Global carbon budget and challenges for making low carbon society- Why Asia matters?

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International Scientific Programs on Global Environmental Change Science

ICSU
International Council for Science

IHDP

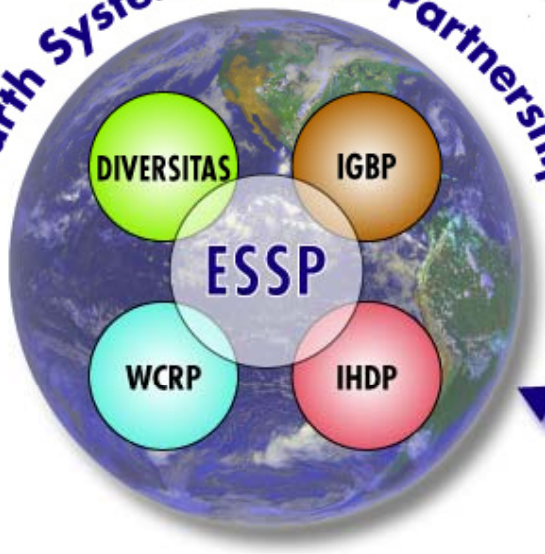
GLOBAL CHANGE
IGBP

WCRP

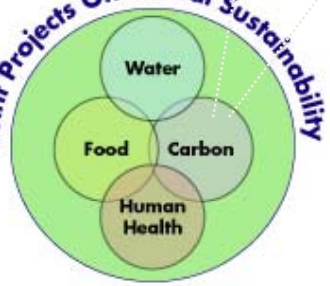
DIVERSITAS

Amsterdam Declaration of 2001

Earth System Science Partnership

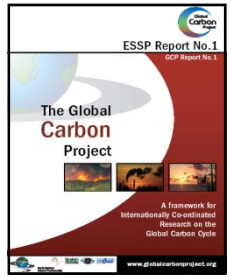


Joint Projects On Global Sustainability



Global Carbon Project

Tsukuba
Canberra



ESSP 2006 Beijing Conference

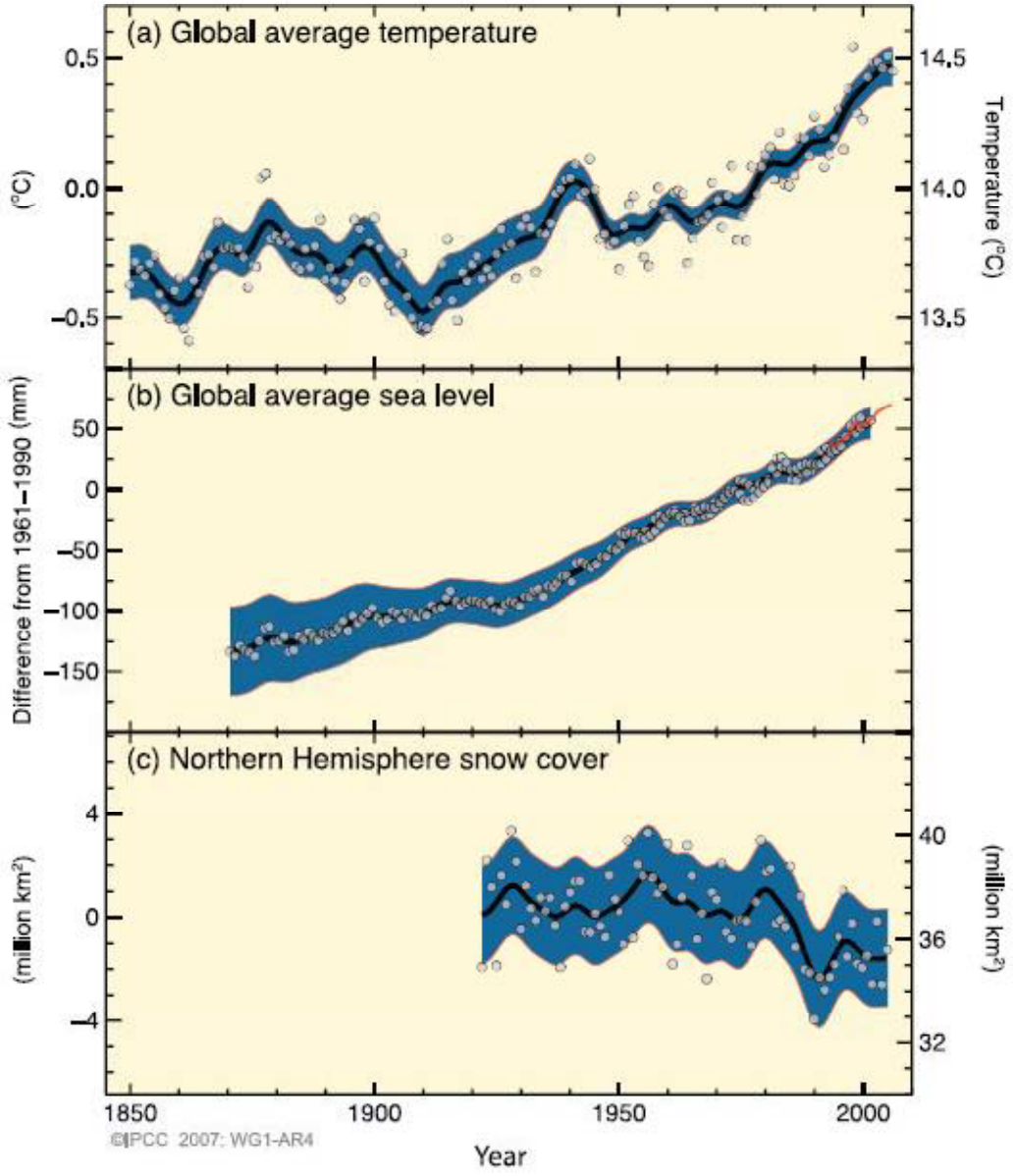
Goal

Policy-relevant understanding of the global carbon cycle and its management

Outline

1. CO_2 in climate change context
2. CO_2 emissions from fossil fuel and cement, and drivers
3. CO_2 Emissions from Land Use Change
4. Natural CO_2 sinks
5. Closing the global carbon budget
6. Conclusion

Few climate change indicators

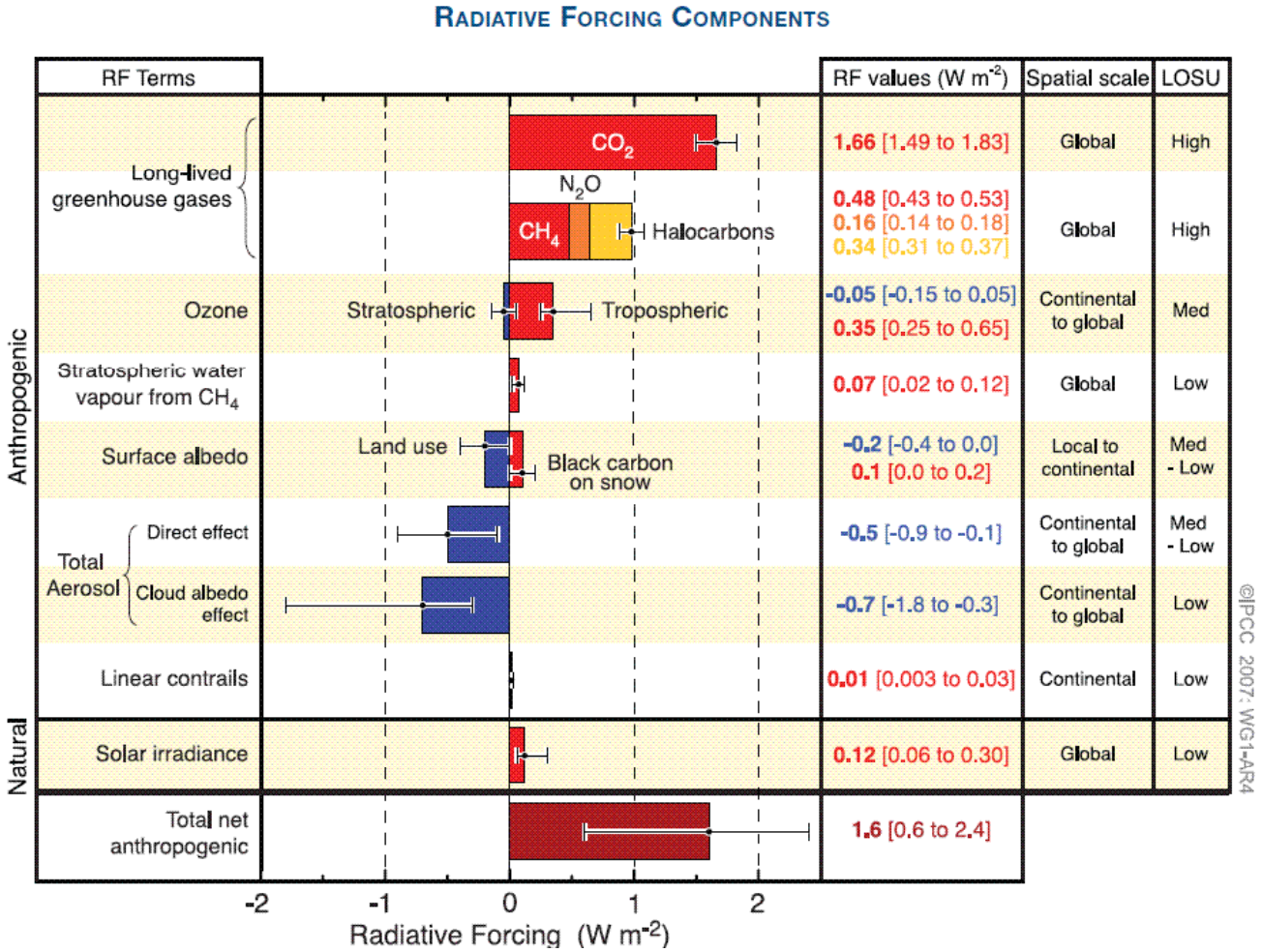


- Earth's surface temperature in rising
- Sea level is rising
- Northern hemisphere snow cover is declining

Source: IPCC AR4 WG 1 Report, pp 14, 6

Radiative Forcing of Various Greenhouse Gases

Radiative forcing is the quantitative measure of the strength of different human and natural agents in causing climate change (relative to 1750)



Global average radiative forcing (RF) estimates and ranges in 2005, IPCC AR4

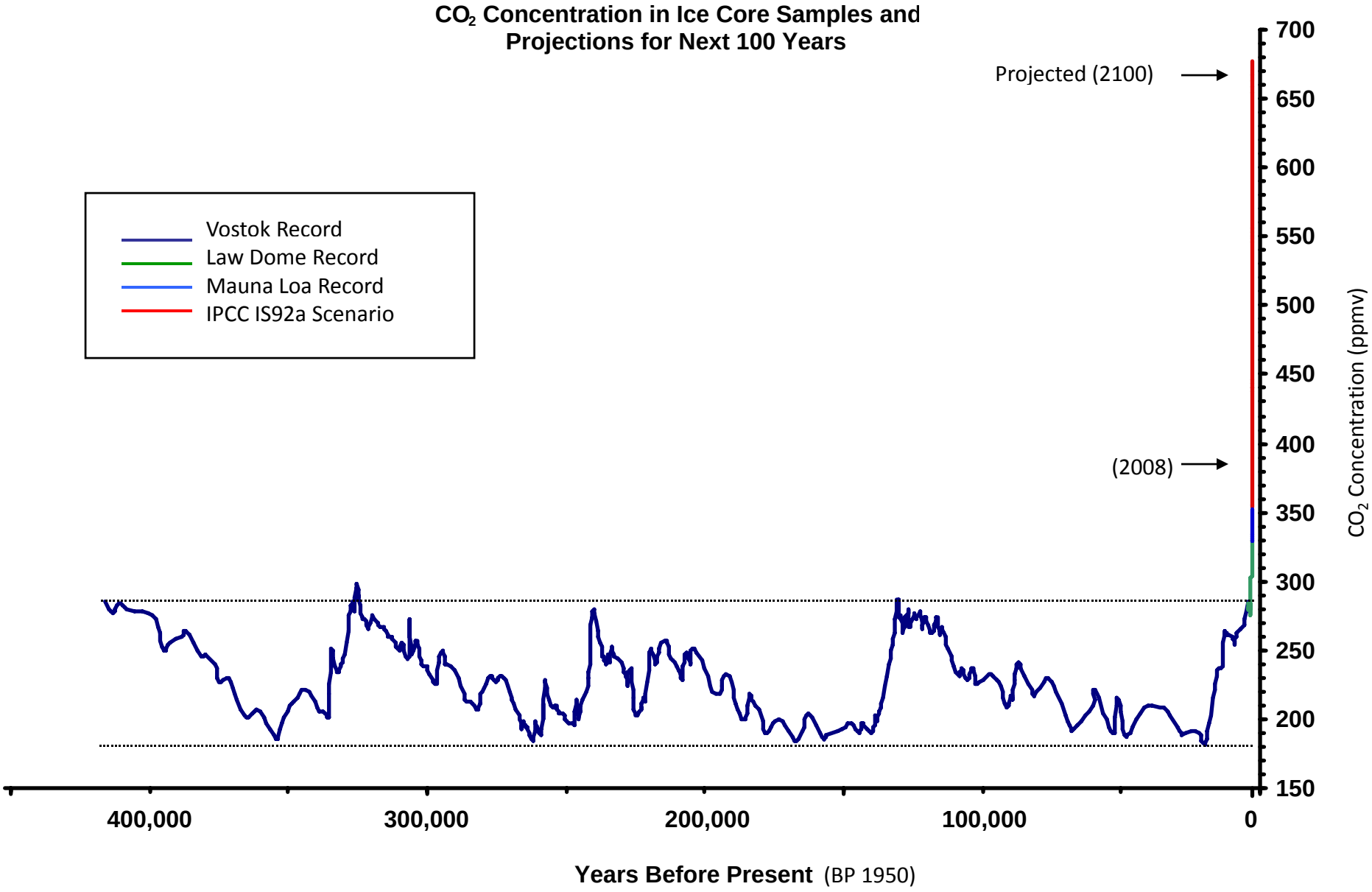
LOSU: Level of scientific understanding

- Anthropogenic radiative forcing strength is far greater than the natural factors such as solar irradiance

