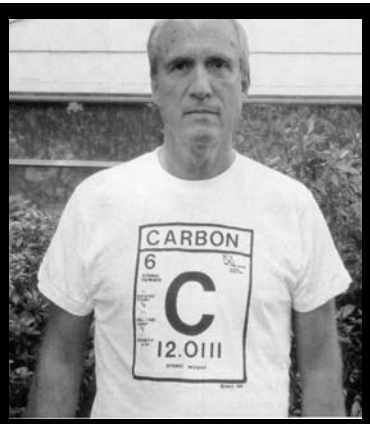
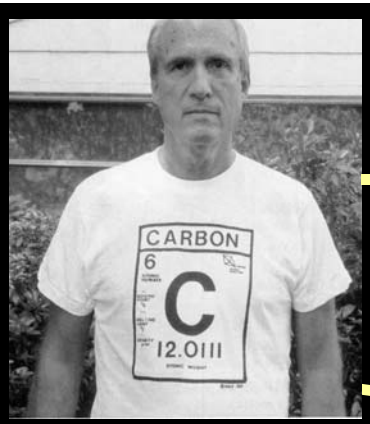

CARBON
6
C
12.0111

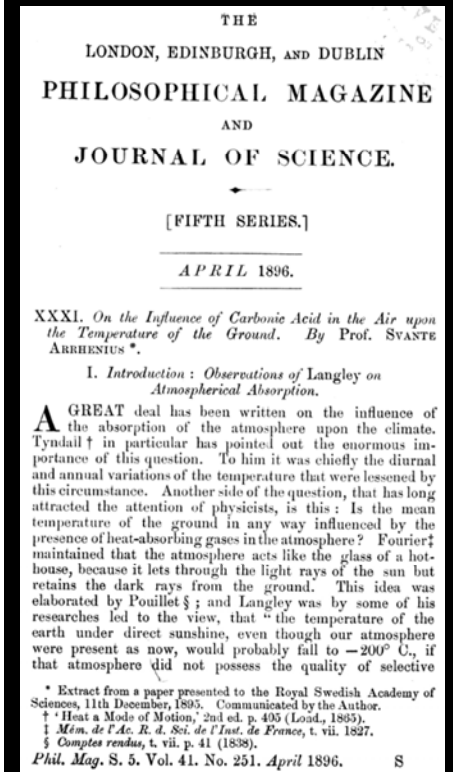

CARBON
6
C
12.0111

Climate sensitivity

-In a bell jar: ~1.2 ^{o}C per CO_2 doubling

-In the Earth system: ~3 ^{o}C per CO_2 doubling

Arrhenius (1896):
2.0-5.5 ^{o}C



THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

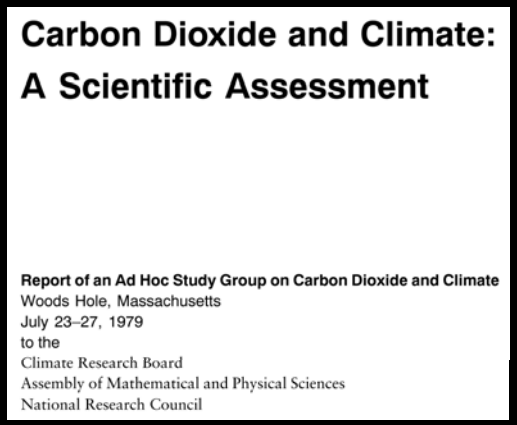
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

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

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Load., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. vii. p. 41 (1838).

