NCEP Meteorological Model Predictions for Dispersion Applications

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NOAA/NWS
National Centers for Environmental Prediction
Environmental Modeling Center

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National Centers for Environmental Prediction (NCEP)

- Among the Nation’s leaders in providing global and national climate and weather analysis, forecasts and guidance
- Develop and Improve numerical weather, climate, hydrological, space and ocean prediction systems
- Applied research in data analysis, modeling and product development
North American Model (NAM-WRF)

NEW EXPANDED NAM

North American Model (NAM) WRF run 4x/day at 12 km to 84 hours
Weather Research and Forecast (WRF) System

The WRF Infrastructure

Global Database

Post Processors

Verification

Data Assim.


Dynamic Core 1: ARW Core
Dynamic Core 2: NMM Core
Dynamic Core 3: [COAMPS Core]

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<td>3DVAR</td>
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Physics Interface

Micro.
LSM
Conv.
P.B.L.
Radiation

Physics Layer
HiResWindow Fixed-Domain Nested Runs

- **FOUR** routine runs made at the same time every day (5 km)
- 00Z: Alaska & Hawaii
- 06Z: Western & Puerto Rico
- 12Z: Central & Hawaii
- 18Z: Eastern & Puerto Rico
- Everyone gets daily high resolution runs *if & only if* hurricane runs are not needed

http://www.emc.ncep.noaa.gov/mmb/mmbplll/nestpage/
<table>
<thead>
<tr>
<th>Run Slot #/day</th>
<th>Mission &amp; (Notes)</th>
<th>F Hrs</th>
<th>Resolution (hor/ver)</th>
</tr>
</thead>
</table>
| **Global Forecast System (GFS)** 4/day | - Global general weather and aviation guidance to 15 days (winds, temp, rainfall)  
- Boundary + initial conditions for NAM, Ocean models  
- Initial conditions for ensemble generation  
- Supports Model Output Statistics  
- Hurricane tracks | 384 hr | ✓ 35 km/ 64l  
✓ 55 km/ 42l after 84 hr  
✓ 75 km/28l beyond 180 hr |
| **Global Data Assimilation System (GDAS)** 4/day | - Provides best guess for GFS analysis, verification & validation  
- 3-D Variational 6-hr update frequency with digital filter | 9 hr with 6 hr update | 35 km/ 64l |
| **Global Ensemble** 4/day | - Probabilistic rainfall (QPF) and general weather to 15 days  
- 14 members with initial condition perturbations generated from Ensemble Transform Technique | 360 hr | ✓ 100km/28l |
Additional NCEP Models with applications for AT&D

- **On-Demand Homeland Security Nests**
  - *On-demand real-time High Resolution WRF 4km Grid Runs*
  - 26 pre-defined nests
  - NOAA responsible for met. model CONUS predictions

- **Rapid Refresh WRF**
  - 13 km CONUS hourly analyses to 18 forecast hours

- **Real-Time Mesoscale Analysis system (RTMA)**
  - 2-D Variable data assimilation at the surface
  - hourly analyses at 5 km resolution

- **Analysis Of Record**
  - *Downscaled from NDAS analysis to provide high resolution climatology than 32 km Regional Reanalyses*

- **WRF-CMAQ Air Quality Forecasts (O3 / PM)**
  - CONUS 12 km 48 hour forecasts 2x/day
Provision of Additional Products

- **NCEP Products to DTRA-MDS**
  - *Global Forecast System* ½ degree 3 hrly predictions to 16 days
  - *Global Ensemble Mean and Spread files to 16 days*
  - *Short Range Ensemble* to 84 hours (4x/day)
  - *NAM-WRF high resolution* 12 km CONUS and North American grids
WRF Output to improve HPAC coupling

