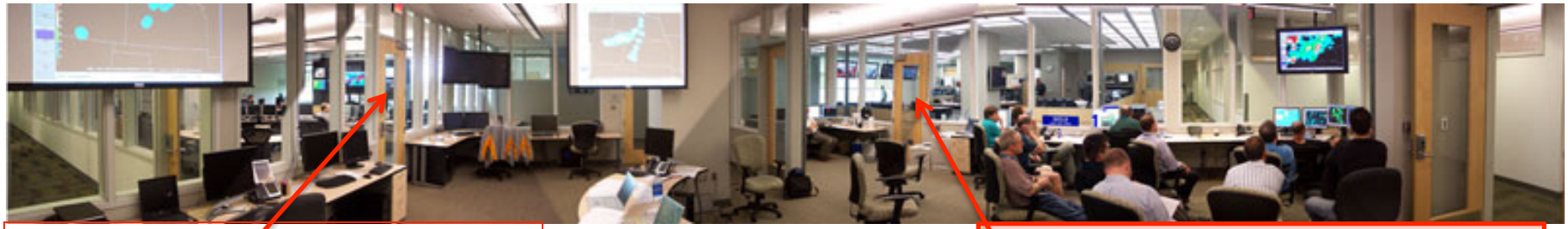
Detection/prediction of hazardous weather events ***up to several hours in advance***

Experimental
Forecast
Program

Prediction of hazardous weather events from ***a few hours to a week in advance***

NOAA Hazardous Weather Testbed

Where practitioners and researchers work together to enhance community collaboration and accelerate the transfer of research to operations…



Local NWS Forecast Office (OUN): Regional responsibility

Experimental
Warning
Program

*Detection and prediction of hazardous weather events **up to several hours in advance***

Warning Research

Forecasting Research

Satellite-based Research

Storm Prediction Center (SPC): Nationwide Responsibility

Experimental
Forecast
Program

*Prediction of hazardous weather events from **a few hours to a week in advance***

Hazardous Weather Testbed

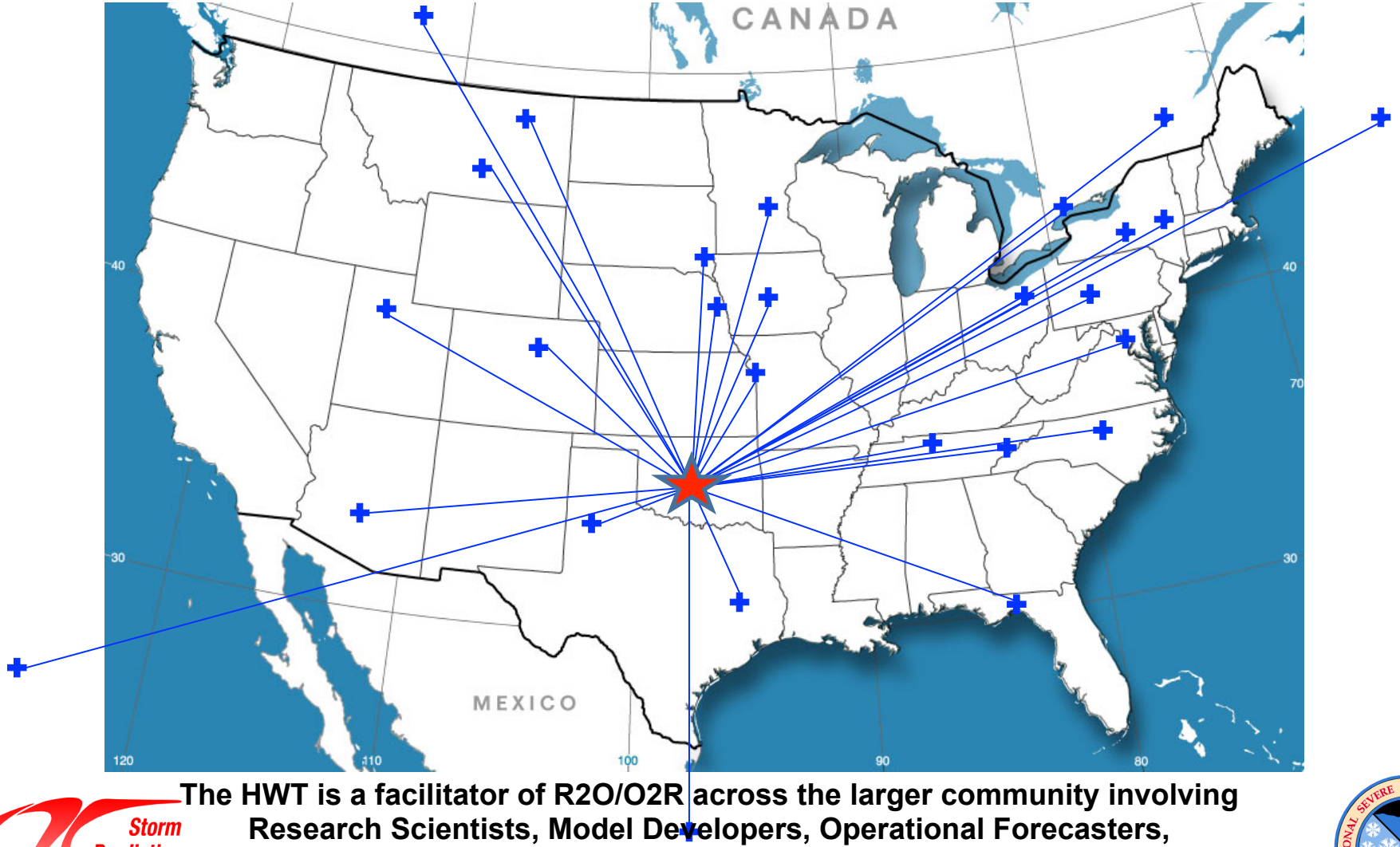
- ***The HWT facilitates scientific & operational interactions to accelerate transition of new science and technology from research to operations***

- HWT is run by NWS/SPC, OAR/NSSL, and NWS/WFO OUN

- Key collaborators include:
  - NOAA /NWS (NCEP, MDL, NWS Regions/WFOs)
  - NOAA /OAR (ESRL/GSD)
  - University of Oklahoma/CAPS
  - NESDIS GOES-R/JPSS Proving Ground
  - NASA/SPoRT
  - NCAR/MMM
  - AFWA
  - Met Office (UK)

2014 HWT Spring Forecasting Experiment Participating External Institutions

NOAA Agencies			Universities		Gov't Agencies	Private Sector
NCEP/EMC-3	NWS/BYZ-1	NWS/MRX-1	Oklahoma-4	PSU-2	AFWA-2	FirstEnergy-1
NCEP/AWC-2	NWS/GGW-1	NWS/TAE-1	Texas Tech-4	NCAR-4	Met Office UK-8	
NCEP WPC-1	NWS/FSD-1	NWS/RAH-1	UA/SUNY-3	Iowa St-2	BOM Australia-1	
NWS/PSR-1	NWS/MPX-2	NWS/BGM-1	TAMU-1		Env. Canada-4	
NWS/SLC-2	NWS/BNA-1	ESRL/GSD-6			SMN-Argentina-1	



