Inverse modeling of greenhouse gas and aerosol precursor emissions using satellite measurements

Status and future perspectives

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Outline

- Brief introduction to inverse modeling
- Current status: CO_2
- Future perspectives: CO_2
- Application to aerosol precursors

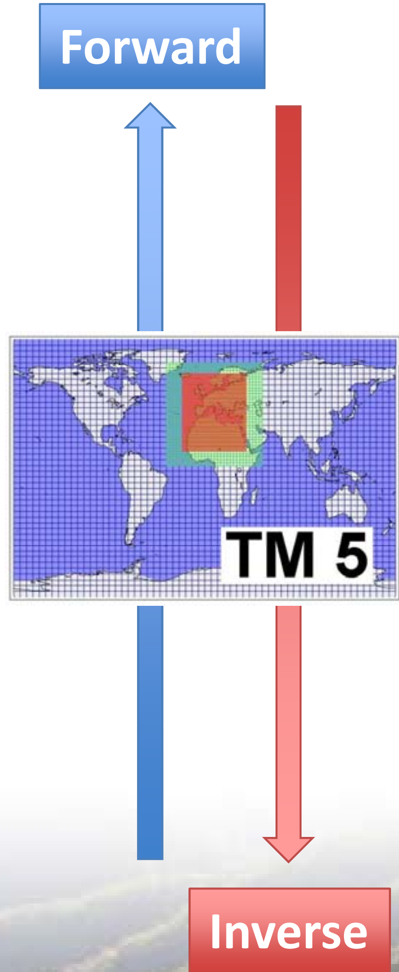
Inverse modelling: Principle

Obs:

Cabauw tower

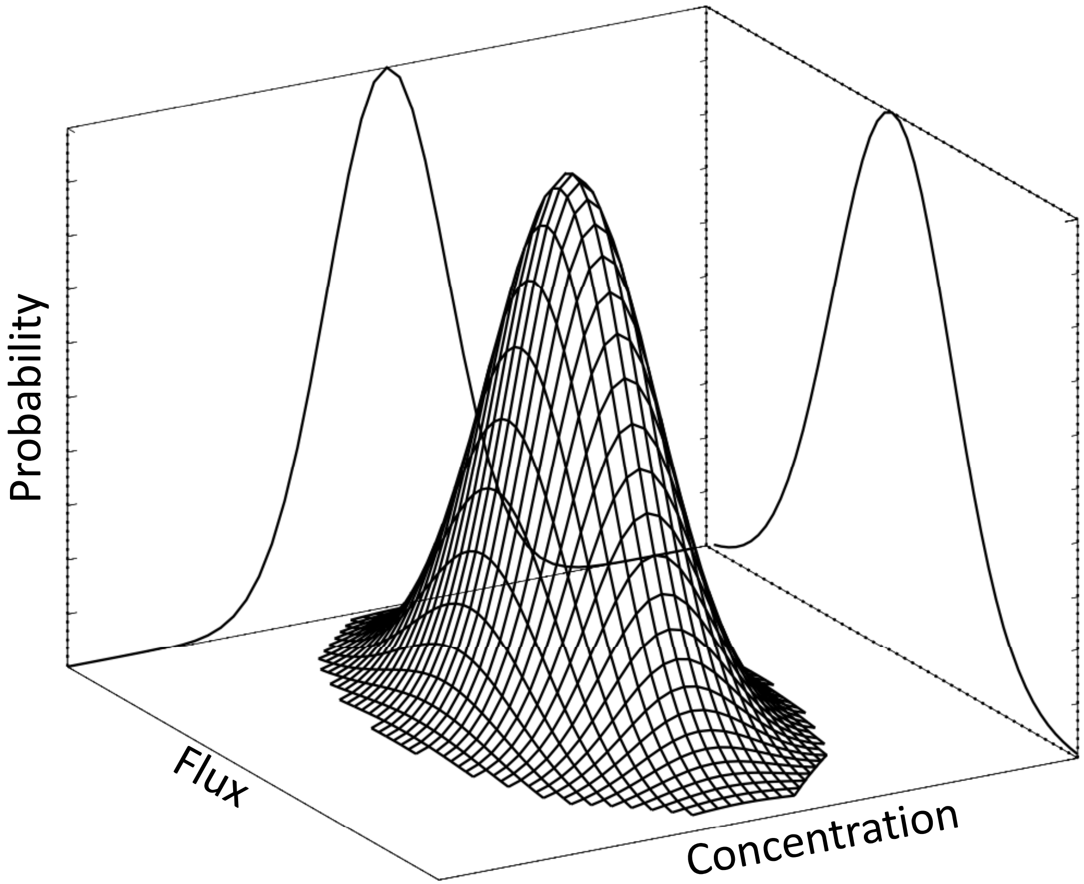
Geophysica

GOSAT

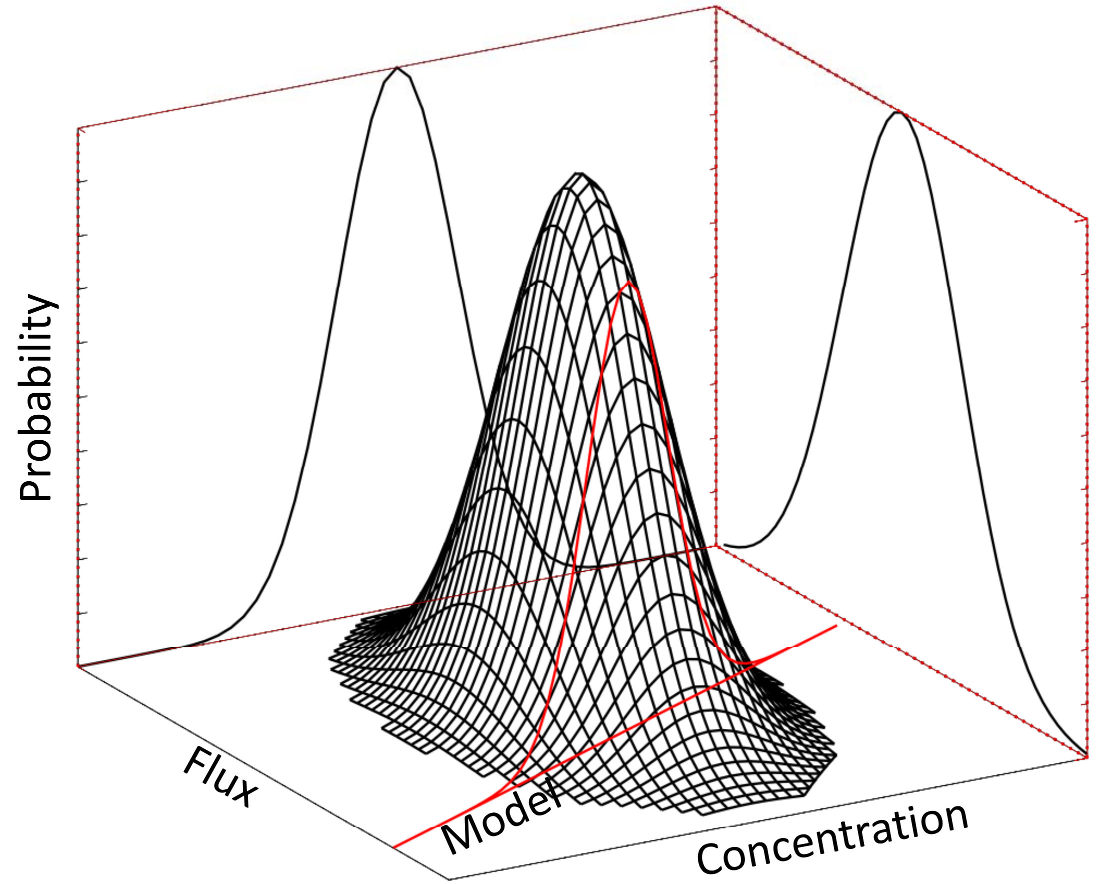


Flux:

