LMDZ for modelling of greenhouse gases & precursors : An overview of LSCE/INVSAT activities

P. Bousquet, F. Chevallier, I. Pison, P. Peylin, P. Ciais, R. Thompson, L. Rivier, A. Fortems-Cheiney, C. Carouge, C. Bacour, F.M. Bréon

Outline

Different model configurations

Modelling CO_2 cycle : forward modelling

Modelling CO_2 cycle : inverse modelling

Modelling CH_4 cycle

Other gases :

N_2O : talk by Rona Thompson

CO : talk by Audrey Fortems-Cheiney

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Forward modelling

PRIOR FLUXES

Forcing data

Meteo. data
Prior param.
calibration

Anthropogenic
and natural
sources & sinks

ATMOSPHERE
LMDZ - INCA

Atmospheric transport
& chemistry

Simulated mixing ratios

Comparison data

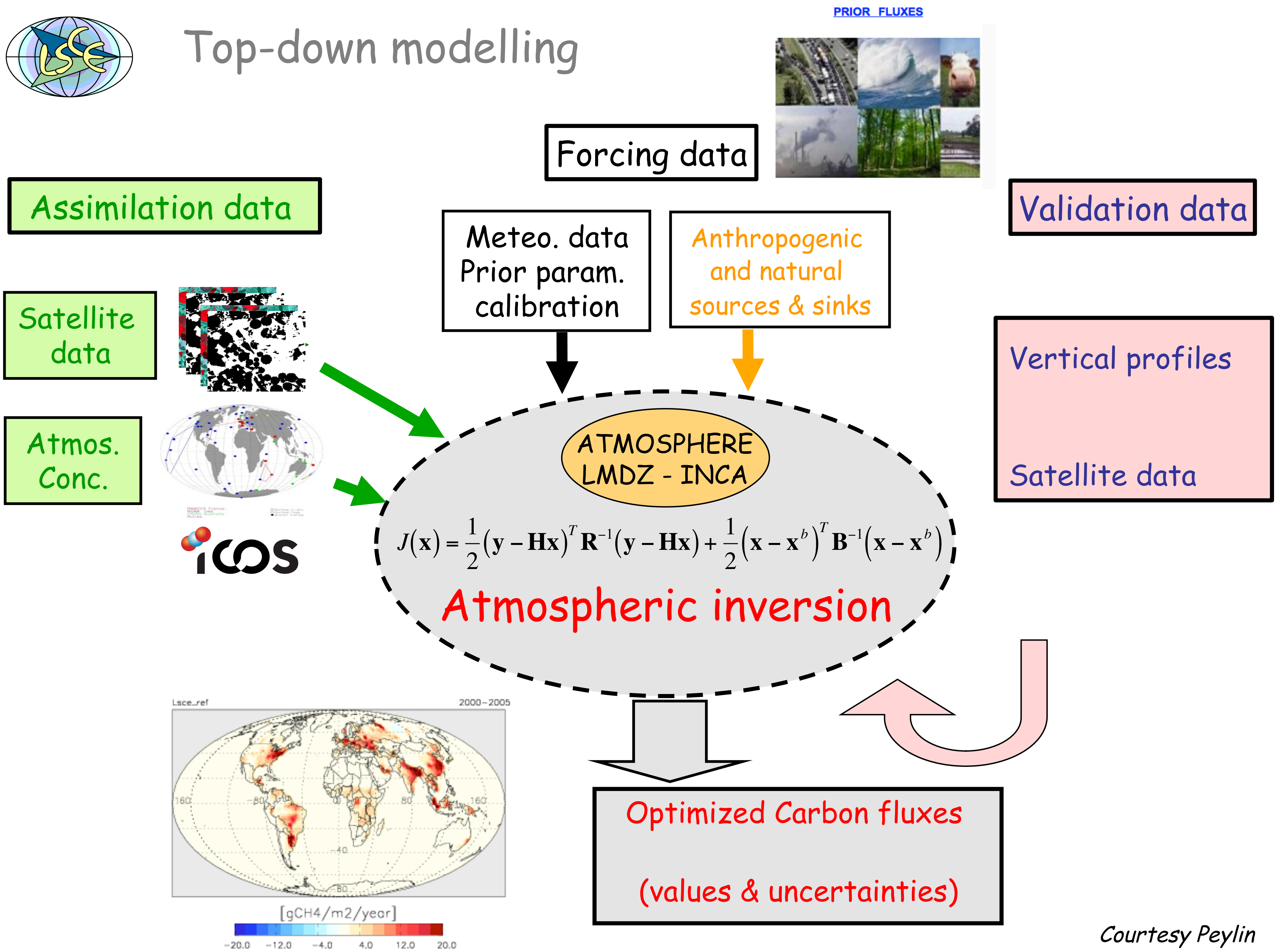
Vertical profiles

Surface data

Satellite data

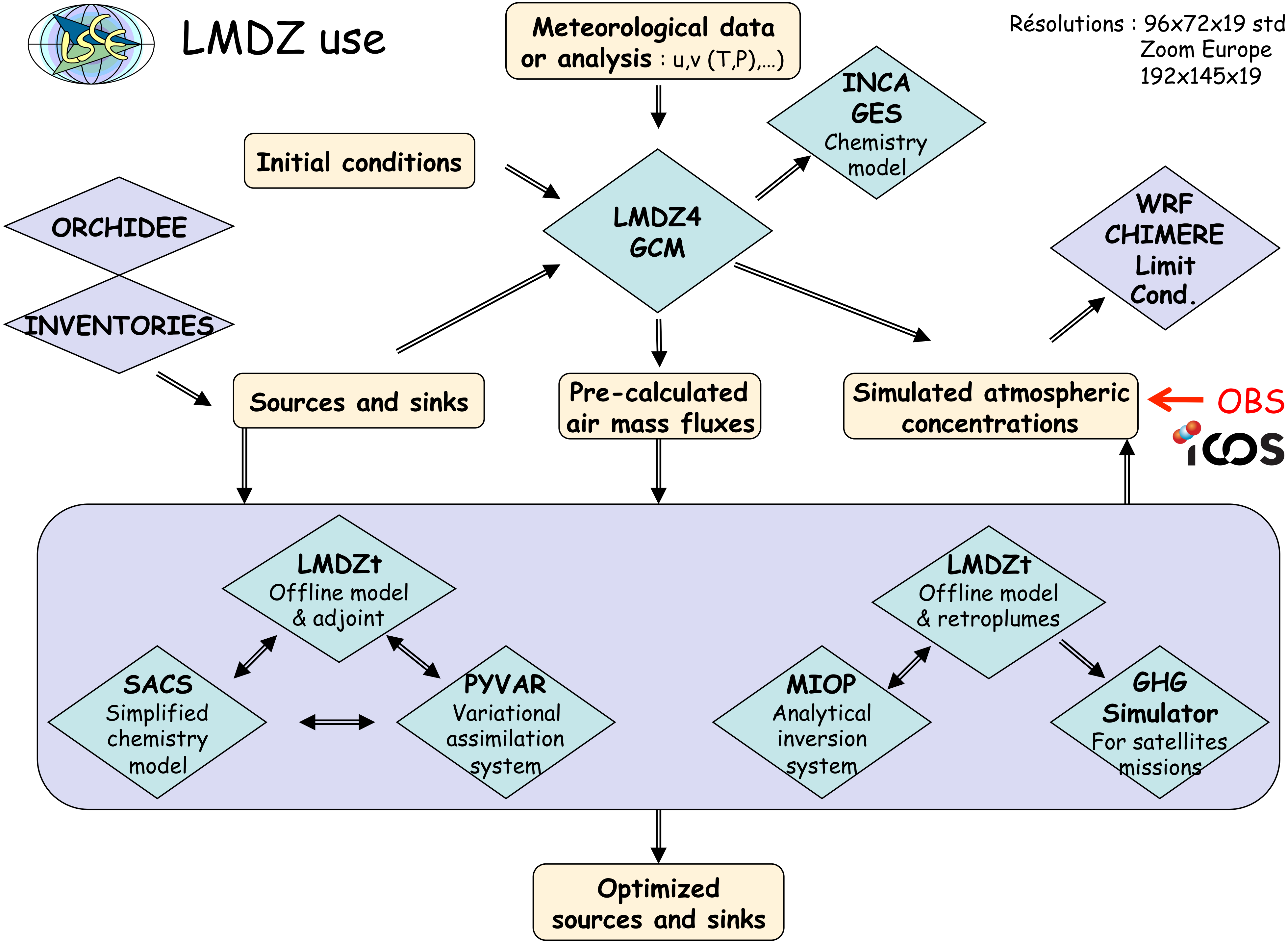
Courtesy Peylin

Top-down modelling



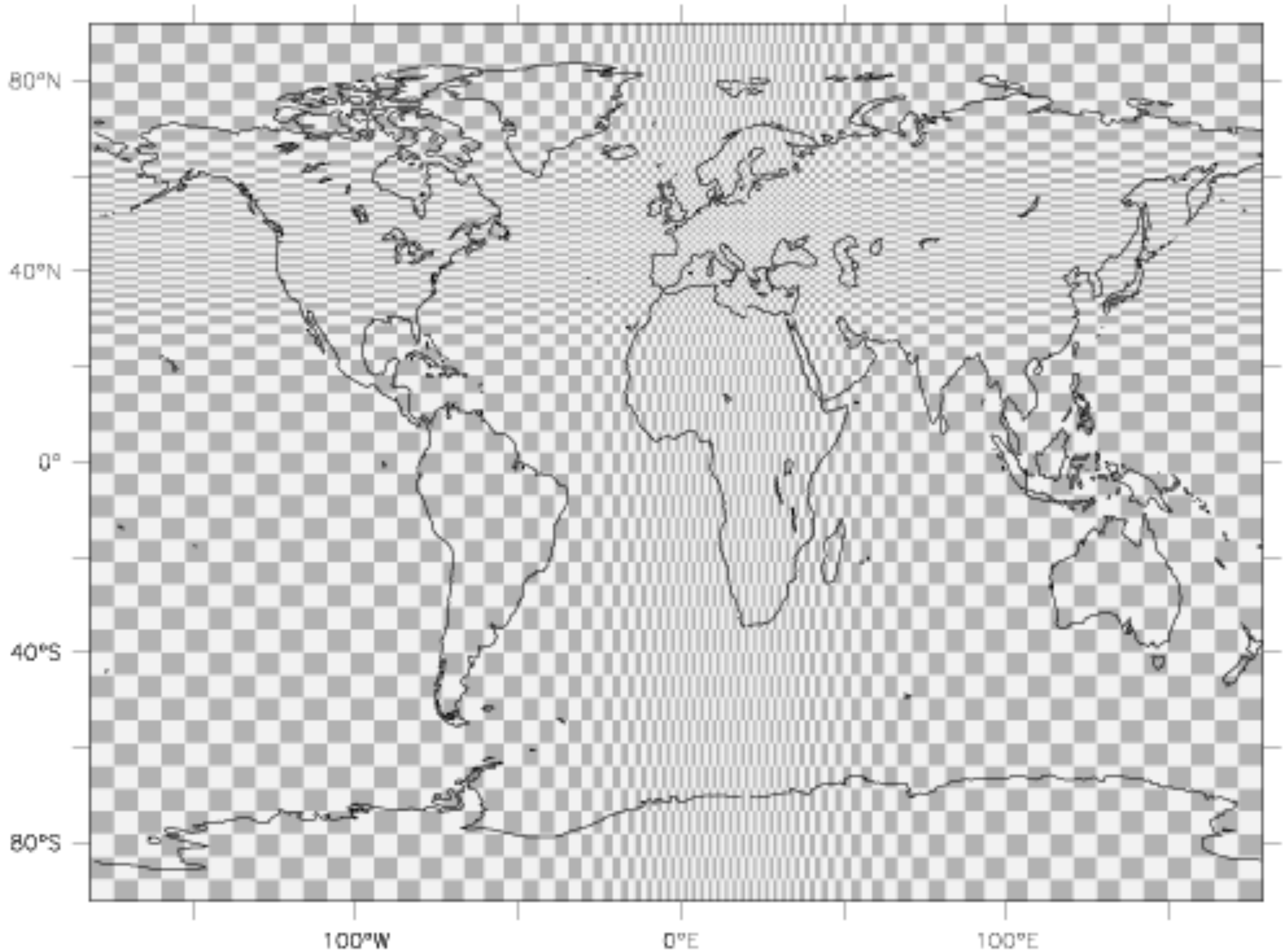
Courtesy Peylin

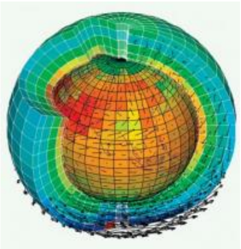
LMDZ use



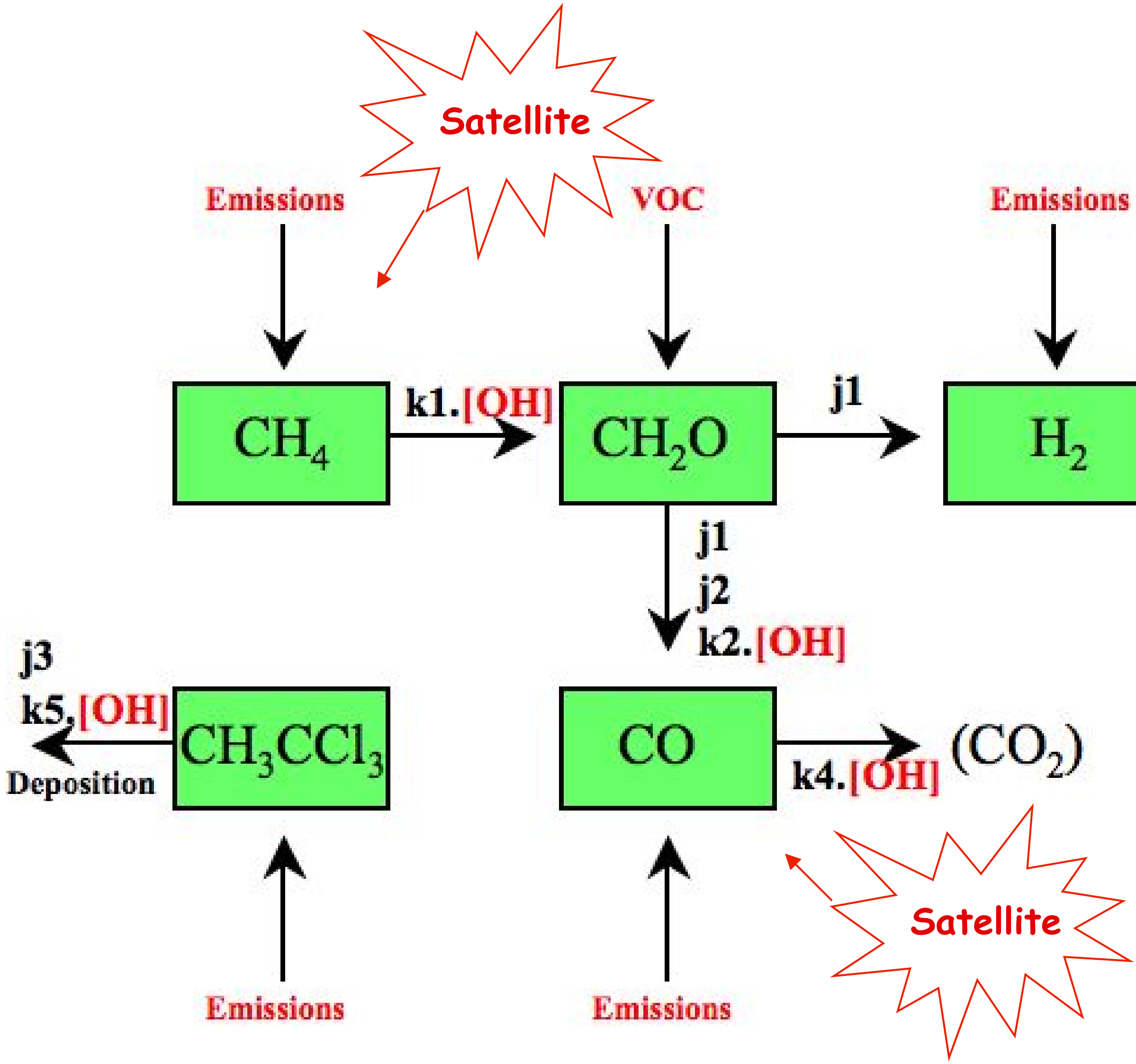
