

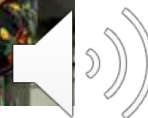
Atmospheric emission reduction scenarios in Colombia: Assessing the sectoral contributions to aerosol, NO_x, and Ozone population-weighted concentration

Alejandra Montejo Barato, MSc. ¹; Sebastian Espitia Cano, Eng. ¹; Ricardo Morales Betancourt, PhD. ¹
; Jorge Bonilla², PhD. ; Claudia Aravena², PhD.

1 –Department of Civil and Environmental Engineering, Universidad de los Andes. 2 –School
economics, Universidad de los Andes

3 – Heriot Watt University, Edimburg

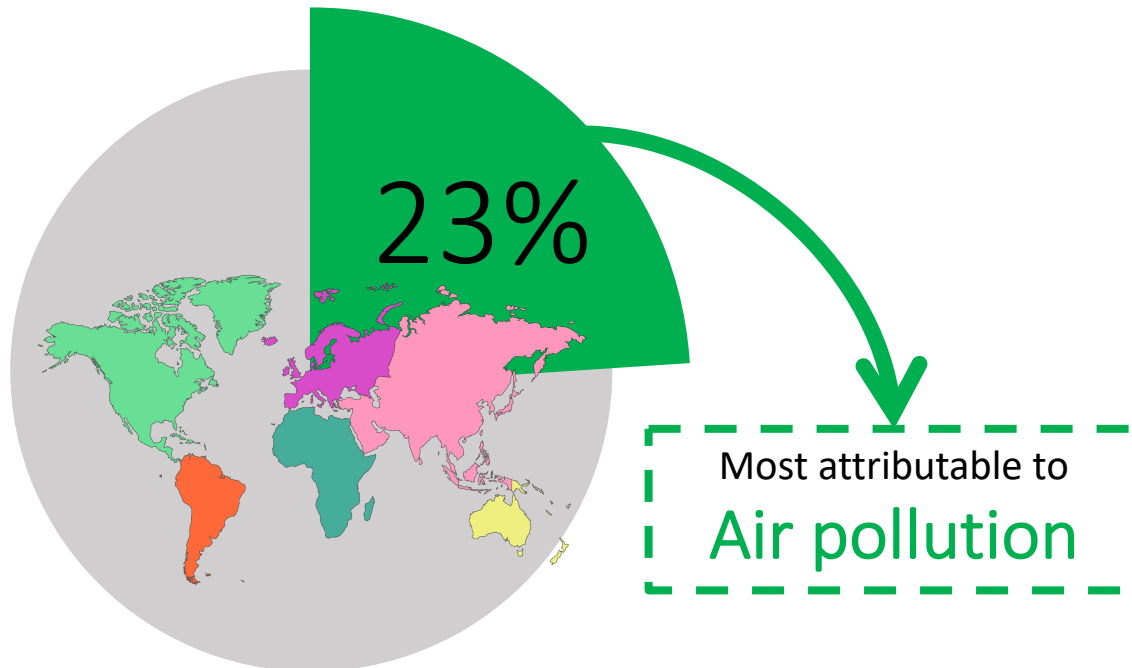
*19th Annual CMAS Conference
Virtual, 2020*



Motivations: Air Quality and Human Health



12.6 million deaths
per year



- Instituto Nacional De Salud, & Observatorio Nacional de Salud. (2018). Carga de enfermedad ambiental en Colombia.pdf. Retrieved from <https://www.ins.gov.co/Direcciones/ONS/Informes/10 Carga de enfermedad ambiental en Colombia.pdf>
- United Nations. (2015). Resolution adopted by the General Assembly on 25 September 2015. In Transforming Our World: The 2030 Agenda for Sustainable Development. New York, NY: United Nations.

Motivations: Air Quality and Human Health

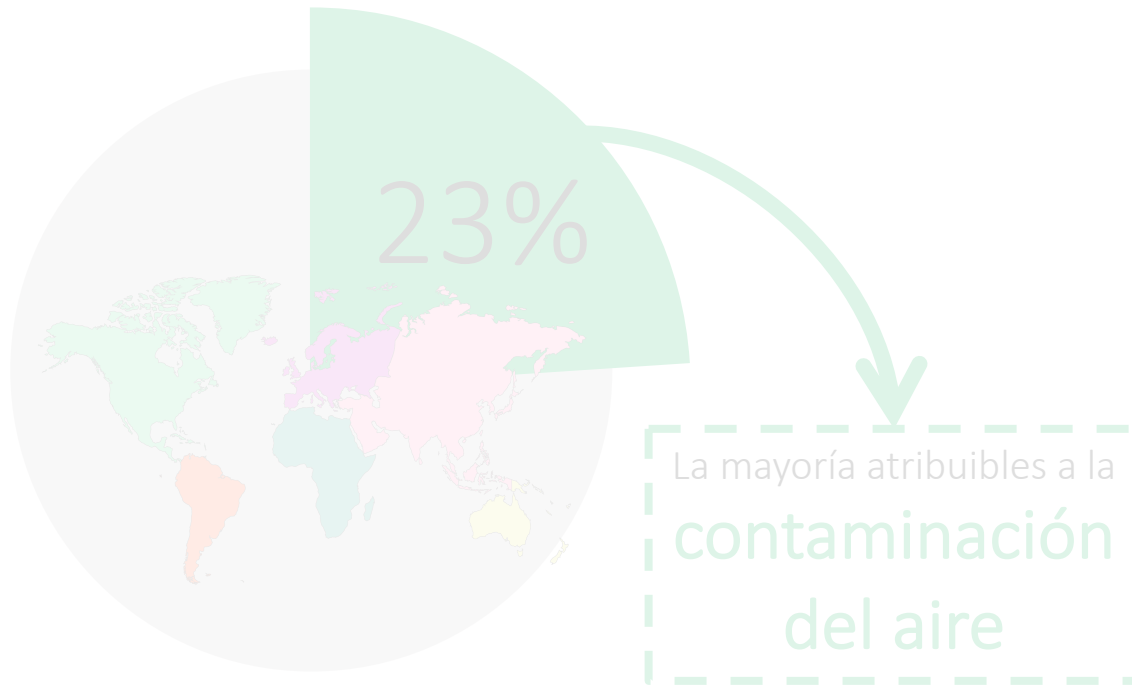


World Health Organization [2012]

12,6 Millones de
muertes al año

In Colombia The National
Institute of Health , found

8 thousand deaths per year
attributable to
atmospheric pollution



INSTITUTO
NACIONAL DE
SALUD

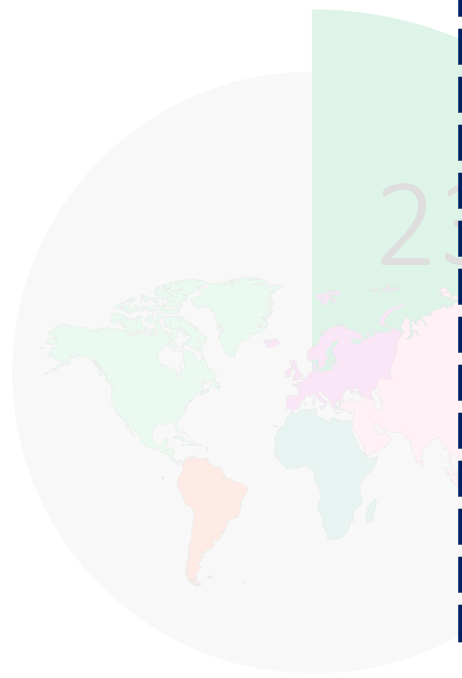


- Instituto Nacional De Salud, & Observatorio Nacional de Salud. (2018). Carga de enfermedad ambiental en Colombia.pdf. Retrieved from https://www.ins.gov.co/Direcciones/ONS/Informes/10_Carga_de_enfermedad_ambiental_en_Colombia.pdf
- United Nations. (2015). Resolution adopted by the General Assembly on 25 September 2015. In Transforming Our World: The 2030 Agenda for Sustainable Development. New York, NY: United Nations.

Motivations: Air Quality and Human Health



12,6 Millon
muertes al



Colombia

The Sustainable Development Goals

2030

Reduce the number of **deaths**
caused by
Environmental pollution

onal de Salud
tró
tes por año
es a
atmosférica



- Instituto Nacional De Salud, & Observatorio Nacional de Salud. (2018). Carga de enfermedad ambiental en Colombia.pdf. Retrieved from <https://www.ins.gov.co/Direcciones/ONS/Informes/10 Carga de enfermedad ambiental en Colombia.pdf>
- United Nations. (2015). Resolution adopted by the General Assembly on 25 September 2015. In Transforming Our World: The 2030 Agenda for Sustainable Development. New York, NY: United Nations.

Motivations: Emission sources

¿What is the sector that contributes the most to the concentrations of air pollutants in Colombia and ...



Motivations: Emission sources

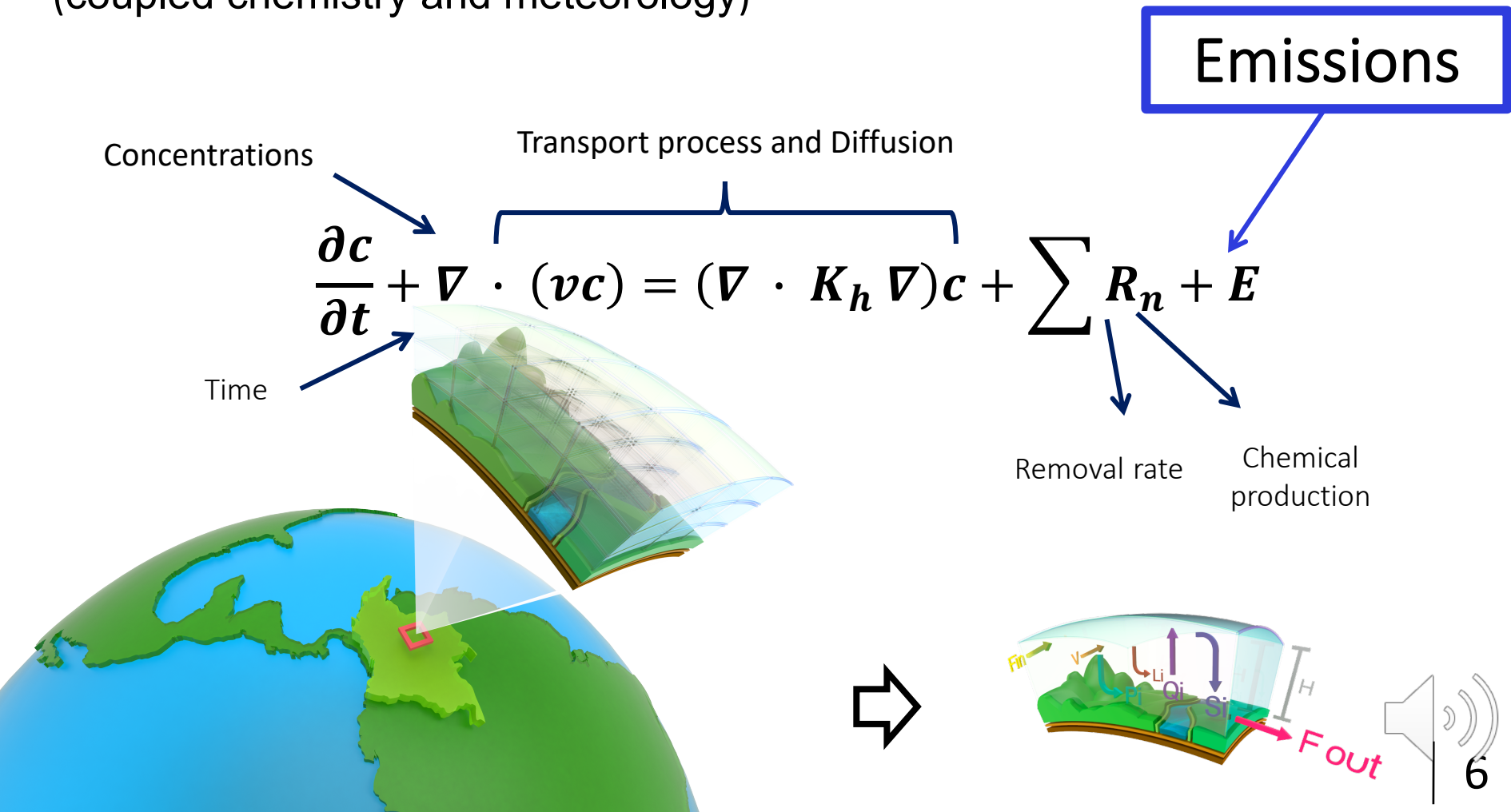
¿What is the sector that contributes the most to the concentrations of air pollutants in Colombia and ...

