Factors and processes controlling climate variations at different time scales: supporting documents

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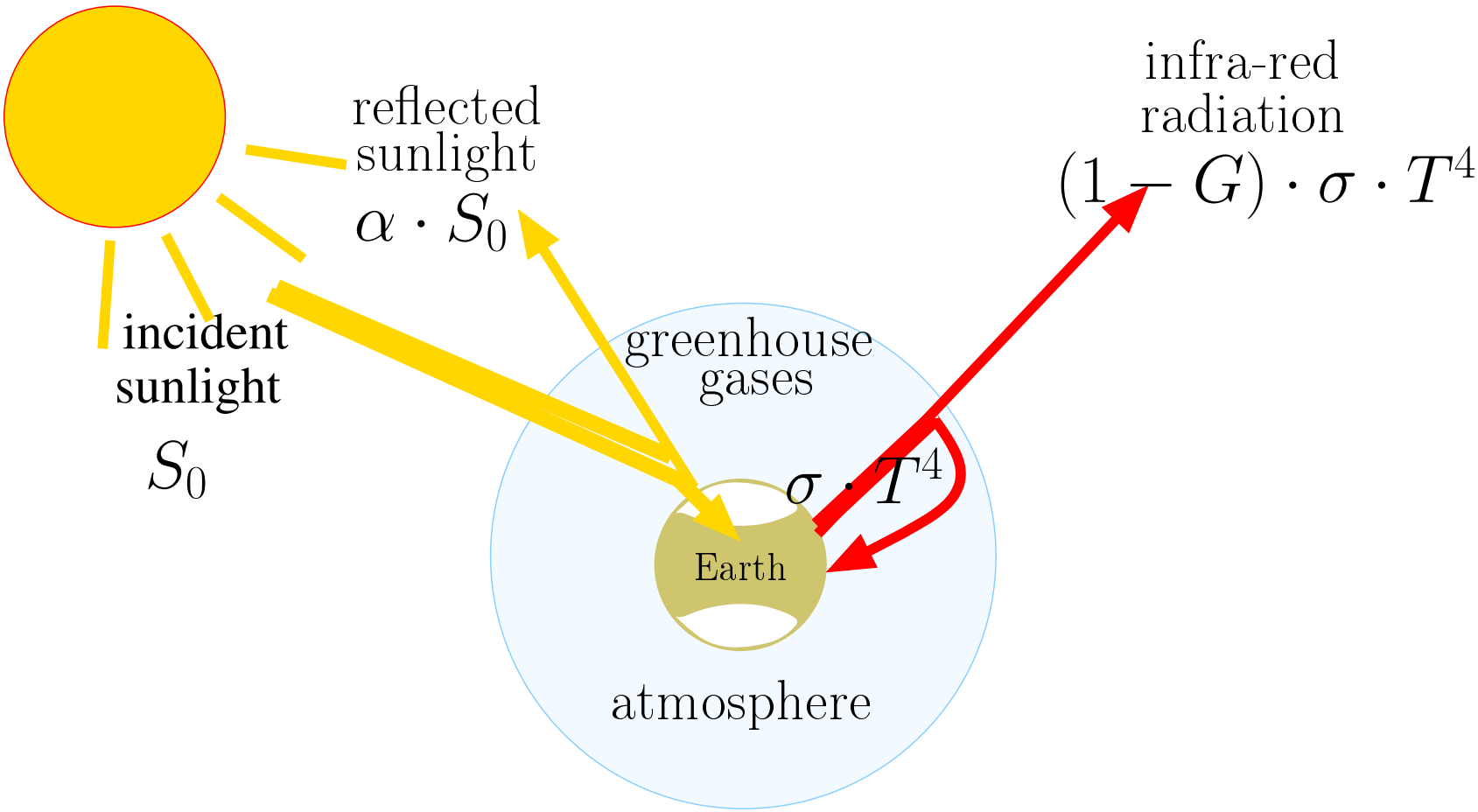
Outline

- Goals
  - understand factors and processes controlling climate variations at different time scales
  - place present-day climate change in the context of past variations and to identify its specificities.

1. The Earth radiative budget
2. Climate variations at geological time scales (>million years)
3. Climate variations at orbital time scales(tens of thousands years)
4. Anthropogenic climate change

1) The Earth radiative budget



$$(1-\alpha) \cdot S_0 = (1-G) \cdot \sigma \cdot T^4$$

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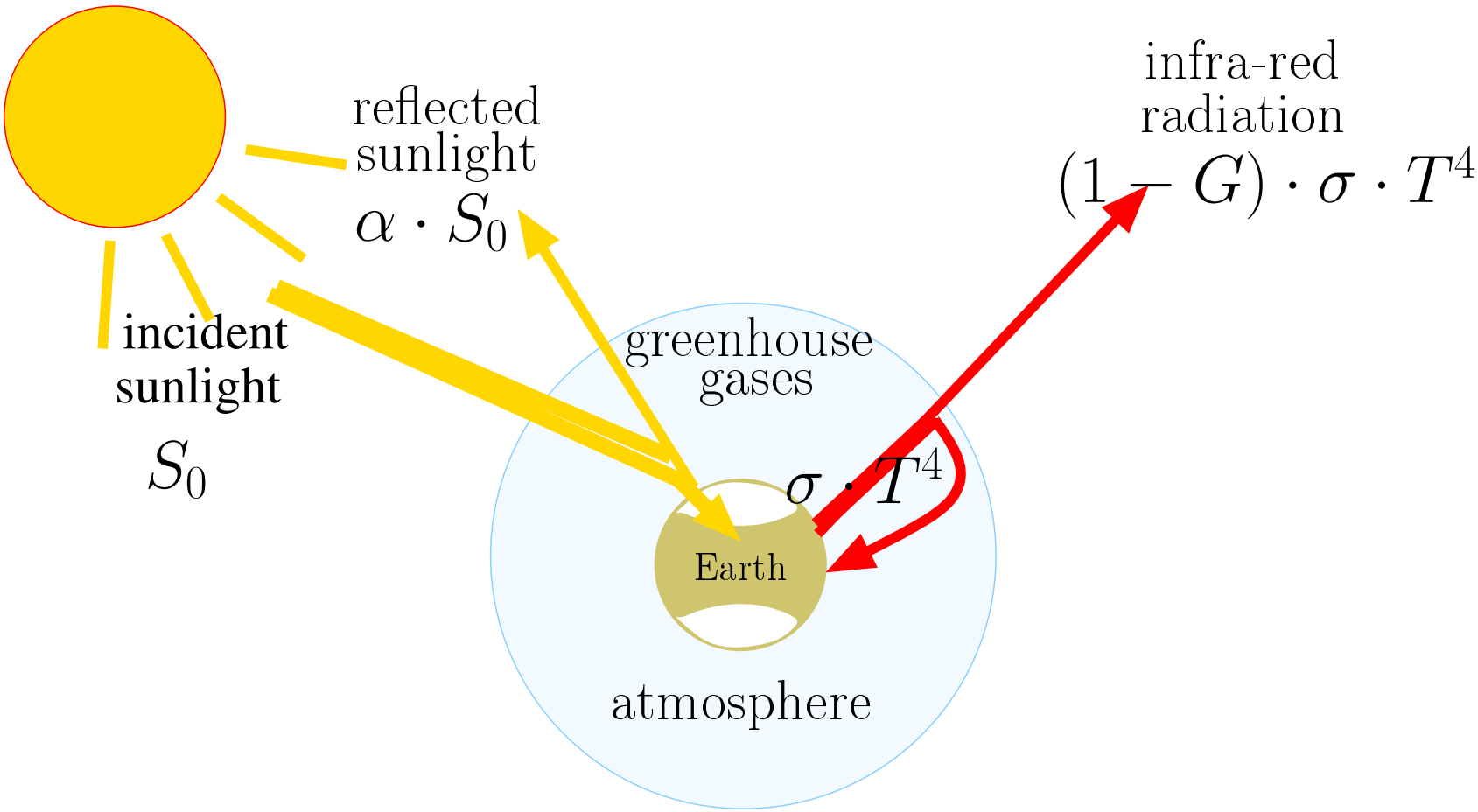

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- Exercise 1: vary S_0, α, G

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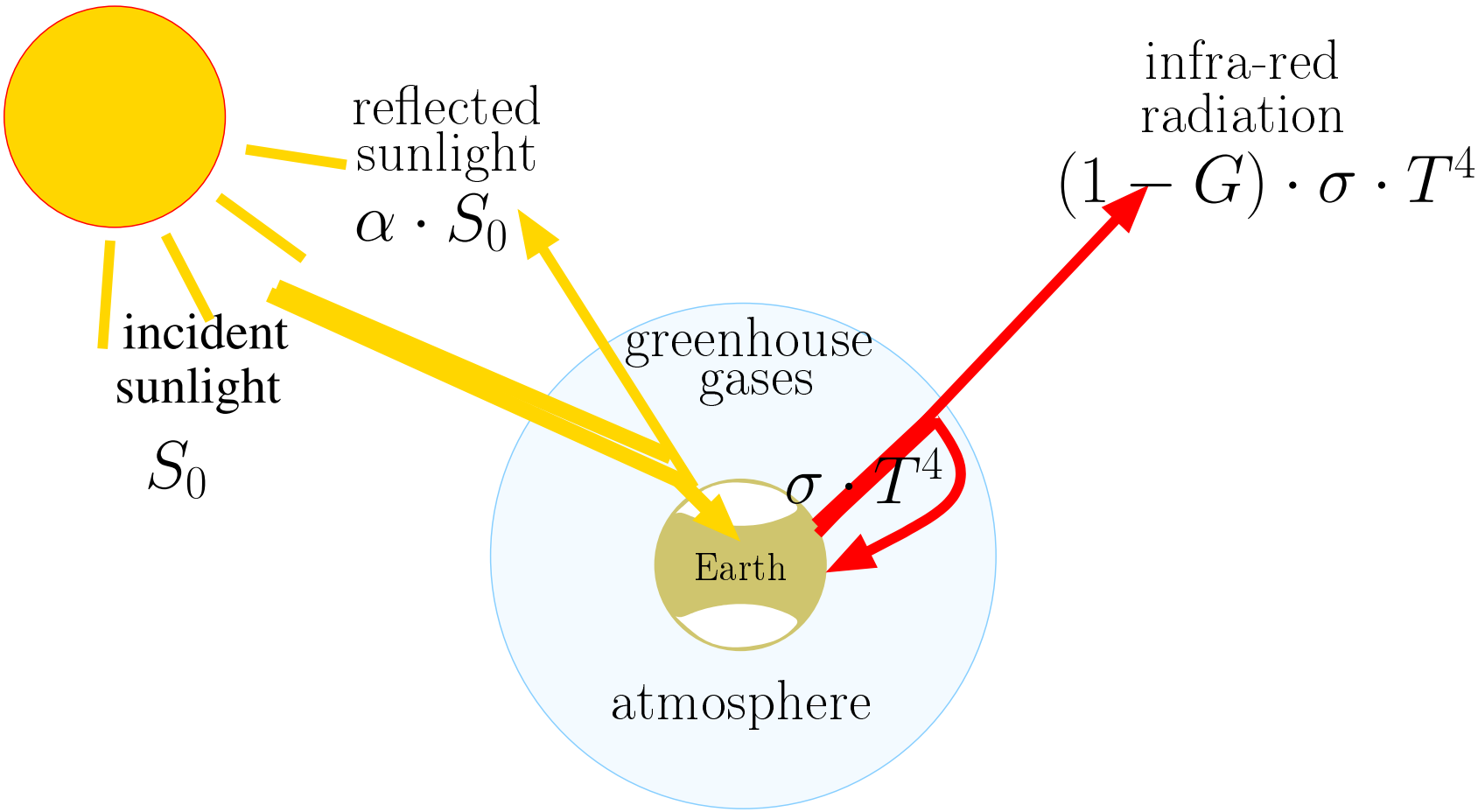

