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CHALLENGES AND OPPORTUNITIES FOR OPEN LOTOS-EUROS MODEL TO REPRODUCE THE DYNAMICS FOR TROPICAL ANDES DOMAIN

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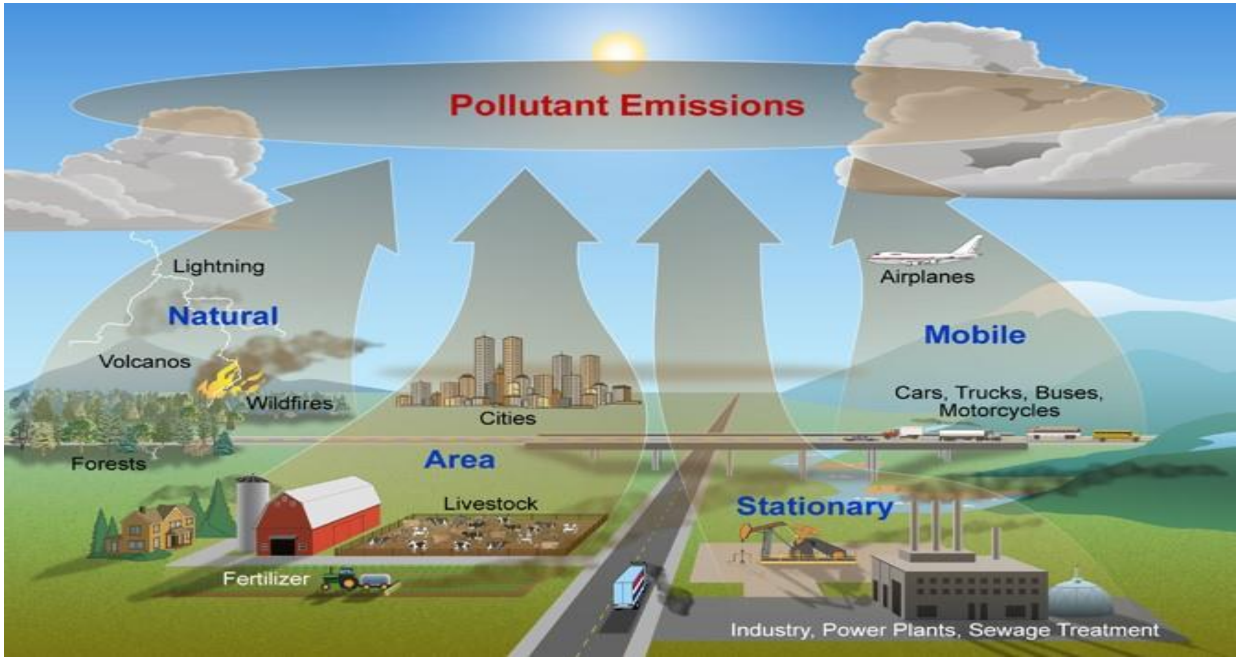
OUTLINE

- Air Quality
- Air Quality Models
- LOTOS-EUROS Model
- Experiment, results and analysis
- Data Assimilation

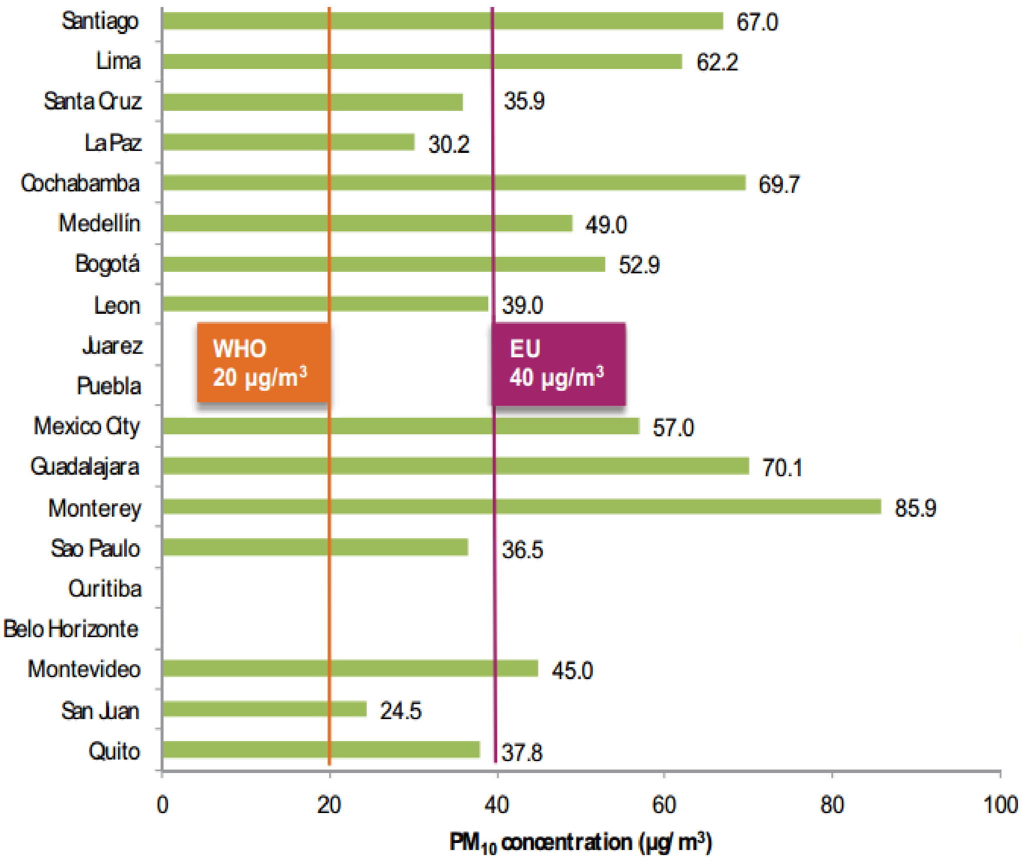
AIR QUALITY (1/3)

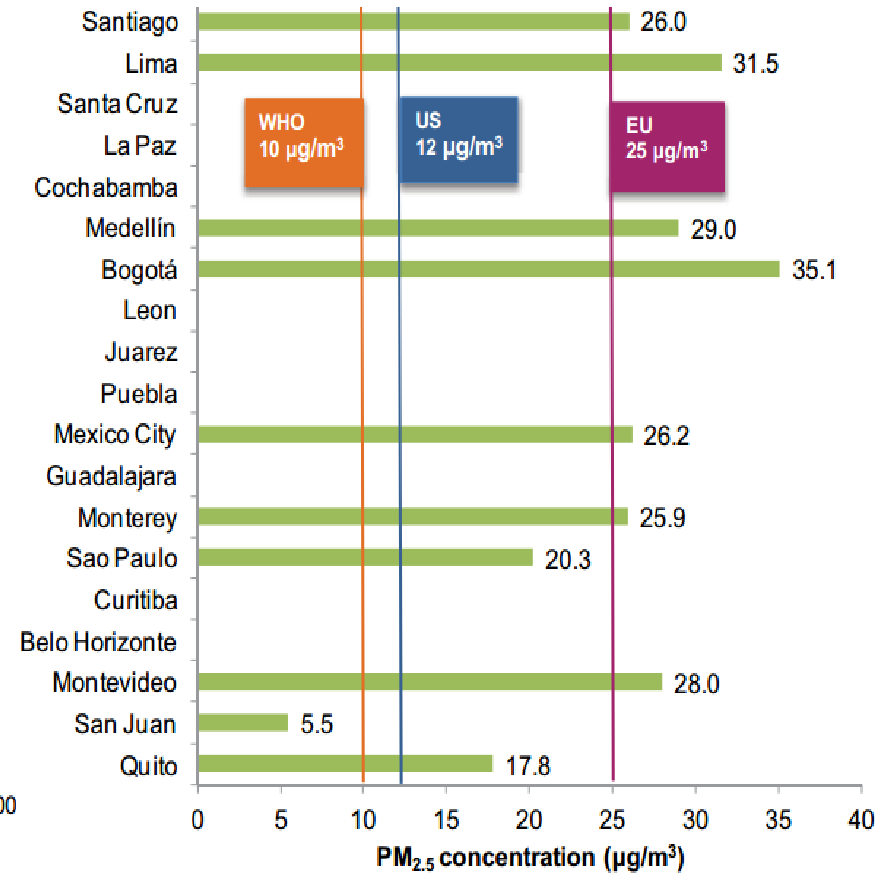
- Air pollution is defined as the presence of solid, liquid or gaseous components in the atmosphere.



