Climate System II

(Winter 2022/2023)

1st lecture:

Challenges of climate change

(Introduction to past and present climate change, course content)

Gerrit Lohmann, Martin Werner

Tuesday, 10:00-11:45

(sometimes shorter, but then with some exercises)

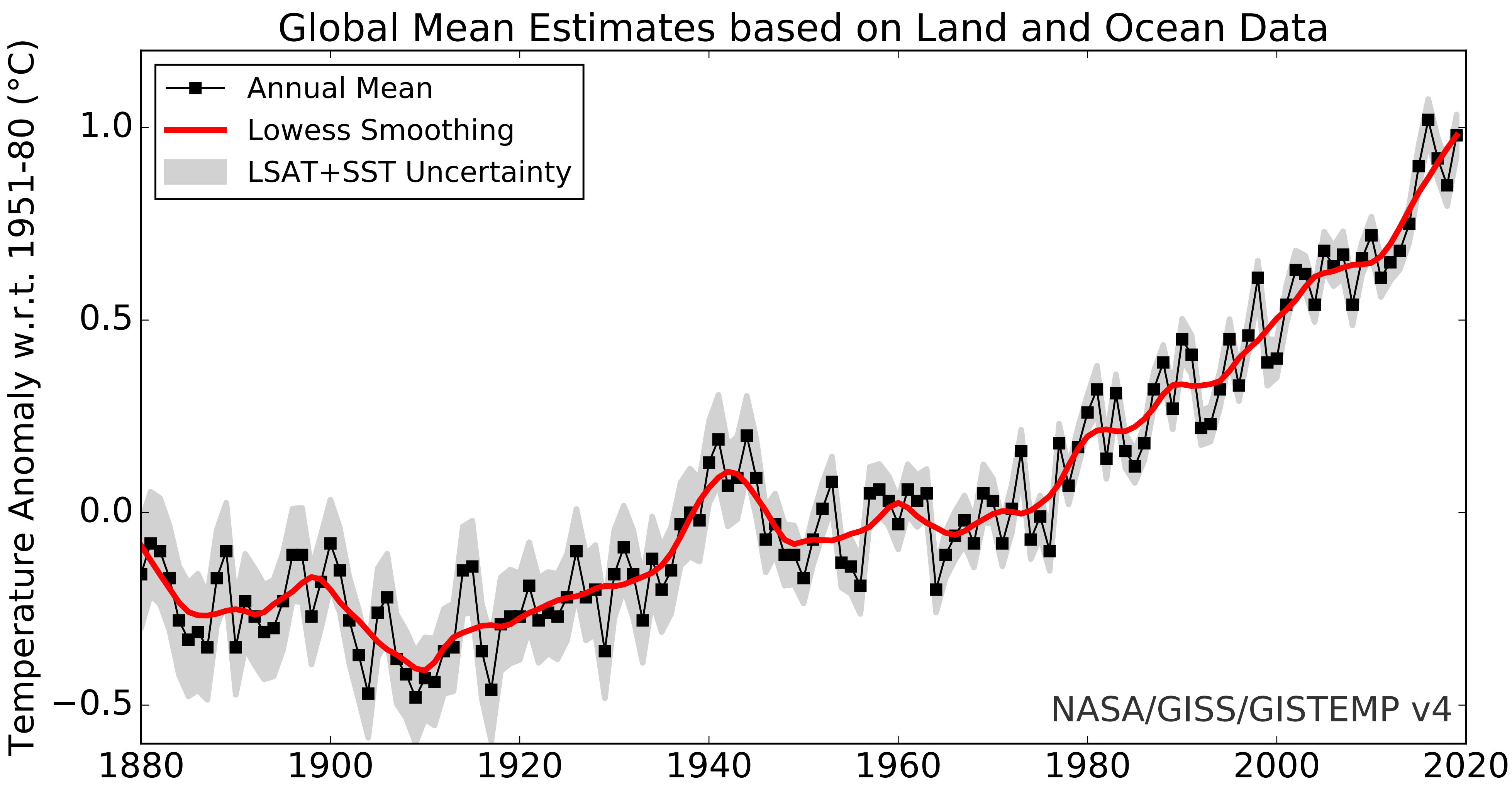
https://paleodyn.uni-bremen.de/study/climate2022_23.html

Climate II

Today (October 18th 2022)

- **Introduction and overview (45min)**
- **Formalities etc. (20min)**
- **Expectations and wishes from your side**

Climate change - the last 140 years

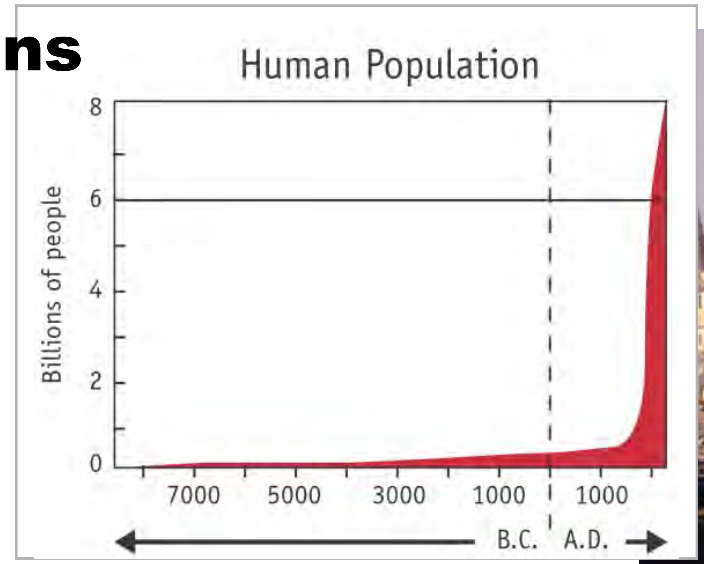


[https://data.giss.nasa.gov/gistemp/graphs_v4/]

The 10 warmest years since 1880:

1. 2016
2. 2019
3. 2017
4. 2015
5. 2018
6. 2014
7. 2010
8. 2005
9. 2013
10. 2007

Human Population: 7 billions



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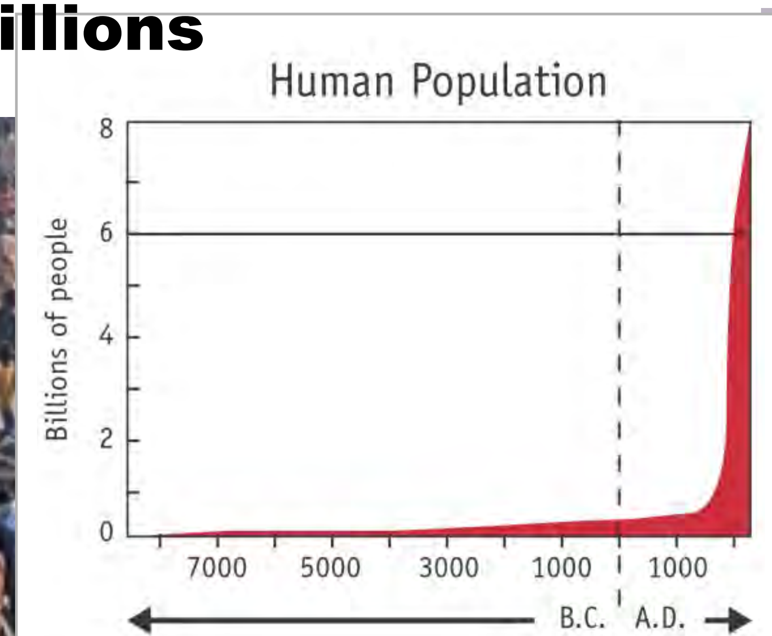
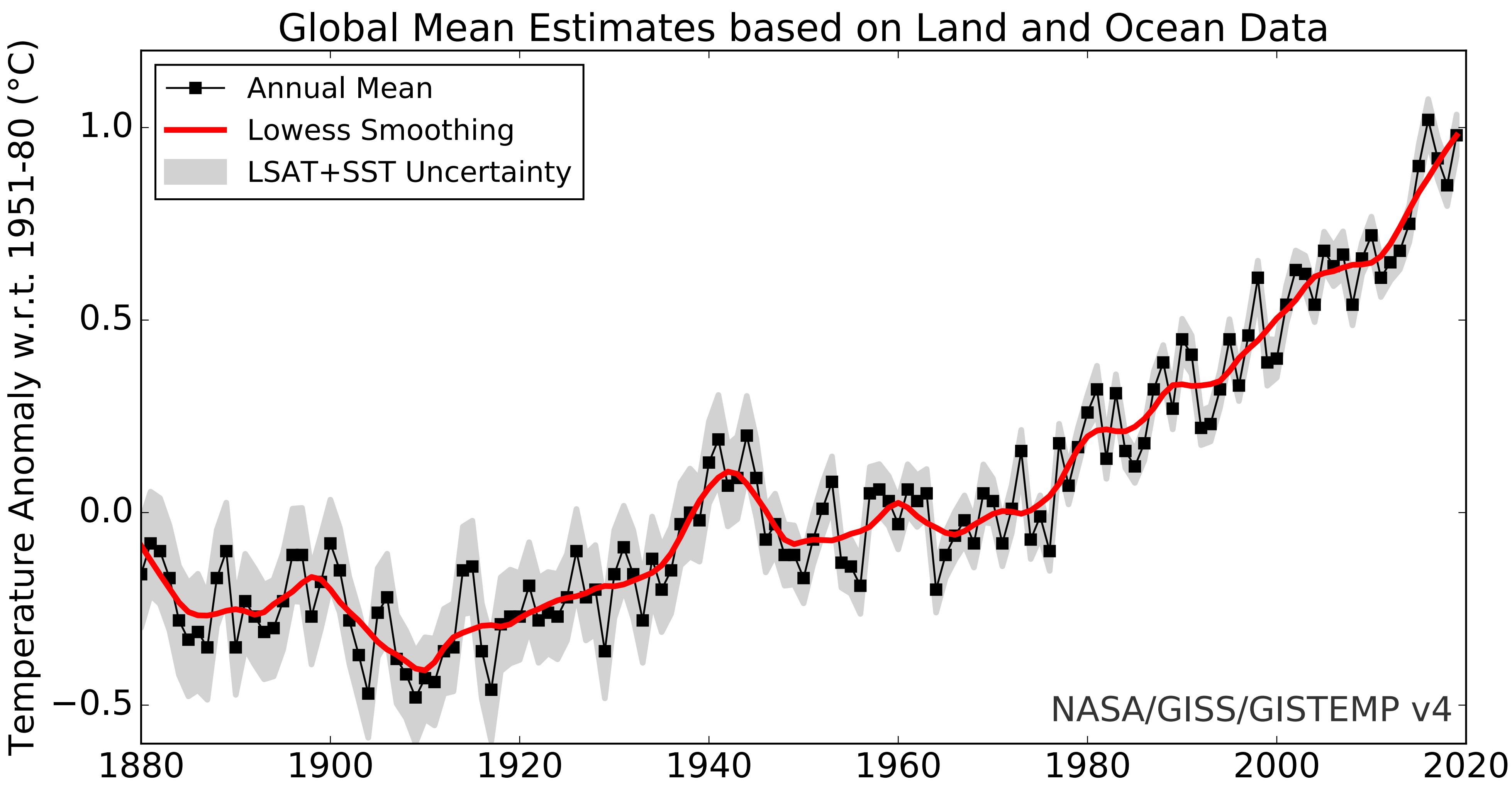


CO_2 Increase:

