Moist processes in the atmospheric model

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April, 2015

☞ Motivation Moist Processes

- ➢ By rule the free atmosphere (above the PBL) is not turbulent, with the exception of cloudy regions
- ➢ Clouds introduce heterogenity at scales not explicitly solved by operational weather and climate models. Heterogenity are due to interactions with radiation, surface processes, PBL, dynamics, etc.
- ➢ Moist processes and clouds involve a wide range of scales: from microscales ($10^{-9} - 10^{-6}$ m, formation of drops and rain) to the planetary organization ($10^{6} - 10^{7}$ m, hierarchies of clouds clusters).
- ➢ Can be splitted into those that produce precipitation and those that do not.
- ➢ Moist processes includes microphysics, convection and clouds
- ➢ Cloud-climate feedbacks is one of the most important source of uncertainities in projecting future global warming.
- ➢ Cloud-climate feedbacks refers to the radiative impact of changing clouds/properties/conver on the climate change.

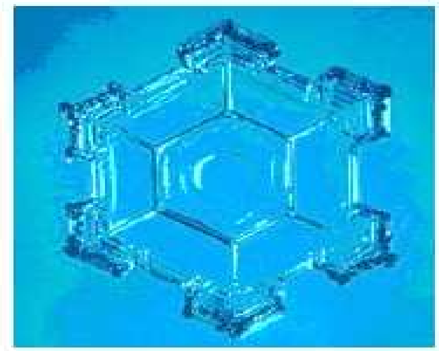
Conventional Parameterizations

Global circulation

Cloud-scale &mesoscale processes

Radiation, Microphysics, Turbulence

Conventional Parameterizations



Global circulation

~ 10^6 – 10^7 m

Cloud-scale &mesoscale processes

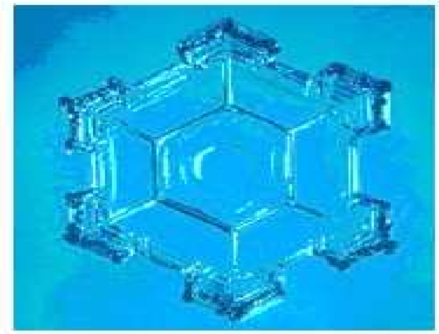
~ 10^3 – 10^5 m

Radiation, Microphysics, Turbulence

~ 10^-9 – 10^-6 m

Parameterized

Super - ~~Conventional~~ Parameterizations



Global circulation	Cloud-scale &mesoscale processes	Radiation, Microphysics, Turbulence
~ 10^6 – 10^7 m	~ 10^3 – 10^5 m	~ 10^-9 – 10^-6 m

Parameterized

☞ Abstract

To improve moist processes we use a hierarchy of 1D version of the atmospheric model and a Cloud (System) Resolving Model.

☞ Presentation Overview

The 1D atmospheric model

☞ 1D model

- ➢ 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)

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.

☞ 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.

☞ Experimental Data

☞ CRM IC:

➢ Use analysis, initialized to produce a profile of: $(p,\ \theta,\ q,\ u,\ v)$ center of the domain

☞ CRM Forcings:

➢ Use analysis, initialized to produce time series profiles of the large scale forcing: $(p, \overline{\frac{\partial \theta}{\partial t}},\ \overline{\frac{\partial q}{\partial t}},\ \overline{u},\ \overline{v},\ \overline{w})$

➢ Use analysis to produce one layer time series of: $(sst,\ lhf,\ shf,\ \vec{\tau})$, the sst is fixed along the integration

☞ Period of study

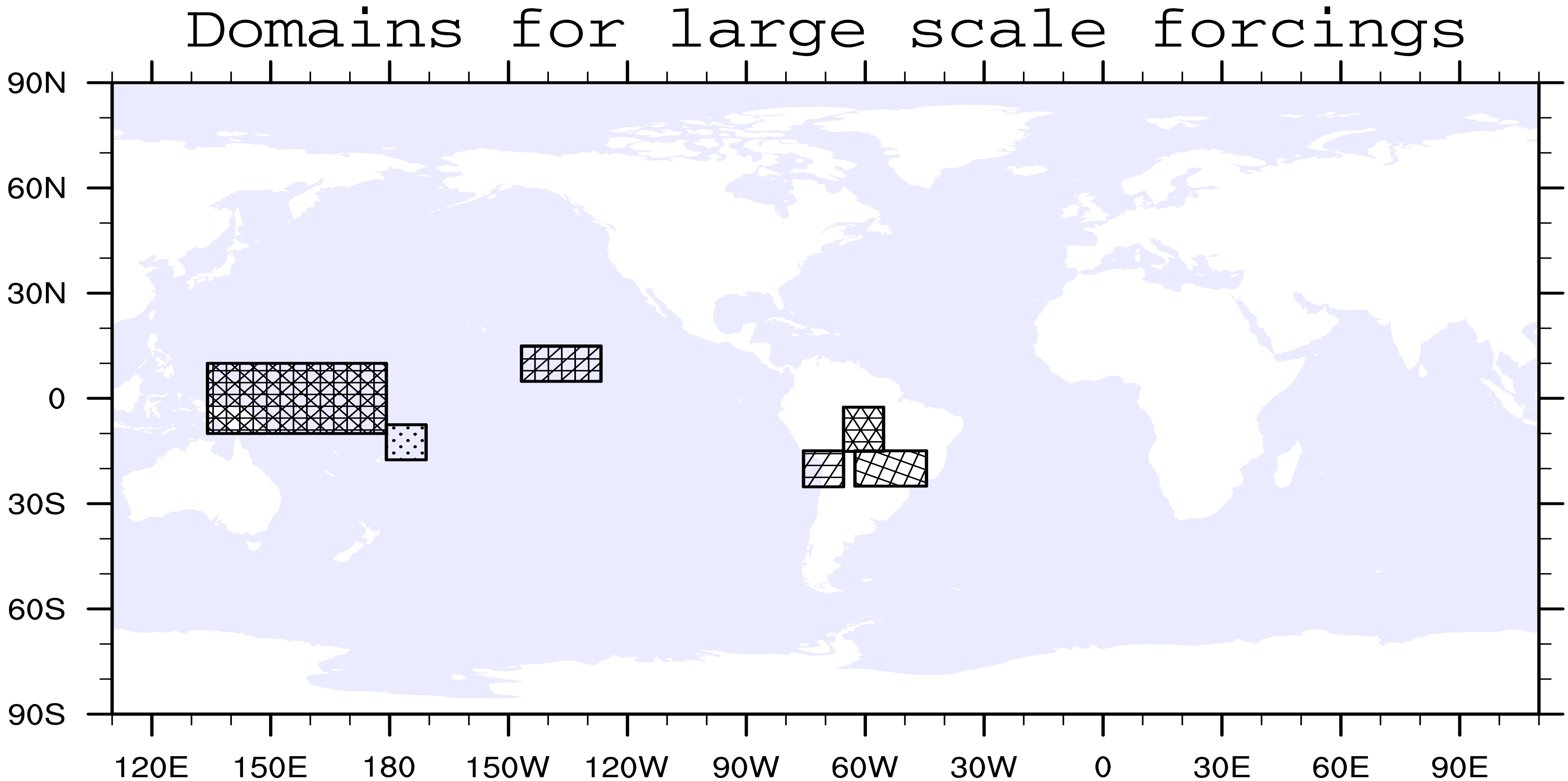
➢ January, 2013

☞ Experimental Data

Exp	Micro	Lon	Lat
SPCZ	sam1mom	180.0/190.0	-17.5/-7.5
SPCZ	m2005		
wPACIFIC	sam1mom	135.0/180.0	-10.0/10.0
wPACIFIC	m2005		
ePACIFIC	sam1mom	214.0/234.0	4.9/14.9
ePACIFIC	m2005		
SP	sam1mom	297.9/315.9	-25.0/-14.9
SP	m2005		
AMAZON	sam1mom	295.0/305.1	-15.1/-2.5
AMAZON	m2005		
ANDES	sam1mom	284.9/295.0	-25.2/-14.9
ANDES	m2005		

☞ Experimental Data

Exp	TMPA (mm/d)	SAM 1MOM	SAM M2005
SPCZ	14.7	[redacted]	[redacted]
wPACIFIC	9.3	[redacted]	[redacted]
ePACIFIC	5.8	[redacted]	[redacted]
SP	6.7	[redacted]	[redacted]
AMAZON	9.2	[redacted]	[redacted]
ANDES	2.1	[redacted]	[redacted]


