Project: **722**
Project title: **High Order Schemes for the COSMO model**
Project leader: **Andreas Will**
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In 2021 a series of annual simulations over domain North-East-Germany (NOG) at horizontal resolution of 0.01° and vertical resolutions of 80 levels up to 22 km has been conducted using non-dissipative dynamics and numerics S4p4d0.00 developed in this project. The configuration developed in the project in 2020 has been used as reference configuration. The aim of these simulations was a further improvement of the model physics and dynamics for regional climate simulations at convection resolving scales.

The resulting optimum model COSMO-CLM-LAU has been applied for investigation of the impact of lakes (LAU-LAKE) and of soil type heterogeneity (LAU-SOIL). The results are consistent with theory of land-lake wind, surface energy and water budget. The analysis of dynamics in the PBL is ongoing.

In the following some results are highlighted.

The optimum configuration of model physics and dynamics can be characterized by the modifications of the reference model version and configuration

- shallow convection parameterization is not needed for dlon=dlat=0.01°.
- S4p4 numerics has no implicite numerical diffusion, conserves the kinetic energy and increases the effective model resolution.
- explicite (and implicte) numerical diffusion is not needed for stabilization of the simulation. This increases substantially the effective model resolution and admits an intensive grid scale dynamics down to $2 \Delta \lam$ grid scale, in particular in the PBL.
- Horizontal Smagorinsky turbulence parameterization using a Smagorinsky coefficient close to the theoretical value dissipates the kinetic energy close to 2 Delta lam resolution and prevents an accumulation of kinetic energy at that scale, in particular in vertical velocity.
- Turbulent length scale close to grid resolution of 0.01° enhances the vertical TKE parameterization. Together with the horizontal Smagorinsky turbulence parameterization it dissipates the kinetic energy close to 2 Delta lam resolution and prevents an accumulation of kinetic energy at that scale in the PBL, in particular in vertical velocity.
- Minimum vertical mixing coefficient close to zero admits a grid scale vertical transport of energy and momentum. At 0.01° this allows for nearly direct simulation of convection in the PBL.

In particular a realistic land-lake wind is found (not shown) in summertime for low horizontal wind conditions only if the LAU optimum configuration is used. The power spectra of the detrended velocity components in the NOG region shown in Figure 1 exhibit the impact of non-dissipative dynamics and numerics and of new turbulence parameterization on the dynamics in the Ekman layer. The simulation ceu011, cde011, LAU002 and LAU035 are the dissipative dynamics simulations at 7km, 2.8, 1.1 and 1.1 km grid resolution respectively. Hereby the LAU035 simulation is using improved external parameters and surface scheme for NOG region. It exhibits a stabilization of atmosphere in PBL at significantly larger scales (10 instead of 3 km). This effect is in particular strong if deep convection parameterisation is not used as in cde011. In comparison herewith the daytime spectra for non-dissipative dynamics and numerics (top right) exhibit an artificial increase of kin. Energy at 2DX resolution. The simulation ceu012, cde012, LAU003 and LAU004 are the simulations with same physics and dynamics configurations as ceu011, cde011, LAU002 and LAU035 respectively but with non-dissipative dynamics and numerics. They exhibit an increased kinetic energy close to 2 Delta lam resolution. The figure bottom left shows the zonal spectra of meridional velocity of LAU003 and LAU004 together with those of LAU045 and LAU065. The LAU045 is using the improved Smagorinsky horizontal diffusion but reference TKE parameterisation. The LAU065 is the optimum configuration with improved horizontal and vertical turbulence parameterisation. LAU045 and LAU065 show no increased kinetic energy at 2 Delta

lam. The major difference between LAU045 and LAU065 is found in figure bottom right showing the power spectra of vertical velocity, which is significantly reduced due to longer turbulent length scale.

