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Characteristics of the Surface-based Turbulent Layer over Three Polar Winters at Dome C, Antarctica as observed by Sodar

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Characteristics of atmospheric turbulence in the stable boundary layer are not well understandable so far. A long-term experiment was performed at Concordia station (Dome C, Antarctica) in 2012, 2014 and 2015 to study the spatial and temporal structure of turbulence in very strong static stability in extremely low temperatures as those observed in winter. Significant thermal turbulence often occurs and extends up to several tens of metres in spite of: (i) the large static stability due to strong temperature inversions extending up to 100–600 m, with a total inversion strength reaching 20–40°C at very low temperatures; (ii) the absence of orographic features; (iii) the absence of the diurnal cycle of solar heating. The thermal turbulence pattern was examined using an advanced high-resolution sodar starting from the lowest few metres with a vertical resolution better than 2 m. Sodar observations were complemented by in situ measurements: a weather station and radiometers near the surface, temperature and wind-speed sensors at six levels on a 45-m tower, and radiosondes. The depth of the surface-based turbulent layer (SBTL) at Dome C during the whole winter was directly measured experimentally for the first time. It has an average depth of $\approx$ 25 m, varying from a few to several tens of metres, against an inversion-layer depth of $\approx$ 350 m. Relationships between the depth of the SBTL and atmospheric parameters such as temperature, wind speed, longwave radiation, Brunt–Väisälä frequency and Richardson number are shown. The SBTL under steady weather conditions was analyzed and classified into three prevailing types: 1) a very shallow layer with a depth < 15 m; 2) a shallow layer of depth 15–70 m with uniform internal structure; 3) a shallow layer of depth 20–70 m with waves. Meteorological conditions (including the shape of temperature and wind speed profiles) accompanying the considered SBTL types are determined and described. Wind speed was found to be a relevant meteorological variable influencing the formation and development of the STL. Wave activity in the SBTL is observed during a significant portion of the time, with sometimes regular (with periodicity of 8–15 min) trains of Kelvin–Helmholtz billow-like waves occurring at periods of 20–60 s, and lasting several hours. The main characteristics of the wavelike structures (shape, spatial and temporal scales) were determined.
Our observational data provide an experimental basis necessary for improvement, developing and verification of advanced modelling and theoretical approaches to deep understanding of the features of turbulence under stable stratification conditions.