Impact of Including WRF members in the NCEP Short Range Ensemble Forecast system

Jeff McQueen, Jun Du, Binbin Zhou, Dusan Jovic, Geoff DiMego and Zoltan Toth

NOAA/NWS/NCEP/EMC

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Rationale for WRF Configuration

• Multi-core:
  – Previous studies by Du (2006), Buizza and Toth (2005)
  – Multi-physics by Stensrud (2000), Du (06), McQueen (05) showed improved spread especially in warm season
  – Proposed increase to
    • 4 model cores (Eta, RSM, WRF-NMM, WRF-ARW)
    • 6 different physics configurations

• GFS initial atmospheric conditions (used for WRF members):
  – Near equal number of members initialized by NDAS (10) and GDAS (11)

• NDAS Land States:
  – WRF NOAH LSM uses same land-use types as in NDAS
  – (24 soil types, 13 land use types)
### SREF System

**Eta & RSM members**

<table>
<thead>
<tr>
<th>Model</th>
<th>Res (km)</th>
<th>Levels</th>
<th>Members</th>
<th>Cloud Physics</th>
<th>Convection</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSM-SAS</td>
<td>45</td>
<td>28</td>
<td>Ctl,n,p</td>
<td>GFS physics</td>
<td>Simple Arak-Schubert</td>
</tr>
<tr>
<td>RSM-RAS</td>
<td>45</td>
<td>28</td>
<td>n,p</td>
<td>GFS physics</td>
<td>Relaxed Arak-Schubert</td>
</tr>
<tr>
<td>Eta-BMJ</td>
<td>32</td>
<td>60</td>
<td>Ctl,n,p</td>
<td>Op Ferrier</td>
<td>Betts-Miller-Janjic</td>
</tr>
<tr>
<td>Eta-SAT</td>
<td>32</td>
<td>60</td>
<td>n,p</td>
<td>Op Ferrier</td>
<td>BMJ-moist prof</td>
</tr>
<tr>
<td>Eta-KF</td>
<td>32</td>
<td>60</td>
<td>Ctl,n,p</td>
<td>Op Ferrier</td>
<td>Kain-Fritsch</td>
</tr>
<tr>
<td>Eta-KFD</td>
<td>32</td>
<td>60</td>
<td>n,p</td>
<td>Op Ferrier</td>
<td>Kain-Fritsch with enhanced detrainment</td>
</tr>
</tbody>
</table>

Adjust conv. Params to account for known biases: e.g: Biases in Convective initiation timing

*Implemented into NCEP Operations on August 17, 2004*
## SREF WRF Upgrades

<table>
<thead>
<tr>
<th>WRF Core</th>
<th>Physics Suite</th>
<th>Breeding</th>
<th>Initial /Lateral Boundaries</th>
<th>Land States</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMM V2.03.1 40L50</td>
<td>EMC</td>
<td>Ctl, n5, p5</td>
<td>GFS ½º PGRB / MREF ET Pair</td>
<td>Truncate from NDAS-12 km</td>
</tr>
<tr>
<td>ARW V2.03.1 45L35</td>
<td>NCAR</td>
<td>Ctl, n1, p1</td>
<td>GFS ½º PGRB / MREF ET Pair</td>
<td>Truncate from NDAS</td>
</tr>
</tbody>
</table>

- Common ensemble product generator
  - *Create mean, spread, prob. products if some members fail*

- Additional outputs added for AWIPS OB7 in 2006
# SREF WRF members

<table>
<thead>
<tr>
<th>Core</th>
<th>3 NMM members</th>
<th>3 ARW members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>40 km</td>
<td>45 km</td>
</tr>
<tr>
<td>Vertical</td>
<td>50 hybrid sigma-P levels</td>
<td>35 Mass levels</td>
</tr>
<tr>
<td>Adv/Physics Time Step</td>
<td>110/600 sec (4 nodes/member)</td>
<td>108/200 sec (5 nodes/member)</td>
</tr>
<tr>
<td>Computer usage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffusion</td>
<td>Increased Smagorinsky deformation</td>
<td>Vertical damping</td>
</tr>
<tr>
<td>Physics</td>
<td>NOAH LSM</td>
<td>NOAH LSM</td>
</tr>
<tr>
<td></td>
<td>MYJ TKE PBL</td>
<td>MRF 1st order PBL</td>
</tr>
<tr>
<td></td>
<td>BMJ Convection</td>
<td>Kain-Fritsch Convection</td>
</tr>
<tr>
<td></td>
<td>Ferrier Microphysics</td>
<td>Ferrier Microphysics</td>
</tr>
</tbody>
</table>
NCEP’s FVS Verification System

• Input observations are from NCEP operational PREPBUFR files which include 1) radiosonde & dropsonde Z, temp, wind & moisture; 2) surface land & marine P, temp, wind, moisture observations; 3) ACARS & conventional aircraft wind, temp [moisture], and 4) Profiler winds.

