HYMN overview modelling results

M. van Weele, TM5 meeting, Wageningen, 7-8 dec 2009

Hydrogen, Methane and Nitrous oxide: Trend variability, budgets and interactions with the biosphere

GOCE-CT-2006-037048 Sep 2006 – Dec 2009

HYMN consortium

No	Partner	Short name	Country
1	Royal Netherlands Meteorological Institute (coordinator)	KNMI	Netherlands
2	University of Bristol	UNIVBRIS	United Kingdom
3	University of Oslo	UiO	Norway
4	University of Heidelberg	UHEI.IUP	Germany
5	Centre National de la Recherche Scientifique- Laboratoire des Sciences du Climat et de l'Environnement	CNRS-LSCE	France
6	University of Bremen	Uni-HB	Germany
7	Belgian Institute for Space Aeronomy	BIRA-IASB	Belgium
8	University of Liège	ULg	Belgium
9	Chalmers Tekniska Hoegskola Aktiebolag	Chalmers	Sweden
10	Forschungszentrum Karlsruhe, Institut für Meteorologie und Klimaforschung – Atmospheric Environmental Research	FZK-IMK-IFU	Germany
11	University of Karlsruhe, Institut für Meteorologie und Klimaforschung – Atmospheric Trace Constituents and Remote Sensing	UniKarl	Germany
12	Commisariat à l'Energie Atomique - Laboratoire des Sciences du Climat et de l'Environnement	CEA-LSCE	France

HYMN key activities

Contributions to monitoring of CH_4 and N_2O

- Improved satellite data CH_4 (SCIAMACHY and IASI)
- Harmonized time series CH_4 and N_2O (FTIR network)

LPJ process model development and evaluation

- LPJ 1990+, trace-gas exchange modules of CH_4, N_2O and H_2
- Evaluation of LPJ exchange fluxes coupled with CTMs using ground-based (incl. FTIR) and satellite observations (incl. SCIAMACHY)

Inverse modeling for CH_4 and H_2

- New estimates of the sources and sinks of CH_4 (SCIAMACHY, surface) and H_2 (surface)

Trends, hydrogen scenarios

- Changes in natural fluxes and possible impacts on OH, CH_4, N_2O, and H_2
- Quantify how the *hydrogen economy* might affect H_2, CH_4 and O_3

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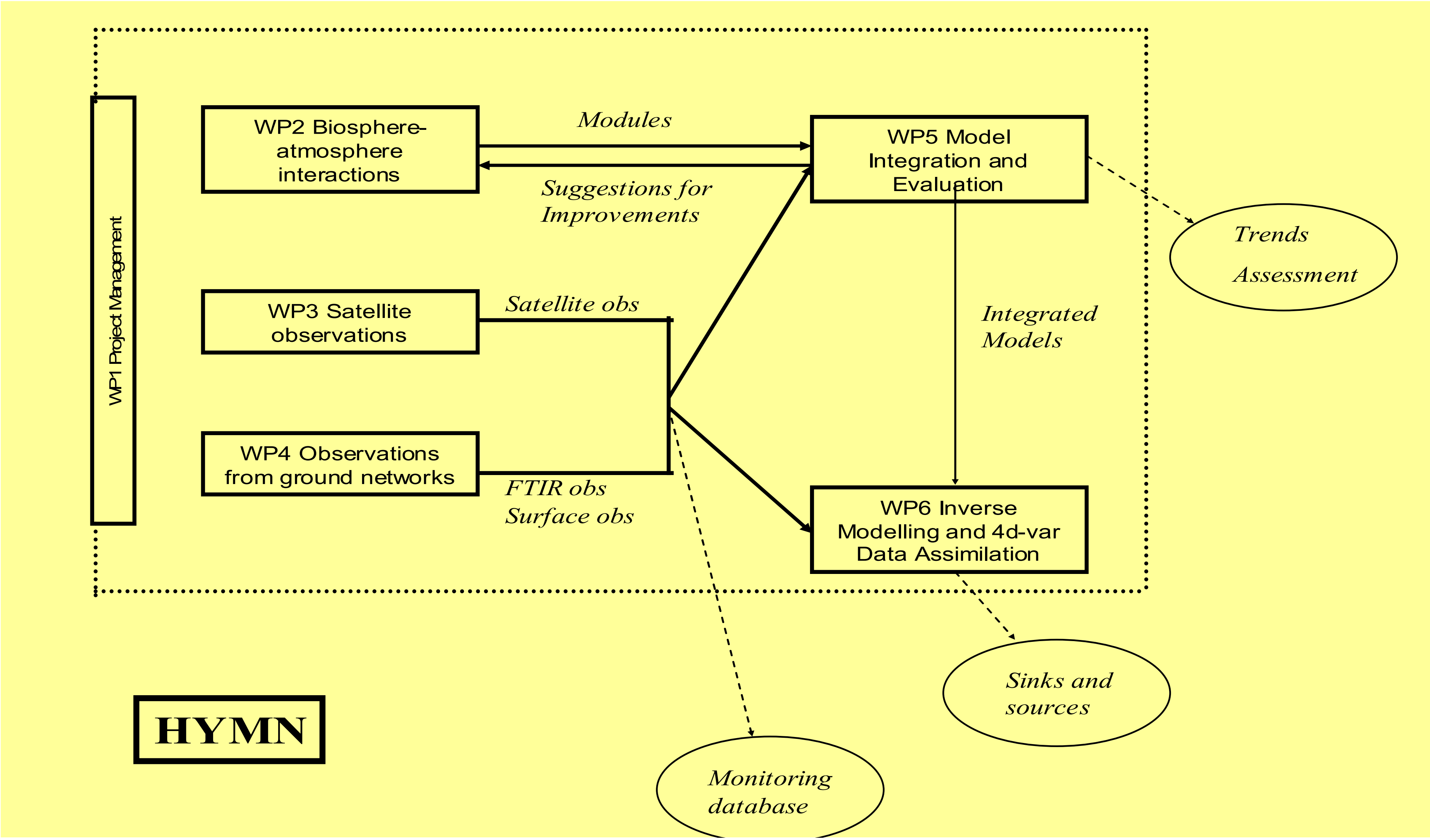
Project overview



Biosphere Atmosphere Interactions

=> Global dynamical vegetation model 'LPJ' with several new modules

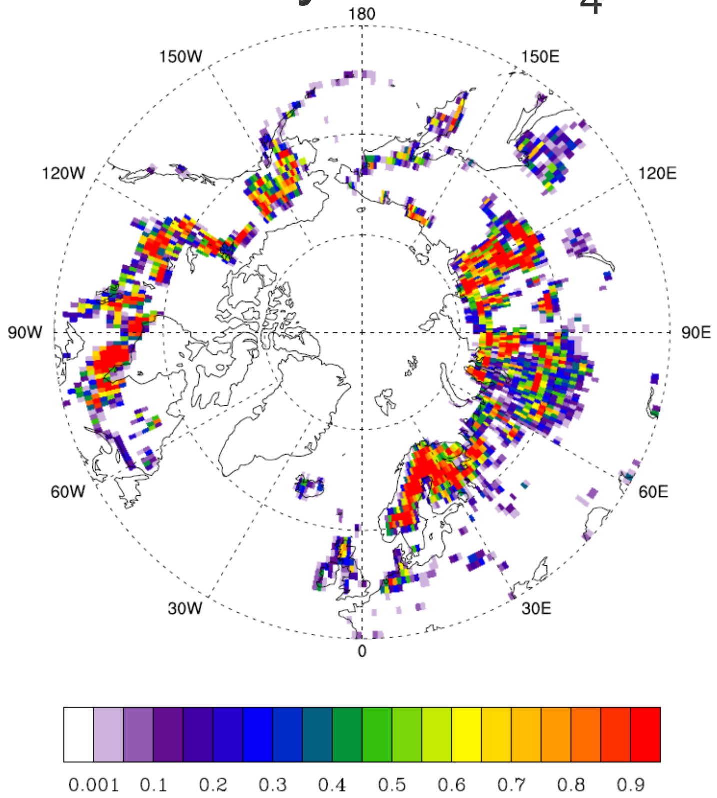
- CH_4 sources and sinks:
  - northern wetlands (incl. peatlands, permafrost)
  - soil oxidation
  - tropical wetlands
  - wet soils
  - rice paddies
- N_2O fluxes from soils
- H_2 deposition fluxes
- Fire modelling and fire emissions for CH4, CO, NOX, H2
- Other gases (incl. isoprene) and dry deposition parameters