Land cover: 22%

CO_2-Emissions: 78%

Climate change - the last 140 years



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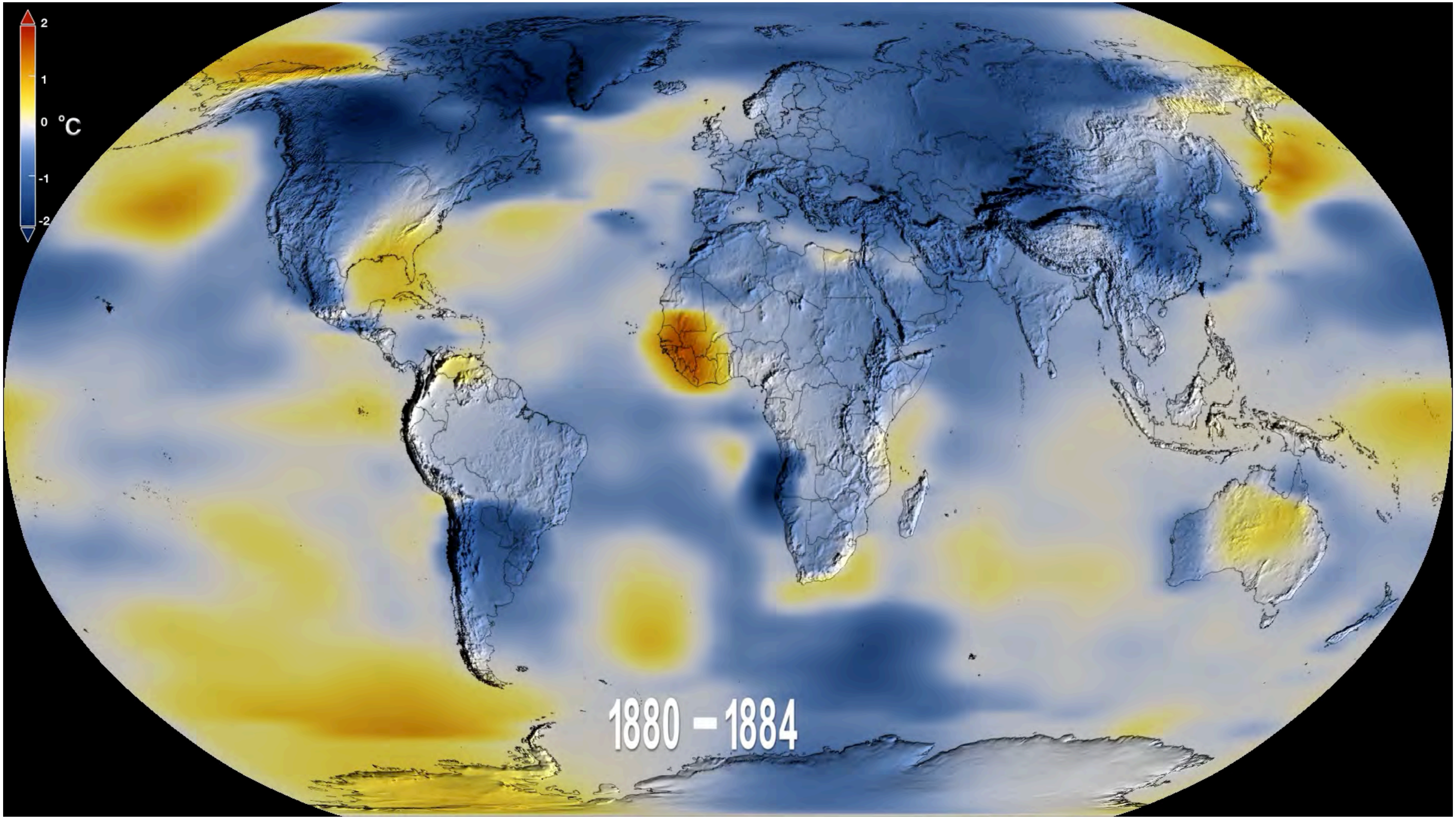
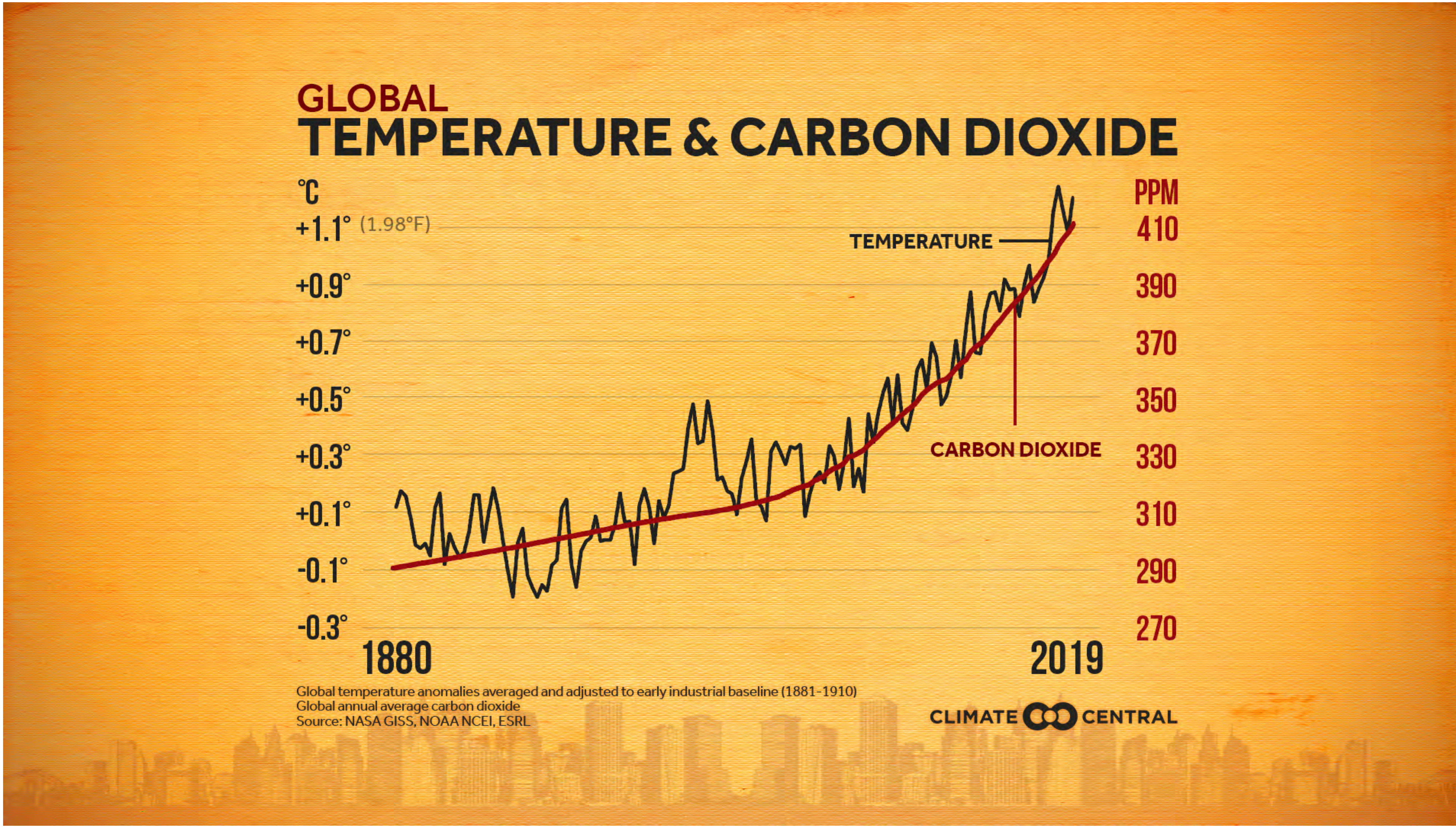


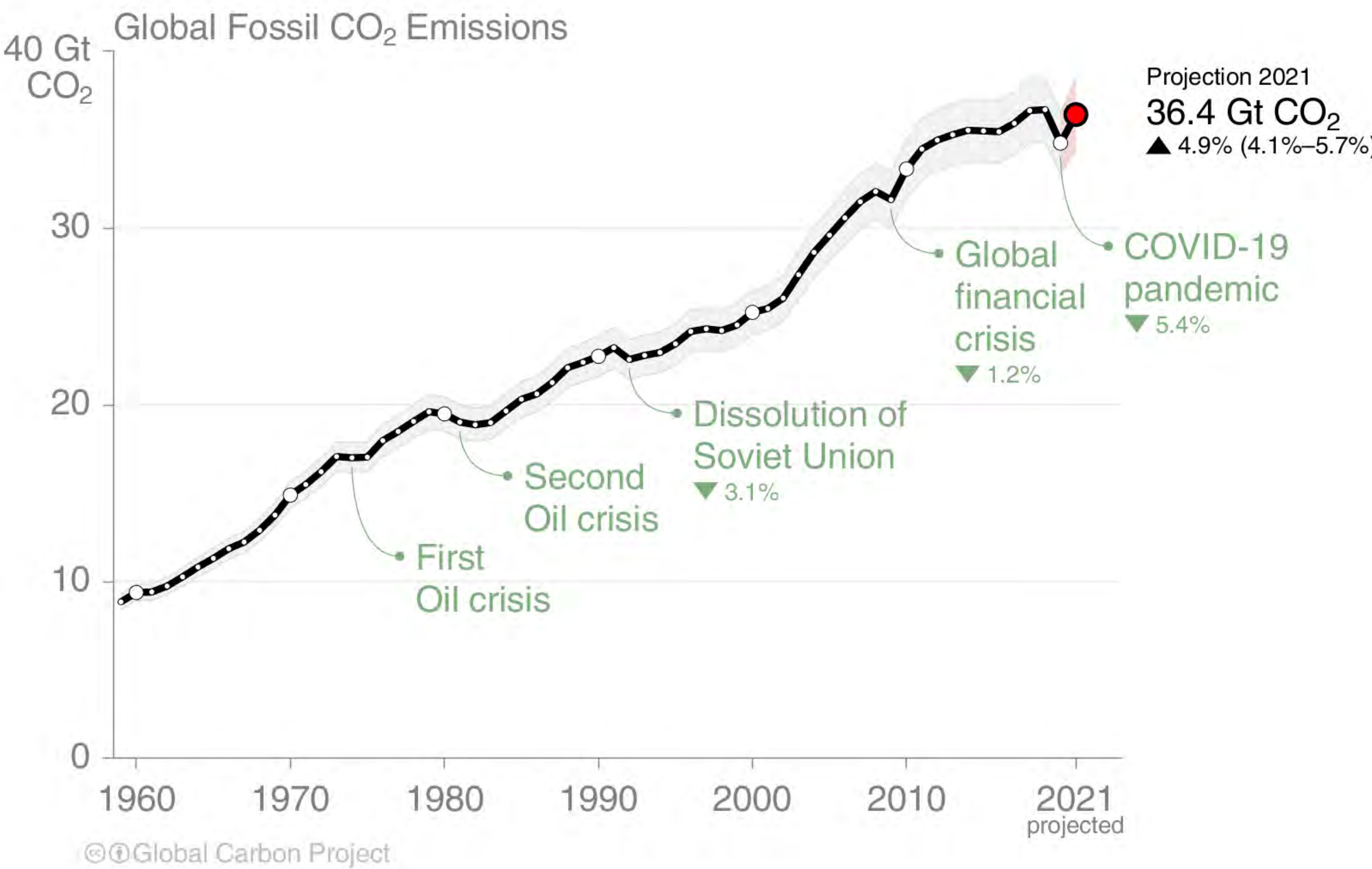
[https://svs.gsfc.nasa.gov/4787]

Global warming and CO_2 increase since 1880



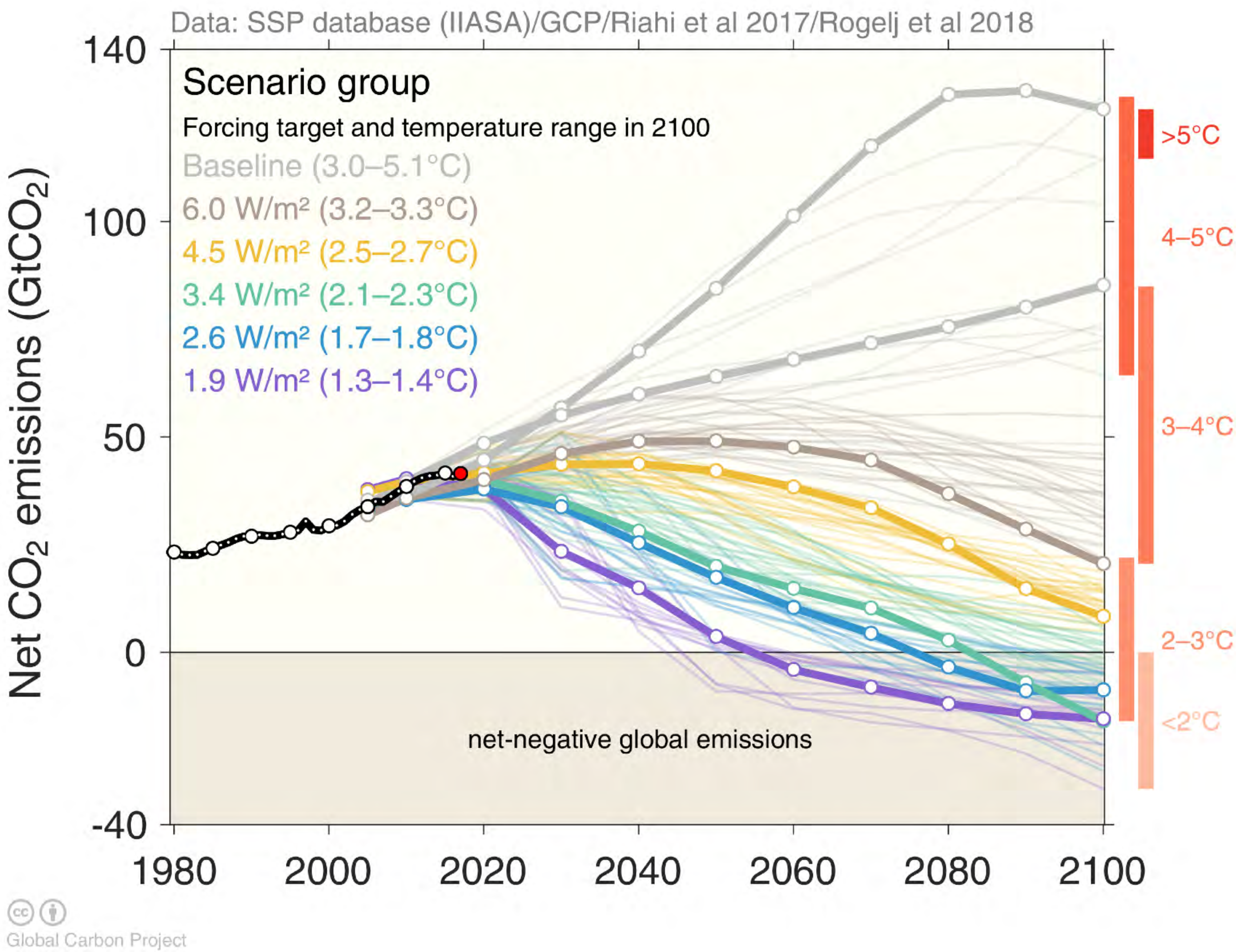
[https://www.climatecentral.org/gallery/graphics/global-temperatures-and-co2-concentrations-2020]

