SIMULATING BOGOTA'S AIR QUALITY USING A WRF-CALMET-CALPUFF COUPLED MODEL

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Introduction

Air pollution in Bogotá is a serious issue of concern because of the high PM_{10} concentration levels the population is exposed to. Air quality standards for PM10 are most frequently exceeded at the Puente Aranda, Fontibon and Kennedy districts at the west of the city, with annual average PM_{10} concentrations of ca. 90 $\mu g/m^3$ [Gaitán et al., 2007]. These levels have been rather steady for the past 10 years, despite the population and economic growth. However, significant emission reductions are needed to reduce the health risk imposed on the population.

Modeling air quality is a powerful management tool used to design and assess the effectiveness of air pollution abatement measurements and plans. Even so, only one successful air quality modeling exercise was used by Bogota's environmental authorities in 2002 [Zárate, 2007], but it was not adopted properly as an air quality management tool. This work aims at assessing the performance of a coupled WRF-Calmet-Calpuff modeling exercise applied over Bogota.

Methodology

The Weather Research and Forecast (WRF) model was used to produce meteorological fields during a modeling period selected for having high PM10 concentrations, over the domains shown in Figure 2.1. Domain D1 had a resolution of 30 km and 100x93 grid points. The first nested domain (D2) uses a spatial resolution of 10 km and 193x163 points grid, covering the entire mainland and maritime part of Colombia, and parts Venezuela, Ecuador, Peru, Panama and Brazil. The second nested domain (D3) uses a horizontal resolution about 3.3 km with 274x 202 grid points. Triple two-way interaction was used in the simulation.

A set of 24 cases (Table 1) was setup and run by modifying WRF modeling parameters and schemes, in order to find one that would produce the lowest values of bias, standard deviation and Mae, with respect to observations from the city's meteorological and air quality monitoring stations, following a statistically-based performance analysis using the Atmospheric Model Evaluation Tool (AMET). Meteorological fields produced in such case were used as the initial conditions to run Calmet at a higher resolution and smaller domain of 70 km x 70 km, as shown in Figure 2.2. Results from Calmet were then used to run the Calpuff dispersion model, for which previously estimated and disaggregated emission inventories (Figure 2.3) were used (Peñaloza, 2010).

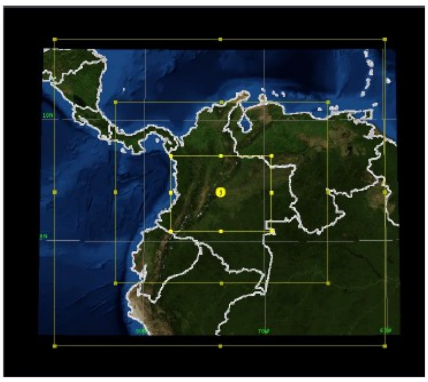

Figure 2-1 . WRF nested modeling domains.

