Global aspects of high carbon ecosystems

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Open Access Earth System Science Data Discussions

This discussion paper is/has been under review for the journal Earth System Science Data (ESSD). Please refer to the corresponding final paper in ESSD if available.

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper

The global carbon budget 1959–2011

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Global Carbon Budget 2013 to be published 17 Nov.

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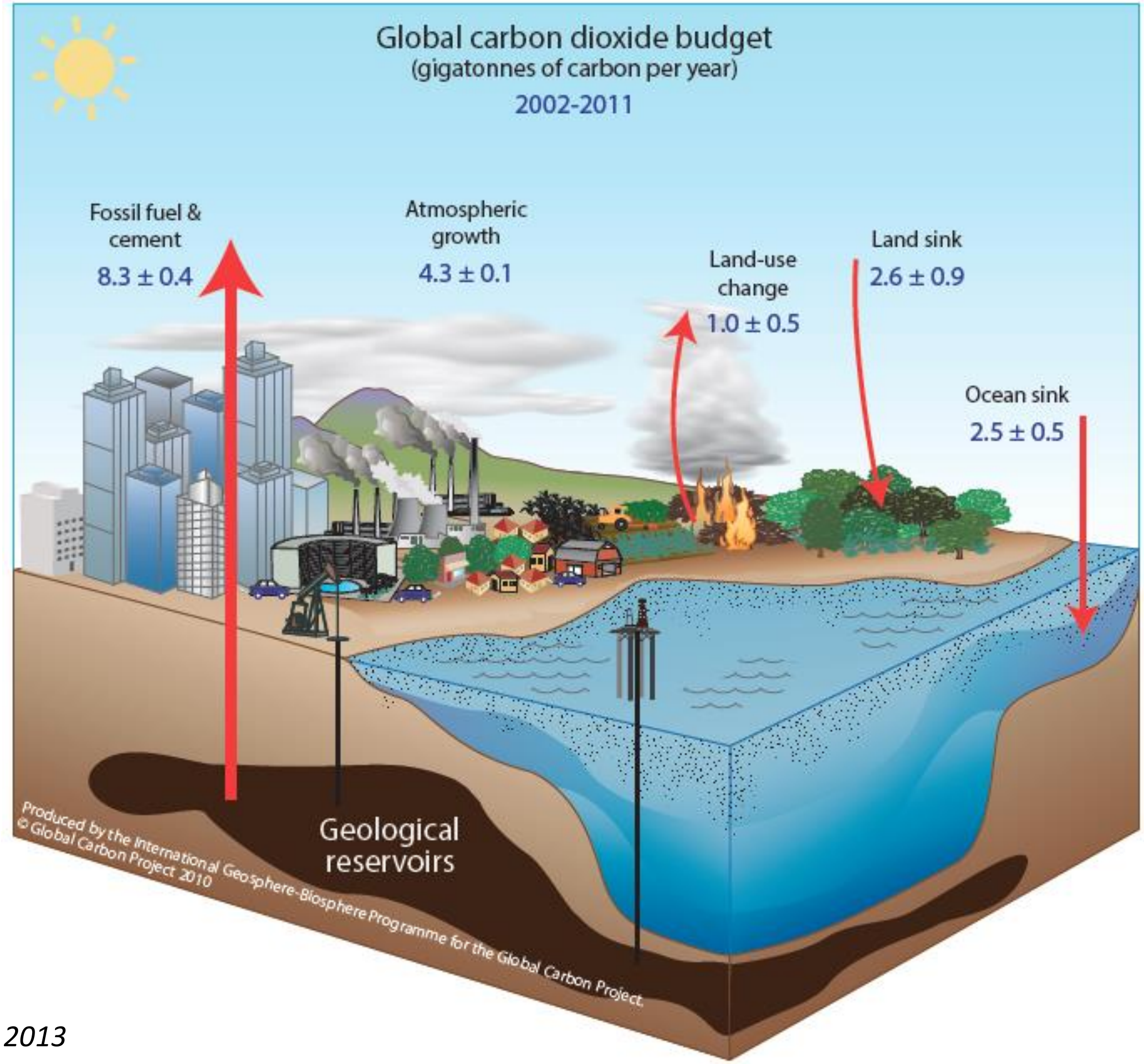
units of GtC (10^{15}gC=3.67 $GtCO_2$)

Global Carbon Project

Carbon balance in the environment

Reservoir	Carbon Stock (Gt C)
Atmosphere	830 (+40%)
Fossil reserves	1000 – 1940
Vegetation	~450
Soils	~1950
Permafrost	~1700
Ocean	38000
Marine biota	3
Ocean Organic C	700
Sediments	1750

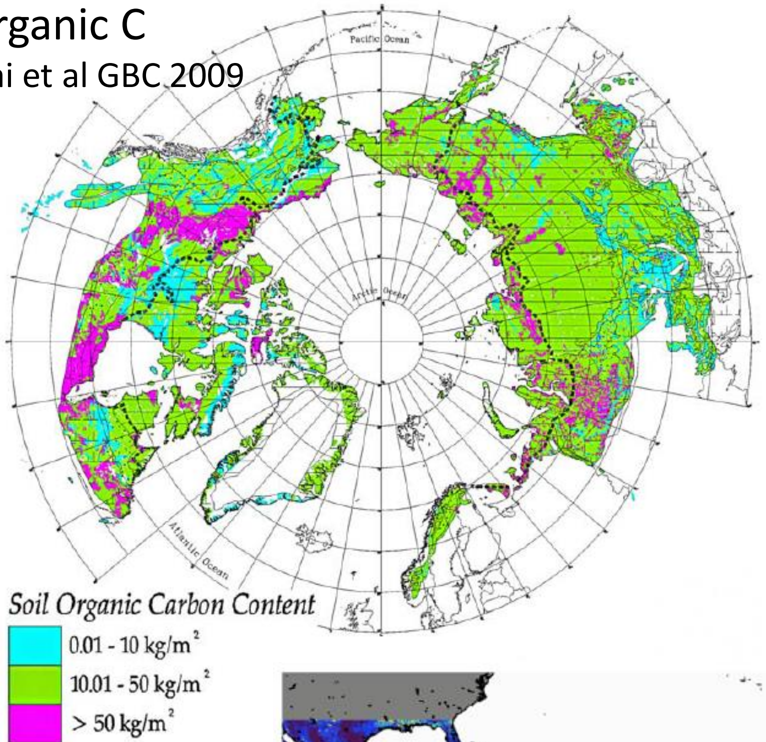
Carbon Flows (Gt C per year)