specifically in Bogotá?

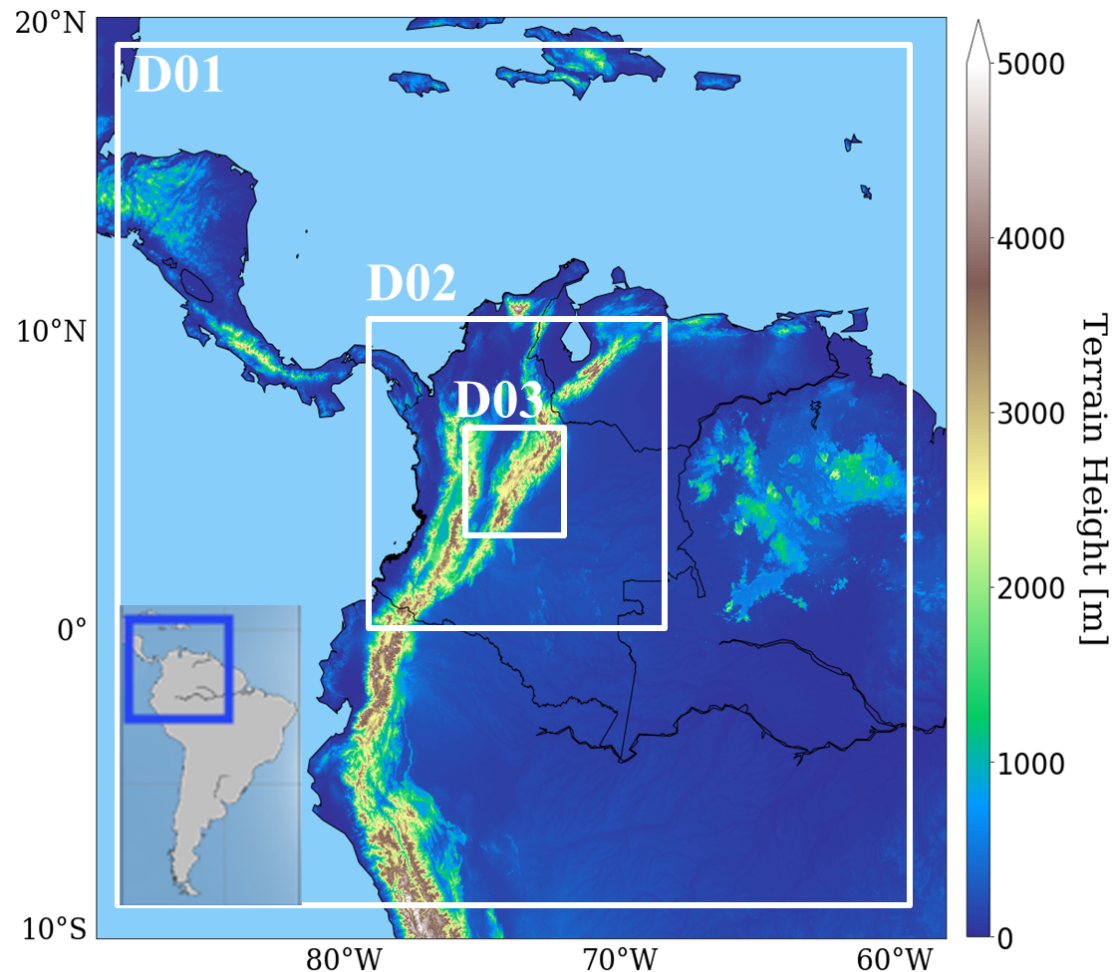


Methodology: WRF-Chem Model - version 3.9.1

- Eulerian Regional Chemical Transport Model
 - On-line model
- (coupled chemistry and meteorology)

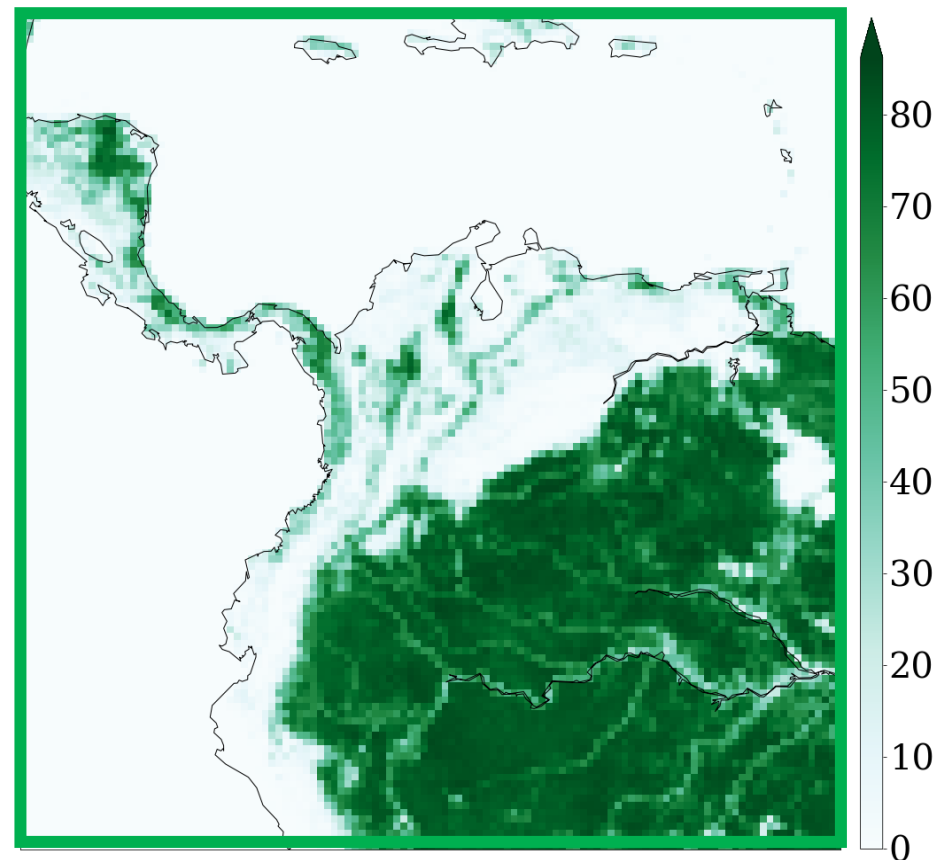


- 3 Nested domains
- **D01**: 121 x 121 grid
Resolution: 27 x 27km
- **D02**: 127 x 127 grid
Resolution: 9 x 9km
- **D03**: 133 x 133 grid
Resolution: 3 x 3
- 41 vertical levels
- Biogenic Emissions:
MEGAN – online
- RACM Gas phase chemistry
- MADE-VBS aerosol scheme
- Simulation date: Sep 2018



Anthropogenic emissions from the global emissions inventory EDGARv4.3.1 were merged with a local emissions inventory for the city of Bogotá.

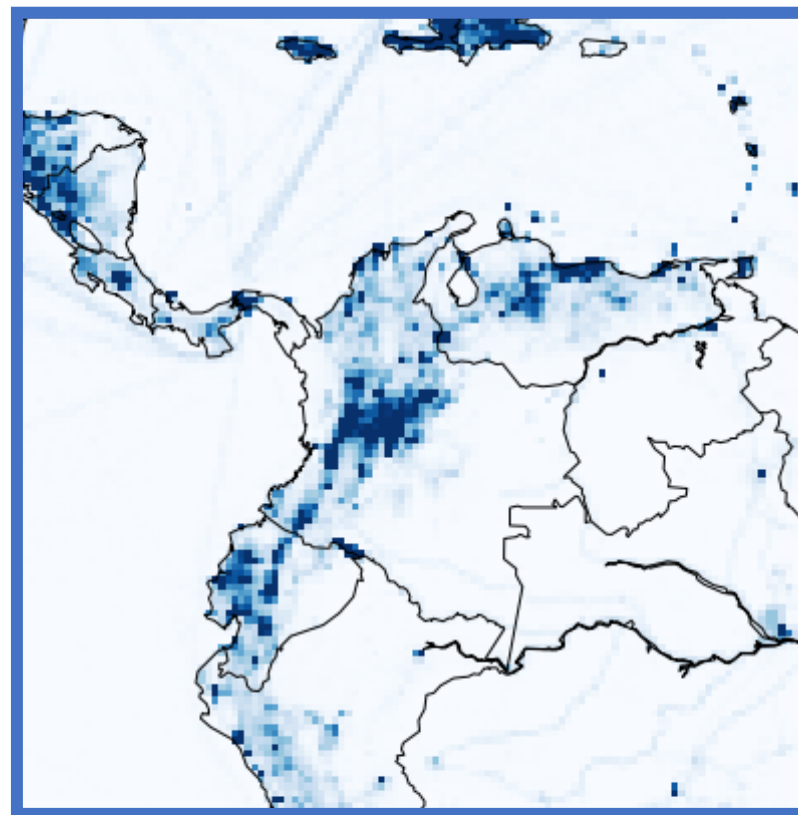
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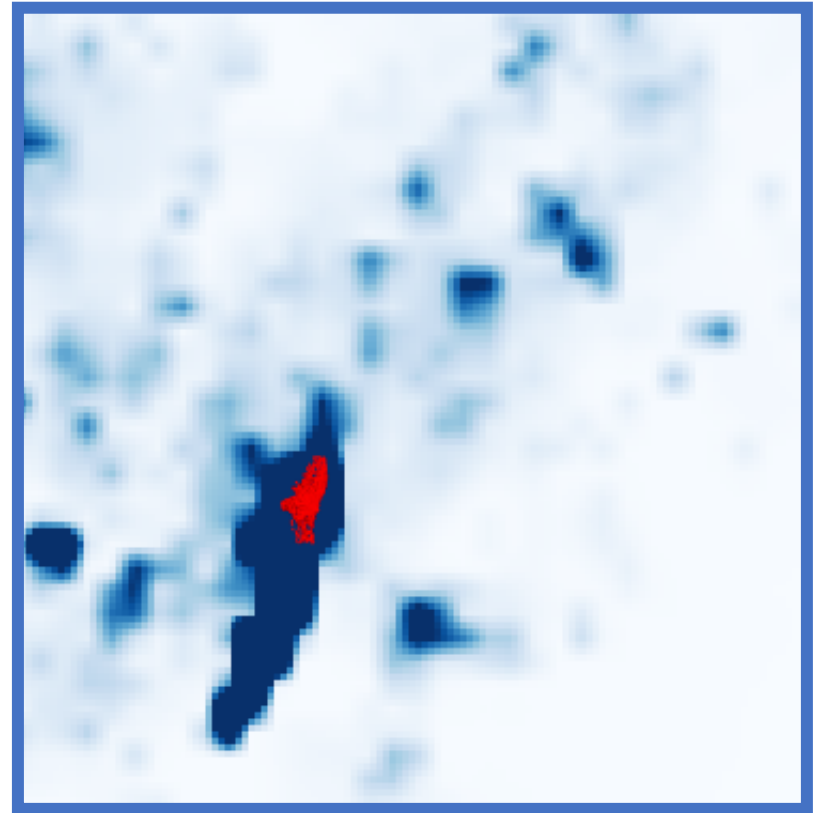
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D01: Edgar V4.3.1



