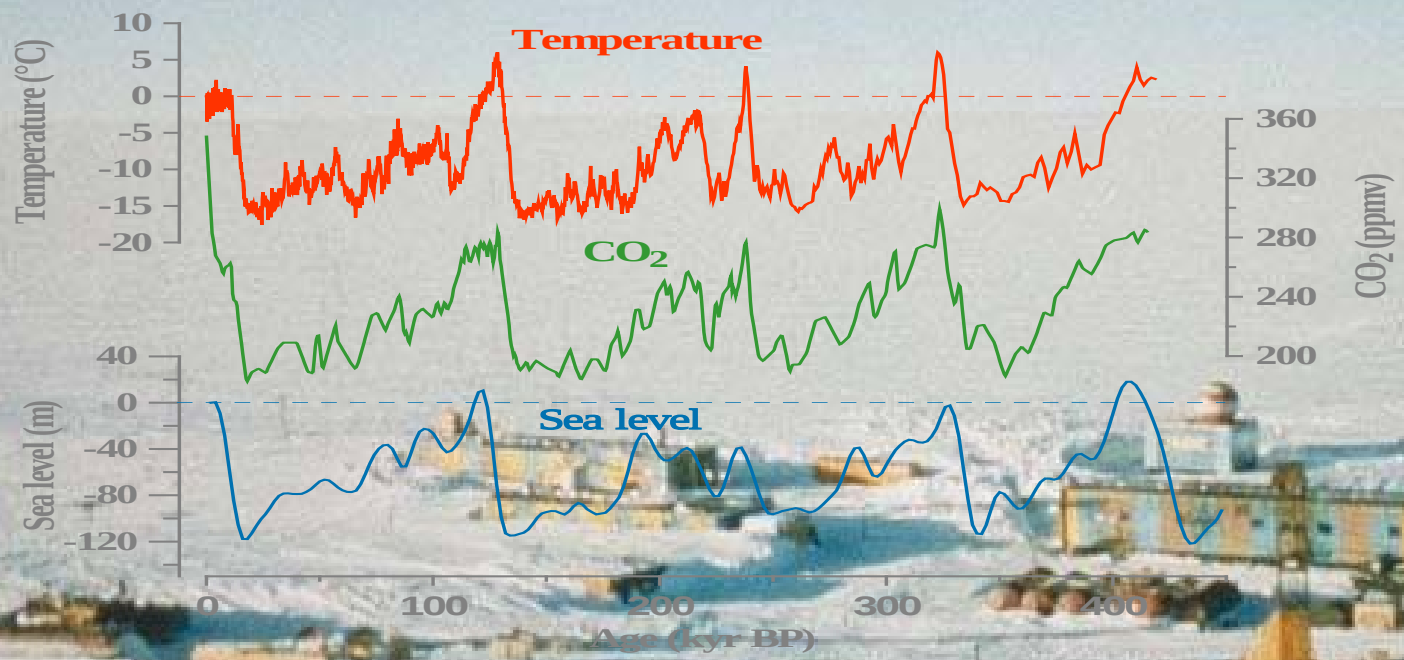
Past and future of Earth's climate as revealed by deep ice drilling in Antarctica

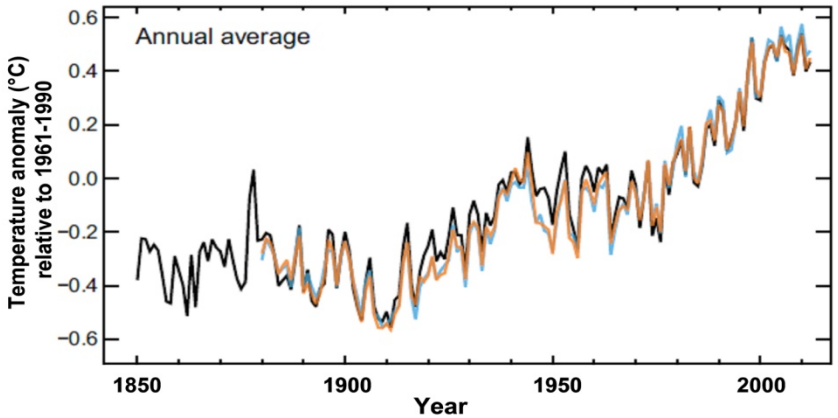


Vladimir Lipenkov

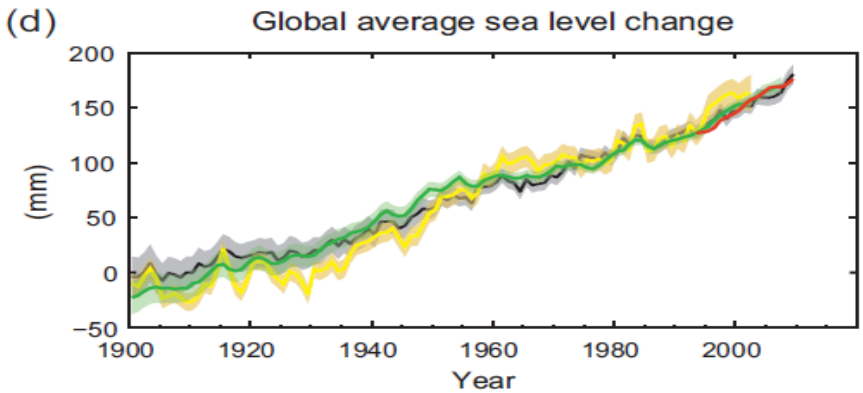
Arctic and Antarctic Research Institute of Roshydromet