source: Ciais et al. 2013 IPCC AR5; Le Quéré et al ESSD 2013

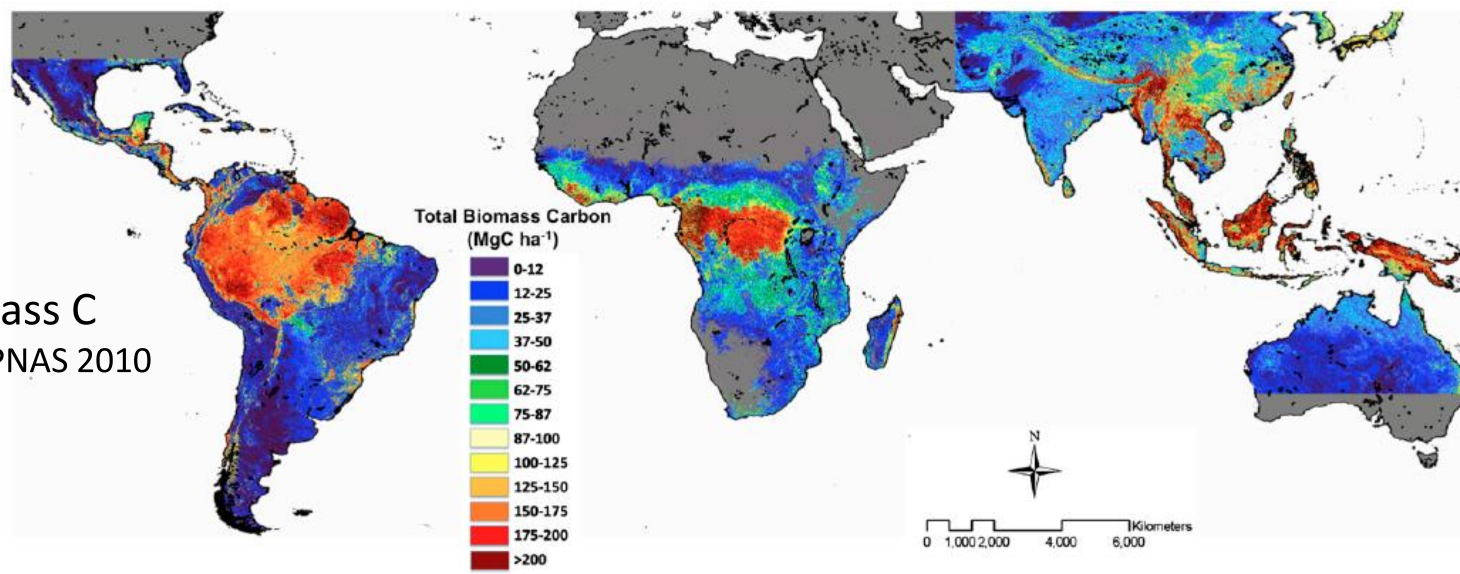
Carbon balance in the environment

Soil organic C
Tarnocai et al GBC 2009

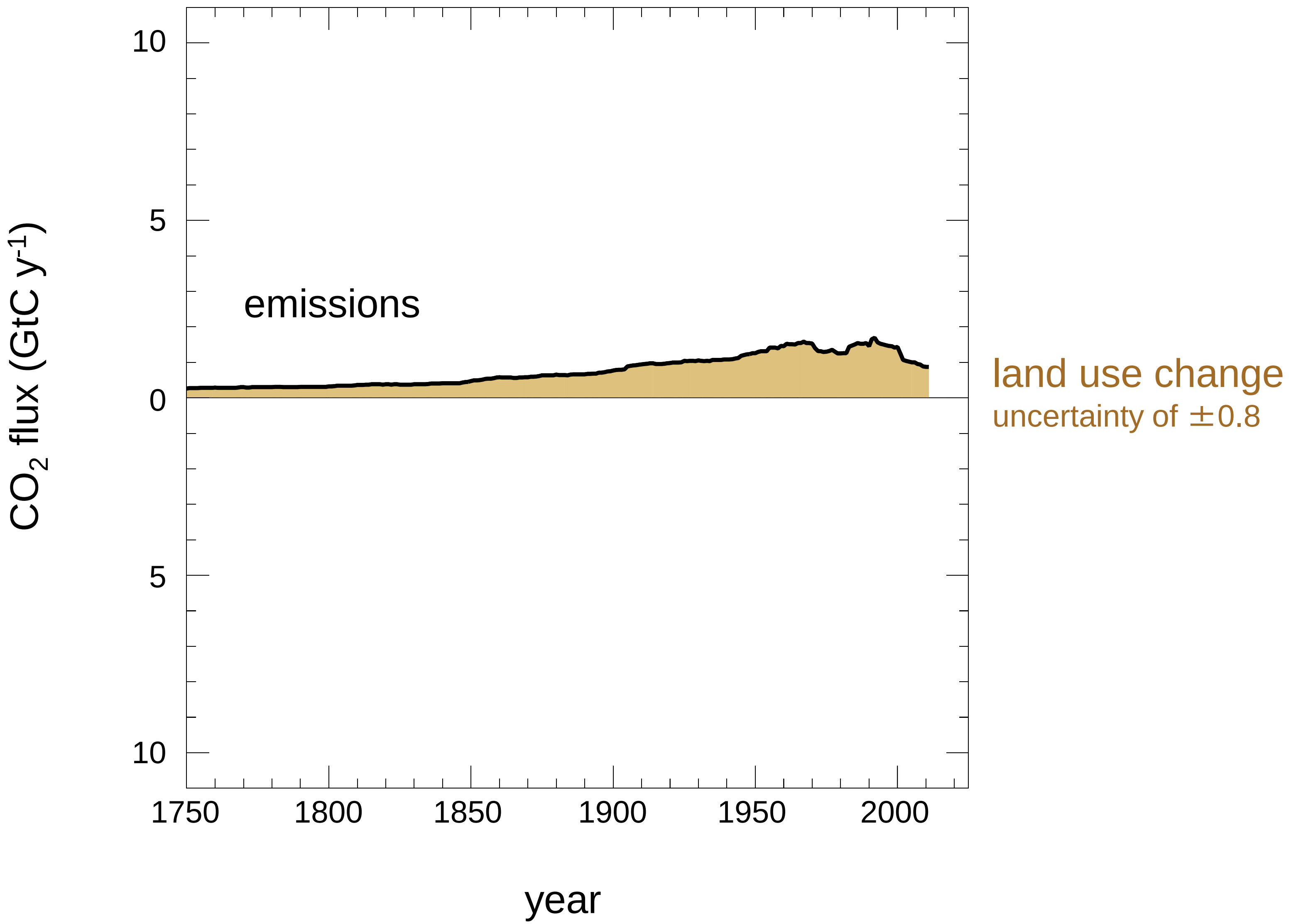


C stocks and flows are highly variable at the regional scale

Total Biomass C
Saatchi et al PNAS 2010

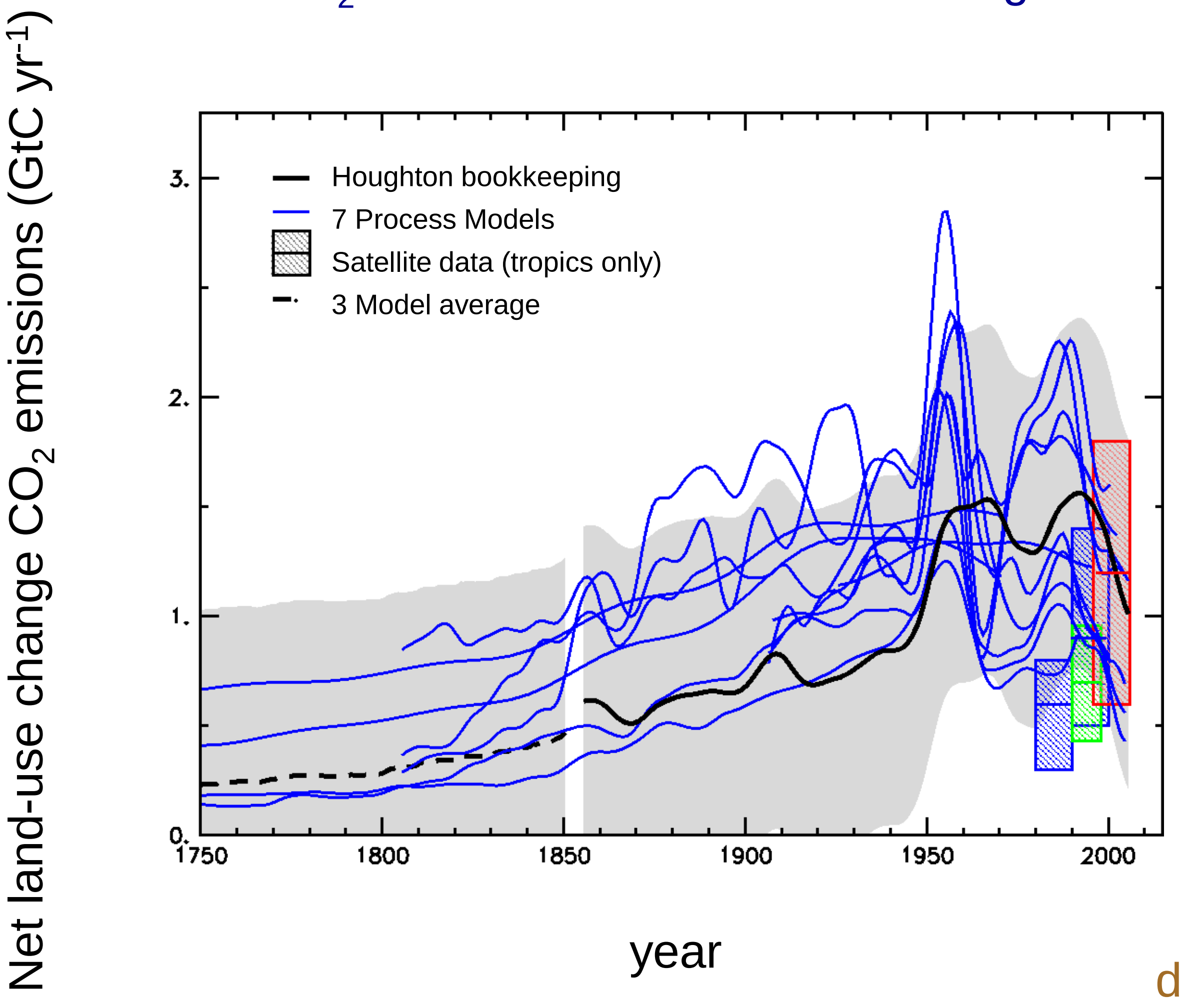


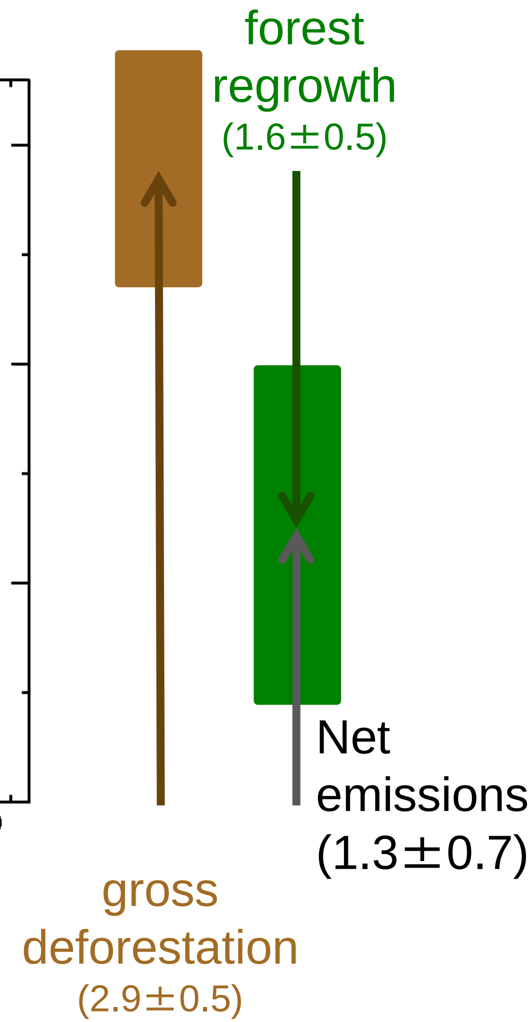
Carbon balance in the environment



source: Ciais et al. 2013 IPCC AR5; Houghton et al. 2013

CO_2 emissions from land use change





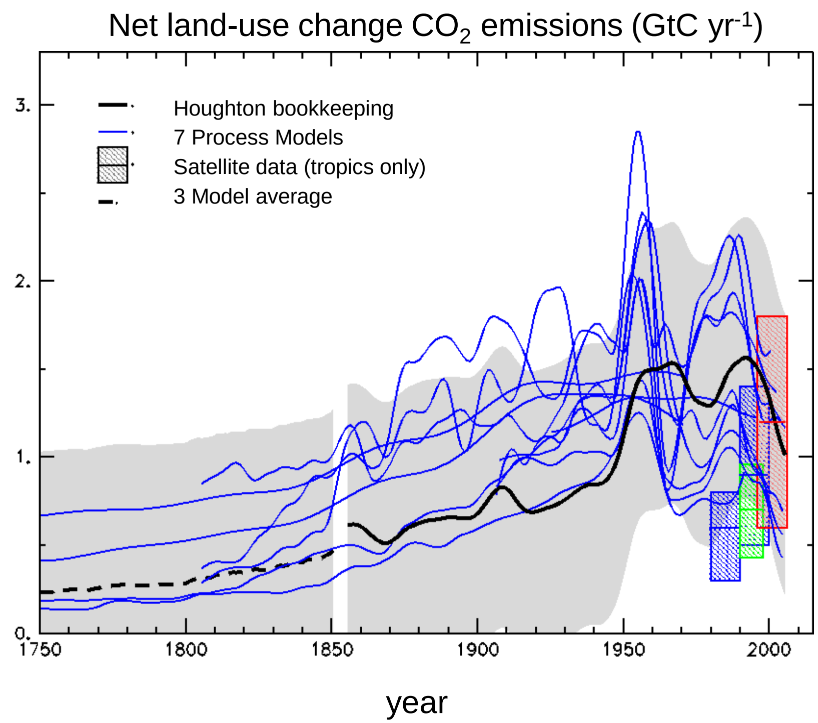
1870 – 2011 Cumulative emissions:
145 [80 to 210] GtC

Pan et al. (2011)
1990 – 2007

source: Ciais et al. 2013 IPCC AR5

CO_2 emissions from land use change

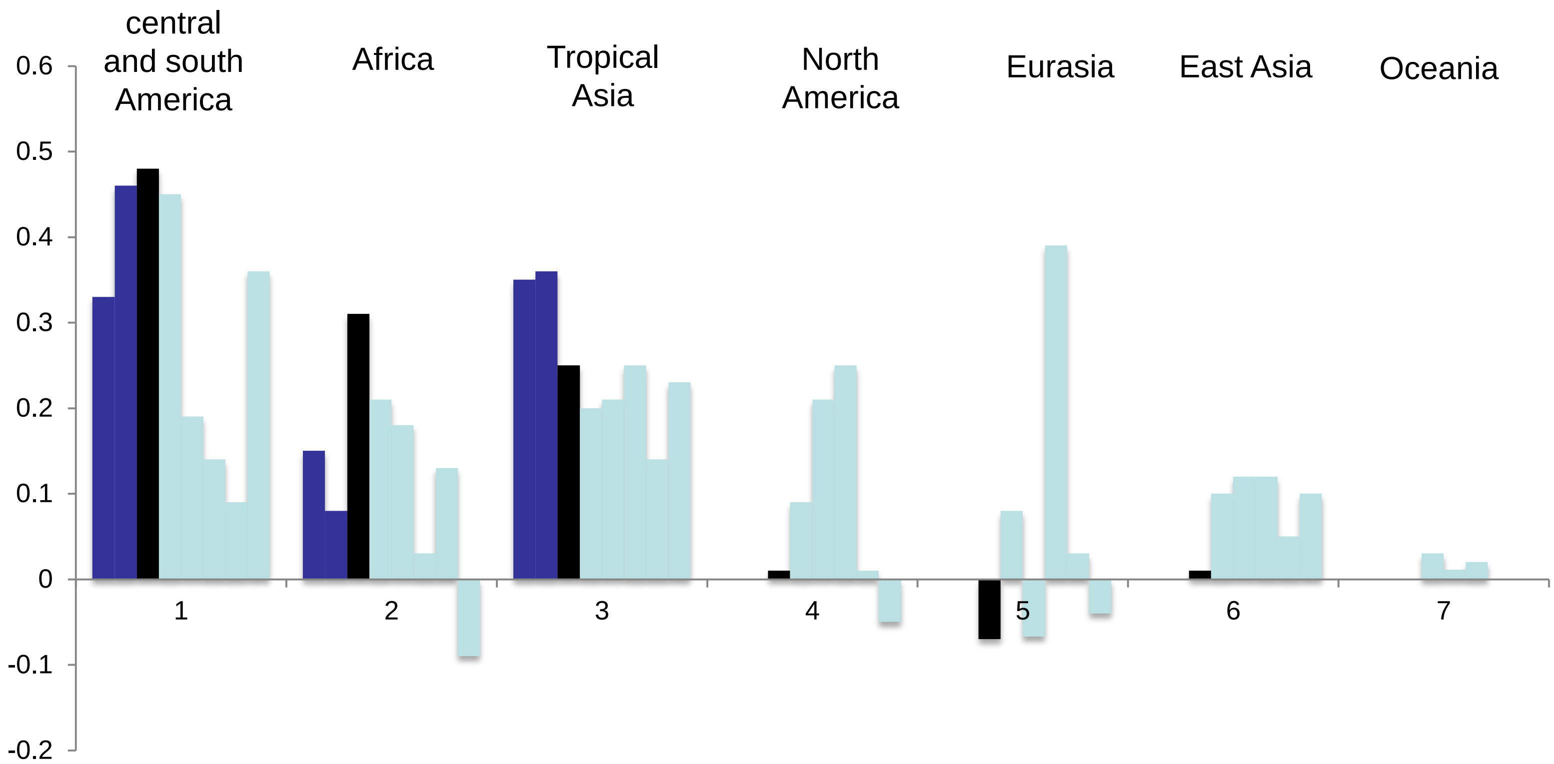
Method	Data	Info
Bookkeeping	FAO forests, observed biomass	Wood/crop harvest, fire suppression, shifting cultivation
Satellite	remote sensing for the tropics	no management, no legacy
Process Models	FAO crops, modelled biomass	harvest, fires, N limitation (in some)



All estimates include deforestation, afforestation and forest regrowth after abandonment of agriculture, but there are differences in land cover change and biomass data, methods, geographical location, and processes

