A scale-aware PBL scheme: for the unified simulation in mesoscale and global circulation models

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With the development of high performance supercomputers, kilometer- or sub-kilometer-scale numerical simulations have been realized. In the past, turbulence is well resolved by three-dimensional (3D) large-eddy simulation (LES) at very fine grid sizes (10~100 m) and for grid sizes greater than 2 km, one-dimensional (1D) planetary boundary layer (PBL) parameterizations represent sub-grid turbulence in the PBL. When it comes to kilometer- to sub-kilometer-scale grid sizes, neither 3D LES nor 1D PBL parameterization perform appropriately, called the "Gray zone". This study readapted the turbulence mixing length in the UW PBL parameterization by adding a partition function which is related to the horizontal resolution and PBL height. The developed UW parameterization (UWnew) and several other 1D PBL schemes were applied to the simulation of an ideal convective boundary layer at "Gray zone" scales using WRF model.

The results show that, in terms of the profiles of the area mean values and sub-grid heat/momentum flux, scale-aware UWnew and ShinHong schemes perform the best at "Gray zone" scales among all the schemes (including UWnew, UW, ShinHong, MYNN2.5, YSU, BouLac). And UWnew scheme shows more rational results in the PBL simulation compared with UW scheme. To specify the performance of UWnew scheme in the simulation at "Gray zone" scales, four simulations with different horizontal resolutions were launched using UWnew and UW schemes. In the case of "Gray zone" scales, the profiles of sub-grid heat/momentum flux from the UWnew simulation is smaller than that of the UW scheme. This is mainly resulted from the reduced turbulent heat/momentum exchange coefficient values in the PBL. The weakened vertical flux confirms that the UWnew scheme improves the simulation of the physical process at "Gray zone" scales in which the process is partly resolved and partly parameterized.

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