Domains for large scale forcings
90N
60N
30N
0
30S
60S
90S
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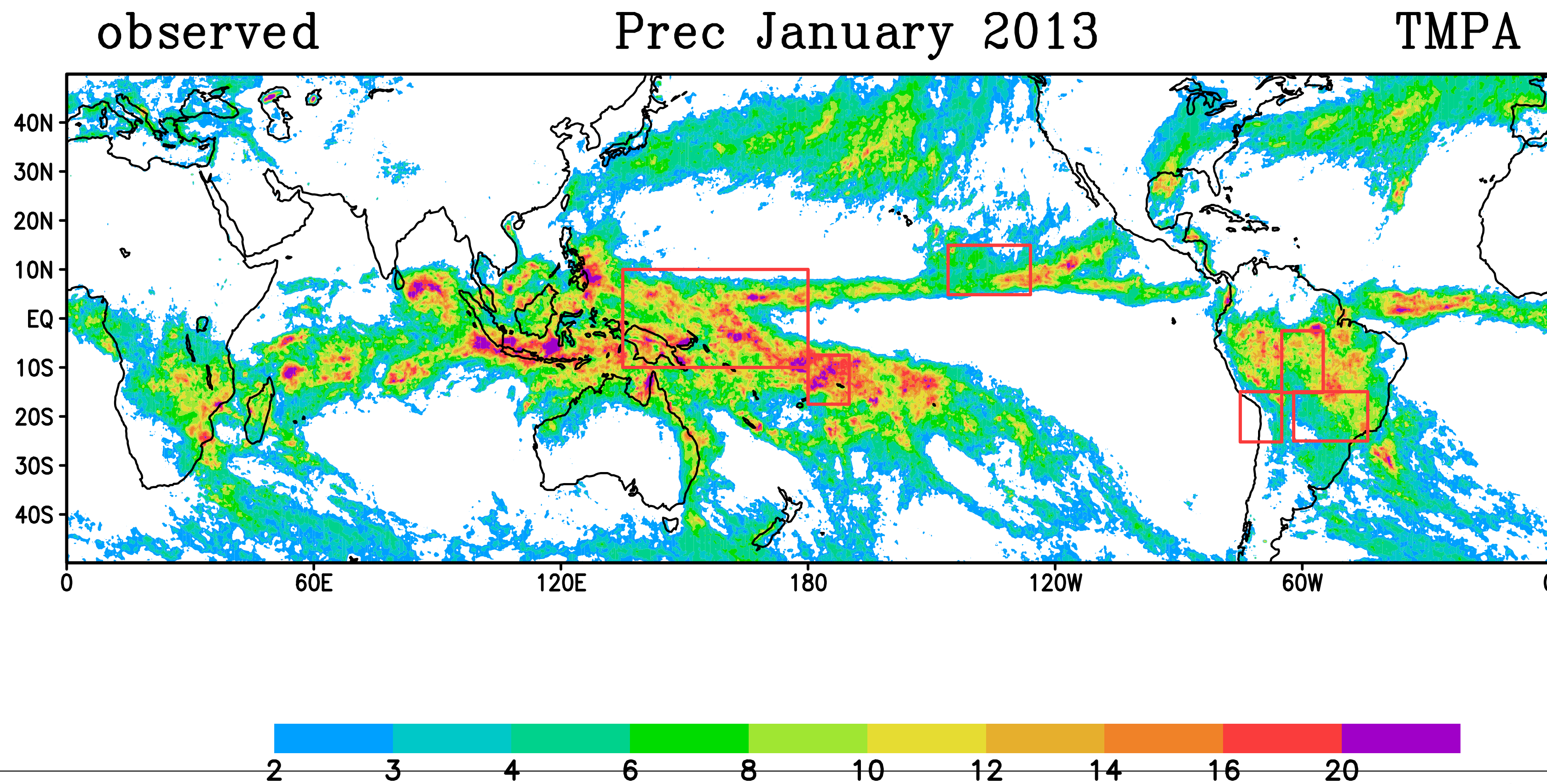
150E
180
150W
120W
90W
60W
30W
0
30E
60E
90E


observed
Prec January 2013
TMPA
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30N
20N
10N
EQ
10S
20S
30S
40S
0
60E
120E
180
120W
60W
0
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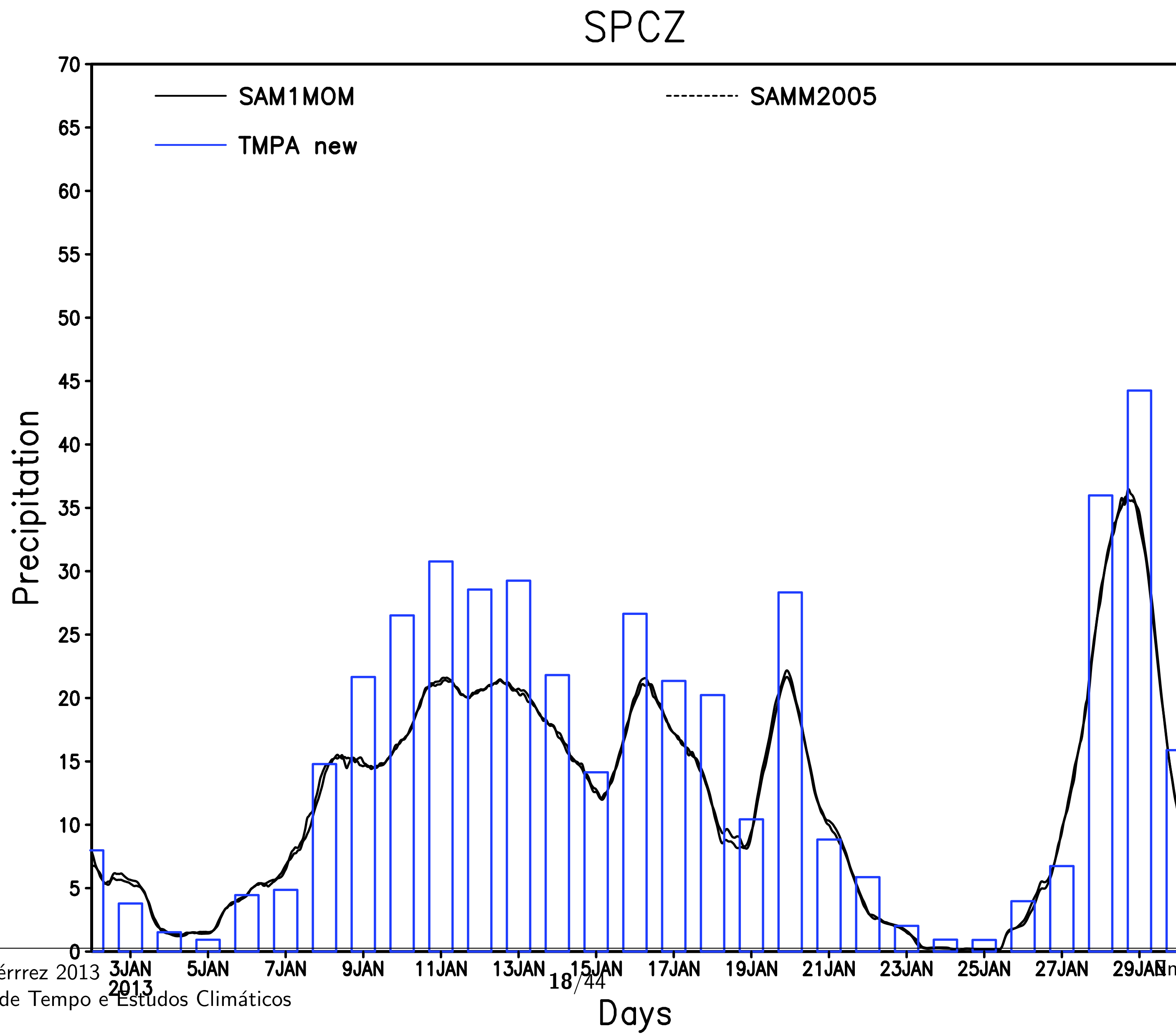
3
4
6
8
10
12
14
16
20

☞ Model integration

- ➢ CRM/SAM was run for 30 model days for each of the above mentioned regions
- ➢ CRM/SAM domains: 288 km $\times$ 288 km $\times$ 64 levels
- ➢ $\Delta X = 1000$m , $\Delta Y = 1000$m, $\Delta T = 10$s
- ➢ Integrated in LES and in CRM mode
- ➢ Using either SAM1MOM or Morrison microphysics