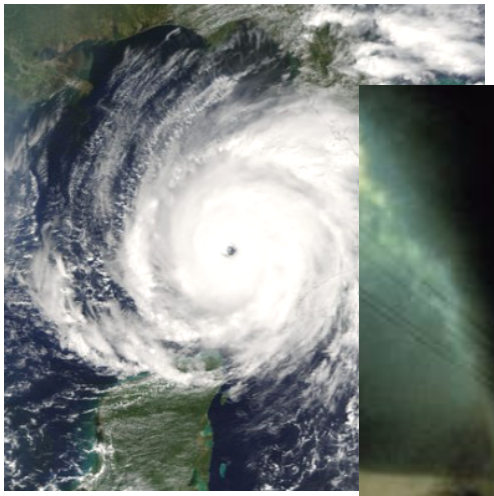
The HWT is a facilitator of R2O/O2R across the larger community involving Research Scientists, Model Developers, Operational Forecasters, University Faculty and Graduate Students

Storm Prediction Center
Norman, Oklahoma

NATIONAL SEVERE STORMS LABORATORY

Weather Impacts on Society

Since 1980 the US has experienced 148 weather-related disasters costing at least $1 billion in standardized losses (4.2 disasters per year)



Hurricanes

Tornadoes

Floods

Blizzards

During 2011-2014 there were 41 $1 billion disasters and more than half were caused by tornadoes & severe thunderstorms

Hazardous Weather Testbed

- ***Science Priorities and Service/Mission Needs***
  - Aligned directly with NOAA/NWS **Weather-Ready Nation** goals
    - Society is prepared for/responds to weather-dependent events
  - HWT focus is on hazardous convective weather events
    - Tornadoes, large hail, damaging winds, flash floods
    - Linked to core NOAA mission: protection of lives and property
  - HWT activities are informed by:
    - **FACETs (Forecasting A Continuum of Environmental Threats)**
      - Provide a cascade of reliable probabilistic hazard information on multiple time-space scales starting days out and leading to the event
    - **Warn on Forecast (WoF)**
      - Development of advanced convection-allowing models
      - Innovative data assimilation
      - Advanced ensemble modeling approaches
      - Extraction of probabilistic forecasts

Hazardous Weather Testbed

- ***Test Project Selection and Management Process***
  - Decades-long tradition of R2O/O2R interactions in Norman
  - **Experimental Warning Program**
    - Radar development, testing, and training for operational use in NWS warning operations
      - Doppler radar, dual-pol radar
    - Current testing of phased array radar
    - More recent GOES-R satellite product evaluations
  - **Experimental Forecast Program**
    - Data Assimilation & NWP model development, testing, and implementation
      - Experimental & operational ensemble and convection-allowing systems (e.g., SREF, WRF, NAM, SSEF)
    - New models improve severe storm forecasting in NWS
  - **Project testing/R2O is an incremental process over multiple years that builds upon tests/evaluations from prior experiments**

Hazardous Weather Testbed

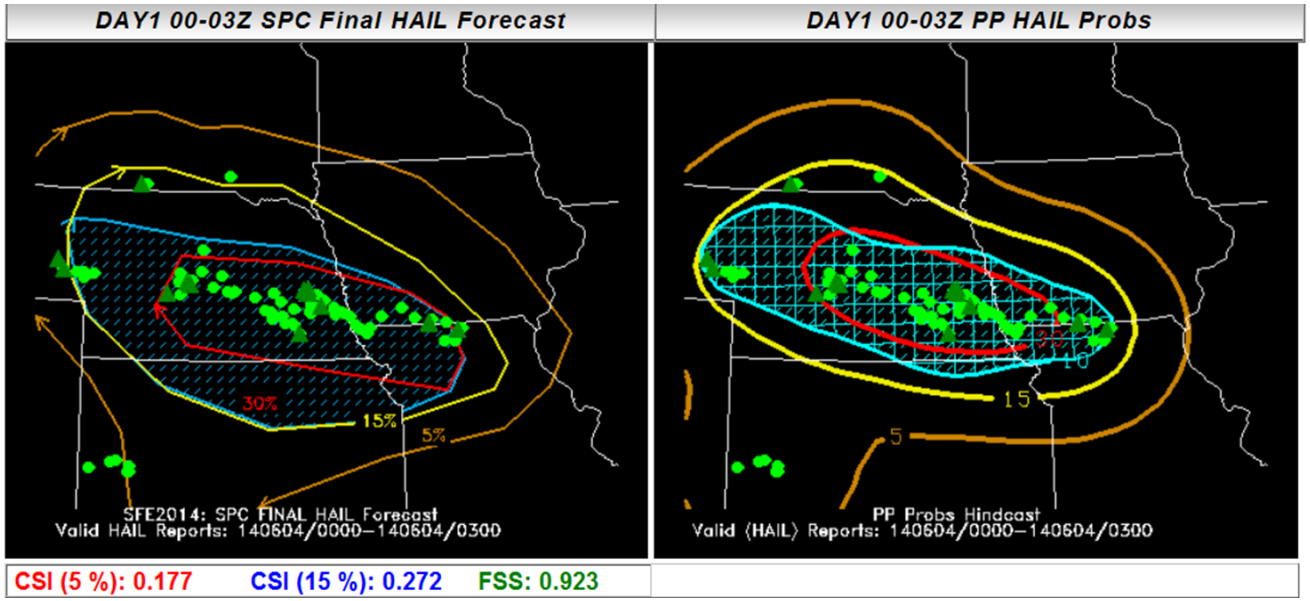
- ***Test Project Selection and Management Process***
  - Recent RFP/Grant process provides new challenges to blend funded projects into the existing HWT operating model
    - NWS R2O Initiative RFP Round 1
    - USWRP/OAR HWT Funding Opportunity
    - USWRP/OAR R2O Transition Funding Opportunity

  - Challenges & Opportunities: Establish new scientific collaborations through external funding model while maintaining established successful interactions based on mutual interests
    - Establish complementary projects outside of traditional Spring Experiment period to include more activities at other times of year

  - CIMMS job announcement (NWS R2O funding) to hire PhD-level R2O Liaison scientist to help manage expanded HWT projects (especially those led by external PIs)

Hazardous Weather Testbed

- ***Significant Accomplishments in FY14 (EFP)***
  - **Experimental High-Temporal Resolution Probabilistic Severe Thunderstorm Hazard-Type Forecasts (Tornado, Hail, Wind)**

