Section 19: Carbon cycle

Reading: Chapter 19

Learning outcomes

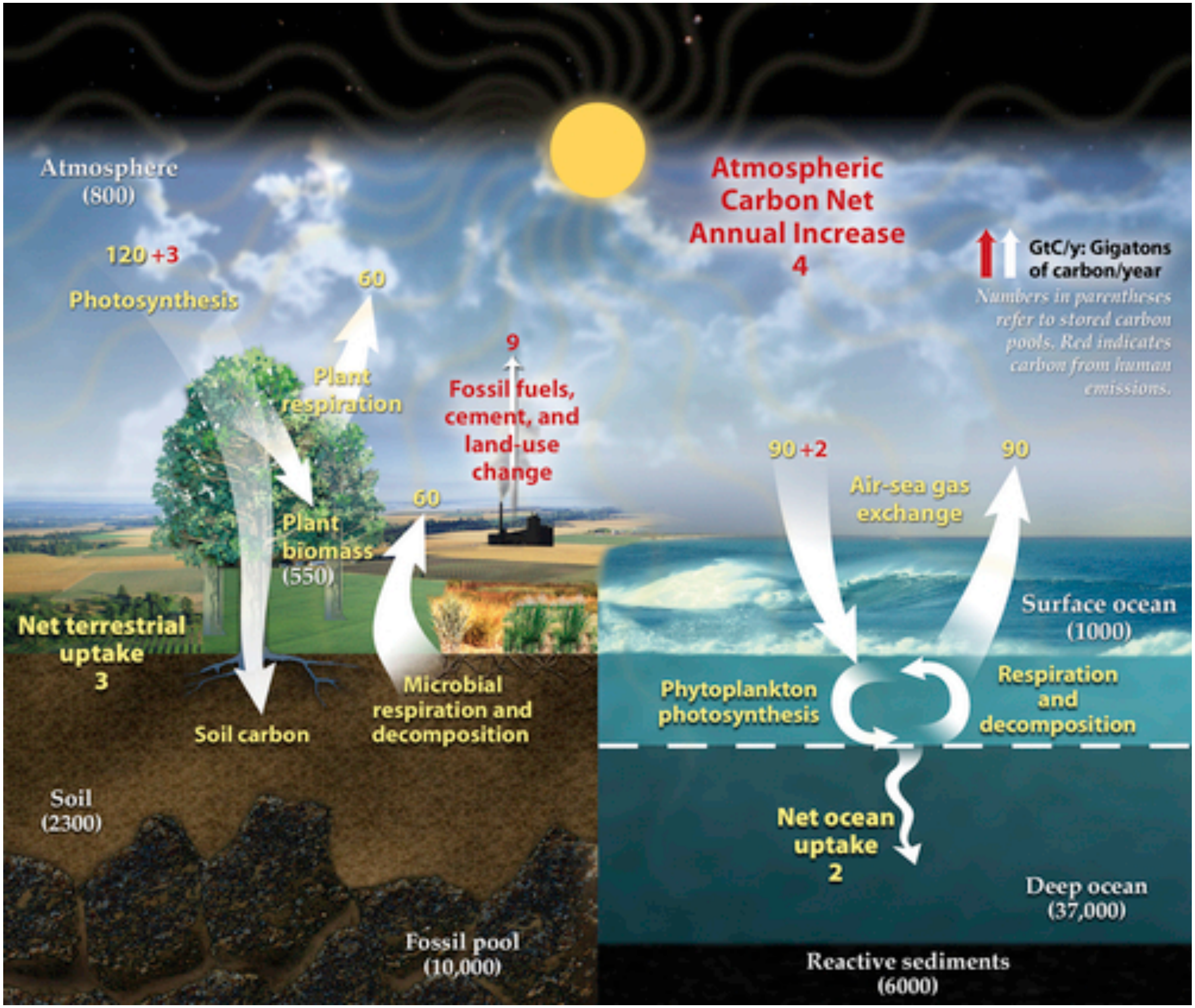
- explain the major stocks and fluxes of the global carbon cycle
- understand important influences of ecosystems on the global carbon cycle
- describe the human perturbations to the carbon cycle and where the emitted carbon is going
- understand the global and US carbon budgets with respect to ecosystem participation

Global carbon cycle (units: Pg C)

(stocks)