Cloud resolving model simulations

Precipitation


SPCZ
SAM1MOM
SAMM2005
TMPA new
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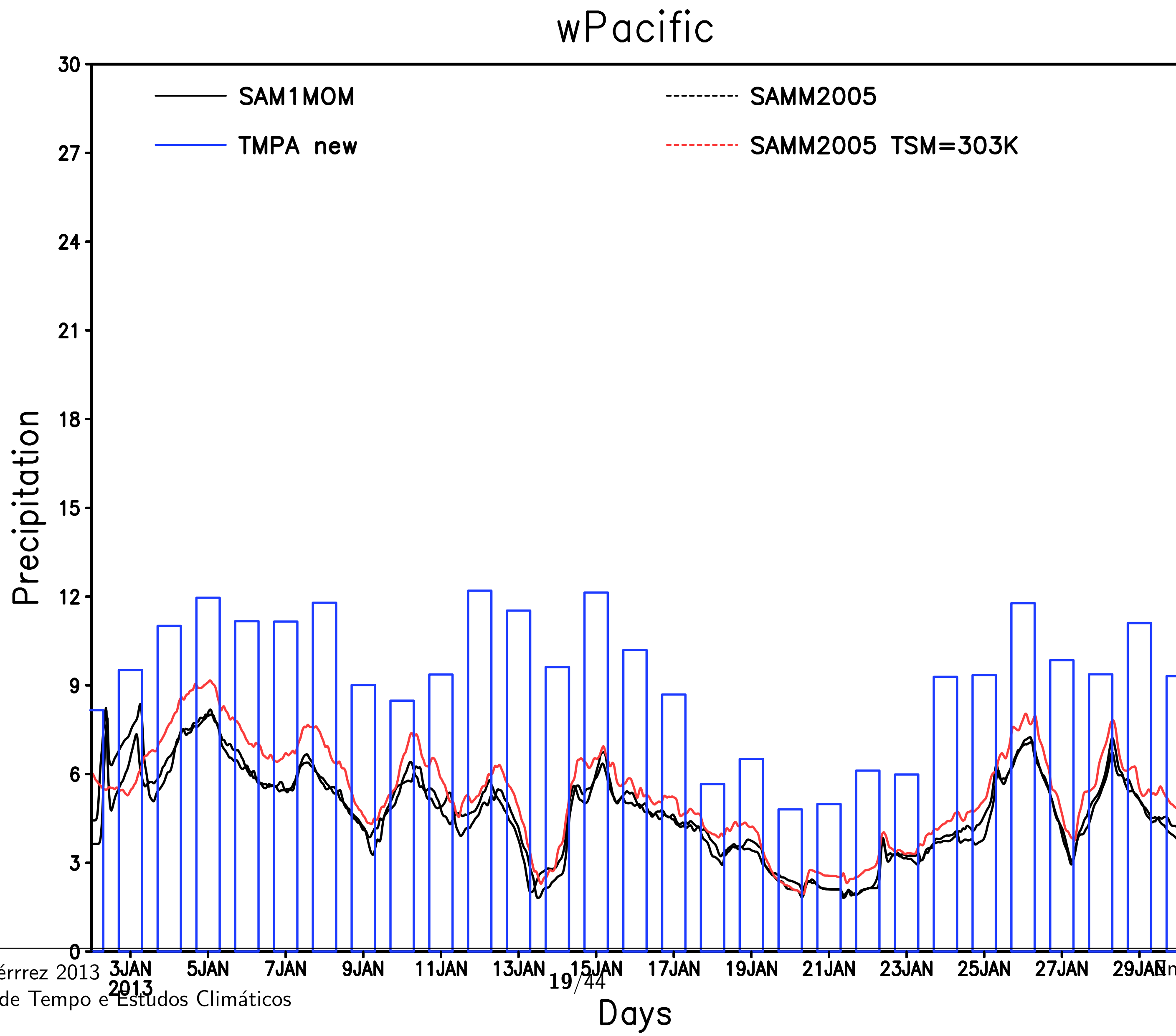
wPacific
SAM1MOM
SAMM2005
TMPA new
SAMM2005 TSM=303K
Precipitation
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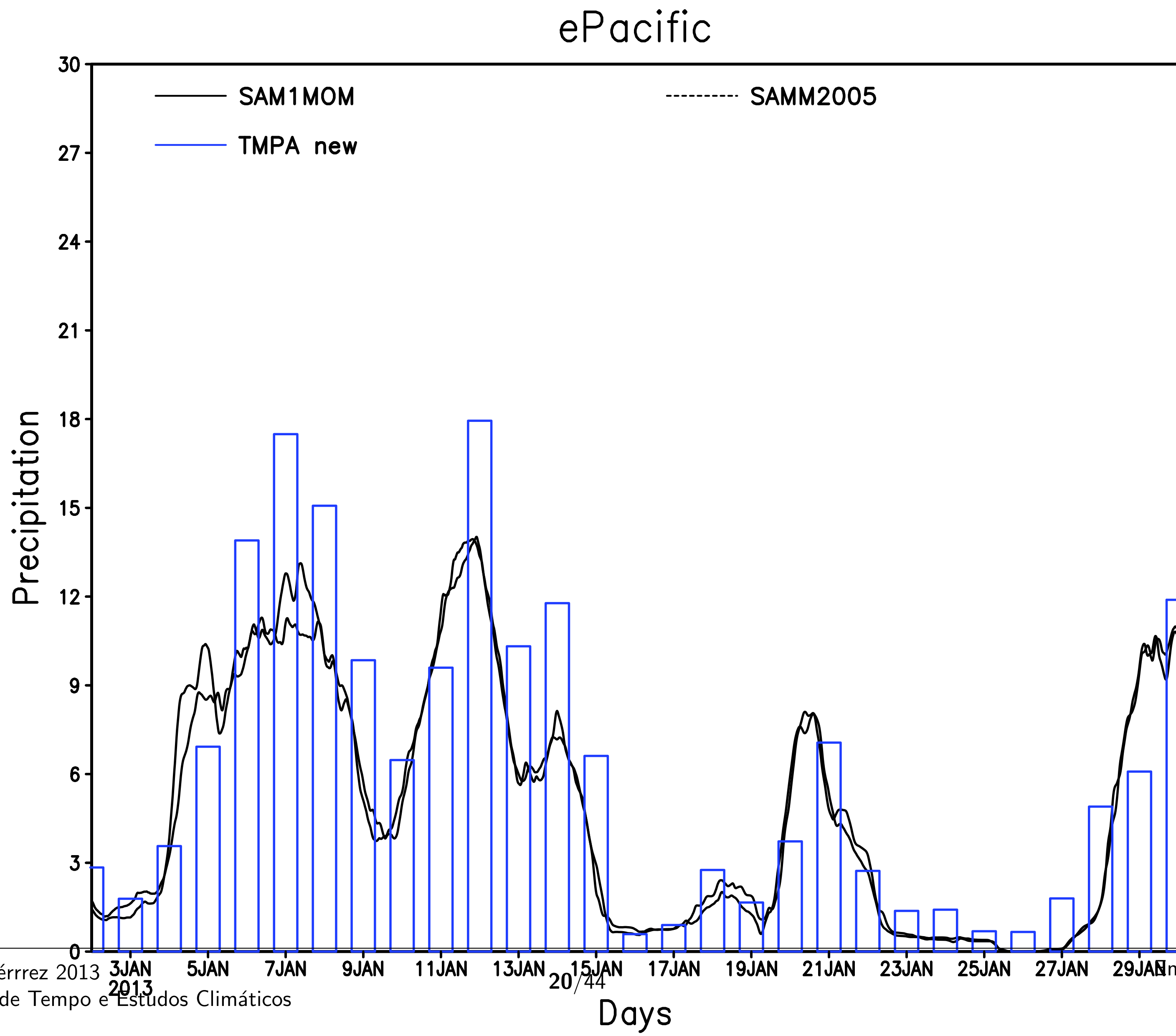
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SAMM2005
TMPA new
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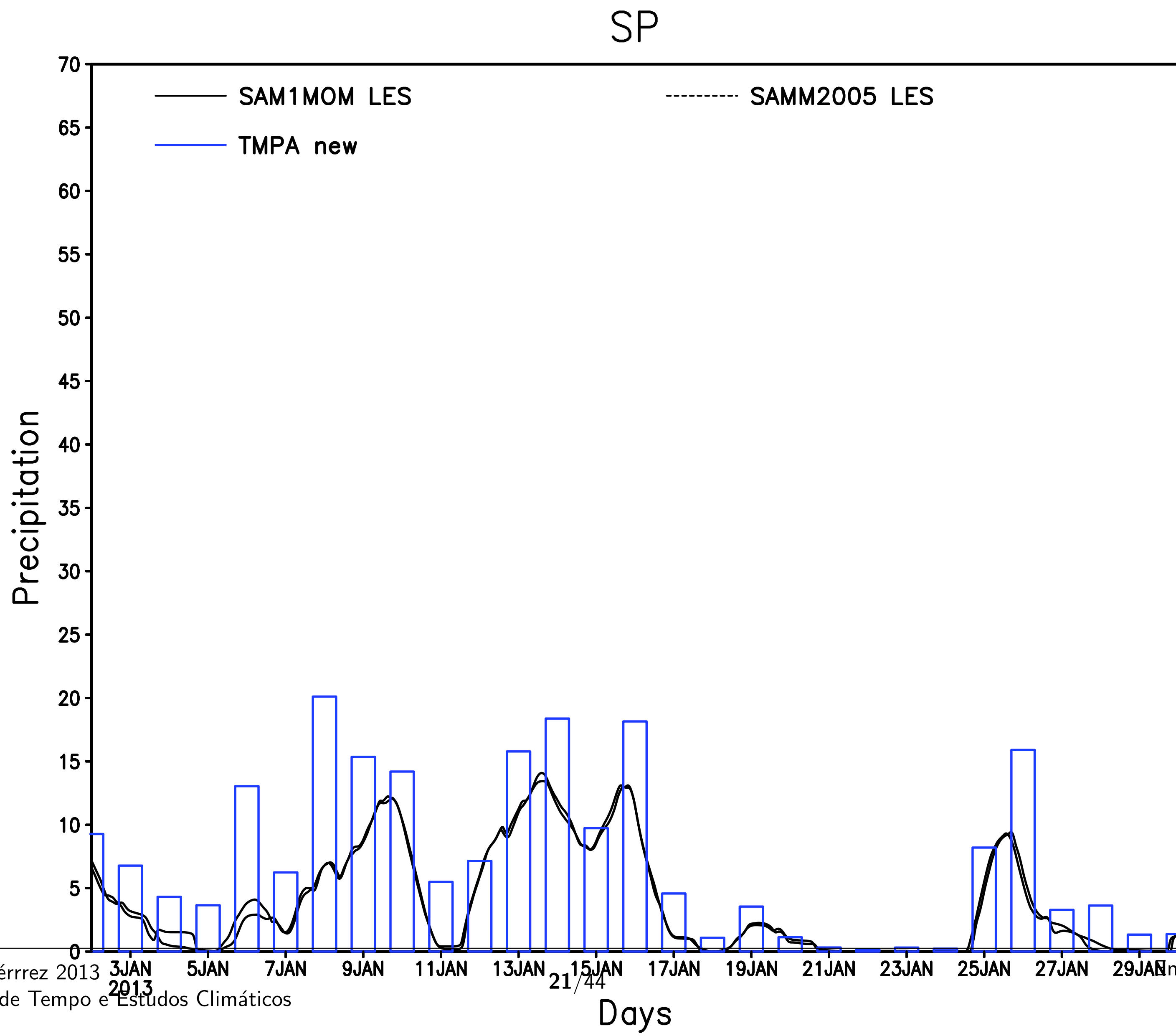
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SAMM2005 LES
TMPA new
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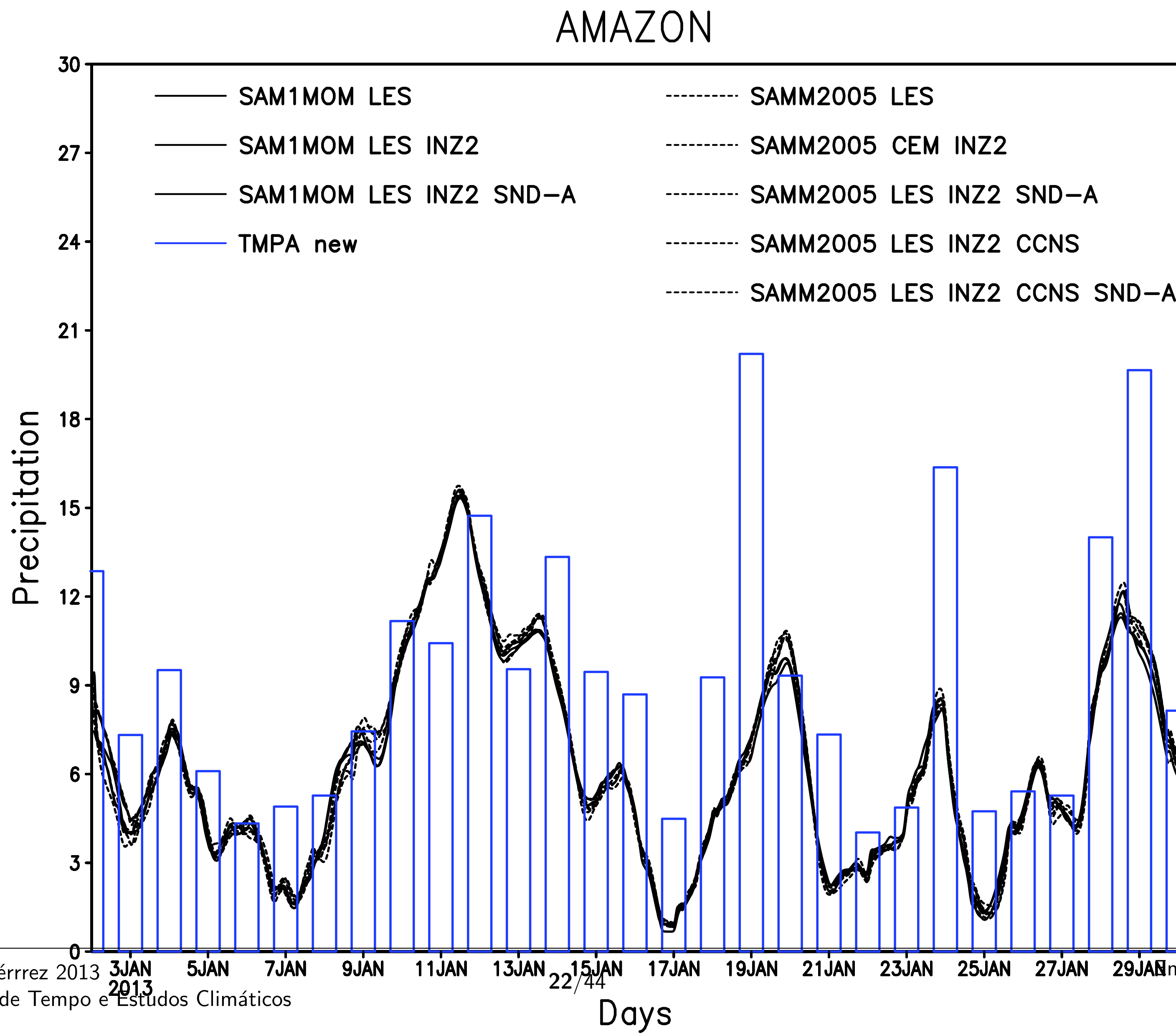
Days


