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Evolution and Variability of Ocean Circulation in a Transient Holocene Simulation

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Ocean circulation plays a major role in long-term climate variability. Applying orbital forcing to a coupled atmosphere-ocean general circulation model including a land surface model (ECHAM5/JSBACH/MPI-OM), we perform a transient simulation from the mid-Holocene to today and study changes in ocean circulation and its variability.

On top of a long-term increase in the Atlantic meridional overturning circulation (AMOC) the dominant temporal modes of variability in ocean circulation appear on inter-annual and multi-centennial time-scales.

The long-term AMOC increase results from water mass property changes in the deep water formation regions. In the Labrador Sea, a density increase of the convected deep water is connected to increased salinity advection from the eastern North Atlantic. In the Nordic Seas, lower temperatures cause a substantial density increase and result in enhanced overflows.

The inter-annual AMOC variability is connected to atmospheric forcing dominated by the North Atlantic Oscillation (NAO). Displayed periods of up to 300 years of one persisting NAO phase could be analogs to climate anomalies like the Little Ice Age and the Medieval Climate Anomaly induced by natural variability only.

The multi-centennial AMOC variability results from salinity anomalies in the convection regions. These salinity anomalies develop in the tropical Atlantic and are advected from the Southern Ocean. The anomalies accumulate in the sub-tropical gyre and after reaching a threshold, they trigger oscillations in AMOC strength when they enter the sub-polar gyre. The amplitude and period of the oscillations is dependent on the phasing of the effects altering salinity in the tropical Atlantic, the Southern Ocean and also on the conditions prevailing in the Arctic Ocean and the Nordic Seas.