Climate System II

Gerrit Lohmann

Martin Werner

https://paleodyn.uni-bremen.de/study/climate2023_24.html

Time: Tuesday 10:15-11:45

Climate System II

Today, October 17, 2021

- Introduction and overview (60 min)

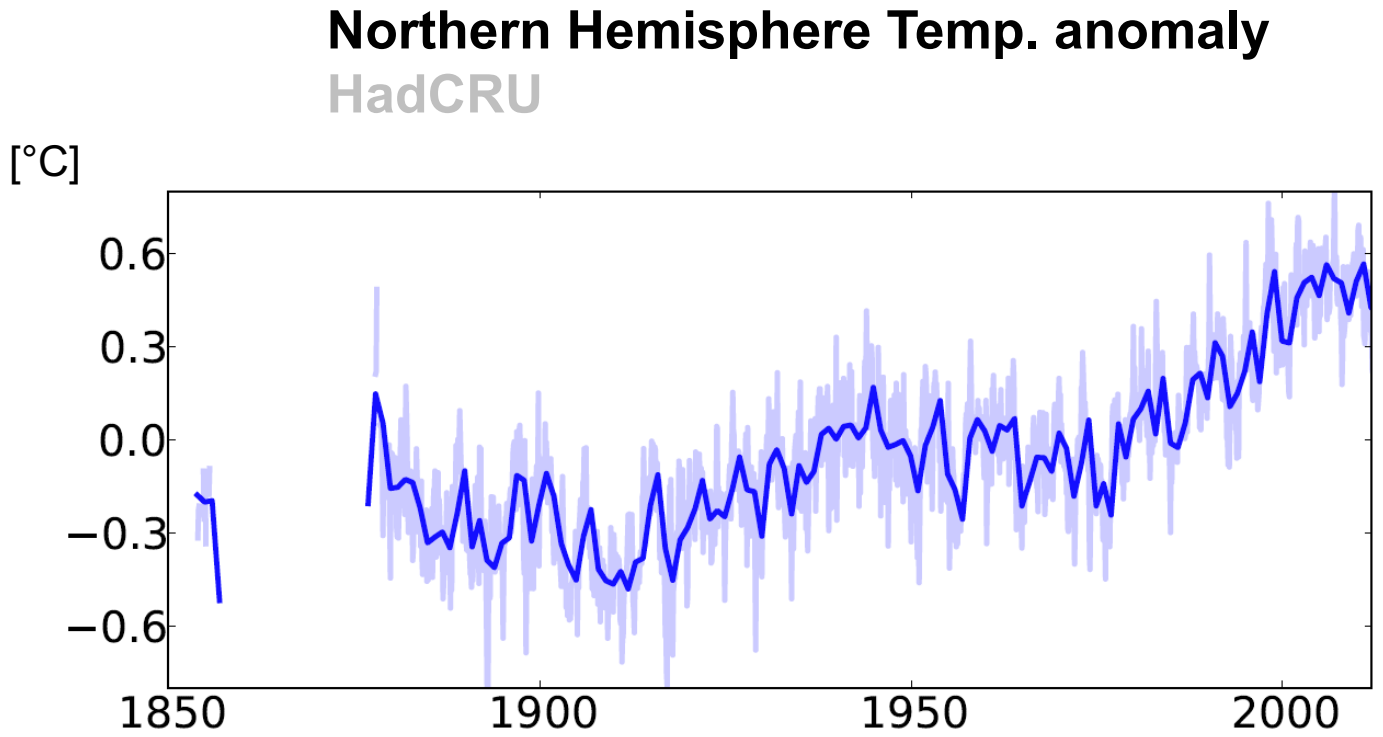
- Formalities etc. (15 min)

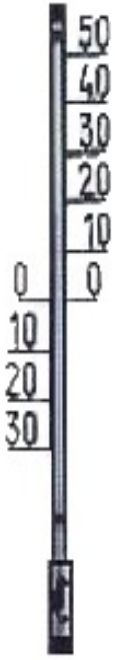
(https://paleodyn.uni-bremen.de/study/climate2023_24.html)

- Expectations and wishes from your side (15 min)

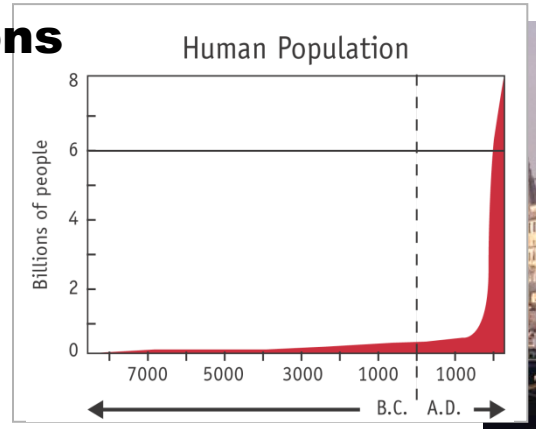
Climate Trends at different Timescales

Temperature of the last **150 years** (instrumental data)



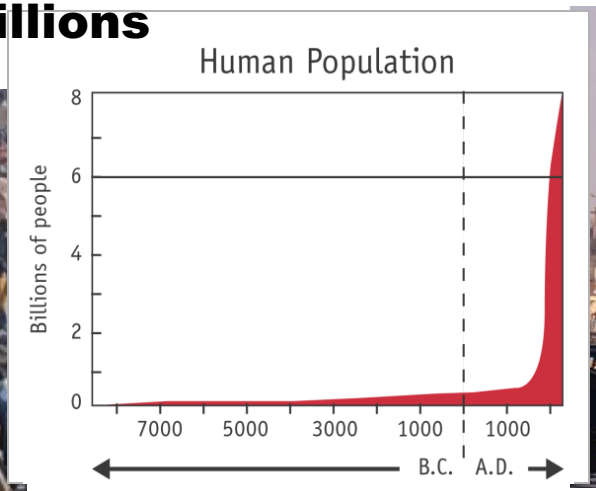


Human Population: 7 billions



The Challenge: Sustainable Management and Energy

Human Population: 7 billions

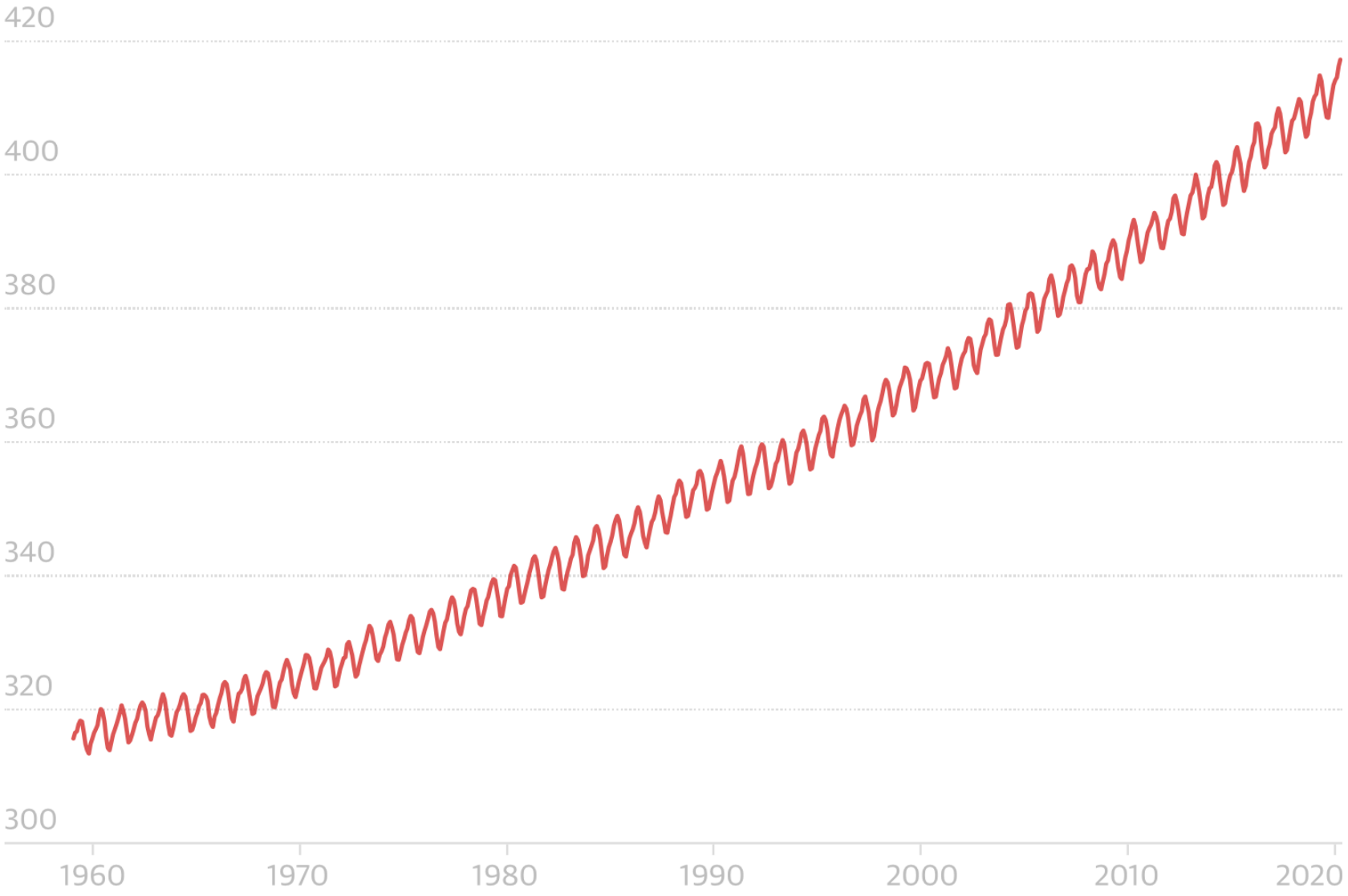


CO_2 Increase:

Land cover: 22%

CO_2-Emissions: 78%

Atmospheric CO2 has reached the highest level on record



Guardian graphic. Source: Scripps Institution of Oceanography, NOAA

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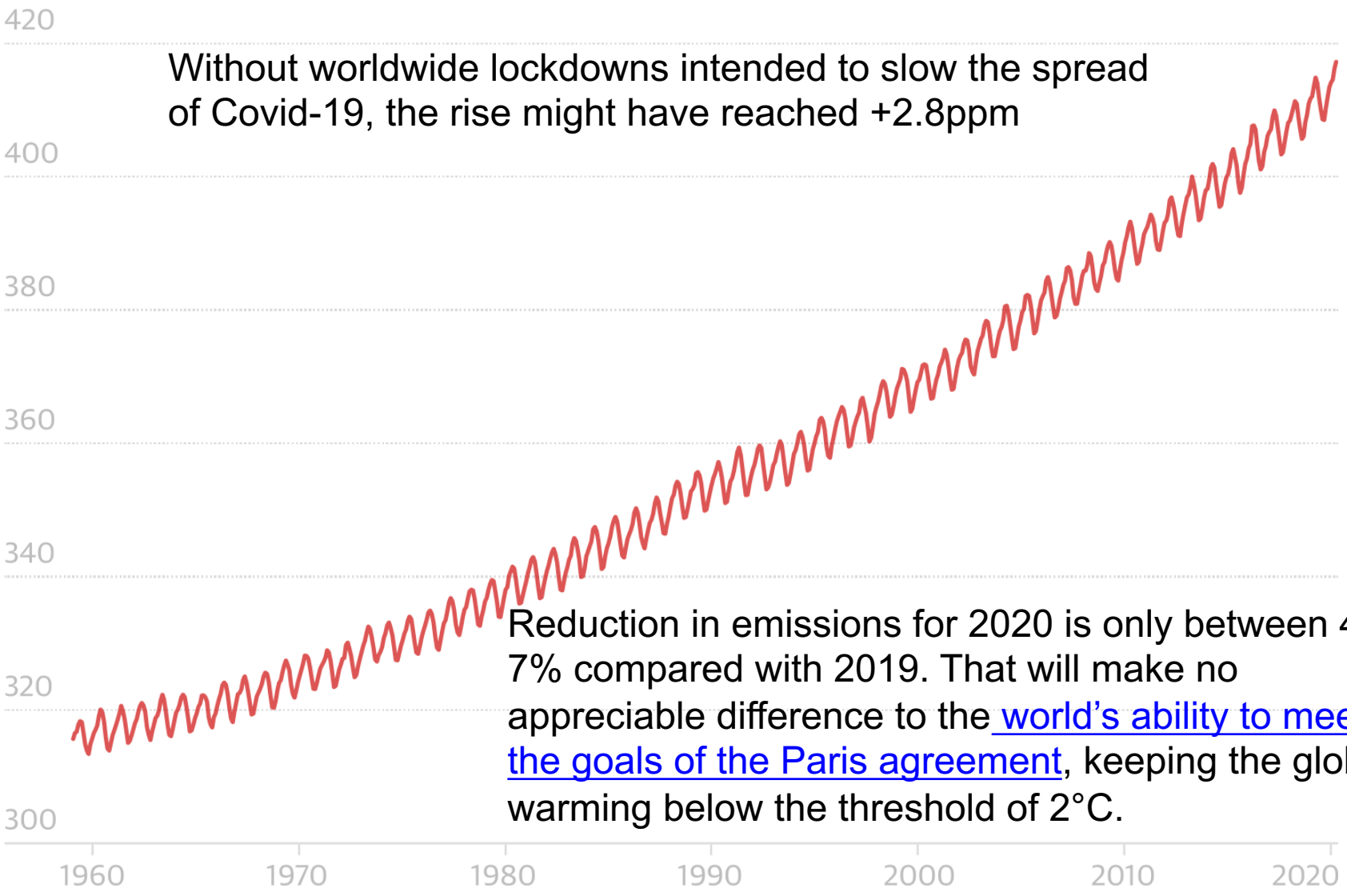
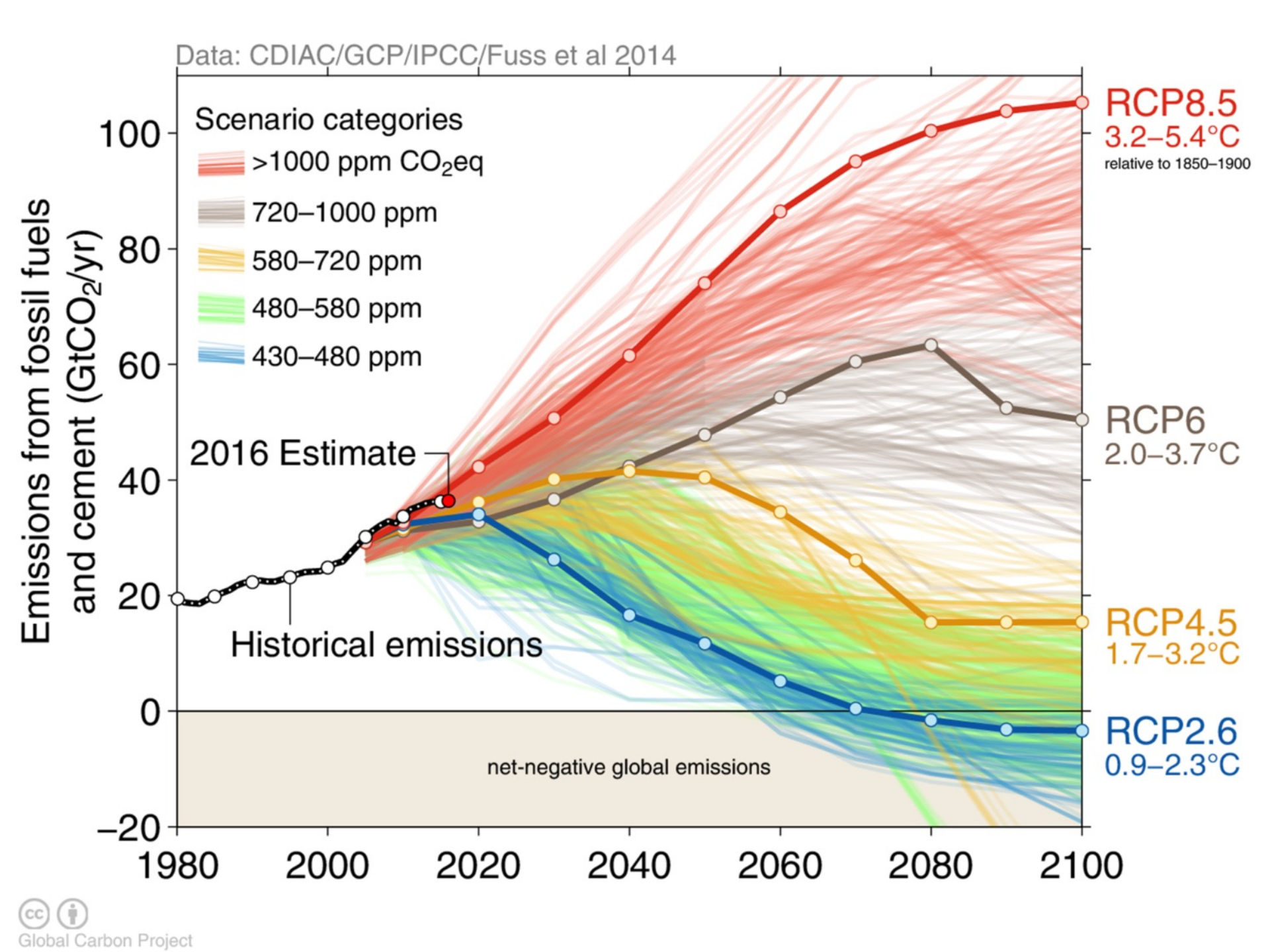
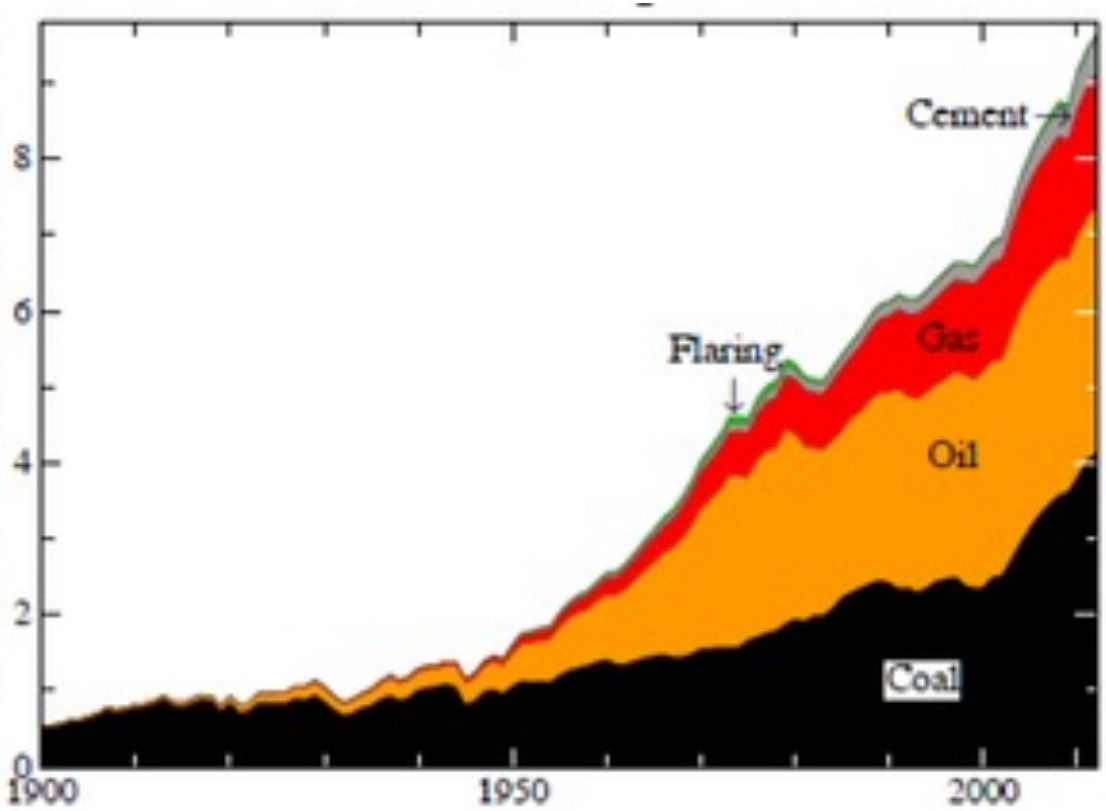


Guardian graphic. Source: Scripps Institution of Oceanography, NOAA

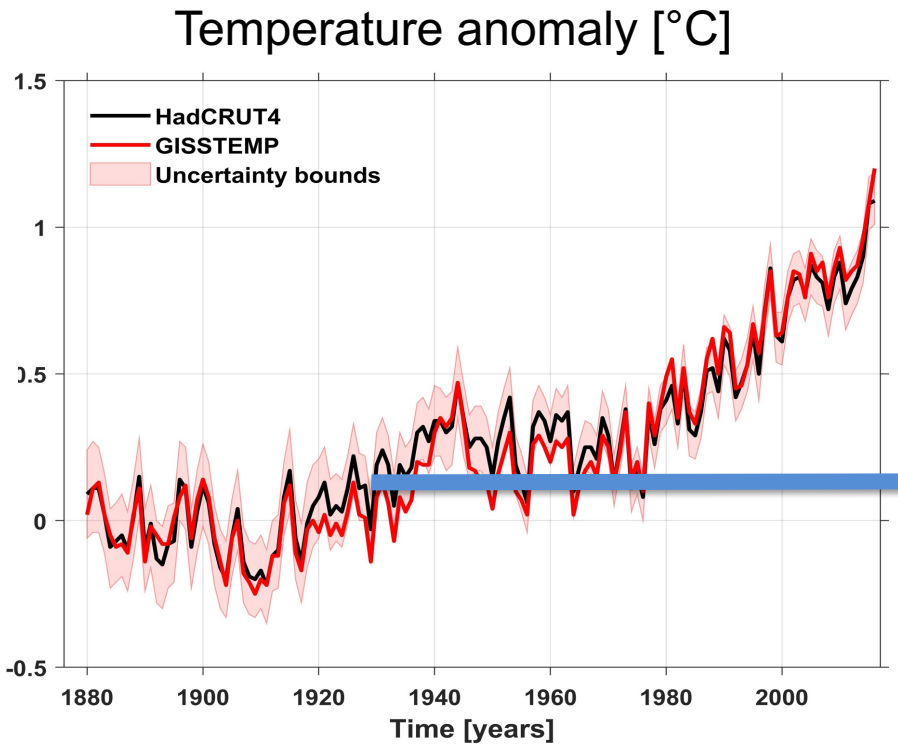

Data: CDIAC/GCP/IPCC/Fuss et al 2014
Scenario categories
>1000 ppm CO_2eq
720–1000 ppm
580–720 ppm
480–580 ppm
430–480 ppm
2016 Estimate
Historical emissions
net-negative global emissions
RCP8.5
3.2–5.4°C
relative to 1850–1900
RCP6
2.0–3.7°C
RCP4.5
1.7–3.2°C
RCP2.6
0.9–2.3°C
Emissions from fossil fuels and cement ($GtCO_2$/yr)
100
80
60
40
20
0
–20
1980
2000
2020
2040
2060
2080
2100
Global Carbon Project

