Carbon cycling from the Precambrian to the Anthropocene

Dave Schimel and Scott Doney

A central issue:

- Carbon fluxes vary at high frequency in time and space but the climate responds to the global integral.
- As a result, processes must be understand locally but integrated globally.
- The paleocarbon cycle provides one source of data on integral responses.

Why study the paleocarbon cycle?

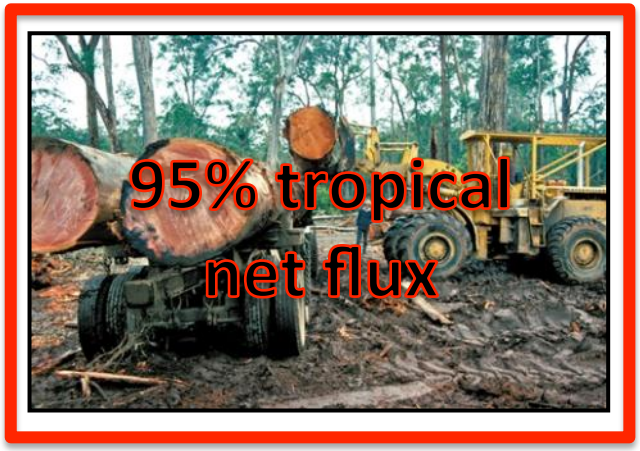
- It is an interesting part of Earth System History and Nature/Science love the subject.
- The paleorecord can confirm or falsify links between carbon and climate.
- The paleorecord may allow quantification of coupled carbon-climate feedbacks under certain conditions.
- The paleorecord helps define the role of the oceans by allowing access to alternate circulation modes.
- The paleorecord helps to define the lifetime of atmospheric CO_2 perturbations.

The global carbon budget

Fate of Anthropogenic CO_2 Emissions (2002-2011)

8.3±0.4 GtC/yr

1.0±0.5 GtC/yr net flux



+

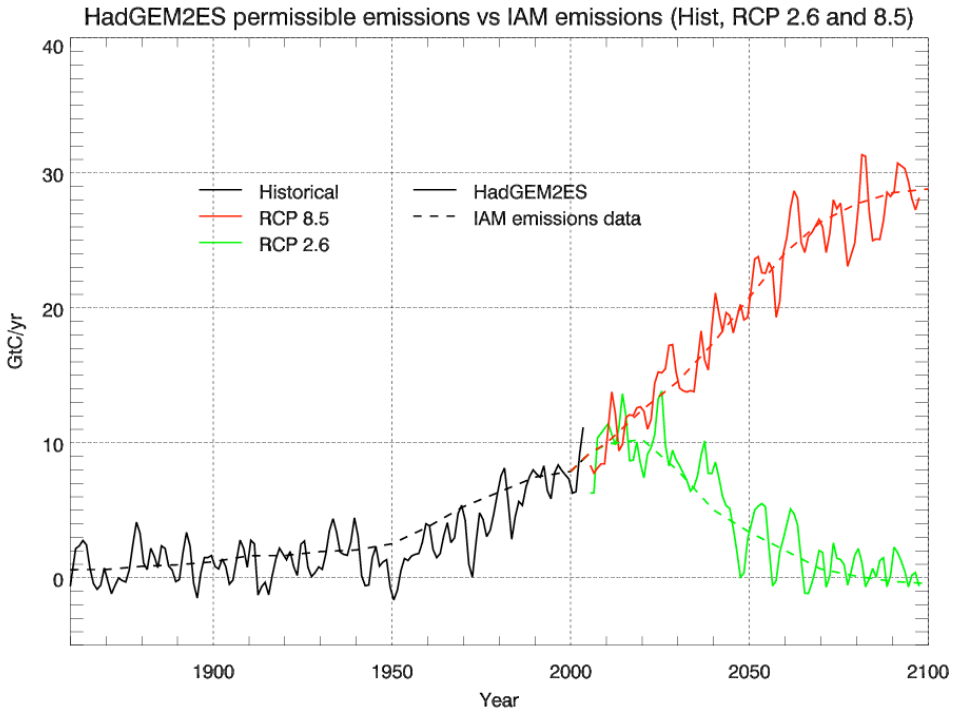
4.3±0.1 GtC/yr

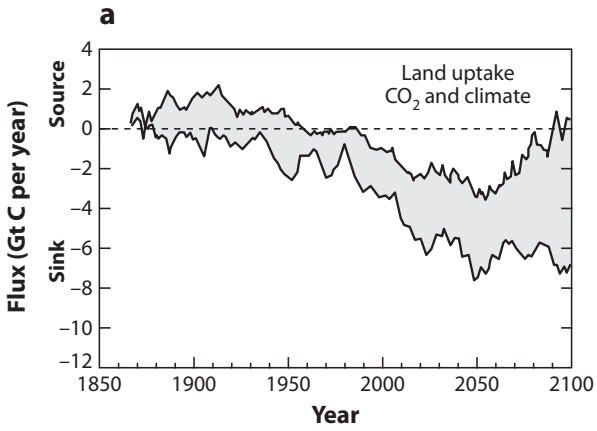
2.6±0.9 GtC/yr

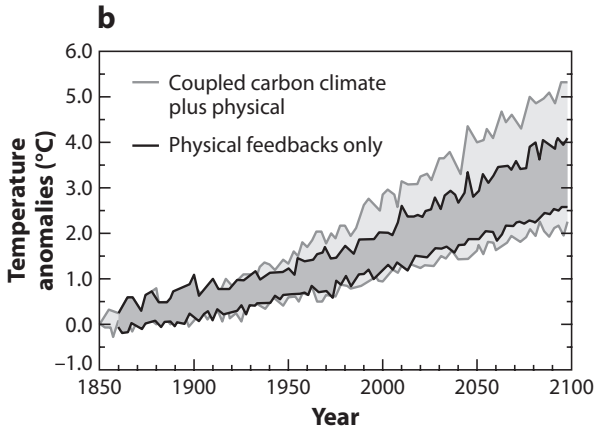
2.5±0.5 GtC/yr

Global Carbon Project, 2012

Given a climate target, ocean and ecosystem feedbacks define the permissible emissions from fossil energy production.







