Investigation of the transport of pollutants from the Metropolitan Area of São Paulo and from the industrial city of Cubatão to nearby areas [1]

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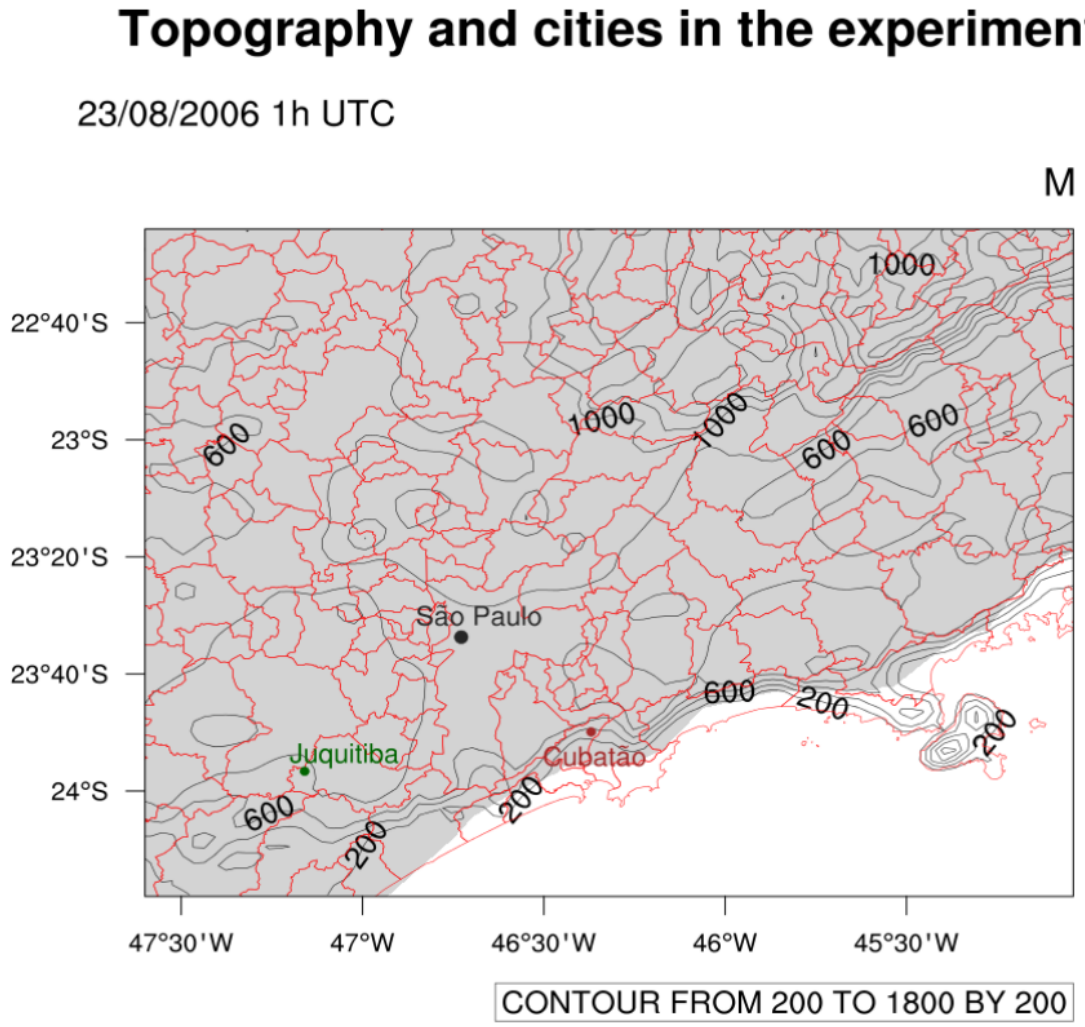
Goal

- Examine pollution episodes at Metropolitan Area of São Paulo (MASP) Cubatão and nearby areas shown at wintertime experiments in São Paulo state.

