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Wind-stress feedback stabilization of thermohaline circulation modes without North Atlantic Deep Water formation during glacial times

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A previous study (Mikolajewicz, 1996) suggested that the wind-stress feedback makes thermohaline circulation (THC) modes without North Atlantic Deep Water (NADW) formation slightly unstable. This result was obtained under modern climate conditions, for which the presence of the massive continental ice-sheets characteristic of glacial times is missing. Here we use a coupled ocean-atmosphere-sea ice model of intermediate complexity, set up in an idealized spherical sector geometry, to show that glacial climates promote wind-stress feedback stabilization of THC modes without NADW formation. It is found that the influence of the wind-stress feedback on the glacial meridional overturning circulation (MOC) response to a freshwater input in high northern latitudes is controlled by two distinct processes: (1) the interactions between the windfield and the sea ice export in the northern hemisphere (NH) and (2) the northward Ekman transport in the tropics and upward Ekman pumping in the core of the NH subpolar gyre. The former has a stabilizing effect on the glacial NADW ‘‘off” mode and dominates the response of the coupled system, while the latter has a destabilizing influence and plays a minor role. Hence, the wind-stress feedback delays the recovery (if any) of the glacial MOC, which is the opposite of what occurs under modern climate conditions. Close to the so-called saddle-node bifurcation of the classical Stommel box model, the glacial MOC appears to be very sensitive to changes in surface wind-stress forcing and exhibits, at equilibrium, a non linear dependence upon the wind-stress feedback magnitude. In particular, the circulation crosses a critical tran-

sition threshold for intermediate wind-stress feedback magnitudes only. This peculiar behaviour is related to the salinity supplied by processes (2). These mechanisms tend to mitigate the stabilising effect of the sea ice export on the collapsed MOC while the strength of the wind-stress feedback is large. The mechanisms presented here may be relevant to the abrupt climate changes that punctuated the last glacial period.