The NOAA Hazardous Weather Testbed: Summary of 2013 Spring Experiments and Preview of 2014 Activities

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5. OU/Center for Analysis and Prediction of Storms, Norman, OK
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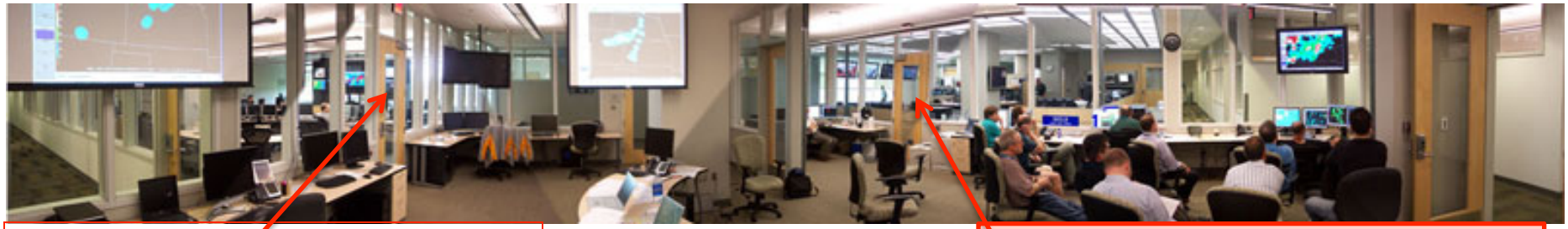
7. NOAA/NWS/Meteorological Development Laboratory, Norman, OK

5th NOAA Testbed and Operational Proving Ground Workshop
April 16-18, 2014
College Park, MD

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 and 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***

Spring Forecasting Experiment

http://hwt.nssl.noaa.gov/Spring_2013/

- ***What is it?*** The cornerstone of R2O-O2R activities for the HWT/EFP. A 5-week experiment conducted each spring to test and evaluate emerging scientific concepts and tools in a simulated operational forecasting environment.

- ***What was new for 2013?***
  - Forecasting emphasis on **probabilistic forecasts of total severe weather valid <u>for shorter time periods</u>** than current operational products with more frequent updates *("continuum of information" FACETs concept supporting Weather Ready Nation goals)*.
    - Updated 21-00 & 00-03Z periods twice in afternoon
    - Provided gridded forecasts to EWP
  - **New model guidance available** for the generation of forecasts:
    - 12Z convection-allowing ensembles (OU/CAPS SSEF, SPC SSEO, and AFWA)
    - Hourly NSSL Mesoscale Ensemble (NME)
    - NSSL WRF-ARW parallel initialized from the NME
    - UKMET Unified Model convection-allowing runs

2013 Spring Forecasting Experiment

Summary of Primary Goals

- Assess the value of frequently updated, higher temporal resolution convective outlooks.

- Determine whether a parallel NSSL WRF-ARW initialized from the NSSL Mesoscale Ensemble (NME) produces improved forecasts over the NAM-initialized version.

- Compare the performance of two UKMET Unified Model convection-allowing configurations to the NSSL WRF-ARW.

- Compare the 12Z-initialized convection-allowing ensembles to their 00Z-initialized counterparts.

- Examine physics sensitivities in the convection-allowing WRF-ARW simulations.

2013 Spring Forecasting Experiment

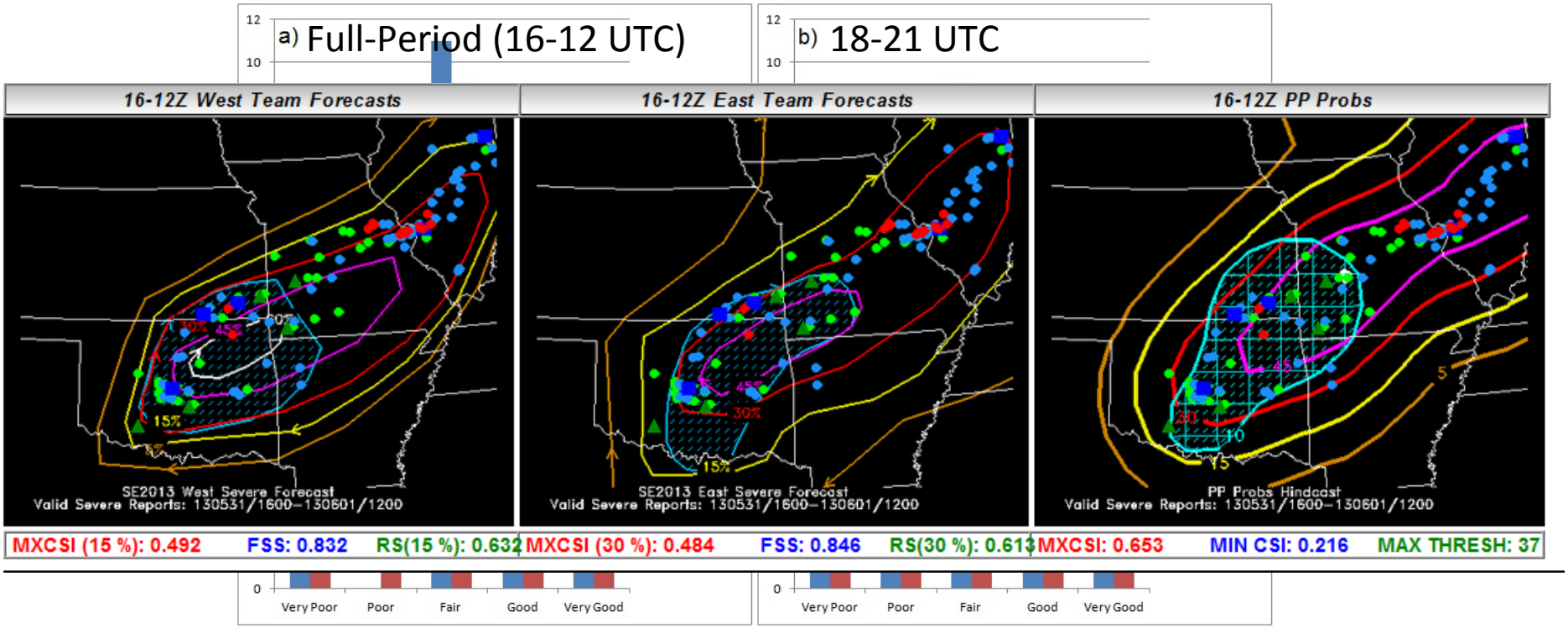
Summary of Daily Activities

- 8:00-9:30 am: Create experimental full-period (16-12Z) probabilistic forecasts of total severe weather – two separate teams with same data access
- 9:30-10:00 am: Evaluate yesterday's forecasts
- 10:00-11:00 am: Evaluate experimental model forecasts for yesterday
- 11:00 am-12:00 pm: Create experimental probabilistic forecasts for 3-h periods: 18-21, 21-00, and 00-03Z
- 1:00-1:30 pm: Weather briefing
- 1:30-2:30 pm: Update forecasts for 21-00 and 00-03Z
- 2:30-3:00 pm: Finish evaluations
- 3:00-4:00 pm: Final update to 21-00 and 00-03Z forecasts

2013 Spring Forecasting Experiment

Subjective Findings: *Experimental Forecasts*

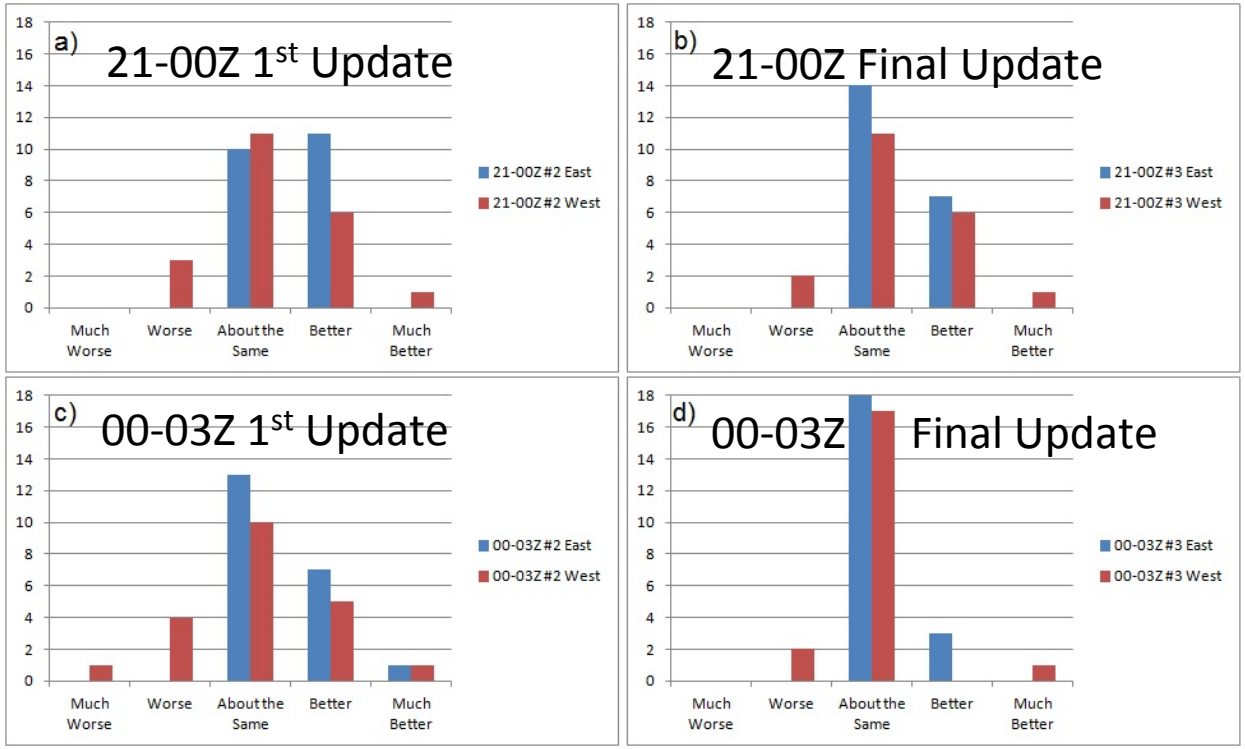
- Forecasts were rated subjectively the next day based on observed storm evolution, operational warnings, and preliminary storm reports
- More “poor” or “very poor” forecasts in the 3-h periods than in the full period, which is not surprising given that an error in expected timing of severe storms has little to no impact on the full-period forecast
- Highest rated forecasts during peak of severe weather occurrence (21-00Z)



2013 Spring Forecasting Experiment

Subjective Findings: *Experimental Update Forecasts*

- The forecast updates rarely resulted in a degraded forecast, nor did they often result in a "much better" forecast.
- The final update was more likely to be "about the same" as the previous forecast than the first update forecast



2013 Spring Forecasting Experiment

Experimental Models: *NSSL WRF Parallel*

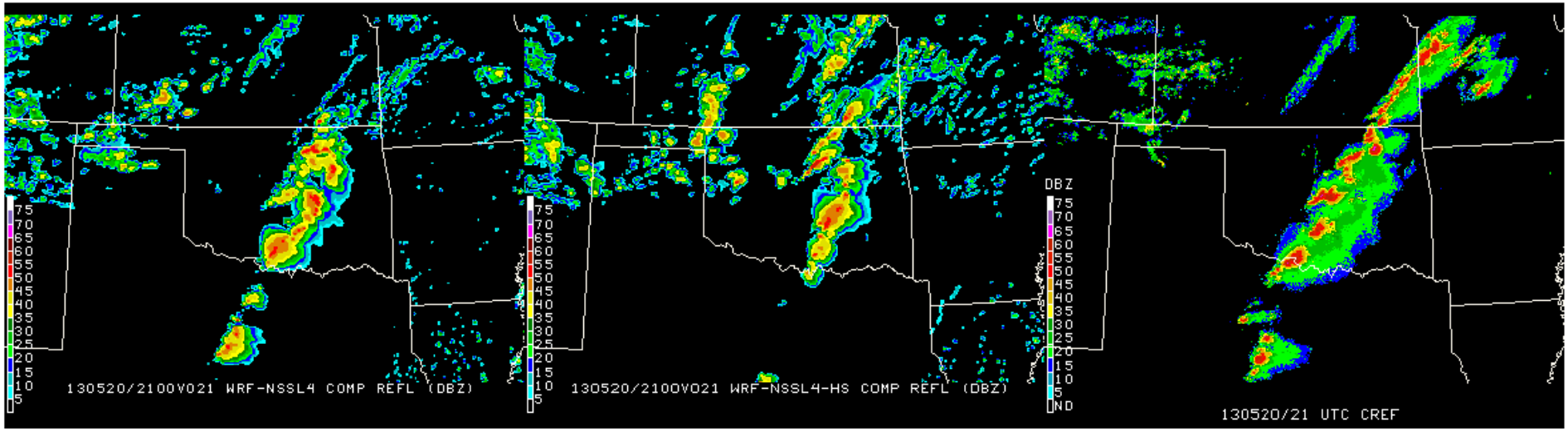
- Studies of several significant severe weather events and analysis/experience with the CAPS SSEF indicate initial condition specification can have a large impact on convection-allowing model predictions.
- To explore this, a parallel version of the NSSL-WRF was run using the "best member" from the 00Z NSSL Mesoscale Ensemble (NME) analysis.
  - The best member was defined as the member with the lowest normalized RMS difference of temperature and horizontal wind components using all 00Z observations.
- The parallel and operational NSSL-WRF versions were identically configured except for their initial conditions so that the impact of initializing with NME, rather than the NAM, could be assessed.

2013 Spring Forecasting Experiment

Subjective Findings: *NSSL WRF Parallel*

- There were often noticeable differences between convection-allowing forecasts from the NSSL WRF initialized from the NAM and those initialized from the NME.
- The NME-initialized forecasts were subjectively rated better (worse) than the NAM-initialized forecasts 30% (40%) of the time.
- On many occasions, the quality of the forecast during the afternoon was strongly tied to how well overnight/early morning convection was depicted earlier in the model integration.

