Biological sources/ sinks of Atmospheric CH_4 and N_2O

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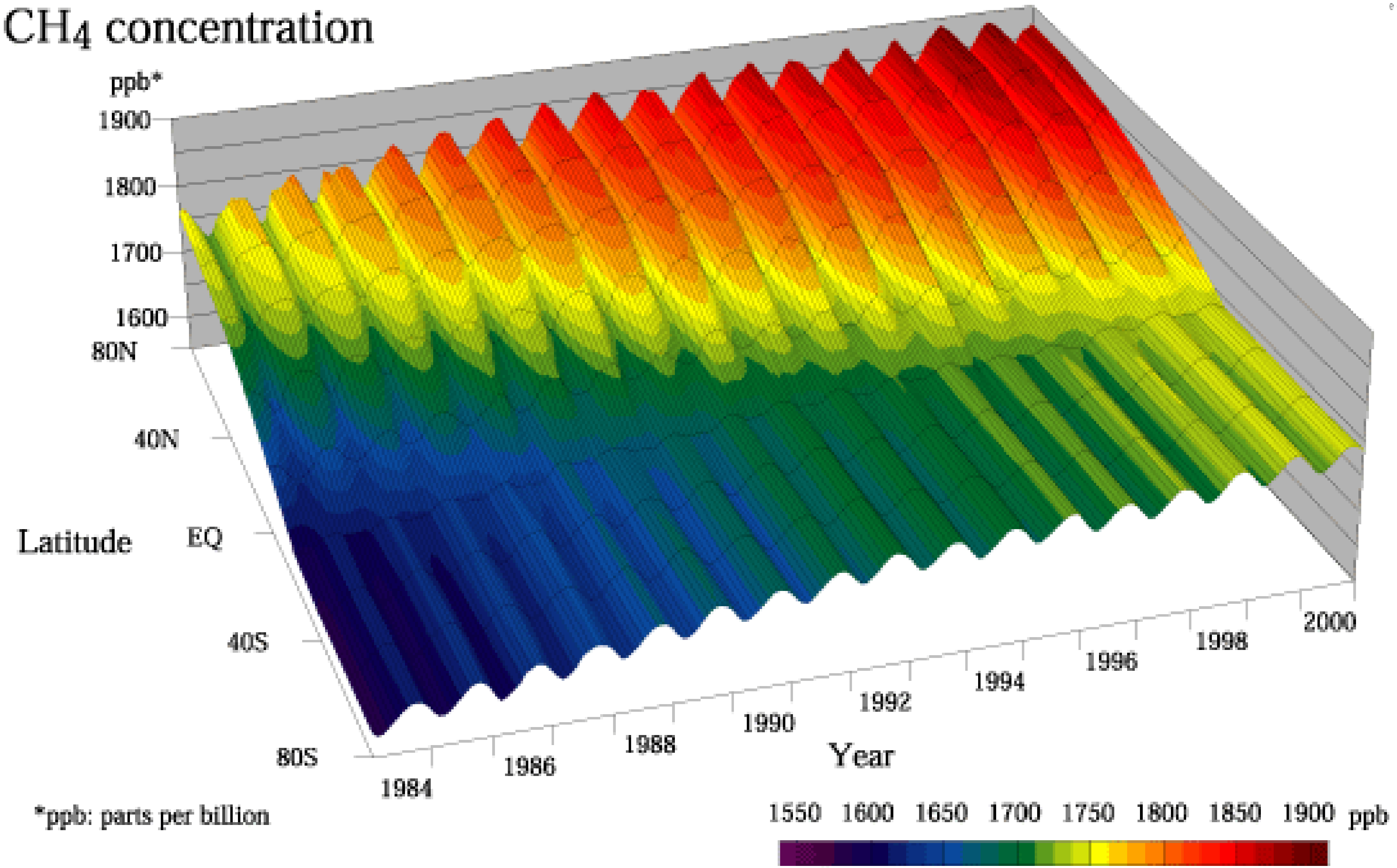

CH4 concentration
ppb*
1900
1800
1700
1600
80N
40N
Latitude
EQ
40S
80S
1984
1986
1988
1990
1992
1994
1996
1998
2000
Year
*ppb: parts per billion
1550 1600 1650 1700 1750 1800 1850 1900 ppb

Source: NOAA

Sources of atmospheric CH_4

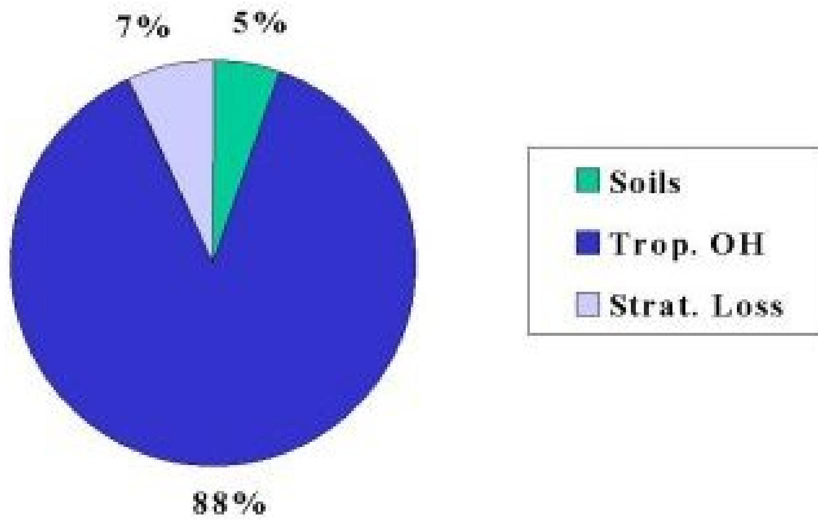
Origin	CH_4 Emission		
	Mass (Tg/a)	Type (%/a)	Total (%/a)
Natural Emissions			
Wetlands (incl. Rice agriculture)	225	83	37
Termites	20	7	3
Ocean	15	6	3
Hydrates	10	4	2
Natural Total	270	100	45

Origin	CH_4 Emission		
	Mass (Tg/a)	Type (%/a)	Total (%/a)
Anthropogenic Emissions			
Energy	110	33	18
Landfills	40	12	7
Ruminants (Livestock)	115	35	19
Waste treatment	25	8	4
Biomass burning	40	12	7
Anthropogenic Total	330	100	55

Houveling et al., JGR, 1999

Sinks of atmospheric CH_4

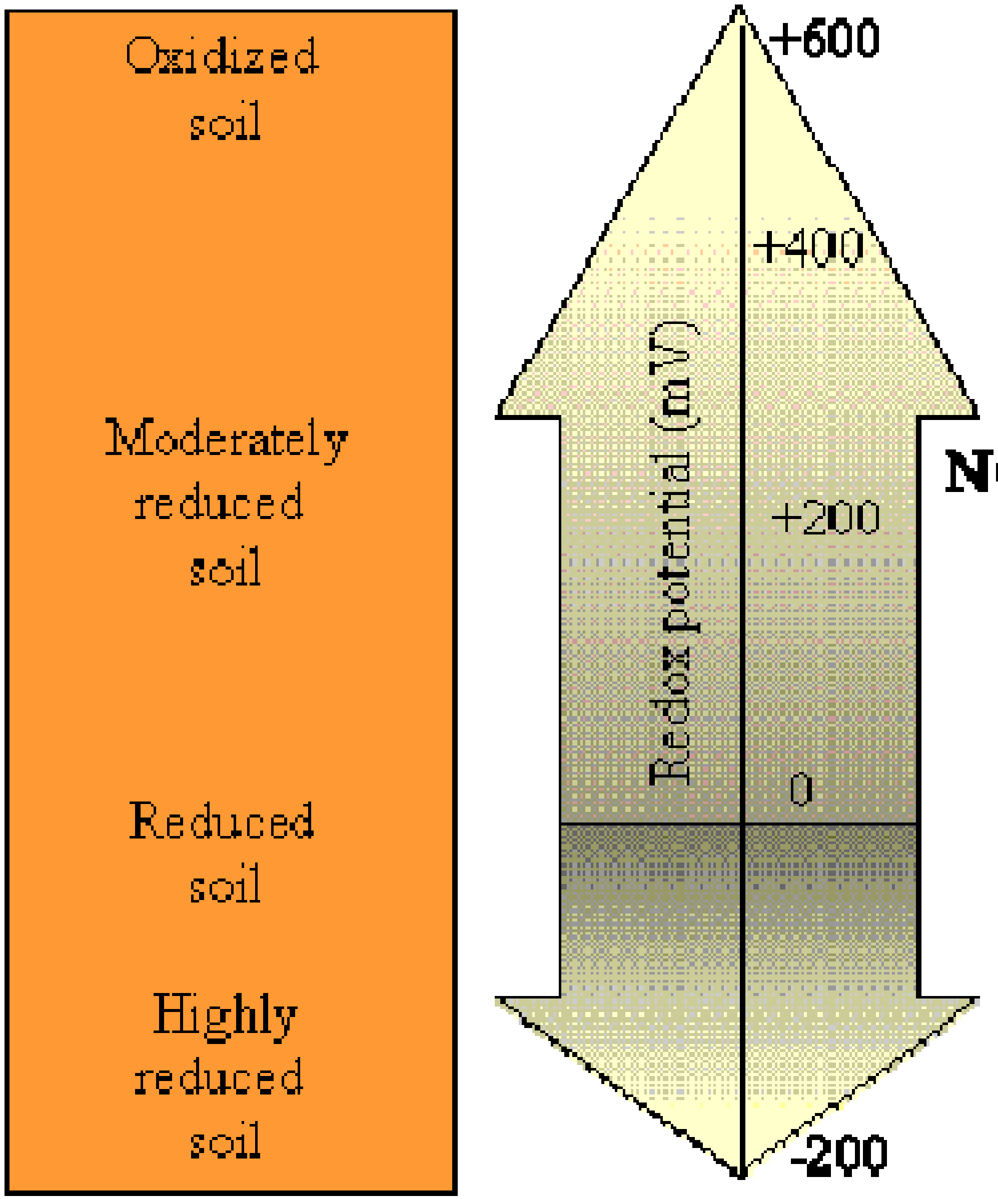
Origin	CH_4 Emission		
	Mass (Tg/a)	Type (%/a)	Total (%/a)
Sinks			
Soils	-30	-5	-5
Tropospheric OH	-510	-88	-85
Stratospheric loss	-40	-7	-7
Sink Total	-580	-100	-97
Emissions + Sinks			
Imbalance (trend)	+20	~2.78 Tg/ ppb	+7.19 ppb/a



Biological sources of CH_4

Methogenesis occurs only under low redox conditions

Example Of The Range In Redox Potentials In Waterlogged Soils And The Location In The Redox Range Where The Various Electron Acceptors Are Active



$O_2 \rightarrow O^{2-}$

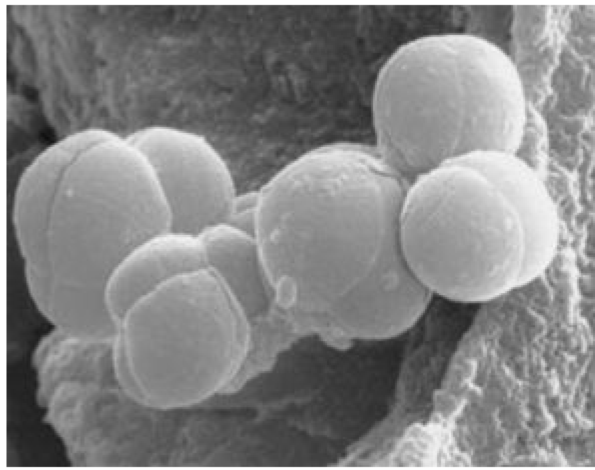
$NO_3^- \rightarrow NO_2^-, N_2O, NH_4^+, N_2$

