P3.2

SINGLE COLUMN SIMULATIONS OF COSMO FOR THE GCSS RICO PRECIPITATING SHALLOW CUMULUS CASE

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1 MOTIVATION

Maritime cumulus clouds, which typically extend to no greater than 4 km altitude are some of the most prevalent cloud types on Earth. They are ubiquitous over much of the tropical oceans, and characterizing their properties is important to understand the global energy balance and climate. To consider these clouds and how rain develops within them in numerical models, a wide range of scales (from micro-meters to tens of kilometers) have to be taken into account. However, key processes, which influence shallow cumulus cloud development and initiation of precipitation are often subgrid-scale in numerical weather prediction (NWP) models.

The broad objective of the Rain in Cumulus over the Ocean (RICO) experiment was to measure and understand the properties of trade wind cumulus at all scales, with particular emphasis on determining the importance of the development of rain. The RICO field campaign took place during November 2004-January 2005 off the Caribbean islands of Antigua and Barbuda within the northeast trades of the western Atlantic (see e.g., Rauber et al., 2007 for details).

RICO focused primary on interrelated scientific issues as the initiation of precipitation in trade wind cumulus, microphysics of rain formation, organization and water budget of trade wind clouds.

Single Column Model (SCM) intercomparison studies based on prescribed initial and boundary conditions demonstrated their scientific value in improvement of numerical weather forecast models (e.g., ARM SCM Intercomparison studies). Initial mean state profiles and mean large scale forcings for a situation favorable for shallow cumulus cloud development provided by the RICO SCM intercomparison case have been used in a short composite simulation based on COSMO-SCM in the COSMO-DE setup (Baldauf et al., 2007) to evaluate assumptions used in cloud microphysics and moist turbulence parameterization.

2 MODEL: COSMO-SCM

The single column model (SCM) framework of COSMO has been developed as a tool supporting the improvement of physical parameterizations for the NWP COSMO model of DWD (Raschendorfer, 2007). It can be used for recalculation of the model at specific grid columns with different physical parameters or formulations for the purpose of comparison, model validation or parameter tuning. Due to the facility of flexible model forcing it is possible to perform sophisticated component testing, involving a lot of specific measurements offered e.g. by meteorological observatories, such as tower measurements of atmospheric properties and their turbulent flux densities.

Model parameters for SCM forcing run:

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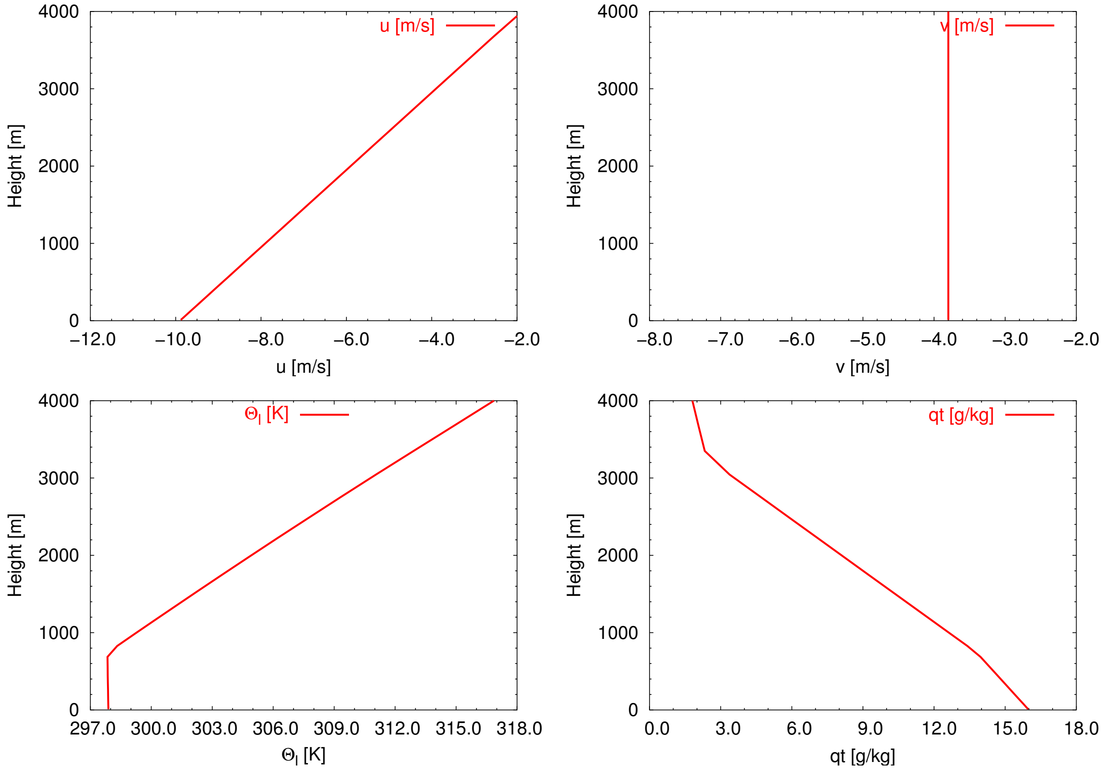