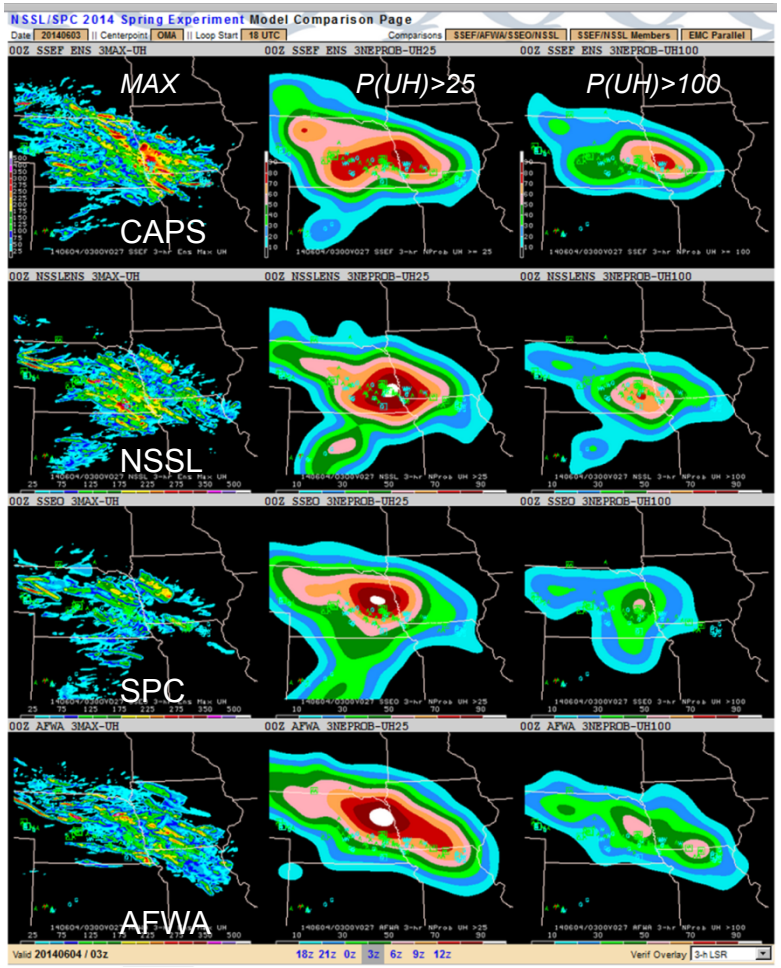


Example: 3-h Severe Hail Probability Forecast Created by HWT Forecast Team (Left) and "Practically Perfect" Verification (Right)

- *Development/testing of ensemble-based NWP calibrated guidance and subjective/objective assessment of model and forecaster skill*
- *Operational impact: Success led to internal SPC short-term tornado forecast experiment this Spring (1 April – 30 June)*

Hazardous Weather Testbed

- ***Significant Accomplishments in FY14 (EFP)***
  - **Test/Evaluation of Multiple Convection-Allowing Ensemble Prediction Systems**

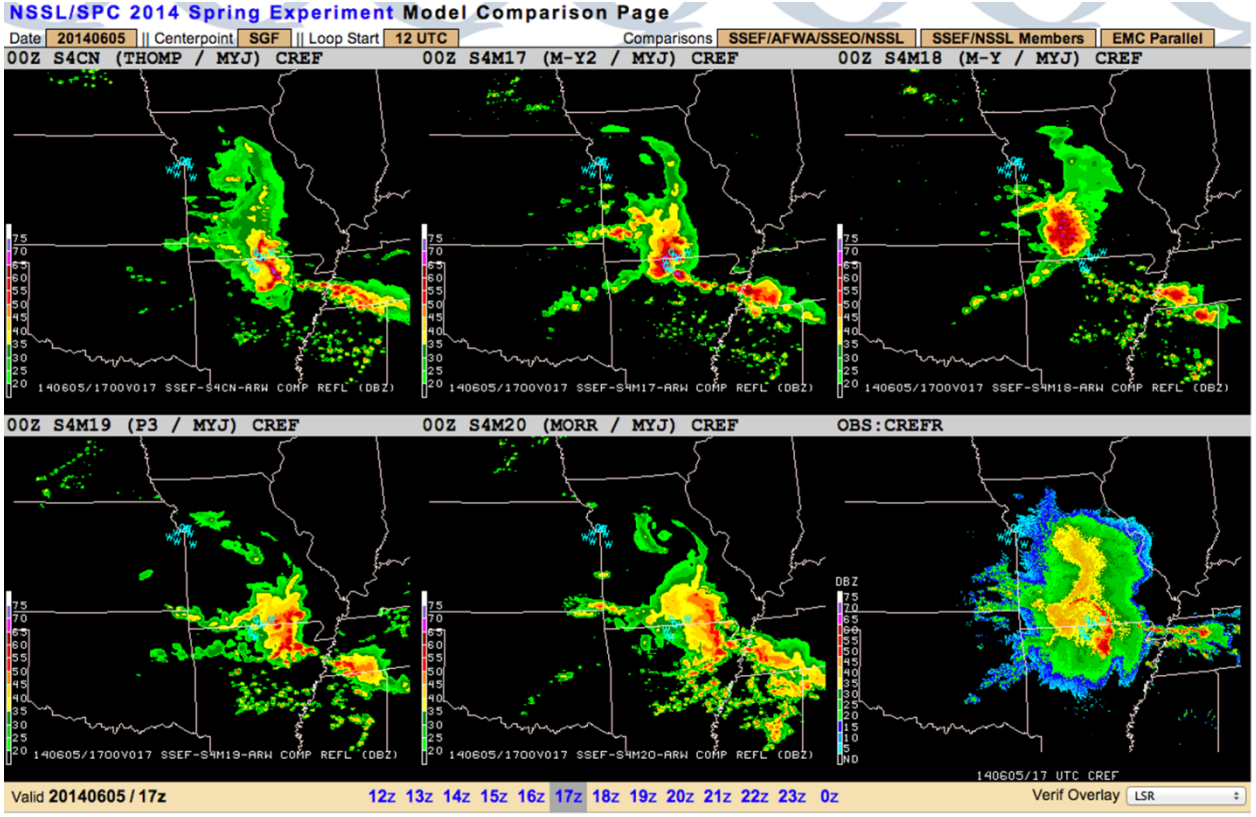


Example: Forecasts from four convection-allowing ensemble systems of Updraft Helicity, a measure of rotating updrafts (supercells) in simulated model storms, showing maximum from any member (left), neighborhood probability of UH> 25 m2/s2 (middle) and >100 m2/s2 (right); valid during 3-h period ending 03 UTC 4 June 2014.

Relevance: Comparison of different CAM ensemble configurations and implications for initial operational system at NCEP/ EMC

Hazardous Weather Testbed

- ***Significant Accomplishments in FY14 (EFP)***
  - **Test/Evaluation of Double-Moment Microphysics Schemes as part of CAPS Storm-Scale Ensemble Forecast (SSEF)**

