The Abdus Salam International Centre for Theoretical Physics

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IAEA International Atomic Energy Agency

1934-40

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Parameterisation issues for Regional Climate Models

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Physical Parameterisations: High-Resolution Modelling
Regional Climate Modelling & Process Evaluation

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Outline

1. Motivating RCMs for parameterization development and process evaluation/analysis.

2. RCM Transferability across different climate regimes

3. An example of convection – land surface interactions.

4. Simulating precipitation over Africa: Sensitivity to model resolution.

5. Cloud-Radiation Parameterizations: Evaluation techniques

6. Tropical Deep Convection at high-resolution

7. The Diurnal Cycle and Low level Jet interactions over USA.

Developing parameterisations for (high resolution) GCMs
Reasons for using RCMs

RCMs can be forced at the boundaries by high quality analyses.

RCMs can be integrated (affordably) at probable resolutions of future GCMs (e.g. 10-100km)

RCMs can be targeted at key failures in present GCMs
e.g. Subtropical stratocumulus, Monsoon circulations etc etc.
RCMs can be integrated without error advection from external regions (of a GCM domain) Subject to the quality of the analyses

Parameterisations can be developed and tested at specified resolutions, with dynamical interaction at the same resolution
A complement to Single Column Models

RCMs can be centred around regions of high quality observations and periods of intensive observation (e.g. CEOP, TOGA, LBA, AMMA)

RCMs can provide 'large-scale' forcing to LES/CRM/SCMs consistent with the analysed large-scale for a defined time period (e.g. RICO)

GEWEX RCM Transferability Working group

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B.Rokel (GKSS) A.Zadra(CMC) and C.Jones (UQAM/SMHI)

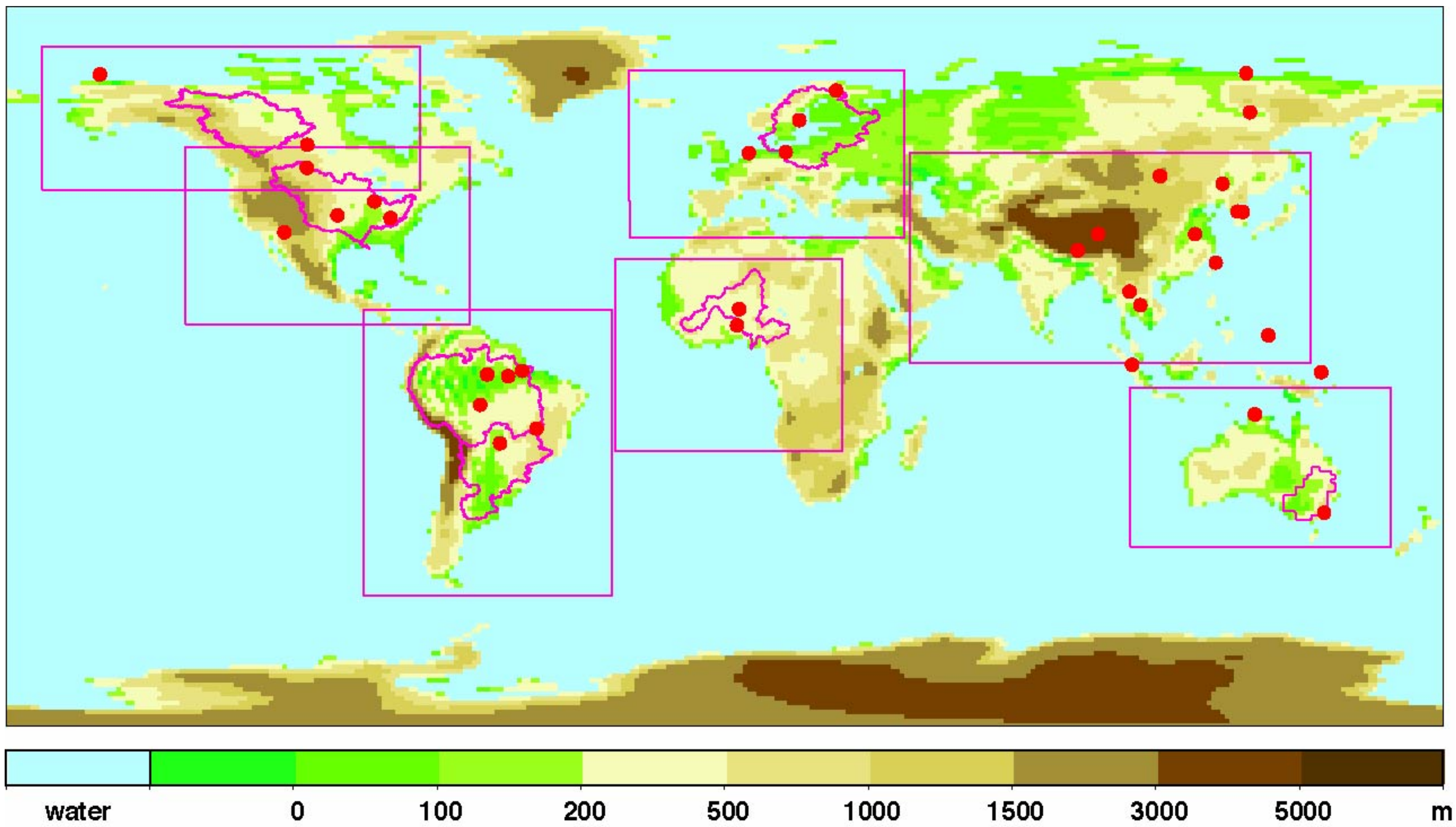
ICTS: Inter-CSE (Continental Scale Experiment) Transferability Study A TWG/CEOP co-sponsored project

Aims: To assess the performance of (unmodified) RCMs across a wide variety of (global) climate conditions using CSE/CEOP observations for model evaluation.

Objectives: Using multi-model, multi-domain evaluation identify common and individual weaknesses and strengths of RCMs with respect to simulating regional water and energy cycles.

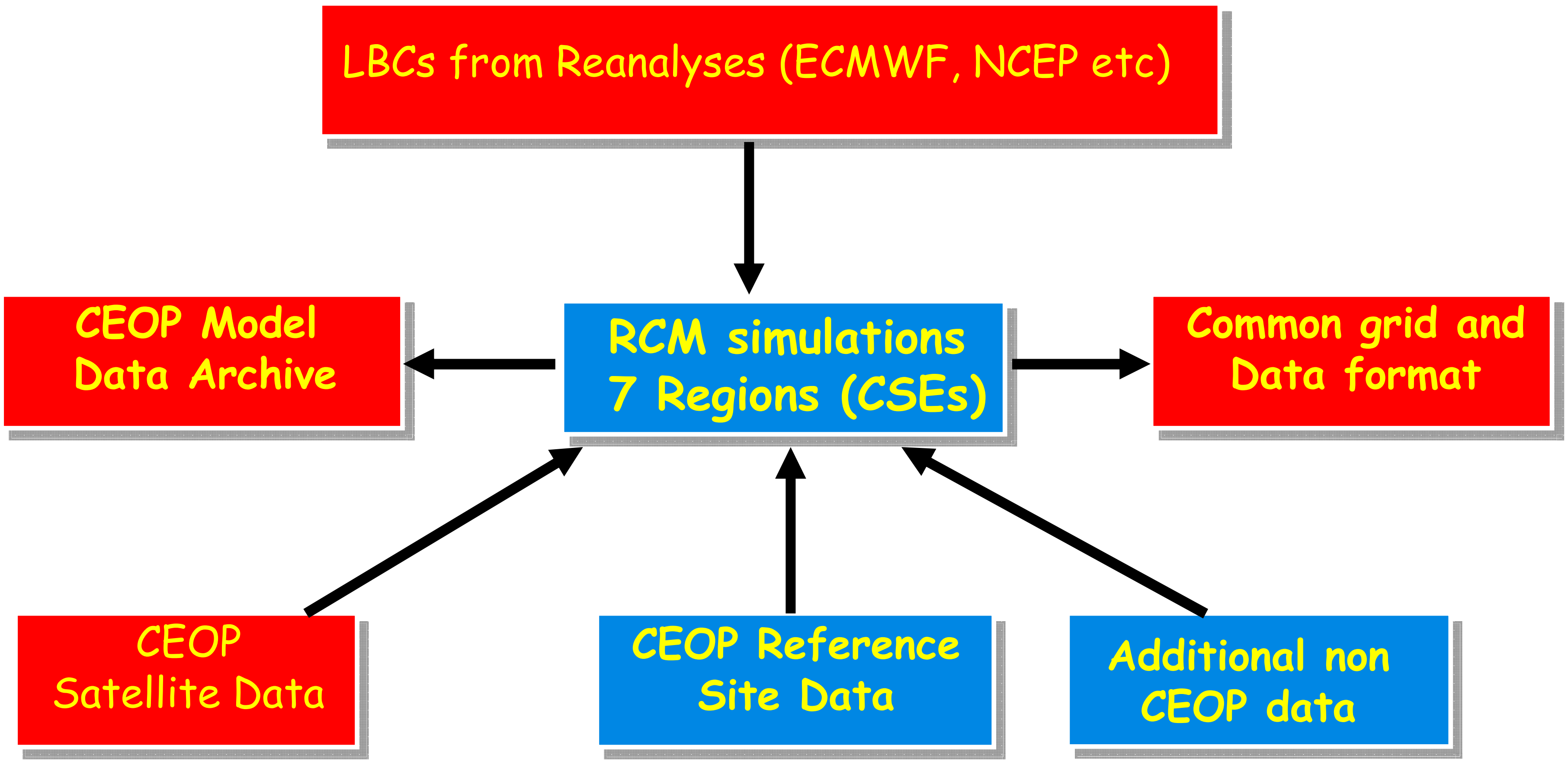
Through an iterative procedure improve RCM abilities to simulate these processes on all model domains.