$MnO_2 \rightarrow Mn^{2+}$

$Fe_2O_3 \rightarrow Fe^{2+}$

$SO_4^{2-} \rightarrow S^{2-}$

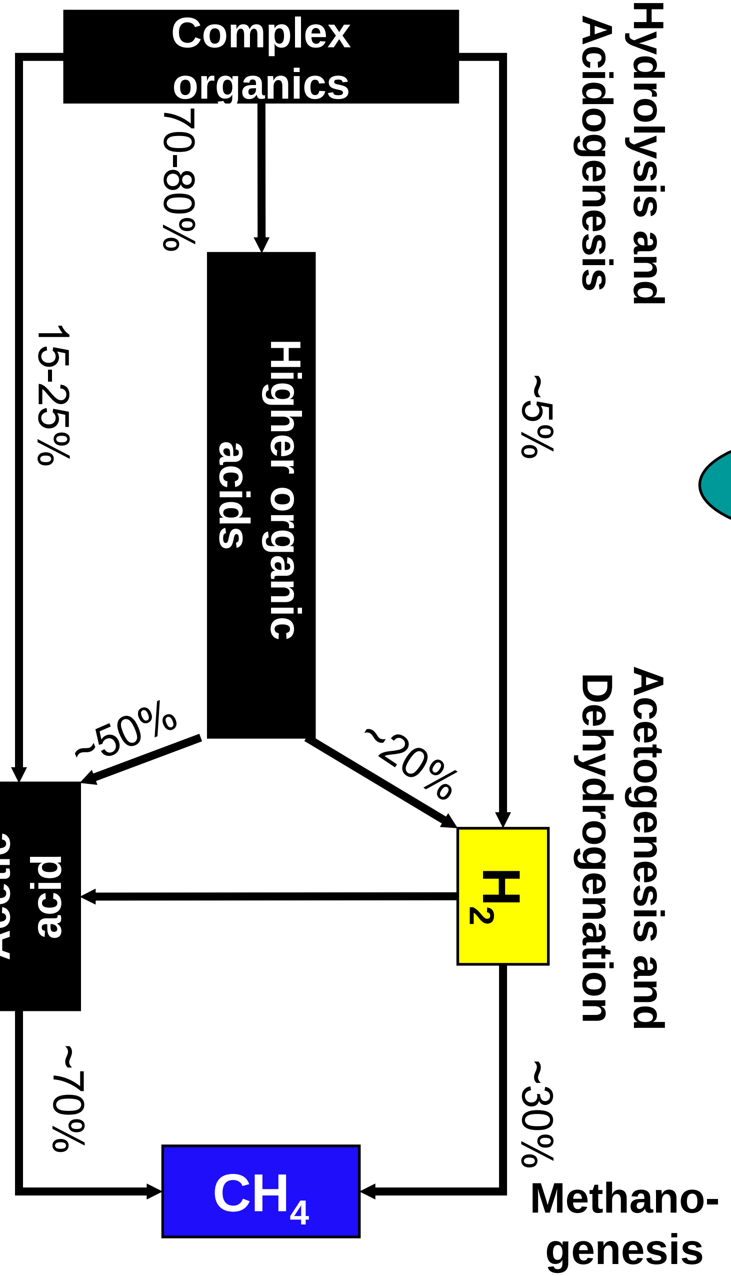
$CO_2 \rightarrow CH_4$

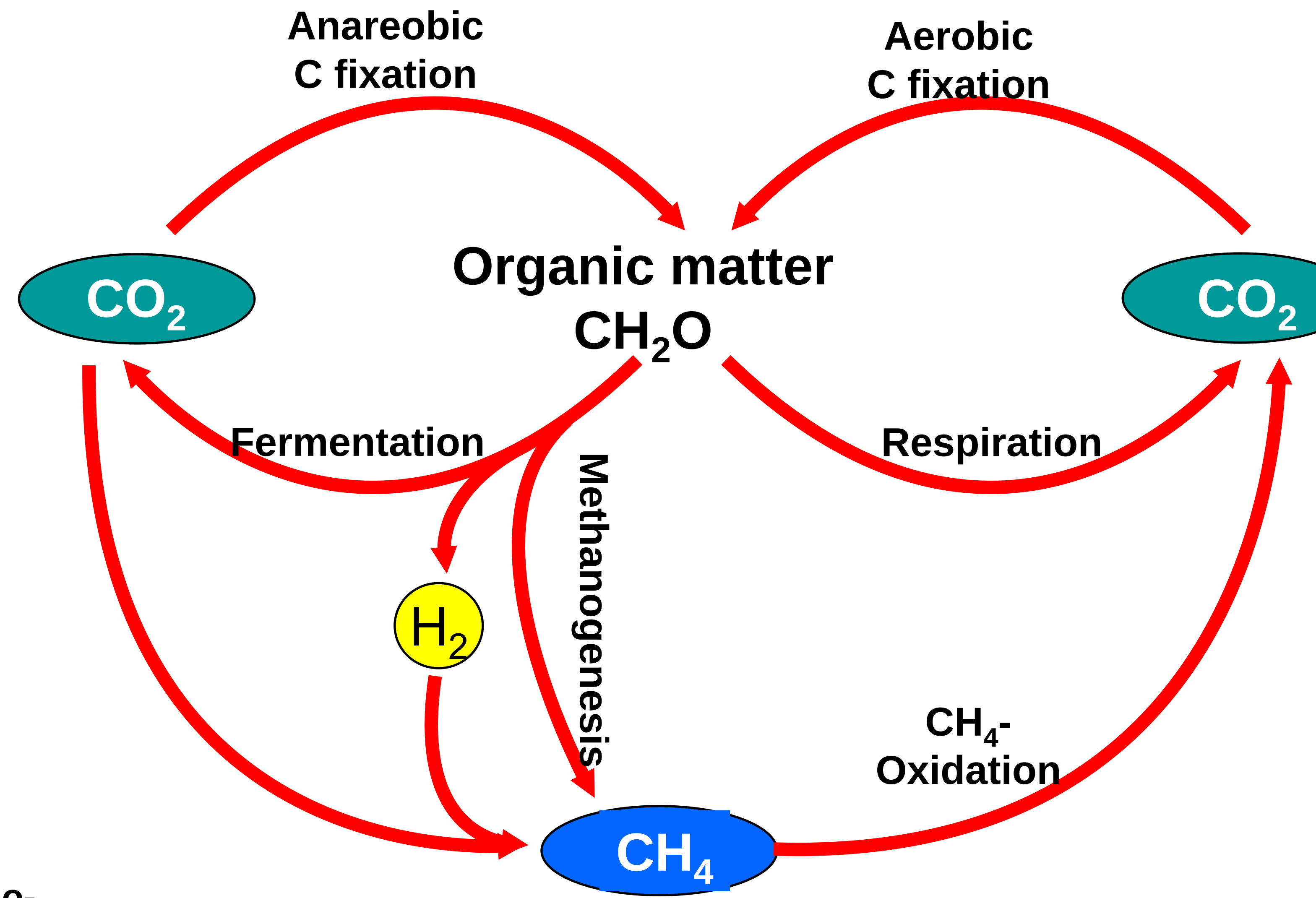


Methanosphaera stadtmanae

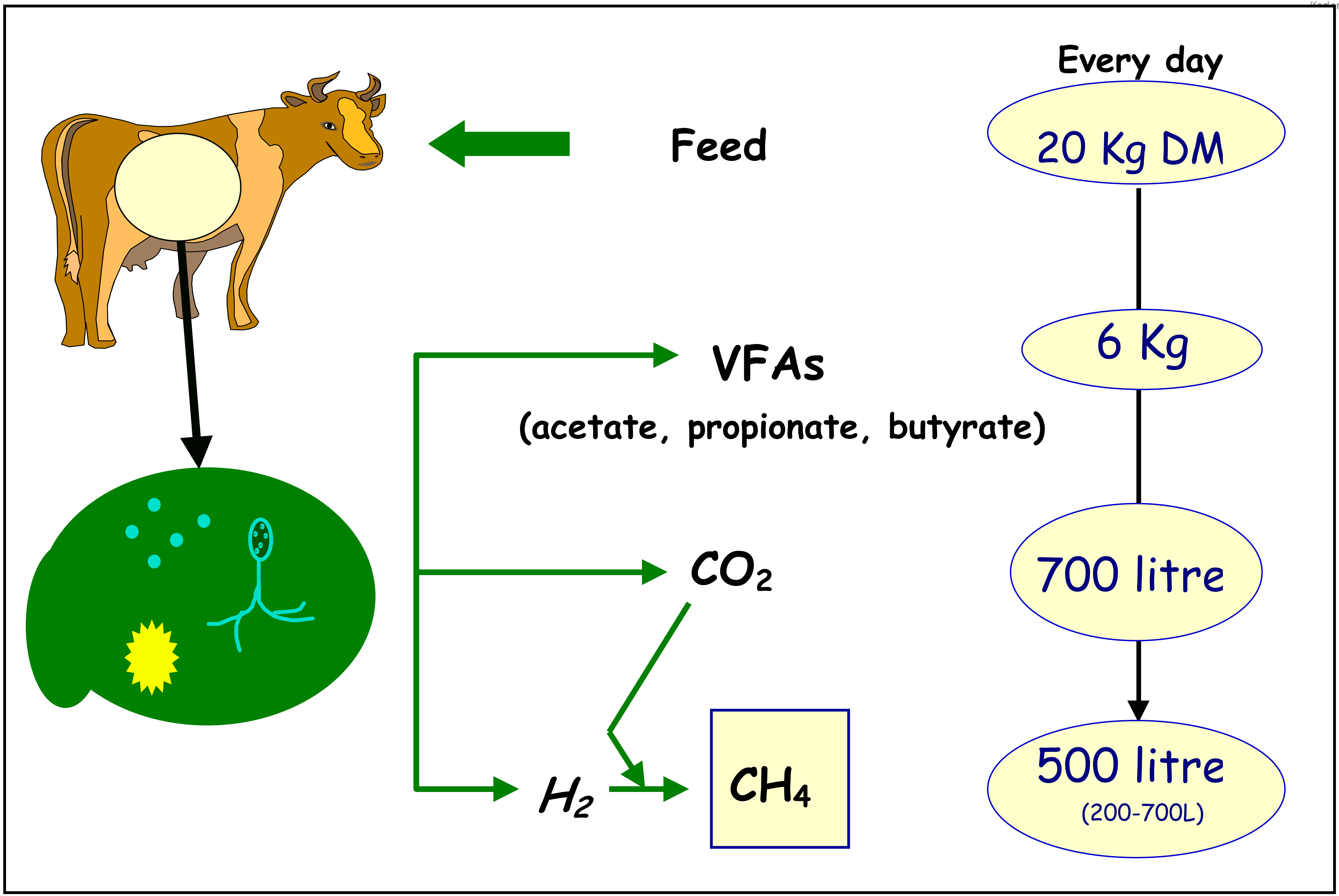
Fermentation and Methanogenesis

Fermentation



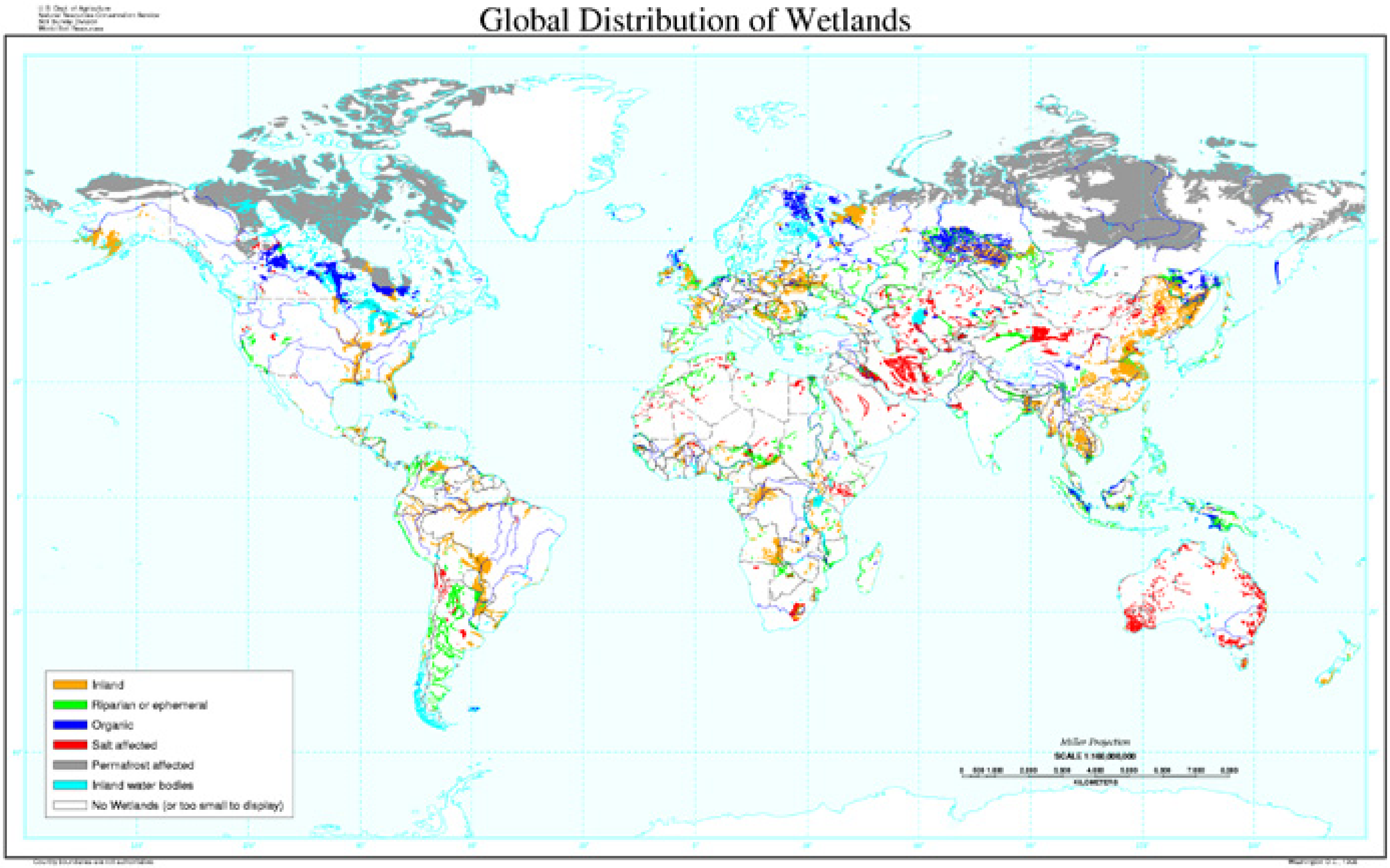


CH_4 and ruminants

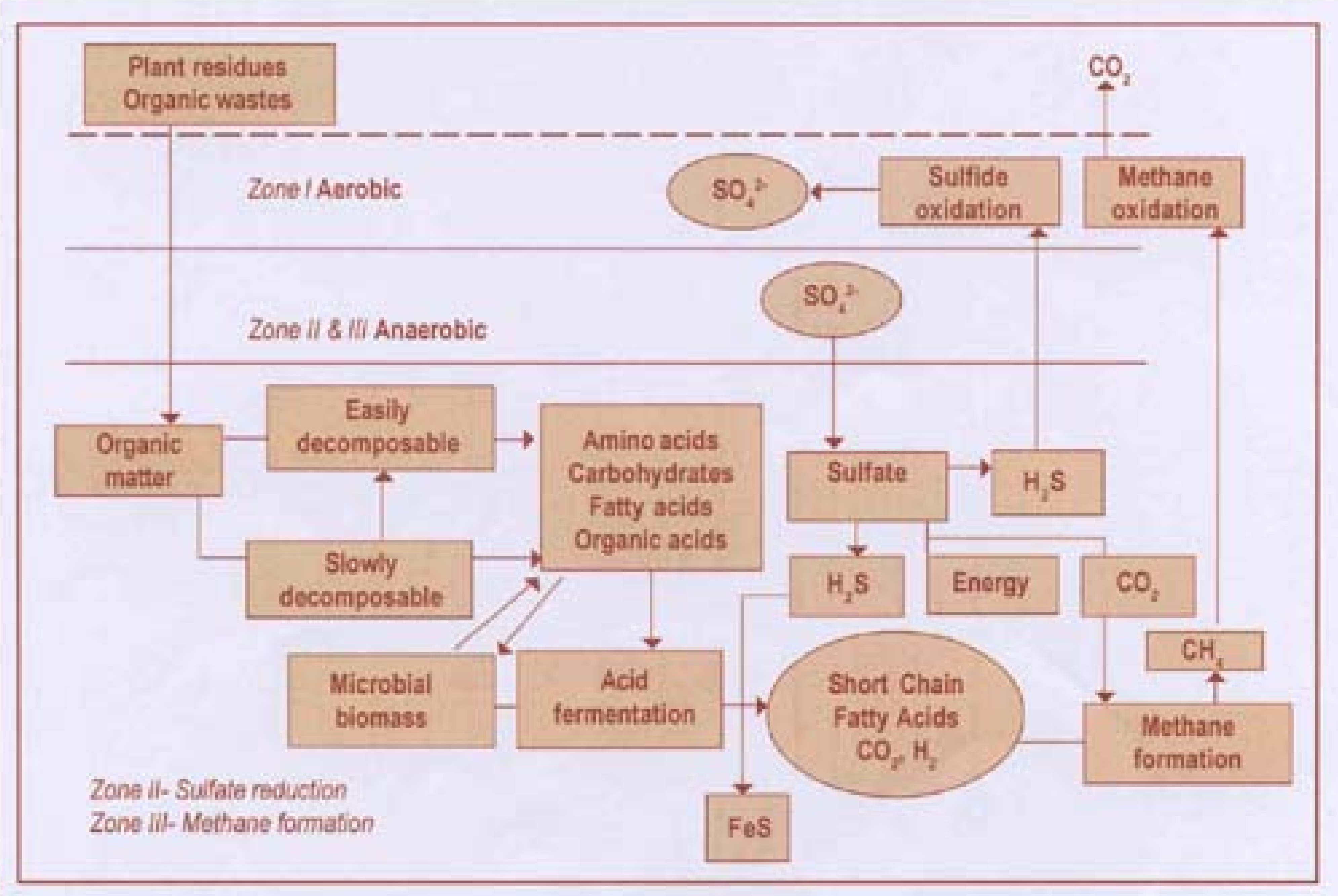


CH_4 and termites

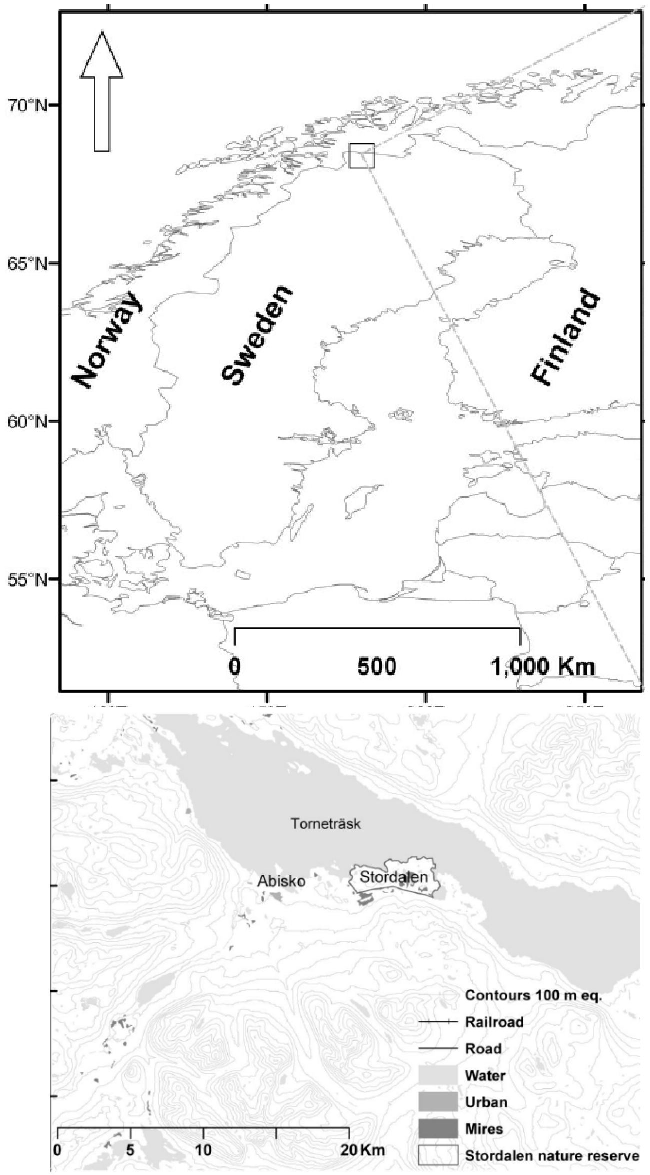
