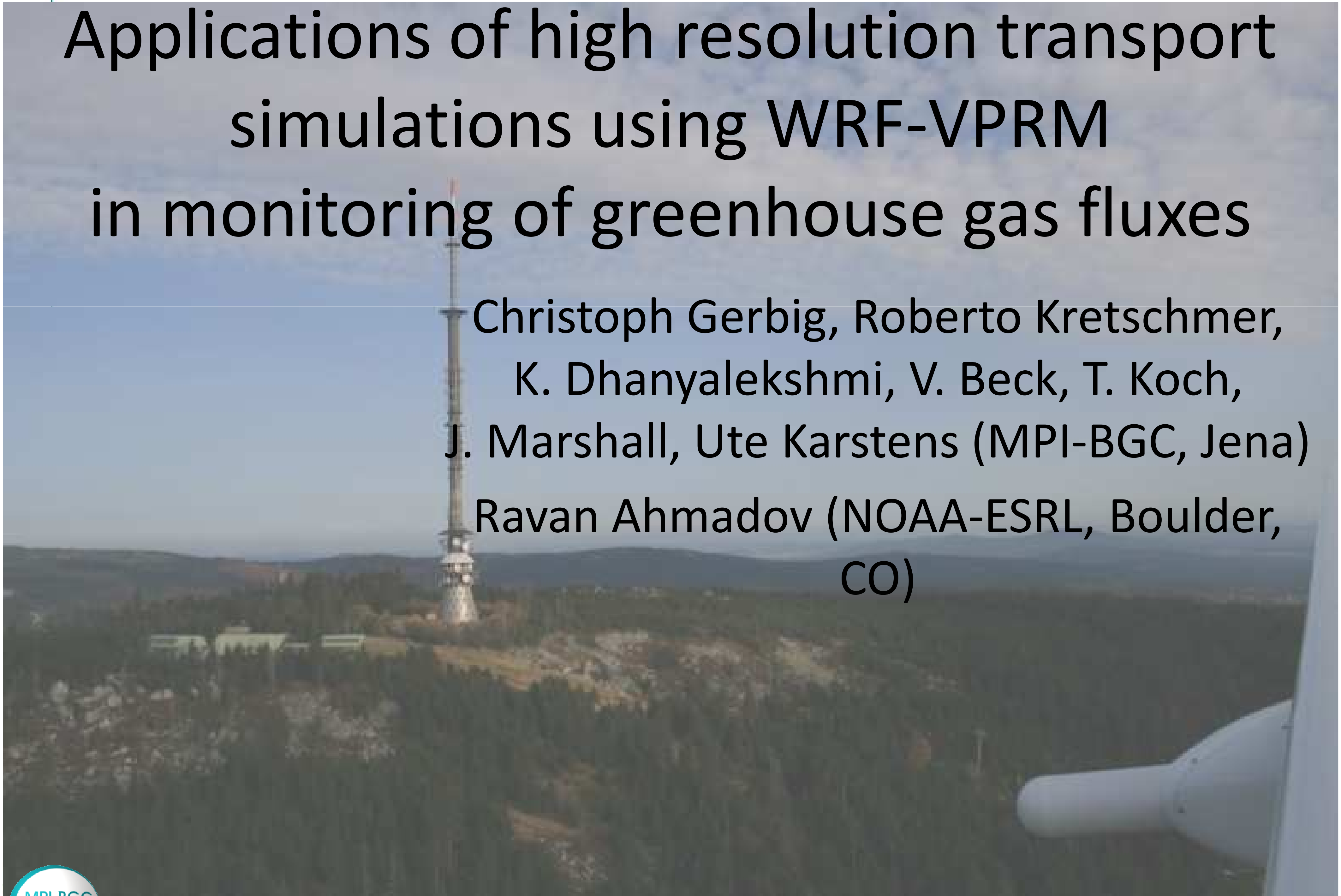


Applications of high resolution transport simulations using WRF-VPRM in monitoring of greenhouse gas fluxes

Christoph Gerbig, Roberto Kretschmer, K. Dhanyalekshmi, V. Beck, T. Koch, J. Marshall, Ute Karstens (MPI-BGC, Jena)

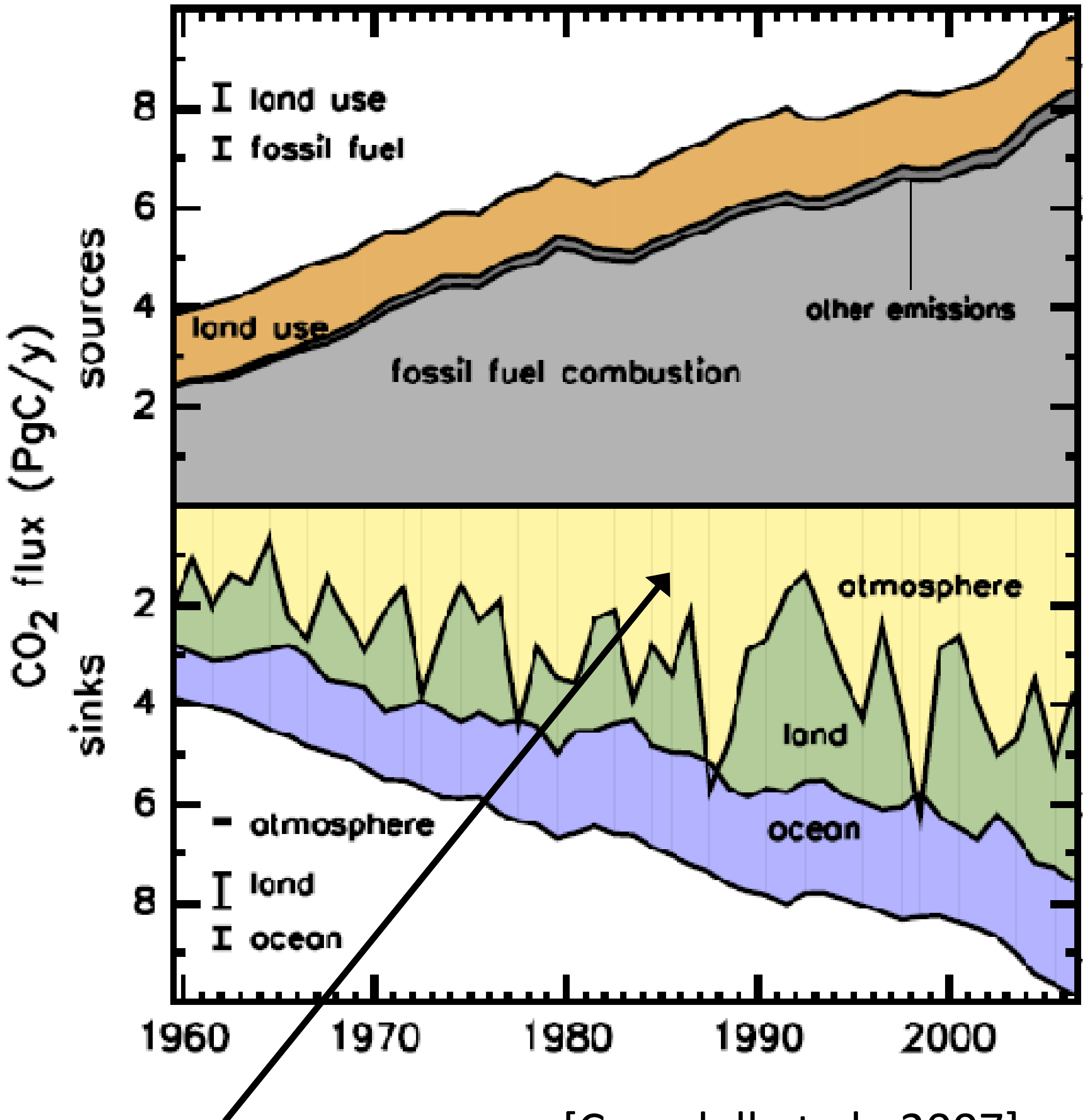
Ravan Ahmadov (NOAA-ESRL, Boulder, CO)

MPI-BGC Jena

Motivation

Scientific questions:

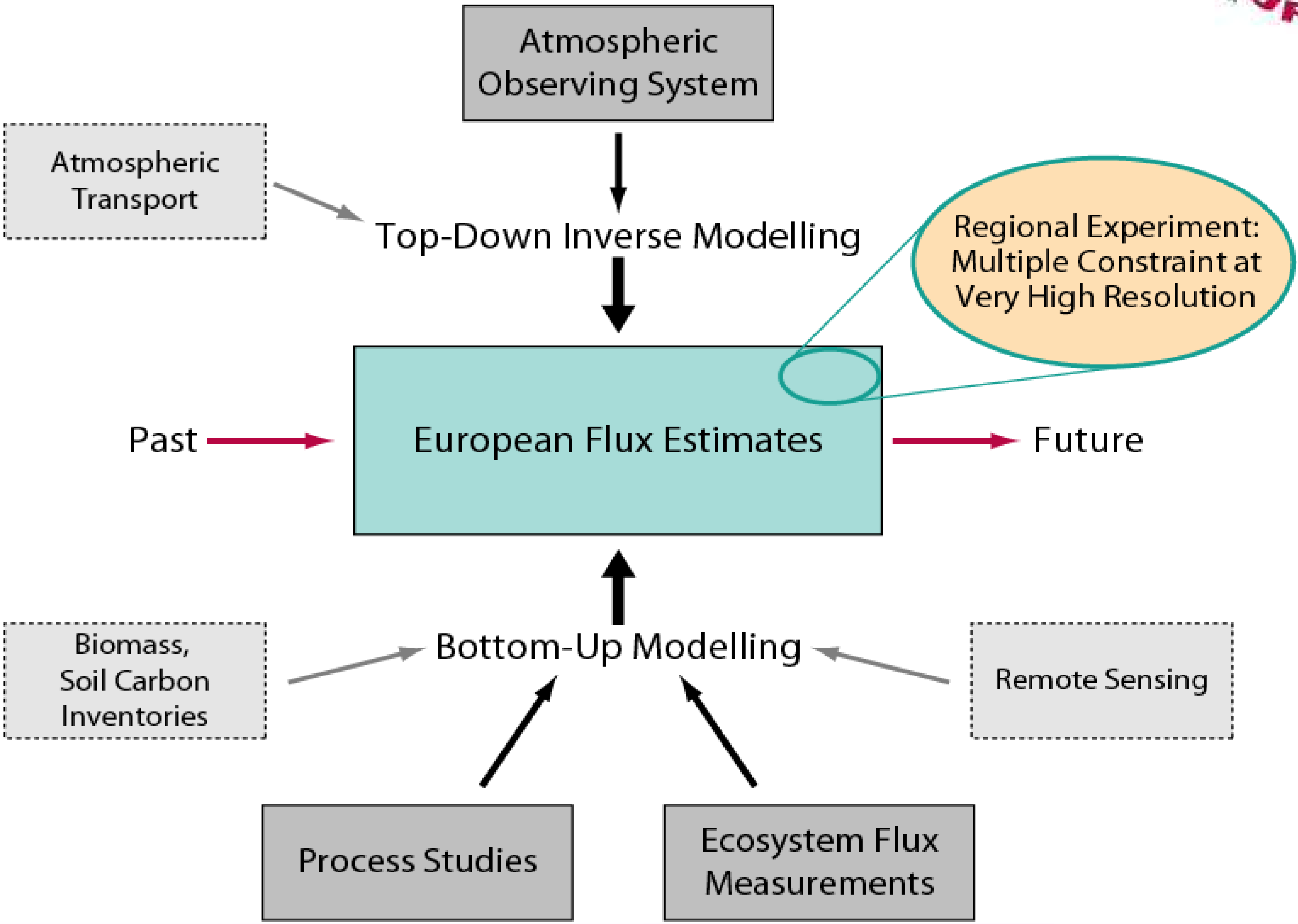
- Where and by which processes is anthropogenic CO_2 sequestered?
- What are the main feedback processes between carbon cycle and climate system?
- What is the carbon budget of a specific region (continent/country)?



