# Storm Prediction Center Highlights
# EMC Annual Review
## December 11, 2007

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Storm Prediction Center, Norman, OK

# STORM PREDICTION CENTER

HAZARDOUS PHENOMENA

- **Hail, Wind, Tornadoes**
- Excessive rainfall
- **Fire Weather**
- Winter weather








# Storm Prediction Center Primary Products

- **Tornado and Severe Thunderstorm Watches**
  - ***Watch Status Reports***
- **Severe Weather Outlooks through Day 8**
- **Short-Term Mesoscale Discussions**
  - ***Severe Convective Weather***
  - ***Heavy Rain***
  - ***Hazardous Winter Weather***
- **Fire Weather Outlooks through Day 8**
- **Categorical and probabilistic products**

# Good News From SPC Perspective

- **Model production suite timeliness and reliability**
  - *Forecasters know when model output will be available*
- **Continued excellent working relationship with EMC/NCO**
  - *Responsive to inquiries and requests (RUC, NAM, SREF, etc.)*
  - *Assistance implementing SPC jobs on CCS; GEMPAK and dbnet*
  - *Implementation of Unified Post concept*
  - *Support and improvements to 4 km WRF-NMM*
    - Recent High Res Window Upgrade
  - *Outstanding collaboration/support for Hazardous Weather Testbed*
    - Special deterministic WRF runs and key partner in SSEF

# SPC Operational Forecasting Examples

## Part 1. GEFS and SREF Guidance for Fire Weather Forecasting

# Ensemble Guidance at the SPC

- **Develop specialized guidance for High Impact Events**
  - Severe weather, fire weather, winter weather

- **Design guidance that…**
  - Helps blend deterministic and ensemble approaches
  - Supports probabilistic forecasts
  - Incorporates larger-scale environmental information to yield calibrated probabilistic guidance
  - Aids in decision support of impact weather
    - Gauge confidence
    - Alert for potentially significant events

# SPC Fire Weather Outlooks

- National Fire Weather Guidance for use by NWS and other federal, state, and local government agencies
- Outlooks delineate areas where forecast weather conditions, combined with pre-existing fuel conditions, result in ***significant*** threat for wildfires
- Currently issued once per day during the overnight hours
  - Day 1, Day 2, and Day 3-8
- Critical, Extremely Critical, and Critical Dry Thunderstorm forecasts
  - Low RH
  - Moderate / strong winds
  - Antecedent conditions / drought (NFDRS)
  - Critical area for dry thunderstorms implies widespread lightning with minimal rainfall

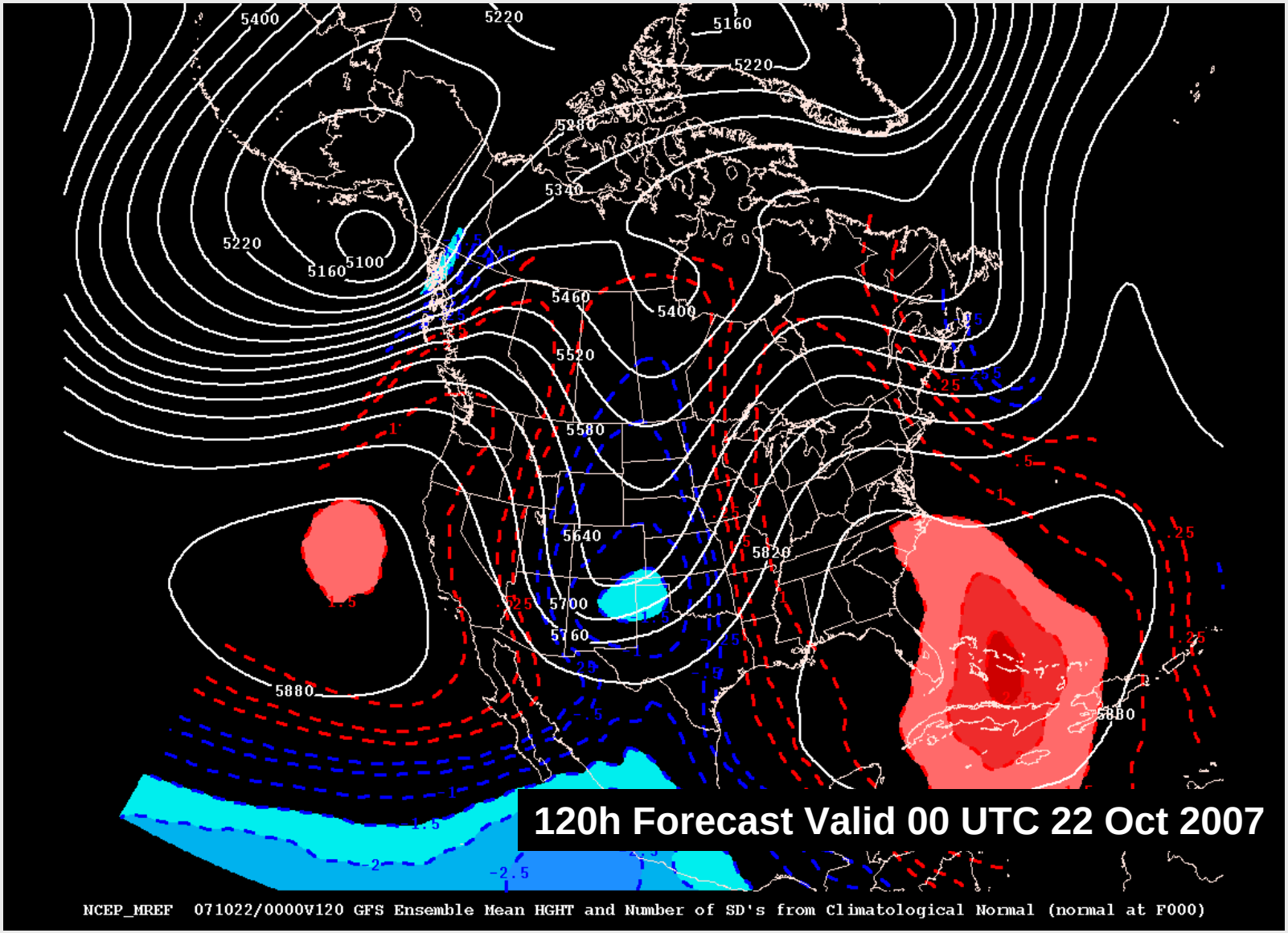
# Case Example – October 21, 2007

- Devastating Wildfires over Southern California
- More than 450,000 acres burned
  - 1700 homes and businesses destroyed, WFO SGX evacuated
  - 10 deaths and 64 injuries

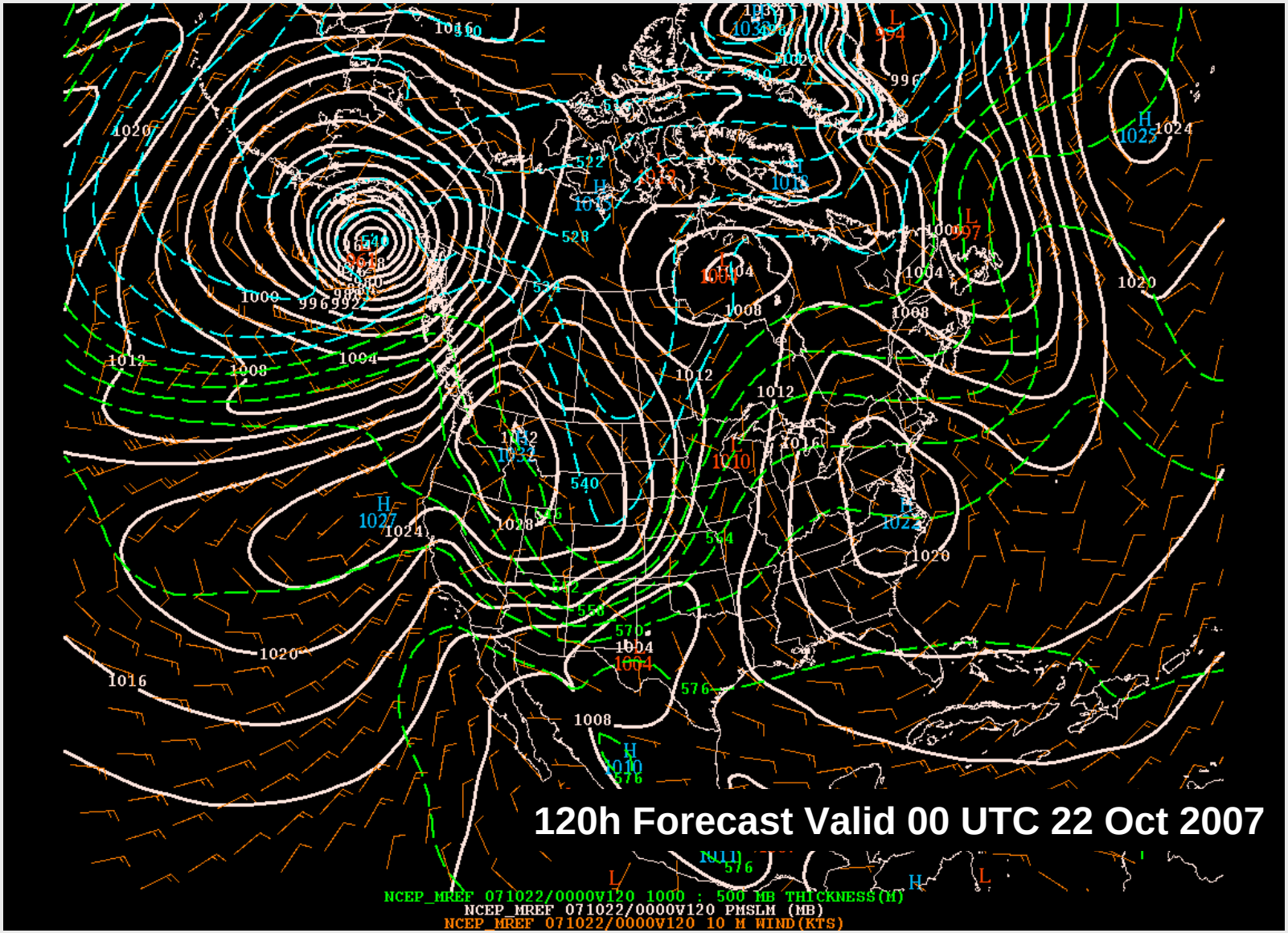
# Examples of GEFS Guidance

*Focus on Medium-Range Pattern and Environment for Fire Weather*

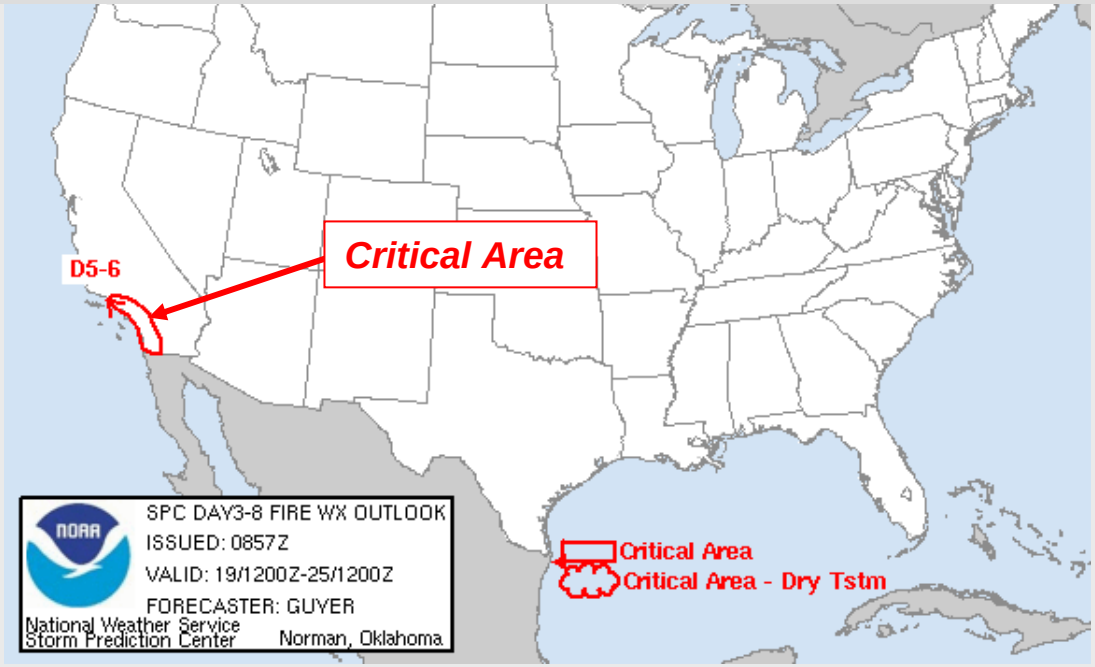
# GEFS Ensemble: Mean 500 mb Height and Departure from Normal (# of SD)



