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Climatological Relevance of Non-Dissipative Numerics for Atmospheric Dynamics at 50km to 2 km grird resolution

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Recently the new full 4th order and energy conserving horizontal discretisation scheme (S4p4) has been implemented in the model system COSMO 5.0, which is used operationally for NWP and RCM. The scheme S4p4 allows allows long time simulation without any numerical horizontal diffusion (d0.00). As shown by Ogaja and Will (2016) this increases the effective model resolution by approximately a factor of two and changes the dynamics in the atmospheric boundary layer significantly.

A series of 200-2014 RCM simulations has been conducted at horizontal resolutions between 50km to 2.8km using the reference C3p2 and the new S4p4 scheme. Hereto the recommended model configuration for 11km resolution was used at 44km, 18km and 11km horizontal resolution and the operational configuration for NWP of the German Weather Service was used at 7km and 2.8 km horizontal resolution. Additional simulations have been conducted in order to better understand the impact of the horizontal diffusion on the simulation result.

We present the phenomenology of differences between C3p3 and S4p4 simulations, discuss the effect of numerical diffusion on dynamics and discuss the mechanism of convective instability in simulations with and without deep convection parameterisation.
It was found that in S4p4 simulations the hoirzontal and the vertical kinetic energy spectrum exhibit the expected k=-5/3 power law down to the theoretical grid resolution. Interestingly, the vertical velocities (up and down) are found to increase with resolution and two times as high in S4p4 simulations. A very prominent systematic increase of the maximum horizontal wind velocity of 3m/s was found in S4p4 simulations without deep convection parameterisation in Alpine region.
In the literature the need for numerical diffusion is justified by artificial structures in NWP forecasts without numerical diffusion. An inspection of these features showed that such artificial structures occur in particular at low horizontal resolutions. They are negligible at convection permitting scales.

The phenomenology can be interpreted as follows: The numerical diffusion damps significantly the meso-scale dynamics, in particular in the atmospheric boundary layer. This is resulting in a strong reduction of vertical transports of moisture, energy and momentum. This transports are usually made by parameterisations. The convection parameterisation is transporting moisture and energy instantaneously, at a practically infinite speed. A reduction of the numerical diffusion has the potential to develop the instability consistently with the physics of the atmosphere and thus to simulate the time delay between instability condition and atmospheric reaction. This explains the moderate impact of S4p4 on the solution with and a strong impact on the solution without deep convection parameterisation and also why simulations using the deep convection parameterisation cannot capture the diurnal cycle of precipitation.

Future developments of numerical methods for atmospheric dynamics should consider not only the mass but also the energy conservation in order to improve the timing of atmospheric instabilities.

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