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An improved parameterization of third-order moments in the COSMO numerical weather prediction model

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The present work aims at a better understanding and improvement of the turbulence scheme of the COSMO numerical weather prediction (NWP) model in convective situations. The COSMO model uses a 1.5-order turbulence closure following the Level 2.5 approach in the Mellor and Yamada (1982) notation. In this framework the only turbulence related prognostic variable is the Turbulent Kinetic Energy (TKE), the other second- and third-order moments are parameterized.

To achieve a better understanding of the turbulence scheme, the budget terms in the TKE equation are investigated separately for two case studies. First, an idealized dry convective case is studied and a COSMO single-column run is compared to large eddy simulation (LES) data. Second, a real-world dry convective case from the LITFASS-2003 measurement campaign is simulated with the (fully) three-dimensional COSMO model at 1 km horizontal resolution. The extensive LITFASS-2003 observational dataset as well as newly generated LES data are used for model validation in this latter case. All the TKE budget terms are derived both from measurements and the LES to evaluate the turbulence scheme of COSMO.

Results reveal that during convective conditions, the turbulent transport term in the TKE budget is too small if compared to measurements and LES data. A new parameterization of the length scale in the transport term can increase the TKE transport. This results in higher and more accurate TKE values near the top of the Planetary Boundary Layer (PBL) and an increased entrainment heat flux. As the new length scale parameterization uses the PBL height, this variable has first to be diagnosed from the COSMO model. Several methods are tested to calculate the PBL height from NWP outputs, and the bulk Richardson number is found to be the most reliable approach.

The improved turbulence parameterization is finally tested in an operational setting. At MeteoSwiss the COSMO model is run operationally at horizontal resolutions of 6.6 km and 2.2 km. Parallel experiments for both resolutions are made for a summer period of one month to test the impact of the new parameterization on predicted atmospheric profiles and precipitation. Precipitation patterns are evaluated with Radar measurements using neighbourhood verification techniques.