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Carbon Budget 2009

GCP-Carbon Budget2009 Contributors

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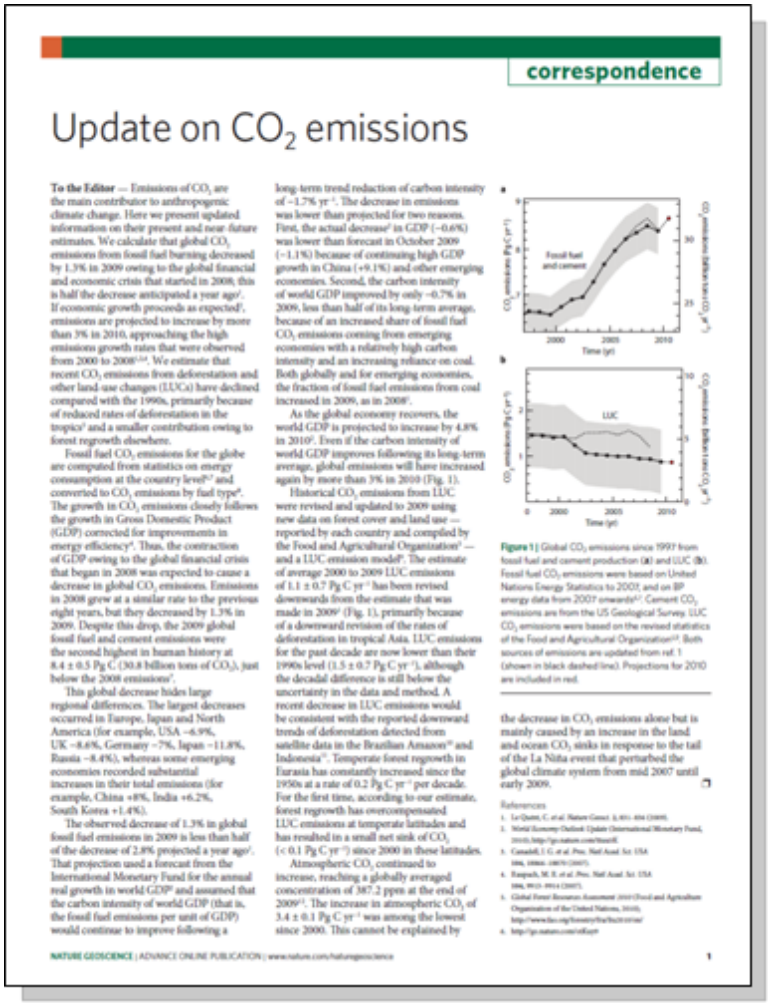

correspondence

Update on CO_2 emissions

To the Editor — Emissions of CO_2 are the main contributor to anthropogenic climate change. Here we present updated information on their present and near-future estimates. We calculate that global CO_2 emissions from fossil fuel burning decreased by 1.3% in 2009 owing to the global financial and economic crisis that started in 2008; this is half the decrease anticipated a year ago[1]. If economic growth proceeds as expected[2], emissions are projected to increase by more than 3% in 2010, approaching the high emissions growth rates that were observed from 2000 to 2008[3,4]. We estimate that recent CO_2 emissions from deforestation and other land-use changes (LUCs) have declined compared with the 1990s, primarily because of reduced rates of deforestation in the tropics[5] and a smaller contribution owing to forest regrowth elsewhere.

Fossil fuel CO_2 emissions for the globe are computed from statistics on energy consumption at the country level[6,7] and converted to CO_2 emissions by fuel type[8]. The growth in CO_2 emissions closely follows the growth in Gross Domestic Product (GDP) corrected for improvements in energy efficiency[9]. Thus, the contraction of GDP owing to the global financial crisis that began in 2008 was expected to cause a decrease in global CO_2 emissions. Emissions in 2008 grew at a similar rate to the previous eight years, but they decreased by 1.3% in 2009. Despite this drop, the 2009 global fossil fuel and cement emissions were the second highest in human history at 8.4 ± 0.5 Pg C (30.8 billion tons of CO_2), just below the 2008 emissions[1].

This global decrease hides large regional differences. The largest decreases occurred in Europe, Japan and North America (for example, USA −6.9%, UK −8.6%, Germany −7%, Japan −11.8%, Russia −8.4%), whereas some emerging economies recorded substantial increases in their total emissions (for example, China +8%, India +6.2%, South Korea +1.4%).

The observed decrease of 1.3% in global fossil fuel emissions in 2009 is less than half of the decrease of 2.8% projected a year ago[1]. That projection used a forecast from the International Monetary Fund for the annual real growth in world GDP[2] and assumed that the carbon intensity of world GDP (that is, the fossil fuel emissions per unit of GDP) would continue to improve following a long-term trend reduction of carbon intensity of −1.7% yr^{-1}. The decrease in emissions was lower than projected for two reasons. First, the actual decrease[2] in GDP (−0.6%) was lower than forecast in October 2009 (−1.1%) because of continuing high GDP growth in China (+9.1%) and other emerging economies. Second, the carbon intensity of world GDP improved by only −0.7% in 2009, less than half of its long-term average, because of an increased share of fossil fuel CO_2 emissions coming from emerging economies with a relatively high carbon intensity and an increasing reliance on coal. Both globally and for emerging economies, the fraction of fossil fuel emissions from coal increased in 2009, as in 2008[3].

As the global economy recovers, the world GDP is projected to increase by 4.8% in 2010[2]. Even if the carbon intensity of world GDP improves following its long-term average, global emissions will have increased again by more than 3% in 2010 (Fig. 1).

Historical CO_2 emissions from LUC were revised and updated to 2009 using new data on forest cover and land use — reported by each country and compiled by the Food and Agricultural Organization[5] — and a LUC emission model[8]. The estimate of average 2000 to 2009 LUC emissions of 1.1 ± 0.7 Pg C yr^{-1} has been revised downwards from the estimate that was made in 2009[8] (Fig. 1), primarily because of a downward revision of the rates of deforestation in tropical Asia. LUC emissions for the past decade are now lower than their 1990s level (1.5 ± 0.7 Pg C yr^{-1}), although the decadal difference is still below the uncertainty in the data and method. A recent decrease in LUC emissions would be consistent with the reported downward trends of deforestation detected from satellite data in the Brazilian Amazon[10] and Indonesia[11]. Temperate forest regrowth in Eurasia has constantly increased since the 1950s at a rate of 0.2 Pg C yr^{-1} per decade. For the first time, according to our estimate, forest regrowth has overcompensated LUC emissions at temperate latitudes and has resulted in a small net sink of CO_2 (< 0.1 Pg C yr^{-1}) since 2000 in these latitudes.

Atmospheric CO_2 continued to increase, reaching a globally averaged concentration of 387.2 ppm at the end of 2009[12]. The increase in atmospheric CO_2 of 3.4 ± 0.1 Pg C yr^{-1} was among the lowest since 2000. This cannot be explained by the decrease in CO_2 emissions alone but is mainly caused by an increase in the land and ocean CO_2 sinks in response to the tail of the La Niña event that perturbed the global climate system from mid 2007 until early 2009.

Figure 1 | Global CO_2 emissions since 1997 from fossil fuel and cement production (a) and LUC (b). Fossil fuel CO_2 emissions were based on United Nations Energy Statistics to 2007, and on BP energy data from 2007 onwards[6,7]. Cement CO_2 emissions are from the US Geological Survey. LUC CO_2 emissions were based on the revised statistics of the Food and Agricultural Organization[5,8]. Both sources of emissions are updated from ref. 1 (shown in black dashed line). Projections for 2010 are included in red.

References

1. Le Quéré, C. et al. Nature Geosci. 2, 831–836 (2009).
2. World Economy Outlook Update (International Monetary Fund, 2010). http://go.nature.com/8ouzfE
3. Canadell, J. G. et al. Proc. Natl Acad. Sci. USA 104, 18866–18870 (2007).
4. Raupach, M. R. et al. Proc. Natl Acad. Sci. USA 104, 10288–10293 (2007).
5. Global Forest Resources Assessment 2010 (Food and Agriculture Organization of the United Nations, 2010). http://www.fao.org/forestry/fra/fra2010/en/
6. http://go.nature.com/vdlaqv

http://www.globalcarbonproject.org/carbonbudget

Friedlingstein P, Houghton RA, Marland G, Hackler J, Boden TA, Conway TJ, Canadell JG, Raupach MR, Ciais P, Le Quéré C. Update on CO_2 emissions. **Nature Geoscience**, DOI 10.1038/ngeo_1022, Online 21 November 2010.
http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1022.html

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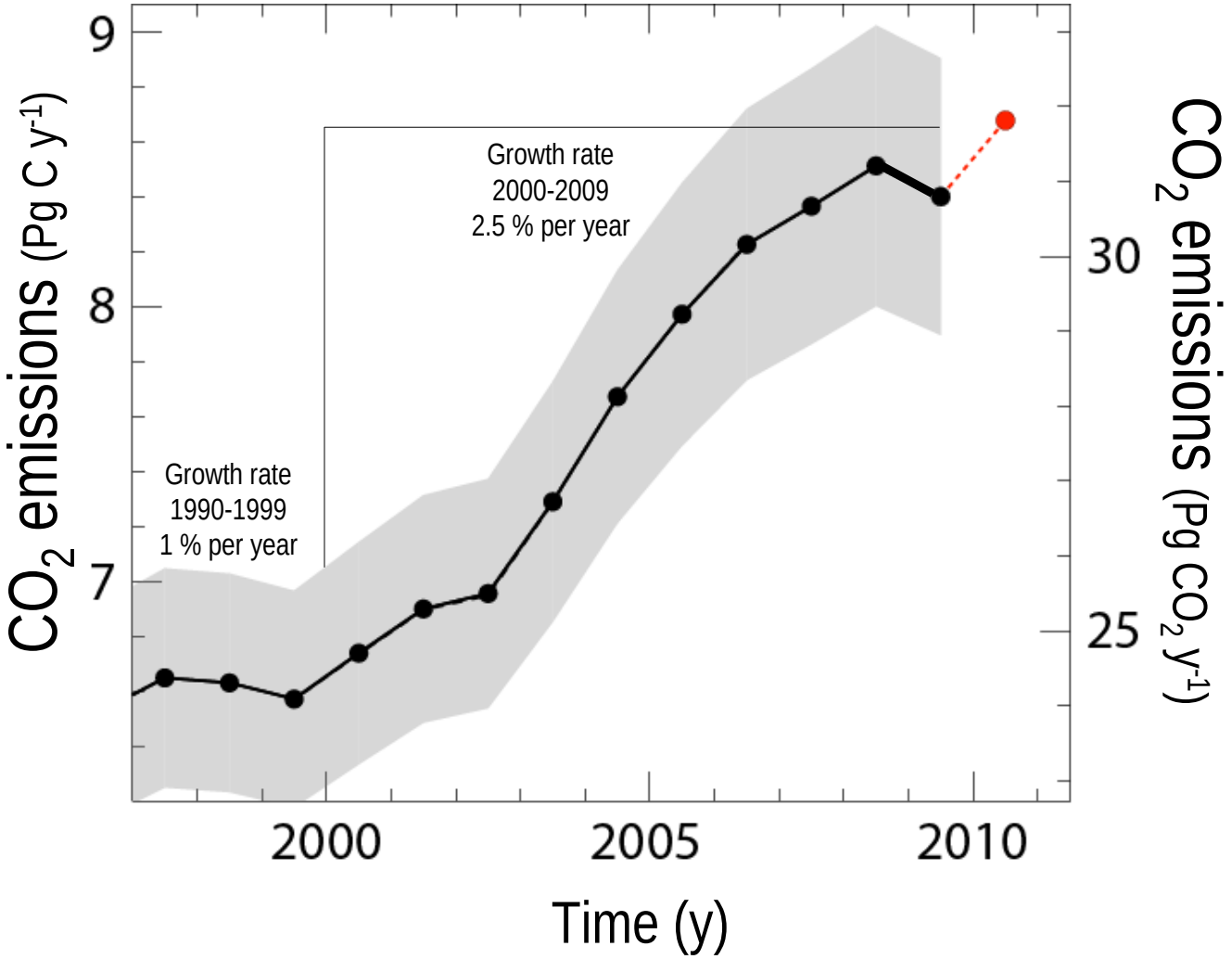
Units

- 1 Pg = 1 Petagram = $1x10^{15}$g = 1 Billion metric tons = 1 Gigaton
- 1 Tg = 1 Teragram = $1x10^{12}$g = 1 Million metric tons
- 1 Kg Carbon (C) = 3.67 Kg Carbon Dioxide (CO_2)

