Inorganic Aerosols Response to SO_2 Emissions Reductions in the Metropolitan Area of São Paulo - Brazil

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Introduction

The Models-3 Community Multiscale Air Quality Modeling System (CMAQ) was used to investigate the spatial and temporal variability of the efficacy of emissions control strategies in the Metropolitan Area of Sao Paulo (MASP). In particular, it was investigate the response of inorganic aerosols to changes in precursor (SO_2, NO_x, NH_3) concentrations. An aerosol sampling campaign was performed during 10 days of the winter 2008 (Aug. 12 – Aug. 22) to compare with modeling results. Meteorological fields were modeled using the Weather Research and Forecasting model WRFv3.1, for the 12-day period, using three nested domains with 27-km grid resolution (34 x 34 cells), 9-km (52 x 52 cells), and a high resolution domain of 3-km (109 x 76 cells). Only the 3-km domain was aligned with the CMAQ domain, which covers the most polluted cities in the MASP (Campinas, Sorocaba, São José dos Campos and Cubatão). The SMOKE emissions model was applied to build a spatially and temporally resolved vehicular emissions inventory for MASP and its surroundings. Seven different scenarios were simulated considering the current emission inventory, a future scenario considering a reduction of 50% of SO_2 emissions, a scenario considering no SO_2 emissions, a reduction of 50% of SO_2, NO_x and NH_3 emissions, a scenario considering no sulfate (PSO4) and nitrate (PNO3) particles emissions, another considering only excluding the PSO4 emissions and the last one considering no PNO3 emissions.

Characteristics of the Metropolitan Area of São Paulo, Brazil

Fig 1- Characteristics of MASP

✓MASP is located in the following geographical coordinates: 23.6 S and 46.7 W. It is almost 70 km distance from the ocean.

MASP = São Paulo city + 38 cities:
19 million inhabitants
7,2 million vehicles
2000 significant industrial plants

Models Configurations

- Meteorological Model: Weather Research and Forecasting (WRF) version 3.1
- Met Data: GFS data (1˚× 1˚)
- USGS – Global Land Cover
- Air Quality Model: Community Multiscale Air Quality Model (CMAQ) version 4.6
- Vehicle Emission Inventory created by: Sparse Matrix Operator Kernel Emission (SMOKE)

WRF

Physics option	Scheme
Microphysics	Thompson et al.
Long wave radiation	RRTM scheme
Short wave radiation	Dudhia scheme
Surface layer	Pleim Xiu scheme
Land surface	Pleim Xiu scheme
Planetary Boundary Layer	Pleim Xiu ACM2 scheme
Cumulus Parameterization	Kain – Fritsh scheme

CMAQ

Mechanism	Option
Gas Phase	Carbon Bond V
Aerosol module	Aero4
Mechanism	*cb05_ae4_aq*

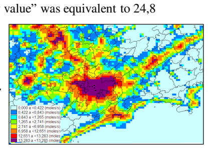
Models Configurations

	Domain-1	Domain-2	Domain - 3
Area	918 km²	468 km²	327km x 228km
WRF Grids	34 ×34×21	52 x 52 x 21	109 ×76×21
WRF Grids Resolutions	27 km	9 km	3 km
CMAQ and SMOKE Grid	102 x 69 [3 km] 306 km x 207 km		

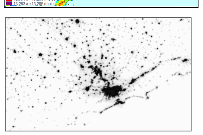
SMOKE model inputs

- *Spatial distribution surrogate*:
  - Earth's city lights created with data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) .
- *Temporal distribution*:
  - Same for the whole area
  - Light-duty fleet: Lents et al., 2004
  - Heavy-duty fleet: CETESB, 2008
- *Fleet distribution and activity*: SPtrans and CETESB, 2008
- *Emission Factors*:
  - CO, NOx and PM_{10}: Sanchez et al., 2009
  - VOC´s and SO_2: CETESB, 2008
  - NH_3: Fraser and Cass, 1998
- *Vehicular Density:*
  - Each "city light intensity value" was equivalent to 24,8 vehicles.km^{-2} .

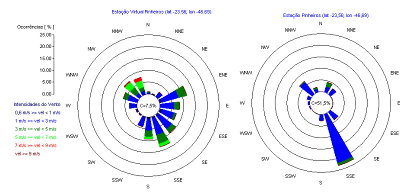
SMOKE output: CO emission at 08 LT

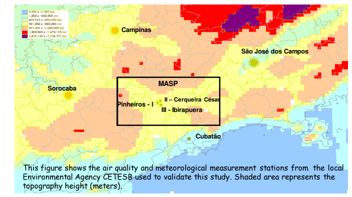


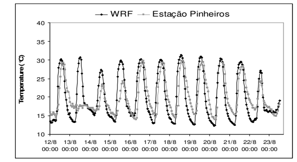
Negative of City Lights in our study area: MASP and surroundings