source: Ciais et al. 2013 IPCC AR5

CO_2 emissions from land use change at the regional level

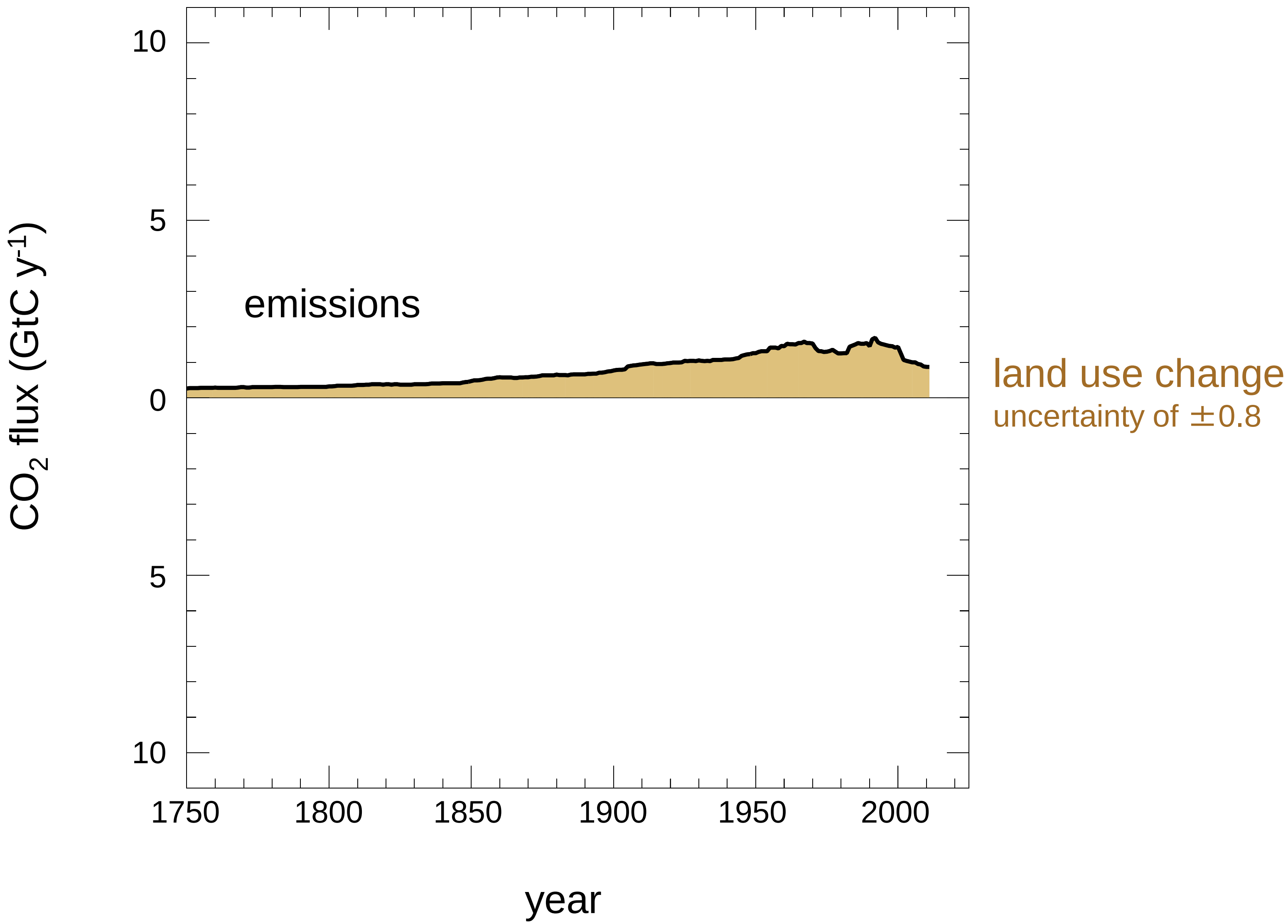


The agreement is far less good at the regional level

2000 – 2009 for Bookkeeping/Satellite/Models

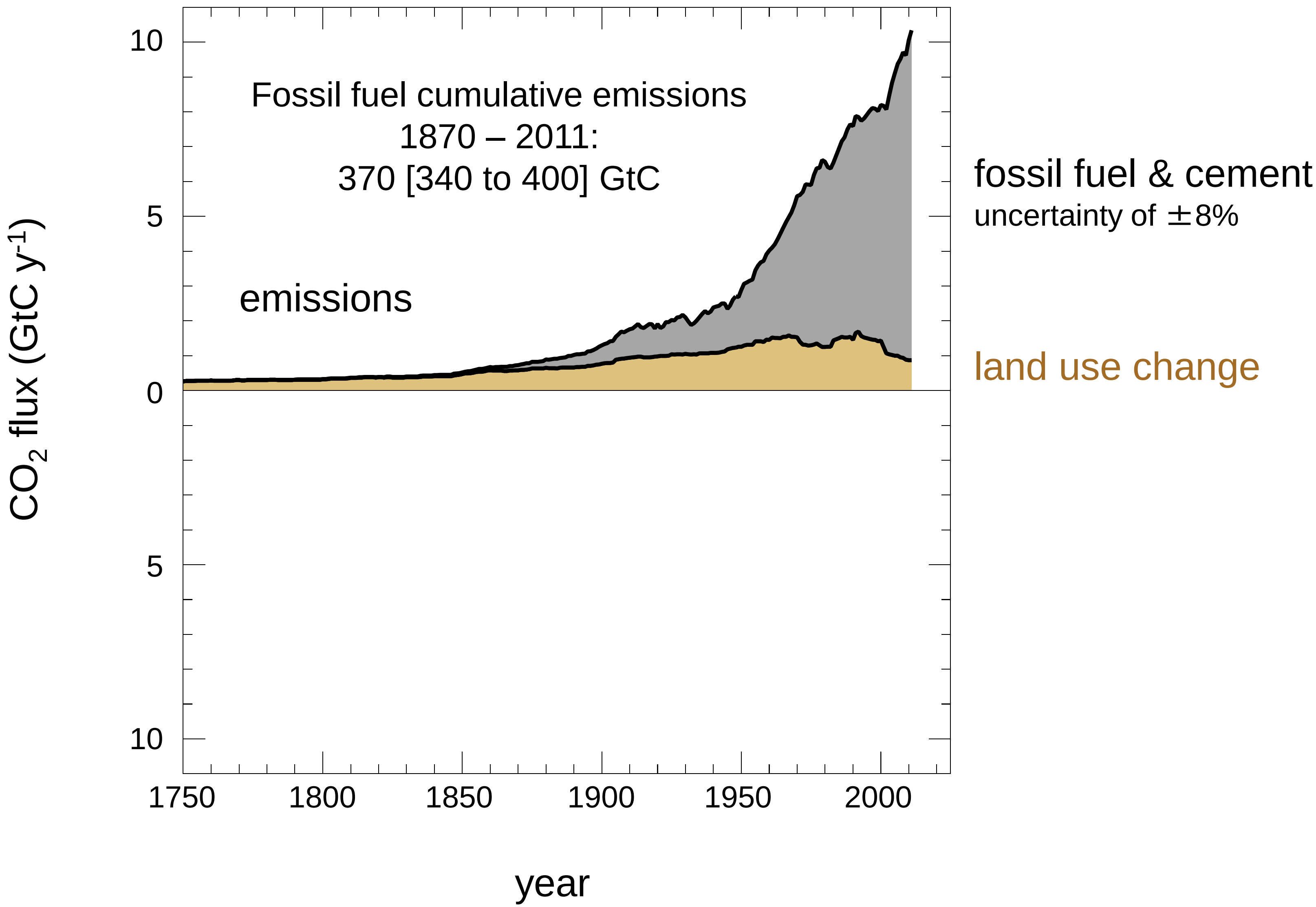
source: Ciais et al. 2013 IPCC AR5

Carbon balance in the environment



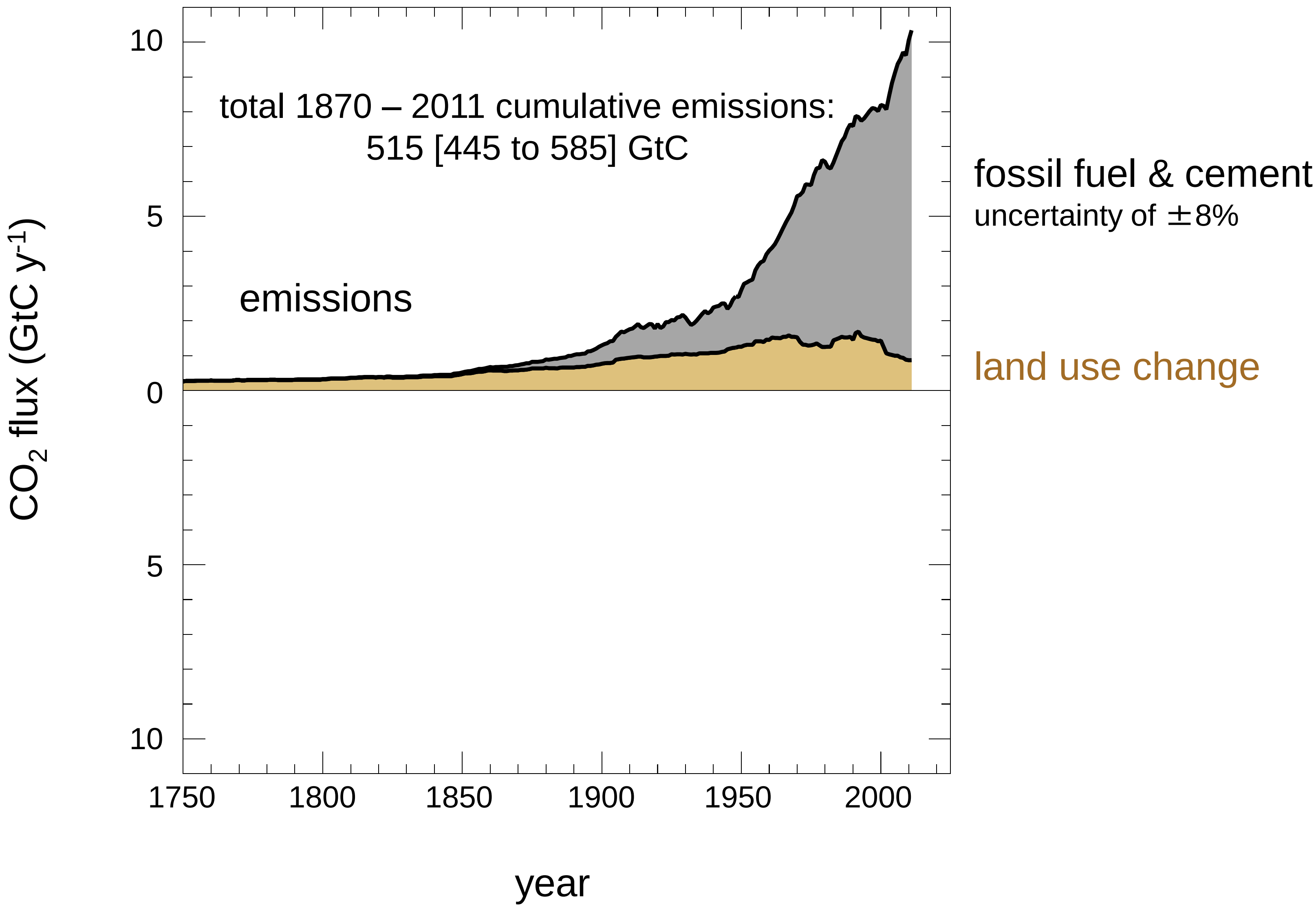
source: Ciais et al. 2013 IPCC AR5; Houghton et al. 2013

Carbon balance in the environment



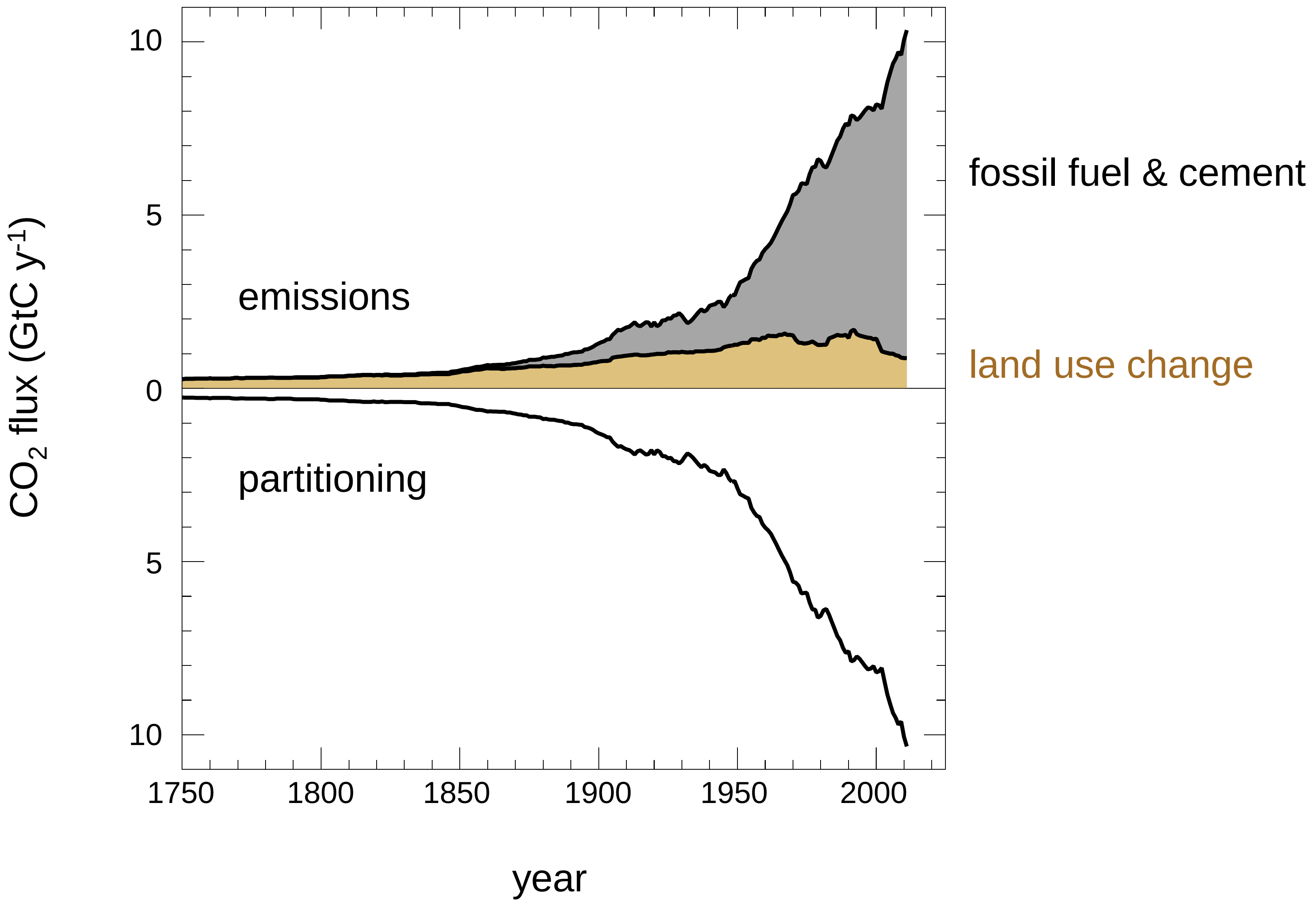
source: Ciais et al. 2013 IPCC AR5; CDIAC emissions

Carbon balance in the environment



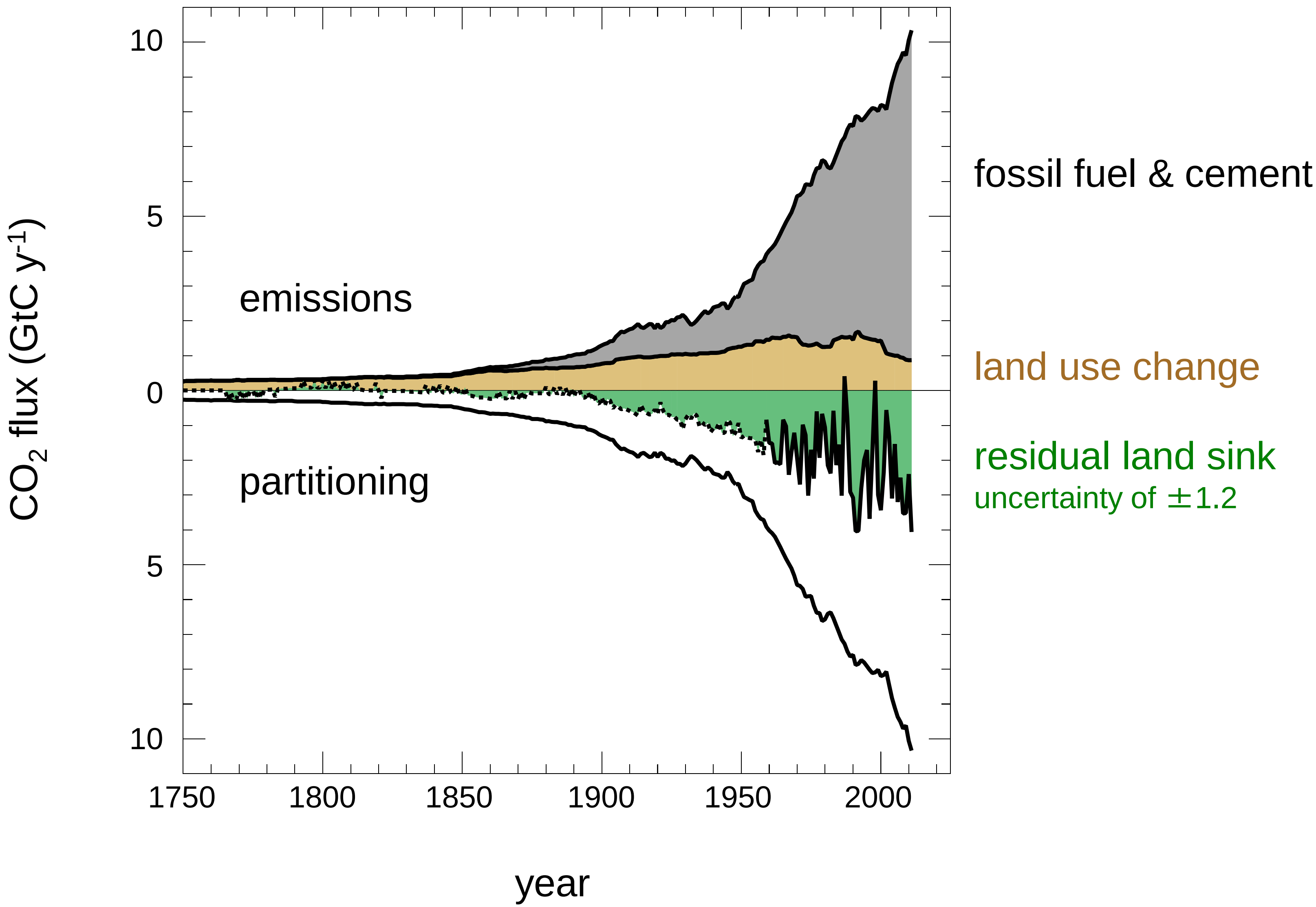
source: Ciais et al. 2013 IPCC AR5; CDIAC emissions