Meteorological data or analysis : u,v (T,P),...)
Résolutions : 96x72x19 std
Zoom Europe 192x145x19
INCA GES Chemistry model
Initial conditions
LMDZ4 GCM
ORCHIDEE
INVENTORIES
WRF CHIMERE Limit Cond.
Sources and sinks
Pre-calculated air mass fluxes
Simulated atmospheric concentrations
OBS
ICOS
LMDZt Offline model & adjoint
SACS Simplified chemistry model
PYVAR Variational assimilation system
LMDZt Offline model & retroplumes
MIOP Analytical inversion system
GHG Simulator For satellites missions
Optimized sources and sinks

Zoomed grid over Europe : 96x72





Multi-species simplified chemistry model



Pison et al., 2009

Hauglustaine, projet européen HYMN ; Chevallier, Bousquet, projet LEFE SACAS

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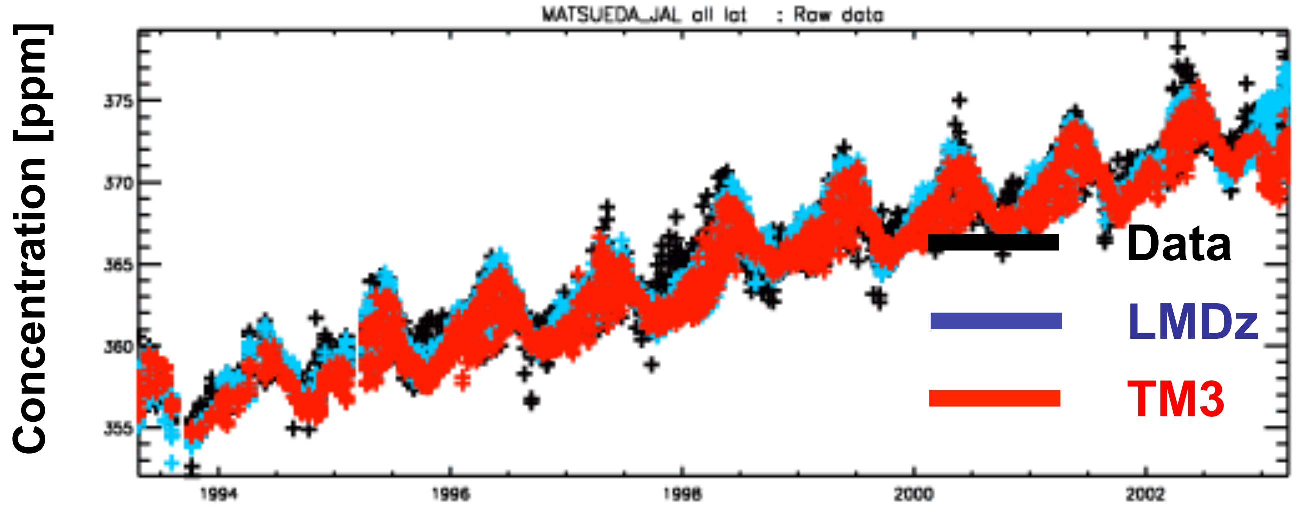
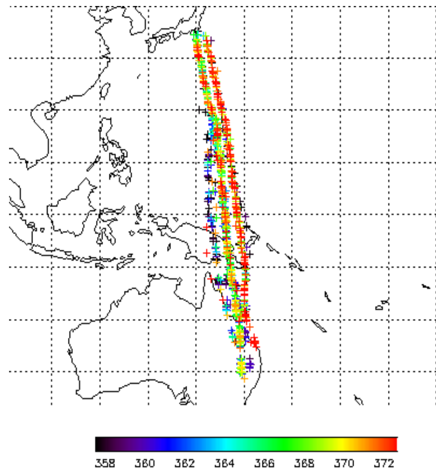
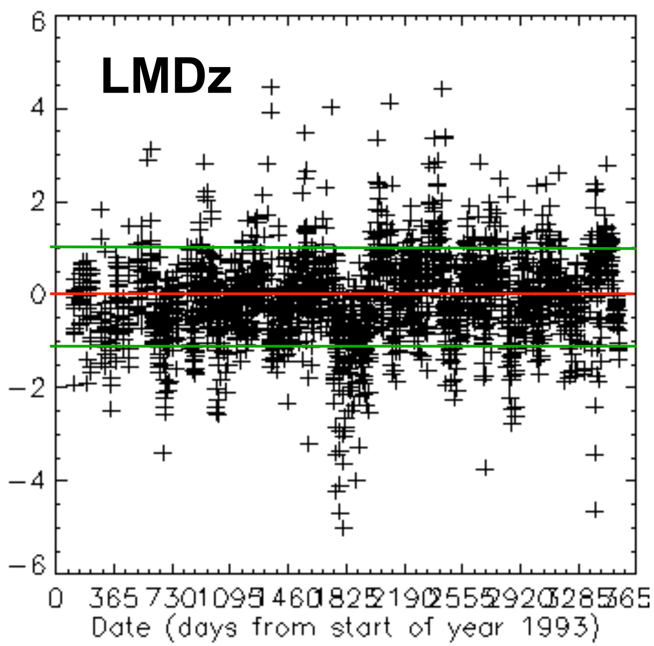
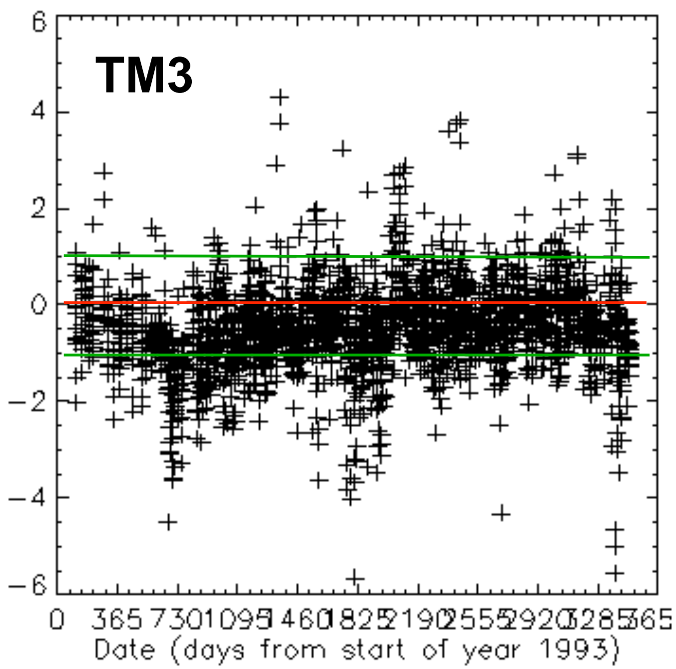
Upper air data





Model - data differences ?

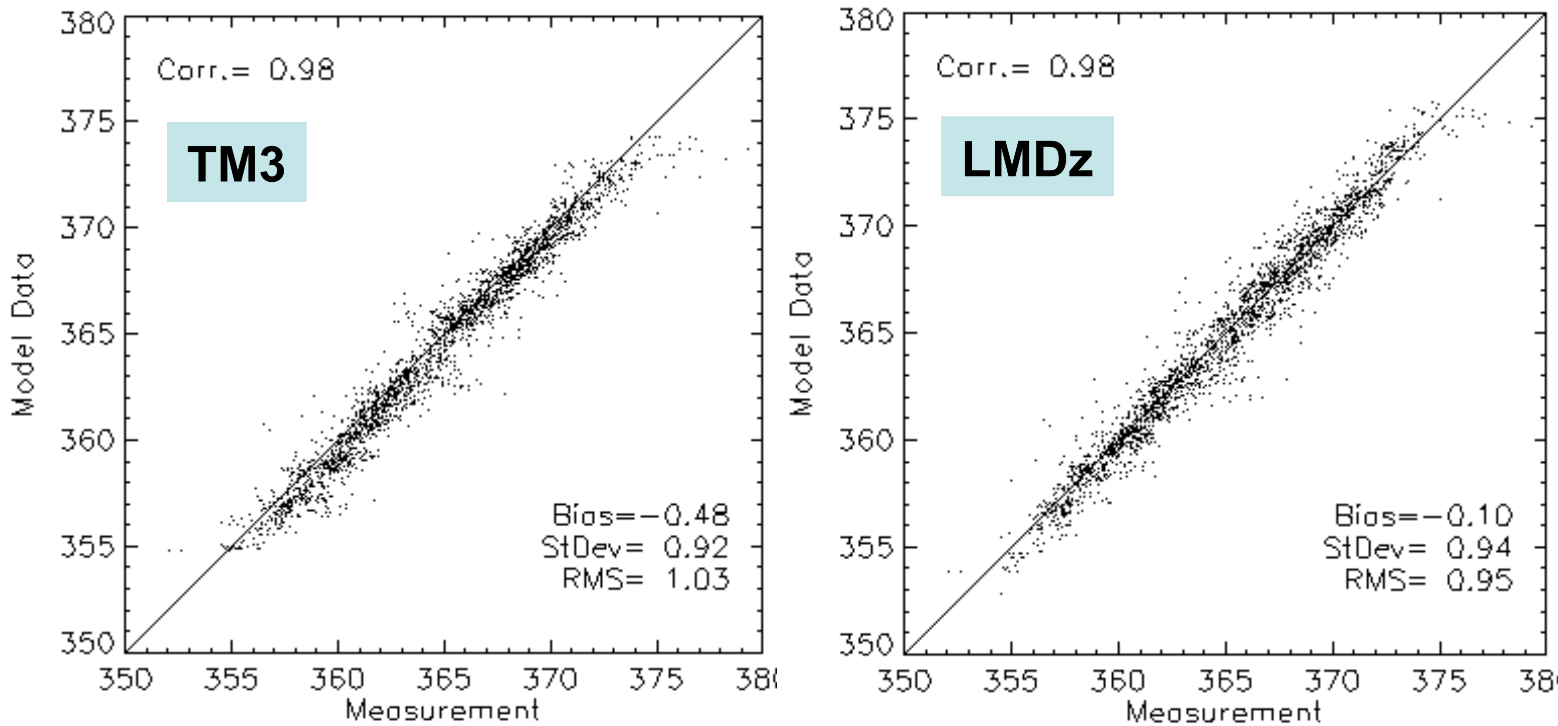




Peylin et al.

