Budget09 released on 21 November 2010
ppt version 29 November 2010

Carbon Budget 2009

GCP-Carbon Budget2009 Contributors

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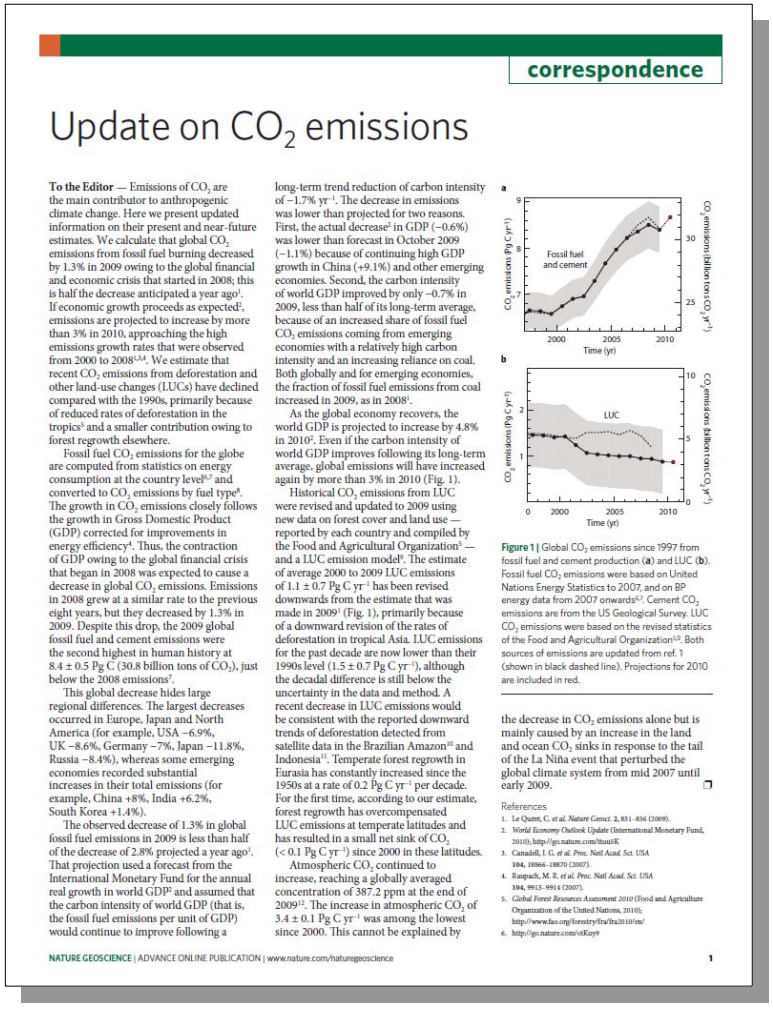
GCP-Carbon Budget2009



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[1,3,4]. 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[4]. 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[7].

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[1].

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[9]. 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[1] (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[5,9]. Both sources of emissions are updated from ref. 1 (shown in black dashed line). Projections for 2010 are included in red.

References
1. Le Quere, C. *et al. Nature Geosci.* **2**, 831–836 (2009).
2. *World Economy Outlook Update* (International Monetary Fund, 2010); http://go.nature.com/ltunsK
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**, 9913–9914 (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/otKuy9

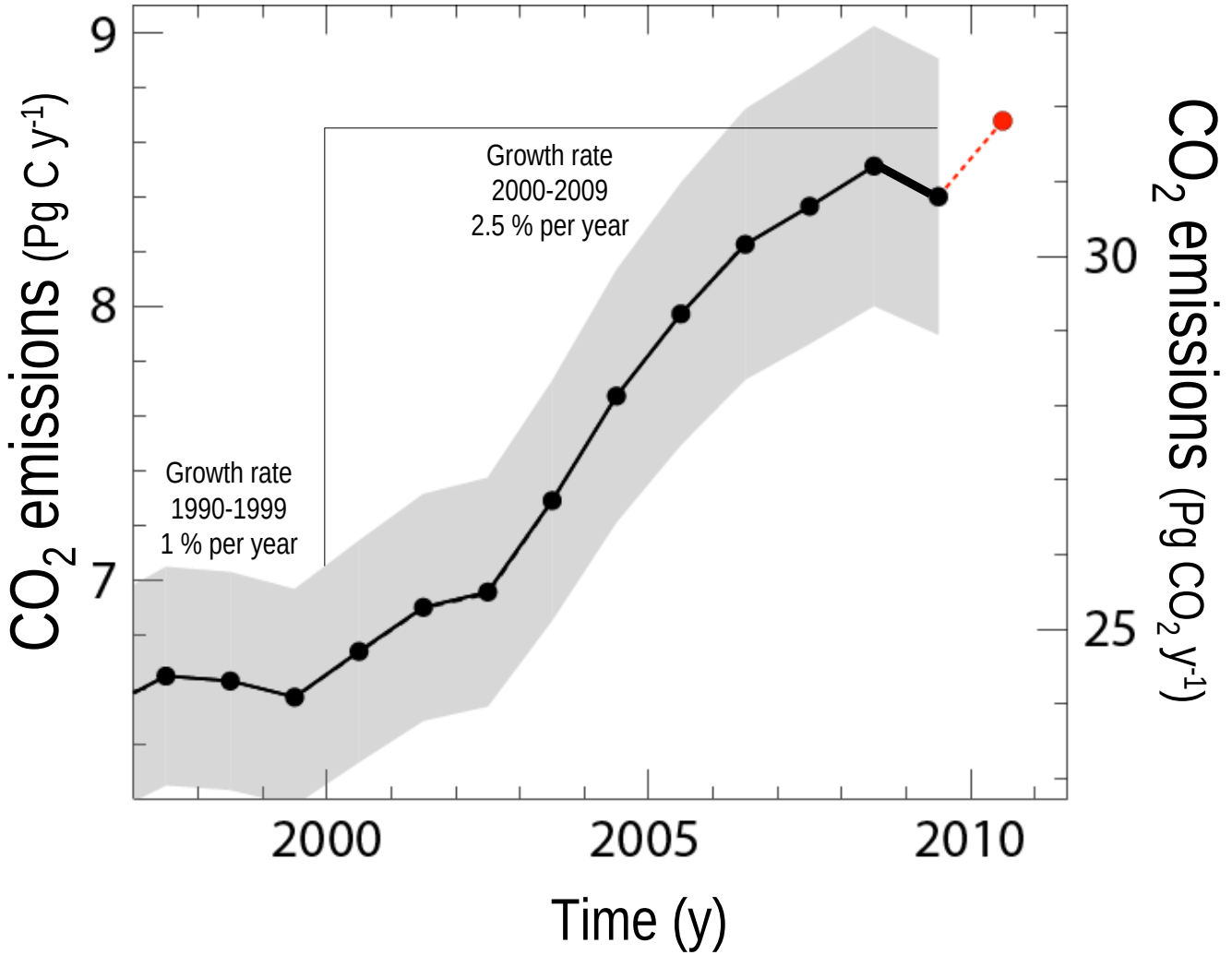
http://www.globalcarbonproject.org/carbonbudget

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

Units

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

Fossil Fuel CO_2 Emissions



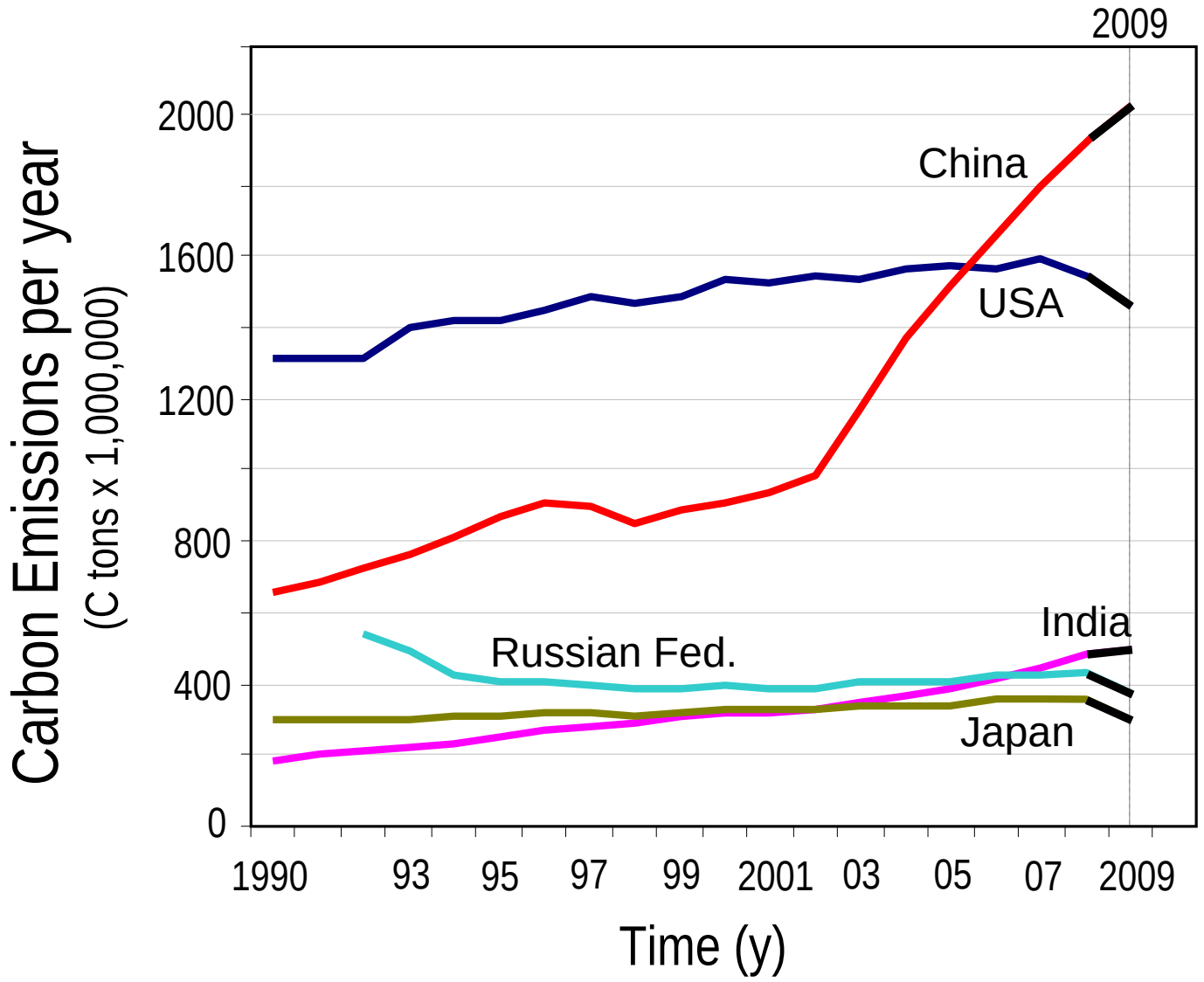
2009:
Emissions:8.4±0.5 PgC
Growth rate: -1.3%
1990 level: +37%

