A three dimensional PBL parameterization to improve wind forecasting at sub-kilometer scales

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Abstract

As a part of the Wind Forecast Improvement Project II, we are developing a planetary boundary layer parameterization that accounts for both vertical and horizontal turbulent mixing (three dimensional mixing). The 3D-PBL parameterization has been implemented in the Weather Research and Forecasting model. The parameterization has been compared with a standard PBL parameterization that only accounts for vertical mixing (one dimensional mixing). The comparison focuses on a case study with heterogeneous surface flux. Results indicate that accounting for the horizontal turbulent fluxes in our 3D-PBL parameterization is necessary to reproduce the theoretical solution at sub-kilometer scales.

Keywords: *Wind, PBL, three-dimensional turbulent mixing, WRF*

Extended Abstract

Numerical weather predictions (NWP) models are being run at sub-kilometer horizontal grid spacing. However, NWP models use planetary boundary layer (PBL) parameterizations that only account for one-dimensional (1D) mixing resulting from vertical gradients in vertical fluxes. Hence, the 1D PBL parameterizations assume statistically homogeneous turbulent motions in the horizontal. Although a convenient assumption for grid spacing of several kilometers, assuming horizontally homogeneous turbulence motions no longer holds at sub-kilometer grid spacing. Hence, to improve wind forecasting at sub-kilometer scales we propose to account for the horizontal gradients in turbulent fluxes in our three-dimensional (3D) PBL parameterization (Kosović and Jimenez, 2015; Jimenez and Kosović, 2016).

The 3D PBL parameterization also improves the mesoscale to microscale coupling. This results from accounting for the horizontal gradients in the turbulent fluxes which generates more realistic turbulence characteristics than the 1D PBL schemes in the transition from the mesoscale to the microscale (sub-kilometer scale). Hence, the 3D PBL parameterization can provide better boundary conditions to the miscroscale model.

The 3D PBL parameterization is based on the turbulence model developed by Mellor and Yamada (1982). Our implementation in the Weather Research and Forecasting (WRF, Skamarock 2008) model uses a pure algebraic model (level 2) to diagnose the turbulent fluxes. The divergence of these fluxes provides the tendencies of the resolved variables due to turbulent mixing.

The performance of this 3D PBL parameterization is compared to a standard 1D PBL parameterization in WRF (Nakanishi and Niino, 2009) and large eddy simulations (LES) in an idealized case. The case prescribes a surface heat flux heterogeneity in the North to South direction. Initially the wind has only a meridional component (2 m/s). Hence, the solution is homogeneous in the along-wind direction. The evaluation focuses on the performance of the 3D PBL and 1D PBL schemes, run at 200 m of grid spacing, to reproduce this solution and the LES results. It will be shown that accounting for the horizontal turbulent fluxes in our 3D PBL parameterization is necessary to ensure the homogeneous along-wind solution at sub-kilometer scales (Fig. 1).

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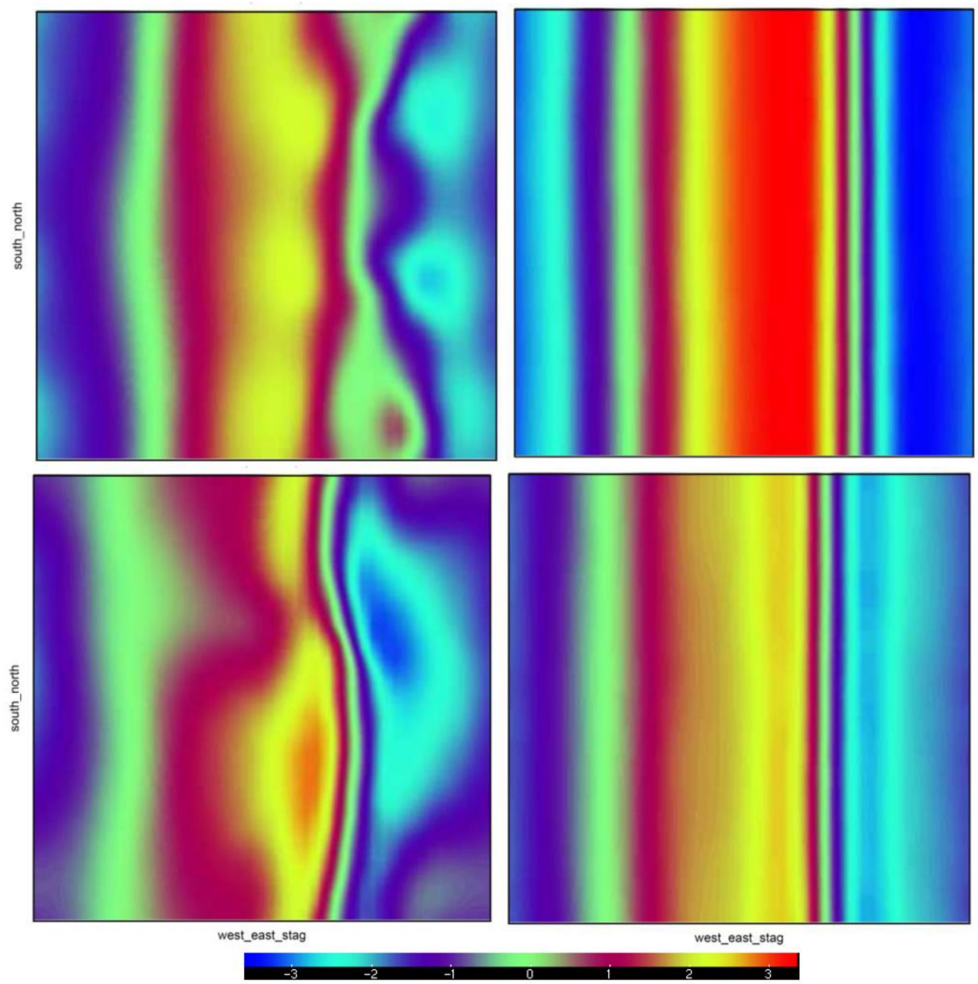

Figure 1: Zonal wind at level 10 (~250 m above ground level) after 1 hour of simulation (upper panel) and 3 hours of simulation (lower panel) using the 1D PBL (left) and the 3D PBL parameterization (right).