Upper air data

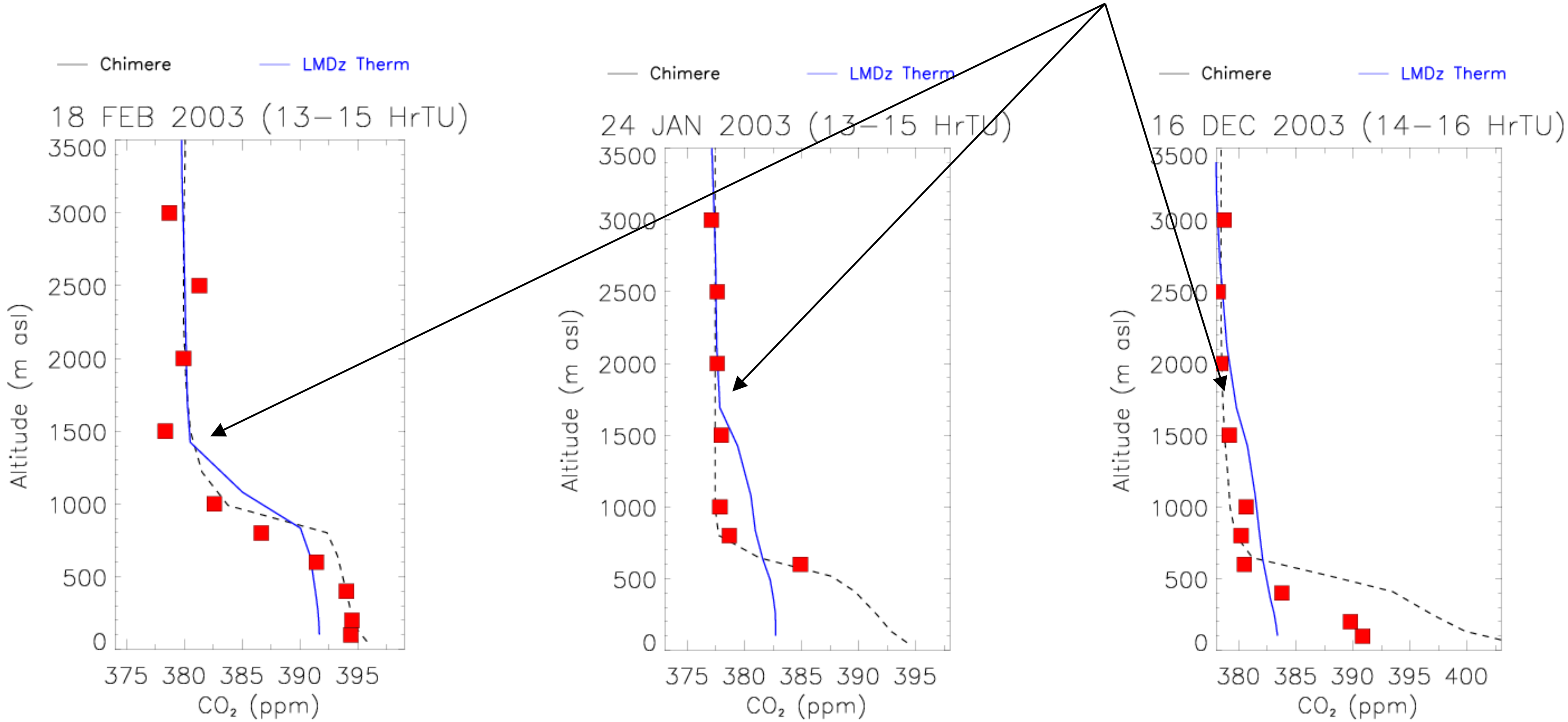
Scatter plots model / measurements



Peylin et al.

Vertical profiles : Orléans profiles (France, winter 2003)

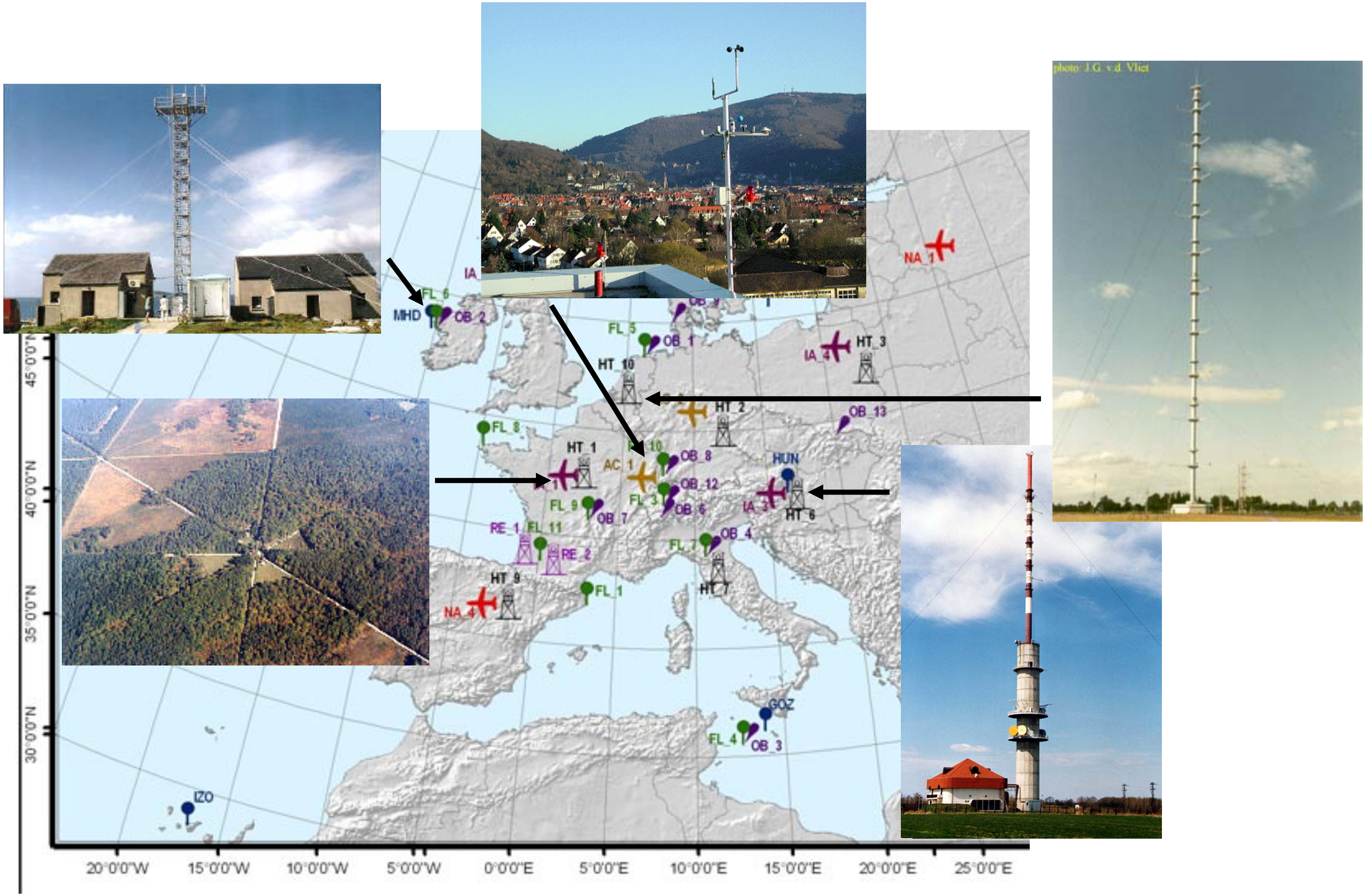
- Underestimation of winter surface CO_2 concentrations (LMDZ)
- Difficulties to properly reproduce PBL height in LMDZ



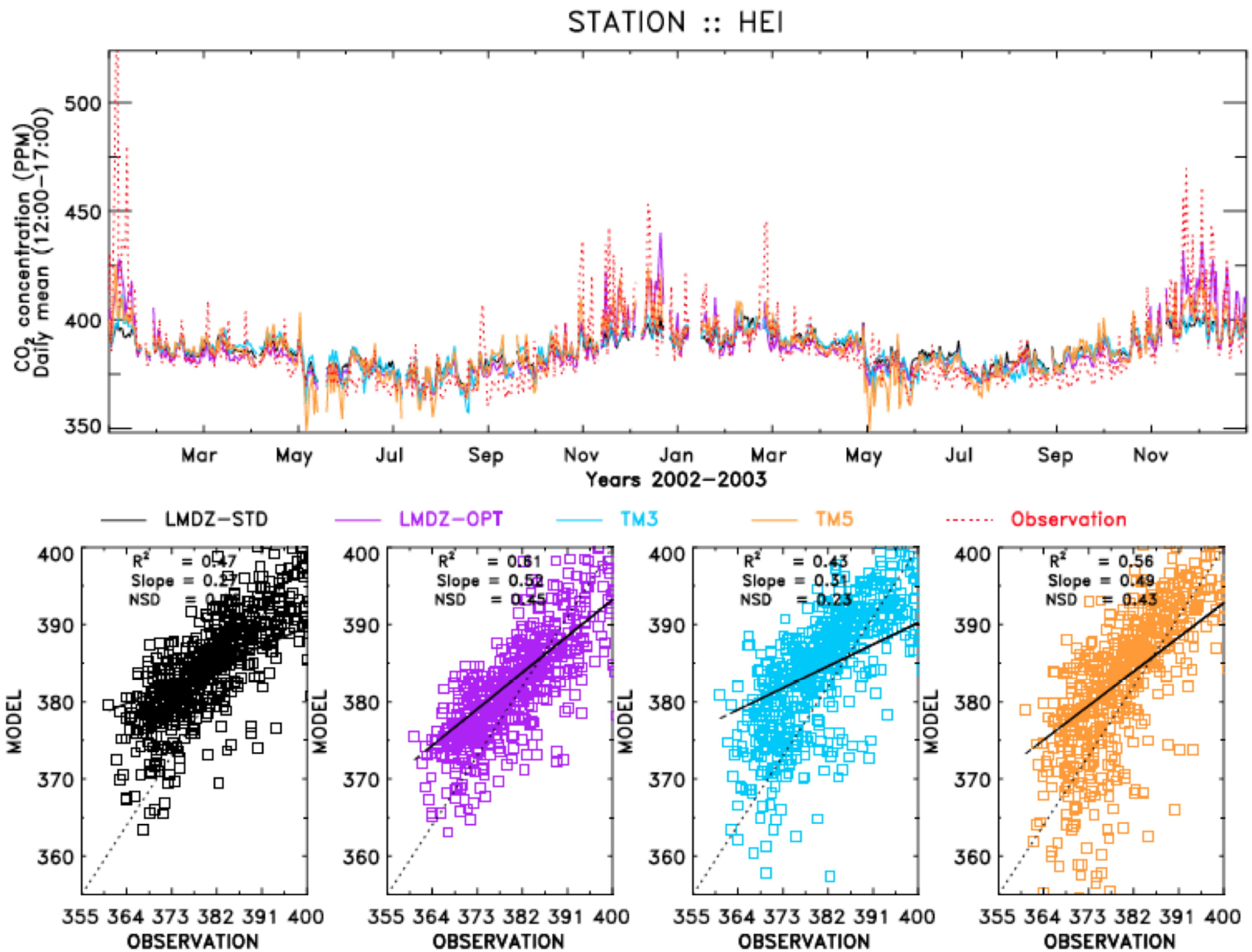
(ppm)	RMS	BIAS
LMDZ THERM	1.3	-0.5
CHIMERE	0.9	-0.4

Ramonet, pers. Comm.

