Project: **722**
Project title: **High Order Schemes for the COSMO model**
Project leader: **Andreas Will**
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In 2019 a detailed analysis of the series of 15 year long simulations comparing the reference scheme (C3p2d0.25) and S4p4d0.00 scheme over Europe at horizontal resolutions 0.44, 0.165, 0.11 and 0.0625 degrees and over Germany at 0.045 and 0.025 resolution has been conducted. In particular additional 3D fields like vorticity, wind velocity and mean vertical up- und downwinds have been investigated in order to understand the impact of non-dissipative dynamics on the climatology. Hereto additional short time (up to one year) simulations have been conducted for assessment of individual parameter sensitivities. The results consistently show, that a much stronger local convection occurs resulting in a reduction of meso- to large scale circulation between the planetary boundary layer and the troposphere stabilizing the stratification in the dissipative dynamics. This however needs to be carefully evaluated.

An additional investigation of predictability indices used in NWP showed a significantly positive predictability only if S4p4d0.00 was used. Various modifications of model physics had no such an effect. Considering sensible dependency on initial conditions resulting in a predictability limit of 4-5 days this result can be interpreted as significant improvement of the diurnal cycle and/or location of atmospheric instabilities determined by the properties of the landscape.

Fig. 1: The Rhone (Rotten) valley (RV) in Wallis, Switzerland is nearly zonally oriented and surrounded by a mountain chain in the North and by a slightly higher mountain chain in the South

