The Importance of CMAQ Modeling in Placing Industrial Centers

Ayres G. Loriato,[1]Taciana T. de A. Albuquerque[1], Erick G. Sperandio Nascimento[1], Renato S. Marinho[2], Nadir Salvador[1], Neyval C. Reis. Jr.[1].
ayresloriato@yahoo.com.br[1]
[1]Federal Universisity of Espírito Santo – Department of Environmental Engineering
[1]Federal Universisity do Espírito Santo – Department of Geography

During the 1970's, large industrial facilities were installed in the northeastern region of Grande Vitória, Espírito Santo, Brazil. These facilities were built to enable production and port exportation of goods from the ore, steel and pelletizing industries, but the prevailing winds in the area carry the resulting gases and particles emissions to the city's most populated sector. This has led to legal disputes between residents and companies, generating additional costs for the enterprises in the form of mitigating actions and upsetting the populace, which has to deal with the impact of the industrial emissions, including breathing the polluted air. In this study, the WRF (Weather Research Forecasting) and the CMAQ (Community Multiscale Air Quality) were used in conjunction with the inventory of the local emission sources to better understand the situation, allowing for future environmental permits to consider the best modeling technologies to preserve the rights of both citizens and investors. This approach supports Gégo et al. (2006), which considers computational modeling as the main tool to be used be agencies to develop emission reduction strategies aimed at reaching admissible and safe air quality.

Palavras chaves:

INTRODUÇÃO

The region of the Great Victory (RGV) has a population of almost two millions of inhabitants and it is a region with large industrial facilities. These facilities were built to enable production and exportation by port of goods from the ore, steel and pelletizing industries. The population of RGV reclaims against the pollution level and also the discomfort caused by the deposition of particles. Not infrequently the local newspapers bring reports of activities of the Public Ministry of Espírito Santo_BR (MPES) against large companies requiring mitigation actions of its polluting operations. The latest court decision, accepting MPES's demand and the state court ruled that a company will be required to install "Wind fence" (wind barrier to contain the transport of dust) in two areas of coke, the steel mill, sintering and patios storage of raw materials, within 4 months. Also prohibits the IEMA (State Institute of the Environment and Water Resources) to grant new licenses or renewals of environmental licenses (Official "The Gazette", edition from 14/07/2012, pg 3). In 2007 three major companies in the Espirito Santo (ES), signed a Term Adjustment of Conduct (TAC) with the MPES, IEMA and community leaders. Vale assumed the commitments of applying dust suppressant in handling the pellets and in the courtyards of coal and ore; study new technologies aimed at improving the control of particulate emissions during loading operations ore and pellets on ships; enclose transfers of conveyor belts; support (IEMA) in the deployment of Network Monitoring and Characterization of Dust settleable the Great Victory; assign a committee to monitor the installation of two new ship loaders equipped with a tube on the end of the boom thus avoiding dispersion of dust during the loading and finally adopt restrictive measures and penalties of operation and production. (Newsletter VALE 2009). Continuing the process of innovation in the environmental area, the Valley has expanded its range of environmental projects in August 2009 to launch controllers particulate matter (PM), "Wind Fence". These actions were completed recently and according to information from the company itself cost exceeds the home of hundreds of millions of dollars. The facts show that today's society is not willing to accept only the provisions of the law, but to require of the state its right to fight over the air that breathe and the discomfort caused by industrial emissions. Therefore any industrial undertaking, potentially polluting, not just get the environmental permits, complying with current legislation, but must use the best available technologies to control emissions in order not to affect the area potentially affected by its activities. Concern over air pollution justifies the need for knowledge of the best simulation techniques to forecast pollution levels and emissions control. The models are the primary tool used by agencies to develop emission reduction strategies aimed at achieving acceptable air quality and safety. (Gego et al. 2006).

The CMAQ was used in this work and is a modeling system that can deal with issues of research on problems of air quality, with applications of meteorological multiple scales and for various pollutants (Wang F. et al, 2010). The model is based on the basic concept of unique atmosphere, in which only the simulation of the concurrent action of the set of all physical and chemical processes in the atmosphere is what constitutes an element capable of conferring accuracy to simulations (Tao et al., 2005).

