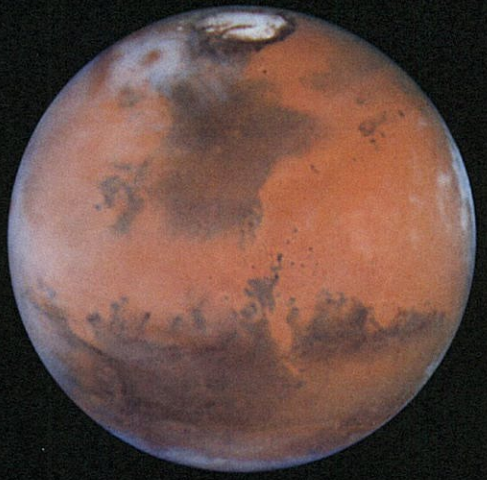
The Faint Young Sun Problem
How to warm up early Earth and Mars?



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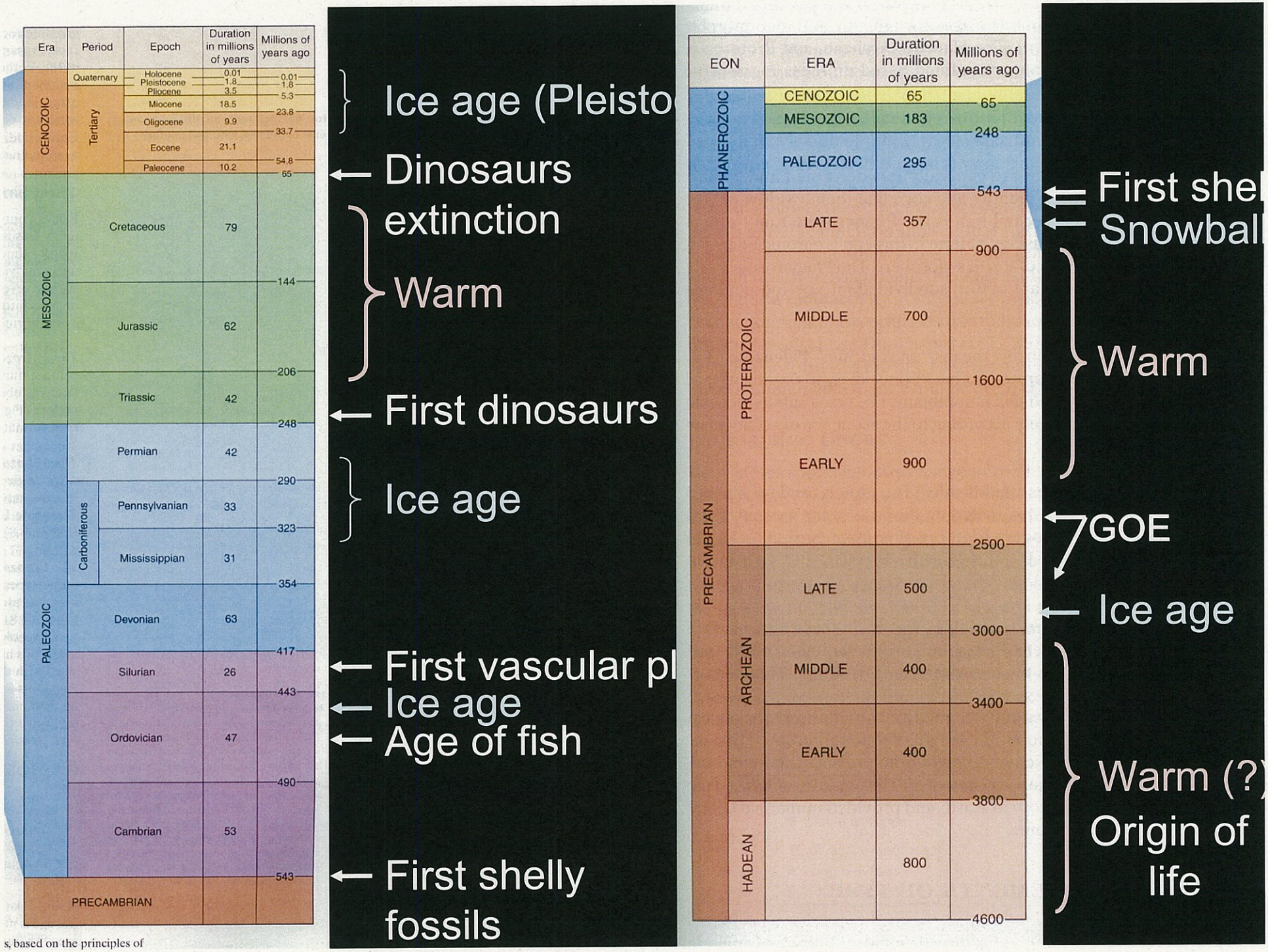
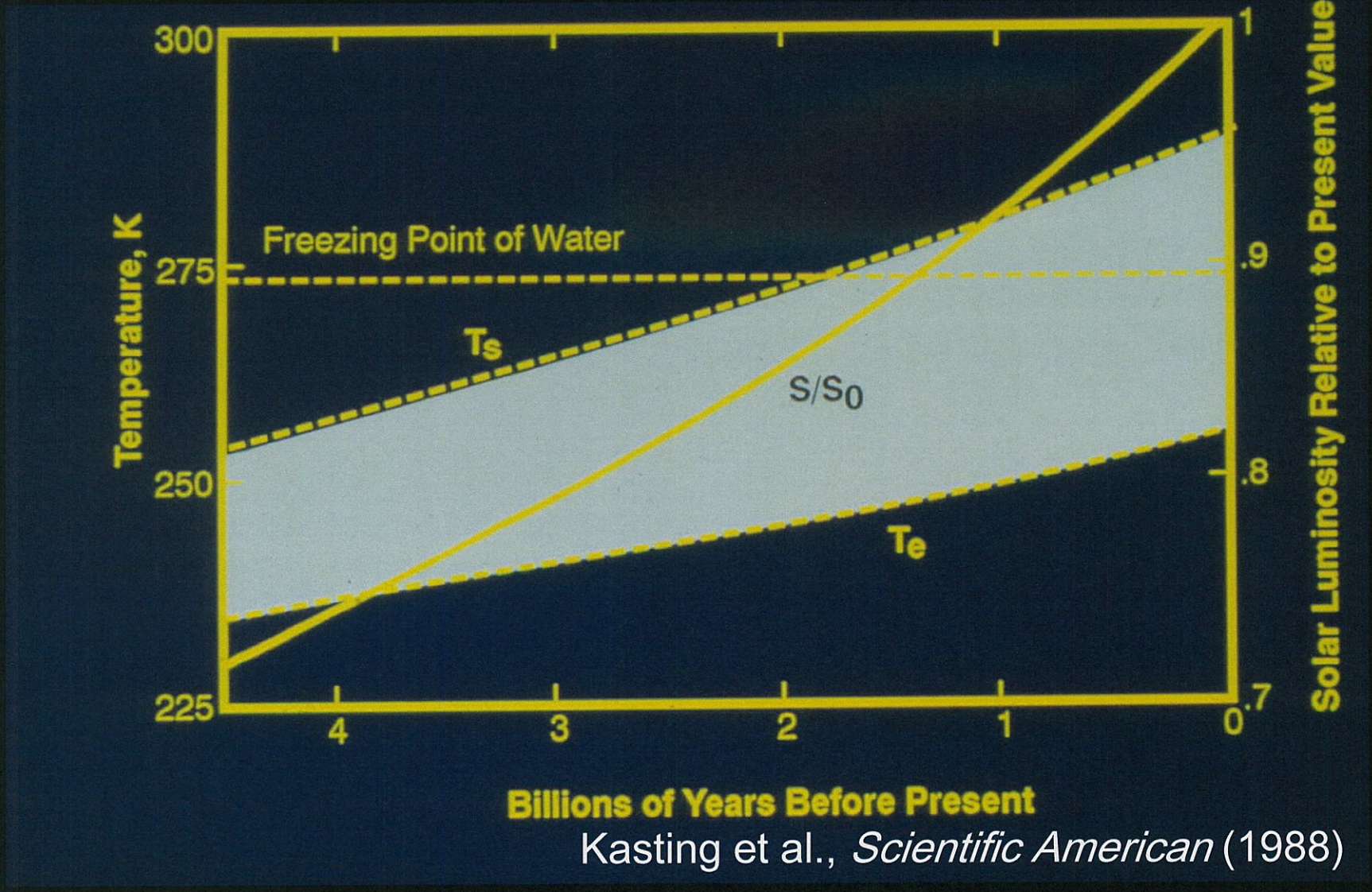
Outline

