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COUPLING WRF AND CALMET MODELS: EVALUATION DURING 15-DAY CASE STUDY IN A CARIBBEAN BAY, CUBA

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Abstract: CALMET meteorological model is evaluated during a typical dry season period in a coastal domain at the Caribbean region, using four different CALMET input datasets. Evaluation was focused in terms of surface wind and temperature modeling performance. As input data, Weather Research and Forecast model (WRF) results are combined to meteorological measurements from different sites. CALMET results statistics (both relative and absolute) are calculated over sites not used as input data providers. Relative wind speed statistics values are high, due to the weak winds along the study period. However, absolute statistics are better. Also, a significant improvement in both wind speed and temperature statistics, both relative and absolute, is observed as more sites provide input data.

Key words: *Caribbean meteorology***,** *CALMET, WRF, statistical model validation*

INTRODUCTION

Modeling plays an important role in establishing laws for the air pollution emissions control, as they must minimize their environmental impact, for instance, establishing legal emissions thresholds, assessing different emission control strategies and, selecting the location of future air pollution sources; in order to guarantee that pollutants ground levels concentrations (glc) remain below legal and recommended thresholds. And, to achieve realistic dispersion modeling results, accurate meteorological information is required, both at ground level and aloft.

CALMET (Scire et al., 2000) has been used for regulatory compliance (Ghannam and El-Fadel, 2013). Besides, WRF and CALMET have recently been coupled in many studies (Radonjic et al., 2010; BSU, 2010; Whitford, 2009). As well, numerous investigators take advantage of the model capacity to investigate wind flows in coastal regions. Indumati et al. (2009) study the effect of the presence of a small water body on the dispersion of pollutants in an urban area. Thus, Lonati et al. (2010) presents a case-study for assessment of the impact on local air quality of port area activities at a planned Newport. While, Poplawski et al. (2011) report the findings of the James Bay Air Quality Study, which investigate the impacts of emissions from cruise ships on local air quality. In addition, Radonjic et al. (2011) demonstrate the good performance of the CALMET in a setting that involves land water interface. Whereas, Ghannam and El-Fadel (2013) integrate MM5 with CALMET for a regulatory assessment of air quality in a coastal urban area.

In this work, CALMET diagnostic model is coupled to a WRF model simulation over a 90x90km^2 Caribbean bay domain during a typical dry season period of 15 days. Different modeling configurations were compared and tested against the available surface meteorological measurements.

STUDY AREA AND EVALUATION PERIODS

Jagua Bay (Figure 1) is a semi-enclosed Bay located in the southern central part of Cuba, with a surface area of 90 km^2. Over there, expansion of an oil industrial complex is expected, close to Cienfuegos city and also a close touristic region (Rancho Luna). The two main industrial air pollution sources are an oil refinery and a power station. In order to check the capability of CALMET model to provide accurate meteorological input to CALPUFF dispersion model for regulatory purposes, different high resolution meteorological simulations along a typical dry season 15 days period are tested. The selected period covers from 02 January 2010 - 05 UTC to 16 January 2010 - 05 UTC, in the typical dry season, with weak winds (2.6 $m \cdot s^{-1}$) and moderate temperatures (17.0 ºC).

