WRF & WRF Ensemble Efforts in MMB

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Where the Nation’s climate and weather services begin
Weather Research and Forecast (WRF) Modeling System

- Develop an advanced mesoscale forecast and assimilation system
- Promote closer ties between research and operations

Concept:

Design for 1-10 km horizontal grids
Portable and efficient on parallel computers
Well suited for a broad range of applications
Community model with direct path to operations

Historic Decision

• Spring 2003 – Nelson Seaman writing WRF Test Plan – i.e. rules of engagement for the BAKE-OFF between NCAR’s Mass-core and NCEP’s Nonhydrostatic Mesoscale Model

• Steve Lord saw the bake-off as a lose-lose situation and declared HiResWindow slot to be a WRF ensemble – i.e. better to engage the community rather than enrage them

• Test Plan reworked to a) validate dynamic cores and b) “test” possible ensemble strategies – physics diversity (cross-bred) vs initial condition breeding w/ lbc anomalies
Weather Research and Forecasting (WRF)

- End-to-end Common Modeling Infrastructure
  - Observations and analysis
  - Prediction model
  - Post-processing, product generation and display
  - Verification and archive
- For the community to perform research
- For Operations to generate NWP guidance
- USWRP sponsorship - many partners: NCAR, NCEP, FSL, OU/CAPS, AFWA, FAA, NSF and Navy
**NCEP WRF Ensemble Design:**

- NCEP CCS computer upgrade will be ~6x for weather
- Therefore, establish 6-member ensemble run in place of single deterministic HiResWindow run
  - 2 Control members
    - NCEP NMM core & NCEP physics, $Dx = 8 \text{ km}$
    - NCAR Mass core & NCAR physics, $Dx = 10 \text{ km}$
  - 4 Additional members
    - bred mode initial condition perturbations
    - SREF anomaly applied to lateral boundary condition
- Qualified cores and evaluated potential ensemble members according to the *WRF Test Plan (Nelson Seaman)*
Two cores currently in WRF Infrastructure

- **Eulerian Mass core V1.0 (Eulerian MC),**
  - Terrain following hydrostatic mass-field vertical coordinate, arbitrary vertical resolution
  - Arakawa C-grid
  - Two-way nesting under evaluation
  - 3rd order Runge-Kutta time-split differencing
  - Conserves mass, momentum, dry entropy and scalars using 5th order (or 6th order) upwind spatial differencing to advect fluxes

[ V2.0 released May’03]

- **Nonhydrostatic Mesoscale Model (NMM)**
  - Hybrid sigma-to-pressure terrain following vertical coordinate
  - Arakawa E-grid
  - Two-way nesting under develop’mt
  - Adams-Bashforth time differ’cing, time splitting
  - Conserves rotational kinetic energy, total energy, mass, enstrophy and momentum using 2nd order nine-point differencing for advection
Two WRF Physics Packages

**Eulerian Mass-Core**: NCAR physics package (MM5 & Eta conversions) (w/options)
- NOAH unified 5-layer land-surface model
- Ferrier gridscale cloud and microphysics
- Kain-Fritsch convection
- Yong-Sei University PBL
- Dudhia shortwave
- RRTM longwave
- [Also adapted to use NCEP physics]

**NMM Core**: NCEP physics package (NMM = modified Eta)
- NOAH unified 5-layer land-surface model
- Ferrier gridscale cloud and microphysics
- Betts-Miller-Janjic convection
- Mellor-Yamada-Janjic 2.5 PBL
- Lacis-Hansen shortwave
- Fels-Schwartzkopf longwave
- [Also adapted to use NCAR physics]
Evaluation Studies: The WRF Test Plan

Purpose: Rigorously evaluate principal configurations of WRF to validate model for future research and operations.

Results: NCEP will select six members for its initial WRF ensemble in Hi-Resolution Windows from eight options run under the WRF Test Plan:

- **2 Control members:**
  - WRF-NMM with NMM physics and Eta IC/BCs
  - WRF-MC with NCAR physics, RUC ICs, Eta BCs

- **2 Cross-bred physics members:**
  - WRF-NMM with NCAR physics and Eta IC/BCs
  - WRF-MC with NMM physics, RUC ICs, Eta BCs

- **2 WRF NMM runs**, like NMM control, but with positive and negative bred perturbations.

