Ice-ocean turbulent exchange in the Arctic summer measured by an autonomous underwater vehicle

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ABSTRACT: The first-ever observed horizontal profiles of summertime ice-ocean boundary layer fluxes were obtained using vertical water velocity, temperature, and salinity collected by an Autonomous Underwater Vehicle during the Surface Heat Balance of the Arctic Ocean (SHEBA) experiment of 1998. Scalars and their vertical fluxes, as well as vertical stability, varied in the horizontal direction with correspondence to changes in the overlying surface. In early summer, fresh meltwater was trapped at the upper ice surface and only entered the ocean through leads. A highly stable fresh layer was formed in the SHEBA lead, which eventually grew to depths greater than the mean draft of the local first-year ice. Near the end of July, a storm removed this layer via shear-generated turbulence, supercritical hydraulic flow speeds, and ice divergence. The mixed layer freshened and deepened at this time. Particularly strong fluxes were observed under and downstream of rough, ridged ice, and properties changed rapidly with distance downstream of leads. The location and signs of the fluxes are suggestive of a mechanism of instability in which fresh surface water is forced under salty water downstream of leads and/or ridges. Simulations from a two-dimensional unsteady model suggest that both mechanical forcing from ice topography and a dynamic instability near downstream lead edges may enhance vertical mixing, particularly when ice velocity is large. The horizontal variability in interfacial fluxes observed at SHEBA may explain the difference between the observed melt rates and those calculated using a bulk relationship because this relationship may not adequately parameterize the large lateral heat fluxes at lead edges and basal heat fluxes under ridge keels.