Modeling of daytime convective development over land with COSMO-EULAG

Bogdan Rosa[1], Wojciech W. Grabowski[2], Damian K. Wójcik[1] and Michał Z. Ziemiański[1]

1. Institute of Meteorology and Water Management
National Research Institute
Warsaw, Poland

2. National Center for Atmospheric Research
Mesoscale and Microscale Meteorology Laboratory
Boulder, CO, USA

Workshop on numerical and computational methods for simulation of all-scale geophysical flows

ECMWF, Reading, 4th October 2016

Motivation and objectives

Two dynamical cores of the model EULAG i.e. anelastic and compressible have been implemented into COSMO weather prediction model. The motivation of employing EULAG to weather forecasting is:

i) the model has considerable advantages concerning conservation properties,
ii) does not impose severe constraints on the maximal allowable steepness of the surface orography,
iii) EULAG features a high numerical robustness confirmed in number of benchmark tests.

To date the new prototype model COSMO-EULAG has been successfully tested in a number of idealized and realistic simulations.

Current efforts are focused on accurate modeling of convective processes and further optimization of the prototype model CE-A/C.

Motivation and objectives

The main goal is to calibrate coupling between EULAG dynamical core and COSMO physical parameterizations to make the code suitable for resolving explicitly convective processes.

Testing and calibration of the new COSMO-EULAG model is one of the main tasks of the new priority project CELO.

Task 4. Optimization and testing of COSMO with EULAG DC

Experiment settings

The test simulation setup is based on observations of the diurnal cycle and convective development during rainy season in Amazonia (Grabowski *et al.* 2006).

1. Computational grid depends on simulation
- horizontal (**100 m - 1800 x 1800 grid points; 2km - 300 x 300**)
- vertical as in COSMO 2.2km (**60 levels**)

2. Initial soundings (vertical profiles of QV, P, T, **V**) from Grabowski et al 2006 linearly interpolated to the COSMO grid.

3. Periodic lateral boundary conditions.

4. Surface latent and sensible heat fluxes applied as analytical functions of time plus 10% random noise.

5. Random perturbation added to temperature and moisture below 1 km height with the amplitude of **0.1K** and **0.1g/kg** every 15 min.

6. No **radiative cooling.**

7. **Shallow convection parameterization switched off.**

8. **Subgrid-scale turbulence** based on 1-D TKE and 3D closure (depends on horizontal resolution)

Experiment settings

The simulations have been performed using 4 different schemes of microphysics parameterizations (**gscp** grid-scale clouds and precipitation)

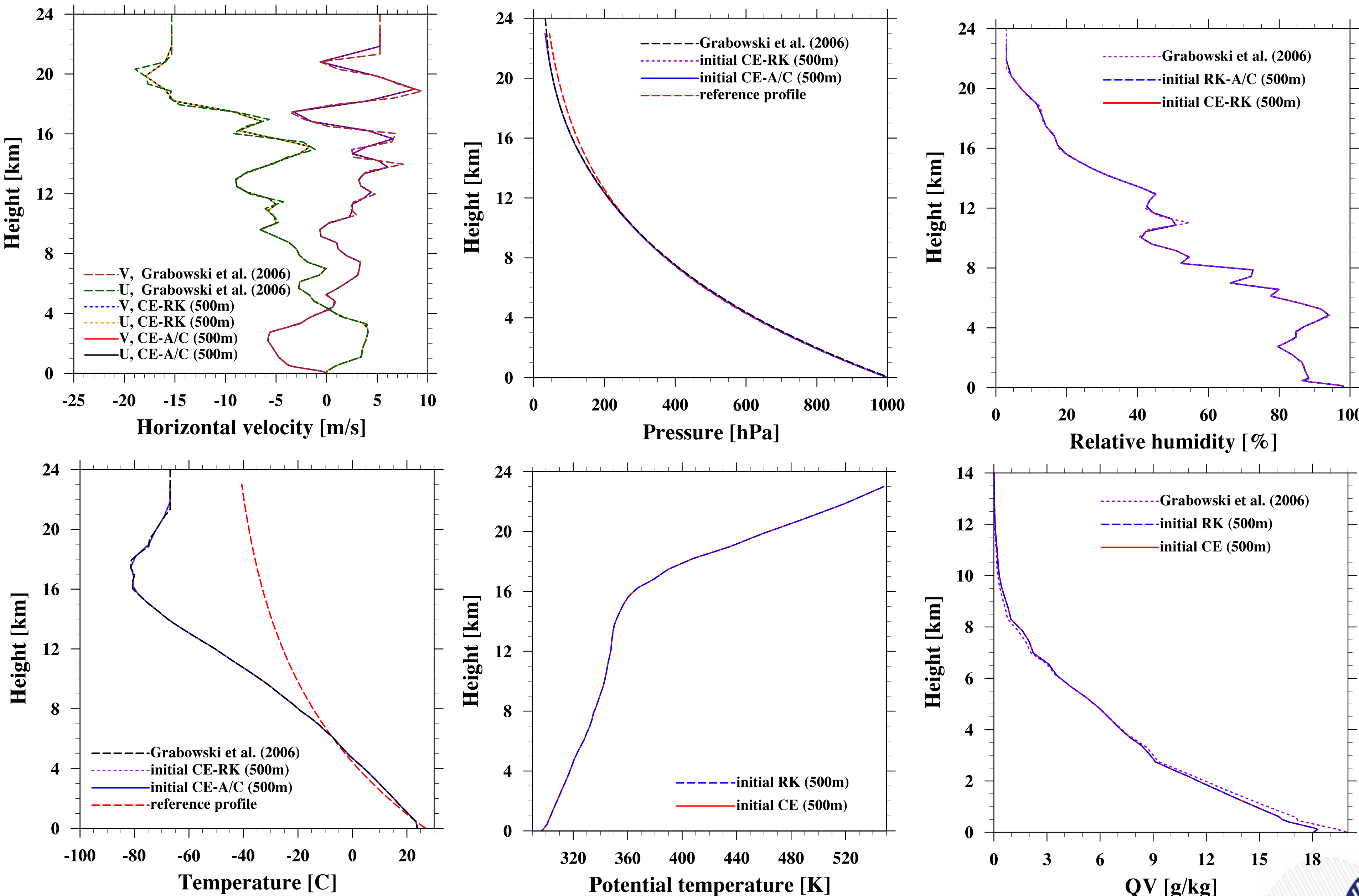
gscp =1 Warm rain scheme which is similar to the original Kessler (1969) scheme

gscp =2 Basic scheme - besides water QV three categories of water are considered QC, QR, QS

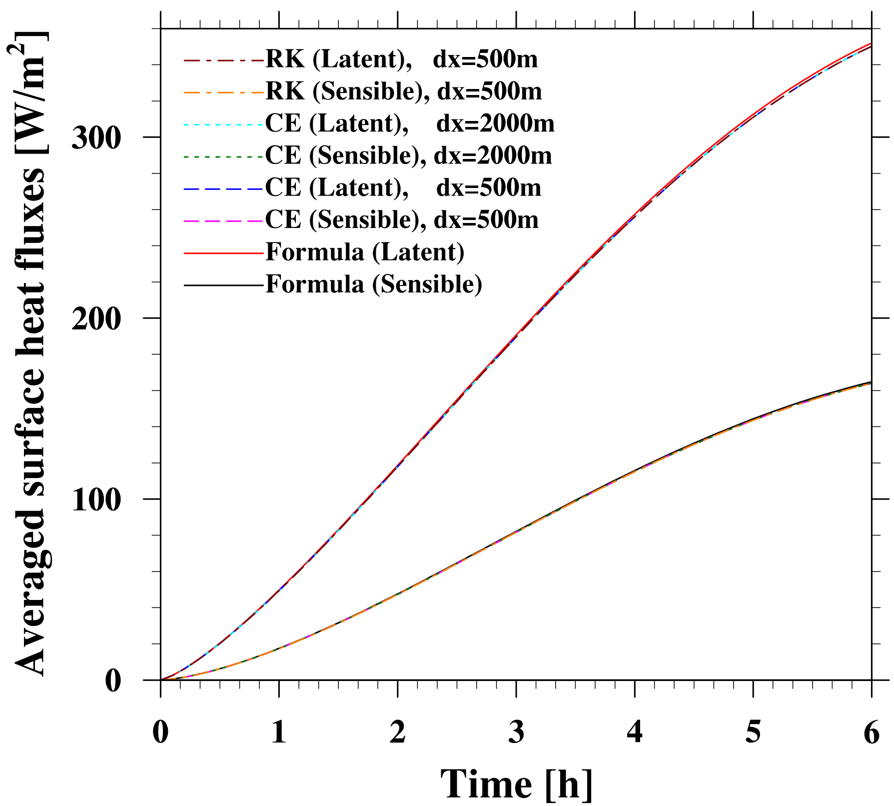
gscp =3 An extension of the basic scheme which includes cloud ice as an additional prognostic variable (QI)

gscp = 4 Graupel scheme. It allows for an explicit simulation of deep convective clouds

Initial soundings



Surface heat fluxes



$$F_S = 270 \times f(t)^{1.5}$$

$$F_L = 554 \times f(t)^{1.3}$$

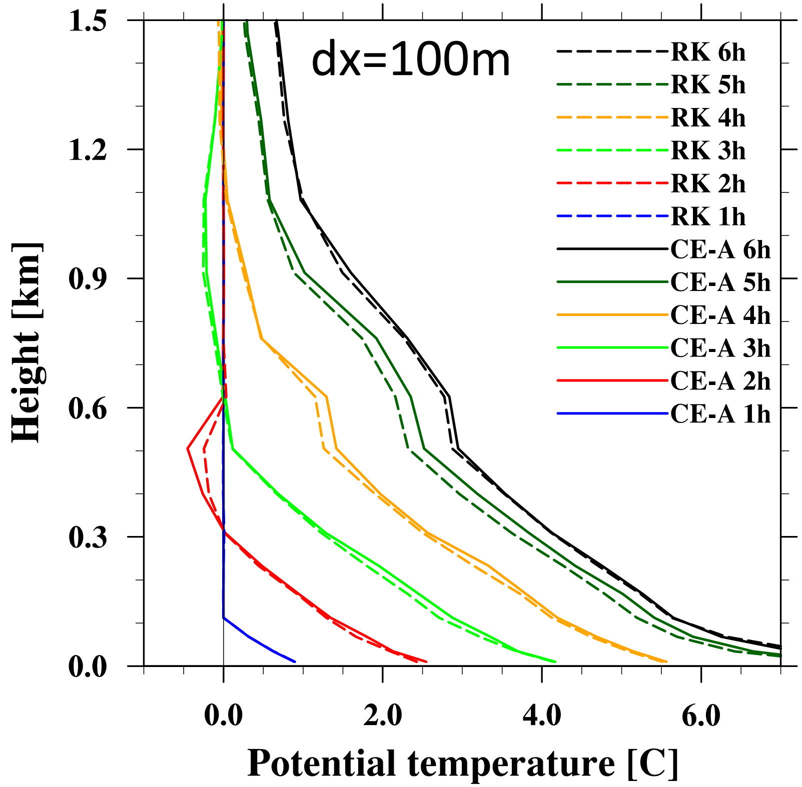
where

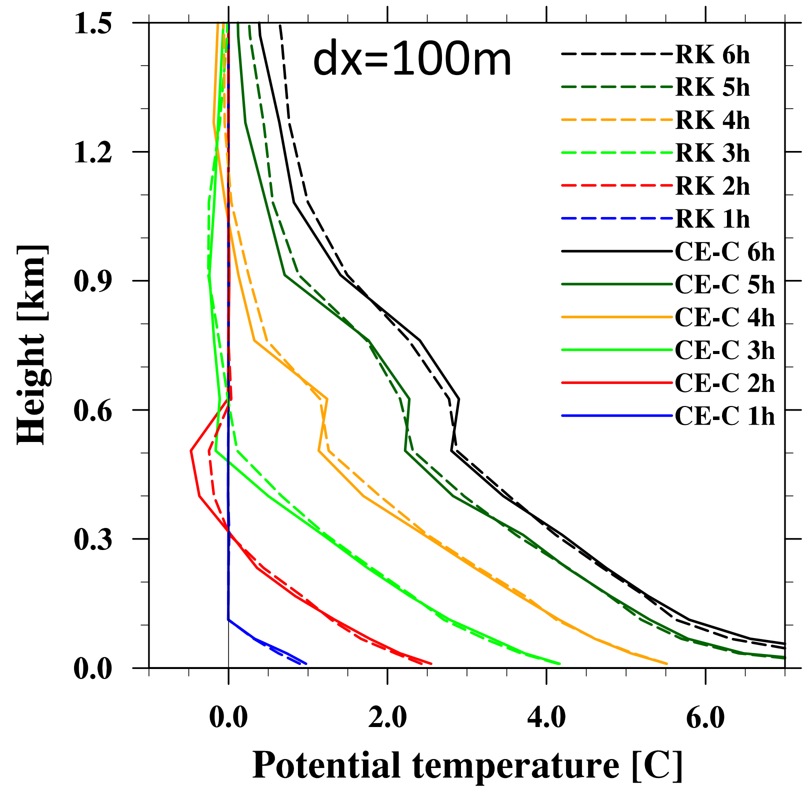
$$f(t) = \max\left\{0, \cos\left(\frac{\pi}{2}\frac{5.25 - t}{5.25}\right)\right\}$$