- 1. Archean Earth faint young Sun problem
- 2. Late Noachian/Early Hesperian Mars faint young Sun problem
- 3. Early Noachian Mars Atmosphere Stability
- 4. Atmospheres and Climate of some known exoplanets



s, based on the principles of

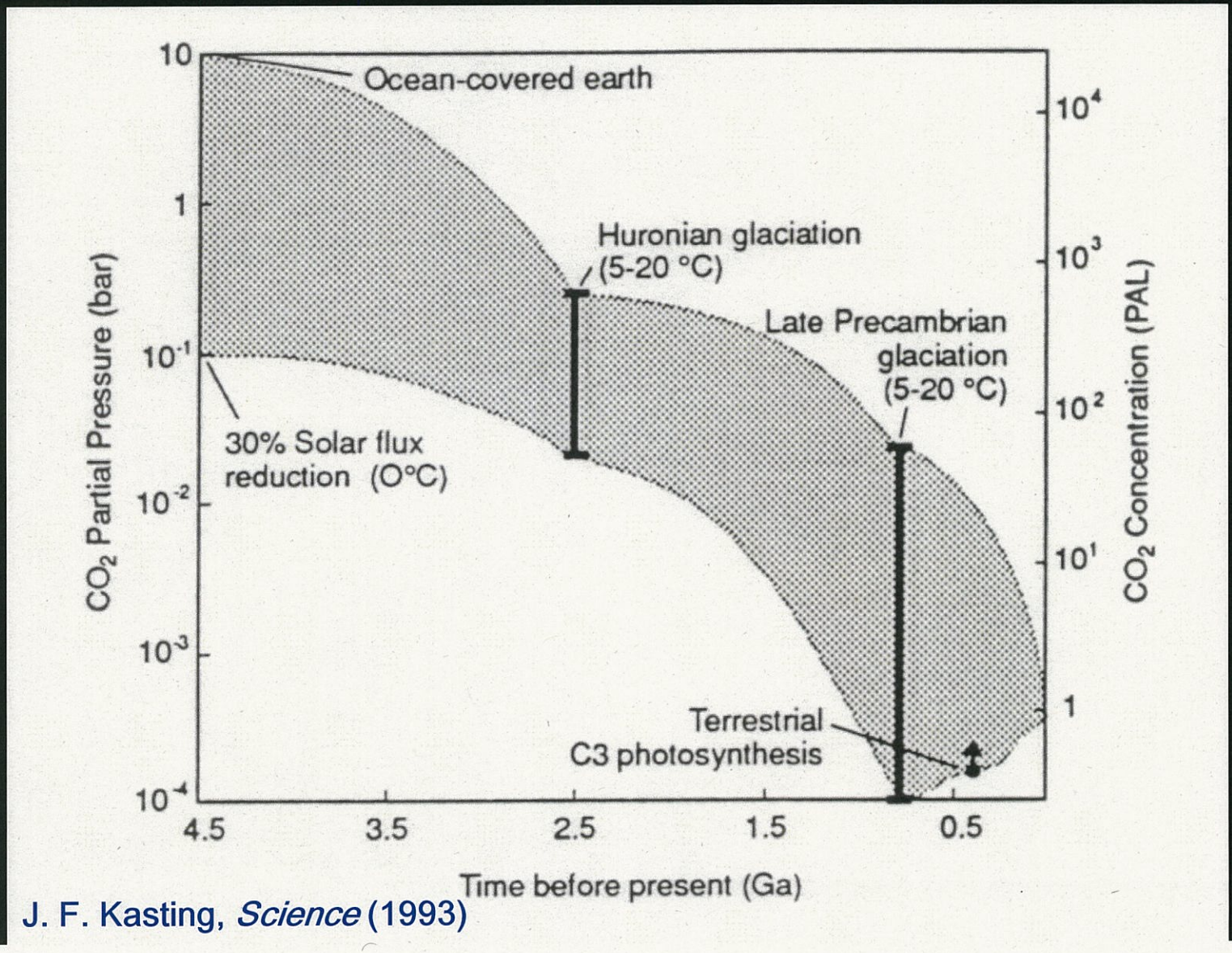
The faint young Sun problem



Kasting et al., *Scientific American* (1988)

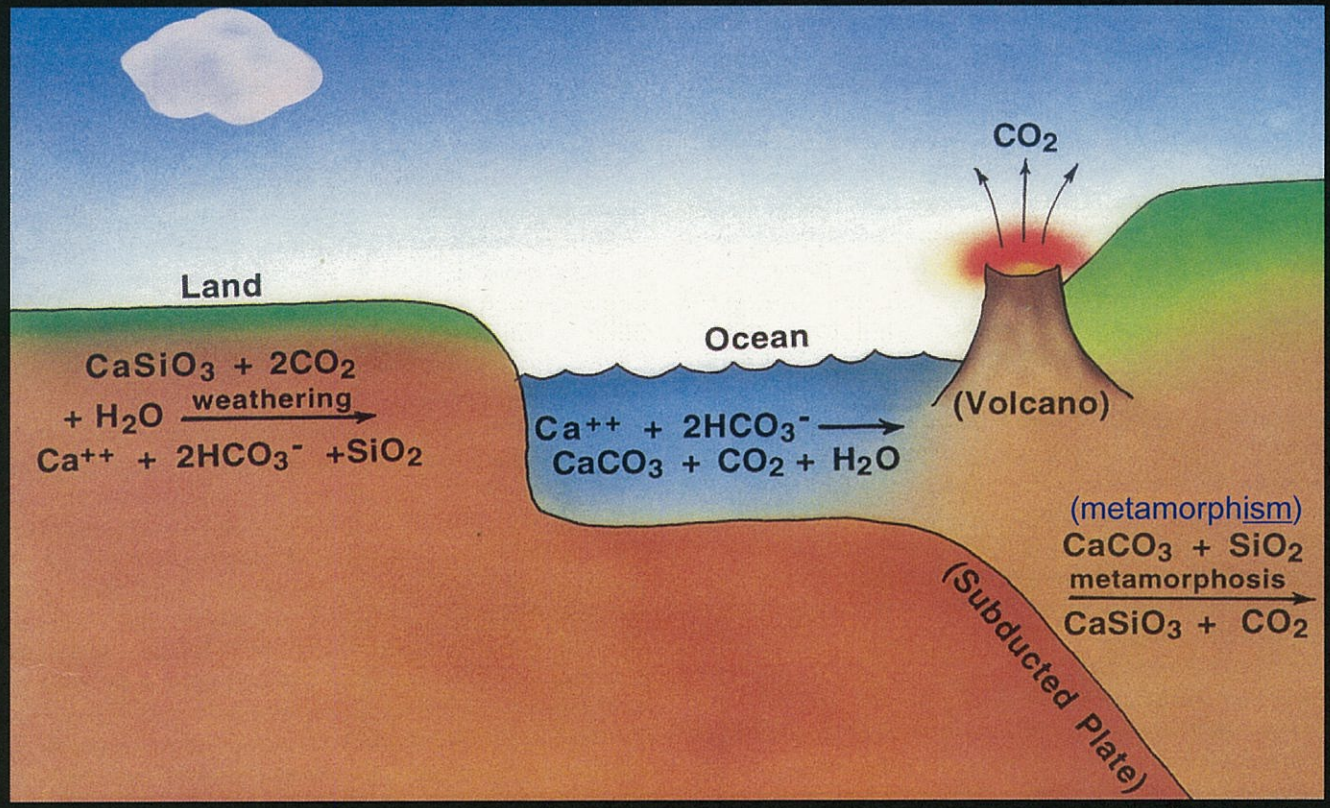
effective temperature: $\sigma T_e^4 = S(1-A)/4$