# GEFS Ensemble Mean: PMSL; 1000-500 mb Thickness; 10m Wind (kt)



# Day 3-8 Fire Weather Outlook Prior to Srn CA Fires
# Issued 0900 UTC October 17 Valid Days 5-6



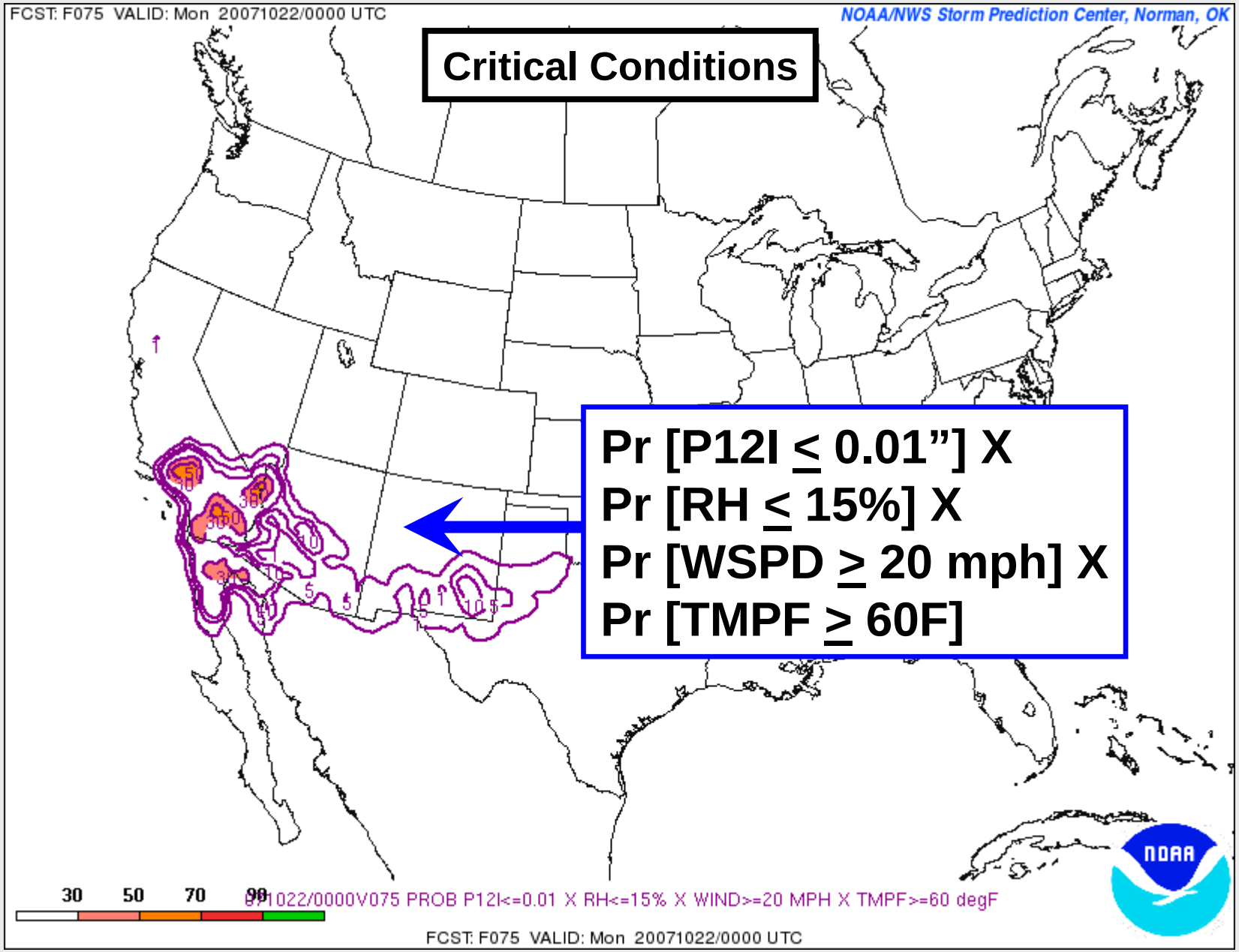

...DISCUSSION...

LATEST MEDIUM RANGE DETERMINISTIC MODELS/ENSEMBLES SUGGEST THE NEXT IN A SERIES OF UPPER TROUGHS WILL LIKELY CROSS THE WESTERN STATES THIS WEEKEND. MODEL CONCENSUS SUGGESTS THIS UPPER TROUGH MAY ULTIMATELY BECOME CUT-OFF OVER THE SOUTHWEST STATES...ALTHOUGH CONSIDERABLE DISCREPANCY EXISTS IN THE PLACEMENT DETAILS. REGARDLESS...IN THIS WAKE OF THIS SYSTEM...IT APPEARS AN OFFSHORE/SANTA ANA WIND EVENT MAY BECOME ESTABLISHED ACROSS SOUTHERN CA BY LATE DAY 4/SATURDAY AND DAY 5/SUNDAY INTO DAY 6/MONDAY. AS SUCH...THE POTENTIAL WOULD EXIST FOR NOCTURNALLY-ENHANCED GUSTY WINDS ACROSS SOUTHERN CA...ALONG WITH WARMER TEMPERATURES AND LOWER RH VALUES.

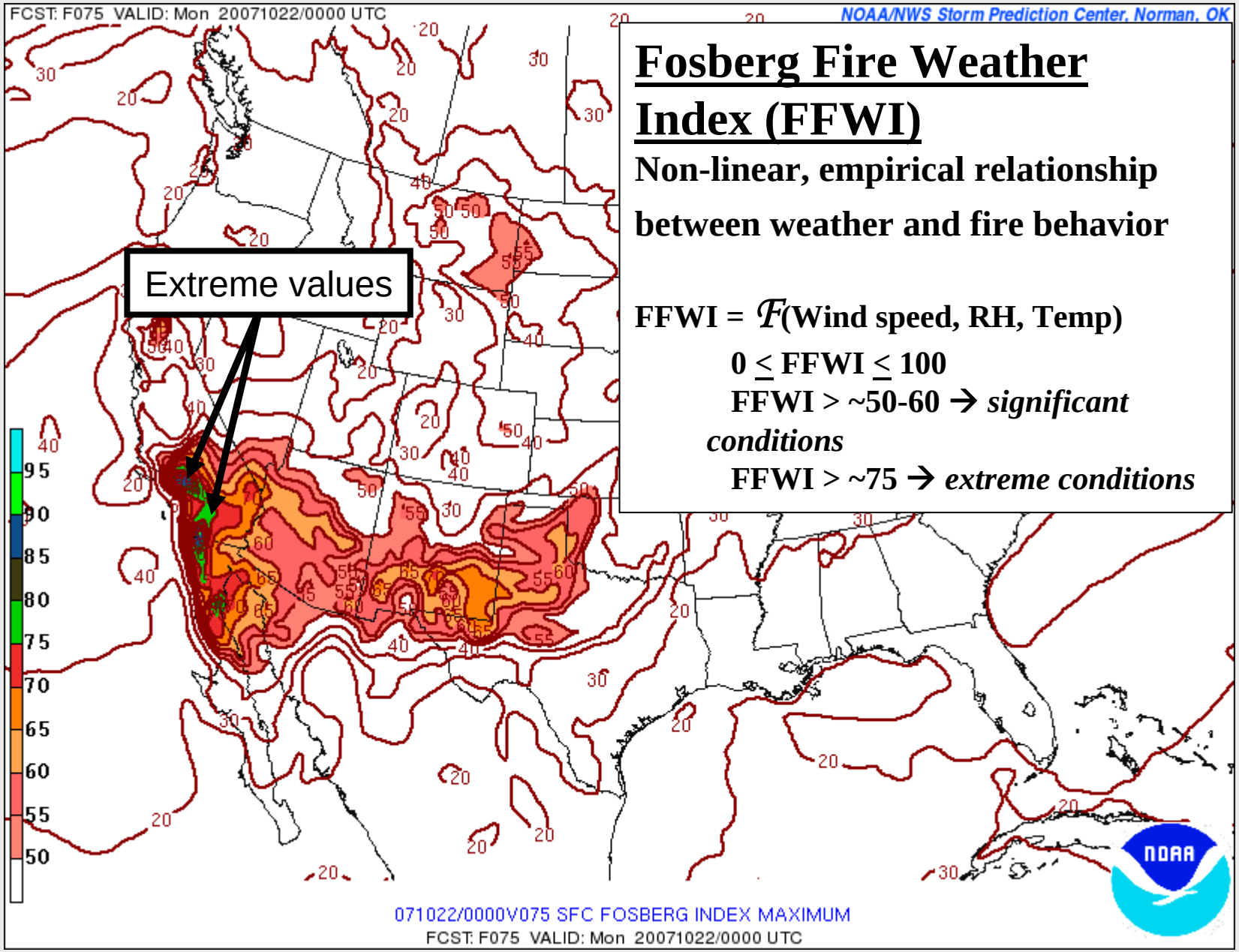
# Examples of SREF Guidance

*Focus on Ingredients-Based Environmental Factors Related to Fire Weather*

# 75 hr SREF Combined or Joint Probability



# 75 hr SREF Maximum Fosberg Index (any member)




## Fosberg Fire Weather Index (FFWI)

**Non-linear, empirical relationship between weather and fire behavior**

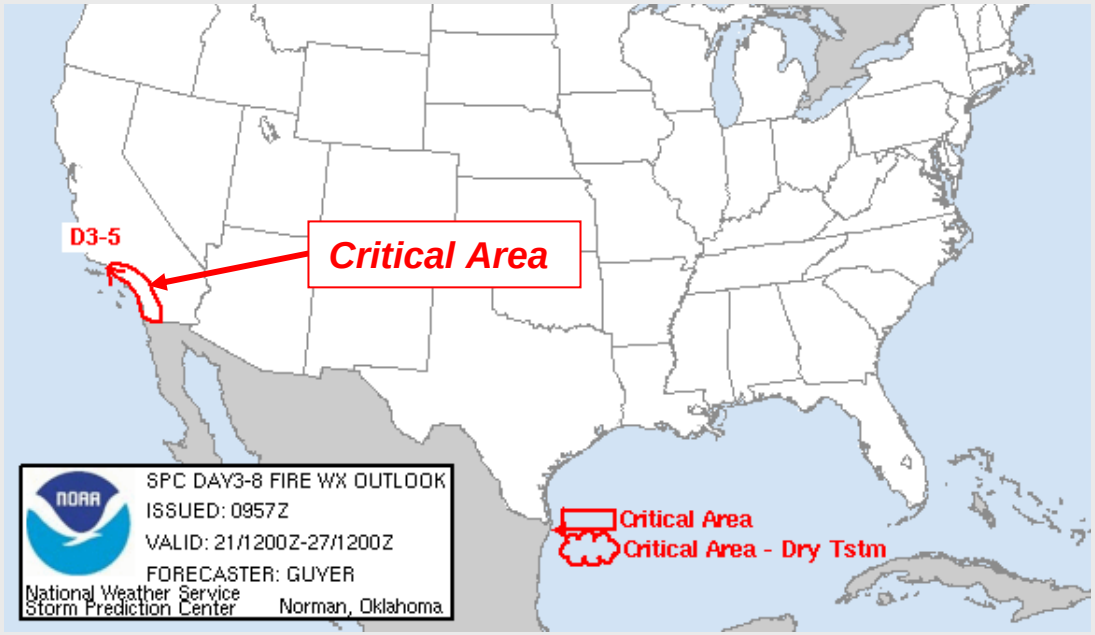
**FFWI = $\mathcal{F}$(Wind speed, RH, Temp)**

**$0 \leq$ FFWI $\leq 100$**

**FFWI > ~50-60 → *significant conditions***

**FFWI > ~75 → *extreme conditions***

# Day 3-8 Fire Weather Outlook Prior to Srn CA Fires
# Issued 0900 UTC October 19 Valid Days 3-5




...DISCUSSION...

LATEST MEDIUM RANGE DETERMINISTIC MODELS/MREF ENSEMBLES CONTINUE TO SUGGEST THAT THE NEXT UPPER TROUGH WILL CROSS THE WESTERN/CENTRAL STATES THROUGH DAY 3/SUNDAY...POSSIBLY BECOMING CUT-OFF/STALLING ACROSS THE SOUTHERN PLAINS EARLY NEXT WEEK. INITIALLY ON DAY 3/SUNDAY...STRONG GUSTY WINDS ASSOCIATED WITH THE UPPER TROUGH/STRONG JET COULD YIELD AT LEAST NEAR-CRITICAL CONDITIONS ACROSS THE SOUTH CENTRAL HIGH PLAINS.

AS HIGH PRESSURE PERSISTS ACROSS THE GREAT BASIN LATE THIS WEEKEND THROUGH EARLY NEXT WEEK...IT APPEARS A POTENTIALLY STRONG OFFSHORE/SANTA ANA WIND EVENT WILL OCCUR FROM EARLY DAY 3/SUNDAY INTO AT LEAST DAY 5/TUESDAY. THE POTENTIAL WILL EXIST FOR NOCTURNALLY-ENHANCED GUSTY WINDS ACROSS SOUTHERN CA...ALONG WITH WARMER TEMPERATURES AND LOWER RH VALUES THROUGH EARLY NEXT WEEK. THESE CONDITIONS...ALONG WITH EXTREME DROUGHT...SUGGEST A CONSIDERABLE FIRE DANGER WILL EXIST ACROSS SOUTHERN CA.

