Evaluation of Multi-Annual CONUS 12 km WRF simulations

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Outline

• Purpose of presentation
• Description of simulations
  – Model configuration
• Operational Evaluation
  – Domain-wide stats
  – Spatial statistics
  – Seasonal precipitation
  – PBL wind assessment using profilers
• Nudging sensitivities
Goals of Presentation

- Examine model performance of across several years and seasons
- Identify major problem areas that may impact air quality model and to direct future research aimed at model improvements
- Compare with “similar” MM5 simulation
  - MM5 physics were similar (PX LSM, ACM2, KF2, nudging, etc)
  - Domain was the eastern US since no CONUS MM5 at 12 km have been run
  - MM5 was for 2005, used out of convenience
Model Configuration

- 12 km North American domain pictured above
- Annual simulations for 2002, 2005, and 2007; 2009-2010 are planned
- 472 (nx) x 312 (ny) grid cells with 34 layers; first layer is ~40 m thick with about 17 layers below 2000 m
- High resolution (30 m) National Land Cover Dataset used for landuse; fractional landuse used to derive surface characteristics within the PXL LSM
- Time varying sea surface temperature
- 6th order diffusion (opt. 1), w_damping, w-Rayleigh damping, km_opt (opt. 4), positive definite advection for scalars and moisture
- Simulations were split into 5.5 day run segments that overlapped by 12 hours. The 12 hours is used for model spin-up, but not used by the air quality model or in the evaluation
- Analysis nudging of U, V, T and Q was enabled with the specific options provided to the right; no temperature and moisture nudging in the PBL
- Surface analysis nudging was enabled per parameter options to the right
- Pleim-Xiu LSM soil moisture and temperature nudging enabled
- All nudging fields including 3-D wind, temperature and water vapor mixing ratio; 10-m wind, 2-m temperature and 2-m mixing ratio were derived from the Obsgrid re-analysis program, which used the 12 km NAM as the base analysis and standard surface observations and rawinsonde soundings for the upper air data

Model Evaluation: The Atmospheric Model Evaluation Tool (AMET), developed by the US EPA and the Univ. of North Carolina's Institute for the Environment, was used to match the annual WRF simulations with point measurements from surface networks and wind profilers. AMET uses the observations collected by the Meteorological Assimilation Data Ingest System (MADIS). For the comparisons to MMS it must be understood that the MM5 simulation was for a different year (2005) and that domain only covered the eastern US, while the WRF domain covered the difficult to model western US.
Domain-wide and regional model performance

Error and bias of near-surface temperature, moisture and wind grouped by month and time of day
Monthly RMSE, Mean Error and Index of Agreement of 2-m Temperature (K)
Monthly MAE
10-m Wind Direction (deg)
Spatial model performance

Spatial statistics grouped by season for near-surface temperature, moisture and wind
RMSE 2-m Temperature (Winter)

2002

2006

2007

MM5
Bias 2-m Temperature (Winter)
RMSE 2-m Temp Differences (Winter)
WRF – MM5

WRF2007-MM52005 of 2 m Temperature (°C) Date: Jan–Mar

An Atmospheric Model Evaluation Tool (AMET) Product
RMSE 10-m Wind Speed (Winter)
Jan 2008 WS Bias, no sfc nudging or 3-D analysis nudging of wind
RMSE 10-m Wind Speed Differences (Winter)
WRF – MM5

WRF2007–MM52005 of Wind Speed (m/s)  Date: Jan–Mar
RMSE 2-m WV Mixing Ratio Differences (Winter)

WRF – MM5
RMSE 2-m Temperature (Summer)
Bias 2-m Temperature (Summer)

Mean bias of 2 m Temperature (°C) Date: BETWEEN 20020701 AND 20020930

Mean bias of 2 m Temperature (°C) Date: BETWEEN 20060701 AND 20060930

Mean bias of 2 m Temperature (°C) Date: BETWEEN 20070701 AND 20070930

Mean bias of 2 m Temperature (°C) Date: BETWEEN 20090701 AND 20090930

MM5
RMSE 2-m Temp Differences (Summer)
WRF – MM5
RMSE 10-m Wind Speed (Summer)
Bias 10-m Wind Speed (Summer)