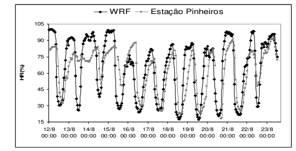


WRF Results: A comparison between WRF (3km) and Pinheiros Station





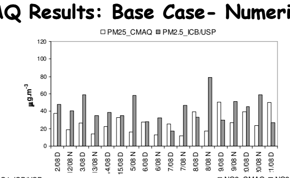


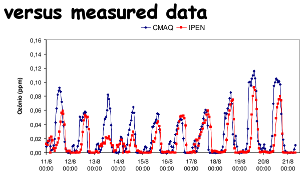


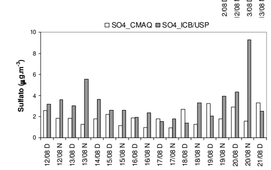
Emission Database and Sensitivity Cases

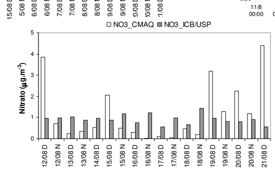
Cases	Emissions Sensitivity
Case-1	Base Case
Case-2	Reducing 50% of the SO_2 emissions
Case-3	No SO_2 emission (SO_2 = 0)
Case-4	Reducing 50% of the SO_2, NH_3, No_x emissions
Case-5	No emissions from PSO_4 and PNO_3
Case-6	PSO_4 =0
Case-7	PNO_3 =0

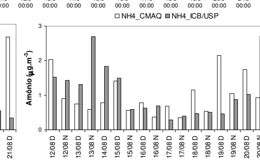
CMAQ Results: Base Case- Numerical versus measured data





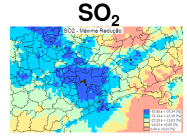




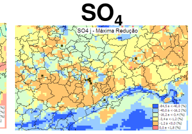


SO_2 | SO_4 | NH_4 | NO_3 | $PM_{2.5}$

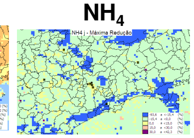
CASE-2



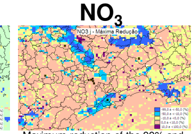
Maximum reduction ~57%



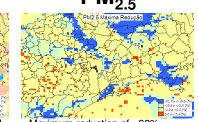
Maximum reduction of the 84,5%



Maximum reduction of ~94%. Increase of the 42%; MASP increases 15%.

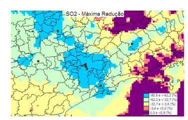


Maximum reduction of the 99% and increase of the100%.

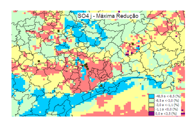


Maximum reduction of ~92% – Maximum Increase of the7,4%. In average reduction of the 2%.

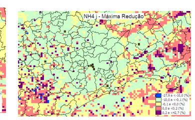
CASE-3



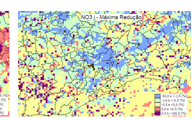
Maximum reduction of ~80%



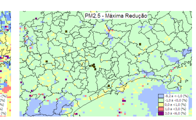
Maximum reduction of ~49%



Maximum Reduction ~28% - Increase of the 43%.

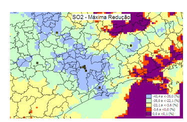


Maximum Reduction ~93% - Increase of the 100%;

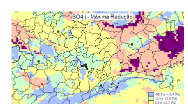


Maximum Reduction ~9%

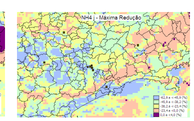
CASE-4



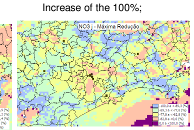
Maximum reduction of ~ 43,5%



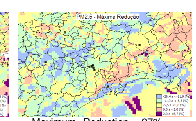
Maximum Reduction of 58,5% - Increase until 25%.



Maximum Reduction of the 62%.



Maximum Reduction of the 100%.



Maximum Reduction ~27% - Increase ~7%

CONCLUSIONS

The results show that between the different scenarios at measurement stations, SO_2 concentration was seen to vary substantially as SO_2 emissions changed, but $PM_{2.5}$ showed much less variation due to the slow conversion of SO_2 to sulfate and the contribution of other $PM_{2.5}$ species. The SO_2 varied considerably among the sceneries, but $PM_{2.5}$ showed much less variation mainly due to the contribution of other $PM_{2.5}$ species. The main results showed that reductions in SO_2 emissions may be less effective than expected at reducing $PM_{2.5}$ concentrations at many locations of the MASP. The spatial and temporal distribution of concentration varies in the whole domain. The largest reduction in $PM_{2.5}$ was obtained when occurred a reduction of 50% of SO_2, NO_x and NH_3 emissions. Experimental data in São Paulo City showed that almost of 70% of the $PM_{2.5}$ mass is composed by the secondary organic aerosols and of Black Carbon, therefore their role need to be considered when making policy decisions to control the $PM_{2.5}$ concentrations in the MASP.

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