Evaluation of precipitation simulated over mid-latitude land by CPTEC AGCM single-column model

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☞ Abstract

➢ A single-column model (SCM) has been developed from the CPTEC AGCM V.4 as a tool to improve and calibrate different physical processes used in the global atmospheric model. In this particular study, the SCM is used to evaluate the performance of the model to simulate precipitation over middle-latitude continent with focus on the multi-closure Grell and Devenyi (GD) deep convection scheme. The SCM simulations are forced with the Atmospheric Radiation Measurement Program's (ARM) Southern Great Plains summer 1997 data. The temporal variation and intensity of precipitation simulated by SCM are compared with cloud resolving model (CRM) results. The CRM results are used as guide to improve the SCM.

☞ Purpose of the work

Develop and improve the physical parametrizations used in the Cptec's AGCM by comparisson with field experiments (e.g.: ARM, TOGA, CHUVA, BOMEX, LBA, etc) and numerical simulations with the CRM over different regions of the globe including both land and ocean.

☞ Presentation Overview

- ➢ The single column model
- ➢ The cloud resolving model
- ➢ Observational Data
- ➢ Experiments and discussions
- ➢ Summary

The single column model

☞ SCM or AGCM 1D

- ➢ Derived from the CPTEC AGCM v4. Forced with the vertical component of velocity and the tendencies of: u, v, T and q.
- ➢ Boundary Layer: Mellor Yamada 2.0 (1982), Mellor Yamada 2.5, Hostlag and Boville modified by Kubota (2012)
- ➢ Surface Processes: SSiB (1991), SSiB2, IBIS (1996)
- ➢ Deep Convection: Kuo (1965), Grell-Devenyi (2002); Shallow Convection: Tiedke (1983); Large scale precipitation: Adjustment due to saturation and Microphysics (Rasch-Kristjansson (1998))
- ➢ Gravity waves: Alpert (1988)
- ➢ Short wave radiation (CLIRAD, Tarasova et al, 2007), Long wave radiation (Hashvanadan, 1987)
- ➢ Ocean fluxes: Bucket model (COLA), Bulk aerodynamic algorithm (NCEP)

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The cloud resolving model

☞ CRM SAM

- ➢ The CRM/SAM is an anelastic, non-hydrostatic model used to simulate different atmospheric conditions including cloudy atmospheres. By being anelastic, it filters sound and lamb waves while retaining buoyancy related waves
- ➢ The SAM can be used as a Large Eddy Simulator (LES) dry or wet. The heat fluxes are homogeneous all over the domain, the Reynolds average can be used. The criterium for cloud is any condensate larger than zero.
- ➢ As a Cloud Resolving Model the model is commonly used to study mesoscale deep convective systems, the heat fluxes are non-homogeneous over the domain, and the criterium for cloud is 1% above supersaturation.

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☞ CRM details:

- ➢ Two advection schemes:
  - ○ *a)* MPDATA (Multidimensional positive definite advection transport - An iterative scheme to reduce the diffusion excess).
  - ○ *b)* UM5 (Ultimate Macho - a higher-order advection scheme).
- ➢ Two radiation schemes: RRTM and CAM3, both from the NCAR (Community Climate System Model).
- ➢ Four options for microphysics including Morrison *et al*, 2005 (a two moment scheme). Microphysics module is the more expensive due to the number of prognostic variables. The transport of those variables by the advective schemes is computationaly expensive
- ➢ A simplified surface model.

