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Title:	Climate change: what causes it and how we know
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Climate change: what causes it and how we know

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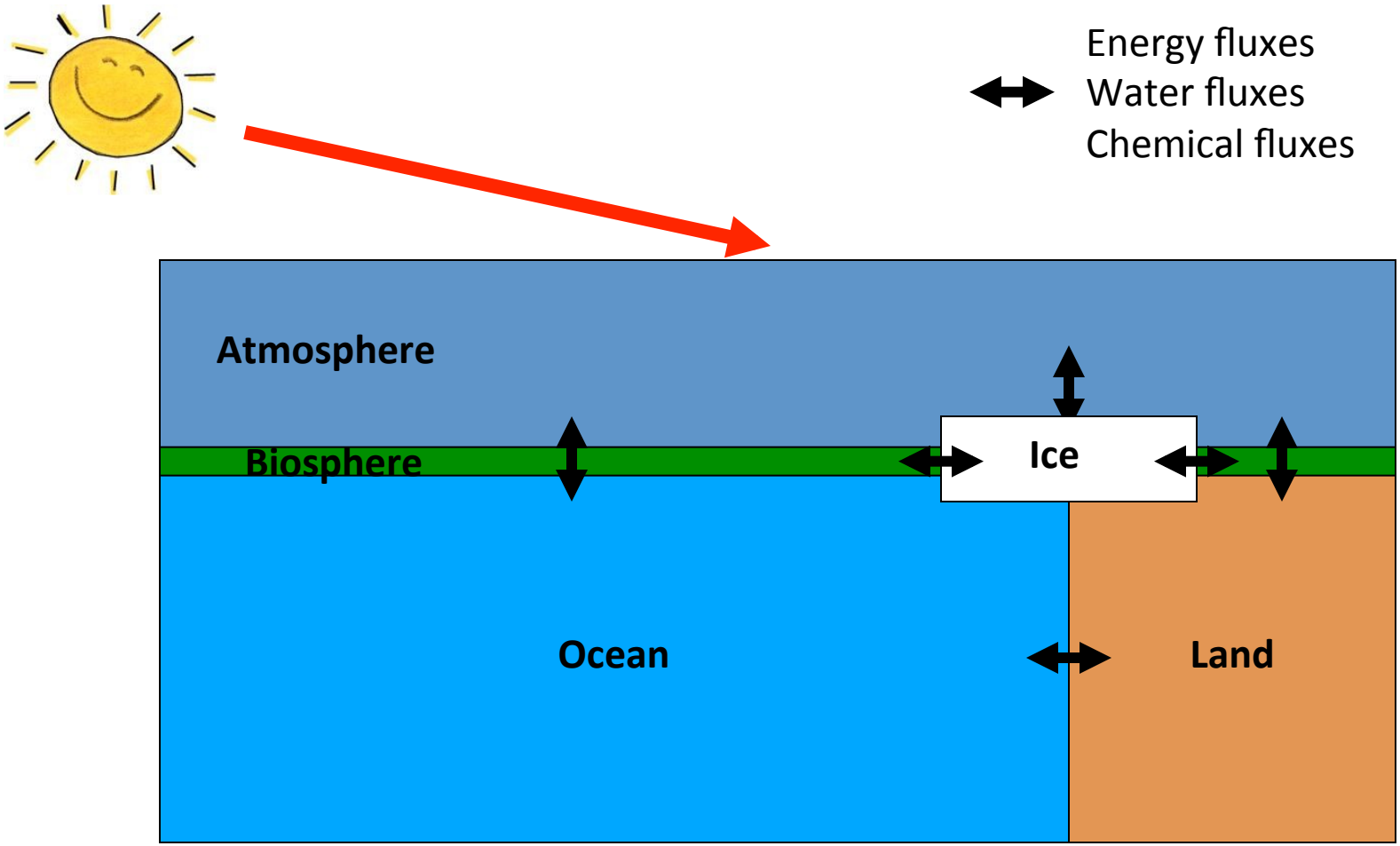
What are the questions?

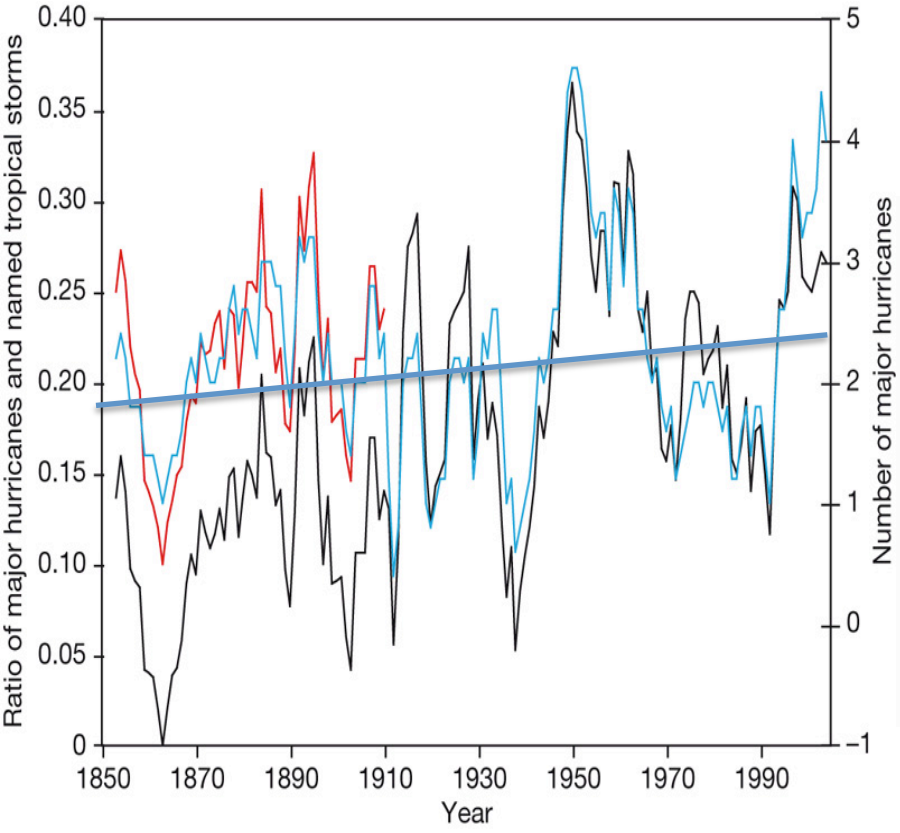
- What is the climate system?
- What is climate change?
- Is climate changing?
- Could natural causes of climate change be responsible?
- Could man-made causes of climate change be responsible?
- What's going to happen?

What is the climate system?

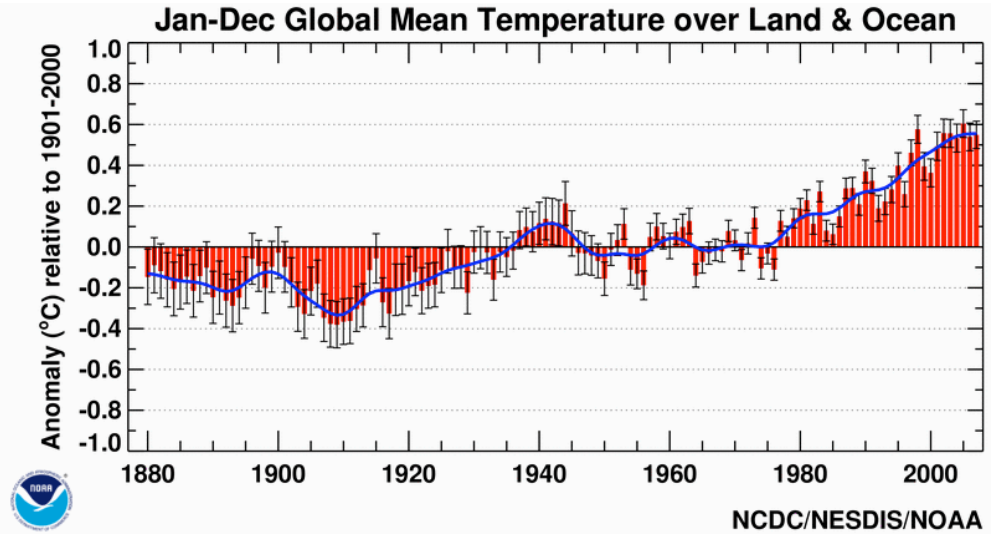


What is climate change?

‘Climate change’ = long-term large-scale trends

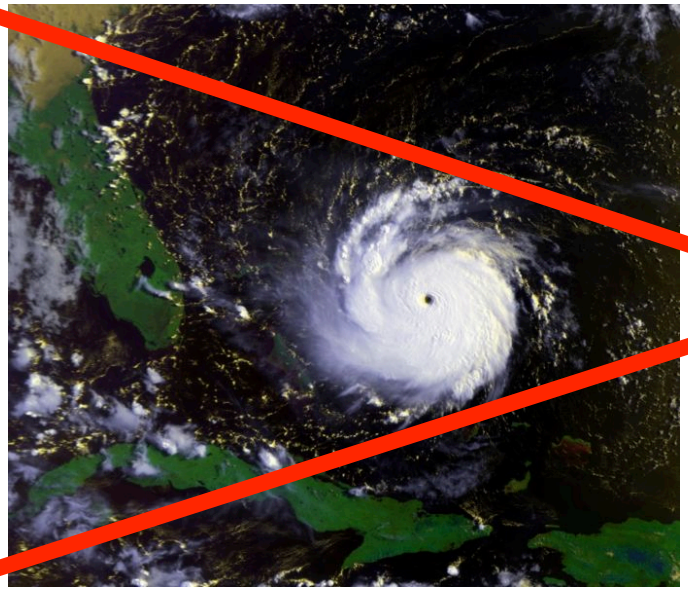


Global temperature

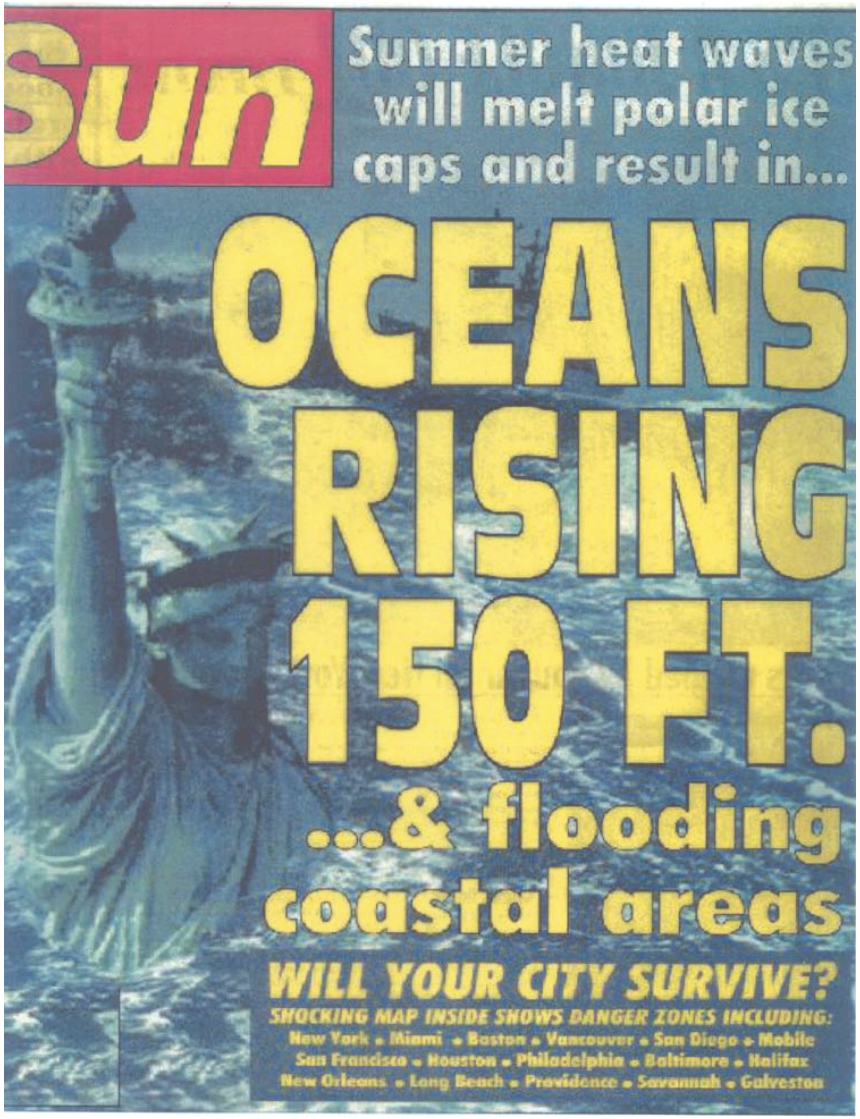


What is climate change?

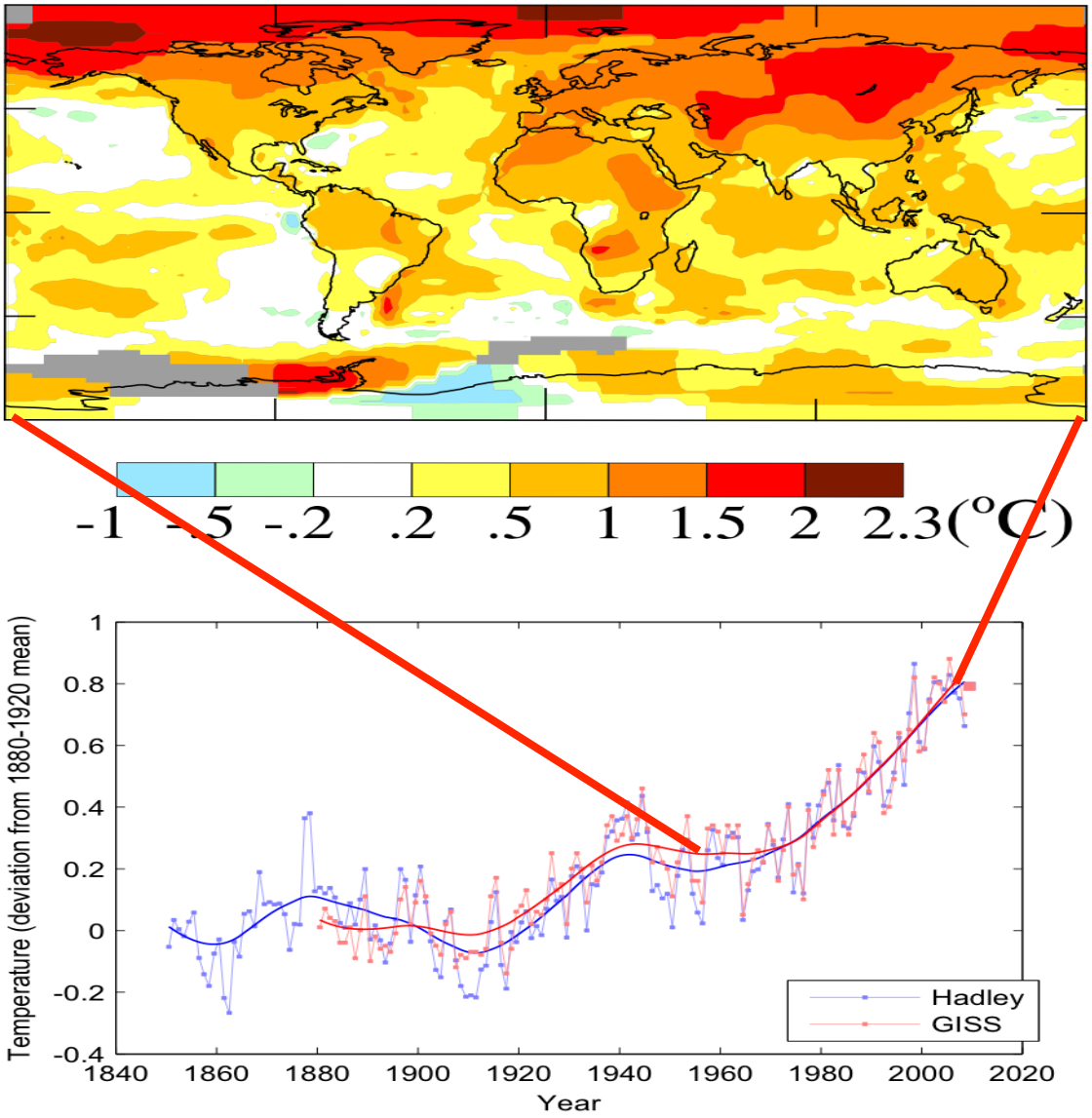
- Climate change is a *change in the average weather* (temperature, precipitation, winds) that a region experiences