AMAZON
SAM1MOM LES
SAM1MOM LES INZ2
SAM1MOM LES INZ2 SND-A
TMPA new
SAMM2005 LES
SAMM2005 CEM INZ2
SAMM2005 LES INZ2 SND-A
SAMM2005 LES INZ2 CCNS
SAMM2005 LES INZ2 CCNS SND-A
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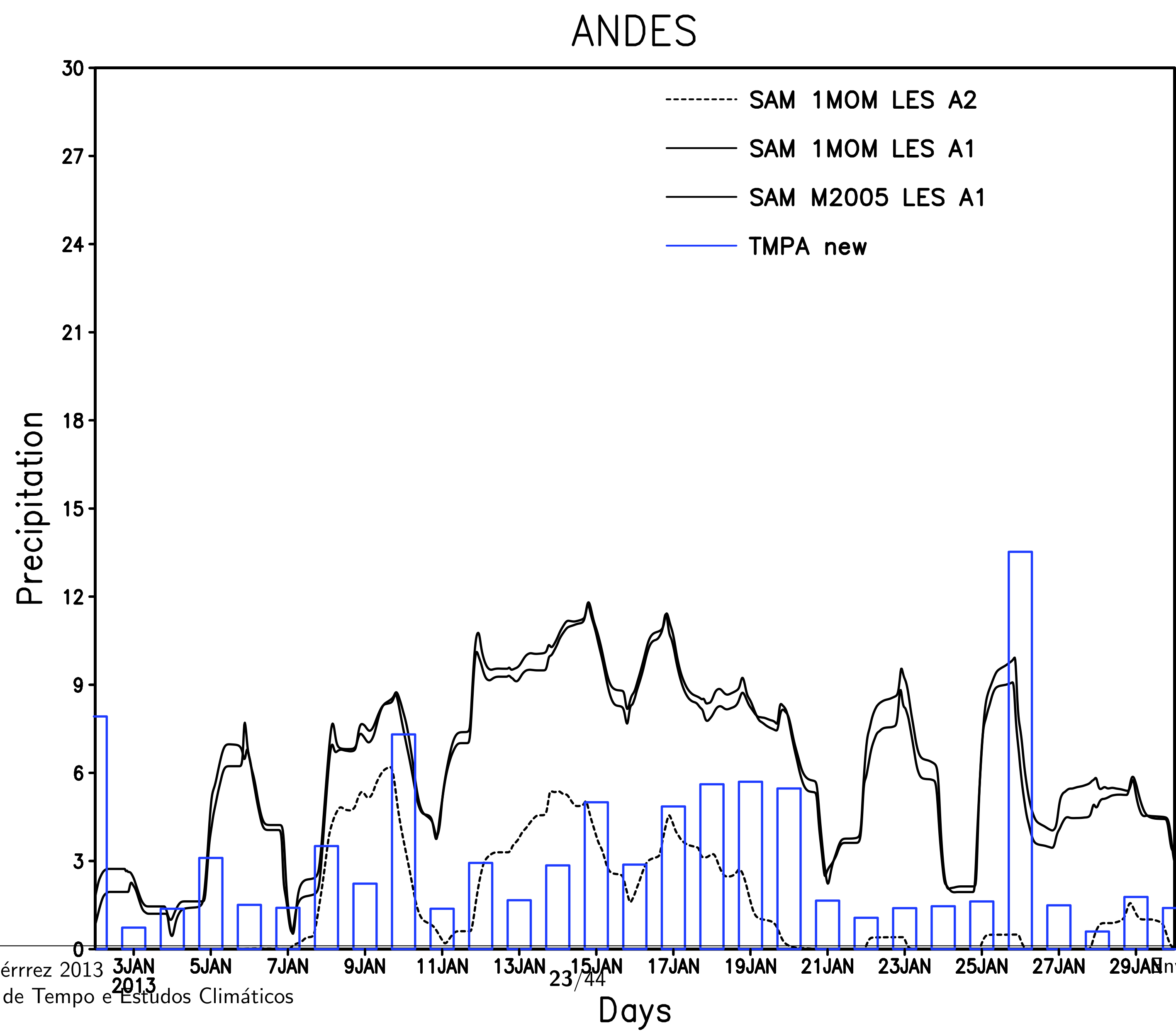
Days


ANDES
SAM 1MOM LES A2
SAM 1MOM LES A1
SAM M2005 LES A1
TMPA new
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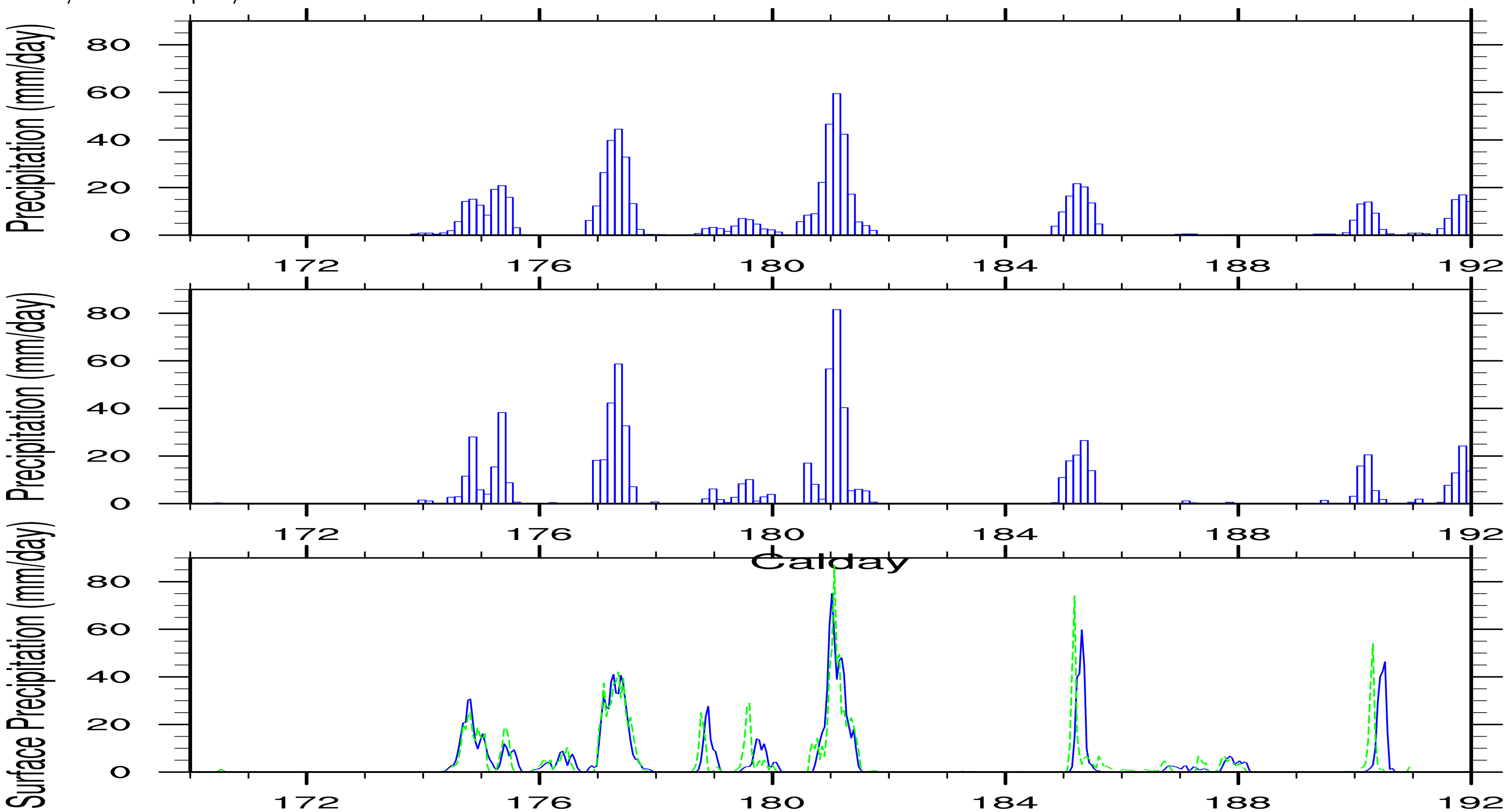
Days

