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Tipping cascades in polar regions drove global change during early Last Interglacial warming

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Irreversible shifts of large-scale components of the Earth system (so-called 'tipping elements') are a concern for pace and severity of future climate change. Positive feedbacks within the climate system can amplify change, with interactions between certain sub-systems including sea ice, permafrost, boreal forests, and ice sheets and sea level, playing important roles in the trajectories of the high latitudes in particular. Since instrumental records do not capture the full range of past or projected climate scenarios, natural archives from warmer periods in the past can be used to identify responses to forcing and modes of climate variability, which provides a comparison to long-term projected simulations. The Last Interglacial (129-116 kyr BP) - the warmest interglacial of the last 800 kyr - was the most recent period during which global temperatures were close to 21st Century projections; this period therefore represents a potentially useful analogue for future change. Compared with pre-industrial times, average global temperatures were up to 2 °C higher, with warming amplified over polar latitudes and comparable atmospheric concentrations of greenhouse gases. While models of Last Interglacial climate tend to agree with available proxy records in terms of the direction of change, they largely underestimate the magnitude; regional maximum Last Interglacial summer temperature anomalies in the high Arctic range up to 8 °C warmer than present day. Quantifying and documenting qualitative regional changes from climate and environmental records during the Last Interglacial can potentially offer insights into future mechanisms and feedbacks that could have global impacts. A potentially important aspect is the inter-connection among various Earth-system feedbacks that may result in 'domino dynamics', where the tipping of one sub-system into a different state can trigger the collapse of an inter-connected sub-system. Here we synthesise the nature and timing of selected high-latitude Last Interglacial tipping elements including sea ice, boreal forest extent, permafrost, ocean circulation, and ice sheets/sea level, focussing on the timescale of onset and recovery and reviewing the thresholds and feedbacks that likely operated at that time. Despite chronological uncertainties, we find that the palaeoclimate evidence indicates early high latitude warming and impacts throughout the Earth System, with slow recovery (back to levels prior to the Last Interglacial) on the order of millennia. Our synthesis demonstrates the high sensitivity of these tipping elements to climate warming, and suggests that immediate-future climates are precariously susceptible to analogous tipping cascades.