

State dependence of climatic instability over the past 720,000 years from Antarctic ice cores and climate modelling

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Climatic variabilities on millennial and longer timescales with a bipolar seesaw pattern have been documented in palaeoclimatic records, but their frequencies, relationships with mean climatic state, and mechanisms remain unclear. Understanding the processes and sensitivities that underlie such changes will underpin better understanding of the climate system and projections of its future change. We investigate the long-term characteristics of climatic variability using a new ice-core record from Dome Fuji, East Antarctica, combined with an existing long record from the Dome C ice core. Antarctic warming events over the past 720,000 years are most frequent when the Antarctic temperature is slightly below average on orbital time scales, equivalent to an intermediate climate during glacial periods, whereas interglacial and fully glaciated climates are unfavourable for a millennial-scale bipolar seesaw. Numerical experiments using a fully coupled atmosphere–ocean general circulation model (AOGCM) with freshwater hosing in the northern North Atlantic showed that climate becomes most unstable in intermediate glacial conditions associated with large changes in sea ice and the Atlantic Meridional Overturning Circulation (AMOC). Model sensitivity experiments suggest that the prerequisite for the most frequent climate instability with bipolar seesaw pattern during the late Pleistocene is associated with reduced atmospheric CO₂ concentration via global cooling and sea ice formation in the North Atlantic, in addition to extended Northern Hemisphere ice sheets.

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