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EFFECT OF THE TERRAIN FEATURES ON THE ACCURACY OF CALMET. A COMPLEX TERRAIN CASE STUDY

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Abstract: Accurate and high resolution meteorological fields are critical to obtain good air quality modelling results, a common tool in air quality management. CALMET diagnostic model is a good solution to obtain high resolution meteorological fields, but its setup includes a wide number of schemes and parameters which should be selected on the specific environment where the model is applied. Particularly, the parameter TERRAD takes into account the influence of the terrain features in CALMET results. In this work, CALMET outputs using different TERRAD values were tested over a complex terrain and coastal environment at the NW of the Iberian Peninsula. Surface wind and temperature results from CALMET were compared to hourly observations from eleven surface stations. As a result, the lowest wind speed RMSE ($2.51 m \cdot s^{-1}$) was achieved using a TERRAD value of 6 km. No significant differences in CALMET surface temperature performance using different TERRAD values were found.

Key words: *CALMET, model calibration, terrain features, complex terrain*.

INTRODUCTION

The management of air quality requires previous knowledge of atmospheric processes, and air quality modelling is currently an important tool to achieve it. However, accurate and high resolution meteorological fields are critical to obtain good air quality modelling results.

CALMET diagnostic model (Scire et al., 2000) is a widespread solution for getting high resolution meteorological fields, using different meteorological inputs (observations, weather forecast models, or both). In CALMET, a large number of calculation options and parameters can be selected, and this selection depends on the specific environment where the model is applied. In a previous experience, Lee et al. (2003) performed a sensitivity study of R1 CALMET parameter for several MM5-CALMET system setups.

Particularly, TERRAD is an empirical parameter that takes into account the effect of the radius of influence of terrain features on meteorological fields; that is, how far is affected the meteorology by valleys, hills, etc. TERRAD value is highly dependent on each specific domain topographic dataset; therefore, testing of different TERRAD values over a specific environment is recommended in order to calibrate it to get a more accurate CALMET simulation. The US Interagency Workgroup on Air Quality Modelling (IWAQM) outlined a list of recommendations for many CALMET settings, and set 15 km as default recommended TERRAD value (Fox, 2009). Moreover, Lakes Environmental (2011) suggested three different criteria to be considered for TERRAD setting: from 4 to 10 grid cells length, ridge to ridge distance, and size of the terrain features needed to be captured. Because of this variety of criteria, statistical assessment of CALMET output over a specific environment is highly recommended.

In the past, several statistical methods were used in meteorological models assessment. The advantages of using RMSE rather than other statistics to evaluate meteorological models output were showed for Willmott (1981), as other statistics generate either overestimation of large errors or masking small ones.

Also, other parameters as BIAS, MGE, etc (Emery et al., 2001; Chang and Hanna, 2004; Mohan and Sati, 2016), are commonly used in many meteorological model evaluations.

In this work, outputs from CALMET diagnostic model were tested using different TERRAD values over a complex terrain and coastal environment at the NW of the Iberian Peninsula, using the same WRF model simulations as CALMET input.