- **2 WRF MC runs**, like MC control, but with positive and negative bred perturbations.
The WRF Test Plan: A collaboration of AFWA, NAVO, FSL, NCAR and NCEP for 1936 runs covering all seasons and 4 domains at 8 km

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<thead>
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</thead>
<tbody>
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<td>31/31</td>
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<tr>
<td>May’03 AFWA East</td>
<td>31/31</td>
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<td>31/31</td>
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<td>31/31</td>
<td>31/31</td>
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</tr>
<tr>
<td>Aug’03 AFWA Central</td>
<td>31/31</td>
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<td>31/31</td>
<td>31/31</td>
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<td>31/31</td>
</tr>
<tr>
<td>Aug’03 AFWA West</td>
<td>31/31</td>
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<td>31/31</td>
<td>31/31</td>
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<tr>
<td>Oct ’03 AFWA East</td>
<td>31/31</td>
<td>31/31</td>
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<td>31/31</td>
<td>31/31</td>
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</tr>
<tr>
<td>Oct ’03 AFWA Alaska</td>
<td>31/31</td>
<td>31/31</td>
<td>31/31</td>
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<td>31/31</td>
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<td>31/31</td>
</tr>
</tbody>
</table>
Example of Ensemble Probability Product

- CAPE > 1000 j/kg Prob
- 0-6km Shear > 40 kts Prob
- Conv Precip > 0.01” Prob
- Severe Convection Prob

Courtesy NOAA-SPC
WRF Test Plan Evaluations:
Average RMSE for Wind Speed vs. Pressure
August 2002

6-h Forecast, West Domain

42-h Forecast, West Domain

WRF Test Plan Evaluations:
Average RMSE for Temperature vs. Pressure
August 2002

6-h Forecast, West Domain

42-h Forecast, West Domain

Verification Statistics for the NCEP WRF Pre-implementation Test: Part 2  Ensemble Results

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Ligia Bernardet and Andy Loughe
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Dan Lohaus and Frank Olson,
Northrup-Grummann, Inc., at Air Force Weather Agency, Offutt AFB, NB

The Remainder of the Developmental Testbed Center Team
PURPOSE

• Combine various groups of the 8 retrospective runs into ensembles
• Evaluate ensembles
  • Verify mean using deterministic scores
  • Verify using ensembles scores
• Choose best 6 member combination
Eight WRF Retrospective Runs

- **Four Physics Diversity (PD) runs of WRF Ensemble:**
  - Initial conditions
    - RUC for WRF-MC runs
    - Eta for WRF-NMM runs
  - Crossbred physics
    - WRF-MC run with NCAR & NCEP physics
    - WRF-NMM run with NCEP & NCAR physics
  - Lateral boundary conditions from Eta

- **Four Initial Perturbation (IP) runs of WRF Ensemble:**
  - Initial condition breeding cycle produces a *pair of runs* for each core
    - WRF-MC with NCAR physics and RUC base initial conditions
    - WRF-NMM with NCEP physics and Eta base initial conditions
  - Apply 4 SREF based anomalies to Eta Lateral boundary conditions
**WRF Ensemble Processing**

- Based on NCEP experience with SREF, the five state variables \((u, v, T, q \text{ and } P_s)\), are perturbed.
- Accomplished within the WRF common modeling infrastructure via a single utility - `diffwrf`.
- Given three input files: File0 (the base field), File1 and File2, the general functionality of `diffwrf` can be written as:

\[
\begin{bmatrix}
\text{Modified variable in File0}
\end{bmatrix} = \begin{bmatrix}
\text{Original variable in File0}
\end{bmatrix} + \alpha \begin{bmatrix}
\text{variable - variable in File1 \text{ in File2}}
\end{bmatrix}
\]
Initial Condition Breeding Cycle

- Required modification of WRF restart file processing.
- File1 and File2 are forecasts made from a pair (+/-) of perturbed states from previous cycle.
- The factor, $\alpha$, depends on the domain-averaged magnitude of the difference field.
- Rescaling ($\alpha < 1$) is only done if the magnitude is larger than a prescribed value (~ analysis error standard deviation) following procedures developed for NCEP’s medium-range ensemble forecast system (Toth and Kalnay, 1997).
- The breeding cycle involves adding scaled perturbations in positive and negative sense from the pair of 24 hours forecast onto initial conditions of the next cycle yielding 2 runs from each control.
Lateral Boundary Condition Anomaly