The ICTS Regional Climate Modelling protocol aims to capitalise on the global coverage offered by CEOP observations
to assess and improve the global transferability of RCMs



Unmodified RCMs were run on a variety of domains around the globe

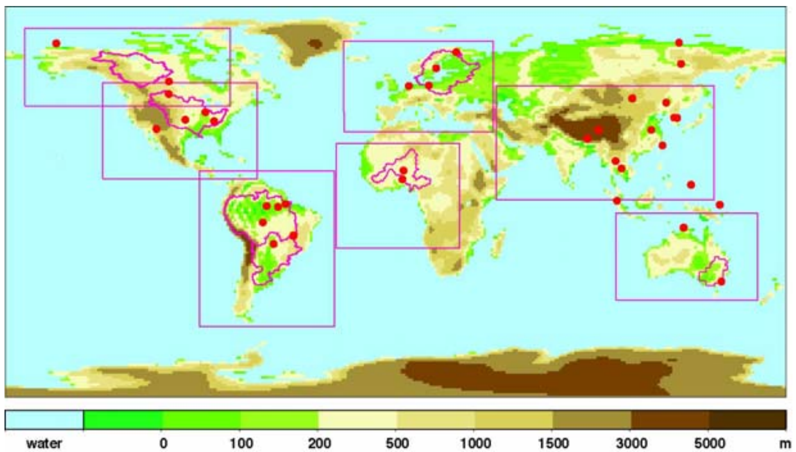
ICTS Modelling and Evaluation structure
Integration period 2000-2004

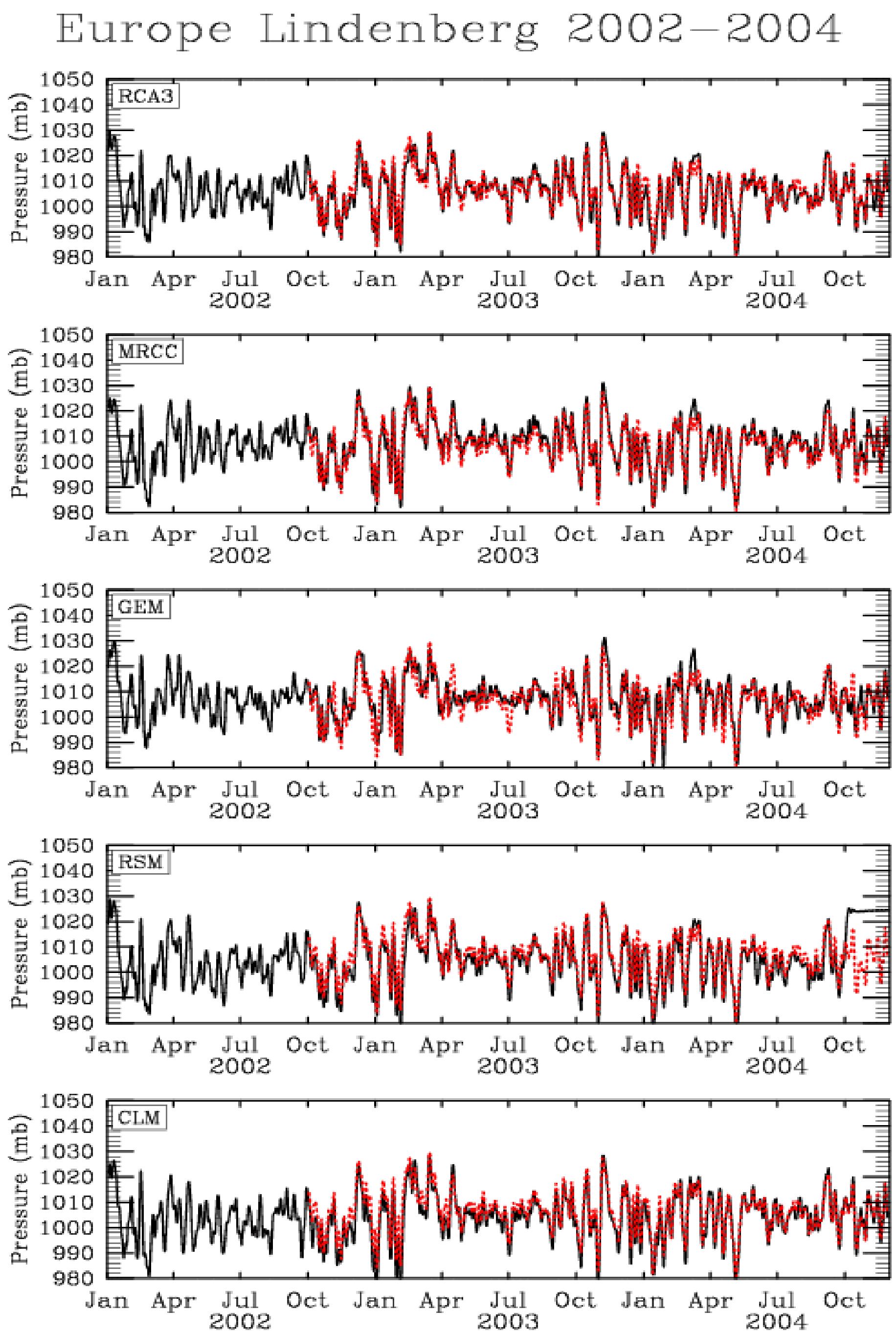


From Burkhardt Rokel GKSS

Forced by analysed boundary conditions RCMs simulate the higher time frequency meteorology accurately (e.g MSLP):

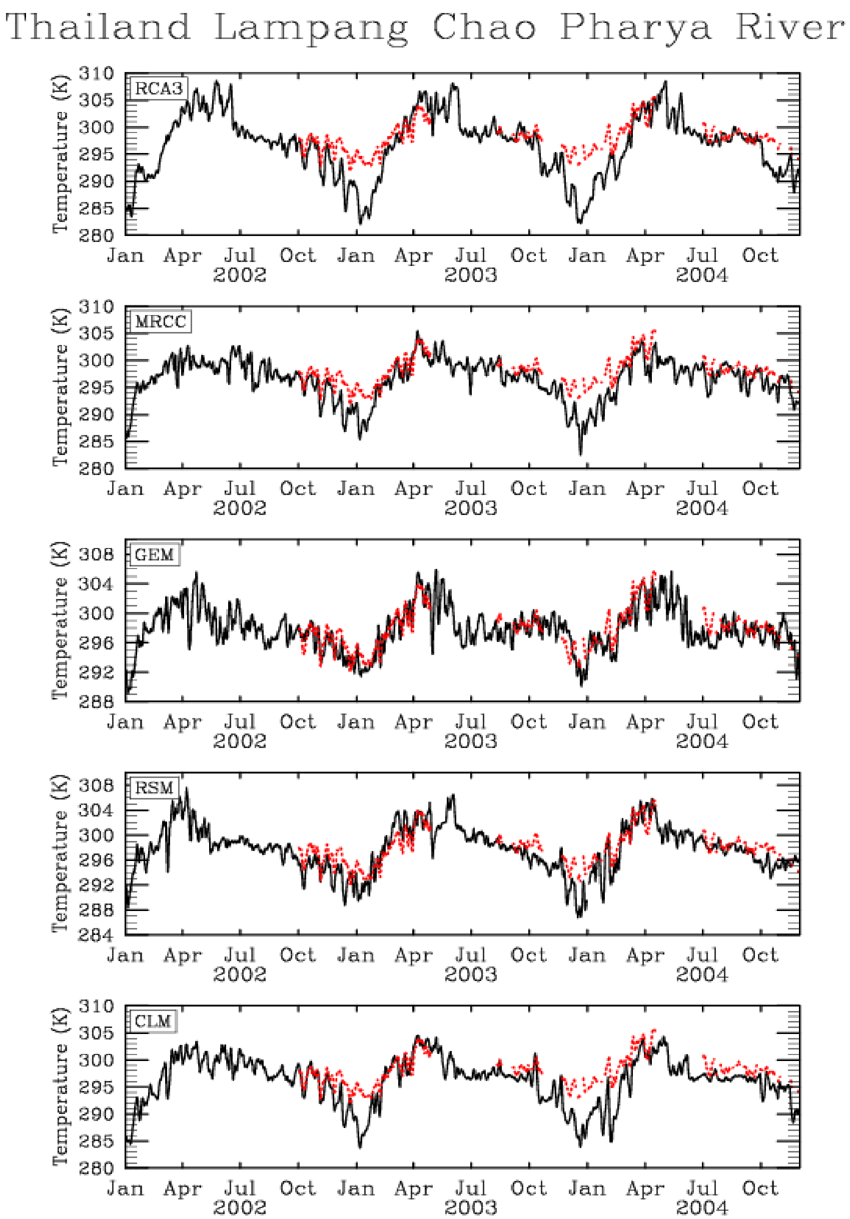
Parameterisations can therefore be developed and evaluated in a realistic large scale meteorological setting