Carbon balance in the environment



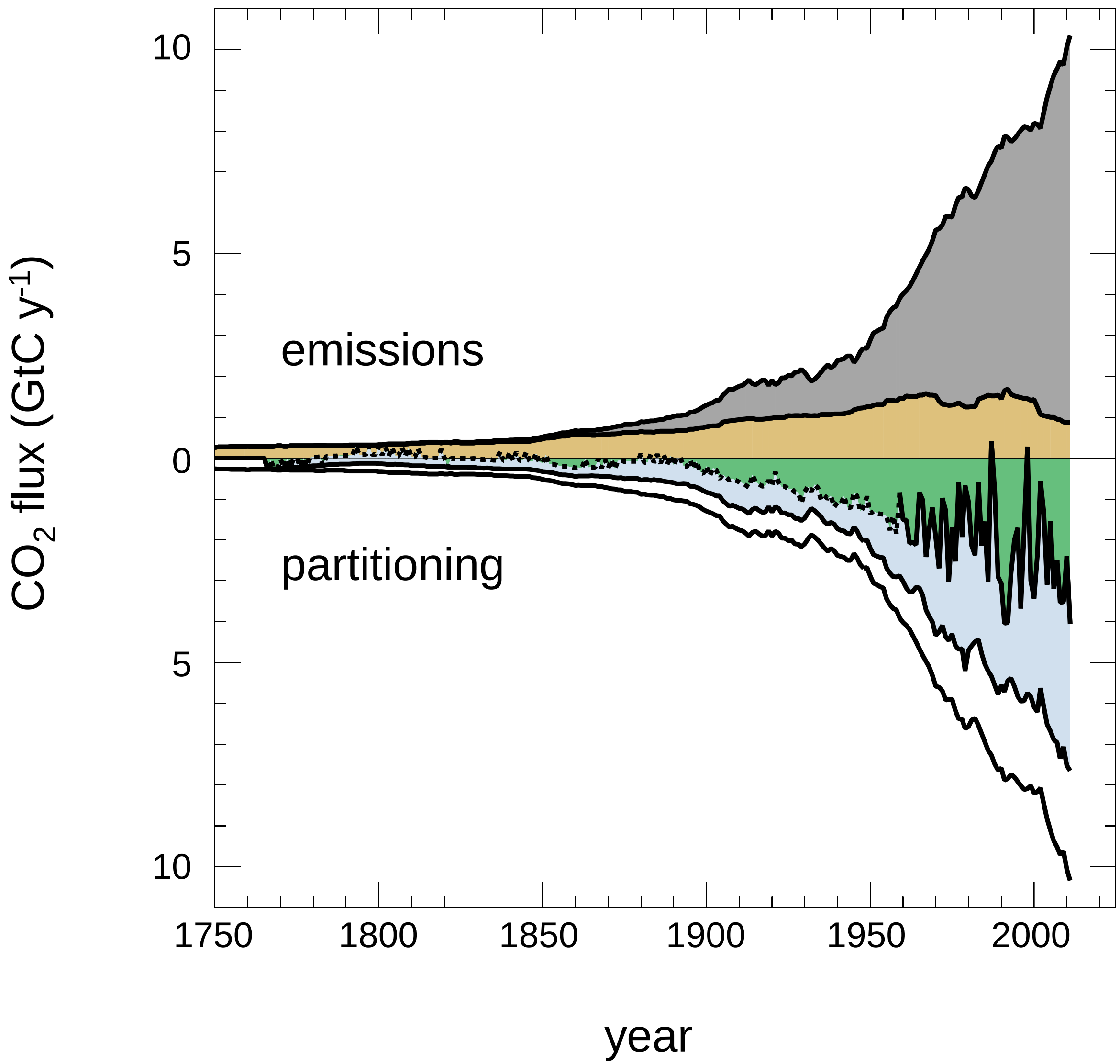
source: Ciais et al. 2013 IPCC AR5; CDIAC/Houghton emissions

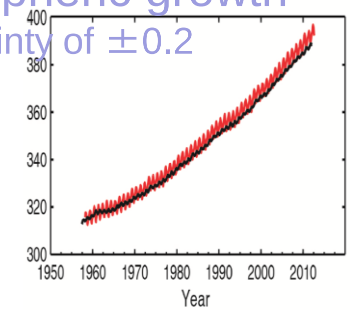
Carbon balance in the environment



source: Ciais et al. 2013 IPCC AR5

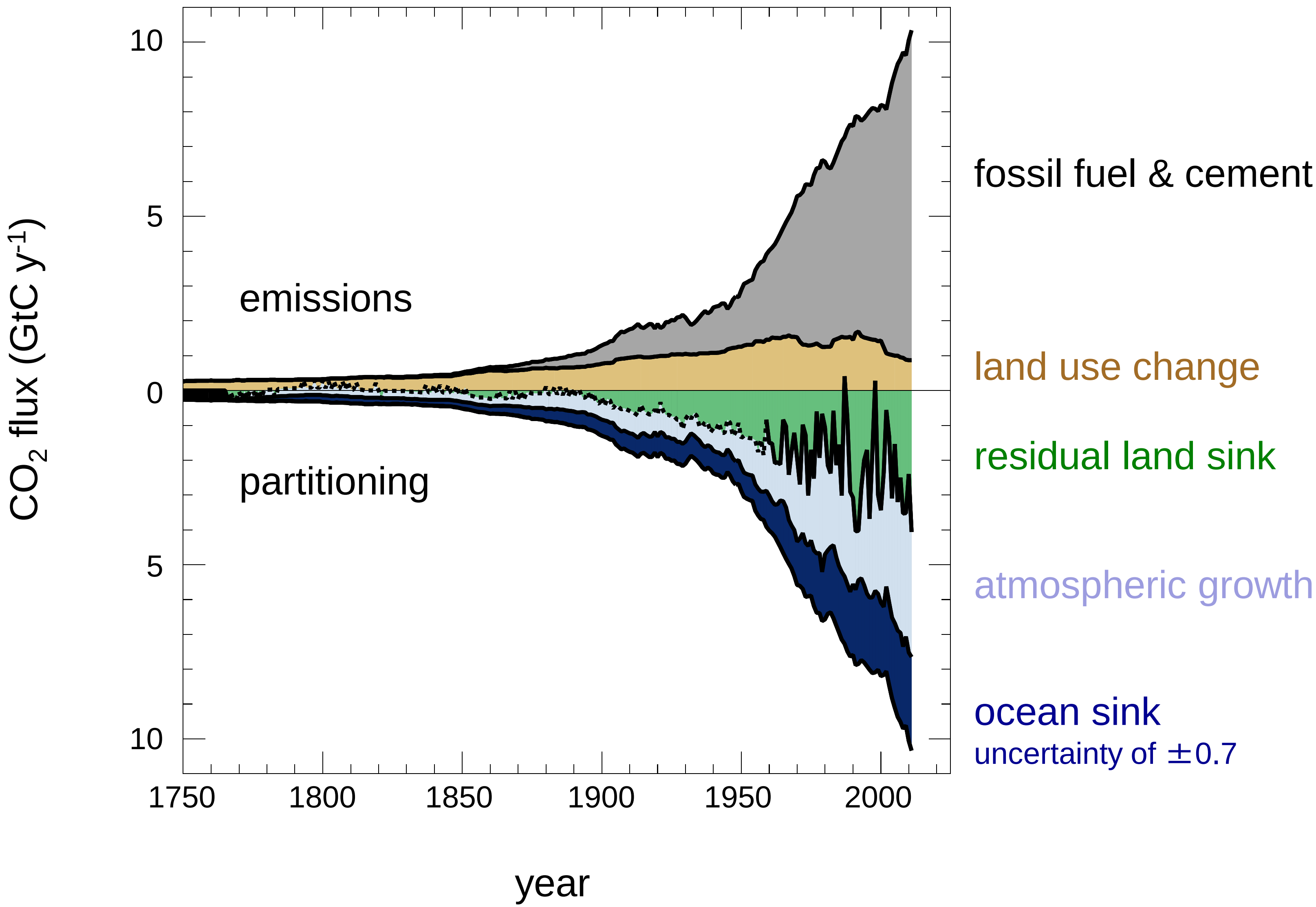
Carbon balance in the environment





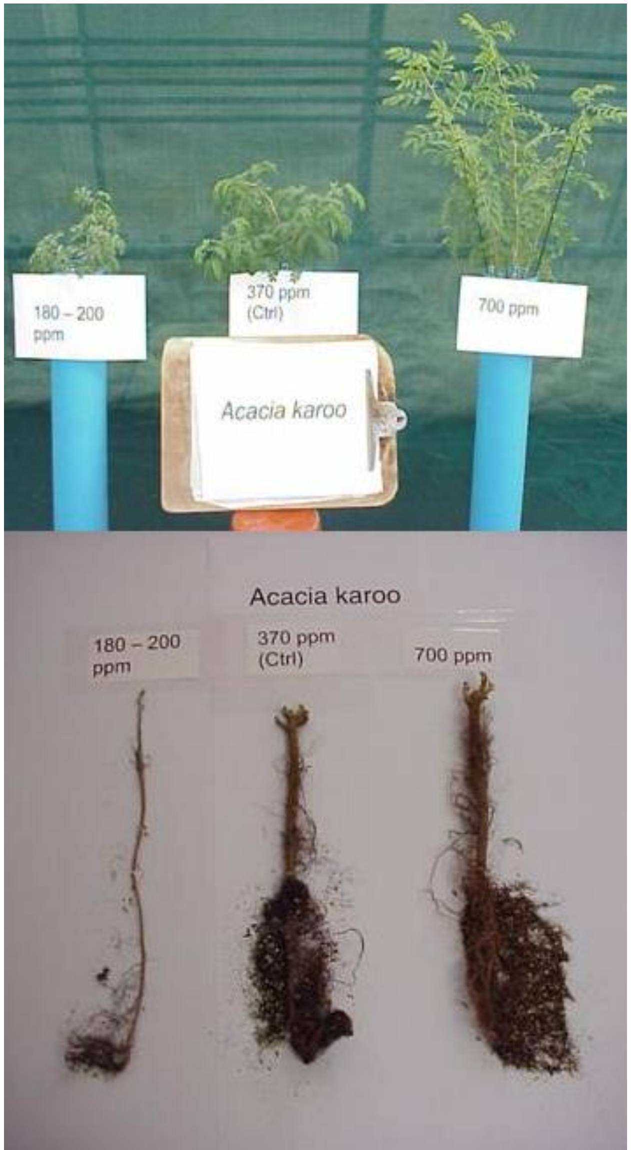
source: Ciais et al. 2013 IPCC AR5; NOAA/ESRL & Scripps Institute of Oceanography

