Sensitivity of the Weather Research and Forecasting (WRF) model using different domain settings

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Abstract

In this study, the sensitivity of the Weather Research and Forecasting model (WRF) is investigated using different domain settings and displacement the domain center to verify the model performance to infer the meteorological variables (temperature, wind speed and direction) in the Metropolitan Area of Vitória (MAV). Changes in the domain size can interfere in the initial and boundary conditions and smooth effects of the topography and shoreline singularities. The atmospheric variables behaviors are very important to predict pollutants dispersion accurately. The study area covers a relatively flat region between the sea and a mountain chain, with very irregular shoreline, an internal island and several isolated peaks with altitudes up to 830 m. It was ran ten different simulations, three with coarse dimension variation (2,000 km, 1.000 km and 500 km), two with smaller domain dimensions variation (99 km and 51 km) and five shifting the domain center (51 km dimension and displacements of 9 km north and 6 km, 12 km, 18 km and 24 km south) from the position of the local meteorological surface station used as a reference surface. The time spent by the simulations varying from 330 to 1677 minutes however the results did not show a wide variation from the results between combinations of architectural mesh tested, suggesting that the study of different physics parameterizations should be more helpful to improve results than domain architecture.

Keywords WRF model, Meteorological model, Climate modeling, Environmental pollution.

1. Introduction

The knowledge of micrometeorology involving atmospheric parameters that determine the reactions, transport and dispersion of air pollutants have a major influence on people's lives, especially in large urban areas near industrial plants, where air pollution causes damage to health and quality of life.

After released into the atmosphere, pollutants can be transported over long distances by convection from larger scales, while its dispersion is given by the set of multiple dimensions eddies, generated by imbalances embedded in large scales by several factors, such as sunstroke, surface irregularities, type and land use, among others (Stull, 1988). These factors can generate turbulence and circulations of meso scales as winds anabatics, katabatics, valley, land and sea breezes, which play an important role in the dispersion of air pollutants, generated nearby and may, in certain periods of the day, increasing concentrations causing nuisance and damage to the health of residents near these regions.

Aiming to anticipate and prevent potential impacts of potentially polluting facilities, numerical models are used that simulate the concentrations space-time caused by releases from known or estimates of future sources. Whereas numerical models of pollutants dispersion require information about the atmospheric parameters of the study area that can be provided by meteorological surface stations, radiosondes, lidar, sodar and minisondes that for a high density, resulting in a high cost, an alternative is the use of numerical models that can make inferences on grids with high density, from small number of local measurements (Ferreira et al. 2007). Among others, the Weather Research and Forecasting (WRF) (Skamarock et al., 2005; Skamarock and Klemp, 2008) has often been used by both the scientific community and environmental control agencies.

In research using models to study the behavior of atmospheric variables, there is a reasonable variation in architecture domains used in both the quantity and size of the domains, parent grid ratio as the grids size. The aim of this work is to verify the sensitivity of the WRF model to these variations.

2. Methodology

Ten rounds were performed using WRF model, version 3.2, in a cluster with sixteen parallel processors, for the period 22 at 24 July 2012, abandoned the first day as spin up. Three rounds were made varying the coarse domain size (500 km, 1000km and 2000 km) using two nests and parent grid ratio 5, two varying the smaller domain size (51 km and 99 km) using three nests and five altering the center of smaller domain relative to its parent. All others parameterizations were kept unchanged for all rounds. The first five rounds were made with domains centered at coordinates 40.28 S and 20.25 W, where is located the Meteorological Surface Station (MSS) and in the remaining five rounds, the center domains was displaced vertically 9 km to north and 6 km, 12 km, 15 km and 24 km to south of the MSS. Table 1 sows all options used in this research. The wind speed and direction at 10 m and temperature at 2 m values inferred by WRF model were compared with those measured by MSS.