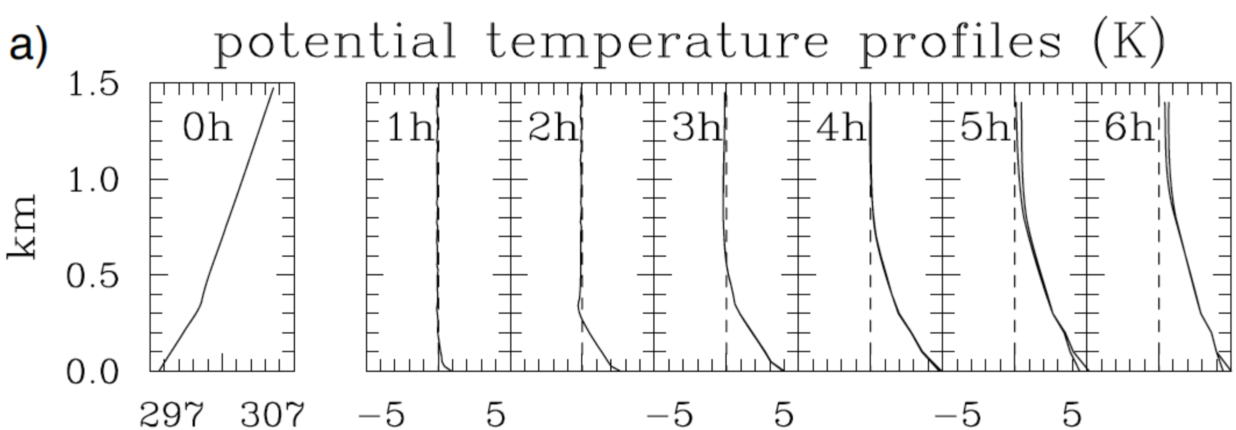
where t - simulation time in hours (i.e. from 0 to 6 h).

Analysis *a posteriori* confirms quantitative agreement between simulation data and the analytical formula.

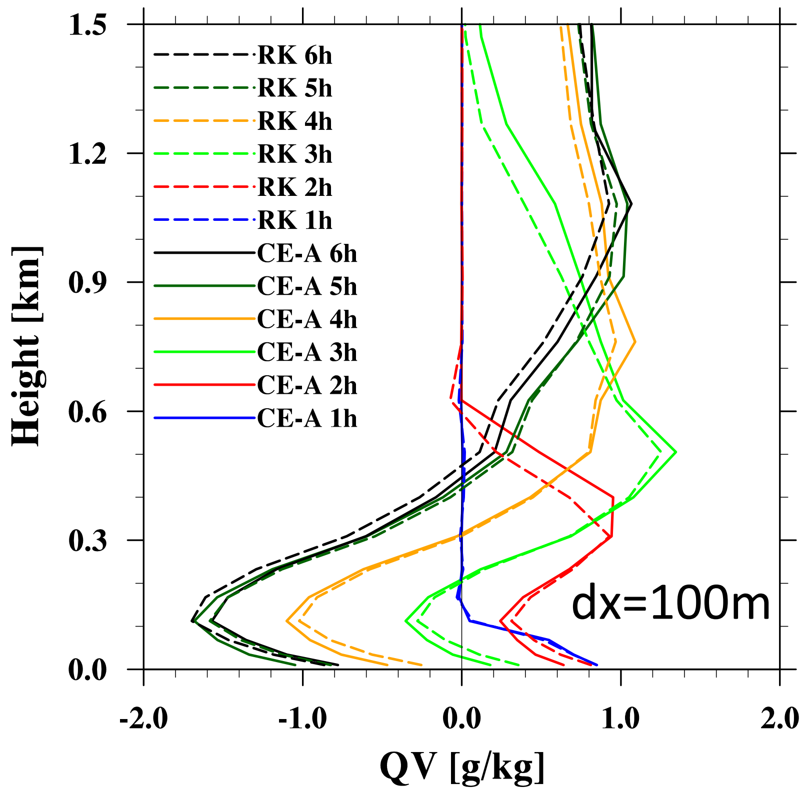
Evolution of the lower-tropospheric potential temperature

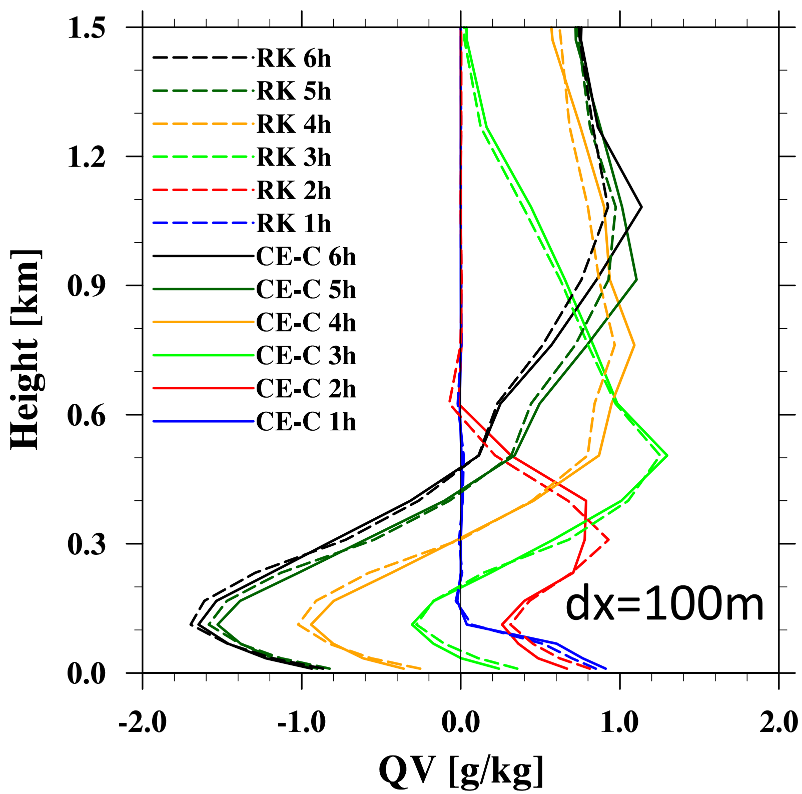


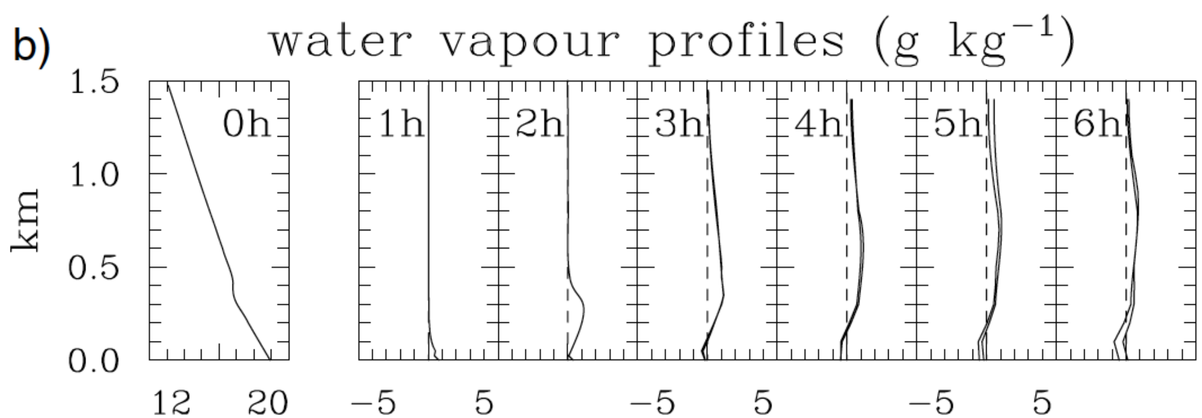




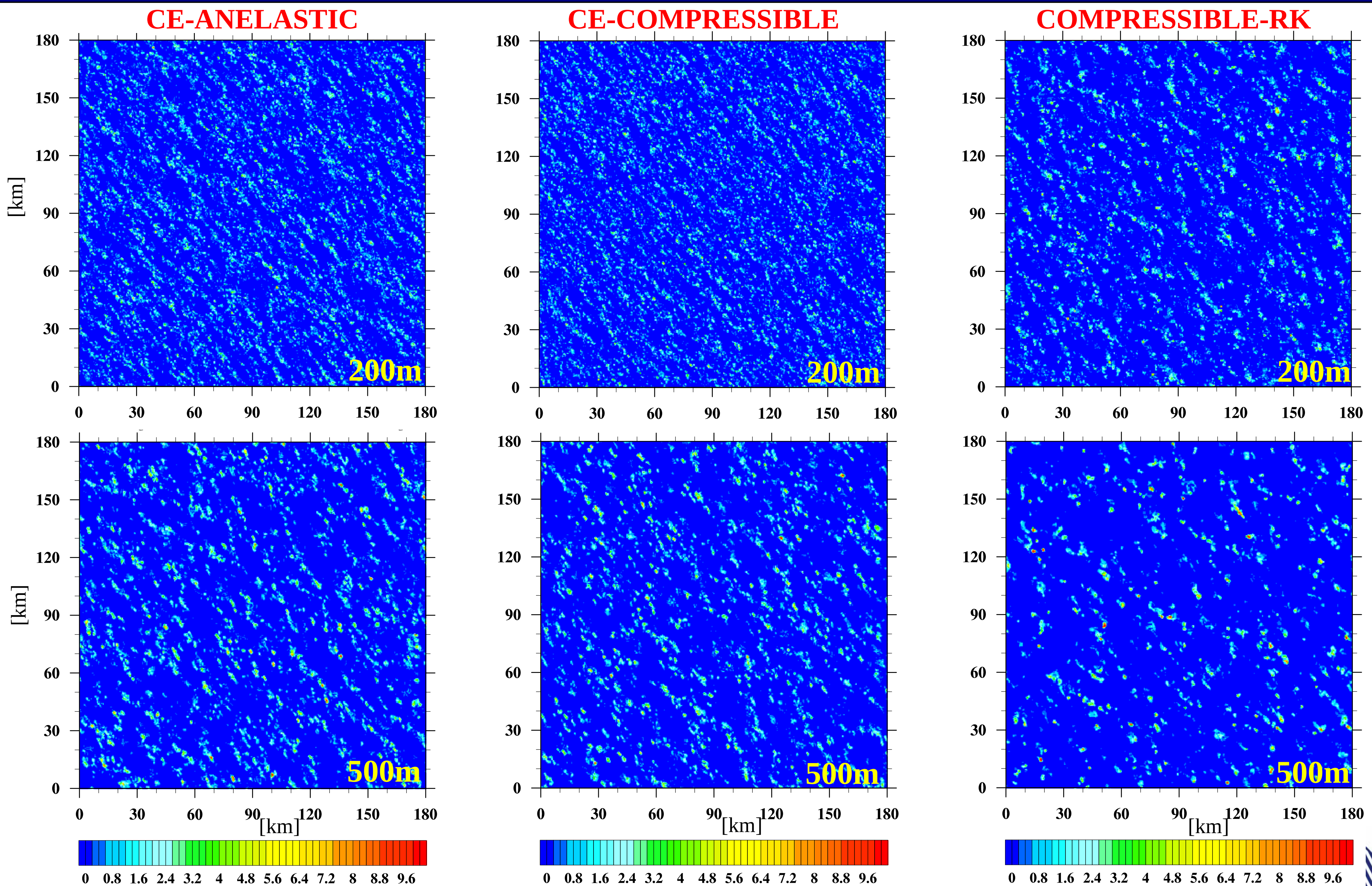
Evolution of the lower-tropospheric water-vapour mixing-ratio