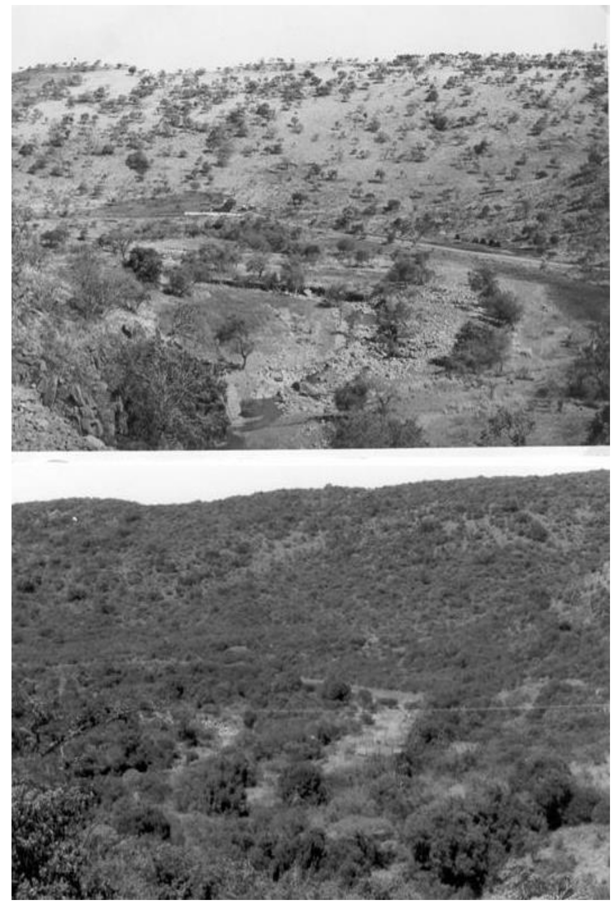
Carbon balance in the environment



source: Ciais et al. 2013 IPCC AR5

understanding the residual land sink



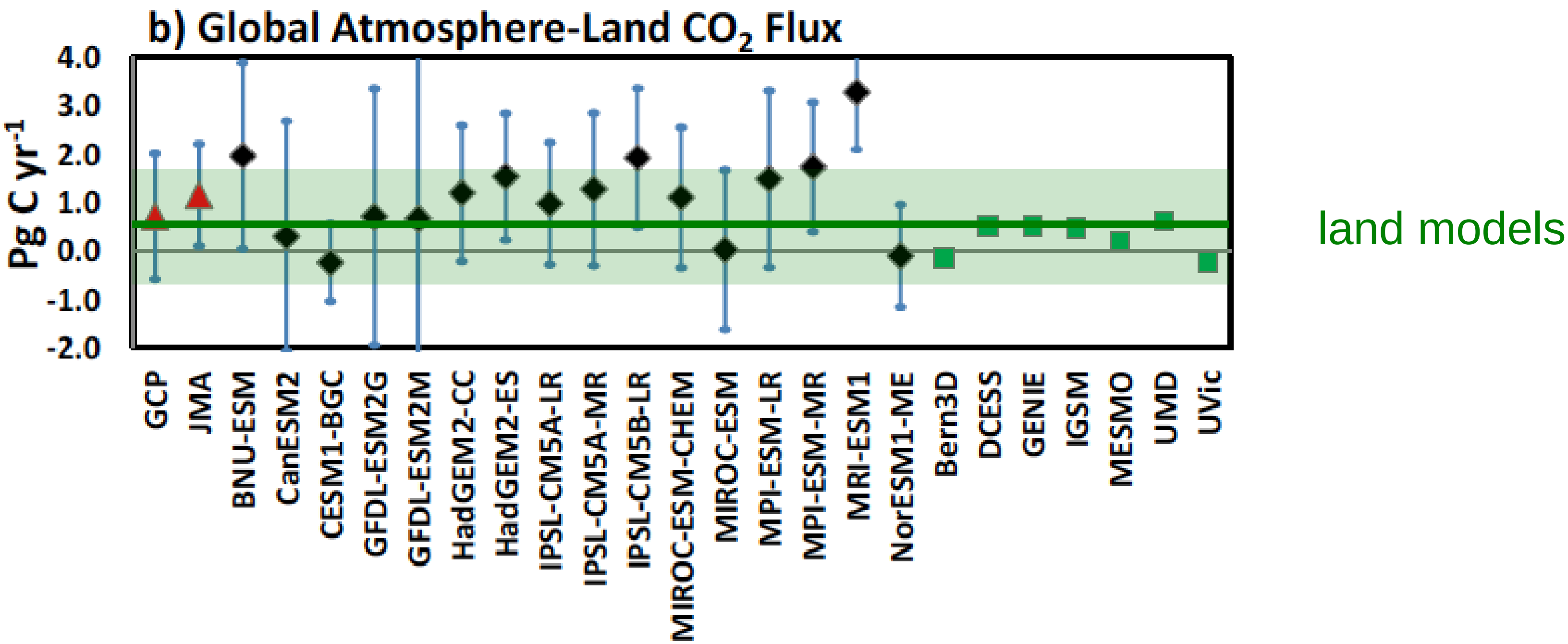


1955

1998

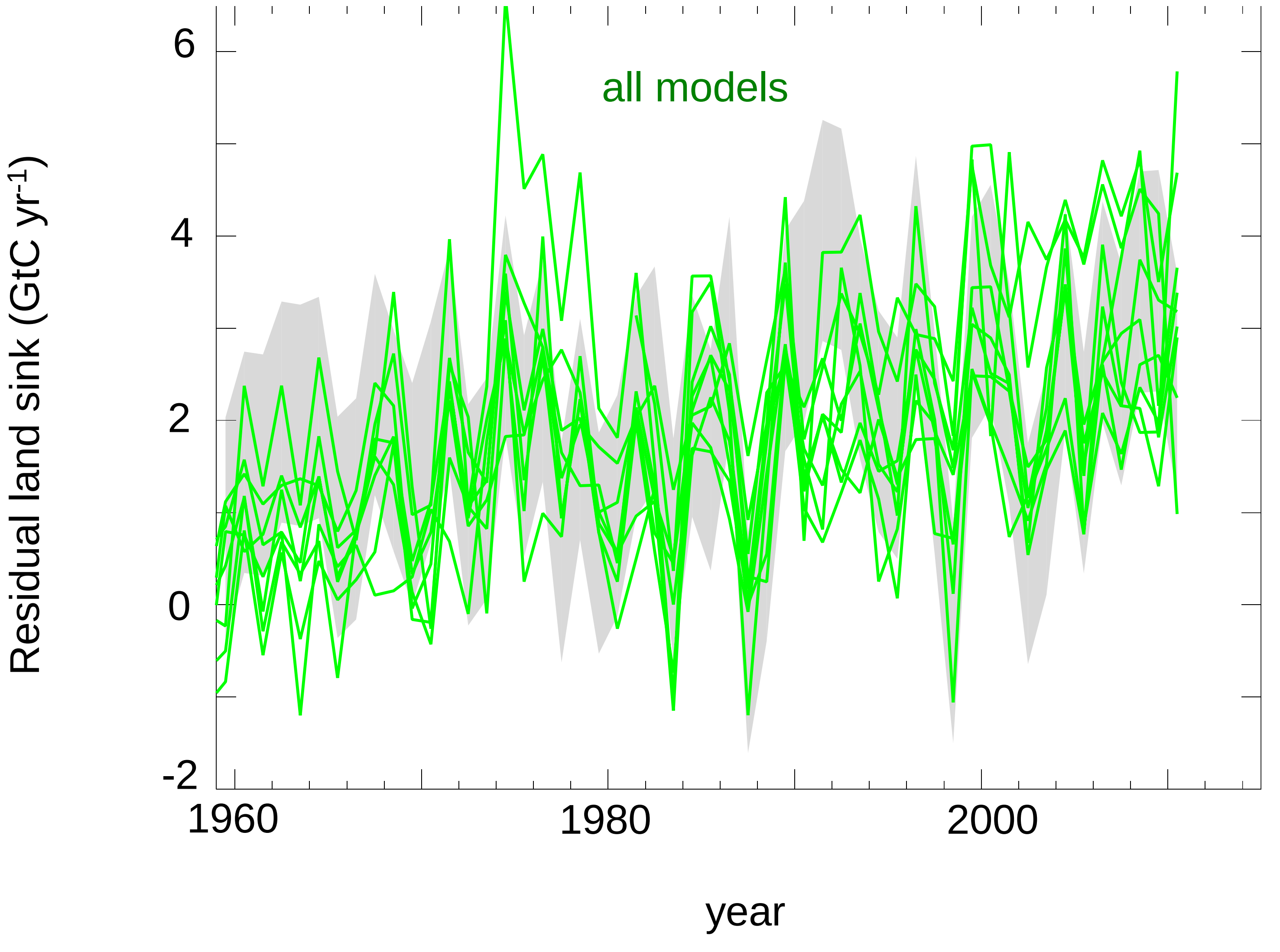
Credits: Guy Mingley and Barney Kgope (SANBI), William Bond (UCT)
NASA LBA-ECO Project
Canadell & Raupach Science 2008
Photo: Timm Hoffmann , IPC, UCT

model evaluation



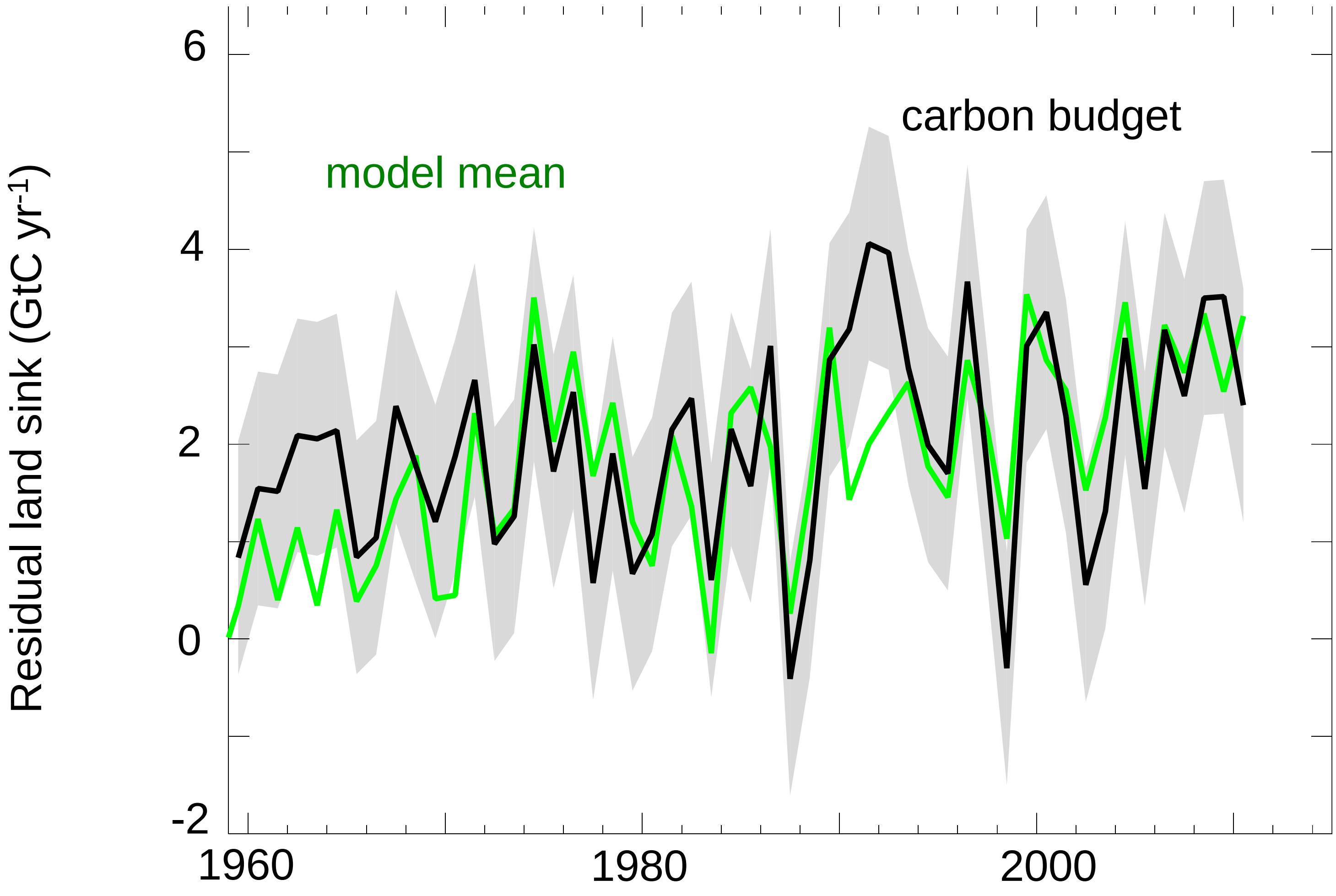
source: Flato et al. 2013 IPCC AR5; Fig. 9.27

variability in the residual terrestrial sink



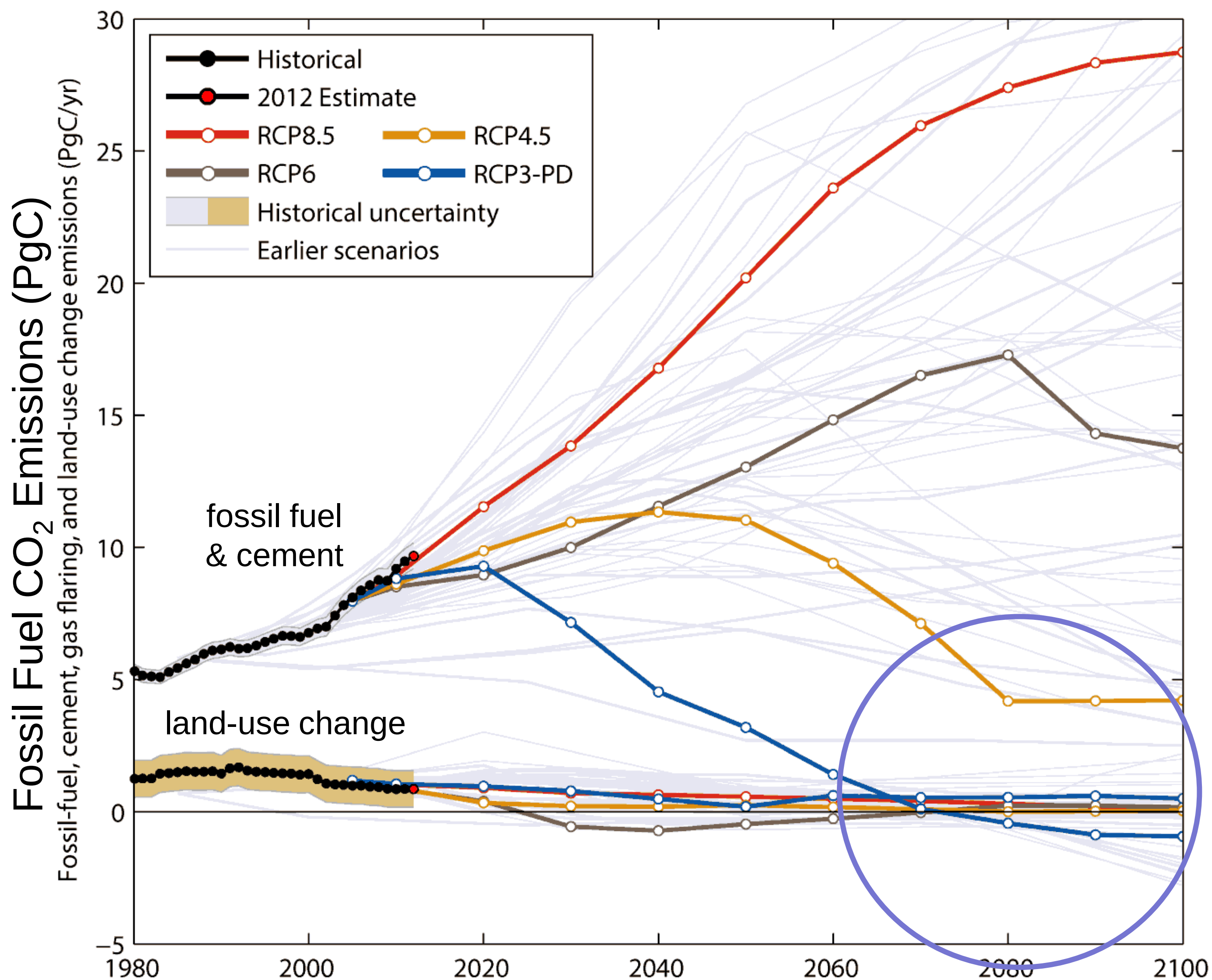
source: Ciais et al. 2013 IPCC AR5; Trendy DGVM models