NAM-initialized **NME-initialized** **OBS**



2013 Spring Forecasting Experiment

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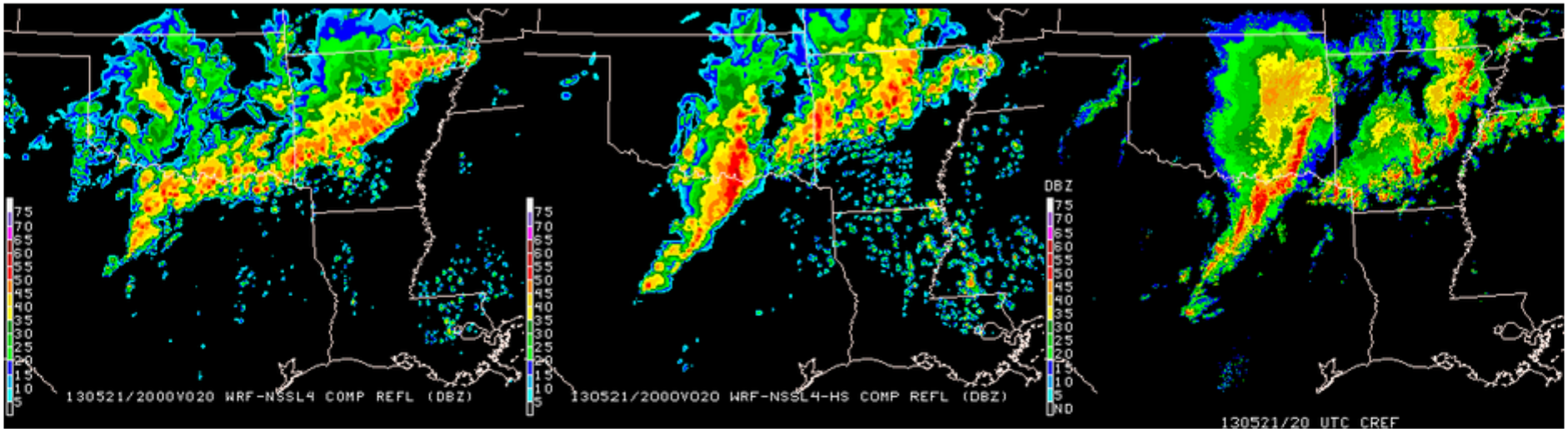
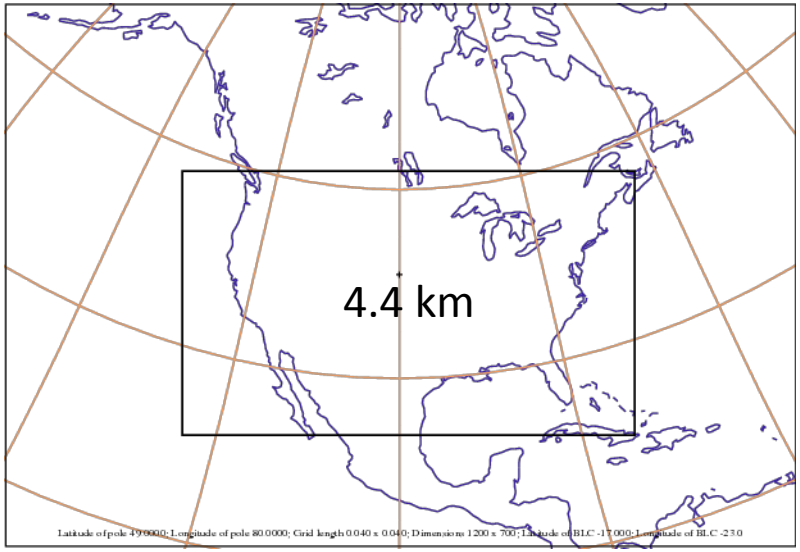


2013 Spring Forecasting Experiment

Exper. Models: *Met Office Convection-Allowing Runs*

- 4.4-km grid spacing forecasts to 48 h nested within the 00Z initialized 25-km global configuration of the Met Office Unified Model (UM)
  - 70 vertical levels
  - Uses different approach to turbulent mixing (2D Smagorinsky) than WRF-ARW and uses shallow convection parameterization at ~4 km grid spacing (WRF-ARW runs do not).
  - Uses single-moment microphysics
- 2.2-km grid spacing forecasts to 45 h nested within the 4.4 km run
  - 70 vertical levels
  - Same turbulent-mixing and microphysics as 4.4 km run, but no shallow convection

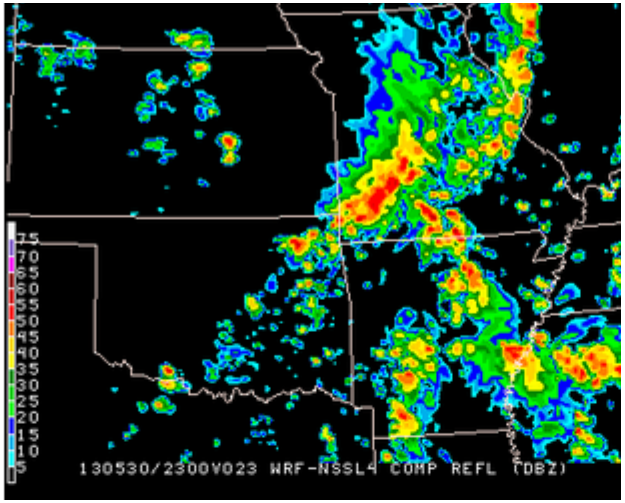


2013 Spring Forecasting Experiment

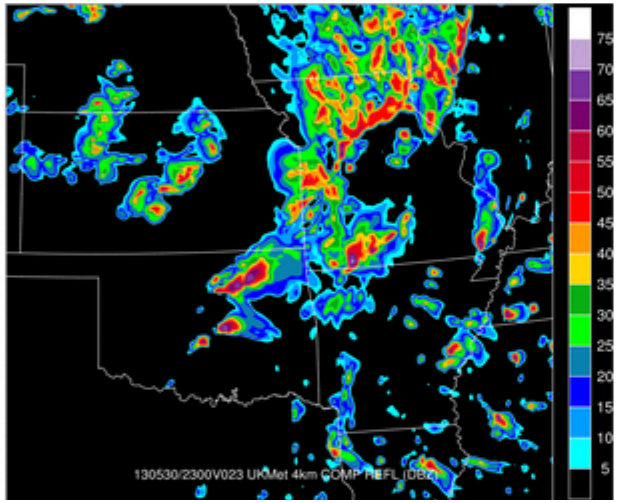
Subjective Findings: *Met Office Convection-Allowing Runs*

- The 4.4-km Met Office UM run was most commonly rated better than the NSSL WRF for a variety of reasons, including:
  - Suppression of convection in the correct locations.
  - Better depiction of timing and placement of convection.

NSSL WRF



4.4 km UKMET



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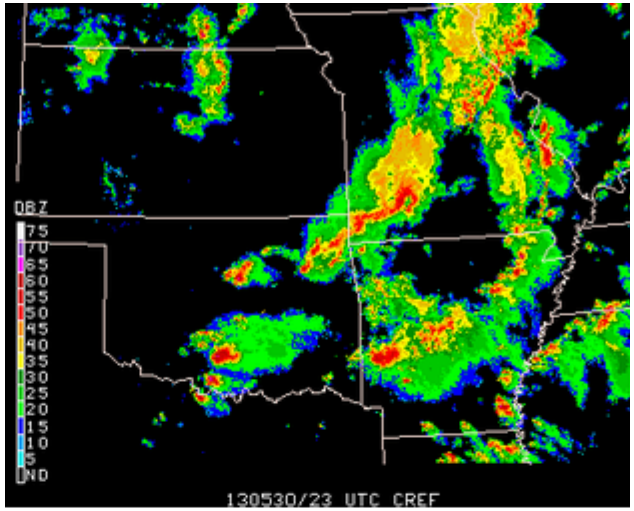
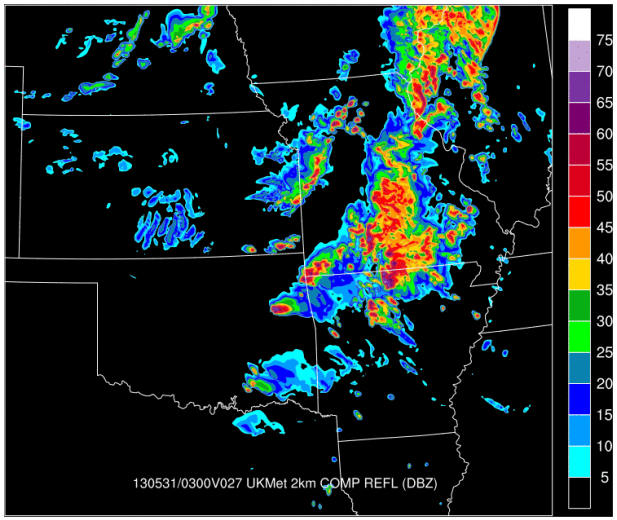


2013 Spring Forecasting Experiment

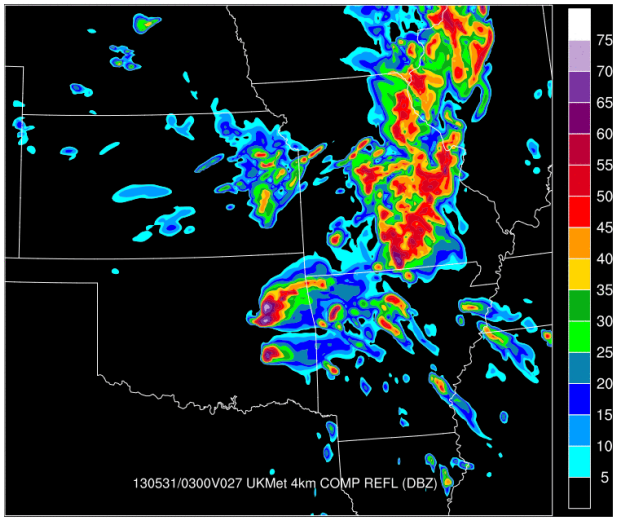
Subjective Findings: *Met Office Convection-Allowing Runs*

- The 4.4-km Met Office UM run was most commonly rated better than the NSSL WRF for a variety of reasons, including:
  - Suppression of convection in the correct locations.
  - Better depiction of timing and placement of convection.
- The UM runs did not appear to handle the upscale growth and transition of storms into linear systems very well (maintained intense cellular clusters).

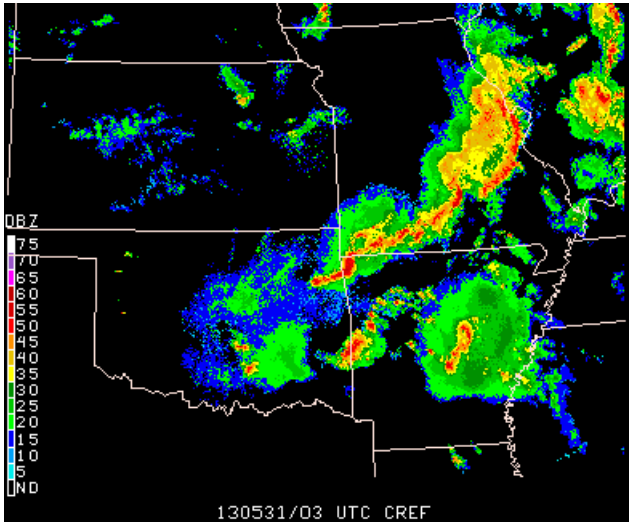
2.2 km UKMET



4.4 km UKMET



OBS



2013 Spring Forecasting Experiment

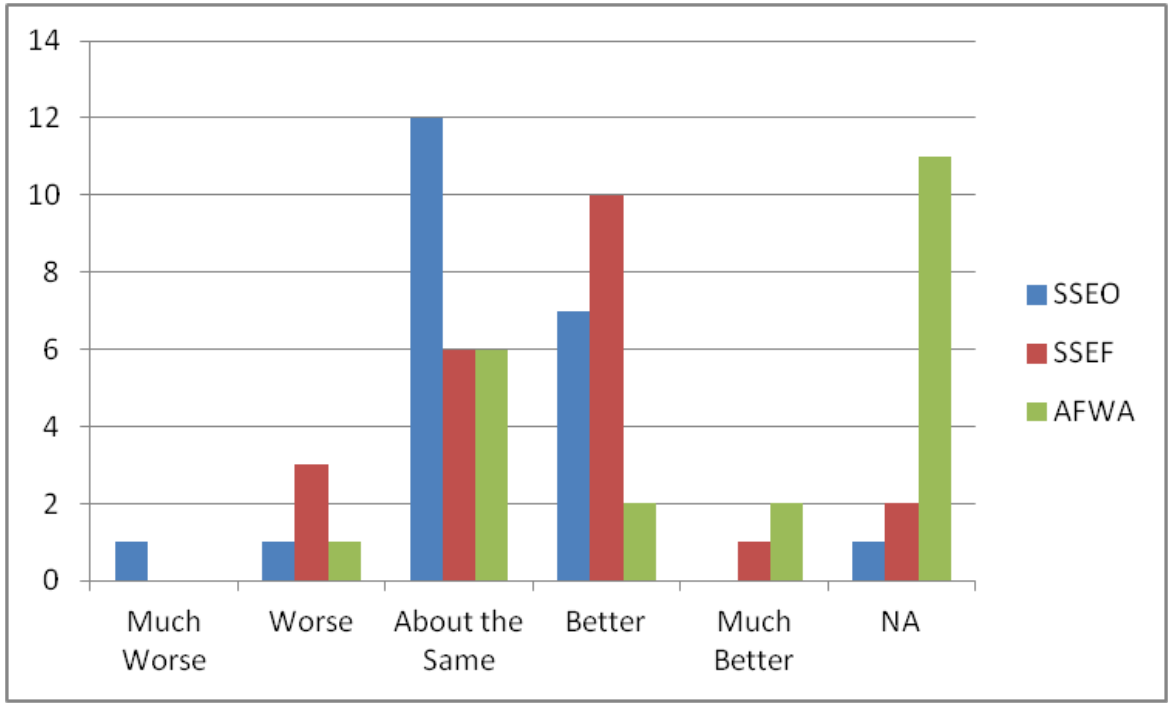
Experimental Models: *12Z Convection-Allowing Ensembles*

- ***OU CAPS Storm-Scale Ensemble Forecast (SSEF) System***
  - 25 members at 00Z with 15 core members for ensemble products and 10 members with physics-only perturbations; 8 members at 12Z; 4-km grid spacing
  - Single model (WRF-ARW), multi-physics, multi-initial conditions: apply SREF perturbations to NAM initial conditions
  - Advanced physics, 3D-Var radar data assimilation and cloud analysis
- ***SPC Storm-Scale Ensemble of Opportunity (SSEO)***
  - 7 members at 00Z & 12Z including 2 time-lagged members
  - Multi-model (WRF-ARW, WRF-NMM, and NMM-B), multi-physics: take available deterministic models and process as an ensemble
  - ICs/LBCs from NAM
- ***Air Force Weather Agency (AFWA) Ensemble***
  - 10 members at 00Z & 12Z with 4-km grid spacing
  - Single model (WRF-ARW), multi-physics, multi-initial conditions: cold start from downscaled global model forecasts (GFS, UKMET, CMC)
  - No data assimilation