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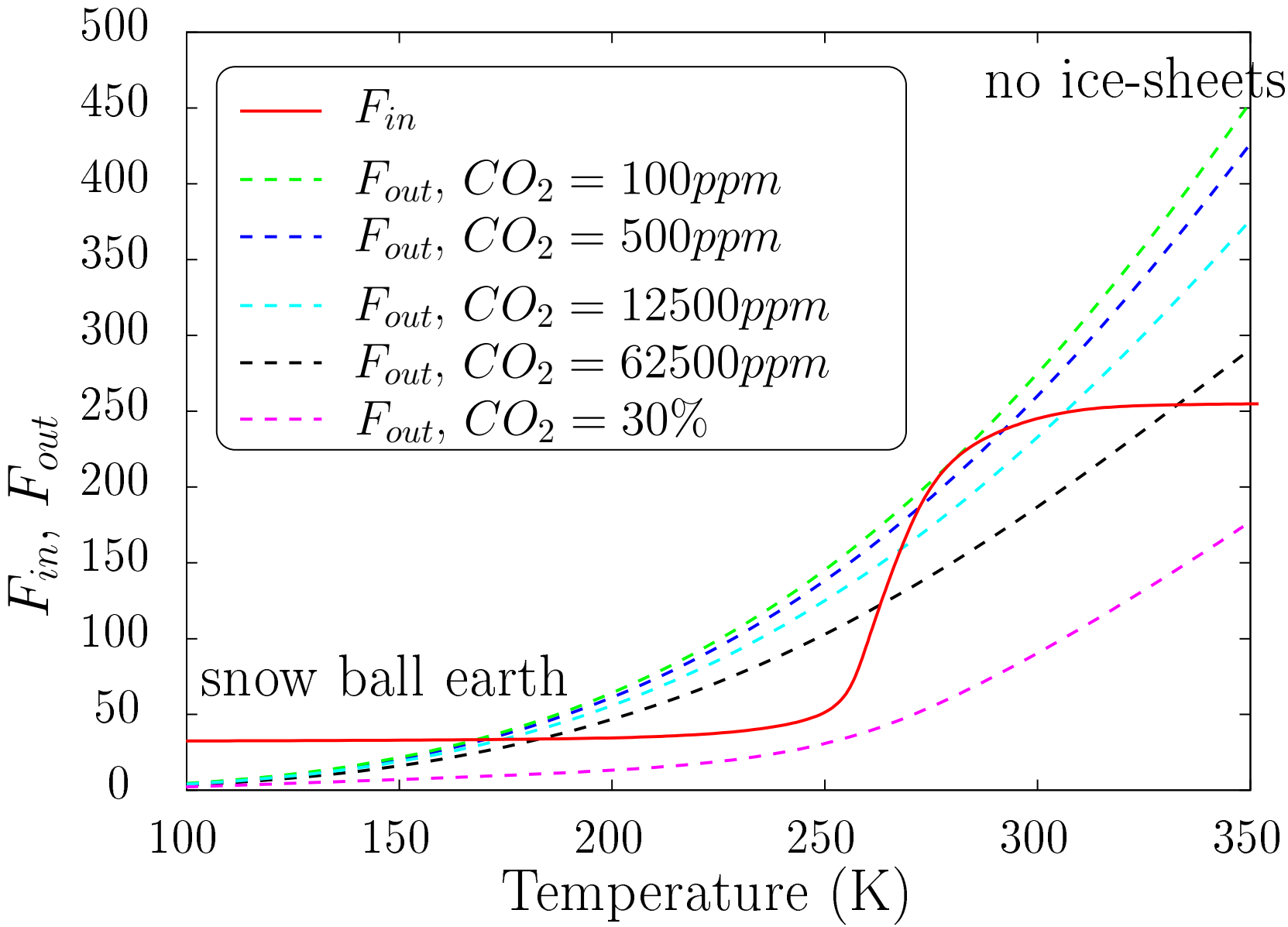
- Exercise 1: vary S_0, α, G
- Exercise 2.1: equilibria

