Application of LMDZ in forward and inverse modelling of N_2O

LSCE, CNRS, CEA

NitroEurope

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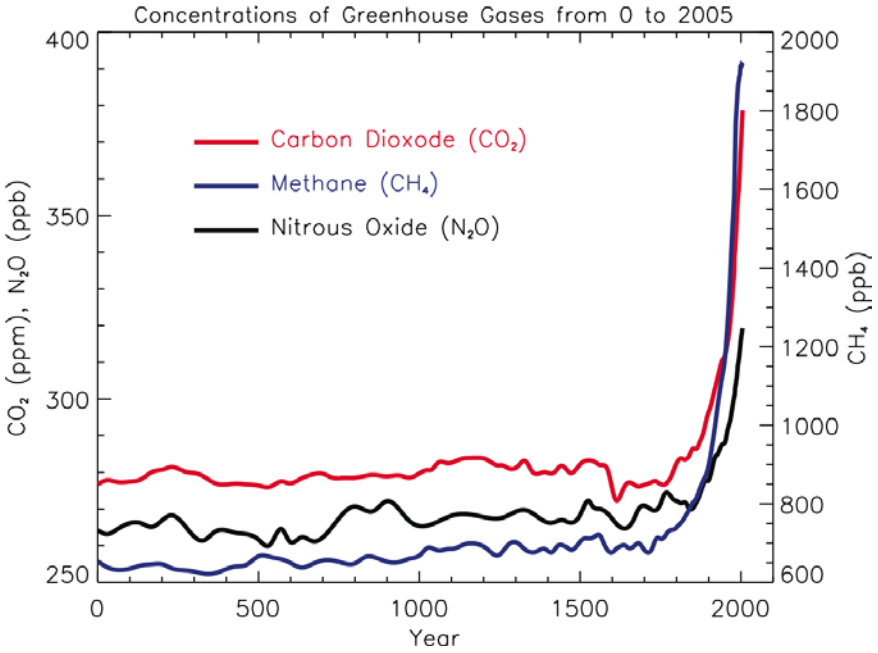
NitroEurope IP

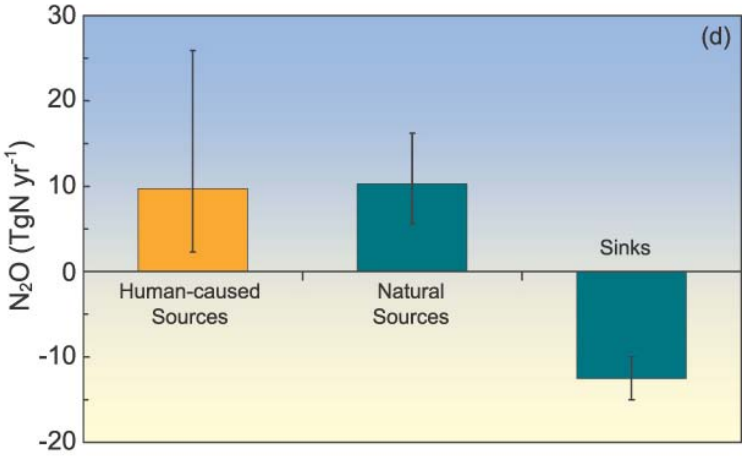
Motivation

① N_2O is the third most important GHG (IPCC AR4, 2007)

② N_2O emissions are the most important ODS emissions in 21st century

③ Improve knowledge of spatial and temporal variability in N_2O fluxes through comparison of atmospheric observations and model simulations





