MAUI: Medellin Air qUality Initiative

Universidad Nacional de Colombia Sede Bogotá

Universidad CES
Un compromiso con la excelencia

Universidad de Antioquia

TNO innovation for life

TU Delft

Universidad EAFIT
Vigilada Mineducación

Air Quality Crisis – Medellin, 2016

Poor Air Quality – A Major Problem

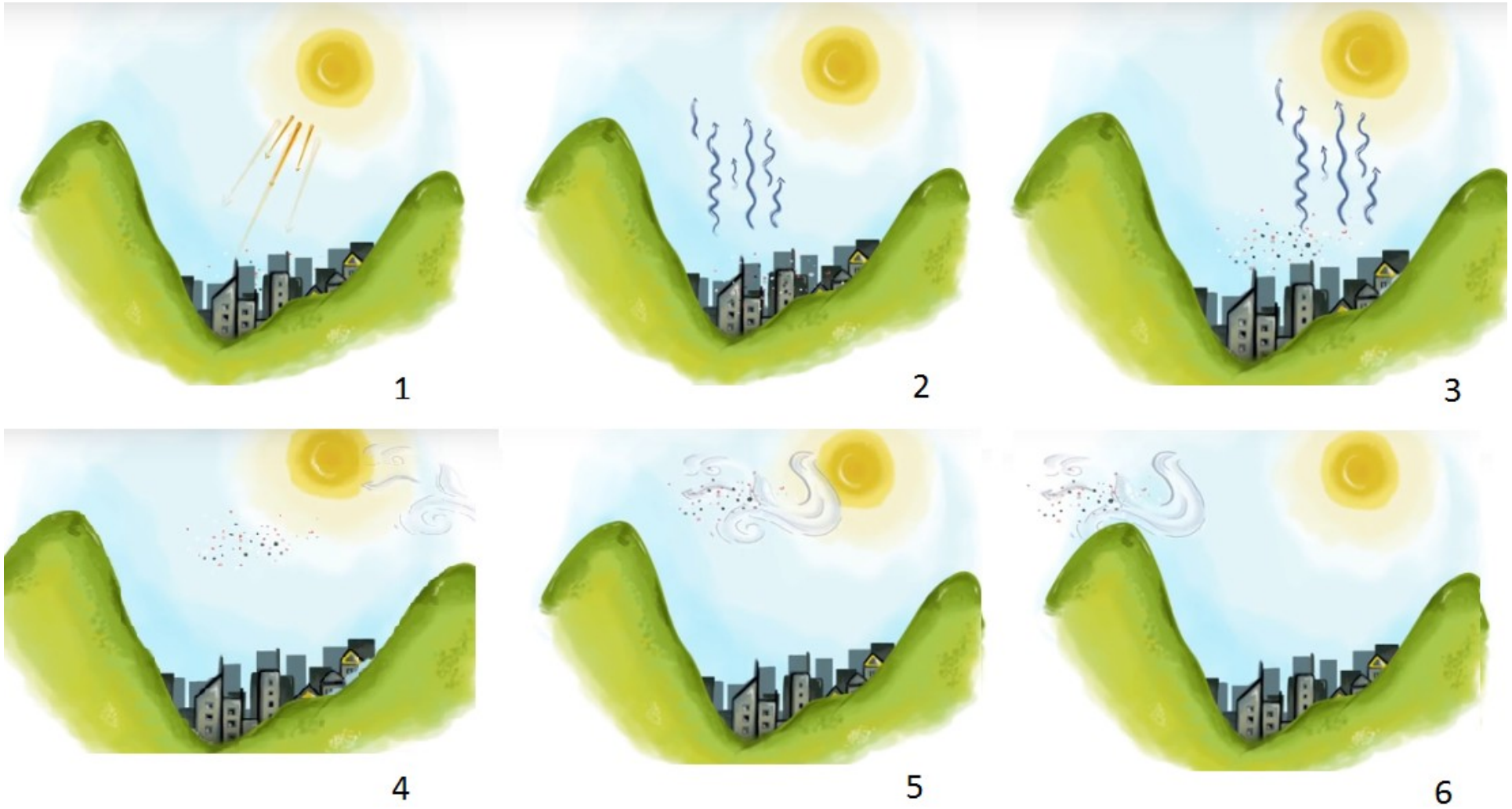
With deaths projecting to reach **3.6 million per year in 2050**, air pollution will soon overtake contaminated water and poor sanitation as the world's leading environmental cause of premature deaths (Green et al., 2013).

Photo: Raul Arboleda (AFP)

Photo: Róbinson Sáenz (El Colombiano)

9,2 % of the deaths in the valley are related to the contamination problem (Metropolitan Area of Medellín, 2016). The air quality in cities of the Aburrá Valley (Medellín, Colombia) and neighboring cities is among **the worst** in Colombia.

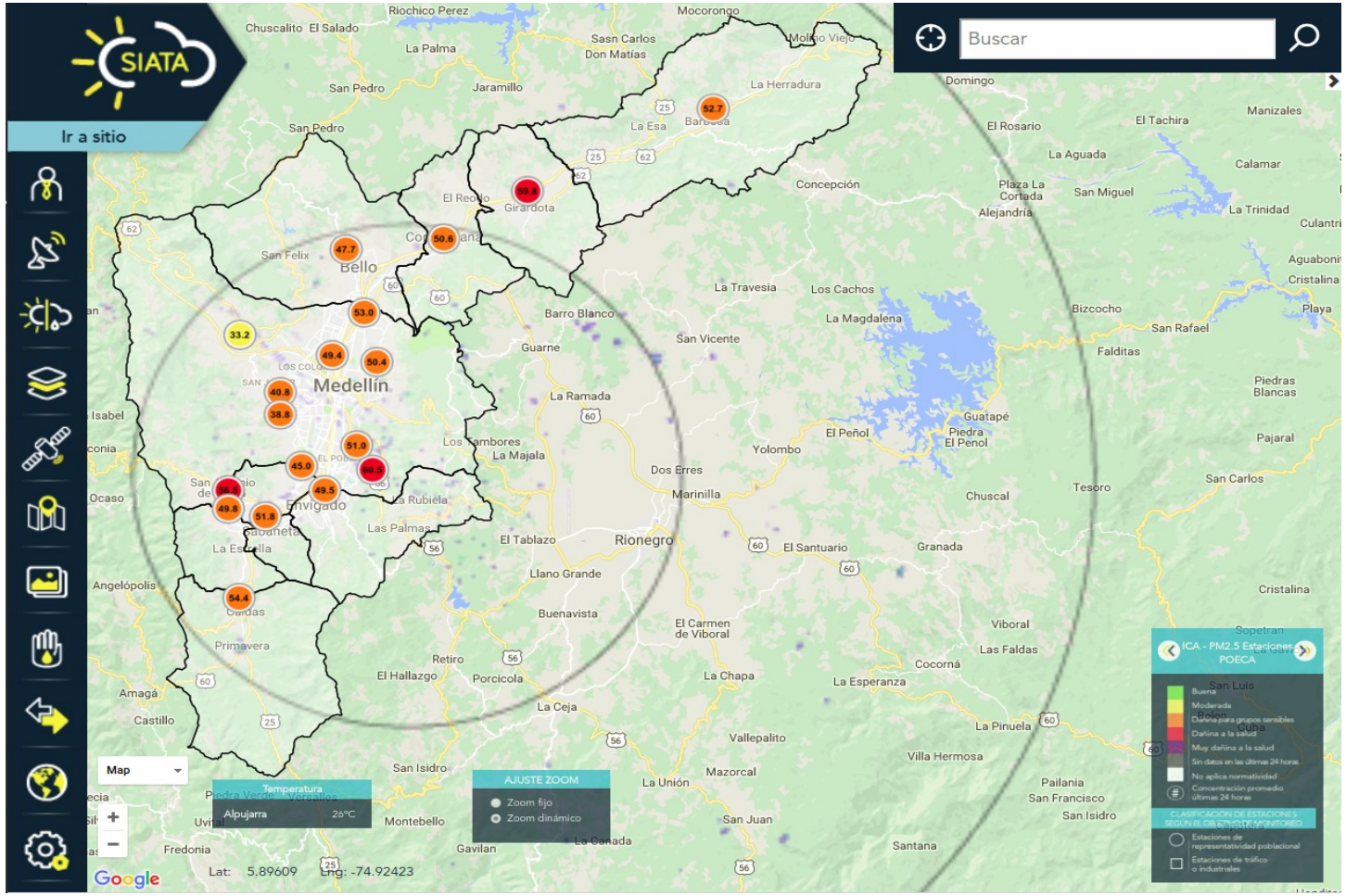
Pollutants and their exit from the valley



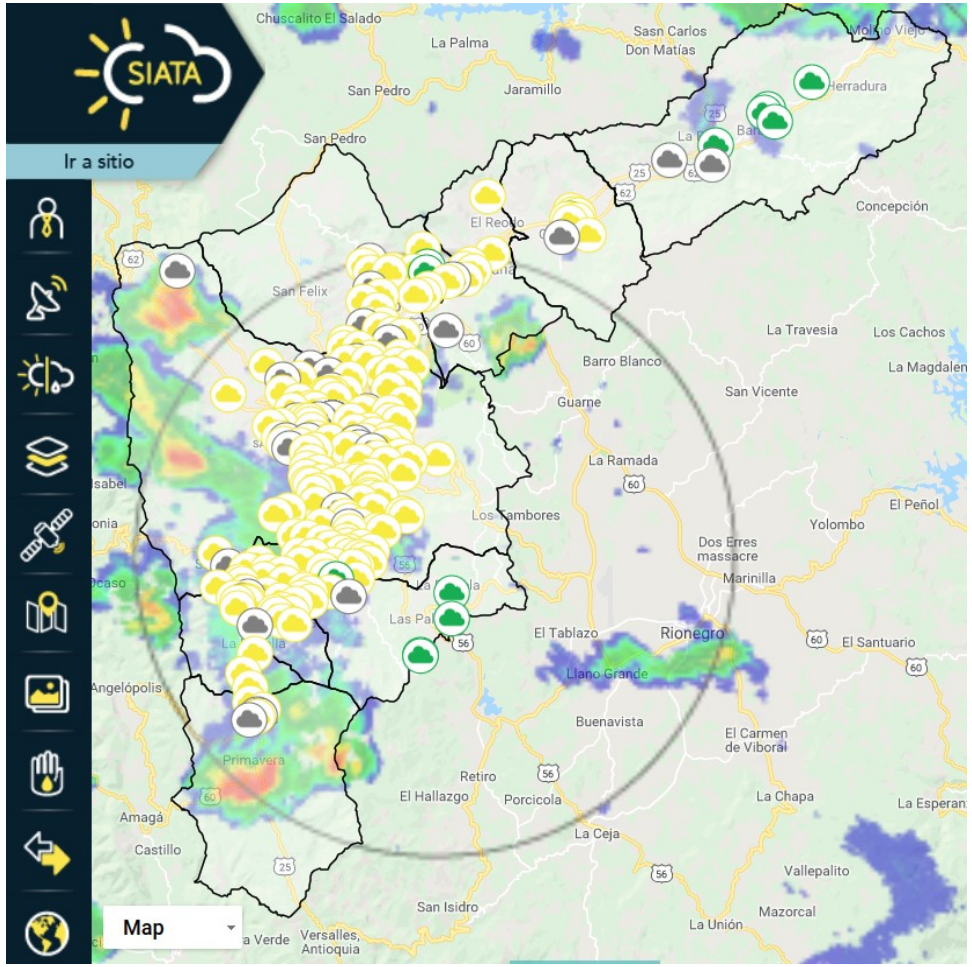
(Collage made from SIATA video images)

Air Quality Monitoring Stations

POECA* Stations



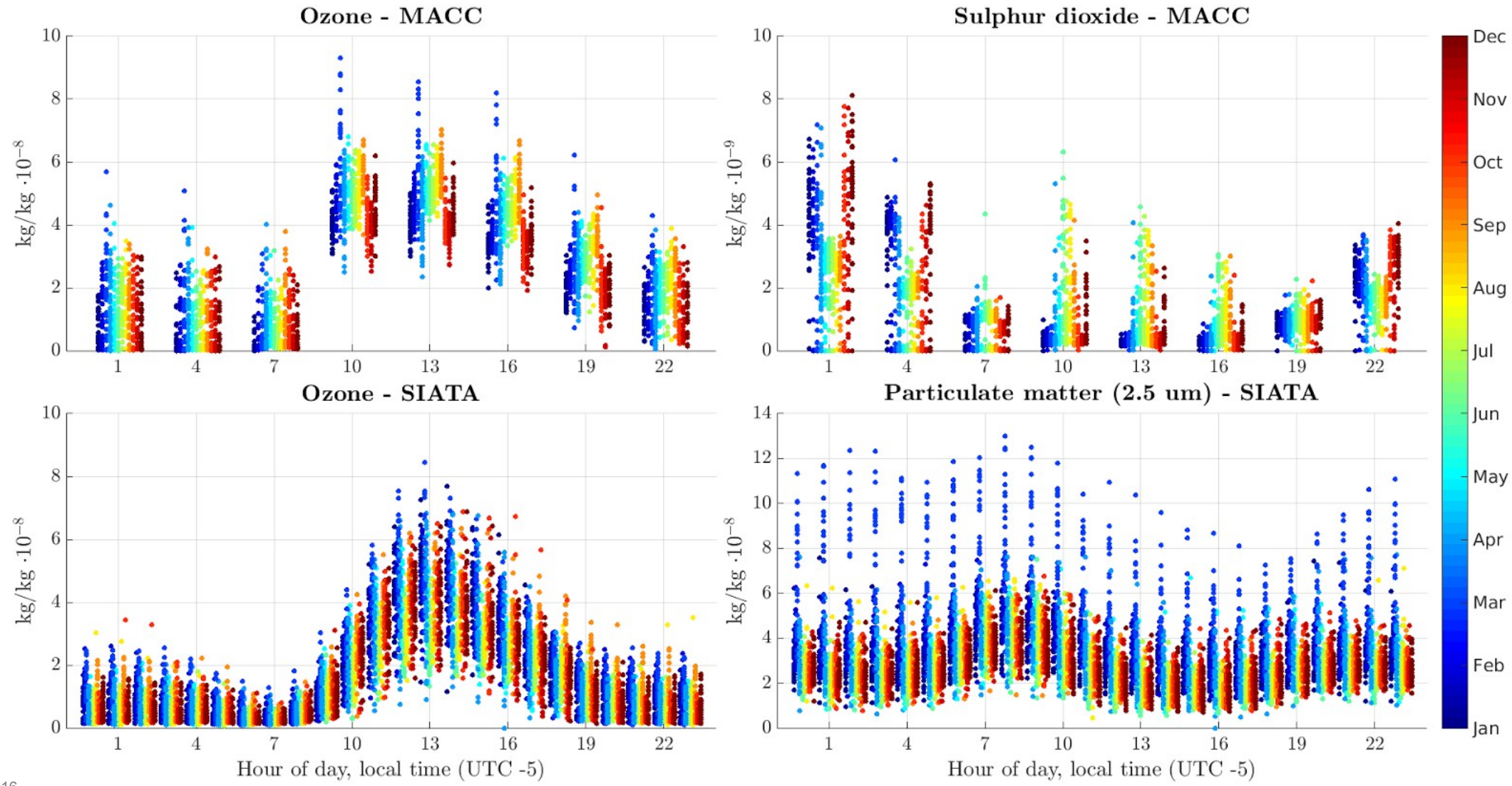
Citizen Scientists Network



Screen capture from https://siata.gov.co/siata_nuevo/ - March 7, 2018 at 07:15 (left); May 31, 2019 at 13:40 (right).

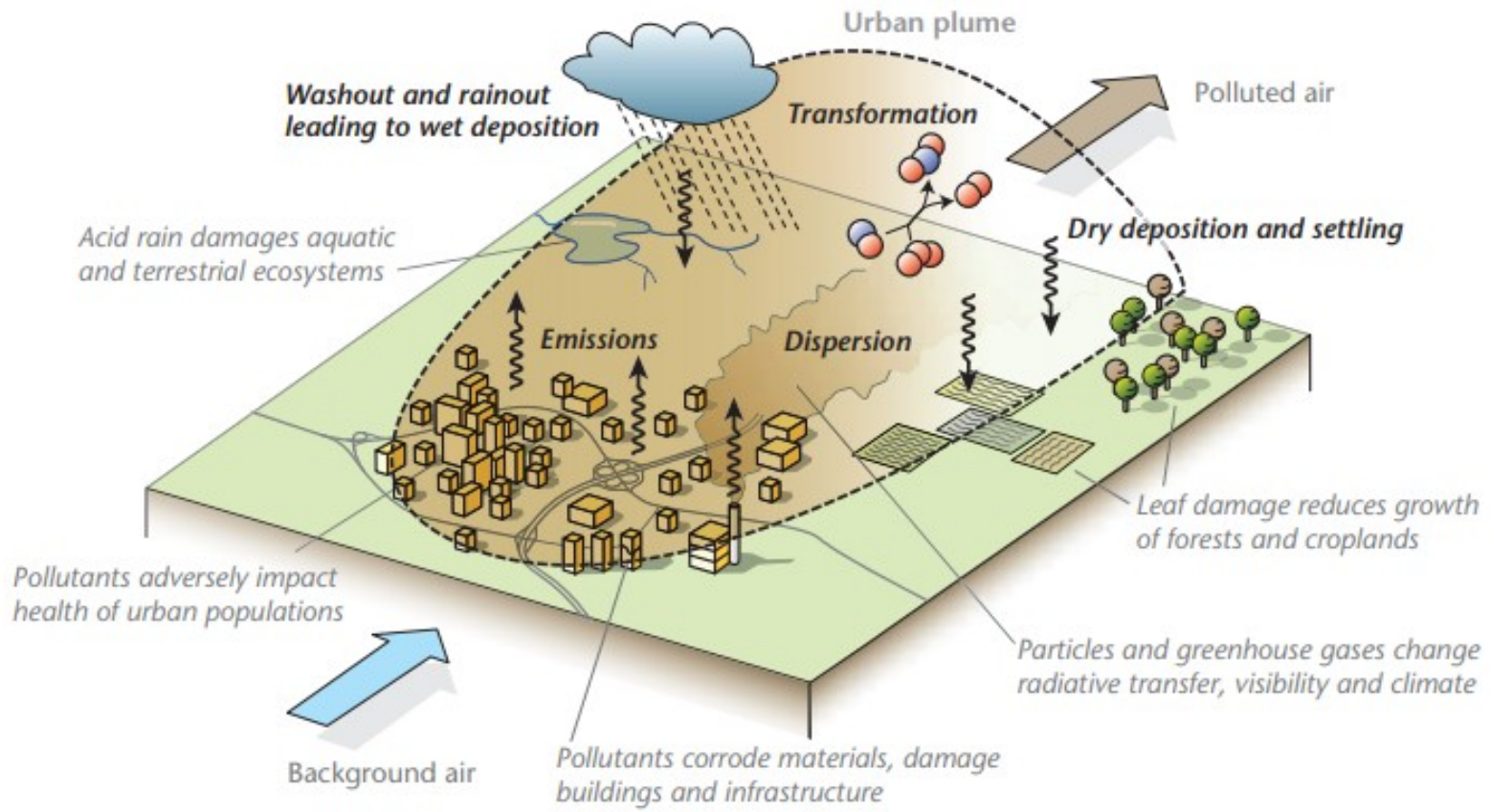
* POECA = Plan Operacional para enfrentar Episodios de Contaminación Atmosférica)

Pollutants' Daily Dynamics inside the Valley



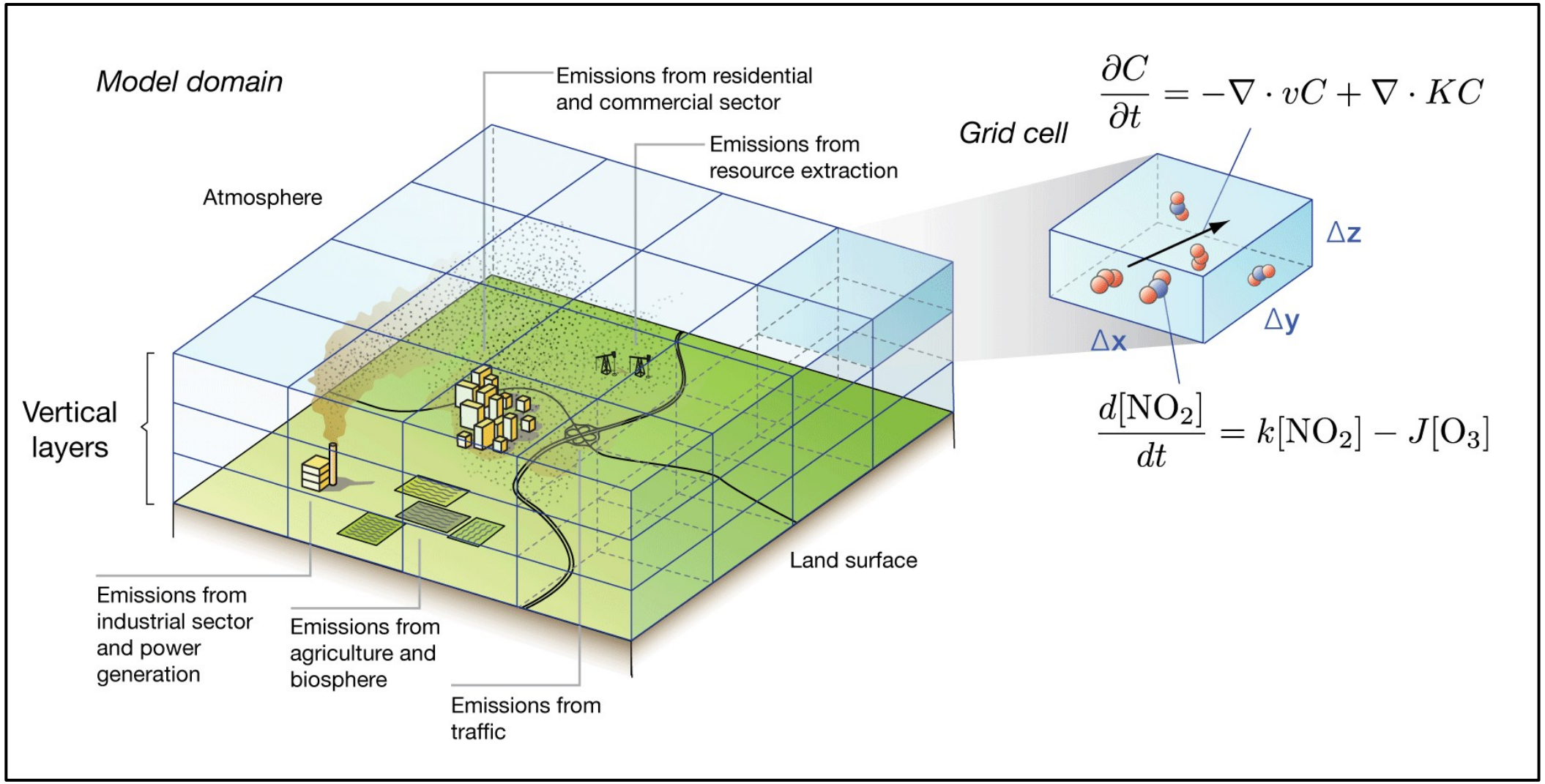
Data for 2016

Atmospheric Pollutant Dynamics



Source: Oke et al., 2017.