Fossil Fuel CO_2 Emissions



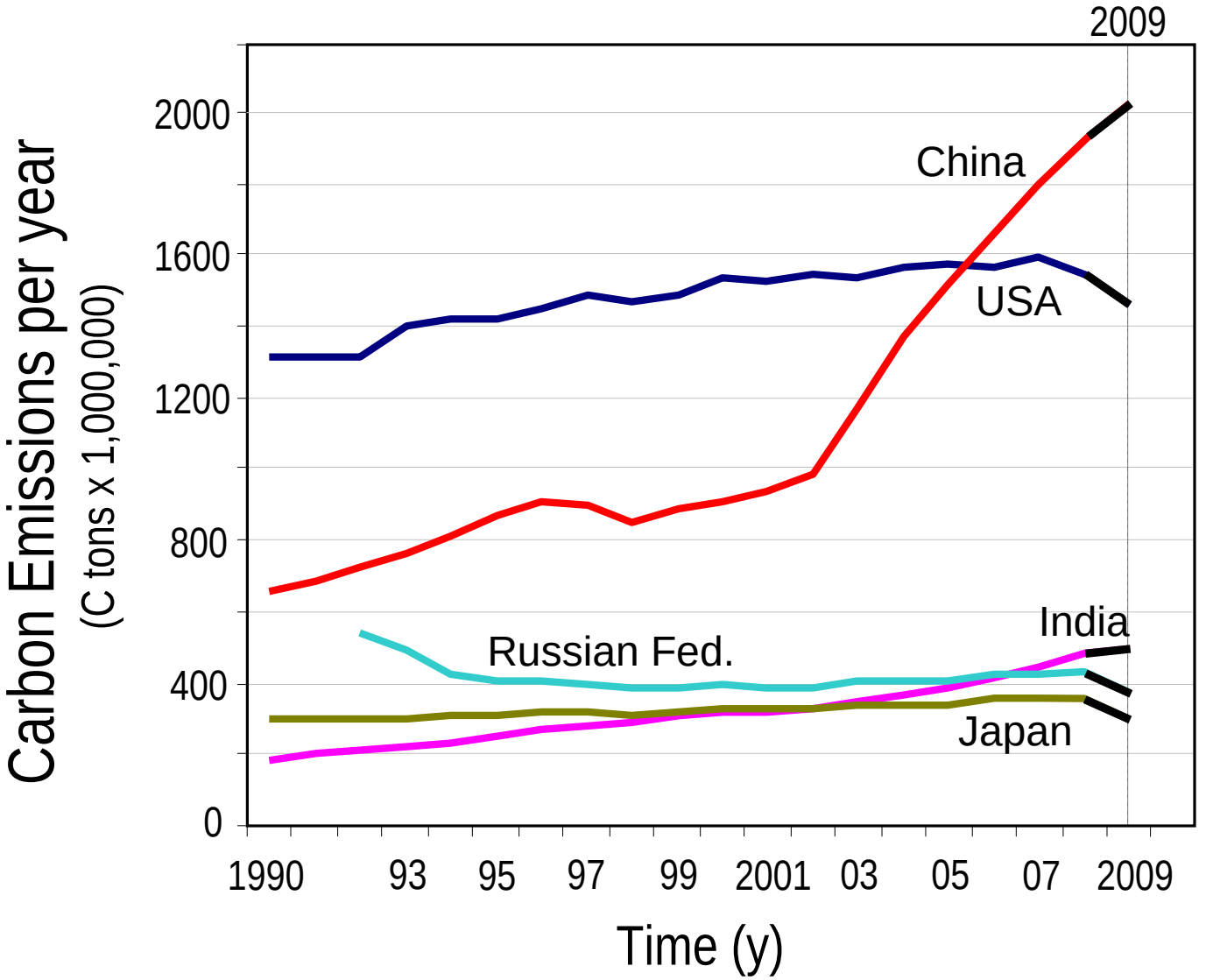
2009:
Emissions:8.4±0.5 PgC
Growth rate: -1.3%
1990 level: +37%

2000-2008
Growth rate: +3.2%

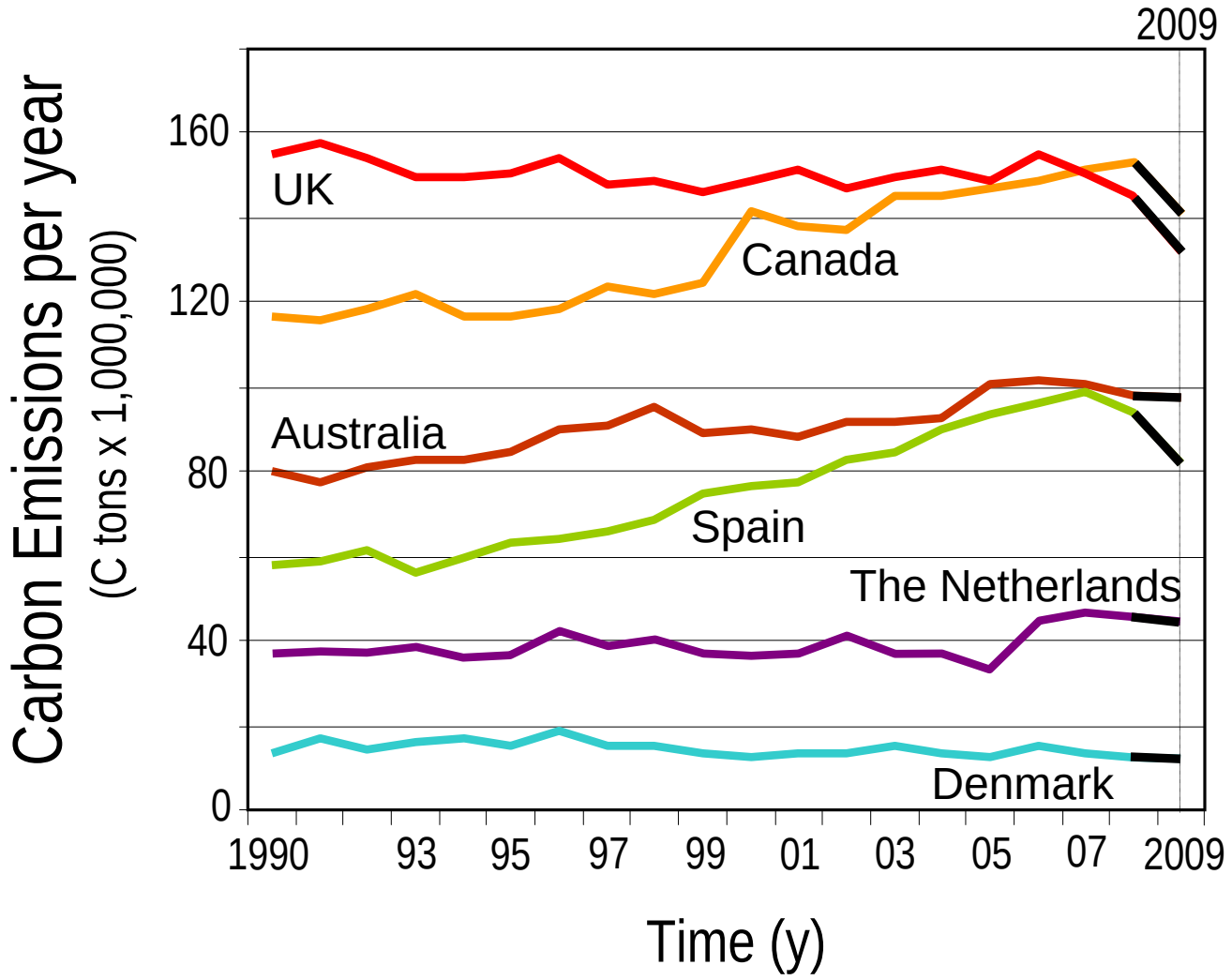
2010 (projected):
Growth rate: >3%

Friedlingstein et al. 2010, Nature Geoscience; Gregg Marland, Thomas Boden-CDIAC 2010

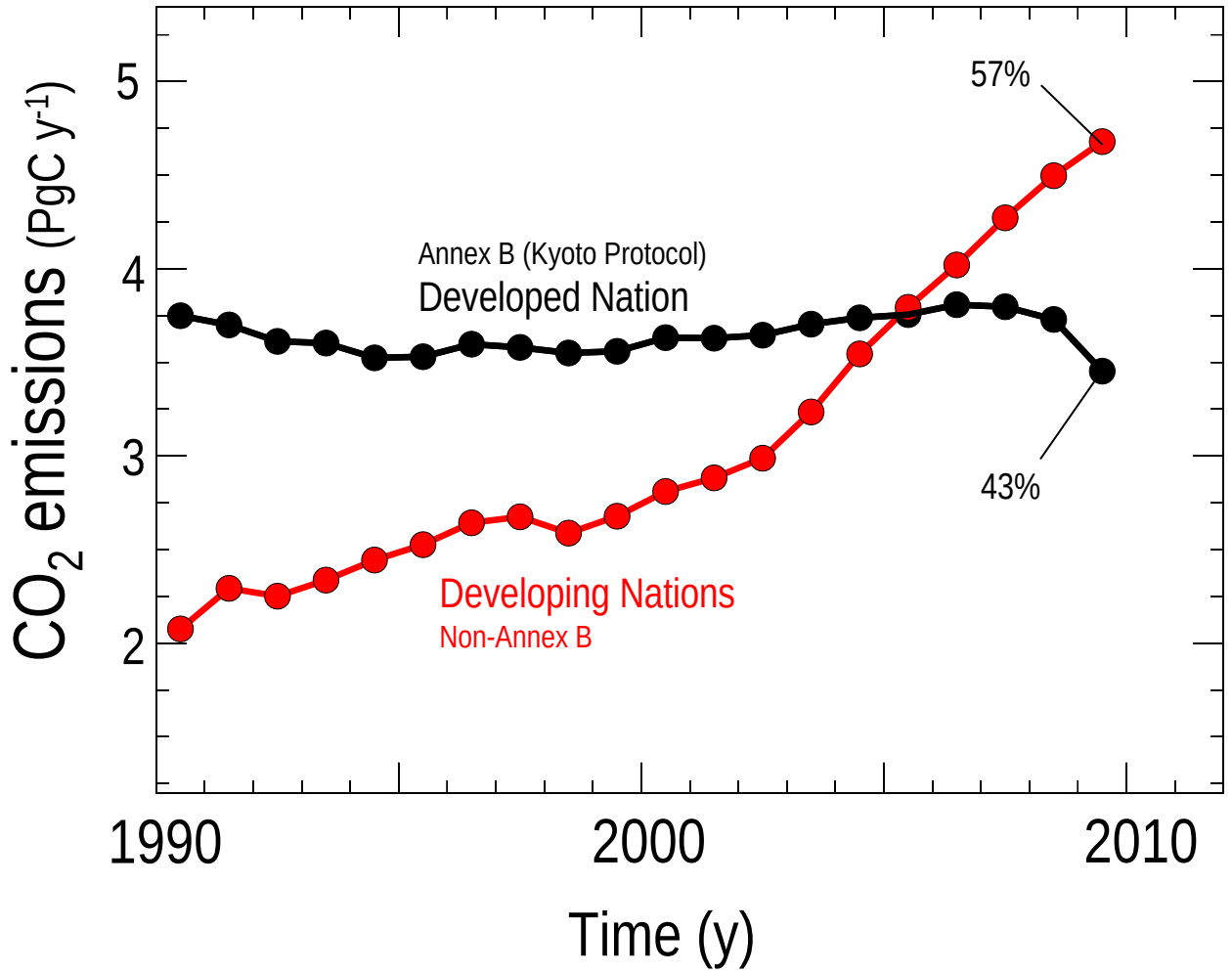
Fossil Fuel CO_2 Emissions: Top Emitters