- As a gas, CO2 is of prime importance

- CO2 has complex dynamic because it is also linked to land and ocean uptakes

CO_2 Concentration in Ice Cores and Atmospheric CO_2 Projection for Next 100 Years



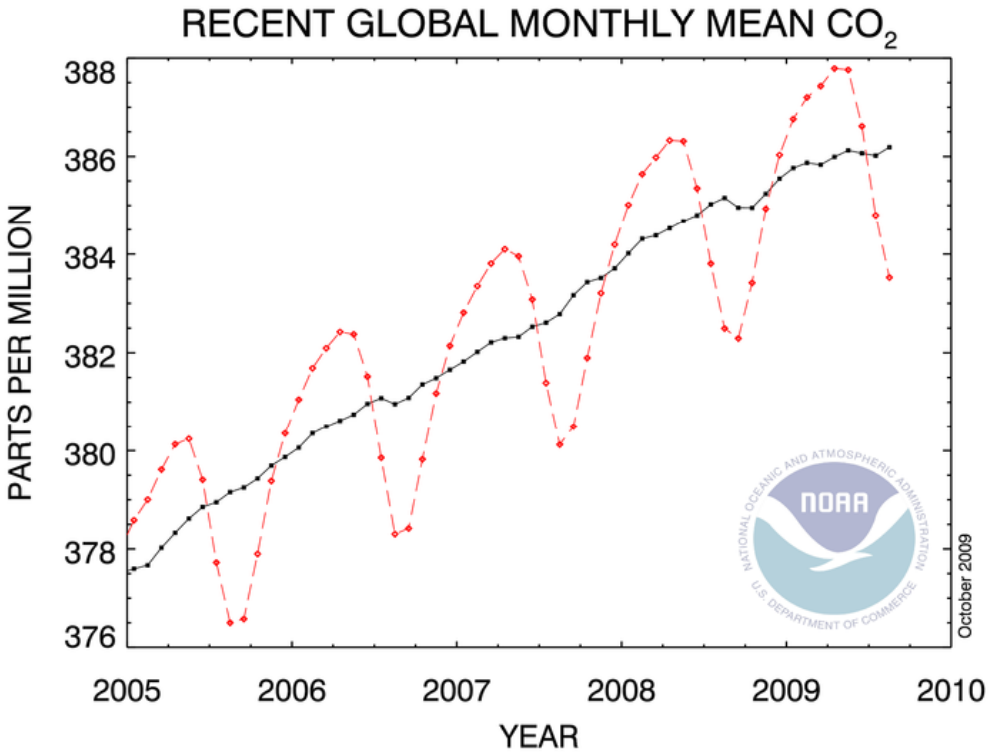
Source: C. D. Keeling and T. P. Whorf; Etheridge et.al.; Barnola et.al.; IPCC

Atmospheric CO_2 Concentration

Year 1750: 280 ppm (about)
Year 2008: 385 ppm

38% above pre-industrial, over 100 ppm rise

1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{1}
1990 – 1999: 1.5 ppm y^{-1}
2000 - 2008: 1.9 ppm y^{-1}



Annual Mean Growth Rate

2008	1.79
2007	2.12
2006	1.77
2005	2.41
2004	1.62
2003	2.22
2002	2.40
2001	1.85
2000	1.24

Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

Factors that Influence the Airborne Fraction

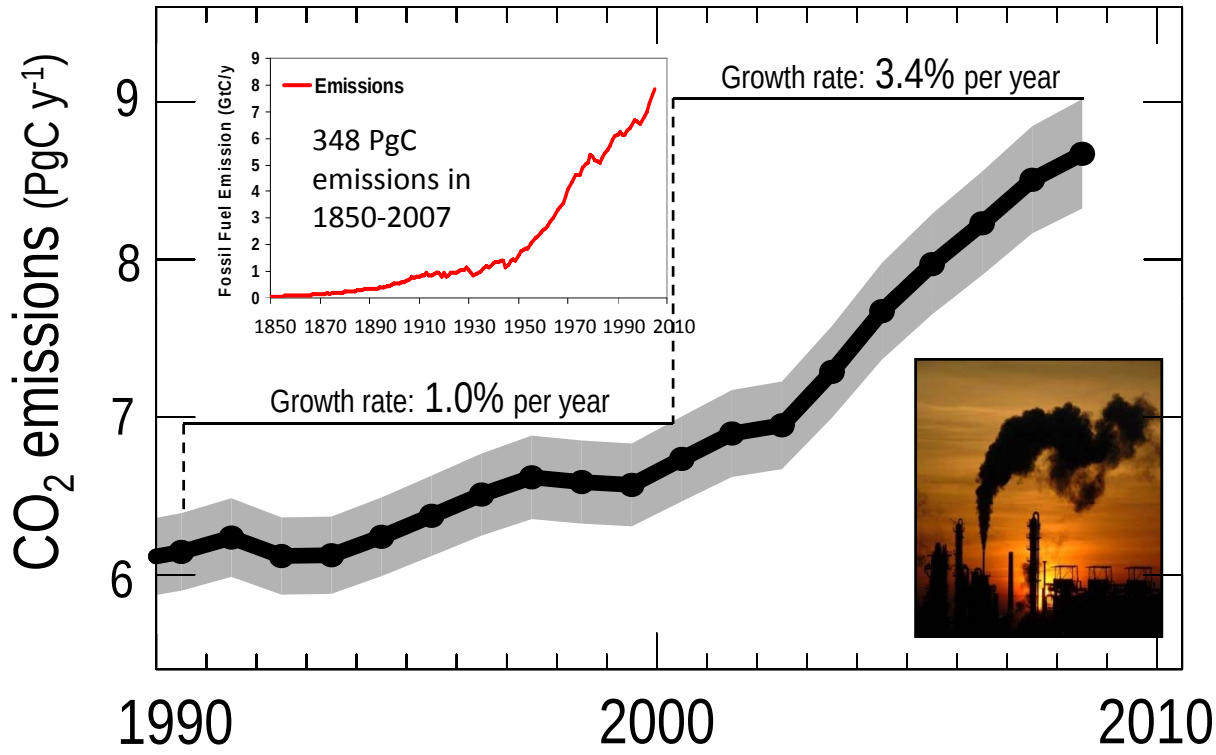
1. The rate of CO_2 emissions.

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, soil respiration, N deposition fertilization, forest regrowth, woody encroachment, …
   - Oceans: CO_2 solubility (temperature, salinity), ocean currents, stratification, winds, biological activity, acidification, …

Springer; Gruber et al. 2004, Island Press

Fossil Fuel Emissions and Cement Production [9]

[1 Pg = 1 Petagram = 1 Billion metric tonnes = 1 Gigatonne = $1x10^{15}g$]



