GHG-WP4: estimates of CO_2 sources and sinks using existing atmospheric inversion models

F. Chevallier,

P. Bousquet, F.-M. Bréon, P. Ciais, *F. Delage*, *L. Klenov*, P. Peylin, P. Rayner

Laboratoire des Sciences du Climat et de l'Environnement

GEMS DoW for GHG-WP4

- Task 4.1: enhanced inversion procedure
  - Adaptation of existing inversion scheme to satellite data from AIRS
  - New version of the inversion scheme
  - First inversion performed and evaluated
- Task 4.2: sensitivity of the inversion to transport parameterizations
  - New evaluation of LMDZ and of its adjoint
  - First evaluation of the sensitivity of the inversion to transport parameterizations
- Task 4.3: development of a routine processing chain in NRT
- Task 4.4: inversion of fluxes over the 2003-2007 period

Developing the inversion scheme

- Flux inversions tend to process observations at increasing temporal resolution, to solve fluxes at increasing spatial and temporal resolutions
  - Exploit individual measurements
  - Resolve grid point fluxes

- Computational challenge
  - Not possible with standard approach based on a suite of matrix operations

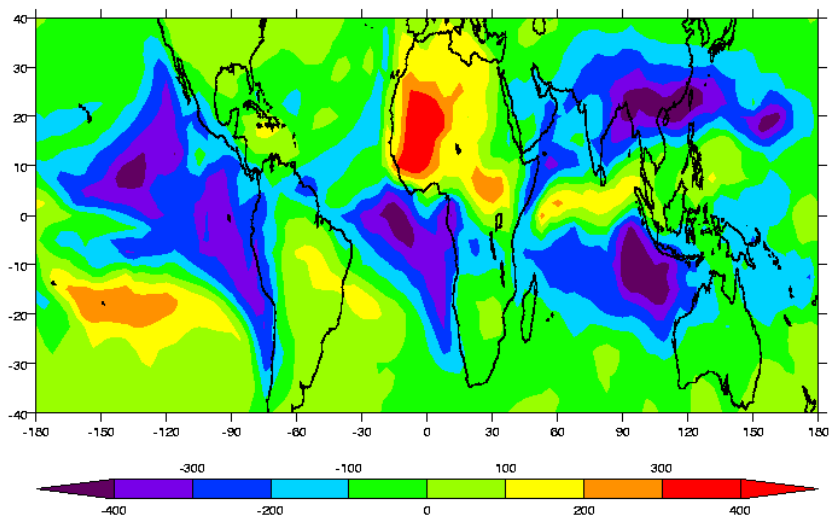
A new variational system

- Implement ECMWF 4D-Var science at LSCE
  - New inversion system
  - 1it/1yr/1x64bit@2.4GHz = 7 hours CPU
- Two minimization algorithms to deal with non-linearities
  - Inner loop/ outer loop system with conjugate gradient (ECMWF)
  - M1QN3 (INRIA)
  - Translated in Python
- Tangent-linear and adjoint models of LMDZ tracer transport
  - Existing retro-transport approach not accurate enough
  - Exact TL and AD coded

- Chevallier et al., *J. Geophys. Res.*, 2005

Application to TOVS

- Upper-tropospheric CO_2 from Chédin et al (2003)
  - 347,400 observations at LMDZ resolution
  - 200,000 variables to optimize