Area Description



- São Paulo: Most important city of MASP. >11 million people and >5 million vehicles. 700m above sealevel.
- Cubatão: It is 40 km farther from MASP. Strong industrial city. Complex terrain
- Juquitiba: Small City in a remote border area of the MASP, rounded by native vegetation.

Methods

- Simulations with mesoscale atmospheric model BRAMS (BRAMS, 2013) and Lagrangian Stochastic Model SPRAY to investigate episodes in a wintertime experiment (Gioia, 2006).
- Studied Experiment: $PM_{2.5}$ and PM_{10} collected in IGC (Instituto de Geociências - Institute of Geosciences of University of São Paulo), São Paulo city; Juquitiba and Cubatão (at Mogi's Valley), every 12h, for one week.

Models Configuration

- BRAMS initialized with CPTEC (Centro de Previsão de Tempo e Estudos Climáticos, a Brazilian Weather Forecast Center) Global Files (time resolution of 12h, and Lat-Lon resolution of 0.9375º, with 28 vertical levels).
- Time resolution = 2s.
- 3 nested grids.
- Time Period: from 23 to 29, August 2006.
- Coupling BRAMS/SPRAY with GAP and SurfPro softwares (provided by Arianet), and USGS landuse data.
- Probability Density Functions (PDF): Gram-Charlier truncated to the third order in the vertical, and Gaussian in the horizontal.
- BRAMS's Grid 2 (3Km resolution): input for SPRAY's CO dispersion simulation (MASP's source)
- BRAMS's Grid 3 (1Km resolution): input for SPRAY's PM_{10} dispersion simulation (Mogi Valleys's source)

