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Processes governing the stability of Atlantic meridional overturning circulation in a future warm climate

C. Li (1,2), J.-S. von Storch (1), and J. Marotzke (1)

(1) Max Planck Institute for Meterology, Hamburg, Germany (chao.li@zmaw.de), (2) International Max Planck Research School Earth System Modelling, Hamburg, Germany

We examine the hysteresis behavior of the Atlantic meridional overturning circulation (AMOC) in response to atmospheric CO_2 change by using the state-of-the-art AOGCM ECHAM5/MPIOM. The atmospheric CO_2 is extremely slowly increased from pre-industrial level to quadrupling over 2000 years, and is held constant thereafter for a further 5940 years until the whole system has reached equilibrium; then the atmospheric CO_2 is extremely slowly decreased from the quadrupling to the pre-industrial level over 2000 years, and is held constant thereafter for a further 3940 years until the whole system has again reached equilibrium. We find no evidence of hysteresis behavior of the AMOC in response to the CO_2 forcing and the anomalous atmospheric freshwater forcing over the NADW formation regions. The AMOC "recovery" trajectory is above the "weakening" trajectory, not below, indicating that the apparent offset is a consequence of the speed of the transient change in CO_2 concentration that is not small enough to ensure an quasi-equilibrium in our experiment. The overshooting recovery of the AMOC is caused by a stronger evaporation over the tropical Atlantic, which leads to anomalously high salinities in the North Atlantic while the CO_2 decreases, resulting in a stronger deep convection and a stronger AMOC. In contrast to the previous studies with water-hosing experiments, a positive overturning freshwater transport (M_{ov}) at the southern border does not damp the freshwater forcing in the North Atlantic and does not promote the recovery of the AMOC throughout our simulations. In a future warm climate, the long-term stability of the AMOC is not only governed by the anomalous freshwater forcing in the deep-water formation regions, but also by a stronger evaporation in the tropical Atlantic owing to the surface warming. However, such a process is not included in the water-hosing experiments. Hence, we can not use the water-hosing experiments to project the long-term stability of the AMOC in a future warm climate.