Global

Carbon Trends

Pep Canadell
Global Carbon Project
CSIRO Marine and Atmospheric Research
Canberra, Australia

Global Carbon Project

Outline

1. Recent Trends
2. Perturbation Budget
3. Sink Efficiency
4. Attribution
5. Processes
6. Future

1. Recent Trends

Carbon Emissions from Net Deforestation

Borneo, Courtesy: Viktor Boehm

Tropical deforestation

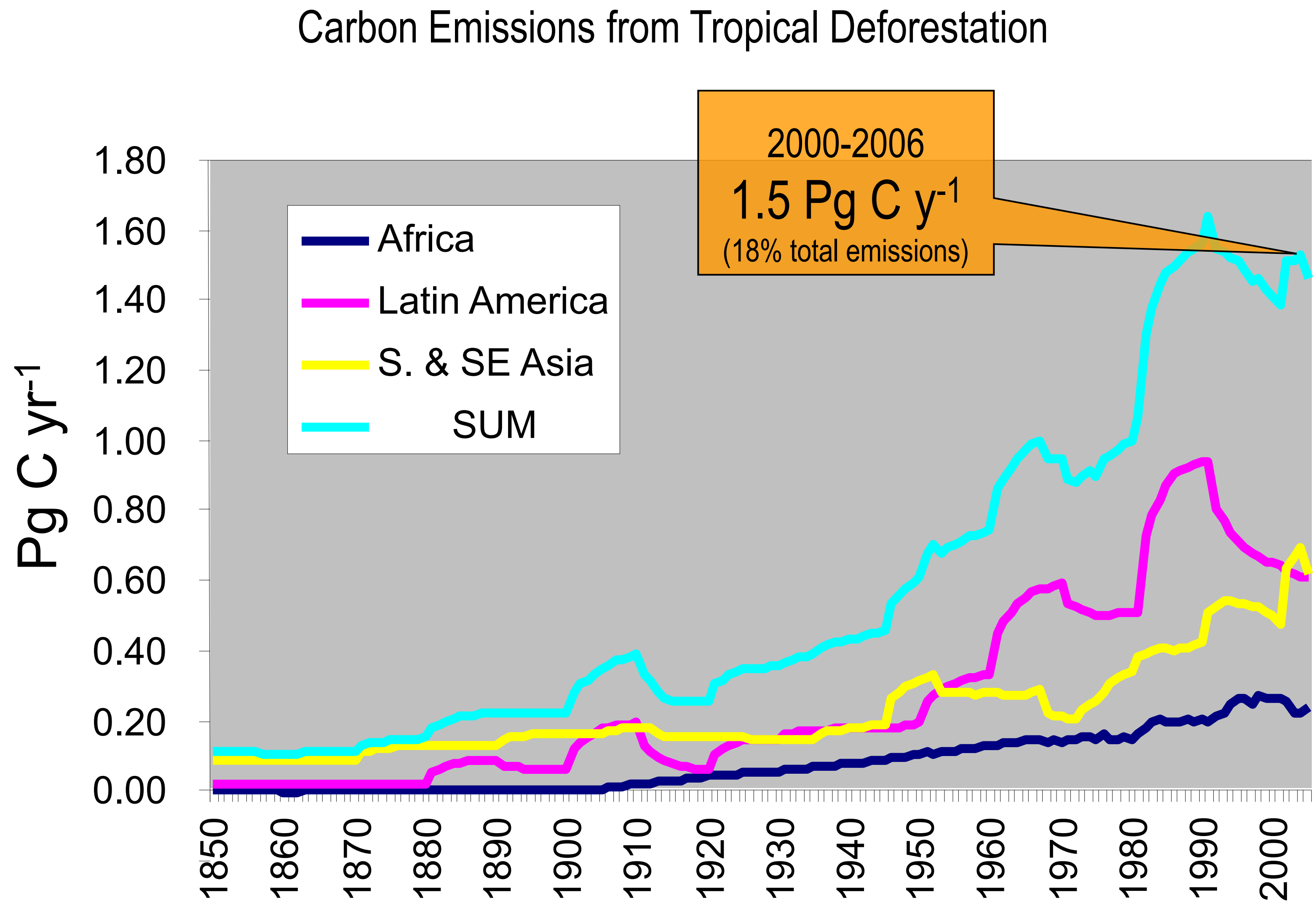
13 Million hectares each year

Trees are worth more dead than alive

	2000-2005
Tropical Americas	0.6 Pg C y^{-1}
Tropical Asia	0.6 Pg C y^{-1}
Tropical Africa	0.3 Pg C y^{-1}
	1.5 Pg C y^{-1}

FAO-Global Resources Assessment 2005; Canadell et al. 2007, PNAS

Historical C Emissions from Net Deforestation

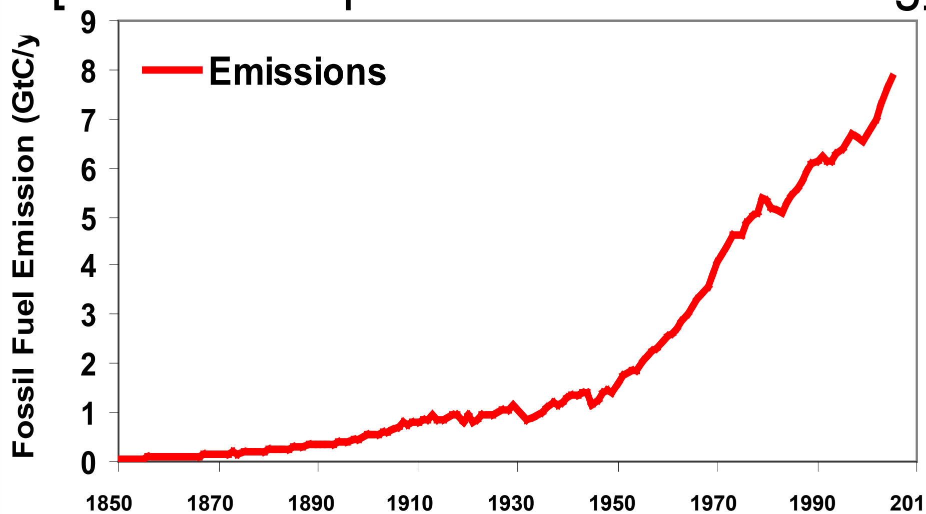


Houghton, unpublished; Canadell et al. 2007, PNAS

Carbon Emissions from Fossil Fuel

2006 Fossil Fuel: 8.4 Pg C

[Total Anthrop.Emis.:8.4+1.5 = 9.9 Pg]

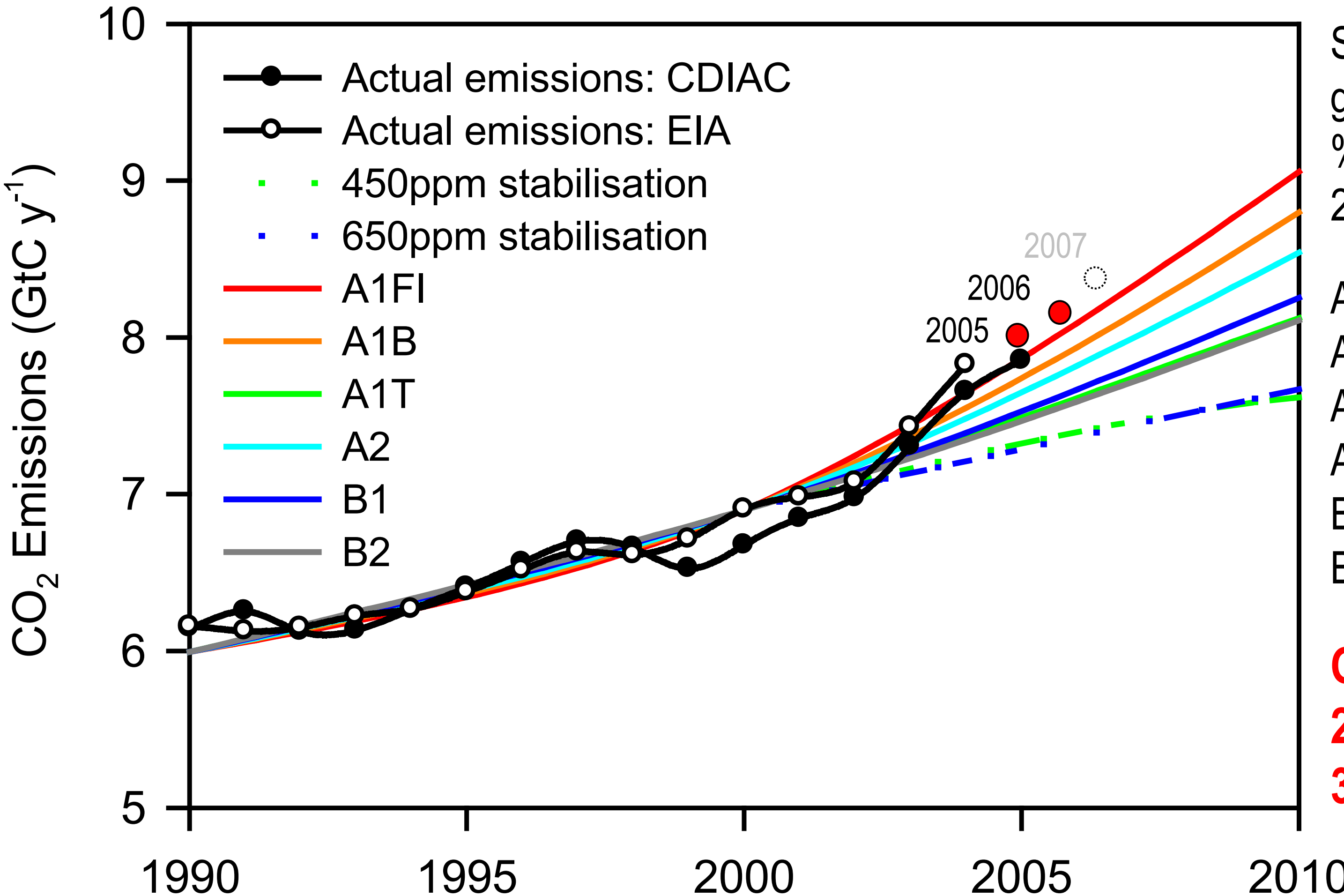


1990 - 1999: 1.3% y^{-1}

2000 - 2006: 3.3% y^{-1}

Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS

Global Fossil Fuel Emissions



SRES (2000) growth rates in % y^{-1} for 2000-2010:

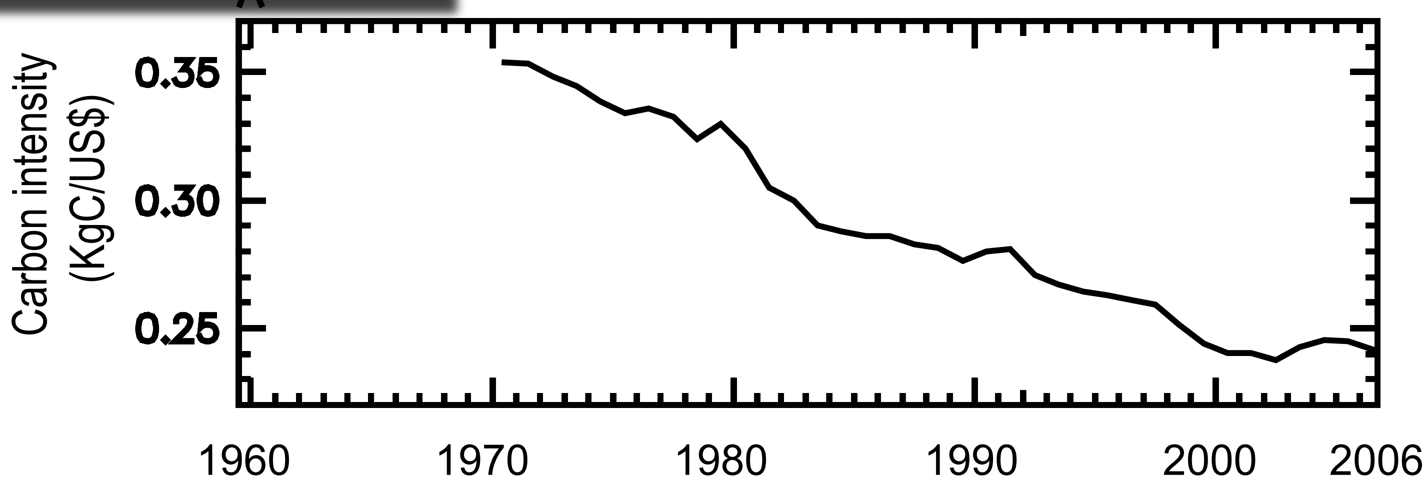
A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Observed 2000-2006 3.3%