trends and variability in the residual terrestrial sink



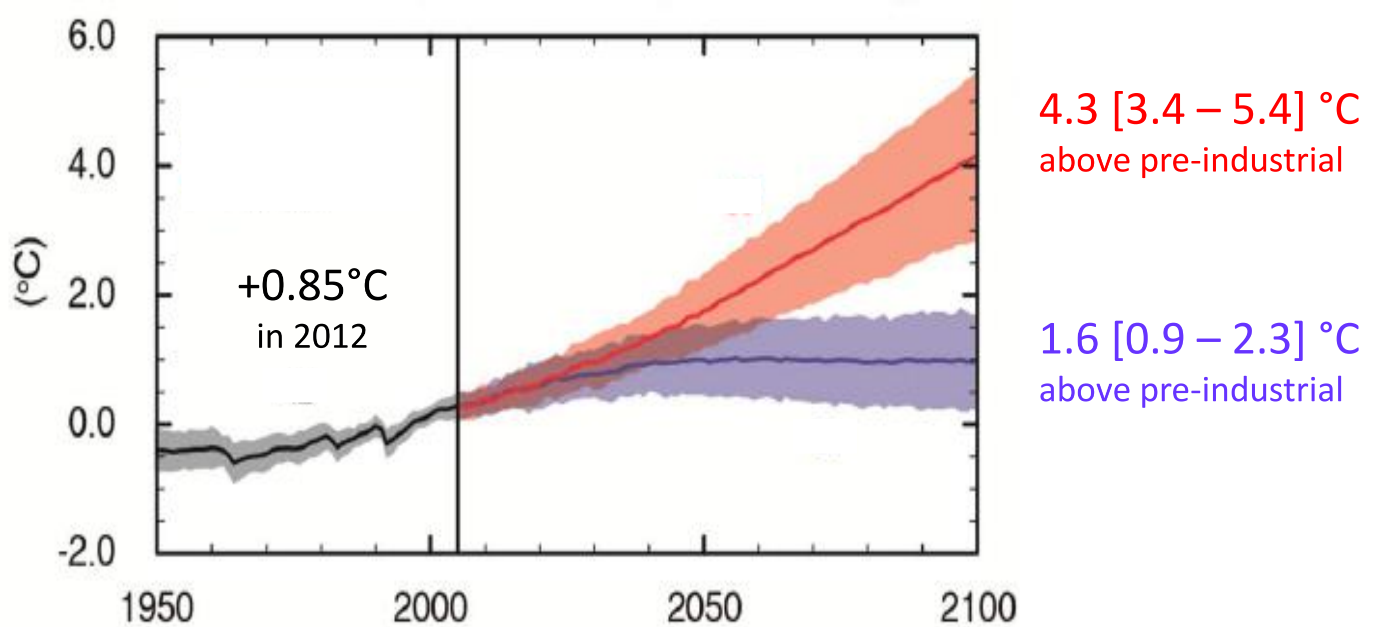
source: Ciais et al. 2013 IPCC AR5; Trendy DGVM models

Future CO_2 Pathways



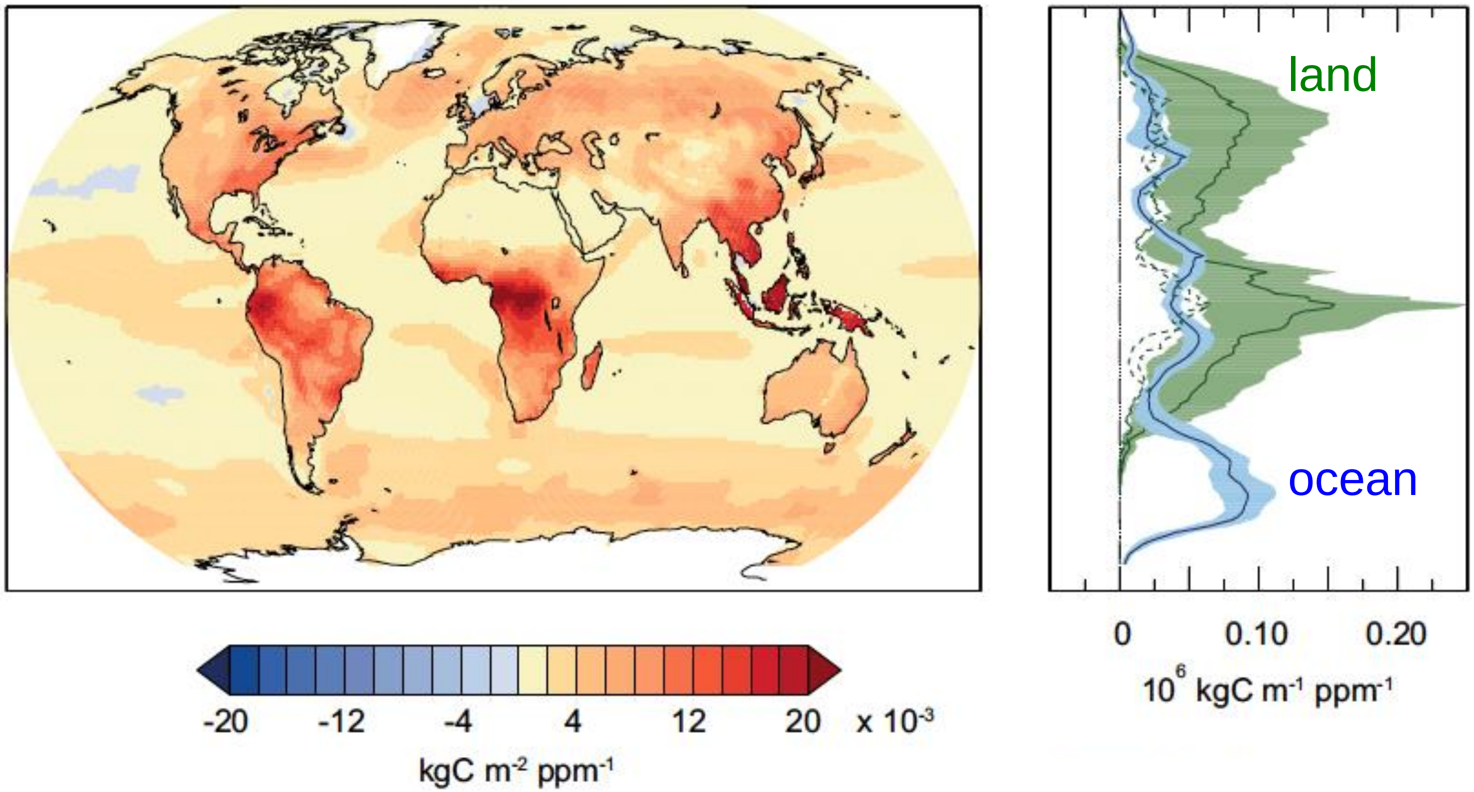
Updated from Peters et al. 2013 and Raupach et al 2007; CDIAC Data; Global Carbon Project 2013

