Case study based on one dimensional model with Kain-Fritsch convection parameterization scheme

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1 Introduction

The problem of convective parameterization is widely recognized by the modeling community to be a crucial component in obtaining successful numerical simulation and forecasts (Emanuel and Raymond, 1993). The major weight in this study is put on the Kain-Fritsch (KF) parameterization of convection, which is one of the most sophisticated convective schemes today. KF scheme is modified Fritsch and Chappell (FC) scheme, KF uses one-dimensional entraining/detraining plume cloud model (ODEDP), while FC - one dimensional entraining plume model (ODEP). In ODEDP is assumed that any mixture that becomes negatively buoyant detrains from the cloud while those mixtures that remains positively buoyant entrains into the cloud (Kain and Fritsch, 1993).

The convection scheme in HIRLAM (with few exceptions) takes its fundaments from the KF scheme as well as single column version of SMHI Rossby Centre Regional Climate Model (RCA1D) where the physical parameterizations follow closely those in the operational version of the HIRLAM model at SMHI (Jones et al., 2004). RCA1D is tool to be used in this study to understand the different features of the KF scheme. Sensitivity studies are performed for the following features of the convection:

- Downdraft effect
- Precipitation fall-out rate effect
- The role of the different trigger functions

The deep convection case is utilized to analyze the impact of these features.

2 1-D experiments setup

All experiments are performed on RCA1D model with the deep convection case. 40 vertical levels are used in the standard RCA1D model setup. Deep convection case was designed from data collected at the Atmospheric Radiation Measurement (ARM) Southern Great Plains site during summer 1997 Intensive

Observing Period. The case is from 2330 UTC 26 June to 24 UTC 30 June 1997 (Julian Day 178 to 182) and was simulated by 2D cloud resolving model (2-D model results further called observations). This case features a weak precipitation event that occurred on Day 179 and a strong precipitation event on Day 180-181, which was mainly associated with a complex of thunderstorms that developed in south-east Kansas in the late evening of day 180 local time. This convective event was well captured by the ARM sounding array (Xie et al., 2002).

3 Results

The results from 1-D experiments with the deep convection case are described in this section. In the first experiment downdrafts were switched off. Downdrafts forms from falling precipitation and rain cooled air with following transport of colder air. Downdrafts have grate bearing on the stabilization of the boundary layer by convection. By switching off the downdrafts we can expect acceleration of cloud water detraining from cloud and growing precipitation amount (Fig. 1). The effect of switching off the downdrafts could be seen on lower percentage of total cloud cover between Julian Days 179-180. Furthermore it has an impact on amount of outgoing longwave radiation and total cloud water path (TCWP) between Julian Days 181-181.5 during strong precipitation event.

Different rates of cloud water conversion to precipitation were tested in another state of experiment. The amount of precipitation that will fall out from a layer in the cloud is a function of vertical velocity speed and the amount of condensate in the layer. A rate constant, which in the reference model is set to 0.03, determines the speed at which condensate fall out. This fall-out rate is main objective in this part of study. Two runs, one with faster (0.09) and one with near normal (0.02) rate are executed to investigate the importance of this empirically derived constant. The intuitively correct would be to have earlier precipitation in the case with higher fall-out rate compared to near normal fall-out rate (Fig.2). These results could be seen from Julian Day 179.5 to 180; later non-linear effects give more or less the opposite results in precipitation and total cloud cover timeseries (Fig. 2).

The next stage was to investigate the trigger functions, which are used in convective parameterization routines. Specifically, the trigger functions 1) estimates the magnitude of the largest vertical velocity perturbation from a source layer and 2) calculates the total amount of inhibition between the source layer and LFC (level of free convection). It is worth mentioning that if the condition for deep convection is not satisfied the scheme directly checks for shallow convection. Two types of triggers were studied: first - only relative humidity, second - only virtual temperature as trigger function. Both trigger functions act quite similar and both give produce peak of total cloud cover and total cloud water path between Julian Day 180.5 and 181 (Fig.3). This peak could be explained by shallow convection occurred exactly during this time in 1-D model run with only shallow convection turned on (not shown).

3.1 Conclusions

Downdrafts act as drying factor and indirectly affect surface radiation budget.

Precipitation fall-out rate is not a crucial factor for deep convection event.

Both relative humidity and temperature trigger function resulted increase of total cloud cover just before heavy rainfall event.