2000-2008
Growth rate: +3.2%

2010 (projected):
Growth rate: >3%

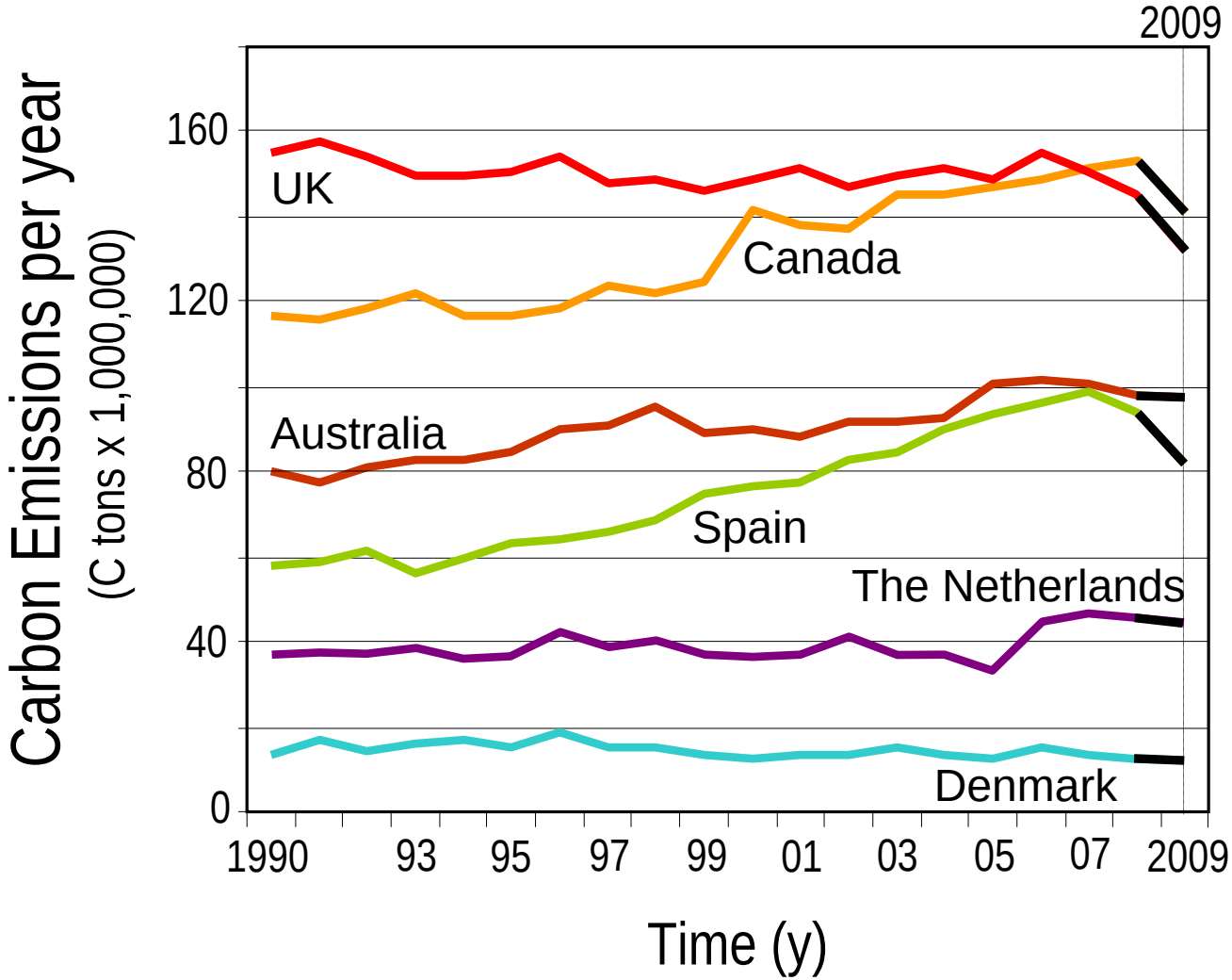
Friedlingstein et al. 2010, Nature Geoscience; Gregg Marland, Thomas Boden-CDIAC 2010

Fossil Fuel CO_2 Emissions: Top Emitters



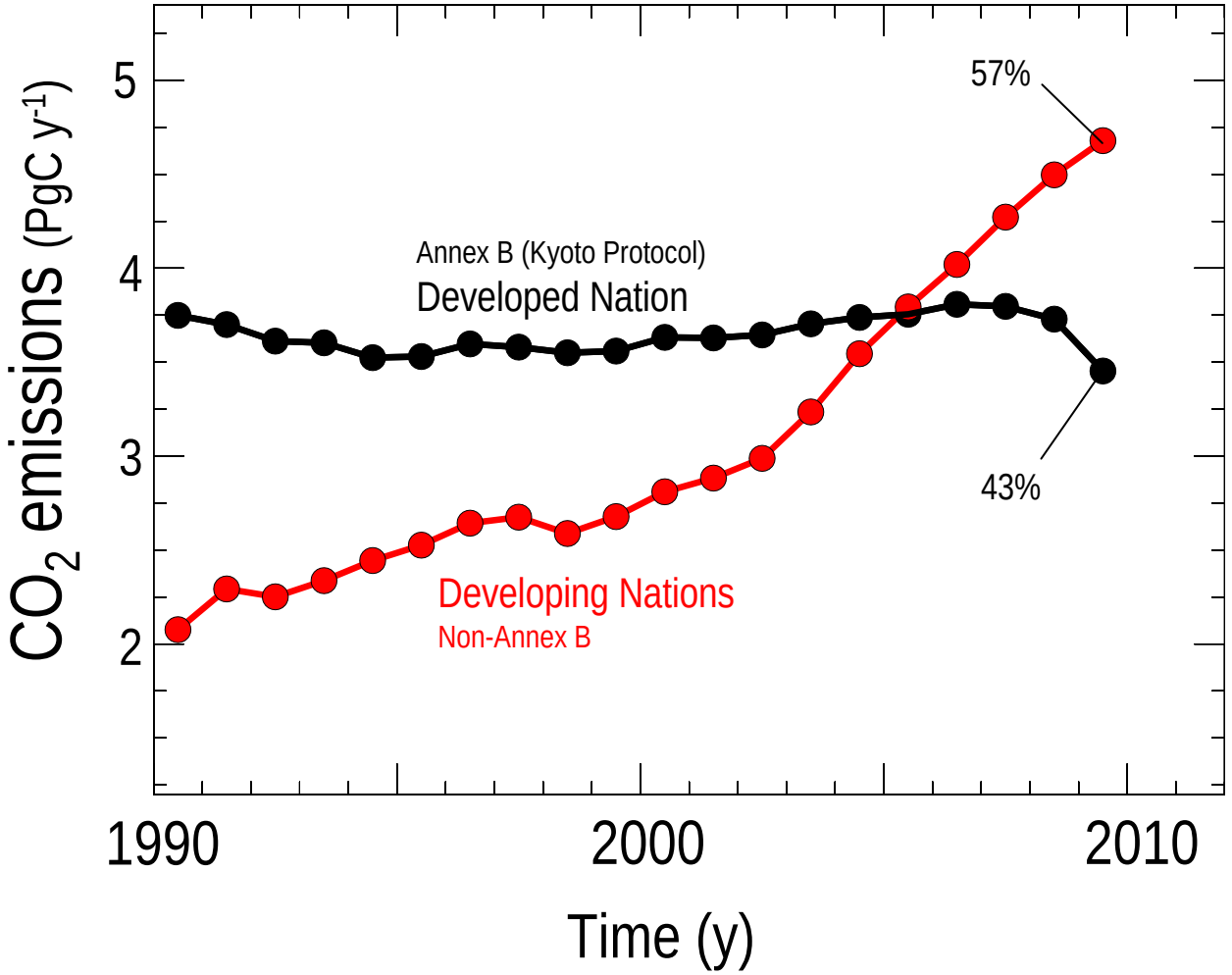
Global Carbon Project 2010; Data: Gregg Marland, Tom Boden-CDIAC 2010

Fossil Fuel CO_2 Emissions: Profile Examples



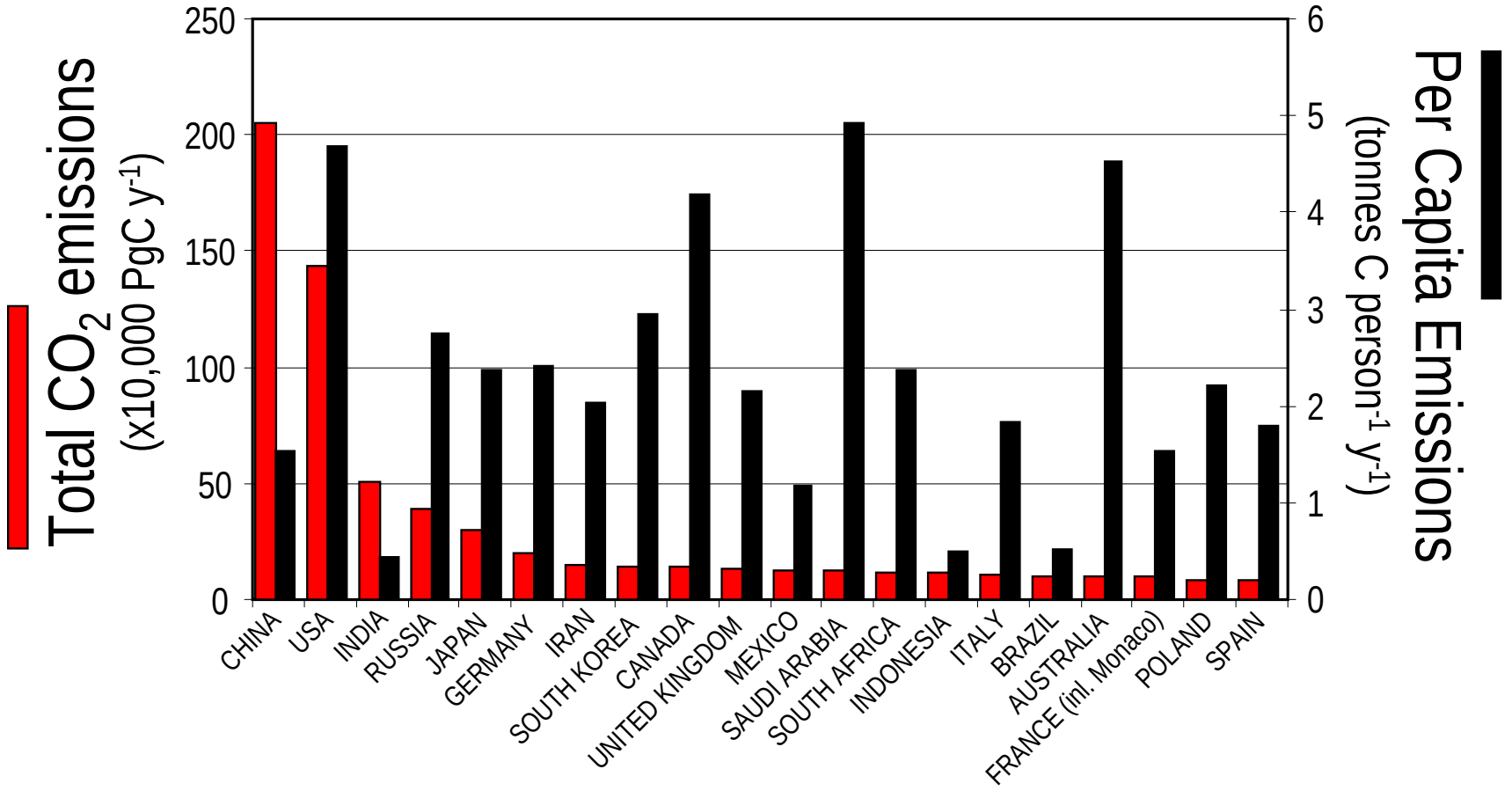
Global Carbon Project 2010; Data: Gregg Marland, Tom Boden- CDIAC 2010