Global Fossil-Fuel CO2 annual emissions (Gt C/year)

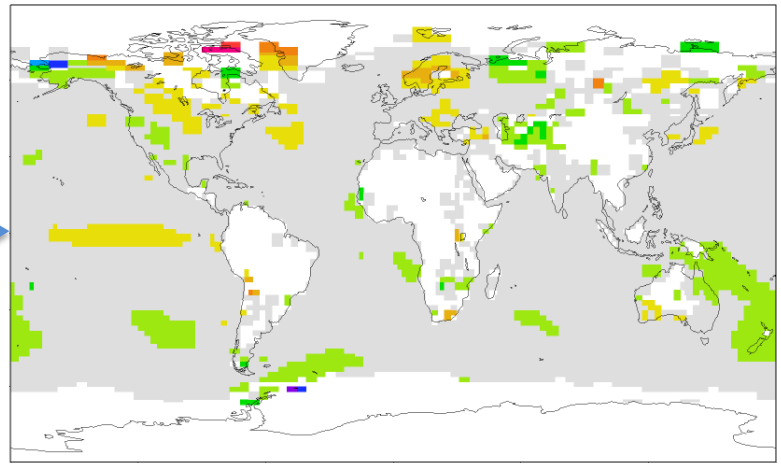


Hansen J, Kharecha P, Sato M, Masson-Delmotte V, Ackerman F, et al. (2013) Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature. PLOS ONE 8(12): e81648. https://doi.org/10.1371/journal.pone.0081648
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0081648

Motivation: Observational Record



Uncertainty largely due to missing information at high latitudes



Temperature Anomaly 1930
White areas: not enough data

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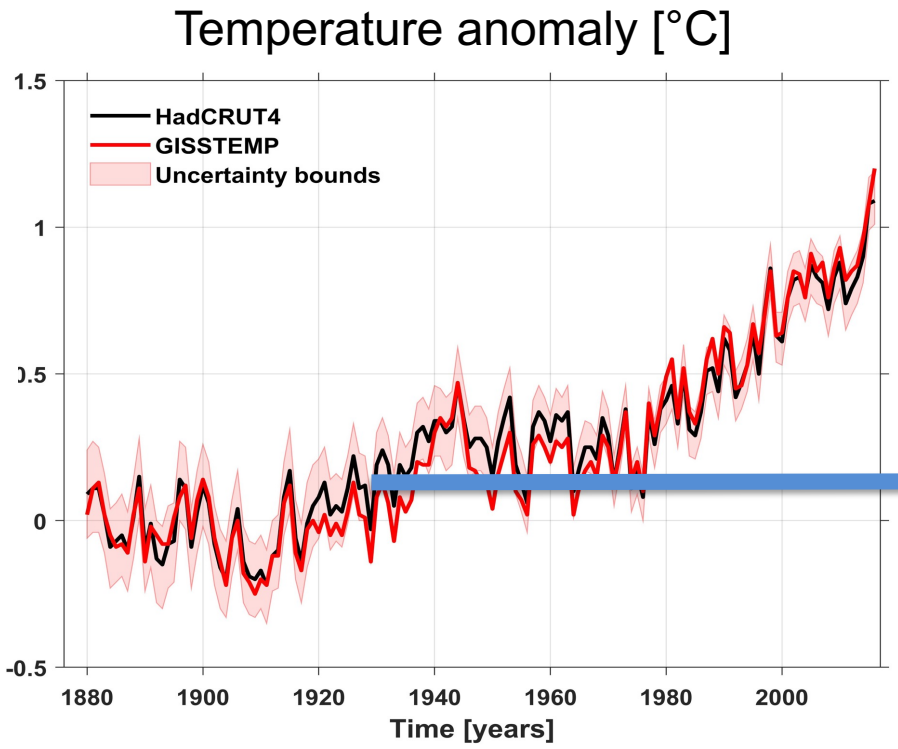

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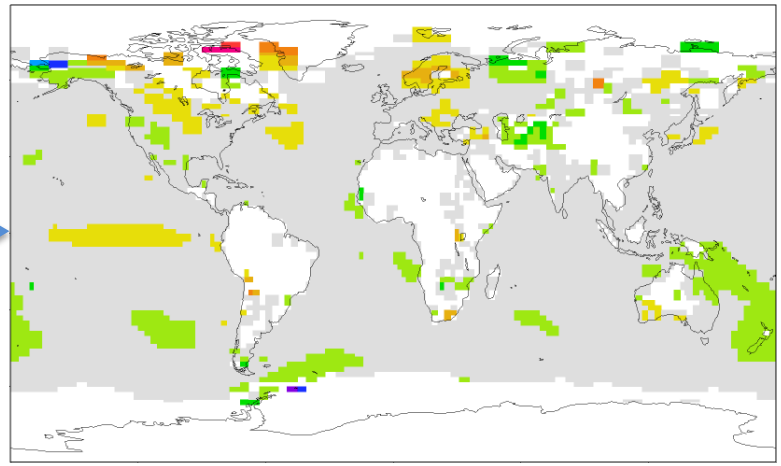


Temperature Anomaly 1930
White areas: not enough data

Climate variability beyond the instrumental record: Decadal, centennial, millennial

Animation

https://data.giss.nasa.gov/gistemp/animations/5year_2y.mp4

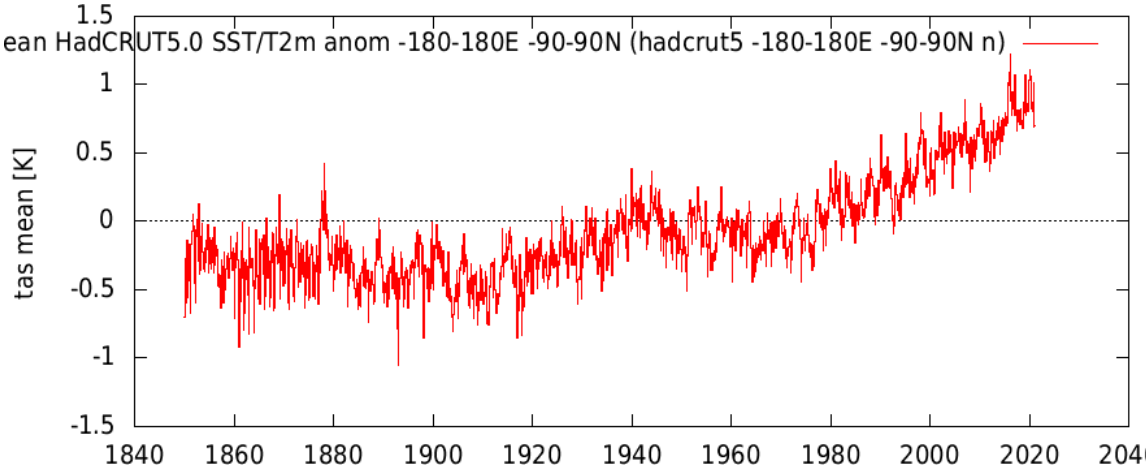
Faster:

https://data.giss.nasa.gov/gistemp/animations/5year_6y.mp4

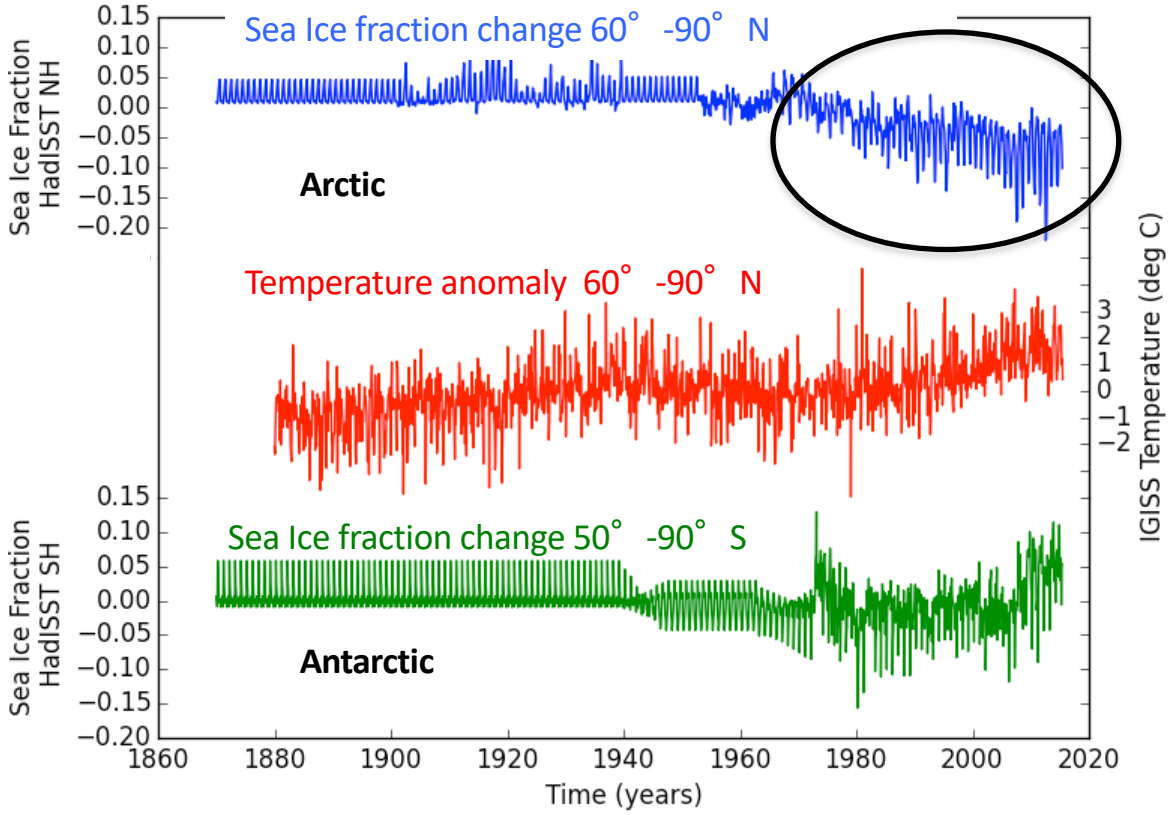
Calculation with Climate Explorer

http://climexp.knmi.nl/

Do it now !