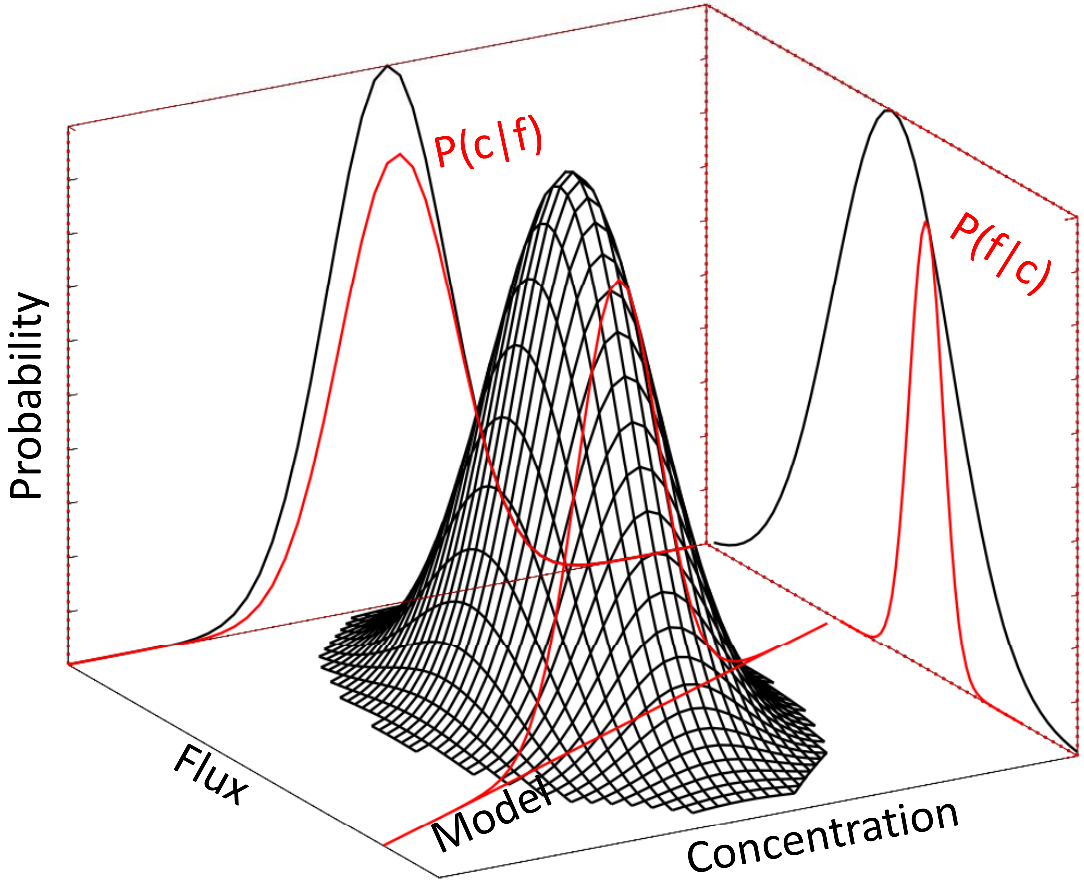
Optimization problem: A priori



Optimization problem: + Model

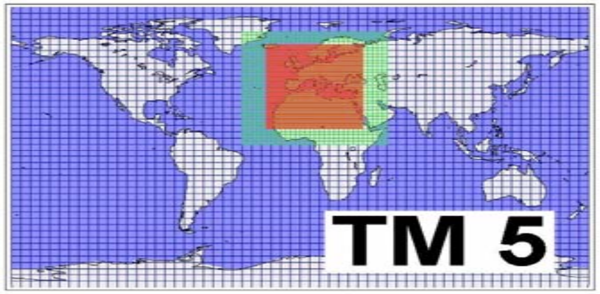


Optimization problem: Posterior

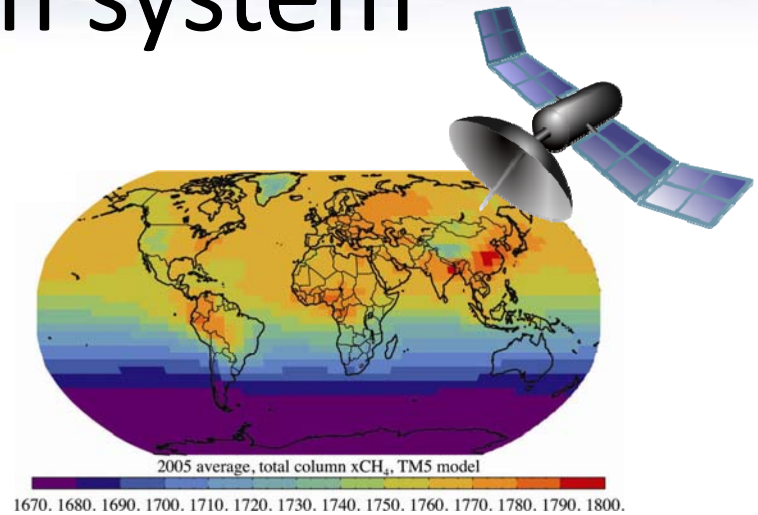


$$S(f) = \frac{1}{2}((c_{obs} - M(f))^t C_c^{-1}(c_{obs} - M(f)) + (f - f_{pri})^t C_f^{-1}(f - f_{pri}))$$