Simulation Area

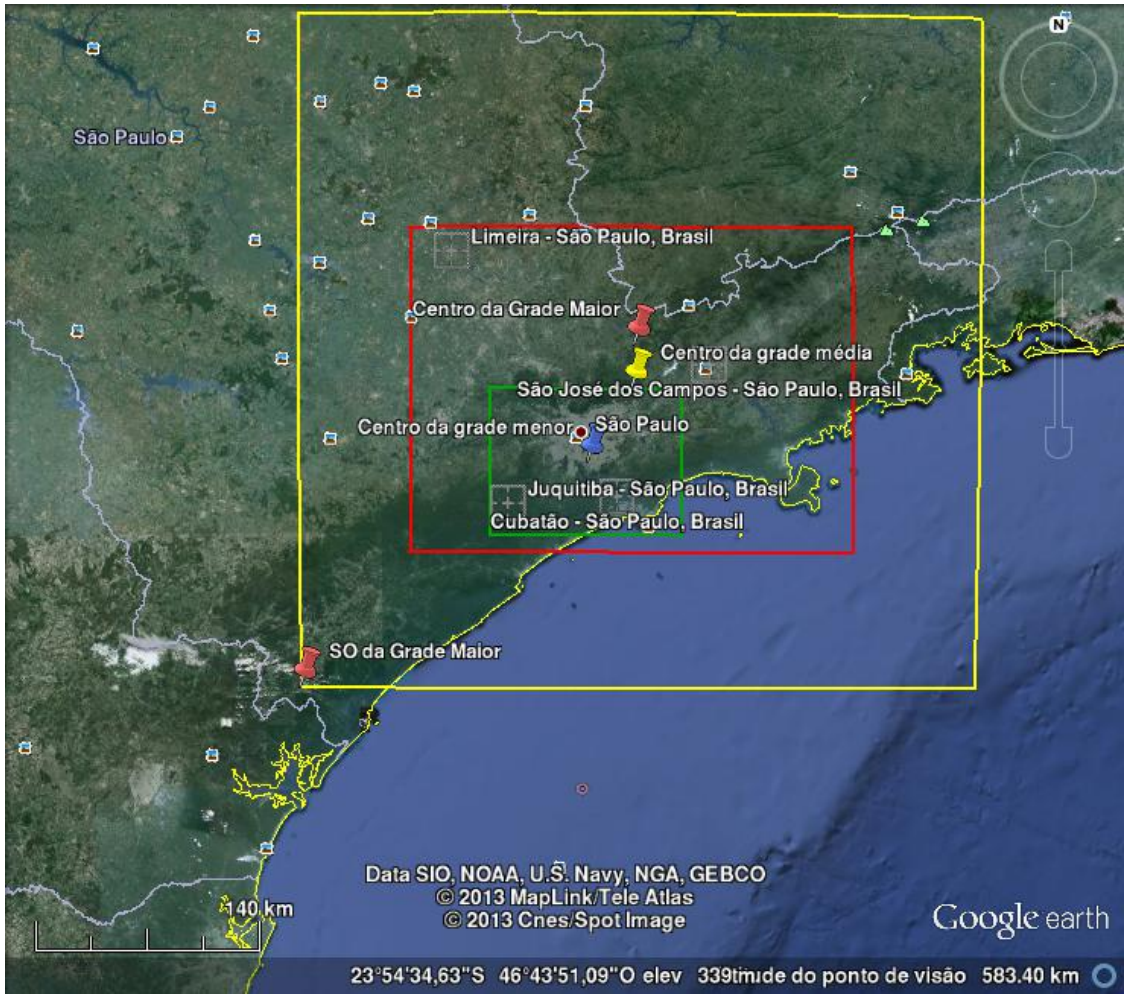