- 3 Nested domains
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- 41 vertical levels
- Biogenic Emissions:
MEGAN – online
- RACM Gas phase chemistry
- MADE-VBS aerosol scheme
- Simulation date: Sep 2018

D03: Edgar V4.3.1 + Local

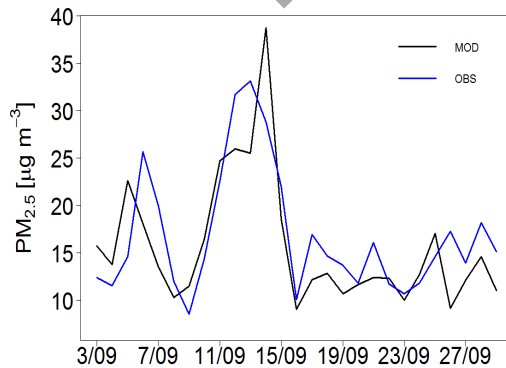


Anthropogenic emissions from the global emissions inventory EDGARv4.3.1 were merged with a local emissions inventory for the city of Bogotá.

Methodology:

Generate a base case simulation

- Compare observed and modeled data



Methodology:

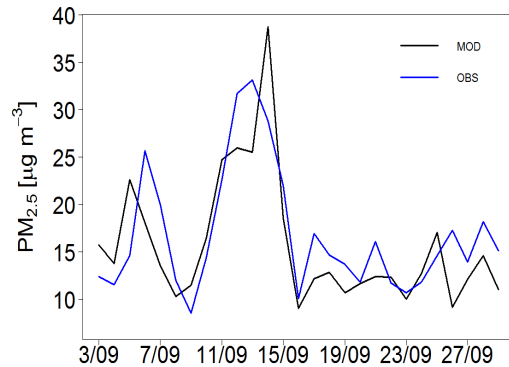
Generate a base case simulation



Evaluate the regional attribution of anthropogenic emissions (Colombia)

- Compare observed and modeled data

- Agricultural
- Electric Power Generation
- Industrial
- Mobile
- Commercial
- Other's sectors.



Methodology:

Generate a base case simulation

- Compare observed and modeled data



Evaluate the regional attribution of anthropogenic emissions (Colombia)

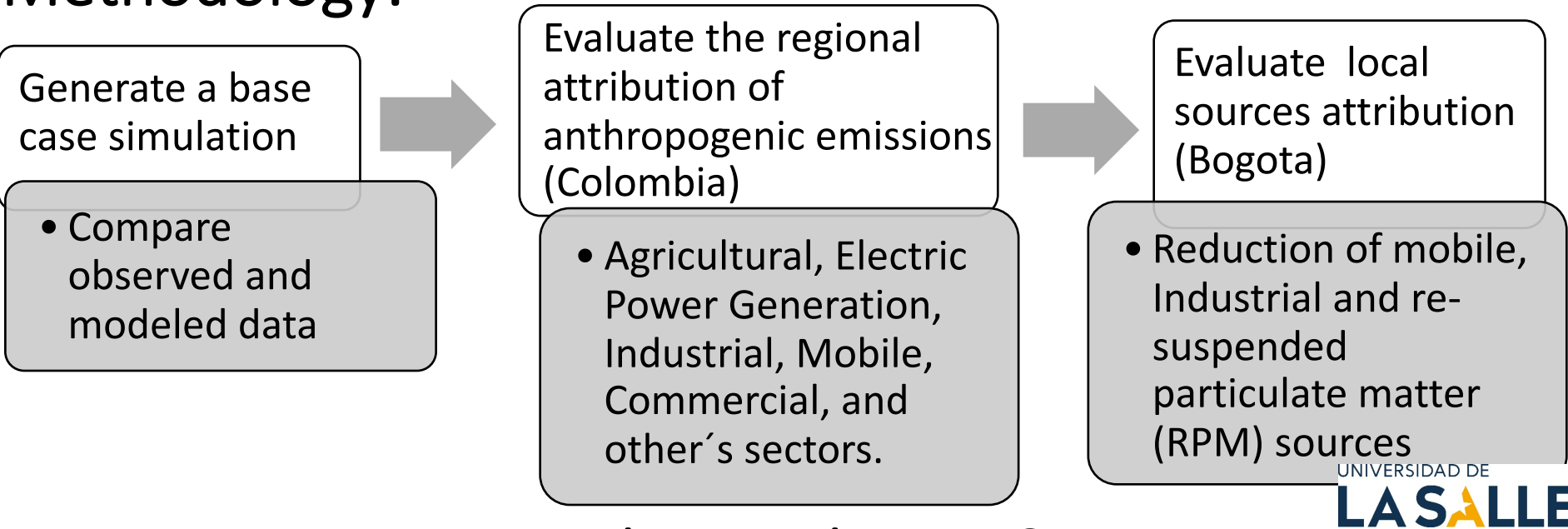
- Agricultural
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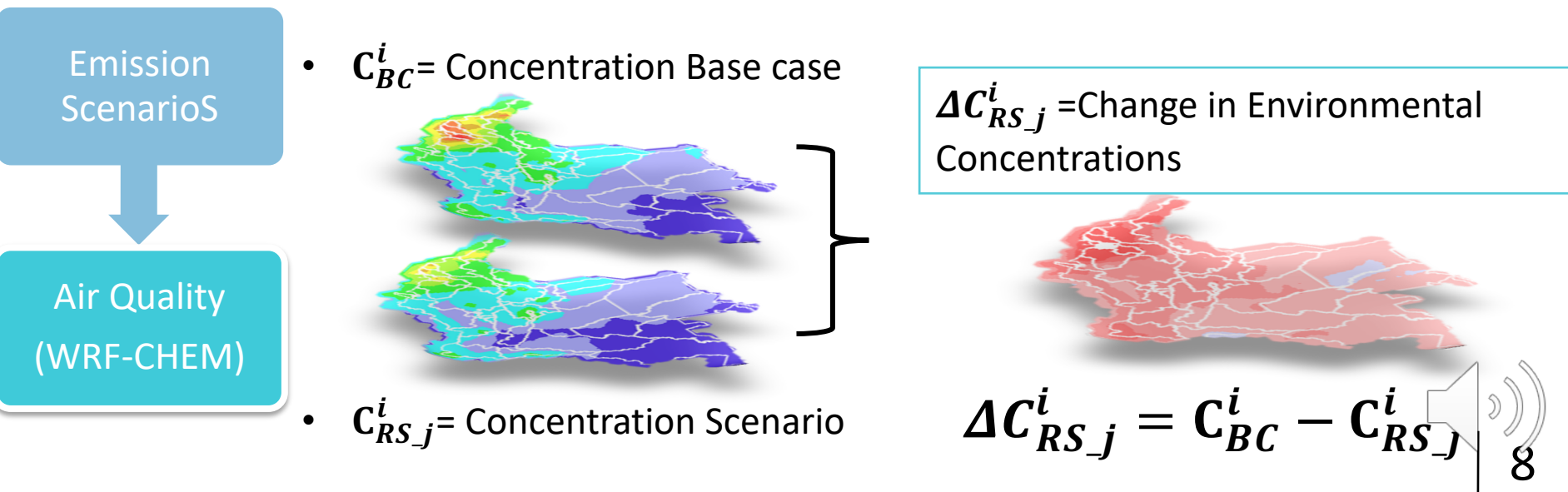
Evaluate local sources attribution (Bogota)

- Reduction of mobile, Industrial and re-suspended particulate matter (RPM) sources

Methodology:



How to measure the attribution?