LMDZ set-up

① Atmospheric transport & chemistry model: LMDZ4-INCA2

② Zoom over Europe to 1x1 degrees

③ Physical time-step: 0.6 min

④ Chemistry time-step: 30 min

⑤ PBL scheme: Tiedtke

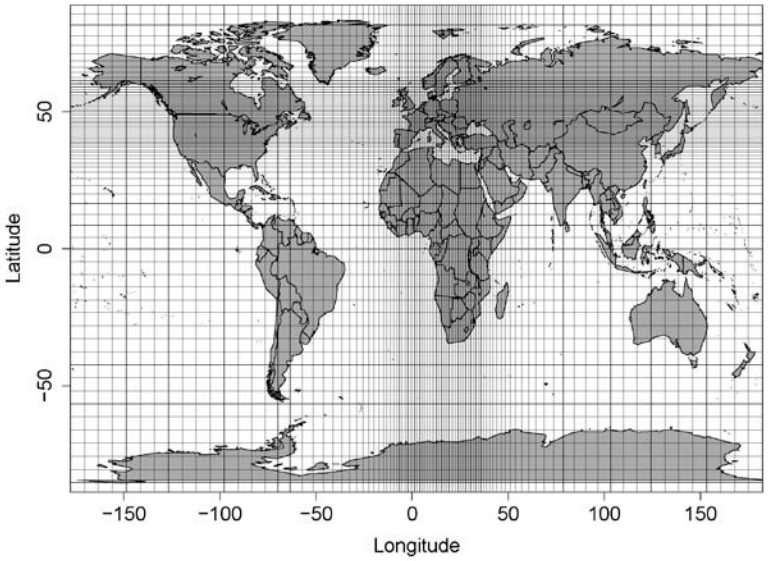
⑥ Simulated N_2O recorded hourly

⑦ Stratospheric photochemistry:

$$N_2O + O^1D \rightarrow N_2 + O_2$$

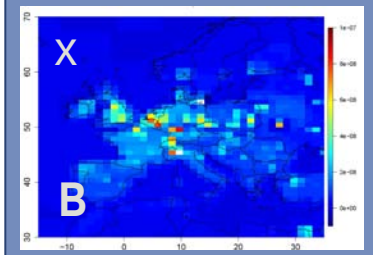
$$N_2O + O^1D \rightarrow 2NO$$

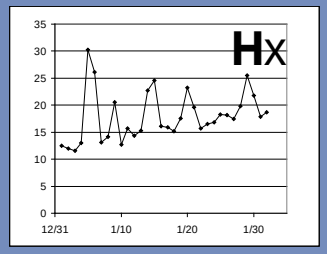
$$N_2O + h\nu \rightarrow N_2 + O^1D$$



Inversion framework

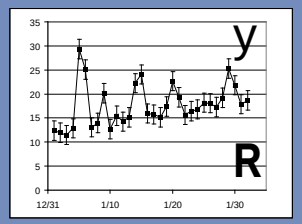
Forward model LMDZ:





Hx-y

Observations:



LMDZ Adjoint model:
$\mathbf{H}^T\mathbf{R}^{-1}(\mathbf{H}x-y)$

$J = (x-x_b)^T\mathbf{B}^{-1}(x-x_b) + (\mathbf{H}x-y)^T\mathbf{R}^{-1}(\mathbf{H}x-y)$

$\nabla J = \mathbf{B}^{-1}(x-x_b) + \mathbf{H}^T\mathbf{R}^{-1}(\mathbf{H}x-y)$

$\mathbf{H}^T\mathbf{R}^{-1}(\mathbf{H}x-y)$

x

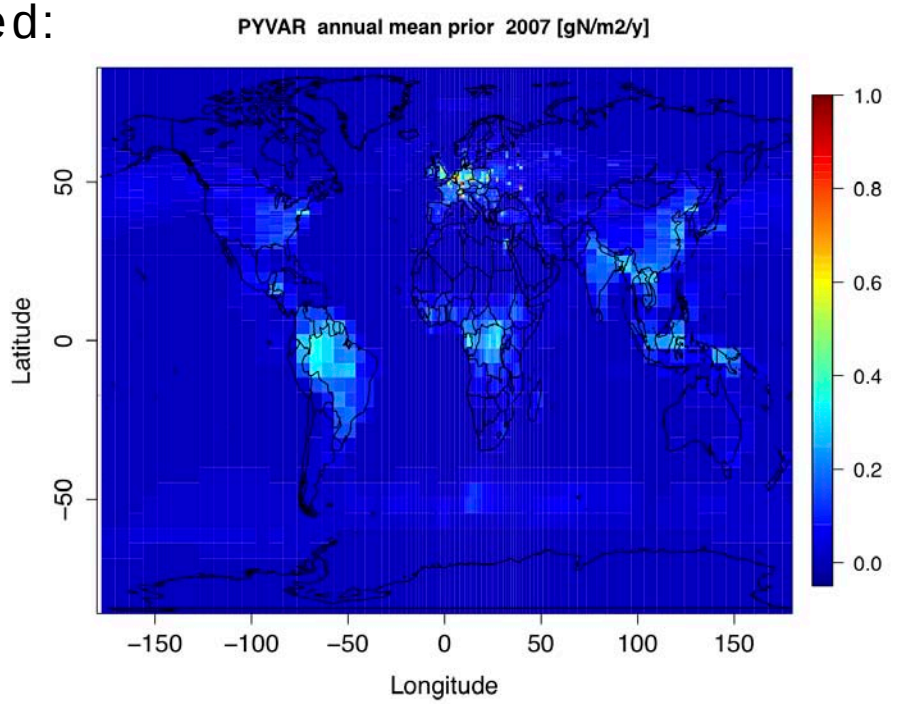
Lanczos algorithm:
$\omega = \mathbf{B}^{-1}(x-x_b)$
$\nabla J(\omega) = 0$

iterations

A priori emission estimates

Climatological emissions estimates used:

Source Type	Dataset	Resolution
Natural soils	GEIA	monthly
Agriculture	EDGAR-4.0	monthly
Industry	EDGAR-4.0	monthly
Fossil fuels	EDGAR-4.0	monthly
Biomass burning	GFED2	monthly
Ocean	GEIA	annual

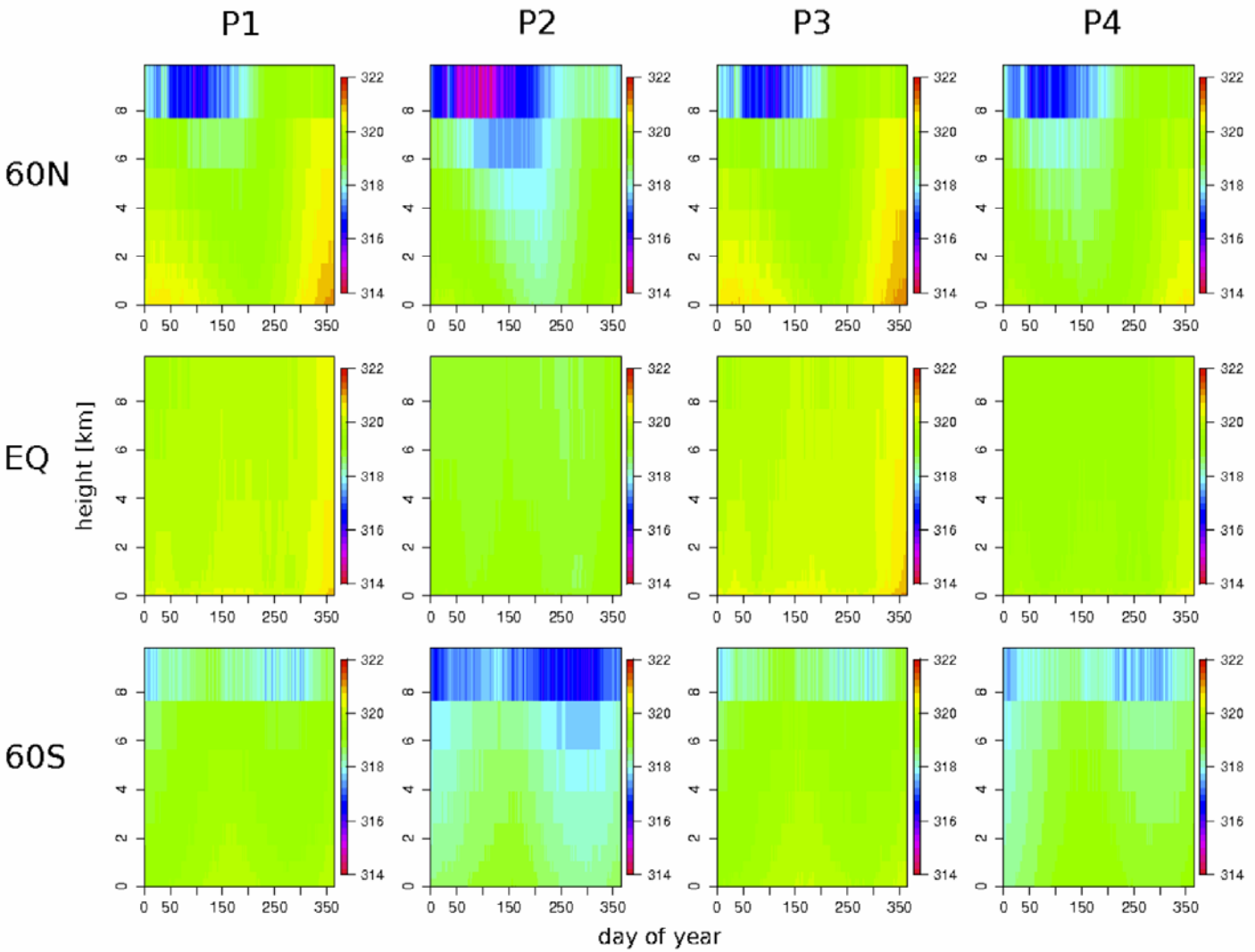


Total prior source: 13.8 TgN/y
Total prior source scaled-up: 16.0 TgN/y
Total sink: 13.8 TgN/y (lifetime of 108 years)