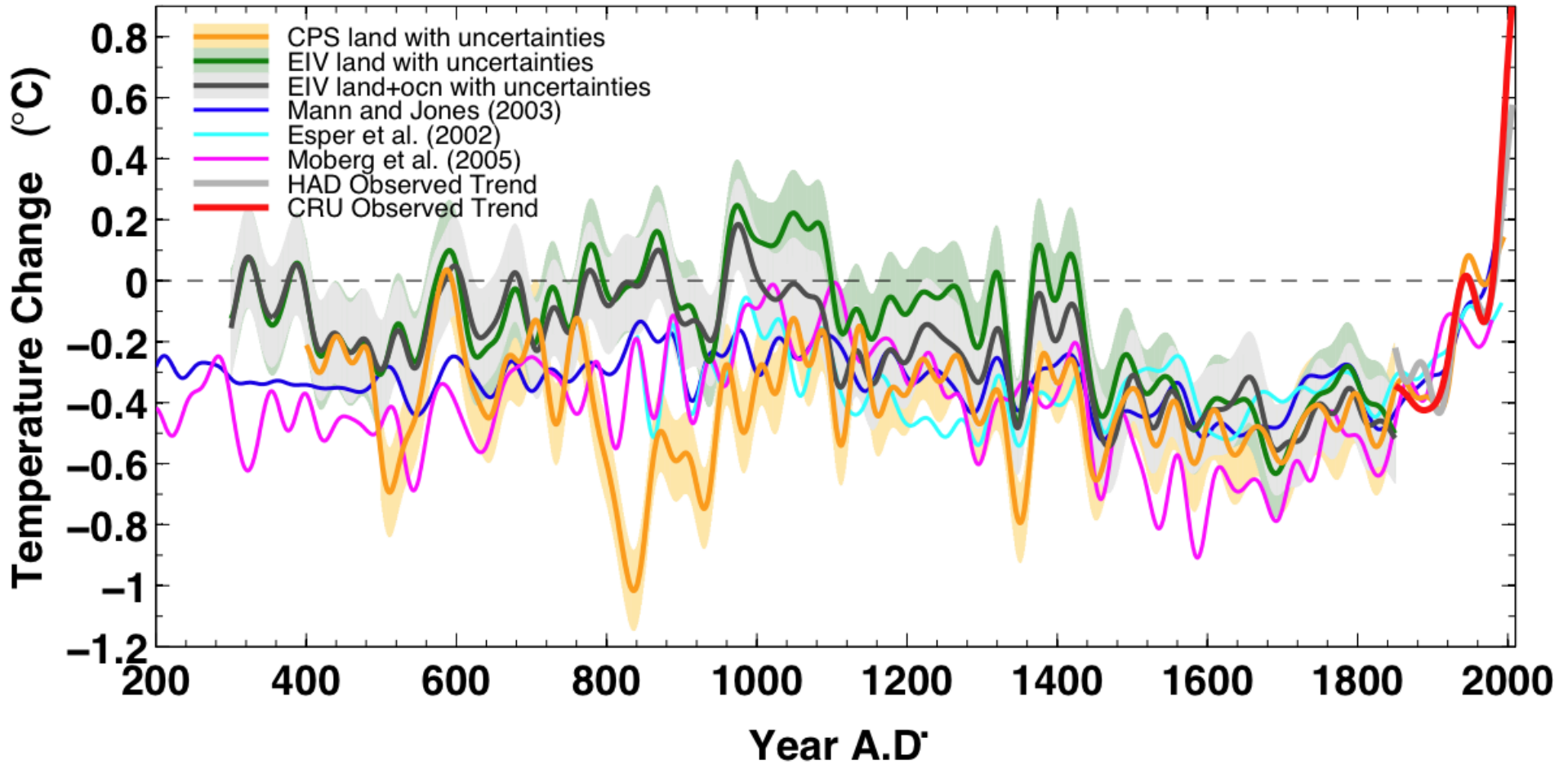


Is climate change happening?

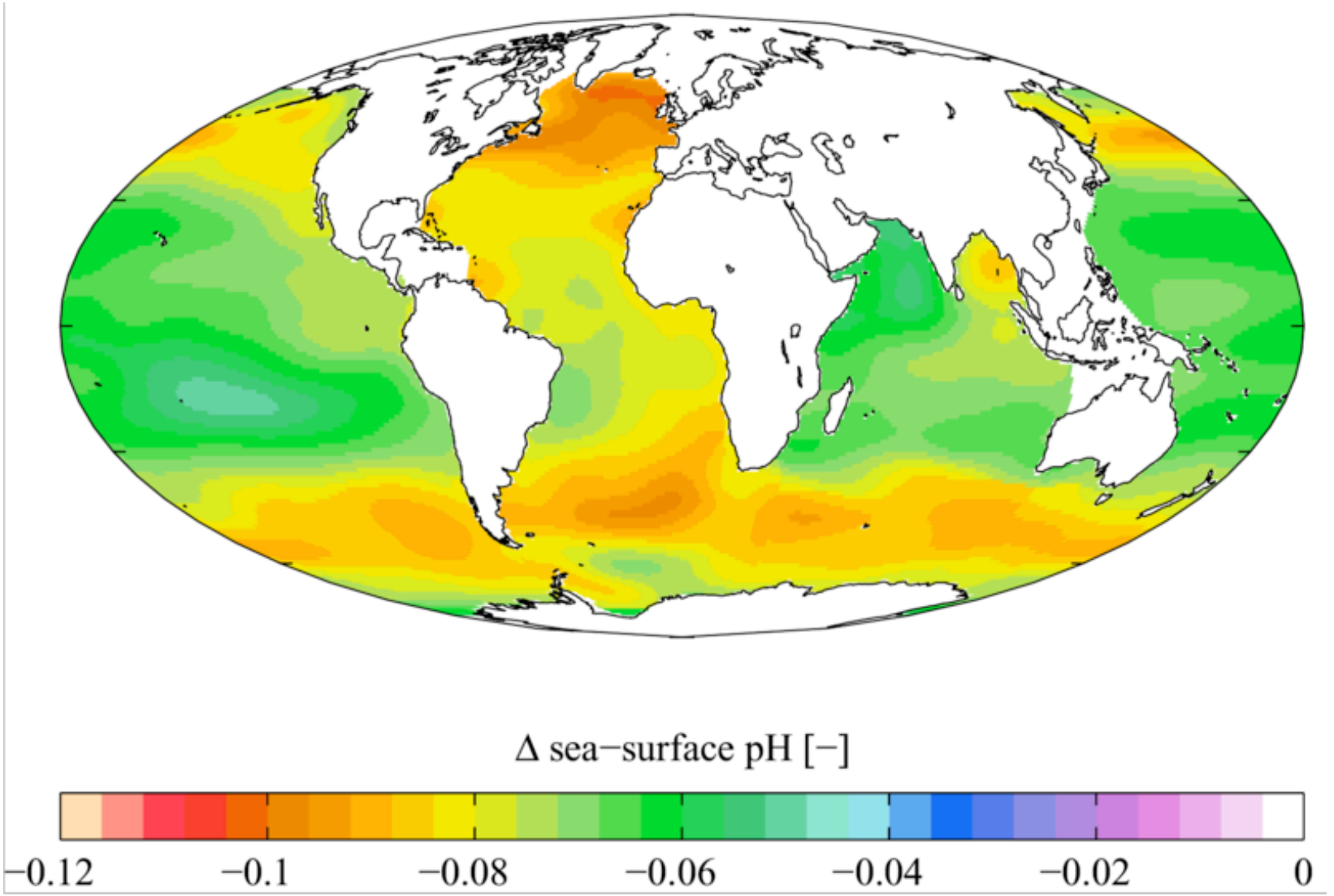


Global average surface air temperature – higher than last 600,000 years



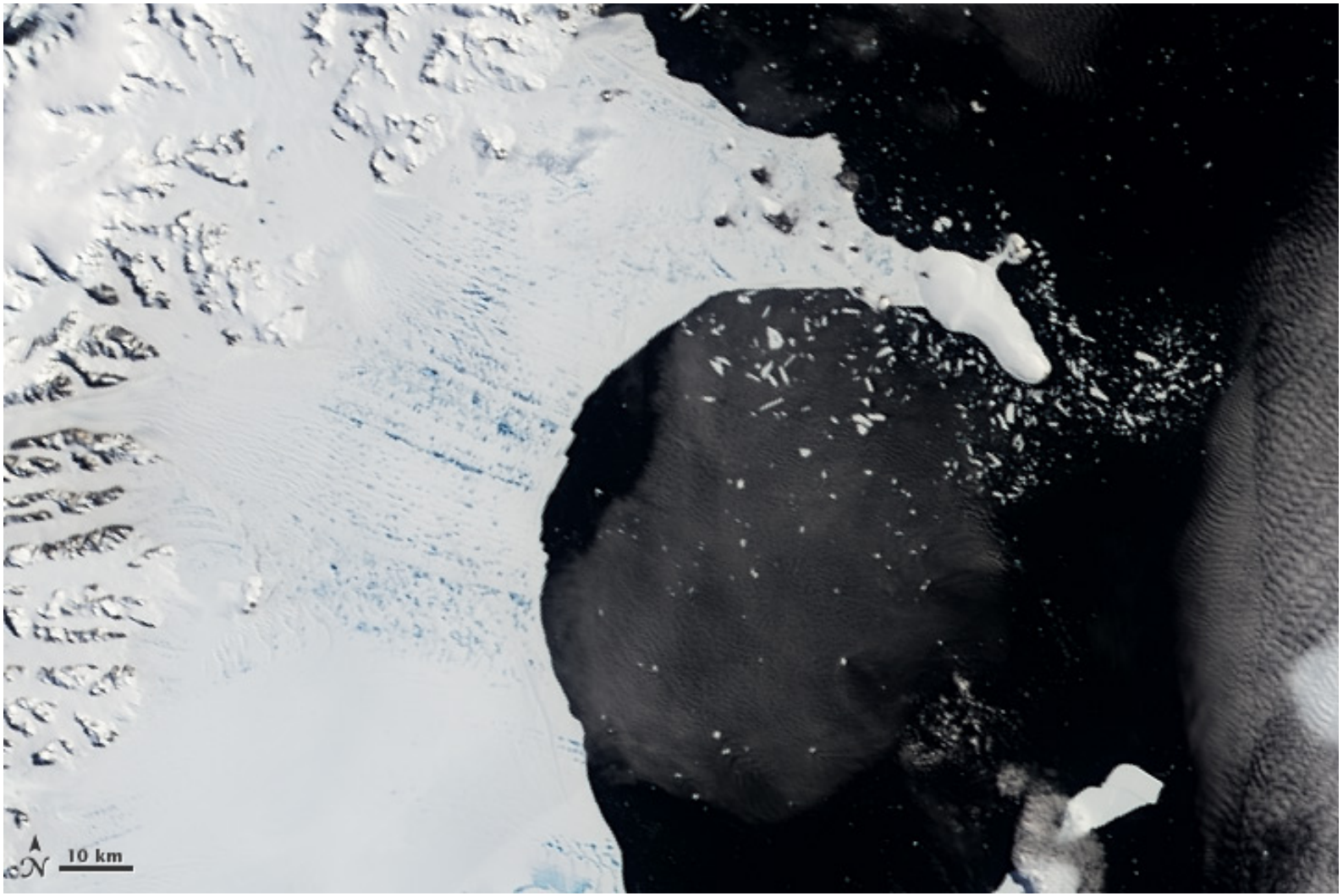

CPS land with uncertainties
EIV land with uncertainties
EIV land+ocn with uncertainties
Mann and Jones (2003)
Esper et al. (2002)
Moberg et al. (2005)
HAD Observed Trend
CRU Observed Trend
Temperature Change (°C)
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
200
400
600
800
1000
1200
1400
1600
1800
2000
Year A.D.