2013 Spring Forecasting Experiment

Subjective Findings: *12Z Convection-Allowing Ensembles*

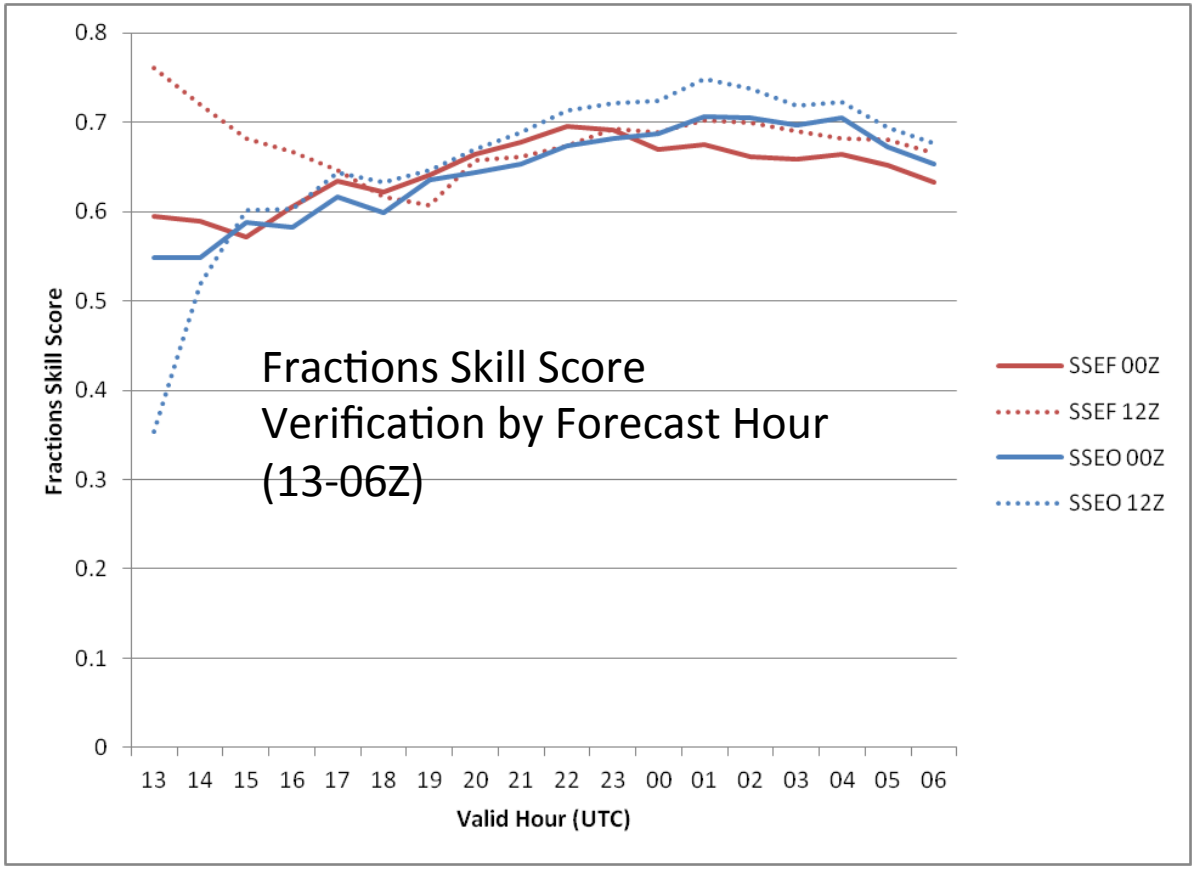
- Neighborhood reflectivity probabilities ≥40 dBZ from 12Z convection-allowing ensembles were subjectively compared to 00Z ensembles and observations with regard to timing, location, orientation, magnitude, etc. of convection.
- The 12Z-initialized convection-allowing ensembles were generally rated "about the same" as or "better" than their 00Z counterparts in terms of simulated reflectivity.



2013 Spring Forecasting Experiment

Objective Findings: *12Z Convection-Allowing Ensembles*

- The impact of radar data assimilation in the CAPS SSEF was evident in the first 4 hours of the 12Z-initialized forecast.
- Otherwise, there was little statistical difference in the FSS among the 00Z and 12Z SSEO and SSEF.



2013 HWT Spring Forecasting Experiment

Display Tools to Extract and Summarize Information

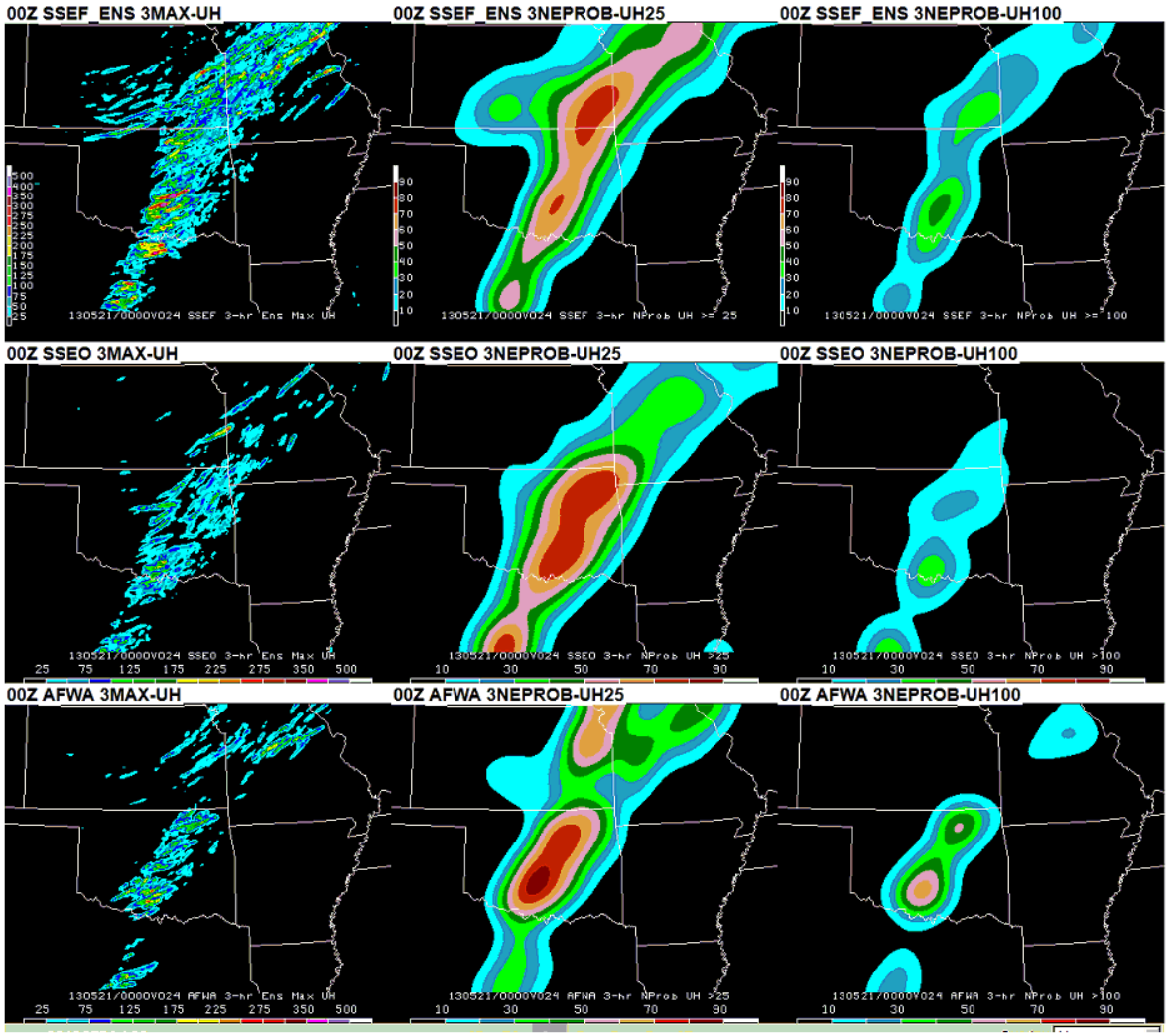
24-hr UH Forecasts CAM Ensembles valid 21-00z 20 May 2013

3-hr Max Any Member | 3-hr NProb>25 m2/s2 | 3-hr Nprob >100 m2/s2

CAPS SSEF

SPC SSEO

AFWA



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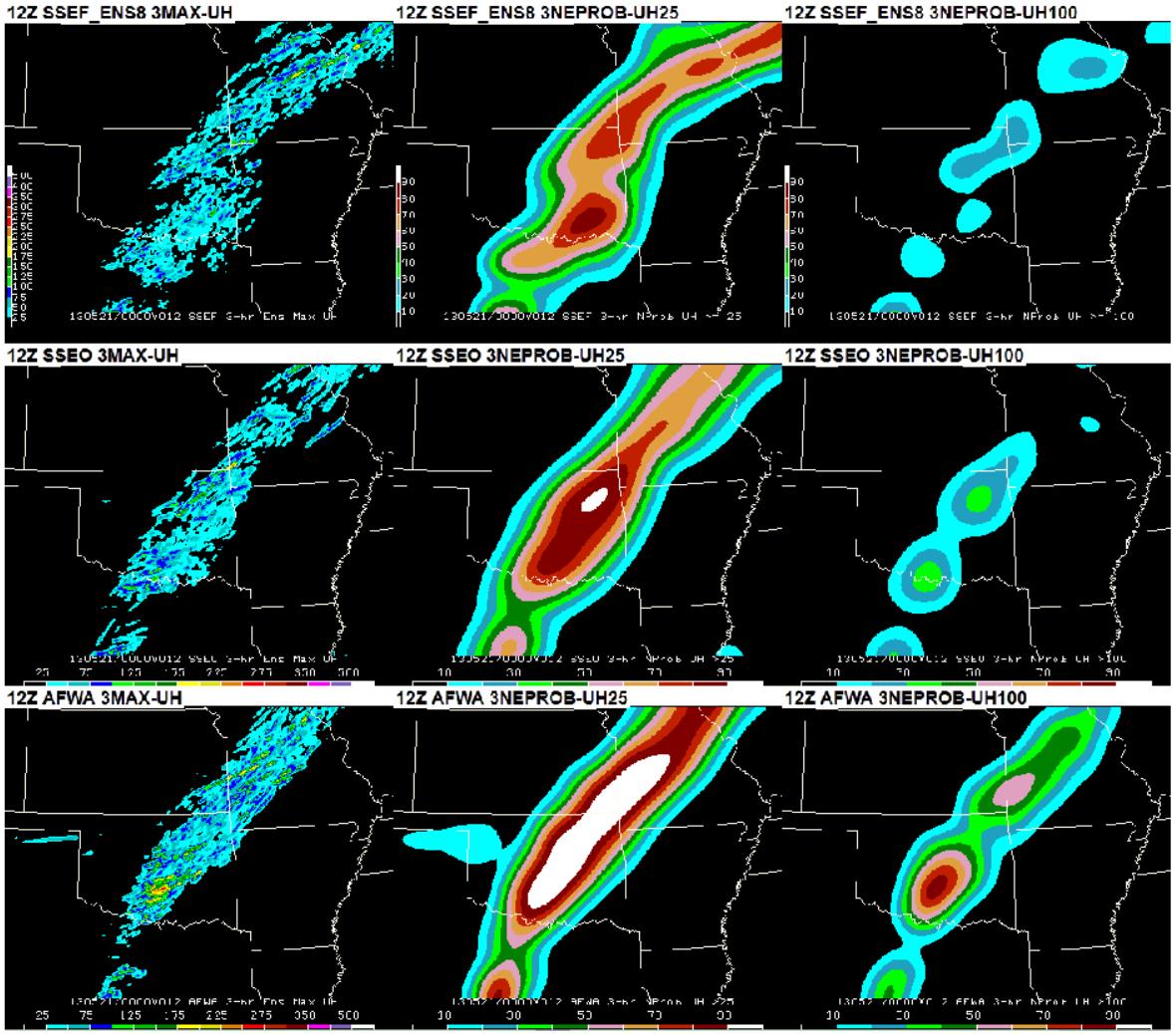
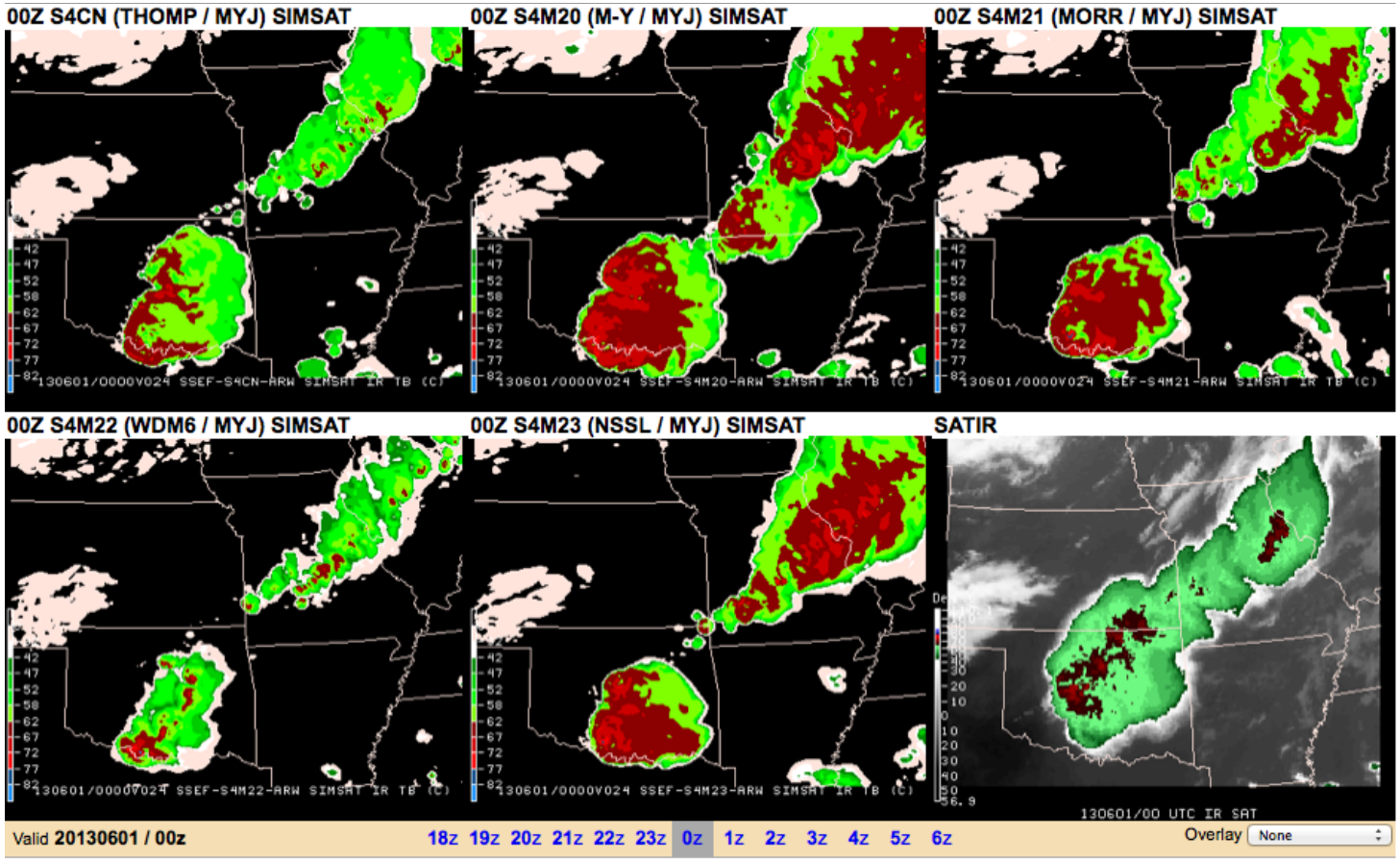


2013 Spring Forecasting Experiment

Subjective Findings: *Microphysics Sensitivity*

- Five microphysics parameterizations were tested in SSEF members to assess sensitivity on convective storm forecasts.
- Systematic differences in the forecasts of simulated satellite and radar reflectivity were apparent in daily evaluations.



2013 Spring Forecasting Experiment

Summary

- The utility of short-term convection-allowing and mesoscale ensemble model guidance in creating frequently updated, high-temporal resolution probabilistic forecasts of severe weather was explored during SFE2013

- The initial conditions had a noticeable impact on NSSL WRF convective forecasts with the quality of the forecast during the afternoon often strongly tied to how well overnight/early morning convection was depicted.

- The current level of sophistication and formality of design in a convection-allowing ensemble did not appear to have a noticeable impact on the overall forecast performance for severe weather prediction.