Jet Propulsion Laboratory

NASA

Condensing a great deal…

We can think of the carbon cycle as being driven by climate and concentraiton dependent processes:

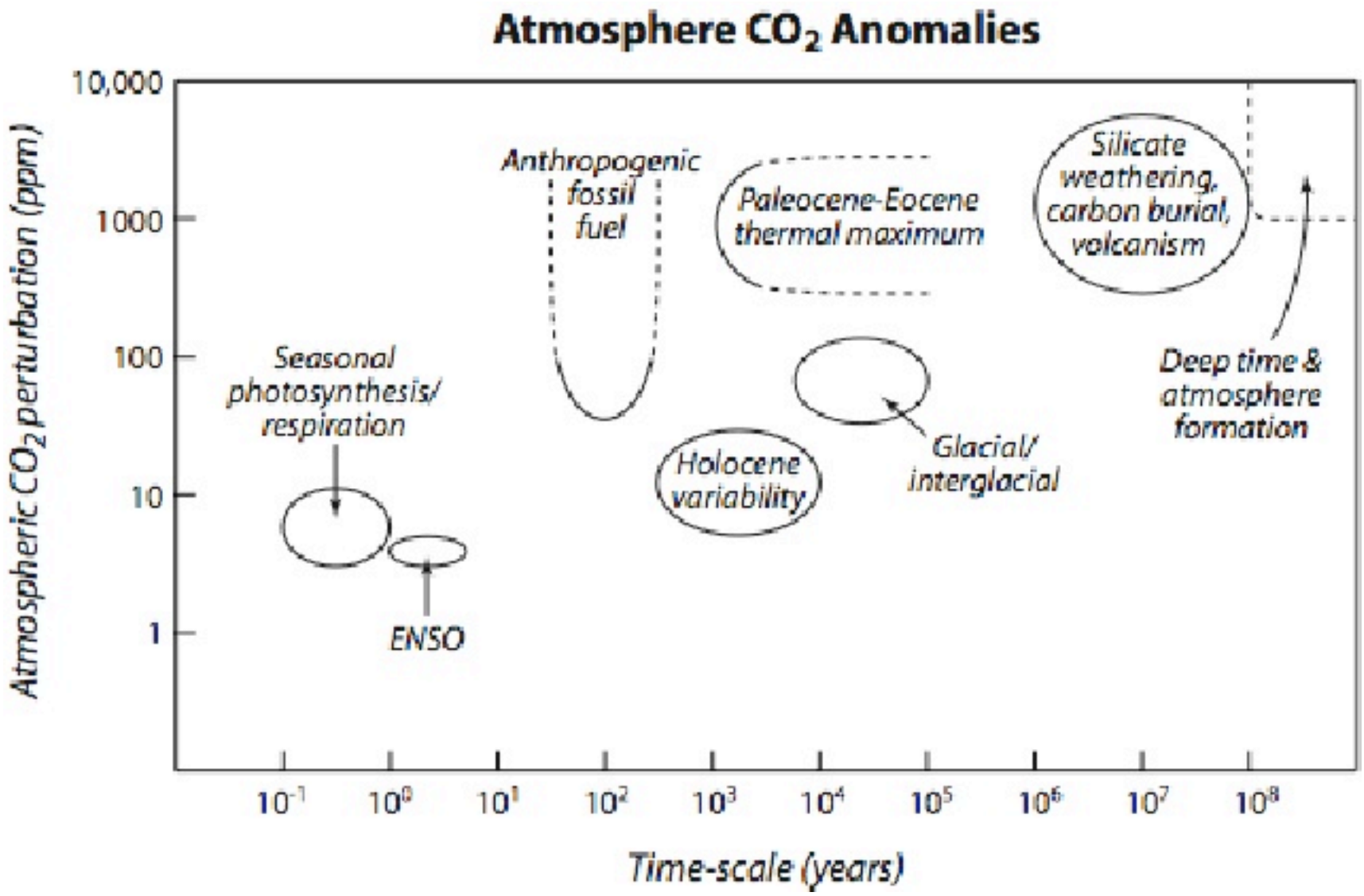
βC and γT

Where:

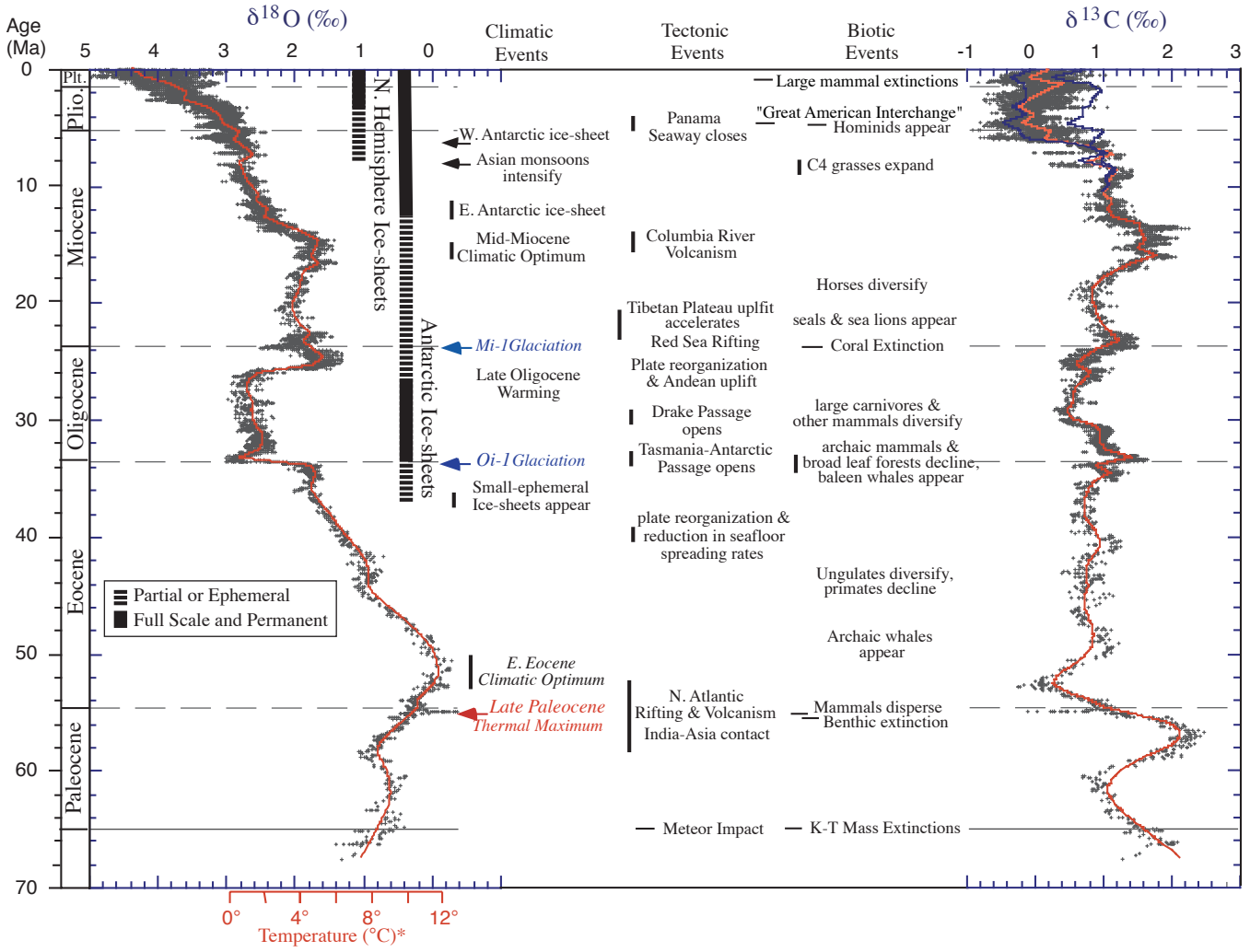
C_β is concentration-dependent uptake and C_λ is climate-dependent uptake