"Airborne fraction"

[Canadell et al., 2007]

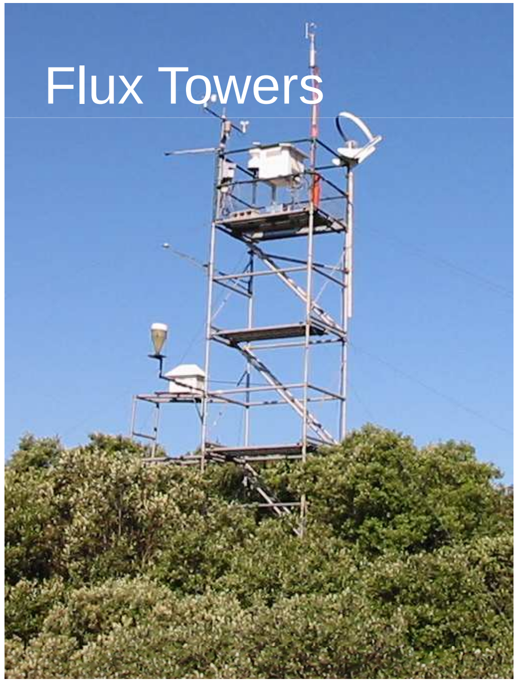
Estimating Carbon Balances: Top-Down vs. Bottom-Up Approach

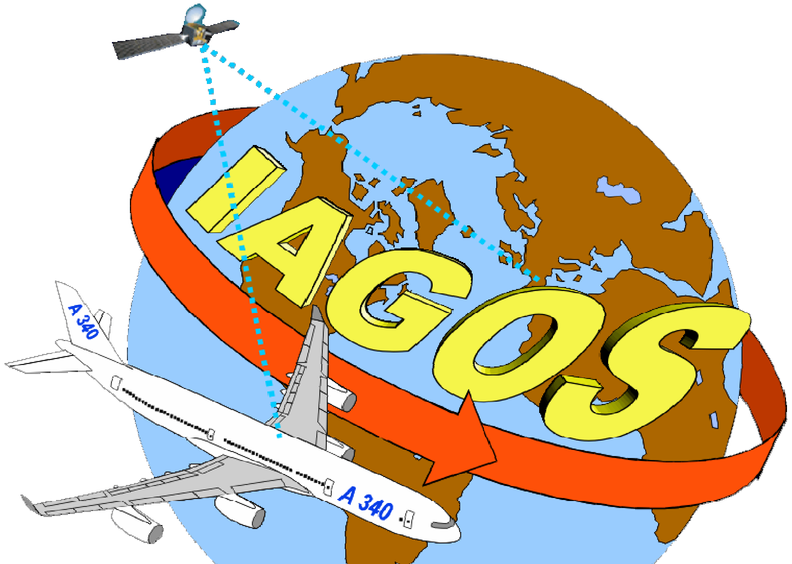


Observational networks (EU Infrastructures)

Ecosystem Flux Measurements

Atmospheric Observing System (GHGs)



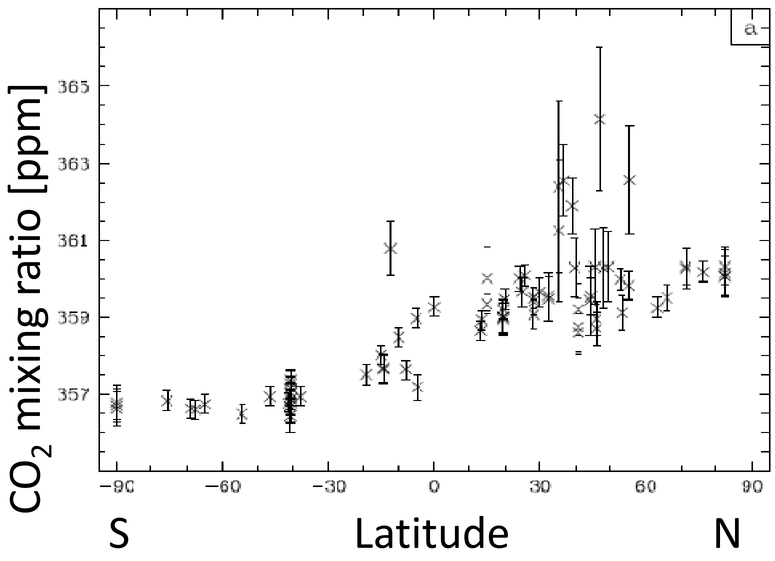


Commercial Airliner

ICOS integrated carbon observation system

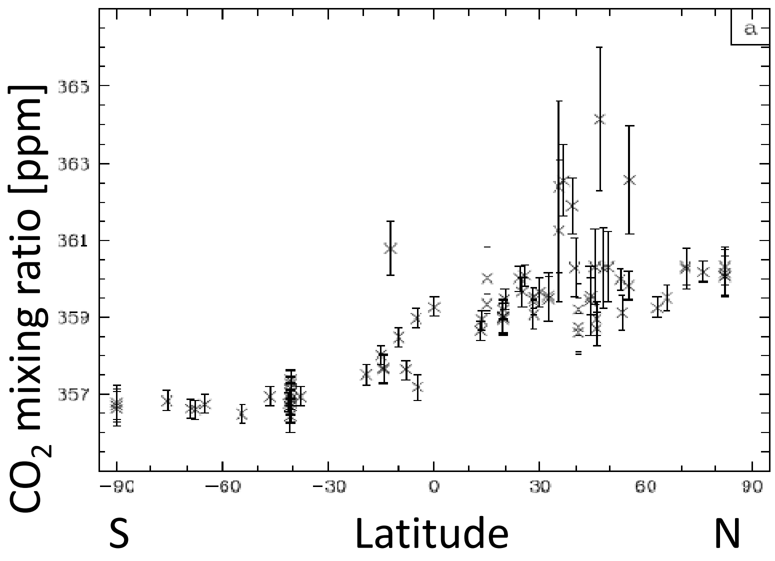
A European infrastructure dedicated to high precision monitoring of greenhouse gases

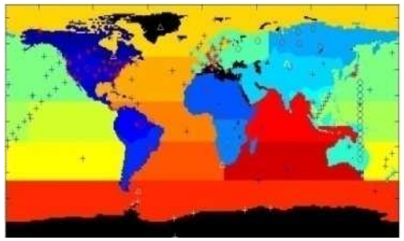
Global scale inverse modeling

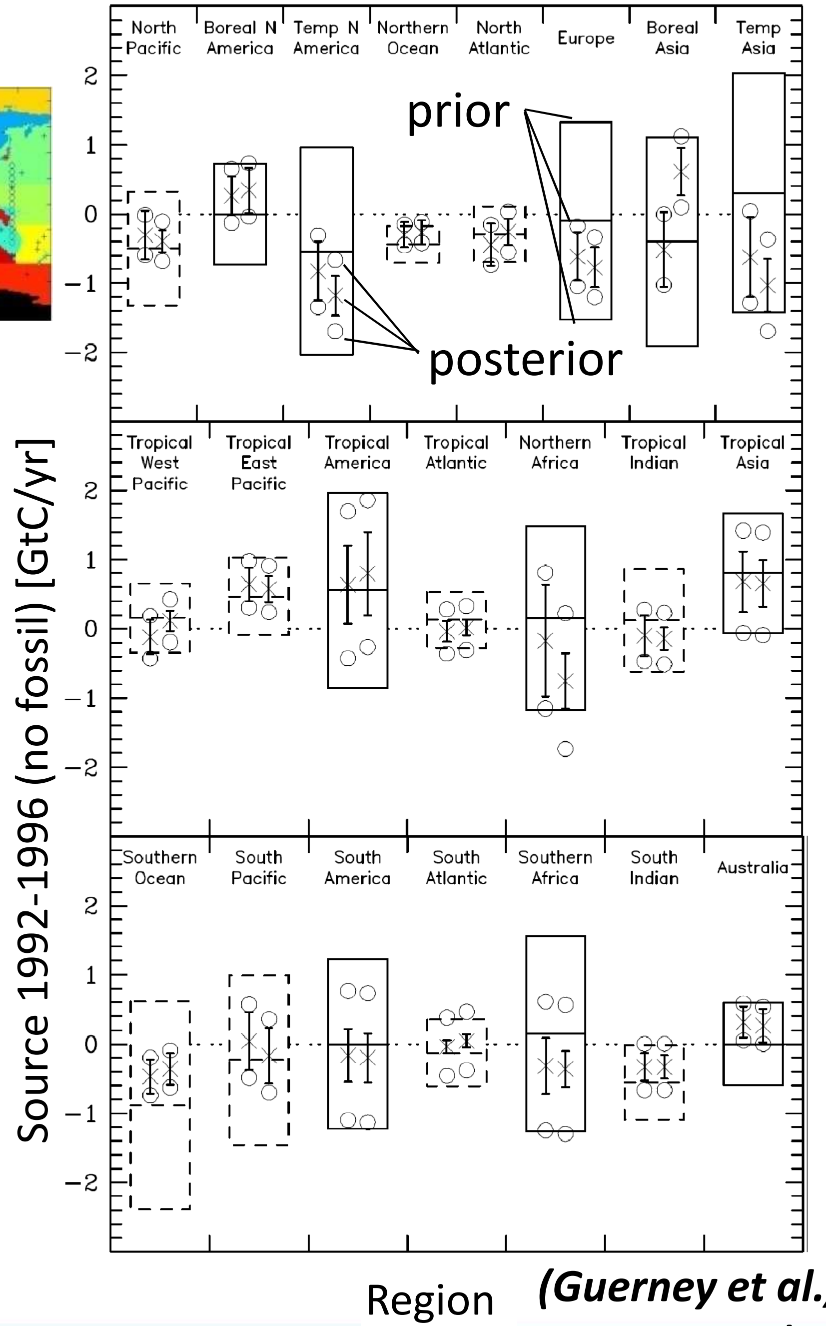


- Global inverse modelling using remote stations
  - Tight constraint on global budget
  - Existence of NH sink („missing sink“)