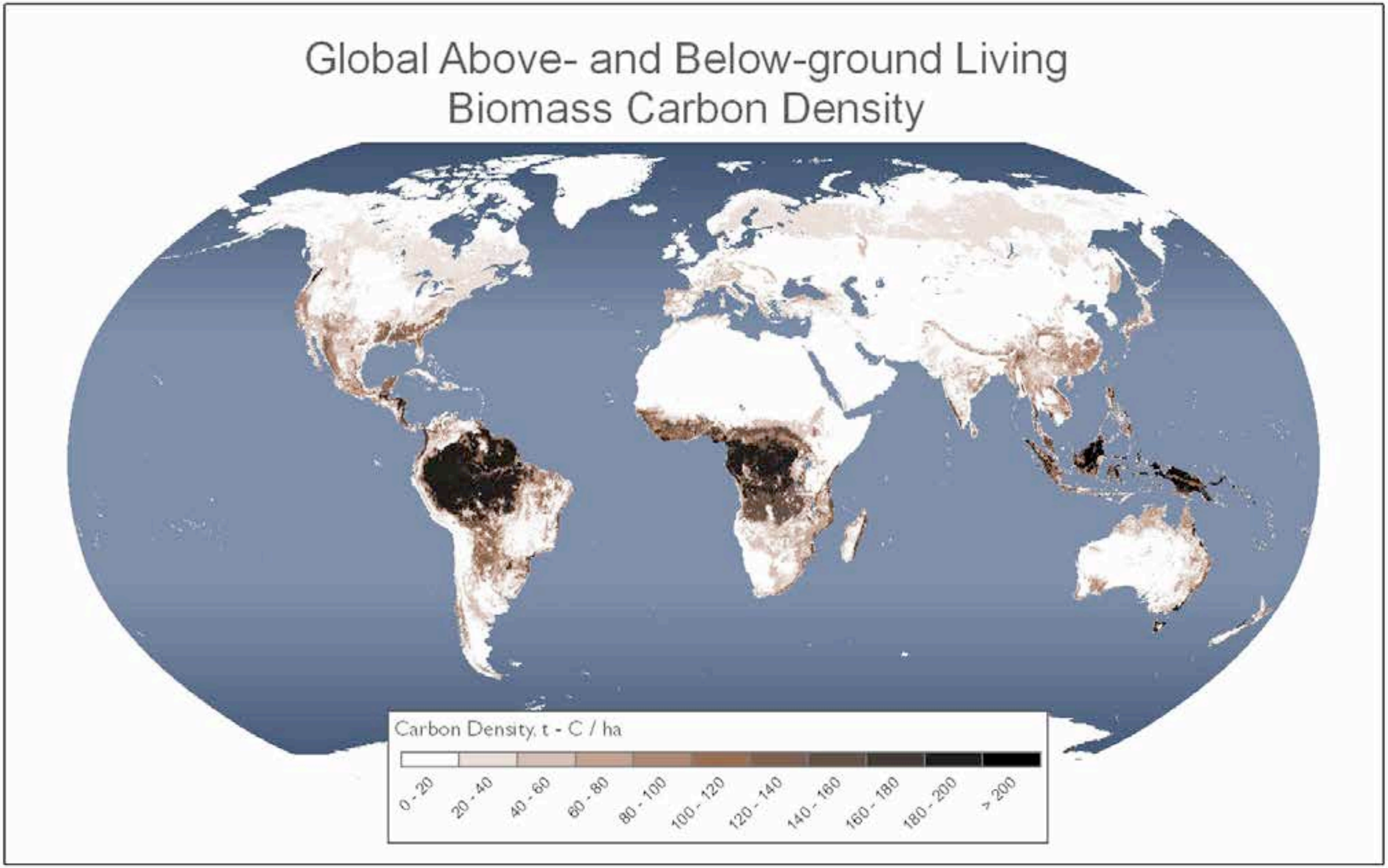
natural fluxes

human activities



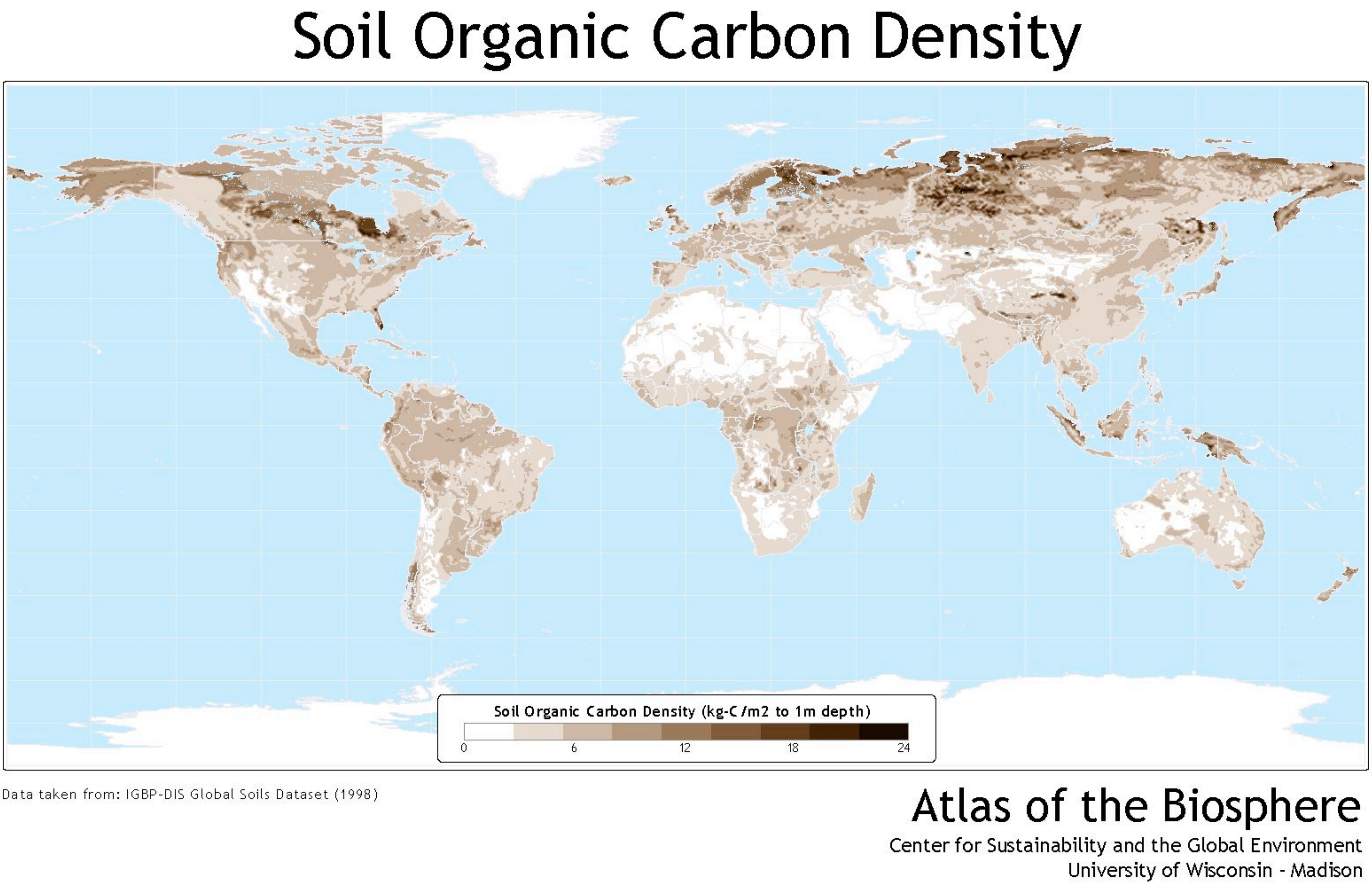
Hannah, 2014; DOE

Carbon stocks

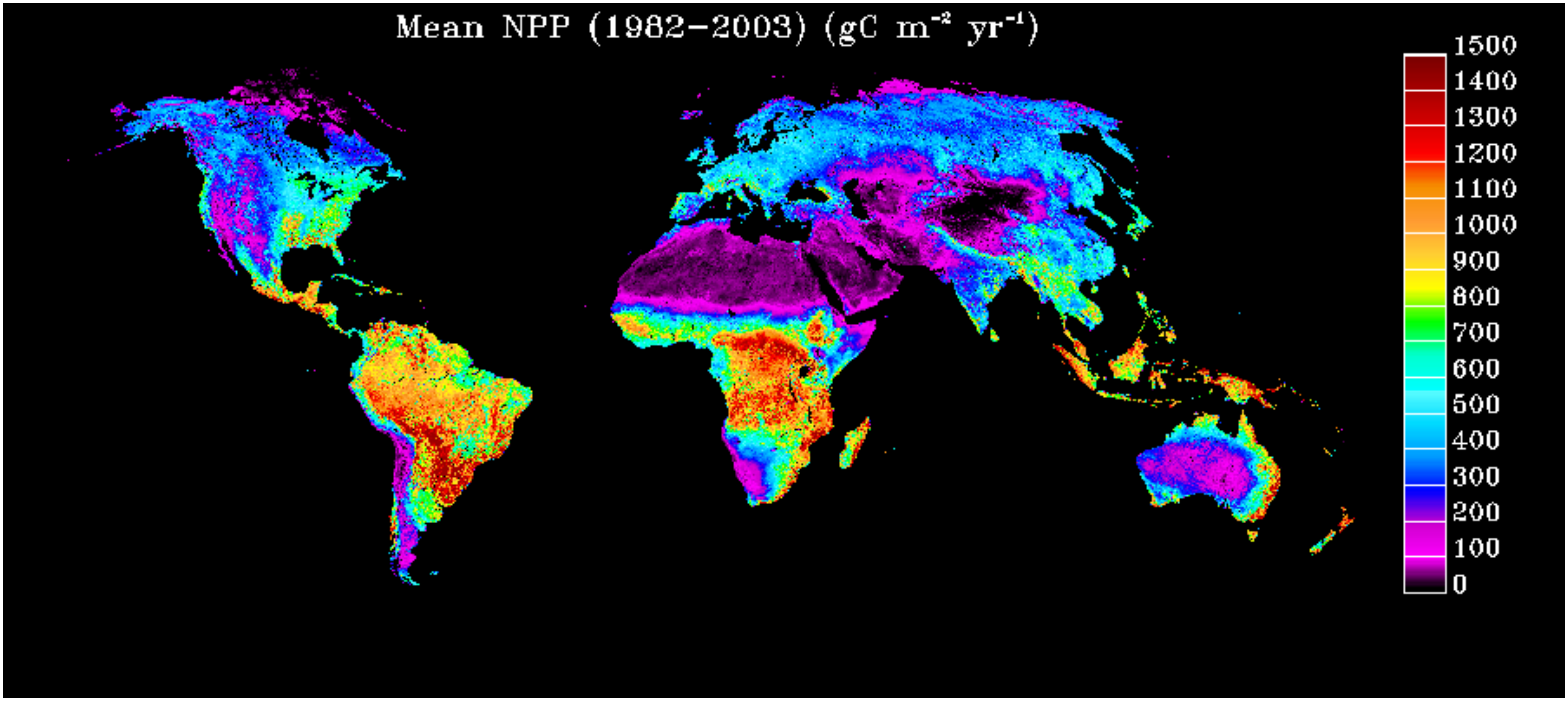


Hannah, 2014; IPCC

Carbon stocks

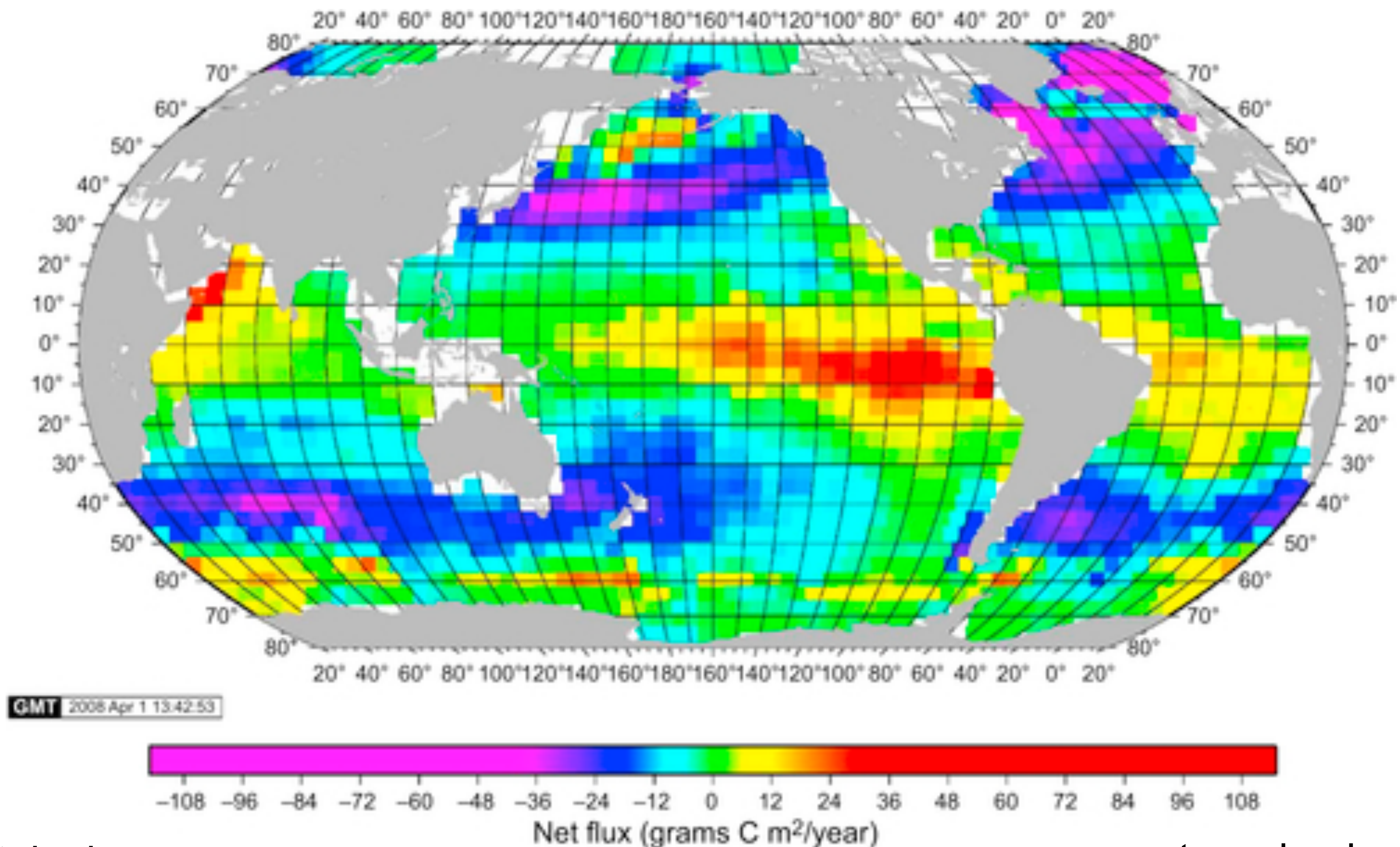


Carbon fluxes



Hicke, 2005

Net CO_2 flux from oceans

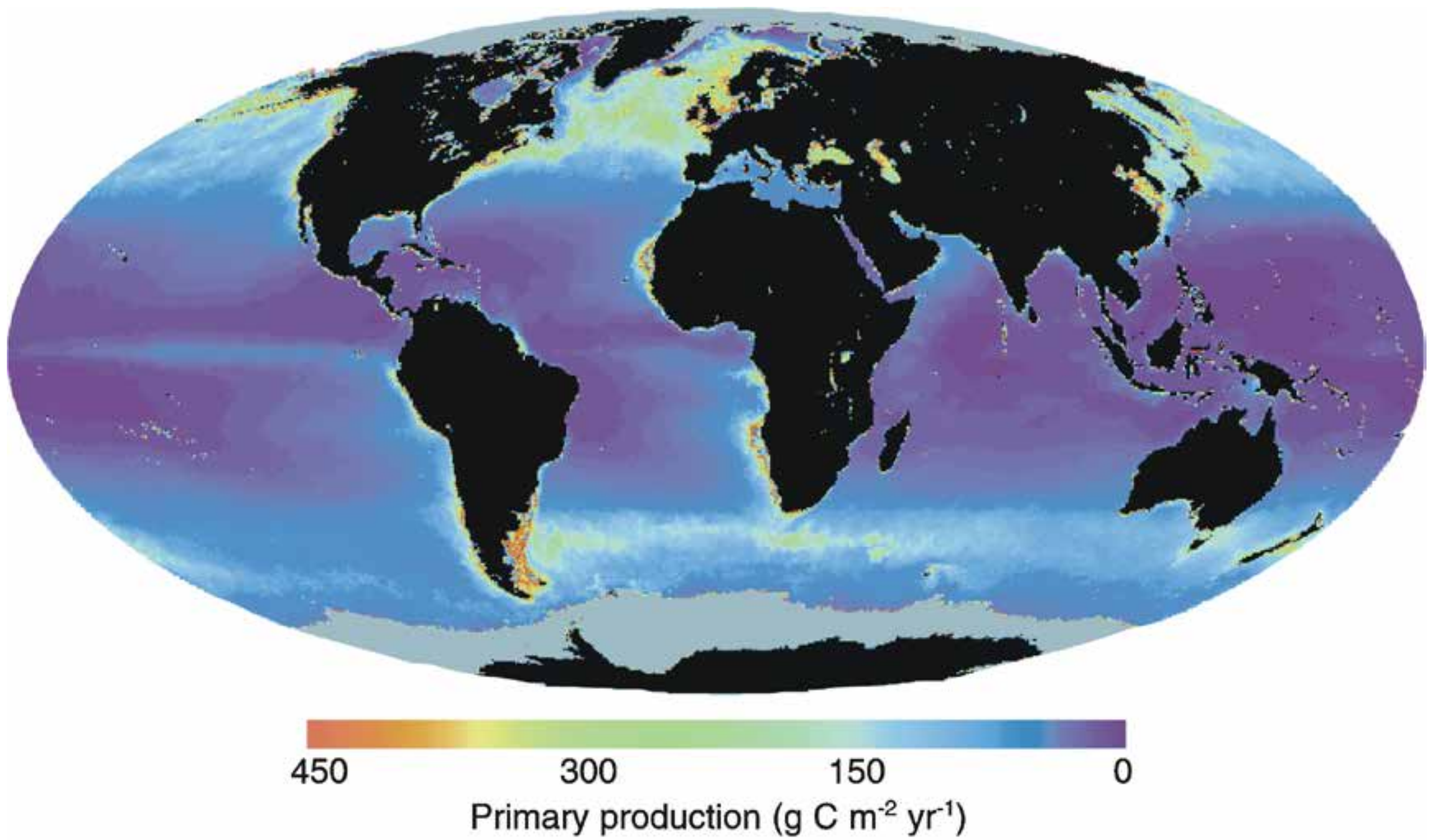


uptake by ocean

outgassing by ocean

Hannah, 2014; NASA

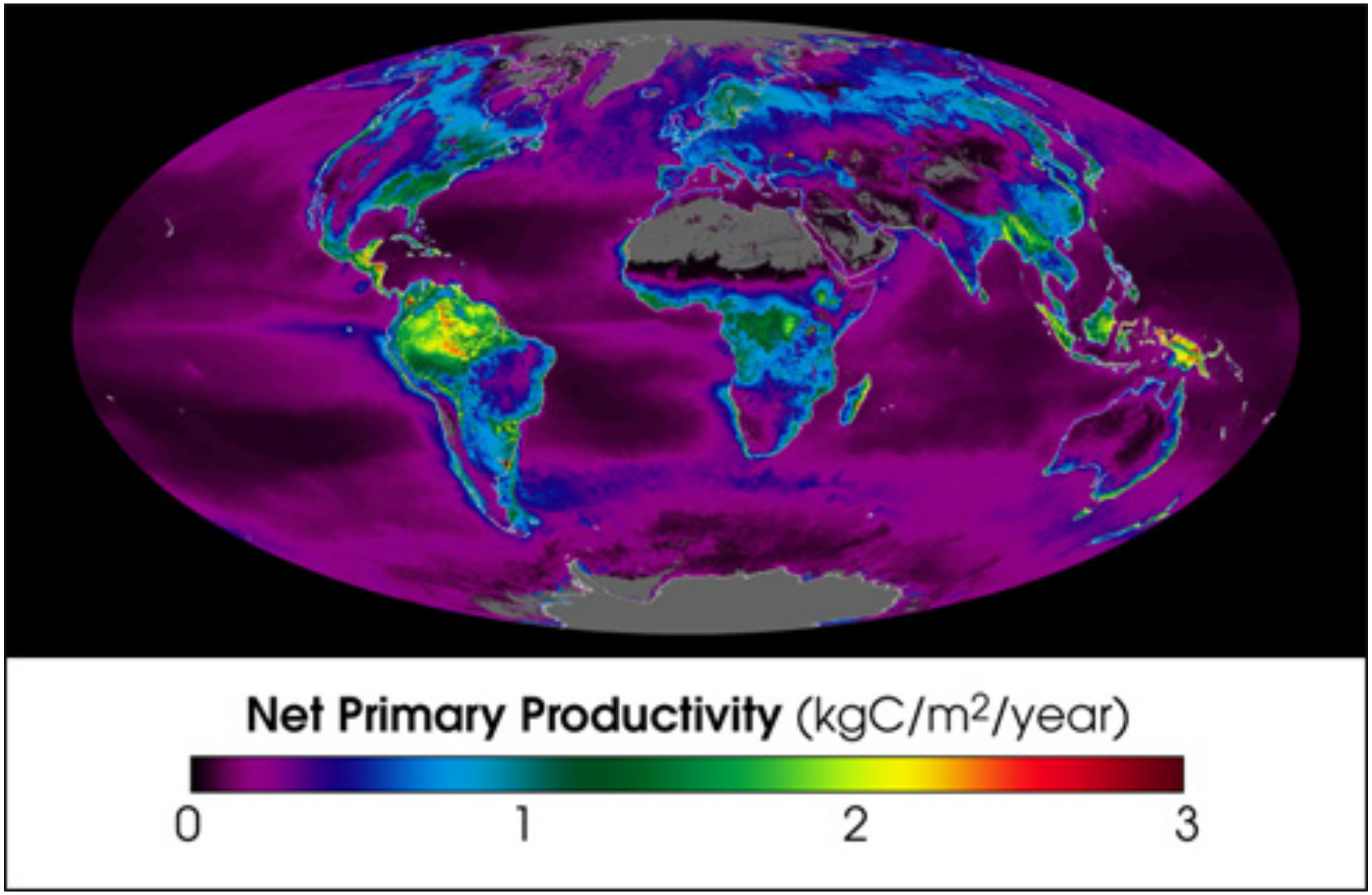
One component of ocean C cycle: biological productivity