St. Petersburg, Russia

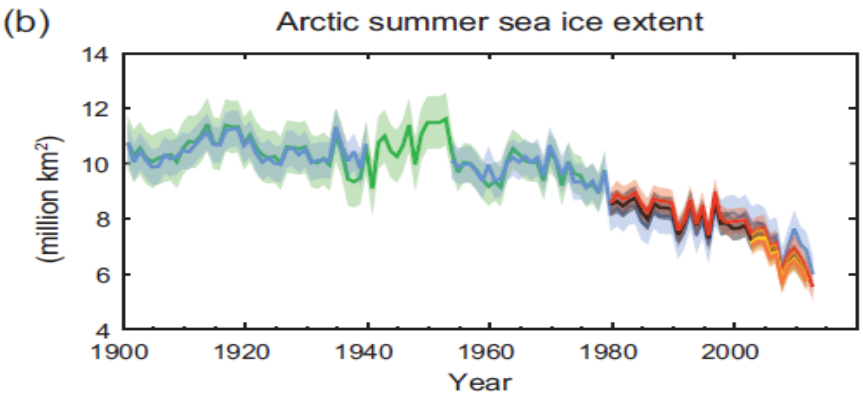
Recent changes in



temperature,



sea level,



Arctic summer sea ice extent

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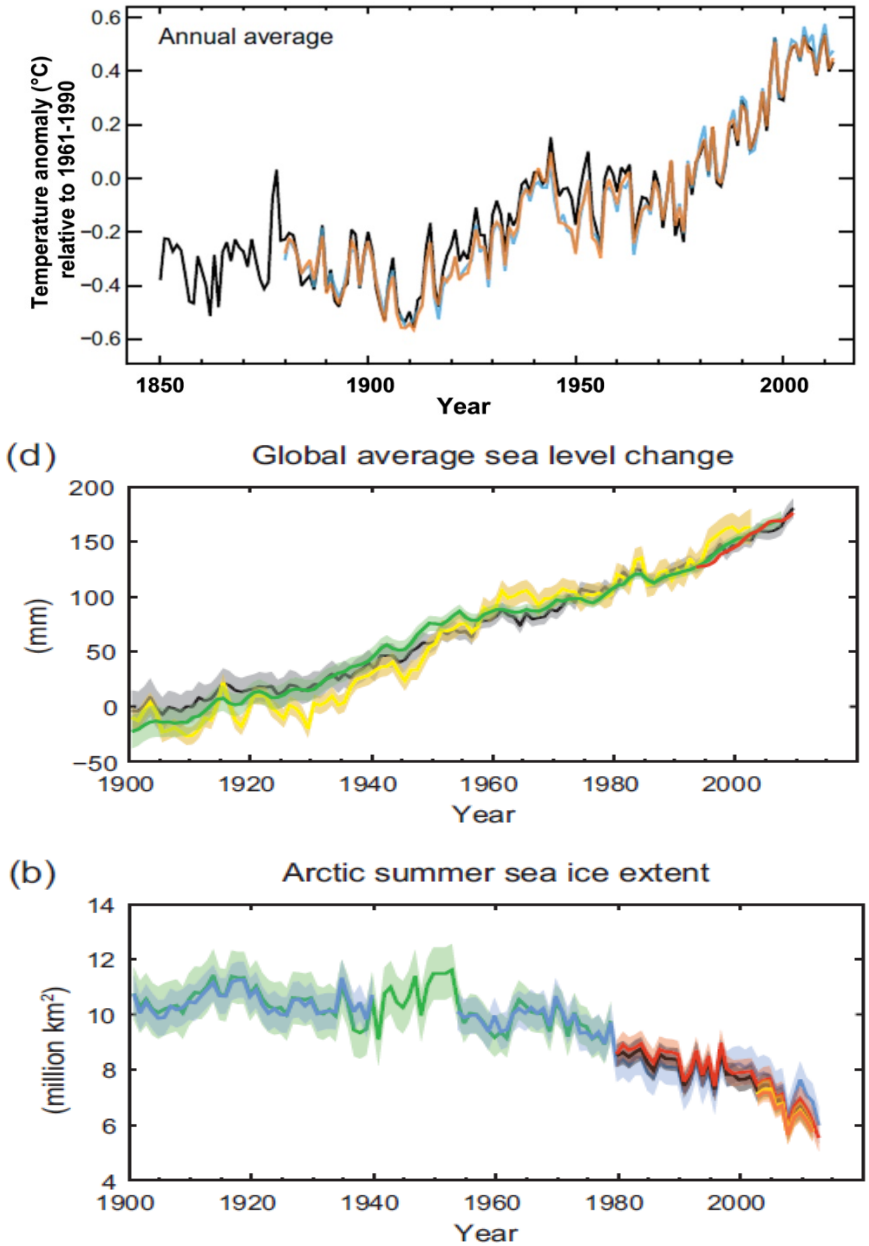
IPCC, 2014: Summary for Policymakers…



IPCC, 2014: Summary for Policymakers…

Questions to be answered:

1. How do the modern trends and rates of changes compare to their natural counterparts?

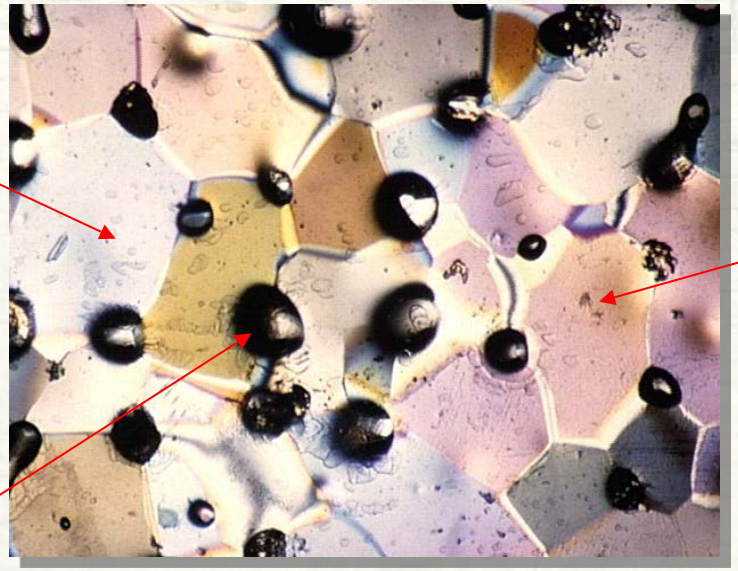
2. What is driving modern trends relative to the past?

3. What are the implications for the future?

Why drill into ‘Big Ice’?

