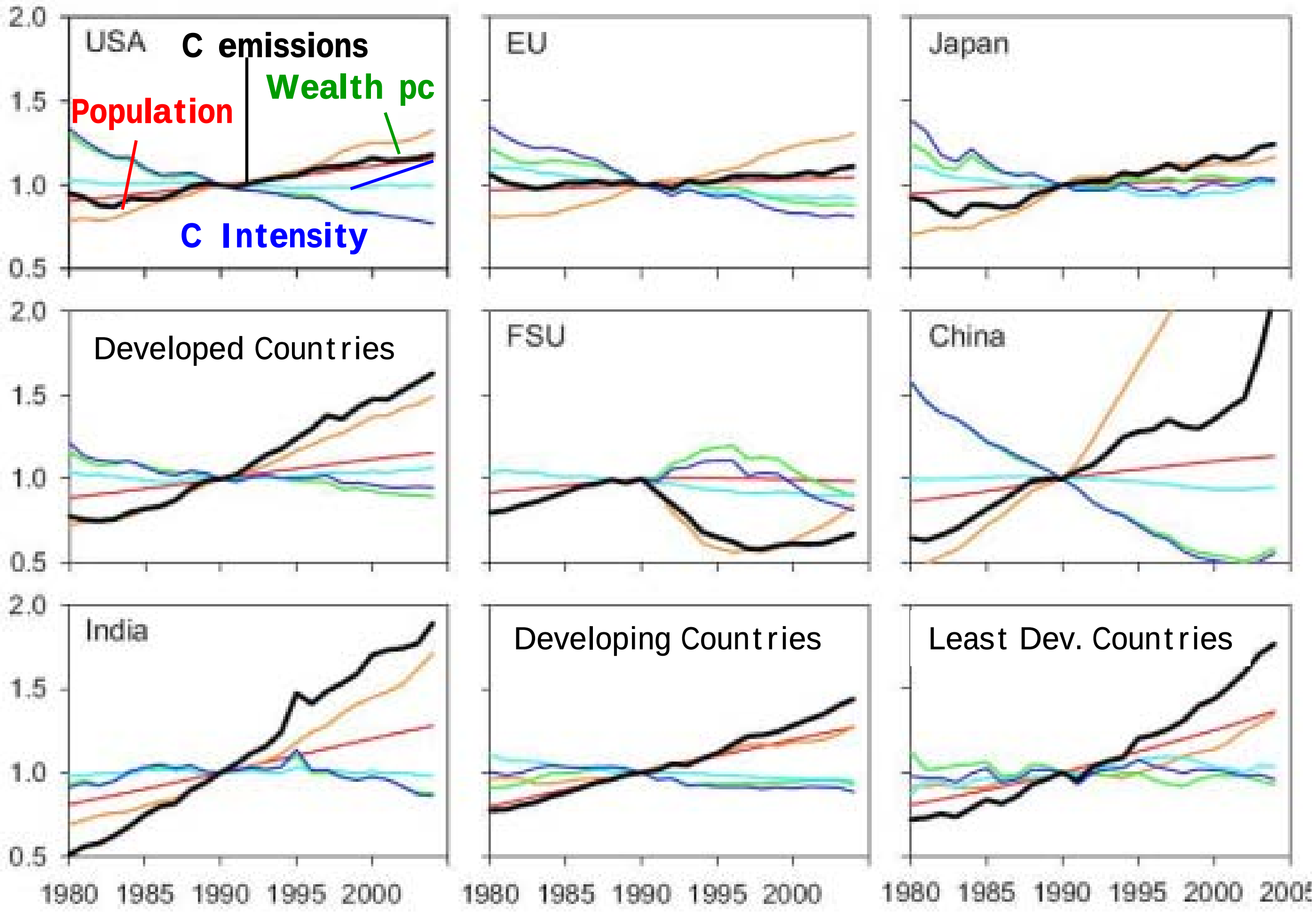
Regional drivers of Anthropogenic CO_2



Raupach et al 2007, PNAS

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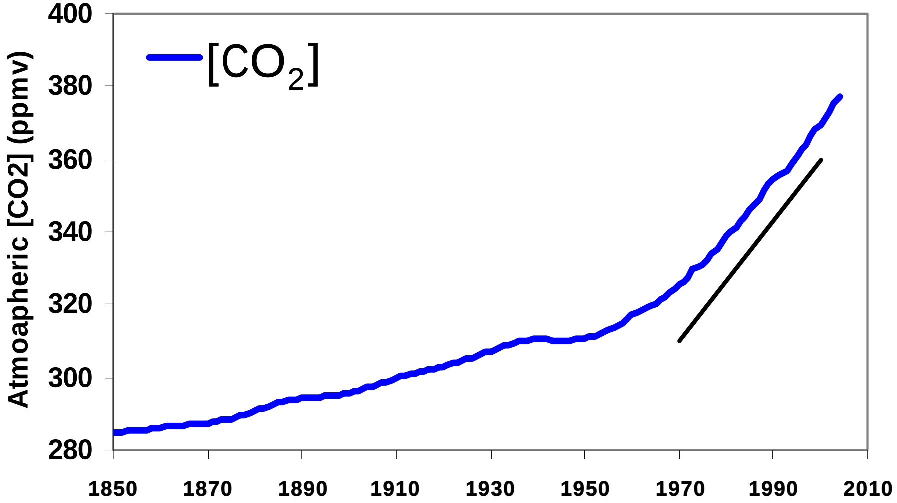
Atmospheric CO_2 Concentration

Year 2007
Atmospheric CO_2
concentration:

382.6 ppm

35% above pre-industrial



1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{1}
1990 – 1999: 1.5 ppm y^{-1}