Scenario 1. Reduction of RPM emissions (S1)

RPM sector PM ₁₀ (Ton/year)	
Quarries:	299.4
Buildings:	674.6
Pavedroads:	10510.9
Unpaved roads:	10457.9

- Emissions on unpaved roads can be solved with paving

Scenario 1. Reduction of RPM emissions (S1)

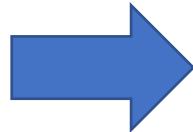
RPM sector PM ₁₀ (Ton/year)	
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Scenario 2. Reduction of industrial emissions (S2)



(Change in
EF and AF)



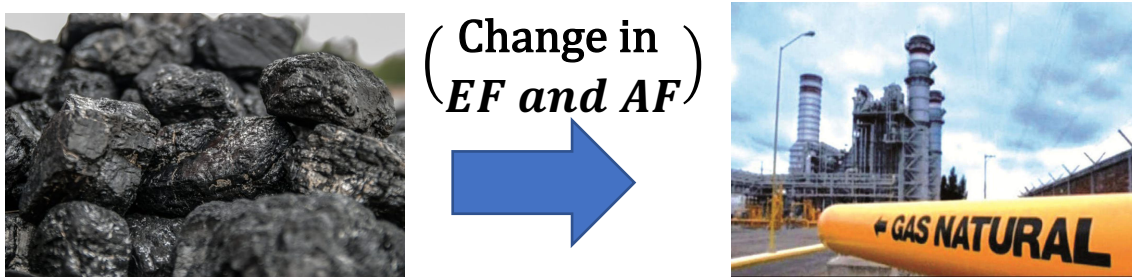
- Technology change from coal to Natural gas

Scenario 1. Reduction of RPM emissions (S1)

RPM sector PM ₁₀ (Ton/year)	
Quarries:	299.4
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Scenario 2. Reduction of industrial emissions (S2)



- Technology change from coal to Natural gas

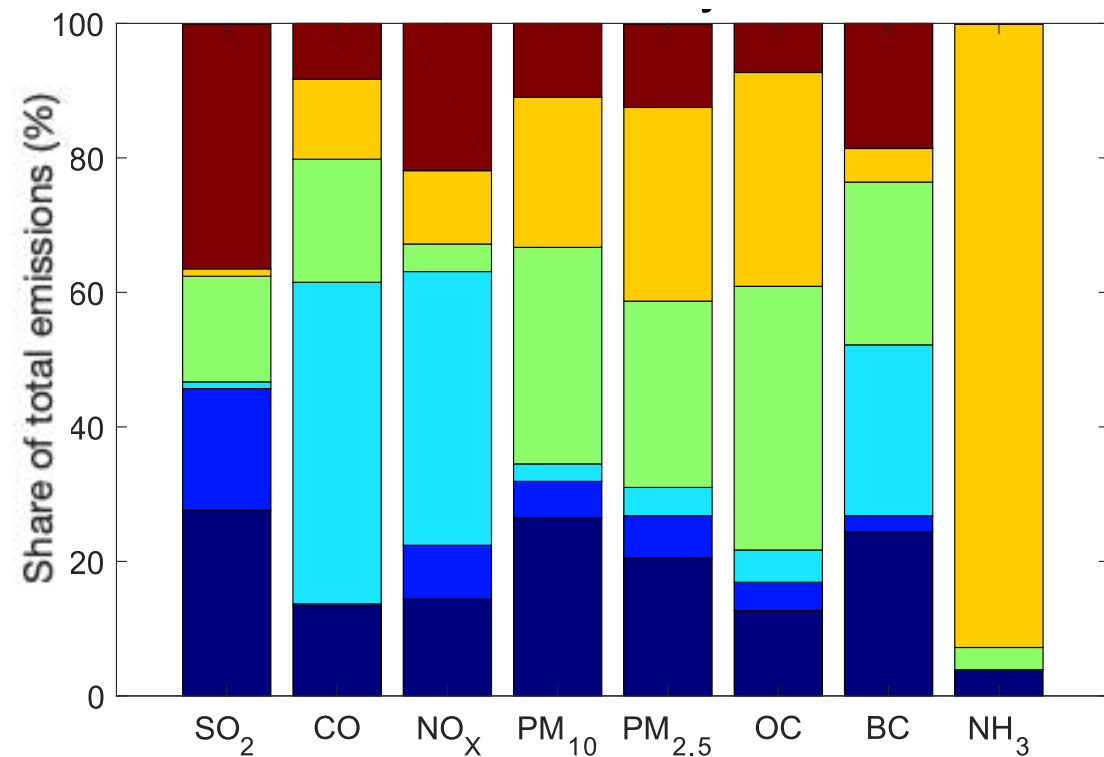
Scenario 3. Reduction of mobile emissions (S3)



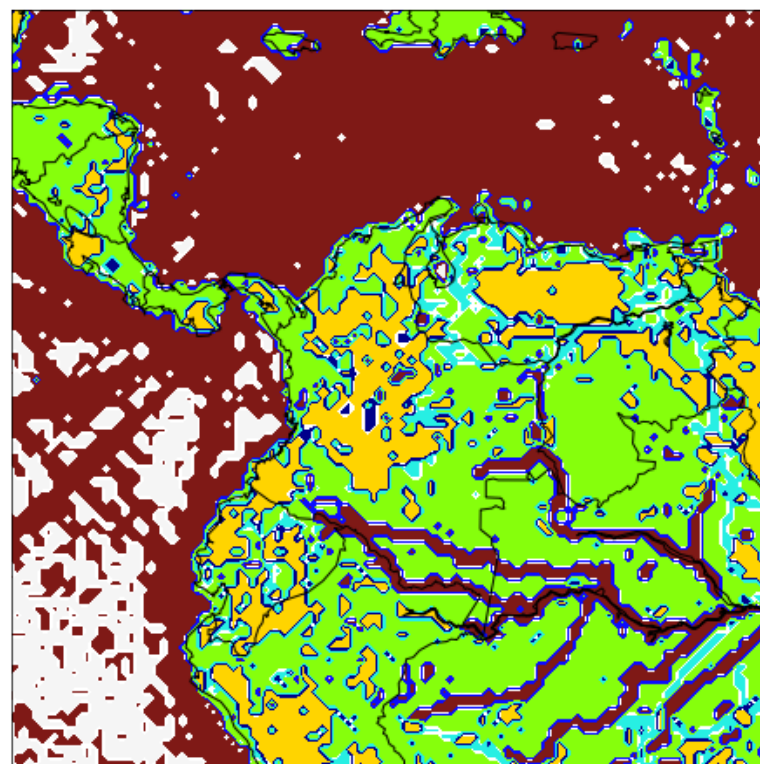
- Heavy-duty vehicles renewal - Euro IV

Domain 1: Colombia – EDGAR Inventory

Percentage of emissions from economic sectors for Colombia



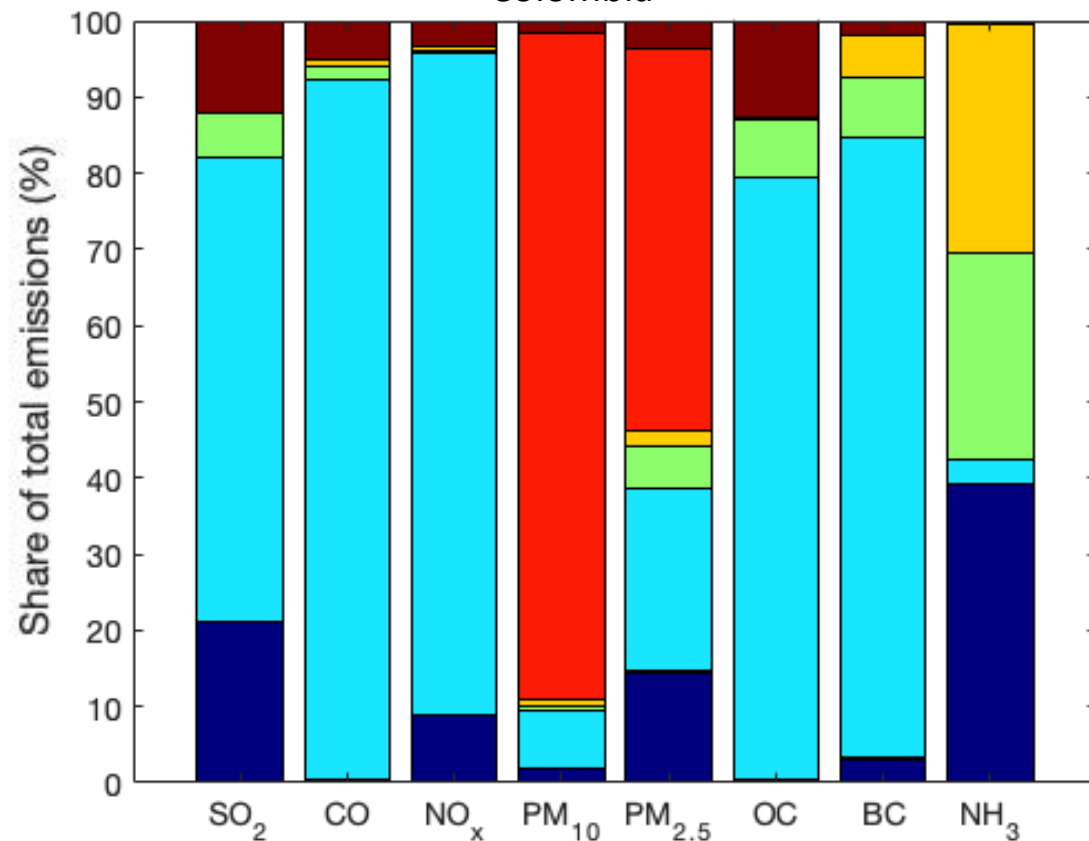
PM_{2.5} Spatial Distribution by Sectors



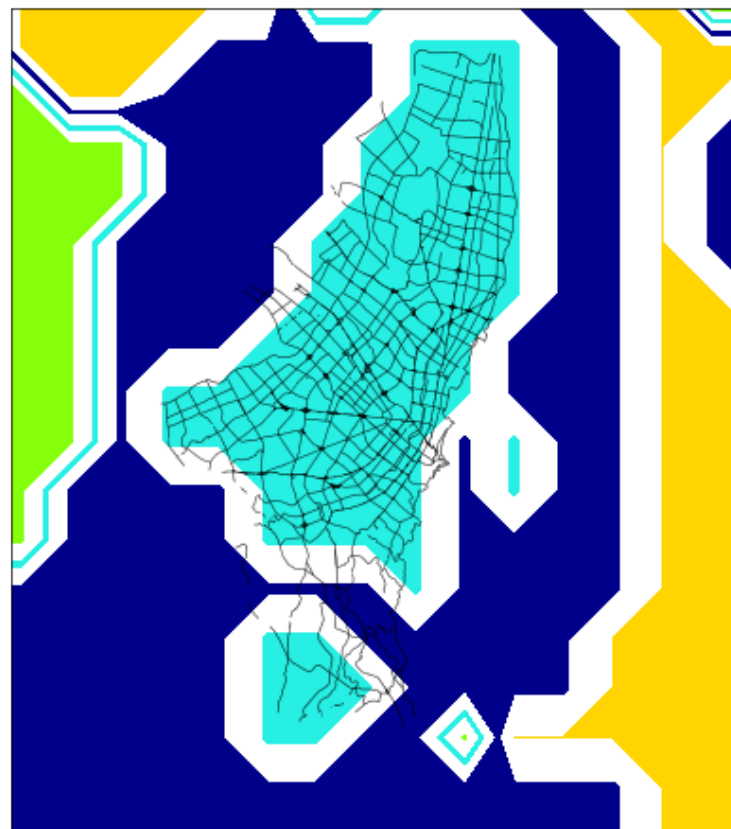
Industrial Energy Mobile Commercial Agricultural Other

