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Acoustic remote sensing study of the influence of internal gravity waves on the lower atmosphere

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The main objective of the presented study is to contribute to the investigation of the effects of internal gravity waves (IGW's) in the lower atmosphere by using a combination of different acoustic remote sensing methods. For this study especially the stably stratified boundary layer was of interest, since IGW's could provide an important vertical mixing mechanism therein.

The IGWs induce mesoscale wind speed and temperature fluctuations in the stable atmospheric boundary layer (ABL) with periods from a few minutes to a few hours, and with horizontal scales from hundred metres to a few kilometres. These fluctuations cause the corresponding fluctuations of the parameters of acoustic signals propagating through the ABL, such as a travel time, amplitude, and the angles of arrival of the acoustic signals.

In this study, the influence of the IGW's on the time variation of the parameters of acoustic signals was detected by means of a cross-coherence analysis of the time series for these parameters measured by a net of spatially distanced receivers. The three measurement campaigns were carried out during a period from 2004 to 2005. Two single experiments of the two cooperating groups, Oboukhov Institute of Atmospheric Physics (OIAP) and Leipzig Institute of Meteorology (LIM) were performed in Melpitz (Germany) and Zvenigorod (Russia) as well as one joint experiment with both cooperation partners in Zvenigorod.

During the experiments, the acoustic pulse sounding method from the OIAP group and the acoustic travel time tomography of the LIM group was employed in combination with other acoustic remote sensing methods (SODAR, RASS) used for monitoring the state of the lower atmosphere.

When using an acoustic pulse sounding, the pulse source (detonation generator) and recievers were positioned at distances greater than 2 km, so the travel time fluctuations were measured along refracting ray paths, whose turning points may have altitudes from 50 m to 300 m. For the acoustic travel time tomography the distances between a source and the recievers were not greater than 300 m, therefore the sound travel times were measured along almost horizontal straight ray paths, connecting each pair source-receiver.

By analysing the time-series of the wind speed and travel time fluctuations, several dominant periods were found in the retrieved coherences and phase spectra, which allowed us to determine the spatial characteristics of the IGW's (phase speeds and wavelengths) observed during the campaigns. The periods range from 2 to 30 minutes and the mean slopes of the distributions of observed spectral density of travel time and horizontal wind speed fluctuations over frequencies were close to those predicted theoretically, i.e. to the slope -2.

The discrete temporal and spatial scales found in the measured fluctuations are typical for the ducted IGW's in the wave guides formed by the temperature and wind stratification in the lower atmosphere.