Der globale Kohlenstoffkreis - Terrestrische Senken

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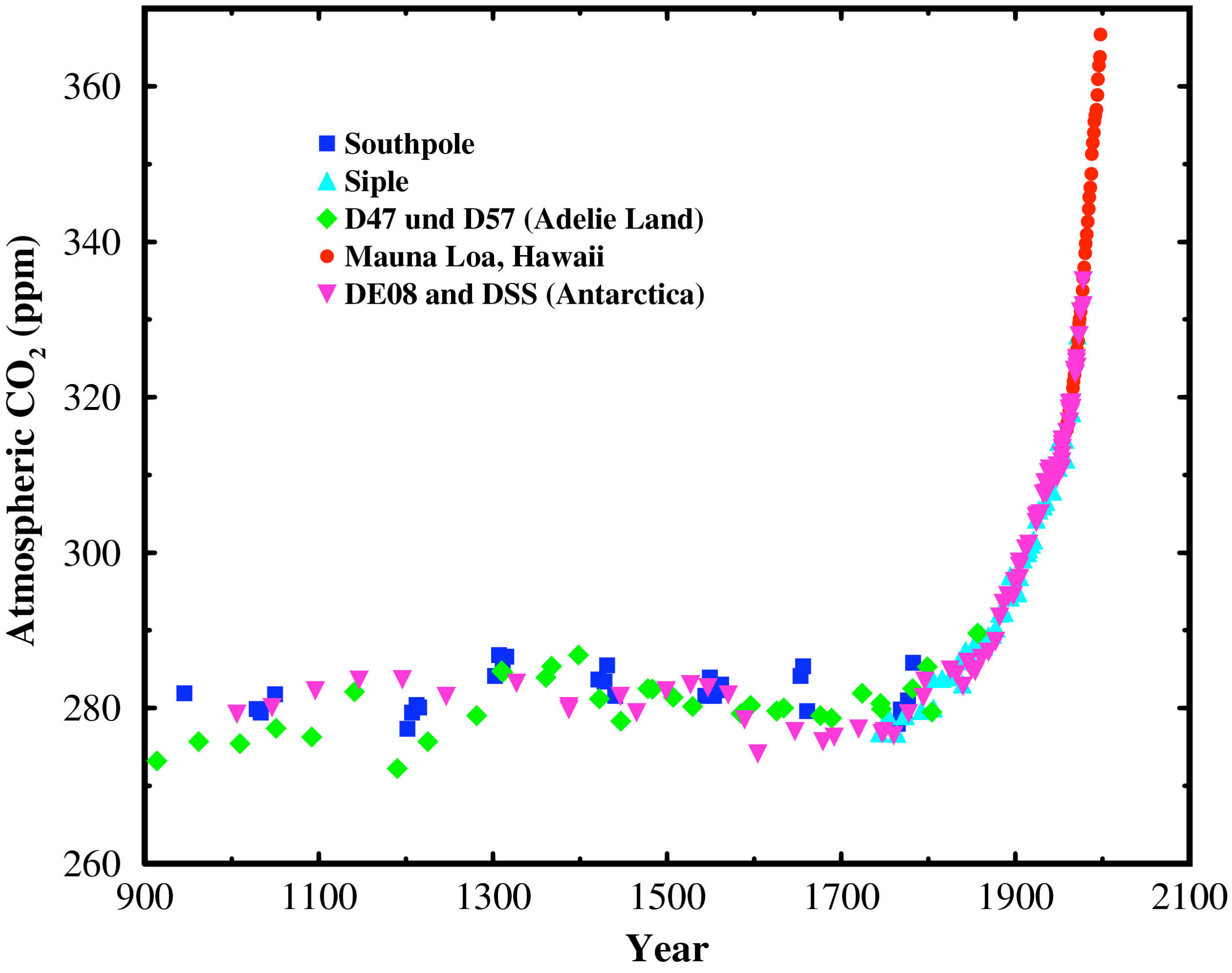
Fortunat Joos

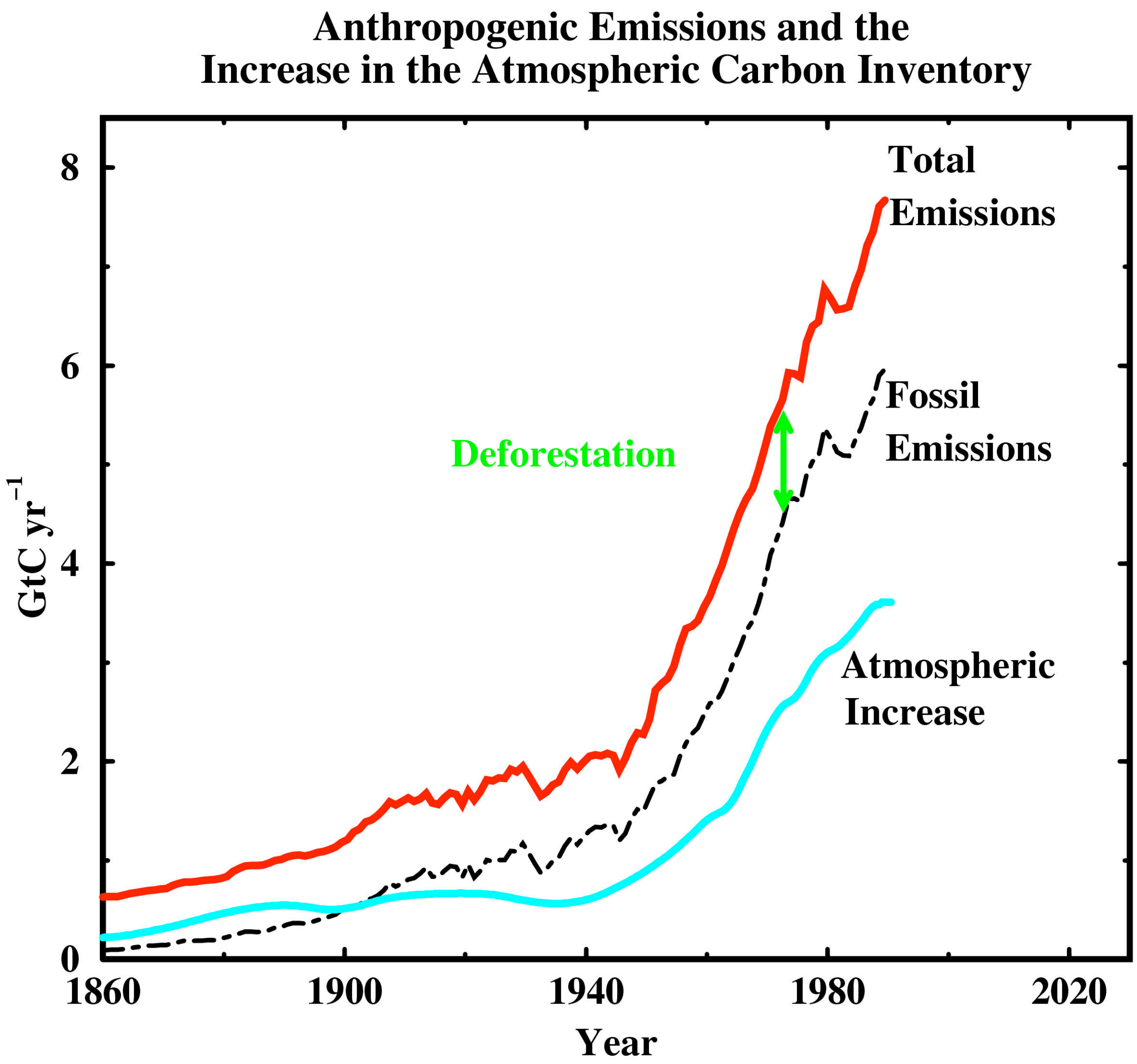
Klima- und Umweltphysik
Physikalisches Institut
Universität Bern
joos@climate.unibe.ch
www.climate.unibe.ch/~joos

Today's CO_2 concentration is higher than at any time during the past 420'000 years