CH_4 and wetlands

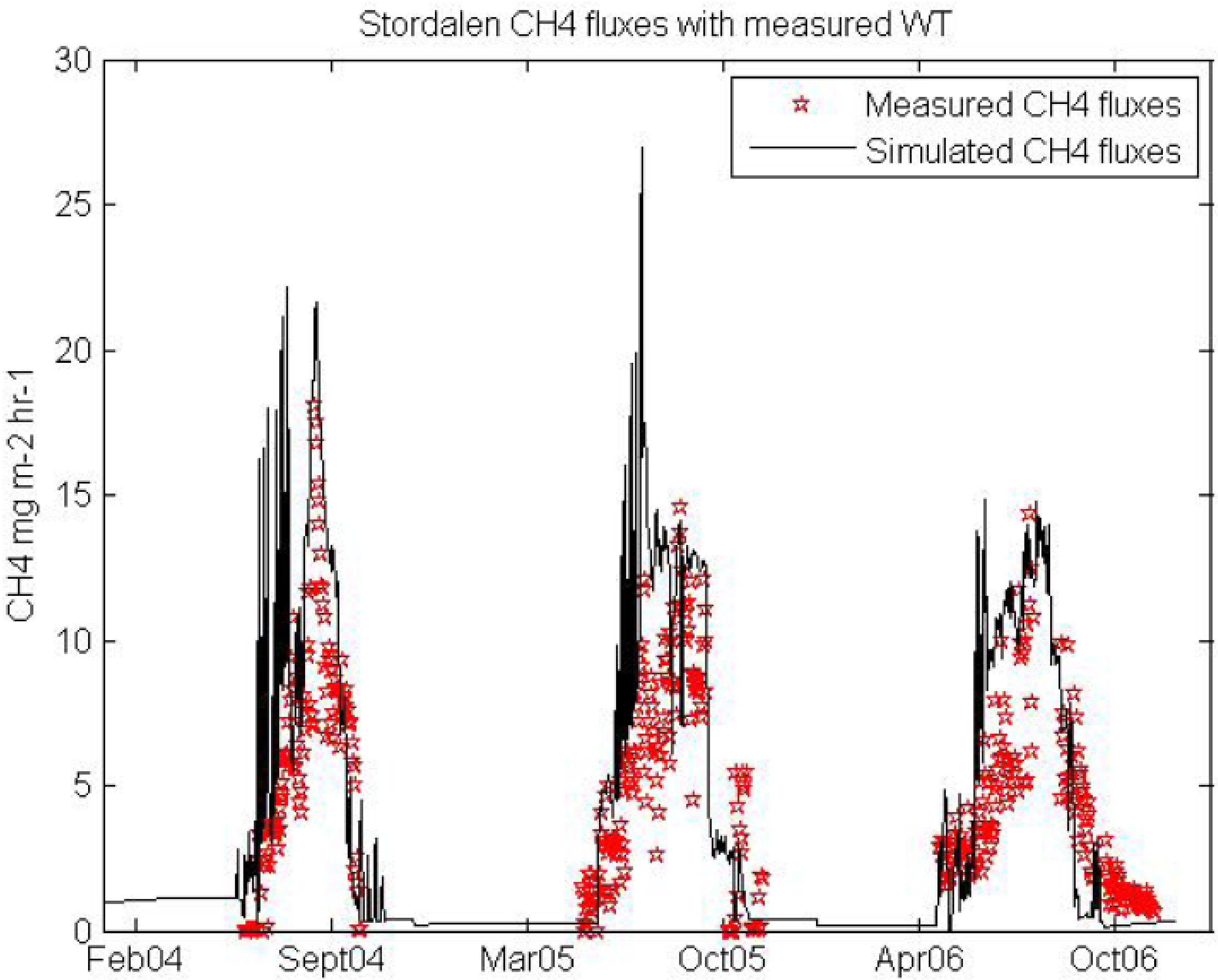


CH_4 and wetlands

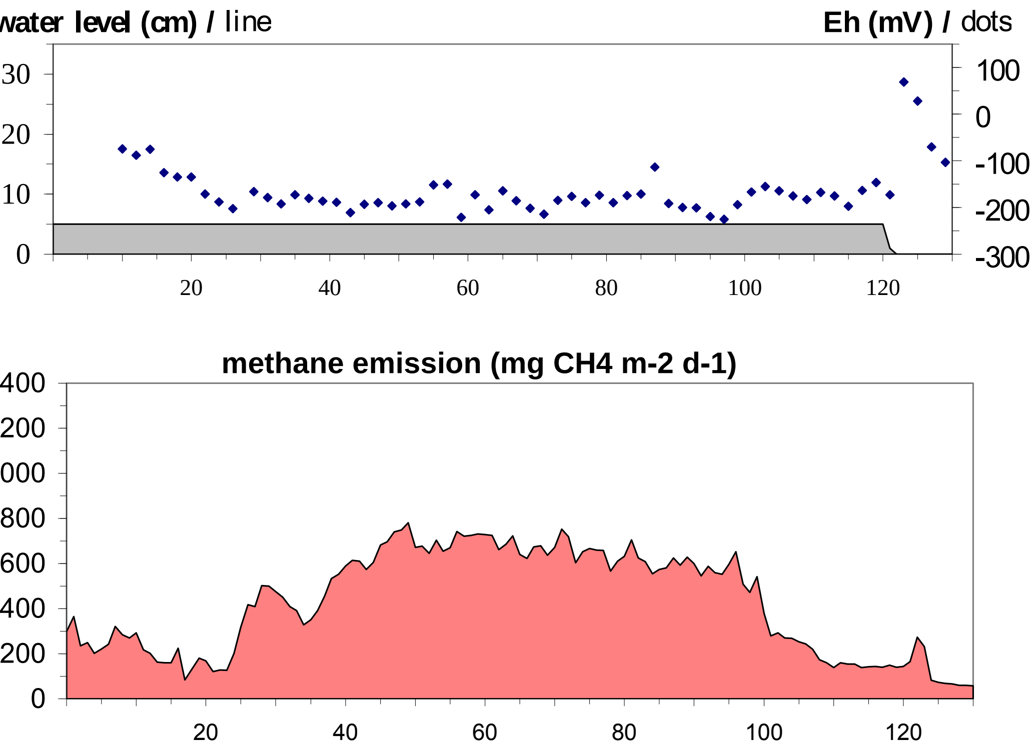


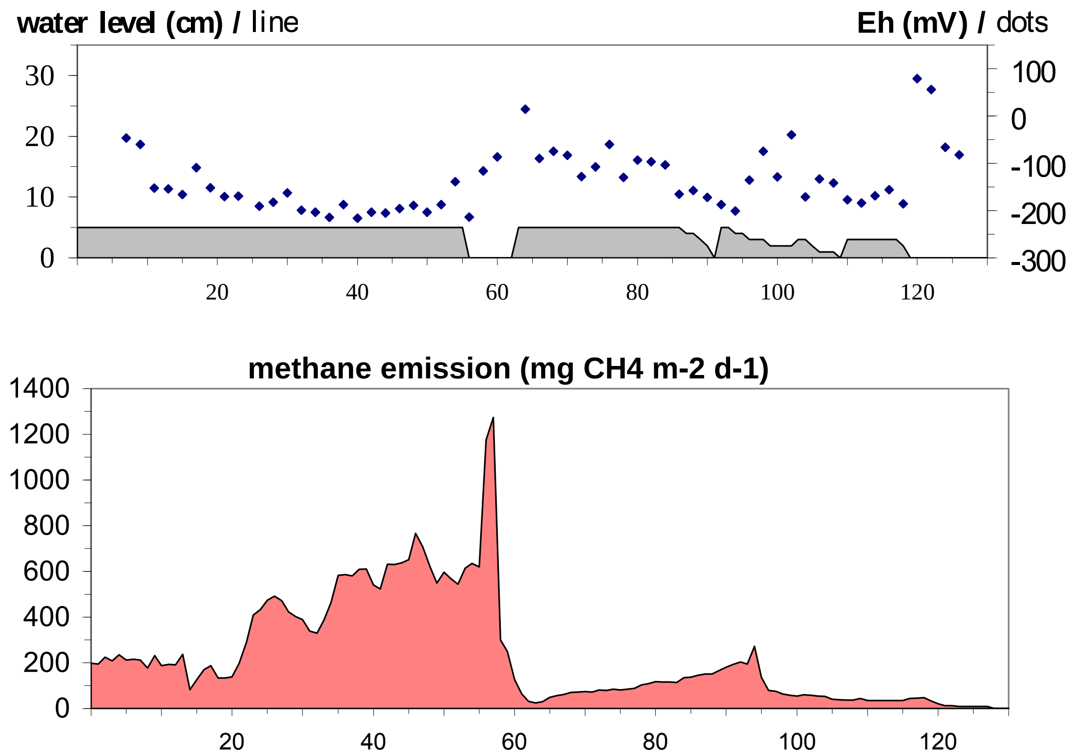
CH_4 emissions from mires - seasonality





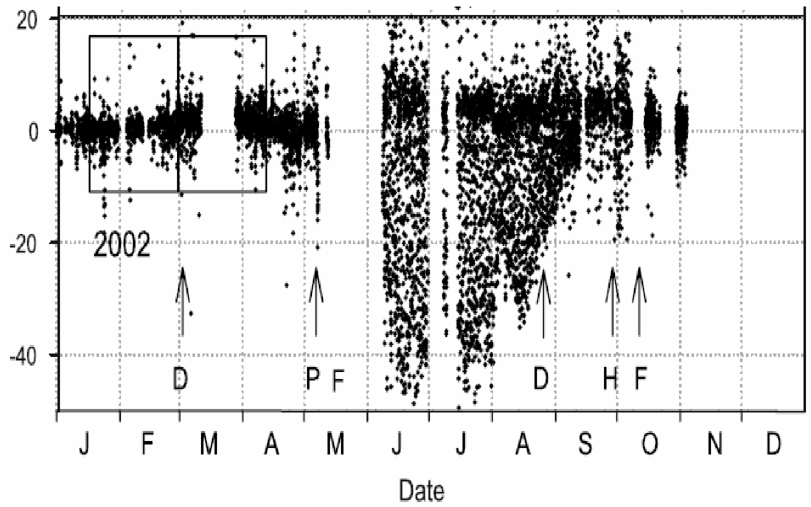
CH_4 emissions from rice paddies – management and water table



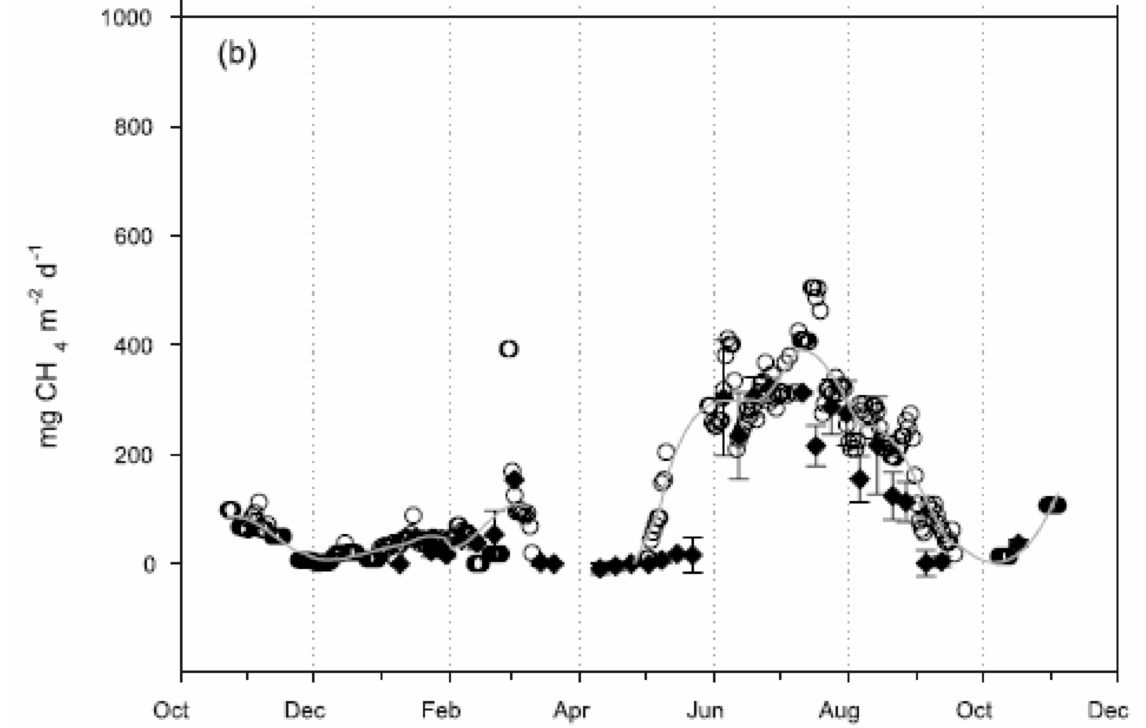


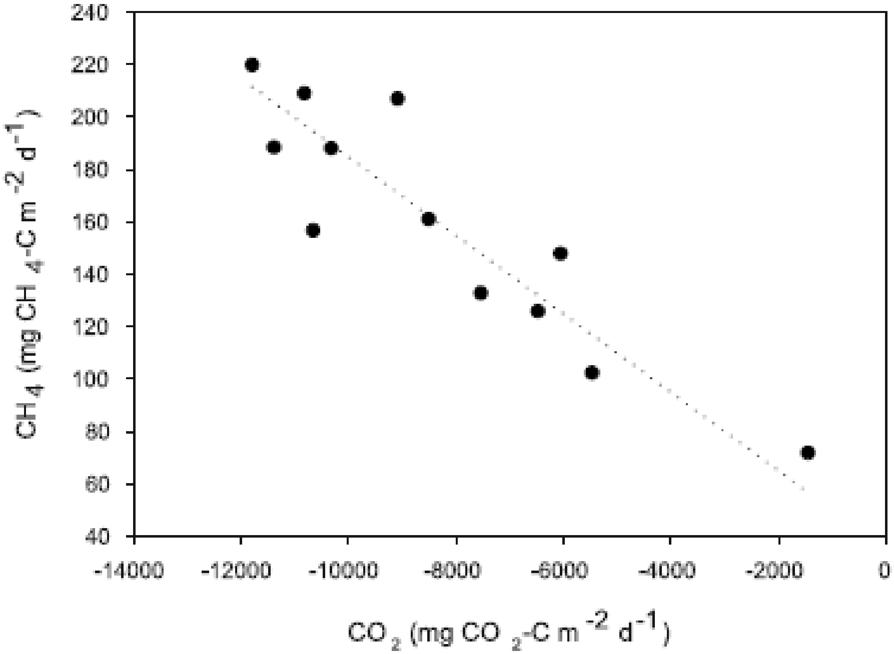
CH_4 emissions from rice paddies – stoichiometry CH_4:CO_2