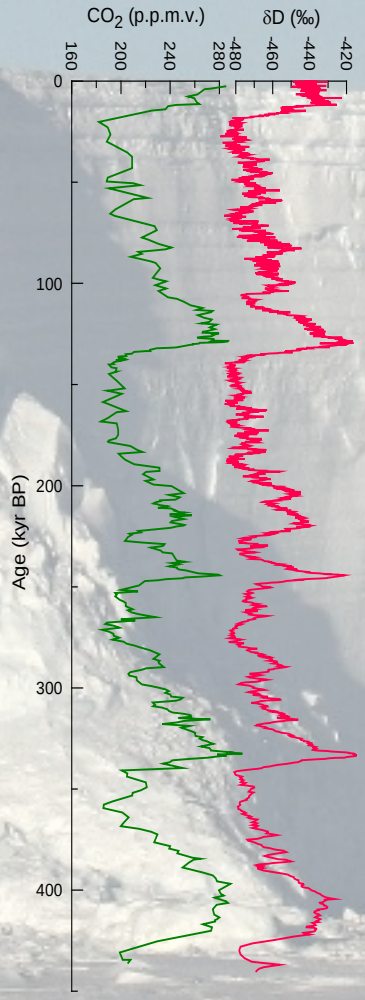
Water
H_2O
$H_2{}^{18}O$
HDO

Air
CO_2
CH_4
$\delta^{15}N$
$\delta^{40}Ar$
$\delta^{18}O$…

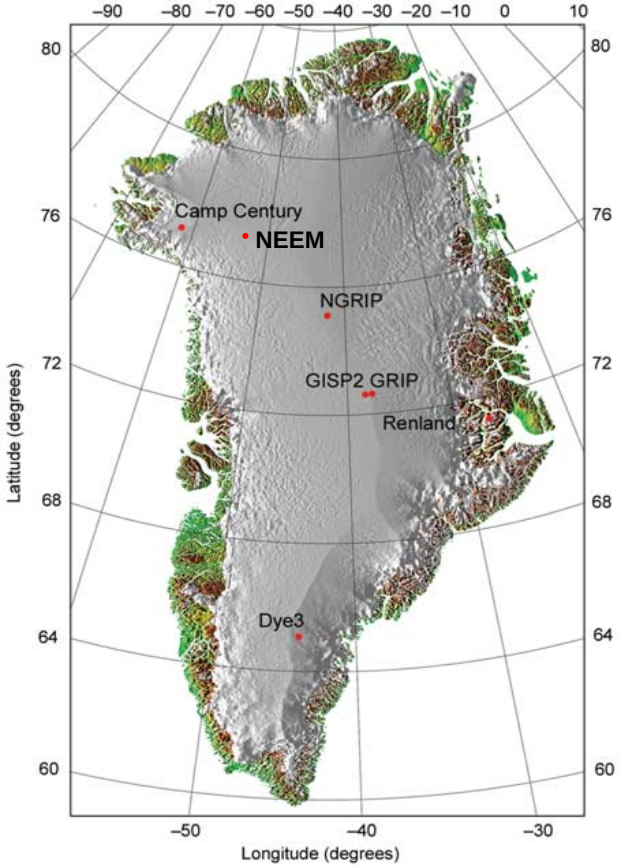


Thin section of ice under polarized light

Impurities:
dust,
sea salt,
^{10}Be
pollution,
volcanism
…



National and international ice drilling projects in Antarctica and Greenland



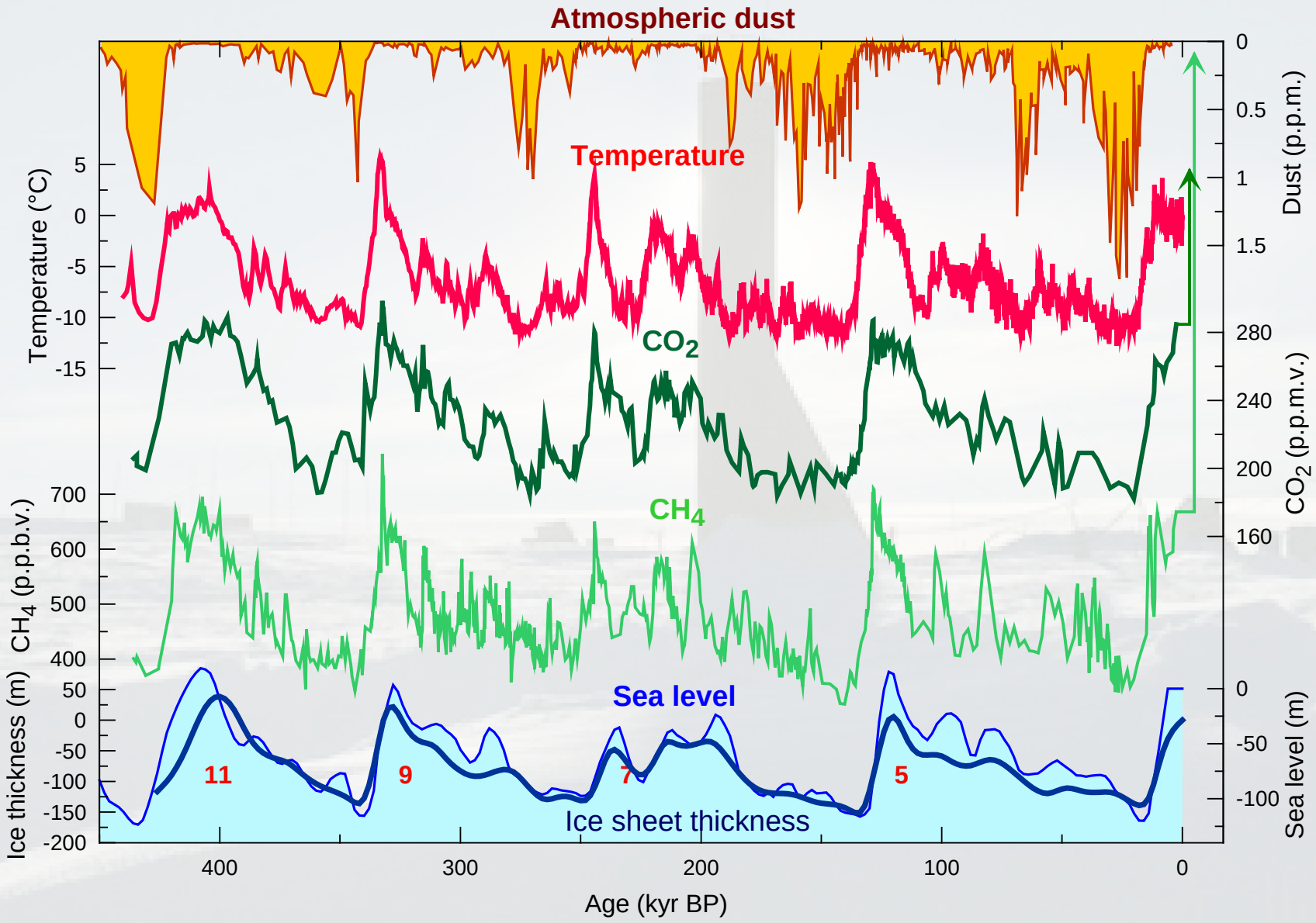
The Vostok Venture

Since 1970:

- the deepest borehole (3770 m)
- climate record: 440,000 years
- first unsealing of Lake Vostok
- the oldest ice (>1.2 Ma) ever recovered from EAIS

