Project: **1096**

Project title: **Turbulence resolving simulation of atmospheric boundary layer processes**

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The goal of this project is to improve the representation of the ABL in weather and climate models with a focus on: 1) scale-adaptivity, and 2) complex-terrain boundary layers. For this purpose experiments on Mistral were performed according to the proposal of the project. Here we present the substantial results following from the simulations.

a) The development of a scale-adaptive unified parametrization for ABL turbulence and boundary-layer clouds

To design a scale-adaptive parametrization, we first need to understand how the statistical properties of the ABL change with the size of the analysis domain. We intend to parametrize shallow convection in a scale-adaptive way with the two-energies turbulence scheme (Bastak Duran et al., 2018) coupled to the assumed PDF scheme (Golaz et al., 2002). The assumed PDF scheme requires as input a set of statistical moments of the flow. Only one of these inputs is a third order moment, the third order moment of the vertical velocity. Because it is a higher order moment, its estimation has the biggest error among all the inputs. It is also the most sensitive parameter of the scheme. Hence, it is important to know what are the typical values of the skewness of vertical velocity in shallow convection. It is expected that the skewness changes with the size of the sub-domain (extremes have a stronger influence in a smaller region). This dependence can then indicate how the skewness should change with the resolution in an NWP model and hence what should be the proper scale-dependent input for the assumed PDF scheme.

To study these properties, we performed large eddy simulations using the MicroHH model. The scale dependence of the processes was studied with the help of on-line statistics with high temporal resolution for sub-domains of varying size. As can be seen from Fig. 1, the standard deviation between sub-domains of skewness increases with decreasing size of the sub-domain (this corresponds to an increase of the resolution in an NWP/climate model) in the whole vertical profile for both cases studied.

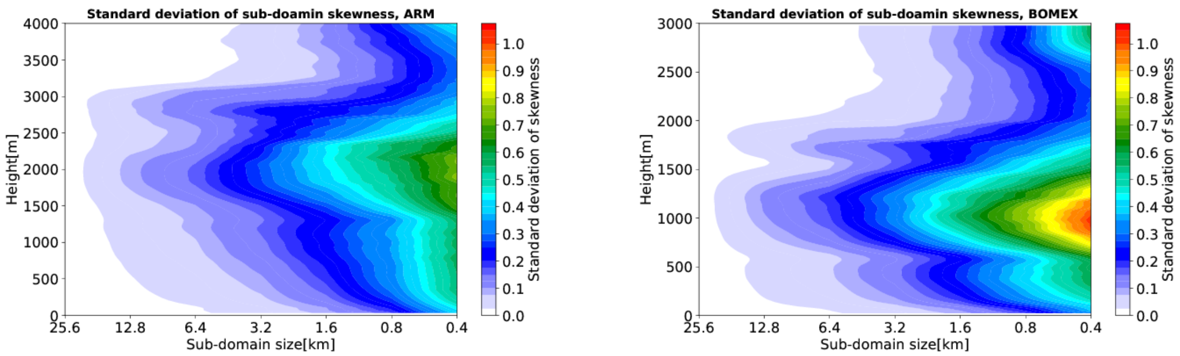

Fig.1: Dependence of the standard deviation between sub-domains of skewness on sub-domain size for two case studies.

b) The analysis of complex-terrain ABLs and the development of suitable subgrid-scale (SGS) models

<u>ICON-LES the stably-stratified atmosphere</u>

An idealized experiment was designed to explore the capabilities of ICON-LES by resolving turbulence processes in the stably-stratified atmosphere. The GABLS experiment (Beare et al., 2006), a well-known benchmark for LES simulations, was selected as a starting point. The spatial resolution for the experiment is set to 12 m in both horizontal and vertical direction. First results for this experiment are now available. The model evidenced a good performance when it is compared with the results reported in Beare et al., (2006). To extend this analysis, we plan to perform a new set of simulations with an increased spatial resolution (up to 3.125 m).

DNS simulations using MicroHH of the Stable Boundary Layer (SBL) over idealized topography

The influence of small-scale orography has been examined in Direct Numerical Simulation experiments using microHH. Figure 2. shows the zonal wind component in a stable stratified boundary layer flow forced by a zonal stream velocity of 30cm/s.