Global scale inverse modeling







(Guerney et al., Nature 2002)

- Global inverse modelling using remote stations
  - Tight constraint on global budget
  - Existence of NH sink („missing sink“)
  - Estimates for continental regions
  - Interannual variations

Regional scale inverse modeling

Sub-continental scale inversions

- including continental stations
- much stronger variability

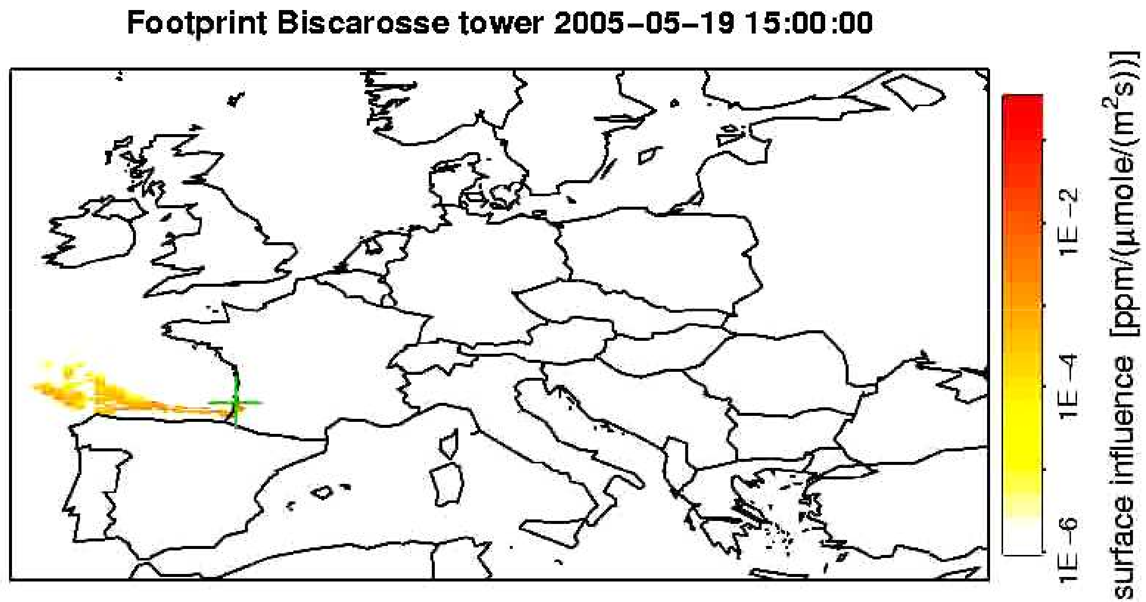
Regional scale inverse modeling

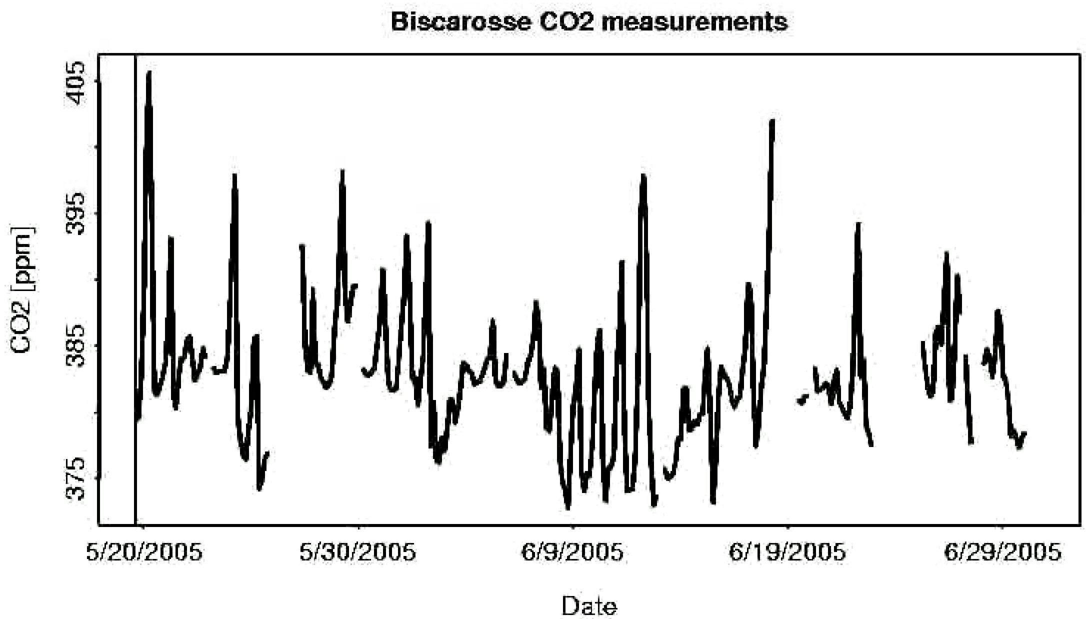
Sub-continental scale inversions

- including continental stations
- much stronger variability

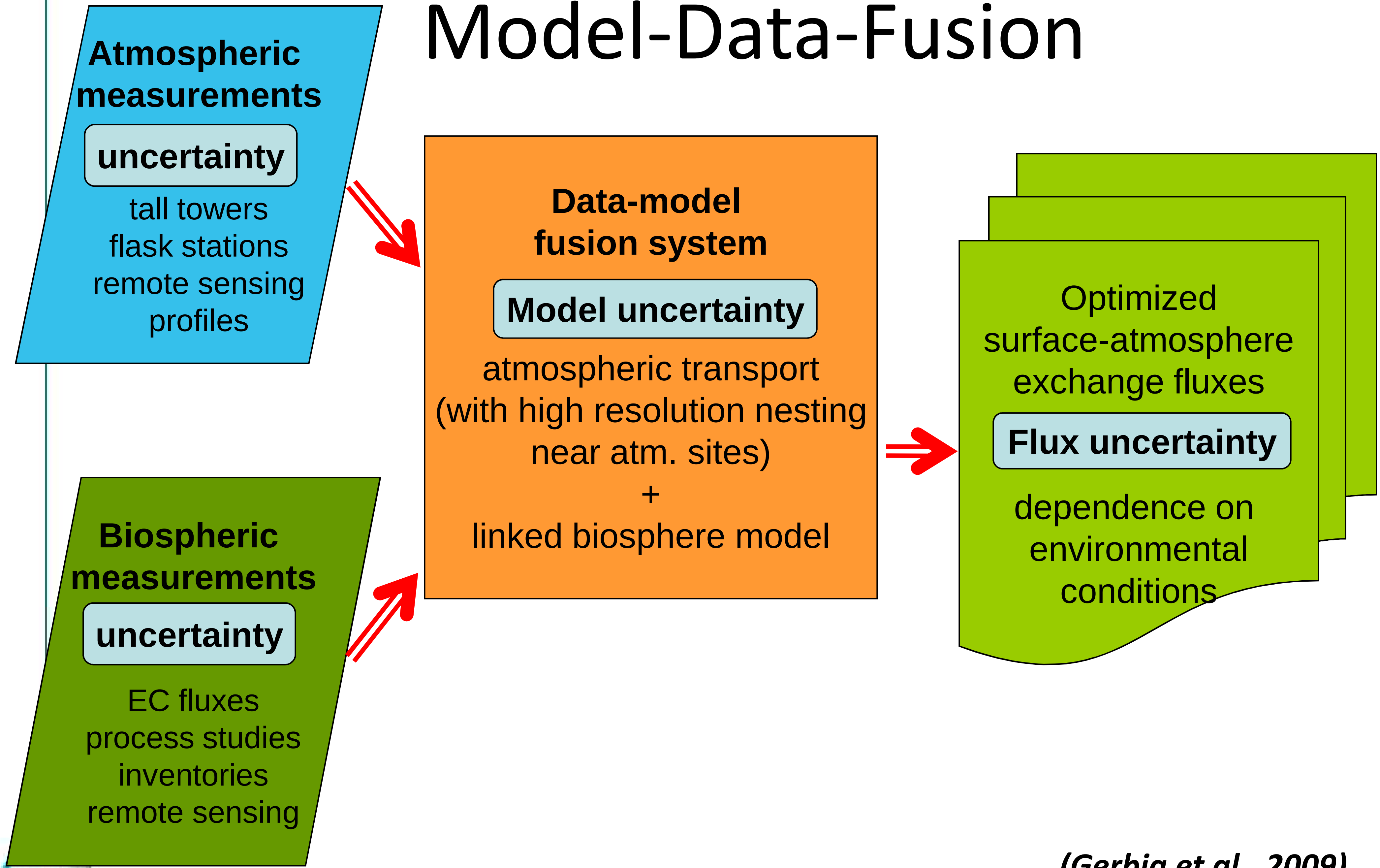
