Contribution of on-road mobile sources to SOA formation in Bogotá: A sensitivity analysis coupling WRF-Chem and the traffic model VISUM

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Introduction

GOAL

- Determine the potential contribution of mobile emissions sources to SOA by performing a sensitivity analysis in a photochemical model.

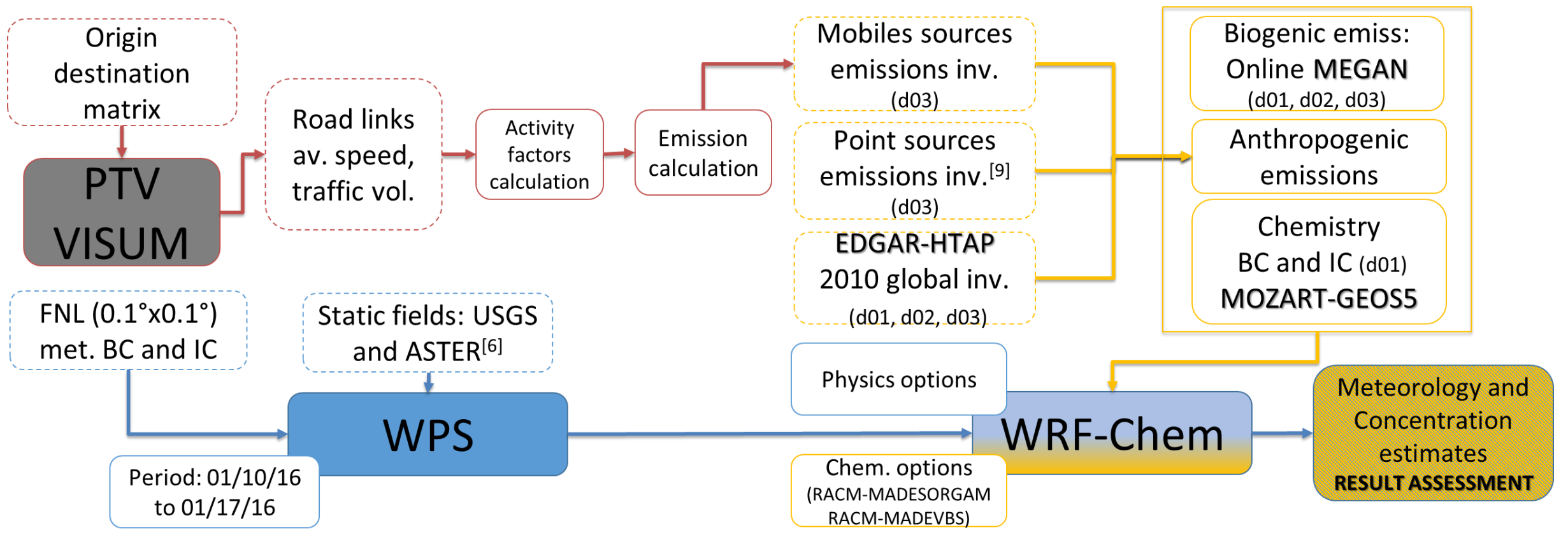
TOOL

- Traffic model: PTV VISUM 14
- AQM: WRF-Chem V 3.9

MOTIVATION

- SOA contribution to PM in Bogotá is scarcely understood

FIGURE 1. **SUMMARY:** modelling process



Methods

1. Implementation of PTV VISUM Traffic model

- PTV VISUM is designed to simulate traffic conditions in a road network. It uses zones, road links and nodes (Figure 2). The traffic model was used to estimate mobile sources activity factors for the road network of Bogotá. Activity diurnal profile was taken from vehicle counts (Figure 3)

FIGURE 2. Schematic diagram of VISUM inputs and output.