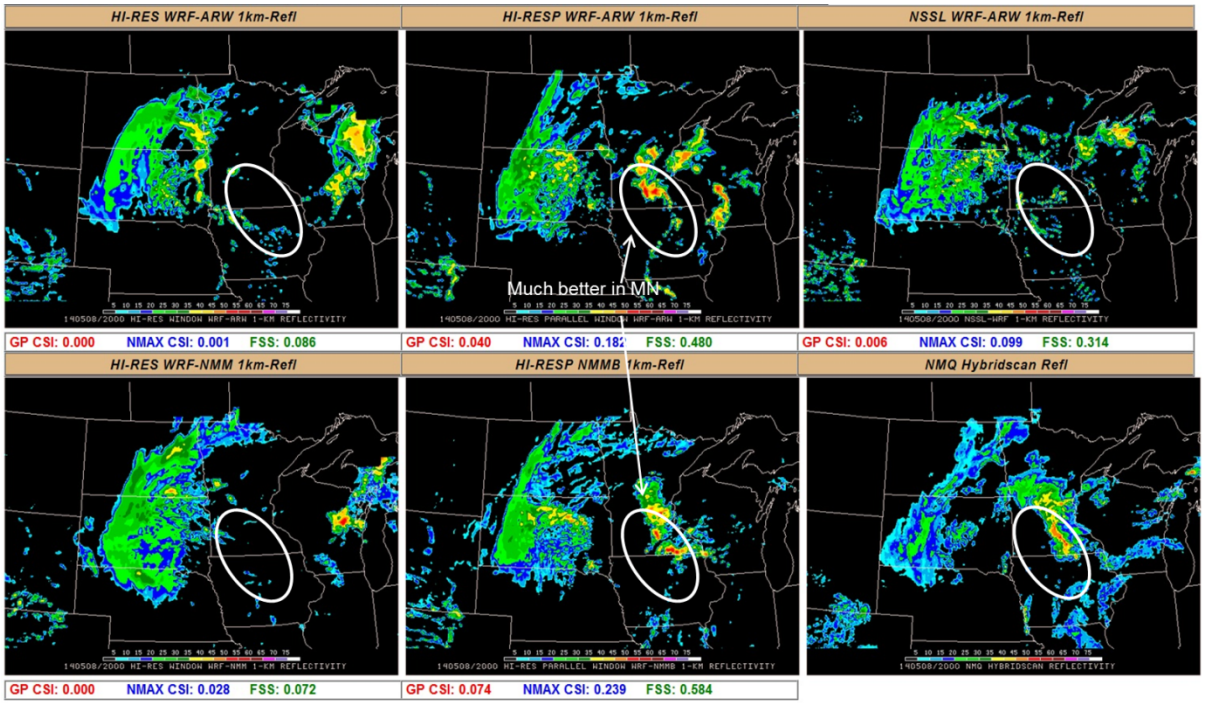


HWT collaboration with top modeling experts has enabled testing and evaluation of cutting-edge microphysics parameterizations in ARW model during peak severe weather season.

Simulated storm realism compared to observed radar/satellite and computational efficiency for potential operational use were explored.

Hazardous Weather Testbed

- ***Significant Accomplishments in FY14 (EFP)***
  - **Test/Evaluation of NCEP/EMC Parallel Convection-allowing Models (as part of longer period pre-implementation evaluation)**



Example: Subjective and objective comparisons of operational Hi-ResW ARW and NMM (left) and parallel versions (middle) compared to NSSL-WRF and observed radar (right) valid 20 UTC 8 May 2014.

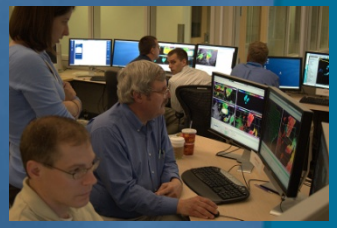
Relevance: HWT evaluations indicated parallel versions generally performed better and the newer model versions were subsequently implemented operationally at EMC in June 2014.

Hazardous Weather Testbed

- ***Top Activities in Progress/Planned for FY15 (EFP)***
  - **Upcoming Spring Forecasting Experiment**
  - **Monday-Friday during May 4-June 5 in HWT Facility**
  - **NWP Modeling Science**
    - Advanced Convection-Allowing Ensembles
      - *3 km CAPS and NCAR EnKF-based Systems*
      - *Compare with traditional 3DVar system (CAPS)*
    - EMC CAM parallel run comparisons with operational Hi-ResW, NAM Nest, and HRRR
    - Explicit prediction of hail size from CAMs
      - *Improved Hailcast in ARW*
      - *Direct hail size from microphysics (Thompson)*
    - Prototype NSSL Warn on Forecast runs to 90-180 min
      - *1-2 times per hour (primarily EWP)*
    - First look at NCAR MPAS global model out to 5 days with variable mesh (3 km) over CONUS

Hazardous Weather Testbed

Experimental Warning Program

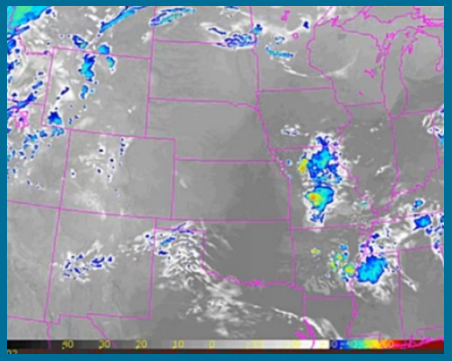


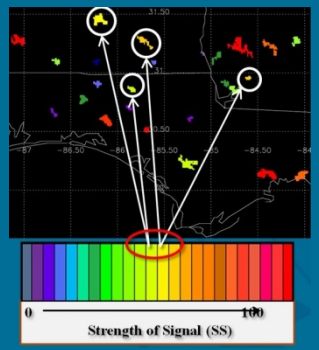
Gabe Garfield

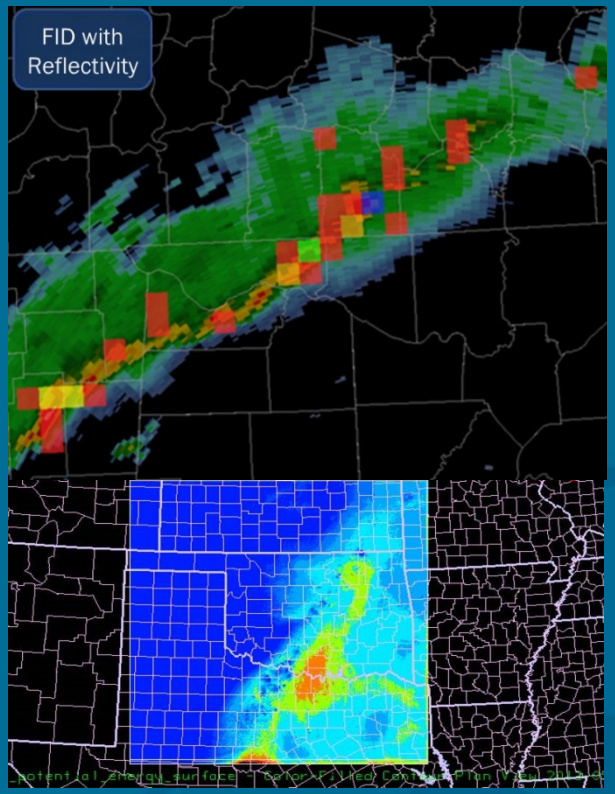
NOAA Hazardous Weather Testbed

University of Oklahoma/National Weather Service

Norman, OK







HWT Experimental Warning Program (EWP)

- Mission: Improve prediction of severe convective weather at the "warning scale" (0-2 hours).
- New sensors, applications, and methods are tested by National Weather Service forecasters in an operational warning environment.
- A vital component to the Research To Operations (R2O) and Operations to Research (02R) process.

What is tested?