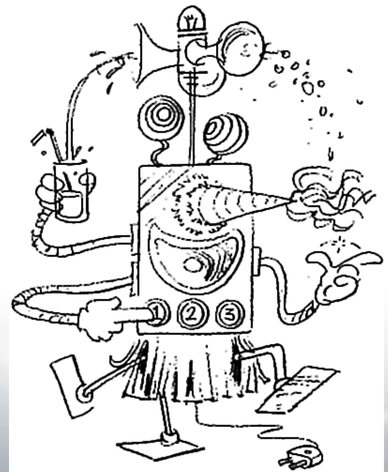
Data assimilation system



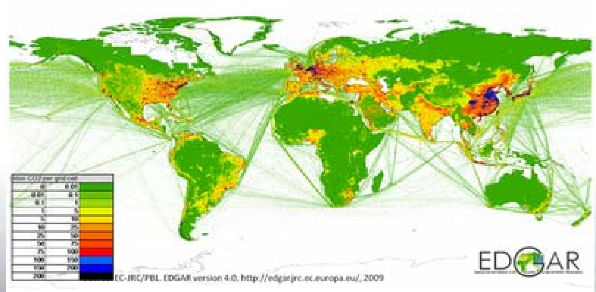
Transport model



Model ⇔ measurements

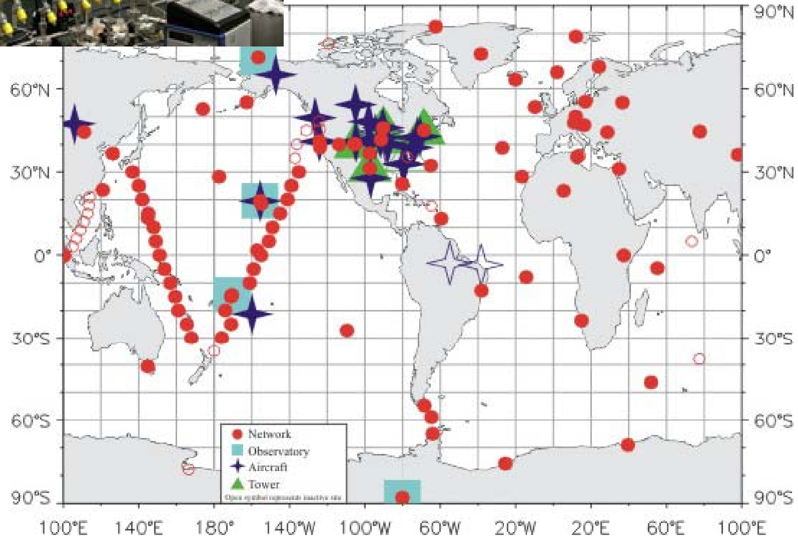


Optimization algorithm

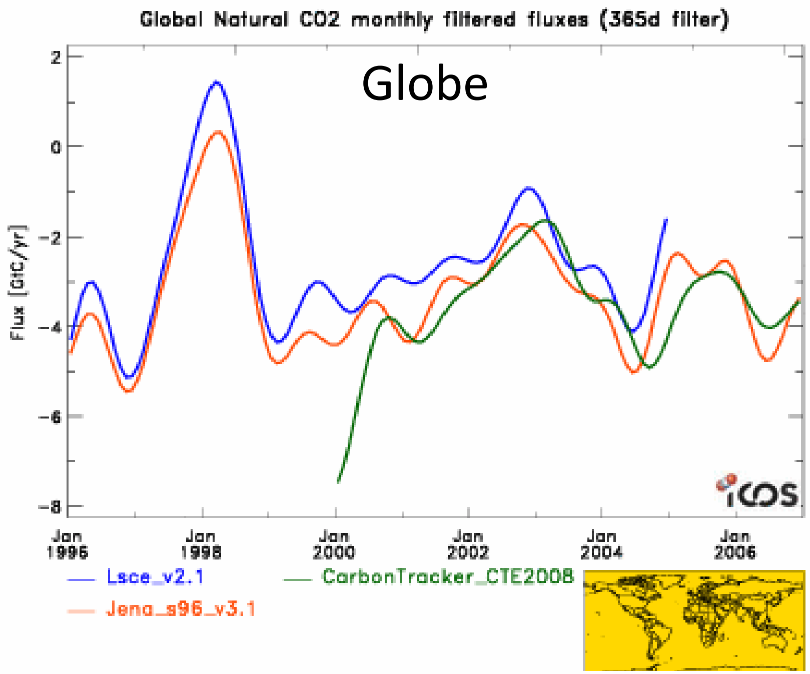


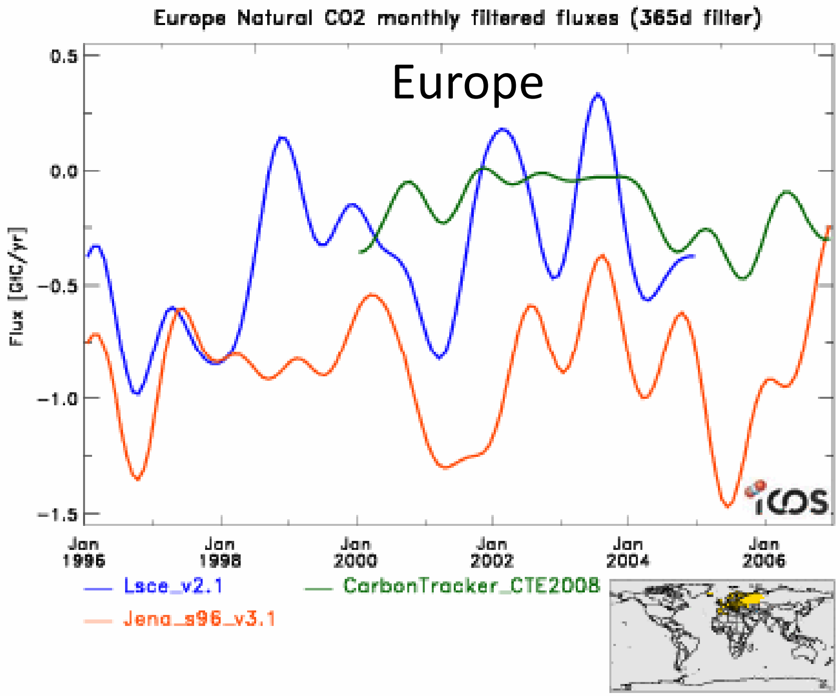
Emissions

CO_2 inversion: Flask data



NOAA ESRL flask sampling network

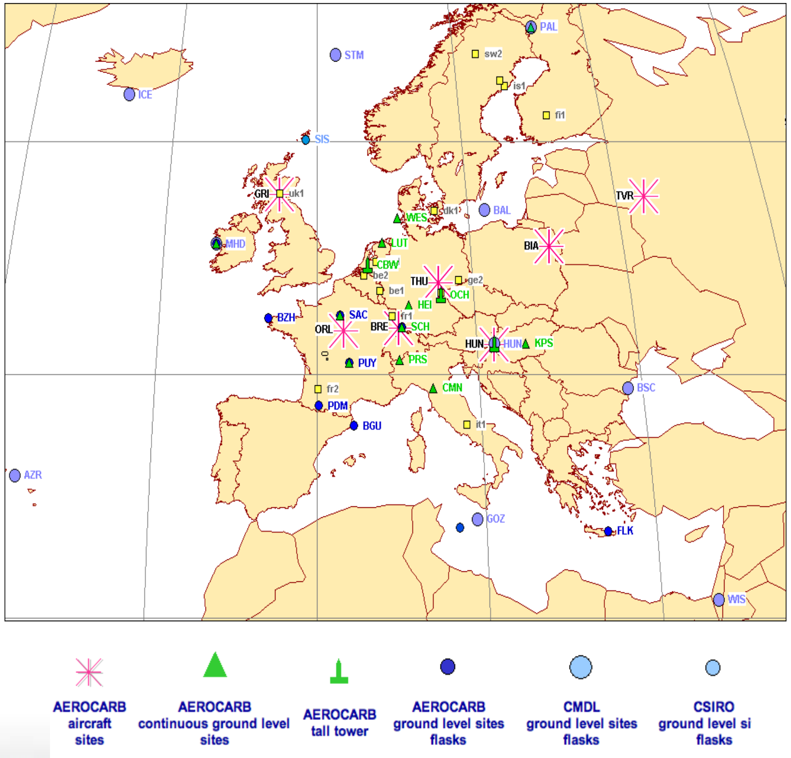




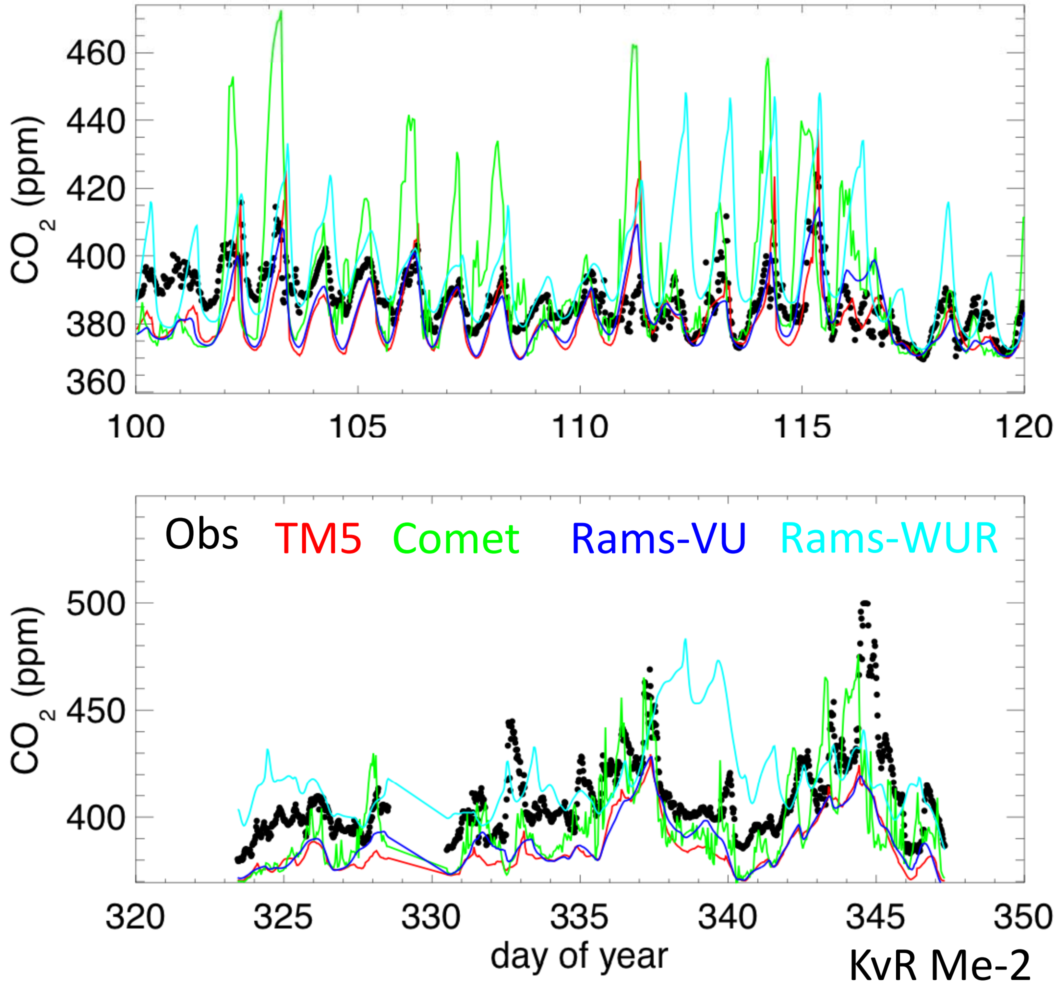
http://www.carboscope.eu

Solution 1: Dense regional networks

European GHG measurement network



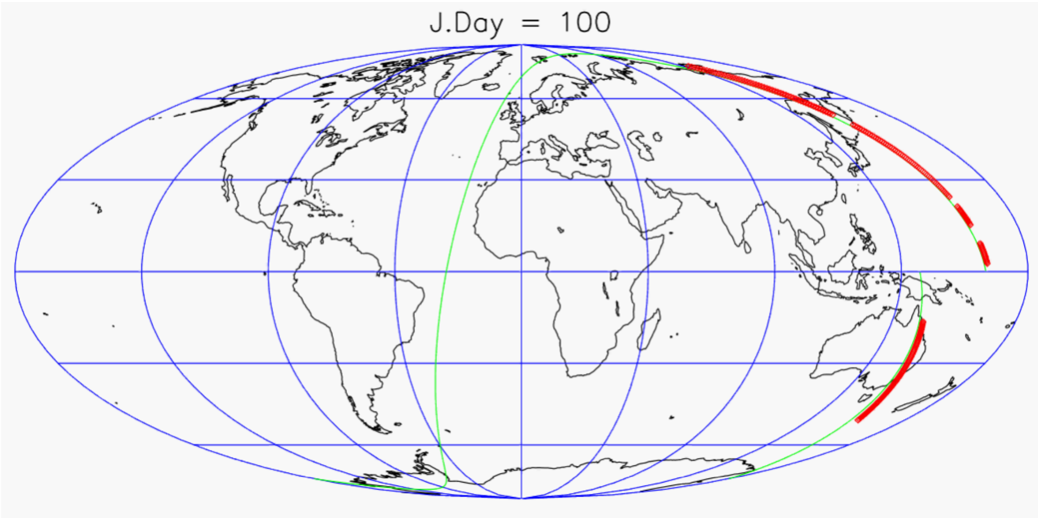
Cabauw tower 120m, NL



Peters et al. (GCB, 2010): NEE for Europe, 2001-2007 = - 165 ± 450 Tg C yr^{-1}

Solution 2: satellites

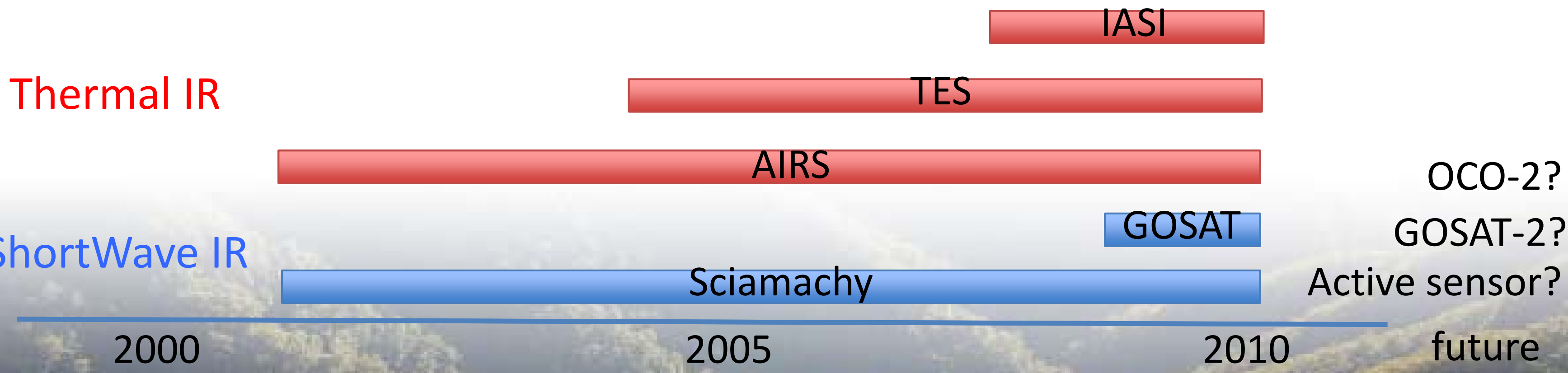
Courtesy F-M Breon



Advantage: data coverage

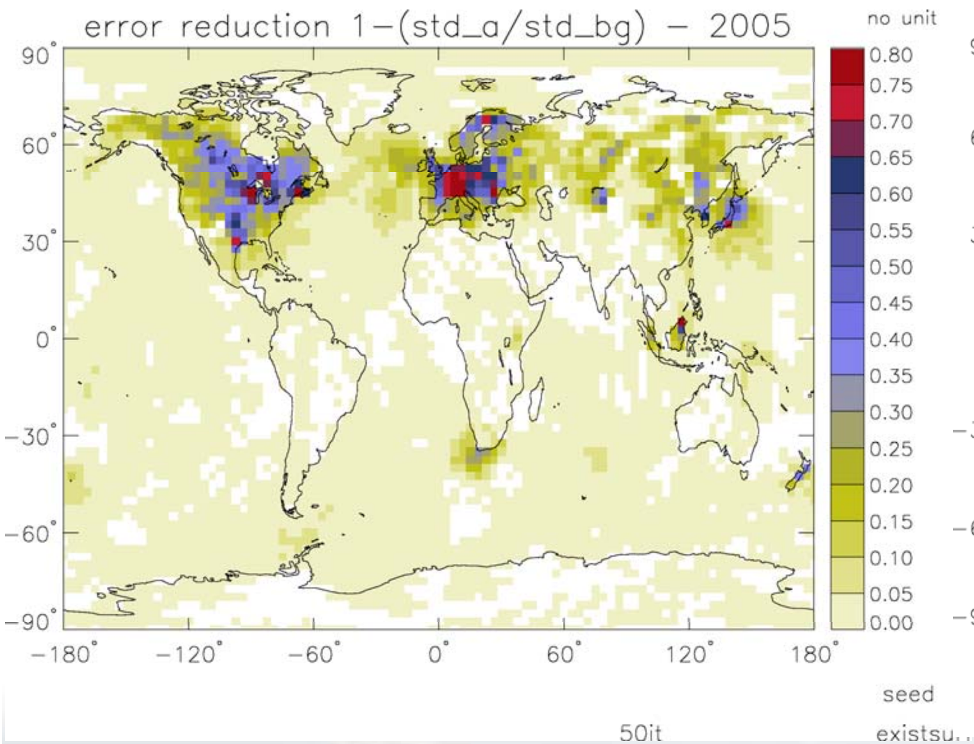
Disadvantage: challenge to reach the required precision on XCO_2 of ~ 1ppm