The study area, Metropolitan of Vitoria Area (MVA) has a complex relief, covers a relatively flat region between the sea and a mountain chain, with several peaks reaching up to 830 meters, an island inside a closed bay, with parts flooded and very irregular coastline.

Table 1: Domain architecture

Group	Set	Domain dimension [km]	Grid dimension [km]	Displacement center/direction	cells
01	01	500, 50	10, 2	-	3125
	02	1000, 50	10, 2	-	10625
	03	2000, 50	10, 2	-	40625
02	04	1863, 891, 297, 51	27, 9, 3, 1	-	26964
	05	1863, 891, 297, 99	27, 9, 3, 1	-	34164
03	06	1863, 891, 297, 51	27, 9, 3, 1	09 km / north	26964
	07	1863, 891, 297, 51	27, 9, 3, 1	06 km / south	26964
	08	1863, 891, 297, 51	27, 9, 3, 1	12 km / south	26964
	09	1863, 891, 297, 51	27, 9, 3, 1	18 km / south	26964
	10	1863, 891, 297, 51	27, 9, 3, 1	24 km / south	26964

For the model converges, by run the first three sets (group 01) was necessary to use a time step 20 seconds, whereas for others (groups 02 and 03) it was used a time step 54 seconds. With this, the time to run Set 03 was too high. The table 2 shows the time required to run each set.

Table 2: Time required to run

Set	01	02	03	04	05	06	07	08	09	10
Time(min)	330	688	1677	560	583	560	560	560	560	560

3. Results

3.1 Temperature

All temperature inferences made by the three groups were approximately equal, underestimating much the higher temperatures and slightly overestimating the lowest, despite the big difference in the time spent to run. Figures 1, 2 and 3 shows the temperature measures by MSS and inferred by model, where there is a slightly better performance for the inferences made by the group 01.

Figure 1: Temperature for coarse domain size variation (group 01)

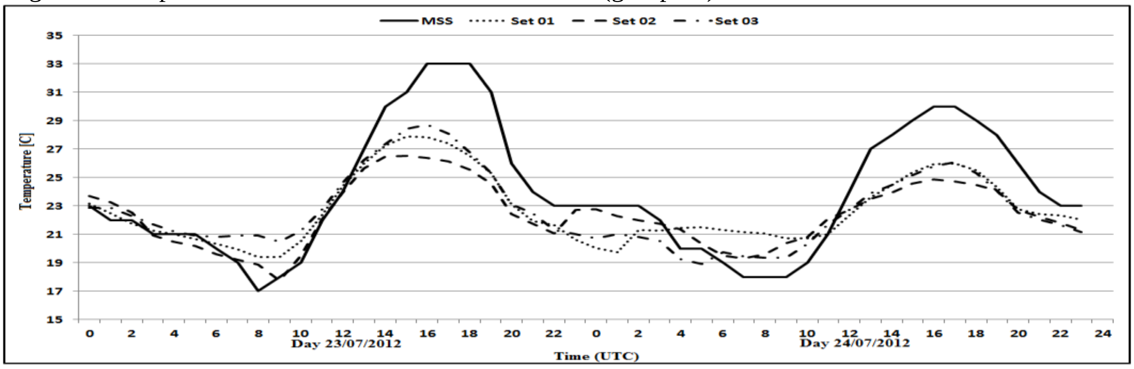


Figure 2: Temperature for inner domain size variation (group 02)