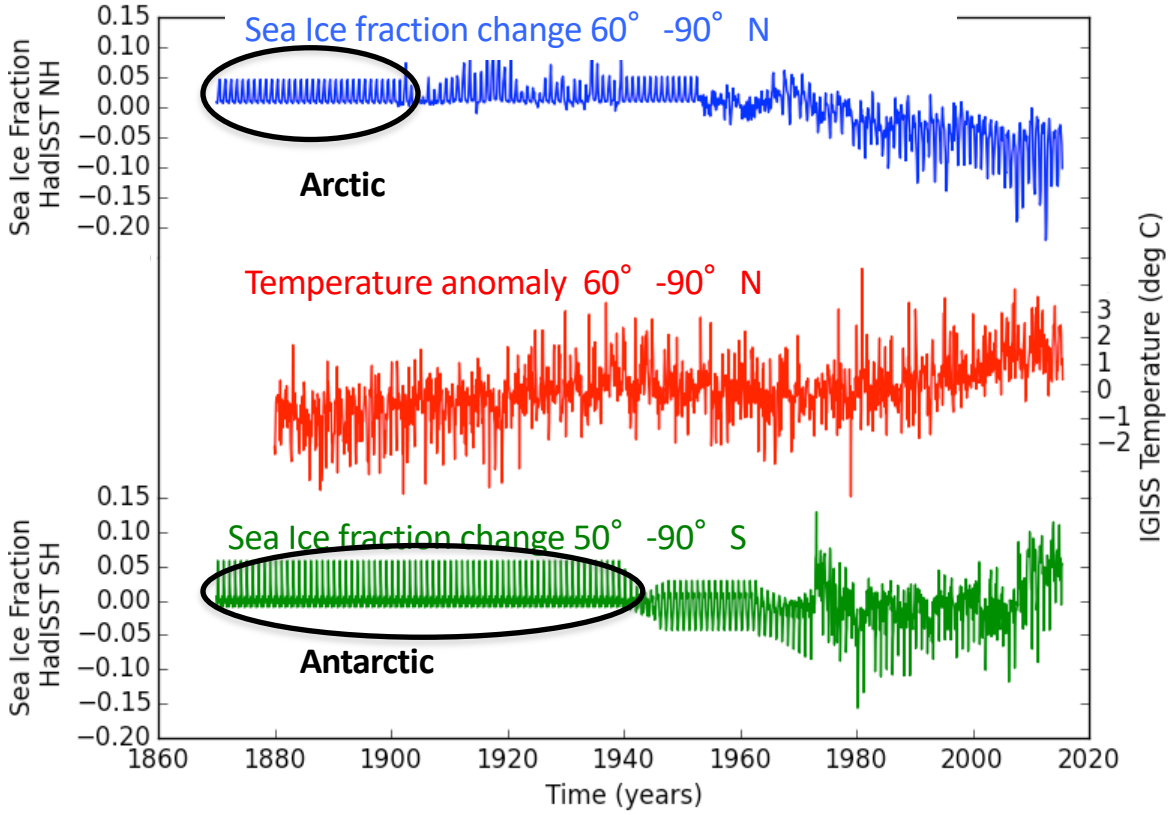


Arctic Sea Ice retreat



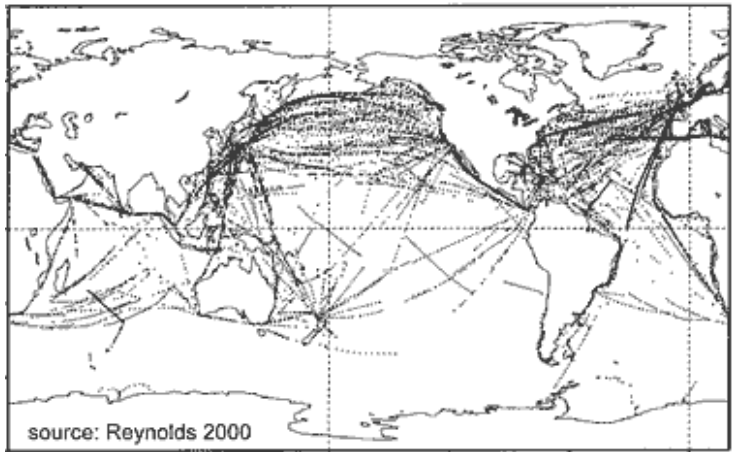
Arctic Sea Ice retreat

Missing Information about Sea Ice



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



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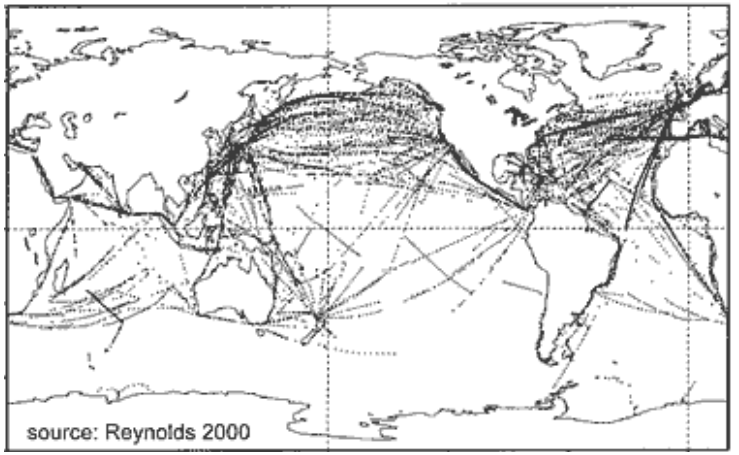
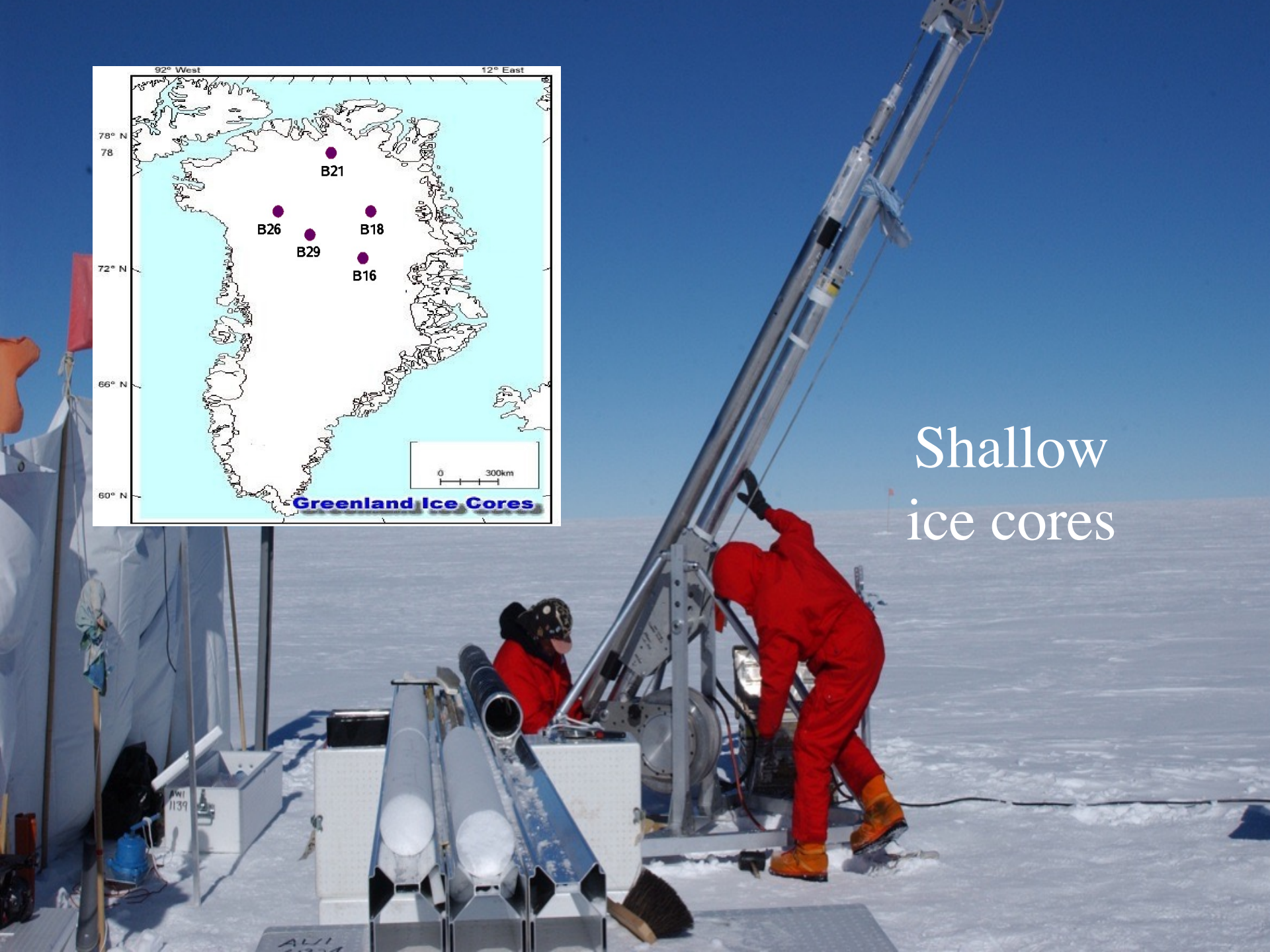


- **For the time before instrumental records, one has to rely on information from proxy data and modeling.**



Shallow ice cores

History

last **1000 Years**

Pieter Breughel d.Ä.

