3rd Klimapolis workshop – 21-24 May 2019
Instituto de Astronomia, Geofísica e Ciências Atmosféricas
Universidade de São Paulo
Session 4: Air quality modelling

Remote sensing data assimilation for the Metropolitan Area of São Paulo: current status and future plans

Anne Caroline Lange and Ediclê de Souza Fernandes Duarte

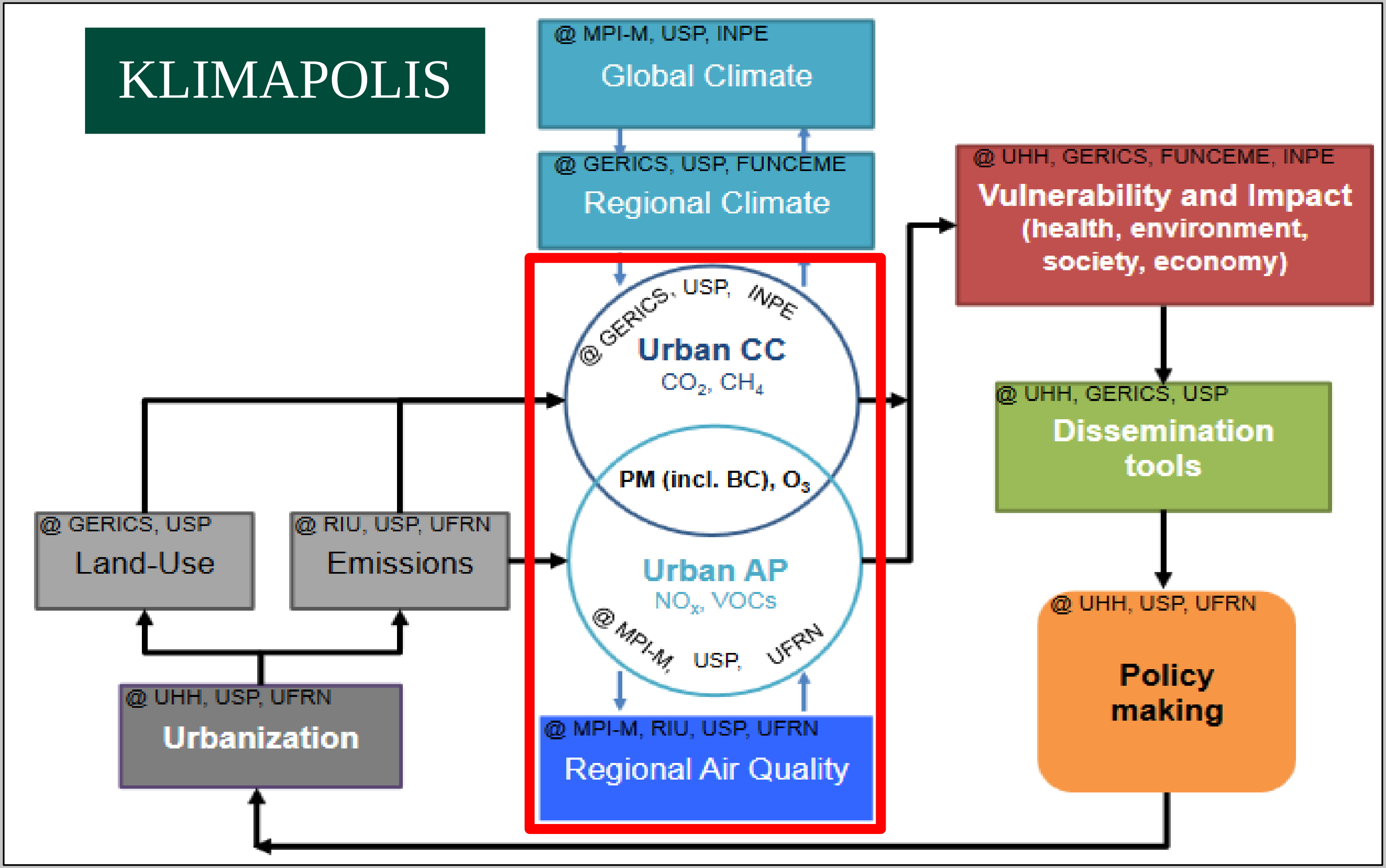
Judith Johanna Hoelzemann, Philipp Franke, Cláudio Claudio Moises Santos E Silva and Hendrik Elbern

