Storm Prediction Center Highlights
EMC Annual Review
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National Weather 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)

120h Forecast Valid 00 UTC 22 Oct 2007
...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 CONSENSUS 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
Critical Conditions

- Pr [P12I ≤ 0.01”] X
- Pr [RH ≤ 15%] X
- Pr [WSPD ≥ 20 mph] X
- Pr [TMPF ≥ 60F]
75 hr SREF Maximum Fosberg Index (any member)

Fosberg Fire Weather Index (FFWI)
Non-linear, empirical relationship between weather and fire behavior

FFWI = \( F(\text{Wind speed}, \text{RH}, \text{Temp}) \)

- \( 0 \leq \text{FFWI} \leq 100 \)
- \( \text{FFWI} > \sim 50-60 \rightarrow \text{significant conditions} \)
- \( \text{FFWI} > \sim 75 \rightarrow \text{extreme conditions} \)
...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)*

<table>
<thead>
<tr>
<th></th>
<th>WRF-NMM</th>
<th>WRF-ARW</th>
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<tr>
<td>Horiz. Grid Spacing (km)</td>
<td>4.0</td>
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<tr>
<td>Vertical Levels</td>
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<td>35</td>
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<tr>
<td>PBL/Turbulence</td>
<td>MYJ</td>
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<td>Ferrier</td>
<td>WSM6</td>
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<td>Radiation (SW/LW)</td>
<td>GFDL/GFDL</td>
<td>Dudhia/RRTM</td>
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<tr>
<td>Initial/Boundary Conditions</td>
<td>32 km NAM</td>
<td>40 km NAM</td>
</tr>
</tbody>
</table>

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)
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

\[ \text{Pr (CPTP)} \geq 1 \times \text{Pr (PCPN)} \geq .01" \]

Calibration period previous 366 days

\textit{Shaded Area Prob } \geq 40\%
SREF Combined Probability
CAPE x Shear x Conv. Precipitation

24 hr Forecast Valid 03 UTC 5 May 2007

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

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

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

Shaded Area Prob $>$ 20%

Max 30%
SREF Probability of STP $\geq 5$

*(Percent of members)*

24 hr Forecast Valid 03 UTC 5 May 2007

**Significant Tornado Parameter**

- (MLCAPE / 1000 Jkg$^{-1}$)
- (6 km Shear / 40 kt)
- (0-1 km SRH / 100 m$^2$s$^{-2}$)

Max 70%

*Shaded Area Prob $\geq 10%$*
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

Circles denote UH ≥ 50 m²s⁻² within 25 mi of grid pt

NMM4

ARW4

Radar
4 km WRF Forecasts and Radar
24 hr forecasts valid 00z 5 May 2007
4 km WRF Forecasts and Radar
25 hr forecasts valid 01z 5 May 2007
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

~02-04z EF3-EF5 tornadoes
12 fatalities
4 km WRF Forecasts and Radar
27 hr forecasts valid 03z 5 May 2007

“Star” Denotes Location of Greensburg KS
4 km WRF and NAM Forecasts
27 hr forecasts valid 03z 5 May 2007
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 perturbations, 4 members with IC & phys perturbations
    - Use 21Z SREF for initial conditions. 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 $\geq 40$ dBZ
Probability of Reflectivity > 40 dBZ Within a Radius

@ grid point

+ 10 miles

+ 25 miles

BREF > 40 dBZ
Probability of Reflectivity > 40 dBZ Within a Radius

@ grid point

+ 10 miles

+ 25 miles

BREF > 40 dBZ
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**
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