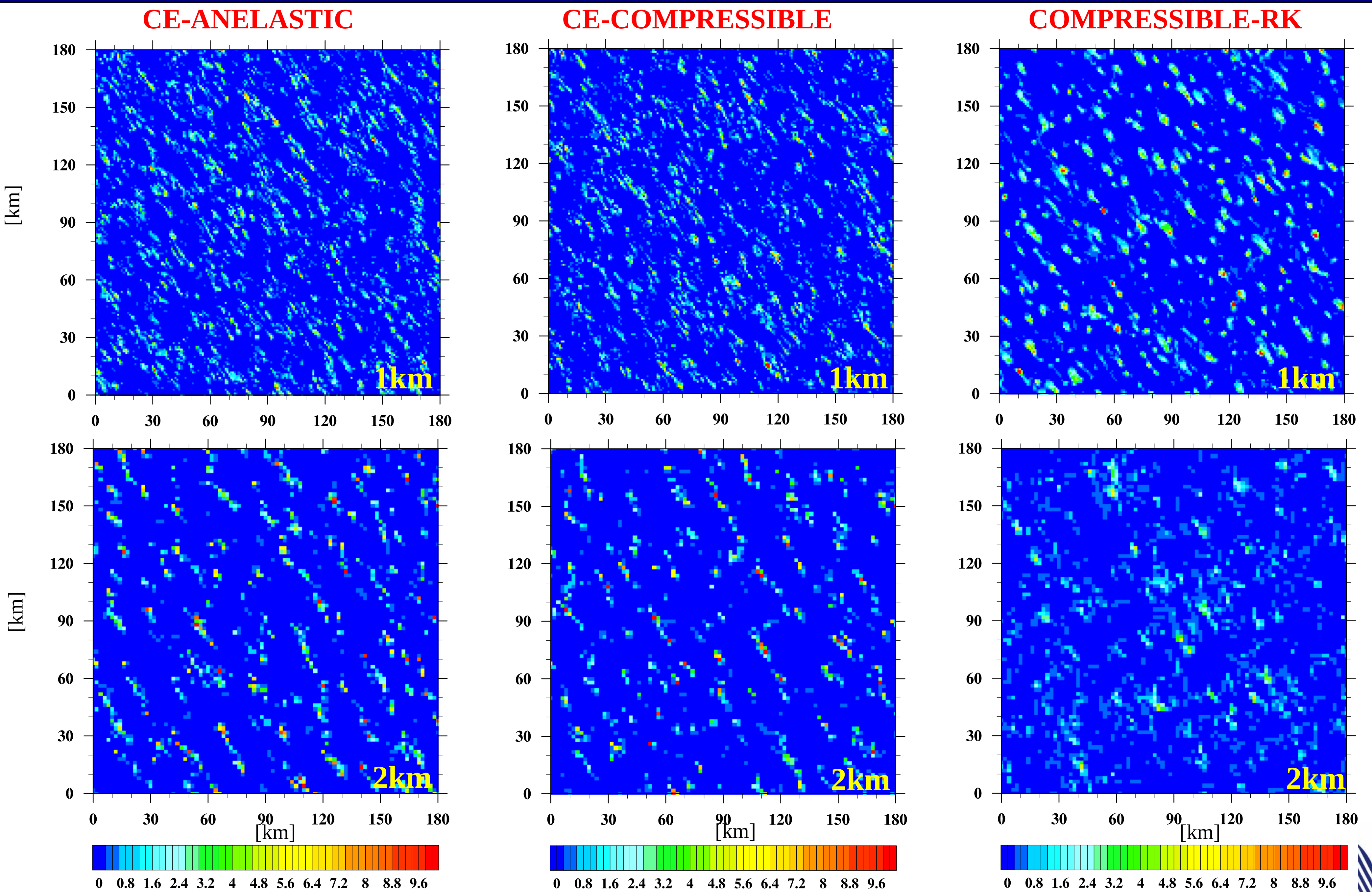




Vertical integrated cloud water [kg/m^2] at t = 6h

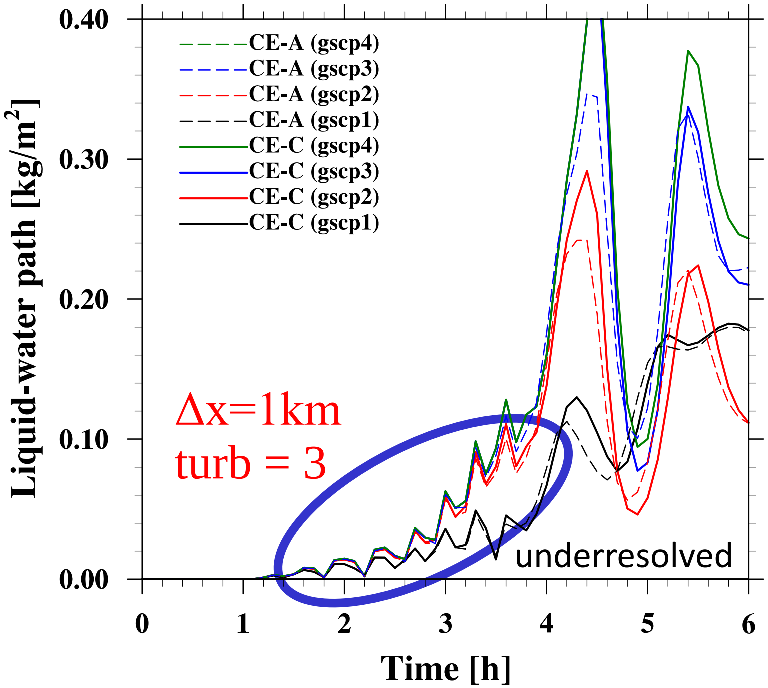


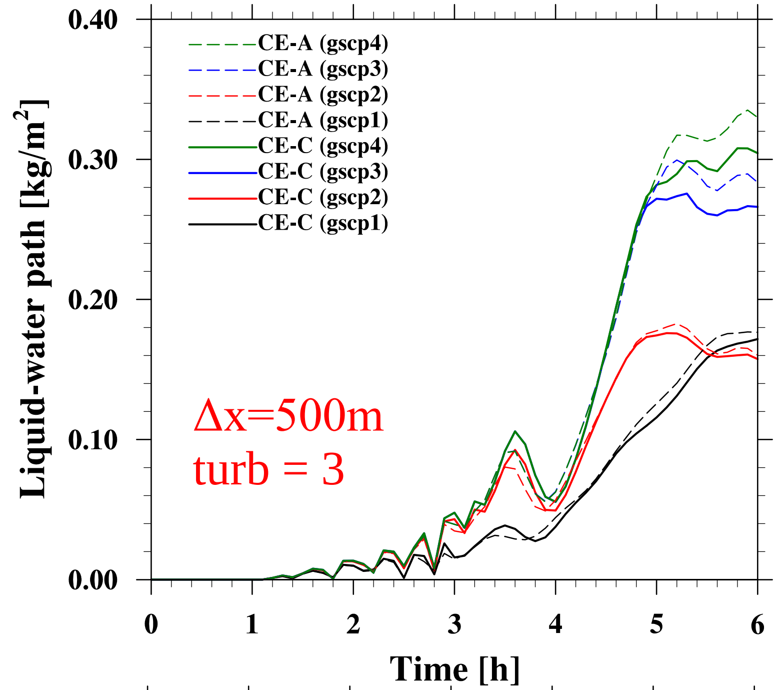
Vertical integrated cloud water [kg/m²] at t = 6h



ECMWF, Reading, 4th October 2016

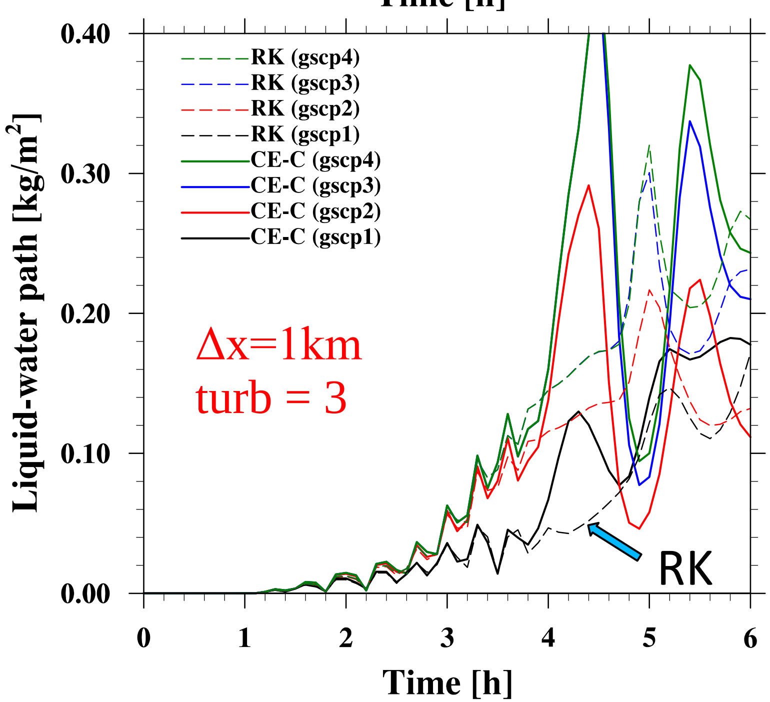
Liquid-water path [kg/m2]