Fossil Fuel CO_2 Emissions: Profile Examples

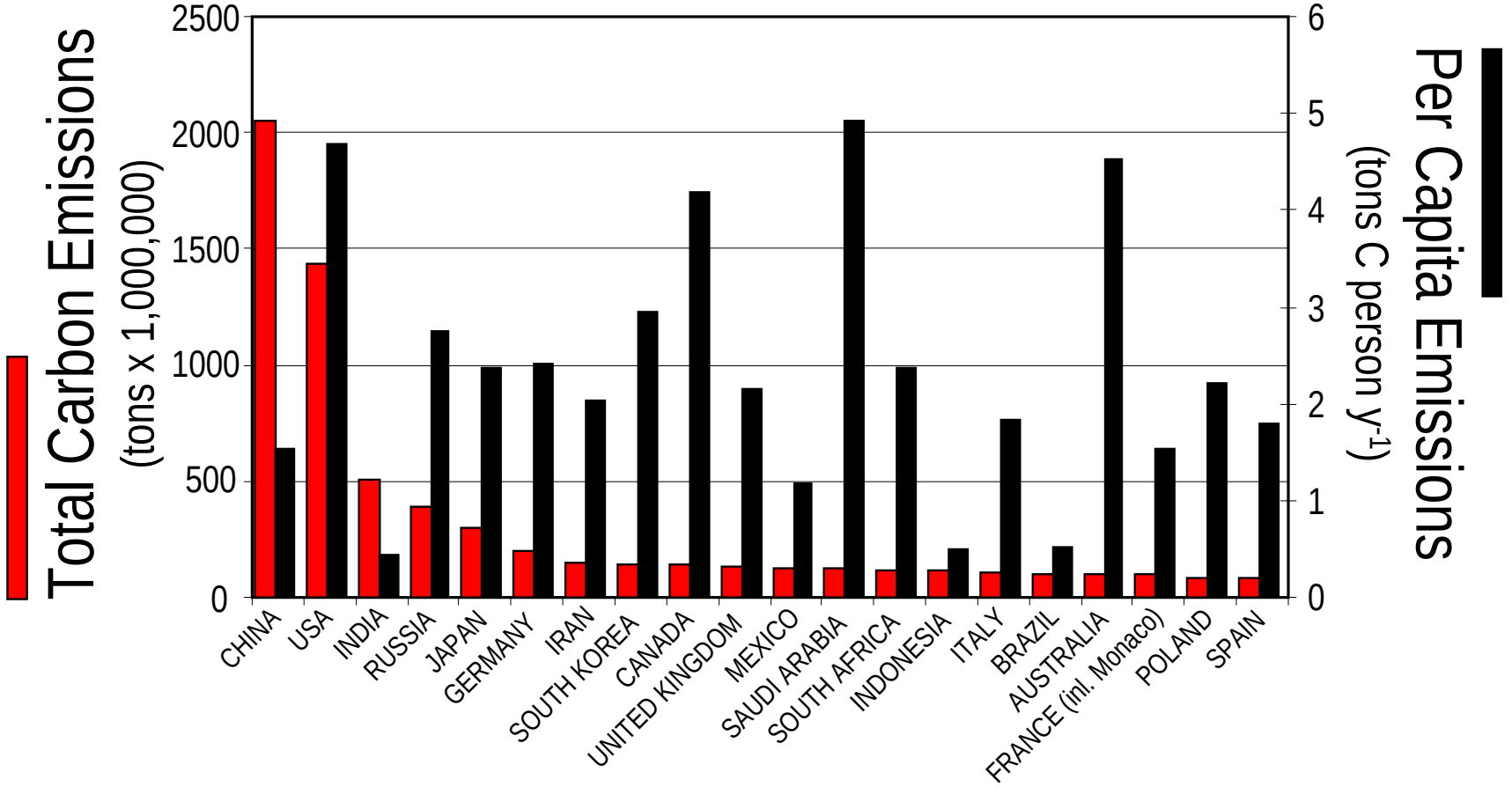


Fossil Fuel CO_2 Emissions

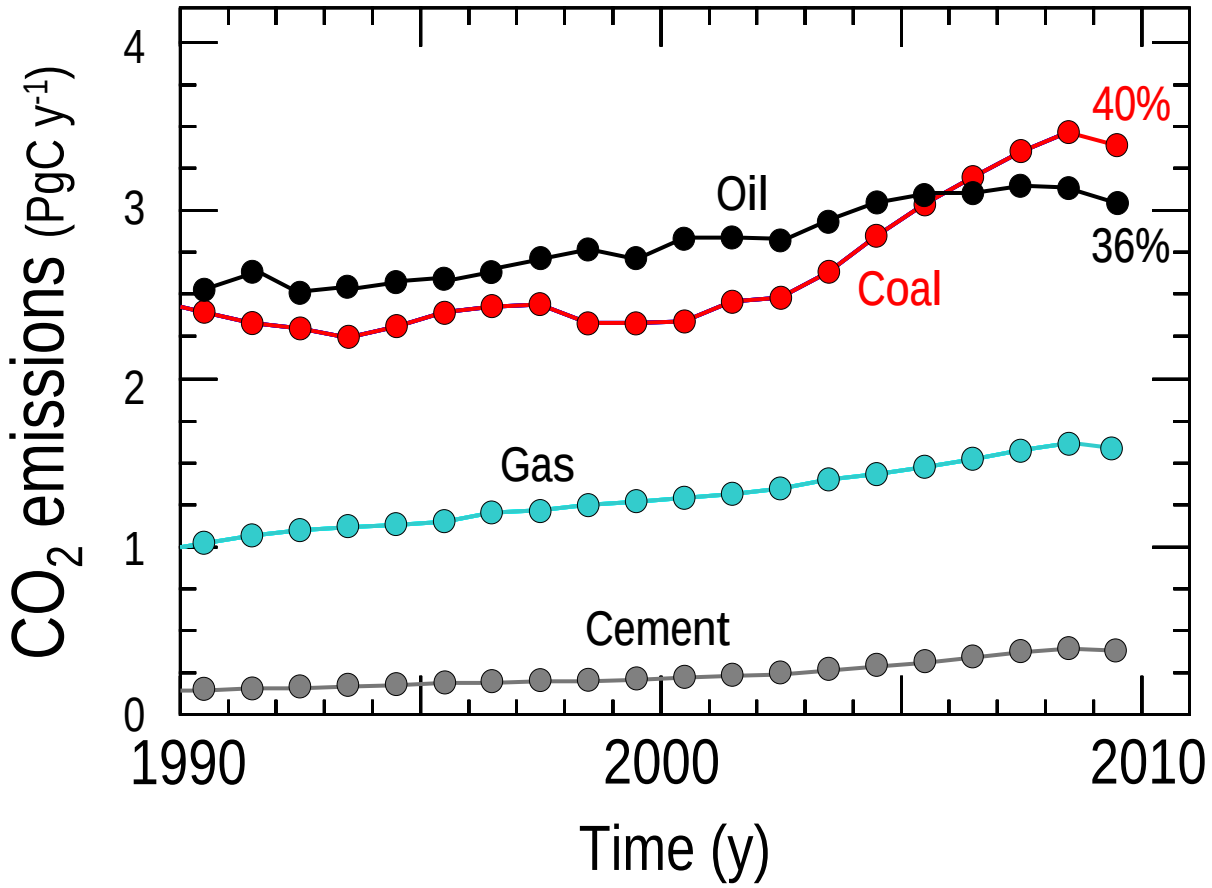


Updated from Le Quéré et al. 2009, Nature Geoscience; CDIAC 20010

Top 20 CO_2 Emitters & Per Capita Emissions 2009

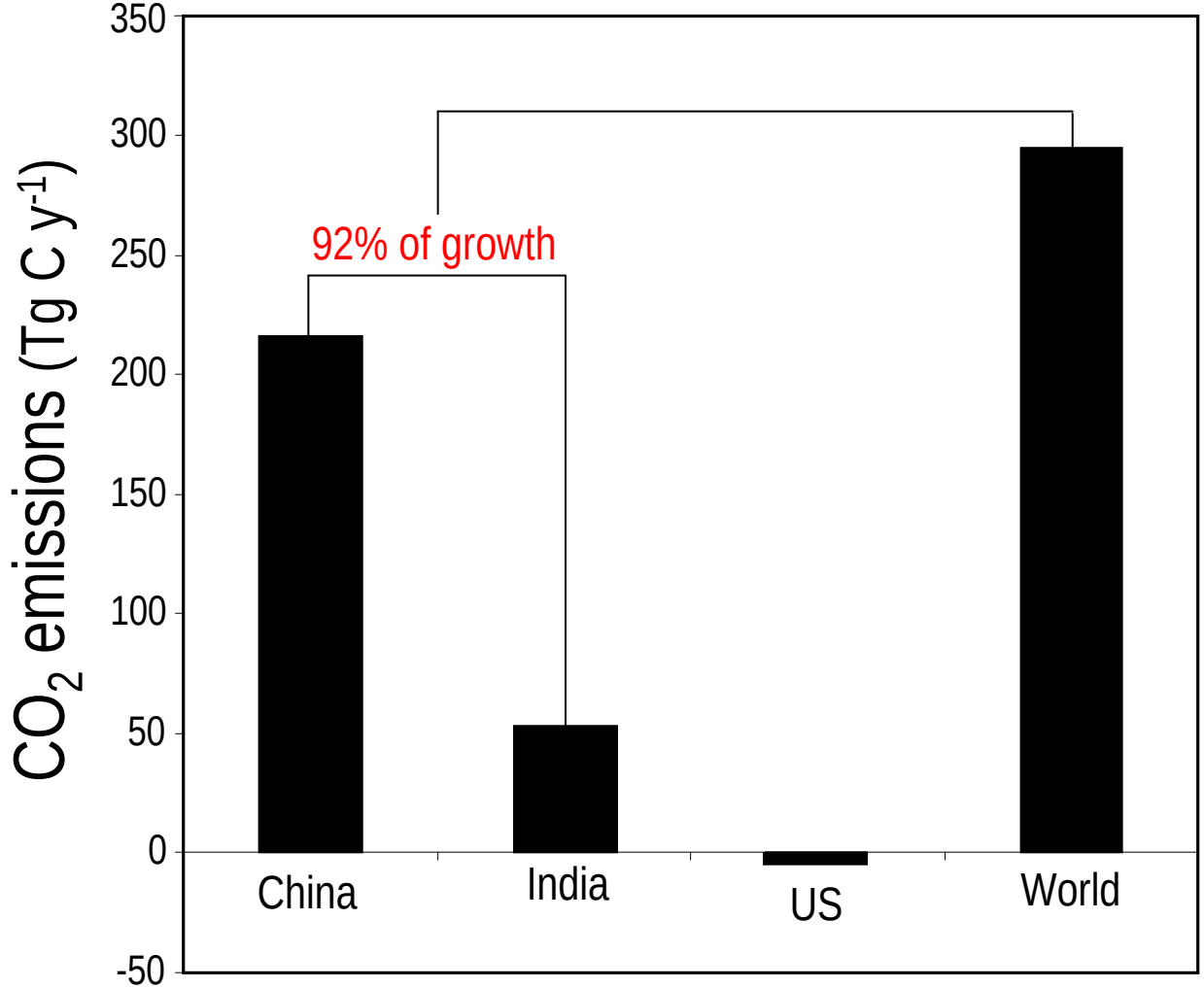


CO_2 Emissions by Fossil Fuel Type



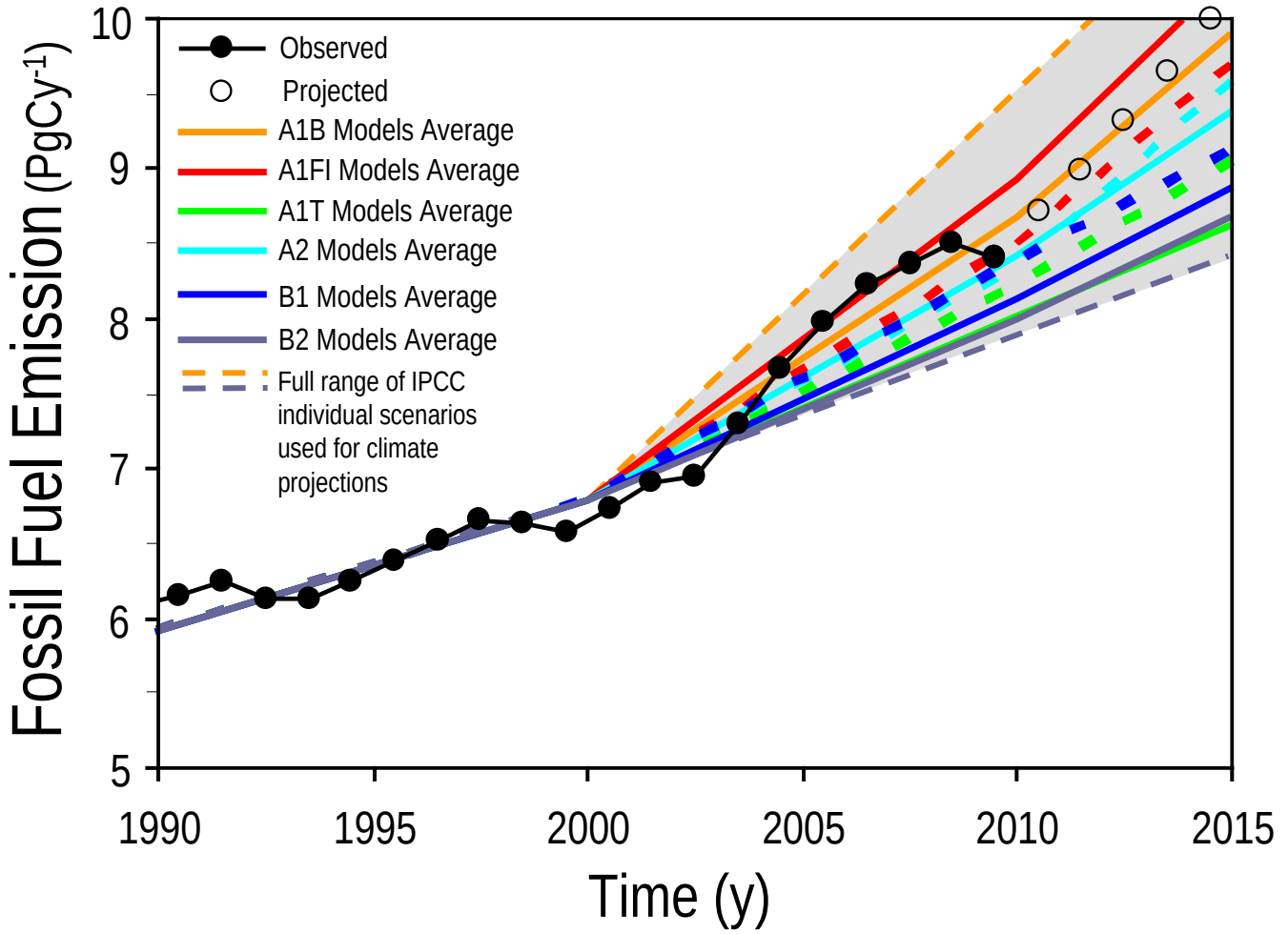
Updated from Le Quéré et al. 2009, Nature Geoscience; Data: Gregg Marland, Thomas Boden-CDIAC 2010

