IL006

http://www.go.warwick.ac.uk/climatechange

The challenges of climate change

Lecture 1
How do we understand past climate?
(or 4.5 billion years of climate history)

Outline of course

- **Do we understand the science behind climate change?**
  - Historical climate
  - Basics of climate science
  - Modeling the climate
  - Understanding the uncertainty
- **What are the implications of climate change?**
  - Biological/environmental implications
  - Economic political implications
- **What human actions can be taken to address climate change?**
  - Individual action
  - Political action
  - Technology
  - Economic action
  - Sources of inertia

Expectations

- Slides will go up online
- The lectures are being recorded and will be made available, but please try to be here.
- 2 hour lectures, we will generally take a break in the middle!
- Multi-choice questions each week from weeks 2-9.

Coursework/multichoice

- All versions of the course will include multi-choice questions (worth 10% of 15CAT, 20% of 7.5 CAT).
- Deadline each Friday BEFORE the lecture (i.e. 10am).
- The 7.5 CAT version of the course will include a 1 hour exam.
- The 15 CAT version of the course will include
  - Seminars
  - A 2500 word essay/literature review
  - A 3 hour exam to enable ideas to be developed in more depth.
  - **IF you are unsure about 7.5 vs 15 CAT it is easier to drop from 15->7.5 than the other way around.**

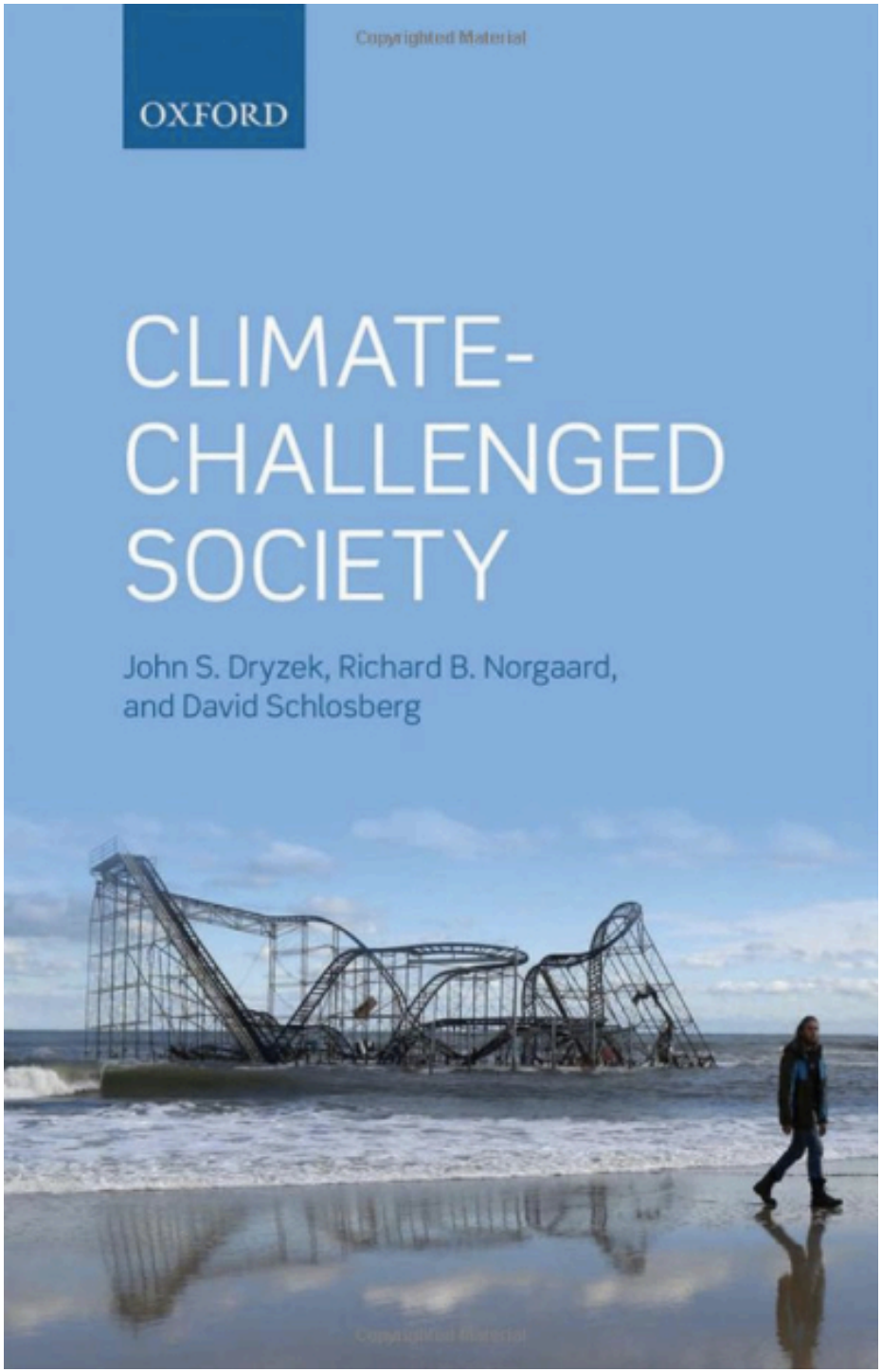
Seminars

- Seminars start next week for 15 CAT version.
- 1 hour per week, 9-10 or 10-11 on Thursdays.
- If you have a clash please email Amy Clarke in IATL (cc. to Andrew Levan and David Mond) and we will try to place you in the appropriate group.
  - Amy.Clarke@warwick.ac.uk
  - A.J.Levan@warwick.ac.uk
  - D.M.Q.Mond@warwick.ac.uk

Book

Climate challenged society:
Dryzek, Norgaard & Schlosberg,
OUP 2013

Particularly useful for second half of course (i.e. not needed first few weeks)



Feedback

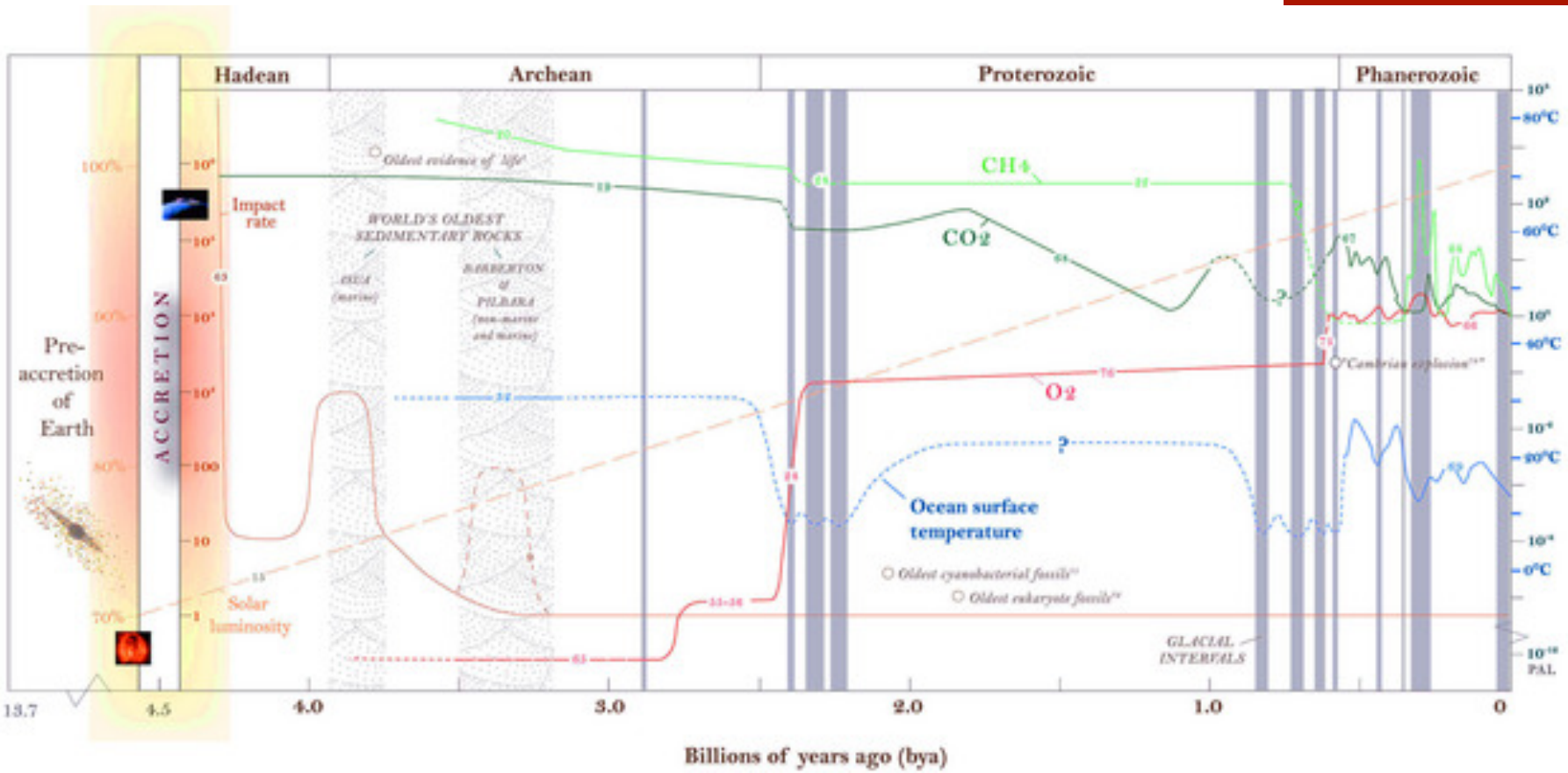
- This is a new course (now in its second year), from a range of different departments. We have made changes based on last years feedback, but it won't be perfect.
- Different lecturers will lecture in different styles (written vs powerpoint vs handouts etc).
- Please do interrupt if you think the lecturer is assuming too much background knowledge from their subject (chances are you won't be alone).
- Please do feedback what you think works, and what you think doesn't.
- A feedback form is available on the module website. It can be anonymous, but we're happy to talk to you about issues (nothing you say will be held against you).