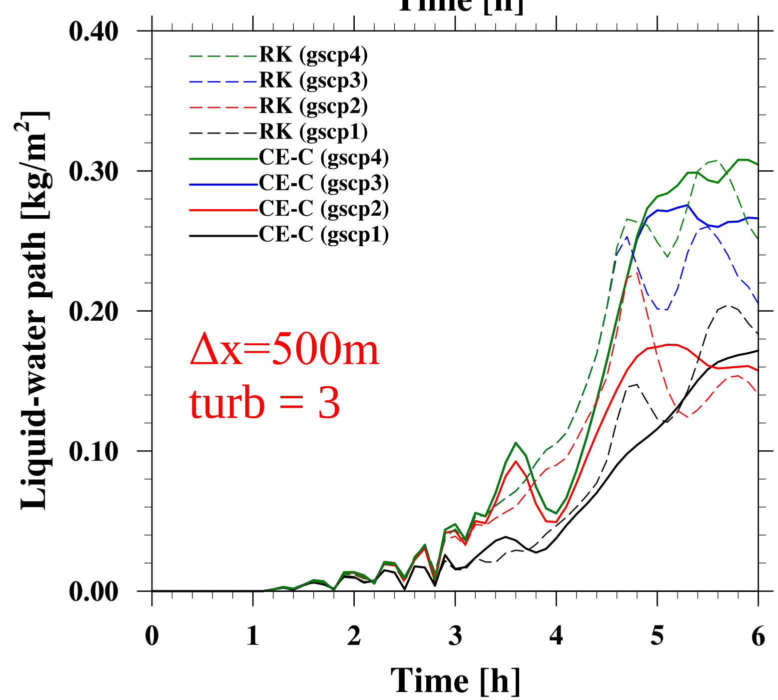




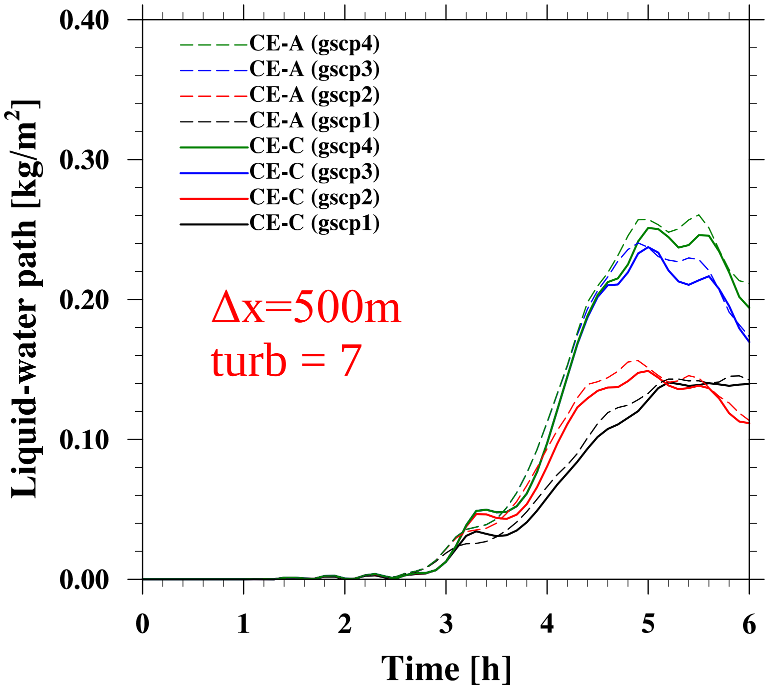
turb – vertical turbulent diffusion

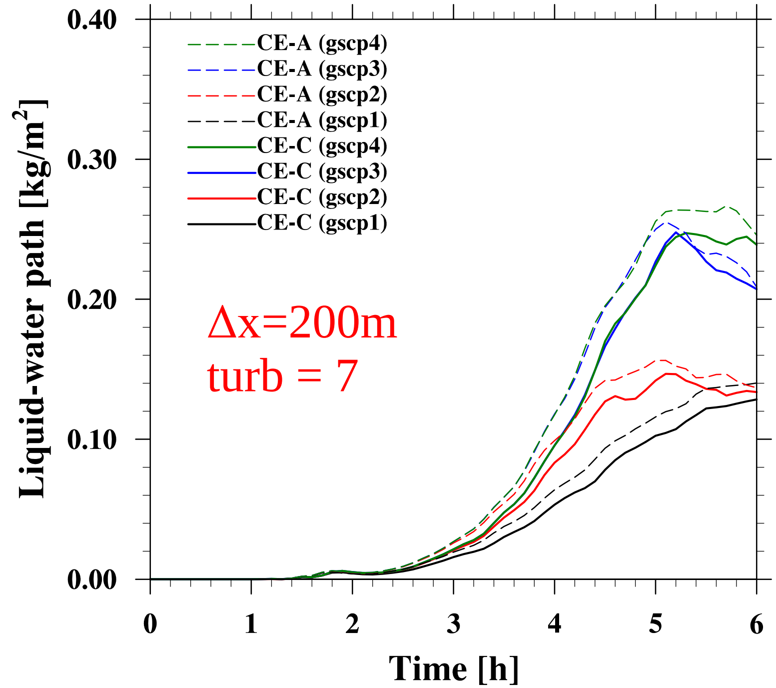
3) 1-D TKE based diagnostic closure

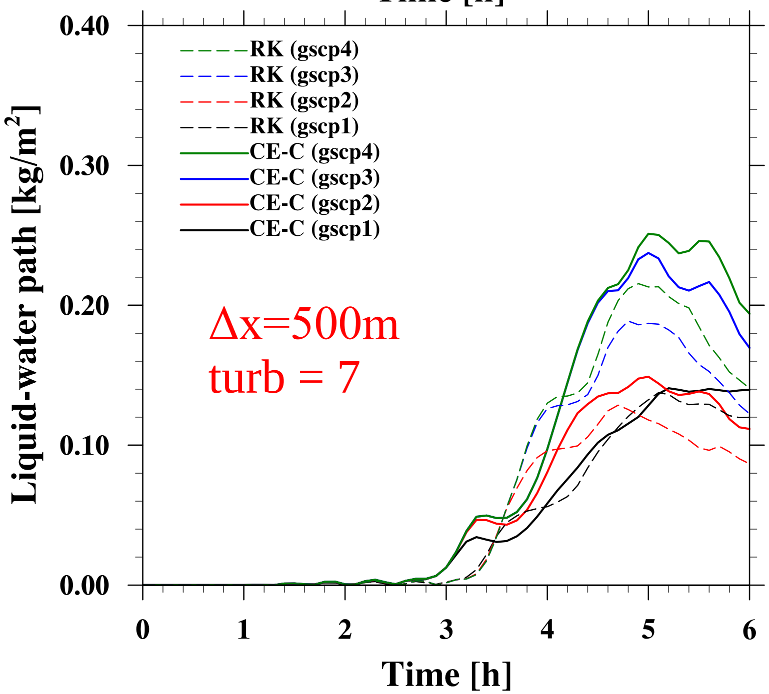


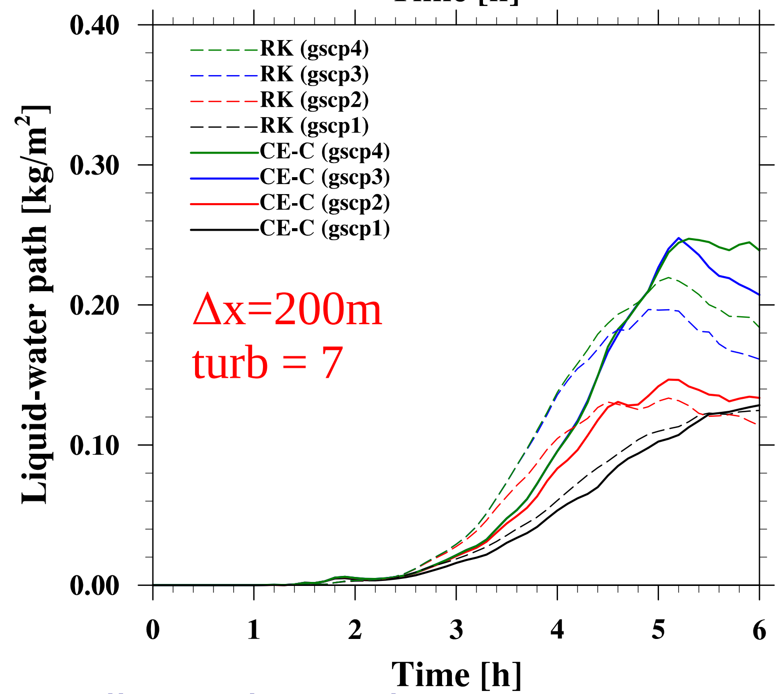


Liquid-water path [kg/m2]





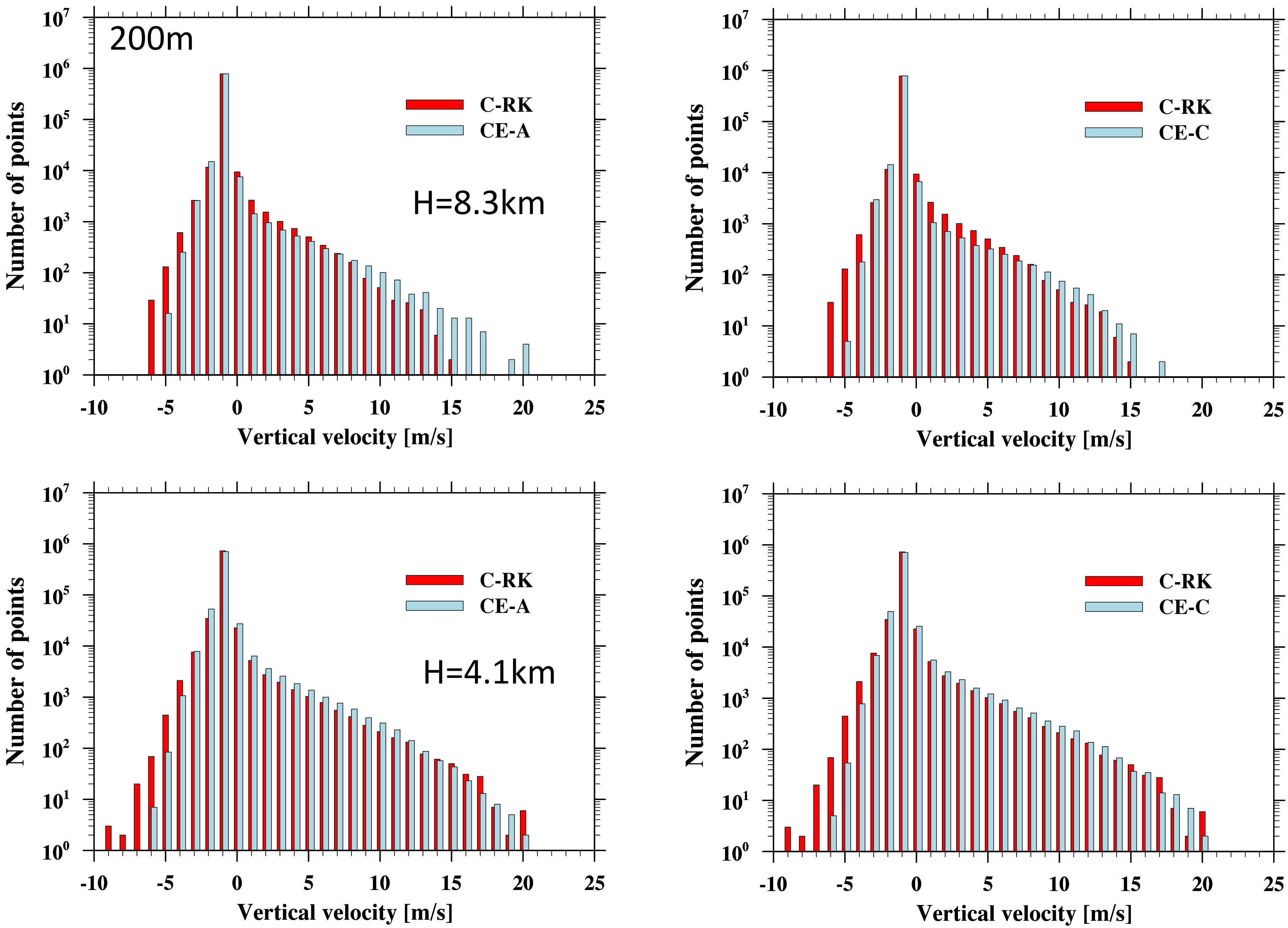




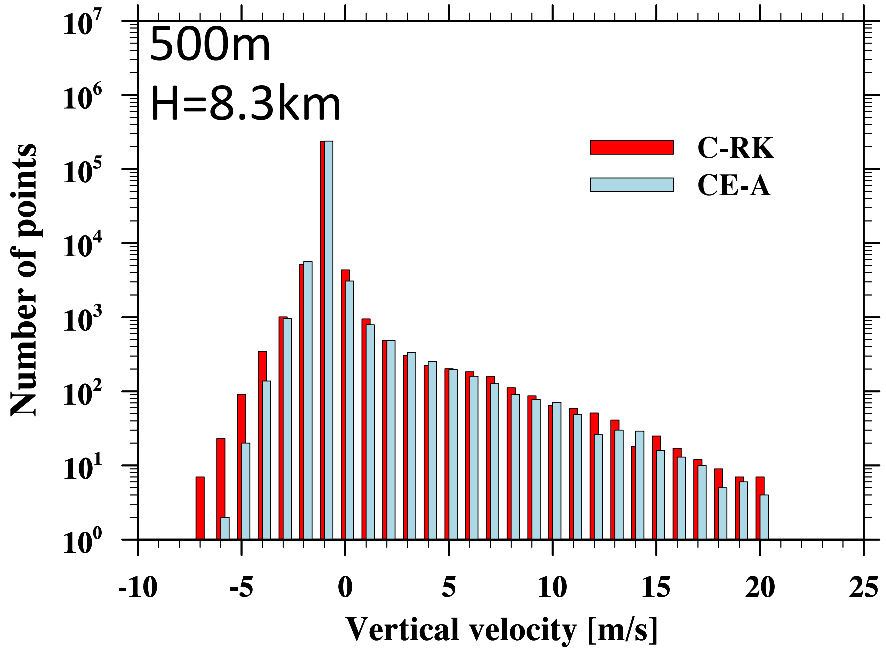
turb – vertical turbulent diffusion

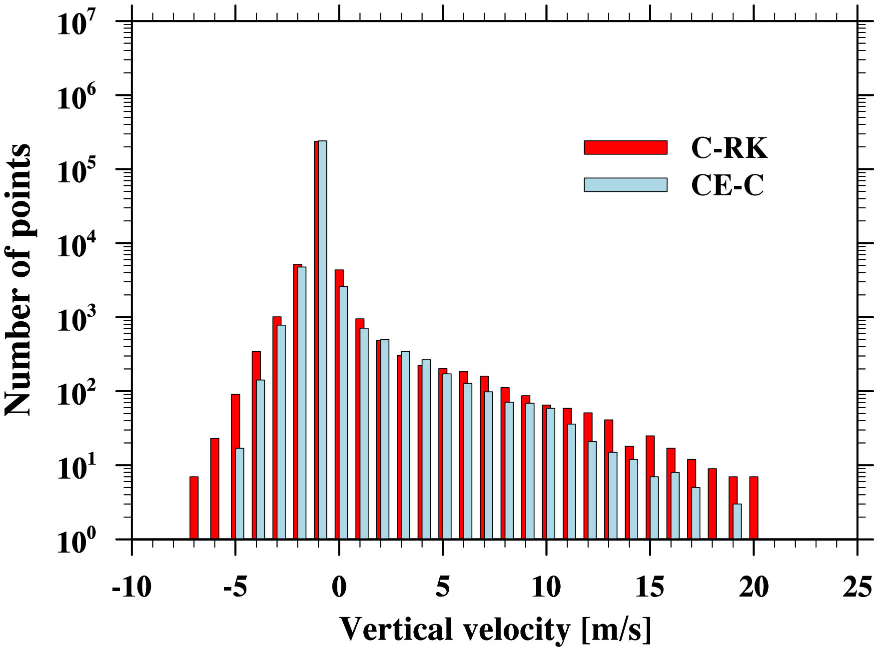
7) 3-D closure for highly resolved LES-like model simulations