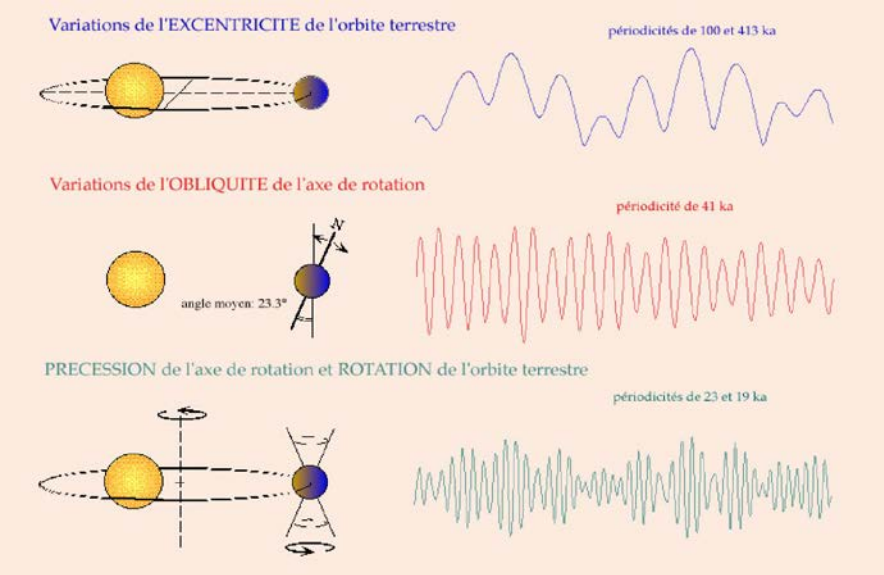
Russian-French-US collaboration at Vostok, 1989-1998

Vostok - “cornucopia of paleoclimatic data”



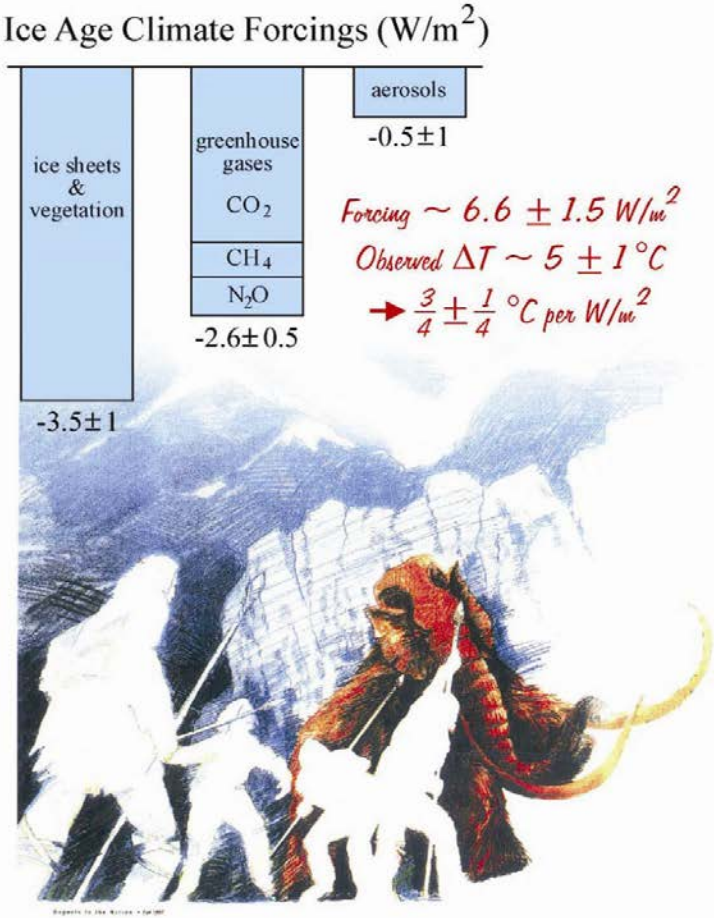
What was driving climate change during glacial-interglacial cycles?

A pacemaker: astronomical forcing



+ A set of strong amplifiers

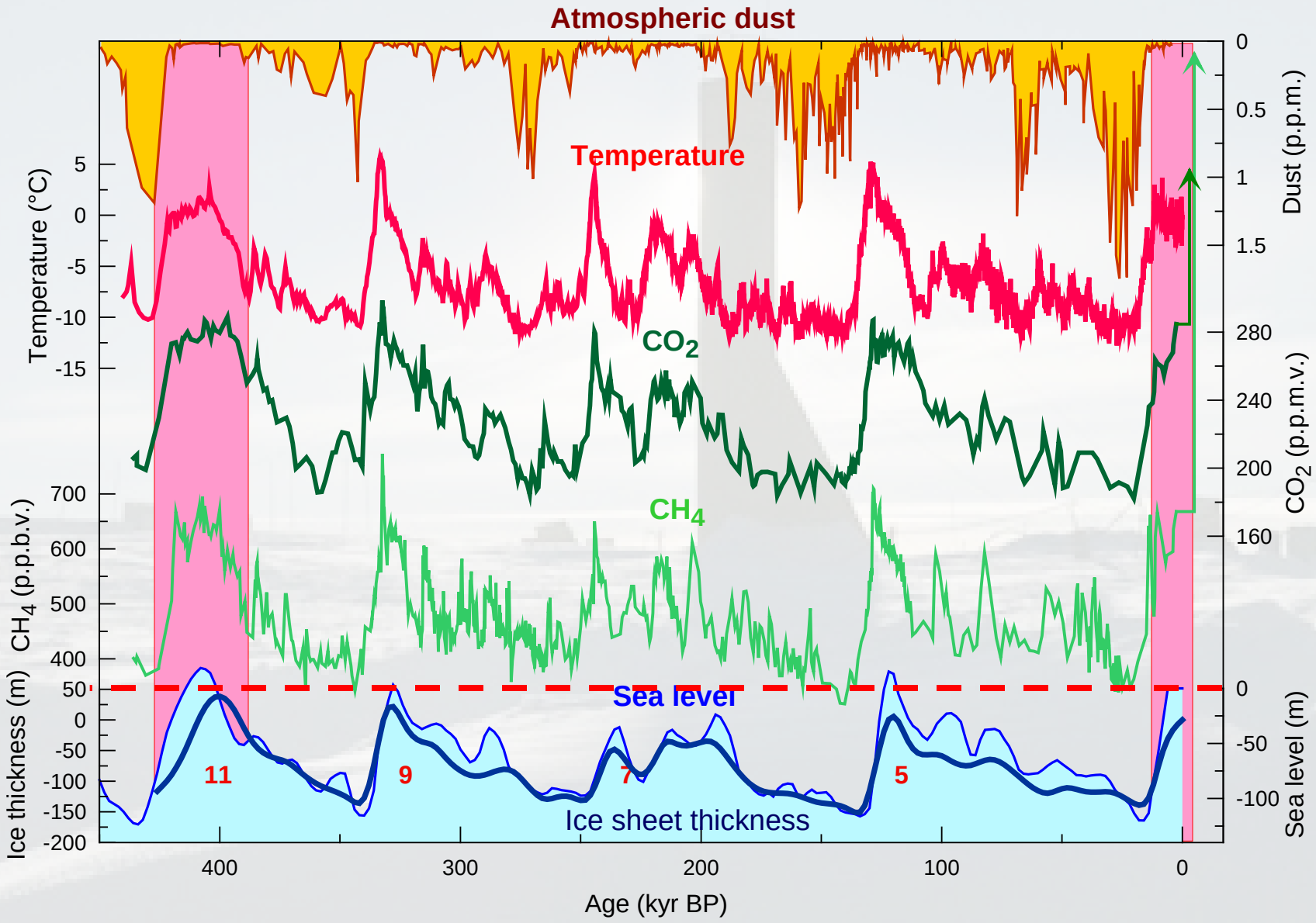
Ice Age Forcings Imply Global Climate Sensitivity ~ ¾°C per W/m².