1990 Emissions: 6.2 Pg C y^{-1}
2006 Emissions: 8.2 Pg C y^{-1}

2008

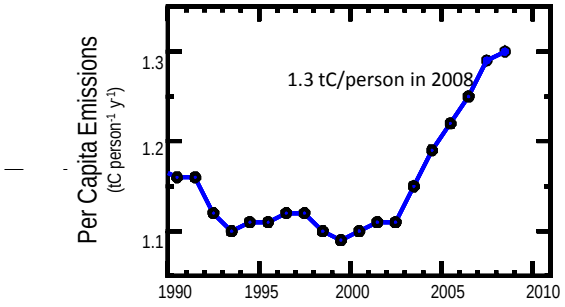
Emissions: 8.7 PgC

Growth rate: 2.0%

1990 levels: +41%

2000 levels: +29%

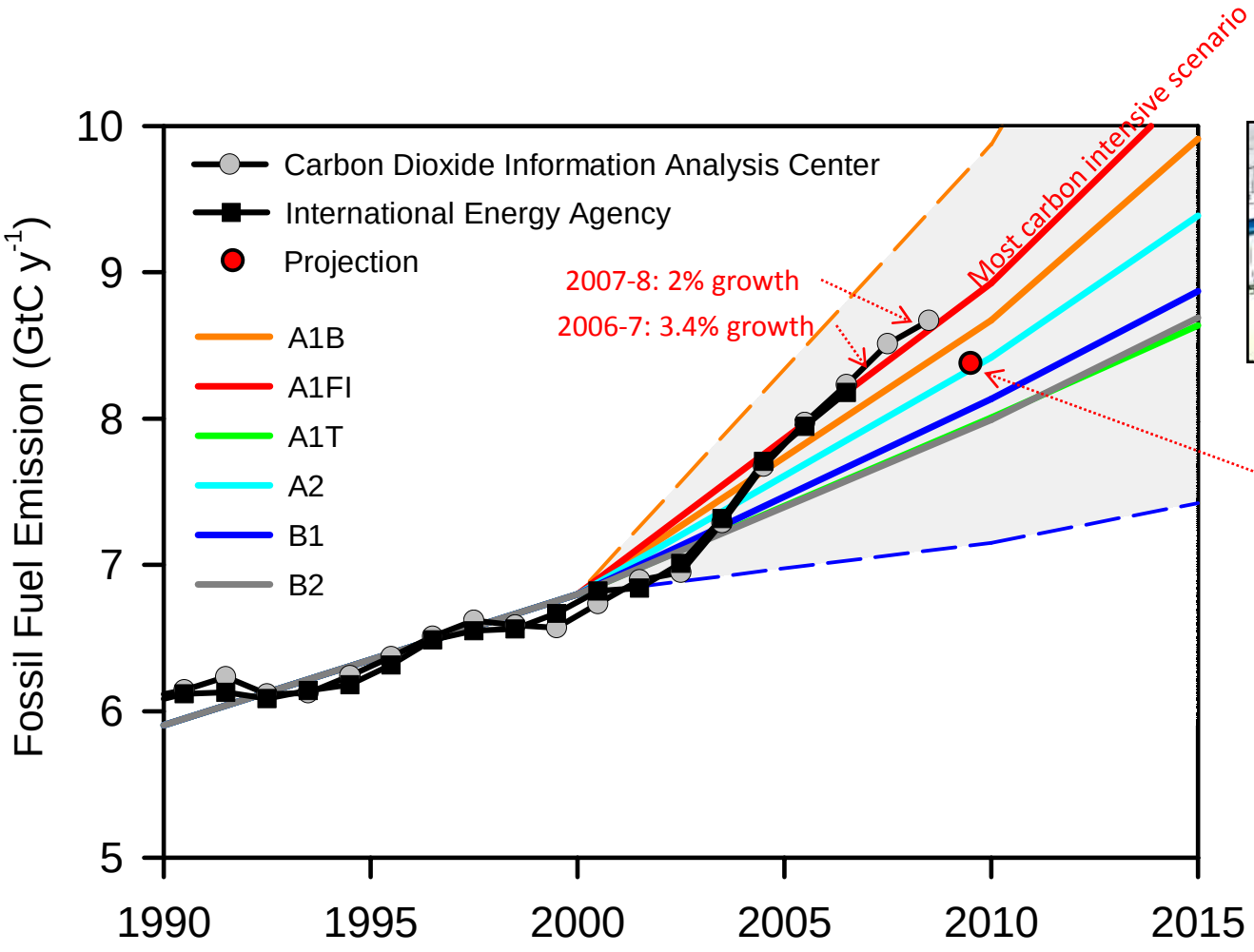
2000-2008
Growth rate: 3.4%



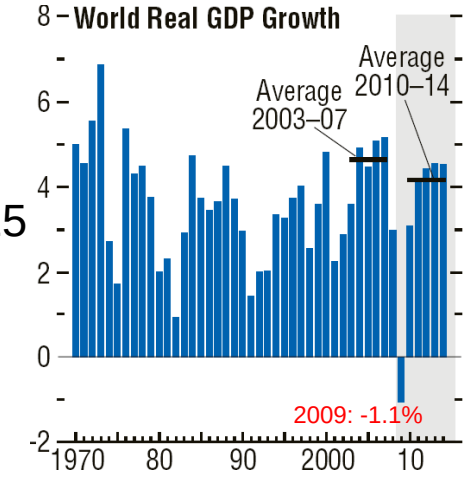
Global emission per capita

Le Quéré et al. 2009, Nature-geoscience; CDIAC 2009

Fossil Fuel Emissions: Actual vs. IPCC Scenarios

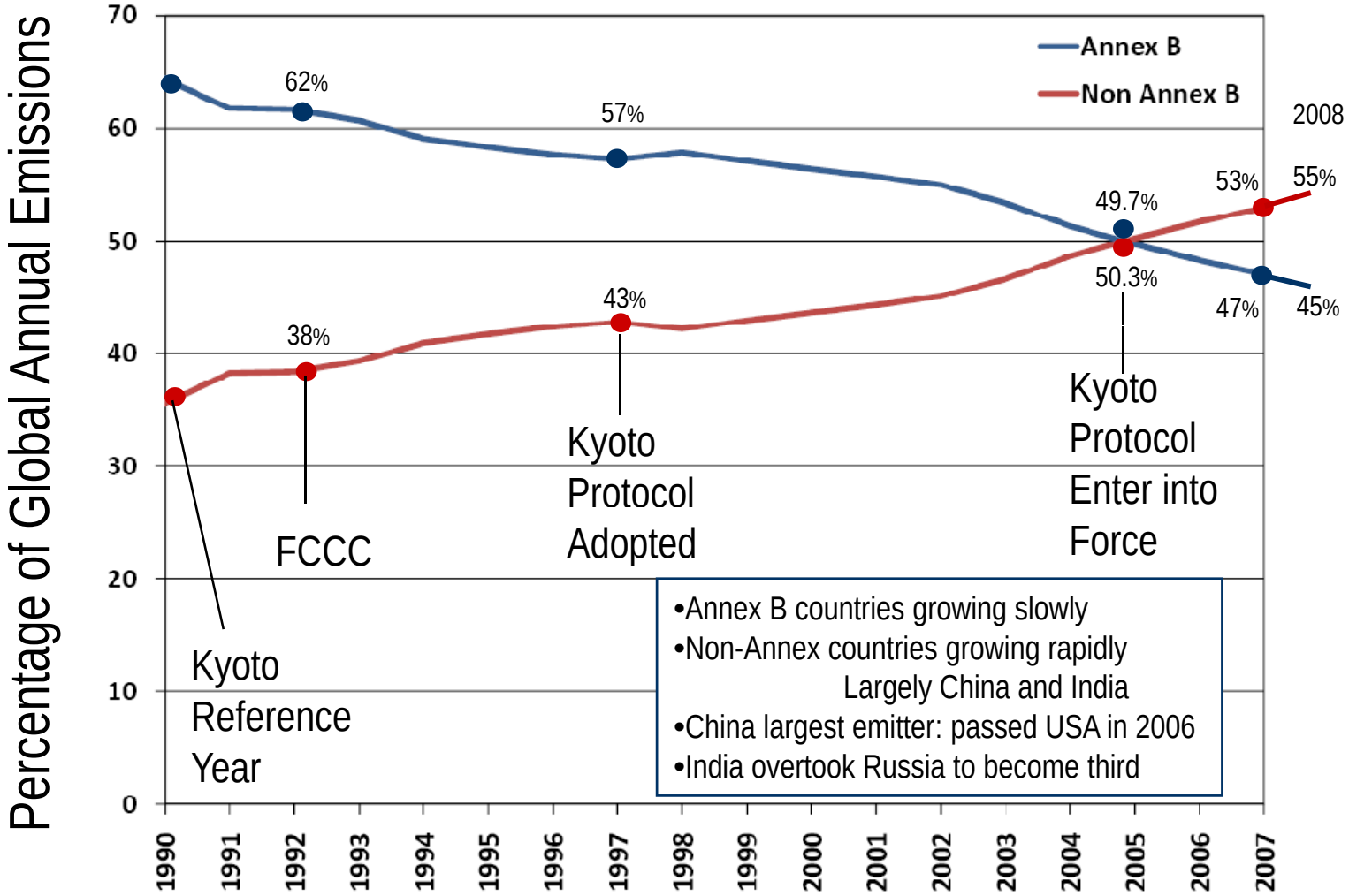


Projection 2009
Emissions: -2.8%
GDP: -1.1%
C intensity: -1.7%



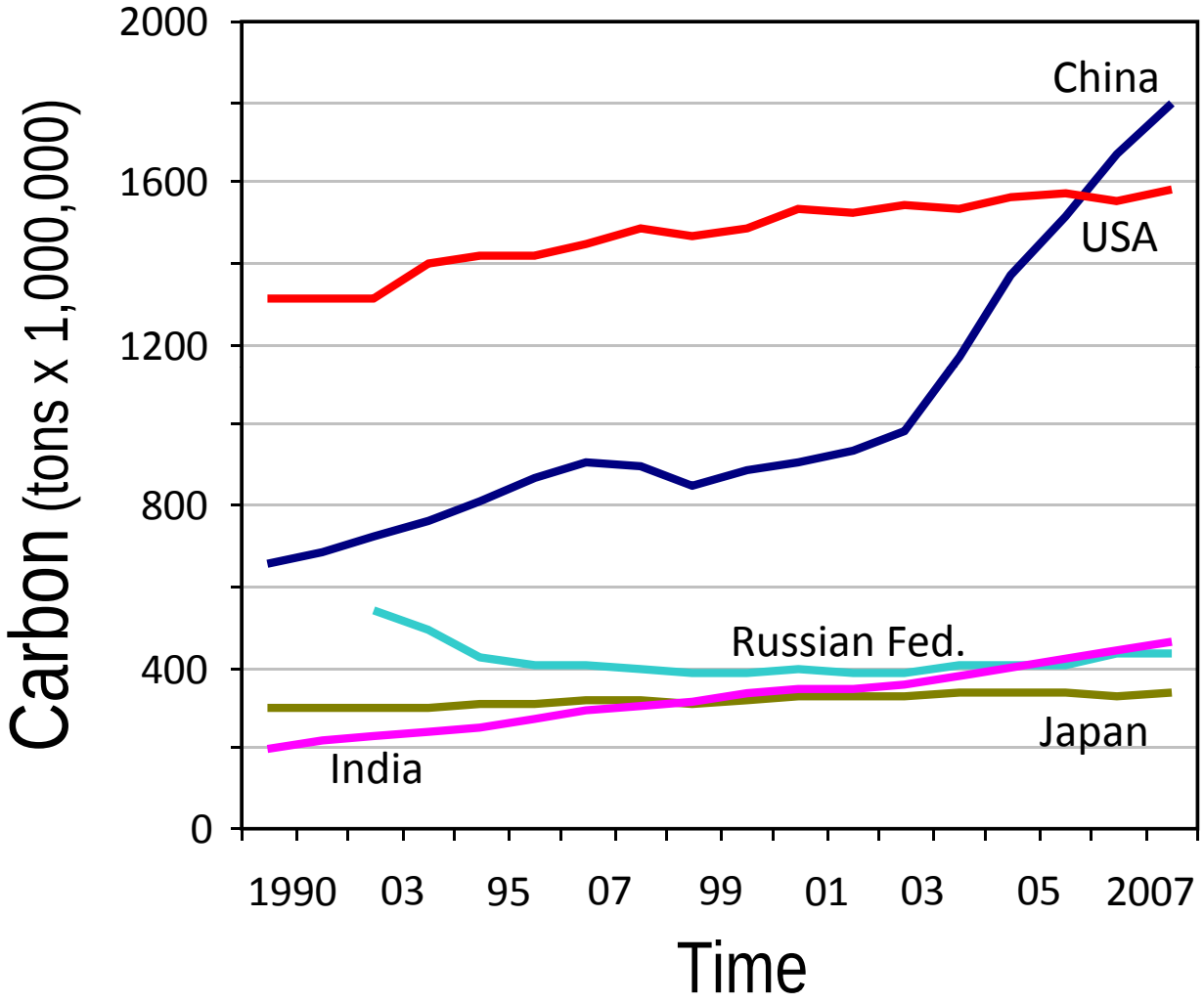
Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature-geoscience; International Monetary Fund 2009

Regional Shift in Emissions Share



Le Quéré et al. 2009, Nature-geoscience; CDIAC 2009

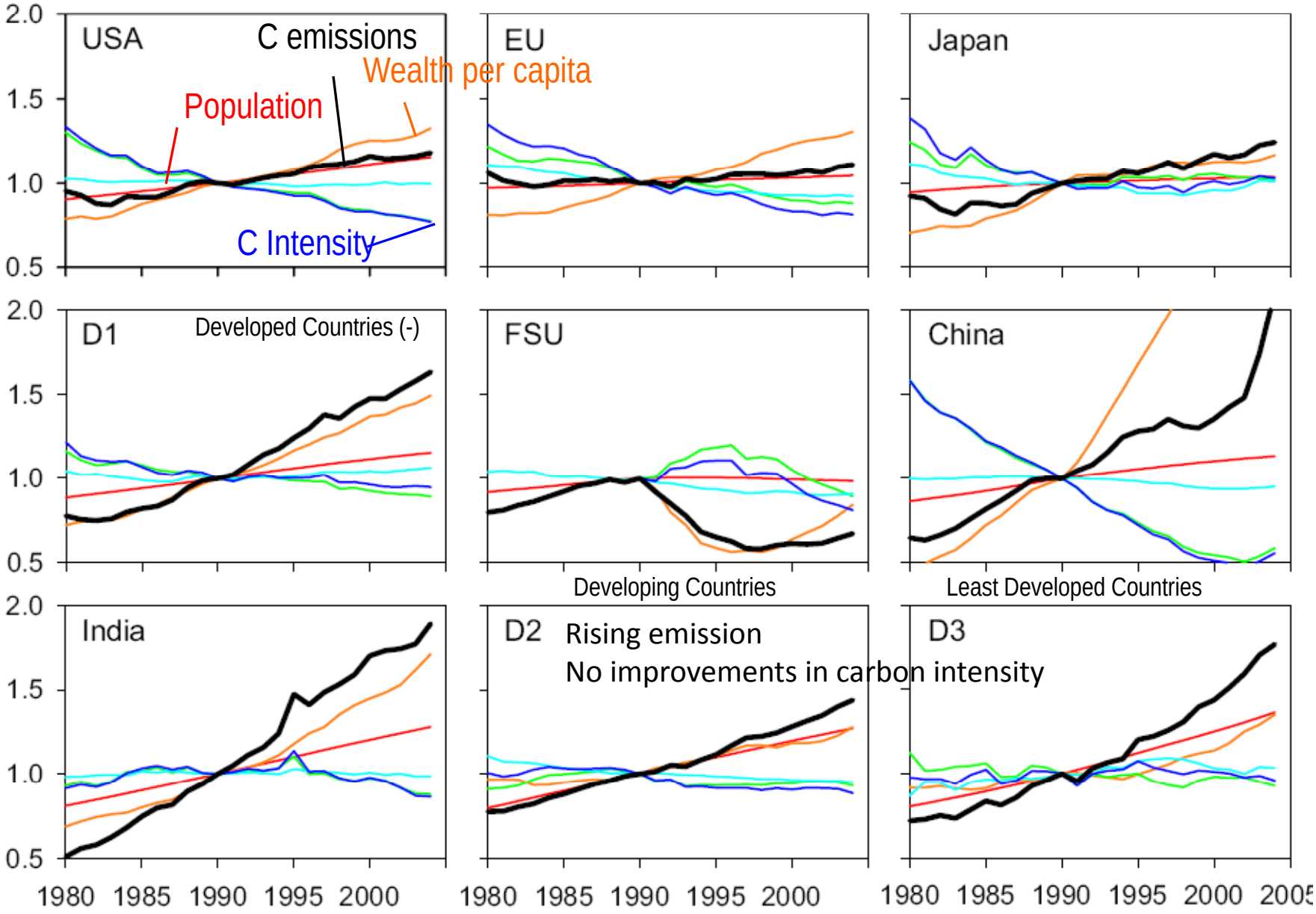
Fossil Fuel Emissions: Top Emitters (>4% of Total)



Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009

Regional Emission Pathways (1980-2005)

Raupach et al 2007, PNAS



Cumulative Fraction of Total Fossil Fuel Emissions 2008

Number of Countries	Country	Cumulative Fraction
1	China	.232
2	USA	.419
3	India	.477
4	Russia	.530
5	Japan	.573
6	Germany	.599
7	Canada	.617
8	UK	.633
9	South Korea	.652
10	Iran	.668
20	Poland	.800
50 (2005)	Belarus	.941
100 (2005)	Moldova	.992
210		1.00