Domain 3: Bogotá – Local inventory

Percentage of emissions from economic sectors for Colombia



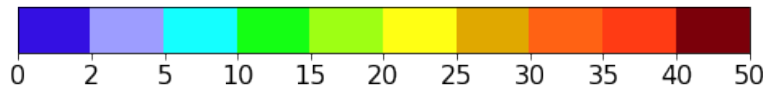
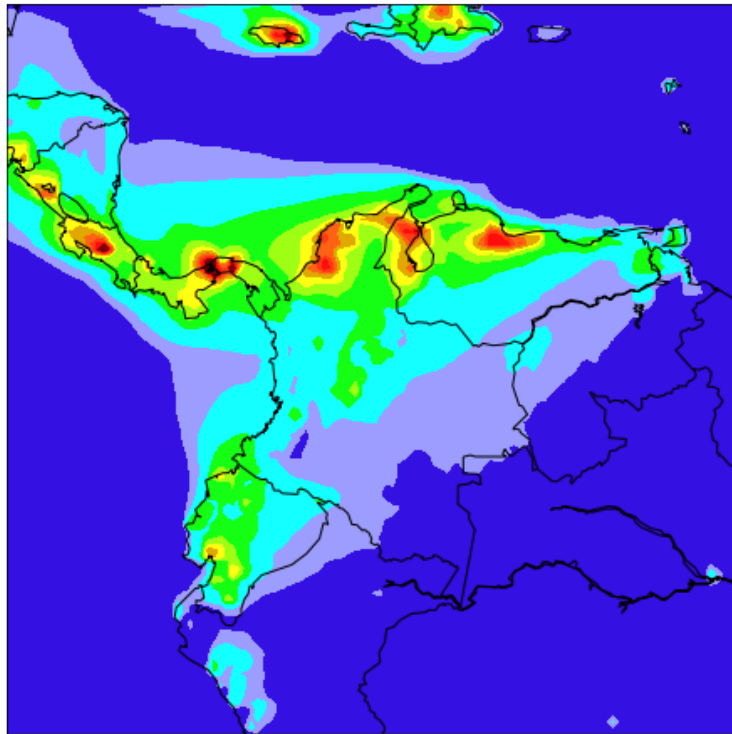
PM_{2.5} Spatial Distribution by Sectors



Industrial Energy Mobile Commercial Agricultural RPM Other

Domain 1:

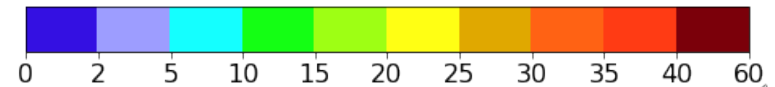
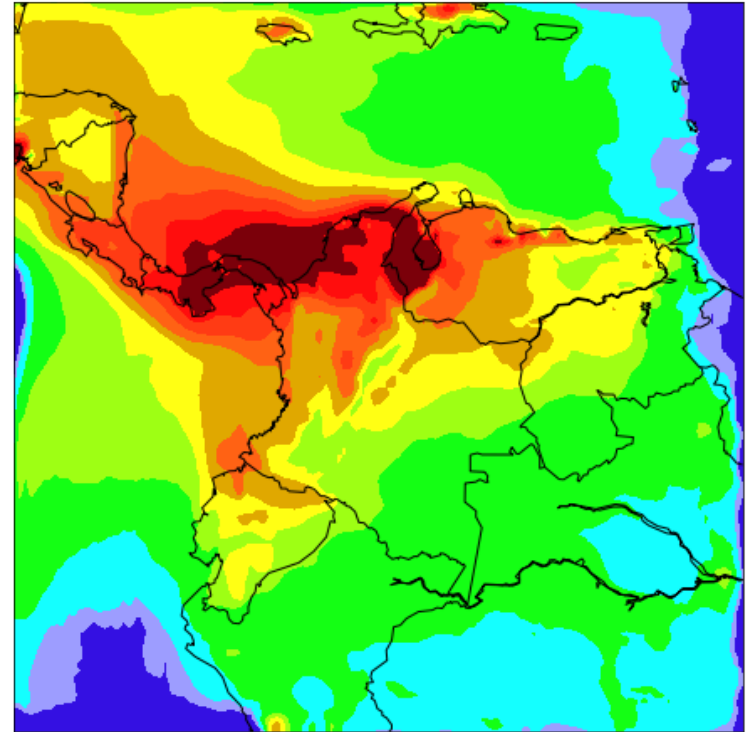
Average daily concentration at
ground level



2.13 $PM_{2.5} \left(\frac{\mu g}{m^3} \right)$

Average
concentration

Maximum 8hr average concentration
above ground level



12.3 $O_3(ppb)$

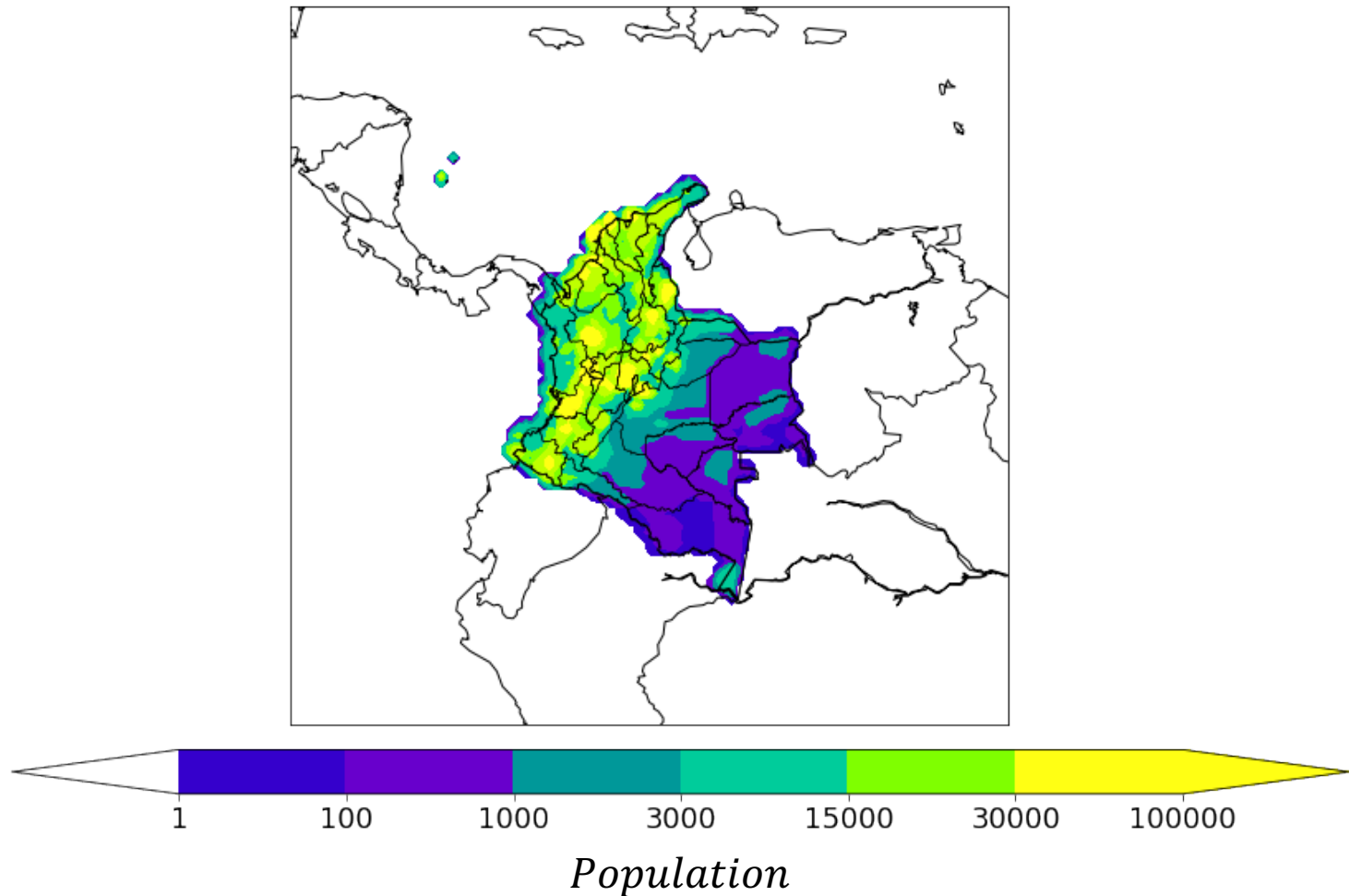
Population-weighted concentration

Results

DANE
INFORMACIÓN PARA TODOS

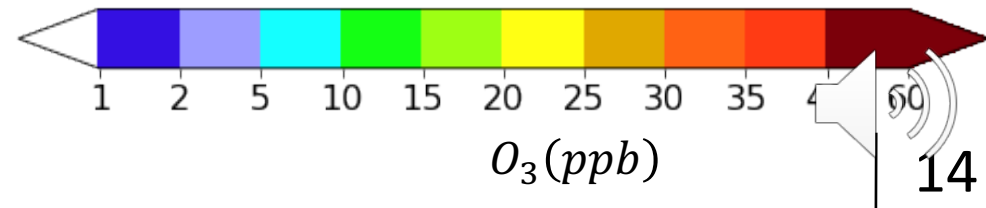
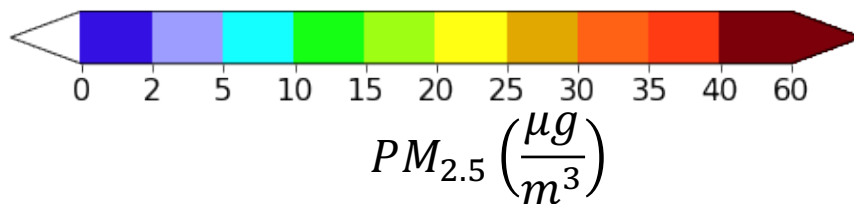
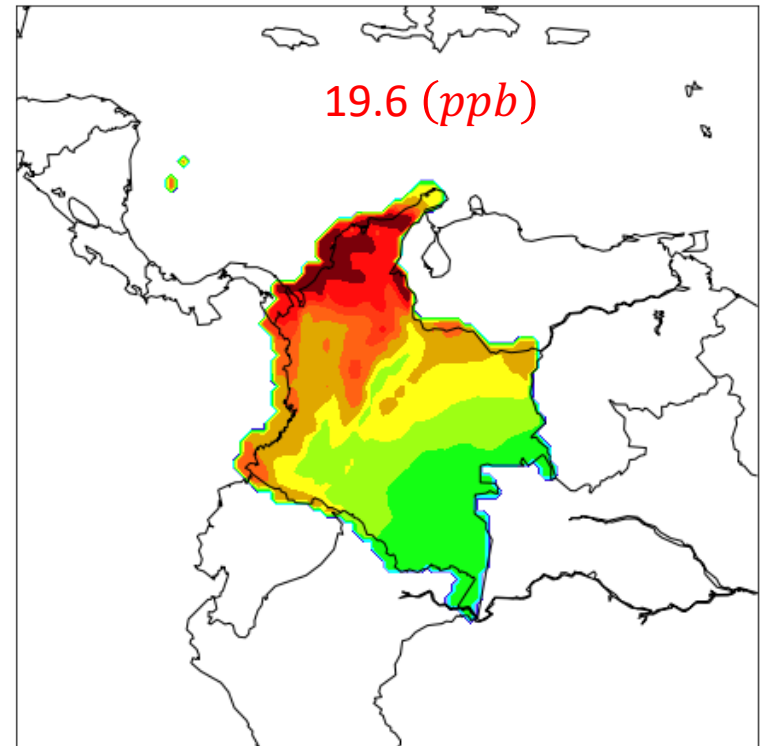
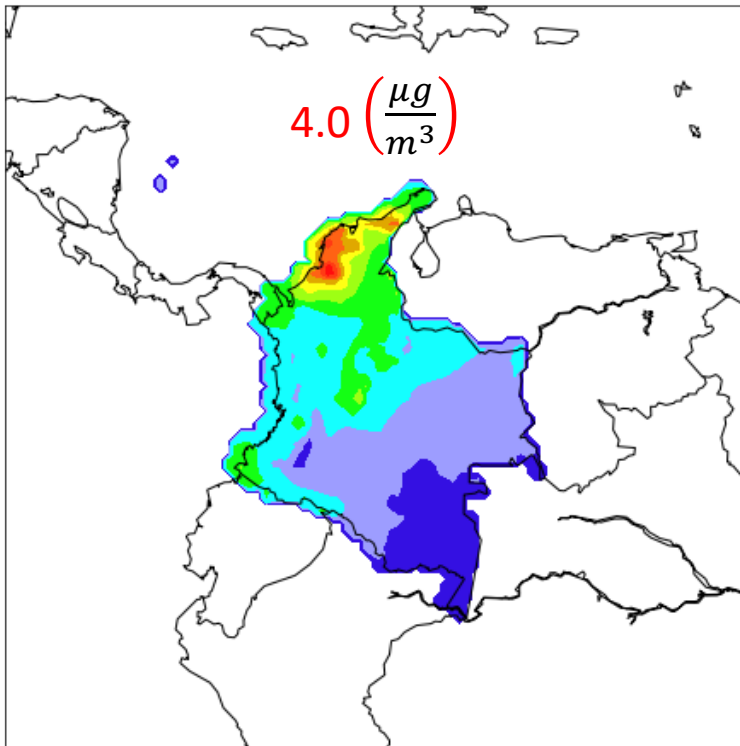
RESULTADOS
**CENSO NACIONAL
DE POBLACION
Y VIVIENDA 2018**

