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AWI

Atmospheric CO_2 and the terrestrial carbon cycle in the past

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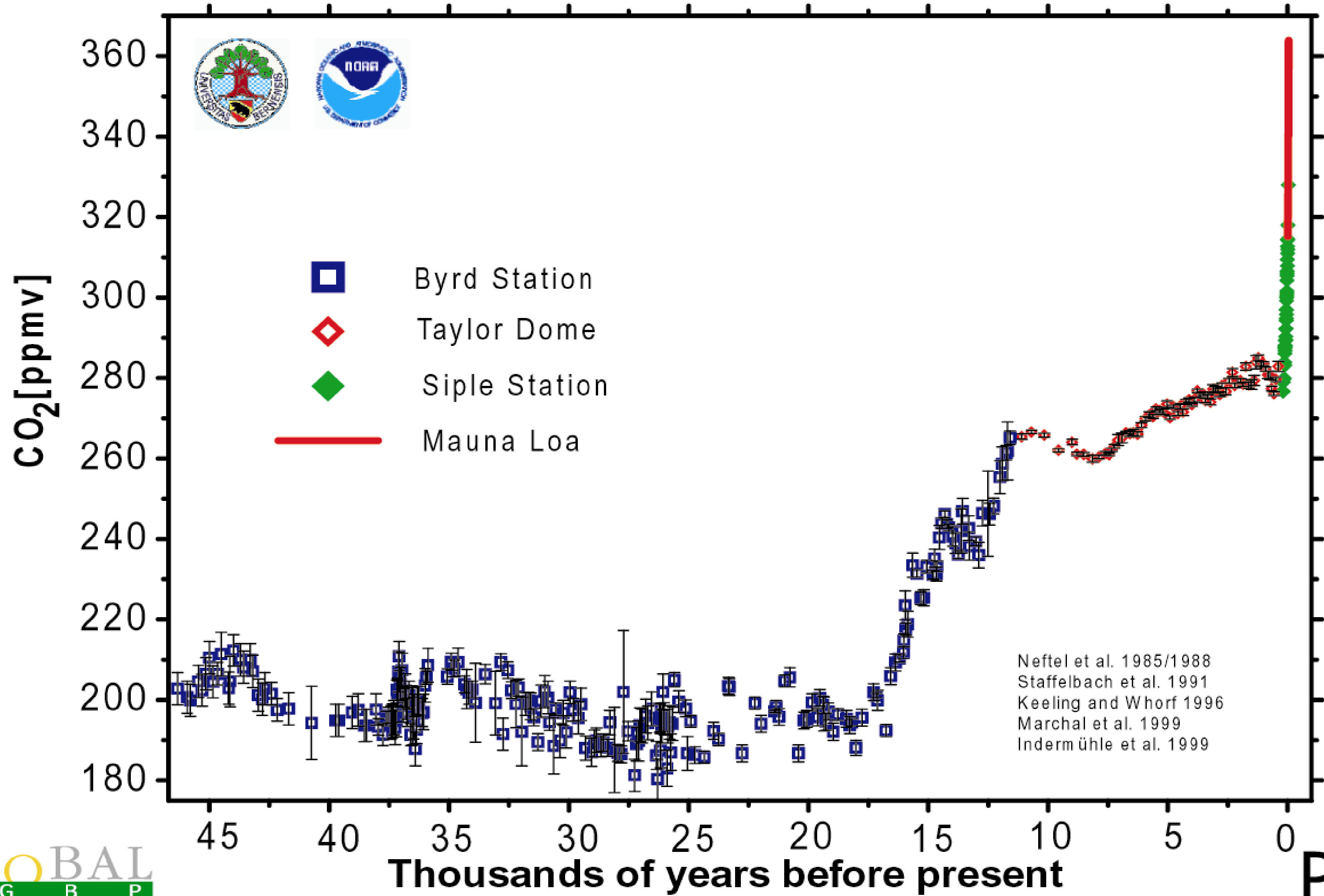
AWI/IUP Blockseminare, University of Bremen

HELMHOLTZ
ASSOCIATION

Atmospheric CO_2 Concentration

Last Glacial Maximum to present



Adapted from: http://www.climate.unibe.ch/gallery_co2.html

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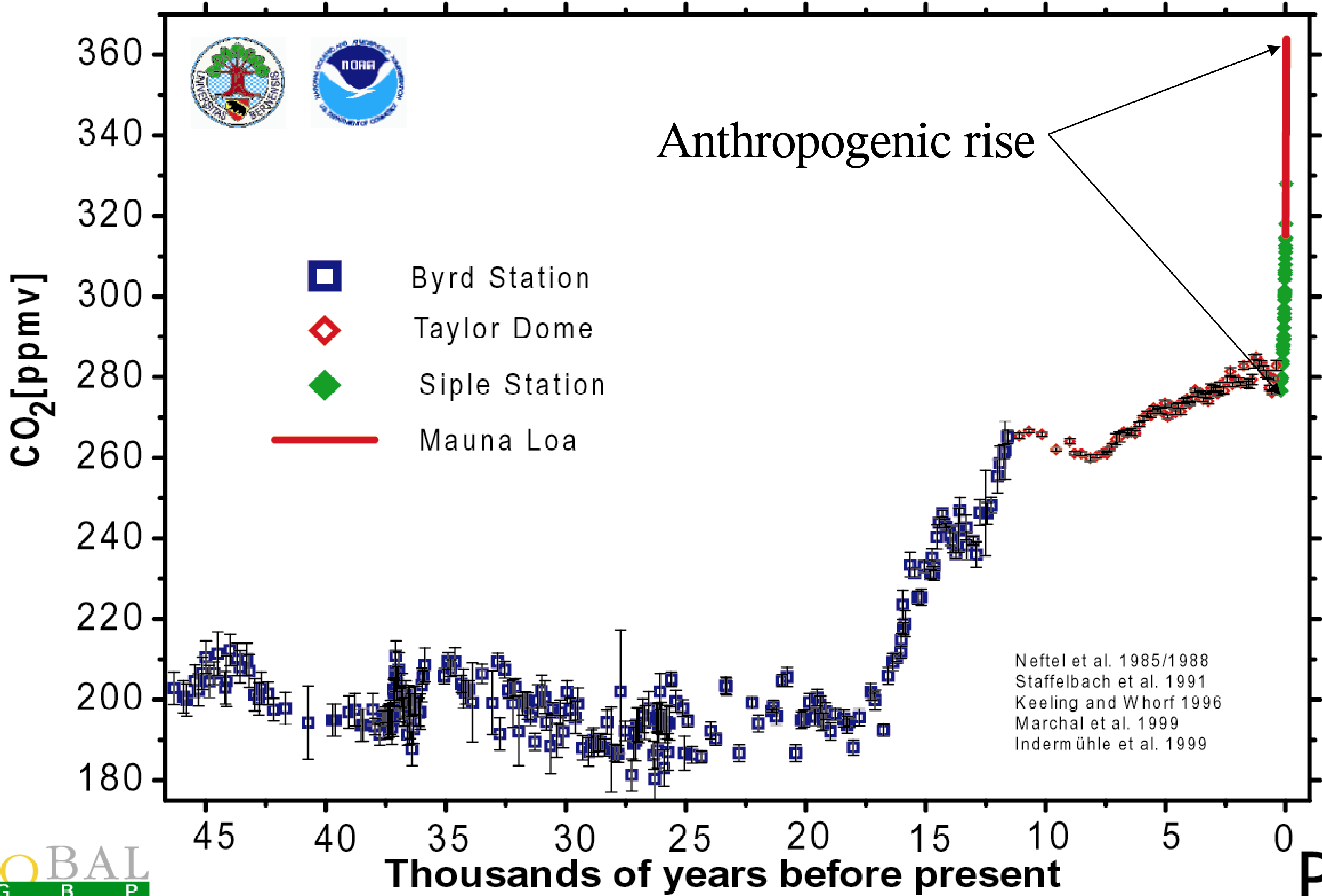

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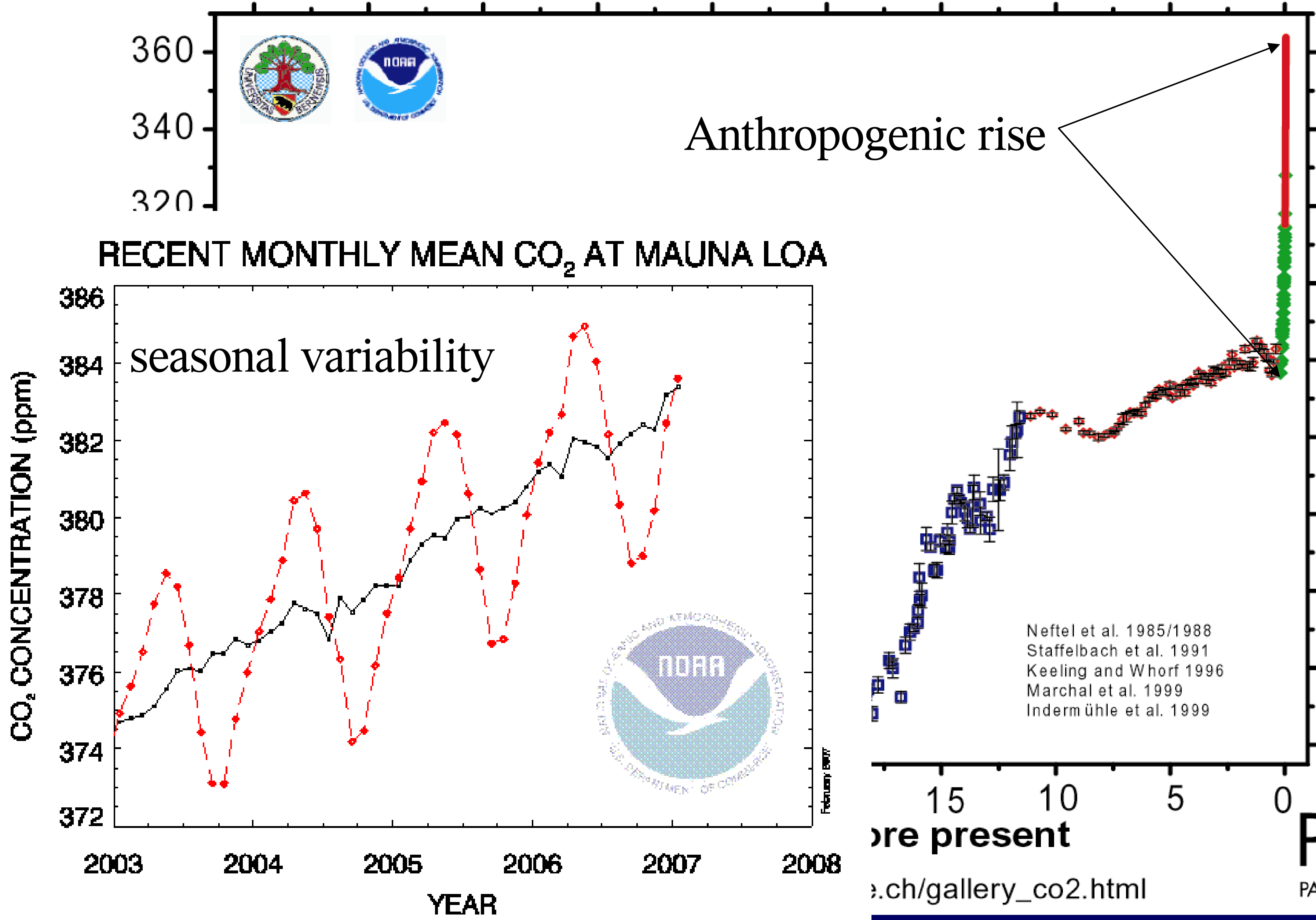

PAGES PAST GLOBAL CHANGES

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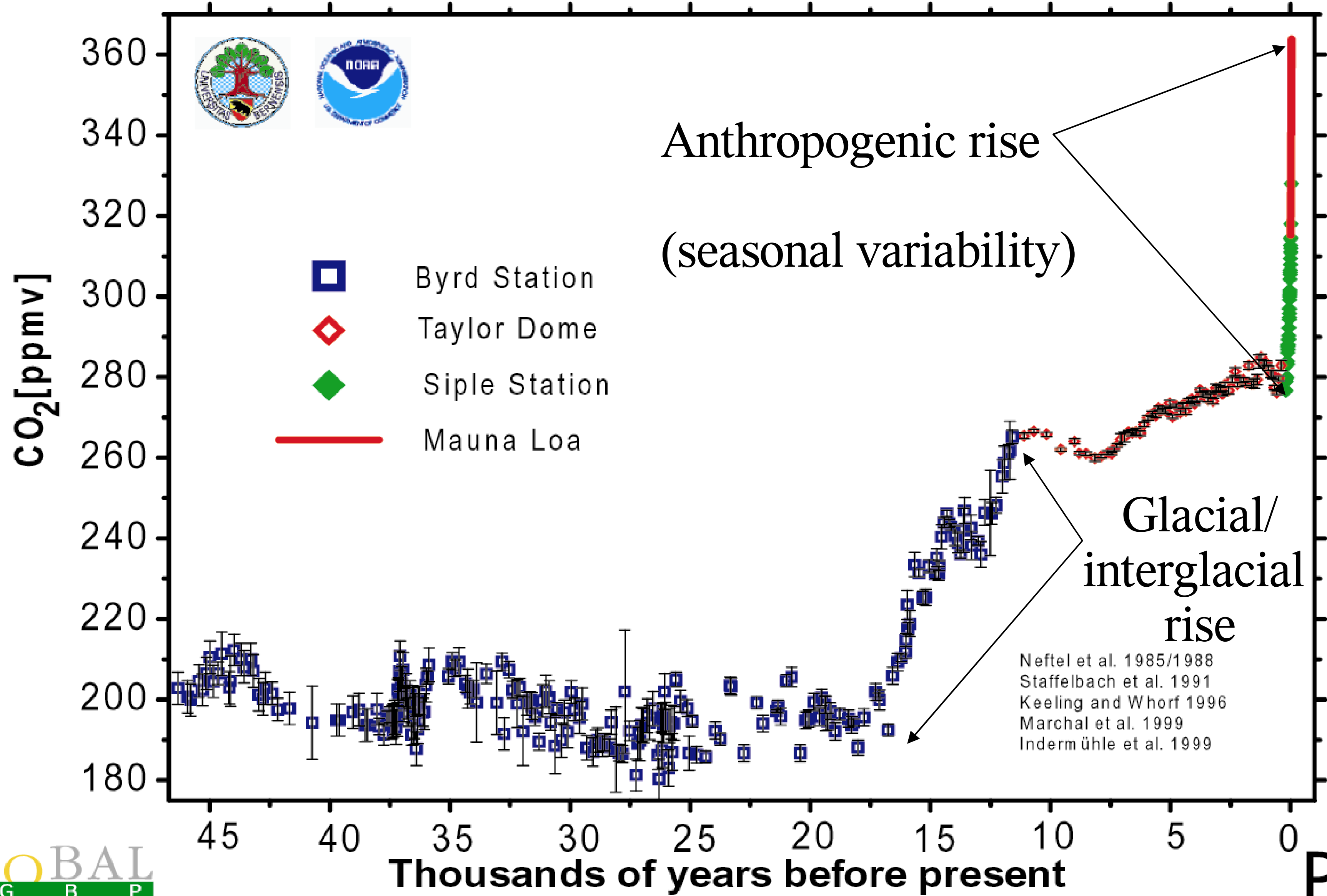

