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CURRENT CHALLENGES IN MODELLING THE STABLE BOUNDARY LAYER IN WEATHER AND CLIMATE MODELS – CONTRIBUTIONS FROM A LAB EXPERIMENT IN THE CNRM-GAME STRATIFIED FLUME

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Résumé :

The atmospheric boundary layer undergoes an evident diurnal cycle. During daytime shortwave radiation heats the surface and convectively generated turbulence heats the near surface air. On the contrary, at night longwave radiative cools the surface and a stably stratified boundary layer (SBL) develops. In stable stratification under strong winds, mechanically produced turbulence is stronger than buoyancy destruction of turbulence, and turbulence remains the main driver of the SBL. However, under low wind speed, turbulence dies out and other processes take over in a natural way, i.e. (orographically generated) gravity waves, intermittent turbulence, drainage flows, radiation divergence, etc. This multiplicity of processes has hampered parameterization development for the stable boundary layer in weather and climate models. As a result, these models typically show relatively large 2m temperature biases at night and e.g. for the Arctic climate (up to 8 K). Moreover the 10m wind speed is overestimated, while the nocturnal low level jet is estimated to weak and too high in altitude. These deficiencies directly affect end user applications in wind energy engineering, transportation, agriculture. Part of the problem is the lack of understanding of the turbulent transport over a wide range of stability. It appears that large scale NWP models perform best on the large scale when more turbulent transport is allowed in the SBL than can be justified from field experiments. However, atmospheric field measurements are often hampered by lack of basic assumptions behind turbulence theories, e.g. stationarity, homogeneity, and reproducability. The CNRM-GAME stratified flume offers the possibility to control stratified flows in terms of stability, flow speed and reproducability. Moreover, the stationarity is reached due to the relatively large dimensions of the flume.
This presentation will give an overview of the processes in the SBL, and summarize their relevance in different large scale flow regimes, and the current understanding of each process. Finally, a substantial part considers the results of the HYDRALAB-III stratified flume experiment, in which a stable boundary layer has been developed by towing a plate at different speeds through water for a range of stratifications. The non-dimensional turbulent variances and momentum fluxes are related to stratification in the flow expressed by the Richardson number.

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