Source: http://www.vpaaz.org/

AIR QUALITY (2/3)





Annual average concentrations of PM_{10} y $PM_{2.5}$ -2011. Source: Air Quality In Latin America: An Overview, CAI

AIR QUALITY (3/3)

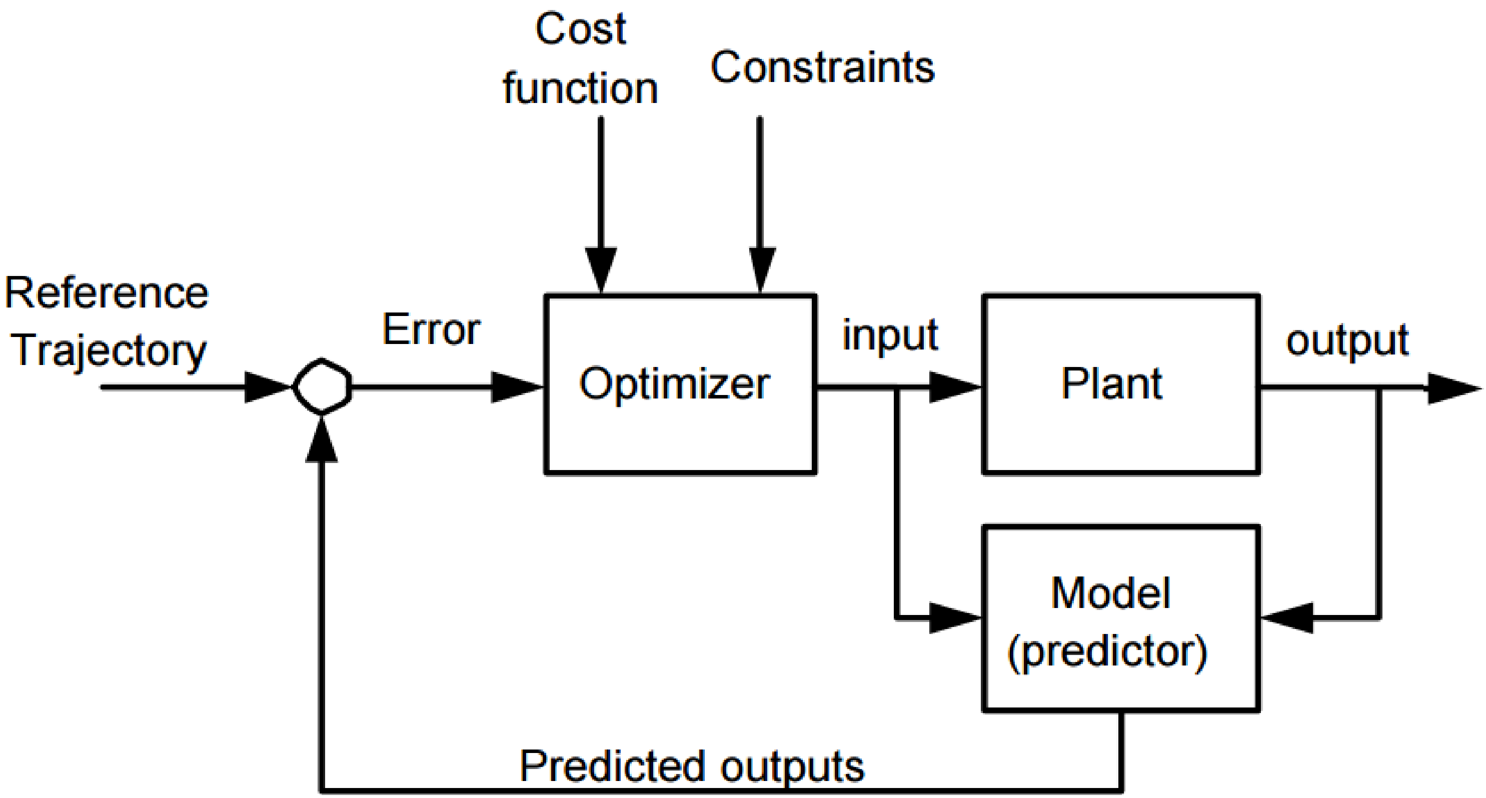
Air quality in Medellín. Source: www.catorce6.com

AIR QUALITY MODELS (1/3)

- Essential to any corrective action is the ability to measure and **estimate** the concentration of atmospheric pollutants.
- The mathematical models known as Air Quality Models (AQM), allow a permanent monitoring and in many cases predictions of the air quality behavior.

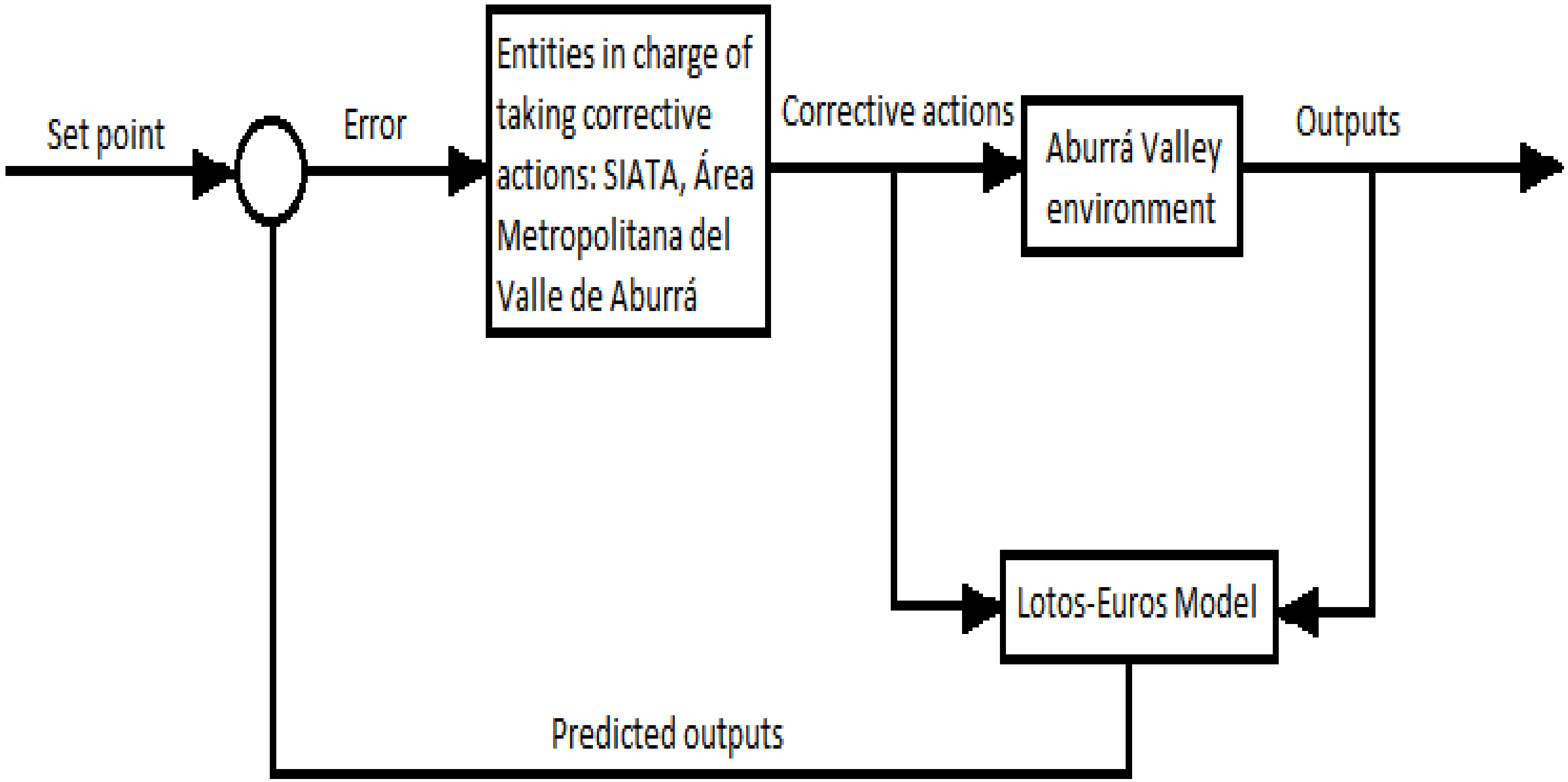
Is it possible to model the atmosphere behavior at the Aburrá Valley scale so that it can to monitor environmental pollutants and predict their behavior?

