Universität Bremen

Global Climate Change and the Arctic
–
Remote Sensing and Models

Episode 1: Polar regions and climate change

Dr. Georg Heygster
Institut für Umweltphysik (IUP)
Universität Bremen

eGeneral Studies: Der Hohe Norden | The Far North | Le Grand Nord (Kanada/Québec)

Overview of the learning unit

Episode 1:
Polar regions and climate change

Episode 2:
Satellite remote sensing in the polar regions

Episode 3:
Interview with the lecturer

Learning target of the episode

Learning target 1:
You can describe the Arctic as part of the global climate system.

Learning target 2:

You understand the global warming is induced by anthropogenic greenhouse gases.

Learning target 3:
You understand the sea ice albedo effect and why global warming is particularly pronounced in Arctic.

Overview: Polar regions and climate change

Part 1:
Polar regions as part of the climate system

Part 2:
Current changes

Part 3:
A glance to future changes

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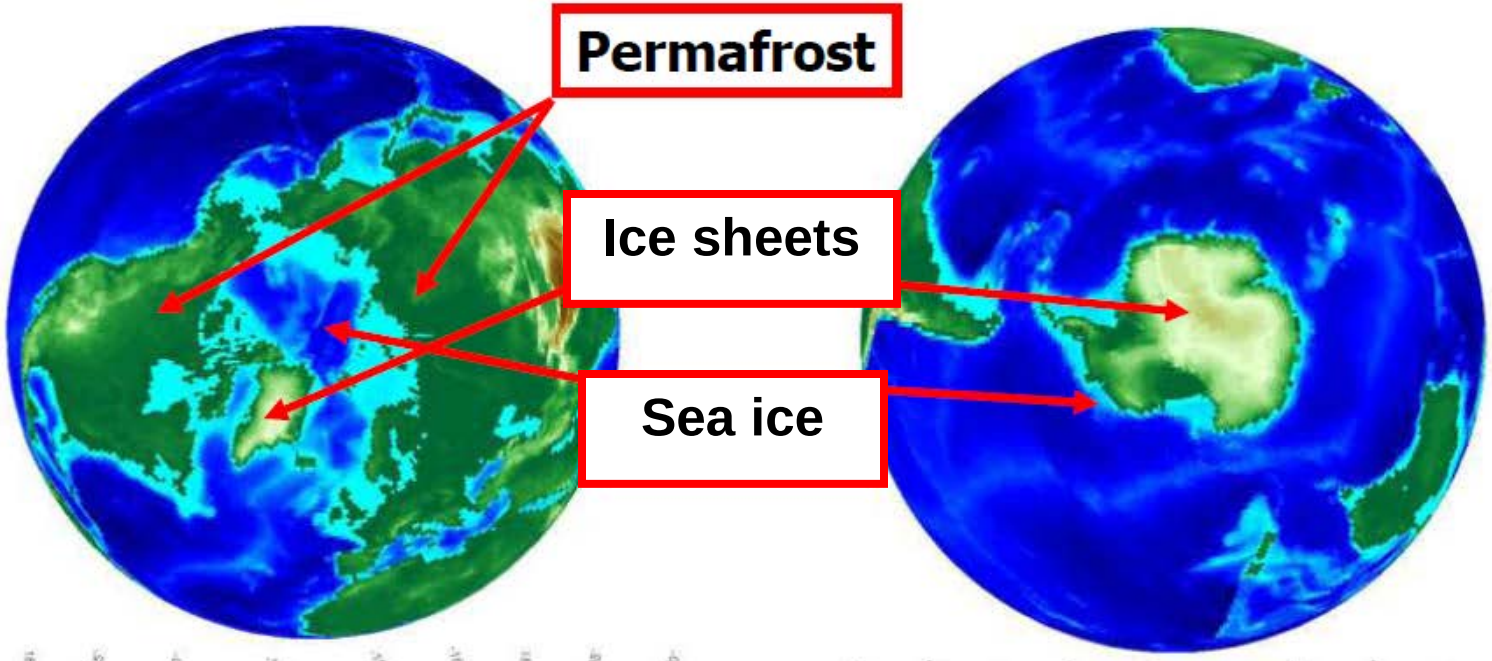
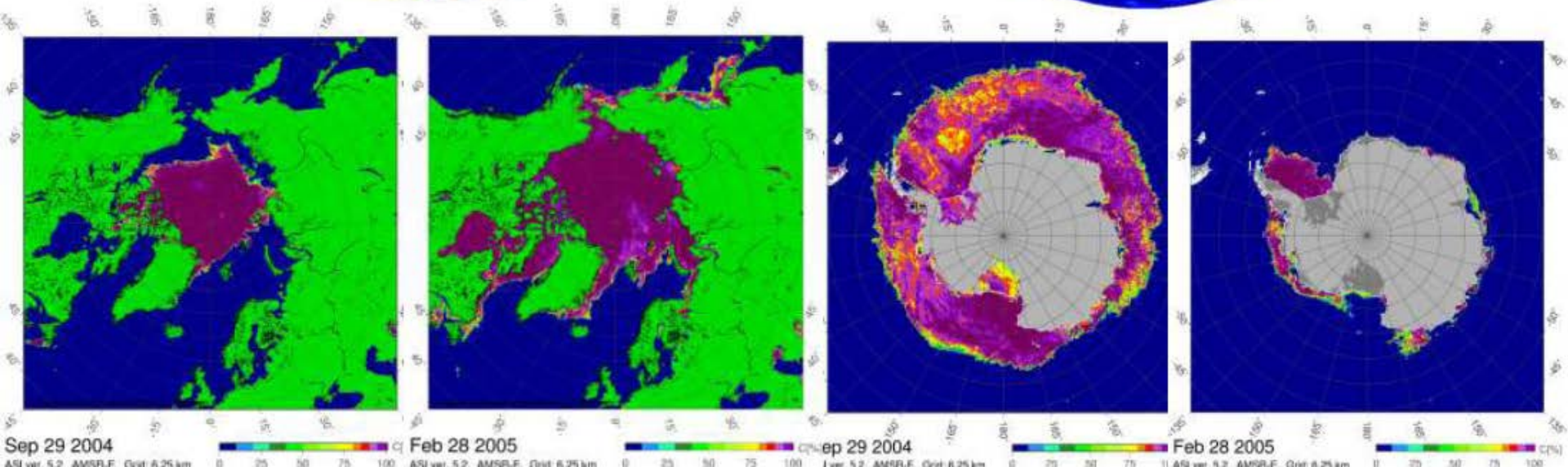
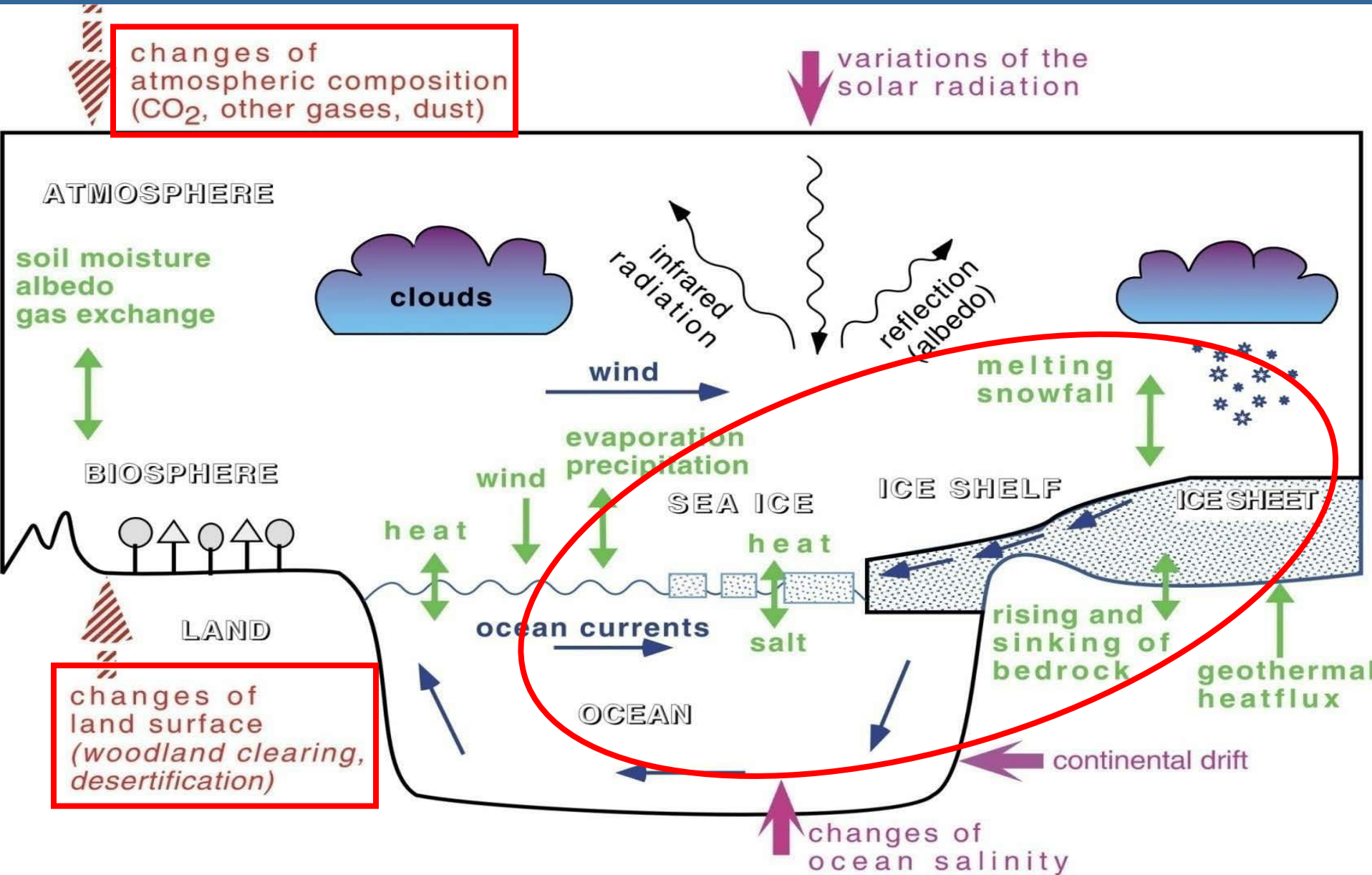
The polar regions