Fossil Fuel CO_2 Emissions



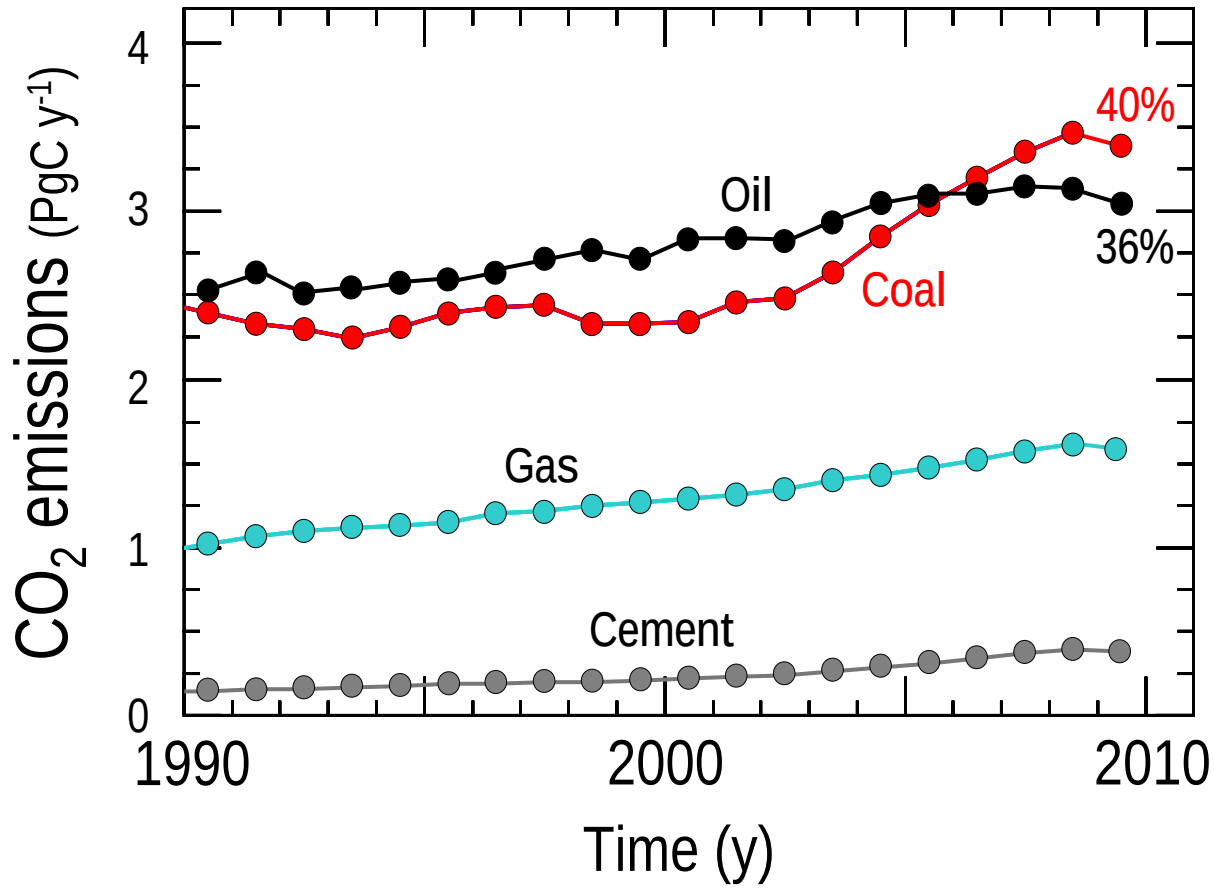
Updated from Le Quéré et al. 2009, Nature Geoscience; CDIAC 20010

Top 20 CO_2 Emitters & Per Capita Emissions 2009



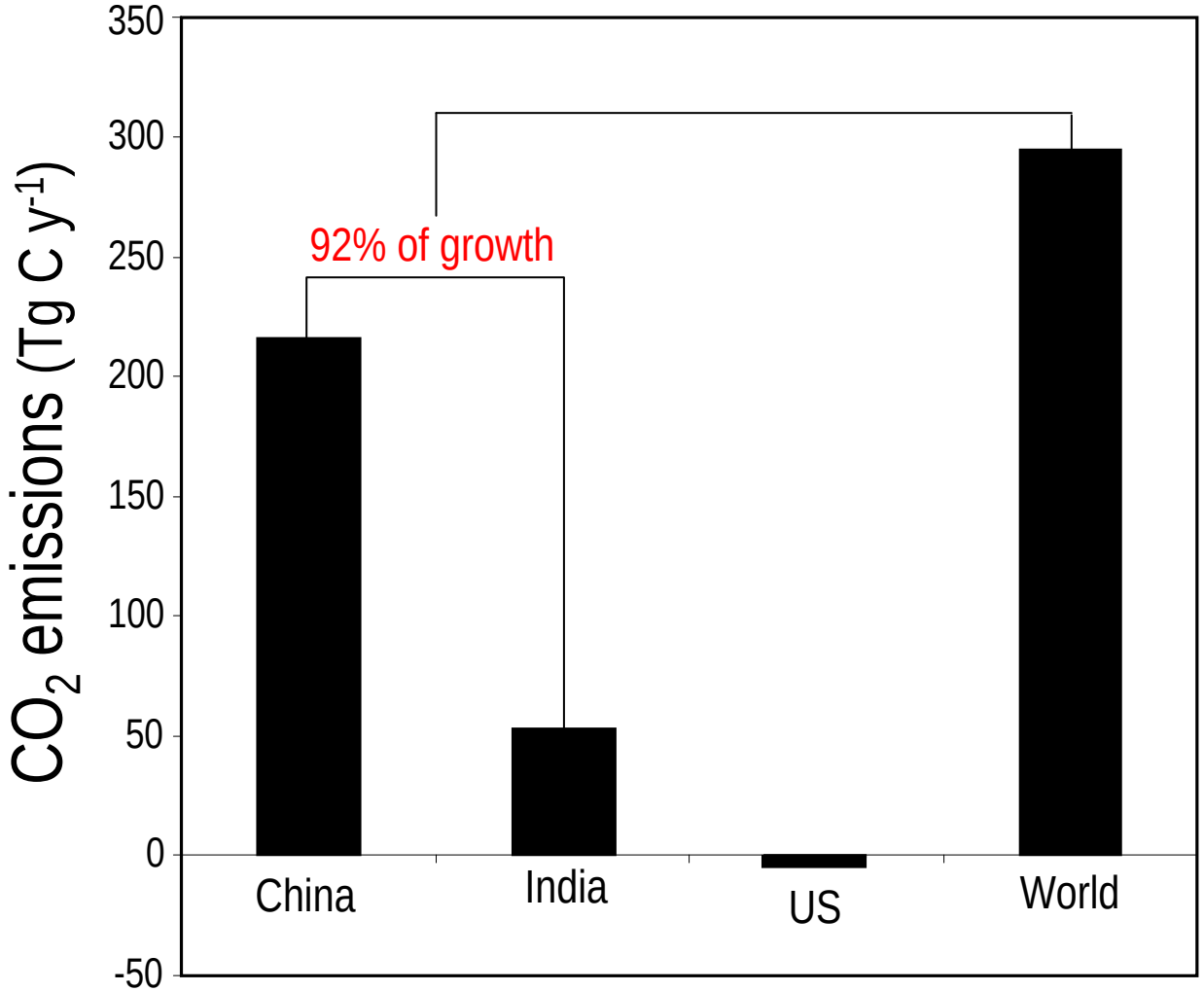
Global Carbon Project 2010; Data: Gregg Marland, Thomas Boden-CDIAC 2010; Population World Bank 2010

CO_2 Emissions by Fossil Fuel Type



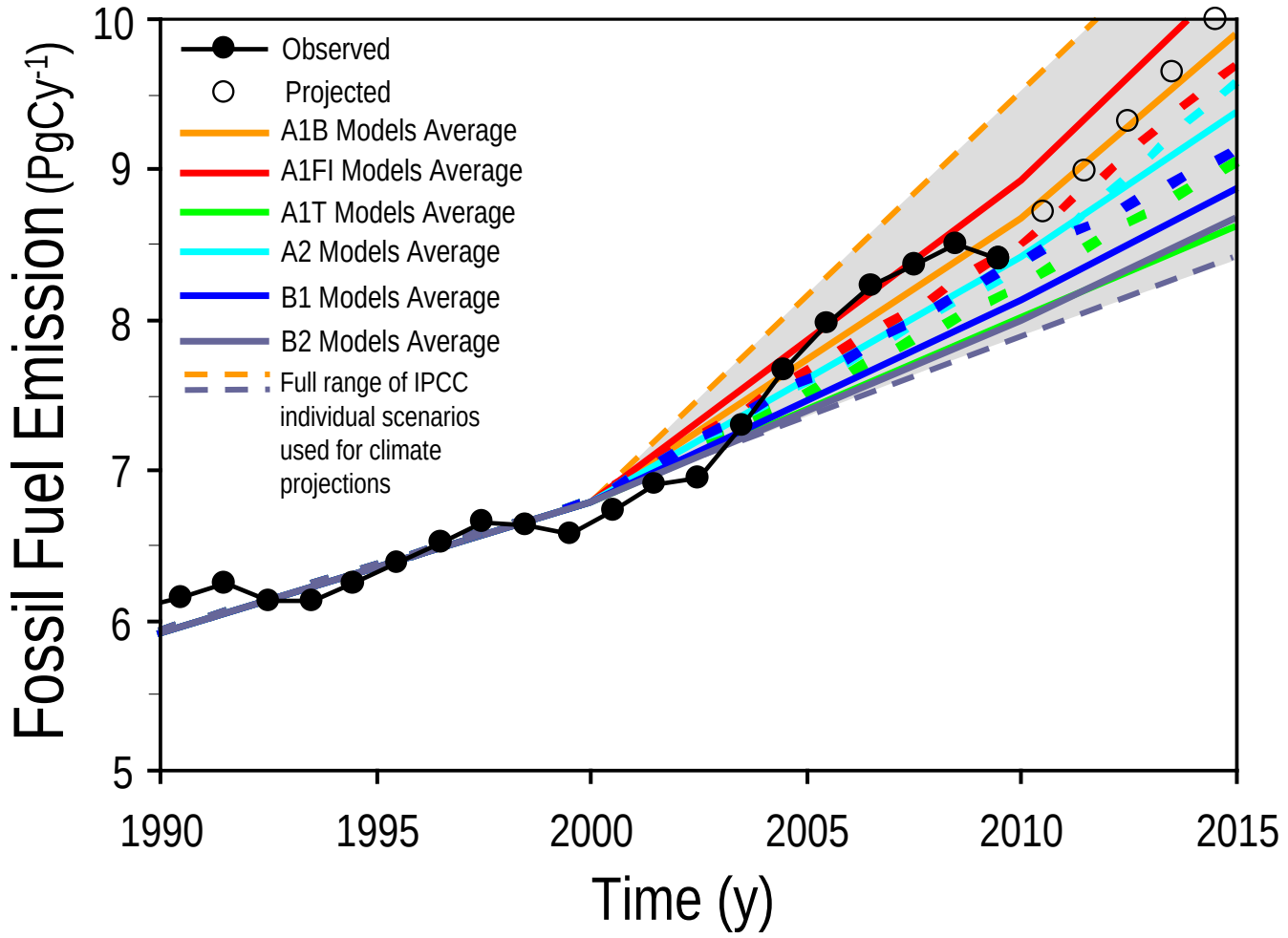
Updated from Le Quéré et al. 2009, Nature Geoscience; Data: Gregg Marland, Thomas Boden-CDIAC 2010

Change in CO_2 Emissions from Coal (2007 to 2009)



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

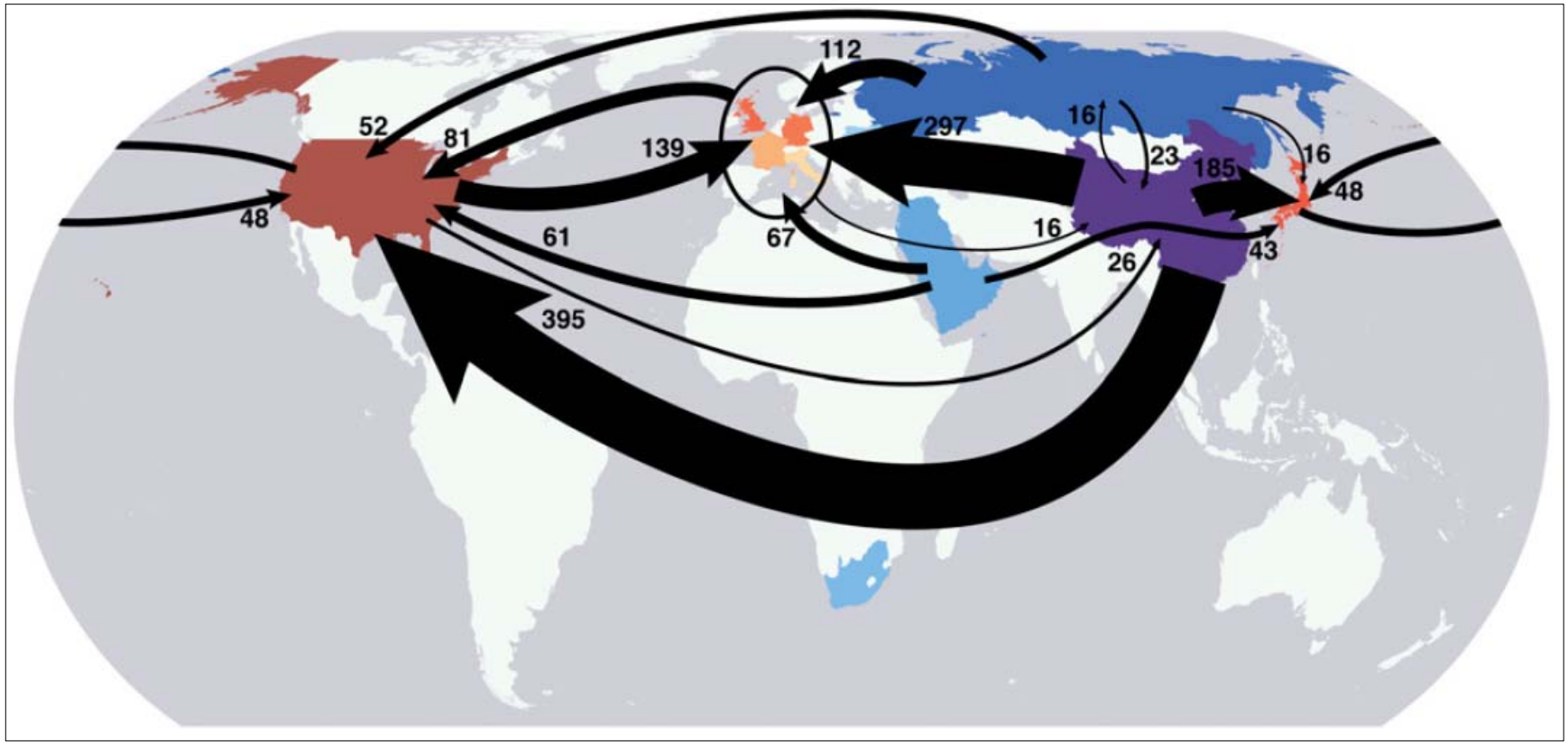
Fossil Fuel Emissions: Actual vs. IPCC Scenarios