Example coastal station

- STILT footprints (LPDM)
- Footprints „see“ the continental biosphere



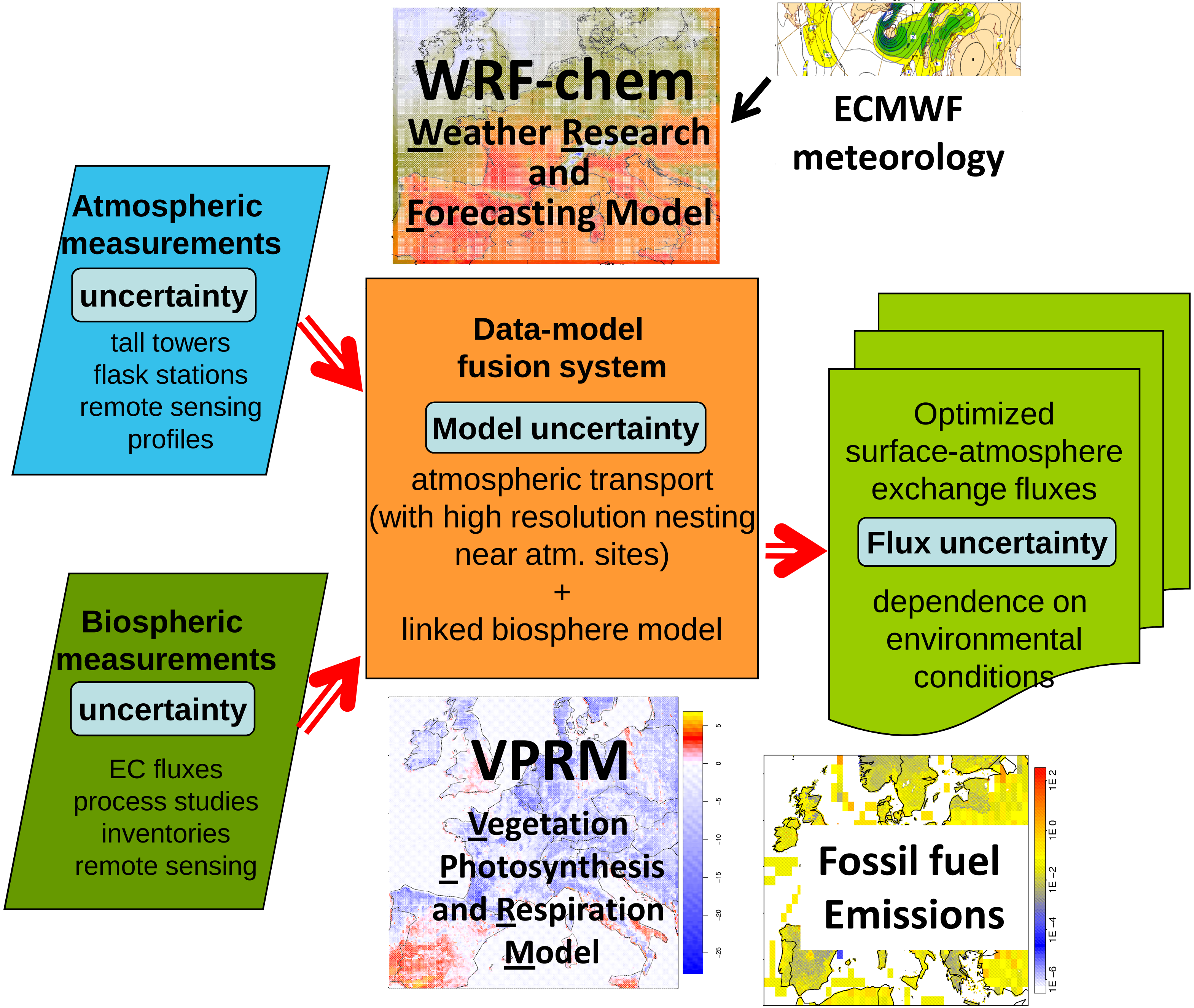


Model-Data-Fusion



(Gerbig et al., 2009)

Model-Data-Fusion

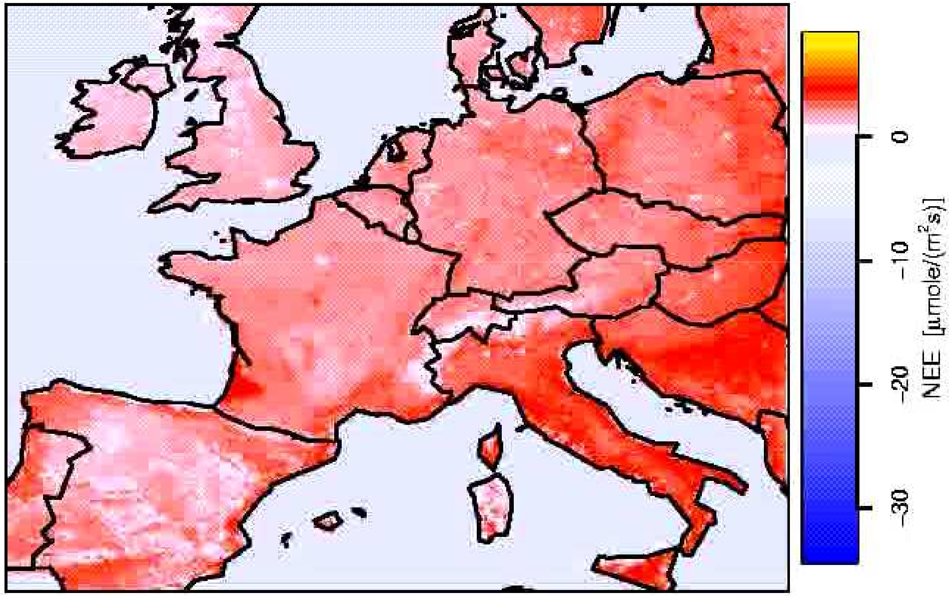


CO_2 as seen by a high resolution model

VPRM
biospheric CO_2 fluxes

fractional vegetation cover + MODIS EVI
fluxes upscaled from Eddy cov. msmts.

Net Ecosystem Exchange, time 2003–07–02_01:00:00



Vegetation–Photosysthesis and Respiration Model, created at MPI–BGC

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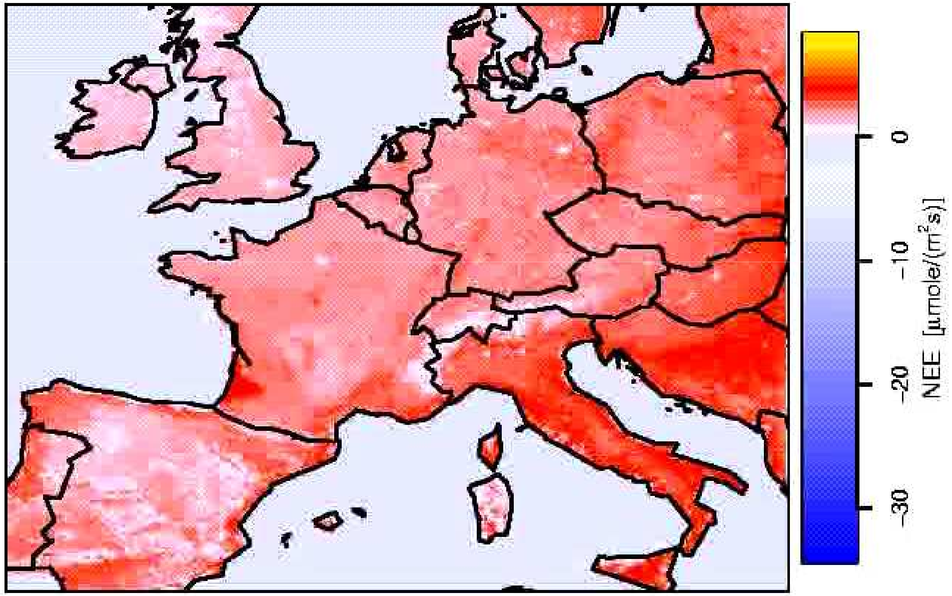
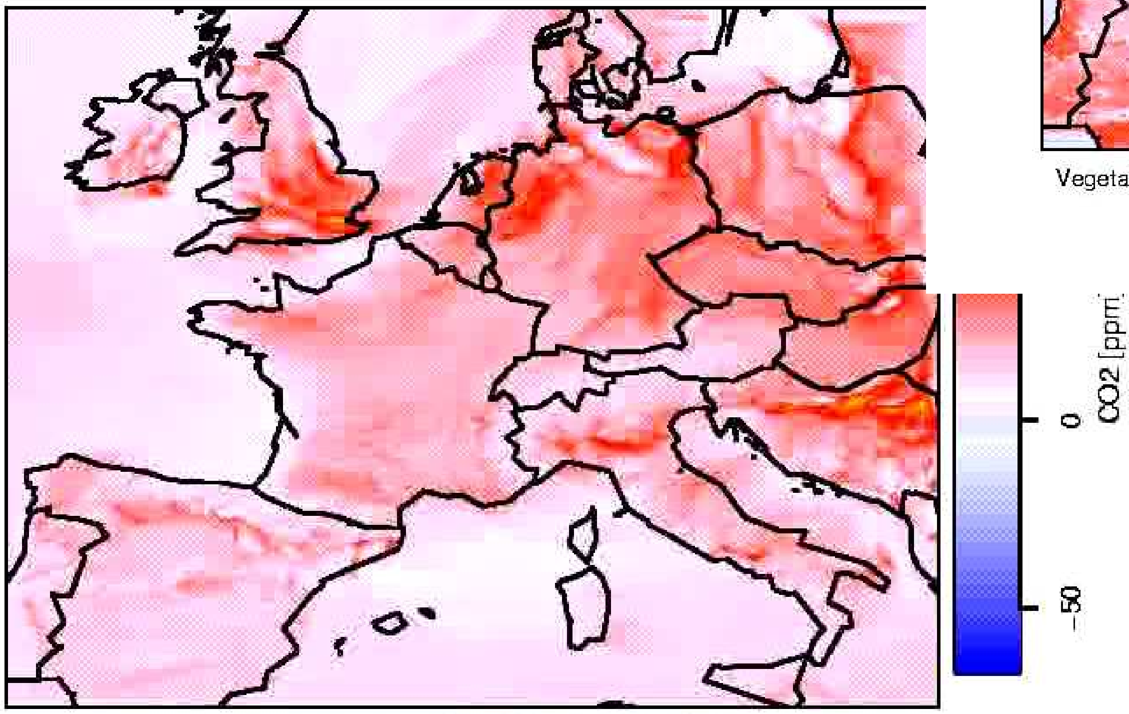


