

Internal gravity waves and mixing in the warming Arctic

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The Arctic is warming at rates well above the global average, and Arctic sea ice has declined dramatically over the past years. Reduced sea ice cover offers the possibility to increase the generation of internal gravity waves, by decreasing the ice-related drag on the tidal currents and by allowing for a larger wind power input into the ocean. At the end of their life cycle, internal waves become unstable and break, mixing the surrounding waters in the process and causing heat, nutrient, and density fluxes. Until now, the interior Arctic Ocean has been characterized by weak interior mixing, which is central to keeping the heat stored in the Atlantic Water at depth. Upon entering the Arctic Ocean, this relatively warm water subducts below a cold and fresh layer of water, which acts as an insulating barrier between this Atlantic Water heat reservoir and the sea ice. Stronger interior mixing associated with increased internal wave generation could erode this barrier to the extent that Atlantic Water heat melts Arctic sea ice from below, accelerating its decline at possibly dramatic rate.

To resolve the role of internal waves in the warming Arctic, state-of-the-art numerical ocean and coupled climate models are required. These models cannot resolve the small-scale turbulent mixing associated with internal wave breaking and hence rely on parameterizations. Typically in the Arctic context, these have been implemented rather crudely, involving constant values tuned to present-day observations. For the reliable modeling of past and future climate states, however, energy constrained parameterizations, which are based on the underlying physics and thereby avoid tuning to present-day conditions, are indispensable. In the framework of the DFG-funded Emmy-Noether group Artemics (Arctic internal wave energetics and mixing and their interdependence with sea ice in changing climate conditions), we will for the first time apply an energetically consistent mixing parameterization in the Arctic Ocean to elucidate the role of internal waves for the fate of Arctic sea ice. To this end, we will build on the internal wave model IDEMIX, which is the only operational framework to date that enables the consistent parametrization of different types of internal gravity waves. It successfully reproduces internal wave effects in numerical ocean models outside of the high-latitude environments. In this project, we will adjust IDEMIX to the specific conditions of the Arctic Ocean, where special environmental constraints and especially the impact of sea ice need to be taken into account for wave energy generation, propagation, and dissipation. Combining numerical modeling with observations, we will develop a representation of these interdependencies between waves and sea ice in IDEMIX that adjusts to the modeled climate conditions. The final goal is to apply this improved IDEMIX framework in transient climate change simulations to explore the role of internal waves in the Arctic Ocean, re-assessing, if necessary, the conclusions drawn from earlier, inconsistent mixing parameterizations, and answering many urgent open questions about the fate of Arctic Ocean dynamics and sea ice in our warming world.