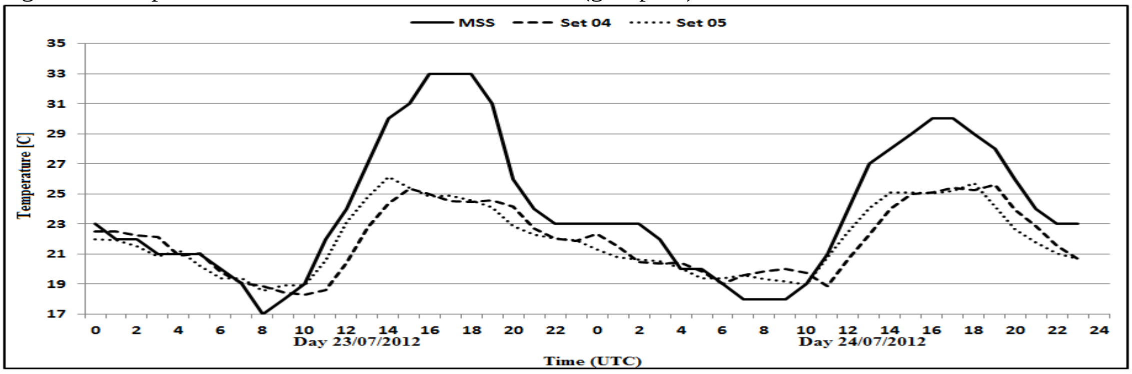
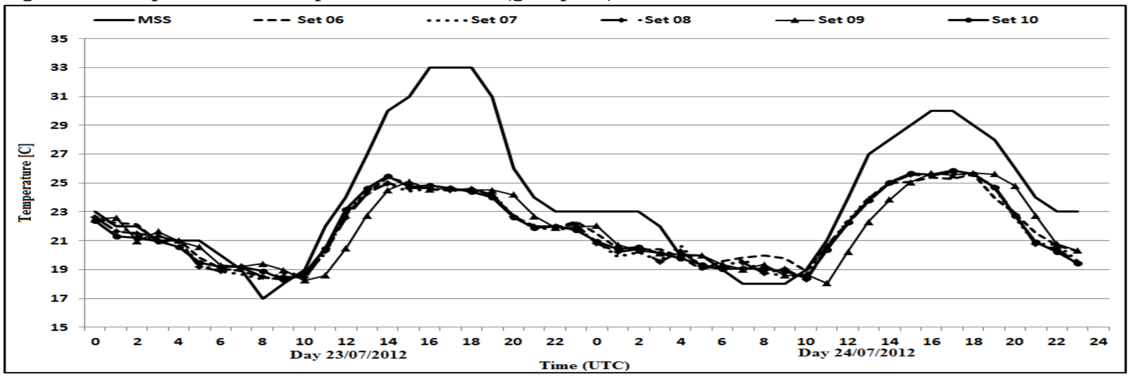


Figure 3: Temperature for displacement center (group 03)



3.2 Wind speed

As can be seen in Figures 4, 5 and 6, with respect to wind speed, only the first group suffered a considerable variation in first day. The other groups have made similar inferences.

Figure 4: Wind speed for coarse domain size variation (group 01)

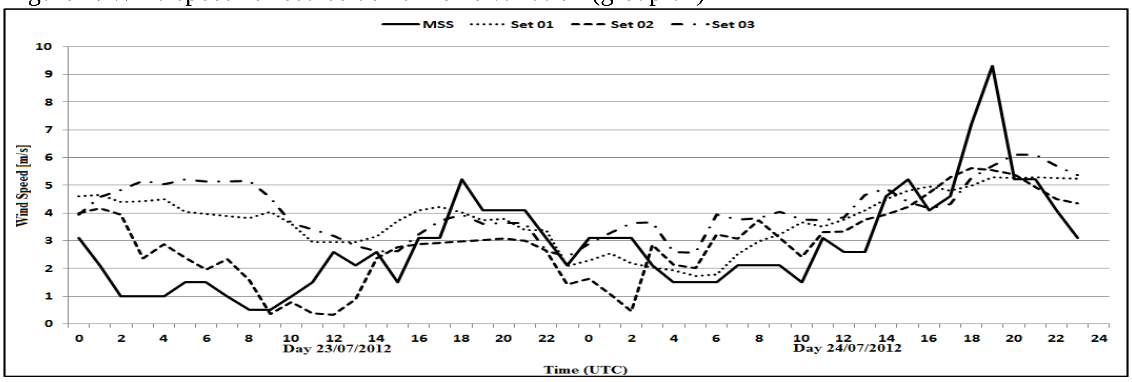


Figure 5: Wind speed for inner domain size variation (group 02)