Surface ocean acidity – higher than in last 55 million years

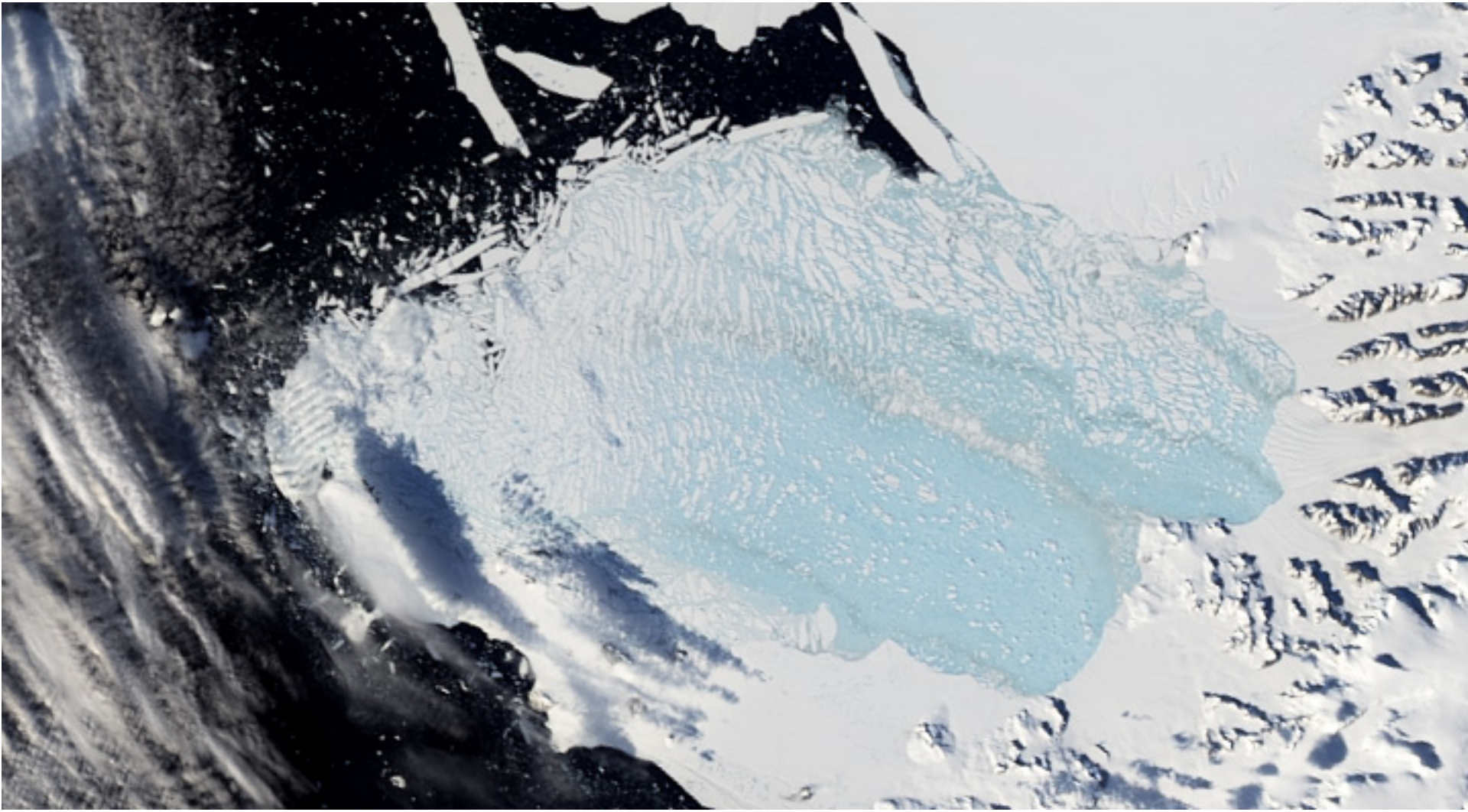


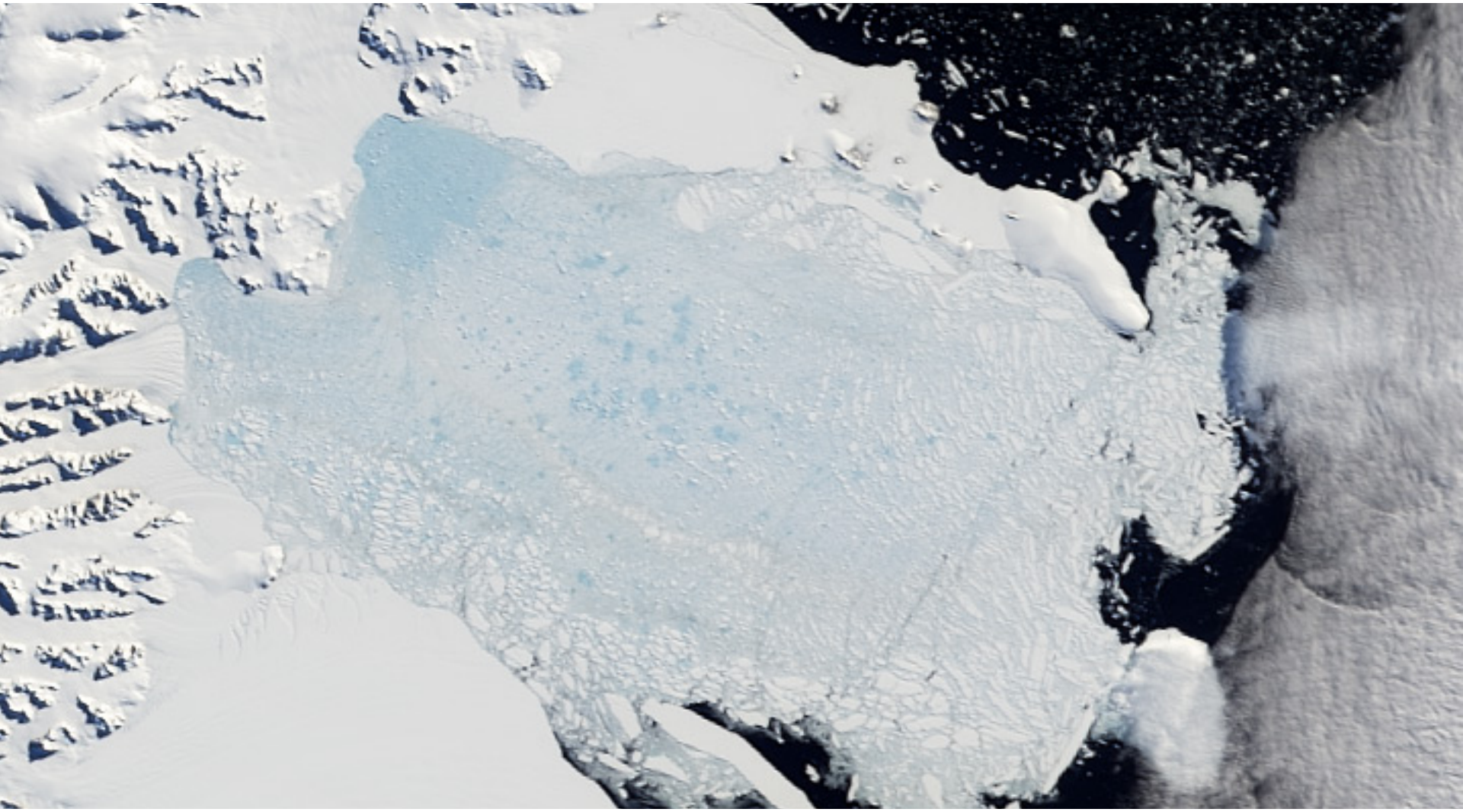
Arctic sea ice: total summer loss within decades – first total loss in 11,000 years

Antarctic ice shelf collapse – first in 12,000+ years




N
10 km

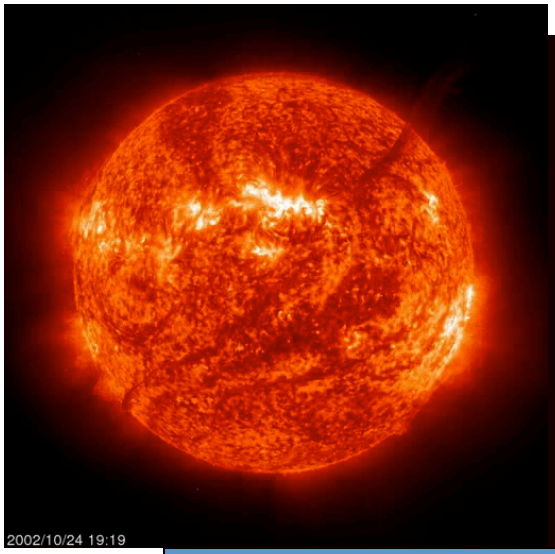


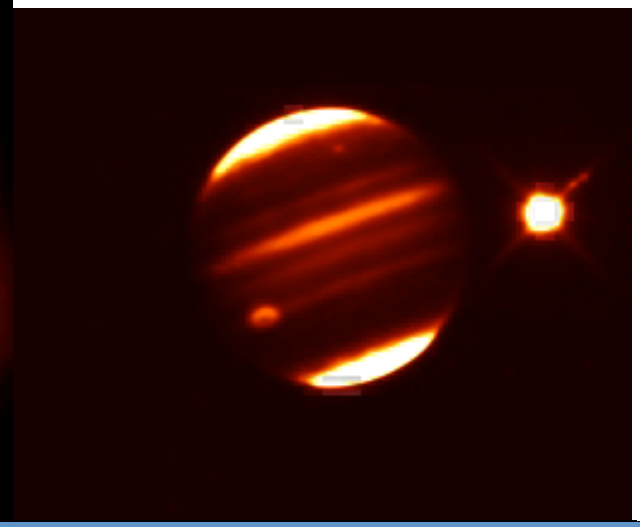


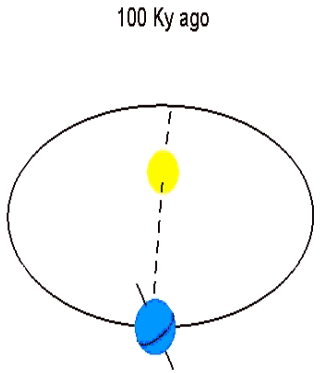
OK, It's changing, but what's the cause?

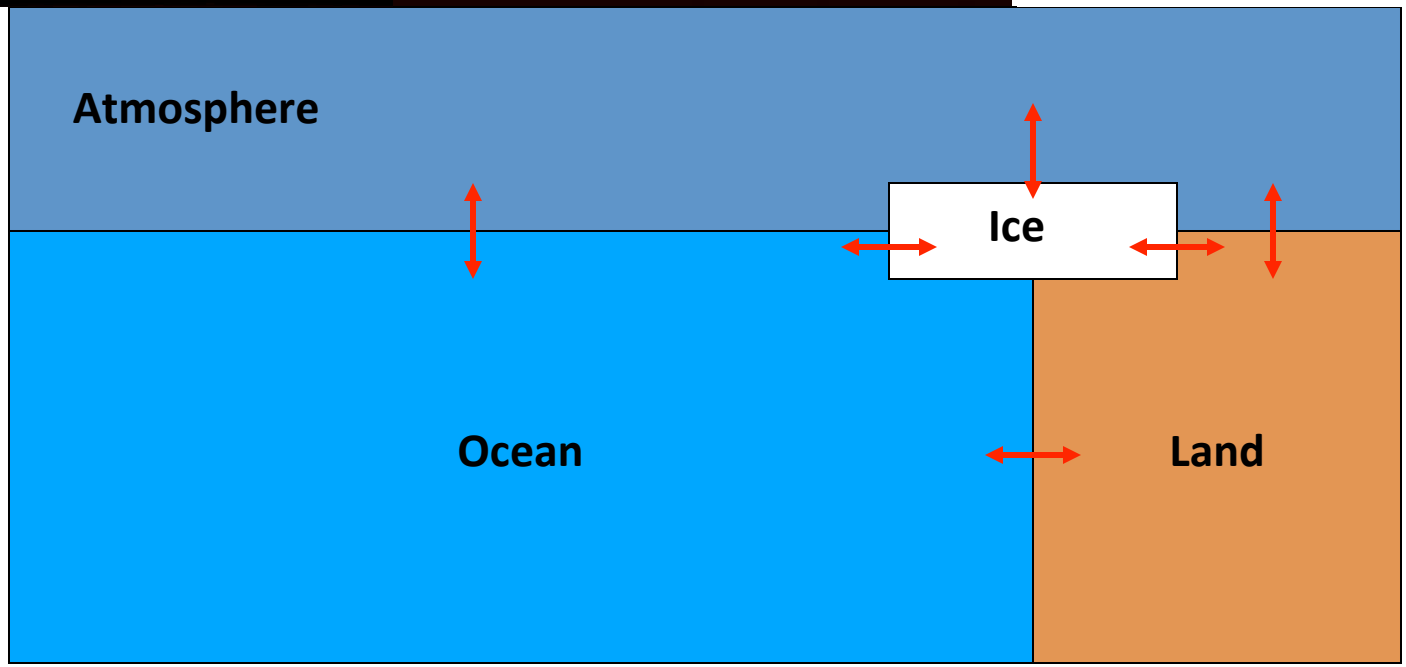
- *Climate change is caused by external forcings.*
- What are the major external forcings?
  - Naturally-derived forcings -> natural climate change
  - Human-derived forcings -> human climate change
- How would changes to such external forcings affect the climate system?

Natural forcings

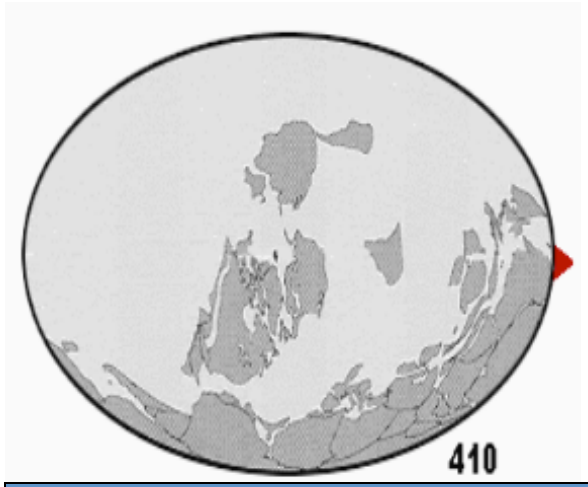


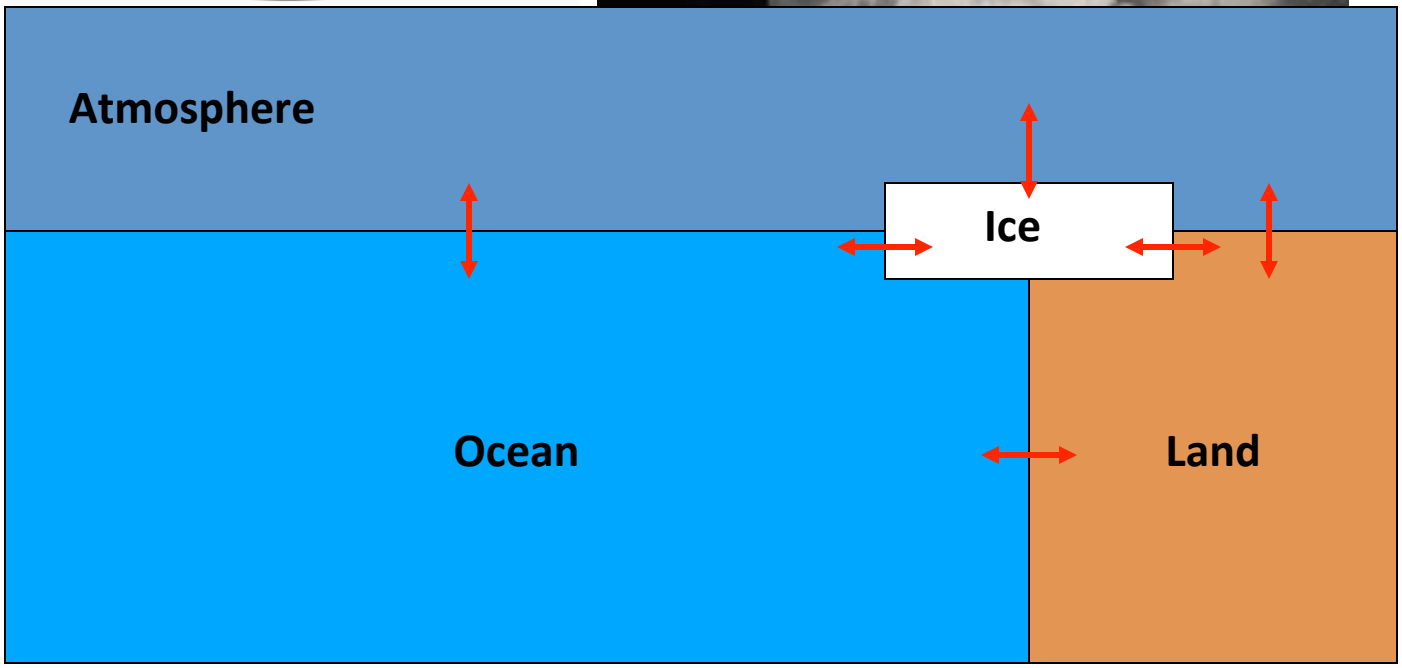






Natural forcings

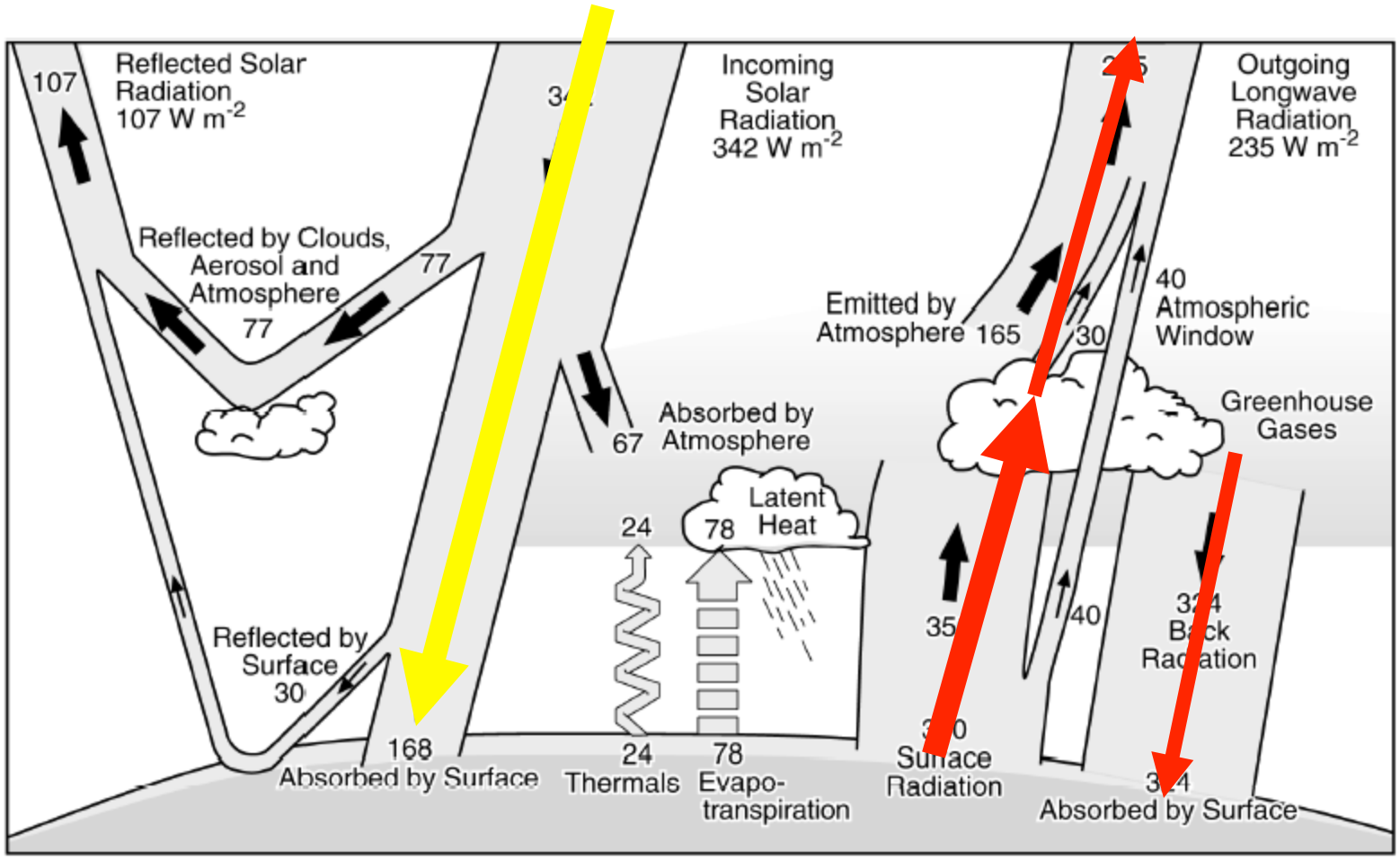




Man-made forcings

- Humans have discovered a highly efficient energy source: fossil fuels
- Combustion of fossil fuels puts CO_2 into the atmosphere