- An effective collaboration with the Met Office (UK) was established through five-week participation and examination of their convection-allowing model runs, which proved to be very competitive with WRF-ARW based models.

2014 Spring Forecasting Experiment

http://hwt.nssl.noaa.gov/Spring_2014/

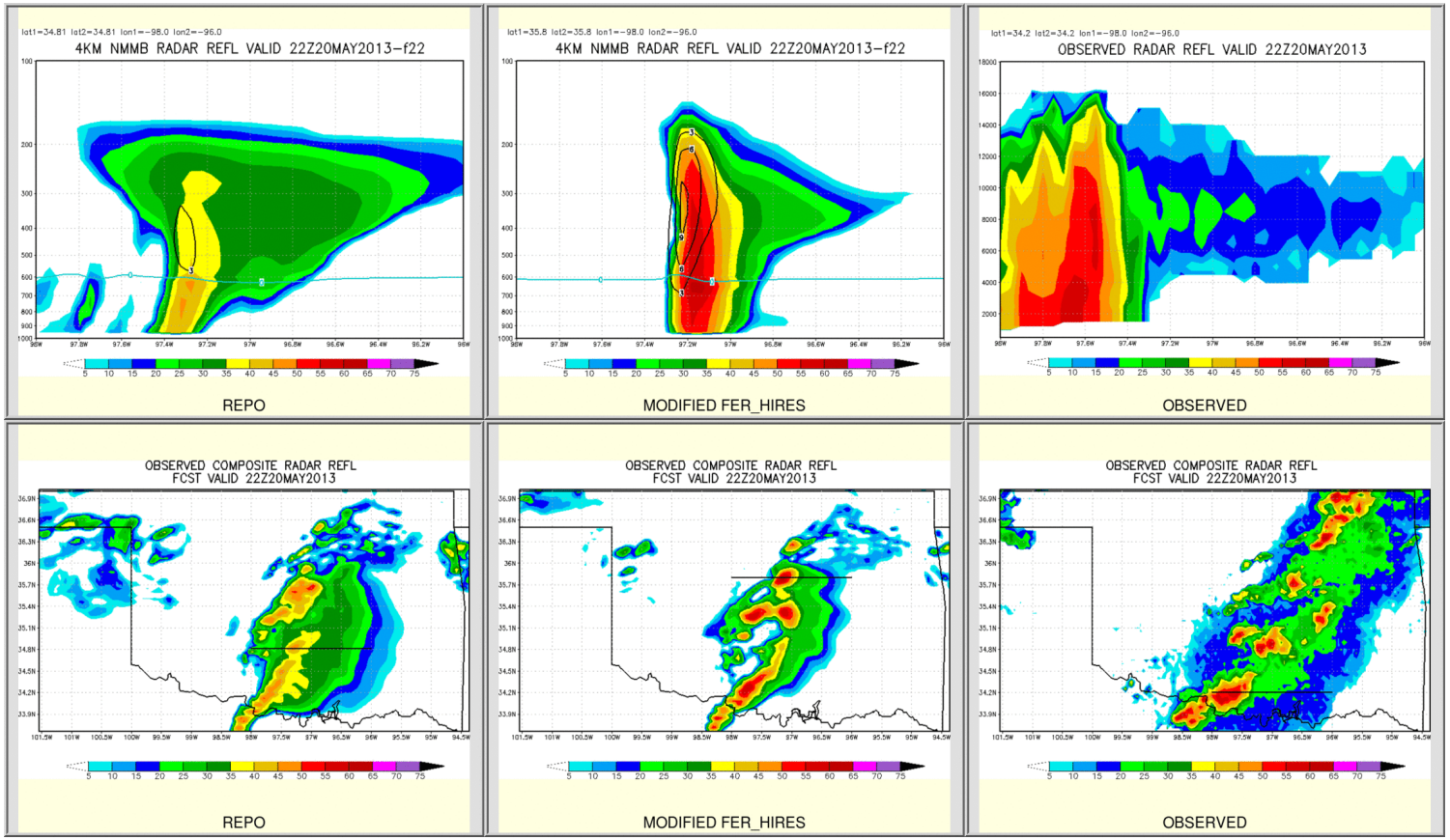
- ***Dates***
  - SFE 2014 will run 5 weeks during May 5 – June 6

- ***What is new for 2014?***
  - Focus on Day 1 **probabilistic forecasts of <u>severe hazard types</u>**
    - Tornado, severe wind, and severe hail
    - Valid for shorter time periods than current operational products
    - <u>3-hr and 1-hr forecast periods</u> valid during 18-03z
      - Issued by 1645z and updated at 21z
    - Provide gridded forecasts to EWP as forecast guidance
    - Aligned with "continuum of information" FACETs vision supporting Weather Ready Nation
  - Examine **Day 2 severe storm predictability**
    - Probabilistic forecasts of severe hazard types for Day 2
    - 00z CAPS SSEF extended to 60-hrs
    - New: NAM Nest, HiresWindows, and extended HRRR
  - **3-D visualization** of SSEF control member storms using WDSS-II
    - Compare ARW model storm structure to observed radar

Simulated Composite Reflectivity

22-hr Forecasts Valid 22z 20 May 2013

Vertical Cross-Section (top); Plan View (bottom)

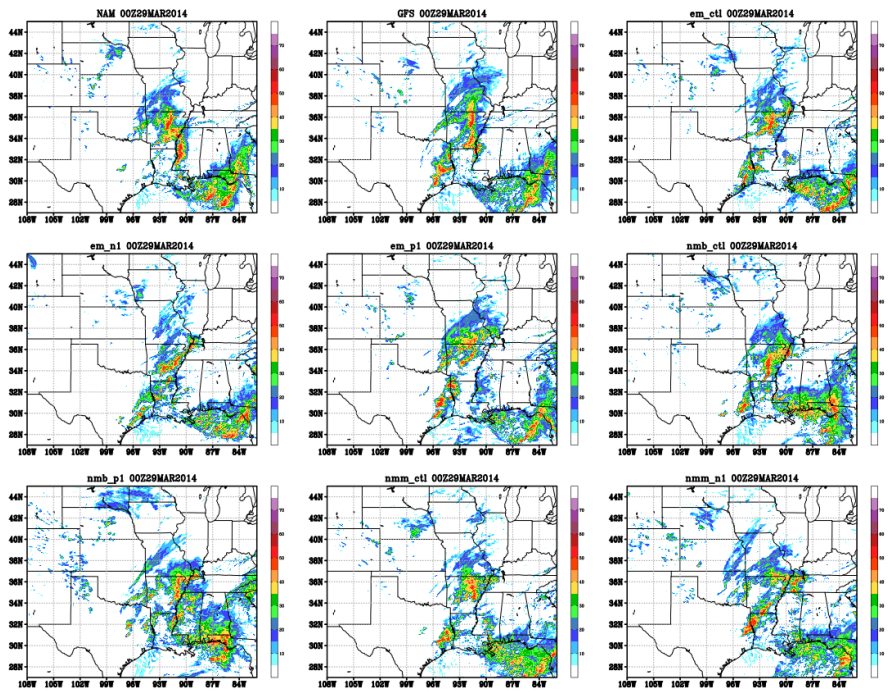


Courtesy: Eric Aligo and Brad Ferrier

2014 Spring Forecasting Experiment

http://hwt.nssl.noaa.gov/Spring_2014/

- ***Science Emphasis Areas***
  - **Convection-allowing Ensemble Systems**
    - 00z and 12z OU/CAPS SSEF (20 members)
    - 00z and 12z SPC SSEO (7 members)
    - 00z and 12z AFWA (10 members)
    - 00z NSSL WRF Ensemble (NSSL-WRFE; 9 members)
      - ***New CAM Ensemble:*** Exclusive focus on sensitivity to ICs/LBCs



- NSSL-WRFE once daily at 00z with forecasts to 36-hr
- 9 members including deterministic NSSL WRF run
- All members configured identically except different IC/ LBCs
- Diversity from SREF perturbations

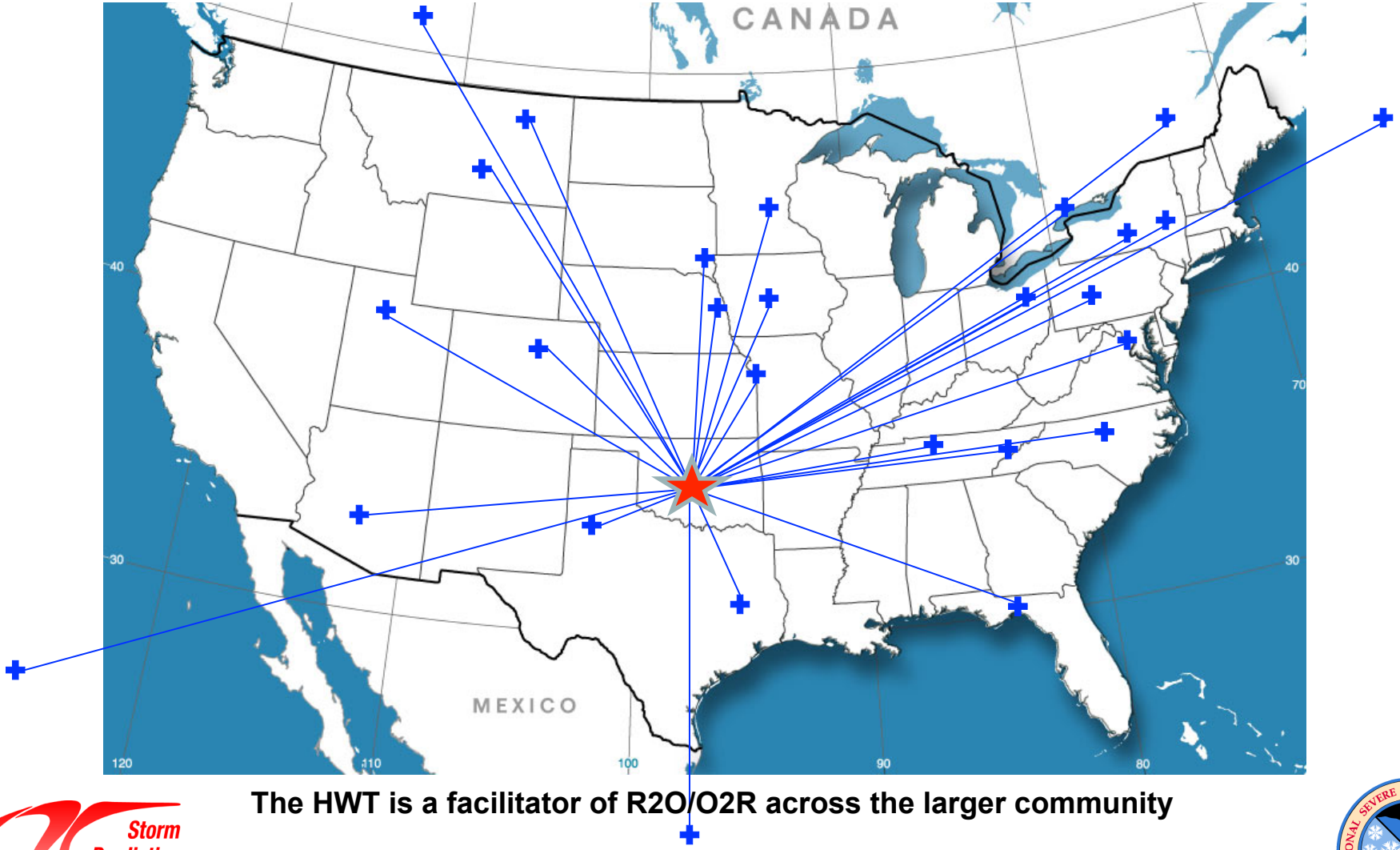
2014 Spring Forecasting Experiment

http://hwt.nssl.noaa.gov/Spring_2014/

- ***Science Emphasis Areas***
  - **Extraction and display of probabilistic storm information**
    - Hourly max storm attribute fields for supercells, wind, and hail
      - New AFWA-modified "Hailcast" applied to SSEF & NSSL WRFE
    - Creation of automated temporal disaggregation guidance
      - Calibrated SSEO fields combined with forecaster-created full period outlooks (to scale/constrain SSEO guidance)
  - **Microphysics and PBL sensitivity testing in CAPS SSEF**
    - Focus on new double-moment microphysics schemes
      - Thompson, Morrison, and Milbrandt
  - **Examination of deterministic Convection-Allowing Models**
    - "You build better ensembles by building better models"
    - EMC: New NAM nest, new HiResWindows (ARW, NMMB)
    - NSSL: ARW
    - GSD: New hourly HRRR (v2) and twice-daily run into Day 2
    - Met Office: New convection-allowing versions of Unified Model

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	



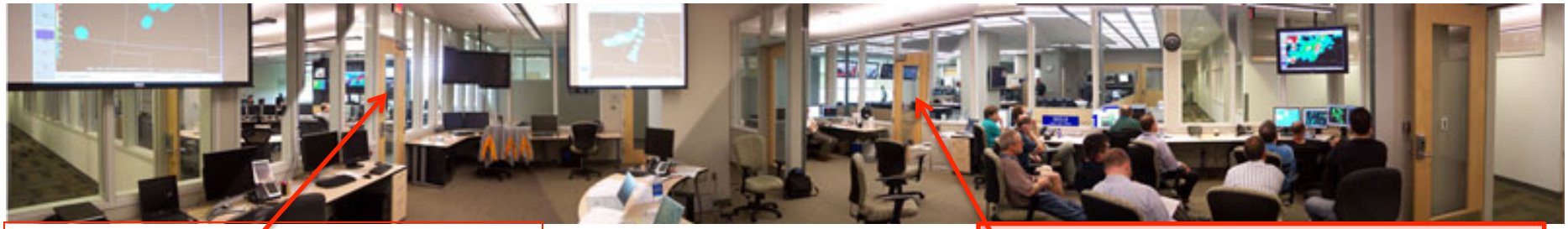
The HWT is a facilitator of R2O/O2R across the larger community

Storm Prediction Center
Norman, Oklahoma

NATIONAL SEVERE STORMS LABORATORY
U.S. DEPARTMENT of COMMERCE
NATIONAL OCEANIC and ATMOSPHERIC ADMINISTRATION

NOAA Hazardous Weather Testbed

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



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Storm Prediction Center (SPC):
Nationwide Responsibility

Warning Research

Forecasting Research

Satellite-based Research

Experimental
Warning
Program

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

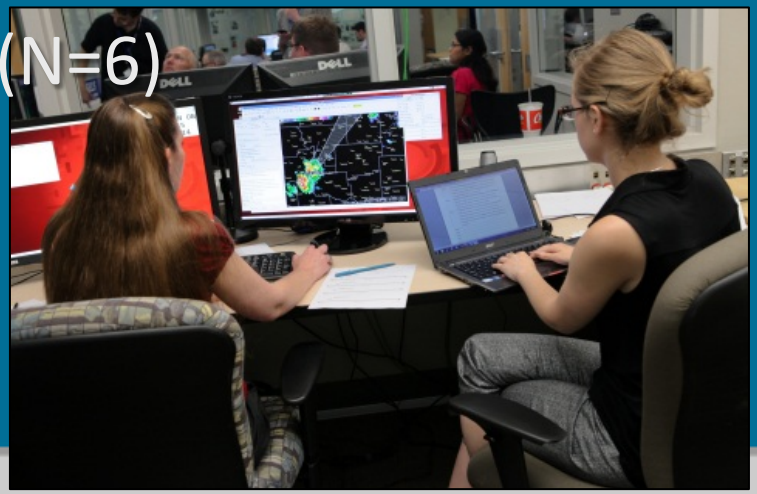
Experimental
Forecast
Program

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

PARISE 2013: Severe Hail and Wind Events

- 12 NWS forecasters worked two non-tornadic severe events sampled by PAR.

