PERFORMANCE ASSESSMENT OF REGULATORY AIR QUALITY MODELS AERMOD AND CALPUFF - A NEAR FIELD CASE STUDY IN METROPOLITAN REGION OF RIO DE JANEIRO, BRAZIL

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Introduction

The AERMOD and CALPUFF air quality models have been recommended by environmental agencies for use in regulatory purpose (EPA, 2005). The AERMOD is recommended for near-field regulatory applications (EPA, 2009) (less than 50 km) and CALPUFF is recommended for environmental impact assessment in long range transport (LRT) (beyond 50 km), it been considered as an alternative model on a case-by-case basis for near field applications involving complex winds (EPA, 2005).

According to Rio de Janeiro Environmental State Institute (INEA, 2004) the mobile sources represent 77% of total pollutant emission, while stationary sources contribute with 22%. However, 88% of SO_2 emission comes from stationary and just 12% from mobile sources. Among the stationary sources, the petrochemical industry has a major contribution on RJMR pollutant emissions with 51% of SO_2, 38% of NOx and 90% volatile organic compounds (VOC).

The most part of the oil and gas national production of Brazil occur on Rio de Janeiro continental shelf (80%) and the recent discover of oil in subsalt layer represents the possibility to increase the oil production in a few years (MME, 2010).

The RJMR is inserted on complex topography area influenced by Atlantic Ocean and Guanabara Bay (fig.1) providing an inhomogeneous condition for atmospheric dispersion. The features of this region, involving different time and space scales phenomena, cause changes in the local atmospheric circulation, such as: South Atlantic Subtropical Anticyclone, Cold Front, South Atlantic Convergence Zone, Convective Activity, valley/mountain and land/sea breeze.

The mainly goal of this study concern to assess the uncertainty of air quality models, by using statistical index, in order to simulate the pollutant transport in inhomogeneous dispersion conditions into RJMR to near-field scenarios.

