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Density-compensated Overturning Circulation in the Labrador Sea

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Many past modeling studies have stressed the importance of Labrador Sea convection to the strength and variability of the Atlantic Meridional Overturning Circulation (MOC). Assessing the importance of that convection has been stymied by the relatively large range of indirect estimates of the diapycnal mass flux (or diapycnal overturning) in the Labrador Sea (from 2Sv to 10Sv). Recent observations from the Overturning in the Subpolar North Atlantic Program (OSNAP) have provided the first direct estimate of the diapycnal overturning in the Labrador Sea during 2014/2016, with a mean of 2.1Sv. This number is weak compared to the total MOC in the subpolar North Atlantic, reported as 14.9Sv (Lozier et al., 2018). This result is surprising as the 2015/2016 convection, one of the largest events ever observed (Yashayaev and Loder, 2017), is assumed to be associated with strong water mass transformation.

To address this puzzle, the OSNAP transport structure is analyzed in temperature and salinity space. This analysis reveals that there is significant transformation (16.5Sv) of warm, salty waters that flow in via the West Greenland Current, into cold, fresh Labrador Sea Water that flows out in the Labrador Current. However, the majority of the transformation (12.4Sv) takes place along isopycnals, indicating strong density compensation. That is to say, the key attribution of the small overturning in the Labrador Sea is the relatively flat compensated-density surfaces along which the transport of the inflow is mostly canceled out by the transport of the outflow. If density is determined by temperature or salinity alone, the tilt of isopycnals would resemble the significantly tilted isotherms/isohalines, leading to an overturning as large as 13-15Sv.

These findings highlight the critical relationship between temperature and salinity in determining the overturning structure in the Labrador Sea and underlines the necessity of a correct estimate of the freshwater flux into the basin. Many models simulate temperature well, but are biased in salinity due to large uncertainties in modeling the atmospheric hydrographic cycle (Schneider et al., 2007; Zhang et al., 2007), sea-ice interactions, and/or Greenland ice sheet melting (Delworth et al., 2007). Such salinity bias can lead to a stronger overturning in density space and therefore exaggerate the impact of convection.