AIR QUALITY MODELS (2/3)



MPC block diagram. Sourcer: Stable Reconfigurable Generalized Predictive Control With Application to Flight Control. (Shi, Kelkar, & Soloway, 2005)

AIR QUALITY MODELS (3/3)



MPC block diagram for the problem of air quality in the Aburrá Valley

LOTOS-EUROS MODEL (1/3)

The **LOTOS-EUROS**

(LOng Term Ozone Simulation- EURopean Operational Smog model)

1970

The LOTOS model

By US UAM

(Urban Airshed Model)

1981

The Eulerian air quality model EUROS

By RIVM

2004

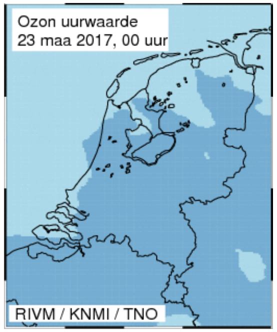
The LOTOS and EUROS model

By TNO and RIVM/MNP

LOTOS-EUROS MODEL (2/3)

SmogProg, Netherlands
Used by Dutch authorities as official forecasts to predict Ozone concentrations and PM in national territory.

MIJN LUCHTKWALITEIT



PANDA, China
Used to collect a set of models and looks for modeling and predicting pollutants concentrations in Chinese territory.

马可·波罗 MARCOPOLO

PANDA 熊貓 PArtnership with ChiNa on space DAta

FIFA WORLD CUP 2016, Brazil
Used to monitoring and predicting Ozone concentrations, Nitrogen Dioxide and PM 2.5 while was the FIFA World Cup.

LOTOS-EUROS MODEL (3/3)

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} + V\frac{\partial C}{\partial y} + W\frac{\partial C}{\partial z} = \frac{\partial}{\partial t}\left(K_h\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_h\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + E + R + Q - D - W$$

Entrainment and Diffusion

$$K_h = \eta|Def|$$

$$|Def| = \sqrt{\left[\left(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y}\right)^2 + \left(\frac{\partial U}{\partial x} - \frac{\partial V}{\partial y}\right)^2\right]}$$

$$\frac{\partial C}{\partial t} = -\Lambda C$$

$$\Delta D = C_0(1 - e^{-\Lambda t})\Delta z$$

Emissions

Model Input

Chemistry

LOTOS-EUROS can use one of two mechanisms of simplified reactions, Carbon Bond-IV (CB-IV) or CB99.

