EGU21-9128
https://doi.org/10.5194/egusphere-egu21-9128
EGU General Assembly 2021

Characteristics and variability of ocean ventilation in the high-latitude North Atlantic in an eddy-permitting ocean model

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A substantial fraction of the deep ocean is ventilated in the high latitude North Atlantic. As a result, the region plays a crucial role in transient climate change through the uptake of carbon dioxide and heat. We investigate the nature of ventilation in the high latitude North Atlantic in an eddy-permitting numerical ocean circulation model using a set of comprehensive Lagrangian trajectory experiments. Backwards-in-time trajectories from a model-defined 'North Atlantic Deep Water' (NADW) reveal the times and locations of subduction from the surface mixed layer at high temporal and spatial resolution. The major fraction (60%) of NADW ventilation results from subduction directly into the Labrador Sea boundary current, with a smaller fraction (25%) arising from open ocean deep convection in the Labrador Sea. There is a notable absence of ventilation arising from subduction in the Greenland–Iceland–Norwegian Seas, due to the re-entrainment of those waters as they move southward. Temporal variability in ventilation arises both from changes in subduction — driven by large-scale atmospheric forcing — and from year-to-year changes in the subsurface retention of newly subducted water, the result of an inter-annual equivalent of Stommel's mixed layer demon. This interannual demon operates most effectively in the open ocean where newly subducted water is slow to escape its region of subduction. Thus, while subduction in the boundary current dominates NADW ventilation, processes in the open ocean set the variability, mediating the translation of inter-annual variations in atmospheric forcing to the ocean interior.