- Two-independent group design:
  - Control: ~5-min updates (N=6)
  - Experiment: ~1-min updates (N=6)



PARISE 2013: Severe Hail and Wind Events

- Impacts of rapid radar (PAR) data on forecaster performance resulted in the Experiment Group outperforming the Control Group:
  - Exceeded control group's mean lead time by 5.5 min.

PARISE 2013: Severe Hail and Wind Events

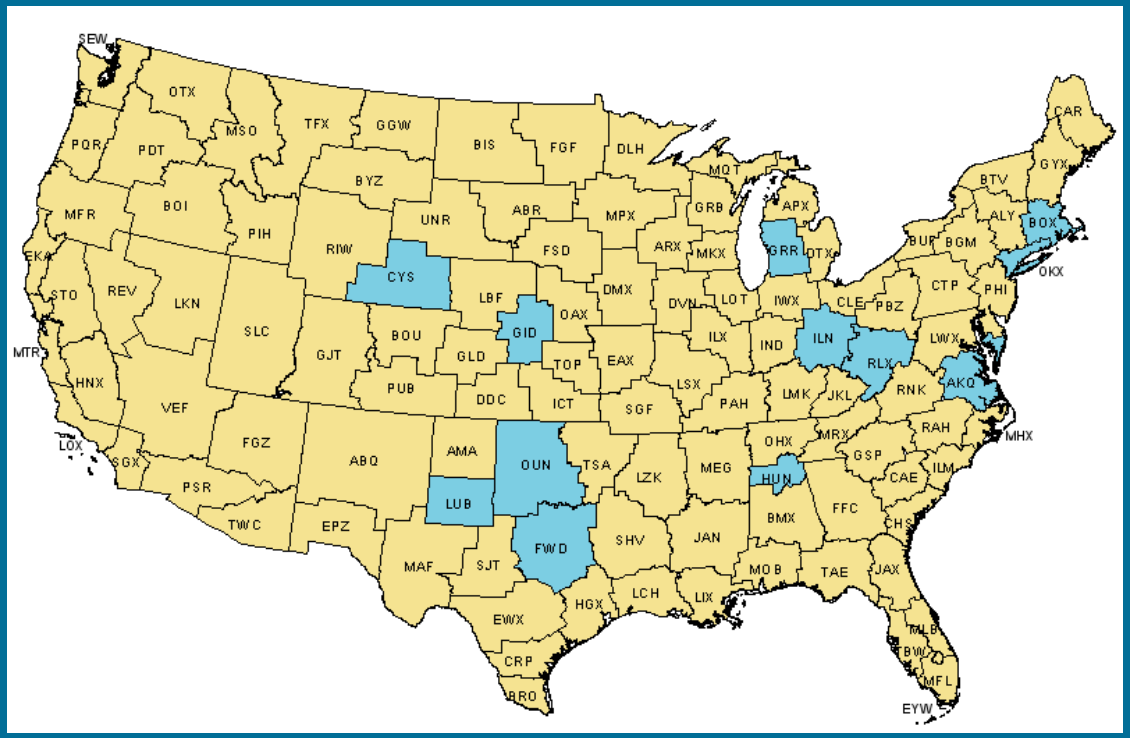
- Improved POD and FAR scores.

	POD	FAR
Control	0.60-1.0	0.23-0.83
Experiment	0.83-1.0	0.19-0.70

- Improved ability to monitor evolution of severe storm attributes.
- More mastery decisions.

EWP Spring Experiment 2013 (SE13)

- 3 weeks (6 May, 13 May, 20 May)
  - 6 WFO forecasters per week.

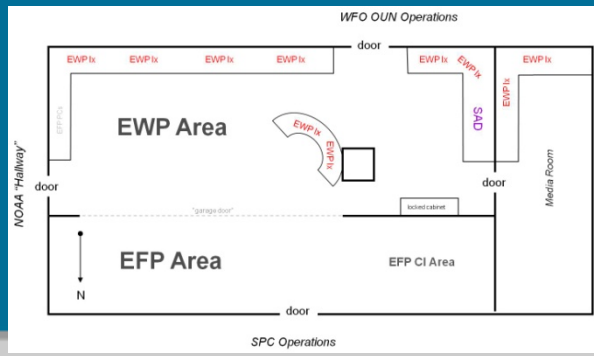


EWP SE13 Focus

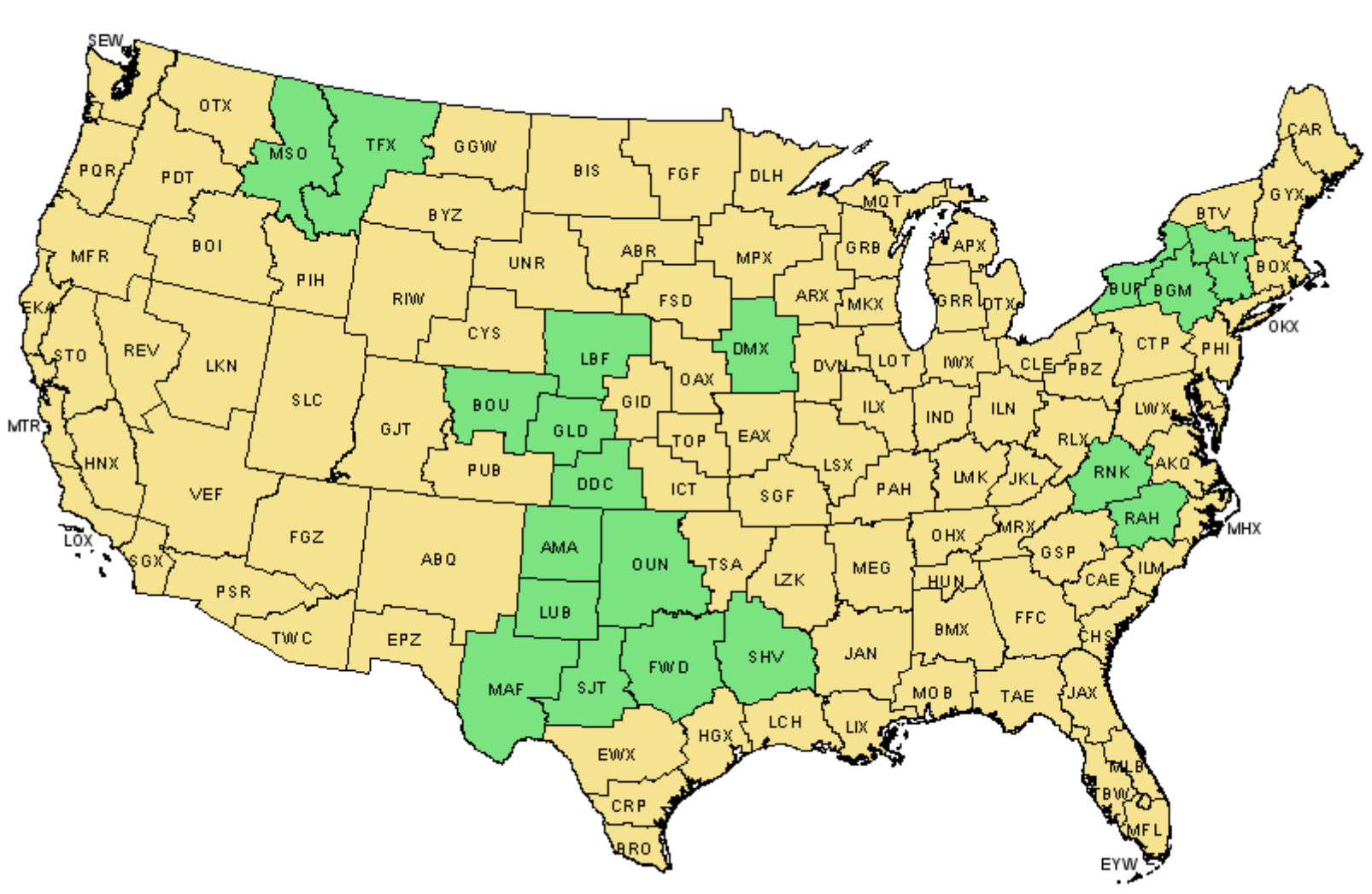
- Application of products in mesoscale forecasting and warning decision making.
- Means of assessment.
  - Surveys (pre- and post-ops).
  - Live blogging.
  - Debriefings (daily, weekly).
  - "Tales From the Testbed" national webinars.

EWP Technology in the HWT

- Situational Awareness Display (SAD)
  - Websites
  - Live television feeds
  - Streaming storm chaser dash cams.
- AWIPS-II workstations (7)
  - Can emulate any CONUS WFO.
  - Displays experimental products.
  - Issue experimental warnings.



CWAs of Operation



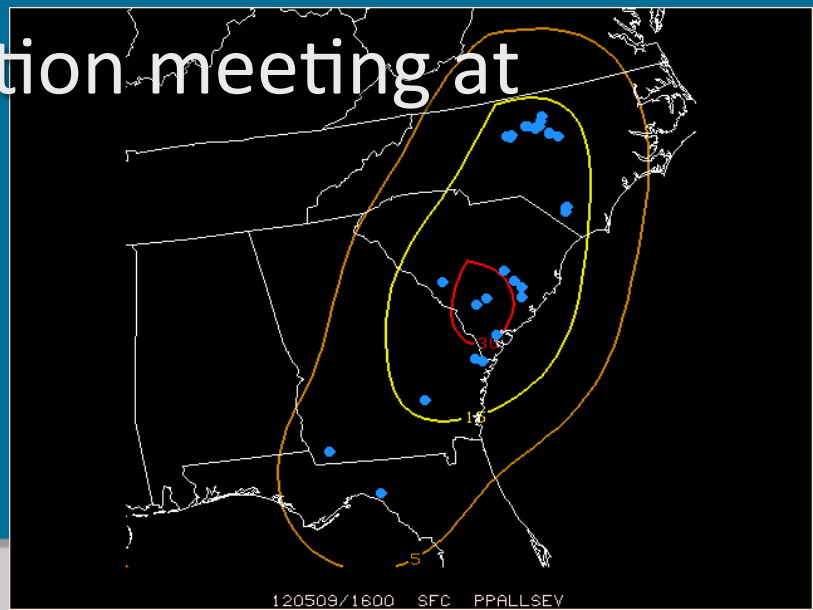
SE13: Two Operational Modes

- Mesoscale: To inform later warning activities and to monitor during warning ("meso desk").
- Warnings: Issued experimental warnings using AWIPS2 WarnGen.
  - Included experimental product in warning description.

EFP Collaboration

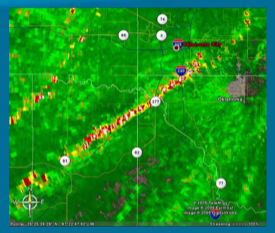
- EFP experimental probabilistic outlooks.
  - 5-15-30-45%-60%; sig severe.
  - Full-day and 3-hourly outlooks.

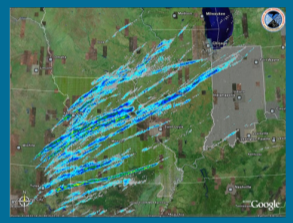
- EWP/EFP 15-min coordination meeting at the start of EWP shift.

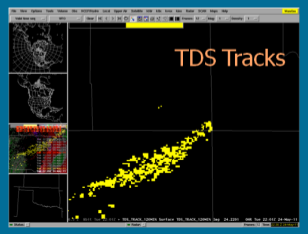


EWP SE13 Tools

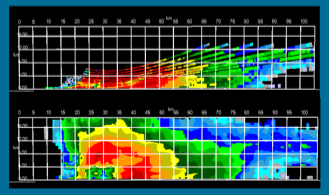
WDSSII Multiple-Radar Multiple-Sensor (MRMS) Applications



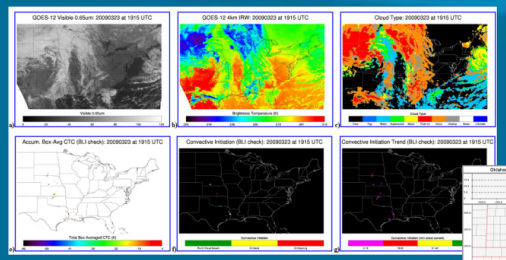


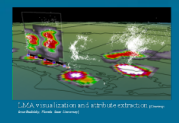


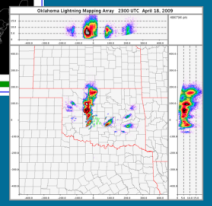
WDSS-II



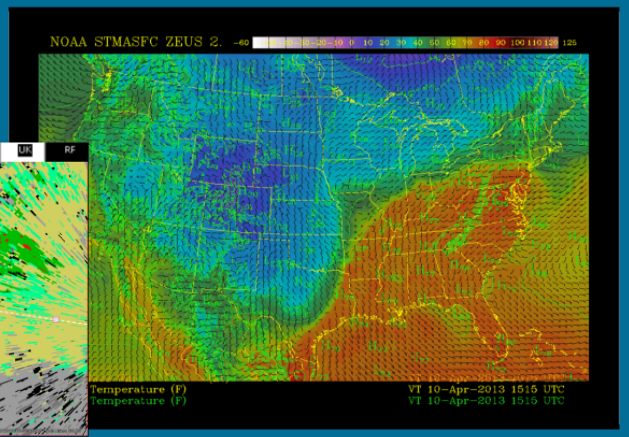
GOES-R / PGLM



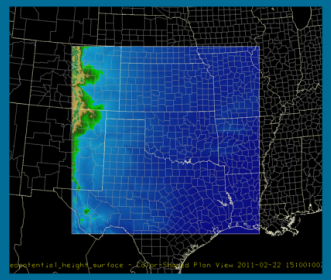


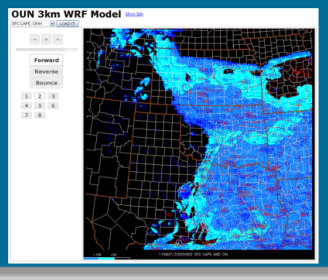


LAPS Space and Time Multiscale Analysis System (STMAS)