Blog

- One suggestion last year was to have a blog that can be used to flag up interesting stories related to climate science.
- We will set one up, and some staff will add articles
- We welcome contributions from you!

Q1: How has climate varied over the lifetime of the planet?

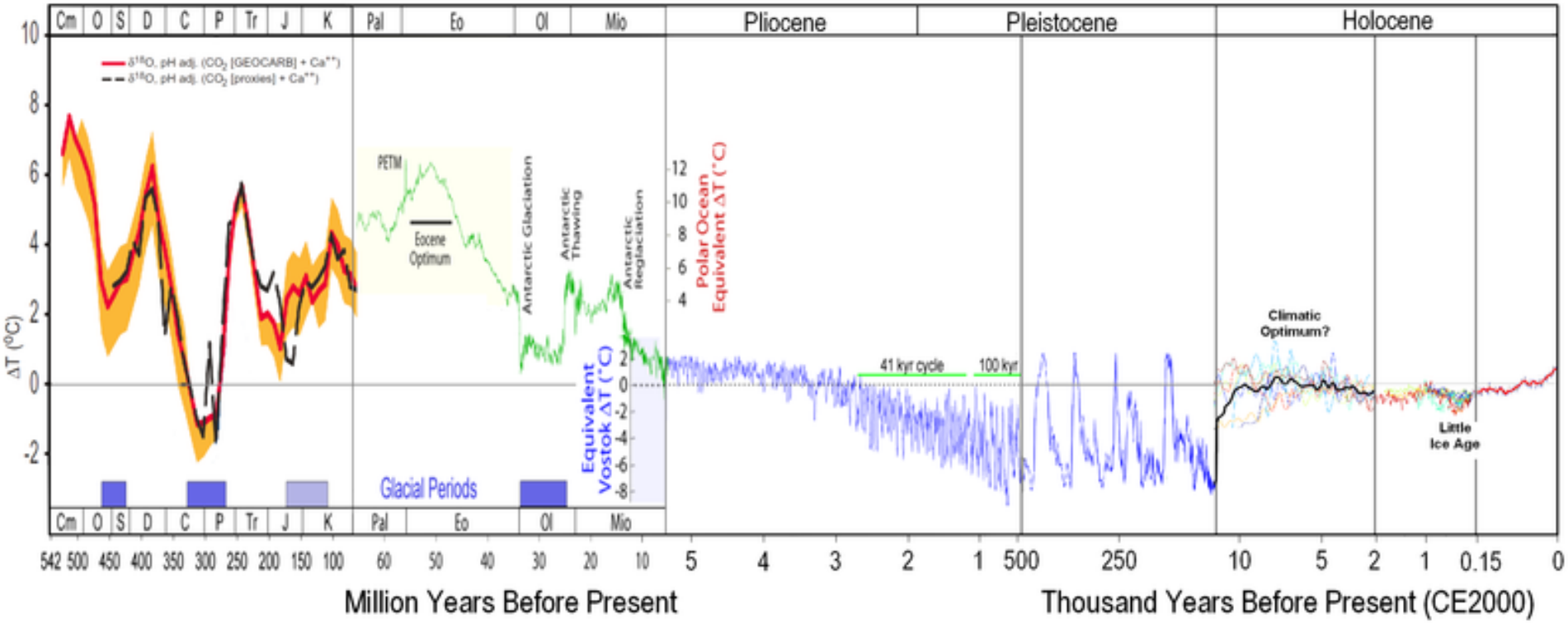
From then to now



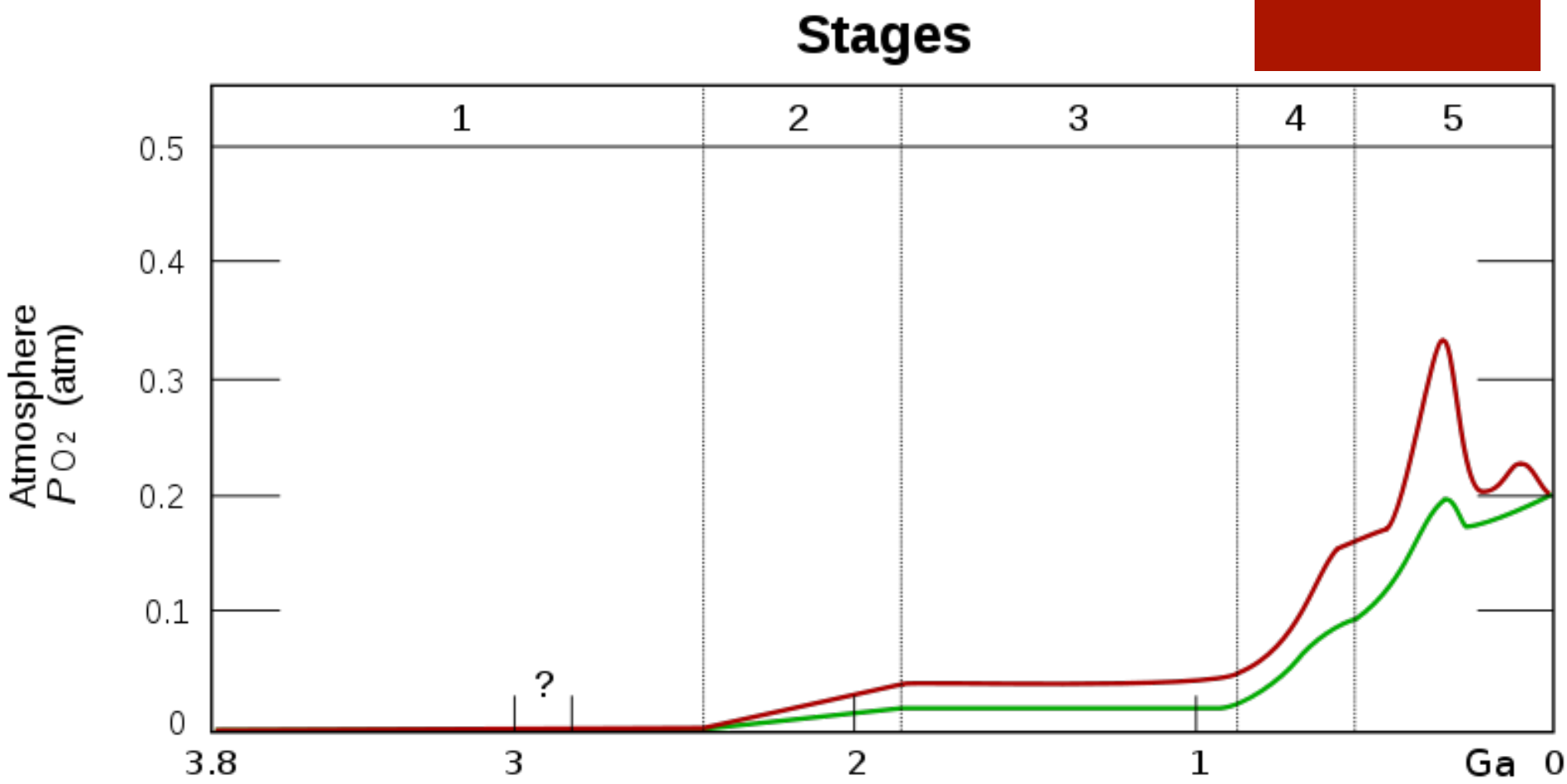
Add water, and wait

ESO

Temperature of Planet Earth

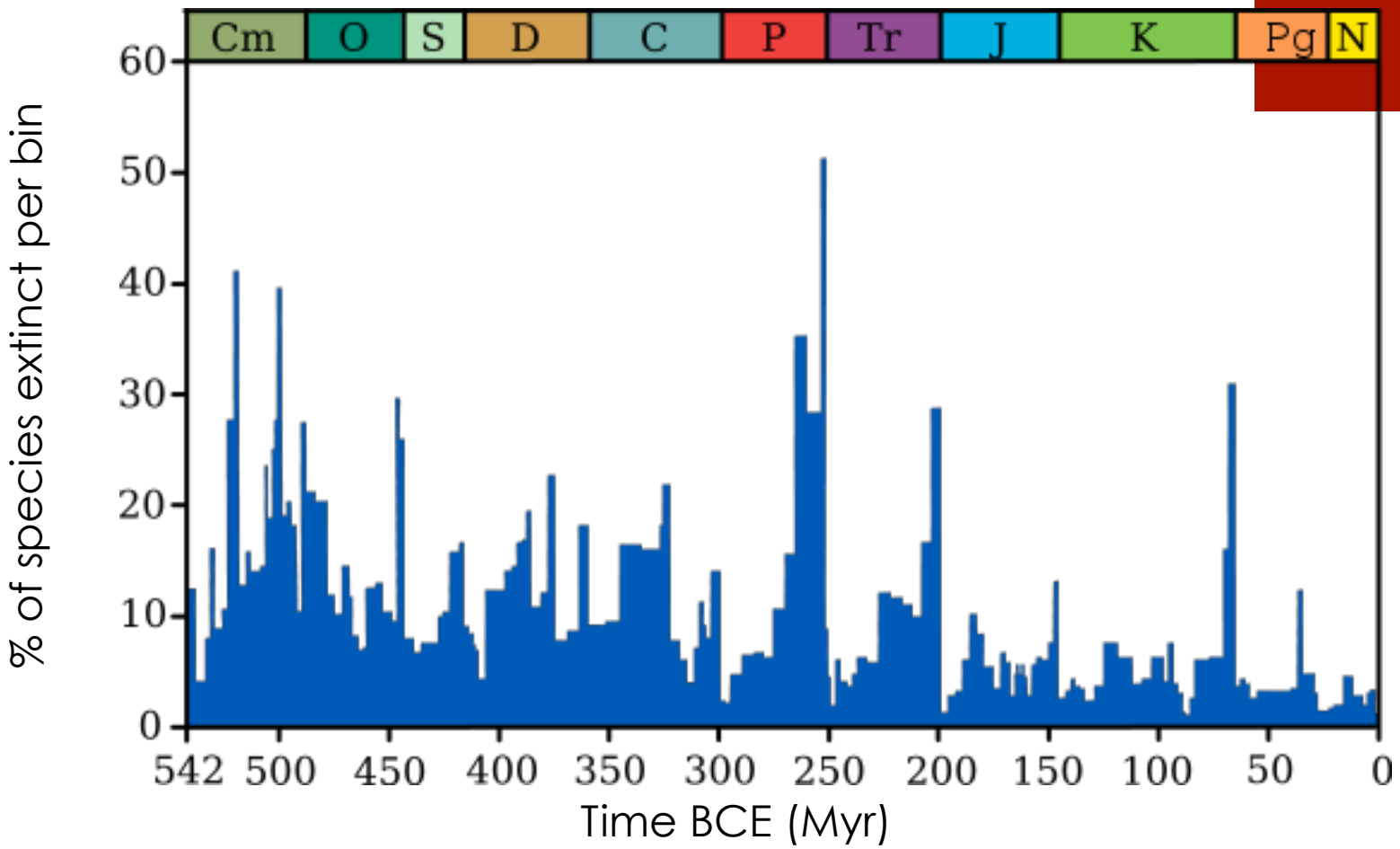


Early atmosphere – the "oxygen apocalypse"



Early photosynthesis changed the atmospheric structure of the planet, altered the greenhouse balance and wiped out much early life.