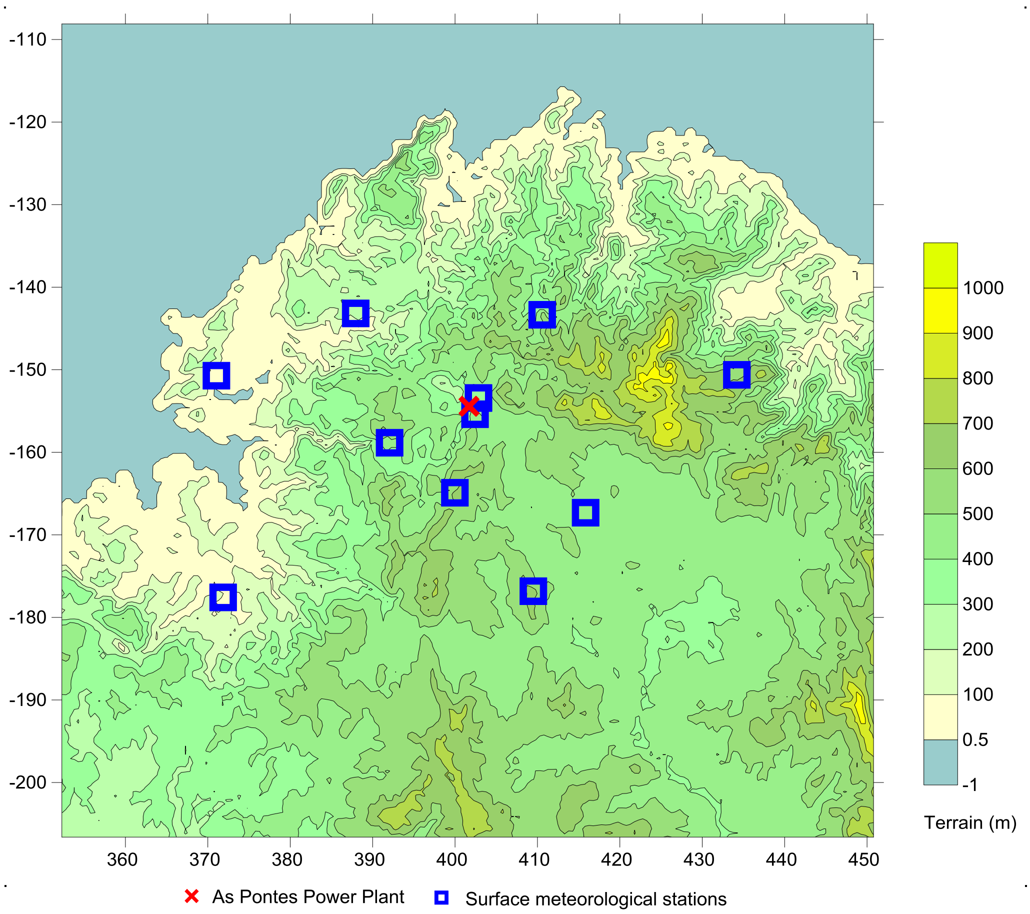

Figure 1. Location (UTM coordinates) and digital elevation model (asl-m) of the CALMET simulation domain inside the D3 domain (Northwestern Galicia), with the location of meteorological surface sites for model assessment. Terrain values [-1,0.5] correspond to sea level.

STUDY AREA AND EVALUATION PERIODS

Galicia is a region located in the northwest corner of the Iberian Peninsula, between 42° and 44° N and 7° and 9°30’ W, with complex terrain and land use, and sea influence. In this work, a study area around As Pontes 1400 MW coal fired power plant with a 356.5 m stack was considered (Figure 1), because of the interest in the application of CALPUFF system to evaluate that power plant plume diffusion (Souto et al., 2014). This study area is centred at As Pontes valley, covering the roughly E-W oriented lowlands around the River Eume (including two large dams as inland surface waters) with the following surrounding geographic features: to the East, two mountain ranges up to 1000 asl-m; to the North, a series of hills running roughly N-S from the coast, with maximum altitudes of 550-750 asl-m; to the West, low coastal hills (< 200 asl-m) bordering the Atlantic coast; to the South, to mountain ranges, with maximum altitudes of 750-850 asl-m; and to the SE, an elevated plain. Consequently, it is a complex terrain, with some granitic mountains, valleys, water surfaces, and a narrow coastal line, all mixed in the same environment.

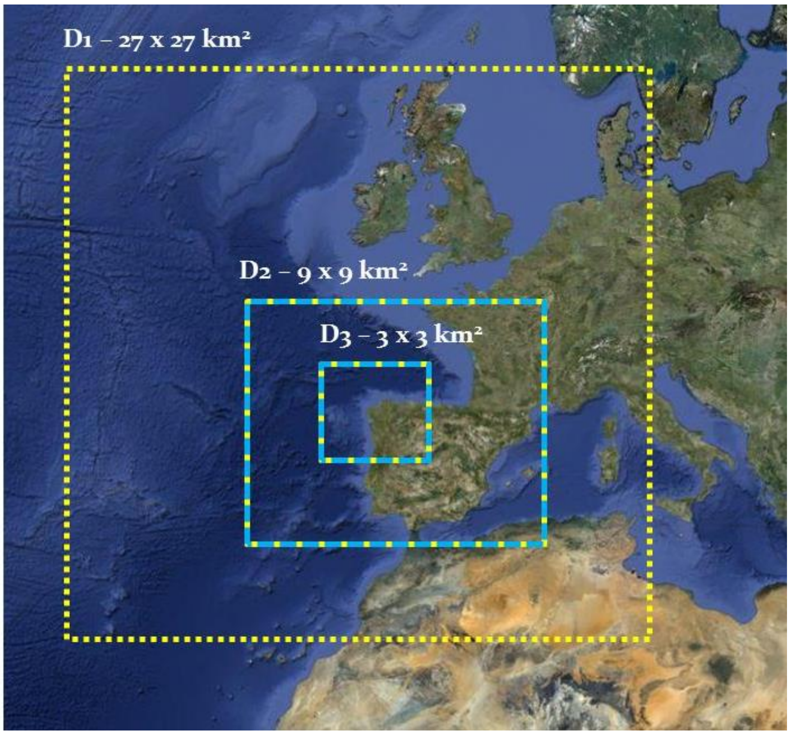

Figure 2. WRF nested domains, including D3 domain that provides the meteorological input to CALMET simulations.