CO_2



CH_4

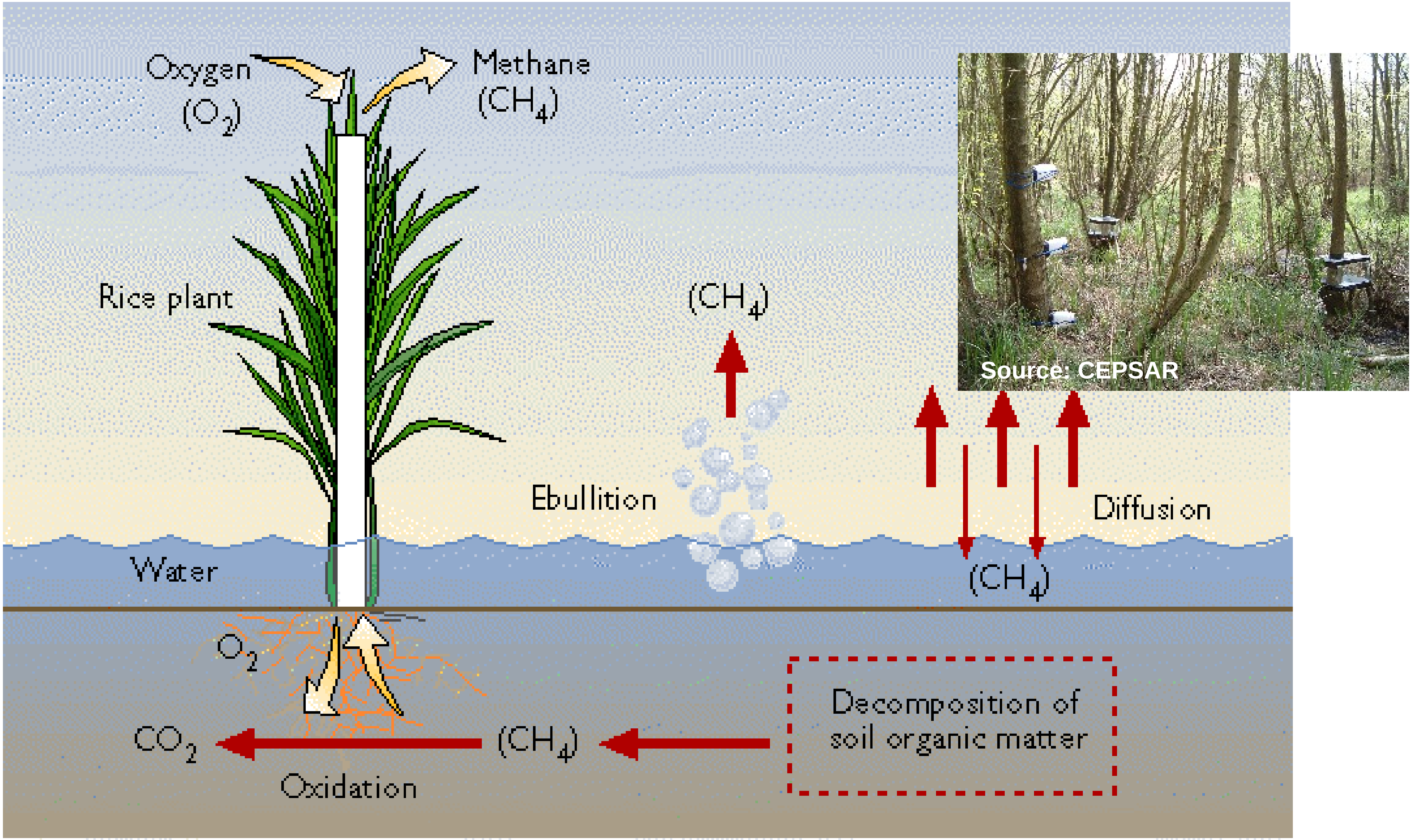




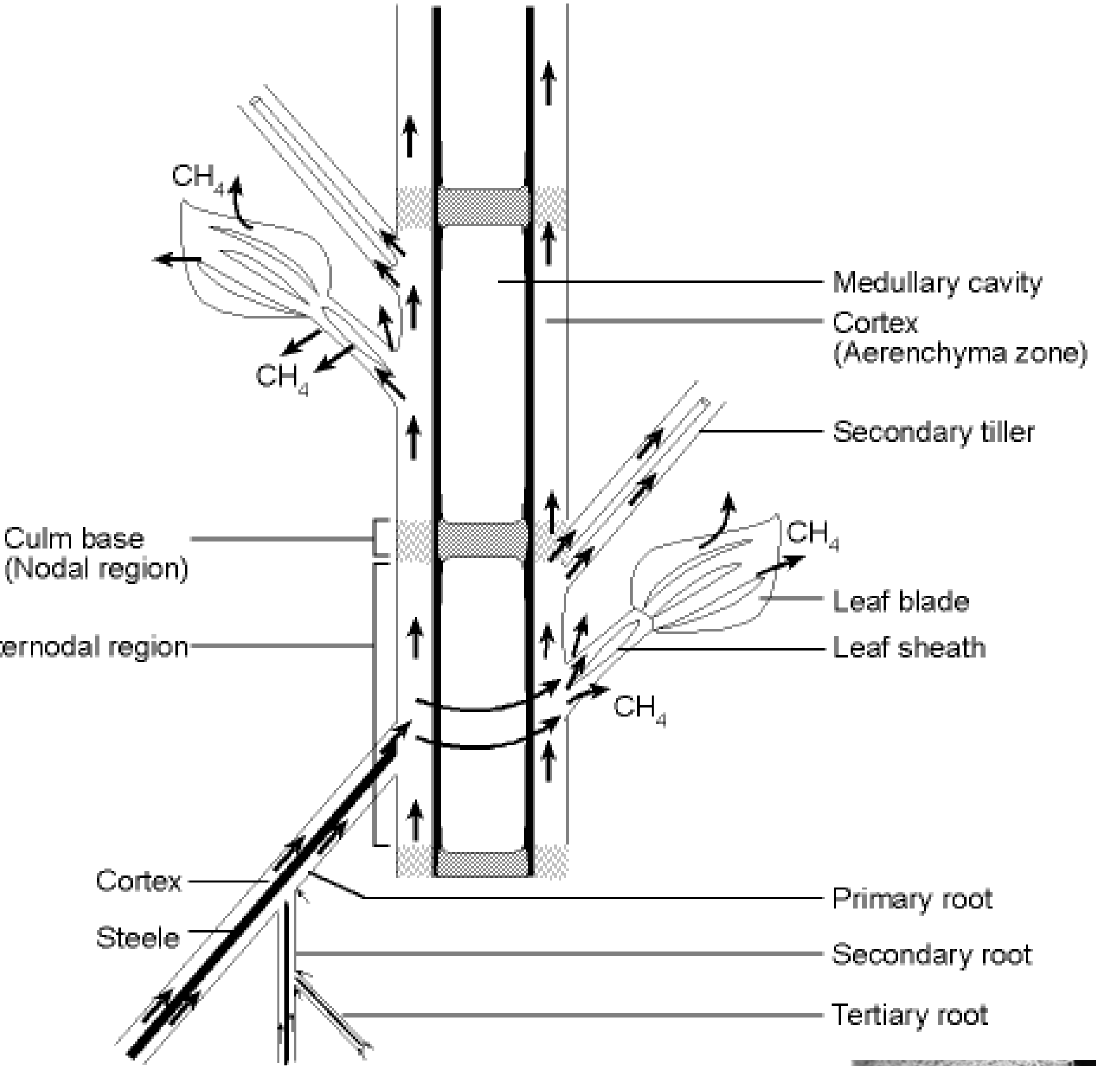
- During rice growth 1.9-2.4% of NEE emitted as CH_4
- Annual CH_4 losses ≈ 4.8 – 5.6% of NEE