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})

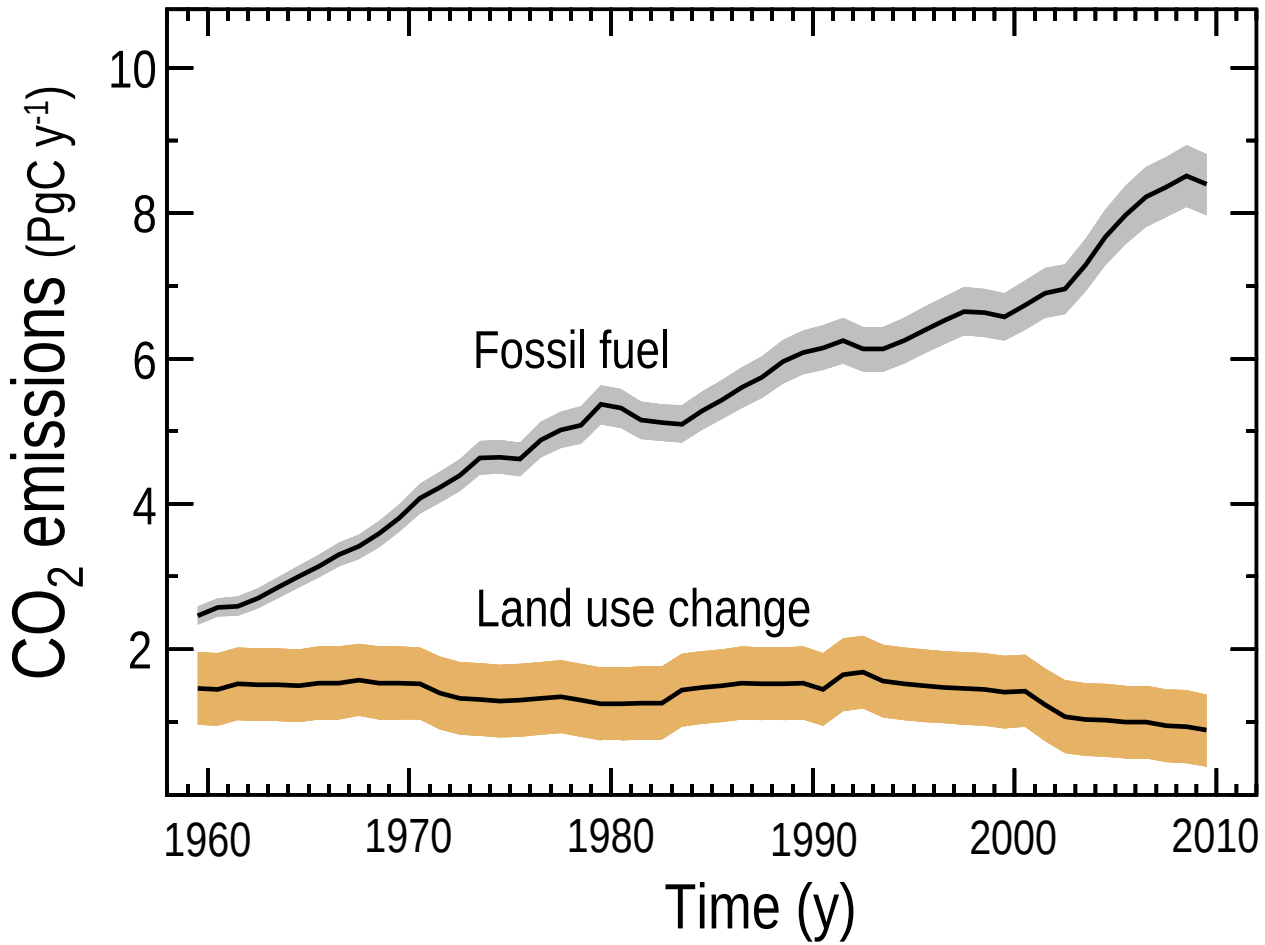
Year 2004



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

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

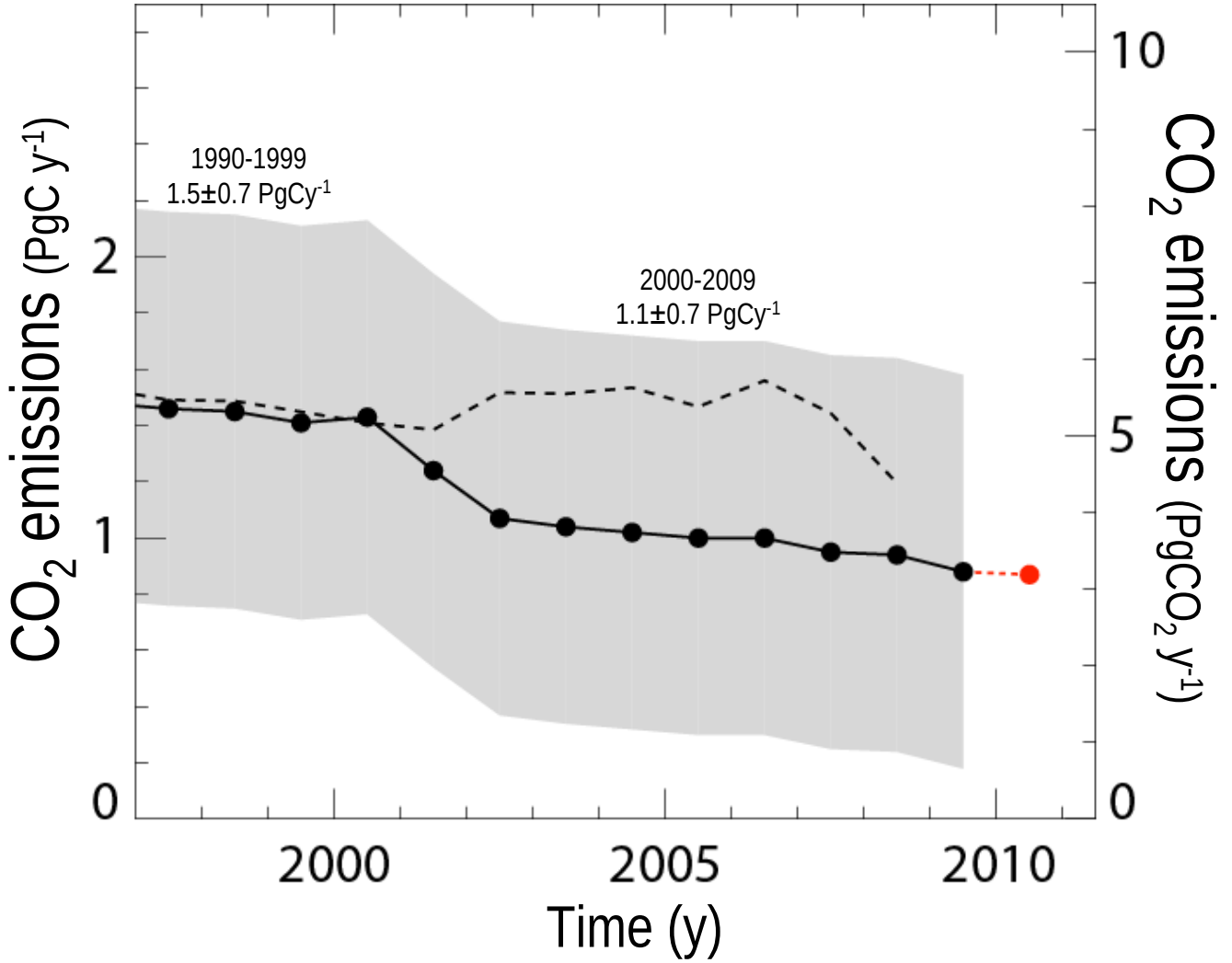
CO_2 Emissions from Land Use Change (1960-2009)