Mass extinctions

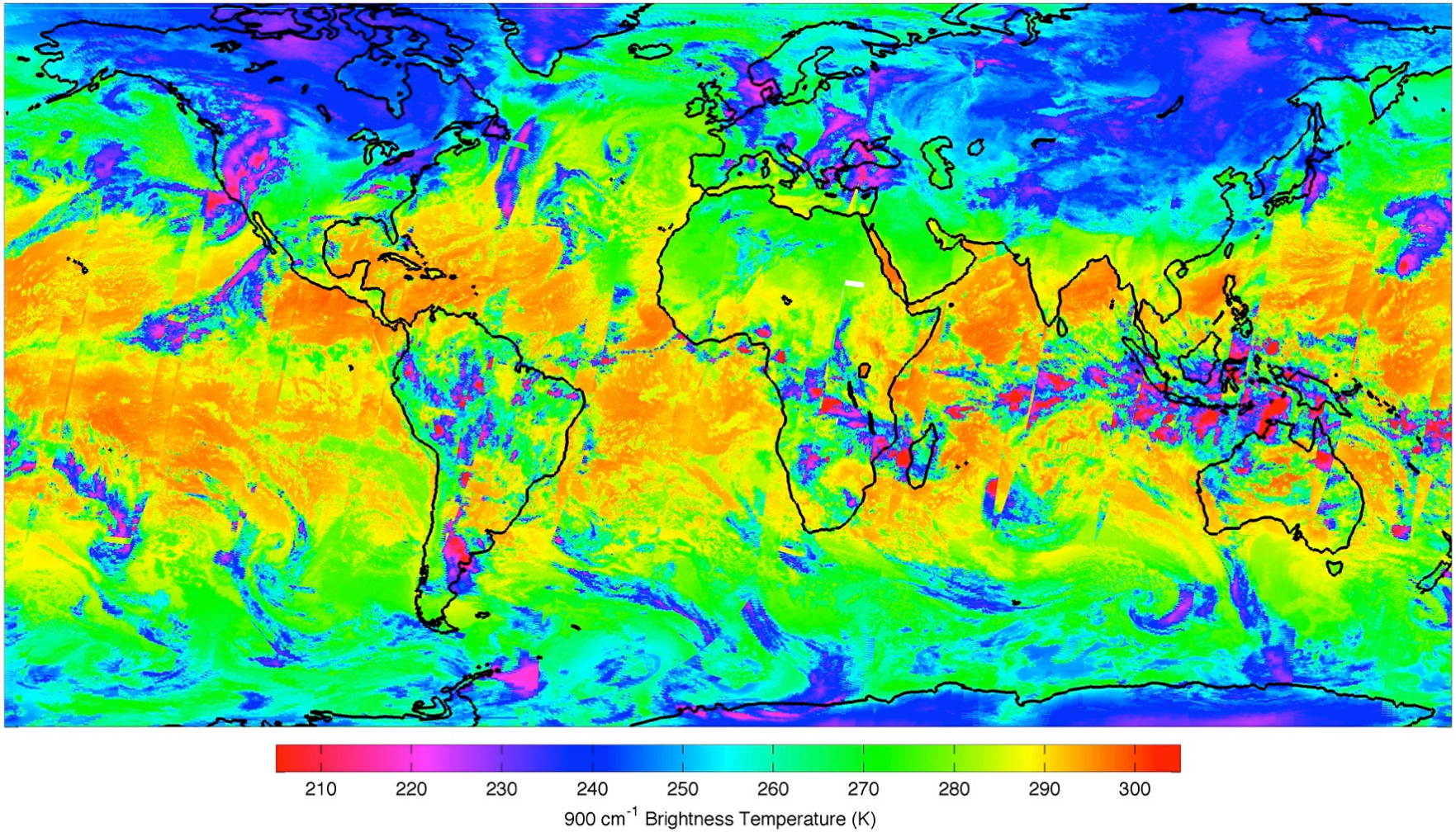


Climate change is not the trigger of most mass extinctions, but it is the driving force

Q2: How do we know?

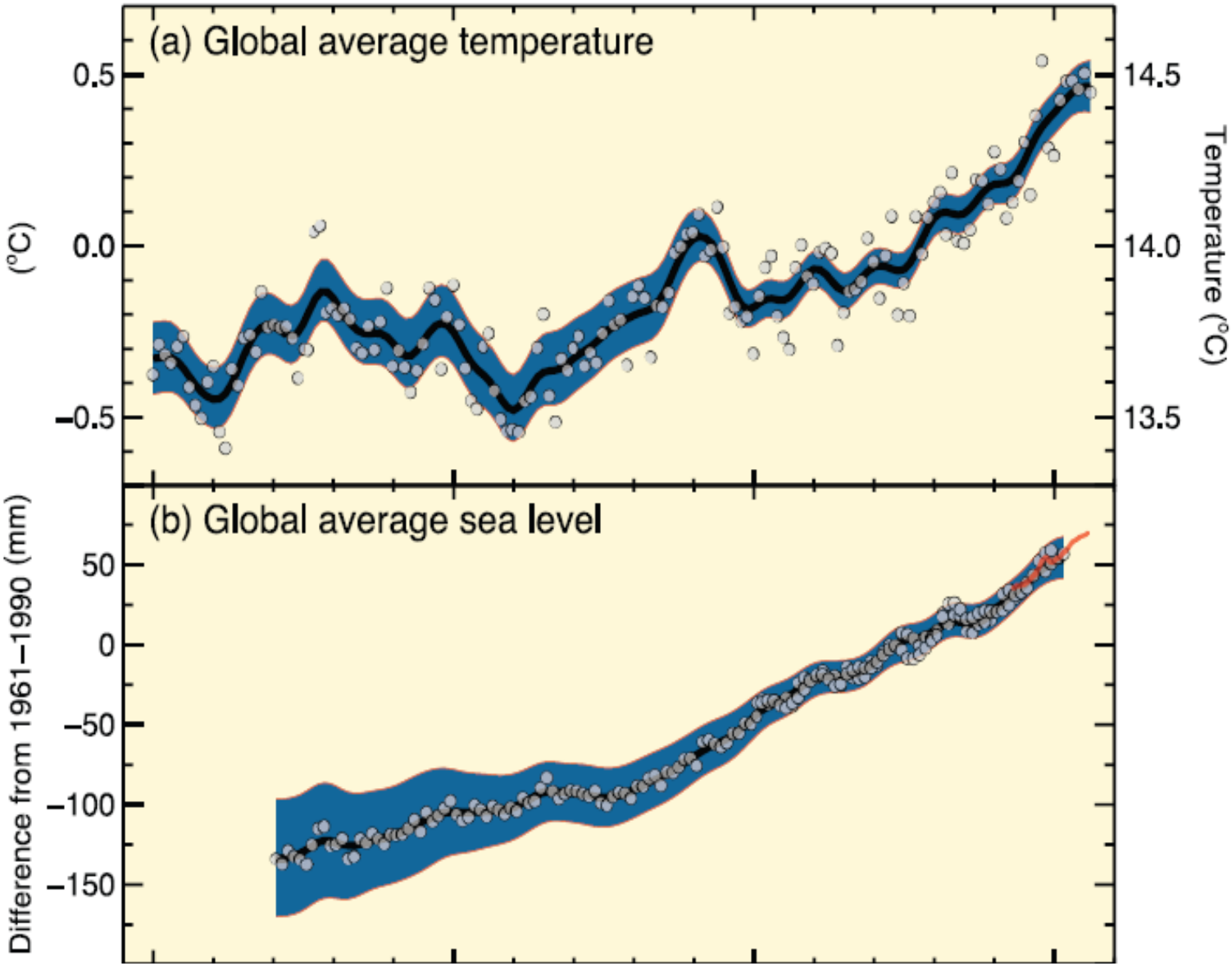
Recent history

- For the past ~30 years we have satellite temperature data, but its more difficult to calibrate than you think.
- Thermometer records go back for several hundred years, but with sparse geographical coverage.
- Crude proxies arise in crop growing records etc.



