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Evaluating turbulent length scales from local MOST extension with different stability functions in first order closures for stably stratified boundary layer

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According to the Monin-Obukhov similarity theory (MOST), in the stratified surface layer of the atmosphere, the mean vertical velocity and scalars gradients are related to the turbulent fluxes of these quantities and to the distance z from the surface in a universal manner. The stability parameter $\zeta=z/L$, where L is the Obukhov turbulent length scale, is the only dimensionless parameter that determines the flux-gradient relationships. This imposes a dependency of the dimensionless velocity and buoyancy gradients on ζ in form of universal nondimensional stability functions for the surface layer. Over the decades a number of them were proposed and derived mostly from extensive field campaigns of measurements in the ABL. The stability functions differ from each other by both open coefficients and functional dependence on ζ. They have a limited range of applicability, which is often extended by incorporating the assumption about their asymptotic behavior.

A generalization of MOST by considering the dependence of the dimensionless gradients on the local stability parameter z/Λ in the framework of first order closures allows the extension of the universal stability functions from the surface layer to most of the ABL. However, because of applicability constraints, differences in the asymptotic behavior and in other implied assumptions, it is not immediately obvious, which set of stability functions will perform best. In this study we analyze a set of stability functions which are implemented in a uniform manner into a one-dimensional first-order closure. The latter applies a turbulent mixing length with generalized local MOST scaling which fits to a surface schemes employing corresponding functions for consistency. We use two numerical experiment setups accompanied with LES data for validation which correspond to the weakly stable GABLES1 case and to LES simulations of the very stable ABL based on measurements at the Antarctic station DOME-C (van der Linden et al. 2019). We also focus on the sensitivity of the 1D model results to coarser grids with respect to both the used surface flux schemes and the ABL turbulence closures since their are meant to be used in climate models because of numerical efficiency.

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