Vegetation–Photosysthesis and Respiration Model, created at MPI–BGC

CO2 at 0.1 km, time 2003–07–02_00:00:00

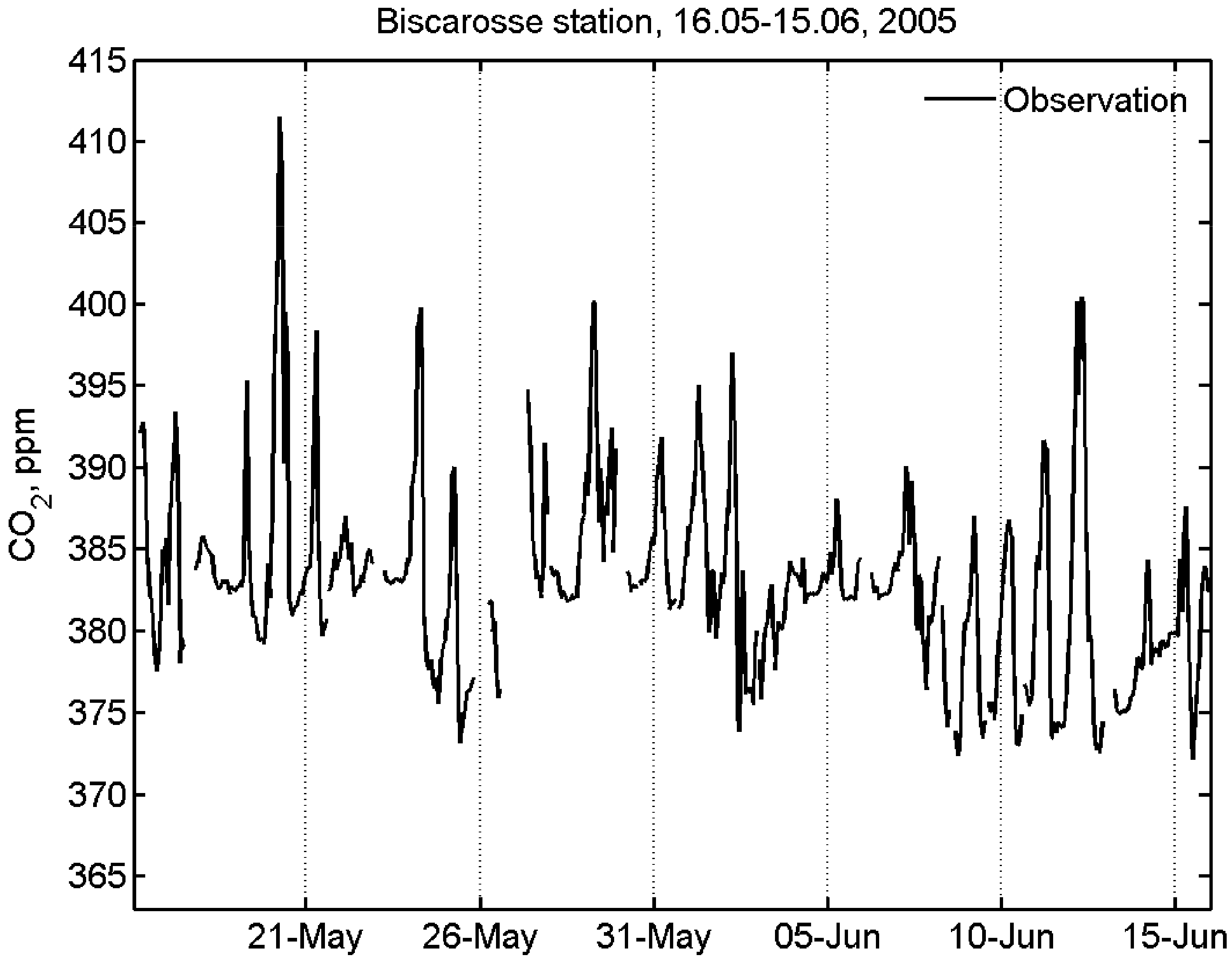


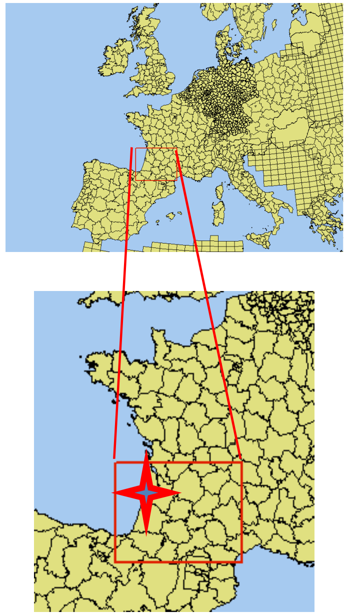
WRF+CASA+VPRM, created at MPI–BGC

WRF-VPRM, 10 km res.
CO_2 (-366 ppm) at 150 m

[Dhanyalekshmi et al., ACPD 2009]

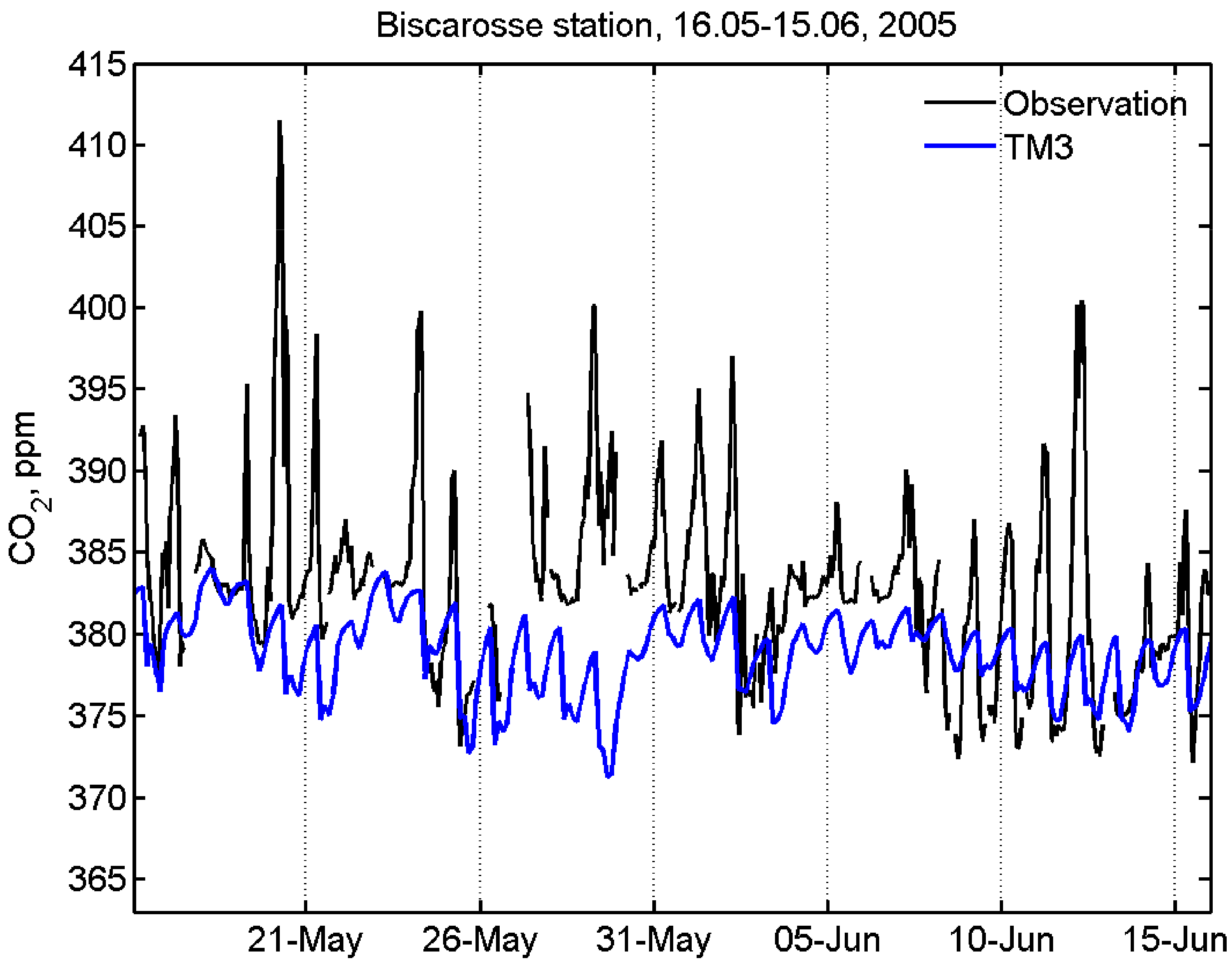
Lessons from CarboEurope: increasing resolution helps



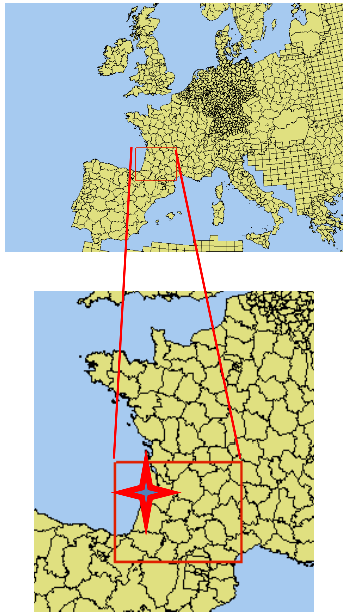


[Ahmadov et al., 2008]

Lessons from CarboEurope: increasing resolution helps



4° x 5°



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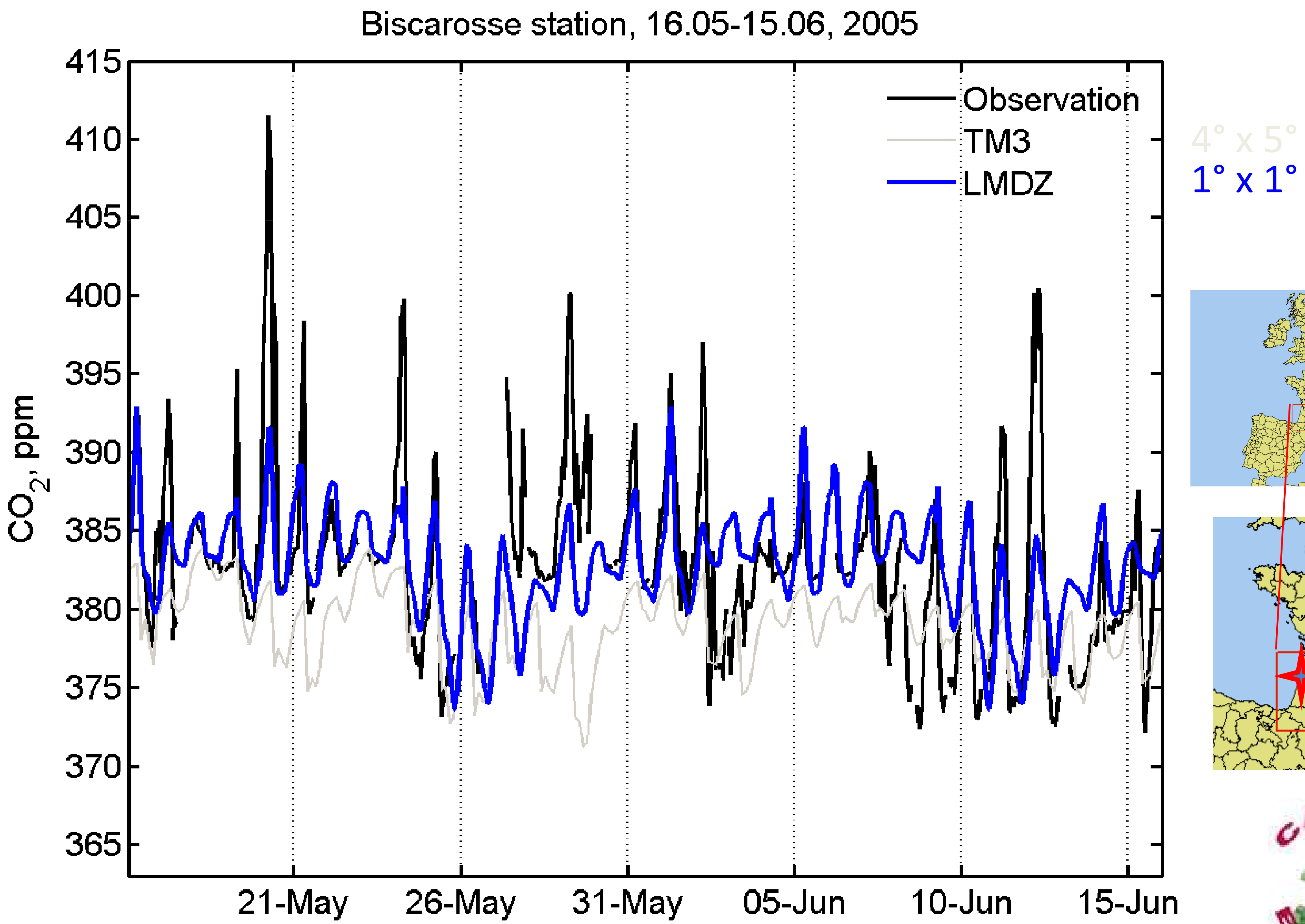
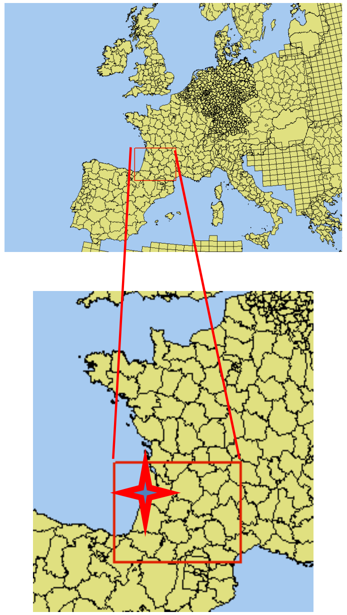
Lessons from CarboEurope: increasing resolution helps