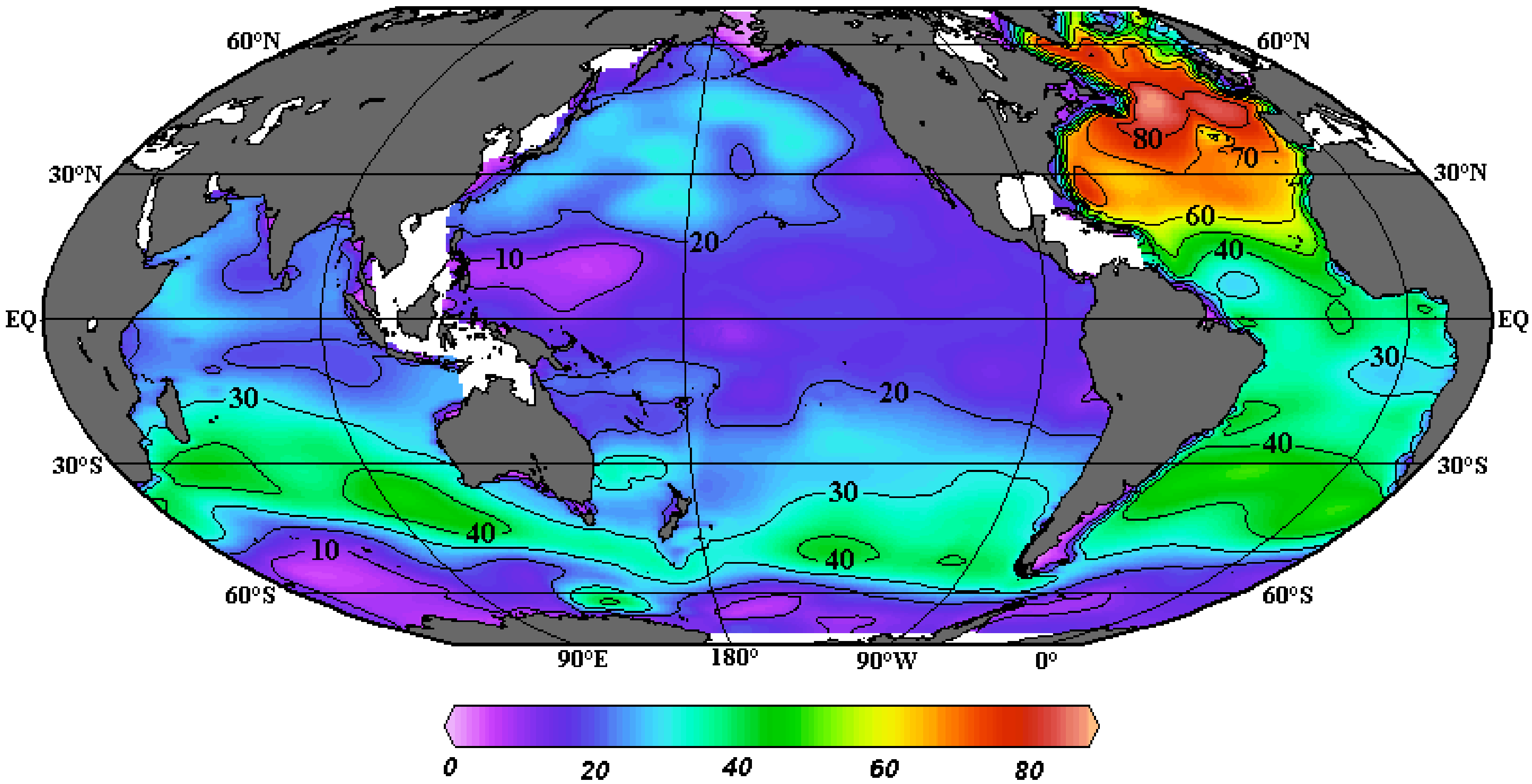
The Atmospheric CO_2 Increase



Carbon emissions from fossil fuel burning dominate

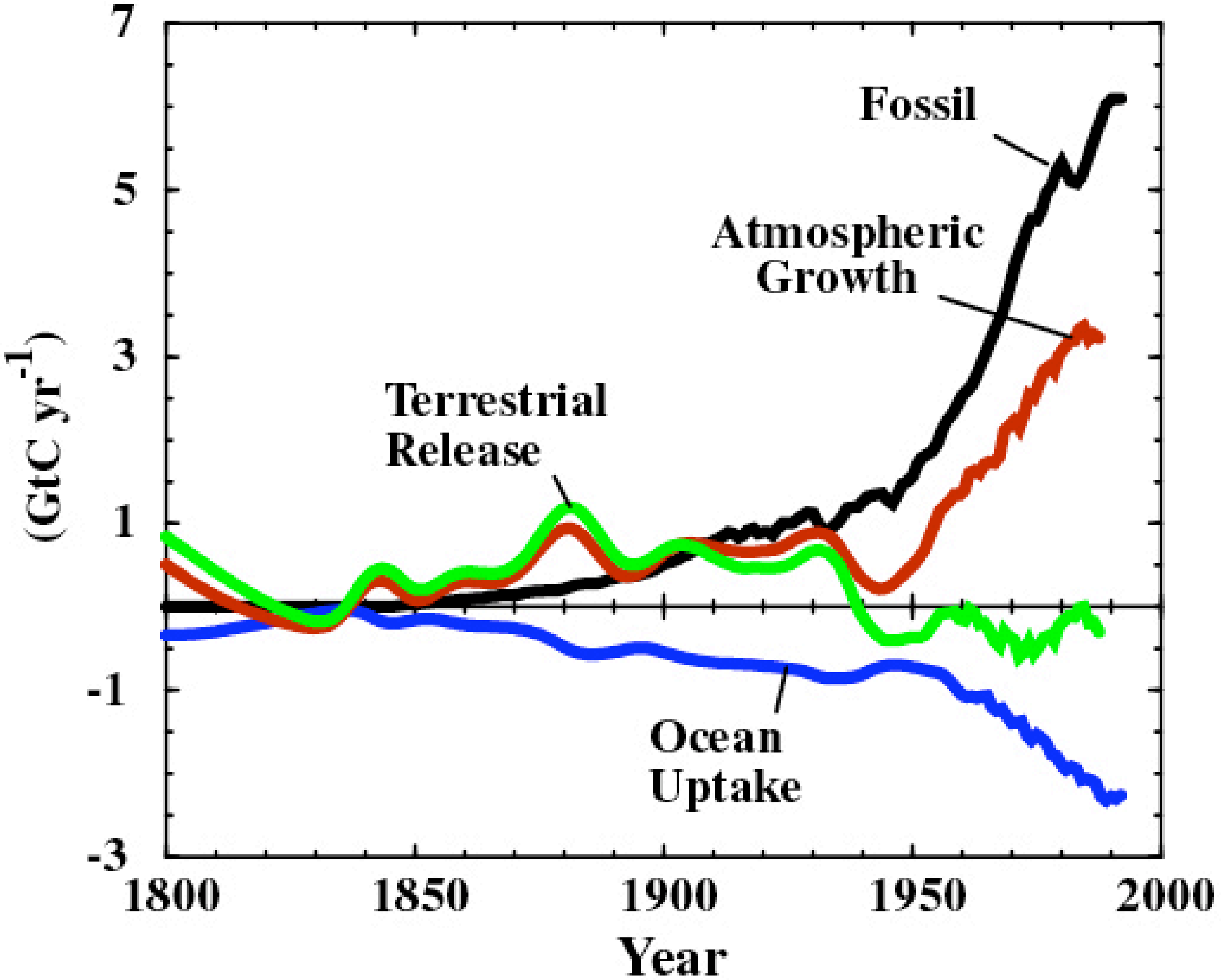


Data-based column inventory of anthropogenic carbon



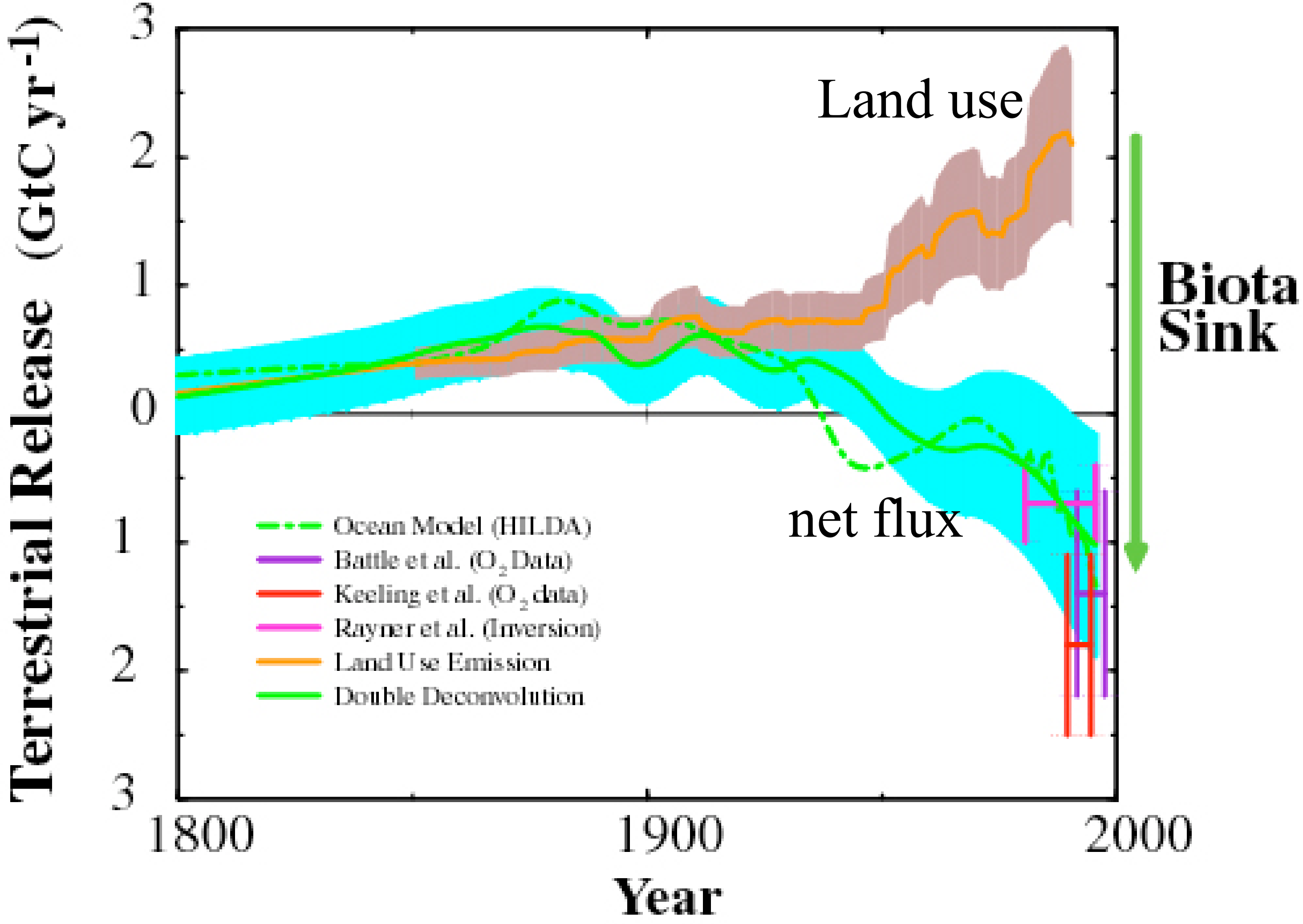
Sabine et al., 2003

The carbon budget over the industrial period

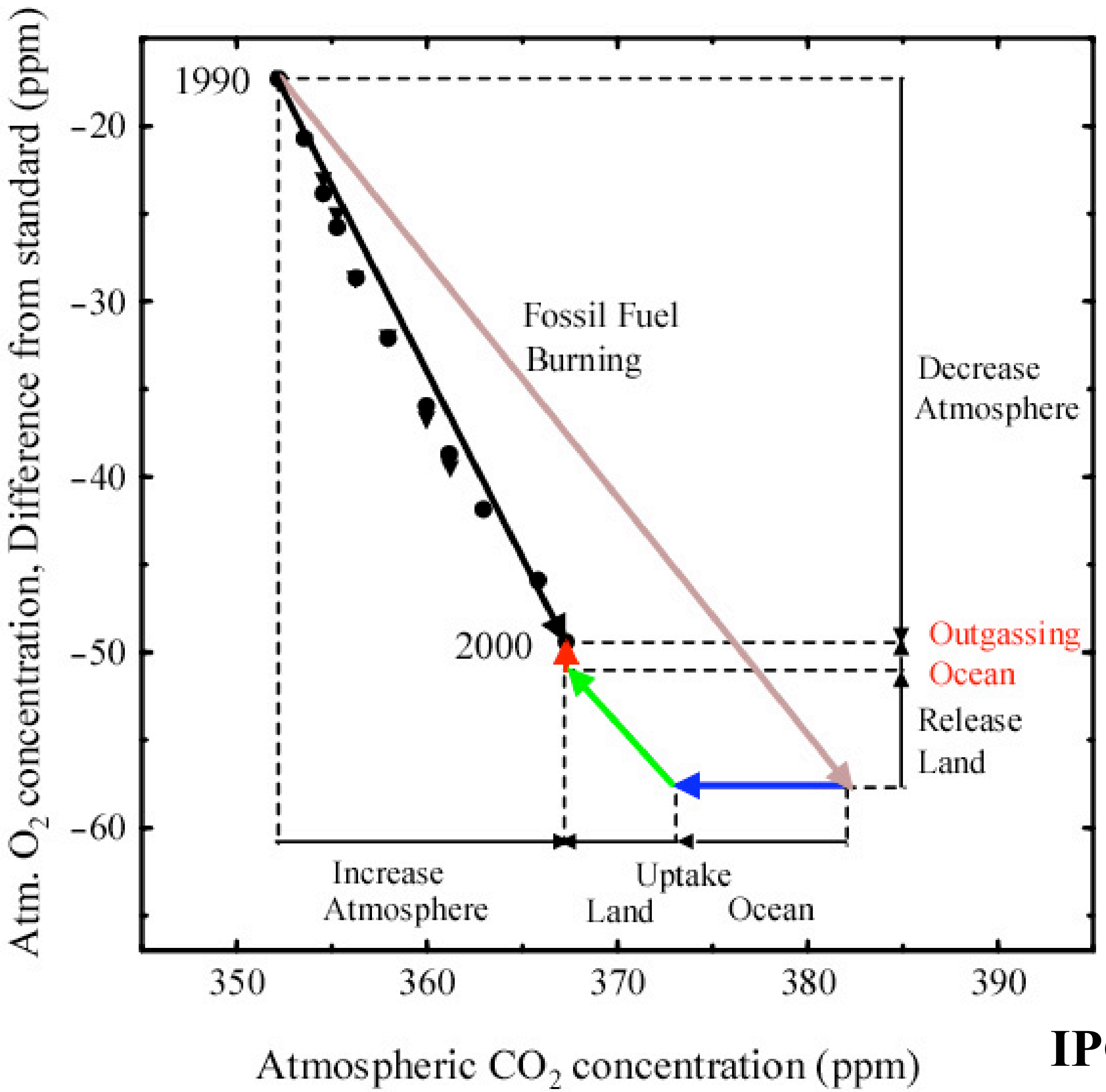


Joos et al., 1999

The residual terrestrial sink flux is inferred from the difference between a release from land use and a small net sink



Quantifying the oceanic and terrestrial carbon sink from measurements of atmospheric CO_2 and O_2



IPCC, 2001

CO_2 budget in GtC yr^{-1} (IPCC, 2001)