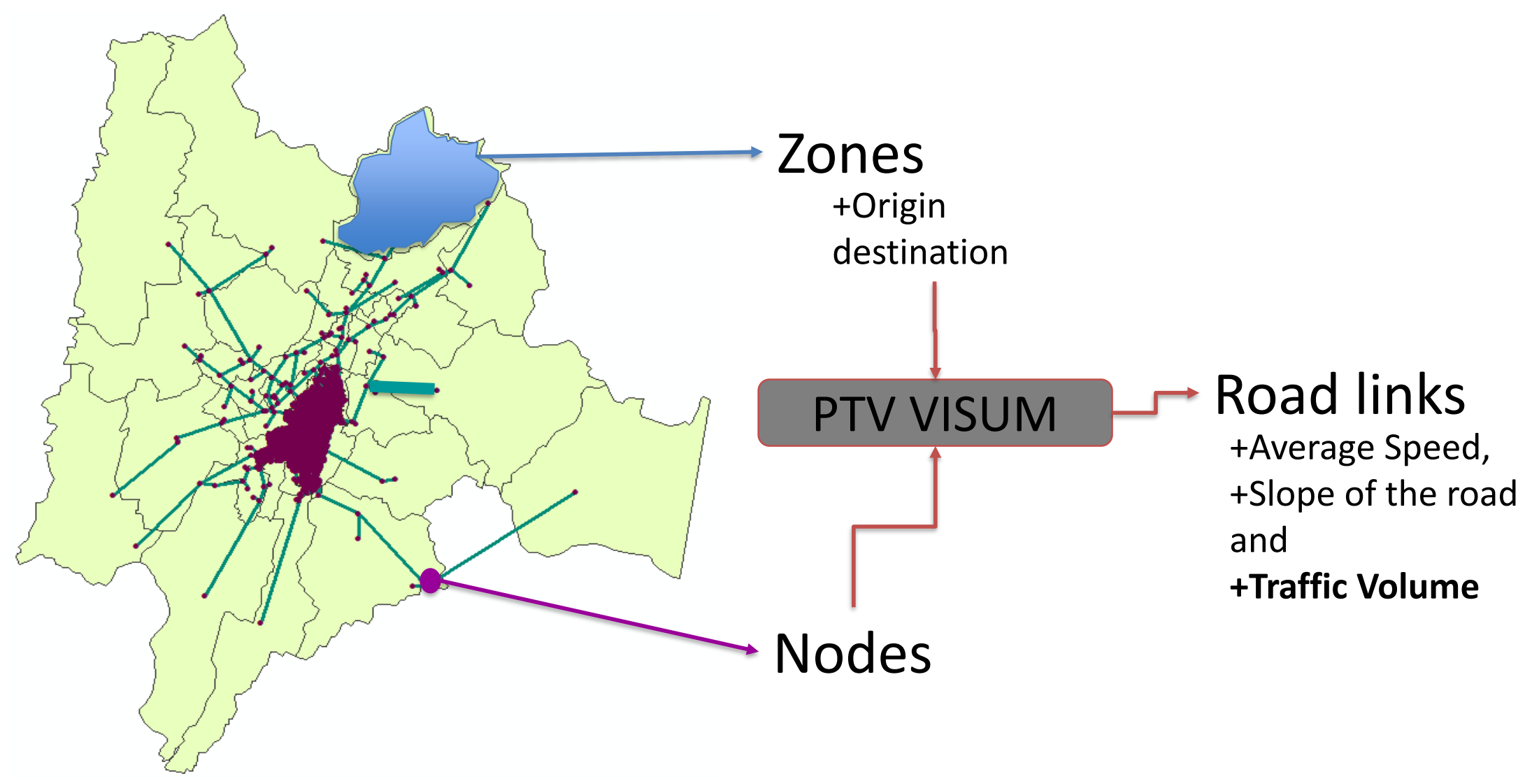
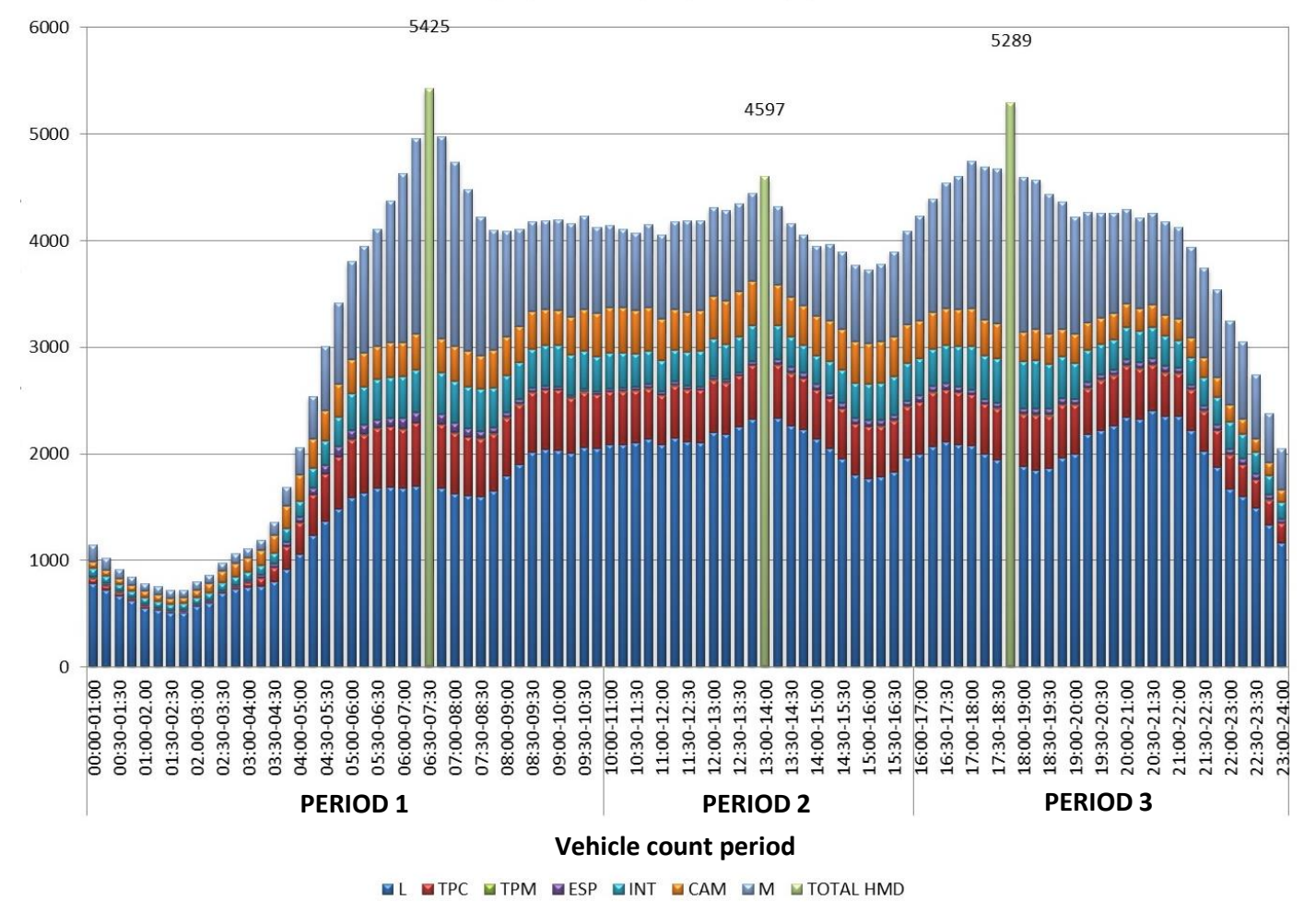
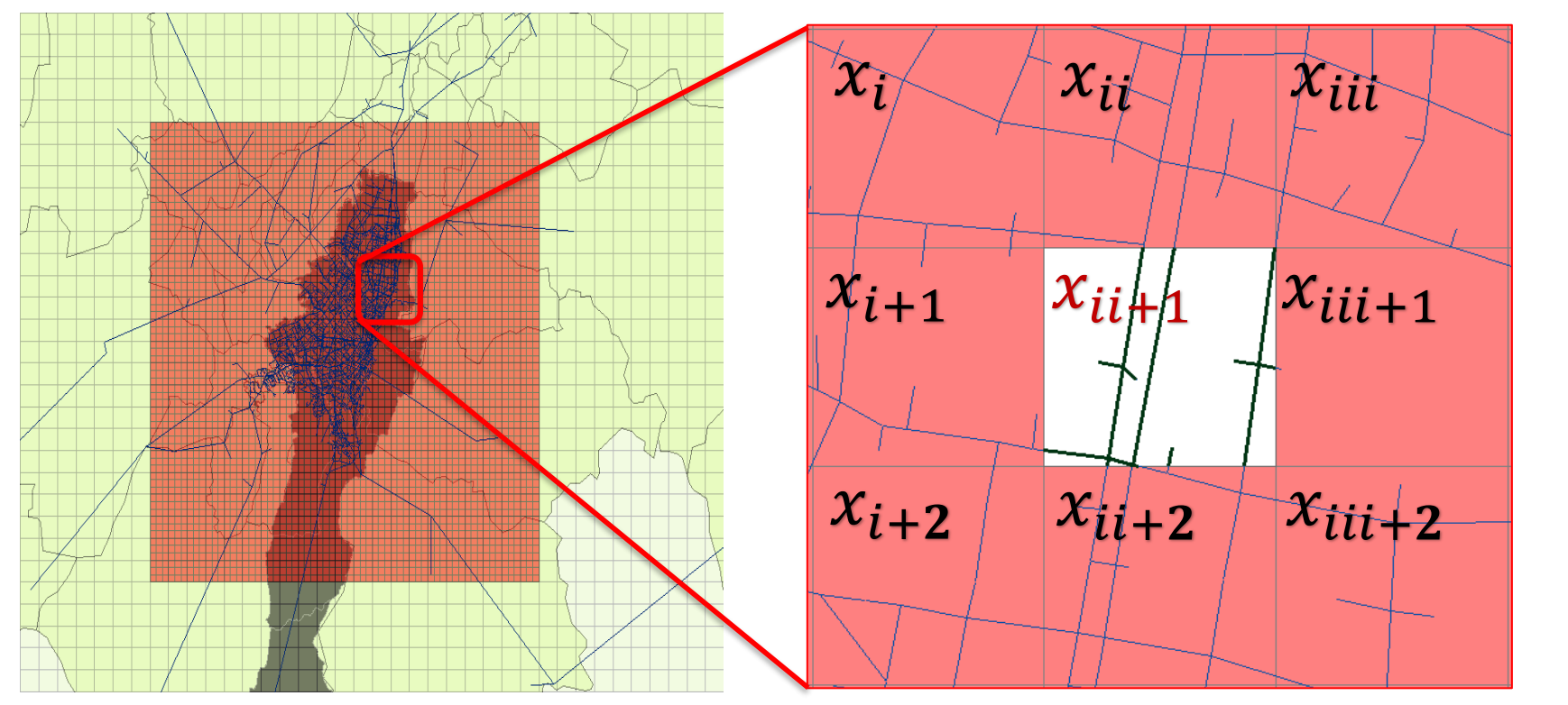