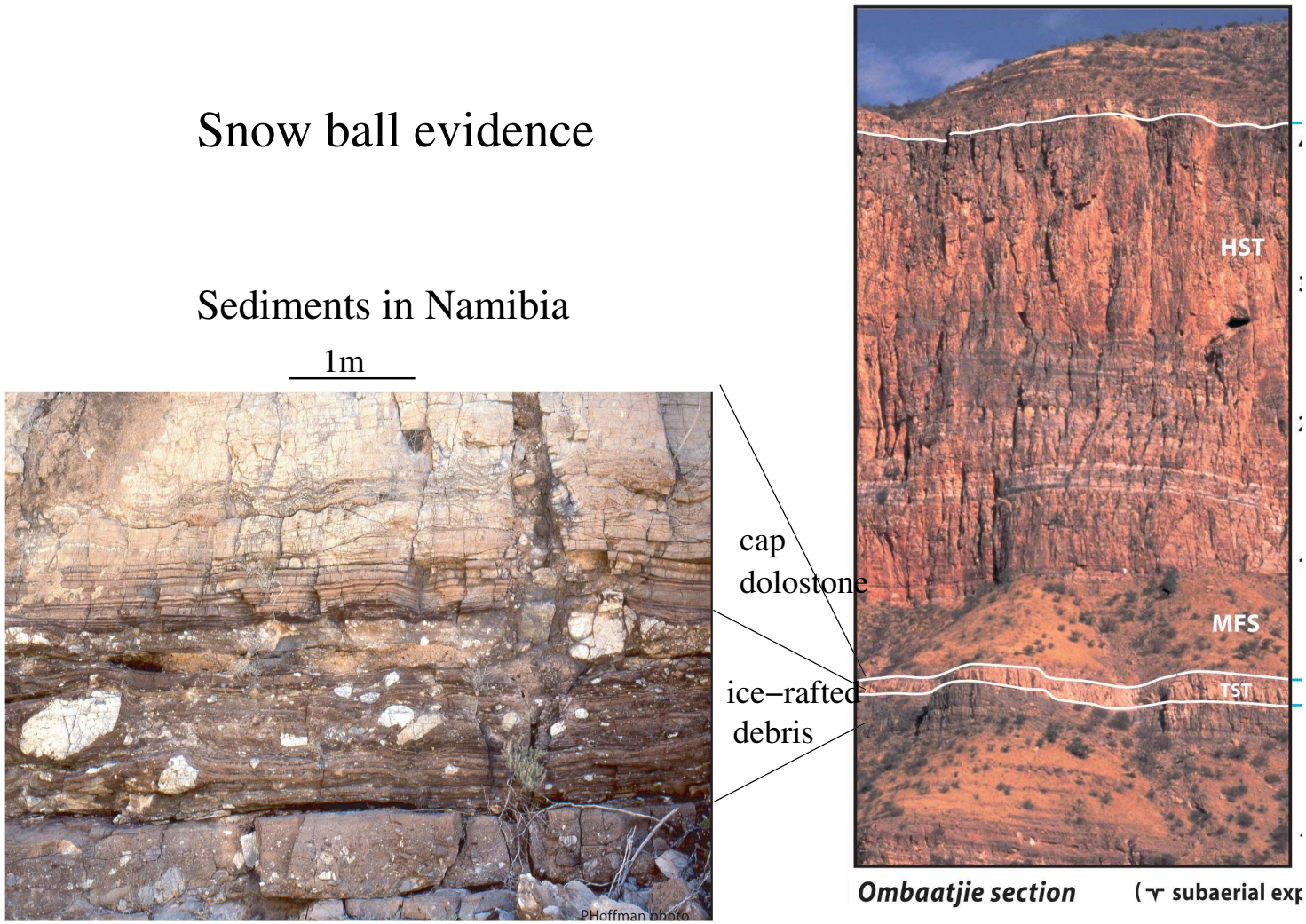
Equilibrium states



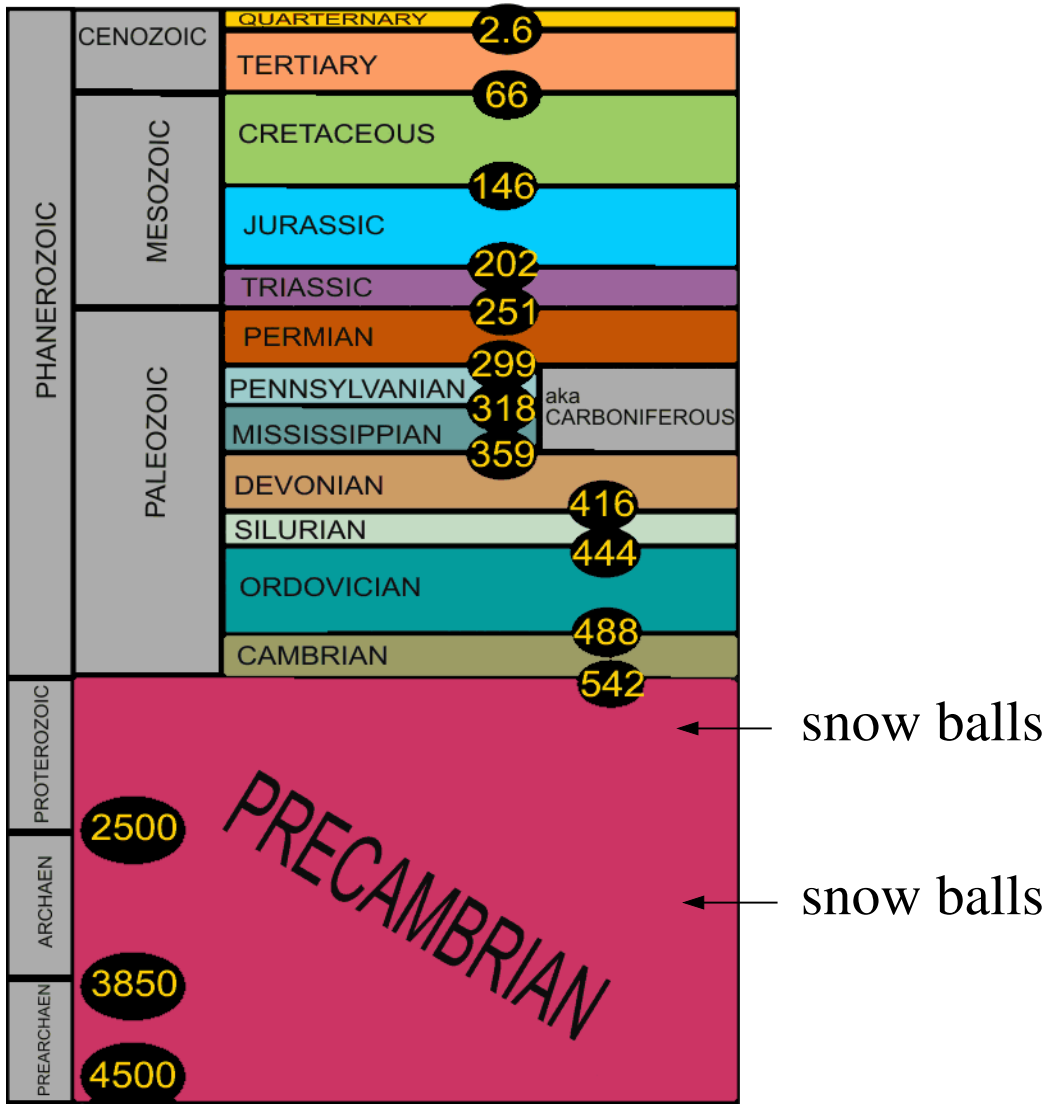
2) Variations at geological time scales

Snow ball evidence

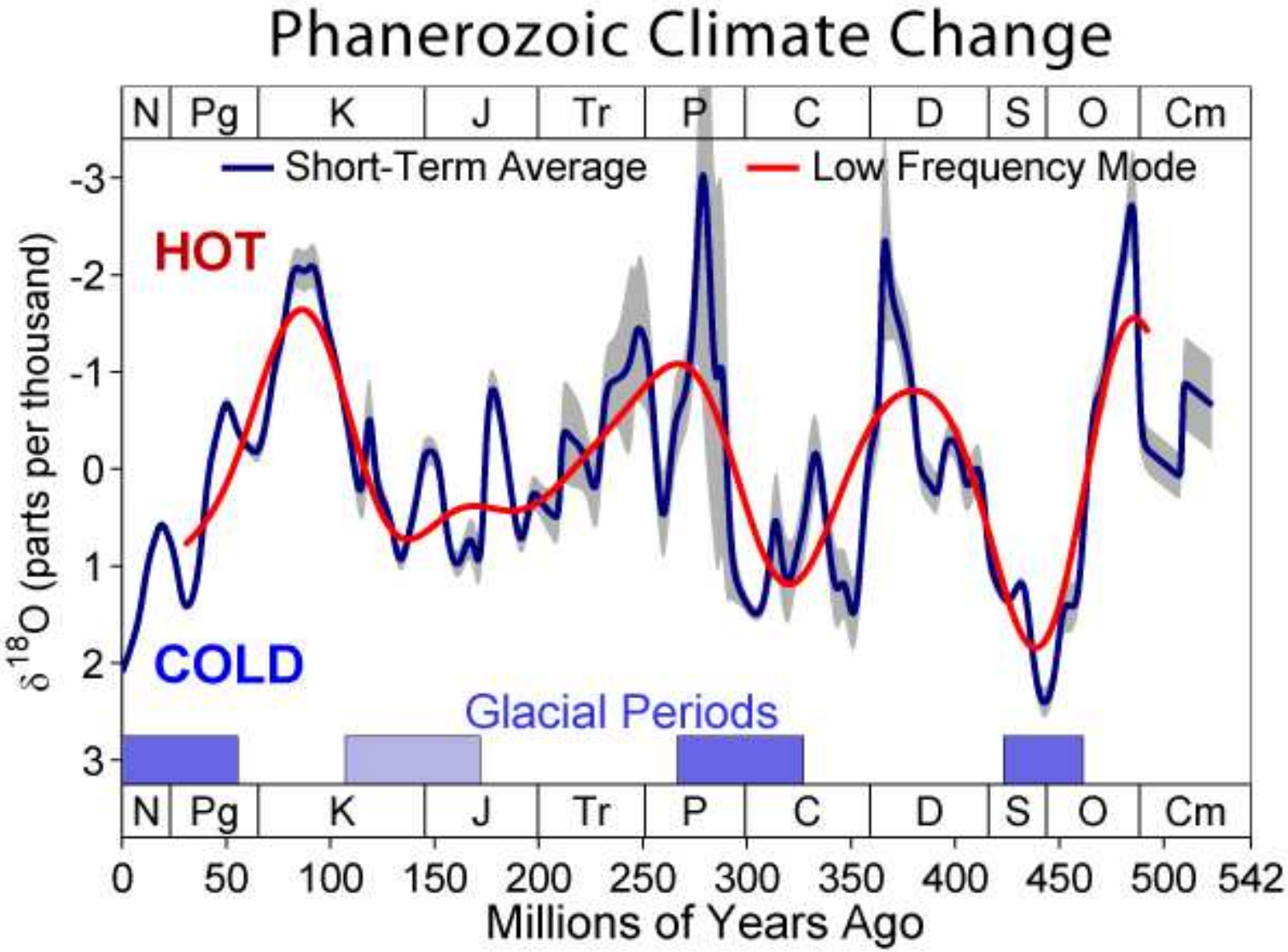
Sediments in Namibia



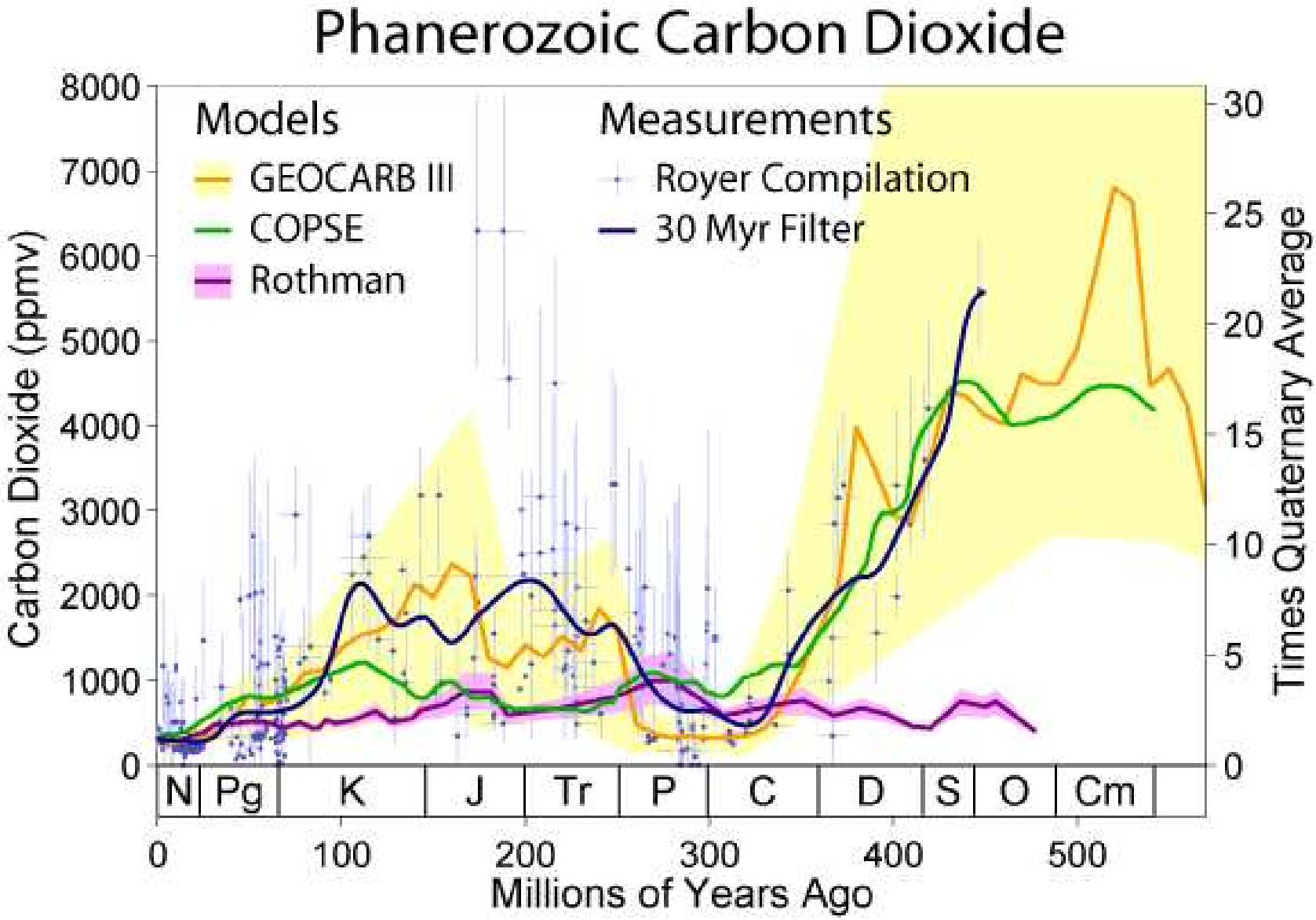
Snow ball earths in Earth's history



Geological evolution of temperature



Geological evolution of CO2



Carbon cycle

- sources ans sinks?

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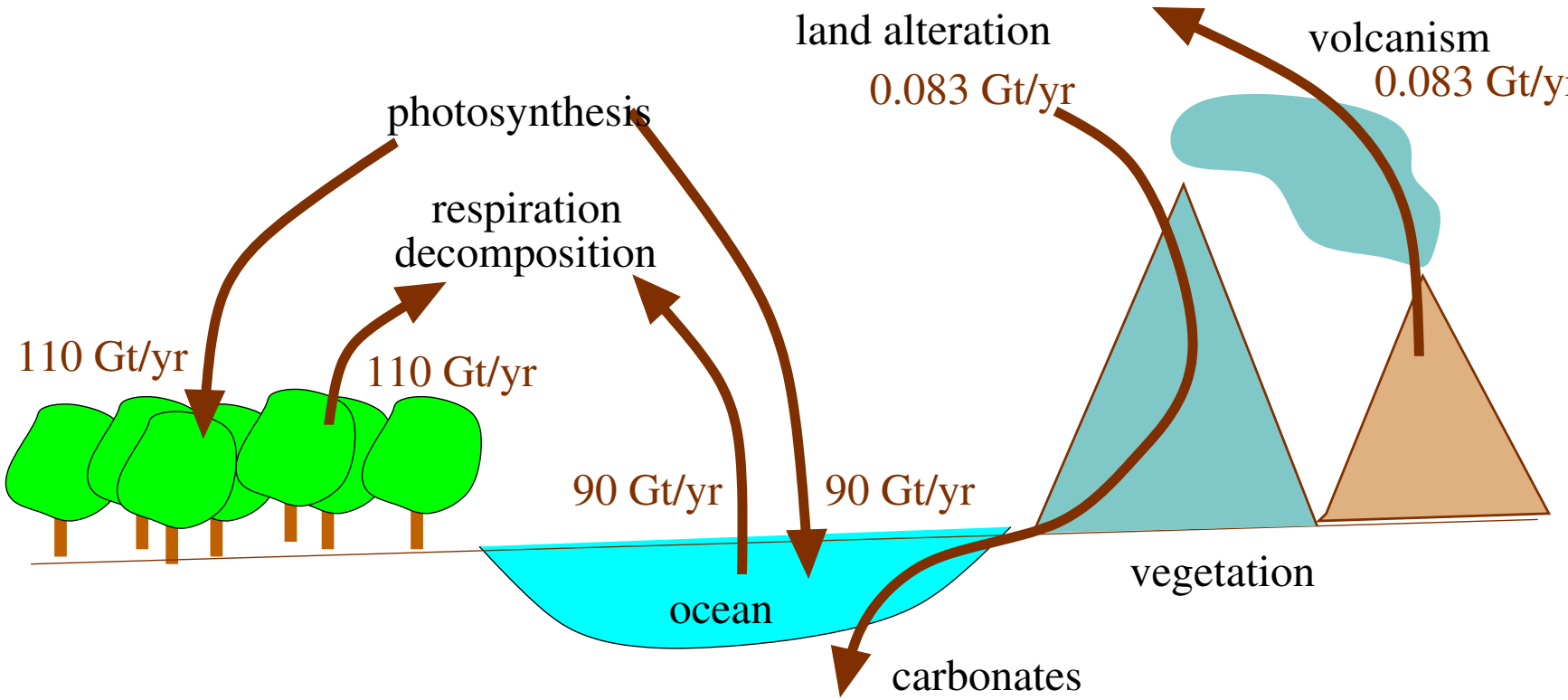