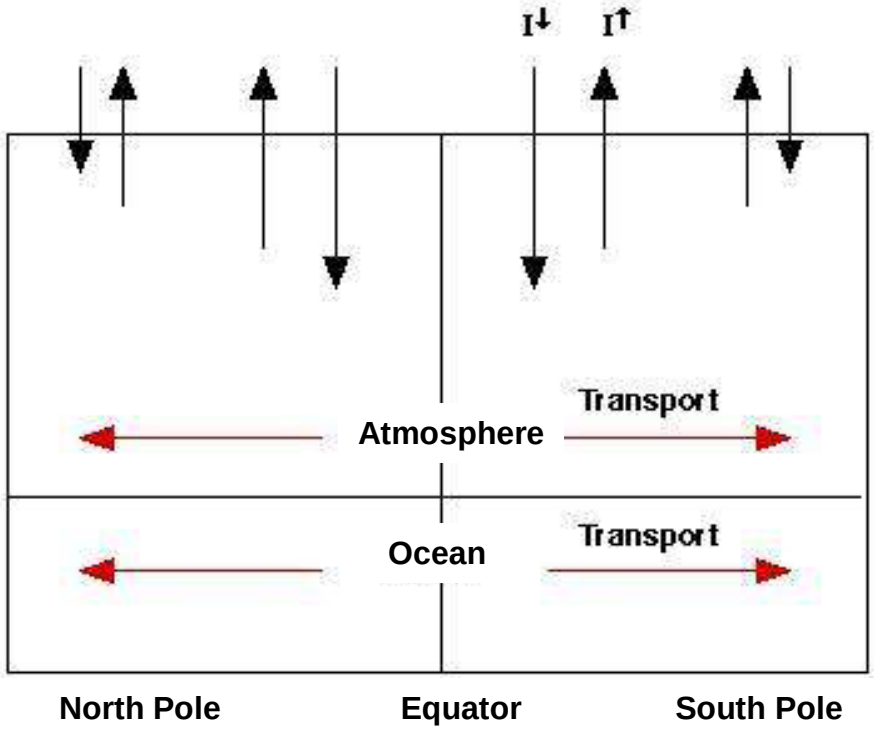
The climate system

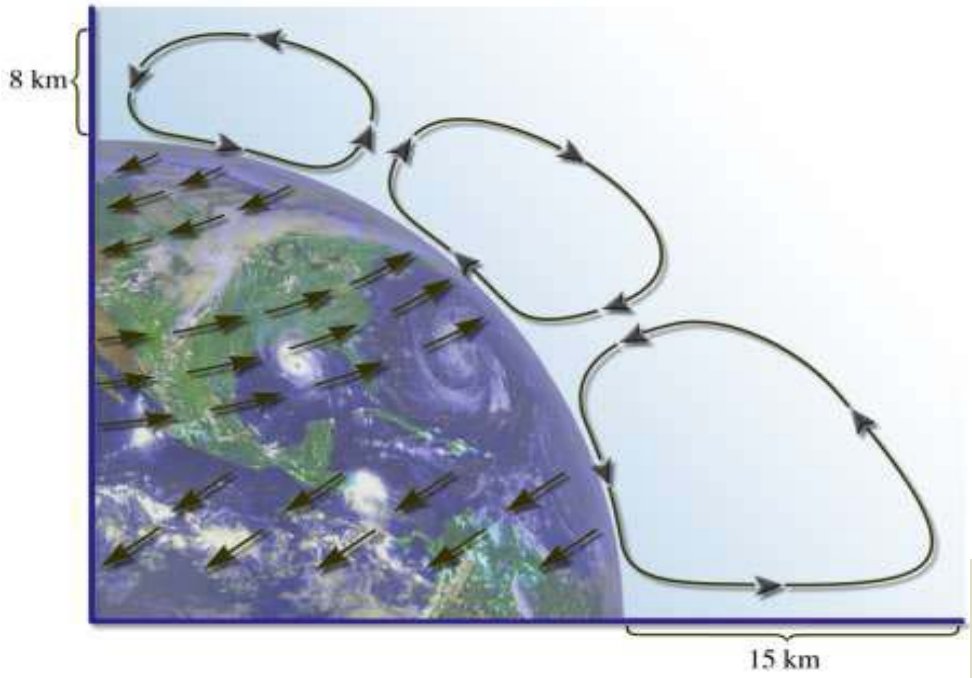


Polar regions – global climate: atmosphere

- Low latitudes: energy collectors
- High latitudes: energy radiators
- Energy transport by temperature contrasts

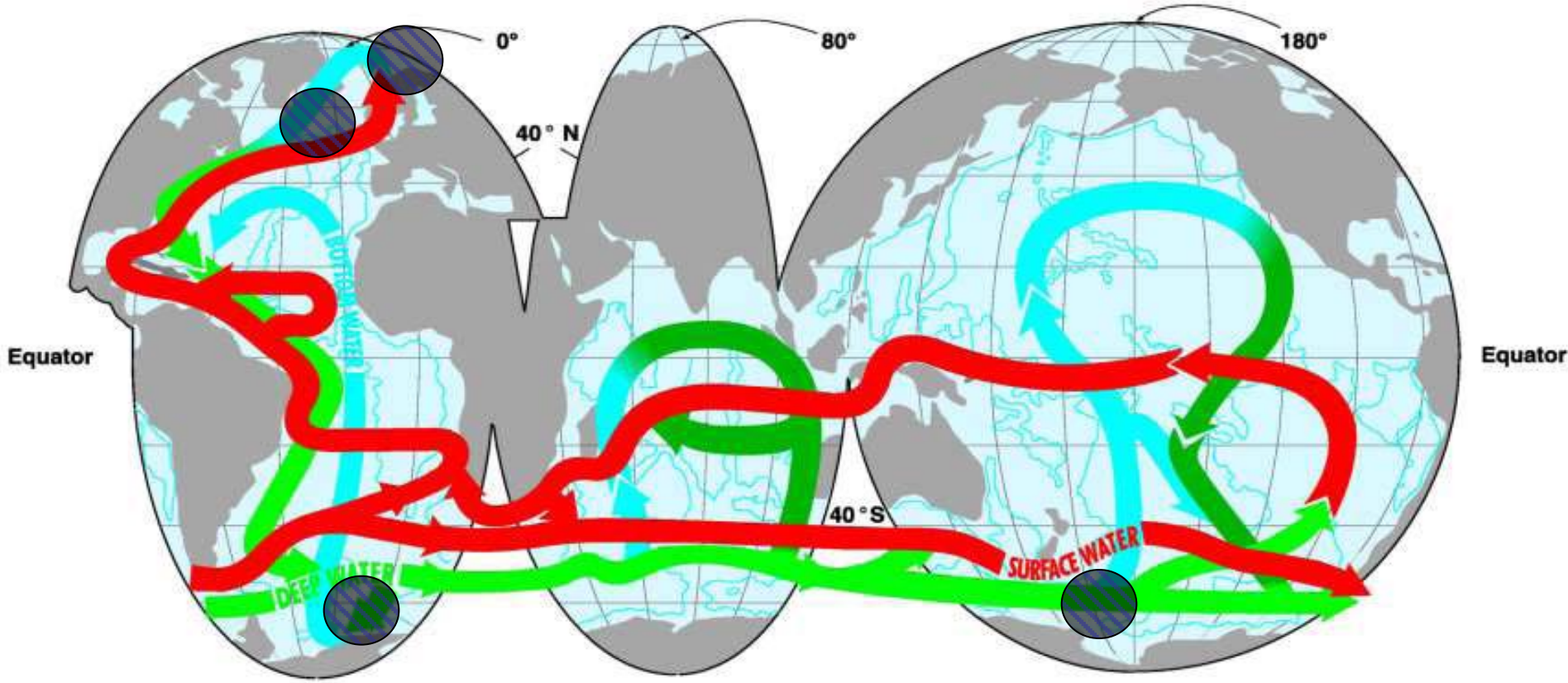
  Equator → Poles



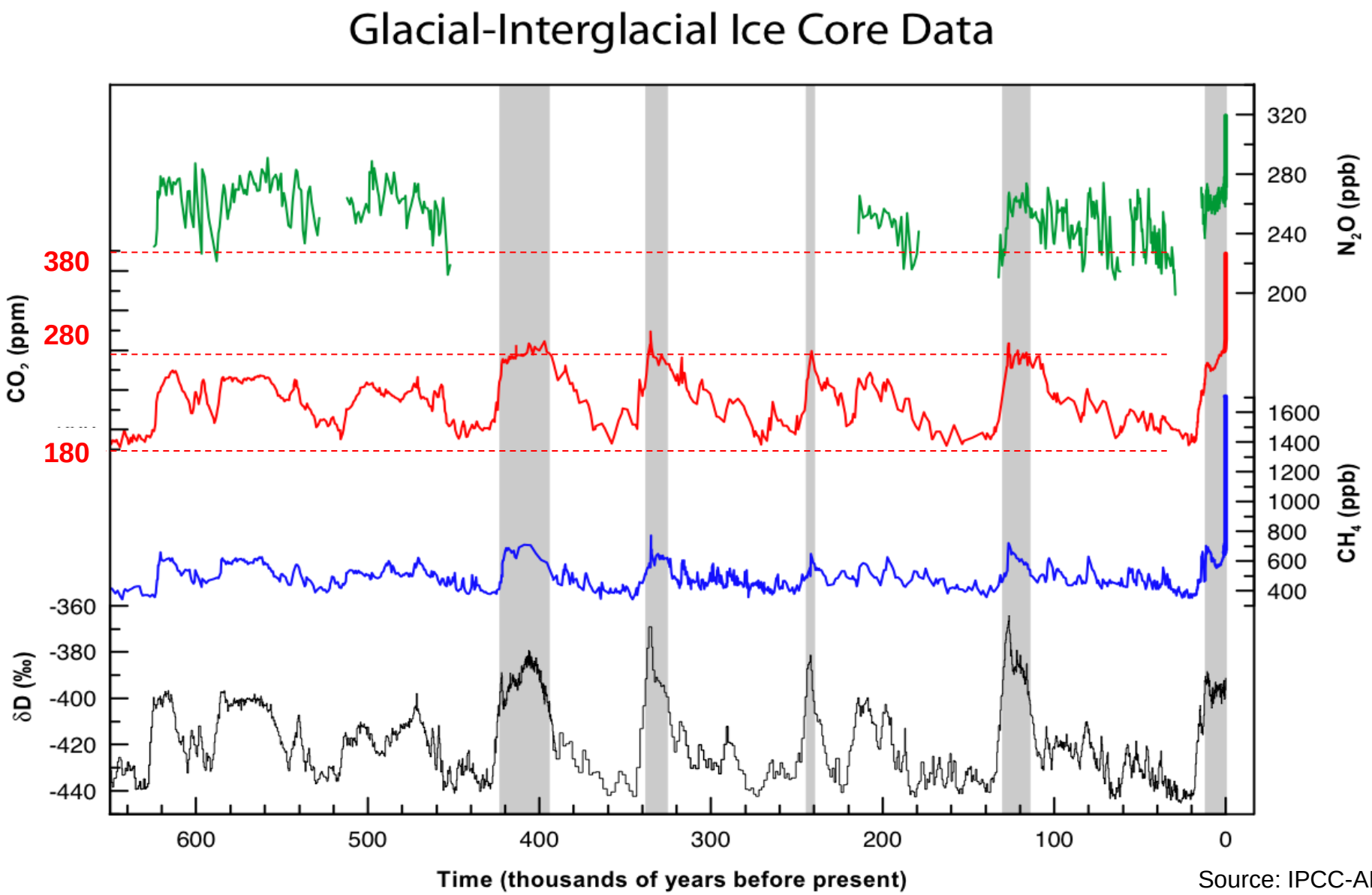


Polar regions – global climate: ocean

Sea ice:
- important fresh water source (North Atlantic, Weddell Sea)
- drives global ocean circulation