Chemistry Transport Models (CTM)



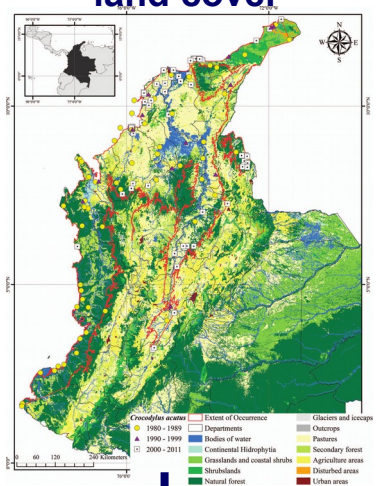
Source: TBD

Chemistry Transport Models (CTM)

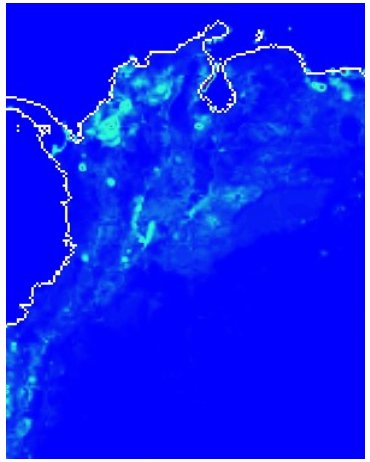
inputs

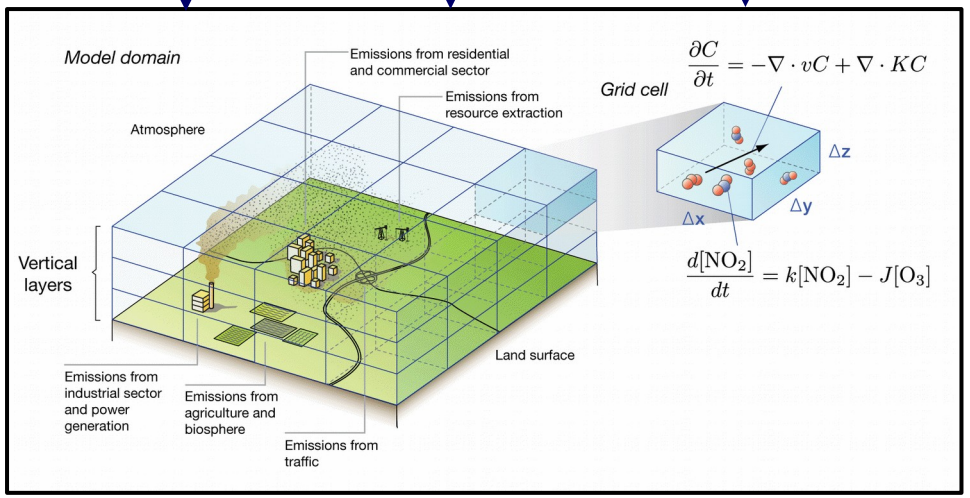
meteorology

land cover



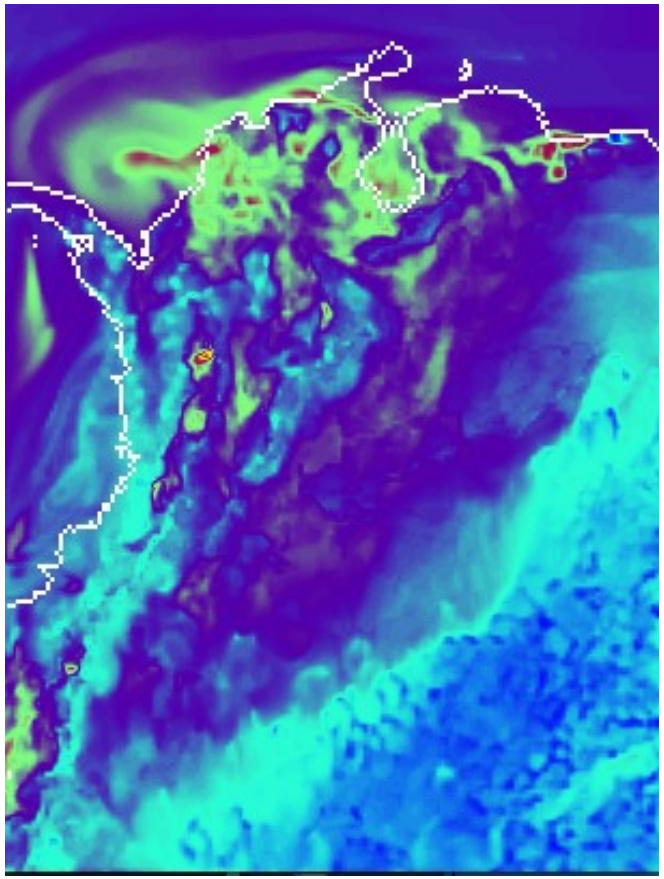
emissions





outputs

concentrations & depositions



Implementing LOTOS-EUROS in NW South America

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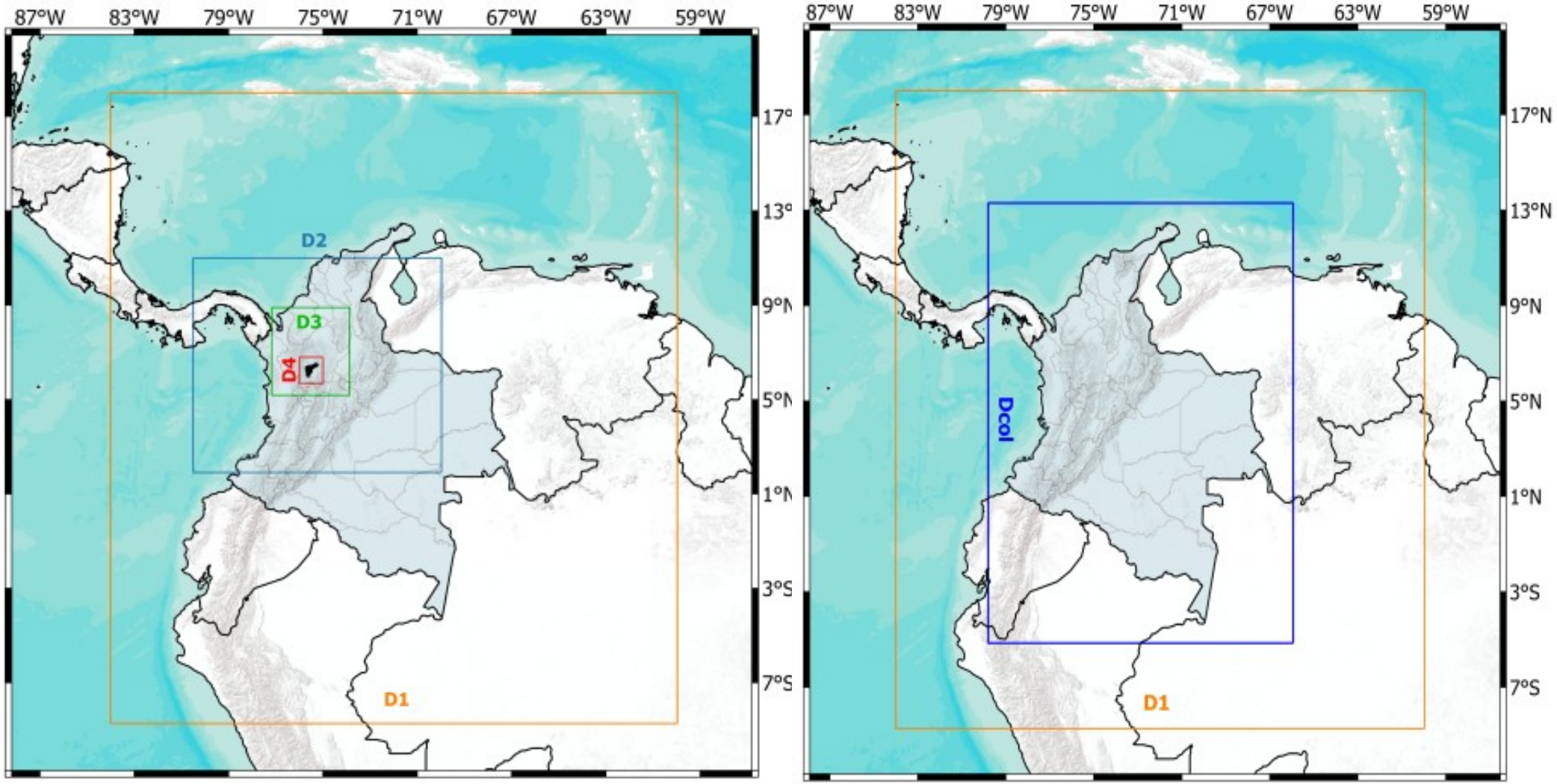
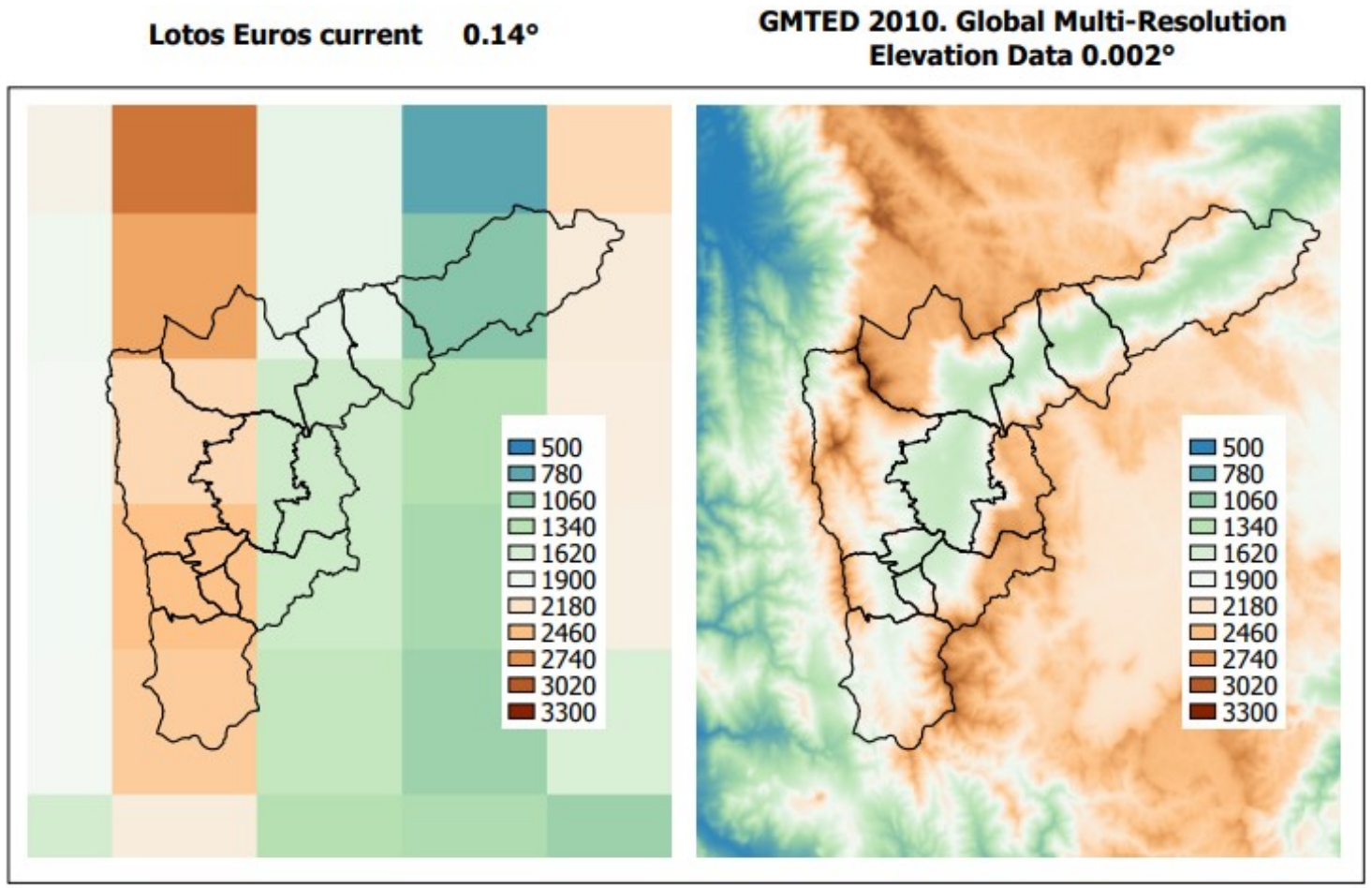
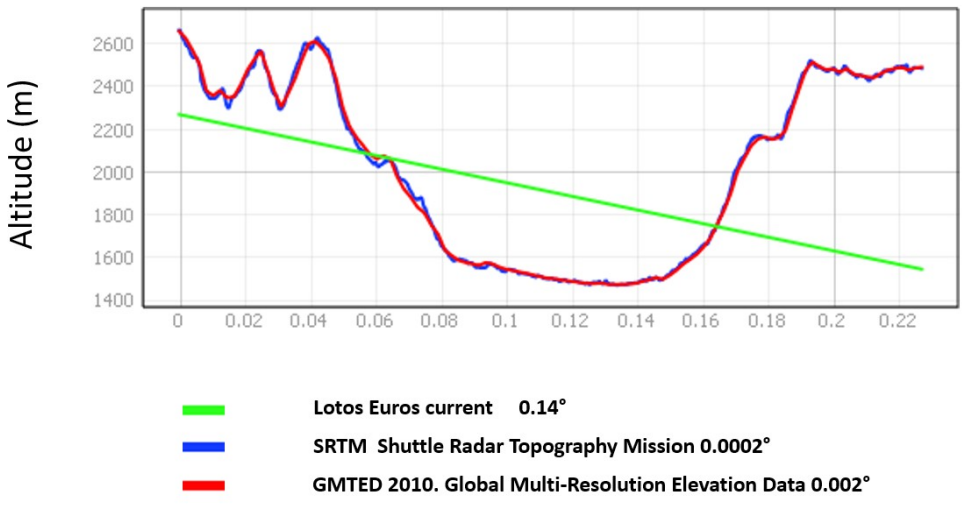
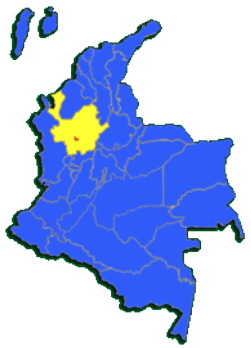