© Springer-Verlag Berlin Heidelberg 2005

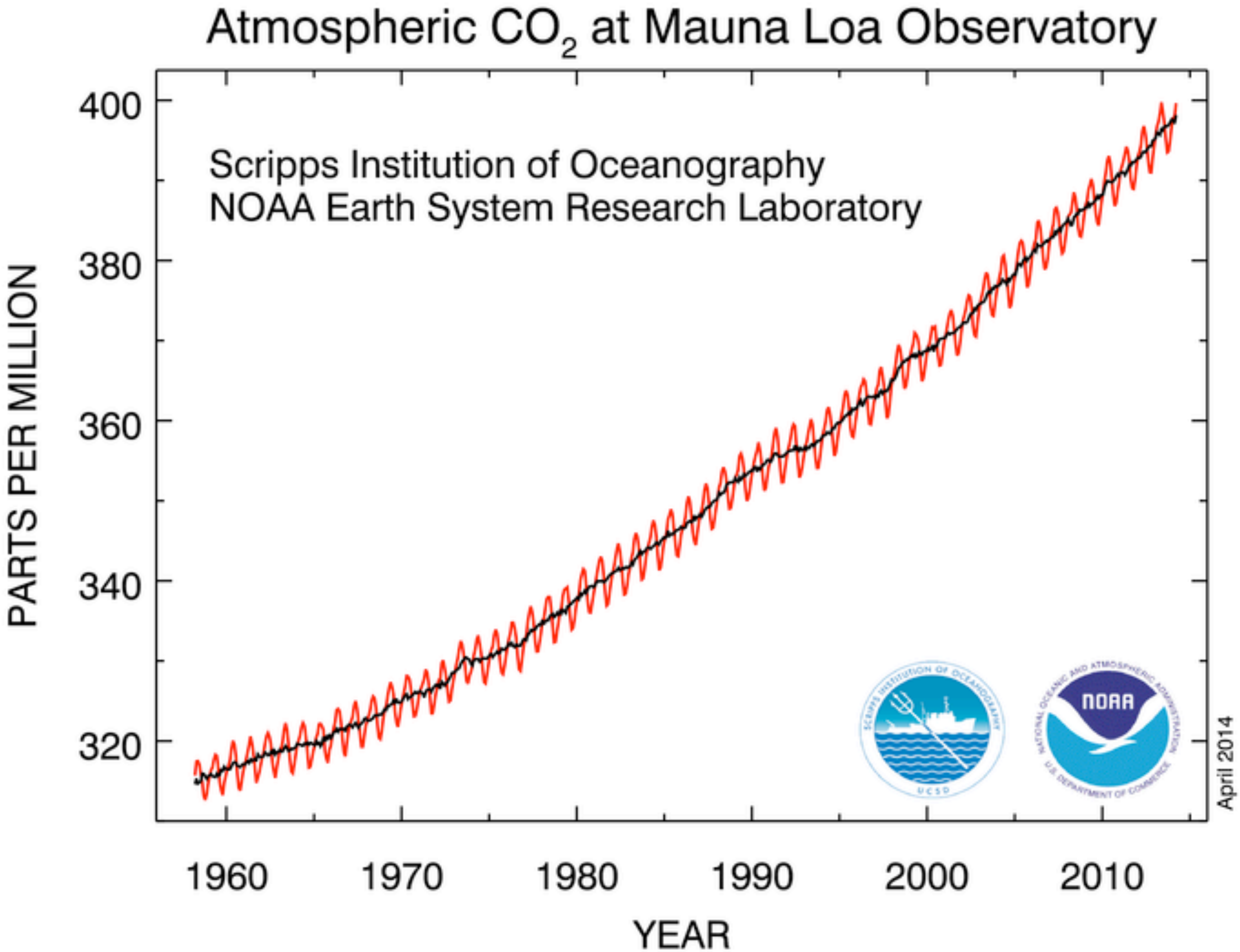
Steffen et al., 2005

NPP over Oceans and Land

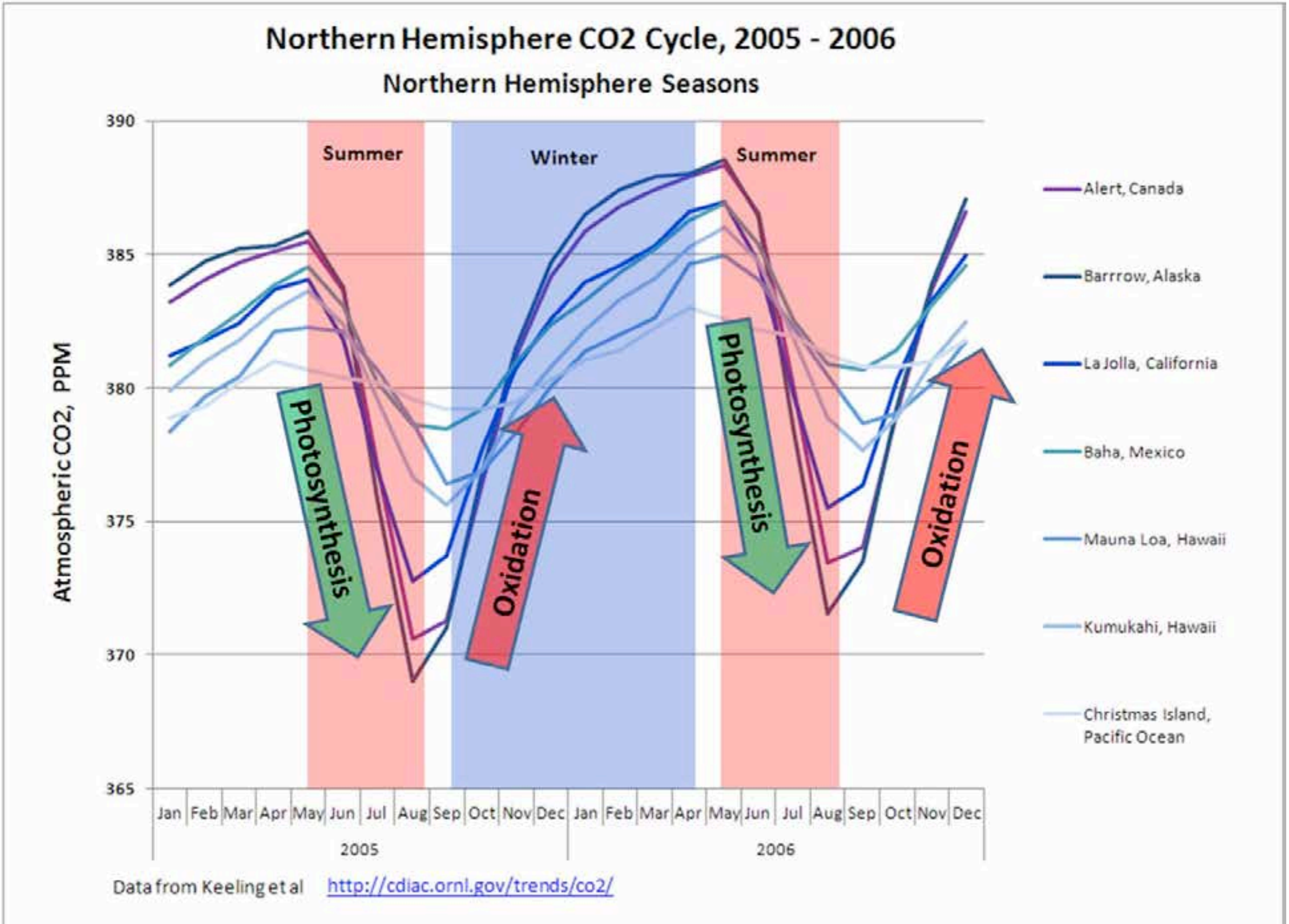


Oceans: 50 Pg C/year Land: 60 Pg C/year

science.hq.nasa.gov/oceans/system/climate.html


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
April 2014

Annual cycle of atmospheric CO2



dougrobbins.blogspot.com/2012/04/modeling-global-co2-

Tropical deforestation

www.argentinaindependent.com/socialissues/environment/amazonian-deforestation-soars/

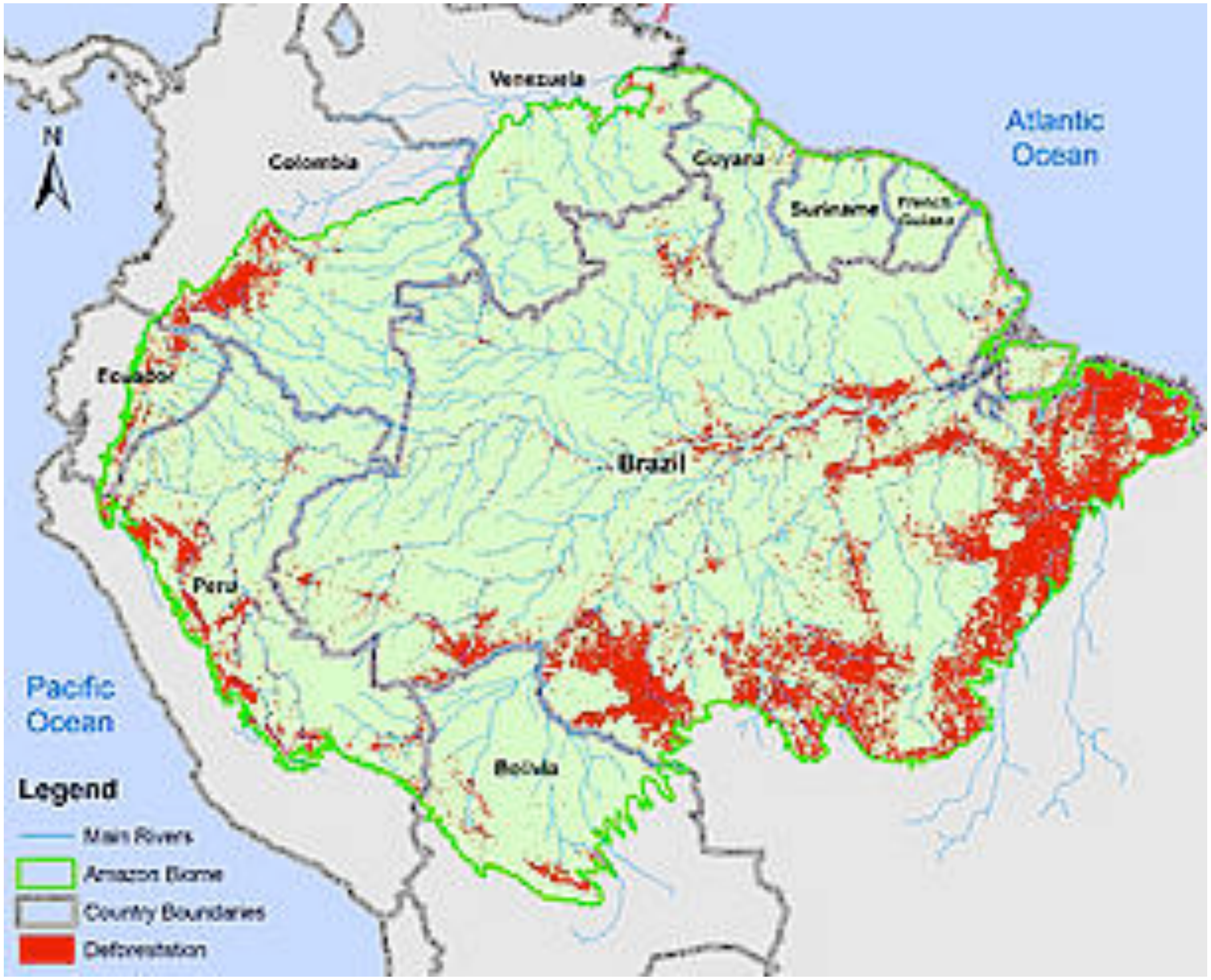
www.ibtimes.com/reversal-fortune-deforestation-amazon-rainforest-increased-28-over-past-year-1472840

www.npr.org/blogs/parallels/2013/05/31/187301981/Battling-Deforestation-In-Indonesia-One-Firm-At-A-Time