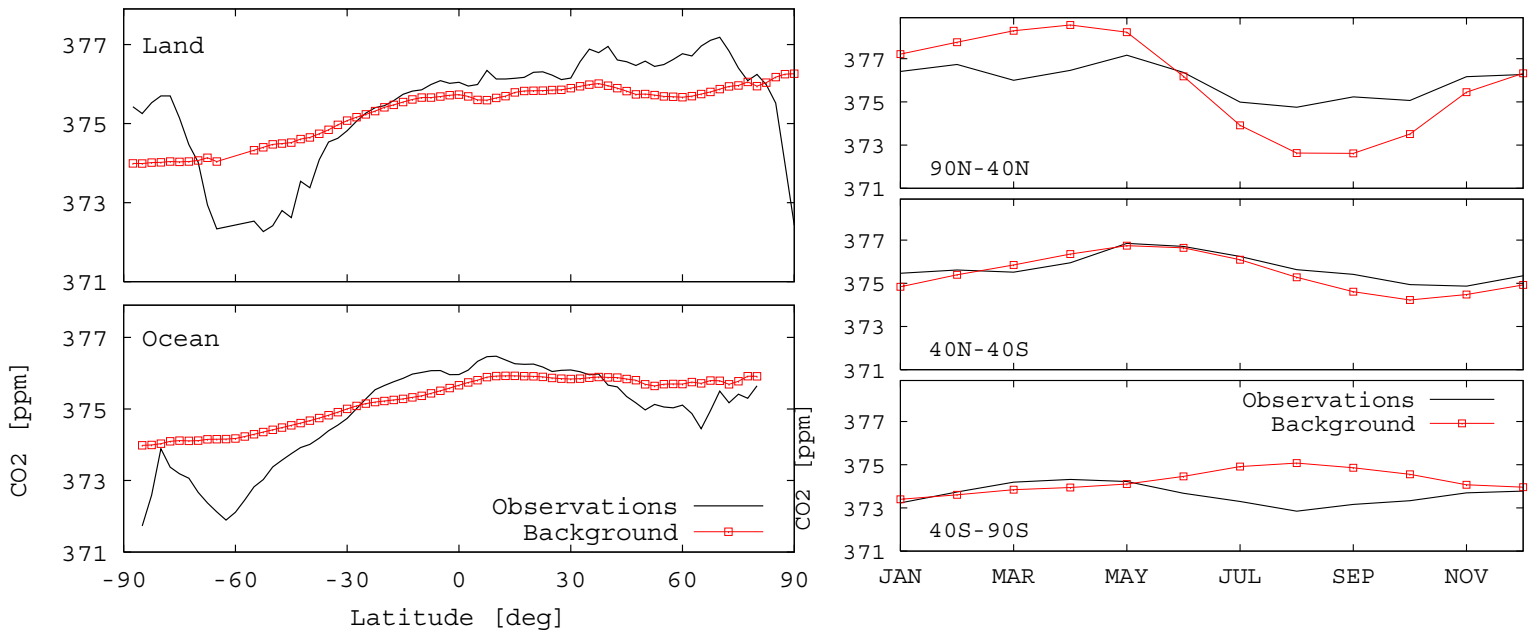


-400 +400

gC/m²/yr

Analysis – Prior June 1990

Application to AIRS

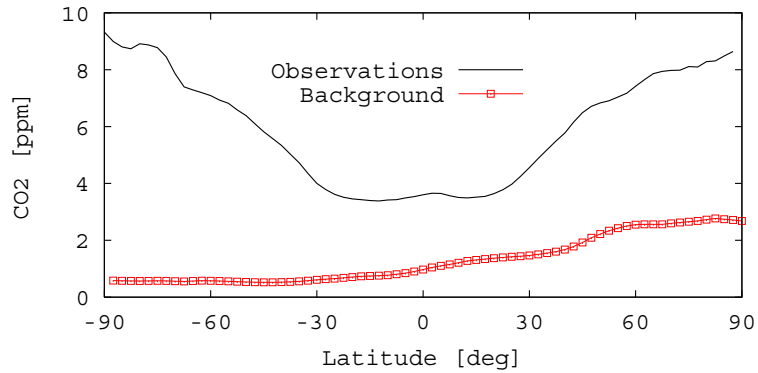


Observations: upper-tropospheric CO_2 from Engelen et al (2004)
Background: climatological fluxes + LMDZ

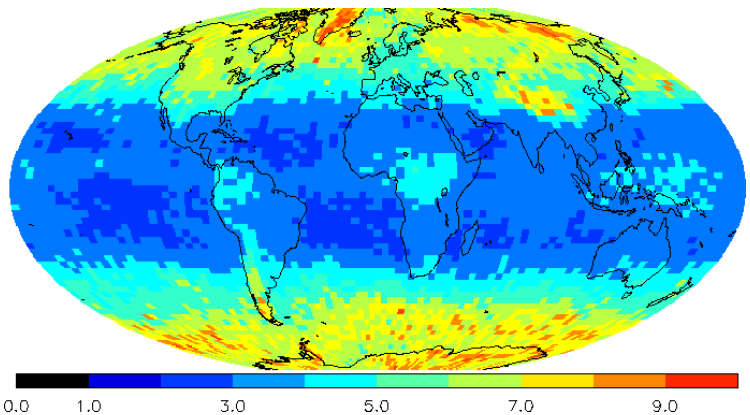
Chevallier et al., *Geophys. Res. Lett.*, 2005
Tiwari et al., *J. Geophys. Res.*, 2006