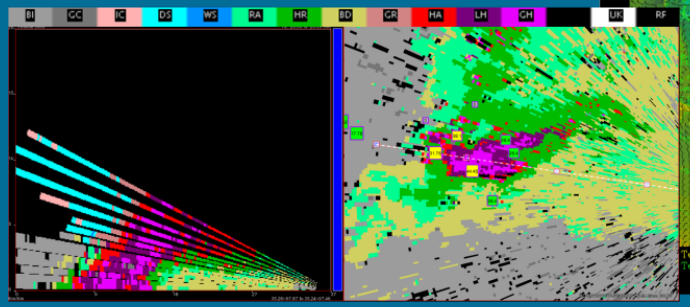


OUN WRF



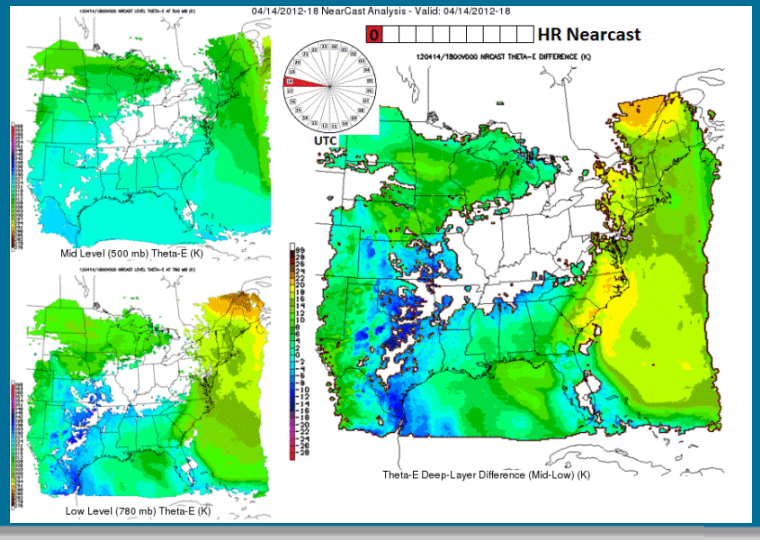


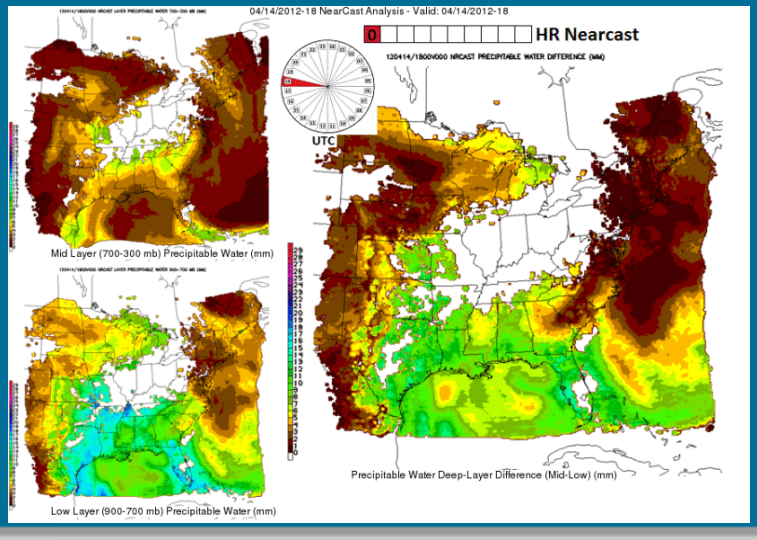
Hail Size Discrimination Algorithm (HSDA)



GOES-R Nearcast

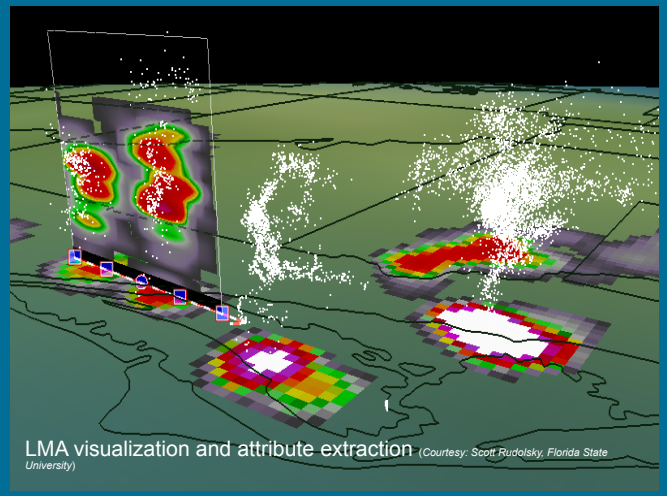
- GOES sounder observed PW/Θ_e fields advected using a Lagrangian model.
- Multi-layer PW differences & gradients
- Level Θ_e and multi-layer Θ_e differences

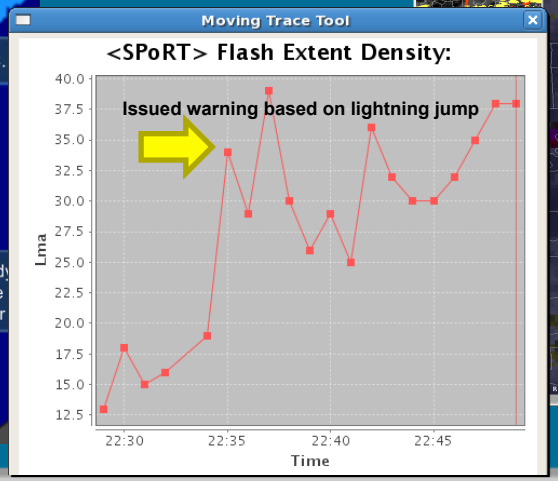


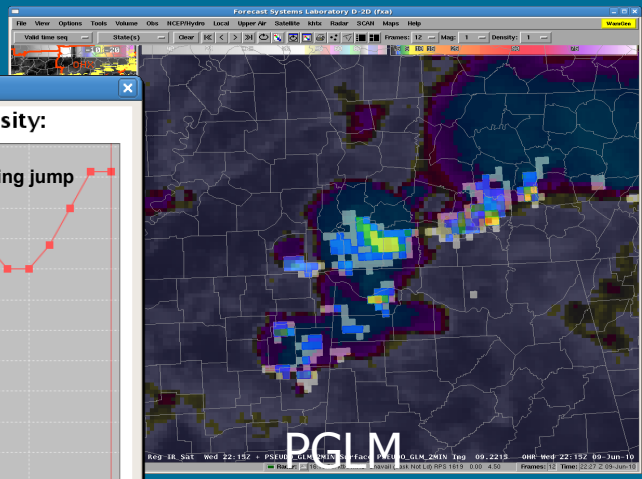


3D Lightning Mapping Array (LMA)

- Cloud-to-ground + intra-cloud = **total lightning**
- Used to create Pseudo GLM proxy and trending tool.
- Do trends correlate with storm severity?





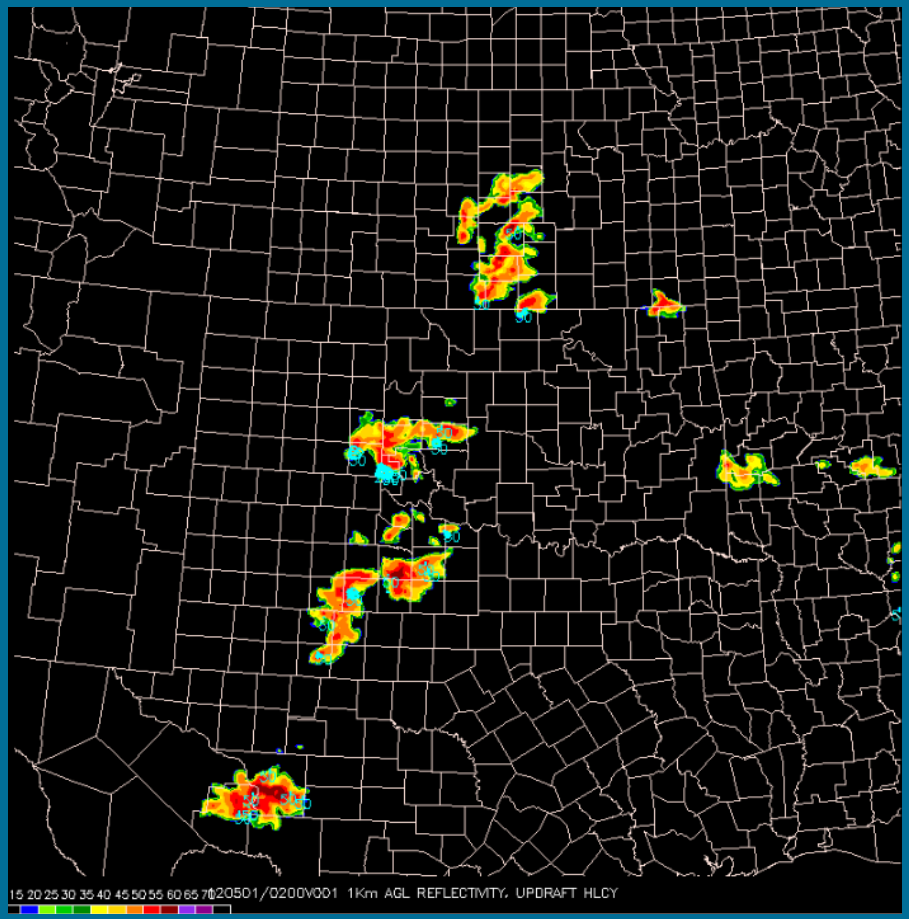


Major Takeaways

- GOES-R Nearcast:
  - Instability forecast useful for determining if storms would increase or decrease in intensity.
- GOES-R PGLM:
  - Tended to show lightning jumps before radar indications.
  - Feedback given to improve “moving trend” tool.

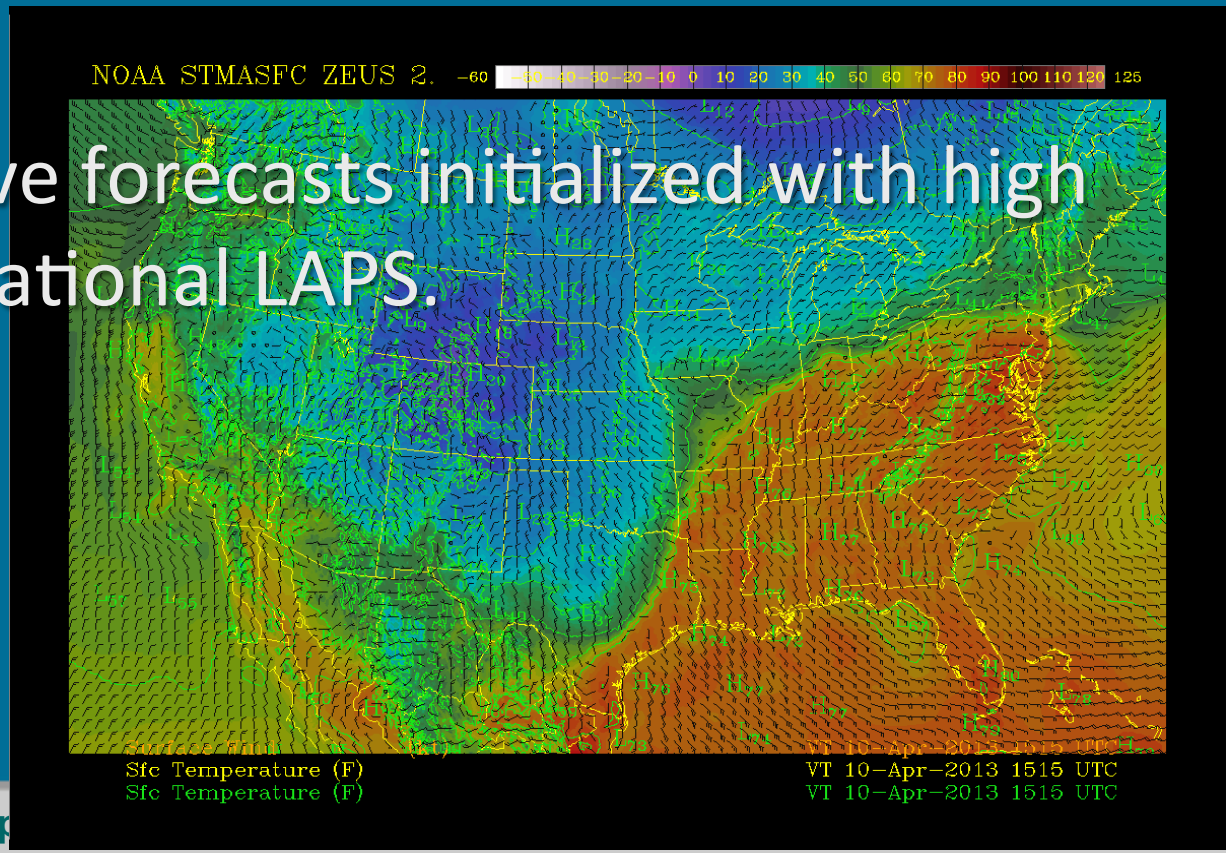
OUN WRF

- Specs:
  - 3-km grid
  - 3DVAR hot start
  - 2-hourly cycle
  - 15 min fcst intervals out to 8 h
- Products:
  - Composite Reflectivity
  - 1-km Reflectivity
  - Instantaneous Updraft Helicity
  - Maximum Hourly Updraft Helicity
  - Maximum Hourly Column Hail
  - 10-m Wind Speed



GSD's LAPS Space and Time Multiscale Analysis System (STMAS)

- Variational, high temporal and spatial resolution LAPS in real time (1 or 3 km; 15 min).
- 0-3 h convective forecasts initialized with high resolution variational LAPS.

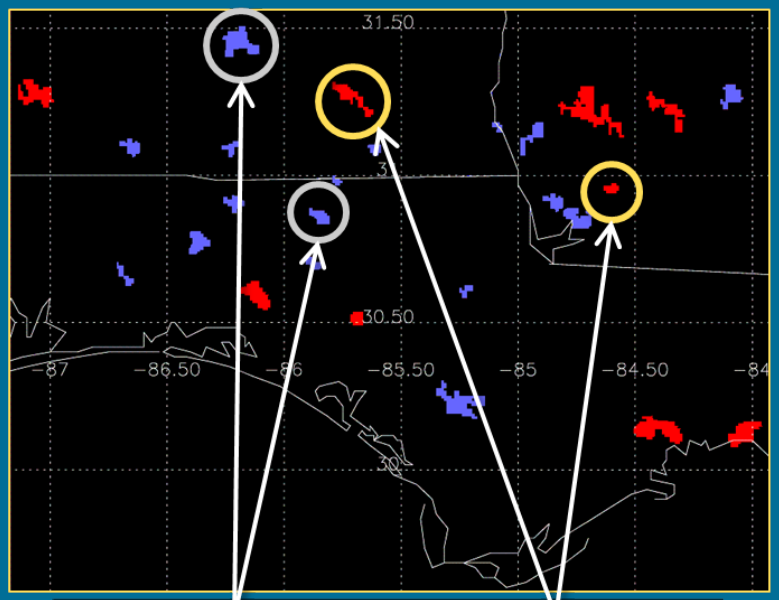


Major Takeaways

- OUN-WRF:
  - Recommend new products:
    - Probability of convection
    - Surface convergence
    - Model reflectivity time ensemble ("d prog dt")
    - Updraft helicity track
- Variational LAPS:
  - Return moisture & instability useful for determining changes in storm intensity in 0-2 hours.