# SPC Operational Forecasting Examples

## Part 2. SREF and 4 km WRF Model Guidance for Severe Weather Forecasting

# Use of SREF and 4 km WRF in SPC Operations

- SREF and 4 km WRF guidance complement (not replace) traditional deterministic models
- SREF provides systematic information
  - *Possible range of forecast solutions*
  - *Measures of forecast uncertainty (probabilities)*
- Convection-Allowing WRF models
  - *Capable of generating explicit convective systems and basic stormscale structures*
  - *Unique guidance on convective initiation, mode, intensity, evolution*

# 4 km WRF Models Used at SPC

- WRF-NMM (EMC) and WRF-ARW (NSSL)
  - Experimental models run once daily at 00 UTC
  - 36 hr forecast over eastern three quarters CONUS
  - Cold start with NAM initial and boundary conditions
  - No parameterized convection
  - Unique convective fields such as:
    - *Simulated reflectivity*
    - *Measures of updraft rotation in model storms*

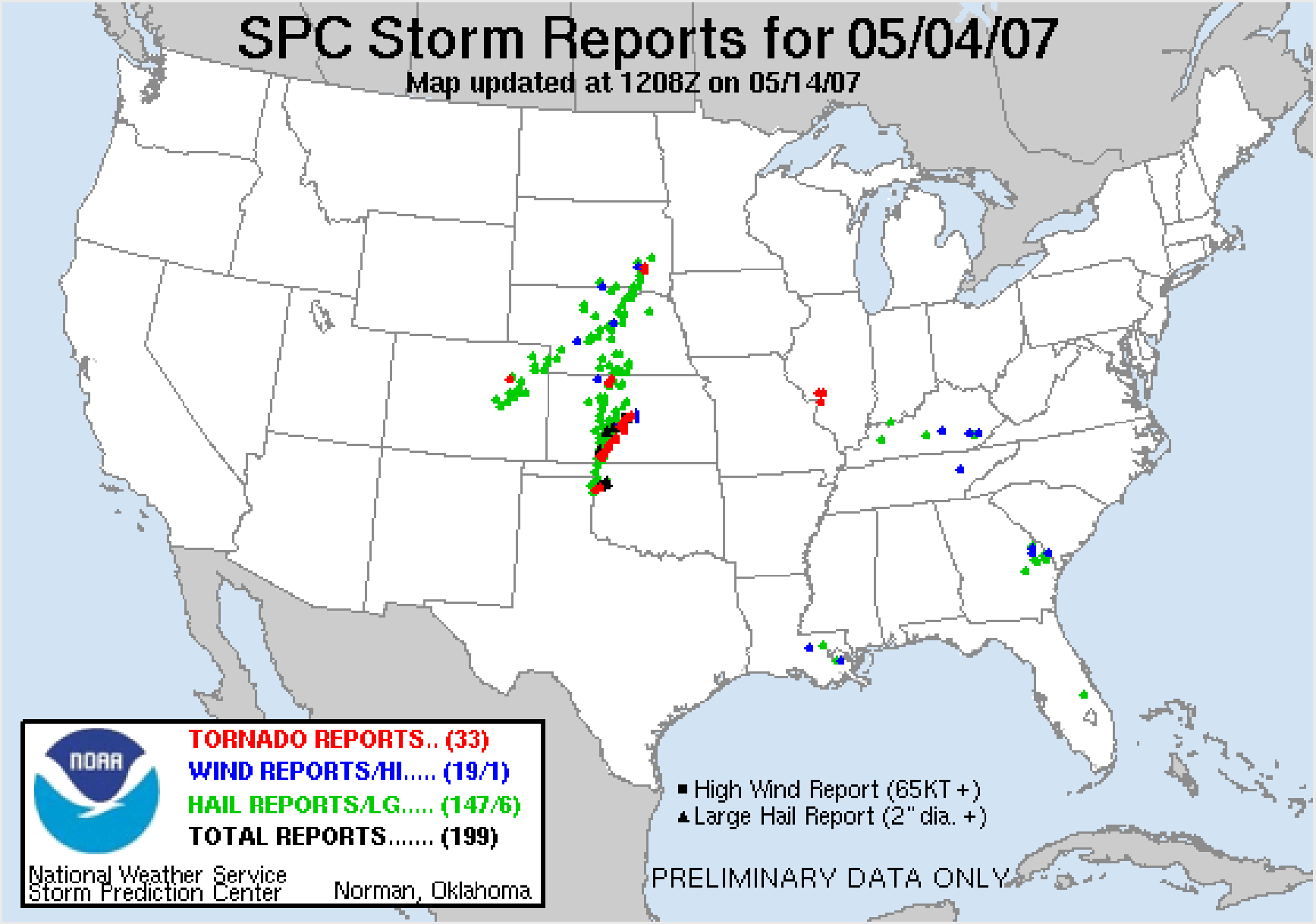
# *High Res. WRF Configurations*
## *(No Parameterized Convection)*

| | WRF-NMM | WRF-ARW |
|---|---|---|
| **Horiz. Grid Spacing (km)** | 4.0 | 4.0 |
| **Vertical Levels** | 35 | 35 |
| **PBL/Turbulence** | MYJ | MYJ |
| **Microphysics** | Ferrier | WSM6 |
| **Radiation (SW/LW)** | GFDL/GFDL | Dudhia/RRTM |
| **Initial/Boundary Conditions** | 32 km NAM | 40 km NAM |

EMC NMM at http://www.emc.ncep.noaa.gov/mmb/mmbpll/cent4km/v2/
NSSL ARW at http: //www.nssl.noaa.gov/wrf/

# Case Example – May 4, 2007

- Local Severe Storm Outbreak Across Central Plains
- Several Long-Track Tornadic Supercells
  - 3 killer tornadoes and 12 deaths (EF-5 at Greensburg, KS)


SPC Storm Reports for 05/04/07
Map updated at 1208Z on 05/14/07
TORNADO REPORTS.. (33)
WIND REPORTS/HI..... (19/1)
HAIL REPORTS/LG..... (147/6)
TOTAL REPORTS..... (199)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
■ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY

# Examples of SREF Guidance

*Focus on Ingredients-Based Mesoscale Forecast Concepts*

# SREF 3 hr Calibrated Probability of Thunderstorms

*21-24 hr Forecast Valid 00 – 03 UTC 5 May 2007*

Uses past CG lightning events to calibrate product of

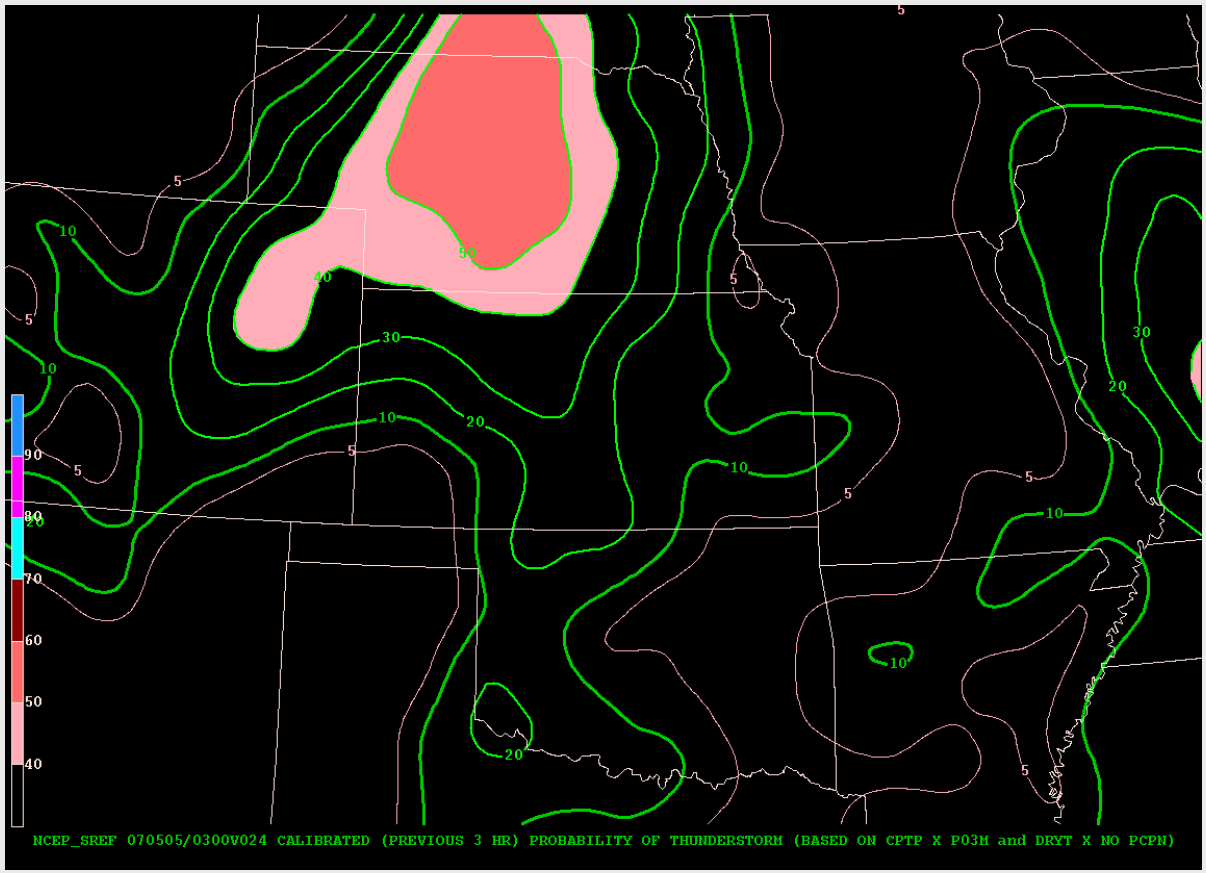
Pr (CPTP) ≥ 1

x

Pr (PCPN) ≥ .01”

Calibration period previous 366 days

*Shaded Area Prob ≥ 40%*



# SREF Combined Probability

## CAPE x Shear x Conv. Precipitation

*24 hr Forecast Valid 03 UTC 5 May 2007*

Prob (MUCAPE $\geq$ 2000 $Jkg^{-1}$)

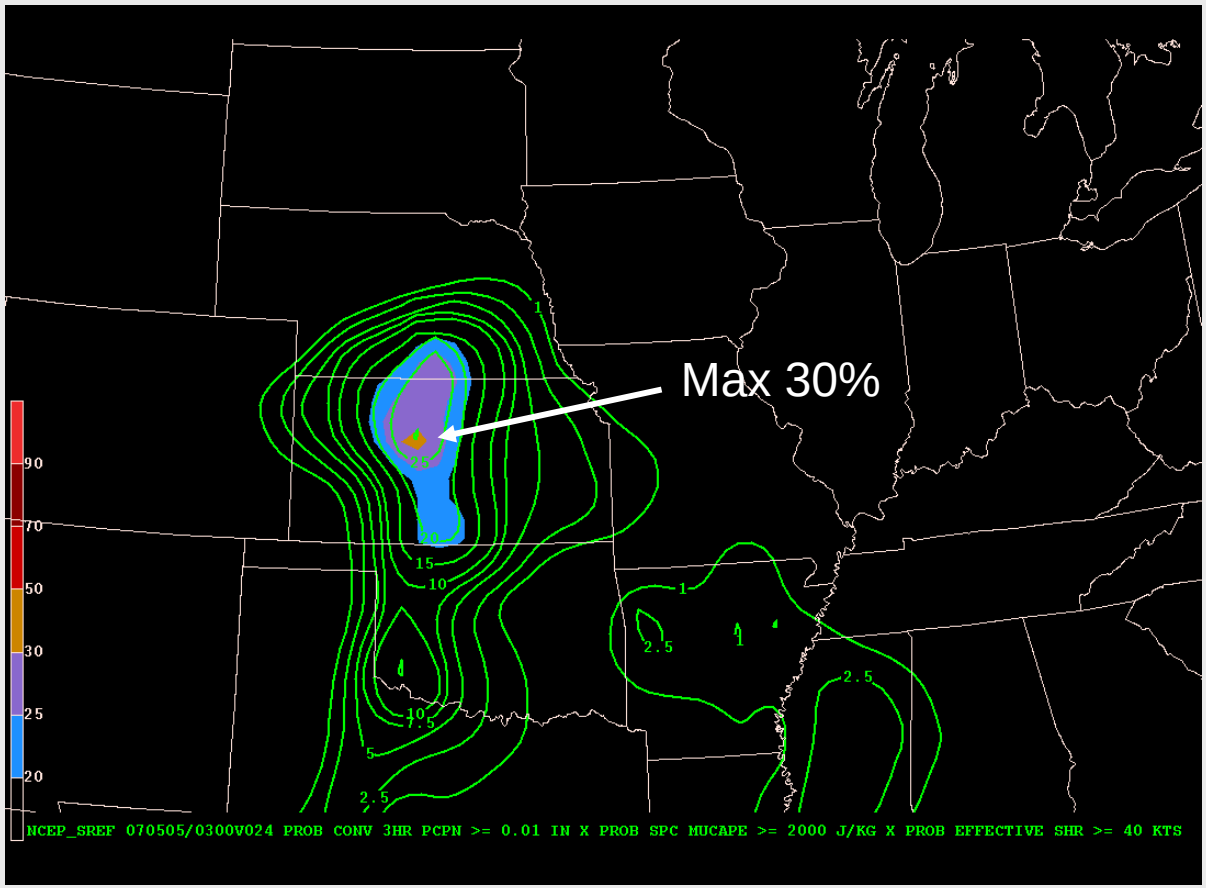
X

Prob (Eff. Shear $\geq$ 40 kt)

X

Prob (3h Conv. Pcpn $\geq$ 0.01 in)

*Shaded Area Prob > 20%*



# SREF Probability of STP ≥ 5

## *(Percent of members)*

*24 hr Forecast Valid 03 UTC 5 May 2007*

**Significant Tornado Parameter**

(MLCAPE / 1000 $Jkg^{-1}$)