2000 - 2006: 1.9 ppm y^{-1}

NOAA 2007; Canadell et al. 2007, PNAS

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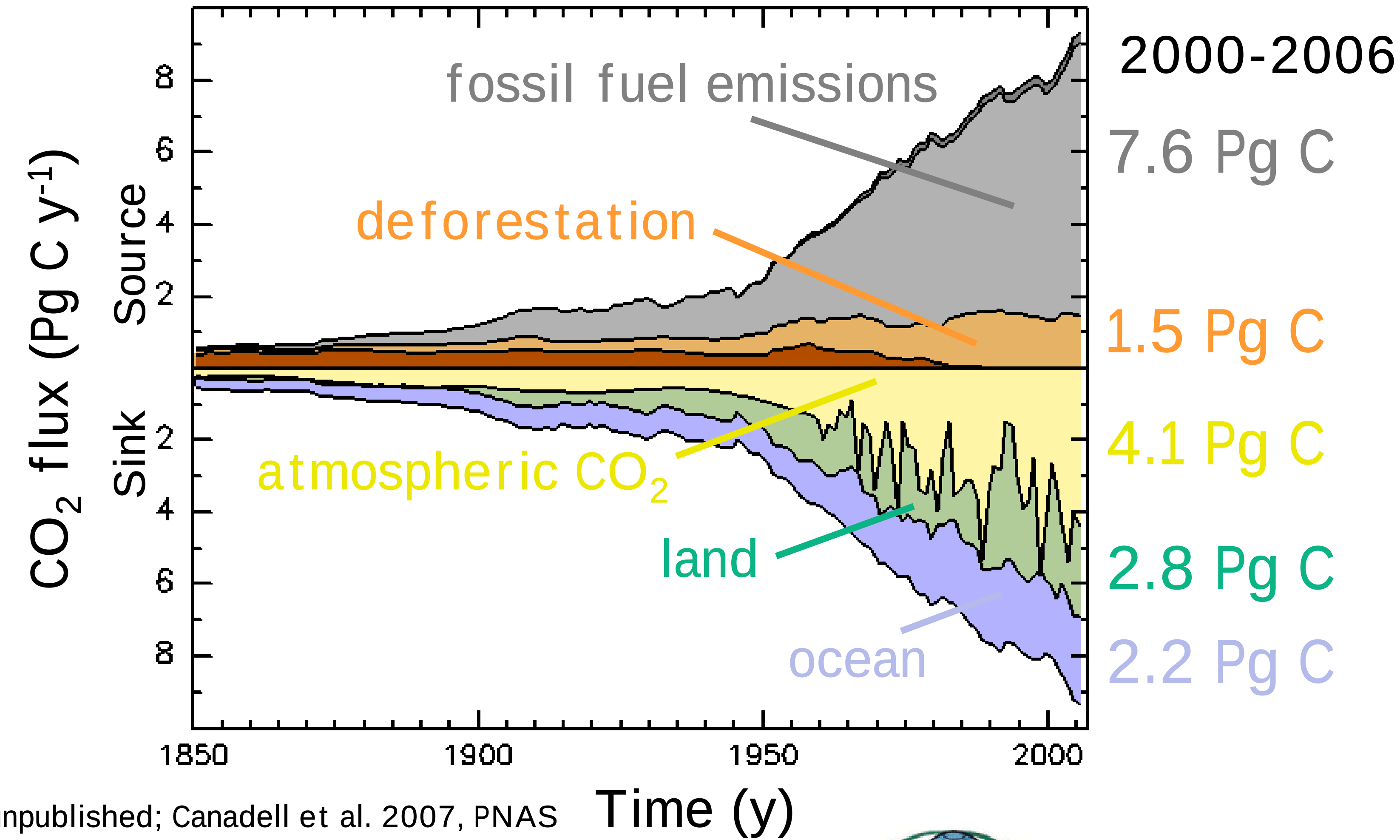
Anthropogenic Perturbation of the Carbon Budget



Le Quere unpublished; Canadell et al. 2007, PNAS

Fate of Anthropogenic CO_2 Emissions (2000-2006)

+

Canadell et al. 2007, PNAS

Atmosphere
45%

Land
30%

Oceans
25%

This is a great service, now worth half a trillion US$
(25€ per ton CO2-equivalents)

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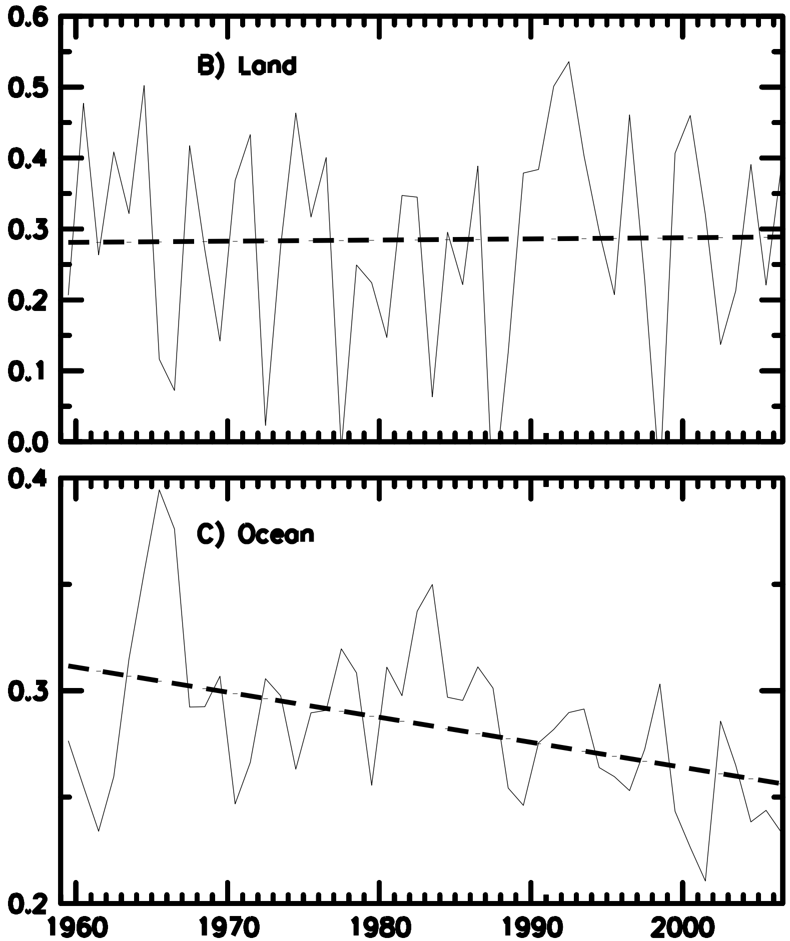
Efficiency of Natural Sinks

Land Fraction

Ocean Fraction



Canadell et al. 2007, PNAS

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Cause of the Declined in the Efficiency of the Ocean Sink

Credit: N.Metzl, August 2000, oceanographic cruise OISO-5

Le Quéré et al. 2007, Science

- Half of the decline is attributed to up to a 30% decrease in the efficiency of the Southern Ocean sink over the last 20 years.
- It is attributed to the strengthening of the winds around Antarctica which enhances ventilation of natural carbon-rich deep waters.
- The strengthening of the winds is attributed to global warming and the ozone hole.