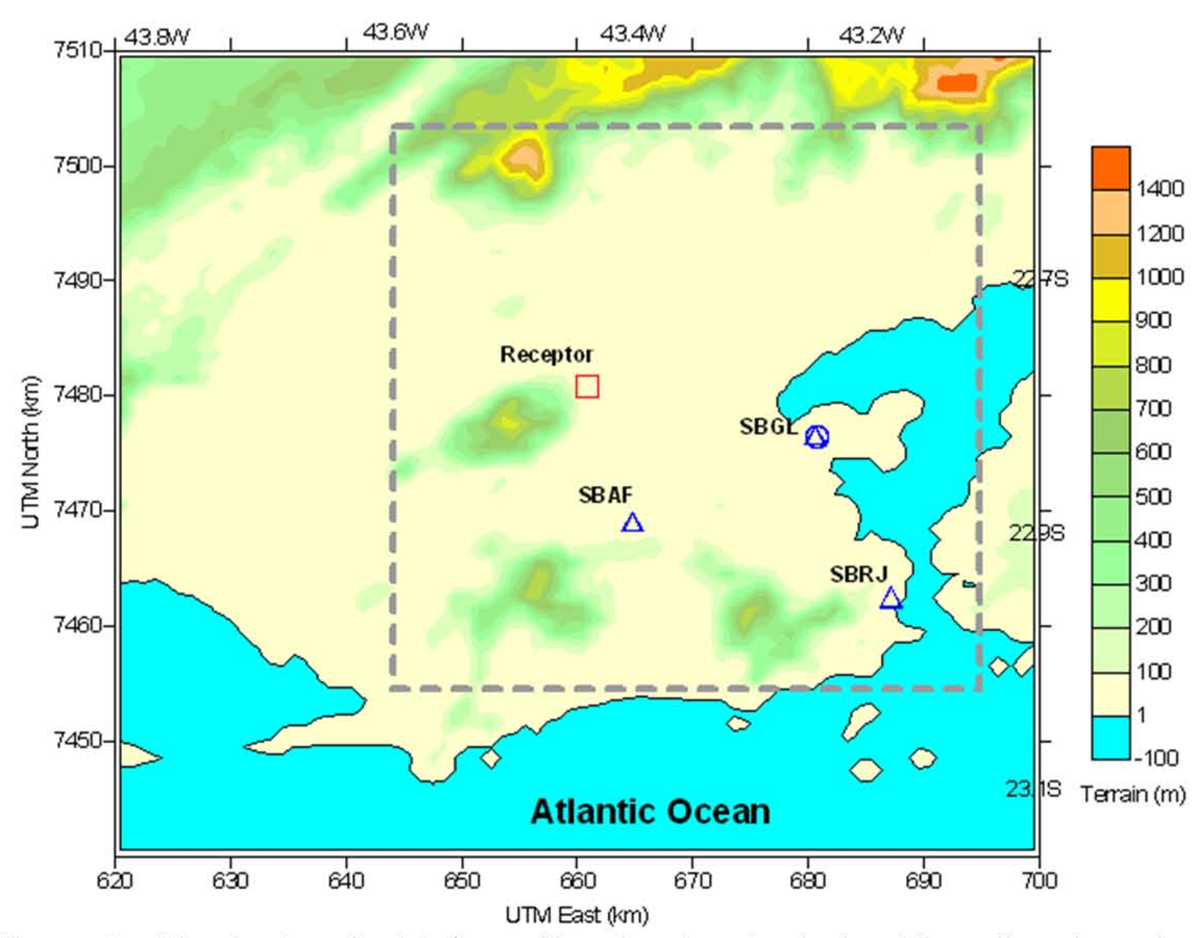

Figure 1 – Rio de Janeiro Metropolitan Region. In dashed lines the domain of AERMOD and CALPUFF simulations.T he red square indicate the SO_2 receptor, at blue triangle the surface meteorological stations and at blue circle the upper air station.

Metodology

The SO_2 concentrations were simulated by AERMOD and CALPUFF for RJMR from 20th August to 20th September 2008 for evaluation against observed data available in a near-field condition. Emission data from both mobile and stationary sources were used as line and area source respectively in AERMOD and just as area sources in CALPUFF.

The model simulations were set up with upper air data from International Airport of Rio de Janeiro (SBGL) located around twenty kilometers from the air quality station and ten kilometers of the major stationary emission sources and surface meteorological data provided from Santos Dummont Airport (SBRJ), Afonsos Airport (SBAF) and SBGL, with different configurations (Table 1).

Table 1 – Descriptions of Simulations

SIMULATIONS	SURFACE STATION	UPPER AIR STATION	METEOROLOGICAL PROCESSOR	DISPERSION MODEL
AERMOD	SBGL	SBGL	AERMET	AERMOD
CALPUFF 1	SBGL	SBGL	CALMET	CALPUFF
CALPUFF 3	SBGL, SBRJ and SBAF	SBGL	CALMET	CALPUFF

Results

The wind rose representative of airports surfaces stations are presented in figure 2. It can be noted that for SBAF occur south and southwest directions predominantly, with maximum intensity of the 8.8 m/s and 11.5% of calm winds. At SBGL the southeast pattern is more evident with maximum intensity similar to the observed at SBAF and calm regime lightly lower just 6.7% of calm winds. At SBRJ the calm regime is around 4.3% with main direction from south sector and maximum intensity of the 11 m/s. The wind regime analysis shows a lightly variability of the atmospheric circulation pattern surrounding the analyzed emissions area strengthening the inhomogeneous features of the region as discussed previously.