CO_2 vs. time *if* no other greenhouse gases (besides H_2O)



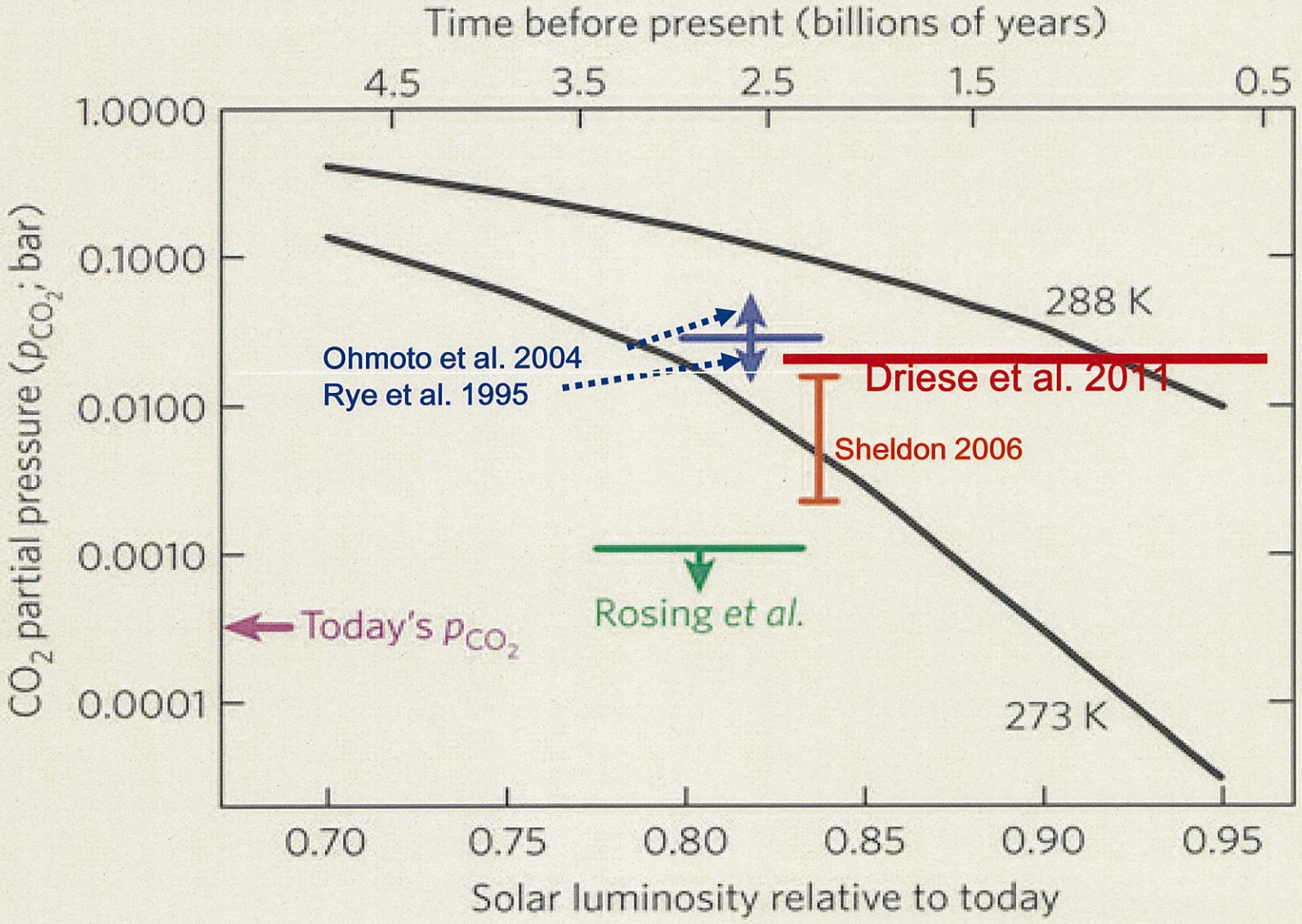
J. F. Kasting, *Science* (1993)