Important: Vertical sensitivity varies
Between various techniques

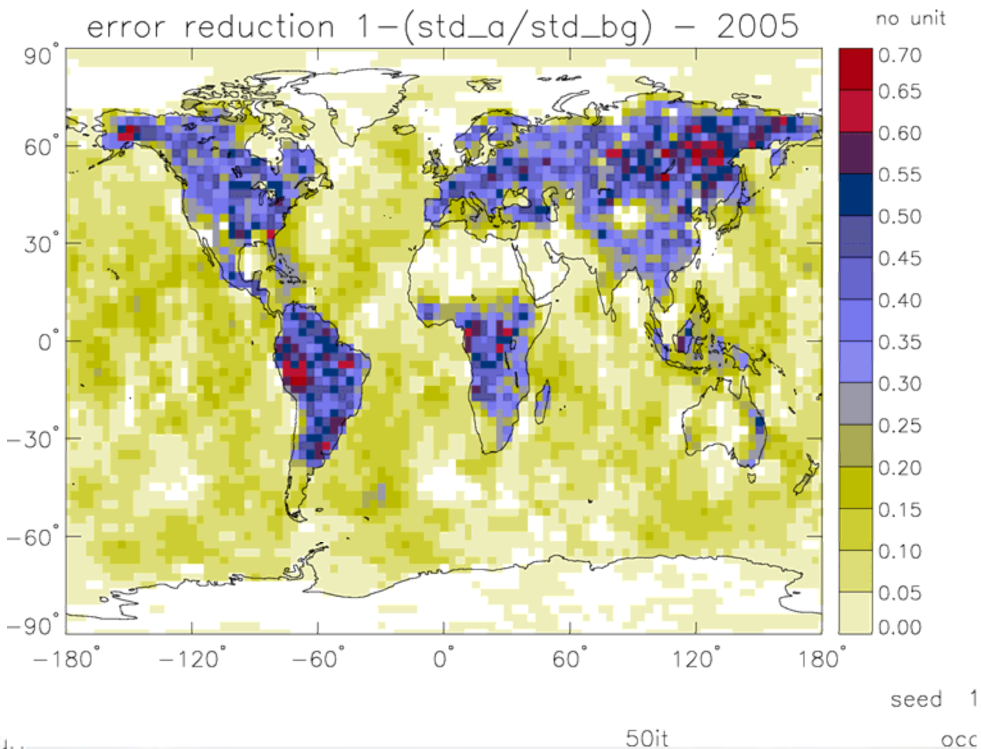


Performance simulation

Surface network



OCO

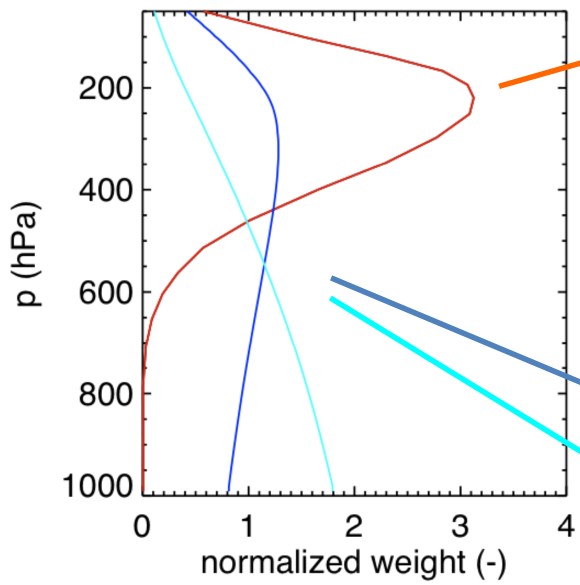


Courtesy Katja Hungershoefer

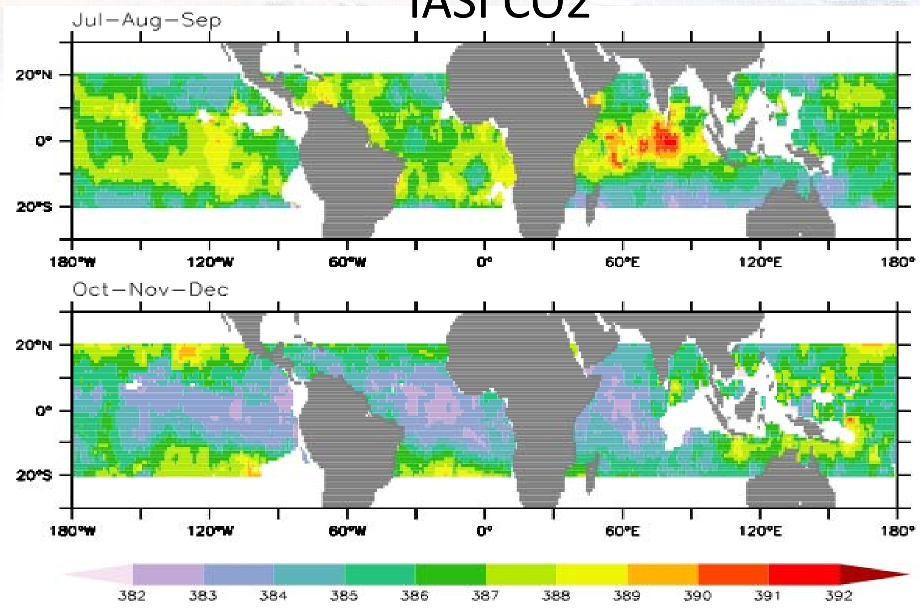
ESA A-SCOPE study

Status: 1 Obs.

Vertical sensitivity

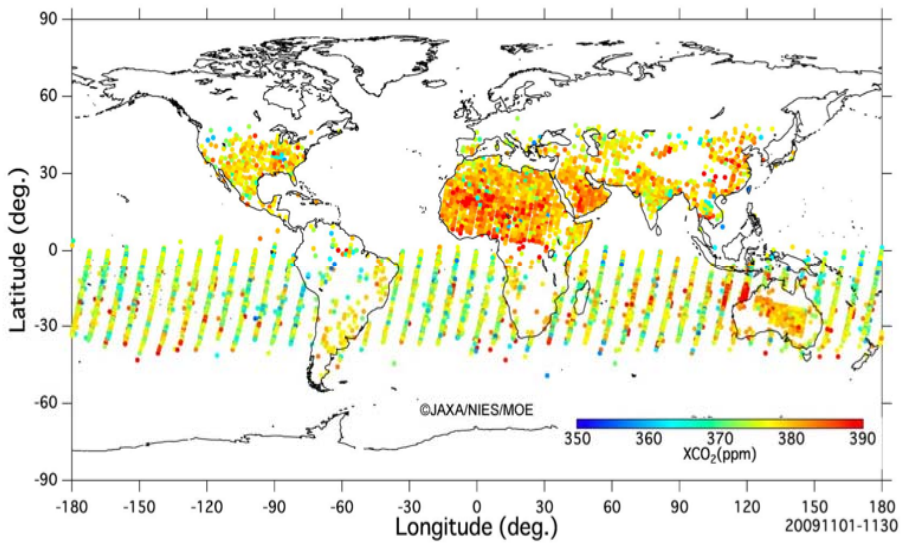


IASI CO2



Crevoisier et al., ACP 2009

GOSAT CO2

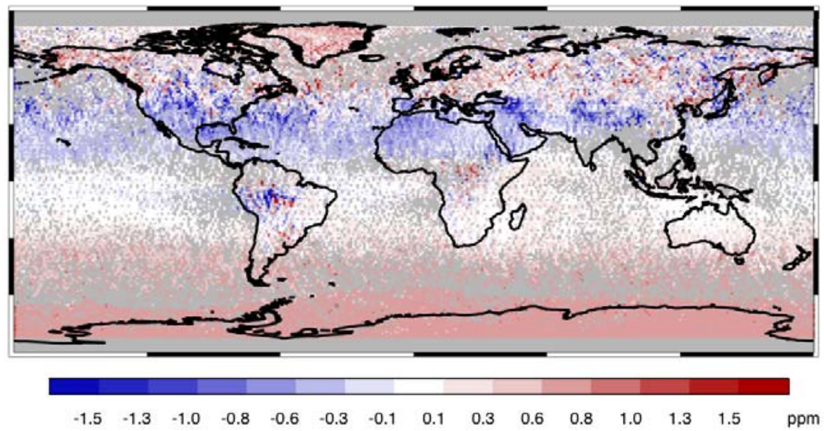


Courtesy Watanabe, 2010

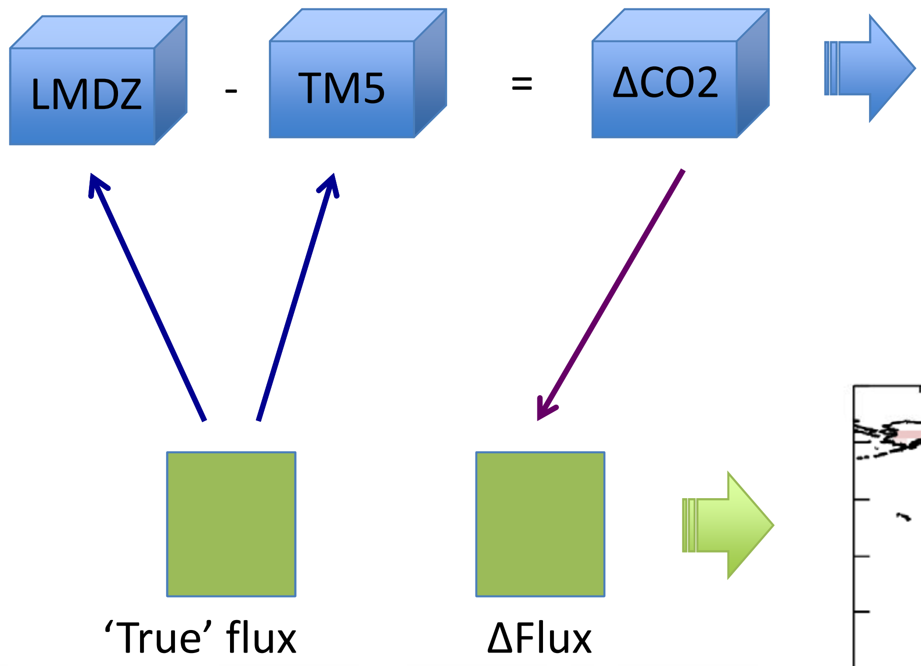
IASI: more accurate
GOSAT: better sensitivity & performance will improve

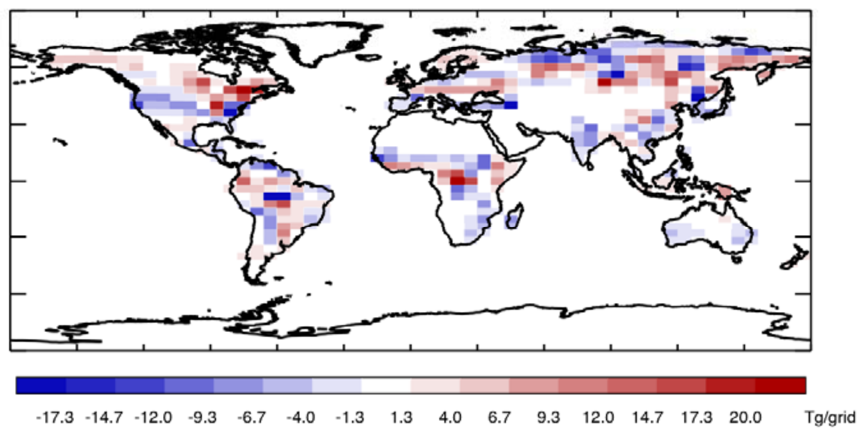
Status: 2. Models

LMDZ – TM5, August 2005



Simulated satellite samples





ESA A-SCOPE study

Results translate into
sizable annual flux uncertainties …

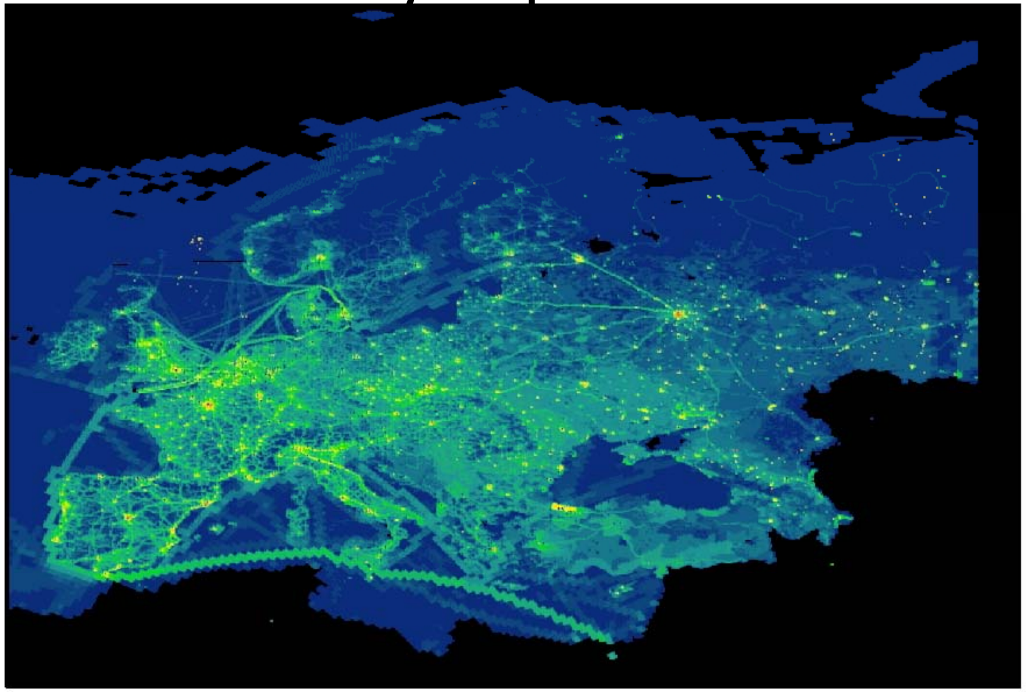
Conclusions

- In-situ: Tall tower networks improve inversion performance on regional scales
- Satellites: Could extend such a performance globally.
- Hurdles: Satellite data inversions challenge measurement techniques and models.