Population in Colombia



Population-weighted concentration

Average daily concentration at ground level weighted by population



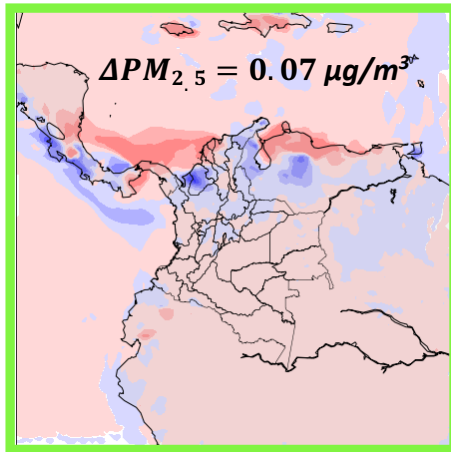
Attribution of PM_{2.5} Concentration - Colombia

Results

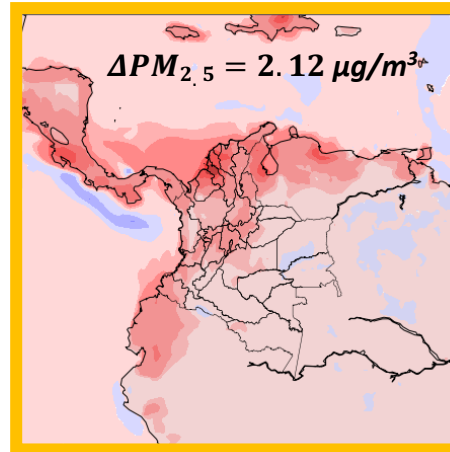
Population weighted average

$$\Delta C_{RS-j}^{PM_{2.5}} = C_{BC}^{PM_{2.5}} - C_{RS-j}^{PM_{2.5}}$$

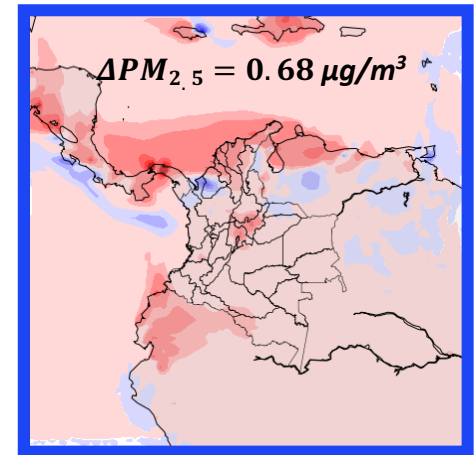
Base Case - Commercial



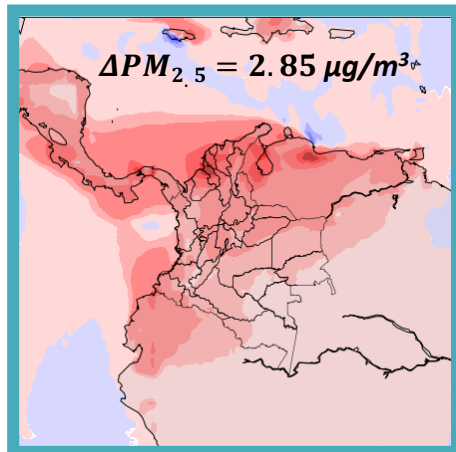
Base case -Agricultural



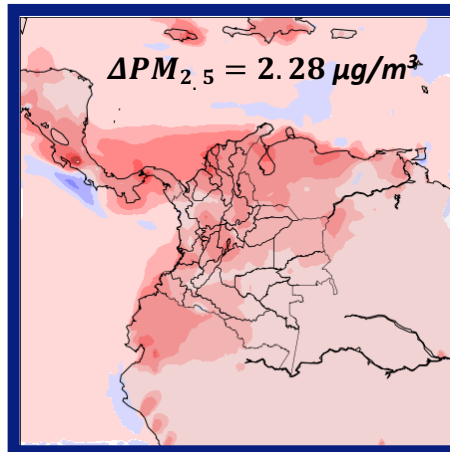
Base case – Energy



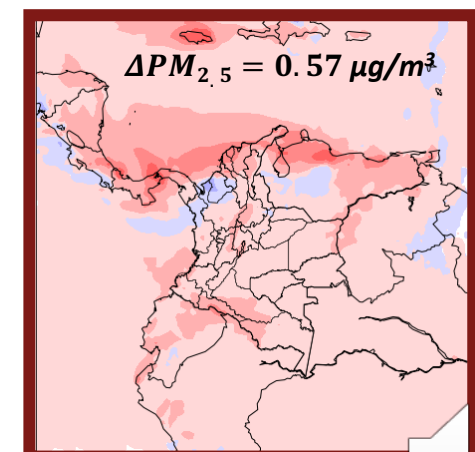
Base case - Mobile



Base case - Industrial



Base case - Others



$\Delta PM_{2.5} \mu g/m^3$



Attribution of NO_x and O_3 Concentration - Colombia

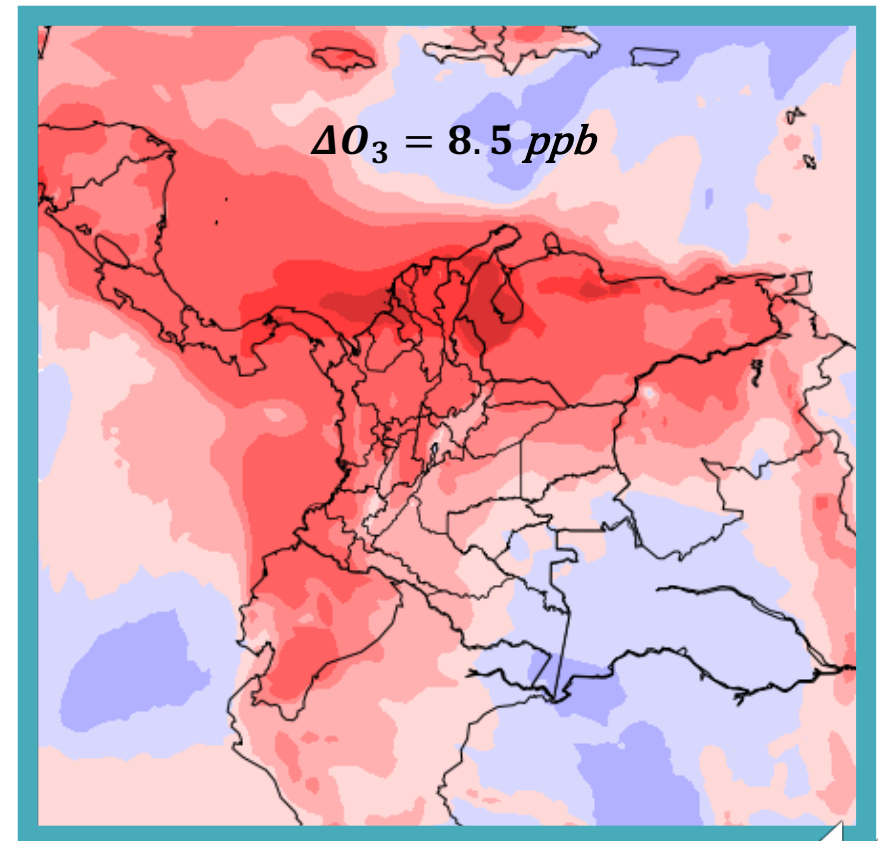
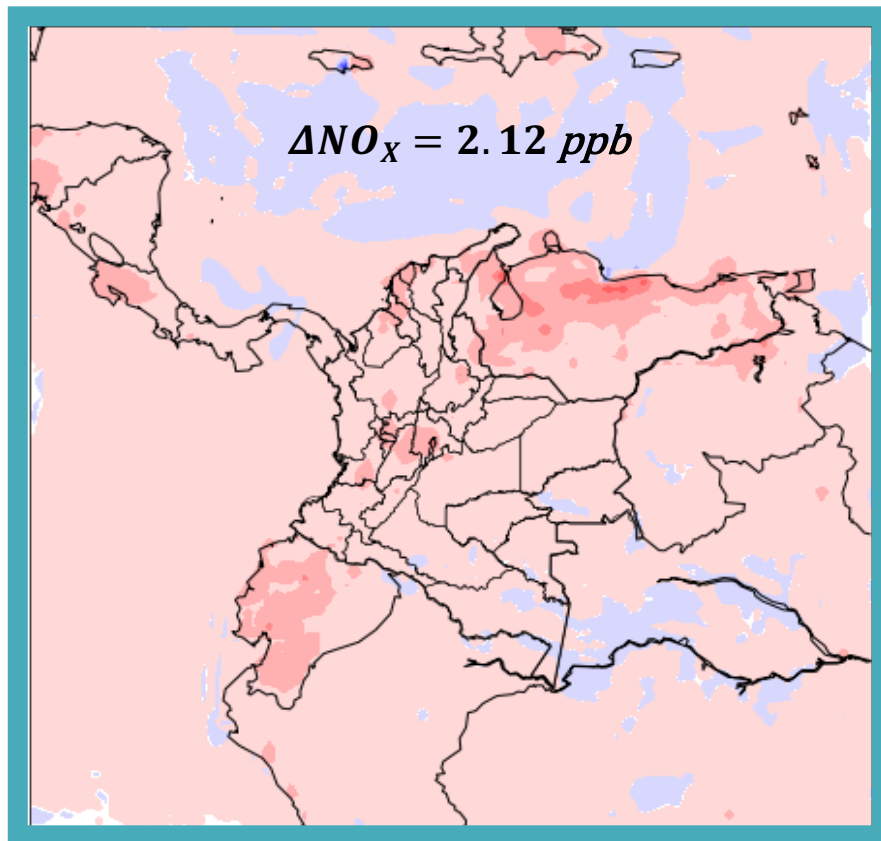
Results