METODOLOGIA

The Weather Research and Forecasting (WRF) model is a meteorological model that is compatible with CMAQ. The processor meteorological used was the WRF-3.2.1 with the following parameterizations:

Nesting of four grids, with the external grid composed of 1369 cells of 27x27 km. The second grid containing 3025 cells of 9x9 km. The third grid have 7225 cells of 3x3 km and the inner grid, the interest for CMAQ is composed of 5896 cells of 1x1 km. The CMAQ is mesoscale model, but there are works with good results like Lim et al. (2010), Jimenez et al. 2006) e Shoki et al. (2006).

Some phisical parameterizations used in WRF were:

ETA_levels = 21 níveis

mp_physics = 8,8,8,8 (Tompson graupel scheme -2_moment scheme in V3.1)

ra_lw_ physics = 1,1,1,1 (Rrtmg scheme)

ra_sw_ physics = 1,1,1,1 (Dudhia scheme)

sf_surface_physics =2,2,2,2 (Unified Noah land surface model)

sf_sfclay_physics = 1,1,1,1 (Monin-Obukhov scheme)

sf_urban_physics =0,0,0,0 (no urban physics)

cu_physics = 2,2,2,2 (Betts-Miller-Janjic scheme)
bl_pbl-physics = 1,1,1,1 (YSU scheme)
Ref_lat = -20.2747
Ref_lon = -40.3072

Inventory Sources

It was used the inventory of sources of IEMA (State Institute for the Environment and Water Resources of the Espírito Santo_BR) to the region of the Great Victory (RGV). The emissions inventory are available on annual data for the pollutants PM_10, PM_2, 5, SO2, CO, NO2 and VOCs. This study uses for the first time in scientific papers, a regional inventory in Brazil, which can be a source of uncertainty in the results. Outside U.S. (United States), China and parts of Europe, the main difficulty of using models that rely on emission inventories is the absence or reliability of the inventory. It is to praise the fact that the state agency's environmental ES (Espírito Santo_BR), is one of the few in Brazil that offers inventory. The sources were grouped into area type and punctual type.

Area sources

The sources of the type area were divided into two types: the sources of vehicular emissions and diffuse sources. The vehicular sources were treated considering the proportionality of the flow of vehicles with emissions pathways. Within each cell of the grid was considered the corresponding portion of the track as a source of emissions. How the traffic flow is not constant throughout the day, week and month, the functions of the temporal report IEMA_ES were used. Diffuse sources are mostly stacks of ore and coal industries located in the northeast of the RGV. These piles, often occupy, even partially, more then one grid cell. Thus, it was necessary to make the emission from these sources proportionality within each cell, namely the spatial distribution of point sources in the grid. The result of these hourly emissions for pollutant PEC (Aerosol elemental carbon), in figure 1a.

Point Sources

Emissions from point sources of RGV, come from chimneys of a large steel industry and a mining company plus dozens of other small scale industries. An overview of these hourly emissions within the grid for pollutants AECJ are in the figure 1b.

