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Detectability of past atmospheric temperature anomalies in the abyssal ocean

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In order to understand past and future climate change, it is important to know how much heat and CO_2 is stored in the ocean and for how long. Adjustments of the ocean's temperature determine how much CO_2 outgasses, how ocean circulation changes, and how much heat feeds back to the atmosphere.

This ocean heat content and its rate of change depend on a) ocean circulation and mixing and b) the history of atmospheric temperature. We use the Bern3D dynamical ocean model, which simulates ocean circulation and mixing (a) and where we can prescribe temperature anomalies (b).

As a case study, we look at climate variability in the past 2,000 years and investigate the detectability of resulting deep ocean temperature anomalies. A recent analysis of early instrumental data indicates that the cooling during the Little Ice Age is still detectable today as a small temperature anomaly in the abyssal ocean. We study how temperature anomalies propagate into the (deep) ocean and how this depends on ocean circulation and mixing. Atmospheric temperature anomalies, in addition to being transported into the ocean interior by the overturning circulation, themselves induce changes in ocean circulation because they directly modify water density and indirectly alter precipitation patterns. Sensitivity experiments allow us to separate the effects of steady-state ocean circulation, mixing and changes in ocean circulation on deep-ocean anomalies. Using color tracers, the water mass changes are tracked in the three major ocean basins. We find that these changes in ocean circulation alter the time of arrival of the surface signal at 3000 m depth by multiple centuries.

Finally, we carry out generic experiments where we impose a series of oscillating atmospheric temperature anomalies with different amplitudes and frequencies, which may represent climate variability. This will help to quantify possible constraints for the detectability of climate change-related signals in the deep ocean.