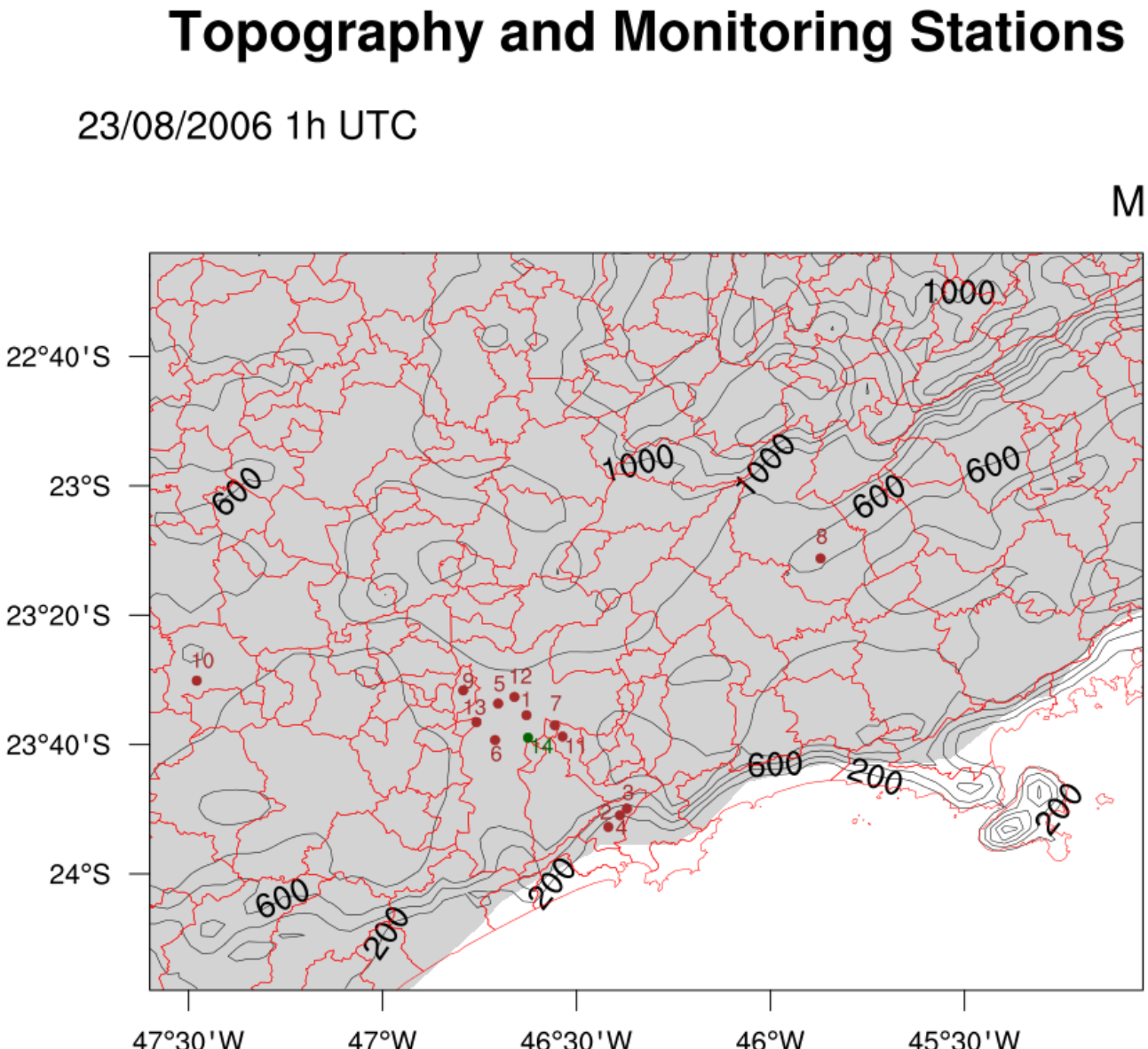
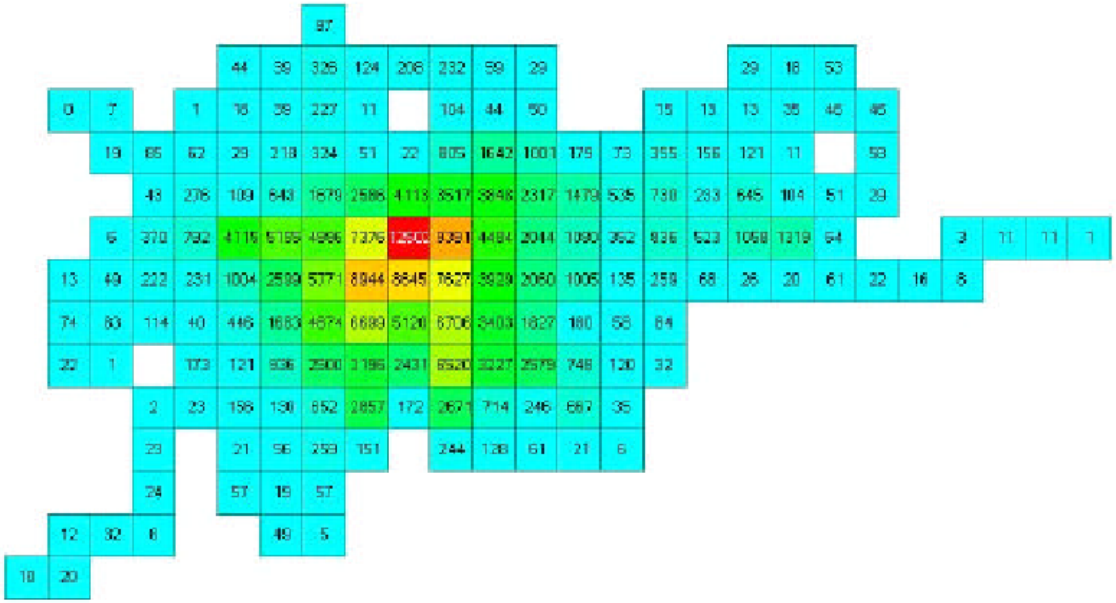


