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Internal variability and predictability of the thermohaline circulation and climate

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Results from a 1400 year calculation using the HadCM3 coupled climate model without external forcings show dominant multidecadal variations in the strength of the thermohaline circulation (THC) of about 2 Sv (10%) with a characteristic time scale of about 100 years. This mode is associated with a similar pattern of climate variability to the observed Atlantic Multidecadal Oscillation (AMO), with broad-scale fluctuations in temperature throughout most of the Northern Hemisphere. Global, Northern Hemisphere and North Atlantic mean surface temperatures are found to vary in phase with the THC, with regressions of 0.05 degrees C/Sv, 0.09 degrees C/Sv and 0.12 degrees C/Sv respectively, suggesting that the modelled mode is significant compared to observed 20th Century climate variability. We propose a mechanism for this variability in which anomalous northward ocean heat transport during a strong THC phase generates a warm AMO and stronger cross-equatorial temperature gradients. This in turn causes a northward displacement of the mean ITCZ, leading to more rainfall and a development of anomalously fresh water in the tropical North Atlantic. Such sustained anomalies slowly propagate to the subpolar North Atlantic in about 5 decades, where they act to slow the THC.

Similarity between the observed AMO and THC-related temperature anomalies in the model allows us to estimate possible past changes in THC strength, which are not known due to a lack of sub-surface marine monitoring. Our results imply that the THC has undergone distinct strong and weak phases in the 20th century and has strengthened over recent decades. In addition, the quasi-periodic variation of the simulated THC suggests the THC has some potential predictability for several decades ahead. We forecast the natural component of future THC change, therefore, by examining periods in the control simulation when THC strength is similar to that reconstructed for the present-day. This shows that the THC is approaching a peak in the next 10

years and is likely to subsequently decline, weakening in about 35 years to levels corresponding to the lowest reconstructed in the 20th century. This natural reduction would accelerate anthropogenic THC weakening and the associated change in the AMO would offset Northern Hemisphere warming by about 0.2C.