In order to compare to previously CALMET simulations over the same environment (Gonzalez et al., 2015) the following testing period was considered: June 1st, 2006 – June 3rd, 2006. This period corresponds to anticyclonic and stable conditions, which are typical in this region during the synoptic pattern High Pressure over Atlantic and Europe (HPAE) (Saavedra et al., 2012).

METEOROLOGICAL MODELING

Simulation domain (Figure 1) covers 99x99 km^2 and a CALMET 0.5 km horizontal resolution grid was set in all simulations. Also, 14 vertical layers were set in order to get a good representation of the PBL vertical structure, with reasonable computational time effort (Gonzalez et al. 2015). About CALMET settings, default values were applied except to the parameter TERRAD.

As CALMET meteorological input, WRF model simulations using three one-way nested grids were done (Figure 2), with a 3x3 km^2 horizontal resolution in the innermost grid. US NCEP GFS reanalysis fields supplied initial and boundary conditions. WRF model settings include: Kain-Fritsch cumulus scheme (outer and medium domain), WSM 3-class microphysics scheme, a RRTM long wave and Dudhia shortwave radiation scheme, 5-layer soil model, and Yonsei University-Pleim-Chang(YSU) PBL scheme (Souto et al., 2013).

Considering Lakes Environmental (2011) criteria, four different TERRAD values from 1 to 10 times the horizontal grid resolution (0.5 km) were initially selected: 0.5, 1, 3 and 5 km. After that, TERRAD value was increased in order to check its performance: 6, 7, 9, 15, 20, and 30 km. Surface wind and temperature CALMET results for every TERRAD value were compared to hourly observations from eleven surface stations located at the simulation domain (see Figure 1) during the same period.

RESULTS

Following Willmott (1981), RMSE statistics were considered to measure the different CALMET simulations performance. Regarding wind speed, every CALMET simulations provide lower RMSE (see Figure 3) than WRF 3x3 km^2 resolution results (2.58 $m \cdot s^{-1}$); also lower RMSE values are obtained with CALMET around the TERRAD range recommended by Lakes Environment (2011), that is, 0.5-5 km. However, the lowest RMSE value (2.51 $m \cdot s^{-1}$) is achieved with TERRAD=6 km, close to the maximum recommended value. This result can be derived by the quite complex topography in this domain that requires taking into account terrain features influence over the wind flow a bit further than usual.