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GLOBAL IGBP CHANGE

PAGES PAST GLOBAL CHANGES

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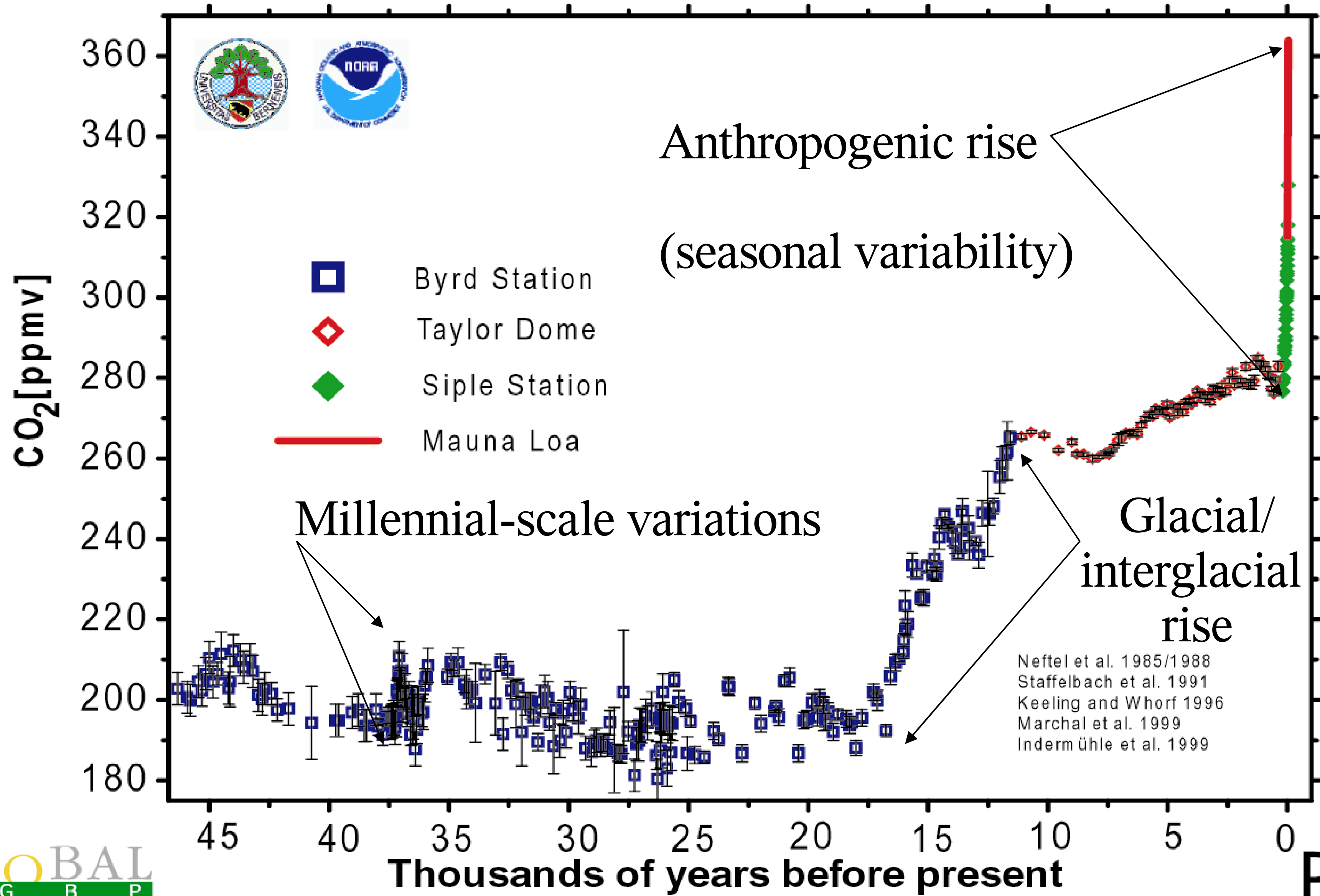

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GLOBAL IGBP CHANGE

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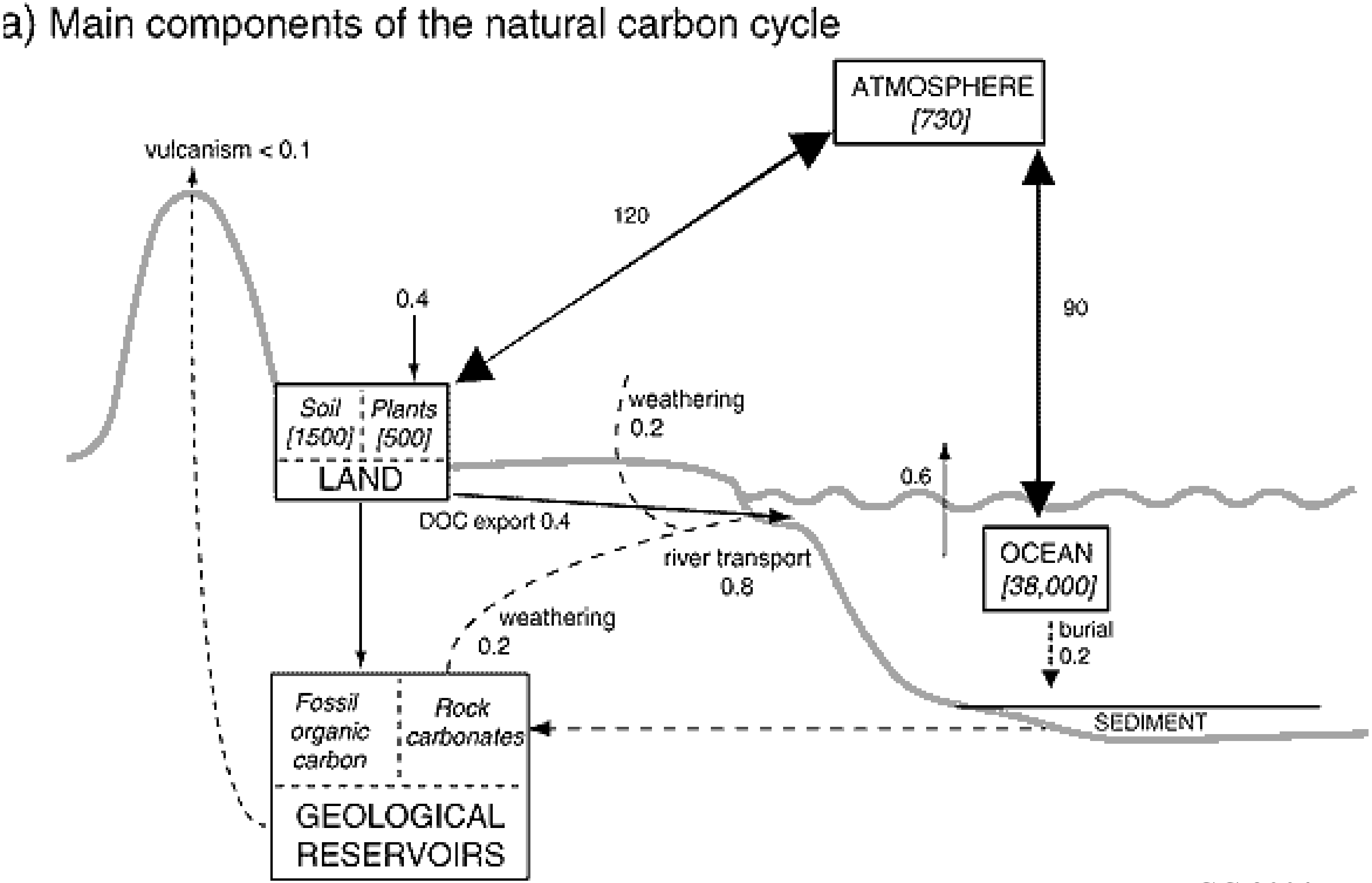
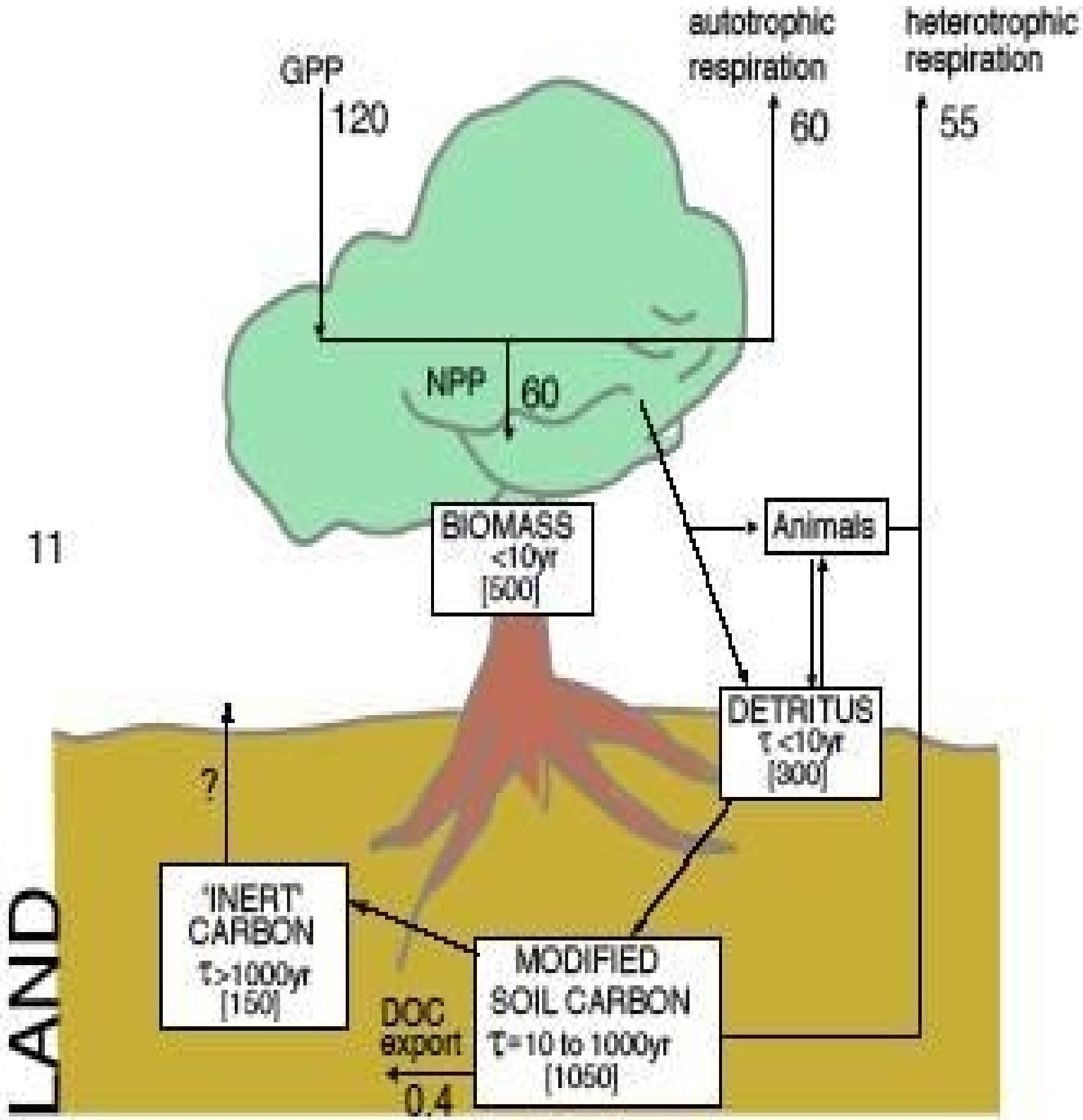
The global carbon cycle



IPCC 2001

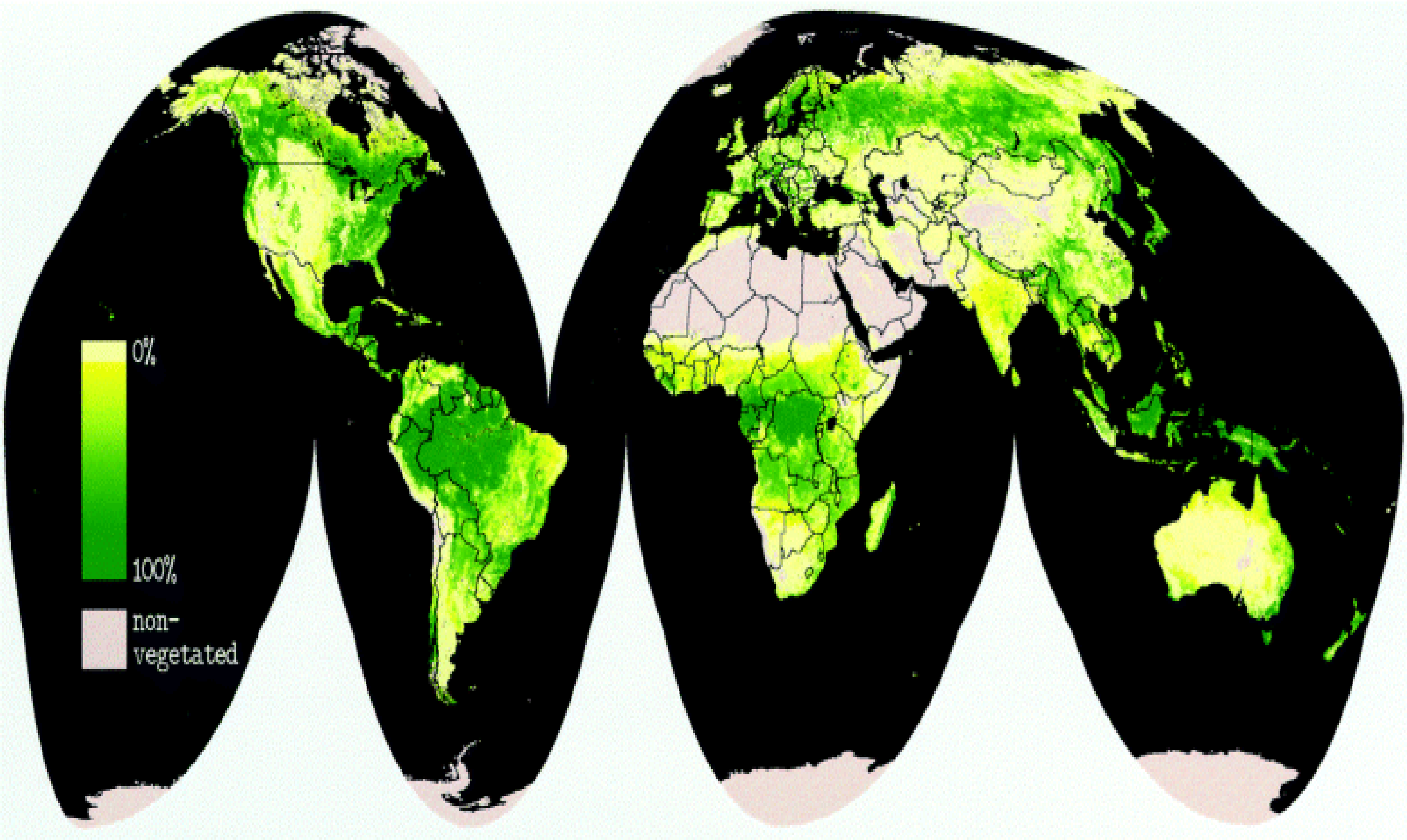
The global terrestrial carbon cycle



modified from IPCC (2001)