Cloud resolving model simulations

Development

Validação da Precipitação

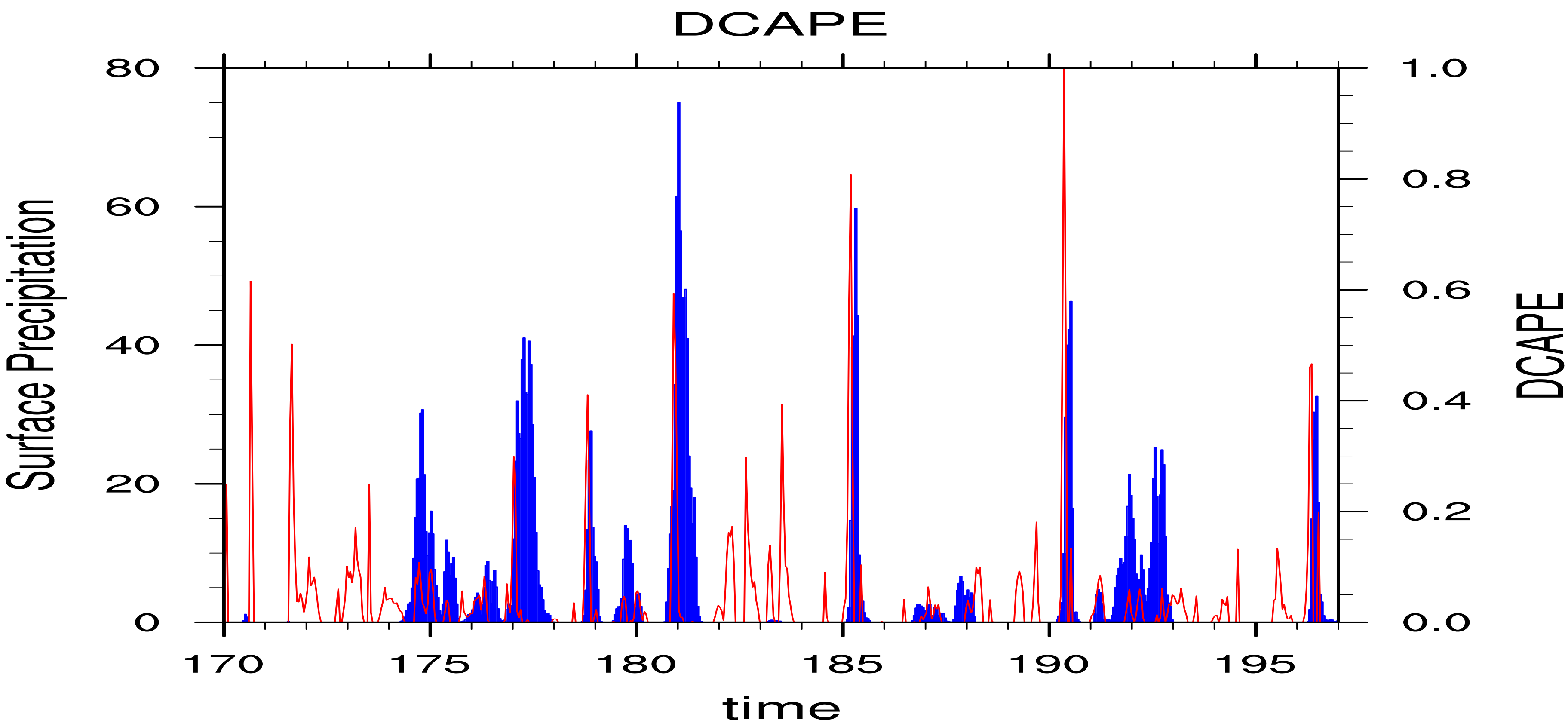


☞ Testando novos fechamentos com o CRM

Segundo Xie et al (2004) convecção não é proporcional ao CAPE e sim a tendência do mesmo:

$$\mu_b \sim Prec \sim dCape/dt$$

Testando fechamentos com o CRM: DCAPE

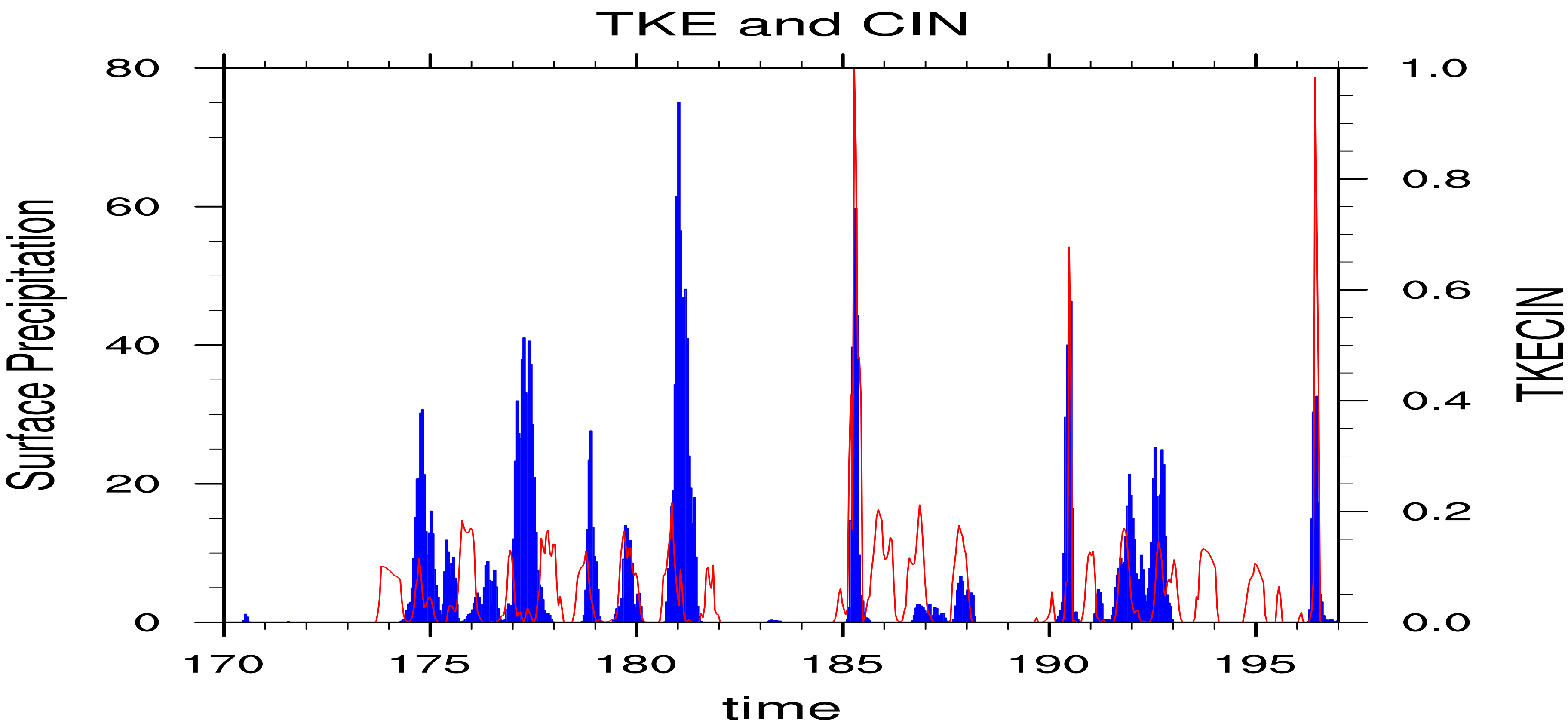


☞ Testando novos fechamentos com o CRM

Segundo Fletcher e Bretherton (2010) convecção é controlada pela turbulencia e a inhbição convectiva

$$\mu_b \sim Prec \sim \sqrt{(\mathsf{tke})}\,\mathsf{Exp}^{-\mathsf{cin}/\mathsf{tke}}$$

Testando fechamentos com o CRM: TKE-CIN



☞ Testando novos fechamentos com o CRM

Utilizando as vantagens de cada um destes fechamentos foi proposto: DCAPE-TKE-CIN

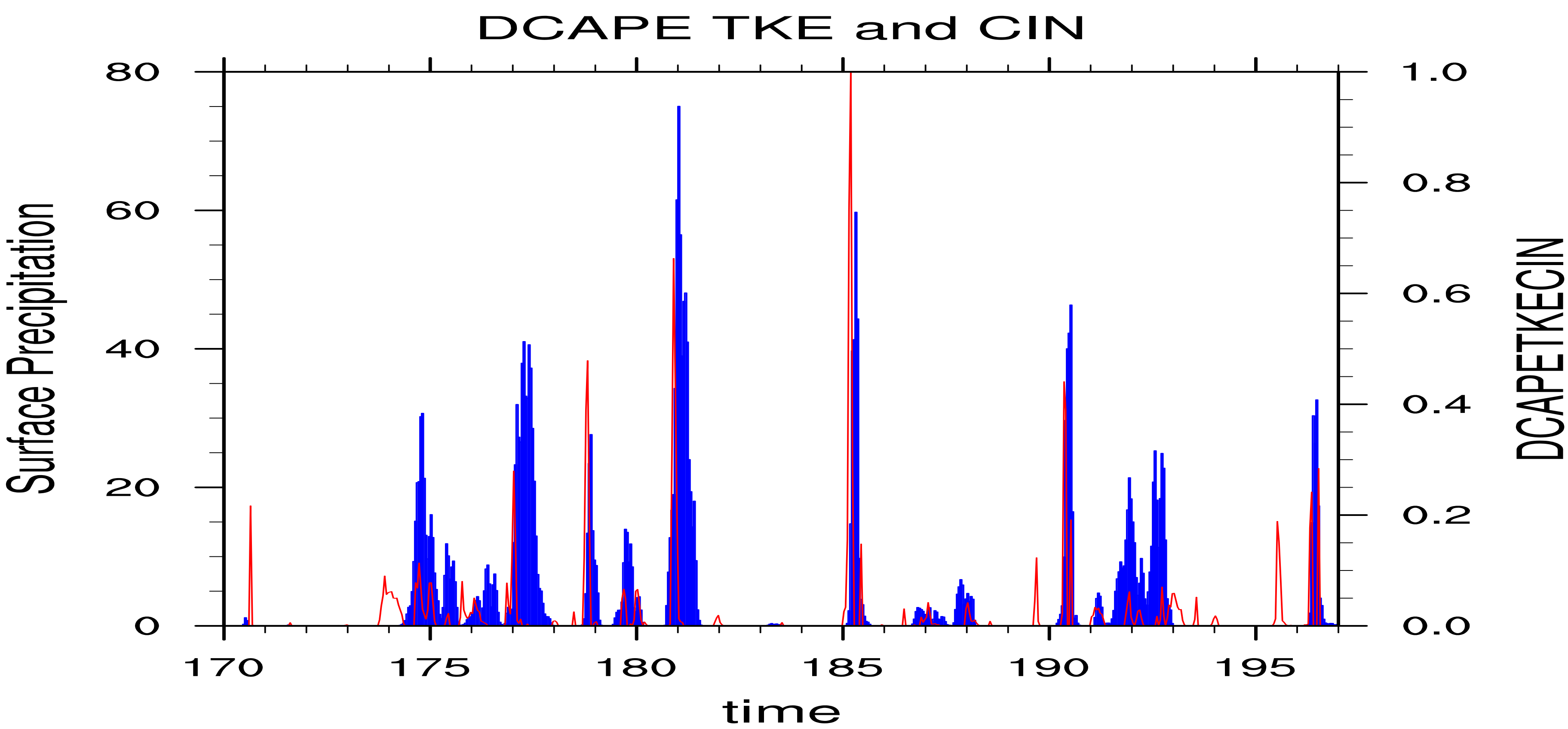
$$\text{dcape} = \text{cape}(T^*, q^*) - \text{cape}(T, q) \tag{1a}$$

