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# Evaluation of the models CALMET and CALPUFF in two sites topographically different in the coal mining zone of department of Cesar, Colombia

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### Abstract

In the coal mining zone in the department of Cesar (Colombia), the programs MM5, CALMET and CALPUFF were used to simulate the PM<sub>10</sub> contribution of the mining projects PLJ, Norcarbón and Hatillo. The objective was to compare results of CALPUFF dispersion model with the registers of monitoring of the zone and to evaluate this dispersion model in two different topographic sites. El Hatillo mining area is located a few kilometres from the village of La Loma, where topographically flat area; the other areas (projects PLJ and Norcarbón) are located in the low mountain zone of the Perijá, near to the La Jagua of Ibirico village. For the introduction of the variable emission in the CALPUFF model, it was considered data as provided in the study of the Monterrey Institute of Technology (Huertas et al., 2012). Although the CALPUFF model is mostly recommended for long distances scenarios, there are exceptions for short distances scenarios, where the model is reliable to measure the behaviour of pollutants (EPA, 2005, 2008). In the present study it was evaluated the CALPUFF in the coal mining zone of Cesar department, where the local weather is influenced by the relationship mountain-valley. The study was performed in the dry period of January (2008). The concentration results obtained by the CALPUFF model were minor compared to the results obtained by System Monitoring Air Quality of the Department of Cesar, SVCADC. However it is necessary a closer examination of the emission factors of the mining projects as well as other emissions that are not related to the mining projects.

*Keywords: Dispersion model; MM5; CALMET; CALPUFF; coal minnig zone.*

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## 1. Introduction

The behaviour of the PM<sub>10</sub> produced in the coal mines “PLJ and Norcarbón” located in the Jagua de Ibirico town (Cesar) and the coal mine “El Hatillo”, located in El Paso town (Cesar) was studied to evaluate the model atmospheric prediction short term MM5 together with the diagnostic meteorological model CALMET and the dispersion model CALPUFF. (Scire et al., 2000). Although the CALPUFF model is mostly recommended for long distances scenarios, there are some exceptions for short distances where the model is reliable to measure the behaviour of pollutants in the air (Macintosh et al., 2010). In the present study CALPUFF model has been used in the coal mining zone of the department of Cesar (Colombia), where the local weather is influenced by the mountain-savannah relationship.

## 2. Features of the models

MM5 is a non-hydrostatic atmospheric model for short-term prediction that solves the dynamic equations of the atmosphere using numerical methods and with a higher resolution than the global models (Penn State University, PSU and the National Center for Atmospheric Research, NCAR). The formulation of a non-hydrostatic dynamics allows an to use efficiently the model for representing phenomena with dimensions of a few kilometers, (up to 1 km). It incorporates the most modern and realistic parameterization schemes of the physical processes related to: atmospheric-radiation; microphysics of clouds and precipitation; cumulus-convection; turbulence; flows of energy and momentum on the surface; winds.

CALMET is a diagnostic meteorological model that takes as input both meteorological data recorded in stations area and height. From these data it generates meteorological output fields. This model uses objective analysis methods seeking an optimal interpolation and extrapolation of observations (Scire et al., 2000).

The design of CALPUFF included: modeling pen emission as PUFF (Puffs or Puffs pollutant discrete packets of pollutants) besides the ability to modify the areas specific and emissions over time. Convenience to model from tens of meters to hundreds of kilometers from a source; estimates consensus in time periods that can range from one hour to one year; ability to consider the roughness or terrain conditions; ability to work with three-dimensional weather information.

The US Environmental Protection Agency (EPA) has the CALPUFF model as part of the recommended software packages for the dispersion of pollutants for evaluating transport of pollutants on a large scale and also for using to local scales where other variable are important (weather, low wind speeds, the effect of fumigation, recirculation or stagnation, effects due to the type of land or coast (Scire et al., 2000)).

## 3. Objectives

The objectives of the present study may be summarize as follows:

- Understand the benefits of implementing the prognostic meteorological model MM5 in the coal mining zone of the department of Cesar (Colombia).
- To evaluate the diagnostic meteorological model CALMET and the air quality dispersion model CALPUFF in two topographically different areas.
- To analyze the behavior of the dispersion of PM<sub>10</sub> simulated for CALPUFF and its effects in the study areas.