FIGURE 3. Traffic volume per vehicle fleet [7] used in EI calculations



L= Light Duty Vehicle, TPC=Public transportation, TPM=BRT, ESP=Special bus, INT=Bus Interstate bus, CAM=Trucks, M=Motorcycles

FIGURE 4. Mapping activity from VISUM to WRF-Chem grid



Activity factors were determined for grid cells (Figure 4) in a distribution compatible with WRF-Chem model configuration

EQUATION 1. Determination of activity factors per grid cell

$$AF_j = \sum_{(l=1) \in x}^{n \in x} Nf_j \times L_{l \in x}$$

Where:
AF_j: activity factors, Nf_j: Traffic Volume, L_l: Road length

2. WRF-Chem model configuration and experimental design

- Meteorological (Table 1) and static field options for the three modelling domains (Figure 4), were selected based on previous studies performed in the city of Bogotá [6].
- Modelling period was selected based on highest PM concentrations and driest period. Experimental design compromise of 4 runs using different chemical options and emissions configurations (Table 2)

FIGURE 4. Modelling domains centered in Bogotá

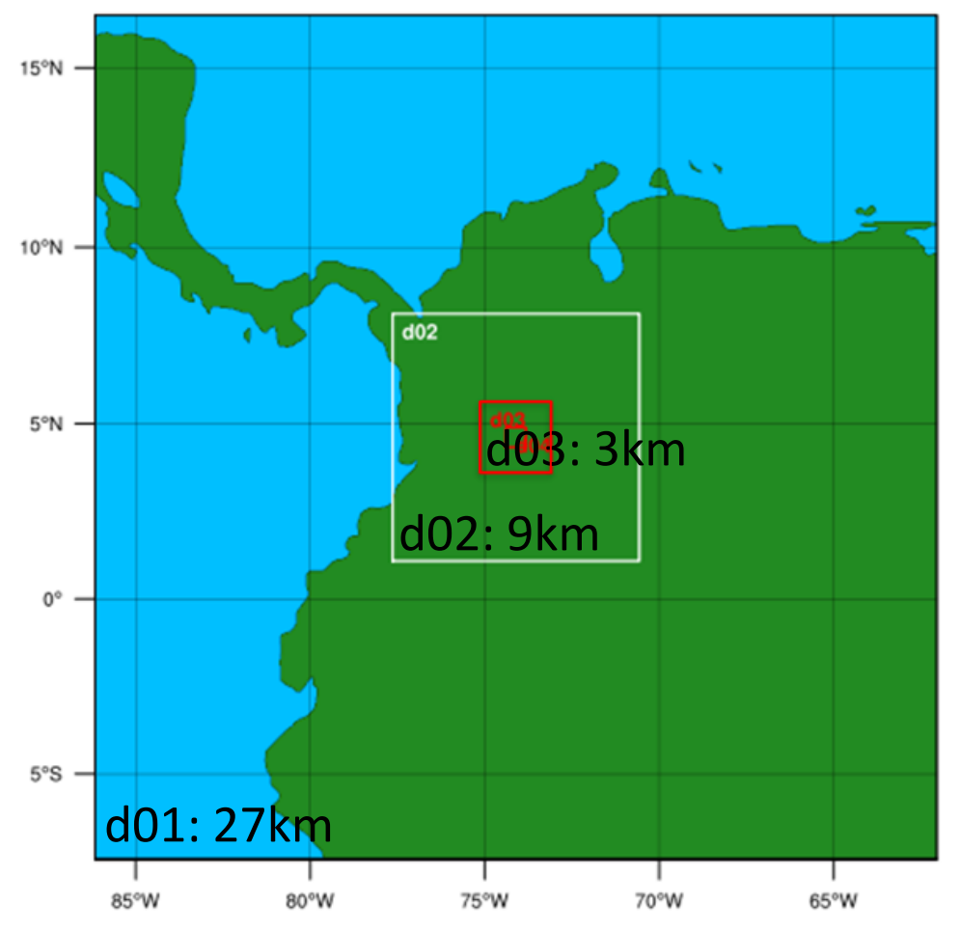


TABLE 1. Selected physics options for WRF-Chem

Physics meteorological options	
Microphysics	Lin et al., (1983)
L/W Surface	Noah LSM
Cumulus param.	Grell-Devenyi

TABLE 2. Experimental design (Chem. Opt)

Exper	Gas-ph chem	Aerosol scheme	Emissions
BsC	RACM	MADE-SORGAM	All emissions
SC1	RACM	MADE-SORGAM	No mob. VOC
SC2	RACM (AQ)	MADE-VBS	All emissions
SC3	RACM (AQ)	MADE-VBS	No mob. VOC

- A 24 hour spin-up time was selected to allow model stabilization

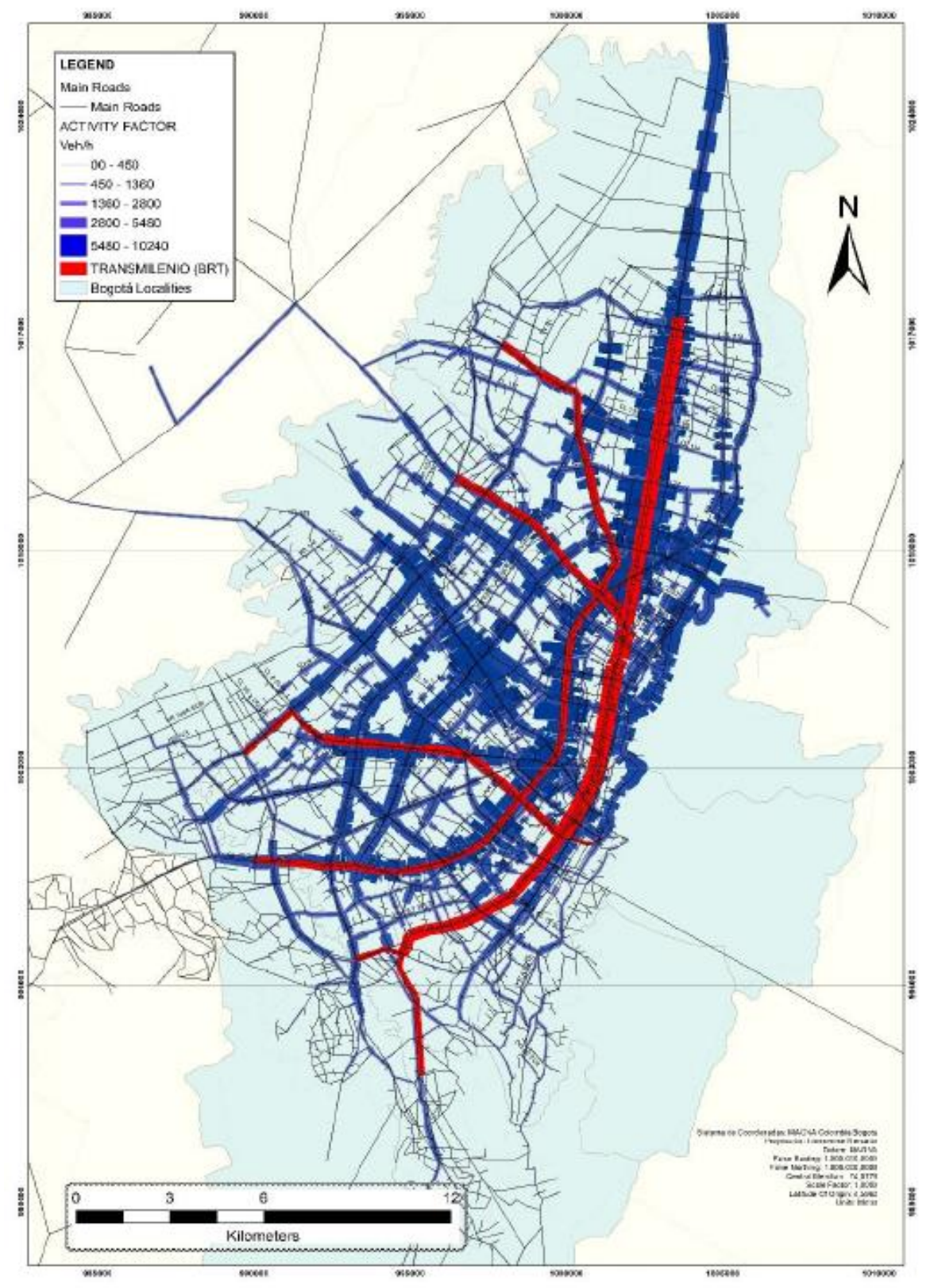
Modelling period selection fulfilled two conditions:

- Dry period: 10 consecutive dry days
- High polluted period: 10 consecutive days were checked for high $PM_{2.5}$ episodes

Results

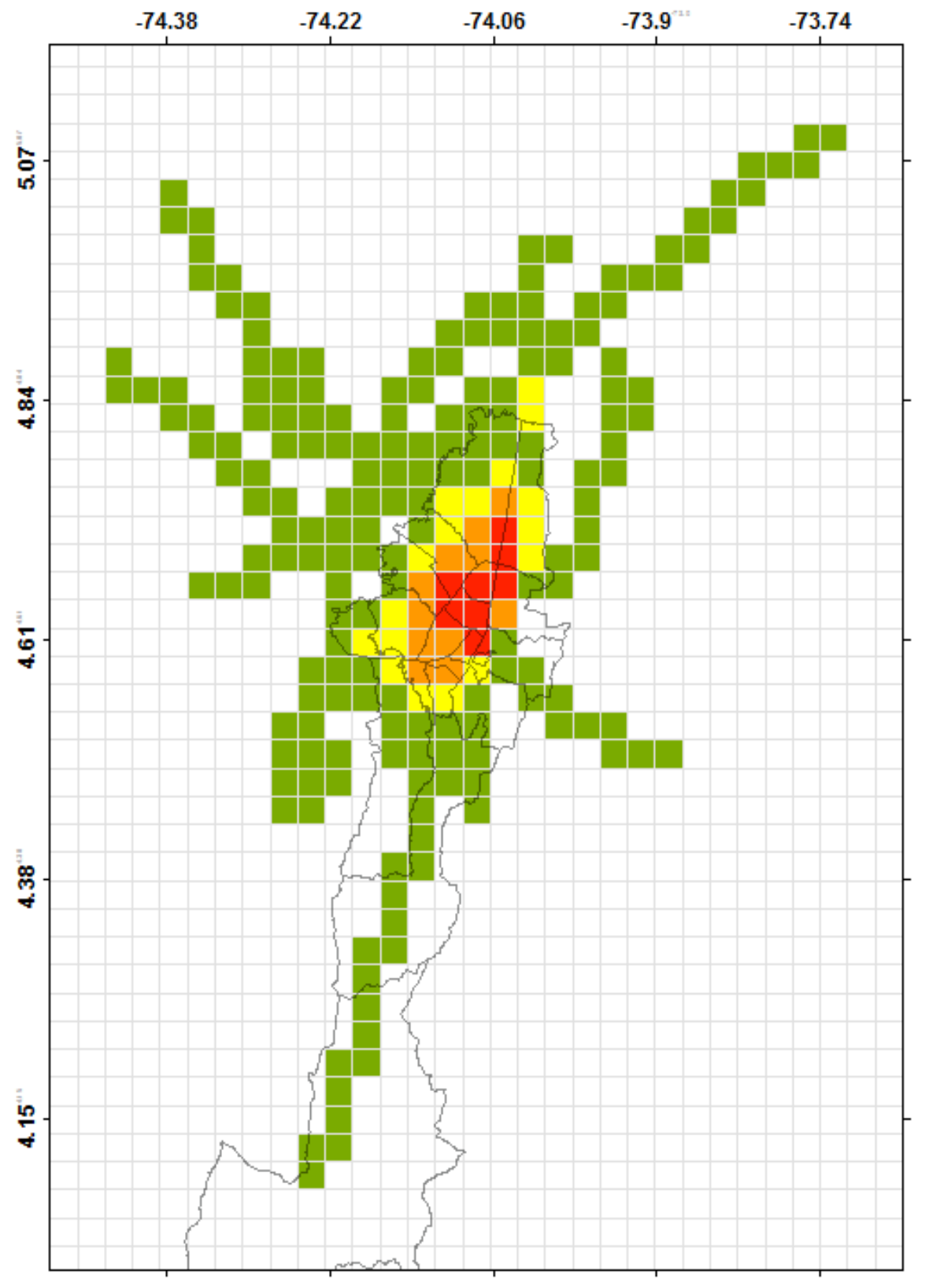
1. From Traffic Model to Emissions

FIGURE 5. Spatial distribution of activity factors



BRT activity General vehicle fleet

FIGURE 6. Spatial distribution of emissions from mobile sources



EQUATION 2.
Emission calculation

$$E_{(x,y,t)} = \sum EF_{i,j} \times AF_{j(x,y,t)}$$

Mobile Emissions (Figure 6) were calculated using Equation 2:

- Activity factors (Figure 5) AF_j
- Emission factors $EF_{i,j}$ for each vehicle fleet were taken from IVE model

3. Comparison of Base Case and Scenarios

FIGURE 13. Average spatial difference of ASOA for (a) BsC – SC1 (b) BsC – SC2 (c) BsC – SC3 (d) SC2 – SC3

