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Turbulent mixing under ice cover and its effect on ice thickness

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Ice cover on polar and temperate lakes creates seasonally developing boundary layer at the ice base with specific features: fixed temperature at the solid boundary and stable density stratification beneath. Turbulent transport in the boundary layer affects the ice growth and melting conditions at the ice-water interface, especially in large lakes and marginal seas, where large-scale water circulation can produce highly variable mixing conditions.
To quantify these effects, we develop a parameterization of the water-ice heat flux based on the Kolmogorov microscales involving the dissipation rate of the turbulent kinetic energy (TKE). The parameterization was tested against direct estimations of turbulent mixing and ice-water heat fluxes in Lake Baikal and small (sub-)polar lakes. The TKE dissipation rate was derived from spectra of velocity fluctuations at a single point under ice, and from correlations (structure functions) of current velocities along vertical profiles in the boundary layer. The TKE dissipation rate varied withinn 2 orders of magnitude. In Lake Baikal, the intensity of mixing was closely connected to mean speeds of the under-ice currents. In small lakes, appreciable turbulence at the ice-water boundary was produced mainly by lake-wide standing barotropic waves (seiches). The water-ice heat flux unambiguously followed the proposed scaling In the whole range of the observed variability. The resulting heat flux from water to ice significantly accelerated melting rate at the ice base.
The outcomes of our analysis open a direct way for a general parameterization of the boundary heat (and mass) flux at the ice base as a function of the boundary layer turbulence. The TKE dissipation rate is a prognostic variable in many turbulence models and can be directly implemented for boundary fluxes parameterizations. Besides, a significant progress has been made during the last decades in methods of the turbulence dissipation measurements allowing its long-term registration in situ and using this data for quantification of boundary-layer processes hardly measurable by other methods.