CO_2 emissions in the last 60 years



[https://www.globalcarbonproject.org/carbonbudget/21/presentation.htm; https://robbieandrew.github.io/GCB2021/]

Global temperatures and CO_2 of the future?



[https://www.globalcarbonproject.org/carbonbudget/archive/2018/GCP_CarbonBudget_2018.pdf]

Global temperatures and CO_2 of the past

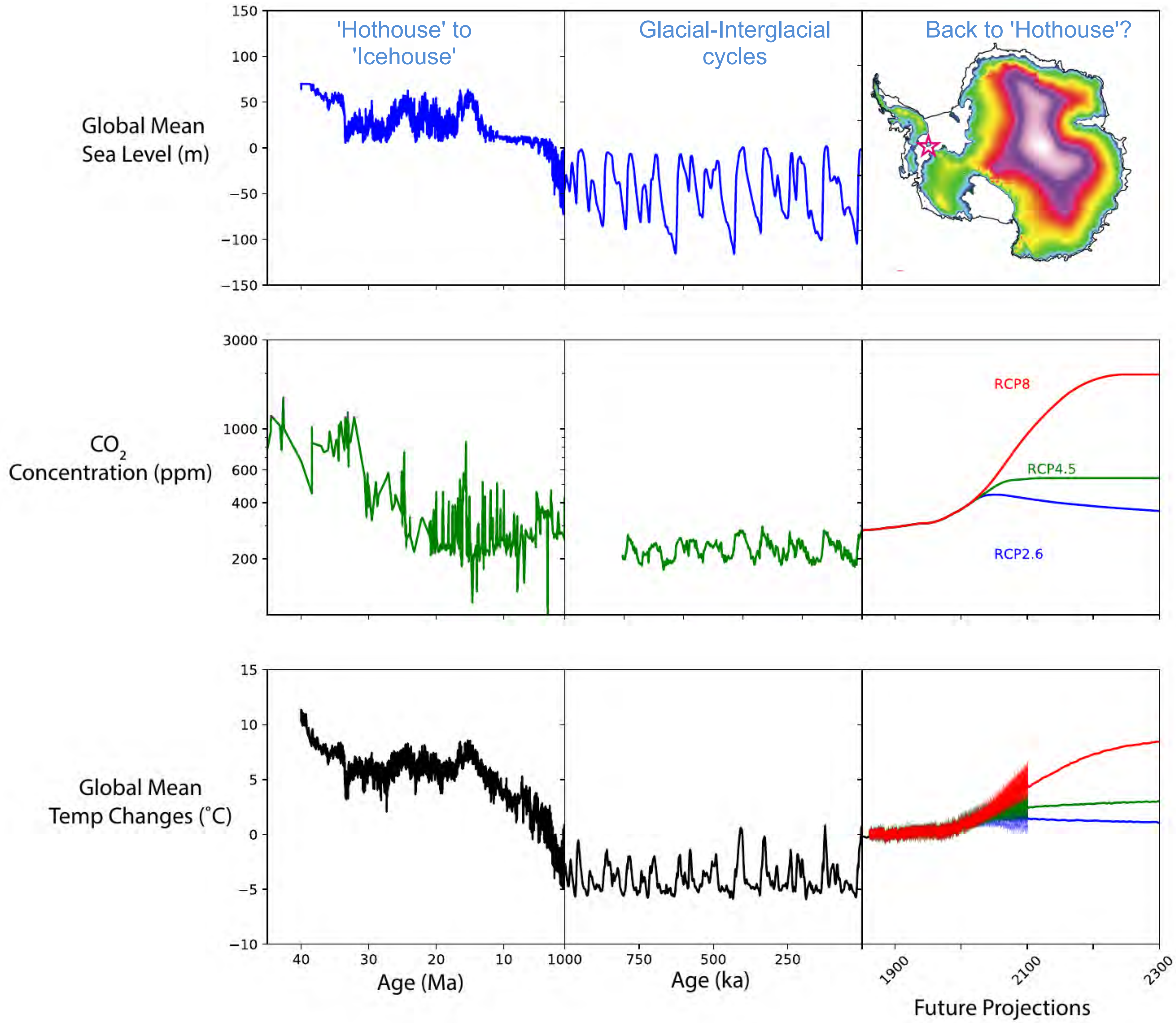
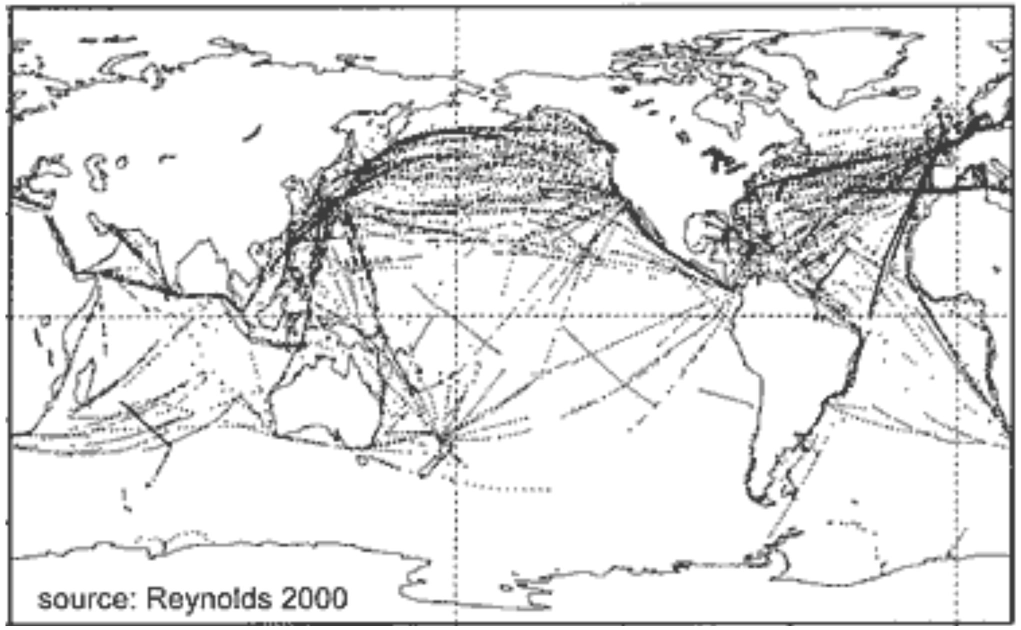


illustration: Paul Gierz, AWI, based on various data sources

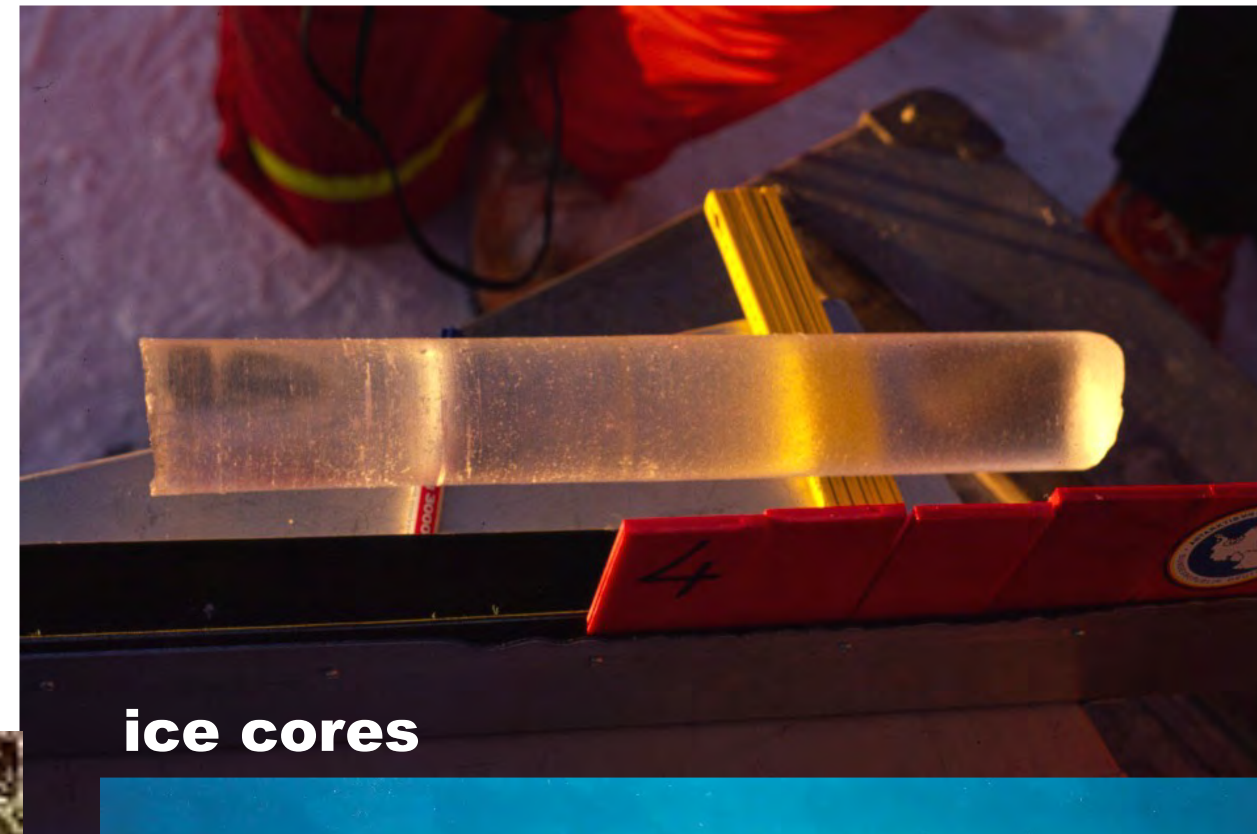
The „climate dilemma“

- The records of direct temperature measurements are short and already fall in the phase of strong human influence.
- Instrumental data are sparce



- For the time before instrumental records, one has to rely on information from proxy data and modeling.