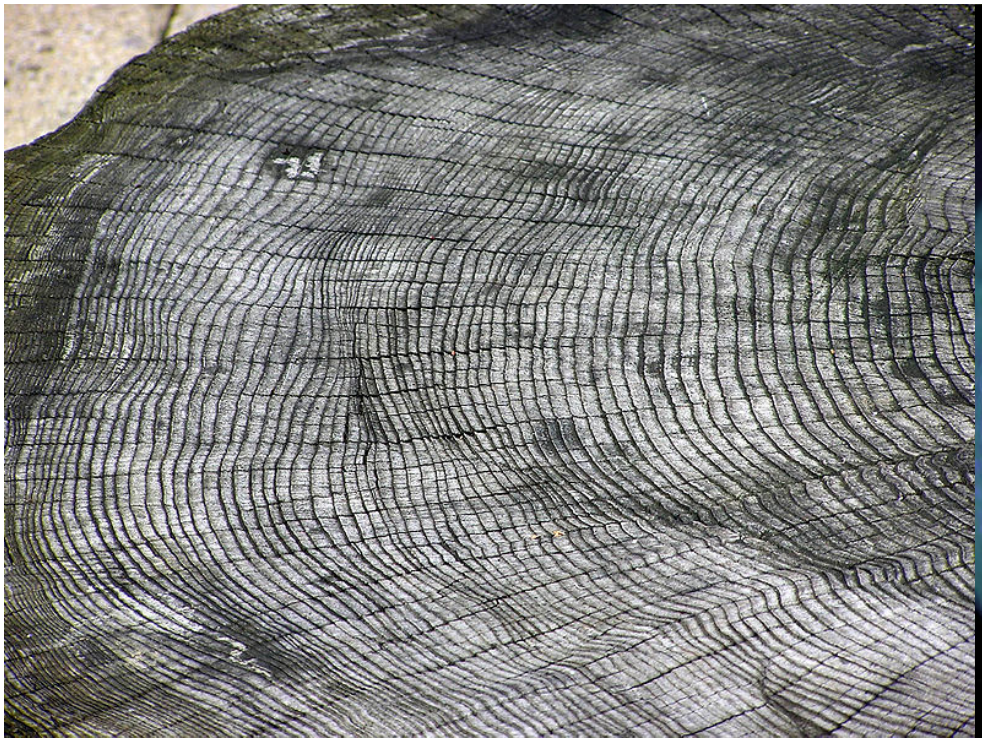
NASA Suomi IR sounder

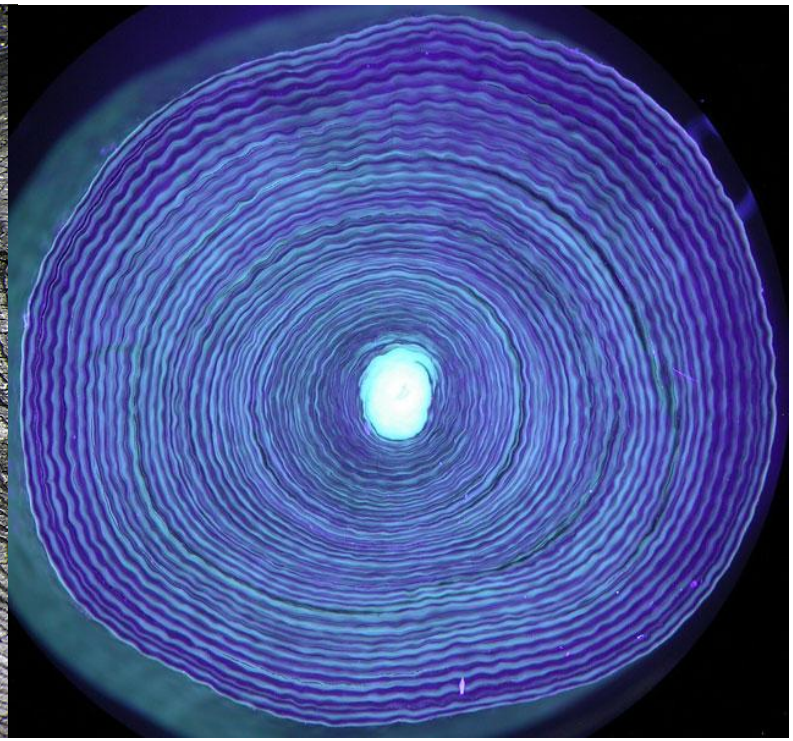
Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover



IPCC AR4

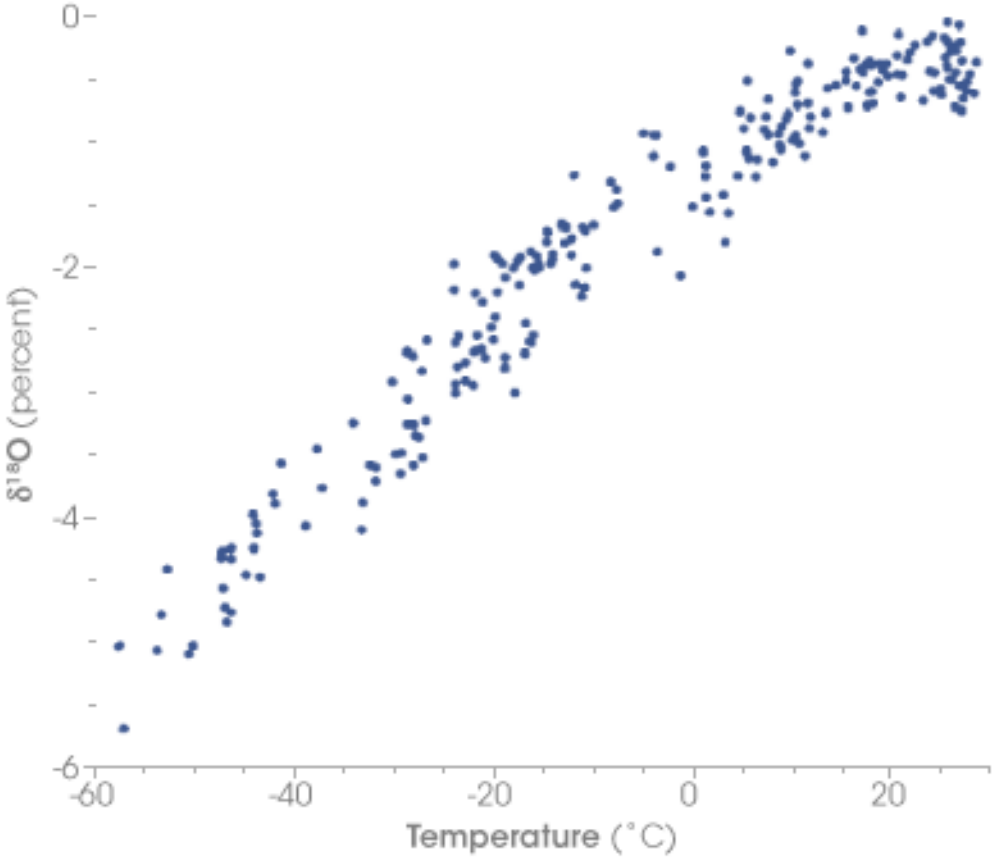
The past few thousand years

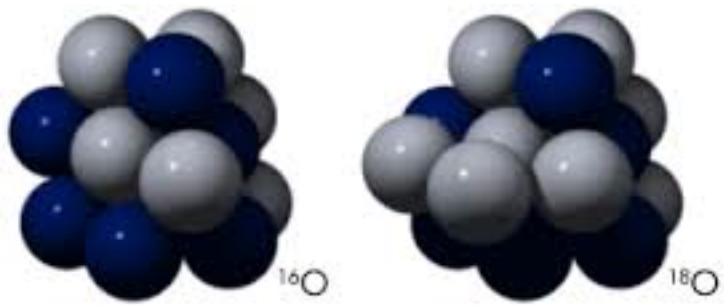




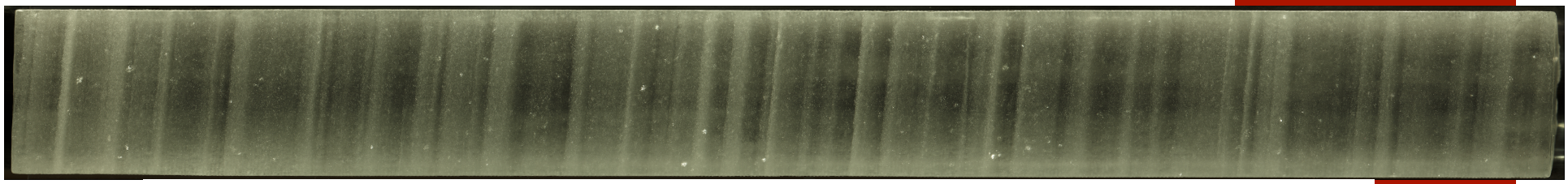
The past million years

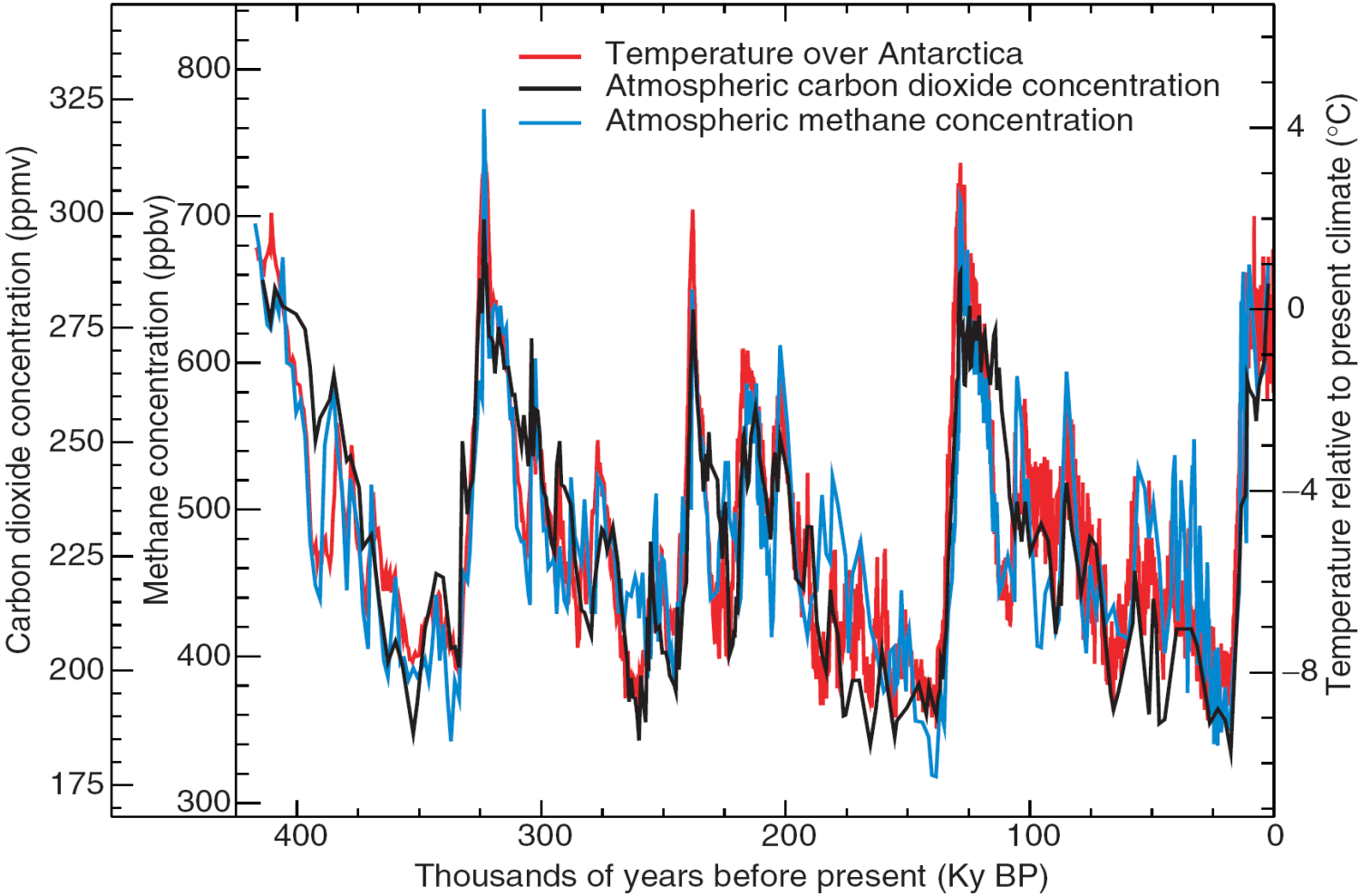
- Isotopic dating (Hydrogen/Deuterium, $^{12}C/^{13}C$, $^{16}O/^{18}O$)
- Differing molecular weights give different evaporation and condensation rates for water





