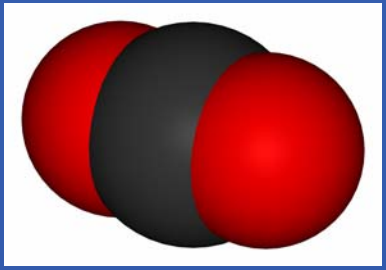

ATMOSPHERIC CO_2 TRANSPORT SIMULATION BY WRF-VPRM: A HIGH PRECISION TRACER FOR WRF VALIDATION

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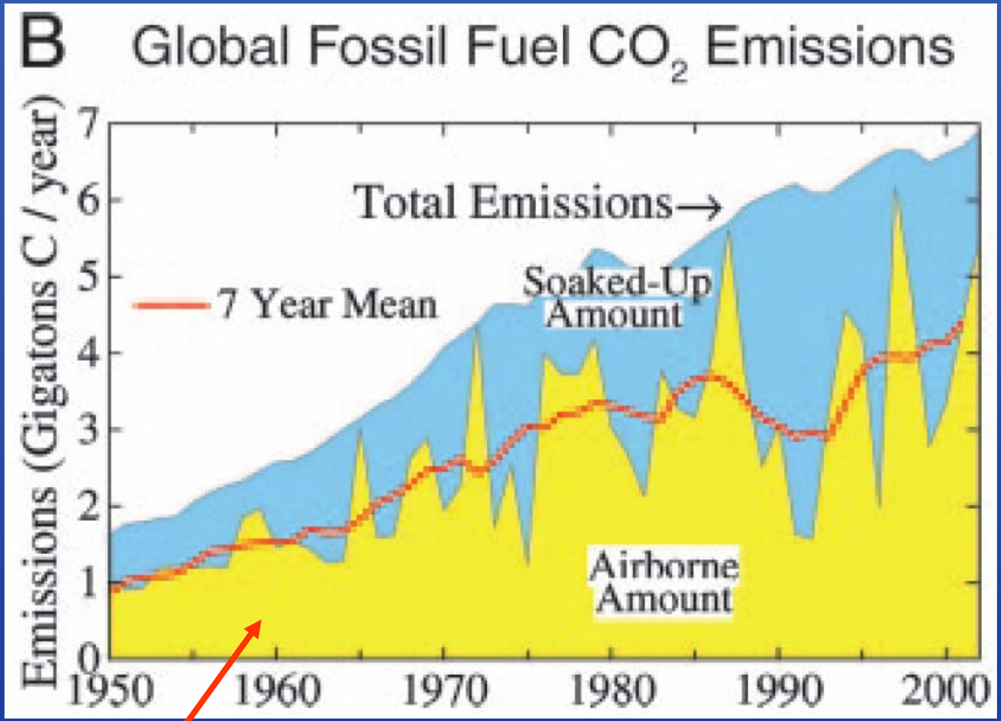
WRF workshop, 2007

Motivation

Scientific questions:

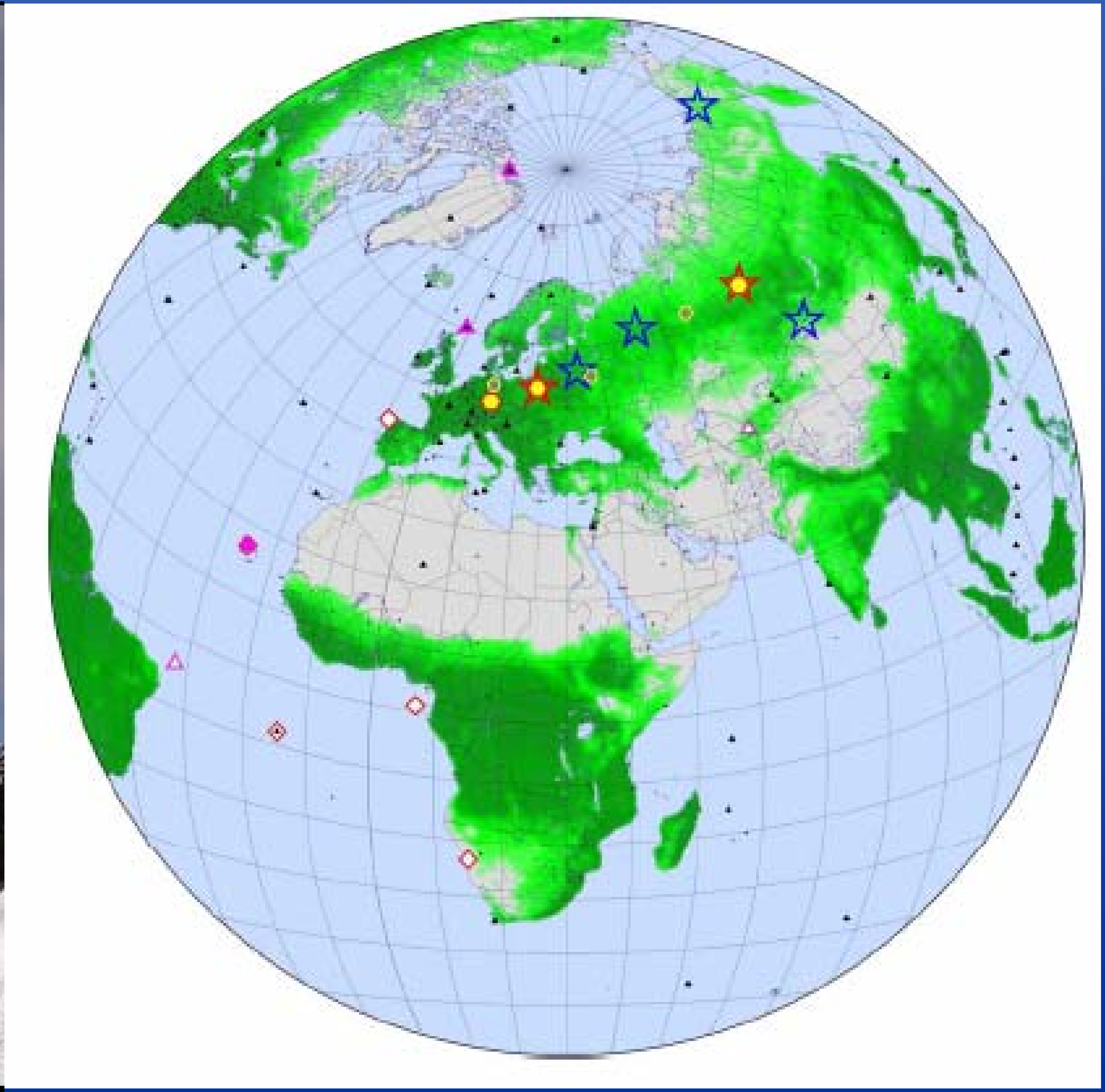
- Where and by which processes is anthropogenic CO_2 sequestered?
- What are the main feedback processes between carbon cycle and climate system?
- What is the carbon budget of a specific region (continent/country)?