Population weighted average

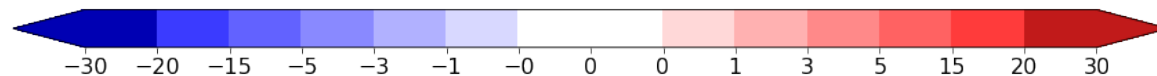
$$\Delta C_{RS-j}^{\text{NO}_x} = C_{BC}^{\text{NO}_x} - C_{RS-j}^{\text{NO}_x}$$

Base case - Mobile

$$\Delta C_{RS-j}^{\text{NO}_x} = C_{BC}^{\text{NO}_x} - C_{RS-j}^{\text{NO}_x}$$



$\text{NO}_x \text{ (ppb)}$

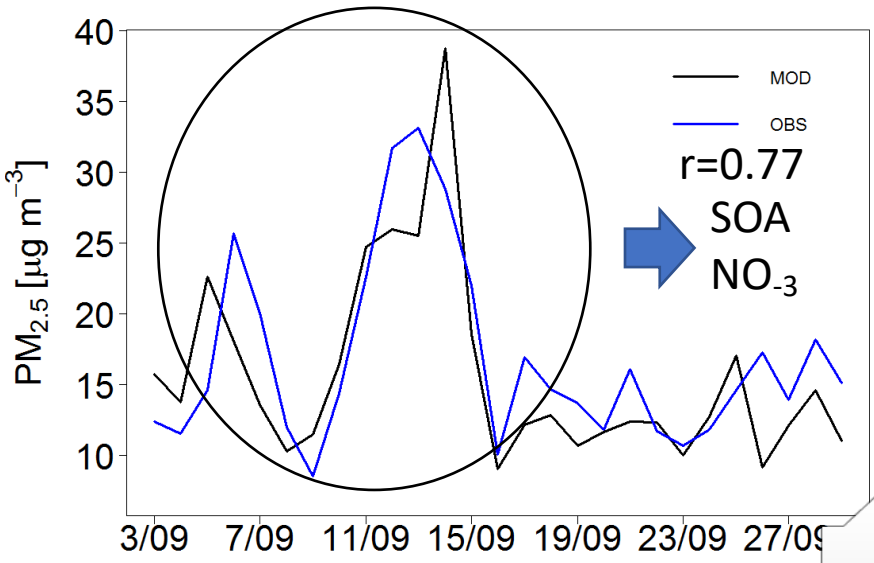
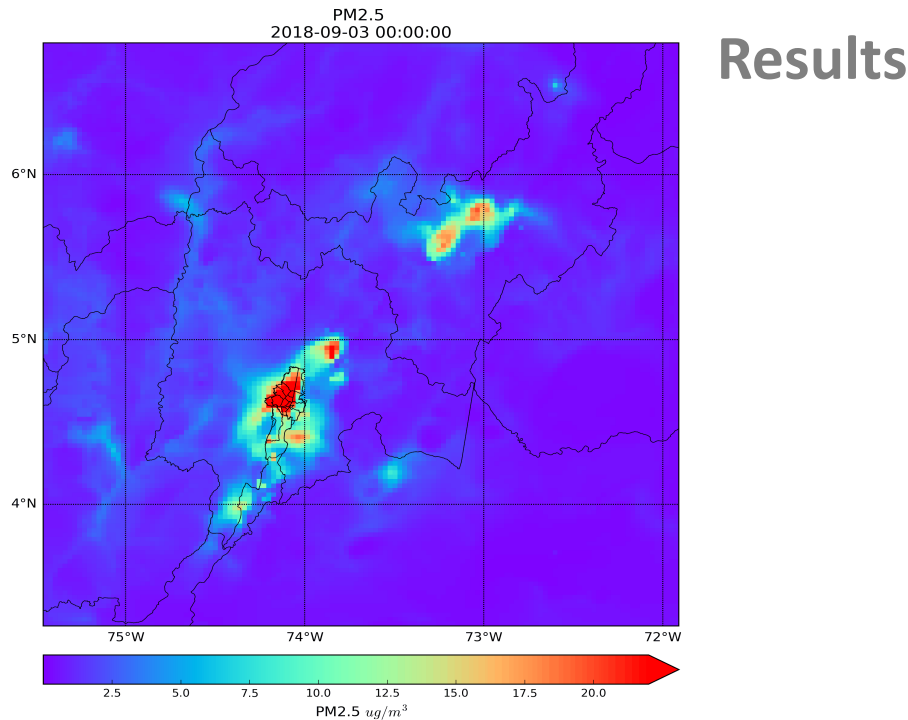
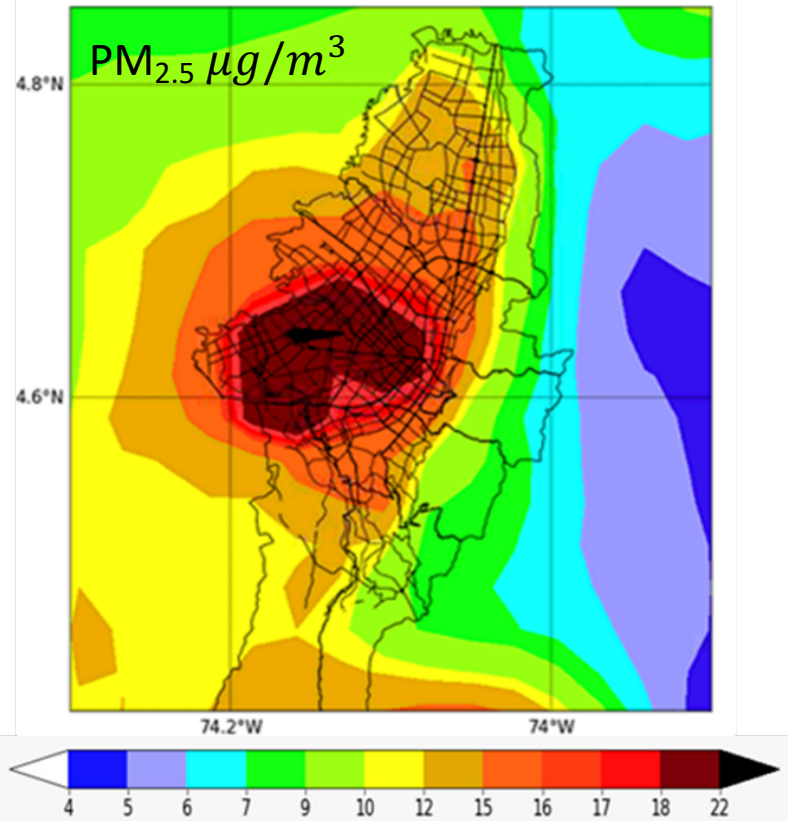


$\text{O}_3 \text{ (ppb)}$

16

Base case simulation D03

Variable	Units	Mean_Obs	Mean_Mod
PM ₁₀	μg/m ³	38.94	39.24
PM _{2.5}	μg/m ³	16.83	15.71
O ₃ max 8 h	ppb	21.64	18.61
CO	ppm	0.87	0.50
NO _x	ppb	43.17	50.35
SO ₂	ppb	2.30	2.92
WS	m/s	1.75	2.41
T	°C	14.52	14.28