Can we estimate emissions from in-situ and satellite data in combination with modeling?

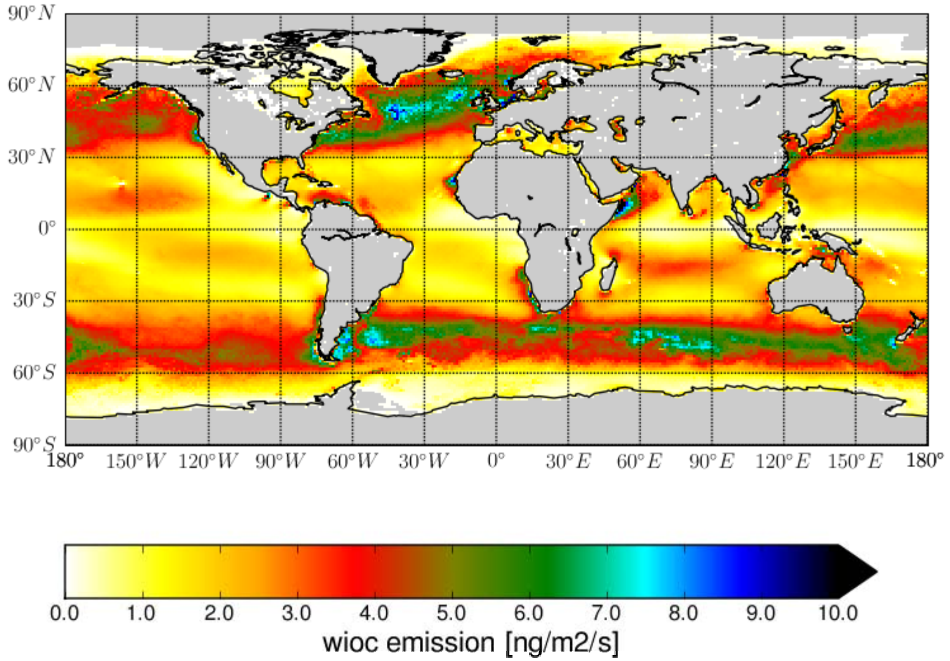
- Main interest is in annual total emissions over an entity (country)
- For modelling applications spatial distribution and timing of emissions are very important

How can satellite data help to improve these maps?

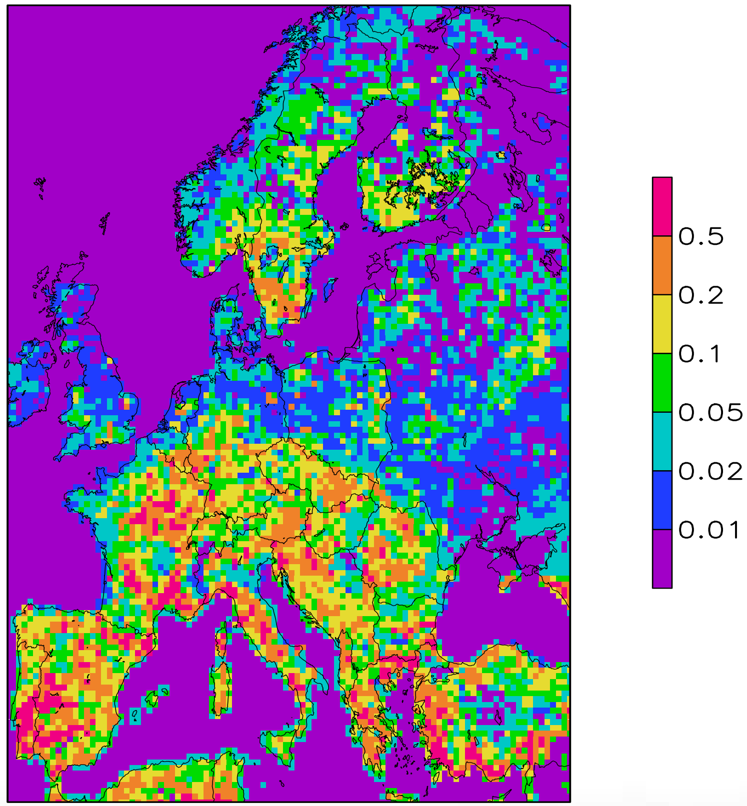


Directly as input: LAI, FRP, ocean colour, whitecap, etc

Marine emissions



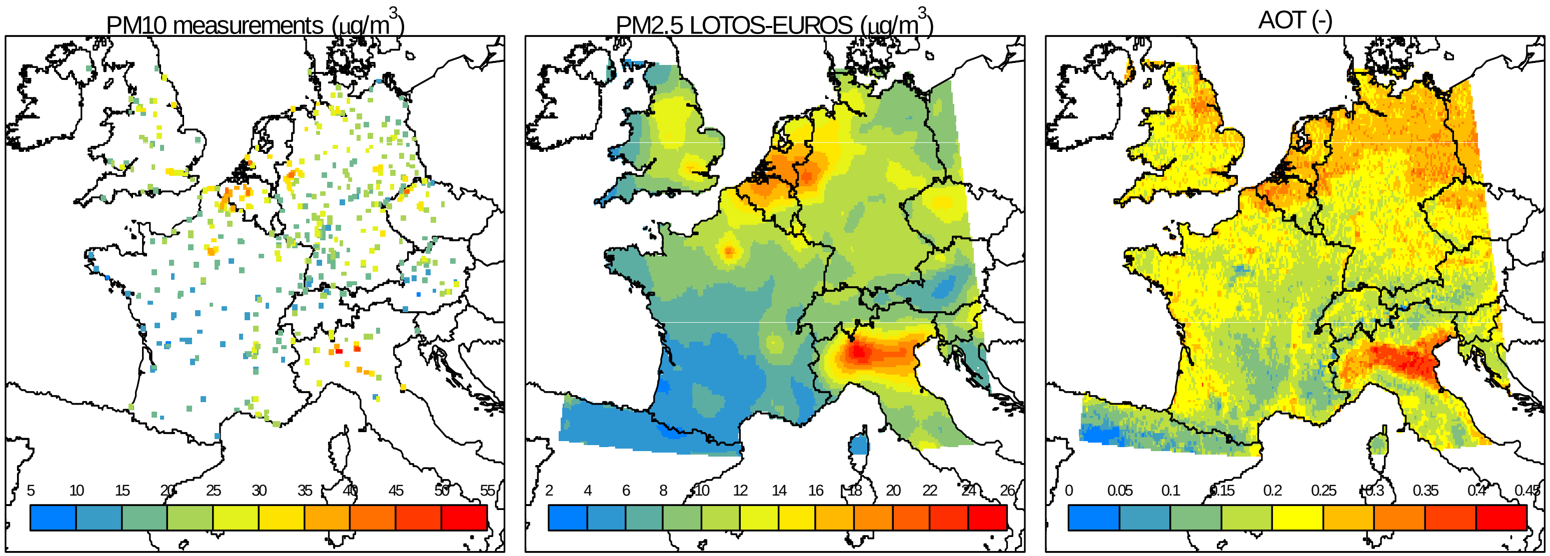
Isoprene



Natural & Biogenic emissions – calculated online in models

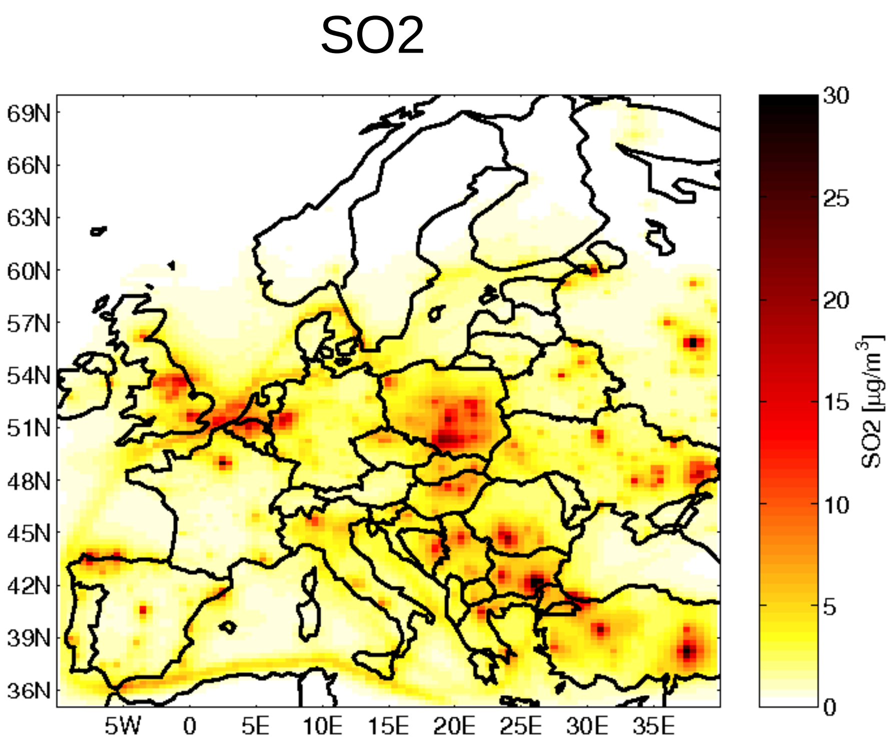
Indirectly via data assimilation: a challenge!