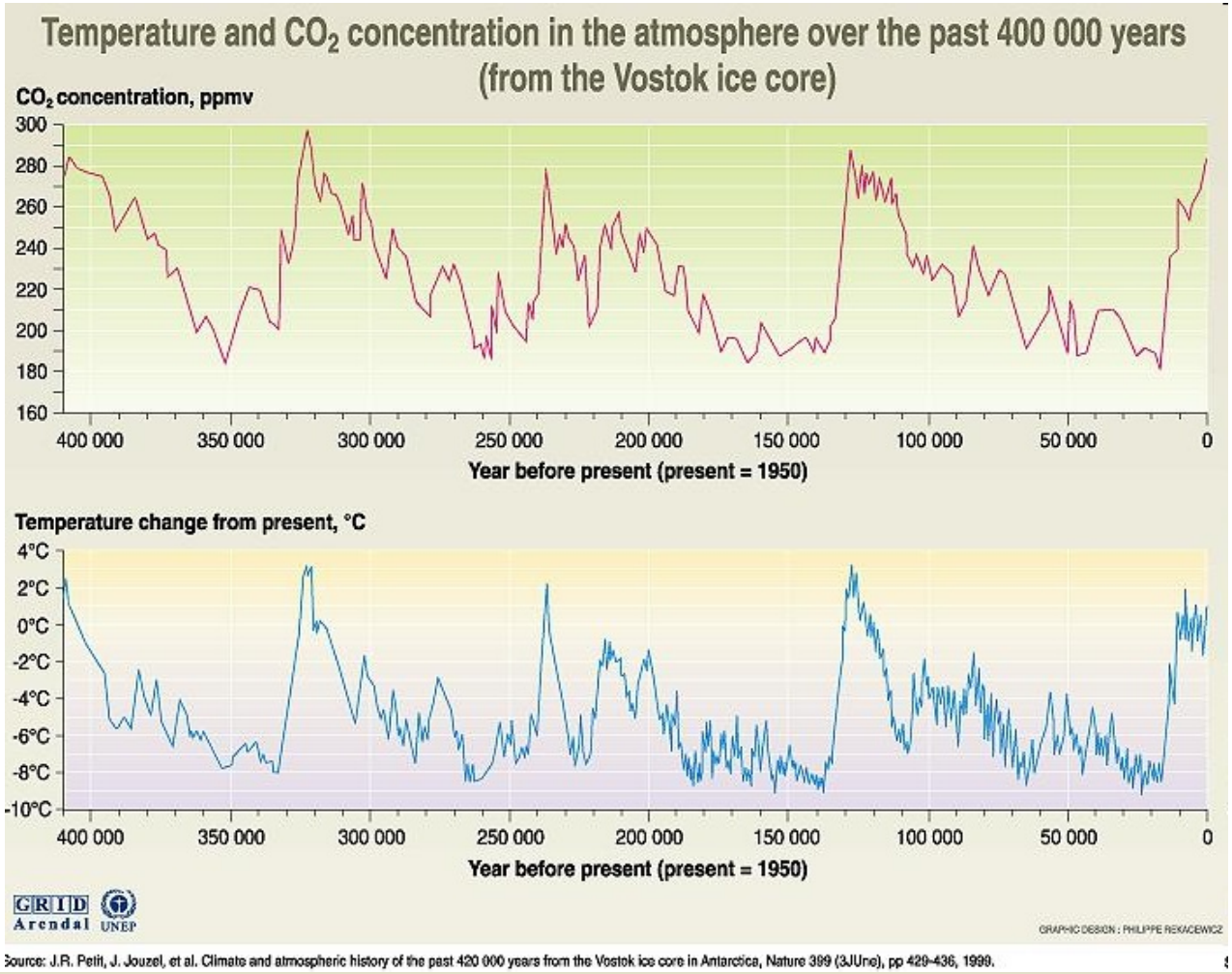


Atmospheric concentration of some greenhouse gases



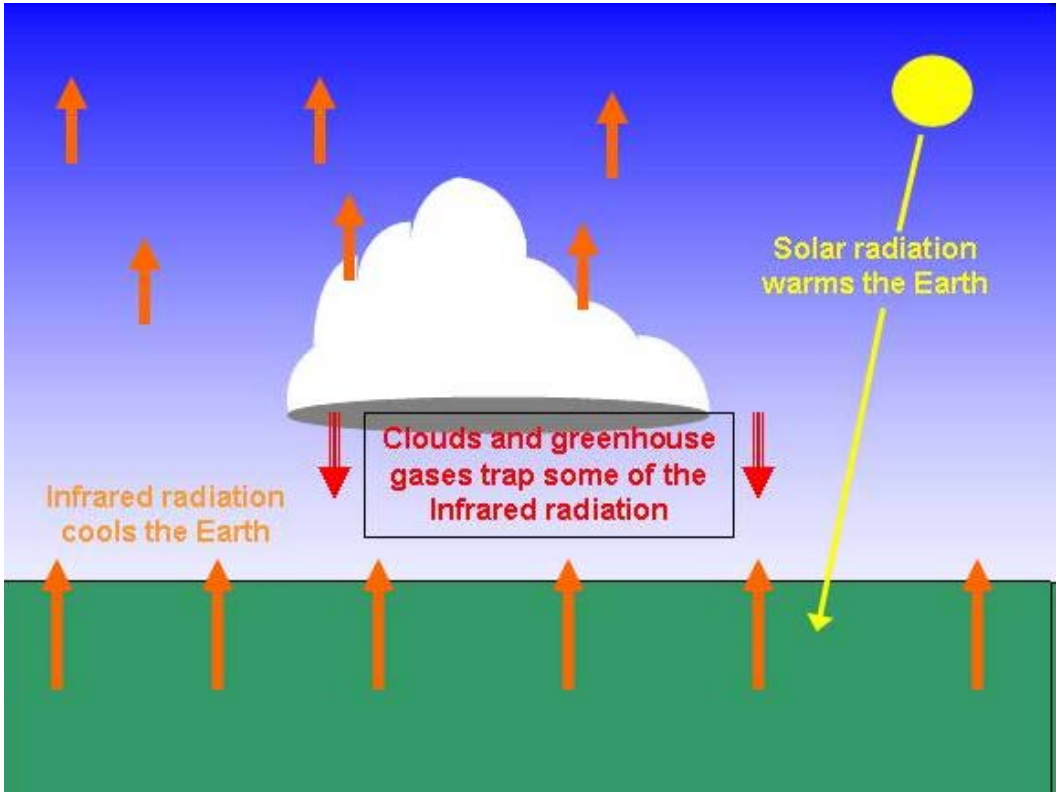
Source: IPCC-AR4

CO_2 and temperature from Vostok ice cores



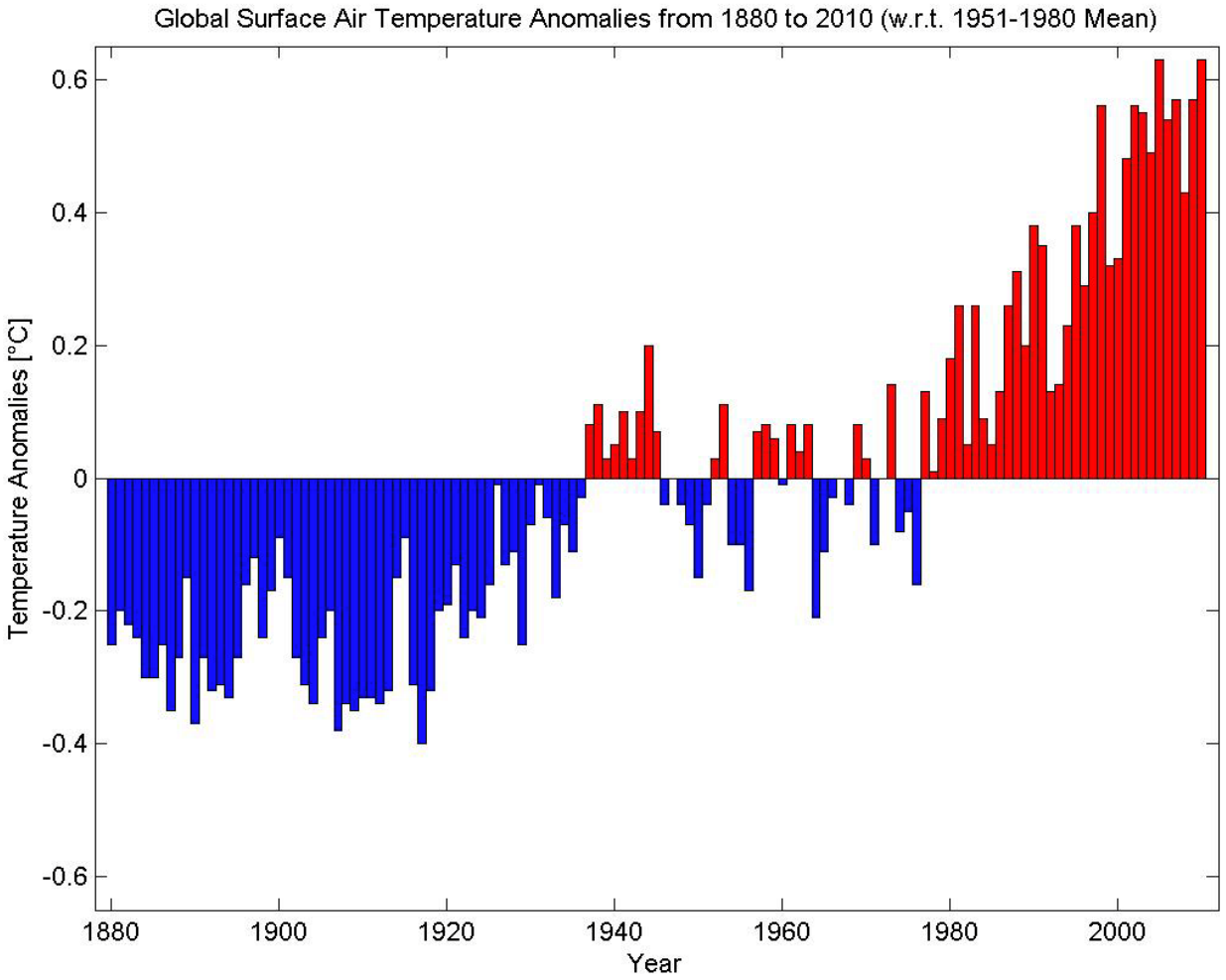
Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

The greenhouse gas (GHG) effect



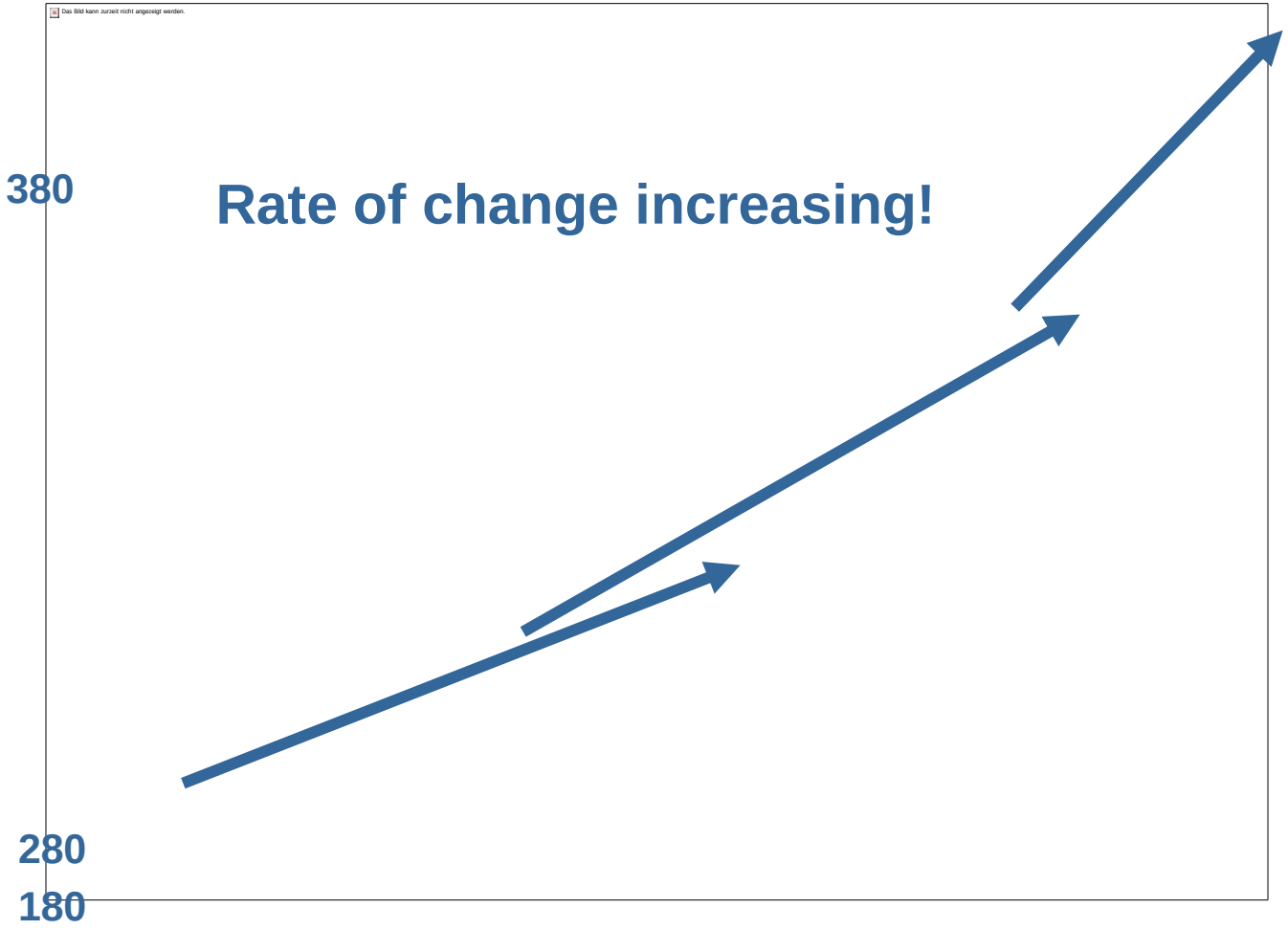
- Most important greenhouse gases: H_2O, CO_2, CH_4
- natural GHG effect: surface temperature + 33°C