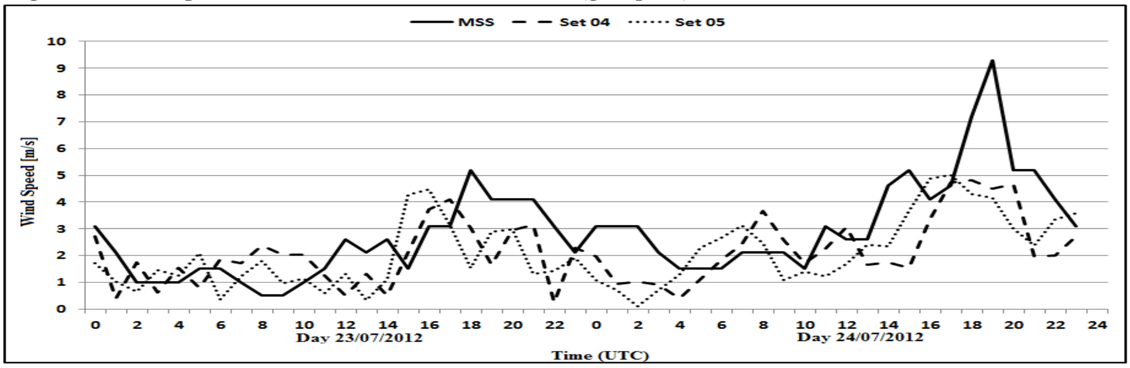
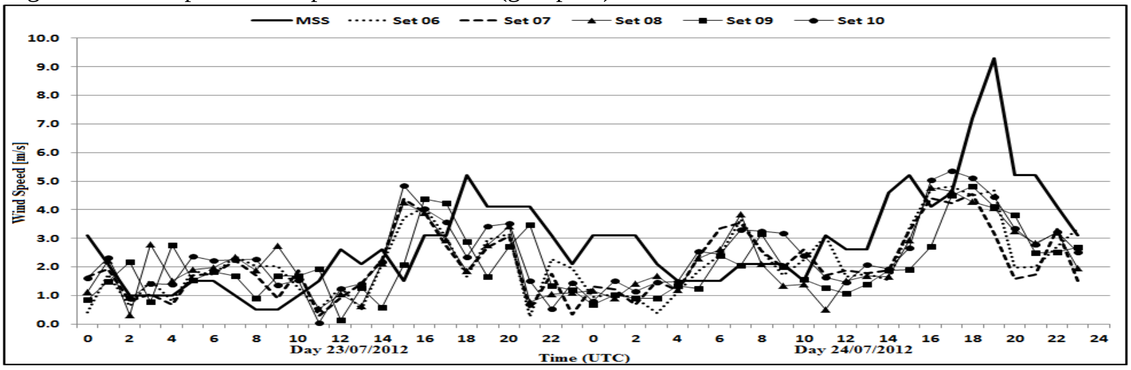