Comparing the variability

- Standard deviations of the fields by latitude band



- Obs-BG departure RMS

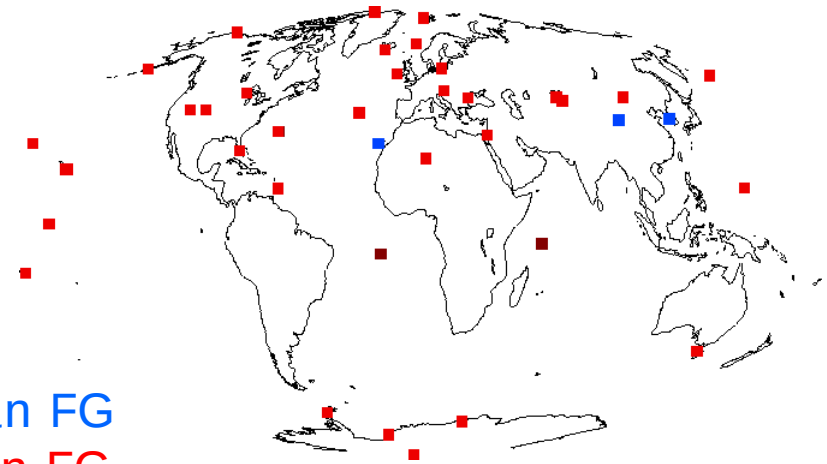


Scale from 0 to 9 ppm

Chevallier et al., *Geophys. Res. Lett.*, 2005

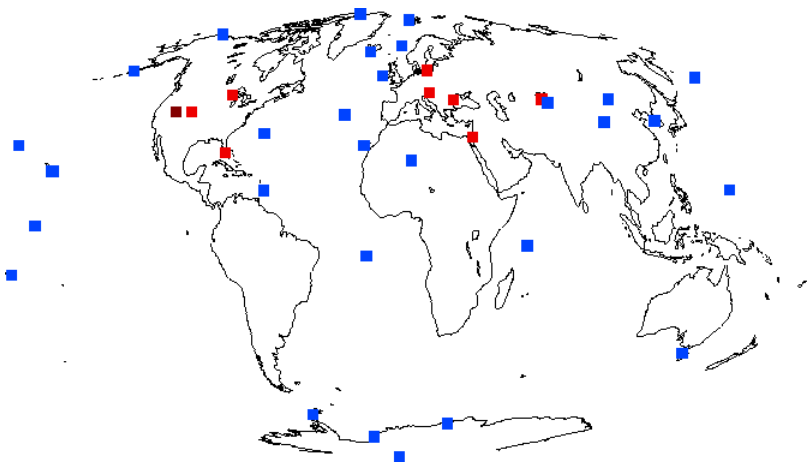
Analysis fit to GLOBALVIEW stations

- Regular flux inversion from AIRS



AN better than FG
AN worse than FG

- Flux inversion with 2.5ppm-biased climatology



Application to OCO

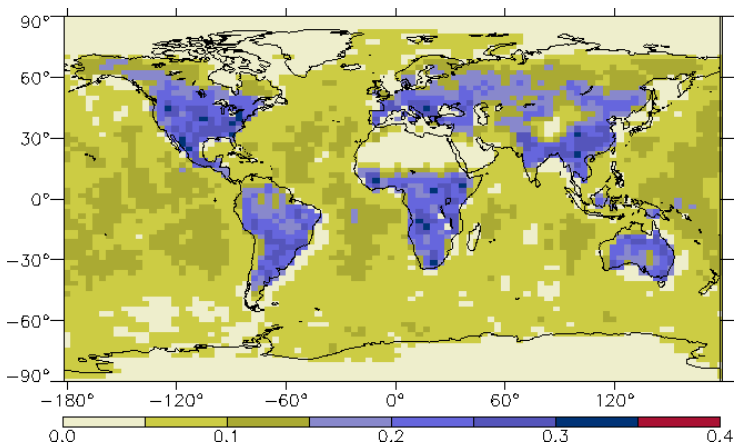
- Error statistics in inversion problem fully consistent with simulation world
  - Sanity check of the inversion scheme
  - Investigate number of iterations

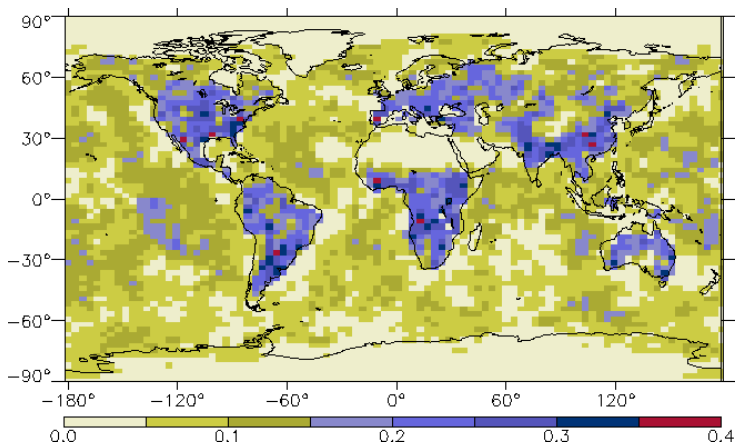
  - Cost function at minimum should be about the number of observations (244,000)
  - We get $J \sim 255{,}000$ at the 55th iterations
  - One outer loop update is enough to care about the non-linearities of the transport numerics

Chevallier et al., *in prep.,* 2006a

Application to OCO

- Error statistics in inversion problem fully consistent with simulation world
  - Get extra diagnostics
    - DFS > 9500 for one year
    - Error reduction



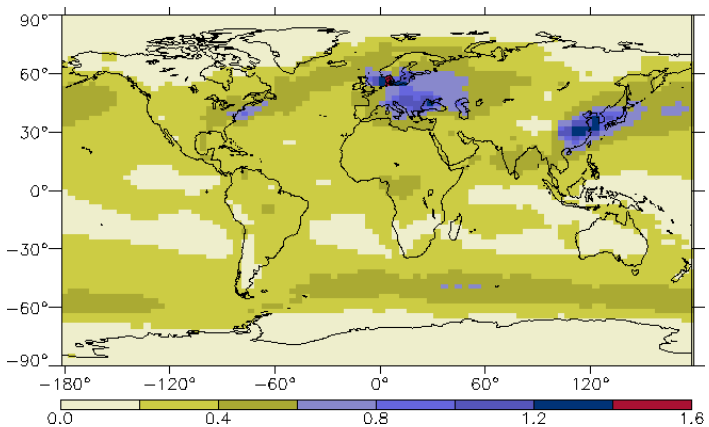


Weekly CO_2 fluxes

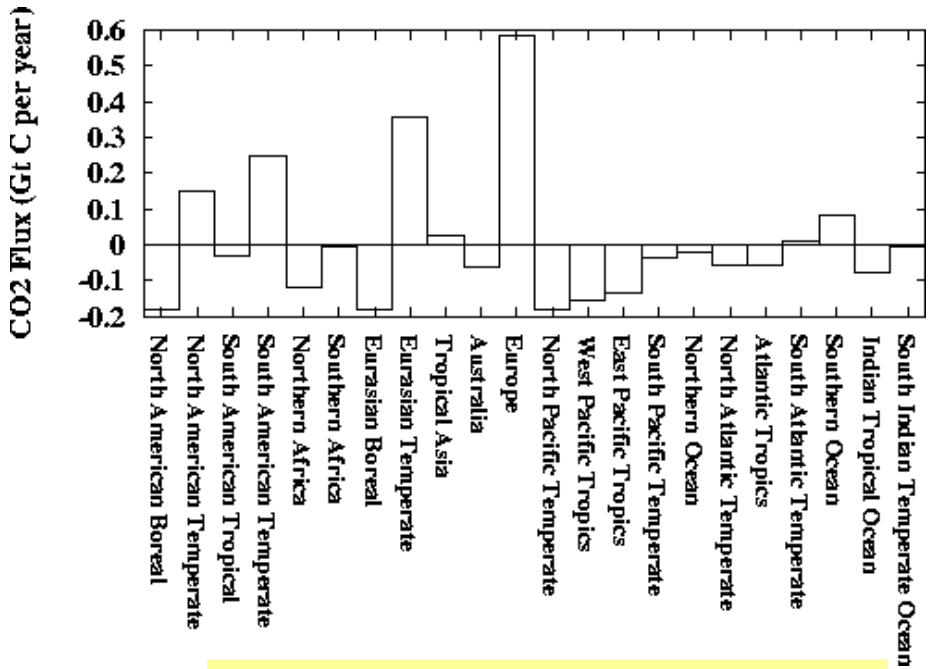
Monthly CO2 fluxes

Application to OCO

- Error statistics in inversion problem fully consistent with simulation world
  - Investigate impact of biases



