Annual evaluation of WRF-ARW and WRF-NMM meteorological simulations over Europe

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9th Annual WRF Users’ Workshop
23-27 June 2008, Boulder, CO USA
Objective

- To analyse the skills of WRF mesoscale models as drivers of air quality modelling systems - concerned in surface and boundary layer accuracy
- Evaluation of WRF configured with the two dynamical cores:
  - WRF-ARW
  - WRF-NMM
- 12 km horizontal resolution for a European domain
- Annual simulation for 2004 – surface and boundary layer
  - Temperature
  - Moisture
  - Wind speed
  - Wind direction

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2004 annual simulation: Model configuration

- **WRF v2.2.1**
  - **WRF-NMM**
    - Time step: 30 s
    - NX, NY, NZ: 360, 564, 38
    - Dx, Dy: 0.078°, 0.07248° (~12km)
    - PTOP: 50 hPa
    - Hydrostatic
  - **WRF-ARW**
    - Time step: 72 s
    - NX, NY, NZ: 481, 401, 38
    - Dx, Dy: 12 km
    - PTOP: 50 hPa
    - Hydrostatic
  - Microphysics: Ferrier
  - LW, SW radiation: GFDL
  - Surface-layer: Janjic scheme
  - Land-surface: NMM LSM
  - Boundary layer: Mellor-Yamada-Janjic
  - Cumulus scheme: Betts-Miller-Janjic
- **IC-BC**: 6h 1-degree FNL analysis
- **366*36 h simulation** - 12 hours of cold-start
Evaluation against 2 datasets

- Surface meteorological stations – Selection of stations with more than 6000 hourly observations
- Meteorological soundings from European network of radiosoundings

- Evaluation with classical statistics: MAE, ME, RMSE, systematic RMSE
Surface evaluation
Performance of the models: general overview

We have identified problems with NMM simulation for May month related to technical aspects. For the following evaluation, the period 29/4/2004 to 26/5/2004 is not taken into account.
**Monthly evolution of mean surface errors (MAE, ME)**

- **Temperature (°C)**
  - MAE-ARW, MAE-NMM, ME-ARW, ME-NMM
  - Underprediction of ARW/overprediction of NMM - Similar absolute errors. Increased underestimation of ARW during spring

- **Wind speed (m/s)**
  - MAE-ARW, MAE-NMM, ME-ARW, ME-NMM
  - Wind speed overestimation – similar performance of both systems.
  - Lower wind speed error during summertime

- **Dewpoint temperature (°C)**

- **Wind direction (deg)**
  - Diagram showing wind direction with symbols for $d_i$ and $d_{win}$
2 m Temperature Monthly errors - spatial distribution

**Lower MAE – NMM**

- Good performance over continental flat terrain
- Major problems - complex terrain and coastal areas with complex topography

(Mediterranean sea)
**2 m Temperature Monthly errors**

- Stagnant situation over the Mediterranean and low baric gradients over Europe
- Summertime - increased errors, but generally below 2.5°C
- Lower errors with NMM in western and central Europe
10 m Wind speed Monthly errors

- No clear spatial pattern error for wind speed.
- NMM presents higher errors along northern European coast.
- Generally errors below 1.5 m/s, except in complex terrain and complex coastal zones.
Evaluation within the boundary layer
Temperature profile 0-2000 m evaluation (MAE, ME, RMSEs)

- Spatial distribution of the absolute error for temperature within 0-2000 m layer.
- Northern plain Europe and coastal areas present MAE below 1.5 °C for both systems. Summer month larger underestimation of ARW.
- Major problems observed in continental areas characterized by complex topography.

Overall monthly error at model levels from 0 to 2000 m agl.

0-2000 m: cold bias ARW – warm bias NMM. Low inter-monthly variability in NMM.

0-2000 m: cold bias for both models. Increase of MAE during summer month with NMM, not clear temporal evolution for ARW.

In general, better results for NMM.
Mixing ratio vertical structure evaluation (MAE, MBE, RMSEs)

- Moisture errors higher under dryer conditions.
- NMM has slightly larger errors during summertime.
- Both models present an homogeneous overestimation of moisture for winter and spring and a slight underestimation in summer.
- Day-night conditions over-underestimation.
- Overestimation to underestimation from 0 to 2000 m for NMM, general overestimation of ARW.

Systematic error increase during summertime.
Wind speed Vertical structure evaluation (MAE, MBE, RMSEs)

Vertical wind speed monthly errors 0-2000m

- Similar pattern of both models – general overestimation of wind speed.
- Daytime larger errors under wintertime conditions, more marked with ARW.
- Nighttime errors remain more constant for the whole year.
- Vertical distribution of the error similar in both systems.
- Larger overestimation at surface levels (0-500 m), changing to a light underestimation over 1000 m.
- Systematic error similar for both systems.
Comparison WRF-ARW v2.2.1 WRF-ARW v3.0

Clear correction of the cold bias for the whole year

Impact over wind speed – overestimation of intense winds
Summary of results

2004 Annual evaluation of the two dynamical cores of WRF modelling system over Europe.

Results have highlighted:

- **Coastal areas:**
  - Good performance during the whole year in northwestern European coasts.
  - Major problems in Mediterranean coasts – systematic error.

- **Complex terrain:**
  - Higher errors during the whole year for temperature, but reasonable good wind results.

- **Continental flat terrain:**
  - Overall best performance – larger errors related to meteorological conditions

- **Larger errors over southern Europe and under high pressure or stagnant conditions situation**

- **Systematic errors higher with ARW configuration – physics problems**

- **Preliminary comparisons of WRF-ARW v2.2.1 and WRF-ARW v3.0 have shown a clear correction of the cold bias in temperature. Such improvement may affect the skills of the wind speed under intense wind events.**
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Thank you for your attention

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Acknowledgments

This work was funded by the project CALIOPE project 441/2006/3-12.1 and A357/200/2-12.1 of the Spanish Ministry of the Environment. The FNL analysis and verification data are provided by the NCAR’s Data Support Section. WRF-ARW and WRF-NMM simulations were performed with the MareNostrum supercomputer held by the Barcelona Supercomputing Center.