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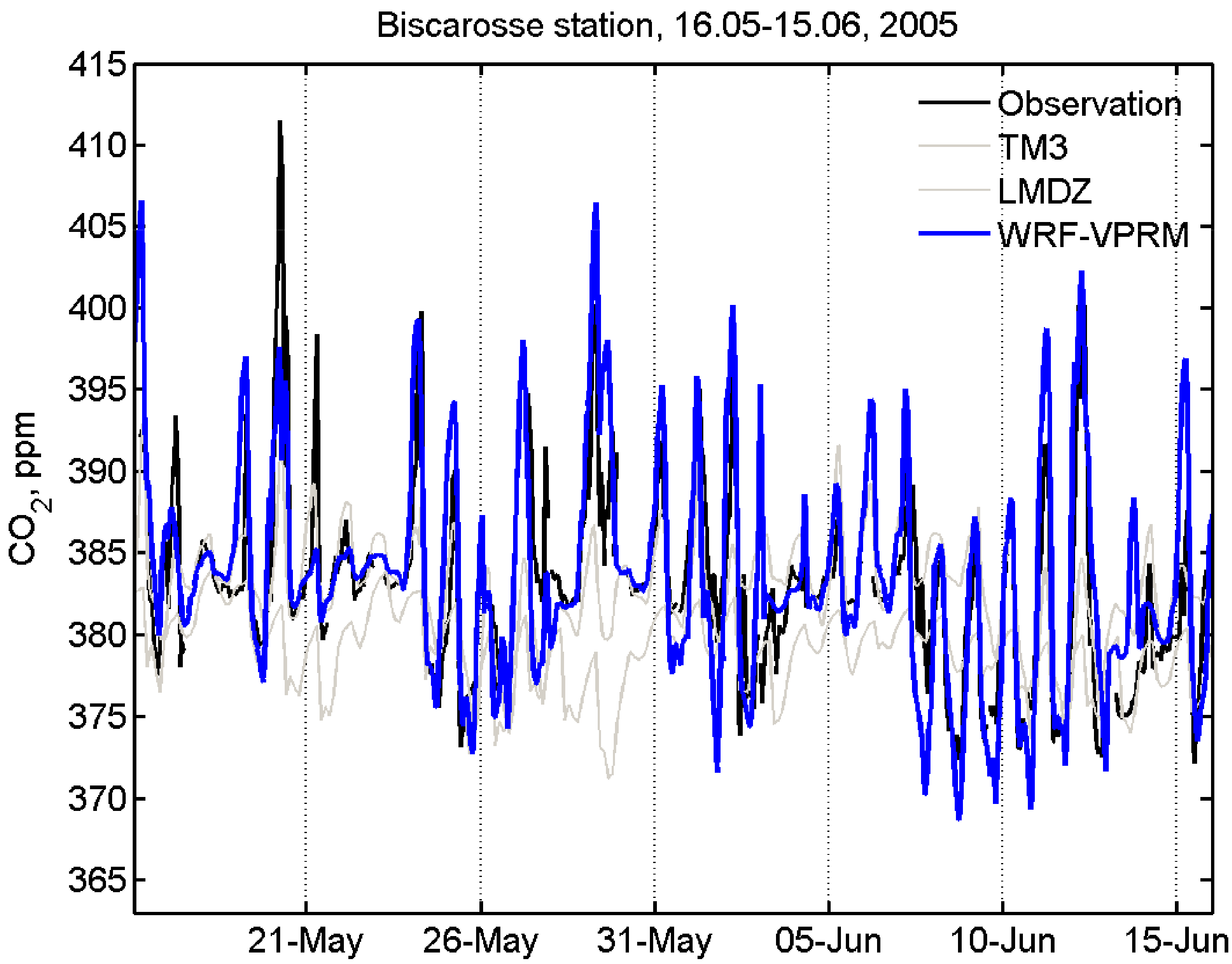
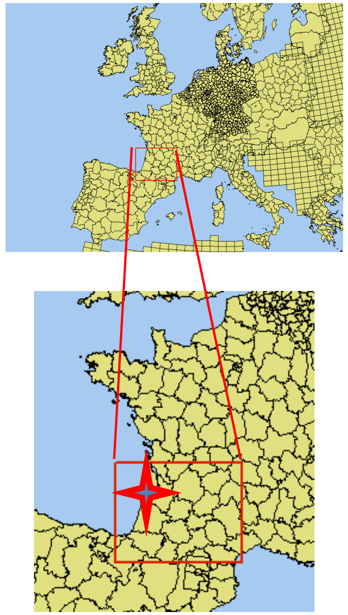
Lessons from CarboEurope: increasing resolution helps



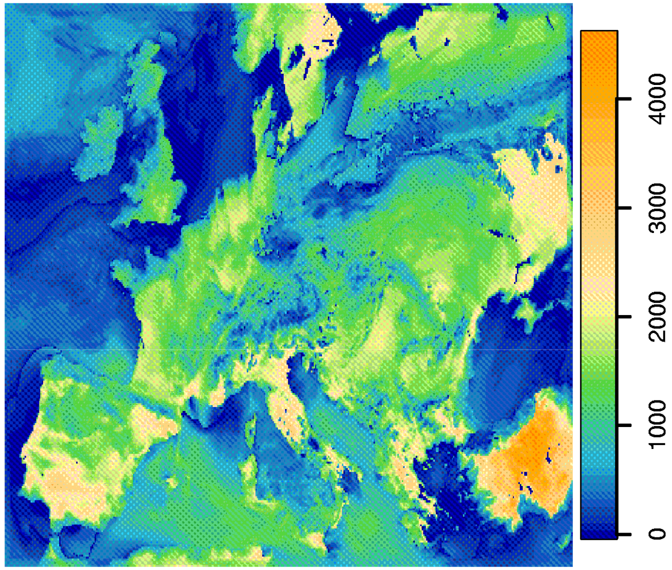


[Ahmadov et al., 2008]

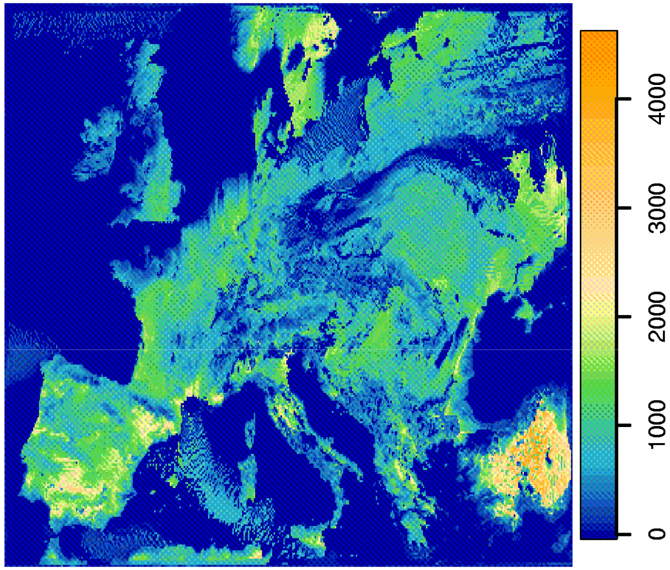
Uncertainties involved (continental stations)

Source of uncertainty	Type	Magnitude	Reference
Transport Model	Advection	~ 5 ppm (summertime)	Lin and Gerbig, 2005
	PBL mixing	~ 5 ppm (summertime)	Gerbig et al, 2007
	Convection	?	
Transport Model + Flux Model	Grid resolution	~ 1 ppm @ 200km (summertime)	Gerbig et al., 2003
Flux Model	Aggregation	depending on Aggregation and Model	Gerbig et al., 2006
Measurement	Precision, accuracy	0.1 ppm (targeted)	WMO
fossil fuel CO_2 signal across EU		~0.5 ppm (annual average)	