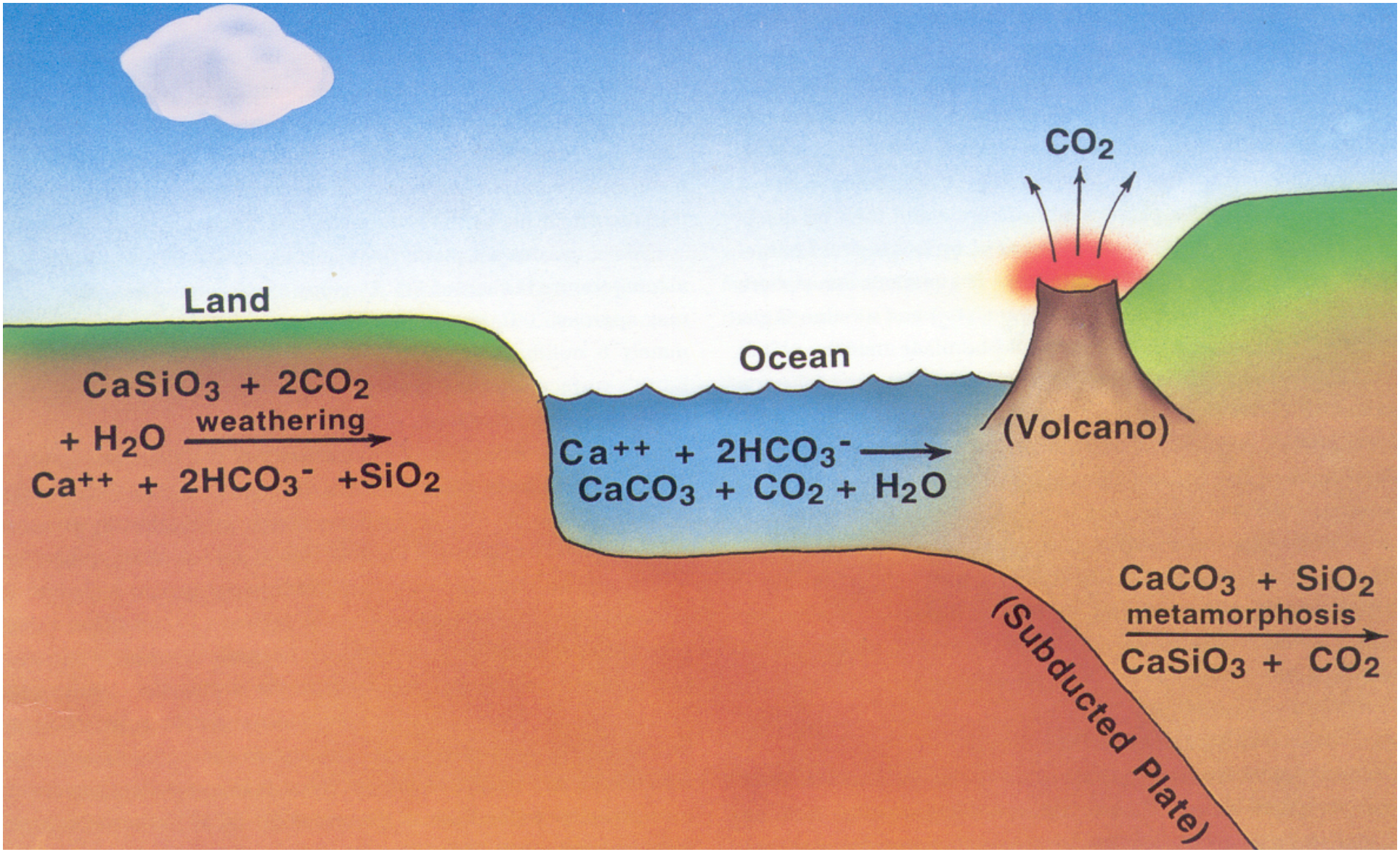
Jet Propulsion Laboratory

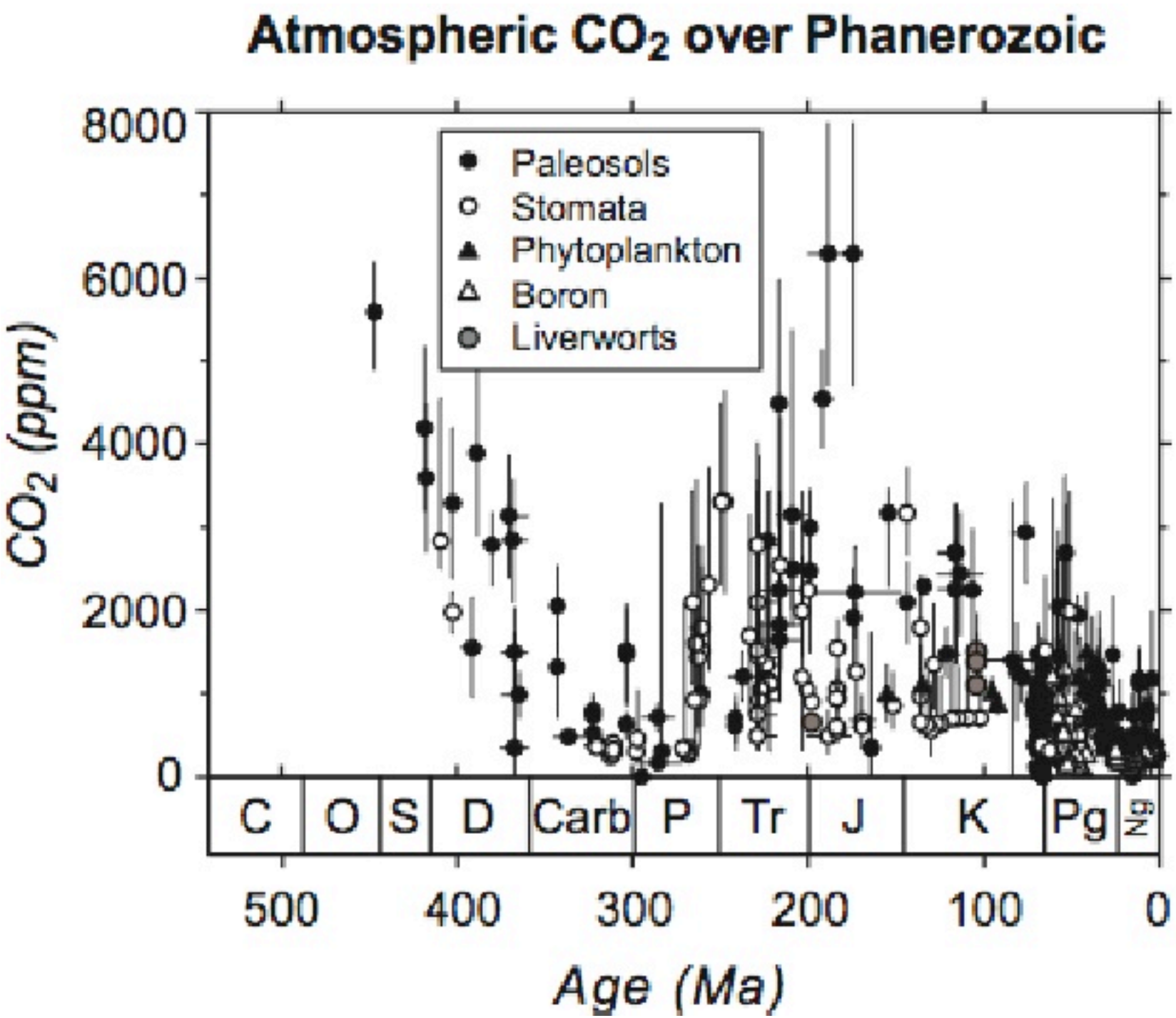
NASA


Atmosphere CO_2 Anomalies
10,000
1000
100
10
1
Atmospheric CO_2 perturbation (ppm)
Anthropogenic fossil fuel
Paleocene-Eocene thermal maximum
Silicate weathering, carbon burial, volcanism
Deep time & atmosphere formation
Seasonal photosynthesis/ respiration
Holocene variability
Glacial/ interglacial