Ice cores

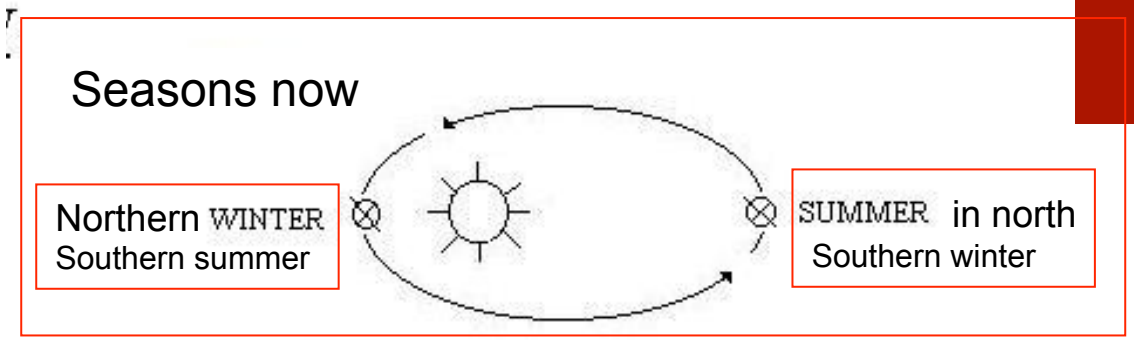




Note the ice ages!

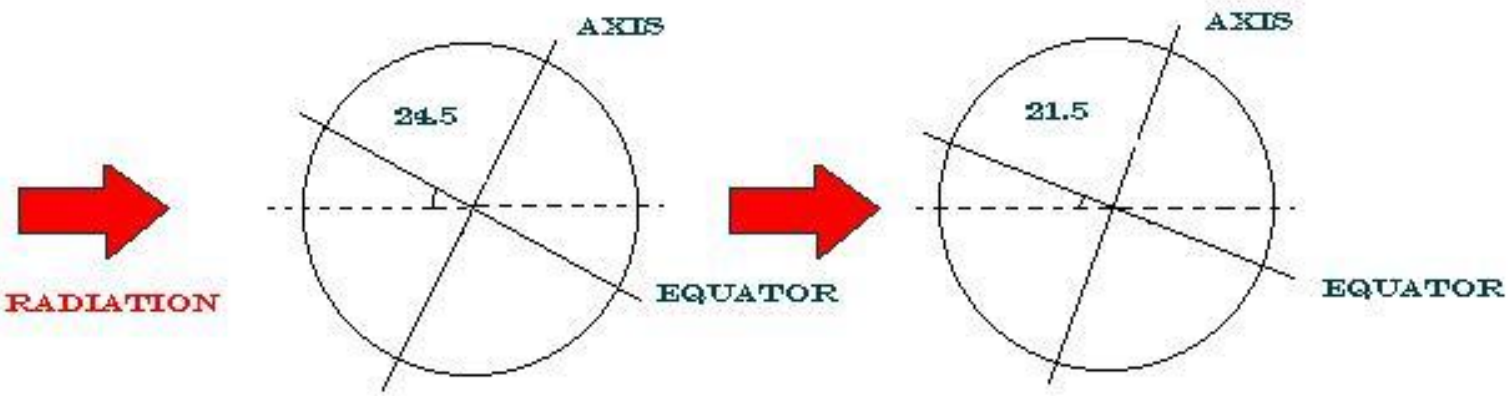
IPCC AR4

Long term orbital “Milankovich” cycles



http://www.homepage.montana.edu/~geol445/hyperglac/time1/milankov.htm

AXIAL TILT



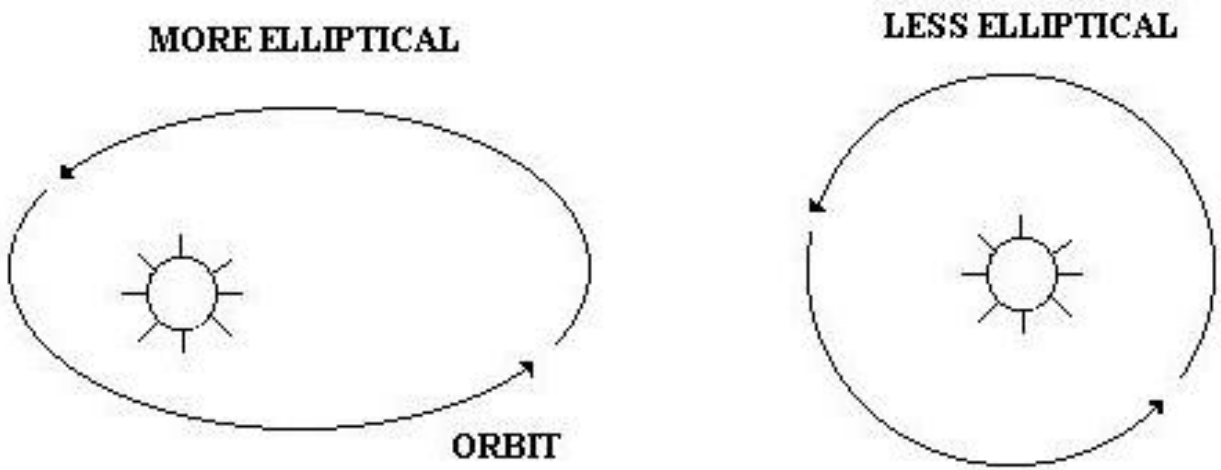
PERIODICITY:

41,000 YEARS

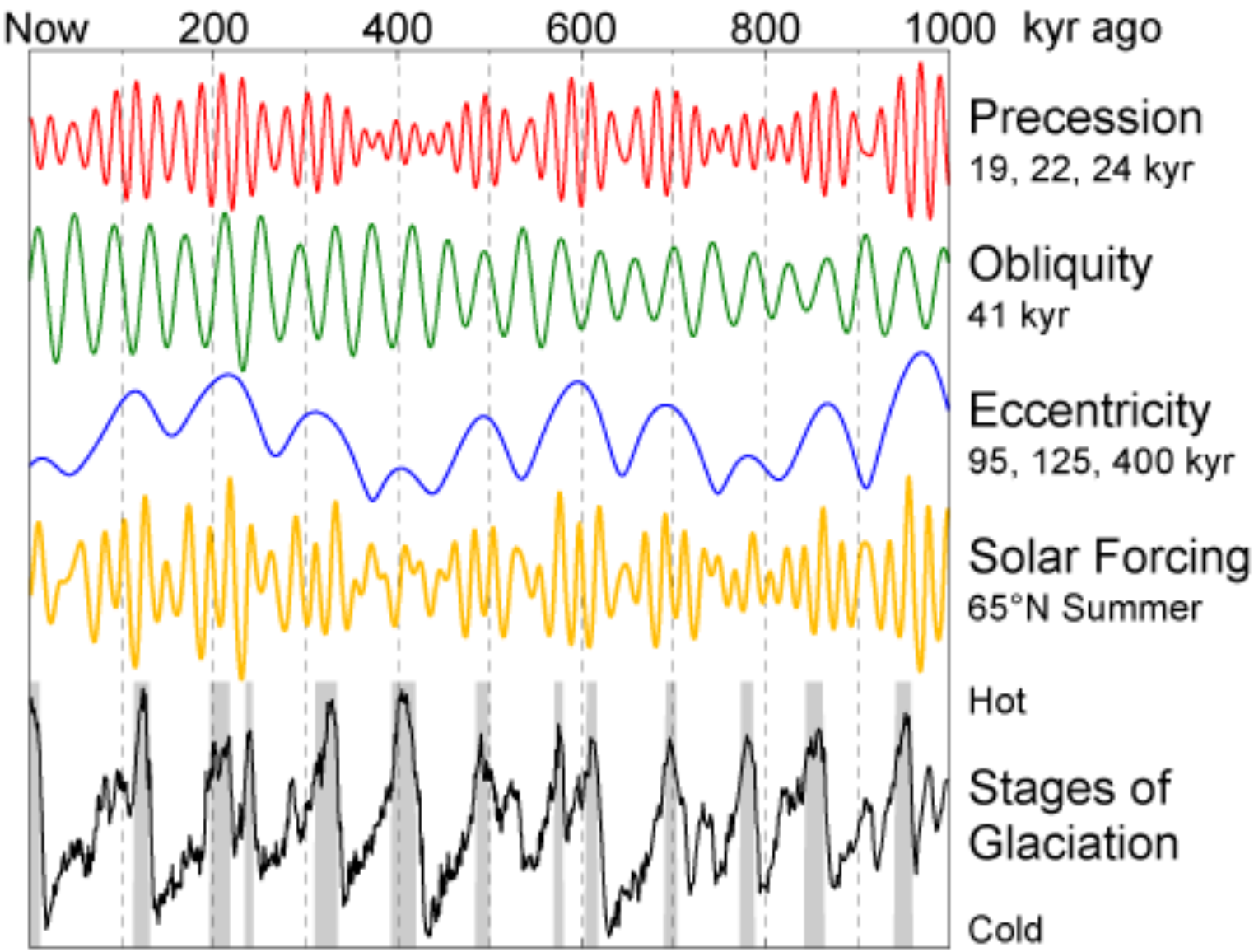
ECCENTRICITY

ECCENTRICITY

PERIOD
100,000 years



Evidence for Milankovitch theory



(wikipedia!)