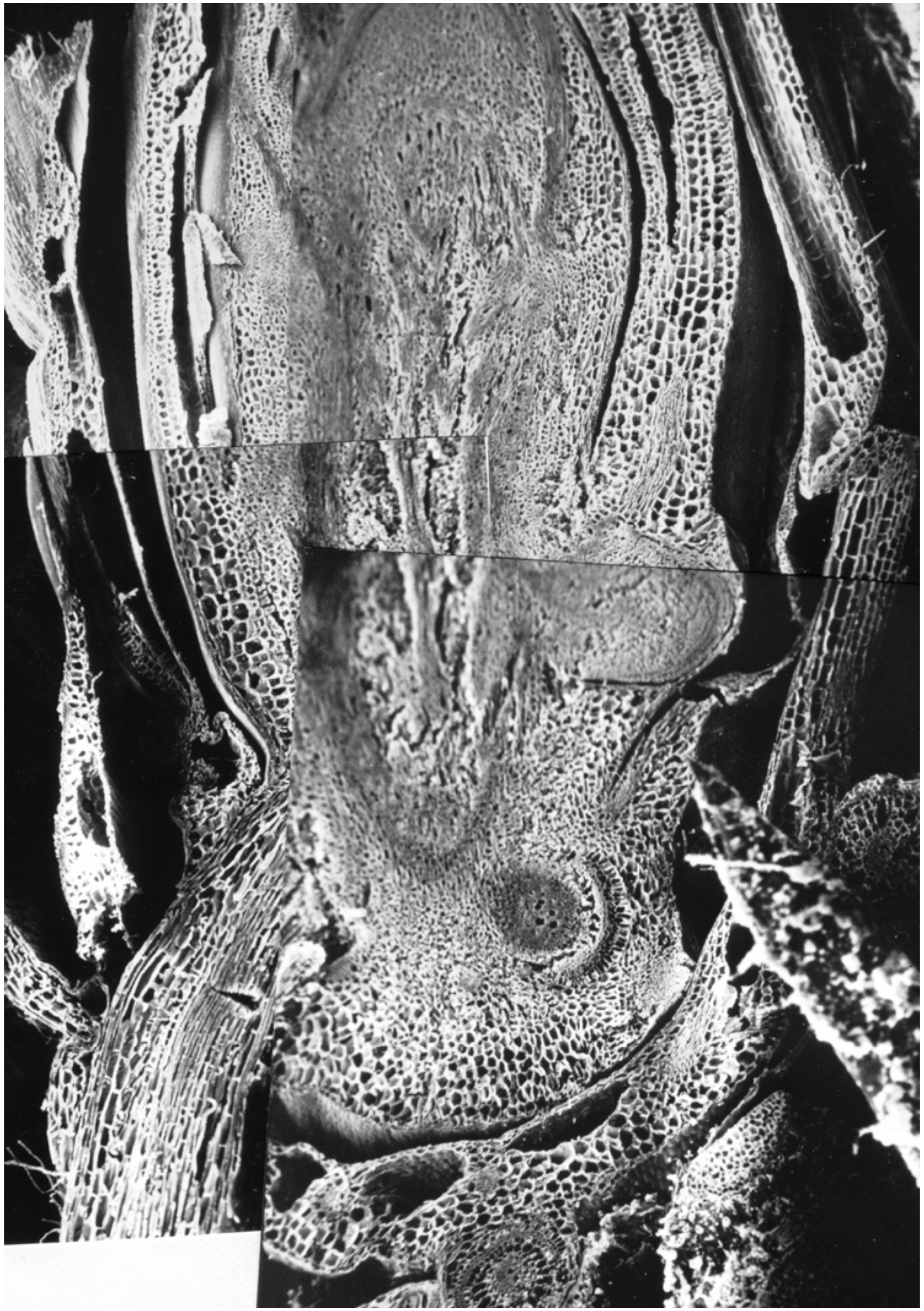
McMillan et al., 2007, JGR

CH_4 emission pathways



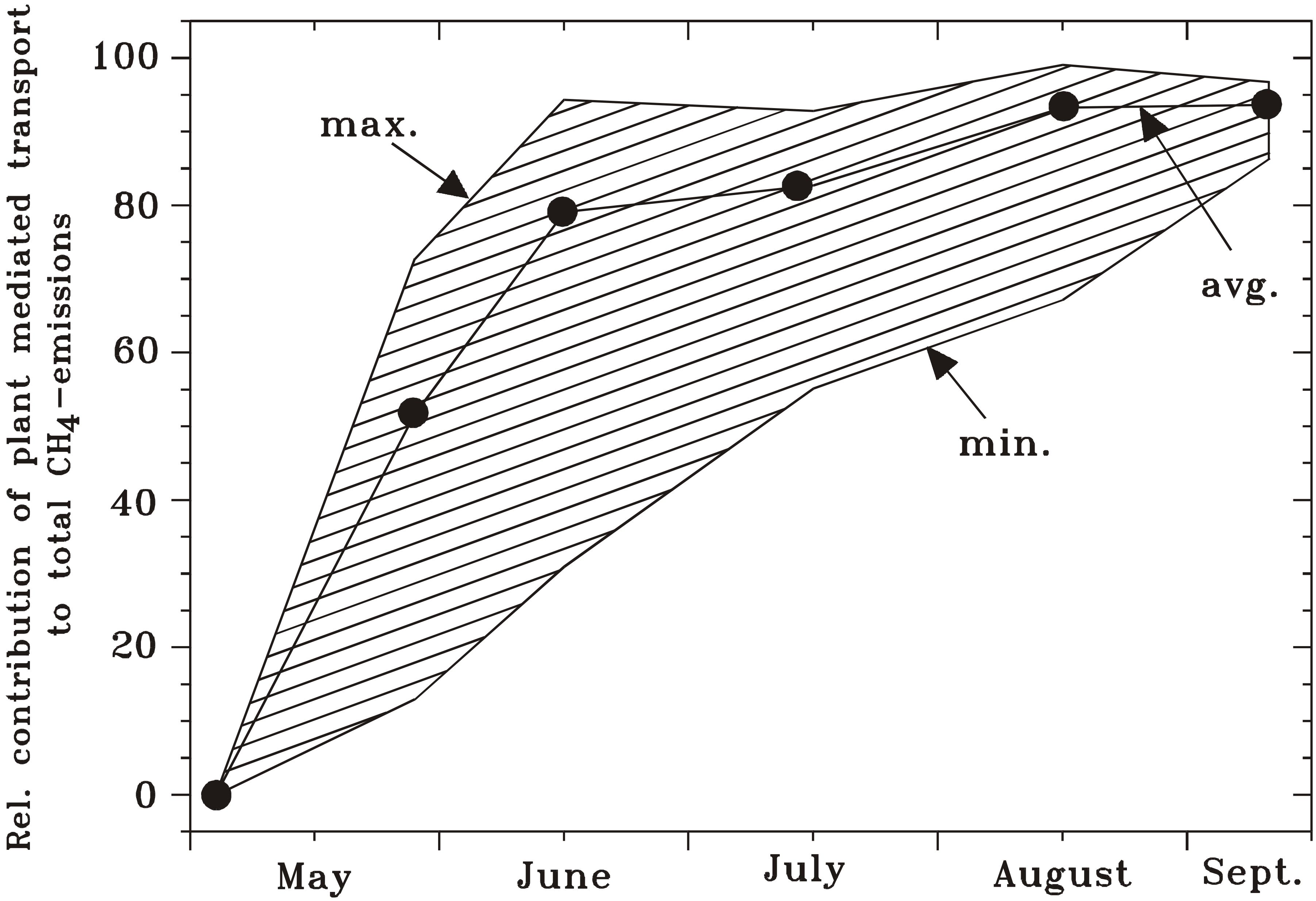
Importance of plant mediated transport



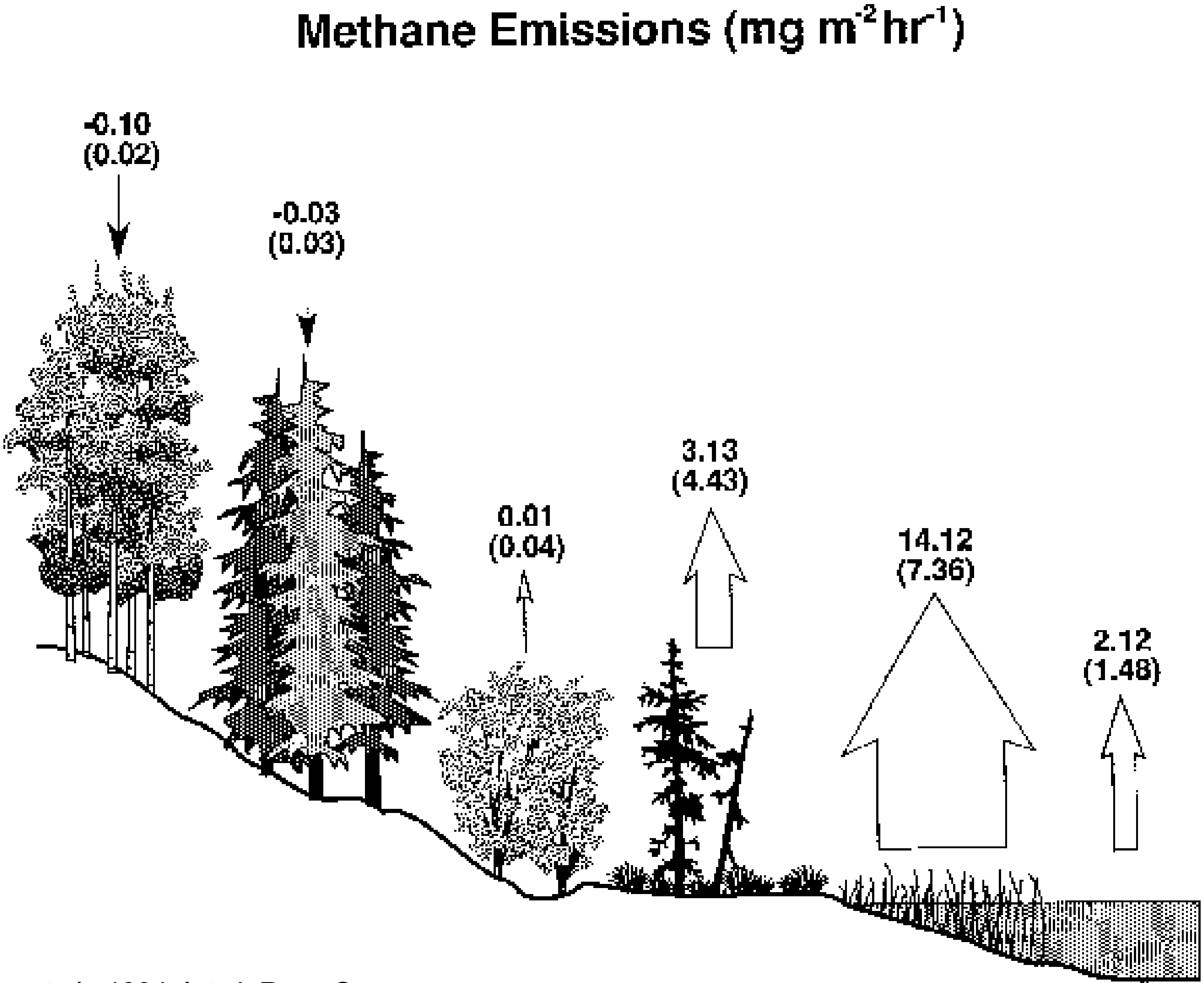


Butterbach-Bahl et al., 1997, PCE
Butterbach-Bahl et al., 2000, Phyton

Importance of plant mediated transport

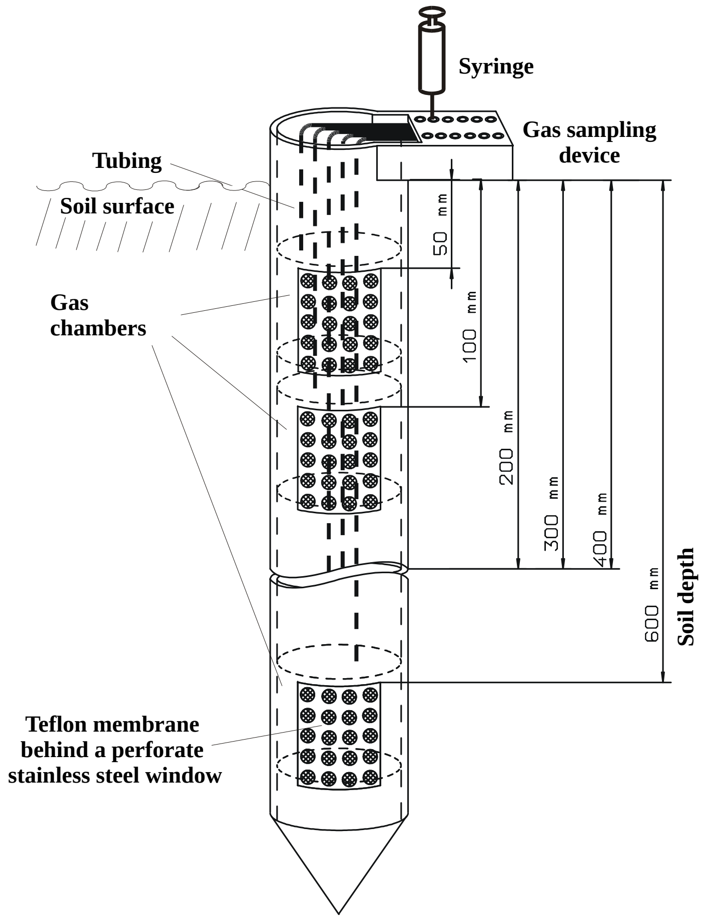


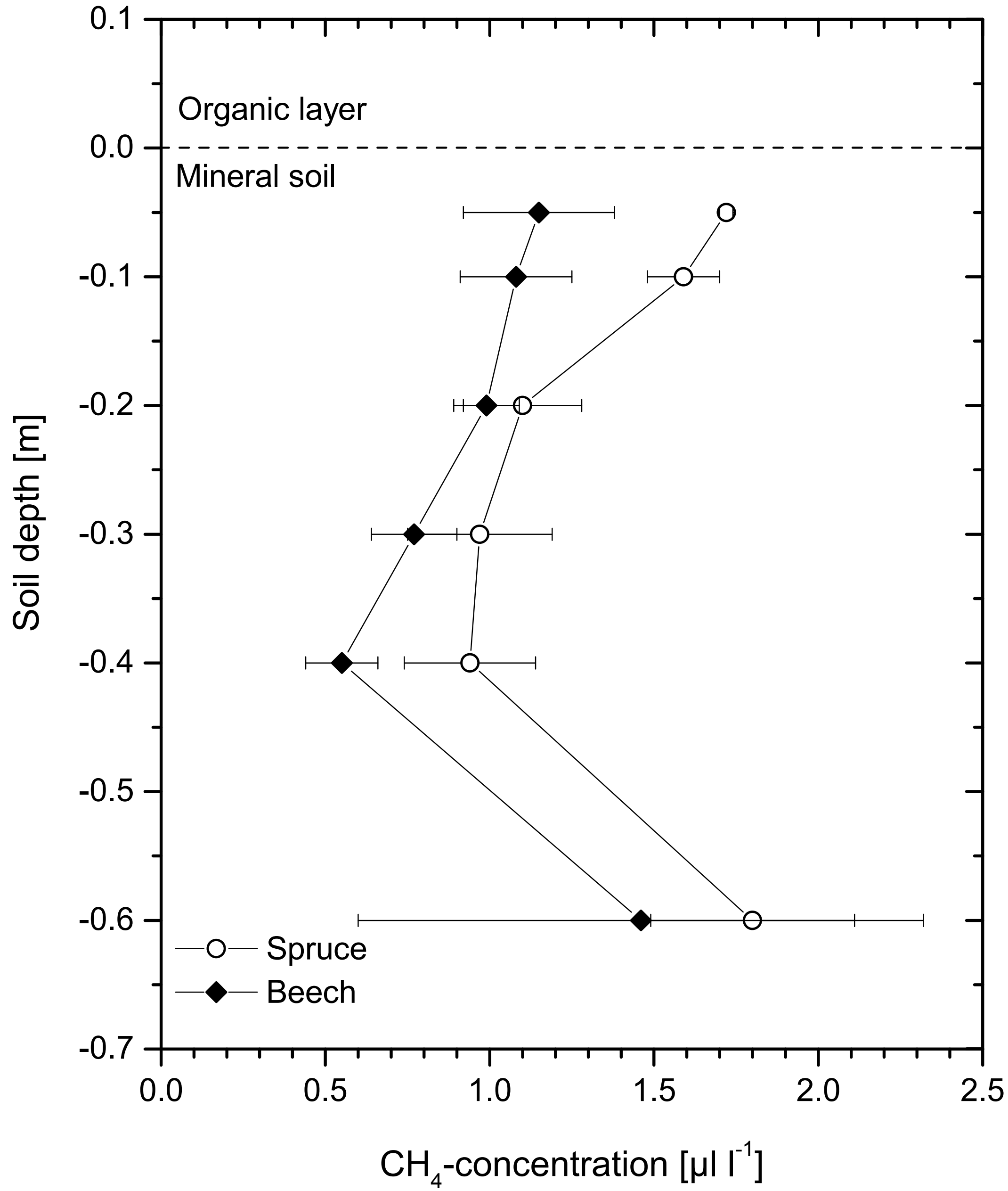
Landscape CH_4 exchange



Morrissey et al., 1994, Int. J. Rem. Sens

CH_4 oxidation in upland soils

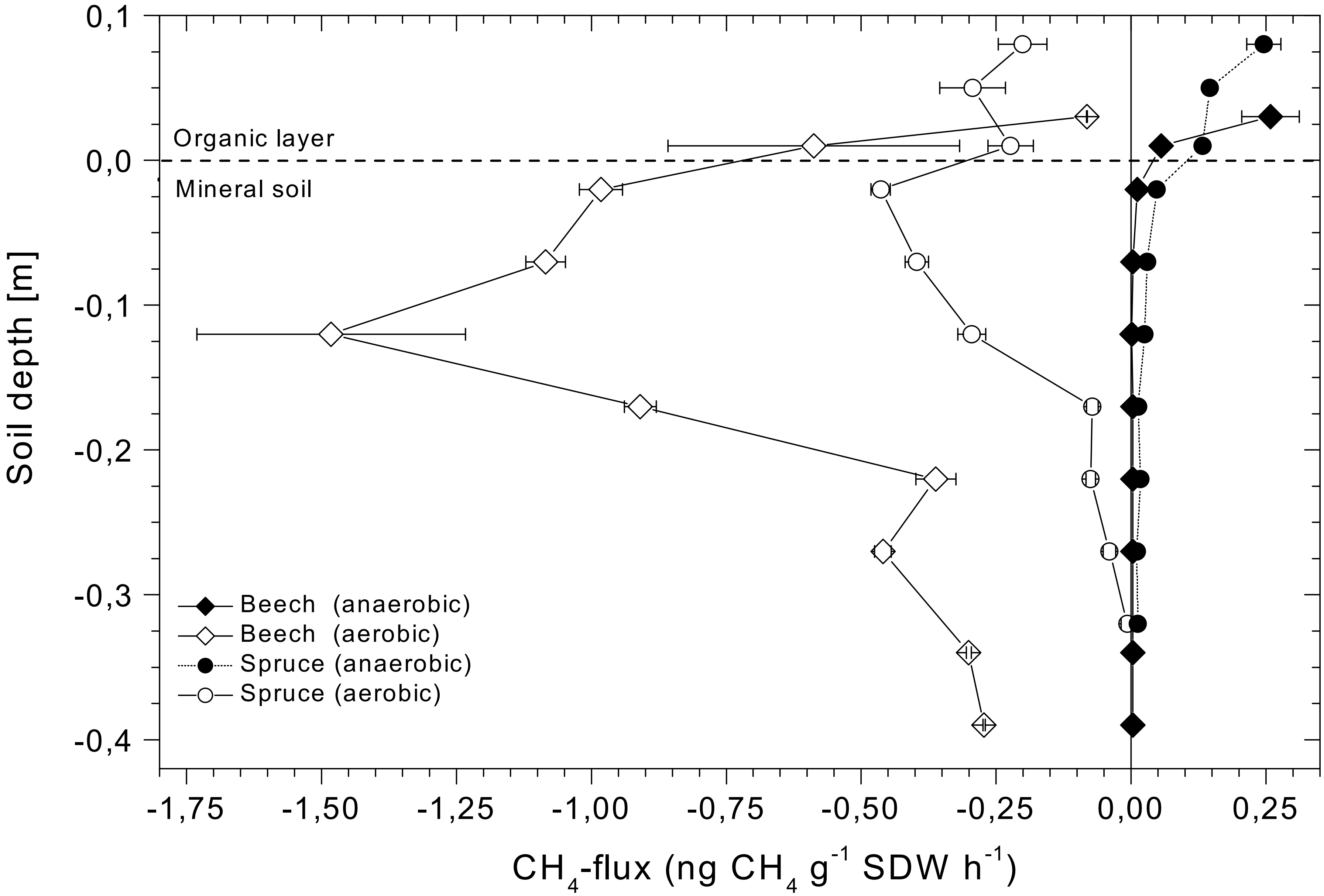




Butterbach-Bahl and Papen, 2002, Plant Soil

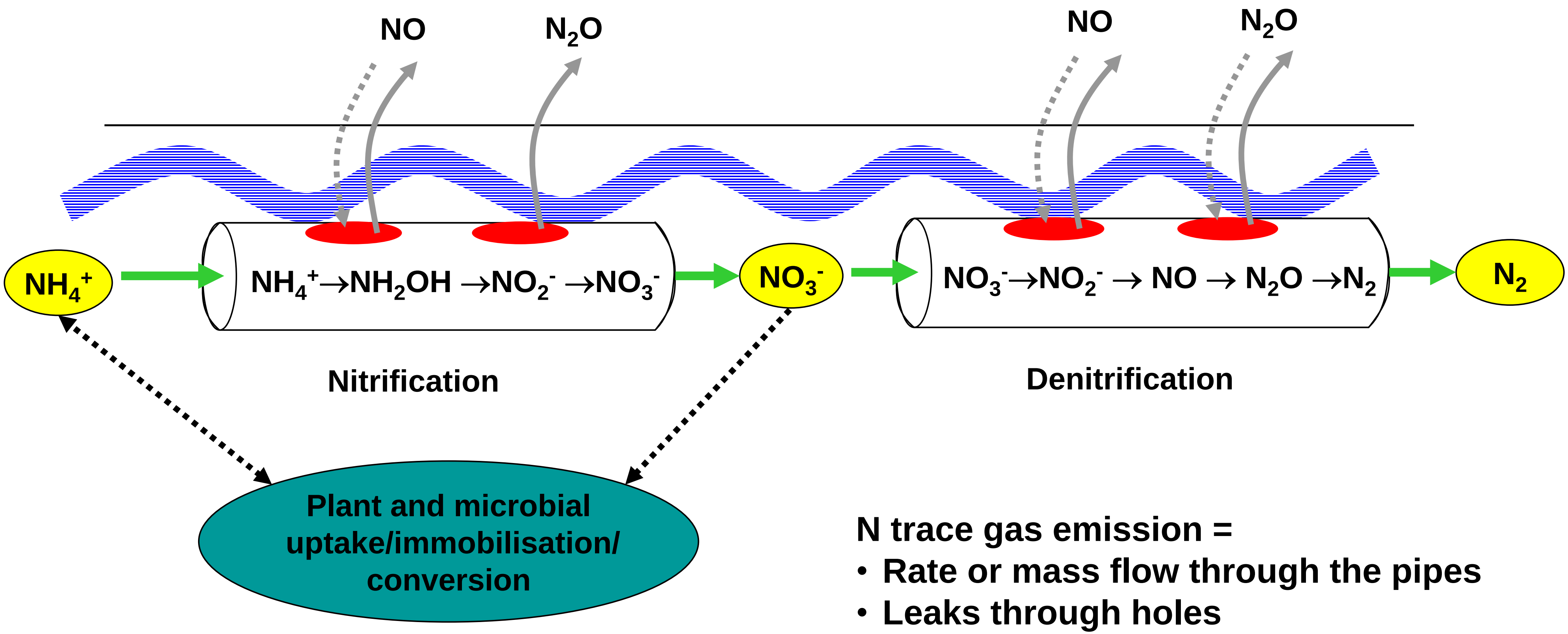
CH_4 oxidation and production in upland soils

