EGU2020-5644
https://doi.org/10.5194/egusphere-egu2020-5644
EGU General Assembly 2020

From small whirls to the global ocean: how eddies affect the Atlantic Meridional Overturning Circulation

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In the North Atlantic Ocean, intense downward motions connect the upper and lower limbs of the Atlantic Meridional Overturning Circulation (AMOC). In addition, the AMOC also displays a pronounced signature in density space, with lighter waters moving northward and denser waters returning southward.

While at first glance it is appealing to associate this sinking of water masses in the North Atlantic Ocean with the occurrence of the formation of dense water masses by deep convection, this is not correct: the net vertical motion over convection areas is small. The downward flow required to connect the upper and lower branches of the AMOC thus has to occur outside the deep convection areas. Indeed, earlier studies have pointed out theoretically that strong sinking can only occur close to continental boundaries, where ageostrophic processes play a role. However, observations clearly indicate that convected water masses formed in marginals seas constitute an important component of the lower limb of the AMOC.

This apparent contradiction is explored in this presentation, by studying the overturning in the AMOC from a perspective in depth space (Eulerian downwelling) and density space (downwelling across isopycnals). Based on analyses of both a high-resolution global ocean model and dedicated process studies using idealized models we analyze the characteristics of the sinking, of diapycnal mixing, and investigate how these are linked.

It appears that eddies play a crucial role for the overturning, both in depth space and density space. They control the characteristics of the yearly cycle of convection and restratification, the magnitude of the Eulerian sinking near continental boundaries, and steer the export of dense waters formed in the interior of the marginal seas via the boundary current system.

These studies thus reveal a complex three-dimensional view on sinking, diapycnal water mass transformation and overturning in the North Atlantic Ocean, involving the boundary current, the interior and interactions with the eddy field. This implies that it is essential to resolve these eddies to be able to properly represent the overturning in depth and density space in the North Atlantic Ocean and its response to changing conditions in a future climate.