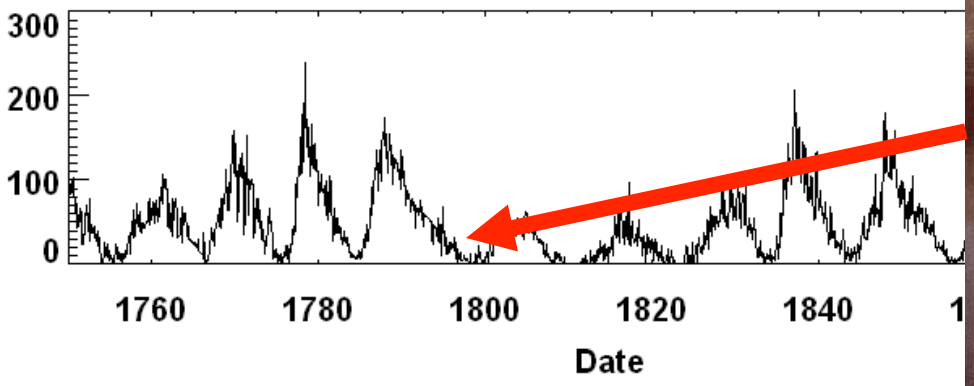
More CO_2 = The Greenhouse Effect

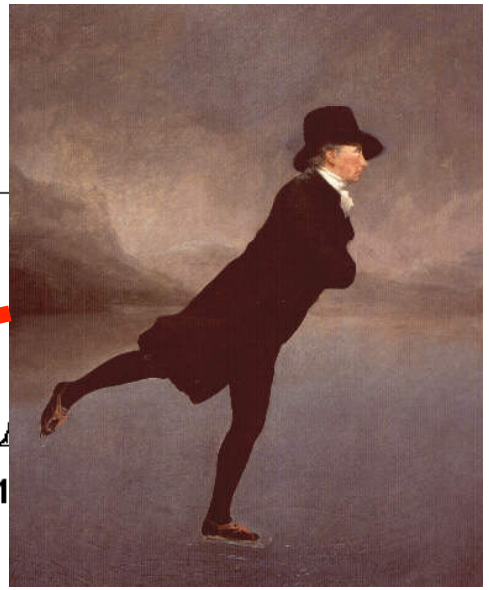


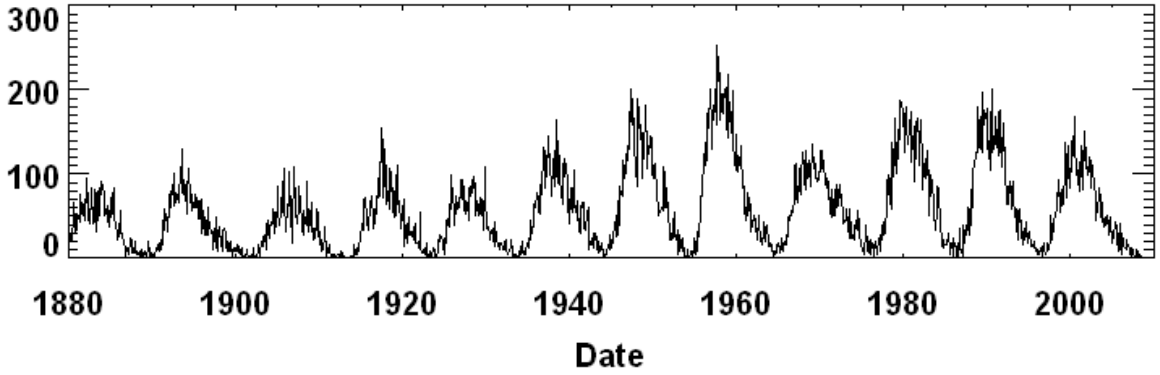
What forcings are relevant today?

- Changes in the strength of the sun
- Asteroids and meteors
- Changes to the Earth's orbit
- Continental drift
- Volcanoes
- Human CO_2 emissions

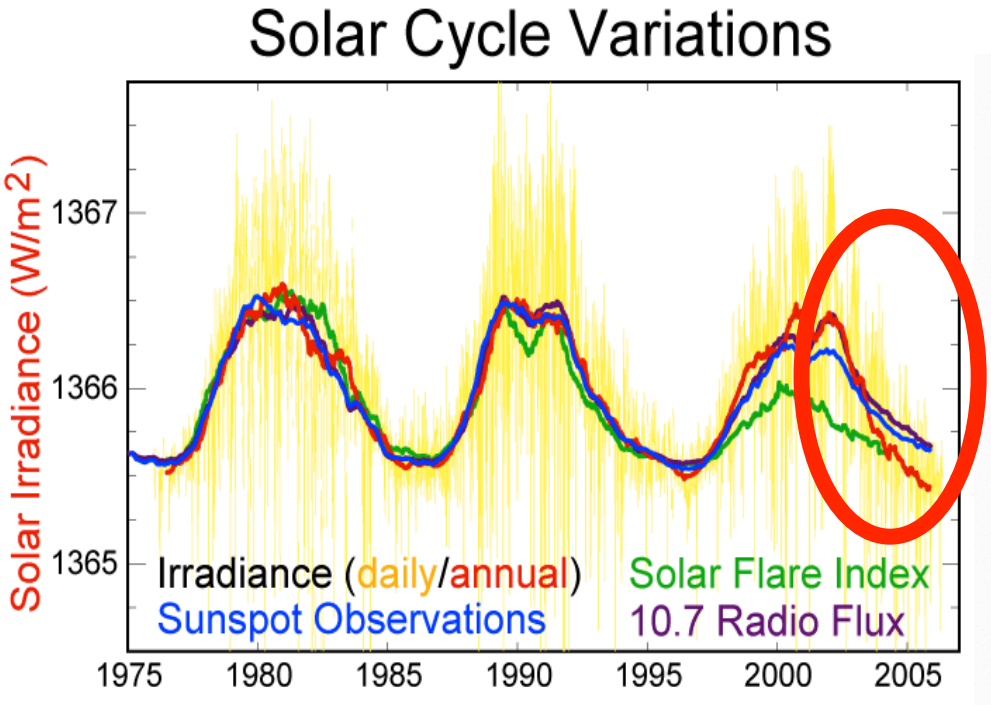
Solar strength

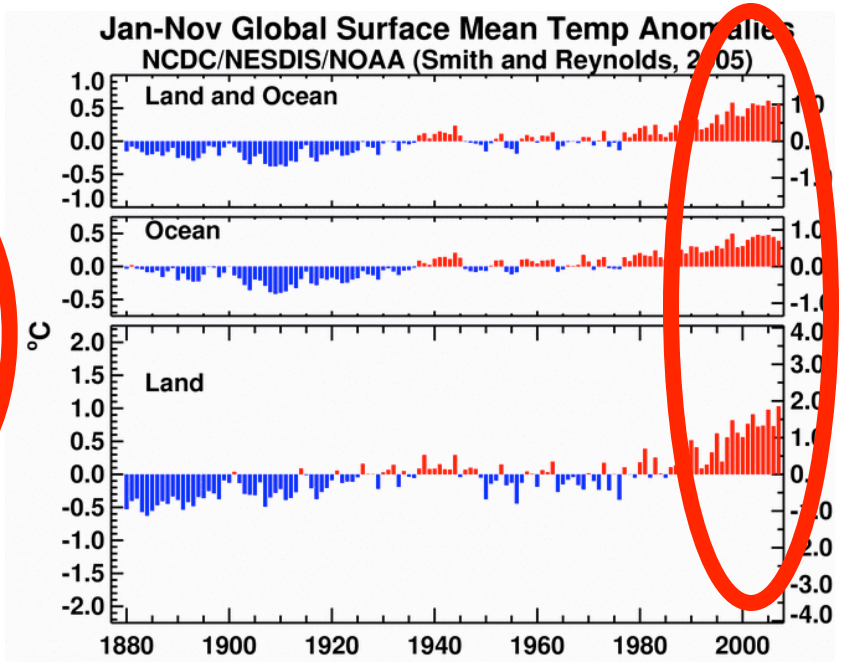






Solar strength: too weak, and no relation to temperature trends





What forcings are relevant today?

- ~~Changes in the strength of the sun~~
- Asteroids and meteors
- Changes to the Earth's orbit
- Continental drift
- Volcanoes
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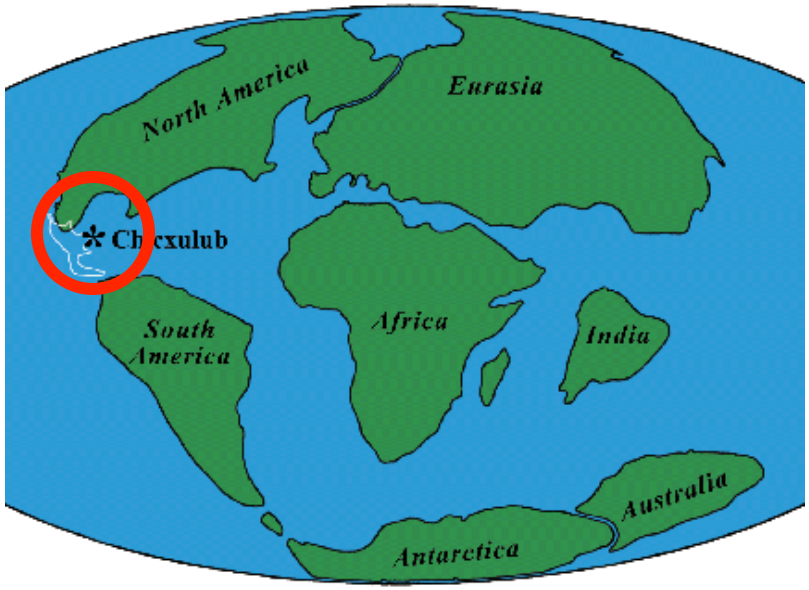
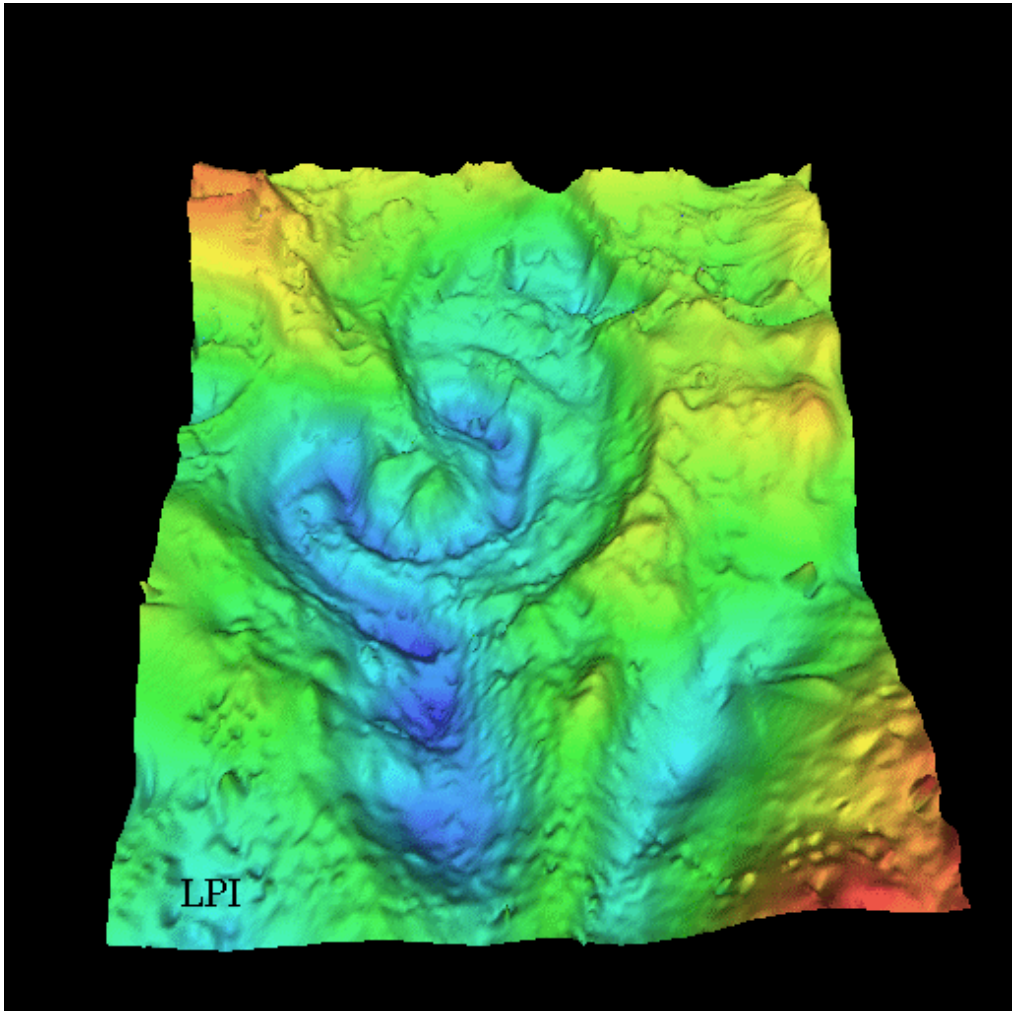
Asteroids and meteors