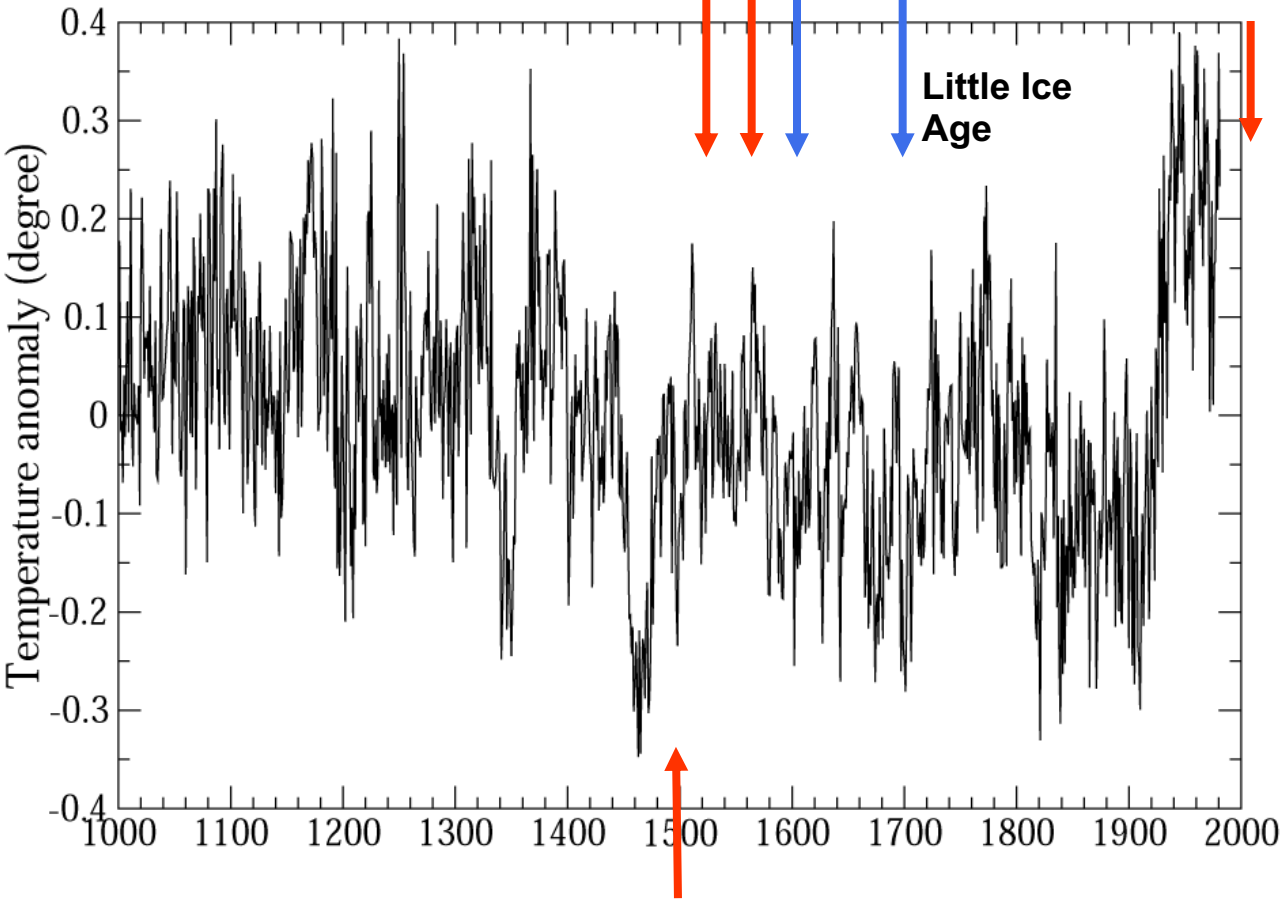
Thermometer

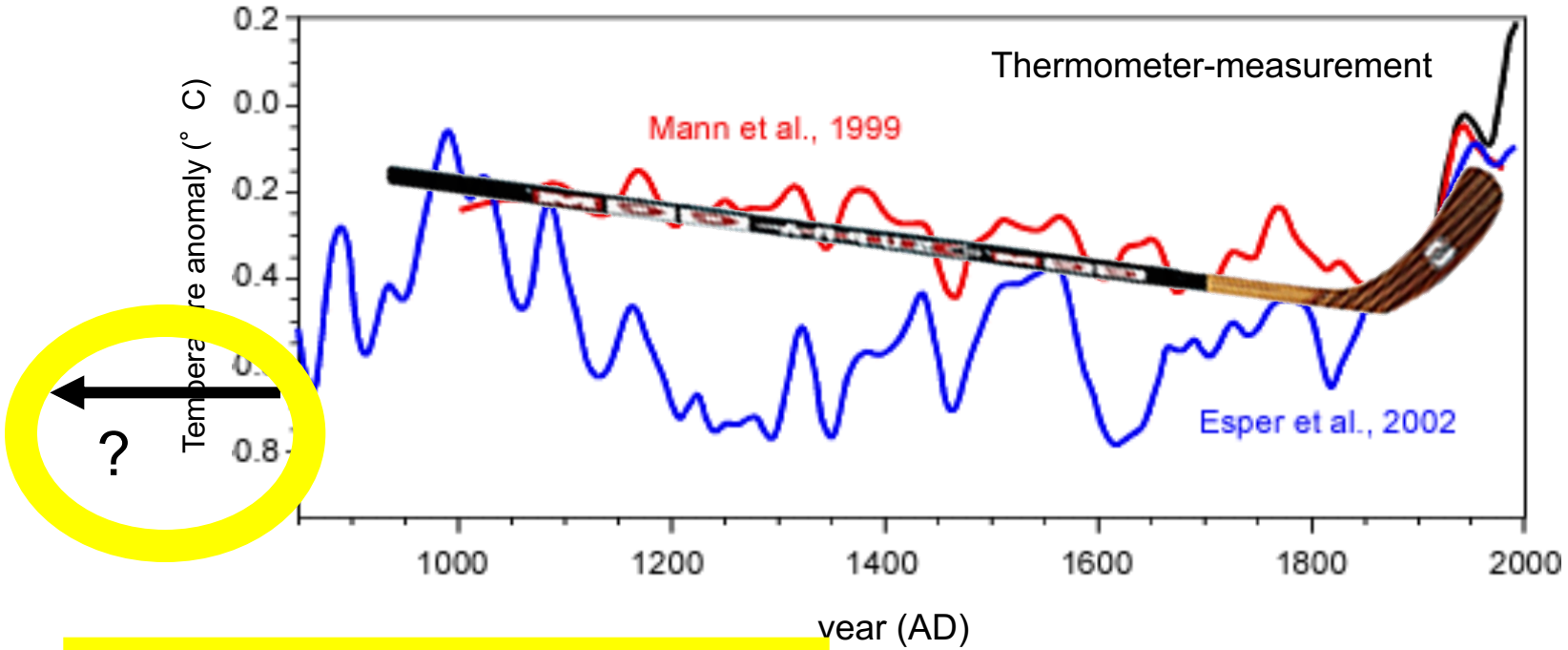
Barometer
(Torricelli)

Little Ice
Age

present

Nicolaus Kopernikus





Further back in time?

Proxy Data

- Indirect data, often qualitative
- Long time series from archives
- Information beyond the instrumental record