☞ Observational Data

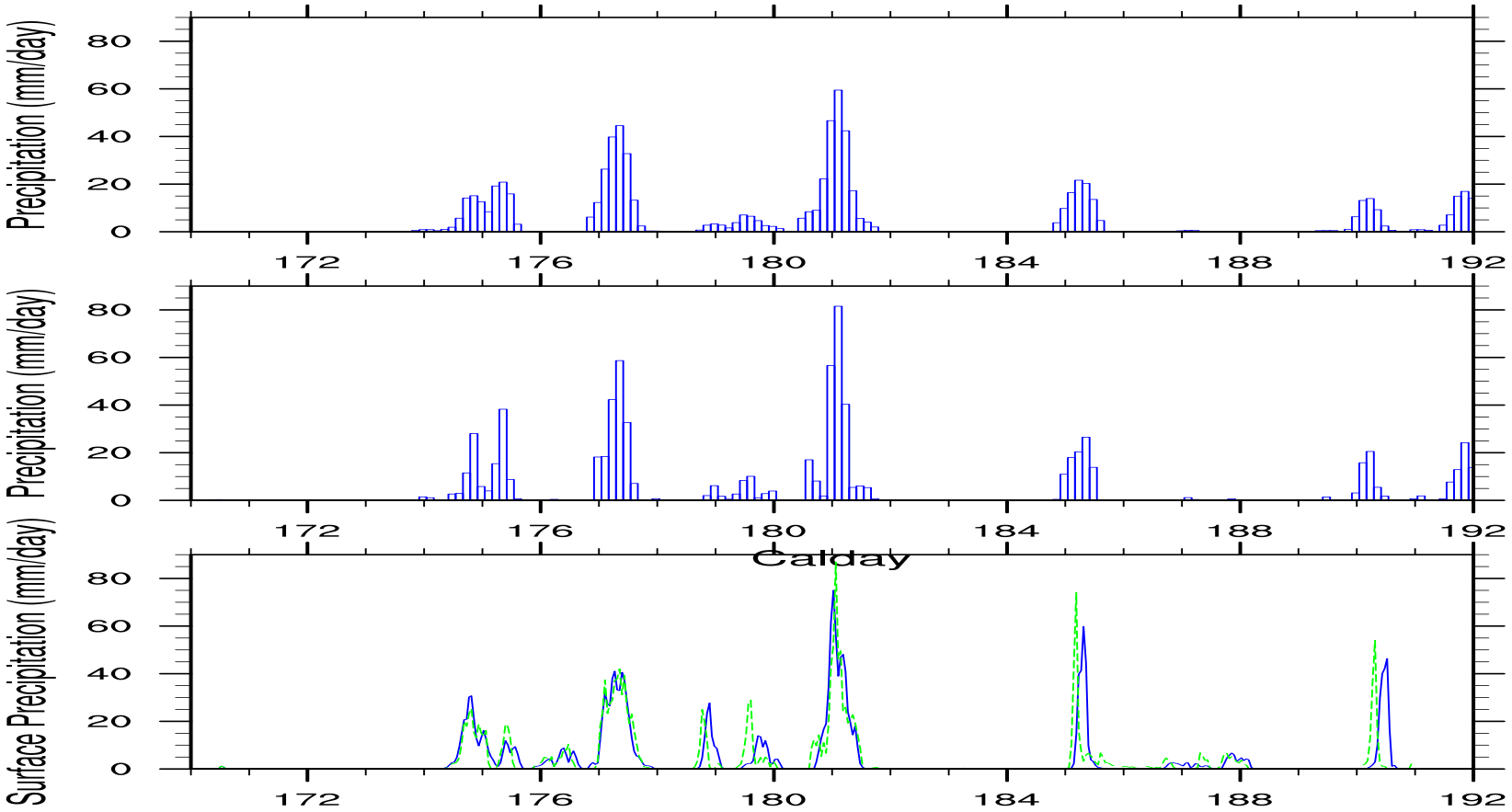
Is used for validation of the simulated precipitation of both the AGCM 1D (SCM) and the CRM. The CRM is used to generate variables not measured in the field experiments.

Two sources are used for the ARM1997 data:

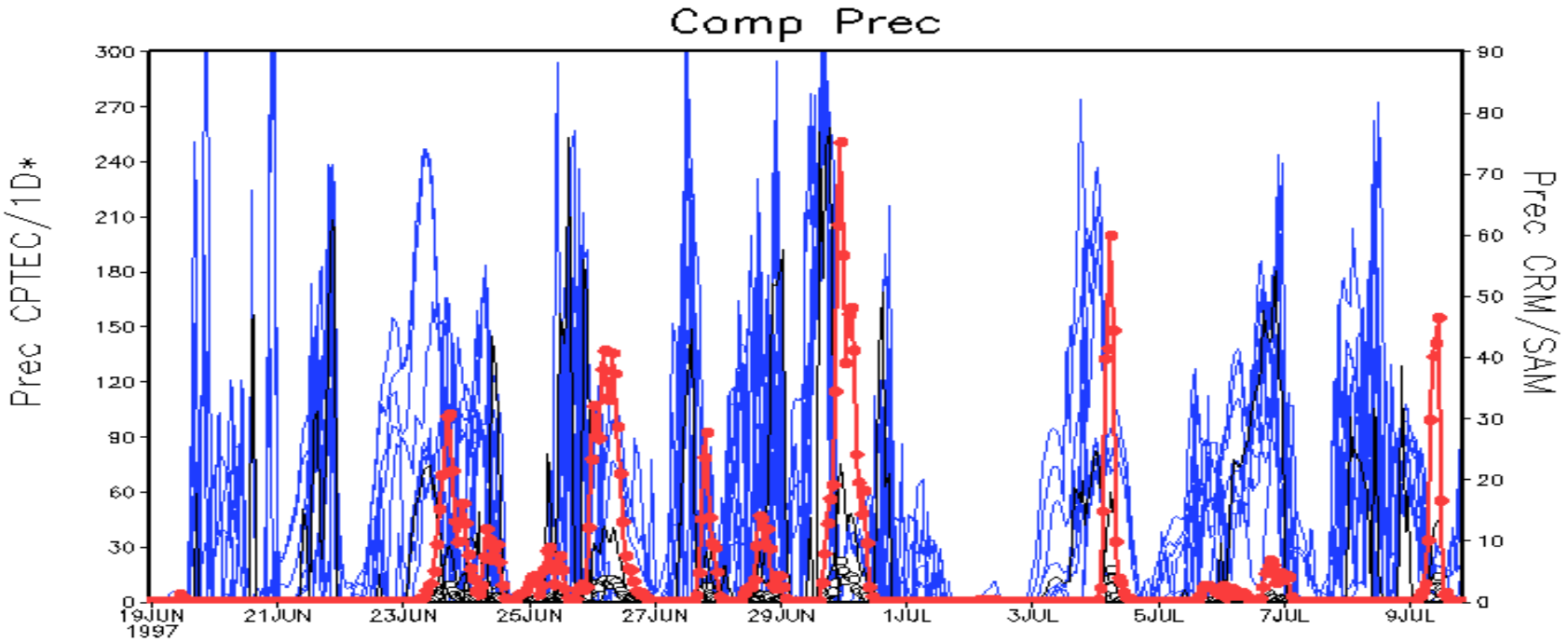
a) The variational objetive analysis from Minghua Zhang - Varana (sgpvarana.bl.970618.2330970717.2330.cdf), each 3 hours