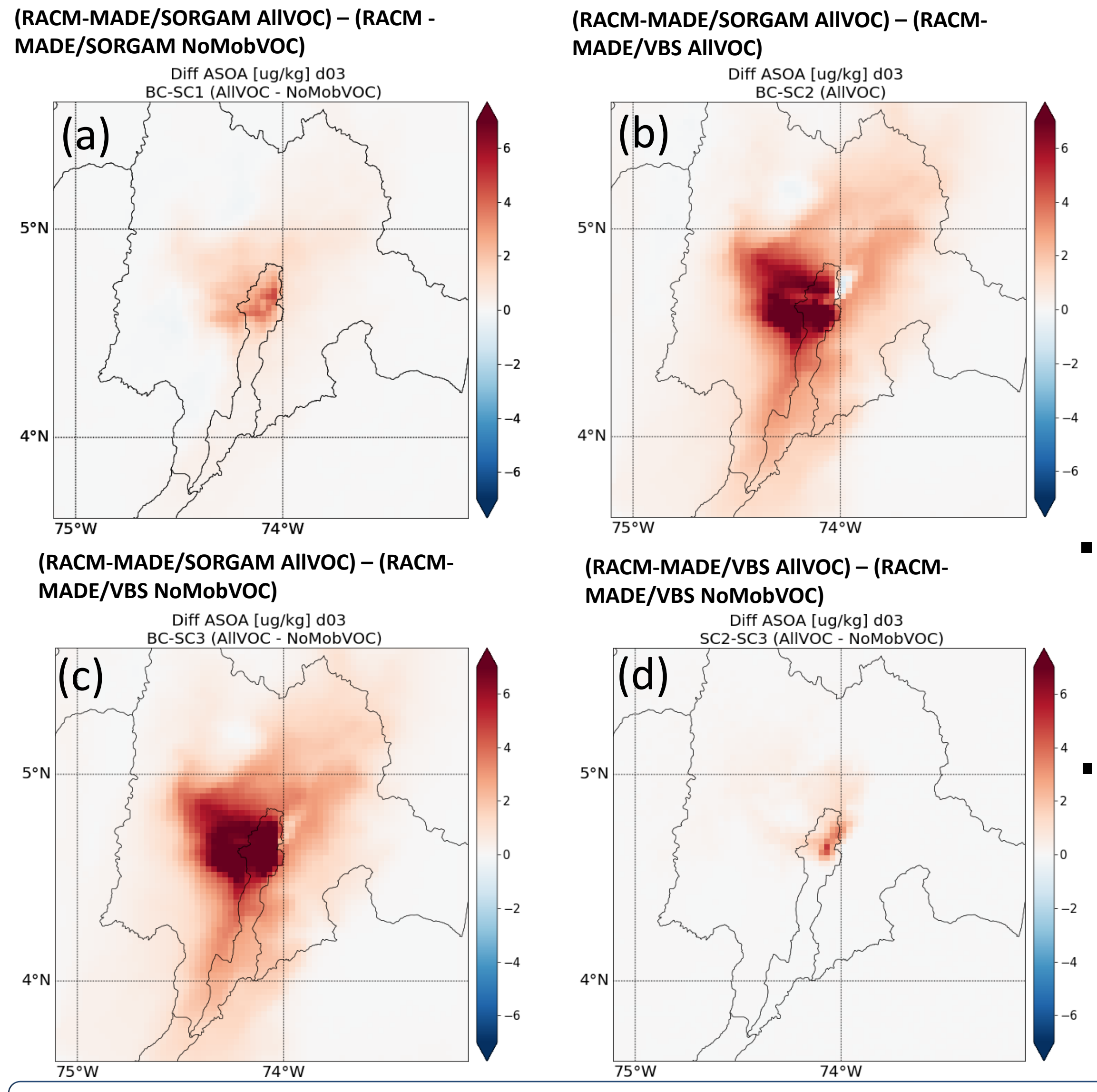
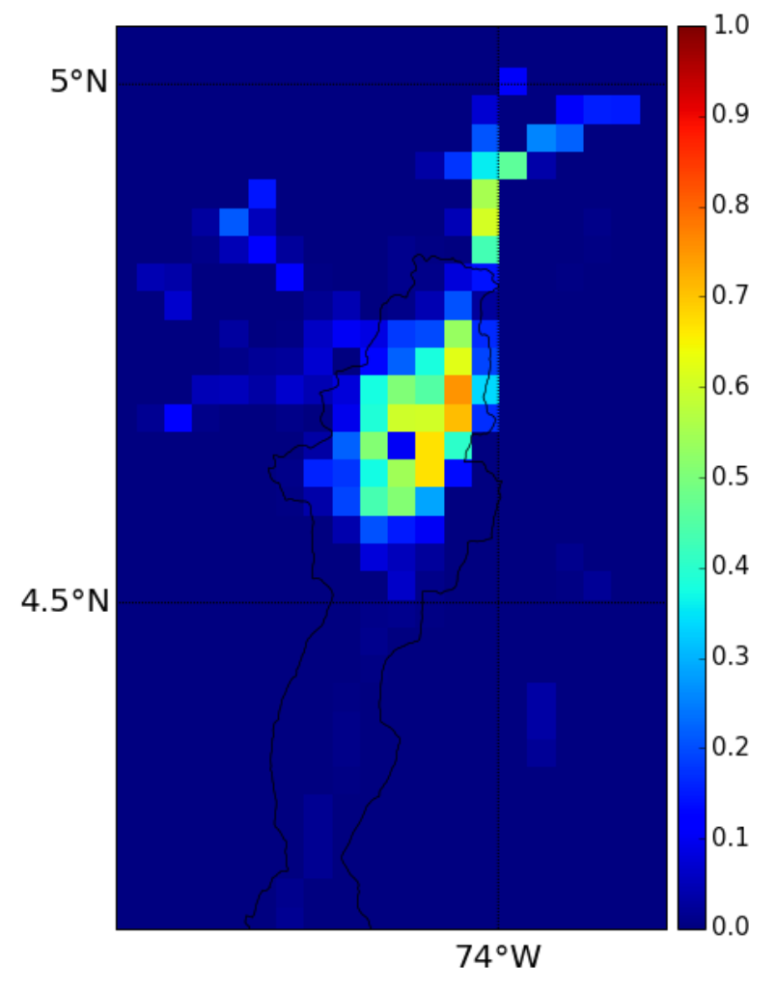


FIGURE 14. Mobile contribution to VOC EI



- Contribution of mobile sources to total emissions of VOC over Bogotá is significant, accounting for 60% on average (Figure 14)
- The average spatial difference of SOA between experiments, show that VOC from mobile sources have an important role in SOA formation in Bogotá.