Climate change - archives of the past



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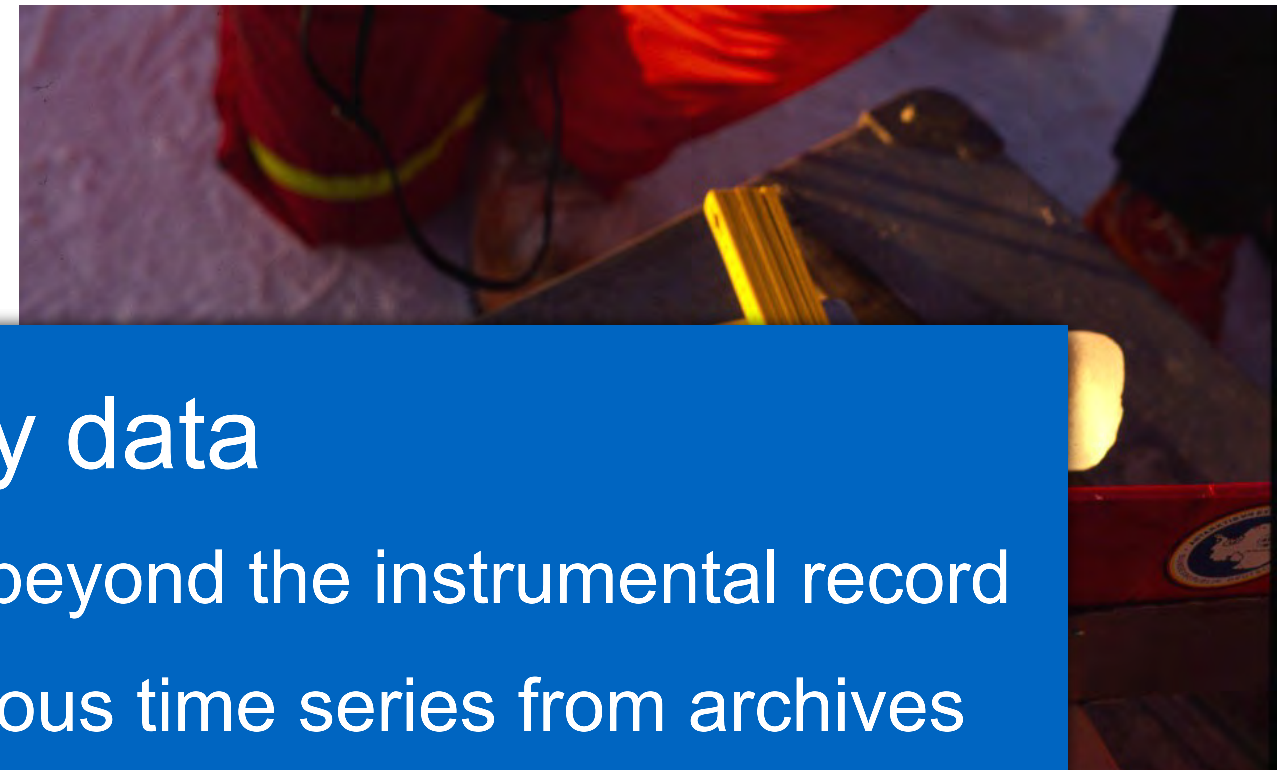


climat proxy data

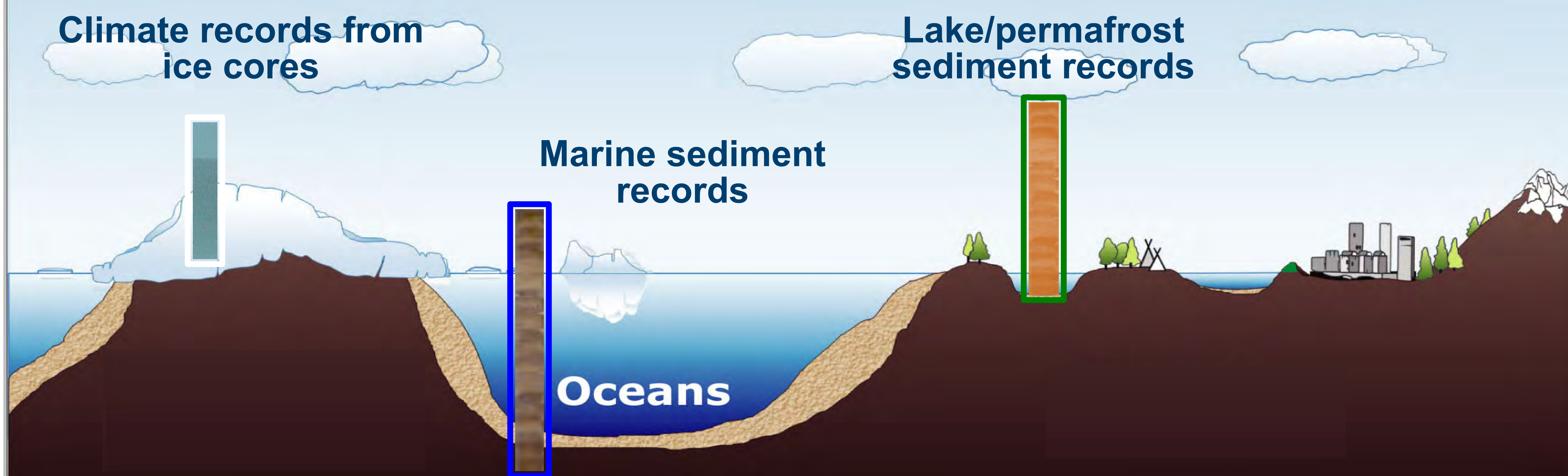
- information beyond the instrumental record
- long continuous time series from archives
- indirect data, often quantitative
- problem of (absolute) dating

Past climate changes - linking different proxy records

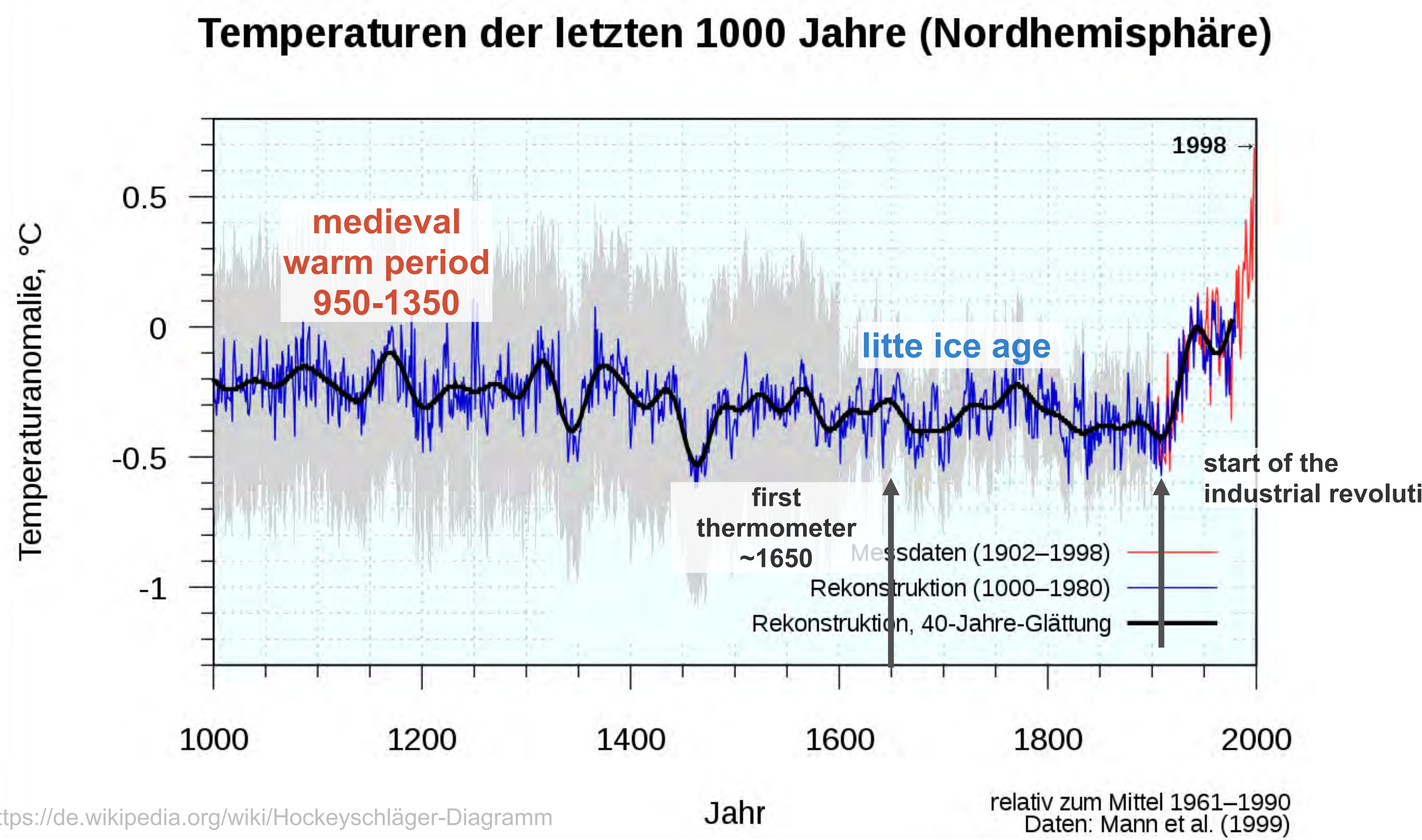
Ice drilling camp, 2009

Polarstern, marine sediments

Lake/permafrost sediments

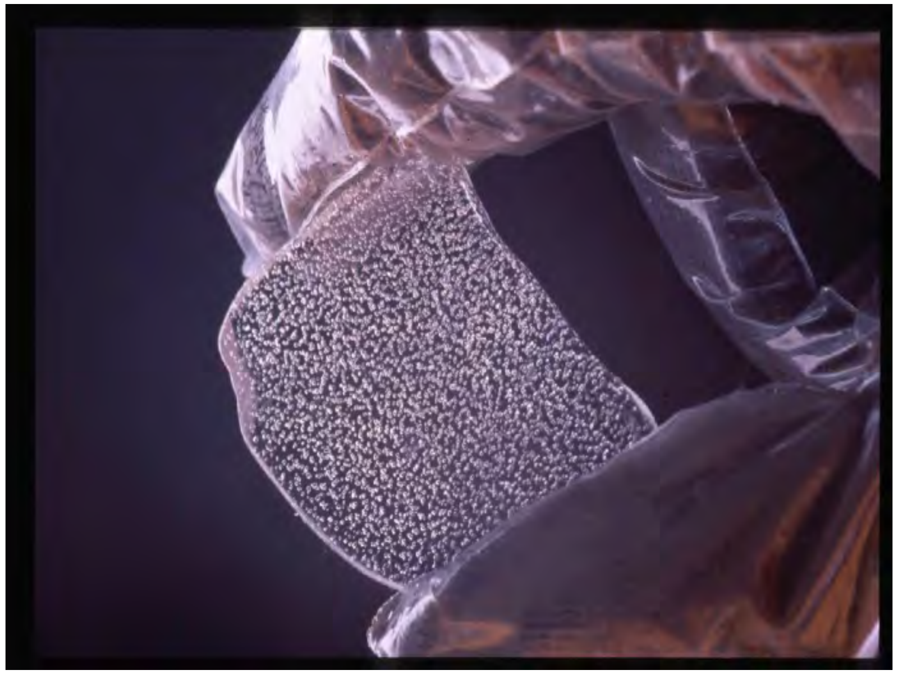


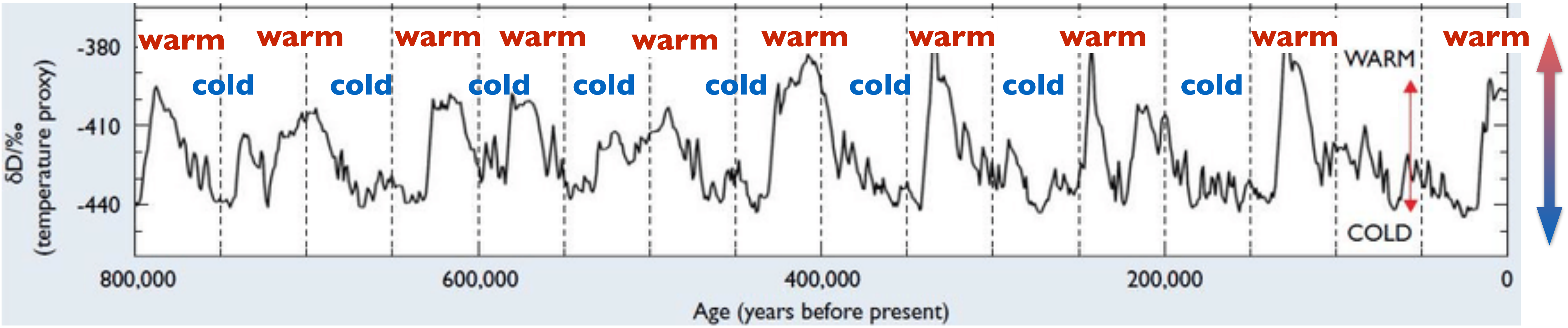
Past climate changes - the last 1000 years



https://de.wikipedia.org/wiki/Hockeyschläger-Diagramm

Past climate changes - the last 800,000 years





https://www.researchgate.net/figure/Ice-Core-Data-from-the-EPICA-Dome-C-Antarctica-Ice-Core-Showing-Concentrations-of_fig3_310329375