Introduction

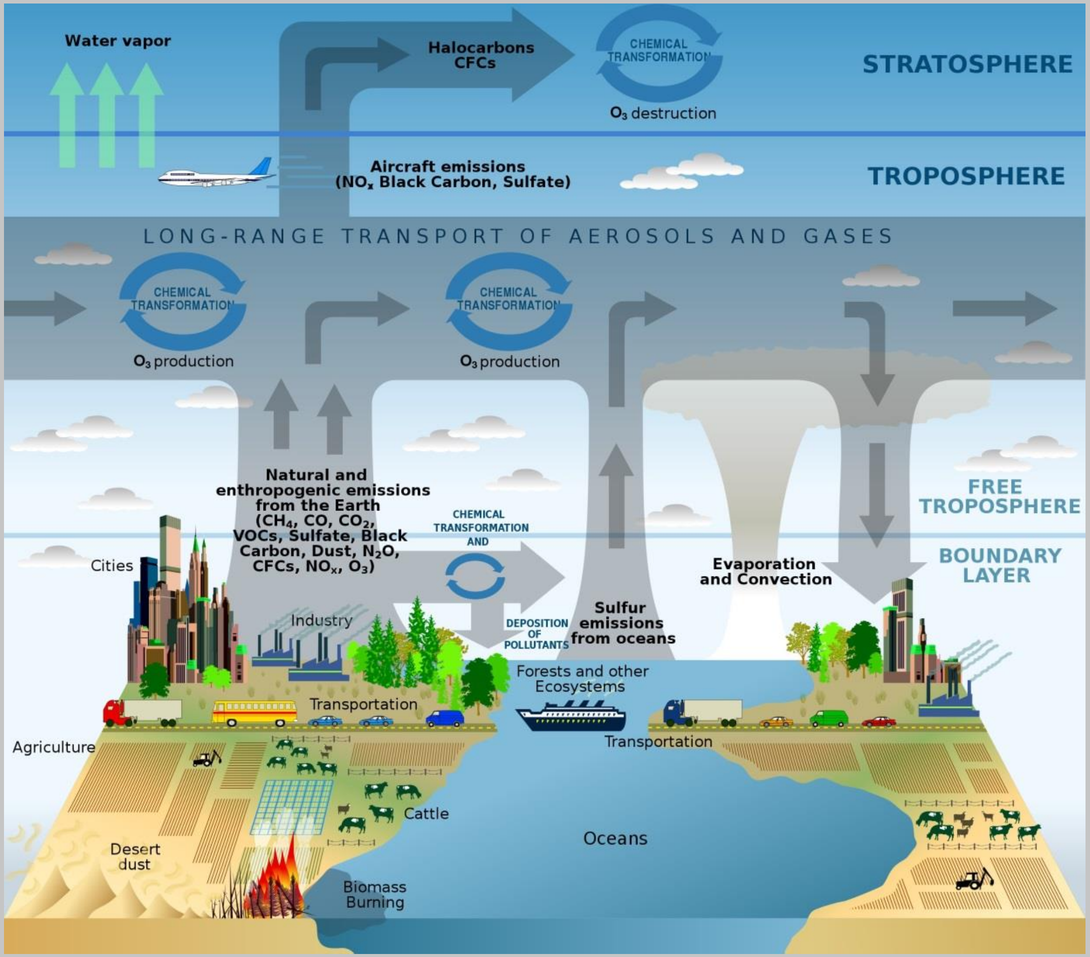
Atmospheric aerosols

85% of the Brazilian population lives in urban areas

urban air quality and climate change



Air Quality Modelling

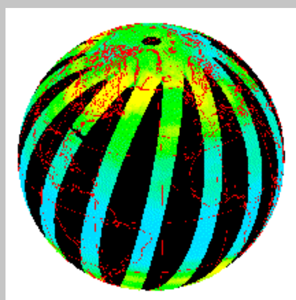


Strategic Plan for the U.S. Climate Change Science Program
Author Phillipe Rekacewicz, 2003

- Understanding of the atmospheric composition
- Sufficient representation of initial values and emission sources
- Analysis of emission strength for anthropogenic and biogenic emissions
- Estimation of forecast uncertainties

How can we receive the best knowledge about the atmospheric state?

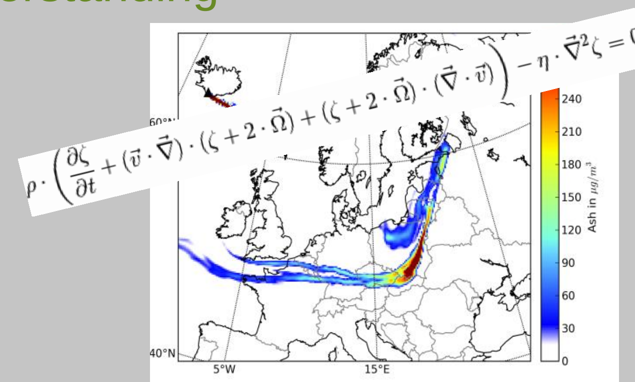
Our knowledge about the Earth system comes from
observations and understanding



Source: crista.uni-wuppertal.de

Source: https://www.earlinet.org

Observations with
uncertainties and biases



Theories and models based on
fundamental laws

Data assimilation provides the best knowledge of the state of the atmosphere by combining model information with available measurements

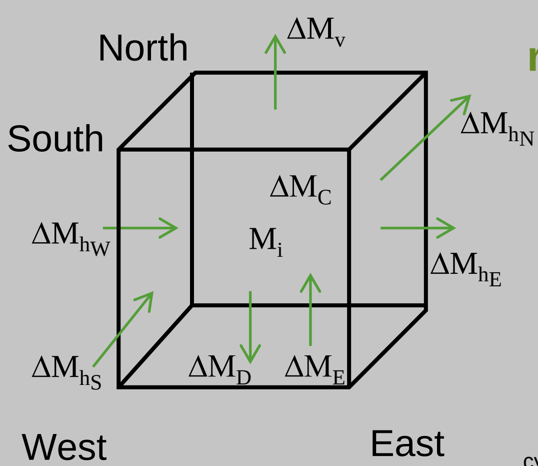
ADVANTAGES

Intelligent interpolation of observations, propagation of information from data-rich regions to data poor regions, quality control of data, provision of statistical information, information on unobserved species, provision of quantitative evaluation of impact of observations

Chemical data assimilation

Atmospheric Chemistry modelling as *initial and boundary value problem*

Well mixed model cell

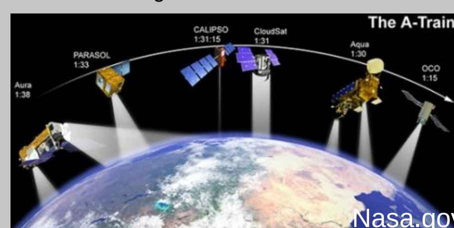


M	species mixing ratio
i	initial
h	horizontal transport
v	vertical transport
E	emissions
D	surface deposition
C	chemical transformations

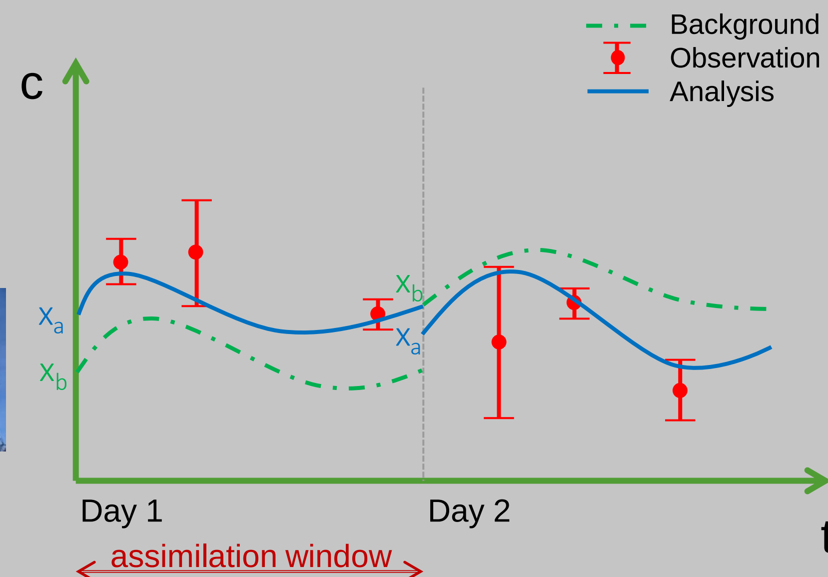
Use of observation to receive more information