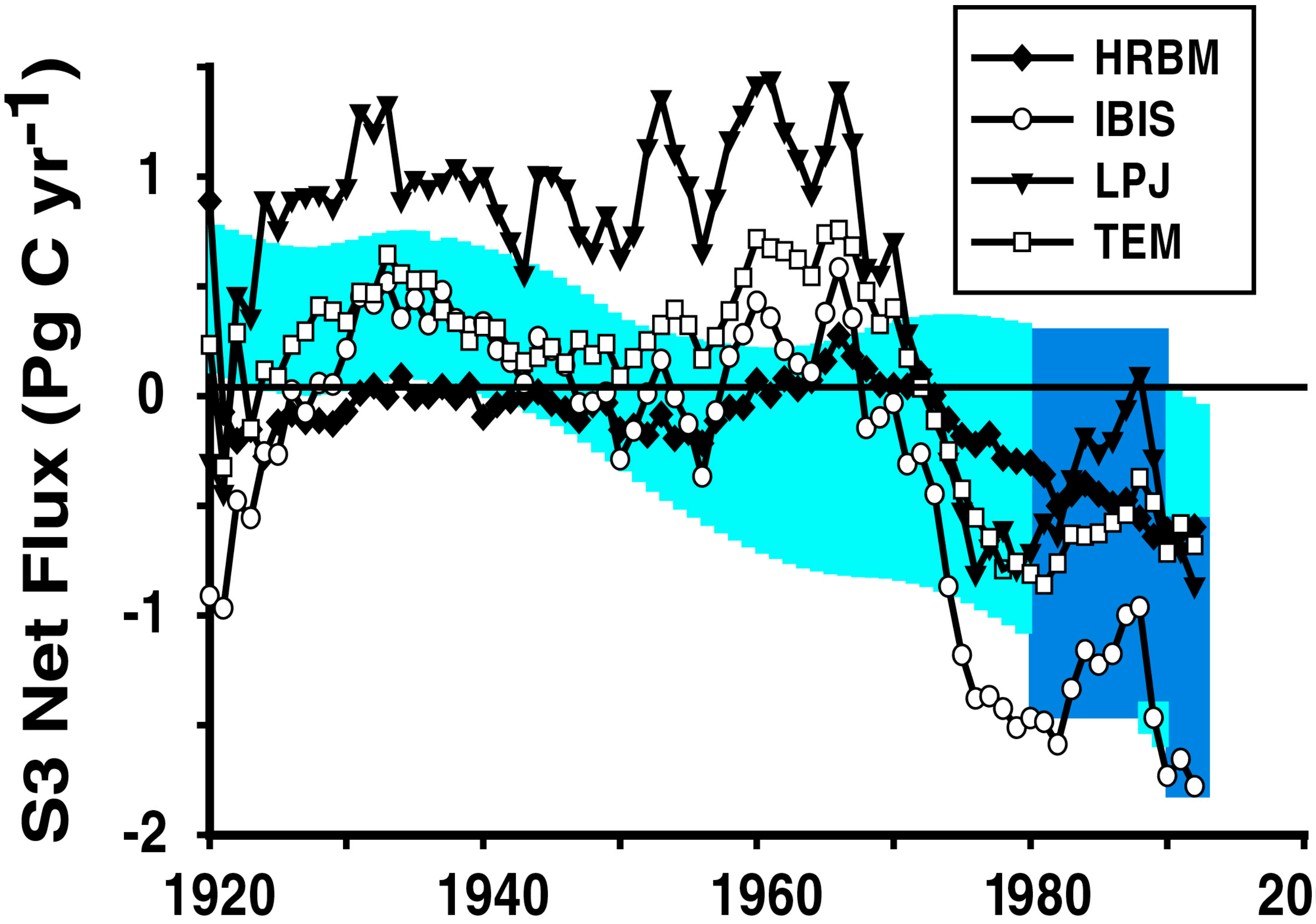
	1980-1989
Atmospheric increase	3.3±0.1
Emissions (fossil fuel, cement)	5.4 ±0.3
Ocean-atmosphere flux	-1.9±0.6
Land-atmosphere flux	**-0.2 ±0.7**
partitioned as follows:	
Land use change	**1.7 (0.6 to 2.5)**
Residual terrestrial sink	**-1.9 (-3.8 to +0.3)**

Schlussfolgerungen

- **Etwa die Hälfte der CO_2 Emissionen wird durch den Ozean und die Landbiosphäre aufgenommen.**
- **Die terrestrische ‚Senke' ist die Differenz zwischen Emission aus Landnutzungs-änderungen und dem Netto Fluss von der Atmosphäre in die Biosphäre. Grösse des Flusses und verantwortliche Prozesse sind unsicher.**
- **Fossile Emission ist der dominierende Faktor für die Entwicklung der CO_2 Konzentration in diesem Jahrhundert.**

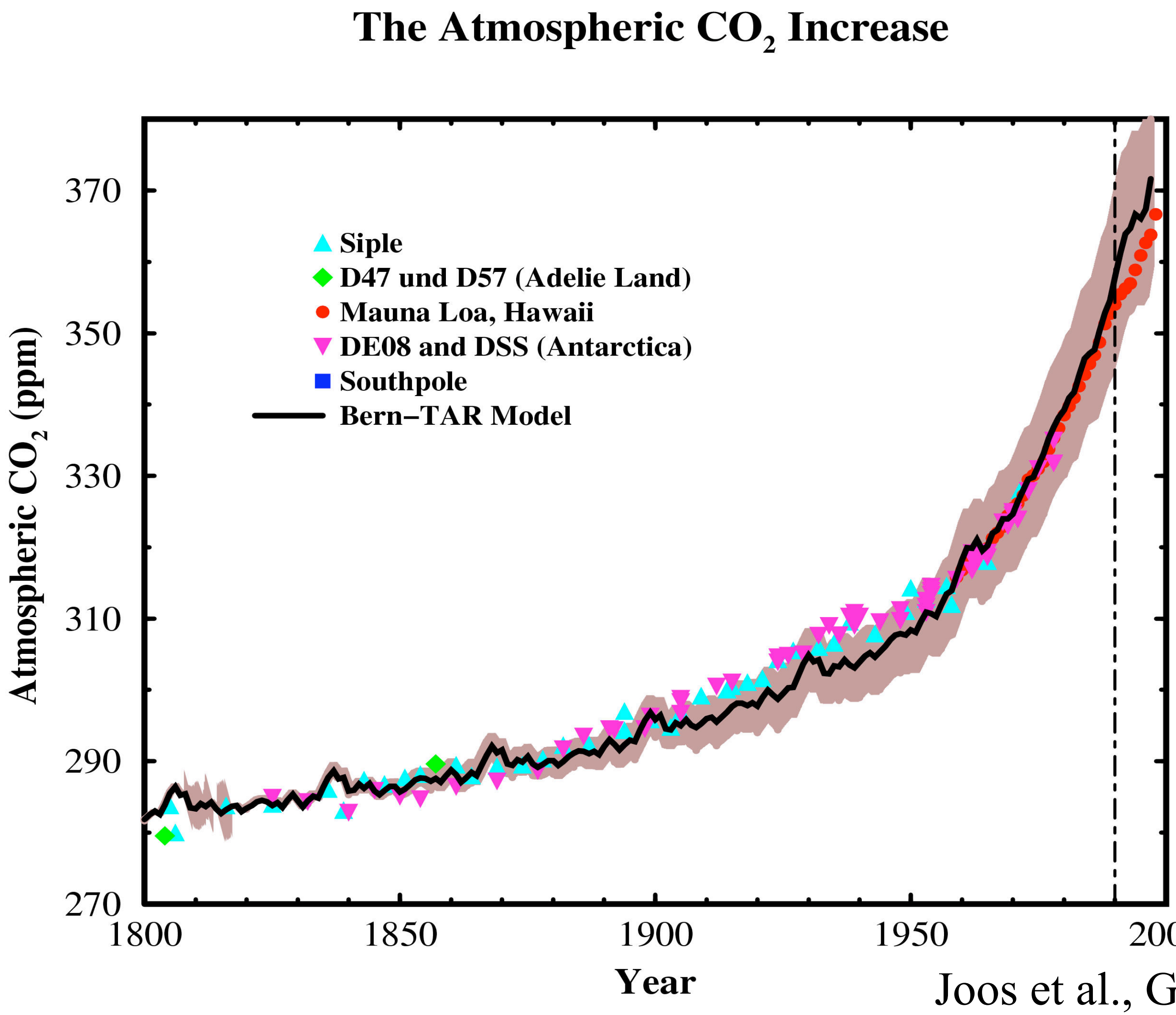
MODEL EVALUATION

Global Net Flux of Carbon from the Atmosphere to the Biosphere: Model versus Reconstructions