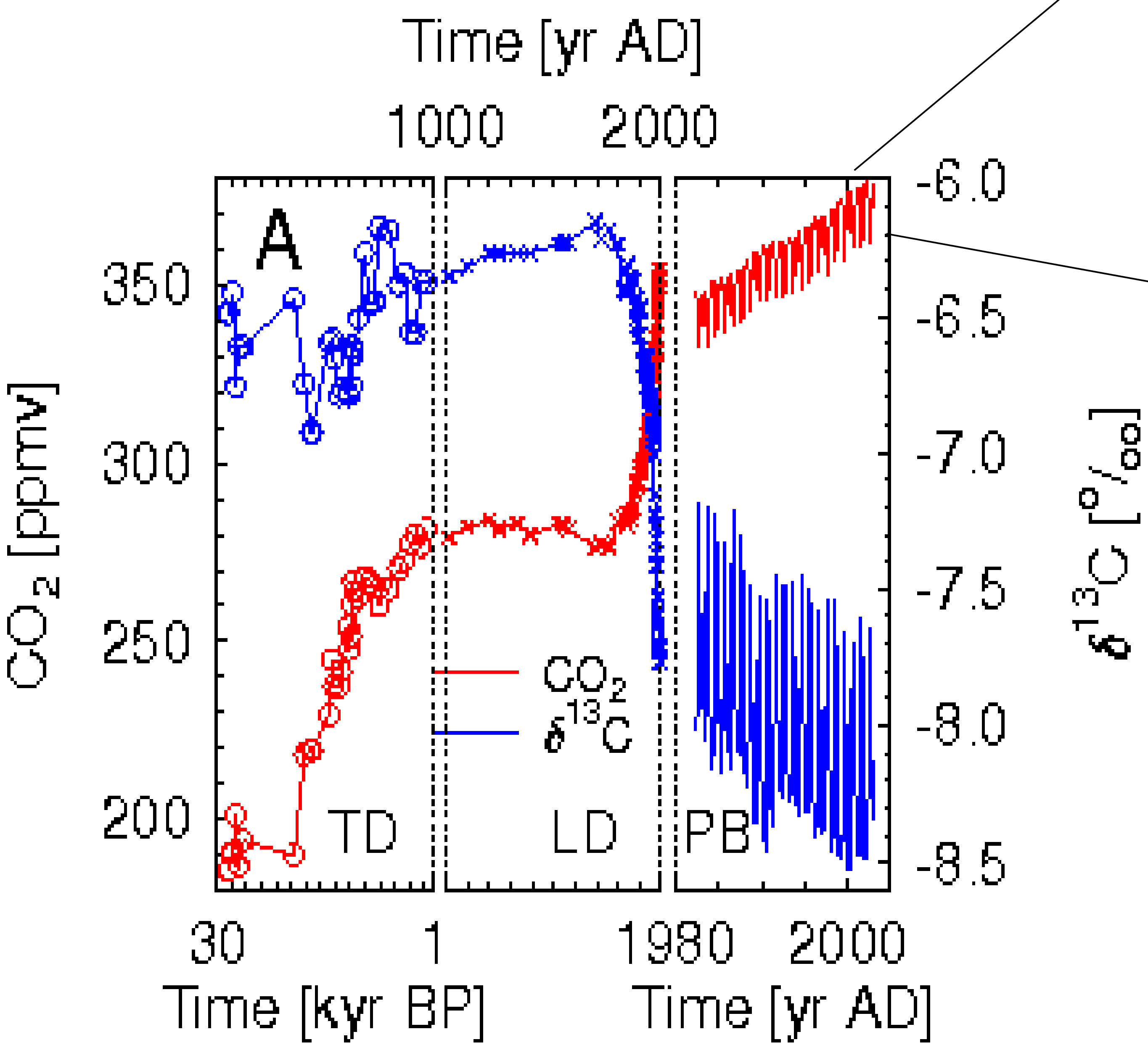
- **GPP** (gross primary production through photosynthesis) ~ 120 PgC/yr
- $\mathbf{R_A}$ (autotrophic respiration) vegetation ~60 PgC/yr
- **NPP** = GPP -R_A (net primary production) ~ 60 PgC/yr
- $\mathbf{R_H}$ (heterotrophic respiration) humus and soil ~ 55 PgC/yr
- **NEP** = NPP – R_H (net ecosystem production) ~ 5 PgC/yr

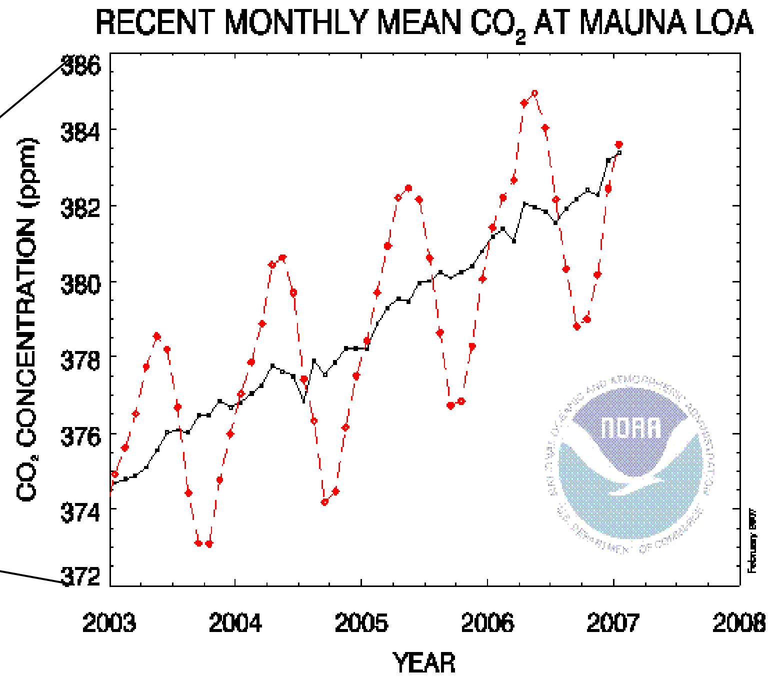
Present day tree cover (remote sensing)



DeFries et al. 2000

1 Seasonal variations



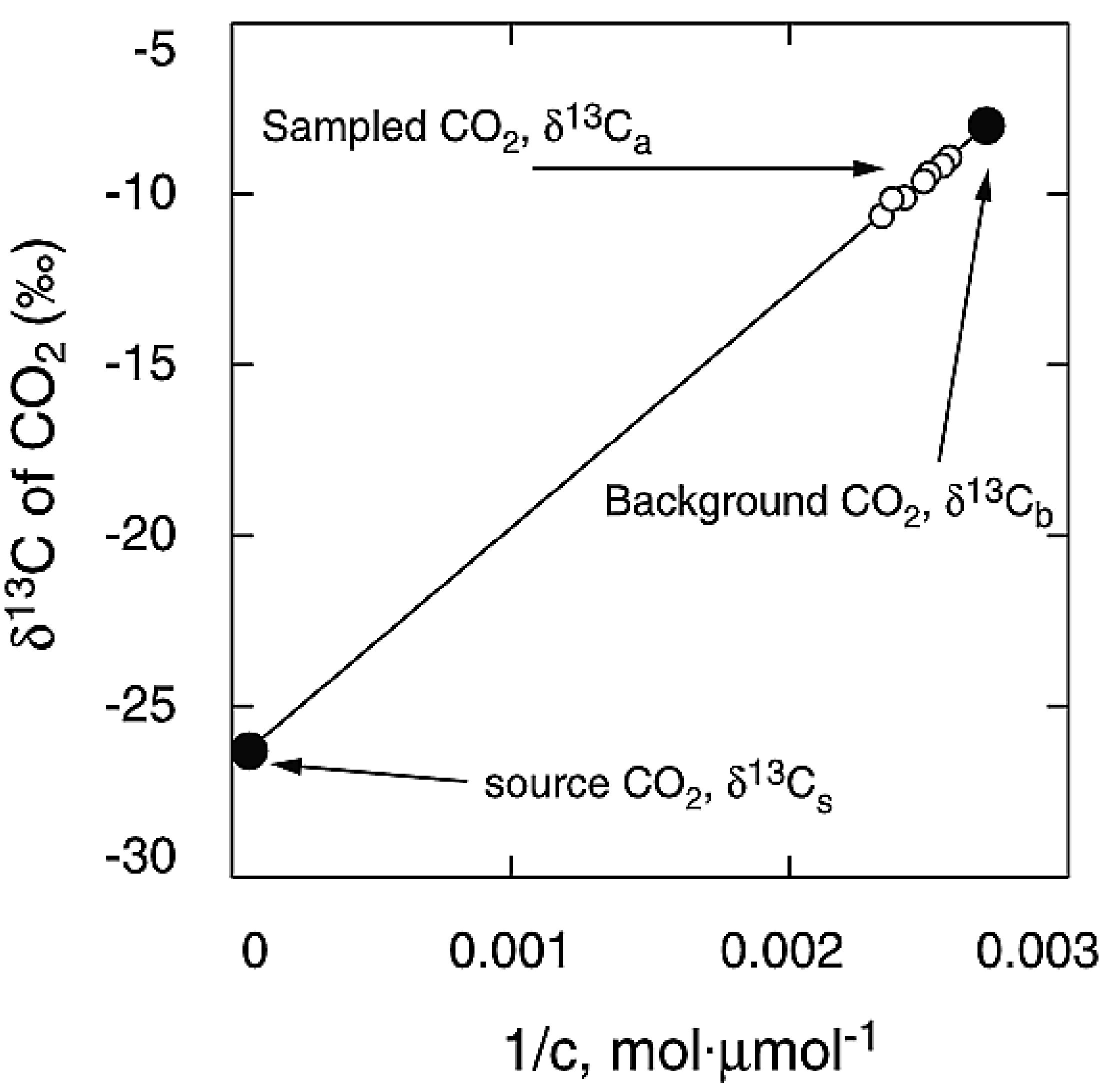


Variations in
CO_2 (red)
and
$d^{13}C$ (blue)

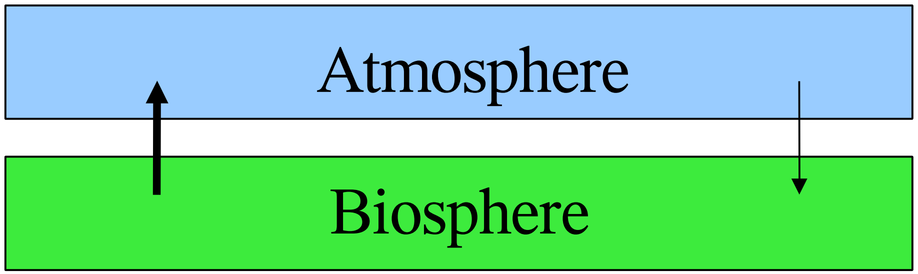
seasonal d(CO2) ~ 8ppmv

Köhler et al., 2006 Biogeosciences

Keeling plot (C.D.Keeling (1958))



Pataki et al 2003



$$C_a = C_b + C_s$$

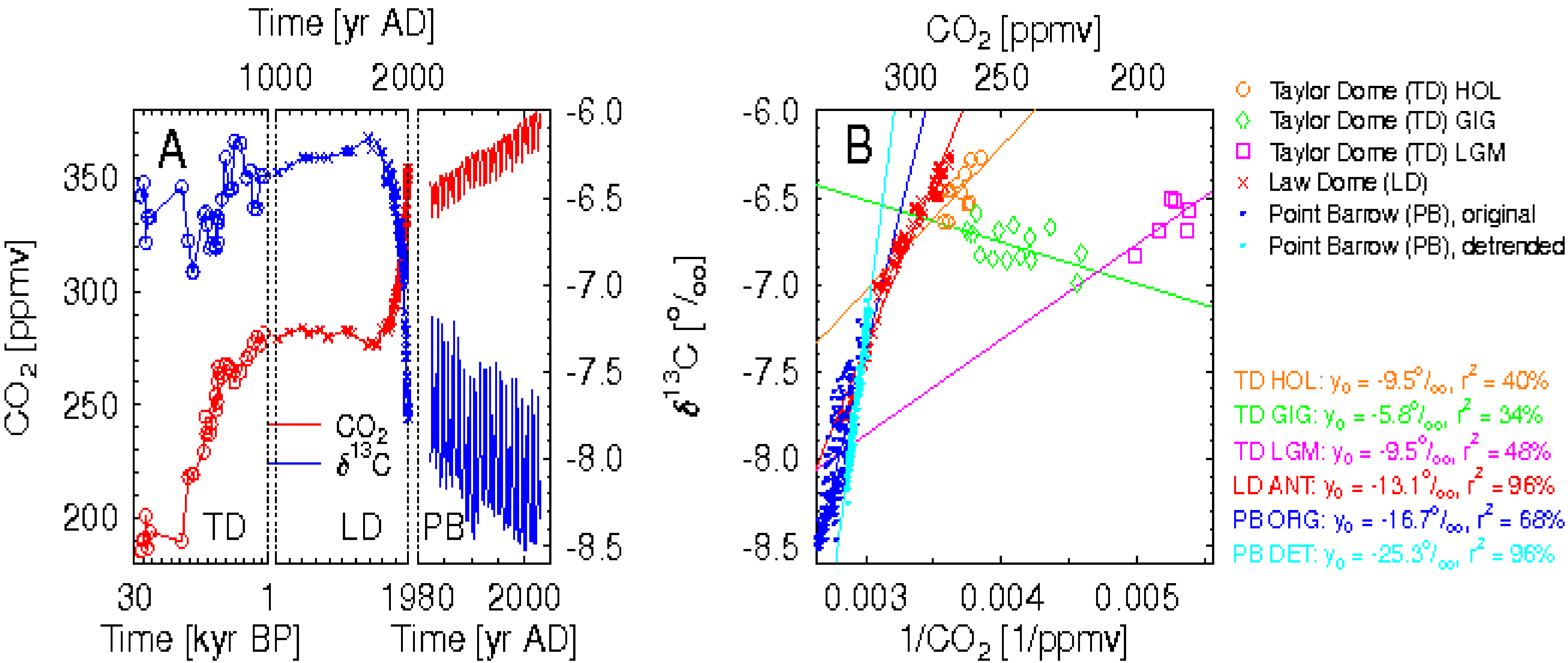
$$d^{13}C_a * C_a = d^{13}C_b * C_b + d^{13}C_s * C_s$$

$$d^{13}C_a = a\frac{1}{C_a} + d^{13}C_s$$

Two important limitations:

- 2 reservoir system
- Fast process

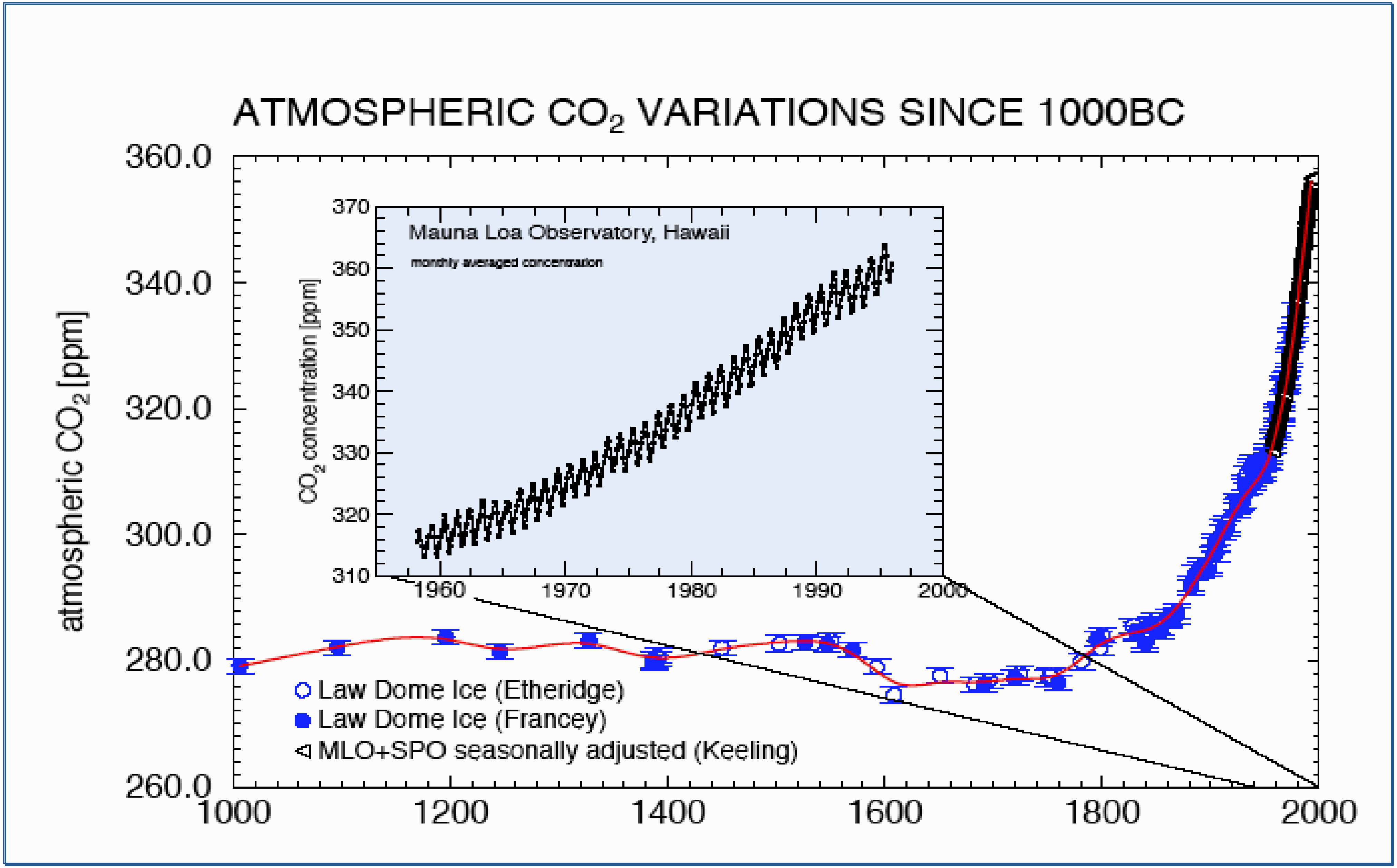
1 Seasonal variations



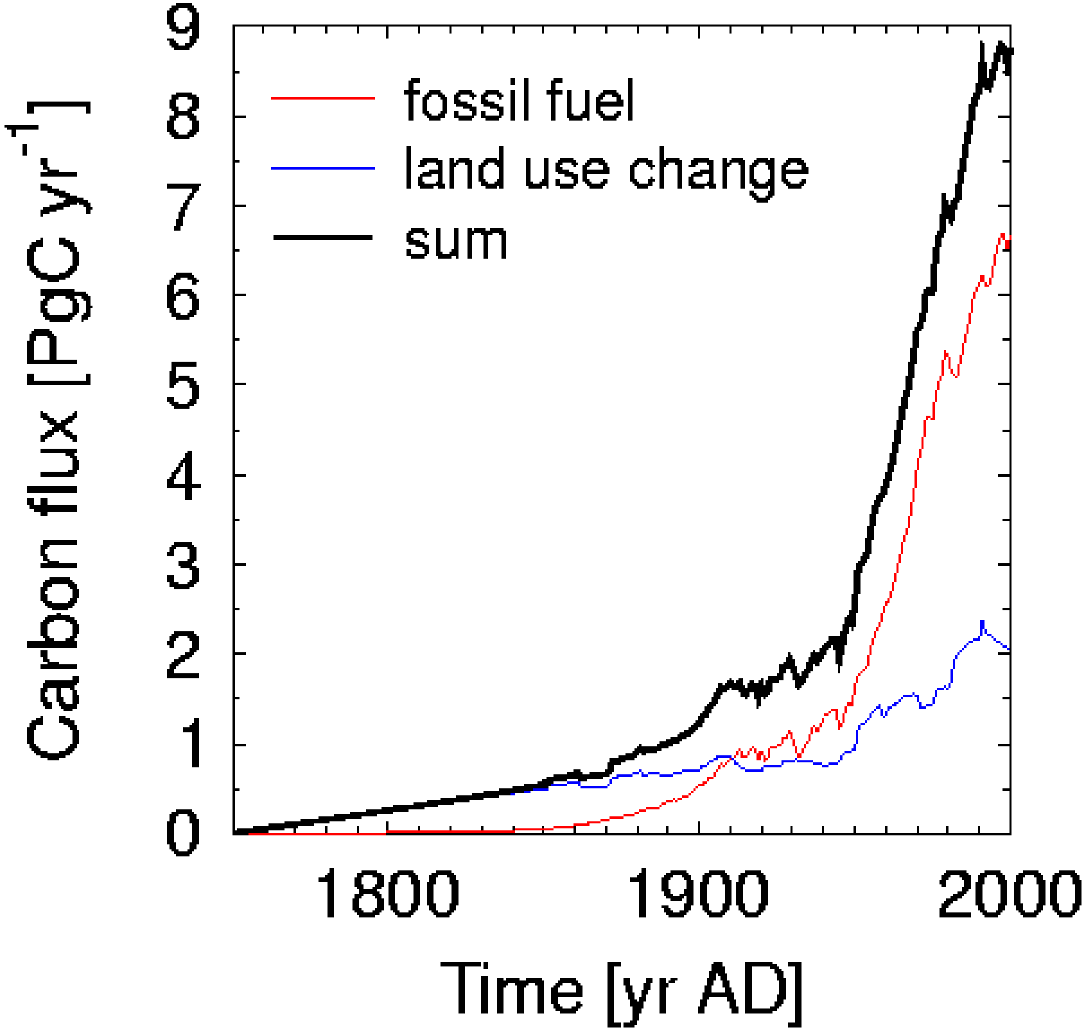
Köhler et al., 2006 Biogeosciences

Seasonal cycle in atm $^{13}C(CO_2)$ has its origin in the variability of the terrestrial biosphere ($d^{13}C_0$ ~ -25 o/oo)

2 Anthropogenic rise



2 Anthropogenic rise – global budget



Cumulative input:

- Fossil fuels 284 PgC
- Land use 181 PgC
- **Sum 465 PgC**

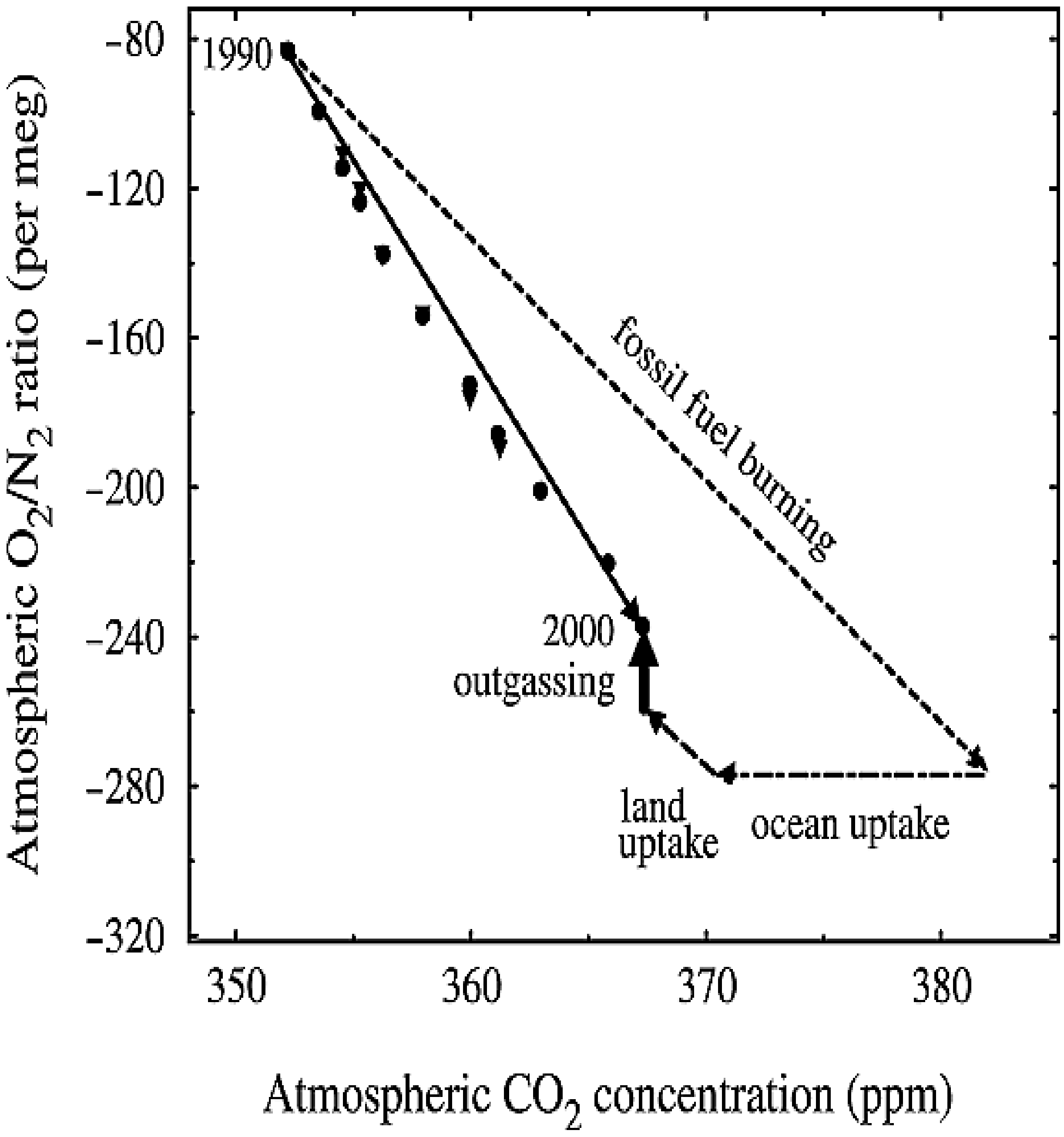
Cumulative uptake:

- Atmosphere (m) 150 PgC
- Ocean (m) 106 PgC
- Terrestial B 209 PgC

(back calculation (O2/N2); most uncertain)

After Marland et al 2005, Houghton 2003

2 Antropogenic rise – recent land uptake



- CO_2 measured
- Fossil fuel burning uses O_2
- Oceanic uptake measured
- Land biotic uptake:
- Land uptake increases O_2/N_2 ratio

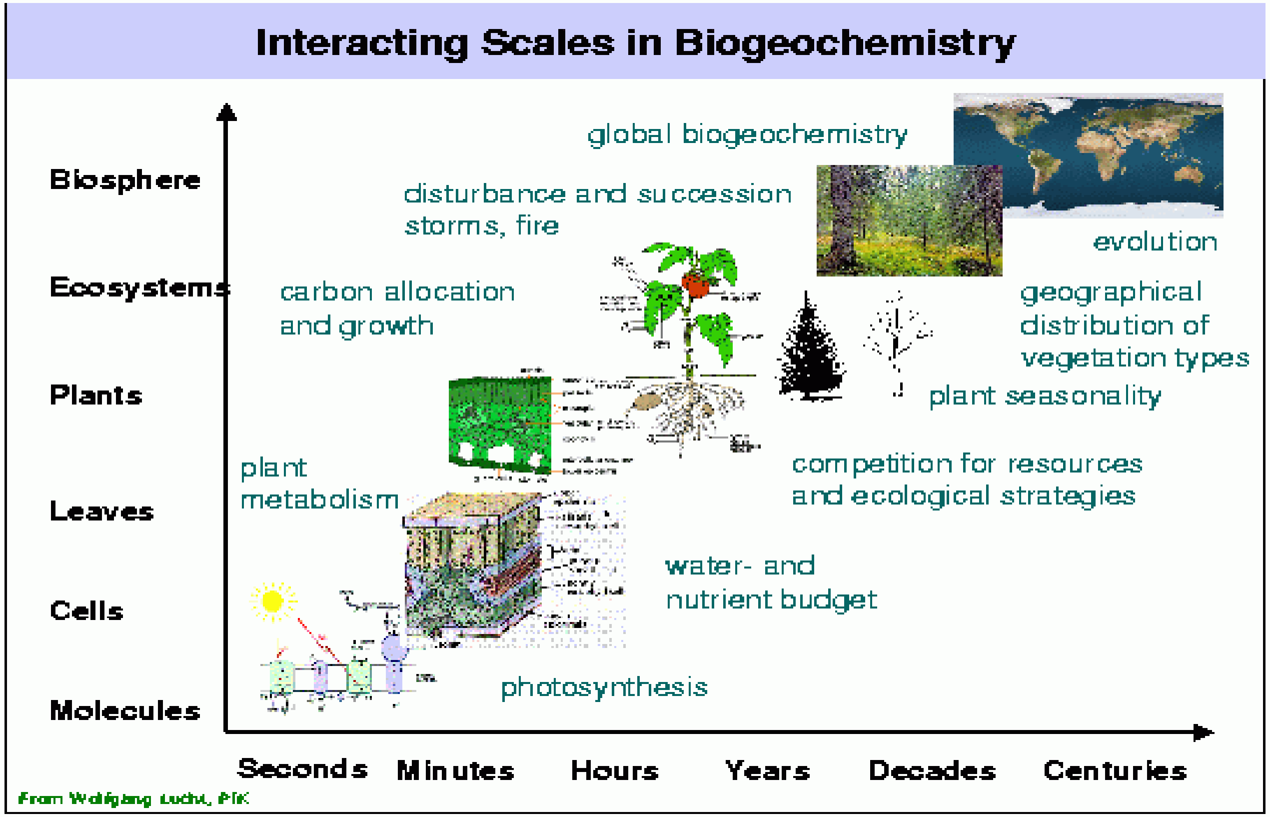
>> Outgassing of O_2 and land uptake can be estimated