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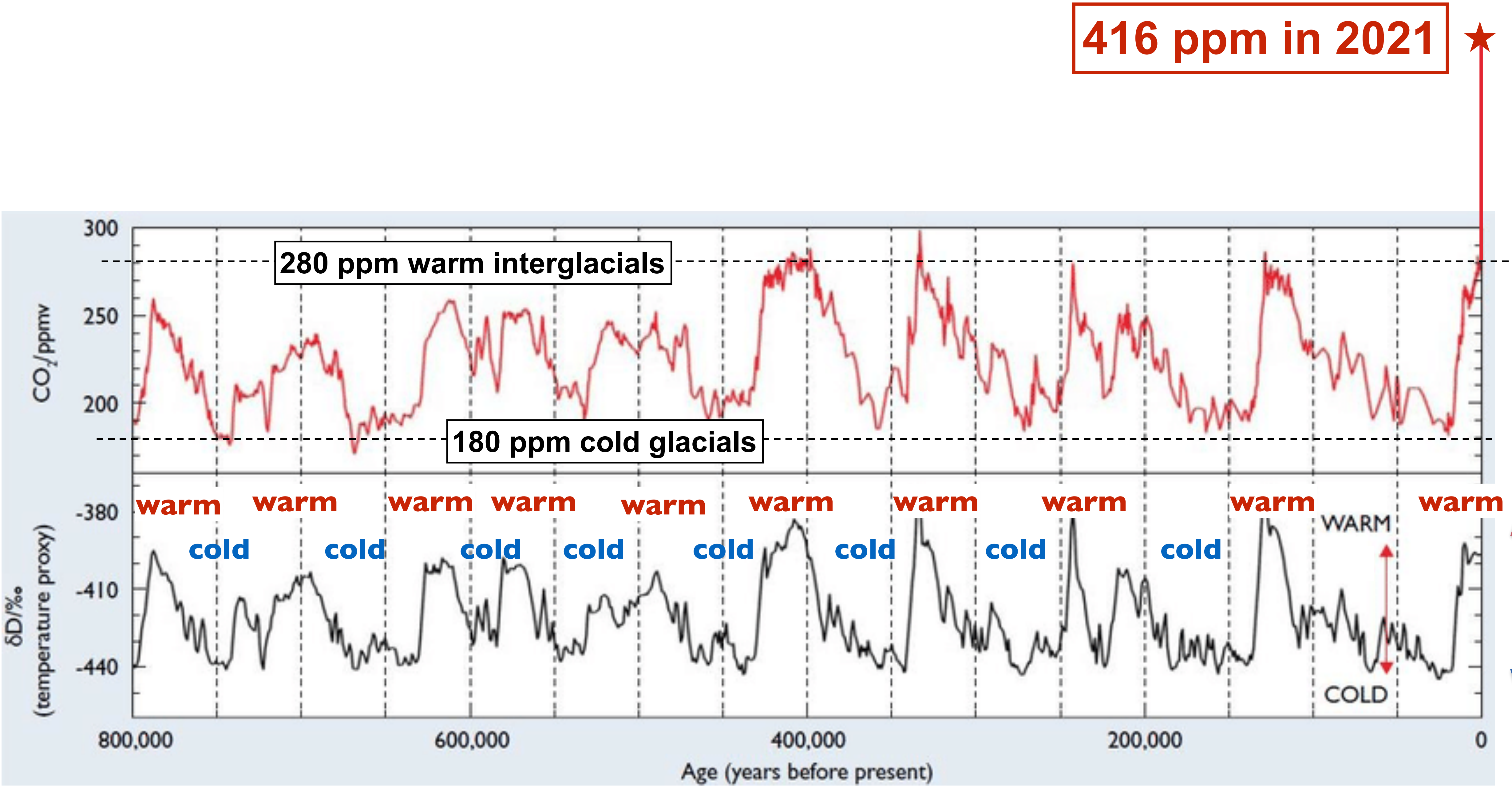

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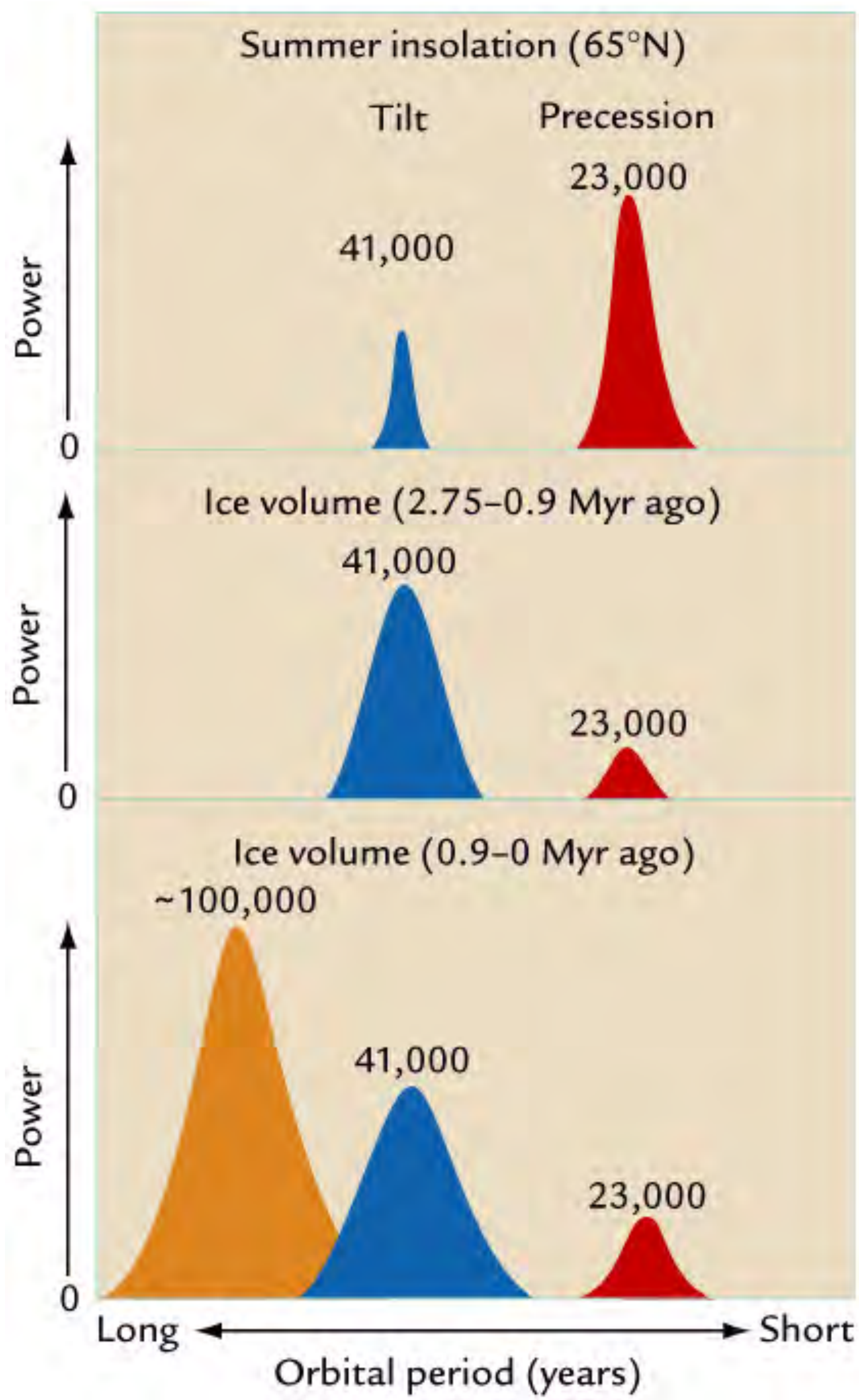
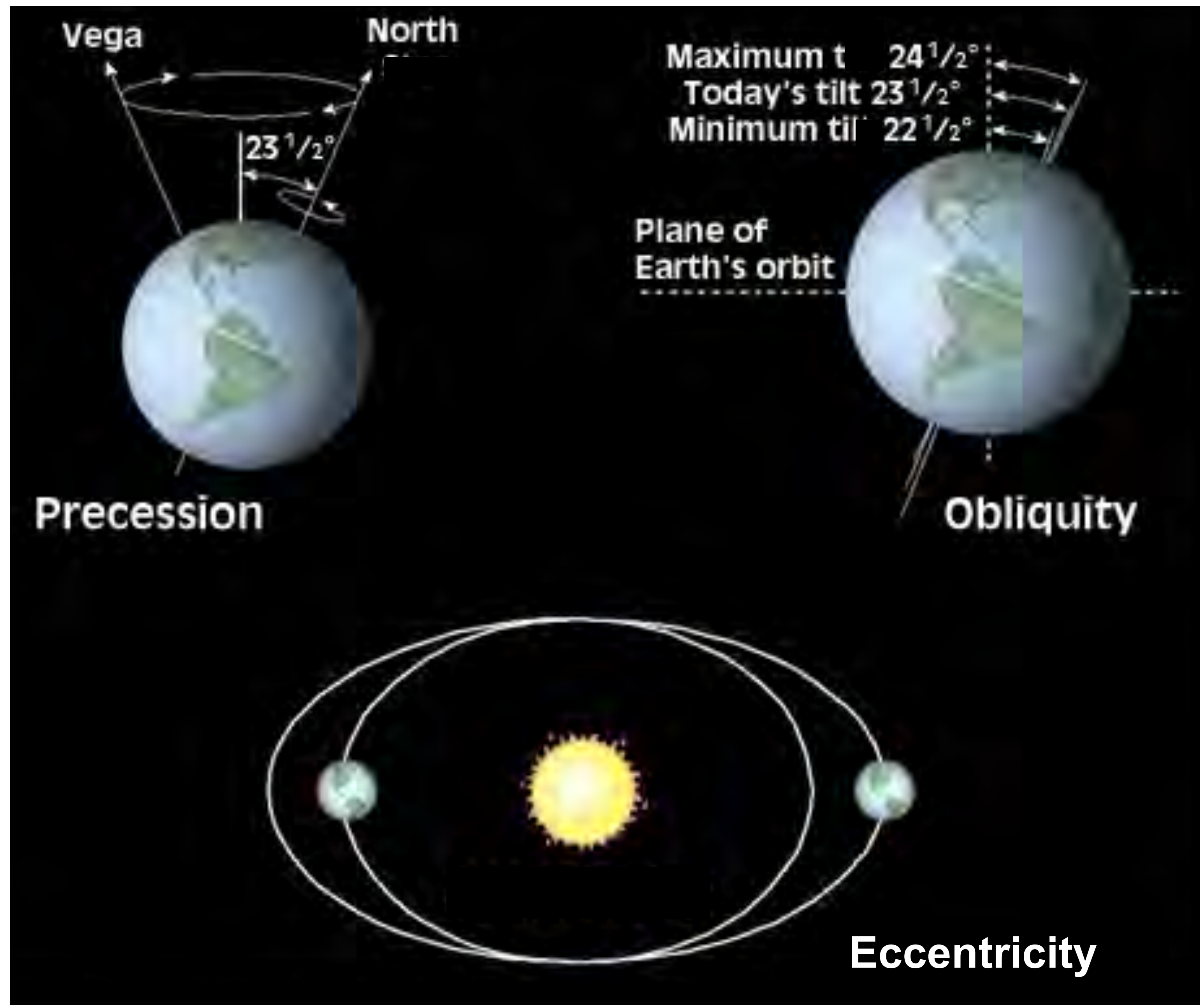
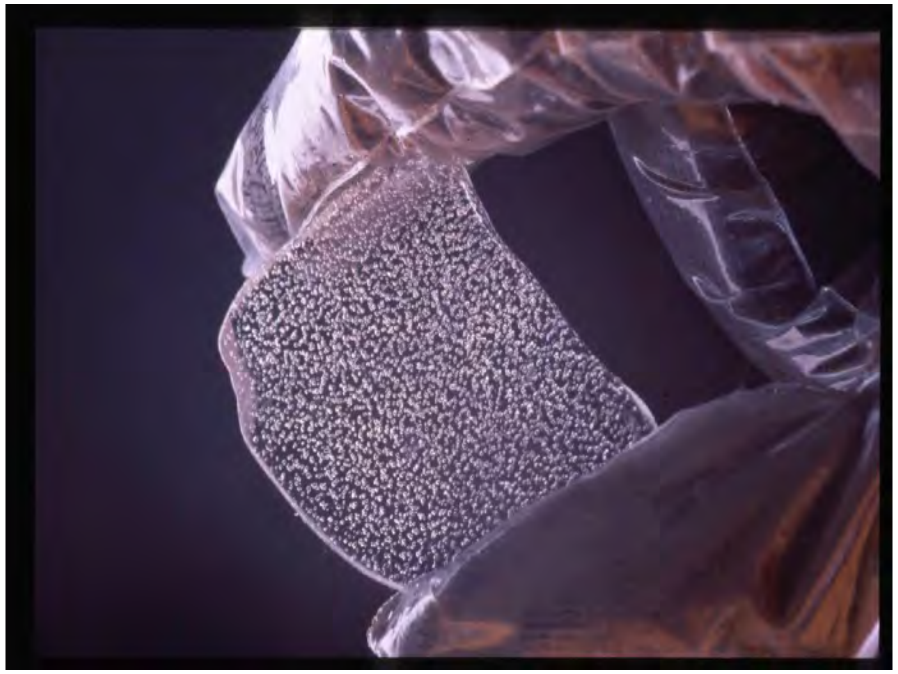
Changes of orbital parameters