Change in CO_2 Emissions from Coal (2007 to 2009)



Global Carbon Project 2010; Data: Gregg Marland, Thomas Boden-CDIAC 2010

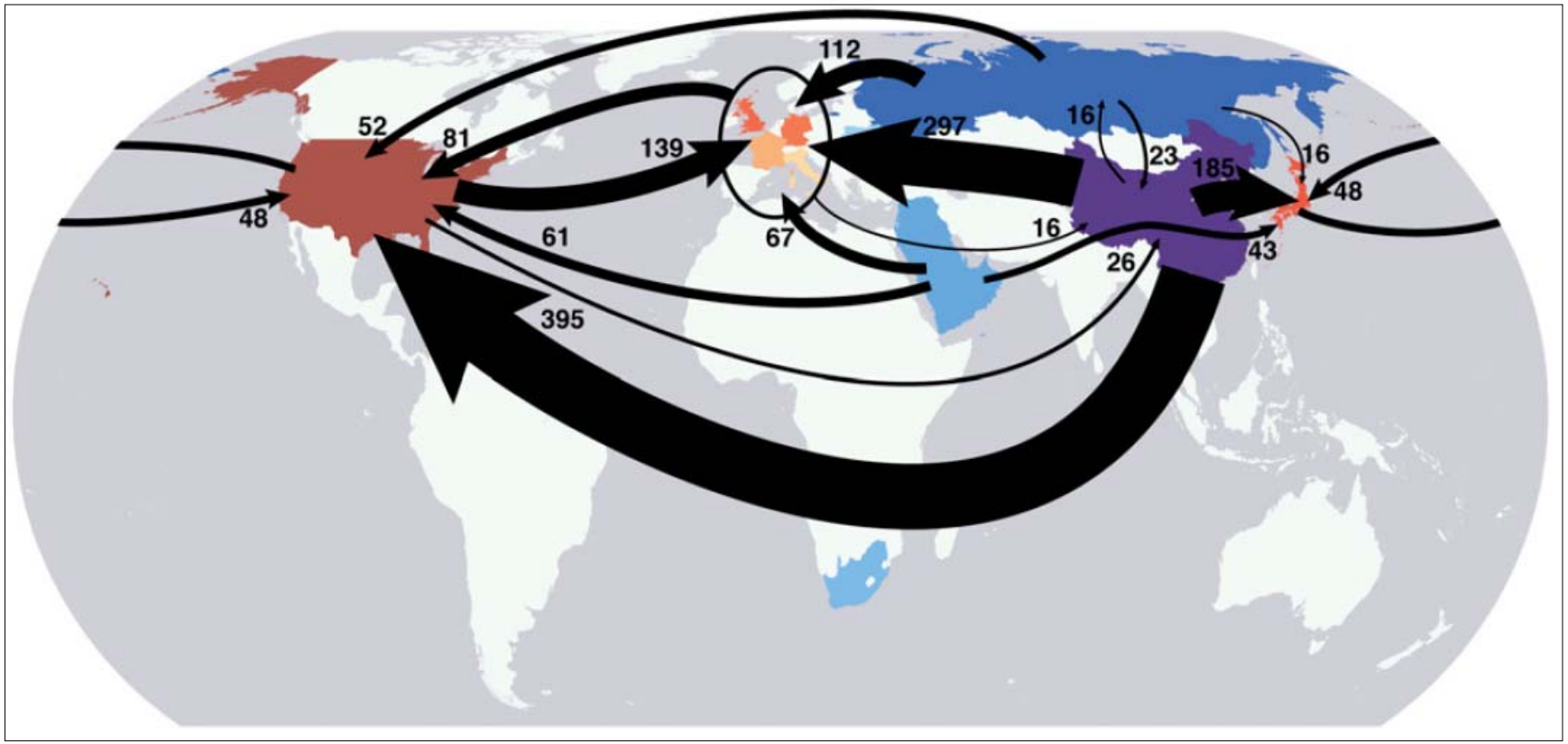
Fossil Fuel Emissions: Actual vs. IPCC Scenarios



Updated from Raupach et al. 2007, PNAS; Data: Gregg Marland, Thomas Boden-CDIAC 2010; International Monetary Fund 2010

Fluxes of Emissions Embodied in Trade (Mt CO_2 y^{-1})

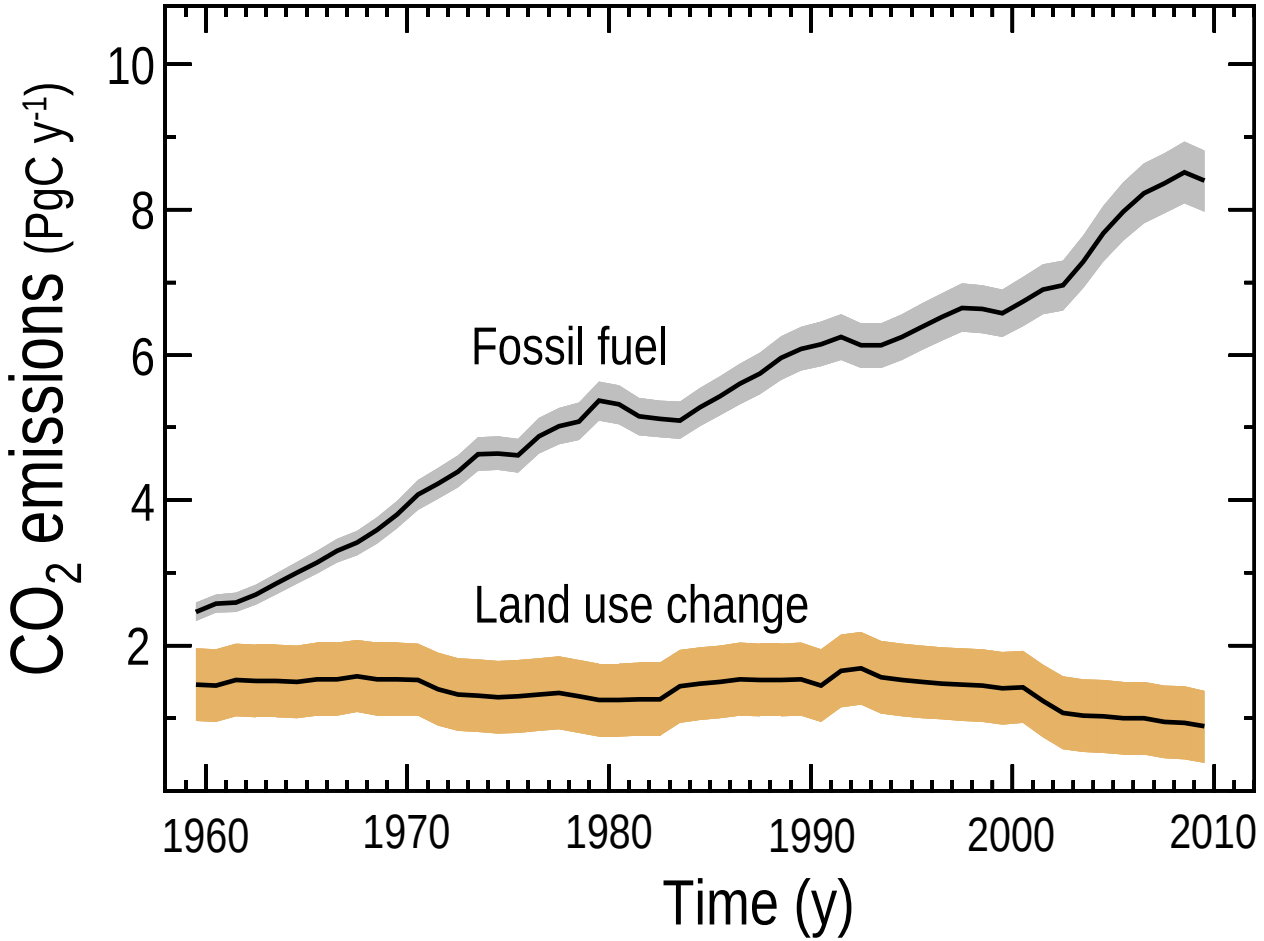
Year 2004



From dominant net exporting countries (blue) to dominant net importing countries (red).

Davis & Caldeira 2010, PNAS; See also Peters & Hertwich 2008, Environ, Sci & Tech.

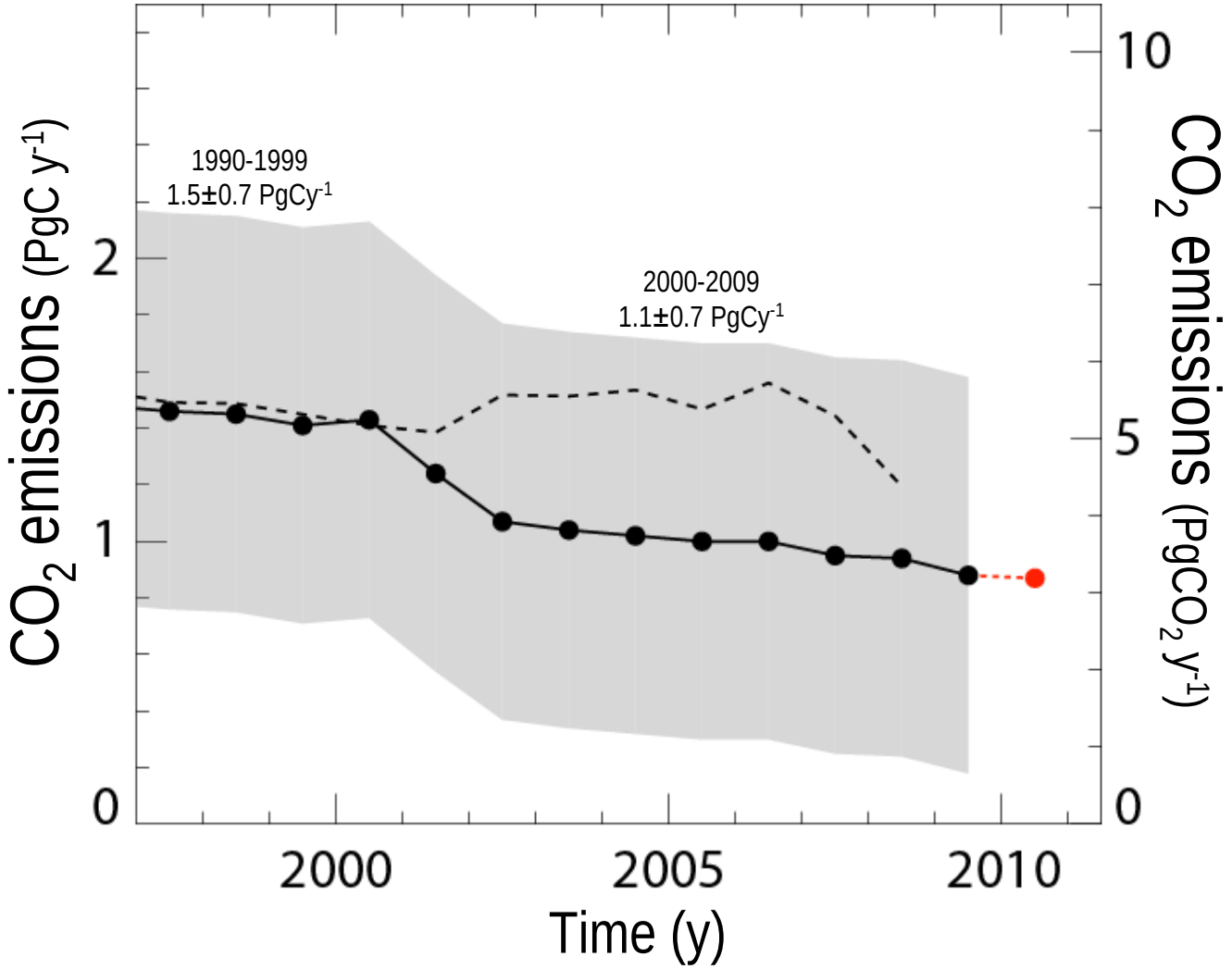
CO_2 Emissions from FF and LUC (1960-2009)