Deforestation patterns

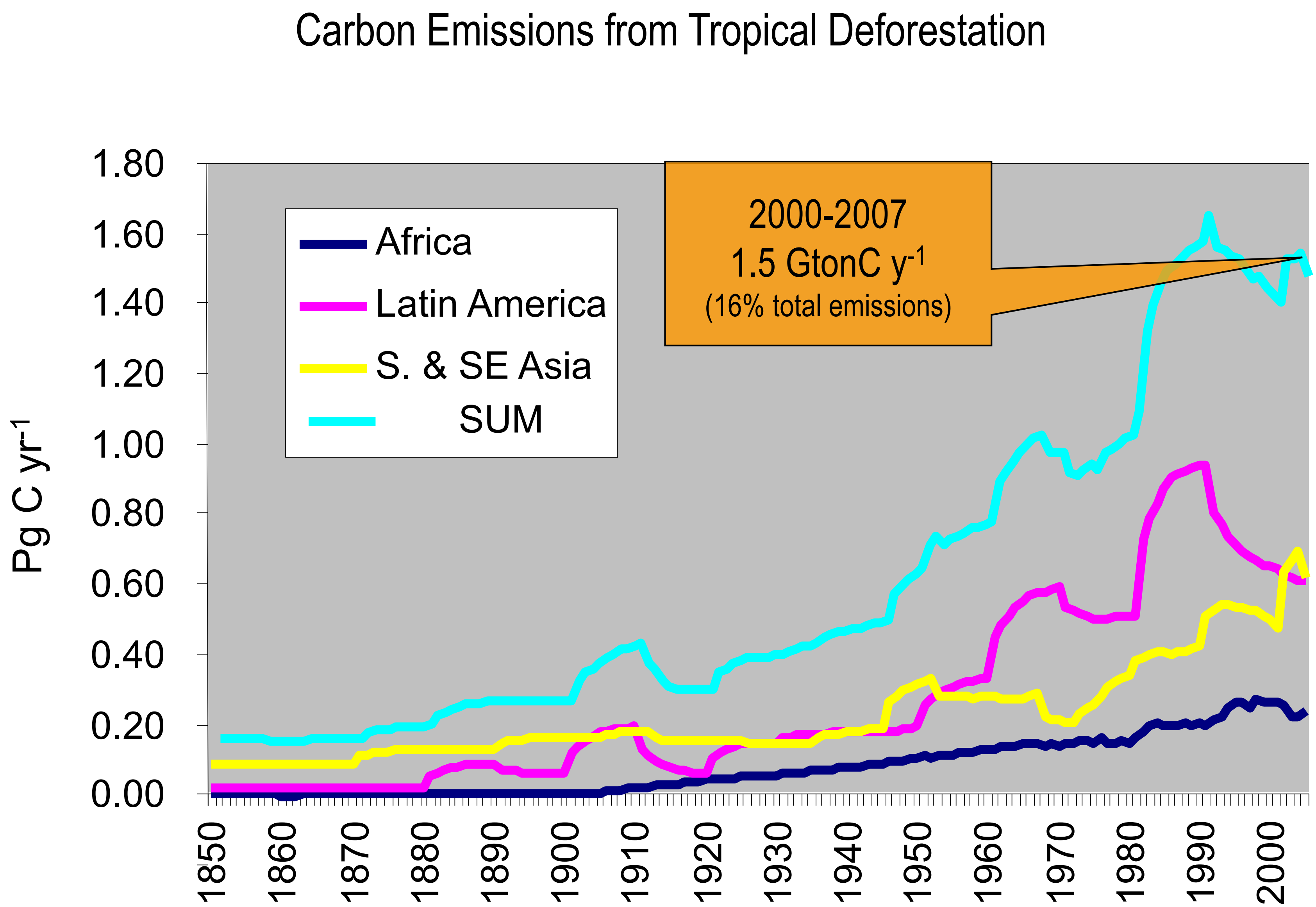
upload.wikimedia.org/wikipedia/commons/b/b6/Fires_and_Deforestation_on_the_Amazon_Frontier%2C_Rondonia%2C_Brazil_-_August_12%2C_2007.jpg

Arc of deforestation (red) in Amazon



http://wwf.panda.org/what_we_do/where_we_work/amazon/problems/

Historical Emissions from Land Use Change



R.A. Houghton, unpublished

Disturbance effects on C cycle: Fires

Global C emissions from fires

Human and climate (change?) influences?

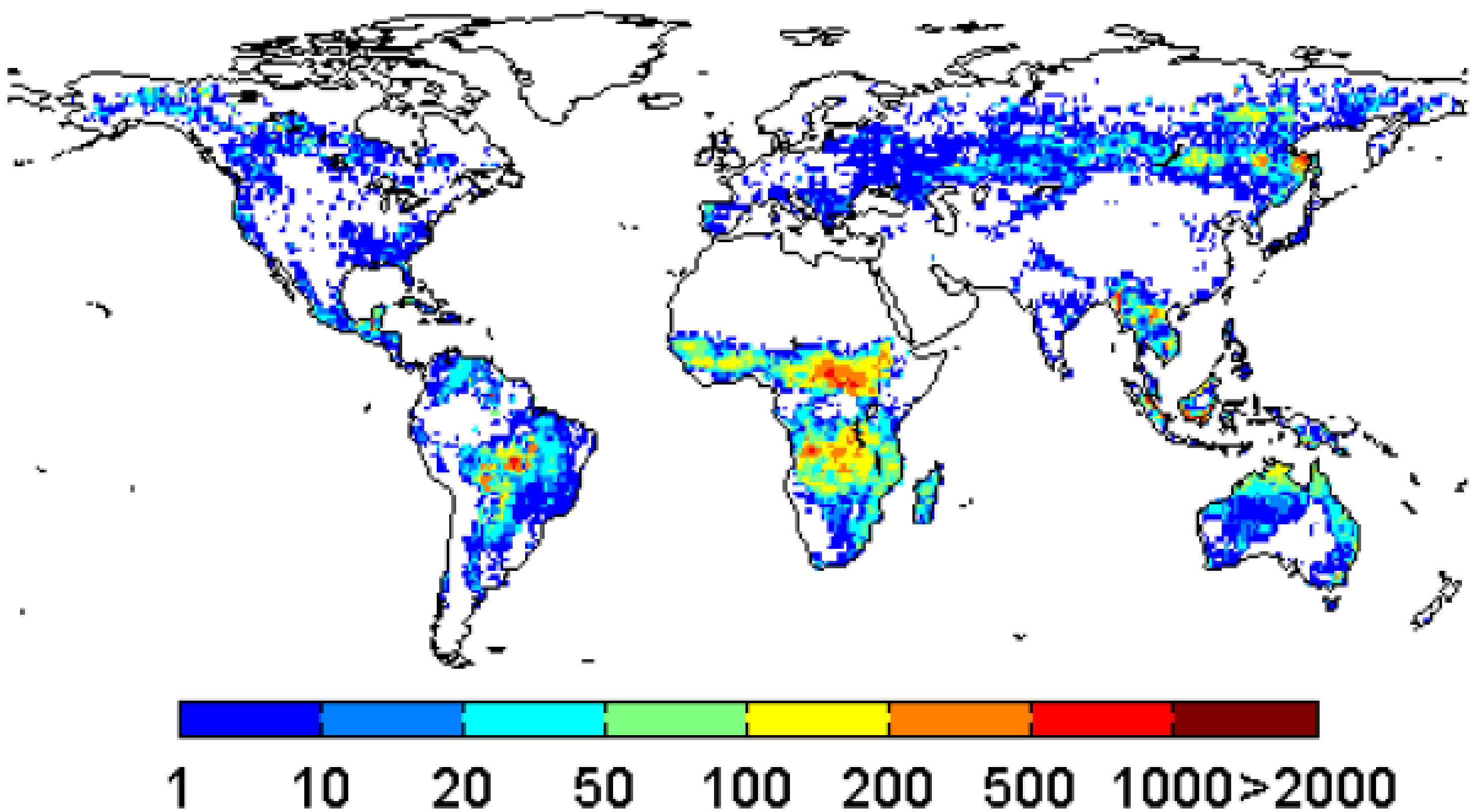
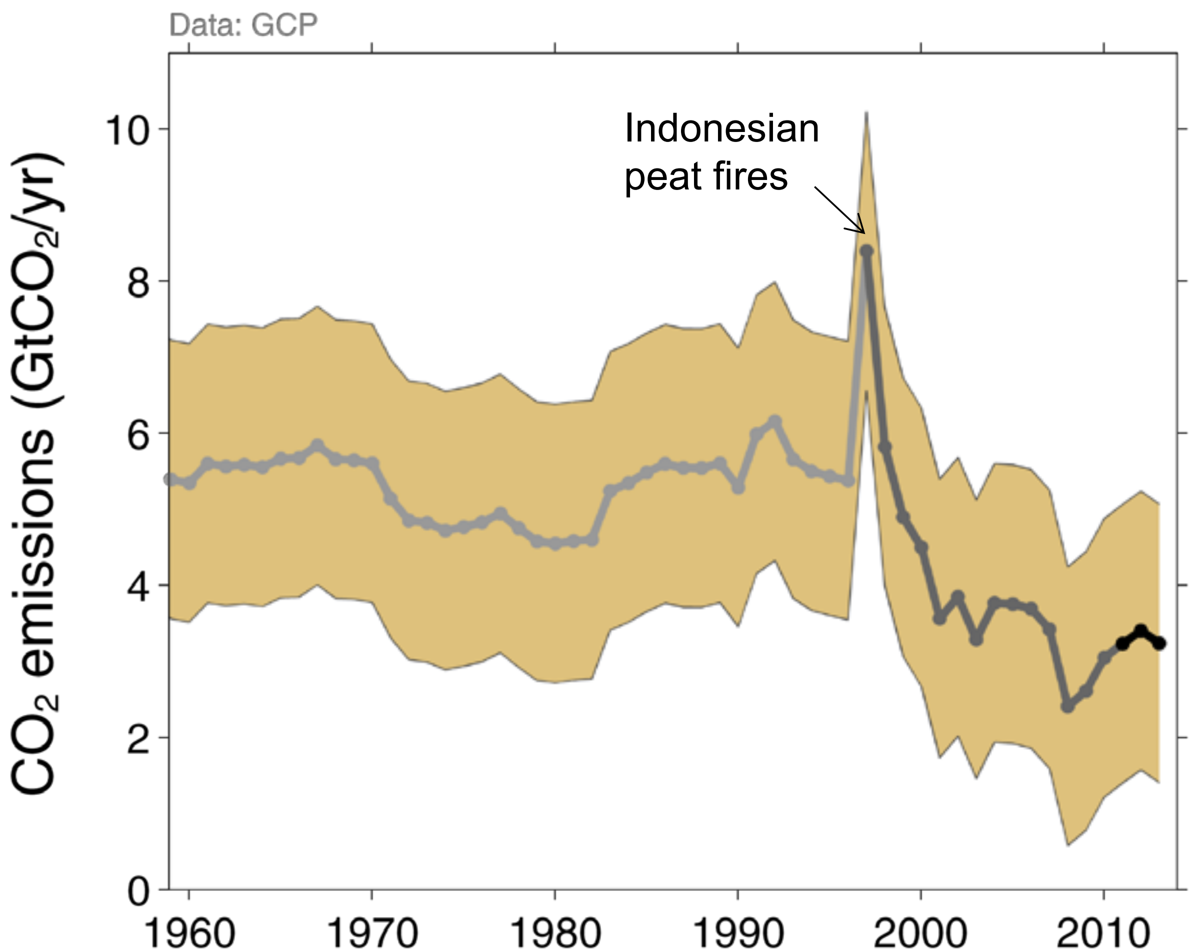


Fig. 6. Mean annual fire emissions (g C m^{-2} year^{-1}) averaged ov
1997–2004.

van der Werf et al., 2006

Land-Use Change Emissions

Global land-use change emissions are estimated 3.3 ± 1.8 $GtCO_2$ during 2004–2013
The data suggests a general decrease in emissions since 1990

