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Reversed North Atlantic subpolar gyre dynamics in present and glacial climates

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The dynamics of the North Atlantic subpolar gyre (SPG) are assessed under present and glacial boundary conditions by investigating its sensitivity to surface wind-stress changes using an intermediate complexity coupled climate model. The SPG is found to be stronger in present than in glacial climates and shows an opposite sensitivity to wind-stress changes in both climates. While in the present it decreases with increasing surface wind-stress, in glacial times it rather increases. Both features result from density changes produced by wind-induced circulation changes. Our results suggest the existence of two dynamically distinct regimes of the SPG, depending on the absence or presence of deep water formation (DWF) in the Nordic Seas and a vigorous Greenland-Scotland ridge (GSR) overflow. In the first regime, the GSR overflow is weak and the SPG strength increases with the wind-stress as a result of a basin-scale reduction in stratification. As soon as a vigorous GSR overflow is established, its associated positive density anomalies in the southern GSR slope contribute to reduce the SPG strength. Our results have implications for past glacial abrupt climate changes, which are explained through latitudinal shifts in North Atlantic DWF sites and strengthening of the North Atlantic current. Regardless of the ultimate trigger, an abrupt shift of DWF into the Nordic Seas could result both in a drastic reduction of the SPG strength and a sudden change in its sensitivity to wind-stress variations.