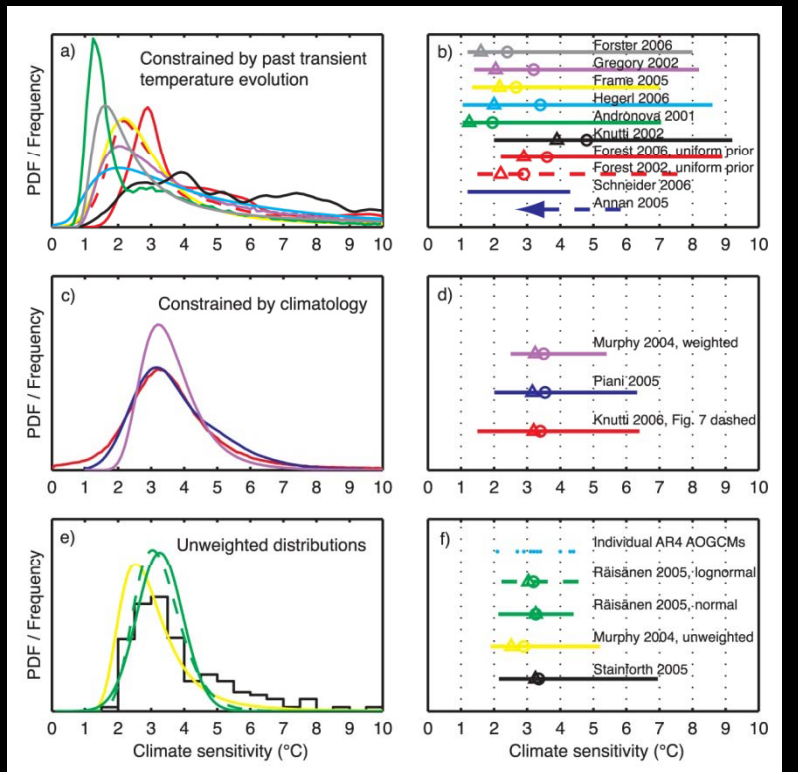
Charney (1979):
1.5-4.5 ^{o}C



Carbon Dioxide and Climate:
A Scientific Assessment

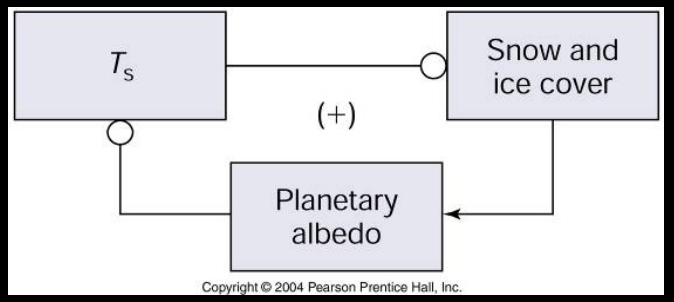
Report of an Ad Hoc Study Group on Carbon Dioxide and Climate
Woods Hole, Massachusetts
July 23–27, 1979
to the
Climate Research Board
Assembly of Mathematical and Physical Sciences
National Research Council

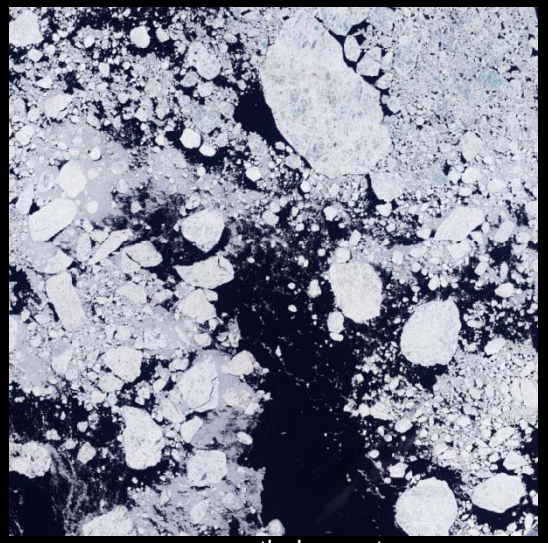
IPCC (2007):
2.0-4.5 ^{o}C



Climate sensitivity

Factors included (IPCC):
- -water vapor
- -sea ice
- -cloud
- -aerosols





earthobservatory.nasa.gov

Factors NOT included:
- -continental ice sheets
- -changing vegetation cover
- -variable mixing ratios of other trace greenhouse gases (CH_4, N_2O)