Plattner et al., 2002, GBC

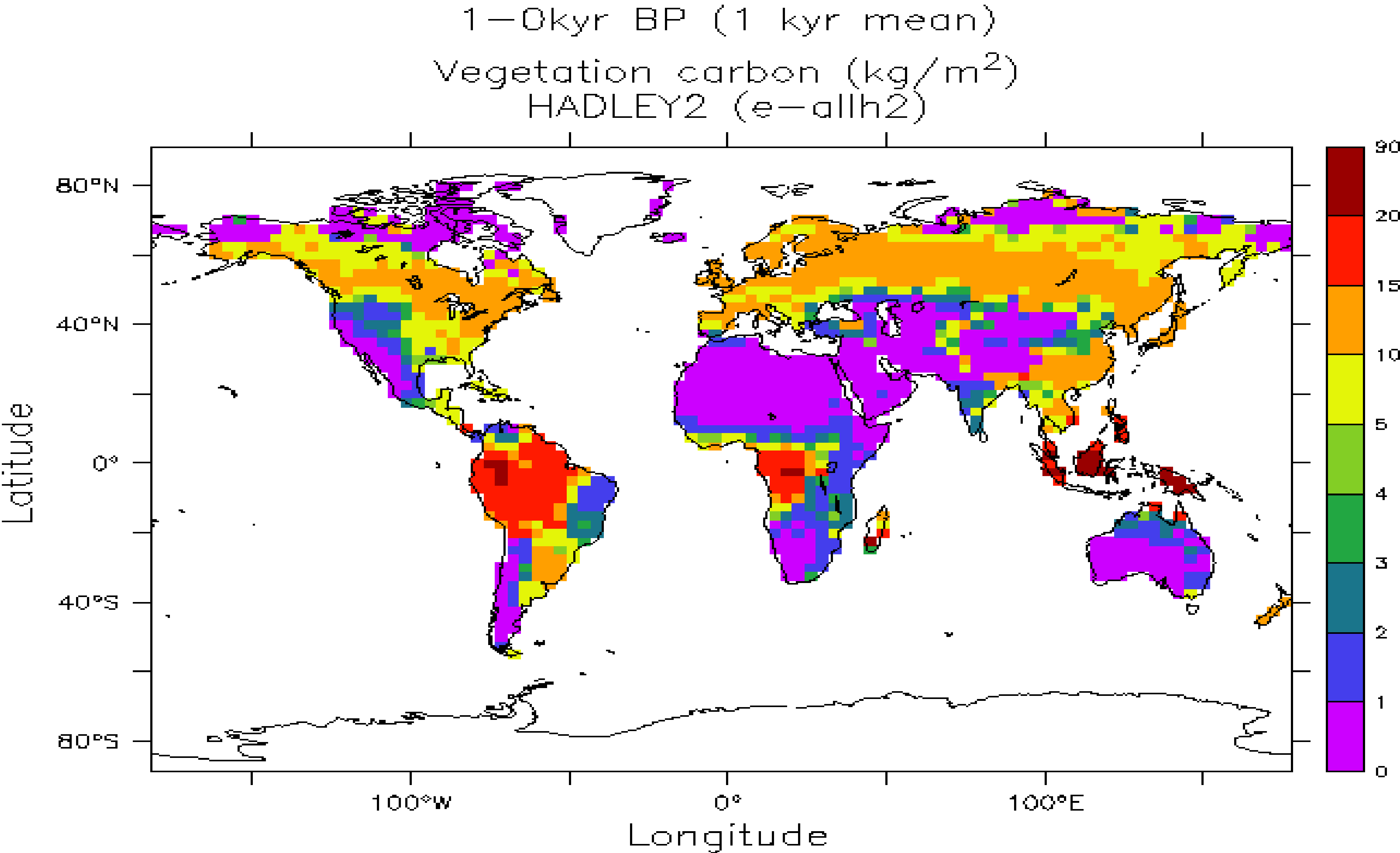
Dynamic Global Vegetation Models DGVM

Global vegetation model include fundamental processes on different levels (photosynthesis, respiration, allocation, disturbances)

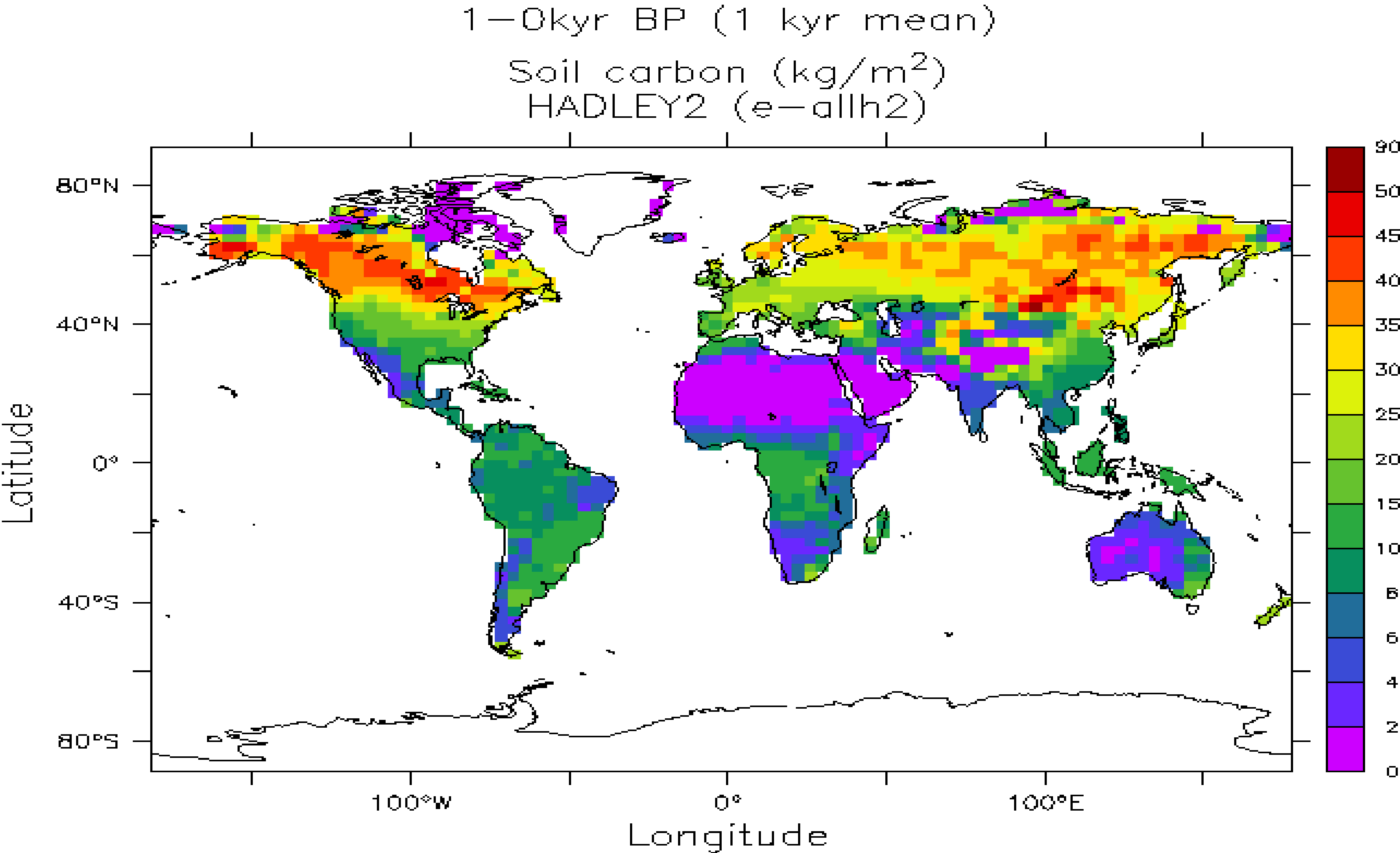
Species need to be grouped into so-called Plant Functional Types (PFT), typically 10 – 20 globally (grasses, temperate or tropical trees, etc).



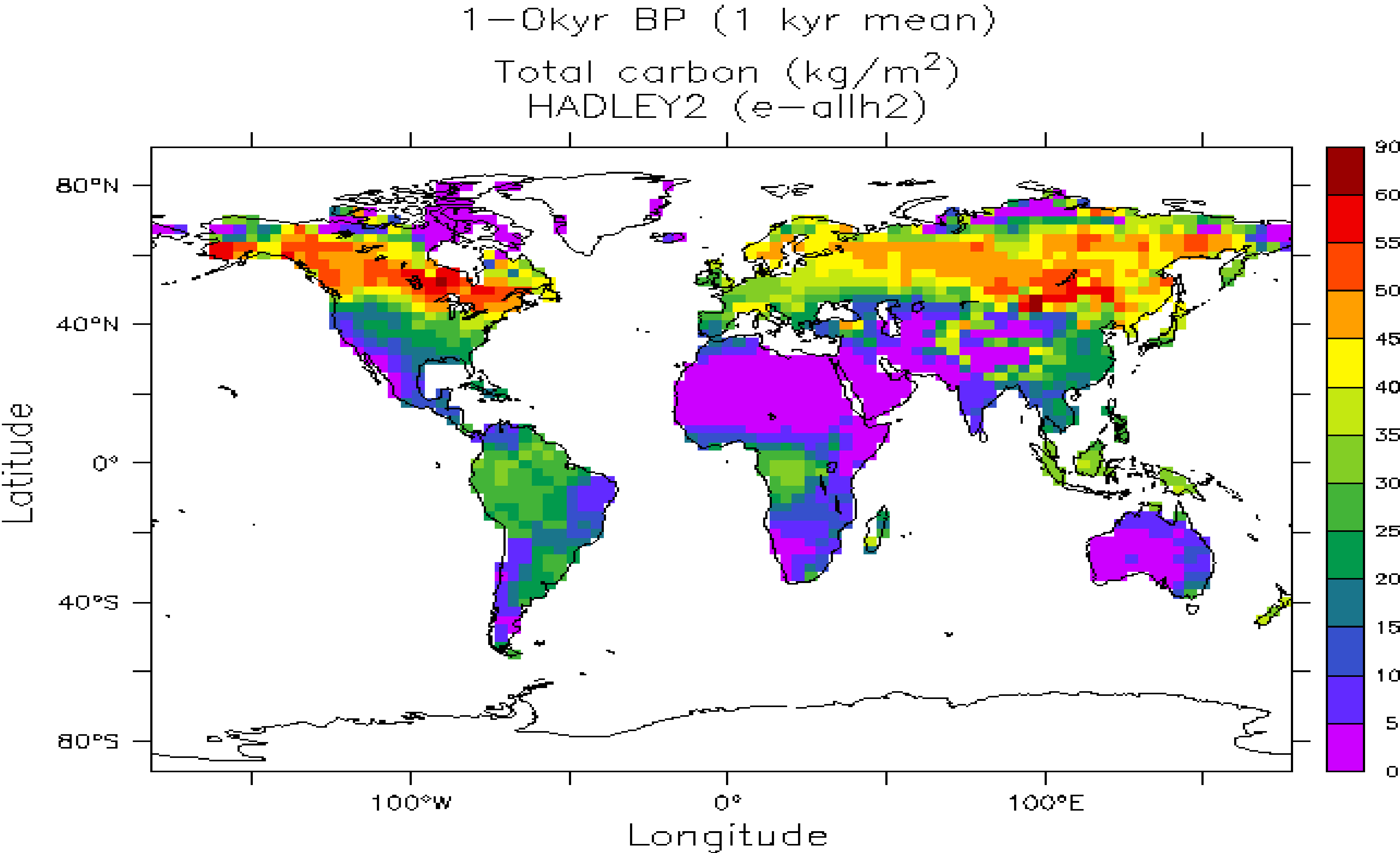
C in Vegetation (Lund-Potsdam-Lena LPJ)



C in Soil (LPJ)


1–0kyr BP (1 kyr mean)
Soil carbon (kg/m^2)
HADLEY2 (e–allh2)
80°N
40°N
0°
40°S
80°S
Latitude
100°W
0°
100°E
Longitude
90
50
45
40
35
30
25
20
15
10
8
6
4
2
0

Total C (LPJ)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35
30
25
20
15
10
5
0

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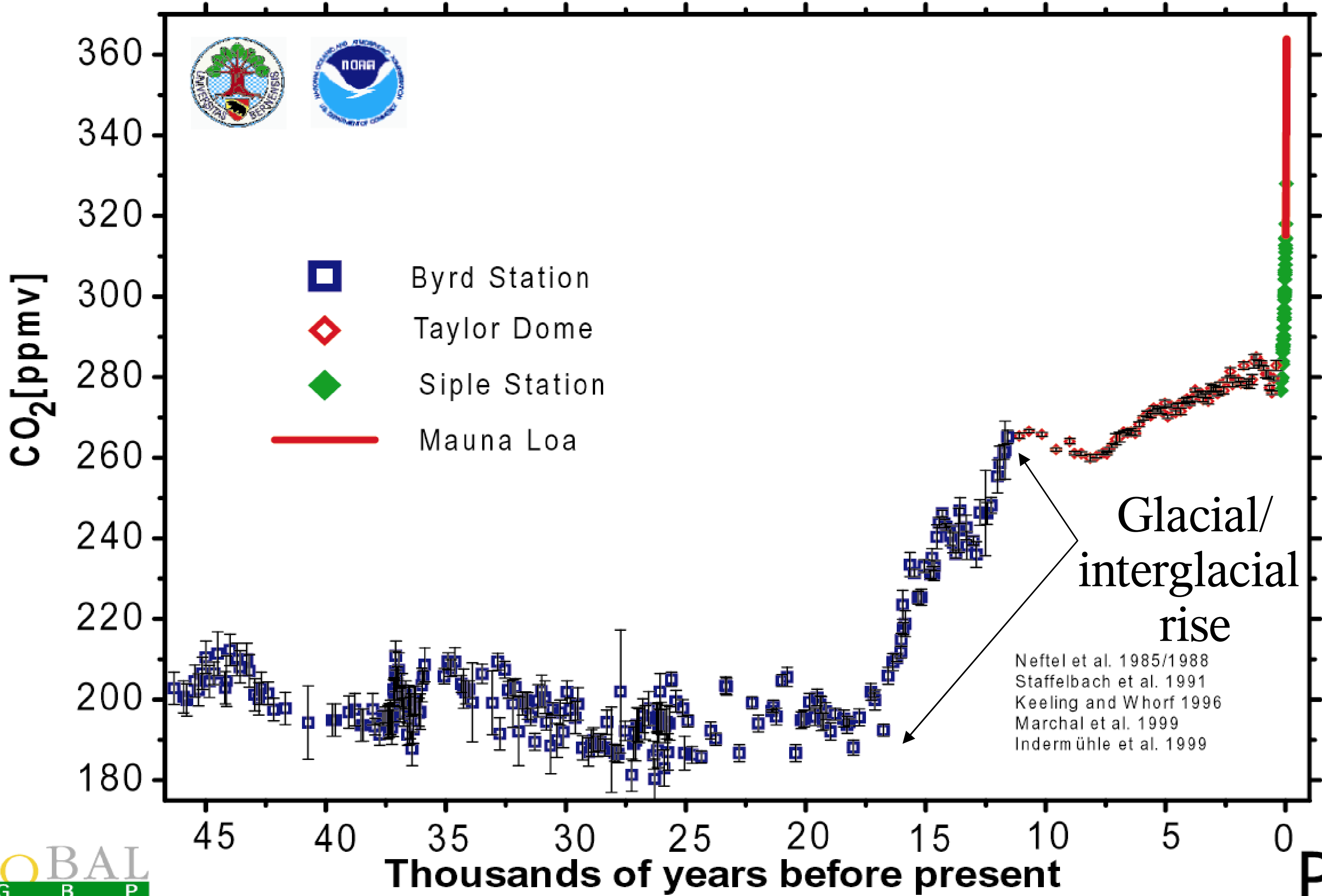