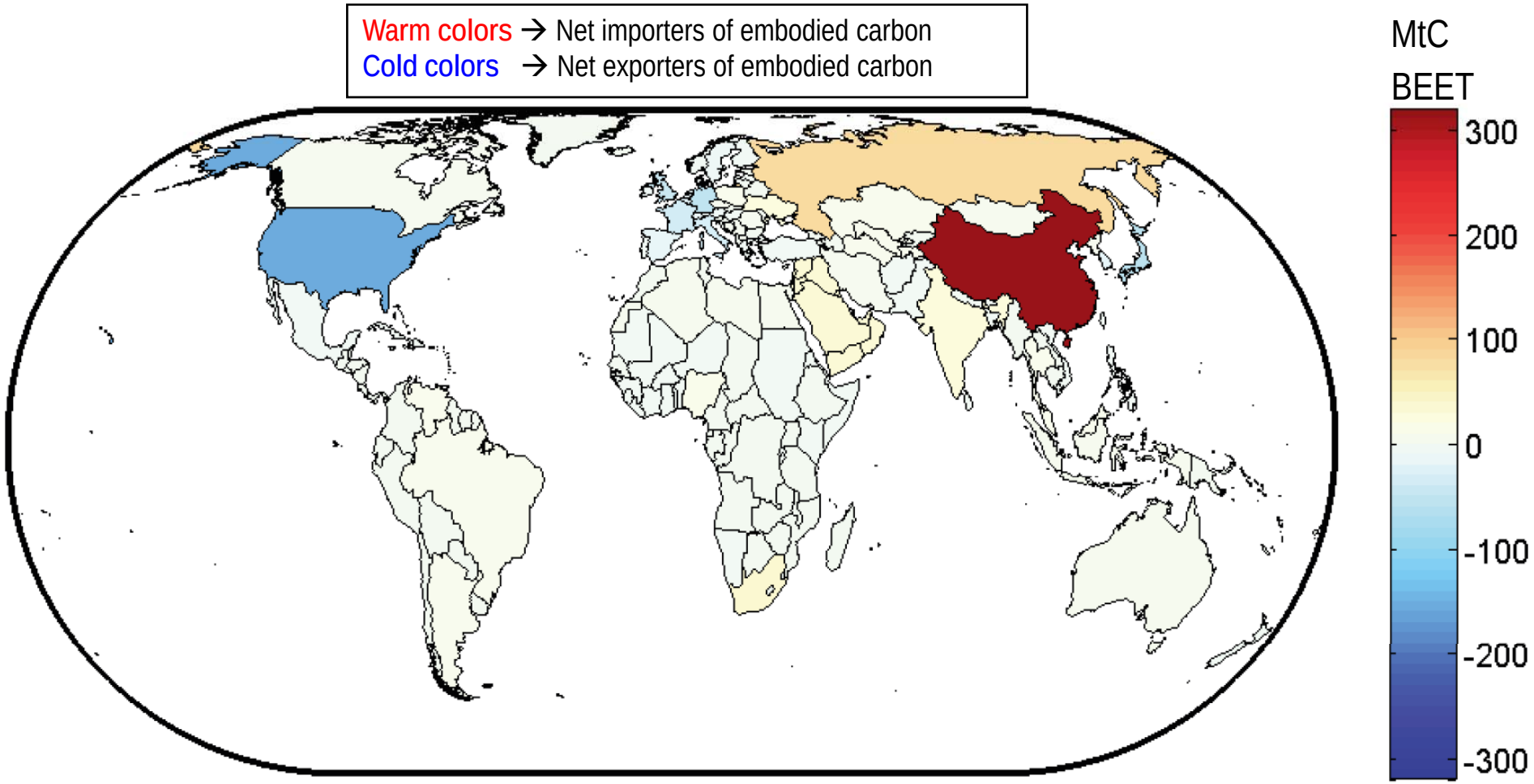
Gregg Marland, CDIAC 2009

3 countries
50% Global Emissions

10 countries
2/3 Global Emissions

Top 5 + EU
80% Global Emissions

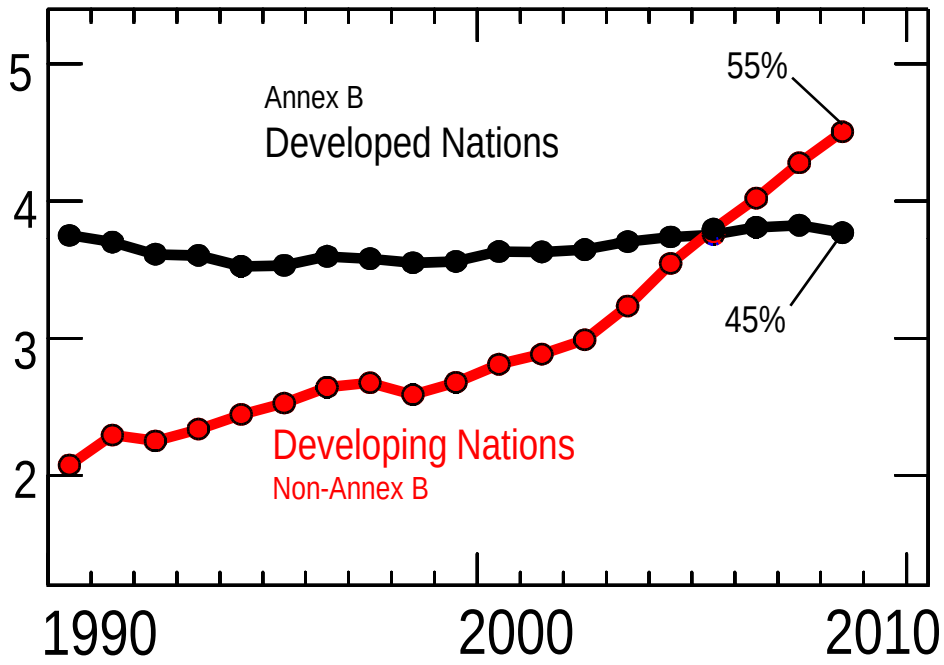
Balance of Emissions Embodied in Trade 2004

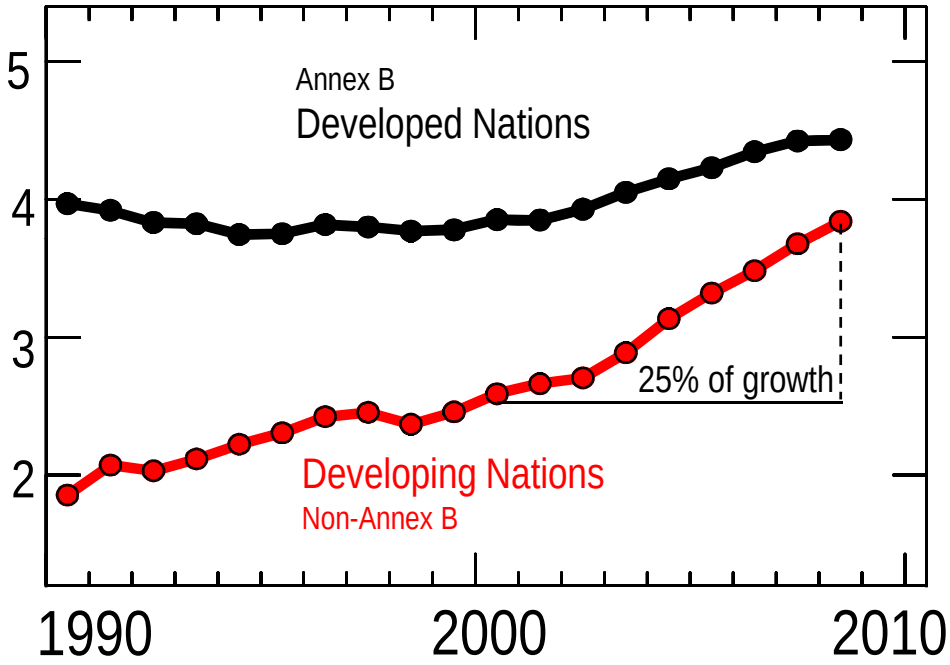


Peters and Hertwich 2008, Environ, Sci & Tech., updated

Transport of Embodied Emissions

CO_2 emissions ($PgC\ y^{-1}$)





carbon emissions from traded products are assigned to the producers

carbon emissions from traded products are assigned to the consumers

Share of Non-Annex is smaller but rising rapidly

Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience; Data: Peters & Hetwich 2009; Peters et al. 2008; Weber et al 2008; Guan et al. 2008; CDIAC 2009

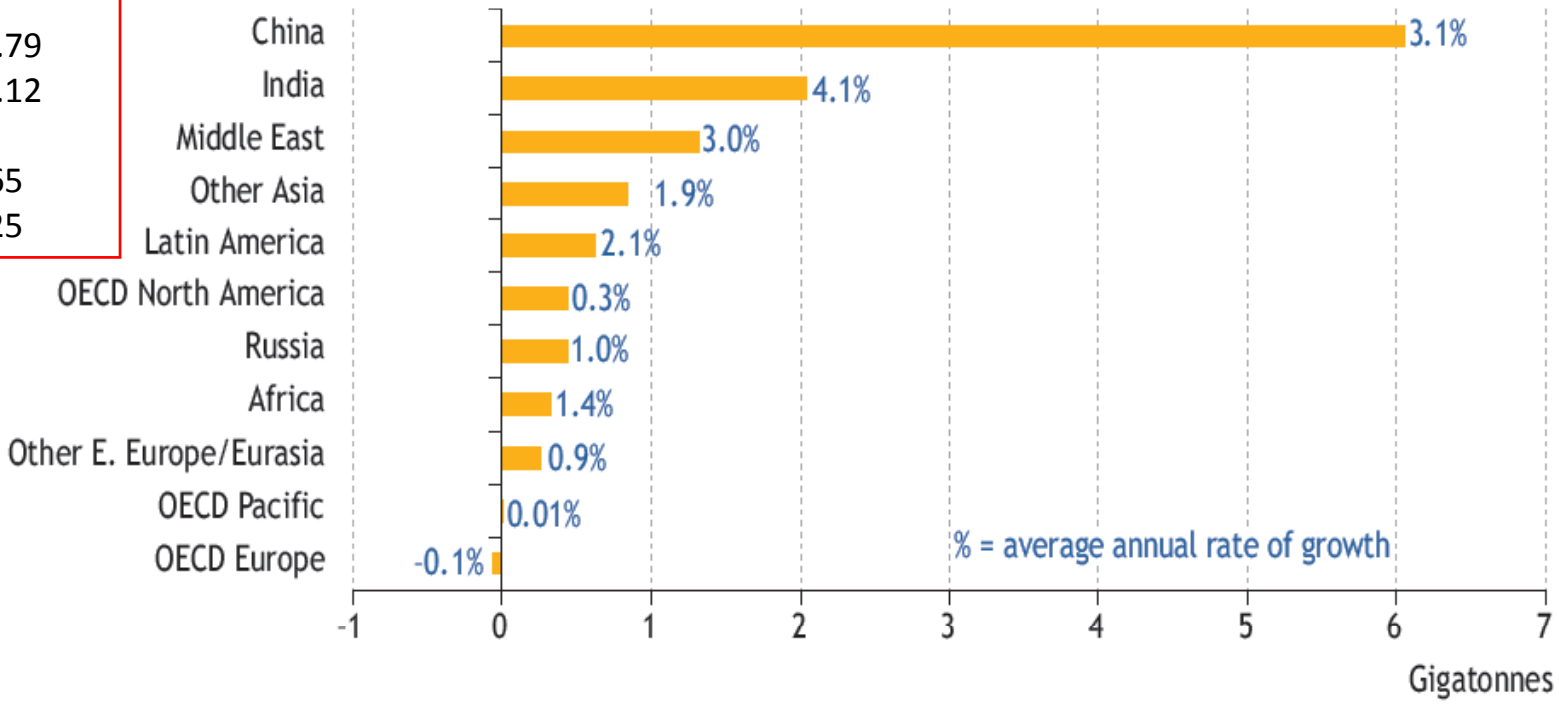
Additional energy-related CO2 emissions by country and region in 2030 vs 2006 (ref scenario)

China contributes 20% to global energy-related CO2 emissions in 2006

Additional global CO2 in 2030 over 2006: 12.6 GtCO2, about half from China

2006 GigaTons CO2
Total: 27.89

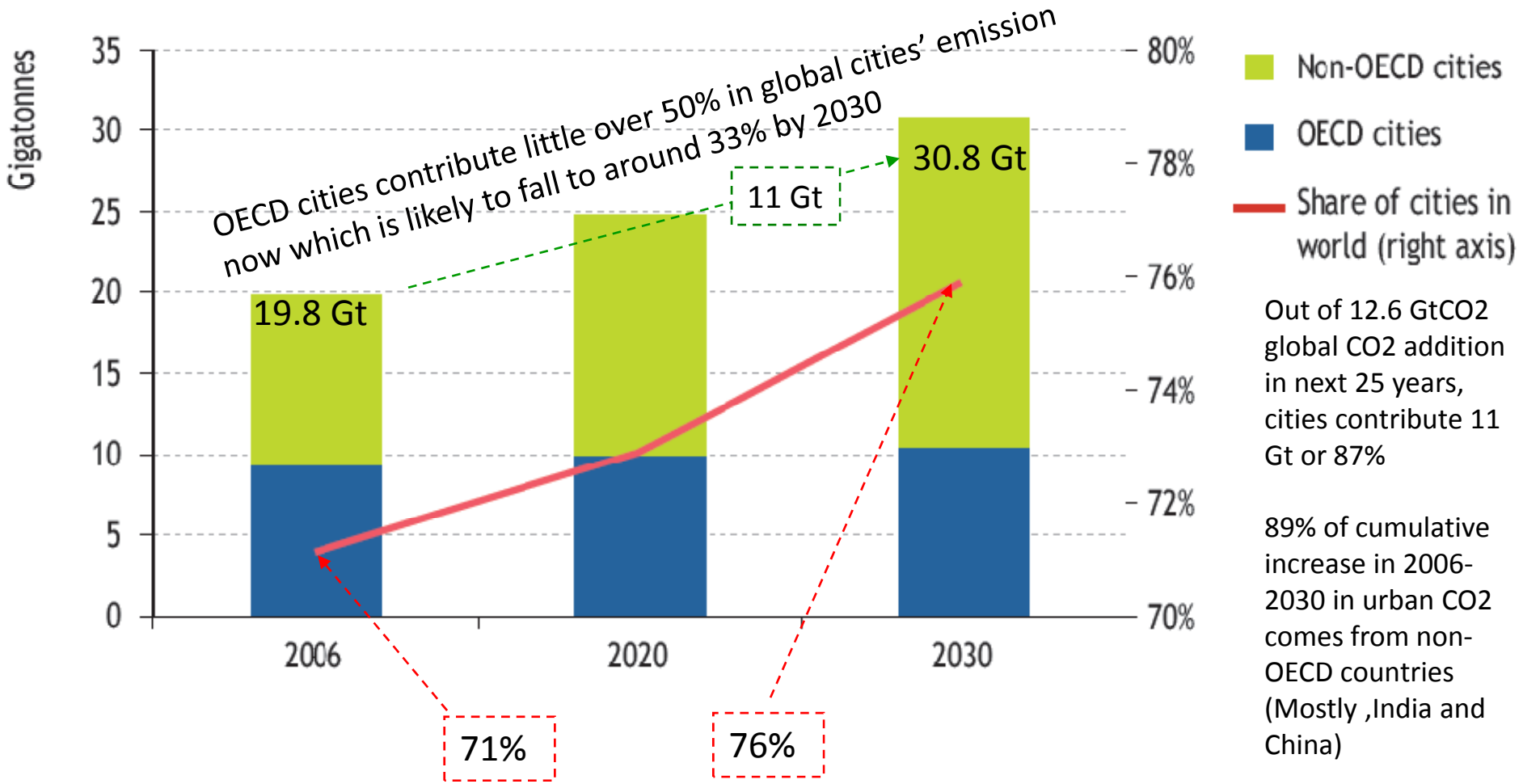
OECD	: 12.79
Non-OECD	: 14.12
China	: 5.65
India	: 1.25



