ASSESSMENT OF WRF-ARW FORECASTS USING WARM INITIALIZATIONS

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SUMMARY

The WRF-ARW model is broadly used in regional-scale numerical weather prediction (NWP) performing forecasts up to few days ahead. In order to perform regional-scale forecasts, mesoscale models are driven by global models like the ECMWF or GFS, which provide initial and boundary conditions. Mesoscale models use the initial and boundary conditions available from the global model grid and perform a downscaling of these conditions to their refined grid. In this process, an initial spin-up period is required in order for the mesoscale model to adjust its high resolution domains to the given conditions. In this study we evaluate two methods of producing quasi-balanced model states for model initialization which can reduce the spin-up period. The impact of the two initialization schemes and NWP domain configuration is also assessed. Results show short spin-up time and after the first 3-6 hours the forecast skills of 10m wind speed and 2m temperature depends only on boundaries conditions provided by the global model.

1. Introduction

Mesoscale models are broadly used in numerical weather prediction (NWP) applied to the regional-scale in order to simulate weather systems. To perform weather forecasts, mesoscale models require initial and boundary conditions typically obtained from a global model. This information, however, is only available at global model resolution, so it is necessary to perform a downscaling of these conditions to the more refined grid of mesoscale models. Inevitably this process requires a spin-up period to produce a model balanced state. Therefore, in the early period of forecast, perhaps 12h in duration, the model does not render appropriately some important atmospheric processes making the simulation during the spin up useless (Warner, 2011). A short spin up time will make the model integration useful for nowcasting. For large domains, it is possible that errors due to different initialization methods stay in the domain for a time longer than the spin up period impacting the *NWP skill.* In this work we present two methodologies which aim to shorten the adjustment time and improve information of the initial conditions given to the mesoscale model in order to improve weather forecasts. The domain configurations and its impact on model skill is also assessed.

2. Methodology

In this work we use the WRF-ARW model version 3.4.1 (Skamarock et al, 2008) driven by GFS forecasts (NCEP, 2003) which have an approximate horizontal resolution of 0.5ºx0.5º. Two WRF configurations were applied to Portugal Mainland, both consisting of two nested domains, a parent domain with 25 km horizontal resolution and a nested domain with 5 km resolution (Fig1). The only difference between these two configurations is in the parent domain, which is much larger in the second configuration. A total of 27 unequal spaced vertical levels are used in both domain configurations.

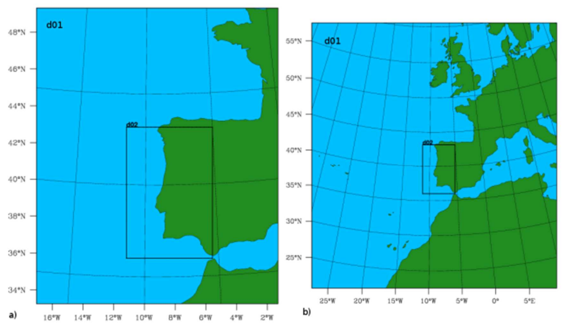

Fig 1 WRF domains d01 and d02 with horizontal resolution of 25 and 5 km respectively, for both configurations OD (left) and BD (right).

For both domain configurations, the WRF is initialized using three different methodologies: (1) the model is initialized using the initial and boundary conditions from the most recent GFS forecast, performing a cold start; (2) the model is restarted from a continuous WRF simulation which was forced by the previous GFS analyses and 3-hour forecasts, including the most recent analysis, with Newtonian relaxation; (3) the model is initialized with the previous 6 hours GFS analysis, the lateral boundary conditions are given by the previous 3-hour GFS forecast, the most recent available GFS analysis and the corresponding forecast. The main difference between method (2) and (3) is that in (2) the model is restarted from a previous continuous WRF run in which the analyses and 3-hour forecast were assimilated through grid-nudging whereas in method (3) starts from a cold initialization from a previous GFS analysis, using the most recent GFS analysis only as BLC, without grid-nudging. The two methods will provide simulated states at the instant of the most recent GFS analysis which must be closer to a balanced WRF model state than that simulated using a cold initialization from the most recent GFS analysis.

Experimental tests were conducted for two different periods by performing daily forecasts during August 2010 (from day 17 to 31) using GFS 12 UTC forecasts, and December 2010 (from day 1 to 15) using GFS 00 UTC forecast.

The skill of the three forecasts methods were assessed by comparing the 2m temperature and 10m wind speed fields, with observations from a network of 15 weather stations from IPMA (*Fig2*), by computing BIAS, RMSE and STDE for each simulation and the network of weather stations as follows:

$$\boldsymbol{Bias} = \frac{1}{N}\sum_{i=1}^{N}\varphi_i'$$

$$\boldsymbol{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{N}(\varphi_i')^2\right]^{1/2}$$

$$\boldsymbol{STDE} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(\varphi_i' - \frac{1}{N}\sum_{i=1}^{N}\varphi_i'\right)^2\right]^{1/2}$$

where

$$\varphi' = \varphi_f - \varphi_{obs}$$

represents the deviation between forecast and observations.