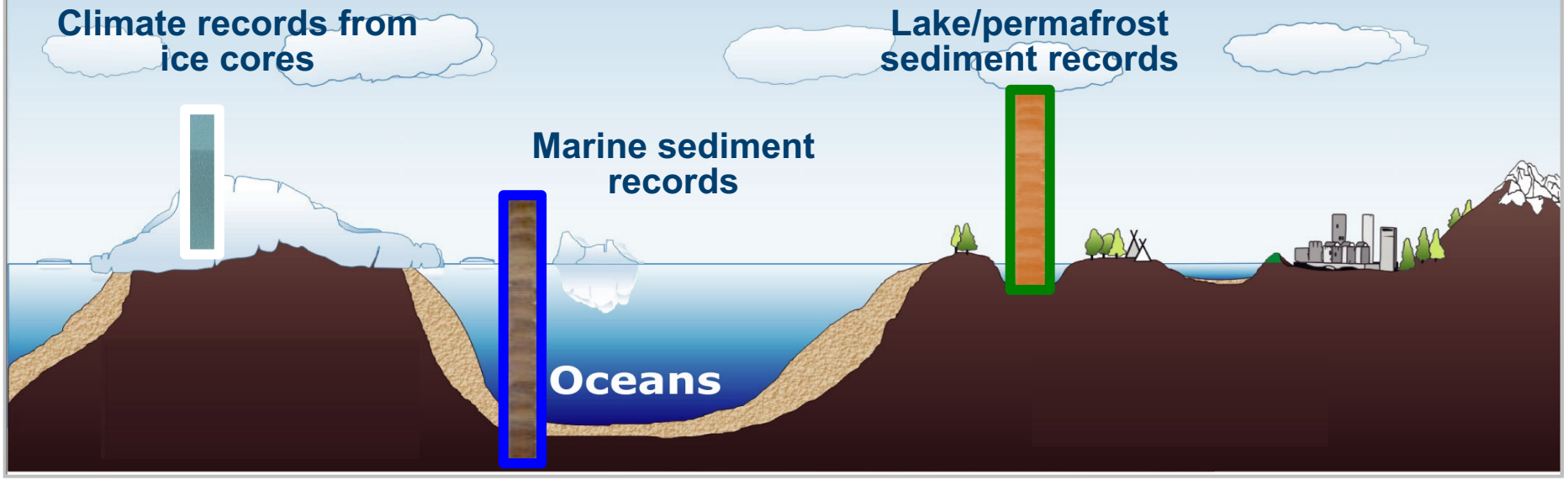
One example in the Bürgerpark/Stadtwald

Earth System:reconstructions

Ice drilling camp, 2009

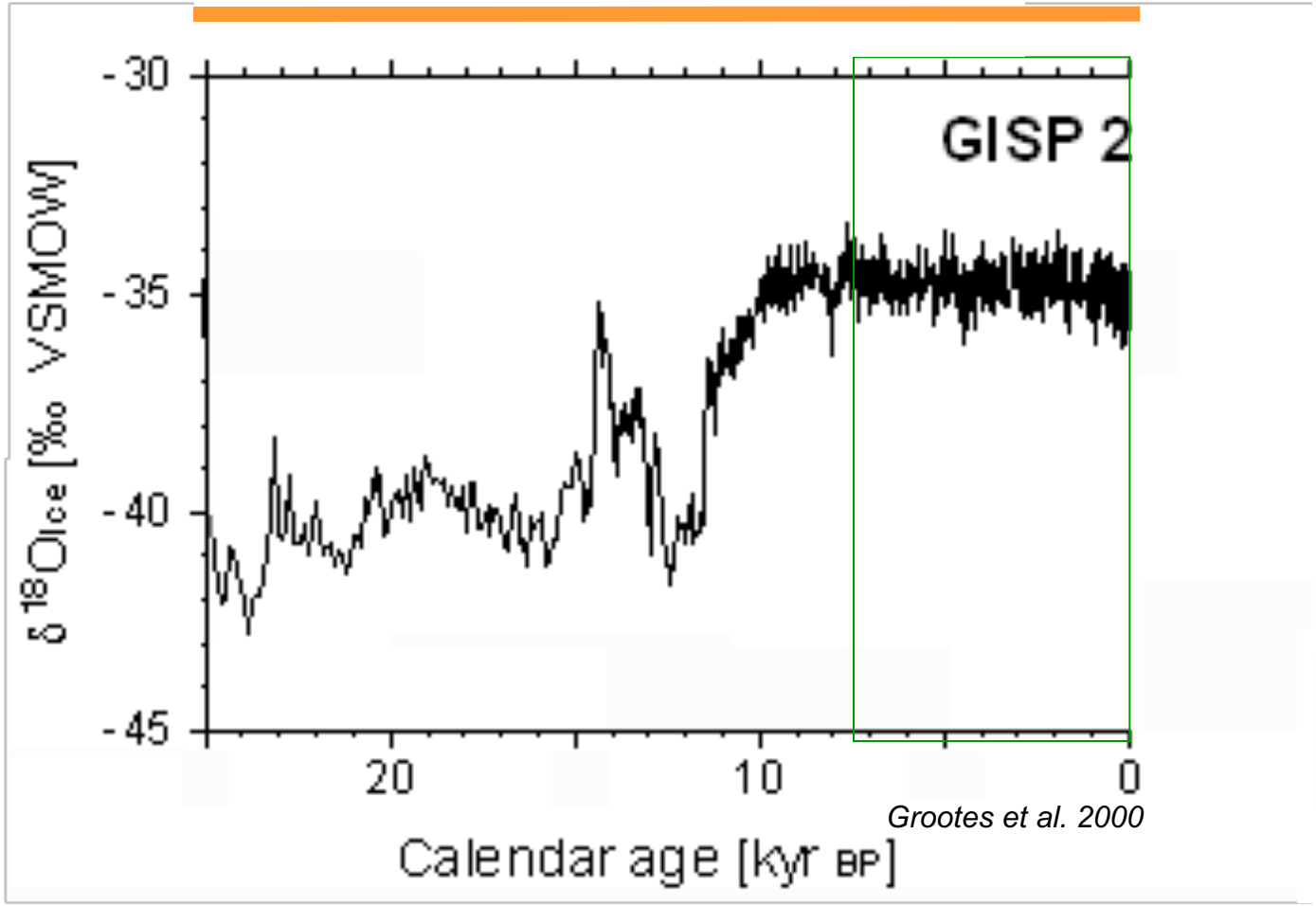
Polarstern, marine sediments

Lake/permafrost sediments

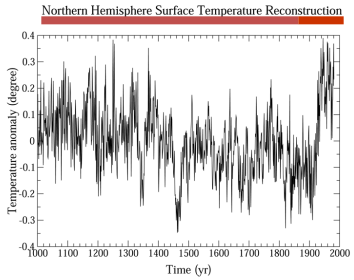


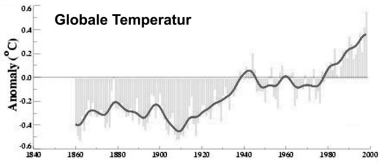
Climate Trends at different Timescales

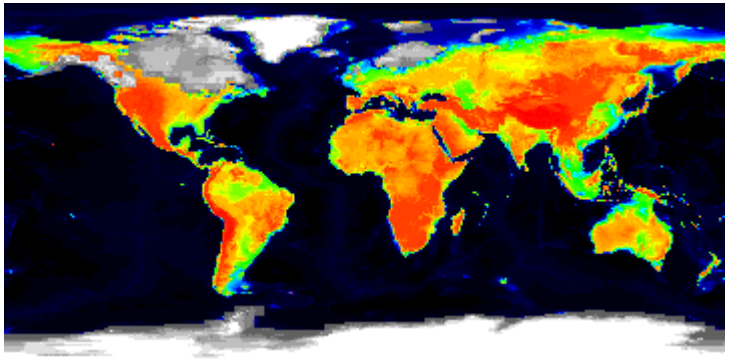
Deglaciation – Greenland ice core

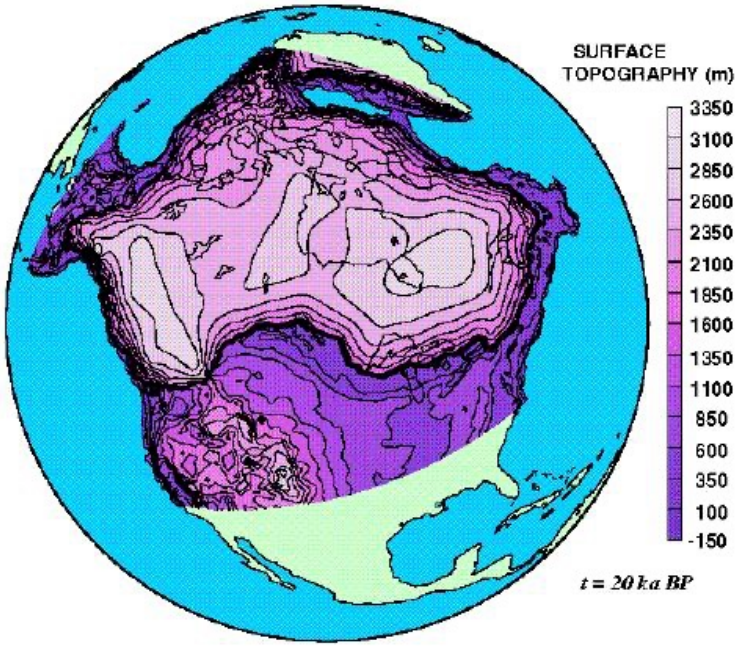


Grootes et al. 2000



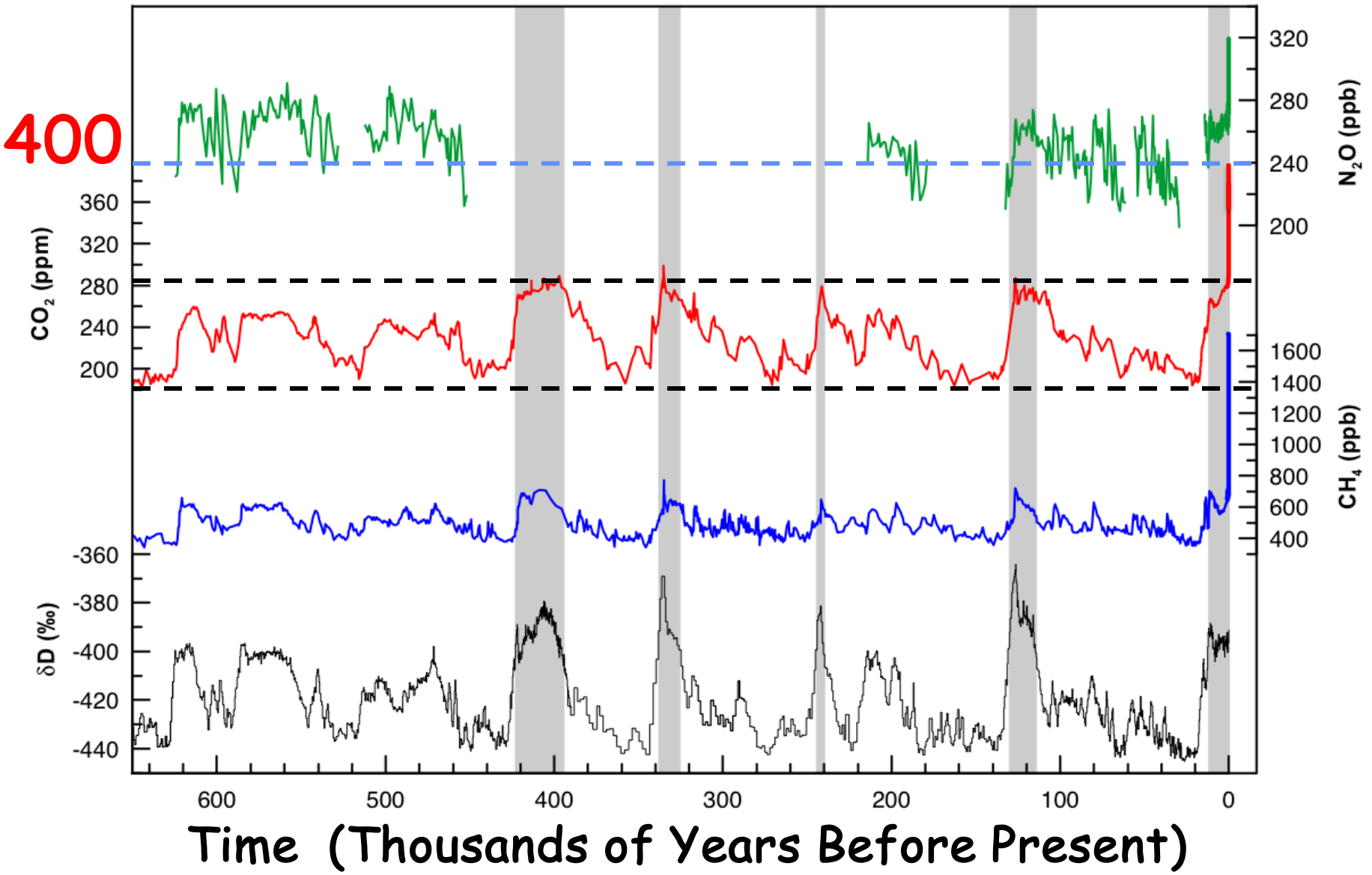




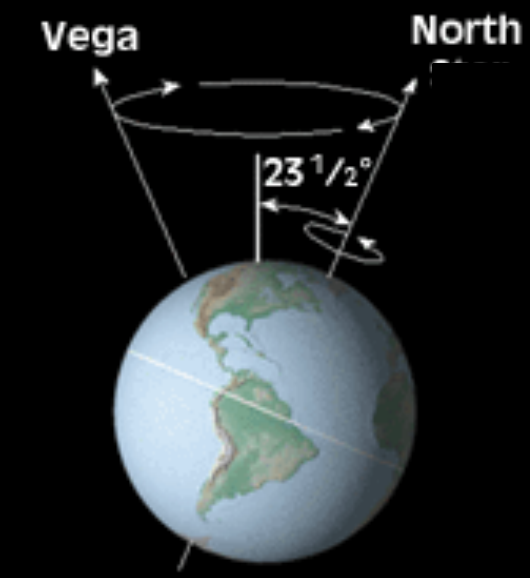


Deglaciation

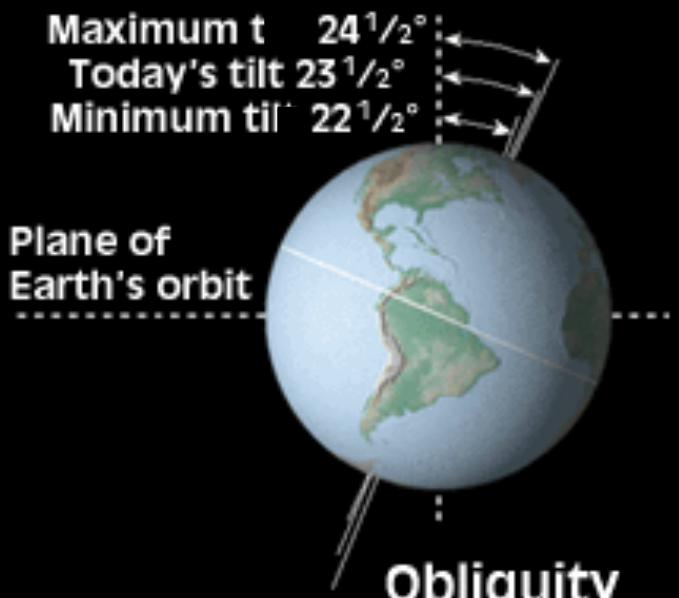
Atmospheric Gas Concentrations from Ice Cores



EPICA 2008



Precession



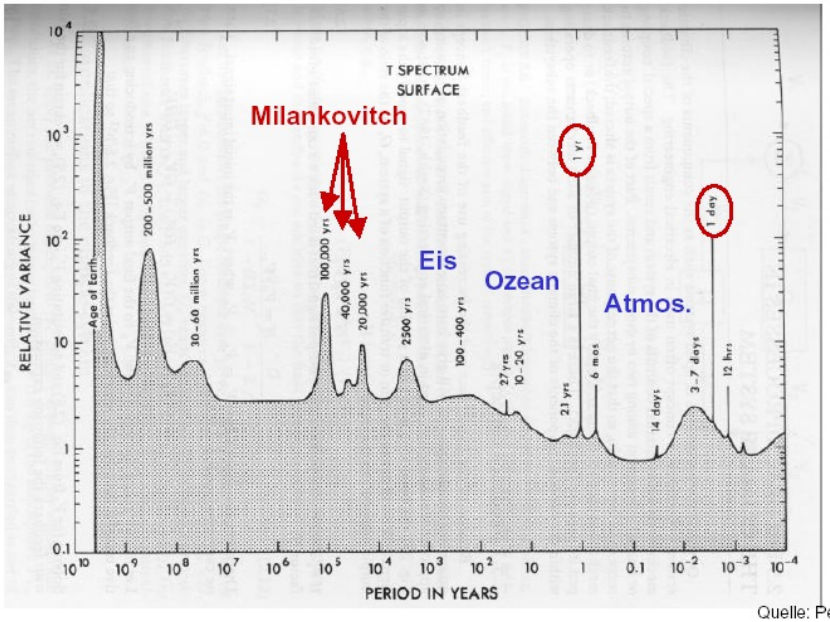
Obliquity

Eccentricity

Orbital focing

- ~20.000, ~40.000, ~100.000 years
- 0.5, 1 year

- Geometry of the Sun-Earth configuration

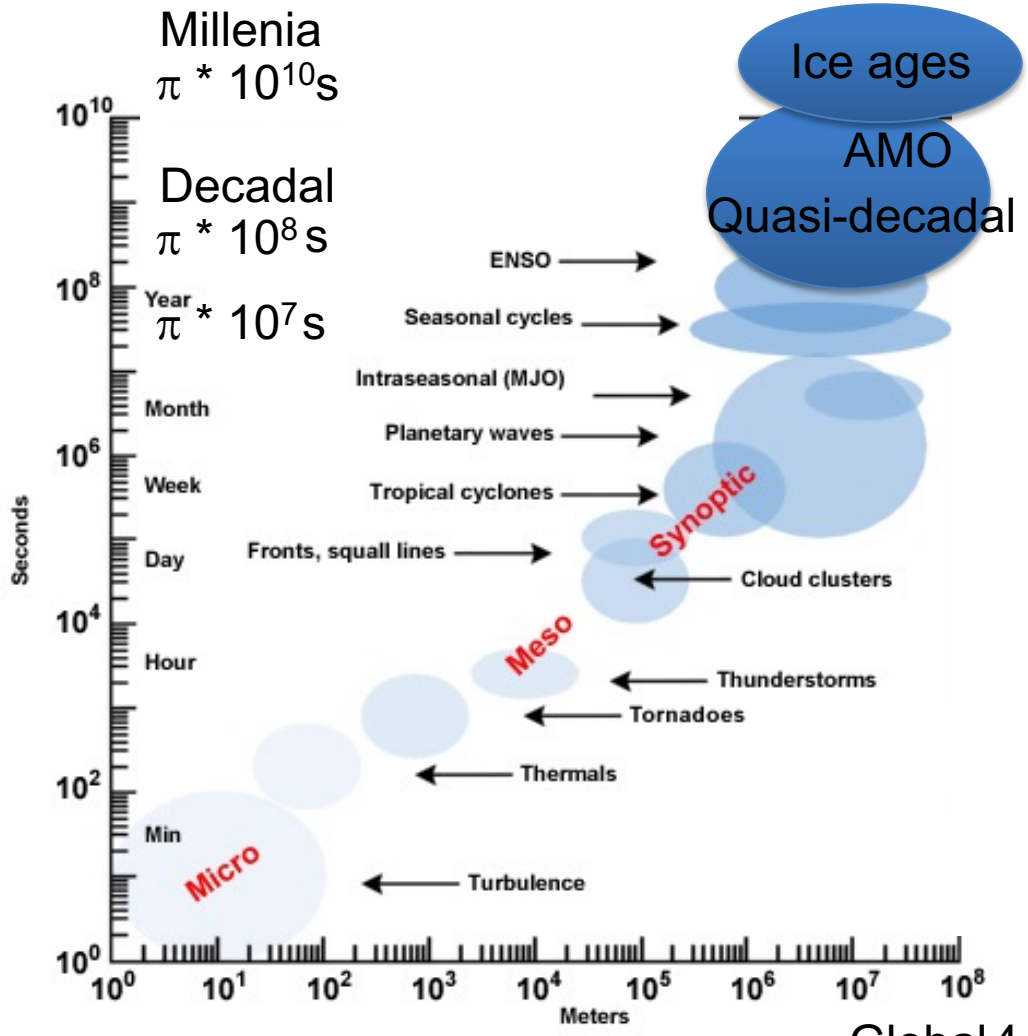


Quelle: Peixoto & Oort

Sunspots Photo: Nasa

Spatio-Temporal Scales

Dissipative Systems (as atmosphere & ocean) cannot maintain large gradients on long time scales