(Note: this is CO2 equivalent; NOT Carbon; need to divide by 3.667 to compare

World Energy Outlook, 2008

Energy-related CO2 emissions in cities by region in the Reference Scenario

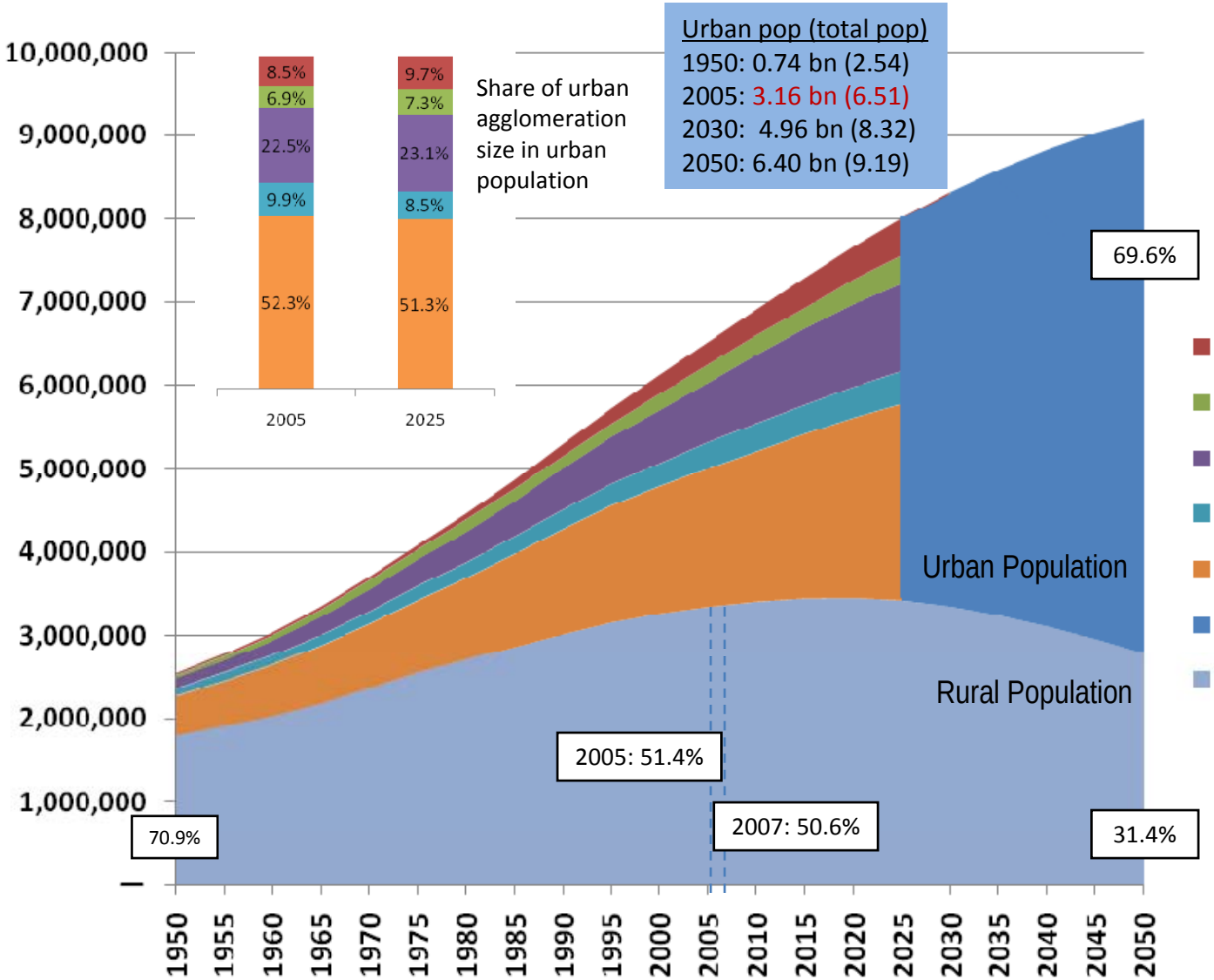


Out of 12.6 GtCO2 global CO2 addition in next 25 years, cities contribute 11 Gt or 87%

89% of cumulative increase in 2006-2030 in urban CO2 comes from non-OECD countries (Mostly ,India and China)

WEO, 2008; Dhakal 2009

Role of urban area: Global urban population and share of urban agglomeration by size



- Almost all future global pop growth from urban population, mostly in Asia
- Additional 1.8 bn in next 25 years (2030-2005), mostly in Asia

<Dhakal, 2009>
Based on UN Urban Population Statistics 2007 updates

Asia's role in global CO2 from fossil fuels

- China over-passed USA as the greatest emitter since 2006
- India surpassed Russia and now third largest emitter
- China (23.2%), India (5.8%), Japan (4.3%), South Korea (1.9%) and Iran (1.6%) are amongst top 10 global CO2 emitters: totalling 36.8% in 2008
- Embodied CO2 emission in trade: China is the biggest carbon importer; Europe, US and Japan are CO2 exporters; meaning, Asia is a key region if we expand debate to consumption responsibility too
- Future new emission is going to happen in Asia, mostly China and India
- Future global incremental emissions will take places urban areas with Asian developing countries playing major role

Carbon Emissions from Land Use Change

Borneo, Courtesy: Viktor Boehm

2000-2007 (Net av. an. emission)	
Tropical Americas, 41%	0.6 Pg C y^{-1}
Tropical Asia, 43%	0.6 Pg C y^{-1}
Tropical Africa, 17%	0.3 Pg C y^{-1}
	1.5 Pg C y^{-1}

Tropical deforestation: 13 Million hectares each year

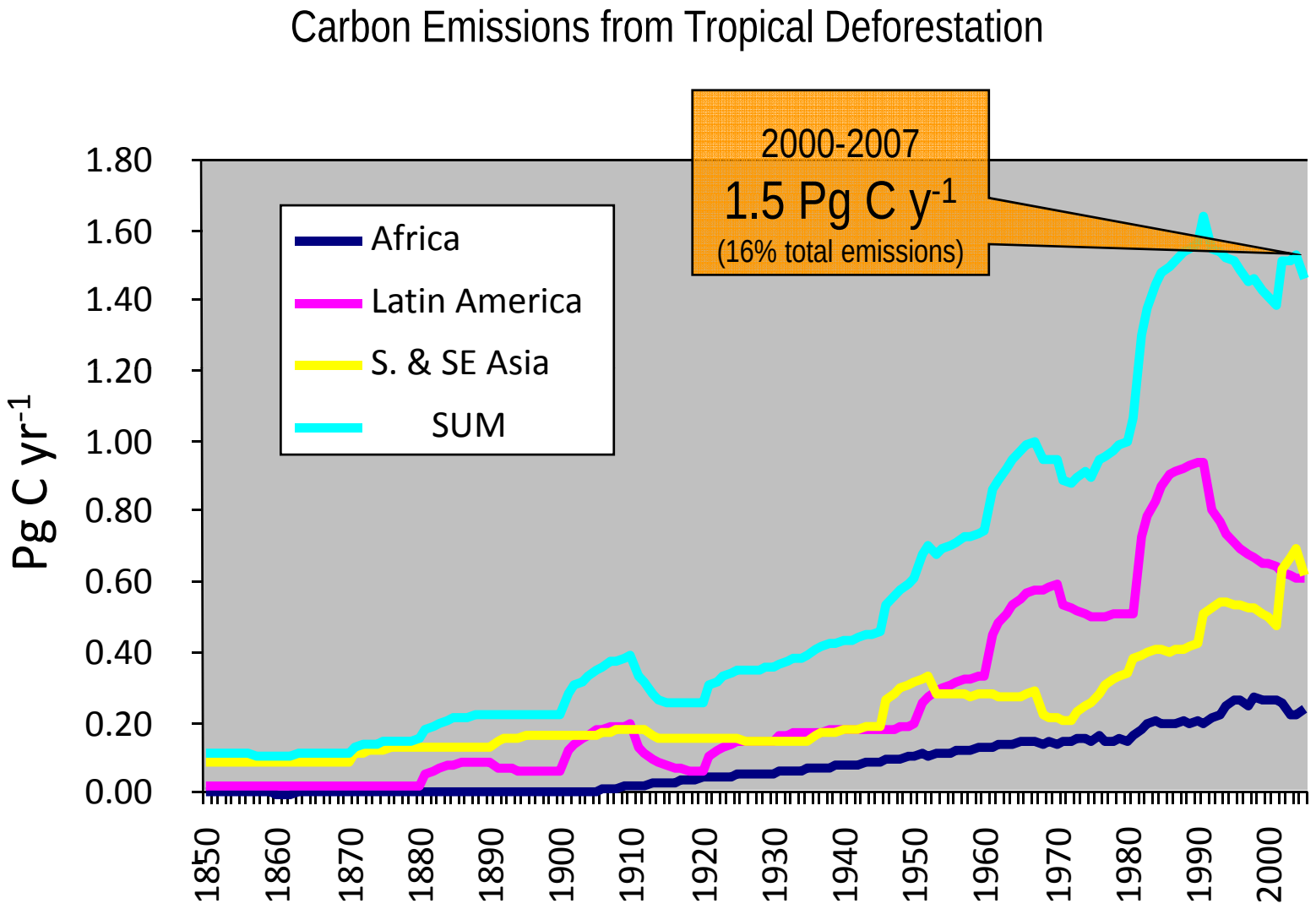
Tropical deforestation mostly responsible for emissions

[2007-Total Anthropogenic Emissions:8.5+1.5 = 10 Pg]

160 Pg C emission in 1850-2007 from Land Use Change

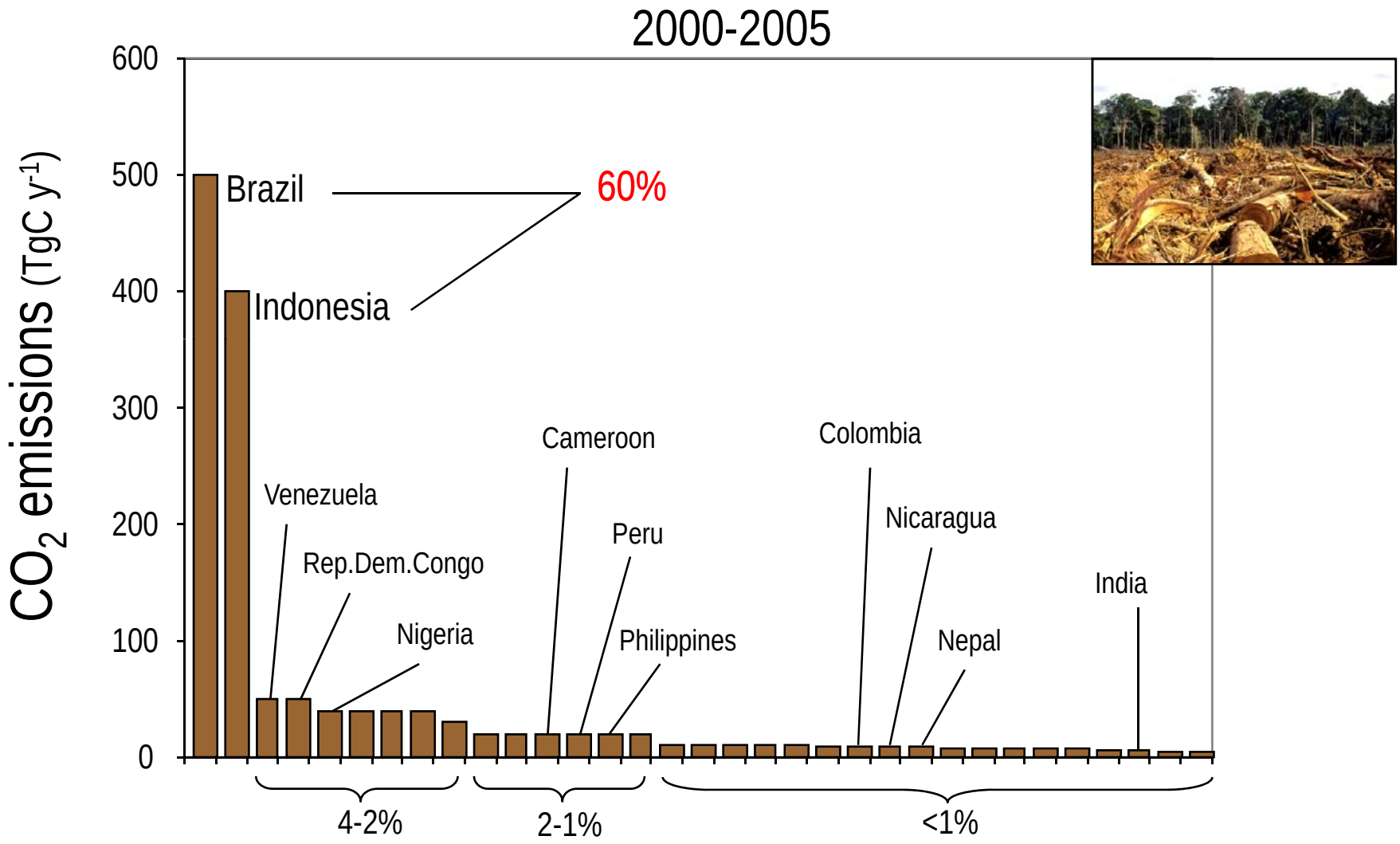
Canadell et al. 2007, PNAS; FAO-Global Resources Assessment 2005