Earth System Science Partnership

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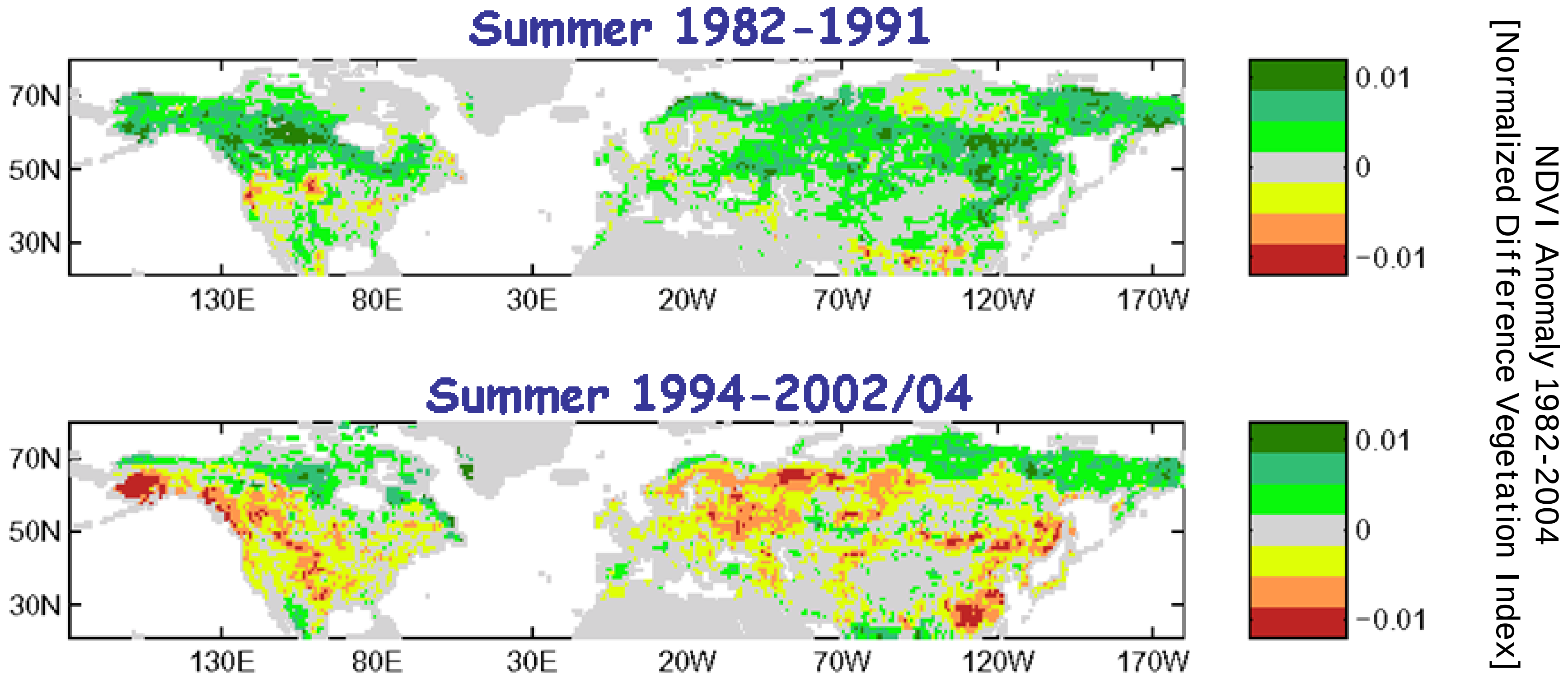
Effects of drought and warmer temperatures on carbon sinks

Major droughts in mid-latitudes, particularly summer
Warmer temperatures, particularly in autumn.



Angert et al. 2005, PNAS; Buermann et al. 2007, PNAS; Ciais et al. 2005, Science

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Attribution of Recent Acceleration of Atmospheric CO_2

1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{-1}
1990 – 1999: 1.5 ppm y^{-1}
2000 - 2006: 1.9 ppm y^{-1}

65% - Increased activity of the global economy

17% - Deterioration of the carbon intensity of the economy

18% - Decreased efficiency of natural sinks

Canadell et al. 2007, PNAS

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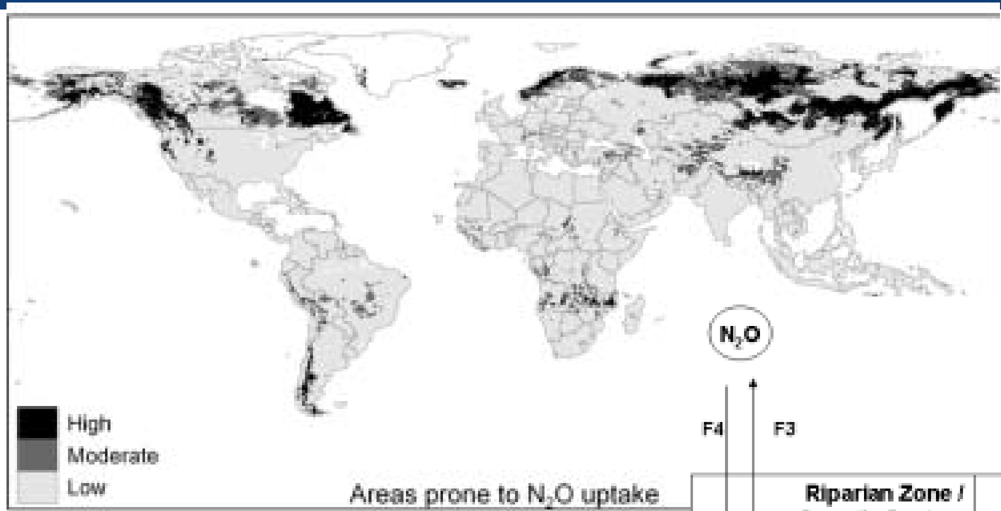
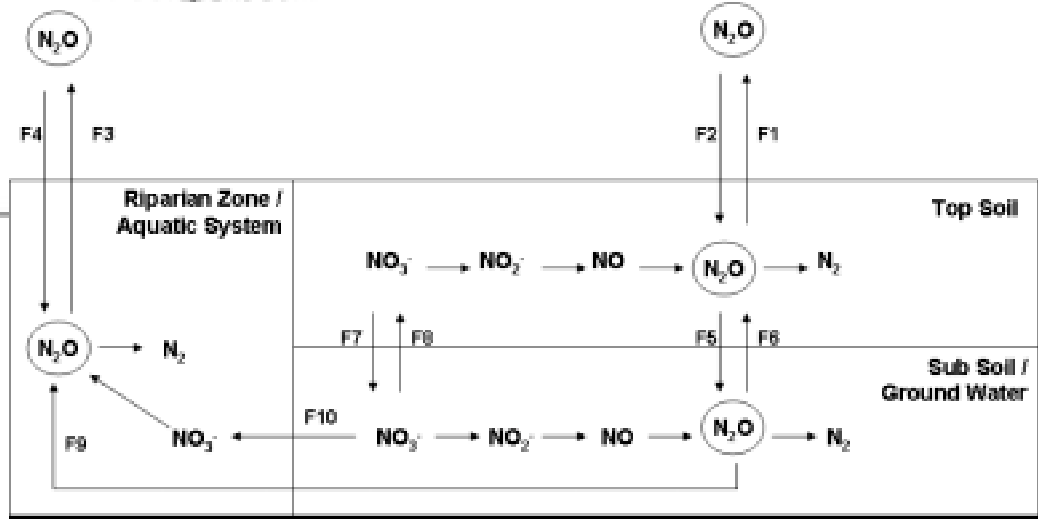
Removal of N_2O by soils

