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A model data comparison of different classes of LSW and interannual to decadal variability in a FESOM model setup

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The climate in the Atlantic region is essentially influenced by the Atlantic meridional overturning circulation (AMOC) which carries warm waters into northern latitudes and returns cold deep water southward across the equator. In the Labrador Sea basin a major component of the cold limb of the Atlantic meridional overturning circulation (AMOC) is formed. The intermediate water mass that is part of this deep convection process is the Labrador Sea Water (LSW) which can be separated into two different classes: the deep LSW (dLSW) and the less dense upper LSW (uLSW). Both LSW modes are formed by convection, accompanied by a strong surface cooling during winter conditions, which leads to an increase in the near-surface density and to an unstable stratification and a homogenization of the water column.

In this study we simulated the deep-water formation in the Labrador Sea using the Finite-Element Sea-Ice Ocean Model (FESOM) in a global model setup with regional focus on the Labrador Sea and Greenland Sea. We evaluated the capability of the model setup to reproduce a realistic deep water formation in the Labrador Sea by analyzing the modeled Labrador Sea hydrography and we compared the modeled and observational derived dLSW and uLSW layer thicknesses for the time interval 1958-2007.

It is shown that the model is able to reproduce different phases in the temporal evolution of the potential density, temperature and salinity, which are known in observational data.

Based on composite maps of the thermal and haline contributions to the surface density flux we can prove that the central Labrador Sea in the model is dominated by the thermal contributions of the surface density flux, while the haline contributions are limited to the branch of the Labrador Sea Boundary Current system, where they are dominated from the haline contributions of sea ice melting and formation. Our model results feature a shielding of the central Labrador Sea from the haline contributions by the Labrador Sea Boundary Current system.

Furthermore we investigated modes of interannual to decadal variability for the period 1958-2004 and attributed the general variability in the model to the atmospheric forcing and to internal modes of the ocean system. Based on a North Atlantic Deep Water (NADW) index defined for a normal and random forced FESOM run, where the interannual to decadal atmospheric variability in the random forced run is replaced by white noise, we identify modes of interannual to quasi-decadal variability of 7yr and 14yr, respectively. The origin of the 14yr variability is attributed to the atmospheric forcing, while the 7yr variability is linked to internal modes of the ocean.

To further isolate the horizontal, but also the vertical variability in the model, we apply a principal oscillation pattern analysis in a three dimensional context. Two exceptional stable interannual modes are captured by the POP analysis and their variability is attributed to a propagating Rossby wave structure.