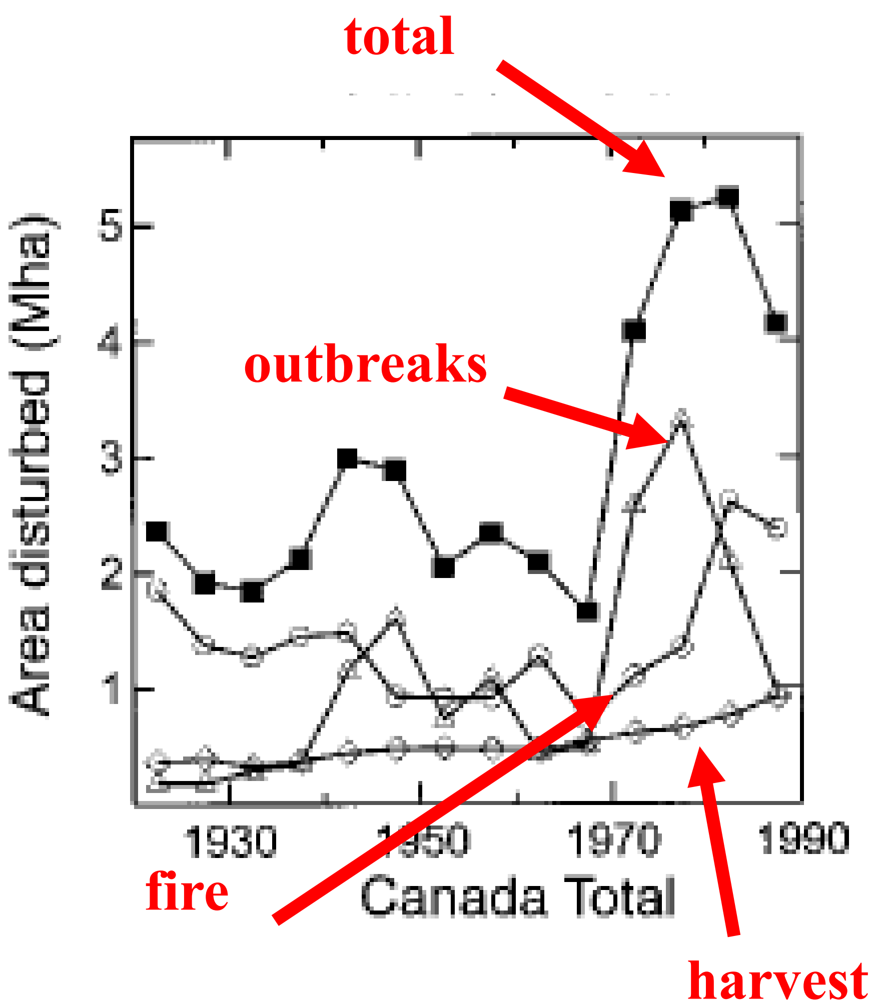


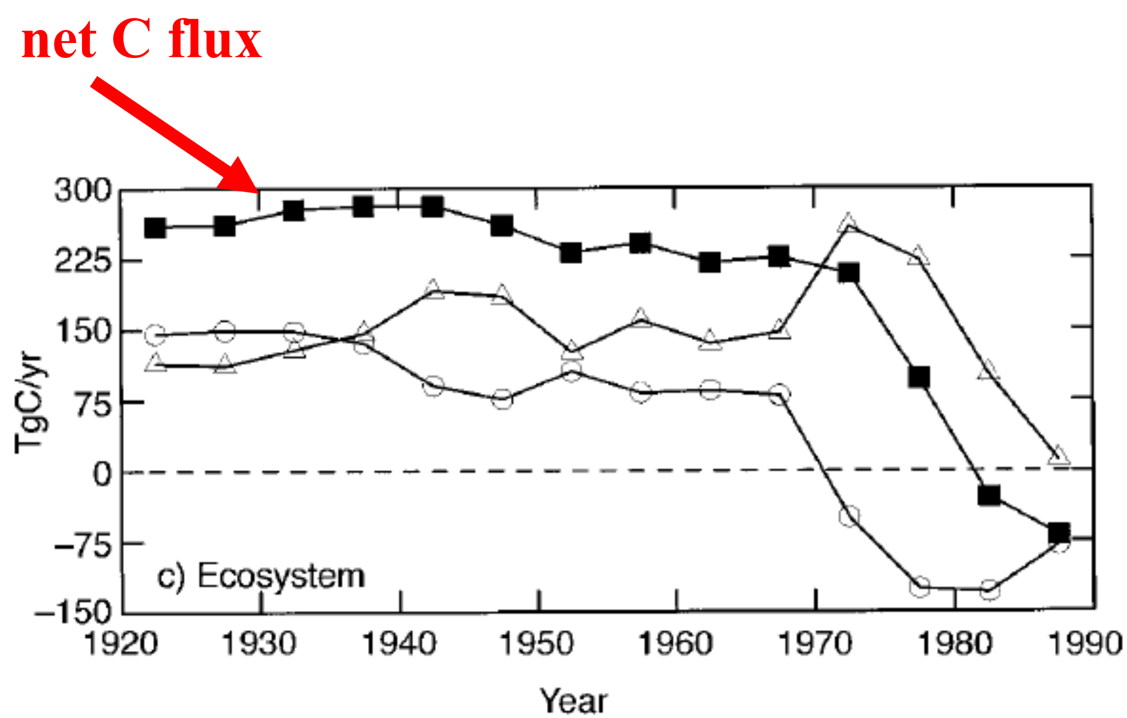
Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH_4 and N_2O which are not shown here

Source: Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

Disturbance effects on C cycle

Canada's forest carbon budget

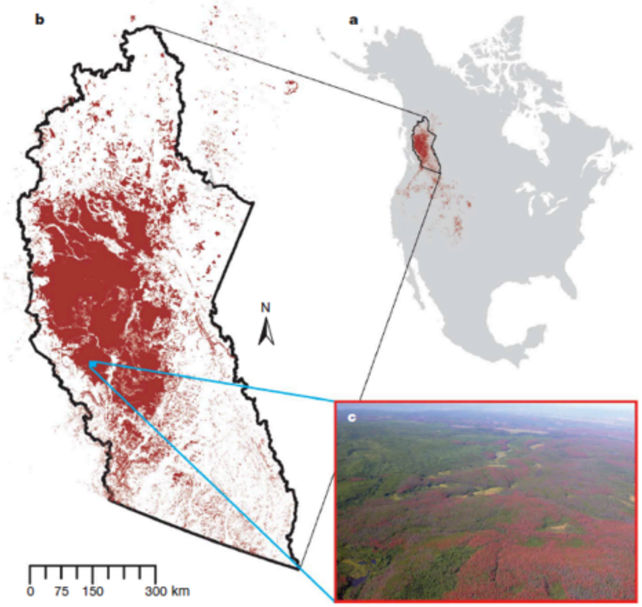


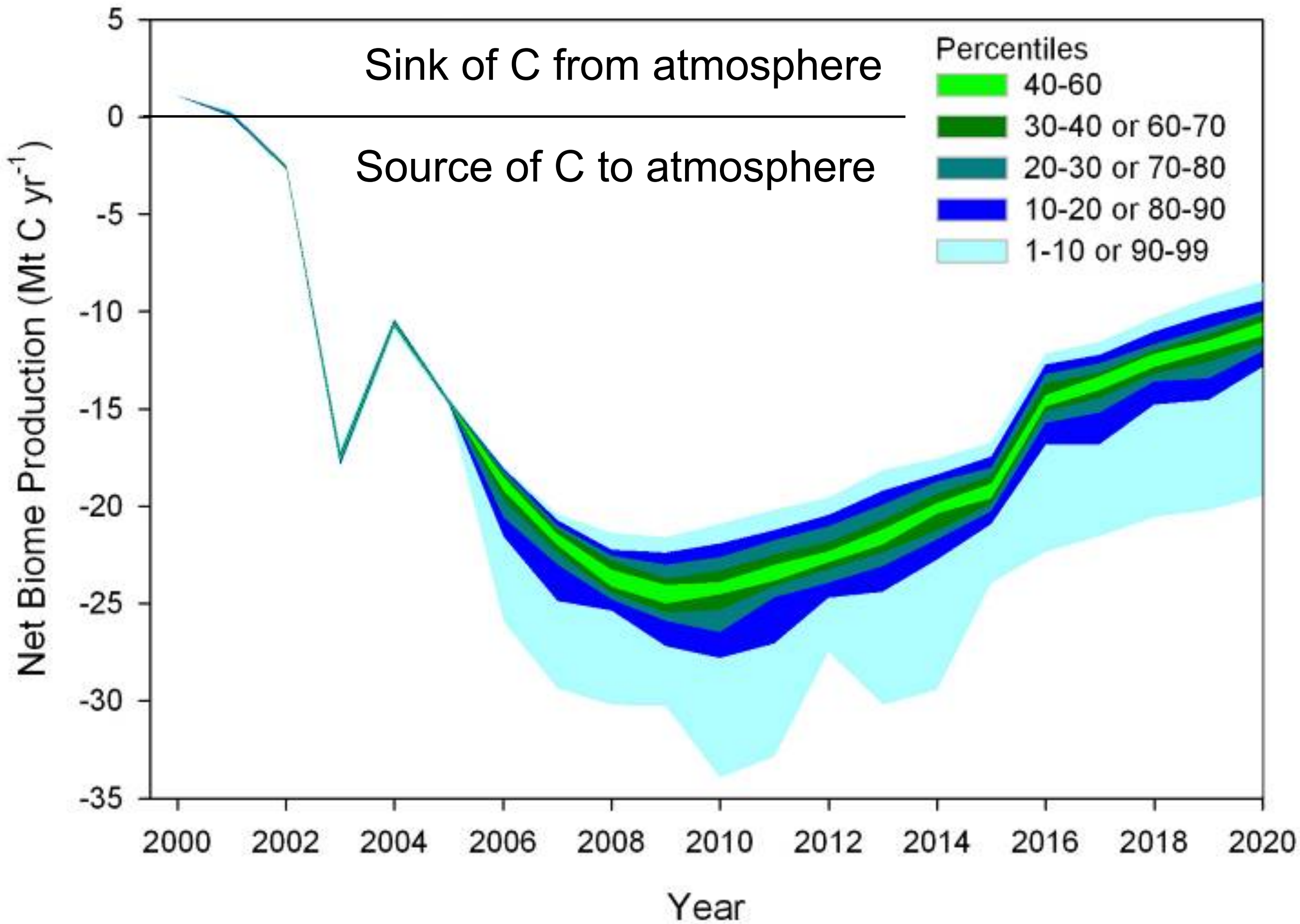


Human and climate (change?) influences?

Kurz and Apps, EA, 1999

Forest disturbances and the C cycle





Cumulative impact: equivalent to 5 years of emissions from Canada's transportation sector