Raupach et al. 2007, PNAS

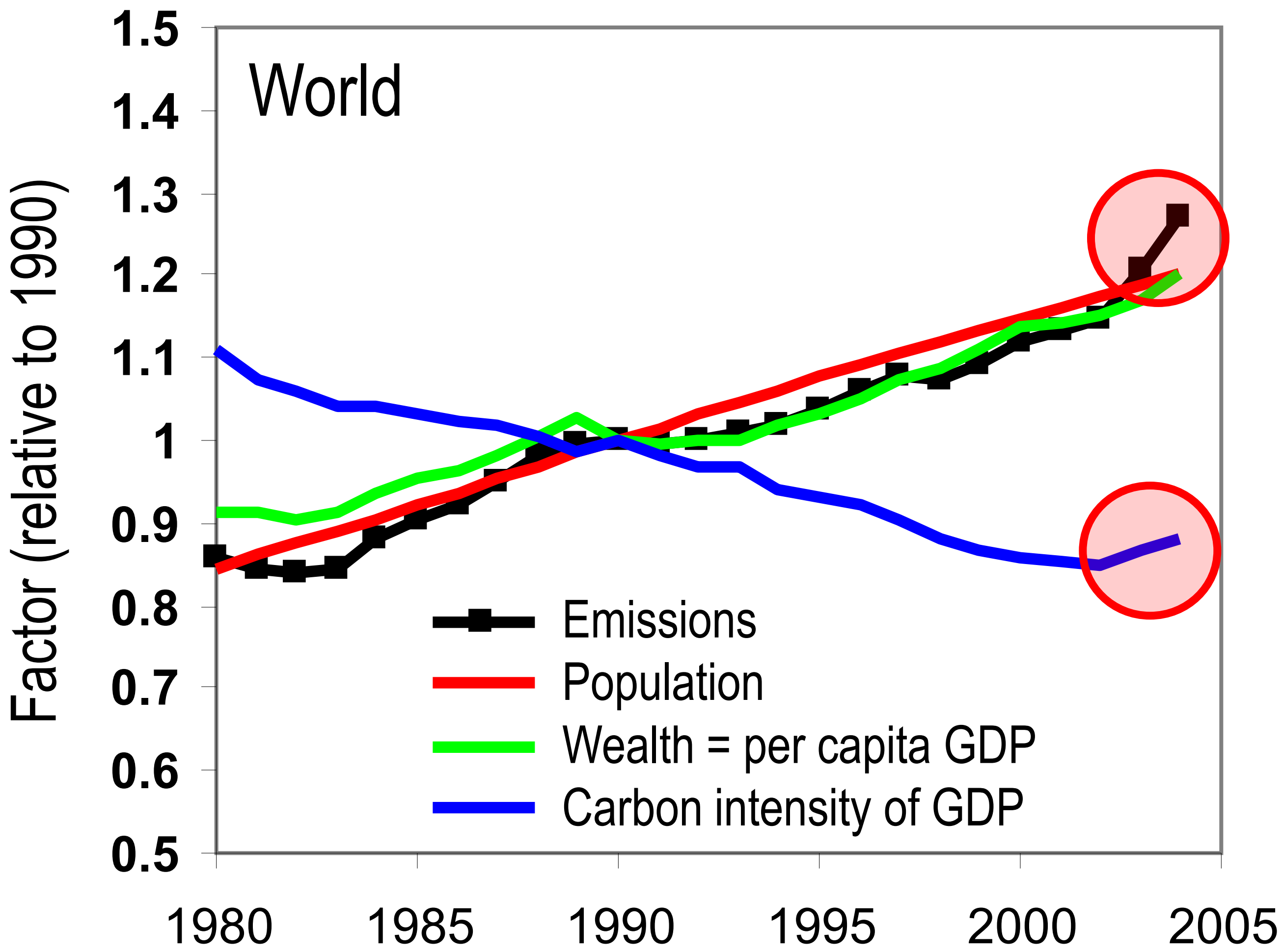
Carbon Intensity of the Global Economy

Kg Carbon Emitted
to Produce 1 $ of Wealth



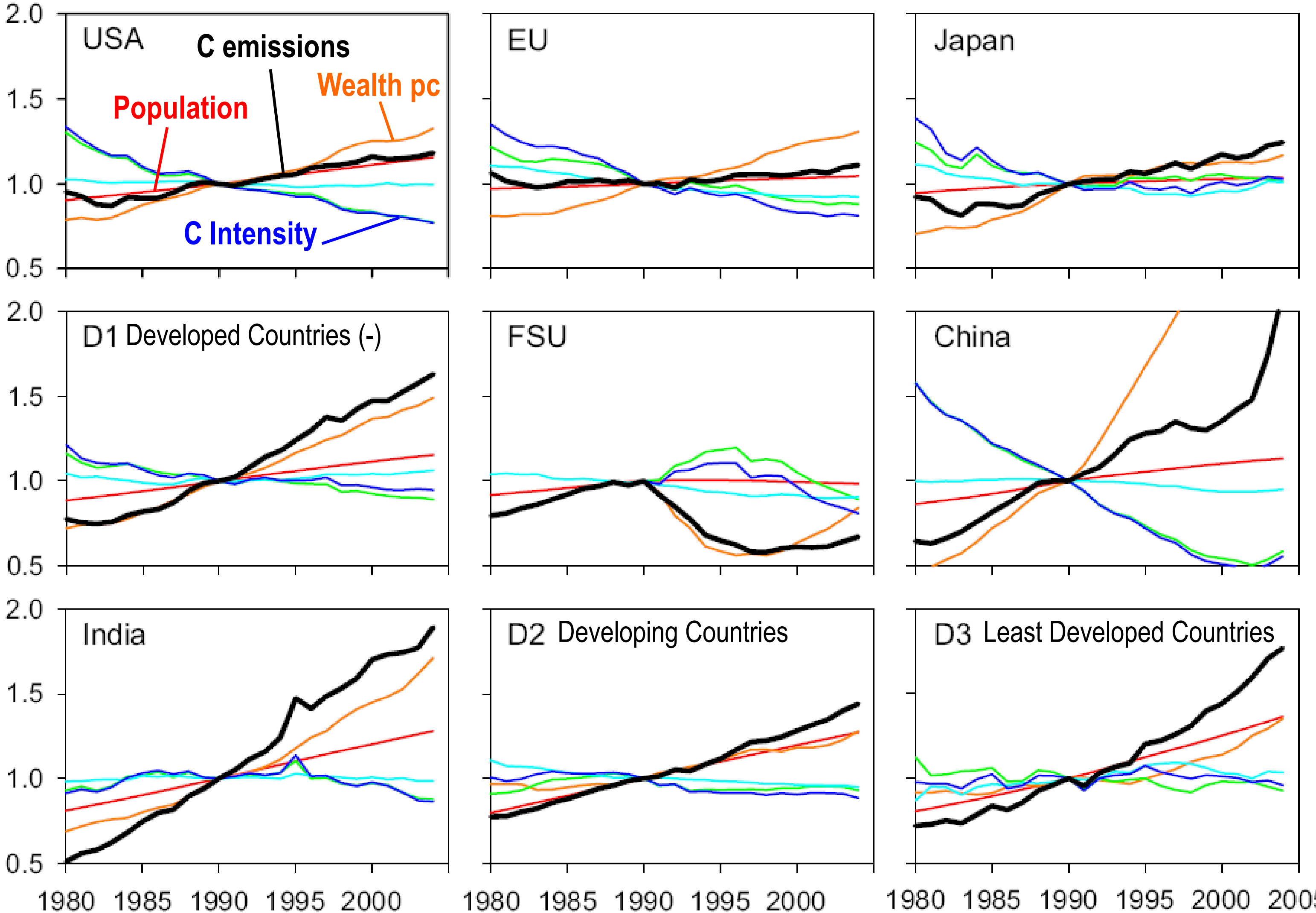
Canadell et al. 2007, PNAS

Drivers of Anthropogenic CO_2



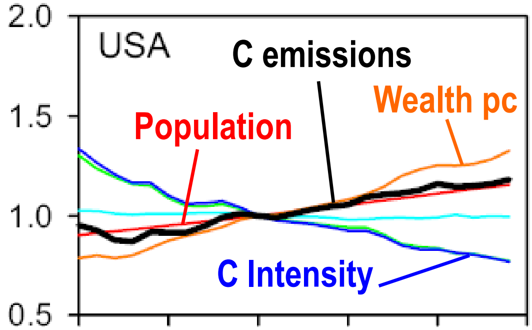
Raupach et al 2007, PNAS

Regional Pathways



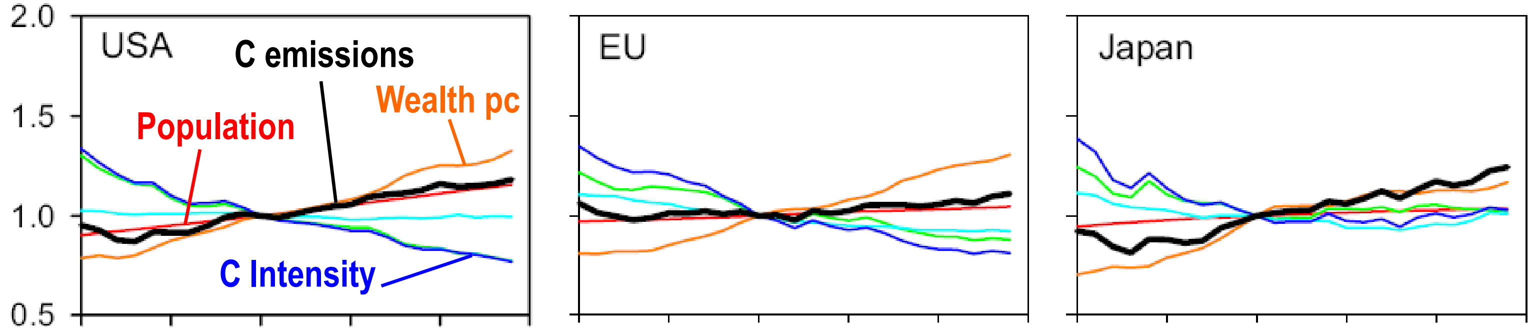
Raupach et al 2007, PNAS

Regional Pathways



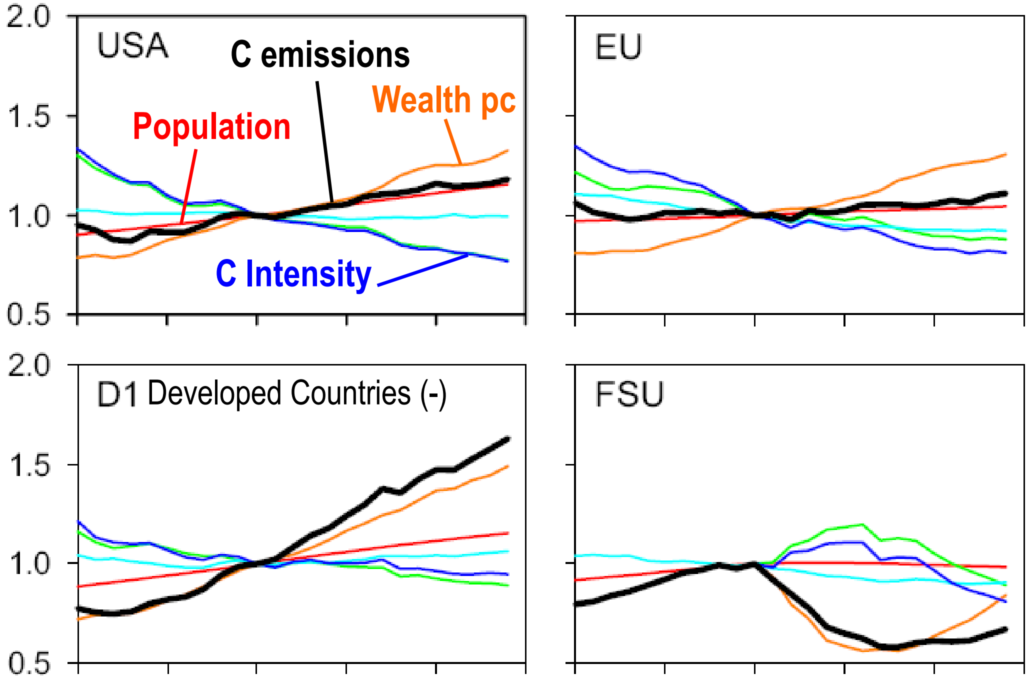
Raupach et al 2007, PNAS

Regional Pathways