Annual-mean of the bias introduced (ppm)

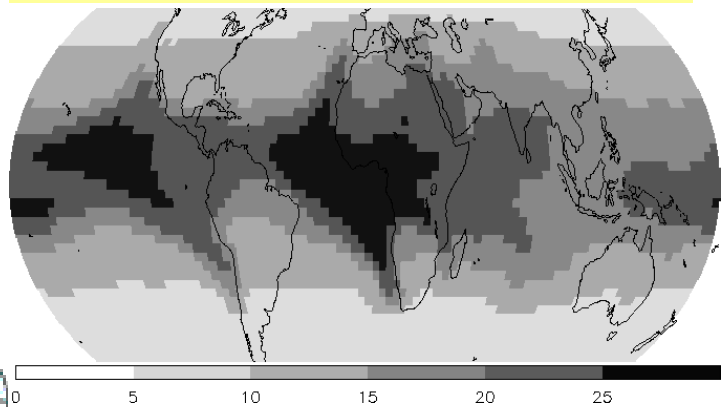


Impact in terms of bias in large regions (ppm)

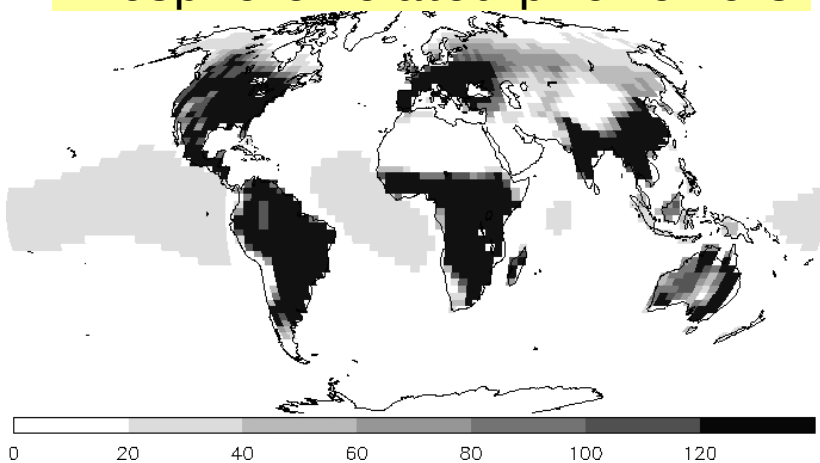
Impact of prior information

- Prior information modelled as multivariate Gaussian probability distribution
  - Error variances, spatiotemporal correlations

Theoretical error reduction
Uniform prior errors



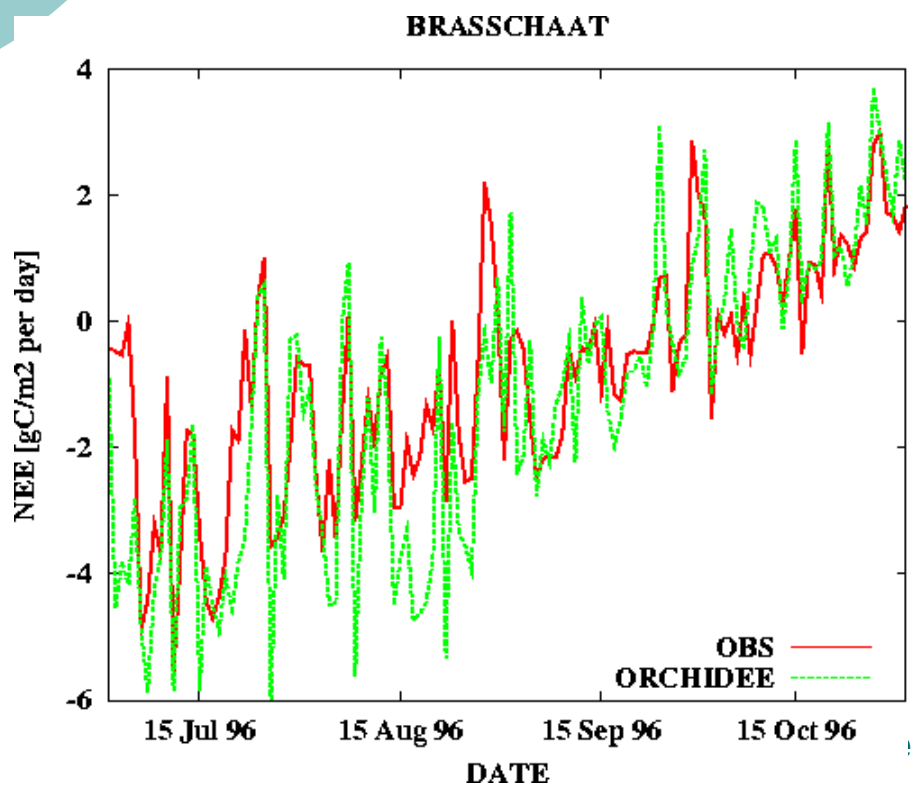
Theoretical error reduction
Biosphere-related prior errors