cyprusremotesensing.com

Leipzig.de



Time series of species mixing ratio



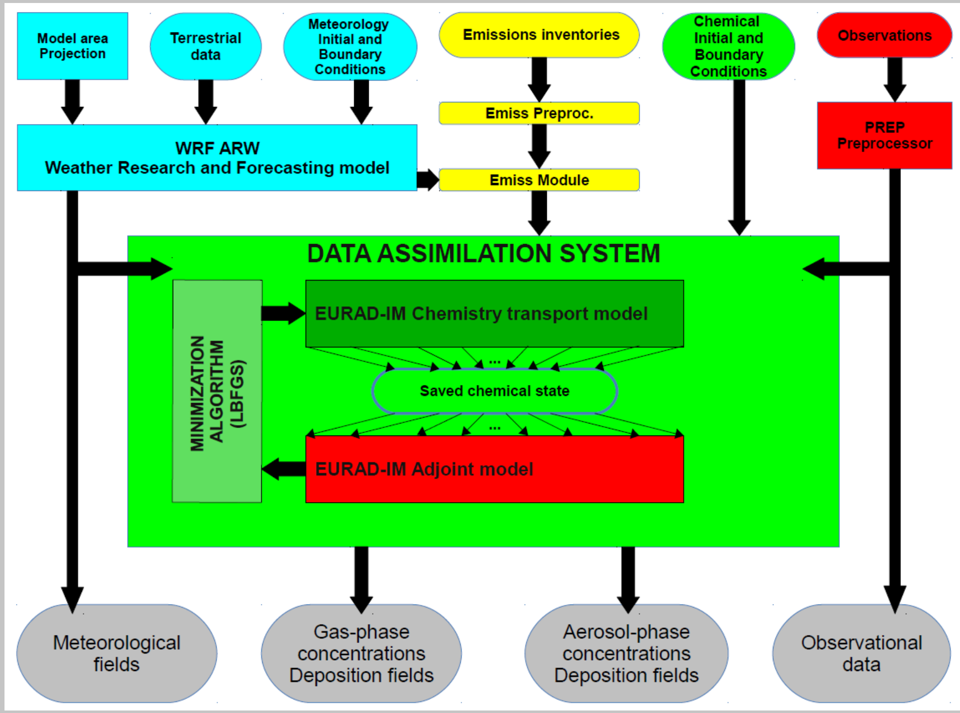
4-dimensional variational data assimilation

$$J(\mathbf{x}_0,\mathbf{e}) = \frac{1}{2}\left((\mathbf{x}_0-\mathbf{x}_b)^T\mathbf{B}^{-1}(\mathbf{x}_0-\mathbf{x}_b) + \sum_{i=0}^{n}\left((\mathbf{y}_i-\mathbf{H}[\mathbf{M}_i(\mathbf{x}_0)])^T\mathbf{R}_i^{-1}(\mathbf{y}_i-\mathbf{H}[\mathbf{M}_i(\mathbf{x}_0)])\right) + (\mathbf{e}-\mathbf{e}_b)^T\mathbf{K}^{-1}(\mathbf{e}-\mathbf{e}_b)\right)$$

EURopean Air pollution Dispersion – Inverse Model

Simulations of chemical reactions, advection, diffusion and other parameterized and simulated processes

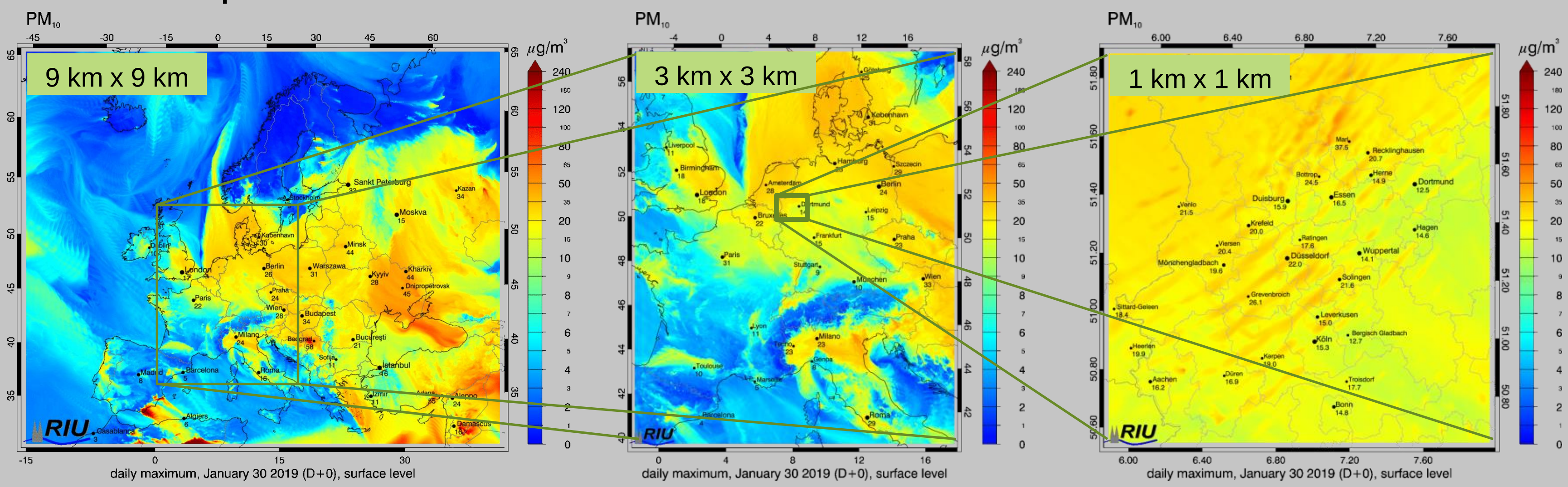
- Chemistry mechanisms
  ~ 100 gas phase constituents
- Aqueous phase chemistry
- Aerosols
  inorganic, secondary organic, mineral dust, sea salt, biomass burning, volcanic emissions