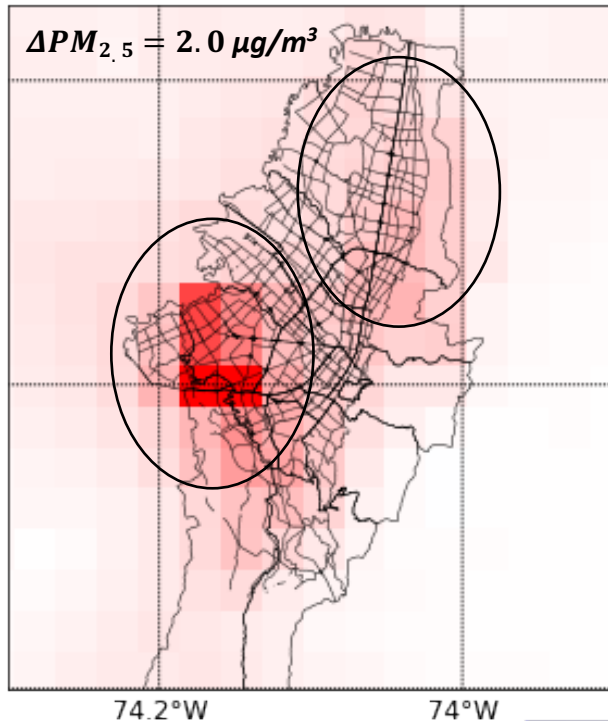


Attribution of PM_{2.5} Concentration -Bogota

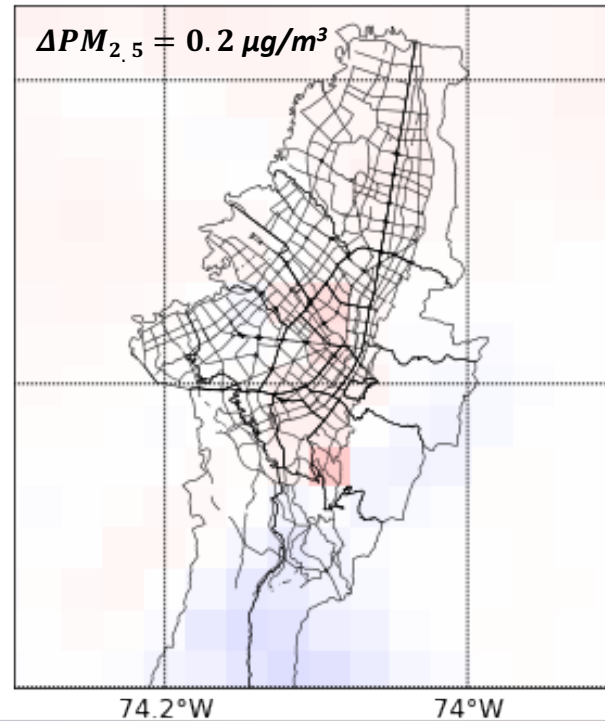
Results

$$\Delta C_{RS_j}^{PM_{2.5}} = C_{BC}^{PM_{2.5}} - C_{RS_j}^{PM_{2.5}}$$

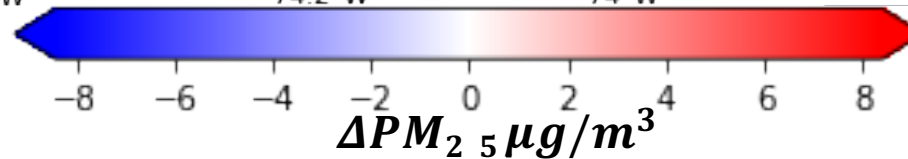
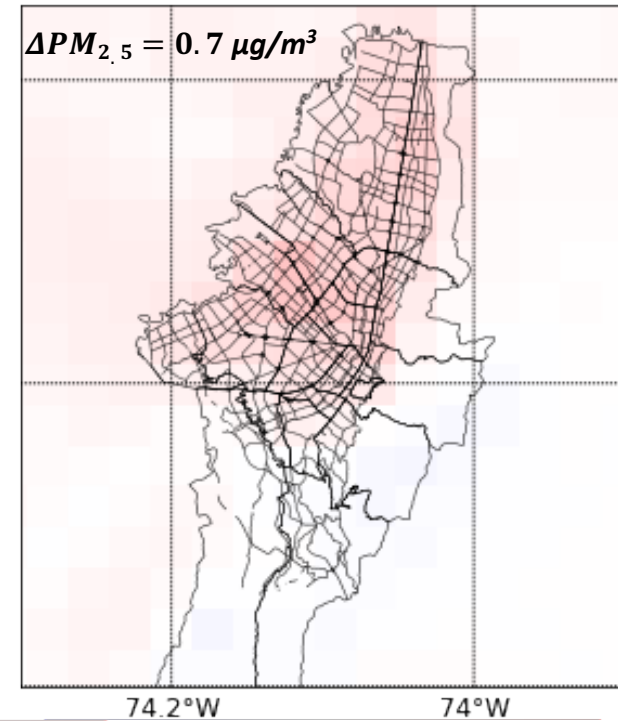
Base Case – RPM (S1)



Base Case – Industrial (S2)



Base Case – Mobile (S3)



- A maximum reduction of $8 \mu g/m^3$ occurs in S1.

- in S2, the maximum reduction is $1.6 \mu g/m^3$

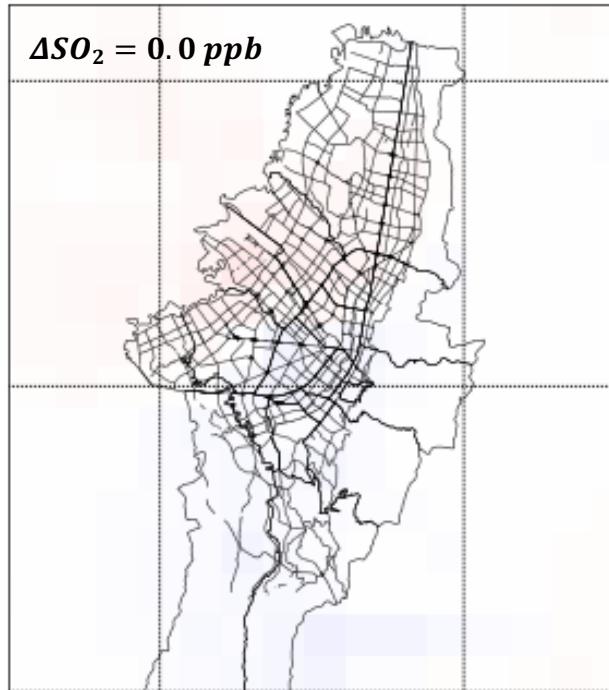
- in S3, the maximum reduction is $2 \mu g/m^3$

Attribution of SO₂ Concentration -Bogota

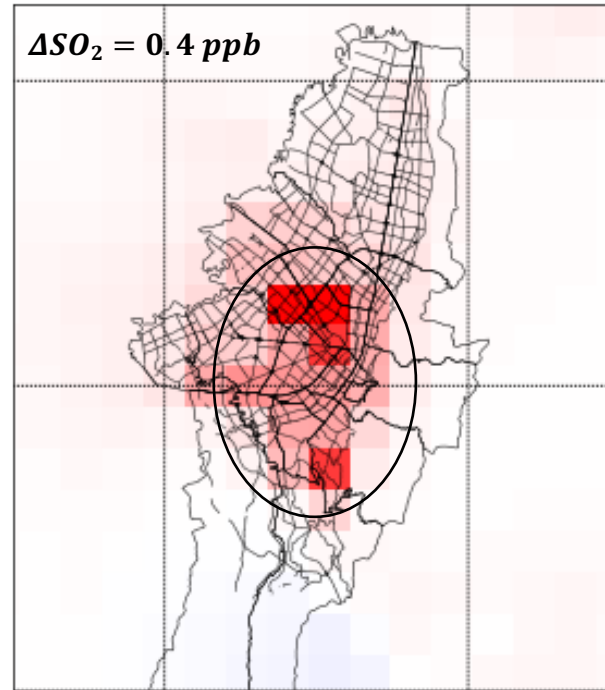
Results

$$\Delta C_{RS_j}^{SO_2} = C_{BC}^{SO_2} - C_{RS_j}^{SO_2}$$

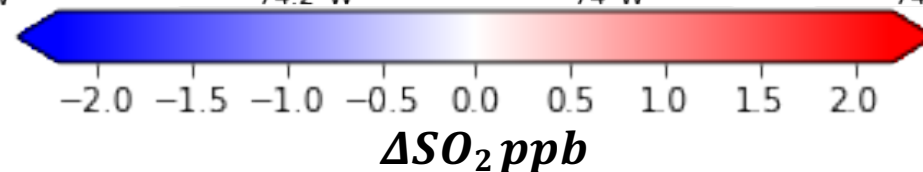
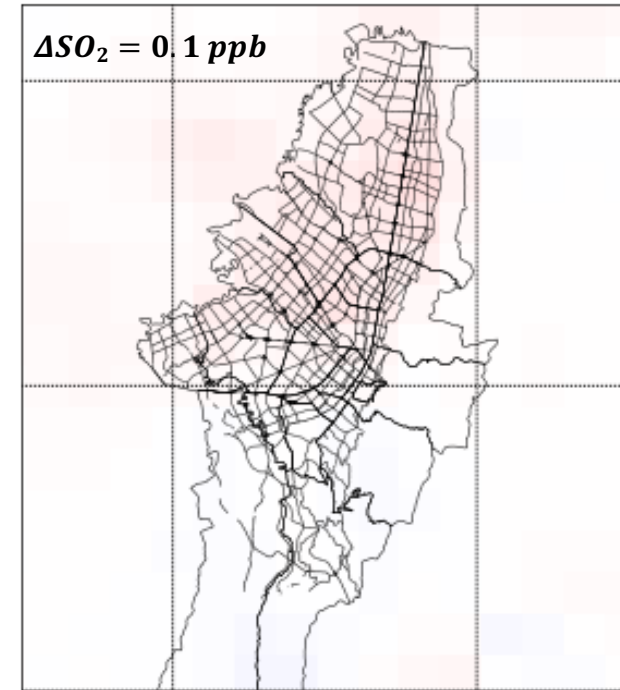
Base Case – RPM (S1)



Base Case – Industrial (S2)



Base Case – Mobile (S3)



- The %change in S1, S2 and S3 are -0.6%, -15.5% and -3.3%
- A maximum change of 2.2 ppb
- in S2, the greatest change occurs in the city center

Conclusions

- This research highlights the potential use of air quality modeling as a tool for the creation of public policies that are aimed at reducing emissions related to economic sectors.
- At the national scale, our results show that the sectors with the greatest contribution to $PM_{2.5}$ concentrations are Mobile and Industrial, contributing 2.8 and 2.3 $\mu g\ m^{-3}$ respectively, to the monthly-mean population-weighted concentration.
- For the city of Bogota, it was found that the paving of unpaved roads, the heavy-duty vehicles renewal and technology change in the industry can generate a maximum reduction of 8.0, 2.0 and 1.6 $\mu g\ m^{-3}$ respectively, benefiting low and middle income areas of the city.

TEAM

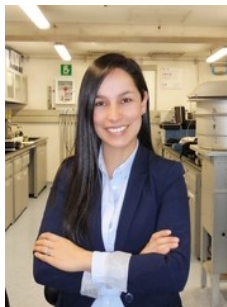
Acknowledgement



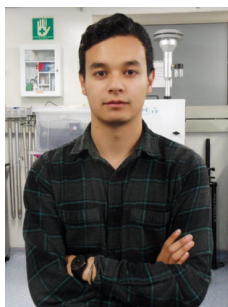
Ricardo Morales
Director



CIIA



Karen Ballesteros
Ph. D Student



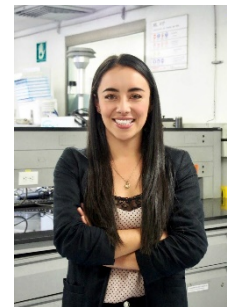
Sebastian Espitia
M.Sc Student



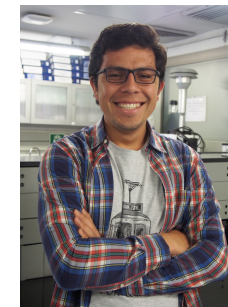
Alejandra Montejó
M.Sc. Student



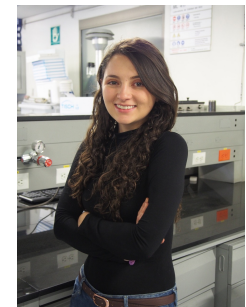
Camilo Moreno
M.Sc. Student



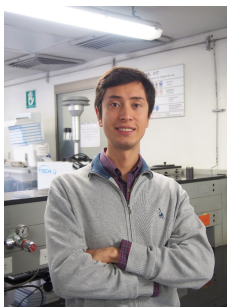
Daniela Méndez
M.Sc. Student



Juan Manuel Rincón
M.Sc.



M. Alejandra Rincón
M.Sc.



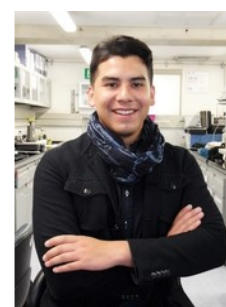
Juan Felipe Mendez
M.Sc.



Catalina Pinto
M.Sc. Student



Maria Paula Perez
M.Sc.



Yadert Contreras
M.Sc.



Juan Pablo Ayala
M.Sc.



Miguel Quirama
M.Sc.