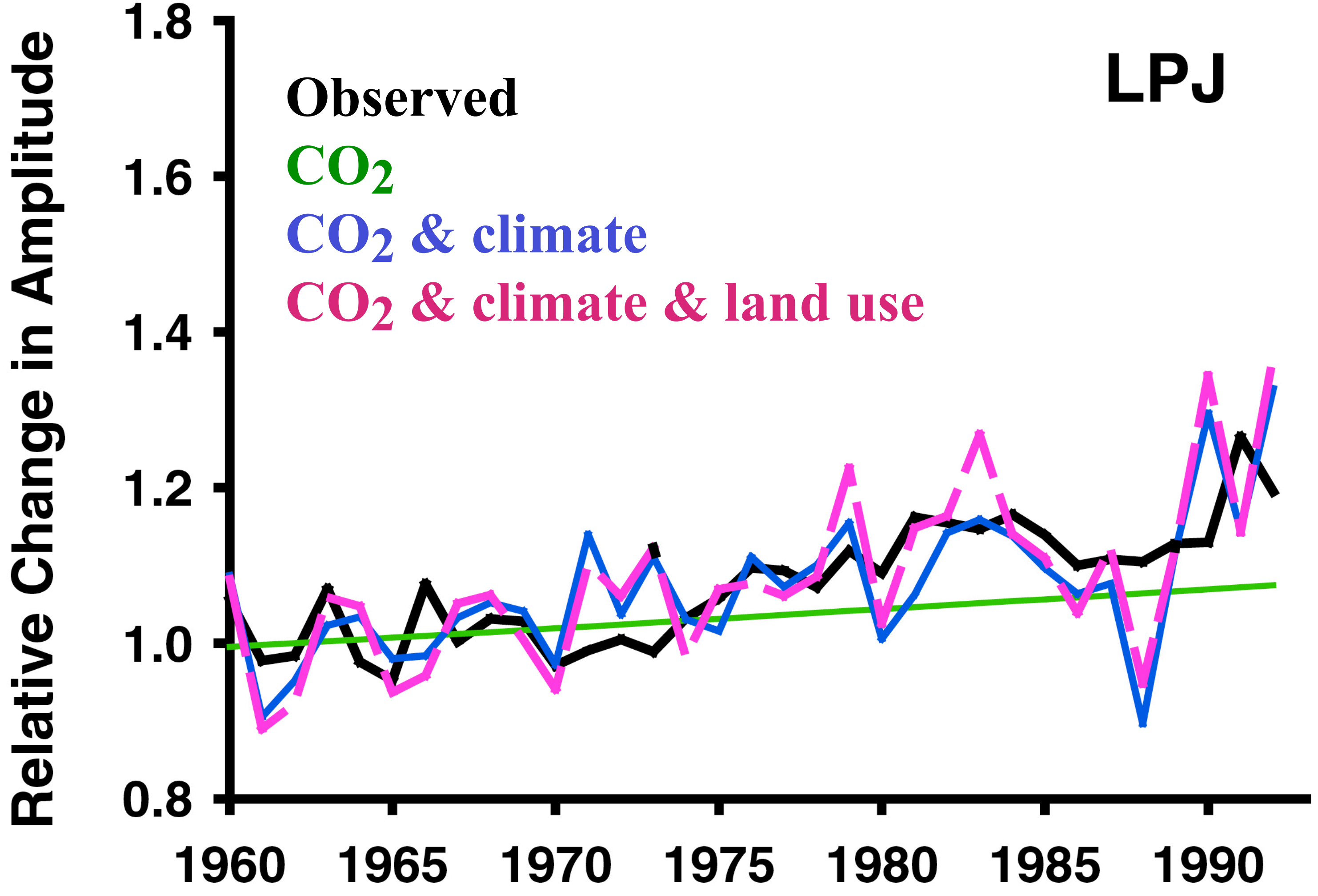
McGuire et al., GBC, 2001

Simulated versus observed CO_2 increase



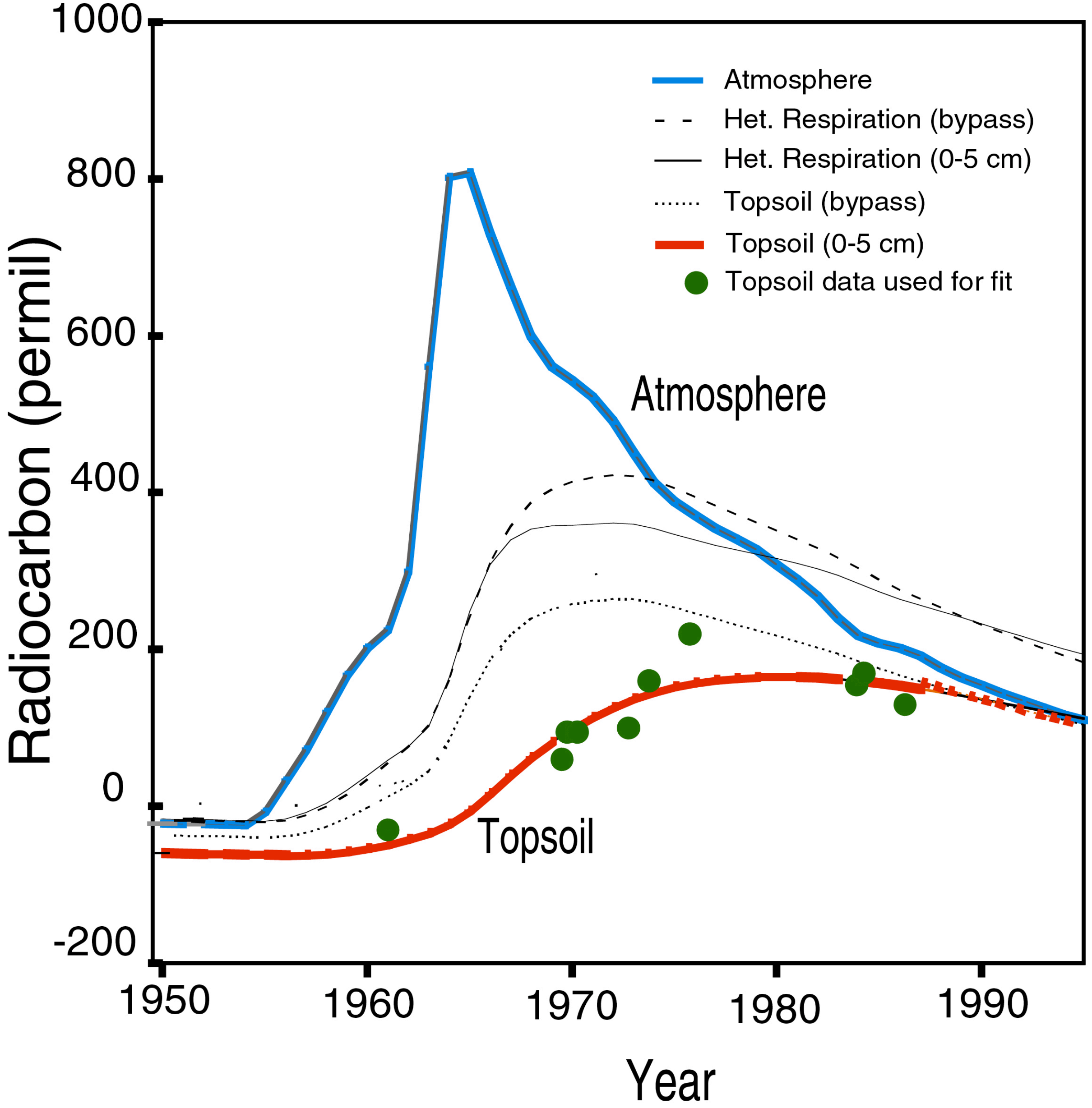
Joos et al., GBC, 2001

The Amplitude of the Seasonal Signal of Atmospheric CO2



McGuire et al., GBC, 2001

Modelled versus Observed Soil Radiocarbon



Perruchoud et al., GBC, 1999

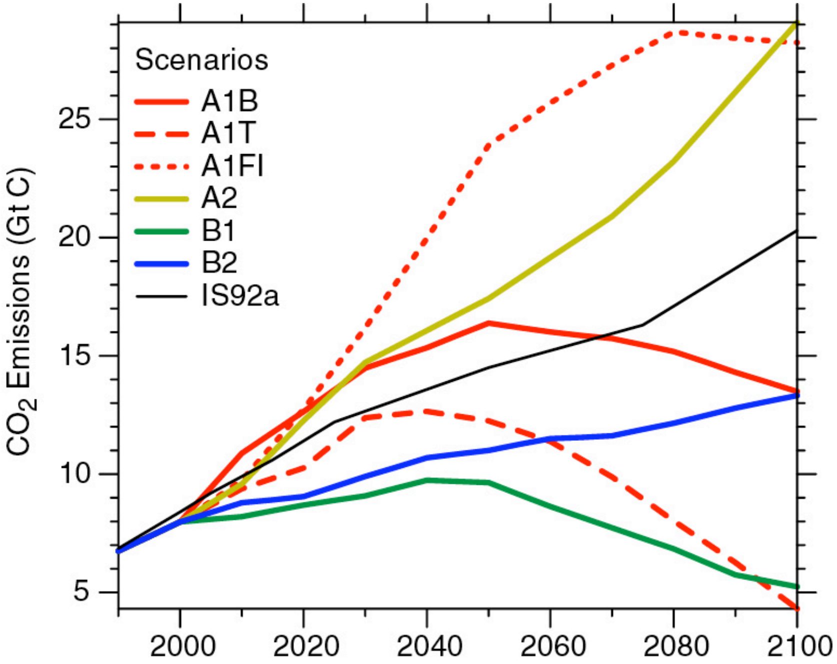
SZENARIEN

CO_2, Totales Radiative Forcing und die global gemittelte Oberflächentemperatur steigen in diesem Jahrhundert für Szenarien ohne klimapolitische Massnahmen.

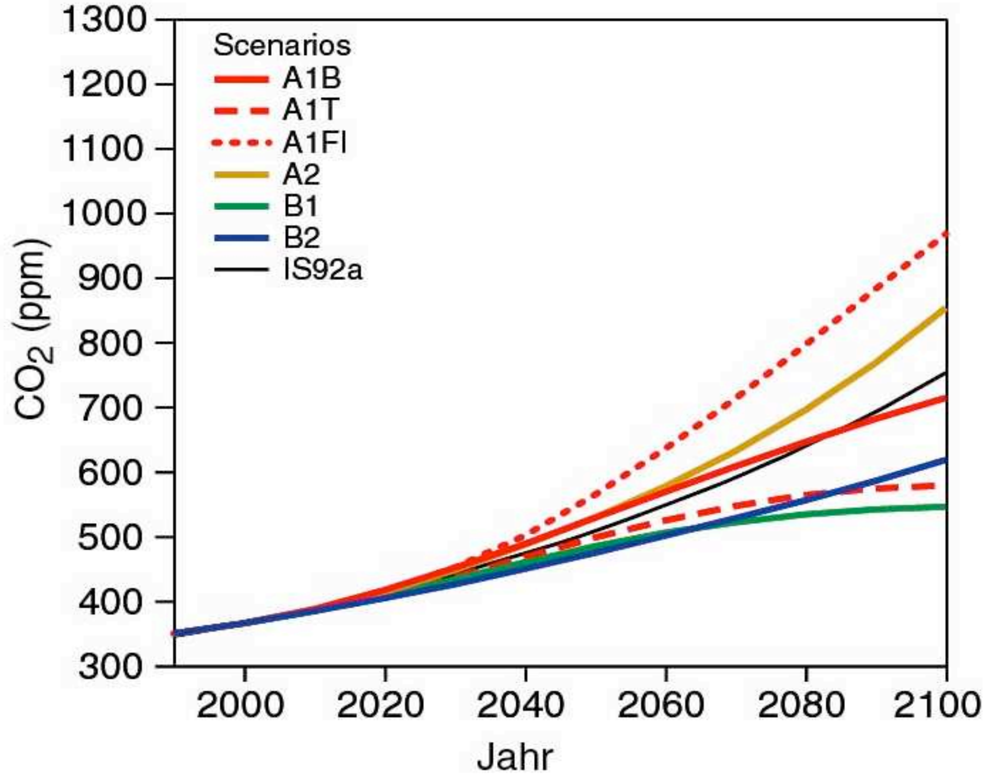
[IPCC, Summary for Policymakers, WG1]

CO_2 in the SRES „no climate policy“ scenarios

Emissions of CO_2 (1990 to 2100)