SAT Convective Initiation: "SATCAST"

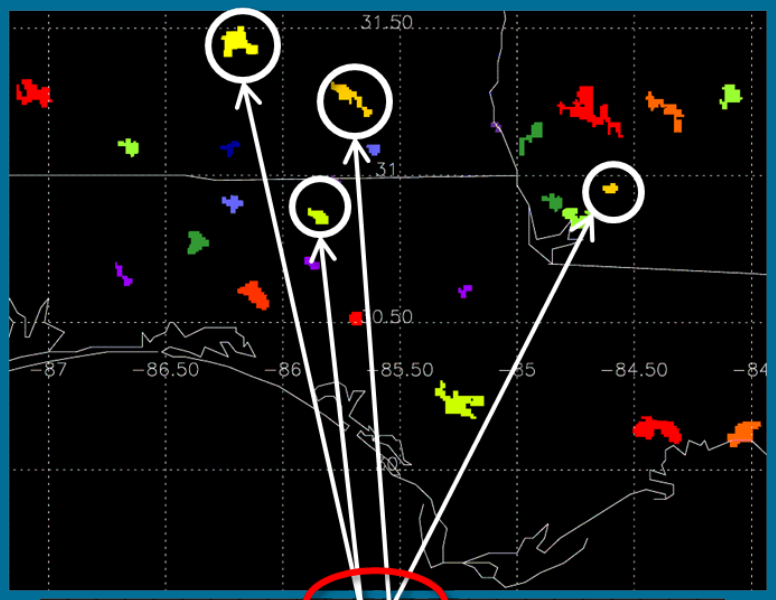
Previous Version of SATCAST



Null (No) Forecasts

Positive (Yes) Forecasts

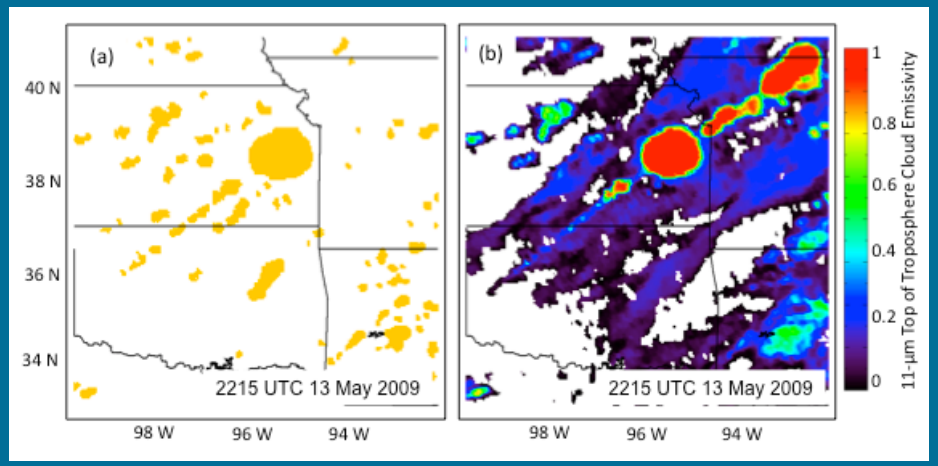
Newest Version of SATCAST

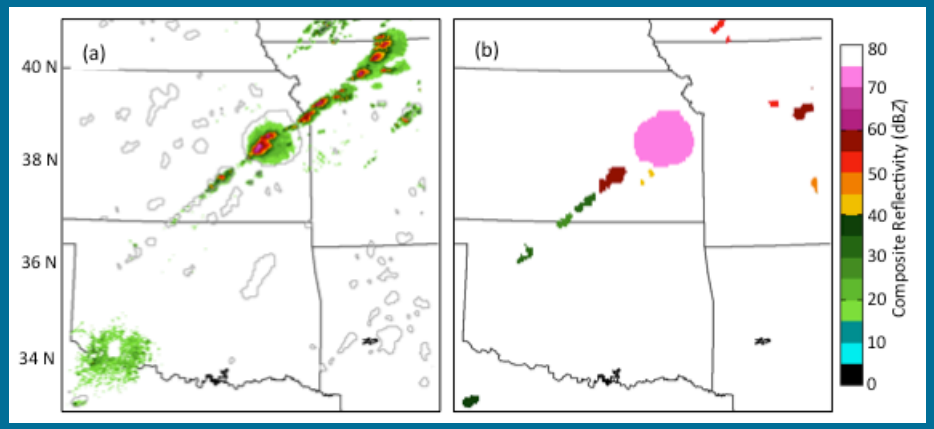


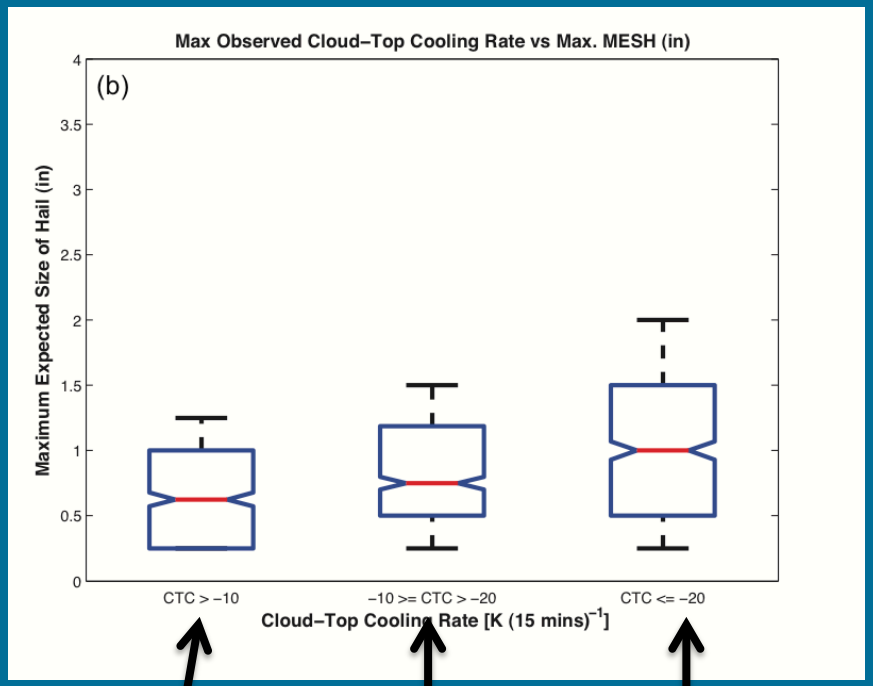
0 — 100

Strength of Signal (SS)

UW Convective Initiation – Cloud Top Cooling: Relating CTC to Radar/MRMS products





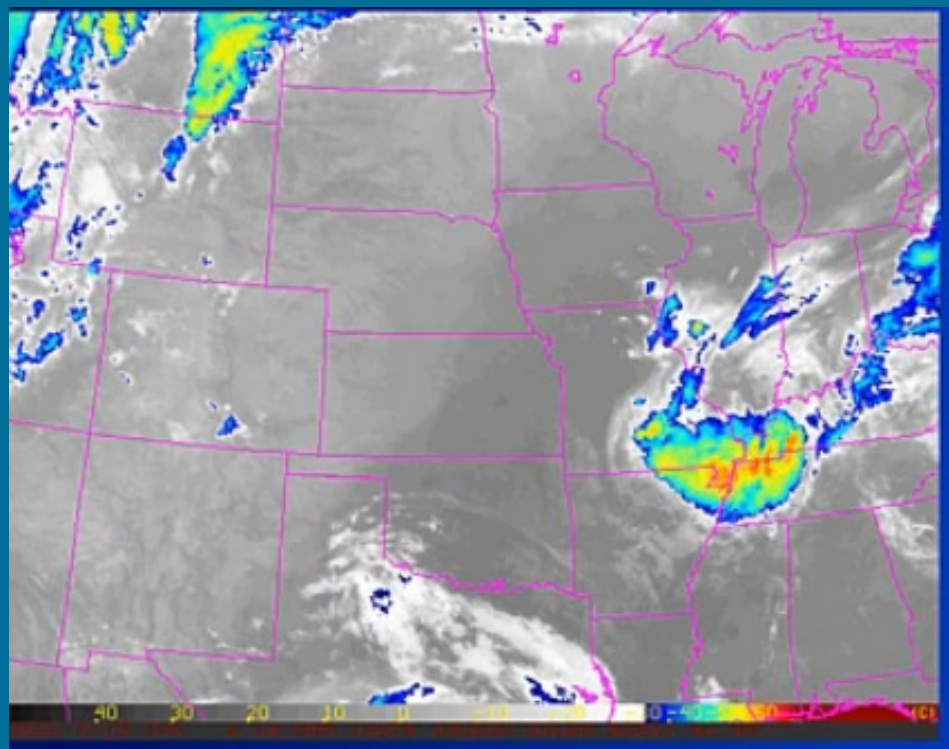


Weak UW-CTC > -10

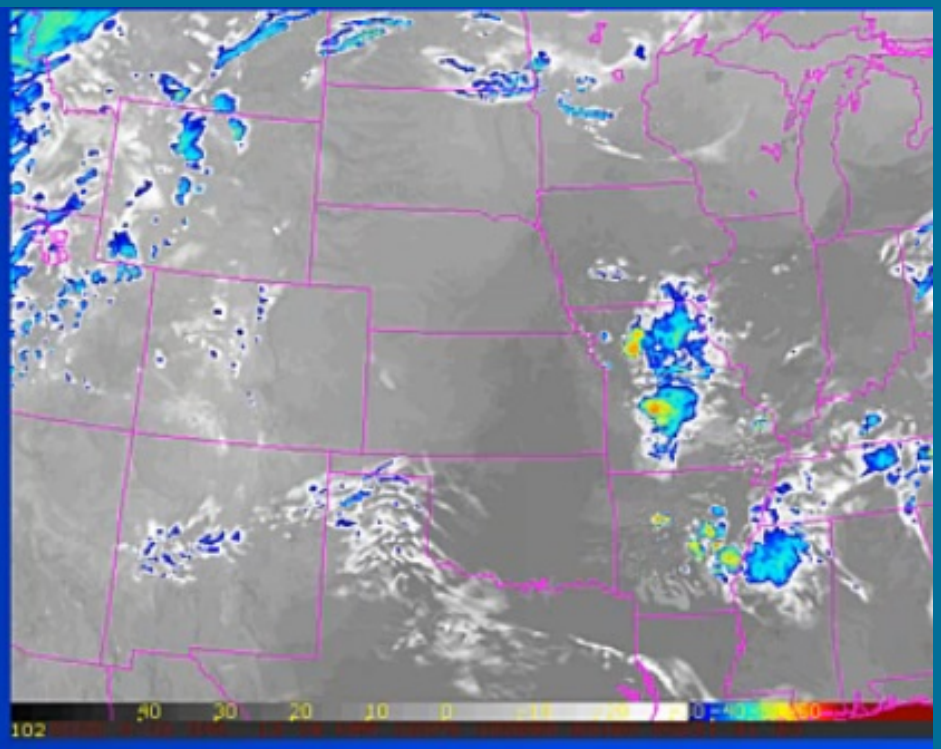
Moderate UW-CTC -10 >= CTC > -20

Strong UW-CTC <= -20

WRF Synthetic Cloud & Moisture Imagery



GOES-13 data from 16 March 2012 valid 09 to 21 UTC



Simulated Imagery based on a 9- to 21-hour foreca from the WRF-ARW

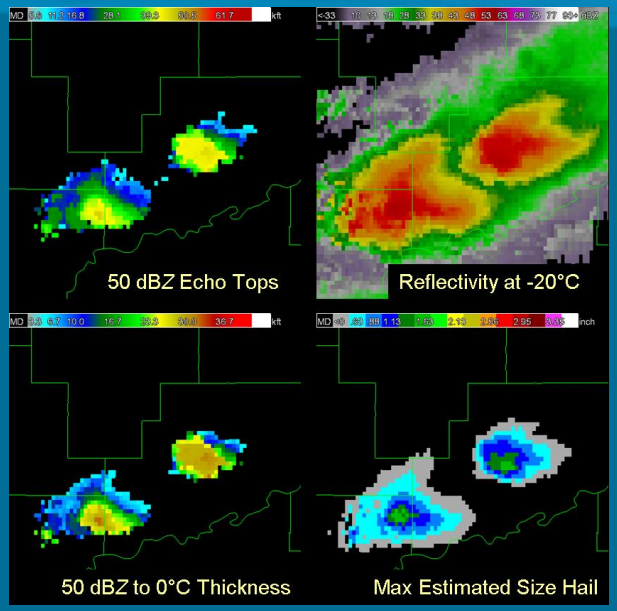
Major Takeaways

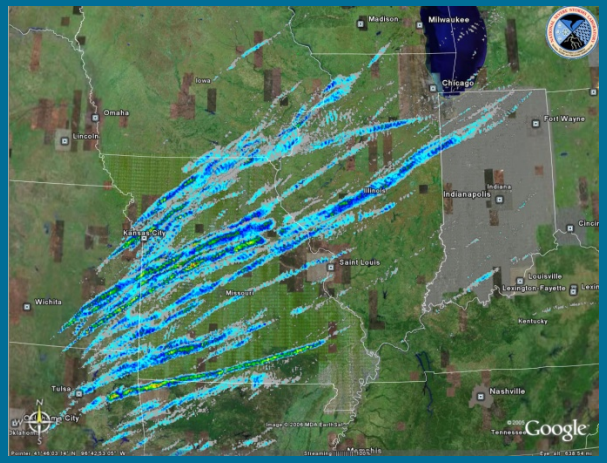
- GOES-R CI / CTC:
  - Increased confidence in CI areas on clear days.
- GOES-R Simulated Satellite:
  - Improved visualization of where and how model (NSSL-WRF) is handling convection.

Multiple-Radar / Multiple-Sensor (MRMS)

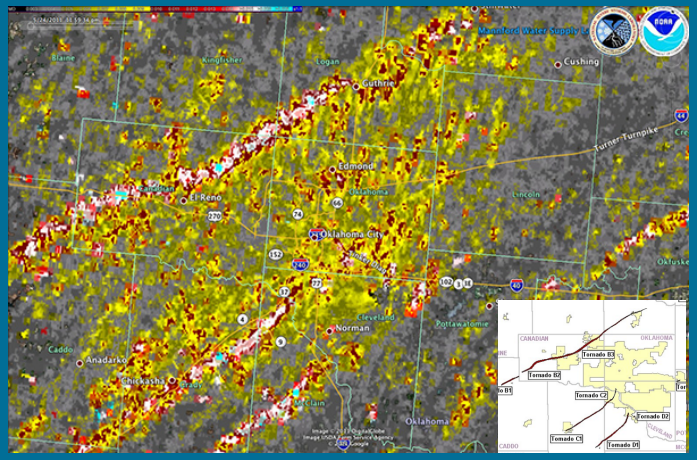
- **Better accuracy** – more "eyes" looking at storms
- **Better lead time** – rapidly-updating "virtual volume scans"