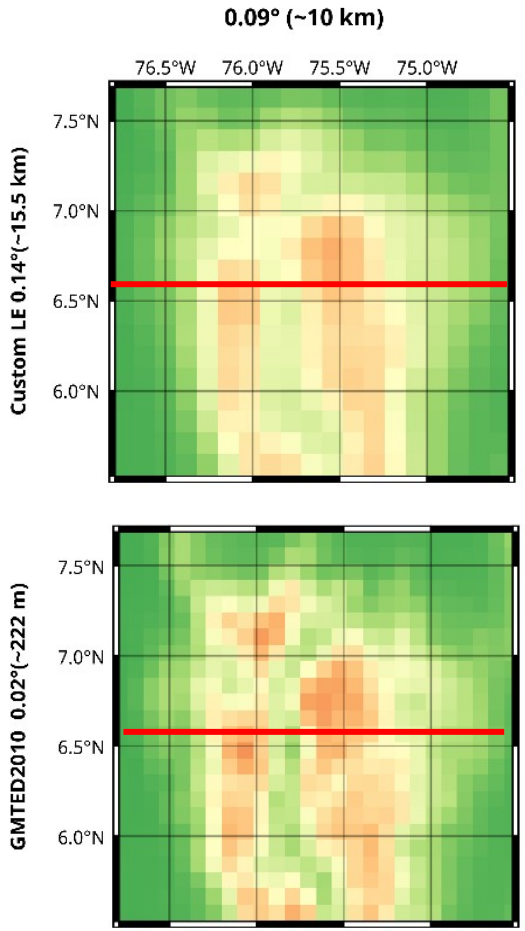
Updating Topography data in LOTOS-EUROS

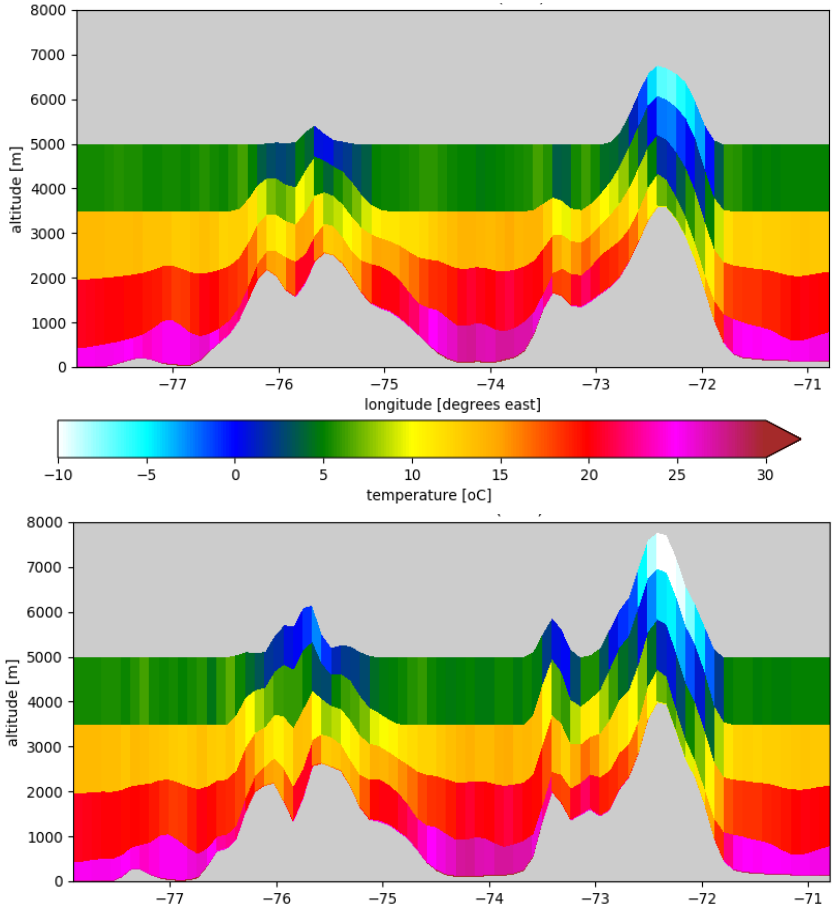


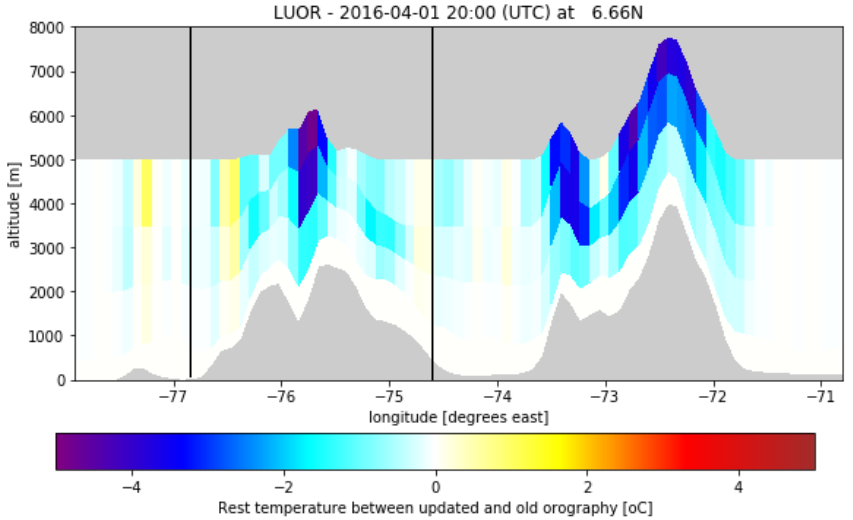


Effects of Updating Topography data in LOTOS-EUROS

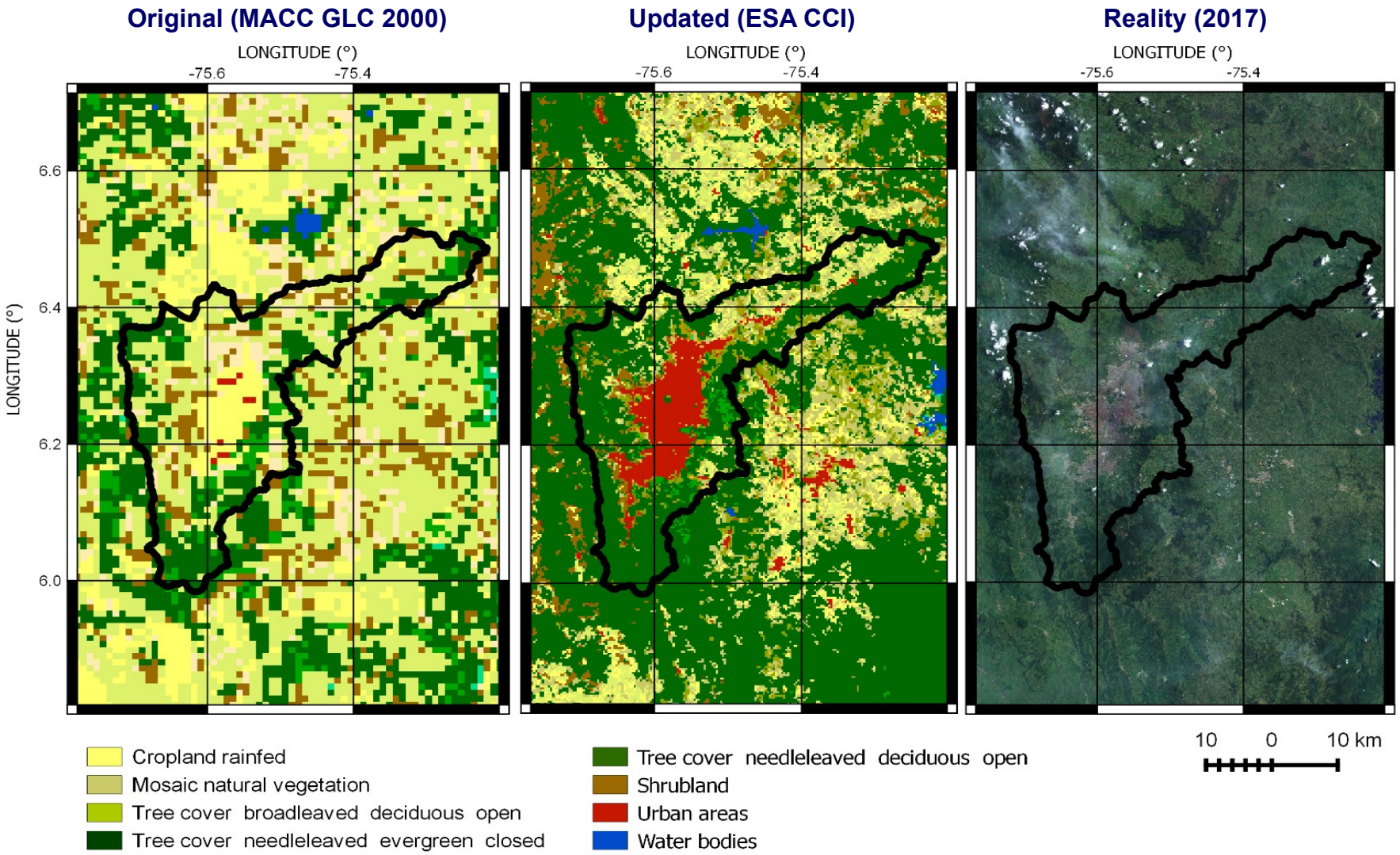






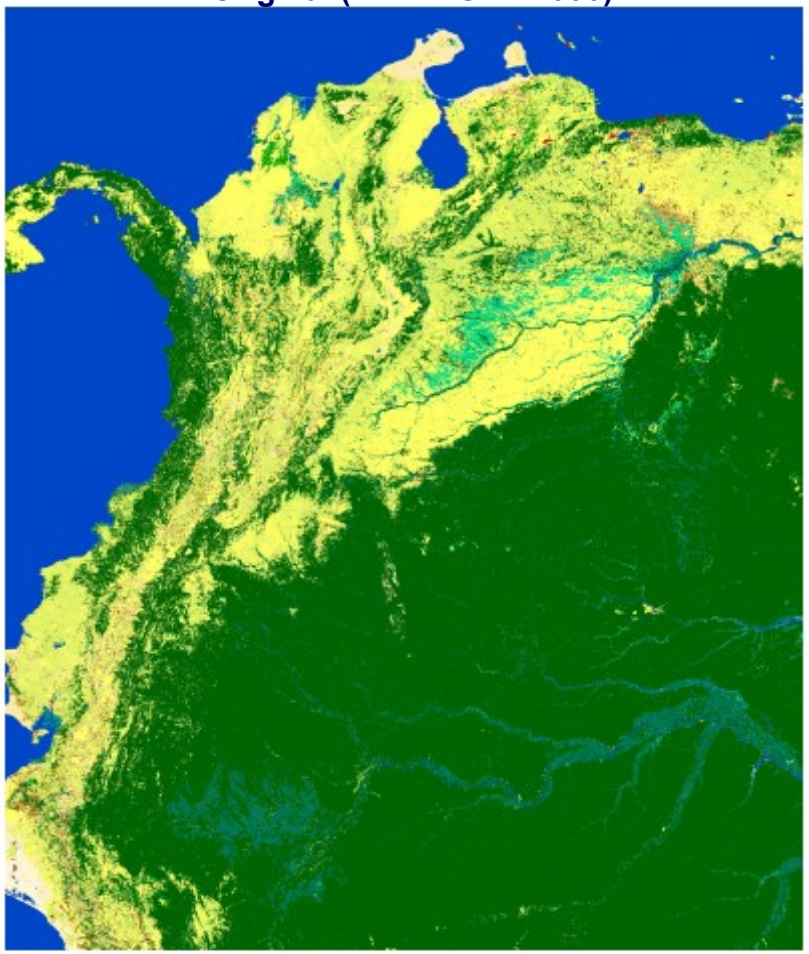


Updating Land Cover data in LOTOS-EUROS



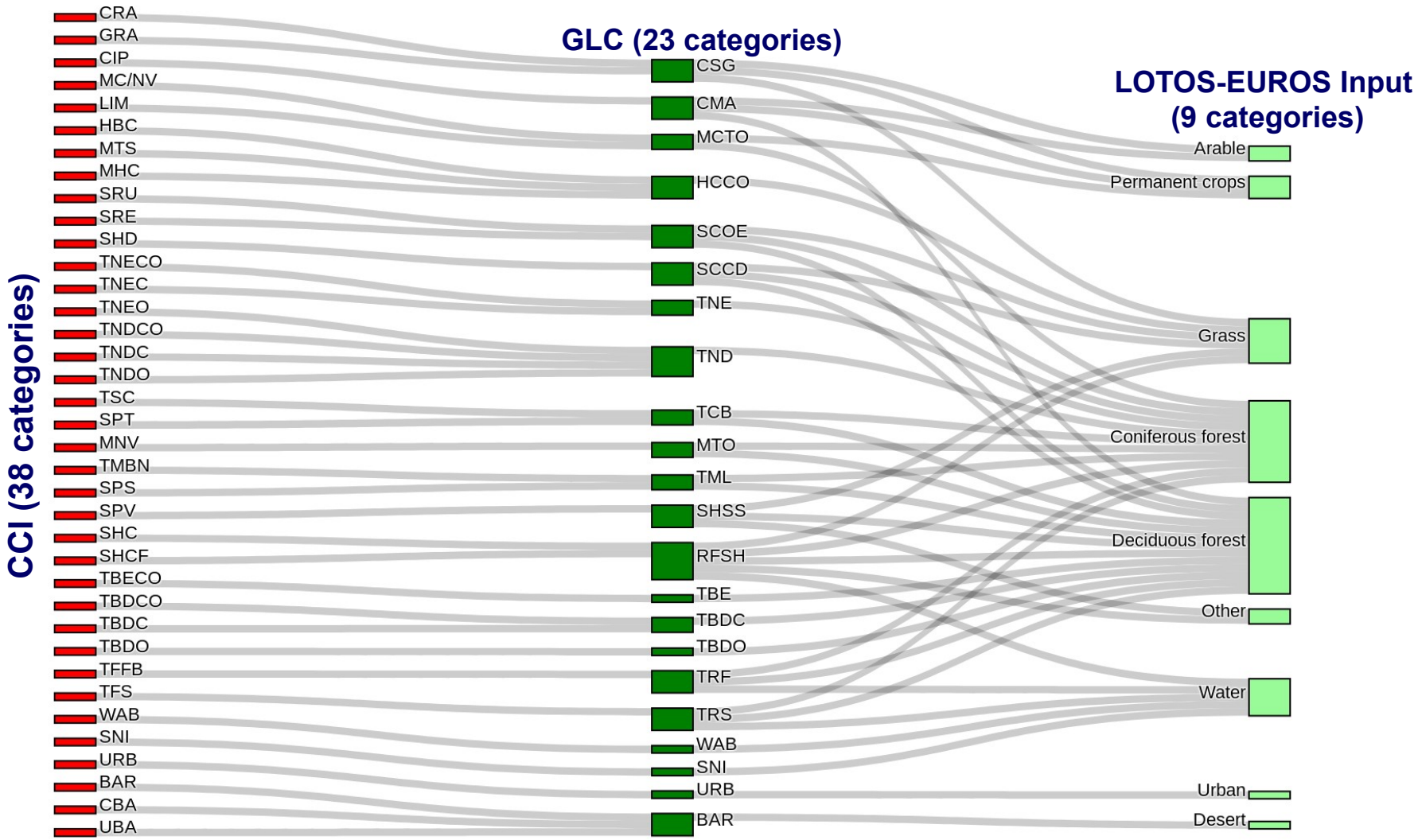
Updating Land Cover data in LOTOS-EUROS

Original (MACC GLC 2000)



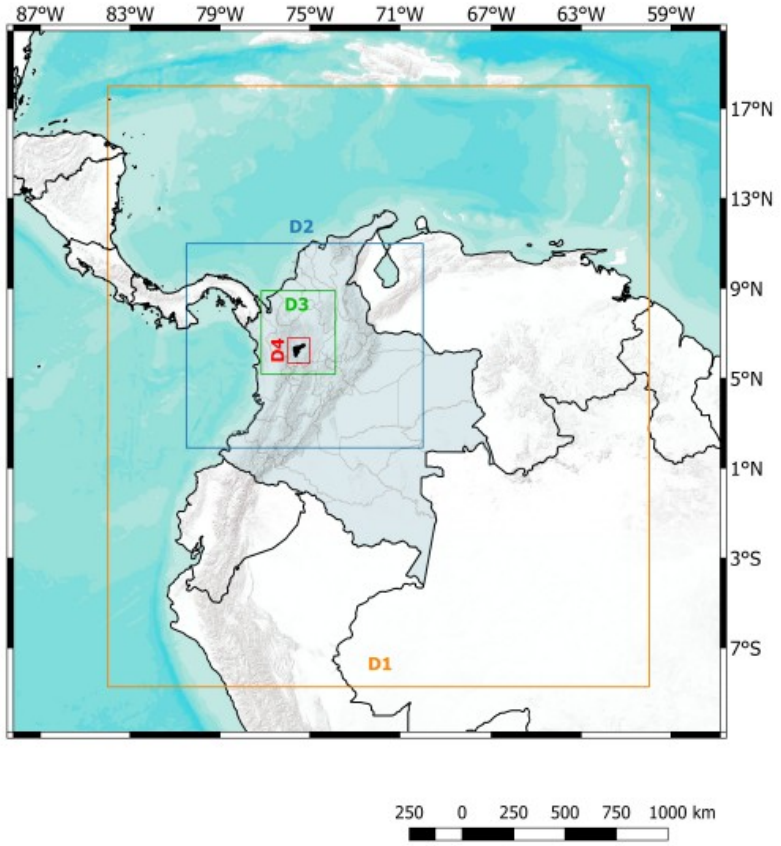
Updated (ESA CCI)

Updating Land Cover data in LOTOS-EUROS



Data Assimilation for the Aburrá Valley

Ensemble Kalman Filter – PM over the Aburrá Valley



Domain	Longitude	Latitude	Cell size
D1	84°W-60°W	8.5°S-18°N	0.27°
D2	80.5°W-70°W	2°N-11°N	0.09°
D3	77.2°W-73.9°W	5.2°N-8.9°N	0.03°
D4	76°W-75°W	85.7°N-6.8°N	0.01°

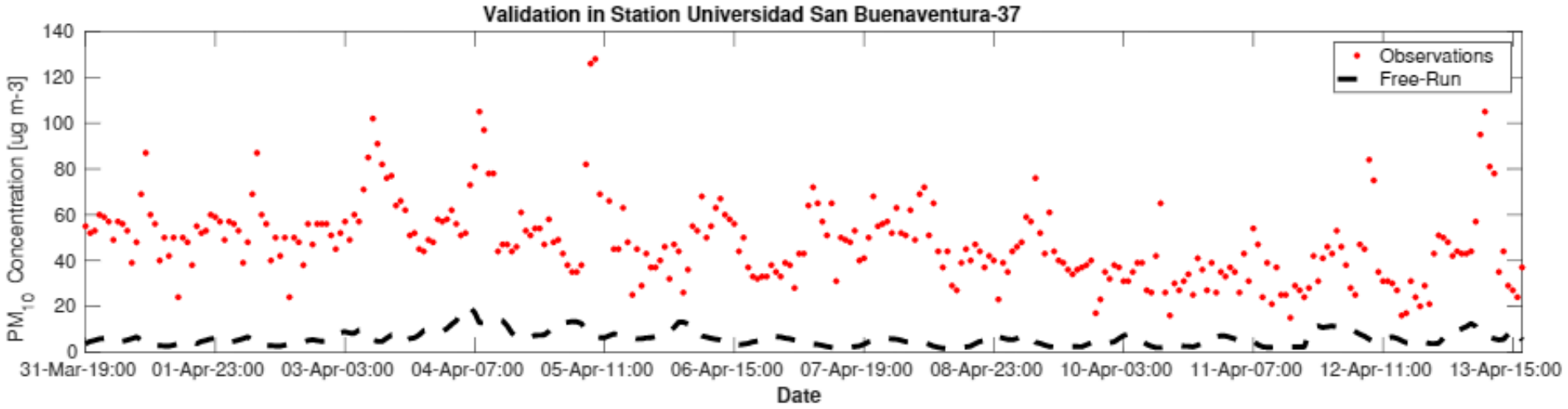
Table 1: Nested domain specifications

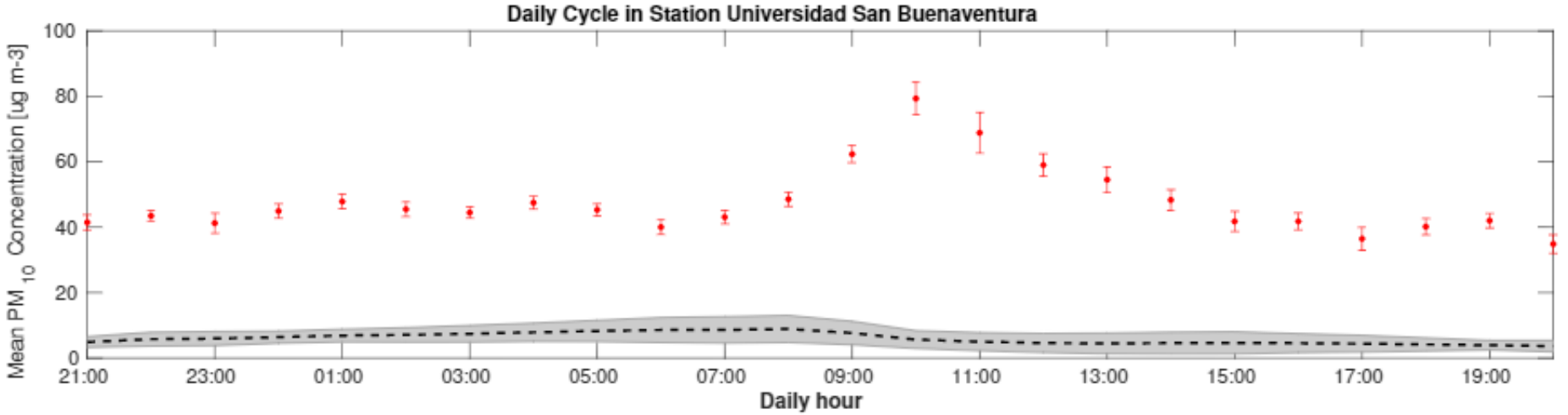
Period	From 31-March-2016 to 25-April-2016
Time resolution	1 hour
Domain	[-76 to -75] west x [5.7 to 6.8] north
Spatial resolution	$0.01° \times 0.01° \sim 1km \times 1km$
Metereology	ECMWF. Temp.Res:3 h. Spat.Res: $0.07° \times 0.07°$
Initial and boundary conditions	LOTOS-EUROS (D3). Temp.Res: 1h. Spat.Res: $0.03° \times 0.03°$
Nominal Emissions	EDGAR V4.2