Karlsruhe Institute of Technology



Butterbach-Bahl and Papen, 2002, Plant Soil

N trace gas production in soils

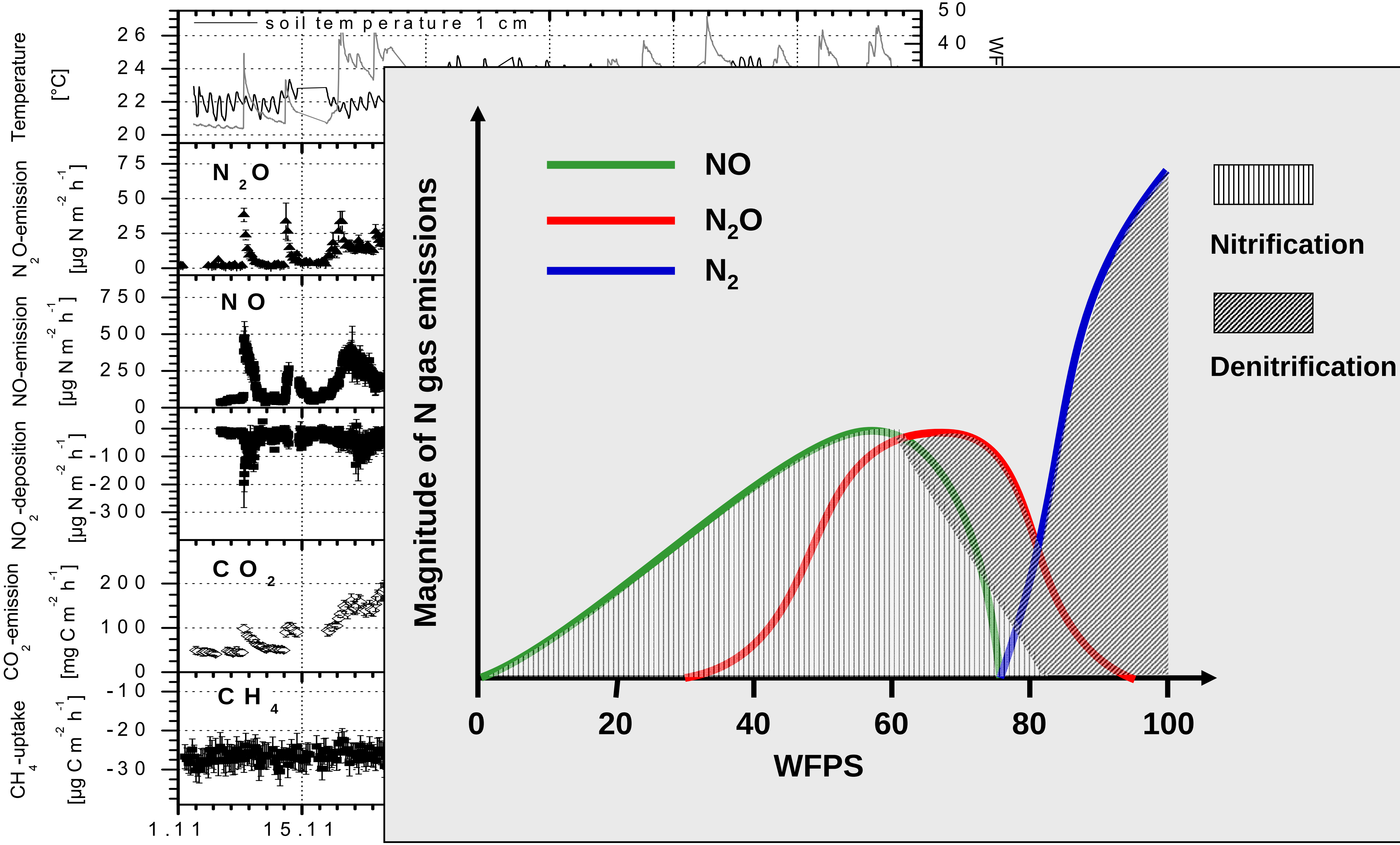


N trace gas emission =

- **Rate or mass flow through the pipes**
- **Leaks through holes**

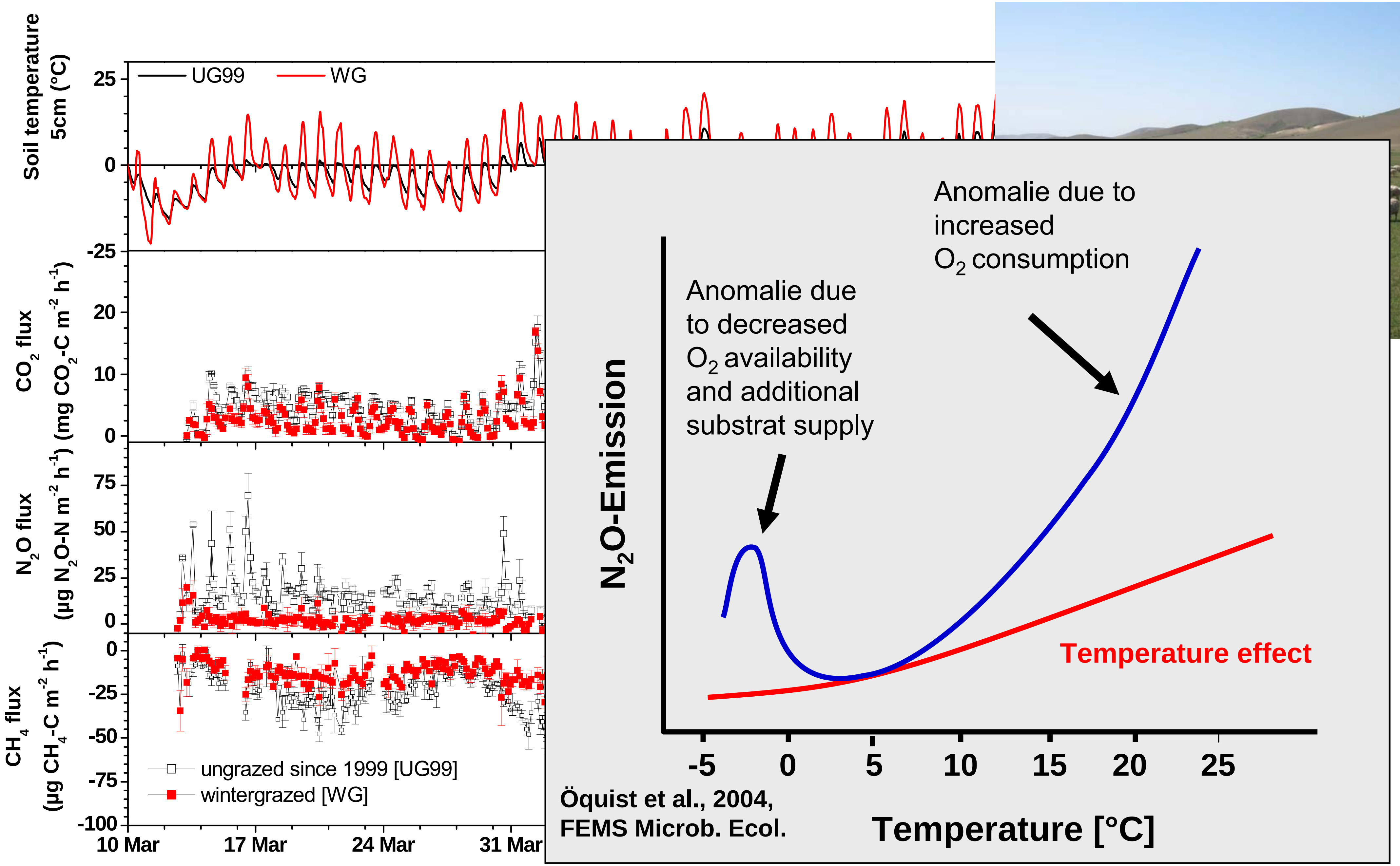
Davidson et al., 1993, 2000

Temporal and spatial variability of N trace gas fluxes



utterbach-Bahl et al., 2004, GBC

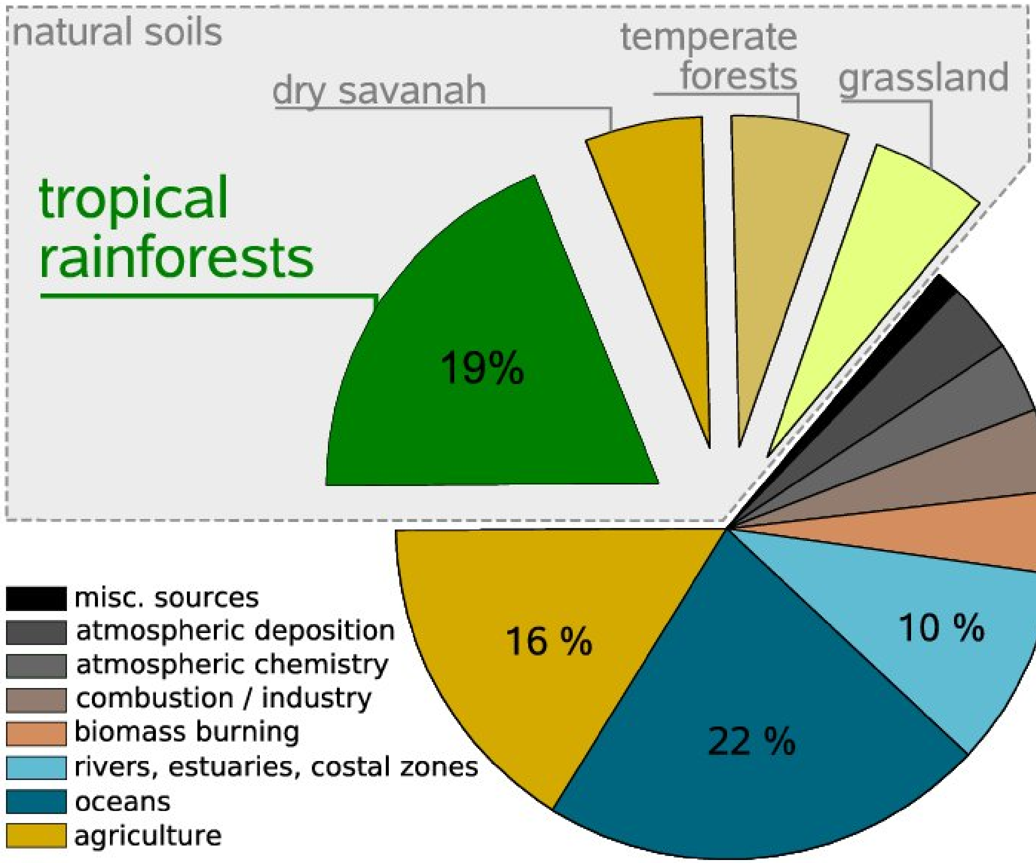
Temporal and spatial variability of N trace gas fluxes



olst et al., 2007, JGR-Biogeosciences, subm.

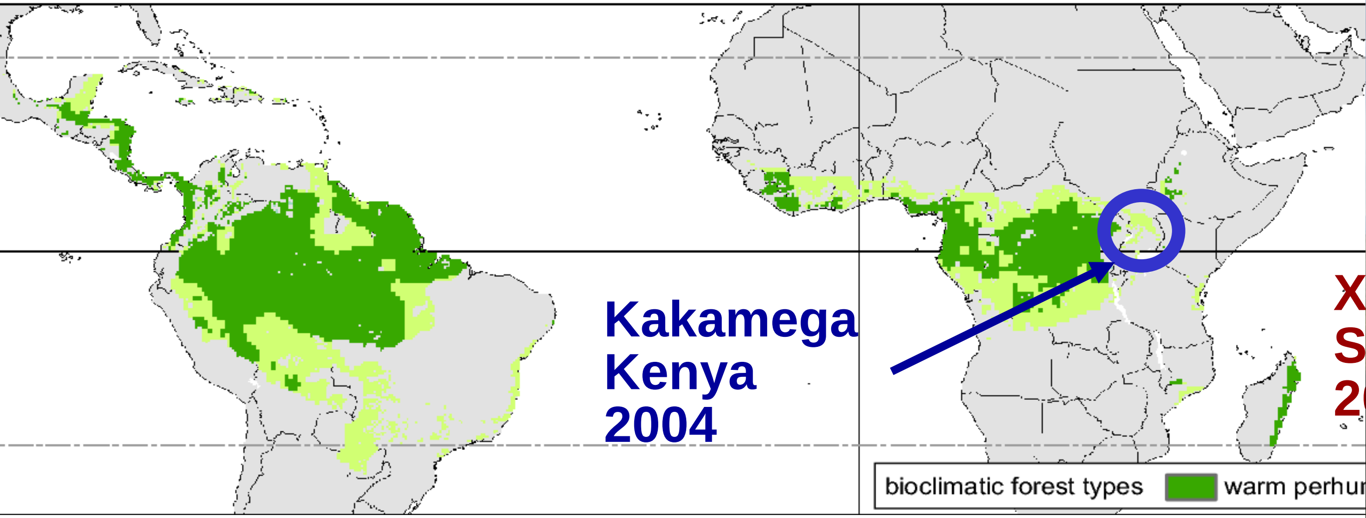
Sources and sinks of N_2O

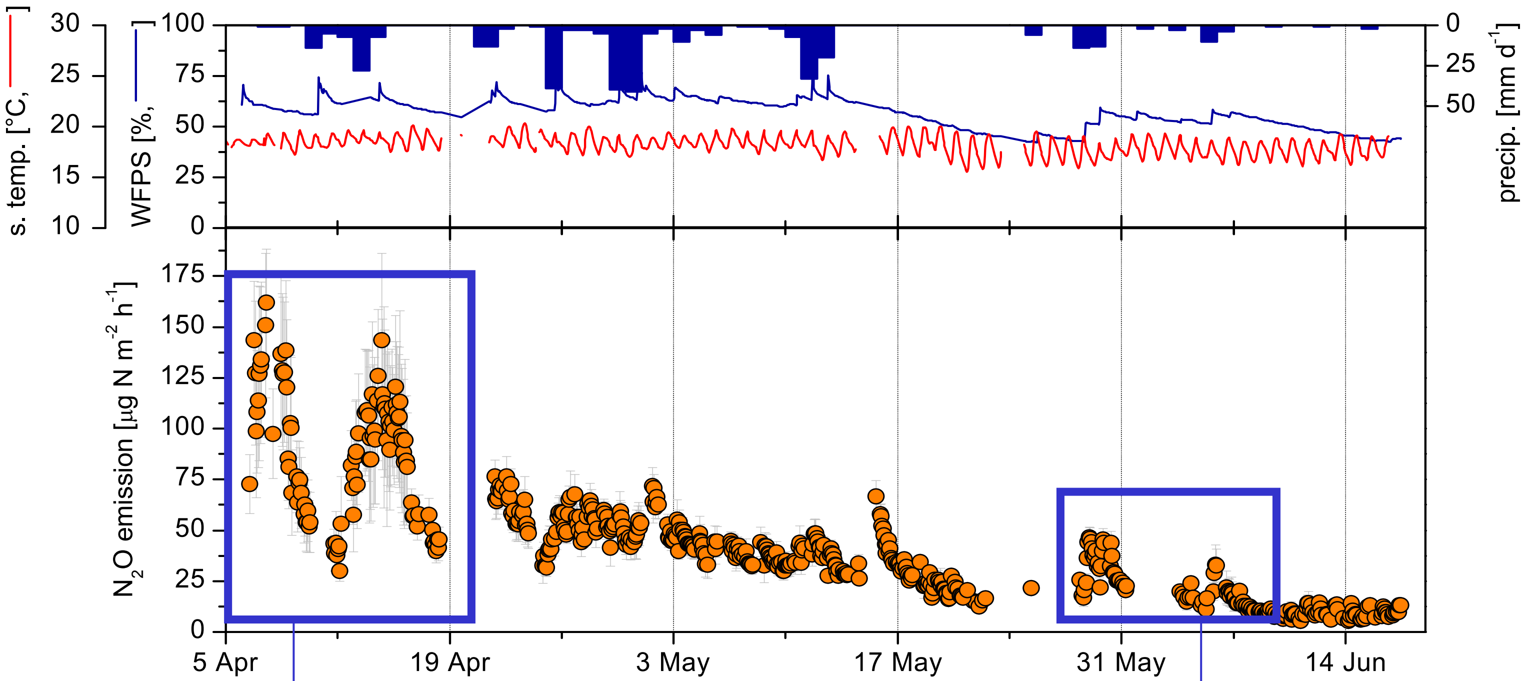
N_2O-sources	Relative contribution to all identified sources [%]	Tg (10^{12} g) N_2O-N a^{-1}	
Natural N_2O sources			
Ocean	18.5	3.0	(1.0-5.0)
Tropical soils			
Wet forests	**18.5**	**3.0**	**(2.2-3.7)**
Dry savannas	**6.2**	**1.0**	**(0.5-2.0)**
Temperate soils			
Forests	**6.2**	**1.0**	**(0.1-2.0)**
Grasslands	**6.2**	**1.0**	**(0.5-2.0)**
Anthropogenic N_2O sources			
Agricultural soils	**20.4**	**3.3**	**(0.6-14.8)**
Biomass burning	3.1	0.5	(0.2-1.0)
Industrial sources	8.0	1.3	(0.7-1.8)
Cattle and feedlots	13.0	2.1	(0.6-3.1)
Total N_2O sources		16.2	(6.4-34.4)
N_2O sinks and atmospheric increase			
Stratospheric destruction		12.3	(9.0-16.0)
Removal by soil microbes		**?**	**(?)**
Atmospheric increase		**3.9**	**(3.1-4.7)**



IPCC 2001, 2007

N_2O emissions from tropical rainforests





Strong peak emissions after first rainfall events

Low N_2O emissions & high soil moisture

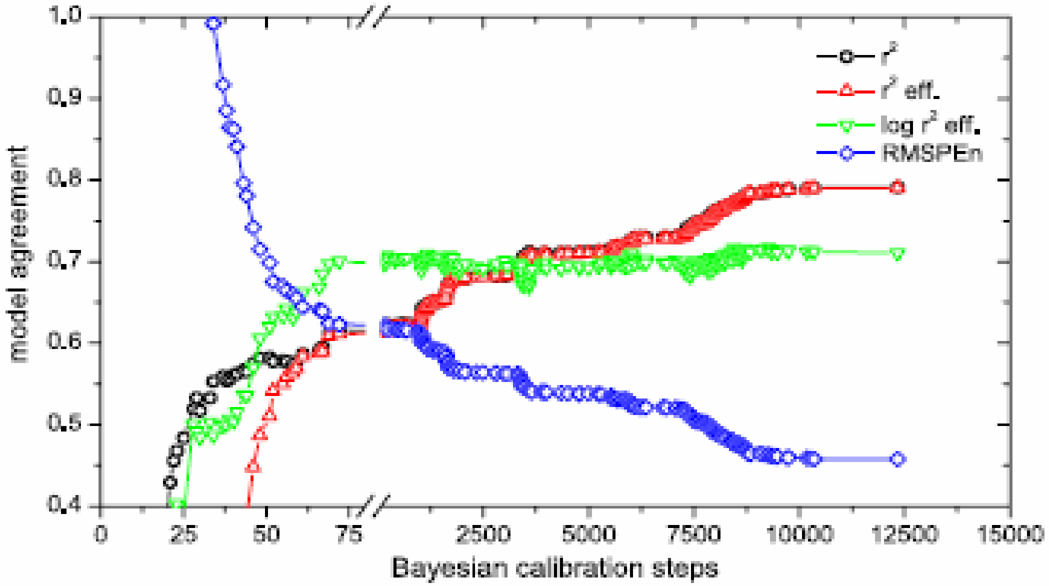
Bayesian calibration of the model

- Re-calibration of model internal parameters (pV)
- *Metropolis Hastings random walk*