4. Composition of $PM_{2.5}$

Color coding

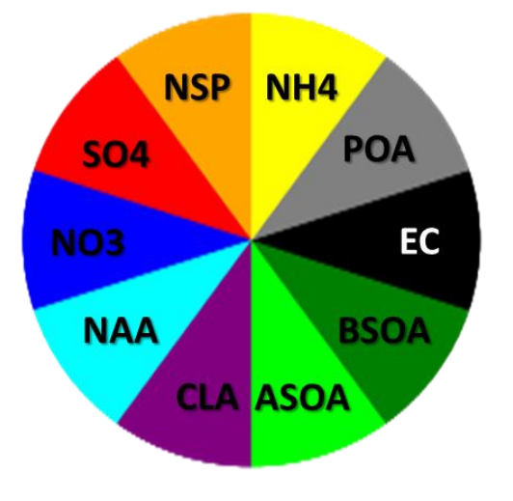
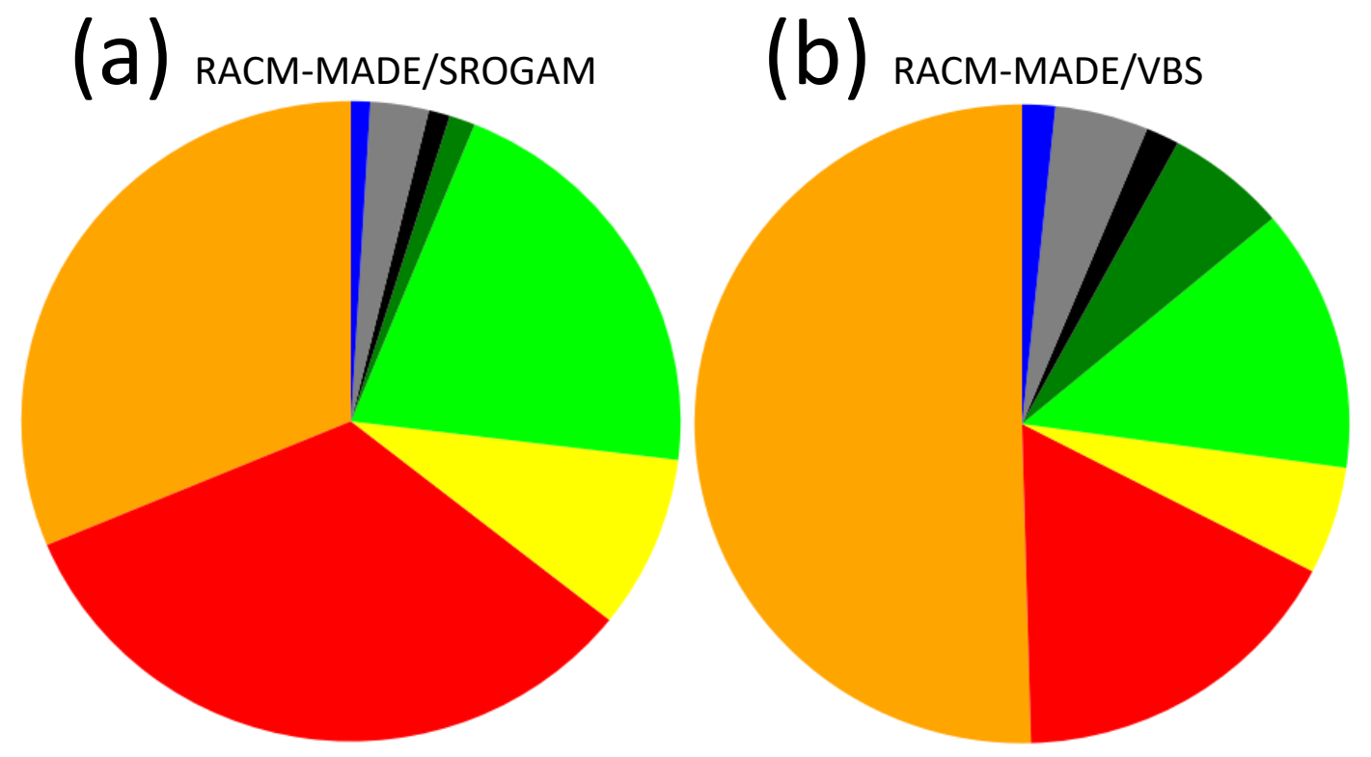


FIGURE 15. Average composition of PM2.5 (a) for BsC (b) SC2



- $PM_{2.5}$ composition shows an important contribution of Anthropogenic SOA (Figure 15)
- BC estimates a bigger contribution of NSP (not speciated) $PM_{2.5}$

2. Base case – RACM/MADE-SORGAM

2.1 Meteorological variables in surface

- A comparison of meteorological variables was performed at monitoring stations (Figure 7)
- Observed PBL height was compared against model estimates (Figure 8)

FIGURE 8. Time series of Planet Boundary Layer height (modeled and observations)

