Geophysical Research Abstracts
Vol. 16, EGU2014-15774, 2014
EGU General Assembly 2014

Higher Order spatial schemes and effective resolution in the COSMO model

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As reported by several authors the limited area models exhibit a substantial difference between the models horizontal grid and effective resolution. Usually the grid resolution is reported. At the same time the effect of increased model resolution is small in comparison to the increased computing costs (approx. one order of magnitude for half grid size). Furthermore, in the last years the computing power increased faster than the storage space. Higher order spatial discretisation schemes have the potential to increase the effective model resolution keeping the storage space needs constant and increasing the computational costs slightly.

A 4th order horizontal discretisation of the Euler equations in the NWP and RCM COSMO model was implemented together with 2 types of the advection term discretisation. The first is an extension of the COSMO higher order discretisation by introduction of 4th order interpolations of the advecting velocity, denoted as C4. The second is a symmetric type of discretization of the advection term (Morinishi, 1999) which can be shown to conserve the 1st and 2nd moments of the advected quantity if the continuity equation is satisfied, here referred to as S4. Both convective schemes can be combined with 4th order discretization of the pressure gradient term, referred to as p4. To make the spatial schemes fully 4th order the metric coefficients and terms are discretised 4th order as well. The 4th order discretisations are referred to as C4p4 and S4p4 and complement the already existing schemes A3p2, A4p2, A5p2 and A6p2. Here AX denotes the central difference (2,4,6) and upwind (3,5) discretisation of the gradient of the advected velocity.

The configuration used is the CLM Community standard configuration. This configuration used the A3p2 scheme together with horizontal diffusion coefficients of strength 0.25, referred to as d025. In cosmo_4.27 the new fast waves solver was used. Additional simulations have been conducted for S4p4d025, S4p4d0 and C4p4d025.

We investigated the simulated kinetic energy spectra of 5y-evaluation runs over Europe of the COSMO model for different spatial discretisation schemes and numerical diffusion settings in order to derive the effective resolution and to quantify the represented wave amplitude.
We calculated the zonal Fourier spectra of the detrended zonal and meridional kinetic energy and compared the meridionally, vertically and time averaged spectra with the observed 500 hPa spectrum of Lindberg et al (1999) adapted to the simulated domain for different layers.
The 3-6 km altitude S4p4d0 spectra exhibit no significant deviation from the observed spectrum up to the maximum simulated wave number kmax (approx 2x18km). The kinetic energy spectrum of C3p2d025 is underestimated by more than 10% for wavenumbers higher than kmax/10 (approx. 400 km). At approx. 100 km resolution only 30% of the kinetic energy is represented by the C3p2d025 discretisation. The spectra for C4p4d025 and S4p4d025 can be found between the spectra of S4p4d0 C3p2d025. The spectra of convective precipitation exhibit for S4p4d0 a reduction by approx. 10% for spatial scales larger than 100km and an increase for scales smaller than 50km.

The results obtained so far show that the effective resolution for standard discretisation of the model is approx 20xdlam (dlam is the grid resolution). It could be analysed, that the effective resolution is decreased by explicite (horizontal numerical diffusion) and by implicite (upwind scheme) diffusion applied. It can be significantly improved by introduction of higher order schemes and by reduction of the horizontal diffusion. The letter is possible only if the numerical scheme is energy conserving.

The properties of the schemes implemented will be discussed and the climatological results obtained will be presented.