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Comparing large eddy simulations with sonic anemometer and LIDAR measurement data during Foehn events in complex terrain

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Simulations of turbulent wind flows in complex, mountainous terrain prove to be challenging tasks for today's numerical simulation models. However, knowing about these wind flow patterns and speeds would be beneficial to assess potential environmental risks for various stakeholders – aviation, wind farms, ski resorts, cable cars or others. With the PALM model system, a state-of-the-art turbulence resolving meteorological model for atmospheric boundary layer flows is available, that can be used to assess these types of questions. By treating topography on a cartesian grid, complex terrain can be accurately represented in simulations.

In this study, the complex local flow patterns in mountainous terrain were analyzed by means of high-resolution large eddy simulations with the PALM model system. This was conducted for the Rhine valley region focusing on a small peculiar topographic feature upstream of Balzers in the area of the border between the Principality of Liechtenstein and Switzerland, were flow splitting is known to occur. There, Foehn events lead to pronounced local wind maxima and pose a damaging risk to the upwind part of the village. The model results were compared with data from measurement masts equipped with sonic and cup-anemometers at the position of assumed wind speed maxima. As well, measurements of a continuous-wave LIDAR system located at the outflow of the side valley were integrated in our study. The validation measurements for the Foehn events in Balzers were taken in December 2020, during which two pronounced Foehn events took place.

In PALM, a nested simulation approach was chosen, with the smallest domain having a resolution of only a few meters. The simulation was forced by COSMO-1 model results in order to factor in the synoptic weather conditions of the respective days. We show model results of the flow patterns that occur in this complex topography, analyze the wind maxima present in the valley and compare the results with local measurement data. This study demonstrates how large eddy simulation tools like PALM can produce insights into complex flow structures in mountainous terrain, and how these insights can be used to make more informed decisions to protect residents from damaging outcomes of environmental risks.