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Assessing a planetary boundary layer scheme by using the GABLS1 experiment in a single-column version of the global model developed based on potential vorticity

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Determining the accuracy of a hydrostatic weather forecast model in representing atmospheric phenomena is a complex process involving various considerations and test cases. This study delineates an objective assessment of a planetary boundary layer scheme based on turbulent kinetic energy in a single-column version of the innovative atmospheric general circulation model developed at the University of Tehran, which is called UTGAM. Single-column models provide simple frameworks to investigate the fidelity of the simulated physical processes in the atmospheric models. Dependable parameterization of the boundary layer processes has significant impacts on weather forecasts. Specifically, an ongoing issue for the operational hydrostatic models is their deficiencies in the accurate representation of the unresolved processes in stably stratified conditions.

We have utilized the first GABLS intercomparison experiment set up as a simple tool to evaluate the diffusion scheme in the UTGAM. Two different sigma-theta and sigma-pressure single-column grid staggering combined with 33 and 14 vertical levels below 3 km height have been used for the low- and high-resolution simulations. The GABLS1 Large Eddy Simulation (LES) results have been used as a benchmark for comparison. The diffusion scheme explored here is the same as the one in the ECHAM model which has been adapted for use in the UTGAM.

Results depict subtle nuances between the sigma-theta and sigma-pressure coordinates in intercomparison between the low and high vertical resolutions separately, which are more apparent in the lower vertical resolution. Nevertheless, it seems that the diffusion processes have been simulated a bit more accurately in the high-resolution sigma-pressure vertical coordinate. The boundary layer scheme in the UTGAM analogous with most of the operational models in the GABLS1 intercomparison experiment overestimate the diffusion coefficients of momentum and heat. The wind profile with height depicts maxima that are higher than the corresponding LES profile. It is inferred that the scheme mixed momentum over a deeper layer than the LES, but the simulated wind profile is better compared to the other operational models in GABLS1. Considering the vertical profiles of potential temperature revealed that the amount of heat mixing is not suitable in this experiment and causes a negative bias in the lower part of the simulated boundary layer. The simulated amounts of surface friction velocity have proved significant differences with the LES results in all separate experiments. However, the latter large amounts seem unlikely to have a detrimental effect on forecast scores in the operational model. Moreover, the sensitivity of the scheme to the lowest full-level has been partially explored. Decreasing the lowest full-level height concurrent with increasing the vertical resolution exerts a modest influence on the simulation of the boundary layer processes. All the results confirm notable improvements by increasing the vertical resolution in both sigma-theta and sigma-pressure coordinates.

Keywords: Simulation, GABLS1, stable boundary layer, vertical coordinate, diffusion coefficients, UTGAM