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A Physically Based Horizontal Subgrid-scale Turbulent Mixing Parameterization for the Convective Boundary Layer in Mesoscale Models

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Compared to the representation of vertical turbulent mixing through various PBL schemes, the treatment of horizontal turbulence mixing in the boundary layer within mesoscale models, with O(10) km horizontal grid spacing, has received much less attention. In mesoscale models, subgrid-scale horizontal fluxes most often adopt the gradient-diffusion assumption. The horizontal mixing coefficients are usually set to a constant, or through the 2D Smagorinsky formulation, or in some cases based on the 1.5-order turbulence kinetic energy (TKE) closure. In this work, horizontal turbulent mixing parameterizations using physically based characteristic velocity and length scales are proposed for the convective boundary layer based on analysis of a well-resolved, wide-domain large-eddy simulation (LES). The proposed schemes involve different levels of sophistication. The first two schemes can be used together with first-order PBL schemes, while the third uses TKE to define its characteristic velocity scale and can be used together with TKE-based higher-order PBL schemes. The current horizontal mixing formulations are also assessed *a priori* through the filtered LES results to illustrate their limitations. The proposed parameterizations are tested *a posteriori* in idealized simulations of turbulent dispersion of a passive scalar. Comparisons show improved horizontal dispersion by the proposed schemes, and further demonstrate the weakness of the current schemes.