[Hansen and Sato, 2004]

Variable “Airborne fraction“

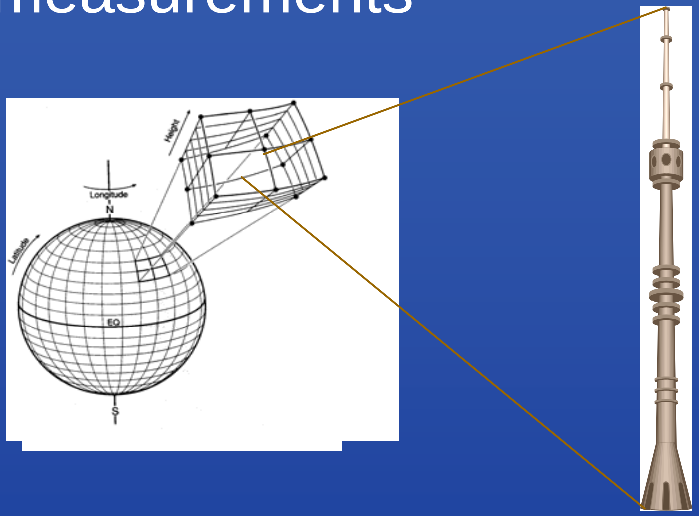
ATMOSPHERIC CO_2 MONITORING NETWORK



Courtesy of M. Heimann

Motivation and main goals

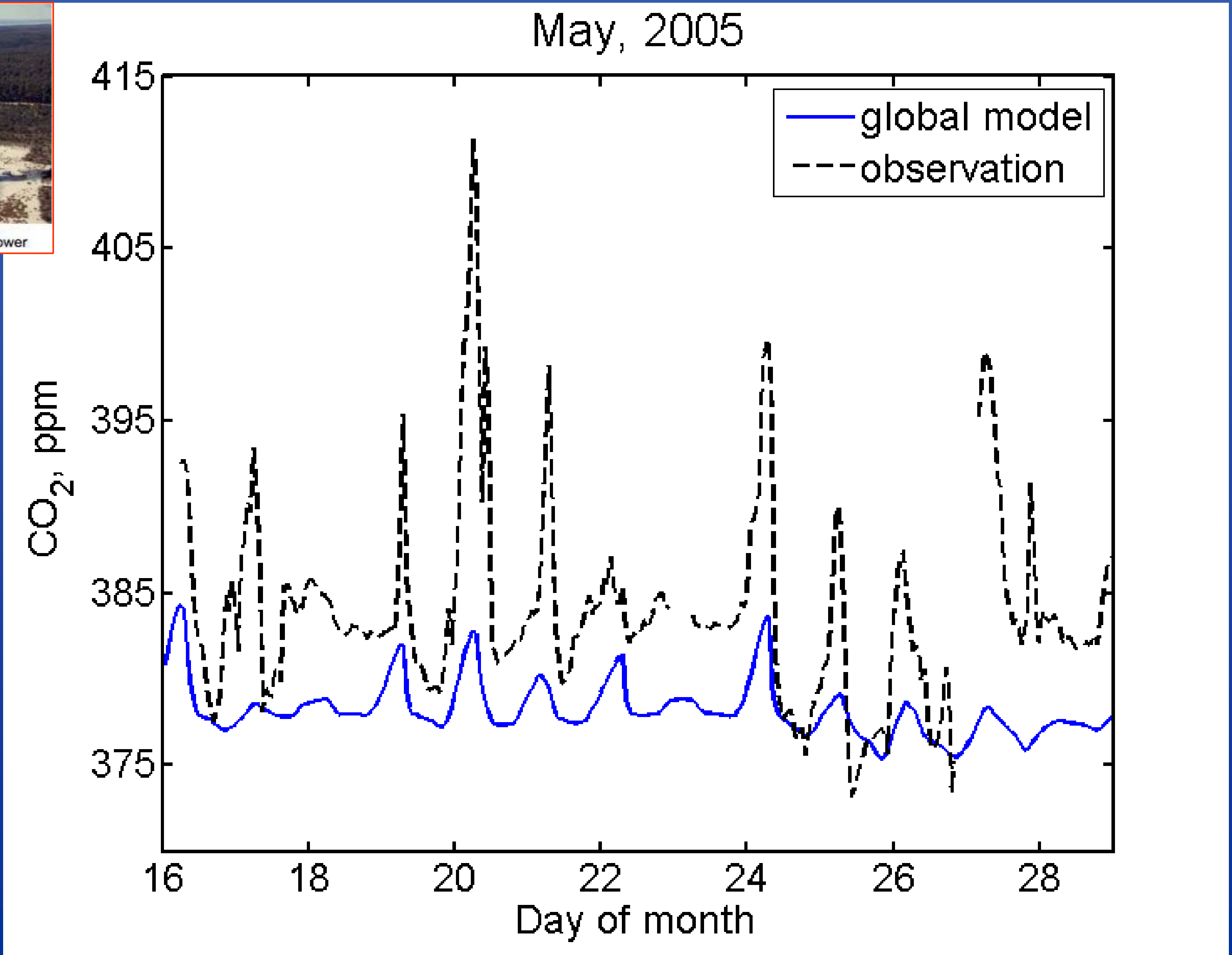
- Regional scale Carbon budget estimation requires:
  - interpreting regional signals in PBL measurements
  - dominant scales of variability:
    diurnal-synoptic (time)
    vegetation patterns (~ km)