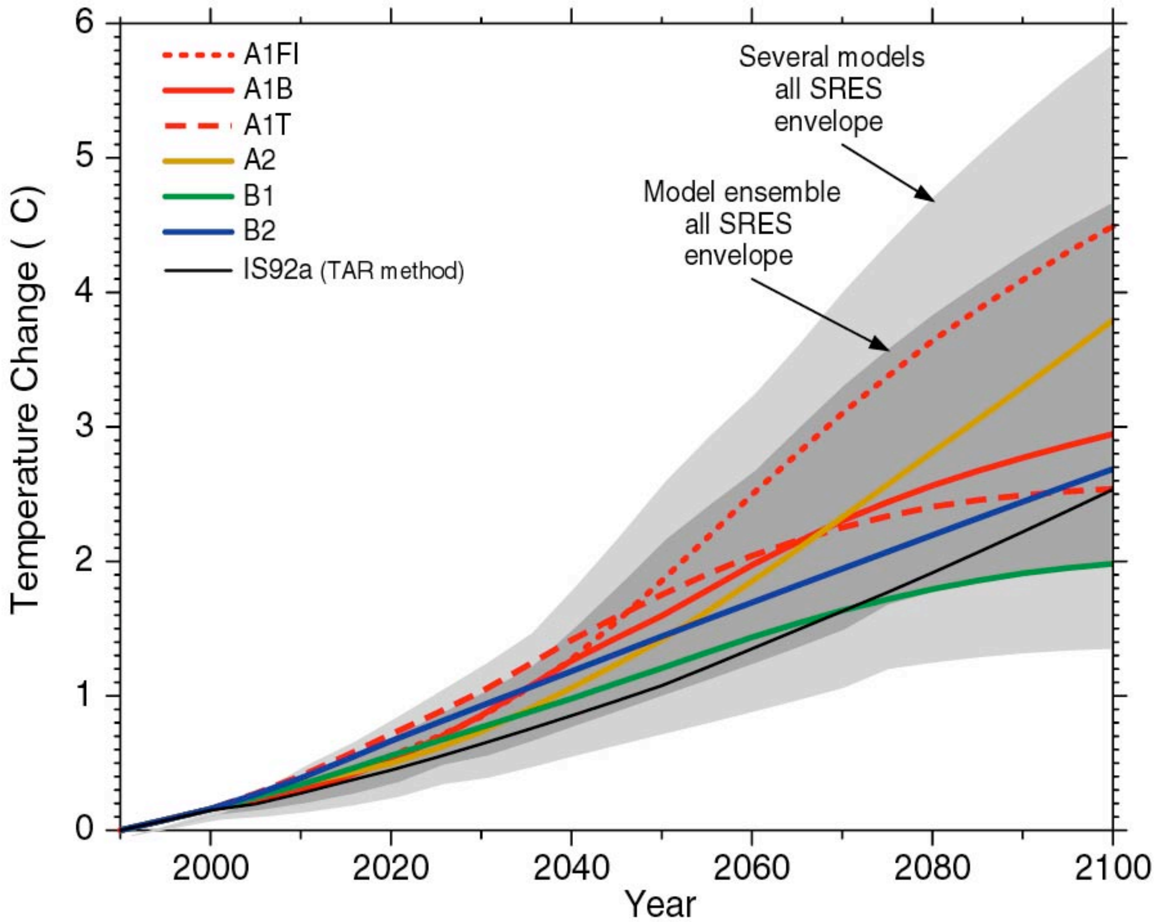


... and projected atmospheric CO_2



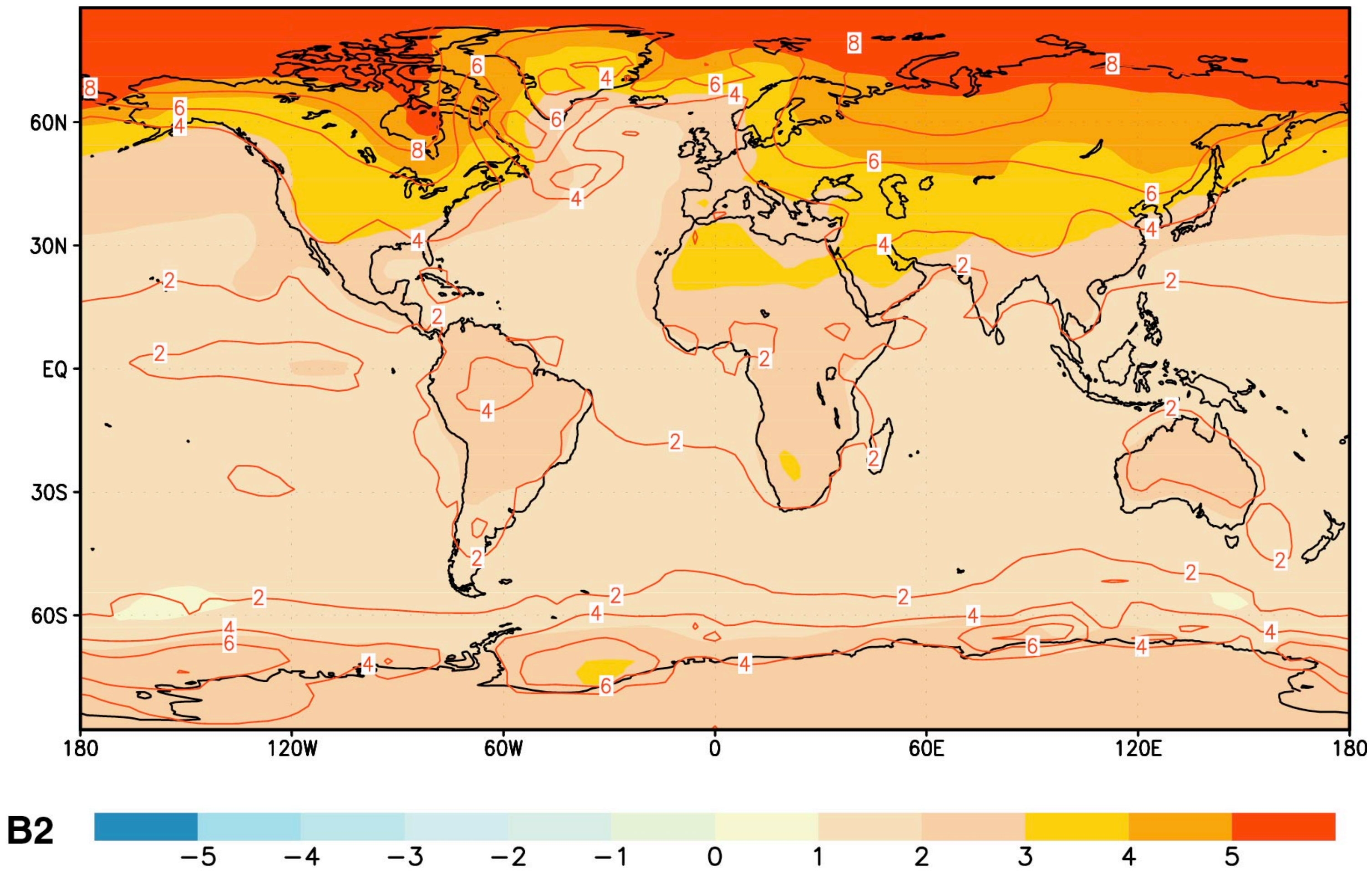
[Summary for Policymakers, WG1]

Temperature Projections 1990 – 2100



[Summary for Policymakers, WG1]

Annual Mean Temperature Changes 2071-2100



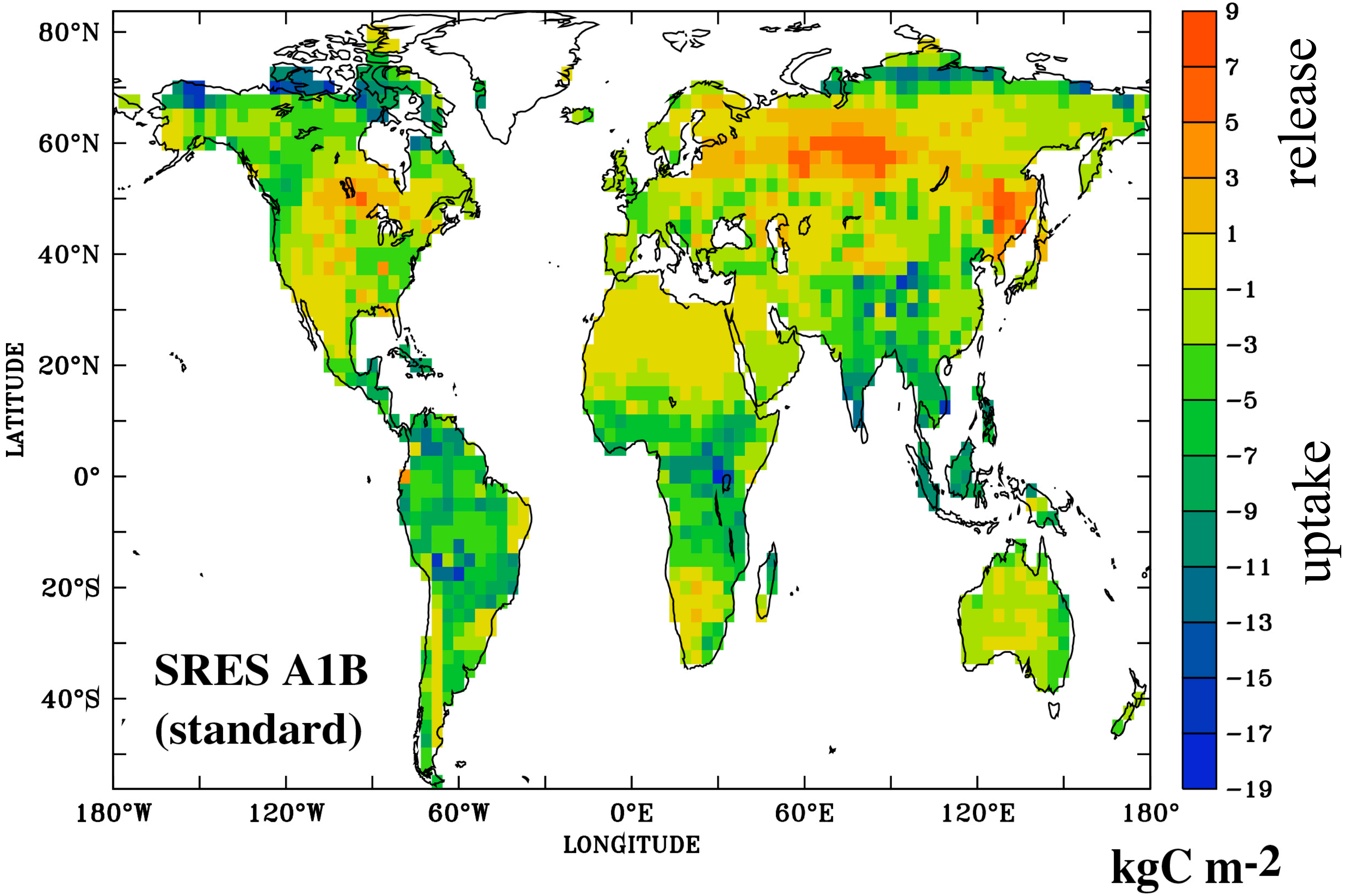
[Technical Summary, WG1]

Observed and projected changes in extremes

Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely[7]	**Higher maximum temperatures and more hot days over nearly all land areas**	Very likely[7]
Very likely[7]	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely[7]
Very likely[7]	**Reduced diurnal temperature range over most land areas**	Very likely[7]
Likely[7], over many areas	**Increase of heat index[12] over land areas**	Very likely[7], over most areas
Likely[7], over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events[b]**	Very likely[7], over many areas
Likely[7], in a few areas	**Increased summer continental drying and associated risk of drought**	Likely[7], over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[c]**	Likely[7], over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[c]**	Likely[7], over some areas

[Summary for Policymakers, WG1]

Changes in carbon storage (2100-1765)



Wird die terrestrische Biosphäre auch in Zukunft CO_2 aufnehmen?

C-Senke

- CO_2 Zunahme

-> CO_2 Düngung ?

C-Quelle

Temperaturzunahme

-> erhöhte Bodenrespirationrate?

- Nachwachsende Wälder, Abholzung, Stickstoffdüngung, Änderungen in Vegetationsstruktur, Feuer, Insektenbefall ….

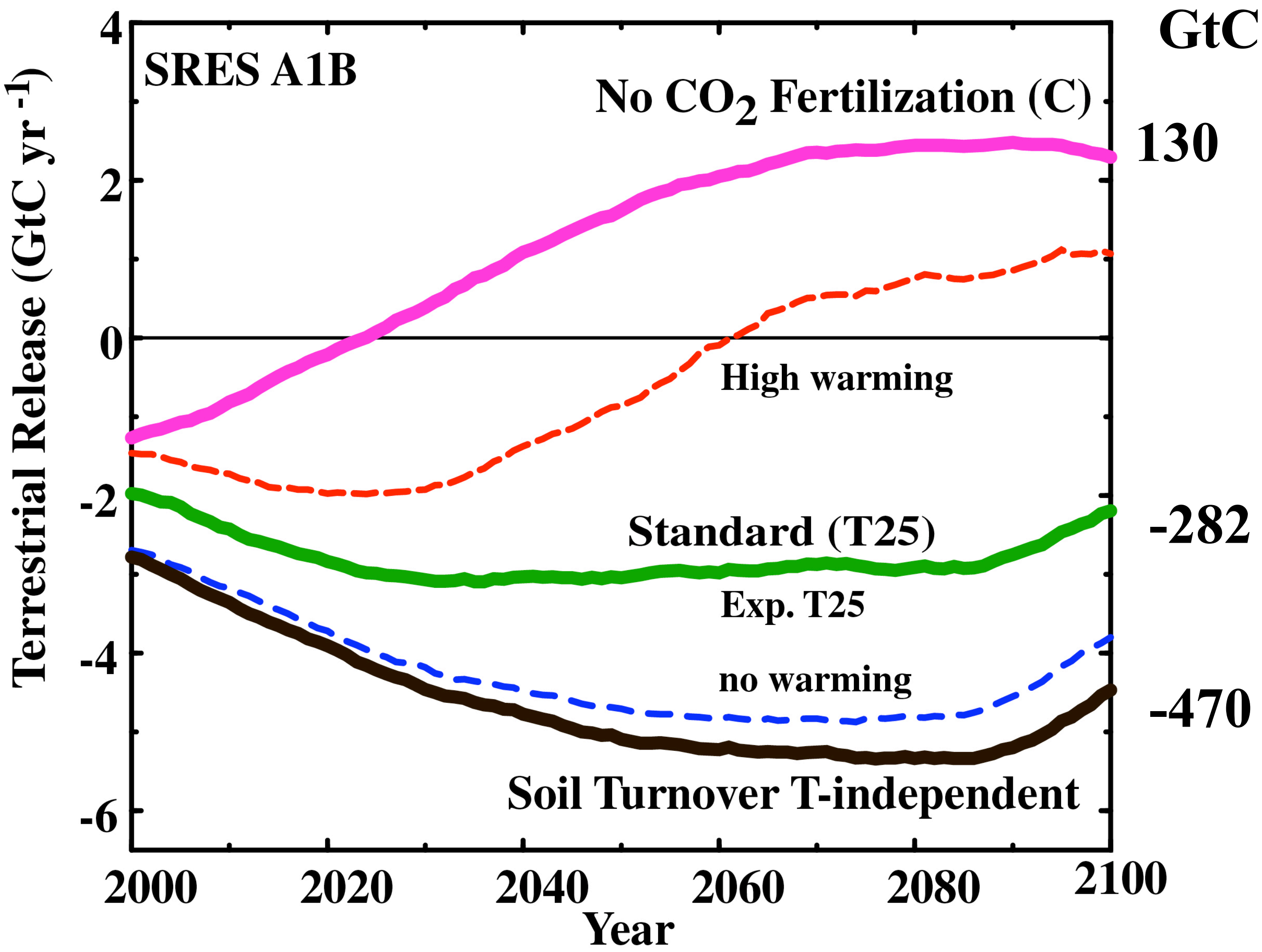
Simulationen mit limitierenden Annahmen:

a) heutige Senke verschwindet rasch

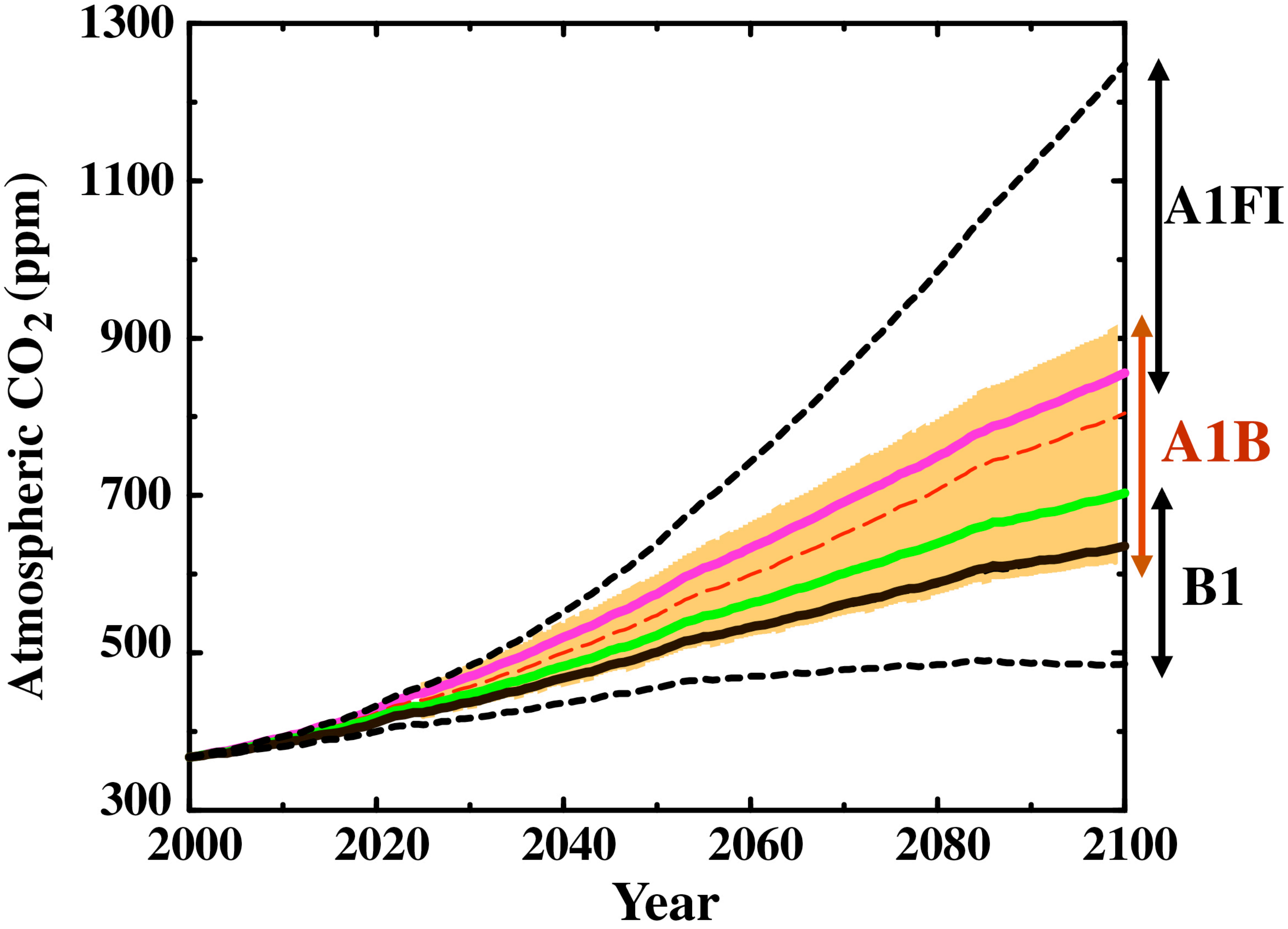
b) Bodenrespirationsrate reagiert nicht auf Erwärmung

(Standard: starke CO_2 Düngung und temperaturabhängige Bodenrespiration)

A future terrestrial carbon sink or source?



Uncertainties in CO_2 at 2100: -10 % to +30 %



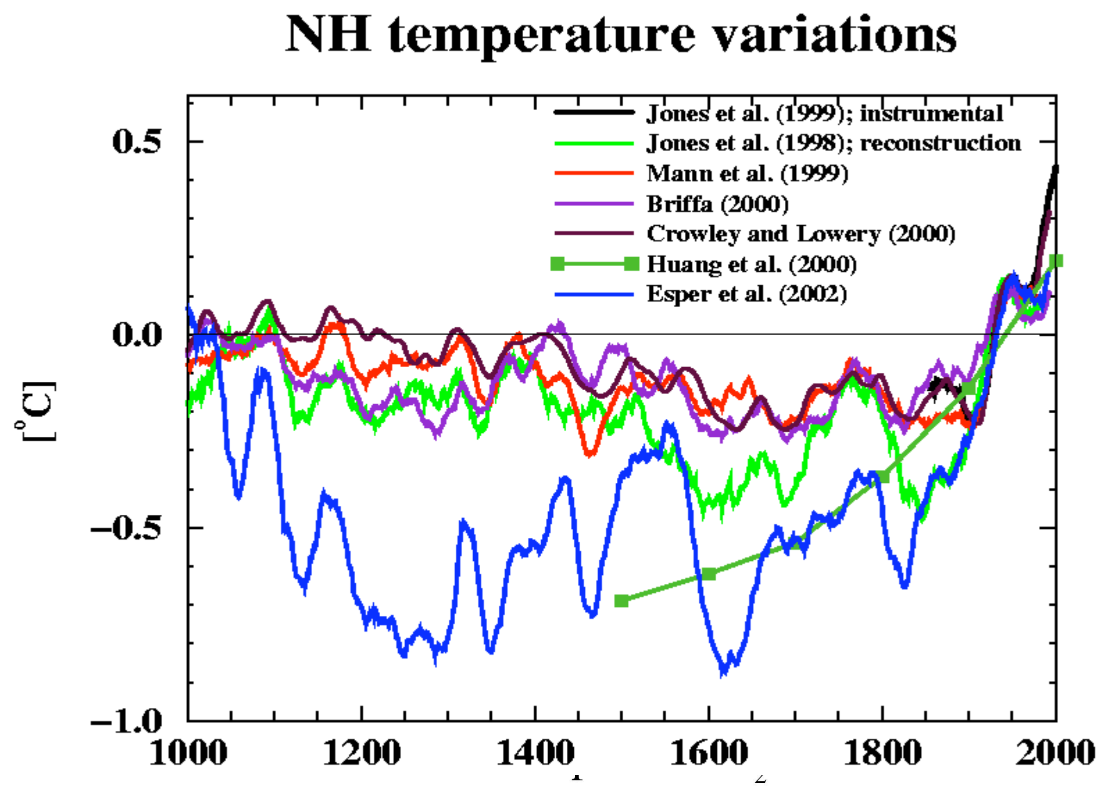
Wechselwirkungen zwischen der globalen Erwärmung und der terrestrischen Biosphäre

Proxydaten geben Hinweise für die Zukunft

Eine Klimaänderung, z.Bsp. durch Änderung der solaren Einstrahlung, führt zu einer Änderung im atmosphärischen CO_2.

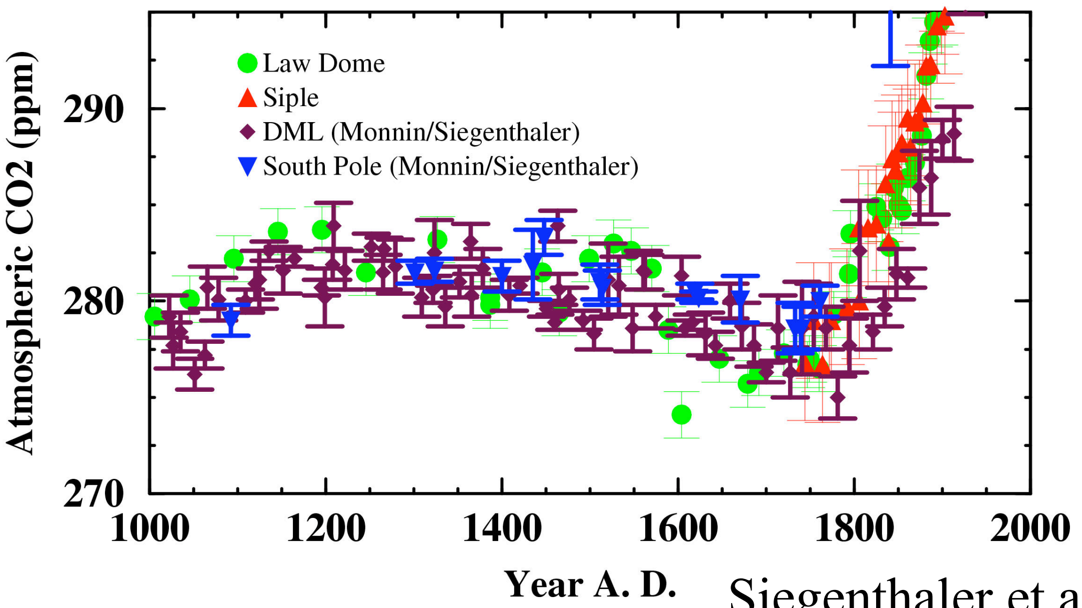
Carbon Cycle - Warming Feedback:

CO_2 Änderung pro Grad Änderung in der mittleren globalen Oberflächentemperatur [ppm/°C]