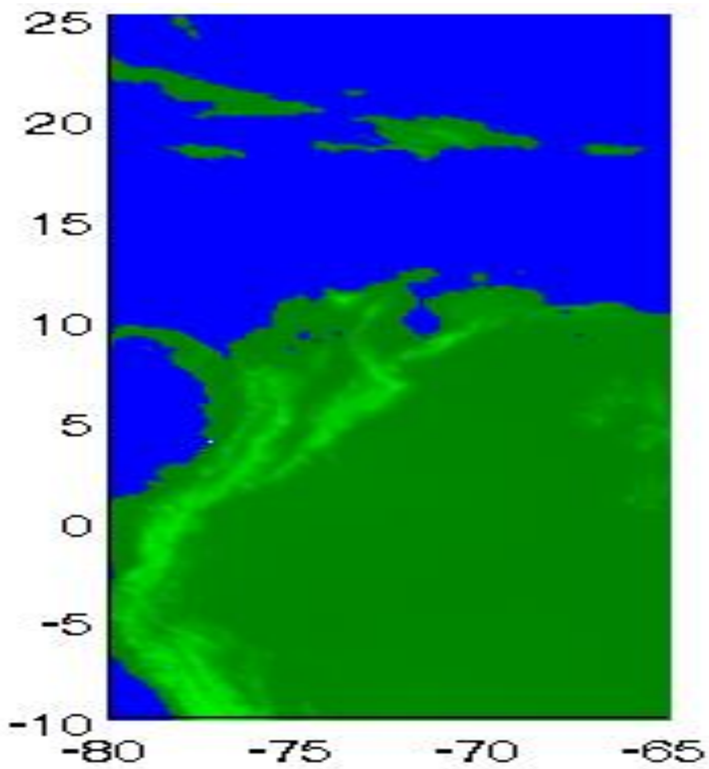
Deposition

Dry and Wet Deposition

EXPERIMENT

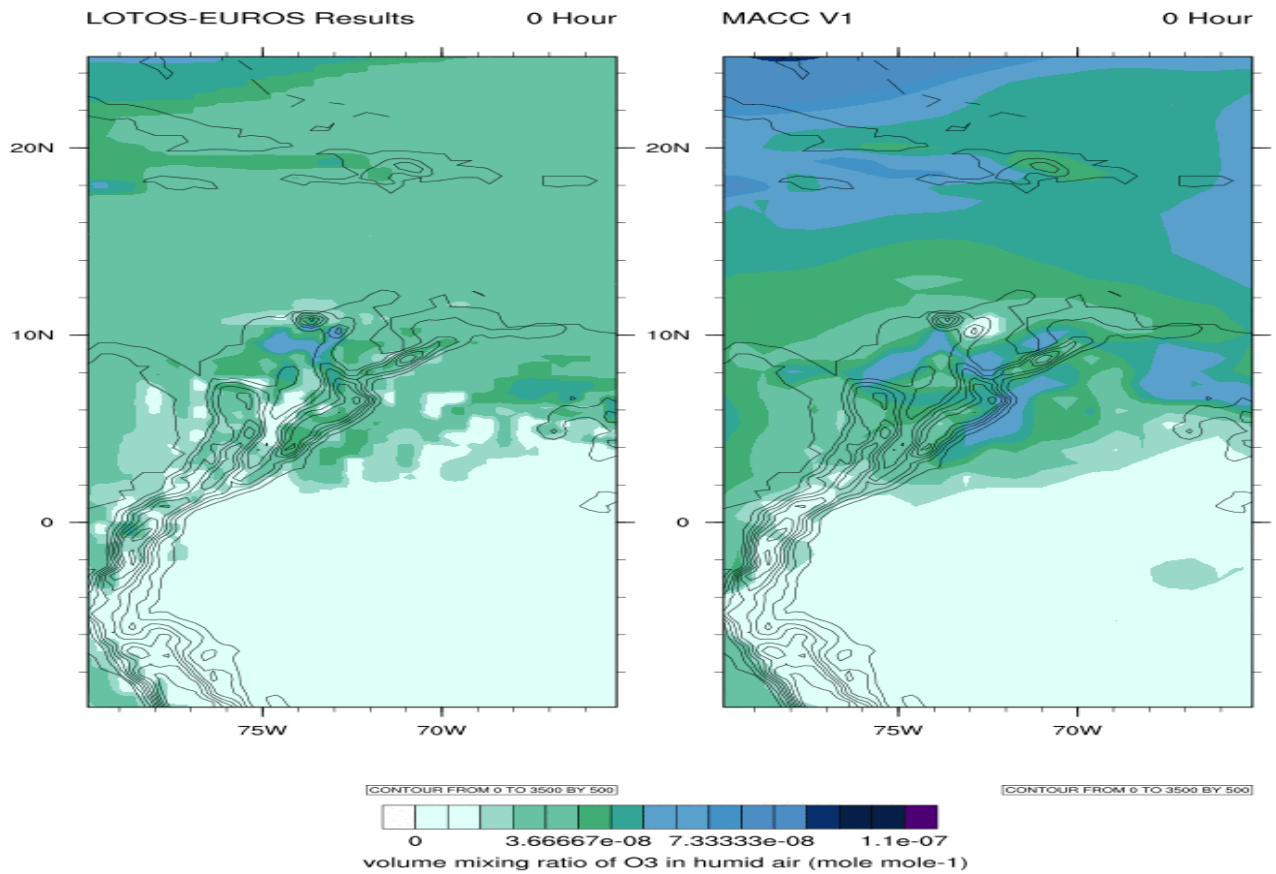
Experiment Parameters

Domain	Between -80 to -65 west degrees, and 25 to-10 north degrees
Resolution	0.25°x 0.25°
Metereological Data	ECMWF database
Emissions	MACC 1 and EDGAR databases
Date	Between the days March 24 and April 4, 2015.

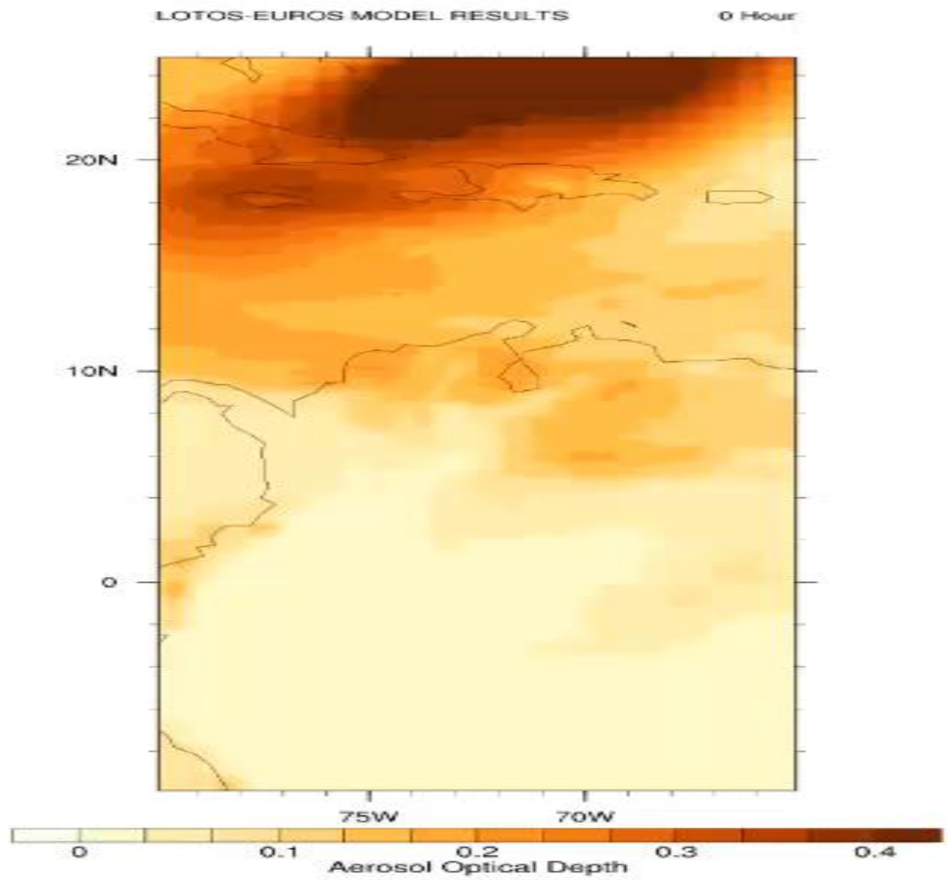


Domain

RESULTS (1/2)

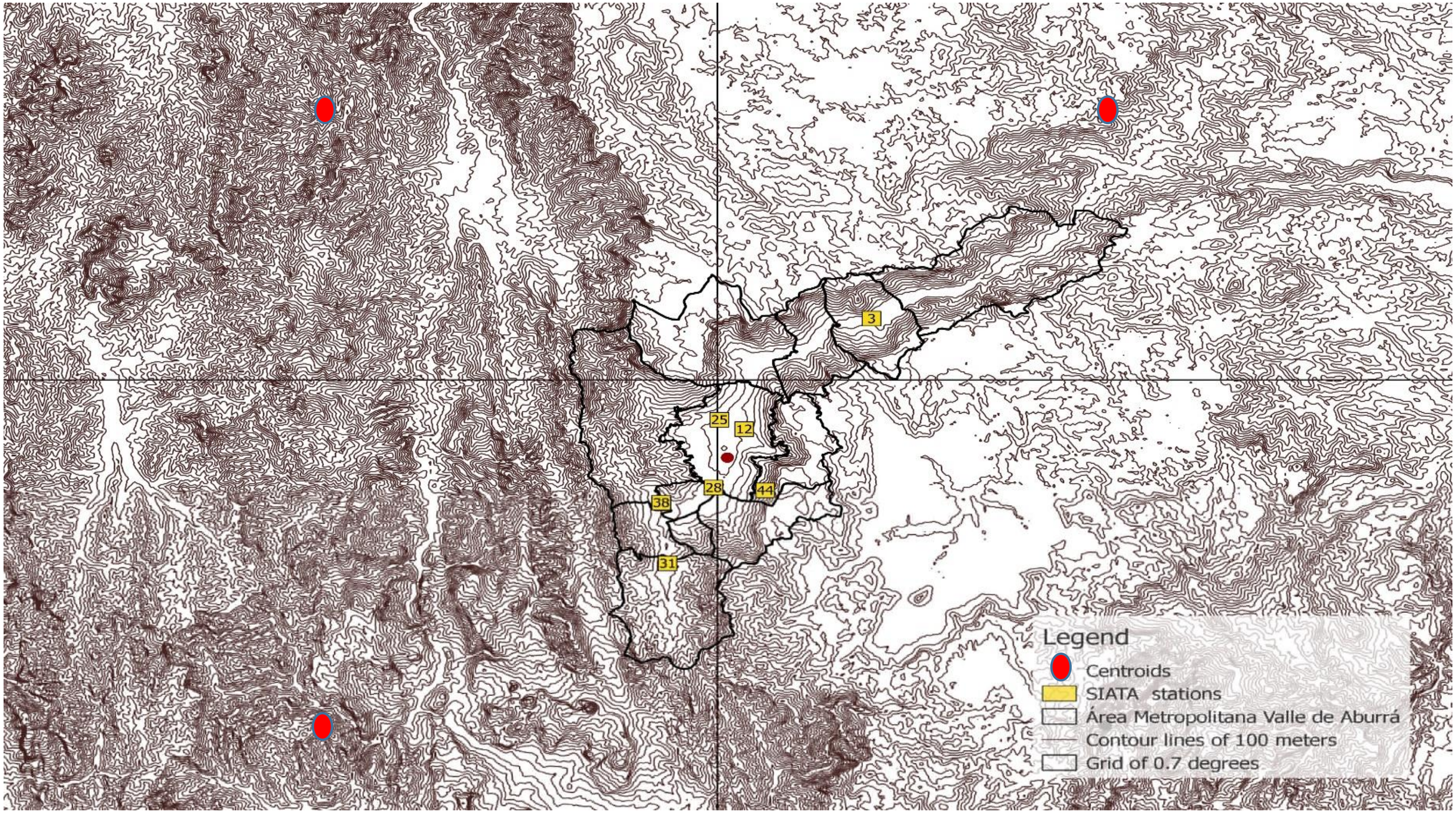

LOTOS-EUROS Results
0 Hour
MACC V1
0 Hour
20N
10N
0
75W
70W
CONTOUR FROM 0 TO 3500 BY 500
0
3.66667e-08
7.33333e-08
1.1e-07
volume mixing ratio of O3 in humid air (mole mole-1)