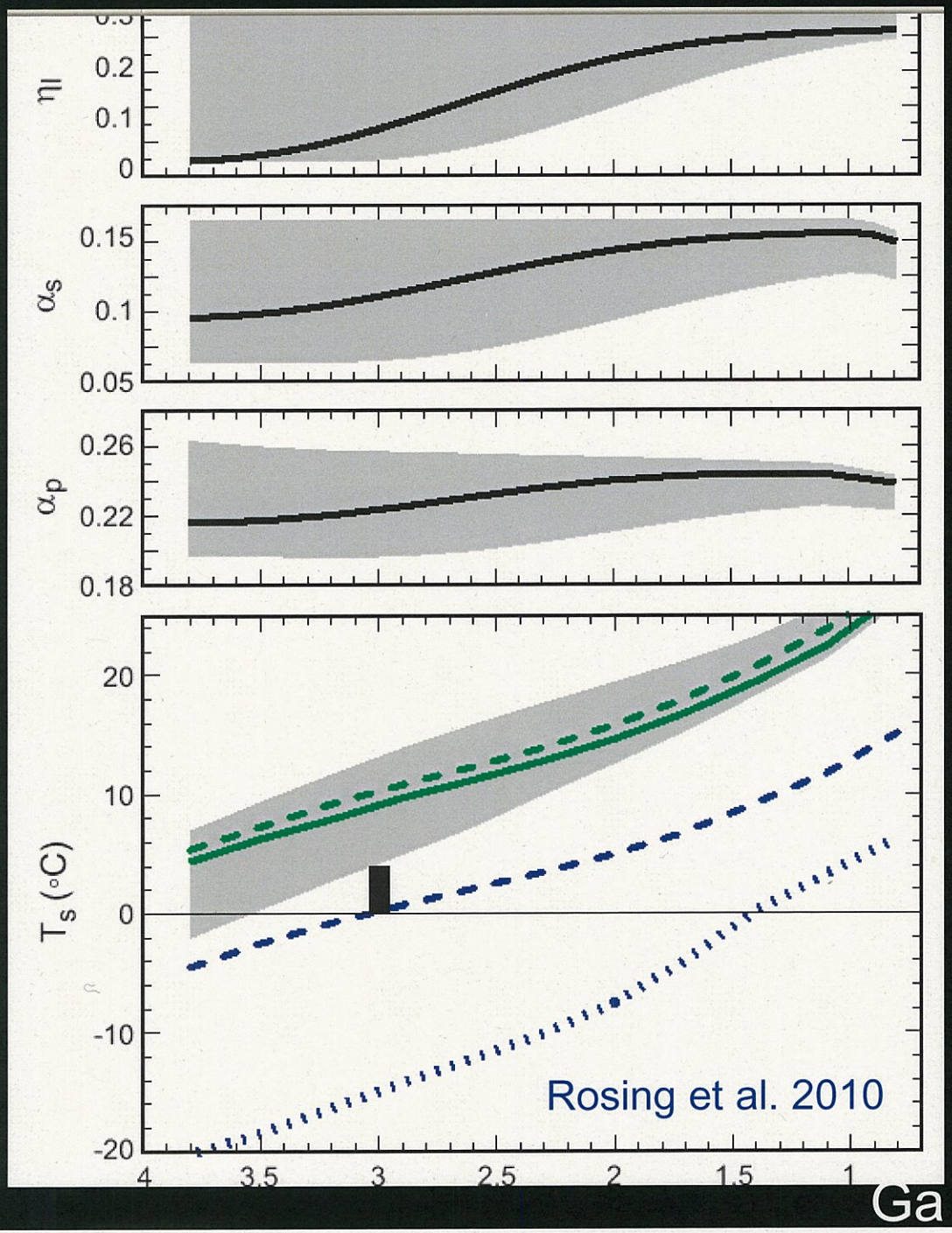
The carbonate-silicate cycle



- Yes! CO_2 could have been higher because of the carbonate-silicate cycle
- This cycle regulates Earth's atmospheric CO_2 level over long time scales and has acted as a planetary thermostat during much of Earth's history, because CO_2 builds up as the climate cools