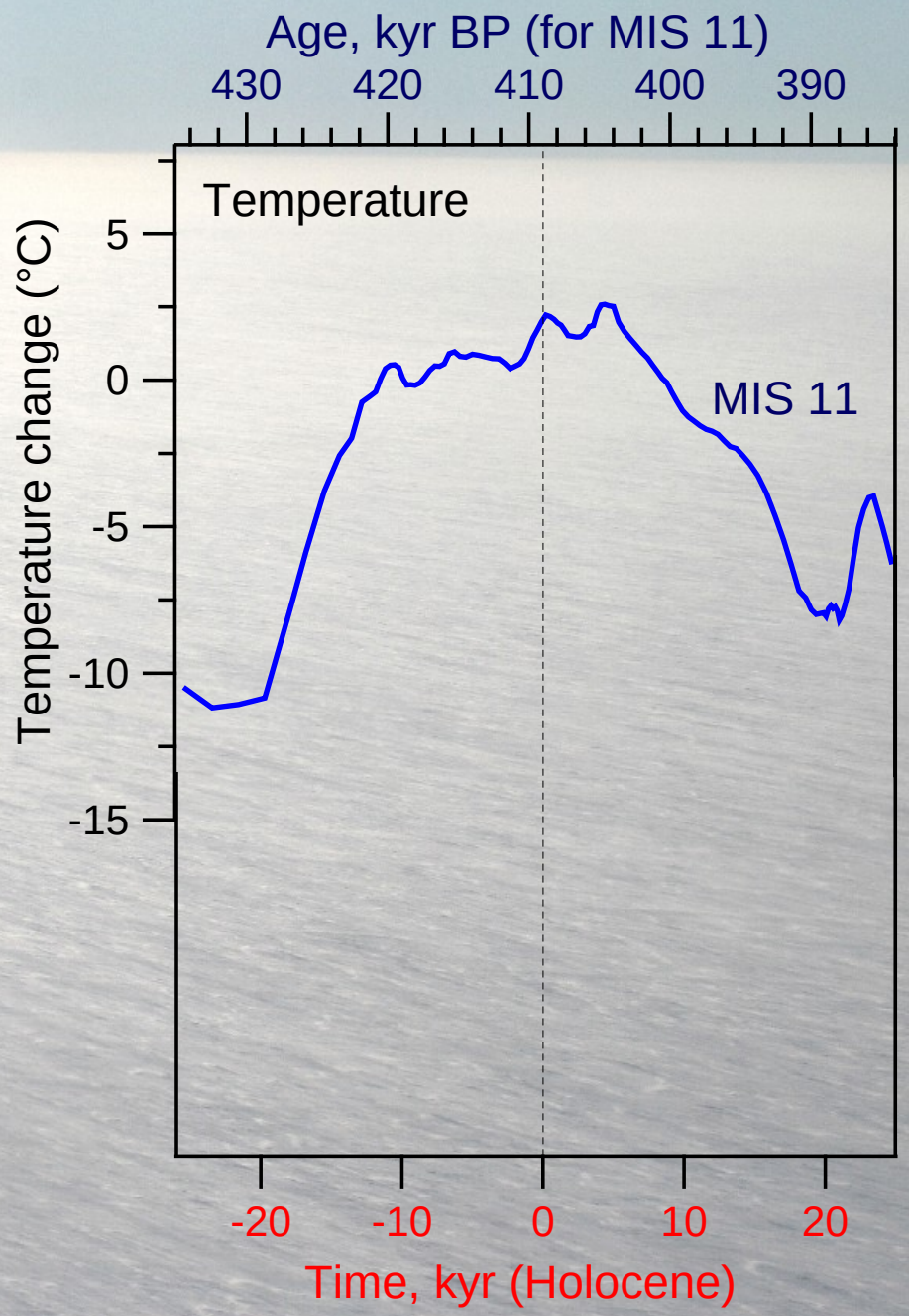
Source: Hansen et al., *Natl. Geogr. Res. & Explor.*, **9**, 141, 1993.