$$T^* = T + dt\frac{\partial T}{\partial t}|_{\text{large scale advection}} \tag{1b}$$

$$q^* = q + dt\frac{\partial q}{\partial t}|_{\text{large scale advection}} \tag{1c}$$

$$\mu_b \sim Prec \sim \alpha(\text{dcape})\frac{\text{dcape}}{\text{dtime}}\sqrt{(\text{tke})}\,\text{Exp}^{-\text{cin}/\text{tke}} \tag{1d}$$

Testando fechamentos com o CRM: DCAPE-TKE-CIN



Dynamics of the precipitation over the eastern Pacific ITCZ

☞

The CRM/SAM is integrated for the whole period using both initial conditions and large scale forcings derived from analysis of the CPTEC model. Two microphysical schemes are used in the simulation the one-moment bulk microphysics SAM1MOM and the two moment bulk Morrison microphysics M2005. The simulated CRM/SAM precipitation is validated against the TRMM Multi-satellite Precipitation Analysis (TMPA) and the results displayed good agreedment. The strong resemblance of the simulated precipitation with the observed values give us confindence about the results. Thus, we move to analyze the dynamics of the cloud and precipitation for this region. It was shown that families of deep clouds with very high cloud base are found during the whole period. Precipitation events are mainly associated to the presence of still deep but low cloud-base middle troposphere clouds. However, further analysis reveals that those low cloud-base middle troposphere clouds can be feeded from above due to the melting of ice-phase precipitation from the high cloud-base clouds.

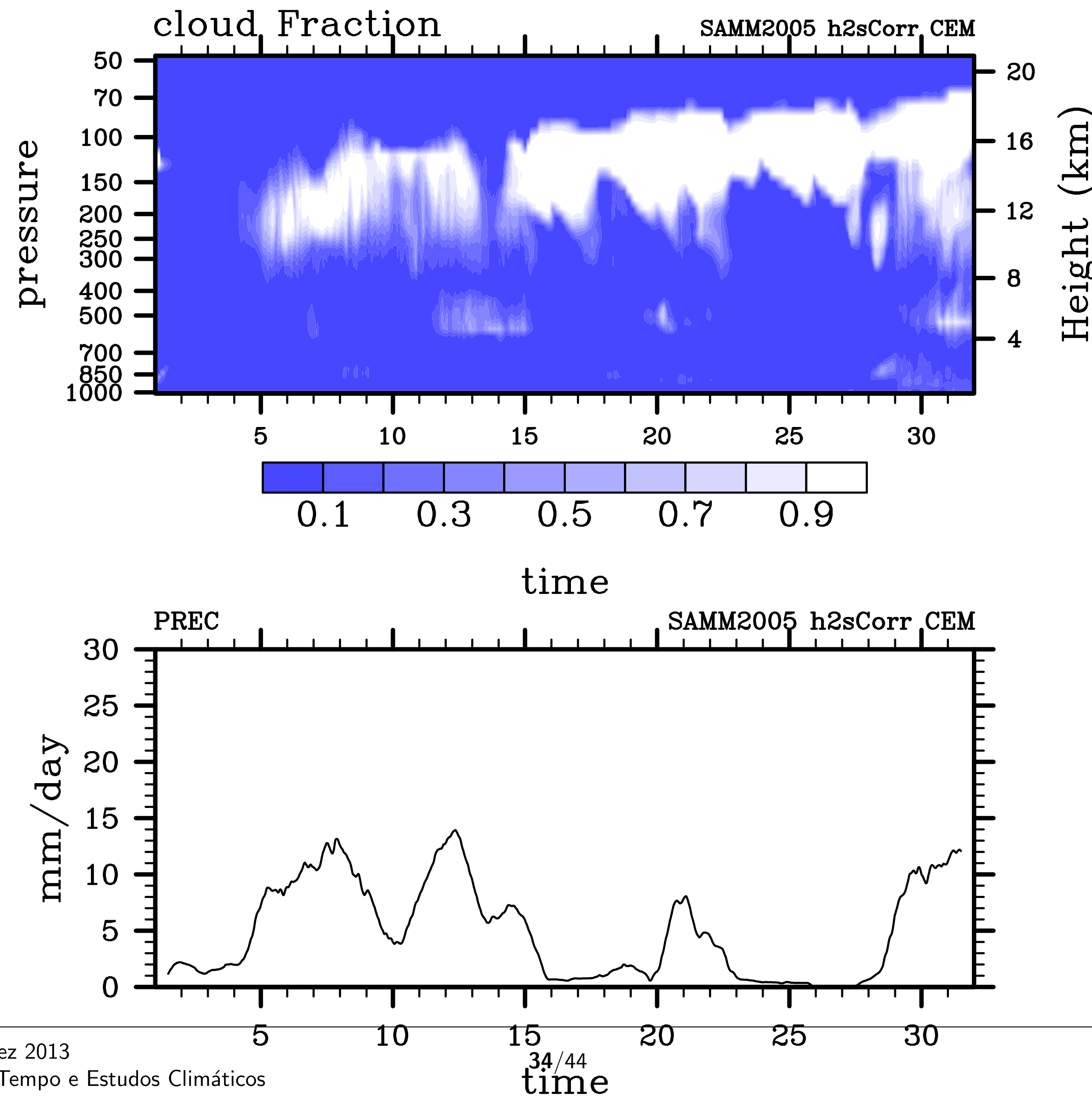
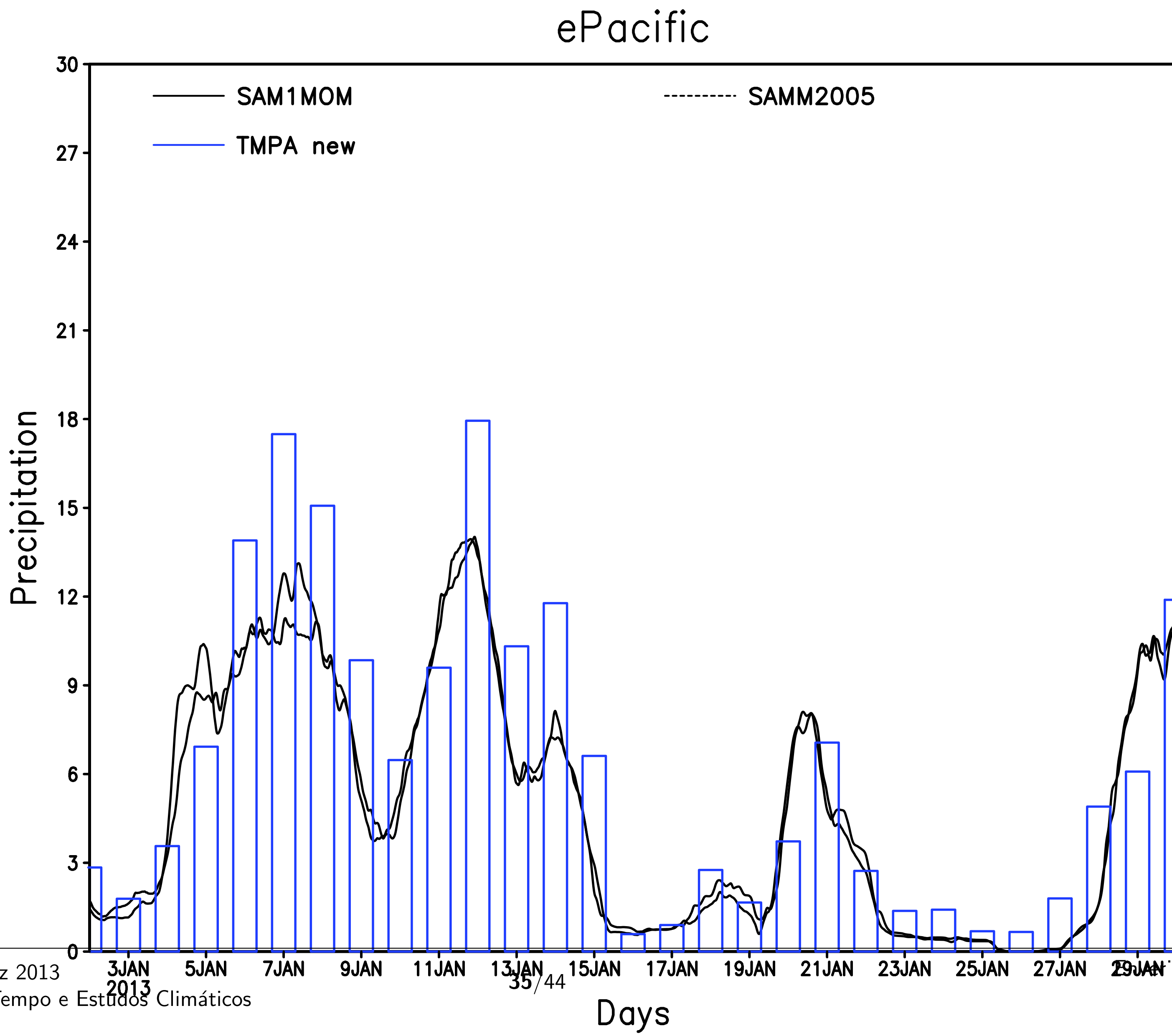