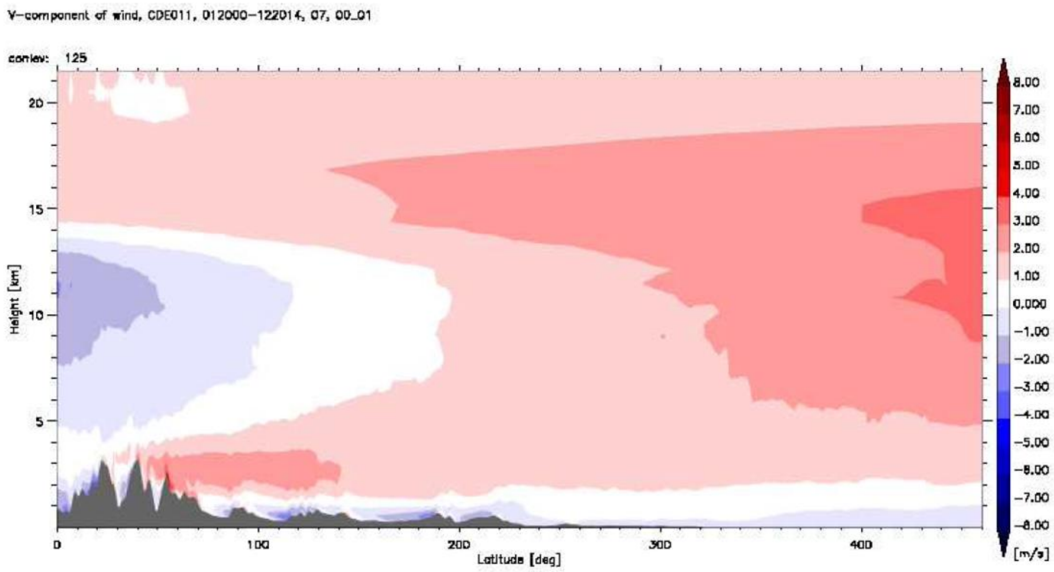

Fig. 2: **July mean meridional wind at 00h using the C3p2d0.25 dynamics**

The impact of non-dissipative dynamics was investigated in more detail for the Rhone valley (RV, see Fig.1) in Wallis, Switzerland. The valley has a width of approximately 20km. As shown by J. Schmidli et al. (2018) a 1km grid resolution is necessary to simulate the summer afternoon anabatic wind in the RV similar to observations using the COSMO-S2 configuration of meteoswiss. The zonal wind in the afternoon was strongly underestimated if a grid resolution of 2km or coarser was used. Figure 2 shows the mean July meridional-vertical wind profile at the longitude of Sitten simulated using a COSMO-DE configuration (2.8km). The top figure shows V at midnight using C3p2d0.25 refernece dynamics. In the afternoon (central figure) the near surface negative wind component is much stronger and exceeds 2m/s. The bottom panel shows the 15h mean using the S4p4d0.00 dynamics. Fig. 3. Shows the cross section of the difference of the 15h mean V in July between the S4p4d0.00 and the C3p2d0.00 simulation. It exhibits a strong reduction of the near surface anabatic flow north of the Alps and a strong reduction of the katabatic flow into the Rhone valley. The anabatic winds in summer afternoon in C3p2d0.25 simulation and a corresponding reduction in S4p4d0.00 are found in the whole Alpine region. A preliminary comparison with observations indicates that the anabatic wind in the pre-Alpine region is much overestimated in C3p2d0.25 simulations.

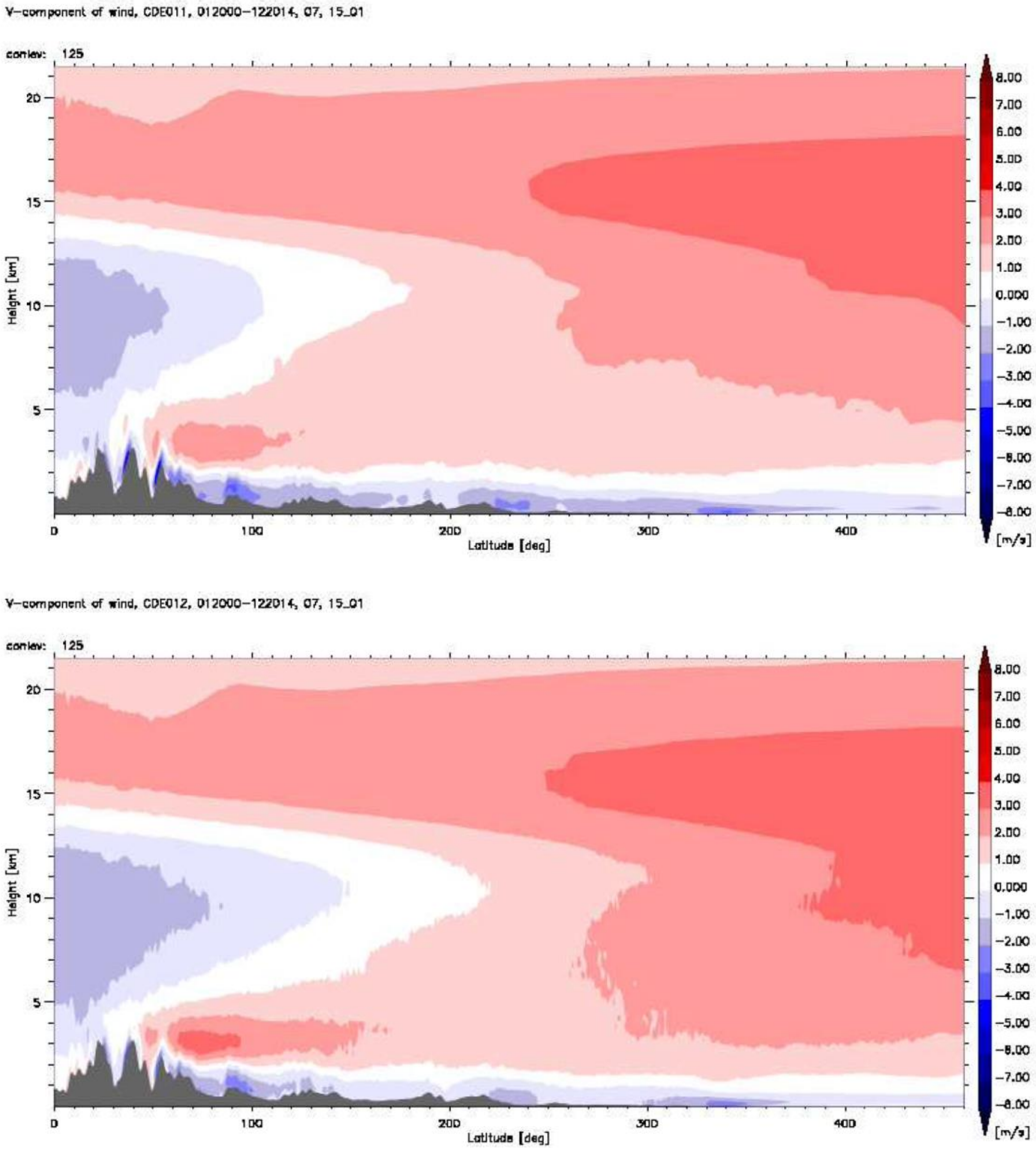

Fig. 3: **July mean meridional wind at 15h using C3p2d0.25 (top) and S4p4d0.00 (bottom) dynamics**