GG=40% of the G/I climate forcing

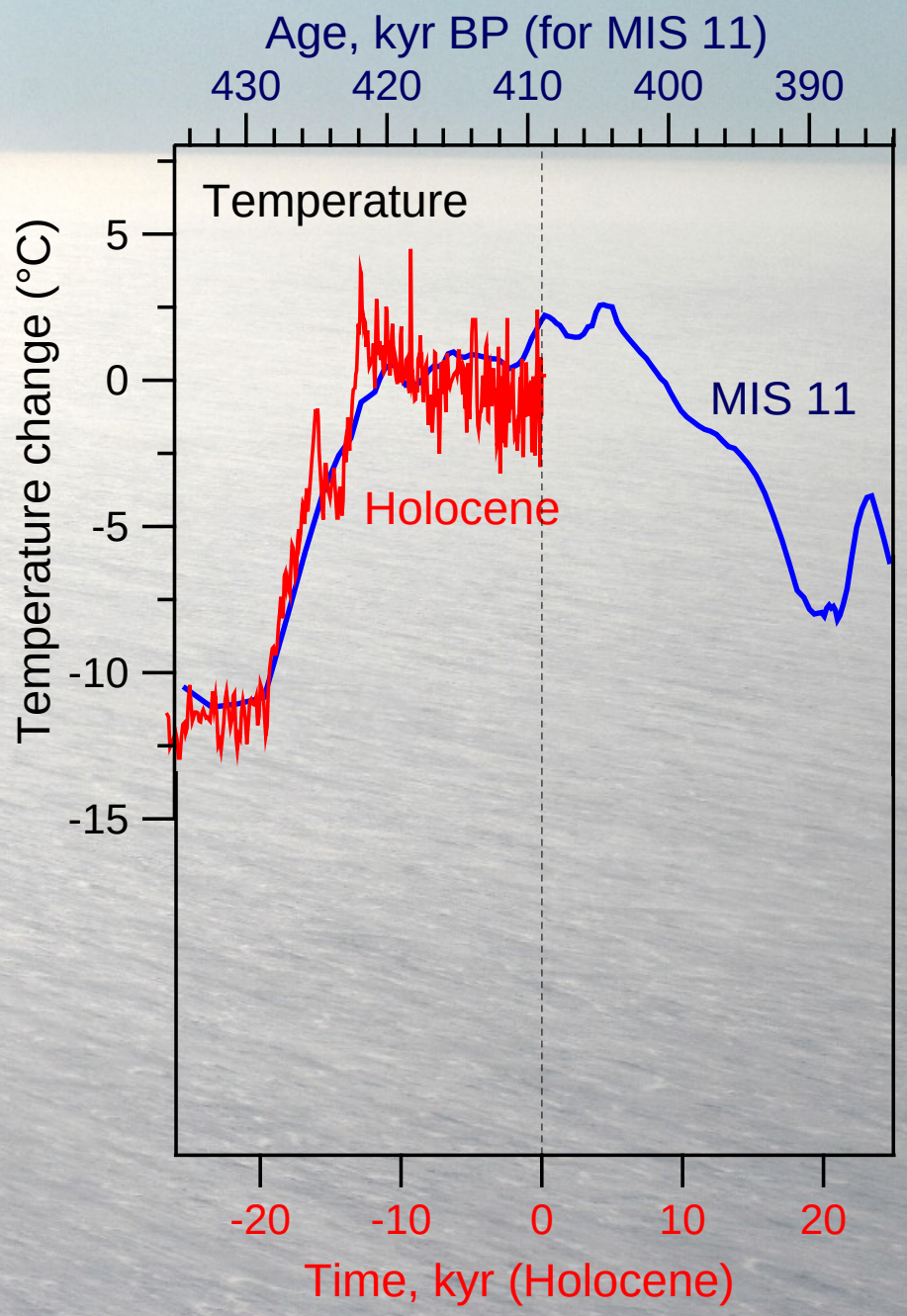
Vostok ice-core records and sea level



MIS 11 scenario for future global changes

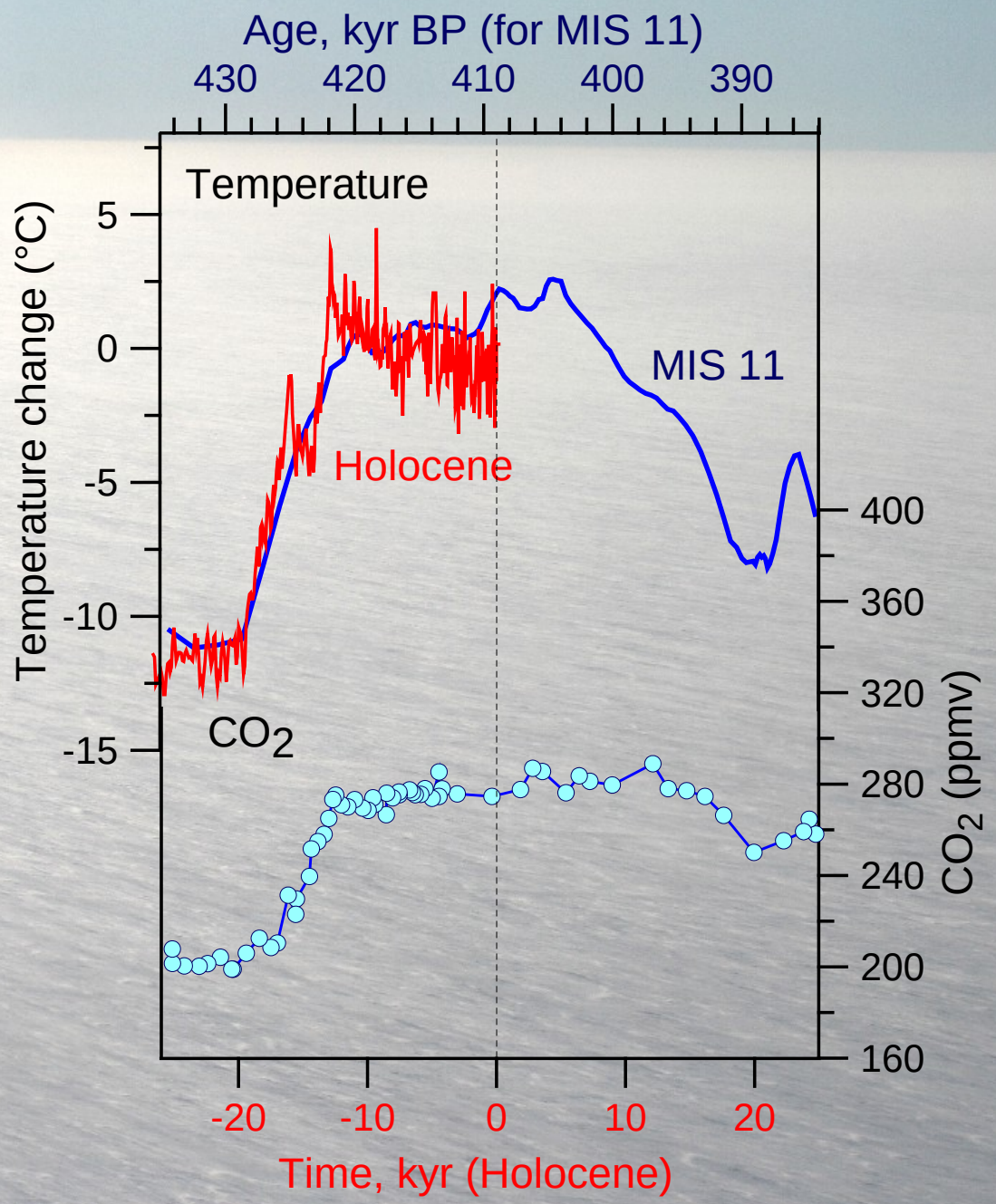


MIS 11 scenario for future global changes



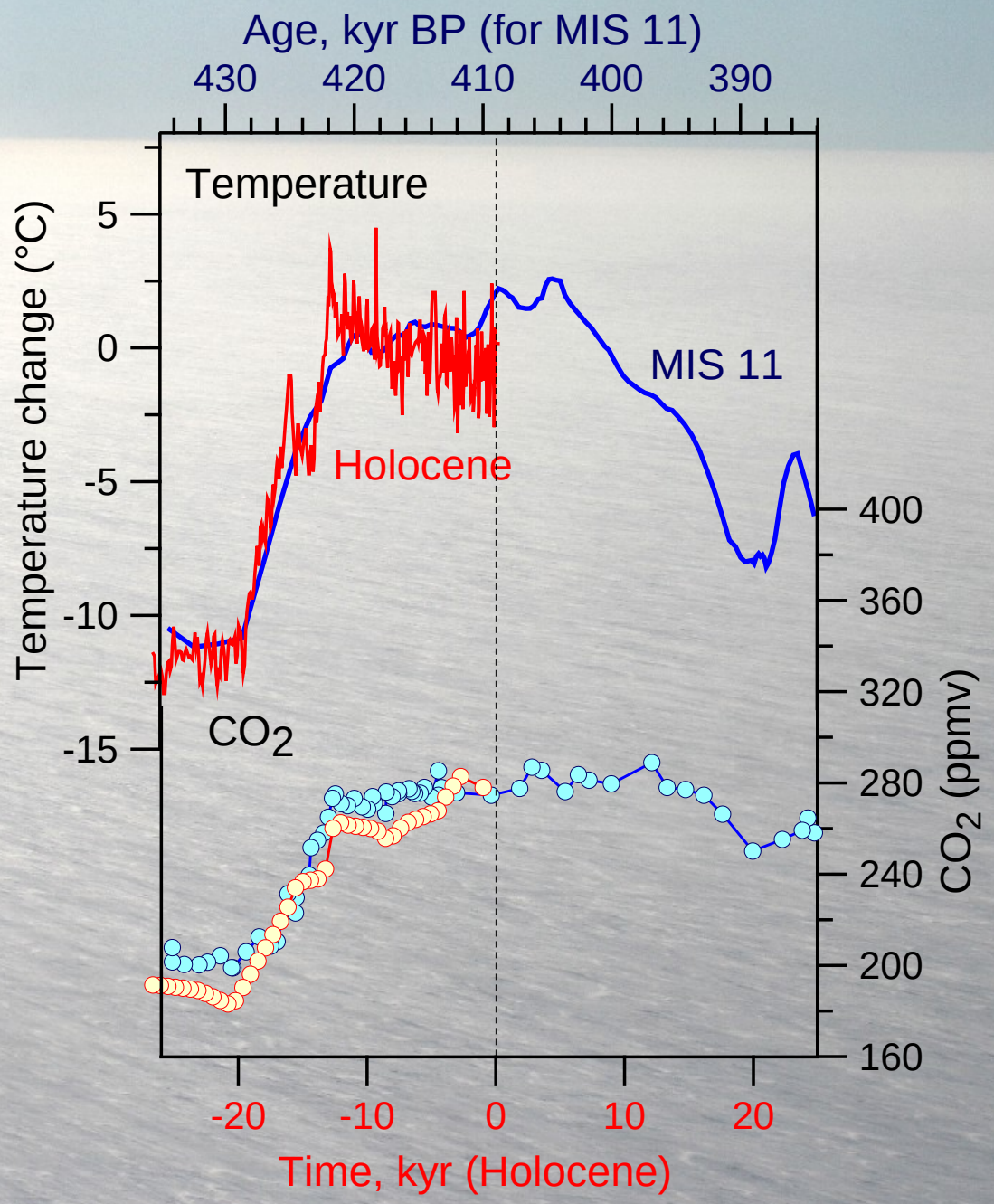
MIS 11 scenario for future global changes

