WRF in NCEP Operations

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Where the Nation’s climate and weather services begin
T O P I C S

• Condensed Chronologies
• WRF Post Processor
• HiResWindow
• Short Range Ensemble Forecast (SREF)
• North American Mesoscale (NAM)
• Future Plans
NMM, ARW in NCEP Operations

**Pre-WRF NMM at NCEP**
- May 2000: nonhydrostatic option released in upgrade to NCEP’s workstation Eta
- February 2002: HiResWindow runs upgraded to use 8 km NMM replaces 10 km Eta (hydrostatic)
- February 2002: On-Call Emergency Response (OCER) capability begins using 4 km NMM to support HYSPLIT
- May 2003: Fire Weather / IMET Support runs implemented using 8 km NMM

**WRF-ARW at NCEP**
- September 2004: HiResWindow first WRF implementation of 10 km WRF-ARW v1.3
- June 2005: HiResWindow upgraded to use 5.8 km WRF-ARW with explicit convection
- December 2005: Short Range Ensemble Forecasting system adds 3 members using 45 km WRF-ARW v2.0
- September 2007: HiResWindow expanded domain and upgraded to 5.1 km WRF-ARW v2.2.1
- **Aug-Sept 2009:** SREF WRF-ARW upgraded to v2.2.1, add 2 members and increase resolution to 32 km
WRF-NMM in NCEP Operations

- April 2004 thru present: NSSL/SPC Spring Program, daily developmental run of 4.5 km WRF-NMM with explicit convection
- September 2004: HiResWindow first WRF implementation of 8 km WRF-NMM v1.3 replaces pre-WRF NMM
- June 2005: HiResWindow upgraded to use 5.1 km WRF-NMM with explicit convection
- December 2005: Short Range Ensemble Forecasting system adds 3 members using 40 km WRF-NMM v2.0
- June 2006: NAM runs use 12 km WRF-NMM v2.1 & WRF-GSI replacing Eta & Eta-3DVar
- September 2007: HiResWindow expanded domain and upgraded to 4 km WRF-NMM v2.2.1
- December 2008: final in series of NAM upgrades
Updates to WRF Post Processor  
**Courtesy of Hui-Ya Chuang**

- **WRF Post Processor version 3.1**
  - Released on April 9, 2009 by DTC
  - Identical to NCEP’s operational NAM code except
    - It does not produce simulated GOES fields due to
    - Linux compile issue for Community Radiative Transfer Model.

- The updates and bug fixes in this release include:
  - a) capability to properly treat all hydrometeor fields from NMM runs using non-Ferrier microphysics schemes;
  - b) improved speed in horizontal interpolation;
  - c) bug fixes for Polar Stereographic and Lambert Conformal projections in the Southern Hemisphere.

- **Future updates will include:**
  - Radar Echo Top height (requested by FAA)
  - Ri-based PBL height (to be compatible with NCEP’s verification & analysis projects which are based on diagnosing PBL height from radiosonde and aircraft soundings using critical Ri (=0.25))
Simulated Imagery from NAM (WRF-NMM) versus GOES observations

GOES water vapor channel

WRF NMM water vapor channel

GOES IR channel

WRF NMM IR channel
NAM 12 hr Forecast Ri-Based PBL Height with Verifying RAOBs
HiResWindow Updates in CY2008

- **Feb 12**
  - Fix WRF Post to get frozen precip included in computation of simulated reflectivity for ARW runs. (NWS Central Region)

- **Apr 15**
  - 1) Fix a bug in the **boundary** smoothing along the eastern boundary of NMM domains;
  - 2) Change compilation options for NMM and task geometry for both NMM & ARW to make codes **run faster**;
  - 3) **Trigger** prelim job from 48 h GFS forecast rather than 84 h GFS forecast;
  - 4) Change the NMM namelists to produce **hourly** model output (added to NAWIPS 4/18);
  - 5) Add **updraft helicity** to NMM output. (NCEP SPC)

- **Aug 6**
  - 1) Change the generating process code (PDS octet 6) from 84 to WRF core specific values of 112 (WRF-NMM) and 116 (WRF-ARW) (for AWIPS NCF);
  - 2) Add vertical motion at 200, 250, and 1000 hPa isobaric levels (for DTRA);
  - 3) Fix WRF Post to properly generate precipitation type and total cloud field percentage for the WRF-ARW.

- **Sep 15**
  - Generation of GRIB2 is changed so distinct GRIB records are made for wind components (AWIPS NCF).