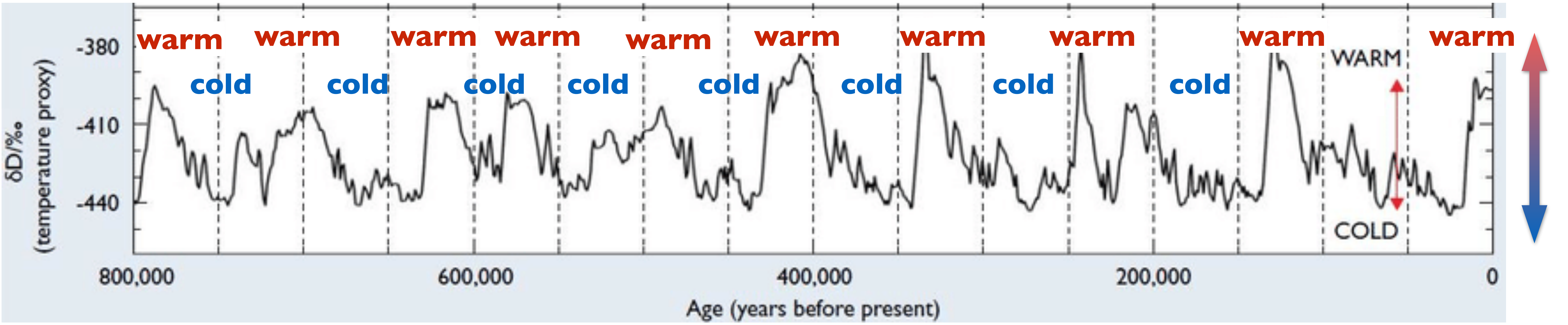




[Ruddiman, Earth's Climate, 2008]

Climate changes on orbital time scales





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Ice sheet growth and decay on orbital time scales

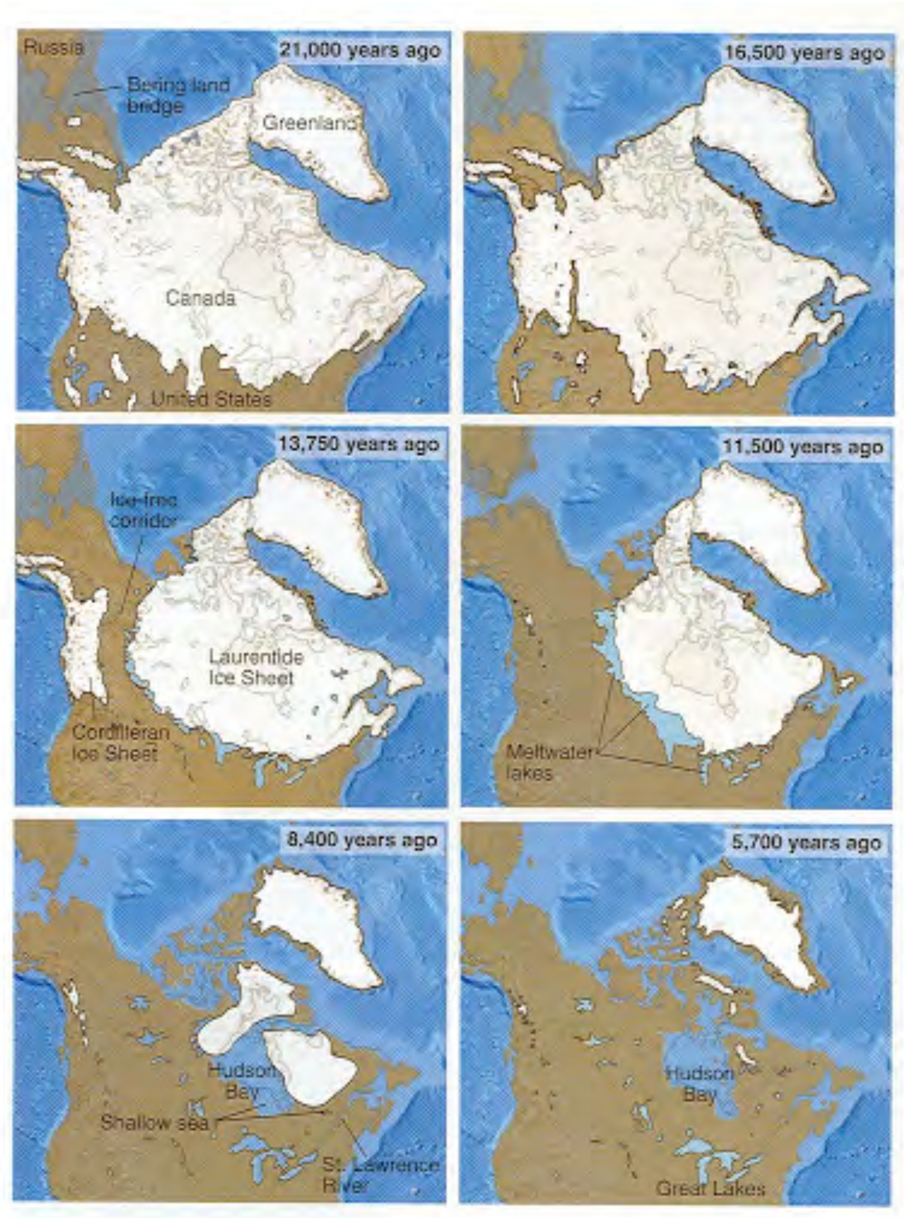
Supplementary Video V1.

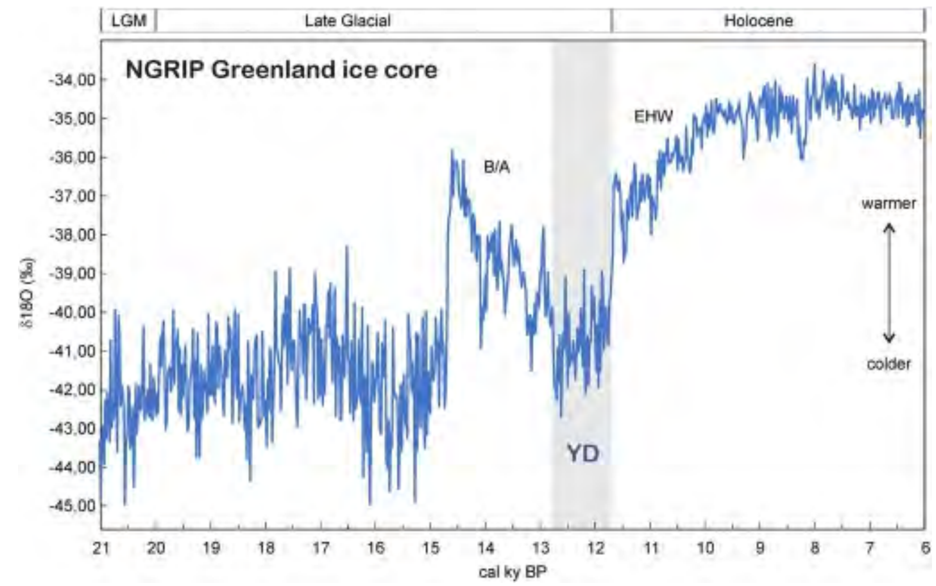
Simulated ice sheet change for the last 400 kyr with IcIES-MIROC model

[from: Abe-Ouchi et al, Nature, 2013]

Climate changes on orbital time scales

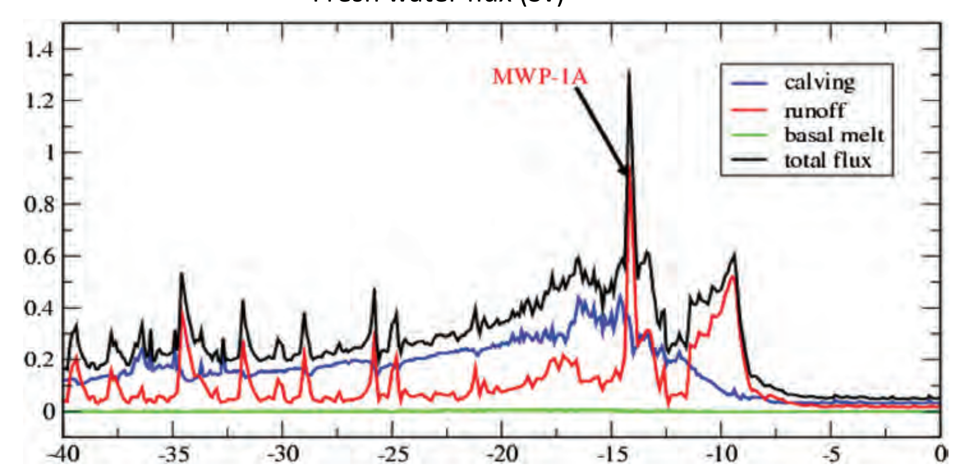
[https://lessthan3ley.wordpress.com/2014/06/25/laurentide-ice-sheet-and-continental-rebound-post-glacial-isostacy/]





[Rull et al., QSR, 2015]

Fresh water flux (Sv)



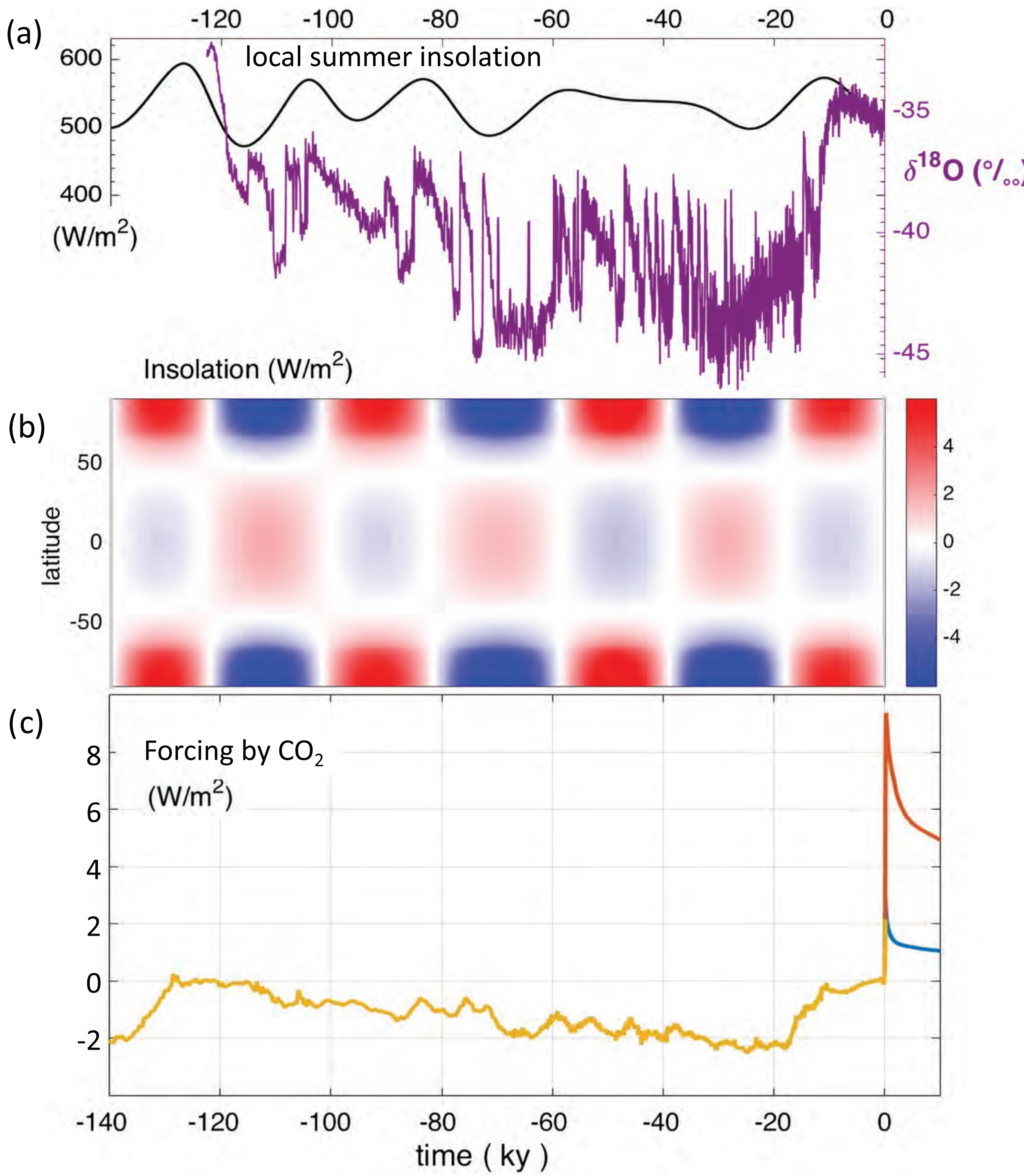
[Lohmann et al. 2020]

Figure 9. Components of the total freshwater flux (in Sv $=10^6$ m^3 s^{-1}) originating from the Northern Hemisphere ice sheets at the end of the last ice age based on Zweck and Huybrechts (2005).