Projected global average surface temperature change



source: IPCC AR5 with updated emissions

Response to atmospheric CO_2 only

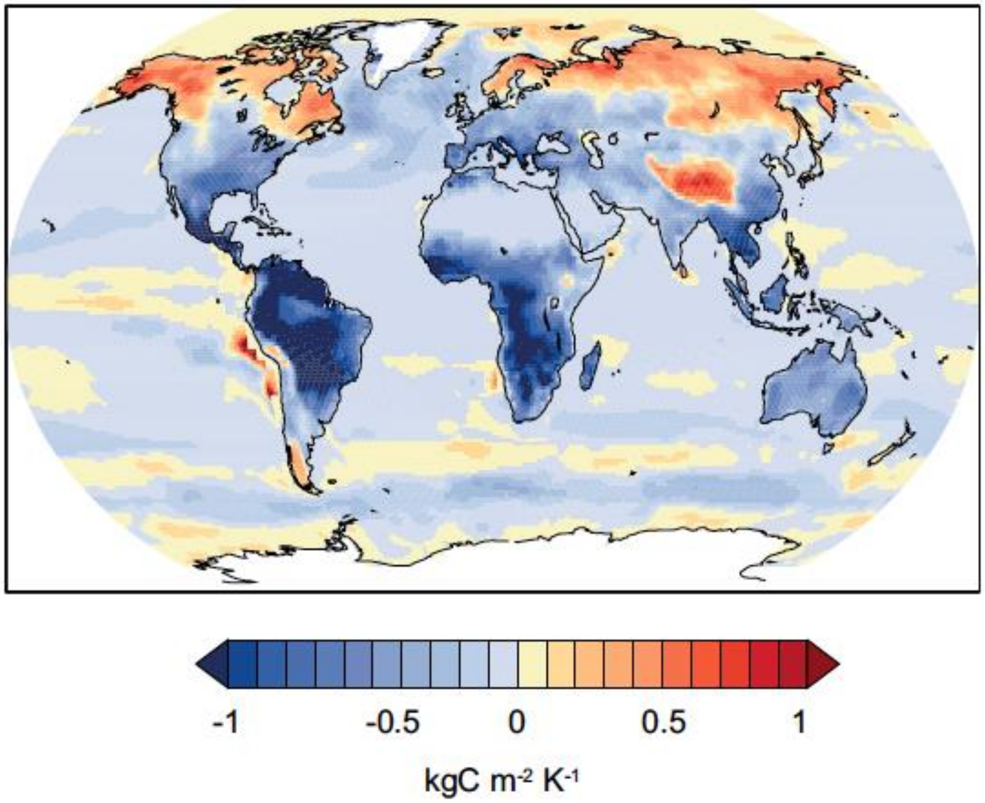


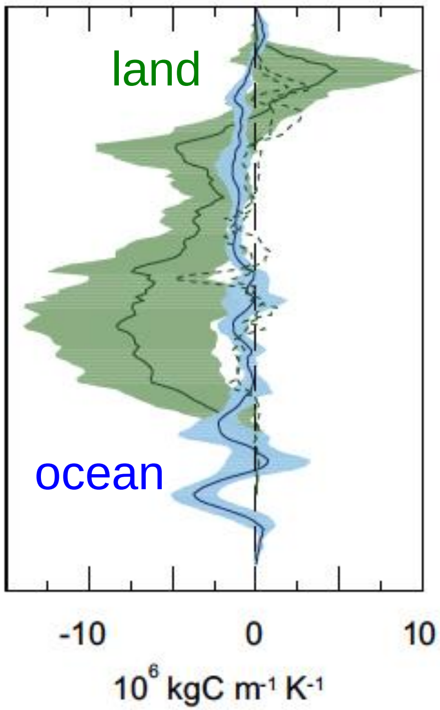
decreasing sink

increasing sink

source: Ciais et al. 2013 IPCC AR5

Response to climate change only





decreasing sink

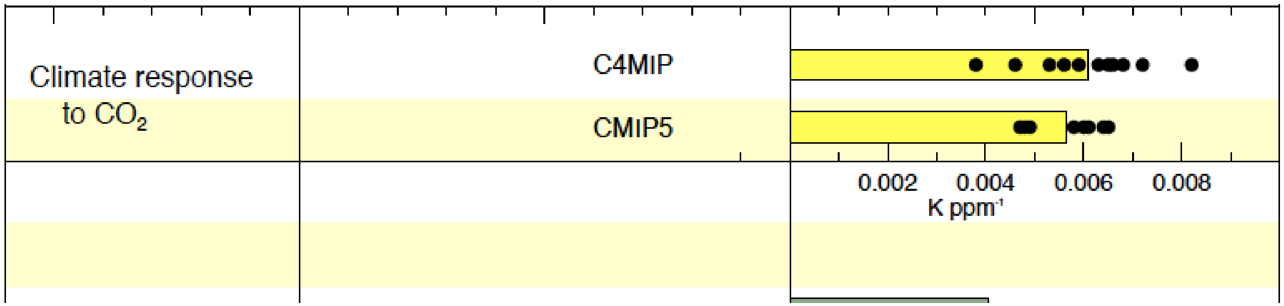
increasing sink

models do not include the release of permafrost C

source: Ciais et al. 2013 IPCC AR5

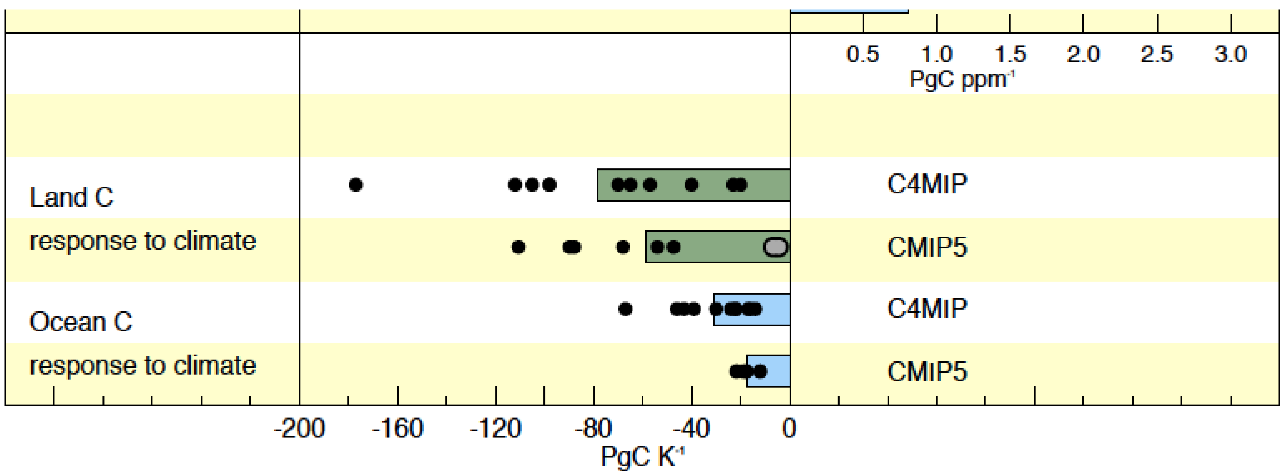
Summary of process in models

Climate response to CO_2



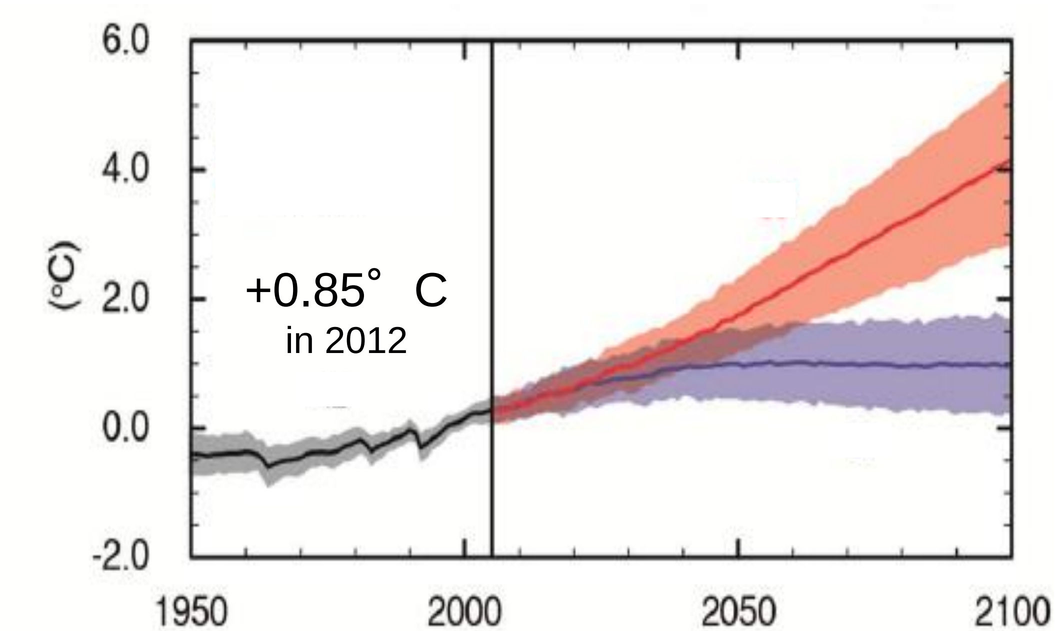
Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (*high confidence*). Further uptake of carbon by the ocean will increase ocean acidification. {6.4}

Sinks response to climate



source: Ciais et al. 2013 IPCC AR5

Projected global average surface temperature change



4.3 [3.4 – 5.4] ° C
above pre-industrial

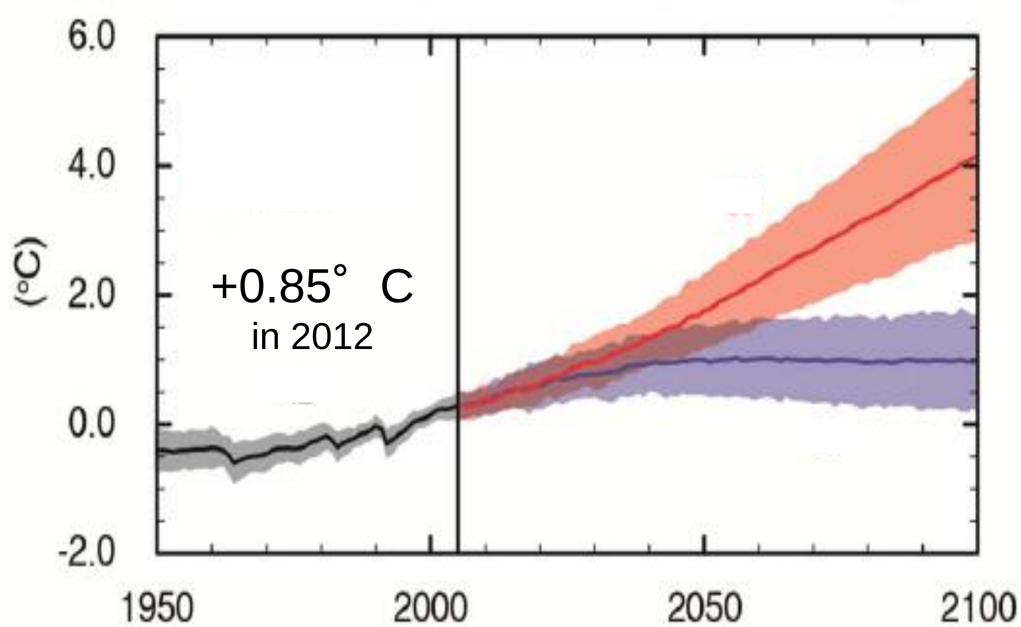
1.6 [0.9 – 2.3] ° C
above pre-industrial

T projections include the carbon-climate feedback, but not its uncertainty

The uncertainty in carbon-climate feedback is included in the compatible emissions

source: IPCC AR5 with updated emissions

Projected global average surface temperature change



4.3 [3.4 – 5.4] ° C
above pre-industrial

1.6 [0.9 – 2.3] ° C
above pre-industrial

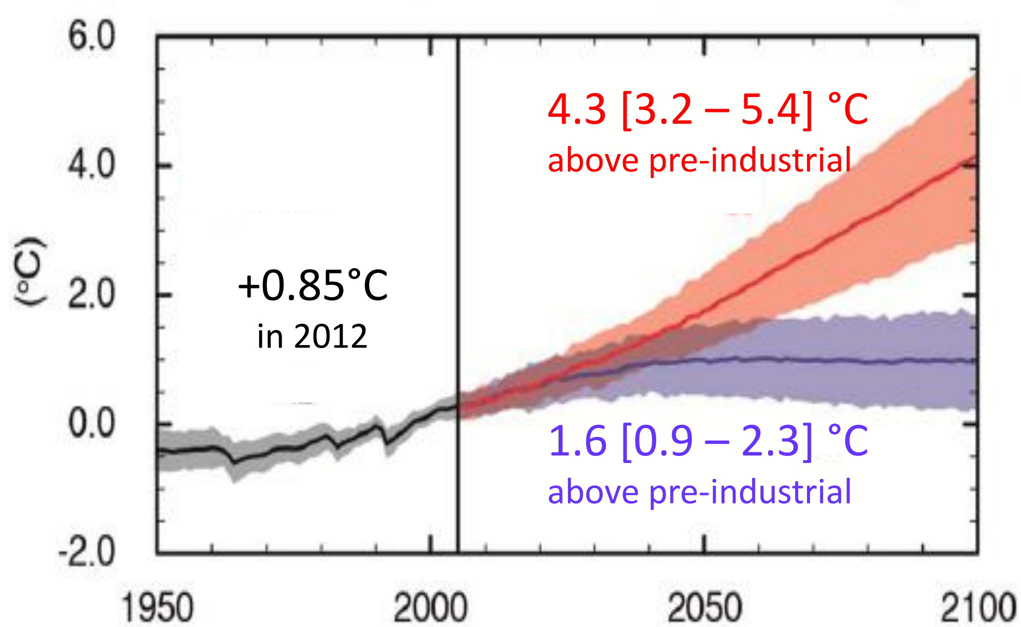
CO_2 already emitted

during 1870 – 2011

515 [445 – 585] GtC

source: IPCC AR5

Projected global average surface temperature change



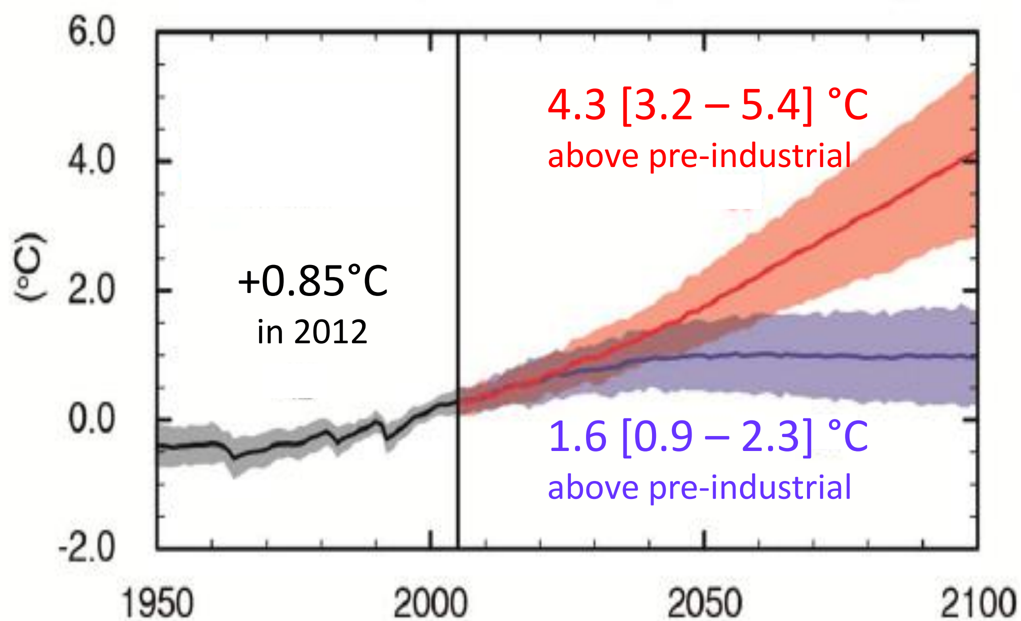
CO_2 already emitted

during 1870 – 2011

515 [445 – 585] GtC

source: IPCC AR5

Projected global average surface temperature change



about 3 x historical emissions

about half the historical emissions

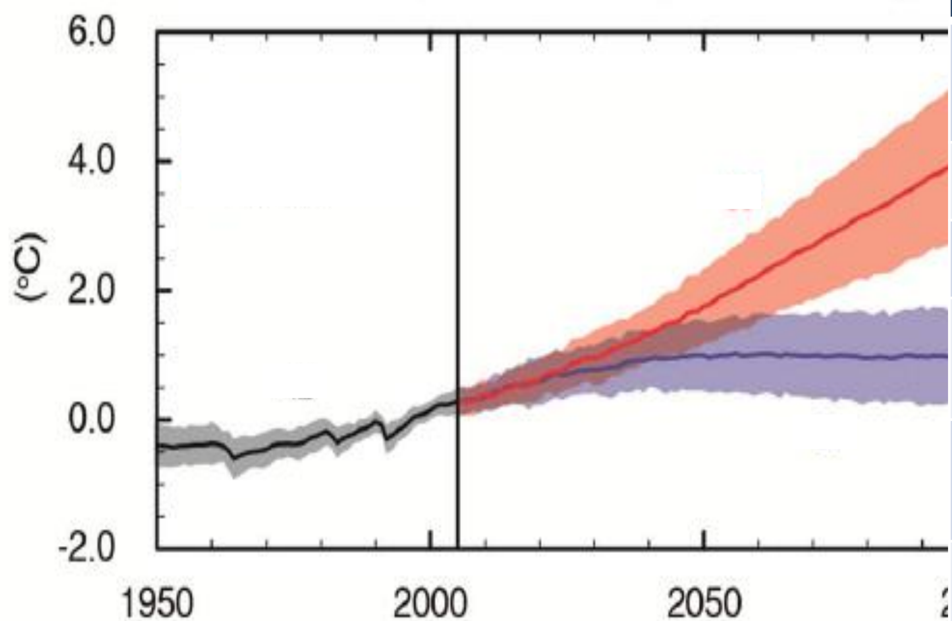
CO_2 already emitted

during 1870 – 2011

515 [445 – 585] GtC

source: IPCC AR5

compatible emissions for all RCPs



Period	Fossil fuel	Land-use change
1870 – 2011	370 [340-400]	145 [80-210]
2012 – 2100		
RCP2.6	270 [140-410]	55
RCP4.5	780 [595-1005]	15
RCP6.0	1060 [840-1250]	-5
RCP8.5	1685 [1415-1910]	45