Carbon cycle

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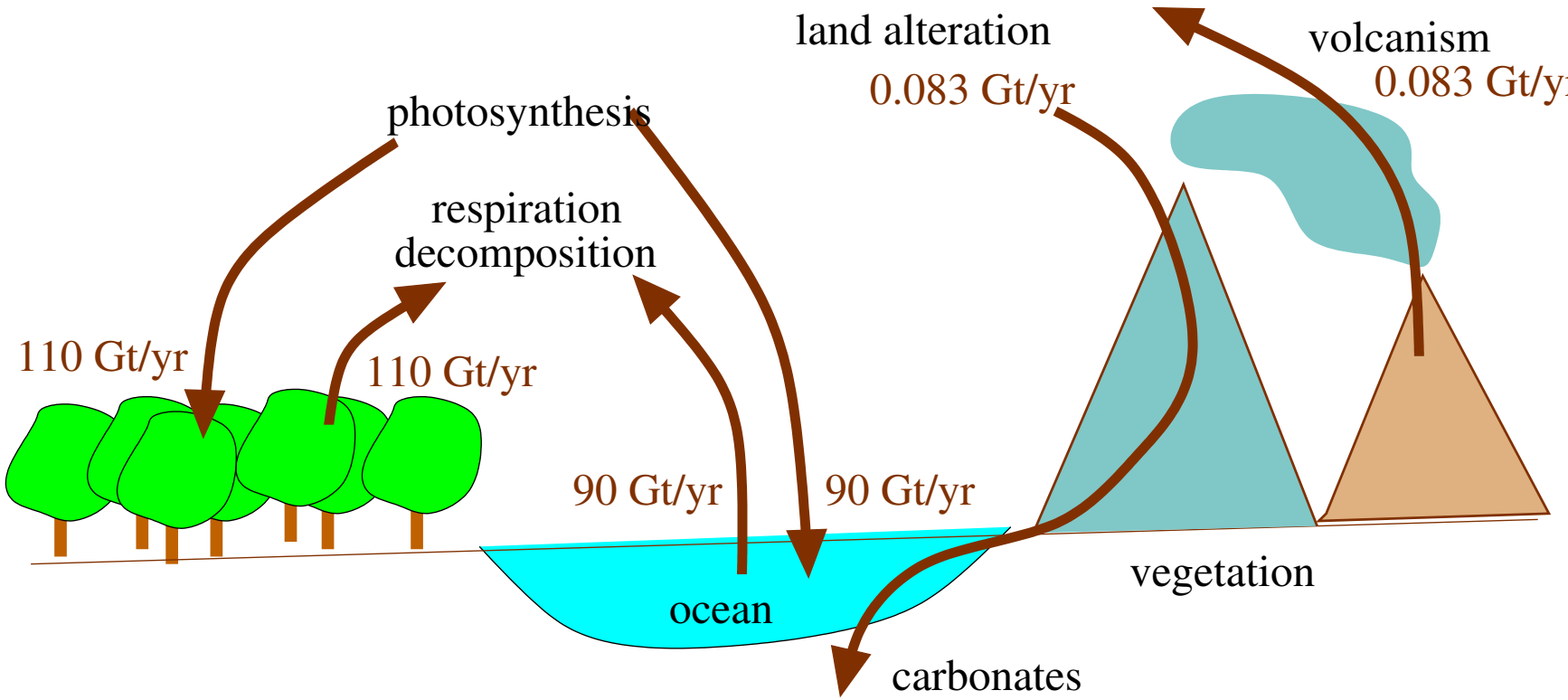
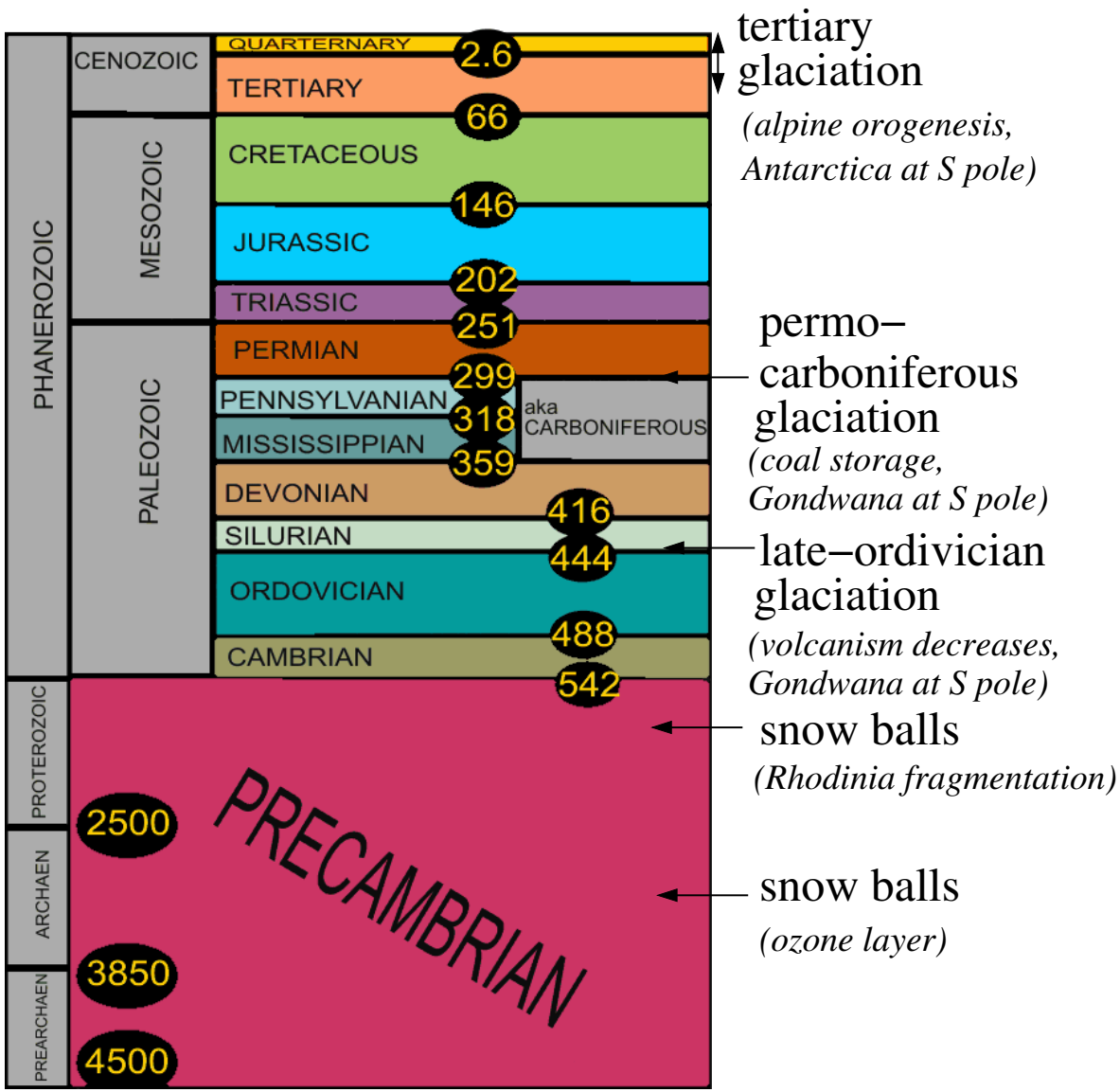


- exercise 2.2

Partial summary (1/2)



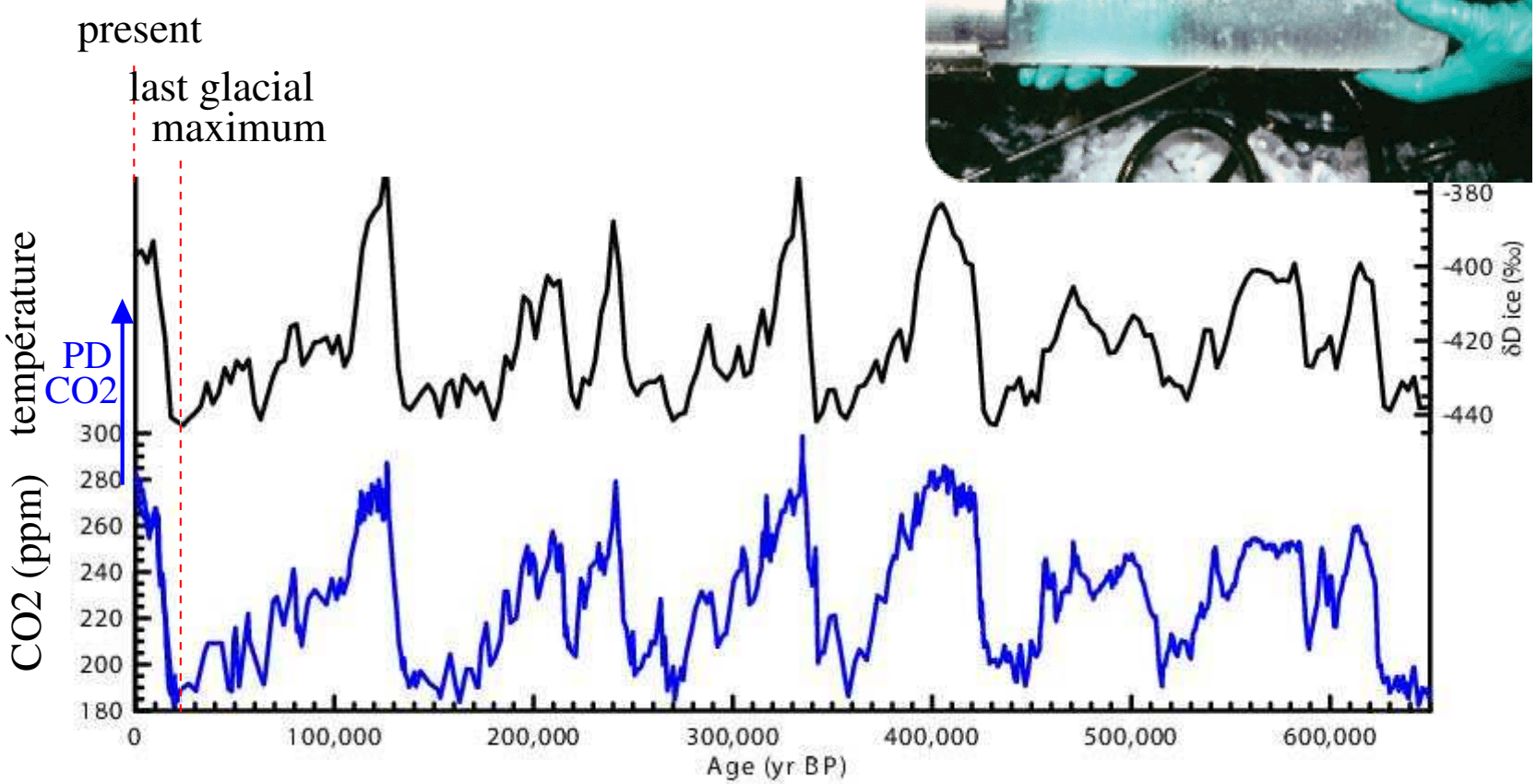
Partial summary (2/2)

- There has been extreme variations in Earth climate in the past
- Climate variations are due to perturbations of the radiative balance
- Natural CO2 variations have played a key role in the past
- Some climate variations are not reversible beyond some thresholds

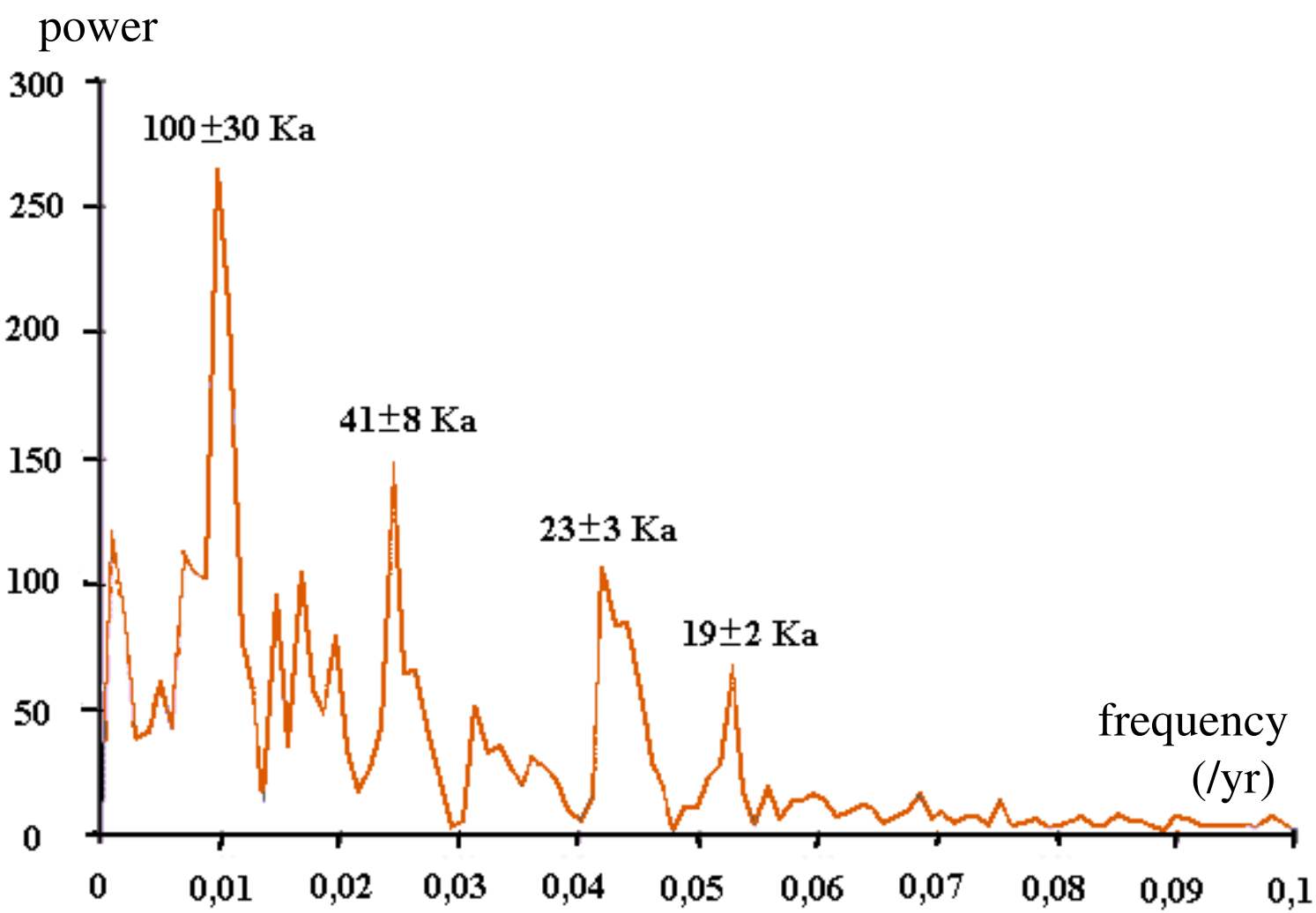
3) Climate variations at orbital time scales