Kurz et al. 2008, Nature

Disturbance effects on C cycle: Storms

Hurricane Katrina's effects on forest C stocks

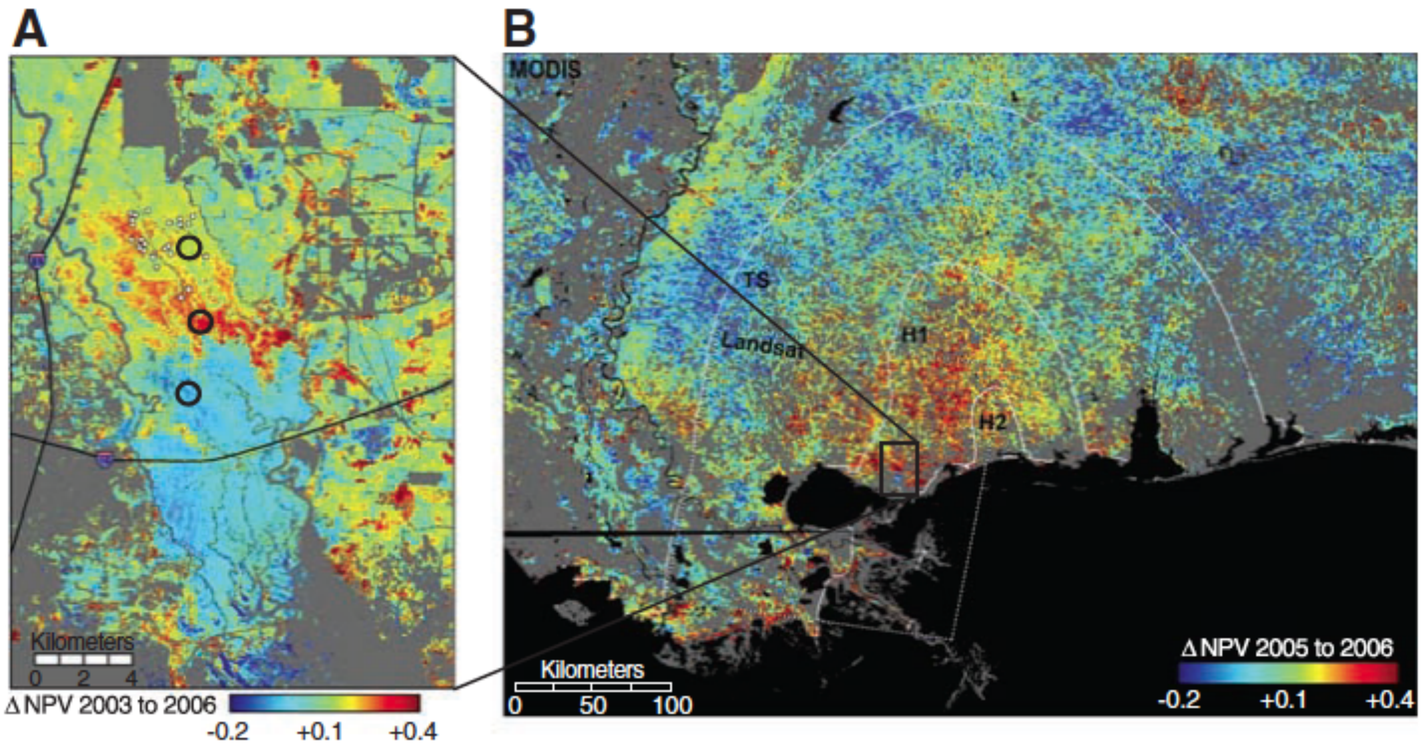
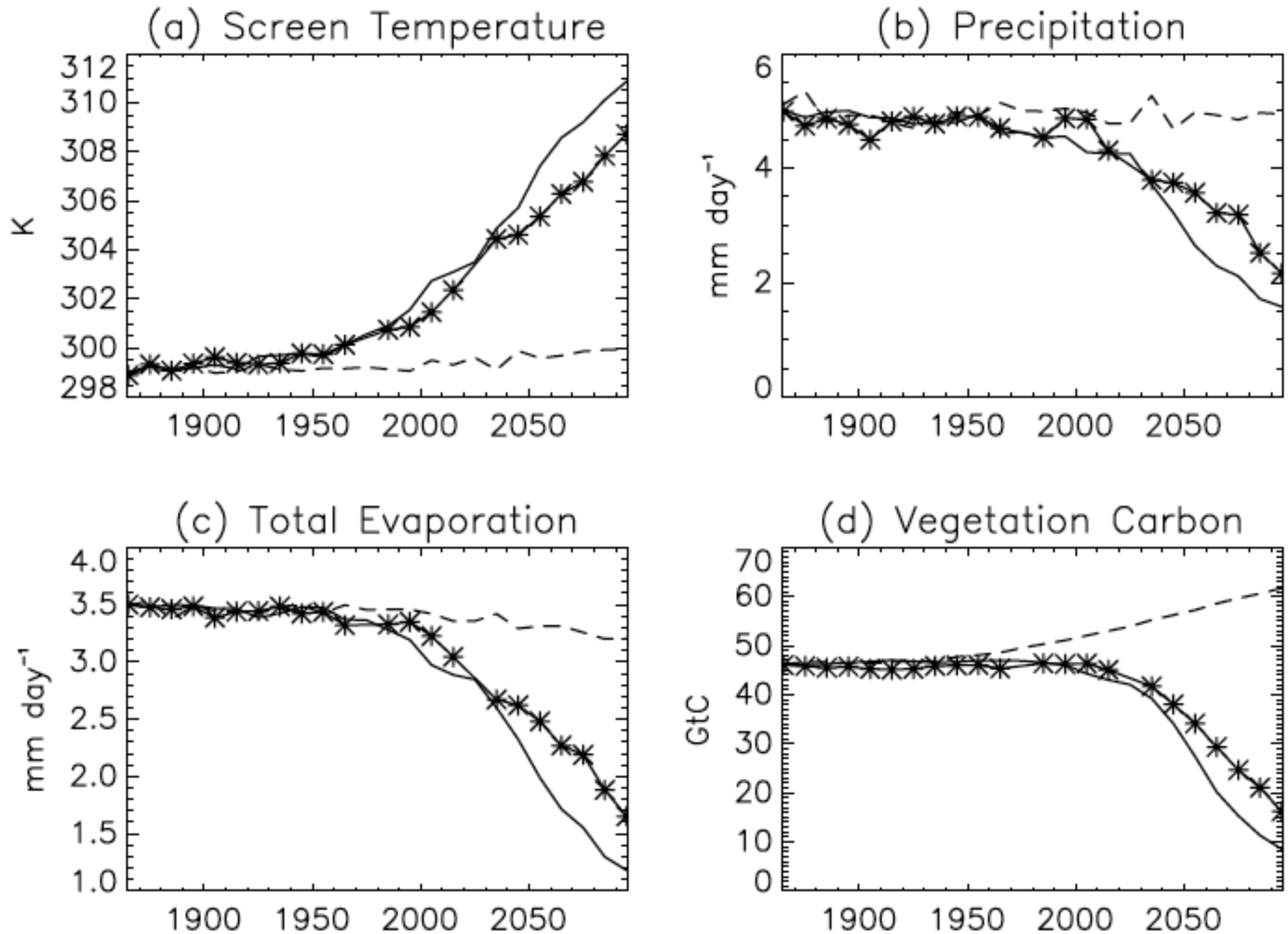


Fig. 1. (**A**) Pre- to posthurricane change in the NPV fraction (ΔNPV) on a Landsat 5 subset for the Pearl River basin (Louisiana-Mississippi state line) provided a quantitative measure of disturbance intensity. By using this map, we established forest inventory plots (white markers) across the disturbance gradient. Open black markers represent (top) moderately resistant, infrequently flooded, bottomland hardwood forest; (middle) minimally resistant, frequently flooded, bottomland hardwood forest; and (bottom) highly resistant, flooded, cypress-tupelo swamp forest. (**B**) MODIS-derived ΔNPV from 2005–2006 provided regional estimates of tree mortality and biomass loss across the entire impact region. Isotachs (white lines) represent tropical storm (TS), category 1 (H1), and category 2 (H2) wind fields (*9*).

- Mortality and damage to 320 million large trees
- 105 Tg C
- 50-140% of net annual C sink in US forests

Chambers et al., 2007

Disturbance effects on C cycle: Drought



Model predictions of Amazon dieoff in response to future climate change

Fig. 7. Evolution of climate and biomass over the Amazon box, from three separate HadCM3LC simulations with dynamic vegetation. (**a**) Screen temperature, (**b**) precipitation, (**c**) evaporation, (**d**) vegetation carbon. The continuous line represents the fully coupled climate-carbon cycle run, the dashed line is from the run without climate effects on the carbon cycle, and the stars are from a run with prescribed IS92a CO_2 concentrations. The related CO_2 scenarios are shown in Fig. 1

Cox et al., 2004

Model predictions of Amazon dieoff in response to future climate change

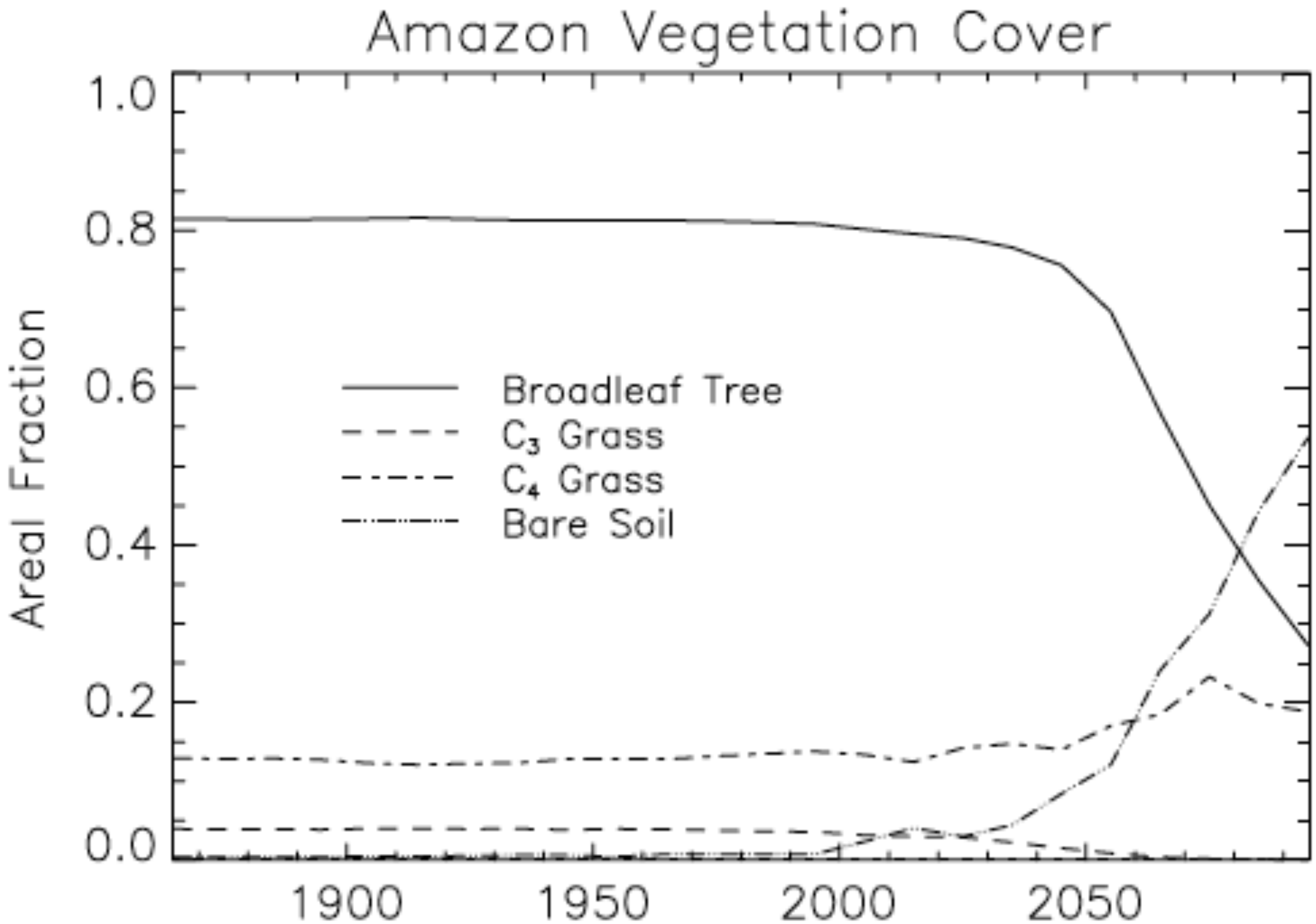
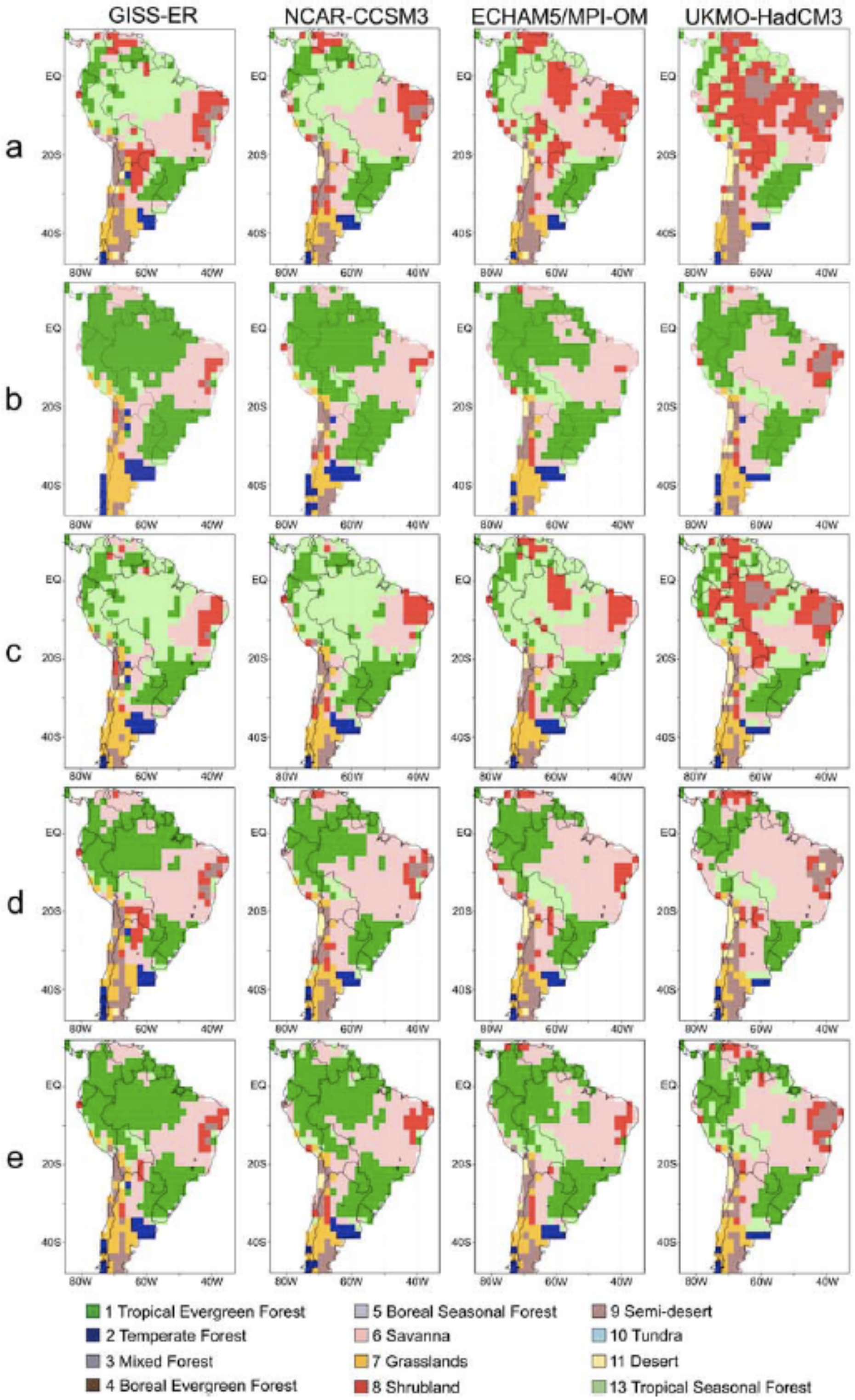