- large freshwater fluxes into the North Atlantic due to melting of ice sheets at the end of each glacial period
  - how did these freshwater fluxes changed the global climate?

Climate changes on orbital time scales

- ice core and marine records from the Arctic **show strong climate variability on shorter time scales**
  - Dansgaard-Oescher (D/O) events: abrupt warming + gradual cooling
  - Heinrich events (H-events): cooling in the North Atlantic, reduction of NA deep water formation
- the forcing mechanisms of these events are still unclear….



[Lohmann et al. 2020]

Abrupt events: Linking atmosphere + ocean + sea ice

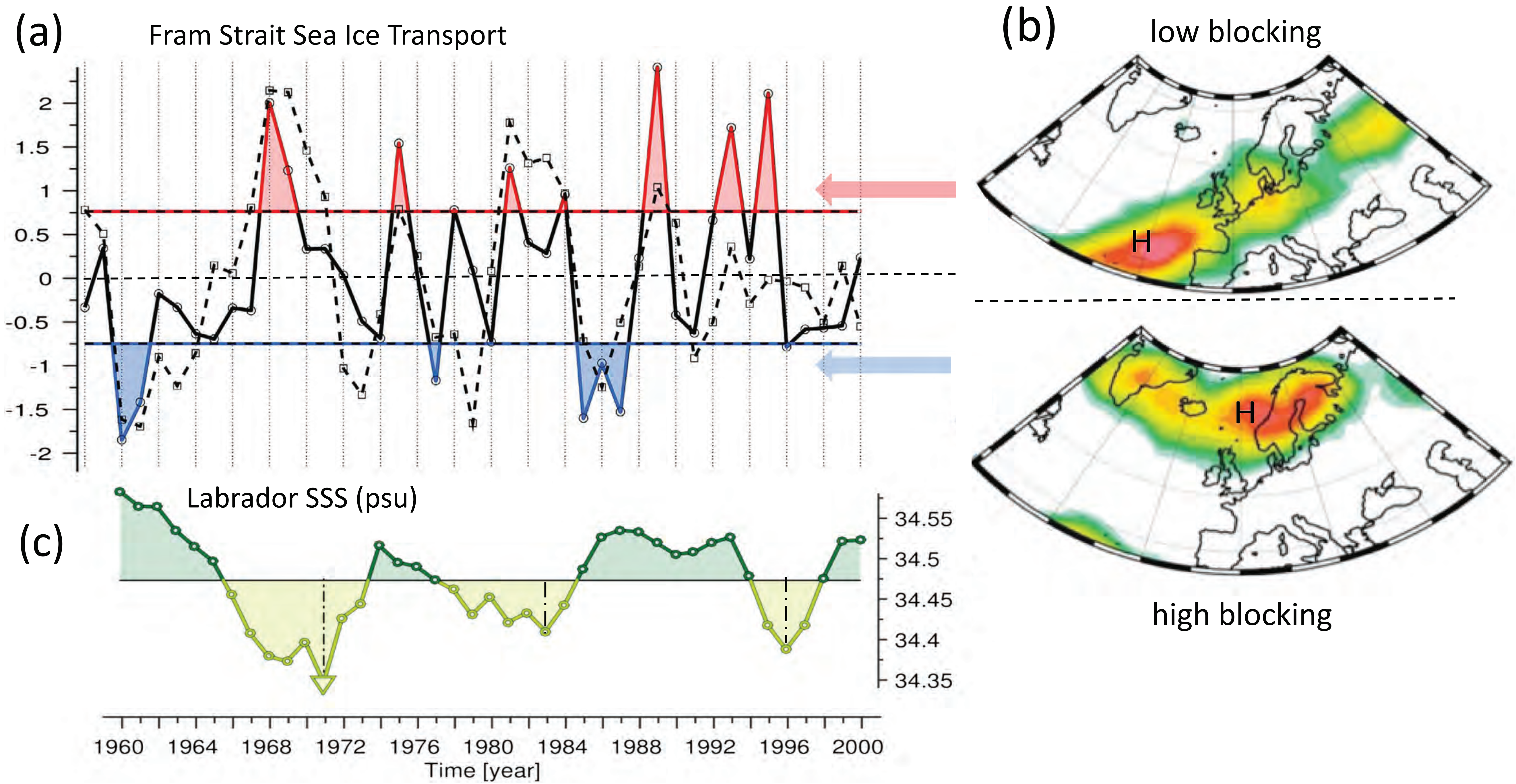


Figure 16. (a) Winter Fram Strait sea ice export time series (normalized): model simulation (solid line) and observations ((b) Atmospheric blocking frequency composite maps with respect to the simulated Fram Strait sea ice export: Maps for above and below 75% standard deviation indicating different regimes of blocking in the North Atlantic realm. (c) The 3 yr running mean winter sea surface salinity in the central Labrador Sea with three major freshwater events, based on Ionita et al. (2016).

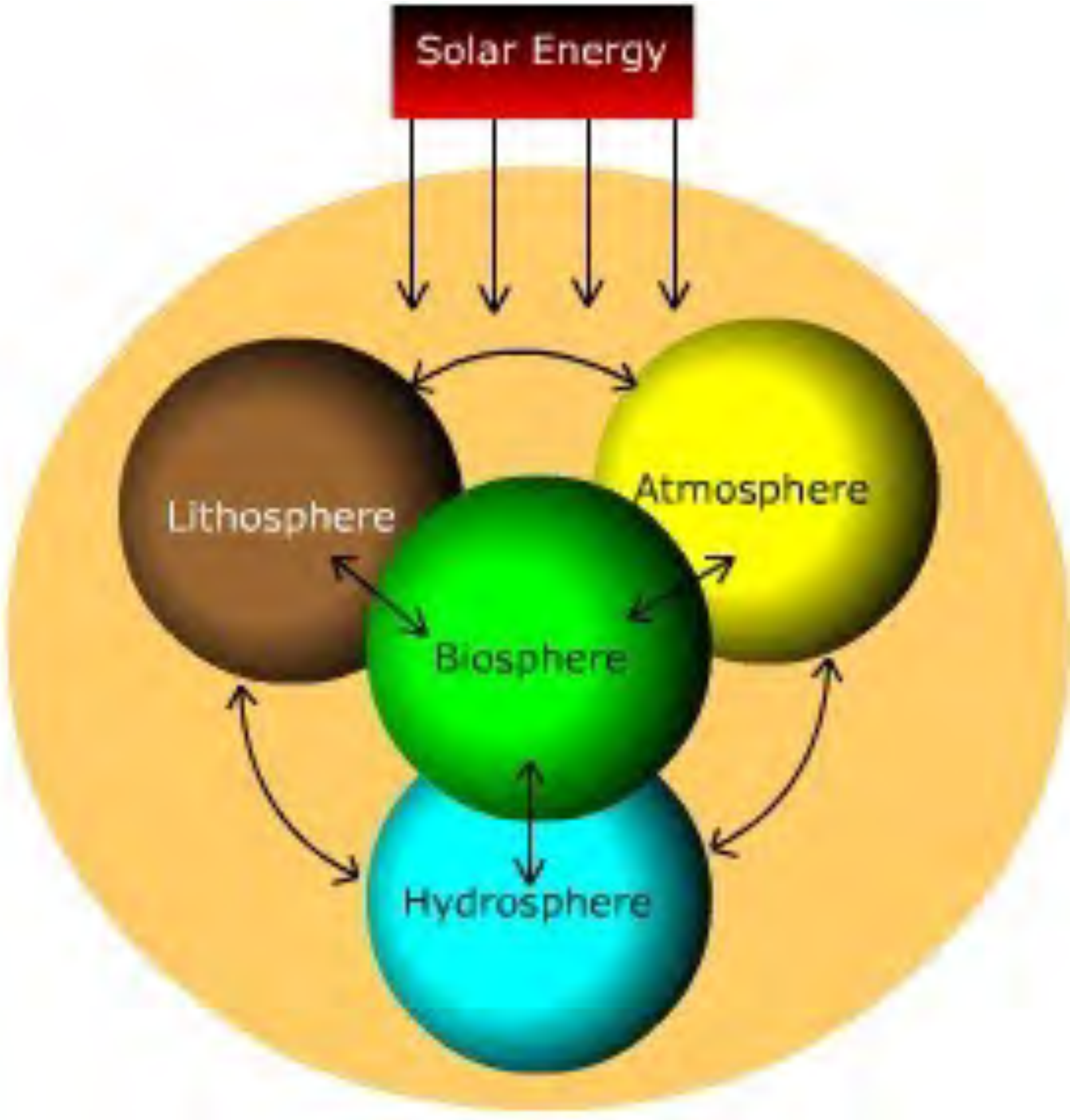
[Lohmann et al. 2020]

Linking climate changes and biogeochemistry

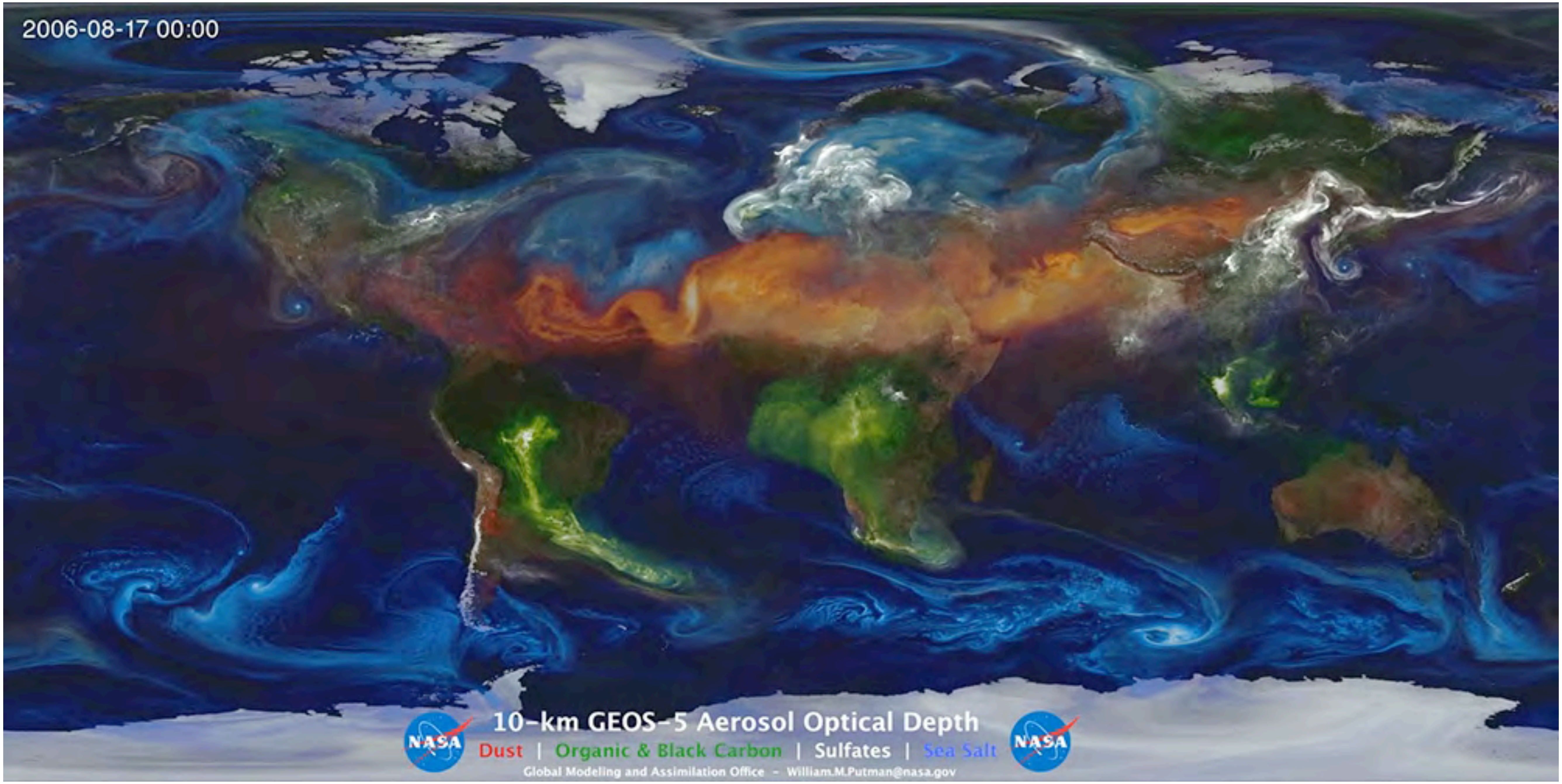
- **Earth system has four parts**
  - ***atmosphere***
  - ***hydrosphere***
  - ***lithosphere***
  - ***biosphere***