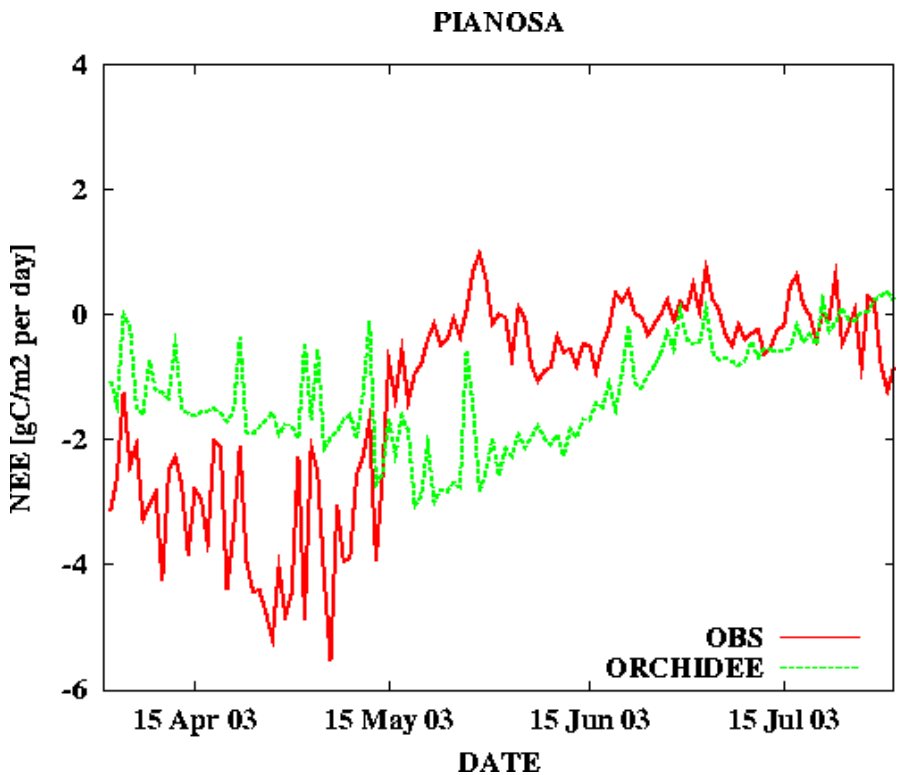


Chevallier et al., *J. Geophys. Res.*, 2005

Validation of ORCHIDEE

- 36 in situ FLUXNET sites between 1994 and 2004
- 31,500 daily-mean fluxes
- Link with FP6 GEOLAND

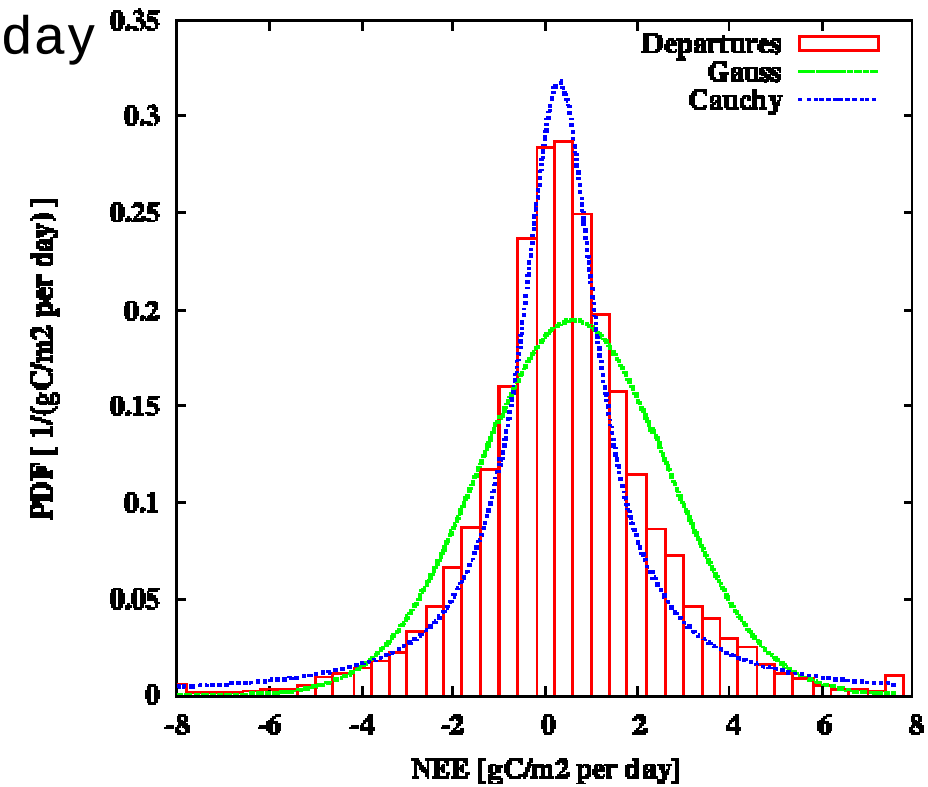




Validation of ORCHIDEE

- 36 in situ FLUXNET sites between 1994 and 2004
- 31,500 daily-mean fluxes
- Std error = 2 gC/m2/day

PDF of the model-minus-observations departures
+ 2 standard distributions



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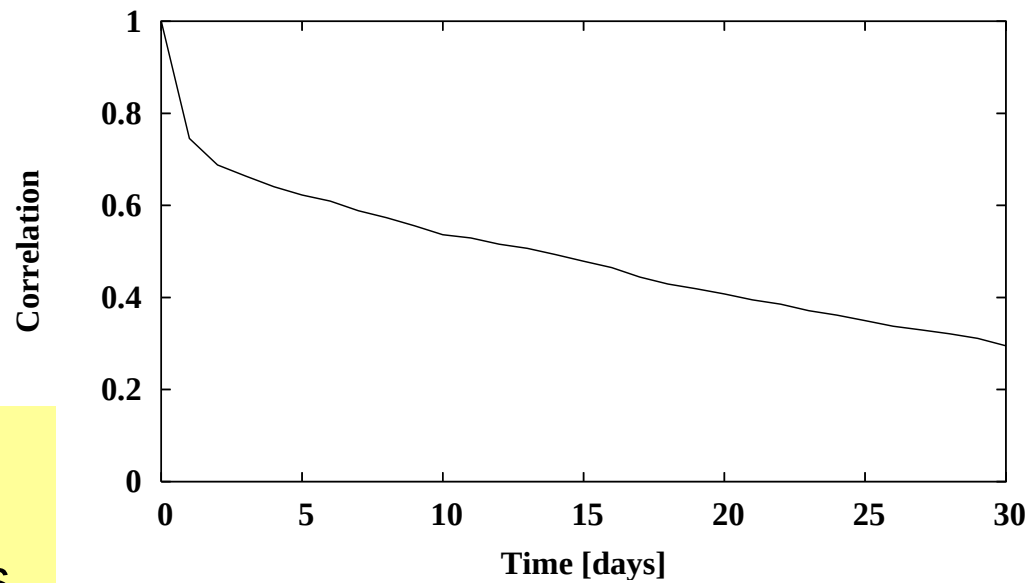