Fig. 6. Evolution of the vegetation cover in the Amazon box from the coupled climate-carbon cycle simulation

Cox et al., 2004



Large uncertainties when modeling future vegetation type

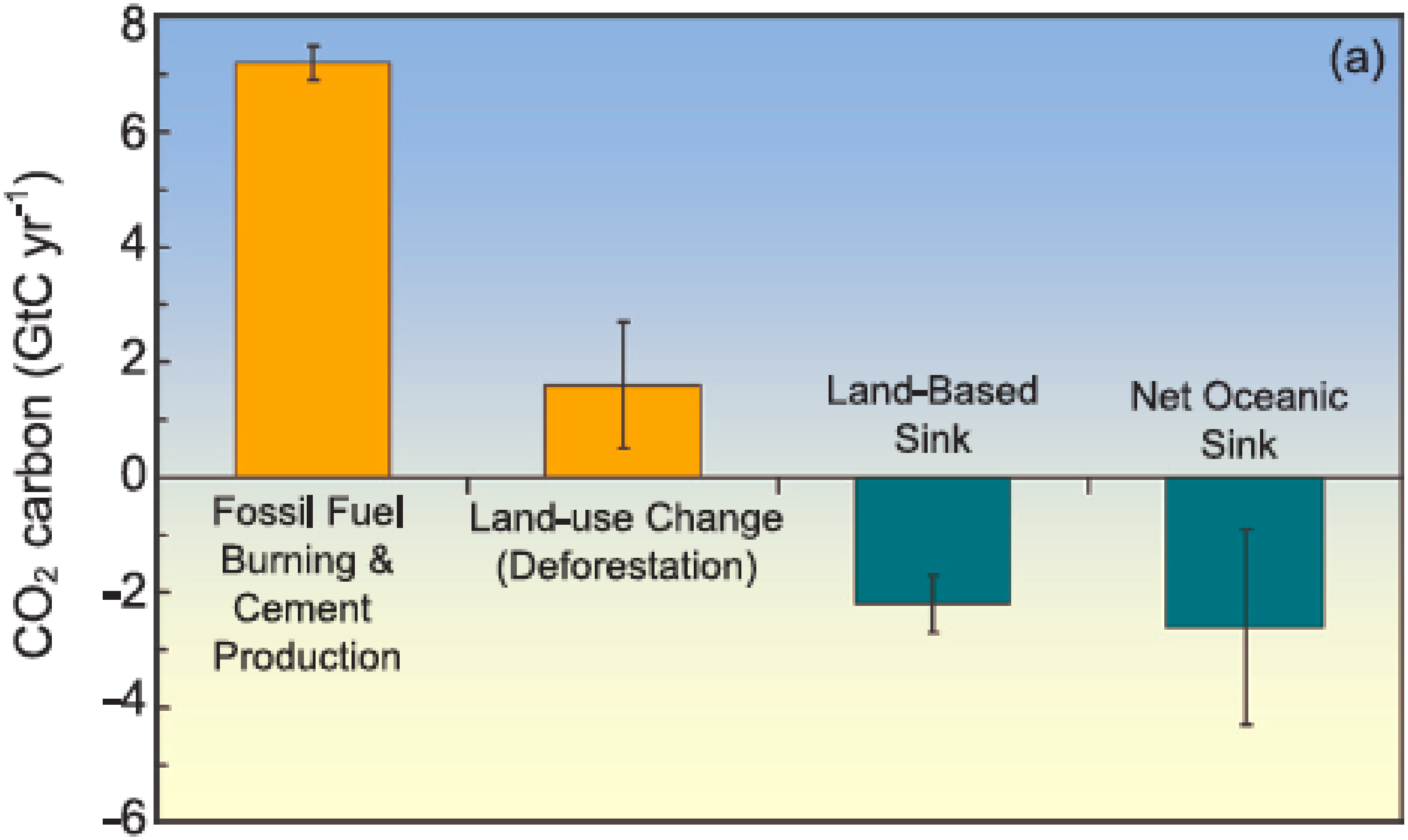
columns: different GCMs

rows: different assumptions about vegetation (amount of CO2 and its effect on photosynthesis)

Lapola et al., 2009

Current sources and sinks of major greenhouse gases

CO_2



IPCC, Fourth Assessment Report, WG I, Chapter 7

Fate of Anthropogenic CO_2 Emissions (2004-2013 average)

32.4±1.6 $GtCO_2$/yr 91%

3.3±1.8 $GtCO_2$/yr 9%

+

15.8±0.4 $GtCO_2$/yr
44%

10.6±2.9 $GtCO_2$/yr
29%

Calculated as the residual of all other flux components

26%
9.4±1.8 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

North American carbon budget

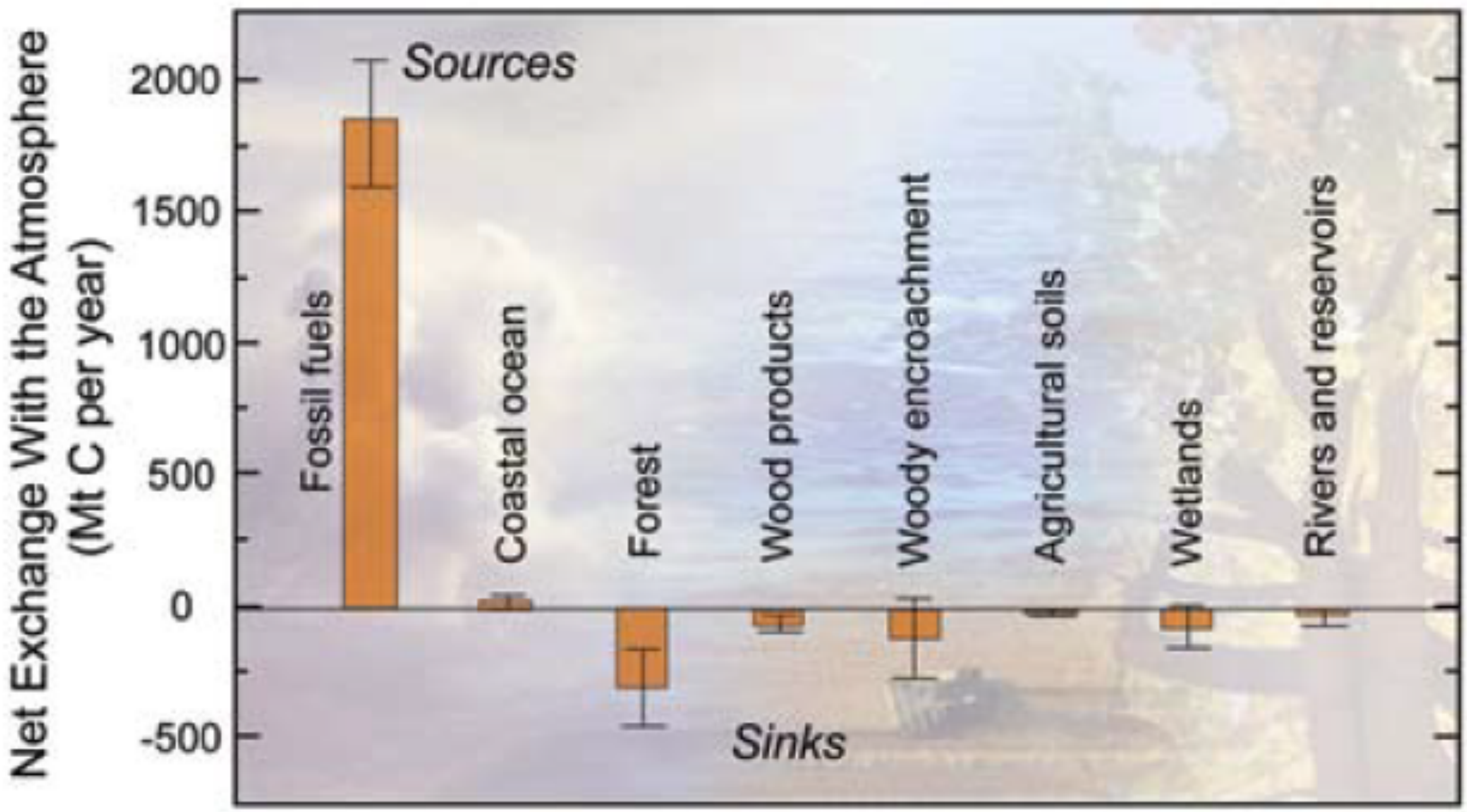


Figure ES.1 North American carbon sources and sinks (million tons of carbon per year) in 2003. Height of a bar indicates a best estimate for net carbon exchange between the atmosphere and the indicated element of the North American carbon budget. Sources add CO_2 to the atmosphere; sinks remove it. Error bars indicate the uncertainty in that estimate, and define the range of values that include the actual value with 95% certainty. See Chapter 3 and Chapters 6-15 of this report for details and discussion of these sources and sinks.