Surface continuous data in Europe



Surface continuous data in Europe



Bousquet et al., 2008

Nudging T ?

STD : u, v nudged
OPT : u, v, T nudged

But strange CO_2 gradients in some zones

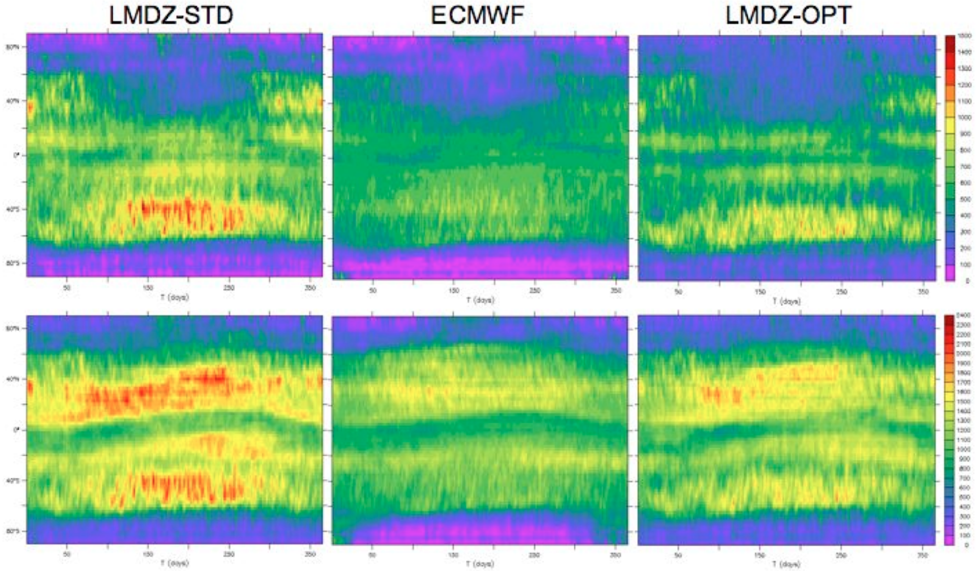


Figure 8: Zonally averaged evolution of planetary boundary layer height for LMDZ model and ECMWF reanalysis calculated with a Bulk-Richardson number. Top: Evolution of the daily minimum of PBL height for LMDZ-STD (left), LMDZ-OPT (right) and ECMWF (middle). Bottom: Evolution of the daily maximum of PBL height for LMDZ-STD (left), LMDZ-OPT (right) and ECMWF (middle).

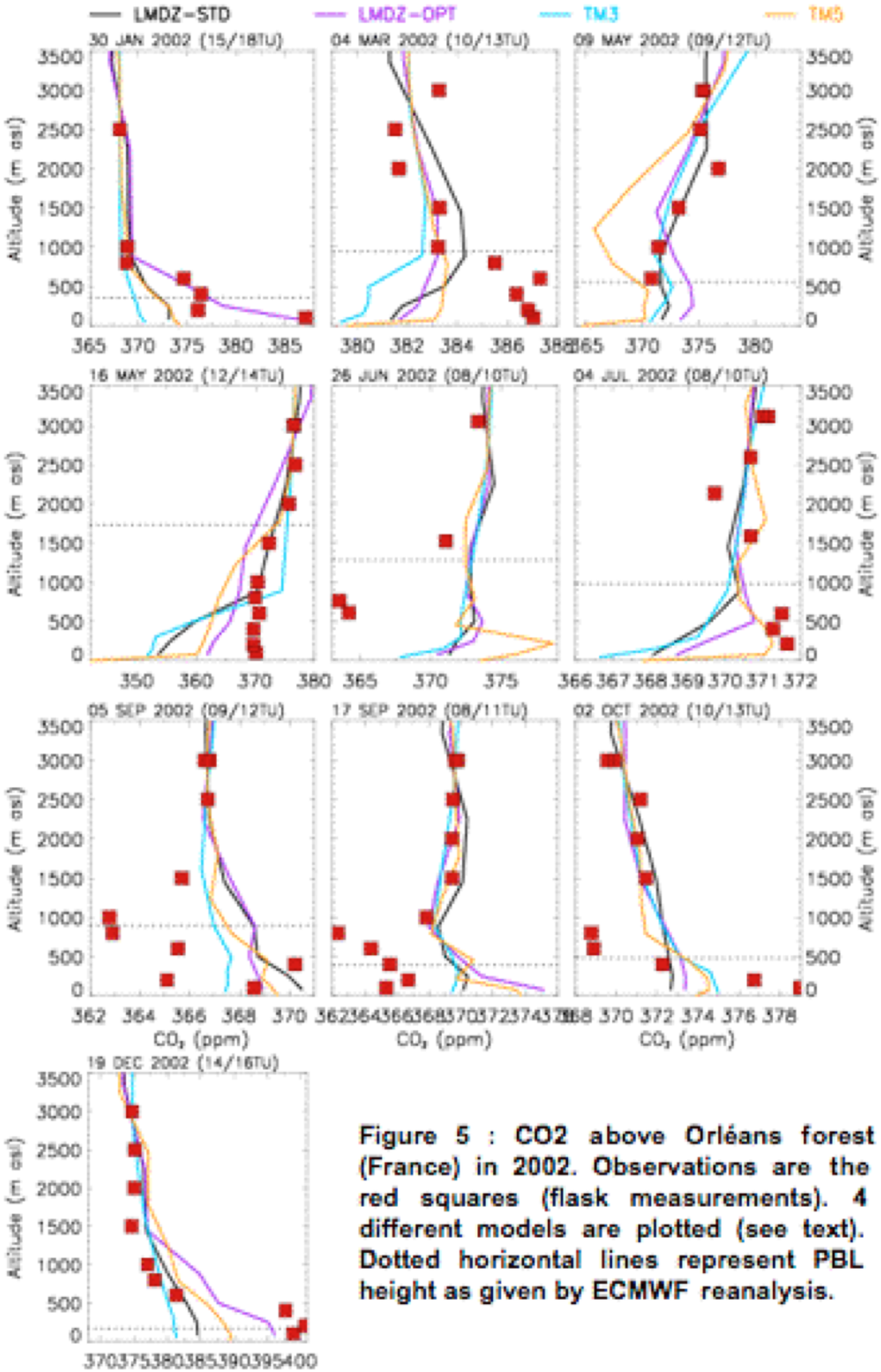
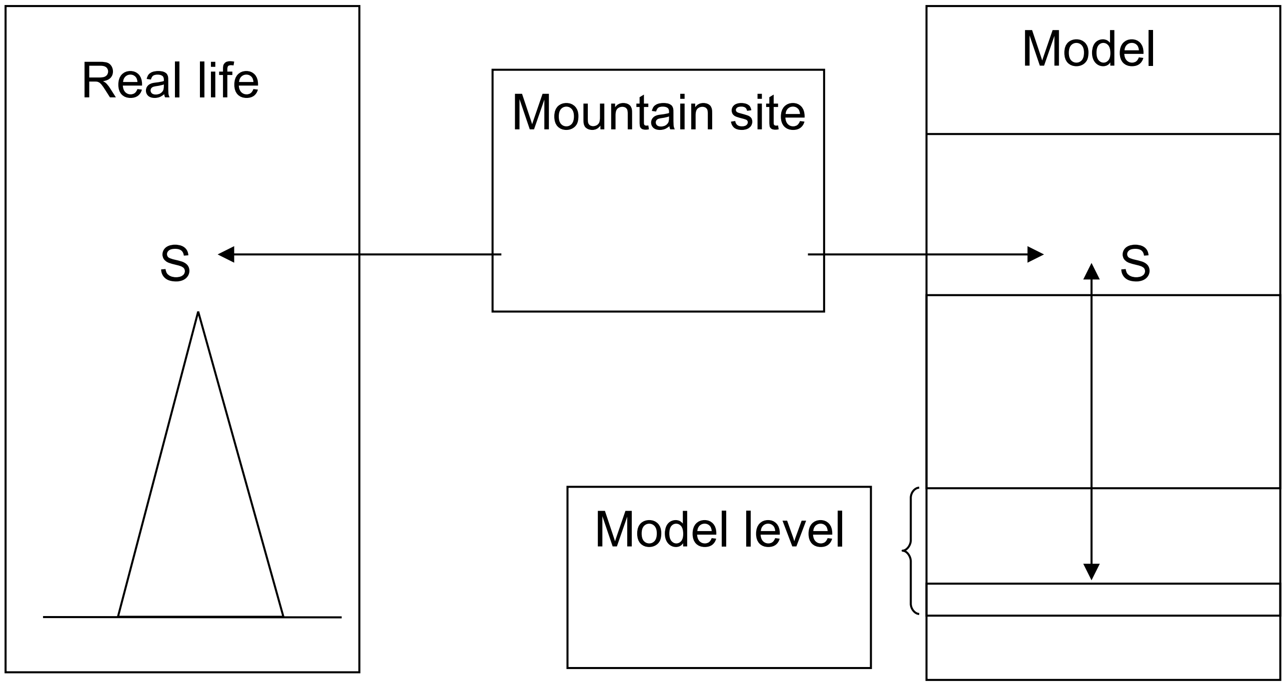


Figure 5 : CO2 above Orléans forest (France) in 2002. Observations are the red squares (flask measurements). 4 different models are plotted (see text). Dotted horizontal lines represent PBL height as given by ECMWF reanalysis.

Bousquet et al., 2008

What model layer to be extracted ?

Problem with mountain sites

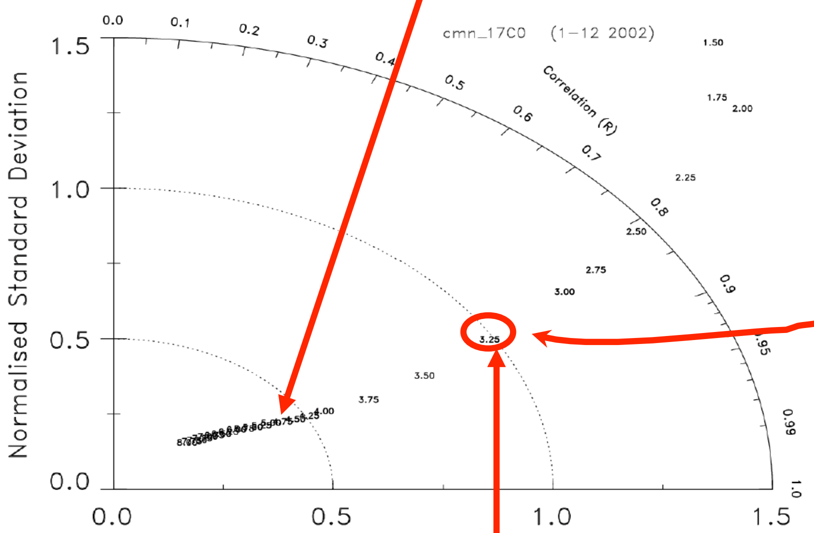


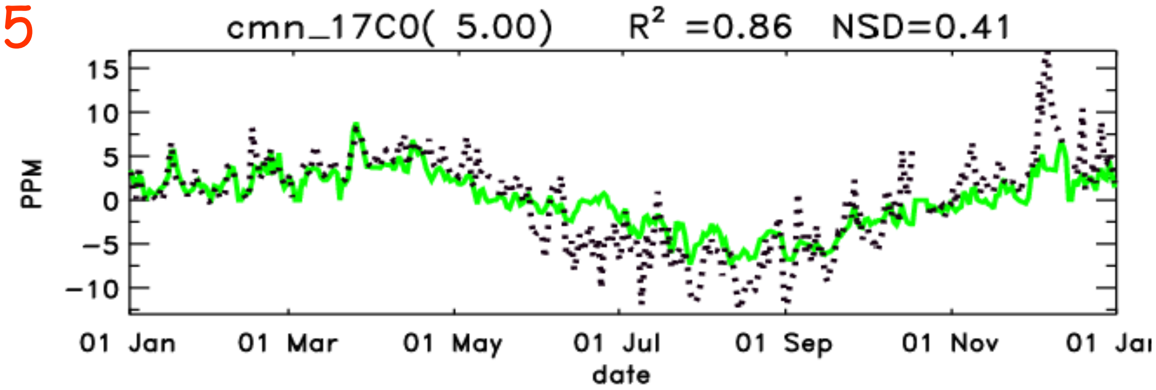
Leroy, pers. Comm.

