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How the Greenland-Scotland Ridge shapes the Atlantic meridional overturning circulation and Northern Hemisphere climate

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Changes in the geometry of ocean basins have been influential in driving climate change throughout Earth's history. Here we focus on the appearance of the Greenland-Scotland Ridge (GSR) and try to understand its impact on climate, including global circulation, heat transport, water mass properties and ventilation timescales, which will be useful for interpreting paleoproxies.

To this end, we use a coupled atmosphere-ocean-sea ice model with idealized geometry and consider two geometrical configurations. The reference configuration (noridge) comprises two wide strips of land set 90° apart extending from the North Pole to 40°S, separating the Northern Hemisphere ocean into a small «Atlantic-like» and a large «Pacific-like» basin. In the ridge configuration a zonally symmetric oceanic ridge, that extends across the Atlantic-like basin at 60°N, mimicking the GSR, is added. We consider three background climates of noridge: a warm case where the northern high latitudes are ice-free, an intermediate case with a small seasonal ice cover and a cold case with a perennial sea ice cover. In all three cases of noridge deep-water formation occurs in the northern parts of the Atlantic-like basin, driving a meridional overturning circulation (MOC) akin to the Atlantic MOC of present-day.

When the ridge is introduced, the flow of warm Atlantic water to the high latitudes is hampered and the ocean heat transport across 70°N decreases by $\sim$40% which causes cooling and freshening of the waters north of the ridge. Consequently, the meridional density structure changes significantly with cold dense water forming north of the ridge and eventually overflows into the North Atlantic. Downwelling shifts south of the ridge, thereby altering the properties of the deep water mass and the structure of the MOC north of 60°N dramatically, although the maximum MOC strength remains unchanged. Despite these changes, the large-scale surface climate response is surprisingly small for all cases.

Our results highlight the possible disconnect between changes in the localization of deep-water formation, the structure of the AMOC and the properties of water masses and changes in Northern Hemisphere surface climate. They also underscore the necessary caution in interpreting paleoproxies in terms of AMOC and climate change.