LUC emissions now
~10% of total CO_2 emissions

Updated from Le Quéré et al. 2009, Nature Geoscience

CO_2 Emissions from Land Use Change



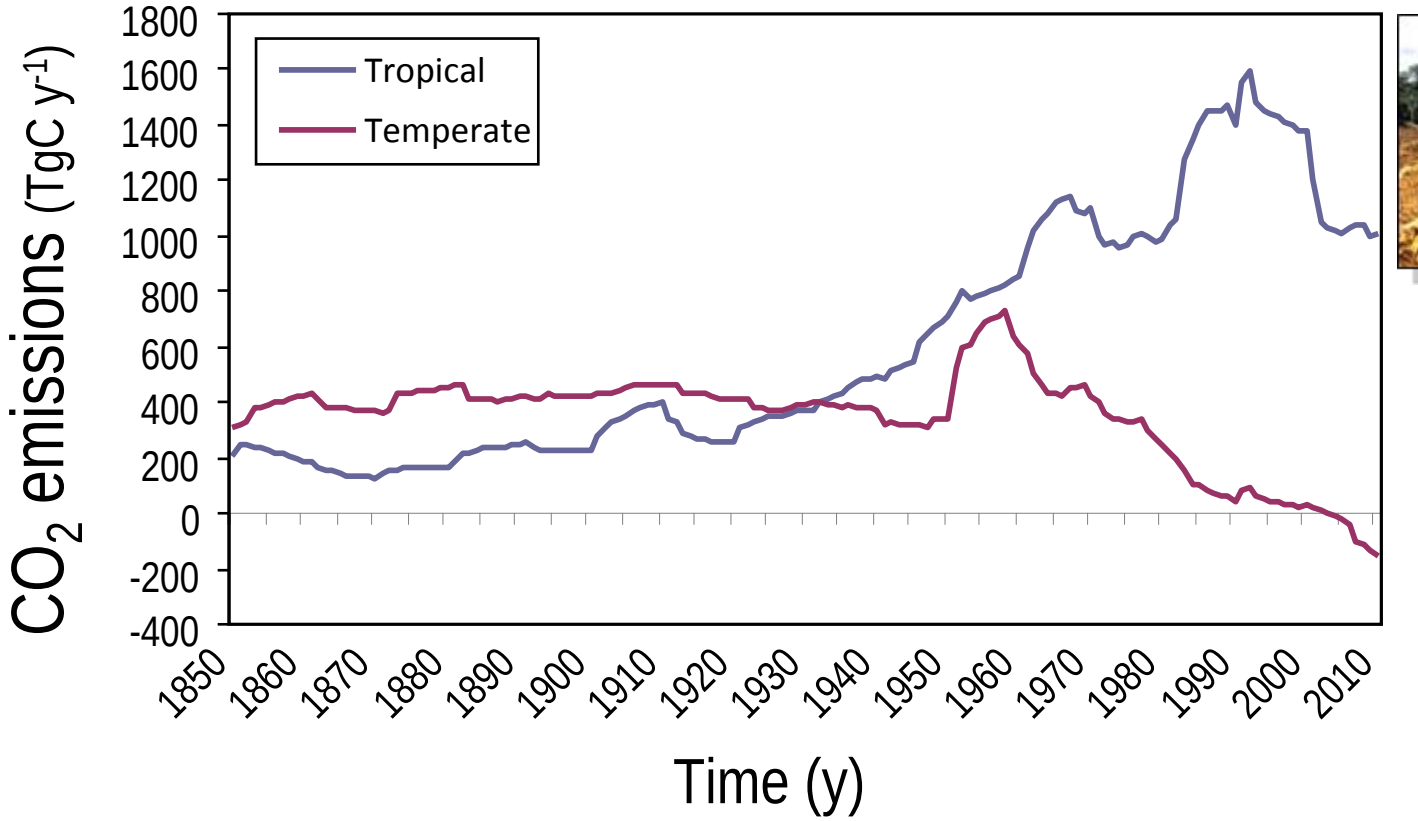
1990s
Emissions: 1.5±0.7 PgC

2000-2005
Emissions: 1.3±0.7 PgC

2006-2010:
Emissions: 0.9±0.7 PgC

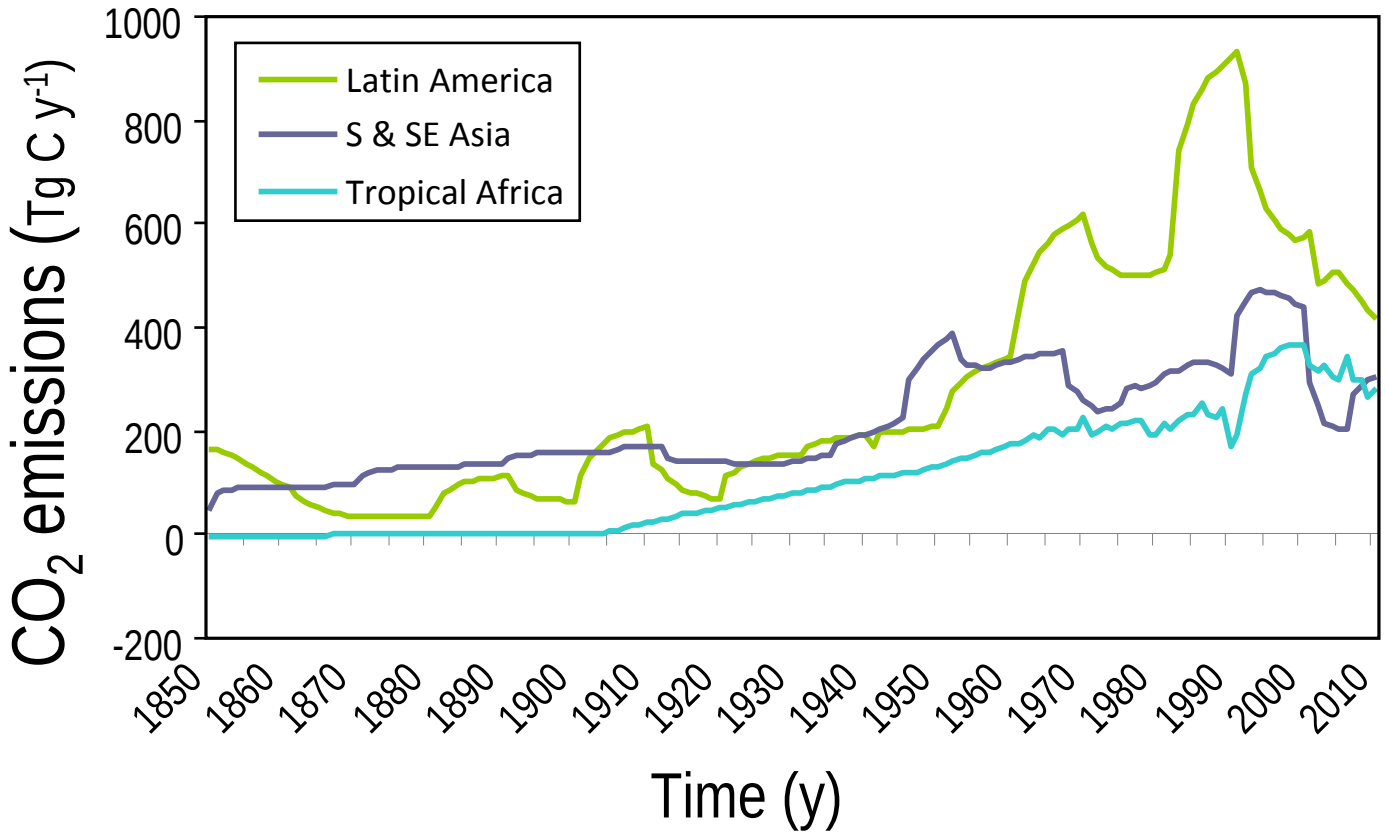
Friedlingstein et al. 2010, Nature Geoscience; Data: RA Houghton, GFRA 2010

Emissions from Land Use Change (1850-2009)



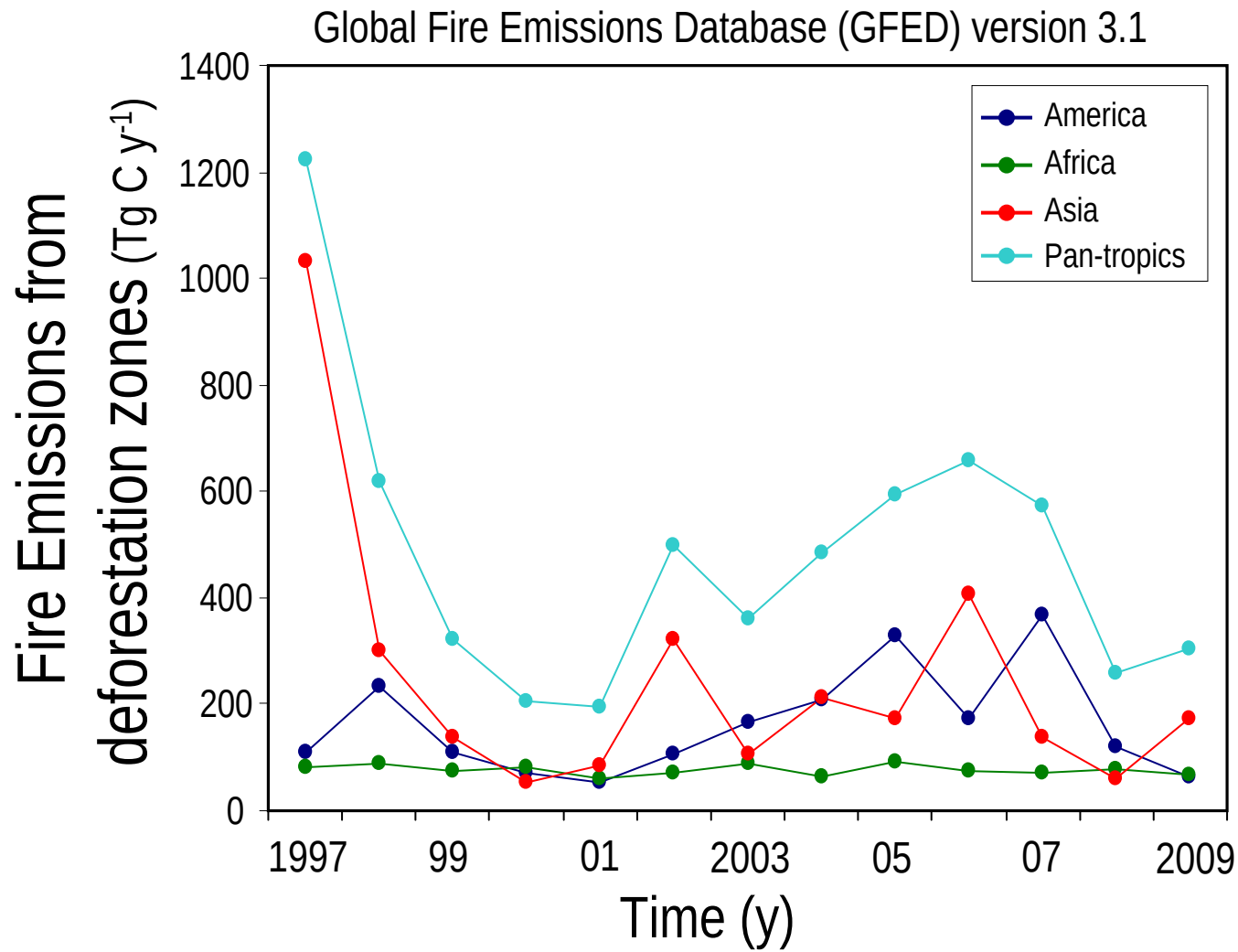
R.A. Houghton 2010, personal communication; GFRA 2010

Emissions from Land Use Change (1850-2009)



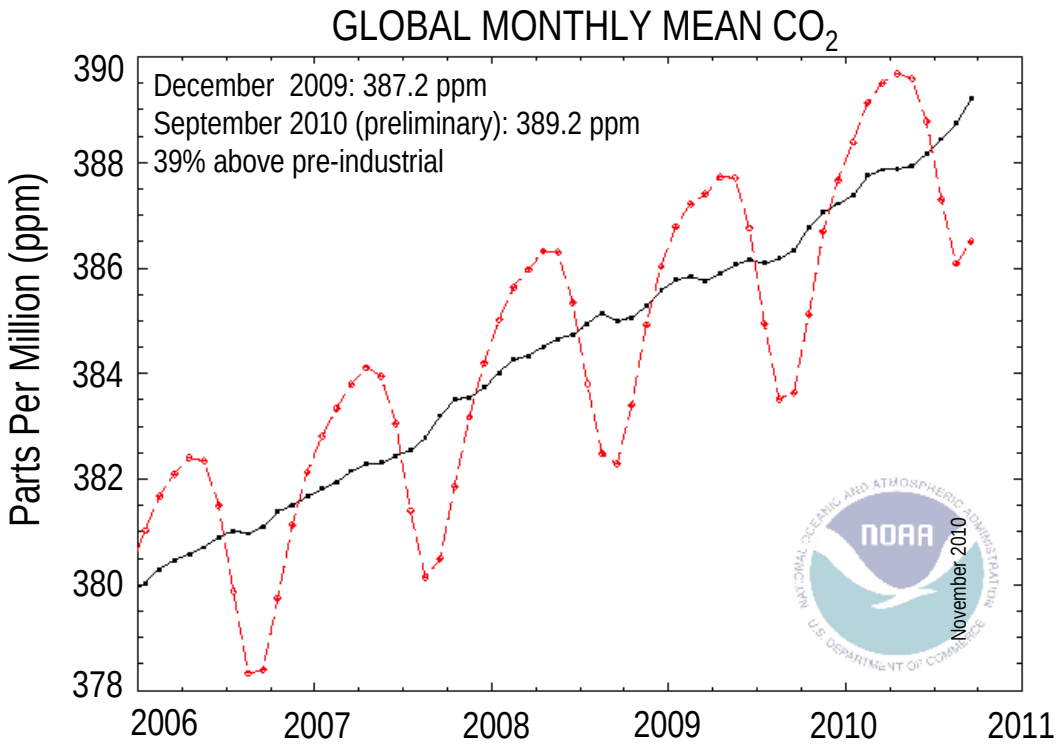
R.A. Houghton 2010, personal communication; GFRA 2010