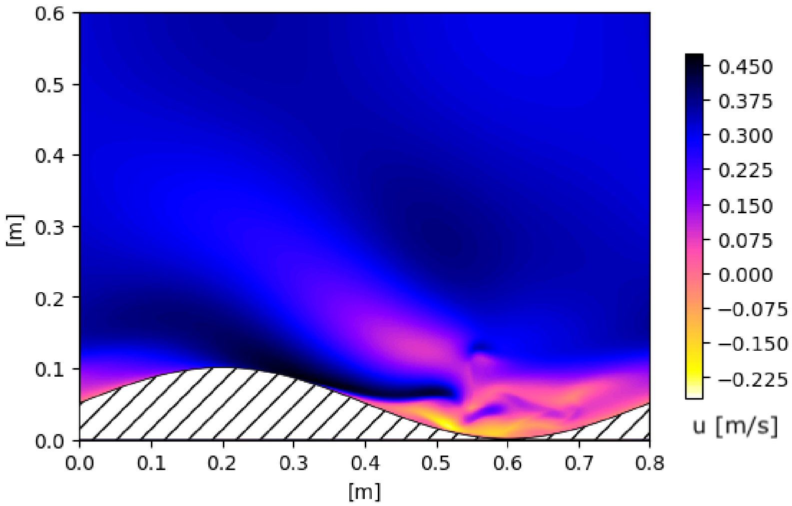

Fig.2: Zonal wind component in a stable stratified boundary layer flow over idealized topography.

c) The improvement of fog forecasting over complex terrain

COSMO was setup to simulate a radiative-fog scenario from the LANFEX (Boutle, 2018) experiment. This involved horizontal grid sizes of ~4 m and the simulation of a SBL structure conducive to fog formation (to our knowledge, COSMO has not been tested at this limit of grid sizes for stable cases). Upon finding that COSMO-LES cannot generate a suitable SBL structure for LANFEX, we decided to simulate the GABLS-1 (Beare et al., 2006) test case in order to isolate the issues surrounding turbulence, dynamics, and, their interactions within COSMO, without the additional complexities of microphysics and radiation. We found that the default turbulence scheme of COSMO forces the flow to laminarize. Upon deactivation of the SGS turbulence scheme, the simulated flow evolution is closer to the other LES models. Next, we incorporated the Samgorinsky scheme from scratch into COSMO. However, while the Smagorinsky scheme, in itself, is sensitive to the Smagorinsky constant as expected, it is still unable to extract the right amount of energy from the resolved flow. This impacts the SBL structure, especially around the middle of the SBL. The signature of this can be seen in Fig. 3 in the potential temperature and the resolved potential temperature variance when compared to LES simulations from other models (Beare 2006).

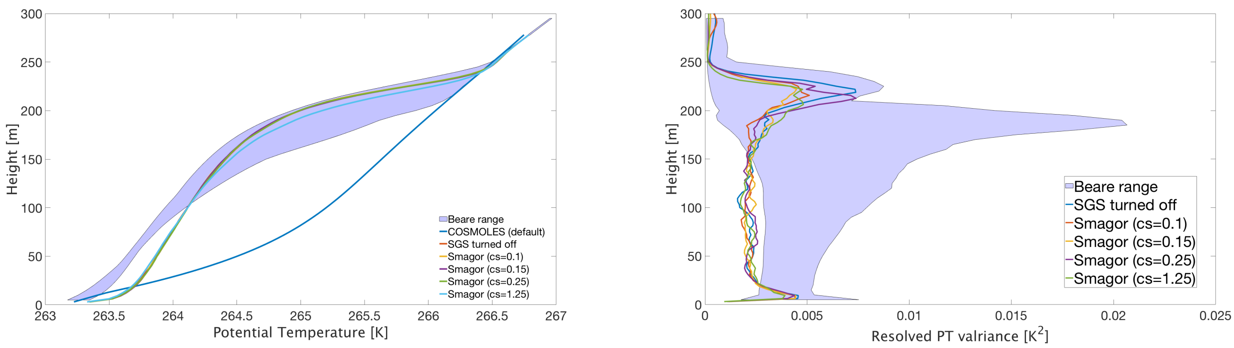

Fig. 3: Profiles of the potential temperature and the resolved potential temperature variance for different versions of COSMO-LES (default vs Smagorinsky implementation with different values for cs).