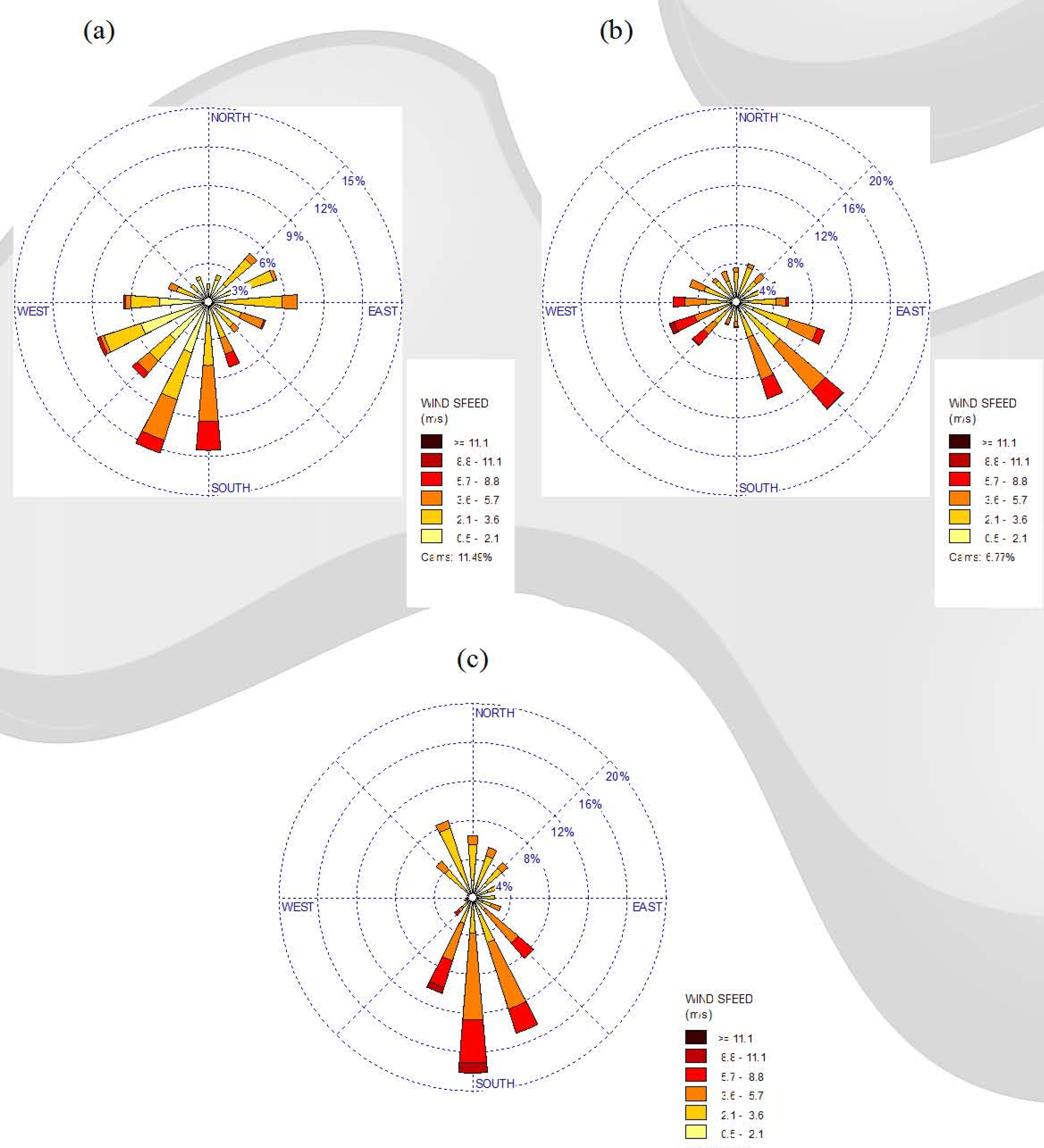

Figure 2 – Wind rose for SBAF (a), SBGL (b) and SBRJ (c) during simulation period.

The statistical results analysis are presented in table 2. The correlation index showed more realistic temporal variability pattern of concentrations by CALPUFF, indicating a potentiality to represent pollutant transport on near-field in RJMR. The measure of mean relative scatter performed by AERMOD NMSE index presents poor value when compared with CALPUFF's values. The FS index shows the comparative values between the two CALPUFF's configurations, where is observed an overestimative of the monitored concentration dispersion field against the behavior obtained with AERMOD. From FB index analysis can be noted that the AERMOD results underestimate observed concentration levels while the CALPUFF's FB index indicates an overestimative.

For regulatory purpose is expected that simulated results should be conservative to concentration level, then it was highlighted that the AERMOD model simulation to RJMR should be done carefully.

Table 2 –Statistical results of AERMOD and CALPUFF evaluations against observed data

STATISTICAL INDEXES	CALPUFF 1	CALPUFF 3	AERMOD
R	0.48	0.52	0.36
NMSE	0.71	0.68	1.67
FS	-0.60	-0.59	0.72
FB	-0.37	-0.44	0.90
FAC2	0.70	0.59	0.33

The Scatter Plots in figure 3 highlights that CALPUFF results were better than AERMOD, mostly overestimating observed data while the last one underestimated data. Also CALPUFF 1 performed better than CALPUFF 3 presenting a higher FAC2. It can be attributed by the weight given for the three surface meteorological data in CALPUFF 3 that are set by the parameters R1 and RMAX1 in CALMET, then this parameter must be best analyzed with sensibility studies to obtain the region appropriate value. In this work the R1 value was equal to eight kilometers and RMAX1 equal forty kilometers.