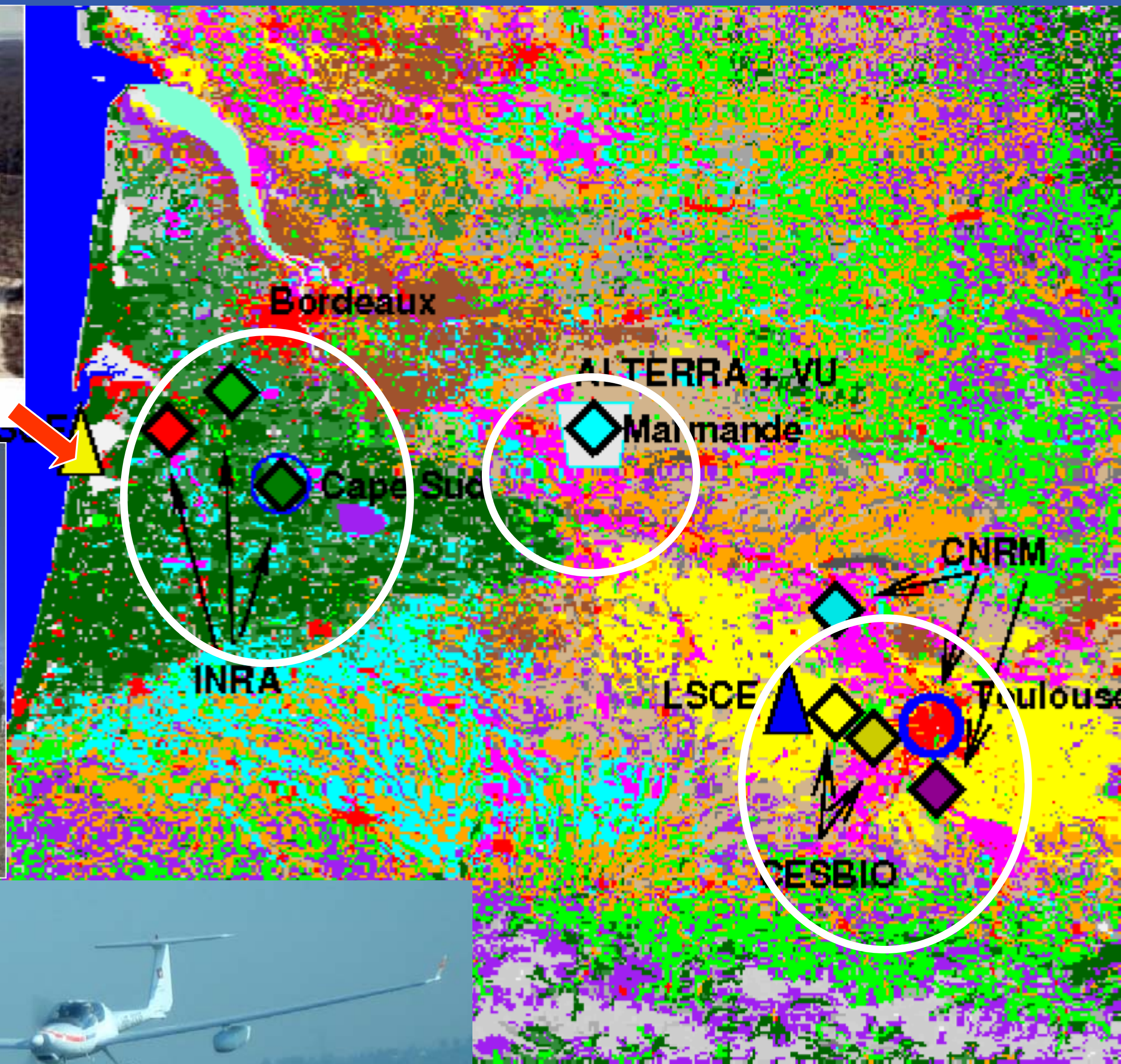
- The global models used in inversions aren‘t able to capture mesoscale effects due to the coarse resolution

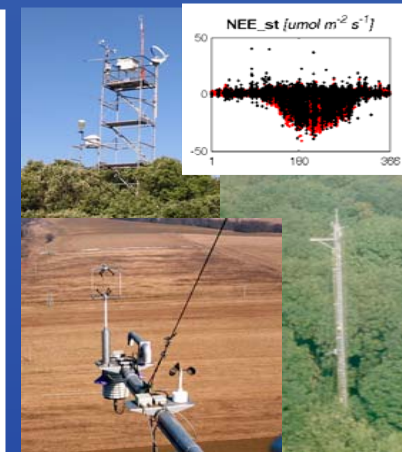
- Bridging the gap:
  - between tall tower and global model

Can we use a global model to interpret tall tower measurements?
LMDZ, horizontal resolution: 1.25° (longitude), 0.83° (latitude)