Figure 1: Initial profiles of zonal and meridional wind velocity, liquid water potential temperature and total moisture.

- Latitude: 18.0 N Deg.
- Longitude: 61.5 W Deg.
- Model time step: 30 s
- Vertical main levels: 50

The model was integrated for 72 h using saturation adjustment, geostrophic wind forcing, large scale subsidence and shallow convection parameterization based on the modified Tiedke-scheme.

3 RICO - SCM INTERCOMPARISON

In order to evaluate assumptions used in COSMO cloud microphysics and moist turbulence parameterization the short composite setup of the SCM Intercomparison study has been used (van Zanten, Nuijens and Siebesma – `http://www.knmi.nl/samenw/rico/`). The setup of this case is based on mean subsidence velocity profiles and the mean large scale temperature and moisture tendencies due to horizontal advection derived from the RACMO (Regional Atmospheric Climate Model) HindCast (high-resolution version of the ECMWF model initialized every 24 hours with the ECMWF analysis at 12 UTC). The RACMO simulation was performed for December 2004 and January 2005 for a small domain, consisting of 90 x 92 gridpoints with a resolution of 20km, in which the RICO research area (61.46W, 17.97N) is contained. The surface conditions prescribed a surface pressure p_s = 1015.4 hPa and sea surface temperature T_s = 299.8 K.

Large scale advection and subsidence are based on the analysis of the RACMO HindCast centered around the RICO Domain. The radiation is based on an offline version of the ECMWF radiation scheme. Since radiative tendencies are prescribed, COSMO-SCM simulations with deactivated radiation scheme were performed.

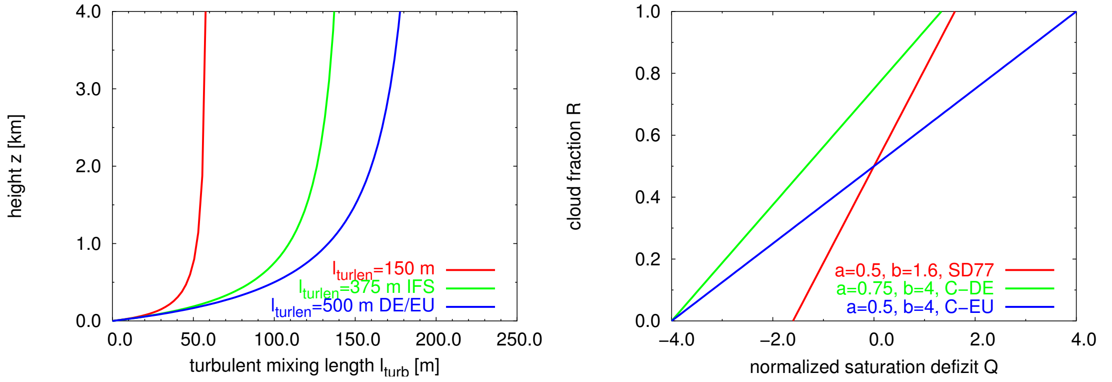

Figure 2: Vertical profiles of turbulent mixing lengths (left) and relationship between normalized saturation deficit and subgrid-scale cloud fraction (right).