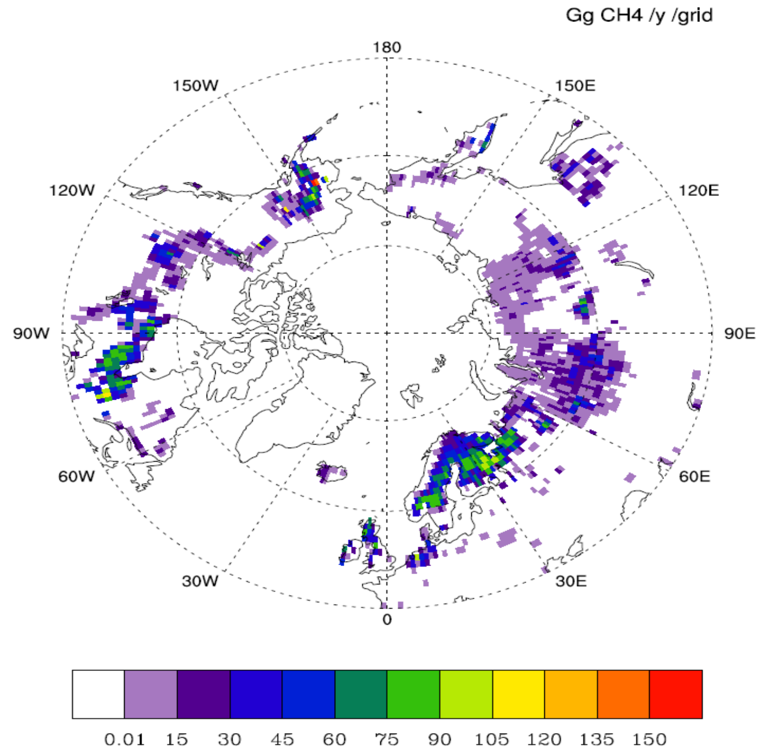
LPJ categories for CH_4

LPJ – organic soils (left) and CH4 emissions northern peatlands (right)

Wania et al., 2007

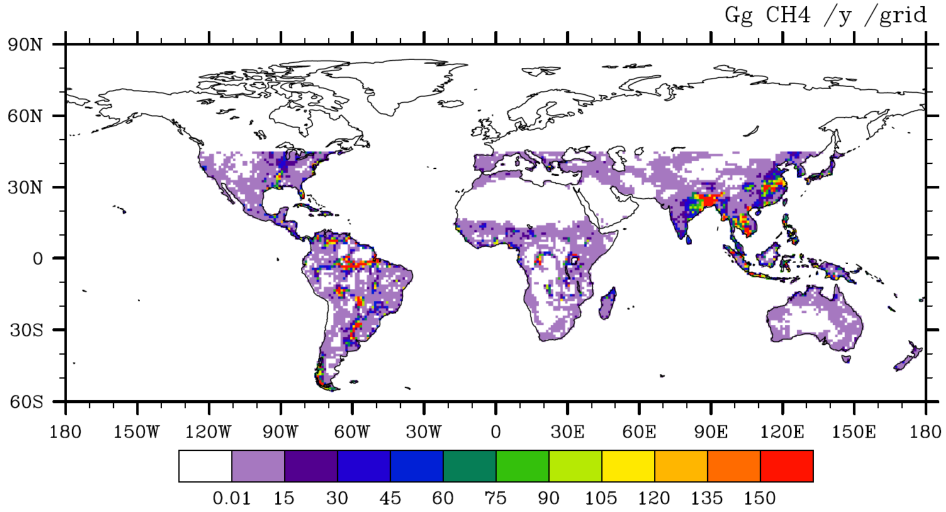
LPJ-WHyMe – CH_4 emissions in peatlands



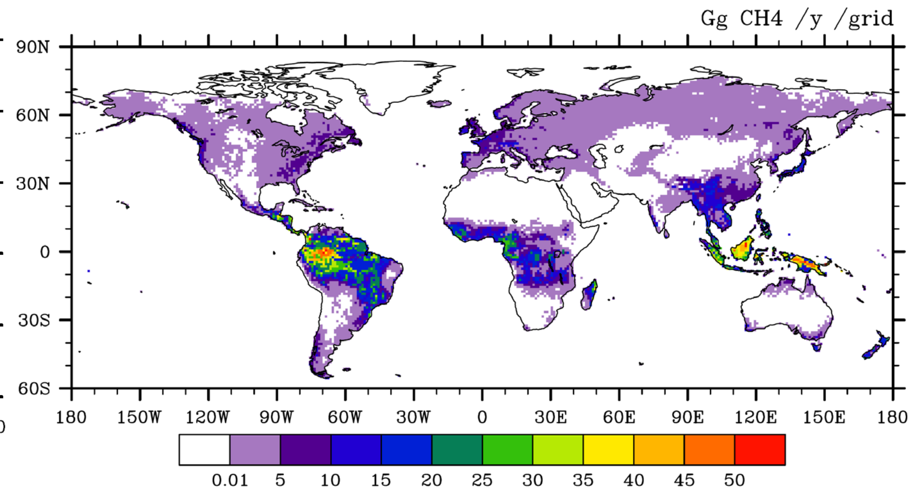


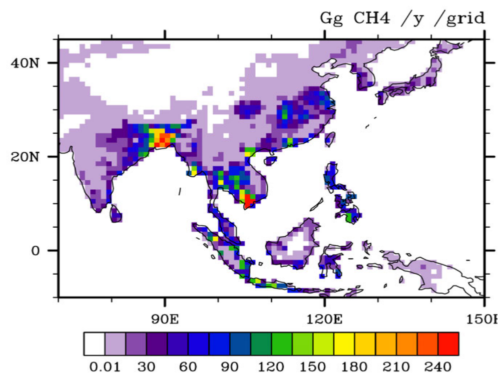
LPJ categories for CH_4

LPJ – CH4 emissions in observed wetlands < 45N, Prigent et al., 2007



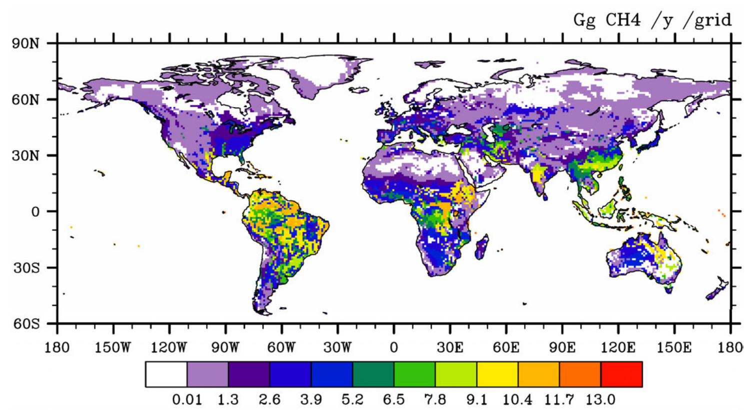
LPJ – wet soil CH4 emissions produced by hydrology in LPJ