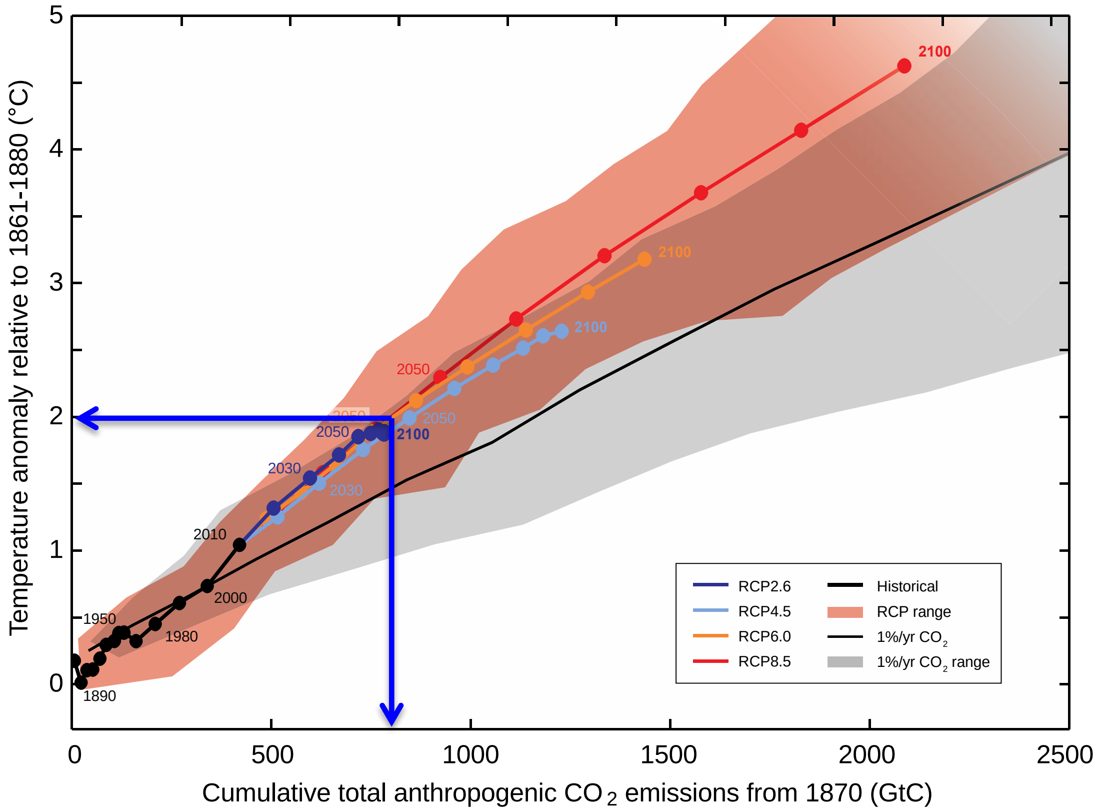
CO_2 already emitted

during 1870 – 2011

515 [445 – 585] GtC

source: IPCC AR5

Cumulative emissions versus temperature

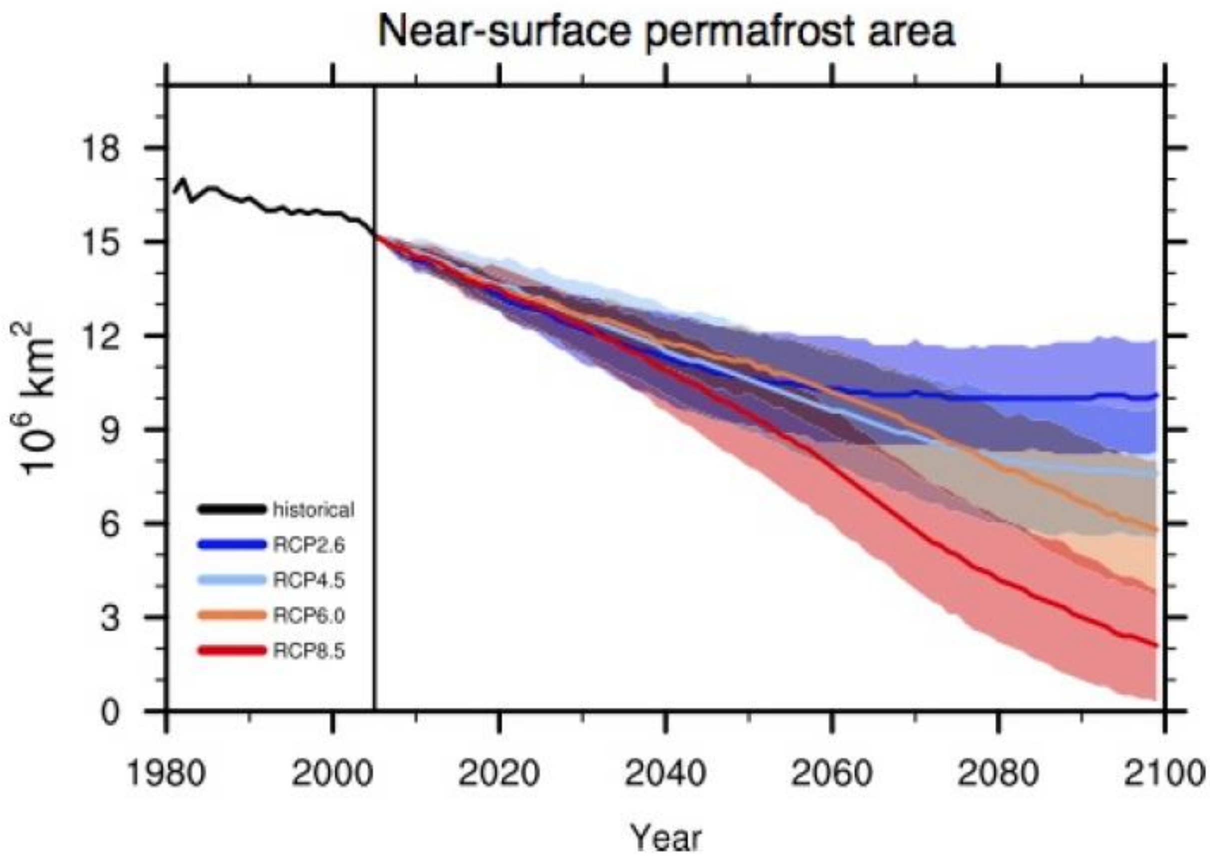


50% chance to keep to 2°C

C Allocation	840 GtC
C Consumed	515 GtC
Left	325 GtC
At Current Emiss.	10 GtC y^{-1}
Years left	33 yrs (2045)
At Current Growth	3% y^{-1}
Years left	<25 yrs (2035)

IPCC AR5 WGI, SPM 2013; Chapter 6, Ciais et al. 2013

Further research need:
How much carbon will be released from permafrost thawing?



C stock in permafrost:

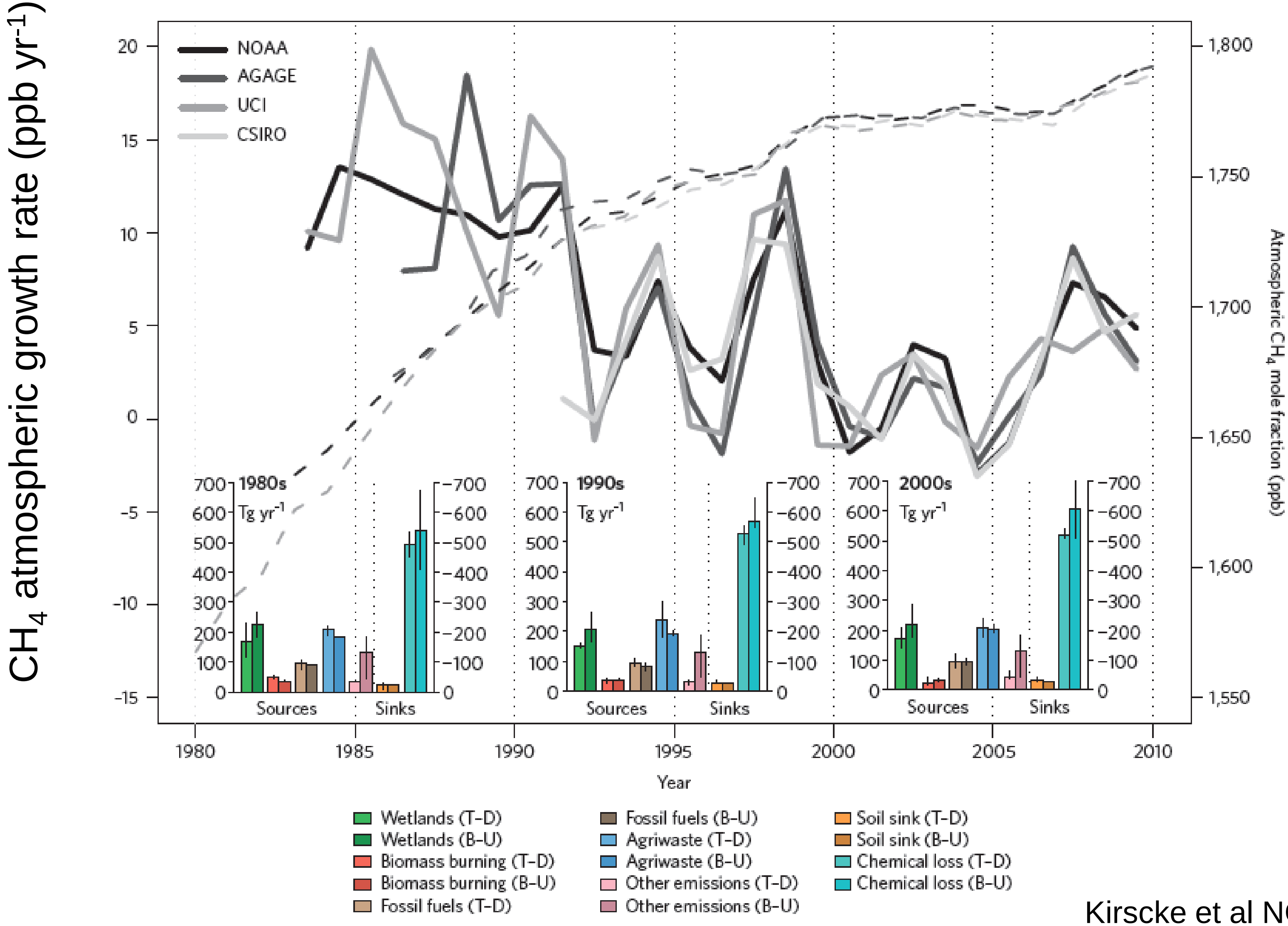
1700 GtC

C released to the atmosphere from permafrost thawing:

50 – 250 GtC (RCP8.5)
(low confidence)

source: IPCC AR5; Collins et al (Ch 12)

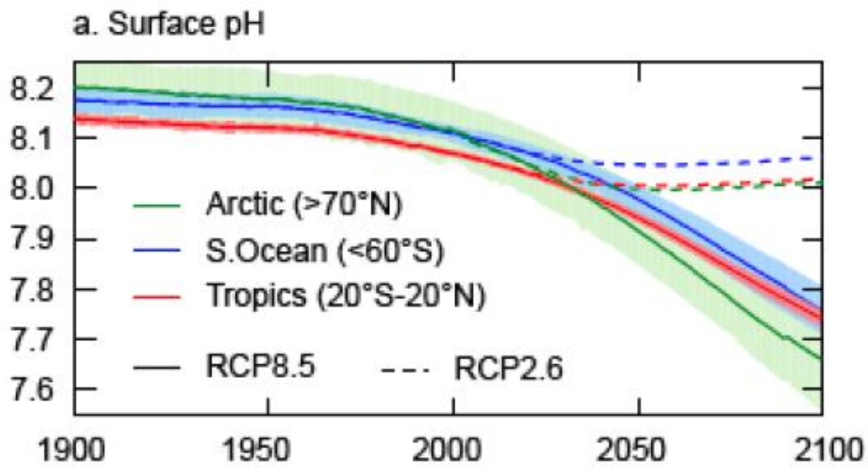
Further research need:
What is the contribution of wetlands to the renewed growth in atm CH_4?



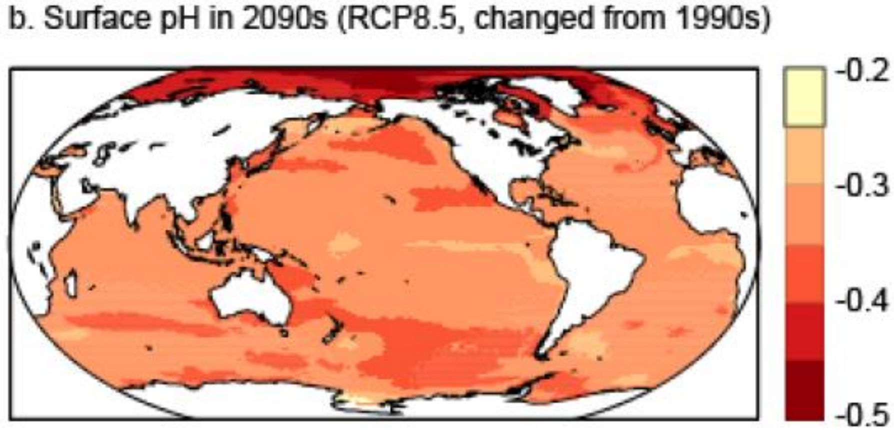
Kirscke et al NGeo 2013

Further research need:
How will ocean acidification affect marine ecosystem services?

surface pH



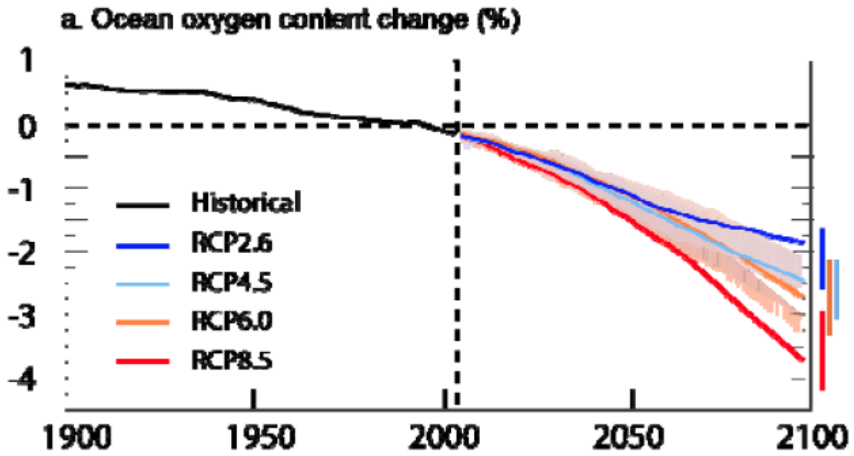
surface pH change in 2090s from 1990s



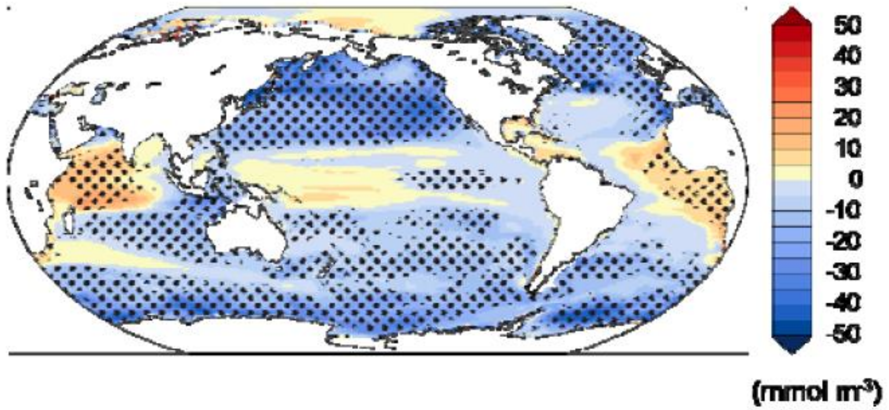
source: Ciais et al. 2013 IPCC AR5

Further research need:
How will ocean deoxygenation affect marine ecosystem services?

ocean oxygen content change (%)



surface O_2 change in 2090s from 1990s



source: Ciais et al. 2013 IPCC AR5

Summary and conclusions:

- Ecosystems store (on land) and sequester (in the ocean) large quantities of C
- Ecosystems are highly variable in time and space, yet their response to climate change and variability is predictable at the large scale
- Cumulative C emissions provide the most accurate information to project temperature changes
- Monitoring vulnerable C pools and fluxes is critical as the climate evolves

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