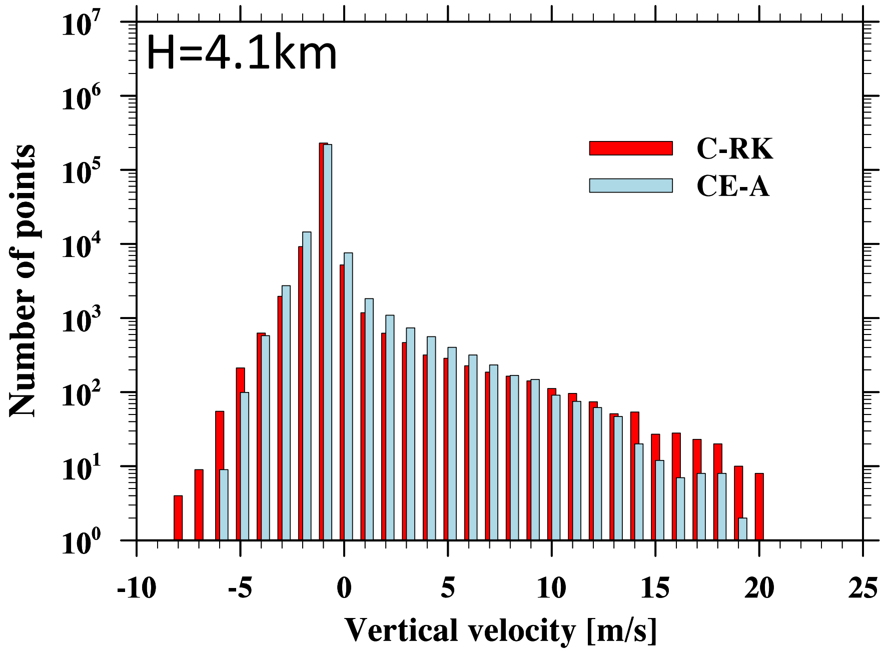
HISTOGRAMS OF VERTICAL VELOCITY AT t=6h

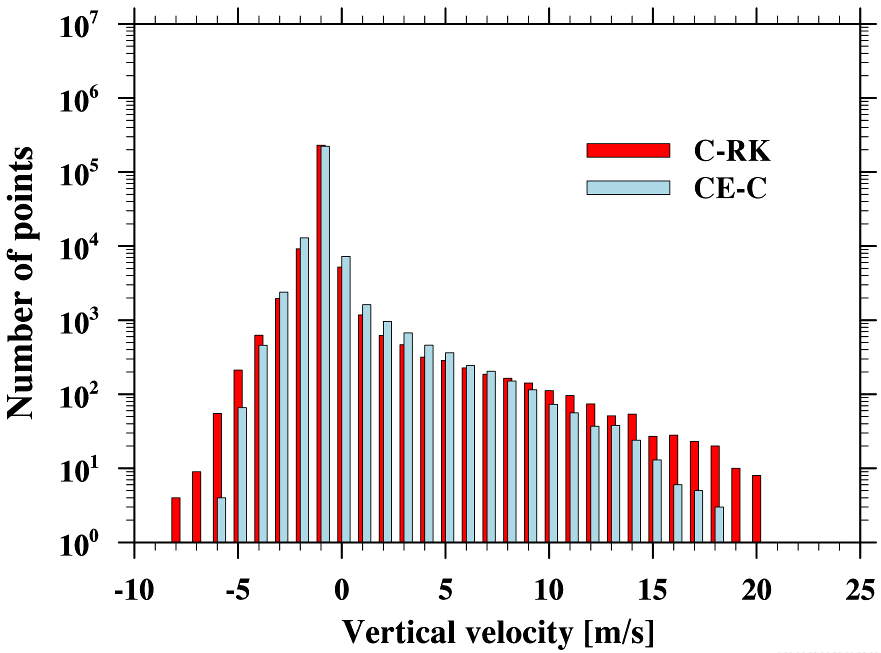


HISTOGRAMS OF VERTICAL VELOCITY AT t=6h



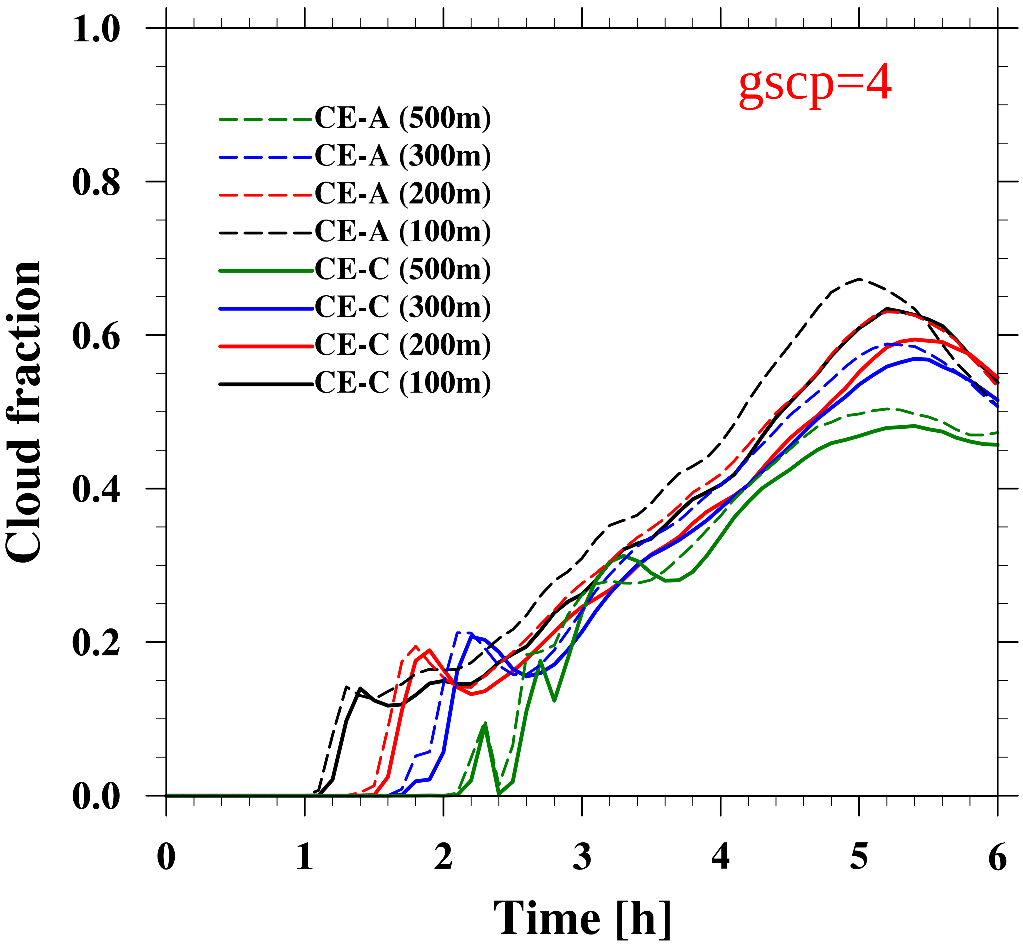


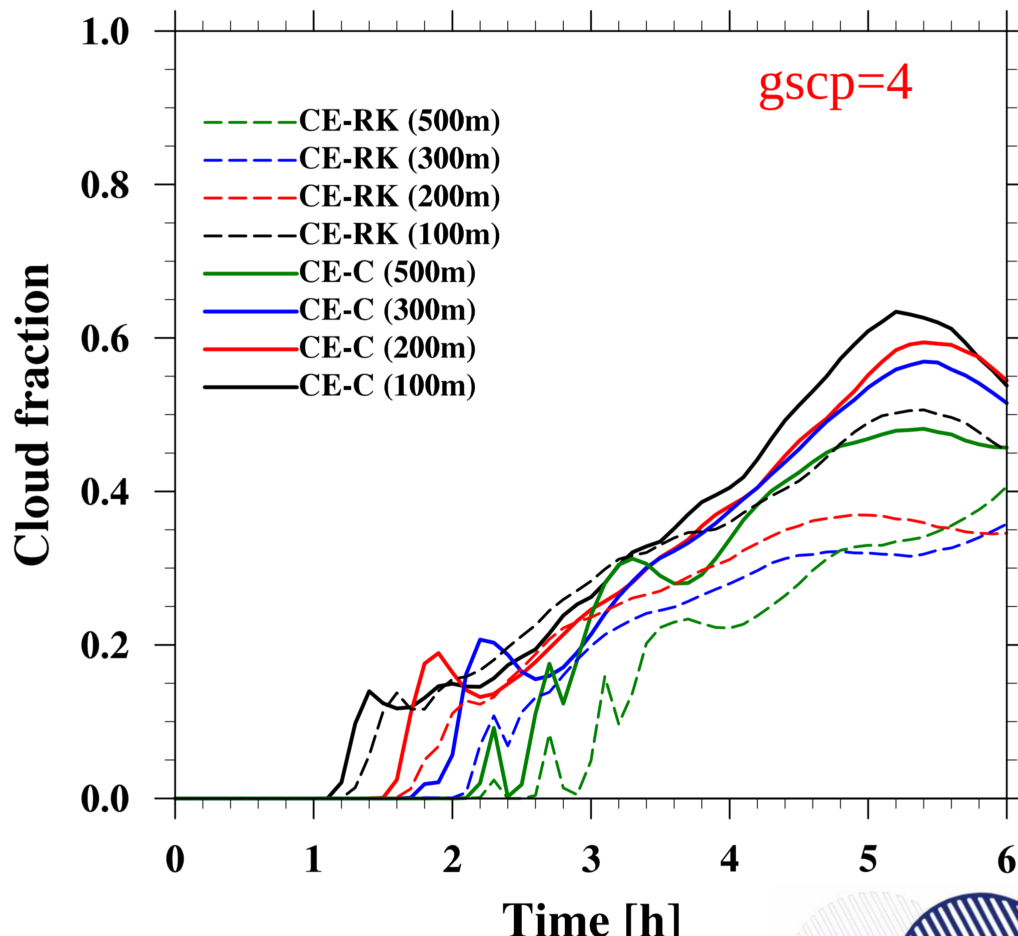




Cloud fraction

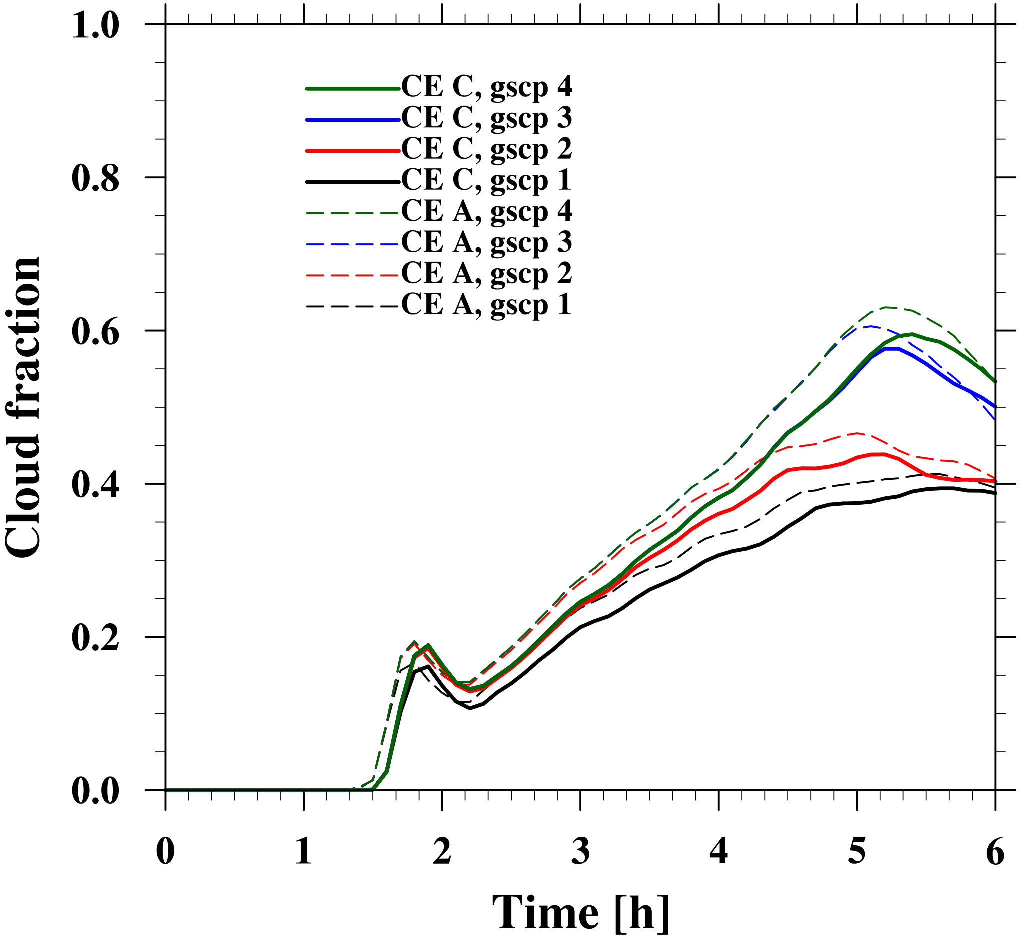
The cloud fraction is defined as a fraction of grid boxes at a given level with the