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



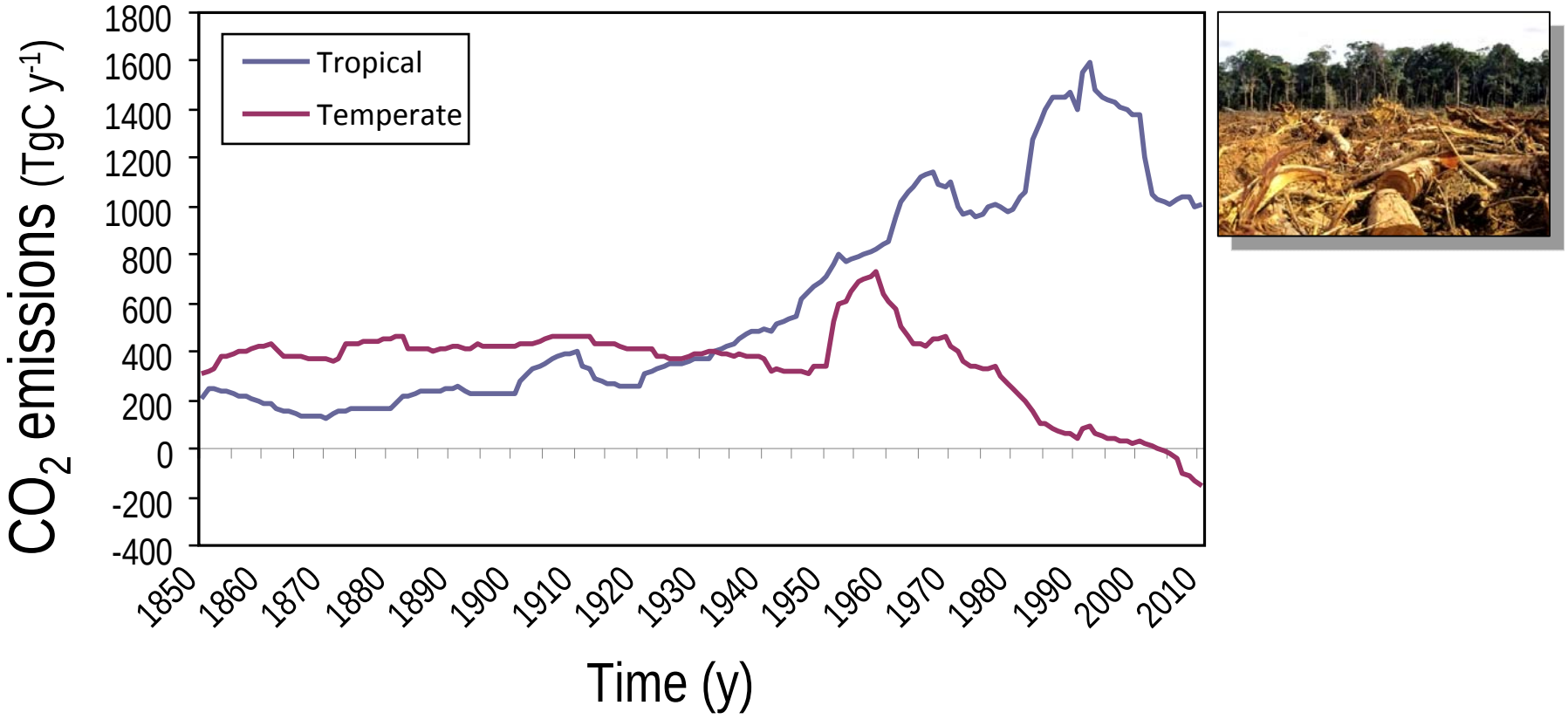
1990s
Emissions: 1.5±0.7 PgC

2000-2005
Emissions: 1.3±0.7 PgC

2006-2010:
Emissions: 0.9±0.7 PgC

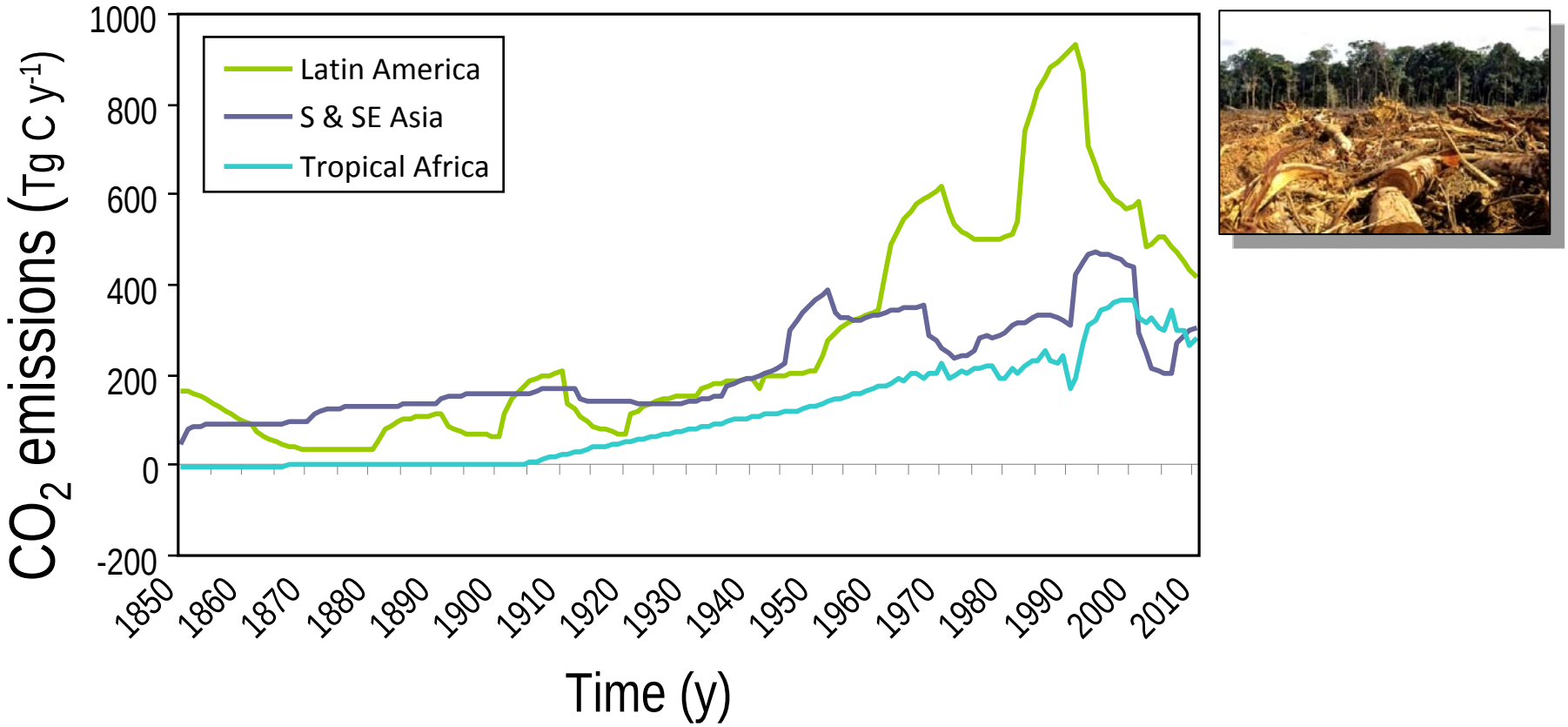
Friedlingstein et al. 2010, Nature Geoscience; Data: RA Houghton, GFRA 2010

Emissions from Land Use Change (2000-2009)



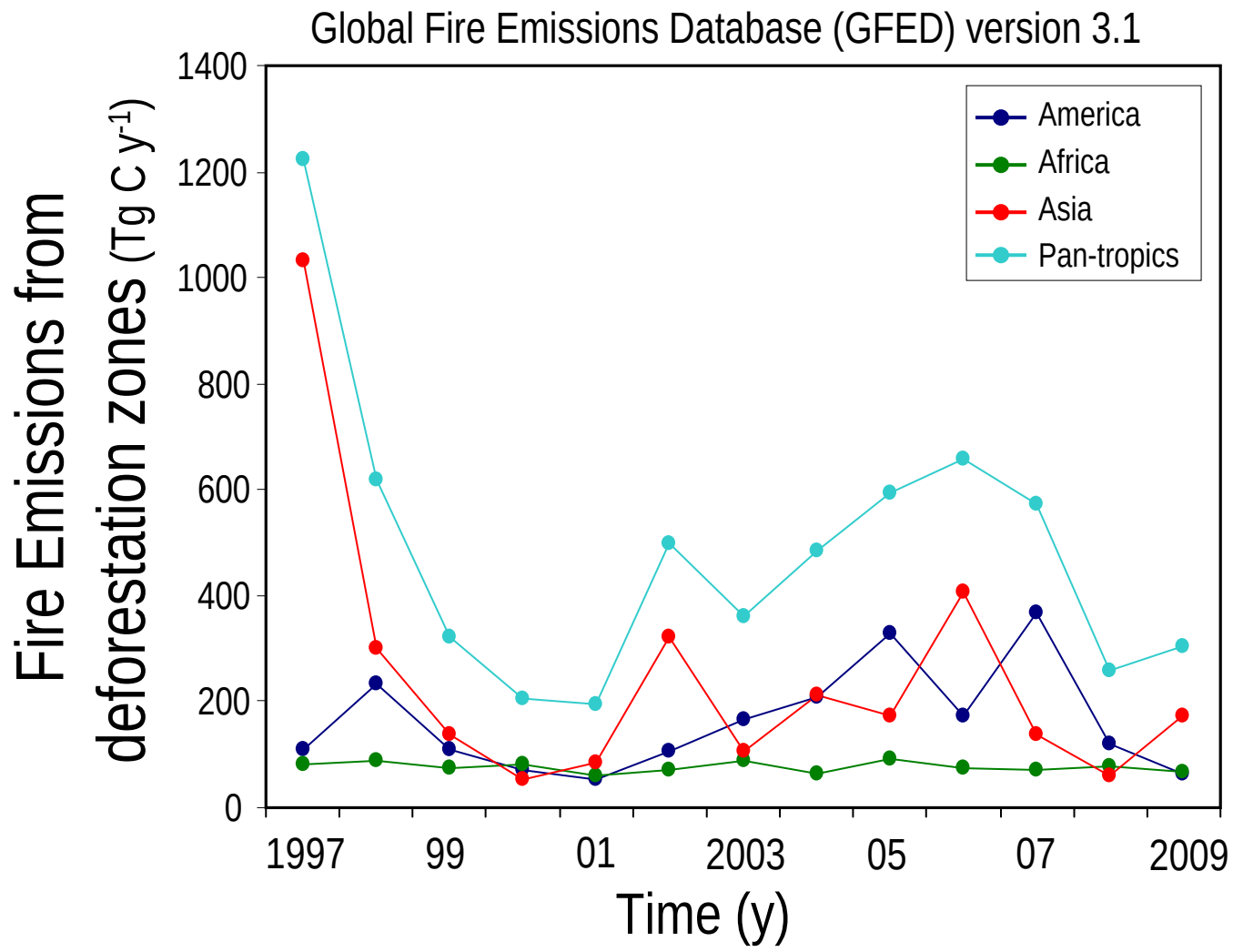
R.A. Houghton 2010, personal communication; GFRA 2010

Emissions from Land Use Change (2000-2009)



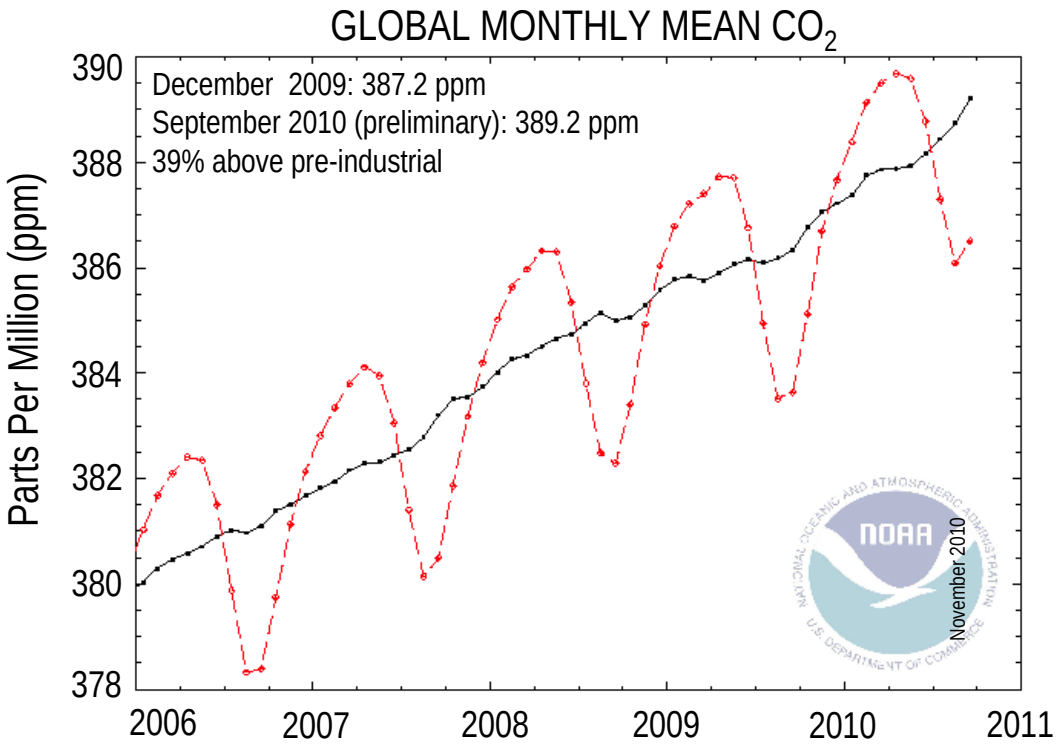
R.A. Houghton 2010, personal communication; GFRA 2010