- New sensors:
  - Radar, satellite, and lightning
- New applications/algorithms:
  - Composite products, satellite proxies, lightning data, short term models, etc.
- New methodologies:
  - Best practices, concepts, products, services
  - Social science

Feedback

- Online survey
- Blog
- Real-time discussions
- Debriefings (daily, weekly)
- In-house warnings

EWP Projects in 2014 (April – August)

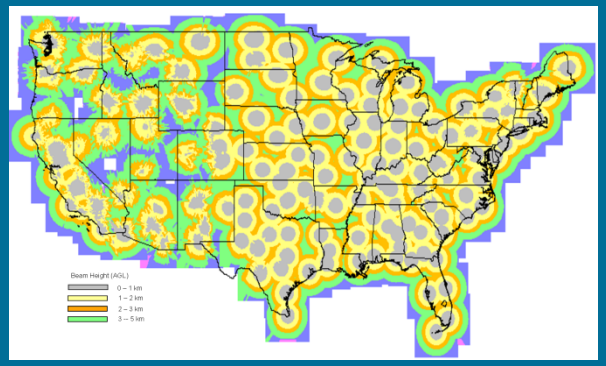
- Multi-Radar Multi-Sensor Best Practices
- Big Experiment
- Probabilistic Hazards Information Experiment
- Hydro Experiment
- Earth Networks Total Lightning Experiment

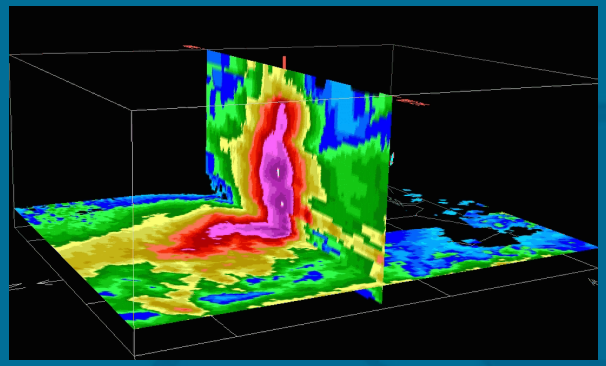
EWP Projects in 2014 (April – August)

- Multi-Radar Multi-Sensor Best Practices
- Big Experiment
- Probabilistic Hazards Information Experiment
- Hydro Experiment
- Earth Networks Total Lightning Experiment

Multi-Radar Multi-Sensor (MRMS)

- **Multi-Radar:** Continuous, 3-D Nexrad radar data
- **Multi-Sensor:** Objective blending of radar data with surface, upper air, lightning, satellite, rain gauge, and NWP environmental data





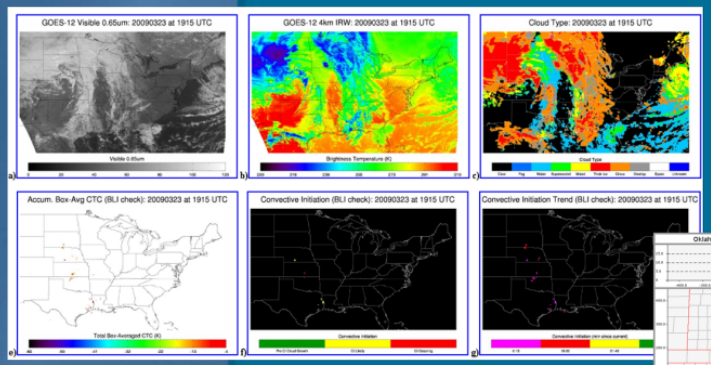
MRMS Best Practices Takeaways

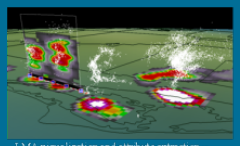
- Ranking storms much faster with MRMS
- Quick diagnosis of storms using MRMS

Big Spring Experiment

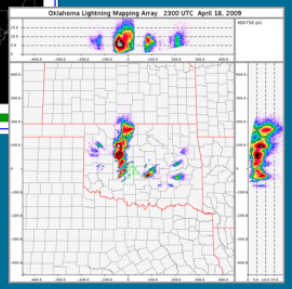
2014

GOES-R / PGLM

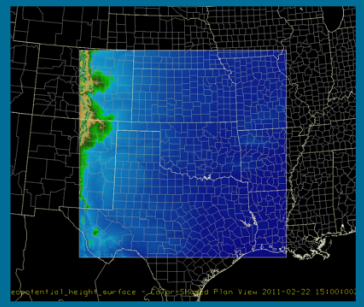


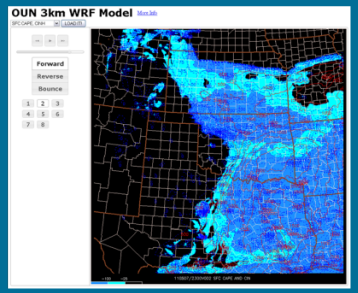


LMA visualization and attribute extraction

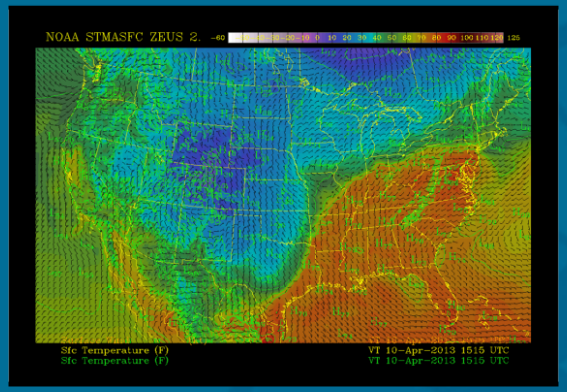


OUN WRF





LAPS Space and Time Multiscale Analysis System (STMAS)



Big Experiment
New in 2014

- Probability of Severe
  - Statistical model (for developing thunderstorms)
- Overshooting Top Detection
  - Satellite algorithm
- Variational LAPS model
  - On-demand, 1-km forecast
- Multi-field trending tool
  - Model output, satellite, radar
- GOES-R Rapid Scan
  - 1-min updates
  - 8-22 May 2014

New in 2014

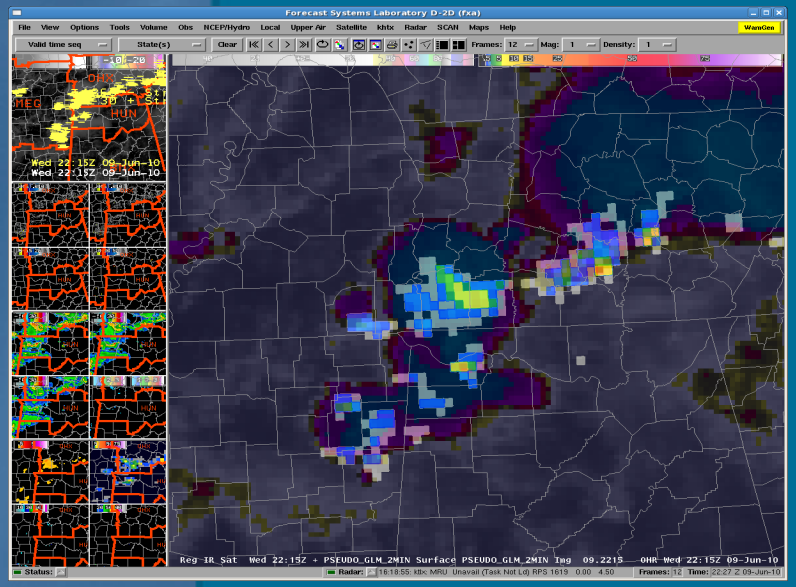
- Every week, a broadcast meteorologist joined us as a forecaster
- Offered unique opportunity for collaboration with partners
  - Focus on communication
  - Speed of analysis