http://wdssii.nssl.noaa.gov/maps





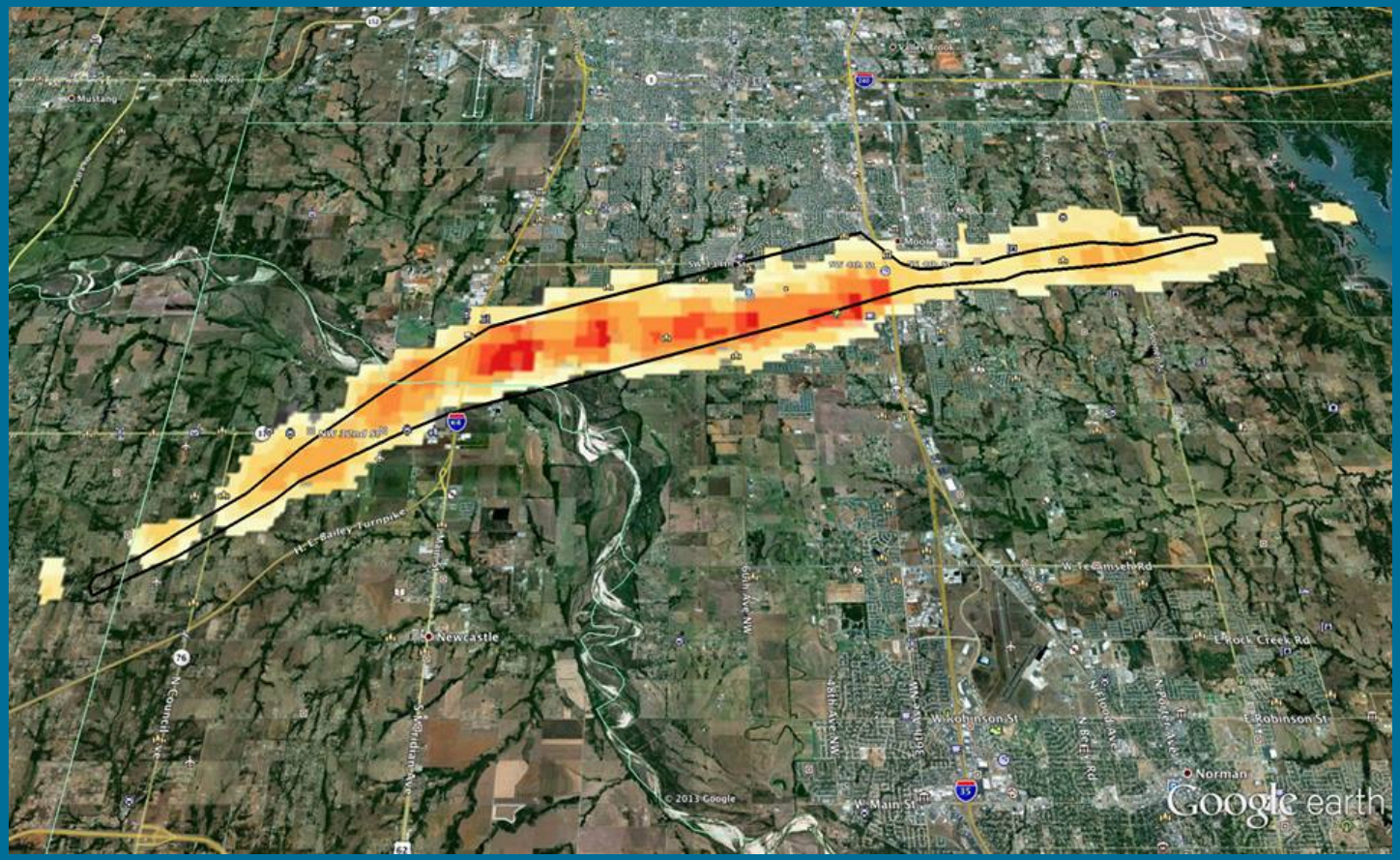
"Hail Swaths (12 Mar 2006)"



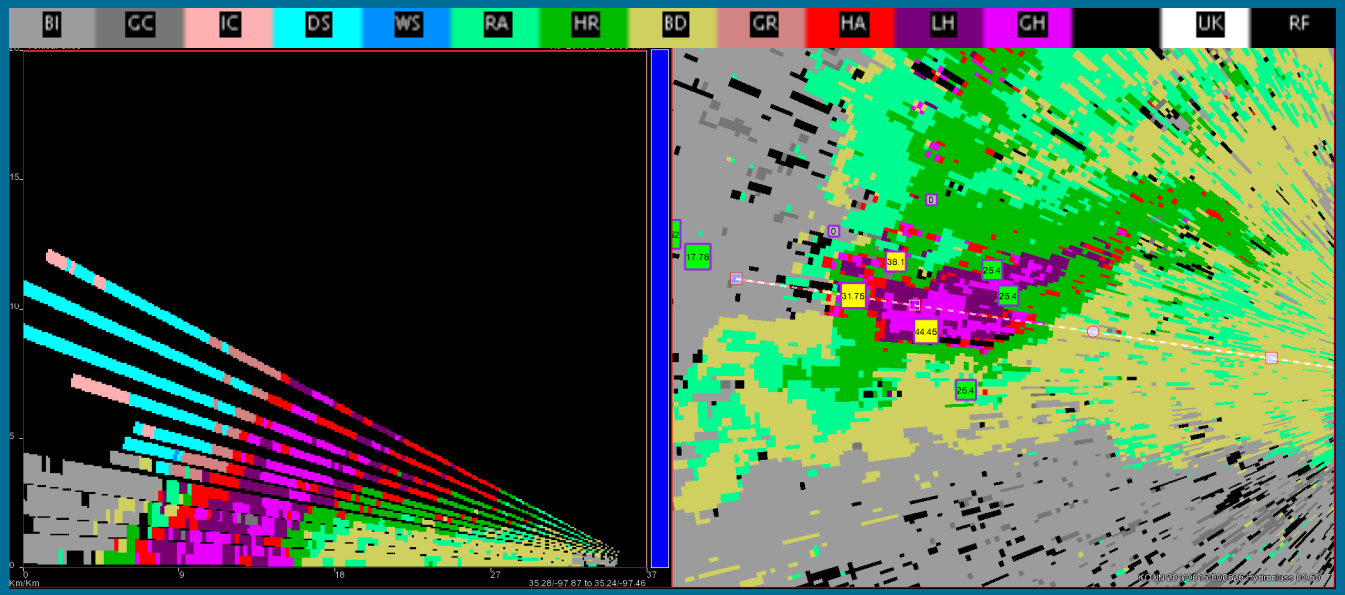
LLSD "Rotation Tracks (24 May 2011 – OK)"

from the NSSL On-Demand Verification System

Dual-Pol Tornado Debris Signature (TDS) Algorithm



Hail Size Discrimination Algorithm (HSDA)



- Splitting Hail category from HCA into:
  - Small Hail (< 1”)
  - Large Hail (≥ 1”)
  - Giant Hail (≥ 2”)

Major Takeaways

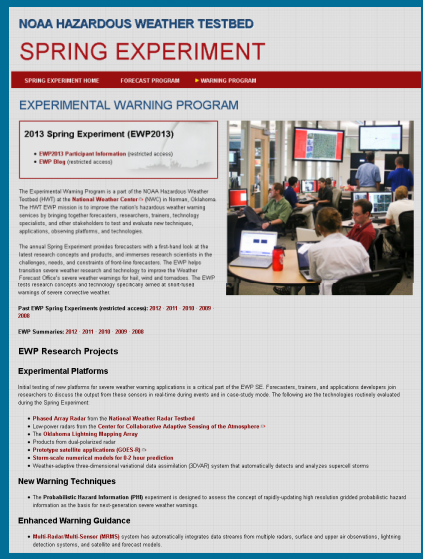
- MRMS:
  - 2-min updates improved situational awareness.
  - Greater efficiency in storm diagnosis and warning polygon positioning.
- HSDA:
  - Skill in discriminating between severe vs. non-severe hail.

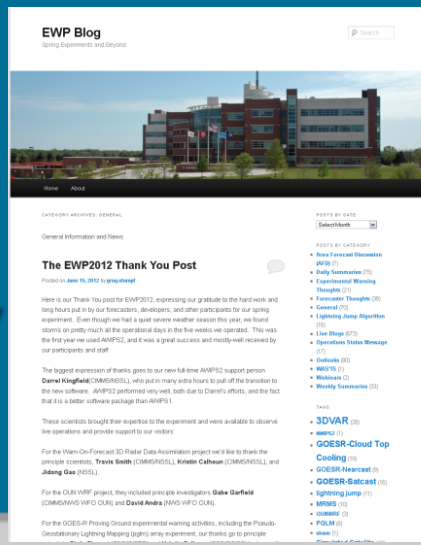
Major Takeaways

- Insights into attracting forecasters to experimental products so that they do not default to their base product "comfort zones."

EWP Web Presence

- External (public)
  - http://hwt.nssl.noaa.gov/ewp
- Internal (private)
  - https://secure.nssl.noaa.gov/projects/ewp2013/
  - Content:
    - Operations Plans
    - Training Materials
- The EWP Blog (private during operations)
  - https://secure.nssl.noaa.gov/projects/ewp/blog/





EWP 2014

- MRMS Experiment (April)
- Spring Experiment (May/June)
  - GOES-R, LAPS
- FACETs: Probabilistic Hazard Information Experiment (May/June)
- Earth Networks DTA Experiment (July/August)
- HWT Call for Proposals (selections soon)
  - HWT hydro joint experiment with HMT/WPC (July)

HWT Comments and/ or Questions?

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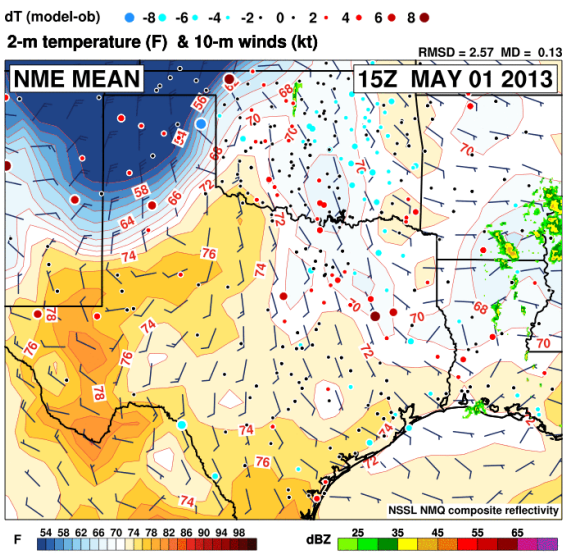
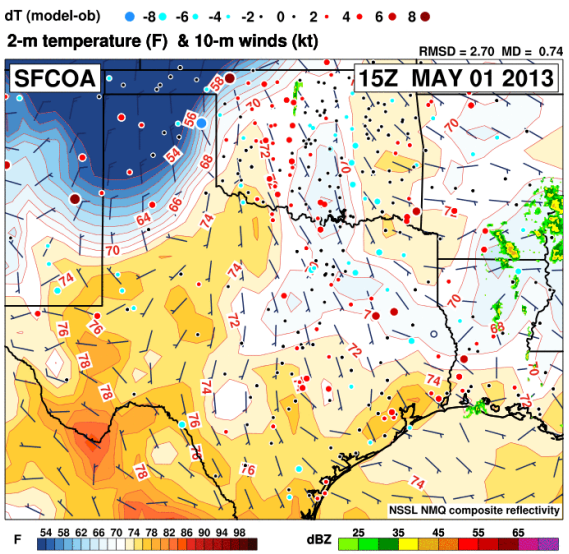
Backup Slides

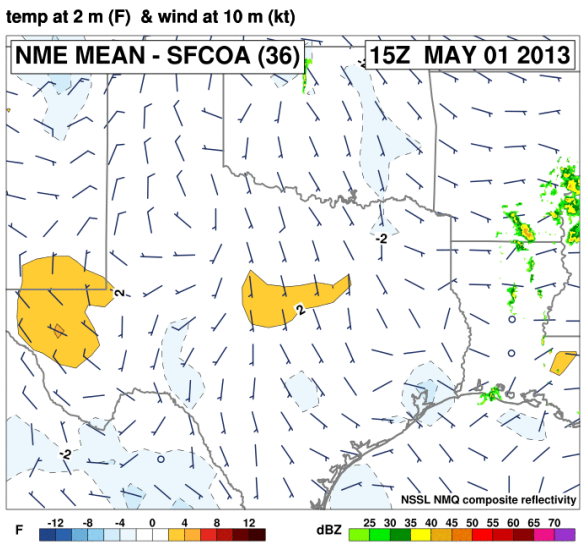
2013 Spring Forecasting Experiment

Experimental Models: *NSSL Mesoscale Ensemble*

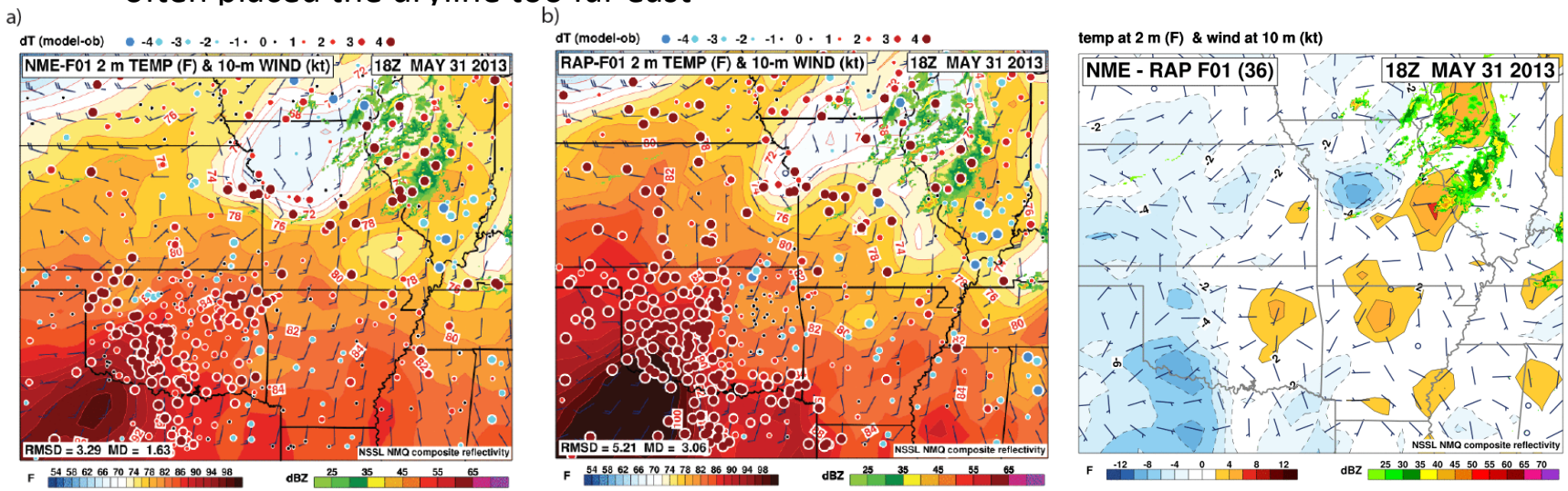
- Hourly NSSL Mesoscale Ensemble (NME; NSSL warn-on-forecast group) analyses were used for forecasting and evaluations.
  - 36 members, 18-km horizontal grid spacing, 51 vertical levels, CONUS WRF-ARW w/physics diversity and WRF-Var IC & LBC perturbations
  - Hourly cycled EnKF data assimilation (from 13Z) using land and marine surface METAR observations, radiosondes, aircraft, and satellite winds
  - Analyses available hourly 14-03Z, full-ensemble forecasts out to 03Z from 14Z, 16Z, and 18Z cycles
  - Compare to SPC Mesoscale Analysis. Which one might provide better forecast guidance and a better background for convection-allowing model forecasts?







2013 Spring Forecasting Experiment

Preliminary Findings: *NSSL Mesoscale Ensemble*

- For 1-h forecasts of 2-m temperature, the NME mean and RAPv2 were subjectively rated about the same for a majority (~65%) of the SFE 5-week period with the NME mean better ~25% of the time
  - Both tended to have a warm bias in the afternoon with the RAPv2 bias generally larger
  - In convectively generated cold pools, the NME mean was generally too warm compared to the RAPv2 and observations
- Results were similar for 1-h forecasts of 2-m dew point temperature with the most substantial differences occurring with the placement of drylines
  - The NME mean placement of dryline location was generally better than the RAPv2, which often placed the dryline too far east