Kain-Fritsch scheme can reasonably forecast heavy precipitation event peak but still lacks occurrence in total cloud cover.

References

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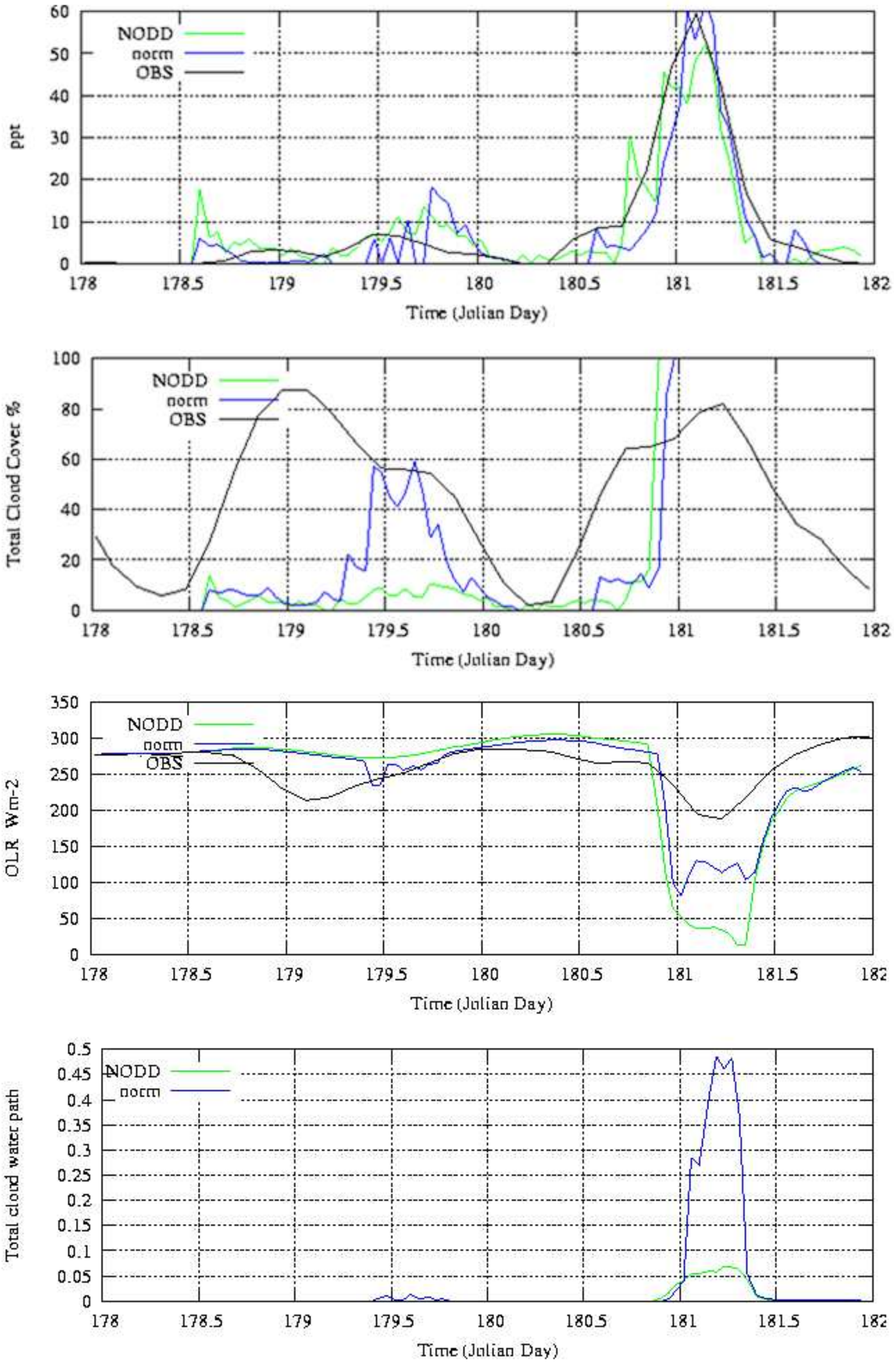

Figure 1: *Precipitation (ppt) in mm/day and total cloud cover (%), outgoing long-wave radiation (OLR) in* Wm^{-2} *and total cloud water path in* kg/m^2 *from RCA1D simulations with no downdrafts (NODD), with downdrafts norm and timeseries of observations (OBS)*