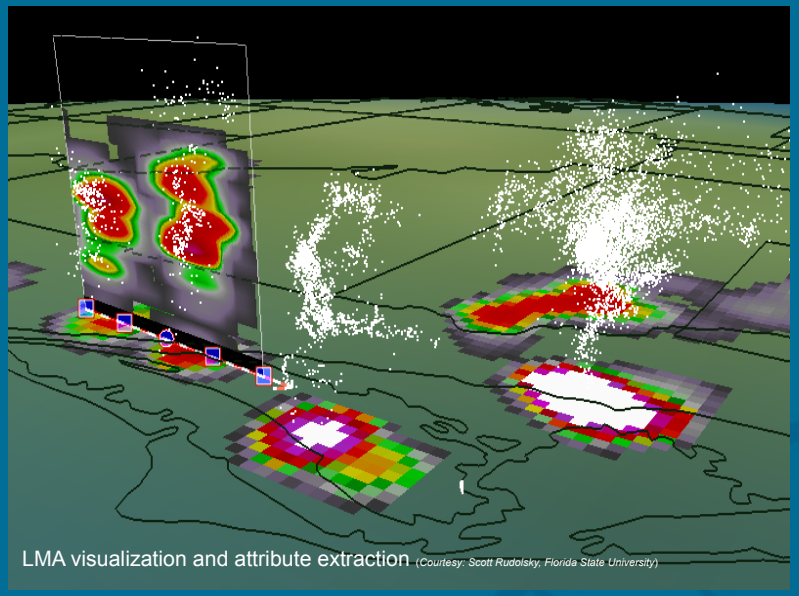
Big Experiment
Collaboration with EFP

- EFP shared experimental probabilistic severe weather outlooks (tornado, wind, hail) twice during operations

Pseudo-Geostationary Lightning Mapper (PGLM)

- Cloud-to-Ground + Intra-Cloud = **Total Lightning**



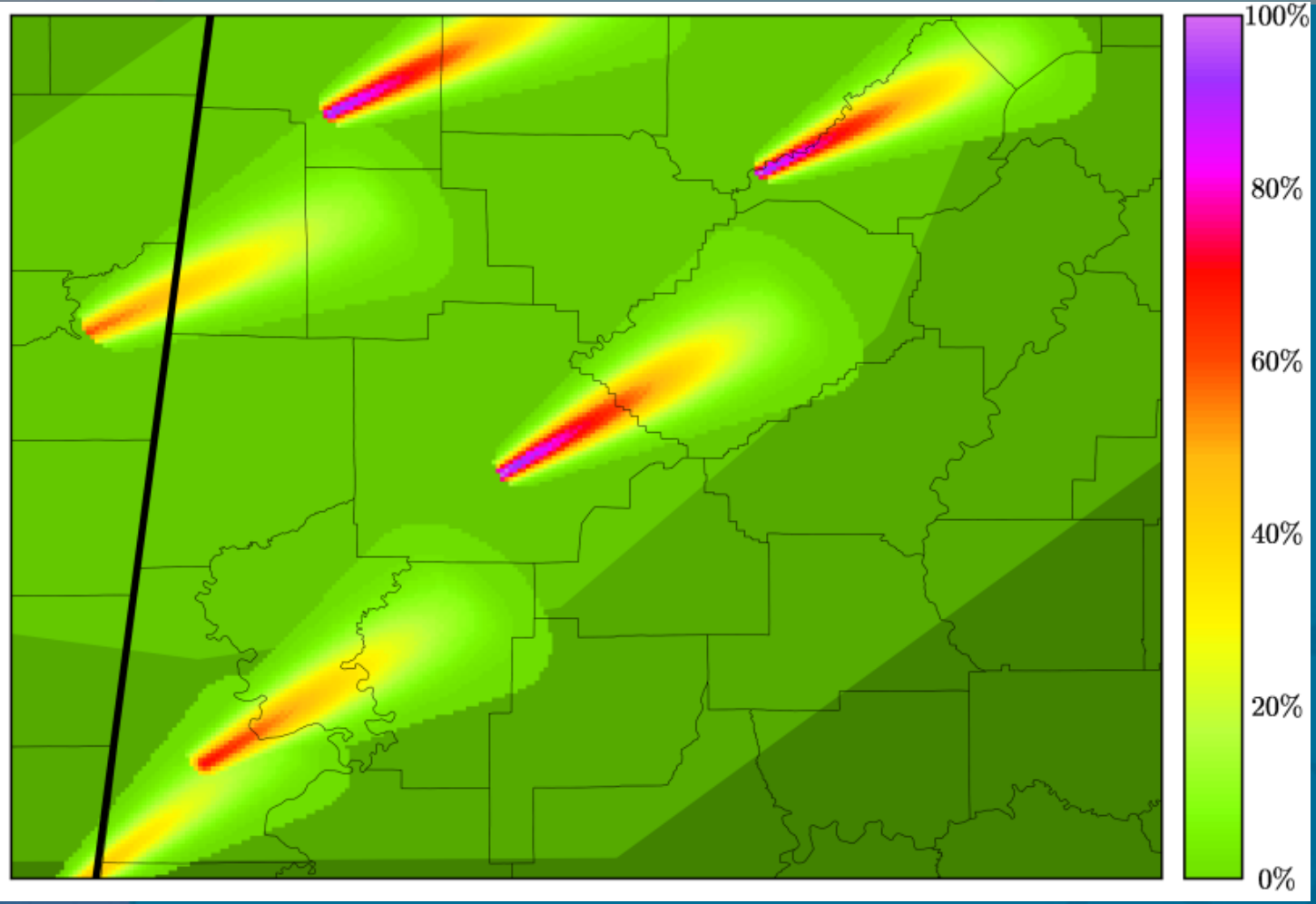

LMA visualization and attribute extraction *(courtesy: Scott Rudolsky, Florida State University)*

Big Spring Experiment

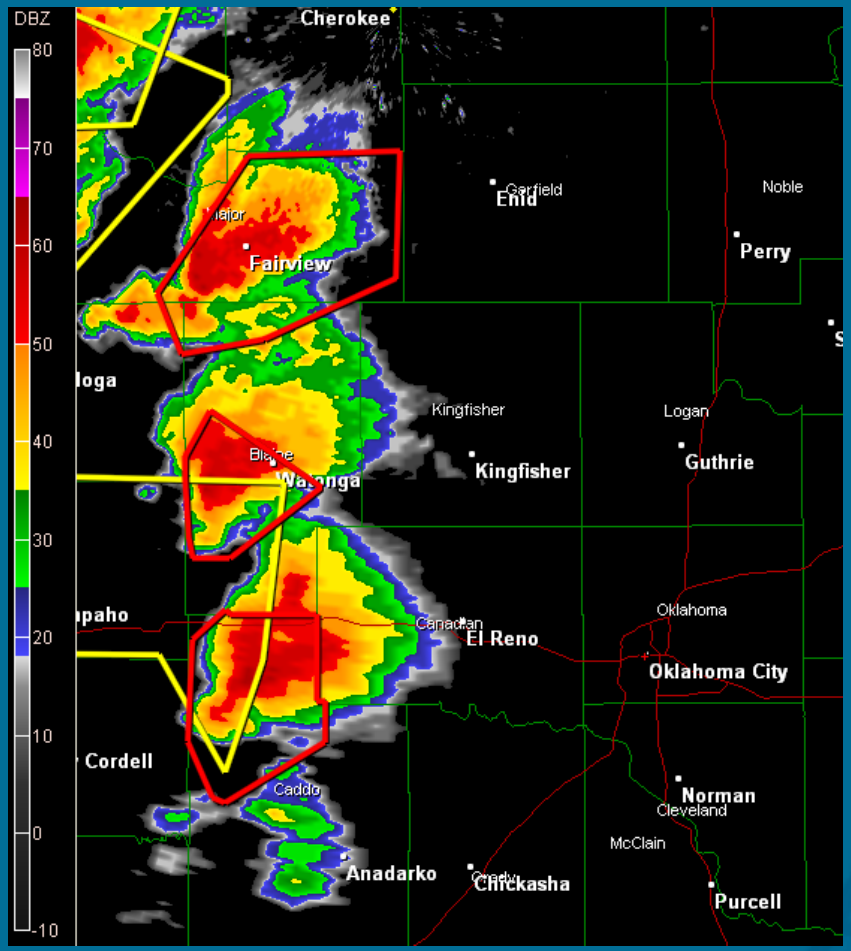
PGLM Takeaways

- Weather Service
  - Lightning jumps and flash density improved situational awareness by highlighting intensifying cells
- Aviation
  - Lightning products enhance short-term forecasting and help determine flight paths
- Broadcast
  - Lightning products useful for broadcast meteorologists working by themselves during severe weather operations