Table 2: Experimental setup

Running LE for the Aburrá Valley

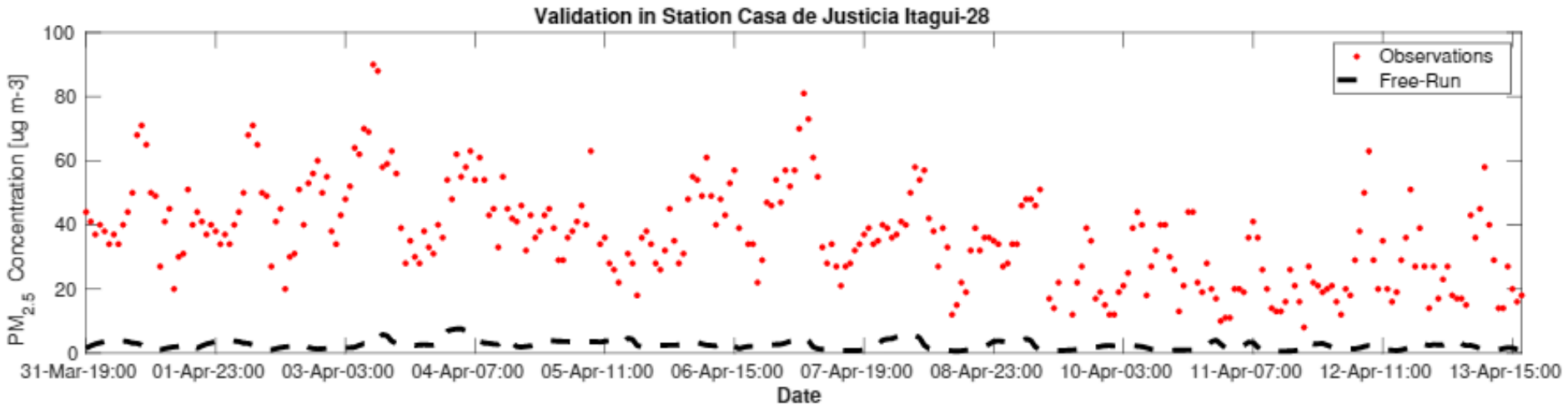
PM_{10}

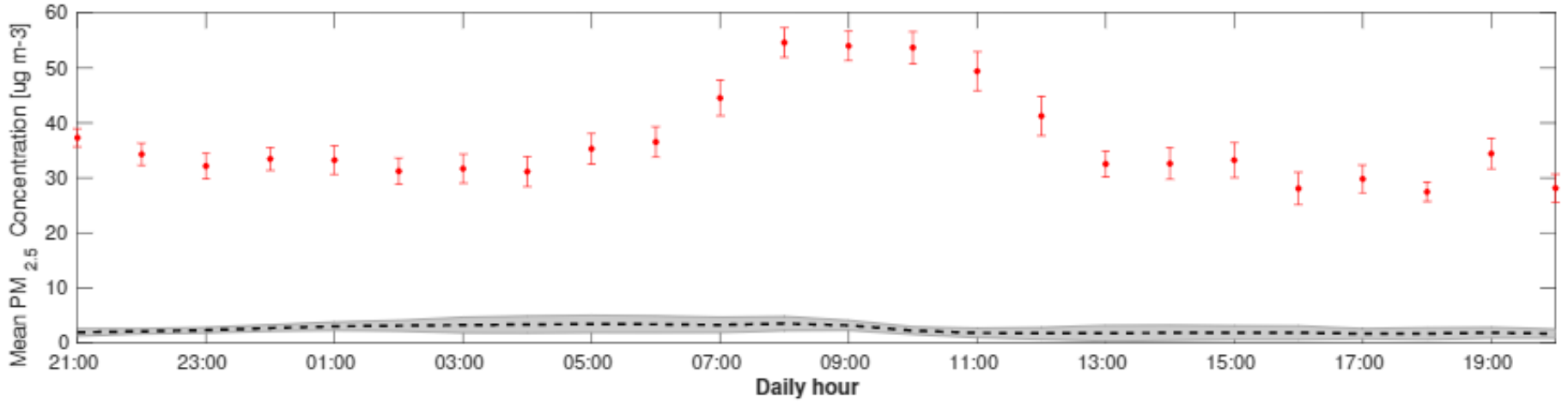




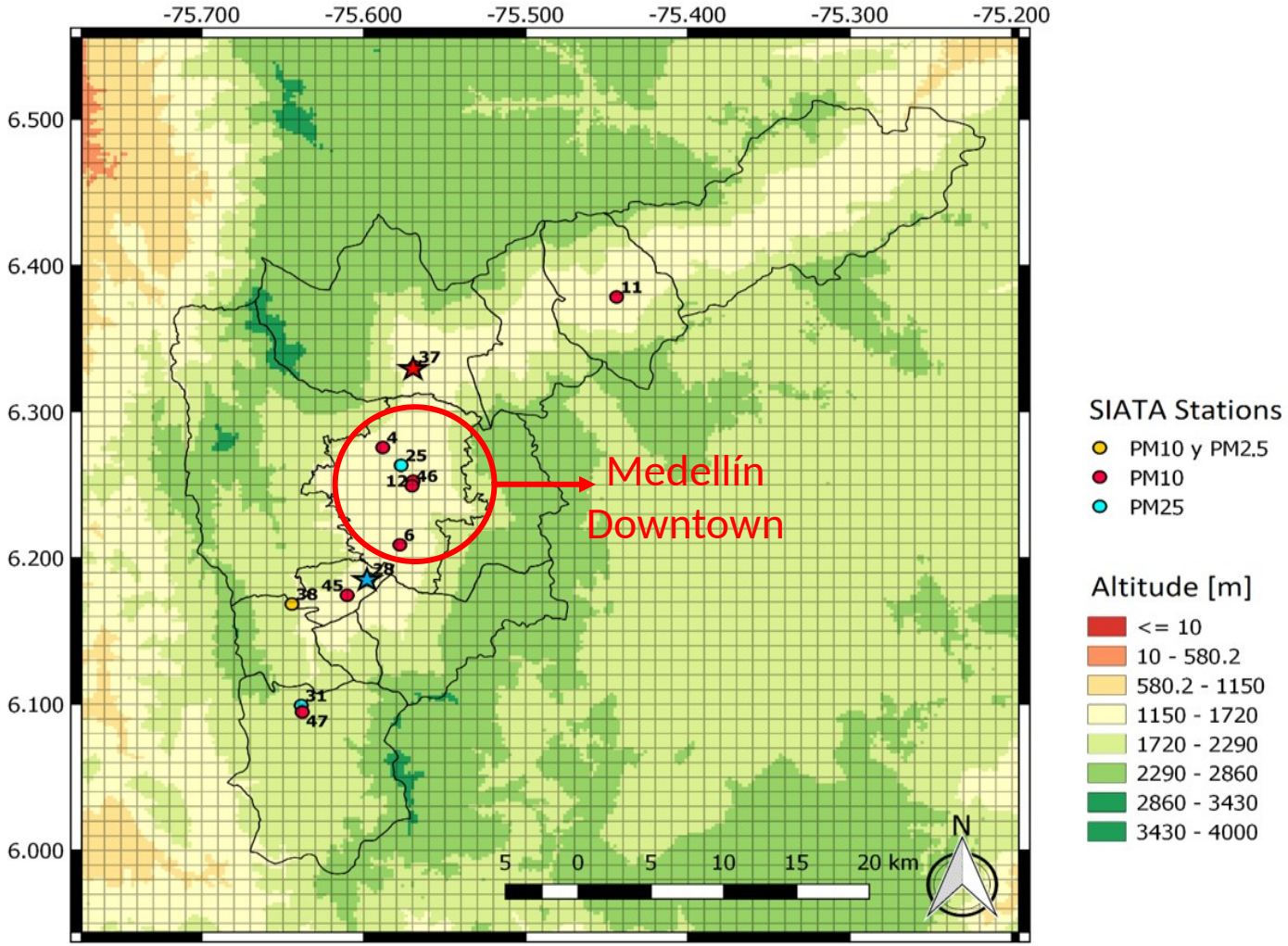
Running LE for the Aburrá Valley

$PM_{2.5}$





Ensemble Kalman Filter – PM over the Aburrá Valley



Ensemble Kalman Filter – PM over the Aburrá Valley

We used a EnKF and a stochastic model for parameter estimation

$$x_t = M(x_{t-1})$$

$$\delta e_t = \alpha \delta e_{t-1} + \sqrt{1-\alpha^2}\, w_t$$

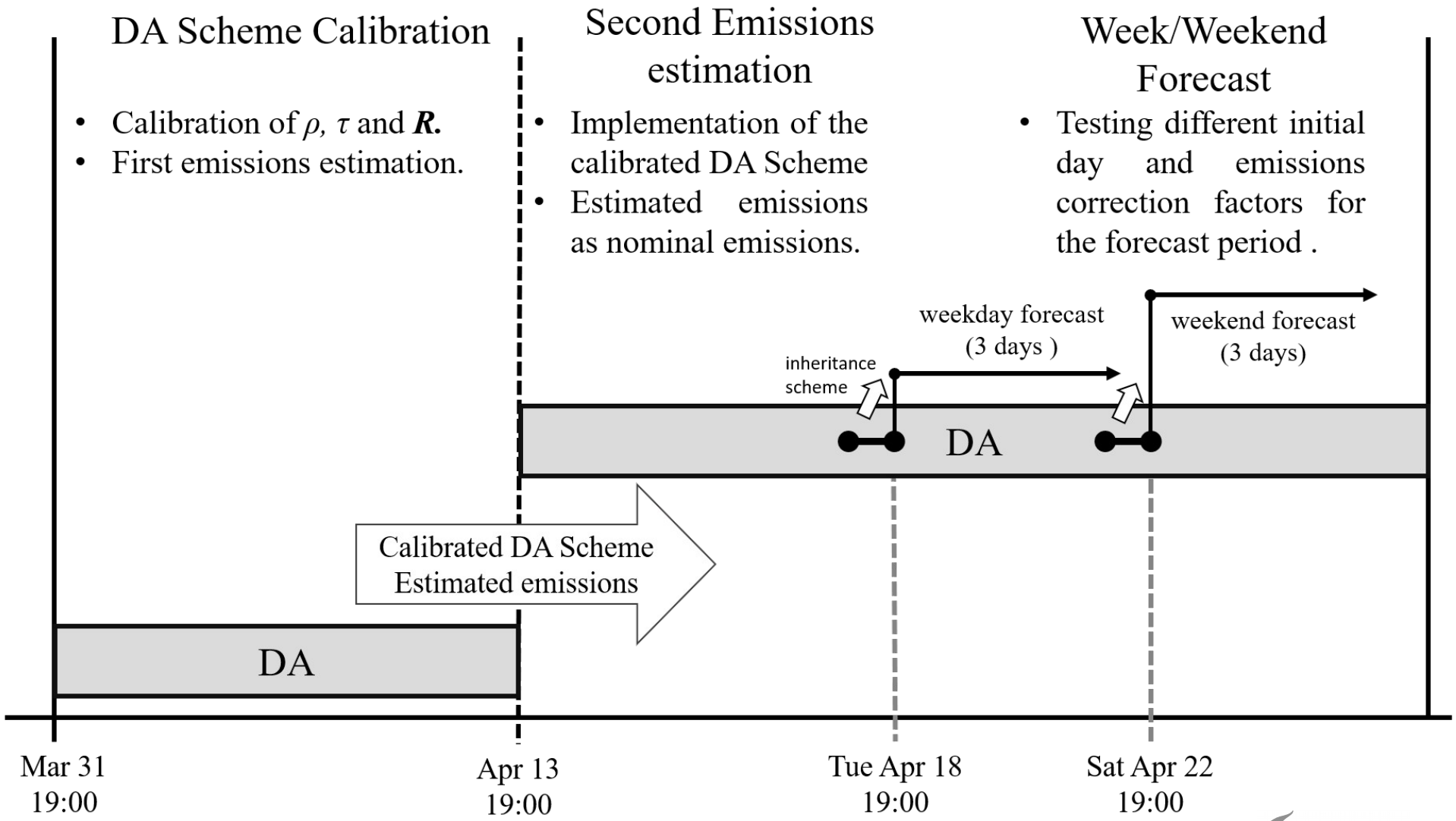
$$\begin{bmatrix} x_t \\ \delta e_t \end{bmatrix} = \begin{bmatrix} M(x_{t-1}) \\ \alpha \delta e_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ \sqrt{1-\alpha^2} \end{bmatrix} w_t$$

The coefficient α represents the time correlation parameter. Using the parameterization $\alpha = exp(-1/\tau)$ for a given time correlation length τ.

We are considering uncertainties in:

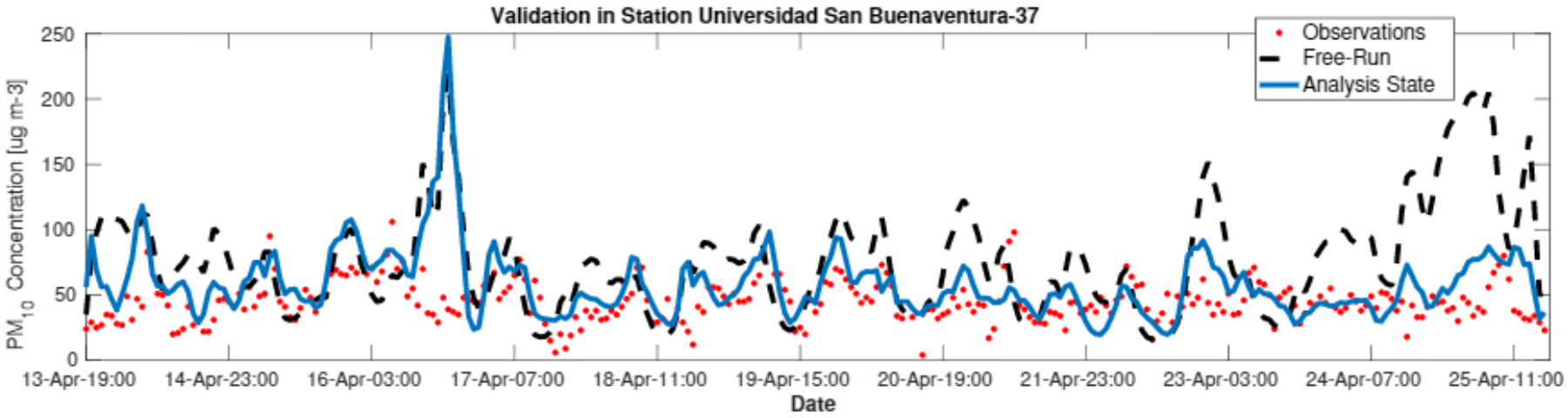
- PM_{10}+BC Emissions
- NH_3 Emissions
- SO_x Emissions

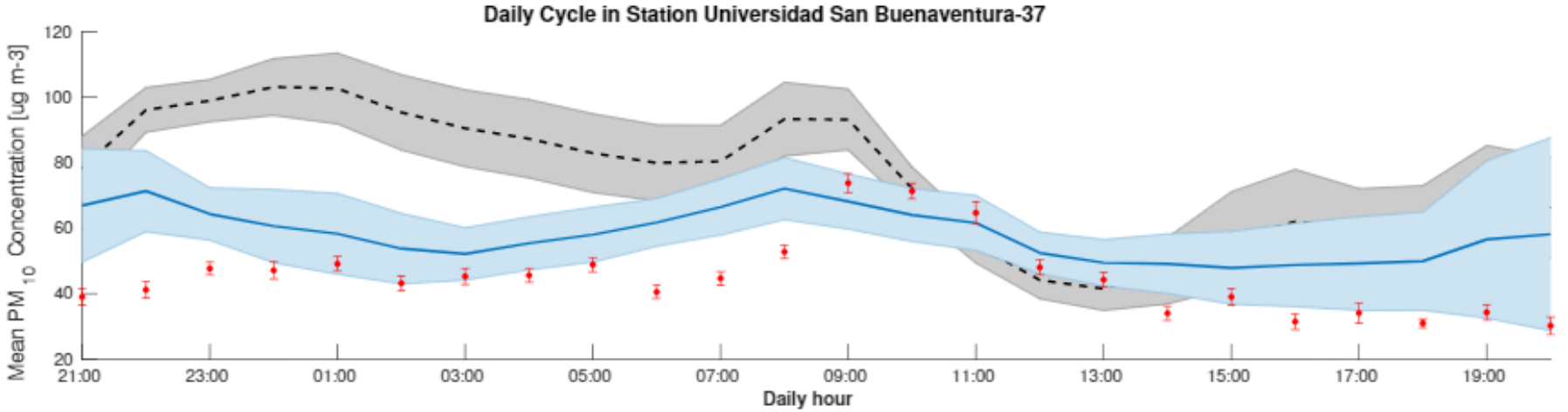
Ensemble Kalman Filter – PM over the Aburrá Valley



Ensemble Kalman Filter – PM over the Aburrá Valley

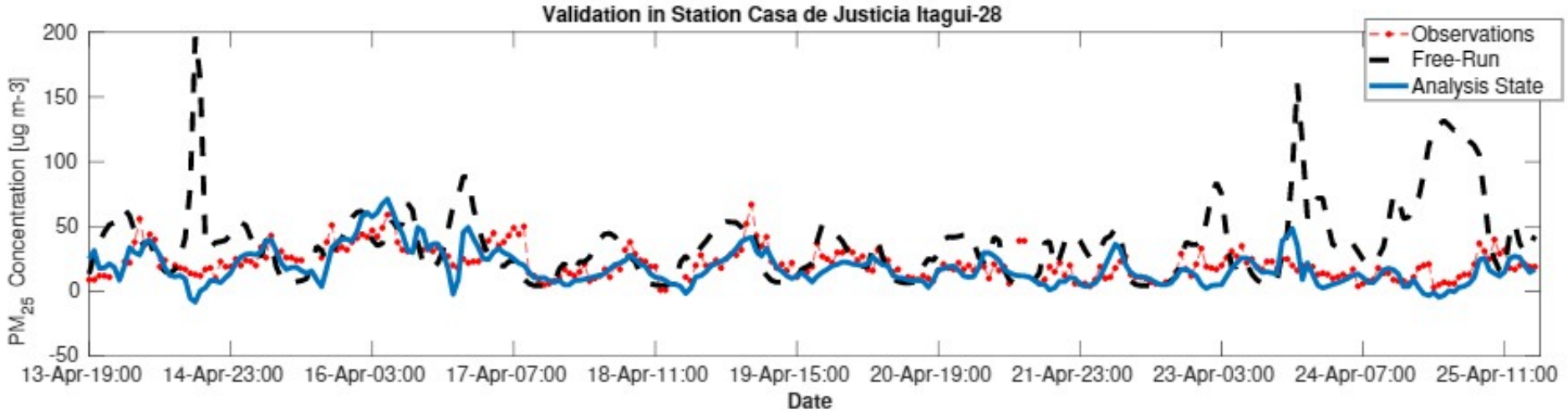
PM_{10}

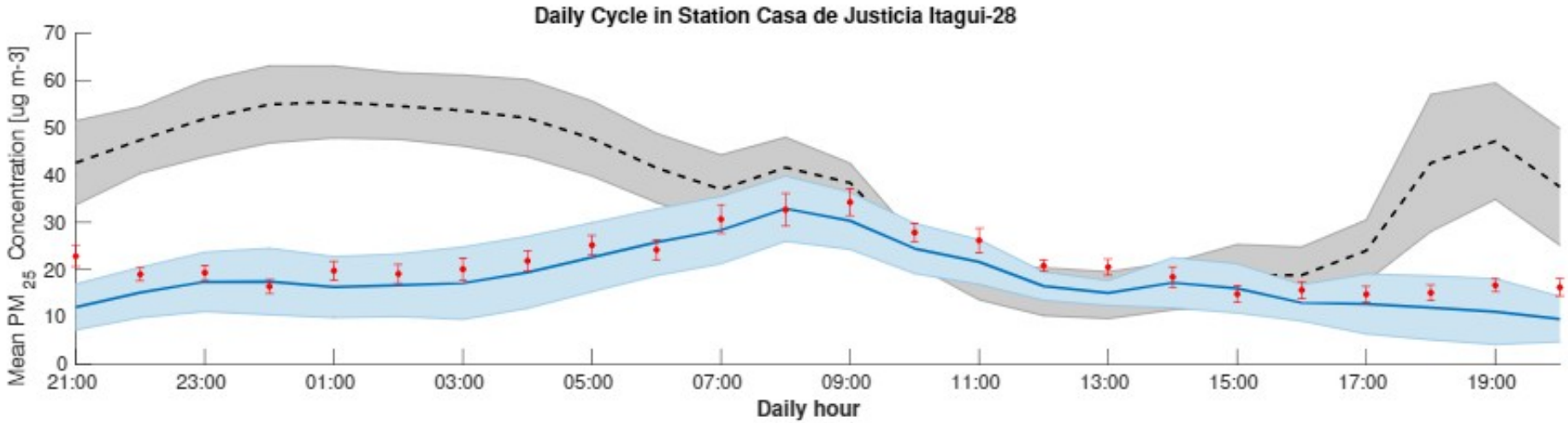




Ensemble Kalman Filter – PM over the Aburrá Valley

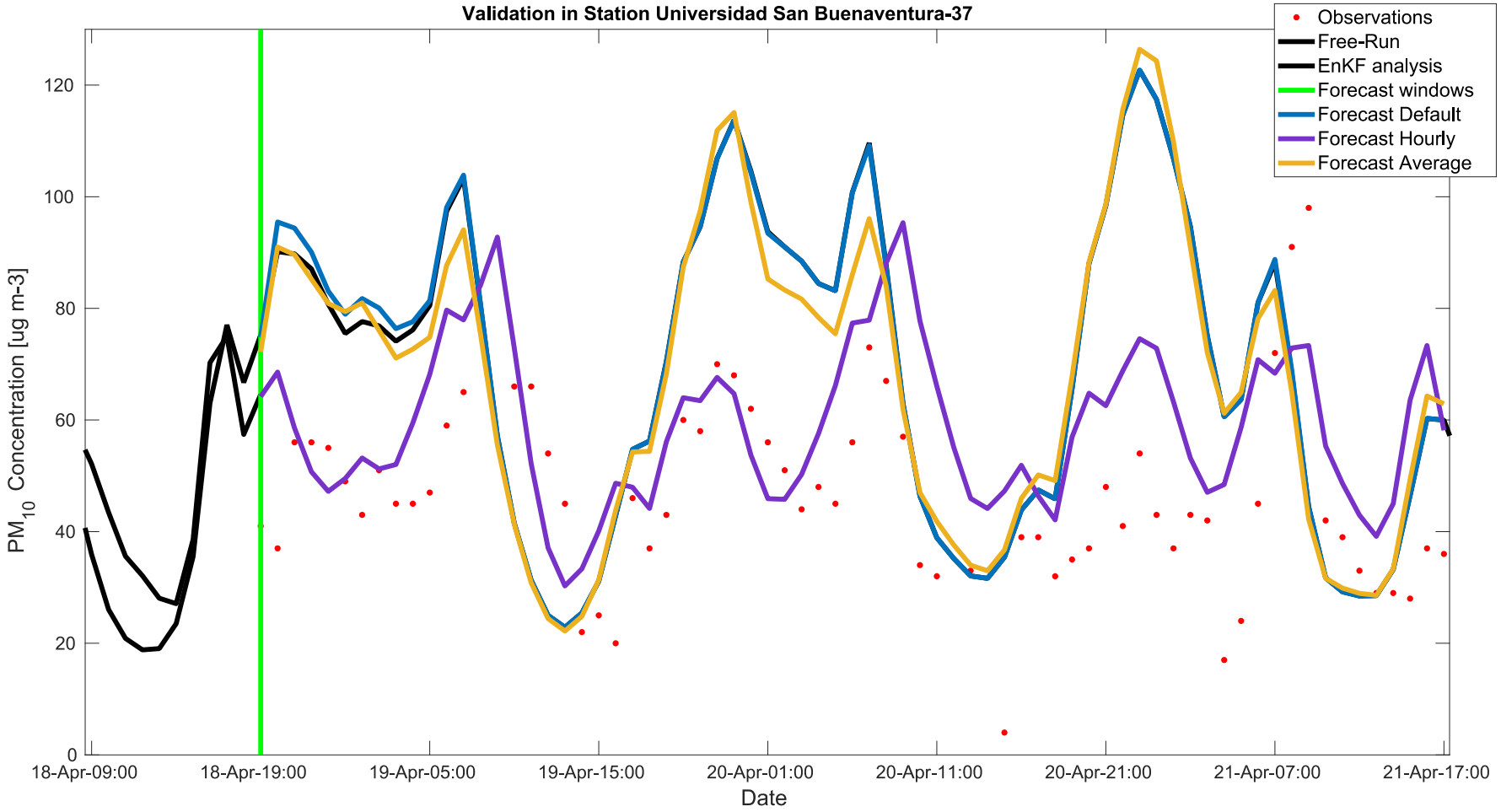
$PM_{2.5}$





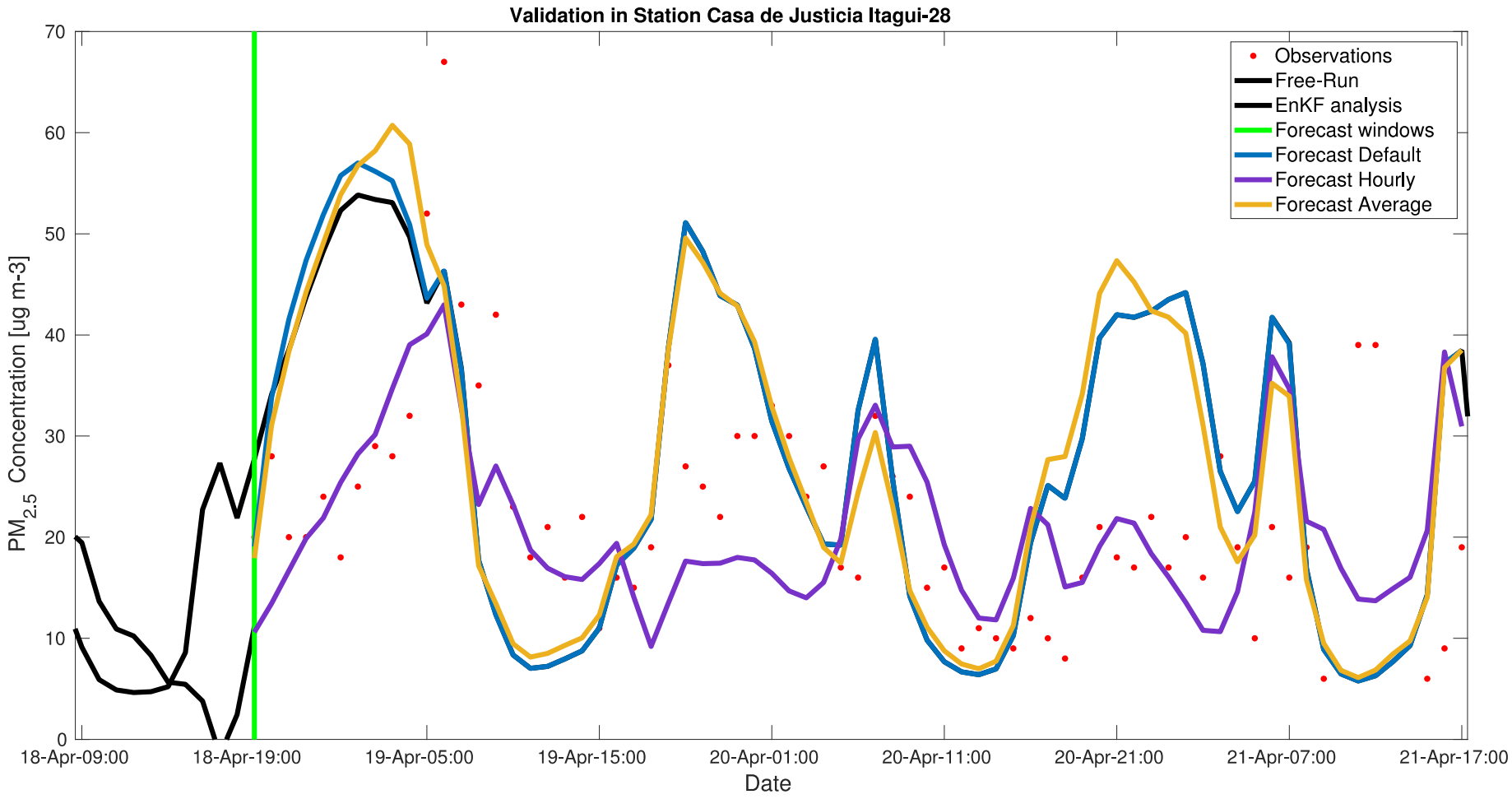
Ensemble Kalman Filter – PM FORECAST over the Aburrá Valley