EURAD–IM Nesting

Copernicus Atmospheric Monitoring Service CAMS

→ operational forecast on different domains

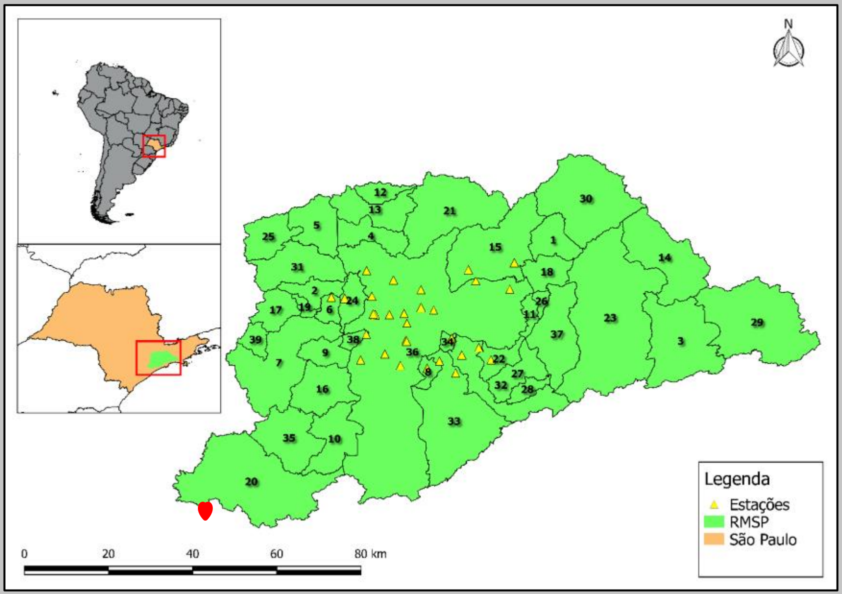


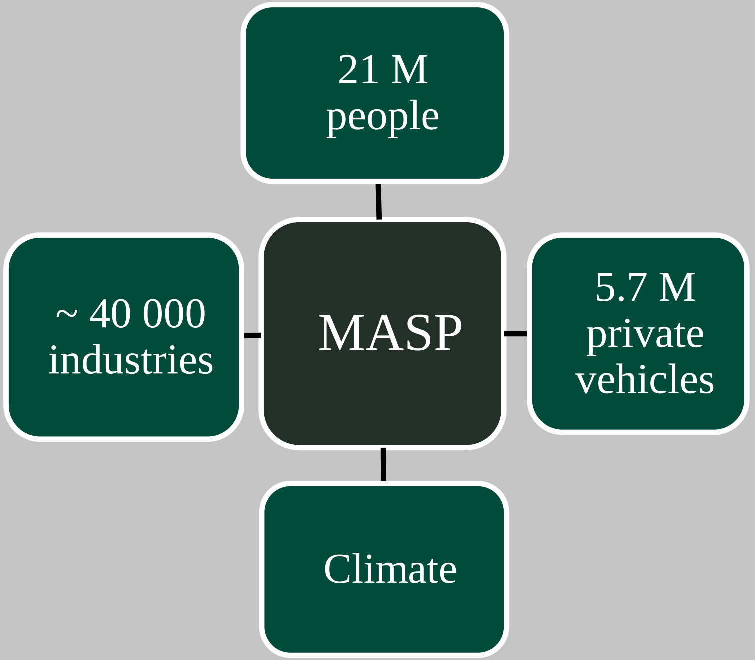
- Meteorological Data and chemical initial and boundary values: ECMWF-IFS
- Emission inventory: TNO emissions for Europe
- Observational data: various data from European networks and satellites

Details will be presented by Hendrik Elbern

Atmosphere Monitoring Service

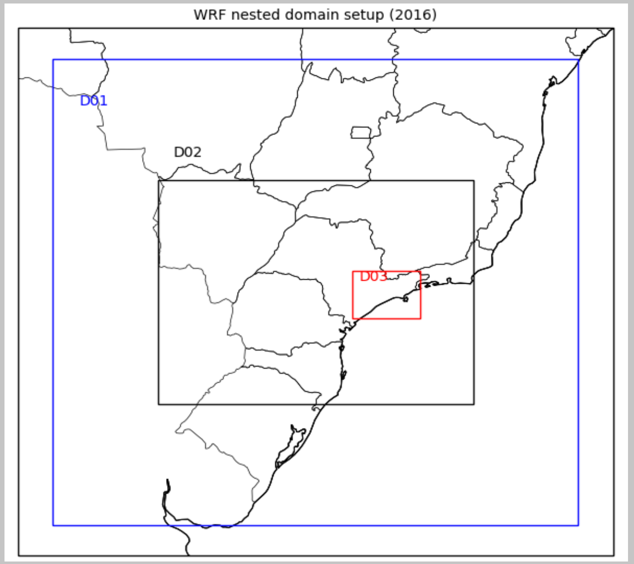
1st area of interest: Metropolitan Area of São Paulo



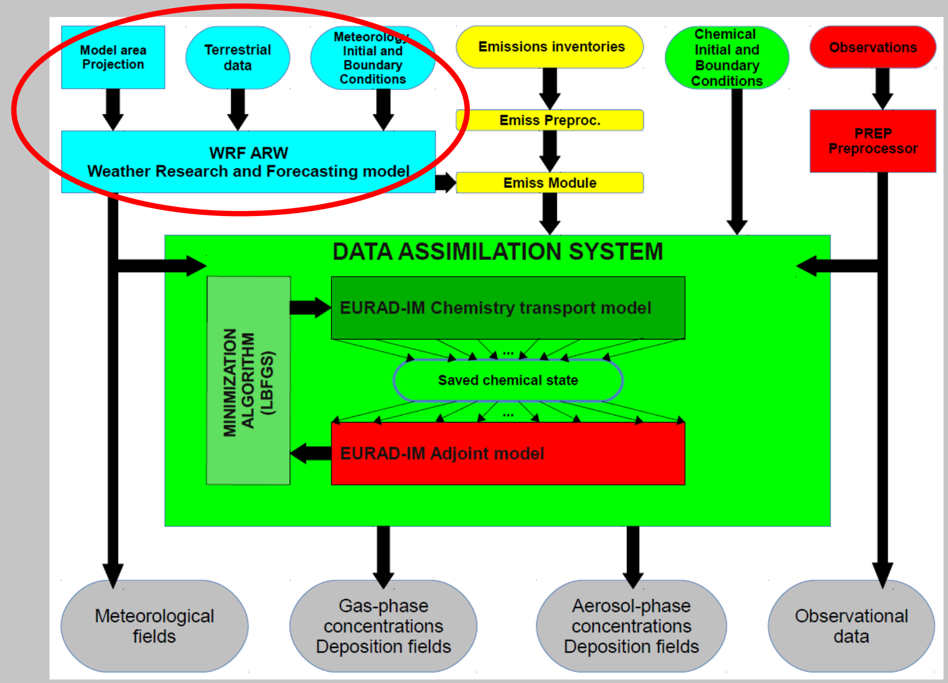


Setup of new model domains for MASP

DomID=1,2,3 ParentID=1,1,2
DOMNAM=D01,D02,D03 DOMAIN= 25Km, 5Km, 1Km
IGRIDM=110,326,351 JGRIDM=101,241,251
TIME-STEP=150,30,6
CENTER-LAT=-23.55 CENTER-LON=-50.0
VERTICAL LEVEL =35 PTOP=10000