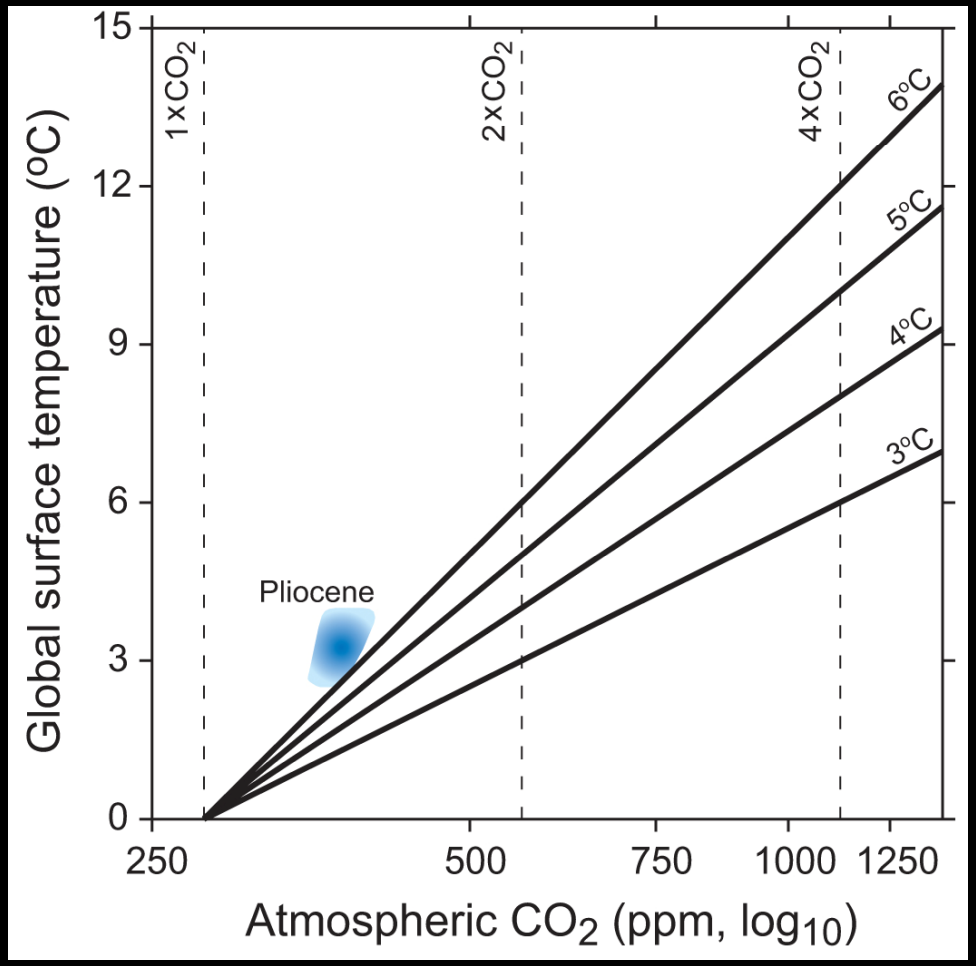
Earth system sensitivity (ESS)

Long-term (>10^3 yrs), Earth-system response in global temperature to a CO_2 doubling

Why ESS is valuable:
-Understanding geologic past
-Understanding present-day climate change (because ESS captures the ultimate equilibrium temperature response)

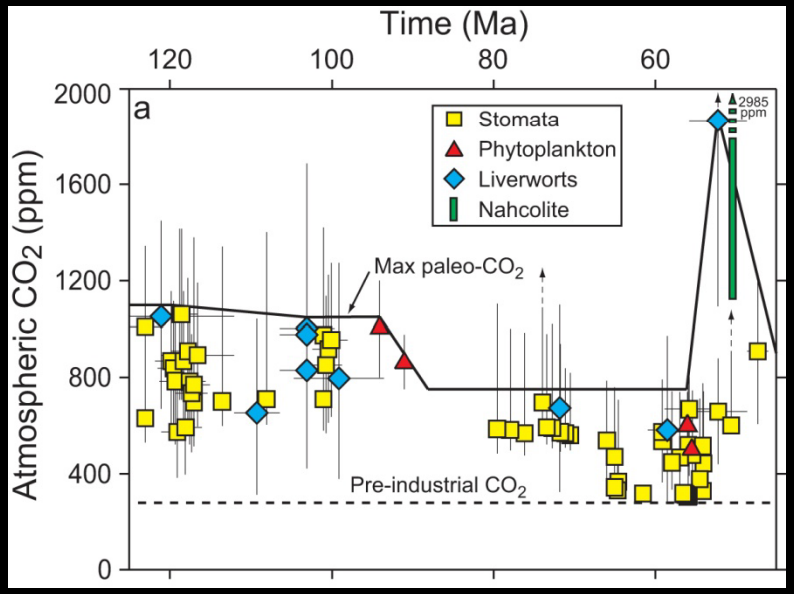
CRITICAL CAVEAT: may take 1000s of years to reach equilibrium. Does this matter? Probably depends on the person…

ESS during Pliocene (4.5-3.0 Myrs ago)