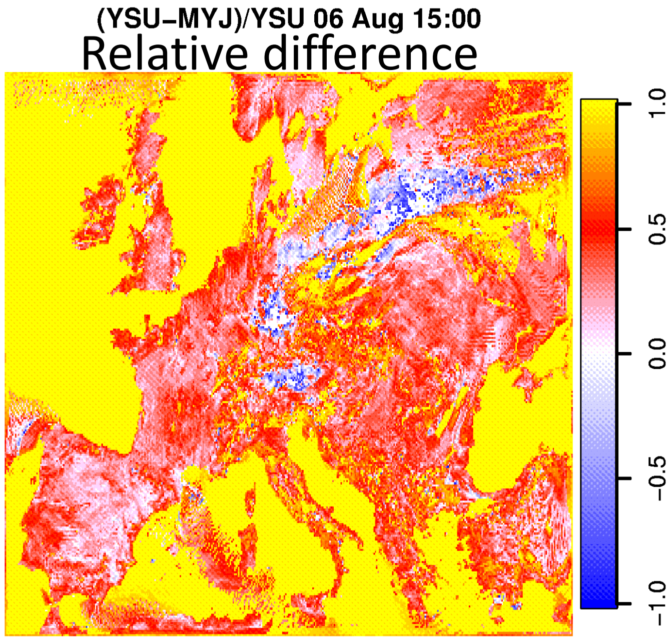
YSU scheme mixing height



MYJ scheme mixing height

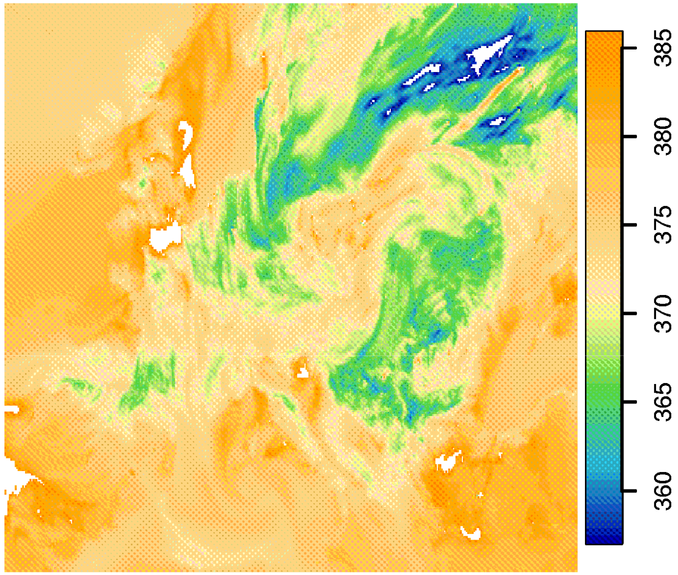


Relative difference

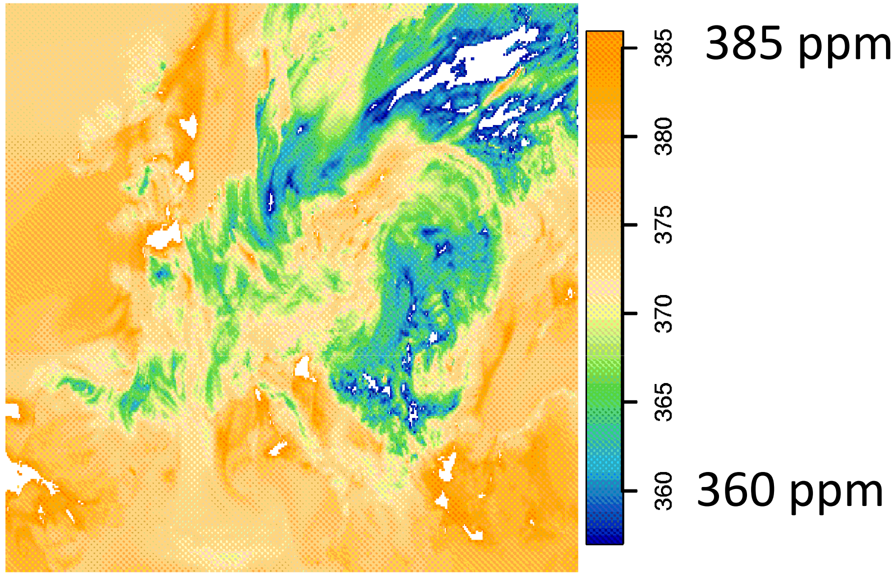


Example impact PBL scheme: mixing height (6th Aug 06, 15:00)

YSU scheme CO_2

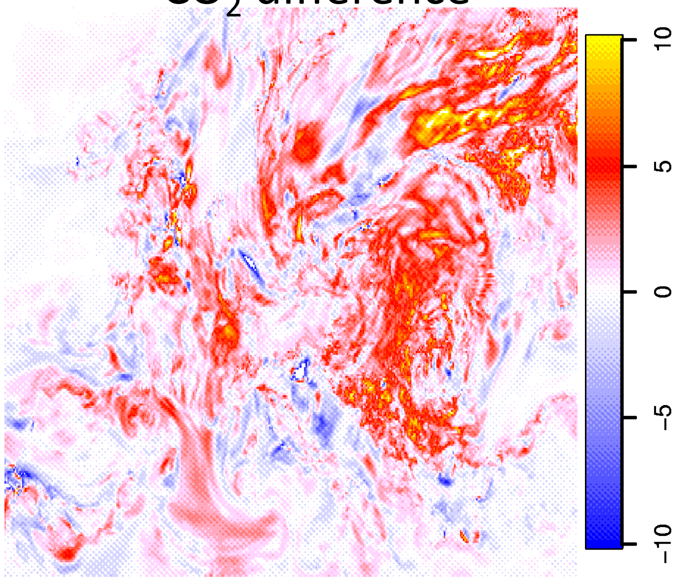


MYJ scheme CO_2



YSU–MYJ 06 Aug 15:00

CO_2 difference

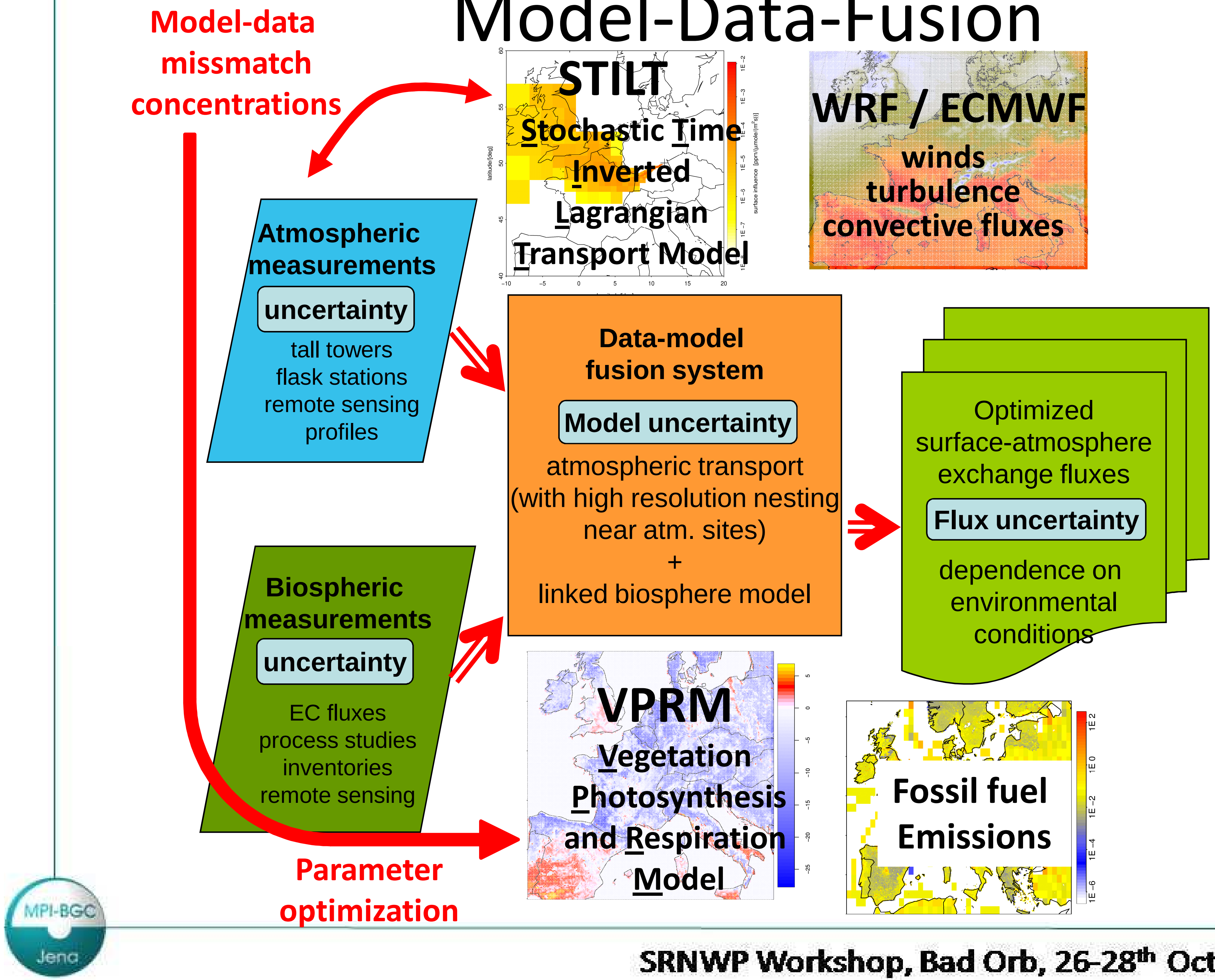


Example impact PBL scheme: CO_2, 2nd model level (~60m)

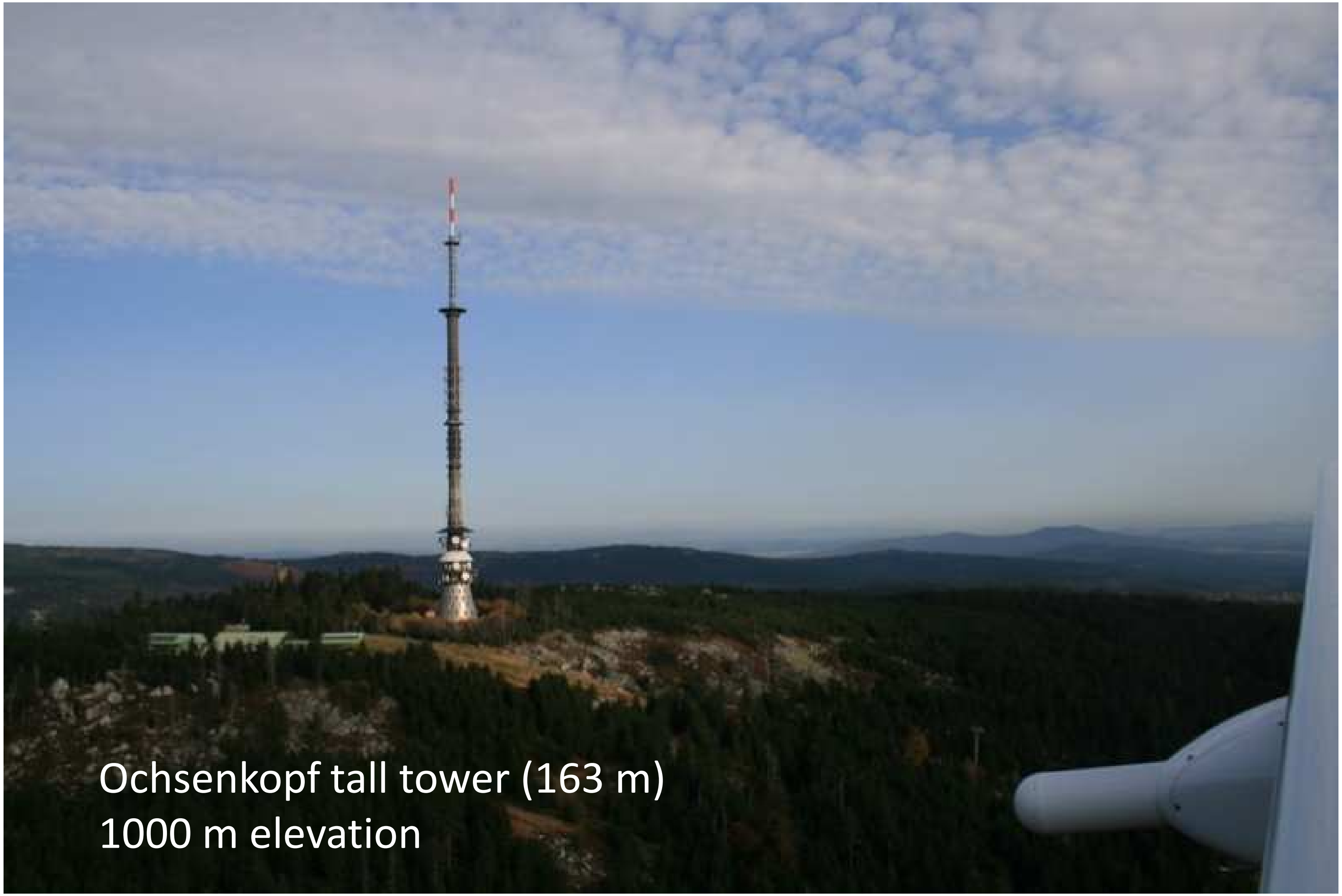
Use observational constraint for mixing height:

- network of ceilometers (cheap Lidars)
- radiosonde derived mixing heights

Model-Data-Fusion



Eulerian + Lagrangian vs. observations



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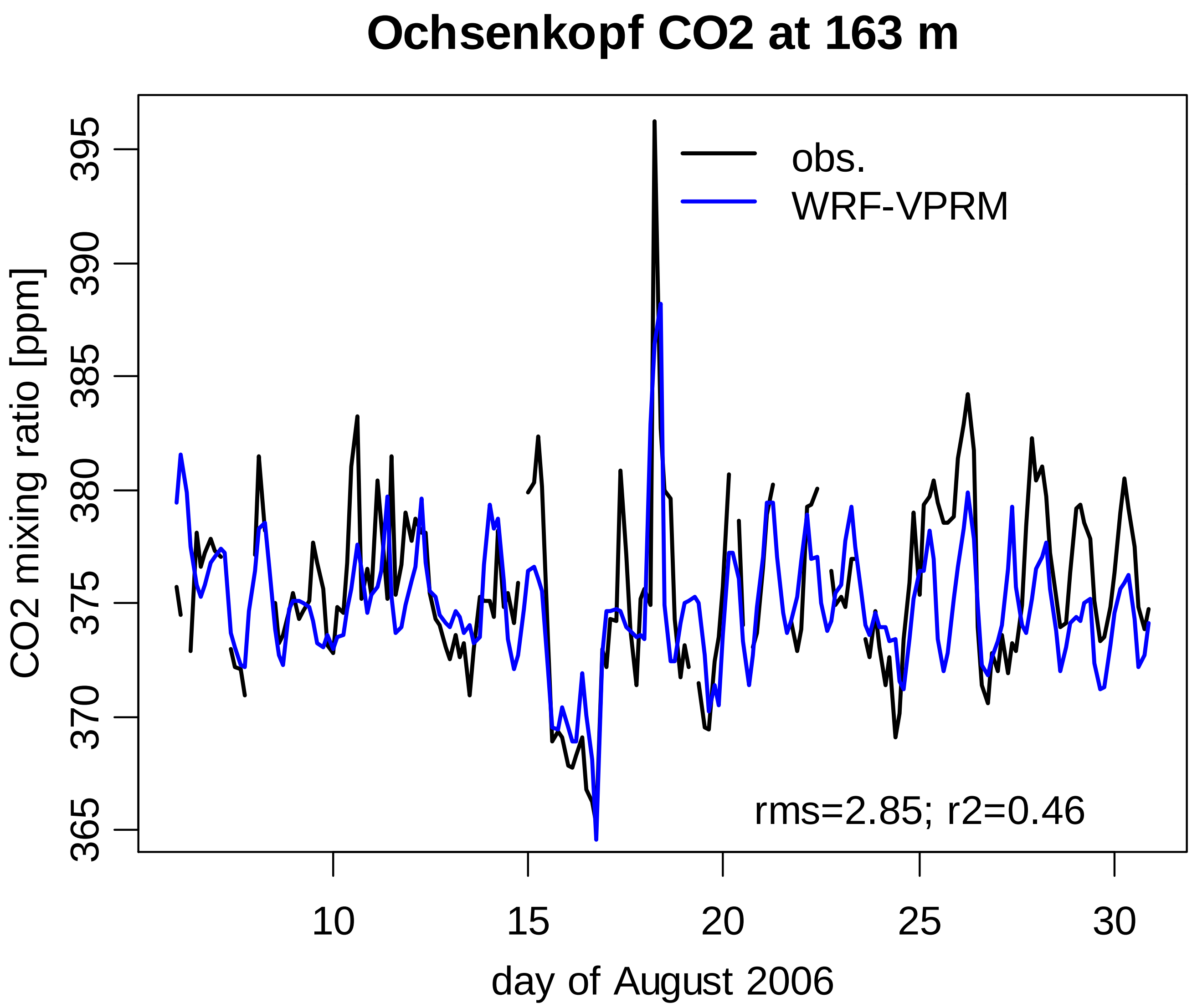
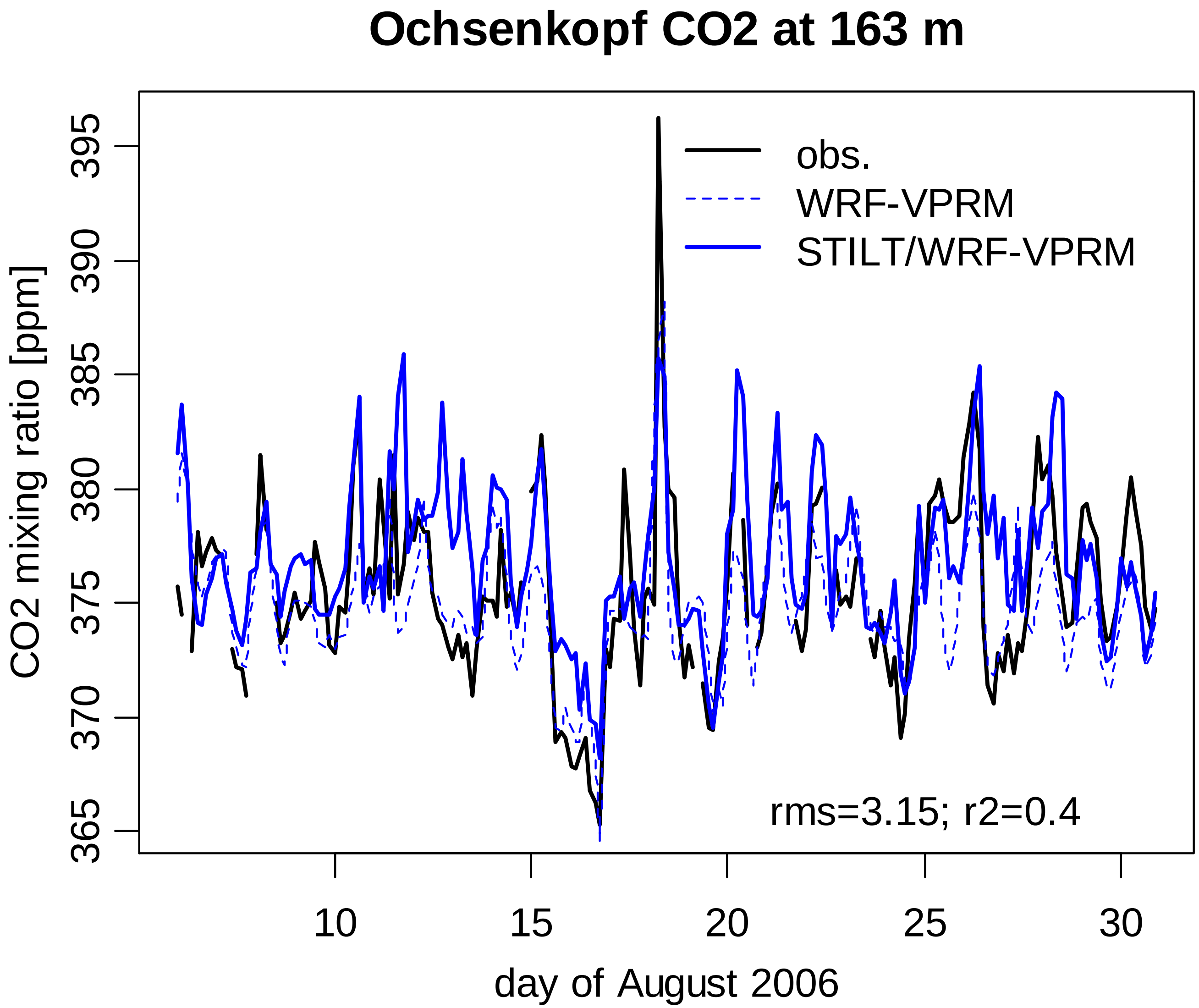


Eulerian + Lagrangian vs. observations



closing remarks

- Regional flux estimation for CO_2 require high resolution models:
  - mesoscale transport phenomena
  - better representation of observing sites
  - fluxes (models) needed at high resolutions, bridging gap to ecosystem measurements
- Mesoscale transport simulations indicate significant performance increase compared to global simulations
- Transport model improvement required
  - Mixing heights (additional data)
- STILT/WRF as transport adjoint for WRF:
  - Inconsistencies to be traced


Thank you!
19/11/2008

WRF-VPRM modeling system setup

Vertical coordinates	Terrain-following hydrostatic pressure vertical coordinate
Basic equations	Non-hydrostatic, compressible
Grid type	Arakawa-C grid
Time integration	3^{rd} order Runge-Kutta split-explicit
Spatial integration	3^{rd} and 5^{th} order differencing for vertical and horizontal advection respectively; both for momentum and scalars; positive definite scheme for moisture and tracers
Domain configuration	the horizontal resolution – 10 km; size 2500x2300 km 30 vertical layers up to 100 mb;
Time step	60 sec
Physics schemes	Radiation - Rapid Radiative Transfer Model (RRTM) Longwave and Dudhia; Microphysics - WSM 3-class simple ice scheme; Cumulus - Kain-Fritsch (new Eta) scheme PBL – YSU; Surface layer – Monin-Obukhov Land-surface – NOAH LSM