- Chixculub impact crater impact
- Occurred at the Cretaceous-Tertiary Boundary





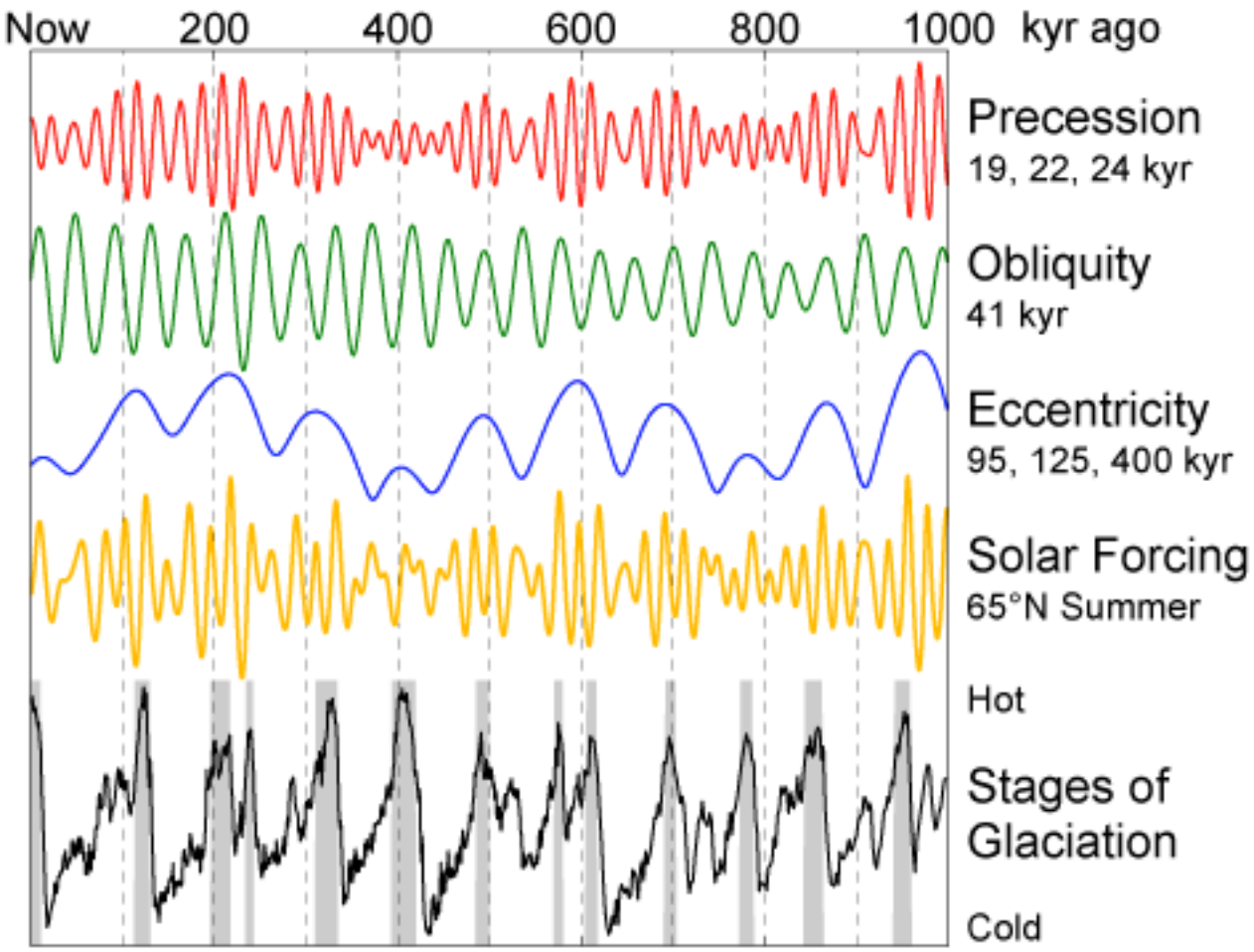
Asteroids and meteors – no big ones in historical period

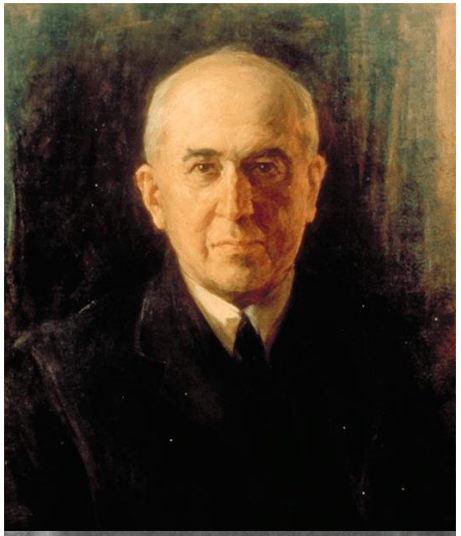
- Chixculub impact strength: 100000000 Mt TNT
- Tunguska (1908) impact strength: 10-15 Mt TNT
- *Tsar Bomba* strength: 50 Mt TNT

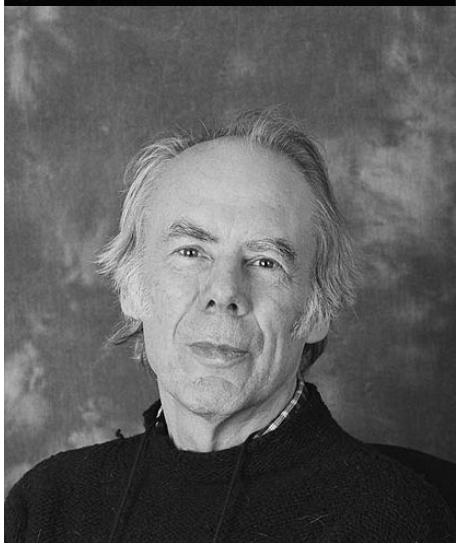
What forcings are relevant today?

- ~~Changes in the strength of the sun~~
- ~~Asteroids and meteors~~
- Changes to the Earth's orbit
- Continental drift
- Volcanoes
- Human CO_2 emissions

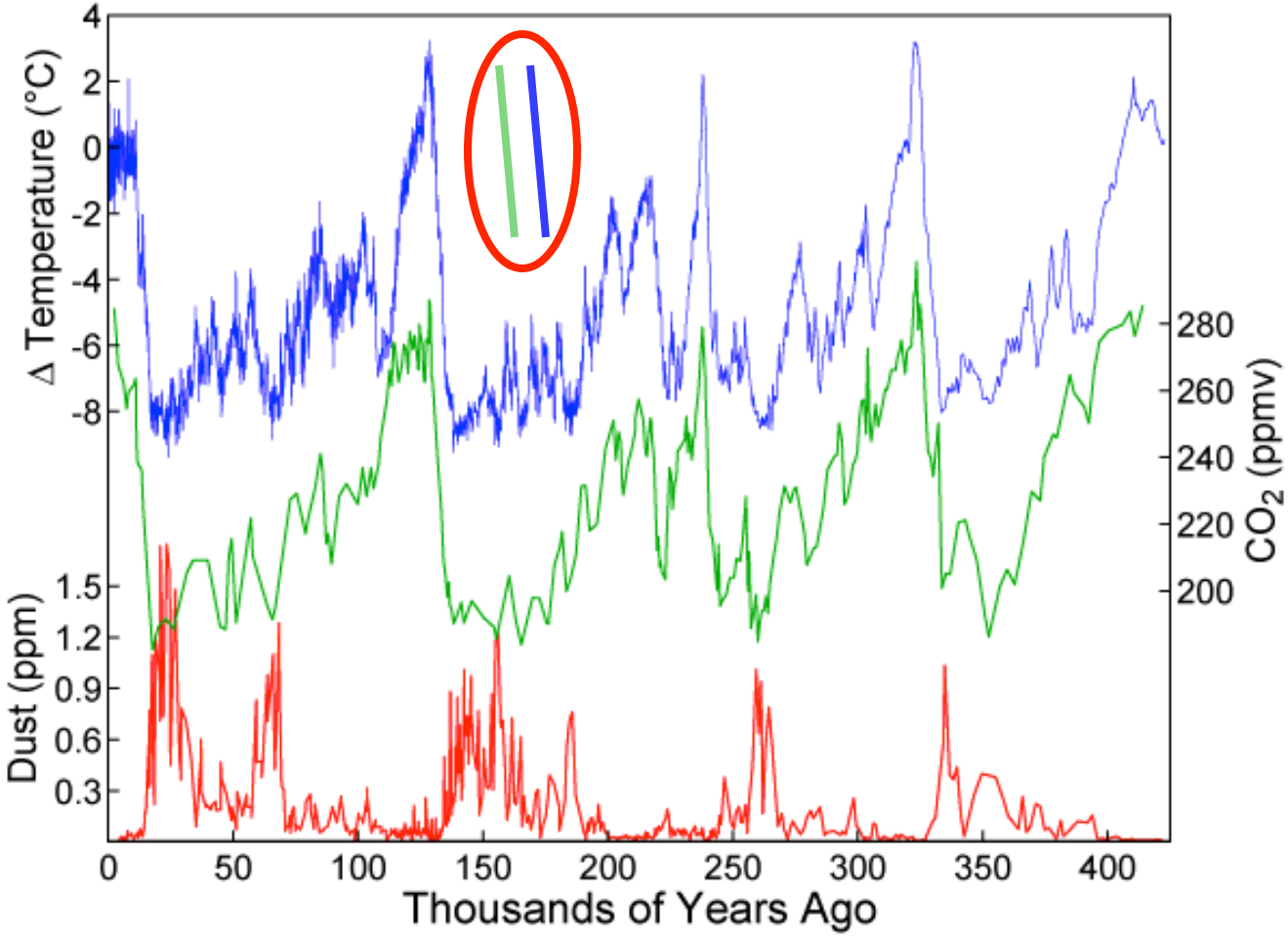
Changes to Earth's orbit



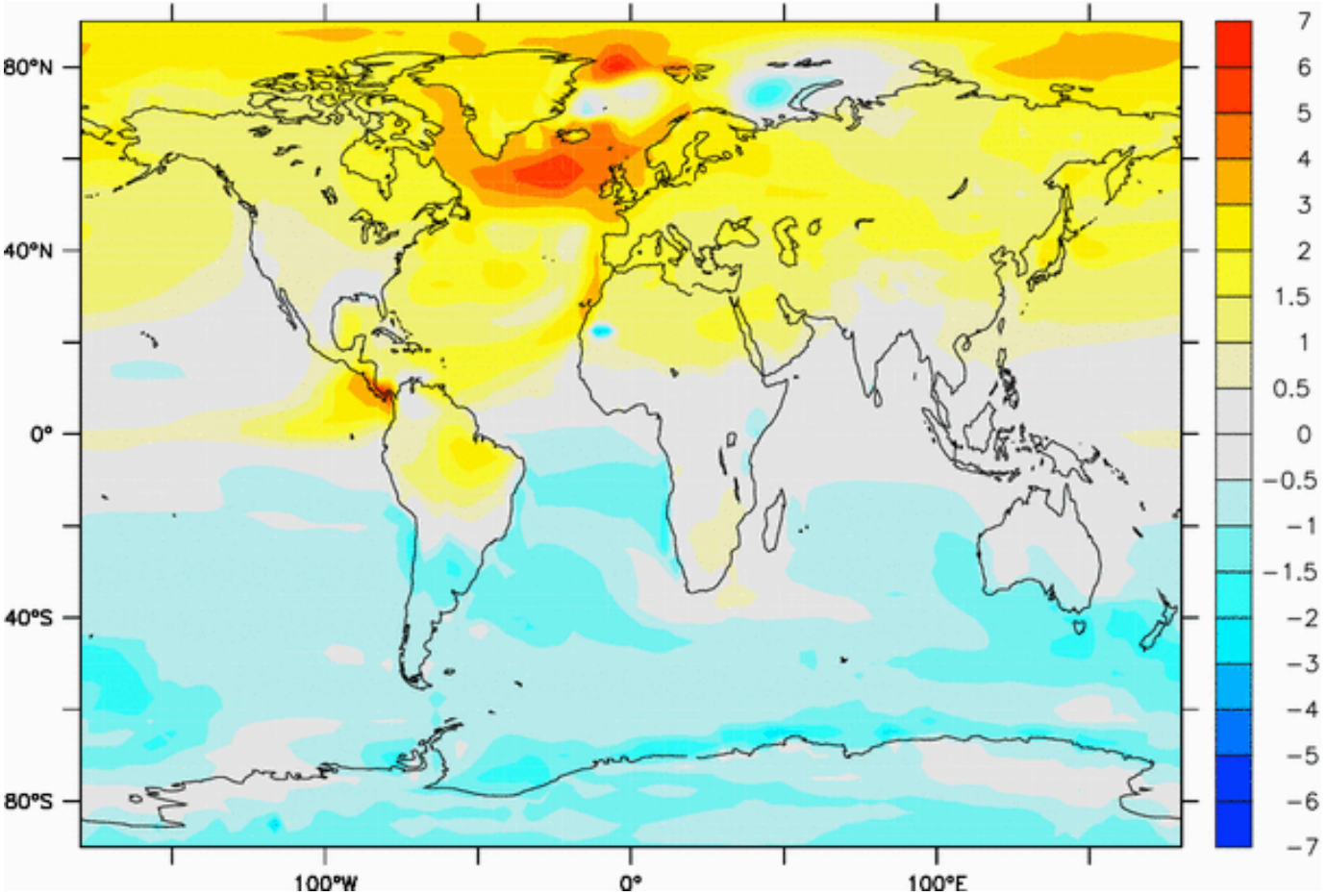




Changes to Earth's orbit – too slow, and in opposite trend to recent temperatures



Continental drift – way too slow



What forcings are relevant today?

- ~~Changes in the strength of the sun~~
- ~~Asteroids and meteors~~
- ~~Changes to the Earth's orbit~~
- ~~Continental drift~~
- Volcanoes
- Human CO_2 emissions

Volcanoes

Tambora (1883)

Pinatubo (1992)

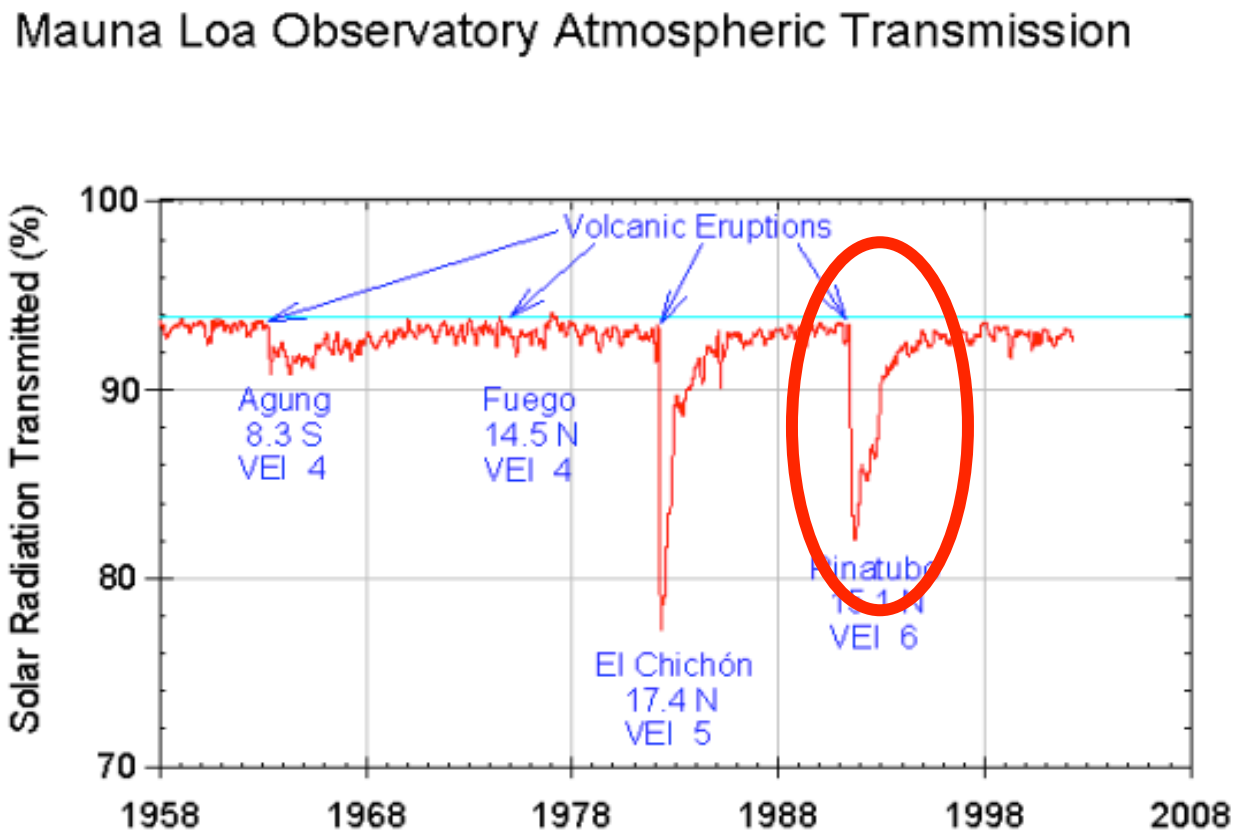
Volcanoes

- Tambora: “the bright sun was extinguish'd... morn came and went--and came, and brought no day"