cloud condensate mixing ratio (water plus ice) larger than the threshold value, selected as 10^{-5} [kg/kg].

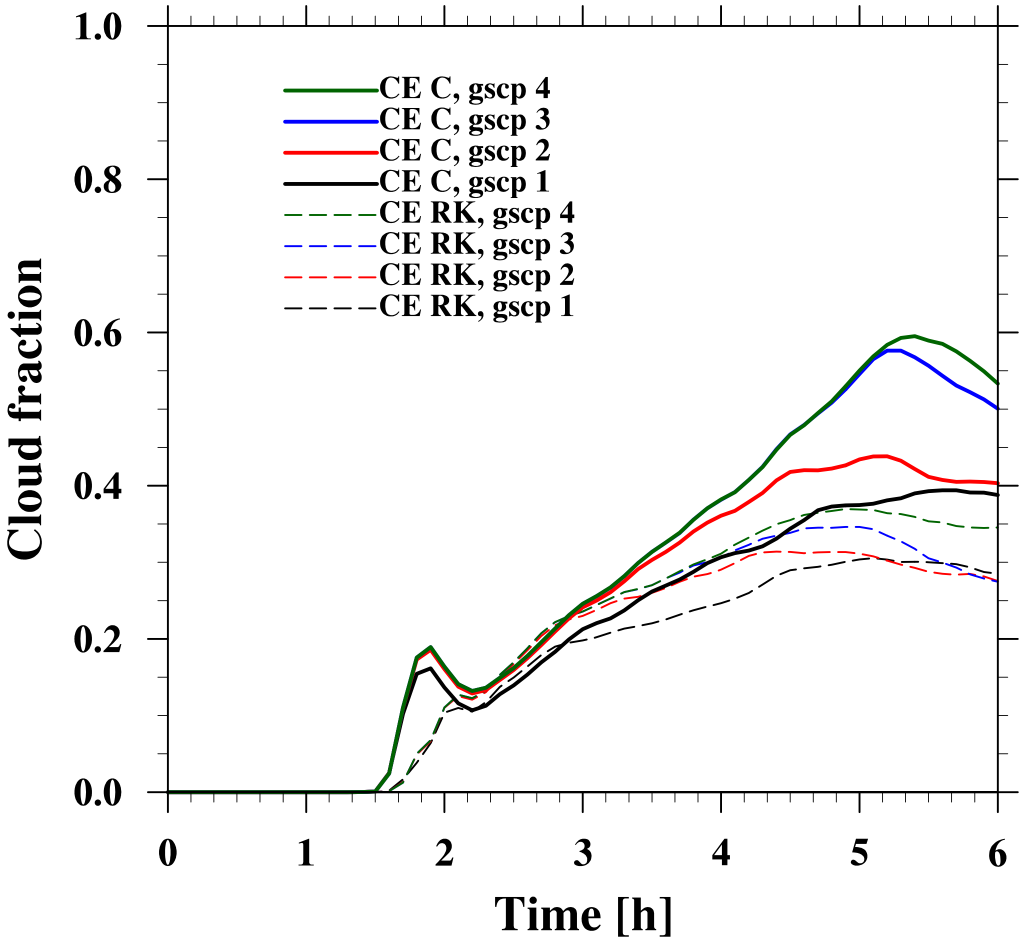




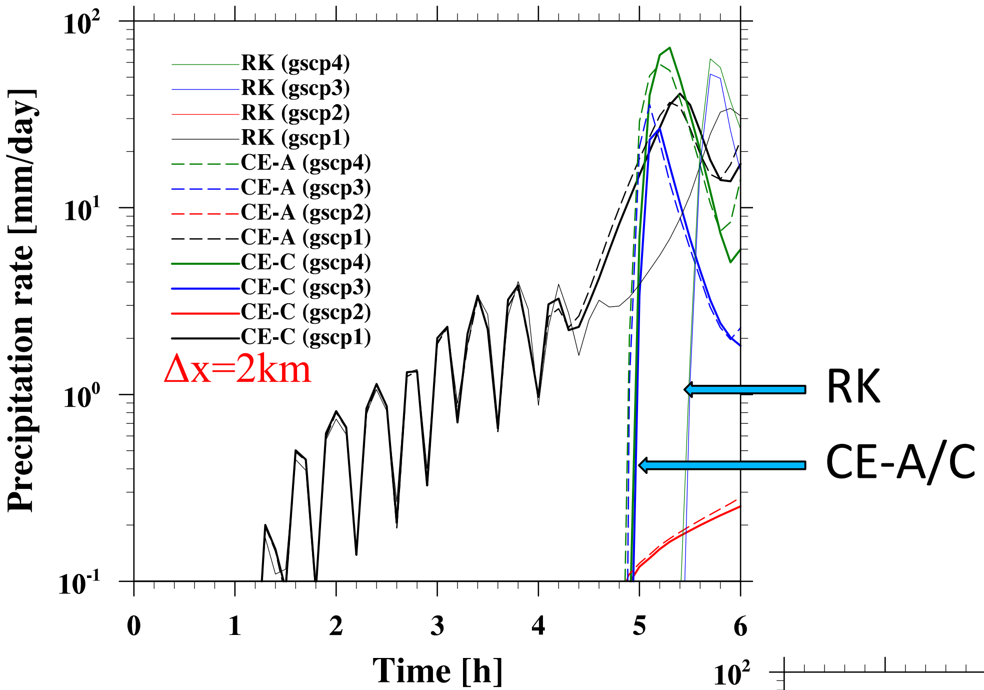
Cloud fraction

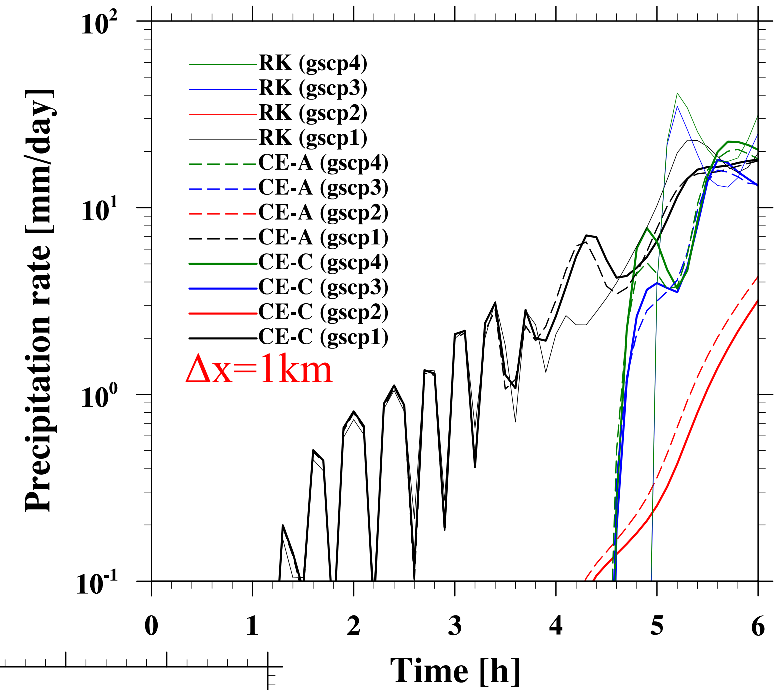
All simulations have been performed at horizontal resolution dx=200m



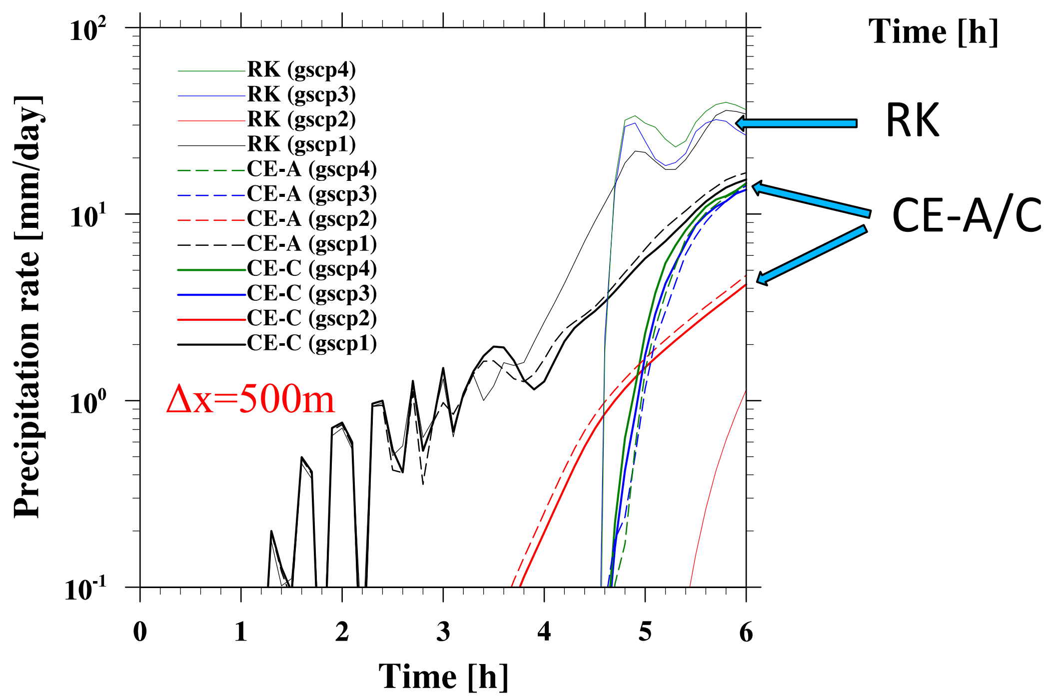


Precipitation rate [mm/day]

