Impact of Higher Order Quadratic Conserving Advection Scheme in the COSMO model on Regional climate Simulation

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Outline

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- Regional Climate Simulation
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- Conclusions

INTRODUCTION:

Higher order quadratic conserving scheme in COSMO model

Horizontal Advection of u: $u\frac{\partial u}{\partial \lambda} + v\frac{\partial u}{\partial \phi}$

divergence form: conservative a *priori*

$$S4^* := \frac{9}{8}\overline{\overline{u}^{O4,\lambda}\delta_\lambda u}^{\lambda} - \frac{1}{8}\overline{\overline{u}^{O4,\lambda}\delta_{3\lambda} u}^{3\lambda} + \frac{9}{8}\overline{\overline{v}^{O4,\phi}\delta_\phi u}^{\lambda} - \frac{1}{8}\overline{\overline{v}^{O4,\phi}\delta_{3\phi} u}^{3\lambda}$$

$$= \left[\frac{9}{8}\delta_\lambda(\overline{u}^{O4,\lambda}\overline{u}^{\lambda}) - \frac{1}{8}\delta_{3\lambda}(\overline{u}^{O4,\lambda}\overline{u}^{3\lambda})\right] - u\delta_\lambda^{O4}(\overline{u}^{O4})$$

$$+ \underbrace{\left[\frac{9}{8}\delta_\phi(\overline{v}^{O4,\phi}\overline{u}^{\lambda}) - \frac{1}{8}\delta_{3\phi}(\overline{v}^{O4,\phi}\overline{u}^{3\lambda})\right]}_{\equiv \frac{\mathbf{F_{i+n/2} - F_{i-n/2}}}{\mathbf{n}\delta\phi}} - \overline{\overline{v}^{O4,\phi}}^{O4,\lambda}\delta_\phi(\overline{u}^{O4,\phi})$$

*: Morinishi,1998(JCP), 'Higher order conservative schemes'

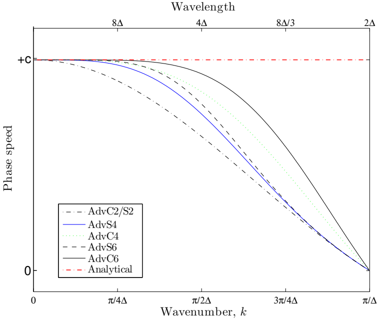
Advantages:

- Higher Order accurate
- Improved model stability due to conservation of the integrated Kinetic energy for non-divergent flows

Motivation: Higher Order Quadratic Conserving Spatial Schemes

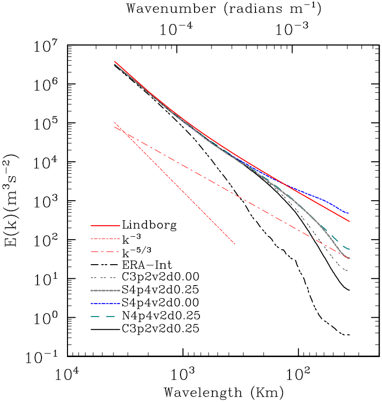
- Conserves 1^{st} and 2^{nd} momments of the advected quantity i.e. kinetic energy

- Reduced phase speed error compared to second order scheme.



- **AdvS4**/*S4p4v2d0.00*: **Quadratic conserving scheme**

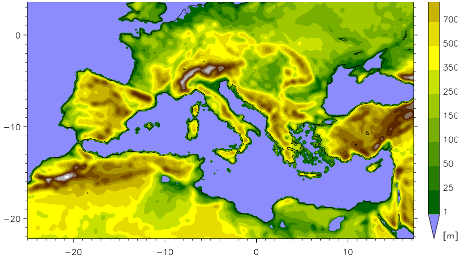
- Effective resolution of the model is increased by atleast a factor of 2



REGIONAL CLIMATE SIMULATION:

Configuration

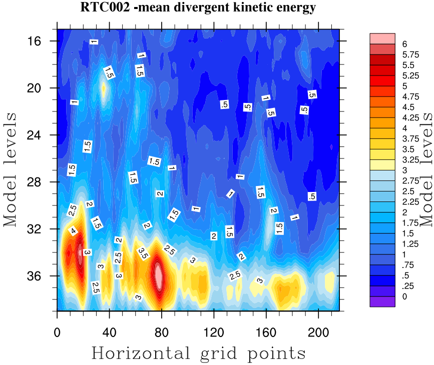
- COSMO-CLM evaluation domain for EU/Euro CORDEX
- ERA-interim 1979-1998
- $\Delta\lambda = 0.165^\circ$
- `ke_tot`(model levels) $= 40$
- Parameterization schemes
  - Prognostic TKE turbulence closure scheme -level 2.5 (Mellor and Yamada (1982))
  - Tiedtke mass-flux convection scheme (Tiedke (1989))