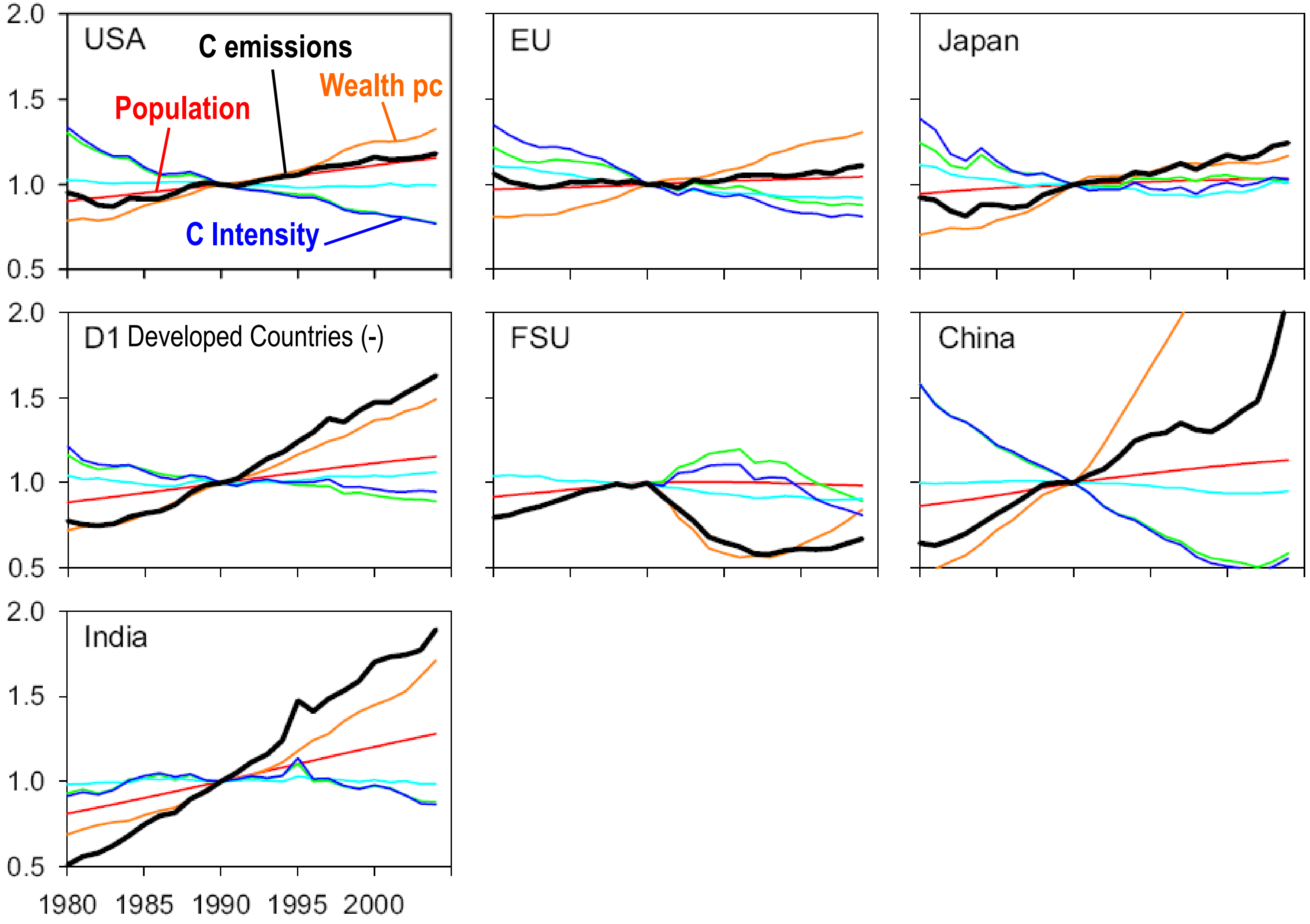
Raupach et al 2007, PNAS

Regional Pathways



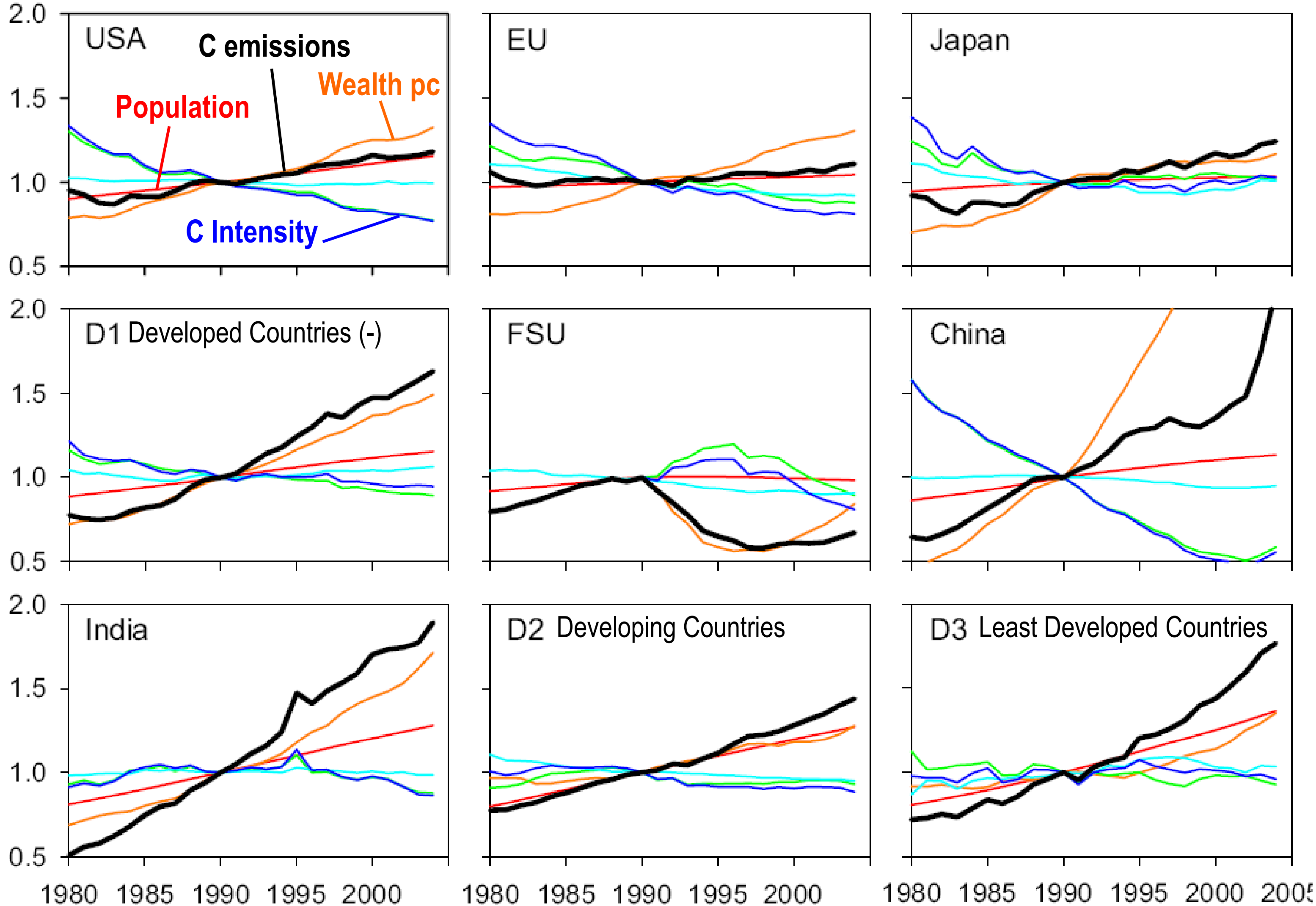
Raupach et al 2007, PNAS

Regional Pathways



Raupach et al 2007, PNAS

Regional Pathways



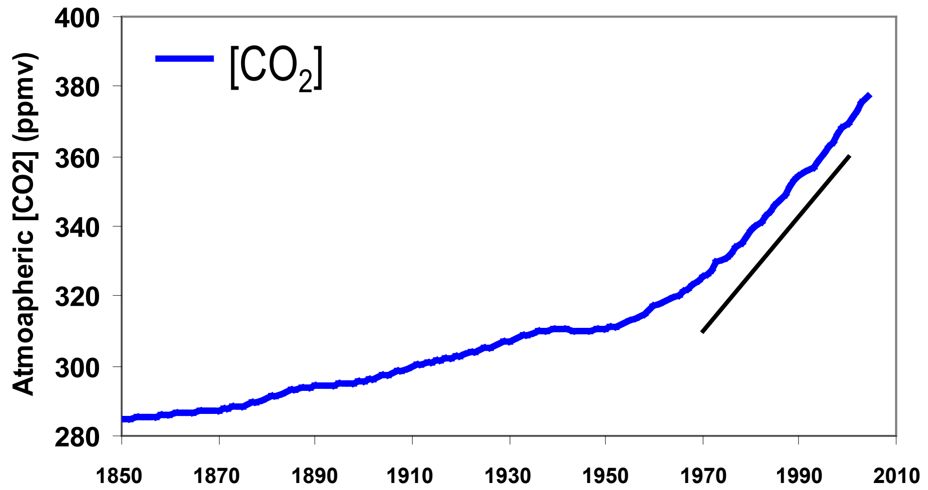
Raupach et al 2007, PNAS

Atmospheric CO_2 Concentration

Year 2007
Atmospheric CO_2
concentration:

382.6 ppm

35% above pre-industrial



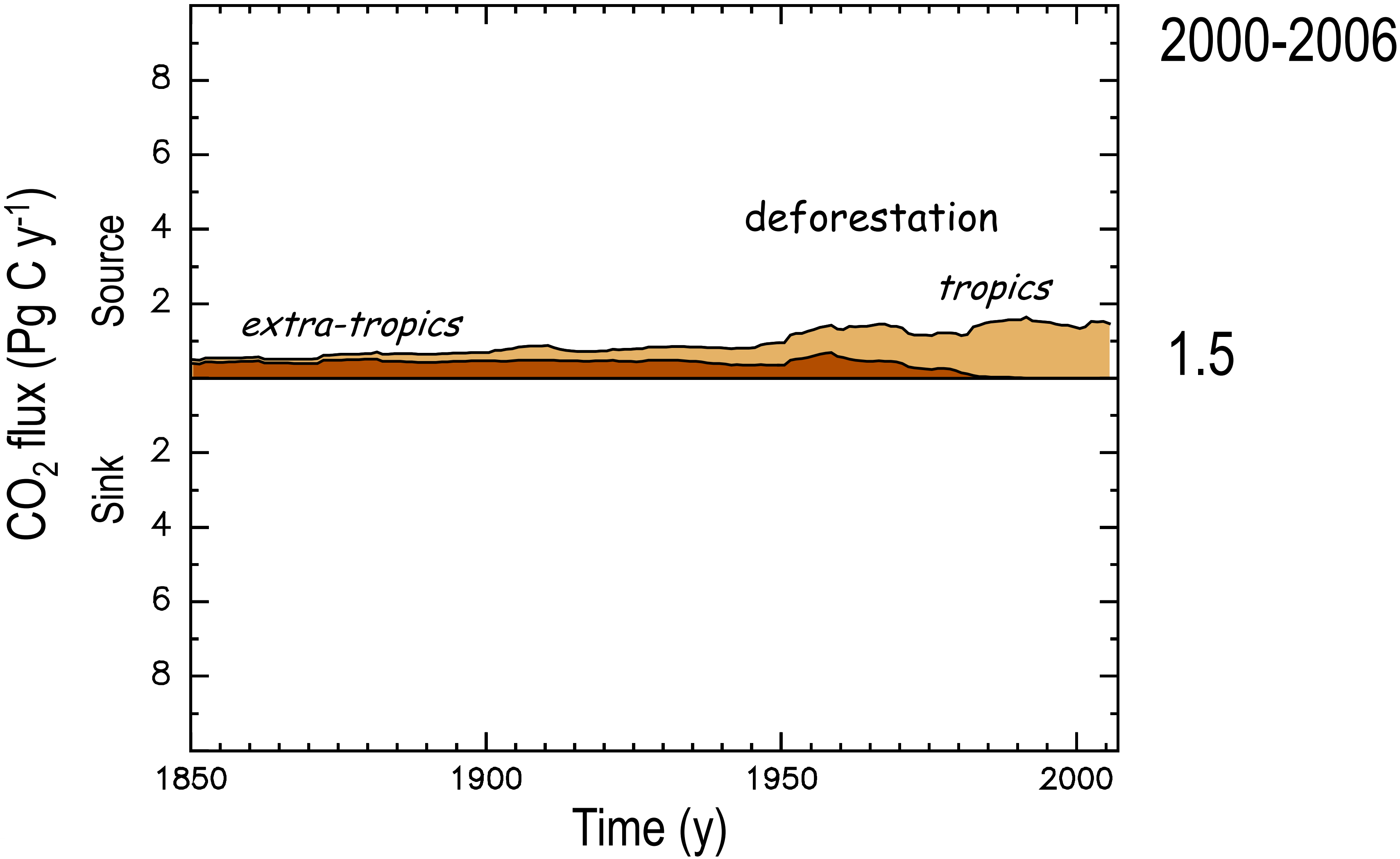
1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{1}
1990 – 1999: 1.5 ppm y^{-1}

