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Simulating pollutant transport in complex terrain with a Lagrangian particle dispersion model

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Lagrangian particle dispersion models (LPDMs) are among the most sophisticated tools to simulate atmospheric dispersion of pollutants, and are widely used in emergency response systems. In these systems, LPDMs should be coupled with a numerical weather prediction (NWP) model, which provides information from the mean wind as well as from the turbulence state of the atmosphere. Mean wind can directly be used from the NWP model, while turbulence characteristics have to be parameterized by a so-called meteorological pre-processor. In most cases, to diagnose turbulence variables, meteorological pre-processors use similarity theory approaches, which are based on turbulence datasets over flat and homogeneous surface. However, turbulence structure in complex terrain, such as in steep and narrow Alpine valleys, can be substantially different from flat conditions.

In this study a new scaling approach from Weigel et al. (2007), based on measurements and model simulations of the Riviera Project in the framework of the Mesoscale Alpine Program (MAP), is investigated with respect to pollutant dispersion. In the Riviera Project, analysis of turbulence measurements in a steep and narrow Alpine valley showed that daytime profiles of Turbulent Kinetic Energy (TKE) scale very well if the convective velocity scale w_* is obtained from the sunlit eastern slope rather than from the surface directly under the measured profiles. This scaling behaviour was also reproduced by high-resolution Large Eddy Simulation runs. To improve the performance of the dispersion model in complex terrain, this new scaling approach is introduced in the meteorological pre-processor of the LPDM and results are validated with a real tracer experiment.

For the evaluation of the dispersion model, the TRANSALP tracer experiment is used. During this experiment passive tracers were released and detected in an Alpine valley in Southern Switzerland on two days in October 1989. To simulate this case the operational emergency response system of MeteoSwiss is applied, which consists of the NWP model COSMO and the particle dispersion model LPDM. As the valleys where the experiment took place are approximately 1 km wide, a very high horizontal resolution of 1 km is used in the COSMO simulations, instead of the operational resolution of 2.2 km. The dispersion model is run both with the original pre-processor using flat-terrain scaling and the new one, applying the novel scaling approach fitted for Alpine valleys. The new scaling method results in higher turbulence values and thus lower concentrations in the valley, which show good agreement with the measured values.