Fire Emissions from Deforestation Zones



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

Atmospheric CO_2 Concentration



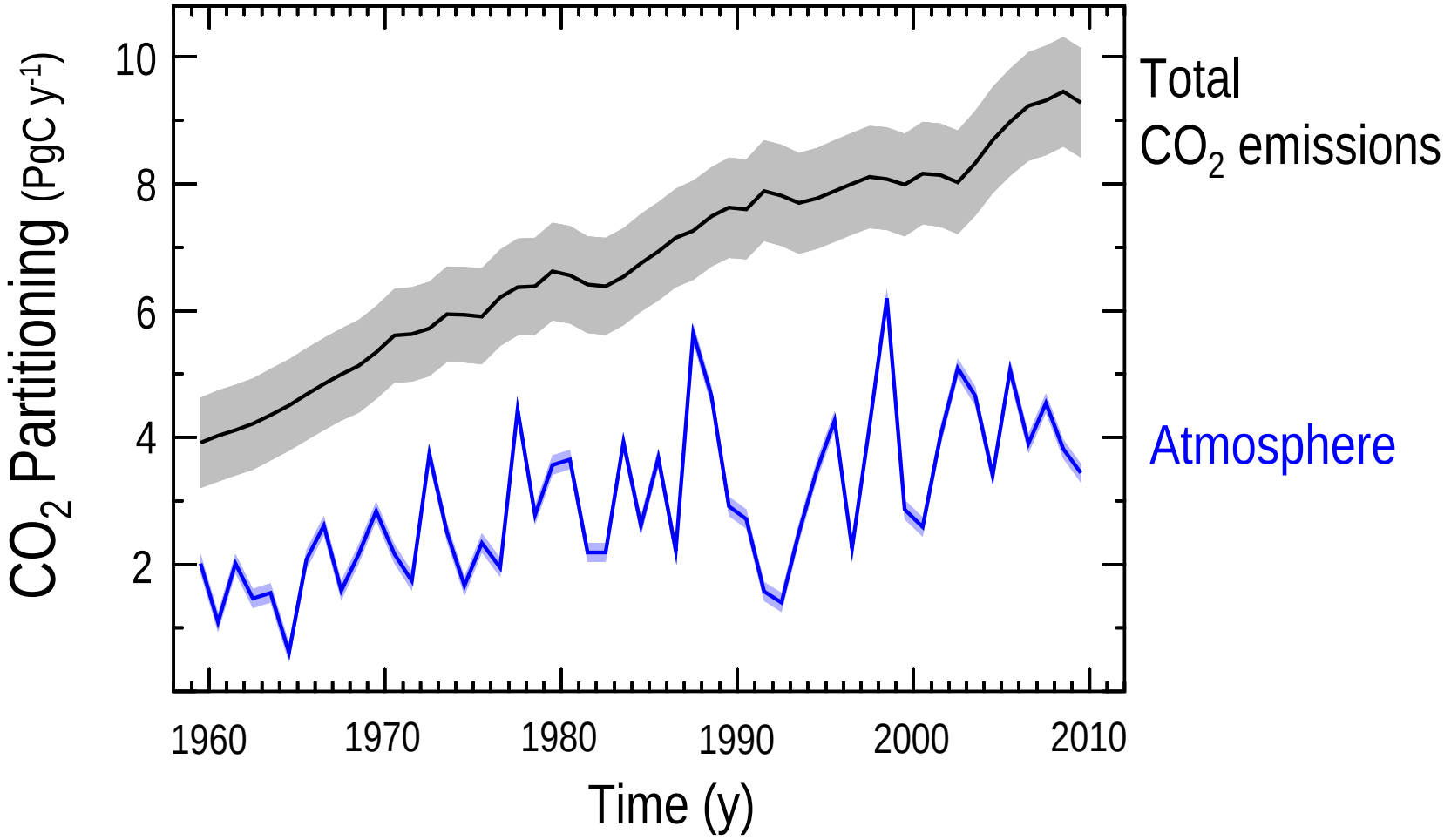
Annual Mea	Growth Rate (ppm y^{-1})
2009	1.62
2008	1.80
2007	2.14
2006	1.84
2005	2.39
2004	1.60
2003	2.19
2002	2.40
2001	1.89
2000	1.22

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

Key Diagnostic of the Carbon Cycle

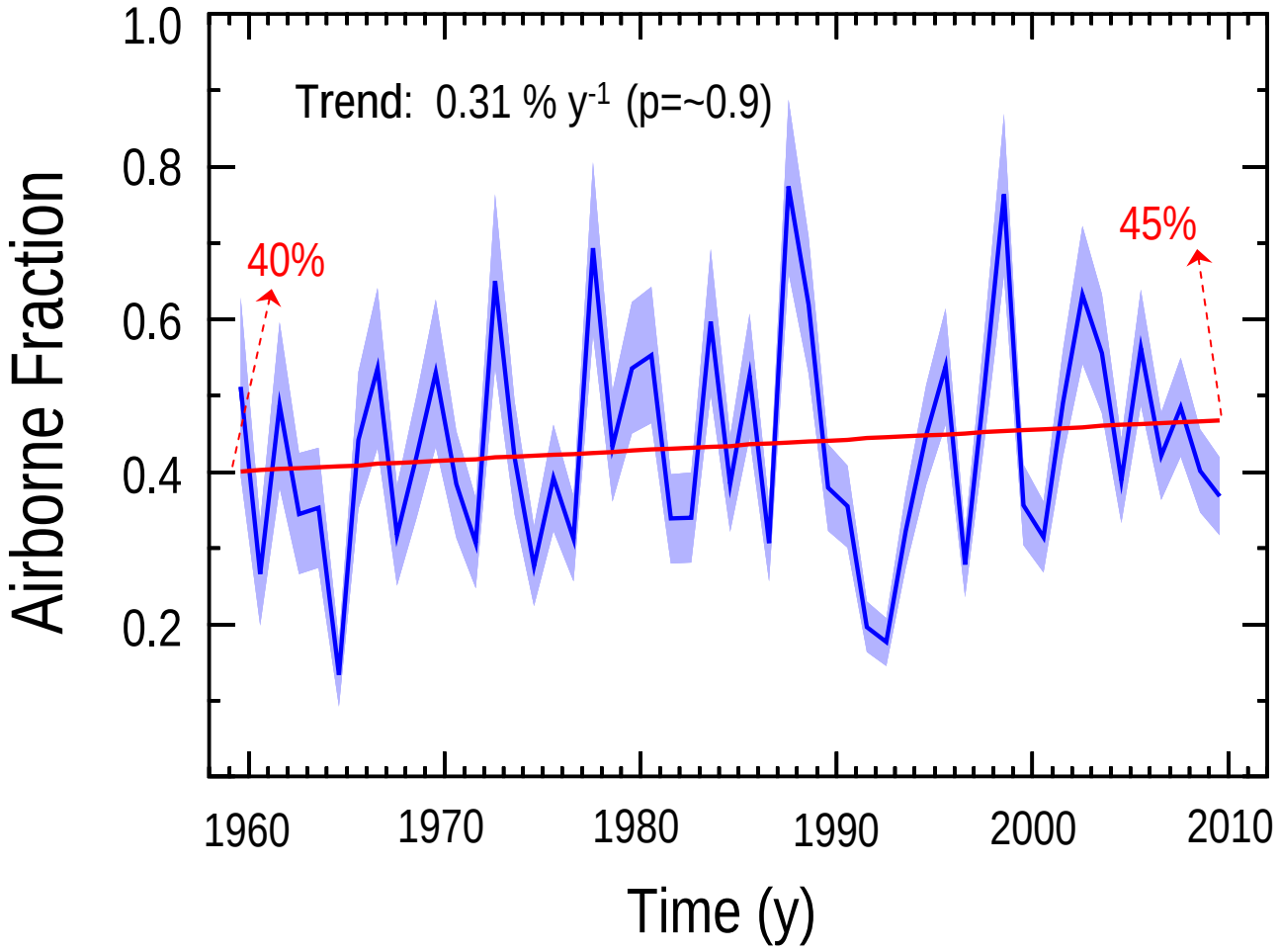
Evolution of the fraction of total emissions that remain in the atmosphere



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

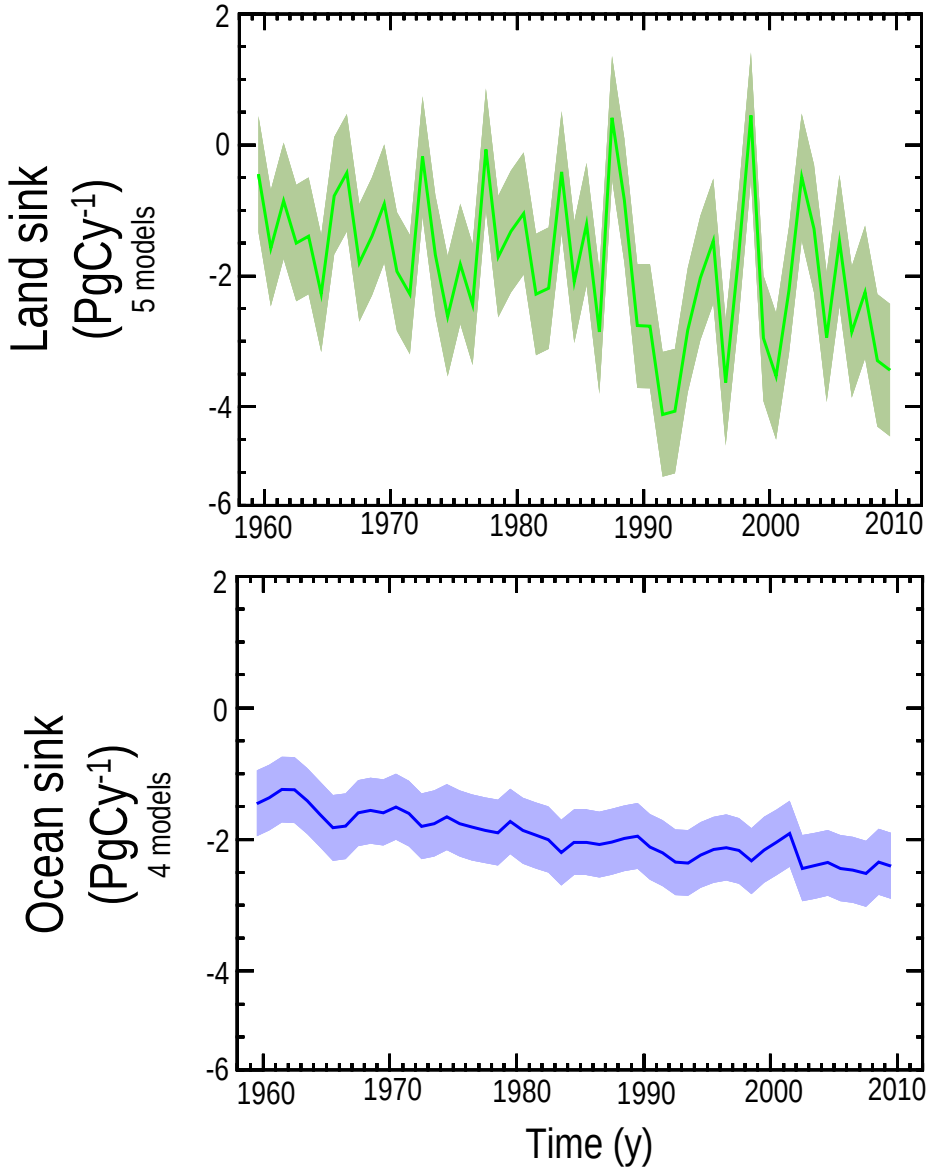
Airborne Fraction

Fraction of total CO_2 emissions that remains in the atmosphere



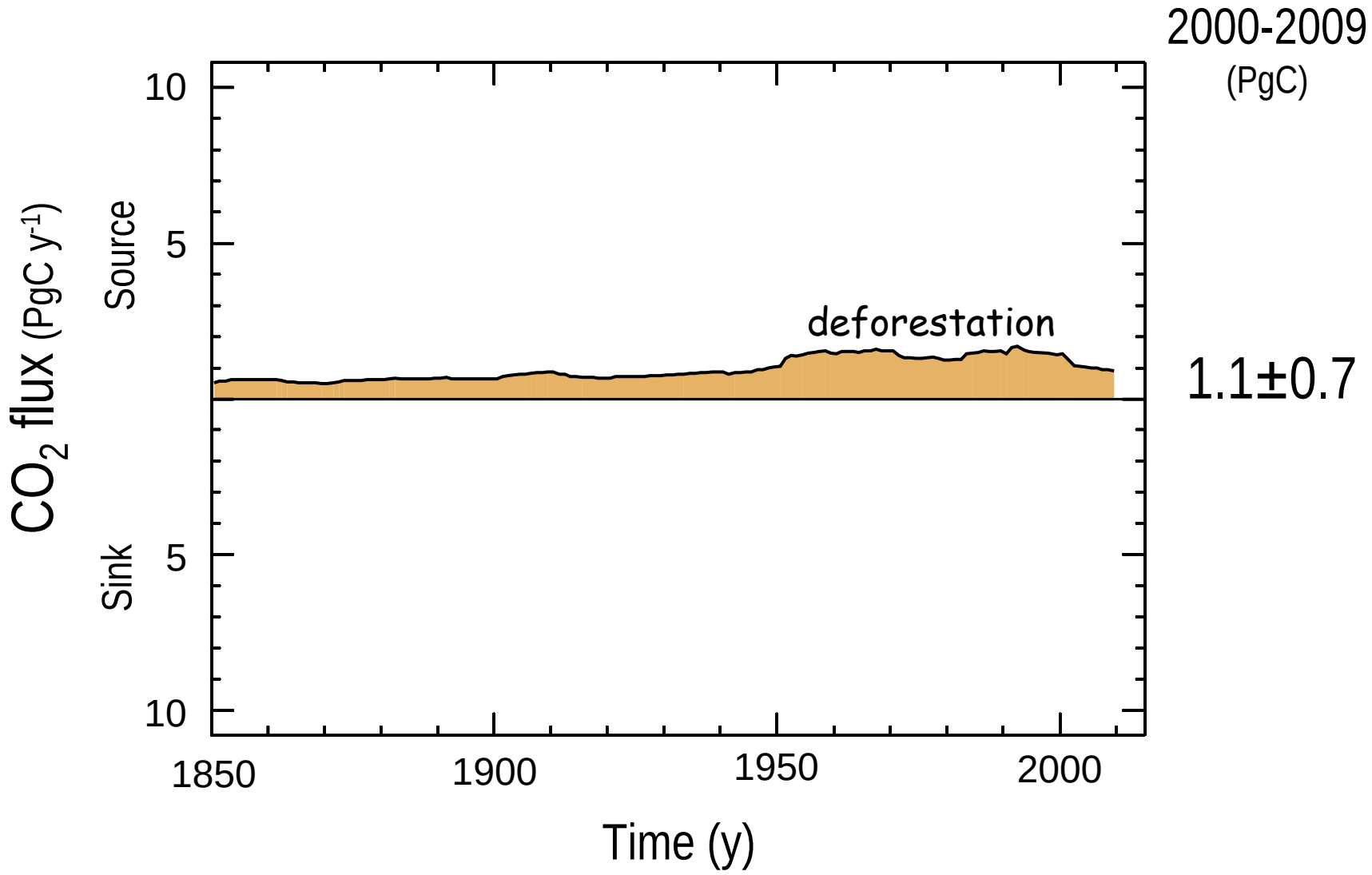
Updated from Le Quéré et al. 2009, Nature Geoscience; Raupach et al. 2008, Biogeosciences; Canadell et al. 2007, PNAS