Carbo Europe Regional Experiment Strategy (CERES) campaign, May-June, 2005

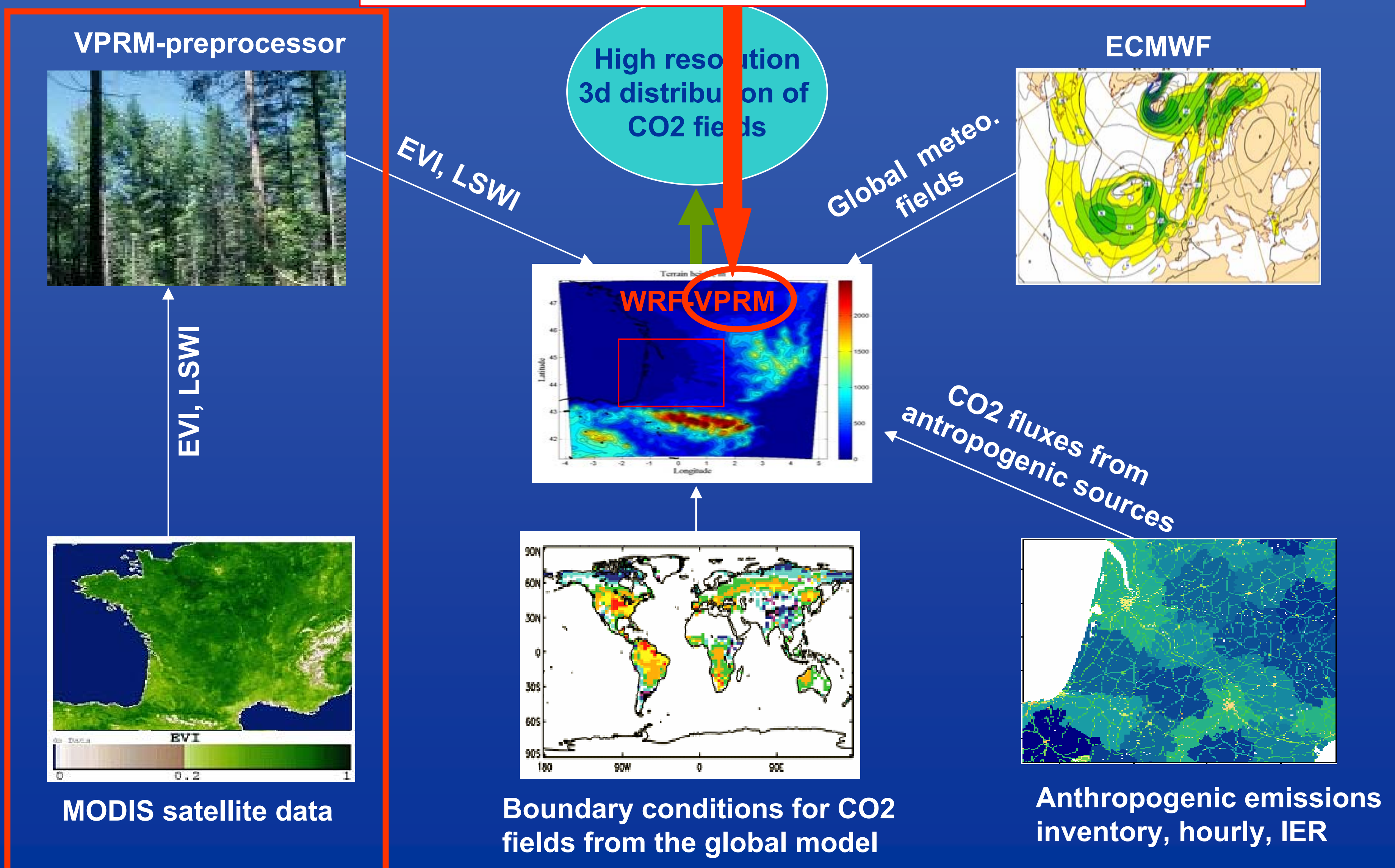




Forward CO_2 transport simulation particularities

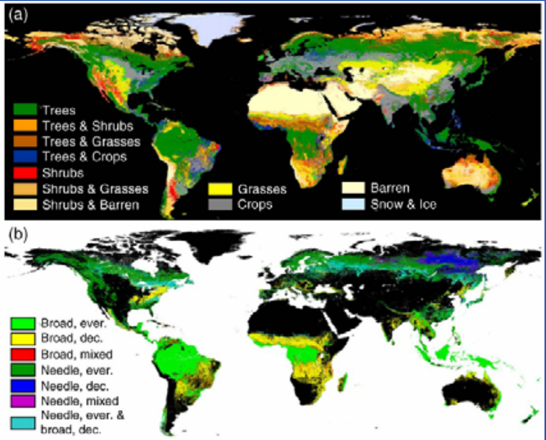
- No chemistry in the air, once it's in the air it may stay there hundreds of years until uptake by the biosphere or dissolving in the ocean;
- Availability of high-precision measurements (~ 0.1 ppm, diurnal change ~20 ppm);
- Very heterogeneous sources and sinks: vegetation, soil, water basins, urban areas;
- Strong diurnal variation of the biospheric fluxes;
- Correlation of biospheric fluxes with solar radiation, air temperature, cloudiness, humidity, soil moisture;

Vegetation Photosynthesis and Respiration Model (VPRM) provides biospheric CO_2 fluxes each time step to WRF



VPRM Vegetation Photosynthesis and Respiration Model

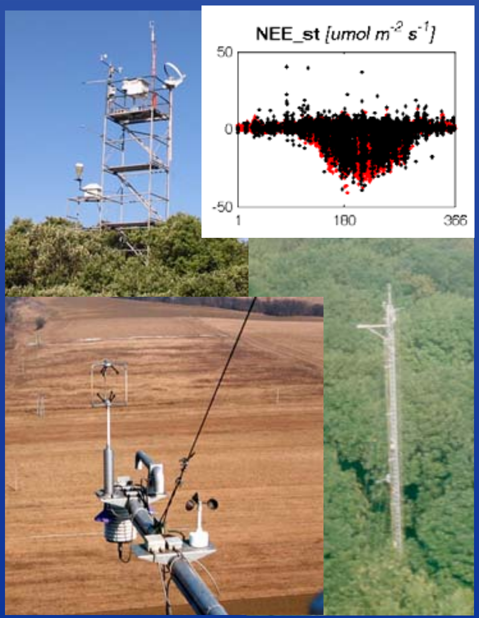
[Pathmathevan et al., submitted to GBC], based on Xiao et al. [2004]



SYNMAP land cover [Jung et al., 2006]

vegetation classes (5)

Optimization of parameters α, β, λ, and PAR_0



Eddy Cov. data [many CE site PI's]

$$NEE = GEE + R \leftarrow = \alpha \cdot T + \beta$$

WRF

$$\lambda \cdot \frac{PAR}{(1 + PAR/PAR_0)} \cdot \mathrm{Tscale}(T) \cdot \mathrm{Pscale}(LSWI, EVI) \cdot \mathrm{Wscale}(LSWI) \cdot EVI$$

MODIS surface reflectances 8 day, 500 m

Main questions:

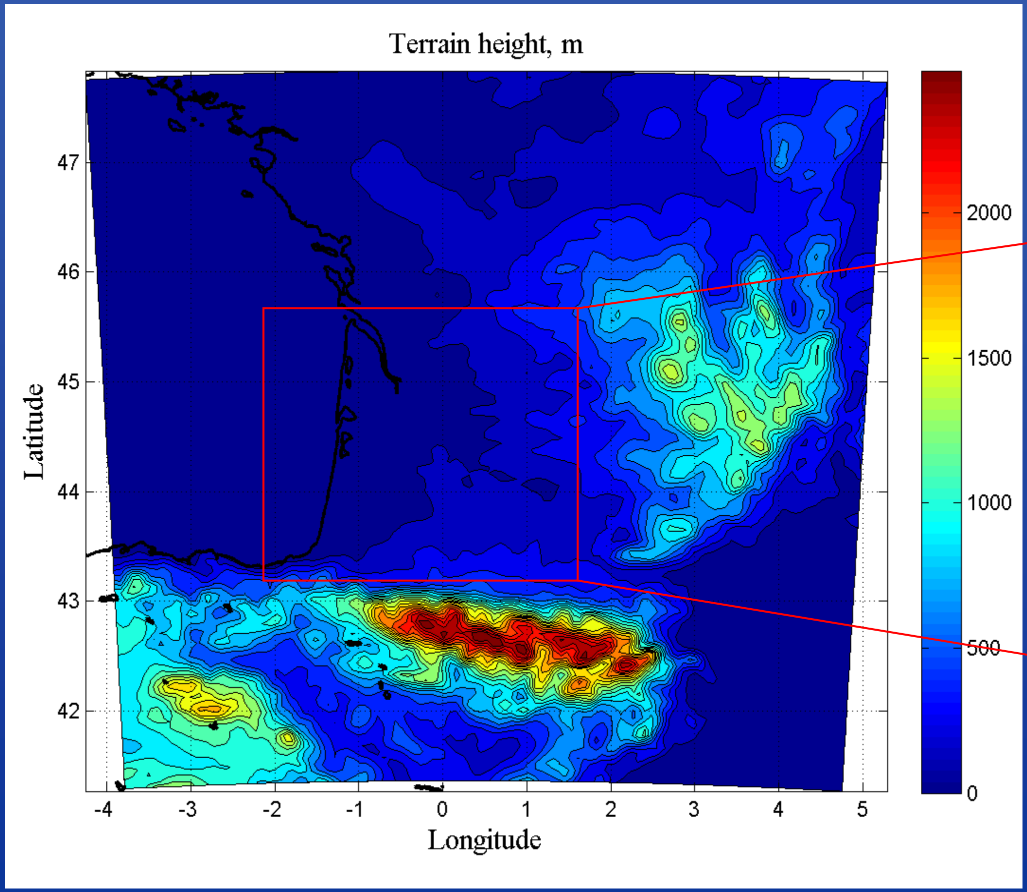
- What does the model show as CO_2 mesoscale circulation?
- Does it capture main features of the observed regional distribution of CO_2 concentration?
- What can we learn from the model by distribution of CO_2 in different type of “artificial” tracers?