Darkness by George Gordon, Lord Byron

- Pinatubo: decreased global temperatures by 0.4°C, increased Antarctic ozone hole

Volcanoes – cause short-term planetary cooling, and CO_2 emitted is trivial compared to humans



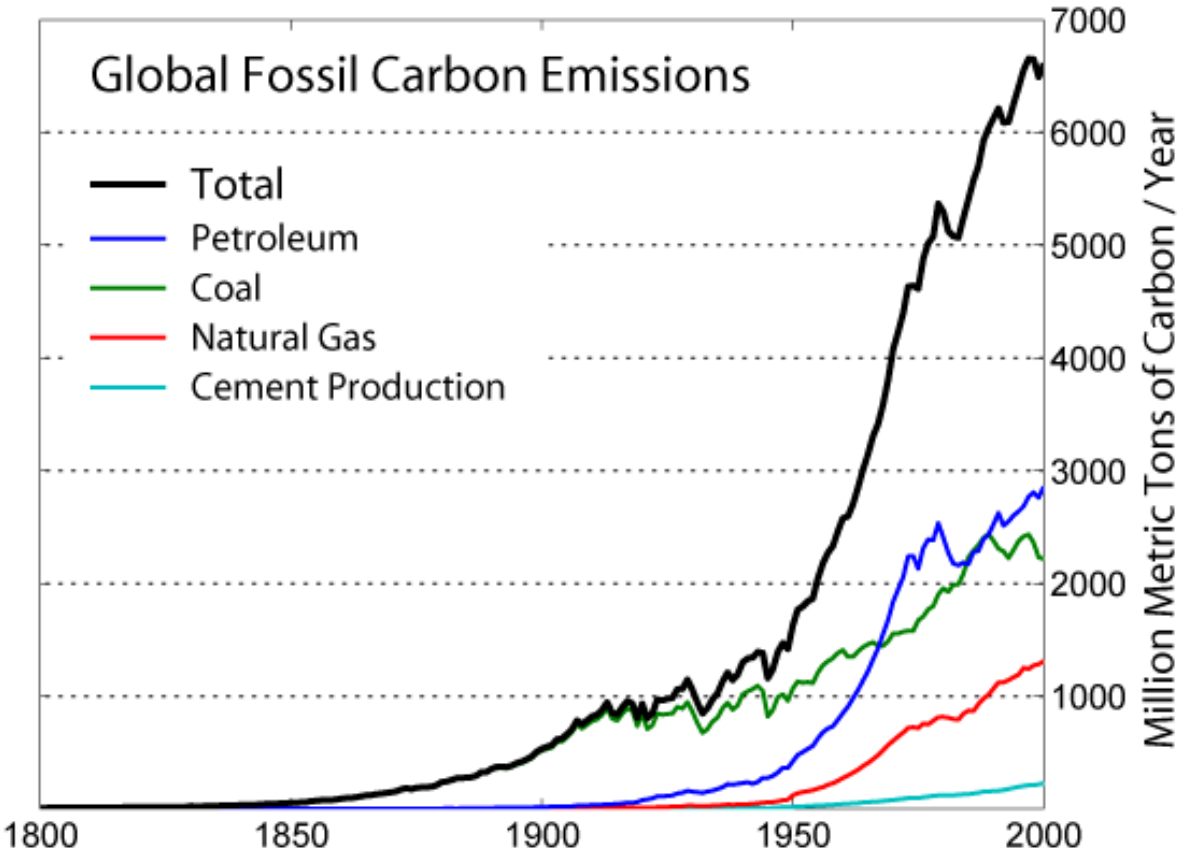
Pinatubo in 1991:
42 million tons of CO_2

Humans in 1991:
23 billion tons of CO_2

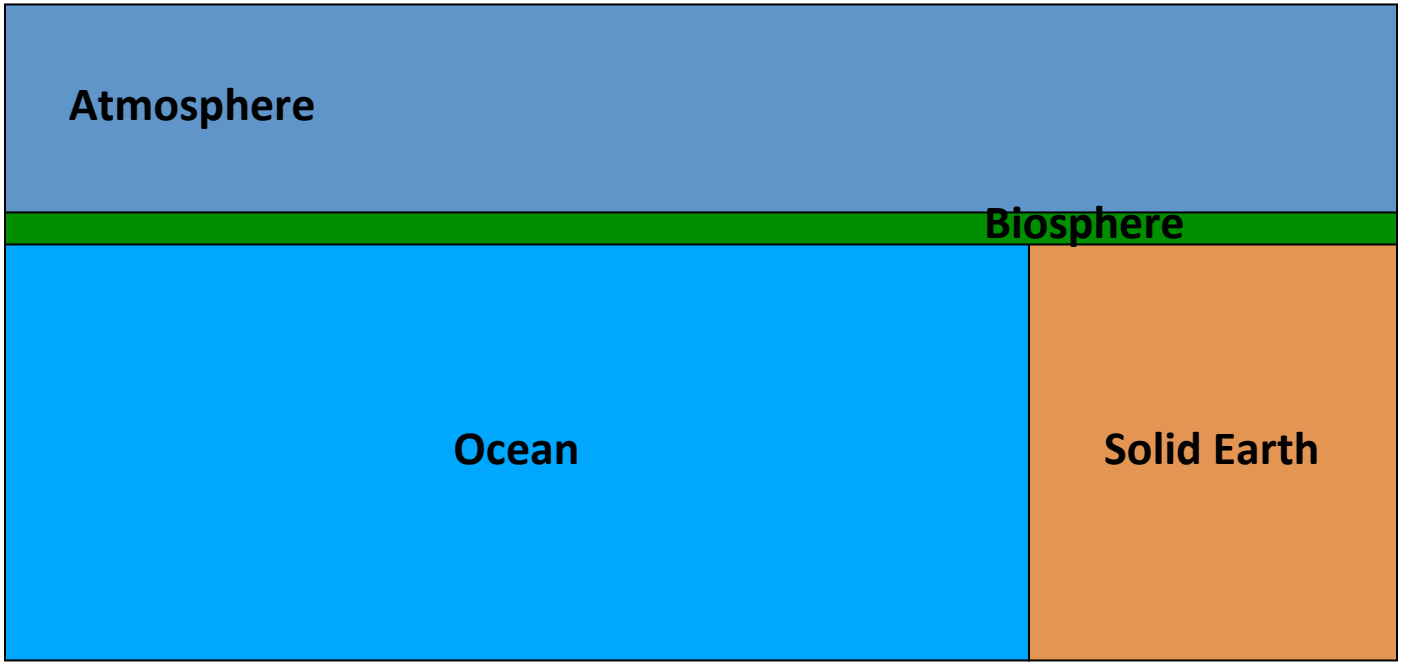
What forcings are relevant today?

- ~~Changes in the strength of the sun~~
- ~~Asteroids and meteors~~
- ~~Changes to the Earth's orbit~~
- ~~Continental drift~~
- ~~Volcanoes~~
- Human CO_2 emissions