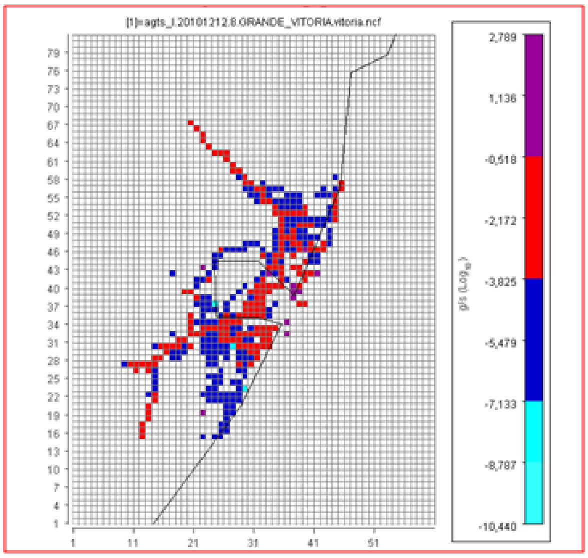

Fig 1a: Emissões de fontes área na data de 12/15/2010 às 19:00GMT

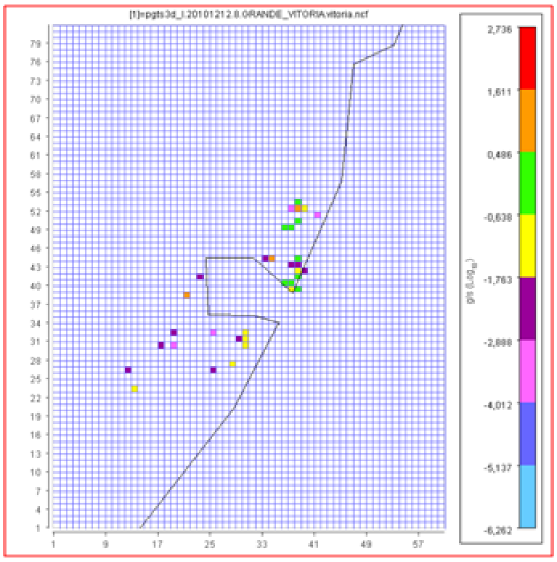

Fig 1b: Emissões das fontes pontuais (Layer3) na data de 12/15/2010 às 19:00GMT

Biogenic Emissions

The MCIP(*Meteorology - Chemistry Interface Processor*) makes the necessary conversions of meteorological data and land use in SMOKE and CMAQ. The land use data of MCIP is used to obtain emission biogenics. The figure shows a emissions of isoprene, one of the most importants biogenic compounds. Accordind Gunther et al (2006) reactive gases and aerosols are produced by terrestrial ecosystems, processed within plant canopies, and can then be emitted into the above-canopy atmosphere. Estimates of the above-canopy fluxes are needed for quantitative earth system studies and assessments of past, present and future air quality and climate. MEGAN (Model of Emissions of Gases and Aerosols from Nature) is designed for both global and regional emission modeling and has global coverage with 1 km^2 spatial resolution.

SMOKE

The SMOKE (Sparse Matrix Operator Kernel Emission) is the most complex processors. Adjusting the inventory data sources so that emissions remain as if they were generated within a cell cubic. It consists of several interconnected arrays that process emissions from point sources, area sources, mobile sources, biogenic sources and other.

