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On the background state dependency of (palaeo) climate sensitivity

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The equilibrium (Charney) climate sensitivity, here indicated by S^a, is the equilibrium change in Earth's global mean surface temperature due to a radiative forcing associated with a doubling of $p\mathrm{CO}_2$, the atmospheric CO_2 concentration. Although known for decades, little progress has been made in constraining upper and lower limits for climate sensitivity. Originally, S^a was derived from climate models where the atmospheric CO_2 concentration is doubled in typically about 100 years. Also palaeo data have been frequently used to determine S^a, and — if slow feedback processes are adequately taken into account — indicate a similar range as those based on climate models used in the IPCC. However, palaeo data usually span a much larger time than the 100 year model experiments.

Here, we focus on the last 800 kyr, where climate variability has occurred on time scales ranging from the 100.000-year ice-age cycles to millennial-scale climate variations. The traditional linear and equilibrium concept of climate sensitivity as is applied in typical (short time scale) climate model simulations might not apply to the climate system's non-stationary and non-linear response to changing forcing.

One example is the background state dependency of the fast feedback processes. In this presentation, we assess the dependency of the fast feedback processes on the background climate state using data of the last 800 kyr and a conceptual climate model. Though still (locally) linear, we propose a different approach to estimate climate sensitivity which better accounts for a possible state dependency of the fast feedbacks. This approach uses local slopes of temperature versus radiative perturbation and is most suitable for palaeo-data spanning a range of background climate states. We find the specific climate sensitivities generally lower during cold (glacial) than during warm periods.

Within the conceptual climate model we further estimate how the background state-dependency of the fast feedback processes might affect the distributions of feedback factors and projected temperature change when noise is included in the forcing of the model. In particular, we investigate the appearance of small but finite probabilities of a very large temperature response and how the shape of the response distribution might be related to state dependency.