Kroeze, C. et a., 2007. Sinks for N2O at the Earth's surface. In: Raey, D.S., Hewitt, M., Grace, J., Smith, K.A. (Eds.), Greenhouse Gas Sinks. CAB International, Wallingford, UK., pp. 227-243.



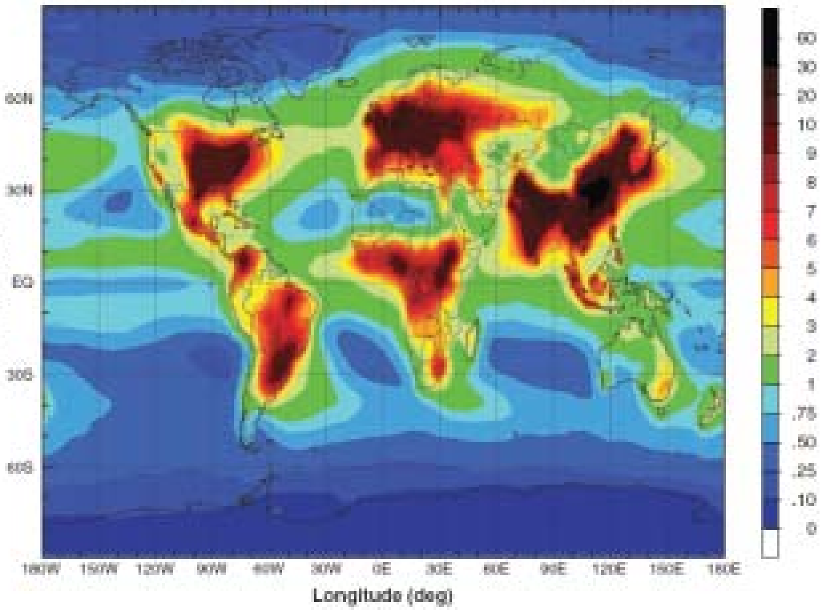


There are distinct patterns of N2O uptake in soils but these have up to now been neglected in the N2O budget. Regionally, this uptake is relevant.

Critical question: can we manage the uptake of N2O in soils?

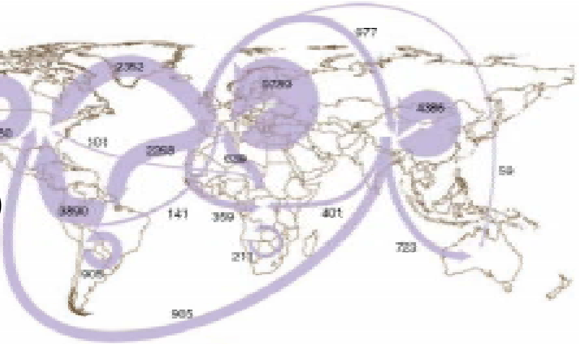
Nitrogen in products

Galloway, J.N. et al., 2008. Transformation of the N-Cycle: Recent Trends, Questions, and Potential Solutions. Science 320, 889-892.

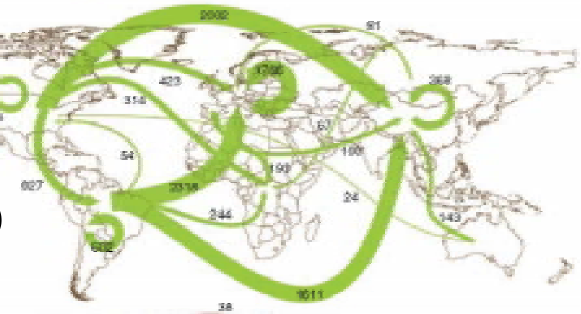


Estimated N deposition, totaling 105 Tg N y^{-1} in kg ha^{-1} y^{-1}

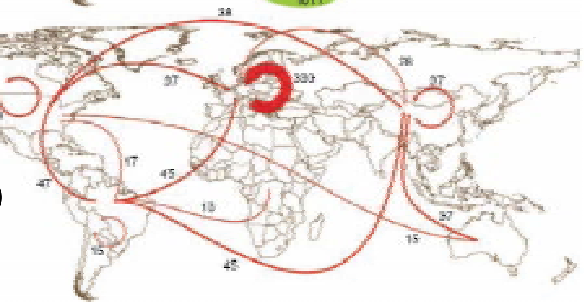
Fertilizer (31 Tg N)



Grain (12 Tg N)



Meat (0.8 Tg N)