4 CONSIDERED PARAMETERS

4.1 *Turbulent mixing length*

The COSMO turbulence parameterization uses a master length scale profile based on Blackadars (1962) formulation:

$$l_{turb} = \frac{\kappa z}{1 + z/l_{\text{turlen}}}, \quad (1)$$

where l_{turlen} is an asymptotic length scale (Fig. 3).
Independent of model resolution for COSMO $l_{\text{turlen}} = 500$ m is applied operationally.

4.2 *Subgrid-scale cloud coverage*

Subgrid-scale cloud coverage is computed in the moist turbulence parameterization using a statistical cloud scheme. Based on the normalized saturation deficit Q according to Sommeria and Deadorff (1977) the subgrid-scale cloud fraction R is approximated by

$$R = a\left(1 + \frac{Q}{b}\right). \quad (2)$$

Apart from the proposed values of a and b by Sommeria and Deadorff (1977) different values are used in COSMO depending on model resolution (Fig. 4), in order to account for deviations from a normal distribution of Q.

4.3 *Cloud droplet number concentration*

In operational COSMO cloud microphysics (Seifert and Beheng, 2001) a cloud droplet number concentration of 500 cm^{-3} is applied. However, measurements of microphysical bulk parameters during the Puerto Rico Aerosol and Cloud Study (PRACS) (Baumgardner et al., 2006) indicate that in most cases a cloud droplet number concentration below 40 cm^{-3} (e.g., 30 cm^{-3}) is more representative for maritime air.

5 RESULTS

5.1 *Reference simulation*

The reference simulation is based on a setup, which is operationally applied in the COSMO-DE model. Here, a turbulent mixing length $l_{\text{turlen}} = 500$ m, subgrid-scale cloud coverage parameters $a = 0.75$, $b = 4$, and cloud droplet number concentration 500 cm^{-3} were used. Resulting hourly averages of liquid water potential temperature, liquid water content, rain water content, turbulent kinetic energy, dissipation, and buoyancy production are shown in Fig. 3.

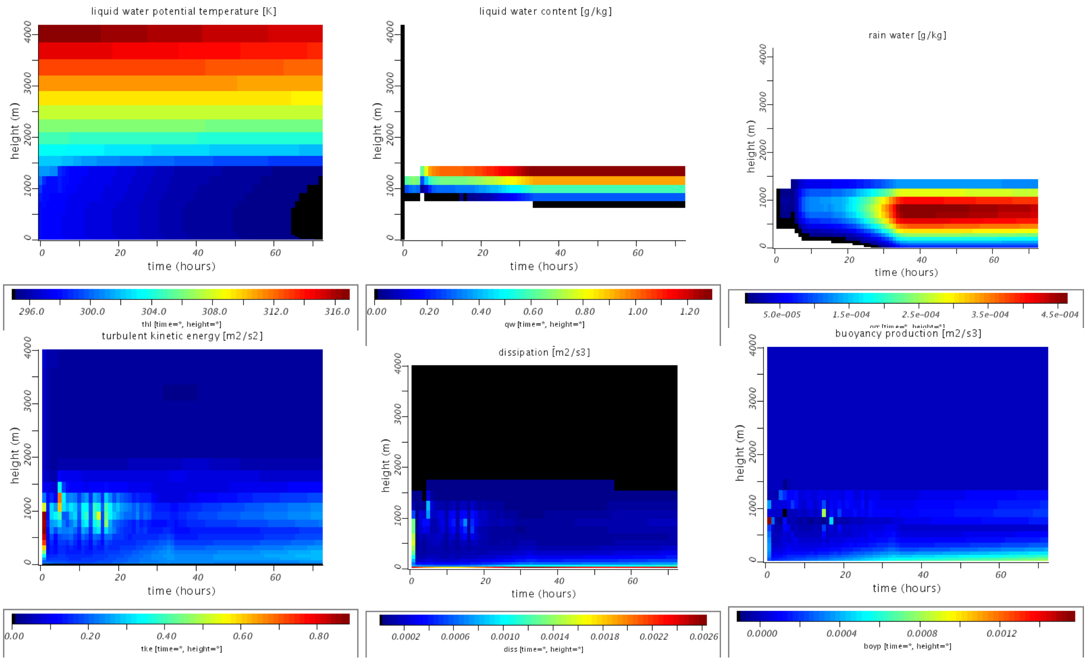

Figure 3: Time-height development of liquid water potential temperature, liquid water content, rain water content, turbulent kinetic energy, dissipation, and buoyancy production (hourly averages of the reference simulation).