ENSO
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
Time-scale (years)

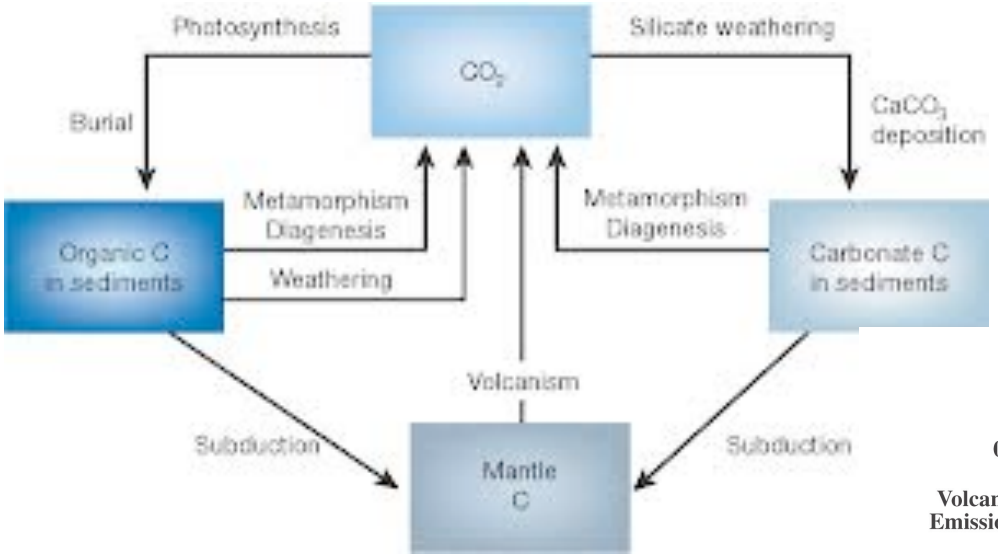
Climate and carbon over the last 65 My

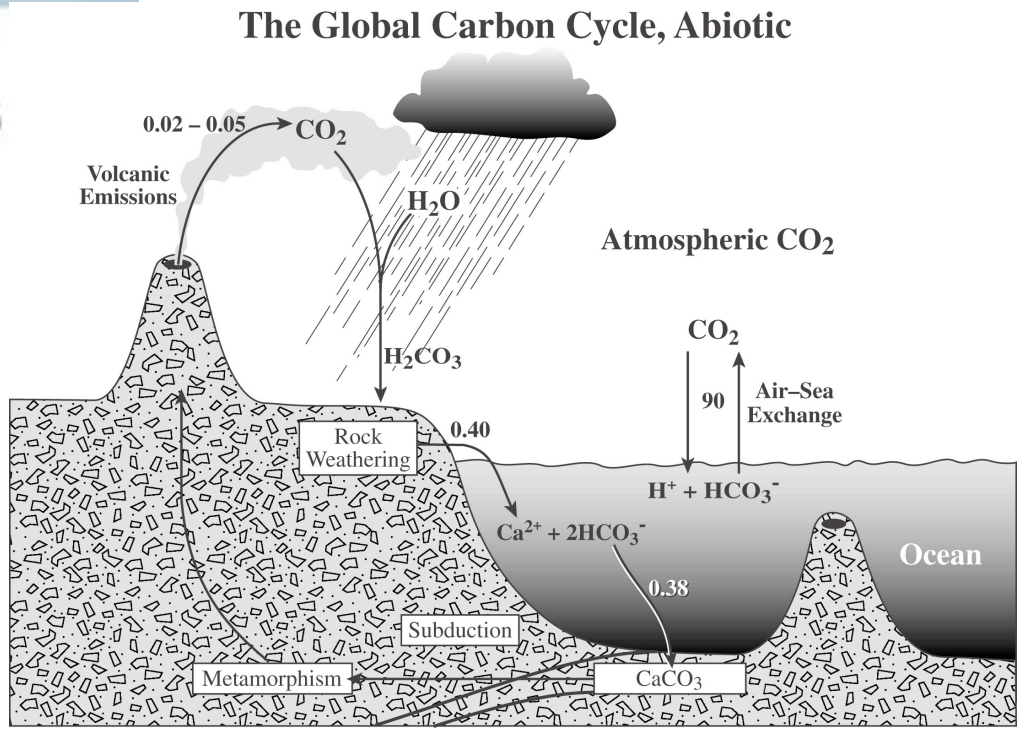



CO_2
Land
Ocean
$CaSiO_3 + 2CO_2$
$+ H_2O$ weathering
$Ca^{++} + 2HCO_3^- + SiO_2$
$Ca^{++} + 2HCO_3^-$
$CaCO_3 + CO_2 + H_2O$
(Volcano)
$CaCO_3 + SiO_2$
metamorphosis
$CaSiO_3 + CO_2$
(Subducted Plate)