Ancient times

- Ocean sediment can provide dating much further back from $CaCO_3$ in crustacean shells.

Q3: Why does this matter today?

Key points from Paleoclimate

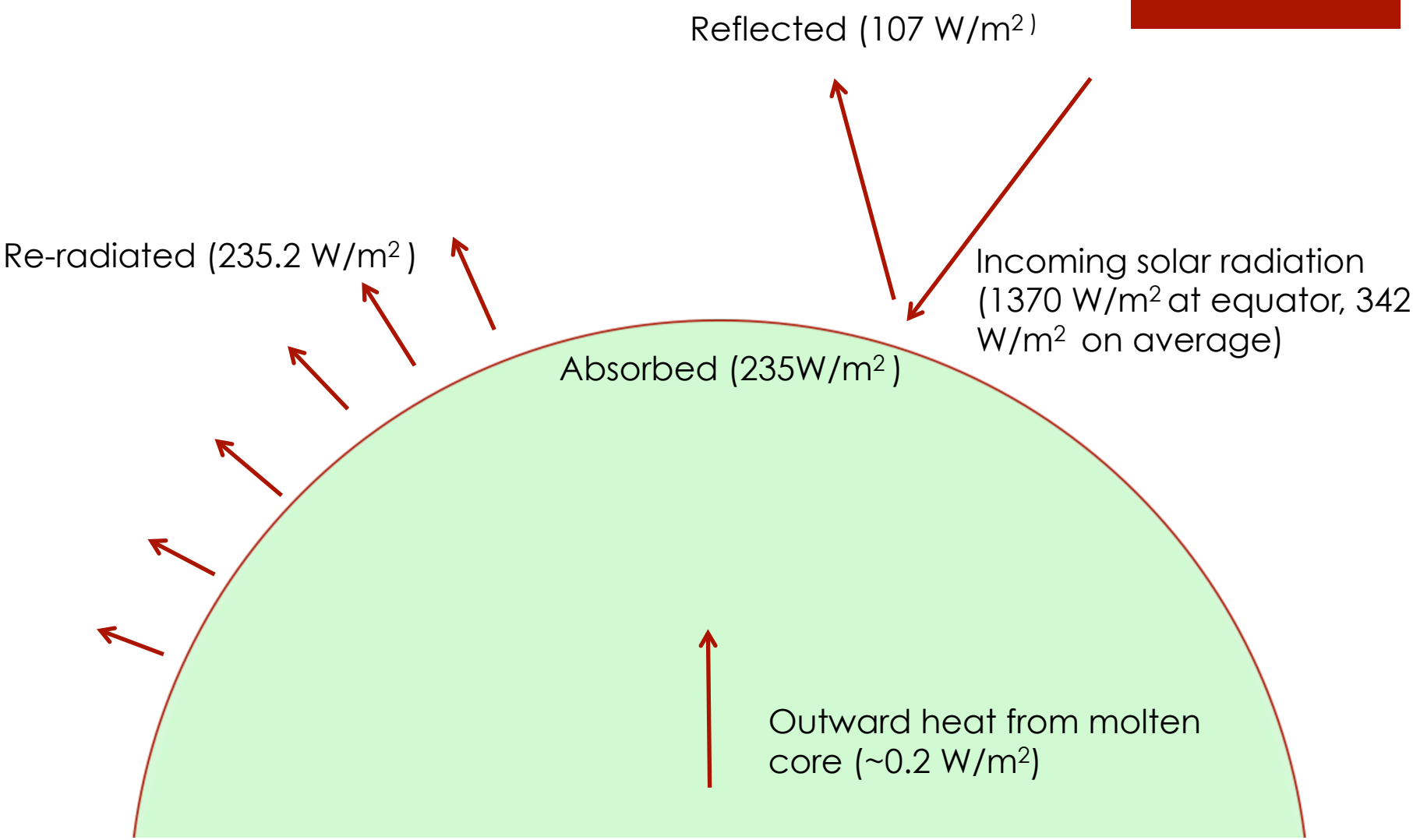
- **Climate change happens – *often slowly, but sometimes fast***
- We have a good record of past climate for much of the history of the Earth.
- Furthermore, we understand the driving forces for most of the the changes.
- In the past life on Earth has transformed its climate. There is no reason this can't happen again.
- Many mass extinction events have been caused by (not necessarily triggered by) rapid climate change.

IL006

The challenges of climate change

Lecture 2
Basic climate physics

The Earth is heated from above



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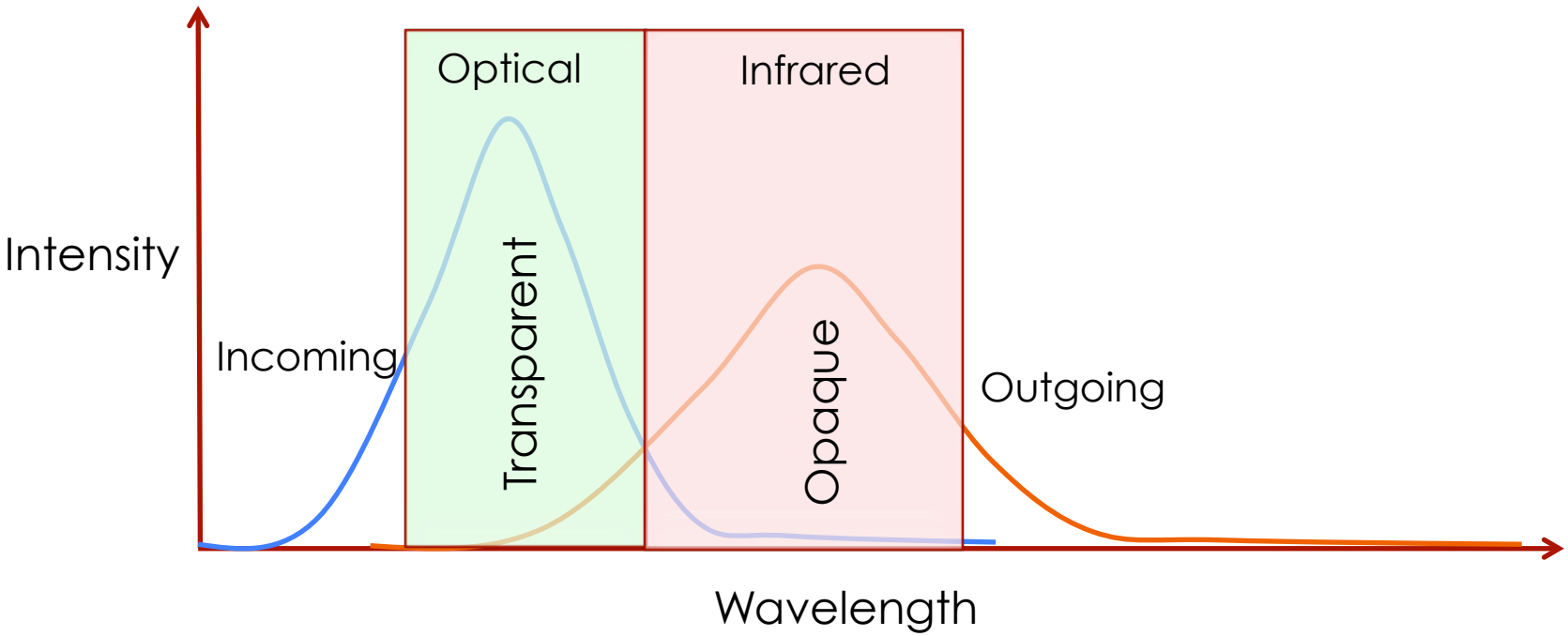
Energy balance

- Incoming energy from the sun has a "temperature" of 6000 degrees. Mostly optical light
- Outgoing energy from the Earth has a temperature of -18 degrees. Infrared light
- The atmosphere has a profound impact.