Meteorological input



Meteorological driver: Weather Research and Forecasting model WRF

Meteorological data provider: Global Forecasting System GFS

Data type: analyses

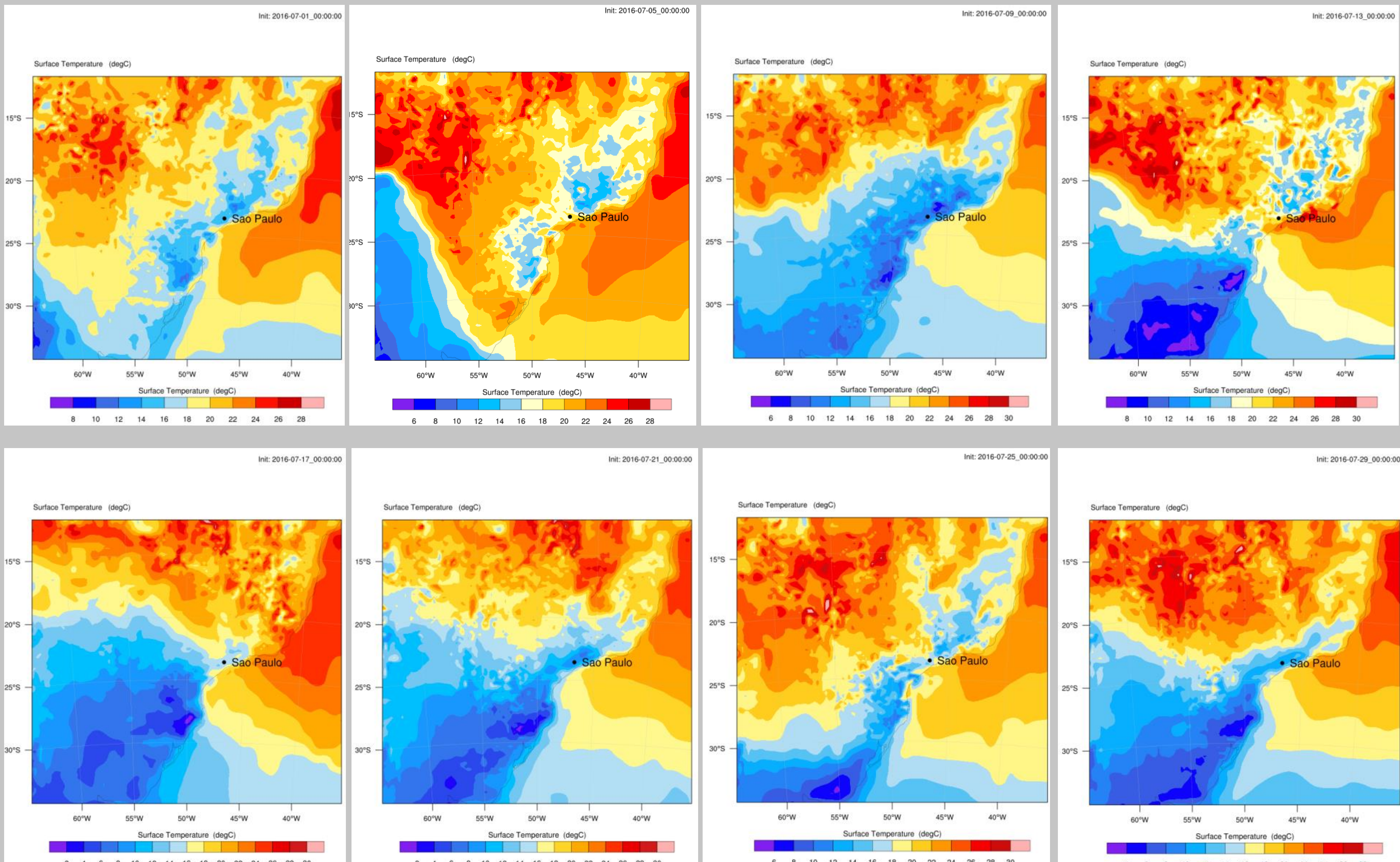
1st case study: analyses of July and October 2016

Due to available:

- computer resources
- observational data
- dry season of winter
- aerosol transport from center of Brasil and the Amazon

1st results on meteorological modelling I

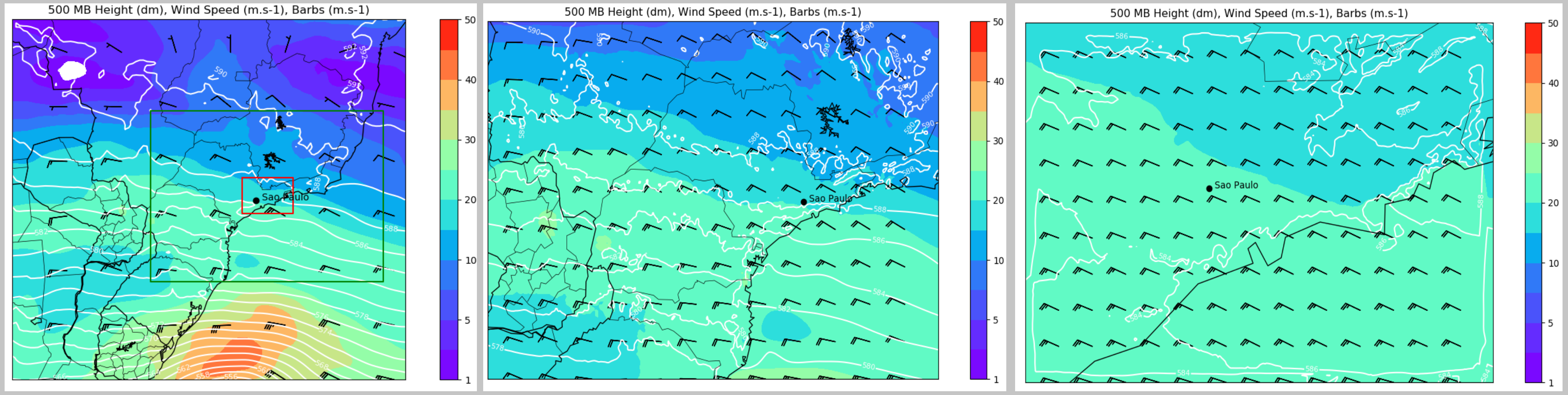
Surface temperature in July 2016



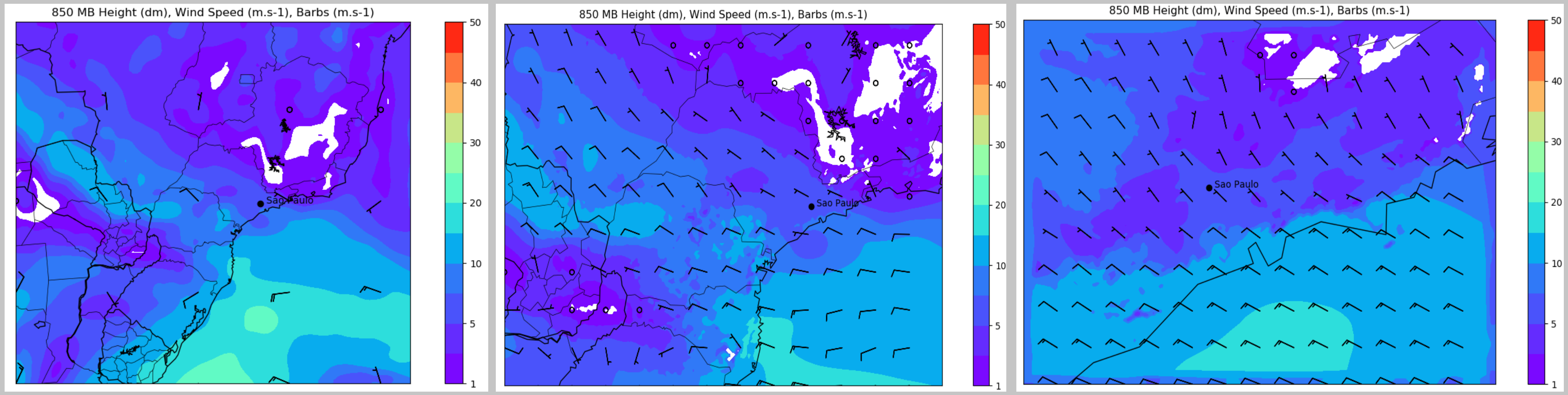
1st results on meteorological modelling II