Mean bias of Wind Speed (m/s)  Date: BETWEEN 2002/07/01 AND 2002/09/30

Mean bias of Wind Speed (m/s)  Date: BETWEEN 2006/07/01 AND 2006/09/30

Mean bias of Wind Speed (m/s)  Date: BETWEEN 2007/07/01 AND 2007/09/30

Mean bias of Wind Speed (m/s)  Date: BETWEEN 2007/07/01 AND 2007/09/30

MM5
RMSE 10-m Wind Speed Differences (Summer)
WRF – MM5
RMSE 2-m Mixing Ratio (Summer)
Bias 2-m Mixing Ratio (Summer)
RMSE 2-m WV Mixing Ratio Differences (Summer)
WRF – MM5
Seasonal Precipitation

Comparison of WRF simulated seasonal precipitation with PRISM
PBL Wind

Comparison of simulated PBL wind with ~55 US wind profilers for summer
Time-Height Mean Wind Speed


WRF

Profiler
Time-Height RMSE/BIAS/IOA Wind Speed (m s\(^{-1}\))

RMSE

Bias

IOA

All Profilers
Time-Height RMSE/BIAS Wind Speed

Mid-Atlantic
Time-Height Mean Wind Speed Plains (Summer 2002)
WRF Wind Flow (with base FDDA)

Layer 7 \( \sqrt{UWINDz*UWINDz + VWINDz*VWINDz} \)

WRF Wind Flow (with NoFDDA < layer 13 [~1-km])

M/S

August 11, 2002 8:00:00
Min= 0 at (362,113), Max= 14 at (303,227)
WRF vs Obs Nocturnal Wind Profiles at Different Times at a mid-Atlantic Location

Base FDDA                     NoFDDA, < 1 km, new SBL          NOAA Profiler Obs

MODELED NOCTURNAL WIND/FDDA PROFILES  
Aug 11 2002 : Site: Ft. Meade, MD

MODELED NOCTURNAL WIND PROFILES  
Aug 11 2002 : Site: Ft. Meade, MD

OBSERVED NOCTURNAL WIND PROFILES  
Aug 11 2002 : Site: Ft. Meade, MD
24-hr Trajectory Path with WRF Winds at RCH, VA

Base FDDA

NOAA HYSPLIT MODEL
Forward trajectory starting at 00 UTC 11 Aug 02
MCIP Meteorological Data

No FDDA < 1 km

NOAA HYSPLIT MODEL
Forward trajectory starting at 00 UTC 11 Aug 02
MCIP Meteorological Data

(Hourly averaged wind profiles from 11-15 August, 2002)
24-hr Trajectory Path (NOAA Profiler Obs from RCH, VA)

NOAA HYSPLIT MODEL
Forward trajectory starting at 00 UTC 11 Aug 02
MCIP Meteorological Data

(Hourly averaged wind profiles from 11-15 August, 2002)
Displacement Distances between Model and Observed Traj.

24-h Trajectory Period: August 2002 Case

Separation Distance (km)

Hours after Start Time of 00 UTC
Main Take Home Points

• Model performance varies some from year to year, but that variability is less than differences of performance from winter to summer (T and Q, mainly; wind speed similar throughout the year)

• Wind speed bias at 10 m is a problem that we think has been mitigated with our 2008 simulations. Surface analysis nudging and FDDA in the PBL may not be advisable; groups may want to independently verify.

• Performance (near surface) across the Plains and Rockies is poor in winter. Performance in Rockies may be a systematic modeling issue and not necessarily a model configuration issue.

• Precipitation is generally well simulated in winter, but warm season convective precip, mainly southern US, is not well simulated and should be a main research area in the near future.

• PBL wind is systematically underestimated, both the nocturnal jet magnitude and within the convective PBL
Future Research Plans

• Nudging technique reassessment
  – Grid nudging vs. spectral nudging
  – Nudging strength and vertical distribution
  – Obs nudging with analysis nudging
  – Nudging to 3-D Var analyses that incorporate more non-standard observations