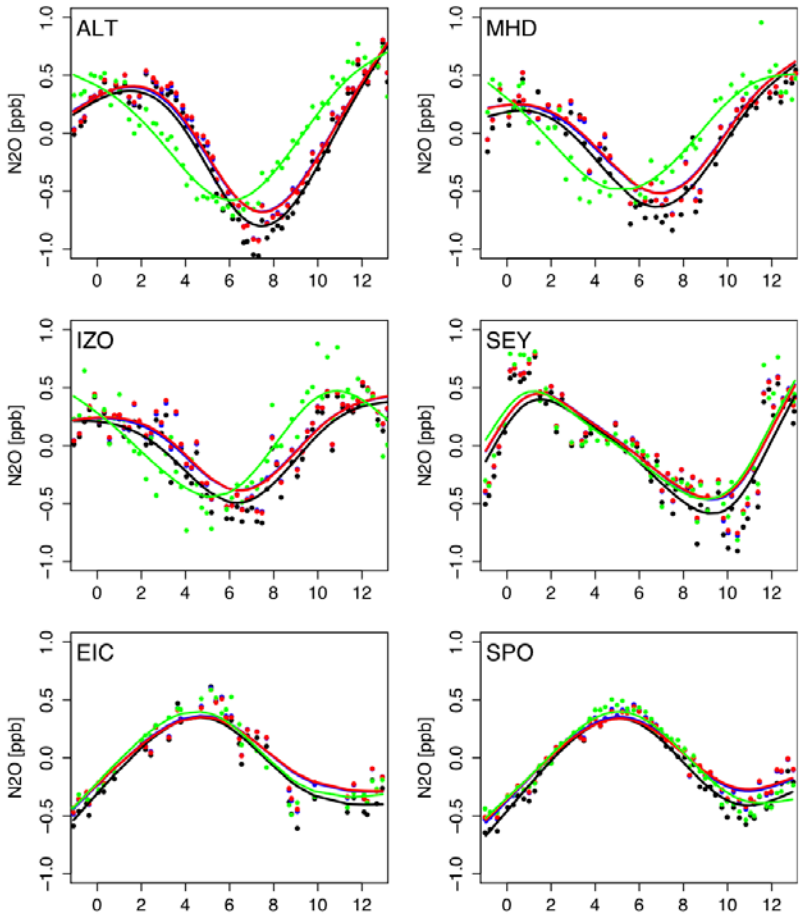
Forward modelling scenarios

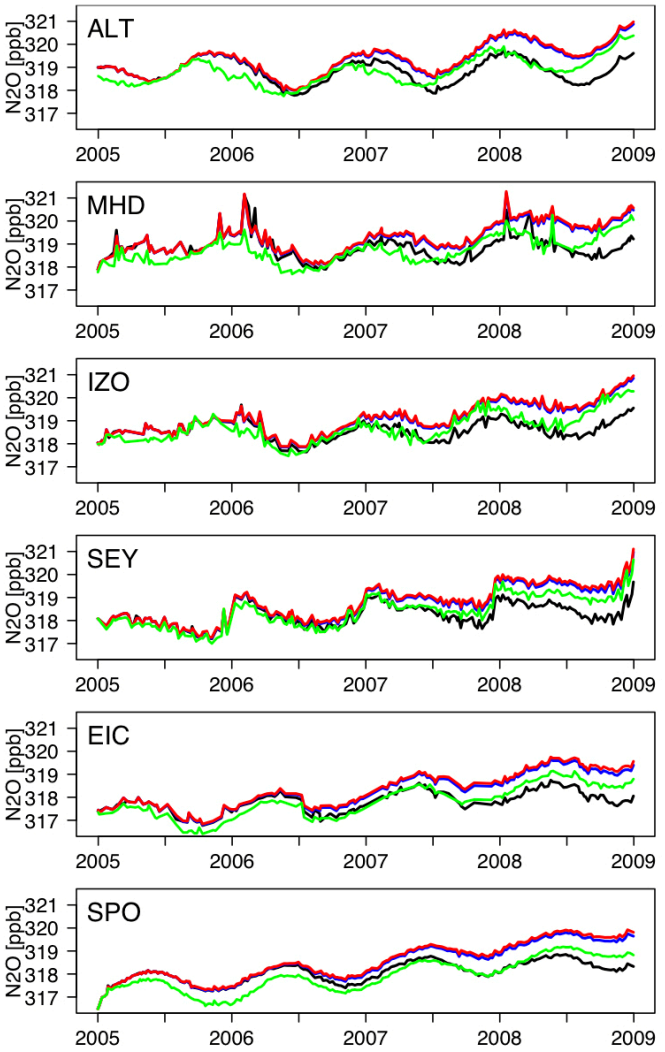
No.	Scenario
P1	T = 122 y
P2	T = 98 y
P3	T = 122 y temporally and horizontally flat sink
P4	T = 122 y recycled vertical mass fluxes