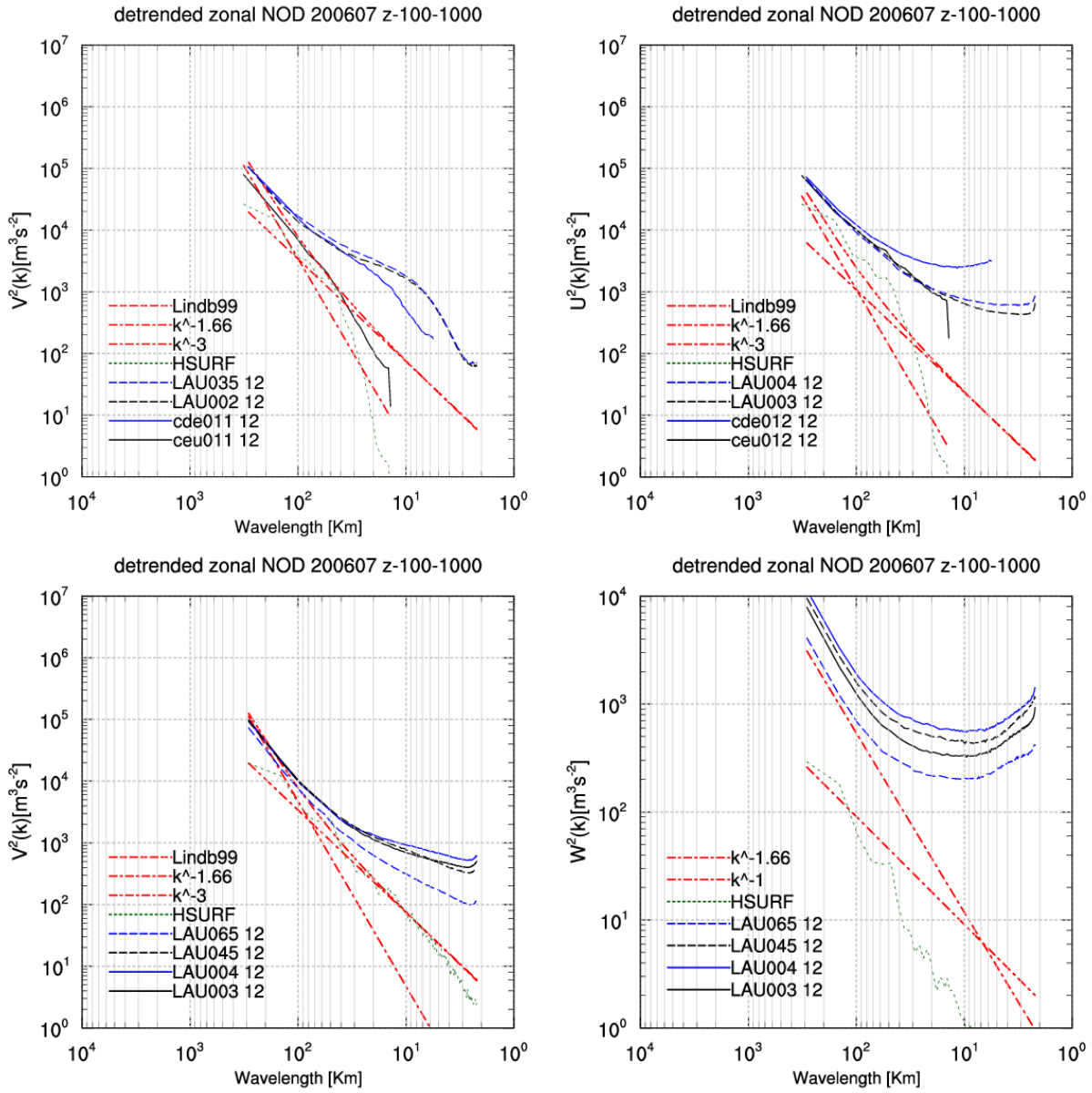

Fig. 1: Power spectra of zonal (U), meridional (V) or vertical (W) velocity at 12h in July 2006 in the Ekman layer for different configurations of dissipative numerics (top left) and non-dissipative numerics with reference turbulence parameterisation (top right) and new turbulence parameterisation (bottom)

Further analysis is needed for better understanding of the vertical dynamics in the PBL

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

Will and J. Ogaja (2017) Higher order horizontal schemes in COSMO 5.0 at different resolutions, CLM-Community Newsletter 8, Feb. 2017.