Figura 1: Vertical profile timeseries of cloud fraction, Morrison microphysics


ePacific
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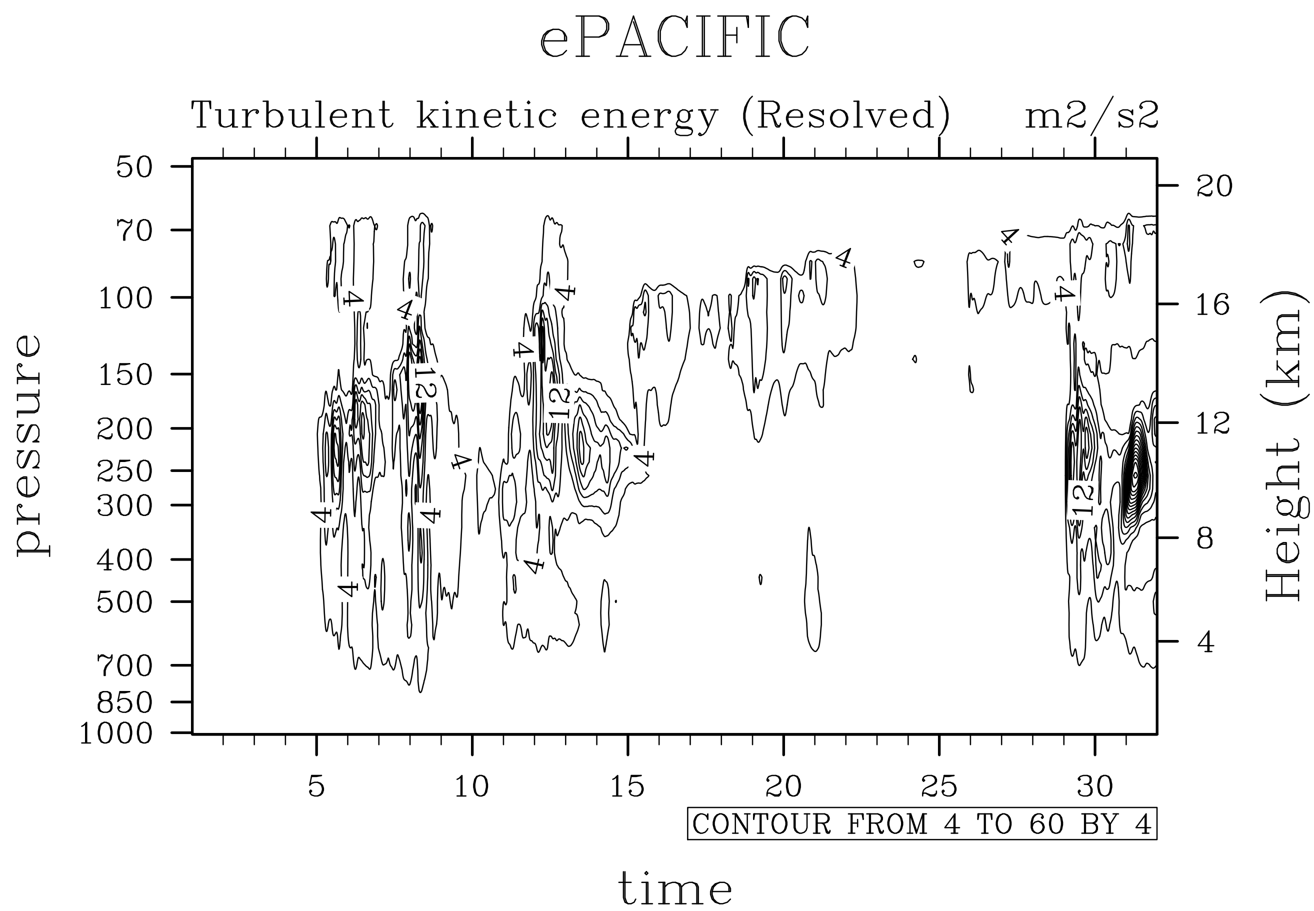