- WRF-SI outputs and NeTCDF variables modified
- File1 and File2 are forecasts made from a perturbed state and the control of NCEP’s SREF (basically the SREF member’s anamoly with respect to its control run)
- The factor, $\alpha$, is usually set to 1
Breeding Pairs with LBC Anomalies

• Lateral boundary condition anomaly applied to WRF-SI’s vinterp NeTCDF outputs using 4 SREF forecasts, namely, p1, p2, n1 and n2 and the control applied to either Eta12 or RUC initial condition forecast, yielding 4 perturbed forecasts, i.e.,

\[
\begin{align*}
\text{eta12} &= \text{eta12} + \alpha [p1 - \text{ct1}] & \text{NMM} \\
\text{eta12} &= \text{eta12} + \alpha [n2 - \text{ct1}] & \text{core} \\
\text{eta12} &= \text{eta12} + \alpha [p2 - \text{ct1}] & \text{Mass} \\
\text{eta12} &= \text{eta12} + \alpha [n1 - \text{ct1}] & \text{core}
\end{align*}
\]
WRF Ensemble Processing
Breeding – Perturbation Data Flow -- Schematic

LBC = ETA218
3,6,…,48 for 17 files

LBC = CTL Sref datafiles
3 – 51 for 17 files
9 – 57 for 17 files

LBC = N1 Sref datafile
3 – 51 for 17 files
9 – 57 for 17 files

LBC = P2 Sref datafiles
3 – 51 for 17 files
9 – 57 for 17 files

SI Processing
GRIDS non-perturbations Vertical & Horizontal

script touch diffwrf

Wrf_real_input_em_…
(17 files)

WRF Real
Wrfbdy_d01

Diffwrf process each time step for a of 16 times skipping over the 0 hour file

GRIDS CTL
Vertical & Horizontal

Wrf_real_input_em_N1
(16 files)

N1 wrfbdy_d01

GRIDS N1
Vertical & Horizontal

GRIDS P2
Vertical & Horizontal

script touch diffwrf

Wrf_real_input_em_P2_…
(16 files)

P2 wrfbdy_d01
FSL’s Verification Website

http://www-ad.fsl.noaa.gov/fvb/rtvs/wrf/retro_runs/
<table>
<thead>
<tr>
<th>Color Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>East / Mass / RUC / NCAR</td>
<td>West / Mass / RUC / NCAR</td>
</tr>
<tr>
<td>East / NMM / Eta / NCEP</td>
<td>West / NMM / Eta / NCEP</td>
</tr>
<tr>
<td>East / (4) all perts</td>
<td>West / (4) all perts</td>
</tr>
<tr>
<td>East / (4) control + swap</td>
<td>West / (4) control + swap</td>
</tr>
<tr>
<td>East / (6) no swap</td>
<td>West / (6) no swap</td>
</tr>
<tr>
<td>East / (8) all members</td>
<td>West / (8) all members</td>
</tr>
</tbody>
</table>
500 hPa Temperature for FH = all
500 hPa Vector Wind for FH = all
500 hPa Height for FH = all (west and east ensembles)
500 hPa RH for FH = all (west and east ensembles)
Ensemble Verification

Based on verification vs radiosonde obs

4 Initial Perturbation (IP) vs 4 Physics Diversity (PD)

IP More Uniform Ranked Histograms
Legend for Subsequent Summaries
All Forecast Ranges Combined

300 mb
400 mb
500 mb
700 mb
850 mb

300 mb
400 mb
500 mb
700 mb
850 mb
CHOICE OF SIX MEMBERS
2 Controls + 2 IP-Breeding Pairs
This 6 Member Ensemble Is Almost As Good As The Complete 8 Member Ensemble

Nearest Truth Western Winter Wind
Nearest Truth Central Summer Temp
WRF System Description – HRW Implementation

Description: The WRF modeling system consists of...

