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Cretaceous Polar Warming through Unforced Climate Variability in the paleo-North Pacific

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Cretaceous geochemical and paleontological evidence indicates that polar regions were considerably warmer than modern, and possibly up to 20°C. Climate models of the Cretaceous have struggled to simulate these warm polar conditions, implying that the models are missing or incorrectly representing the climate physics. This has led to suggestions of higher methane concentrations, greater oceanic heat transport, enhanced polar stratospheric clouds, and reduced cloud coverage through a reduction in biological CCN.

Here we report a mechanism for Cretaceous polar warming through natural climate variability. We have developed a series of mid-Cretaceous simulations with prescribed pre-industrial and elevated atmospheric pCO_2 (1x, 10x and 16x PAL) levels using the NCAR CSM 3.0 coupled ocean-atmosphere model.

In the 10x simulation, Northern Hemisphere high-latitude (70-90°) mean-annual surface temperatures initially stabilize at ∼5°C. At model year 800, the Northern Hemisphere high latitudes (70-90°) experience an abrupt (<50 years) warming event of >2°C that persists throughout the remainder of the model run (>600 yrs). Locally the warming is up to 5°C. Greenland mean-annual temperatures exceed 10°C, and are slightly higher than Greenland temperatures in the 16x simulation. This warming event is associated with the sudden intensification of deep-water formation in the Cretaceous North Pacific Ocean, which increases North Pacific meridional overturning and oceanic heat transport. Enhanced oceanic heat transport leads to North Pacific sea-surface warming, a drastic (∼66%) decrease in Arctic sea ice, and a reduction in high-latitude low cloud fraction due to enhanced regional atmospheric convection. The polar warming is sustained through the development of anomalous cyclonic atmospheric circulation in the North Pacific, which enhances mid-latitude Westerlies and subpolar easterlies and the surface heat flux into the North Pacific at mid-to-high latitudes. Our simulated Cretaceous polar temperatures approach but are still cooler than proxy polar temperatures.

The warming event in the 10x Cretaceous simulation is reminiscent of the early twentieth-century warming event in the Arctic. However, unlike that multi-decadal event, this warming event is persistent. Our model results demonstrate a mechanism for unforced polar warming and climate change in a high CO_2 world.