Zonal mean N_2O mixing ratios for each scenario



Forward modelling scenarios





P1: T = 122 y reference case

P2: T = 98 y strong sink

P3: T = 122 y flat sink

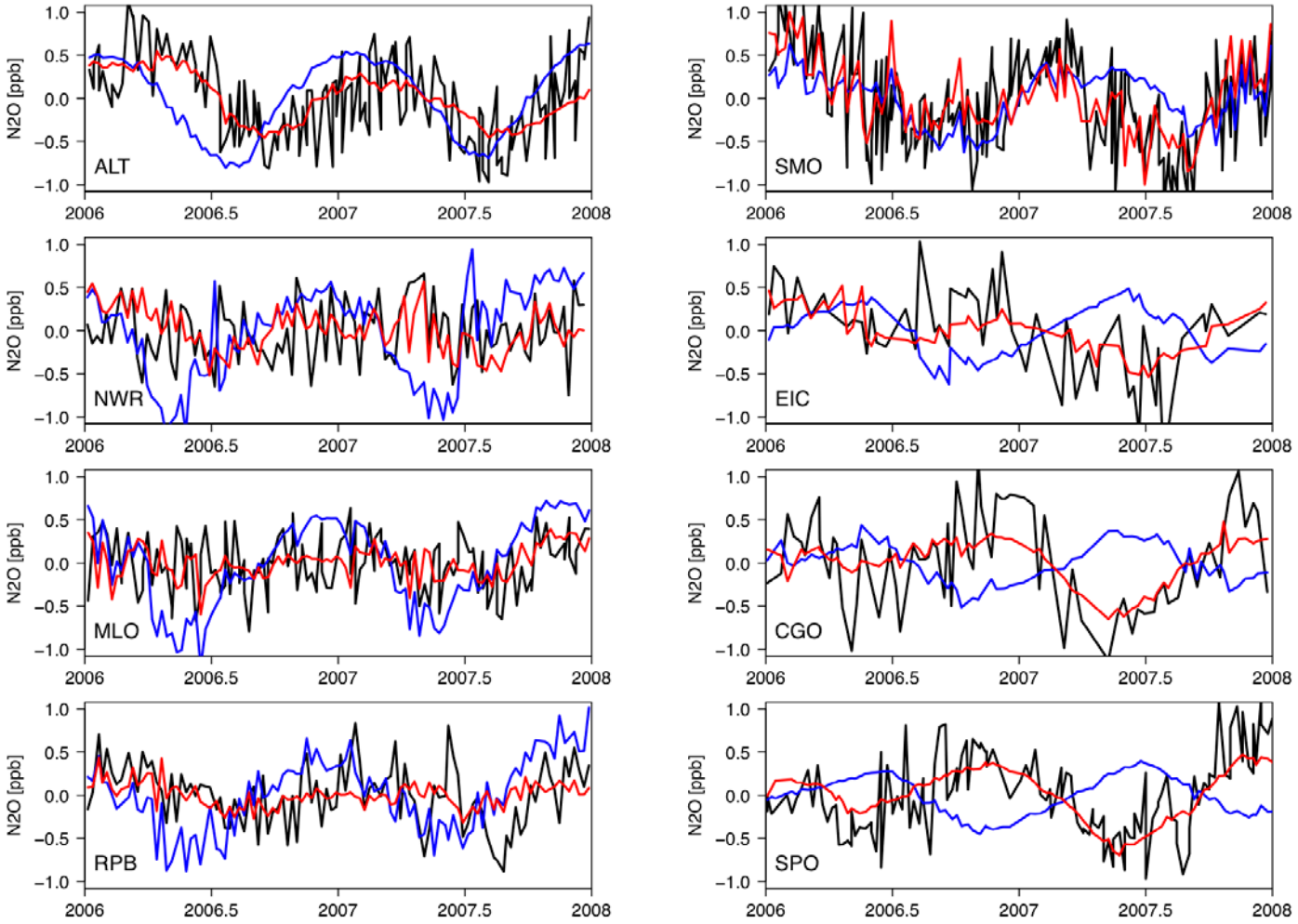
P4: T = 122 y recycled vert. mass fluxes