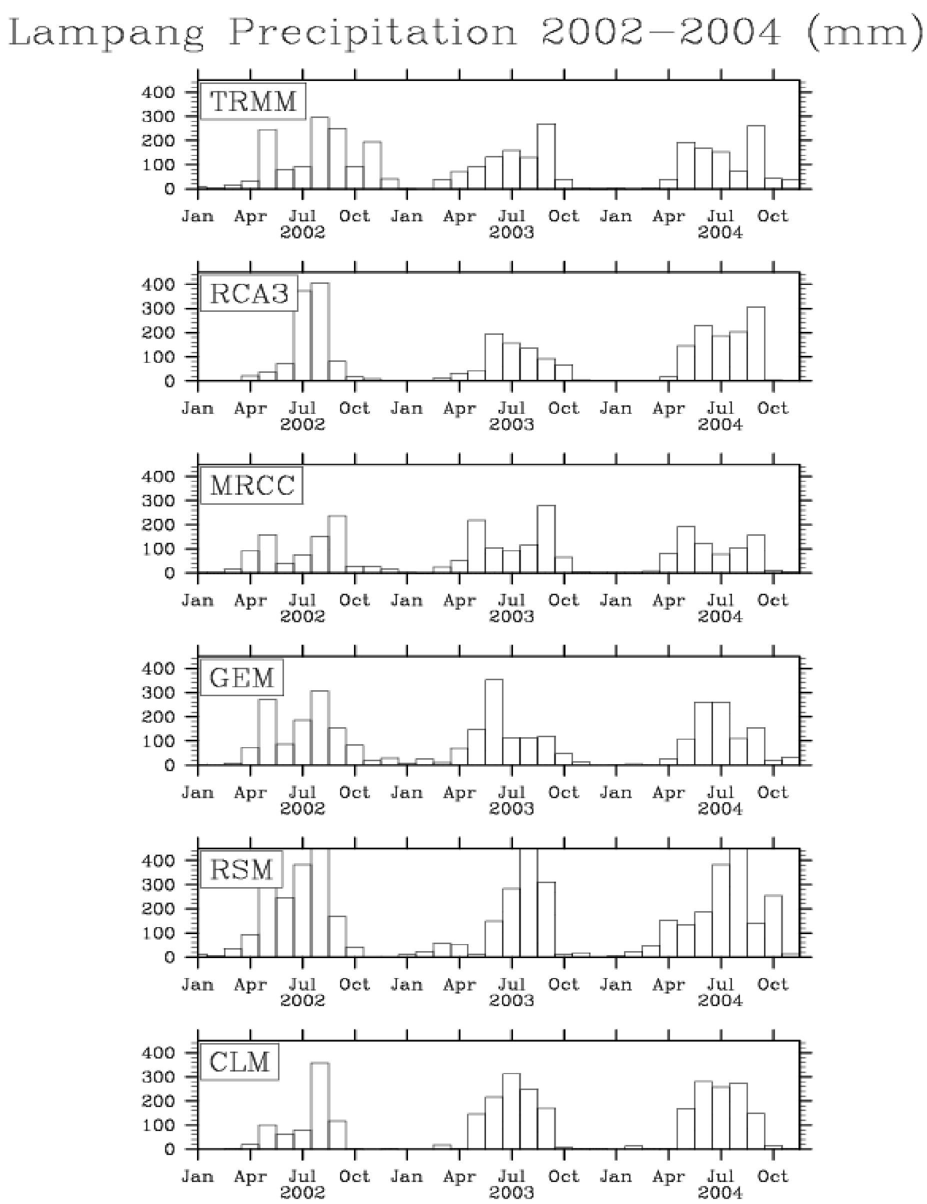




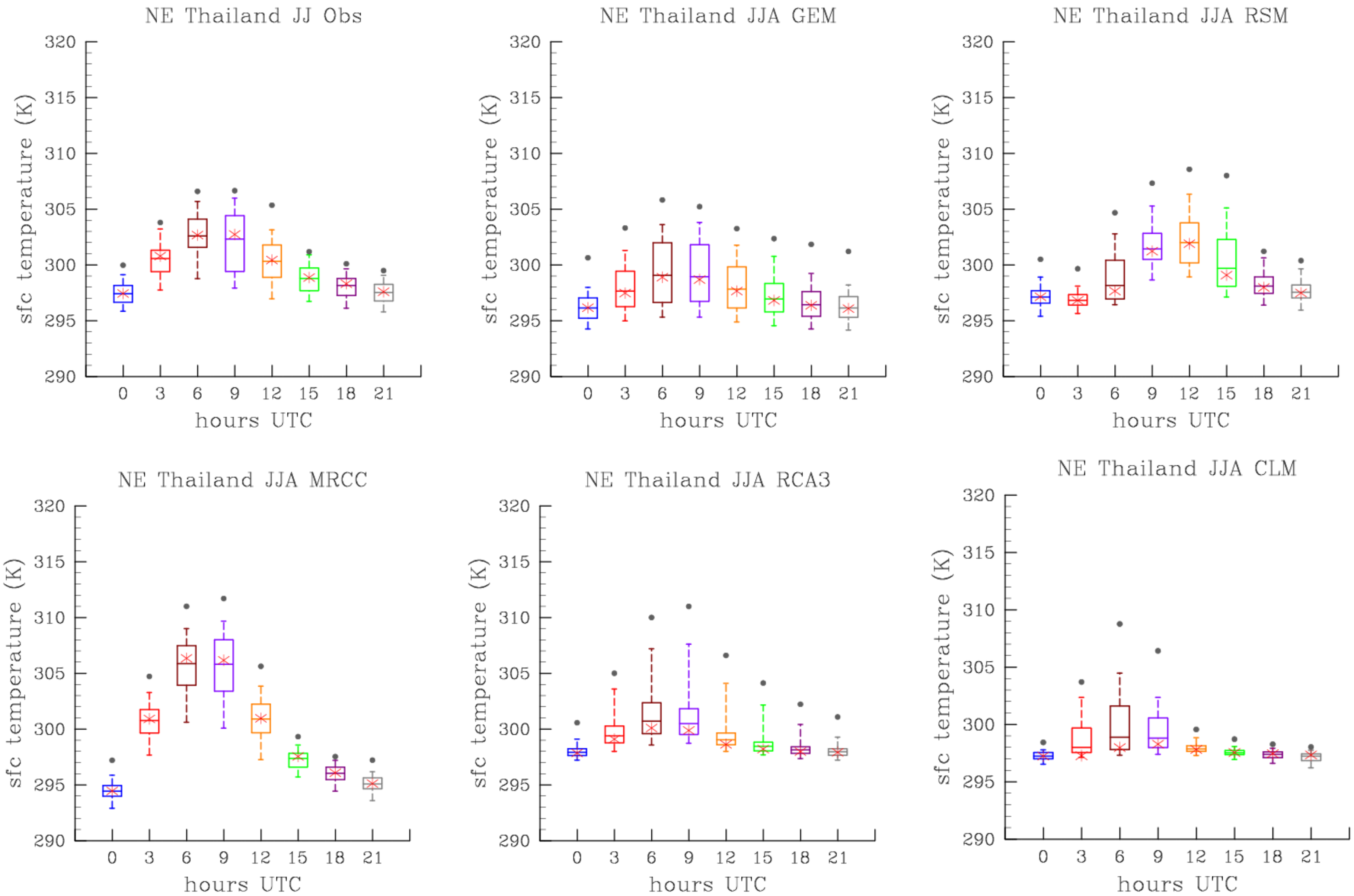
Frequent, high-quality CEOP observations allow a detailed evaluation of a wide range of simulated variables, across a variety of geographic locations