Figure: Simulated Area using BRAMS. Grid Resolution: 12Km (G1 - Larger), 3Km (G2 - within G1) and 1Km (G3 - smaller)

Stations


Topography and Monitoring Stations
23/08/2006 1h UTC
M
22°40'S
23°S
23°20'S
23°40'S
24°S
47°30'W
47°W
46°30'W
46°W
45°30'W
1000
600
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14

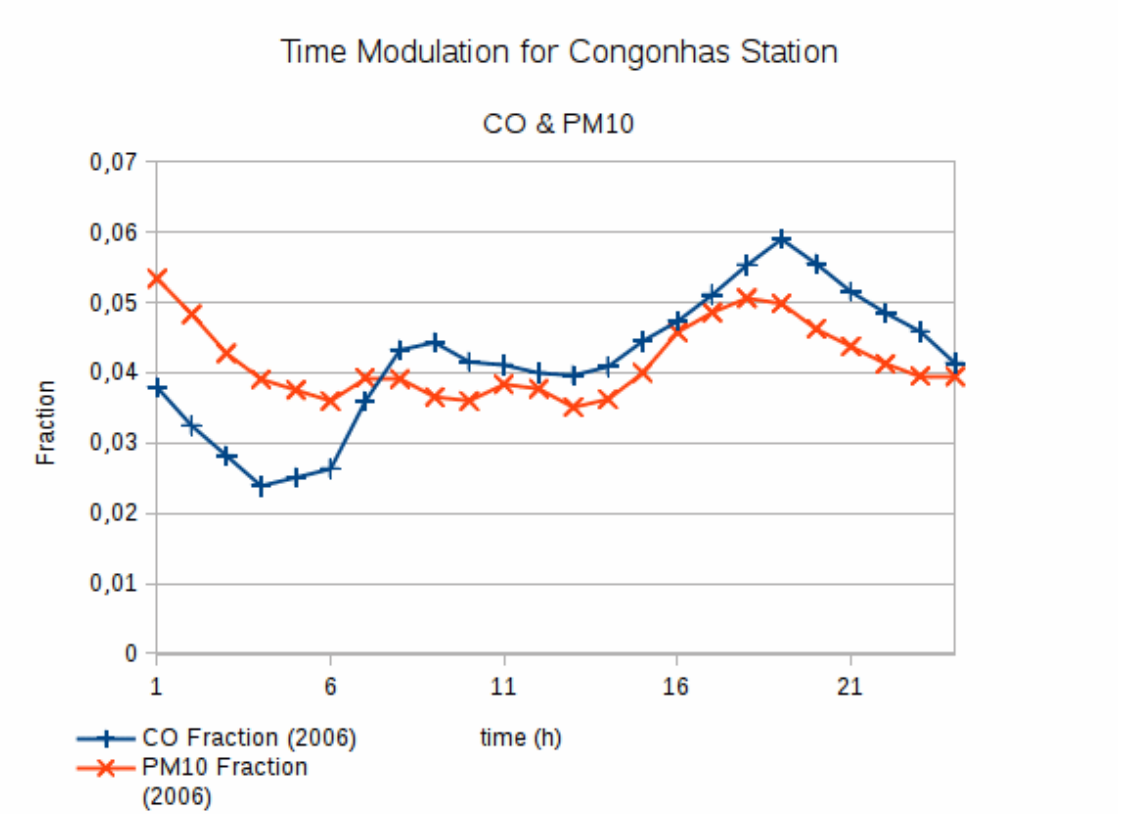
MASP's CO sources



(Keer et al, 2005)

- 169 squares with:
- Resolution:$5km^2$.
- Fleet composition and traffic flow, estimated by Kerr, A., et al., 2005, for the year 2000 at MASP (a total of $1.69x10^6 t.y^{-1}$).
- Reduction factor of 1.5 from 2000 to 2006 CO emissions related with measures at Congonhas' station (CETESB, 2001 and 2007).