Figura 3: Vertical profile timeseries of TKE

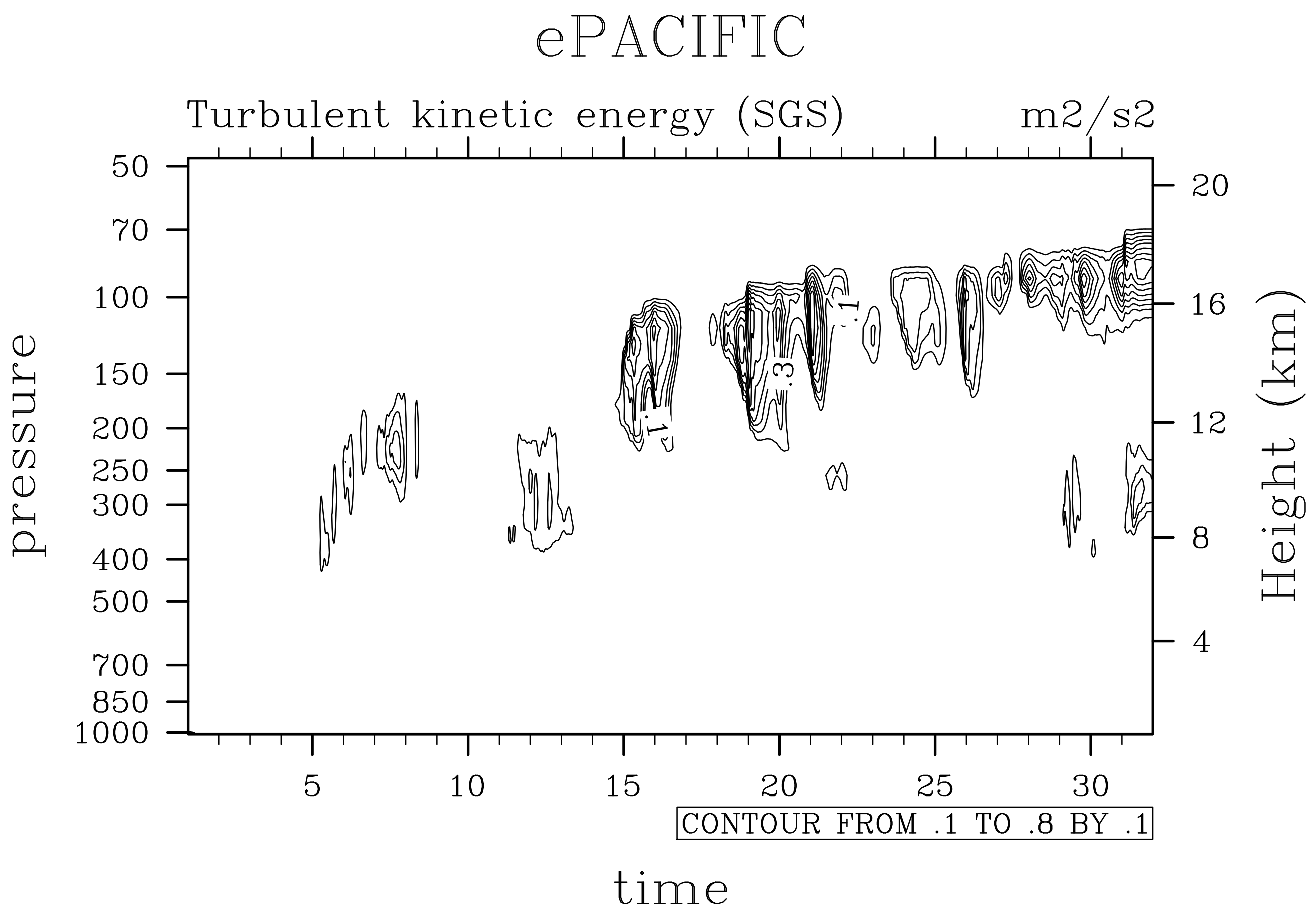

Figura 4: Vertical profile timeseries of TKES

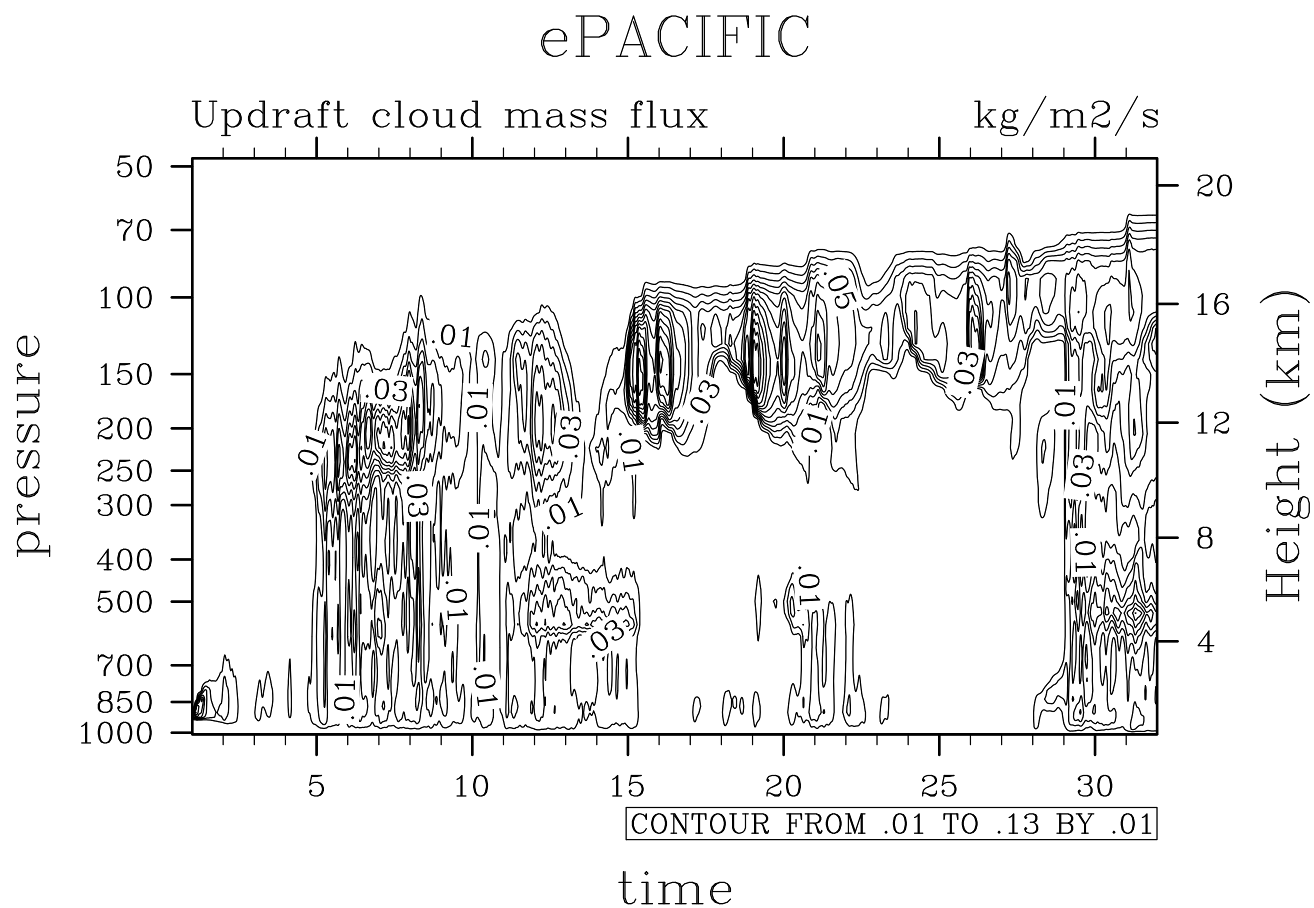

Figura 5: Vertical profile timeseries of updraft cloud mass flux

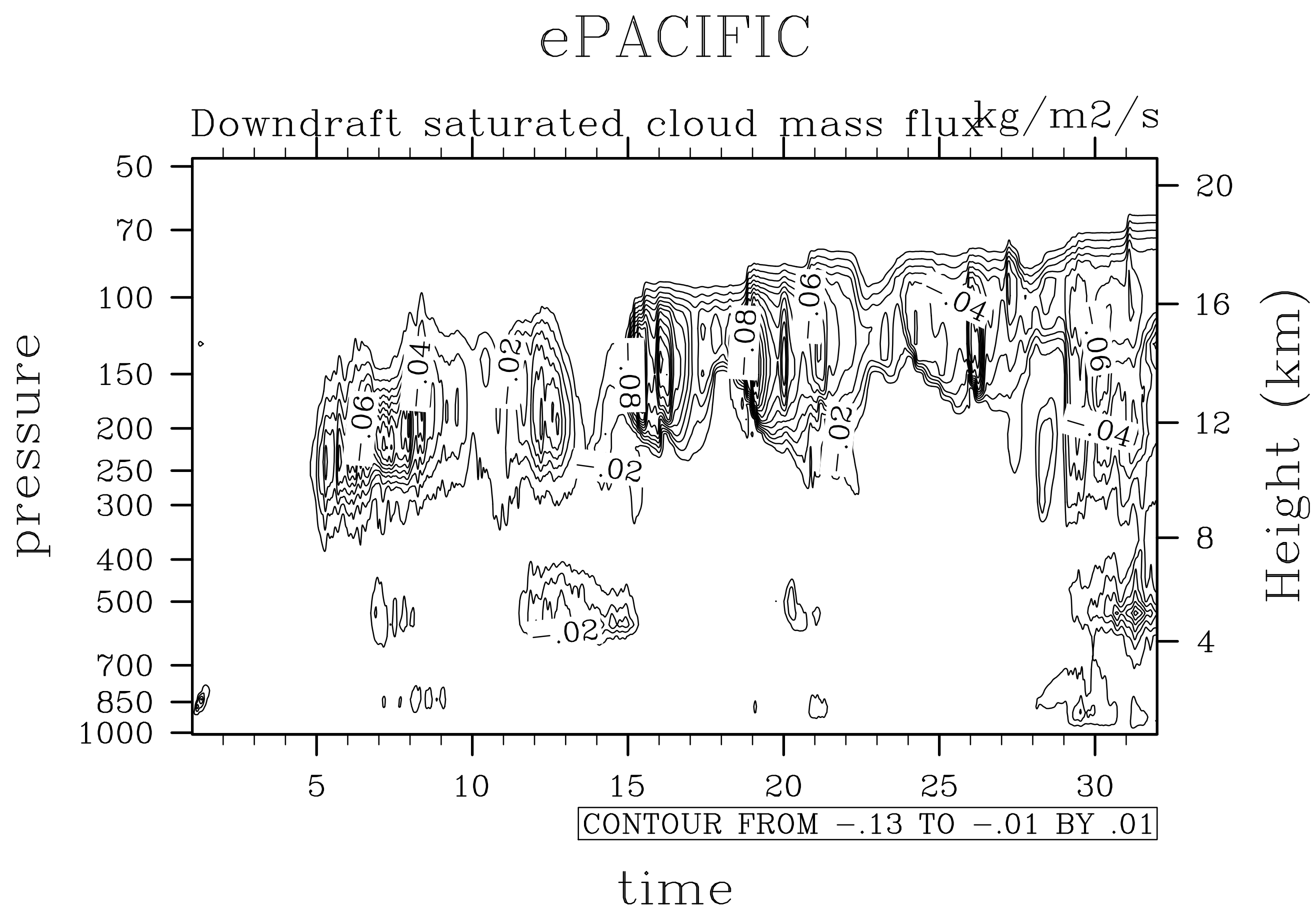

Figura 6: Vertical profile timeseries of downdraft cloud mass flux (saturated)

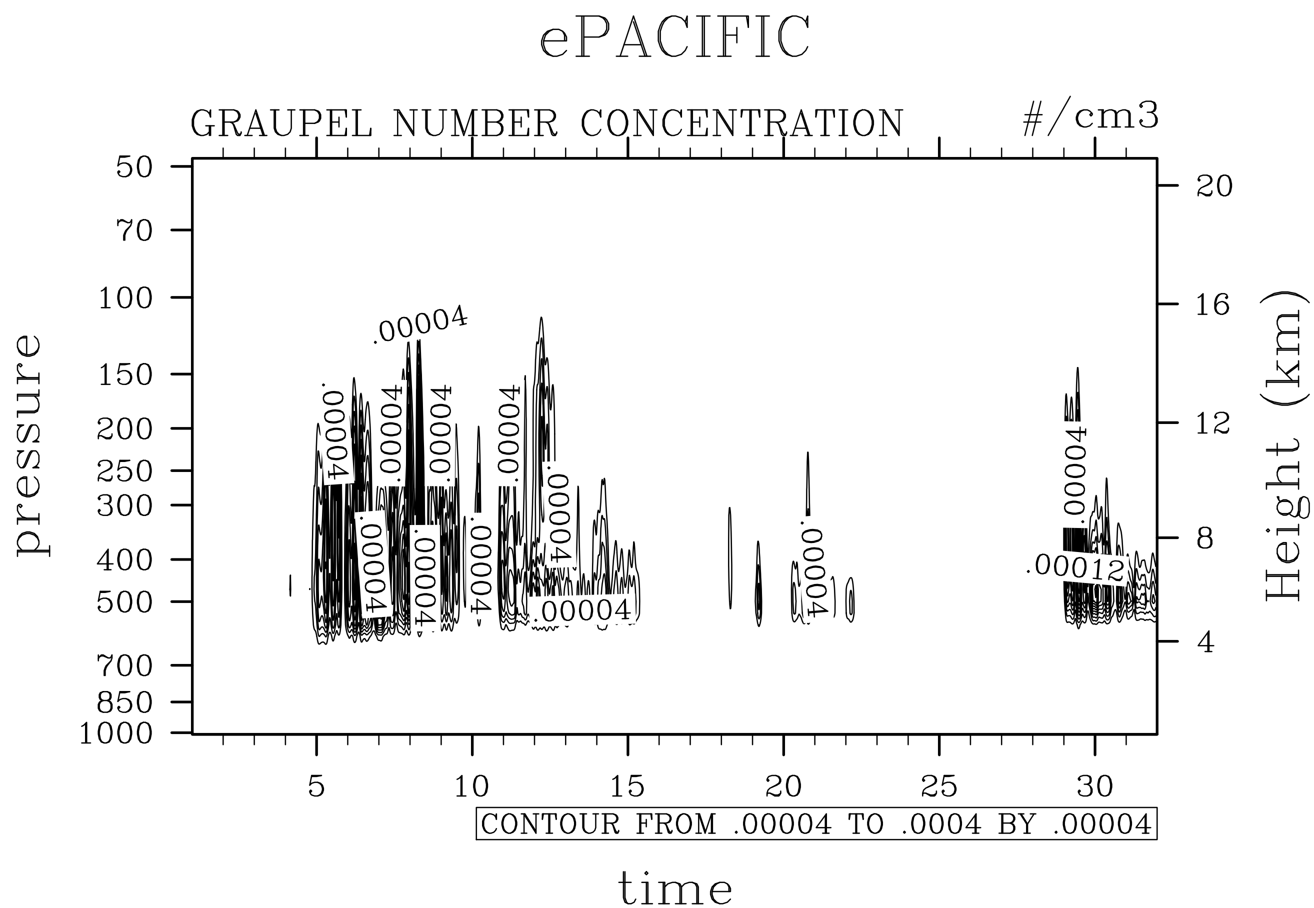

Figura 7: Vertical profile timeseries of number graupel concentration

Cloud resolving model simulations

Summary

☞ Summary

➢ A new set of experiments for the South America and neighboring oceans are build and used to feed the CRM/SAM model.

➢ The CRM/SAM seems to be useful for the simulation of precipitation and mass flux for both continental and ocean areas.

➢ Although for precipitation the model seems to be well calibrated, with good results for both the one moment and two moment microphysics. The one moment microphysics produce less clouds, this could be implications for long term simulations.

➢ CRM/SAM is also being used for the developing of new parameterizations schemes for deep convection.

➢ CRM/SAM can be used together with observational results to gain deep understanding of the processes controling the development of precipitation

☞ Acknowledgements

To the RedeClima project for the finantial support of the first author and to the INCT for Climate Change who supports the participation in this workshop.

☞

Many Thanks!