Simulated 2m temperature and precipitation NE Thailand 2002-2004

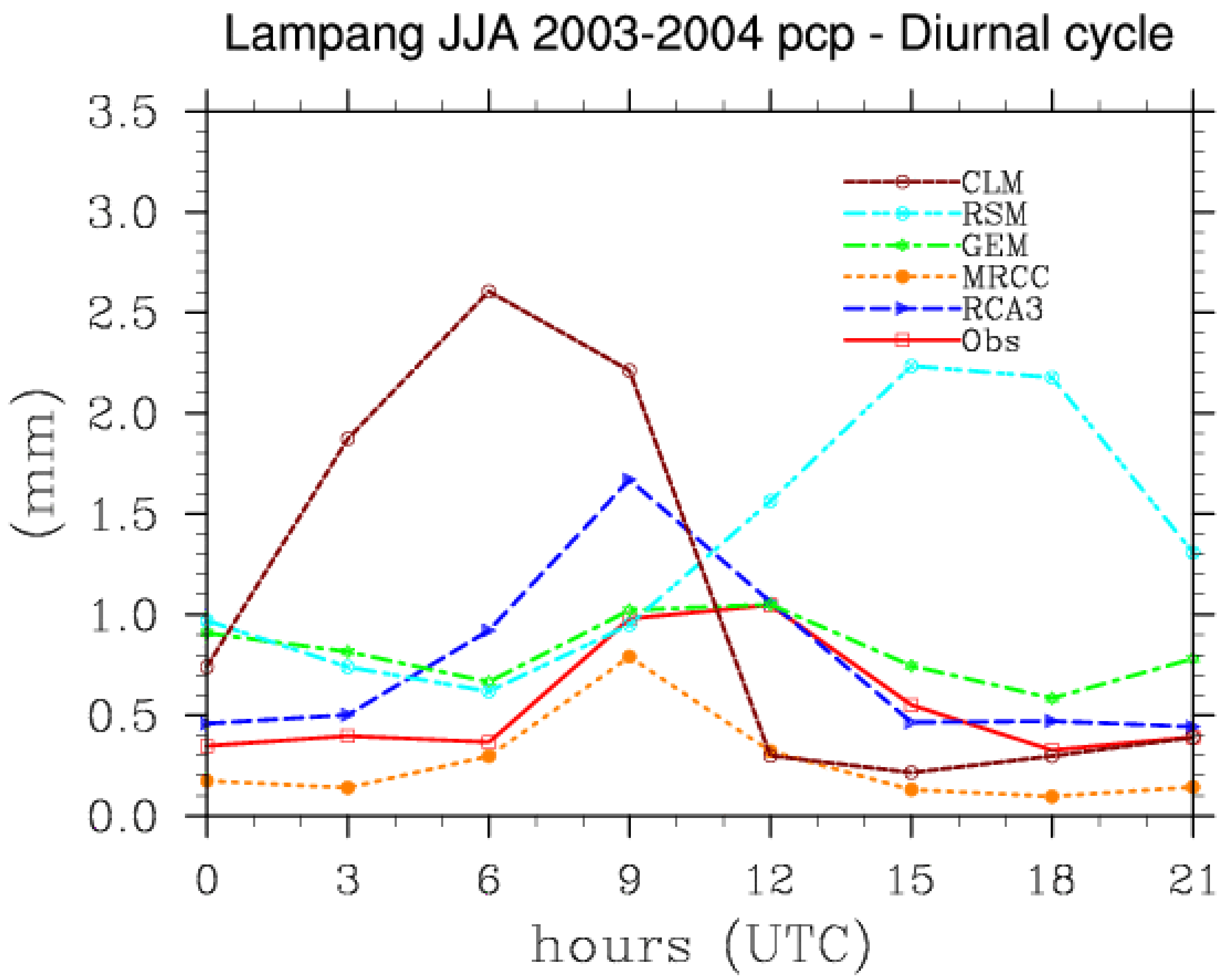




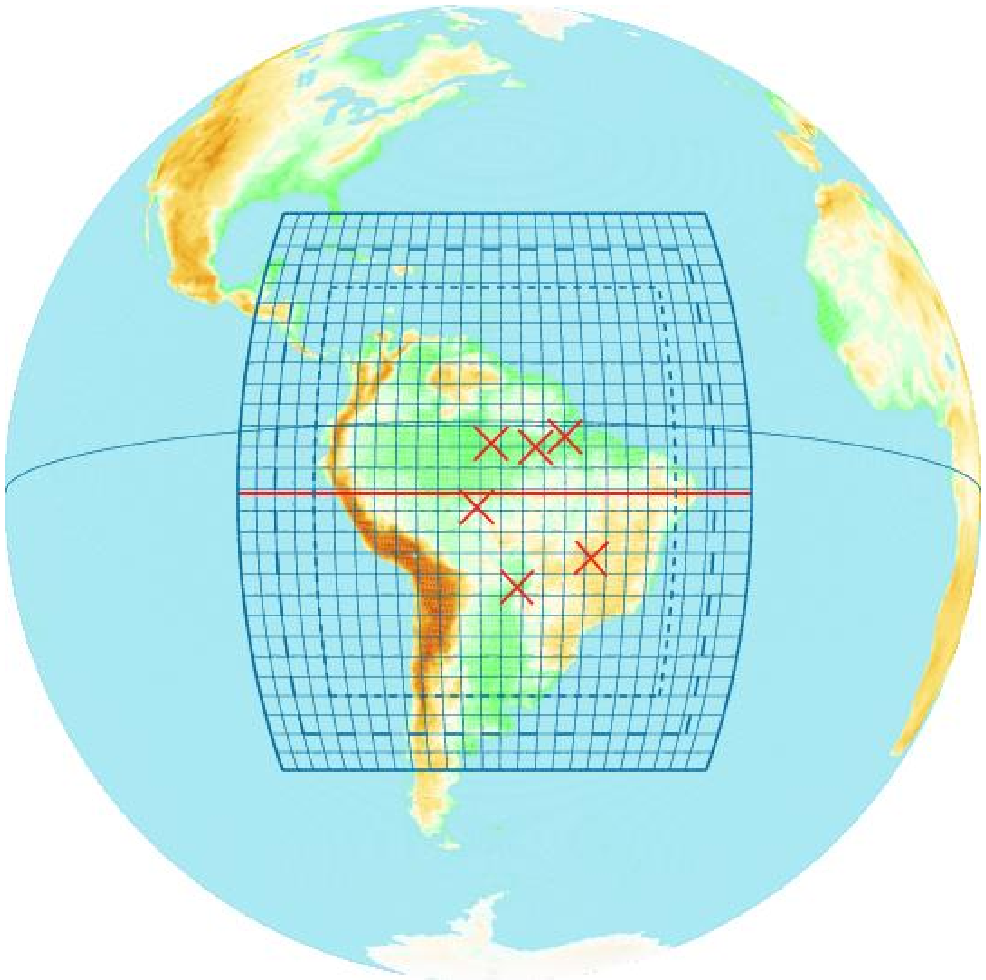
Mean Diurnal Cycle of 2m-temperature in North East Thailand
JJA 2003-04 : Local Time = UTC +6.5 hours



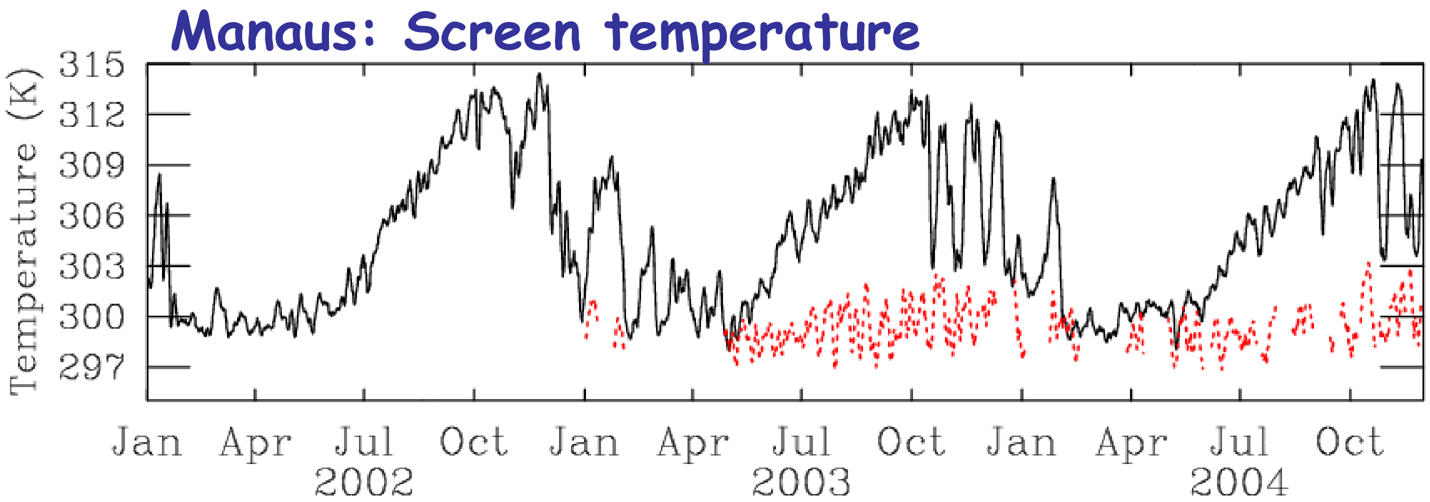
Mean Diurnal Cycle of Precipitation North East Thailand (JJA 2003-04): Local Time = UTC + 6.5 hours

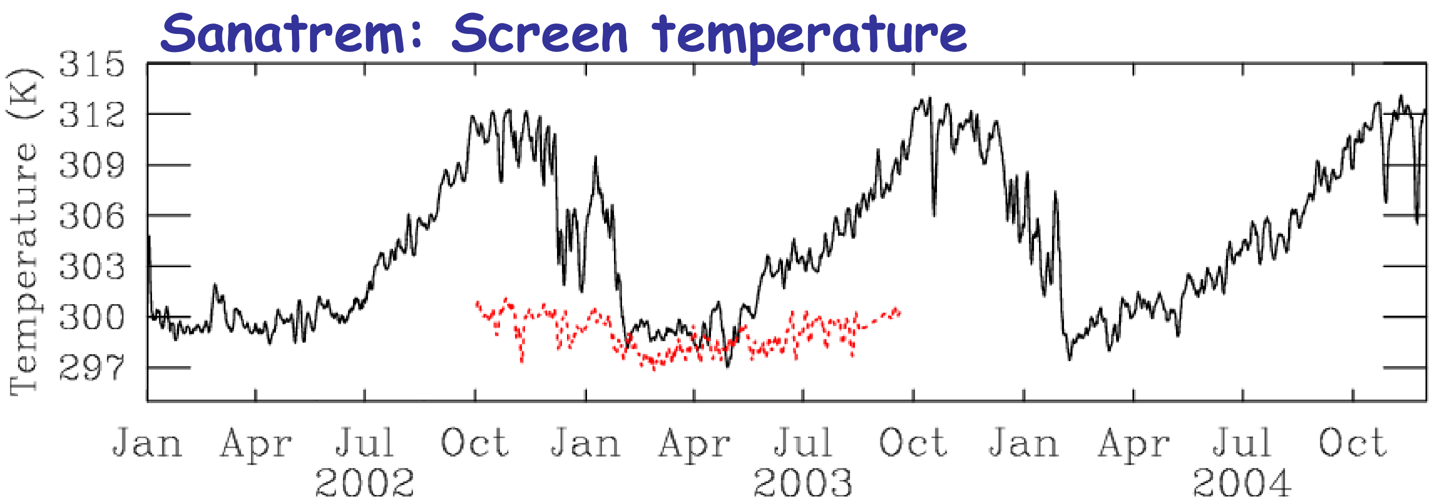


Problems simulating the subtropical dry season over South America and the use of CEOP observations



In the original ICTS runs the RCA3 model had a large warm bias in screen temperature during the dry season over South America





CEOP Observations ...... RCA3_original —

RCA3 has 3 soil layers, with a thin (1cm thick) top soil layer included to simulate rapid diurnal changes in surface temperature.

