Inorganic Aerosols Response to \(\text{SO}_2\) 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 São Paulo (MASP). In particular, it was investigated the response of inorganic aerosols to changes in precursor (\(\text{SO}_2\), \(\text{NO}_x\), \(\text{NH}_3\)) 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 modelled using the Weather Research and Forecasting model (WRF)\textsuperscript{v.3.1}, 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, Sorocabá, 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 \(\text{SO}_2\) emissions, a scenario considering no \(\text{SO}_2\) emissions, a reduction of 50\% of \(\text{NO}_x\) and \(\text{NH}_3\) emissions, a scenario considering no sulfate (PSO4) and nitrate (PN3O) particles emissions, another considering only excluding the PSO4 emissions and the last one considering no PN3O emissions.

Characteristics of the Metropolitan Area of São Paulo, Brazil

\textit{MASP} is located in the following geographical coordinates: 23.5 and 46.7 W. It is about 70 km distance from the ocean. MASP = São Paulo city + 38 cities: 13 million inhabitants, 7.2 million vehicles 2000 significant industrial plants

Models Configurations

- Meteorological Model: Weather Research and Forecasting (WRF) version 3.1
- Emission Inventory created by: Sparse Matrix Operator Kernel Emission (SMOKE)

WRF Physics Options

- Microphysics: Thompson et al.
- Longwave radiation: RRTM scheme
- Shortwave radiation: Dudhia scheme
- Surface Radiation: Runge-Kutta
- Land surface: Noah-ZS scheme
- Runaway Boundary Layer Scheme: Runout 1A/BK2 scheme
- Canopy Parametrization: Ek - Elith scheme

CMAQ Source Options

- Gas Phase: Carbon Bond V
- Aerosol nucleation: Aging
- Mechanism: \textit{aer}_fc

Models Configurations

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Emissions Sensitivity</th>
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</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>(\text{SO}_2) emissions reduced by 64%</td>
</tr>
<tr>
<td>No (\text{SO}_2) emissions</td>
<td>(\text{SO}_2) emissions reduced by 64%</td>
</tr>
<tr>
<td>Reduction of 50% (\text{SO}_2) emissions</td>
<td>(\text{SO}_2) emissions reduced by 64%</td>
</tr>
<tr>
<td>No emissions from (\text{PSO}_4) and (\text{PN}_3\text{O}) particles</td>
<td>Reduction of 50% (\text{SO}_2) emissions</td>
</tr>
<tr>
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</tr>
</tbody>
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SMOKE model inputs

- Spatial distribution over state:
  - Eleven city lights created from data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLI).
- Temporal distribution:
  - Same for the whole area
  - Light-duty fleet: Lemis et al., 2004
  - Heavy-duty fleet: CETESB, 2008
- Fleet distribution and activity: SPtrans and CETESB, 2008
- Emission Factor:
  - \(\text{CO}, \text{NO}_x\) and \(\text{PM}_2.5\): Sanchez et al., 2009
  - \(\text{VOC}\) and \(\text{SO}_2\): CETESB, 2008
  - \(\text{NH}_3\): Plante and Cass, 1998
- Vehicular Density:
  - Each “city light intensity value” was equivalent to 24.8 vehicles km\(^{-1}\).

EMISSION DATABASE AND SENSITIVITY CASES

CASE-2

Maximum reduction of \(-3\%\) Maximum reduction of the \(\text{NO}_x\) of \(-3\%\) Maximum increase of the \(\text{NO}_x\) of \(\text{NO}_x\)

CASE-3

Maximum reduction of \(-3\%\) Maximum reduction of the \(\text{NO}_x\) of \(-3\%\) Maximum increase of the \(\text{NO}_x\) of \(\text{NO}_x\)

CASE-4

Maximum reduction of \(-3\%\) Maximum reduction of the \(\text{NO}_x\) of \(-3\%\) Maximum increase of the \(\text{NO}_x\) of \(\text{NO}_x\)

CONCLUSIONS

The results show that between the different scenarios at measurement stations, \(\text{SO}_2\) concentration was seen to very substantially as \(\text{SO}_2\) emissions changed, but \(\text{PM}_2.5\) showed much less variation due to the slow conversion of \(\text{SO}_2\) to \(\text{SO}_4\) and the contribution of other \(\text{PM}_2.5\) species. The \(\text{SO}_2\) varied considerably among the scenarios, but \(\text{PM}_2.5\) showed much less variation mainly due to the contribution of other \(\text{PM}_2.5\) species. The main results showed that reductions in \(\text{SO}_2\) emissions may be less effective than expected at reducing \(\text{PM}_2.5\) concentrations at many locations of the MASP. The spatial and temporal distribution of concentration varies in the whole domain. The largest reduction in \(\text{PM}_2.5\) was obtained when the occurrence of a reduction of 50\% of \(\text{SO}_2\), \(\text{NO}_x\), and \(\text{NH}_3\) emissions. Experimental data in São Paulo City showed that almost of 70\% of the \(\text{PM}_2.5\) mass is composed by the secondary \(\text{PM}_2.5\) species. The main results showed that reductions in \(\text{SO}_2\) emissions was obtained through a reduction of 50\% of \(\text{SO}_2\), \(\text{NO}_x\), and \(\text{NH}_3\) emissions. Experimental data in São Paulo City showed that almost of 70\% of the \(\text{PM}_2.5\) mass is composed by the secondary \(\text{PM}_2.5\) species. Therefore, their risk need to be considered when making policy decisions to control the \(\text{PM}_2.5\) concentrations in the MASP.

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