Geophysical Research Abstracts
Vol. 15, EGU2013-8704, 2013
EGU General Assembly 2013

Numerical Simulation of Turbulence Collapse and Intermittency in an SBL

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Direct numerical simulation of a turbulent Ekman layer is used to investigate some aspects of a planetary boundary layer under the influence of stable stratification. In particular, we study bulk properties of the flow under atmospheric conditions in which the flow relaminarizes partly, i.e. it is globally intermittent, or completely. The physical model depends on two non-dimensional parameters: (1) a Reynolds number determining the bulk shear and (2) a Froude- or Richardson number characterizing the stratification. In our study, we fix the Reynolds number and vary the stratification over an interval that covers from neutral conditions to very stable conditions, the latter mimicking the turbulence collapses sometimes observed in arctic wintertime or nocturnal boundary layers.

The weakly, intermediately and strongly stably stratified regimes of turbulence known from observations, modelling as well as theoretical considerations are reproduced in the simulations. In the very stable regime, spatio-temporal intermittency emerges on rather large spatial but small temporal scales if a sufficiently large domain is used. Qualitatively, the spatio-temporal patterns of intermittency in the wall-region resemble those observed in turbulent channel flows over a wide range of stratifications and Reynolds numbers. Quantitatively, however, we show that, with the rotational effects considered here, the arrangement of those patterns is linked to the external intermittency in the outer layer that is also present in a neutrally stratified reference case. These results suggest that – through the establishment of large-scale modes – the rotation of the wind in Ekman flow plays an important role for the structure of global intermittency. Hence, findings from non-rotating geometries should be complemented with rotating configurations.