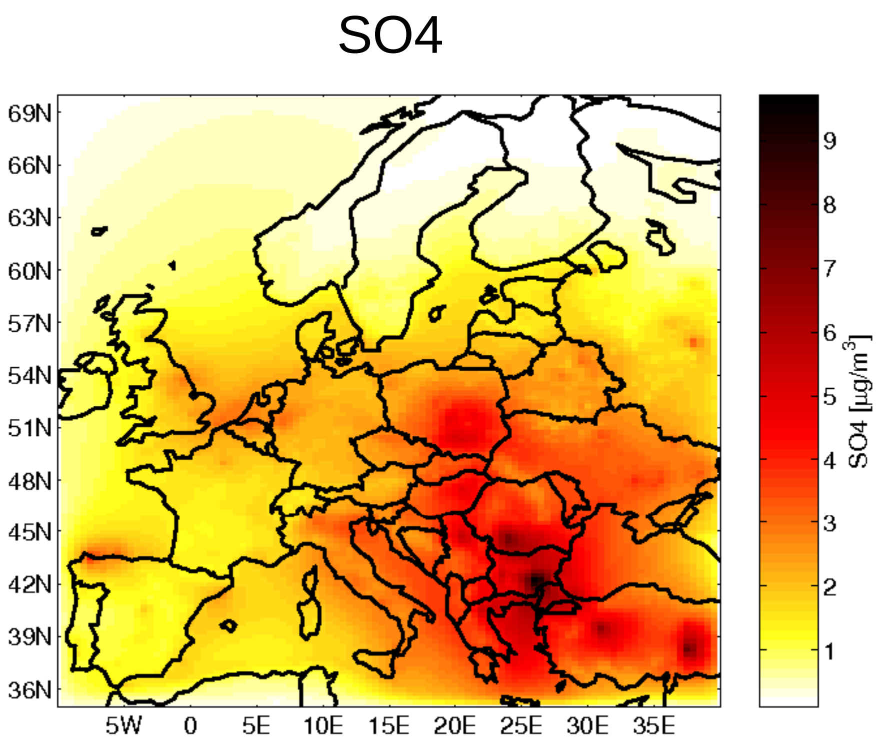
- To disentangle the uncertainty due to the emission input from other model uncertainties
  - The assimilation "blames" all errors to a limited amount of parameters
- To keep the system realistic and balanced
- To combine different sources of data – multi component



Ground based Model Satellite

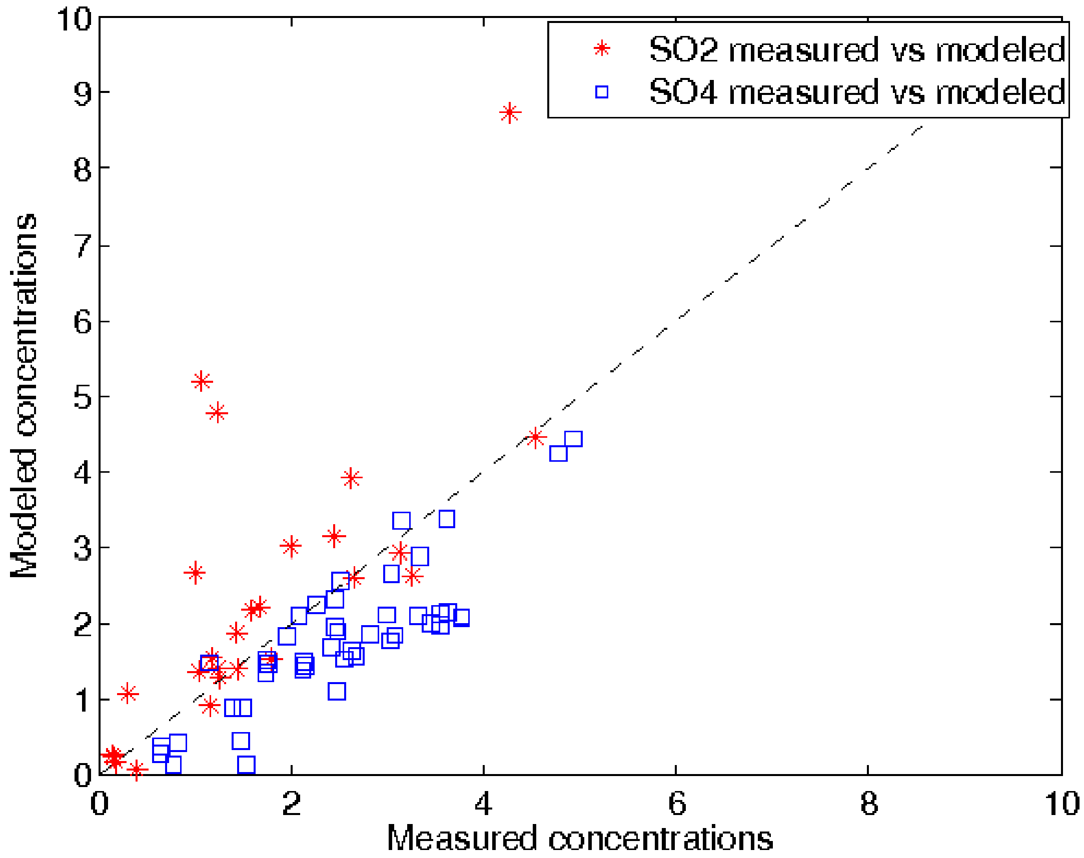
Assimilation of SO2 and SO4 – a case study





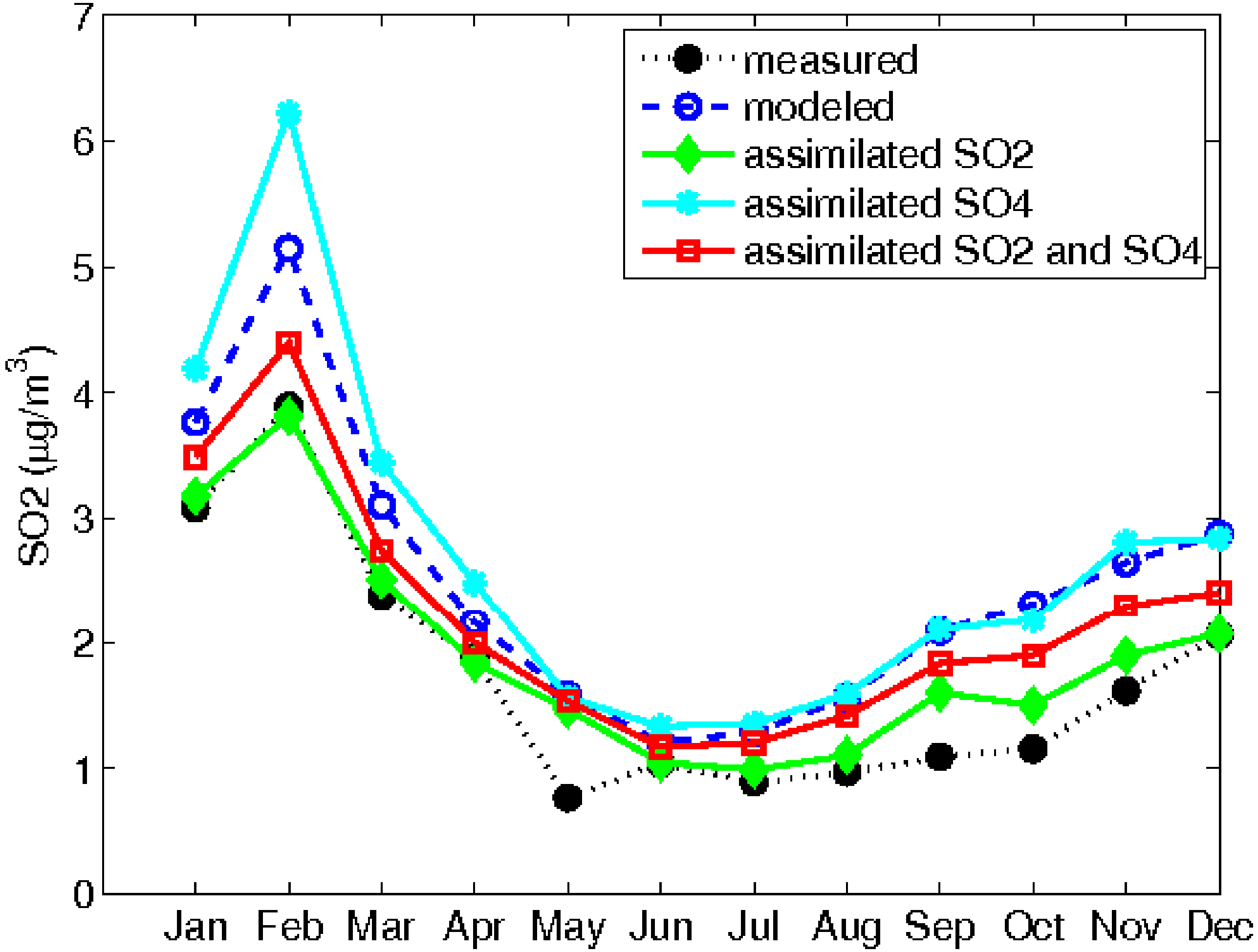
Annual mean for 2003

Modelled annual mean concentrations SO2 and SO4



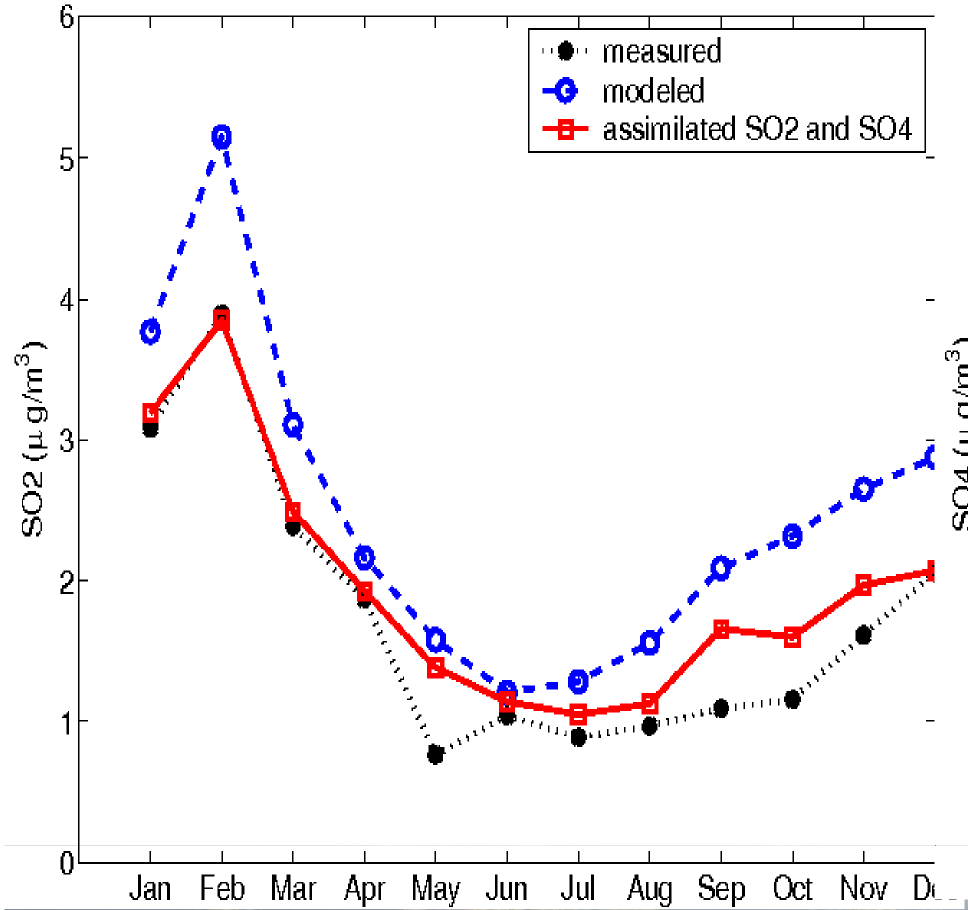
	SO2	SO4
OBS	1.6	2.5
MOD	2.3	1.8
OBS/ MOD	1.4	0.7