Fire Emissions from Deforestation Zones



van der Werf et al. 2010, Atmospheric Chemistry and Physics Discussions

Atmospheric CO_2 Concentration



Annual Mea	Growth Rate (ppm y^{-1})
2009	1.62
2008	1.80
2007	2.14
2006	1.84
2005	2.39
2004	1.60
2003	2.19
2002	2.40
2001	1.89
2000	1.22

1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{1}
1990 – 1999: 1.5 ppm y^{-1}
2000 - 2009: 1.9 ppm y^{-1}

Data Source: Pieter Tans and Thomas Conway, 2010, NOAA/ESRL

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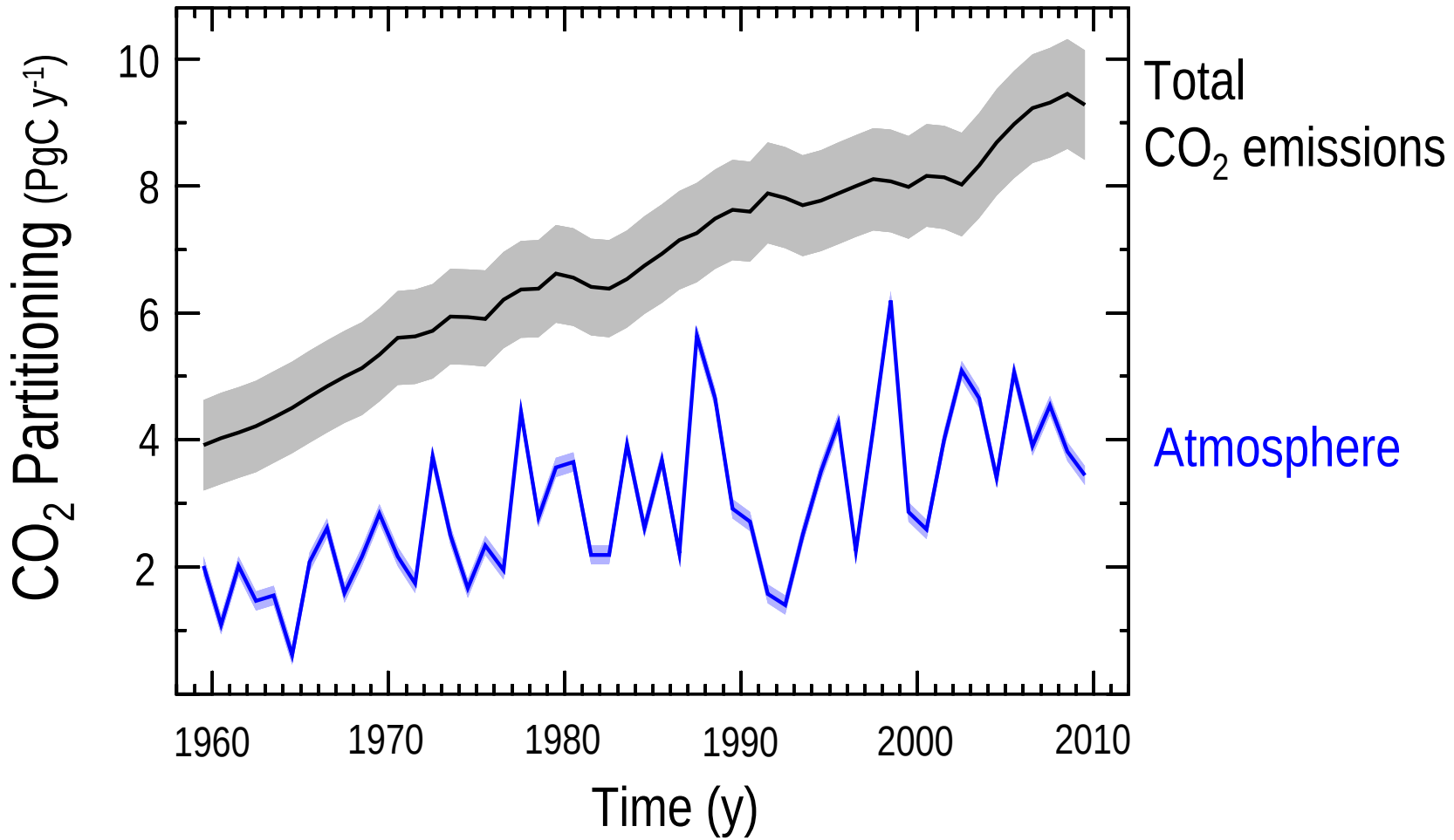
Key Diagnostic of the Carbon Cycle

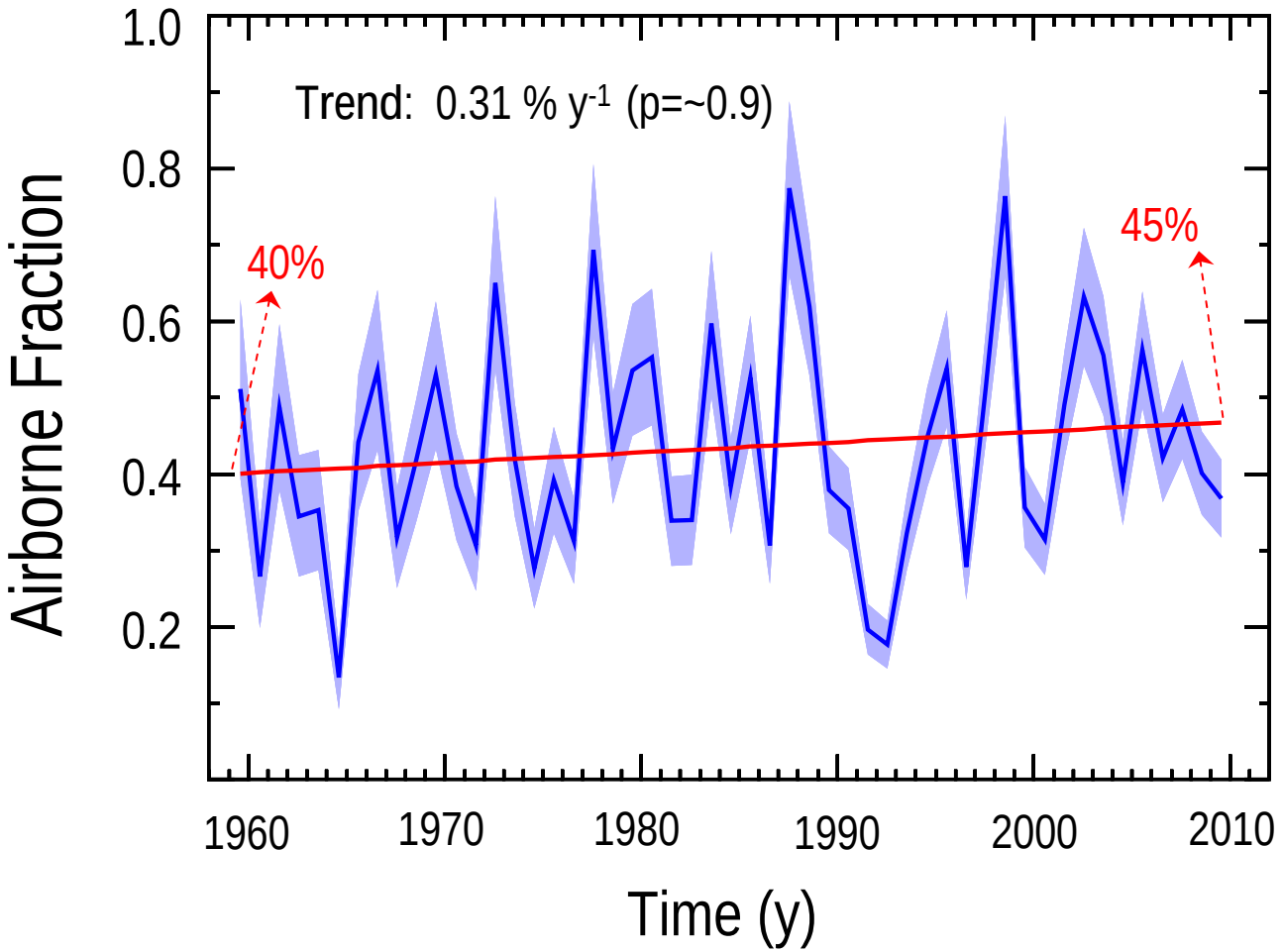
Evolution of the fraction of total emissions that remain in the atmosphere



Updated from Le Quéré et al. 2009, Nature Geoscience; Data: NOAA 2010, CDIAC 2010