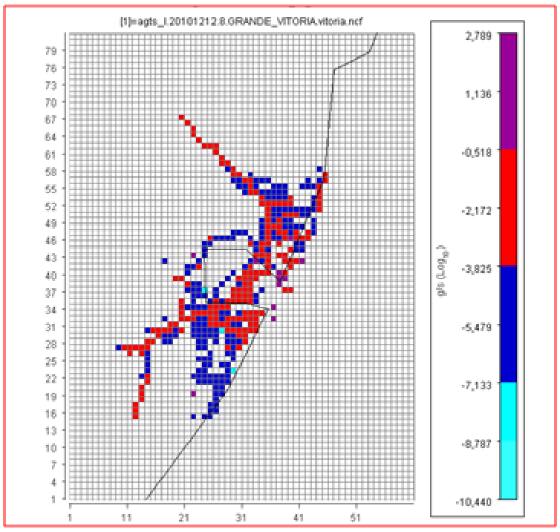

Fig 1a: Emissões de fontes área na data de 12/15/2010 às 19:00GMT

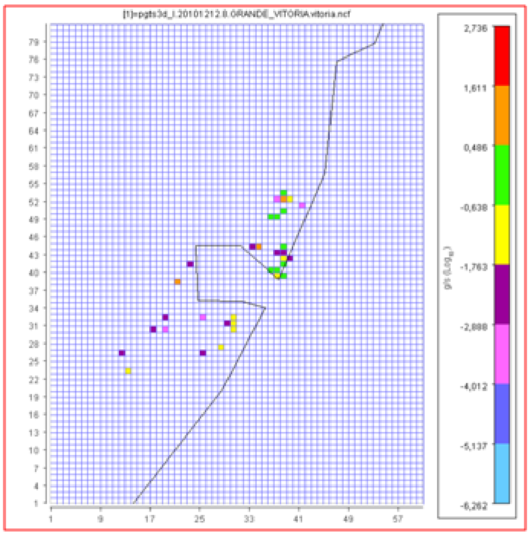

Fig 1b: Emissões das fontes pontuais (Layer3) na data de 12/15/2010 às 19:00GMT

RESULTS

Most large industries facilities are located in the northeast of the main cluster housing in the region and most of the complaints in relation to concentrations of pollutants refers to industrial pollution. Because of this, this study aimed to study the transport of a marker eminently industrial emissions as AECJ (Aerosol elemental carbon in mode of accumulation). Figures 2a, 2b, 2c and 2d show the simulated concentration AECJ within the CMAQ grid in times of 9:00, 12:00, 15:00 and 18:00 pm the day 15/12/2010. The plume distribution of concentrations remains with its maximum concentration on the most densely populated region of the RGV throughout the day.