<table>
<thead>
<tr>
<th>Component</th>
<th>Source</th>
<th>Code History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two dynamical cores</td>
<td>NCEP &amp; NCAR</td>
<td>new</td>
</tr>
<tr>
<td>Two complete physics suites</td>
<td>NCEP &amp; NCAR</td>
<td>modified MM5 &amp; Eta</td>
</tr>
<tr>
<td>Preprocessing for ICs/BCs</td>
<td>FSL &amp; NCEP</td>
<td>new</td>
</tr>
<tr>
<td>Post-processing for product generation</td>
<td>NCEP</td>
<td>modified Eta</td>
</tr>
<tr>
<td>Statistical evaluation package</td>
<td>NCEP</td>
<td>modified Eta</td>
</tr>
<tr>
<td>Software engineering infrastructure</td>
<td>NCAR</td>
<td>new</td>
</tr>
<tr>
<td>Ensembling software</td>
<td>NCEP</td>
<td>new</td>
</tr>
</tbody>
</table>
Implementation Strategy – Phase 1

• Phase 1— Implement new model (Threshold): IOC (21 September 2004)

  • Two deterministic “control” versions of WRF will run four times daily, once for each of four large windows (twice for small windows).
    - NCAR EM core: 10-km horizontal resolution, 50 layers
    - NCEP NMM core: 8-km horizontal resolution, 60 layers

  • 80-min run window (clock time) shared with GFDL Hurricane model
  • Availability contingent on tropical weather situation.
    - If 1 tropical storm present, WRF runs for HI & PR will be dropped out.
    - If 2 tropical storms present, WRF-EM run will be dropped.
    - If 3 or more tropical storms present, both WRF runs will be dropped.
Implementation Strategy – Phase 2

• Phase 2— Implement 6 member WRF ensemble target Feb/March 2005

• Two “control” versions & two breeding cycle pairs will run four times daily, once for each of four large windows (twice for small windows).
  - NCAR EM core: 10-km horizontal resolution, 50 layers
    Positive bred mode plus Negative bred mode
  - NCEP NMM core: 8-km horizontal resolution, 60 layers
    Positive bred mode plus Negative bred mode

• 80-min run window (clock time) shared with GFDL Hurricane model but with increased computer power with CCS upgrade complete
• Availability still contingent on tropical weather situation.
  - If 1/2 tropical storm present, WRF-EM bred mode runs will be dropped.
  - If 3/4 tropical storms present, WRF-NMM bred mode runs will be dropped.

• Two control versions ALWAYS run
Review of Operational Readiness:

1. **Objective Verification**

Key:

Compared to the operational NMM, WRF has…

- Significant positive impact: ++ (2)
- Small positive impact: + (1)
- About neutral impact: ↔ (0)
- Small negative impact: - (-1)
- Significant negative impact: -- (-2)

<table>
<thead>
<tr>
<th>Good to Go</th>
<th>Area has Some Risk</th>
<th>Remedial Action Required</th>
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</thead>
</table>
## Review of Operational Readiness:
### 1. **Objective Verification**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Season</th>
<th>West HRW Domain</th>
<th>East HRW Domain</th>
<th>NET</th>
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<tbody>
<tr>
<td>Wind profile</td>
<td>Jan-Mar 04</td>
<td>Bias: ++</td>
<td>Bias: ++</td>
<td>3</td>
</tr>
<tr>
<td>Height profile</td>
<td>Jan-Mar 04</td>
<td>Bias: --</td>
<td>Bias: ++</td>
<td>2</td>
</tr>
<tr>
<td>Temp. profile</td>
<td>May-Aug 04</td>
<td>Bias: -</td>
<td>Bias: -</td>
<td>-4</td>
</tr>
<tr>
<td>Rel. Hum. profile</td>
<td>May-Aug 04</td>
<td>Bias: ↔</td>
<td>Bias: +</td>
<td>1</td>
</tr>
<tr>
<td>10-m Winds</td>
<td>Jan-Mar 04</td>
<td>Bias: ++</td>
<td>Bias: +</td>
<td>3</td>
</tr>
<tr>
<td>2-m Temp.</td>
<td>All</td>
<td>Jan-Aug ↔</td>
<td>Jan-Aug+</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May-Aug:+</td>
<td>May-Aug+</td>
<td></td>
</tr>
<tr>
<td>Large Scale* Precipitation</td>
<td>Jan-Mar 04</td>
<td>ETS: -</td>
<td>ETS: ↔</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bias: --</td>
<td>Bias: +</td>
<td></td>
</tr>
<tr>
<td>Large Scale* Precipitation</td>
<td>May-Aug 04</td>
<td>ETS: ↔</td>
<td>ETS: +</td>
<td>-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bias: --</td>
<td>Bias: --</td>
<td></td>
</tr>
</tbody>
</table>