Probabilistic Hazards Information (PHI) Experiment



Standard Warning

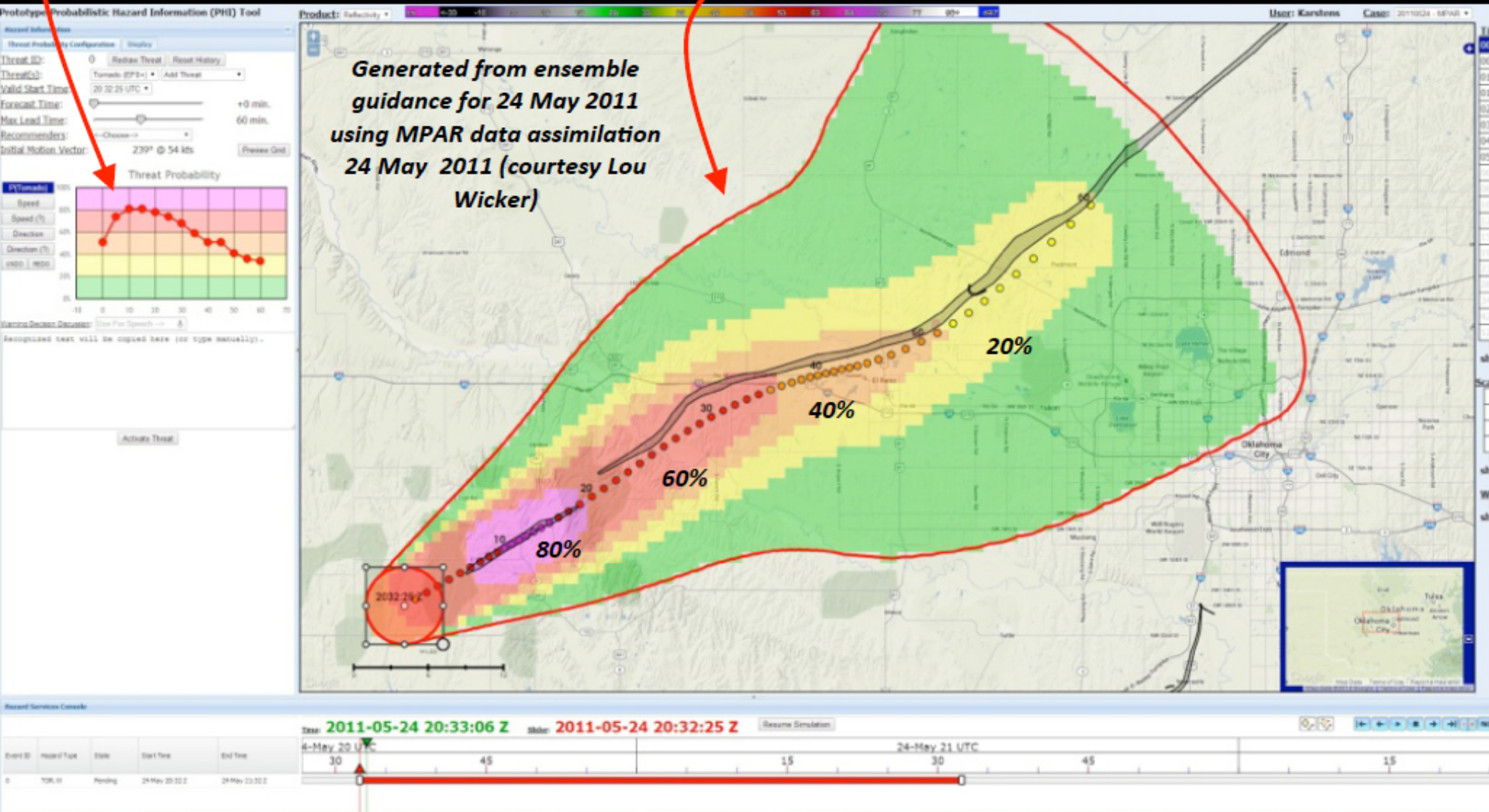


Probabilistic Hazard Information (PHI)

Probabilities generated from ensemble forecasts can be used to inform:

- Forecast probability of occurrence
- Forecast uncertainty of location

Prototype PHI Tool – Karstens et al.

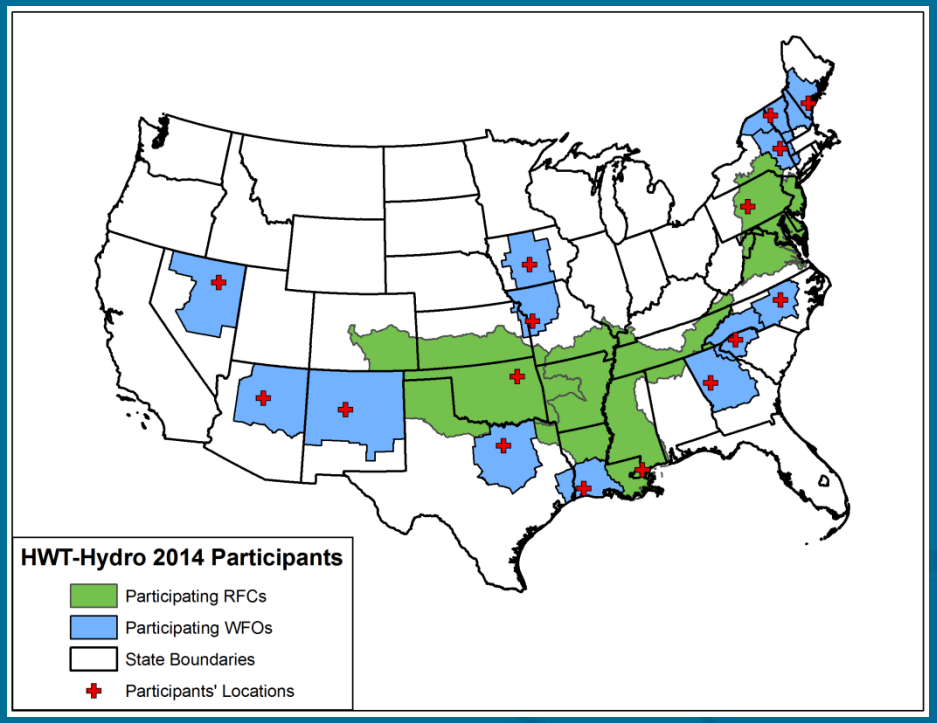


PHI Takeaways

- "On-the-fence" decisions reduced significantly
  - Allows for low-probability hazard information to be communicated to the public
  - Results in richer and more detailed information for more storms
- Different way of thinking
  - Forecasters are thinking more about the meteorology of the event as compared to current warning system
    - Enhanced situational awareness