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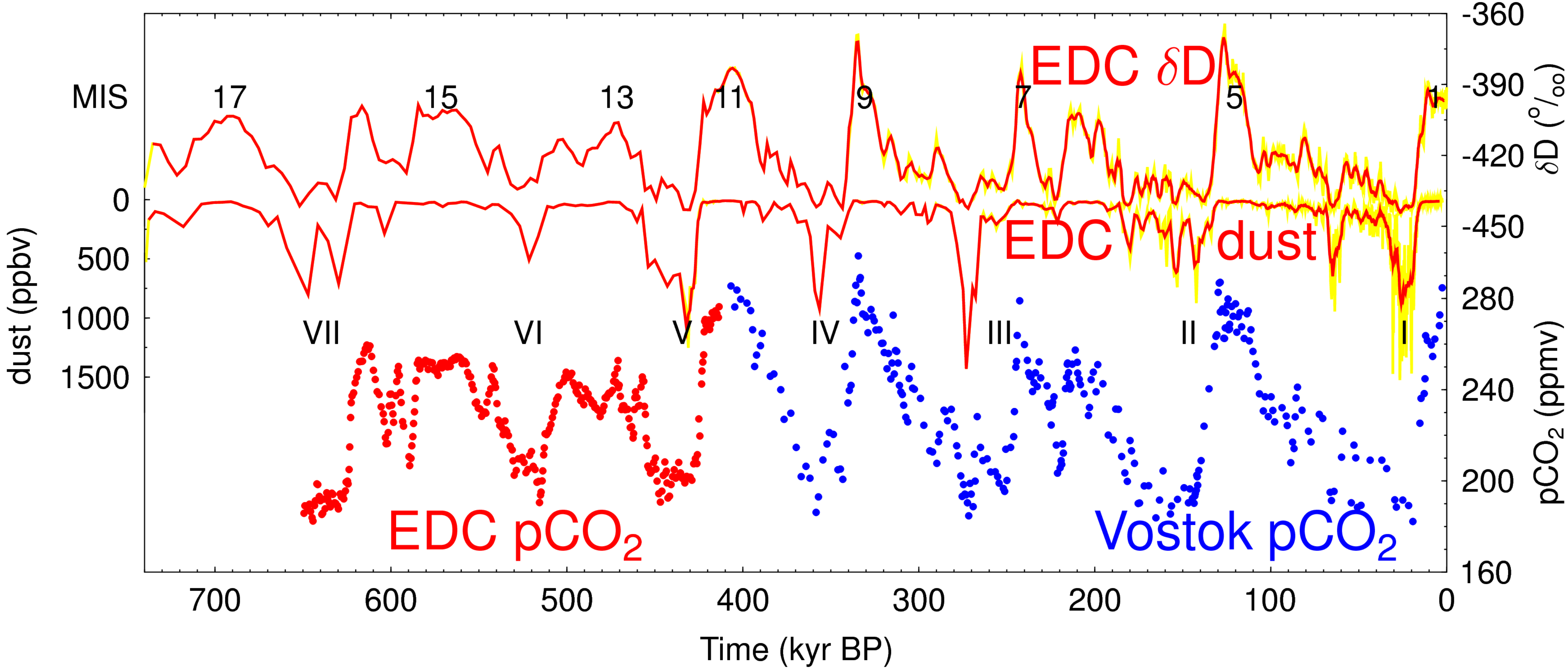
3 Glacial/interglacial



Petit et al., 1999; EPICA, 2004; Siegenthaler et al., 2005

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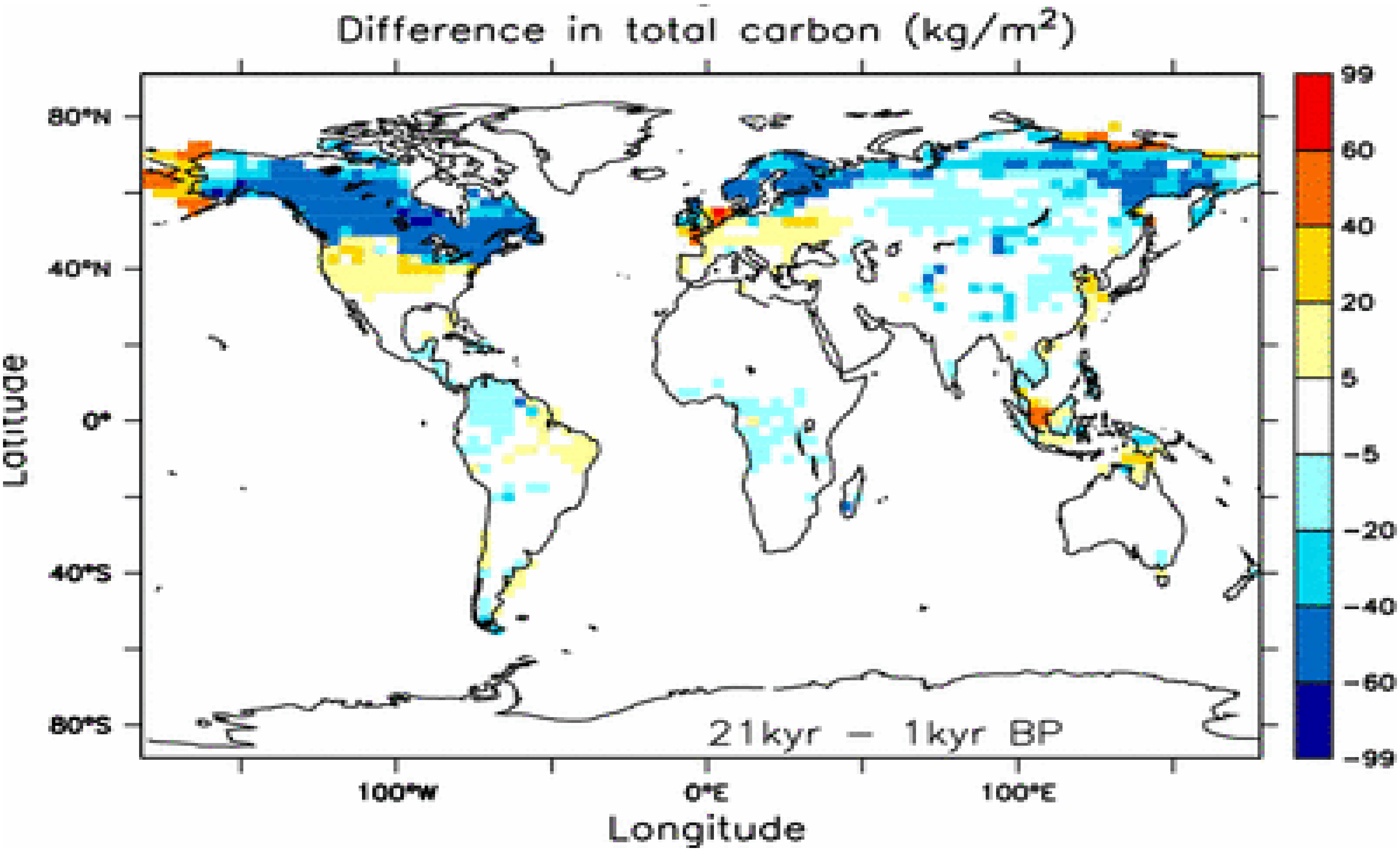

Köhler et al 2005, Climate Dynamics

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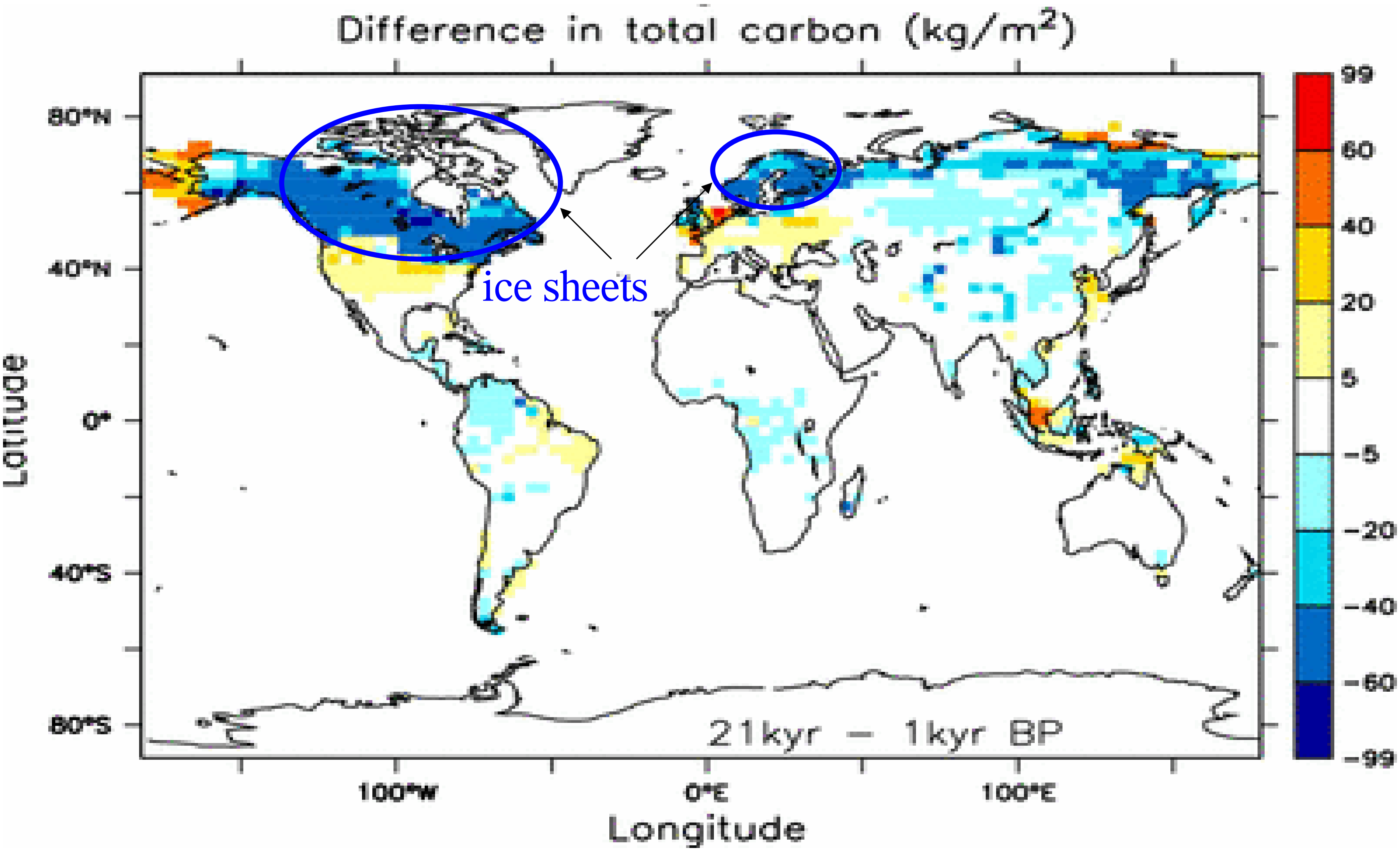

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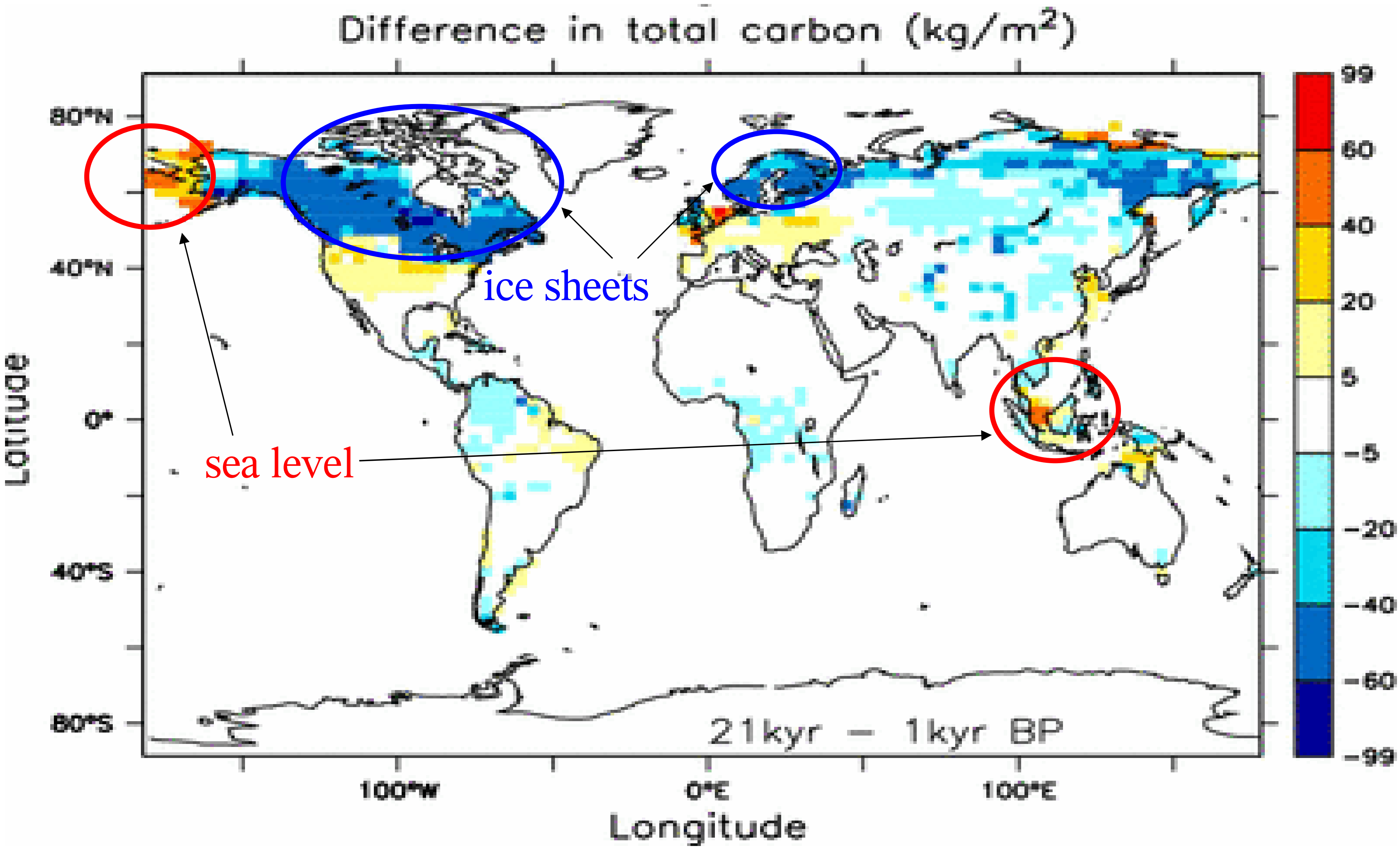