*No mature objective score for SMALL Scale Precipitation*
"WRF-NMM has more fine-scale precip structure than oper. NMM"

Operational NMM

Early WRF-NMM

WRF-NMM with New BMJ Convection

Verification

24 hour accumulations, 24-48 hours, ending 12 Z February 6, 2004

Implemented in Initial Operational Configuration
24 Hour Accumulated Precipitation Valid 12Z 6 September, 2004, 42 Hour Forecast

Tropical Storm Francis:

Subjective Comparison

OPS. NMM
OPS. Eta
CPC RFC 1/8 deg Verification
WRF NMM
WRF EM
24 Hour Accumulated Precipitation Valid 12Z 30 August, 2004, 42 Hour Forecast

Tropical Storm Gaston:

Subjective Comparison
Production Suite Made Up of Four Uniform Cycles per Day

NCEP Production Suite
Weather, Ocean & Climate Forecast Systems
Version 3.1 October 20, 2004

Percent Used

6 Hour Cycle

- RR/RTMA
- FireWX
- WAVES
- HUR/HRW
- GFSfcst
- GFSanal
- GFSens
- NAMfcst
- NAManal
- SREF
- Air Quality
- GlblOcean
- Monthly
- Seasonal
North American Mesoscale WRF Plans

- Date of Eta replacement moved to March 2006
- Increase horizontal resolution from 12 km to 10 km
- Move model top from 25 mb to 2 mb (will help assimilation of satellite radiances)
- Eta 3D-VAR to be replaced by Gridpoint Statistical Interpolation (GSI)
- Assimilate mesonets, GPS IPW, boundary layer Profilers and (hopefully) Level II radial velocity
North American Mesoscale WRF Plans

- Minimize transition tasks - produce complete set of existing NAM look-alike output
- Extend BUFR sounding files to 84 hour with only slight (5 minute?) delay compared to current 60 hr BUFR file delivery
- Replace non-WRF NMM applications in Fire Weather / IMET Support and On-Call Emergency Response nested runs
- Maintain ability to quickly run a replacement 12 km Eta (run 12 km EDAS in background mode) in the event of an ‘infrastructure related’ failure for which a quick solution is unlikely
PLANS FOR THE FUTURE

For each of the possible upgrades/phases of the CCS contract with IBM
## North American Meso Guidance System

<table>
<thead>
<tr>
<th>Prediction Model (DGEX included)</th>
<th>Analysis and Data Assimilation</th>
<th>Computer Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 km 60 level Meso Eta earlier delivery</td>
<td>12 km 3DVAR improved use of surface observations</td>
<td>Current Phase I</td>
</tr>
<tr>
<td>10 km 60 level WRF 2mb top, nonhydrostatic dynamics, imp. physics called more frequently</td>
<td>10 km GSI analysis, 2 mb top, cloud analysis, AIRS, GOES imagery</td>
<td>Phase II</td>
</tr>
<tr>
<td>8 km 70 level WRF fire weather IMET support incorporated, improved physics</td>
<td>8 km, 88D reflectivity, hydrometeor analysis, cloud and aerosol absorption and scattering in radiative transfer</td>
<td>Phase III</td>
</tr>
<tr>
<td>6.5 km 85 level WRF .2 mb top, OCER incorporated, improved physics, ozone + aerosols</td>
<td>6.5 km .2 mb top, advanced 4DDA, NPP, NPOESS, IASI + air quality</td>
<td>Phase IV</td>
</tr>
</tbody>
</table>
## HiResWindow and Fire Wx/IMET