X

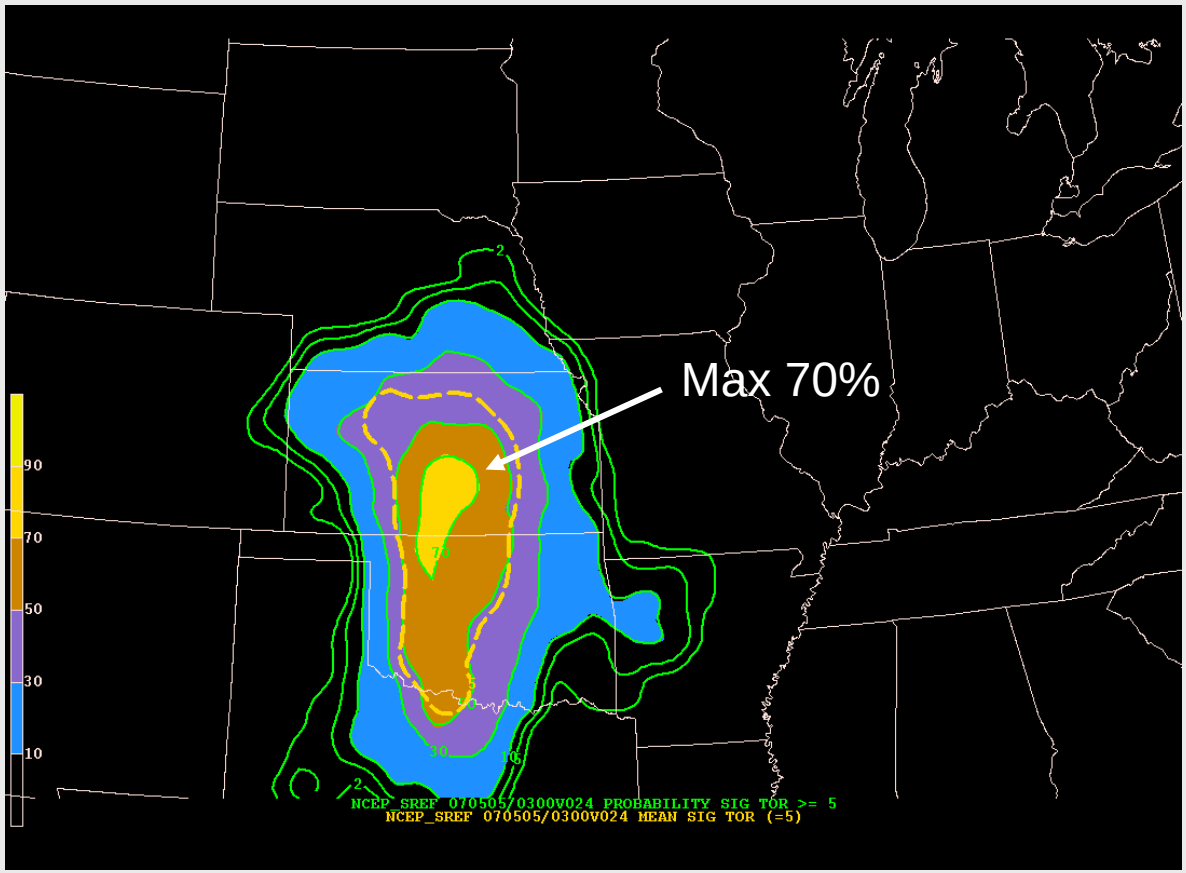
(6 km Shear / 40 kt)

X

(0-1 km SRH / 100 $m^2s^{-2}$)

X

(MLLCL / 1000 m)




*Shaded Area Prob ≥ 10%*

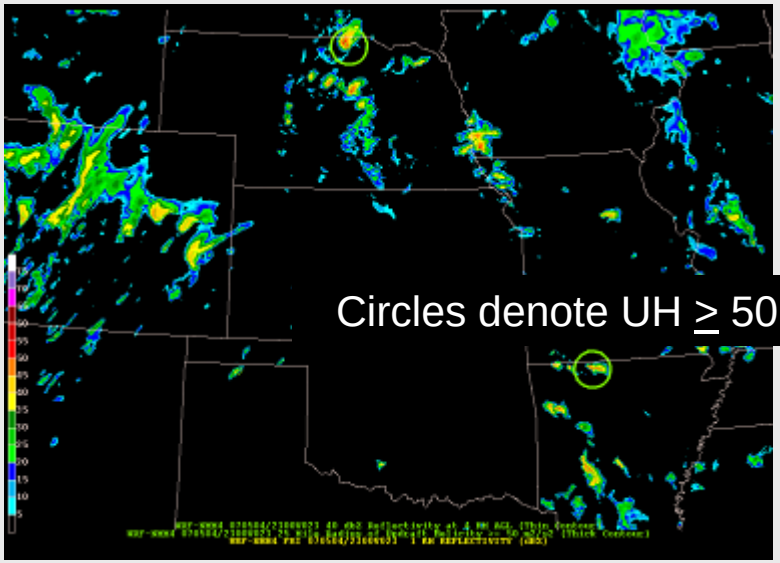
# Examples of 4 km WRF-NMM and WRF-ARW Guidance

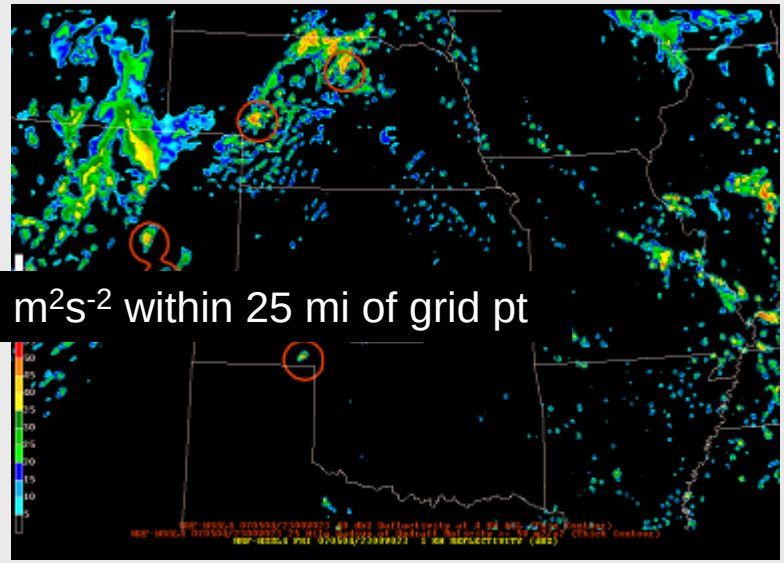
*Focus on Simulated Reflectivity to Provide Near-Stormscale Convective Characteristics*

# 4 km WRF Forecasts and Radar

## *23 hr forecasts valid 23z 4 May 2007*

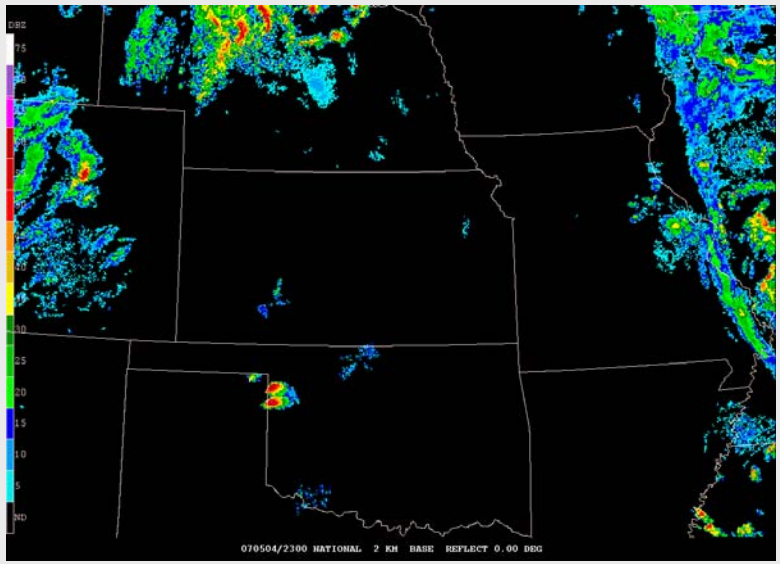
**NMM4**





**ARW4**

Circles denote UH $\geq$ 50 $m^2s^{-2}$ within 25 mi of grid pt

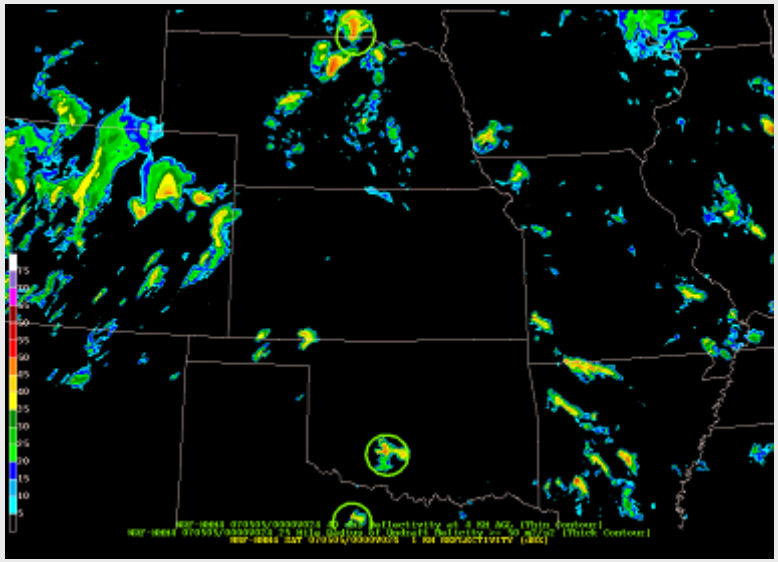


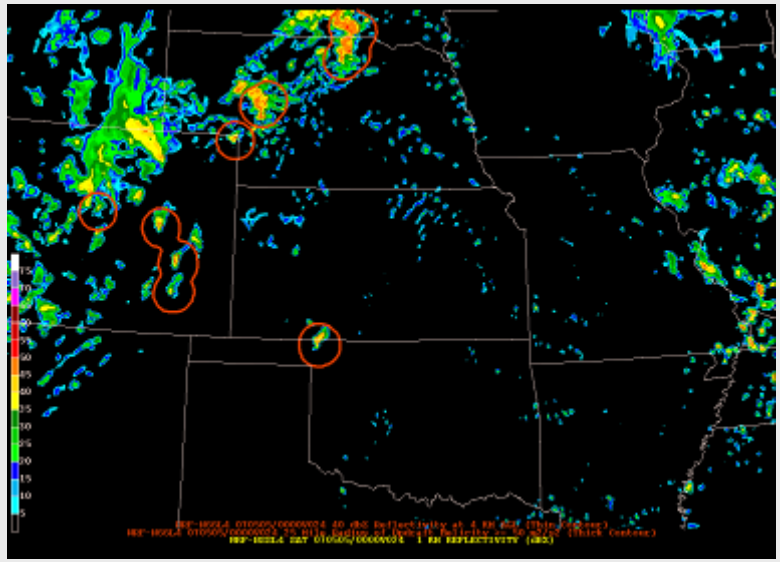

Radar

# 4 km WRF Forecasts and Radar

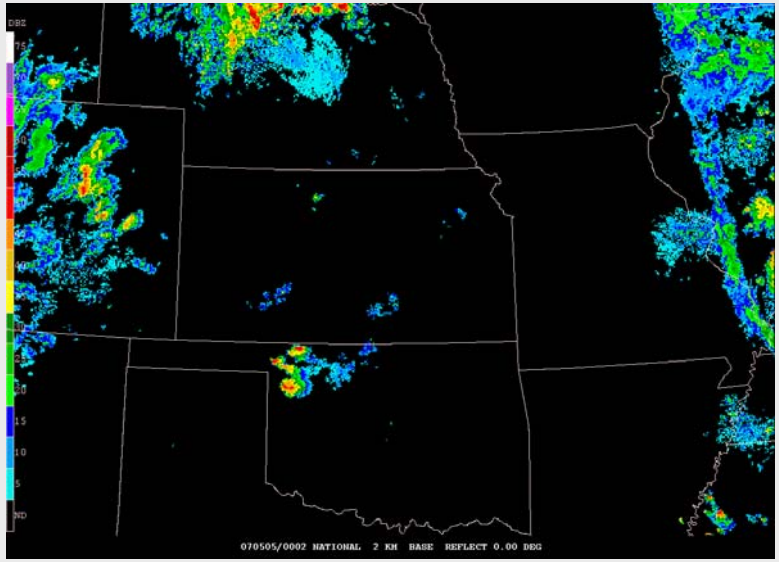
*24 hr forecasts valid 00z 5 May 2007*

**NMM4**





**ARW4**

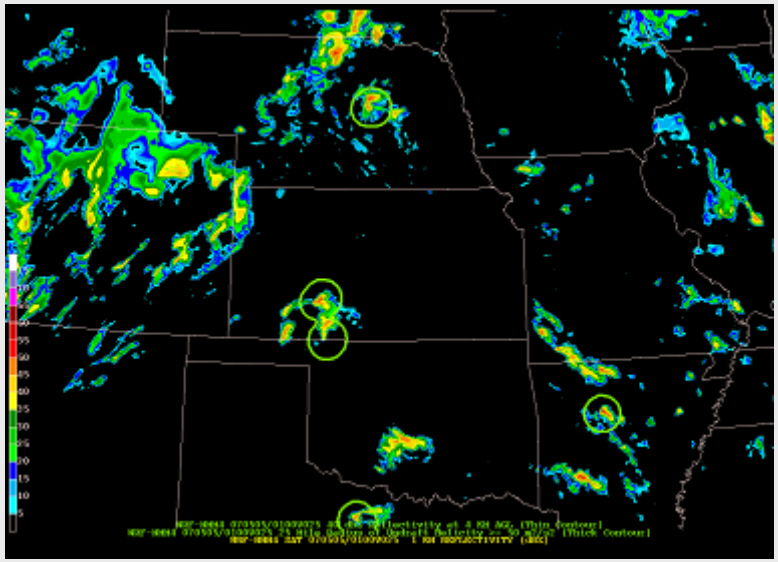


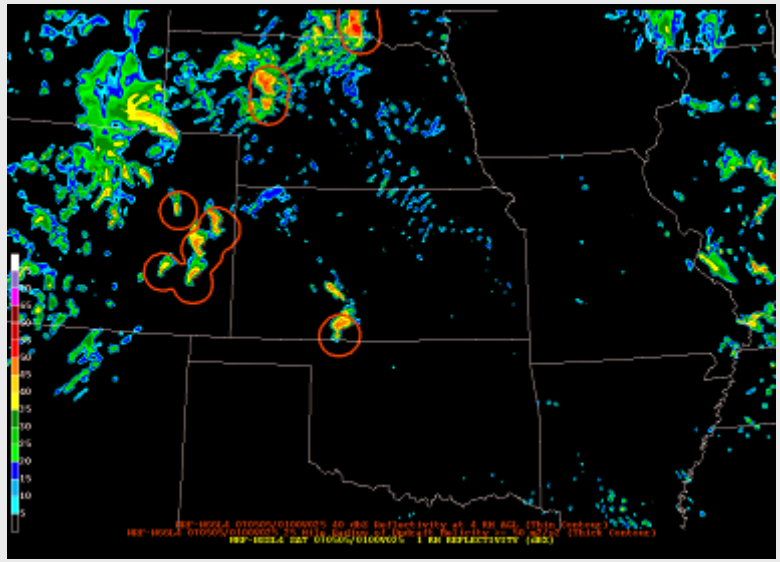

Radar

# 4 km WRF Forecasts and Radar

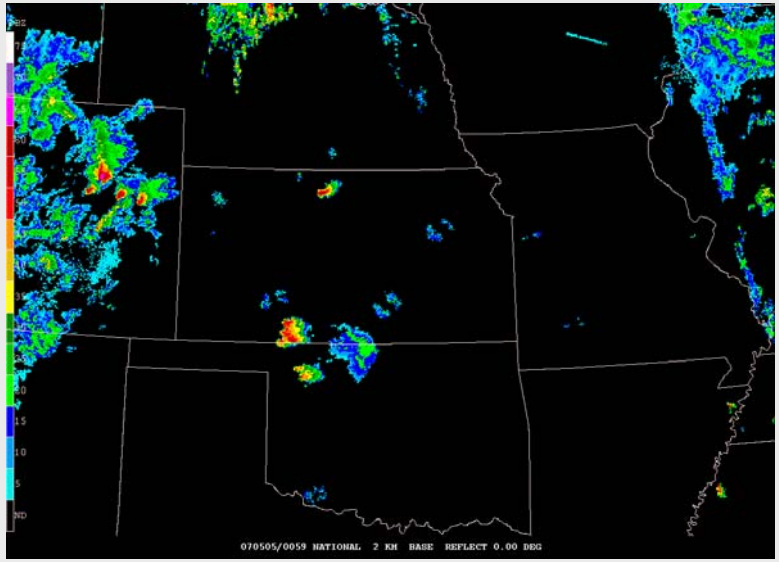
## *25 hr forecasts valid 01z 5 May 2007*