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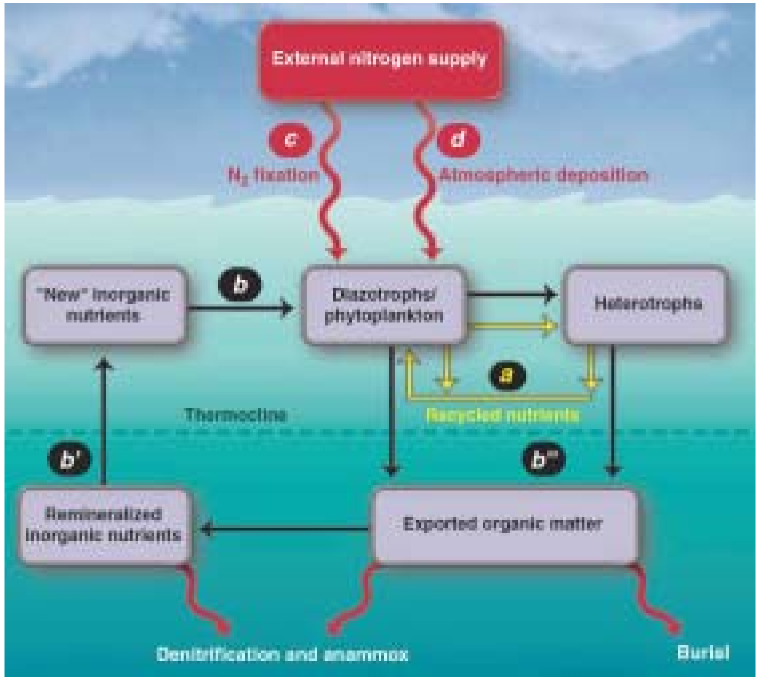
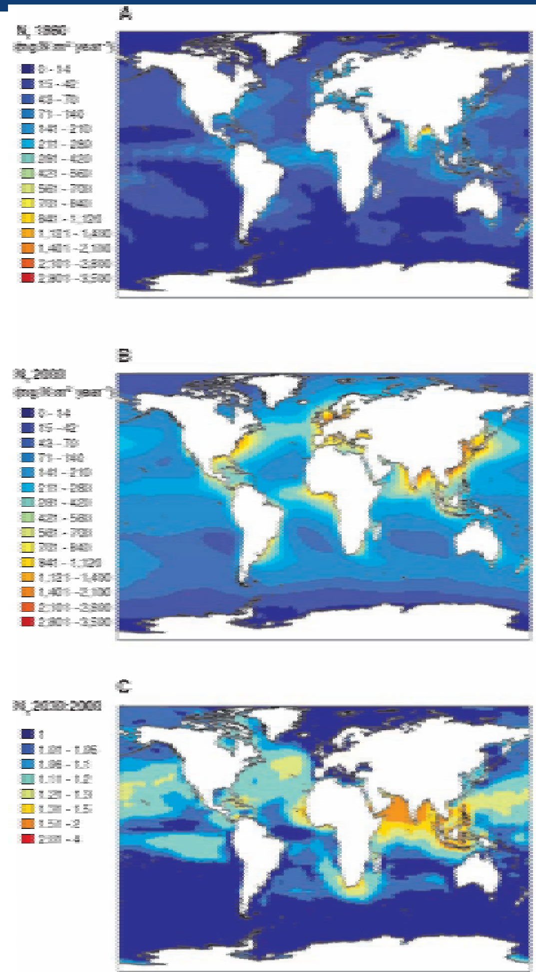
Impacts on the global Nitrogen Cycle and impacts on N_2O





Although ~10% of the ocean's drawdown of CO2 result from atmospheric nitrogen fertilization, about two-thirds is offset by N2O emissions. This effect is expected to increase in the future.

Duce, R.A., et al. 2008. Impacts of Atmospheric **Anthropogenic Nitrogen on the Open Ocean.** Science 320, 893-897.

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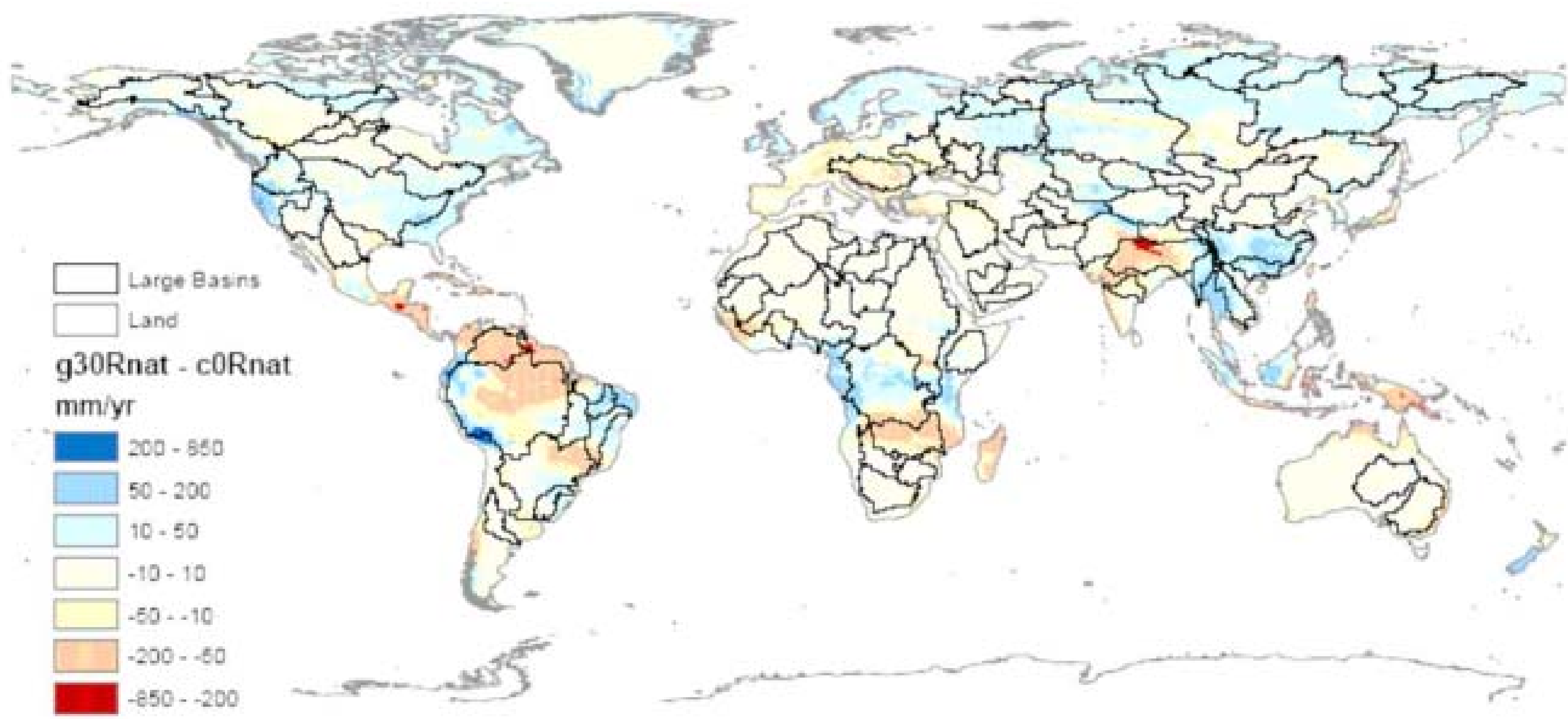
Effect of Climate Change on Water Runoff (IMAGE)