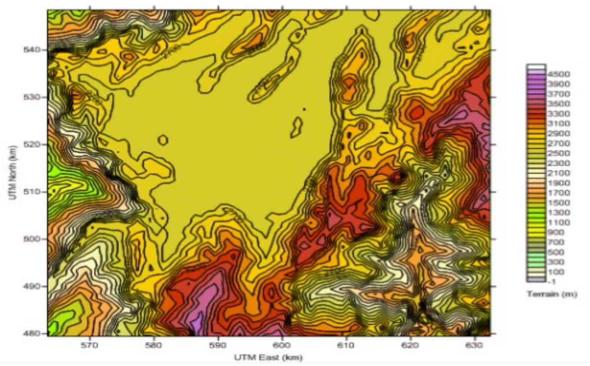

Figure 2-2 . Topography of the Calmet modeling domain

Table 1. WRF modeling cases

case	PBL	Mycrophisic	Land-surface	Shortwave	Longwave
case01	Yonsei	WSM5	5-layer	GFL]D	RRTM
case02	Yonsei	Purdue Lin	Noah LSM	MM5	GFLD
case03	Yonsei	WSM6	RUC	Goddard	CAM
case04	Yonsei	Eta Grid-scale	5-layel	GFLD	RRTM
case05	Yonsei	Purdue Lin	Noah LSM	MM5	GFLD
case06	Yonsei	WSM6	RUC	Goddard	CAM
case07	Yonsei	WSM5	5-layer	GFLD	RRTM
case08	Yonsei	Eta Grid-scale	Noah	MM5	GFLD
case09	Yonsei	Purdue Lin	RUC	Goddard	CAM
case10	Yonsei	WSM6	5-layer	GFLD	RRTM
case11	Yonsei	Eta Grid-scale	Noah LSM	MM5	GFLD
case12	Yonsei	Eta Grid-scale	RUC	Goddard	CAM
case13	Mellor-Yamada	Purdue Lin	5-layer	GFLD	RRTM
case14	Mellor-Yamada	WSM6	Noah LSM	MM5	GFLD
case15	Mellor-Yamada	Eta Grid-scale	5-layer	Goddard	CAM
case16	Mellor-Yamada	Eta Grid-scale	RUC	GFLD	RRTM
case17	Mellor-Yamada	Purdue Lin	Noah LSM	MM5	GFLD
case18	Mellor-Yamada	WSM6	RUC	Goddard	CAM
case19	Mellor-Yamada	Eta Grid-scale	5-layer	GFLD	RRTM
case20	Mellor-Yamada	Eta Grid-scale	Noah LSM	MM5	GFLD
case21	Mellor-Yamada	Purdue Lin	RUC	Goddard	CAM
case22	Mellor-Yamada	WSM6	5-layer	GFLD	RRTM
case23	Mellor-Yamada	Eta Grid-scale	Noah LSM	MM5	GFLD
case24	Mellor-Yamada	Eta Grid-scale	RUC	Goddard	CAM

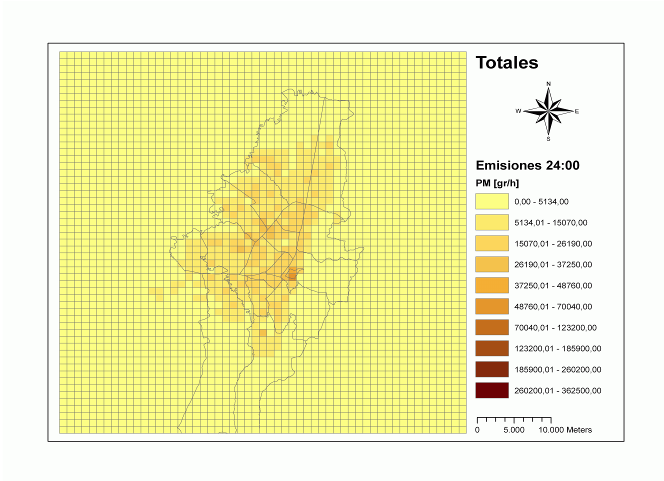

Figure 2-3 Example of emission inventories disaggregation

Results

Case 01 was the WRF simulation with the best statistical agreement with the observed meteorological fields (Table 1). Using results from Case 01 as initial conditions, Calmet estimated the mixing layer height fields shown in Figure 3.1, shown here as an example of Calmet's results. Figure 3.2 shows CO and PM_{10} concentrations and their comparison with observations at four air quality monitoring stations during the simulated period, as estimated by Calpuff. Simulated PM10 concentrations show very slight fluctuations, when compared with those observed at the monitoring stations. In contrast, simulated CO concentrations show similar fluctuations to those observed, but they do not match observations well. A map of average PM_{10} concentration distributions over the city, however, shows higher PM_{10} concentrations in the west of the city at similar levels to those observed.