b) Analysis of Marat Khairoutdinov (arm9707.nc), each 3 hours

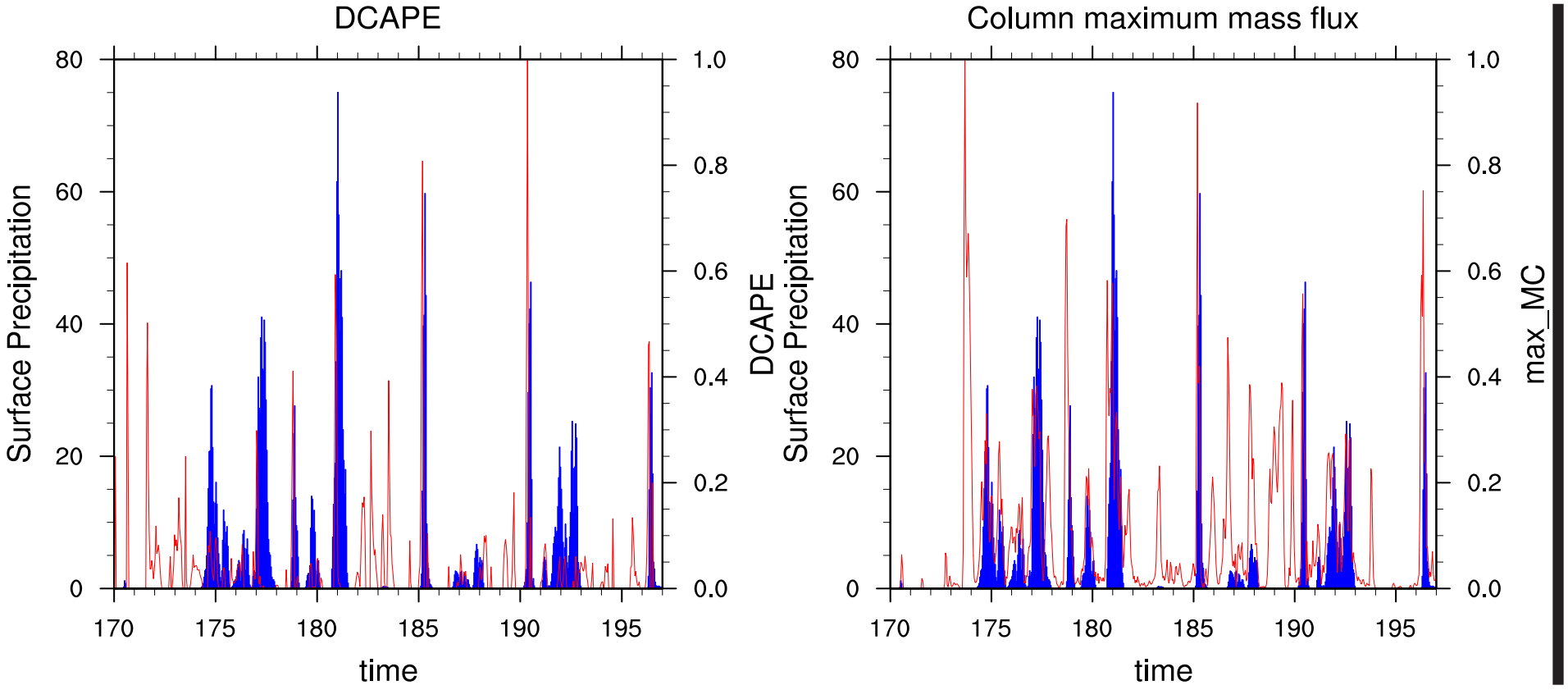
Precipitation Validation

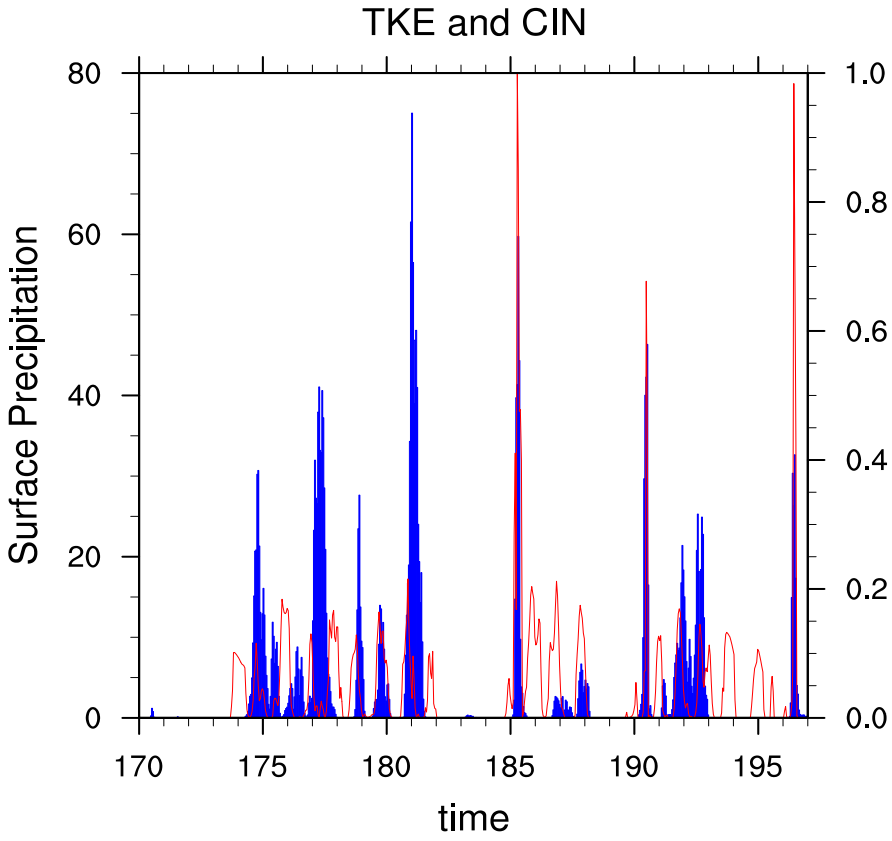


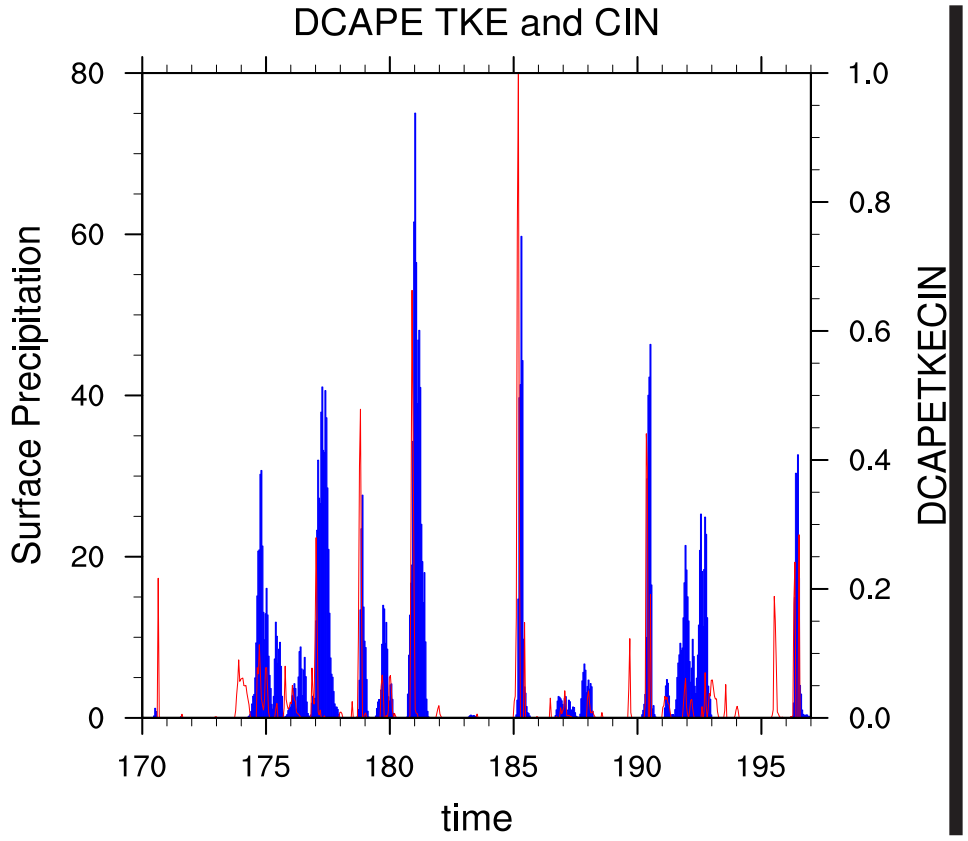
Single Column ensemble - original



Triggers with the CRM




TKE and CIN
Surface Precipitation
TKECIN
time
0
20
40
60
80
0.0
0.2
0.4
0.6
0.8
1.0
170
175
180
185
190
195


DCAPE TKE and CIN
Surface Precipitation
DCAPETKECIN
time
0
20
40
60
80
0.0
0.2
0.4
0.6
0.8
1.0
170
175
180
185
190
195

Triggers with the AGCM 1D

☞ Grepar1 = 17: TKE-CIN, Fletcher and Bretherton, 2010

$$\mu_b = \alpha(\mathsf{cloud})\sqrt{(\mathsf{tke})}\,\mathsf{Exp}^{-\mathsf{cin}/\mathsf{tke}} \tag{1}$$

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Triggers with the AGCM 1D

☞ Grepar1 = 20: DCAPE-TKE-CIN, Blended between: Xie et al, 2004 and Fletcher and Bretherton, 2010

$$\mathsf{dcape} = \mathsf{cape}(T^*, q^*) - \mathsf{cape}(T, q) \tag{2a}$$

$$T^* - T = \frac{\partial T}{\partial t}\Big|_{\mathsf{large\ scale\ advection}} \tag{2b}$$

$$q^* - q = \frac{\partial q}{\partial t}\Big|_{\mathsf{large\ scale\ advection}} \tag{2c}$$

$$\mu_b = \alpha(\mathsf{dcape})\frac{\mathsf{dcape}}{\mathsf{dtime}}\sqrt{(\mathsf{tke})}\ \mathsf{Exp}^{-\mathsf{cin}/\mathsf{tke}} \tag{2d}$$