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

NOAA 2007; Canadell et al. 2007, PNAS

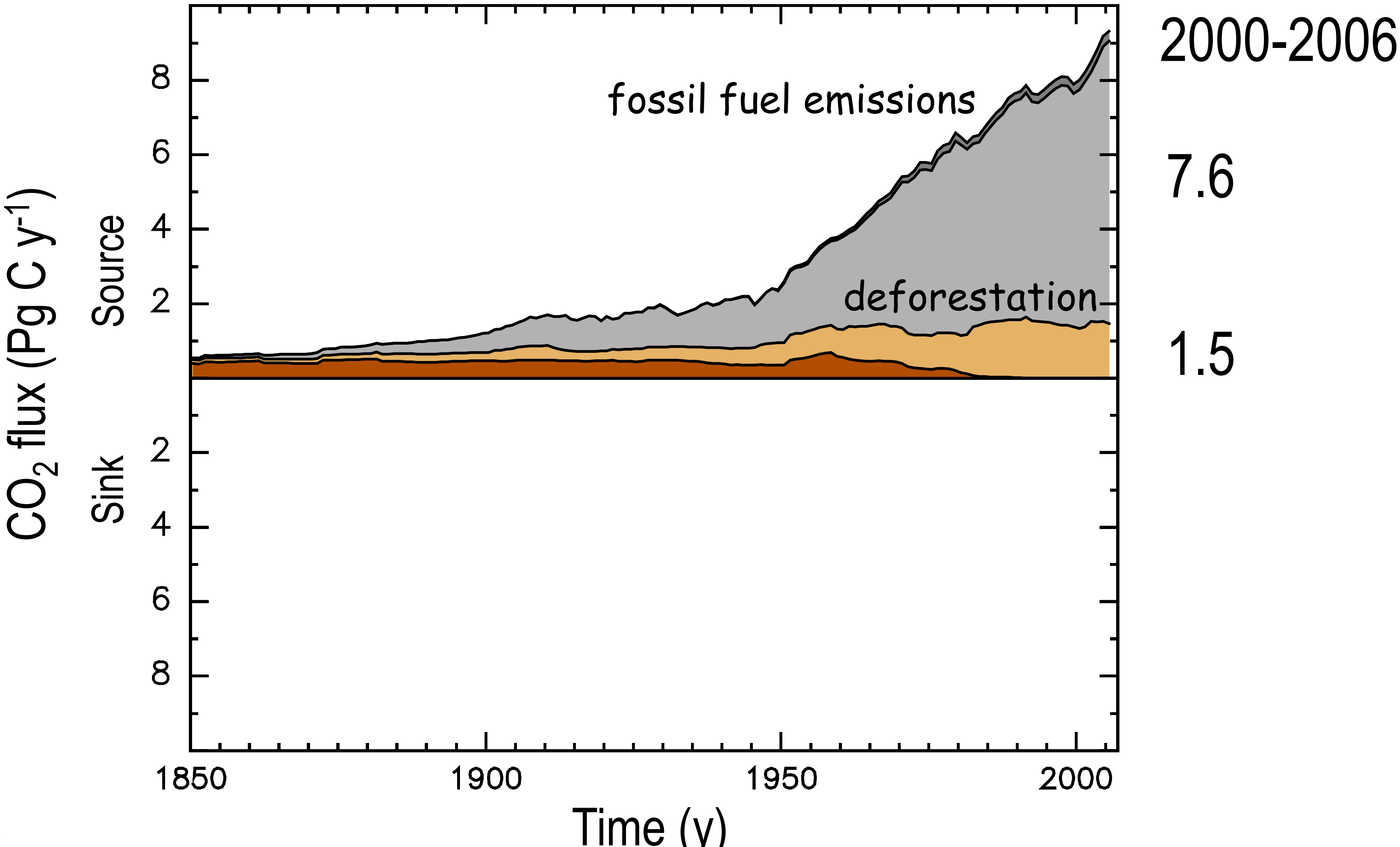
2. Perturbation Budget

Anthropogenic Perturbation of the Carbon Budget



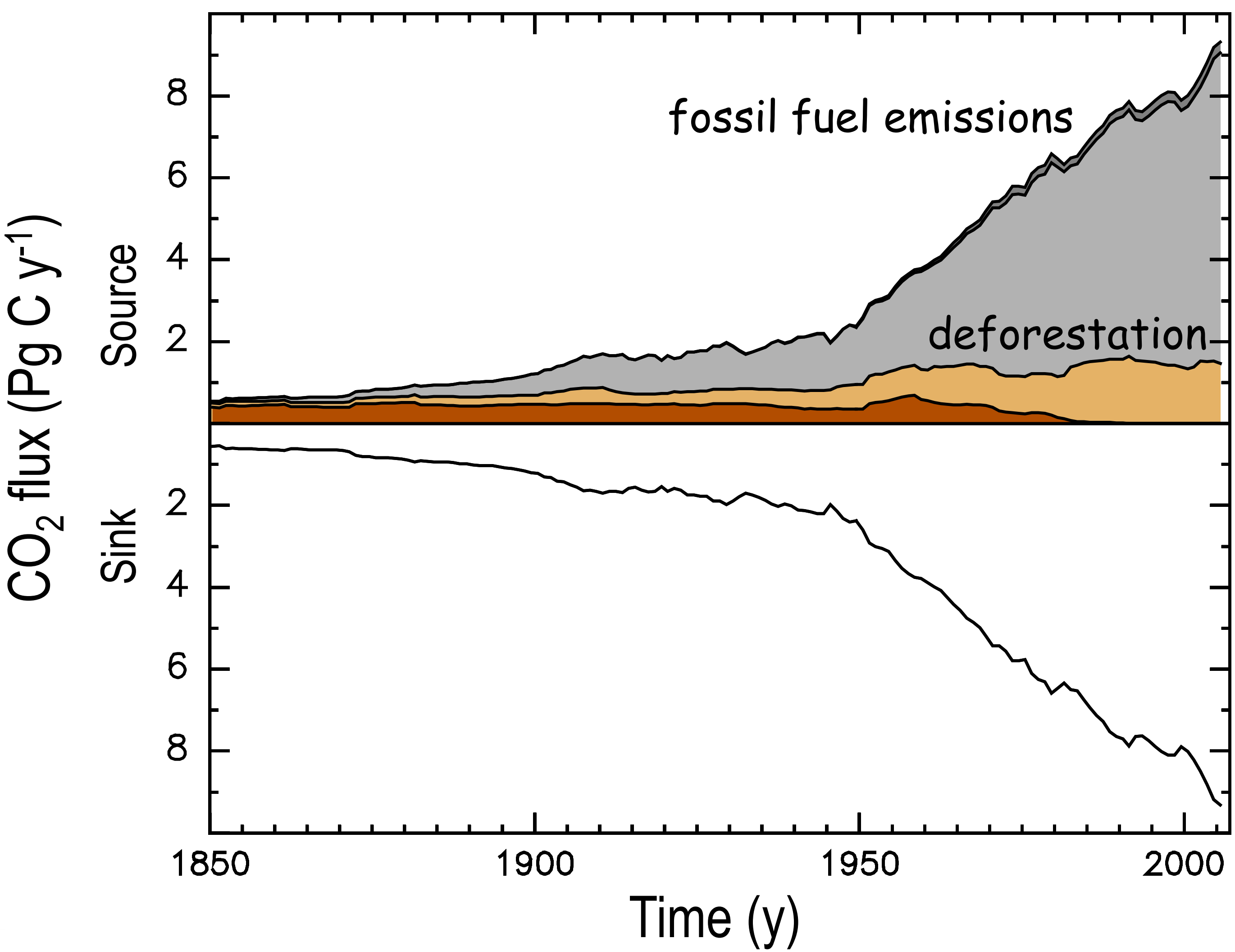
Le Quere unpublished; Canadell et al. 2007, PNAS