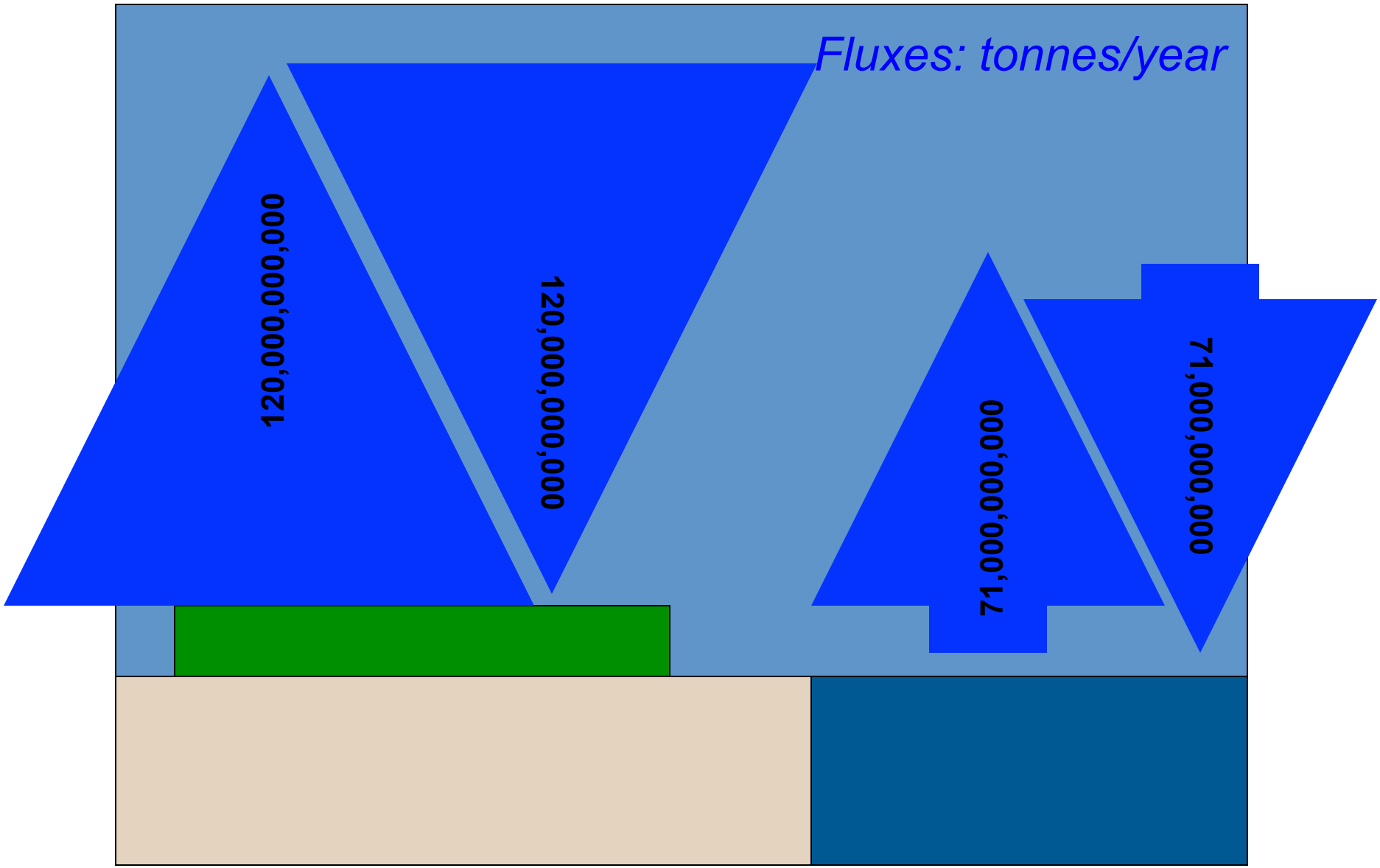
Human CO_2 emissions



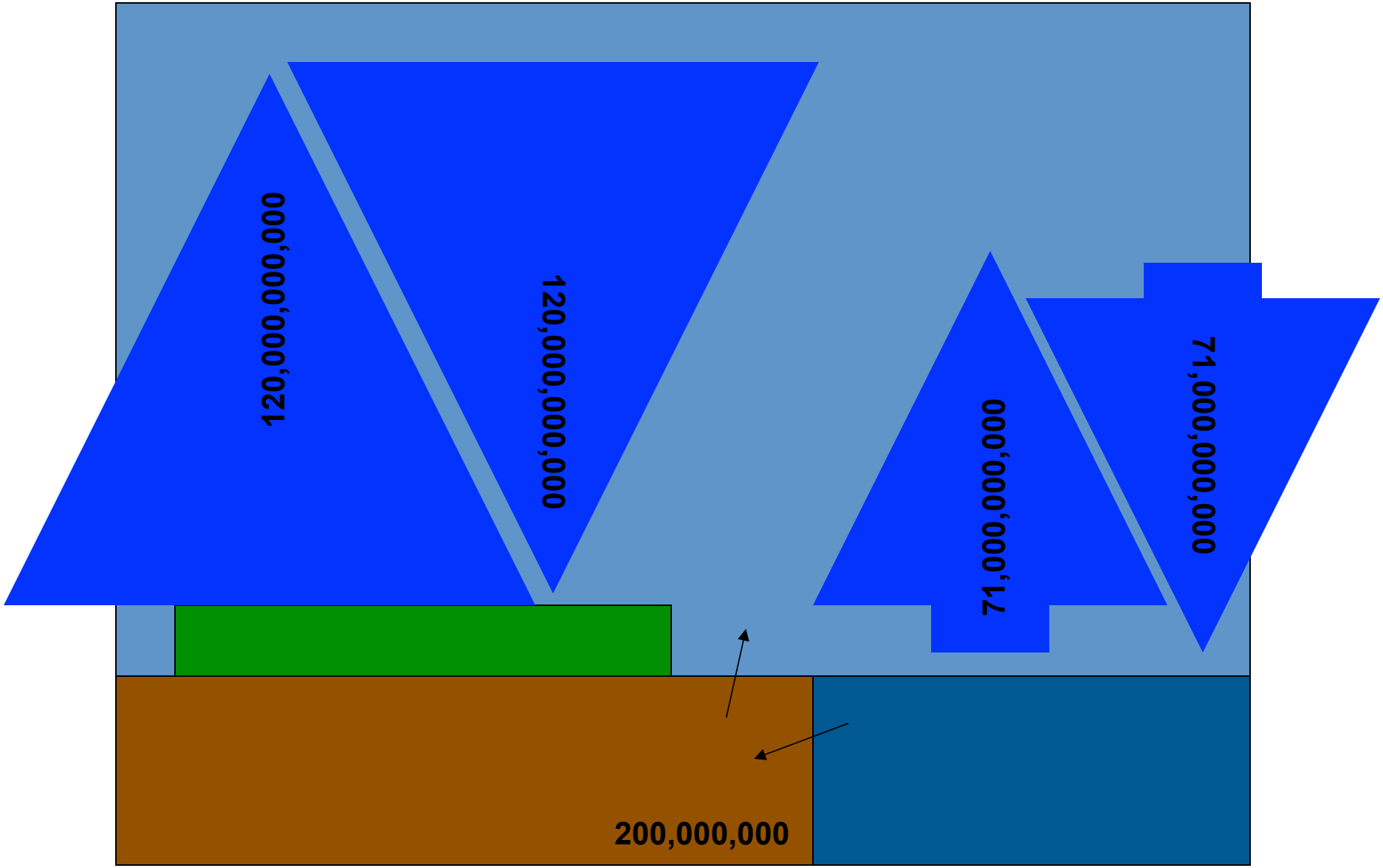
The Carbon Bathtub



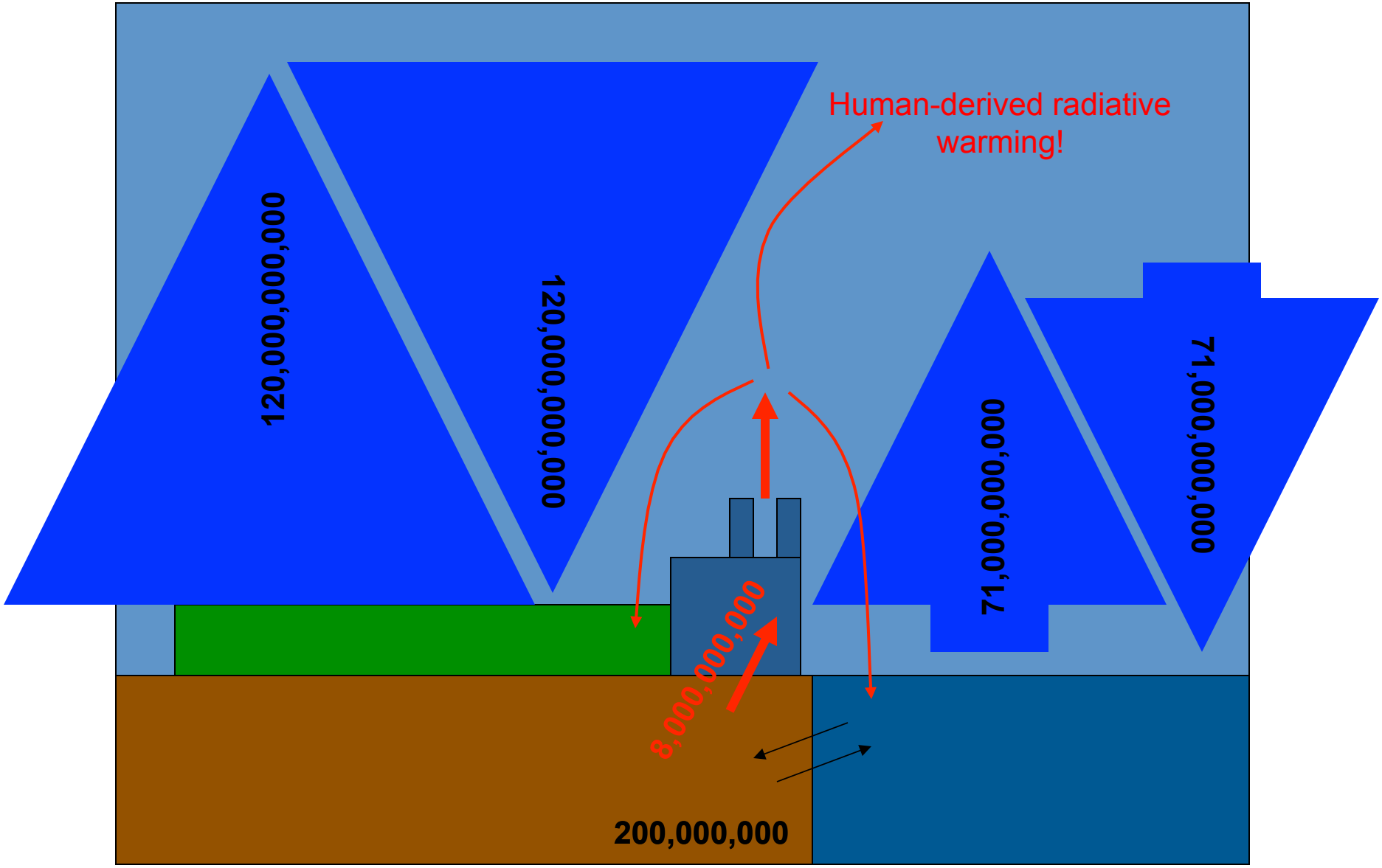
Carbon fluxes: fast carbon cycle



Carbon fluxes: slow carbon cycle



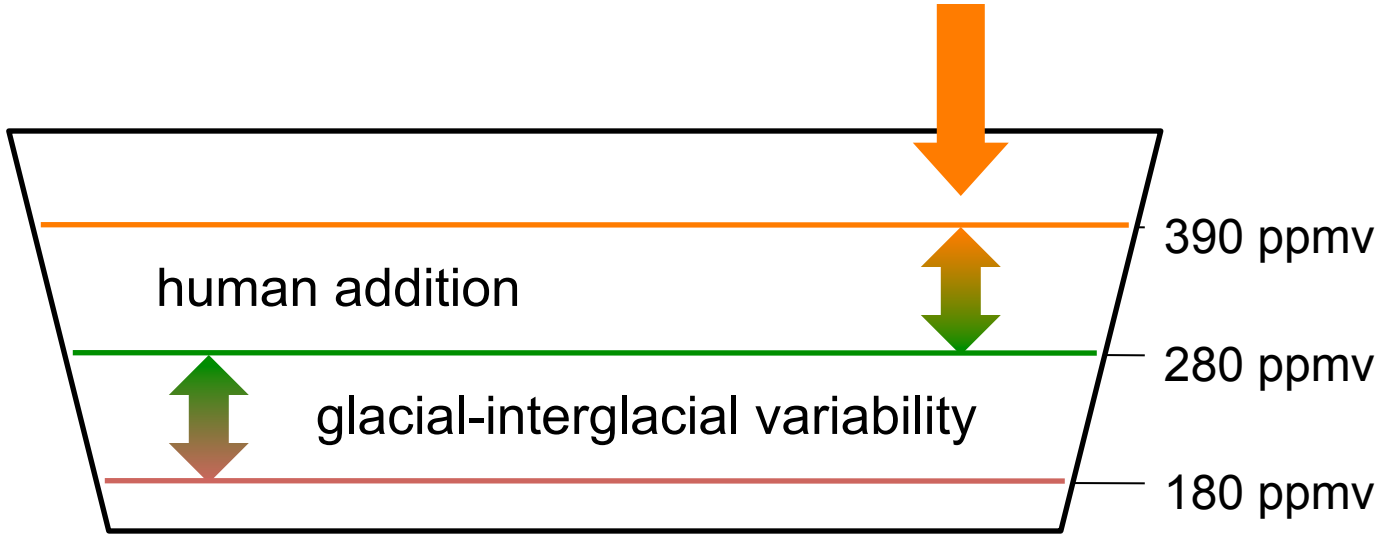
Carbon fluxes: anthropogenic emissions



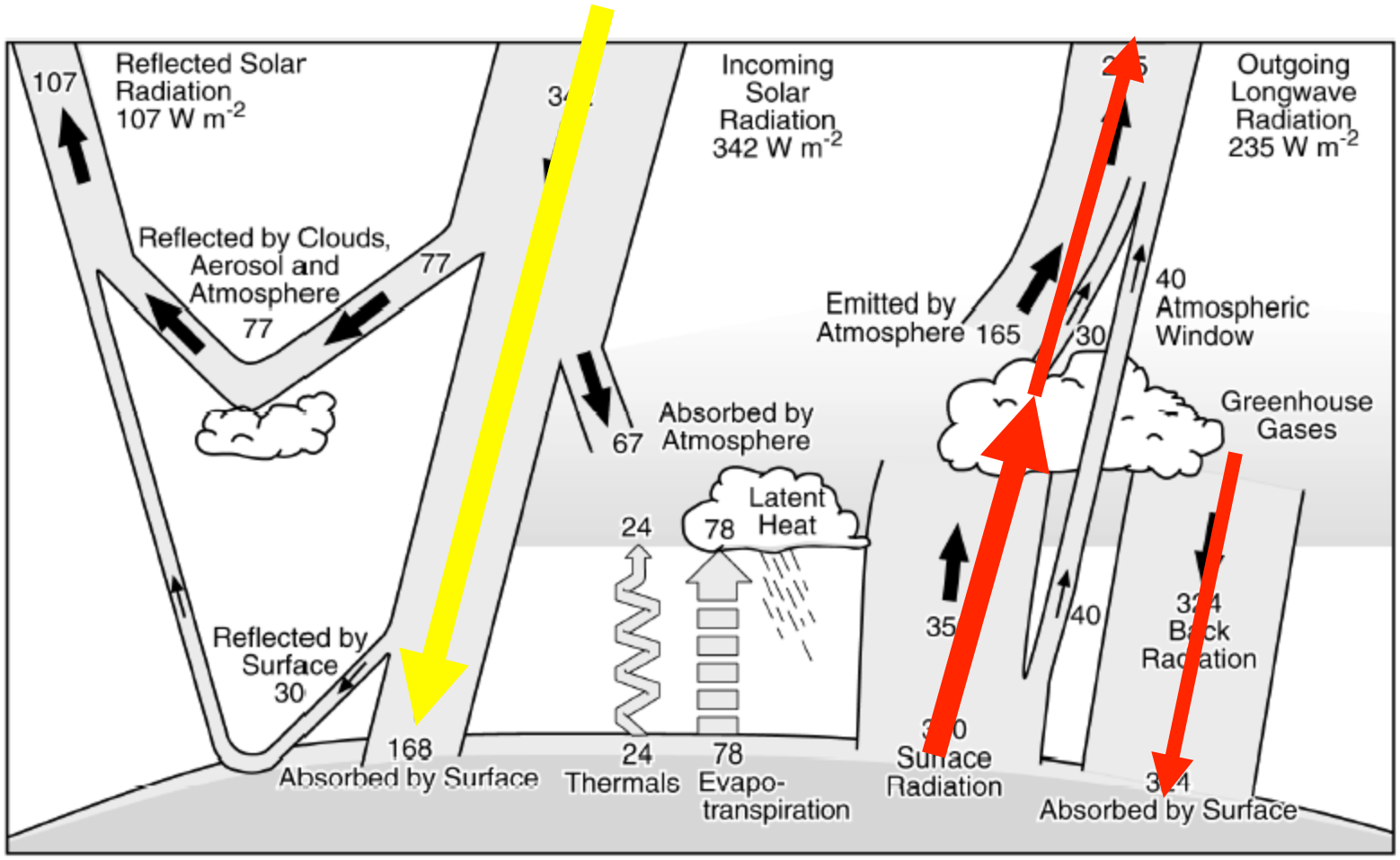
The component of the Carbon Bathtub that we mostly think about: the atmosphere

Total global historical emissions: 300 Gt C

(*into the atmosphere: 100 Gt C*)



More CO_2 = The Greenhouse Effect



Impact of CO_2 increases on Earth's temperature has been well-known for over over 100 years…

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

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JOURNAL OF SCIENCE.

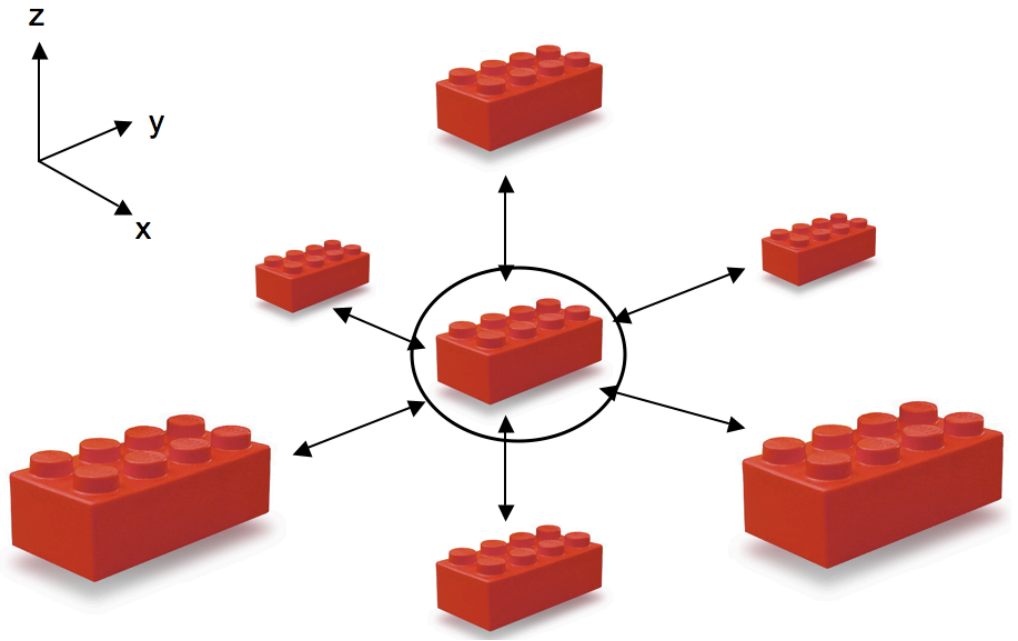
[FIFTH SERIES.]

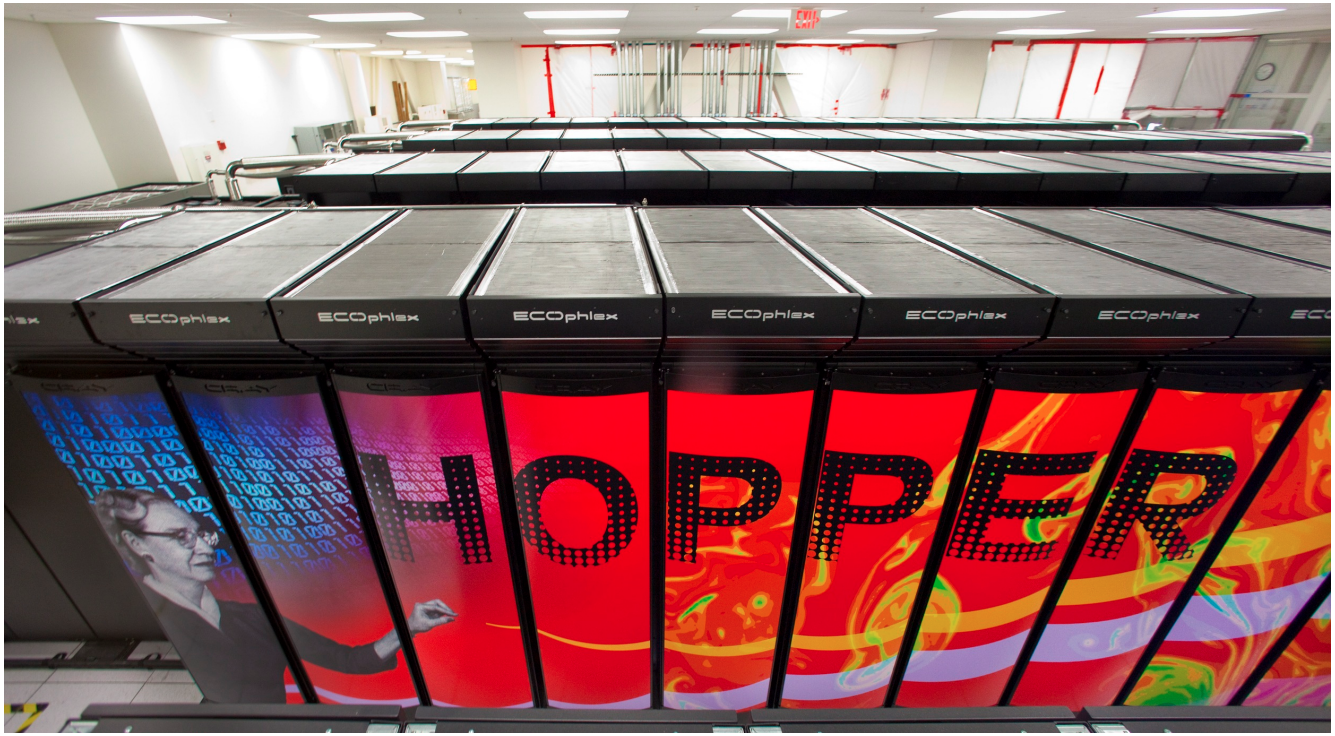
APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

…and we're refining our detailed understanding of how CO_2 affects climate with climate models