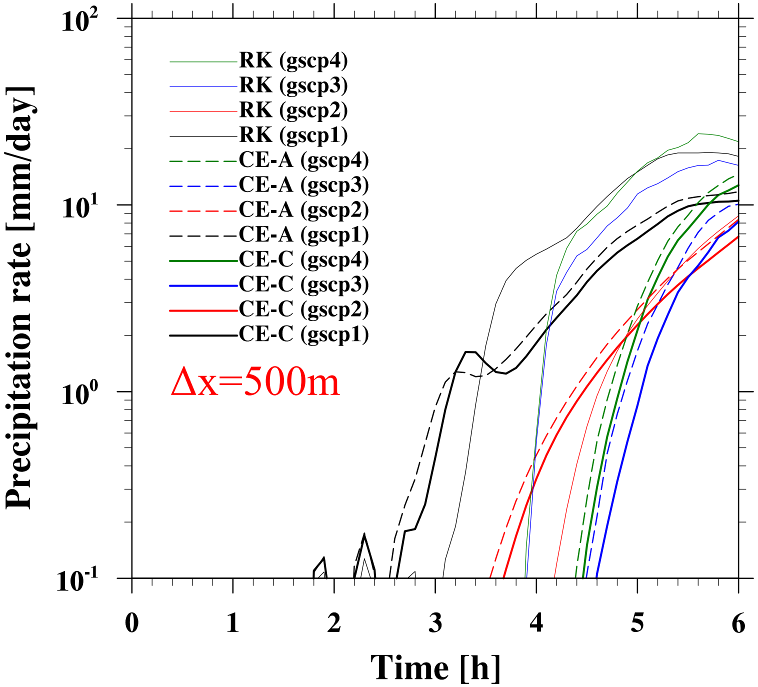


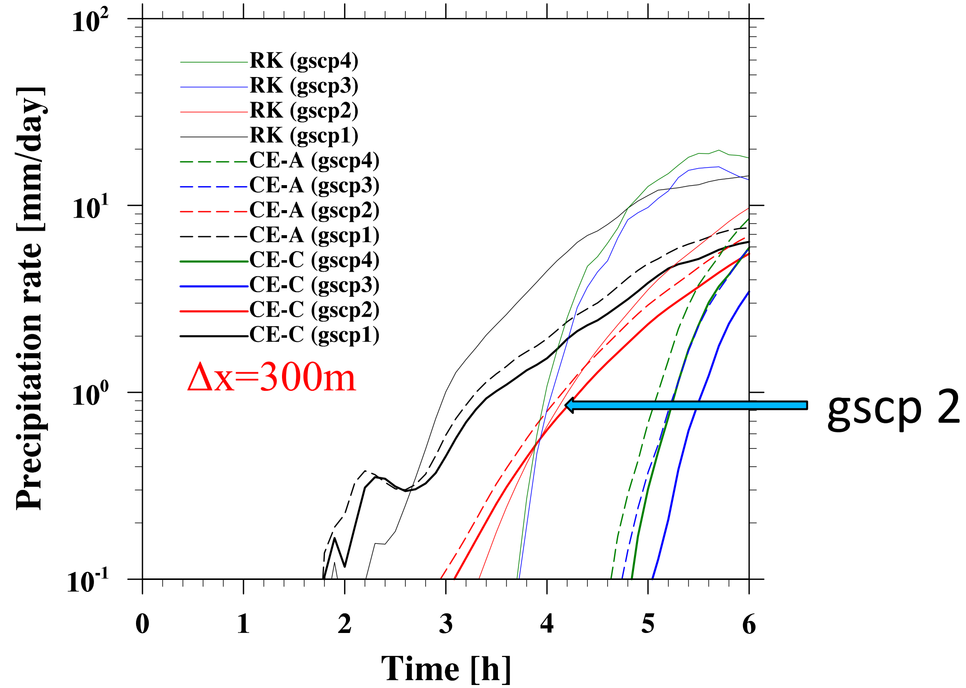


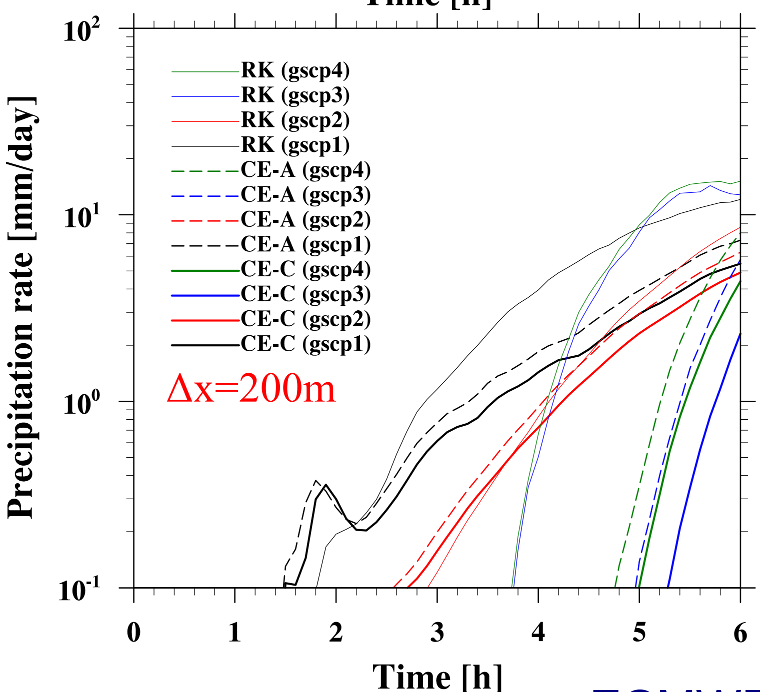
vertical turbulent diffusion
1-D diagnostic closure

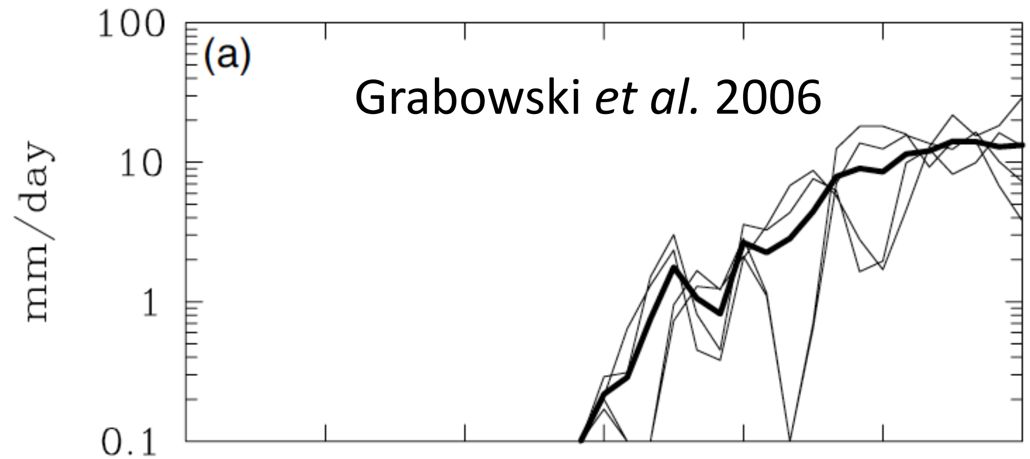


Precipitation rate [mm/day]

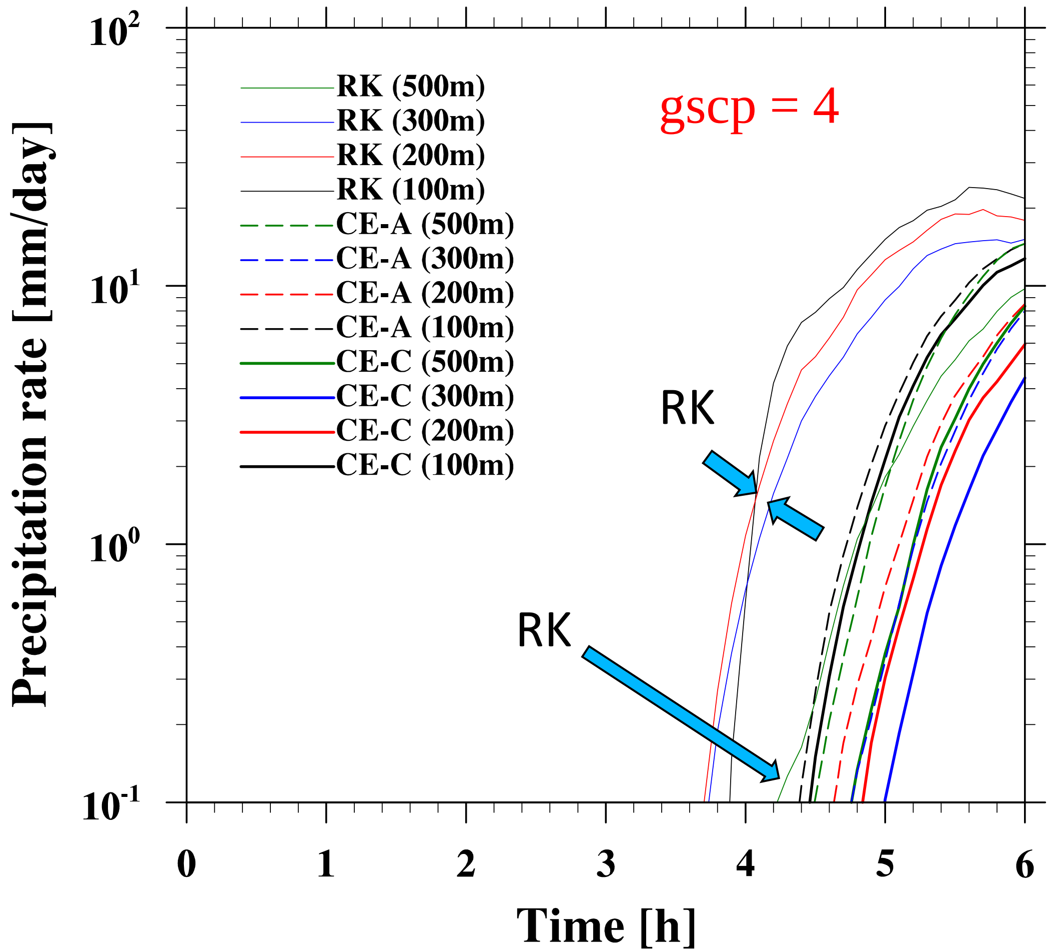






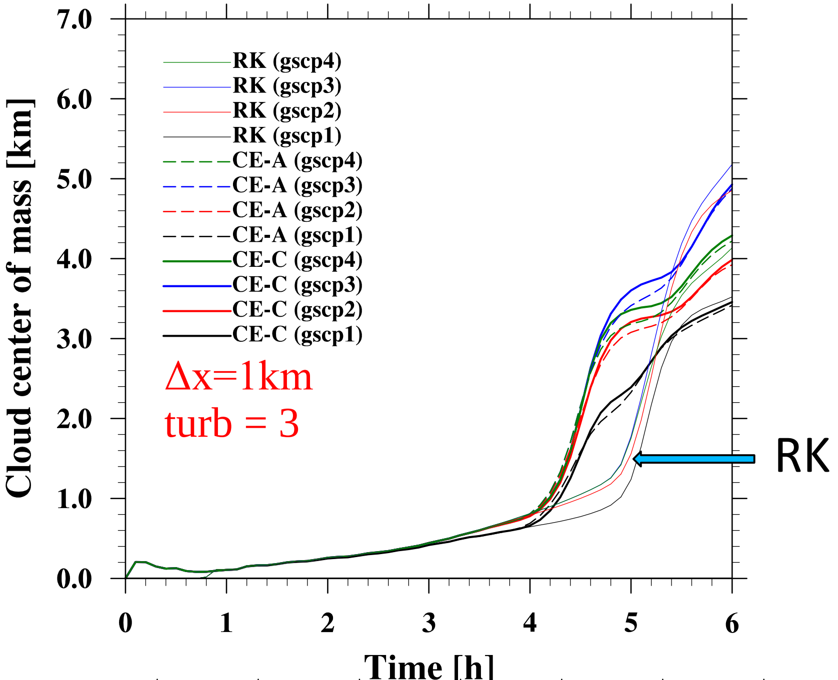


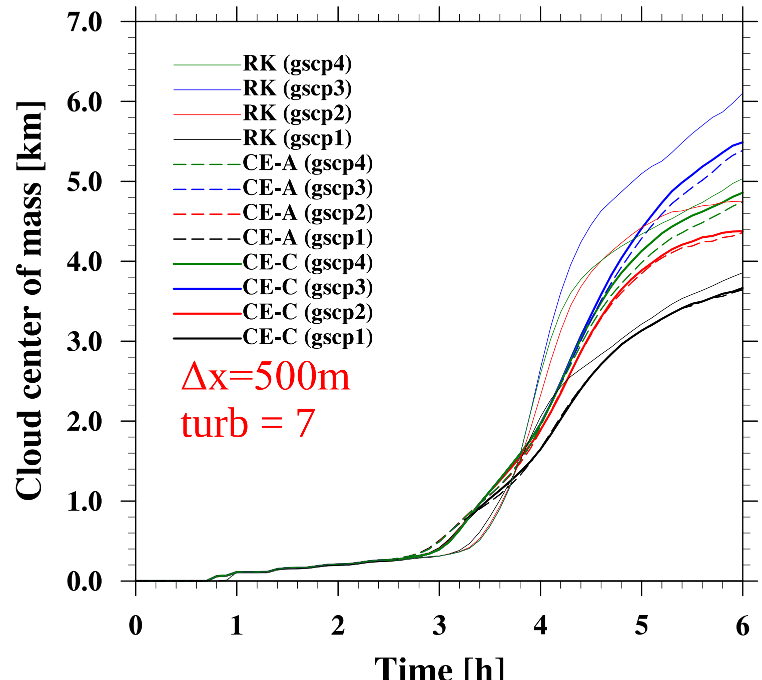
Precipitation rate [mm/day]

