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Unified parameterization of turbulence and boundary layer clouds using the updated two-energies turbulence scheme

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The unified parameterization of turbulence and clouds in the atmospheric boundary layer is one of the challenges in current weather and climate models. An update of the two-energy turbulence scheme is presented, the 2TE+APDF scheme. The original version of the two-energy scheme is able to successfully model shallow convection without the need of an additional parameterization for non-local fluxes. However, the performance of the two-energy scheme is worse in stratocumulus cases, where it tends to overestimate the erosion of the stable layers. To alleviate this problem, we propose several modifications: an update of the stability parameter to consider local stratification, a more flexible computation of the turbulence length scale, and the introduction of the entropy potential temperature to distinguish between a shallow convection and a stratocumulus regime. In addition, the two-energy scheme is coupled to a simplified assumed PDF method in order to achieve a more universal representation of the cloudy regimes. The updated turbulence scheme is evaluated for several idealized cases and one selected real case in the ICON modeling framework. The results show that the updated scheme corrects the overmixing problem in the stratocumulus cases. The performance of the updated scheme is comparable to the operational setup of the ICON model, and can be thus used instead of the operational turbulence and shallow convection scheme in ICON. Additionally, the updated scheme improves the coupling with dynamics, which is beneficial for the modeling of coherent flow structures in the ABL, such as, for example, cloud streets.