Geopotential height and wind on 13 July 2016

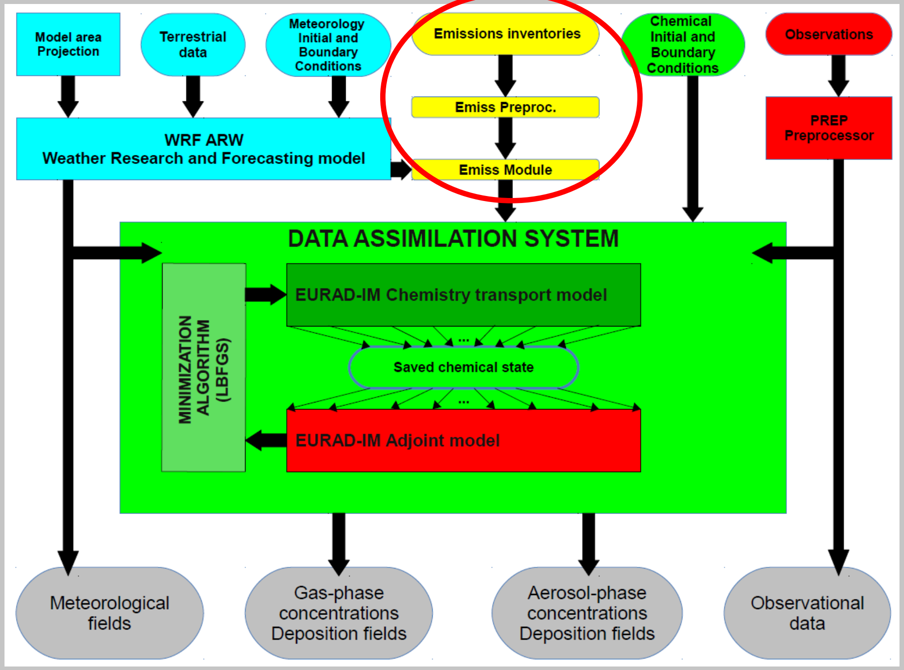
500 hPa



850 hPa



Emission data



Global inventory: EDGAR (Emission Database for Global Atmospheric Research)

Global wildfire emissions: GFAS (Global Fire Assimilation System)

- Fire radiative power observations from satellite based sensors
- Daily estimates of biomass burning emissions

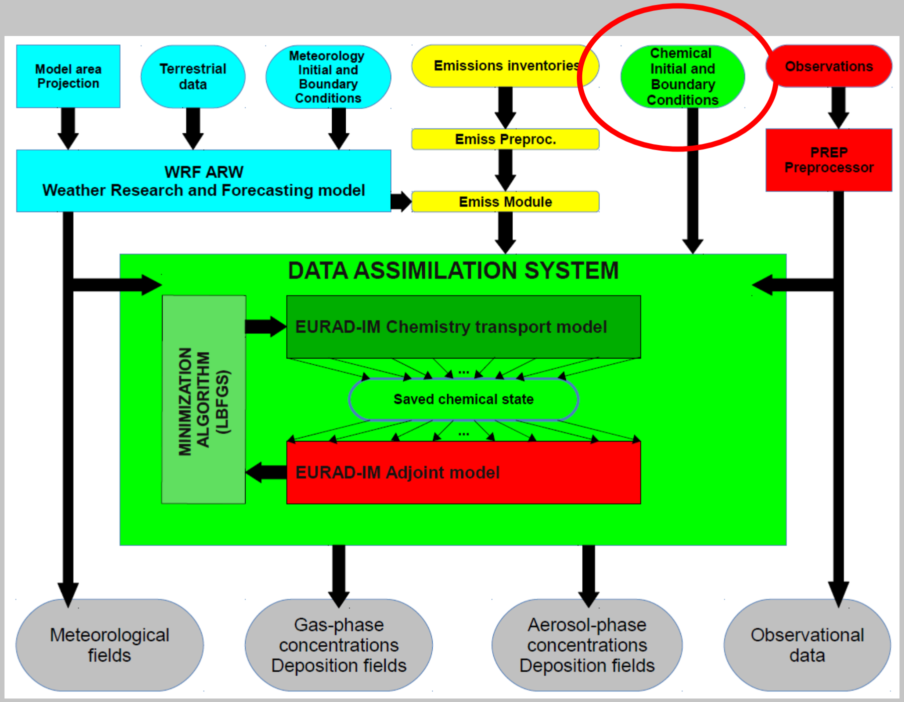
VEIN Emissions: vehicular emission inventory

Aggregation of emission data with land use data using arcGIS

Initial and boundary values

Extracted from the CAMS analysis

- Coarse resolution is not detailed enough for regional modelling

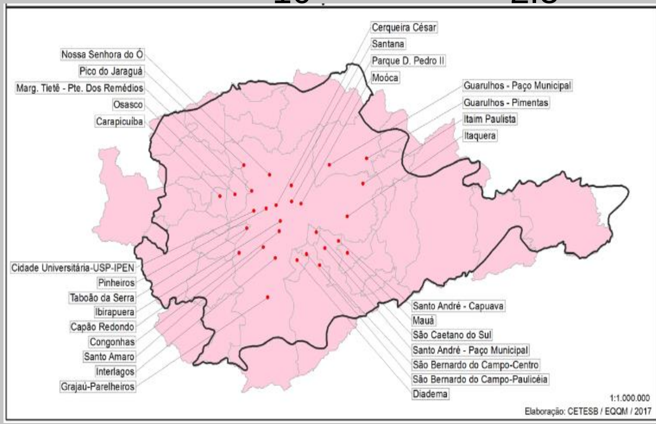


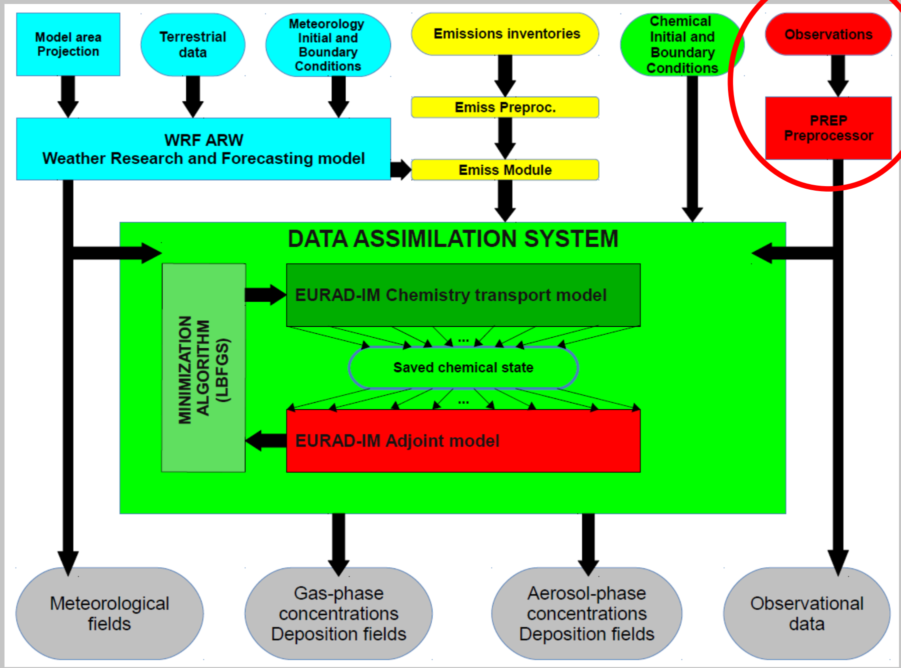
With data assimilation, initial value and emission factor optimization will be performed and the analyses will be evaluated.