**NMM4**





**ARW4**

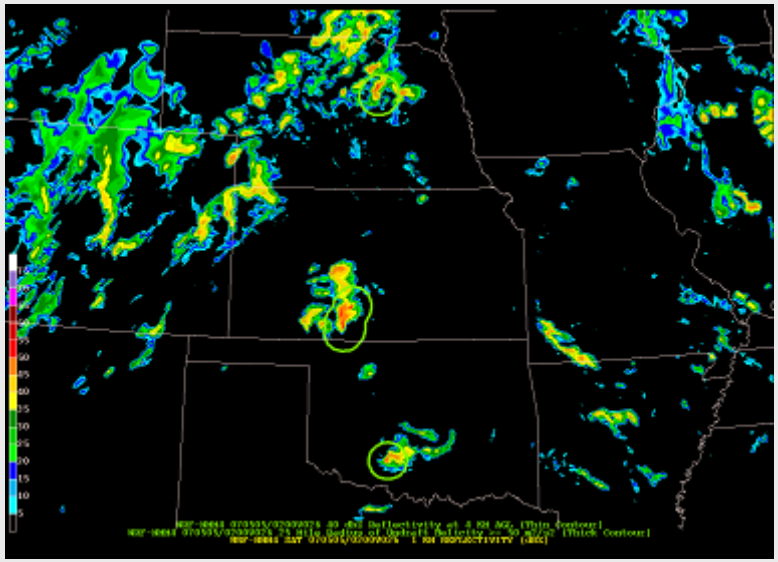


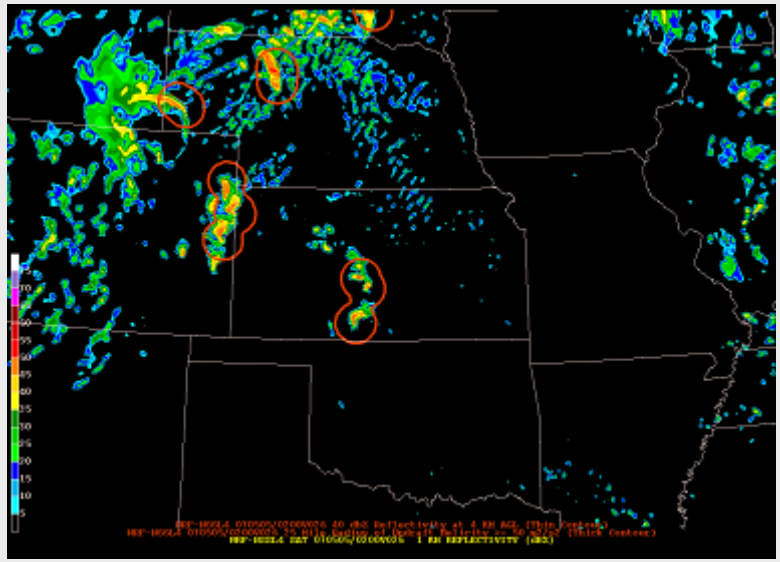

Radar

# 4 km WRF Forecasts and Radar

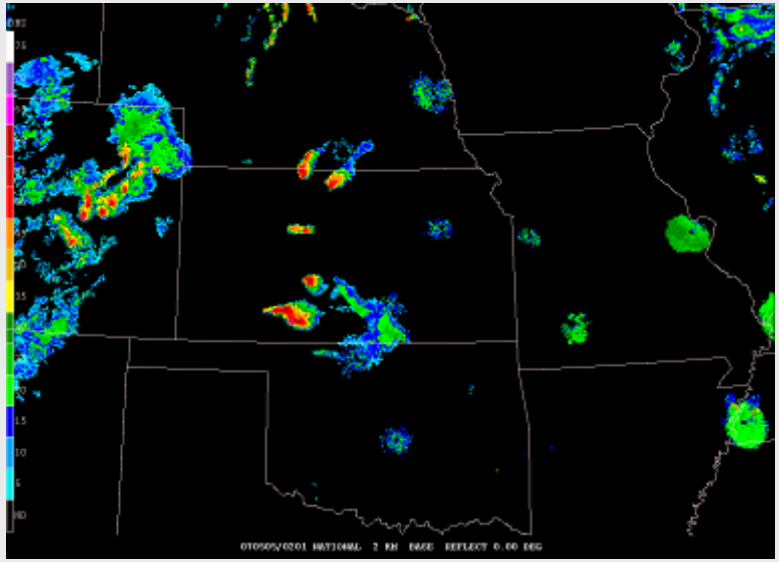
*26 hr forecasts valid 02z 5 May 2007*

**NMM4**





**ARW4**

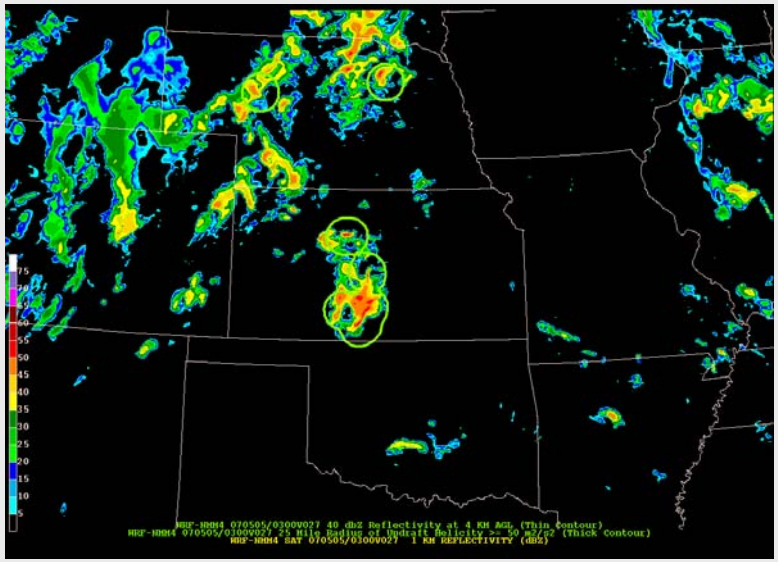


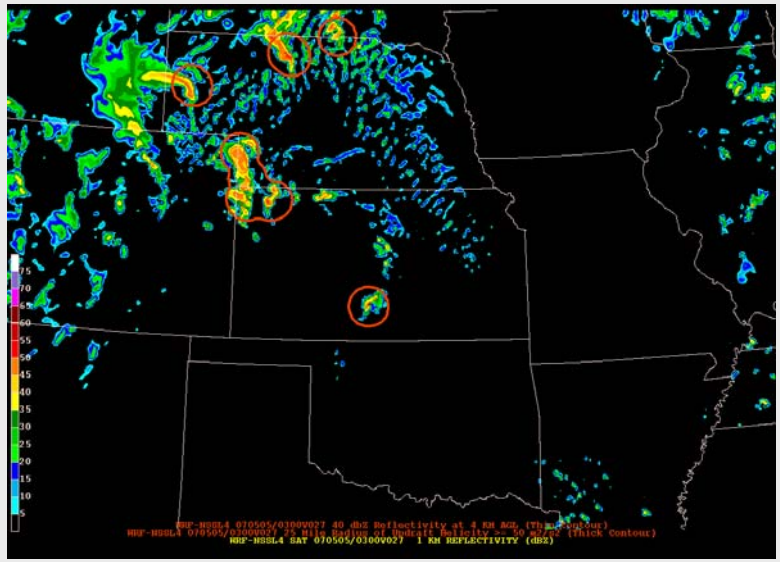
Radar

# 4 km WRF Forecasts and Radar

## *27 hr forecasts valid 03z 5 May 2007*

**NMM4**





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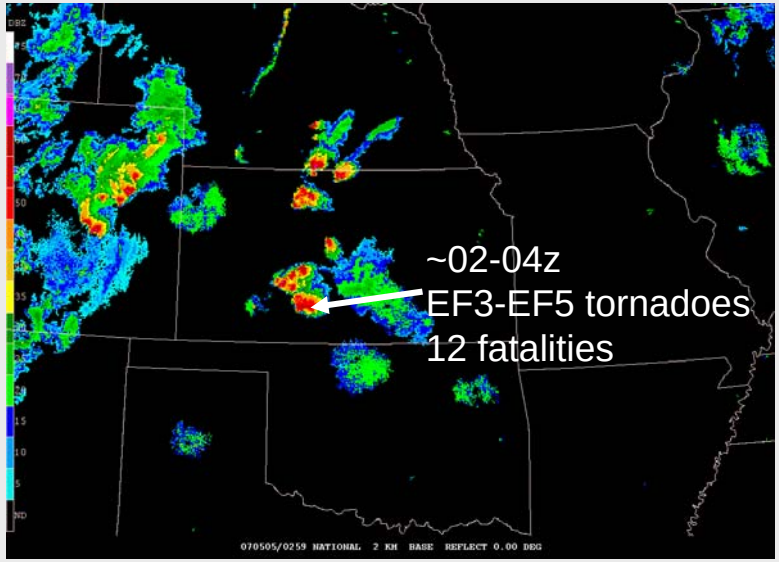


Radar

# 4 km WRF Forecasts and Radar

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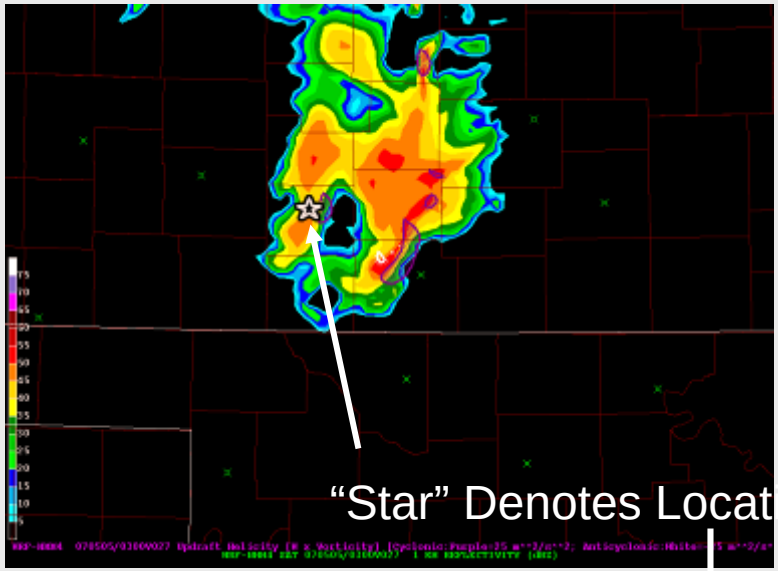
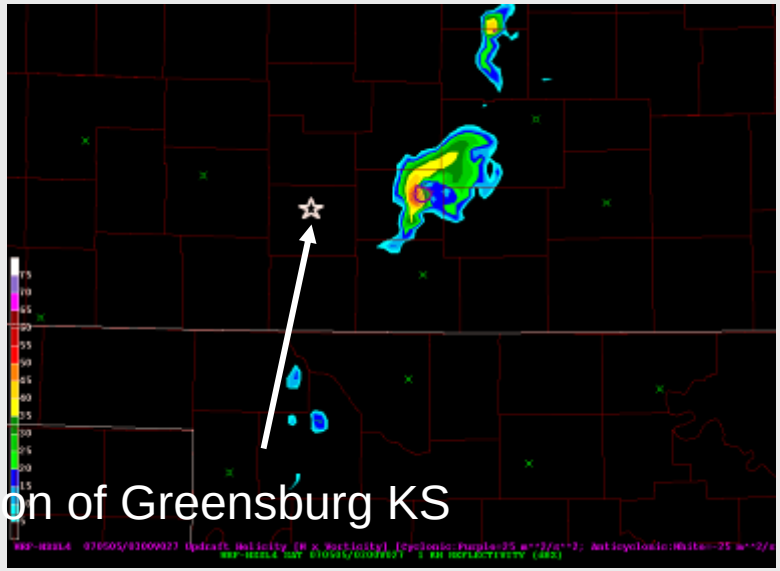
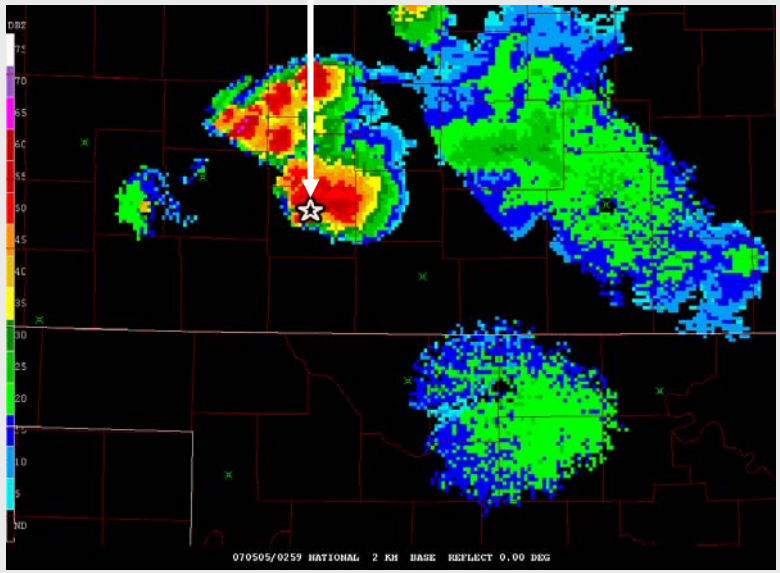