Global mean temperature rising

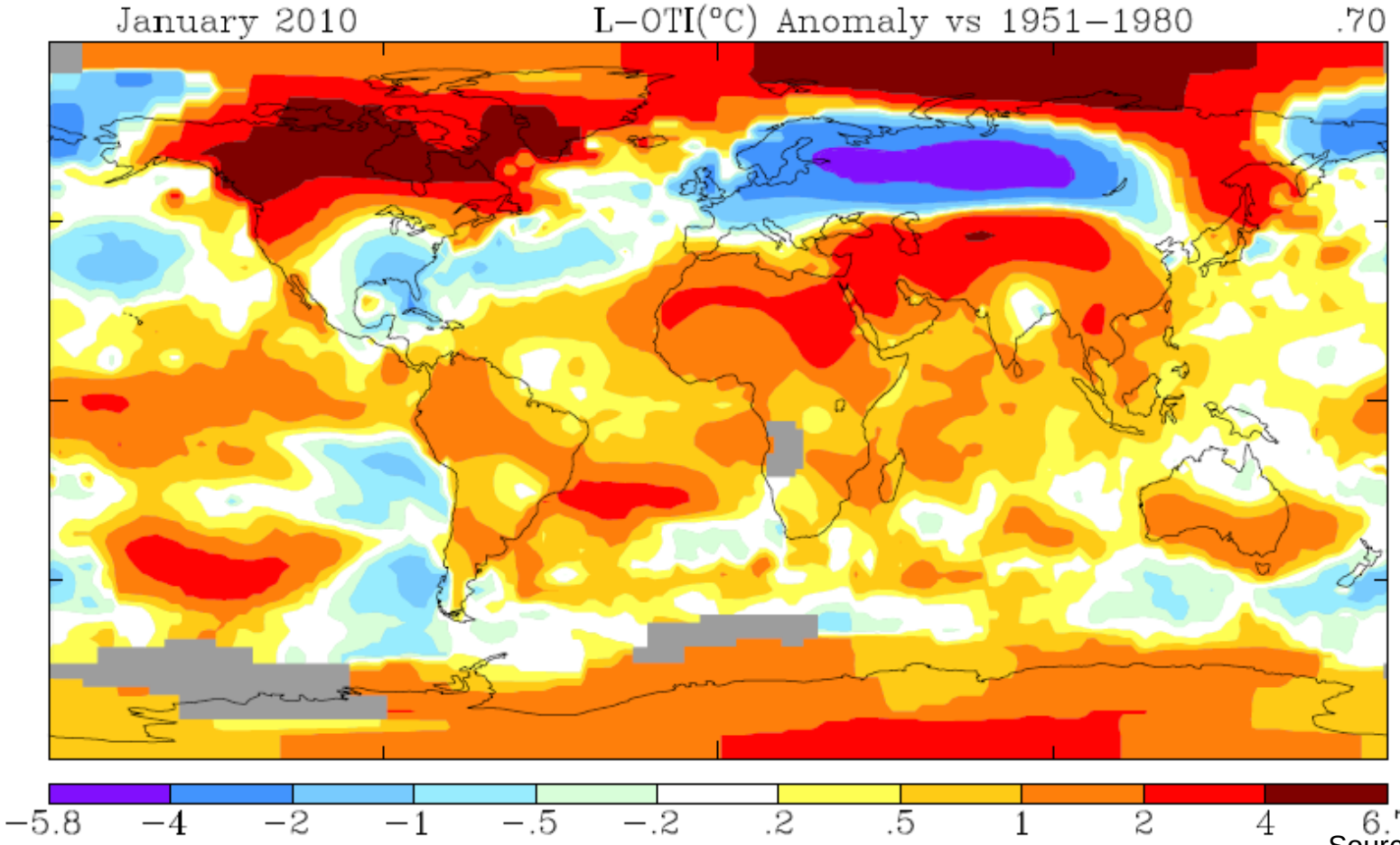


Source: GISS data

CO_2 concentration at Mauna Loa, Hawaii, 1958 - 2010

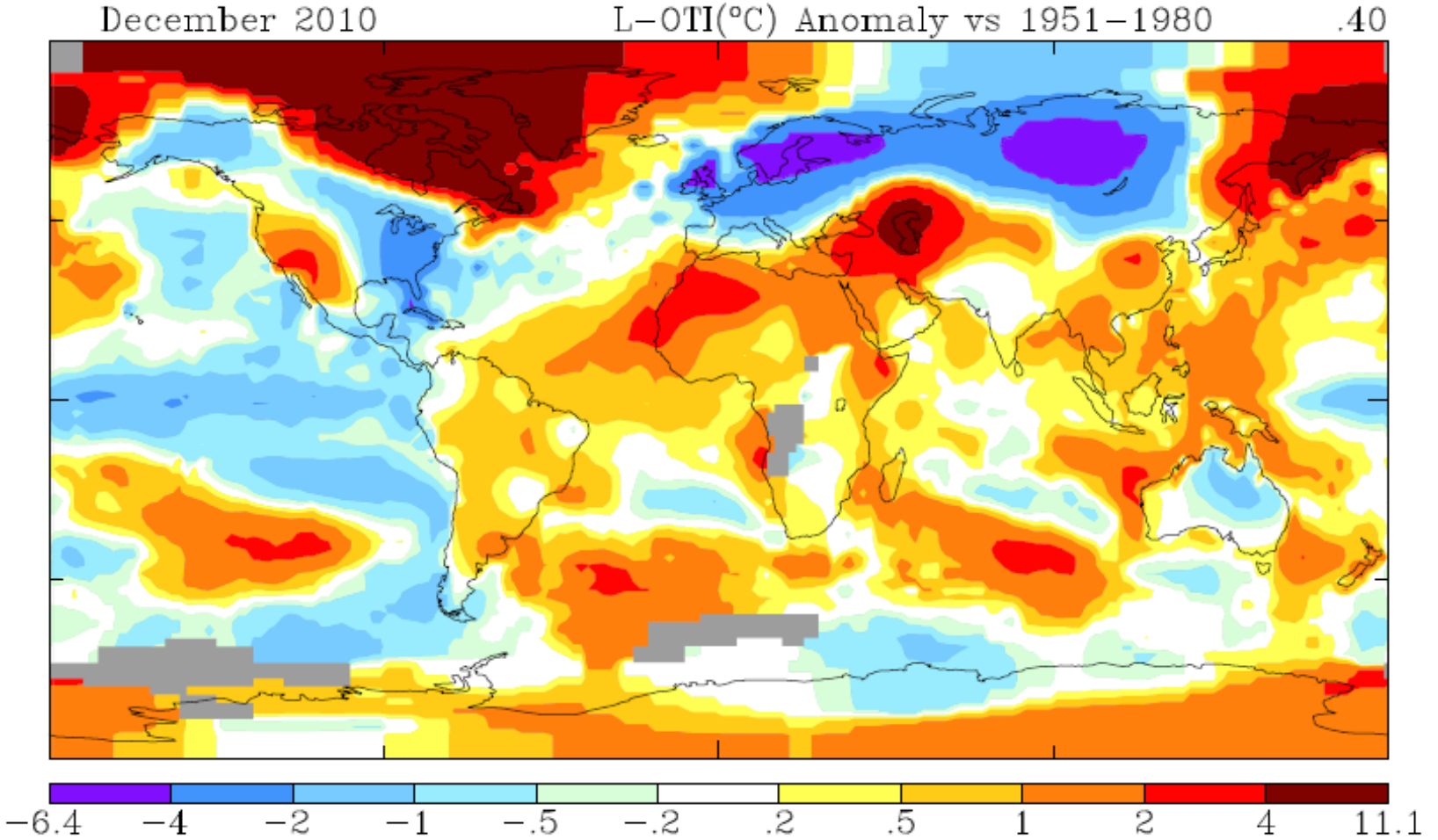


January 2010 globally far too warm



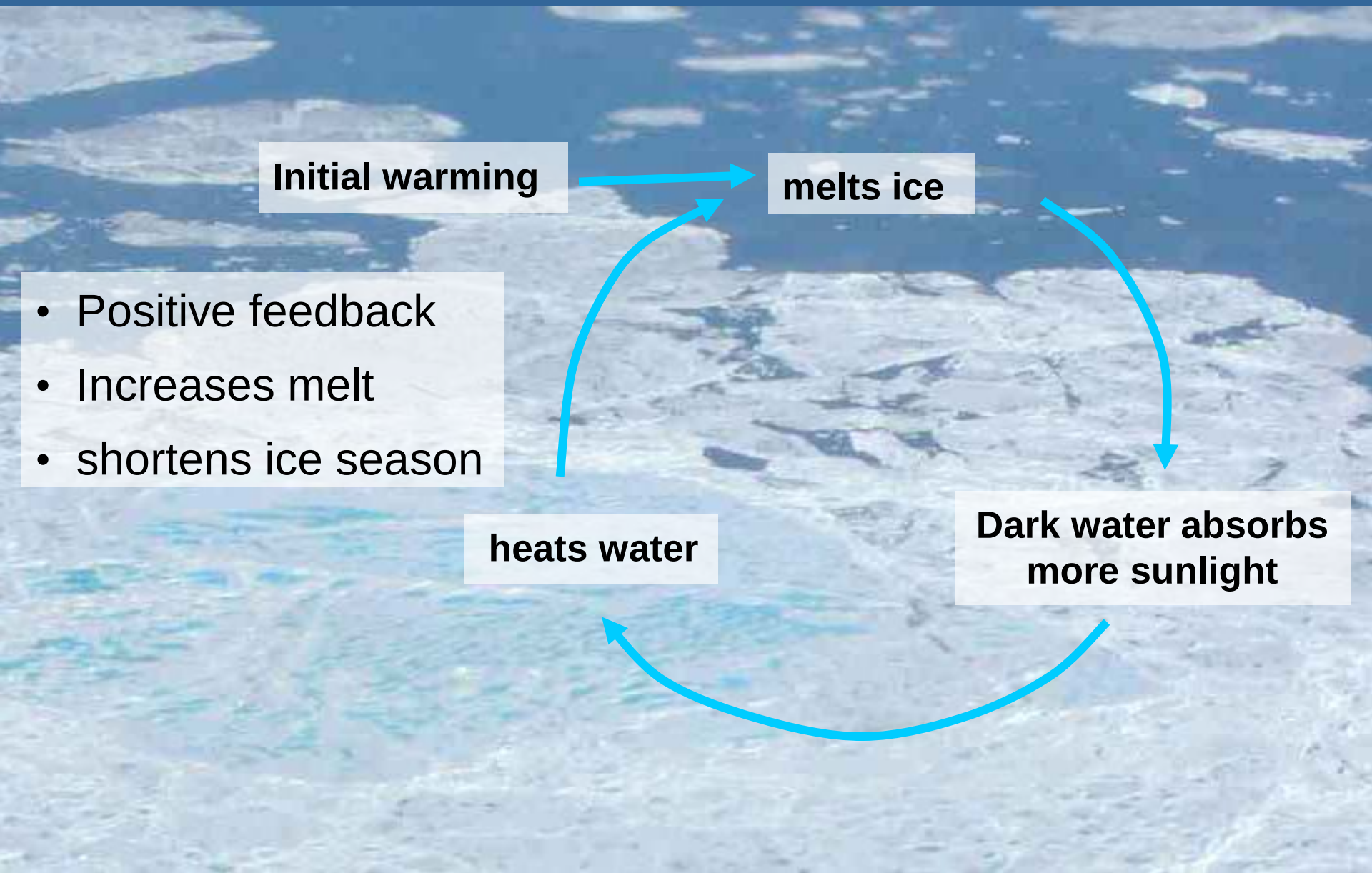
Source: GISS Data

December 2010 globally far too warm



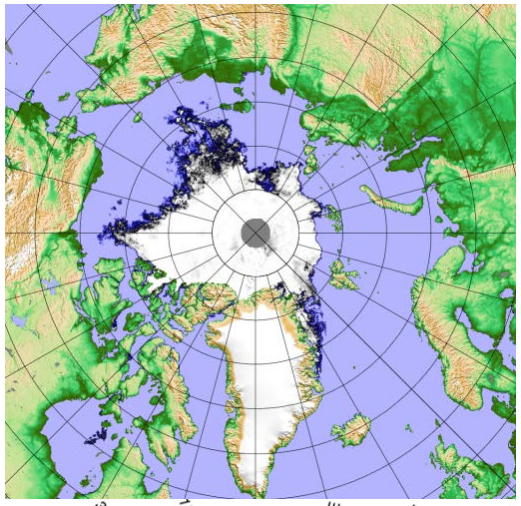
Source: GISS Data

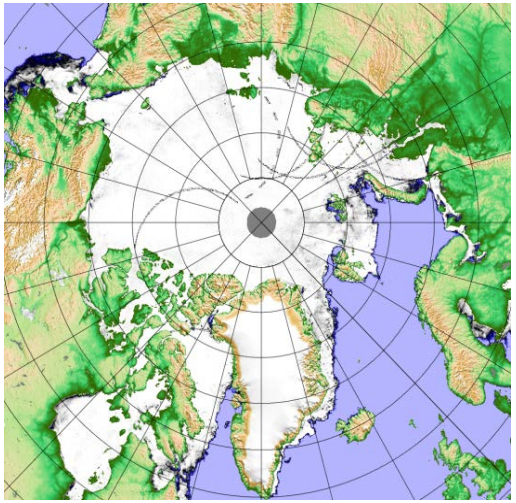
Ice albedo effect

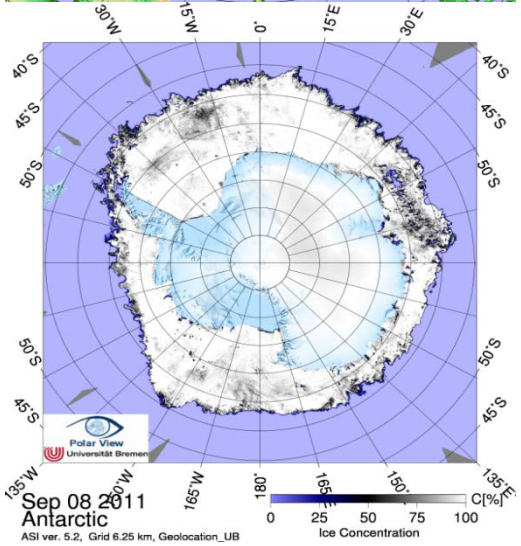


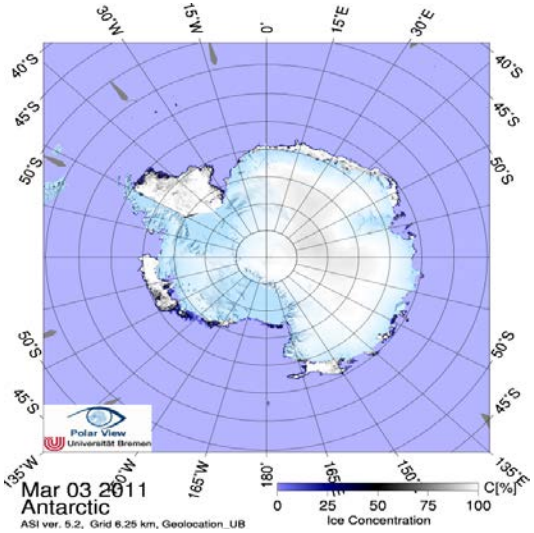
- Positive feedback
- Increases melt
- shortens ice season