RESULTS (2/2)



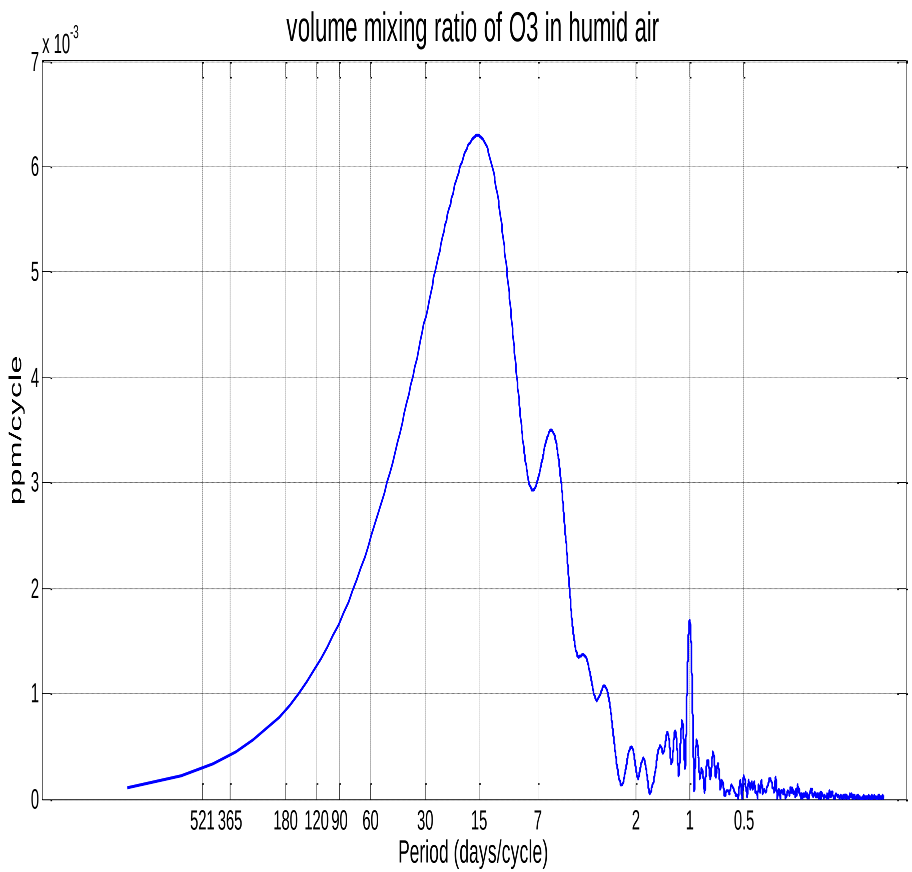
LOTOS-EUROS MODEL RESULTS
0 Hour
20N
10N
0
75W
70W
0
0.1
0.2
0.3
0.4
Aerosol Optical Depth

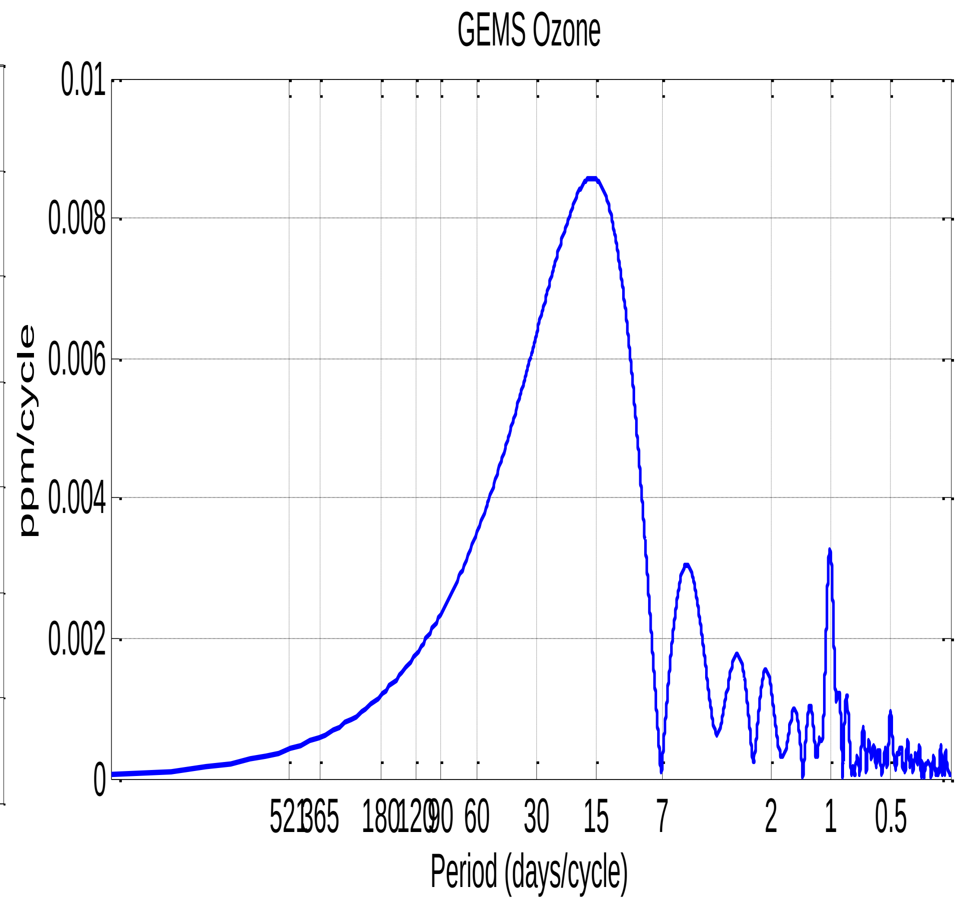
PRELIMINARY ANALYSIS (1/5)



Aburrá Valley

PRELIMINARY ANALYSIS (2/5)





