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Problems of measurements of weak turbulence with ultrasonic anemometer-thermometers

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Accurate measurement of turbulent parameters under weak turbulence at low temperatures in the atmospheric stable boundary layer still remains a challenge, especially in polar regions. The main instruments to measure atmospheric turbulence parameters are three-dimensional ultrasonic anemometer-thermometers (hereinafter, sonics). Many studies evidence that in some cases the behaviour of spectra of wind speed and temperature looks unreliable. We compared devices of two renowned manufacturers: Gill Instruments Ltd and Metek Scientific HmbH; one model of Gill HS50, and two models of Metek USA-1 and uSonic-3. Measurements were carried out at Concordia station (Dome C, Antarctica), during the summer period, and in a suburban area of Rome (Italy) in all seasons. The behaviour of turbulence spectra at the higher frequency range (in the inertial subrange) under stable stratification was carefully analysed with different approaches and compared with previous results. Relationships between thermal and mechanical turbulence intensities under different stability conditions were considered. The comparison showed both advantages and disadvantages of different sonics depending on weather conditions and a field of application.

1) USA-1 and uSonic-3 by Metek generate elevated electronic quasi-white noise signal in the frequency range > 1 Hz that distorts spectrum slopes and structure parameter estimates (especially for temperature) under weak turbulence conditions. So, it is not possible to measure accurately spectra at frequencies within the inertial subrange, and, accordingly, the wind and temperature structure parameters CV2 and CT2 for weak turbulence. However, it has essential advantage since keeps stable correct functioning under low temperatures up to –40°C and resistance to extremely low temperatures up to –80°C. A built-in heater allows measurements of the mean wind components up to –50°C, however, increases the intensity of turbulent fluctuations.

2) As for HS50 Gill, it is capable to provide accurate measurements of weak-turbulence parameters in the inertial sub-range even under neutral and very stable stratification conditions. However, it has some inherent limitations, as follows: (i) measured sonic temperature is not correct (overestimation of 2-6°C) at all conditions; (ii) sometimes non-stable measurements of the sonic temperature (jumps, non-regular low-frequency trends, spikes in a random way) occur at low temperatures (less than –30°C), that can distort flux estimates and create ambiguities when studying sub-mesoscale phenomena; (iii) the manufacture prohibits its operation at temperatures lower than –40°C; (iv) the absence of correct measurements when the flow direction is around 180 °in reference to the head direction.

Also, different calculation methods of turbulent parameters (eddy-covariance and spectral approaches) were verified and compared for different stability conditions. Summarizing, the proper choice of the instrument and calculation approach depends on what variables and characteristics of turbulence we want to determine.