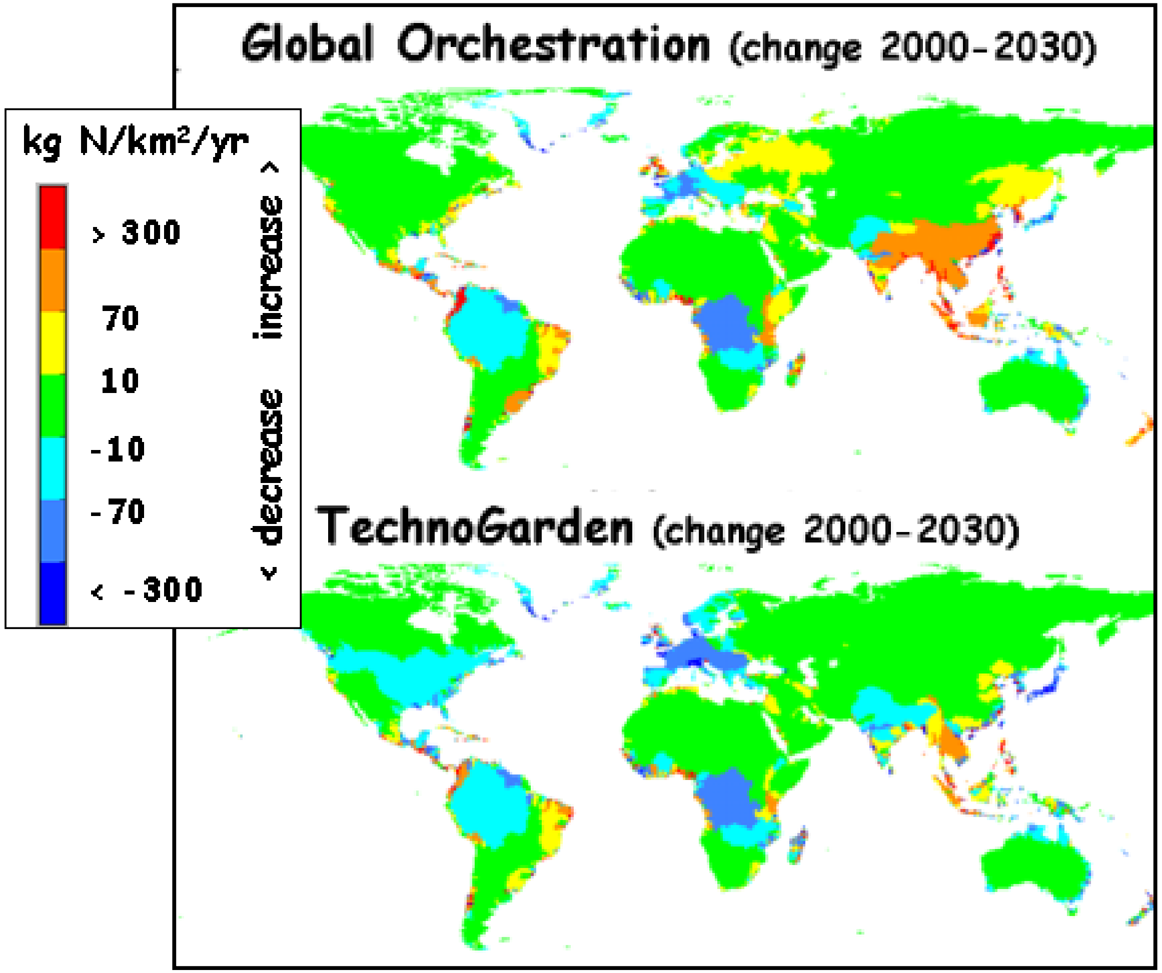
Seitzinger et al. MA scenarios preliminary results



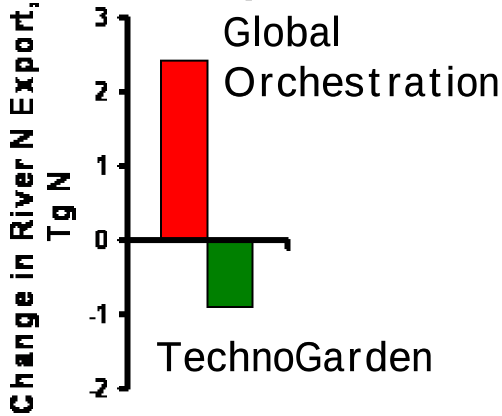
Changes in runoff between 2000 and 2030 in the Global Orchestration scenario (Blue positive values are increases)

Regional change in Dissolved Inorganic Nitrogen (DIN) Yield from 2000 to 2030

Seitzinger et al. MA scenarios preliminary results



Global Change in DIN Export



Large regional differences: N yield to coastal water strongly influenced by management, runoff, dams, agriculture, climate change and other feedbacks.

Development of the global water use scenarios

Global water use scenarios (13 scenarios, 5 international studies)

(Uncertainty of, for example, population, economic activity, rate of technological change):

- Increase between 2000 and 2050 for nearly all scenarios
- Mean changes between 2000 and 2050: +38% (+25 to +84%)

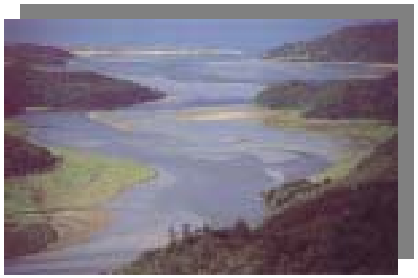
Pattern of change Ą accelerating and then slowing

Large regional differences

- Industrialized countries: water withdrawals stabilizing or sinking
- Developing countries: pressure on water resources growing up to 2050

Most rapidly growing water sectors in Africa & rapidly developing world: both **domestic & industry**






Alcamo et al. 2008. Global Water Outlook to 2025

Applied Earth System Science and ESSP Rapid BIOFUELS assessment (with SCOPE)

Earth System Science Partnership

AIMES

Global Carbon Project

Global LAND Project

What are the policy issues?