Comparison of frequency analysis between LOTOS-EUROS and MACC for O_3

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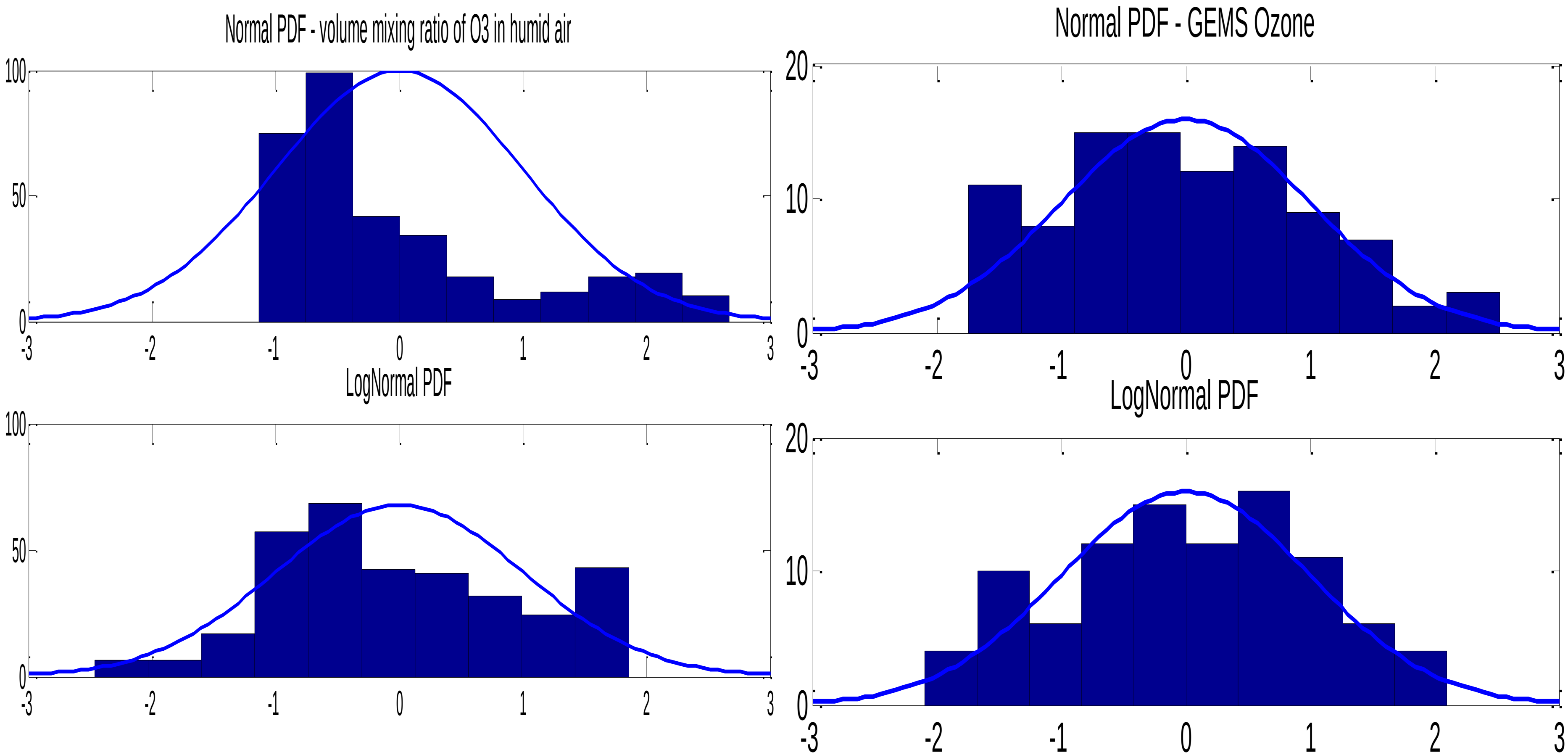
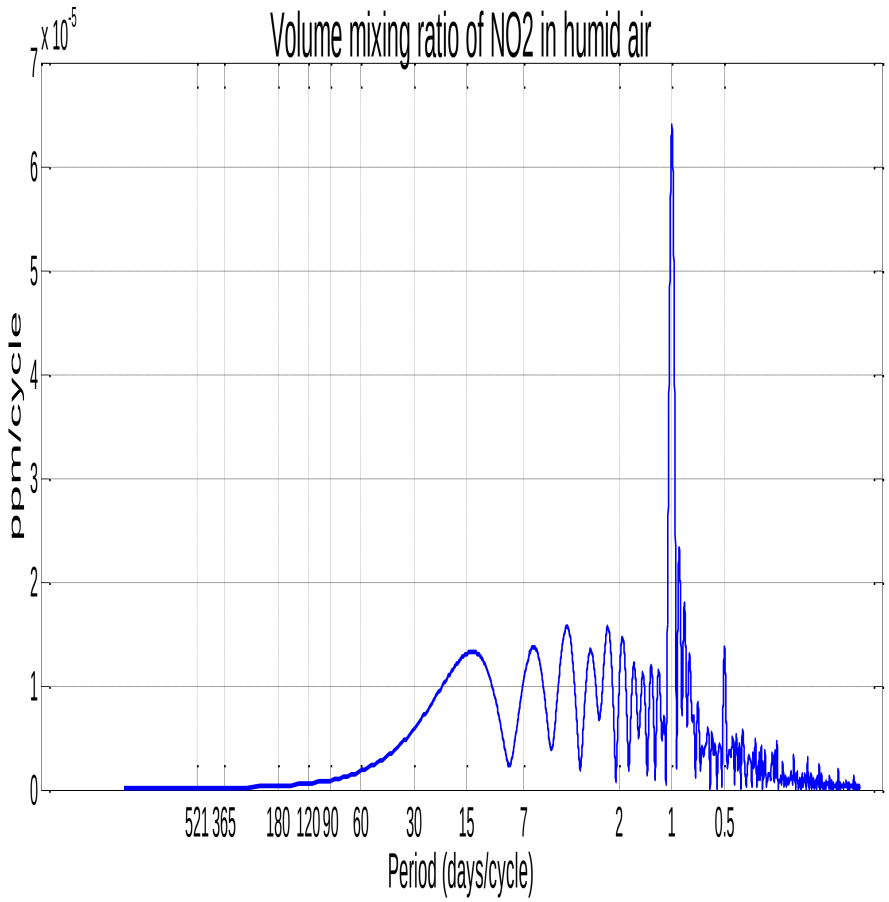
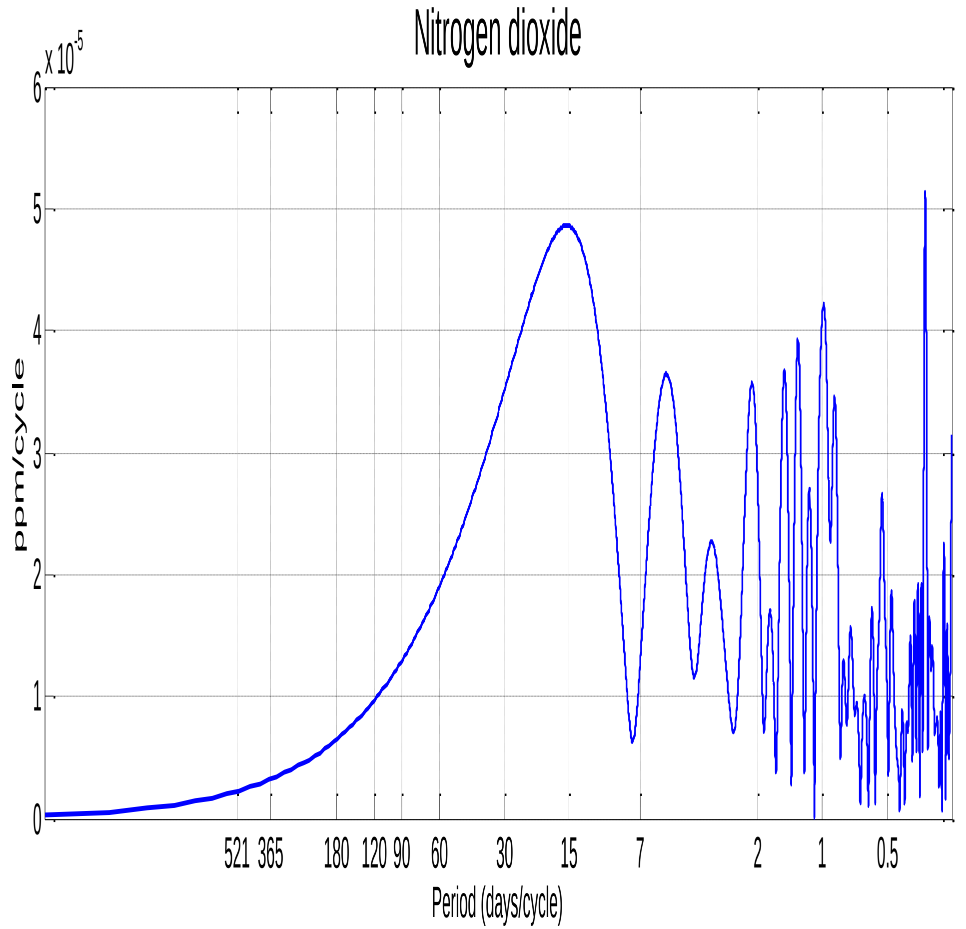
PRELIMINARY ANALYSIS (3/5)