ARW4

“Star” Denotes Location of Greensburg KS

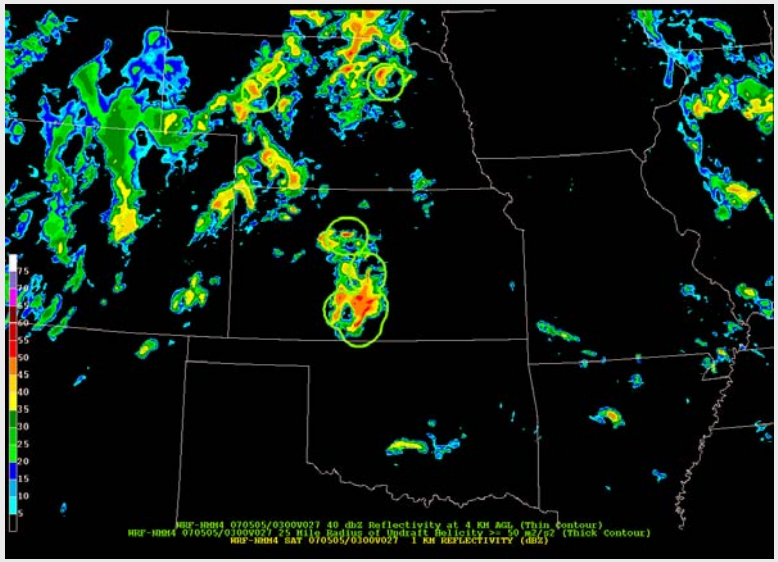


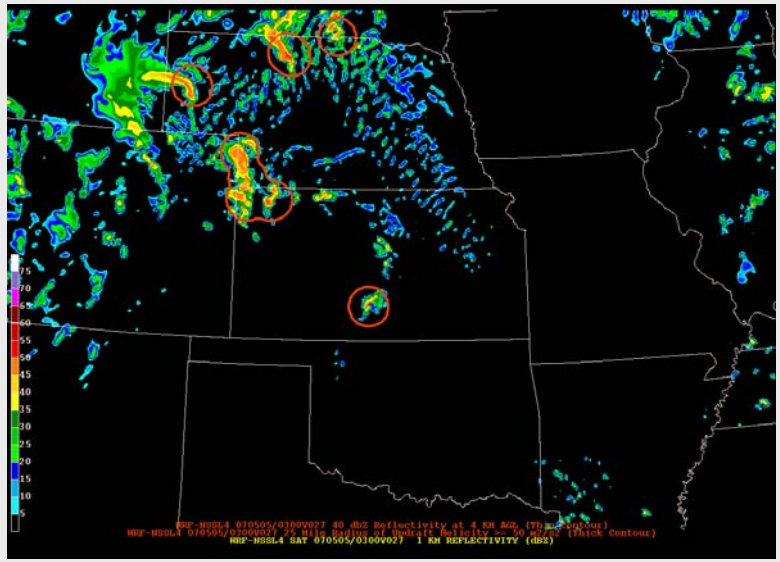

Radar

# 4 km WRF and NAM Forecasts

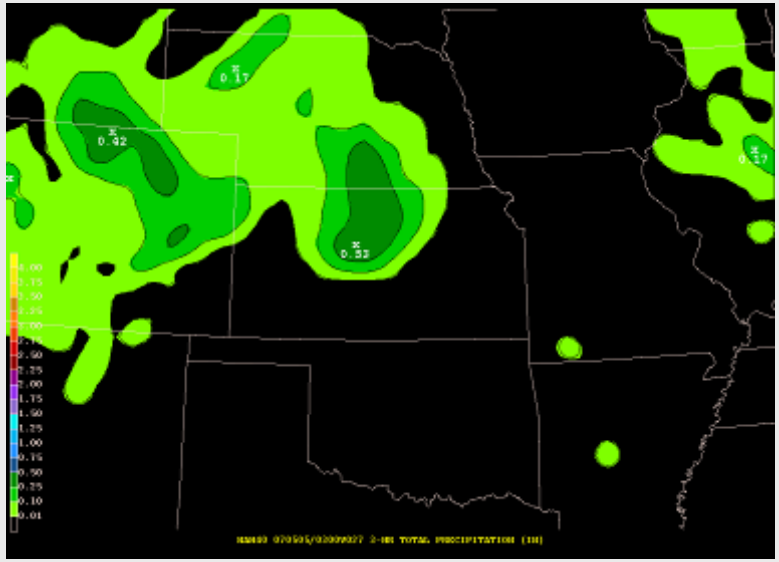
## *27 hr forecasts valid 03z 5 May 2007*

**NMM4**





**ARW4**



NAM 3hr Pcpn

# Use of WRF Models in Severe Weather Forecasting

- Convection-allowing WRF models offer insights into convective initiation, evolution, intensity, and **mode**
  - *Often credible mesoscale prediction of convective systems*
  - *4 km grid length permits approximation of stormscale structures*
- **Key forecaster challenge – stormscale uncertainty**
  - *WRF convective forecasts often appear plausible*
  - *What level of confidence to place in convective details?*
    - Uncertainty is inherent in convective forecasting
- **Suggests role for Storm Scale Ensemble Forecast system**
    - Hazardous Weather Testbed Spring Experiment 2007
    - Evolution toward “Warn-on-Forecast” concept
      - Focus on convective outlook and watch time scales

# 2007 Spring Experiment

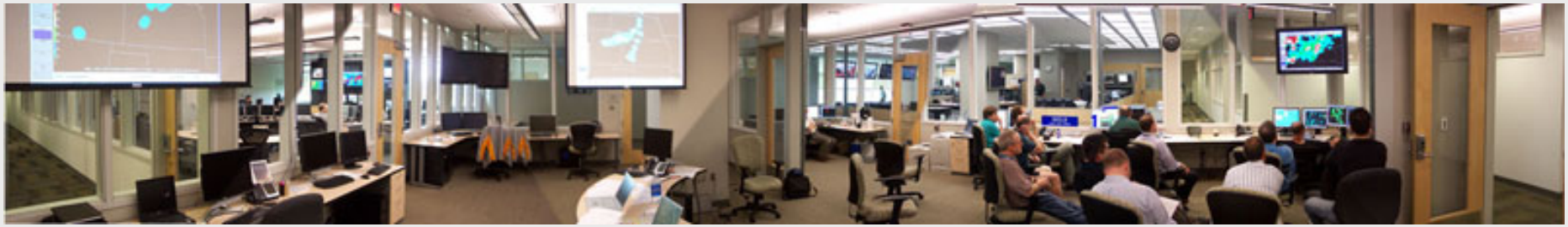
http://hwt.nssl.noaa.gov/Spring_2007

When:

- **8 am to 4 pm daily from 30 April to 8 June**

Where:

- **National Weather Center HWT (between OUN WFO and SPC)**



Participation:

- **~60 researchers and forecasters from government agencies, academia, and the private sector**

- **6-10 active participants at any time**

# 2007 Spring Experiment

http://hwt.nssl.noaa.gov/Spring_2007

## Primary experimental focus

- **Continue to explore convection-allowing WRF models**
  - Five near-CONUS runs: $\Delta x$ = 2 km (CAPS)
    $\Delta x$ = 3 km (NCAR)
    $\Delta x$ = 4 km (EMC, NSSL, CAPS)
  - Evaluate storm behavior, PBL structure, & impacts of physics, resolution

- **Explore convection-allowing WRF Storm Scale Ensemble Forecasts (SSEF)** (2007-2009)
  - Year 1:
    - **10 WRF-ARW members** (run by CAPS and PSC)
    - **$\Delta x$ = 4 km over two-thirds CONUS**
    - 6 members phys-only perts, 4 members with IC & phys perts
    - Use 21Z SREF for initial conds. - focus on 21-33 h forecasts

# HWT Spring Experiment 2007 Participating Institutions:

## NOAA Agencies

- NCEP/AWC (2)
- NCEP/EMC (3)
- NCEP/HPC
- NCEP/SPC (9)
- NWS/BTV
- NWS/LWX
- NWS/MAF
- NWS/OCWWS
- NWS/OUN
- NWS/RAP
- NWS/SLC
- NWS/SRH
- OAR/NSSL (5)
- OAR/GSD (3)
- OAR/PSD

## Universities

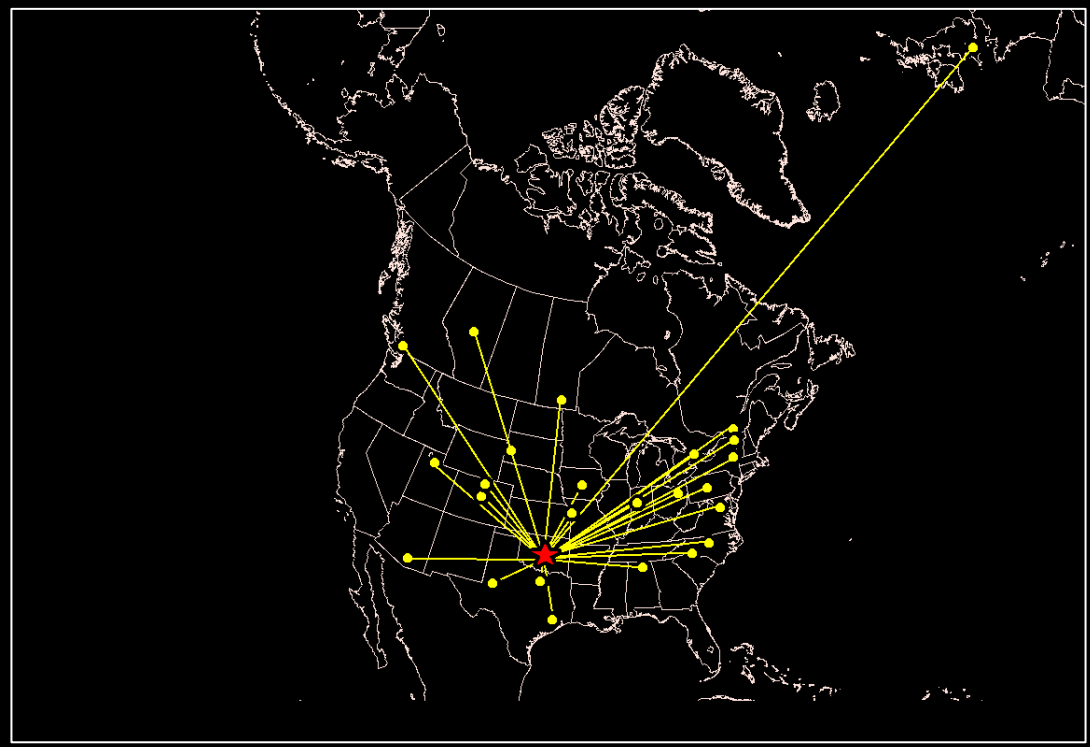
- Albany-SUNY (2)
- Arizona (2)
- Colorado State
- Iowa State
- North Carolina State (4)
- Oklahoma (2)
- Penn State
- Purdue (2)
- UNC-Charlotte
- York (Ontario)

## Gov't Agencies

- NCAR (5)
- Environ. Canada (6)
- UK Met Office
- USRA (Huntsville)