Observational data

CETESB observations:

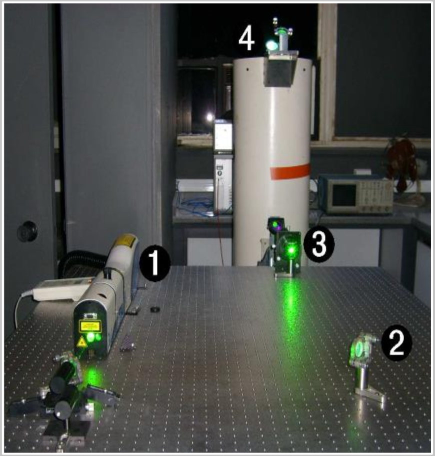
PM_{10} and $PM_{2.5}$





Lalinet Lidar observations:

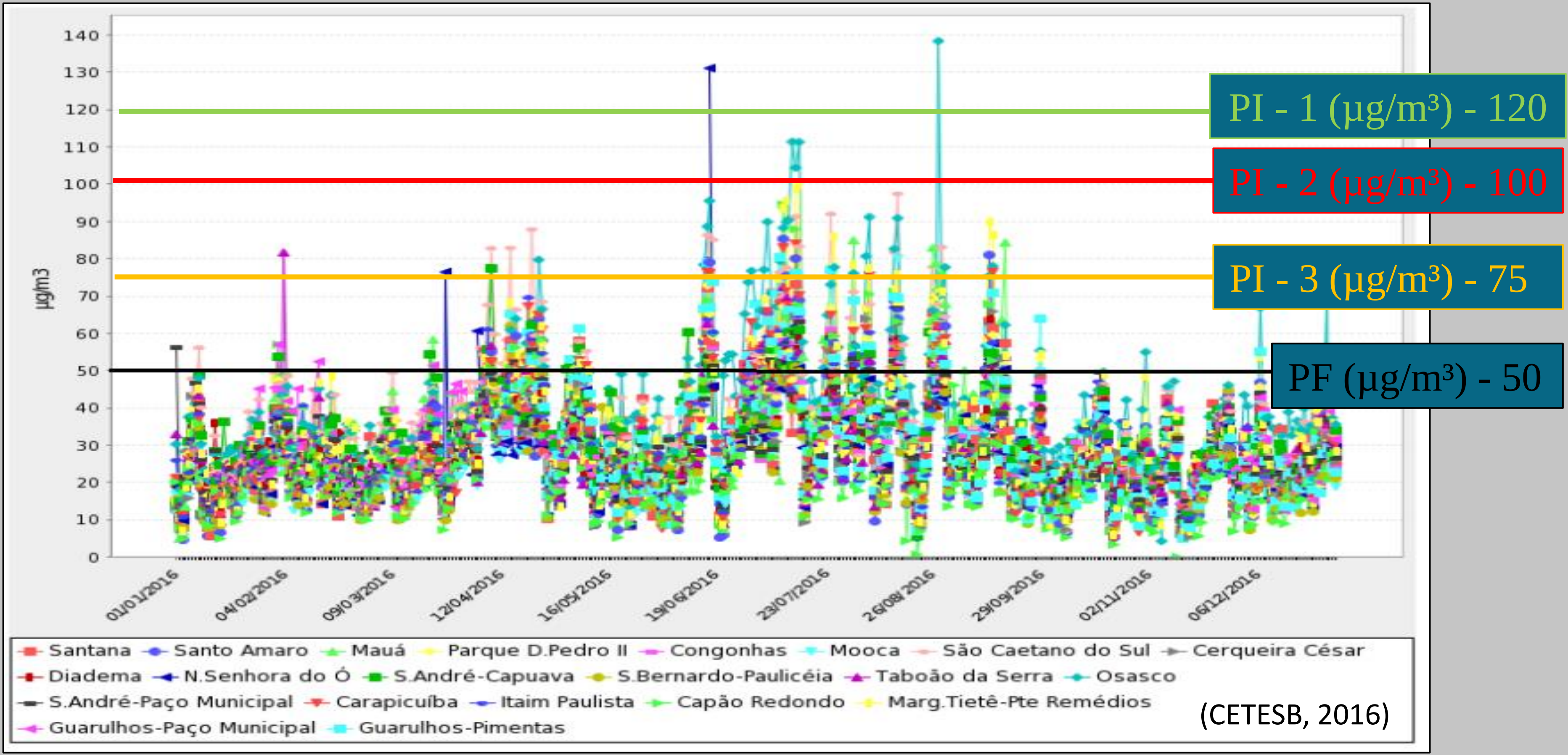
backscatter and extinction coefficients



Aeronet observations:

AOD - aerosol optical depth

CETESB data – PM_{10}

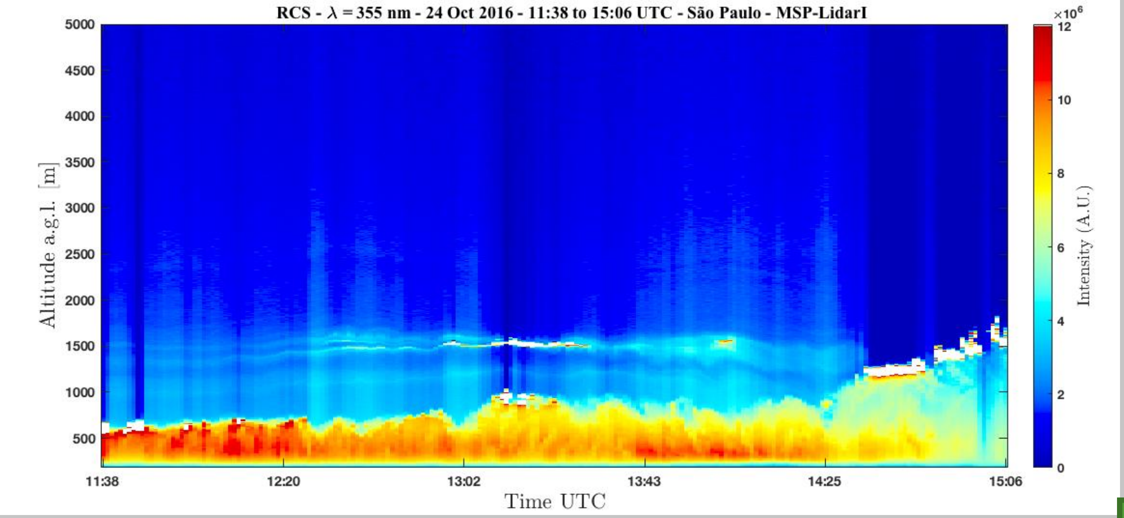


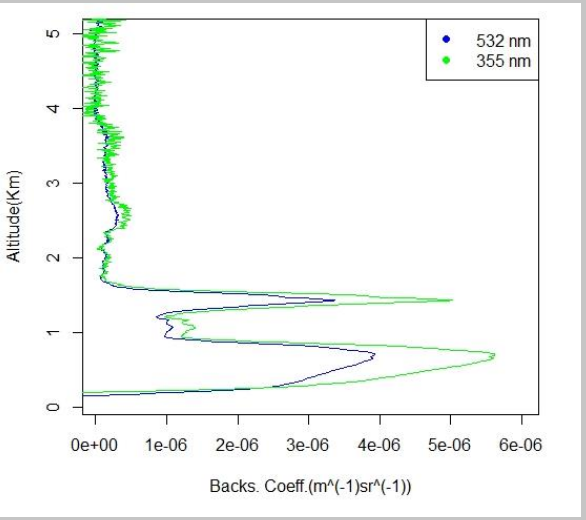
(CETESB, 2016)

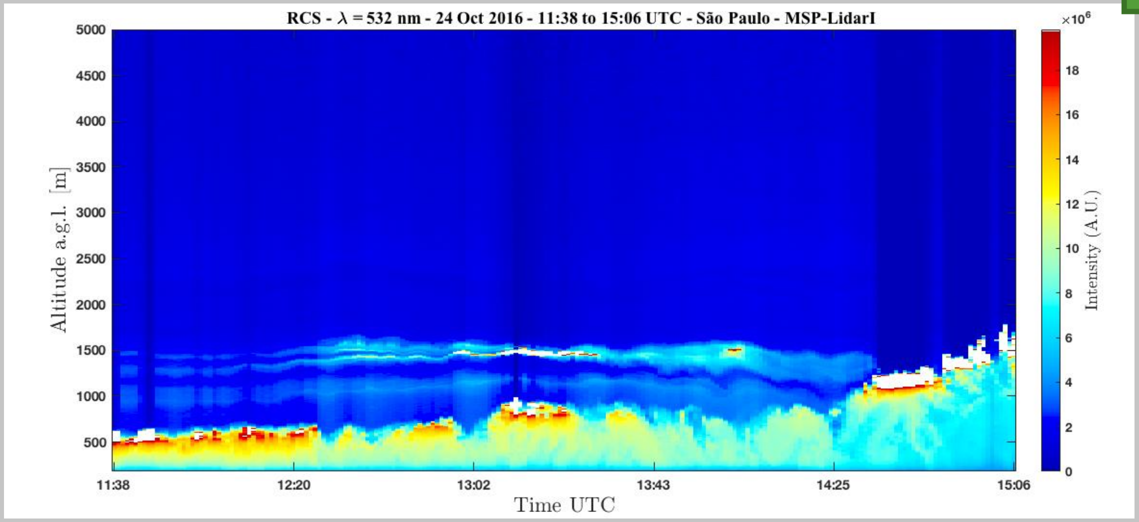
- significant seasonal variations of PM_{10} concentrations
- High PM_{10} concentrations occur in the period from May to September for all stations in the MASP

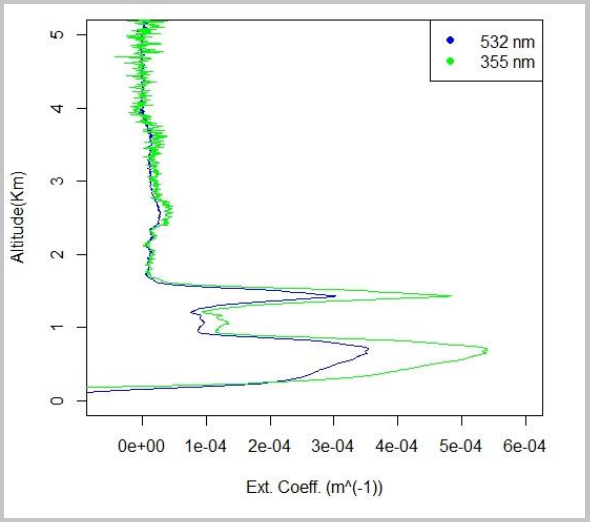
Sao Paulo Lidar data

24/10/2016







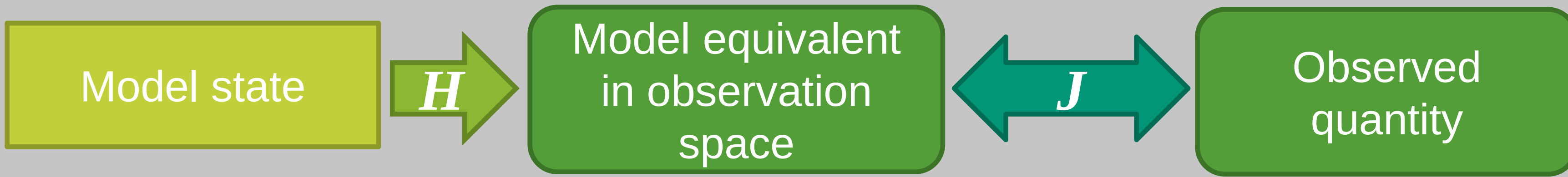


Assimilation of observational data

$$J(\mathbf{x_0},\mathbf{e}) = \frac{1}{2}\left((\mathbf{x_0}-\mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x_0}-\mathbf{x}_b) + \sum_{i=0}^{n}\left((\mathbf{y}_i - \mathbf{H}[\mathbf{M}_i(\mathbf{x}_0)])^T \mathbf{R}_i^{-1}(\mathbf{y}_i - \mathbf{H}[\mathbf{M}_i(\mathbf{x}_0)]) \right) + (\mathbf{e}-\mathbf{e}_b)^T \mathbf{K}^{-1}(\mathbf{e}-\mathbf{e}_b) \right)$$

The observation operator

- provides the link to allow the comparison of model state and observation



- maps the model state from model space into the observation space
- has to be individually developed for each observation type
- can be a “simple” interpolation in space and/or time
- can include complex conversion algorithms as radiative transfer models

Outlook

- Good emissions are decisive for successful air quality simulations
  → Aspired closer collaboration with the group of Ma. Fatima Andrade (IAG/USP)

- Operation of EURAD-IM for
  → Sao Paulo Metropolitan Area
  → North-East Brazil

- Applying Copernicus Atmosphere data repository for
  → Boundary data from global modelling (meteo data and constituents)
  → Environmental satellite data

- First inter-comparison study of air quality in MASP for July and October 2016 with
  → Group of Ma. Fatima Andrade (IAG/USP) – WRF-Chem
  → Group of Taciana Toledo (UFMG) – CMAQ

Thanks!

Contact:

Anne Caroline Lange (RIU, Cologne) - al@eurad.uni-koeln.de

Ediclê de Souza Fernandes Duarte (UFRN, Natal) - edicless@yahoo.com.br