The CO2 concentrations throughout MIS 11 were not especially high – they were lower than e.g. during MIS 9 (340 ka BP)



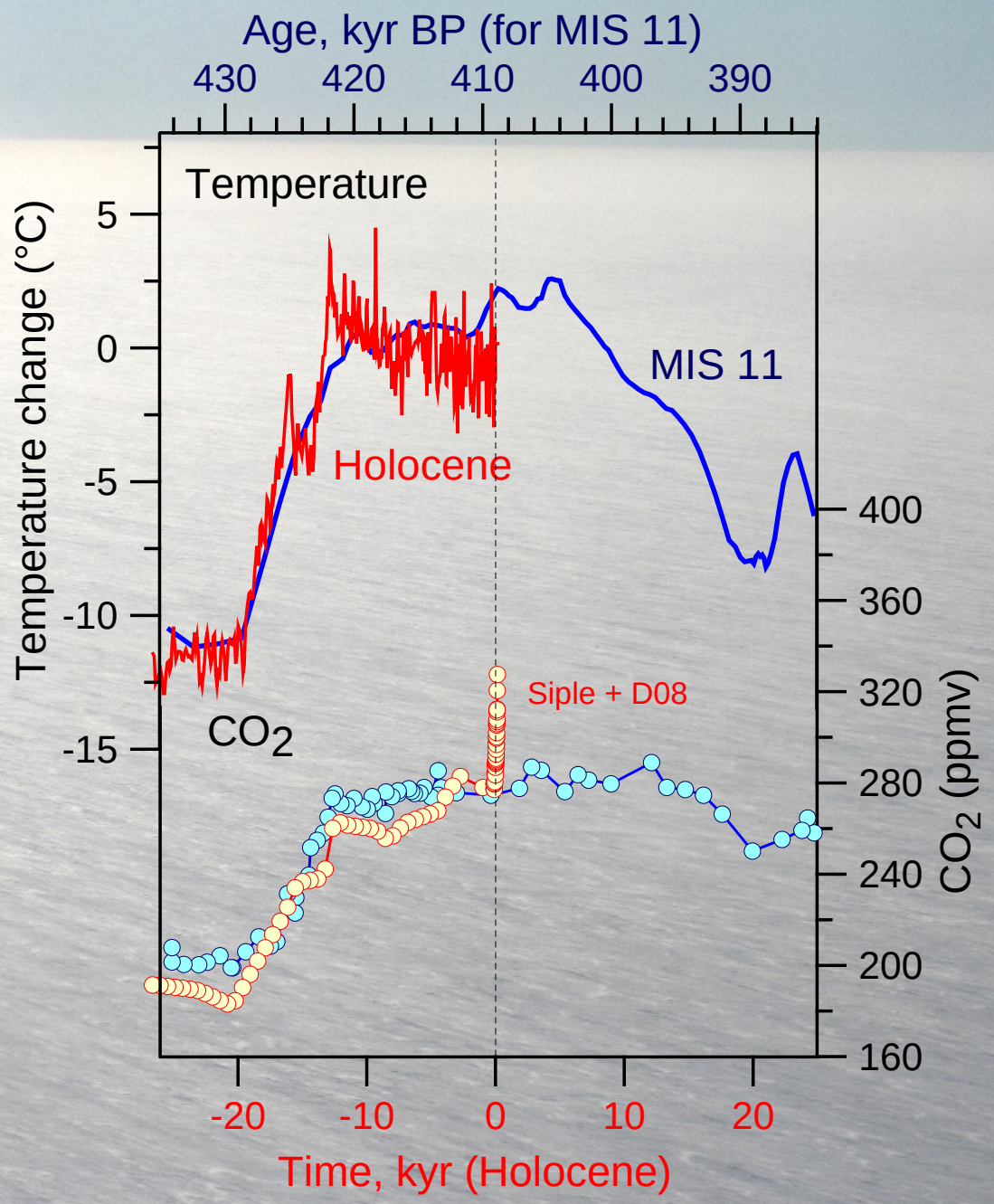
MIS 11 scenario for future global changes

Antarctic ice tells us that MIS 11 has been similar to the current interglacial, and that without the anthropogenic impact on the climate we would probably have another 16,000 years of ‘mild’ climate before the next ice age would come.