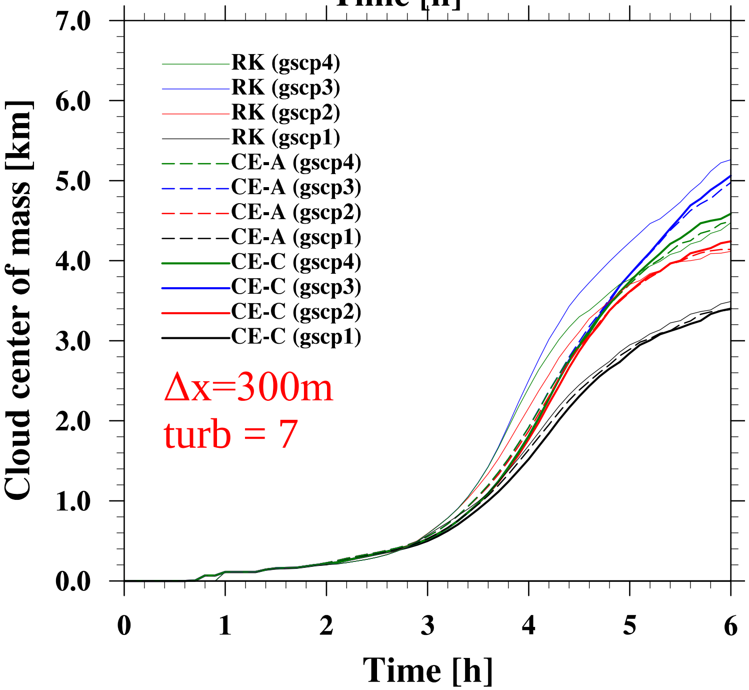


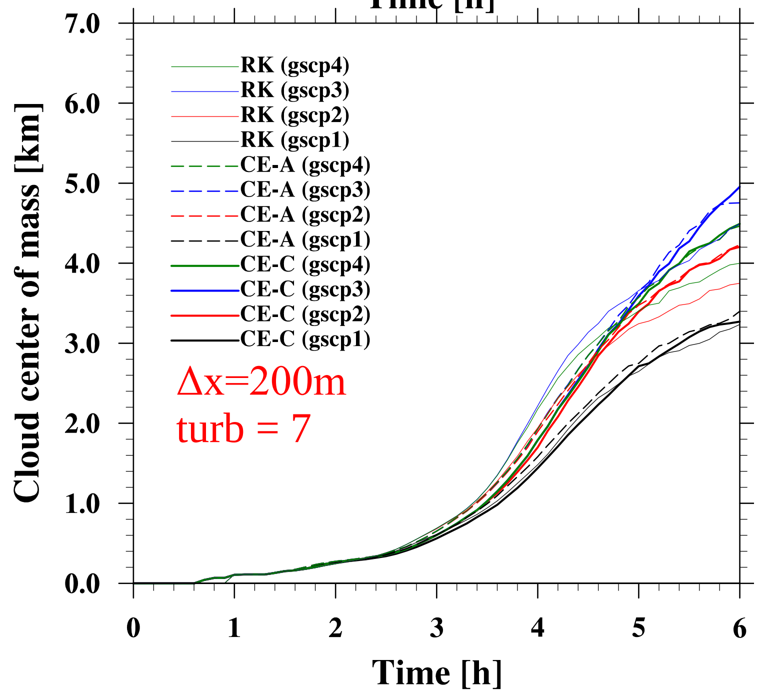
1. Results from high resolution simulations with the three dynamical cores are in qualitative agreement with the reference solution from Grabowski et al. 2006 (especially for gscp = 2).
2. Formation of precipitation in simulations with CE-A/C is slightly slower than in CE-RK for gscp = 3 and 4 and faster for gscp =1 and 2.
3. Amount, temporal structure and onset of precipitation strongly depend on microphysics parameterization scheme.

Height of cloud center of mass [km]

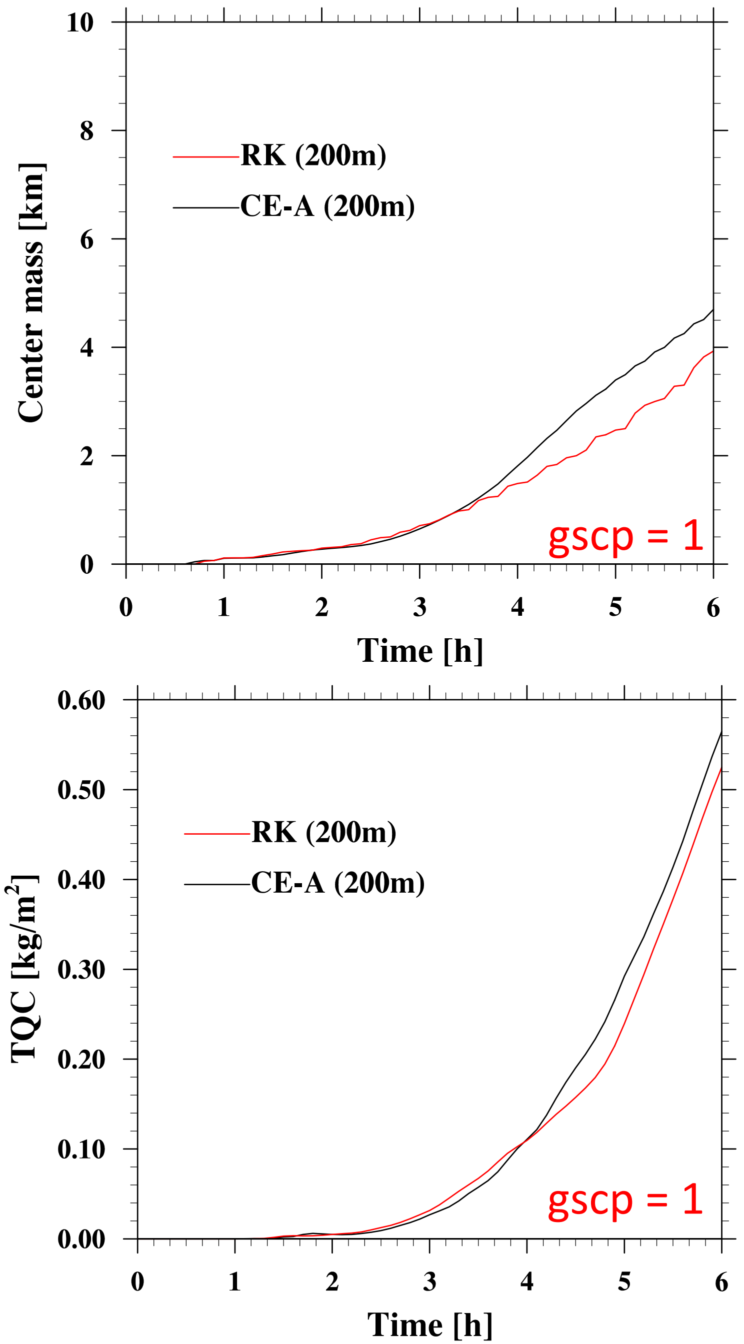








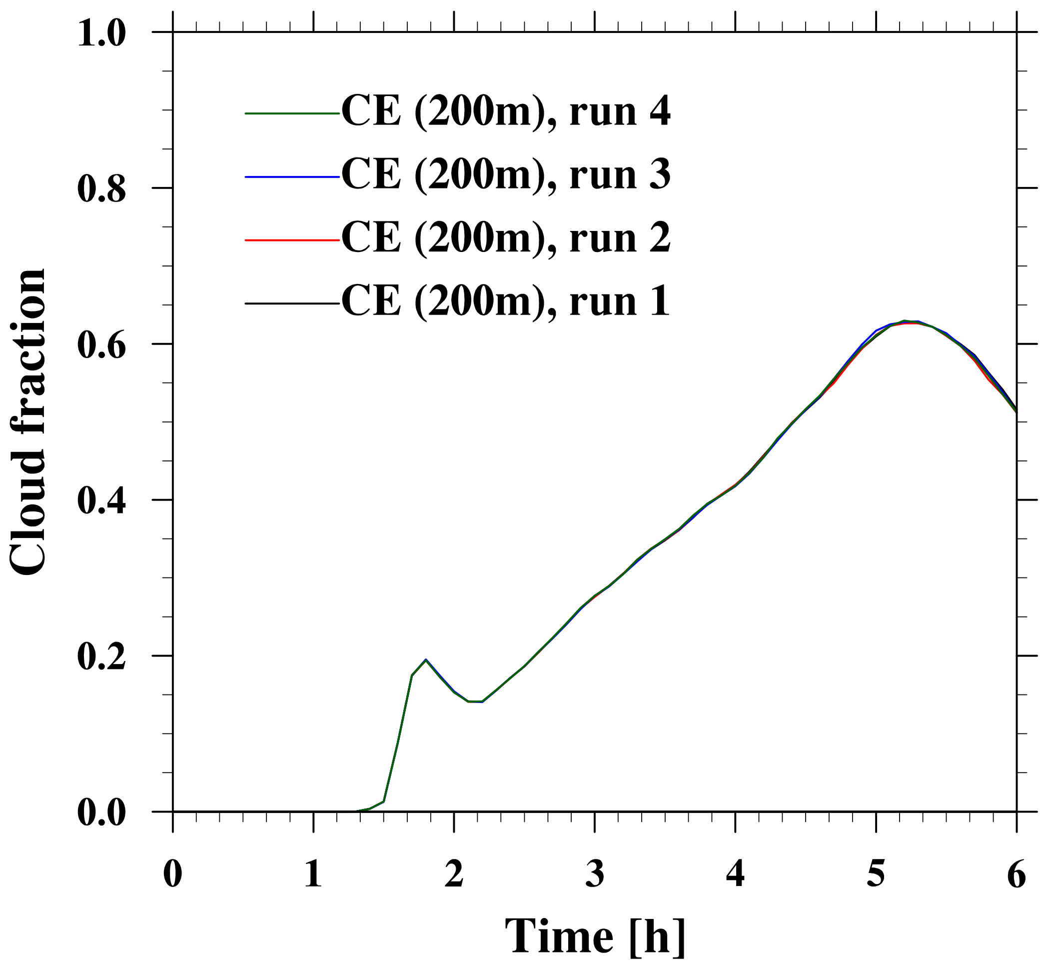
Simulations with precipitation switched off



The simulations with CE-A and COSMO-RK have been performed using “warm rain scheme” but without including grid scale precipitation

It means, that effects of precipitation formation on temperature and the prognostic moisture variables (water vapour, cloud water) **were not considered**.

Sensitivity to random noise



For each run we used different seed to initialize random generator.

We conclude that the results are not sensitive to the random noise.

Conclusions

1. General characteristics of cloud field and precipitation strongly depend on horizontal resolution with clouds and precipitation developing consistently earlier for higher model resolutions
2. The characteristics of cloud field and precipitation depend also strongly on microphysics scheme which influences both onset and evolution of precipitation rate
3. The influence of anelastic effect (the difference between EULAG compressible and anelastic solution) is generally smaller compared to the effect of numerical realization of the dynamical core (the difference between compressible EULAG and RK solutions) for cloud cover and precipitation