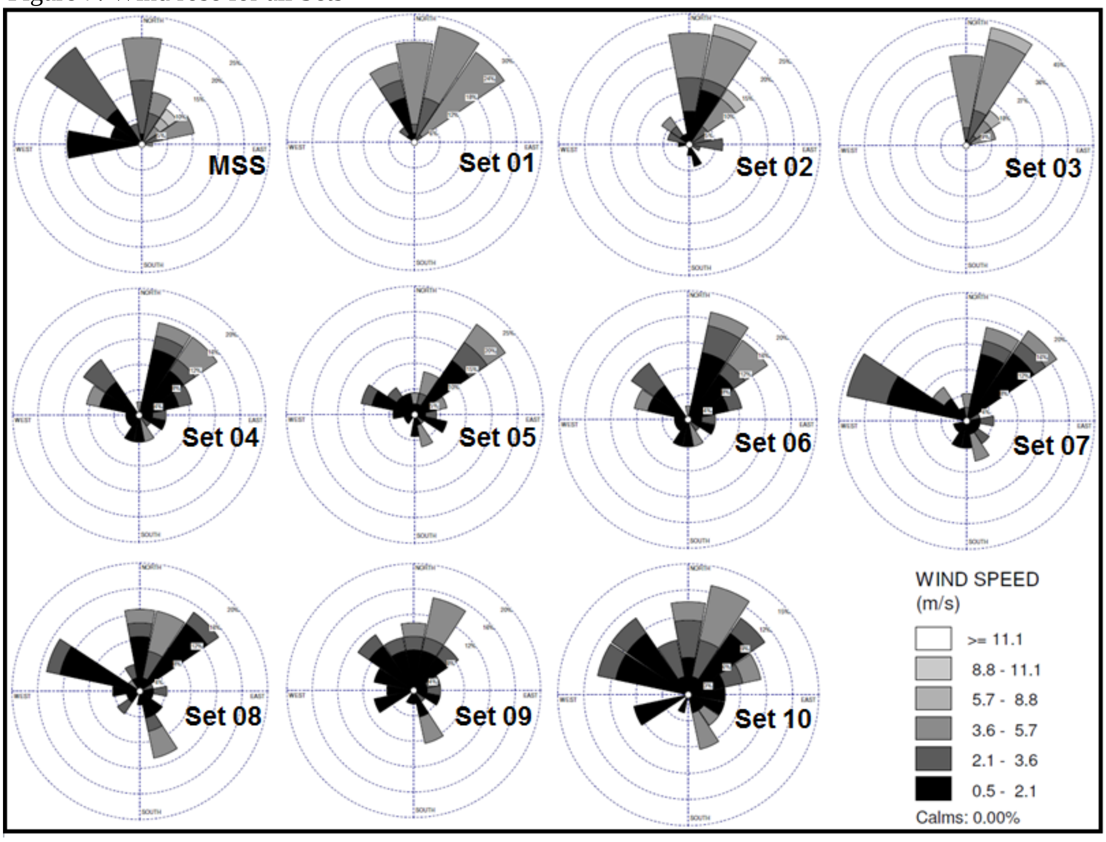
Figure 6: Wind speed for displacement center (group 03)



3.3 Wind direction

As can be seen in Figure 07, although none of the three groups make good inferences about the wind direction, the group 01 showed larger variations than the other two groups.

Figure 7: Wind rose for all Sets



4. Conclusions

Tests showed that the architecture of domains adopted can increase significantly the computational effort, requiring bigger and better computation capabilities and although the better performance of groups 02 and 03, which were executed with greater coarse domain and three nests have been a little better, no groups could make good inference, if comparing the results of the WRF model with MSS measurements. This suggests that test with physical parameterizations options can result in better results than domain architecture.

5. References

Ferreira, A.P.; Castanheira, J.M.; Rocha, A.; Ferreira, J. Estudo de sensibilidade das previsões de superfície em Portugal pelo WRF face à variação das parametrizações físicas. 124f. Tese. Universidade de Aveiro. Aveiro, PT. 2007.

Skamarock, W. C., J. Klemp, D. Gill, D. Barker, W. Wang, and J. Powers. A description of the Advanced Research WRF Version 2. NCAR Tech. Note NCAR/TN-468&STR, 88 pp. 2005.

Skamarock, W.C., and J.B. Klemp. A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. Journal of Computational Physics 227, 3465-3485. doi:10.1016/j.jcp.2007.01.037. 2008.

Stull, R.B., An introduction to boundary layer meteorology. Springer Publishing, New York. 1988.