Time Modulation (Daily cicle of the sources)



- CO and PM_{10} time modulation based on 2006 Congonhas's station pattern.
- Why Congonhas's? - Near a high traffic Avenue (represents the MASP's CO and PM_{10} time emission profile)
- ratio $CO/PM_{10} = 40.7$ (first aproximation: PM_{10} emissions related with vehicular fleet)

Cubatão's PM_{10} Sources

Wind

Comparisons between observed and simulated horizontal wind at 10 m (N from 120 to 167)

Station	σ_s (u,v) ($m.s^{-1}$)	σ_o (u,v) ($m.s^{-1}$)	RMSVE ($m.s^{-1}$)	r_u	r_v	P (for the worse r)
1	2.25	1.90	1.65	0.5590	0.8214	<0.001
3	2.98	3.16	3.12	0.2317	0.7439	<0.005
4	2.57	2.54	2.73	0.2448	0.6354	<0.005
5	2.29	2.18	1.61	0.6739	0.8279	<0.001
6	2.49	2.42	1.43	0.7896	0.8667	<0.001
7	2.64	1.95	2.10	0.6968	0.7640	<0.001
8	2.25	1.90	1.65	0.5590	0.8214	<0.001
9	2.75	2.12	1.66	0.7359	0.8595	<0.001
10	2.37	2.11	1.93	0.5099	0.8006	<0.001
14	2.60	2.46	2.79	0.4452	0.4608	<0.001

- $\sigma^2 = \sigma_u^2 + \sigma_v^2$
- σ_s, σ_o and RMSVE are close
- r: Good correlation and large sample to compare (N)
- P: Good significance levels

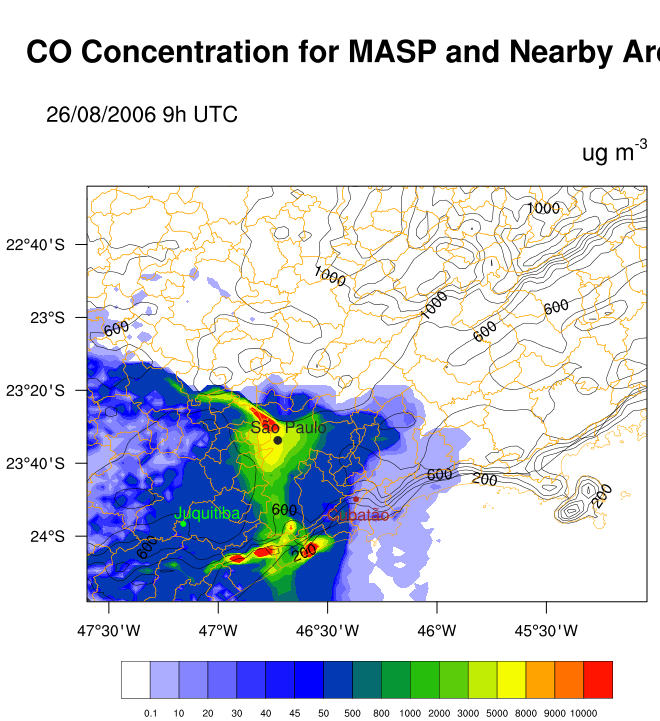
CO simulation results

CO concentrations - Comparison between observed and simulated values (N from 53 to 93)