Glacial-interglacial cycles

Vostok ice_core records

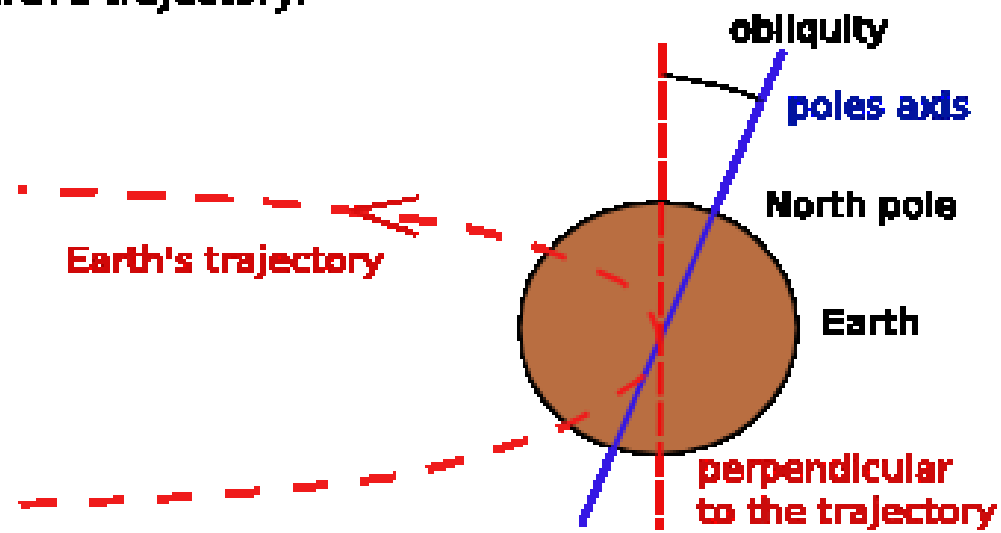


Spectral analysis

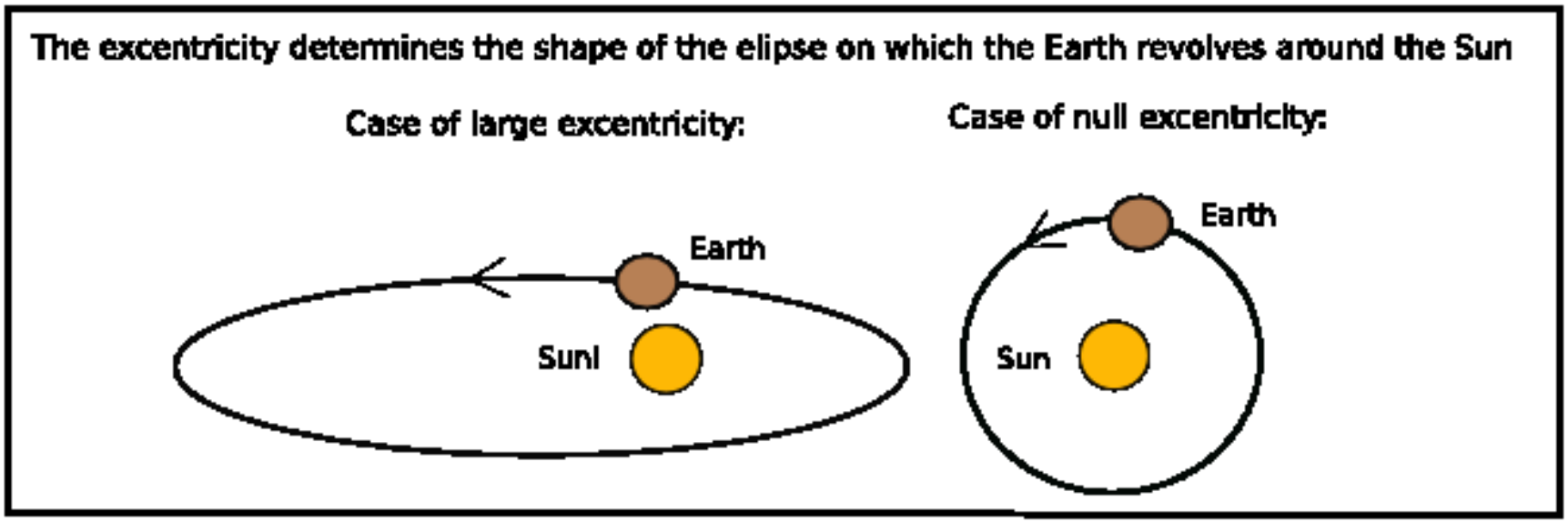


Obliquity

The obliquity is the inclination angle of the poles axis relatively to the perpendicular to the Earth's trajectory:



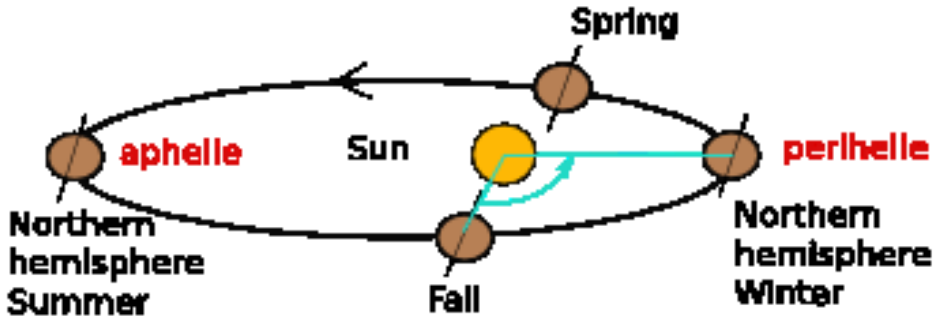
Excentricity



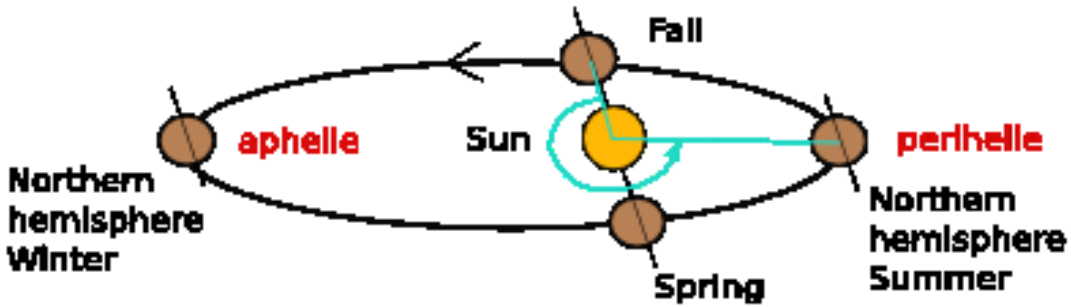
Precession

The precession determines the evolution of the proximity to the Sun during the seasonal cycle

For example, now, the Earth is closest to the Sun during the Northern hemisphere winter:



10 000 ago, it was the contrary:



Role of orbital parameters

- Exercise 3

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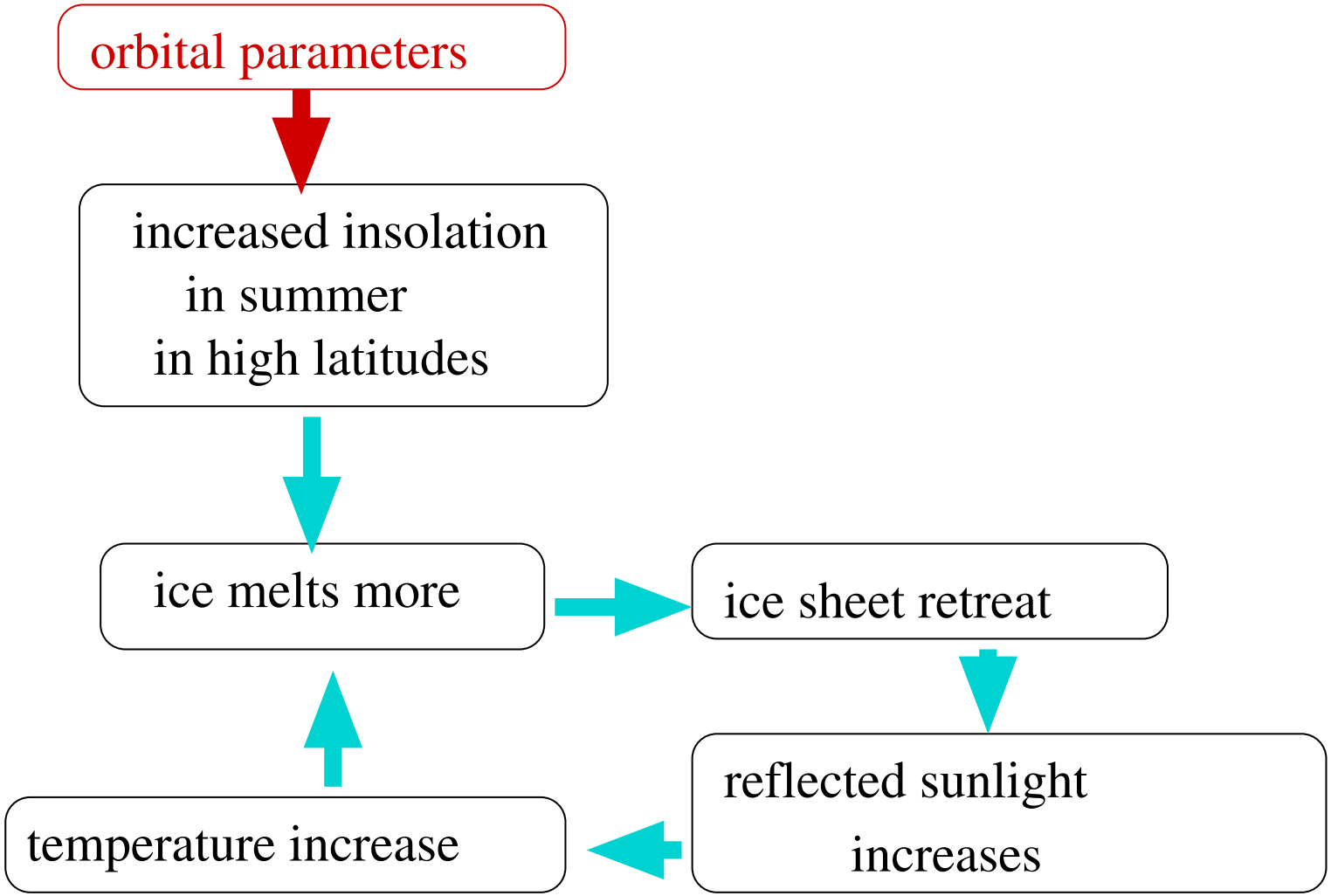
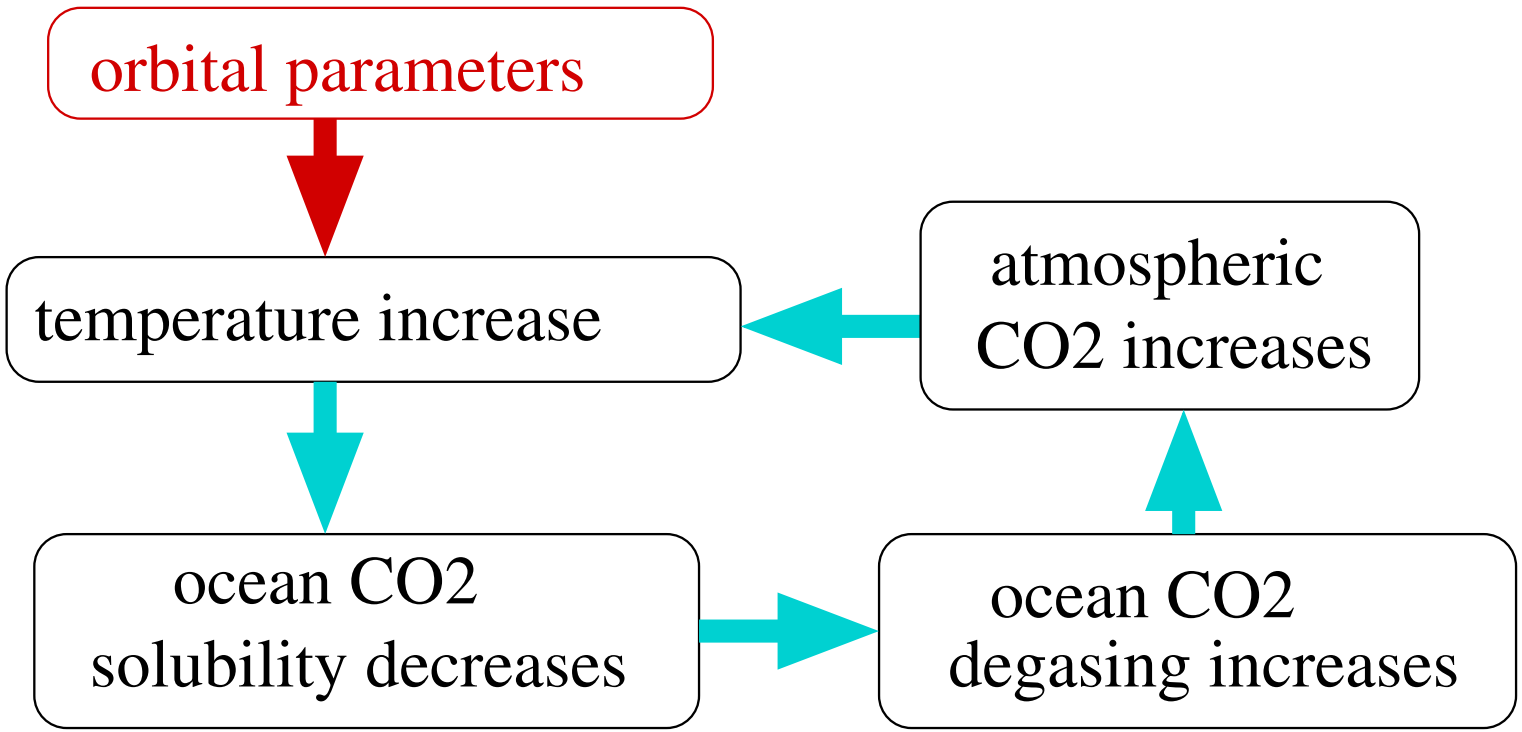
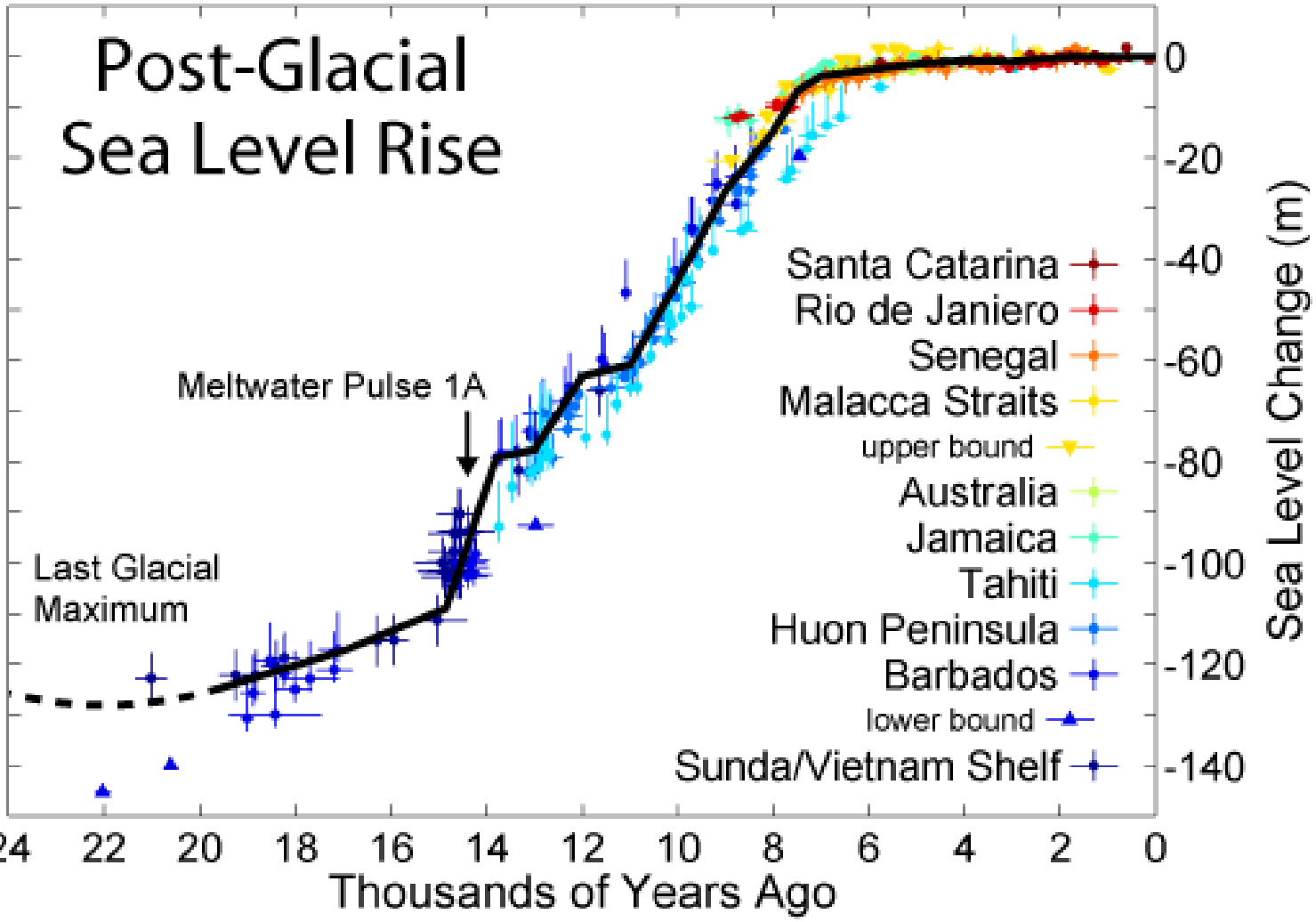
- Clonclusion: ice sheet feedback at orbital scale



Carbon cycle feedback

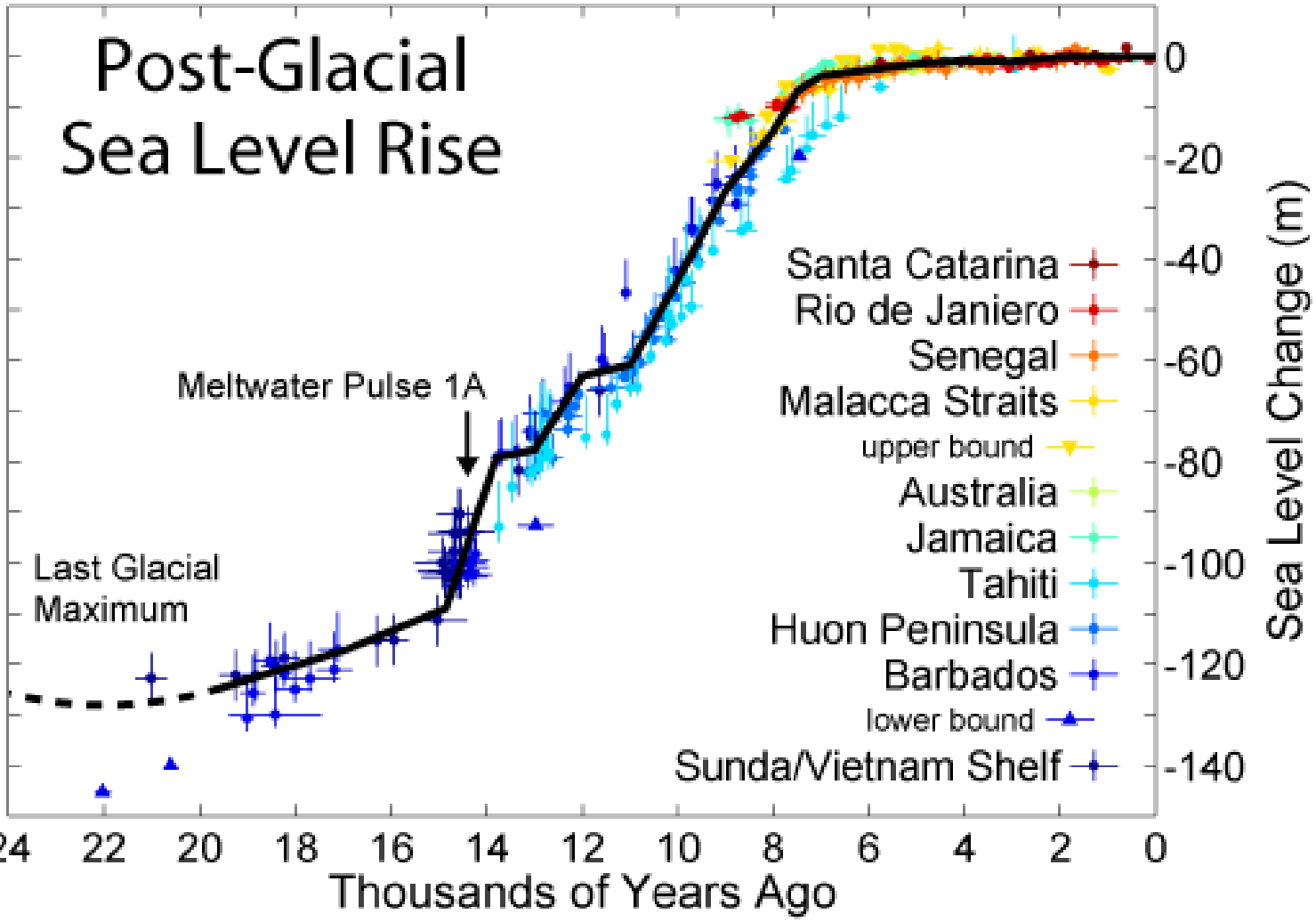


Impact on sea level



Causes?

Impact on sea level



Causes?

- thermal dillatation
- ice-sheet melt

Partial summary

- Climate varies naturally at the scale of tens of thousands years
- We are in an interglacial period, but CO2 concentration is anomalously high
- Past variations allow us to test our conceptual understanding of climate feedbacks and to test the realism of climate models used for projections.

