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Simulated changes in vegetation distribution, land carbon storage, and atmospheric CO_2 in response to a collapse of the North Atlantic thermohaline circulation

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Measurements on air enclosed in glacial ice show that atmospheric CO_2 varied by 20 ppmv within several millenia with large iceberg discharges into the North Atlantic (NA) during Heinrich events 4 to 6. The iceberg discharges have been linked to changes in the NA Thermohaline Circulation (THC). Here, we analyse how abrupt changes in the NA THC affect the terrestrial carbon cycle by forcing the Lund-Potsdam-Jena Dynamic Global Vegetation Model with climate perturbations from freshwater experiments with the ECBILT-CLIO ocean-atmosphere model. Changes in the marine carbon cycle are not addressed. Modelled NA THC collapsed and recovered after about a millennium in response to prescribed freshwater forcing preturbing glacial background climate. The initial cooling of several Kelvin over Eurasia causes a reduction of extant boreal and temperate forests and a decrease in carbon storage in high northern latitudes, whereas improved growing conditions and slower soil decomposition rates lead to enhanced storage in mid-latitudes. The magnitude and evolution of global terrestrial carbon storage in response to abrupt THC changes depends sensitively on the initial climate conditions which are here varied between preindustrial and glacial background climate. Terrestrial storage varies between -67 and $+50$ PgC for a range of experiments that start at different times during the last 21,000 years. Simulated peak-to-peak differences in atmospheric CO_2 and δ^{13}C are between 6 and 18 ppmv and 0.18 and $0.30\ ^{\circ}/_{\circ\circ}$ and compatible with the ice core records.