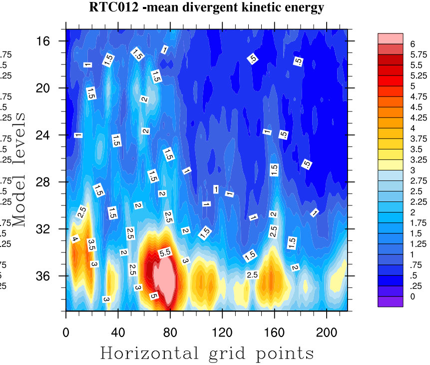
Simulation-ID:	Configuration-ID:	hor.dif. [ ]	dt [s]	simulated time [y]
RTC002	*C3p2v2d0.25*	0.25	150	79-98
RTC004	*N4p4v2d0.25*			
RTC016	*S4p4v2d0.25*			
RTC012	*S4p4v2d0.00*	0.00		

Summer mean Kinetic Energy from Divergent wind ($m^2 s^{-2}$)

C3p2v2d0.25 meridional average

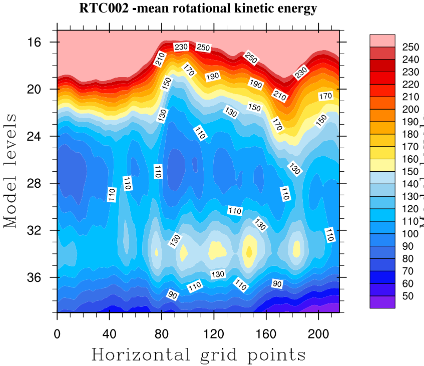


S4p4v2d0.00 meridional average

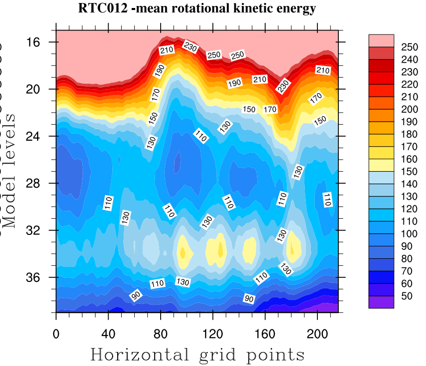


Summer mean Kinetic Energy from Rotational wind(m^2s^{-2})

*C3p2v2d*0.25 meridional average



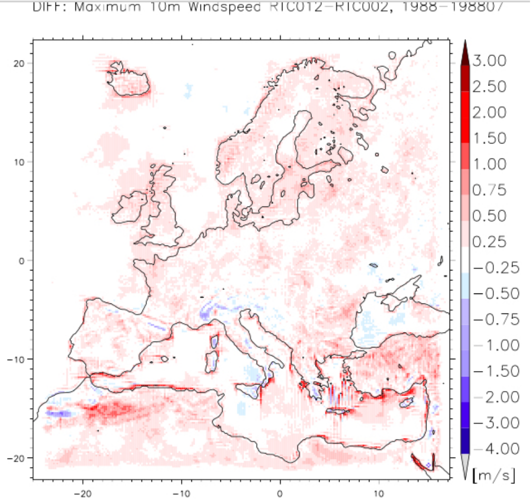
*S4p4v2d*0.00 meridional average



Precipitation, 2m Air temperature and uv_10m maximum

- Differences between observations and simulations
- Relative differences between simulations using different spatial schemes

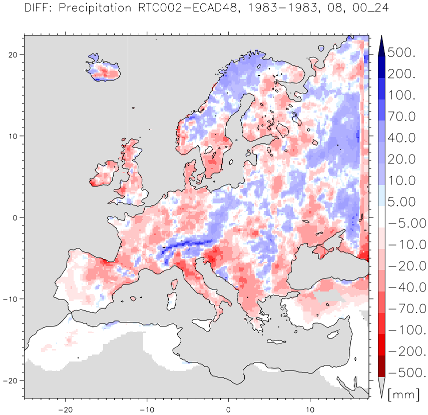
The difference in maximum 10m wind speed ($S4p4v2d0.00$-$C3p2v2d0.25$)



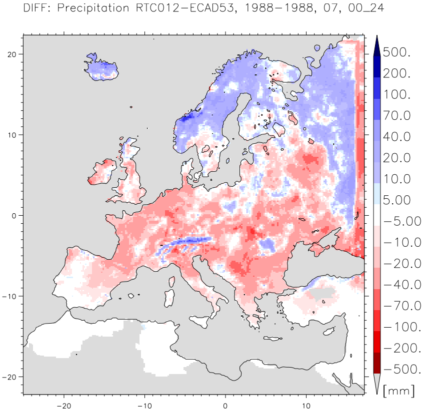
- Significant increase in 10m wind speed