Considering a higher effective model resolution and smaller Ekman number of the S4p4d0.00 dynamics, the result indicates that numerical diffusion is increasing the spatial scale of stabilization of the stratification of the atmosphere. The S4p4 dynamics exhibits significantly stronger local up- und downdrafts resulting in a small scale vertical transport of energy and momentum. These stronger up- und downdrafts are found in the summer afternoon in the S4p4d0.00 dynamics as shown in Figure 3 b. This finding, if confirmed by other studies might be of high relevance for climate and climate change modelling since scale interaction is an important aspect of feedbacks in the climate system.

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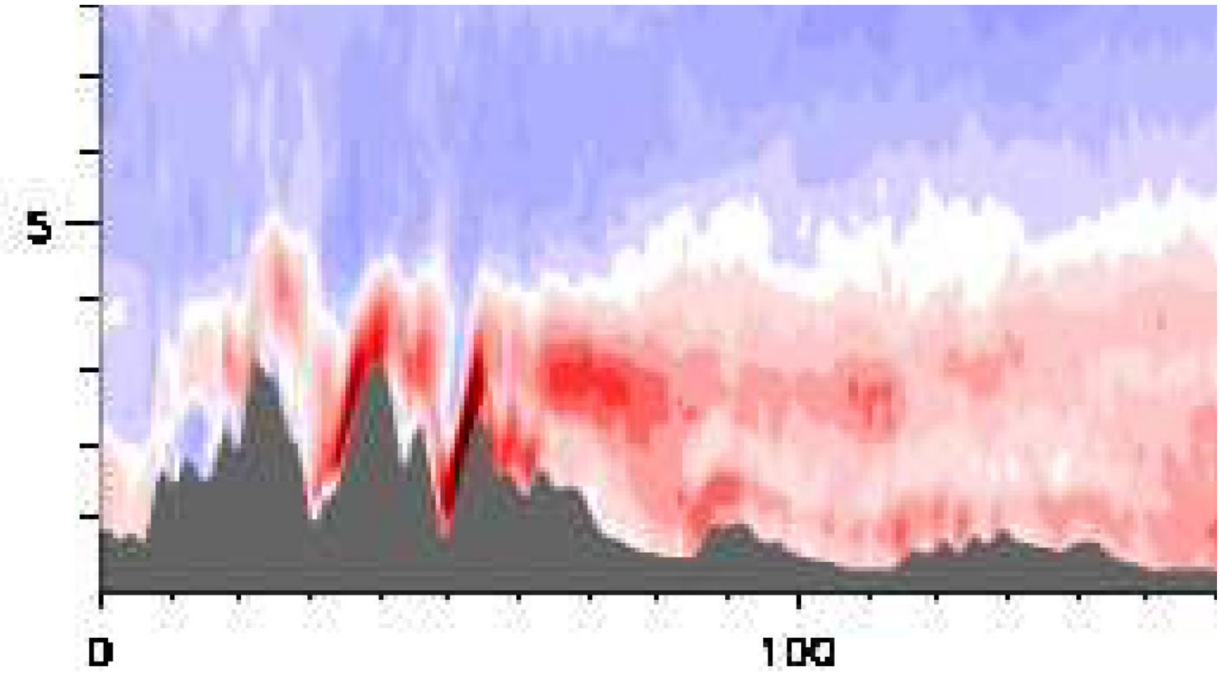