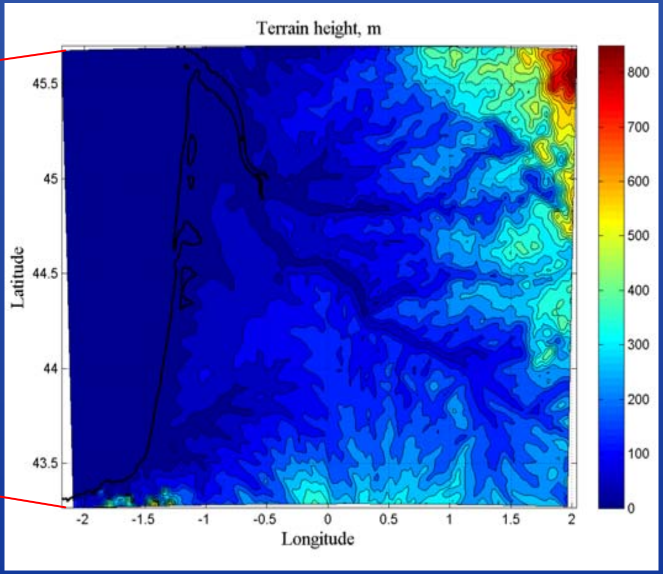
WRF domains for CERES study

10 km, 690x690 km

50 vertical levels, 20 in lowest 2 km

2 km, 320x280 km





WRF modeling system setup

Vertical coordinates	Terrain-following hydrostatic pressure vertical coordinate
Basic equations	Non-hydrostatic, compressible
Grid type	Arakawa-C grid
Time integration	3rd order Runge-Kutta split-explicit
Spatial integration	3rd and 5th order differencing for vertical and horizontal advection respectively; both for momentum and scalars
Domain configuration	2 domains with resolution – 10 and 2 km for outer and inner domains respectively; size 690x690 km and 320 x 280 km; 51 vertical levels for both domains up to 150 mb;
Time step	60 and 12 sec for outer and inner domains respectively
Physics schemes	Radiation - Rapid Radiative Transfer Model (RRTM) Longwave and Dudhia; Microphysics - WSM 3-class simple ice scheme; Cumulus - Kain-Fritsch (new Eta) scheme (only for the coarse domain!) PBL – YSU; Surface layer – Monin-Obukhov Land-surface – NOAH LSM

WRF-VPRM setup

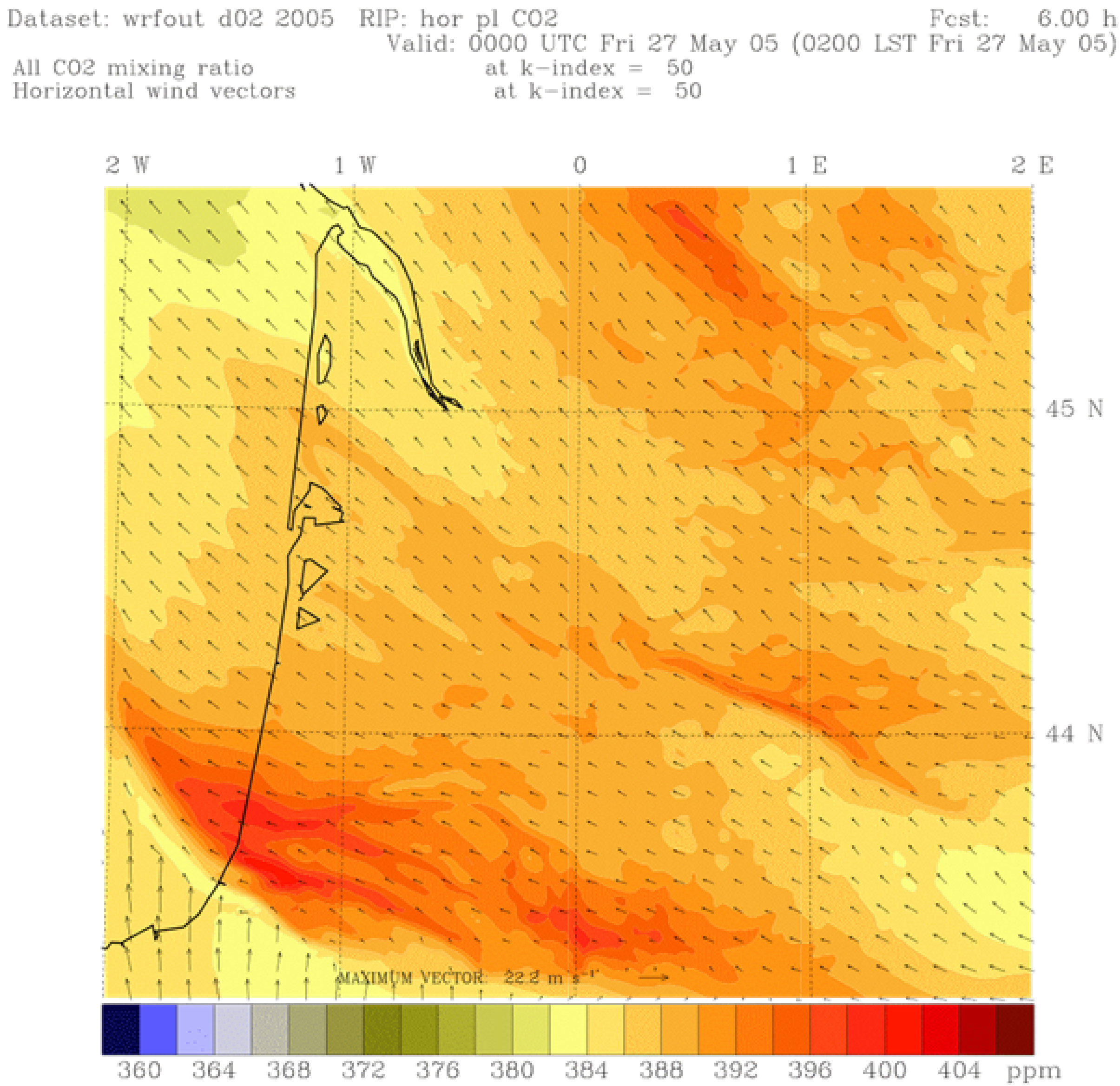
- Five components of CO_2 in WRF-VPRM:
  - Global background CO_2
  - Anthropogenic CO_2
  - VPRM respiration CO_2
  - VPRM photosynthesis CO_2
  - Total CO_2