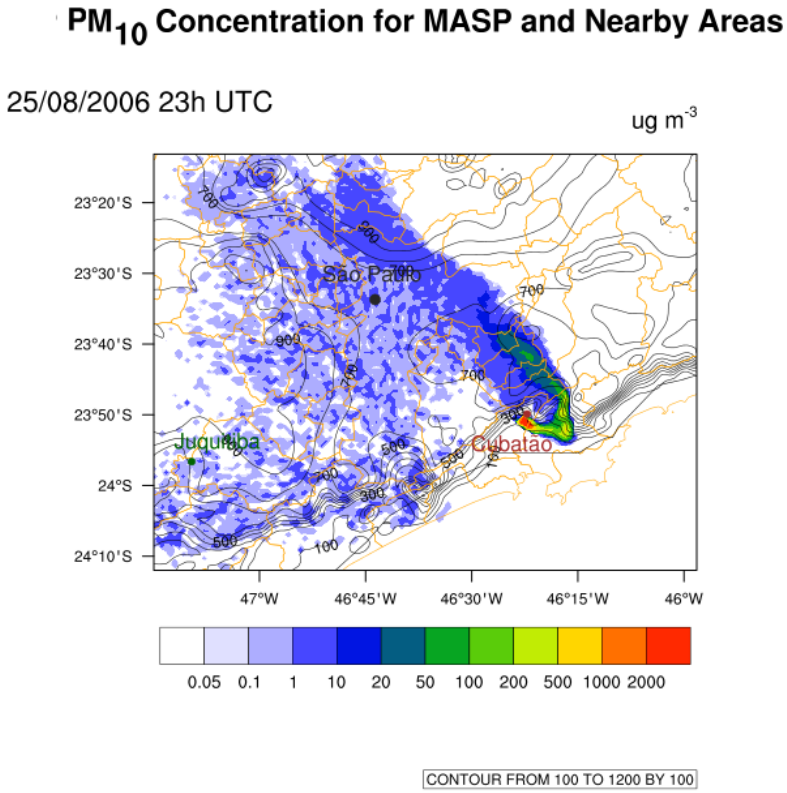
Station	σ_o ($x10^2$ $\mu g.m^{-3}$)	σ_s ($x10^2$ $\mu g.m^{-3}$)	RMSE	r	P	$<CO>_o$ ($x10^2$ $\mu g.m^{-3}$)	$<CO>_s$ ($x10^2$ $\mu g.m^{-3}$)	N	s/o
1	35.4	7.81	45.5	0.30	<0,002	13.4	46.9	91	3.51
5	36.7	14.0	42.2	0.37	<0,001	22.7	49.9	93	2.2
7	12.6	17.1	11.8	0.77	<0,001	19.9	17.0	53	0.86
11	7.7	8.90	8.7	0.54	<0,001	13.8	10.7	91	0.78
12	48.3	11.8	68.5	0.27	<0,01	15.2	65.2	75	4.28
13	25.7	19.6	27.5	0.30	<0,01	22.8	31.4	84	1.37

- Even low r_s have good significance levels (due to large N)
- σ and average CO for station 12 are poorer because it is in a high traffic Streets and Avenues.
- Station 1 is a park rounded by high traffice Avenues. Due to CO Source resolution, model preditics high emission at this point.
- Better resolution for CO Source could improve the results for average CO values and σs.

Pollutants dispersion



CO dispersion down to the coast.



PM_{10} dispertion up to the montain range.

PM_{10}

Comparation between episodes measures and simulation for PM_{10}

City	Measure	Start date	Finish date	$<PM_{10}>o$ ($\mu g.m^{-3}$)	$<PM_{10}>s$ ($\mu g.m^{-3}$)	Ratio s/o
Cubatão	daytime	25/08/2006	25/08/2006	107	33	0.31
Juquitiba	Daytime	25/08/2006	25/08/2006	39	1	0.03
São Paulo	daytime	25/08/2006	25/08/2006	57	50	0.88
Cubatão	night time	25/08/2006	26/08/2006	73	115	1.57
Juquitiba	night time	25/08/2006	26/08/2006	81	2	0.02
São Paulo	Night time	25/08/2006	26/08/2006	84	146	1.74

World Health Organization Daily Guideline exceedance for MP_{10} (WHO, 2005): $50 \mu g/m^3$

- PM_{10} Results for IGC are well explained by vehicular related emission (initial gess).
- MASP's contributions for PM_{10} episodes in Juquitiba: up to 3%.
- Cubatão's PM_{10} episodes were well simulated, but better knowlegde about sources can improve the results.

Conclusion

- BRAMS/SPRAY were able to simulate reliable concentration fields for vehicular CO emitted in the MASP, as well as the PM_{10} emitted by fertilizer plants at Cubatão.
- Simulations and measures are well correlated
- For Juquitiba, clearly, PM_{10} emitted in MASP related with vehicular fleet is not the main source for the measures in this city.

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THANK YOU!
More Questions:
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Figure for São Paulo city: Rafael Neddermeyer
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