## 4. Methods

### 4.1 Description of the study area

The behavior of the dispersion of PM<sub>10</sub> generated in mining projects PLJ and NORCARBÓN located in the town of The Jagua de Ibirico and EL HATILLO mining project located in the town of The Paso is determined for their topographic differences. Two receivers were taken in each of the study sites, which were the same points of the SVCADC: the stations ZM1 and ZM2 (CORPOCESAR SVCADC, 2008).

*La Jagua de Ibirico.* This town is located in the central region of the department of Cesar, at the foot of the Cordillera Oriental. Its land area is 93,728 km<sup>2</sup>, with a municipal seat of 123.5 hectares, located at 9°25'N and 73°W. It includes a variety of climatic zones, from the hot plains to the mean climate of the “mountains” of the Motilones. Its main activity is the exploitation of coal. The municipal seat is 160 meters of altitude and its average temperature is 30 °C.

*La Loma- El Paso, Cesar.* It is a town with a great potential development, mainly in coal mining as a strategic natural resource. Located in the valley of Cesar River, it is topographically characterized by flat (savannah). Its population has grown exponentially in the last ten years and most of its inhabitants are people who are directly related to the coal business. It is 50 m of altitude and the average temperature is 32 °C.

### 4.2 Meteorology

Runs of the meteorological model forecast MM5 for the days 2, 8, 14, 20 and 26 of January 2008 in the maximum domain, the domain 1 (3312 km x 3388 km), with a central point in the city of Bogotá and a distance of grid points 36 Km These runs were made in the Laboratory of Meteorology graduate of the National University of Colombia, Bogotá. Besides the surface weather information that was used same period of Borrego station, located in the Pribbenow mine of Drummond, these days were considered to compare them with records of the monitoring of SVCADC. Both the meteorological data obtained from the modeling and from the validation were performed. Although it is not a period of time that can be sufficiently representative for scientific studies, this first step is given to present the advantages of modeling with CALPUFF in this kind of areas.

## 5. Results

### 5.1 Meteorology

The comparison was made between the meteorology data (obtained by the surface weather station Borrego) and the CALMET model results at 20 m. Furthermore the comparison was based in the more important variables, i.e., direction and wind speed, together with the heights of mixed layer. We noted that the grid point of the sheep CALMET station behaves almost in the same way as the surface measurement. In the evaluation of the grid points of La Loma and La Jagua de Ibirico, the study could appreciate that the CALMET model, which takes the information provided by the MM5, had a good behavior. This could be improved with more details of surface weather stations in the area of study.

## 5.2 Emissions

The sources of pollution (PLJ, Norcarbón, El Hatillo) were taken as source areas that continuously are emitting particulate matter. For introducing the variable model emission in CALPUFF, this study took the PM<sub>10</sub> emission factors calculated in the modeling study by Technology of Monterrey in 2008 (EPA, 1998; Angulo et al., 2011; Huertas et al., 2012).

## 5.3 Background Concentration

The background concentration used was the monthly average of SVCADC ZM11 station, Minguillo. In January 2008 the background was 34.19 µg/m<sup>3</sup>.