Overall error time correlations

Validation of ORCHIDEE

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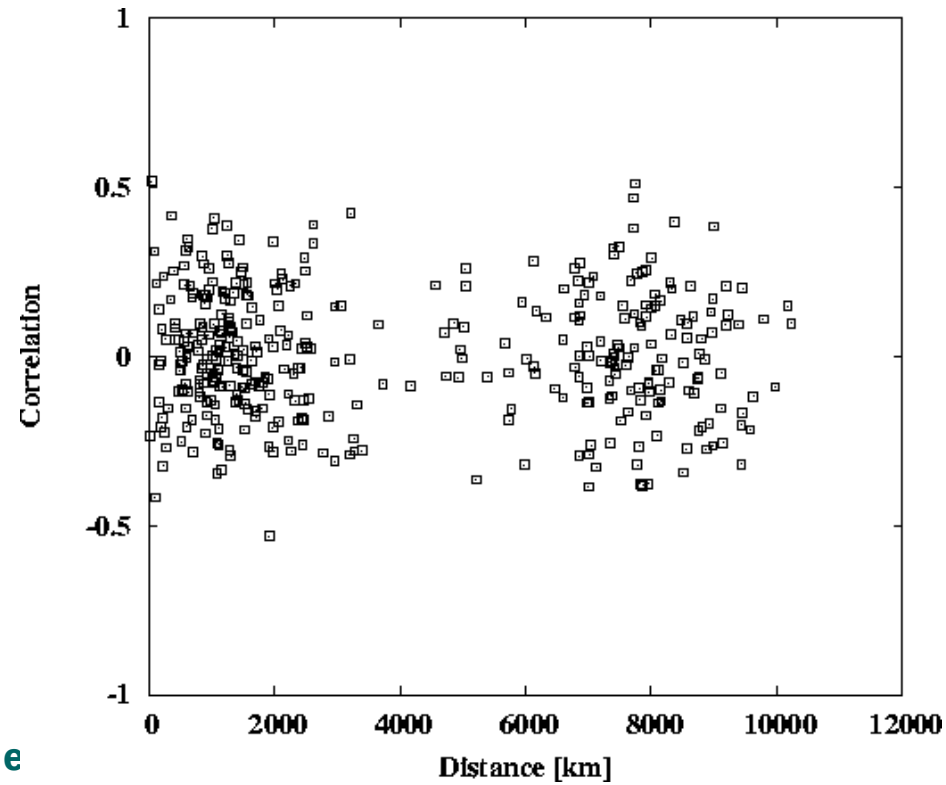
- 31,500 daily-mean fluxes
- Std error = 2 gC/m2/day



Error space correlations for each site

Validation of ORCHIDEE

- Convenient approximation of prior errors as multivariate Gaussian distributions is not legitimate in flux inversions
  - ... at least when using daily fluxes from ORCHIDEE
  - Flux error distribution closer to a Cauchy distribution
  - No particular spatial error structure
  - Time dependency of the correlation rather linear after lag-day 2

Chevallier et al., *in prep*., 2006b

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  - First evaluation of the sensitivity of the inversion to transport parameterizations
- Task 4.3: development of a routine processing chain in NRT
- Task 4.4: inversion of fluxes over the 2003-2007 period