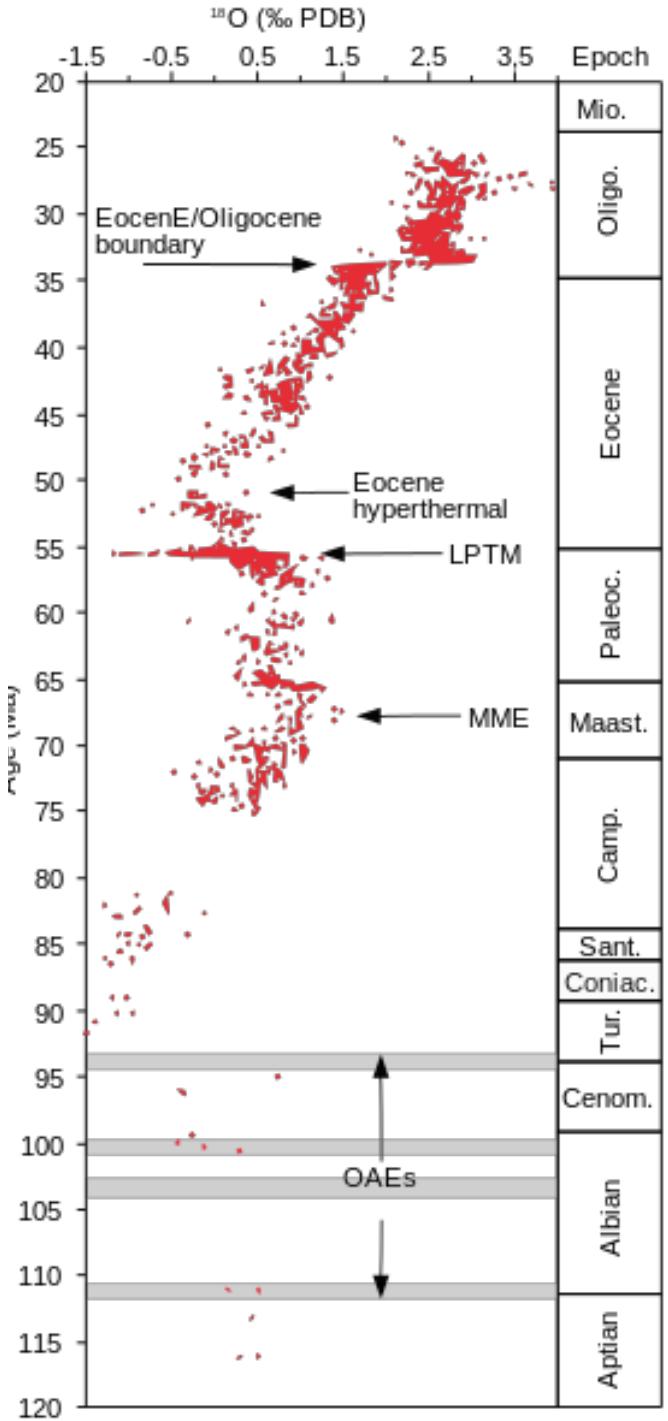

Atmospheric CO_2 over Phanerozoic
Paleosols
Stomata
Phytoplankton
Boron
Liverworts
CO_2 (ppm)
8000
6000
4000
2000
0
C
O
S
D
Carb
P
Tr
J
K
Pg
Ng
500
400
300
200
100
0
Age (Ma)

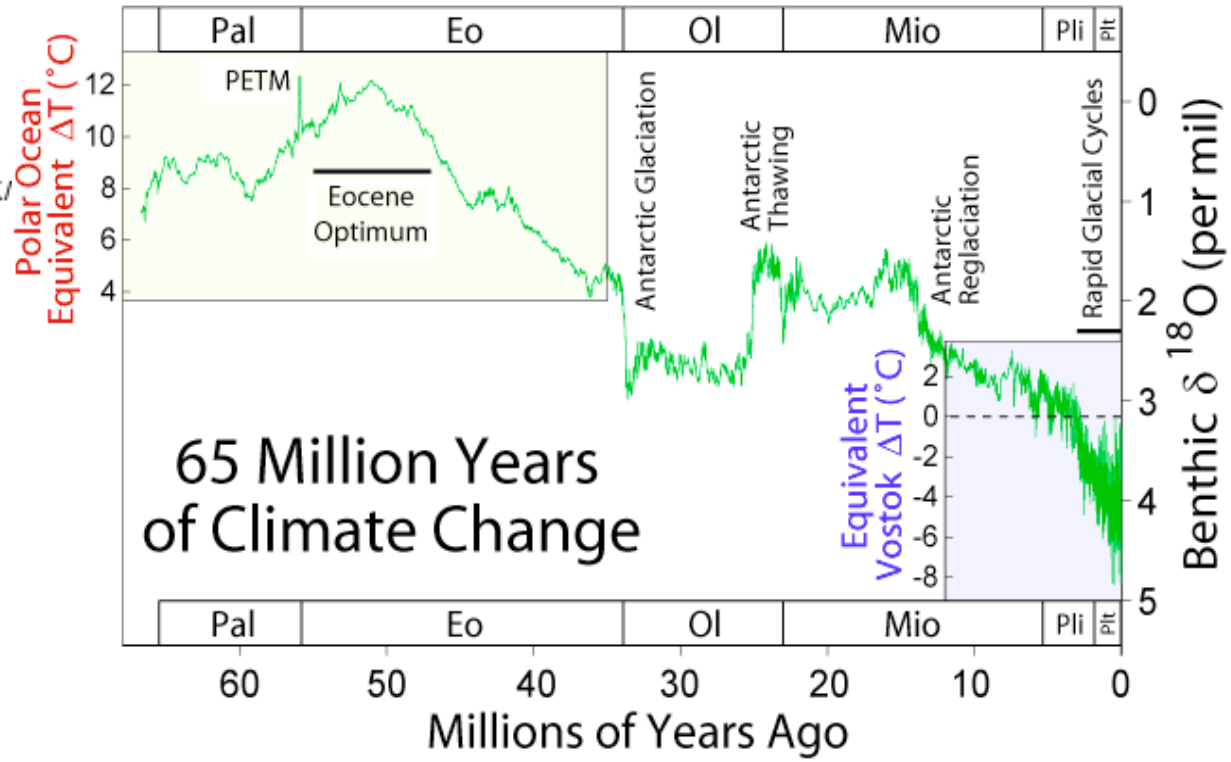
Processes in the geological carbon cycle