Anthropogenic Perturbation of the Carbon Budget



Le Quere unpublished; Canadell et al. 2007, PNAS

Anthropogenic Perturbation of the Carbon Budget



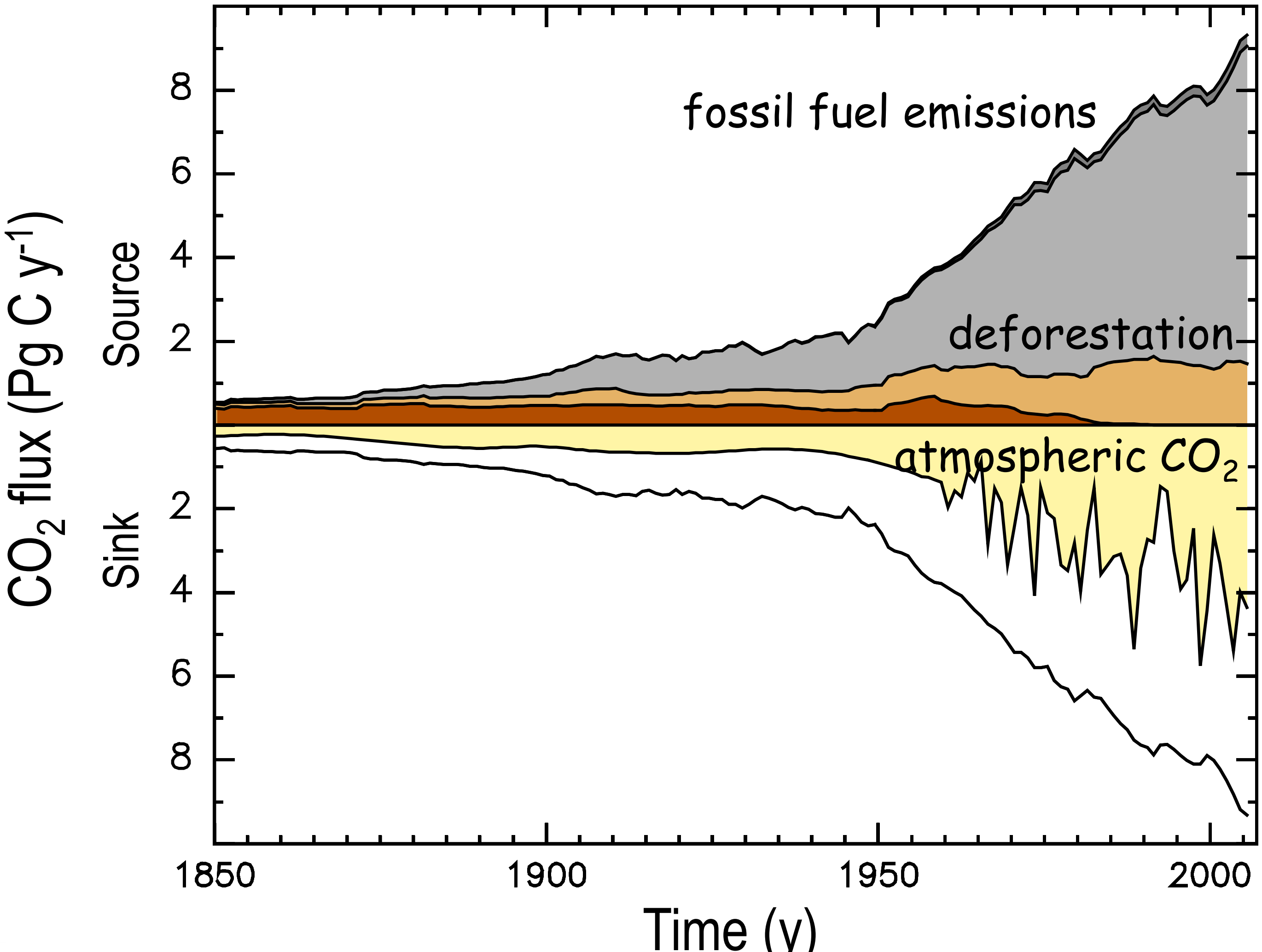
2000-2006

7.6

1.5

Le Quere unpublished; Canadell et al. 2007, PNAS

Anthropogenic Perturbation of the Carbon Budget



2000-2006

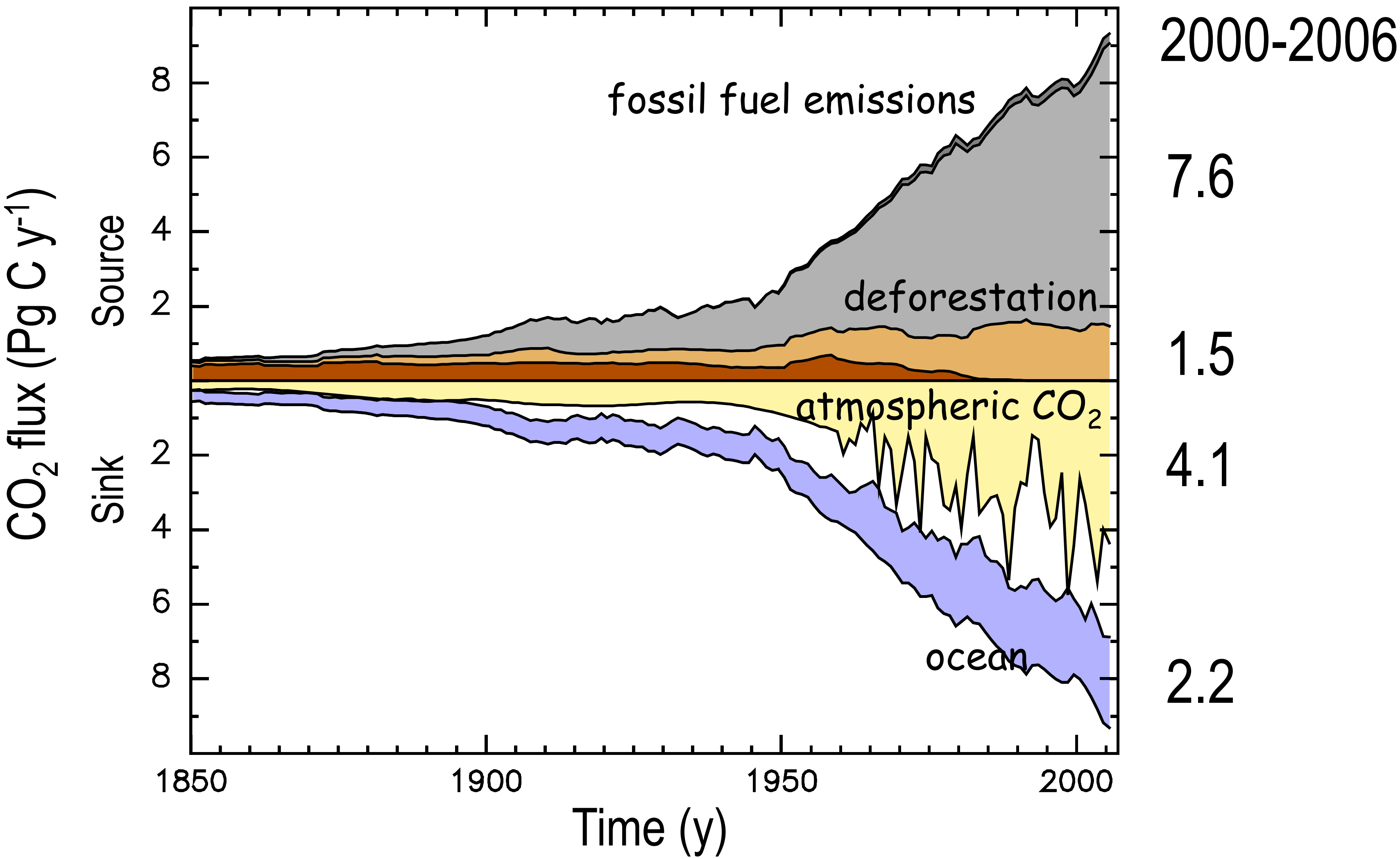
7.6

1.5

4.1

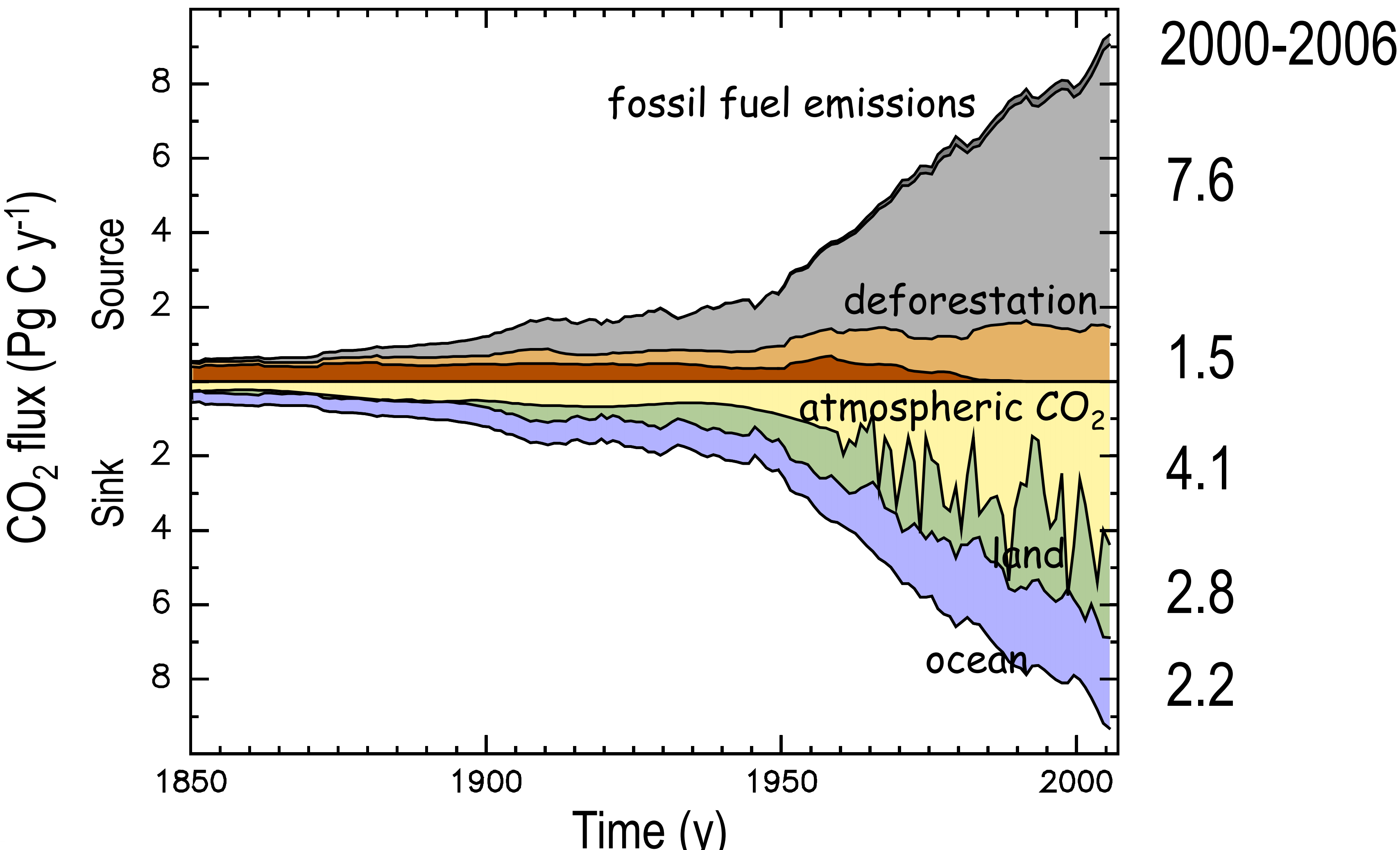
Le Quere unpublished; Canadell et al. 2007, PNAS

Anthropogenic Perturbation of the Carbon Budget



Le Quere unpublished; Canadell et al. 2007, PNAS

Anthropogenic Perturbation of the Carbon Budget

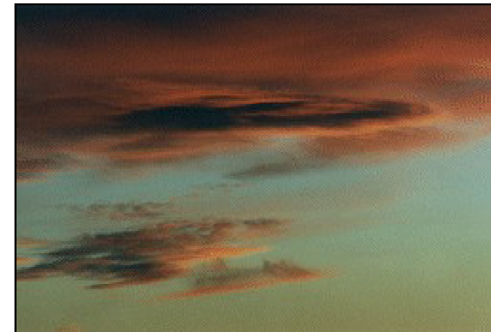


Le Quere unpublished; Canadell et al. 2007, PNAS

Fate of Anthropogenic CO_2 Emissions (2000-2006)

+

Atmosphere
45%



Land
30%

Oceans
25%

Canadell et al. 2007, PNAS

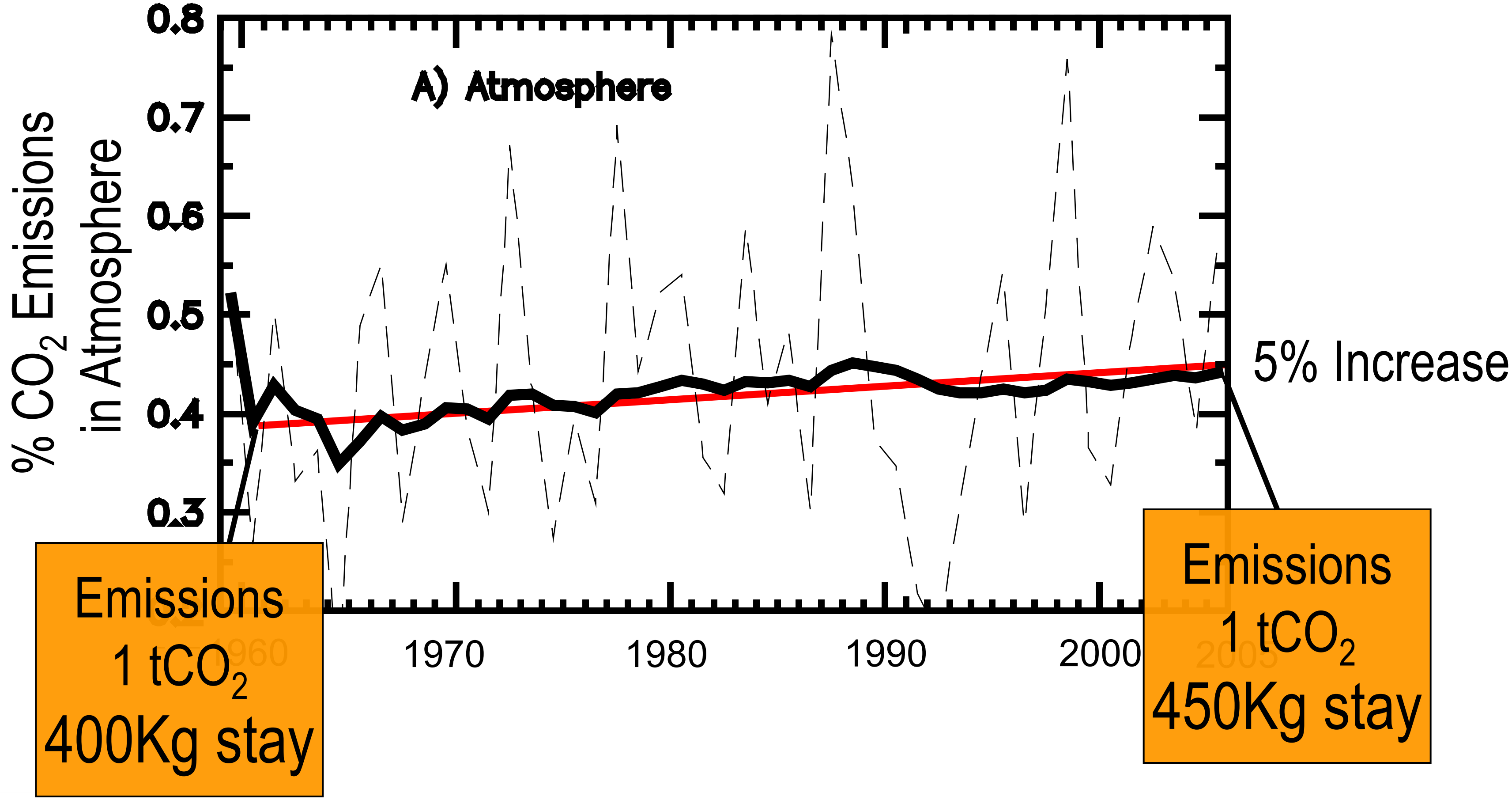
Climate Change at 55% Discount

Natural CO_2 sinks are a service provided by the planet which constitutes an effective 55% emissions reduction NOW worth US$300 Billions per year if we had to provide it through mitigation measurements (assuming $20/ton CO_2-equivalents).

