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Evaluation of PBL Parameterizations in WRF at Sub-Kilometer Resolution: Turbulence Statistics in the Convective Boundary Layer

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Evaluation of the planetary boundary layer (PBL) parameterization up to the present time has focused on profiles of mean and parameterized vertical flux, since the parameterization has been developed for horizontal resolution that cannot resolve any turbulence in the PBL. Meanwhile, recent increase in computing power has been allowing numerical weather prediction at horizontal resolution finer than 1 km, at which kilometer-scale large eddies in the PBL are partly resolvable. In this study, the performance of five PBL parameterizations in the Weather Research and Forecasting (WRF) model is evaluated at sub-kilometer resolution. The evaluation focuses on resolved high-order turbulence statistics, given that modeling at the high resolution is aimed at improving the simulation of resolved fields. The five parameterizations include four nonlocal PBL schemes – the Yonsei University (YSU), Asymmetric Convective Model 2 (ACM2), Eddy Diffusivity Mass Flux (EDMF), and Total Energy Mass Flux (TEMF) schemes, and one local scheme – Mellor-Yamada-Nakanishi-Niino (MYNN) level 2.5 model.

Key findings are as follows. 1) None of the PBL schemes are scale-aware. Instead, each PBL scheme has its own best performing resolution in parameterizing subgrid-scale (SGS) vertical transport and resolving eddies, and the resolution appears to be different between heat and momentum. 2) All the selected PBL schemes reproduce total vertical heat transport well, as resolved transport compensates defects of SGS transport. This interaction between the resolved and SGS transports is not found in momentum transport. 3) The local PBL scheme maintains a weakly stable temperature profile in the upper PBL, which was not accomplished by coarser-resolution simulations. 4) The best schemes in simulating mean, energy spectrum, and vertical-velocity histogram, i.e. the first-, second- and third-order statistics, do not coincide.