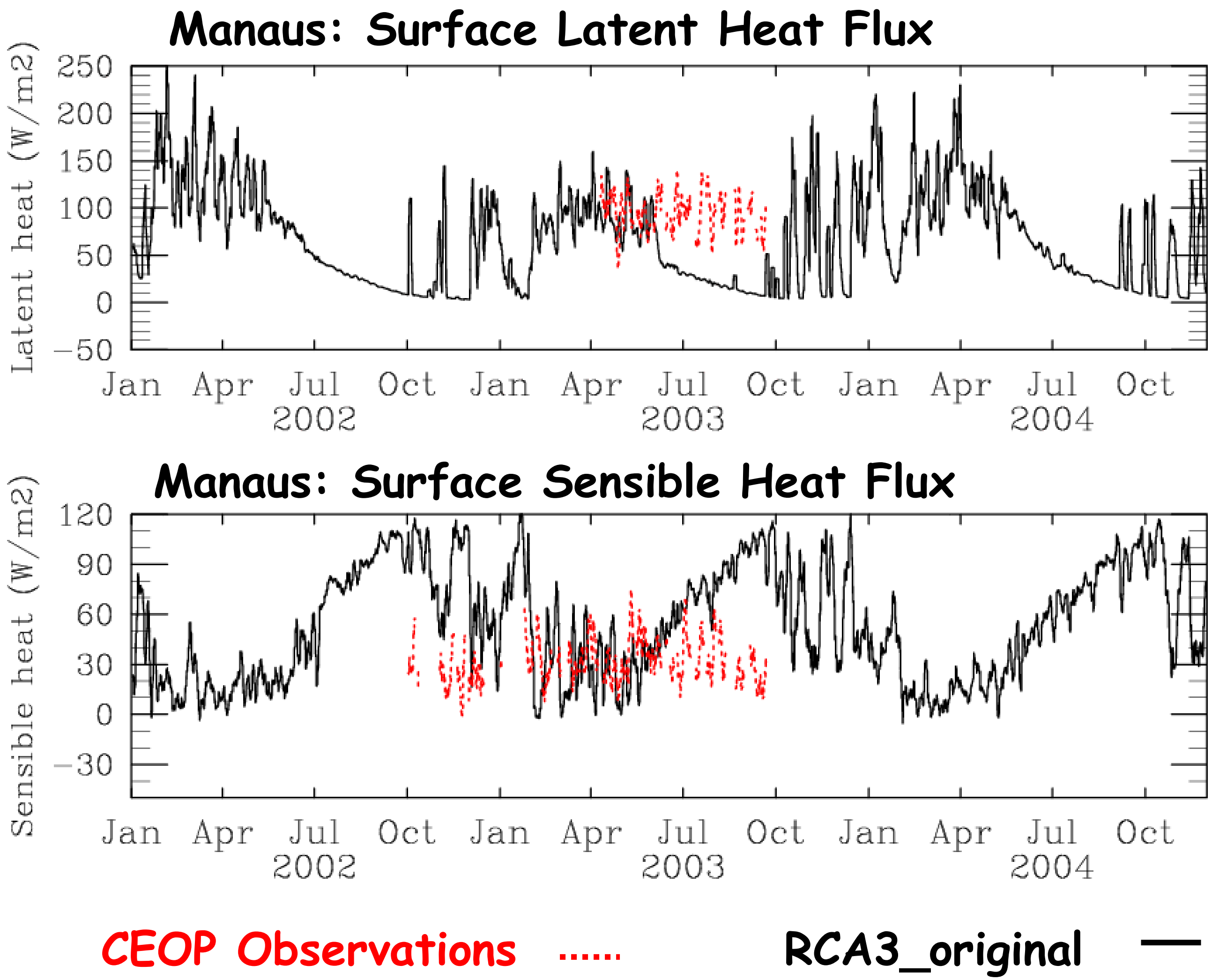
In the original ICTS runs a number of key vegetation related parameters were either parameterised or specified in a manner that had been developed and validated for mid-latitude conditions

e.g. Leaf Area Index (LAI) and vegetation rooting depth (ZW2)

A new set of RCA simulations were recently made for ICTS whereby surface physiographic data was specified based on the Global ECOCLIMAP data set. This data set includes observational based estimates of LAI, rooting depth and soil thermal conductivity.

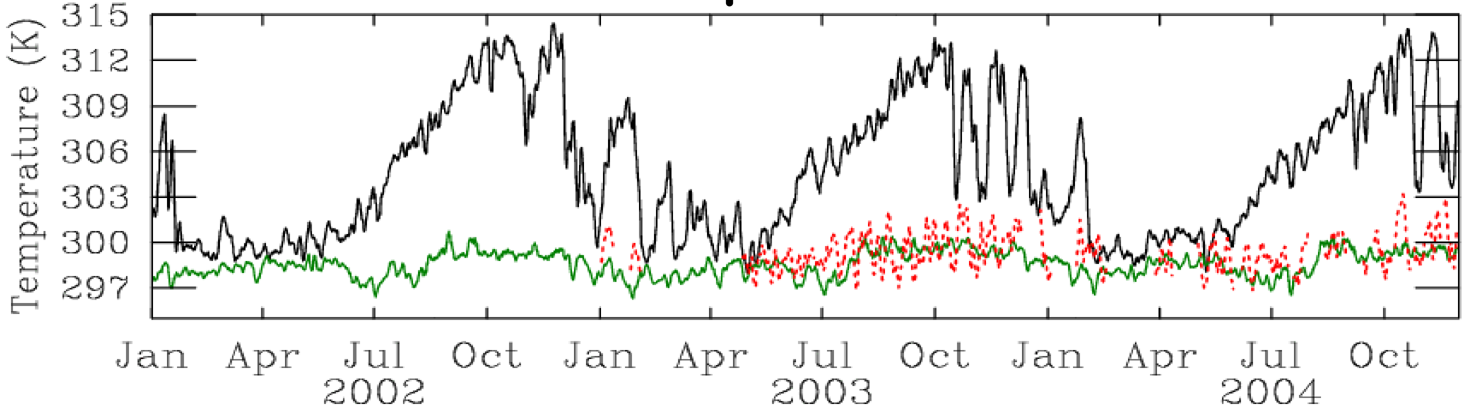
ECOCLIMAP LAI has a different annual cycle in the tropics compared to the original RCA3. Tropical rooting depths are much deeper in ECOCLIMAP (up to ~5m compared to ~1m in original RCA3)

In the original RCA3 runs, the surface latent heat flux fell close to zero in the dry season, with a commensurate increase in the surface sensible flux. The shut down of evaporation led to the surface layer warming rapidly and development of the large warm bias seen earlier

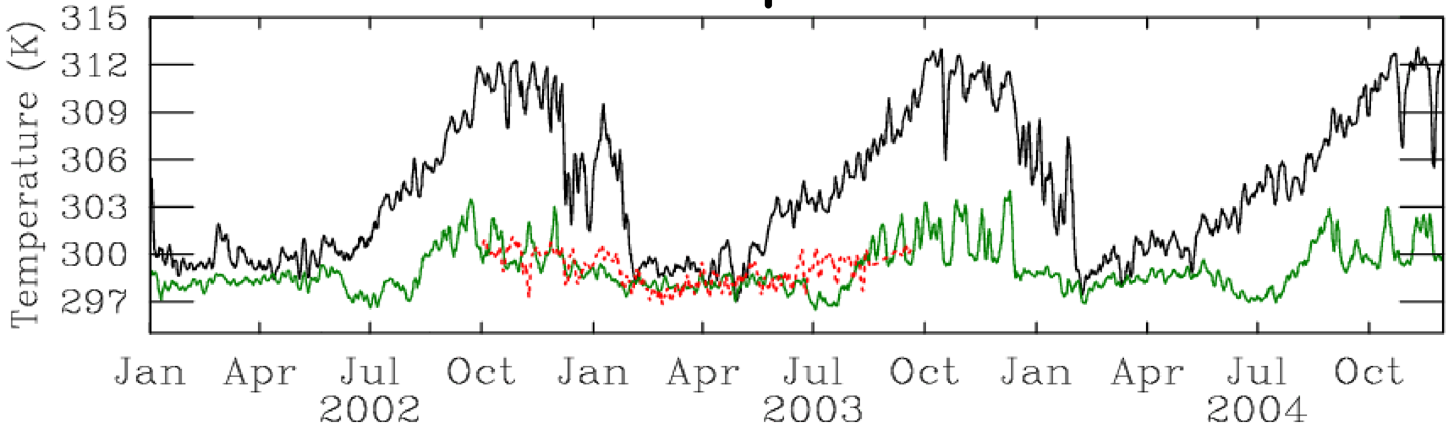


Using the ECOCLIMAP surface physiography data set the new RCA3 runs (RCAECO) show much better agreement of near-surface temperature with the CEOP observations over South America.