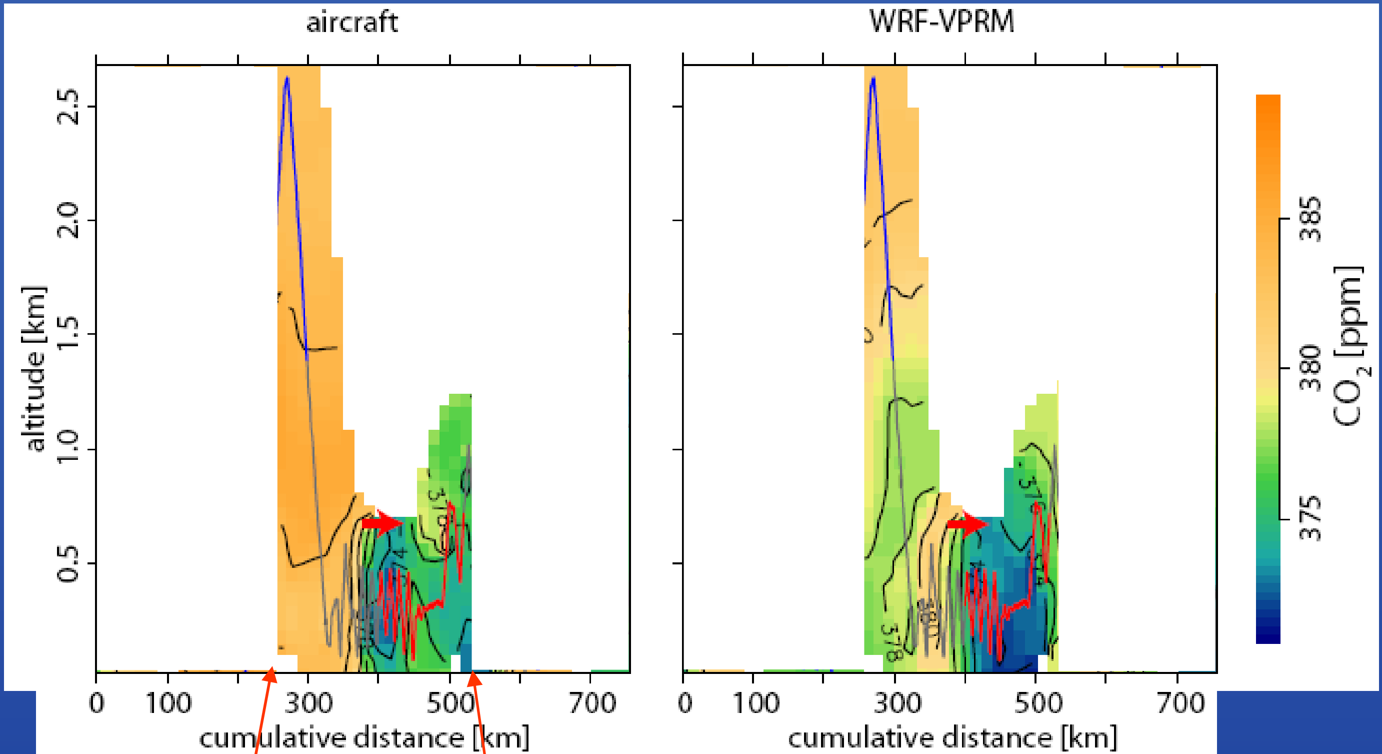
- ICs and LBSc from global model for total CO_2

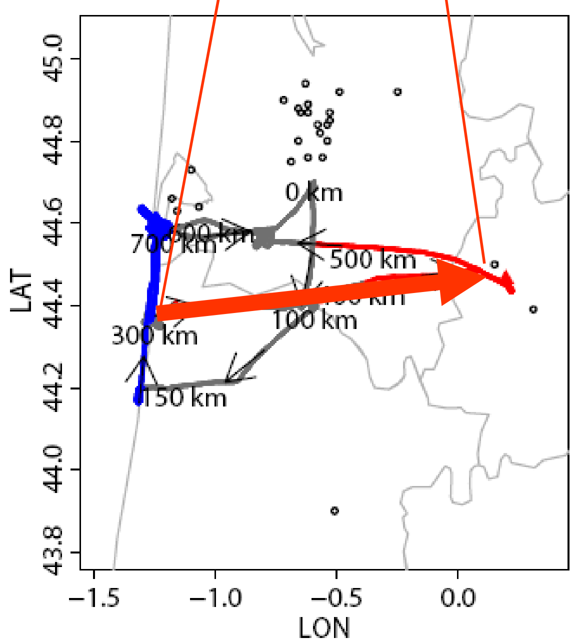
- Zero ICs and zero-gradient outflow, zero-inflow LBCs for other components