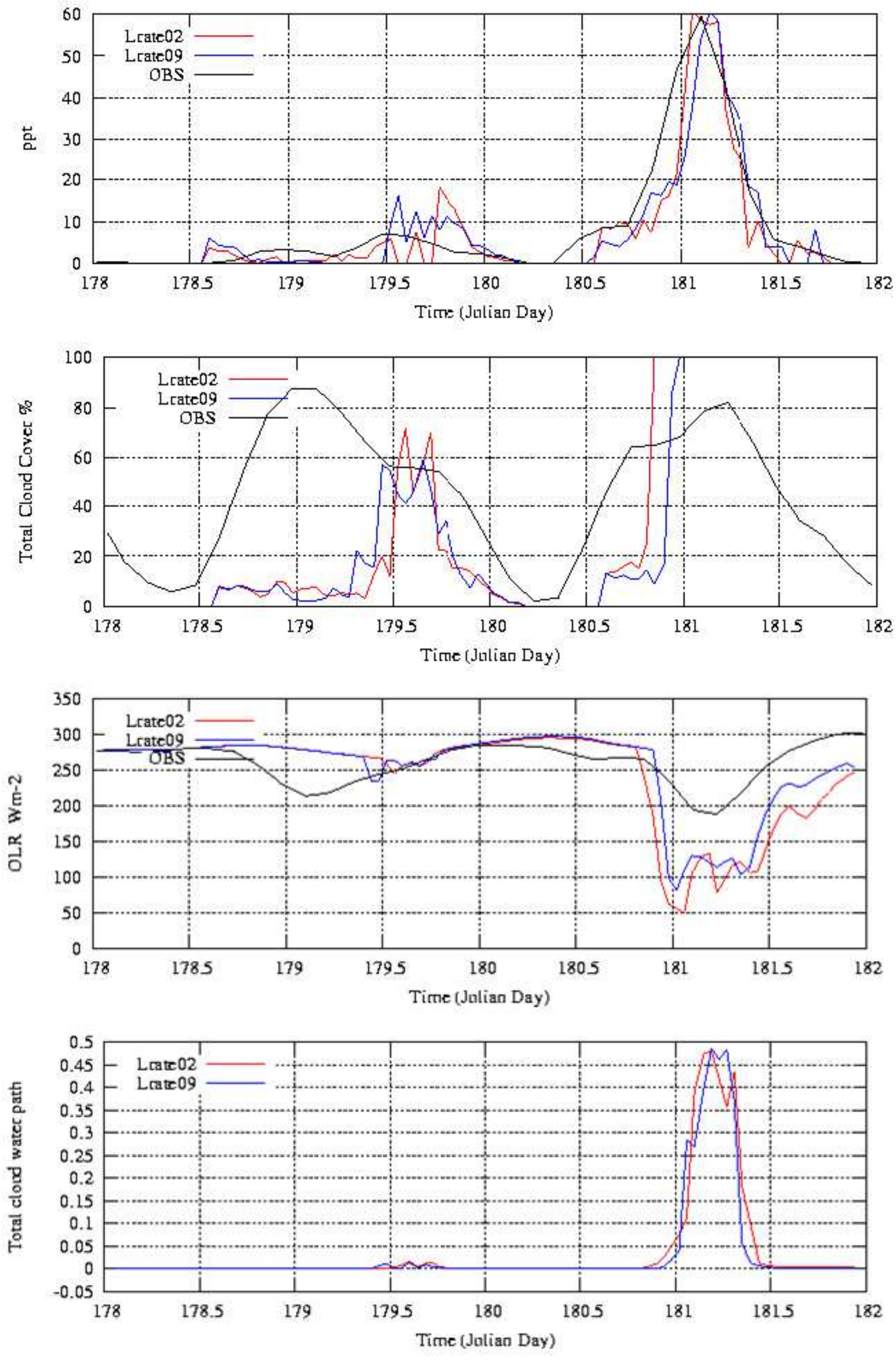

Figure 2: *Precipitation (ppt) in mm/day and total cloud cover (%), outgoing long-wave radiation (OLR) in Wm^{-2} and total cloud water path in kg/m^2 from RCA1D simulations with precipitation fall-out rate equal to 0.02 (Lrate02), 0.09 (Lrate09) and timeseries of observations (OBS)*