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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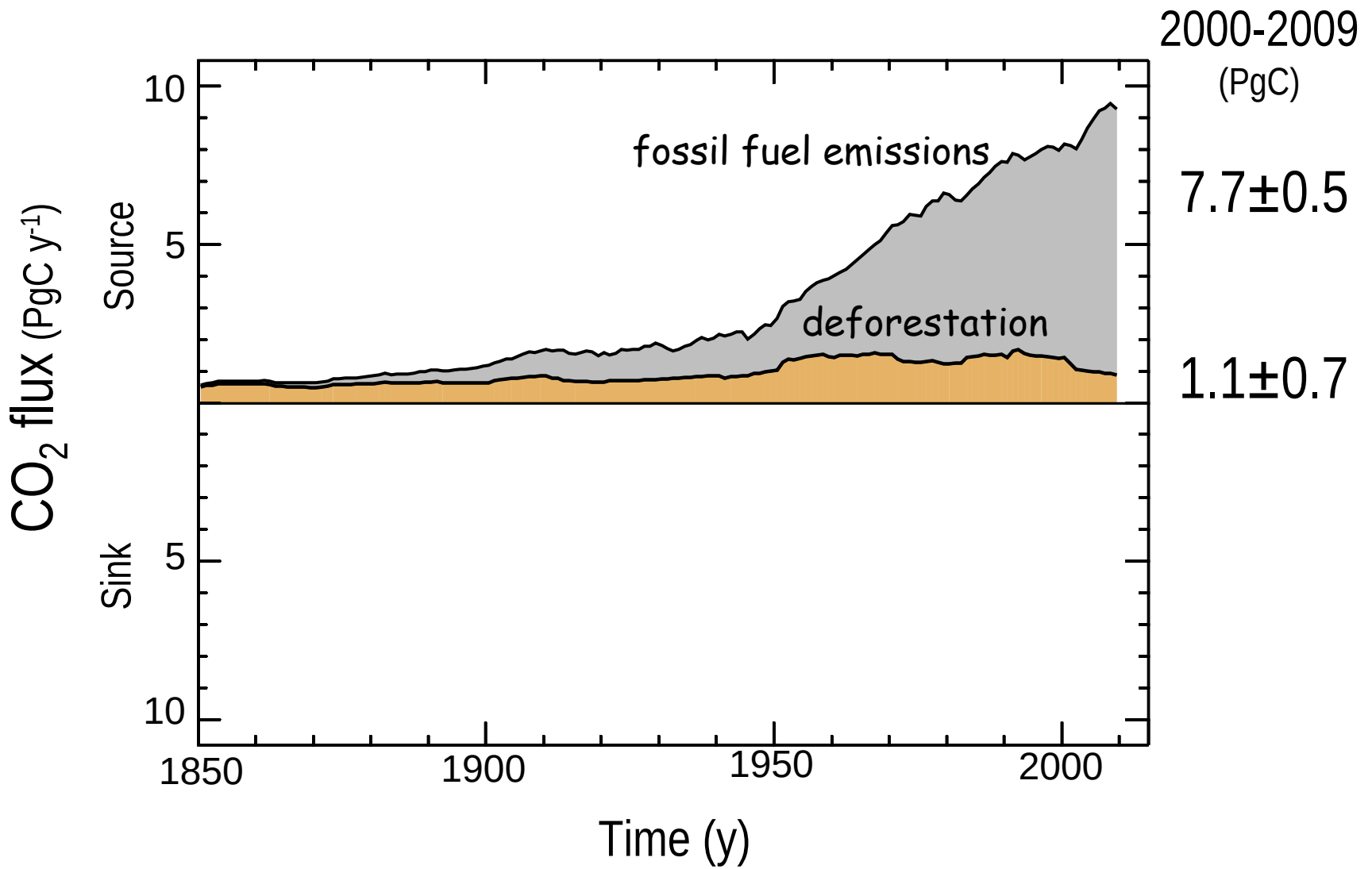

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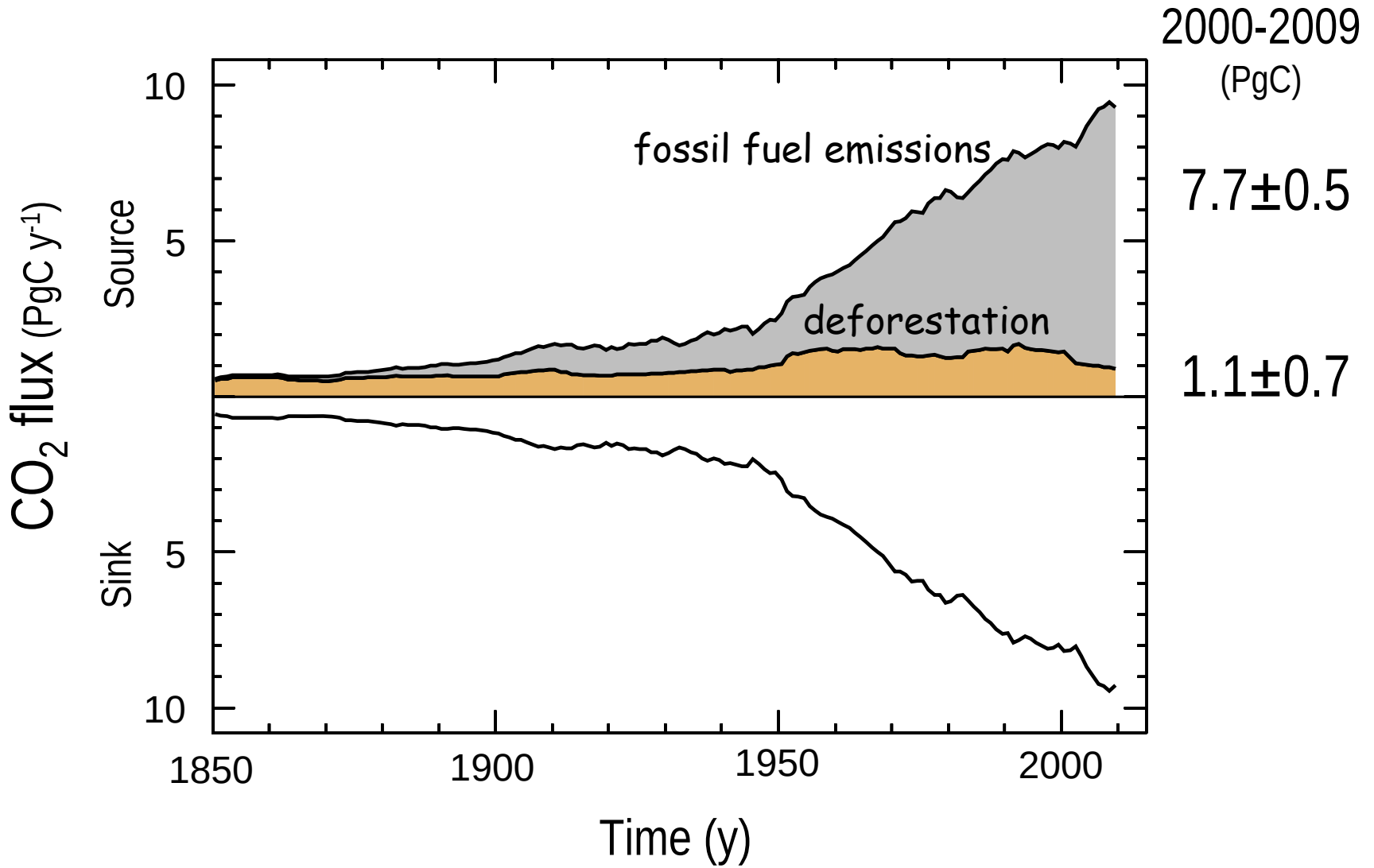

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

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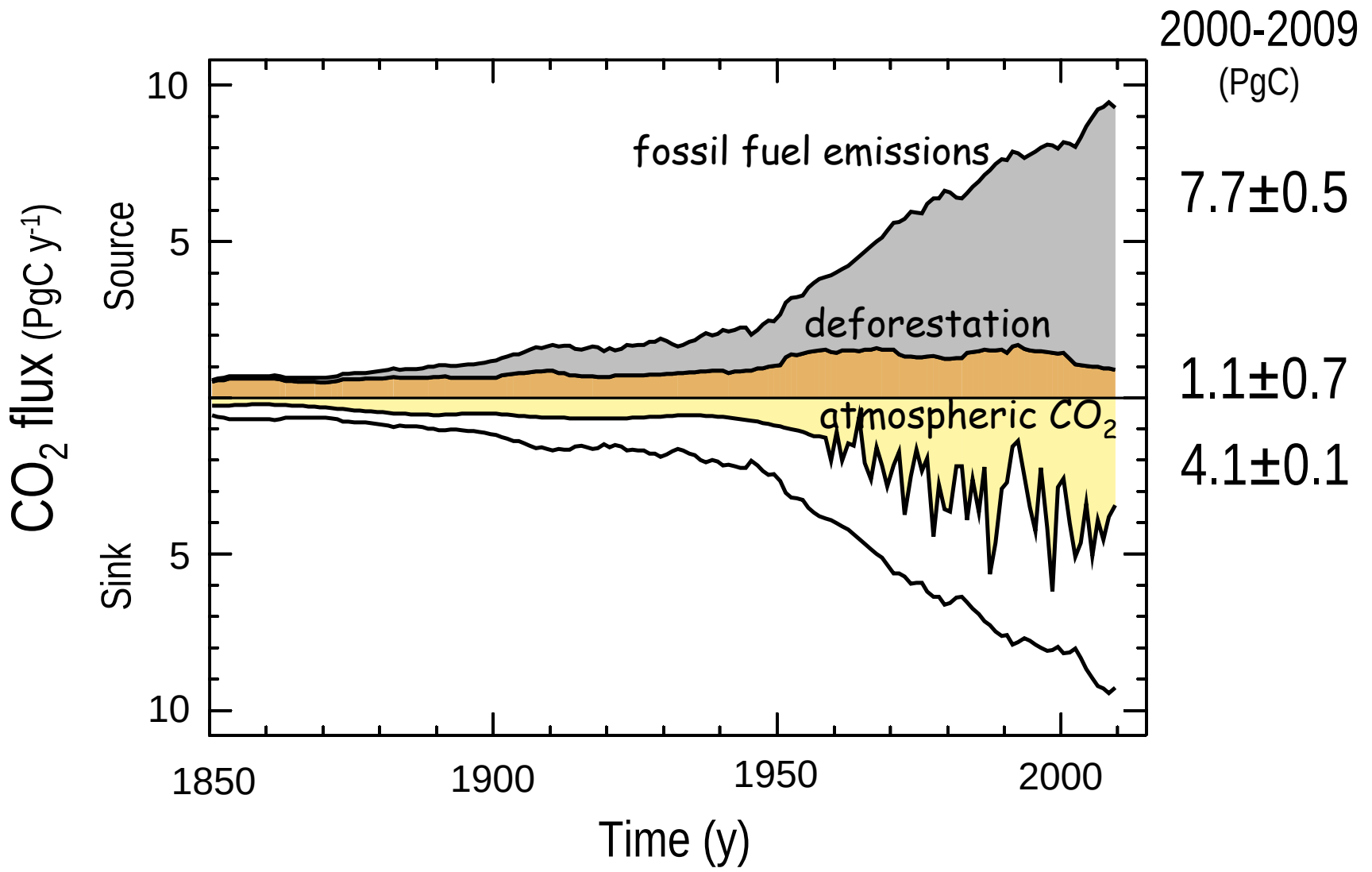