Prior versus Posterior mixing ratios

observation
prior
posterior

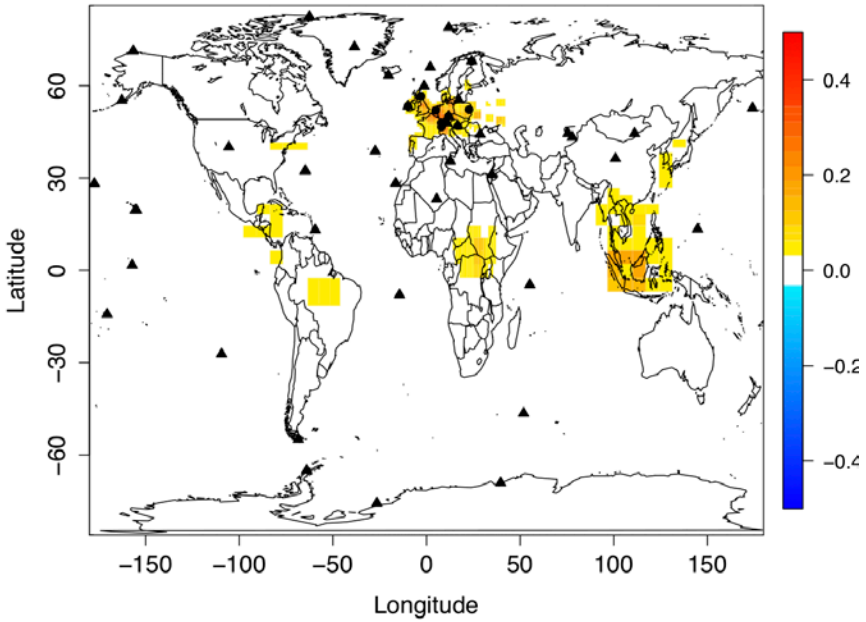
Northern Hemisphere

Southern Hemisphere

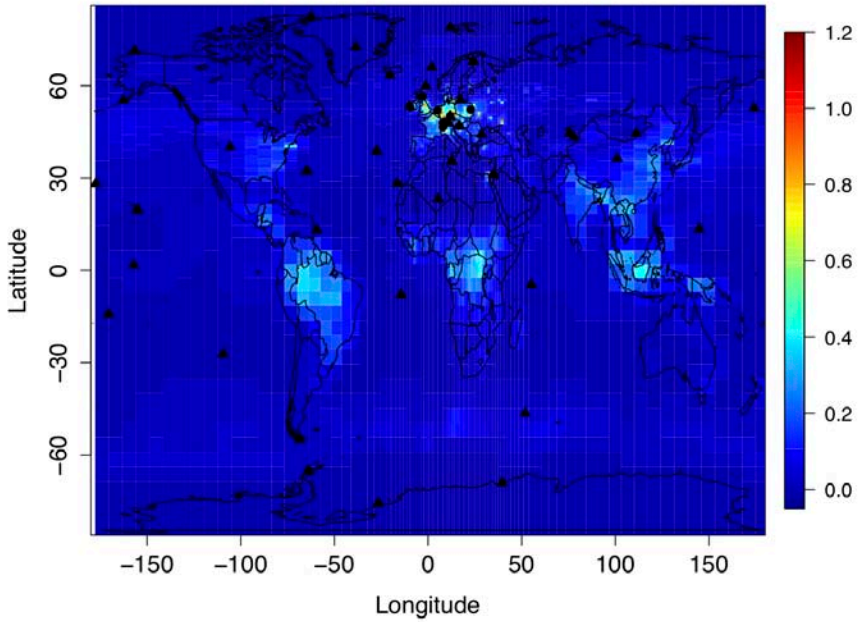


Global estimates of N_2O emissions

Annual mean 2007 posterior-prior emissions [gN/m^2/y]