3. Sink Efficiency

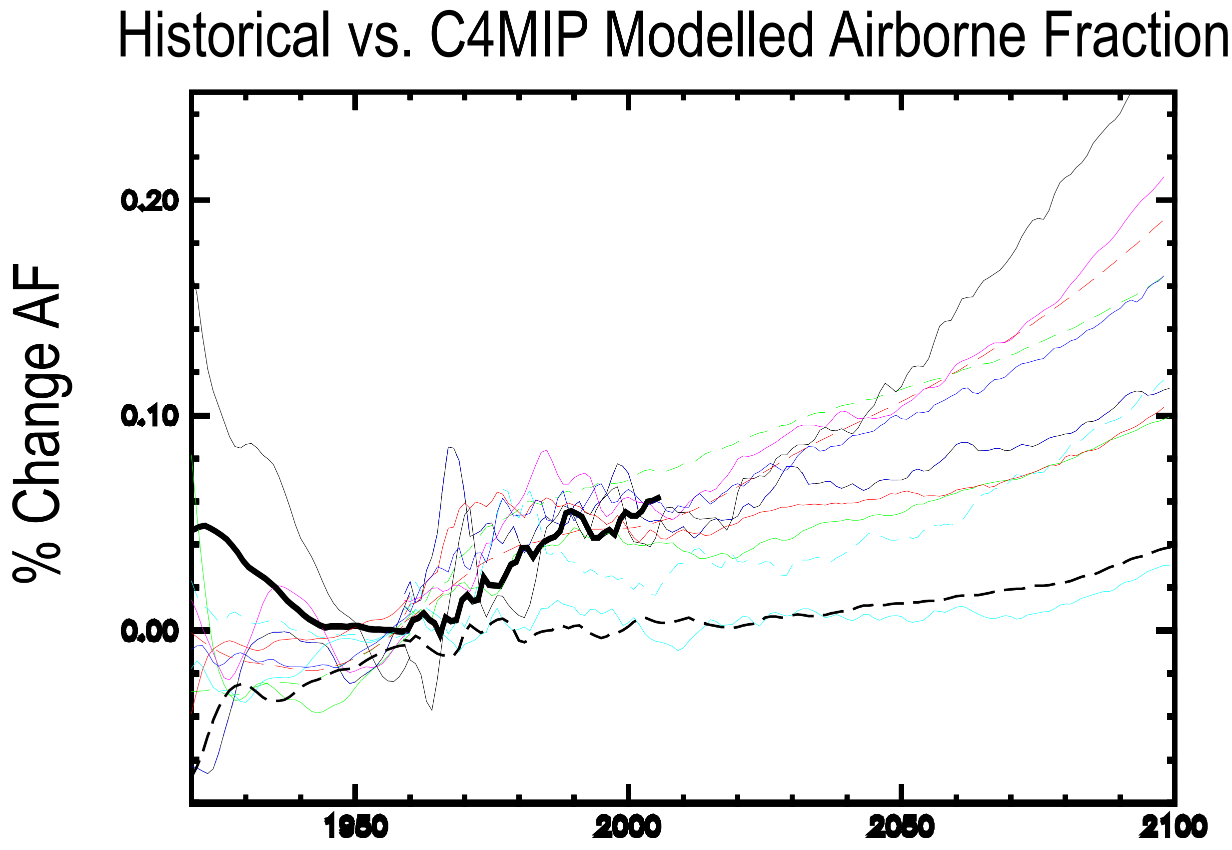
Dynamics of the Airborne Fraction

Increase in the fraction of anthropogenic emissions that stays in the atmosphere



Canadell et al. 2007, PNAS

Dynamics of the Airborne Fraction

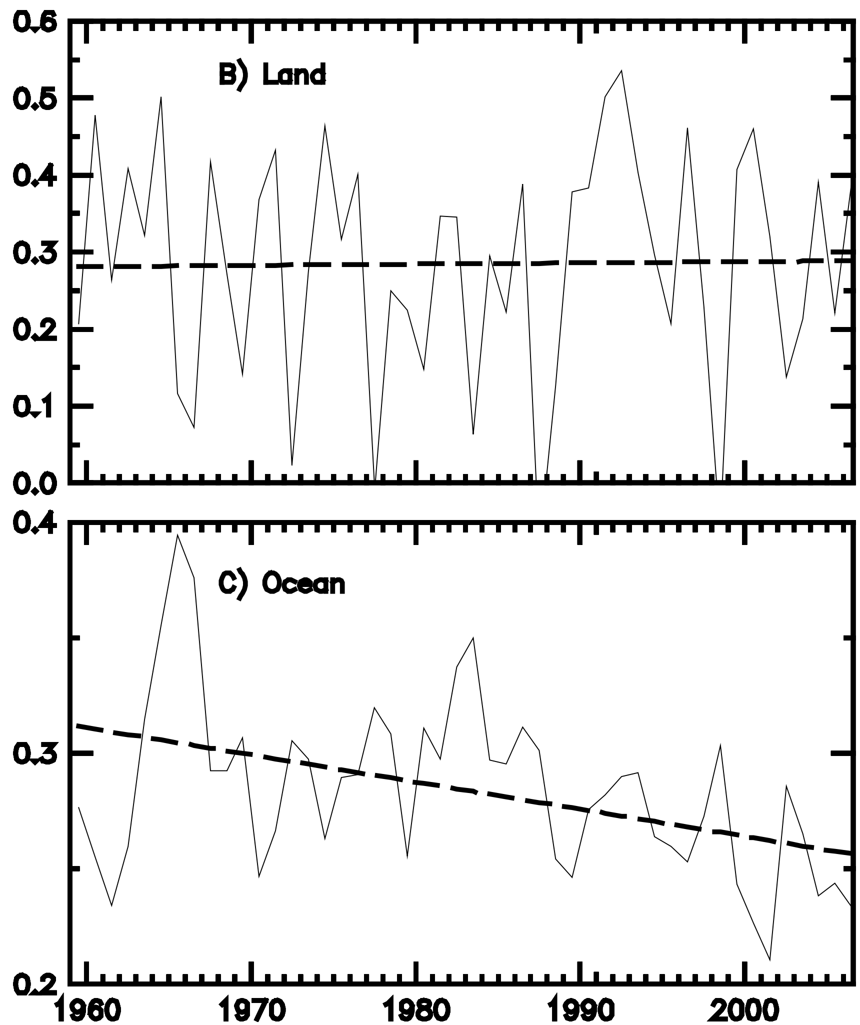


Friedlingstein et al. 2007, unpublished

Efficiency of Natural Sinks

Land Fraction

Ocean Fraction



Canadell et al. 2007, PNAS

Global Carbon Project

Earth System Science Partnership

DIVERSITAS

GLOBAL IGBP CHANGE

IHDP

WCRP World Climate Research Programme

4. Attribution

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 global economy

18% - Decreased efficiency of natural sinks

5. Processes

Factors Affecting the Airborne Fraction

1. The rate of CO_2 emissions.
2. The rate of CO_2 uptake and ultimately the total amount of C that can be stored by land and oceans:
   - **Land**:
     (-) CO_2 fertilization effect, forest regrowth (woody encroachment N deposition fertilization, …)
     (+) soil respiration, fire,…
   - **Oceans**:
     (-) CO_2 solubility (temperature, salinity), …
     (+,-) ocean currents, stratification, winds, biological activity, acidification, …

Canadell et al. 2007, Springer; Gruber et al. 2004, Island Press

Cause of the Declined in the Efficiency of the Ocean Sink

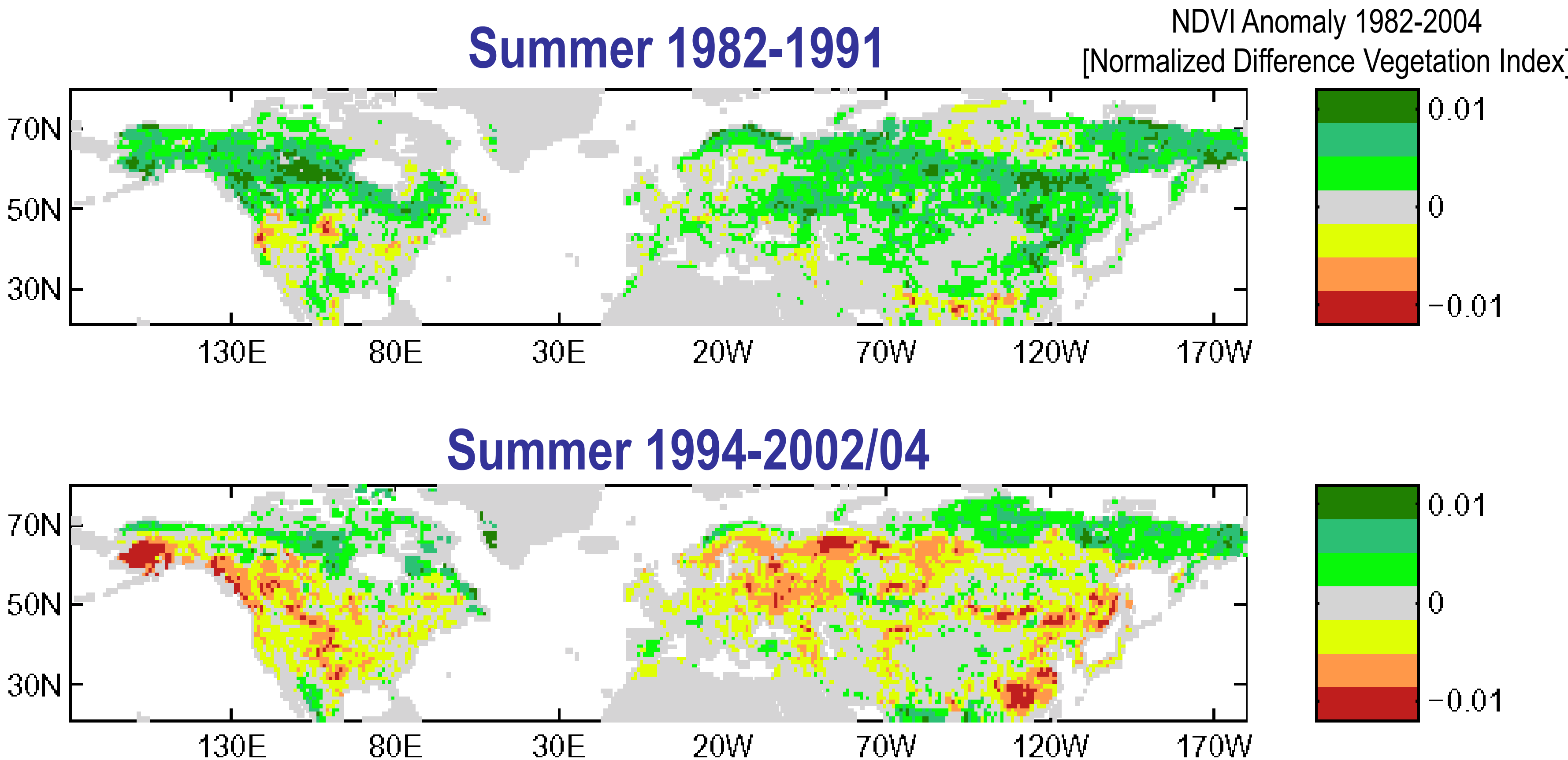
Credit: N.Metzl, August 2000, oceanographic cruise OISO-5

- 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.

