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A scale-aware subgrid mixing parameterization in an operational NWP model

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In mesoscale simulations with horizontal grid sizes considerably larger than the scale of energy containing eddies, the boundary layer is assumed to be horizontally homogeneous. It is common practice in mesoscale simulations to treat the vertical and horizontal diffusions separately. Conventional one-dimensional planetary boundary layer schemes are usually used to represent vertical mixing. Horizontal diffusion is usually treated by the deformation-based Smagorinsky closure. The horizontal diffusion becomes more important as the model's grid sizes approach the gray zone (e.g., subkilometer and kilometer). Using the Smagorinsky closure at gray zone resolutions may not be justified. In large-eddy simulations (LESs), the horizontal diffusion is usually represented by TKE-based closure, which is consistent with the vertical diffusion. But, the horizontal diffusion using the TKE-based closure may not be justified at gray zone resolutions either.
In this study, a series of real cases are carried out to study the sensitivities of convection statistics to the two horizontal diffusion parameterizations (Smagorinsky and TKE-based closures) in the Shanghai Meteorological Service (SMS) operational NWP model. Three aspects about horizontal diffusion parameterization are investigated: 1) The suitability of the Smagorinsky closure (that is usually used in mesoscale simulation) at gray zone; 2) The limitation of TKE-based horizontal diffusion (that is usually used in LESs) in the mesoscale simulation; 3) The justification of a pragmatic blending approach for the horizontal diffusion at gray zone resolutions in a newly developed scale-adaptive three dimensional TKE scheme.