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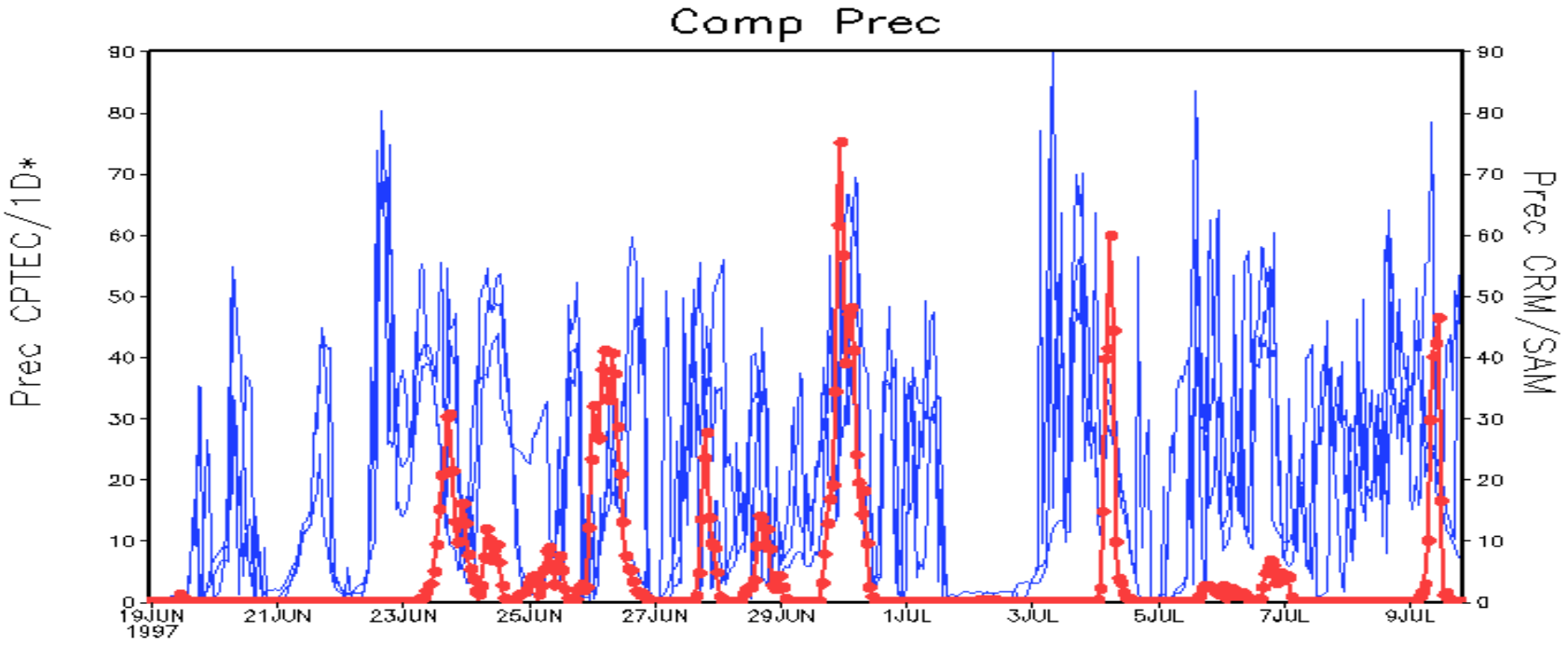
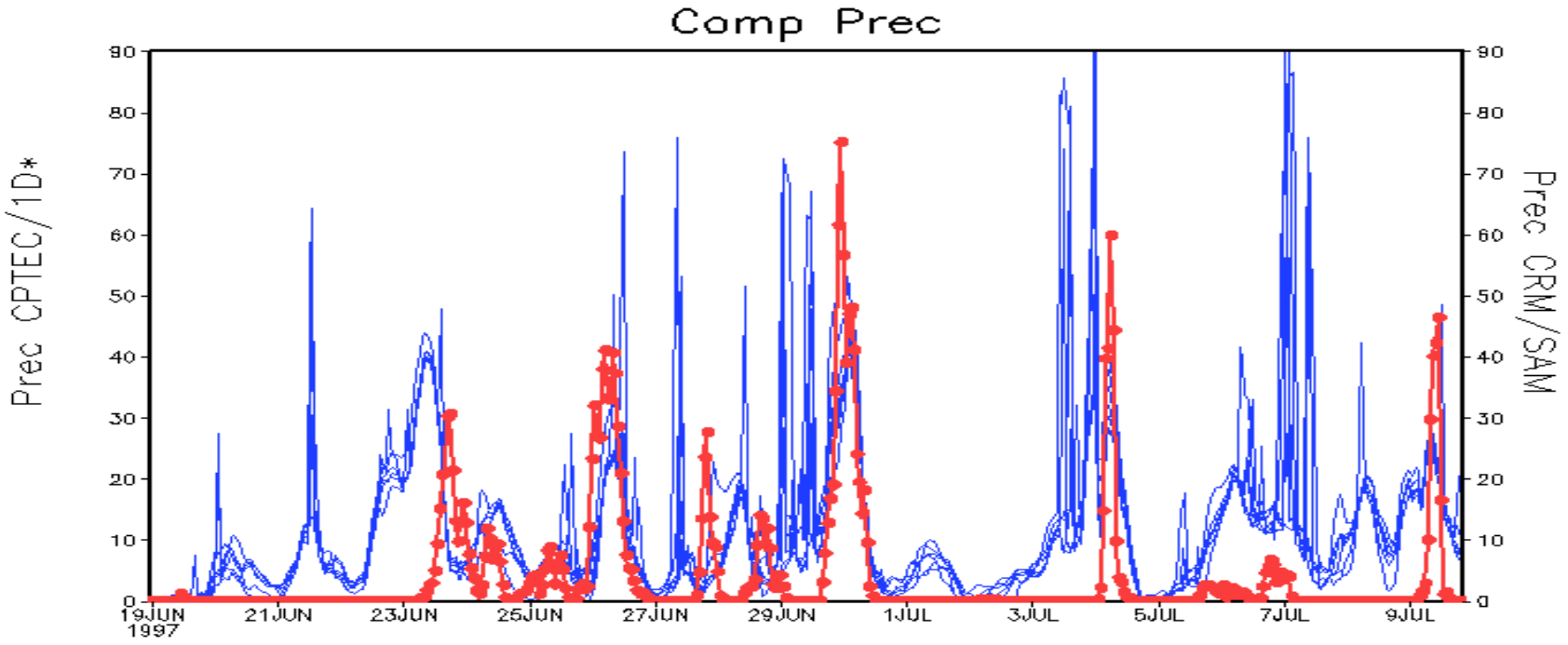
Triggers with the AGCM 1D