- Instantaneous and time-averaged surface sensible heat, latent heat, and momentum fluxes
- Roughness length, vegetation types and fraction
- Shelter level, skin, and soil temperature, moisture, and wind
- Cloud fraction
- Mixing length
- 3D Wind, temperature, and specific humidity
- 3D Turbulent Kinetic Energy
- 3D eddy diffusivity of heat
- PBL height
- Time-averaged winds, TKE and mixing lengths
- Eddy energy dissipation rates
- 3-D eddy diffusivity of momentum
- 3-D wind variance from ensemble
- Large Scale Variance proportional to wind variance?
NCEP AT&D Focus for HPAC

• Improved Coupling of Mesoscale Models w/ HPAC
  – Special real-time High Resolution Nested Grid Runs (eg: Torino Olympics)
  – Additional turbulence Fields output to NCEP GRIB files and to DTRA servers
  – Evaluation of WRF turbulence characteristics with PSU & Hanna Consultant.
  – Development of a real-time PBL height and cloud cover verification system

• Development and Testing of a High Resolution Ensemble Prediction Systems
  – NCEP WRF ensemble breeding system for initial condition diversity
  – Uses both ARW and NMM cores and physics suites
  – Began testing a 10 member WRF HREF
  – Providing experimental ensemble wind variance fields needed to drive HPAC uncertainty calculations

• Incorporation of probabilistic verification for Ensemble System evaluation
  – Deterministic FVS developments: pbl hgt & cloud cover verification
  – Probabilistic: Ranked Histograms, spread, statistical consistency, outlier diagrams added for ensemble verification
High Impact on-demand Nests
Torino Olympics
WRF nested runs (Dusan Jovic)

- WRF-NMM V2.1 using H-WRF nested grid configurations
- 24 h forecasts at 00 and 12 UTC
- 4 km Alps nest w/in 12 km Europe Domain
- 50 levels
- 90 mins w/ 64 IBM Processors

- Initialized with ½ degree GFS Pressure grids
- Ferrier Microphysics ➔ No convective Param.
- MYJ TKE, NOAH LSM
Torino Olympics
 NCEP 4 km Domain

Full 4 km WRF Nested Grid Domain
Zoomed view around Torino
Torino Olympics
February 18, 2006 case winds

Some down valley Flows captured
Mediterranean low is better captured in larger domain
Synoptic-orographic interactions are important
HPAC multi-model simulations

MM5 & WRF

• WRF & MM5 Plumes near Torino Olympics

• Blue lines: HPAC uncertainties w/ constant large scale variances

• Courtesy Pat Hayes, DTRA-NGC

Feb. 22, 00Z release (Case 5)
**Short Range Ensemble Forecast**

*WRF members added to:* 21 multi-model members

*Run 4x/day to 84 hours (6 WRF, 10 Eta, 5 RSM)*

<table>
<thead>
<tr>
<th>Core</th>
<th>3 NMM members</th>
<th>3 ARW members</th>
</tr>
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<tbody>
<tr>
<td>Horizontal</td>
<td>40km</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 (32 procs/member)</td>
<td>108/200 sec (40 procs/member)</td>
</tr>
<tr>
<td>Computer usage</td>
<td></td>
<td></td>
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<tr>
<td>Diffusion</td>
<td>Increased Smagorinsky deformation</td>
<td>Vertical damping</td>
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<tr>
<td>Physics</td>
<td>NOAA LSM</td>
<td>NOAA LSM</td>
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<tr>
<td></td>
<td>MYJ TKE PBL</td>
<td>MRF 1&lt;sup&gt;st&lt;/sup&gt; order PBL</td>
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<td></td>
<td>BMJ Convection</td>
<td>Kain-Fritsch Convection</td>
</tr>
<tr>
<td></td>
<td>Ferrier Microphysics</td>
<td>Ferrier Microphysics</td>
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Ensemble Products to DTRA-MDS

**Means/ Spread(uncertainties)**
- Heights at 1000, 850, 700, 500, 250 mb
- U+V at 1000, 850, 700, 500, 250 mb & 10 m
- Temperature 850, 700, 500 mb & 2 m
- Dew Point (RH) 850, 700, 500 mb & 2 m
- QPF at 3, 6, 12 and 24 hour totals
- 12-hr Snowfall
- Sea Level Pressure
- Precipitable Water