But the geologists provides limits on atmospheric CO_2 for early Earth

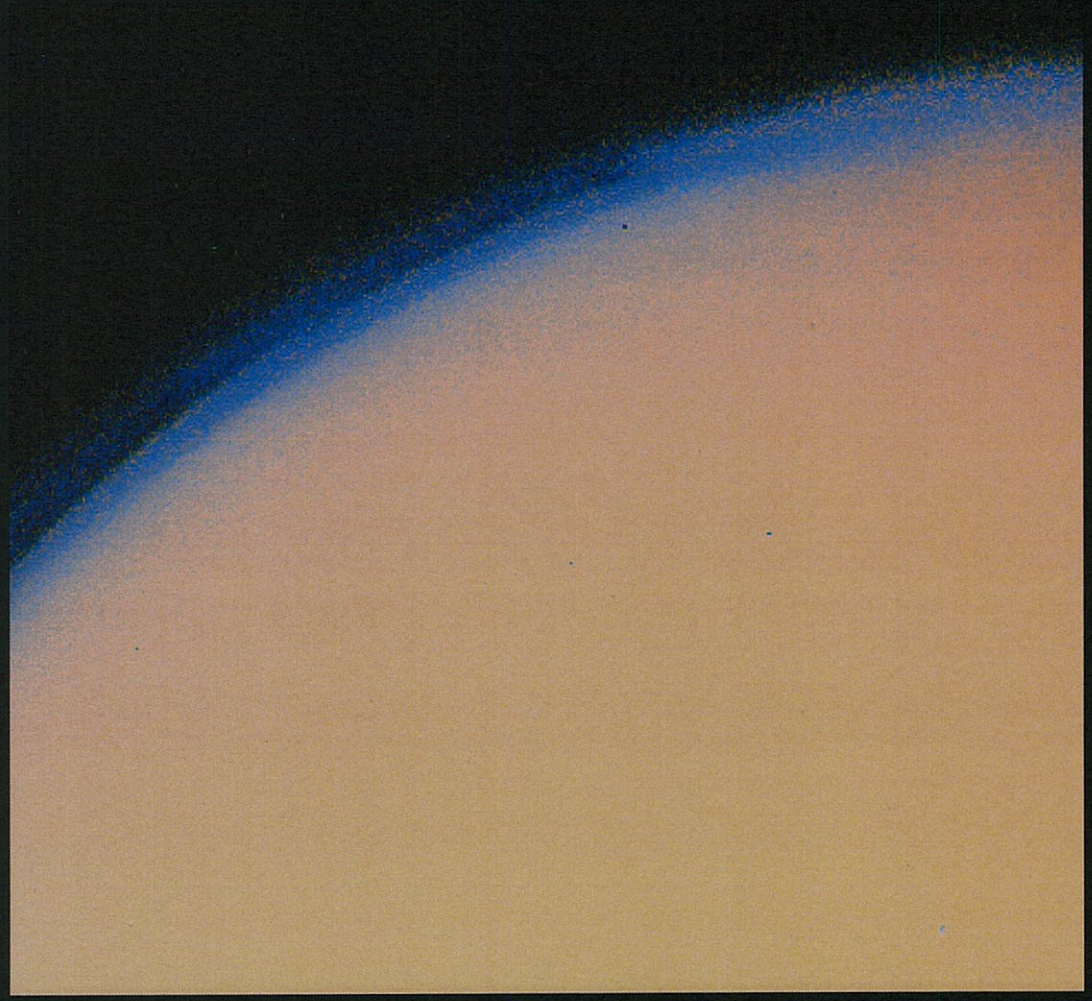




By adjusting cloudiness, surface albedo, and using 900 ppmv of CO_2 and CH_4, Rosing et al. can bring surface T ~10 K above freezing temperature.