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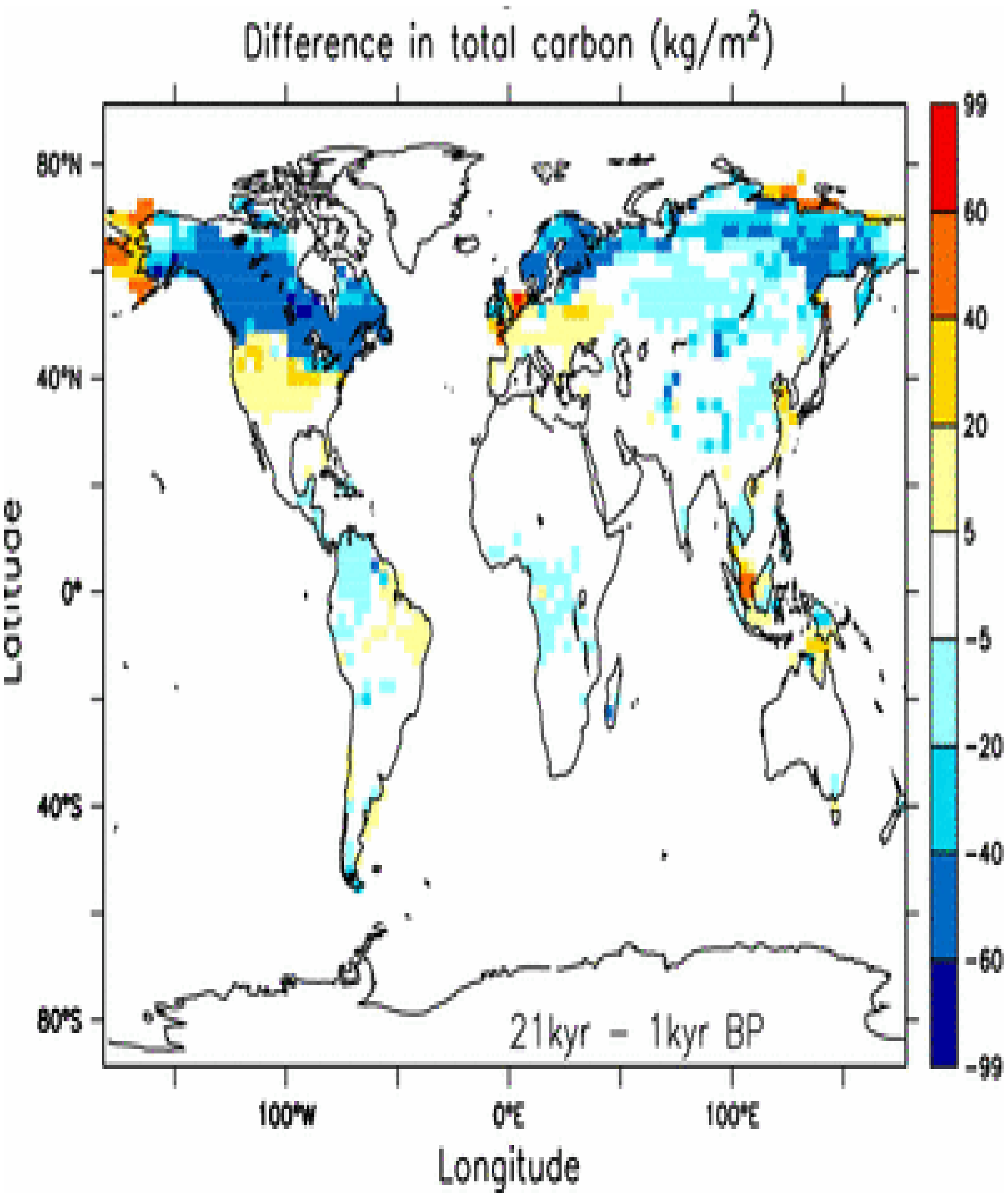


Results with LPJ

Difference Preindustrial to Last Glacial Maximum LGM (~20,000 yr BP):

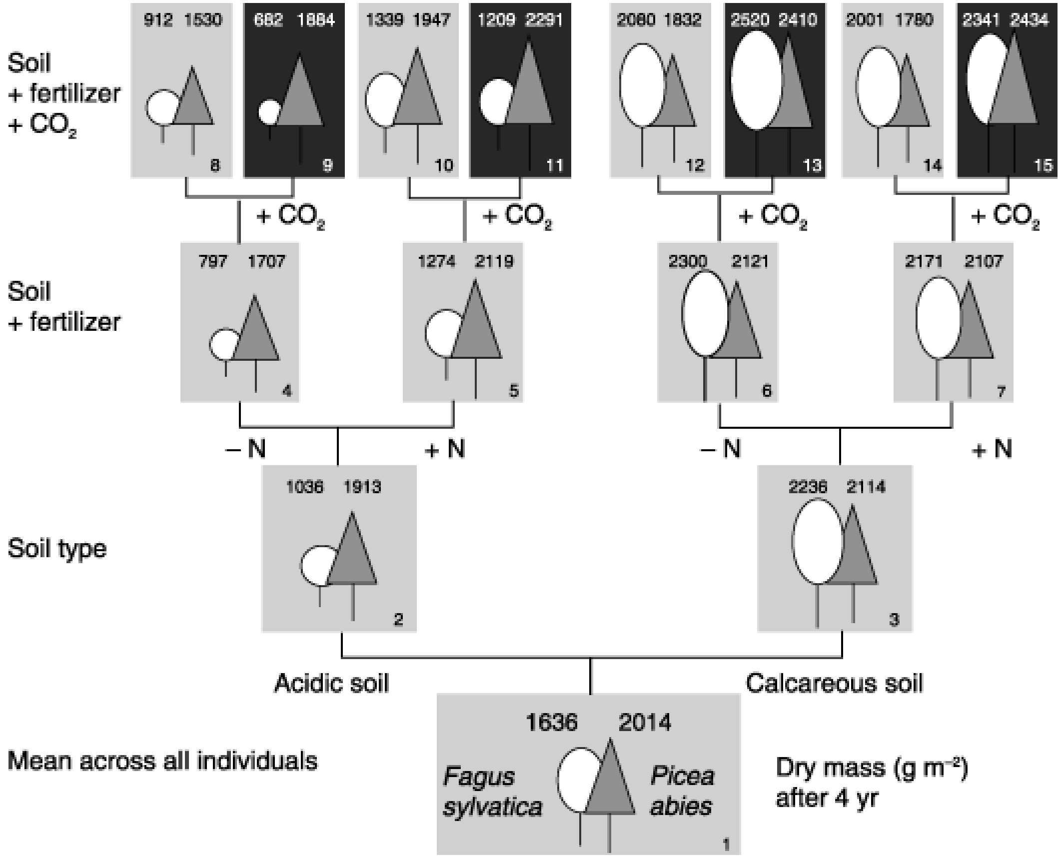
- Ice sheet retreat +600 PgC
- Sea level rise (+120 m) -200 PgC
- Rise in dT (+(5-10)K) -250 PgC
- **Rise in CO_2 (+90 ppmv) +650 PgC**
- **Total +800 PgC**

Range given by various studies (d[13]C, pollen-based vegetation reconstructions, modelling): +(300-1000) PgC

C rise in biosphere leads to a DROP in CO_2 by ~30 ppmv opposite to observations

Joos et al., 2004, GBC; Köhler et al 2005, Climate Dynamics

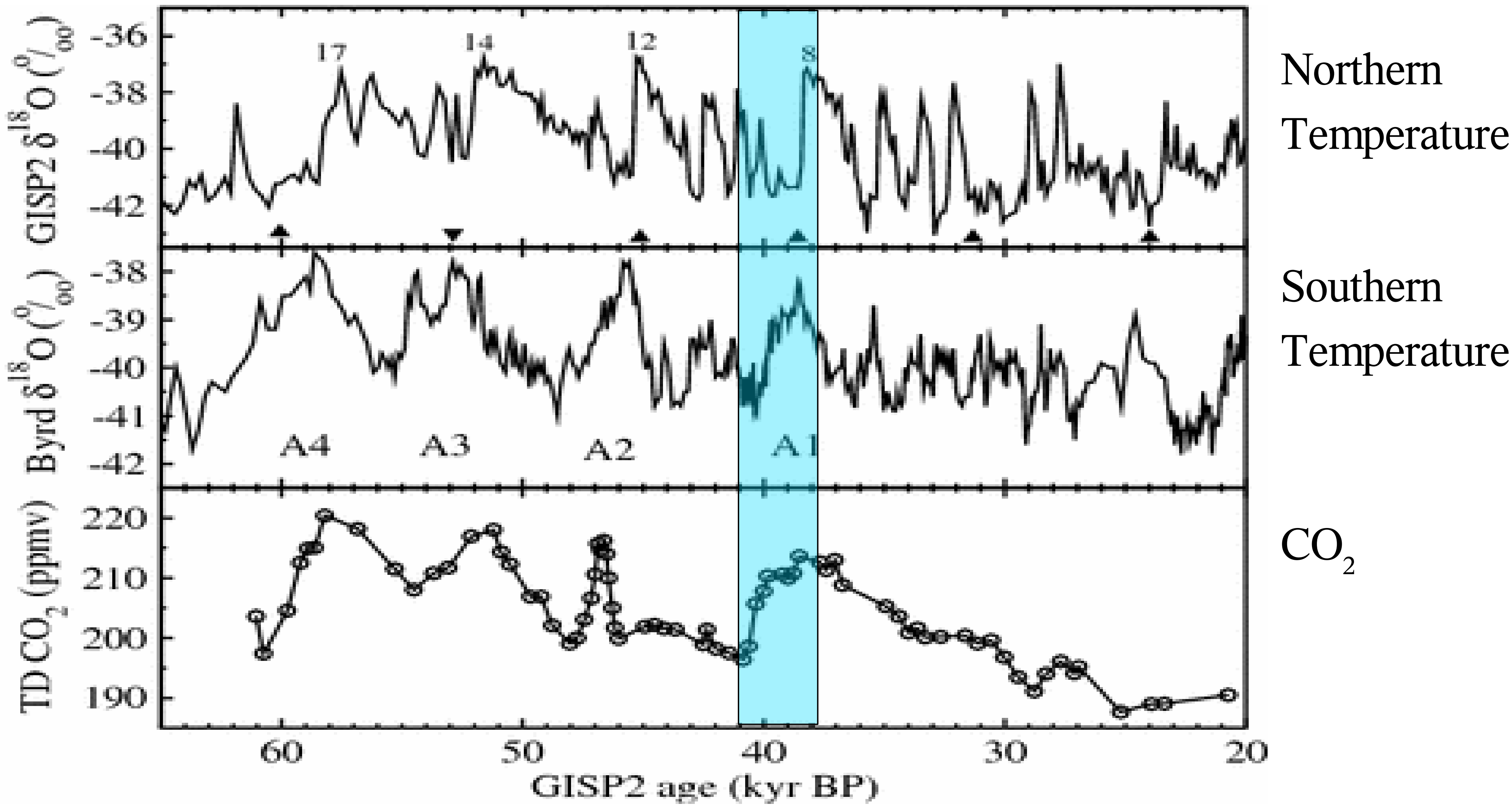
CO_2 fertilisation



Experiments show species specific response to elevated CO_2. Uptake rates seem to increase, but also the respiration rates: Storage in plants not necessary increased. Soils are important.