5.2 *Adapted turbulent mixing length and subgrid-scale cloud fraction*

In an experimental setup the turbulent mixing length was reduced to $l_{\text{turlen}} = 150$ m and the parameters in subgrid-scale cloud coverage according to Sommeria and Deadorff (1977) were applied ($a = 0.5$, and $b = 1.6$), while cloud droplet number concentration is 500 cm^{-3} (Fig. 4).

5.3 *Adapted cloud droplet number concentration*

The experimental setup (reduced turbulent mixing length, subgrid-scale cloud coverage according to Sommeria and Deadorff (1977)) was used. Furthermore a lower cloud droplet number concentration of 30 cm^{-3} was applied (Fig. 5).

6 CONCLUSIONS

In order to evaluate assumptions used in COSMO cloud microphysics and moist turbulence parameterization SCM simulations for the RICO SCM Intercomparison project (based on the short composite setup) have been conducted. A reference simulation with operational COSMO-DE settings and experiments with reduced turbulent mixing length, adapted subgrid-scale cloud fraction parameterization parameters (only used for the moist turbulence scheme), and reduced cloud droplet number concentration were performed. The results show that in comparison to the reference simulation the reduced turbulent mixing length together with adapted subgrid-scale cloud fraction decelerate cloud development and rain production. This could related to the reduced turbulent kinetic energy, buoyancy production, and dissipation in the boundary layer of the experiment during first 24 hours of the model integration. Applying a reduced cloud droplet number concentration as expected has a strong impact on

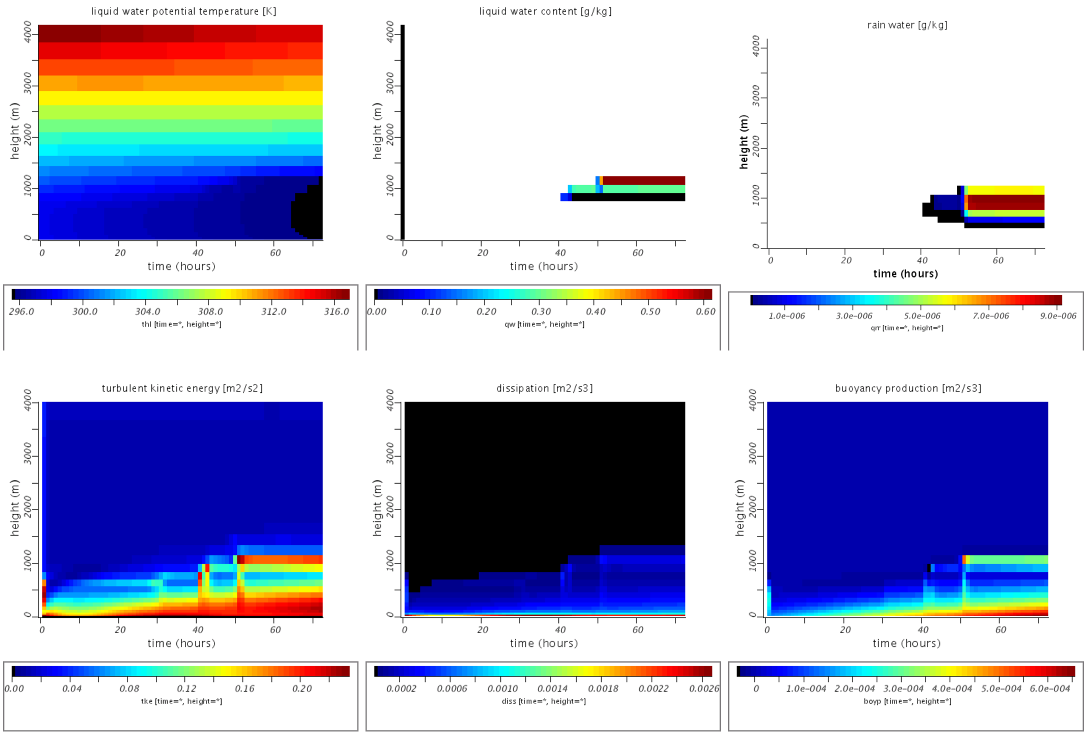

Figure 4: As in Fig. 3 for the simulation using adapted turbulent mixing length and subgrid-scale cloud fraction.

the rain water content, whereas a negligible impact of switching off the shallow convection scheme (not shown) was found.