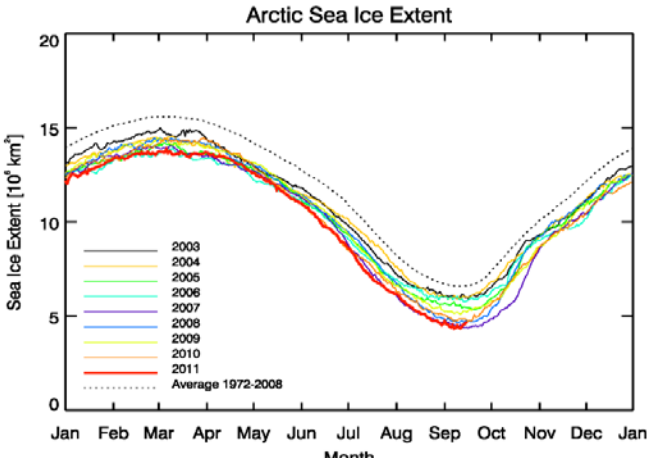
Arctic and Antarctic sea ice

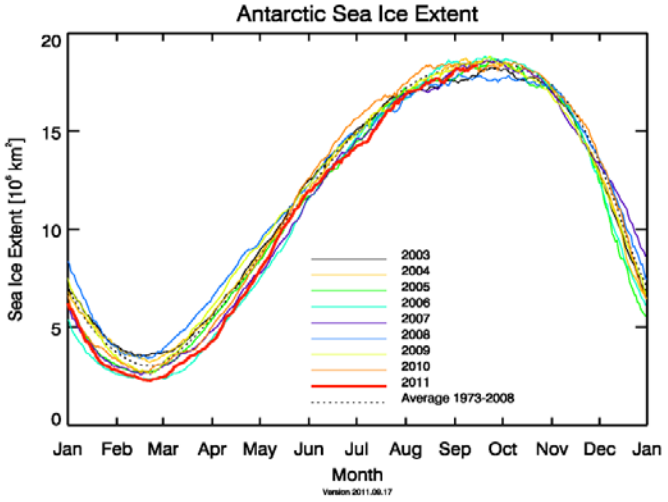




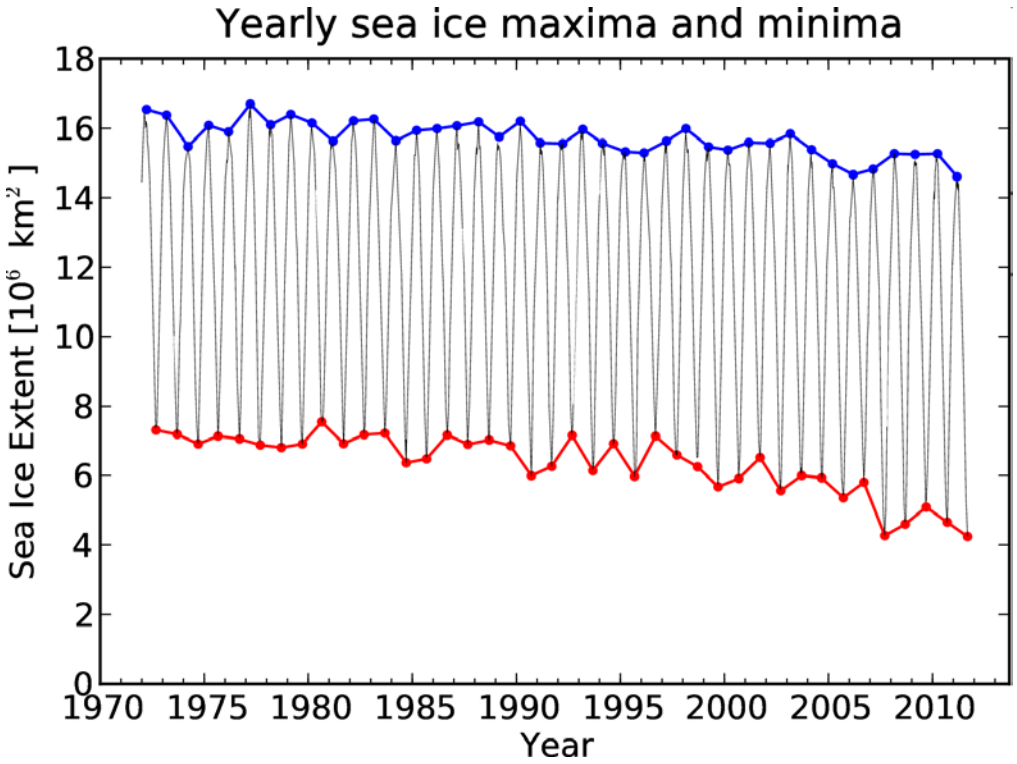








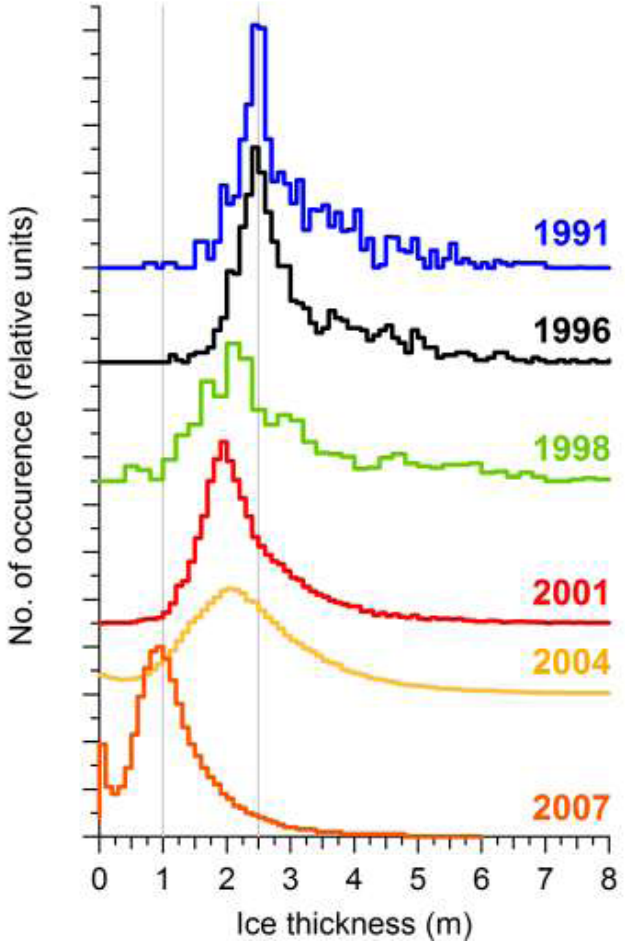
Trend of summer Arctic sea ice cover



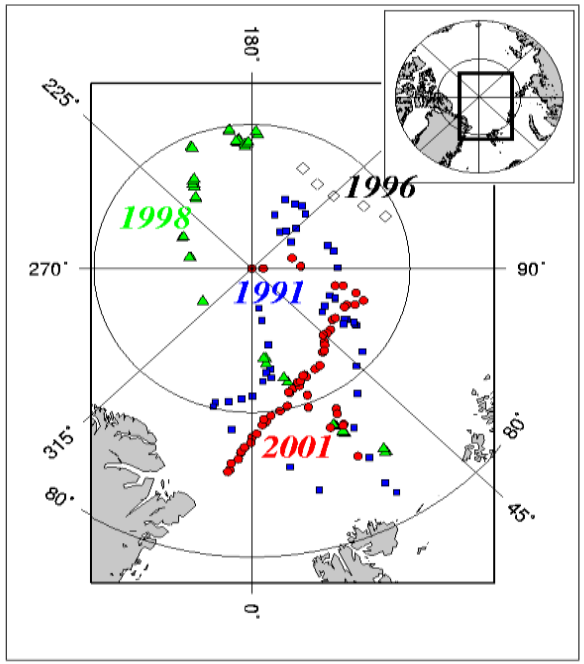
- Arctic: -2.7 % per decade
- Antarctic: no significant trend
- Consequences of reduced sea ice in Arctic
- changes of global weather and precipitation patterns
- more wave action on coasts → damages

Sea ice thickness

Sea ice thickness



Source: Rabenstein, Hendricks,Leinweber, 2007

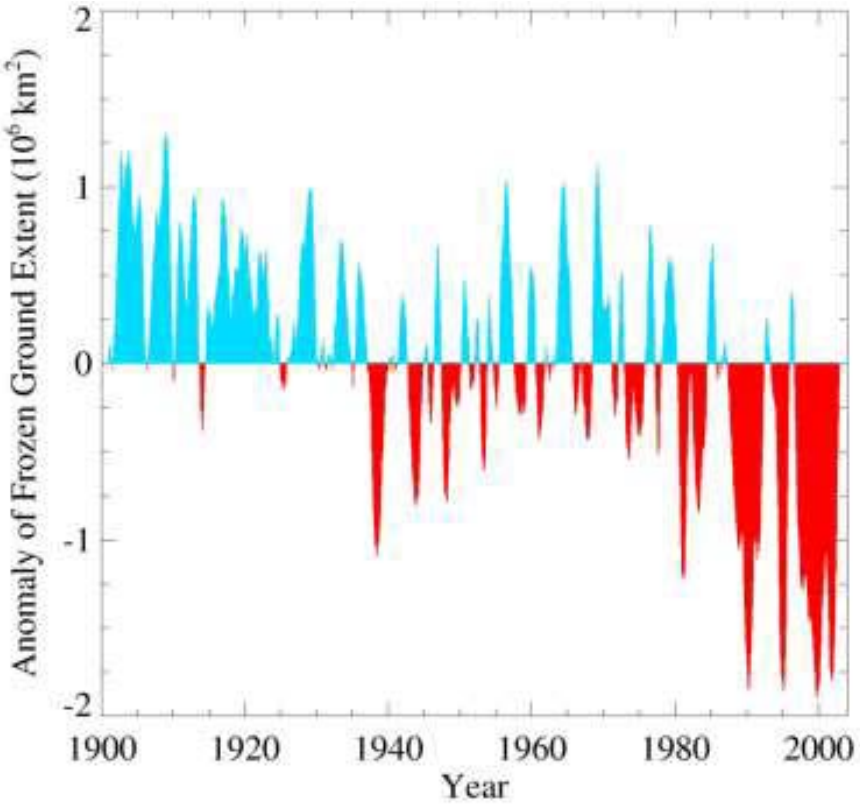


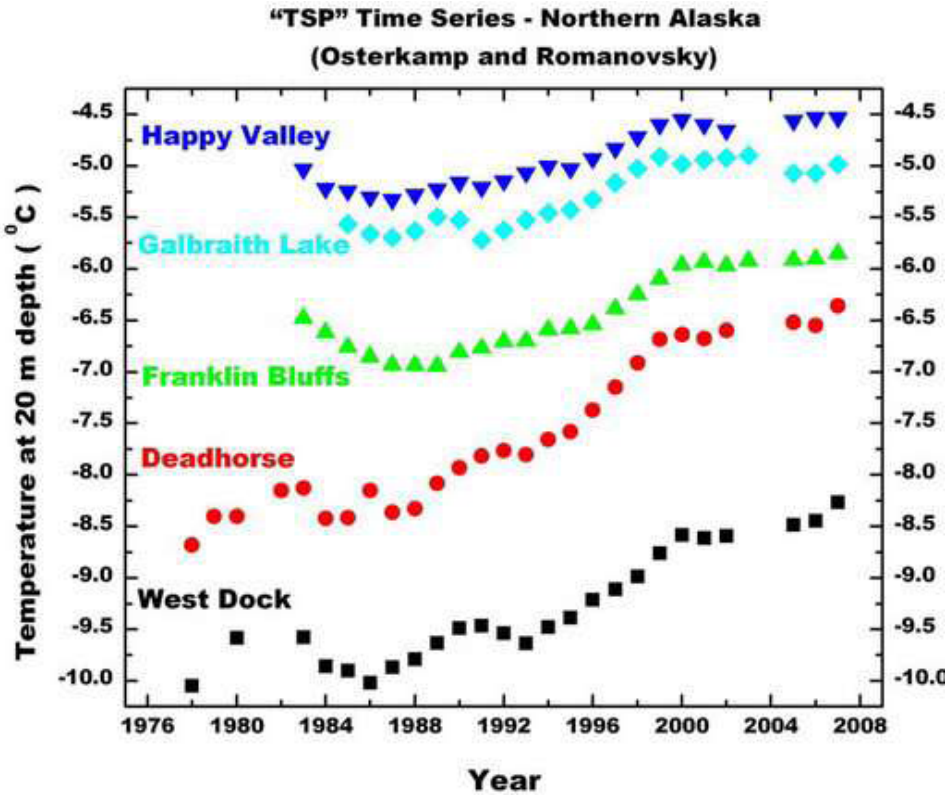