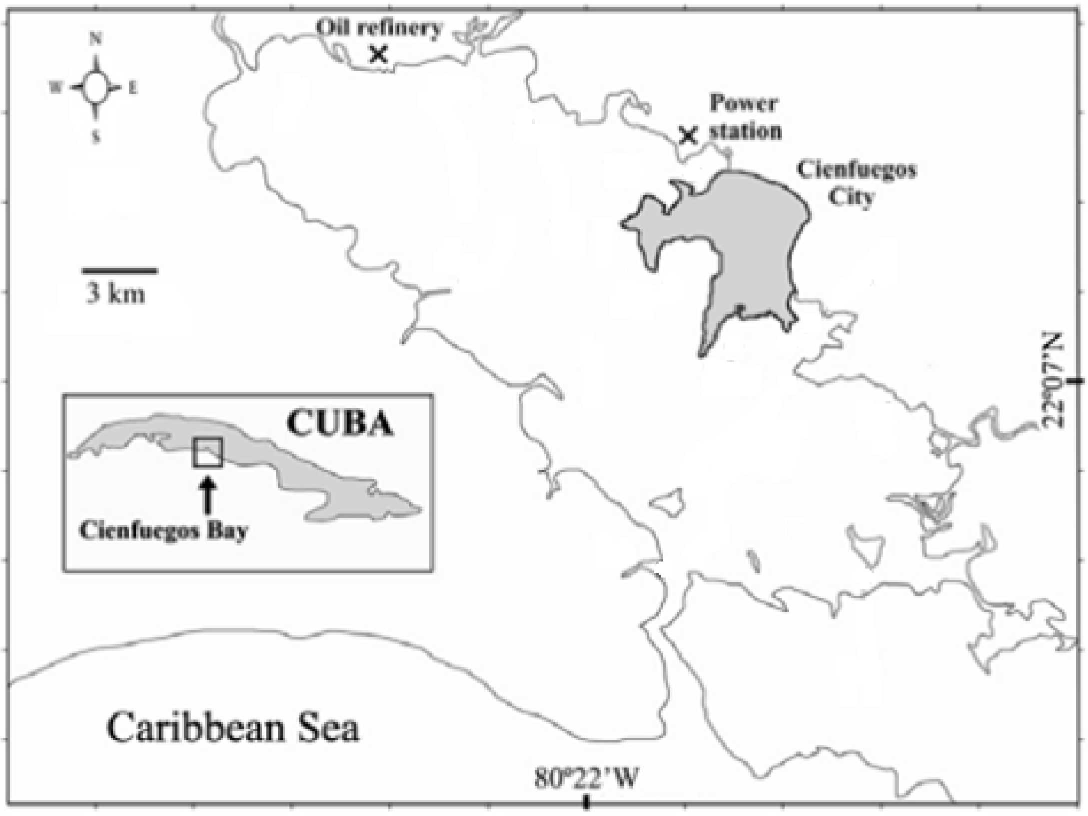

Figure 1. Location and physical geography of the study area (Díaz-Asencio et al., 2009).

Table 1. CALMET simulations and validations performed using different meteorological inputs and check datasets, provided by seven surface meteorological sites (see Fig. 2).

Simulations	CALMET meteorological inputs and grids	Input dataset sites	Check dataset sites
Met_1	WRF results	-	7 sites (all)
Met_2	WRF results and 2 surface meteorological sites	Cienfuegos, Aguada	Centro, Delfinario, Refinería, Cruces, Abreus
Met_3	WRF results and 4 surface meteorological	Cienfuegos, Aguada, Delfinario, Cruces	Centro, Refinería, Abreus
Met_4	WRF results and 5 surface meteorological	Cienfuegos, Aguada, Delfinario, Cruces, Abreus	Centro, Refinería

METEOROLOGICAL MODELING

CALMET diagnostic model is nested to WRF model (Skamarock et al., 2008) simulation over a 90x90km^2 Caribbean bay domain around the refinery (Fig. 2). About CALMET simulations, a 1x1 km^2 horizontal resolution and 10 vertical layers grid is applied; vertical layers are (top-faces): 20, 40, 80, 160, 320, 640, 1200, 2000, 3000 and 4000 agl-m. Also, CALMET diagnostic wind module is applied; for the rest of options, default regulatory choices are applied. As it is shown in Table 1, four different CALMET configurations were tested against different surface meteorological sites input datasets and check datasets, selected from a total of seven sites in the domain.

RESULTS

CALMET surface wind fields, obtained also using only WRF results as input, are representative of the flows observed in this complex coastal domain over dry periods. As an example, Fig. 2 shows the wind size and direction over the simulation domain at 5 LST, with a weak inland breeze. Overwater stronger winds, and more variable inland winds, are observed. As the study domain is quite flat, differences are mainly due to the coastal influence.