Körner, 2006

4 Millennial-scale variability



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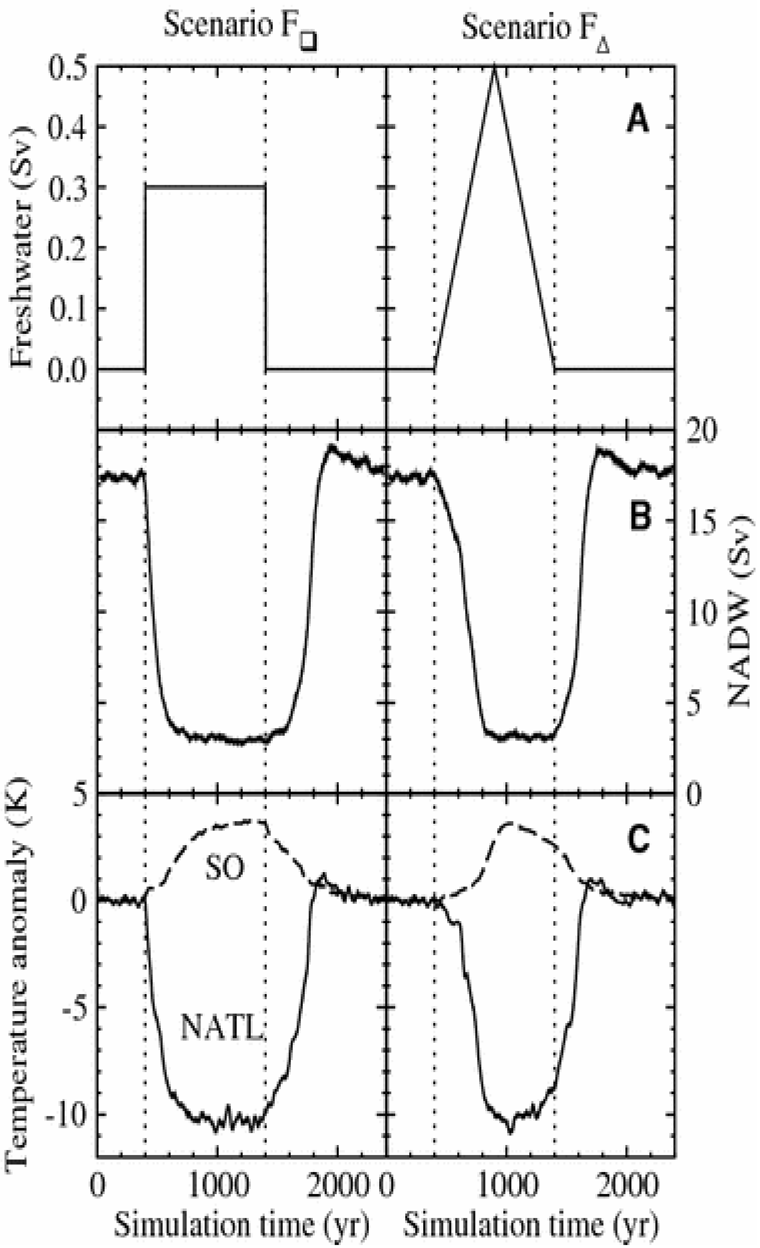
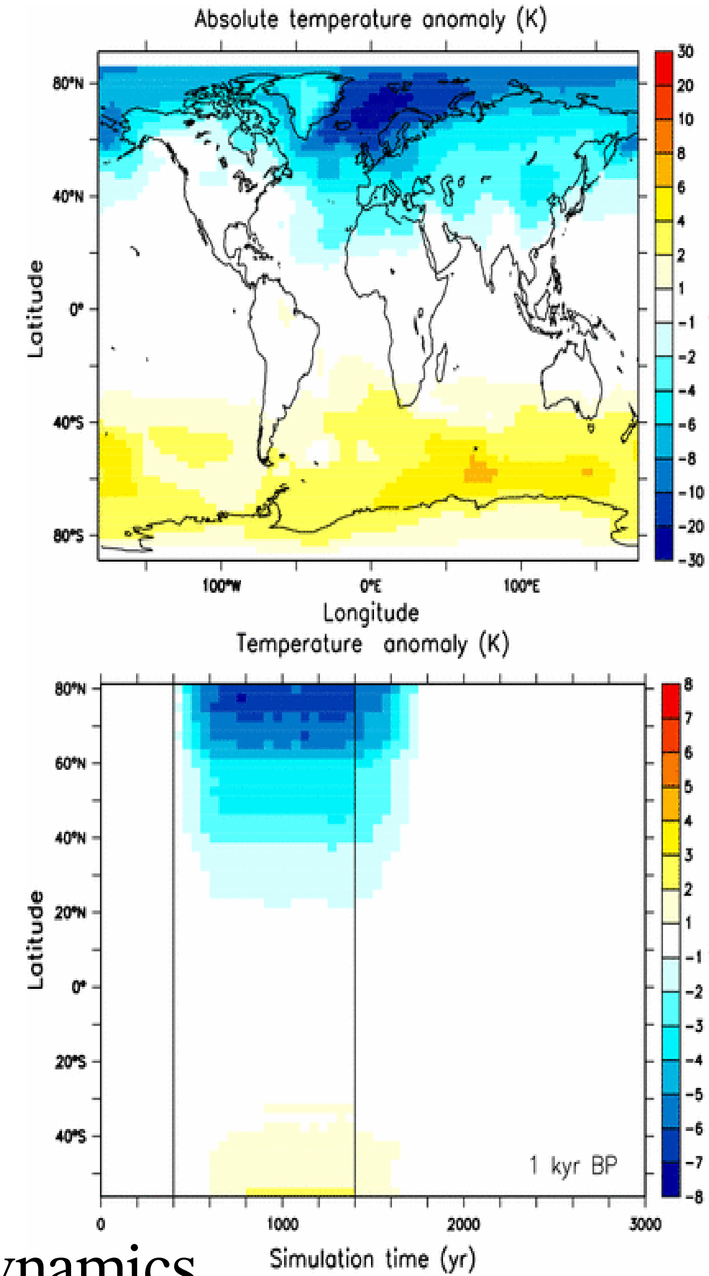
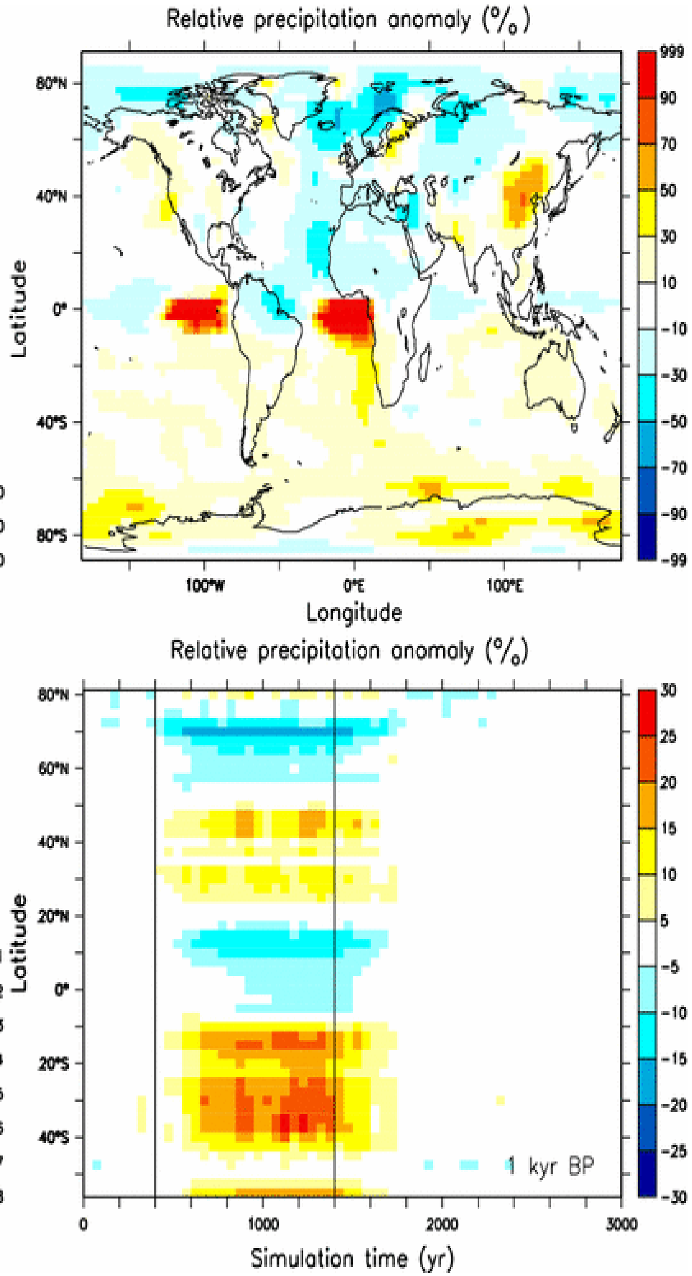


d(Temperature)



d(Precipitation)



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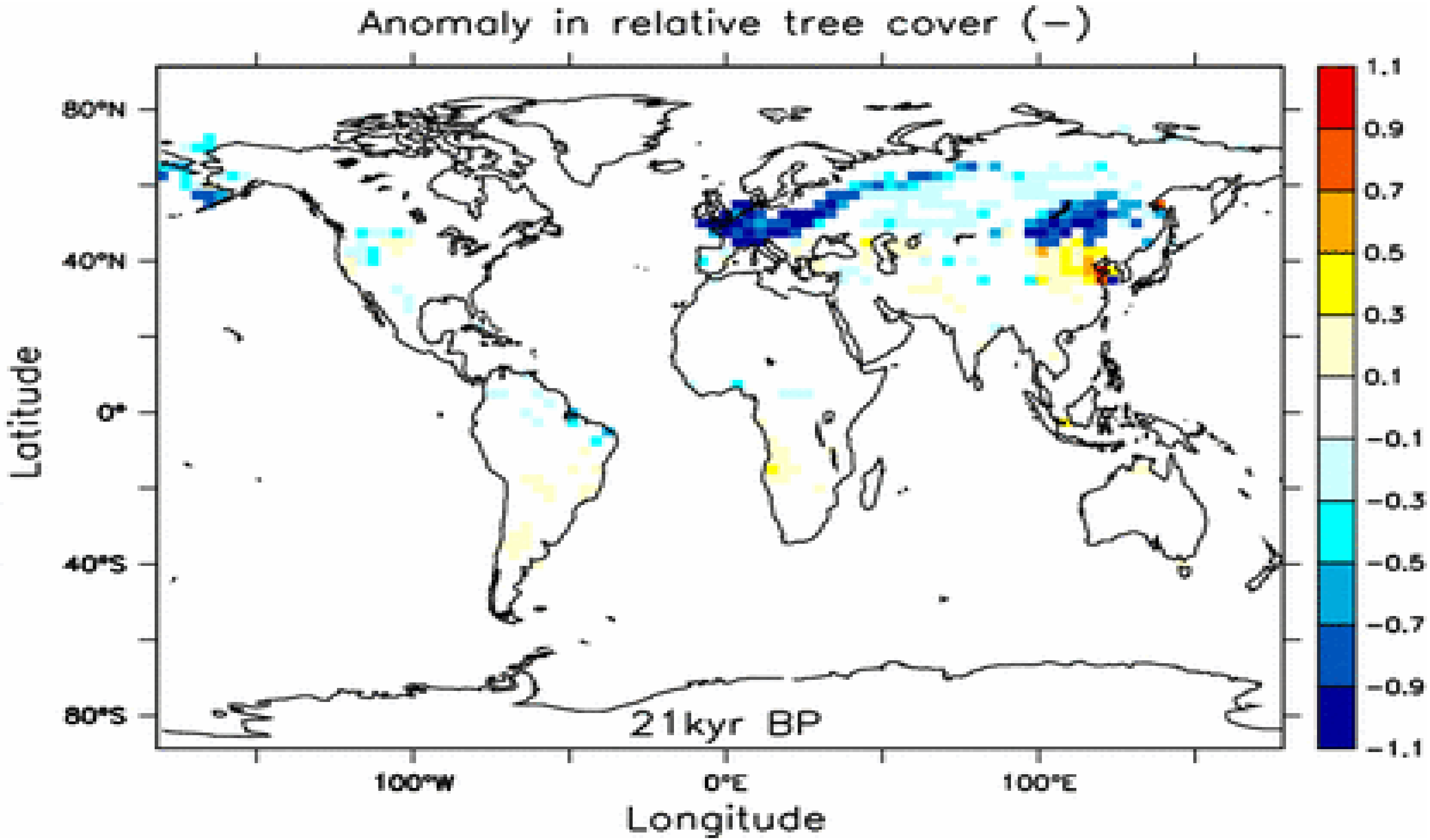

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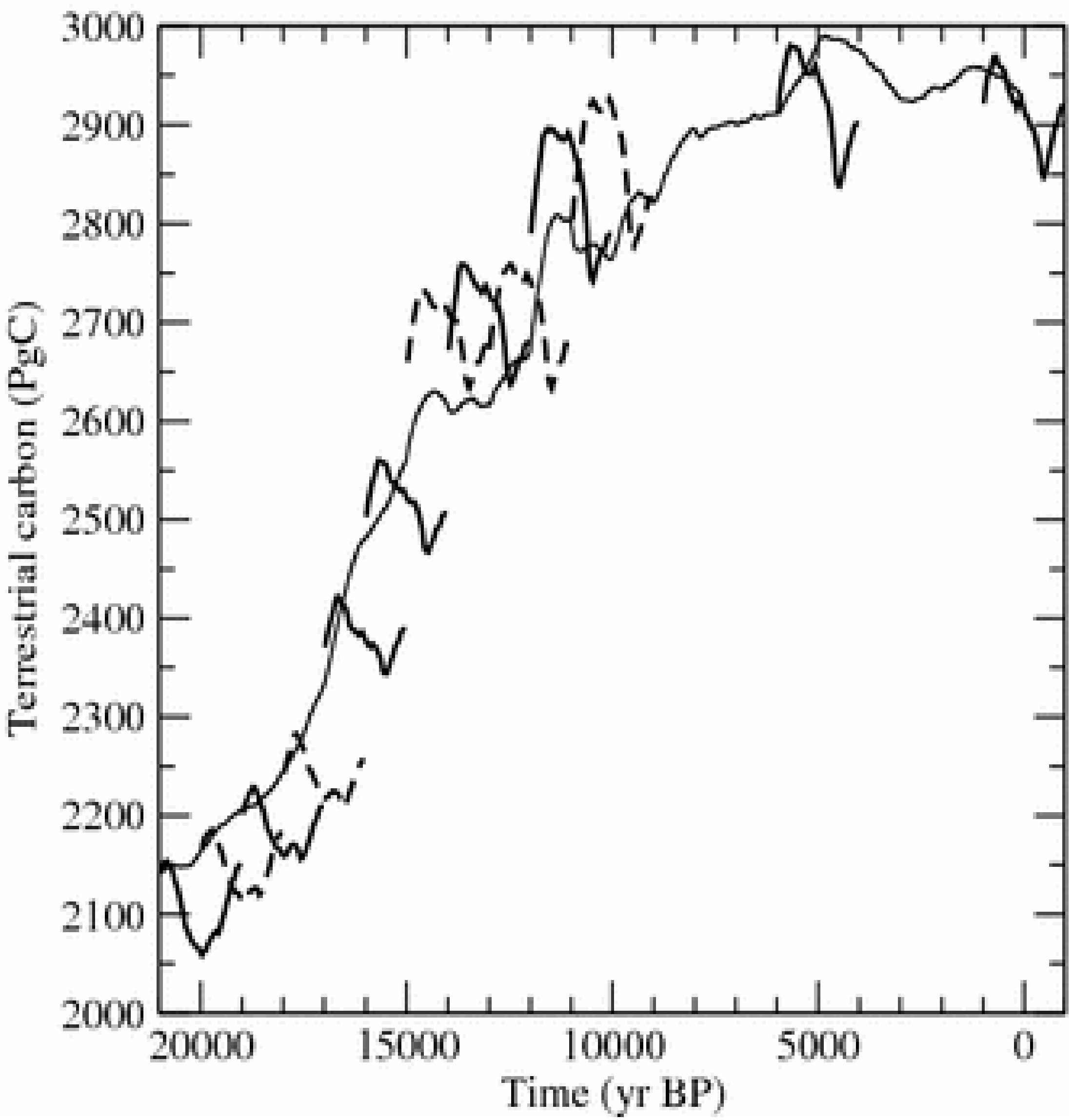

1. The overall response of the terrestrial carbon cycle depends on the background climate.

The pattern are the same:
- southward shift of northern treeline
- lower respirational losses in soil carbon

2. During glacial conditions about 50% of the observed variability in CO_2 (10-20 ppmv) can be explained by the terrestrial biosphere.

Köhler et al 2005, Climate Dynamics

Conclusions

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- and reduced via land carbon uptake (C sink: -209PgC).

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4 Millennial-scale variability (bipolar seesaw) causes a southward shift in the northern treeline and changes in the respirational losses of the soils (dC ~ 100PgC and dCO_2 ~10 ppmv).