PM_{10}



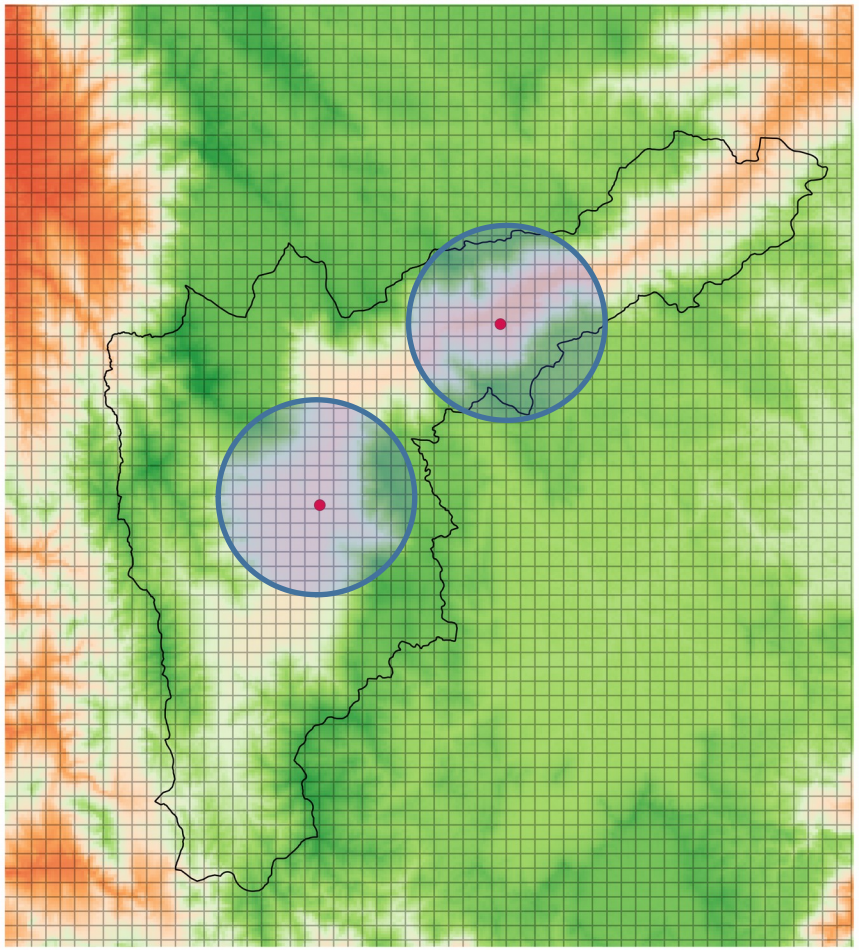
Ensemble Kalman Filter – PM FORECAST over the Aburrá Valley

$PM_{2.5}$

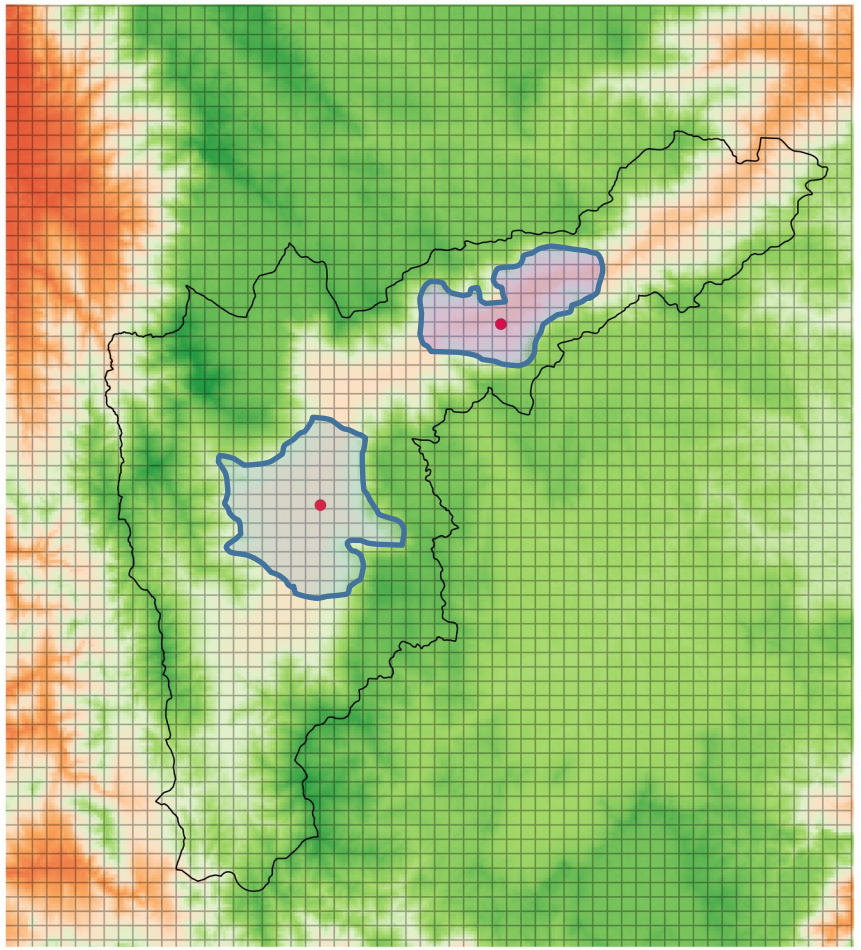


Ensemble Kalman Filter for over Aburrá Valley

Ensemble Kalman Filter (EnKF)



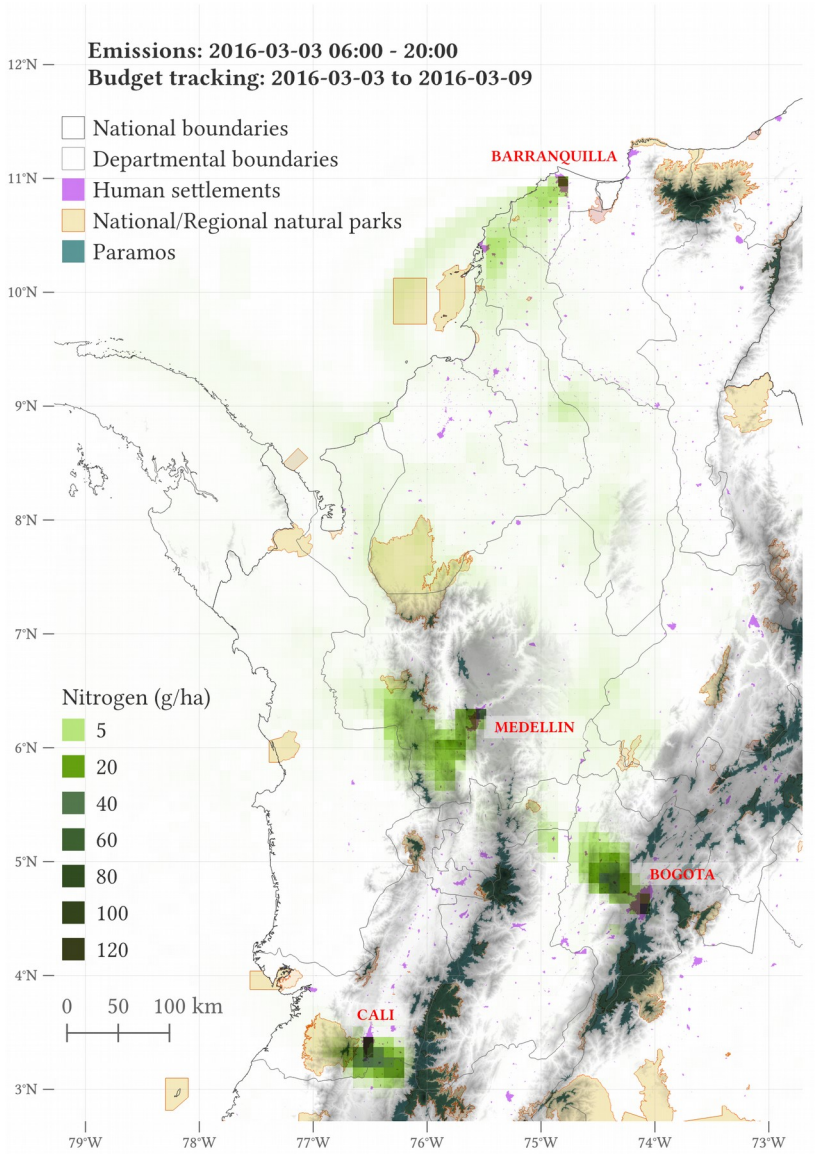
EnKF with prior knowledge (EnKF-KA)



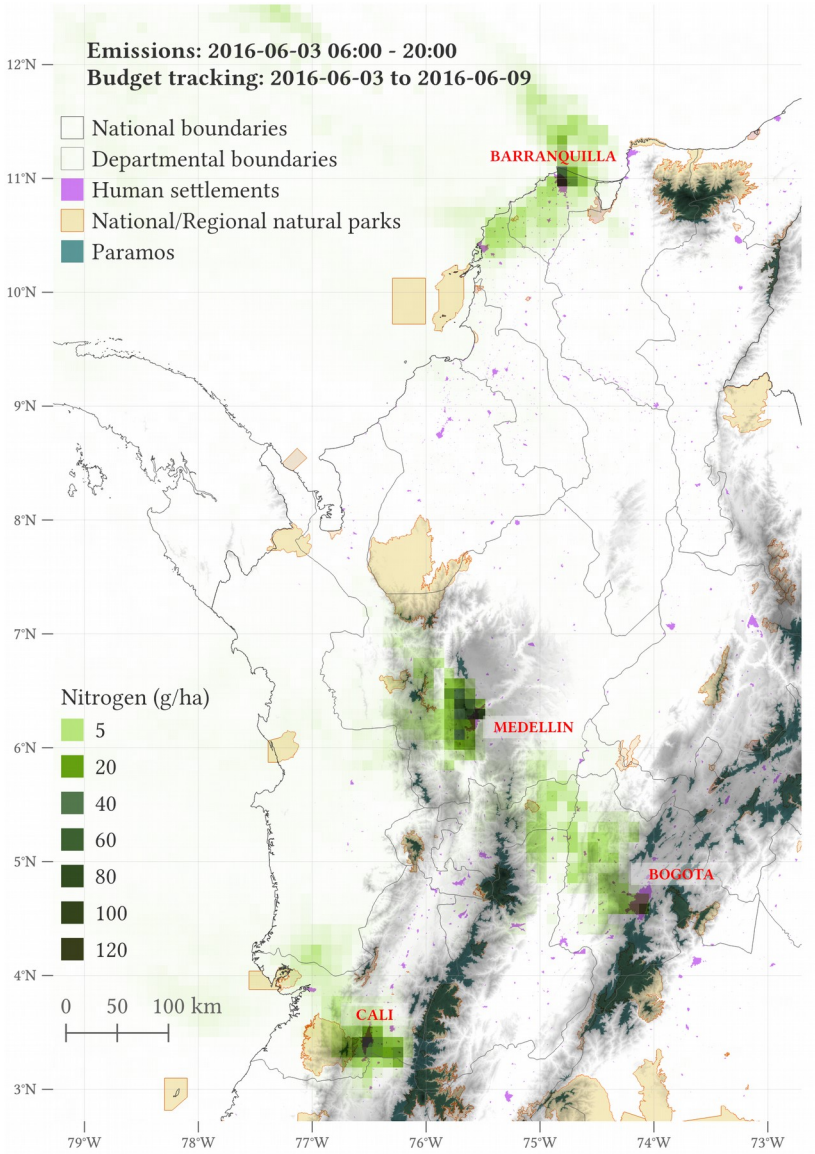
What is the fate of urban atmospheric pollutants?