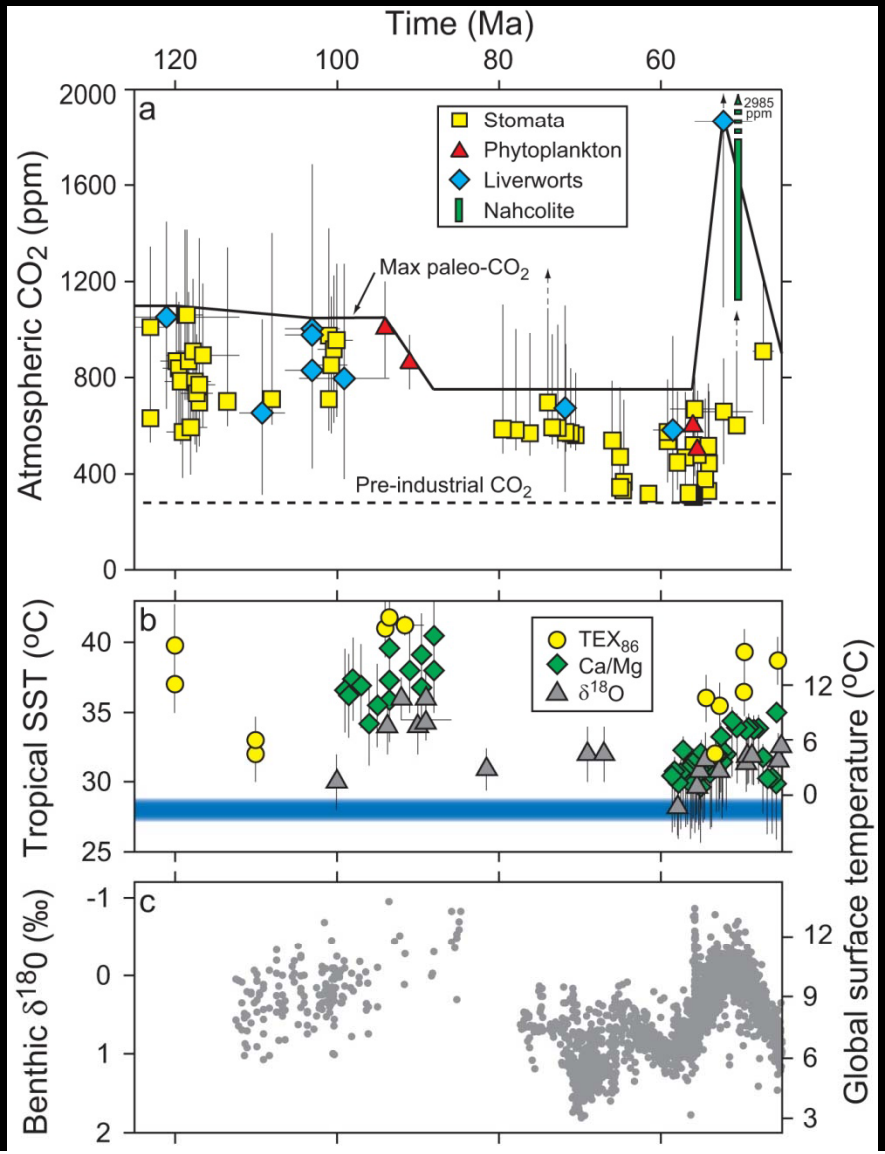
Data from Pagani et al. (2009, *Nature Geoscience* 3: 27-30)

ESS during the Cretaceous and early Paleogene (125-45 Myrs ago)



Royer, Pagani & Beerling (in prep)

ESS during the Cretaceous and early Paleogene (125-45 Myrs ago)