Le Quéré et al. 2007, Science

Effects of Drought and Warmer T^a on Carbon Sinks

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

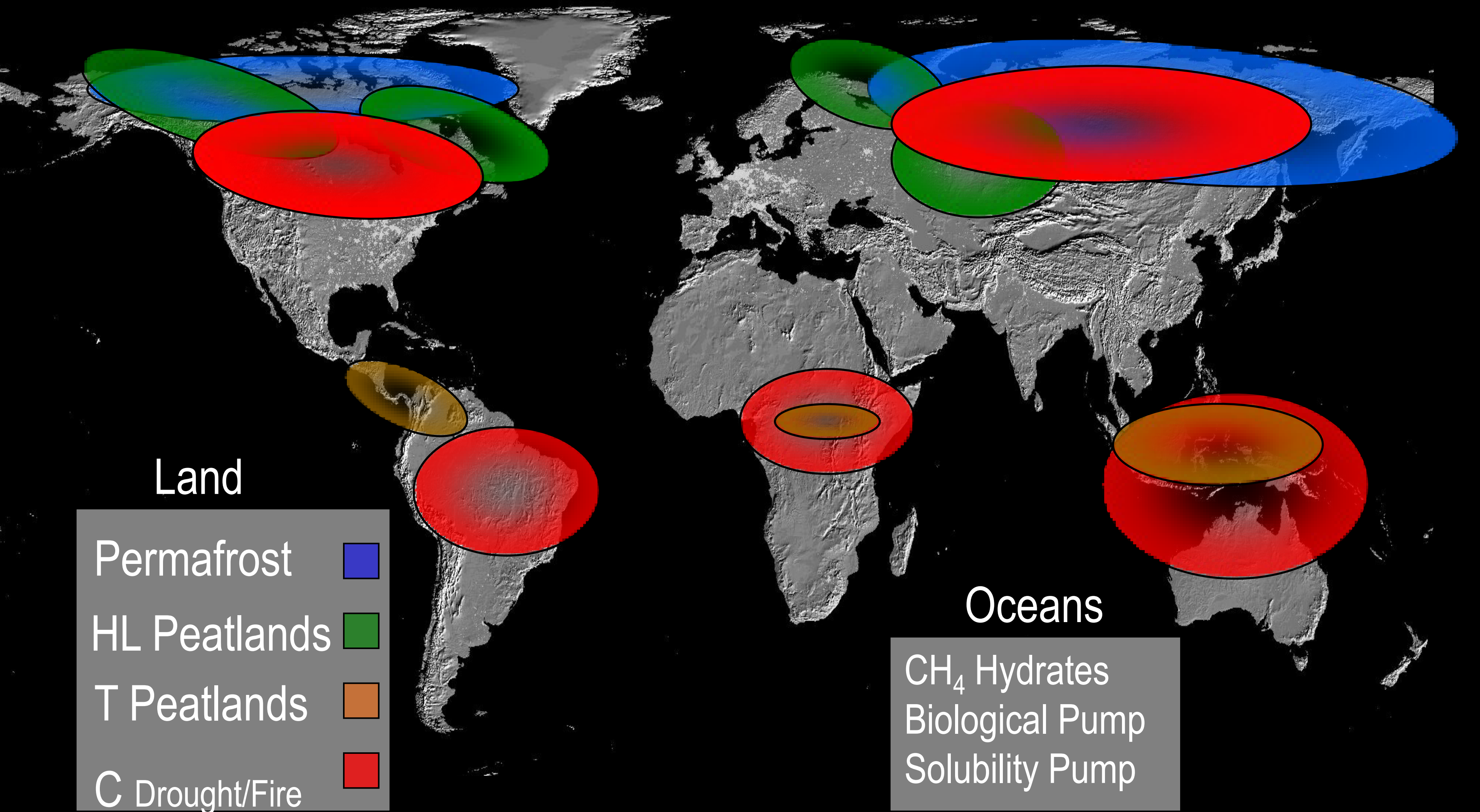


Angert et al. 2005, PNAS; Buermann et al. 2007, PNAS; Ciais et al. 2005, Science

6. Future

Vulnerability of Carbon Pools in the 21st Century

Hot Spots of the Carbon-Climate System

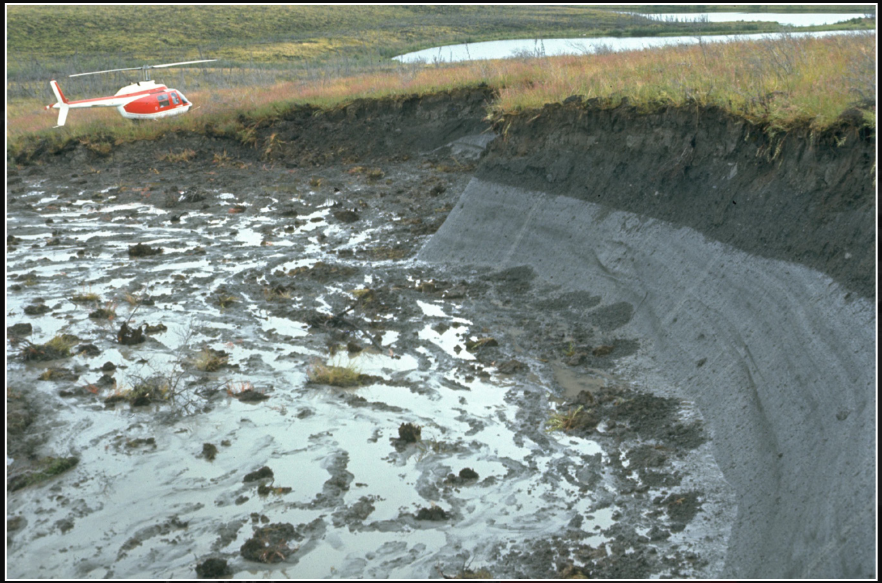


Many of these Pools and Processes are not included in Earth System models

Canadell et al. 2007, Springer
Gruber et al. 2004, Island Press

Permafrost

Hot Spots of the Carbon-Climate System



200-400 Pg C - frozen soils vulnerable to warming

Land

Permafrost

HL Peatlands

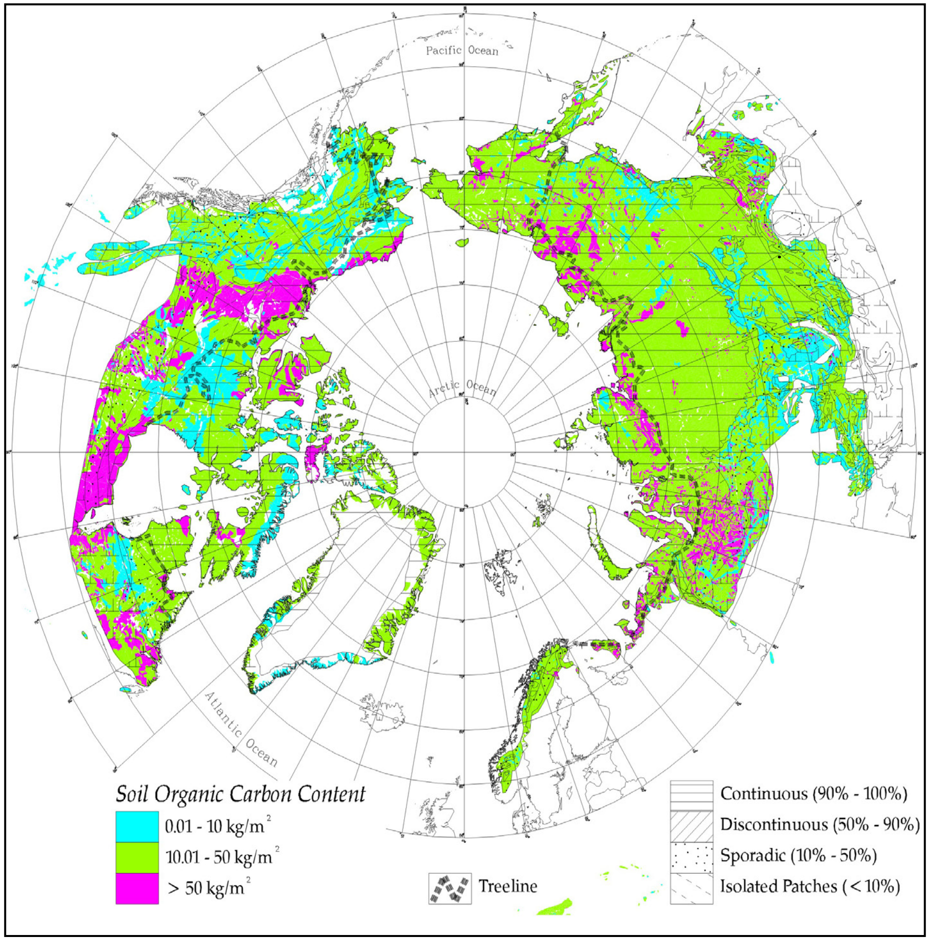
T Peatlands

Veg.-Fire/LUC

Many Pools and Processes not included in Earth System models

Canadell et al. 2007

Pool Size of Frozen Carbon (C Pg)



Permafrost zones	0-30 cm	0-100 cm
Continuous	110.38	298.75
Discontinuous	25.5	67.44
Sporadic	26.36	63.13
Isolated Patches	29.05	67.10
Total	**191.29**	**496.42**

Soil or deposit type	**C stocks**
Soils 0–300 cm	**1024**
Yedoma sediments	407
Deltaic deposits	241
Total	**1672**

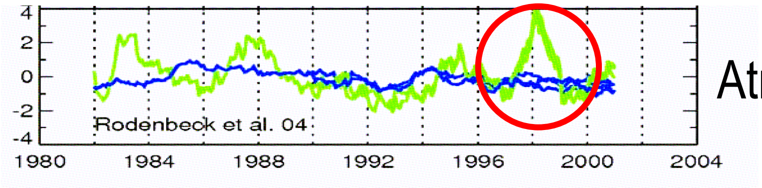
Tarnocai et al, in preparation

Peatlands

400 Pg C – cold peatlands vulnerable to climate change

100 Pg C – tropical peatlands vulnerable to land use and climate change

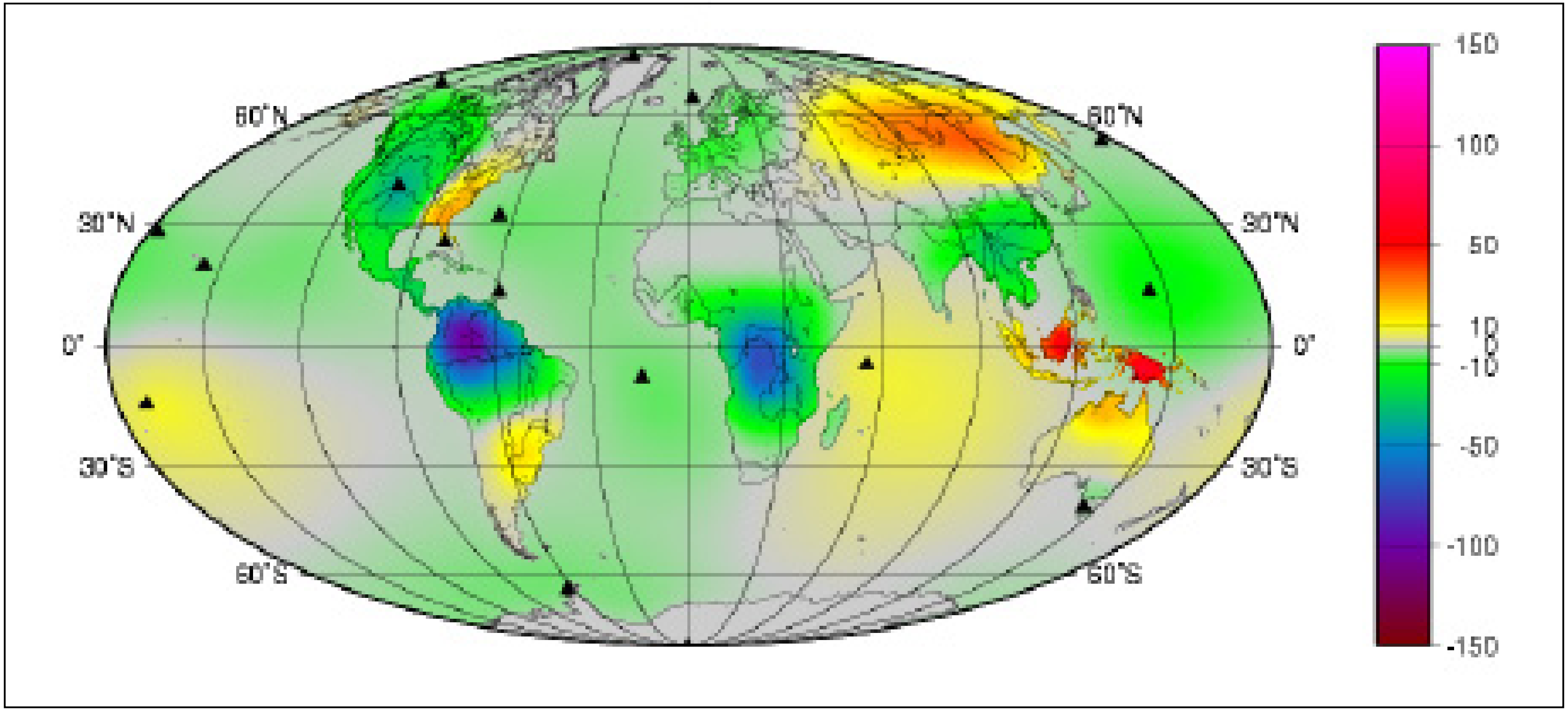
ENSO-Drought x Land Use x Fire



Atmospheric CO_2 Growth Rate

Oct 1998 - Sept 1999

Flux Anomalies La Niña (g C m^2 yr^{-1})