4) Anthropogenic climate change

- exercise 4.1

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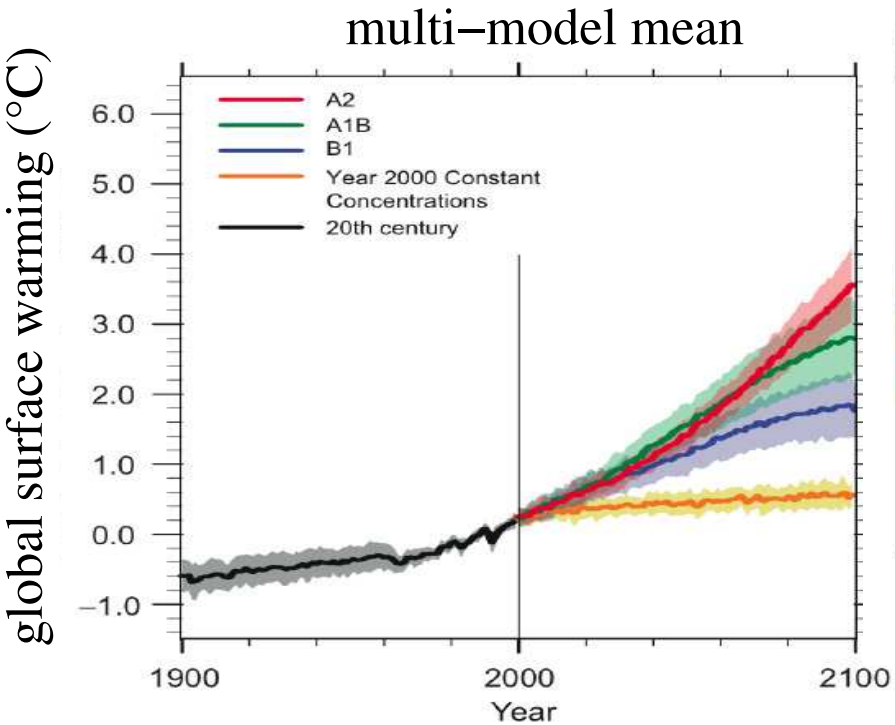
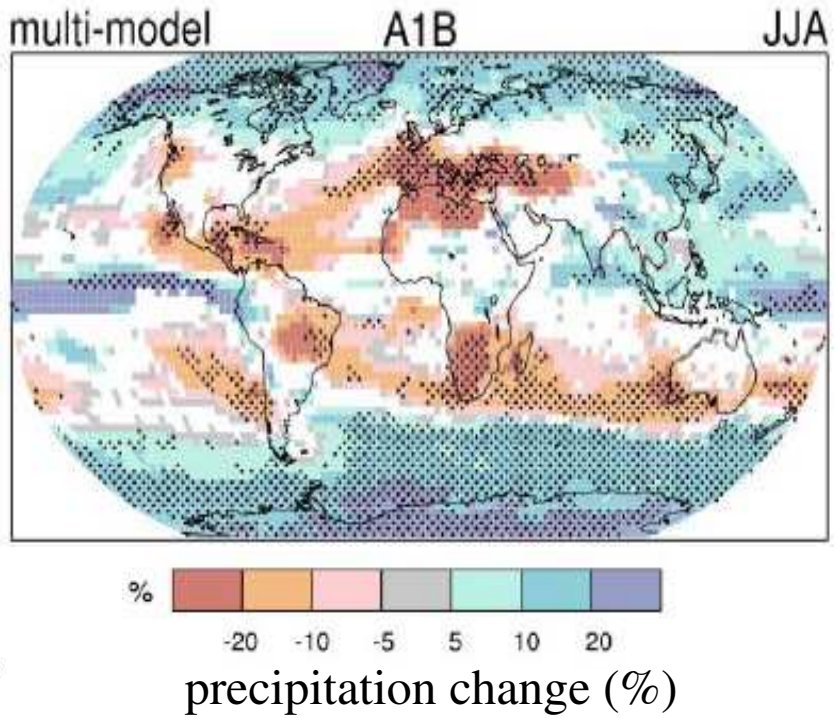
- exercise 4.1
- IPCC projections:





Carbone cycle feedbacks

- exercise 4.2

Carbone cycle feedbacks

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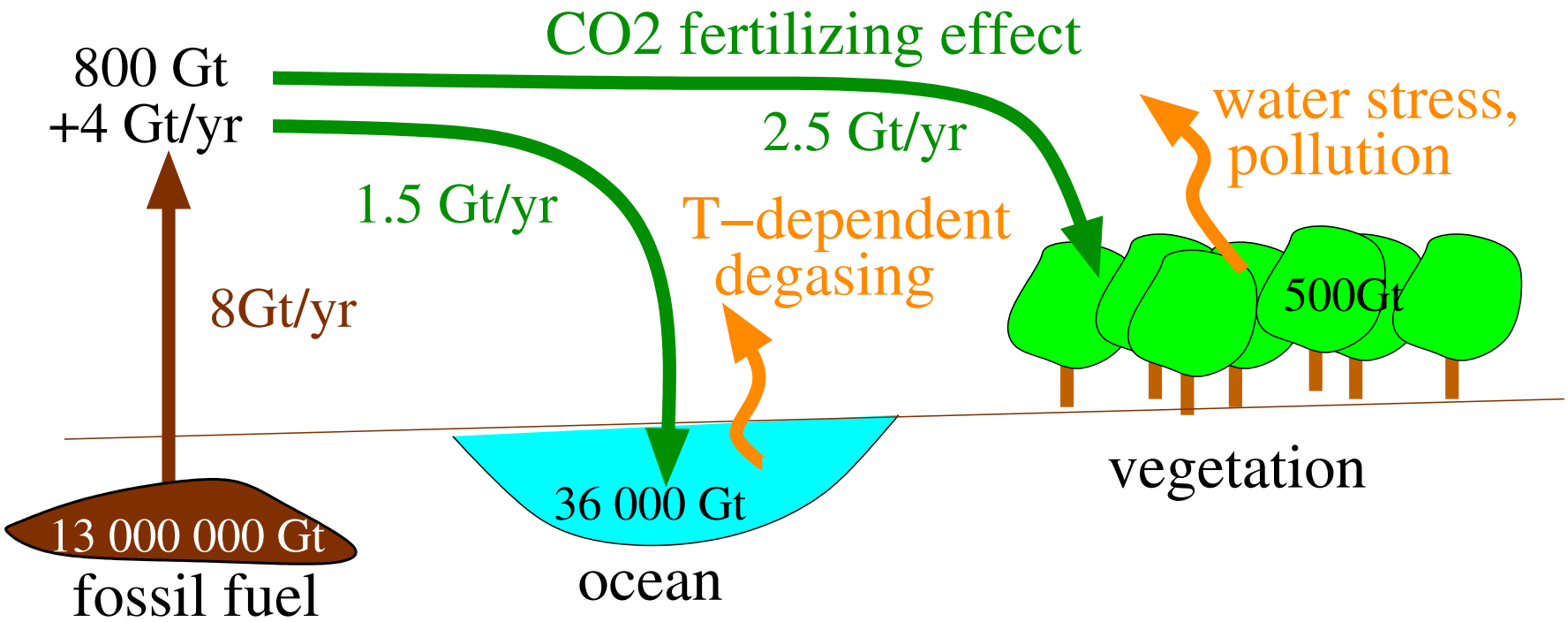
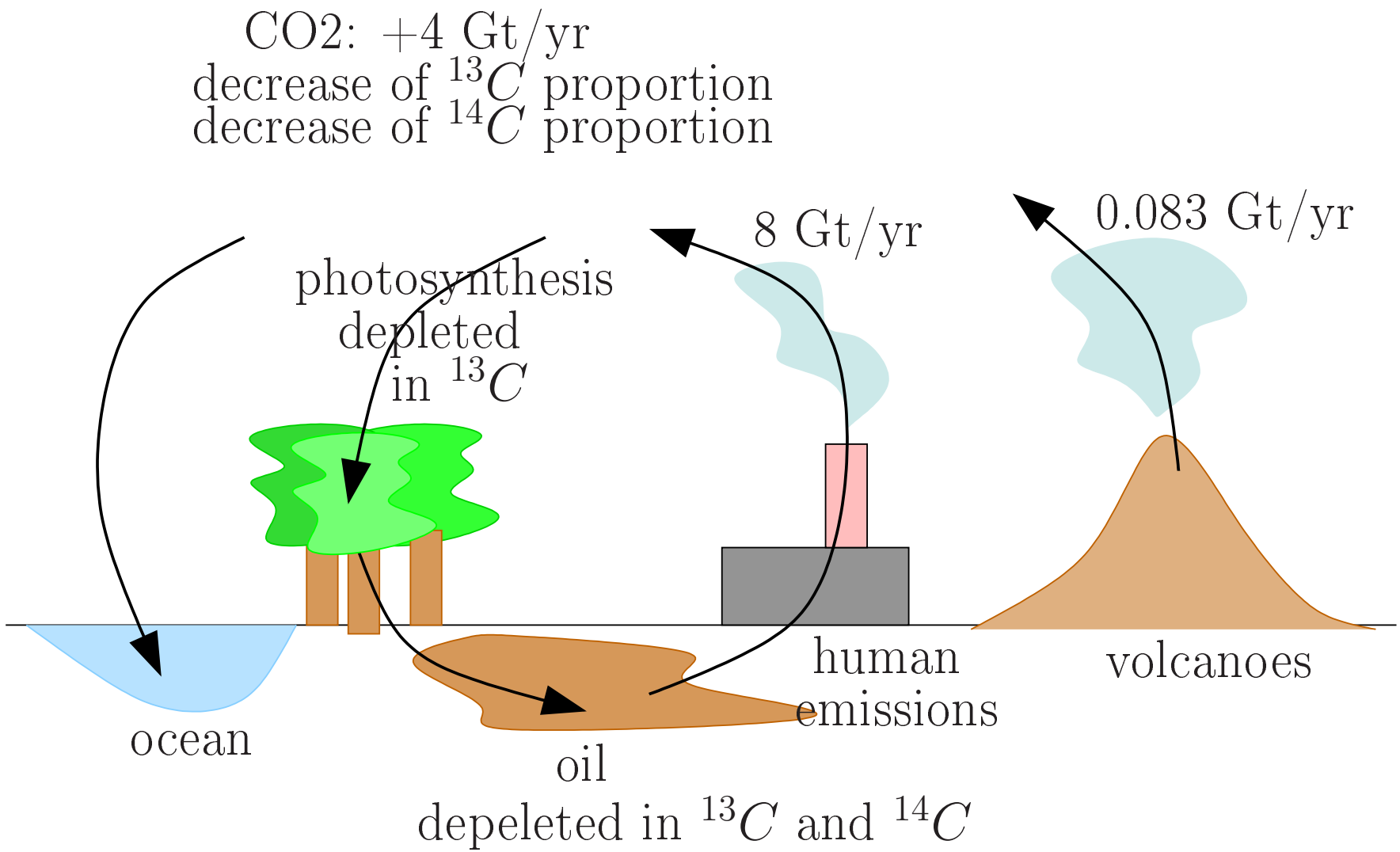


Are we sure CO2 increase is anthropogenic?