Results: SO2 annual cycle over all assimilation stations

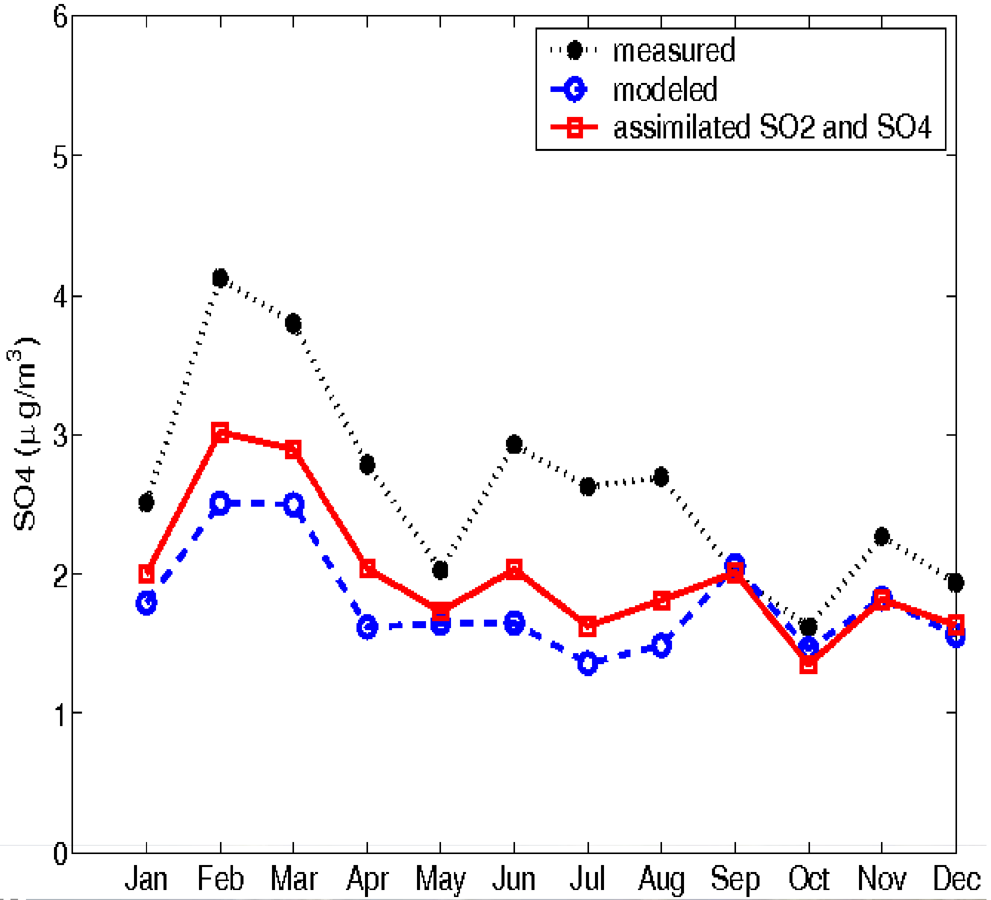


Results: SO2 & SO4 annual cycle over all stations by including uncertain conversion rates

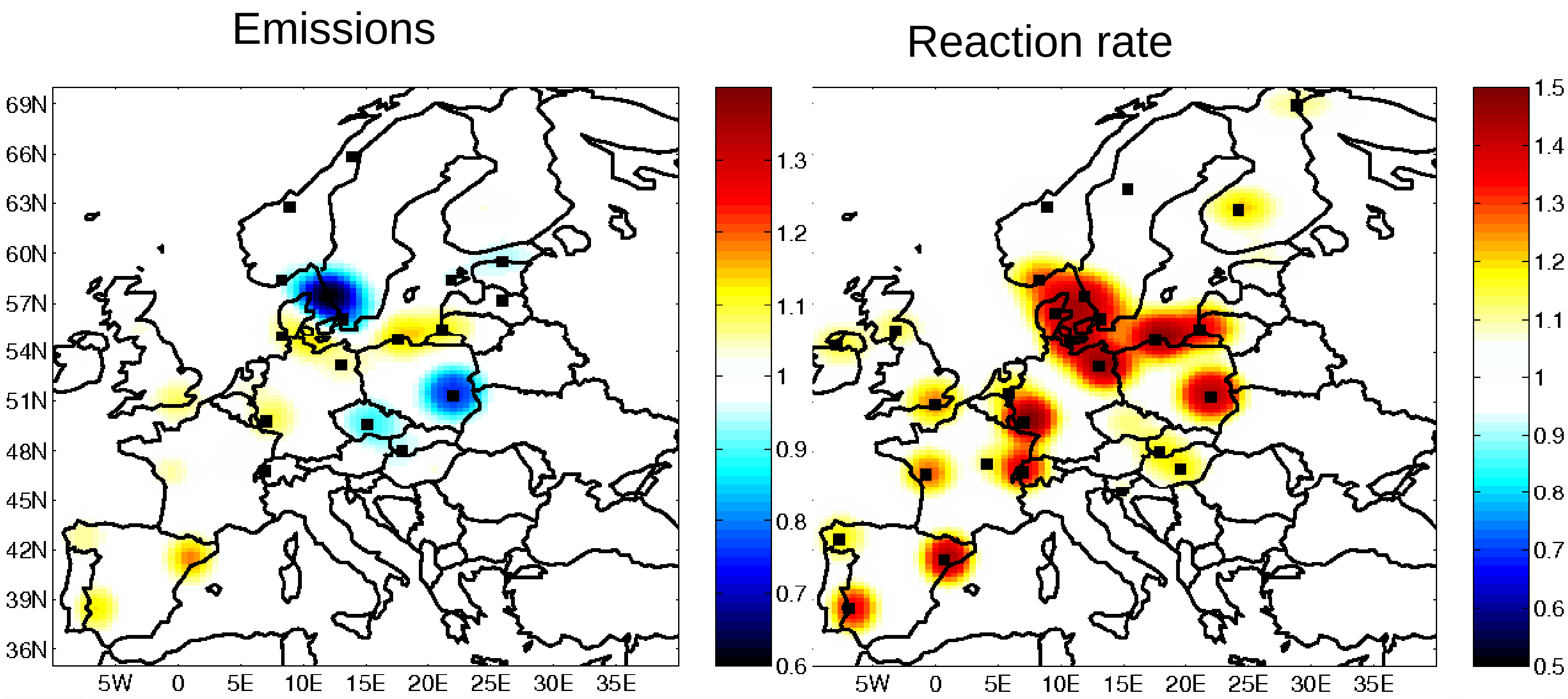
SO2



SO4



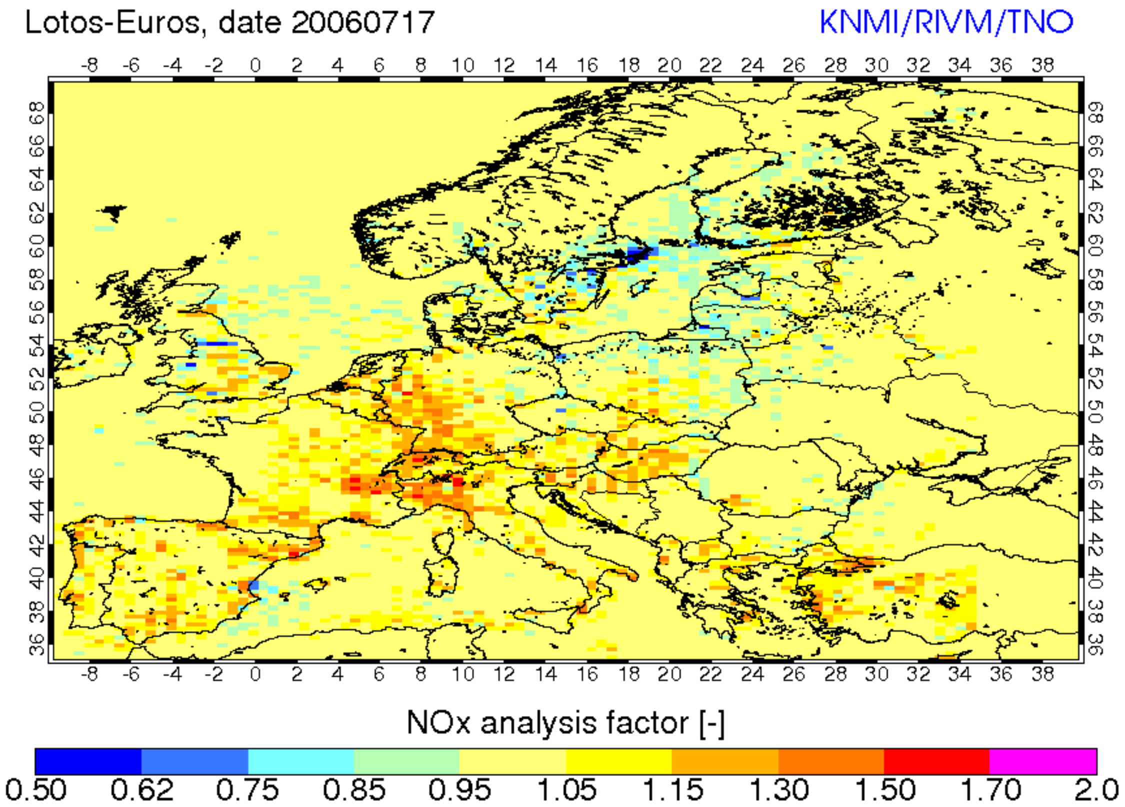
Annual mean estimated multiplication factors

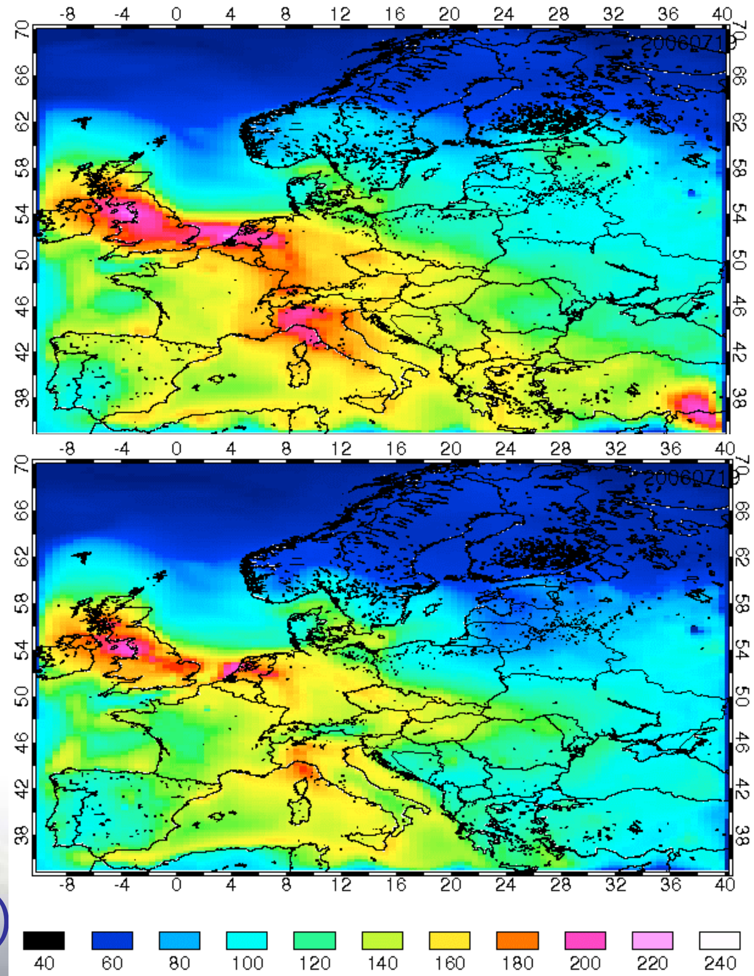


Also after acknowledging the shortcomings of the model it indicates that the shipping emissions and those in Poland may be too high