What are the earth system linkages, land use needs, systemic feedbacks and uncertainties?

What are plausible scenarios?

What are the key vulnerabilities?

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Methane budget and isotopic structures of source and sinks

Mikaloff-Fletcher et al. (2004) Global Biogeochemical Cycles

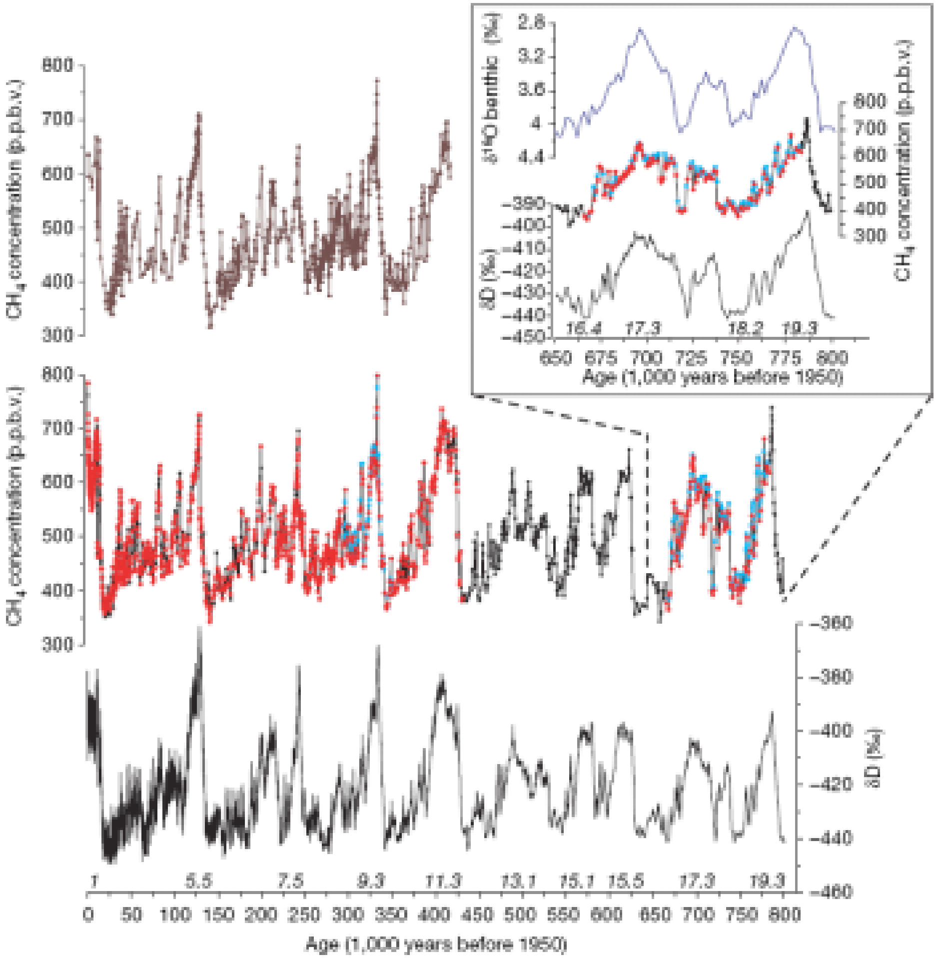
Sources	A Priori Estimates, Tg CH_4/yr	Range of Estimates Reported by *IPCC* [2001], Tg CH_4/yr	Mean Isotopic Signature
Total wetlands		92–237	−58‰[b]
Swamps	91[c]		
Bogs and tundra	54[c]		
Rice agriculture	60[d]	25–100	−63‰[b]
Ruminant animals	93[d]	80–115	−60‰[b]
Termites	20[e]	20–20	−70‰[b]
Biomass burning	52[f]	23–55	−25‰[b]
Energy		75–109	
Coal	38[d]		−37‰[b]
Natural gas and other industrial	57[d]		−44‰[b]
Landfills	50[g]	35–73	−55‰[b]
Ocean	10[h]	10–15	−60‰[b]
Hydrates	5[h]	5–10	−60‰[b]
Total source	**530**	**500–600**	∼−53‰[b]

Sinks	A Priori Estimates, Tg CH_4/yr	Range of Estimates Reported by *IPCC* [2001], Tg CH_4/yr	Isotopic Fractionation
Tropospheric OH	507[i]	450–510	5.4‰[j]
Stratospheric loss	40[k]	40–46	12‰[l]
Soils	30[k]	10–30	22‰[m]
Total	**577**		∼6.7‰

Methane records and EPICA/Dome C *and* D

Earth System Science Partnership

Loulergue, L. et al. 2008. Orbital and millennial-scale features of atmo-spheric CH4 over the past 800,000[thinsp]years. Nature 453, 383-386.



They suggest that changes in the strength of tropical methane sources and sinks (wetlands, atmospheric oxidation), possibly influenced by changes in monsoon systems and the position of the intertropical convergence zone, controlled the atmospheric methane budget.