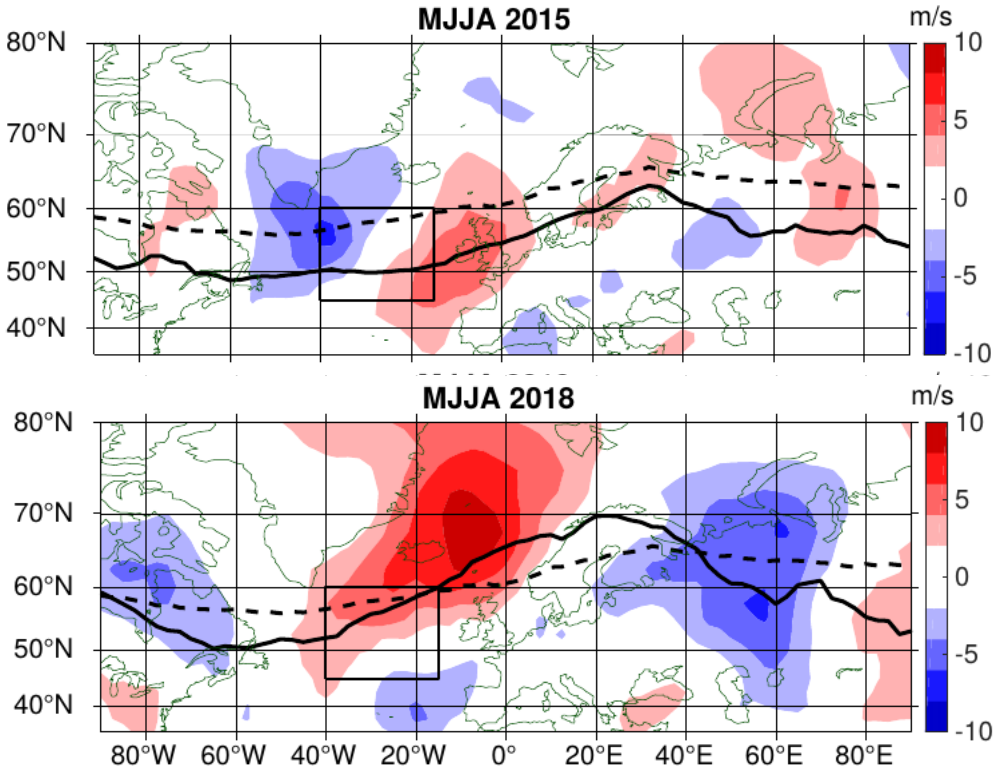
Spatial || temporal Scales

Global $4 * 10^7$

Drivers of Jet Stream Anomalies

North Atlantic SSTs influence the jet stream waviness over the Euro-Atlantic sector.
Shown by Duchez et al. 2016 for the 2015 summer heat wave.

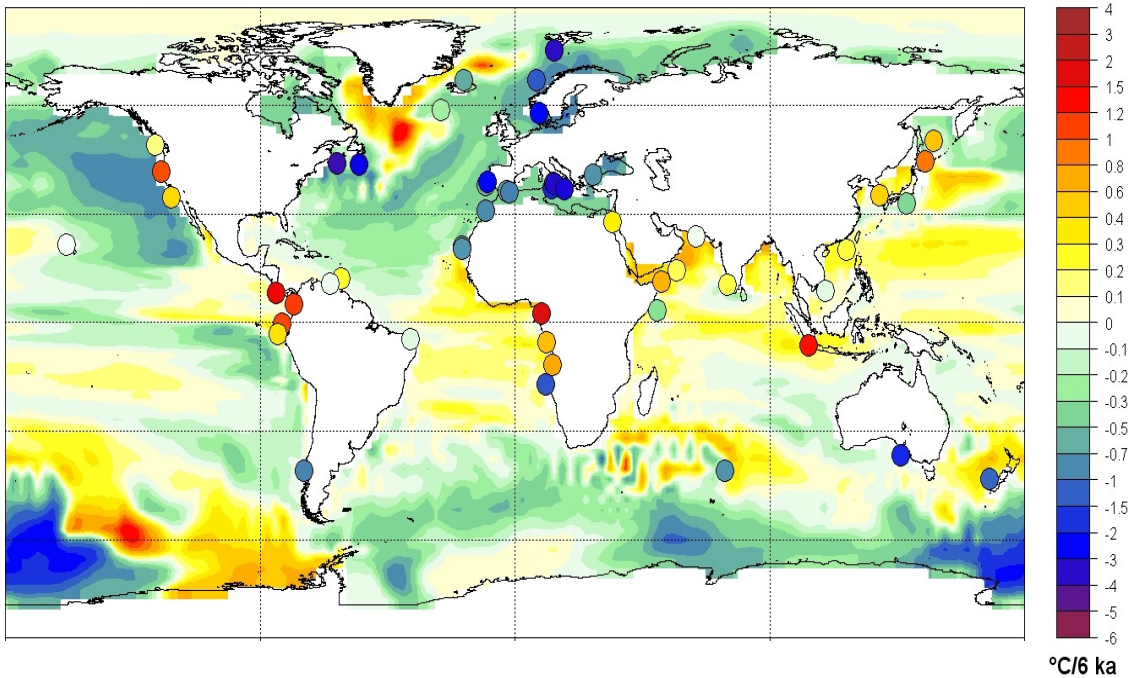
Summer meridional wind anomalies (shading) and mean jet stream position (contour)



Figures adapted from Krüger et al. 2020, WCD in review; GEOMAR

Marine temperature trends (last 6000 years)

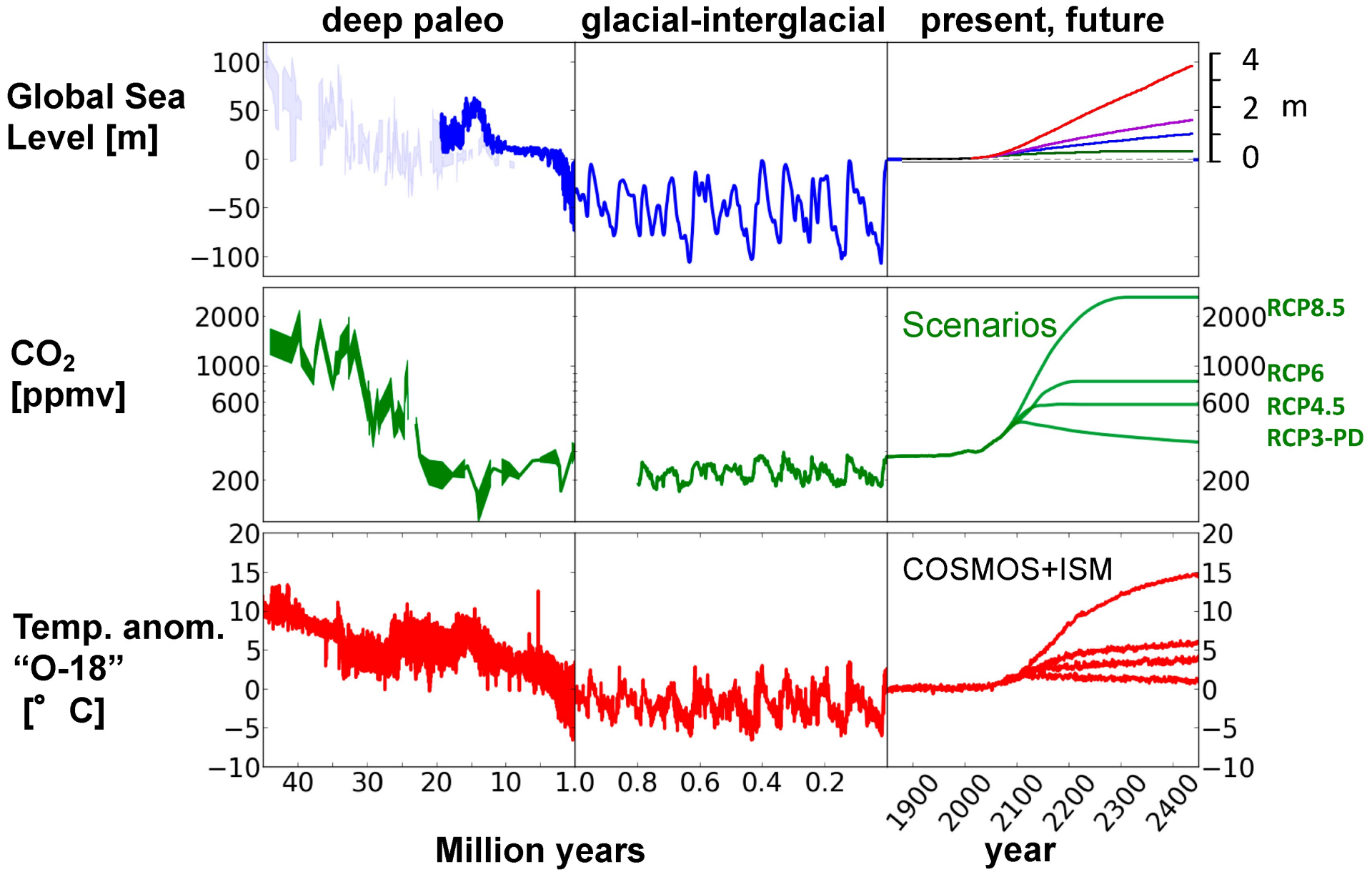
Annual mean sea surface temperature trends



