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# Parameterization of the stable ABL in climate models: understanding the effects of stability, model resolution, and the need for excessively high turbulent diffusivities

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The parameterization of the stable atmospheric boundary layer is crucial to the overall performance of large-scale weather forecast and climate models. This problem is difficult mainly because, under stable conditions, atmospheric turbulence is damped by buoyancy such that small-scale mixing processes, anisotropy, or waves could become dominant. A long-standing issue concerning the parameterization of the stable boundary layer is that most operational climate models use schemes which significantly and deliberately overestimate turbulent mixing to parameterize the stable boundary layer. This overestimation is needed primarily to prevent climate models from reaching a surface radiative balance state where the land surface is decoupled from the atmosphere under very stable conditions. Although efforts towards a complete understanding of this issue indispensably involve the investigation of the interaction between a land model and an atmospheric model, a more fundamental question which does not involve the land atmosphere coupling is whether a parameterization scheme of the stable boundary layer based on the eddy diffusivity model is able to accurately capture the mean profiles of variables such as wind speed and temperature and the turbulent momentum and scalar fluxes, which are critical to the performance of weather and climate models. This question is raised considering that (1) such schemes ignore the change of direction of the velocity gradient and that (2) most climate models adopt a time step significantly larger than the time scale of turbulence and a resolution beyond the length scale of turbulence. The relevant questions we address in this presentation include: (1) Is a local eddy diffusivity model able to capture the dynamics of the stable ABL given the “correct” diffusivity values? (2) how do other factors such as time step, resolution and atmospheric stability affect the accuracy of eddy-diffusivity ABL closure schemes? (3) how, if at all, does this accuracy depend on whether the stable ABL is in an equilibrium steady-state or a transient developing state? These questions are investigated in this study using the single column climate model of the Geophysical Fluid Dynamics Laboratory (GFDL). Observational data and large-eddy simulations are used as references. The results indicate that (1) the local eddy diffusivity model is able to accurately capture the dynamics of the stable ABL as long as the “correct” diffusivity values are modeled. (2) A scheme using “short tail” stability functions as determined by several previous LES and observational studies produces better results than schemes using an artificially enhanced mixing through “long tail” functions. (3) Results are quite sensitive to the spatial and temporal resolutions of the single-column model; particularly; finer spatial resolutions in the climate model need to be paired with smaller time steps to obtain reasonable results. Otherwise the mean quantities and the turbulent fluxes will present sharp jumps in the upper portion of the stable ABL; (4) preliminary results in terms of atmospheric stability and transient ABL development indicate that these factors do have significant impacts on the accuracy of the closure scheme.