Manaus: Screen temperature

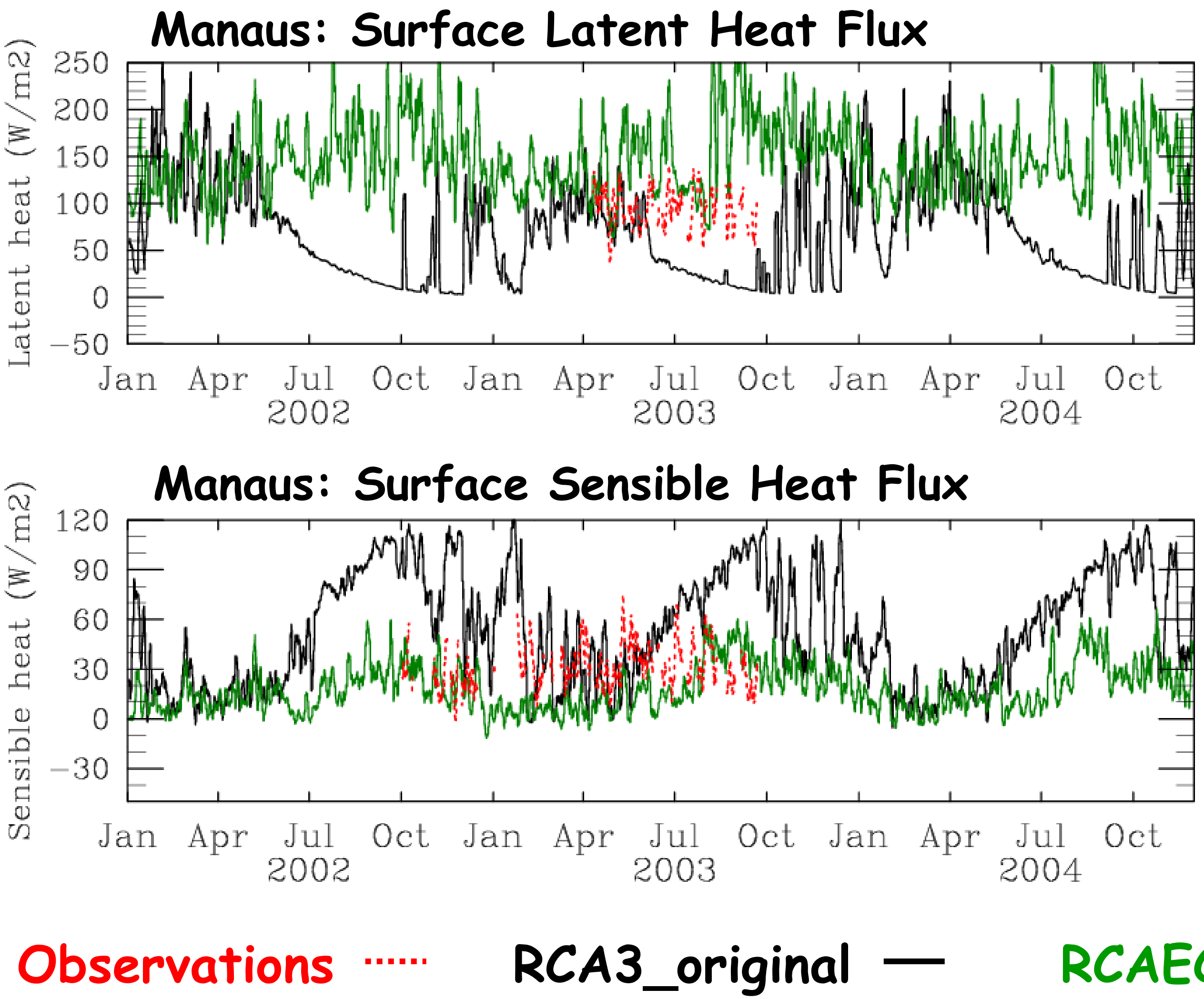


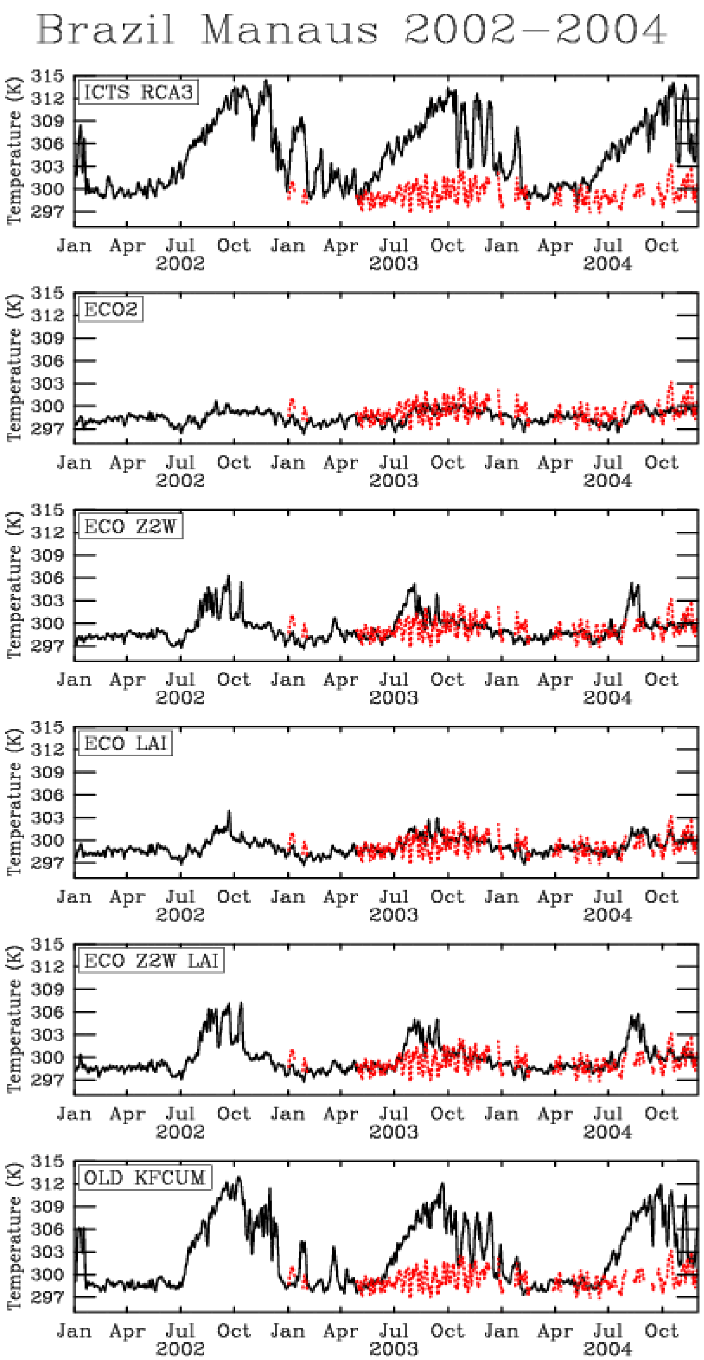
Sanatrem: Screen temperature



CEOP Observations ...... RCA3_original — RCAECO —

In RCA3ECO surface evaporation is maintained throughout the dry season, with a marked reduction in the surface sensible flux. Net surface radiation is now mainly balanced by evaporative cooling rather than surface warming leading to a 12°C cooling relative to RCA3.