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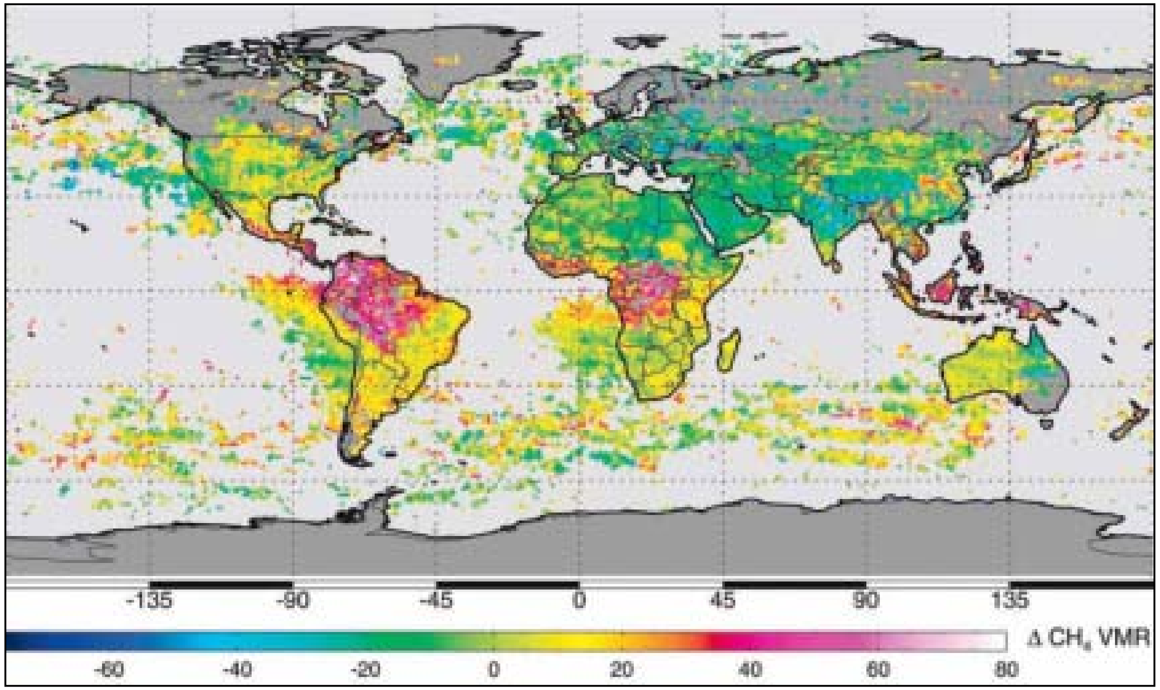
Satellite SCIAMACHY Retrieval of methane source and sinks



Frankenberg *et al.*, 2005 *Science*

An Amazon CH_4 Anomaly?

Excess ~26 Tg CH_4 y^{-1} over the Amazon in 1998-1999 according to Mikaloff-Fletcher et al. (2004)

Possible sources: Wetlands (Melack et al. 2004), Land Use Change (Steudler et al. 1996; Keller et al. 2005) or Upland Forest (Carmo et al. 2006)

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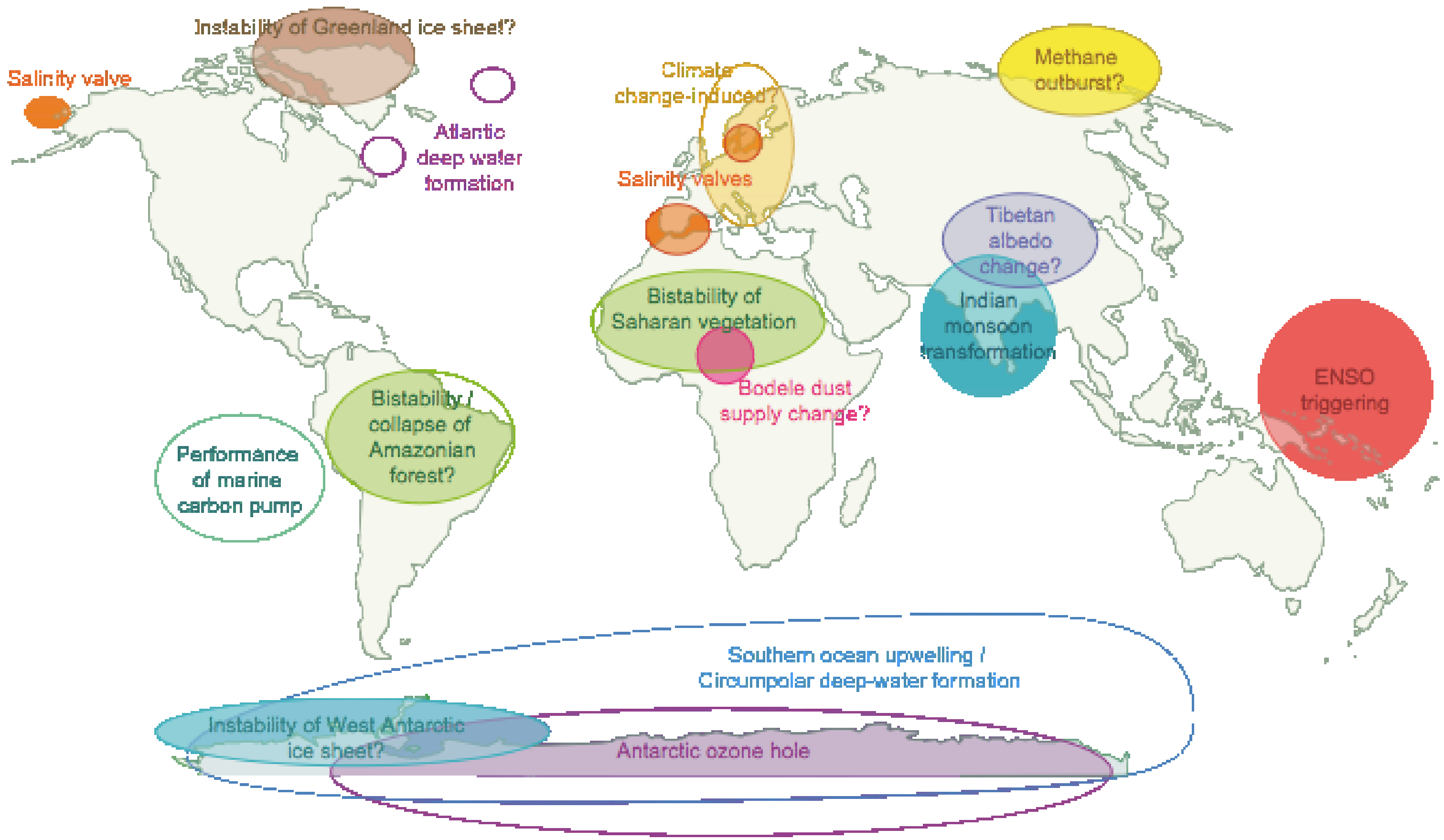
Switch and choke points



Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S., Schellnhuber, H.J., 2008. Tipping elements in the Earth's climate system. PNAS 105, 1786-1793.

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