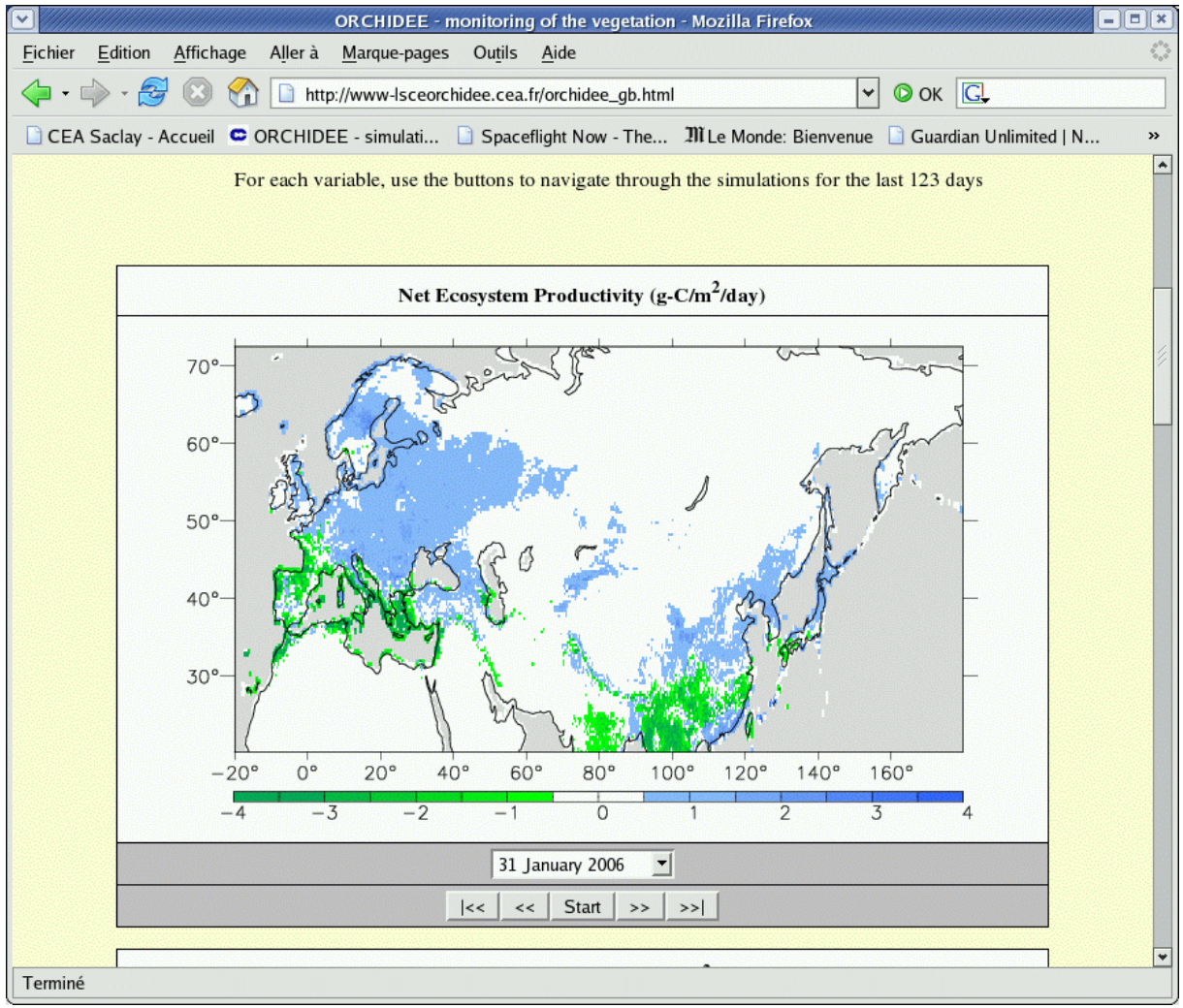
Plus…

- Evaluation of the usefulness of OCO
- Investigation of prior errors
- 2 papers published
- 2 papers in preparation

DoW M13-30

- Task 4.1: enhanced inversion procedure
  - New version of the inversion scheme
  - Investigate prior error
  - New inversions of AIRS performed and evaluated
  - Study IASI retrievals
- Task 4.2: sensitivity of the inversion to transport parameterizations
  - New evaluation of LMDZ
  - First evaluation of the sensitivity of the inversion to transport parameterizations
- Task 4.3: development of a routine processing chain in NRT
  - Set-up LMDZ part
- Task 4.4: inversion of fluxes over the 2003-2007 period

http://www.lsce-orchidee.cea.fr/



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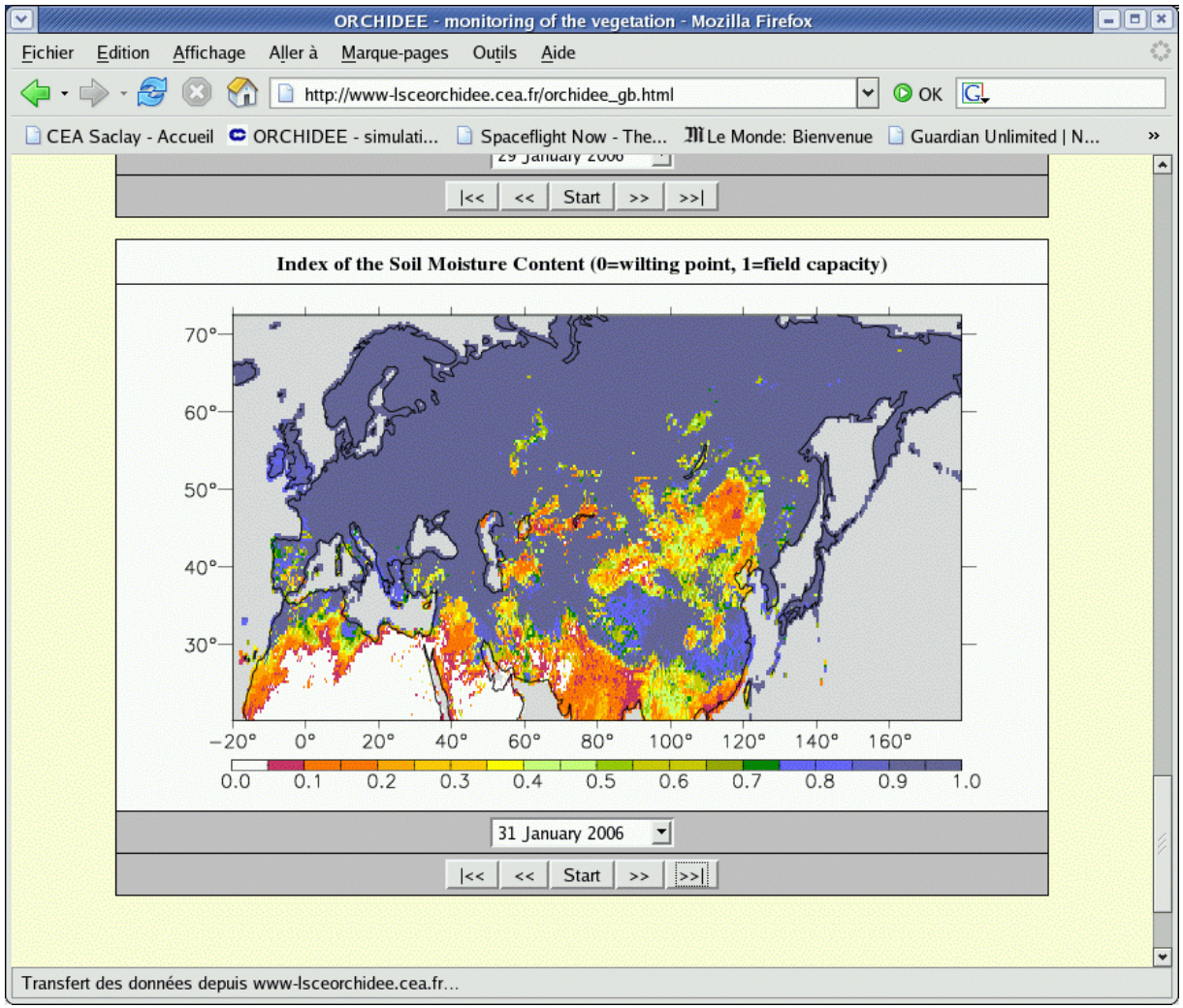