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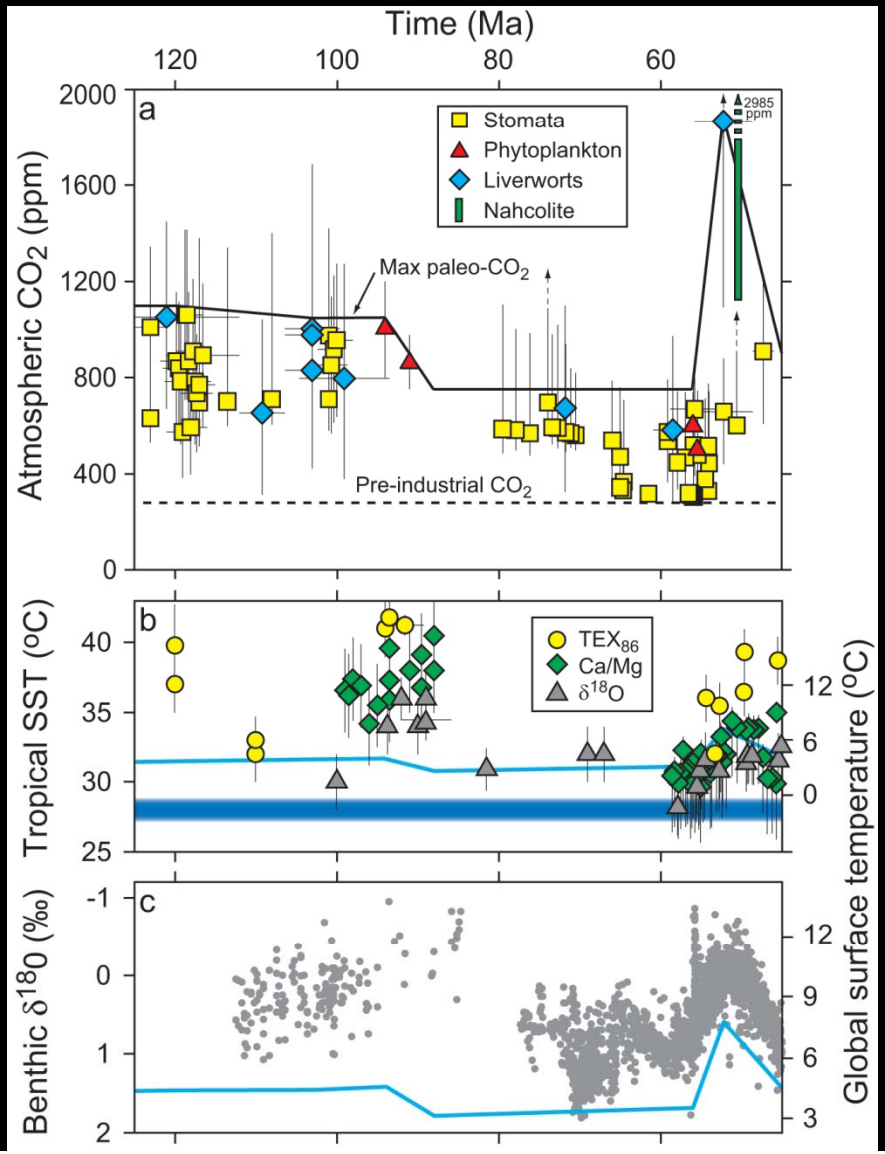

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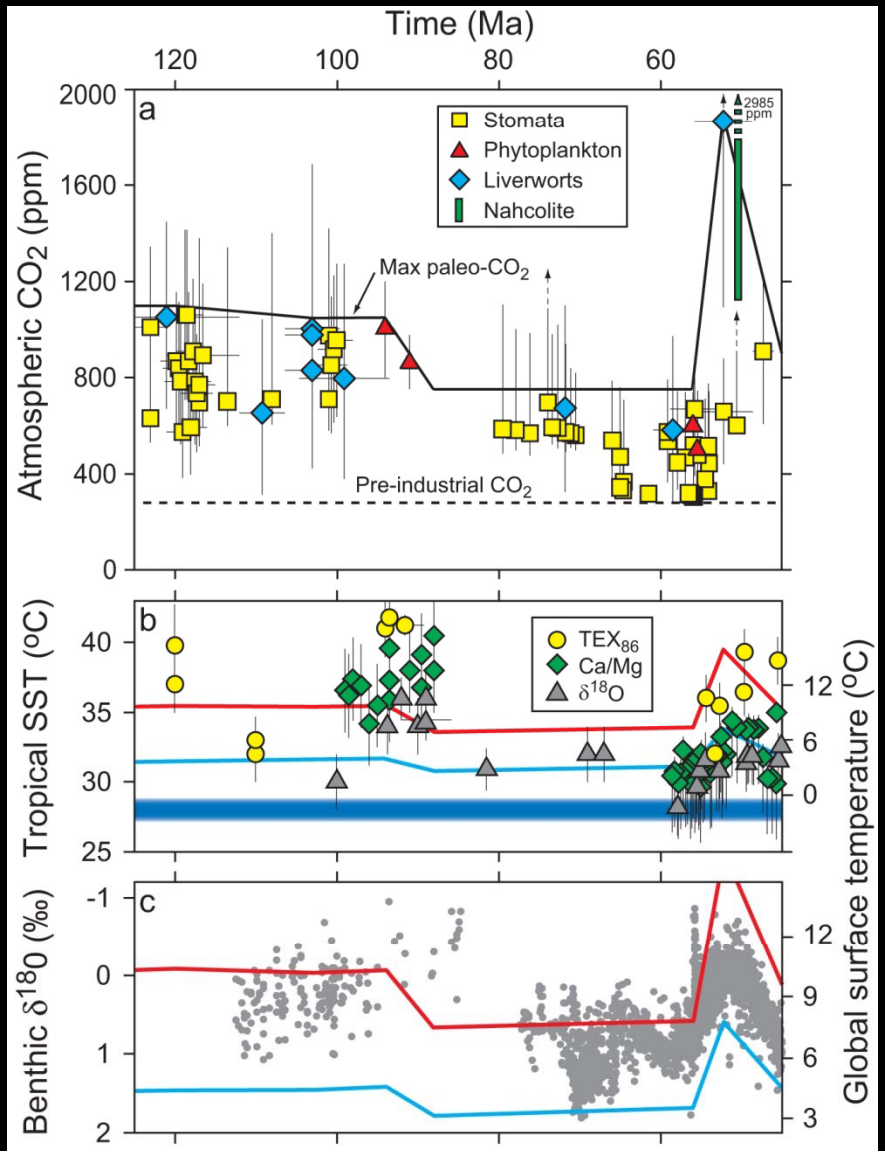