## Private Sector

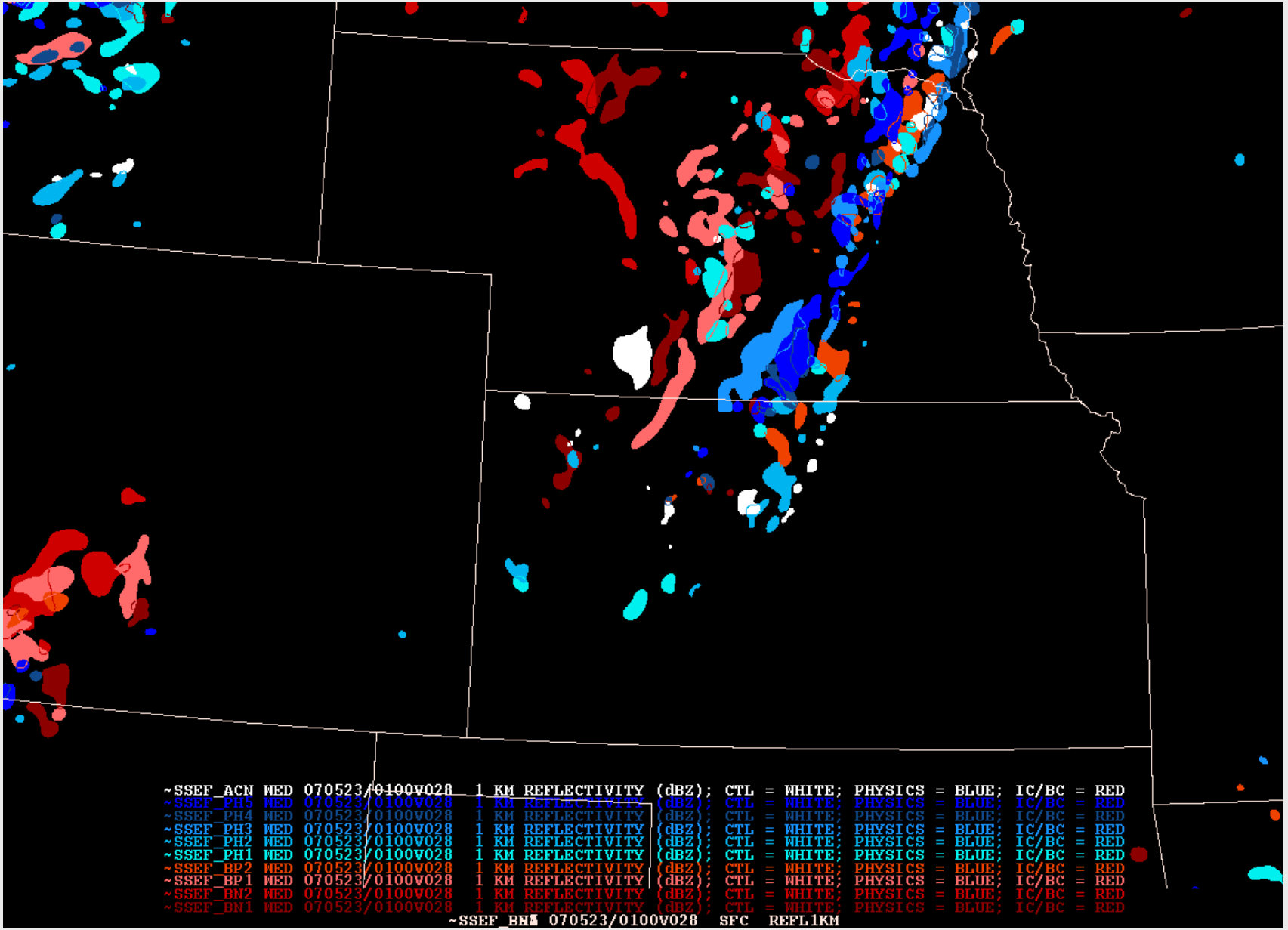
- Merrill Lynch
- FirstEnergy



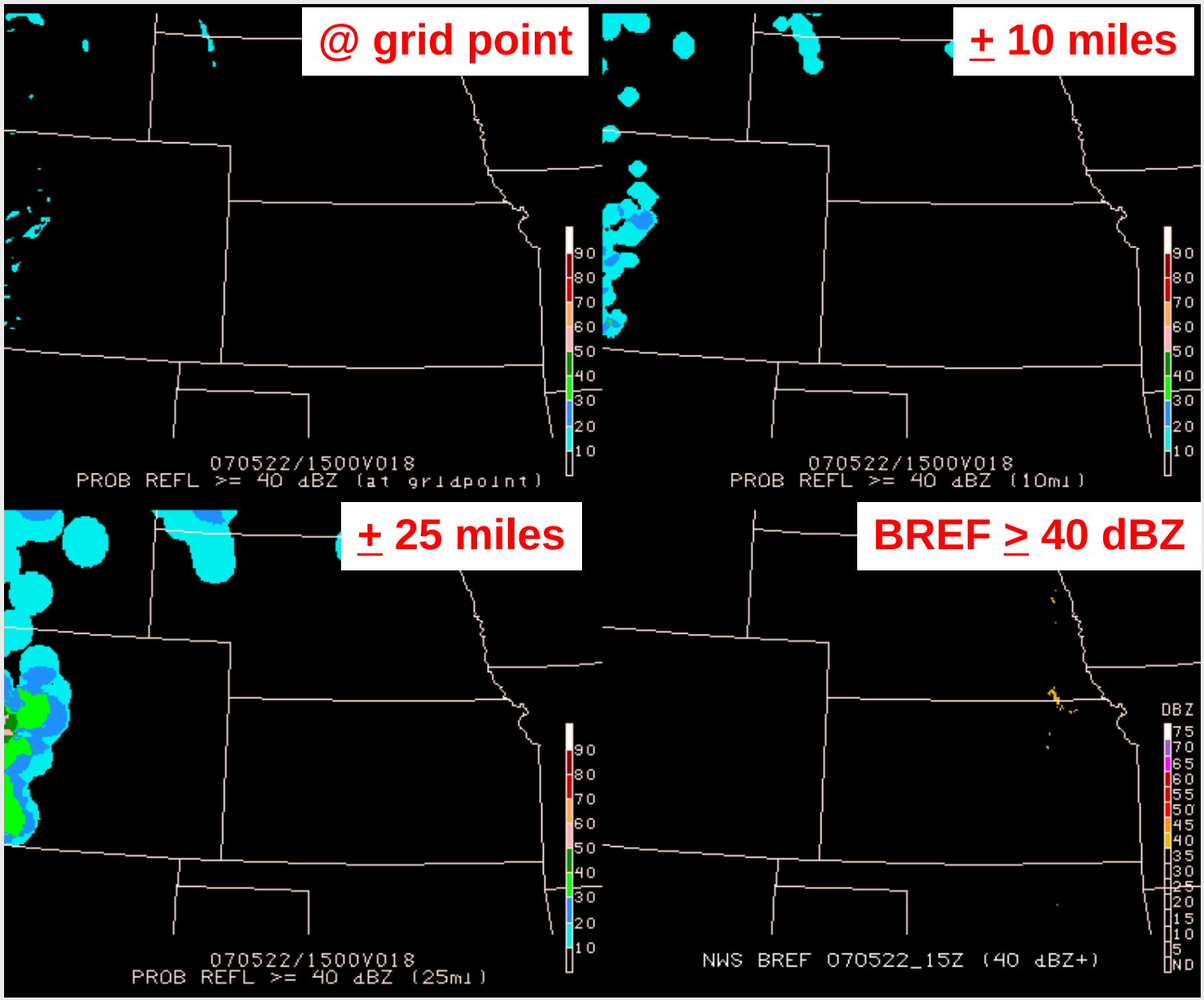
# Some Types of SSEF Products
## *Focus on Thunderstorm Characteristics*

- Simulated Reflectivity
  - Spaghetti, mean, median, probability matching, exceedance probability, maximum, postage stamps, linear mode
  - *Microphysics dependent*
- Updraft Helicity (Supercell Indicator)
  - Exceedance probability, maximum
  - *Resolution dependent*
- Maximum Updraft Vertical Velocity (Hail)
  - *Resolution dependent*
- Lowest Level Maximum Wind (Wind Gust Potential)
  - Exceedance probability, maximum

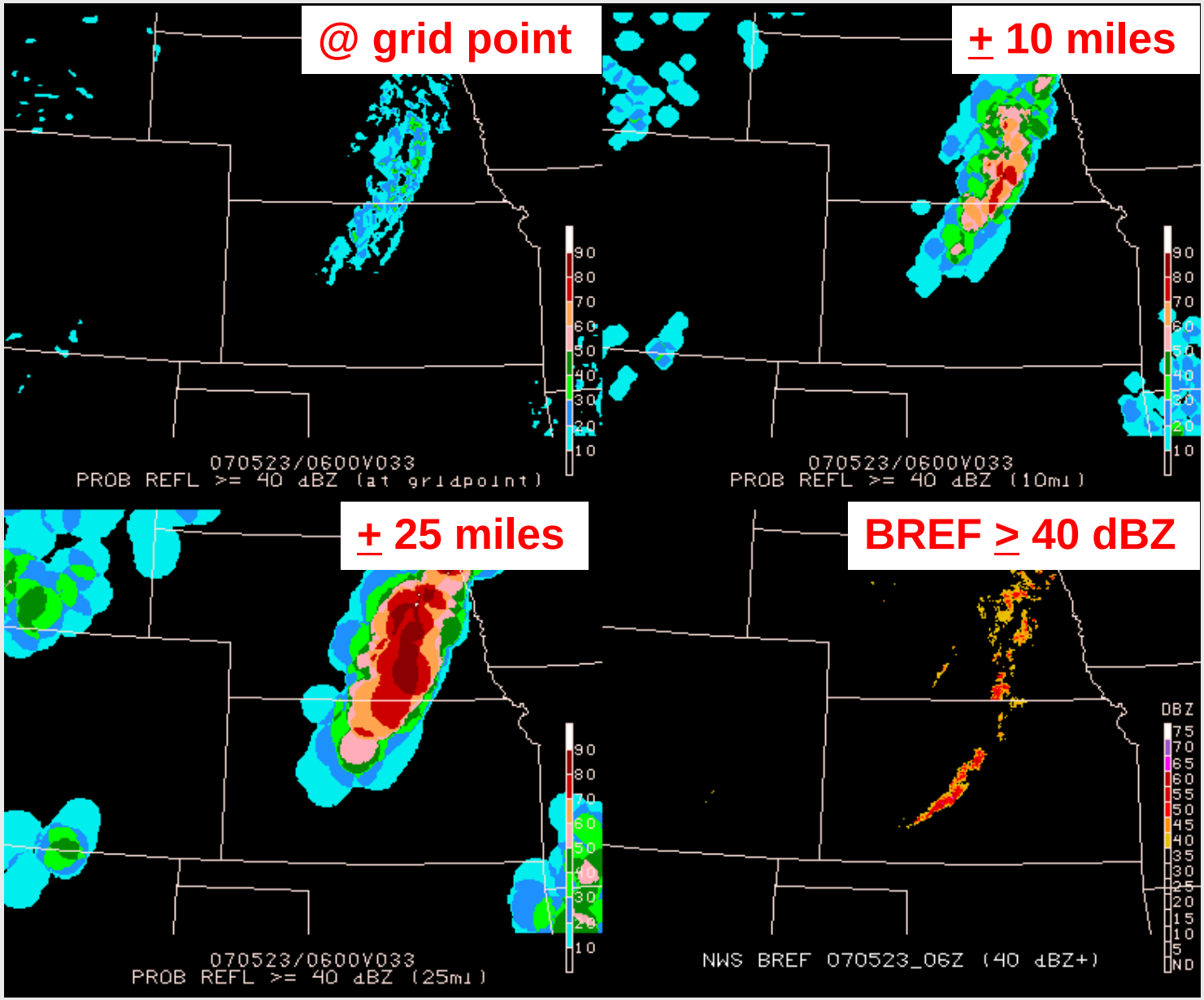
# “Spaghetti” Plot for Reflectivity ≥ 40 dBZ



# Probability of Reflectivity ≥ 40 dBZ Within a Radius



# Probability of Reflectivity ≥ 40 dBZ Within a Radius



# 2007 Spring Experiment

http://hwt.nssl.noaa.gov/Spring_2007

## Daily Forecast and Evaluation:

- **Produce a preliminary SPC-like probabilistic forecast for severe weather over region of interest by 16Z**

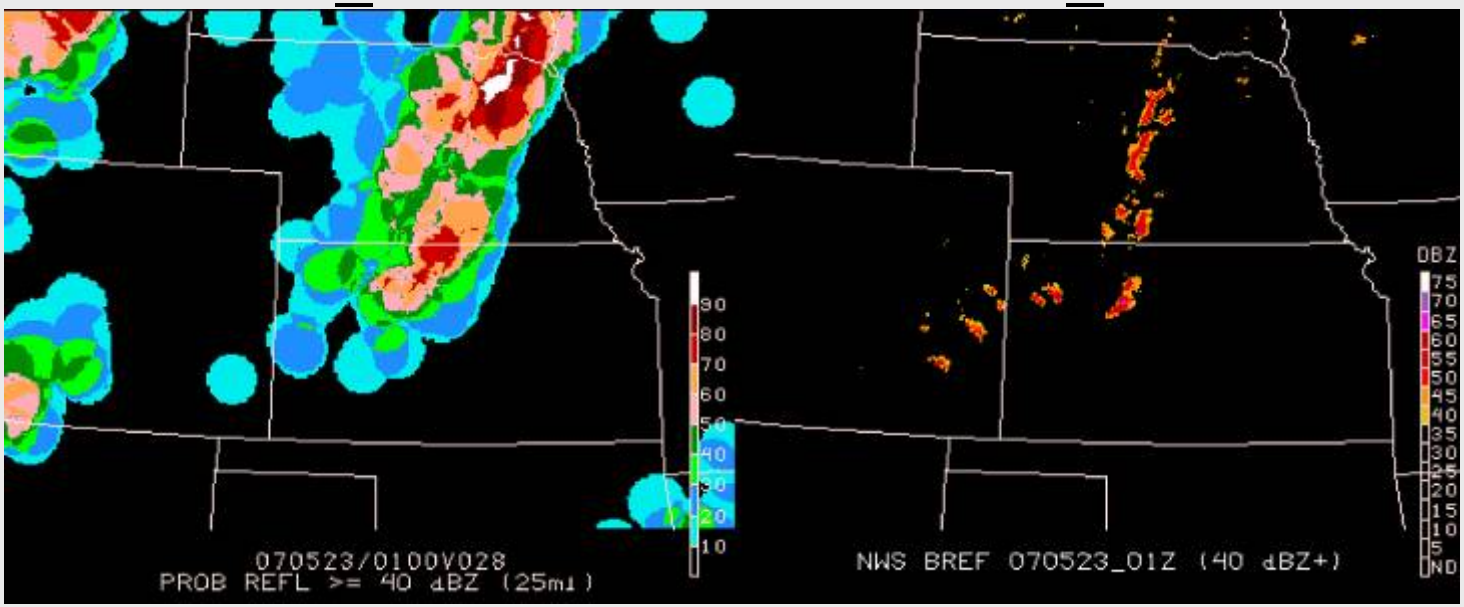
  - Forecast valid from 18-00Z, 21-03Z, or 00-06Z

