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Abrupt Climate Change in Ice Core Records: Oscillations and Noise Induced Transitions

Content

Rapid changes in the strength of the Atlantic Meridional Overturning Circulation (AMOC) have been implicated as a cause for abrupt climate transitions during the last ice age. Past AMOC strength may affect components of the Earth System associated with changes observed in continuous records of isotopic and chemical impurity measurements from Greenland ice cores (e.g. δ¹⁸O, Na⁺, Ca²⁺ ,NH₄⁺, NO₃⁻). These records provide an inference of high northern latitude surface temperature and sea ice extent, as well as changes in atmospheric circulation, and are therefore indirectly associated with AMOC strength (Capron et al. 2021). Complex coupled climate models that simulate ice age climate are able to simulate millennial time-scale Dansgaard-Oeschger (D-O) oscillations that agree well with the observed ice core record. These D-O events or oscillations can be modulated under changes in internal and external forcing such as atmospheric carbon dioxide concentration and the Earth's orbitally controlled insolation. Regularity in the pacing of D-O events is now thought to be part of an oscillatory behaviour that can exhibit regular cyclicity when a control parameter (associated with internal or external forcing) passes through a critical point which results in an unstable oscillatory state (Vettoretti et al. 2022). Nonlinear systems such as the ones that might describe the D-O oscillation are very sensitive to noise, and transitions between warm and cold states may be caused by noise perturbations possibly associated with internal climate variability. Possible mechanisms associated with noise induced D-O transitions will be discussed in an effort to shed light into the erratic signal observed in the ice core records.

Capron, E. et al. The anatomy of past abrupt warmings recorded in Greenland ice. Nature Communications 12, 2106 (2021).

Vettoretti, G. et al. Atmospheric CO₂ control of spontaneous millennial-scale ice age climate oscillations. Nature Geoscience 15, 17 (2022).

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