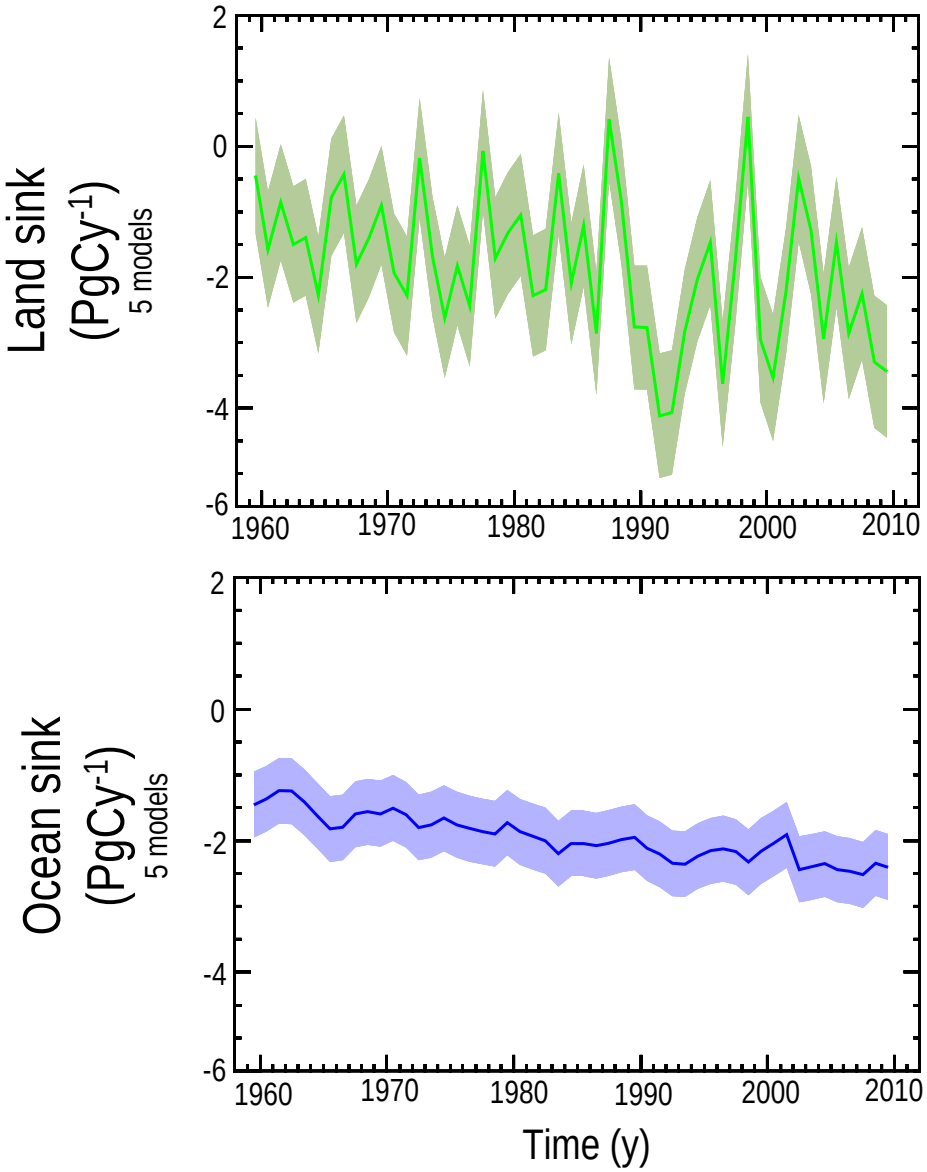
Airborne Fraction

Fraction of total CO_2 emissions that remains in the atmosphere



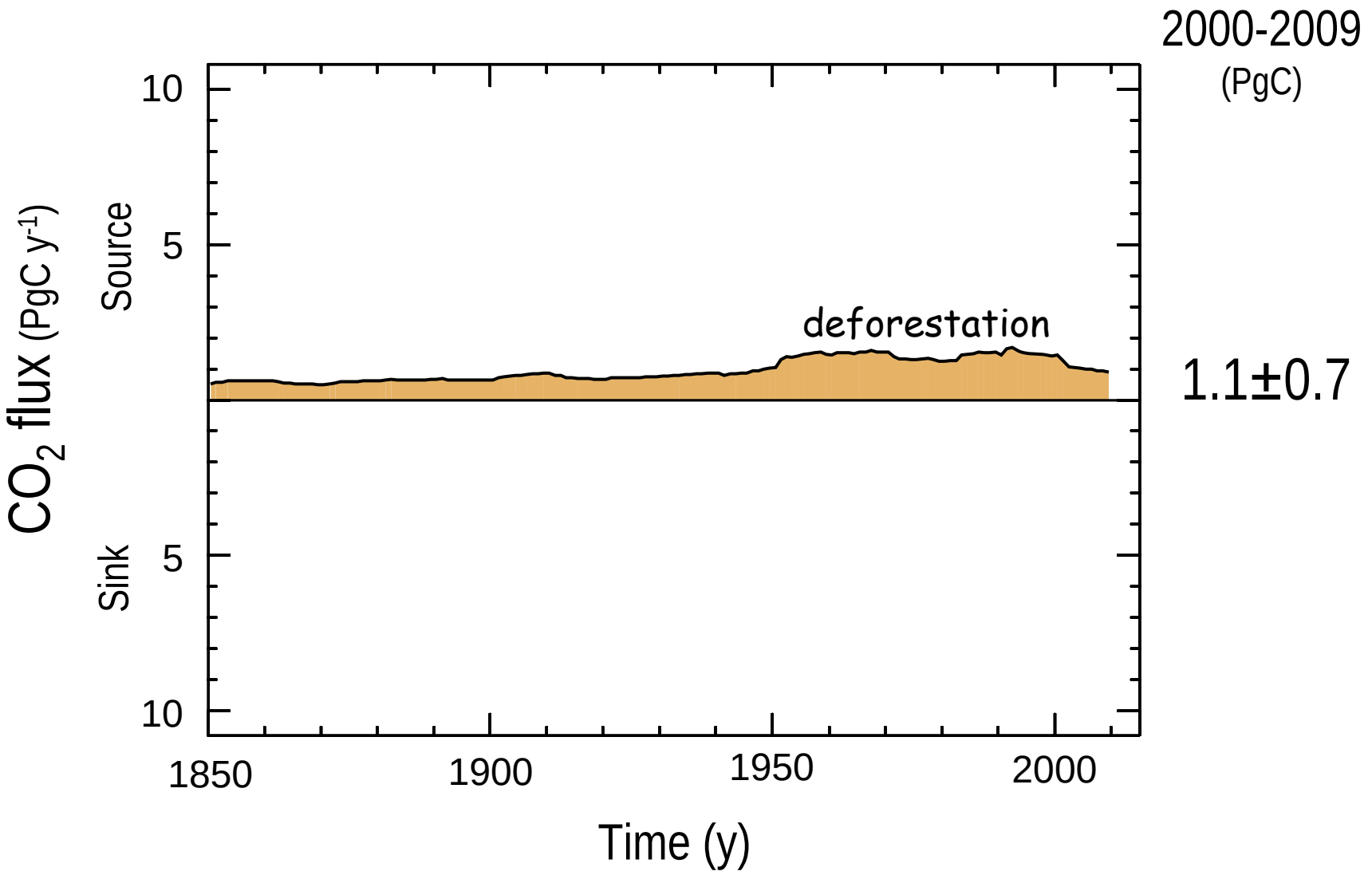
Updated from Le Quéré et al. 2009, Nature Geoscience; Raupach et al. 2008, Biogeosciences; Canadell et al. 2007, PNAS

Modelled Natural CO_2 Sinks



Updated from Le Quéré et al. 2009, Nature Geoscience

Human Perturbation of the Global Carbon Budget



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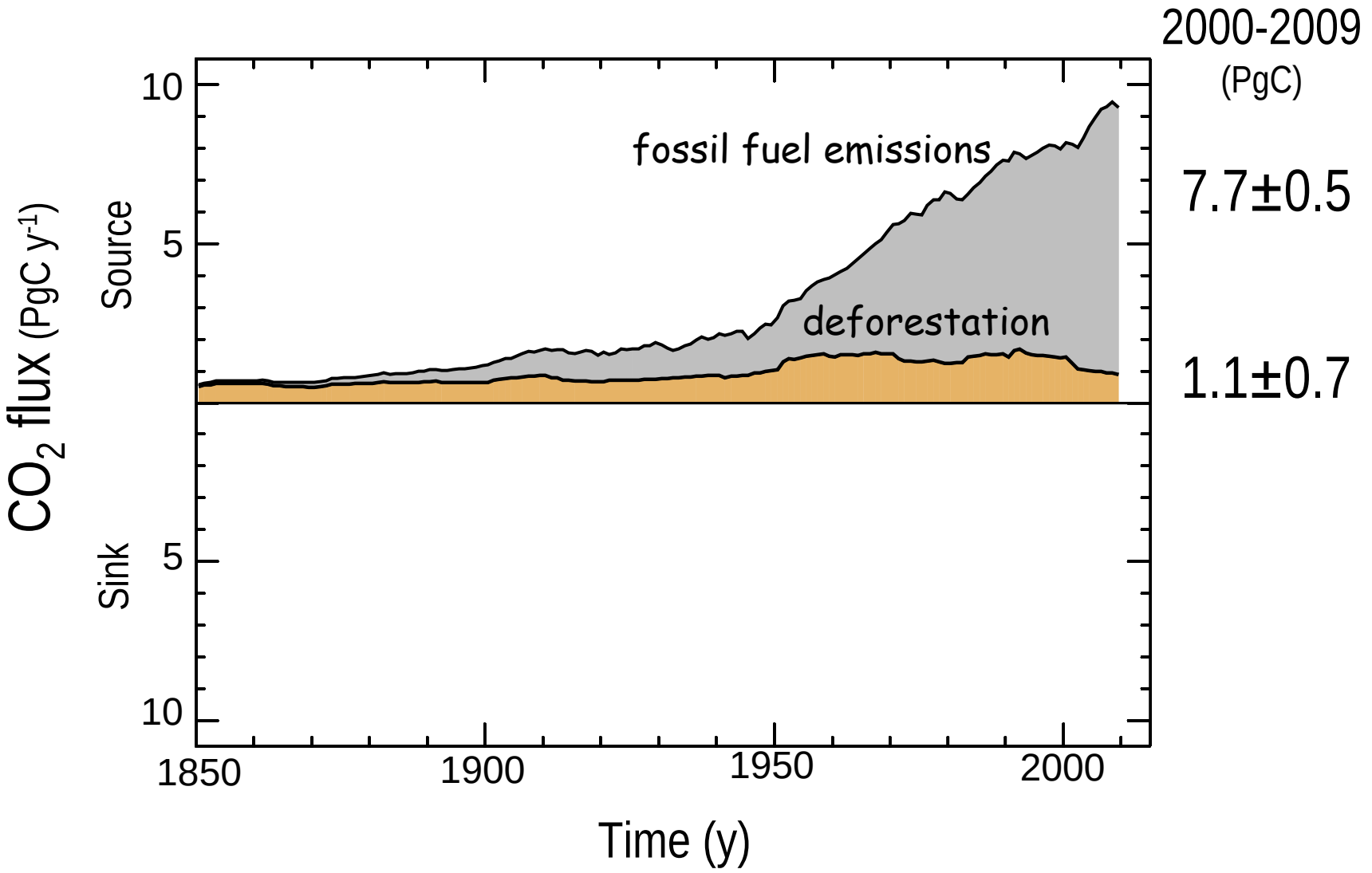

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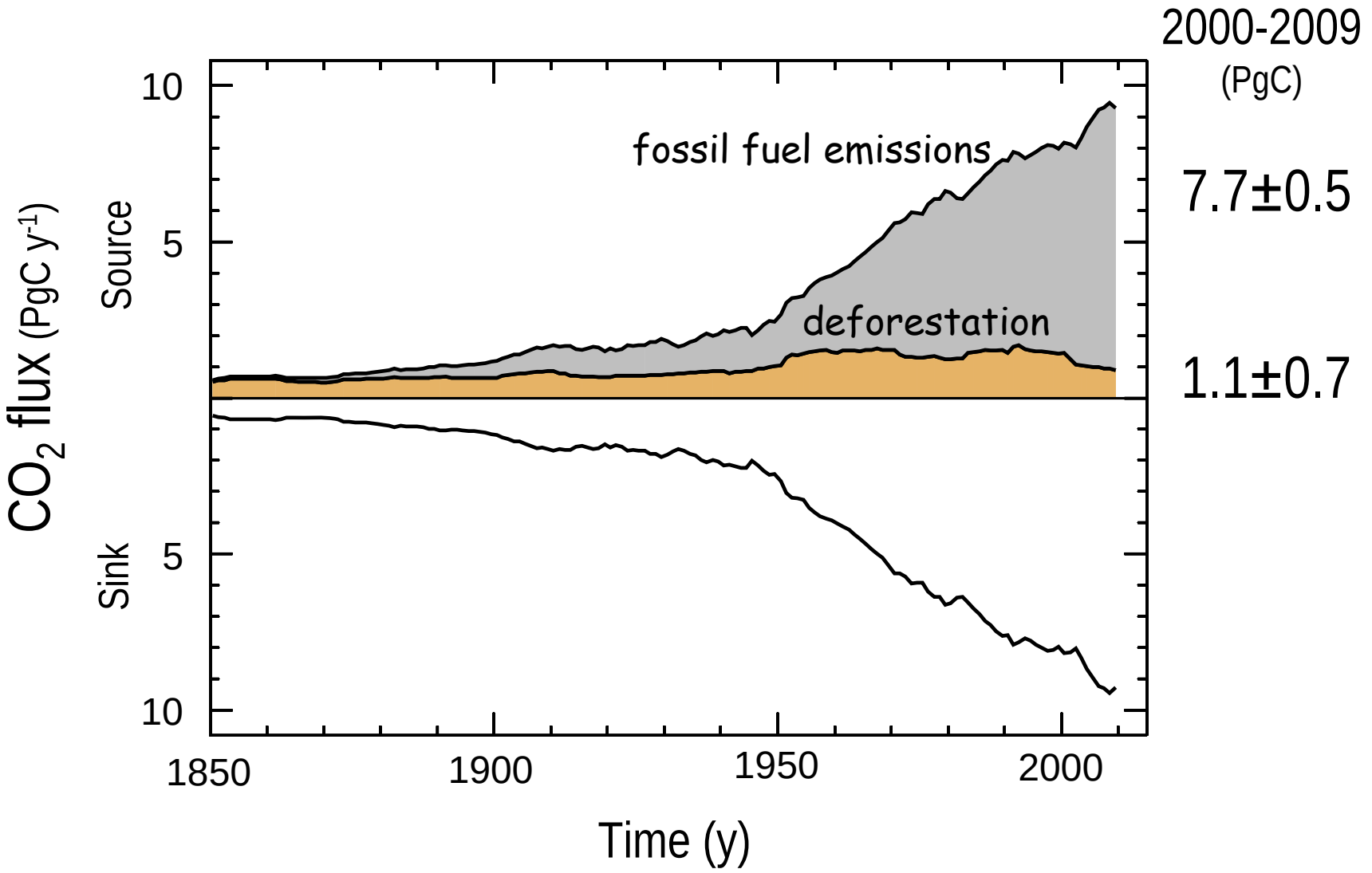

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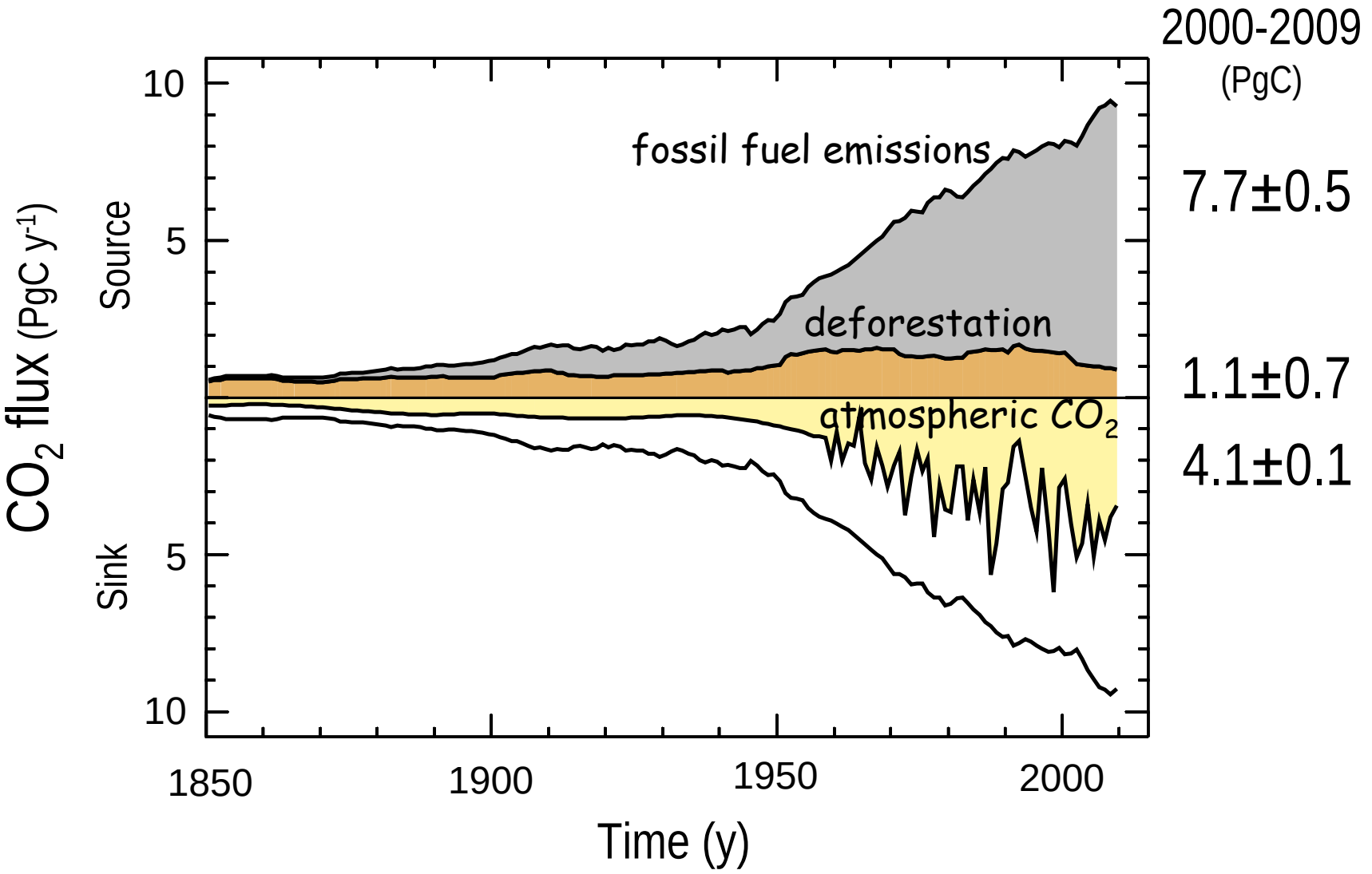