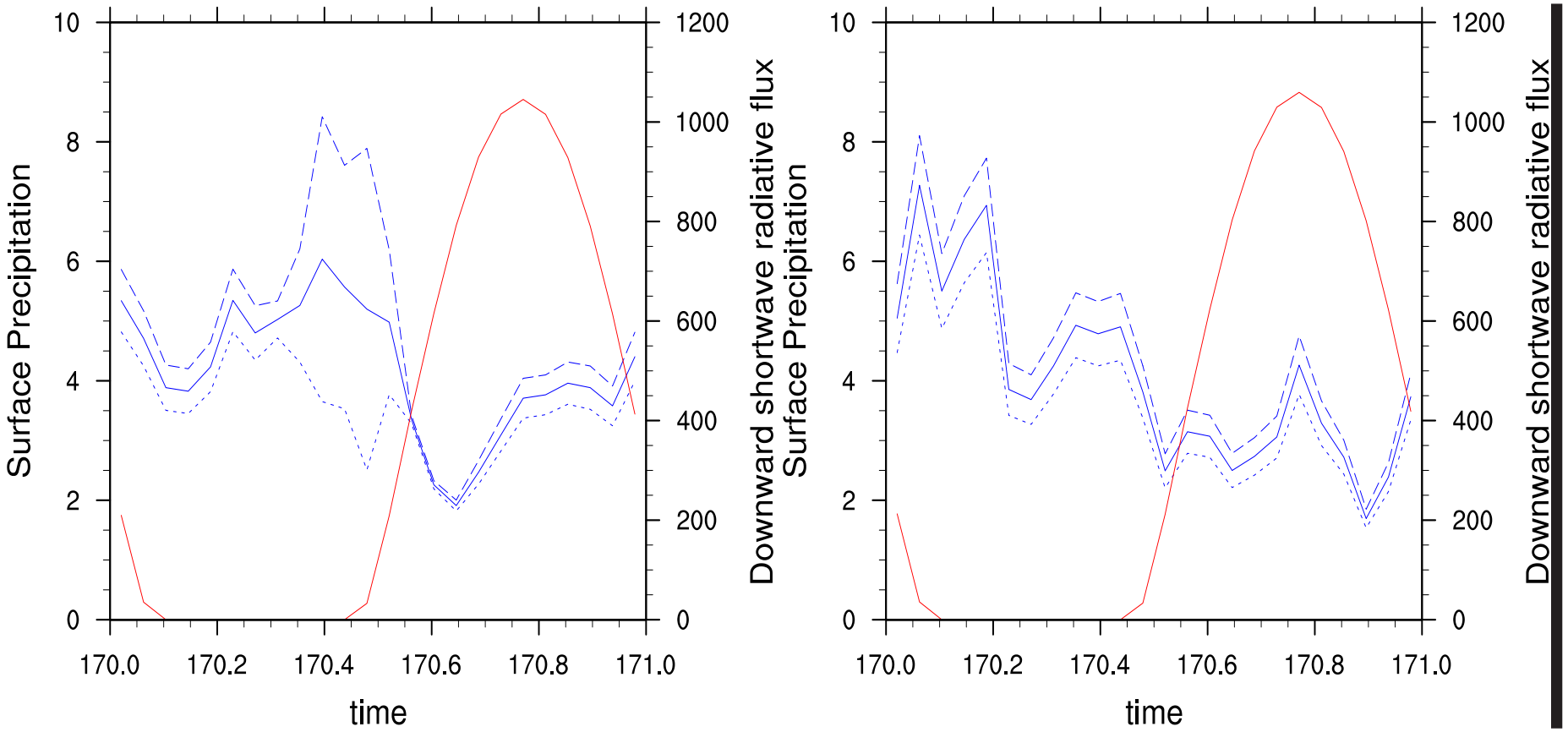
Single Column ensemble, grepar1=17, TKE-CIN or Fletcher and Bretherton, 2010