Urban centers as point sources

March, 2016

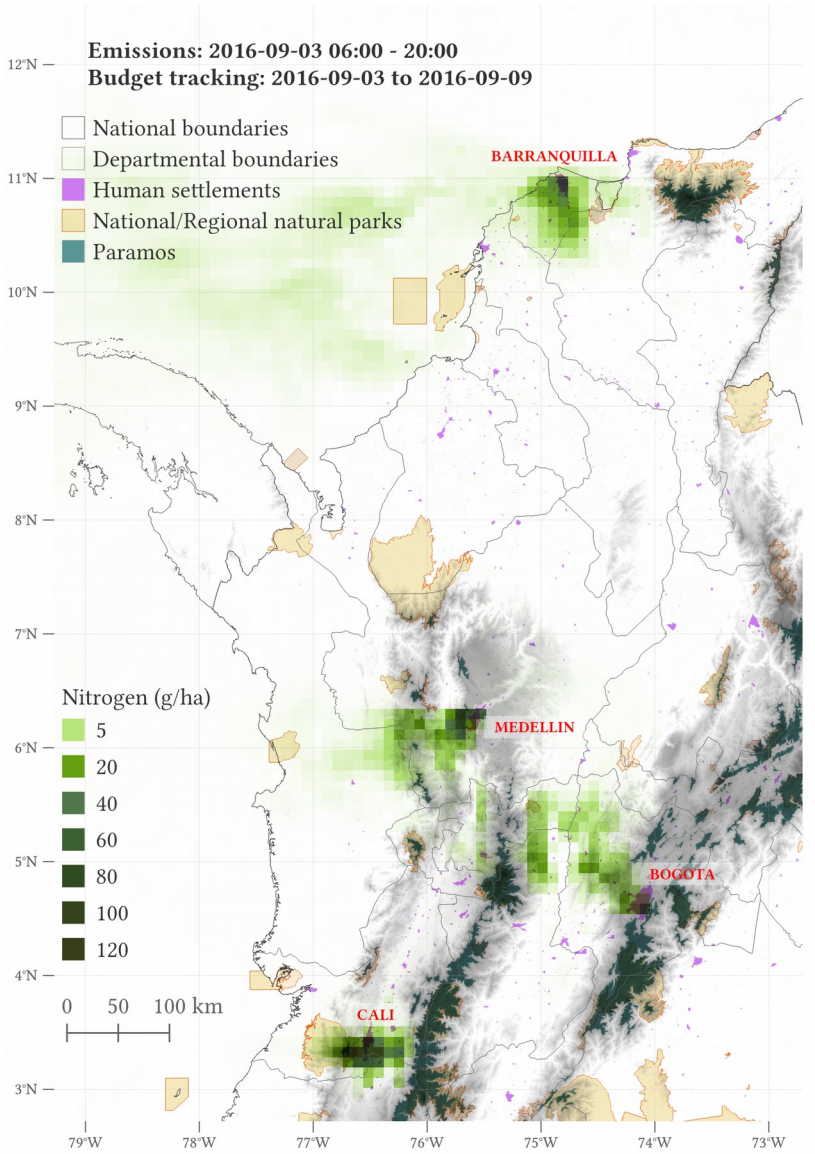


June, 2016

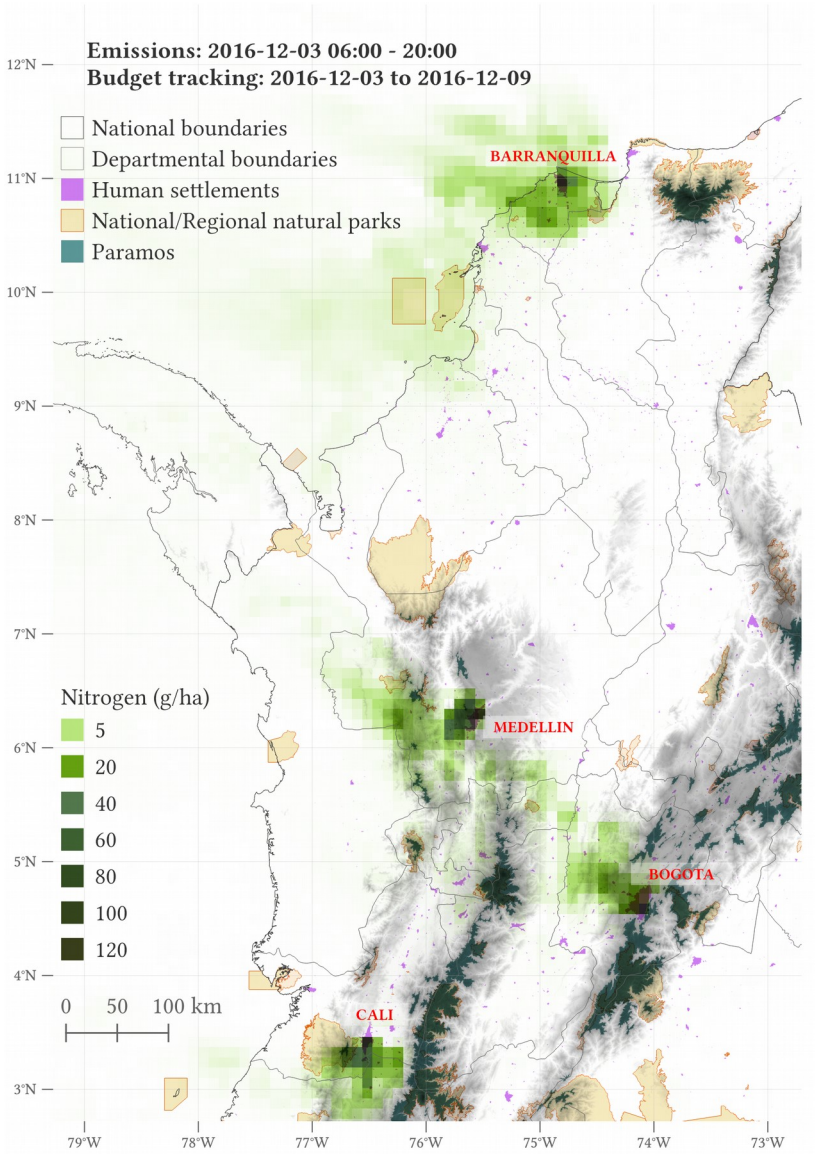


Urban centers as point sources

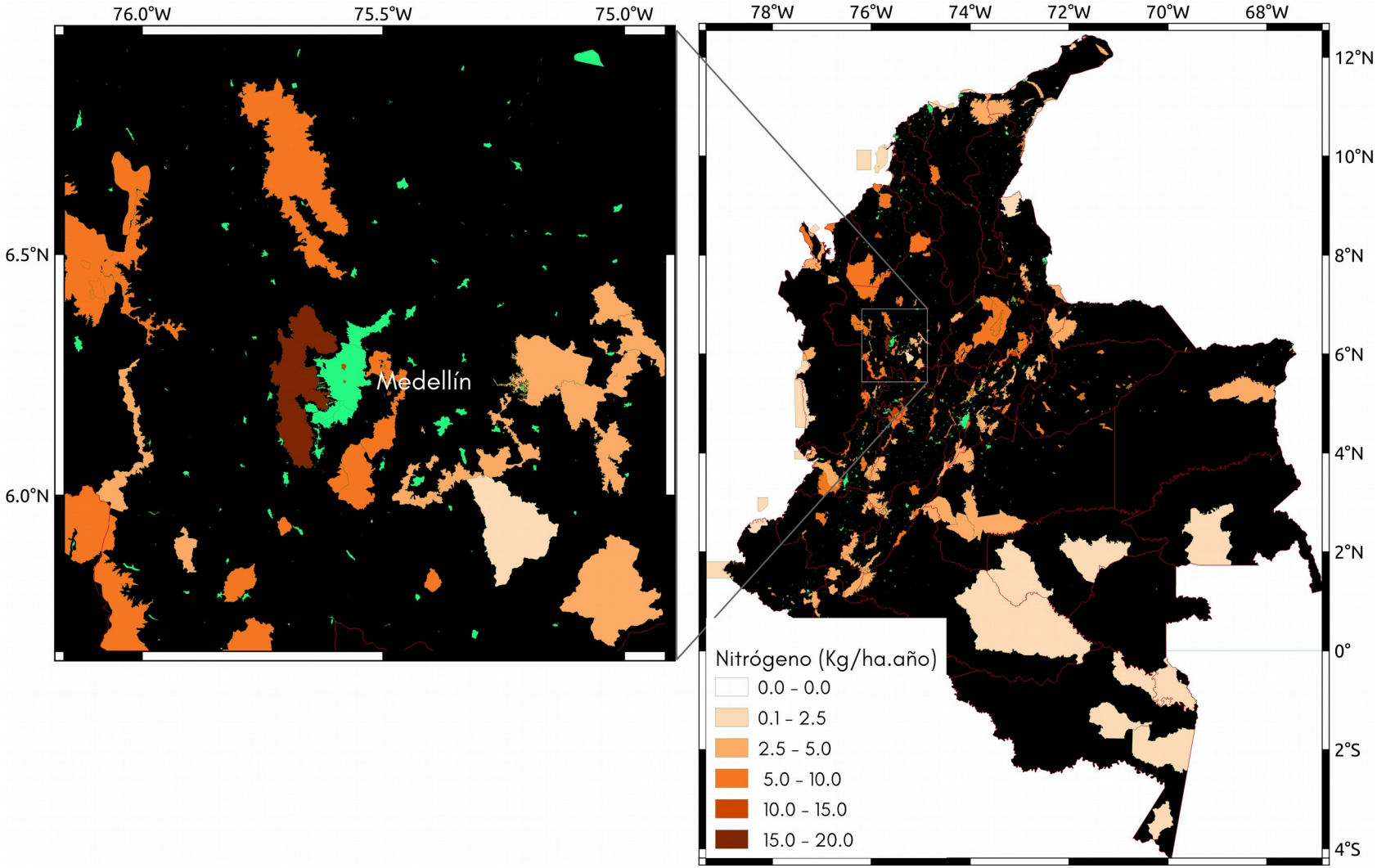
September, 2016



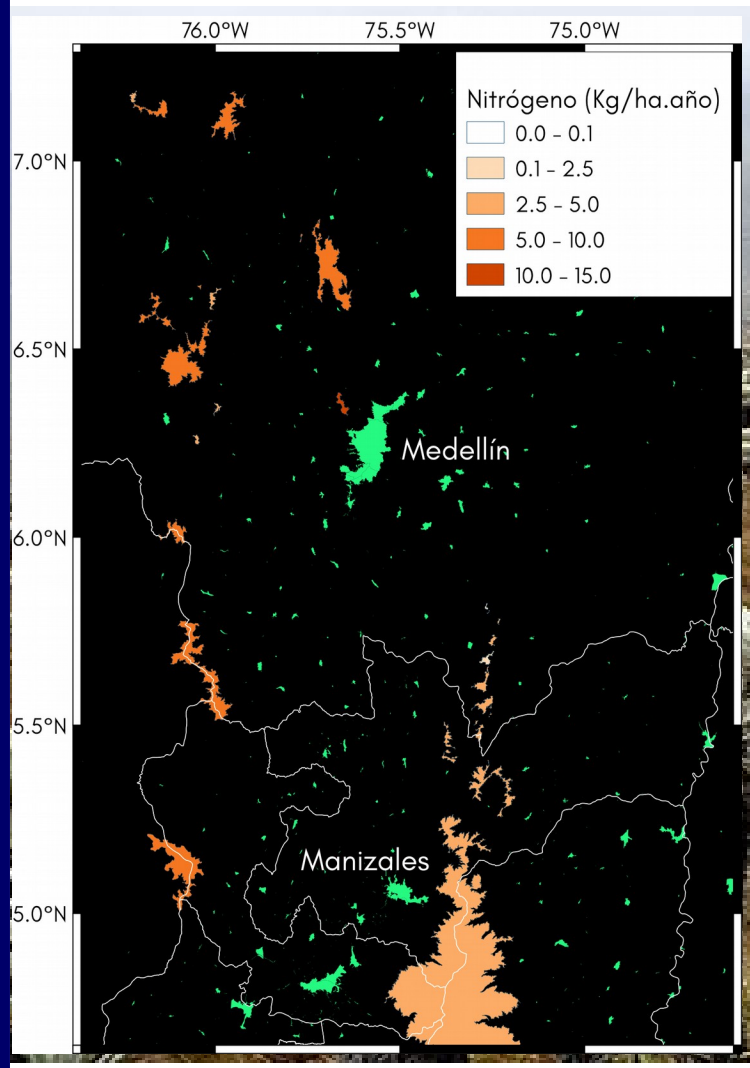
December, 2016

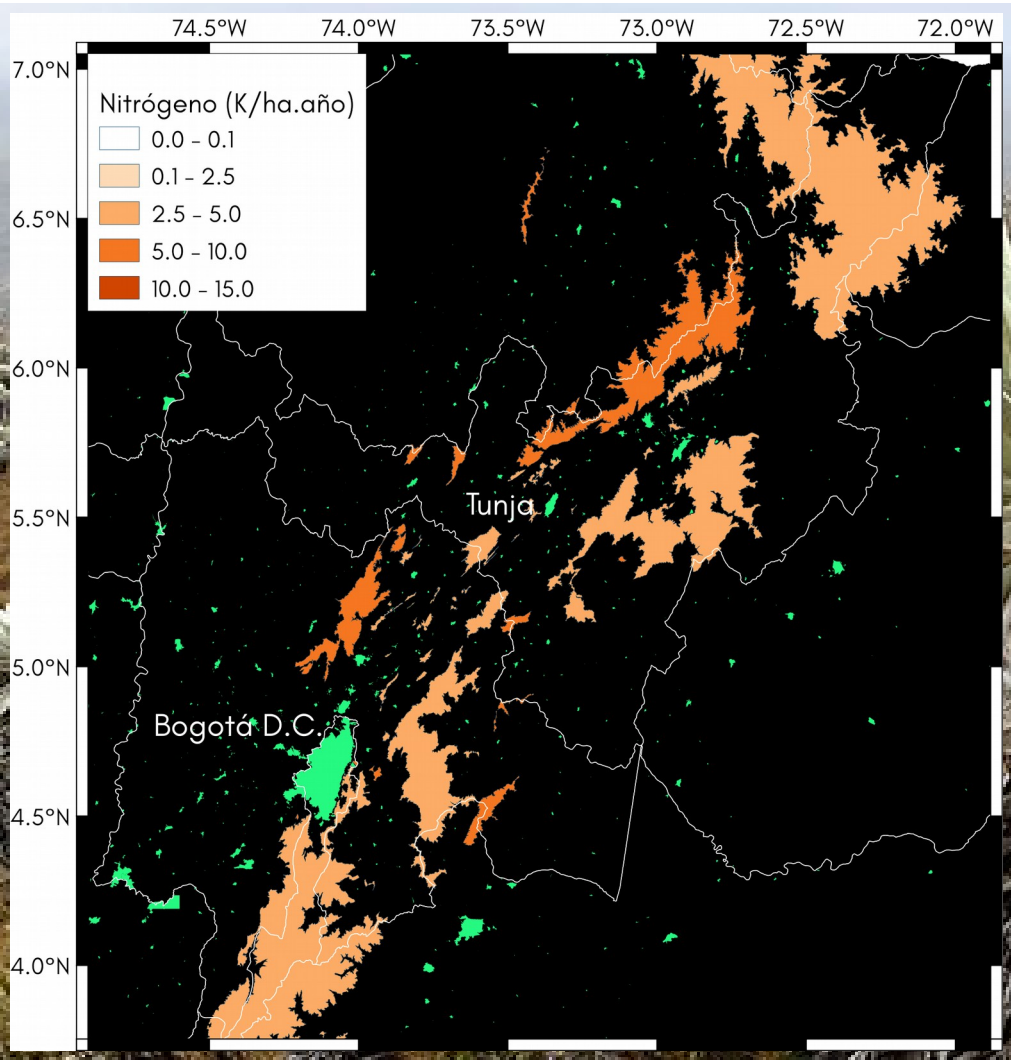


Nitrogen deposition in Colombia's Protected Areas (2016)

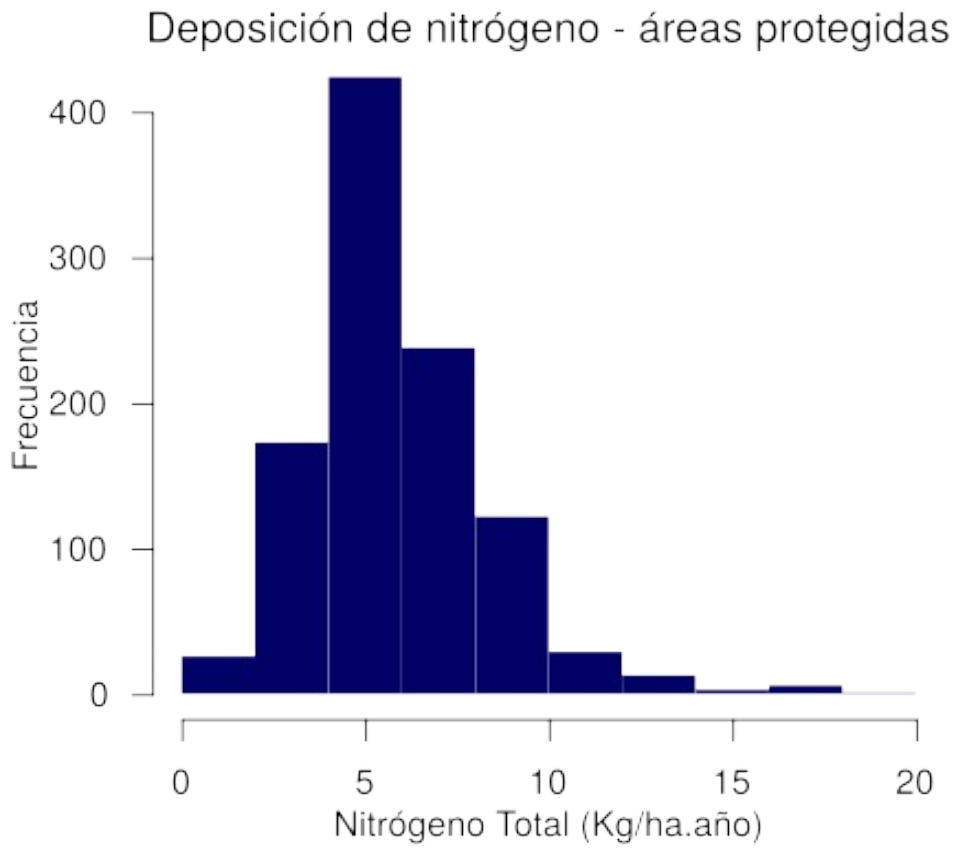


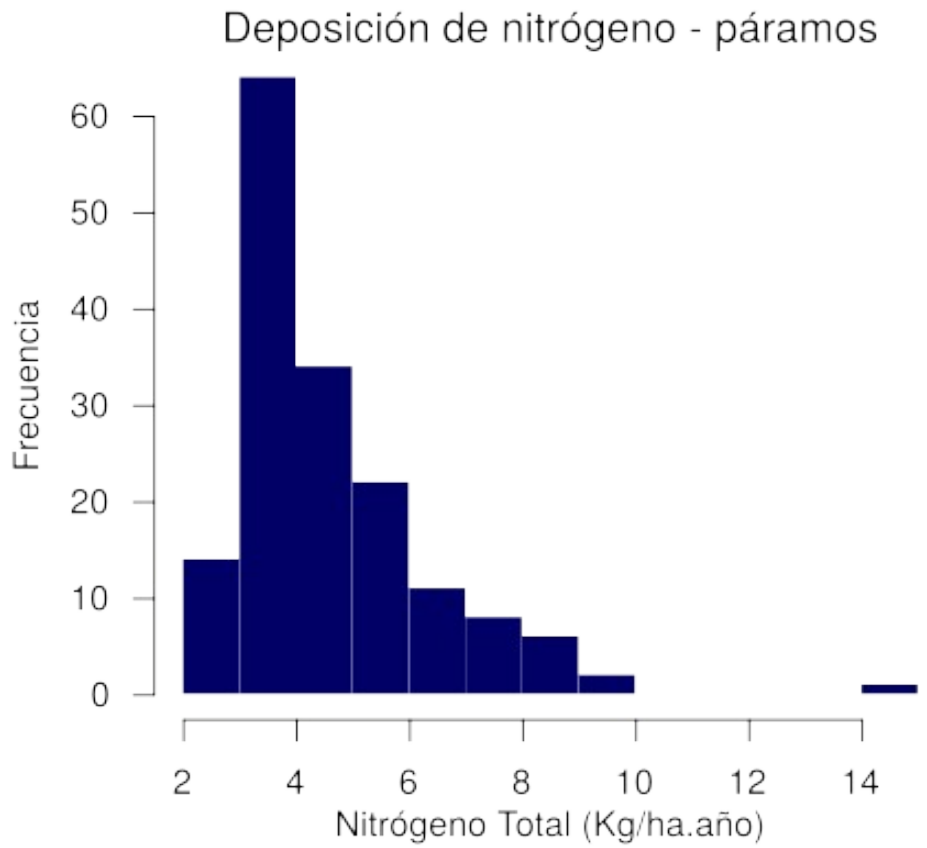
Nitrogen deposition in Colombia's Paramos (2016)



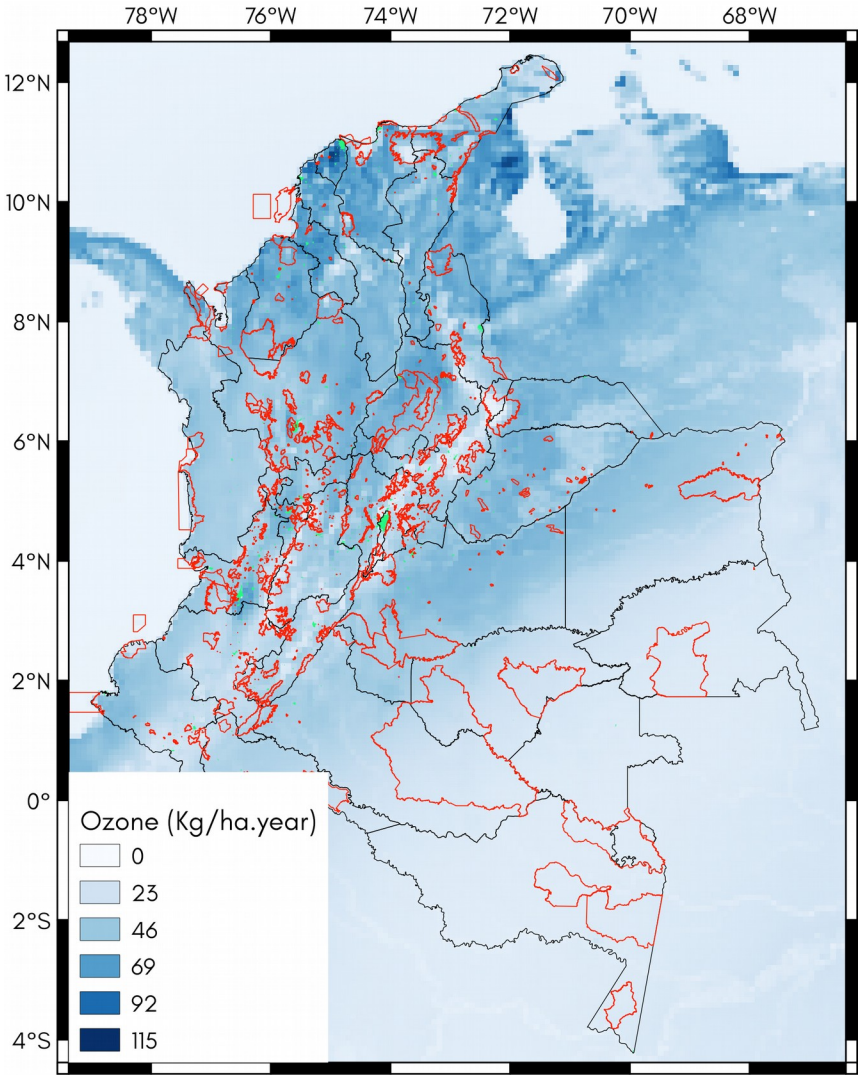


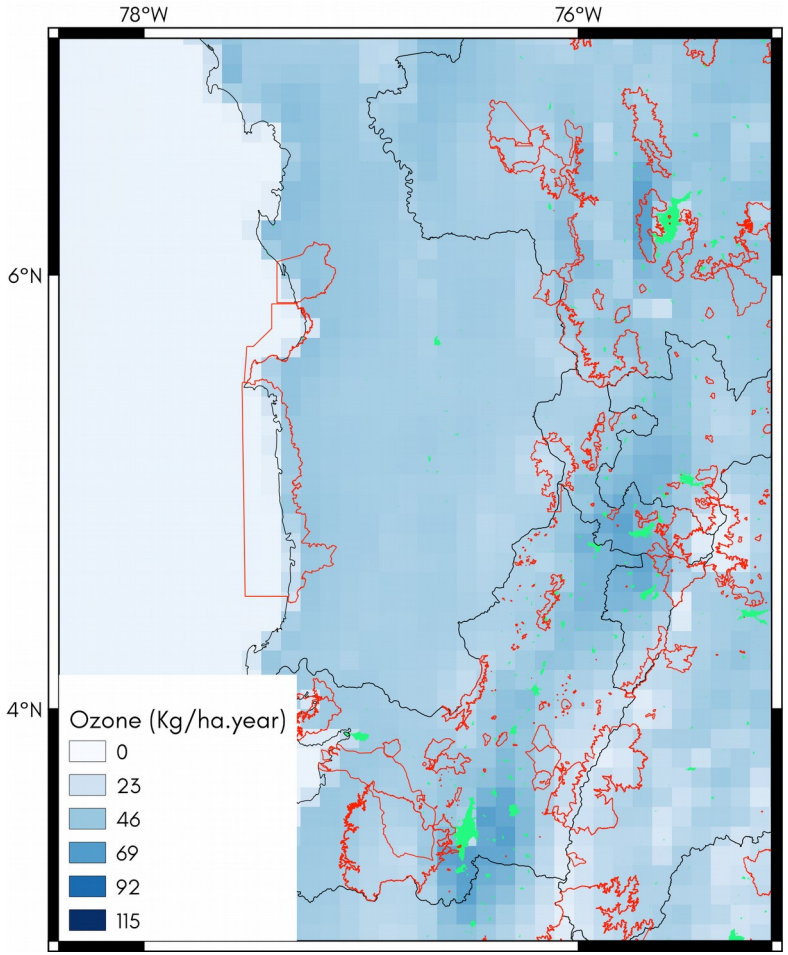
Nitrogen deposition in Colombia (2016)



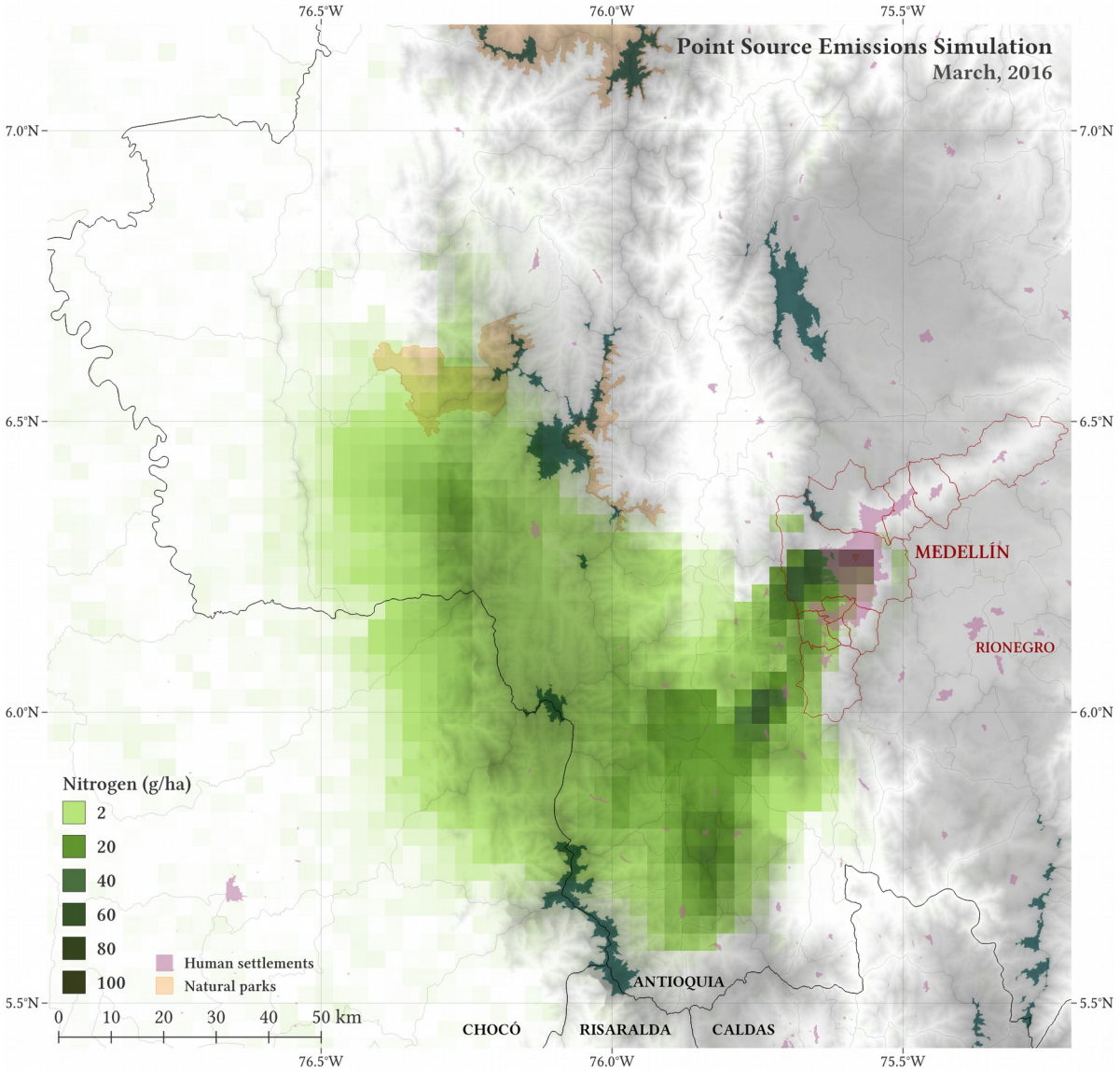


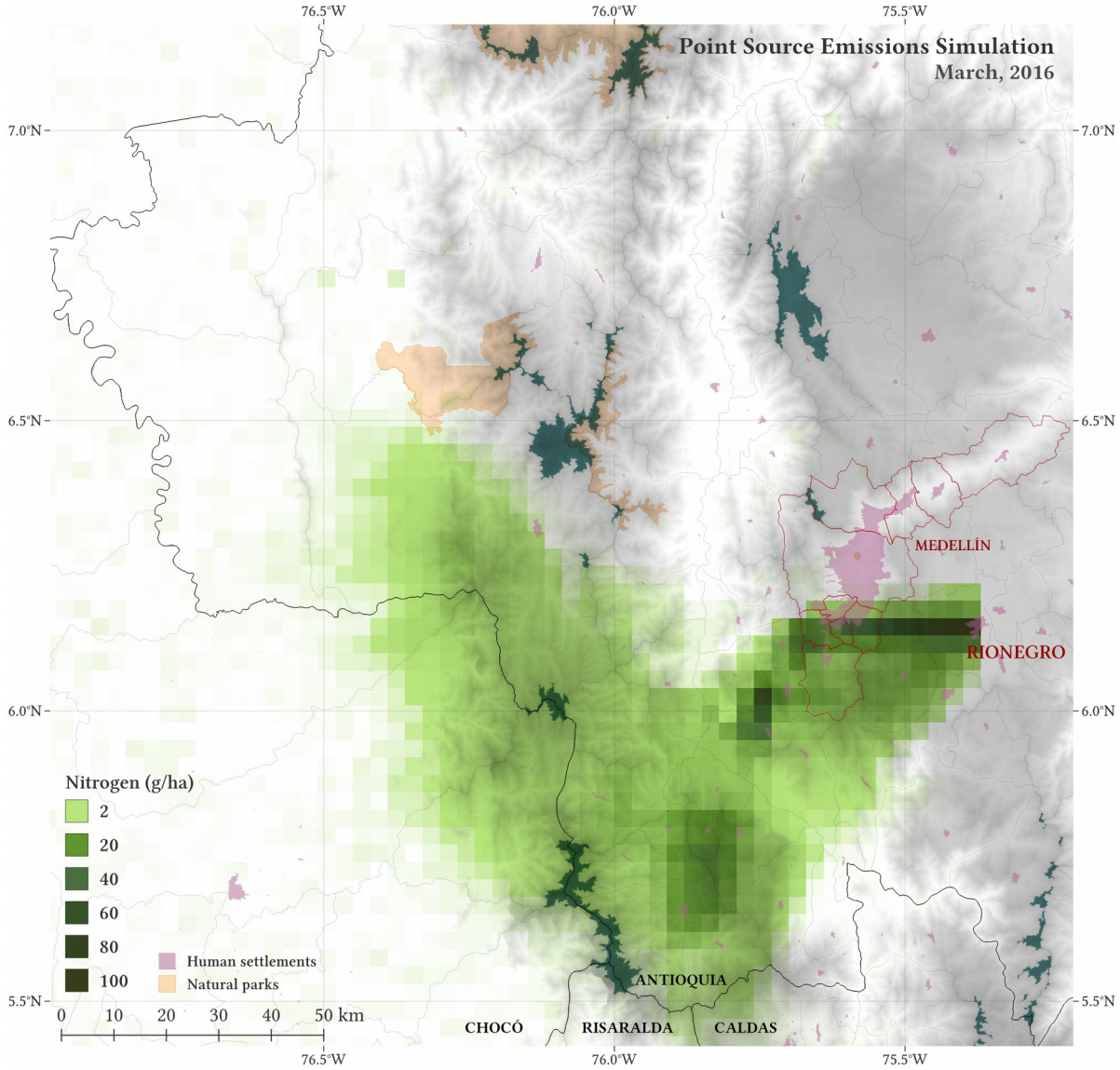
Ozone deposition in Colombia (2016)