Alkenone-based temperature trends

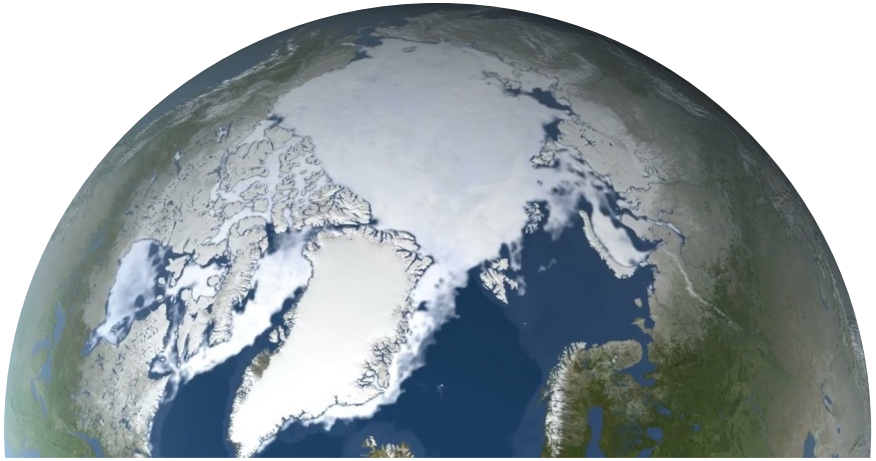
Lohmann et al., 2013, CP

Natural variability and perturbed climate

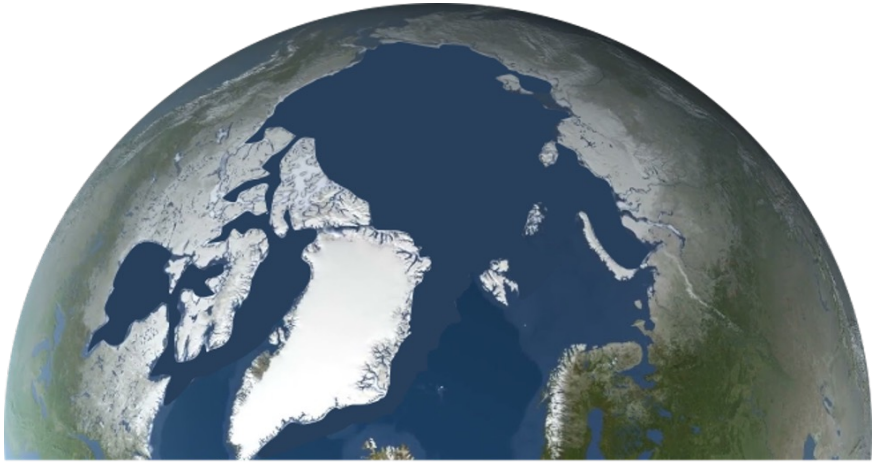


Into the Blue

TODAY



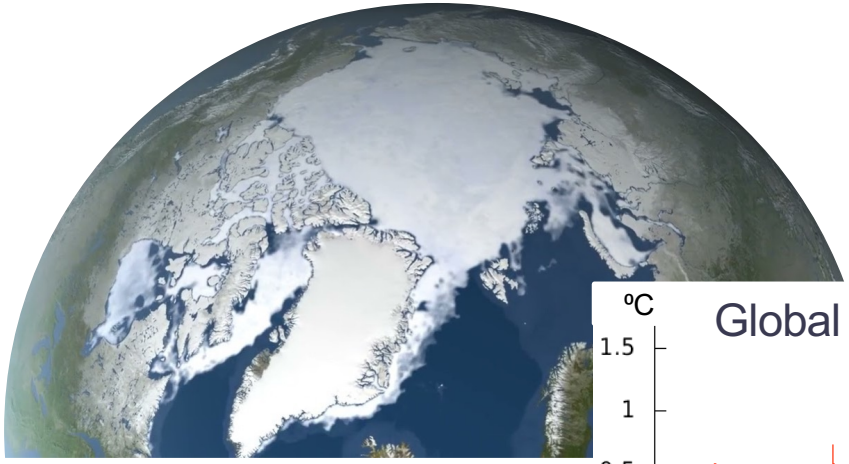
OUR FUTURE

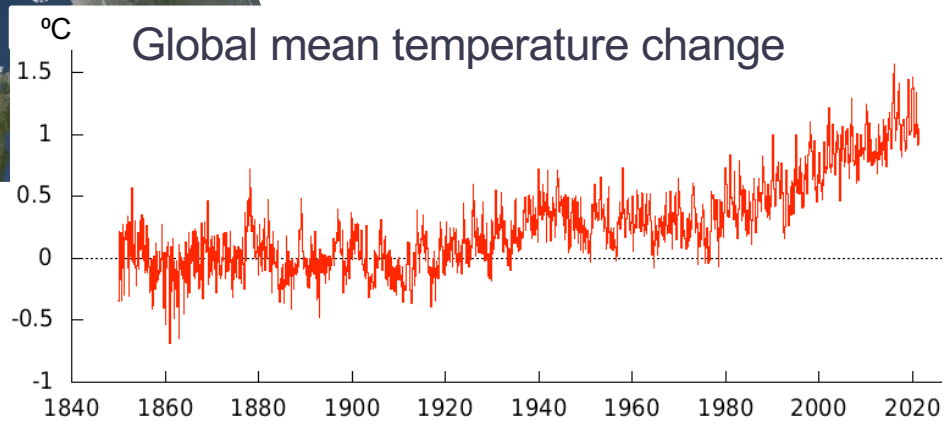


What will happen with our Arctic in a warmer world?

Why We Must Look Into The Past

TODAY





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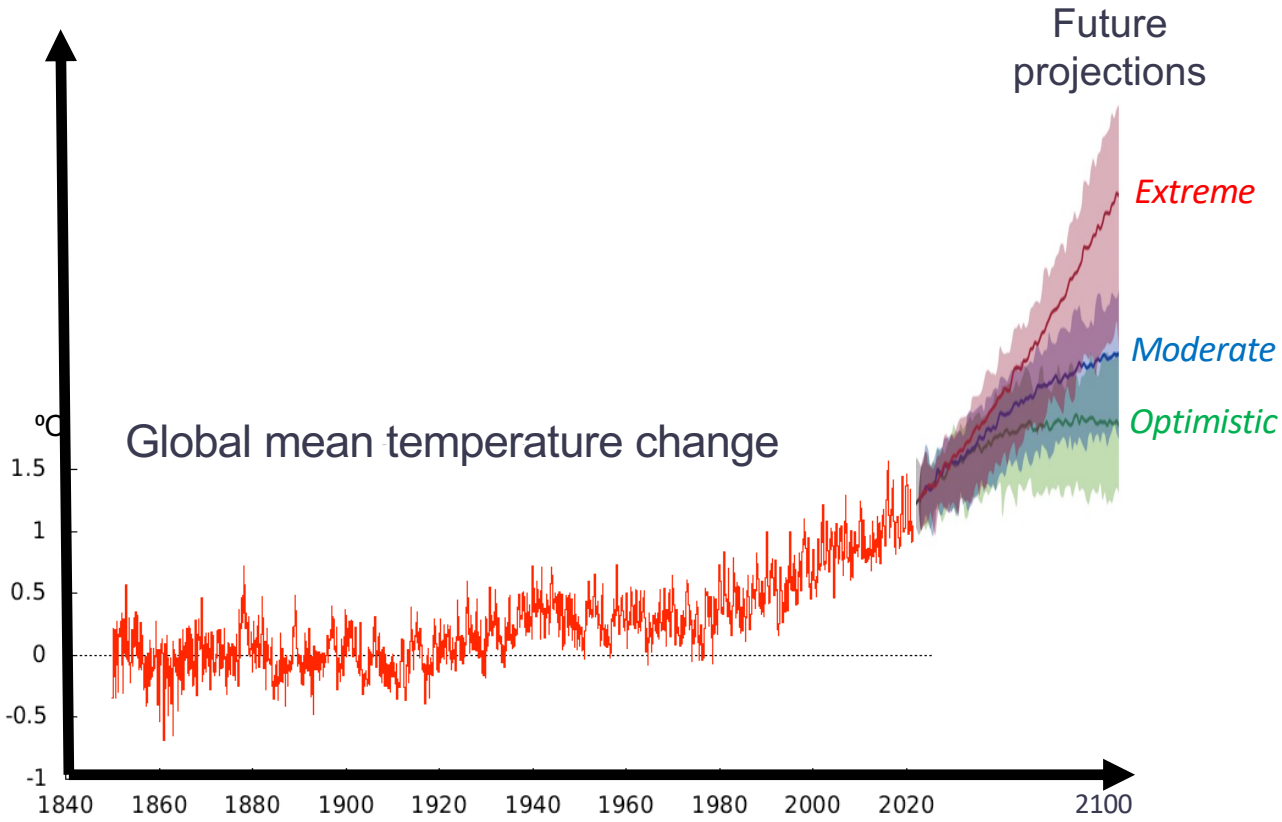


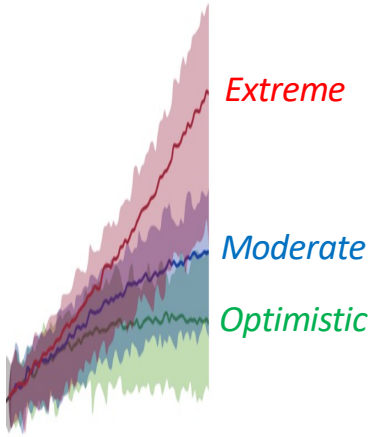
Why We Must Look Into The Past

Miocene
~17 million years

Pliocene
~3 million years

Interglacial
~130 000 years

Future projections



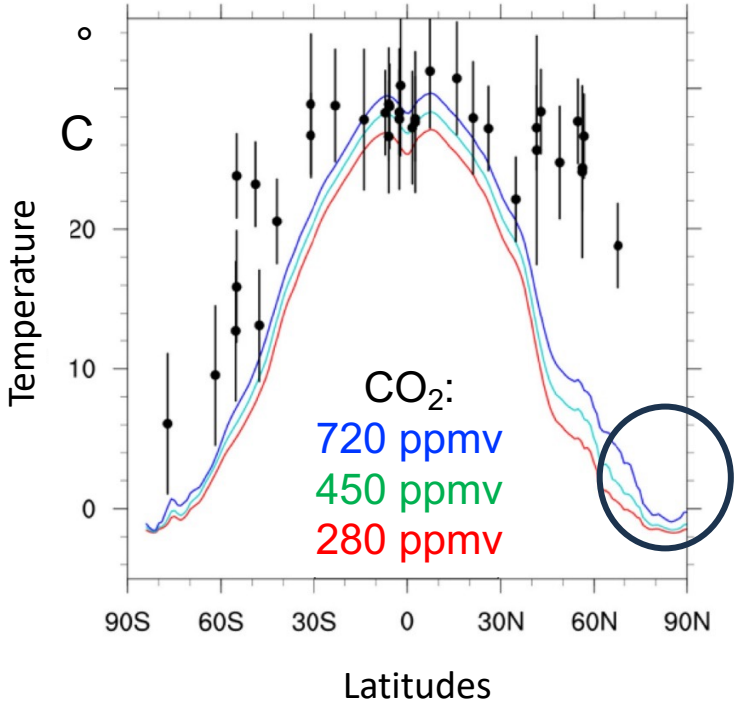
Lack of key Arctic archives

IODP ACEX Expedition, 2004

Lack of key Arctic archives

IODP ACEX Expedition, 2004

Lack of model skill



Hossain et al., 2023

Content

https://paleodyn.uni-bremen.de/study/climate2023_24.html

1) Oct 17 Challenges of climate change (GL)

Content: Intro and warming up, climate change, consequences

2) Oct 24 Global water cycle (MW)

Content: Water in the Earth system components, Oxygen Isotopes and ice cores, signature in ice cores, drilling ice cores

Oct 31: no lecture

3) Nov 7: Ice Ages and Astronomical theory (GL)

Content: Basics in astronomy (Keppler's laws), Orbital parameters, Dynamics of ice ages, Termination, Mid-Pleistocene transition

Overview articles by A. Berger, Labeyrie et al., Wally, GL, wikipedia

Here is Exercise 1 "Tropic of Cancer"

Exercise 2 "Earth orbital variations" Rmd file: Orbital_2020.Rmd, data file: ins_data.txt