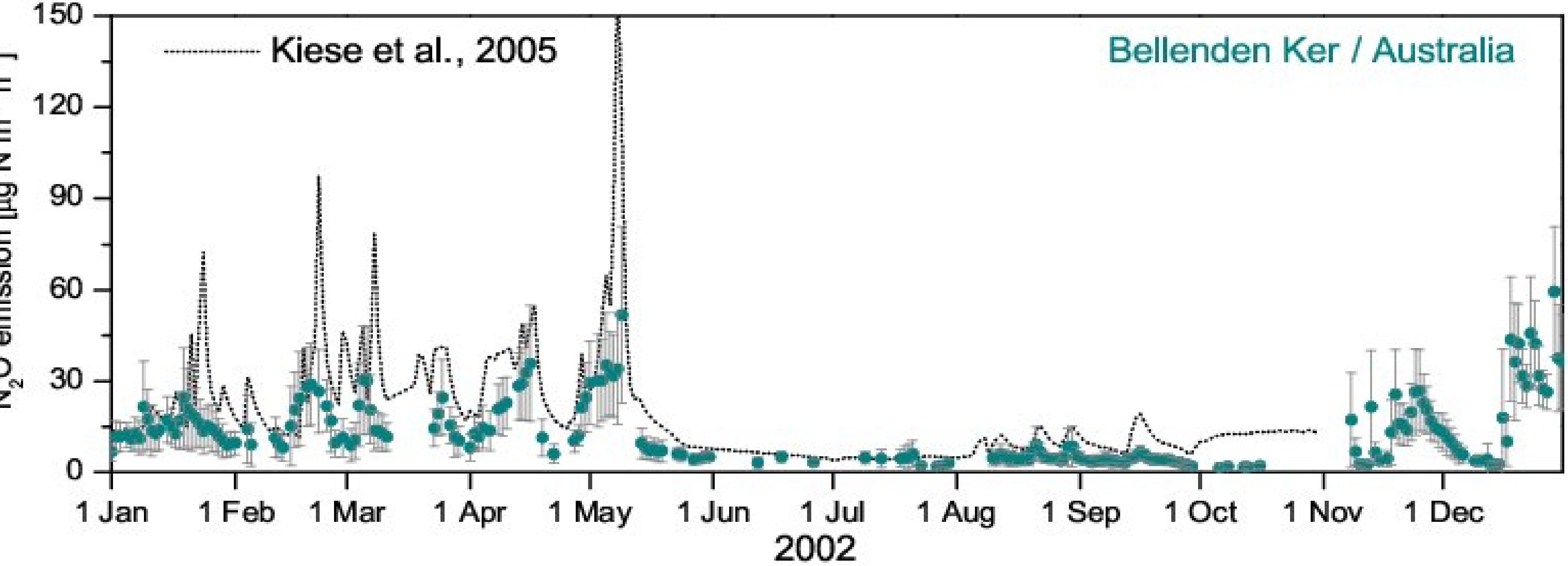
$$\Theta' = \Theta_t + \epsilon \qquad (1)$$

$$\beta = \frac{p(D|\Theta')p(\Theta')}{p(D|\Theta_t)p(\Theta_t)} \qquad (2)$$

- also enables to calculate parameter uncertainty of pV



Model testing



Werner et al., 2007, Global Biogeochem. Cycl.

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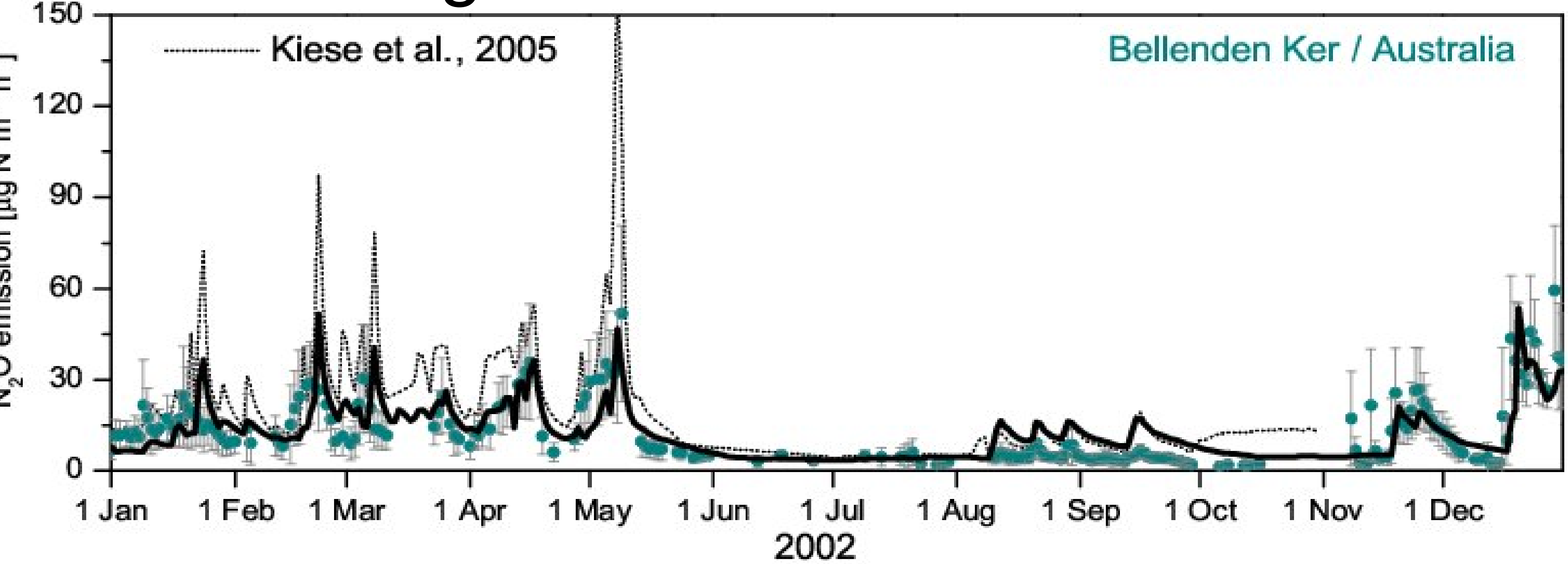

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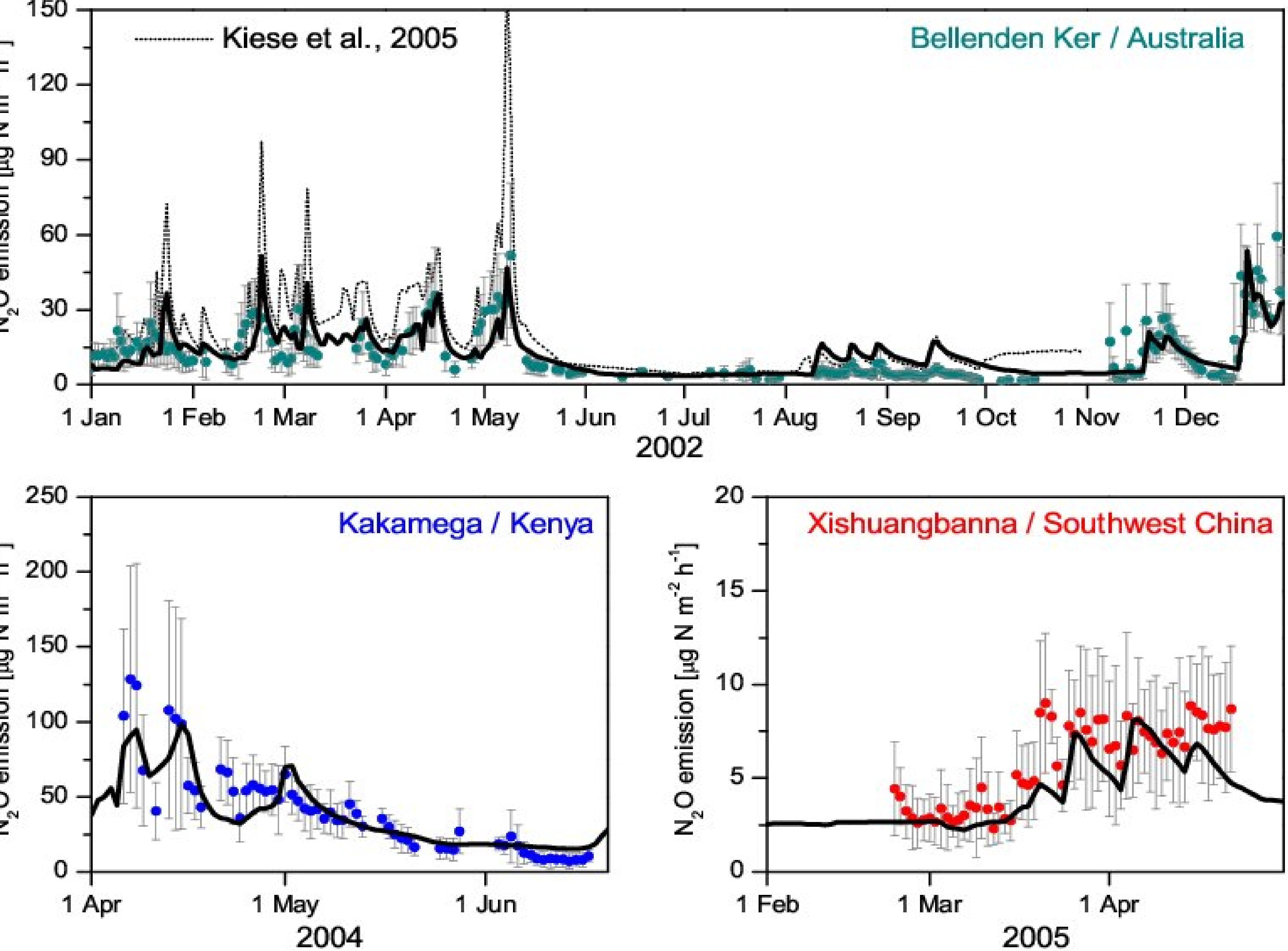

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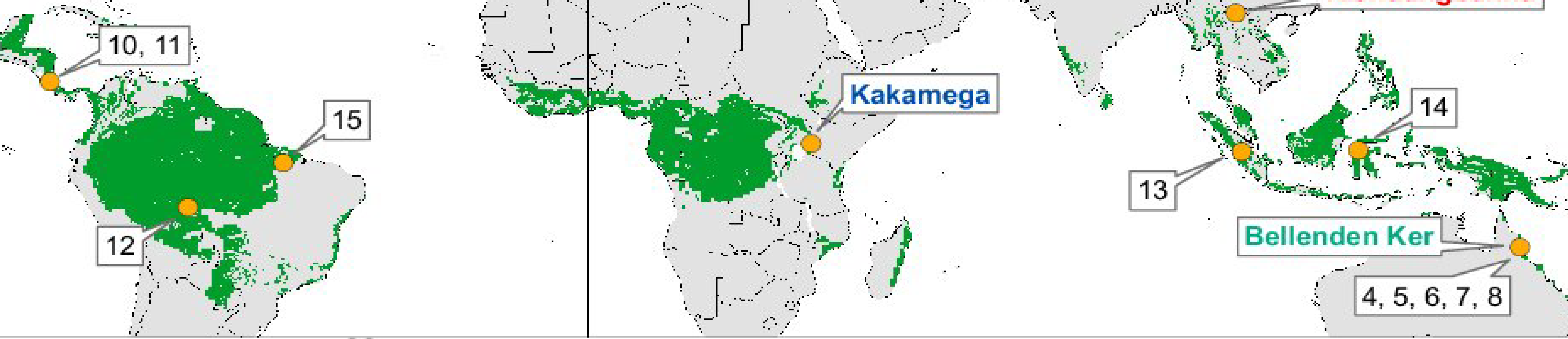

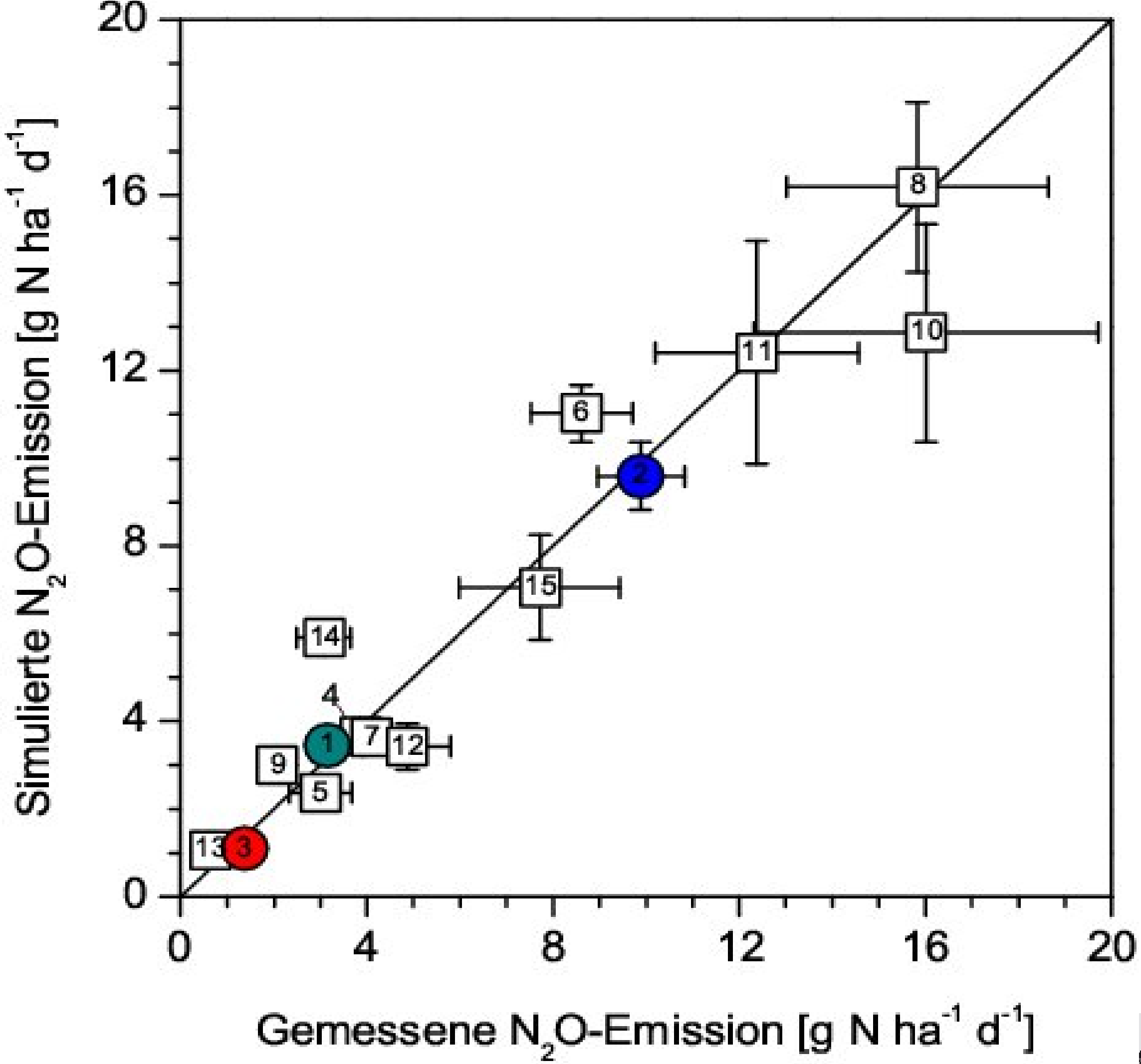

Werner et al. 2007 Global Biogeochem. Cycl.

Global GIS

Drivers:
integrated binary dataset:
CRU climate dataset
FAO global soil database

LPJ-DGVM

Lund-**P**otsdam-**J**ena **D**ynamic
Global **V**egetation **M**odel

SMITH et al., 2001, SITCH et al., 2003; ZAEHLE and SITCH, 2005]

BIOMASS

wood mass, leaf mass,
litter mass

Global GIS

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BIOMASS

wood mass, leaf mass,
litter mass

Climate

ECMWF RA-40 Forecast
0.5x0.5°; daily
(1991- 2000)

temperature (min/max);
rainfall; PAR

Soil

spatial: FAO global soil
map; 0.25x0.25° (rs)
profile data: ISRIC-WISE

topsoil attributes:
pH, SOC, texture, BD, ...