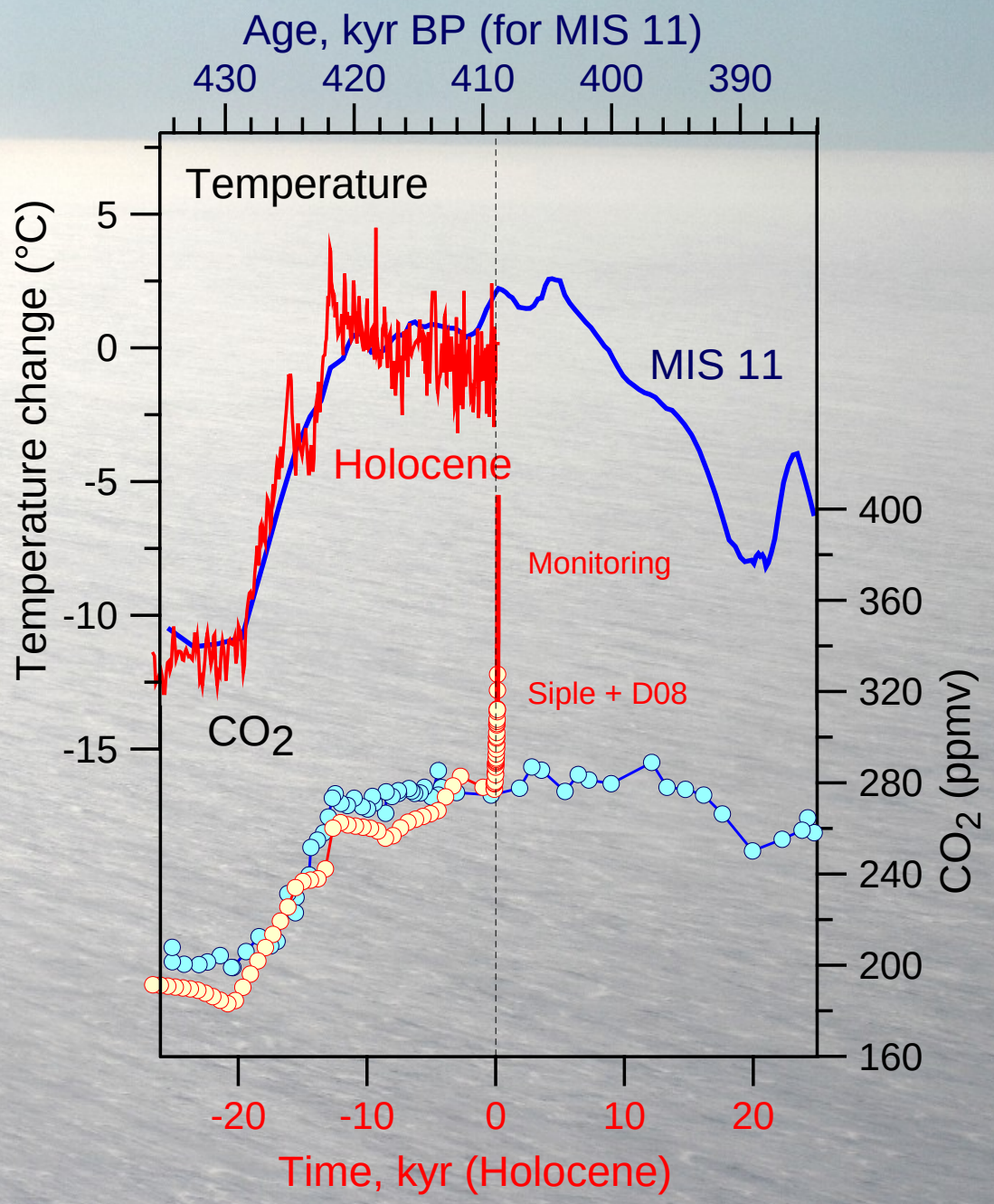
MIS 11 scenario for future global changes

But will it really come?



MIS 11 scenario for future global changes

Today's atmospheric concentration of carbon dioxide (415 ppm in 2019) exceeds by far the natural range over the last 440,000 years (180-300 ppm) as revealed by the Vostok ice core, and has likely been unprecedented over the past few million years.



Implications for the future: What we can learn from the past

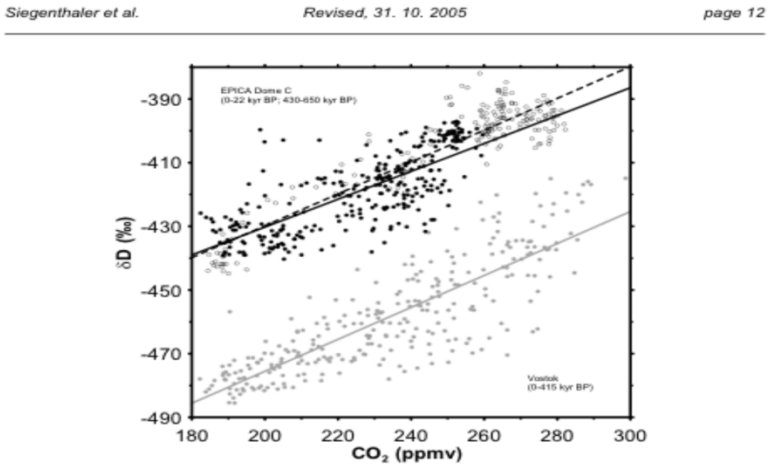


Fig. 3. Correlation between δD, a proxy for Antarctic temperature, and CO_2 for three data sets. The new data from Dome C covers the beginning of MIS 12 to MIS 16 (black dots; black line: linear fit $\delta D = 0.44\ ‰ppmv^{-1} \times CO_2 - 517.80‰$, $r^2 = 0.57$), and the period from MIS 1 to MIS 11 is covered by data from the Vostok ice core (gray dots (*7*); gray line: linear fit, $\delta D = 0.50\ ‰ppmv^{-1} \times CO_2 - 575.86‰$, $r^2 = 0.70$) and Dome C Holocene and termination I (black circles (*9*, *11*); black dashed line: linear fit, $\delta D = 0.50‰ppmv^{-1} \times CO_2 - 529.87‰$, $r^2 = 0.84$). The offset in the δD values from these two cores is due to the different distance to the open ocean, elevation and surface temperature of the two sites (*29*).

Siegenthaler et al., Science, 2006

The proportionality between CO_2 and temperature remains the same under different climates

1) Because the main forcing on a timescale of thousands of years will not vary significantly, greenhouse gases (GG) will have an even stronger influence

2) We are making exceptional changes to the GG atmospheric composition by creating the highest GG level for the last several million years

3) Human-caused GG changes would be slow to reverse in the future

Thank you!