<table>
<thead>
<tr>
<th>HiResWindow</th>
<th>Fire Weather IMET Support</th>
<th>Computer Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 km WRF 6 member ensemble</td>
<td>8 km nested WRF-NMM</td>
<td>Current Phase I</td>
</tr>
<tr>
<td>7 km WRF 8 member ensemble</td>
<td>6.5 km nested WRF with improved physics</td>
<td>Phase II</td>
</tr>
<tr>
<td>6 km WRF 10 member ensemble</td>
<td>5.5 km included in NAM-WRF run</td>
<td>Phase III</td>
</tr>
<tr>
<td>5 km WRF 12 member ensemble</td>
<td>4.5 km included in NAM-WRF run</td>
<td>Phase IV</td>
</tr>
</tbody>
</table>
# Hurricane, Rapid Refresh & Air Quality

<table>
<thead>
<tr>
<th>Hurricane Model</th>
<th>Rapid Refresh (RR)</th>
<th>Air Quality</th>
<th>Computer Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 nests 18 + 55 km L 42, coupled Atl &amp; Pac with GFS physics</td>
<td>20 km 50 level RUC 3DVAR</td>
<td>12 km Sfc ozone, New England</td>
<td>Current Phase I</td>
</tr>
<tr>
<td>2 nests 12 + 40 km L64 Hurricane-WRF &amp; new ocean (HYCOM)</td>
<td>13 km 60 level RUC improved physics</td>
<td>10 km Sfc ozone National</td>
<td>Phase II</td>
</tr>
<tr>
<td>2 nests 8 + 30 km L64 Hurricane-WRF with 4DDA</td>
<td>10 km 60 level Rapid Refresh-WRF</td>
<td>8 km Sfc ozone, particulates</td>
<td>Phase III</td>
</tr>
<tr>
<td>2 nests 5 + 20 km L100 Hurricane-WRF with imp. physics &amp; enhanced ocean model</td>
<td>8 km 70 level RR-WRF improved physics</td>
<td>6.5 km Sfc ozone, particulates</td>
<td>Phase IV</td>
</tr>
</tbody>
</table>
Nonhydrostatic Mesoscale Model (NMM)

• See Janjic, Gerrity, and Nickovic, 2001 for model equations, solution techniques & other test results [MWR, Vol. 29, No. 5, 1164-1178]

• Highly refined version of nonhydrostatic option released in May 2000 upgrade to NCEP’s workstation Eta

• NMM retains full hydrostatic capability
  - Incorporate nonhydrostatic effects through $\varepsilon$ where $\varepsilon=(1/g) \frac{dw}{dt}$
  - Then split prognostic equations into:
    • hydrostatic parts plus
    • corrections due to vertical acceleration
  - Set $\varepsilon$ to zero to run in hydrostatic mode
# Nonhydrostatic Mesoscale Model Feature Comparison With Meso Eta

<table>
<thead>
<tr>
<th>Feature</th>
<th>Meso Eta Model</th>
<th>Nonhydrostatic Meso Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamics</td>
<td>Hydrostatic</td>
<td>Hydrostatic plus complete nonhydrostatic corrections</td>
</tr>
<tr>
<td>Horizontal grid spacing</td>
<td>12 km E-grid</td>
<td>8 km E-grid for FireWx/IMET</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 km E-grid for Homeland Security</td>
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<tr>
<td>Vertical coordinate</td>
<td>60 step-mountain eta levels</td>
<td>60 sigma-pressure hybrid levels</td>
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<tr>
<td>Terrain</td>
<td>Unsmoothed with Silhouette</td>
<td>Unsmoothed</td>
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<tr>
<td></td>
<td>treatment lateral boundary set</td>
<td>Grid-cell mean</td>
</tr>
<tr>
<td></td>
<td>to sea-level</td>
<td>everywhere</td>
</tr>
</tbody>
</table>
Hybrid versus Step (Eta) Coordinates

\[
P_{\text{top}}
\]

\[
\sigma = 0 \quad 420\text{mb}
\]

Pressure domain

\[
\sigma = 1
\]