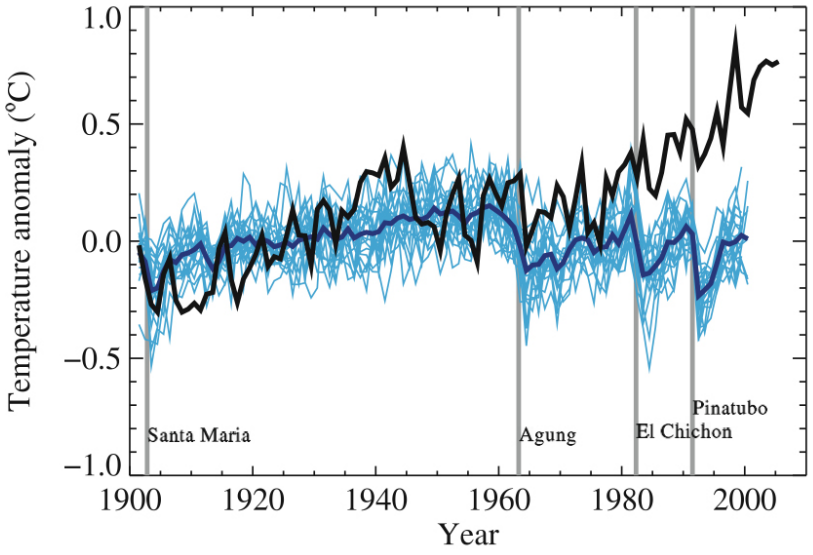


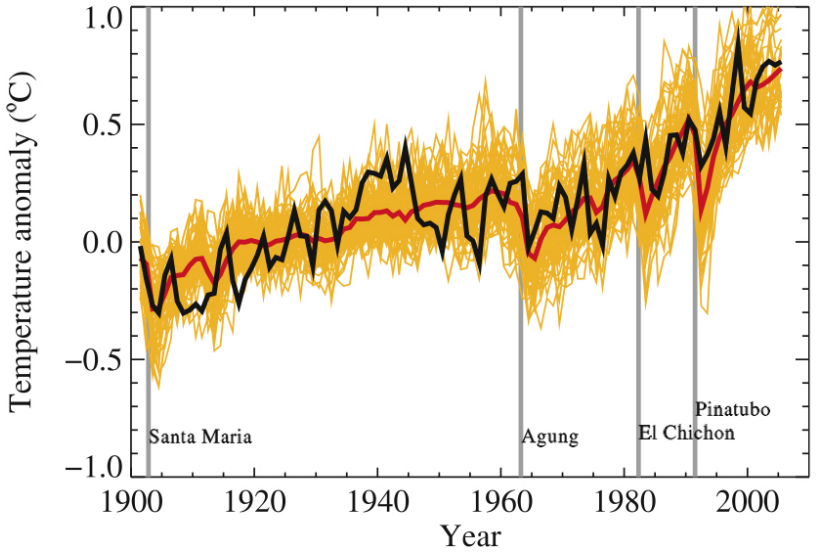

ECOphlex
HOPPER


STORAGETEK

Isolating effect of human CO_2 emissions

- Climate models are forced with different combinations of climate forcings, with results compared to observations
- Only realistic when CO_2 forcing is added





What forcings are relevant today? Theory, observation and models all point to human emissions

- ~~Changes in the strength of the sun~~
- ~~Asteroids and meteors~~
- ~~Changes to the Earth's orbit~~
- ~~Continental drift~~
- ~~Volcanoes~~
- Human CO_2 emissions

So, could the contemporary change still be due to something else other than human emissions?

- Sure, but ***first*** you'd have to identify a major as-yet-undiscovered climate forcing that explains all physical/chemical/biological observations…
- …***then*** you'd have to explain why our current understanding of the carbon cycle, CO_2 and basic physics is fundamentally wrong.

Where do we go from here?

Total cumulative emissions to date: 300 Gt C

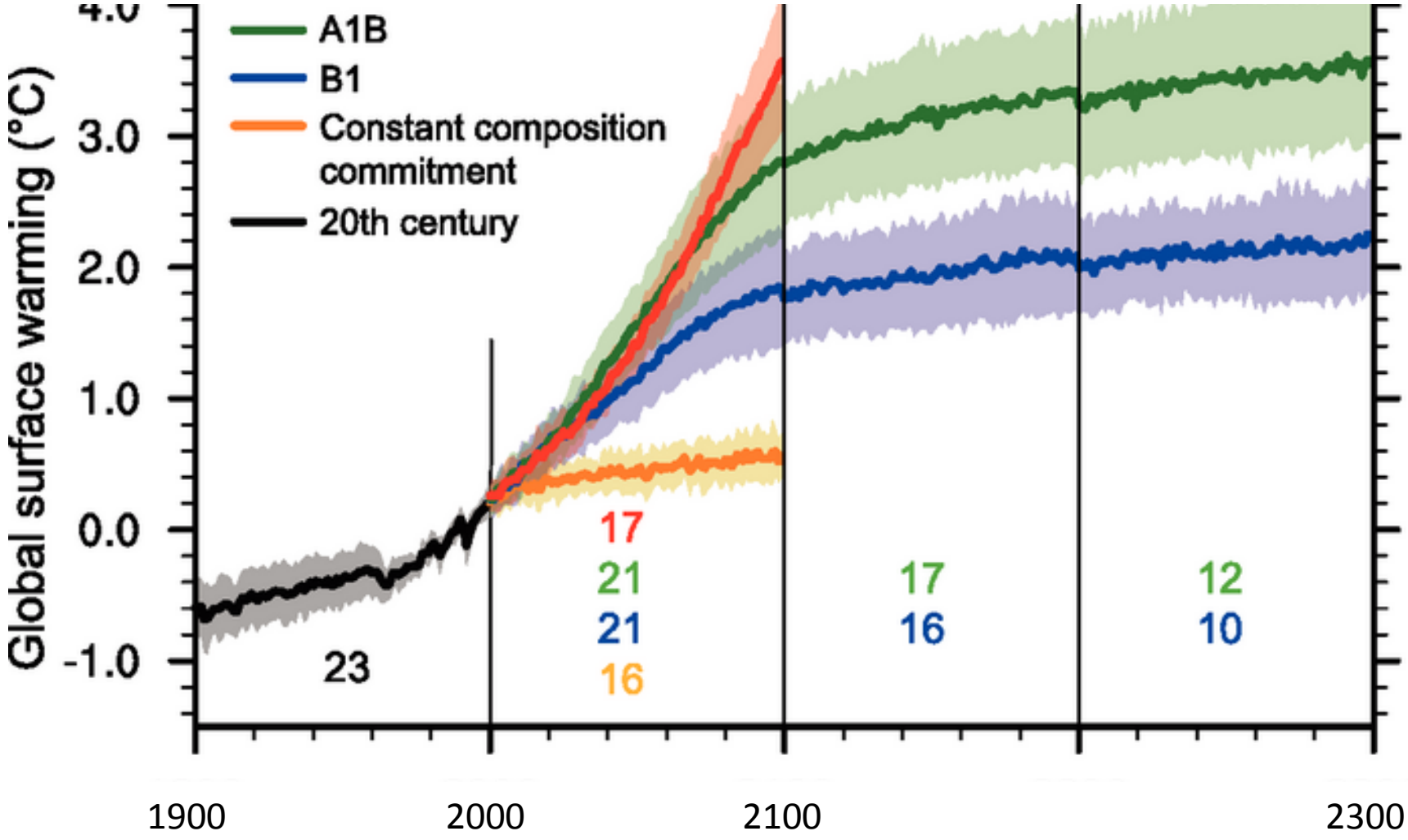
Estimated economically recoverable reserves: 5000 Gt C

Estimated methane hydrate reserves: 10000 Gt C

So what happens next?

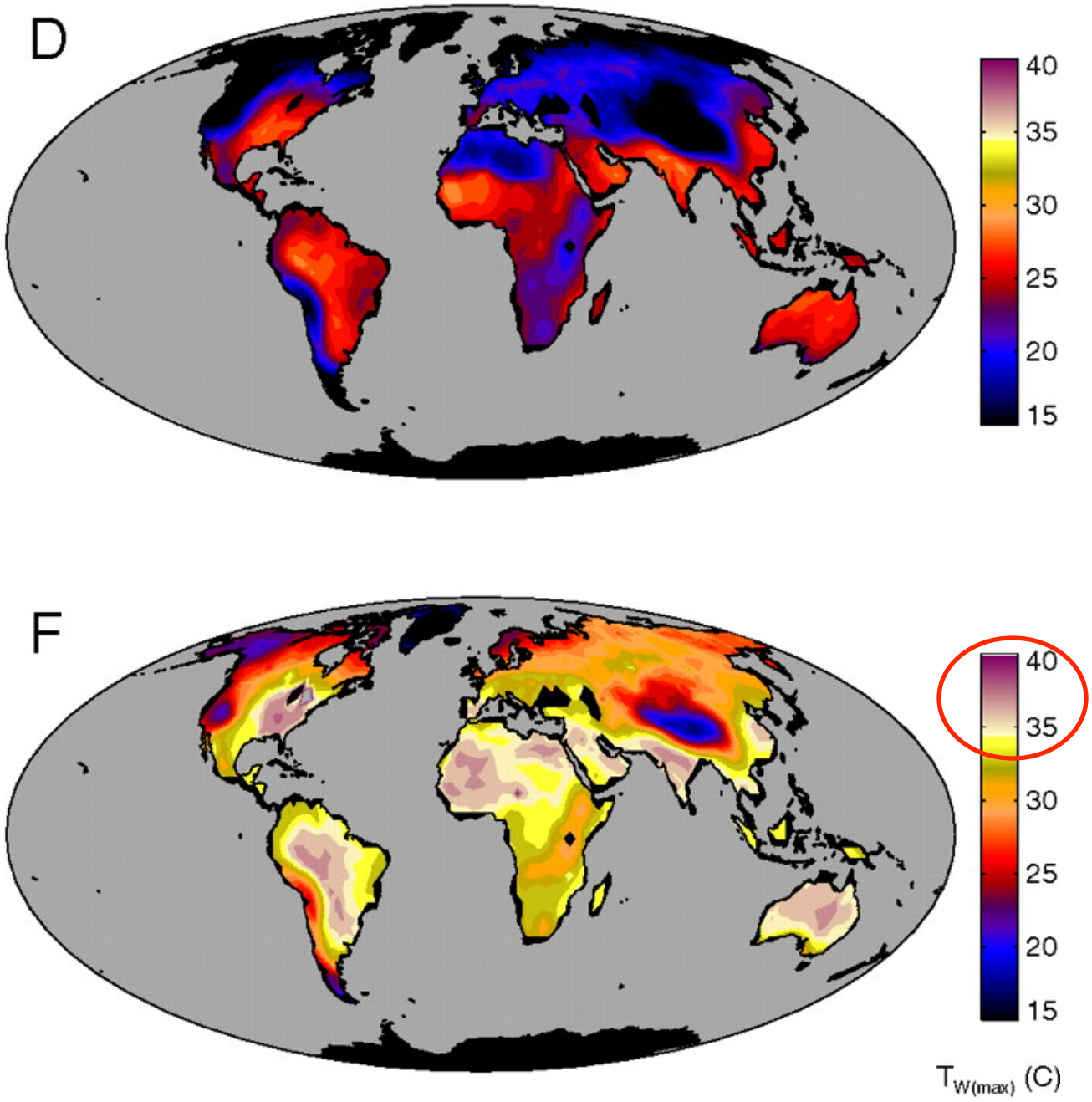
It’s up to us!

So what happens next?

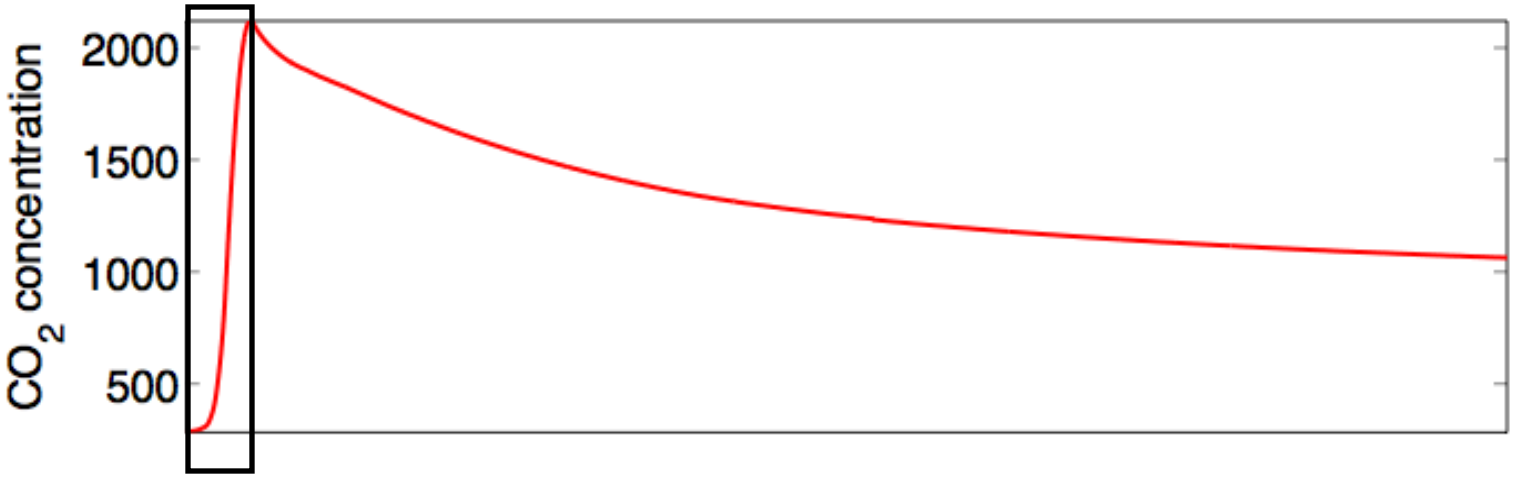


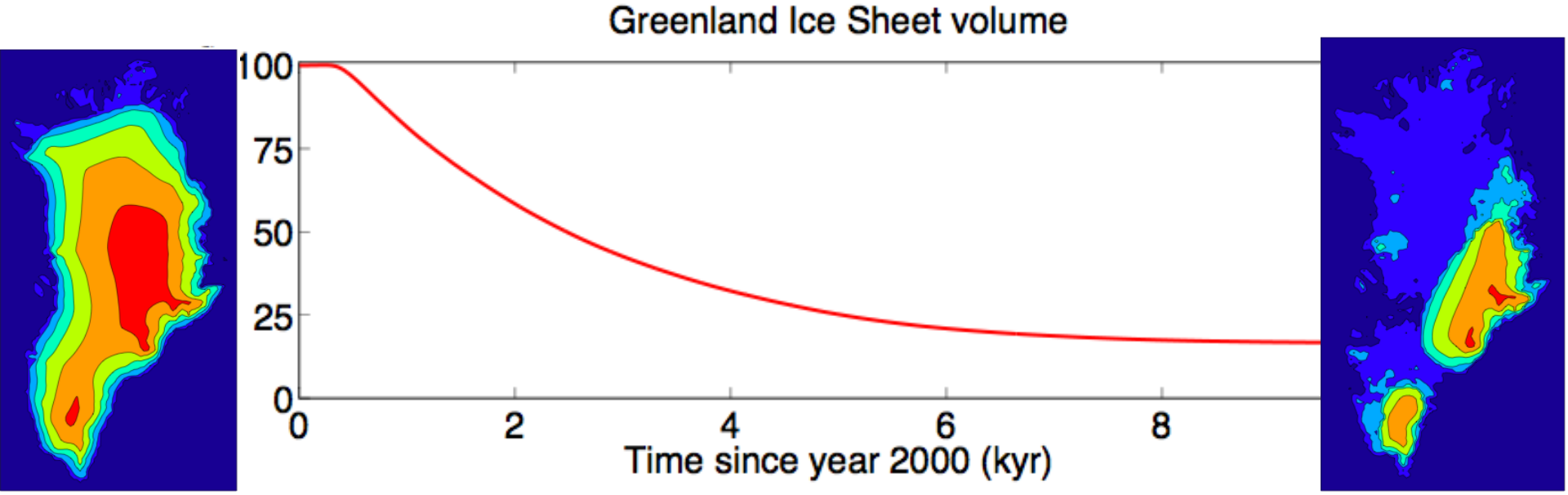
Present-day

5000 Gt C
(Year 2300)



10000 year simulation





600 million people displaced

Summary?

- Climate change has always happened, but current climate change is **unprecedented**
- Natural forcings **cannot** explain current change, human forcings **can**
- **Economic potential** for much more severe climate change, if no major shifts in global emission levels occur
- **Climate system evolution in future will be dominated by present and future human forcing**

Who contributes the most?