Forest Area

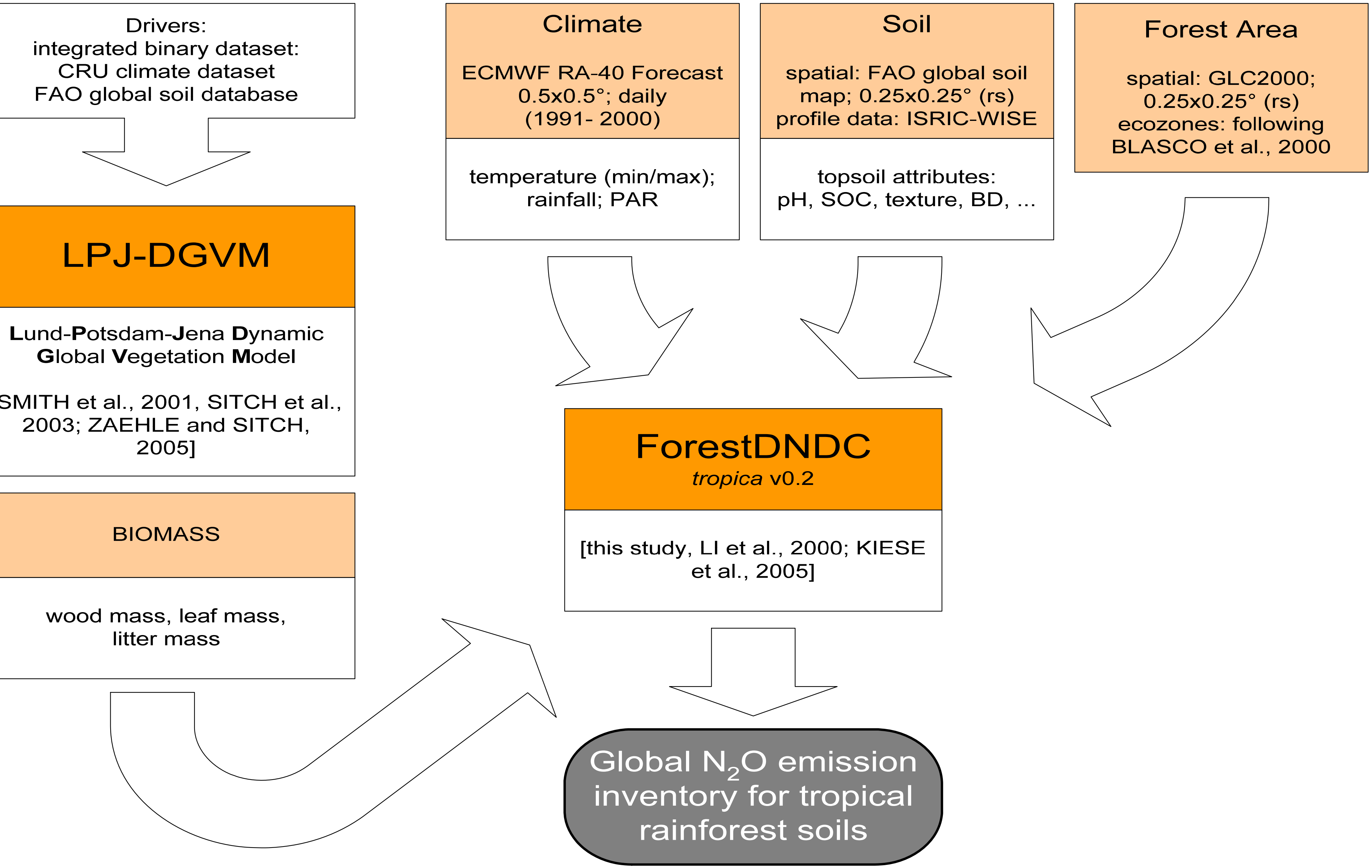
spatial: GLC2000;
0.25x0.25° (rs)
ecozones: following
BLASCO et al., 2000

ForestDNDC

tropica v0.2

[this study, LI et al., 2000; KIESE et al., 2005]

Global GIS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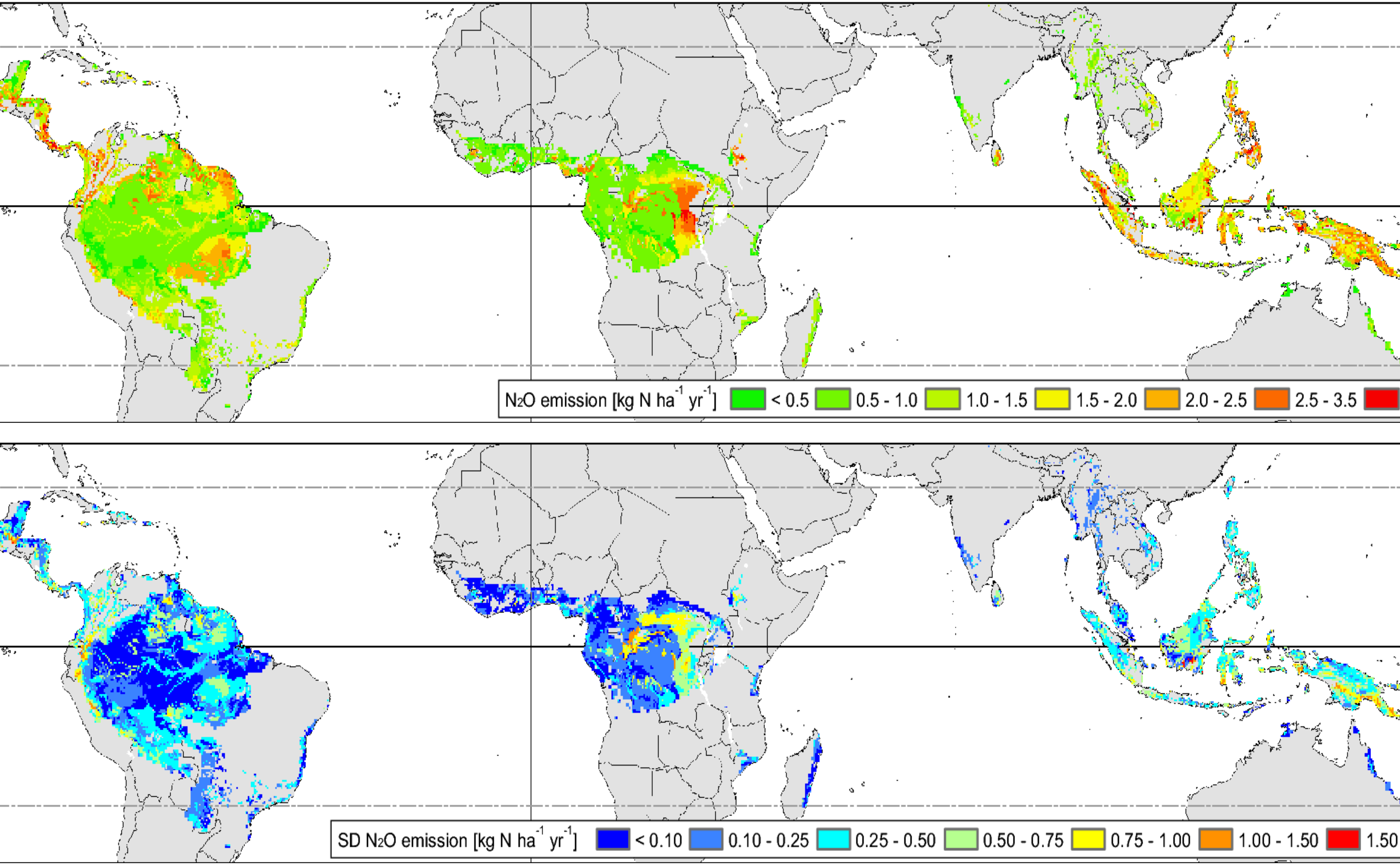
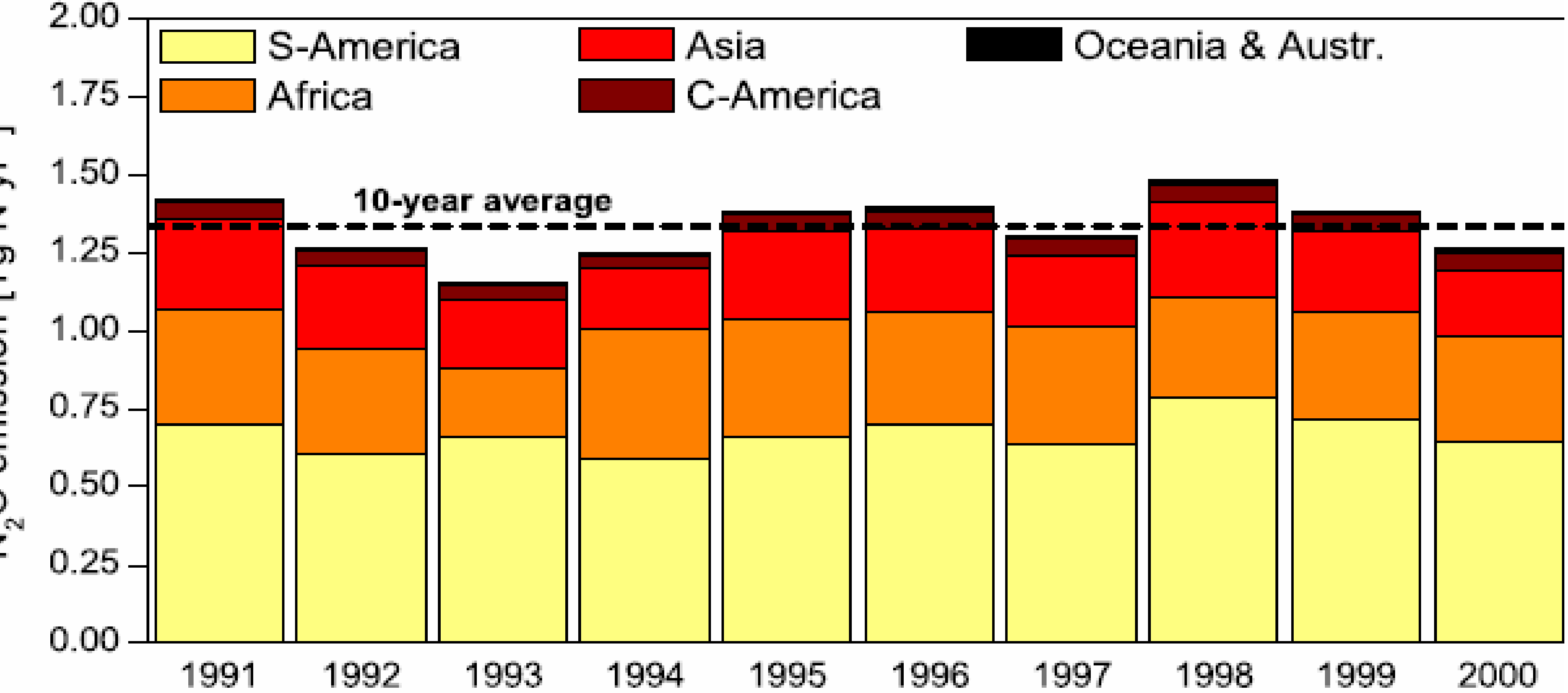
Global N2O emission inventory for tropical rainforest soils

Global N_2O inventory



erner et al., 2007, Global Biogeochem. Cycl.

Interannual variability



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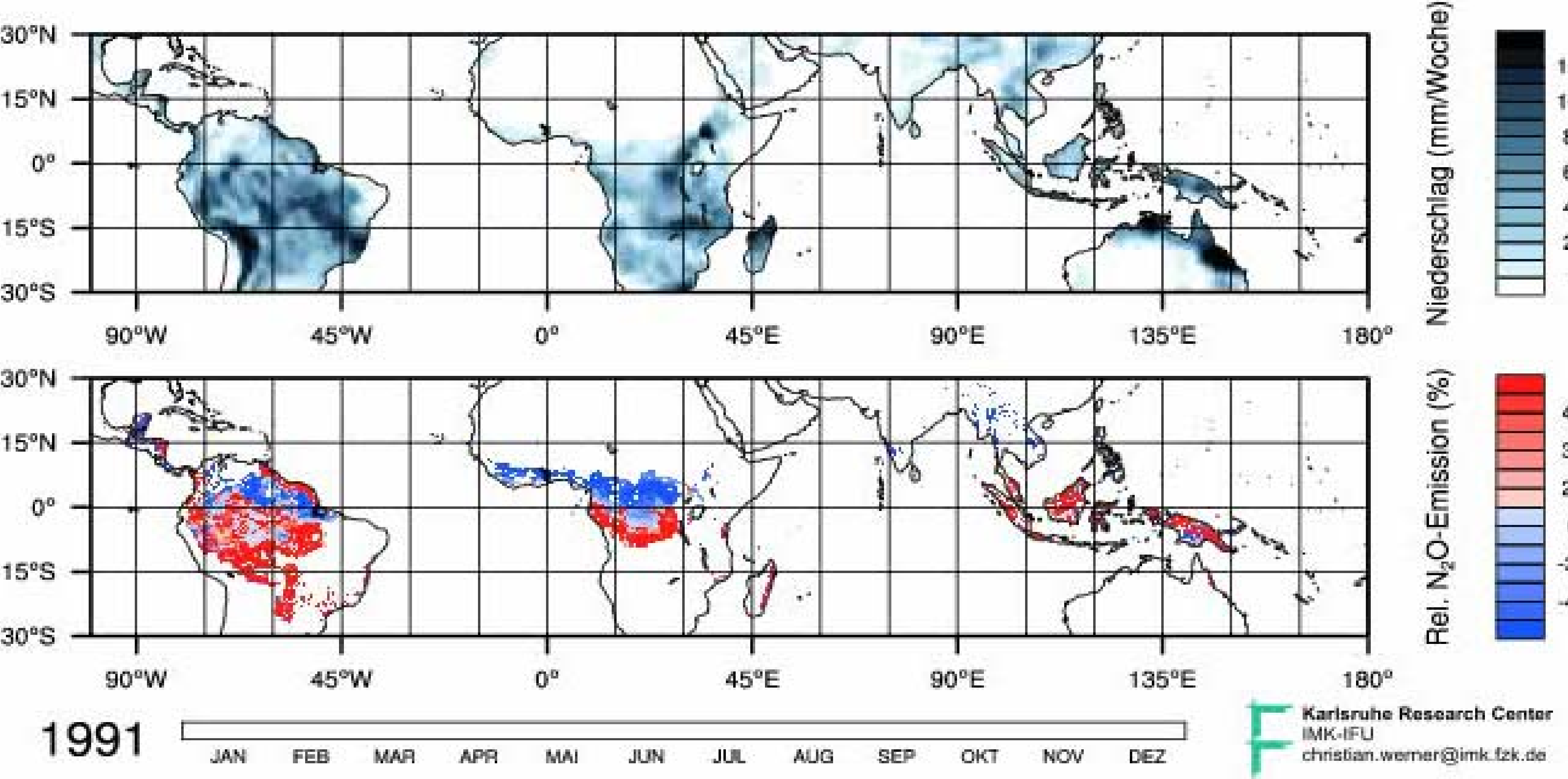
30°N
15°N
0°
15°S
30°S
90°W
45°W
0°
45°E
90°E
135°E
180°
Niederschlag (mm/Woche)
Rel. N2O-Emission (%)
1991
JAN
FEB
MAR
APR
MAI
JUN
JUL
AUG
SEP
OKT
NOV
DEZ
Karlsruhe Research Center
IMK-IFU
christian.werner@imk.fzk.de

Comparison with earlier estimates

- What is the area we are talking about?
  (all N_2O emissions scaled to the area used in this study)
- Matson and Vitousek 1990: 1.8 (2.4) Tg N yr^{-1}
- Bouwman et al. 1995: 1.5 (2.3) Tg N yr^{-1}
- Potter 1998: 1.3 Tg N yr^{-1}
- Breuer et al. 2000: 2.6 (3.5) Tg N yr^{-1}
- Stehfest and Bouwman 2006: 1.5 (1.2) Tg N yr^{-1})

- This study: 1.3 (0.9 -2.4) Tg N yr^{-1}

Werner et al., 2007, Global Biogeochem. Cycl.