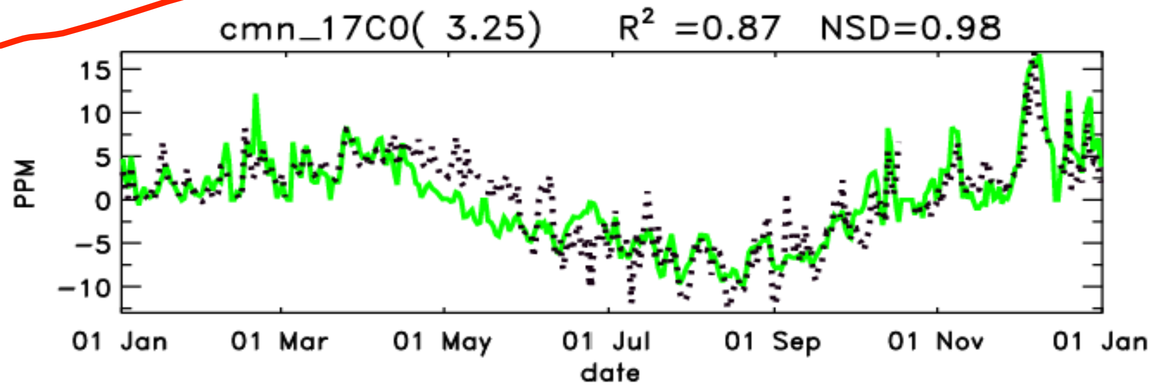
What model layer to be extracted ?

Station
Monte Cimone

Station level=5







optimized level=3.25

Model .... Observations

The NSD in this case is clearly improved but some seasonal variations are also perceptible

Leroy, pers. Comm.

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TRANSCOM intercomparisons

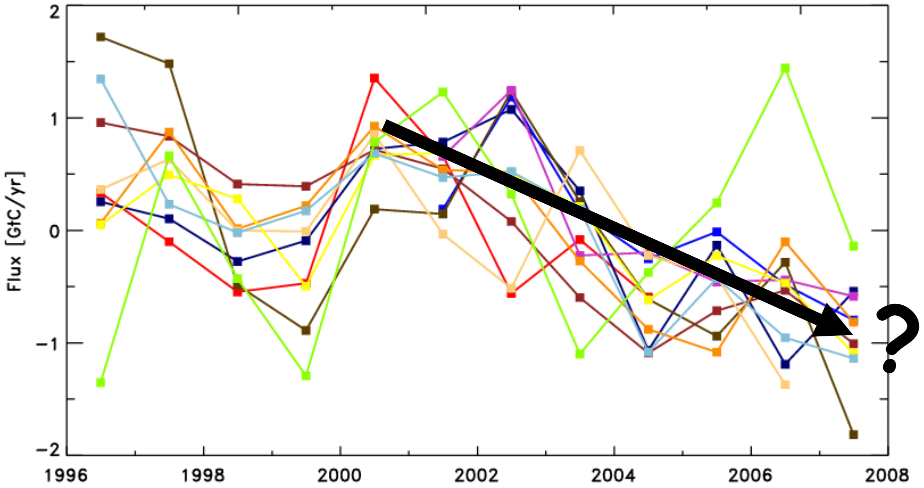
- International effort to compare transport models
- Example for inversion comparisons :
- Since 1993, tens of paper published
- www.purdue.edu/transcom

Name	Time period	Transp. model	Winds	Atm Data	Flux spatial res.	Flux temp. Res.	Inverse Method
Lsce_an_v2.1	1996 - 2004	LMDZv4	ECMWF	Monthly mean	gridcell	Monthly	Bayesian matrix
Lsce_var_v1.0	1990 - 2007	LMDZv3	ECMWF	Raw	gridcell	weekly	variational
Jena_s96_v3.2	1996 - 2006	TM3	ECMWF	Raw	gridcell	weekly	variational
Carbntrckr_US	2000 - 2008	TM5 zoom	ECMWF	Raw	156 ecoregions	weekly	Kalman smoother
Carbntrckr_EU	2000 - 2007	TM5 zoom	ECMWF	Raw	156 ecoregions	weekly	Kalman smoother
Rigc_patra	1993 - 2007	NIES/ FRCGC	ECMW	Monthly mean	64	monthly	Bayesian matrix
T3 mean	1995 - 2008	13 models	13 models (climatology)	Monthly mean	22	Monthly	Bayesian matrix
JMA	1985 - 2007	JMA	NIES	Monthly mean	22	monthly	Bayesian matrix
Nicam_Niwa	1988-2007	NICAM-TM	NCEP	Monthly mean	22	monthly	Bayesian matrix
C13_MATCHRayner	1992 - 2005	MATCH	NCEP 1999 (climatology)	Monthly mean (+ 13C)	116	monthly	Bayesian matrix
C13_CCAM Law	1992 - 2005	CCAM	NCEP 1999 (climatology)	Monthly mean (+13C)	146	monthly	Bayesian matrix

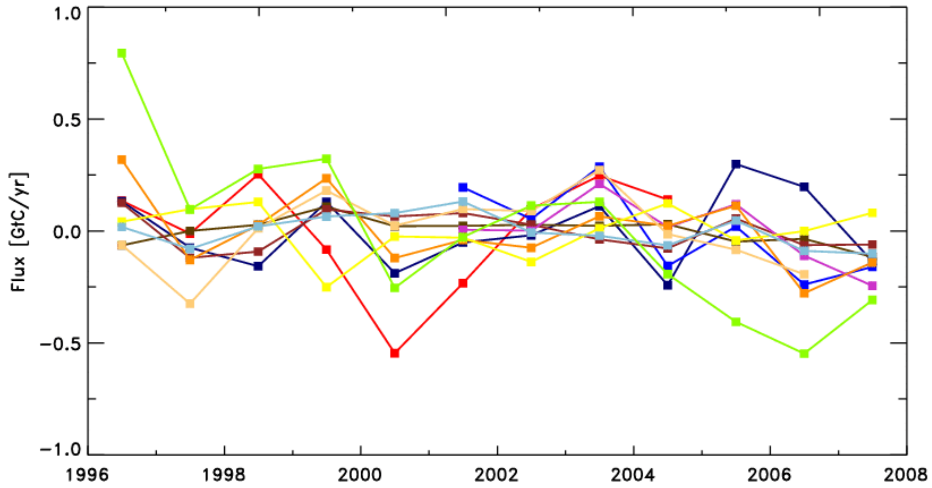
TRANSCOM intercomparisons : CO_2 inversions

CO_2 flux anomaly in GtC/yr

N. America

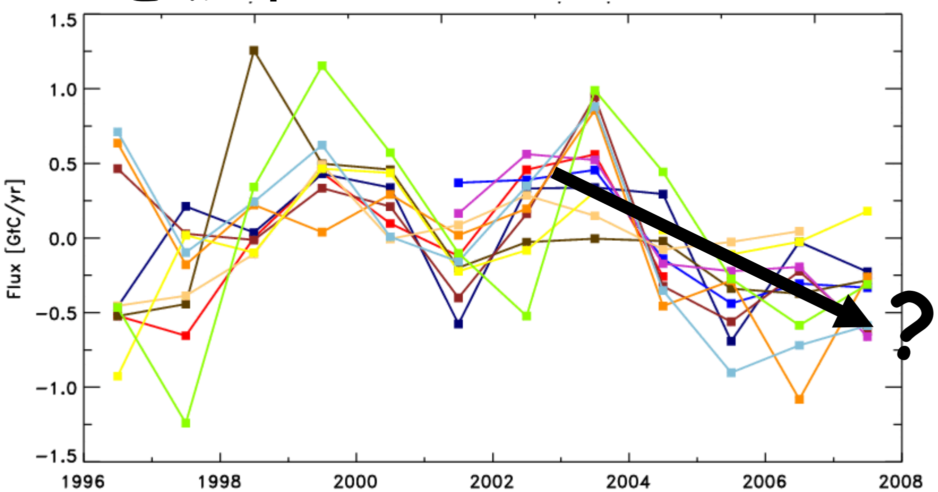


N. Atlantic



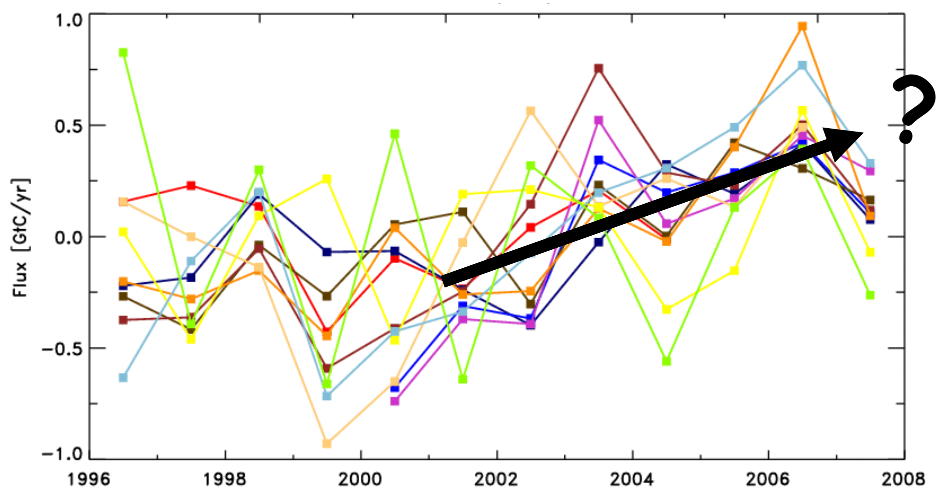
LSCE_an_v2.1
JENA_s96_v3.2
CTracker_EU
LSCE_var_v1.
C13_MATCH
CTracker_US
TRCOM_me
RIGC_patra
JMA_2010
C13_CCAM
NCAM_Niwa

Europe



Peylin et al., in prep

N. Asia



CO2 / CH4 simulator

- Objectifs
  - Relier la précision en terme de concentrations en CO_2 atmosphérique observées à une précision en termes de flux de CO_2 émis par la surface
  - Comparer l'apport de différents scénarios d'observation

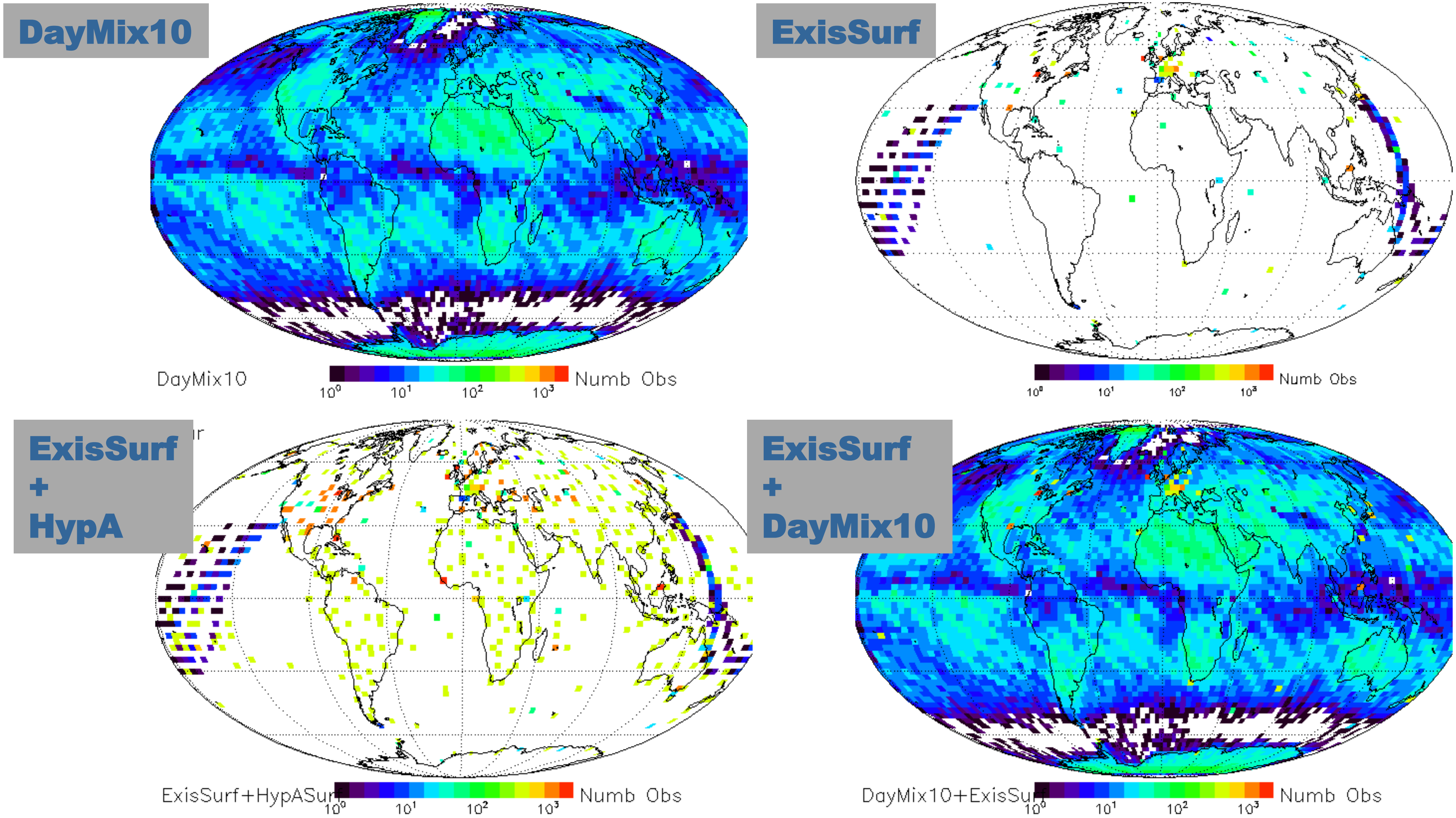
- Principe
  - Erreur a posteriori sur les flux de CO_2 émis par la surface indépendante des observations elle mêmes : $A = (H^T R^{-1} H + B^{-1})^{-1}$