Historical Emissions from Land Use Change



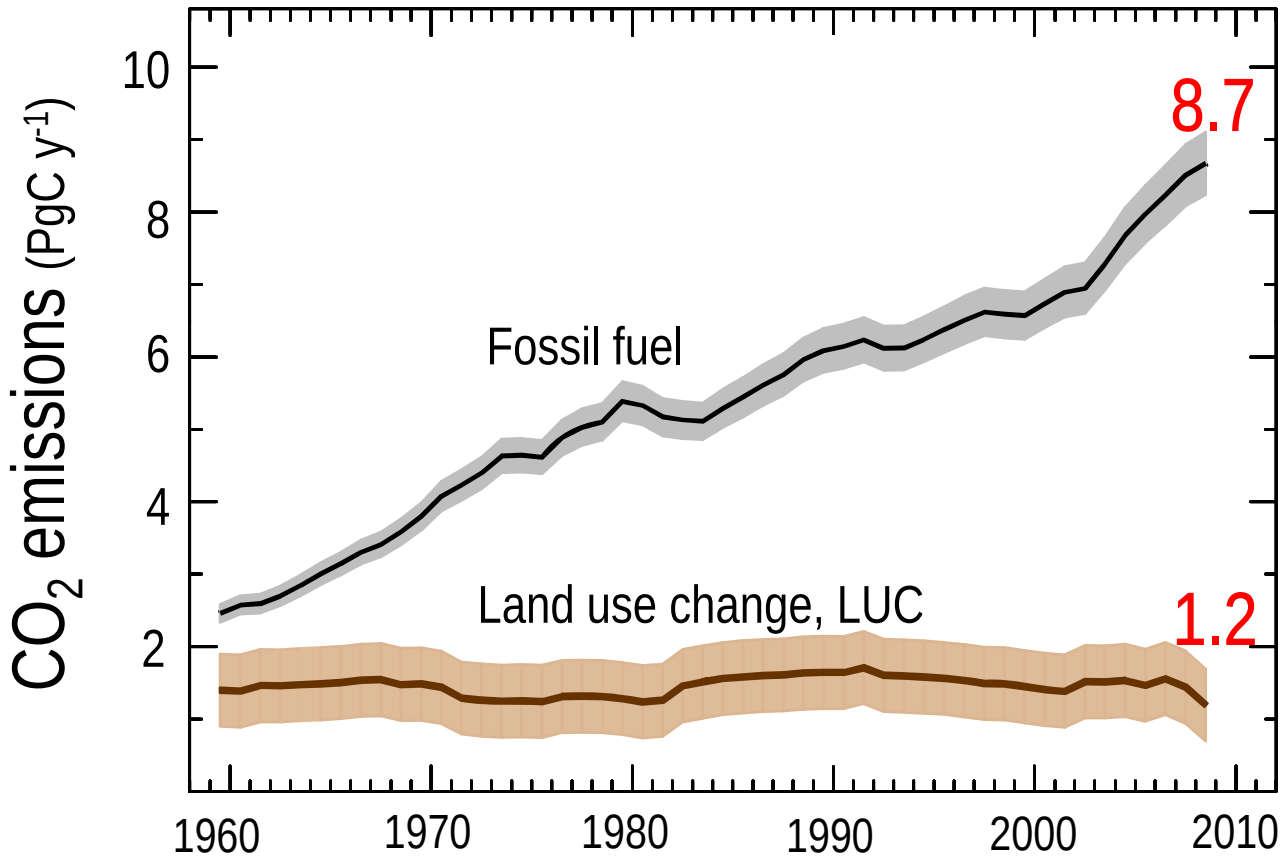
R.A. Houghton, unpublished

Net CO_2 Emissions from LUC in Tropical Countries



RA Houghton 2009, unpublished; Based on FAO land use change statistics

Total Anthropogenic Emissions 2008



9.9 PgC

12% of total anthropogenic emissions

2008 CO2 emissions from LUC has significantly decreased from previous year
Probably due to wet La Niña conditions and reduced reforestation rate

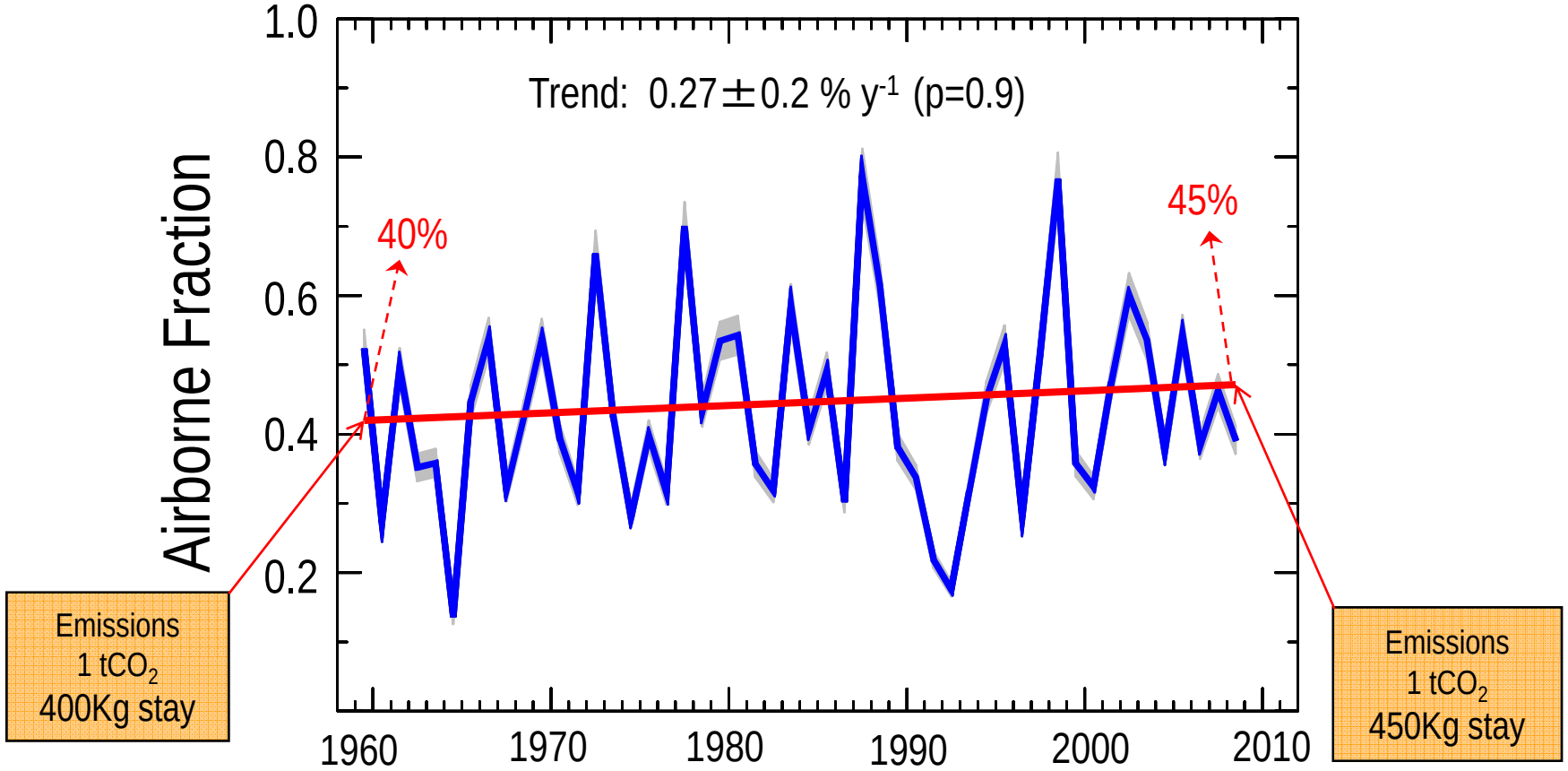
Le Quéré et al. 2009, Nature-geoscience; Data: CDIAC, FAO, Woods Hole Research Center 2009

Asia's role in global CO2 from land use change

- Asian contribution in increasing dramatically in global CO2 emission from the land use change
- Indonesia remains key country
- Despite being big countries, the CO2 from land use of China and India are smaller unlike their fossil fuel CO2 emissions

Airborne Fraction

Fraction of total CO_2 emissions that remains in the atmosphere



Means the efficiency of sinks in removing CO2 from atmosphere has decreased by 5% over the last 50 years, and will continue to do so in the future

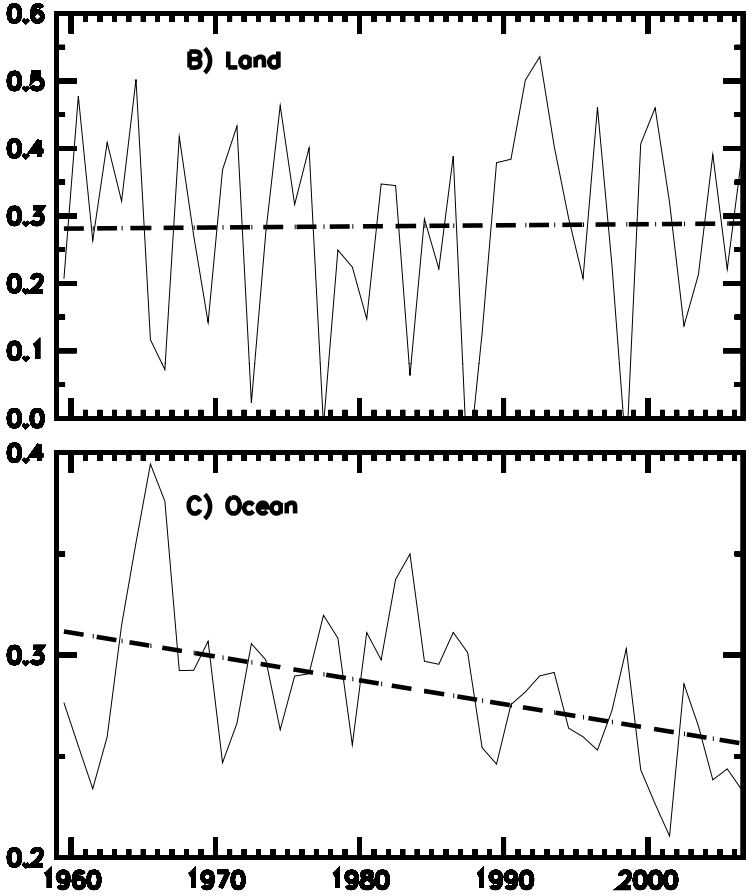
Le Quéré et al. 2009, Nature-geoscience; Canadell et al. 2007, PNAS; Raupach et al. 2008, Biogeosciences

Efficiency of Natural Sinks

Long term trends show that the natural sink has increased size but the efficiency of sink (to uptake the additional carbon as fraction of total anthropogenic CO2 emissions) has declined to keep airborne fraction from increasing