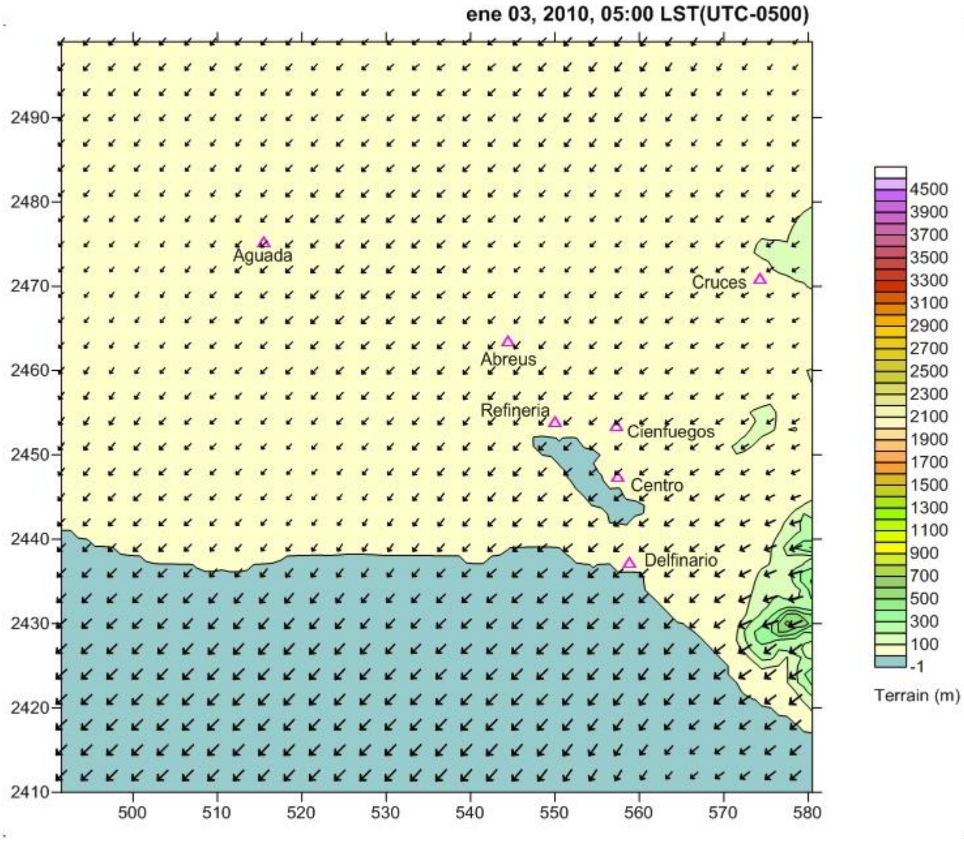

Figure 2. Surface wind field from by CALMET simulation (Met_1, using only WRF results) at 3/Jan/2010 5 LST over the study domain, with the topography and coastal line, and the location of seven surface meteorological sites applied.

Also, Fig. 2 shows the location of the meteorological sites providing either input or check datasets in each simulation (see Table 1). CALMET hourly surface wind speed and temperature results in the check sites are compared to the corresponding surface measurements, using different absolute (BIAS, MAGE, RMSE) and relative (MNBE, MFB, MNGE, NME, NMB) statistics, following (Jiménez et al., 2006).

Table 2. Statistics for hourly wind speed (absolute in $m \cdot s^{-1}$) results from the CALMET simulations performed.

	MB	MNBE(%)	MFB(%)	MAGE	MNGE(%)	NME(%)	NMB(%)	RMSE
Met_1	2,516	2554,485	84,383	2,674	2558,273	123,818	116,523	3,039
Met_2	1,203	770,687	47,395	1,835	788,922	79,462	52,101	2,214
Met_3	0,577	746,365	31,332	1,514	772,896	62,775	23,941	1,851
Met_4	-0,345	9,791	-9,369	1,082	50,123	36,114	-11,499	1,353

About wind speed results (Table 2), relative statistics achieve high values, as mean wind speed is usually low, with a significant improvement increasing the number of sites in the input dataset. Attending to the absolute statistics, differences are not so significant, but an improvement using more sites for input is also observed.

Table 3. Statistics for hourly surface temperature (absolute in ºC) results from the simulations.