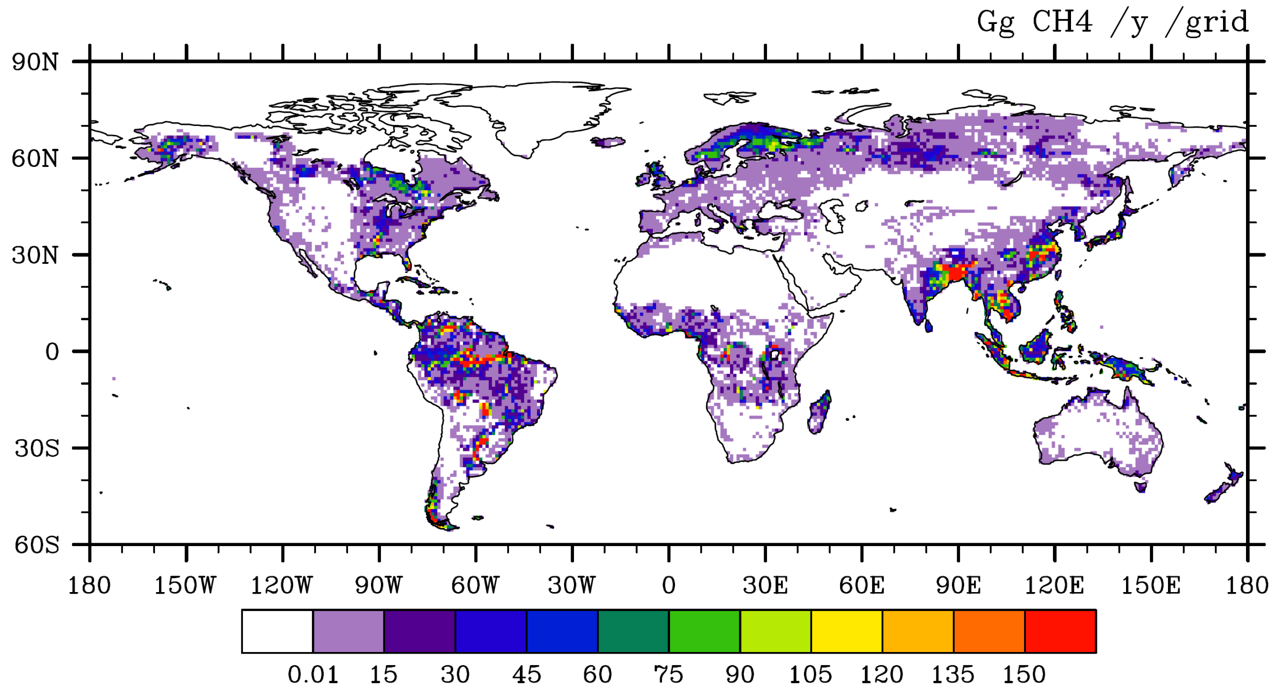


←Emissions of rice paddies

Soil uptake →



Biosphere Atmosphere Interactions: CH_4



LPJ Simulated net emissions

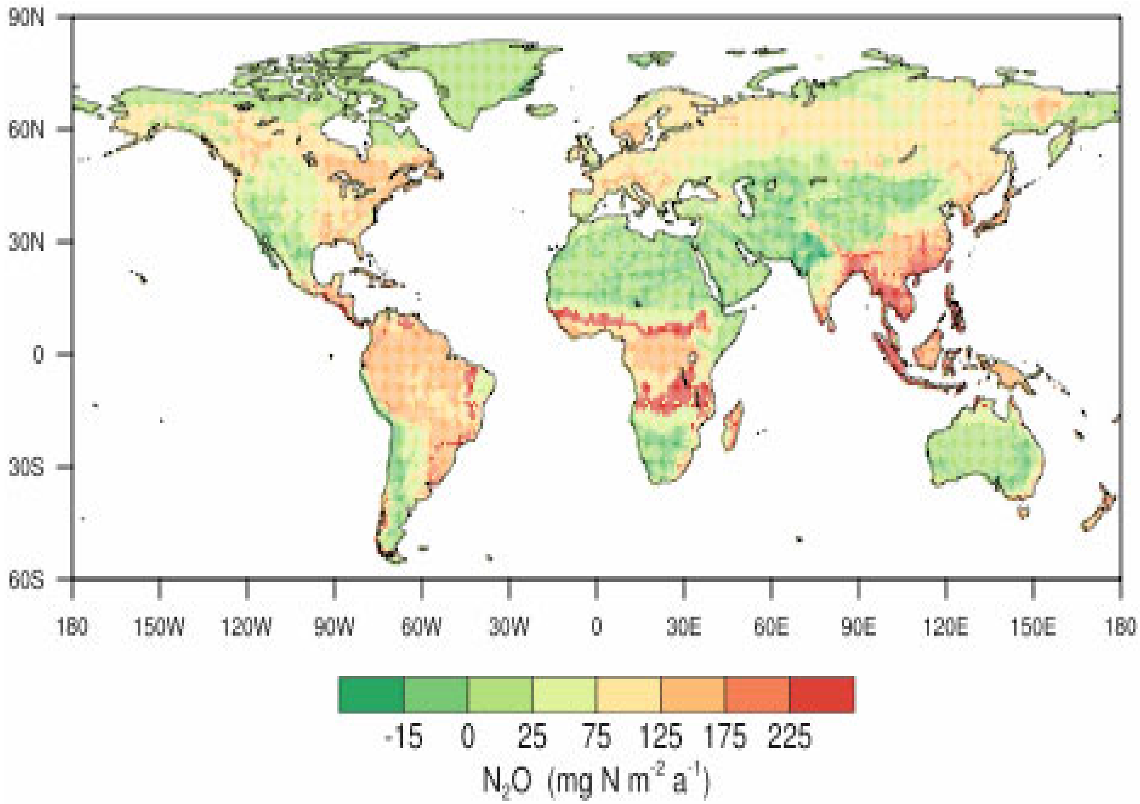
CH4

All LPJ categories

Year 2004

Highest emissions per grid cell in ...
… South America and Africa: inundated wetlands
… SE Asia: rice cultivation and inundated wetlands
… Scandinavia, Siberia, Canada, Alaska: peatlands