TOT_PREC July 1979-1988 differences

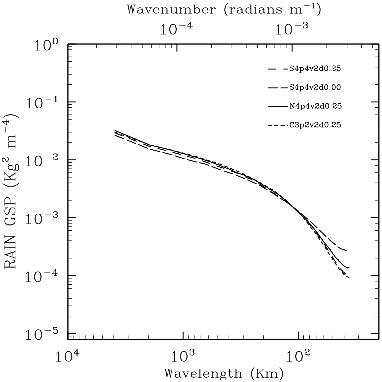
C3p2v2d0.25 – *ECAD*

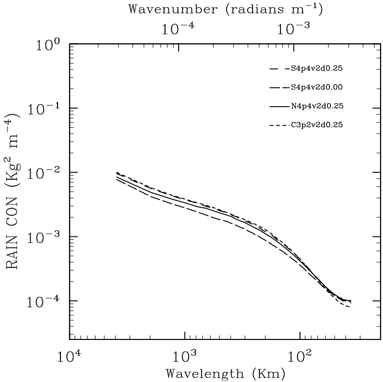


S4p4v2d0.00 - *ECAD*



Power spectra of precipitation(SUMMER)

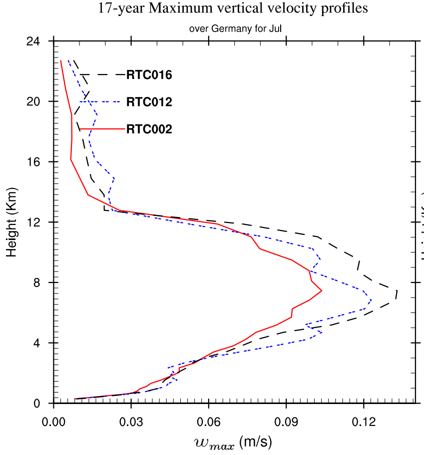




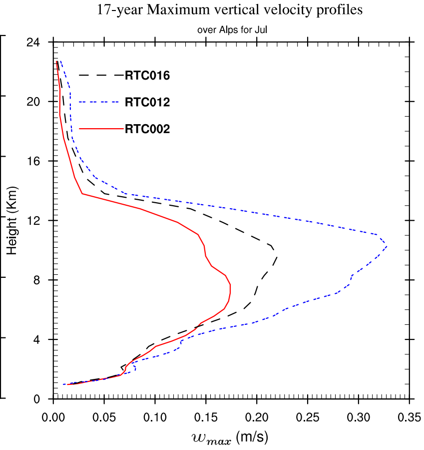
Convective precipitation(RAIN_CON) contributes majorly for the differences between schemes in summer

Summer Maximum updraft (m/s)

summer maximum w, Germany

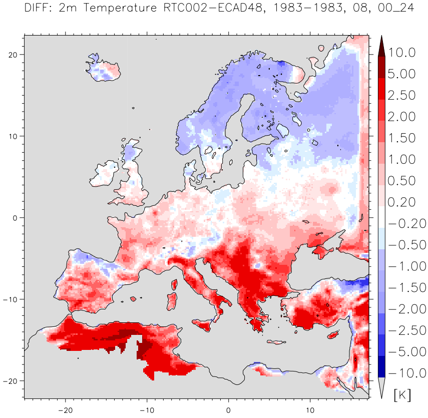


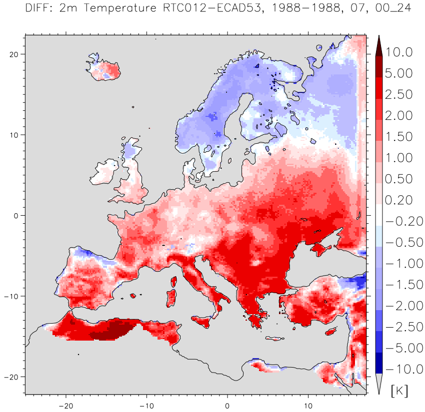
summer maximum w, Alps



T_2M evaluation: July 1979-1988 differences

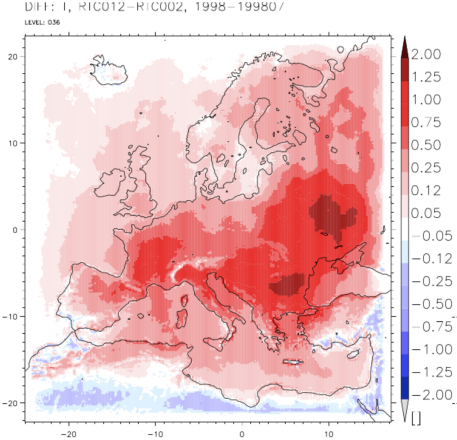
C3p2v2d0.25 – *ECAD* *S4p4v2d0.00* - *ECAD*