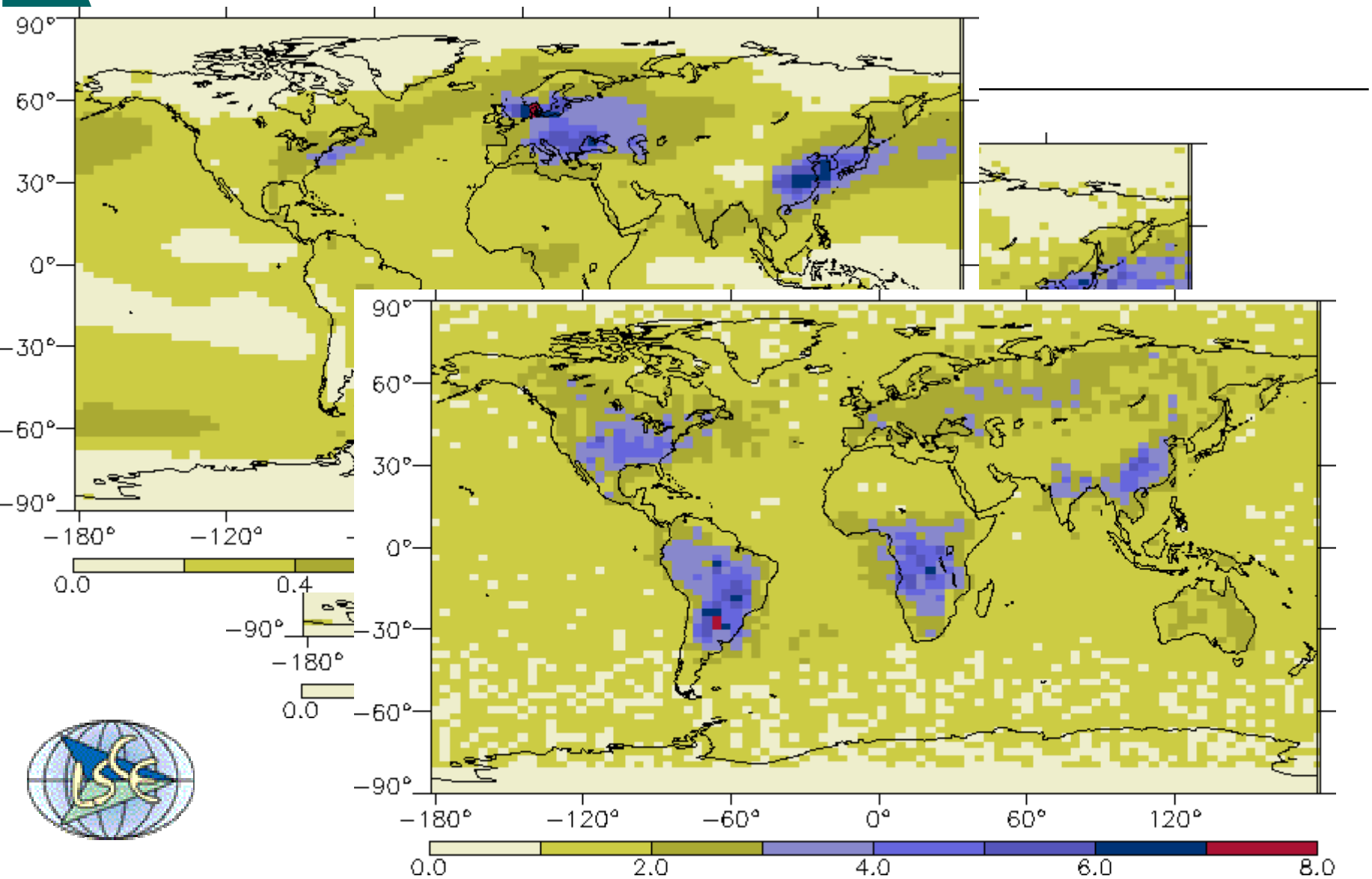
90°
60°
30°
0°
−30°
−60°
−90°
−180°
−120°
−60°
0°
60°
120°
0.0
2.0
4.0
6.0
8.0
0.4

Error Reduction
1
0.8
0.6
0.4
0.2
0
North American Boreal
North American Temperate
South American Tropical
South American Temperate
Northern Africa
Southern Africa
Eurasian Boreal
Eurasian Temperate
Tropical Asia
Australia
Europe
North Pacific Temperate
West Pacific Tropics
East Pacific Tropics
Eight
Mo
CO2 Flux (GtC per year)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
North American Boreal
North American Temperate
South American Tropical
South American Temperate
Northern Africa
Southern Africa
Eurasian Boreal
Eurasian Temperate
Tropical Asia
Australia
Europe
North Pacific Temperate
West Pacific Tropics
East Pacific Tropics
South Pacific Temperate
Northern Ocean
North Atlantic Temperate
Atlantic Tropics
South Atlantic Temperate
Southern Ocean
Indian Tropical Ocean
South Indian Temperate Ocean