But CH_4/CO_2~1 should produce haze…

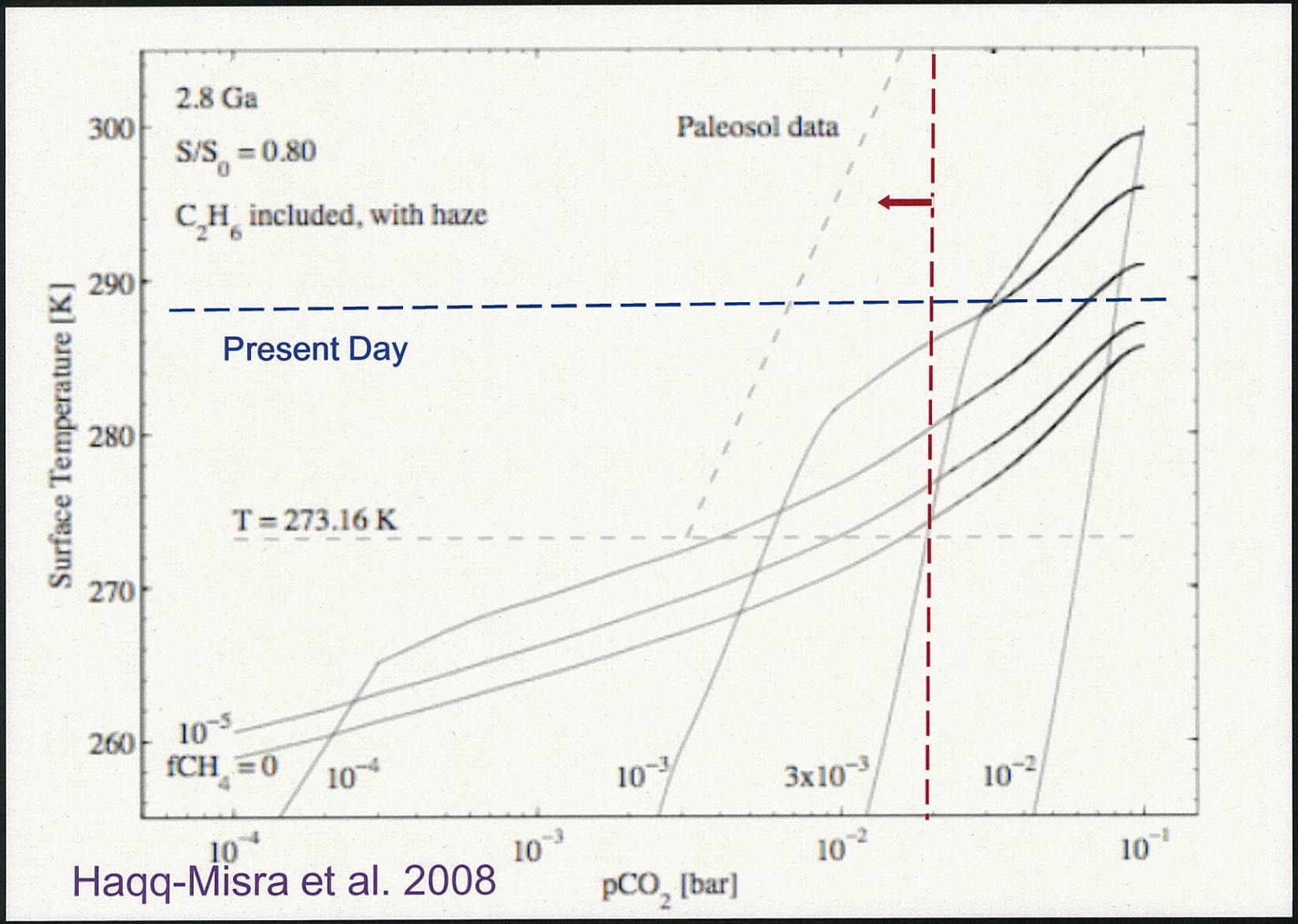
Titan's organic haze layer



- Haze is thought to form from photolysis (and charged particle irradiation) of CH_4
- It can produce an *anti-greenhouse effect*

(Picture from Voyager 2)

$CH_4/CO_2/C_2H_6$ greenhouse with haze



Haqq-Misra et al. 2008