## 5.4 Results of dispersion of PM10

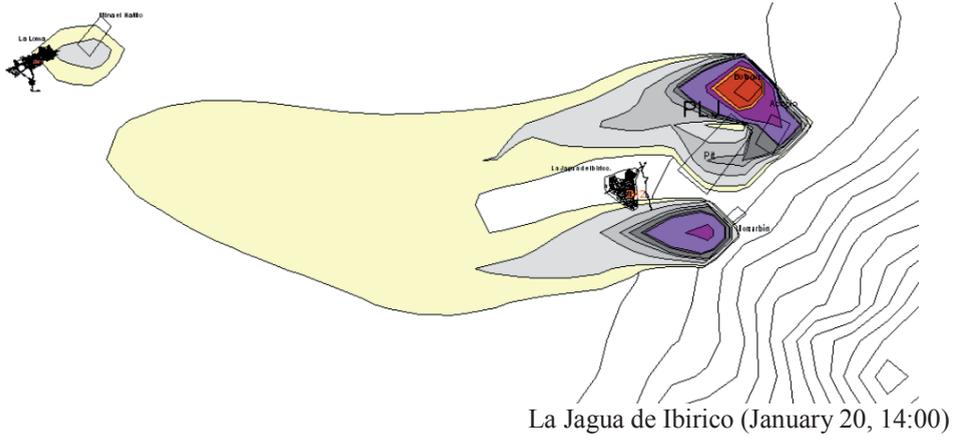
The behavior of the PM<sub>10</sub> dispersion thrown by CALPUFF for each of the study sites (Table 1; Fig. 1) showed significant differences due to the complexity of the meteorology of the area. The CALMET meteorological model for the site located in the low mountains (the town of La Jagua de Ibirico) showed that the mixed layer heights were considerably higher than in the plain siting, the village La Loma. For its location in the low mountain (at higher altitudes) the contamination plume of mining projects PLJ and Norcarbón can travel greater distances. Meteorological data simulated by CALMET were consistent with the data recorded by the weather station Borrego, which supports the PM<sub>10</sub> results obtained.

CALPUFF was able to obtain the behavior of the concentration levels for each day, presenting a schedule report of PM<sub>10</sub> concentrations. It also revealed the concentration peaks of each receptor. La Loma receptor showed much variability in their concentration levels hours; a common daily behavior pattern was observed in study days as for the receptor of La Jagua de Ibirico.

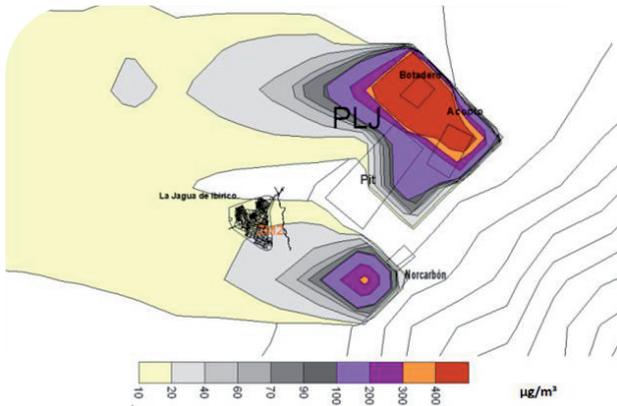
No doubt that CALPUFF is a very useful model in studies of environmental impact of coal mining areas. It has the great advantage to allow the use of real weather data together with data of prognostic models more easily. It also considers the problem of absence of radiosonde data in the Cesar mining area. It should be mentioned that unfortunately the modeling studies in this zone used radiosonde data obtained from areas totally different and distant of the study objective. In this preliminary study it is suggested that use of MM5 forecast model is a great option that should be considered for investigating studies in areas of open pit mining operation.

Table 1. Concentrations results of CALPUFF vs. SVCADC (µg/m<sup>3</sup>).

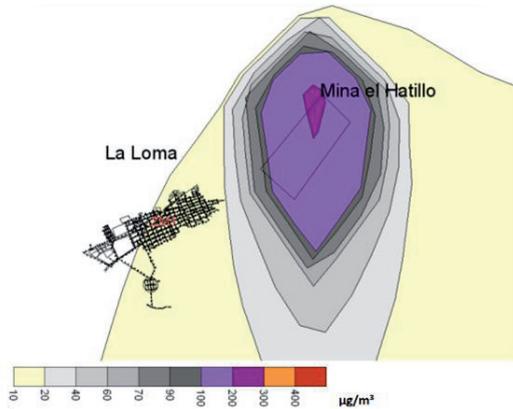
Day of monitory	ZM1 SVCADC LA LOMA	CALPUFF	ZM2 SVCADC LA JAGUA	CALPUFF
January 2	45.58	40.41	59.88	35.46
January 8	57.57	38.31	-	-
January 14	-	-	53.32	43.71
January 20	57.74	44.89	63.39	50.77
January 26	50.50	41.19	65.85	44.24



La Jagua de Ibirico (January 20, 14:00)



La Jagua de Ibirico (January 20, 14:00)



La Loma (January 20, 14:00)

Fig. 1. CALPUFF in the coal mine zone in the department of Cesar, Colombia.

## 5. Acknowledgments

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