• Forecasts to be verified come from isobaric and surface output of post-processor in GRIB format.

• Verified Fields include temperature, wind and moisture fields on pressure and shelter levels.

• Adding more verified fields such as sensible weather, wind shear, and PBL height
Ensemble Mean Errors

**SREF precip, 2m Temp bias**

**Summer 06 prcp bias**

- **NAM**
- **SREF**
- **GFS**

**Winter 06-07 prcp bias**

- **NAM**
- **SREF**
- **GFS**

**Summer 06 2 m Temp bias**

- **NAM**
- **SREF**

**Winter 06-07 2 m Temp bias**

- **NAM**
- **SREF**
Ensemble Mean Errors

SREF mean error with height

Summer 06 temp bias

Winter 06-07 temp bias

Summer 06 Wind RMSE

Winter 06-07 Wind RMSE
SREF 48h Temps Talagrand Diagrams

500 mb Temp Summer 06

500 mb Temp Winter 06-07

850 mb Temp Summer 06

850 mb Temp Winter 06-07
SREF 48h Winds Talagrand Diagrams

500 mb Winds Summer 06

500 mb Winds Winter 06-07

850 mb Winds Summer 06

850 mb Winds Winter 06-07
Model Sub-group Performance

2 m Temp errors by Forecast hr

RMSE

2 m Temp Summer 06

2 m Temp Winter 06-07

BIAS

2 m Temp Summer 06

2 m Temp Winter 06-07
Model Sub-group Performance

48 h Temperature Statistical Consistency

Ens. Mean Squared Error / Ensemble Variance

MSE/VAR : best ~ 1

- Eta group errors are large in upper trop/lower strat (var is small)
WRF Member Errors
Precip, 2 m Temperatures

Summer 06 Precip Scores by threshold (inches)

Winter 06-07 Precip Scores

Summer 06 2m Temp bias

Winter 06-07 2 m Temp bias
WRF member errors
Temp, wind errors with height

Summer 06
Temp bias

Winter 06-07
Temp bias

Summer 06
Wind RMSE

Winter 06-07
Wind RMSE
Summary

Overall System Performance:
- *Deterministic and Probabilistic verifications are generally positive:*
  - Moderate reduction of errors and incr. spread
  - Improved core, physics and IC diversity
  - Strongest impact on lower level variables
- **Still better performance in East U.S. compared to West**
- **GFS errors now comparable to ensemble mean errors**

- **WRF sub-sets yield best accuracy and spread statistics except for low level temps**

- **WRF individual member performance**
  - **Low temp bias errors are significantly larger than Eta or RSM member biases**
  - **Low level performance better in summer season**
  - **Bias correction techniques (Du, et al, 2007) have improved these errors**
  - **Differences between WRF ARW & NMM larger than differences between initial condition pert within a core**

- **Fall 2007 upgrades to WRF should improve WRF low level performance**
  - **Corrections to Ferrier microphysics – radiation interactions**
  - **All 21 SREF members will be at 32 km**
BACKUP SLIDES
SREF Operational Performance

Outlier Percentage

48 h forecasts (November 2005)

- Outlier percentage reduced for SREF/21 system
- WRF sub-member agree best with obs as compared to Eta and RSM sub-members
SREF Cold Season Case Study
November 20, 2005 09 Z Run – MSLP (48 h forecast)

SREF Operational
Slightly stronger low when WRF members are added

SREF Parallel
SREF Performance
Statistical Consistency (Nov. 2005)

- Ens. Mean Squared Error/ ensemble Variance best ~ 1 (Eckel and Mass, 2005)
- **SREF-21 improved over SREF-15**
- **WRF subset yields lowest SC compared to Eta subsets**
• Eastern US Nest: NEC, APL, SEC, GMC, MDW, LMV, ECA
• Western US Nest: NPL, SPL, NMT, SMT, GRB, SWD, NWC, SWC, WCA
• Central US Nest: GMC, MDW, LMV, NPL, SPL, NMT, SMT, SWD
WRF/NMM and ARW add diversity and greater spread.