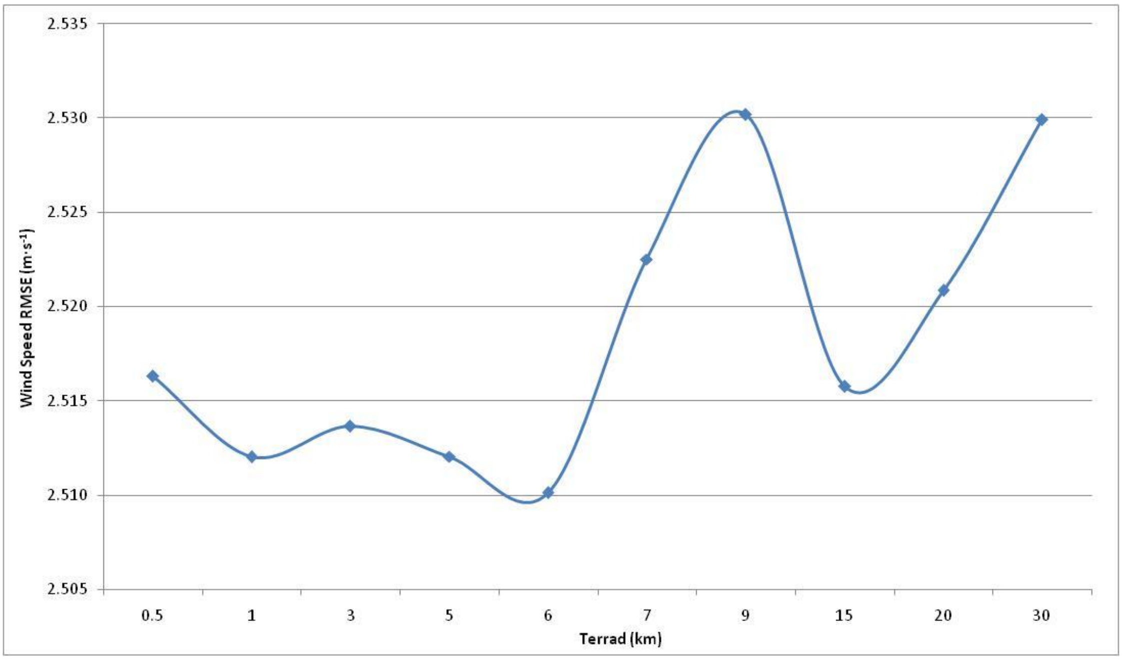

Figure 3. Wind speed RMSE variation from CALMET simulations using with different TERRAD values

About surface temperature, RMSE values are very similar using different TERRAD values (Table 1); although land uses could affect to the surface temperature, actually CALMET results are derived from WRF output, which is the same for every CALMET simulation; therefore, any surface temperature improvement requires either better WRF simulations or surface temperature measurements as additional input.

Table 1. Temperature RMSE results from CALMET simulations using different TERRAD values

TERRAD (km)	Temperature RMSE (°C)
0.5	2.2941
1	2.2939
3	2.2931
6	2.2928
9	2.2927
15	2.2926
20	2.2926
30	2.2925

CONCLUSIONS

The influence of complex terrain features in CALMET requires the calibration of different parameters and model options. In this work, TERRAD empirical parameter shows its influence over surface wind speed results in a complex terrain and coastal environment. Although every CALMET simulations provide lower wind speed RMSE than WRF (3x3 km^2 resolution) simulation, RMSE differences using different TERRAD values simulations are small, because of the higher influence of that same WRF output applied as CALMET input. However, an improvement (lowest RMSE) using TERRAD=6 km is obtained, which is a bit higher than the maximum TERRAD recommended value (5 km). This can be related to the complex terrain features, as higher complexity can require higher TERRAD values, in order to consider the influence of further topographic features over the wind flow. On the other hand, no influence of TERRAD value is observed in surface temperature performance, as temperature has a lower sensitivity to the topographic features.

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REFERENCES

Chang, J.C. and Hanna, S.R., 2004: Air quality model performance evaluation, *Meteorology and Atmospheric Physics*, **87**, 167-196.

Emery, C., E. Tai and G. Yarwood, 2001: *Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes*, Environ International Corporation.

Fox, T., 2009: *Memorandum: Clarification on EPA-FLM Recommended Settings for CALMET*, August 31st, 2009.

Gonzalez, J. A., A. Hernandez-Garces, A. Rodriguez, S. Saavedra and J.J. Casares, 2015: Surface and upper-air WRF-CALMET simulations assessment over a coastal and complex terrain area. *International Journal of Environment and Pollution*, **57,** 249–260.

Lakes Environmental, 2011: CALPUFF Air Dispersion Modeling Workshop: Course Slides, Barcelona, Spain, Oct 19-21, 2011.

Lee, R.F. and Thé, J.L., 2003: The effect of CALMET surface layer weighting parameter R1 on the accuracy of CALMET at other nearby sites: a case study. In: Guideline on Air Quality Models: The Path Forward, October 22-24, 2003, Mystic, CT, no. 03-A-32.

Mohan, M. and Sati, A. P., 2016): WRF model performance analysis for a suite of simulation design. *Atmospheric Research*, **169**, 280-291.

Saavedra, S., Rodríguez, A., Taboada, J.J., Souto, J.A. and Casares, J.J., 2012: Synoptic patterns and air mass transport during ozone episodes. *Science of the Total Environment*, **441**, 97–110.

Scire, J.S., Robe, F.R., Fernau, M.E. and Yamartino, R.J., 2000: A User's Guide for the CALMET Meteorological Model (Version 5), Earth Tech, Concord, MA.

Souto, J.A., Saavedra, S., Rodriguez, A., Dios, M., Cartelle, D. and Vellon, J.M., 2013: Evaluation of the PRESAXIO air quality forecasting system: PBL schemes WRF comparison and air quality modeling validation. In: 15th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes (HARMO15), Madrid, May 6-9 2013.

Souto, J.A., Moral, C., Rodríguez, A., Saavedra, S., Casares, J.J. and Hernández-Garces, A., 2014: Simulation of plume dispersion using different stack configurations and meteorological inputs. *International Journal of Environment and Pollution*, **55,** 139-147.

Willmott, C.J., 1981: On the validation of models. *Physical Geography*, **2**, 184–194.