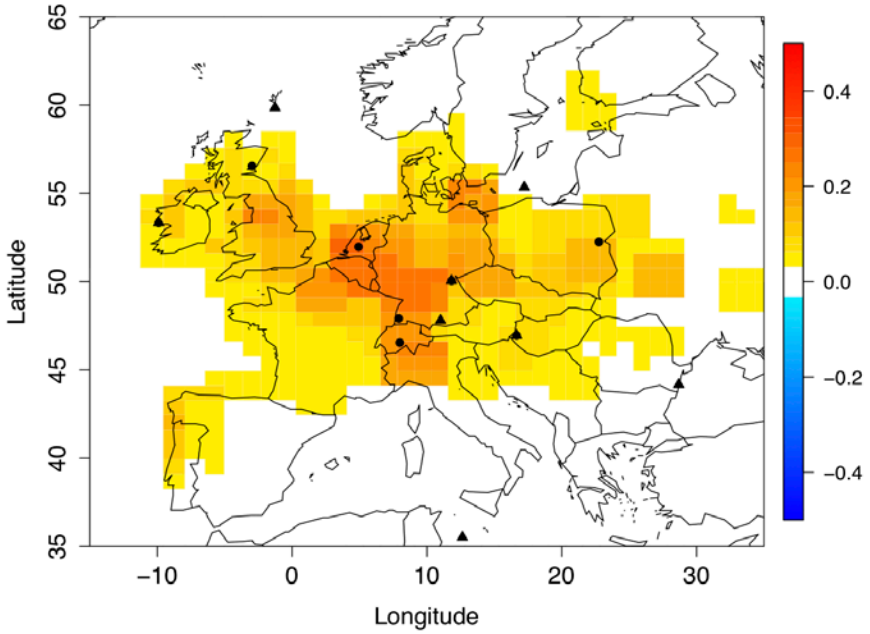
Annual mean 2007 posterior emissions [gN/m^2/y]



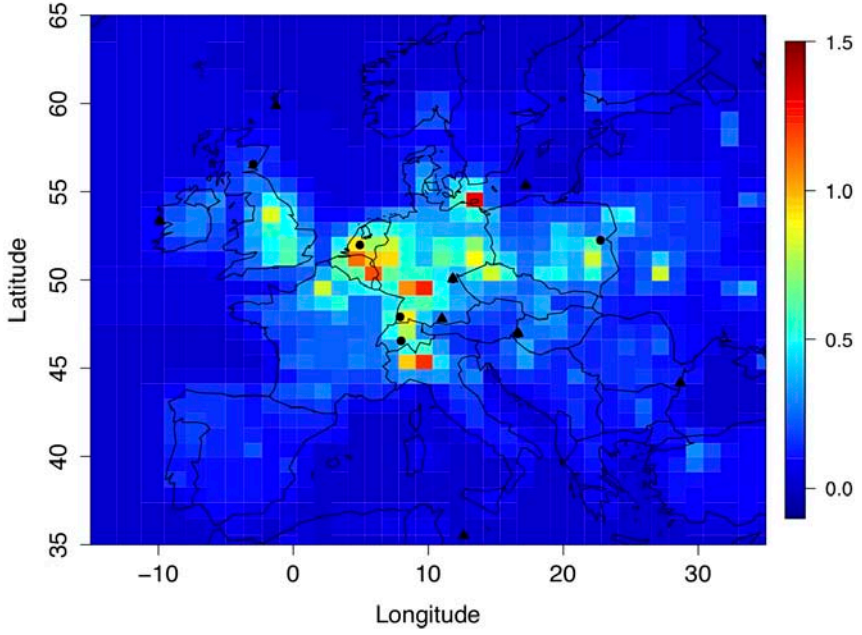
Total sink: 13.8 TgN/y (lifetime of 108 years)
Total posterior source: 19.4 TgN/y

European estimates of N_2O emissions

Annual mean 2007 posterior-prior emissions [gN/m²/y]



Annual mean 2007 posterior emissions [gN/m²/y]



EU27 total emissions [TgN/y]

Year	Prior	Posterior
2006	0.66	0.96
2007	0.66	0.93

Discussion & Conclusions

① Substantial errors exist in prior estimates of N_2O emissions

② Atmospheric inversion of N_2O predicts greater emissions in the tropics, especially tropical Africa and southeast Asia, and in Europe

③ European emissions: inversion predicts greater emissions over most of central and western Europe and in particular in Benelux, west Germany, and Po valley in Italy.

④ Global total posterior emission = 19.4 TgN/y

Discussion:

Seasonality of N_2O in southern hemisphere poorly simulated by prior model – errors in Cross Tropopause Flux (CTF)?

Need better validation of CTF for modelling of tracers especially those with stratospheric losses?