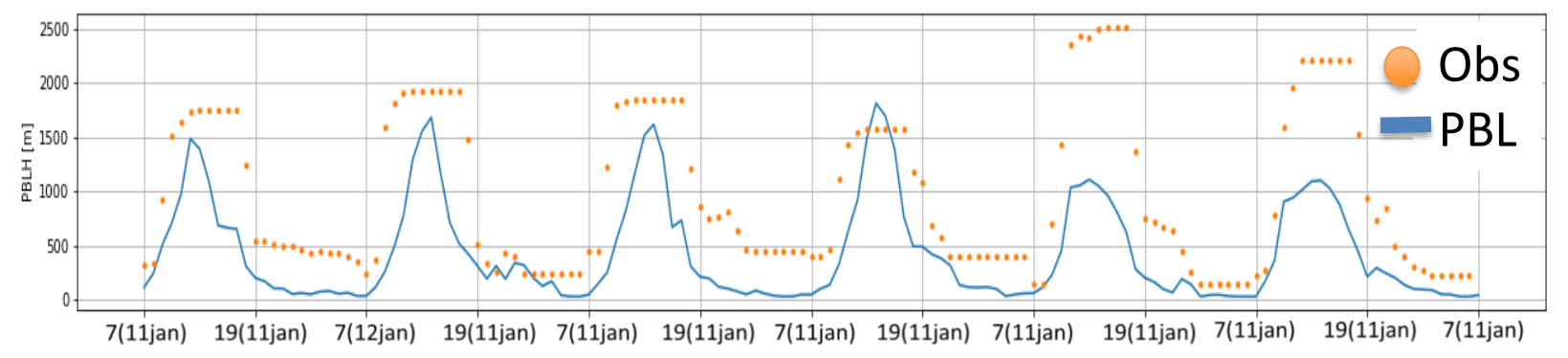
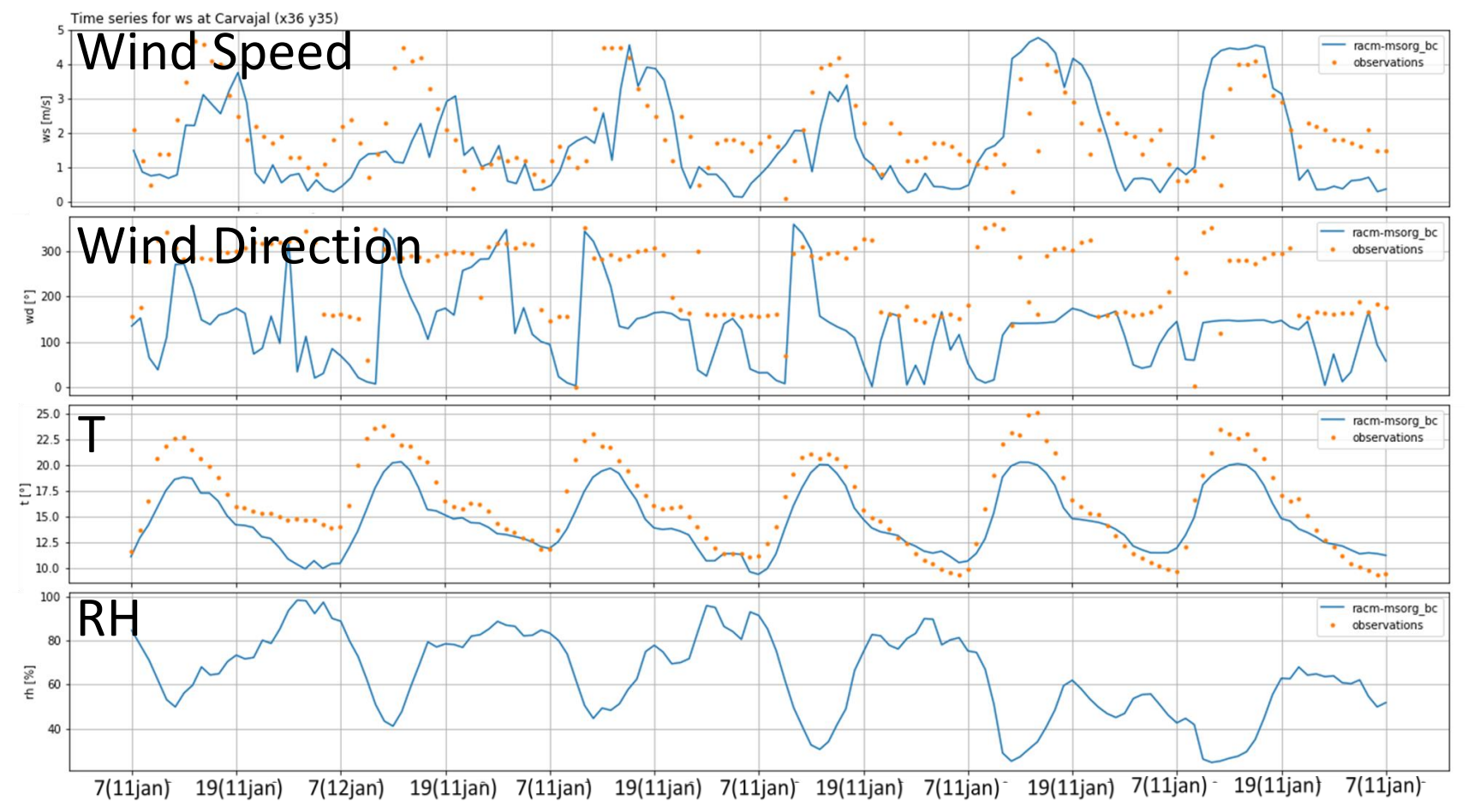
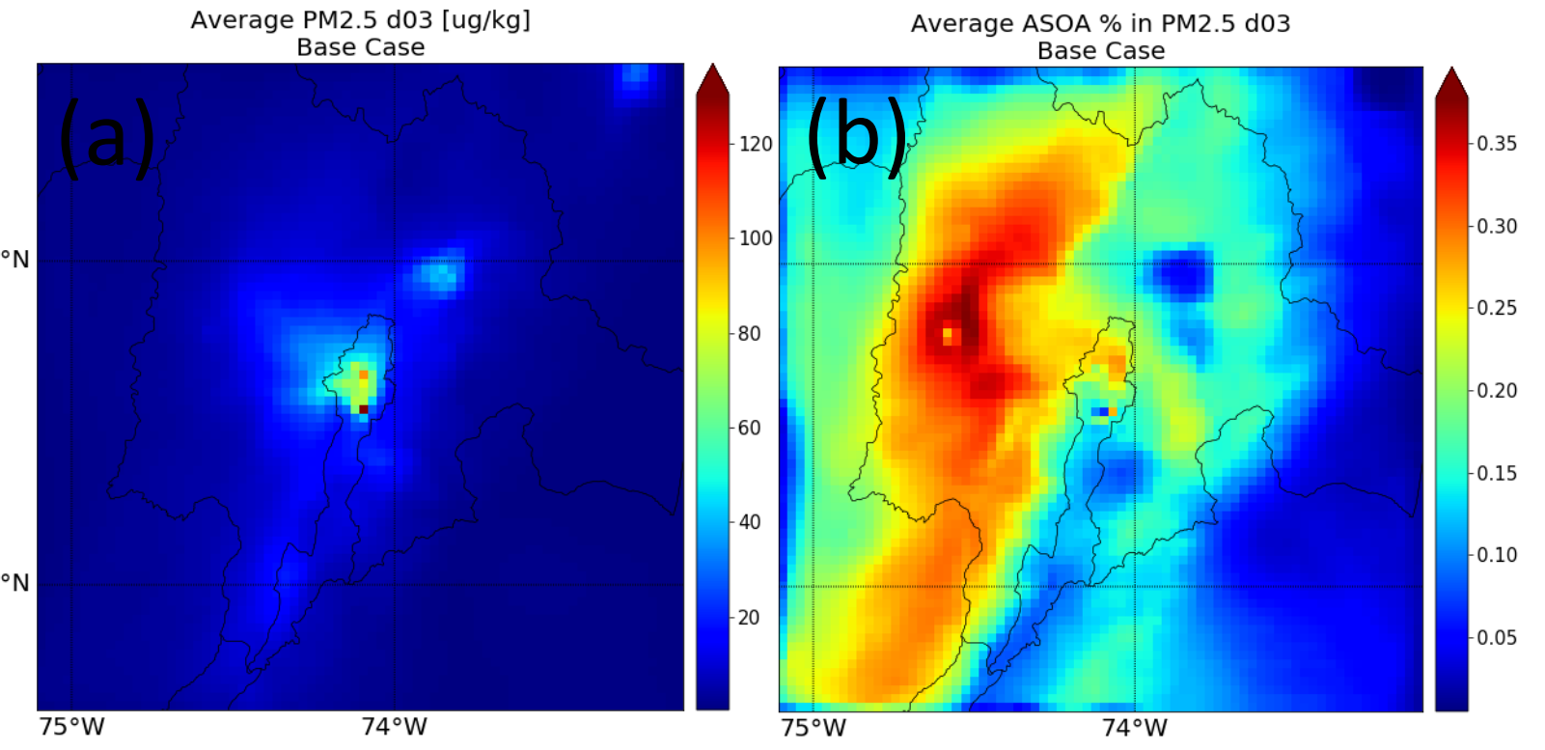


FIGURE 7. Time series of meteorological Variables at *Carvajal* AQ monitoring station



2.2 Spatial distribution of PM concentrations

FIGURE 9. Base case (a) $PM_{2.5}$ average concentration and (b) ASOA % in $PM_{2.5}$



- The diurnal behavior of pollutants shows a strong dependency on PBL height (Figure 10)