Biosphere Atmosphere Interactions: N_2O

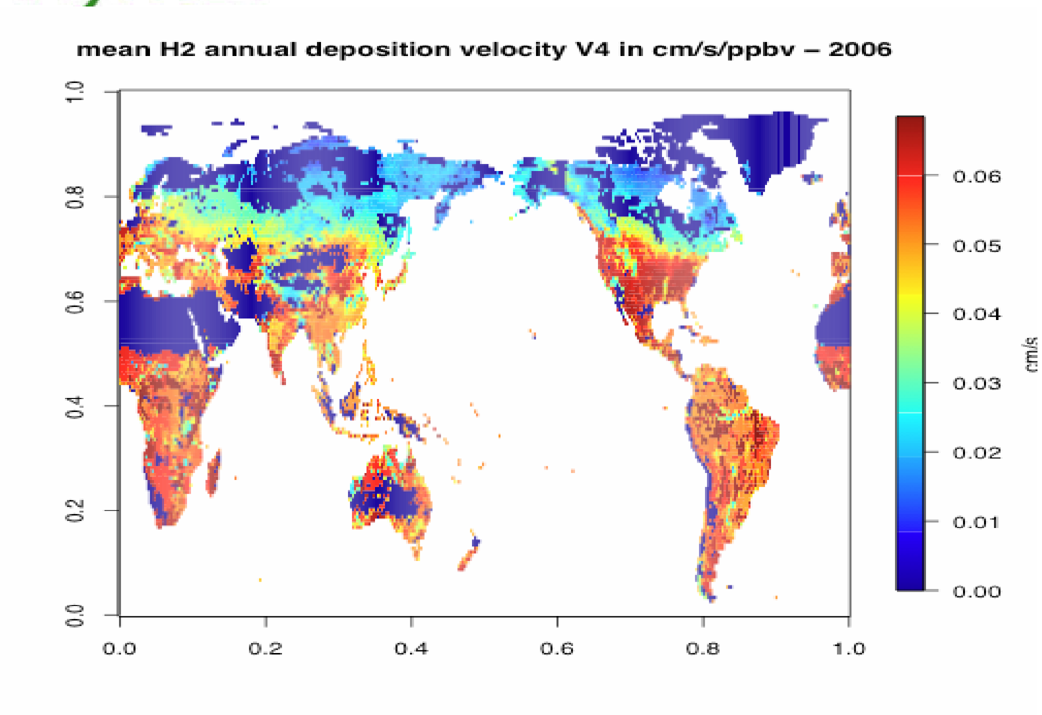


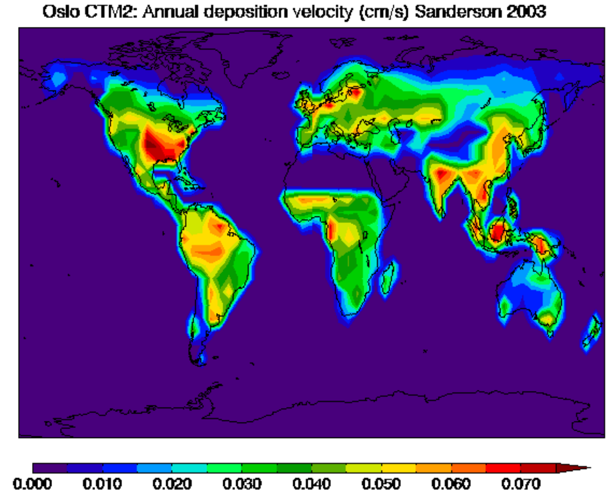
HYMN N_2O budget uncertainties

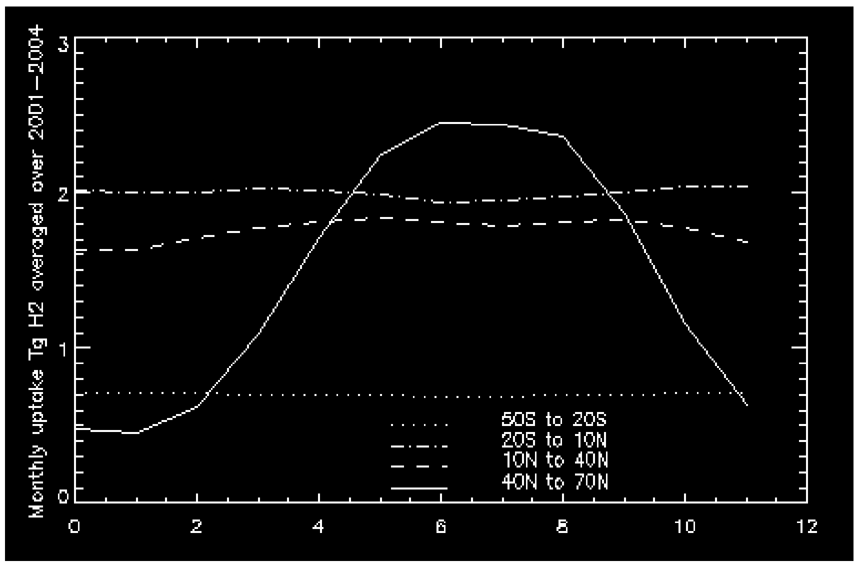
Anthr. emissions (Tg/a)		
	6.8	+/- 0.5
Net natural flux		
	10.8	+/- 3.1
Soils	**8.6**	
Oceans	2.2	
Trend (+1 ppb/yr)		
	5.0	+/- 0.7
Implied stratospheric sink		
	12.6	+/- 3.2

LPJ N_2O net natural soil emissions
8.6 Tg/a N_20-N

Biosphere Atmosphere Interactions: H_2





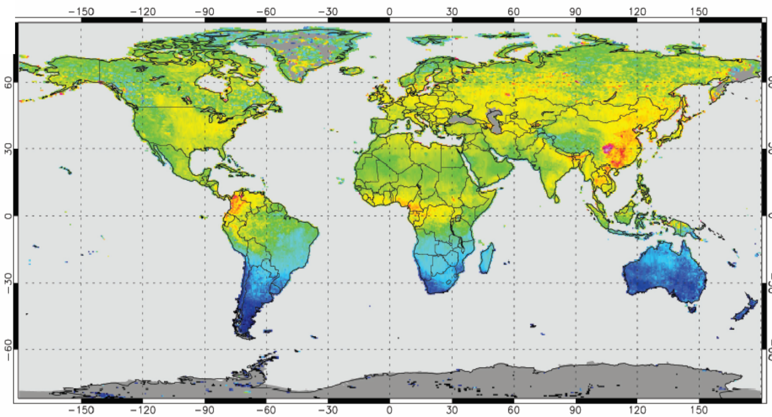


Total uptake LPJ	70 Tg/a
Chemical loss	19 Tg/a
Chemical production	37 Tg/a
H_2 emissions inferred	52 Tg/a