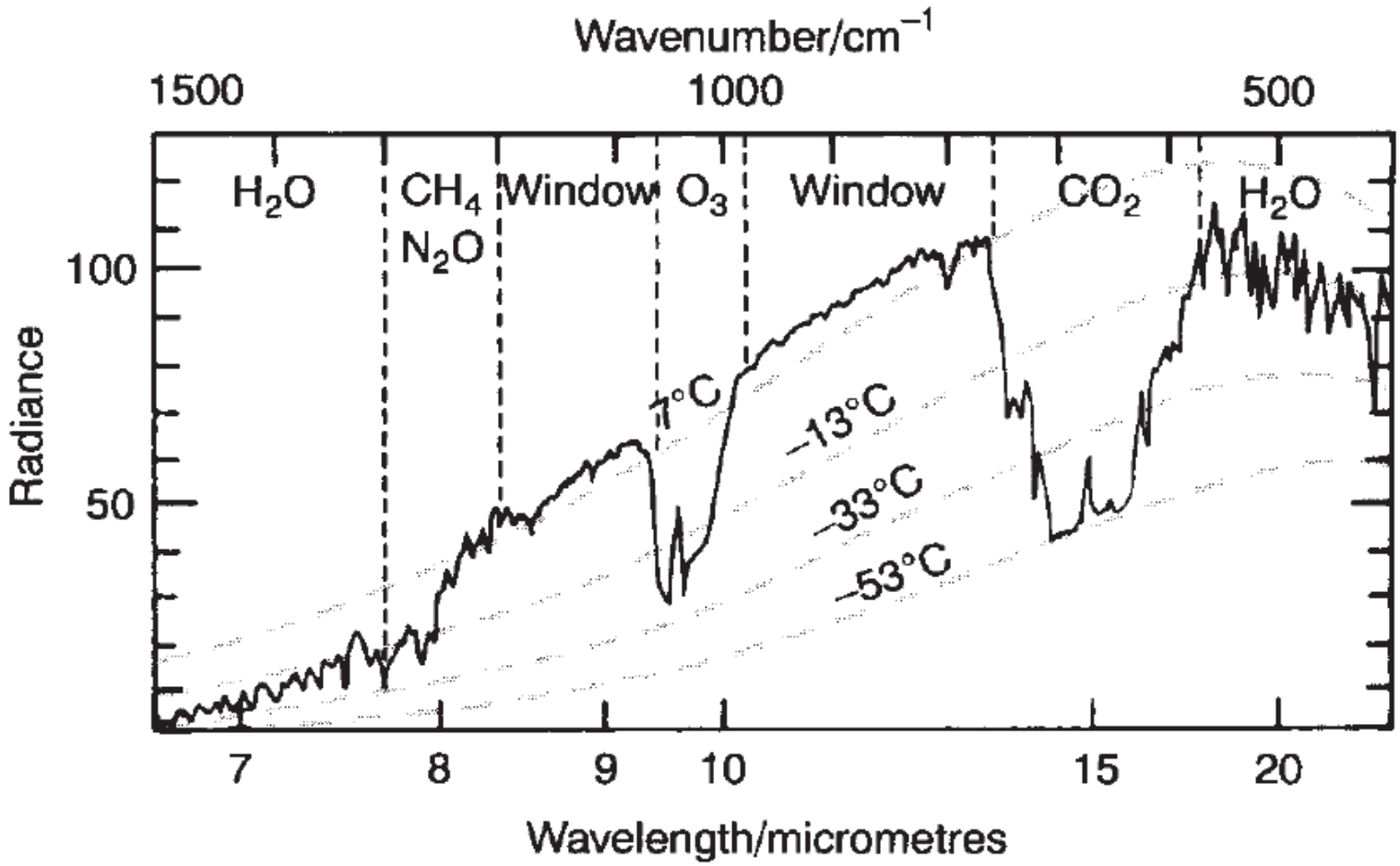
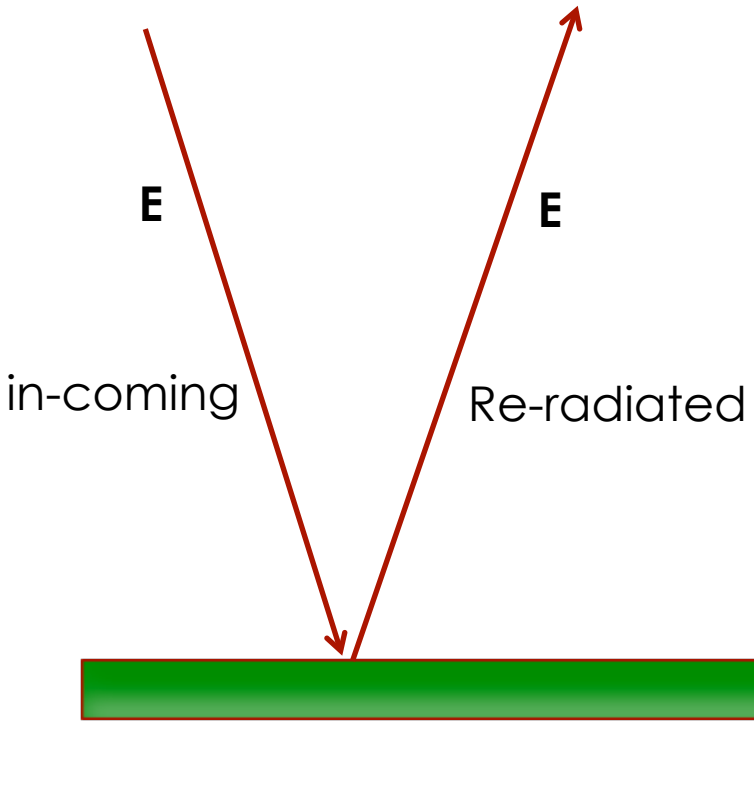
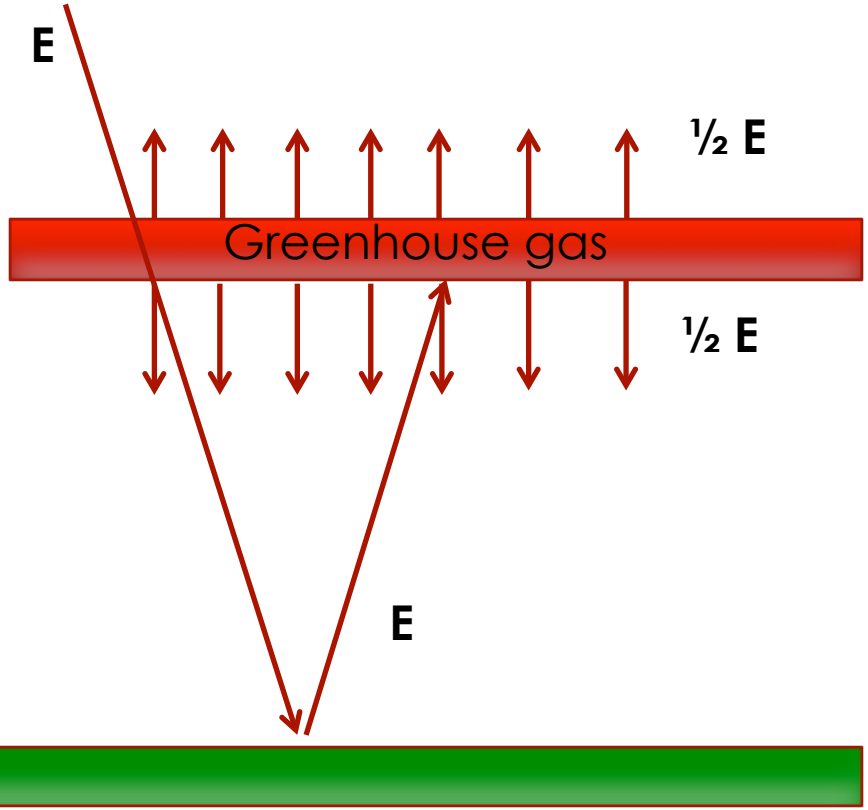


Figure 3. Thermal radiation in the infrared (the visible part of the spectrum is between about 0.4 and 0.7 μm) emitted from the Earth's surface and atmosphere as observed over the Mediterranean Sea from a satellite instrument orbiting above the atmosphere, showing the parts of the spectrum