Fig 2 Network of weather stations used to evaluate model skills

3. Results and Discussion

Experimental tests were conducted for December and August 2010. Each test included a set of 6 simulations, constituted by 3 forecasts methods and 2 domains configuration (OD-operation domain and BD-larger domain). An ensemble mean was also compared with observations by computing the mean of the six simulations.

Figures 3 and 4 show the BIAS, RMSE and STDE for 2m Temperature and 10m Wind speed, obtained during December 2010 period.

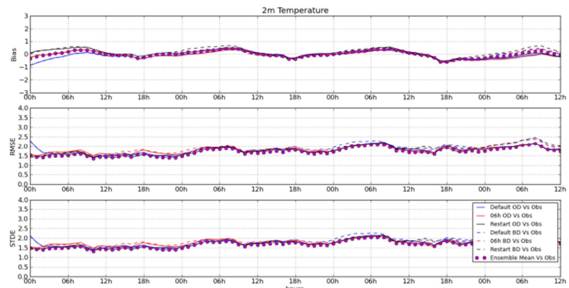

Fig 3 T2m BIAS (top), RMSE (middle) and STDE (bottom), obtained for the 6 experiments and ensemble mean during December 2010 period.

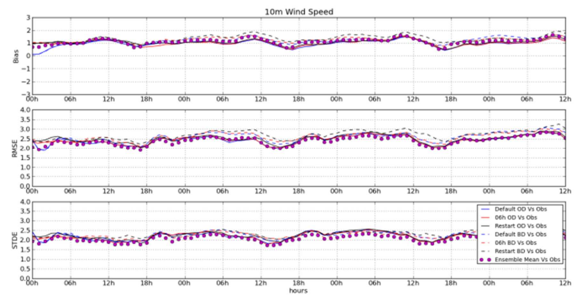

Fig 4 10m Wind speed BIAS (top), RMSE (middle) and STDE (bottom), obtained for the 6 experiments and ensemble mean during December 2010 period

Results show very small differences between forecast methods or domain configurations, after the first 3-6h. The left panels of Fig. 5 show the ensemble spread (STD) of the six simulations for 2m Temperature and 10m Wind. The ensemble spread is much smaller (~1/3) than the STDE, showing the little influence of the domain size and initialization method. The forecast skill is largely determined by the boundary conditions given by the GFS. Using the six WRF simulations initialized 24-hours before most recent GFS analysis and the six most recent WRF simulations, we constructed a 12-member ensemble with more distinct initial conditions and with different boundary conditions. The spread (STD) of this ensemble is a little larger than the 6-member ensemble. However, it is yet much smaller than the STDE. This confirms the strong constraints imposed by the global model (GFS) simulations.

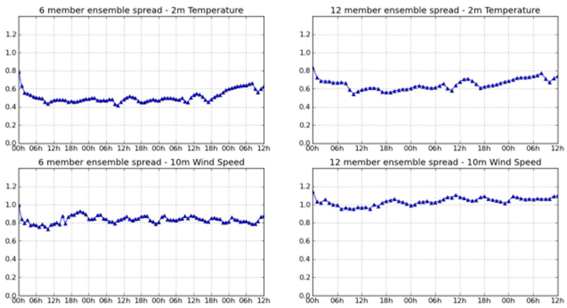

Fig 5 6 and 12 ensemble spread obtained for 2m Temperature and 10 Wind Speed during December 2010 period

It is clear from Figs. 3,4 and 5 that WRF model isn't sensitive to the initial conditions or changes in domain configuration, and that it converges rapidly to the boundary conditions provided by global model GFS. The results show that after the first 3-6 hours the simulations are a boundary condition problem this result could be due to the fact that during winter, atmospheric fluxes are stronger and the initial states of atmosphere that we try to improve are rapidly substituted by another atmosphere states provided by global model GFS trough domain boundaries. To test this possibility we repeated the experiment for a calmer period during August 2010.

Figure 6 and 7 shows the BIAS, RMSE and STDE for 2m Temperature and 10 m Wind speed, obtained during August 2010 period.

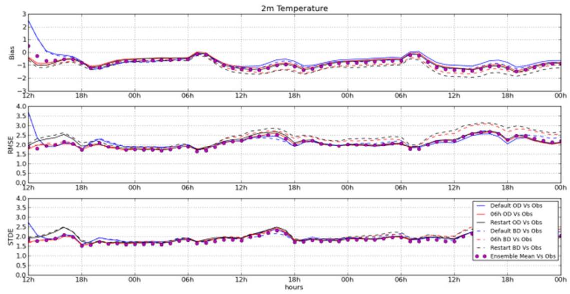

Fig 6 T2m BIAS (top), RMSE (middle) and STDE (bottom), obtained for the 6 experiments and ensemble mean during August 2010 period.