**Probabilistic Fields**
- 3-hr/6-hr QPF GE 0.01”, 0.25”, 0.50”, 1.0”
- 12-hr/24-hr QPF GE 1”, 0.25”, 0.50”, 1.0”, 2.0”
- 12-hr Snowfall GE 1”, 4”, 8”, 12” (have 2.5, 5, 10, 20”)
- Temperature at 2 m & 850 mb LE 0°C
- 10 m Wind GE 25 kt, 34 kt, 50 kt
- CAPE GE 500, 1000, 2000, 3000, 4000
- Lifted Index LE 0, -4, -8
- Surface Visibility LE 1 mi, 3 mi
- Cloud Ceiling* LE 500 ft, 1000 ft, 3000 ft
- Probability of precipitation types (have rain, frozen, & freezing)
- 6-hr/12-hr/24-hr QPF Best Category
Ensemble Covariance Products

Daily ensemble products

Binbin Zhou, EMC


\[ EKE = 0.5 \times (UUE + VVE + WWE) \]

\[ UUE = \frac{1}{N} \sum (U_{m,ij} - U_{ij})^2 \]

\[ VVE = \frac{1}{N} \sum (V_{m,ij} - V_{ij})^2 \]

\[ UVE = \frac{1}{N} \sum (U_{m,ij} - U_{ij})^2 (V_{m,ij} - V_{ij})^2 \]

\[ WWE = \frac{1}{N} \sum (W_{m,ij} - W_{ij})^2 \]

Ensemble mean sensible heat flux
Ensemble mean latent heat flux
U and V spread
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.

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

- Recently added sensible weather (eg: Visibility), wind shear, and PBL height

- Grid verification of cloud cover using AFWA cloud cover products

New FVS On-line System
Web-based MYSQL Database
Texas Air Quality Experiment
Aug-Oct 2006
NAM PBL evaluation
using TEXAQS06 profilers

12hr fcst PBL height Valid 00Z17AUG2006

NAM
PSD: Longview Profiler
Shreveport, LA Raob
Mean Squared Error
Ensemble Variance

Statistical Consistency (August 2006)
48 hour Forecast Winds

- SREF-21 improved
- WRF subset yields lowest statistical consistency compared to Eta subsets

Best ~ 1 (Buizza, et al. 1999)
SREF Operational Performance
Outlier Percentage
48 h forecasts (August 2006)

- Outlier percentage reduced for SREF/21 system
- WRF sub-member agree best w/ obs as compared to Eta and RSM sub-members
• For ATD: physics perturbation techniques are promising
  – PBL parameterization
  – Land Surface Model specifications
  – Convective parameterizations
  – Stochastic physics efforts

• Will also need IC perturbations esp. for strong synoptically forced events

• Postprocessing
  – Bias correct winds, temp, rh, precip
  – Use ensemble wind variance as estimate of LSV (Wind error correlated with Wind variance, Coielle, 2005)
  – Reforecasting Project
  – Cluster ensemble members to drive Scipuff most likely scenarios (COSMO-LEPS approach)
Dispersion Ensemble Configurations

1. One HPAC run (Ens. Median/variance)
2. One HPAC run for each member
3. One HPAC run for main clusters

Cluster analysis can choose a smaller set of members statistically different from one another that correspond to the daily weather pattern.
Soil Moisture Perturbations

Impact on T2m is significant

Jun Du & George Gayno

Diff of T2m, F72 fr 06082021(NMM_ctl3-NMM_ctl4)

T2m diff (namSM – gfsSM, NMM)

With nam soil moisture (NMM)

With gfs soil moisture (NMM)
10 WRF members configured for Eastern U.S.