- **Biogeochemical cycles**
  - ***The chemical interactions (cycles) that exist between the atmosphere, hydrosphere, lithosphere, and biosphere***

- **Abiotic (physio-chemical) and biotic processes drive these cycles**



Linking climate changes and biogeochemistry



Animation 1. Aerosol optical thickness of black and organic carbon (green), dust (red-orange), sulfates (white), and sea salt (blue) from a 10 km resolution GEOS-5 "nature run" using the GOCART model. The animation shows the emission and transport of key tropospheric aerosols from August 17, 2006 to April 10, 2007.

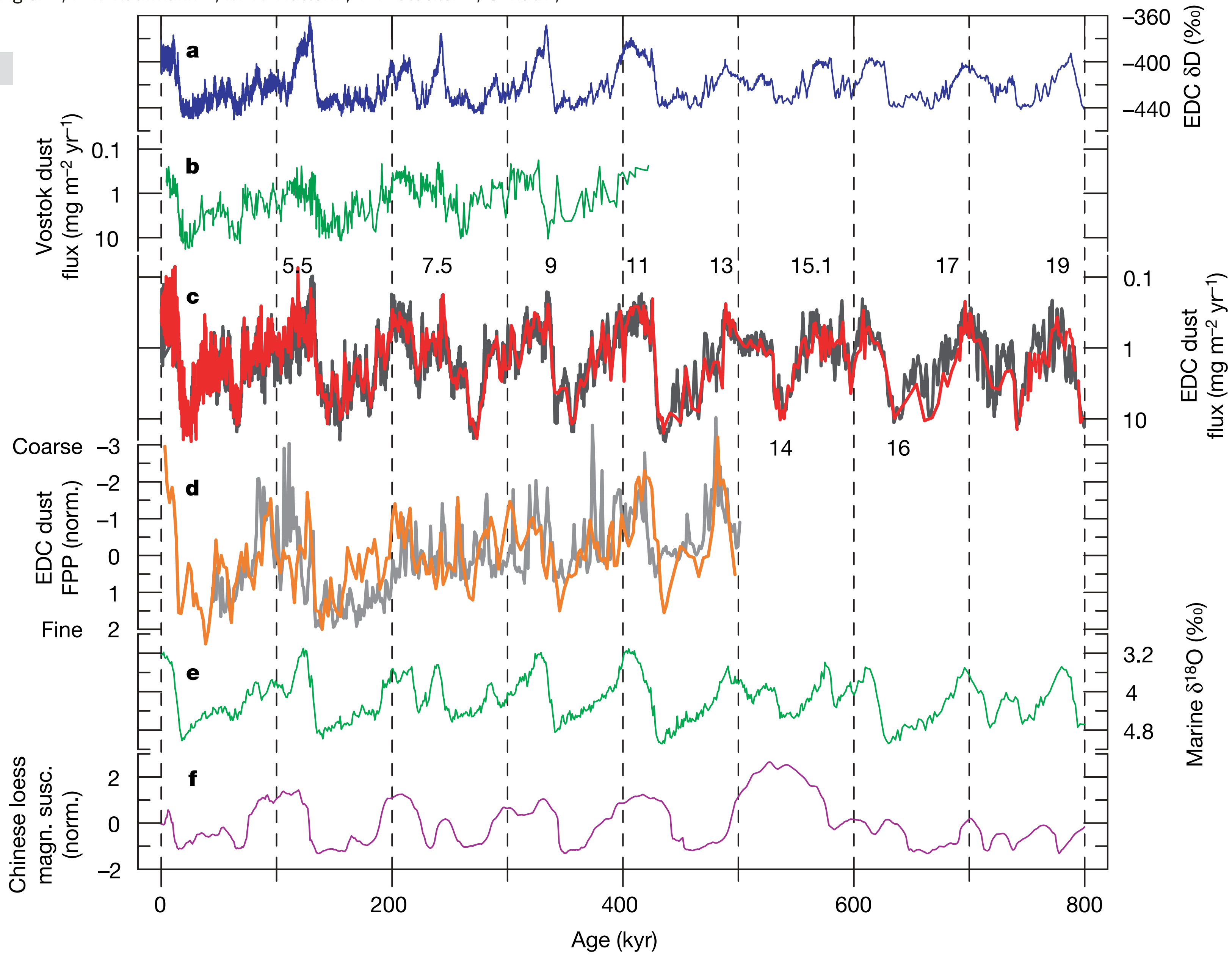
(http://gmao.gsfc.nasa.gov/research/aerosol/modeling/nr1_movie/)

Climate and dust changes on glacial-interglacial time scales

Dust–climate couplings over the past 800,000 years from the EPICA Dome C ice core

F. Lambert[1,2], B. Delmonte[3], J. R. Petit[4], M. Bigler[1,5], P. R. Kaufmann[1,2], M. A. Hutterli[6], T. F. Stocker[1,2], U. Ruth[7], J. P. Steffensen[5] & V. Maggi[3]

Vol 452 | 3 April 2008 | doi:10.1038/nature06763



temperature

dust

ice volume

Figure 1 | EDC dust data in comparison with other climatic indicators. **a**, Stable isotope (δD) record from the EPICA Dome C (EDC) ice core[8] back to Marine Isotopic Stage 20 (EDC3 timescale) showing Quaternary temperature variations in Antarctica. **b**, Vostok dust flux record (Coulter counter) plotted on its original timescale[11]. **c**, EDC dust flux records. Red and grey lines represent, respectively, Coulter counter (55-cm to 6-m resolution) and laser-scattering data (55-cm mean). Numbers indicate Marine Isotopic Stages. Note that the vertical extent of the scales of **b** and **c** is larger than for the other records. **d**, EDC dust size data expressed as FPP (see Methods). The orange and grey curves represent measurements by Coulter counter (2-kyr mean) and laser (1-kyr mean), respectively. **e**, Marine sediment $\delta^{18}O$ stack[18], giving the pattern of global ice volume. **f**, Magnetic susceptibility stack record for Chinese loess[17] (normalized).

Global temperatures and CO_2 of the past

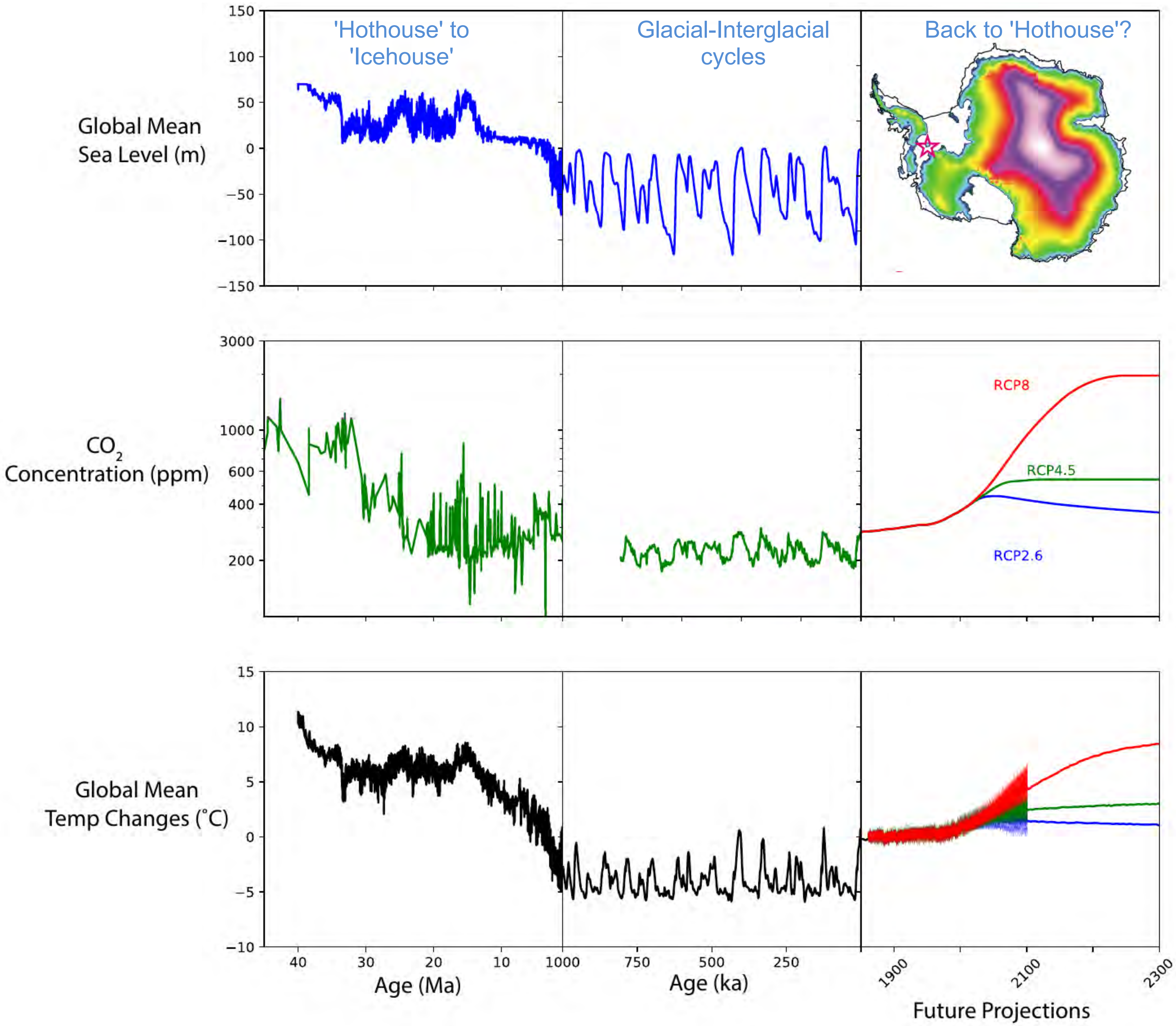


illustration: Paul Gierz, AWI, based on various data sources

Climate II - Content

- Oct 18: Challenges of climate change (MW)
- Oct 25: The global water cycle (MW)
- Nov 1: Ice Ages and Astronomical theory (GL) + exercise
- Nov 8: Ice Ages and Astronomical theory (GL) + exercise
- Nov 15: The Last Glacial Maximum (MW) + exercise
- Nov 22: Biogeochemical cycles (MW)
- Nov 29: Climate variability and data analysis (GL) + exercise
- Dec 6: Vegetation and dust (MW)
- Dec 13: Climate variability and extremes (GL)
- Dec 20: Climate teleconnectivity and Feedback analysis (GL)
- Jan 10: The last 100 million years (GL) + exercise
- Jan 17: Regional and global changes (MW) + exercise
- Jan 24: Permafrost and further archives of climate change (MW)
- Jan 31: The current debate (GL)
- Oral exam on XXX

Climate System II
(Winter 2022/2023)

1st lecture:

Challenges of climate change

(Introduction to past and present climate change, course content)

End of lecture.

Slides available at:

https://paleodyn.uni-bremen.de/study/climate2022_23.html