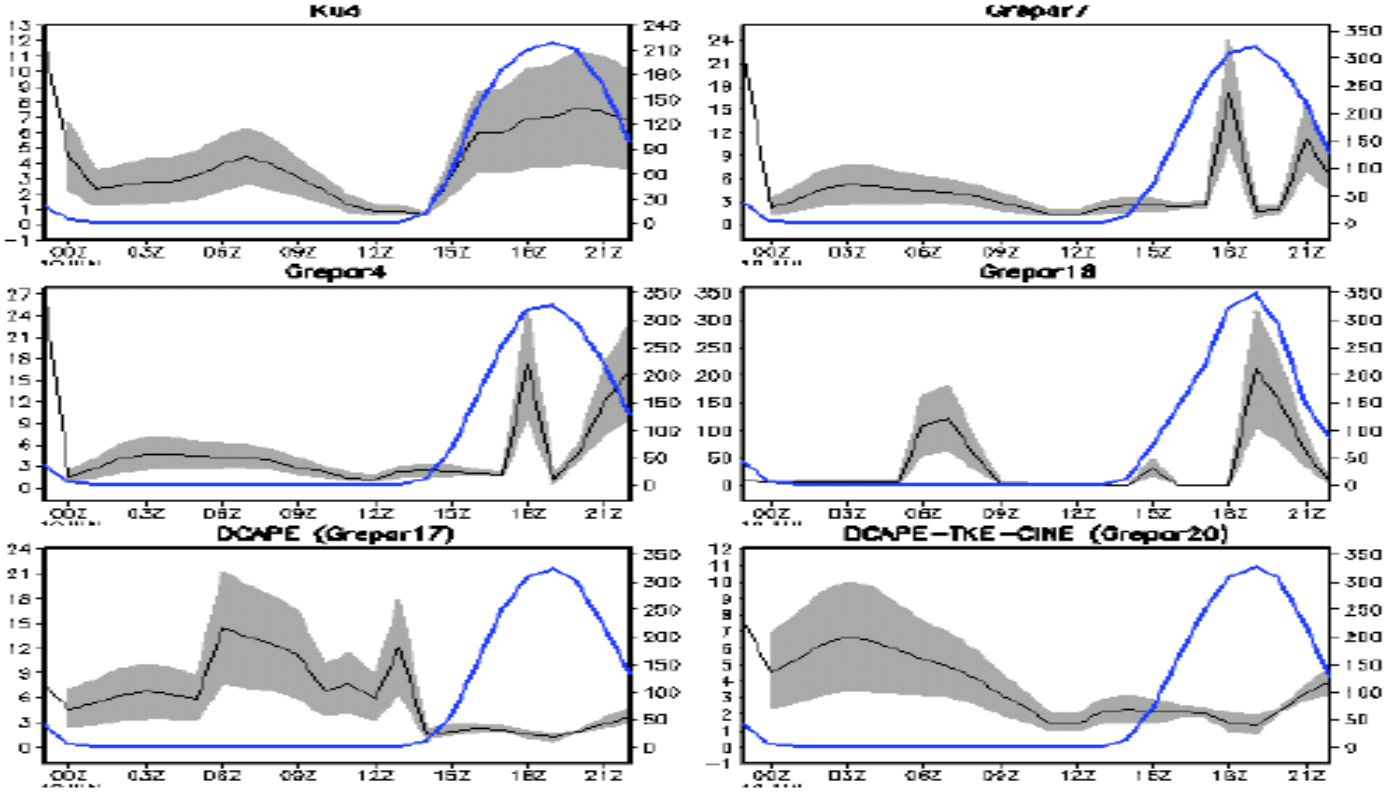
Single Column ensemble, grepar1=20, DCAPE-TKE-CIN or Blended Xie and Fletcher-Bretherton



Diurnal Cycle with the CRM; SAM6.9.4 M2005 vs SAM6.8.2 Bulk Microphysics



Diurnal Cycle with the SCM old and new closures



☞ Summary

- ➢ Precipitation intensity is improved. Better results are obtained for the blended scheme
- ➢ Even when precipitation intensity and Diurnal cycle are improved, day time deep convection was drastically damped. Are these improvements valid for other regions?. Maybe right answers by wrong reasons!
- ➢ Currently we are working over ocean with TOGA experiment and over land with the LBA. However, for more exhaustive test we are going to use the CHUVA project datasets.

☞ Acknowledgements

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☞ Finally

Many Thanks!