Rodenbeck et al. 2003; Rodenbeck et al. 2004

Drought x Land Use x Disturbances

Hot Spots of the Carbon-Climate System

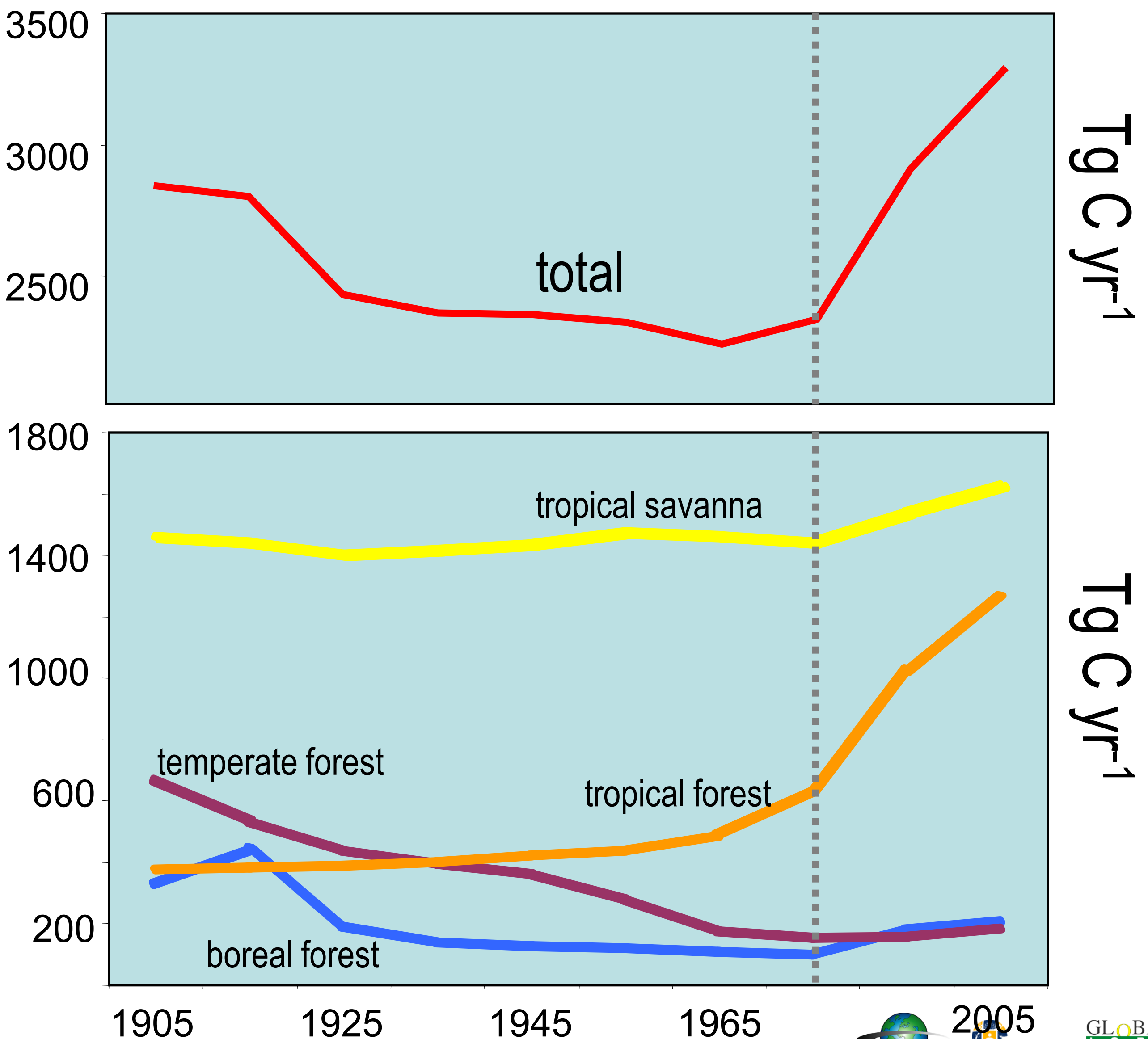
>200 Pg C
vegetation and soils
vulnerable to
drought x land use x fire

Permafrost
HL Peatlands
T Peatlands
Veg.-Fire/LUC

Many Pools and Processes not included in Earth System models

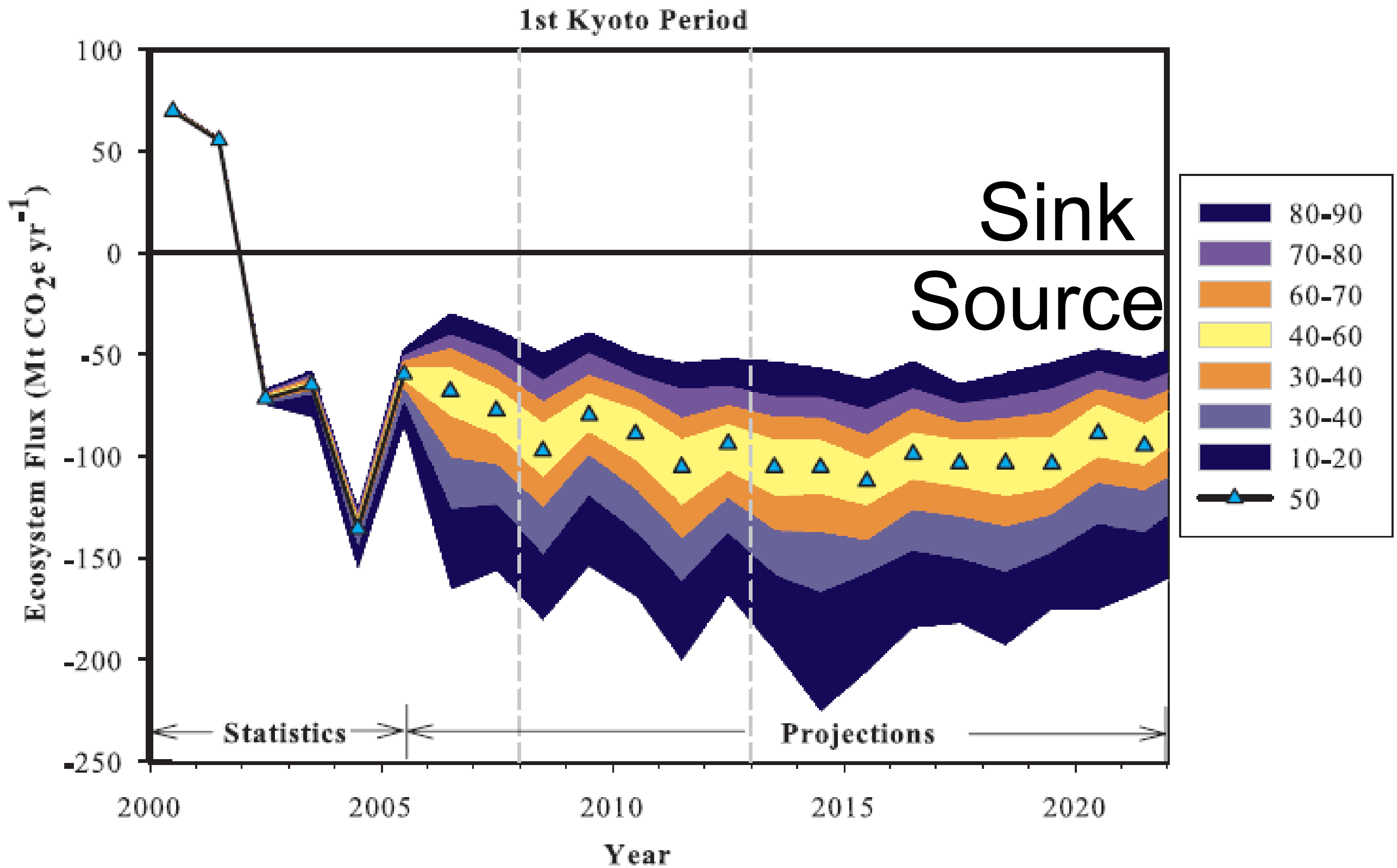
Field and Raupach 2004
Canadell et al. 2007

Increased Fire Emissions of Carbon



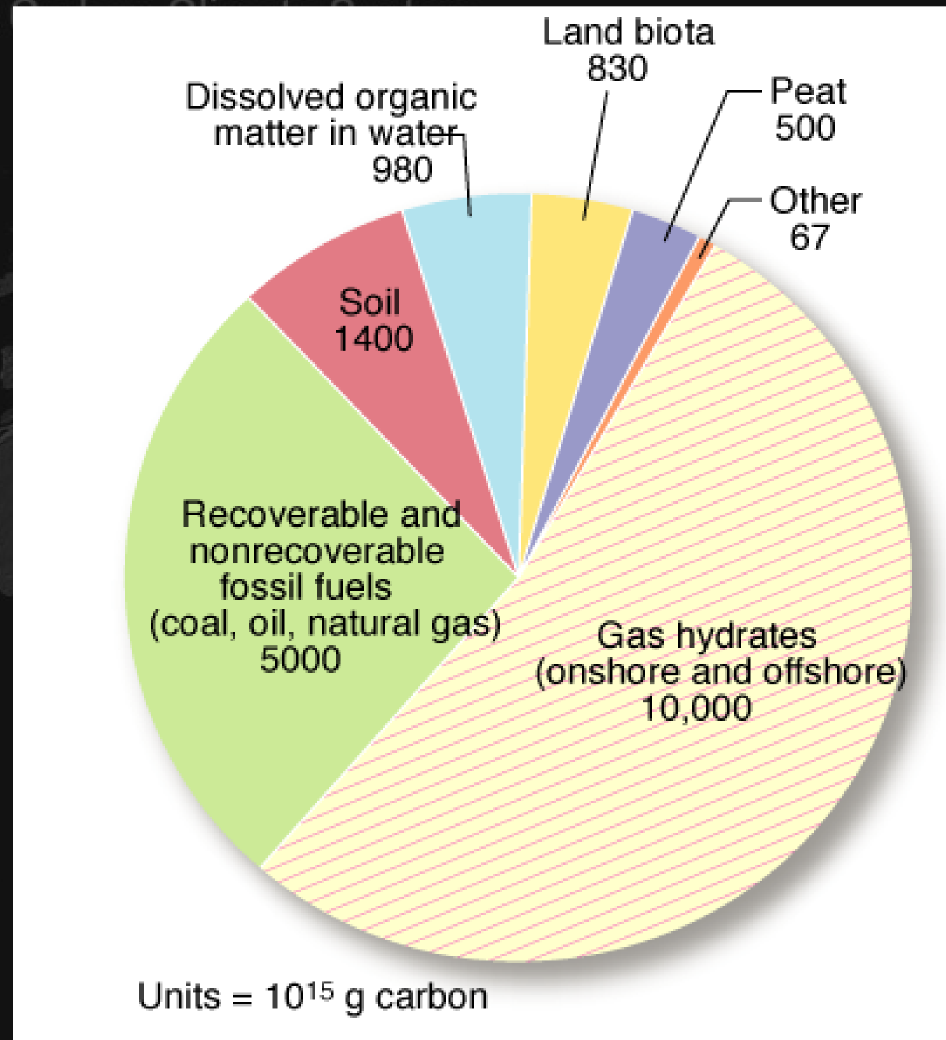
Mouillot et al. 2006

Annual Net C balance of Canada's Managed Forests



Kurz et al. 2008, PNAS

Methane Hydrates



Many Pools and Processes not included in Earth System models

Field and Raupach 2004
Canadell et al. 2007

7. Conclusions

Conclusions (i)

Since 2000:

- The growth of carbon emissions from fossil fuels has tripled compared to the 1990s and is exceeding the predictions of the highest IPCC emission scenarios.

- Atmospheric CO_2 is growing at 1.9 ppm per year
  (compared to about 1.5 ppm during the previous 30 years)

- The carbon intensity of the world's economy has ceased to improve (after 100 years of doing so).

Conclusions (ii)

- The efficiency of natural sinks has decreased by 5% over the last 50 years (and will continue to do so in the future), implying that the longer it takes us to reduce emissions, the larger the cuts needed to stabilize atmospheric CO_2.

- Uncertainties on the stability of large Earth carbon pools shows the real potential for significant carbon-climate feedbacks not currently account in climate models.

Global Carbon Project

www.globalcarbonproject.org