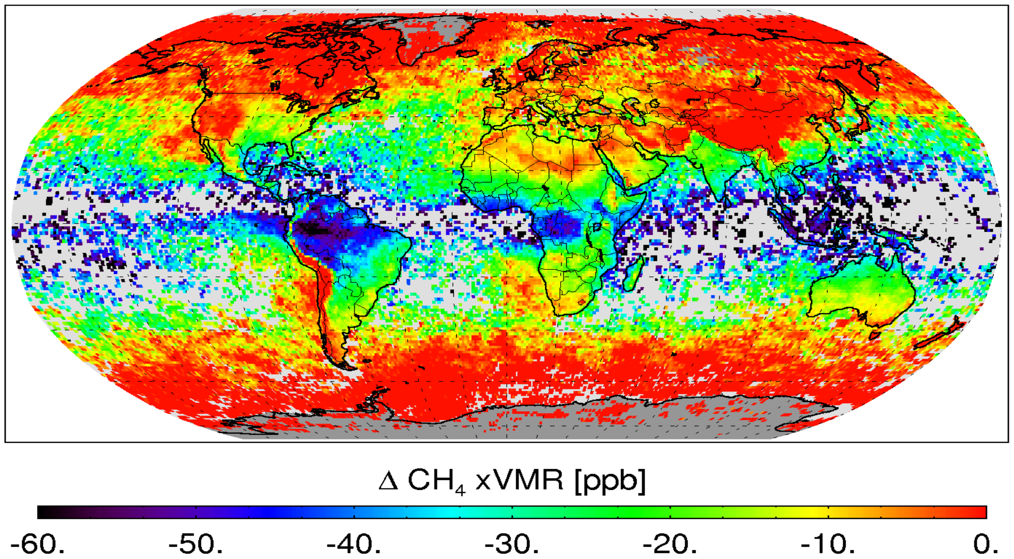
Improved SCIAMACHY methane

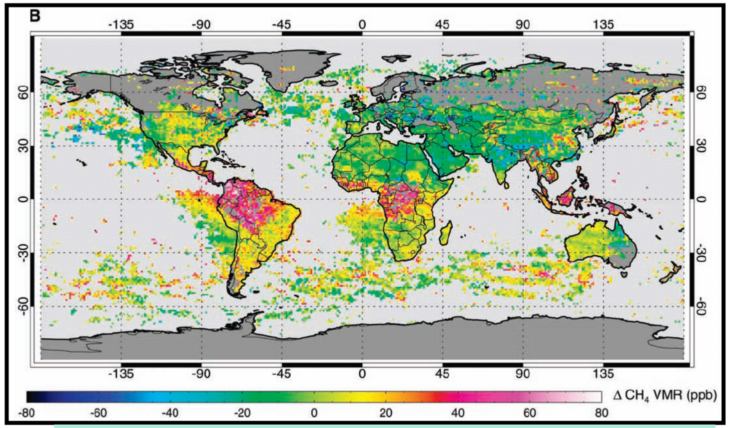
Improved knowledge of atmospheric water vapor and CH_4 spectroscopy

Implications for SCIA CH_4 retrievals



2-year mean 2003-2004)





Frankenberg et al, Science, 2005

Frankenberg et al, GRL 2008

Harmonized FTIR observations

Improvement, homogenization, characterisation, and evaluation of existing FTIR observational data sets and continuation of the observations in 2006-2009

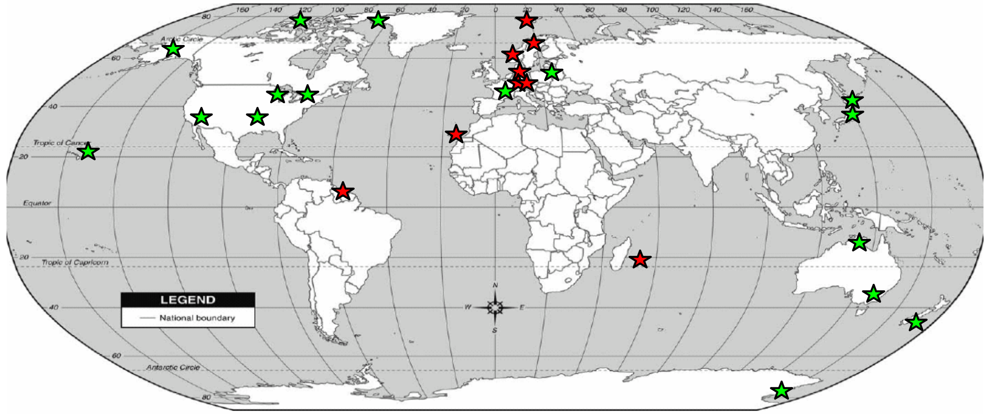
⇒ Optimized and harmonized retrieval strategy of CH_4 and N_2O

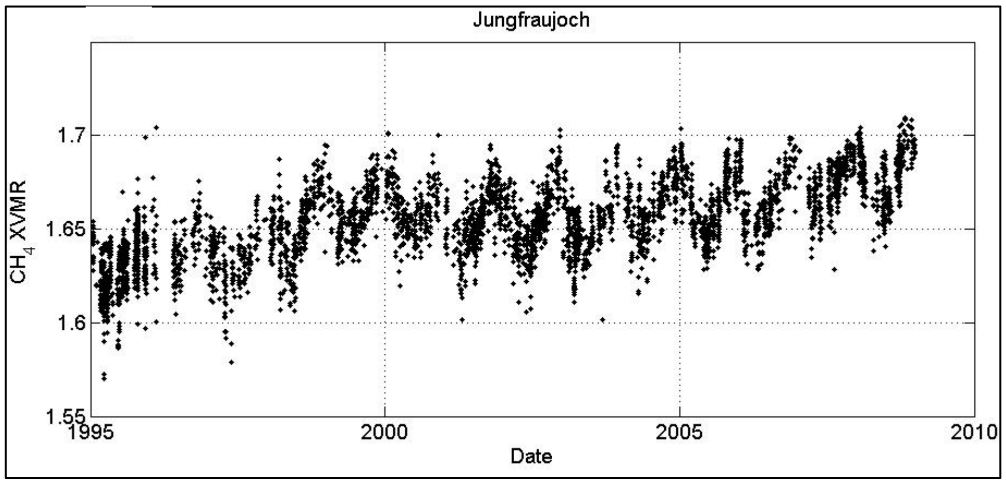
⇒ Laboratory cell-based spec-troscopic measurements (CH_4)