Comparison of distribution between LOTOS-EUROS and MACC for O_3

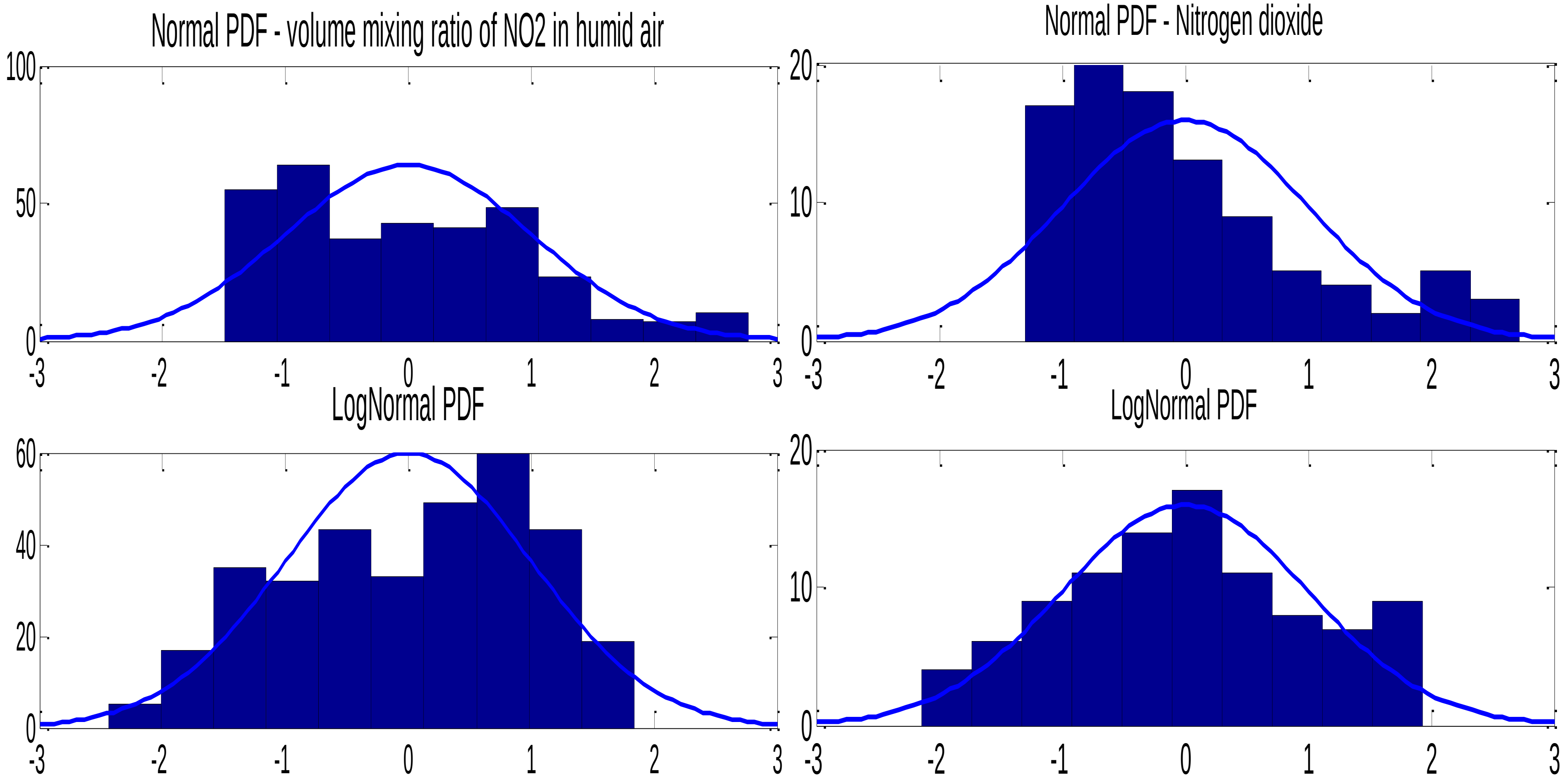
PRELIMINARY ANALYSIS (4/5)





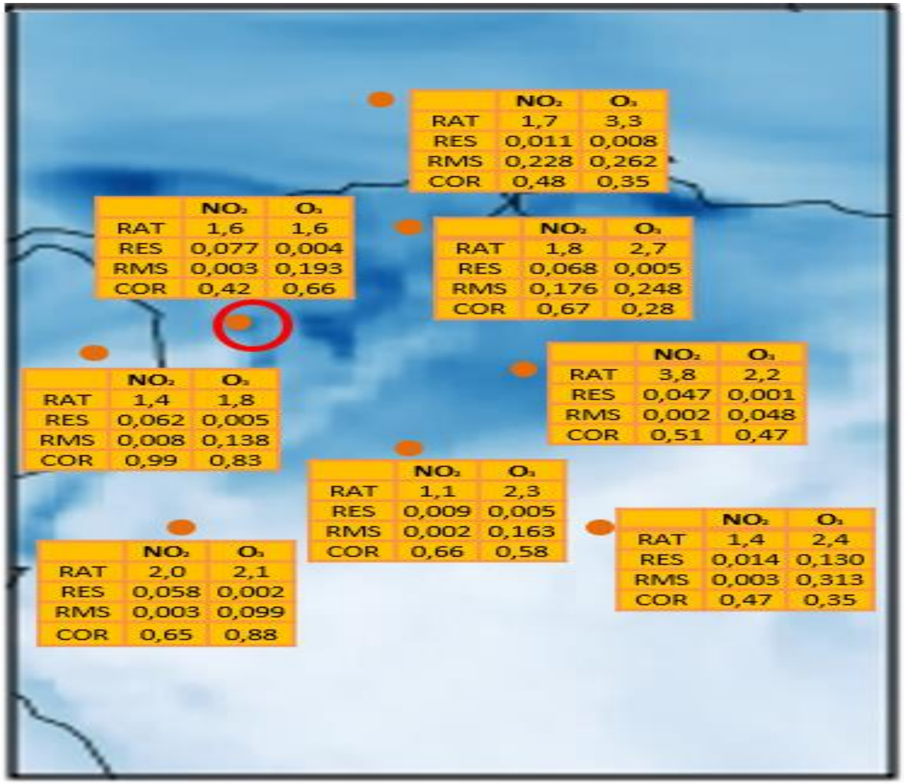
Comparison of frequency analysis between LOTOS-EUROS and MACC for NO_2

PRELIMINARY ANALYSIS (5/5)



Comparison of distribution between LOTOS-EUROS and MACC for NO_2

STATISTICAL MEASUREMENT



Distributions and statistical measures of the comparison points. The red circle is the Aburrá Valley (Medellín) location.

Statistical measures features for all the domain

Variable	NO_2	O_3
Ratio	1.8	2.1
Residual	0.003	0.005
rms	0.053	0.183
Corr. Coef	0.62	0.65

CHALLENGES

Units changes
We must continue testing the TNO solution and compare.

At current resolution

LOTOS-EUROS is not able to represent the dynamics in certain cities.

Zooming
With the best run of the model to provide boundary conditions.

Data Assimilation

Ensemble Kalman filter or Variational Methods.