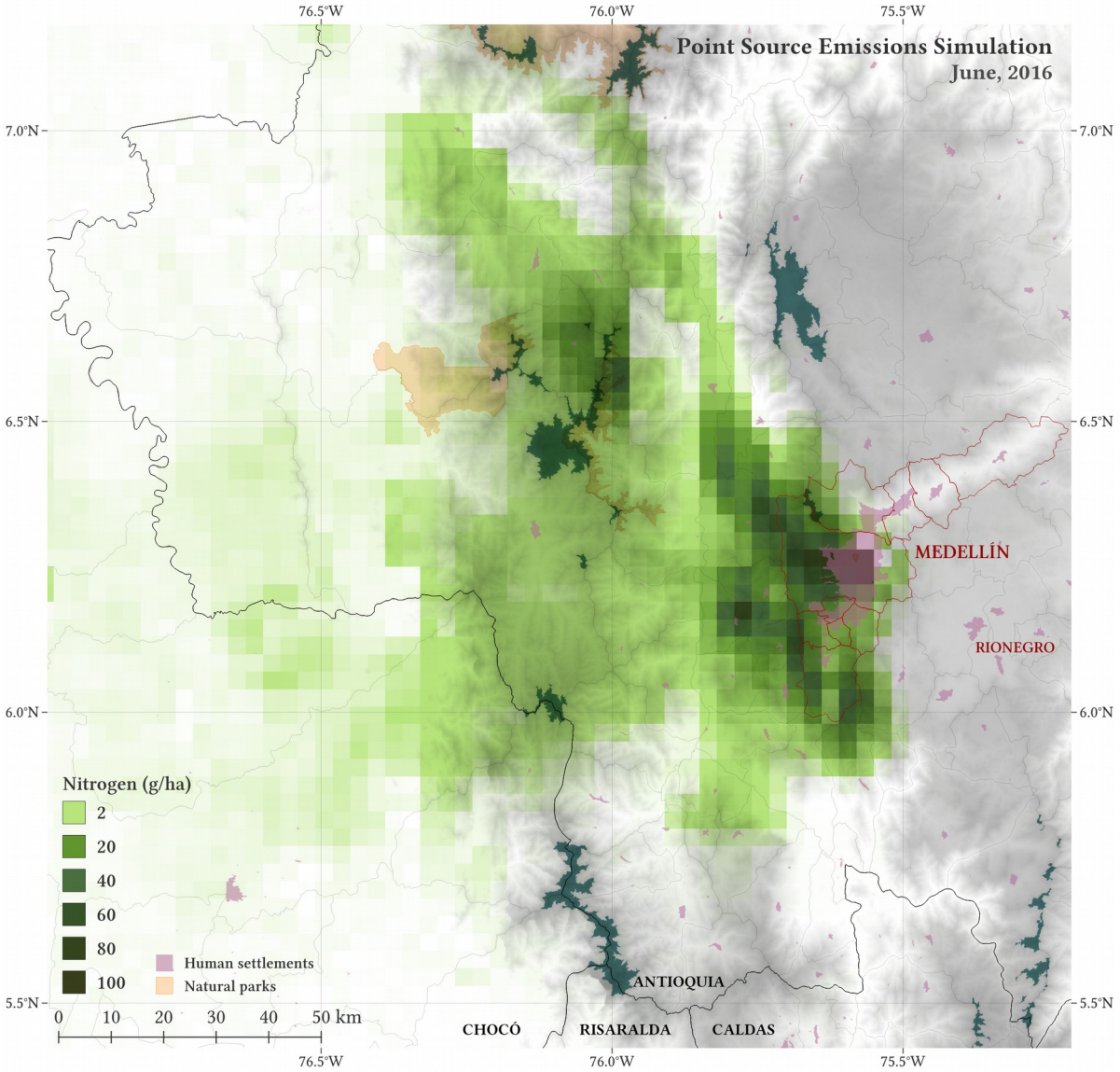


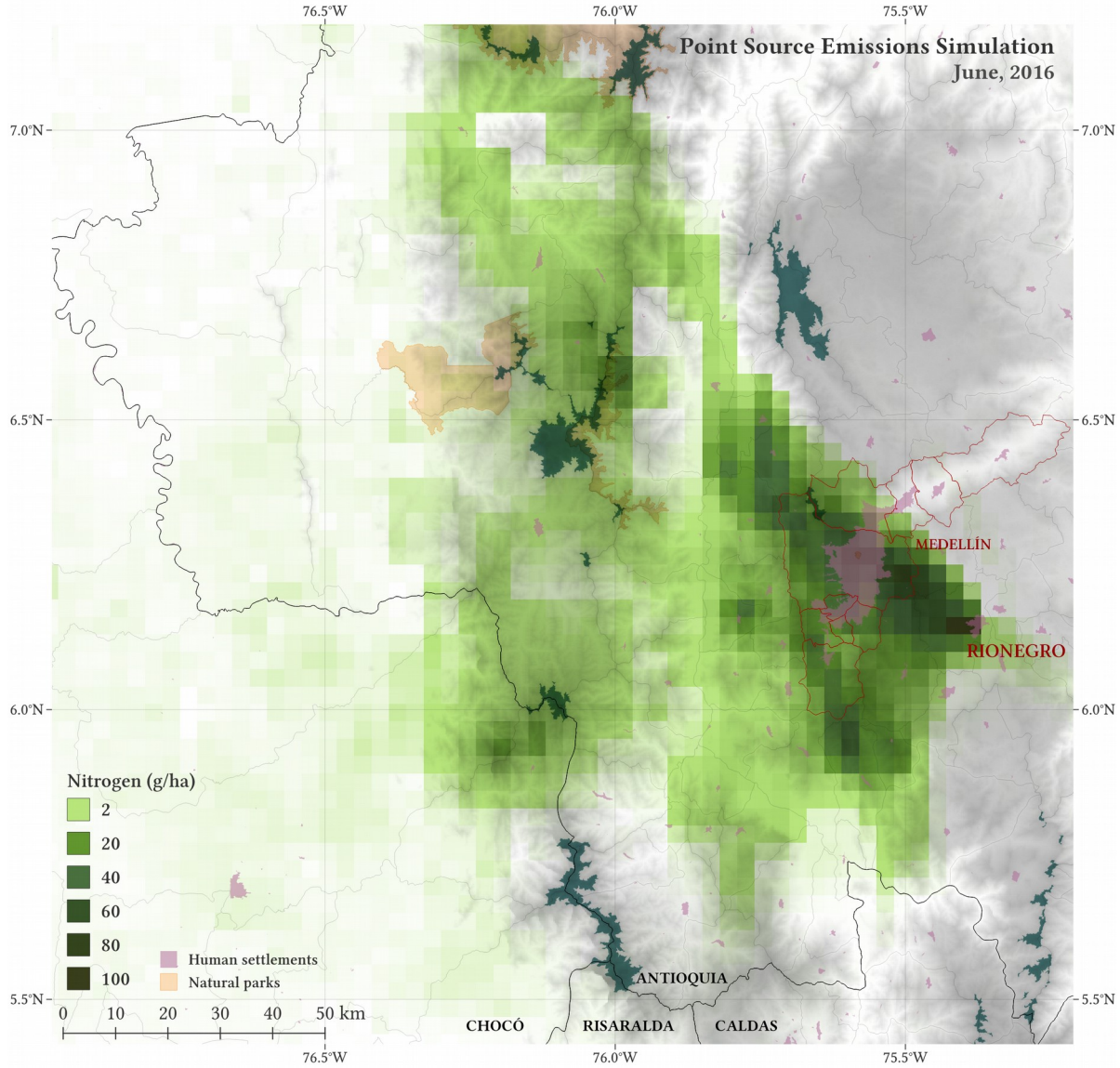
Urban centers as point sources – March 2016



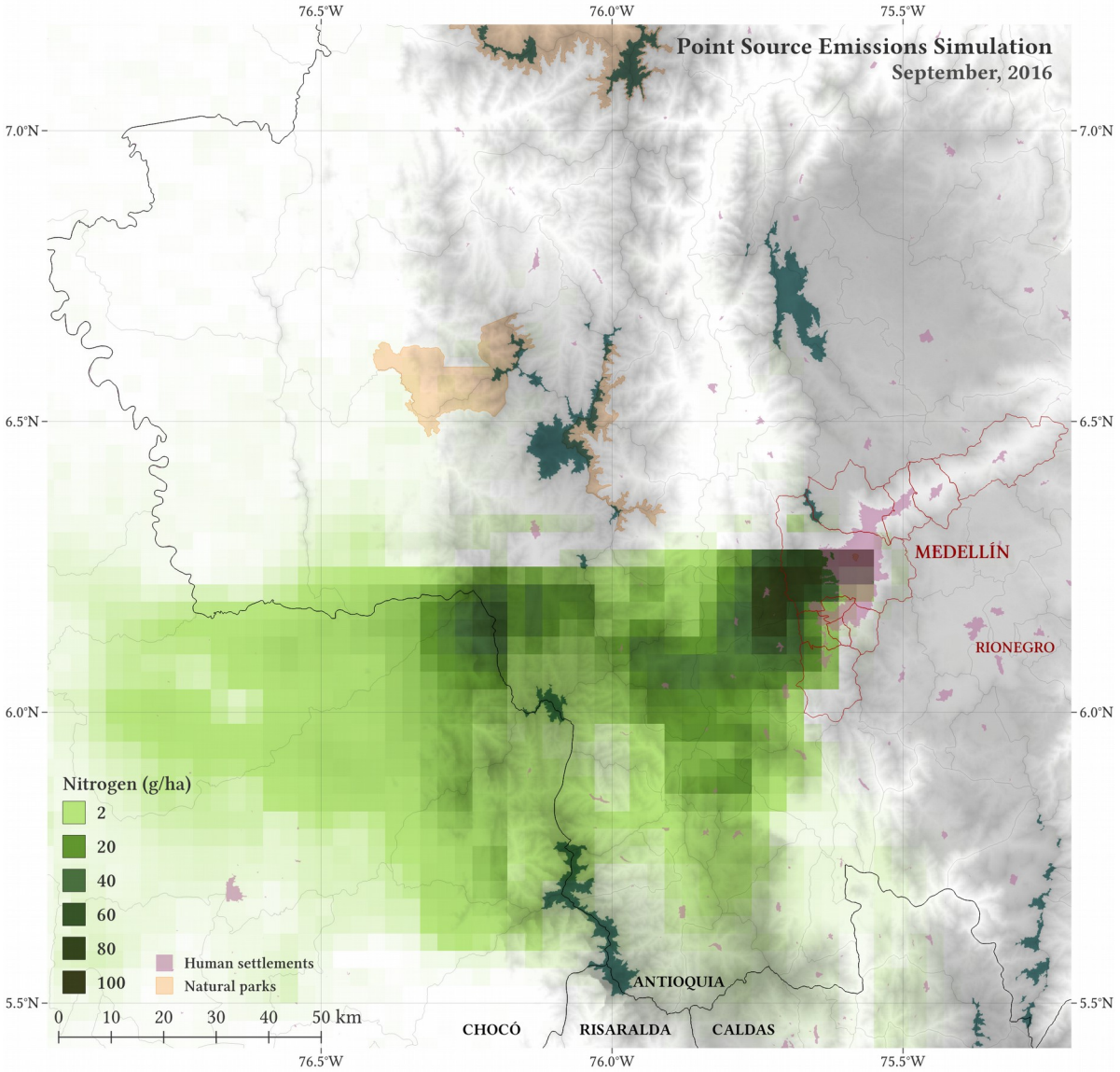


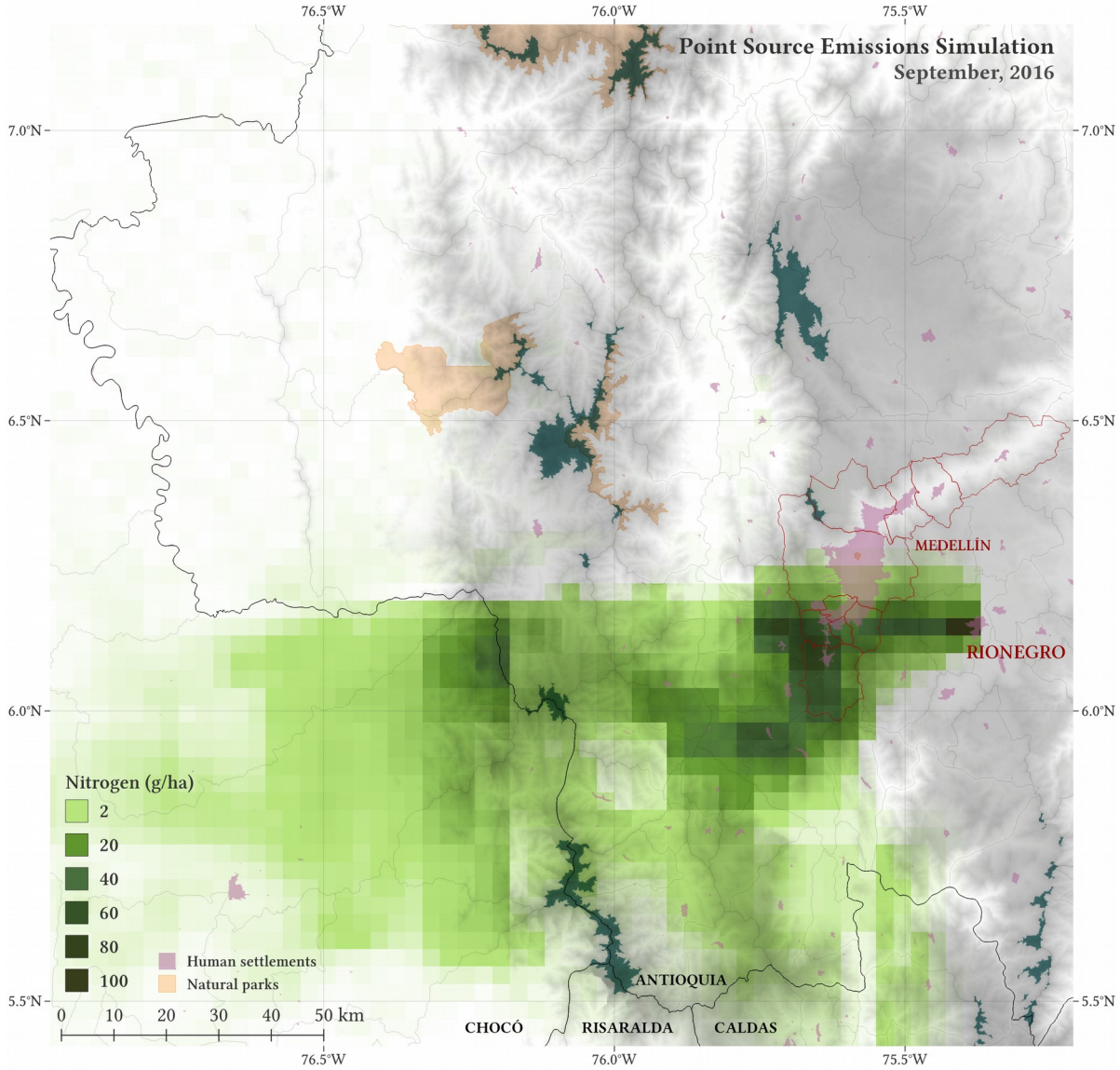
Urban centers as point sources – June 2016



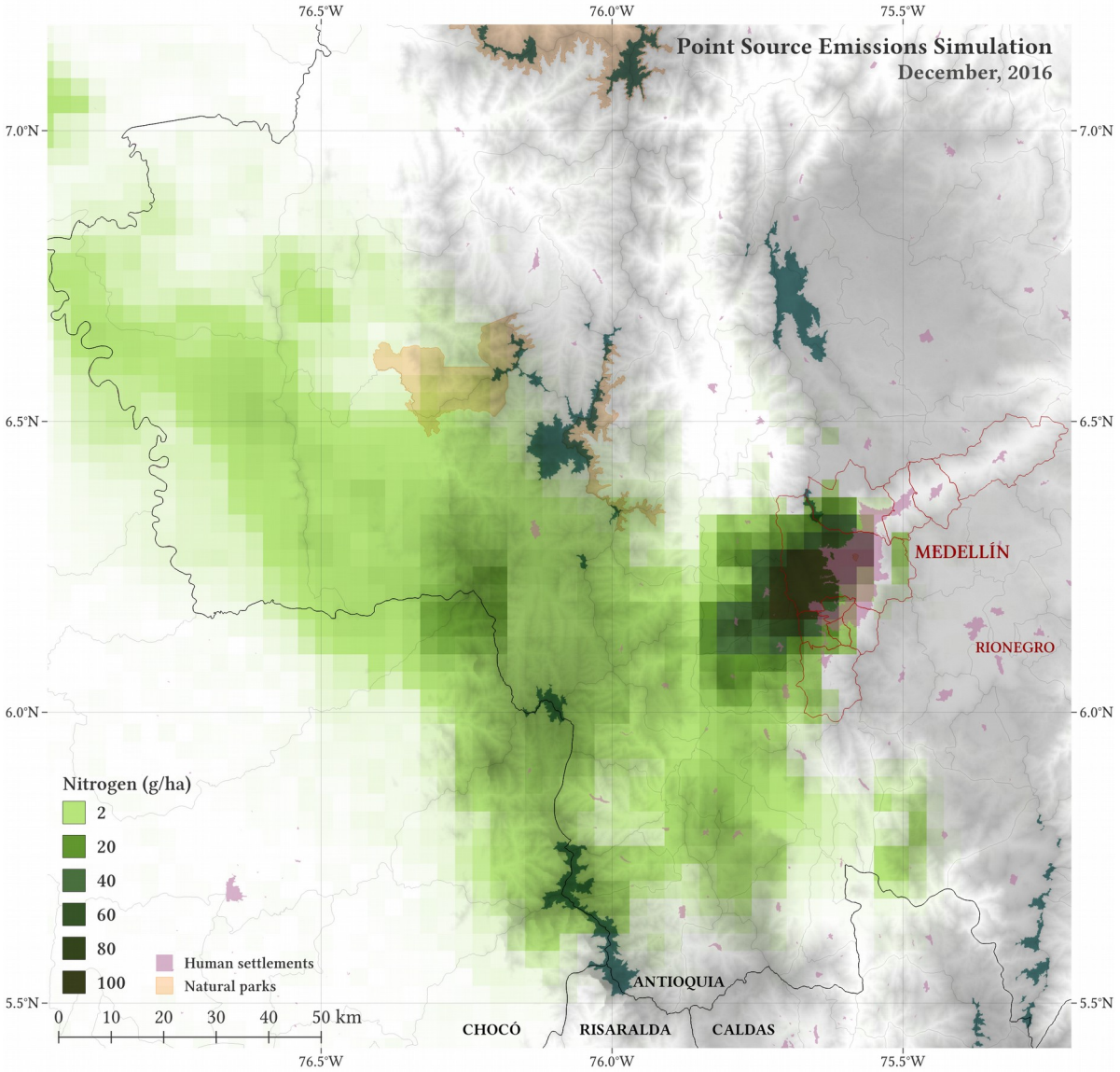


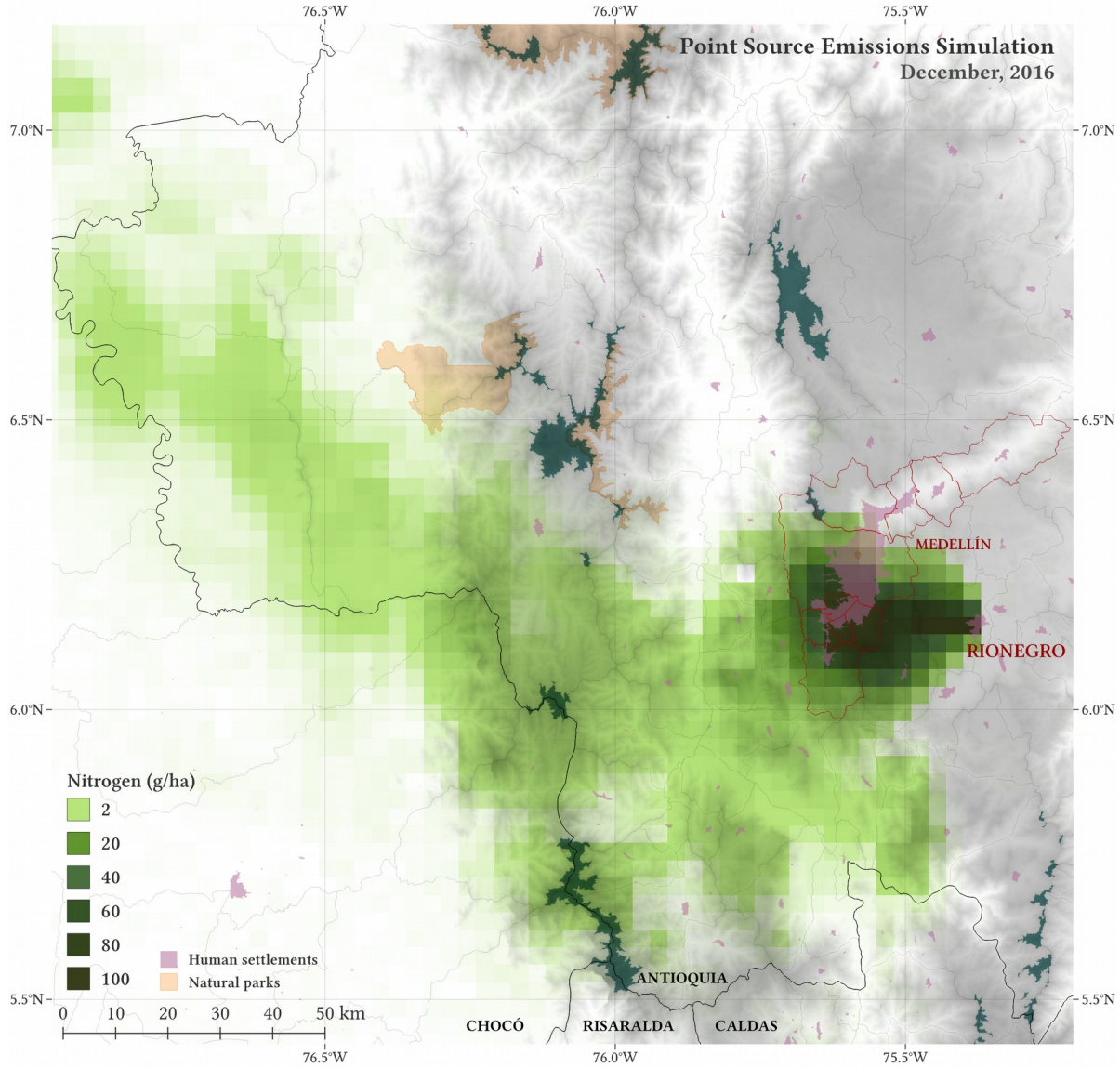
Urban centers as point sources – September 2016