- 12 km DX, 48 hour forecasts, 2x/day (06 & 18 Z)
- 5 WRF ARW members (1 control, 2 breeding pairs)
  - Physics: YSU PBL, Kain-Fritsch Convection, RRTM radiation
- 5 WRF NMM members (1 control, 2 breeding pairs)
  - Physics: MYJ TKE, Betts-Miller-J convection, GFDL radiation

Synoptic diversity: LBC & Breeding

- Breeding: 12 hour forecast differences to drive IC perturbations
- Lateral Boundary Conditions updated every 3 hours
  - GENS 1-4 ET members for 2 NMM perturbed pairs
  - GENS 5-8 ET members for 2 ARW perturbed pairs
  - GENS Ctl for NMM and ARW control
Met Ensembles for ATD

HREF 12 km mean/spread

2 m Temperature mean/spread

850 mb Temperature mean/spread
Met Ensembles for ATD

HREF 12 km mean/spread

10 m Winds

850 mb Winds
Future Work

• Evaluate 12 km Relocatable HREF System
  – Add pbl & LSM diversity to initial condition diversity system
  – Compare against SREF, GENS, ARPS 4 km for NCEP/SPC spring program

• High Resolution Testing
  – Test the addition of a 4 km nest to HREF NMM control
  – Evaluate with DCNET and URBANET data

• Provision of Products
  – Provision of ensemble median, wind variance and length scales to MDS for SCIPUFF sensitivity testing

• Complete evaluation of WRF turbulence & PBL fields for coupling with HPAC w/ PSU, Titan and Hanna Consultants

• Improved probabilistic verification package
BACKUPS
SREF Performance
48 h forecast Spread (Nov. 2005)

- SREF-21 improved over SREF-15
- Temperature:
  - Spread is smallest in West and near Tropopause
- Winds:
  - Spread is greatest in West and near Tropopause
SREF Operational Performance

Outlier Percentage

48 h forecasts (November 2005)

- Outlier percentage reduced for SREF/21 system
- WRF sub-member agree best w/ obs as compared to Eta and RSM sub-members
ARL HYSPLIT Web Interface

- Web based interface that allow user to customize:
  - Source location
  - Source strength
  - Deposition effects
  - Release Duration
  - Forecast Length
  - Graphical Display
  - ESRI GIS
  - Google Earth Interface
Torino Olympics
Snow Storm Forecasts (3h prcip)
00 UTC Feb. 17, 2006 18 h Forecasts

WRF-NMM 4km Zoom
MM5 4 km
FVS VERIFICATION

Parameters:
- Temperature
- RH
- Winds
- Pressure/Heights

Domains:
- NAM, WRF
- GFS

Editbufr
Prepfits
Gridtobs

Statistic type:
- SL1L2 STATISTICS
- FHO (threshold) STATISTICS

VSDB RECORDS:
- SL1L2
- FHO

Compute and plot:
- Bias
- RMSE
- Correlation
- Thread score
- Probability of detection

FVS
(from NMC/CMA, Y. Li)
Two field campaigns provide intensive observations for potential use in regional analysis.

2006 Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study (8/1 - 9/30)

WAVES_2006: Water Vapor Validation Experiment – Satellite/Sondes in Beltsville, MD (7/17– 8/10)
Torino Olympics
February 18, 2006 case temperature
IHOP May 29, 2002 case

- WRF-NMM Initialized from NDAS at May 28, 2002, 12Z
- 4 km, 50 Level, 48 hour forecasts
- Central U.S. Nest (260x410)
- Mellor-Yamada-Janjic TKE
- NOAH LSM
- Ferrier Micro-physics
- Betts-Miller-J Convection
Ensemble Covariance Products

Binbin Zhou, EMC

$EKE = 0.5 \times (U^2 + V^2 + W^2)$, where $U$, $V$, $W$ are ensemble variances
HiResWindow Fixed-Domain Nested Runs

Proposed ~4km run Configuration

- **F**OUR routine runs made at the same time every day
- 00Z: ECentral & Hawaii
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Spread is largest in East and near Tropopause