- Exemple : Satellite versus réseau sol
  - Mode alterné = DayMix (1 jour NADIR 1 jour GLINT)

    résolution spatiale : 10 km, modèle d'erreur : OCO + systématique
  - Réseau sol : réseau existant, réseau existant + réseau hypothétique A
  - DayMix10 + réseau sol existant

Satellite vs. Surface network

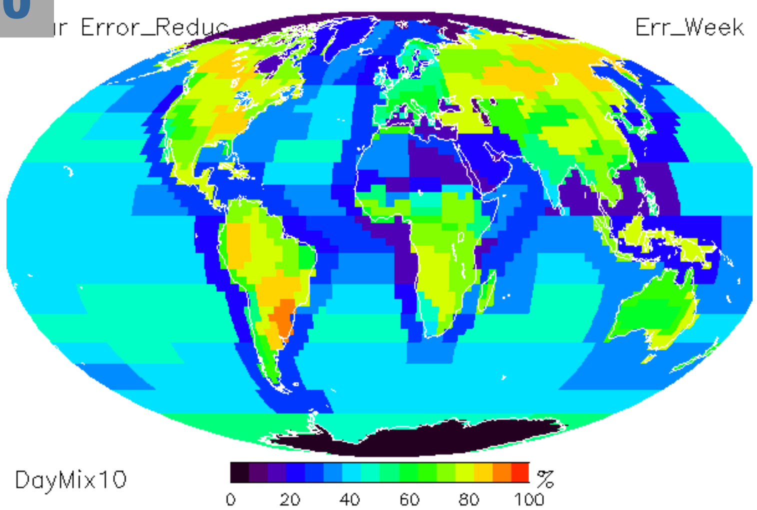
Number of observation constraints



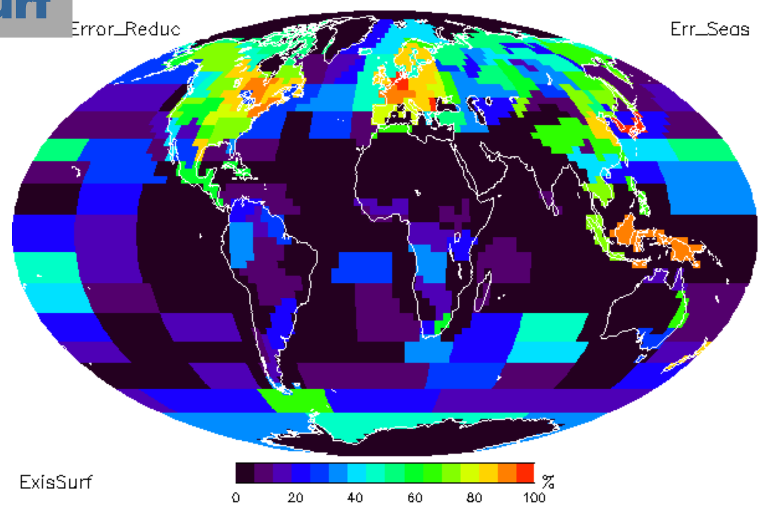
Satellite vs. Surface network

Error reduction in %

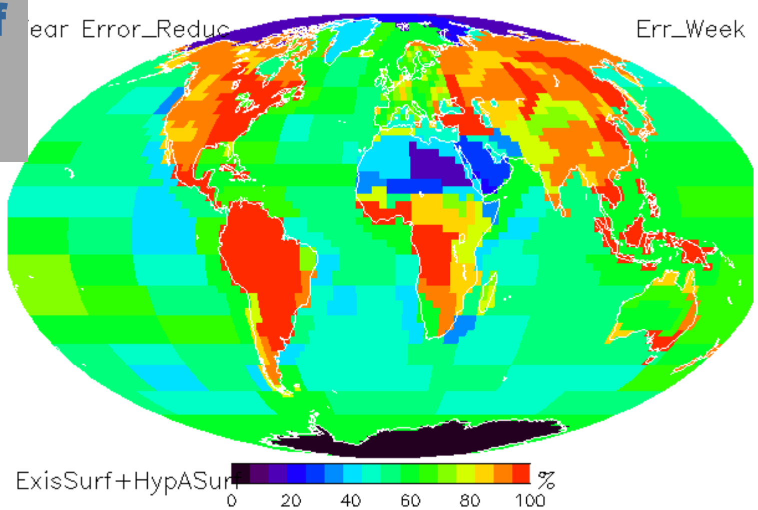
DayMix10



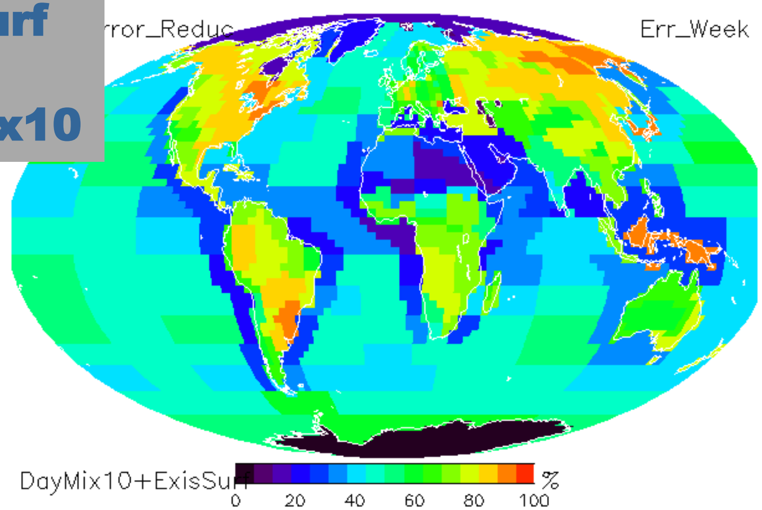
ExisSurf



ExisSurf + HypA

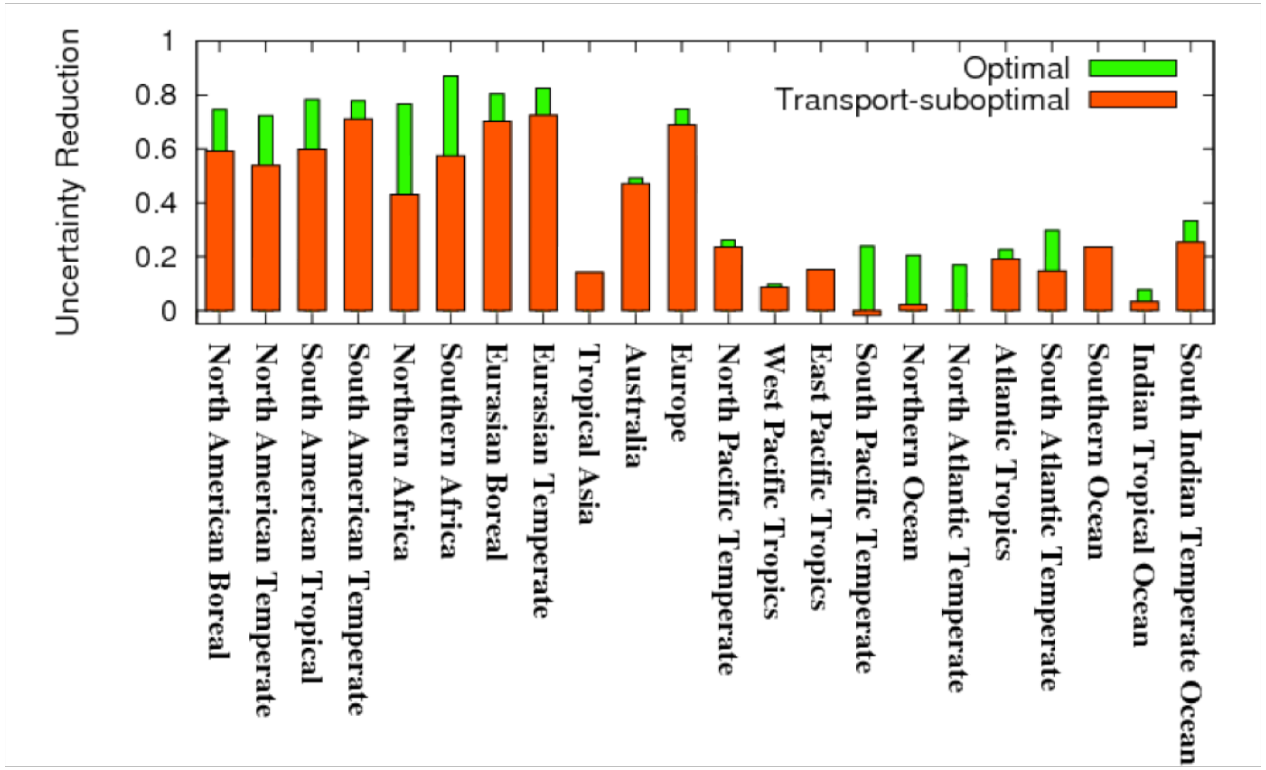


ExisSurf + DayMix10



Accounting for Transport model errors

- Impact of transport errors on flux inversion
- Collaboration with Univ. of Edinburgh
- Exploit GOSAT observations simulated with either LMDZ (consistent with inversion system) or GEOS-CHEM (inconsistent with the inversion system)