	MB	MNBE(%)	MFB(%)	MAGE	MNGE(%)	NME(%)	NMB(%)	RMSE
Met_1	1,391	12,412	9,880	2,267	16,631	13,351	8,194	2,932
Met_4	-0,139	-0,301	-0,866	1,288	8,033	7,486	-0,806	1,650

As surface temperature follows a higher dependence from the input dataset that surface wind, expecting a continuous improvement using more sites input, only Met_1 and Met_4 simulations are compared against the corresponding measurements. Both relative and absolute statistics achieve reasonable values, with an improvement using 5 sites for input (Met_4), as expected.

CONCLUSIONS

CALMET diagnostic wind model nested to a WRF model simulation was tested over a Caribbean coastal region, Jagua Bay, in order to check its capability to represent wind and temperature patterns along a dry season period. Also, different surface measurements datasets jointly to WRF results were applied as either CALMET input.

Compared to the different available surface data CALMET simulation with only WRF results provide good wind and temperature relative statistics, but absolute wind statistics are too high; the typical weak winds during this dry season period are not favorable to achieve better results.

As more surface measurements are applied as CALMET input, better statistics were obtained; taking into account that none of the input data were used as checking data in the model evaluation; even though the limited number of available sites.

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References

BSU 2010, Forecasting for Wind Energy Grid Integration. Boise State University, Final Report.

Díaz-Asencio, L., Armenteros, M., Díaz-Asencio, M., Fernández-Garcés, R., Gómez-Batista, M. and Alonso-Hernández, C. 2009. Spatial and temporal variations of meiofaunal communities in Cienfuegos Bay, Cuba. Revista de biología marina y oceanografía 44(1), 13-22.

Ghannam, K. and El-Fadel, M. 2013. Emissions characterization and regulatory compliance at an industrial complex: an integrated MM5/CALPUFF approach. Atmospheric Environment 69, 156-169.

Hong, S.-Y. and Lim, J.-O.J. 2006. The WRF single-moment 6 class microphysics scheme (WSM6). Journal of the Korean Meteorological Society 42(2), 129-151.

Indumati, S., Oza, R. B., Mayya, Y. S., Puranik, V. D. and Kushwaha, H. S. 2009. Dispersion of pollutants over land–water–land interface: Study using CALPUFF model. Atmospheric Environment 43(2), 473-478.

Jiménez, P., Jorba, O., Parra, R. and Baldasano, J. M. 2006. Evaluation of MM5-EMICAT2000-CMAQ performance and sensitivity in complex terrain: high-resolution application to the northeastern Iberian Peninsula. Atmospheric Environment 40(26), 5056-5072.

Lonati, G., Cernuschi, S. and Sidi, S. 2010. Air quality impact assessment of at-berth ship emissions: Case-study for the project of a new freight port. Science of the Total Environment 409(1), 192-200.

Poplawski, K., Setton, E., McEwen, B., Hrebenyk, D., Graham, M. and Keller, P. 2011. Impact of cruise ship emissions in Victoria, BC, Canada. Atmospheric Environment 45(4), 824-833.

Radonjic, Z., Telenta, B., Chambers, D. and Janjic, Z. 2010. WRF-NMM Mesoscale Weather Forecast Model and CALMET Meteorological Preprocessor Wind Simulations over the Mountaneous Region. EGU General Assembly Conference Abstracts 12, EGU2010, 2941.

Radonjic, Z., Chambers, D., Telenta, B. and Janjic, Z. 2011. Coupled NMM-CALMET Meteorology Development for the CALPUFF Air Dispersion Modelling in Complex Terrain and Shoreline Settings. Geophysical Research Abstracts 13, EGU2011, 3729.

Scire, J. S., Robe, F.R., Fernau, M.E. and Yamartino, R.J. 2000. A User’s Guide for the CALMET Meteorological Model. Earth Tech, USA.

Skamarock, W. C. and Klemp, J.B. 2008. A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. *Journal of Computational Physics*, 227(7), 3465-3485.

Whitford, J. 2009. Durham–York Air Quality Assessment. Appendix D. CALPUFF Methodology. Technical Study Report, Project No. 1009497.