7 REFERENCES

Baldauf, M. et al., 2007: Kurze Beschreibung des Lokal-Modells Kuerzestfrist LMK und seiner Datenbanken auf dem Datenserver des DWD., Tech. Report., Deutscher Wetterdienst.

Baumgardner, D. et al., 2006: Aerosol-cloud interactions on a mountain peak in Puerto Rico., 12th Conference on Cloud Physics, Madison (WI).

Blackadar, A. K., 1962: The vertical distribution of wind and turbulent exchange in a neutral atmosphere. J. Geophys. Res., 67, 3095-3102.

Raschendorfer, M., 2007: A single column framework applied to the COSMO local model, Tech. Report., Deutscher Wetterdienst

Rauber, R.M., B. Stevens, et al., 2007: Rain in Shallow Cumulus Over the Ocean: The RICO Campaign. Bull. Amer. Meteor. Soc., 88, 1912-1928.

Seifert, A. and Beheng, D., 2001, A double-moment parameterization for simulating autoconversion, accretion and selfcollection., Atmospheric Research, Vol. 59-60, 265-281.

Sommeria, G., and J. Deardorff, 1977: Subgrid-Scale Condensation in Models of Nonprecipitating Clouds. J. Atmos. Sci., 34, 344-355.

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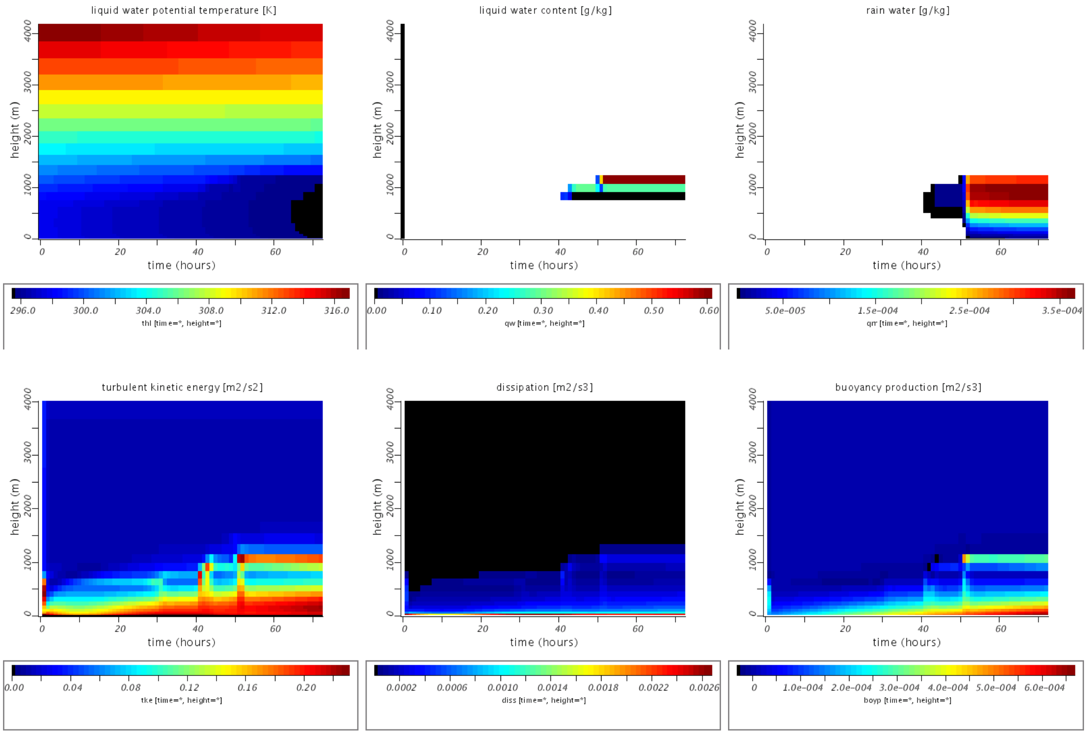

Figure 5: As in Fig. 3 for the simulation using adapted turbulent mixing length, subgrid-scale cloud fraction, and cloud droplet number concentration.