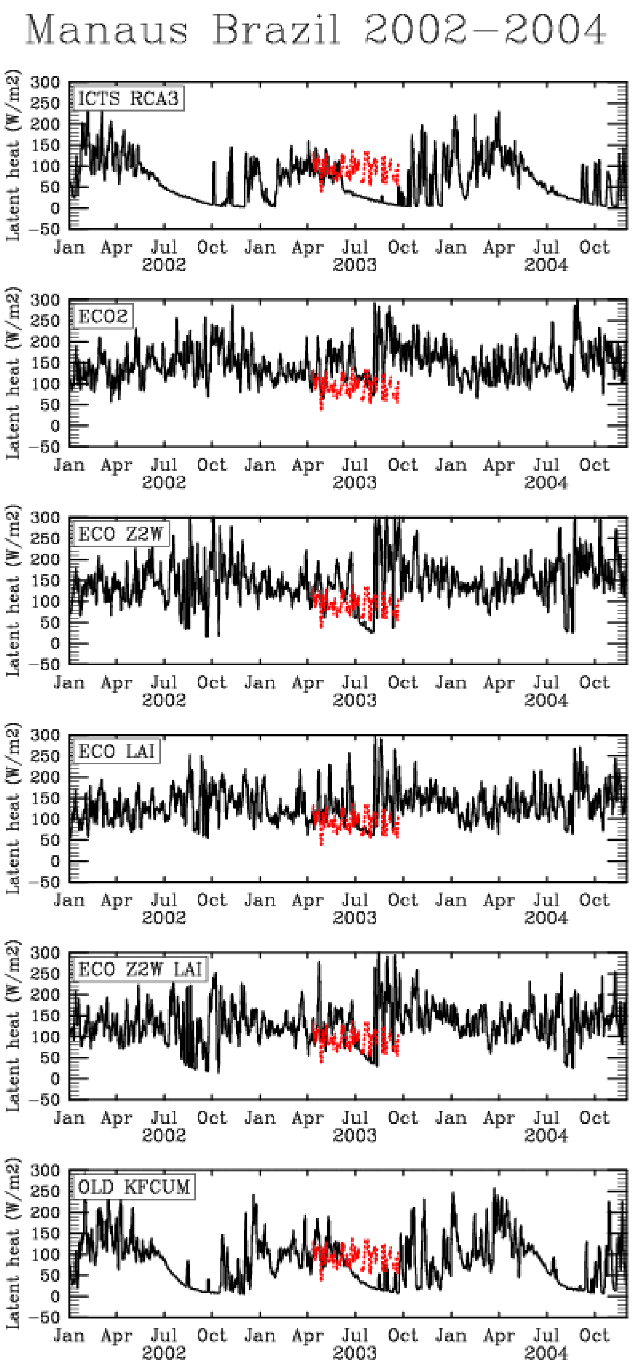




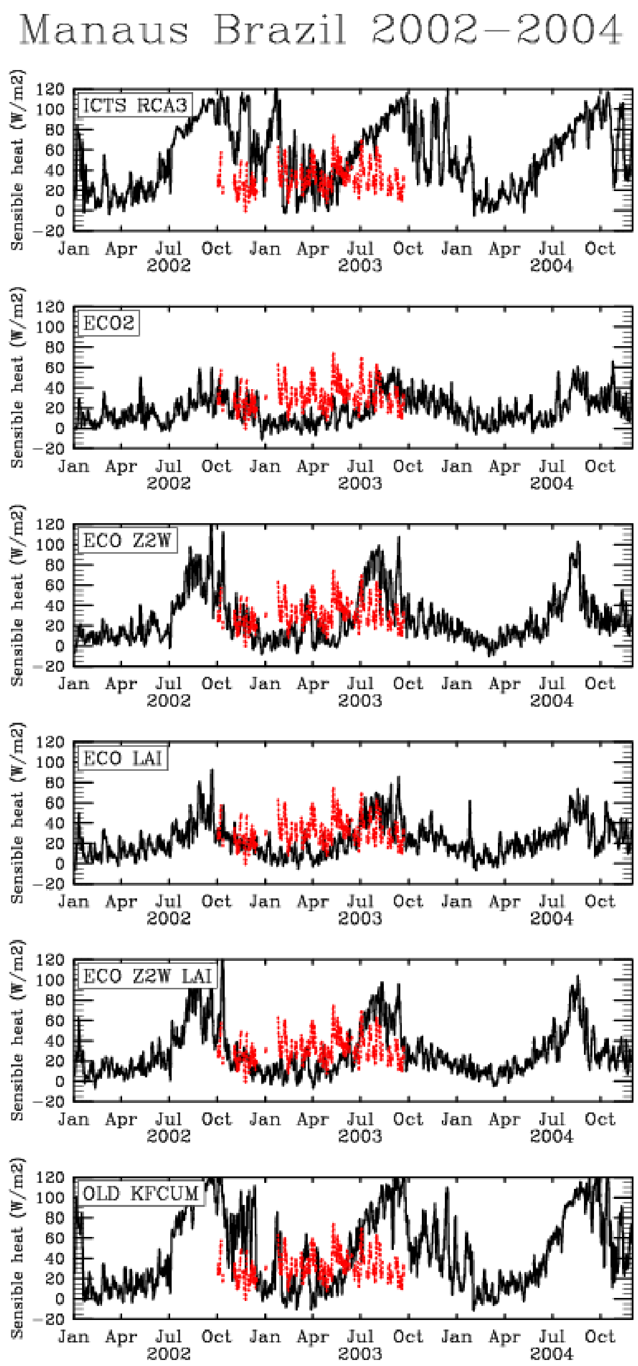
To determine which physiographic variables were important in reducing the surface temperature bias in RCAECO, extra RCA runs were made with the original LAI and Z2W (rooting depth) values separately reset to the original values. A further run was also made with **both** LAI and Z2W set to the original RCA3 values.

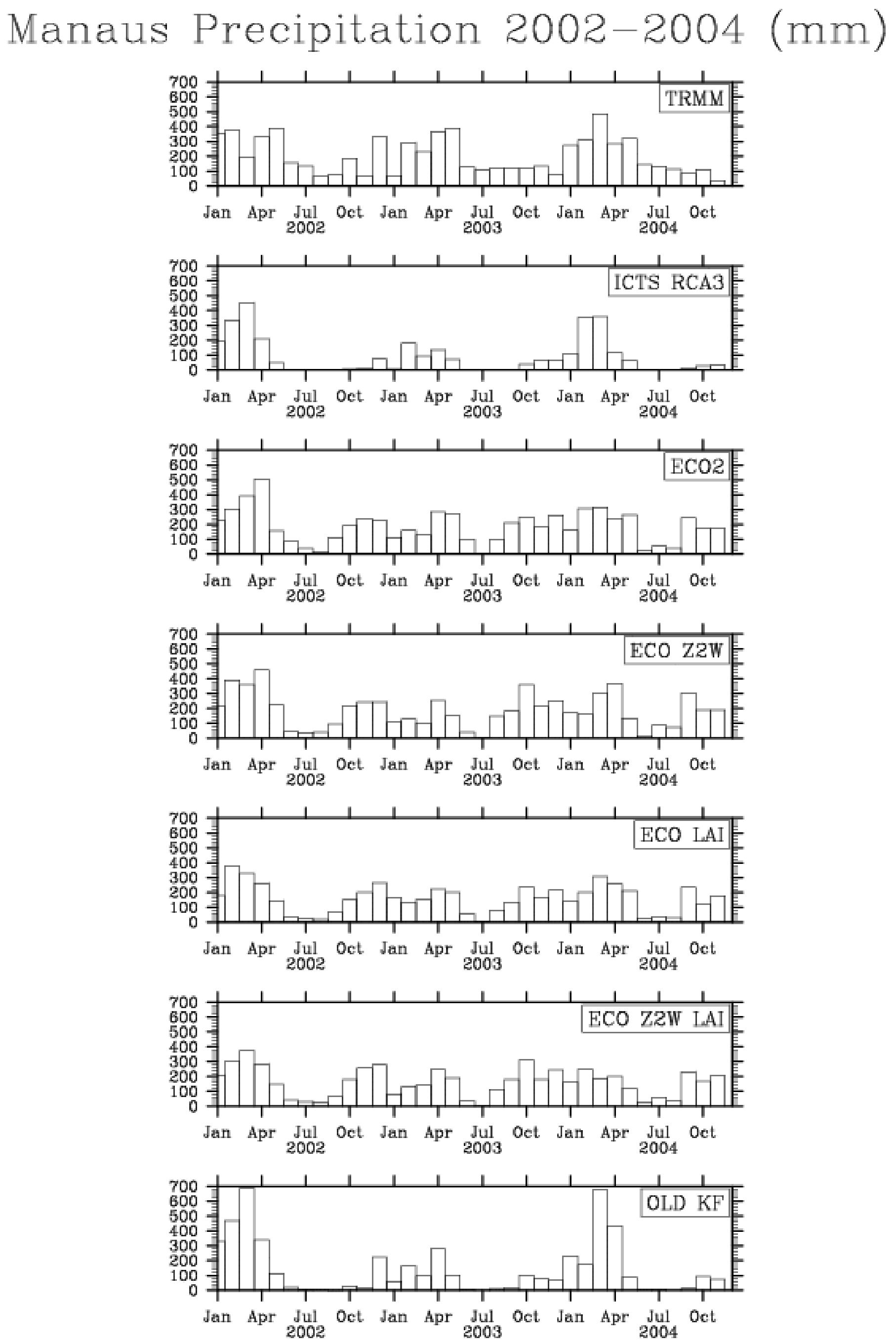
The warm bias in the modified ECOCLIMAP runs only partially returned to the original RCA3 warm bias (e.g. ECO_Z2W_LAI)

Modifications to the convection scheme had also been made between RCA3 and RCAECO. On going back to the original convection along with the LAI and Z2W values the original warm bias is largely retrieved.