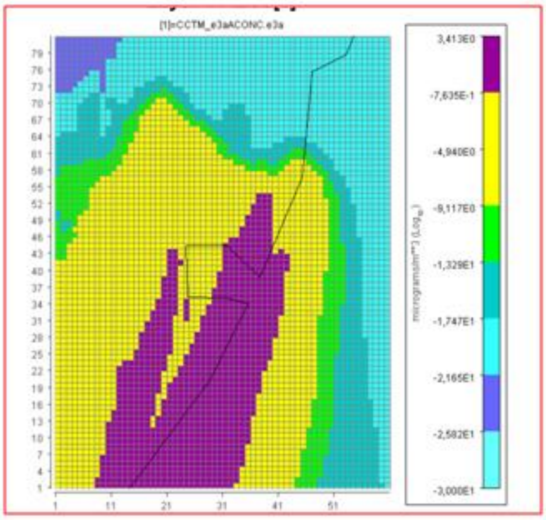

Fig 2ª: Concentração de AECJ na data de 12/15/2010 às 09:00GMT

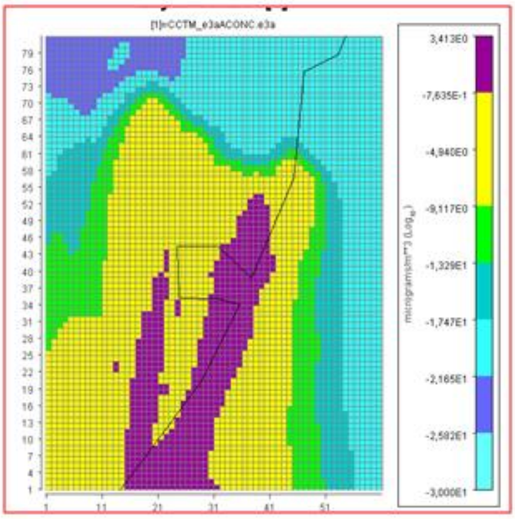

Fig 2b: Concentração de AECJ na data de 12/15/2010 às 12:00GMT

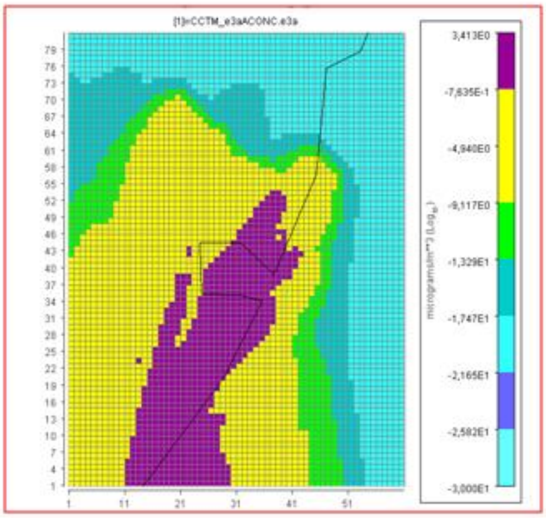

Fig 2c:Concentração de AECJ na data de 12/15/2010 às 15:00GMT

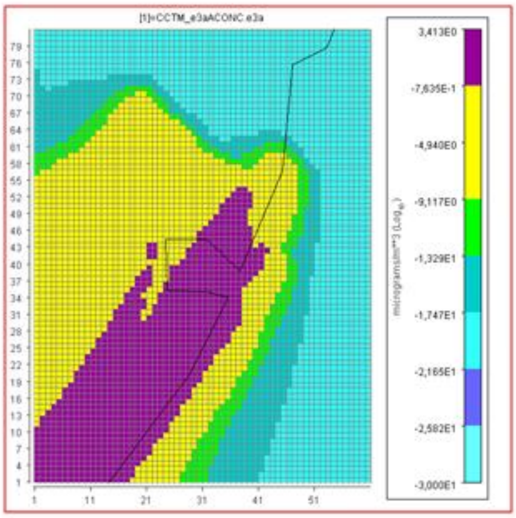

Fig 2d:Concentração de AECJ na data de 12/15/2010 às 18:00GMT

DISCUSSION

Models predict volume averaged concentrations, whereas monitors measure concentrations at a single point in space. This introduces uncertainty in model performance evaluation if pollutant concentrations are spatially inhomogeneous. The errors in models comes from a number of factors such as the variety of spatial concentrations of pollutants, but also the emissions inventory, meteorological data, parameters and chemical mechanism numerical routines (Park et al., 2006). It's no different for this simulation because a regional inventory can bring uncertainty and the chemical speciation itself, but it is an evolution and an incentive to work elsewhere in the availability and improvement of emission inventories and chemical speciation of pollutants. Actions of this kind would allow a modeling of better quality, higher reliability in the opinions of environmental agencies and a much lower cost both to investors and to the population potentially affected by the project.

CONCLUSIONS

According to Park et al., 2006, errors in models comes from a number of factors such as the of spatial variability of pollutants concentrations, but also the emissions inventory, meteorology, chemical mechanism parameters and numerical routines. However the estimate found in the CMAQ simulations allow agents to take the right decisions while preserving the interests of society. The case study shows situations of large industries established in the 1970s, faced legal disputes with organized societies of residents who feel harmed by the emissions from these sources. Today, several developments, discuss environmental permits and becomes increasingly evident the importance of model simulations, that they not only protect the interests of investors but also the population affected by the emissions of pollutants, because even if the concentrations are within the limits maximum required by law, justice and society no longer accept the hassle, requiring mitigating actions involving large investments.

REFERENCES

ALBUQURQUE, T. T. A. **Formação e transporte de partículas finas inorgânicas em uma atmosfera urbana: O exemplo de São Paulo.** Tese de Doutorado – Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo-USP. São Paulo, 2010.

Gégo, E., Porter, P. S., Hogrefe, C., Irwin, J. S. .**An objective comparison of CMAQ and REMSAD performances.** Atmospheric Environment 40 (2006) 4920–4934.

Gunther, A., karl, T., Harlet, P., Wiedinmier, C., Palmer, P. L., Geron, C.. **Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature).** Atmos. Chem. Phys., 6, 3181–3210, 2006.

Park, S. K., Coob, C. E., Wade, K., Mulholland, J., Hu, Y., Russel, A. G.. **Uncertainty in air quality model evaluation for particulate matter due to spatial variations in pollutant concentrations.** Atmospheric Environment 40 (2006) S563–S573.

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

Liu, X. H., Zhang, Y., Olsen, K. M., Wang, W. X., Do, B. A., Bridgers, G. M.. **Responses of future air quality to emission controls over North Carolina,**
Part I: Model evaluation for current-year simulations. Atmospheric Environment 44 (2010) 2443e2456.

Shoki, R. S., San José, R. Kitwiroon, N., Fragkou, N., Péres, J. L., Middleton, D. R.. **Prediction of ozone levels in London using the MM5–CMAQ modelling system.** Environmental Modelling & Software 21 (2006) 566–576.

Tao, Z., Larson, S. M., Williams, A., Caughey, M., Wuebbles, D. J.. **Area, mobile, and point source contributions to ground level ozone: a summer simulation across the continental USA.** Atmospheric Environment 39 (2005) 1869-1877.

Wang F., Chen,D. S., Li, M. J., Ren, Z. H.. **Identification of regional atmospheric PM10 transport pathways using HYSPLIT, MM5-CMAQ and synoptic pressure pattern analysis.** Environmental Modelling & Software 25 (2010) 927e934.