State of the Carbon Cycle Report, 2007

Historical C fluxes from US forests

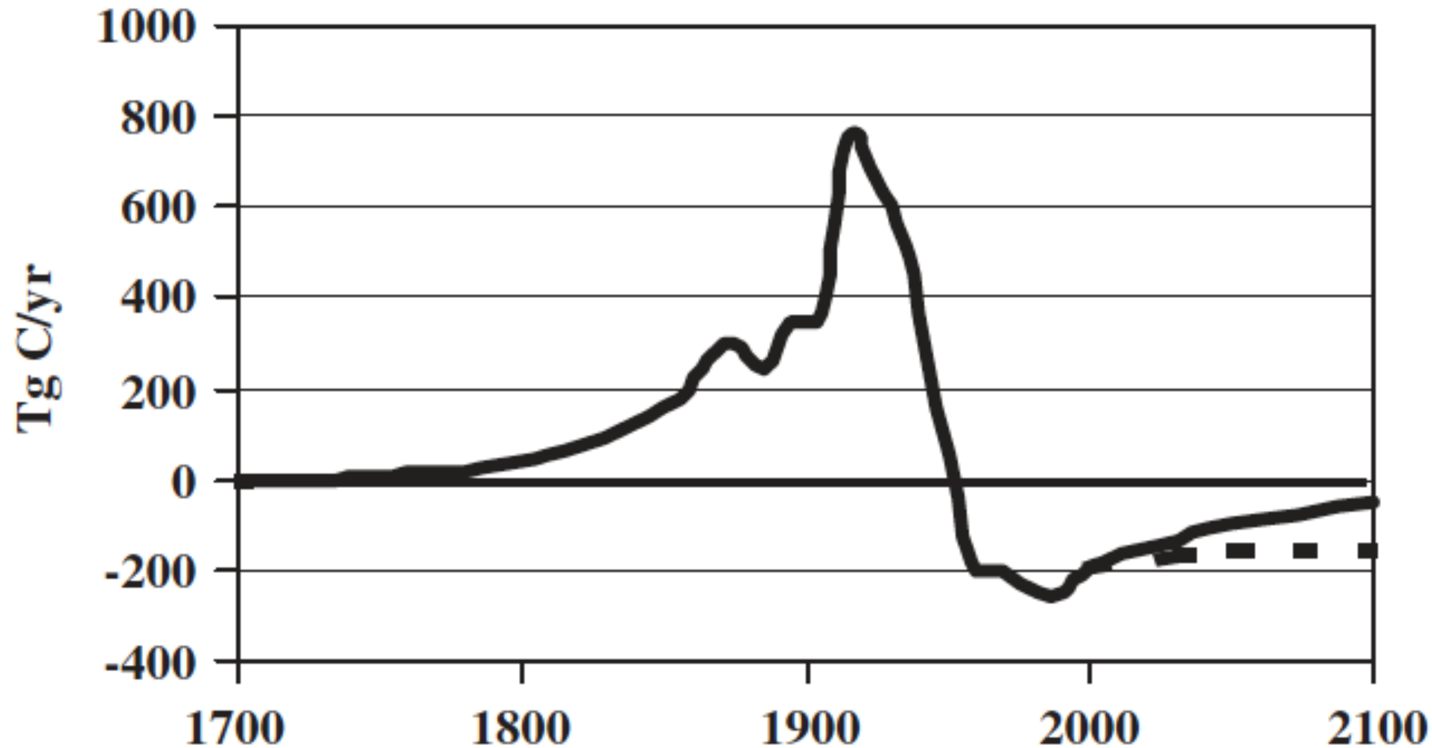
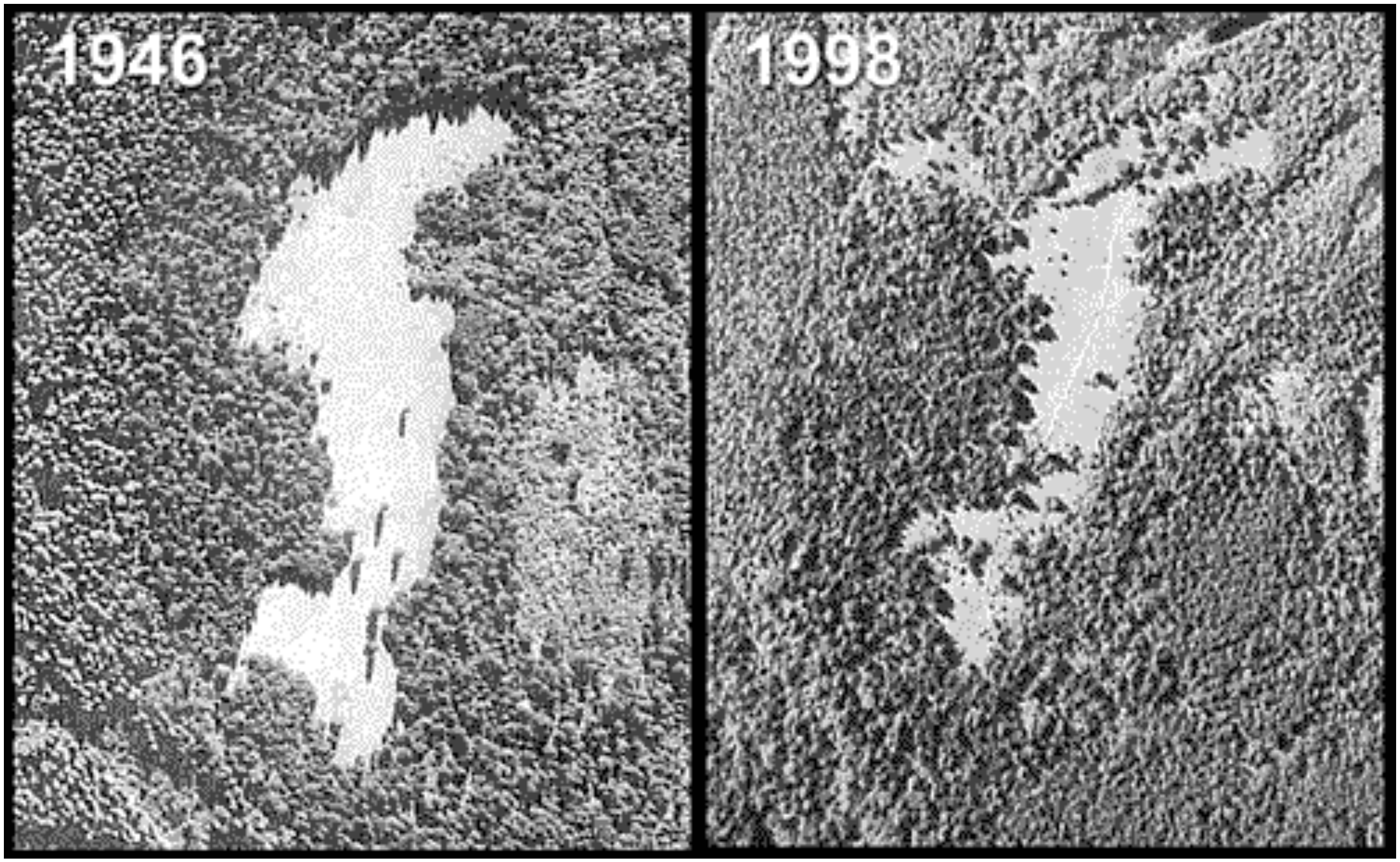


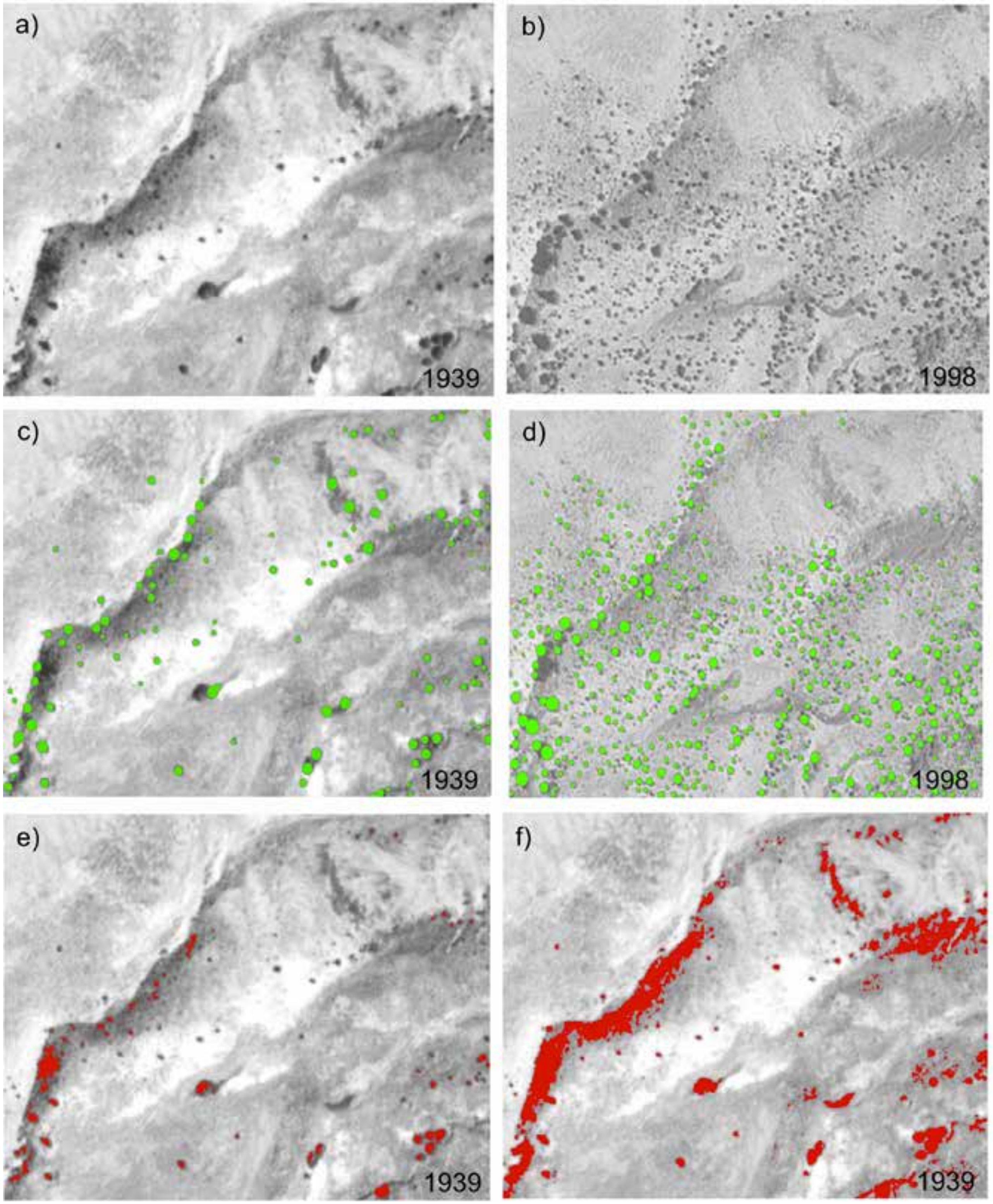
Fig. 5. Carbon emissions in the United States from drain on the saw-timber stand, and sequestration from regrowth, 1630–2000. Projections from 2000–2100 show a continuation of current trends (solid line) and a possible alternate trend (dashed line) that reflects implementation of policies to increase carbon sequestration by the forest sector.

Birdsey et al., 2006

Woody encroachment: meadows



Lepofsky et al., Cons. Ecol., 2003

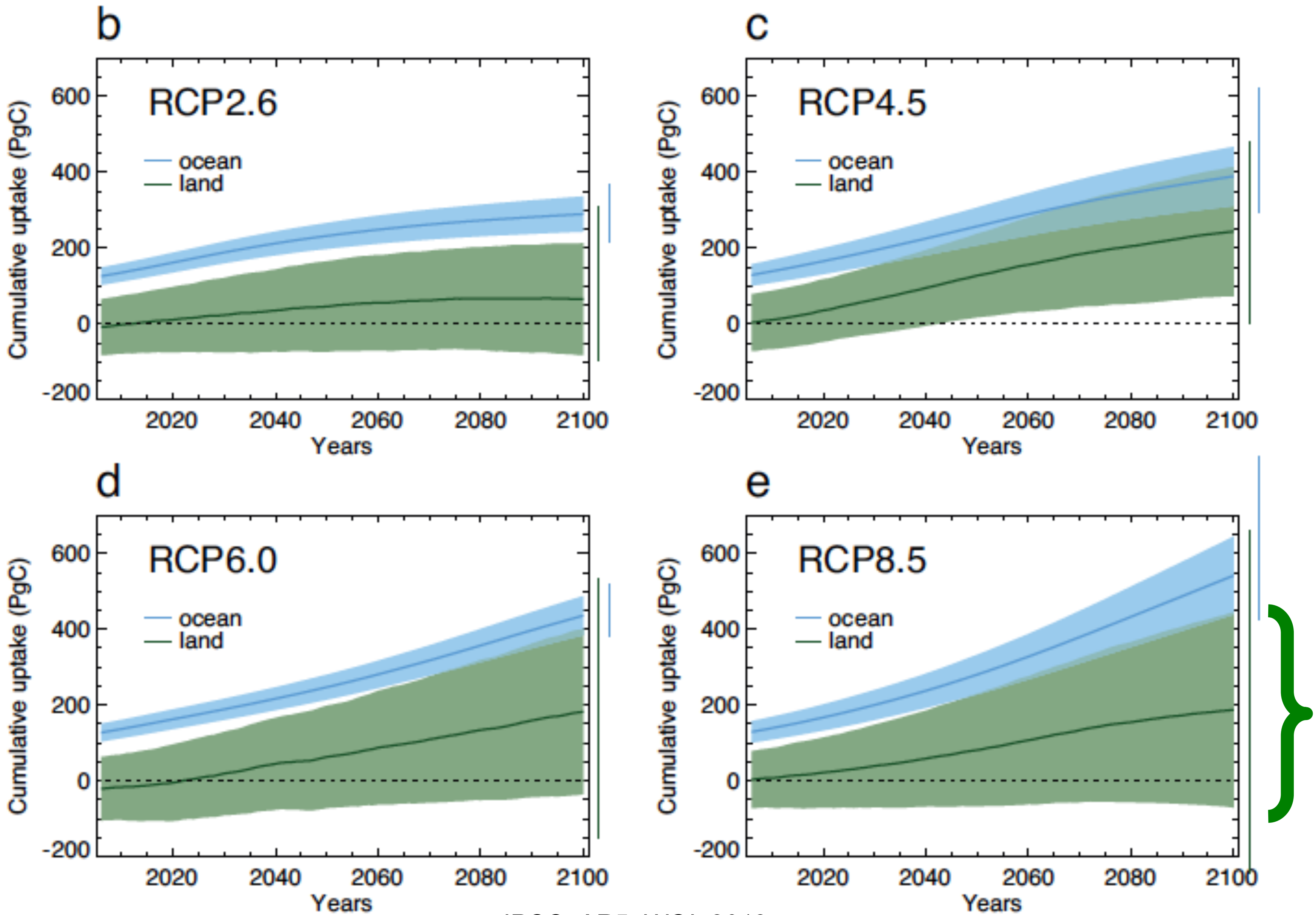


Woody encroachment: juniper expansion

Strand et al., 2006

Prof. J. Hicke

Large uncertainties in model results for future uptake of carbon on land



IPCC, AR5, WGI, 2013