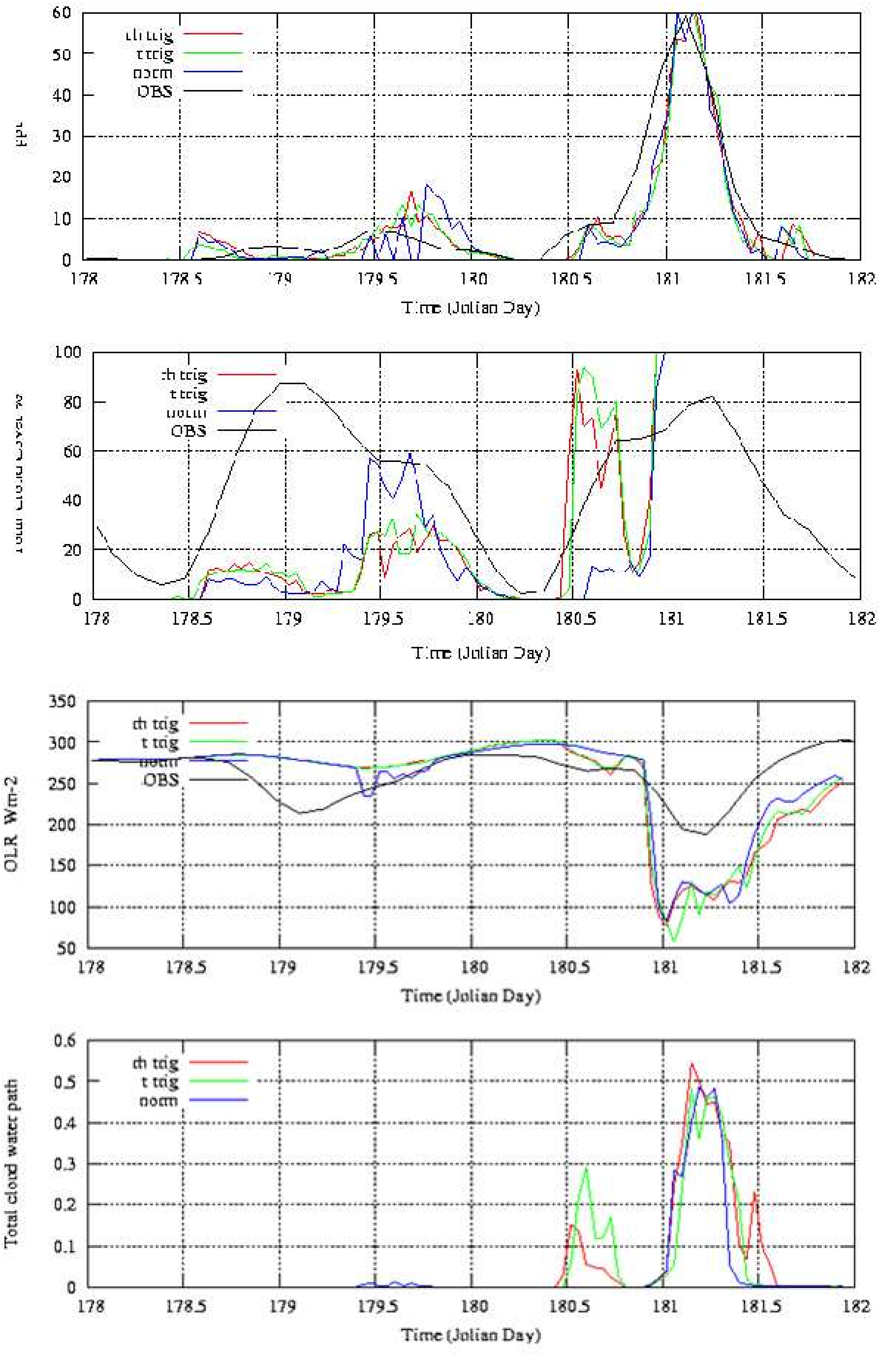

Figure 3: *Precipitation (ppt) in mm/day and total cloud cover (%), outgoing longwave radiation (OLR) in* Wm^{-2} *and total cloud water path in* kg/m^2 *from RCA1D simulations with only relative humidity (rh trig), only temperature (t trig) and both trigger functions (norm); timeseries of observations (OBS)*