⇒ FTIR time series CH_4, N_2O

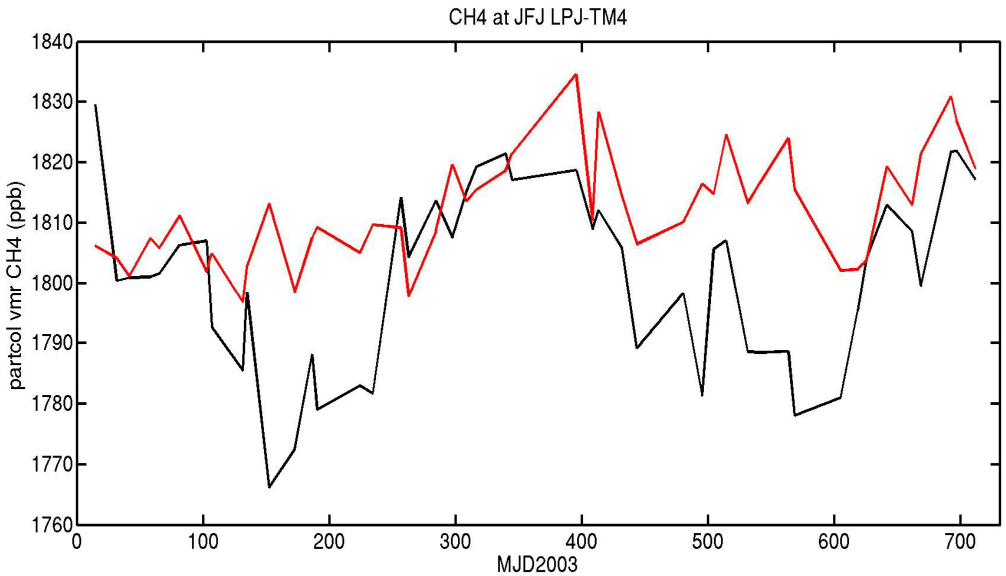
⇒ Satellite comparisons

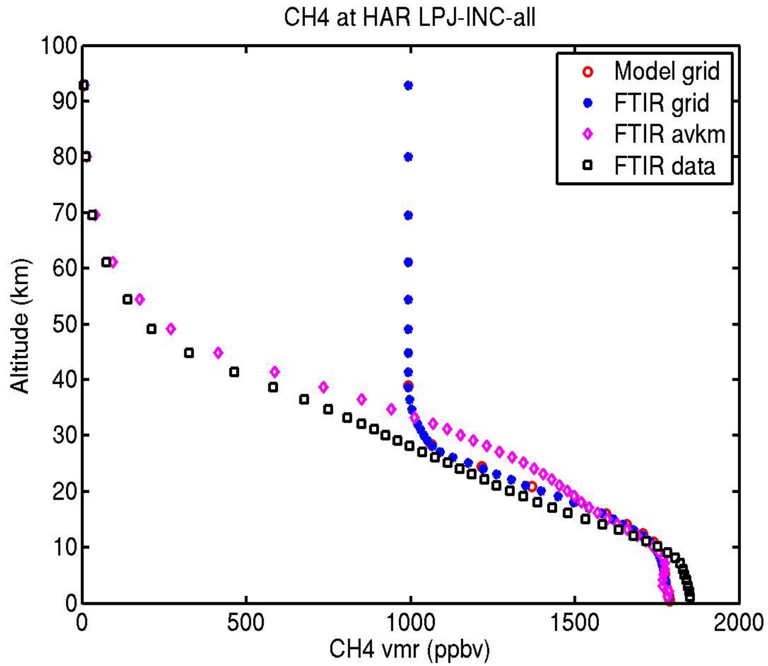
⇒ FTIR - Model comparisons





FTIR – CTM comparisons



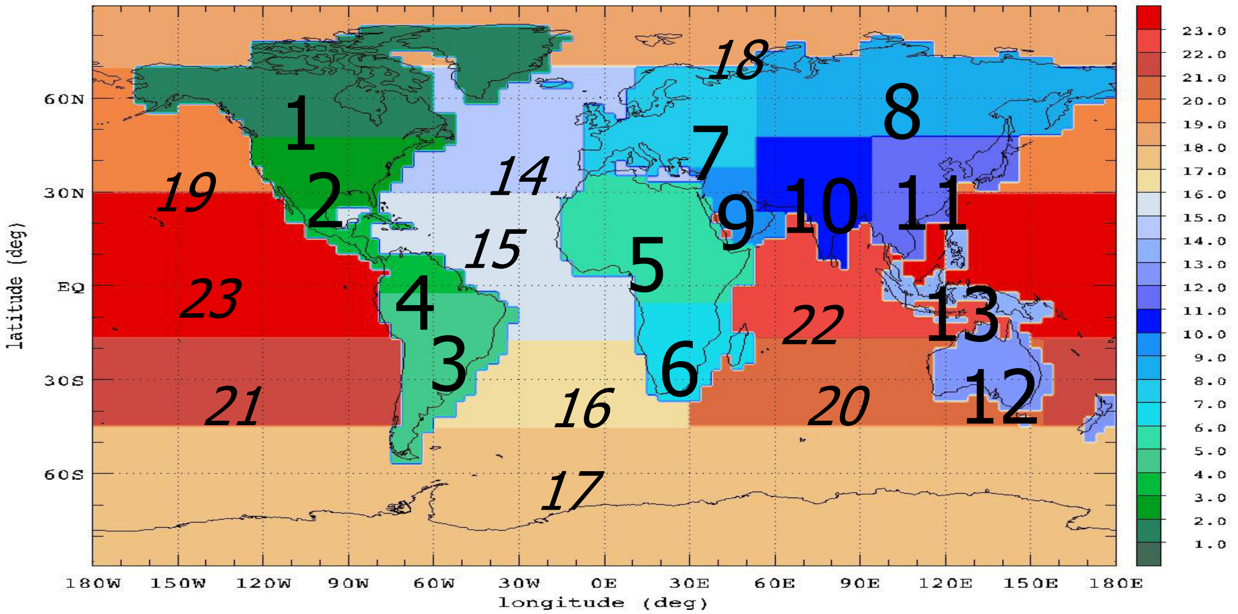


Tropospheric column mean mixing ratio
Jungfraujoch (black); TM4 model (red)
(TM4 nudged to climatology in stratosphere)

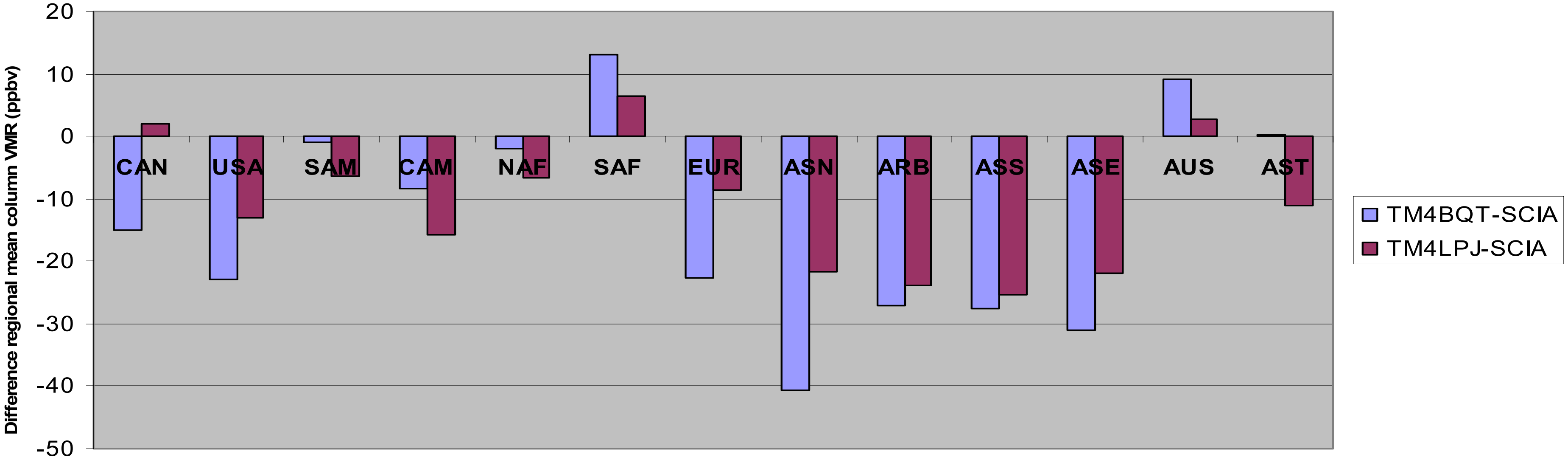
Underestimation of tropospheric seasonality?