- **Nov 4**
  - WRF post input code is corrected to eliminate risk of seg fault failure.
HiRes Window Fixed-Domain Nested Runs
Configuration/Schedule as of September 2007

- 4-5 km explicit runs of both NMM & ARW at same time every day - *if & only if* no hurricane runs are needed
- 00Z: ECentral & Hawaii
- 06Z: WCentral & Puerto Rico
- 12Z: ECentral & Hawaii
- 18Z: Alaska & Puerto Rico

- **Daily displays of both ARW + NMM are at:**
  [http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/] (see next slide for example) and
  [http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/]

- **Soon (if not already) to ‘appear’ on AWIPS-Satellite Broadcast Network and NOAA-port**
Model Analyses & Forecast Page

Now Includes Sim. Reflectivity w/Zoom

To view model images, click on the desired image resolution in the table below.

More information is available in the Product Description Document.

Select Regions:
- North America
- South America
- Africa
- Japan
- Korea
- China
- Australia
- Europe
- India
- Middle East
- Africa
- South America
- Central America
- Caribbean
- South Wales
- Eastern Pacific
- Western North Atlantic
- Polar Ice Shelf

### Model Analyses and Forecasts

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### Hurricane Graphics

- Full Domain
- Nested Domain

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Plans for HiResWindow

- Improve initial conditions (Liu & Parrish)
  - Apply GSI analysis (as 3rd ‘outer-loop’)
    - Using radial winds only
    - Sharpen background error covariances
  - Apply Diabatic Digital Filter (ala RUC)
    - Force latent heating from 88D reflectivity mosaic

- Improve resolution to ~2-3 km

- Replace NMM with NMMB
Short Range Ensemble Forecast (SREF) System

- Four-per-day runs started July 2006
- Bias Correction added December 2007
- Routine displays etc. are available at:
  
  http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html
  http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/

- Fall 2008 Upgrade was delayed until after NCEP’s new computers are accepted (~Aug 2009)
SREF FALL-20089 Upgrade

**SREF System:**
- Upgrade WRF version from 2.0 to 2.2
- Increase horizontal resolution NMM (40->32km), ARW (45->32km)
- Increase WRF membership from 6 to 10
- Decrease Eta membership from 10 to 6
- Replace Zhao with Ferrier for 3 RSM SAS members
- Use global ET perturbations for 10 WRF members

**SREF Products**
- Increase output frequency to hourly out to 39 hr
- Add hourly BUFR soundings out to 87 hr
- Add cloud base, composite 88D reflectivity, echo top, Ri based PBL height
- Add wind-variance fields (for dispersion modeling)
Fig. 5: Day 3 SREF 09z 3 Feb 2008: 63-hr forecasts valid at 00 UTC 6 Feb 2008 (Super Tuesday Tornado case, provided by David Bright of SPC)

SREF Forecasts of Probability of Sig. Tornado Parameter $\geq 3$

New SREF indicates higher probability over lower MS Valley (also note mean STP = 3 contour in new SREF but not in old SREF)
Fig. 7: Equitable Threat score (ETS) and Bias score of 24h-accumulated precipitation forecasts of ensemble mean over CONUS, averaged over the period of Oct. 15 – Nov. 16, 2008. New SREF is in dash line and old SREF in solid line. Both ETS and Bias score improved, smaller bias and larger ETS for all thresholds especially heavier precipitation, for the new SREF (against Stage-II precip analysis)
Fig 8: Probabilistic forecast measured by RPSS: large improvement for all fields (Feb. 5 – Apr. 14, 2009)
Reliability diagram for 2 m Temperature
Probabilistic Forecast at 87 hr
SREF CONUS Region 2m Temperature
Average Reliability For 2009020509 – 2009041409

Observed Frequency (%)
Forecast Probability (%)
North American Mesoscale (NAM)

• All operational NAM changes to WRF-NMM and WPS through the December 2008 implementation, including GWD, have been committed to NCAR/DTC repository and are in the v3.1 release.
• Bug-fixes (not implemented in NAM yet due to moratorium) were also included in v3.1 release
  – First layer advection of w and z missing factor of 2
  – Initialize constant in turbulence scheme
  – Pass separate cloud & hydrometeor fields to radiation
• Displays etc. are available at:
  http://www.emc.ncep.noaa.gov/mmb/mmbplll/opsnam/
  http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/
DECEMBER 2008 CHANGES