6 hours for spin-up

CO_2 concentration and wind field near the surface, May-27, 2005



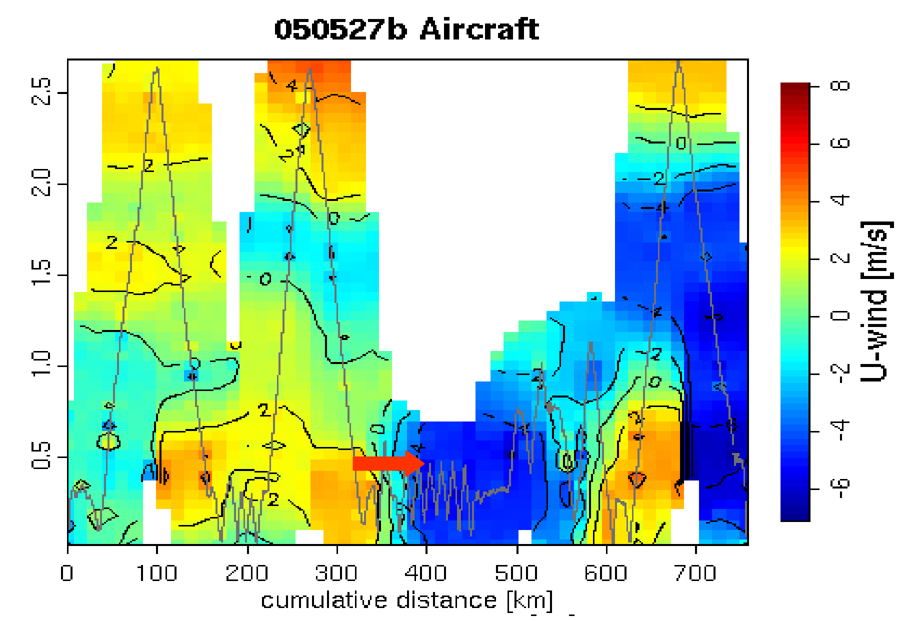


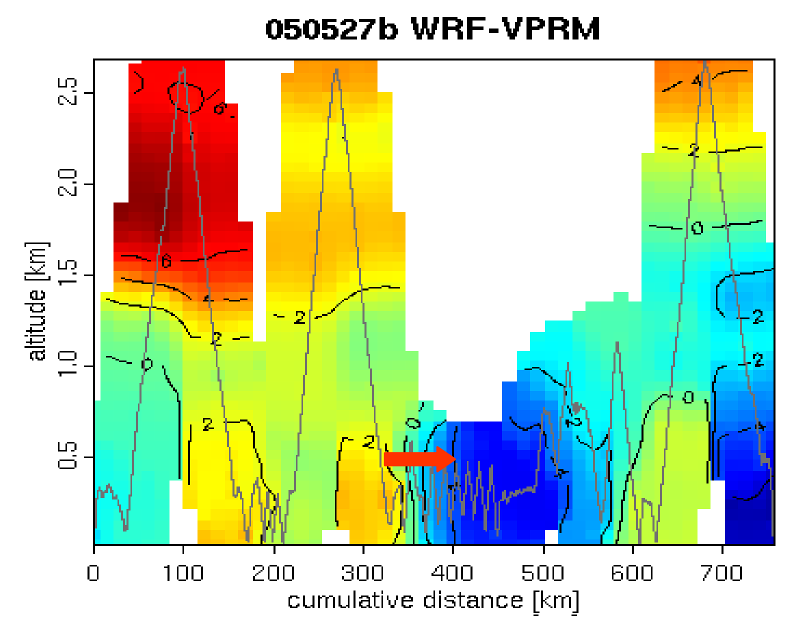


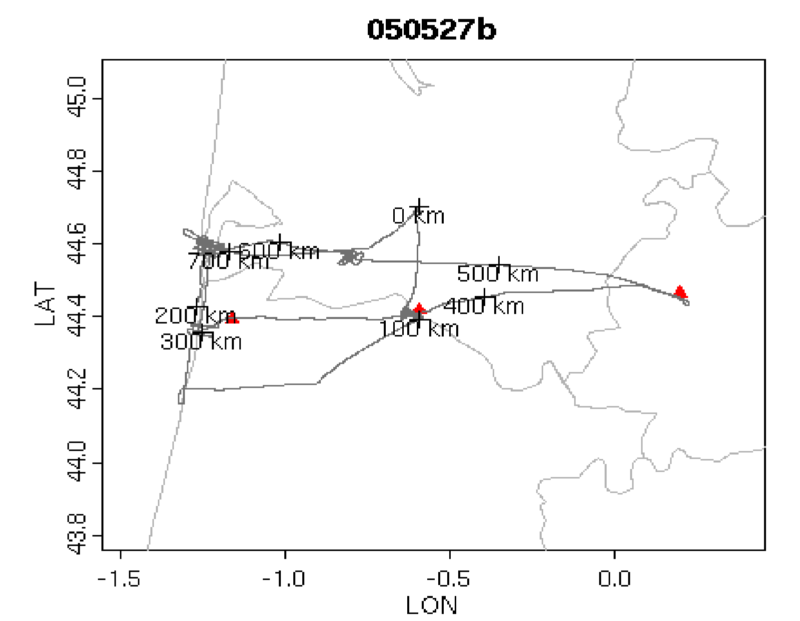
27th May 2005, afternoon flight

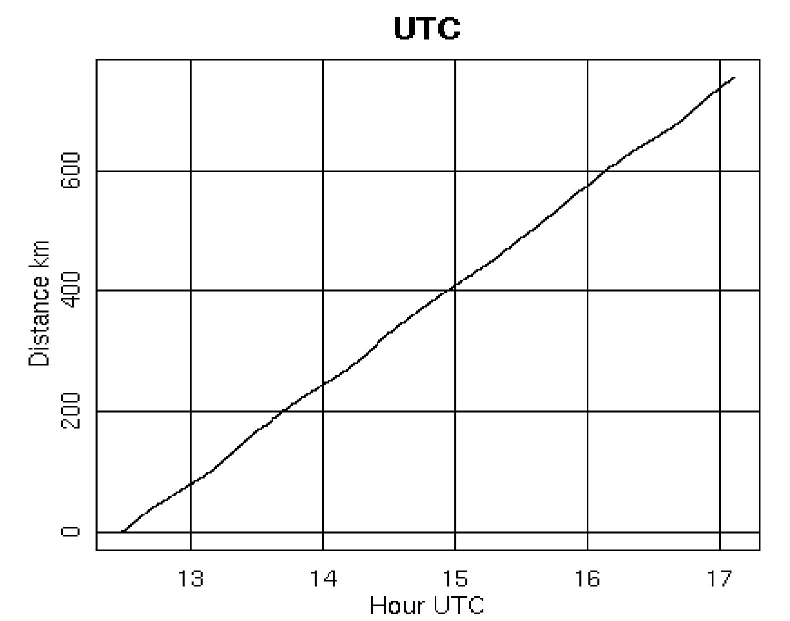
Ahmadov et al., Submitted to JGR

27th May 2005, afternoon flight

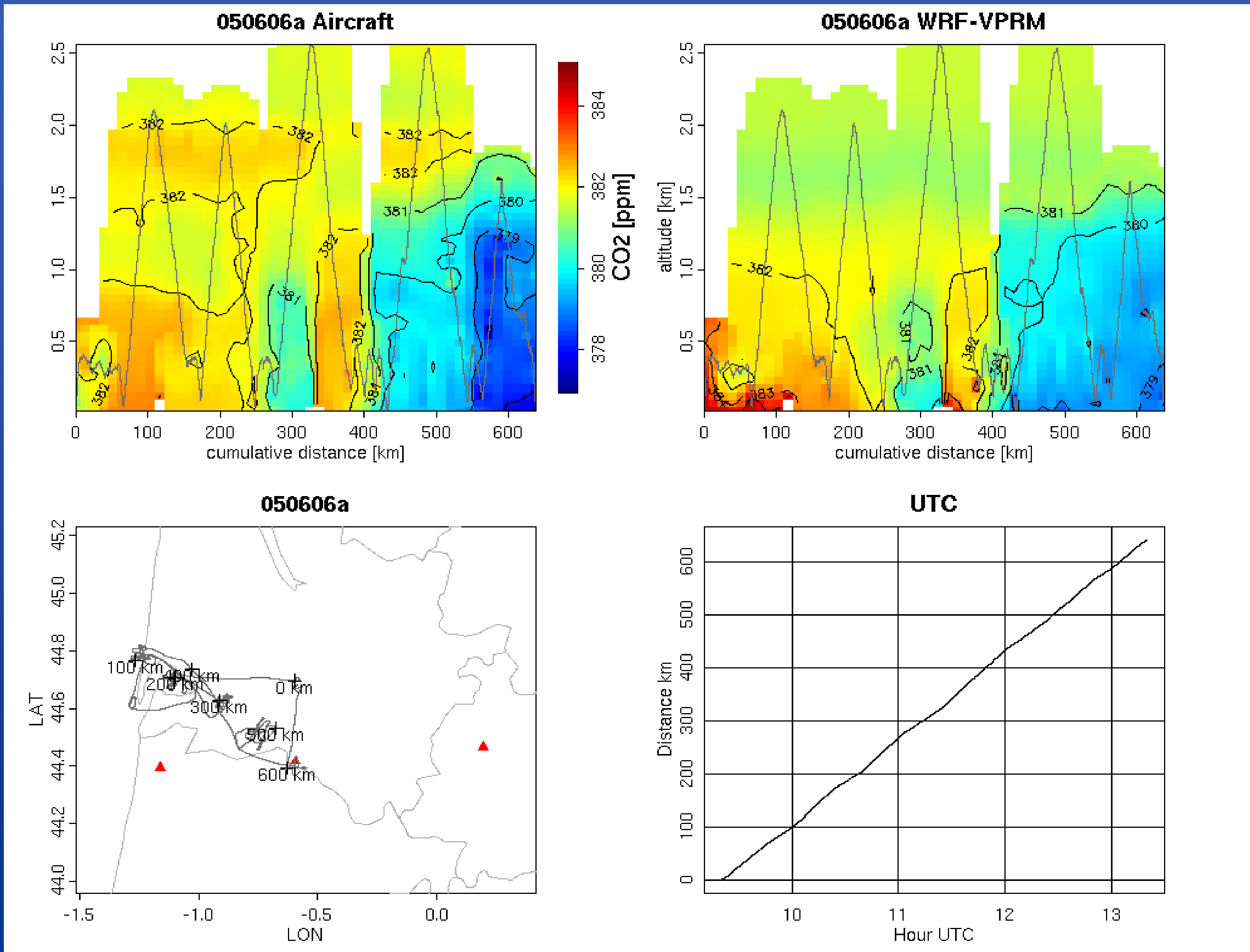




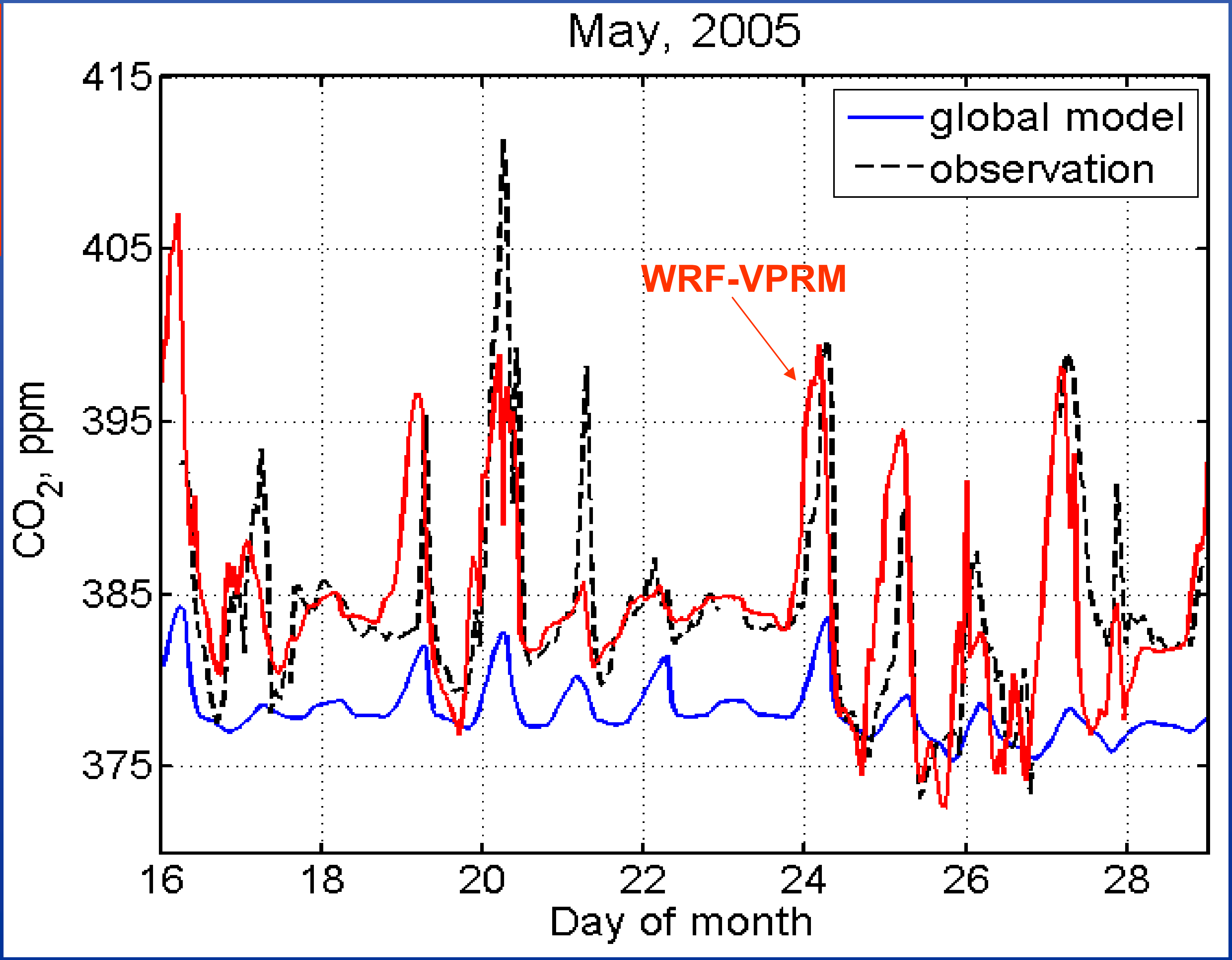




IOP4, flight 6th June 2005



A tower made CO_2 measurement interpretation by using global model – LMDZ, horizontal resolution: 1.25° (longitude), 0.83° (latitude)



Intercomparison between 5 coupled mesoscale models (Sarrat et al., 2007)

T2M	03H		06H		09H		12H		15H		18H		Mean/24H	
	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias
MNH-CNRM	4.3	-2.2	3.0	-1.7	2.7	-0.8	3.4	0.2	3.8	0.9	4.0	-0.4	3.4	-0.8
WRF-MPI	3.6	0.0	2.3	0.1	2.3	-0.7	3.0	-1.3	3.4	-1.6	4.4	-2.3	3.2	-0.8
RAMS-AMVU	4.5	-2.4	4.3	-3.1	2.5	-0.6	3.6	2.1	4.2	2.8	3.4	0.6	3.8	0.4
RAMS-ALTE	6.0	-4.7	6.4	-5.8	6.1	-5.3	4.7	-3.4	4.0	-2.3	4.0	-1.8	4.9	-3.4
RAMS-CEAM	3.7	-1.7	3.4	-2.6	2.5	-1.1	2.7	-0.2	3.1	-0.6	3.6	-1.5	3.1	-1.2

Table 2: RMS and bias on T2M at 3, 6, 9, 12, 15 and 18H UTC and a mean on 24H.