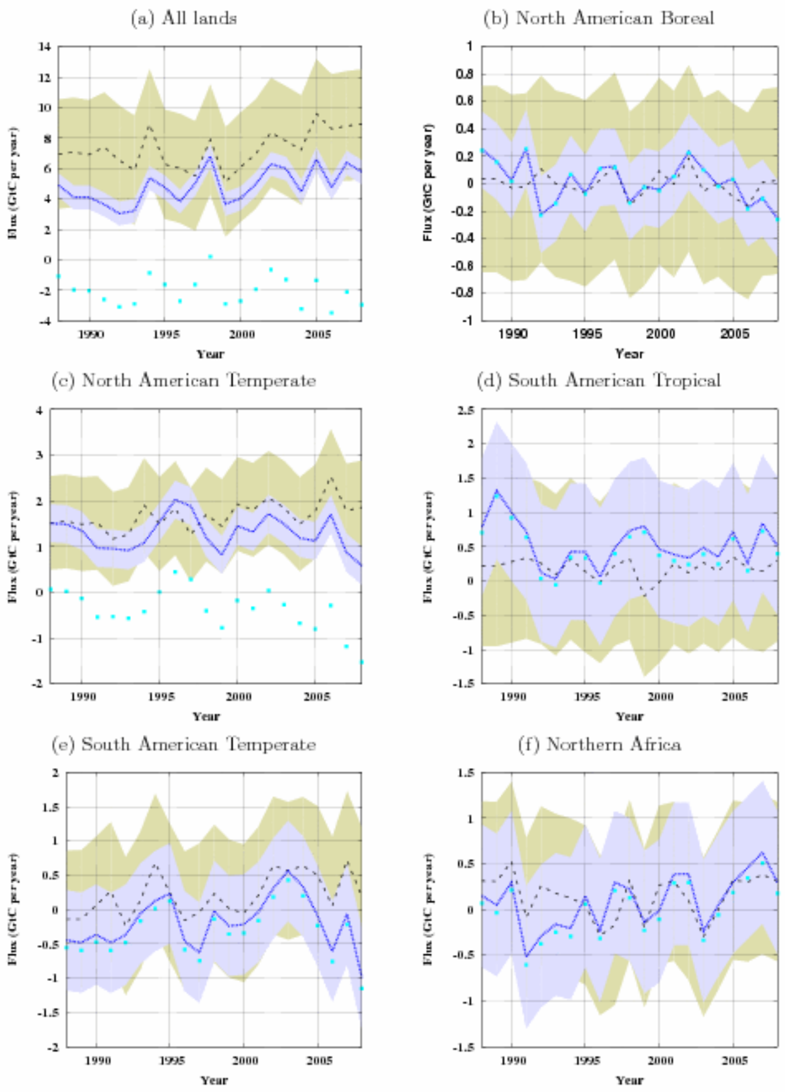
Chevallier et al., 2010

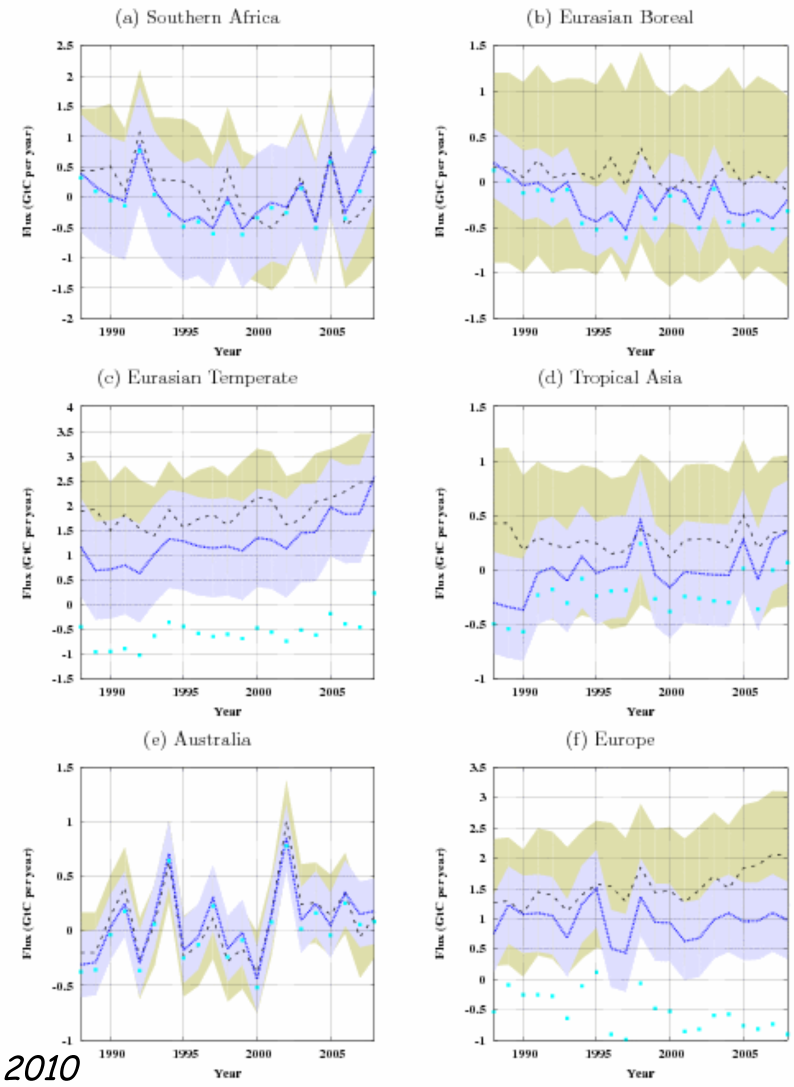
---> Projet FP7 QUOTA on quantification of transport model errors for atmospheric inversions

Inversion of CO_2 sources and sinks

Coordination Action Carbon Observation System

Build a 21-yr reference inversion with state-of-the-art system





Chevallier et al., 2010

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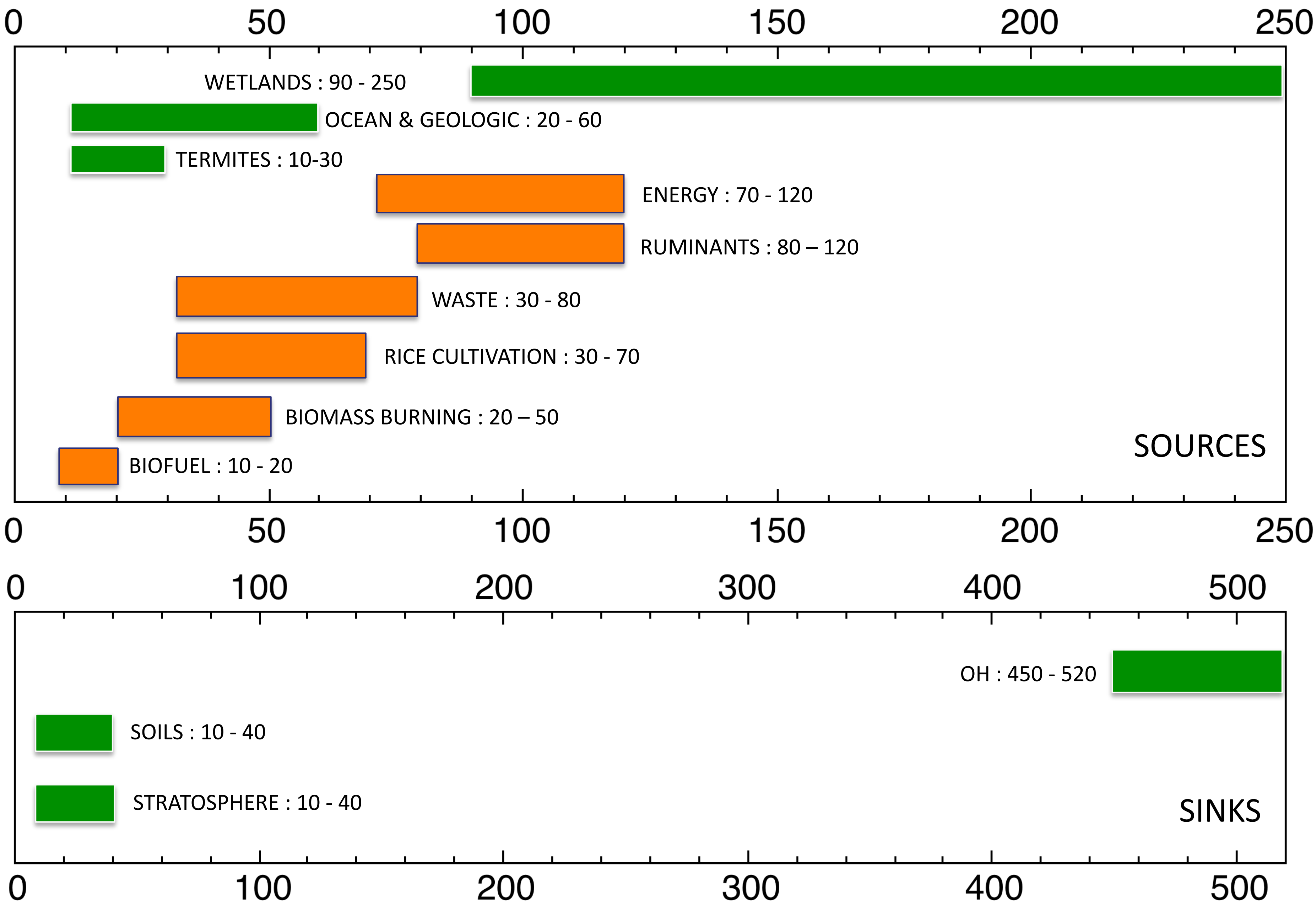
Litterature range of methane sources and sinks ($TgCH_4/yr$)



Evolution of atmospheric methane (surface)

Lower growth rate period
1991-1996

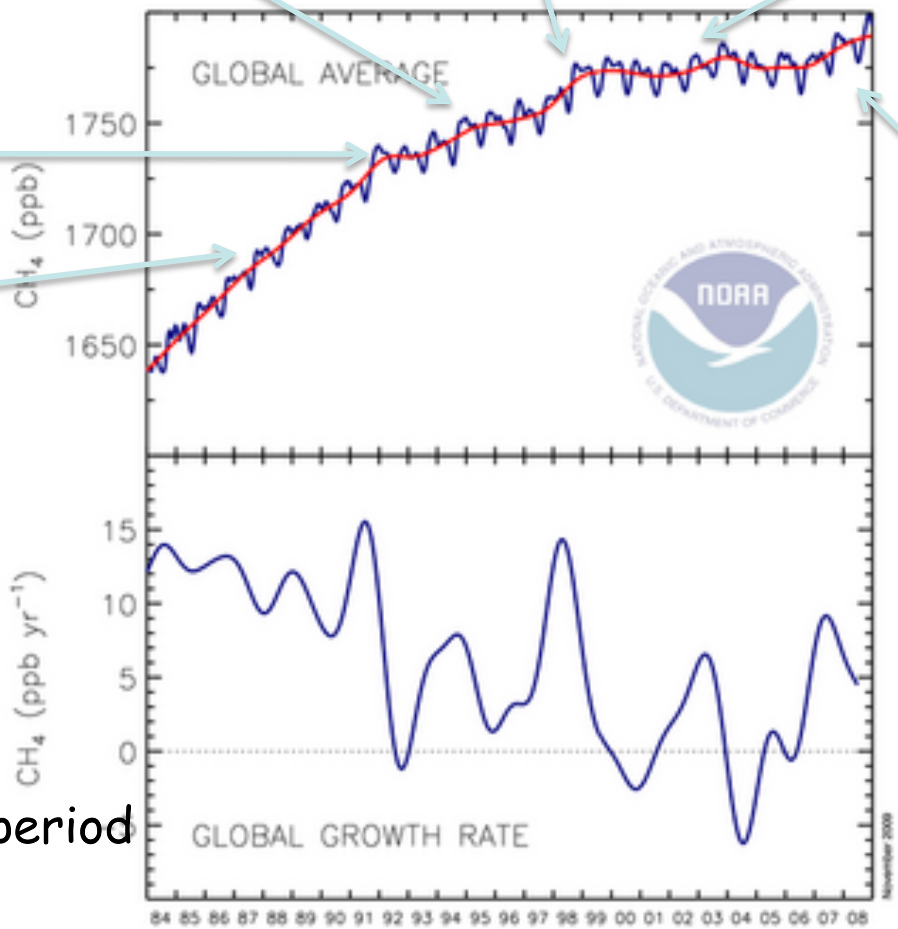
El Niño
1997-1998

Stabilisation period
1999-2006

Pinatubo,
USSR collapse
1991-

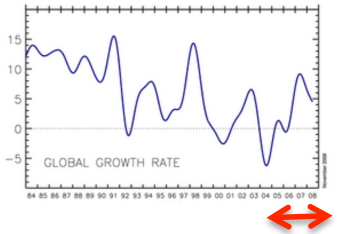
Recent increase
2007-?

High growth rate period
< 1991



NOAA, ESRL

2006-2008 anomaly in methane emissions



- 2006-2008 yearly-averaged CH_4 emission anomalies. Reference period : 1999-2006

- Good agreement in 2007. More work needed in 2008.

