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PREFACE

GEWEX ATMOSPHERIC BOUNDARY-LAYER STUDY (GABLS) ON STABLE BOUNDARY LAYERS

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The Global Energy and Water Cycle Experiment (GEWEX) is a program initiated by the World Climate Research Programme (WCRP) to observe, understand and model the hydrological cycle and the related energy fluxes in the atmosphere, at the land surface and in the upper oceans. Consequently the atmospheric boundary layer is an important aspect of the energy and water cycle, which has become crucially important in this new age of coupled atmosphere-land surface-ocean modelling. As such, in 2001, the GEWEX Atmospheric Boundary-layer Study (GABLS) was established. The overall objective of GABLS is to improve the understanding and the representation of the atmospheric boundary layer in regional and large-scale climate models. Such activity is important in itself and also very relevant for other activities in GEWEX, and more generally for the activities within WCRP and the International Geosphere-Biosphere Program (IGBP).

Given the state of art, it was decided to place the first focus of GABLS on the representation of the stable atmospheric boundary layer (SBL) in models of various complexity (Holtslag et al., 2003). Stable conditions prevail in the atmospheric boundary layer over the continental land and polar regions during night, and may occur during the whole day in wintertime. It appears that much of the warming predicted by climate models occurs during such stable atmospheric conditions (see, for example, Figure 9.10, pages 546–548 in Cubasch and Meehl, 2001). Consequently the representation of the SBL is very relevant for proper modelling of regional and global climates.

At the same time it is realized that the current parameterisation of the SBL is still rather poor, and that progress is slow (e.g. Beljaars and

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Holtslag, 1991; Holtslag and Boville, 1993; Beljaars and Viterbo, 1998). Unfortunately regional and global climate models show great sensitivity to the model formulation of mixing in stratified conditions. As an example, Viterbo et al. (1999) studied the vertical mixing in the ECMWF model in stable conditions. From two model runs with the same forcing conditions, but with (slightly) different stability functions in the mixing scheme, they noticed that differences in the mean winter temperatures at a height of 2 m between the two model runs can be as large as 10 K over continental areas.

In addition, King et al. (2001) found similar results between model runs for the winter climate over Antarctica. Also over Europe, it was found that significant differences are present between the 2-m temperatures of a 30-year regional climate simulation with observations for present day winter climate (e.g., Lenderink et al., 2003). It also appears that the magnitude of the diurnal temperature cycle is typically underestimated over land. These results are to a large extent influenced by the boundary-layer scheme in stable conditions, though other atmospheric processes (clouds and radiation) and land-surface processes obviously also play a role (Viterbo et al., 1999).

Climate models and weather forecast models need to make an overall representation of the smaller-scale boundary-layer and near-surface processes. The relevant small-scale processes in the stable boundary layer are: clear air radiation, drainage flow, generation of gravity waves and shear instabilities, fog and dew formation, the occurrence of a low-level jet, and generation of discontinuous/intermittent turbulence. In addition, the phenomenology of the stable atmospheric boundary layer is quite diverse, e.g. shallow and deep boundary layers with continuous turbulence through most of their depth, and boundary layers with intermittent turbulence or even laminar flow (see also, papers in previous special volumes of Boundary-Layer Meteorology on the stable boundary layer; e.g. volume 90, number 3 in 1999).

The small-scale processes influence the vertical and horizontal exchange of quantities between the surface and the atmosphere as well as the mixing in the atmosphere on a variety of scales. The overall representation of these processes and the related ‘spatial averaging’ is highly non-trivial due to the fact that there are many non-linear processes, and also because the environment has often a heterogeneous character on a variety of scales (Mahrt, 1987; Mahrt and Vickers, 2003). This normally is a motivation to allow for ‘enhanced-mixing’ in models as compared with tower observations (e.g., Beljaars and Holtslag, 1991). Another reason for having enhanced mixing is to prevent the models reverting to a decoupled mode, which in turn may lead to runaway characteristics close to the ground (Derbyshire, 1999; Steeneveld et al., 2006). In addition, it is known that turbulent mixing in stratified flow has an inherent non-linear character and may, as such, trigger positive feedbacks. These positive feedbacks, in turn, may cause unexpected transitions between totally different SBL regimes (e.g., Delage, 1997; Derbyshire, 1999; Van de Wiel et al., 2002).

Within GABLS, a rather simple case was selected as a benchmark to review the state of the art and to compare the skills of single column (1D) models (Cuxart et al., 2006) and large-eddy simulation (LES) models (Beare et al., 2006). The papers in this special volume report on these findings. The case studied is based on the results originally presented by Kosovic and Curry (2000). As such the stable boundary layer is driven by an imposed, uniform geostrophic wind, with a specified surface-cooling rate over (homogeneous) ice. Overall it turns out that, with the same initial conditions and model forcings, the results of the LES models are surprisingly consistent (Beare et al., 2006). As such the LES outputs can serve as suitable reference for the 1D models. Moreover, the results of the LES models are consistent with field observations and local scaling ideas (Nieuwstadt, 1984), at least for the case studied here.

In contrast, the 1D models indicate a large range of results for the mean temperature and wind profiles as well as for the heat and momentum flux profiles (Cuxart et al., 2006). As expected the models in use at operational weather forecast and climate centres typically allow for enhanced mixing, while typical research models show less mixing, more in agreement with the LES results for this case. Because of the enhanced mixing in weather and climate models, these models tend to show too strong surface drag, a too deep boundary layer, and an underestimation of the wind turning in the lower atmosphere. However, by decreasing the mixing and surface drag, a direct impact on the atmospheric dynamics ('Ekman pumping') is noted (e.g., Beljaars and Viterbo, 1998). Consequently, cyclones may become too active, corresponding with too high an extremes for wind speed and for precipitation. When the models with enhanced mixing are coupled to a surface energy balance, they also produce a too high surface temperature (e.g., Steeneveld et al., 2006).

Given the latter arguments and the current GABLS findings, there is still a clear need for a better understanding and a more general description of the atmospheric boundary layer under stably stratified conditions in atmospheric models for weather and climate. This may also benefit air quality and earth system studies. The seven contributions in this issue of Boundary-Layer Meteorology aim to provide useful information in this direction, but can only be seen as a first step. Future activities within GABLS will focus on the full diurnal cycle and a coupling of the boundary layer to the land surface (see http://www.gewex.org/gabls.htm and related links) for future activities.

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