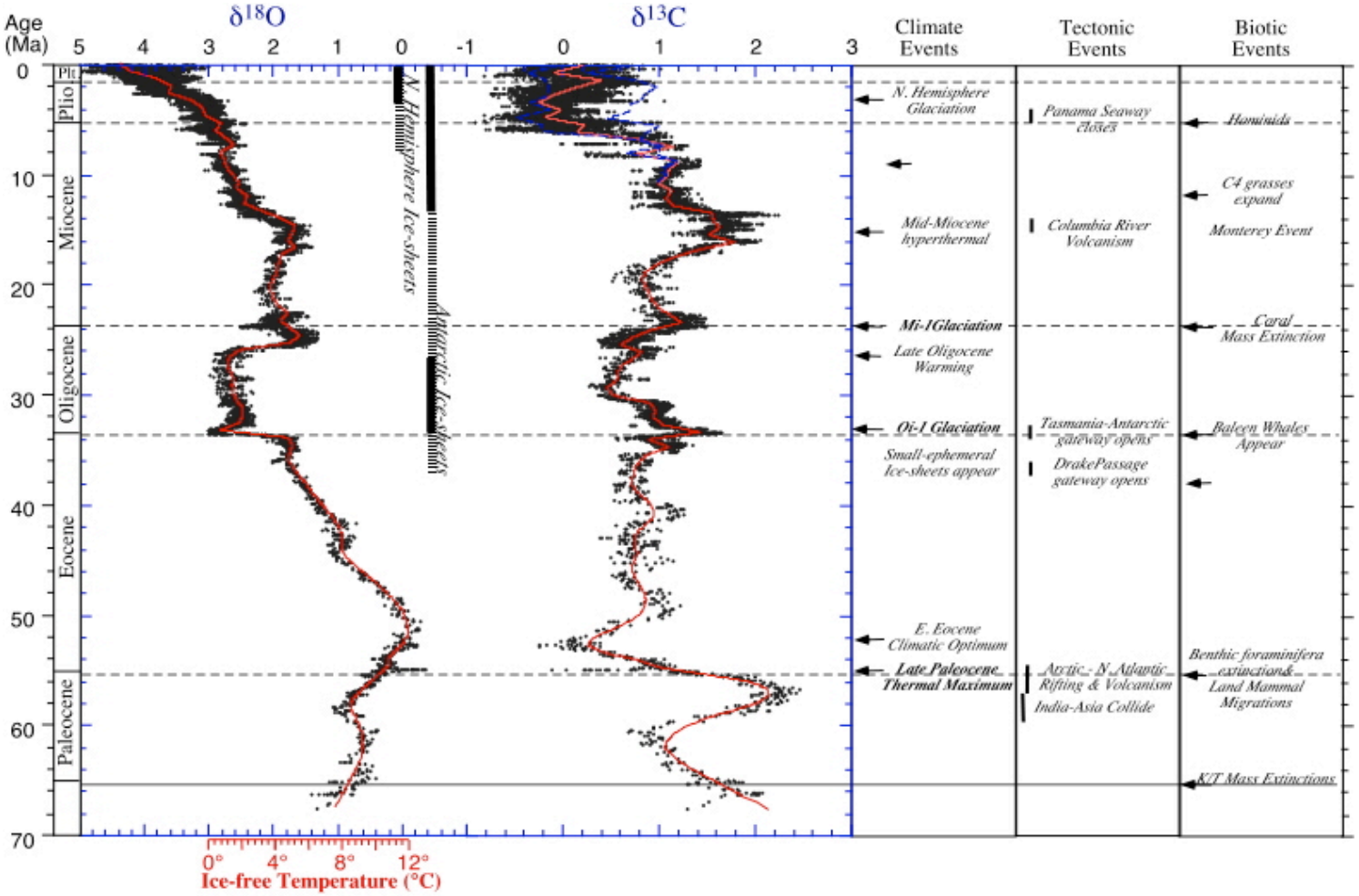


The Paleocene-Eocene Thermal Maximum





PETM Details and setting



Details of temperature and carbon during the PETM

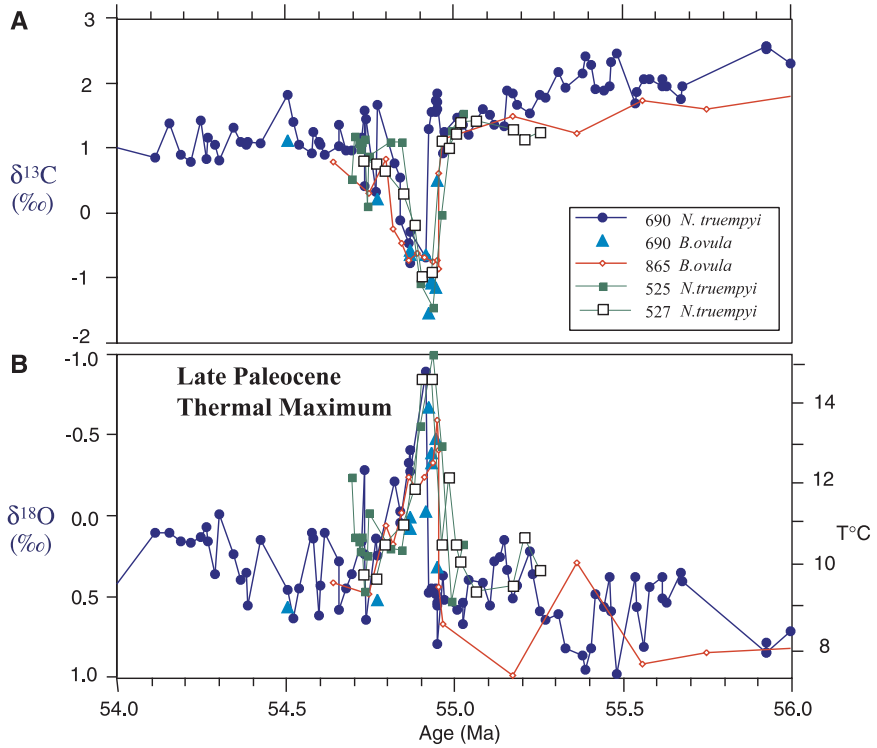
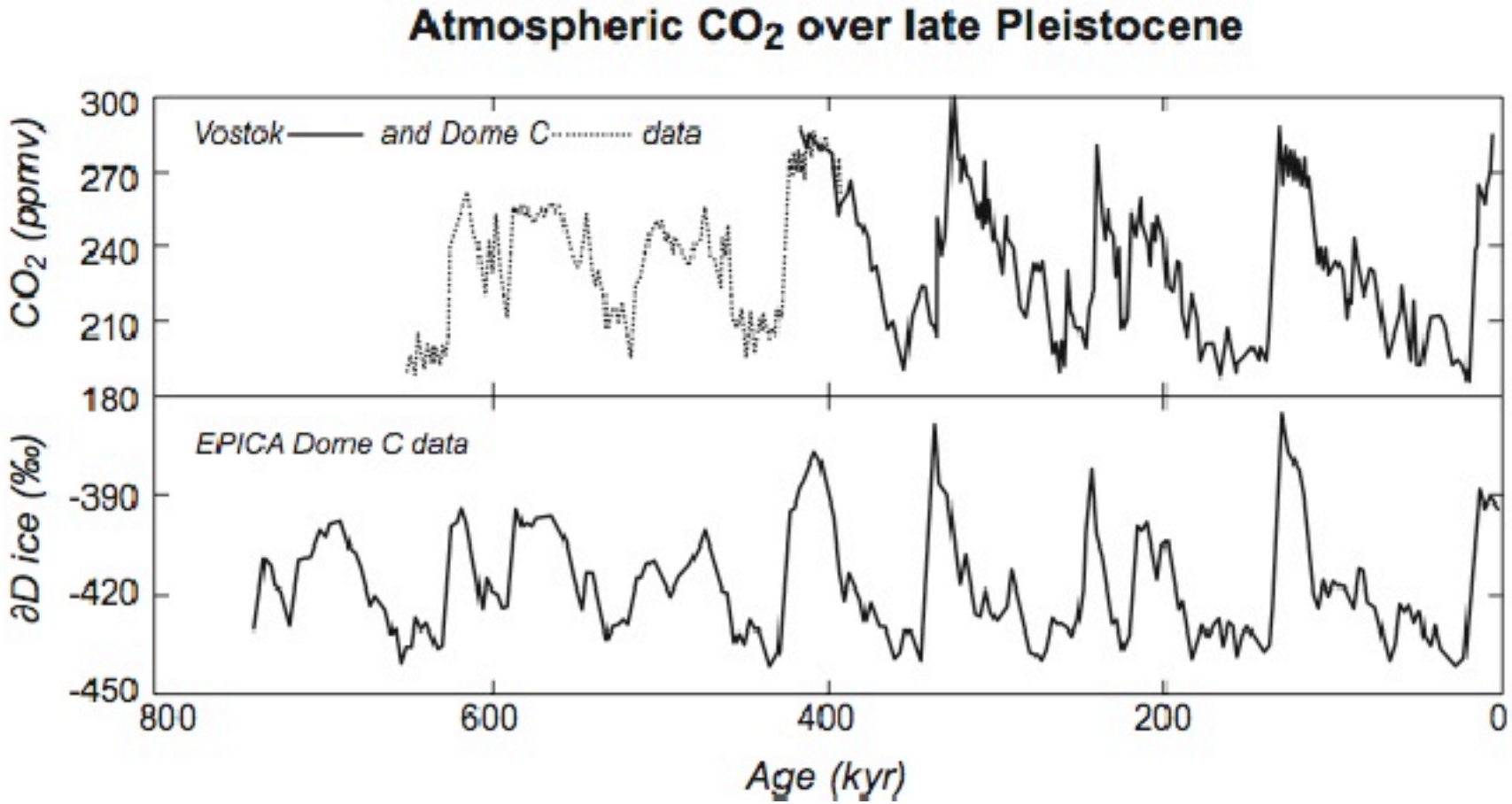
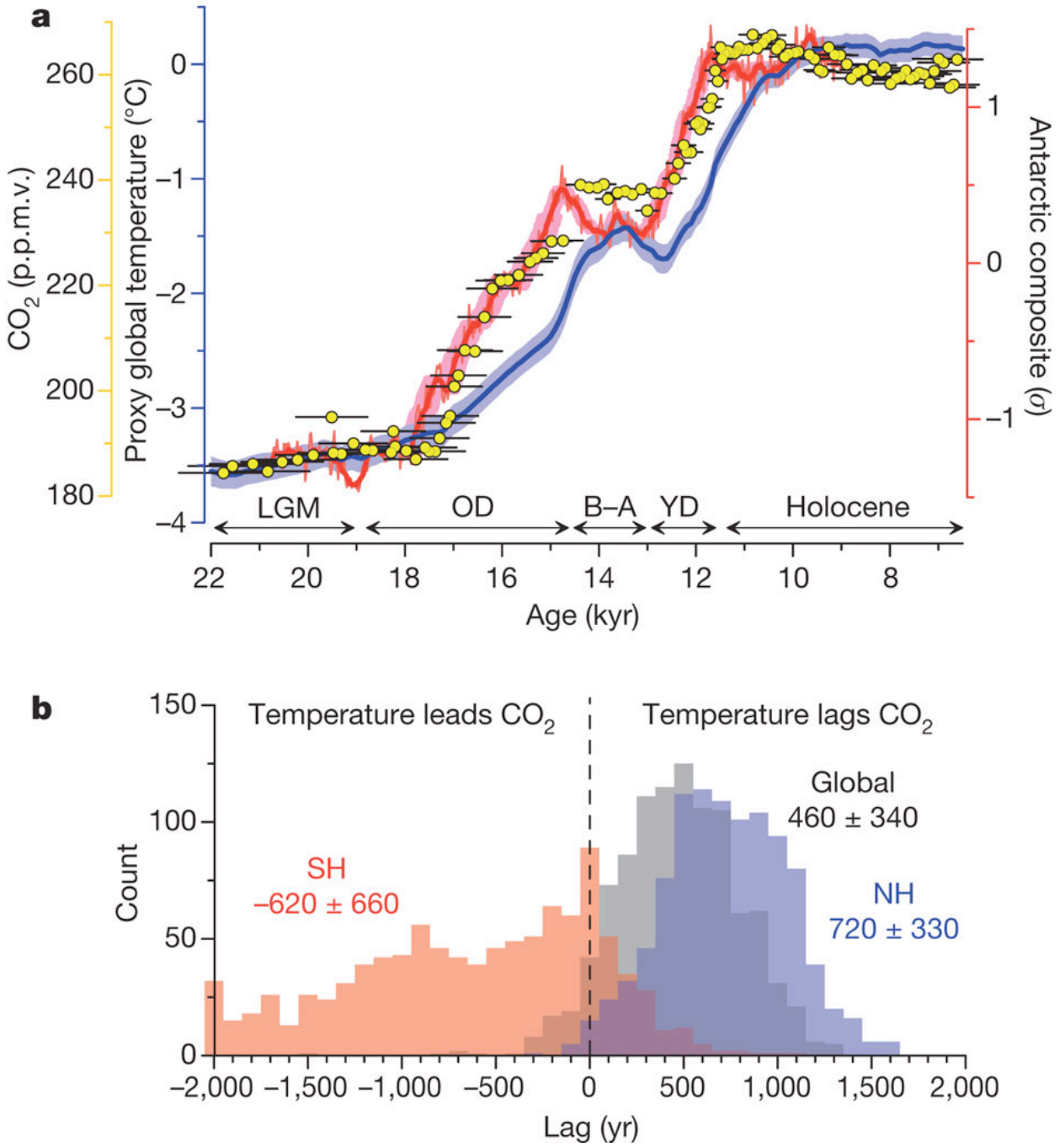


Fig. 5. The LPTM as recorded in benthic $\delta^{13}C$ and $\delta^{18}O$ records (**A** and **B**, respectively) from Sites 527 and 690 in the south Atlantic (*73*), and Site 865 in the western Pacific (*26*). The time scale is based on the cycle stratigraphy of Site 690 (*30*) with the base of the excursion placed at 54.95 Ma. The other records have been correlated to Site 690 using the carbon isotope stratigraphy. Apparent leads and lags are artifacts of differences in sample spacing. The oxygen isotope values have been adjusted for species-specific vital effects (*118*), and the temperature scale on the right is for an ice-free ocean. The negative carbon isotope excursion is thought to represent the influx of up to 2600 Gt of methane from dissociation of seafloor clathrate (*111*).