Temperaturvariationen

verknüpft durch den ‚Carbon Cycle - Warming Feedback‘

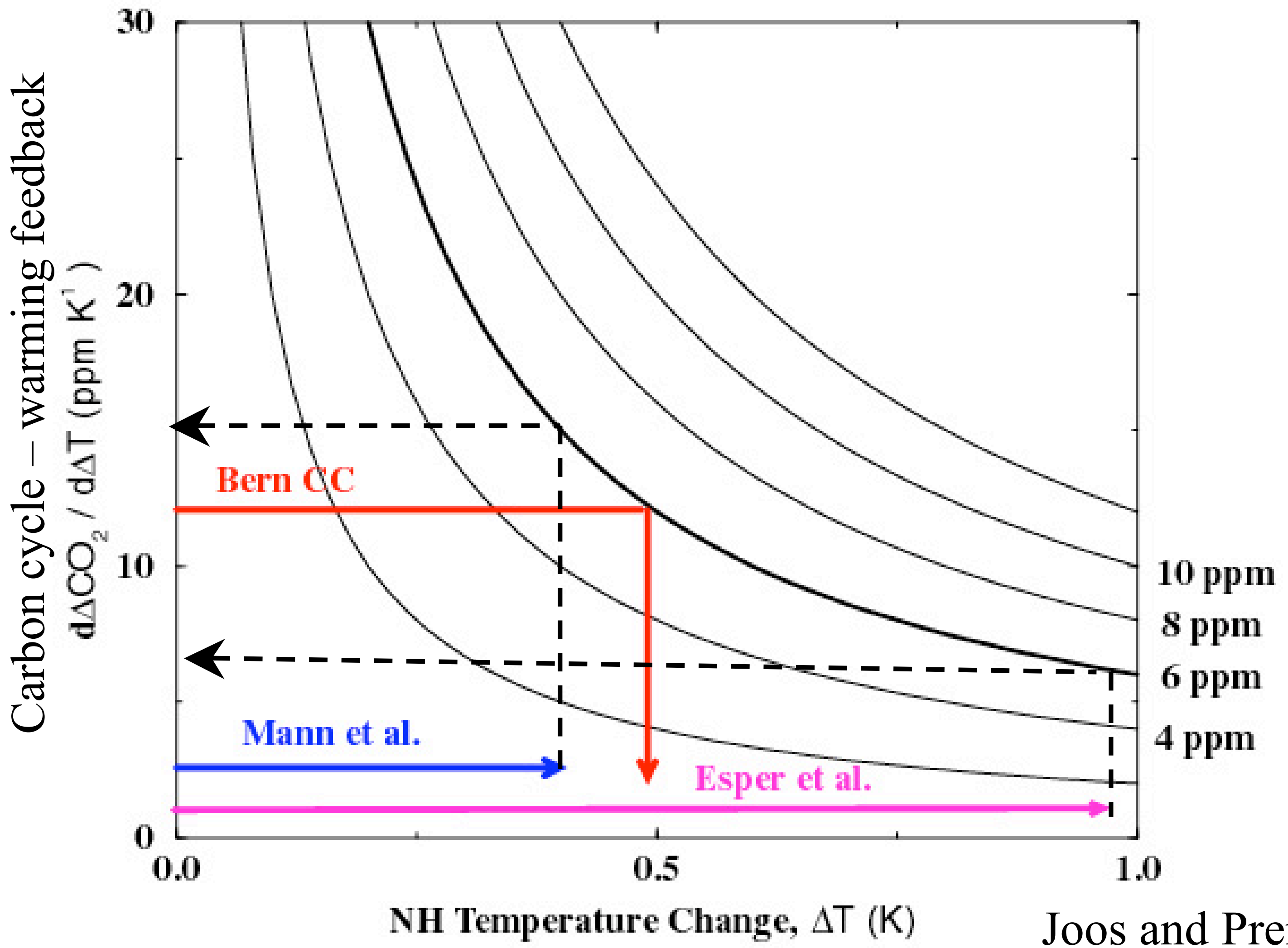


CO_2 Variationen

Siegenthaler et al., submitted, 2004

Linking variations in CO_2, in NH temperature, and the carbon cycle-warming feedback:

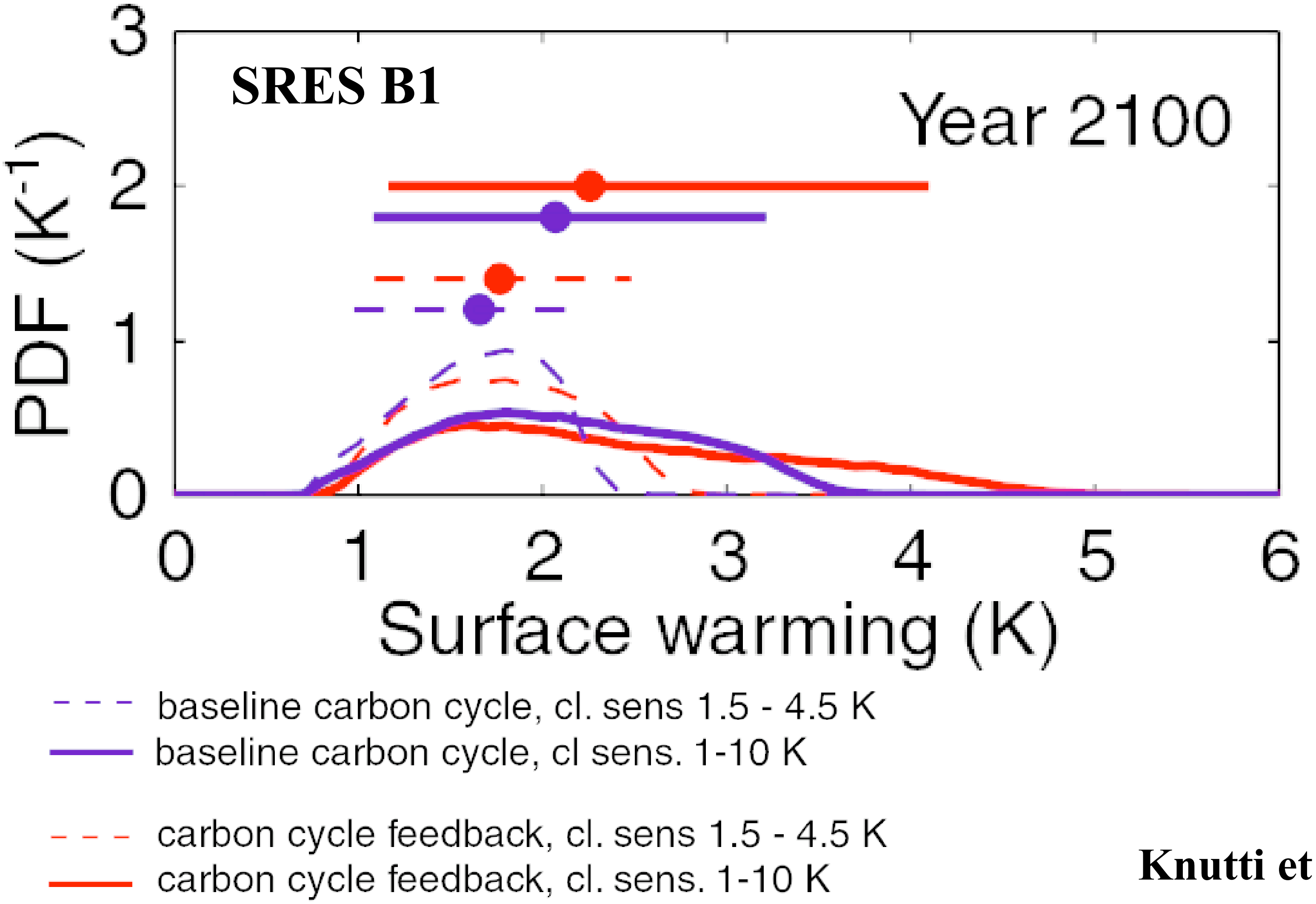
$$\Delta T = \Delta CO_2(\text{ice}) * (d\,\Delta CO_2/d\,\Delta T)^{-1}$$



Joos and Prentice, 2003

Evaluating the overall impact in a probabilistic way

The carbon cycle-warming feedback leads to an increased probability for high warming



Knutti et al, 2003

Schlussfolgerungen

- **CO_2 und mittlere Oberflächentemperatur steigen für Szenarien ohne klimapolitische Massnahmen.**
- **Unsicherheiten in Senkenprozessen führen zu einer Unsicherheit im atmosphärische CO_2 von rund -10% bis +30% in 2100.**
- **CO_2 und Temperaturproxydaten ergeben einen carbon cycle - warming feedback von 7 bis 15 ppm/^{o}C (für ‚geringe' Klimavariationen).**

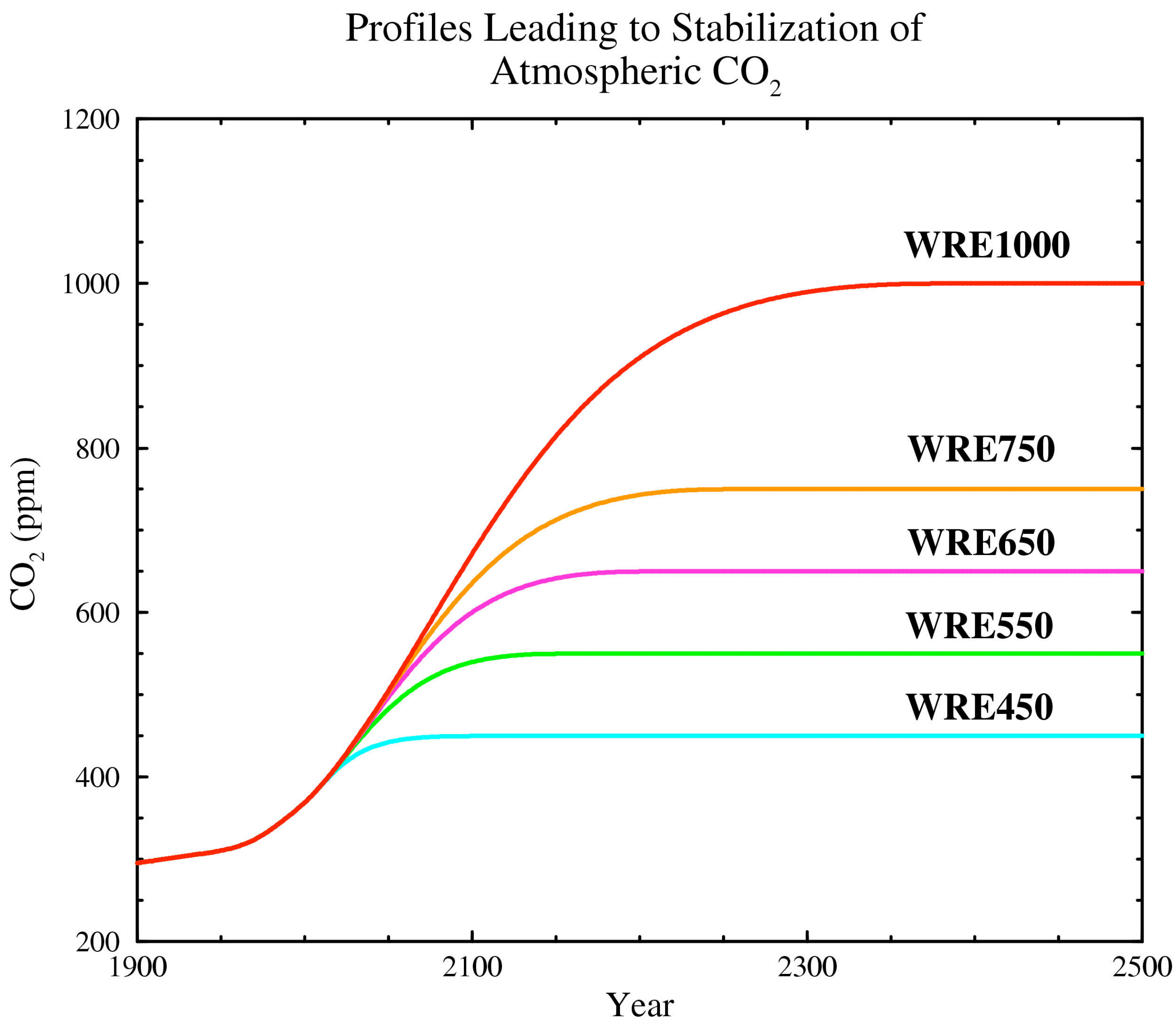
UN Framework Convention on Climate Change

(in force since 21.3.1994, ratified by 165 countries)