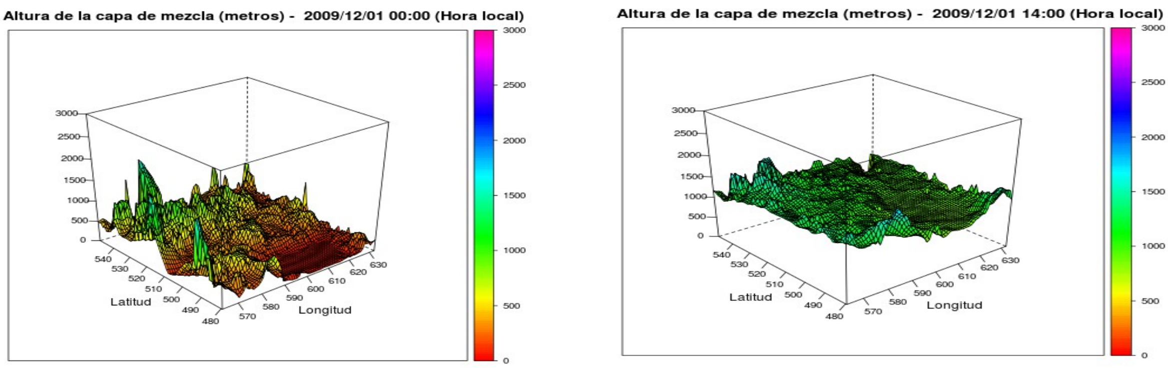

Figure 3.1. Mixing layer height in the simulation domain for 1 December at 00:00 and 14:00.

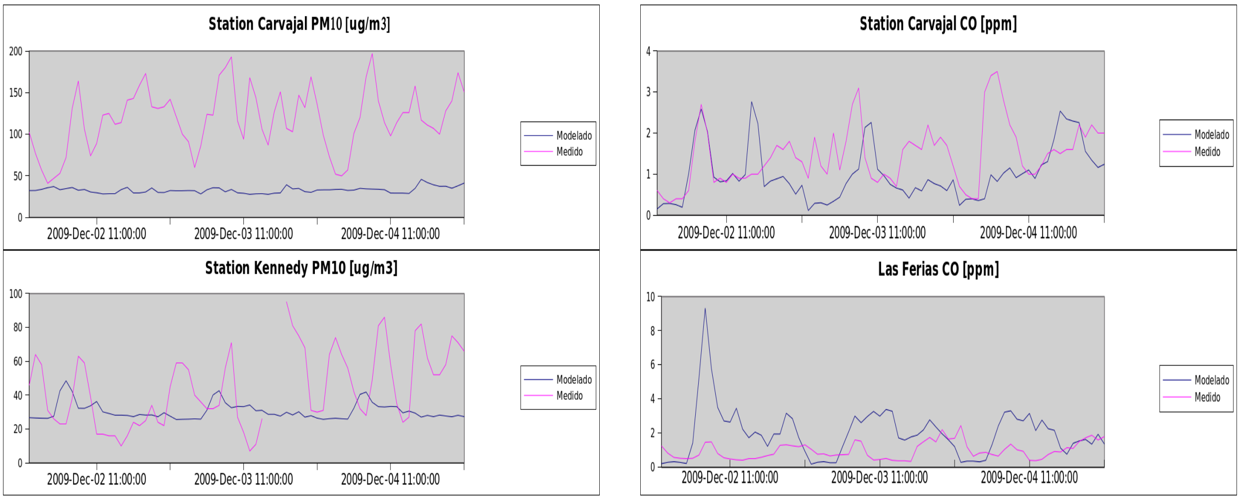

Figure 3.2 Examples of PM_{10} concentration levels for Bogotá during the modeling period

Conclusions

The WRF-Calmet-Calpuff coupled modeling exercise proved to be a useful approach to simulate air pollution in Bogota. A set of WRF modeling parameters was found to produce low values of bias, standard deviations and Mae, with respect to meteorological observations. Calmet results showed a reasonable behavior of mixing layer height throughout the modeling period, fairly consistent with energy fluxes. CO average concentrations and distributions over the city agreed with those observed at monitoring stations. However, although CO fluctuations were at similar levels to those observed, PM_{10} fluctuations did not show any kind of agreement with observations. This may be related to corrections needed in the PM_{10} emission fields and fluctuations or to errors in selected PM_{10} modeling parameters such as deposition rates. Further work is needed to improve the detailed performance of the coupled modeling exercise.

References

- Departamento Técnico Administrativo del Medio Ambiente (DAMA). Informe anual de calidad del aire de Bogotá año 2008. 2009.
- Zárate, E., Belalcázar, L. C., Clappier, A., Manzi, V., and Van den Bergh, H. (2007). Air quality modeling over Bogota, Colombia: Combined techniques to estimate and evaluate emission inventories. Atmospheric Environment, 41(29):6302–6318.
- Gaitan, Mauricio; Cancino, Juliana y Behrentz, Eduardo. Analisis del estado de la calidad del aire en Bogota. rev.ing. [online]. 2007, n.26, pp. 81-92