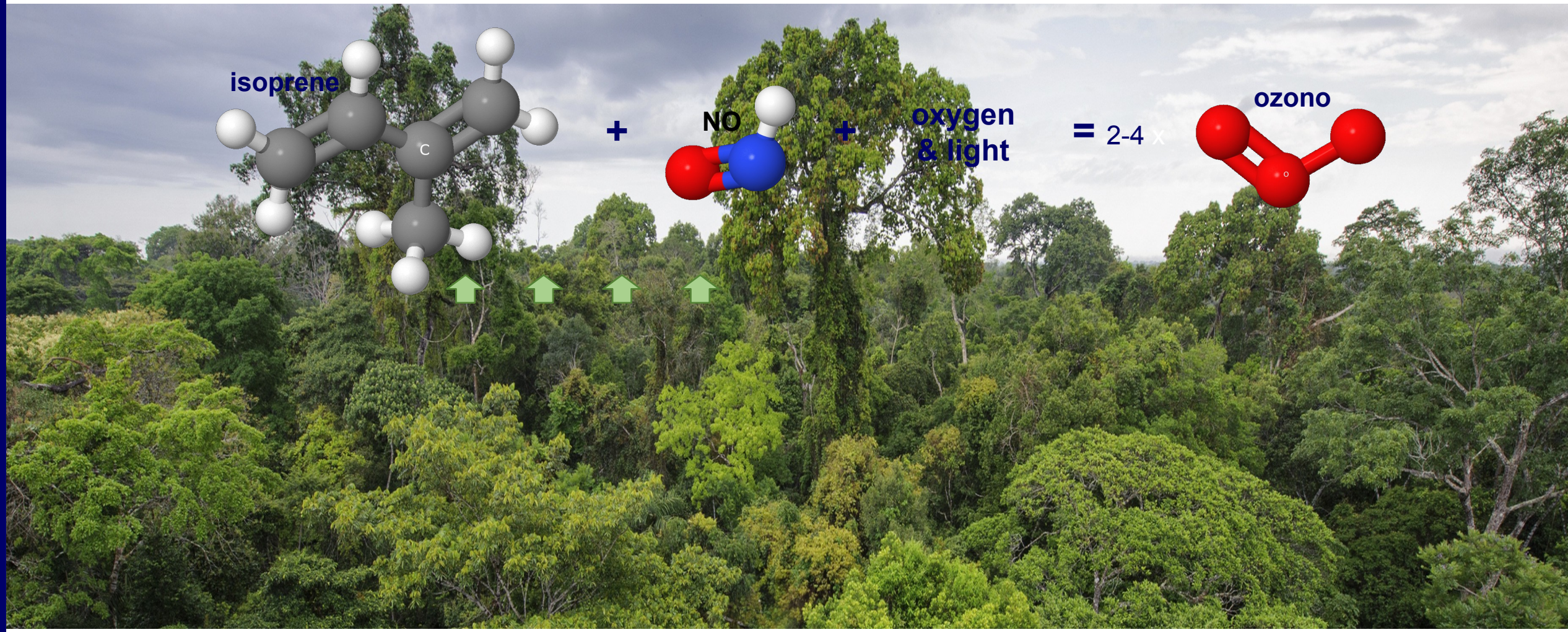


Urban centers as point sources – December 2016





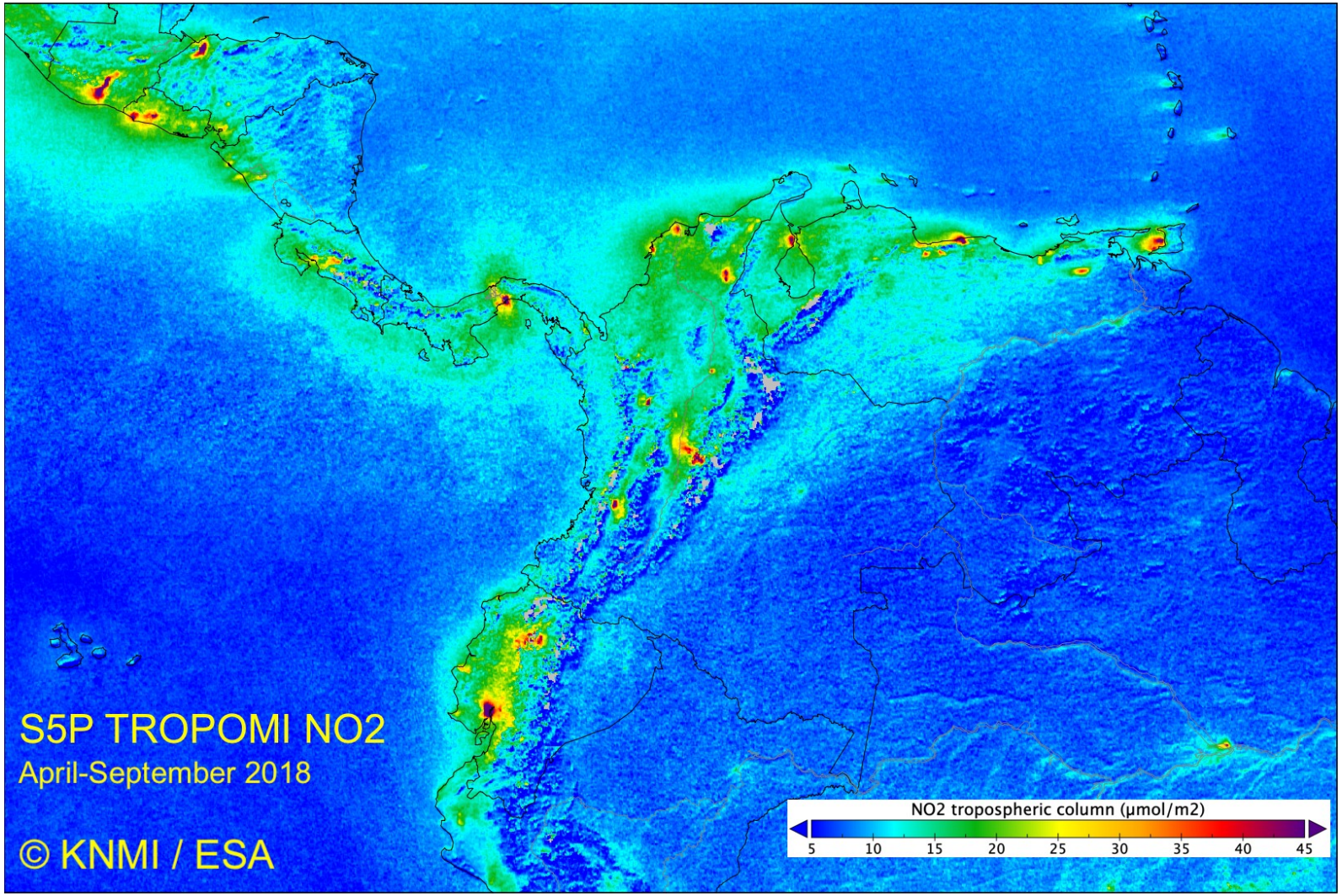
Need better models for tropospheric ozone



Satellite Data for Better Simulations

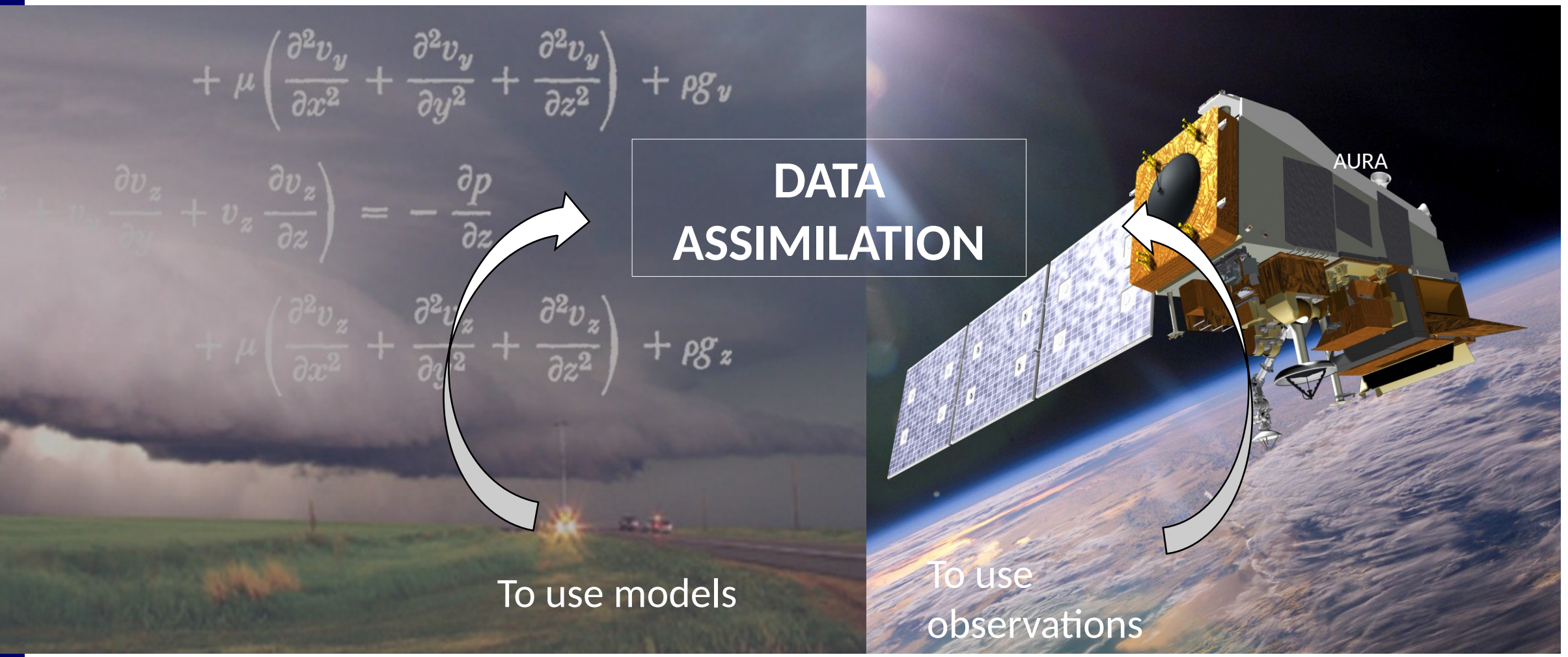
TROPOMI (Sentinel 5P)

Source: ESA

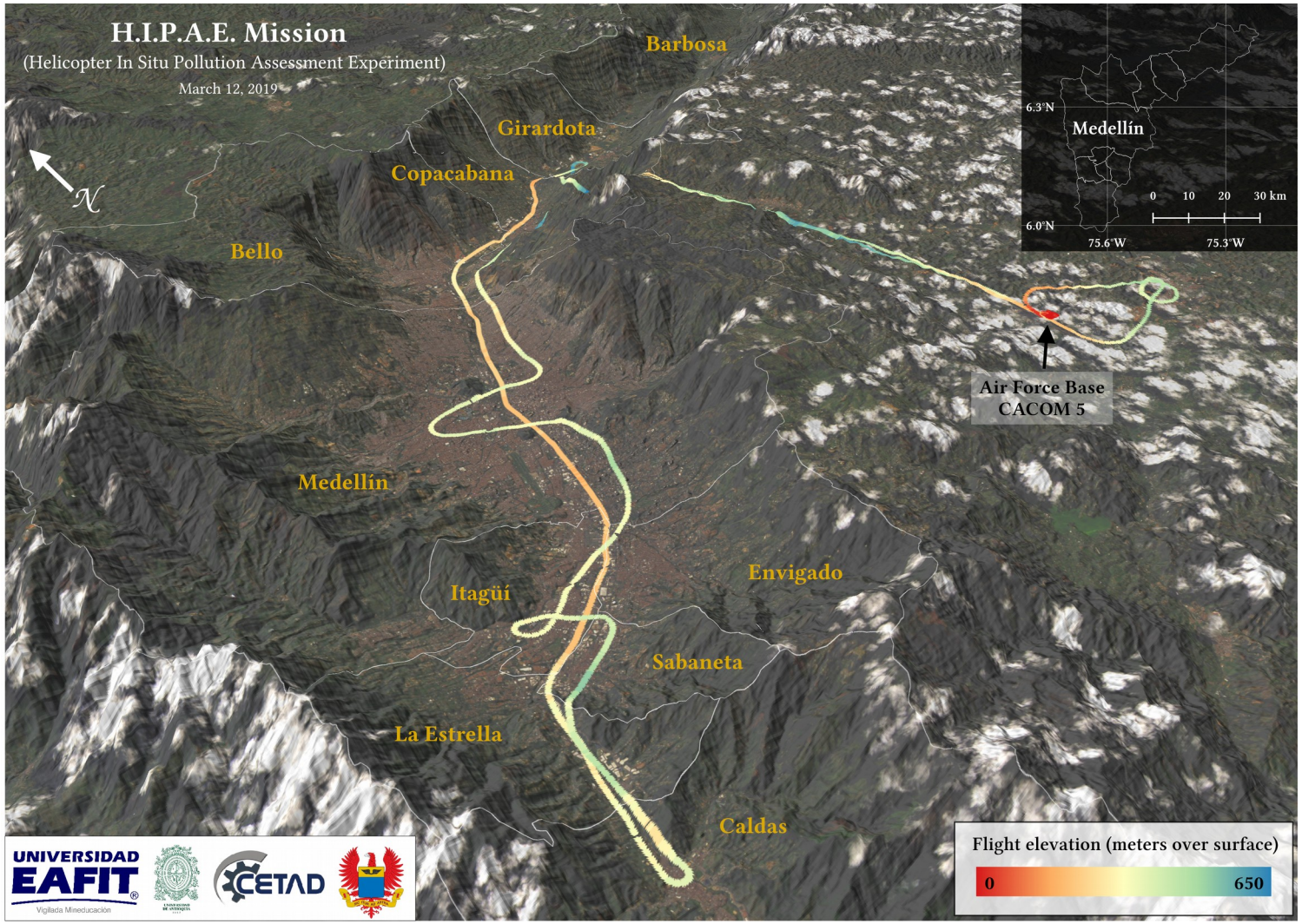


Data composite image provided by Hank Eskes (KNMI)

Satellite Data for Better Simulations



Novel ways of generating data – H.I.P.A.E.

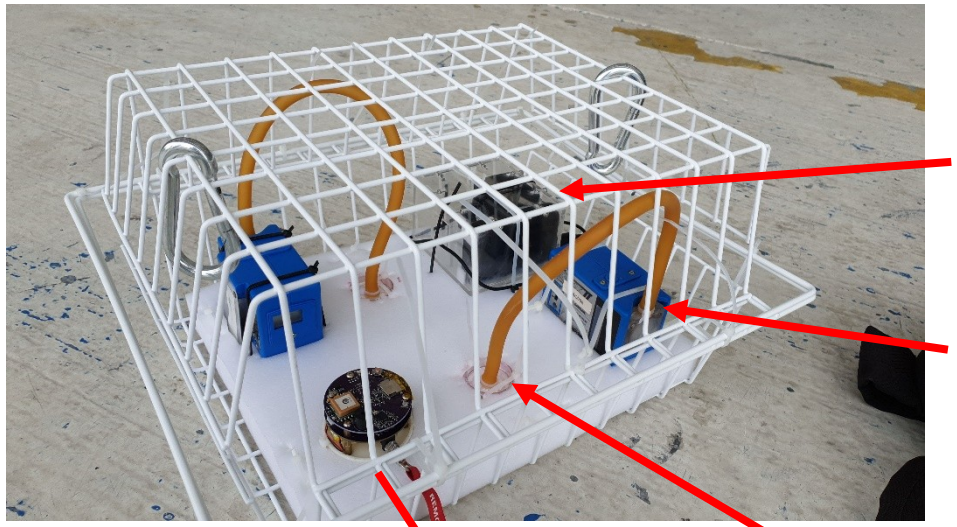


Novel ways of generating data – H.I.P.A.E.

Case for the hanging experiments

Counterweight

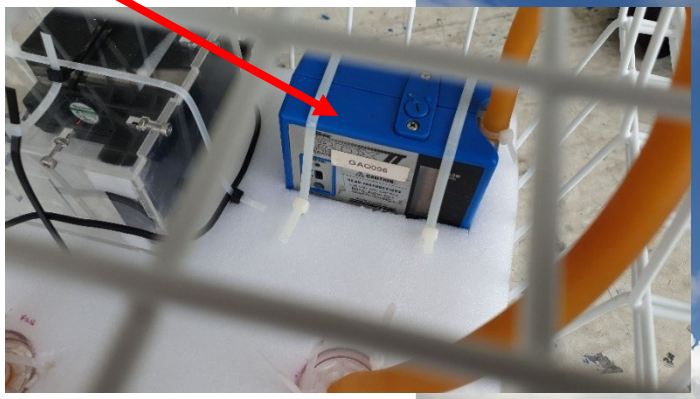
Novel ways of generating data – H.I.P.A.E.

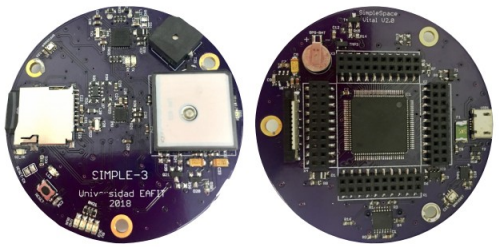


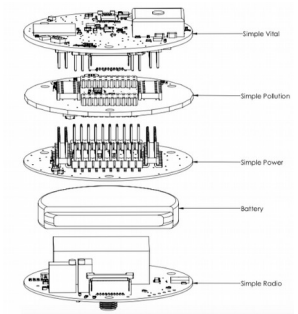
Particle counter

Air pumps

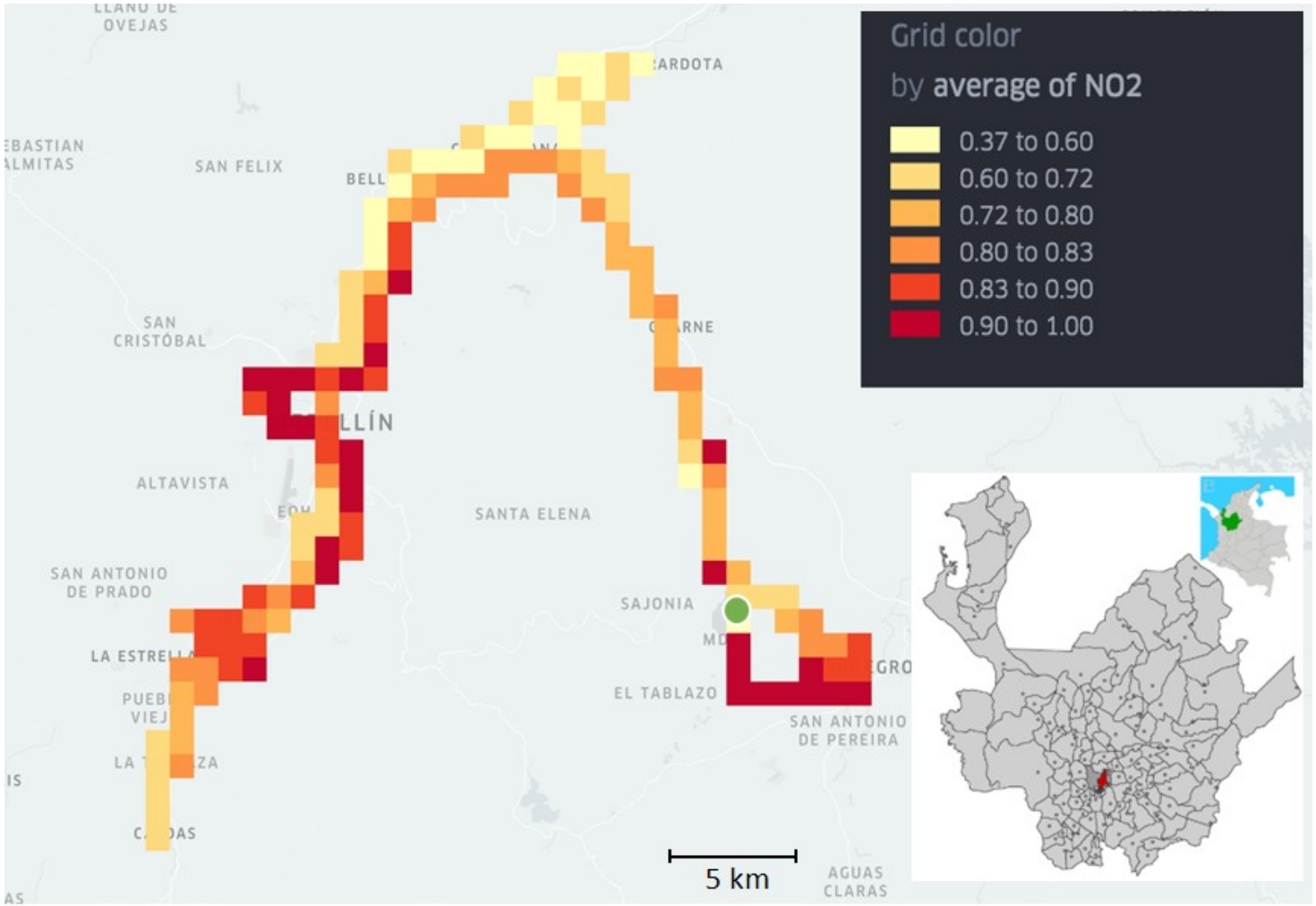
Nano filters trap for pollution







Novel ways of generating data – H.I.P.A.E.



Thank you.