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Ocean mixing and polynyas at Maud Rise, Weddell Sea

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Abstract

The Weddell Sea Polynya is an intermittent, ice free area in the marginal ice zone with an extent of up to 350 000 km². It was first observed by satellites in the winter seasons of 1974-1976. In 2016 and 2017, an open-ocean polynya opened over the Maud Rise oceanic plateau in the eastern Weddell Sea, which was the largest since the 70's. Polynyas have an important role in ocean-atmosphere heat exchange, deep water and sea-ice formation. A deep layer of relatively warm Circumpolar Deep Water below the mixed layer provides the potential heat source to keep the polynya open during winter, but it is not yet fully understood how this heat is transported towards the surface. Due to its rare occurrence, most of what we know about the Weddell and Maud Rise Polynyas is based on modelling studies.

This thesis is delineated into two main themes related to the Maud Rise Polynya. Firstly, this work assesses the presence and magnitude of Southern Ocean polynyas in global climate models. For this purpose, a novel algorithm to detect polynyas in satellite observational products and climate model output is applied to sea-ice concentration and thickness data. We find that both coastal and open-ocean polynyas are not well represented in climate models in terms of extent or frequency. This part discusses methods to improve the models towards a more realistic representation of polynyas.

The second theme of the thesis uses new hydrographic observations at Maud Rise and the regional vicinity from autonomous profiling floats programmed to profile at high-frequency (1-3 days), that I deployed and managed. These unique observations are used in two subsequent studies. In the first, salinity and temperature profiles collected over several annual cycles indicate strong spatial gradients between relatively cold and fresh water over Maud Rise and warmer, saltier water surrounding it (Maud Rise Halo). These spatial patterns are tightly correlated with the Maud Rise bathymetry. At the transition between those two water masses at the flank of Maud Rise, interleaving is shown to occur, which causes double diffusive and thermobaric mixing to depths of 800 m. The second study focuses on the upper ocean mixed layer dynamics. The deepest wintertime mixed layers occurred over Maud Rise, but polynyas usually form over the Maud Rise Halo - a region of warm water flow surrounding the plateau region. We find that the winter water over Maud Rise is substantially thicker, and that entrainment of this winter water in autumn makes the mixed layer comparatively cold and fresh compared to the halo region. In this study a comparison with earlier profiling float observations during the 2016 and 2017 polynyas reveals that the mixed layer is significantly saltier in the autumn season. This allows for the mixed layer to deepen more rapidly and by doing so entrain warmer water from below into the mixed layer. This results in a delayed onset of sea-ice formation. In conclusion, this thesis contributes to an improved understanding of the Maud Rise oceanography and related drivers of polynya formation, by focusing on (1) large-scale forcing seen in climate models, (2) intermediate depth water mass interleaving and mixing processes and (3) mixed layer processes as a regulator to polynya occurrence.