  - Use information currently available to SPC operations; *includes output from 2-4 km deterministic WRF model forecasts*

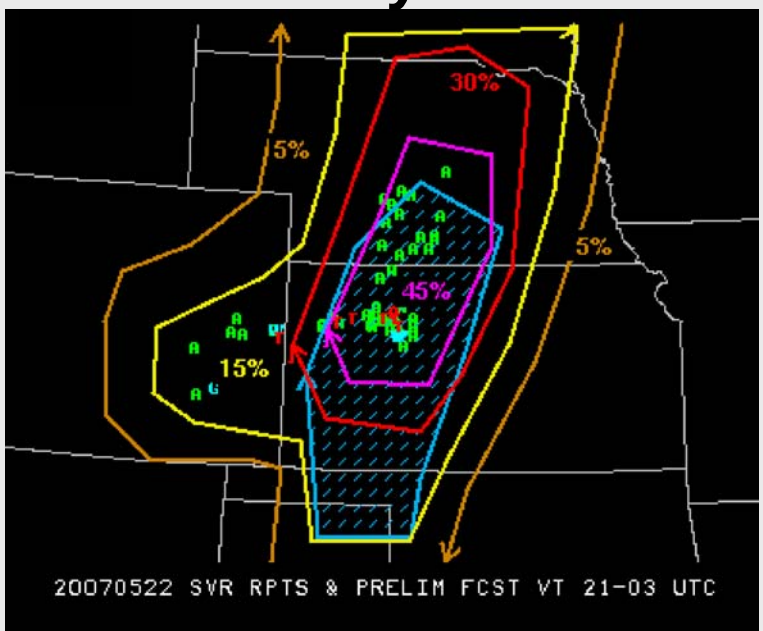
- **Produce an updated graphical forecast by 17Z after interrogating SSEF output**

**Prob refl ≥ 40 dBZ:**

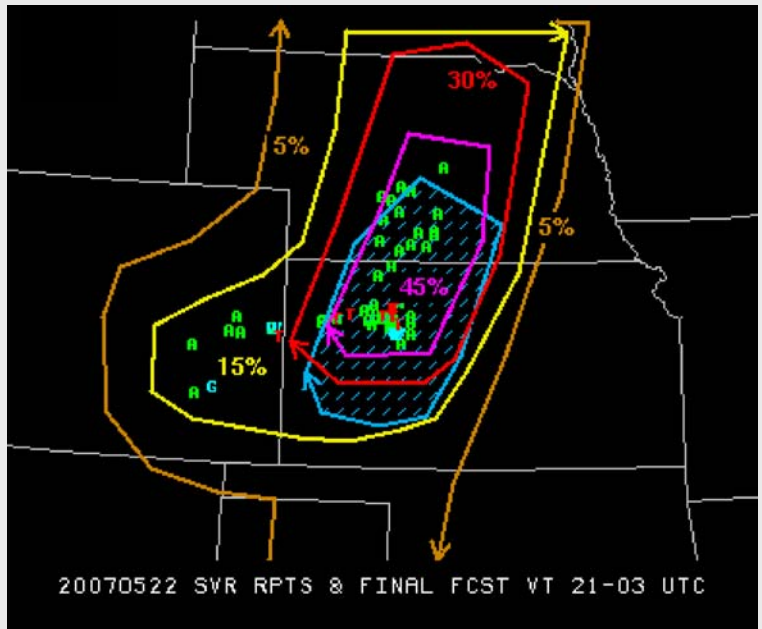
**Obs refl ≥ 40 dBZ:**




**Preliminary forecast:**

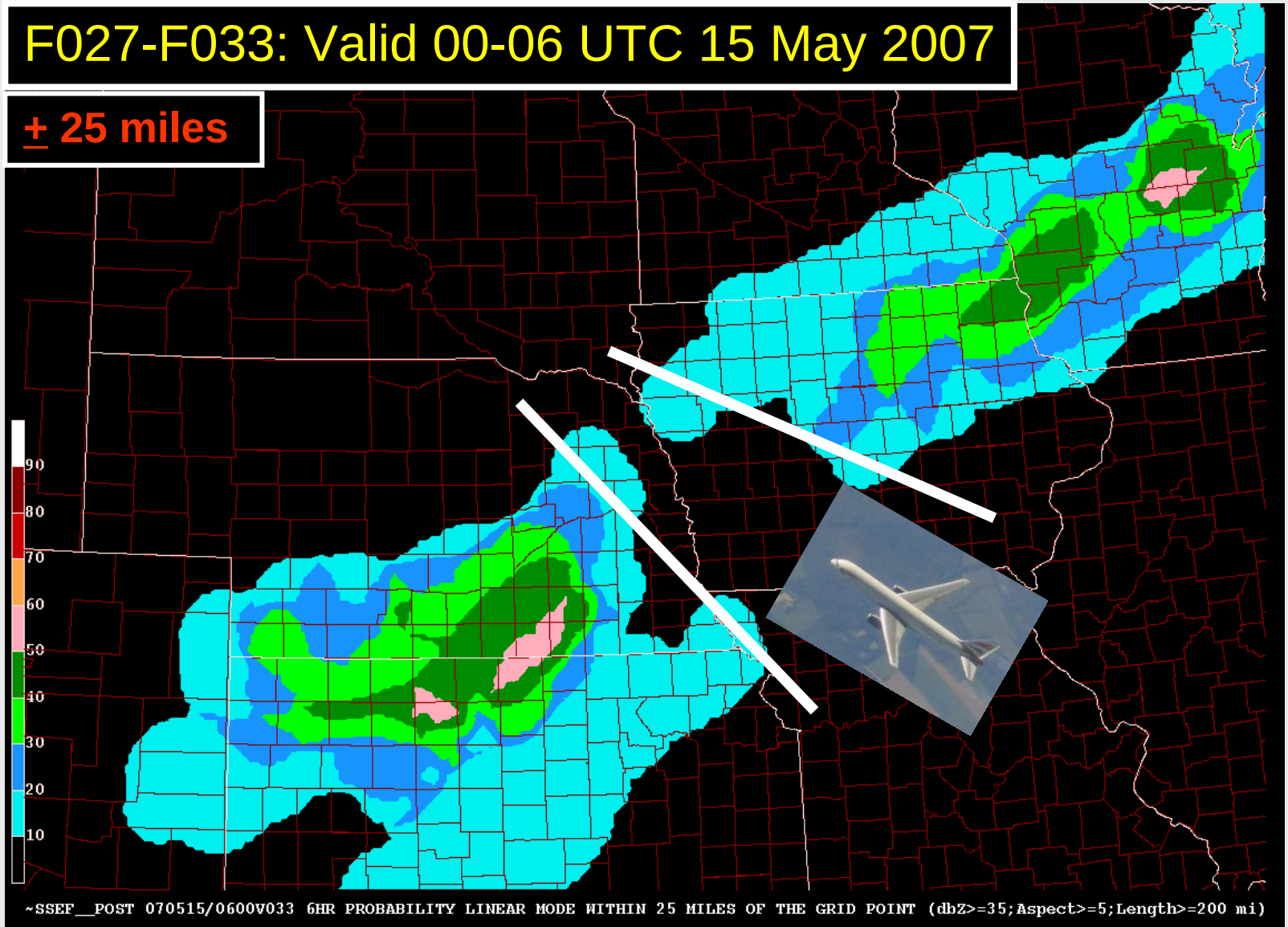



**Final forecast:**

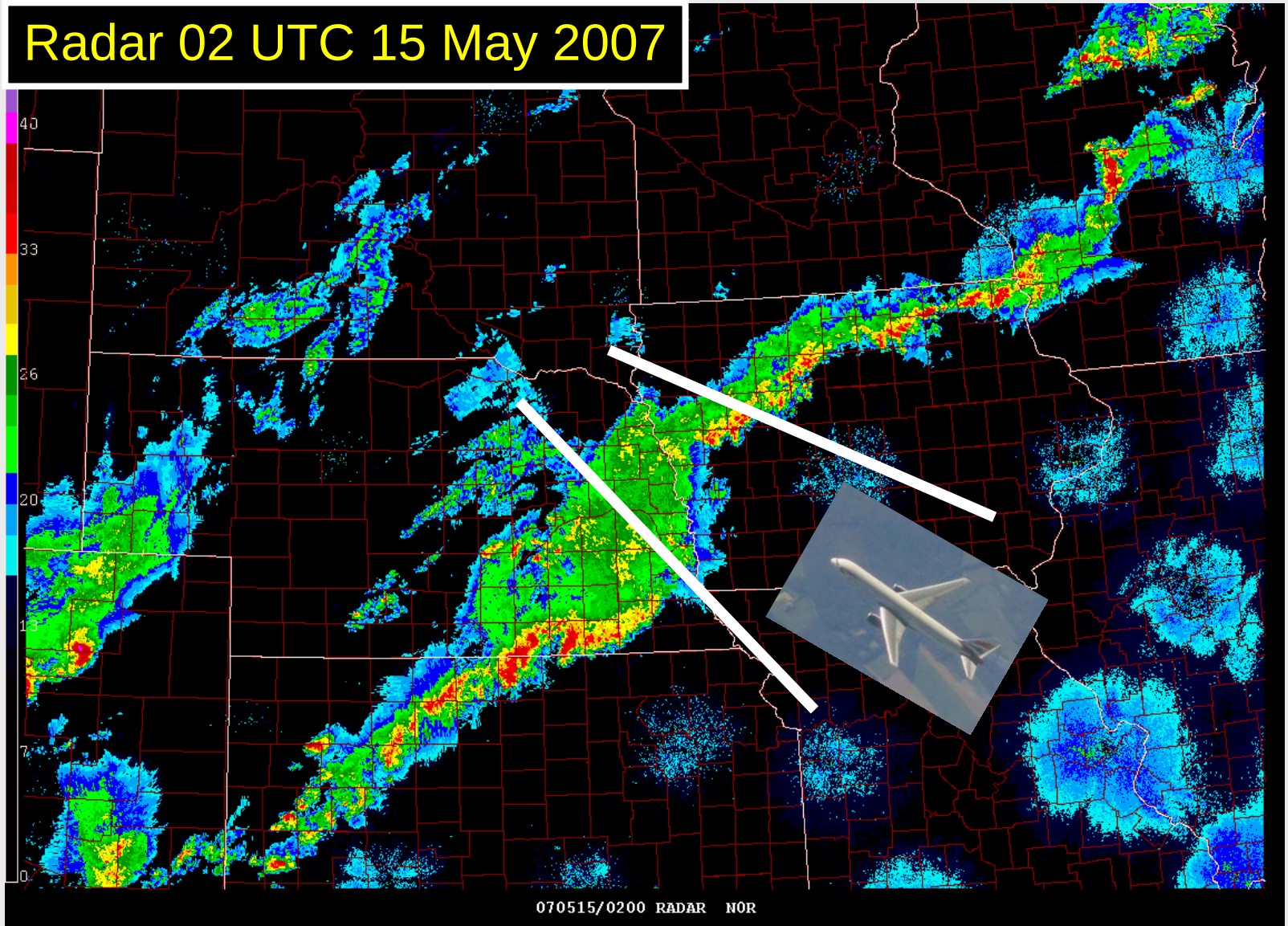


# 6 hr Probability of Linear Convective Mode

*(Refl ≥ 35 dBZ; Aspect Ratio 5:1; Length ≥ 200 mi)*



# 6 hr Probability Linear Convective Mode



# HWT Spring Experiment
## *SSEF Summary - I*

- **SSEF proof-of-concept testing and initial product design was successful**
  - Probabilistic thunderstorm forecast information shows promise
    - ***High Impact Events*** *- Severe Weather, QPF/Flooding, Aviation Support*
  - Spread-skill relationship more apparent in strongly forced situations
  - Detailed convective mode information required examination of simulated reflectivity from individual members
    - *Postage stamp displays considered very informative*
  - SSEF appears to have value for outlook and watch time scales
    - *Very complex data assimilation, storm modeling, and computing challenges must be solved for warning applications (Warn-on-Forecast)*

# HWT Spring Experiment
## *SSEF Summary - II*

- **Some Key Challenges**
  - Large IC sensitivity often evident
    - 21z versus 00z and impact of IC perturbations
  - Cold start for model integrations
    - How will new data assimilation (including radar, lightning, etc.) methods impact convection-allowing model forecasts?
  - What are appropriate perturbation strategies for SSEF?
  - Resolution sensitivity of convective scale parameters
    - What are meaningful threshold values (e.g., updraft helicity)?
  - Better ensemble systems result from better models
    - WRF model systems still under development

# HWT Spring Experiment
## *SSEF Summary - III*

- **Tentative Future Plans**
  - SSEF is multi-year project partially funded by CSTAR
  - 2008
    - *Build off 2007 results to construct better ensemble with improved statistical attributes and physical processes*
    - *Include WRF-NMM members for multi-model diversity*
    - *Incorporate 3DVAR cloud and radar data into 2 members*
    - *Launch On-Demand 2 km WRF runs over movable regional domain*
  - 2009
    - *Increase resolution - SSEF at 2 km and On-Demand at 1 km*
    - *Replace 3DVAR with GSI – radar and satellite data assimilation*
    - *Test automated storm mode object-oriented algorithms*
    - *Continue to leverage new high performance computing and networking capabilities*

# SPC Request List

- SREF and GEFS Ensemble Forecast Systems
  - Continued access to all member grids including non-bias corrected
- SREF
  - Comparable grid length and increased resolution for all base models
  - Move toward better integration with NAM cycles (00, 06, 12, 18 UTC)
- NAEFS
  - Addition of moisture and instability variables to output
- RUC/Rapid Refresh
  - Support for larger domain into Alaska (SPC/AK Fire Weather Initiative)
  - Develop convection-allowing nest within RUC/RR to provide hourly convective scale forecasts to 6-9 hrs
- Hi Res Window
  - Hourly output grids
  - Real-time creation of hourly GEMPAK grids as models run
  - Move toward CONUS scale convection-allowing model