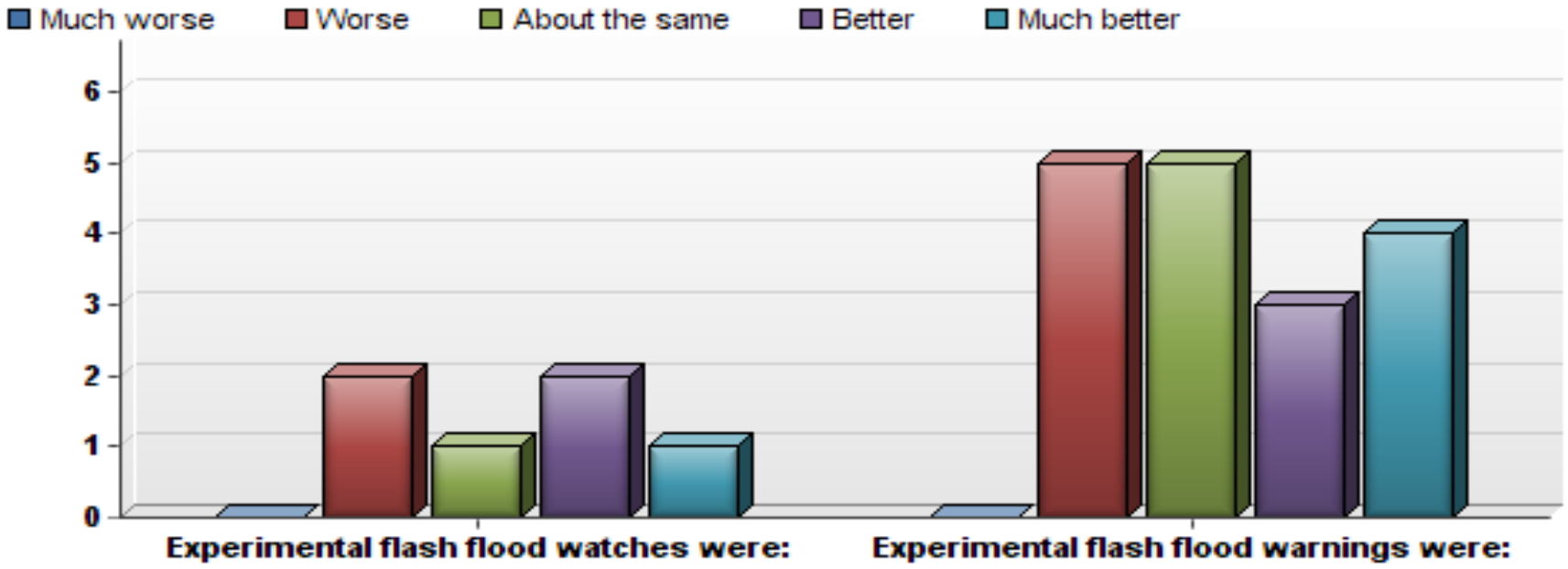
Hydrology Experiment

- Experimental flood / flash flood products used to issue watches and warnings.
- Experimental flash flood watches issued in in the 0-6 hr time-frame (similar to SPC watches).
- Probabilities assigned to the experimental watches and warnings (uncertainty and magnitude).

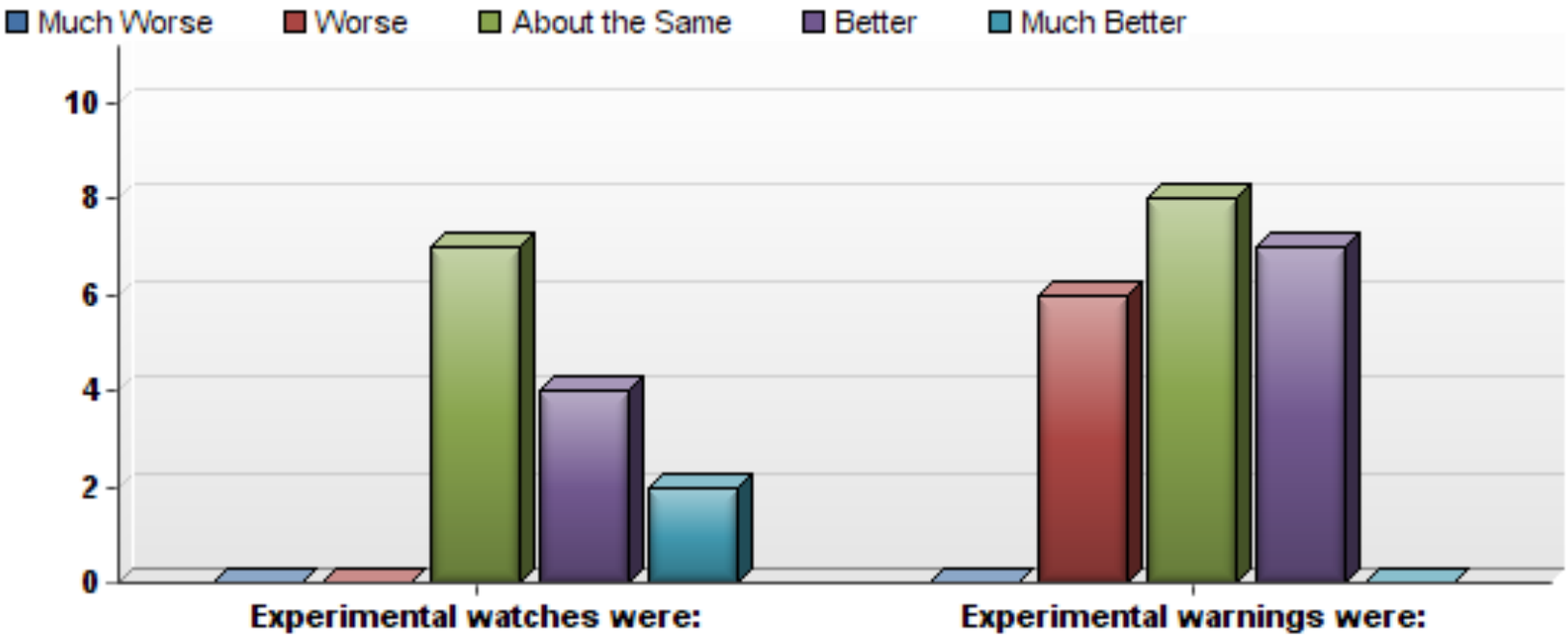


Results

Flash Flood Watches and Warnings



Results
Flood Watches and Warnings



New for 2015

- Lightning
  - Comparison between Earth Networks and Lightning Jump products
- Satellite
  - Rapid-scan satellite algorithms
- Probabilistic Hazards Information
  - Testing model-derived “first guess” probability
- NEWS-e Model
  - First attempt at warning on forecast using a high-resolution ensemble of models

New for 2015

- Emergency management will join PHI experiment to test communication of probabilities.

Questions?