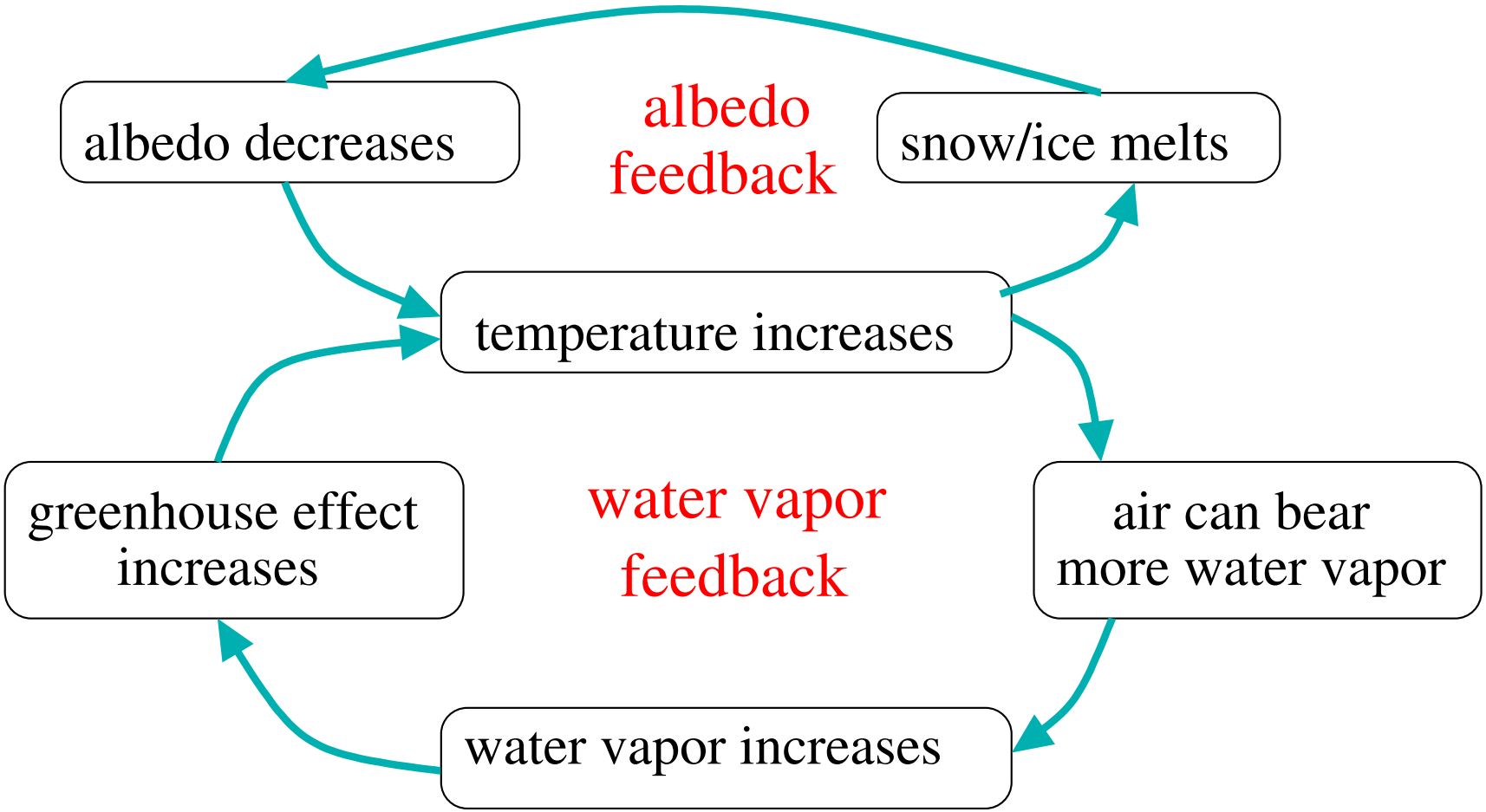


Climate feedbacks

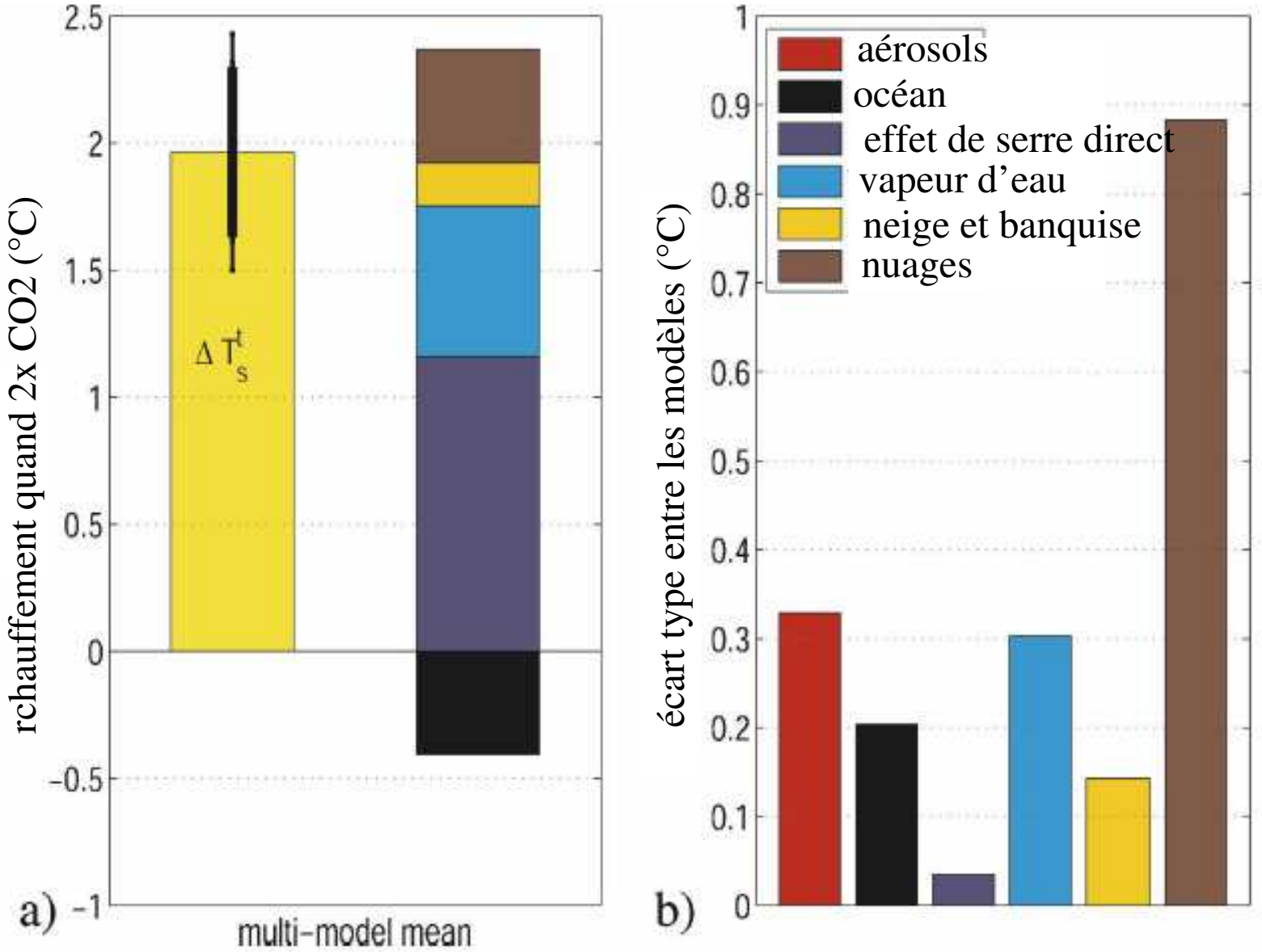
- exercise 4.3

Climate feedbacks

- exercise 4.3



Climate feedbacks: quantitative



Reversibility of changes

- exercise 4.4

Reversibility of changes

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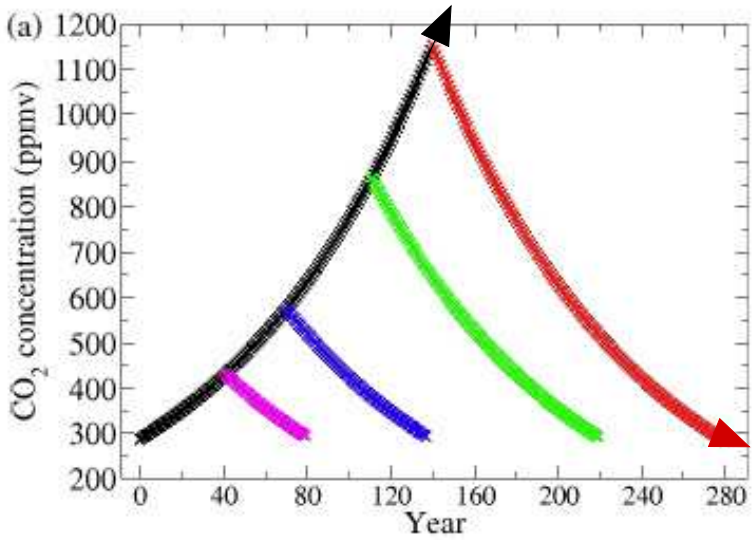

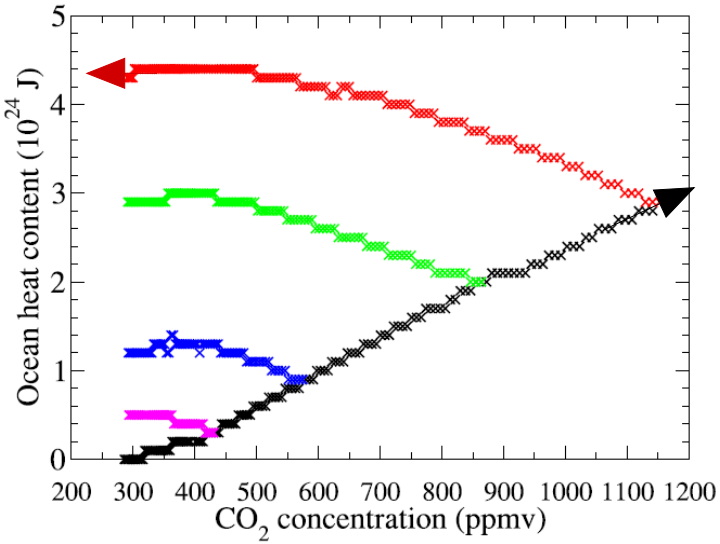

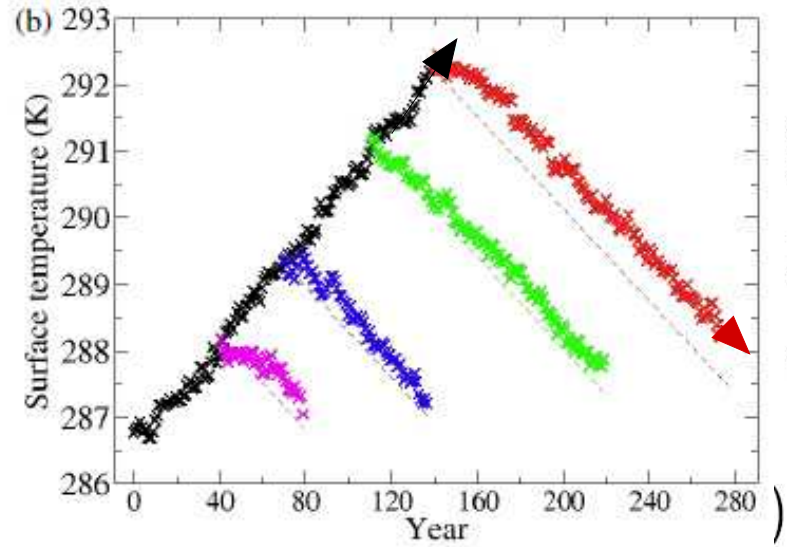

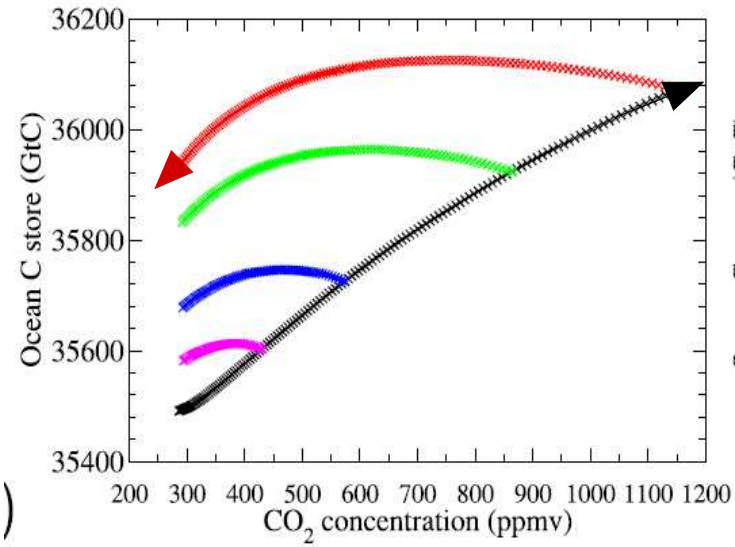

Summary

- Recent CO2 increase is anthropogenic
- This leads to an increase in temperature, which is doubled by climate feedbacks
- Still some uncertainties on some feedbacks (especially clouds) and on hydrological impacts of climate change
  $\Rightarrow$ work on evaluating/improving models still needed.
- Changes are not immediately reversible
  $\Rightarrow$ consequences for mitigation and adaptation strategies