Land Fraction

Ocean Fraction



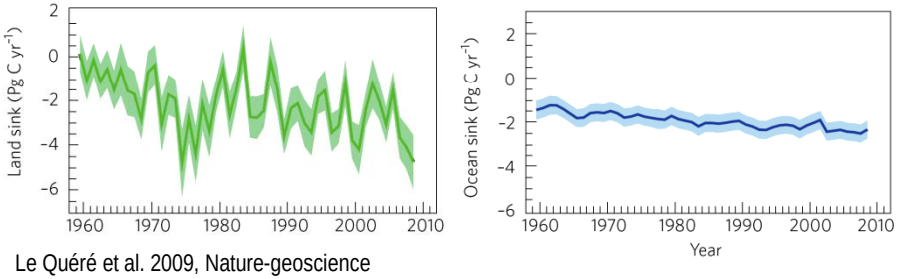
Net uptake

Land
3 PgC/yr in 2000-8

3.6 PgC in 2006
2.9 PgC in 2007
4.7 PgC in 2008 (La Niña)

Ocean
Slower growth of ocean sink compared to growth pace of emissions

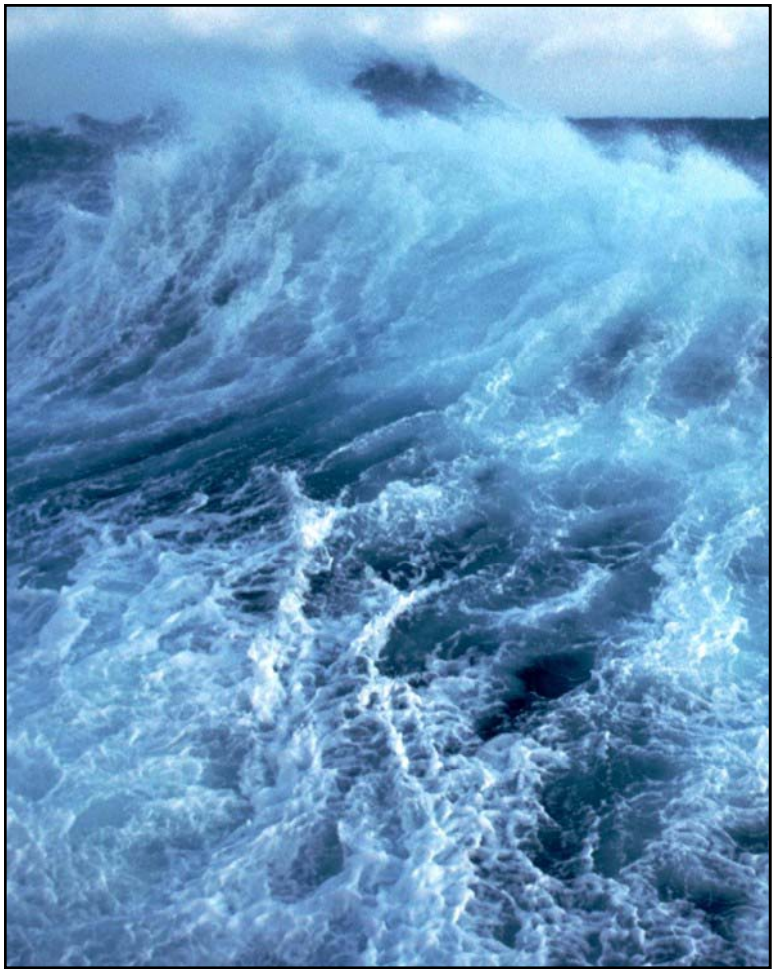
2.3 PgC/yr in 2000-8



Le Quéré et al. 2009, Nature-geoscience

Canadell et al. 2007, PNAS

Causes of the Declined in the Efficiency of the Ocean Sink

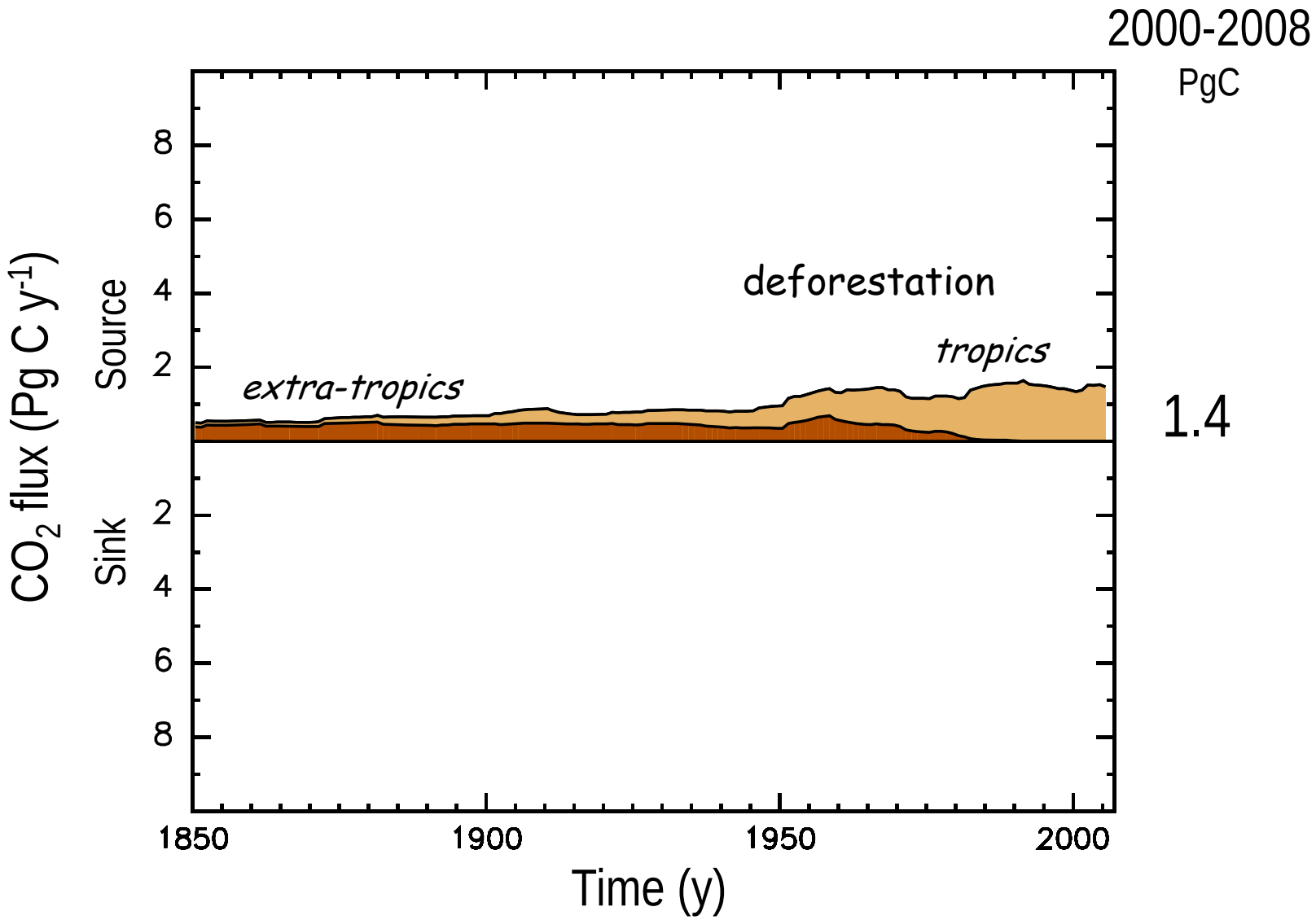


Credit: N.Metzl, August 2000, oceanographic cruise OISO-5

- Part of the growth decline is attributed to a 30% decrease in the efficiency of the Southern Ocean sink over the last 20 years.
- This sink removes annually 0.7 Pg of anthropogenic carbon.
- The decline 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

Human Perturbation of the Global Carbon Budget



Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience

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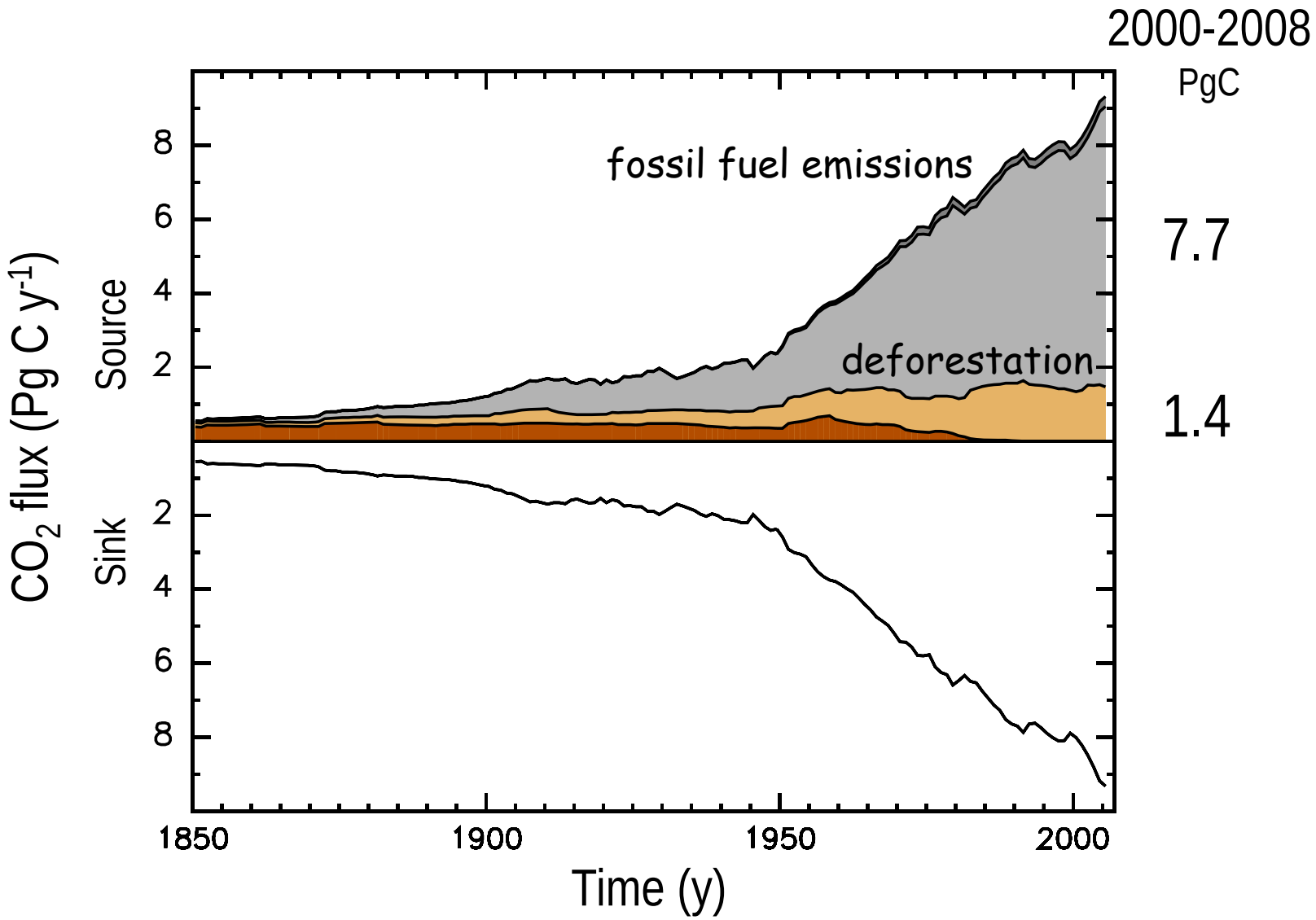

Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience

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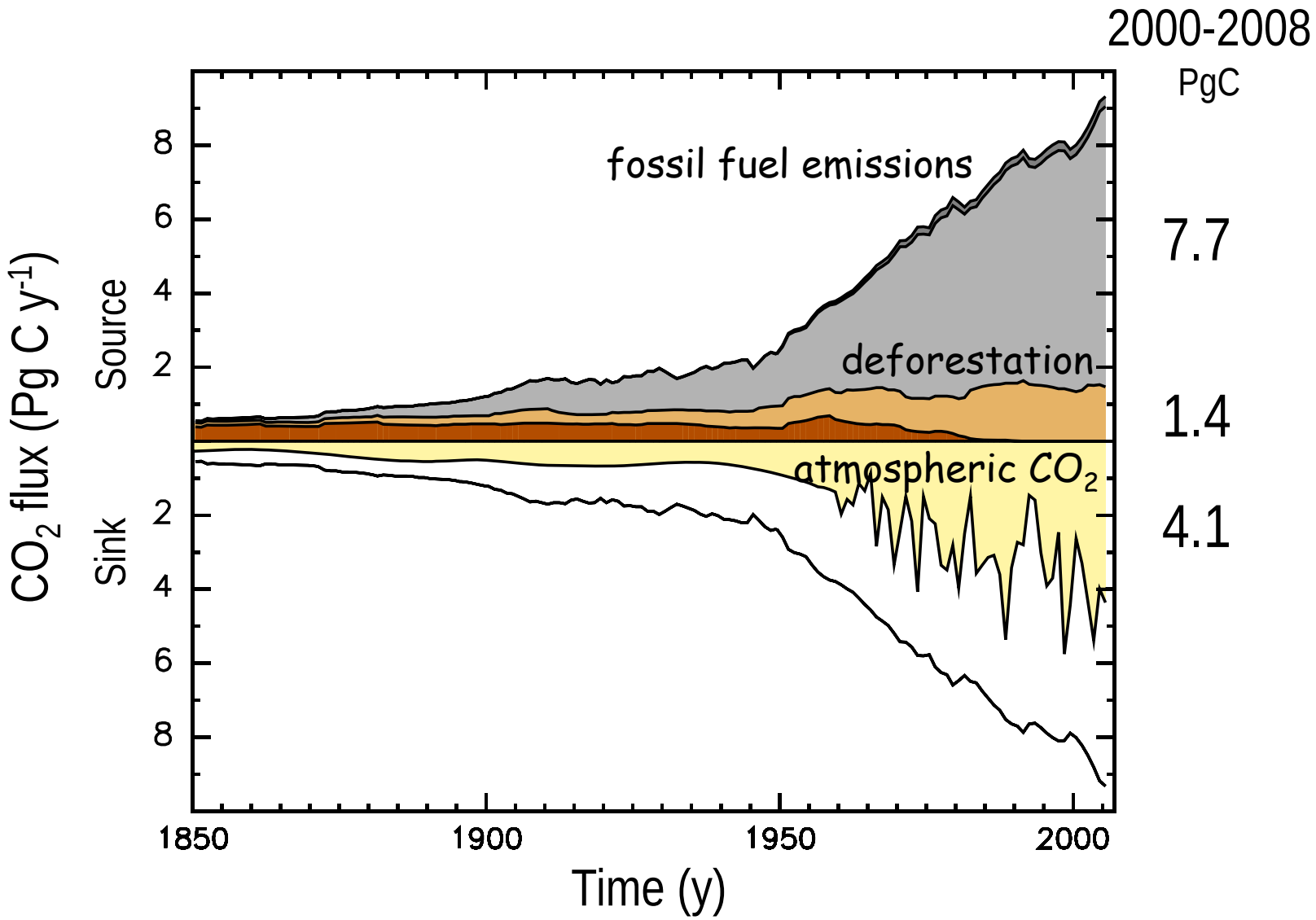

Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience

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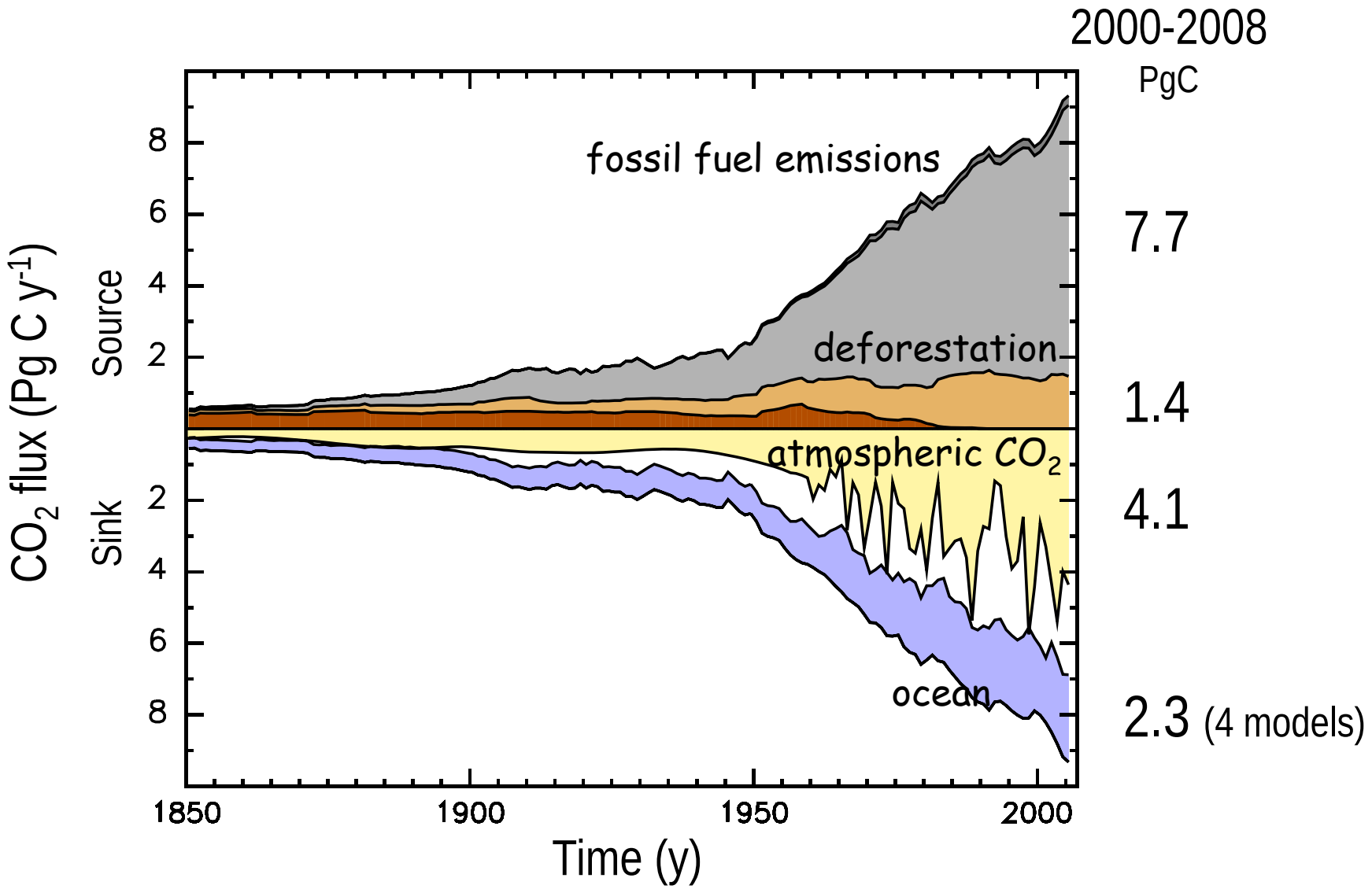

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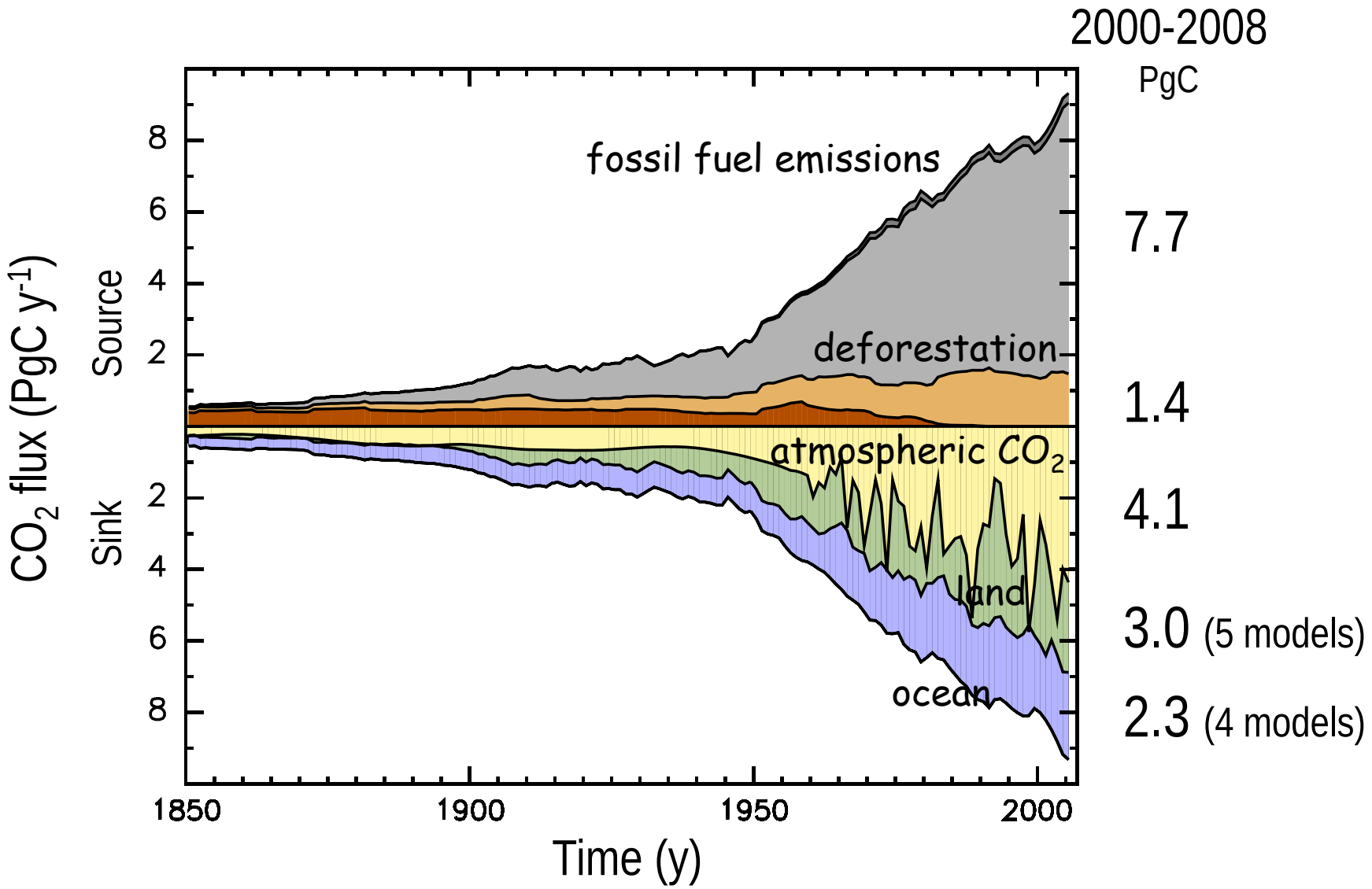

Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience

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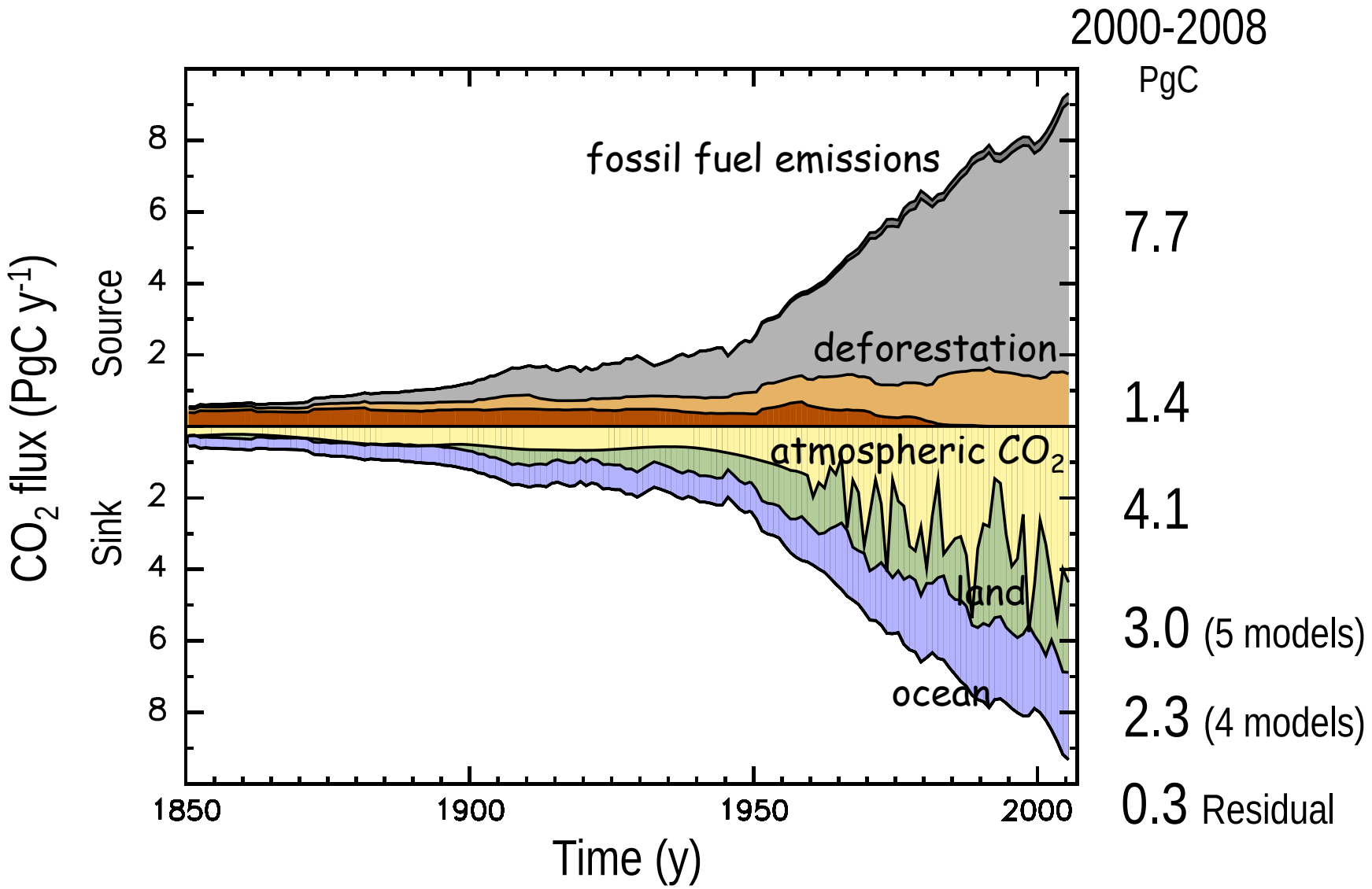

Global Carbon Project 2009; Le Quéré et al. 2009, Nature-geoscience

Fate of Anthropogenic CO_2 Emissions (2000-2008)

1.4 PgC y^{-1}

7.7 PgC y^{-1} +

4.1 PgC y^{-1}

45%

3.0 PgC y^{-1}

29%

55% of emission is taken back by sink

26%

2.3 PgC y^{-1}

Le Quéré et al. 2009, Nature-geoscience; Canadell et al. 2007, PNAS, updated

Conclusions (i)

- Anthropogenic CO_2 emissions are growing 3.5 times faster since 2000 than during the previous decade
- Anthropogenic CO_2 emissions are growing above the worst case emission scenario of the Intergovernmental Panel on Climate Change (IPCC)
- Developing Countries are now emitting significantly more carbon than Developed Countries
- The economic crisis will likely have a transitional impact on the growth of CO_2 emissions and a undetectable effect on the growth of atmospheric CO_2 (because the much larger inter-annual variability of the natural sinks)

Conclusions (ii)

- The efficiency of natural sinks has decreased by 5% over the last 60 years (and will continue to do so in the future), a trend not fully captured by climate models.
  - implying that the longer it takes to begin reducing emissions significantly, the larger the cuts needed to stabilize atmospheric CO_2.
- Sink-source dynamics have led to an acceleration of atmospheric CO_2 growth 27% faster since 2000 than in the previous two decades, implying a stronger climate forcing and sooner than expected.
- Asia plays important role in both emission from the fossil fuel and the land use changes and key region for carbon management at carbon source and land carbon sinks

GCP-Carbon Budget Consortium

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