Meteo data

WRF

Emissions

Not available

OPPORTUNITIES FOR THE TEAM

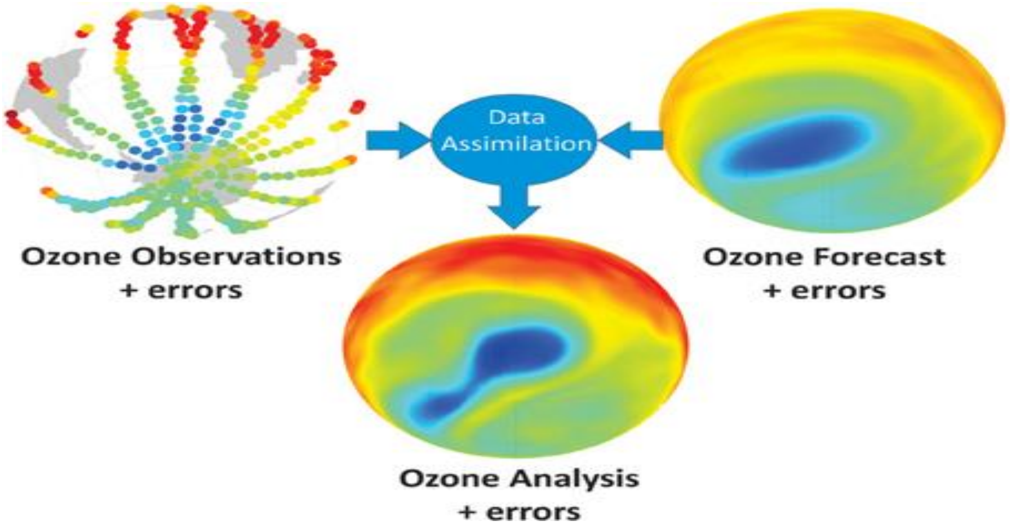
LOTOS-EUROS Coupling with a meteorological model like WRF. The WRF model is currently implemented in the region for the GIGA Research Group of the Universidad de Antioquia.

WRF is able to do a representation of the meteorology in a higher resolution than the databases available for the region.

Data Assimilation

DATA ASSIMILATION (1/2)

Data assimilation is a mathematical process that provides integration between measured values (observations) and a dynamical transport model, to improve the operation of the model.



Data Assimilation. Source: Data assimilation: making sense of Earth Observation, (Lahoz and Schneider, 2014)

DATA ASSIMILATION (2/2)

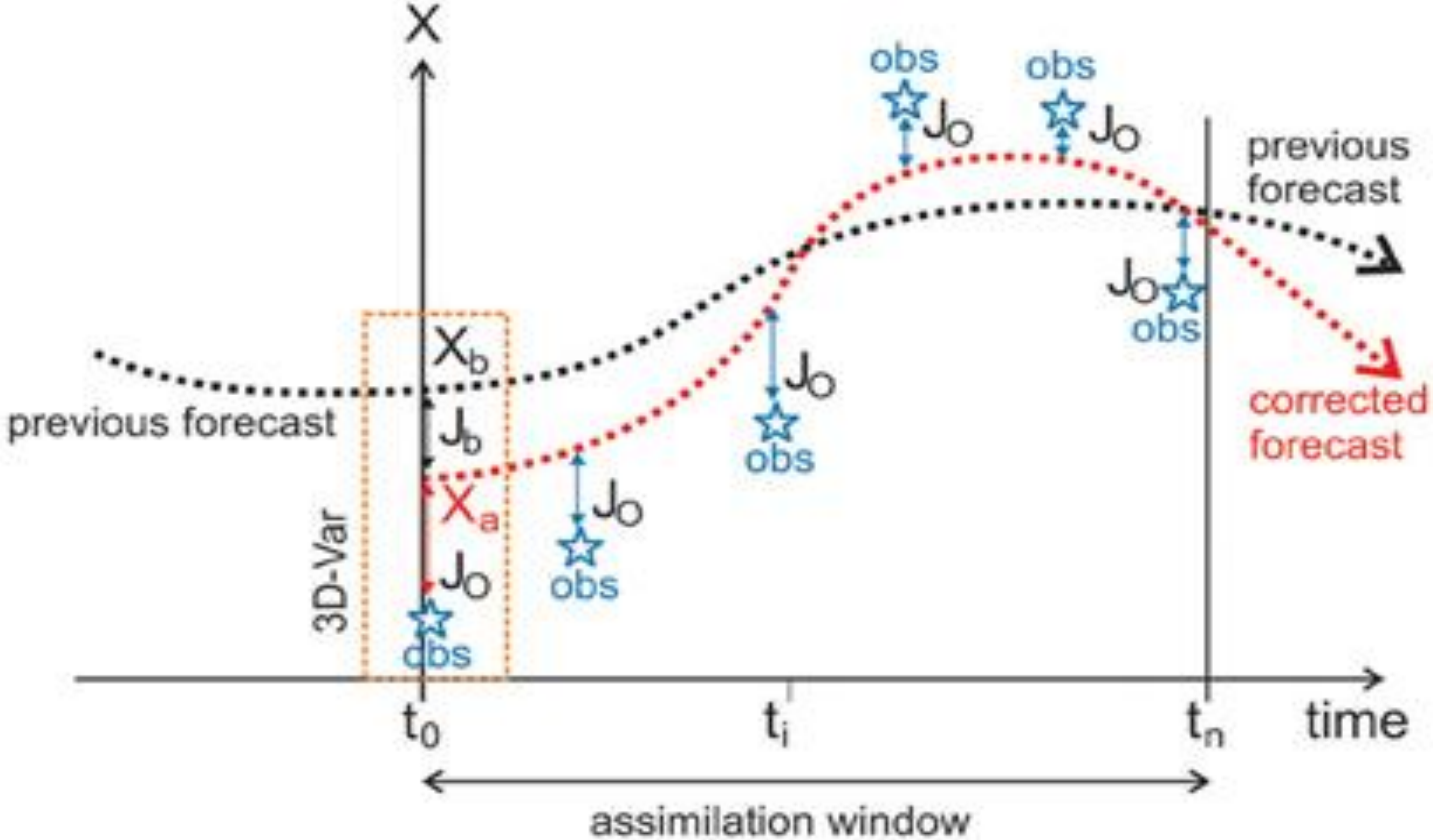
Filtering methods.

Sequential method that looks for improvements in the prediction of the model reducing the covariance error between observations and model outputs

Variational methods.

Looks for the optimal states set that minimize cost functions between observations made and model outputs

VARIATIONAL METHODS (1/2)



Variational Methods. Source: Data assimilation: making sense of Earth Observation, (Lahoz and Schneider, 2014)

VARIATIONAL METHODS (2/2)

- Consider the discrete model of a nonlinear dynamical system given by

$$X(t_{i+1}) = M_i\big(X(t_i), U(t_i)\big)$$
$$Y(t_i) = H\big(X(t_i)\big) + \eta(t_i)$$

- The method 4D-Var minimize the functional cost like shown next using the initial state value as decision variable

$$J(X_0) = \frac{1}{2}\left(X^b - X_0\right)^T B_o^{-1}\left(X^b - X_0\right) + \frac{1}{2}\sum_{i=0}^{N}\Big(Y(t_i) - H\big(X(t_i)\big)\Big)^T R_i^{-1}\Big(Y(t_i) - H\big(X(t_i)\big)\Big)$$

ENSEMBLE KALMAN FILTER

- The EnKF was designed to resolve two major problems related to the use of the Extended Kalman Filter (EKF) with nonlinear dynamics in large state spaces.

- The EnKF is a sequential filter method, it means that the model is integrated forward on time, and when a measurement is available, is used to reinitialize the model before the integration.

FUTURE WORKS

- One of the main objectives is to increase the Resolution LOTOS-EUROS to allow the representation of the pollutants dynamics in the Aburrá Valley

- To contribute to forecasting systems of Air Quality in Aburrá Valley using LOTOS-EUROS Model through Data Assimilation taking into account the need for more data provided by SIATA and other governmental agencies.

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THANKS!