Apply FTIR sensitivity as a function of altitude to derive what FTIR would have observed if the CTM output represented the true state

Model evaluations for 2003 and 2004



Regional mean column vmr differences with SCIAMACHY CH4 (ppb)



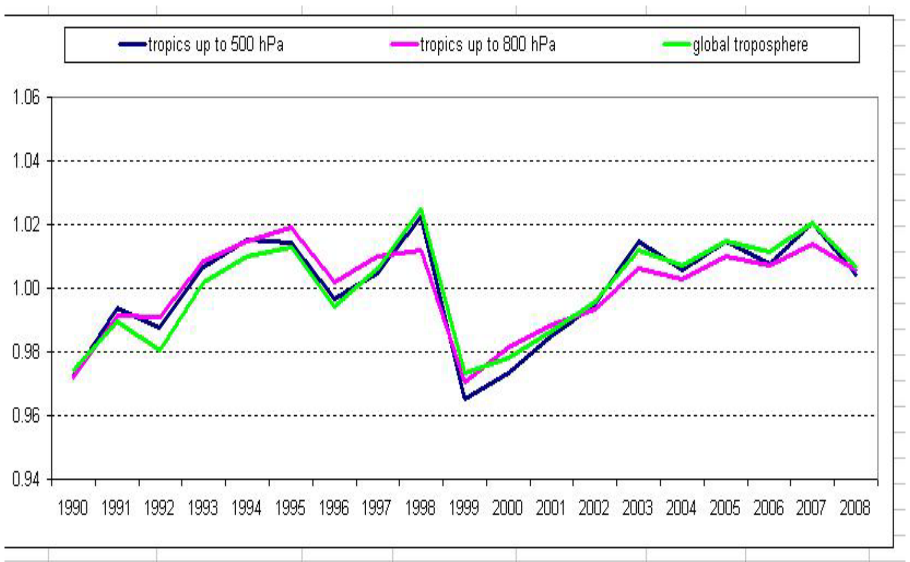
Variations in CH_4 loss

Tropics dominate loss

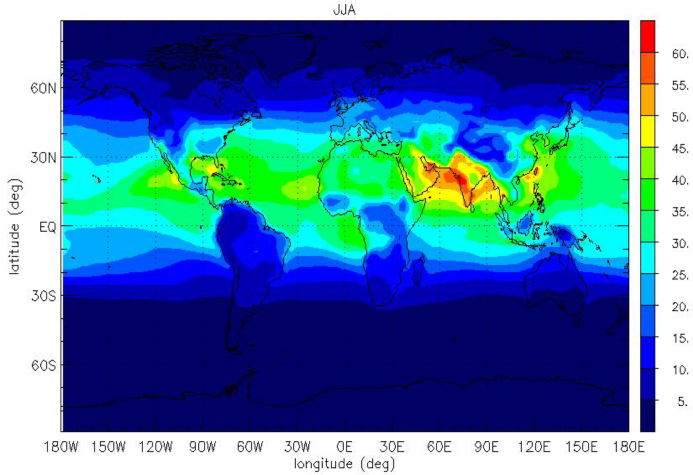
Annual loss per latitude band:

90 N – 30 N	14%
30 N – 30 S	77%
30 S – 90 S	9%

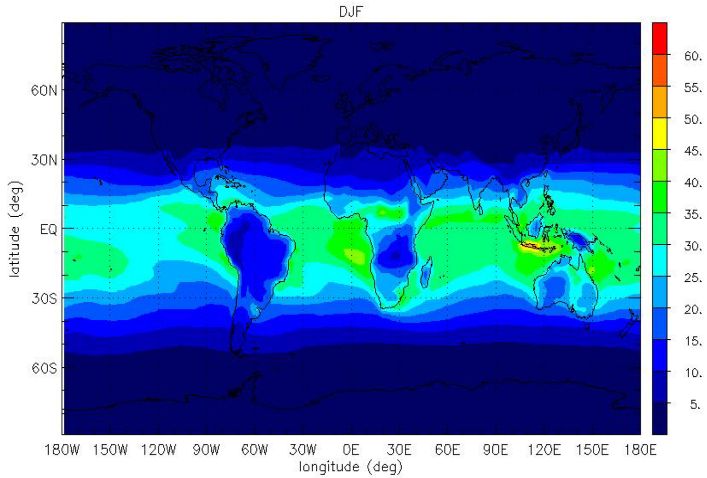
CH_4+OH inter-annual variability 1990-2008



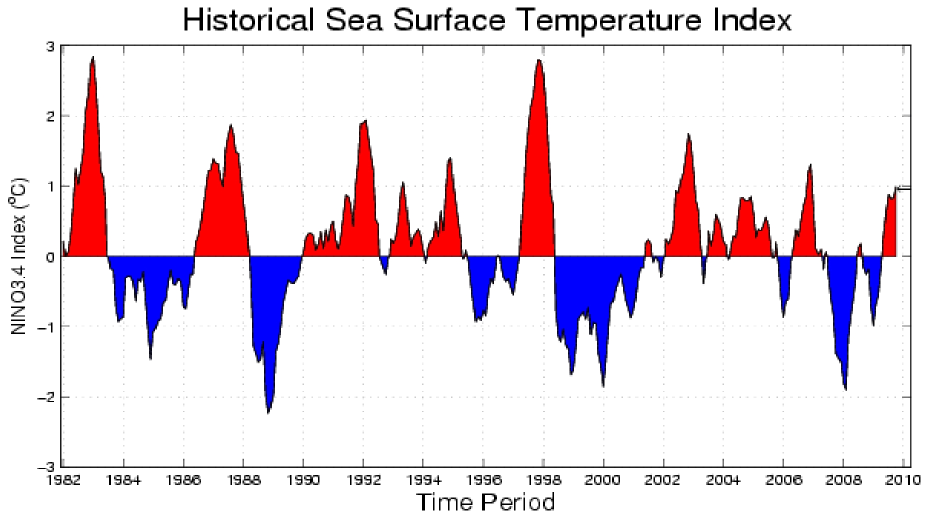
Northern summer (JJA)

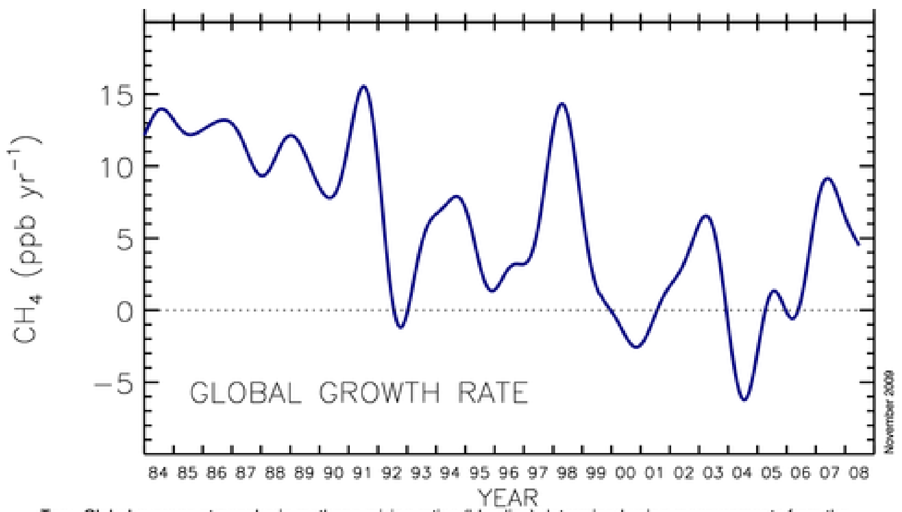


Southern summer (DJF)



Variations, but also slow increase in loss?





Top: Global average atmospheric methane mixing ratios (blue line) determined using measurements from the Carbon Cycle cooperative air sampling network. The red line represents the long-term trend. Bottom: Global average growth rate for methane. Contact: Dr. Ed Dlugokencky, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6228, ed.dlugokencky@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.

=> Meteorologically induced variations: +/- 2% since 1990

+ emission induced variations or trends?

