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Interhemispheric teleconnections as recorded in proxy data during termination-I: views obtained from ocean, atmosphere and conceptual model examinations

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The last ice age came to an end between 20 ka BP (thousand years before present) and 10 ka BP. This time span that has been punctuated by a series of abrupt climate shifts, which are documented in high resolution proxy-data. Ice core records from Greenland and Antarctica reveal that during the last deglaciation gradual warming in the Southern Hemisphere preceded an abrupt temperature increase in the northern high latitudes at the onset of the Bølling/Allerød 14,600 years ago, which in turn was accompanied by a cold reversal in Antarctica. Subsequently, climate conditions in the Northern Hemisphere dropped back to glacial conditions during the 1,300 years lasting cold phase, associated with the Younger Dryas that ended about 11, 600 years ago. These interhemispheric climate changes have been linked to shifts in the Atlantic thermohaline circulation (THC) and associated variations in northward oceanic heat transport. Using global three-dimensional models of the ocean and the atmosphere, as well as a conceptual model we have analyzed THC changes that arise in response to different deglacial warming and meltwater scenarios. Focus is given to the succession of meltwater pulses that influence the THC during deglaciation and their imprint in spatio-temporal temperature pattern. A further aspect is the examination of deglacial changes in the stability behavior of the THC with respect to North Atlantic meltwater fluxes. Our modeling results show that gradual deglacial global and Southern Ocean warming leads to an abrupt amplification of a stalled THC. The resumption of the THC is associated with heat release from the sub-surface ocean in the North Atlantic, as well as large-scale salinity advection of near-surface waters from the South Atlantic/Indian Ocean and the tropics to the formation areas of North Atlantic deep water. The restarted THC possesses a strong insensitivity against deglacial meltwater pulses, and simultaneously a distinct bistability in the hysteresis curve for cumulative positive freshwater fluxes to the North Atlantic. Therefore, the restarted ocean circulation bears the potential for a long term weakening of the THC in accordance with the Younger Dryas. A comparison of the presented deglaciation scenarios with proxy data shows that a lead of increasing Southern Hemisphere temperatures, relatively to Greenland temperatures, can be reconciled with a gradual global warming trend and a superimposed oceanic "seesaw" response to meltwater pulses, associated with the Heinrich-I sequence. Therefore, the temporal evolution of deglacial temperature pattern as recorded in proxy data can be understood as an interplay of processes in both hemispheres, connected by the THC.