Assimilation OMI NO2 measurements with LOTOS-EUROS

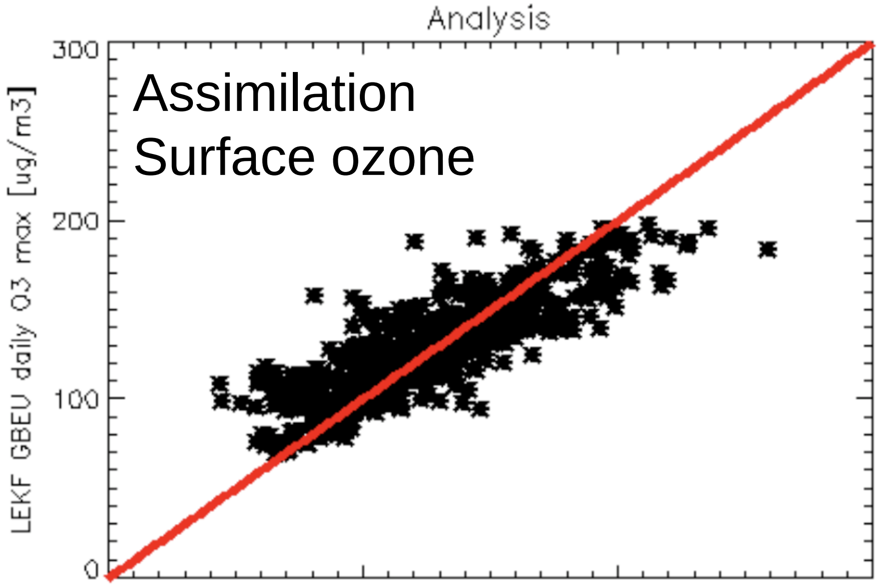
Impact for ozone at the surface

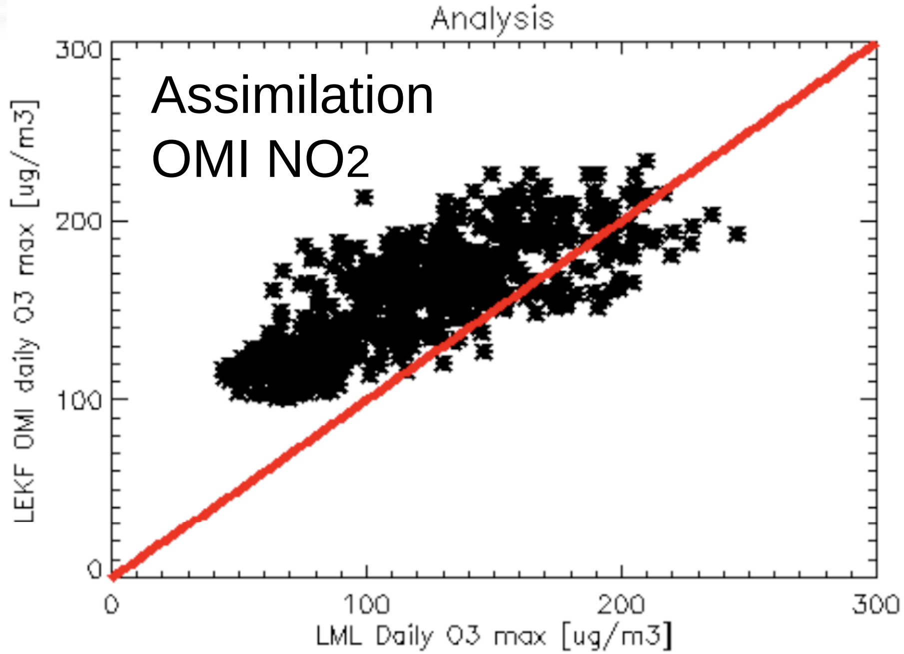


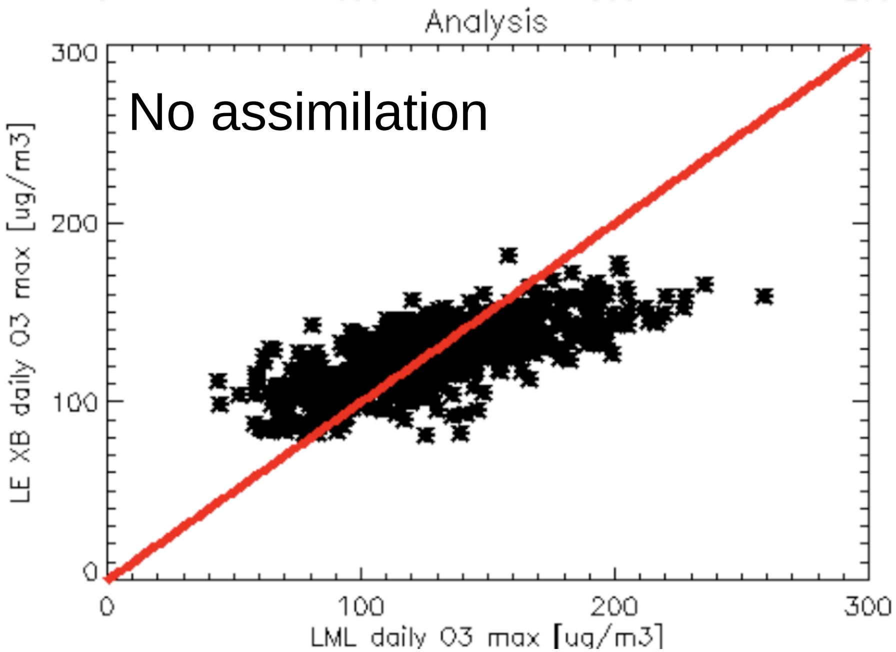


Analysis NOx emissions / inventory (yellow=1)

Impact of assimilation on ozone peak value





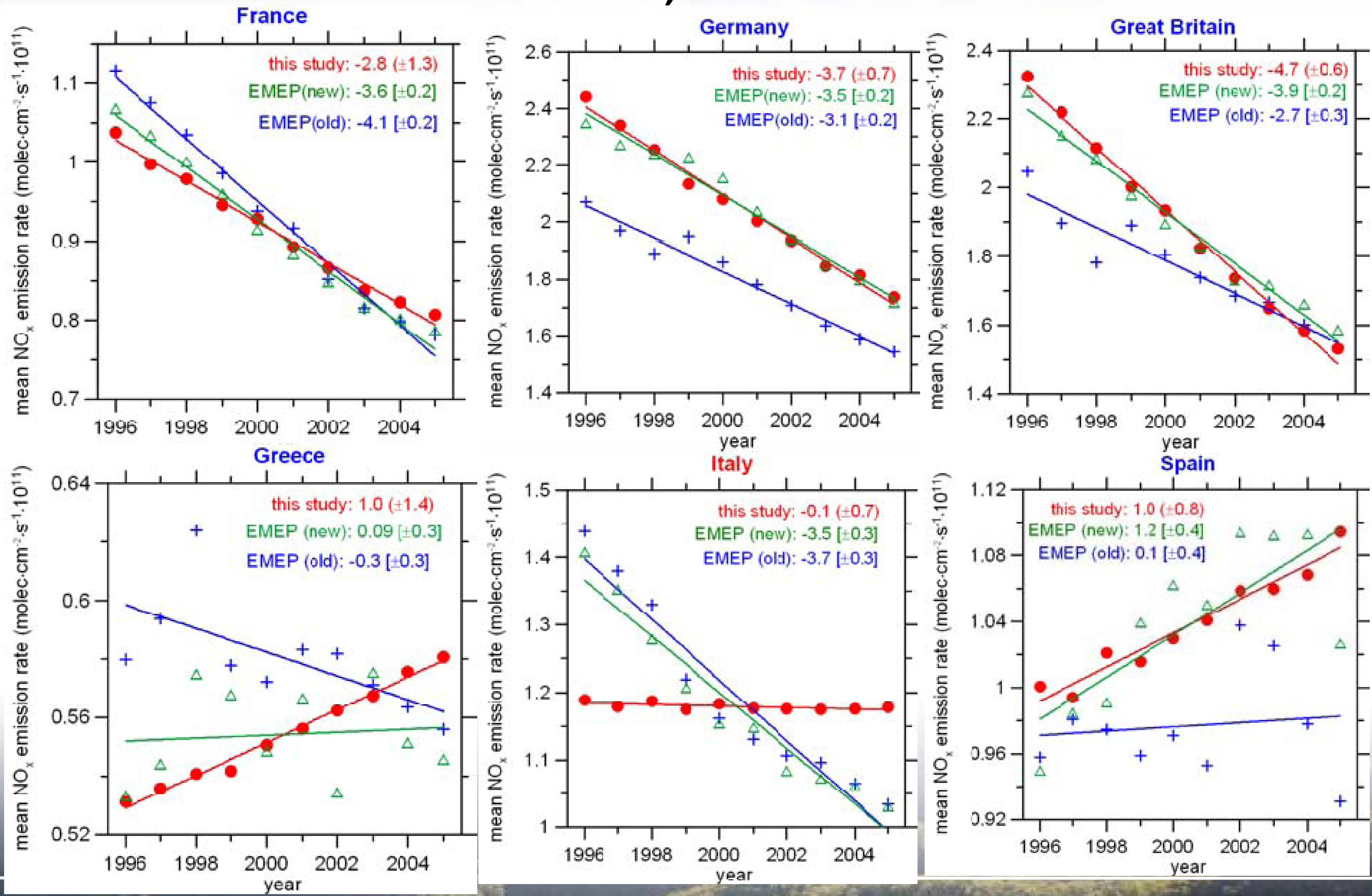


Is the NOx lifetime OK?

NO2 bias in the model effects ozone negatively

Note, OMI NO2 may be ~25% high

Estimating NOx emission trends: Konovalov et al., 2006



Where can we use our present capabilities to provide information on emissions?

- Search for trends in the parameter estimates?
  - Does the EO data indicate that the emission trend is not as expected?
  - The system does the meteo correction, etc for you.
- To indentify locations of new and significant emission sources
  - The areas with consistently high model-measurement deviations
- To identify time profiles – needed: geostationary data
- Emission estimates
  - Only in hotspot locations, mostly qualitatively
- Direct variables such as land use, LAI, Fire Radiative Power, White cap, etc