HU2M	03H		06H		09H		12H		15H		18H		Mean/24H	
	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias
MNH-CNRM	25.7	-7.3	23.4	-9.9	15.4	2.1	15.5	1.7	10.8	-1.6	12.6	-0.1	18.9	-3.0
WRF-MPI	28.4	-15.5	22.2	-10.6	14.5	1.7	15.4	4.5	14.2	8.1	19.0	15.5	19.8	2.2
RAMS-AMVU	31.3	20.5	27.1	14.9	22.6	15.2	17.3	5.1	12.5	2.4	25.9	19.1	22.9	11.7
RAMS-ALTE	23.5	4.0	23.1	10.1	20.0	12.9	18.3	11.4	15.6	11.5	13.4	9.2	19.8	8.3
RAMS-CEAM	33.6	27.0	30.4	23.8	17.7	12.2	13.8	5.5	12.3	7.1	21.5	19.2	23.7	17.7

Table 3: RMS and bias on HU2M at 3, 6, 9, 12, 15 and 18H UTC and a mean on 24H.

SUMMARY:

- WRF model is able to capture mesoscale redistribution of CO_2
- VPRM captures main spatiotemporal variability in CO_2 fluxes
- CO_2 measurement sites can be „contaminated“ by mesoscale flows

FUTURE:

- WRF-VPRM will be applied to tall tower sites
- WRF land-use data improvement, validation of different physics options
- WRF-CHEM passive tracer transport code will be used
- Estimation of regional C budgets through mesoscale inverse modelling by coupled WRF-VPRM-STILT (Stochastic Time Inverted Lagrangian Transport Model) modeling system

THANK YOU FOR THE ATTENTION!

Many thanks to B.Skamarock for providing us with his code of WRF used for CO transport simulation!