Most frequent thickness

- 1991: 2.5 m
- 2007: 1 m

Source: Haas, 2004

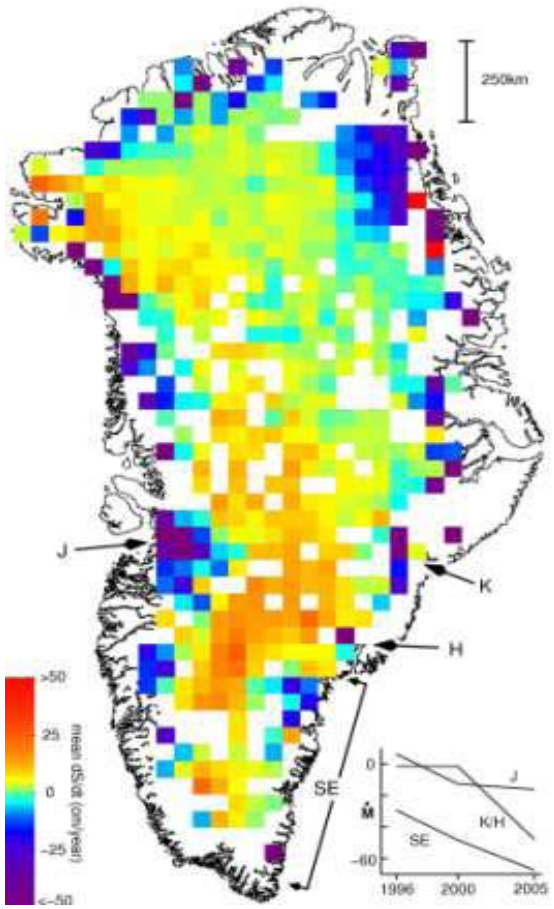
Permafrost



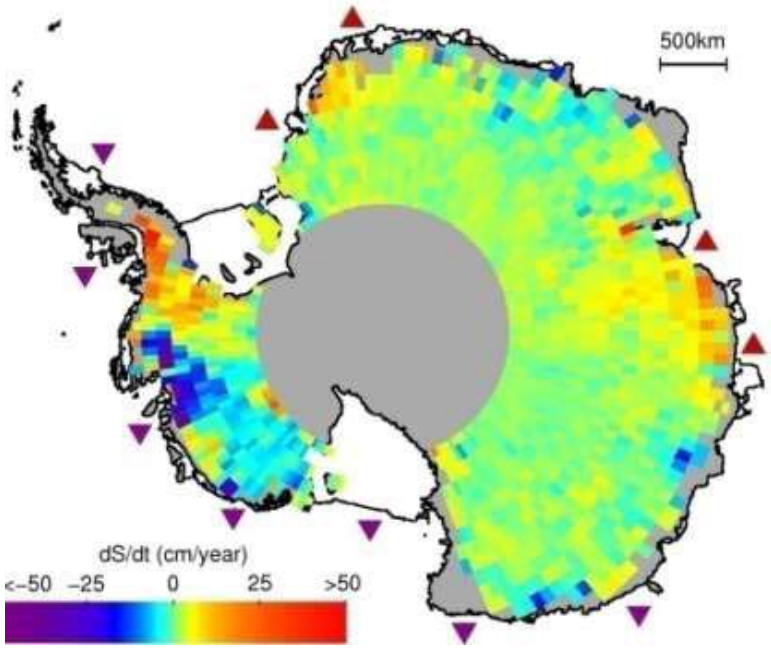


- Permafrost area receding, releasing methane to atmosphere
- Permafrost temperatures increasing

Ice sheets



IPCC-AR4



- Greenland sheet decreasing, mainly by surface melting
- Antarctic sheet decreasing, mainly by bottom melting

Sea level rise

Source of sea level rise	Rate of sea level rise (mm per year) 1961 – 2003	1993 – 2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]

Currently: 50% thermal expansion, 40 % ice melt, 10% unexplained.