Sigma domain

\[
\eta = 0
\]

\[
\eta = 1
\]
## Nonhydrostatic Mesoscale Model

### Physics Features Comparison With Meso Eta

<table>
<thead>
<tr>
<th>Physics Feature</th>
<th>Meso Eta Model</th>
<th>Nonhydrostatic Meso Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbulent mixing</td>
<td>Mellor-Yamada Level 2.5 dry</td>
<td>Mellor-Yamada Level 2.5 including moist processes</td>
</tr>
<tr>
<td>Surface exchange</td>
<td>…+ Paulson functions</td>
<td>…+ Holtslag and de Bruin functions</td>
</tr>
<tr>
<td>Land-sfc</td>
<td>NOAH LSM</td>
<td>NOAH LSM</td>
</tr>
<tr>
<td>Gridscale</td>
<td>Ferrier</td>
<td>Ferrier</td>
</tr>
<tr>
<td>Convective</td>
<td>B-M-J</td>
<td>B-M-J’ (some retuning)</td>
</tr>
<tr>
<td>Radiation</td>
<td>GFDL</td>
<td>GFDL’ (some retuning)</td>
</tr>
</tbody>
</table>
HiRes Window Fixed-Domain Nested Runs

21 September Became WRF Runs of Two Control Configurations

- Routine runs made at the same time every day
- 00Z: Alaska-8 & Hawaii-8
- 06Z: Western-8 & Puerto Rico-8
- 12Z: Central-8 & Hawaii-8
- 18Z: Eastern-8 & Puerto Rico-8
- Everyone gets a daily high resolution run when <2 hurricane runs need to be made

http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/

Alaska-8 domain is smaller than depicted
26 Selectable 8 km Domains For Fire Weather / IMET Support Identical To 4 km Homeland Security Domains
Special WRF-NMM Runs for SPC/NSSL Spring Program

• Beginning in April, EMC ran:
  – 4.5 km version of its WRF-NMM
  – Without any calls to parameterized convection
  – Initialized off 12 km Eta (at 40 km resolution)
  – Daily runs to 30 hours from 00z
  – Central/Eastern US domain

• SPC requested that this run be continued as long as possible
Domains of Integration for Spring Program

NCEP NMM (red), NCAR (blue), CAPS (cyan)
Spring Program 21 hr Forecast Example

http://www.nssl.noaa.gov/etakf/compare/wrf/
Example of Explicit 4.5 km WRF-NMM
courtesy of Jack Kain

WRF 24 hour 4.5 km forecast of 1 hour accumulated precipitation valid at 00Z April 21, 2004 (better than 12 hour forecasts by operational models)
Web Site Displaying 4.5 km WRF-NMM
http://www.emc.ncep.noaa.gov/mmb/mmbplll/cent4km/

<table>
<thead>
<tr>
<th>1 h Precipitation totals (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01h 02h 03h 04h</td>
</tr>
<tr>
<td>01h 06h 07h 08h</td>
</tr>
<tr>
<td>09h 10h 11h 12h</td>
</tr>
<tr>
<td>13h 14h 15h 16h</td>
</tr>
<tr>
<td>17h 18h 19h 20h</td>
</tr>
<tr>
<td>21h 22h 23h 24h</td>
</tr>
<tr>
<td>25h 26h 27h 28h</td>
</tr>
<tr>
<td>29h 30h 0-30h NMM WRF Loop</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 h Precipitation totals (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>03h 06h 09h 12h</td>
</tr>
<tr>
<td>15h 18h 21h 24h</td>
</tr>
<tr>
<td>27h 30h 0-30h NMM WRF Loop</td>
</tr>
</tbody>
</table>
4km WRF Runs vs 12km Eta

Mean Scores (15 days): Convective Initiation, Evolution, and Mode

- 00z 4km WRF-EM-CAPS
- 00z 4km WRF-EM-NCAR
- 00z 4km WRF-NMM-EMC
- 12z 12km Eta

Mean Subjective Verification Rating

- Initiation
- Evolution
- Mode
HiResWindow WRF Runs vs Eta

Mean scores (22 days): Convective Initiation, Evolution, and Mode

<table>
<thead>
<tr>
<th></th>
<th>Initiation</th>
<th>Evolution</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>12z 8km WRF/NMM-EMC</td>
<td>4</td>
<td>4</td>
<td>5.5</td>
</tr>
<tr>
<td>12z 10km WRF/EM-EMC</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12z 12km Eta</td>
<td>4</td>
<td>4</td>
<td>4.5</td>
</tr>
</tbody>
</table>