The glacial period

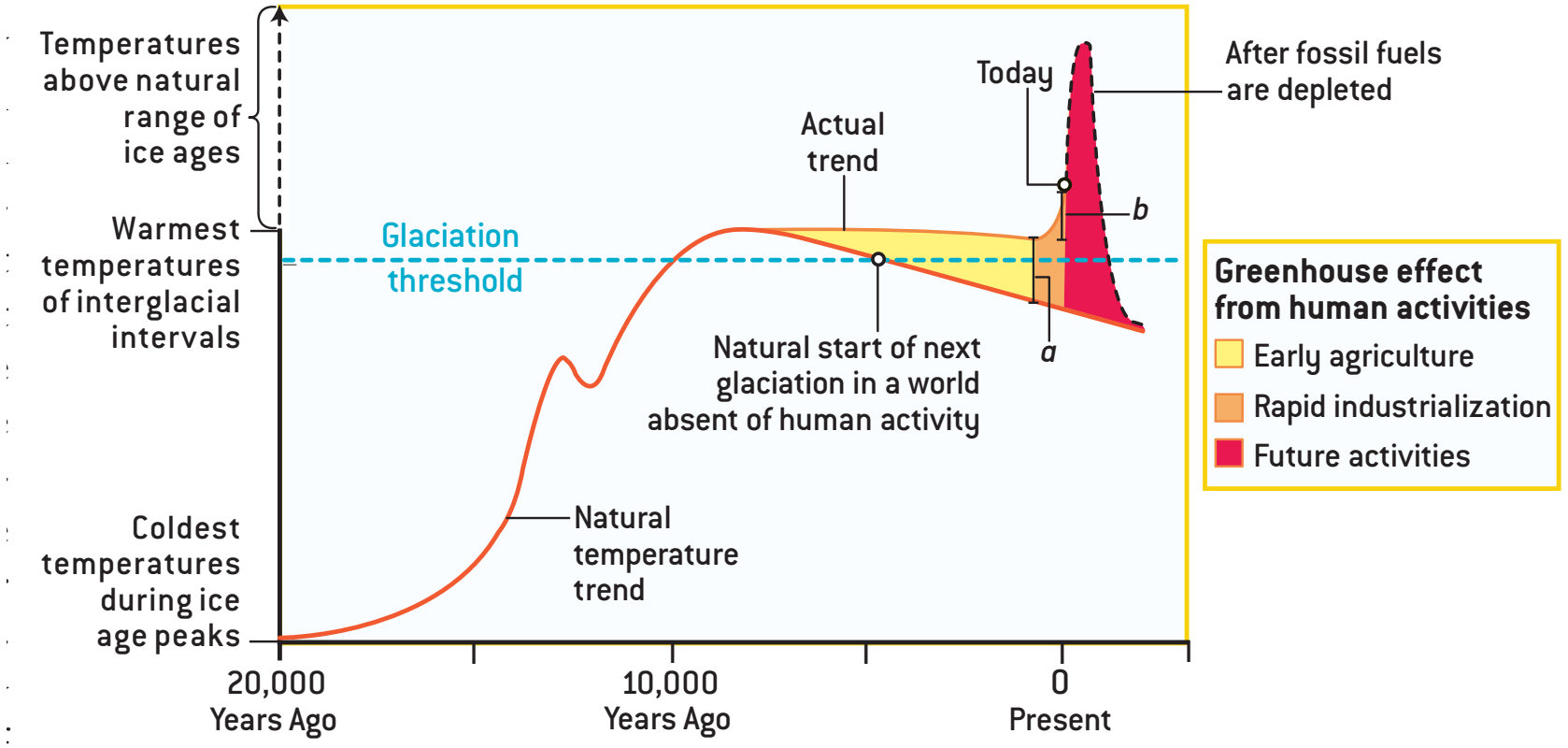


Leads and lags in deglaciation: climate sensitivity and amplification

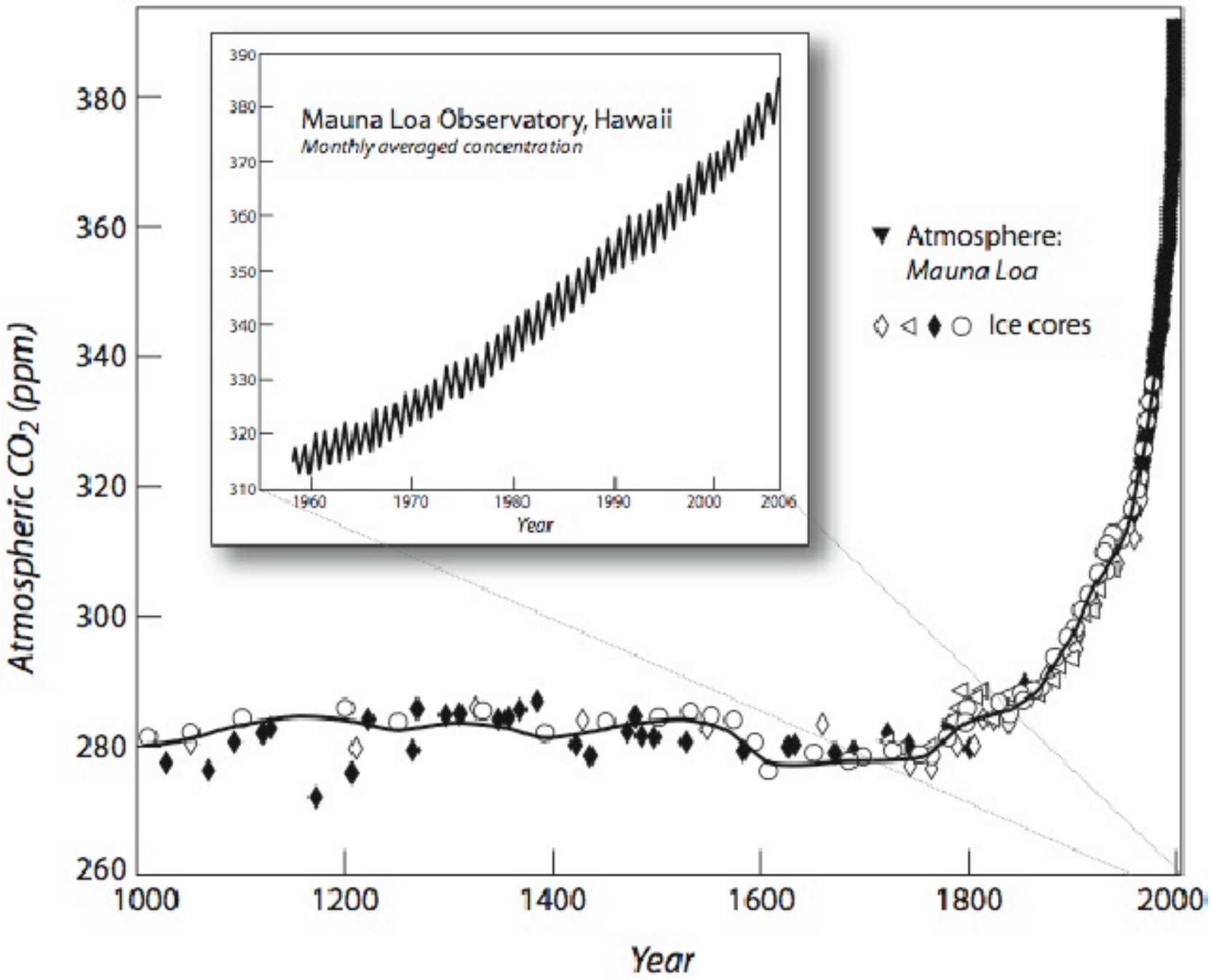


…”the global proxy database suggests that parts of the northern mid to high latitudes were the first to warm after the LGM, which could have initiated the reduction in the AMOC that may have ultimately caused the increase in CO_2 concentration”

Bill Ruddiman's hypothesis: an older anthropocene



Atmospheric CO_2 Variations Since 1000 AD



Why study the paleocarbon cycle?

- The long time scales and aggregated spatial scales force examination of the whole system. We see the carbon cycle as "*one*" in the ice core/ ocean sediment/geological record*.

*caveat: there is some local information in the paleorecord, and we have some ability to decouple terrestrial and marine effects.