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Stable boundary-layer regimes observed in Arctic during SHEBA experiment

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Structure of the stable boundary layer (SBL) in the Arctic is discussed based on measurements made during the Surface Heat Budget of the Arctic Ocean experiment (SHEBA). Turbulent and mean meteorological data collected at five levels on a 20-m tower over the Arctic pack ice during 11 months of measurements cover a wide range of stability conditions, from the weakly unstable regime to very stable stratification. According to our SHEBA data, stratification and the Earth's rotation control the SBL over a flat rough surface. Different SBL regimes are described in terms of the Monin-Obukhov stability parameter (z/L), the Ekman number (Ek) that quantifies the influence of the Earth's rotation, and the bulk Richardson number (Rib) that determines the intensity of the turbulence. These three non-dimensional parameters govern four major regimes which we identify as follows: (i) surface-layer scaling regime (weakly stable case), $z/L < 0.1$ ($Ek >> 1$ and $Rib << 0.2$); (ii) transition regime, $z/L > 0.1$ and $Ek > 1$; (iii) turbulent Ekman layer, $Ek < 1$ and $Rib < 0.2$; and (iv) intermittently turbulent Ekman layer, $Rib > 0.2$ (supercritical stable regime). Traditional Monin-Obukhov similarity theory works well in the weakly stable regime. As stability increases, the near-surface turbulence is affected by the turning effects of the Coriolis force (the turbulent Ekman layer). In this regime, the surface layer, where the turbulence is continuous, may be very shallow (less than 5 m). Turbulent transfer near the critical Richardson number is characterized by small but still significant heat flux and negligible stress. The supercritical stable regime where the Richardson number exceeds a critical value 0.2 is associated with collapsed turbulence and the strong influence of the Earth's rotation even near the surface.