Source: IPCC-AR4

Polar regions and climate change

Part 1:
Polar regions as part of the climate system

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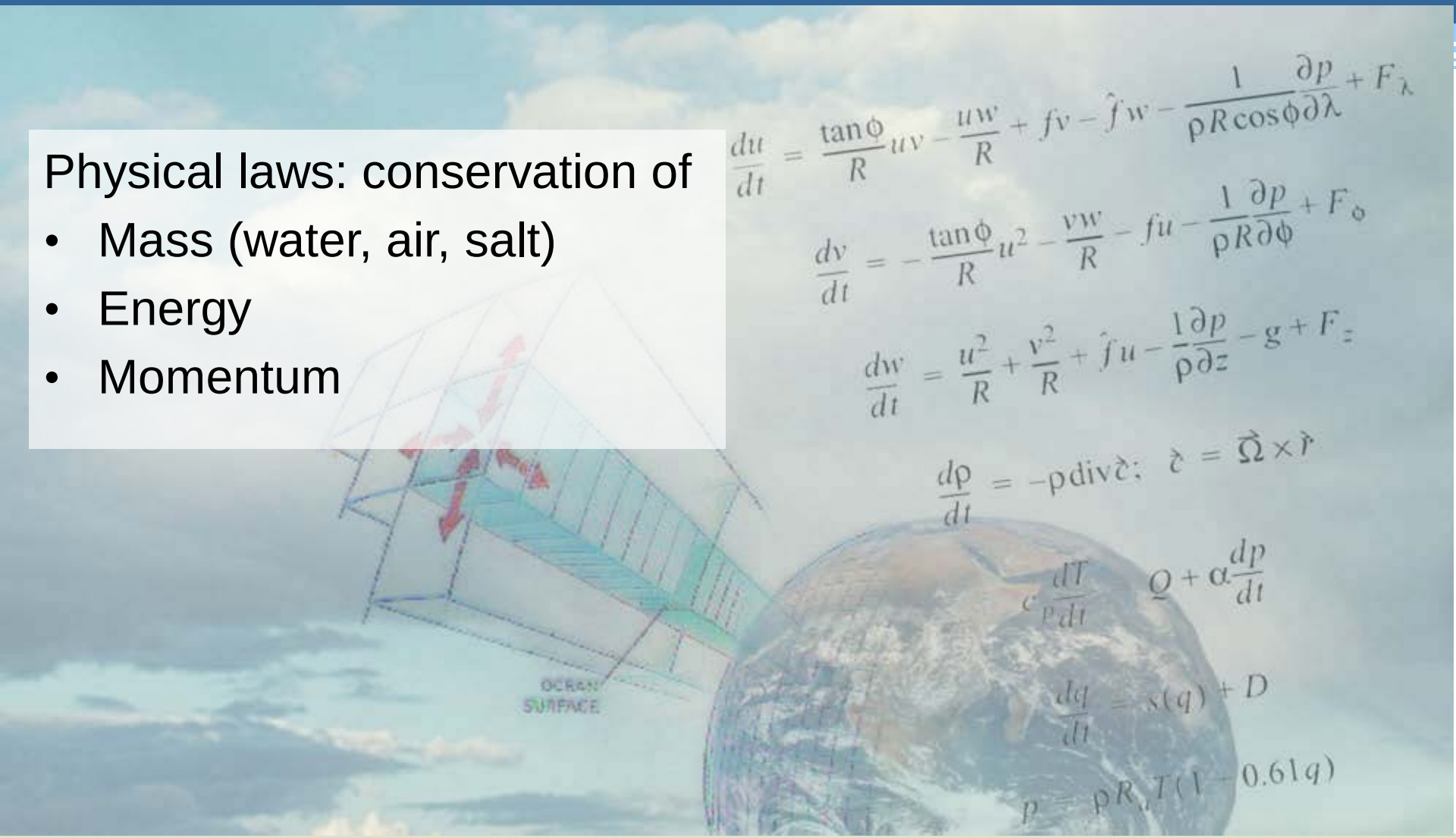
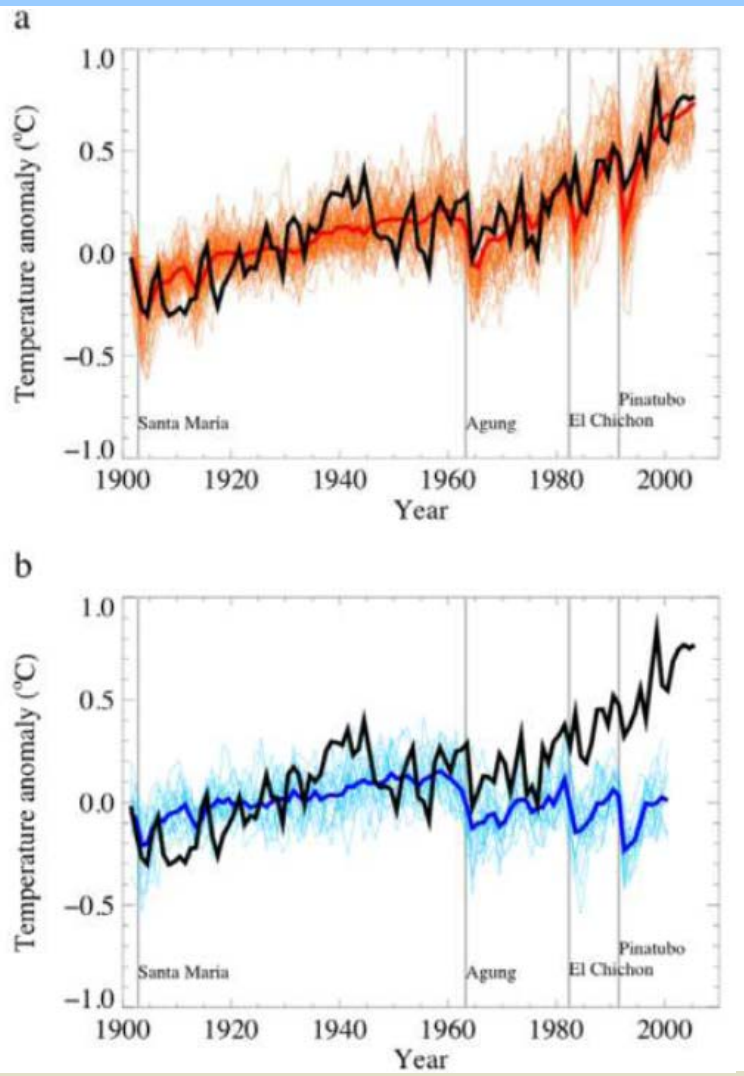
Tool: climate models

Physical laws: conservation of

- Mass (water, air, salt)
- Energy
- Momentum



Climate simulations: last 100 yr



Observed global temperature anomaly

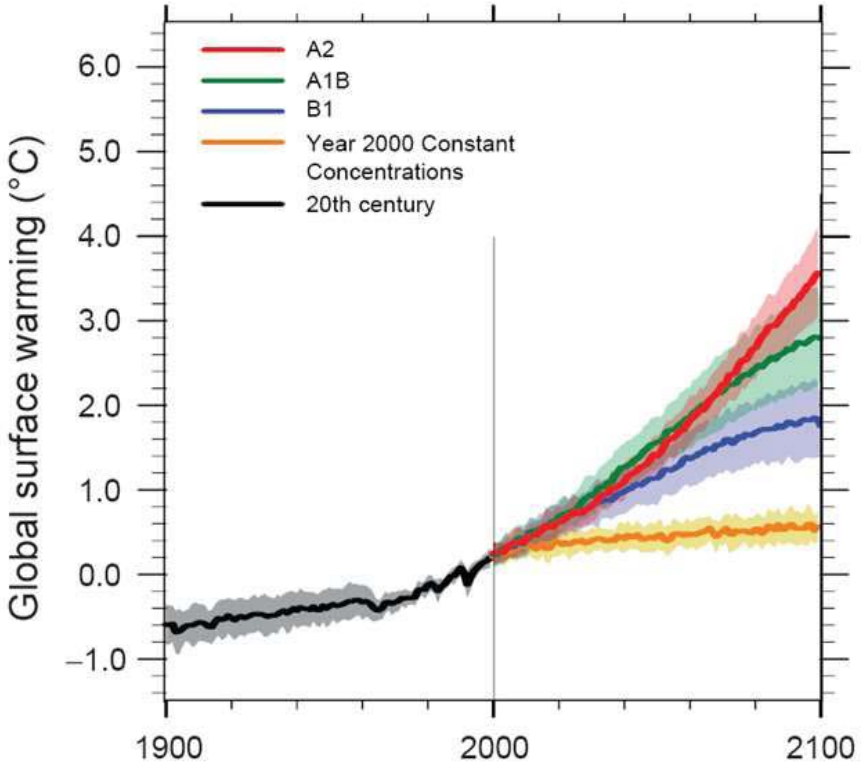
Including anthropogenic greenhouse gases emissions