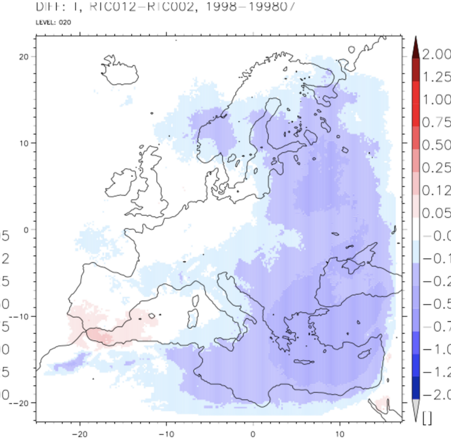
Absolute air temperature:**Relative differences**

S4p4v2d0.00-*C3p2v2d0.25* lev:36



(a) RTC012-RTC002

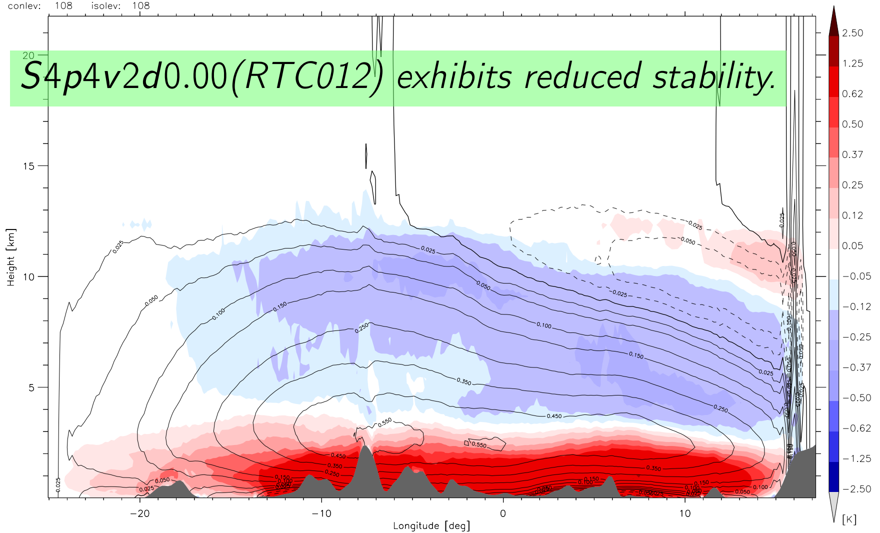
S4p4v2d0.00-*C3p2v2d0.25* lev:20



(a) RTC012-RTC002

Height-lon cross section: T(Temperature) and PP(Pressure deviation)

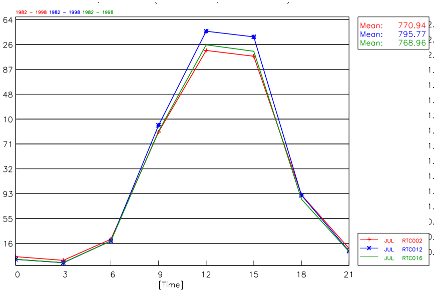
Relative differences $S4p4v2d0.00$**(RTC012)**-$C3p2v2d0.25$**(RTC002)**



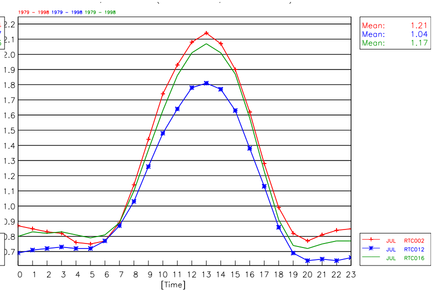
$S4p4v2d0.00(RTC012)$ *exhibits reduced stability.*

Diurnal cycle for Conv. Precipitation and PBL Height

PBL Height(July), Germany



Convective precipitation(July), Germany



Conclusions

- Quadratic conserving Fourth order advection scheme $S4p4v2d0.00$(RTC012) is as stable as the third order upwind scheme $C3p2v2d0.25$ (with potential for longer time steps) and with higher effective resolution ($\approx 5\Delta\lambda$) compared to the third order upwind scheme ($\approx 8\Delta\lambda$).
- The increased effective resolution changes the regional climate significantly, particular in summer.
  - intensifies small scale turbulence, increases the height of the planetary boundary layer and reduces the convective precipitation in summer months.
  - The reduced precipitation in summer results to reduced soil moisture content and an increase in the summer 2m air temperature(T_2M) positive bias.