A greenhouse

Energy in = Energy out





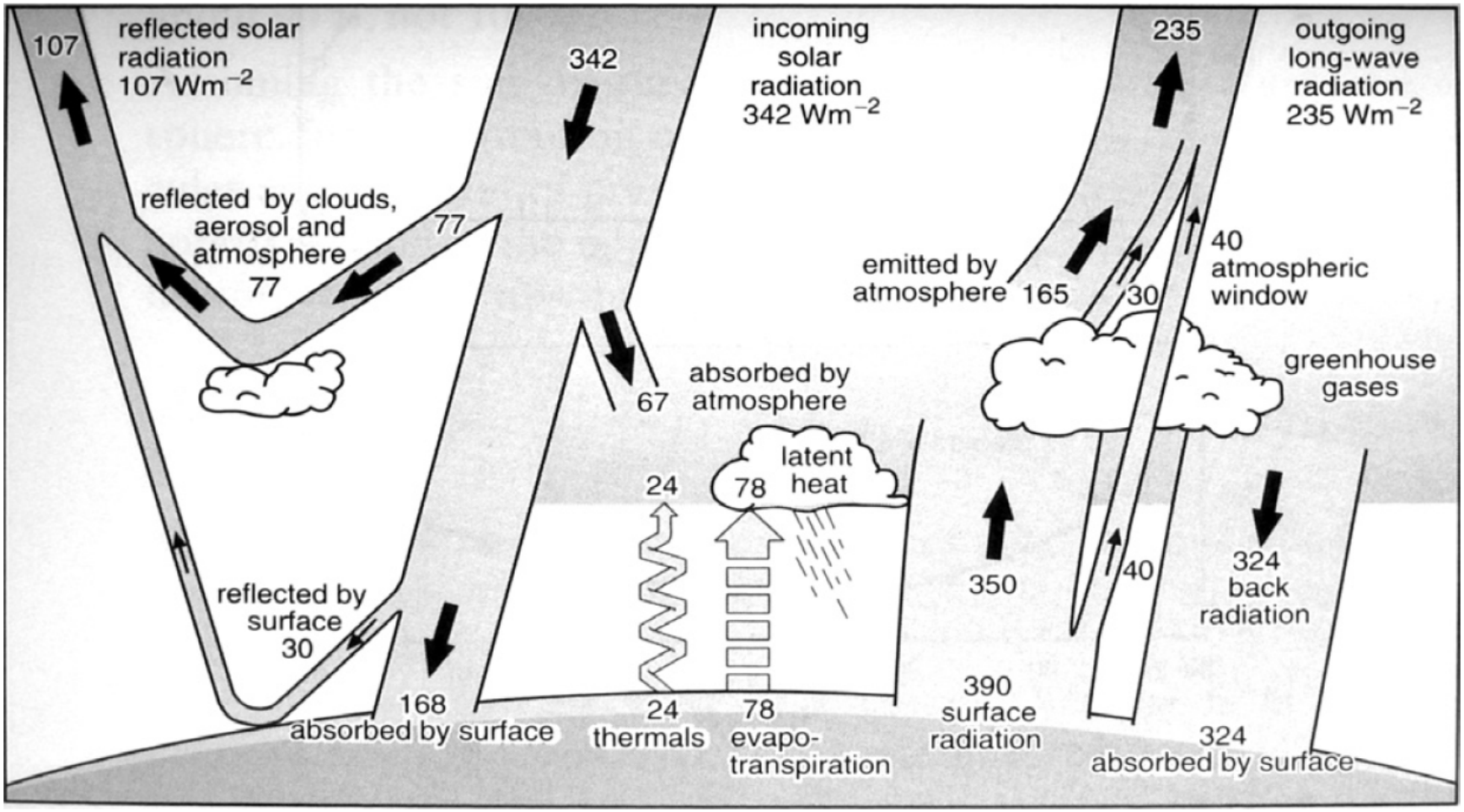
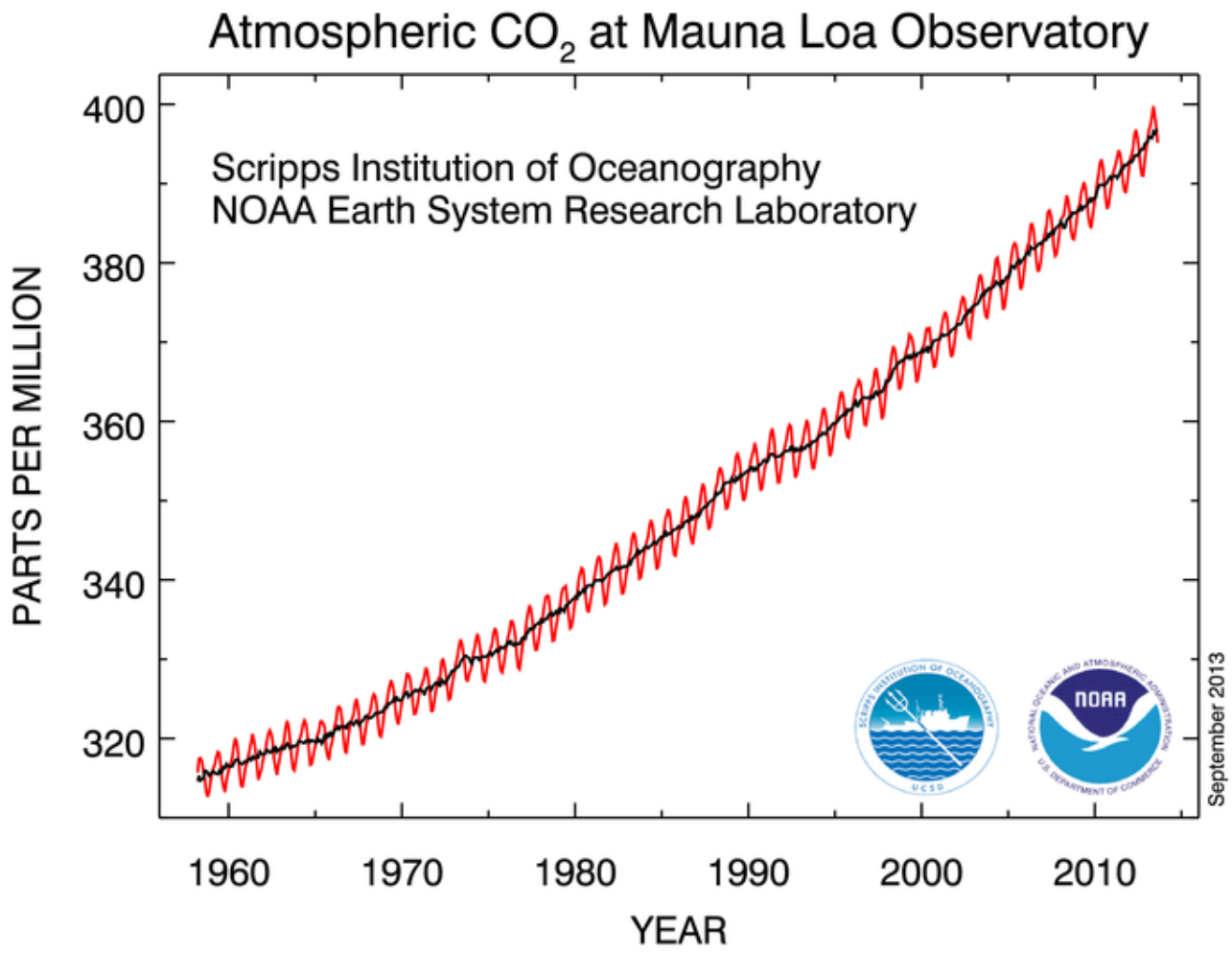


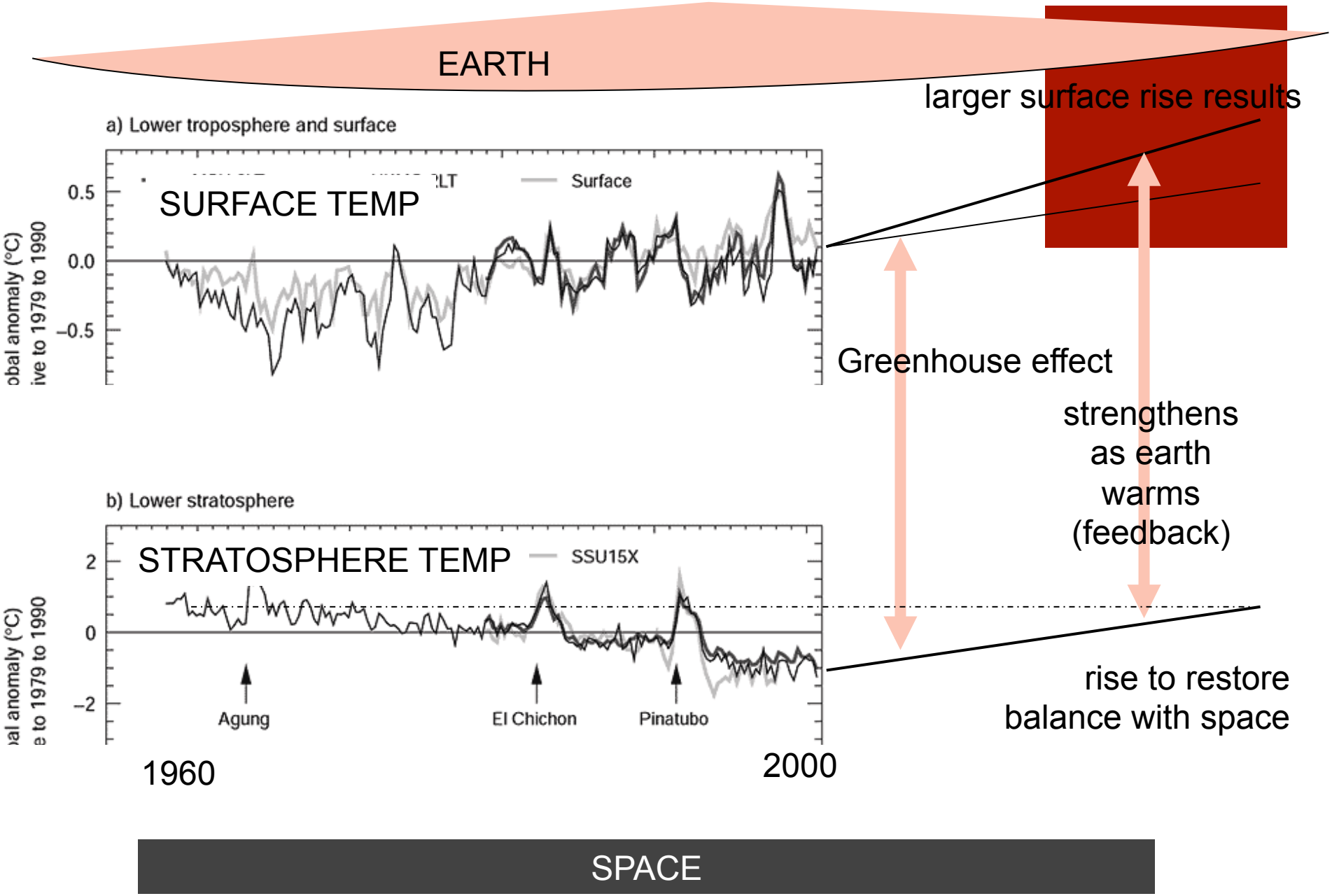
Figure 2. The Earth's radiation and energy balance [4]. The net incoming solar radiation of 342 Wm^{-2} is partially reflected by clouds and the atmosphere, or at the surface where 49% is absorbed. That heat is returned to the atmosphere, some as sensible heat but most from evaporation and transpiration (taken together these are known as evapotranspiration), which is later released as latent heat of condensation within the atmosphere. The rest is radiated as thermal radiation from the surface much of which is absorbed by the atmosphere or by clouds that also emit radiation both upwards and downwards. Part of the infrared radiation that is lost to space comes from cloud tops and parts of the atmosphere that are much colder than the surface.

Greenhouse gases

- Most gases with 3 or more atoms in each molecule act as greenhouse gases because of asymmetry in their charge distribution
- Global Warming Potential is calculated relative to the effect of carbon dioxide (e.g. how much damage will 1 kg of methane do relative to carbon dioxide).
- BUT – Water vapour is responsible for most of the natural greenhouse effect.

Anthropogenic greenhouse gases




EARTH
larger surface rise results
a) Lower troposphere and surface
SURFACE TEMP
Surface
0.5
0.0
−0.5
Greenhouse effect
strengthens
as earth
warms
(feedback)
b) Lower stratosphere
STRATOSPHERE TEMP
SSU15X
2
0
−2
Agung
El Chichon
Pinatubo
rise to restore
balance with space
1960
2000
SPACE

Summary

- The expected temperature of the Earth can be calculated from some basic physics, and is >20 degrees cooler than the actual temperature
- The reason for this is because of the greenhouse effect.
- The greenhouse effect is *enhanced* by the addition of carbon dioxide, methane etc by human activity.
- This means the Earth is currently out of equilibrium and is warming up.