• NDAS “Partial Cycling”
• NMM Model Changes
  – Vertically mix/diffuse each hydrometeor species
  – Radiation change: double absorption coefficients for water and ice in clouds
  – Land-sfc model changes to address problematic 2-m dew point temps over snow cover
• GSI Analysis Changes
  – New observations: MetOp-a radiances and TAMDAR/AMDAR aircraft data
  – New version of radiative transfer model w/default climatology
• Use hi-res (23 km) AFWA snow depth analysis
Impact of partial cycling: vertical profile of cumulative RMS errors from Dec 07 – Feb 08

- Solid = Ops NAM
- Dash = PII NAM with 3/08 changes
- Dash-dot = PII NAM with 3/08 changes + NDAS

Partial Cycling

Black = 24-h Fcst
Red = 48-h Fcst
Blue = 72-h Fcst
Plans for Future

• NOAA Environmental Modeling System (NEMS)
  – Need to run GFS, NAM, SREF, GDAS/NDAS etc.
    concurrently and with minimal data motion

• ESMF-based, to be used NOAA-wide
  – NCEP/EMC (NAM, GFS, HYCOM etc.)
  – ESRL/GSD (Rapid Refresh, FIM, NIM)
  – OAR/GFDL (coupled climate)

• National Unified Operational Prediction Capability (NUOPC) … subject to the availability of funds ^_^
A Possible Production Suite 2017.5 If NextGen Supports It

NCEP Production Suite
Weather, Ocean & Climate Forecast Systems
NEXTGEN Enhanced Version 2017.5

Two 3 Hour Cycles: Four Times-Per-Day
Percent Used

Marine
GFS
GEFS
CFS
NAM
SREF
GRDAS

Marine
HUR/HRW
GFSfcst
NAMfcst
SREF
GEFS
CFS
GRDAS

Terminal

A Possible Production Suite 2017.5 If NextGen Supports It
**NOAA Environmental Modeling System (NEMS)**
(uses standard ESMF compliant software)

* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC, NOAA/GFDL)

2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments

Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISL, COAMPS...)
Physics (GFS, NRL, NCAR, GMAO, ESRL, GFDL...)

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**ESMF Superstructure**
(component definitions, “mpi” communications, etc)
**NAM**
- WRF-NMM (E-grid)
- GSI analysis
- 4/Day = 6 hr update
- Forecasts to 84 hours
- 12 km horizontal
- 60 layers with 2 mb top
- 12 hr pre-forecast assimilation period with 3hr updates (catch-up)

**RUC**
- Non-WRF RUC model
- RUC 3DVAR analysis
- 24/Day = hourly update
- Forecasts to 18 hours
- 13 km horizontal
- 50 layers with 50 mb top
- Continuous forward cycle with no pre-forecast assimilation period
2010-2011

NAM
- NEMS based NMM
- B-grid replaces E-grid
- Parent remains at 12 km
- Multiple Nests Run to 48hr
  - ~4 km CONUS nest
  - ~6 km Alaska nest
  - ~3 km HI & PR nests, and/or a ~1.5-2km DHS/FireWeather/IMET

Rapid Refresh
- WRF-based ARW
- Common GSI analysis
- Expanded 13 km domain to include Alaska
- Experimental 3 km HRRR
CONUS, Alaskan & FireWx Nests Imbedded in NAM Parent

PARENT

CHILD1

CHILD2

GRANDCHILD1
Dots represent water points  Domain is Puget Sound

12 km Terrain

4 km Terrain
B-grid is an E-grid rotated 45 degrees (and vice-versa)
2012-2013

NAM/Rapid Refresh ENSEMBLE (NRRE)

- NEMS-based NMMB/ARW models & GSI analysis
- Common NAM parent domain at 10-12 km
- Initially ~6 member ensemble made up of equal numbers of NMMB- & ARW-based configurations
- Hourly updated with forecasts to 24 hours
- NMMB & ARW control assimilation cycles with 3 hour pre-forecast period (catch-up) with hourly updating
- NAM 84 hr forecasts are extensions of the 00z, 06z, 12z, & 18z runs.
2012-2013

High Resolution Rapid Refresh ENSEMBLE
(HRRRE)

• Each member of NRRE contains
  – 3 km CONUS and Alaskan nests
  – Control runs initialized with radar data

• Positions NWS/NCEP/ESRL to
  – Provide NextGen Enroute AND Terminal guidance
  – Provide PROBABILITY guidance
  – Improve assimilation capabilities with radar & satellite
  – Tackle Warn-on-Forecast as resolutions evolve towards ~1 km

• NAM nests are extensions of the 00z, 06z, 12z & 18Z runs.

Both NRRE and HRRRE
Require Bigger NCEP Computer