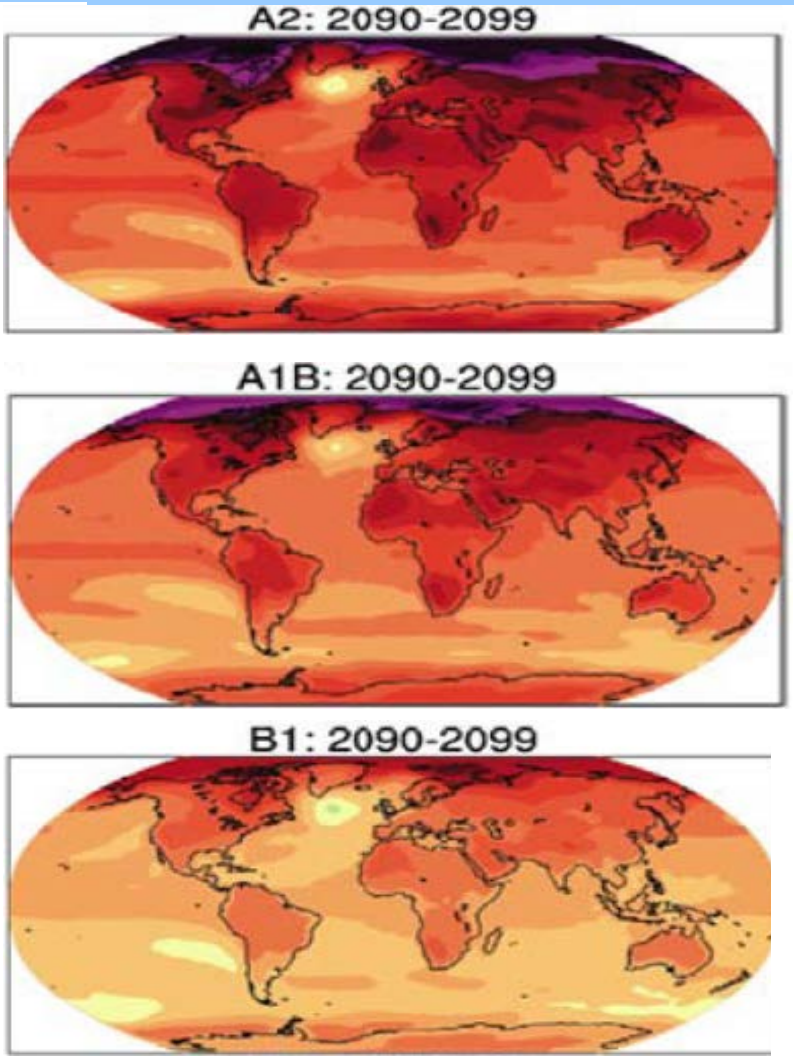
Warming of last 50 years is man-made

Excluding anthropogenic greenhouse gases emissions

Source: IPCC-AR4

Global warming projections





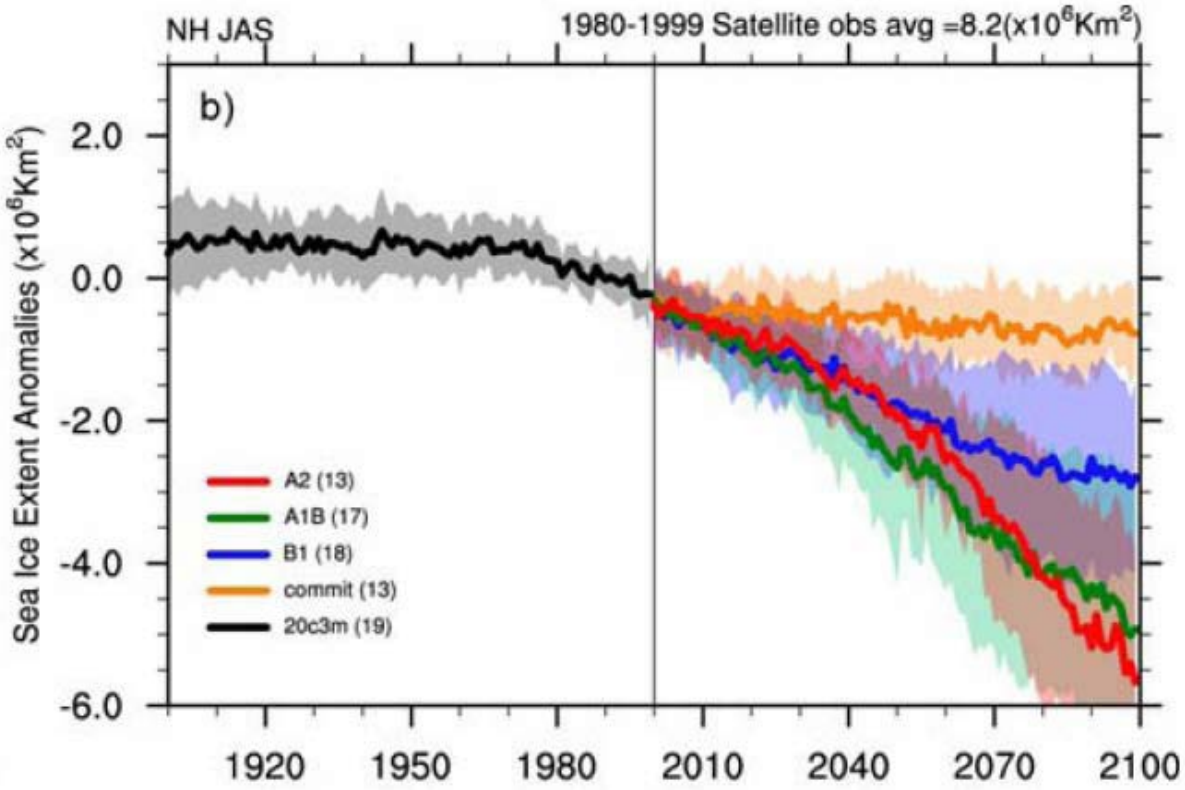
A2 high economic growth, GHG correlated

A1B moderate growth

B1 low growth

Source: IPCC-AR4

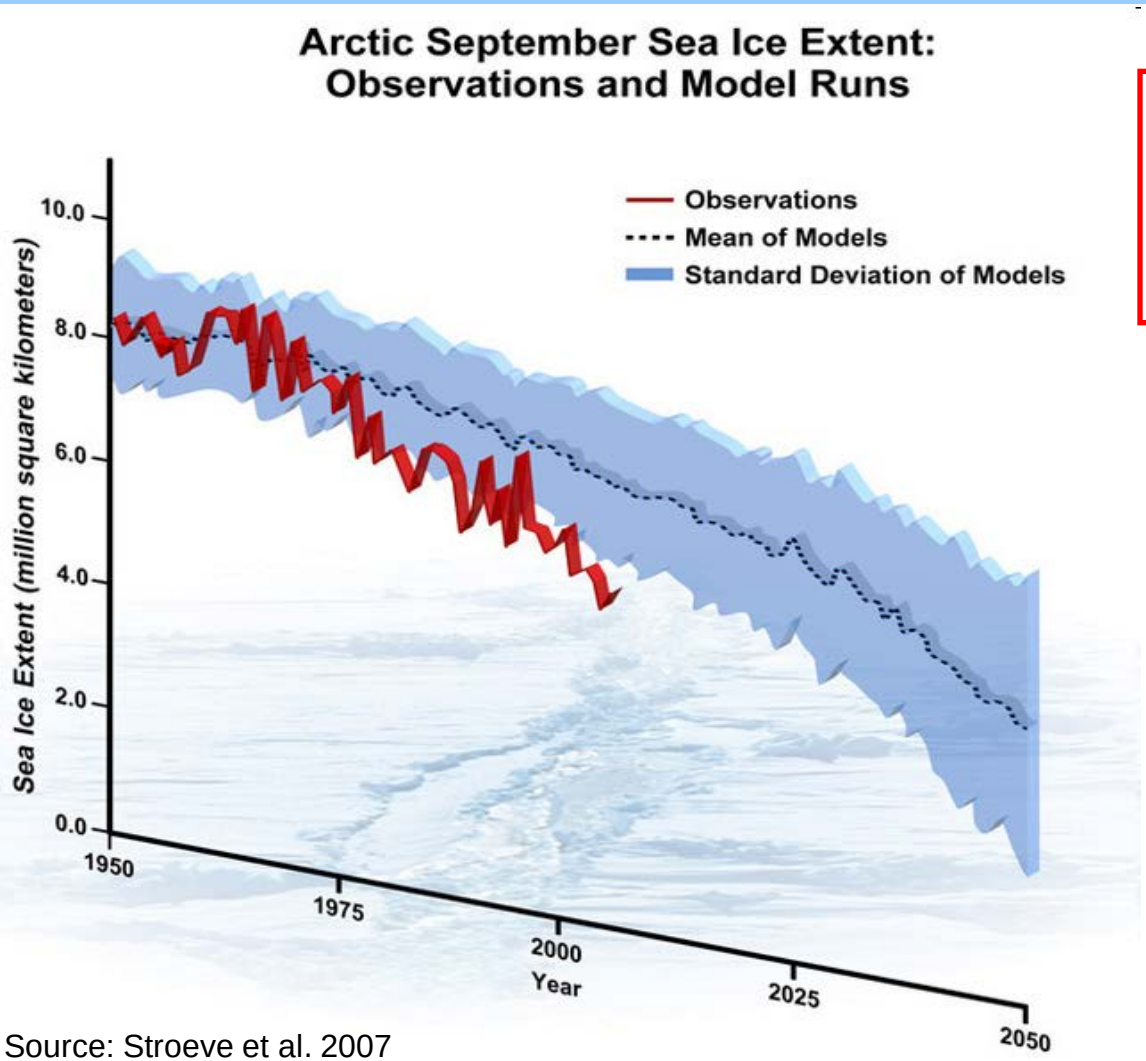
Projected sea ice extent



In some projections, Arctic sea ice disappears almost entirely by 2080

Source: IPCC-AR4

Projected sea ice extent

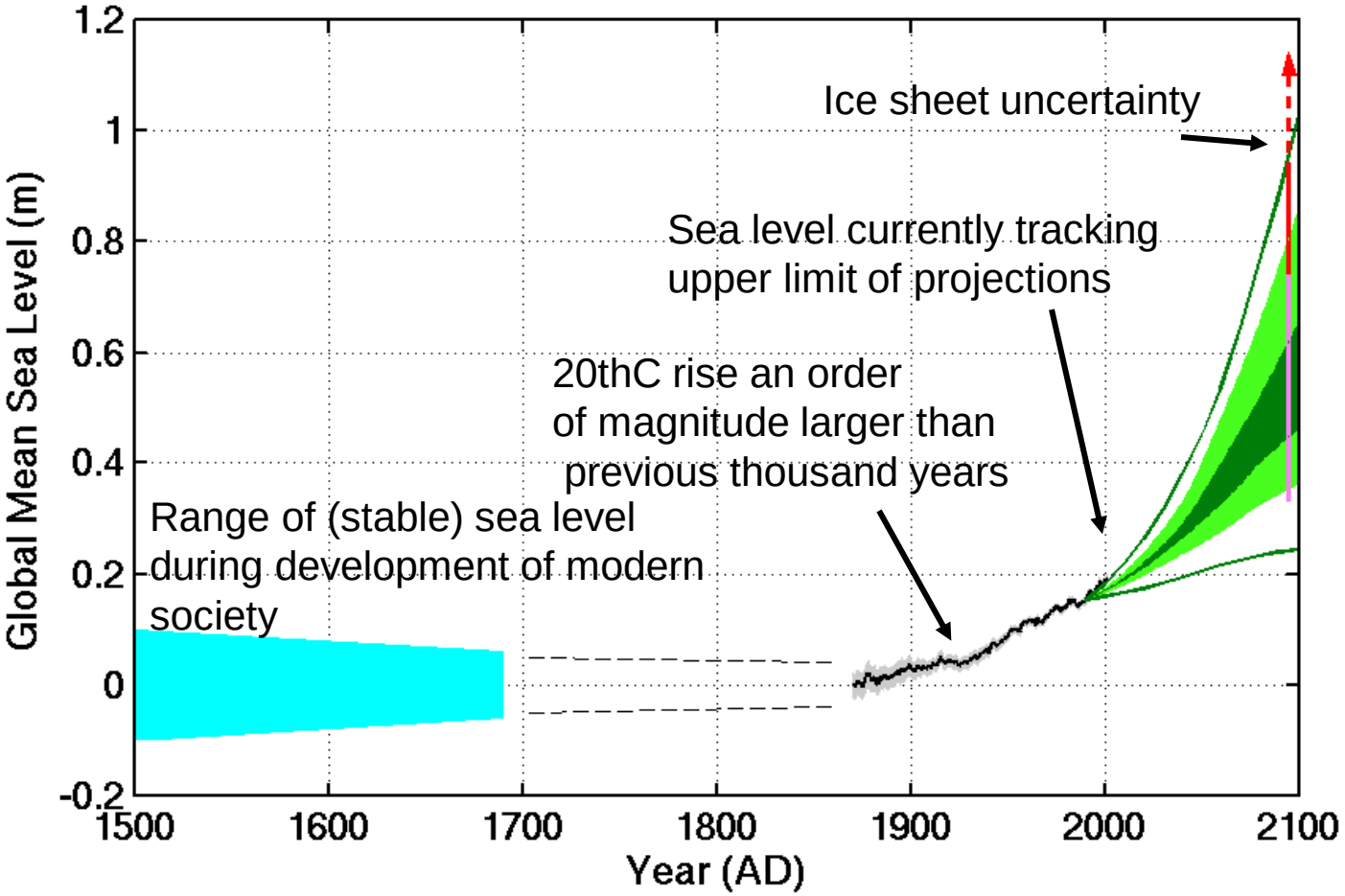


Source: Stroeve et al. 2007

However: current sea ice decline is faster than any models predicts!

- Arctic may be ice free in summer by 2030…2040 Consequences of reduced ice:
- changes of global weather and precipitation patterns, more precipitation in Arctic, more frequent droughts in mid-latitudes
- more wave action on coasts → damages

Sea level rise



Source: IPCC-AR4

Conclusions

- The Arctic is part of the global climate system
- Global warming
  - Induced by anthropogenic GHG
  - Particularly pronounced in Arctic, mainly because of sea ice albedo effect
- Despite uncertainties: Climate models are one of the best predictive tools of our society
- Climate models predict significant changes
- Mitigation and Adaptation are required and costs affordable

Exercises for Self Study

1. What is different in the understanding of between climate change in the past, today and maybe the future. Use for example the website: http://www.epa.gov/climatechange/science/futurecc.html

2. Inform yourself about the current change of the sea level by climate change. Which new information do you find on Alfred-Wegner Institute and Institute für Umweltphysik?

3. How is the Canadian government trying to counter the climate change? (http://www.climatechange.gc.ca/default.asp?lang=En)

References

Literature:

- http://www.epa.gov/climatechange/science
- Haas, C. (2004): Late-summer sea ice thickness variability in the Arctic Transpolar Drift 1991-2001 derived from ground-based electromagnetic sounding
- Rabenstein, L., Hendricks, S., Leinweber, V., (2007): Ice thickness variability in the Transpolar Drift

Further reading:

http://www.ipcc.ch/