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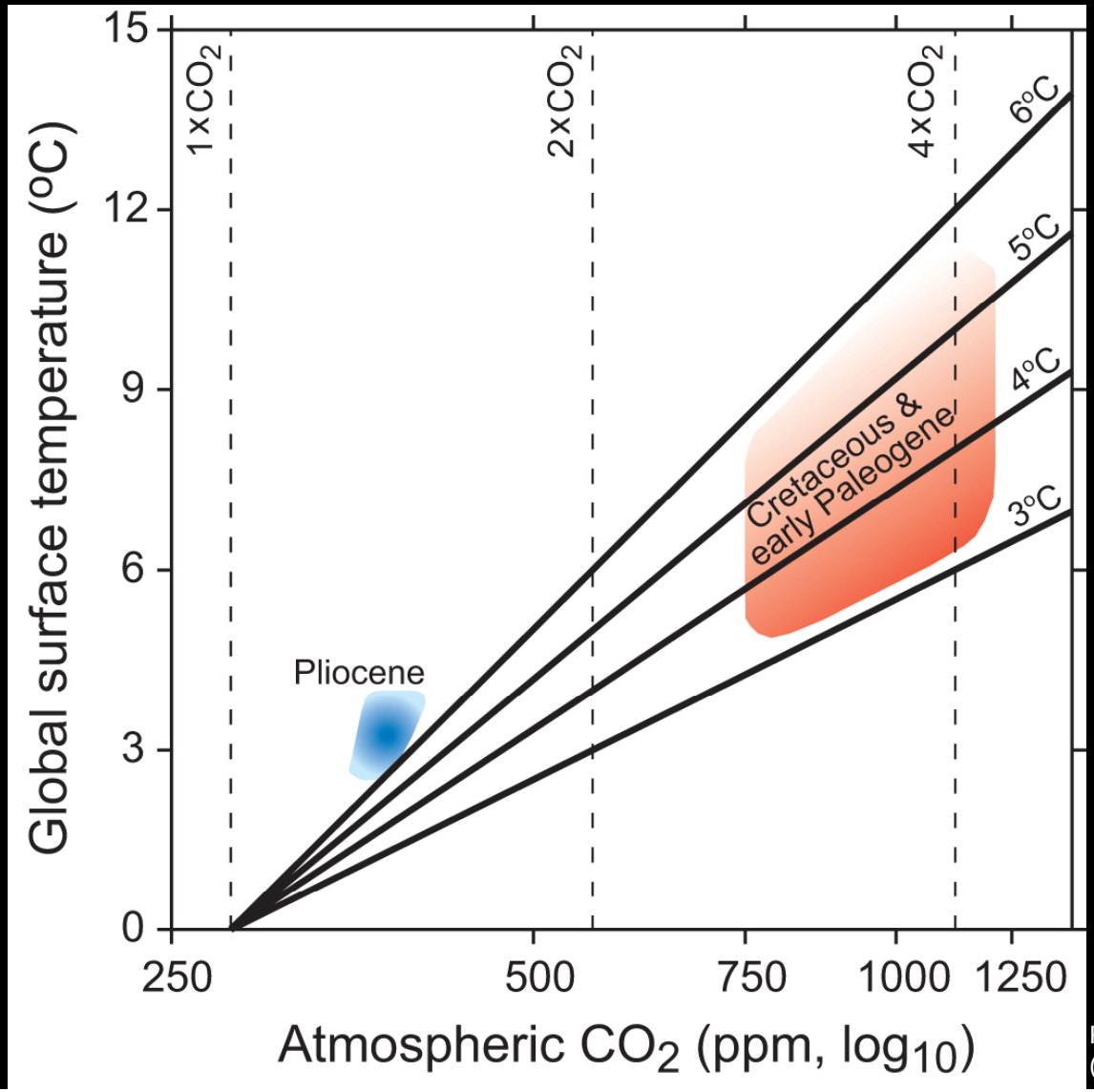