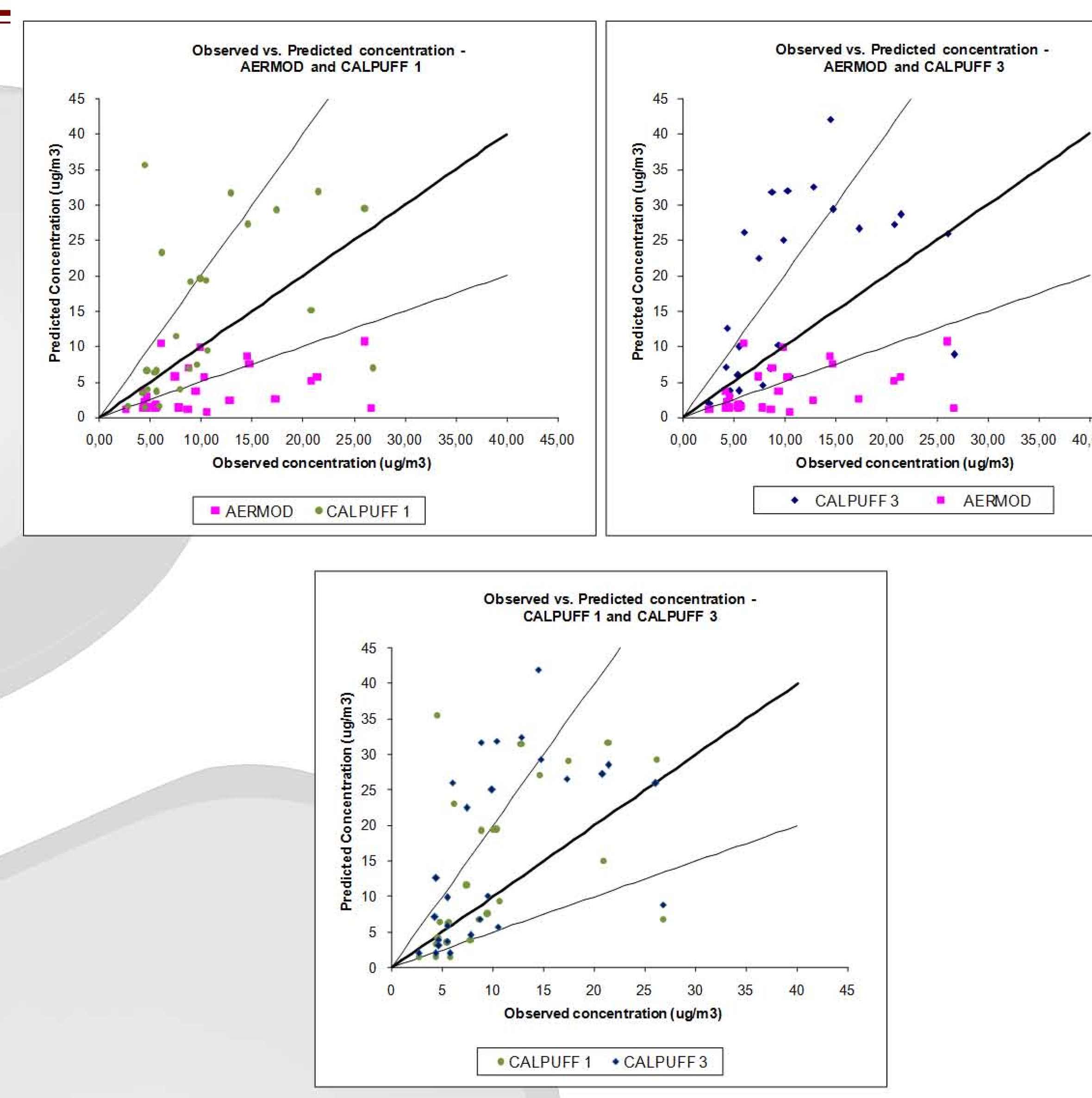

Figure 3 – Observed vs. Predicted concentration by AERMOD, CALPUFF 1 and CALPUFF 3.

Conclusions

The evaluation of modeling concentrations results against observed data performed by statistical indexes indicated that the CALPUFF simulations presented best performance than AERMOD one in near-field scenarios at RJMR.

The CALPUFF pattern tends to overestimate the monitoring data against the behavior obtained with AERMOD. It shows that the CALPUFF model performed a conservative pattern, however is hoped that the use of removal process would improve results.

The highest meteorological data assimilation from surface stations on CALMET played an important role on correlation and NMSE results while worsened the FAC2 and FB. Thus it is important to emphasize that extensive studies of wind station weight are required in order to play more realistic CALPUFF simulations in RJMR with several wind data.

Besides AERMOD is the recommended model for regulatory purposes in near-field situations, CALPUFF indicated be more promissory for studies in this region based on the relevant features inhomogeneous local conditions for atmospheric dispersion. Based on these results the use of air quality models require more studies for this region in longer periods and a variety of atmospheric conditions.

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