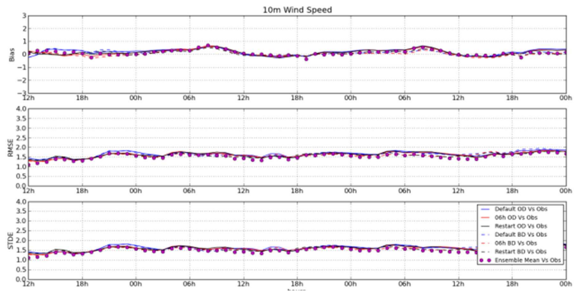

Fig 7 10m Wind speed BIAS (top), RMSE (middle) and STDE (bottom), obtained for the 6 experiments and ensemble mean during August 2010 period.

Results showed higher differences between methods for 2m Temperature than for 10m Wind speed. This is also evident by observing the ensemble spread (*Fig8*).

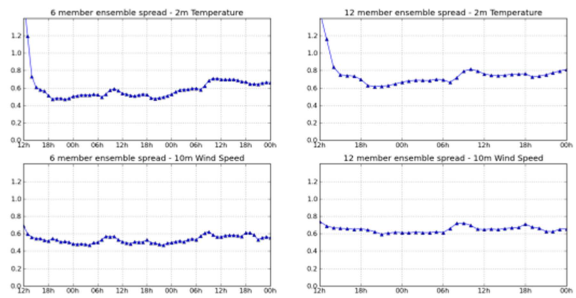

Fig 8 6 and 12 ensemble spread obtained for T2m and 10 Wind Speed during August 2010 period

In the presence of a less intense atmospheric flux the WRF continues insensible to initial conditions, by showing small spreads between forecasts methods when comparing with observations errors.

4. Concluding remarks

The main objective of this work was to study the spin up period and the sensitivity of the WRF model to initial conditions by assessing its skills to simulate 2m Temperature and 10 m Wind speed. Two 15-day periods were considered, first December 2010 (from day 1 to 15) where daily forecasts were performed, starting at 00 UTC and for a total length of 86h. The second period was August 2010 (from day 17 to 31), also with daily forecasts, but in this case starting at 12 UTC with a total length of 60 hours. Three initialization methods were applied. The first method consisted in initializing the WRF model by using the initial and boundary conditions from the most recent GFS forecast, performing a cold start. The second method consisted in restarting a WRF forecast from a previous WRF simulation which was forced by previous GFS analysis and 3-hour forecasts, including the most recent analysis, with Newtonian relaxation. On the third method model is initialized with the previous 6 hours GFS analysis, the lateral boundary conditions are given by the previous 3-hour GFS forecast, the most recent available GFS analysis and the corresponding forecast. Preliminary results obtained for December 2010 revealed a lack of WRF sensitivity to the initialization method and a short spin up period (3-6h) for the meteorological variable analysed. This result suggested that due to stronger atmospheric fluxes during winter, the state of the atmosphere that we were trying to improve with initialization method was being rapidly substituted by another state provided by GFS boundary conditions. Because of this result, we repeated the experiment with a larger parent domain, but maintaining the same nested domain. Results showed the same behaviour and revealed a lack of sensitivity to both forecast methods and domain configuration. Based on 3 forecast methods and 2 domains configurations we were able to construct an ensemble of 6 members. Errors computed with the ensemble mean are similar to the ones of each ensemble member, revealing that the differences from each ensemble member are much less significant than each member and the observations. Because the WRF is strongly constrained by the global model simulation significant improvements of its forecast skills seems to be only possible by using multi-model global forecasts or ensemble of forecasts produced by a single global model with optimal perturbed initial conditions (Marsigli et al, 2013).

References

Marsigli, C., Montani, A. and Paccagnella, T. (2013), Perturbation of initial and boundary conditions for a limited-area ensemble: multi-model versus single-model approach. Q.J.R. Meteorol. Soc.. doi: 10.1002/qj.2128

NCEP: The GFS Atmospheric Model, NCEP Office Note 442. Global Climate and Weather Modelling Branch, ECM, Cam Springs Maryland, 2003.

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Barker, D. M, Duda, M. G., Huang, X.-Yu., Wang, W. And Powers, J. G.: A description of the Advanced Research WRF version 3. NCAR Technical Note, NCAR/TN475+STR, 125pp, 2008.

Warner, T. T.: Numerical Weather and Climate Prediction. Cambridge University Press, N.Y., 526pp, 2011.