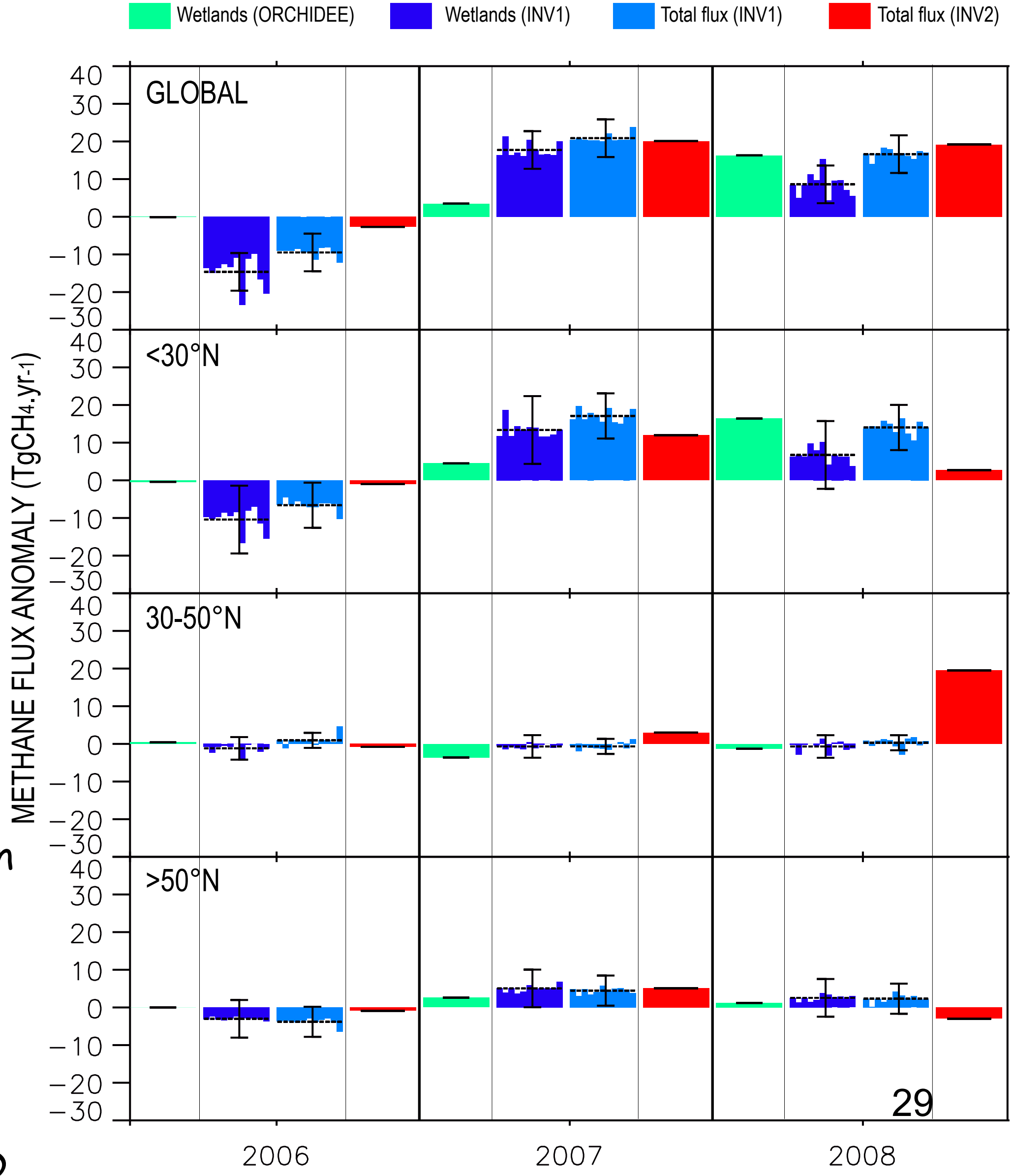
- 2 inversions, and 1 bottom-up model (ORCHIDEE) :

Wetlands from the ORCHIDEE model
Ringeval et al., 2010.

WETLANDS from a synthesis inversion
Update from Bousquet et al., 2006.

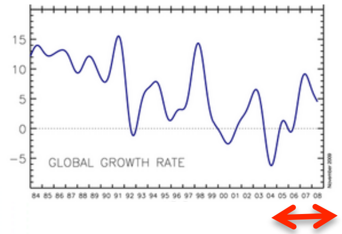
TOTAL emissions from a synthesis inversion
Update from Bousquet et al., 2006.

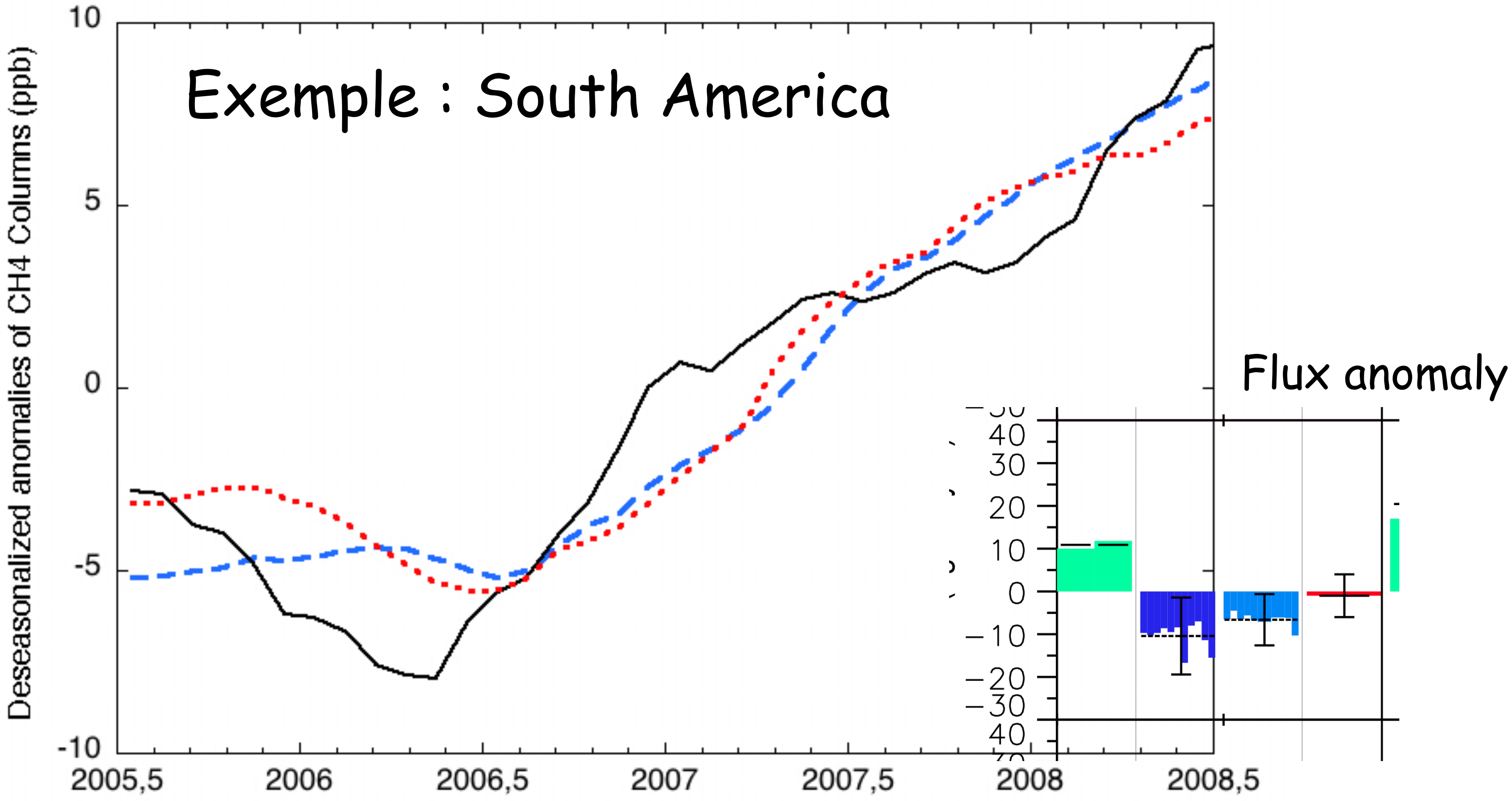
TOTAL emissions from a variational inversion *Update from Pison et al., 2009.*



Bousquet et al., 2011, ACPD

Optimized concentrations are consistent with independant SCIAMACHY CH_4 column-averaged data





4D-VAR inversion (Pison et al., submitted)
Analytical inversion (Bousquet et al., ACPD)
SCIAMACHY (Frankenberg et al., 2008)

Conclusions 1

- LMDZ is a state-of-the art global low-to-middle resolution model comparable to other global models

- Very good for large-scale simulations (upper air) or global inversions (monthly, CO_2, CH_4, ..)

- Improvements of the PBL scheme (e.g. PBL height) are necessary to be competitive with high-resolution global models (TM5) or meso-scale models (CHIMERE) for the representation of continental CO_2 variability.

Conclusions 2

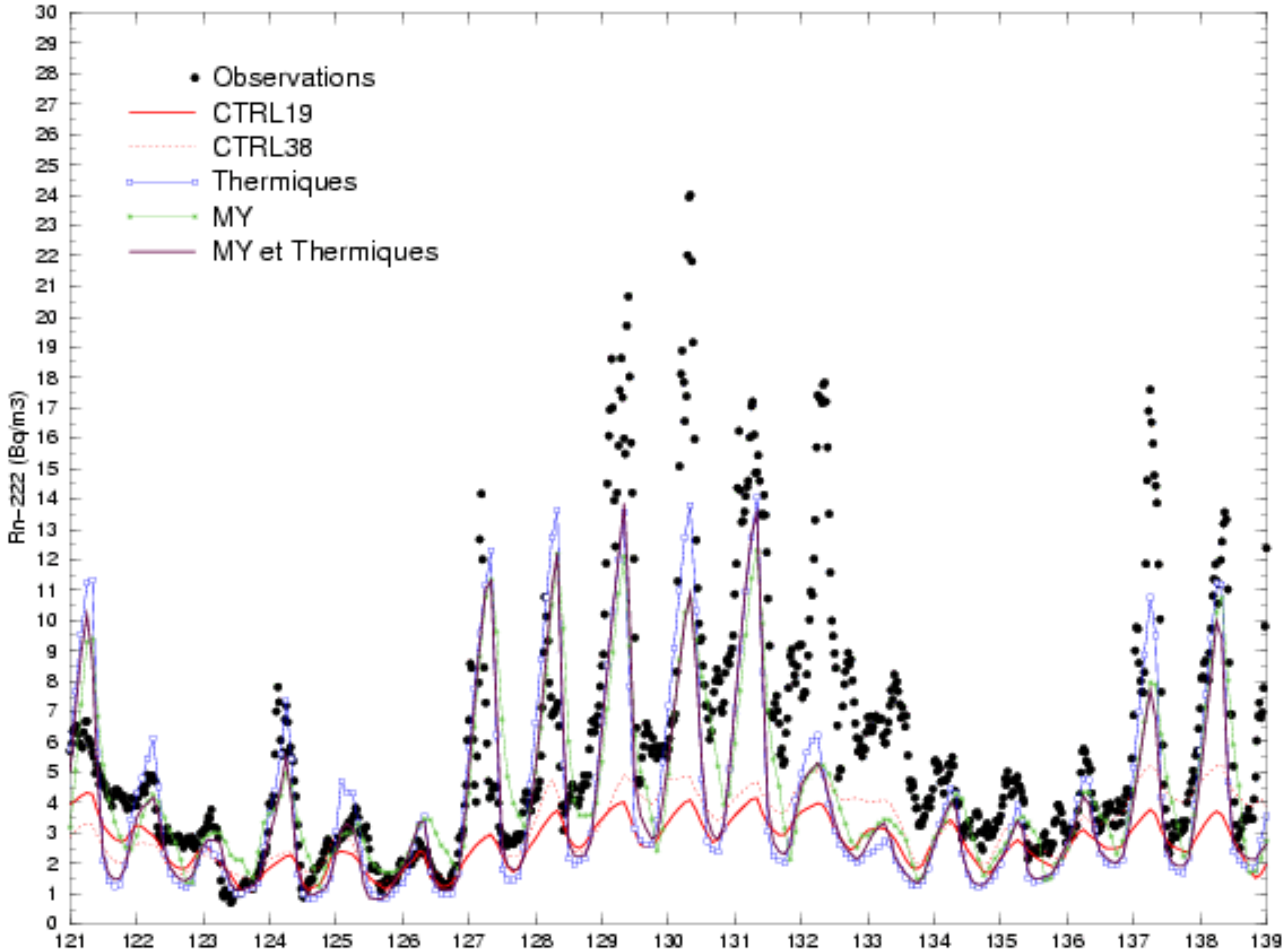
LMDZ Strengths :

- Global model (long-lived tracers)
- One code to perform forward and backward simulations
- Part of the IPSL climate coupled model (synergies & support)
- Fast, possible integrations over long periods (30 years)
- Potential of improvement of continental PBL (New physics, thermals).

LMDZ Weaknesses :

- Global model (limited resolution & parametrisations)
- Variability of tracer concentrations in the continental PBL is underestimated
- Part of the IPSL climate coupled model (climate modelling constraints)
- Rough nudging to meteorological obs.

Rn222 validation



Mai 2001 - Heidelberg (D)

Idelkadi, Hourdin, pers. Comm.