FIGURE 10. Time series for PM_{10} at Carvajal RMCAB station

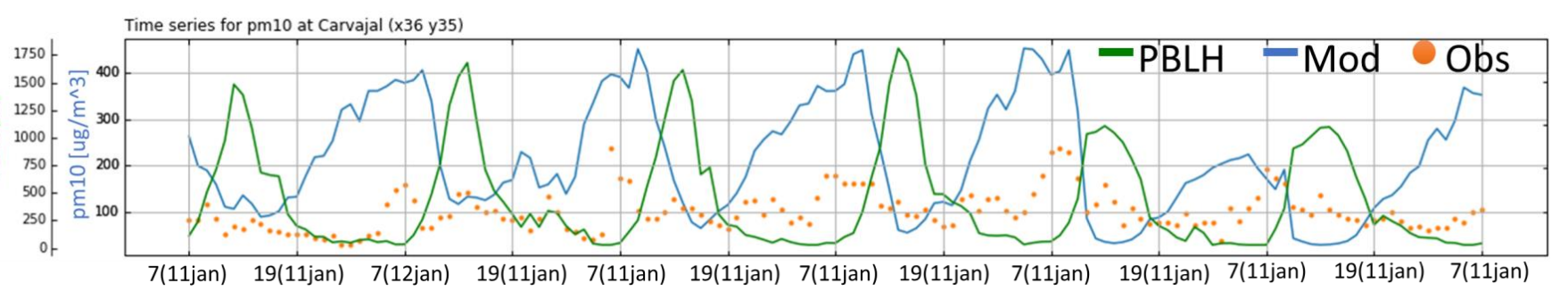


FIGURE 11. PM Coarse Average vertical profile for d01

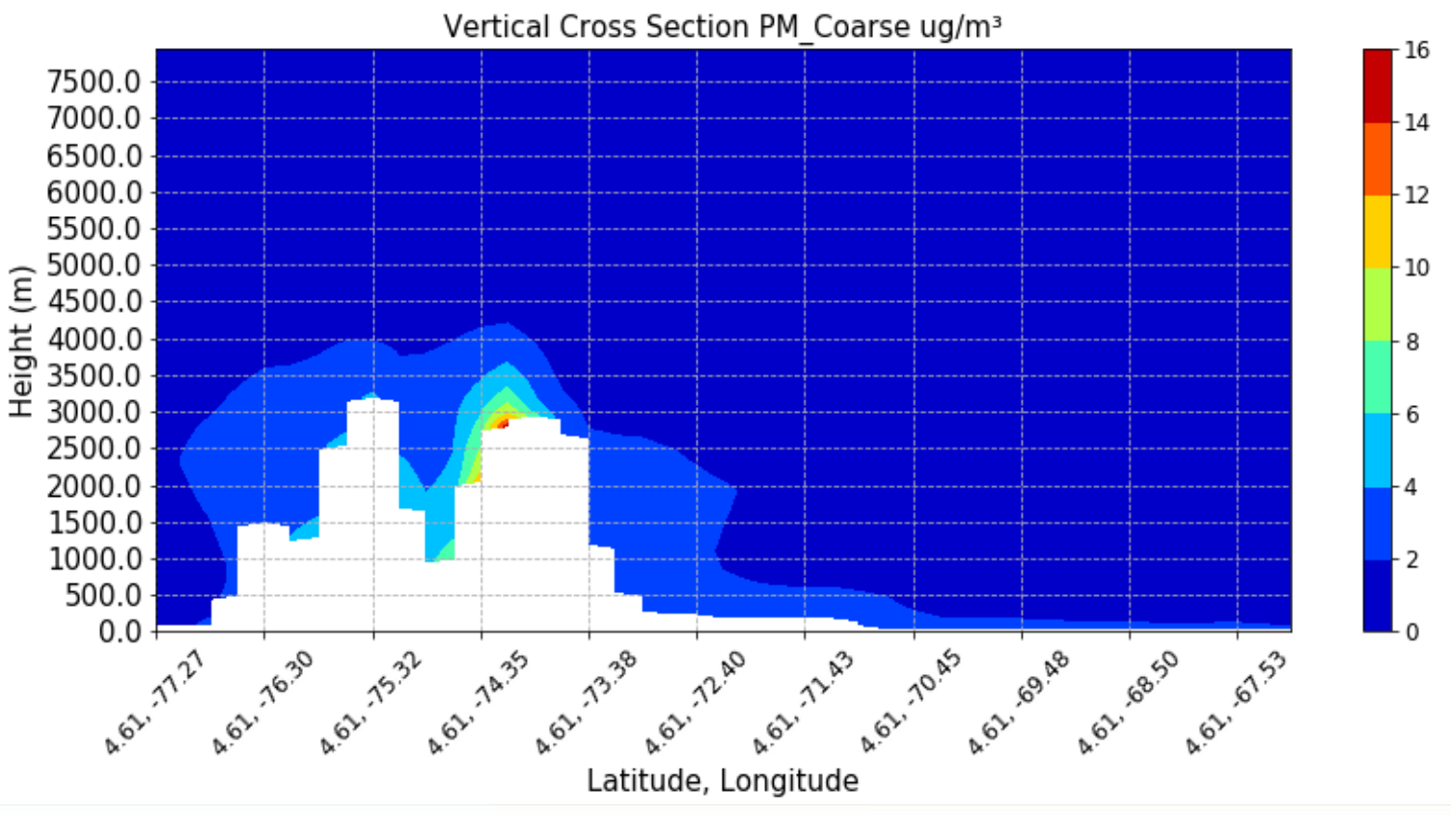
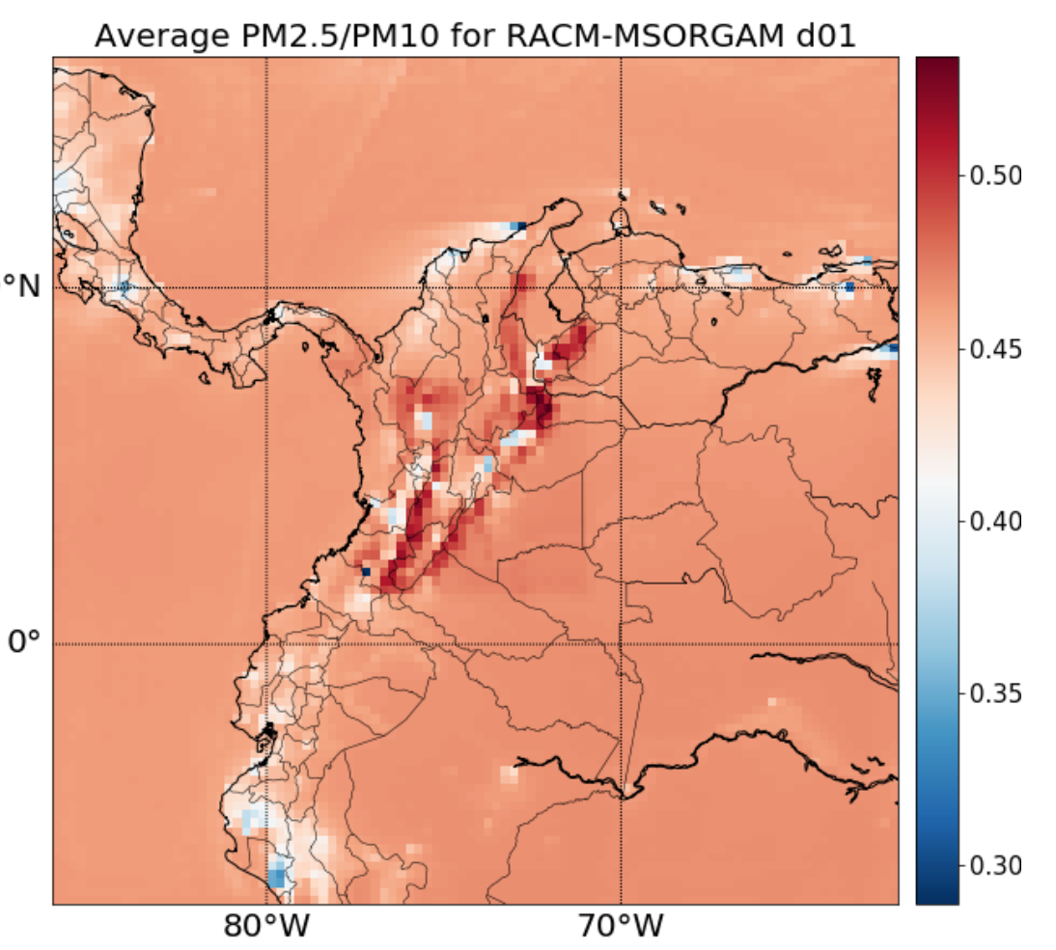


FIGURE 12. Average ratio $PM_{2.5}/PM_{10}$ for the outermost domain



Concluding remarks

- WRF-Chem was implemented using global emissions inventory EDGAR HTAP 2010 for outermost domains (d01, d02).
- Local emissions inventories combined with varying EDGAR HTAP emissions were provided for inner most domain d03.
- Mobile emissions are a significant source of SOA precursors in Bogotá.
- WRF-Chem is able to capture meteorological variables behavior. Pollutant hourly behavior is highly influenced by PBL height at different site locations.
- The model is not being able to perform much transport between the first model layers. Further evaluations are required to determine the cause of such lack of concentrations in higher layers of the atmosphere.
- Model configuration of RACM-MADE/SORGAM estimated more SOA compared to RACM-MADE/VBS

Acknowledgements

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