# The warm deep ocean conveyor during Cretaceous time

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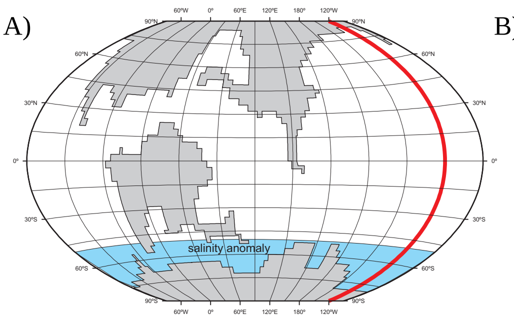
Deep-ocean water is usually associated with its high-latitude deep-water sources. In this understanding of deep-water production the warm deep ocean during Mesozoic-Cenozoic time is a challenge. It may be questioned whether warm deep-ocean water, which is direct geologic evidence, does reflect warm polar surface-ocean regions. The latter is a deduced supposition, rather than geologic fact. The problem is that for the warm Cretaceous, it is difficult to maintain strong poleward heat transport in the case of reduced oceanic thermal contrasts. Usually, atmospheric feedbacks, in conjunction with the increase of atmospheric concentrations of greenhouse gases, are employed in order to explain the warm equable Cretaceous-Eocene climate. However, there are indications that southern subpolar ocean was warmer than the northern oceans. There is no feasible physical mechanism – sea-water density depends on both temperature and salinity – that could maintain warm subpolar surface oceans in both hemispheres, an assumption often used in atmospheric modeling. This study explores a hypothesis that a warm deep ocean could coexist with relatively cool subpolar (high-latitude) sea surface in one hemisphere and a warmer subpolar sea surface in another hemisphere. Numerical ocean circulation experiments confirm that having one relatively cool high-latitude sea surface in at one hemisphere is sufficient for driving a strong meridional overturning and corresponding poleward heat transport that might have kept the abyssal ocean warm during the Cretaceous and other warm-climate periods in geologic history.

A)




B)

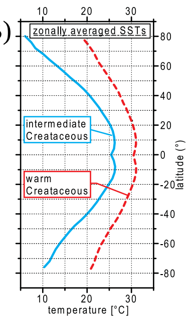



**Figure 1.** A: Reconstruction of land–sea distribution for mid-Cretaceous time. Crosshatched area around Antarctica is circumglobal band of surface ocean with salinity anomalies added in sensitivity tests. Solid line shows position of sections in Figure 3. B: Zonally averaged sea-surface temperature representing two surface climates: intermediate (solid line) and warm (dashed line) Cretaceous climate scenarios.

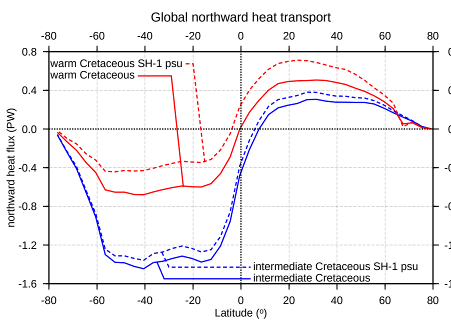



**Figure 2.** Global northward heat flux in PW (1 PW = $10^{15}$ W): intermediate Cretaceous scenario (control run and experiment with low-salinity anomaly (-1 psu) in Southern Hemisphere); warm Cretaceous scenario (control run and experiment with low-salinity anomaly (-1 psu) in Southern Hemisphere).

A) B)

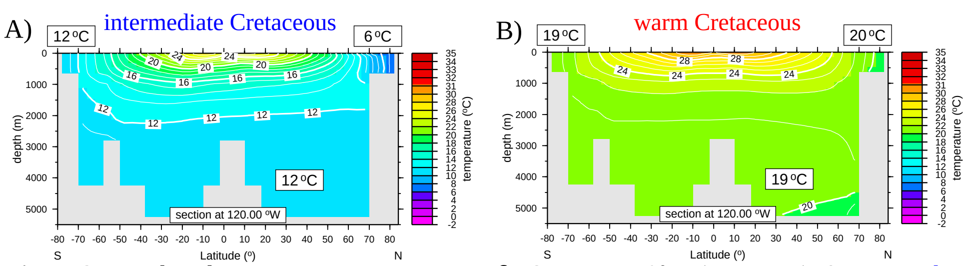



**Figure 3.** Meridional temperature sections in Pacific Ocean at 120°W (see Fig. 1). A: intermediate Cretaceous scenario; B: warm Cretaceous scenario.

B) C) A)

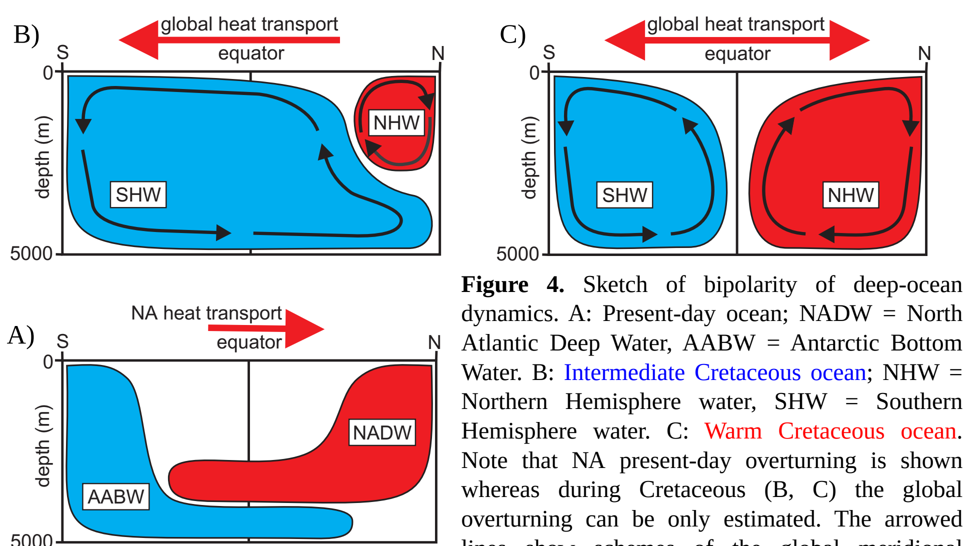



**Figure 4.** Sketch of bipolarity of deep-ocean dynamics. A: Present-day ocean; NADW = North Atlantic Deep Water, AABW = Antarctic Bottom Water. B: Intermediate Cretaceous ocean; NHW = Northern Hemisphere water, SHW = Southern Hemisphere water. C: Warm Cretaceous ocean. Note that NA present-day overturning is shown whereas during Cretaceous (B, C) the global overturning can be only estimated. The arrowed lines show schemes of the global meridional overturning.

**Reference:** Haupt, B.J. and D. Seidov: Warm deep-water conveyor during Createaceous time, Geology, 29(4), 295-298, 2001