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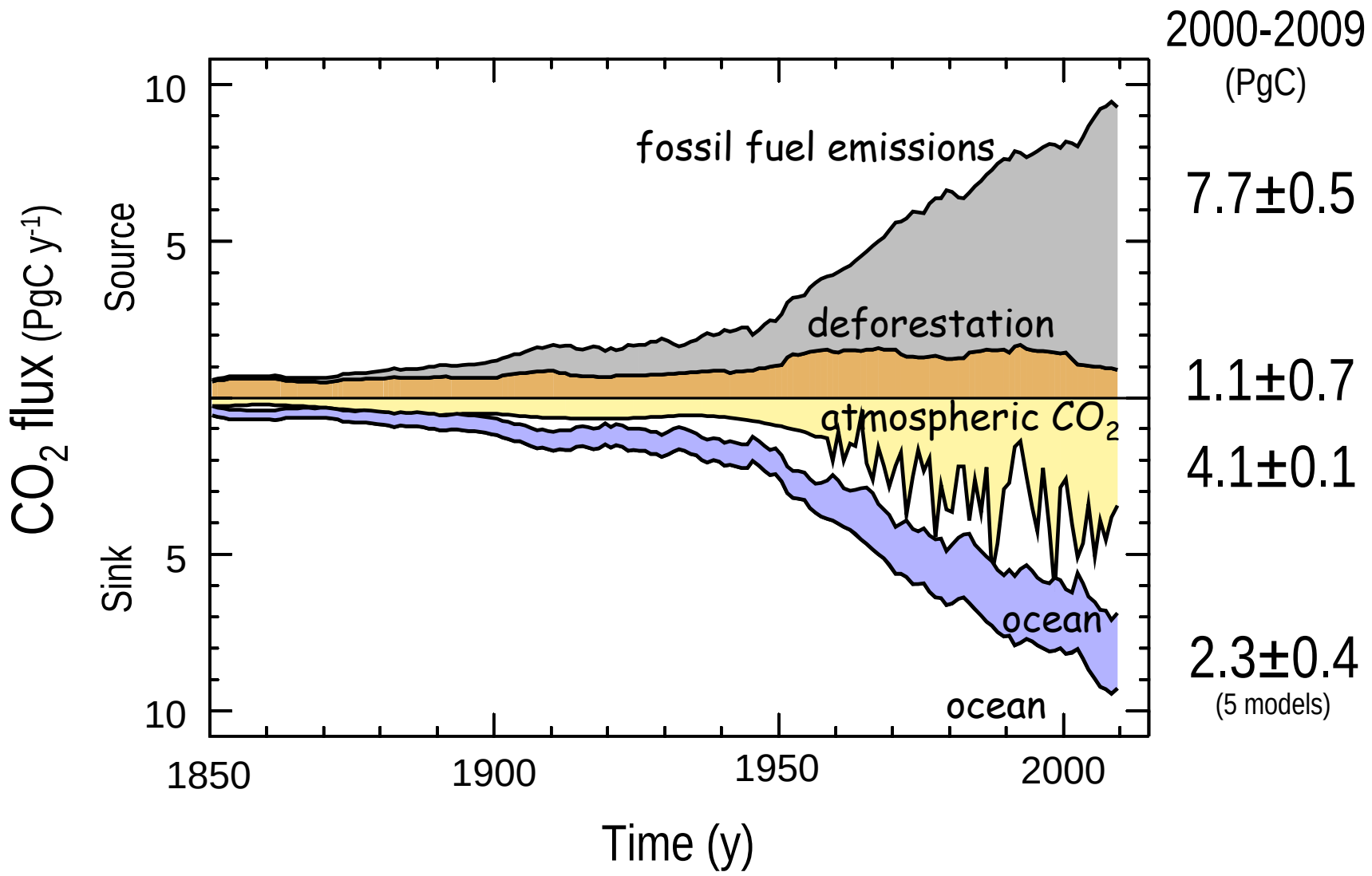

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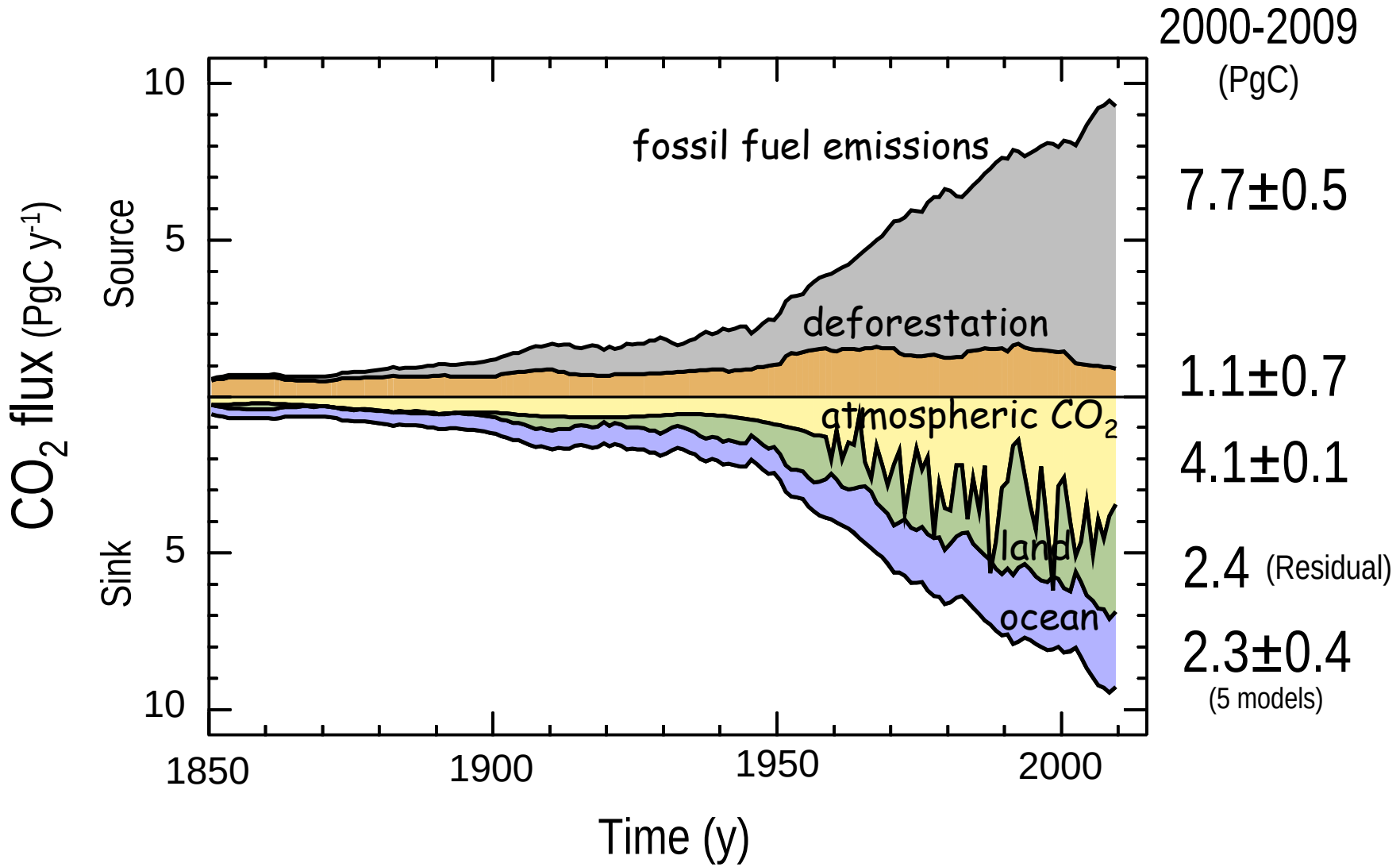


Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

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

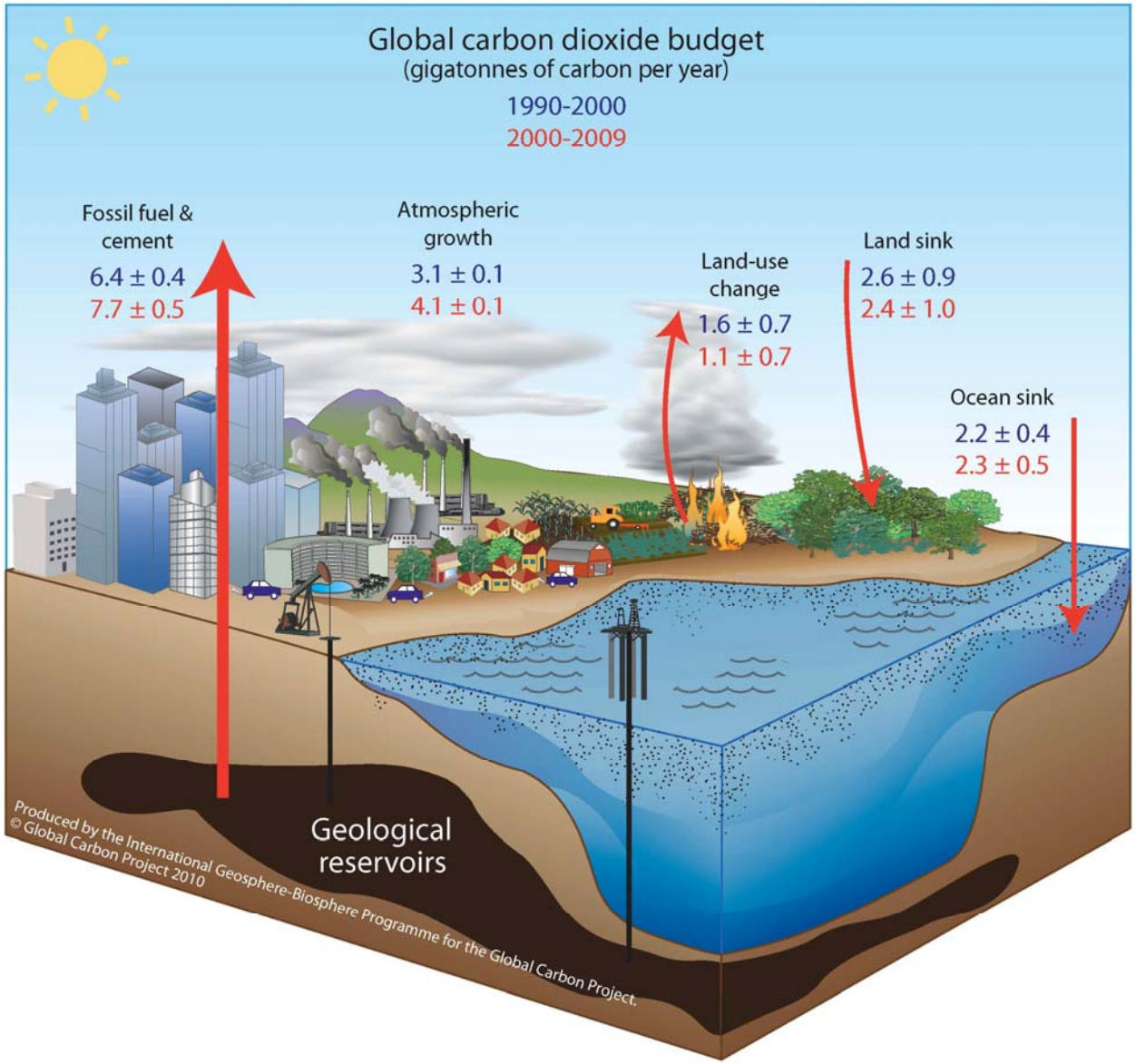
26%

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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