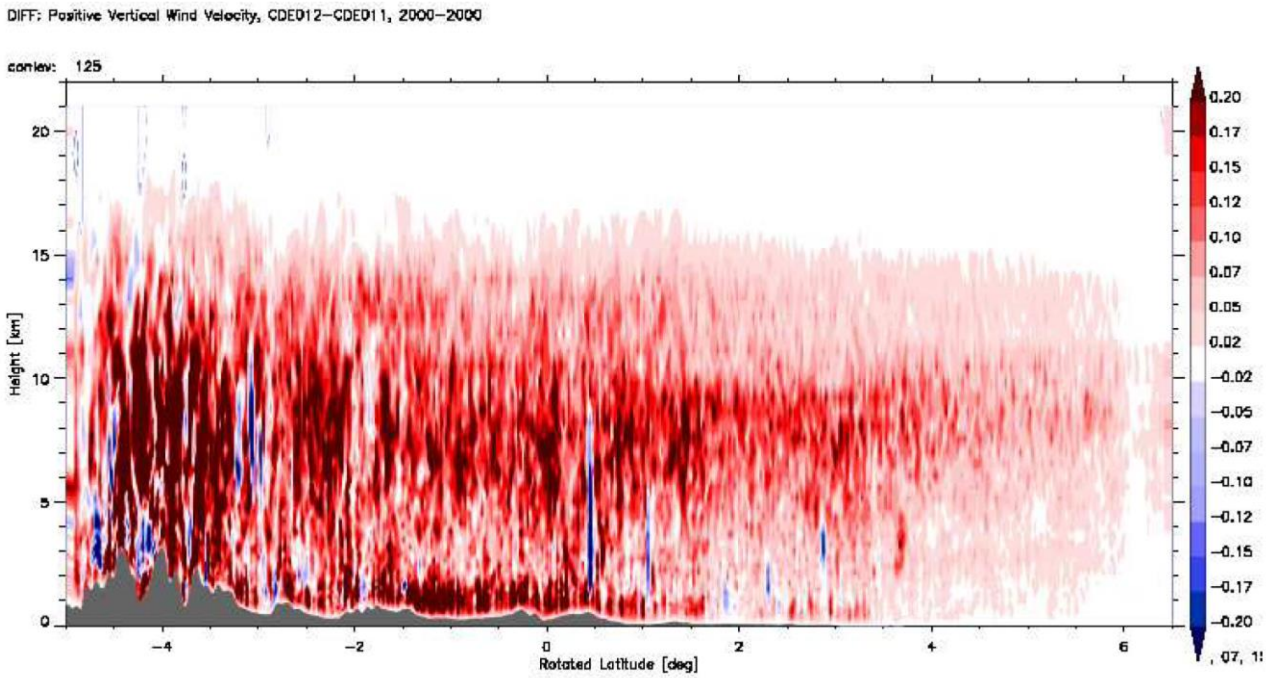

Fig. 3: **S4p4d0.00-C3p2d0.25 difference of July mean meridional wind at 15h**

The results of the COSMO-DE simulations using C3p2d0.25 and S4p4d0.00 dynamics have been used for analysis of the predictability quality, which is regarded as a measure of added value of downscaling. More than 50 simulations at convection permitting scale with different configurations of model physics and dynamics have been analysed and the so called Log-ODDS-Ration and its components have been computed. The COSMO-DE simulation with S4p4d0.00 dynamics was the only one showing a predictability significantly higher than an arbitrary forecast in the whole model domain, i.e. far away from the inflow boundary at which the Reanalysis is prescribed. In particular the COSMO-DE S4p4d0.00 simulation exhibits a much smaller false alarm ratio than other simulations. This result confirms the conclusion drawn from the analysis of the diurnal cycle in summer in the Alpine region. If the scale of stabilization of the stratification is not increased, less precipitation events are generated at the wrong time and/or the wrong place.

Due to agreements taken in the CLM-Community the developer of the S4p4d0.00 dynamics will focus on operationalization and further development of non-dissipative dynamics rather than investigation of the impacts on the climate change signal.

Literature

Ogaja, J., A. Will (2016): Will Fourth order, conservative discretization of horizontal Euler equations in the COSMO model and regional climate simulations. *Met.Z.*, DOI 10.1127/metz/2016/0645

Schmidli, J. , S. Bölng and O. Fuhrer (2018), Accuracy of Simulated Diurnal Valley Winds in the Swiss Alps: Influence of Grid Resolution, Topography Filtering, and Land Surface Datasets, https://doi.org/10.3390/atmos9050196

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