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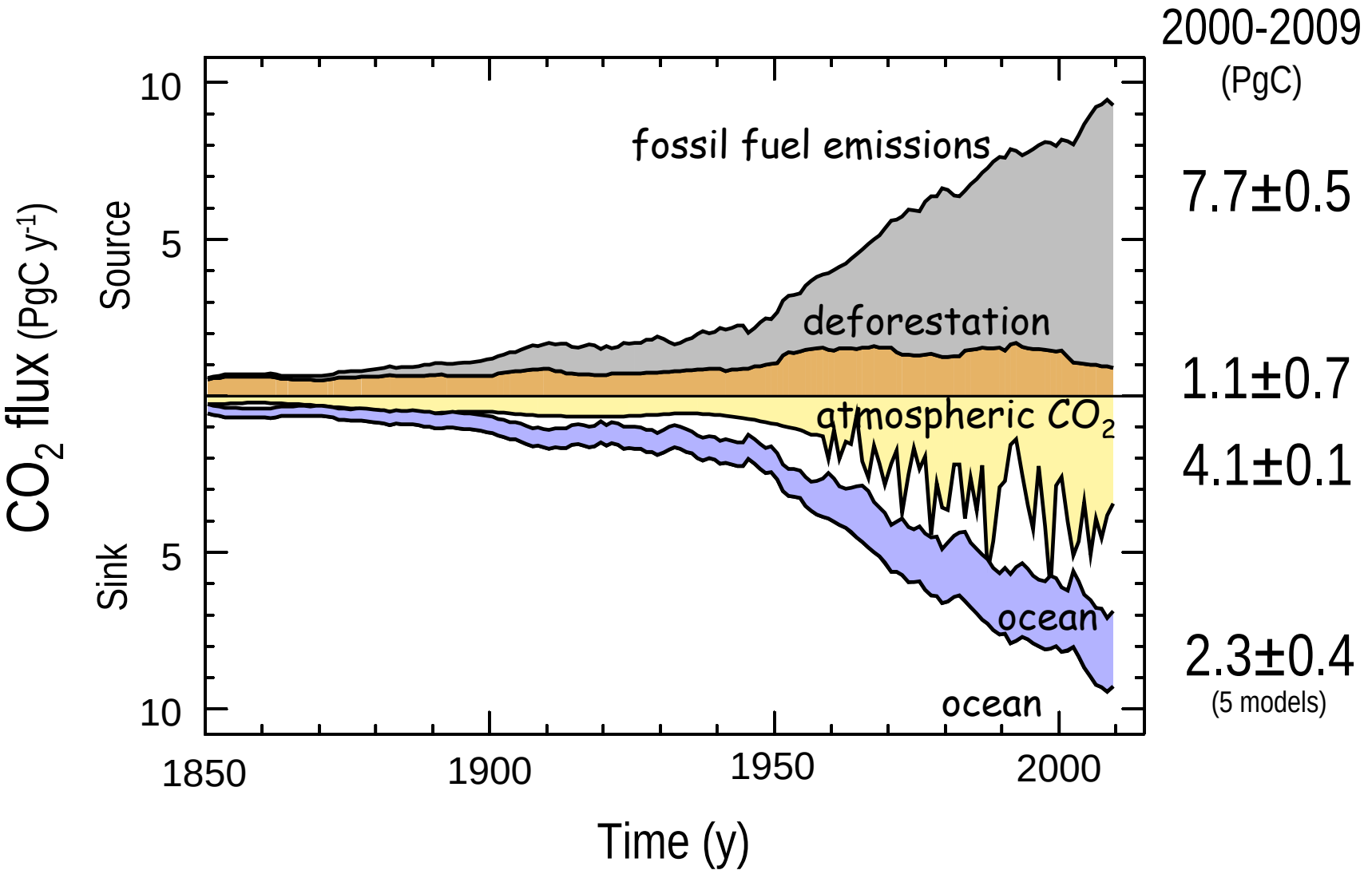

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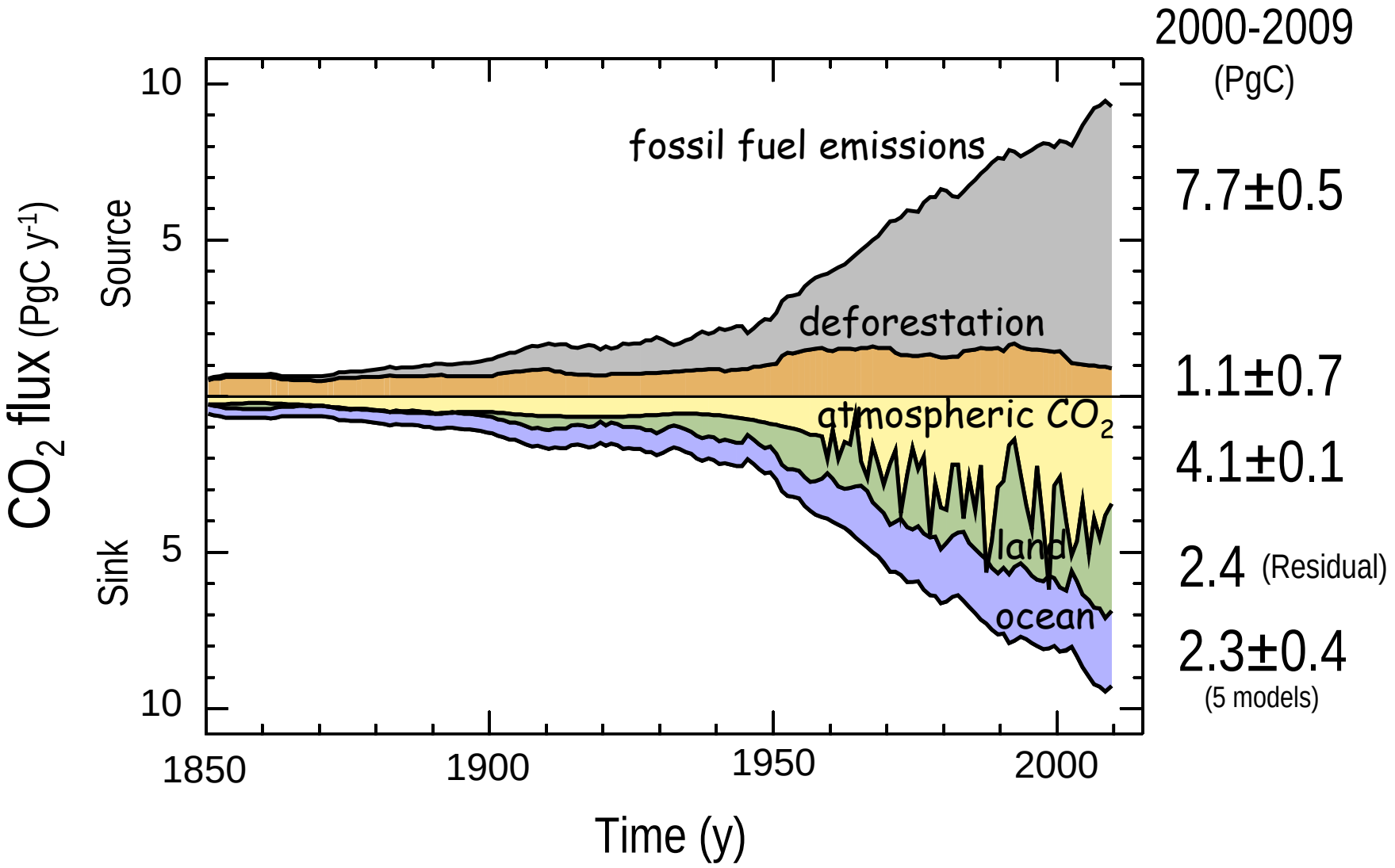


Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

Fate of Anthropogenic CO_2 Emissions (2000-2009)

1.1±0.7 PgC y^{-1}

7.7±0.5 PgC y^{-1} +

4.1±0.1 PgC y^{-1}

47%

2.4 PgC y^{-1}

27%

Calculated as the residual of all other flux components

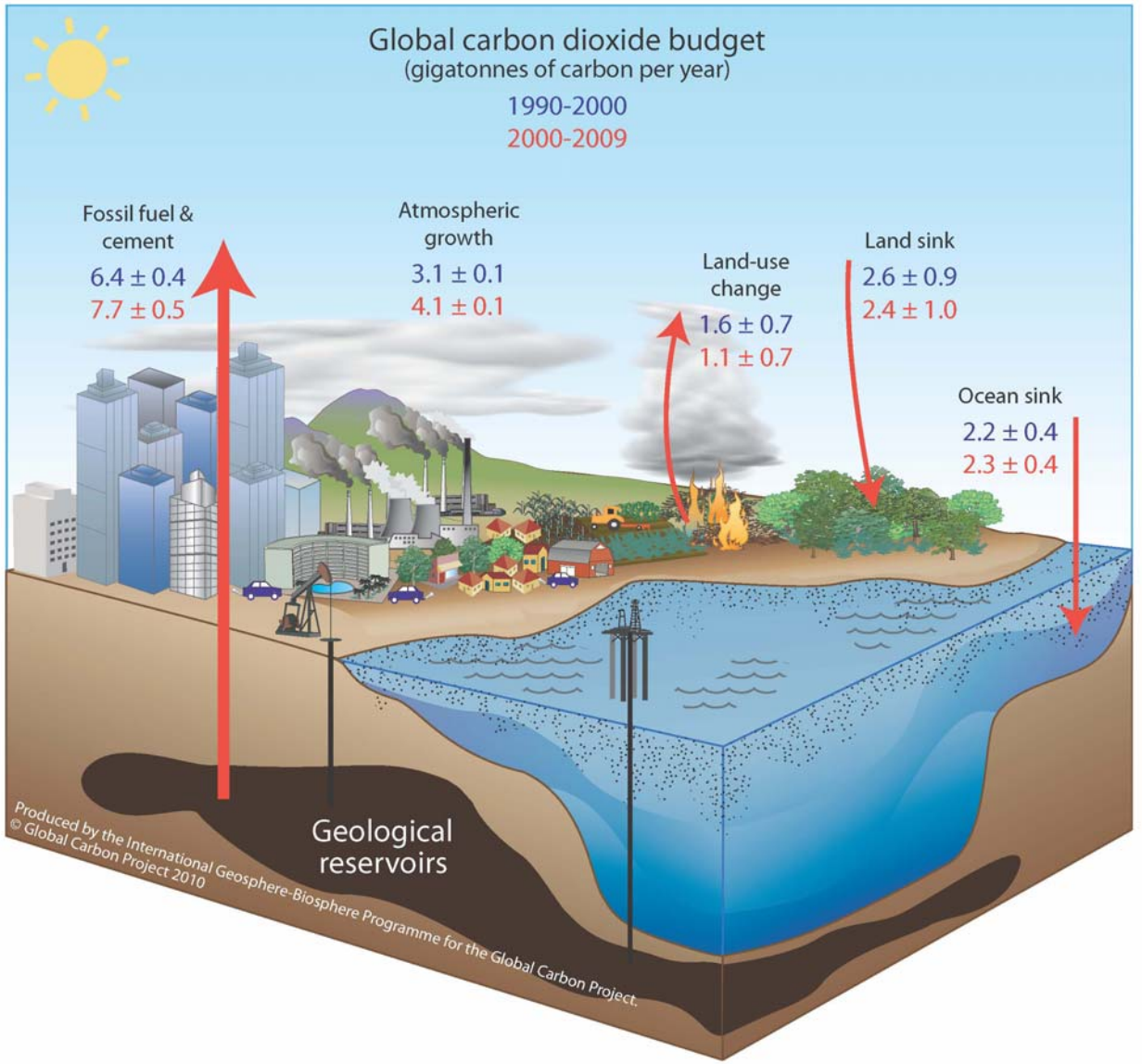
26%

2.3±0.4 PgC y^{-1}

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

Anthropogenic Global Carbon Dioxide Budget



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