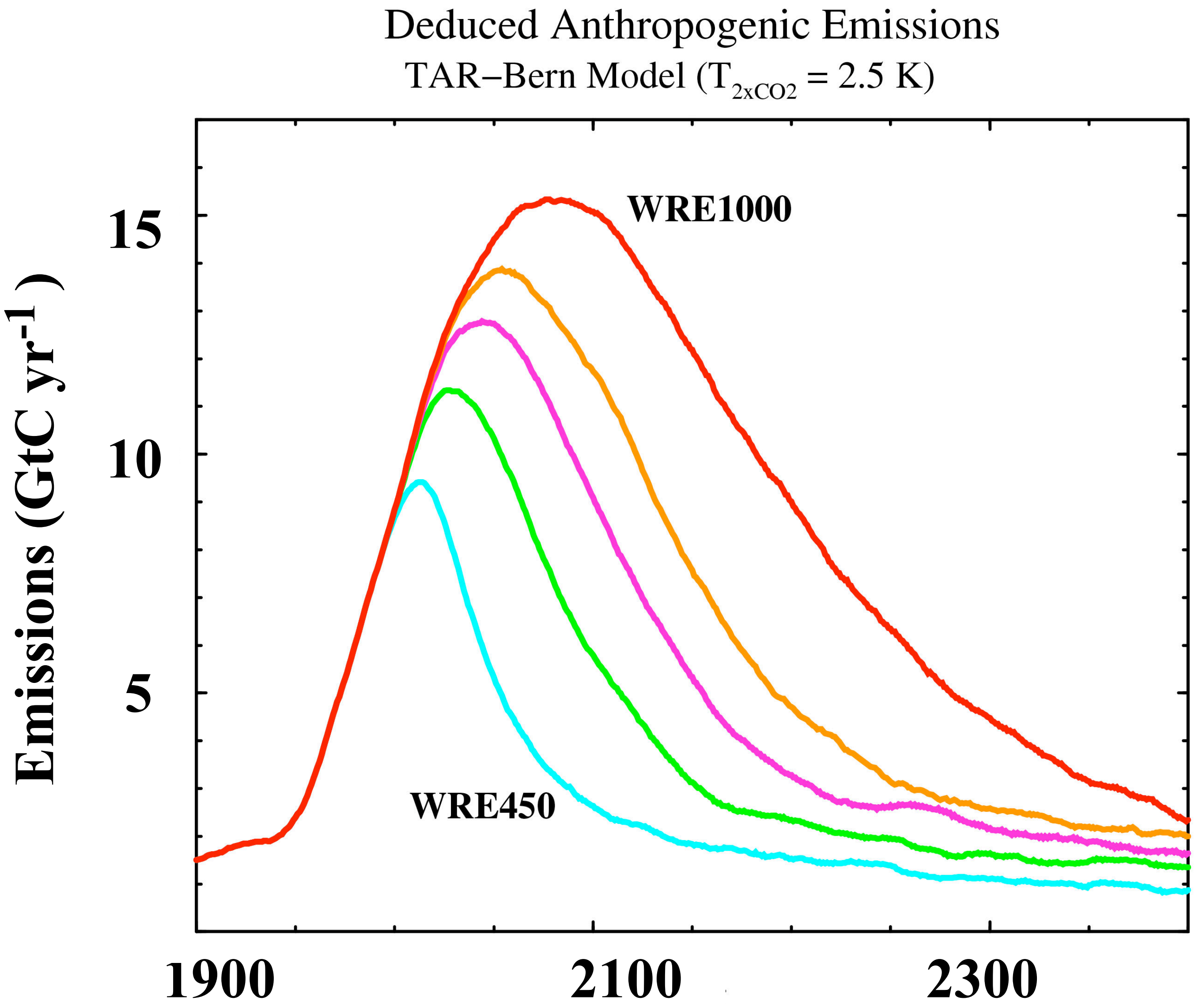
Article 2:

The ultimate objective ... is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system ....

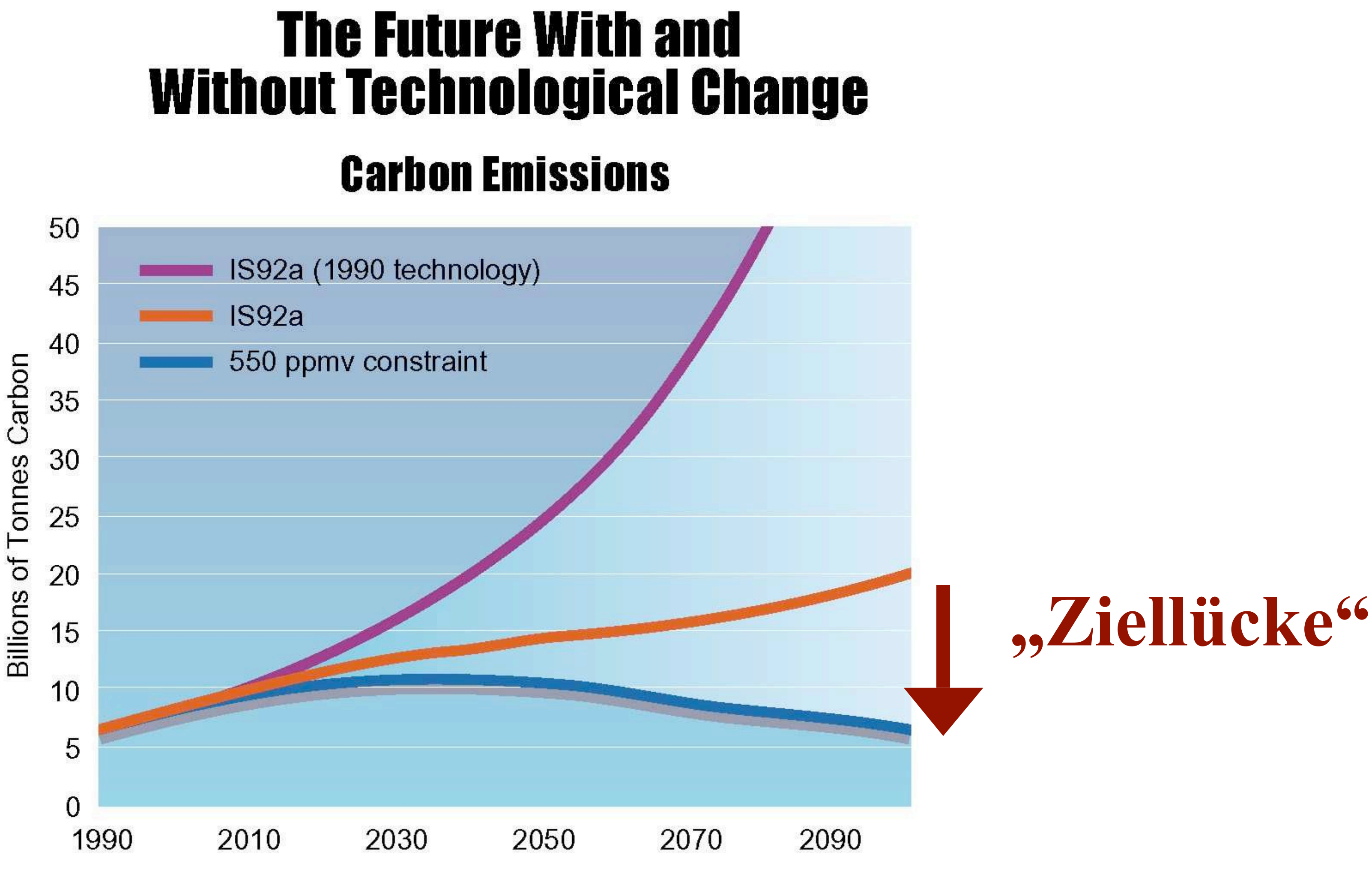
Profiles leading to stabilization of atmospheric CO_2



Carbon emissions must be reduced below present level to stabilize atmospheric CO2



Massnahmen sind nötig um die Ziellücke in den CO_2 Emissionen zu schliessen



Schlussfolgerungen

- **Eine Stabilisierung der atmosphärischen CO_2 Konzentration verlangt eine deutliche Reduktion der Emissionen.**
- **Klimapolitische Massnahmen sind nötig, um das Stabilisierungsziel der UNFCCC zu erreichen.**

Ziellücke und Landmanagment

Chancen und Risiken

Die terrestrische Biosphäre im Vergleich mit fossilen Emissionen:

Vegetation:	**~ 600 GtC**
Boden und Streu:	**~ 2000 GtC**
Total:	**~ 2000 - 3000 GtC**
Veränderung Eiszeit-Warmzeit	**~ + 500 GtC**

Fossile Emissionen

SRES Szenarien (2000-2100):	**1000 -2200 GtC**
Fossile Resourcen (konventionell)	**~5000 GtC**

Landnutzung kann die Ziellücke nicht schliessen

CO_2 Freisetzung durch Abholzung bis heute: **200 GtC** (94 ppm)

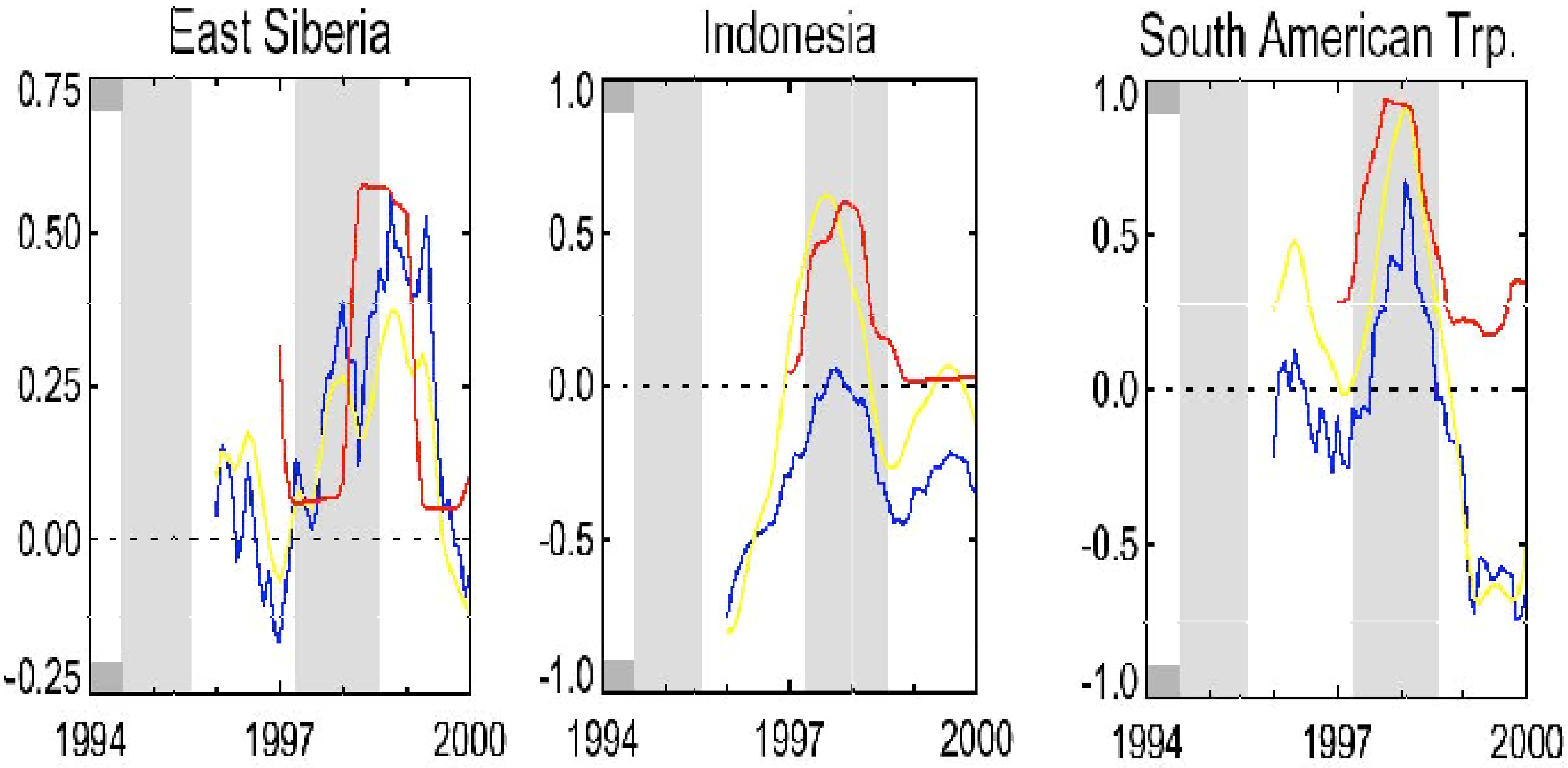
Umwandlung der existierenden Wälder in
Weideland: **400 to 800 GtC** (188 to 376 ppm)

IPCC, SPM WGI:
„Hypothetically, if all of the carbon released by historical land-use changes could be restored to the terrestrial biosphere over the course of the century (e.g., by reforestation), CO_2 concentration would be reduced by **40 to 70 ppm**."

SRES Szenarien:
Fossile Emissionen (2000-2100): **1000 - 2200 GtC**
CO_2 Konzentration um 2100: **500 - 1200 ppm**

Wie permanent ist eine terrestrische Speicherung?

Fire frequencies and carbon fluxes (1995-2000)



Heimann et al, 2003

Schlussfolgerungen

- **Landnutzung kann nur einen sehr beschränkten Beitrag zur Schliessung der Ziellücke beitragen.**
- **Das Potential für terrestrische CO_2 Freisetzung ist grösser als für CO_2 Speicherung.**
- **Bewahren von bestehenden terrestrischen C-Pools wichtig.**
- **Fossile Energieträger sind dominant.**