Acknowledgements

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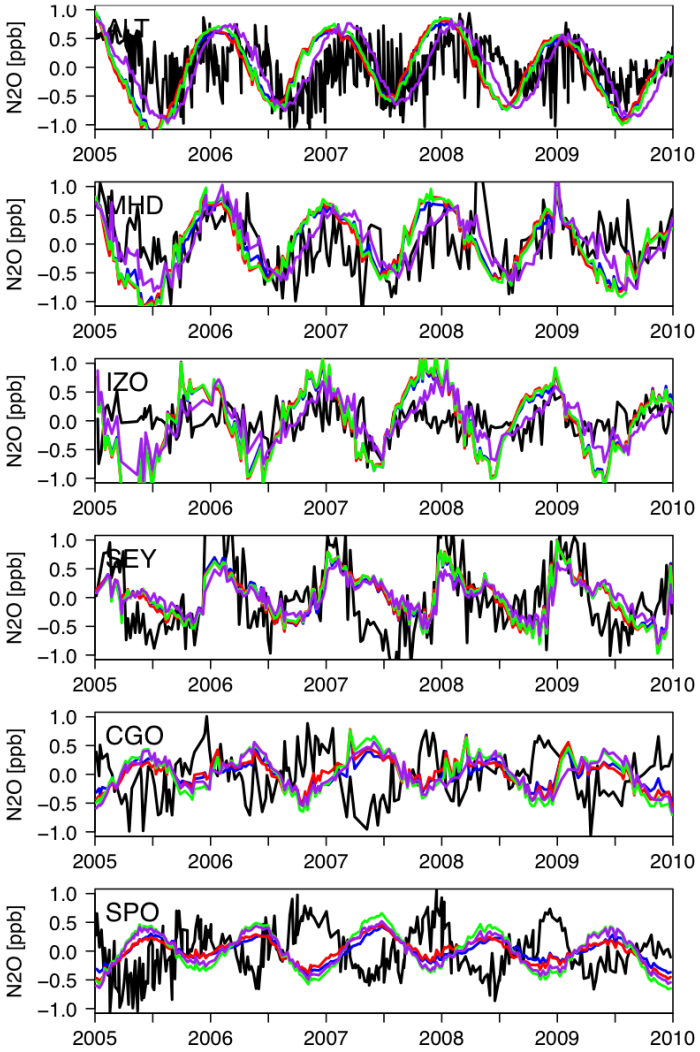
Discussion slide 1

Comparison of prior flux estimates



Prior fluxes:

Orchidee et PISCES

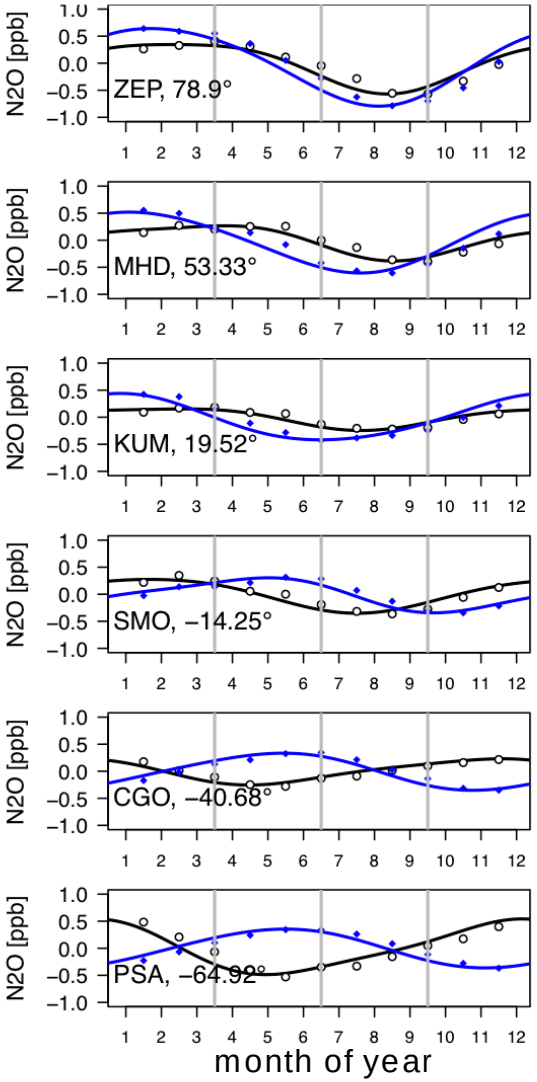
Orchidee et Nevsion 1995

Orchidee et Nevison 2004

Bouwmann et Nevison 2004

Observations

mean seasonal cycle



model

observation

Discussion slide 2