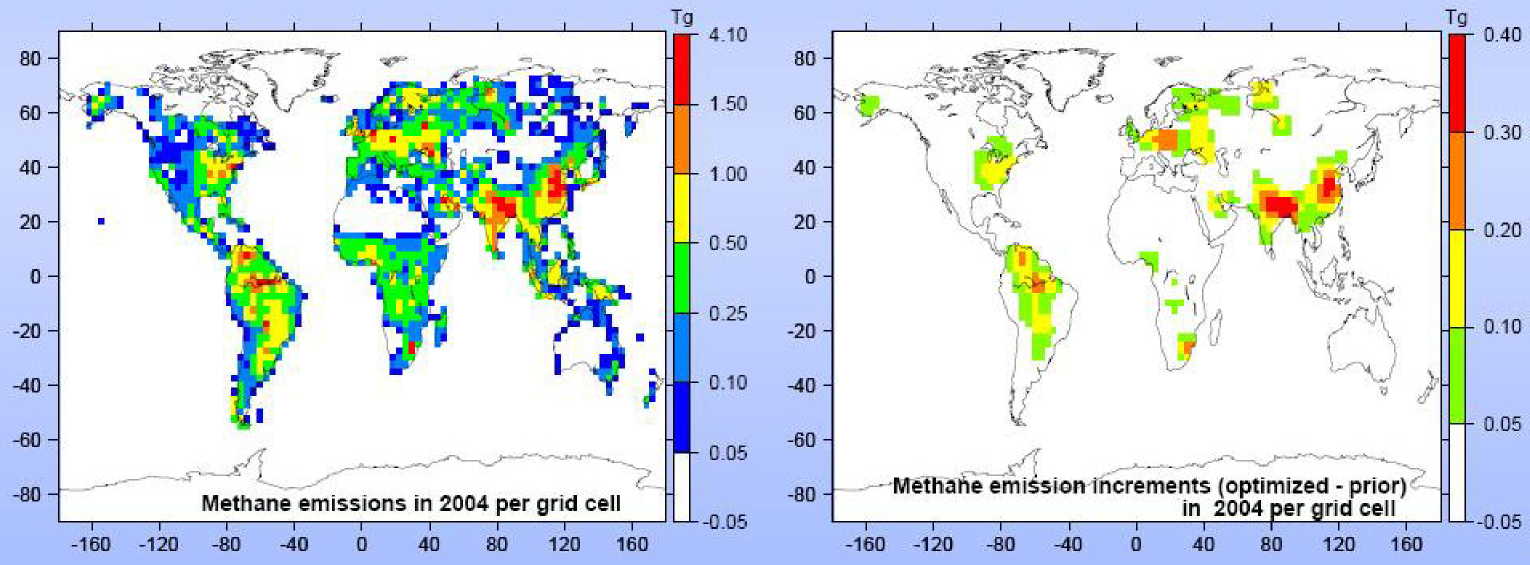
TM5 sensitivity: ~ 0.7% per TgN emissions added in the tropics

⇒ +5-7 TgN since 2000 reduces CH_4 lifetime by 3-5% (~15-25 Tg per year)

What about trends since 2000 in:
CO (no trend)
C_2H_6 (down, emissions down?)
methylchloroform (?)

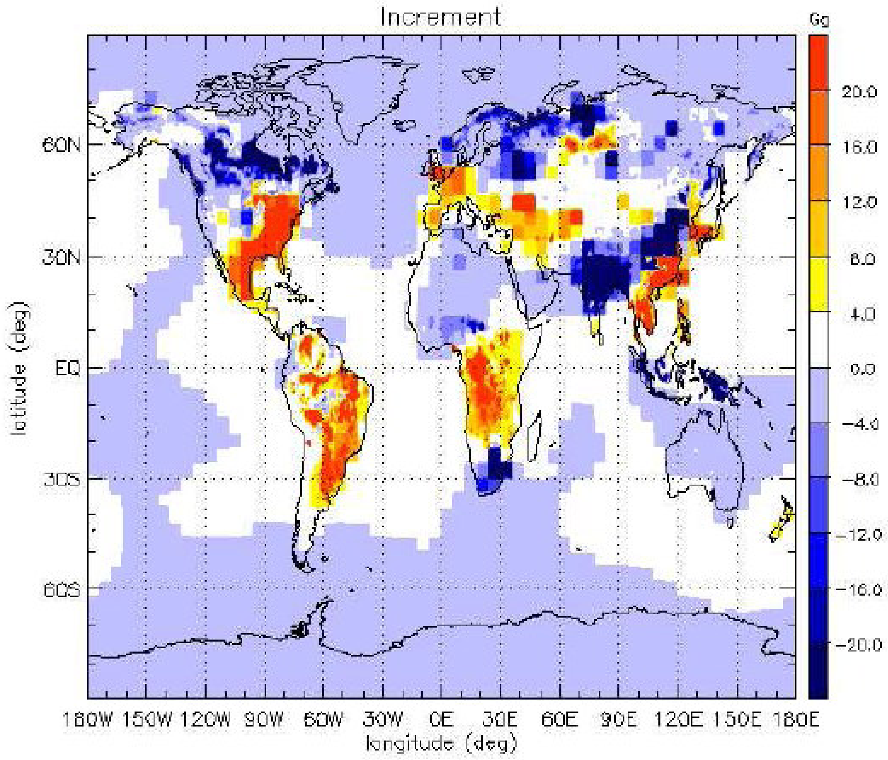
Inverse modelling

Optimized 2004 CH_4 emissions by LSCE's variational system and spatial distribution of increments as obtained with SCIAMACHY data

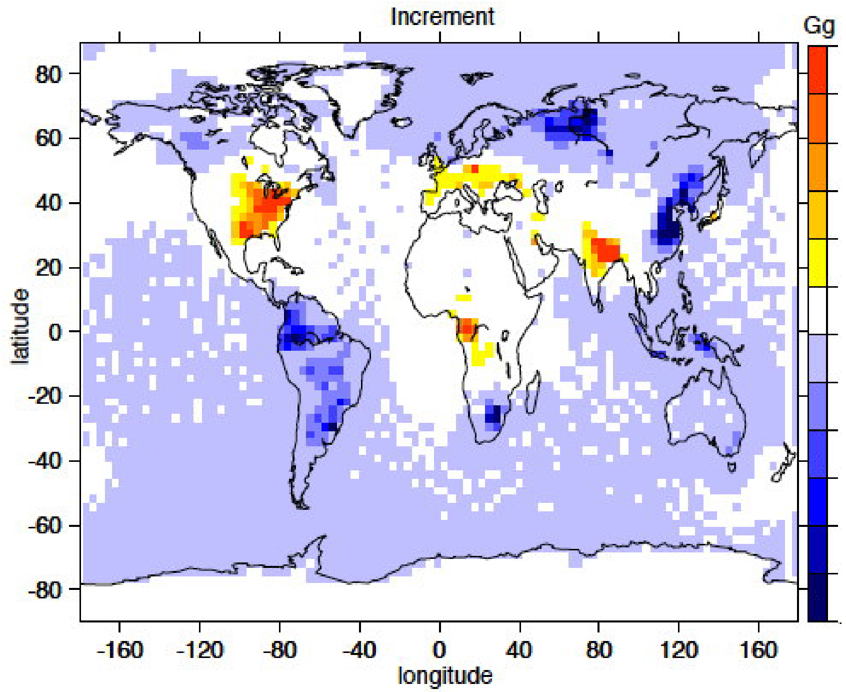


=> Much improved spatiation of methane emissions on a global scale

Comparisons TM5 and LSCE 4Dvar: more work to do



(e) Increment KNMI



(f) Increment LSCE