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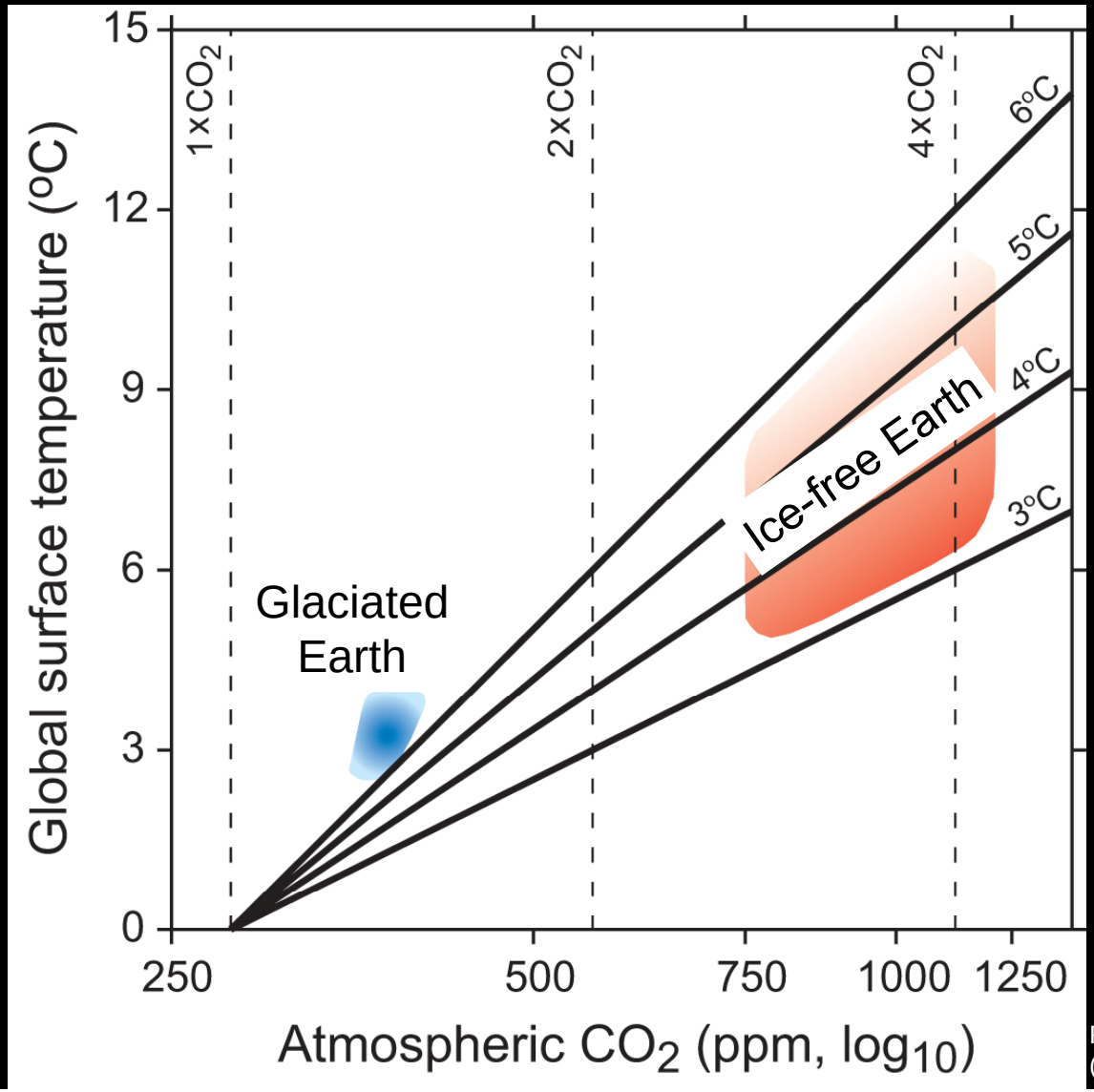
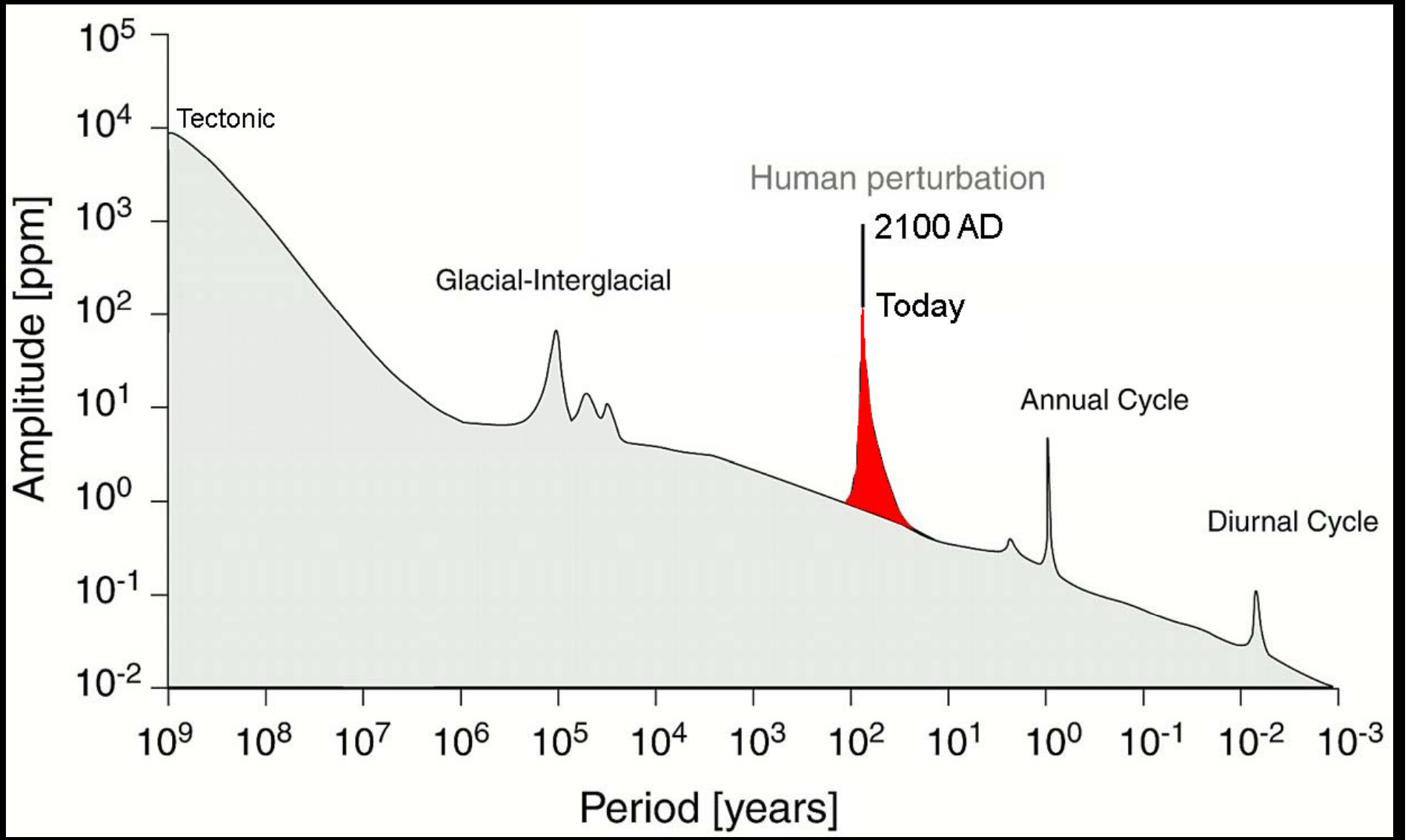


Royer, Pagani & Beerling (in prep)

It's not just magnitude of CO_2 change…



modified from Falkowski et al. (2000, *Science* 290: 291-296)

45 miles down…55 to go…