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An Evaluation of Algebraic Turbulence Length Scale Formulations using Budget-Based Diagnostics

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The most frequently used turbulence parameterizations in numerical weather prediction (NWP) and general circulation (GC) models are turbulence schemes with a prognostic turbulence kinetic energy (TKE). These turbulence schemes are strongly dependent on an ad-hoc quantity, the turbulence length scale. The turbulence length scale is used to parameterize the molecular dissipation of TKE and is also required for calculating the turbulence exchange coefficients. Traditionally, the turbulence length scale formulations do not take into account the transfer of TKE across scales, as they are designed for scales above the energy production range of the turbulence spectra. However, with computational power growing, it has become increasingly possible to simulate at scales within the energy production range, that is within the gray zone of turbulence. At resolutions within the gray zone, the cross-scale transfer of TKE needs to be taken into account in order to accurately represent the turbulence. For this purpose, a turbulence length scale diagnostic was developed that can be used for resolutions in the gray zone. This is achieved by calculating the turbulence length scale from the so-called effective dissipation rate, a combination of the cross-scale TKE transfer and the dissipation rate. The effective dissipation rate is estimated from the budget of the TKE using large-eddy simulation (LES) data. A similar approach can be used to calculate turbulence length scale from the budgets of scalar variances. This study makes use of three different turbulence length scale diagnostics based on: the TKE, the variance of the total specific water content, and the variance of the liquid water potential temperature. Four algebraic turbulence length scale formulations are evaluated using the turbulence length scale diagnostics as a reference. The evaluation of the algebraic turbulence length scale formulations is conducted for several idealized LES cases, simulated using the MicroHH model. These LES cases represent a variety of different atmospheric boundary layer conditions.