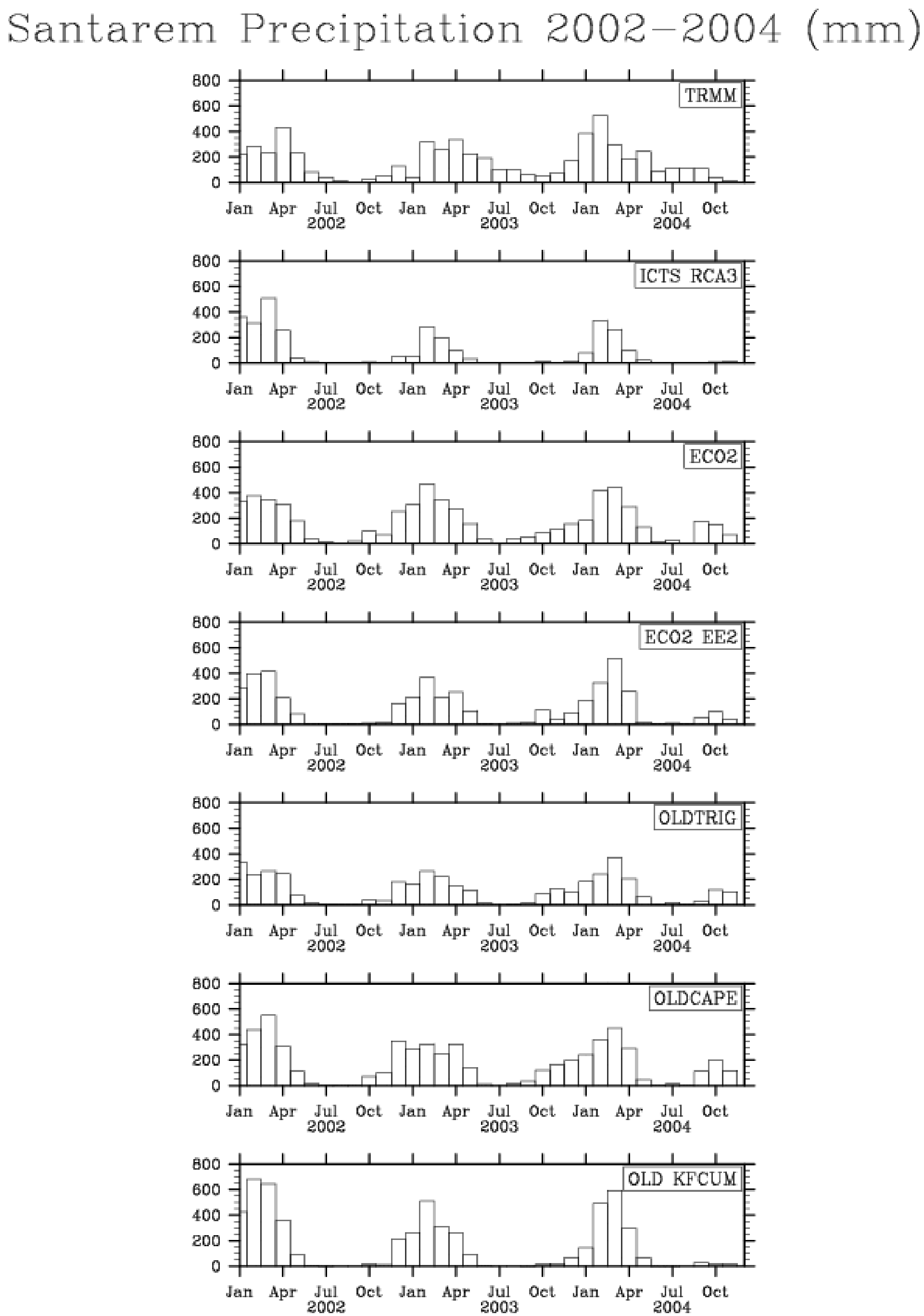
The combined impact of the convection and surface terms are confirmed when looking at the surface flux variables.





Combined with, and forcing, the reduction in surface evaporation (latent flux) is a marked reduction in precipitation in the dry season (to zero in the original ICTS RCA3 runs)

A weak rainfall rate during the dry season appears important for maintaining surface evaporation and thus constraining surface warming.



ECO2 run illustrates the full ECOCLIMAP + new convection runs of RCA3 compared to the original ICTS RCA3 runs at Santarem

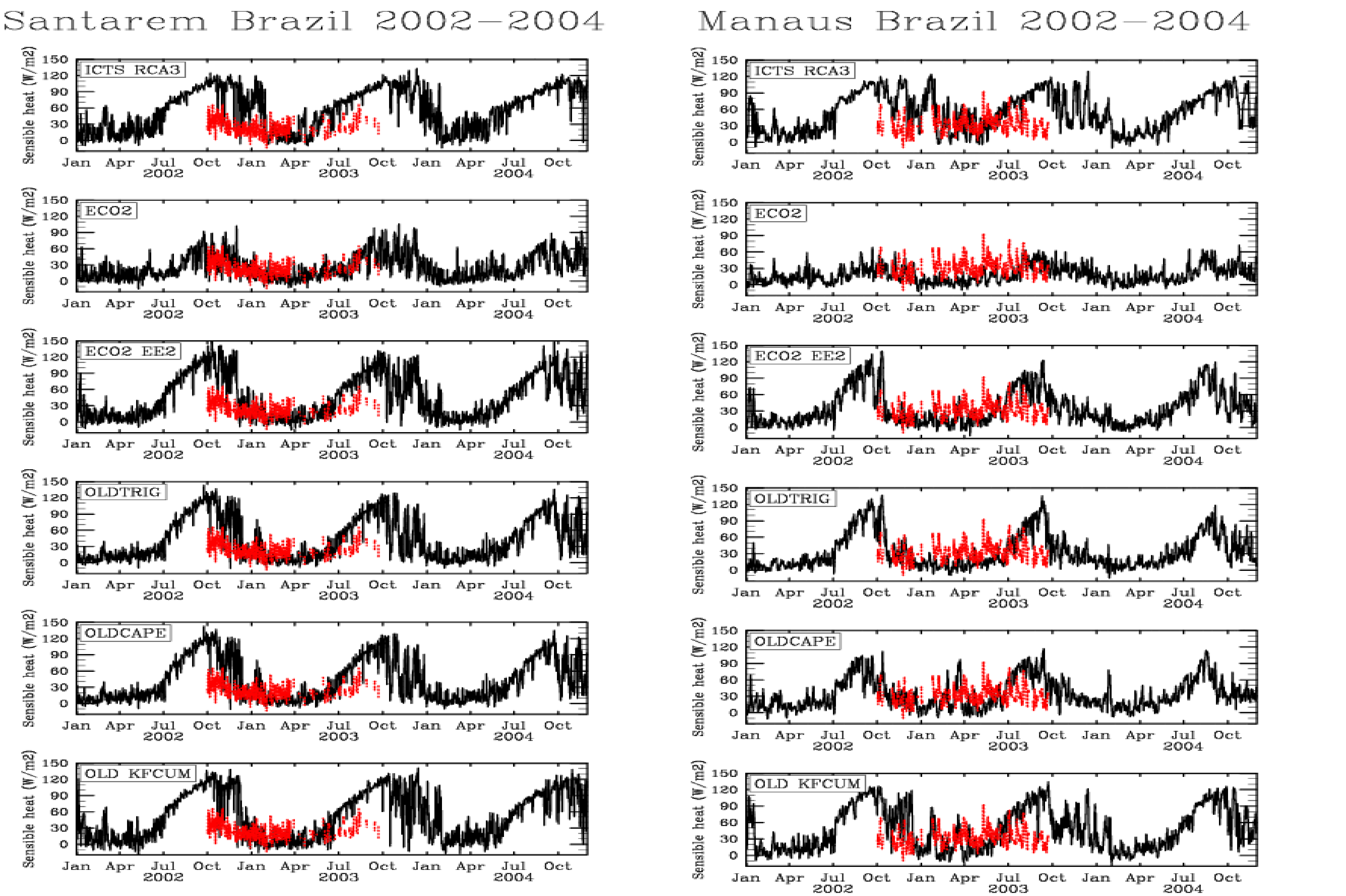
3 convection changes were each individually set back to the original RCA3 values to determine which change was important in maintaining precipitation during the dry season.

EE2: Entrainment rate increased for relatively dry environments.

OLDTRIG: New trigger function set back to original, based solely on temperature perturbations at LCL

OLDCAPE: New CAPE calculation for an dilute updraft set back to original undilute CAPE profile for The KF CAPE closure

Each convection change plays a role in maintaining dry season rainfall constraining the surface fluxes & temperatures at Manaus & Sanatrem



Summary of ICTS analysis.

CEOP observations, particularly of surface turbulent fluxes, combined with TRMM precipitation observations proved extremely useful in understanding and improving a large bias in the Rossby Centre Regional Climate Model over S. America.

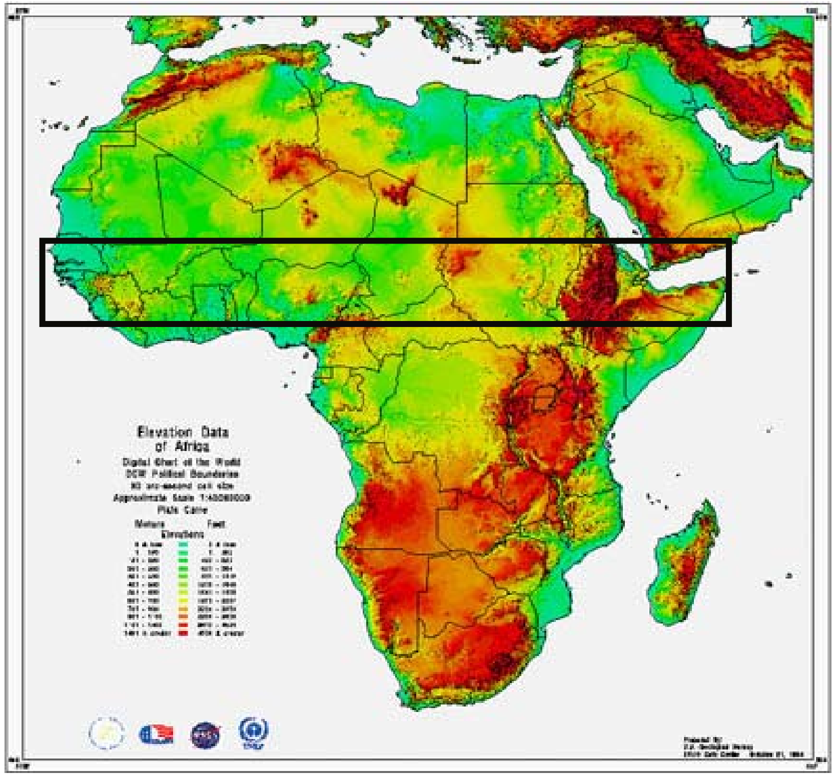
Surface turbulent fluxes in subtropical dry seasons are very sensitive to the representation of surface physiography and the maintenance of weak convective precipitation.

Using a thin upper soil layer, surface temperature is very sensitive to errors in the surface water and energy balance. But a thin, top soil layer may be required to simulate the diurnal cycle accurately.

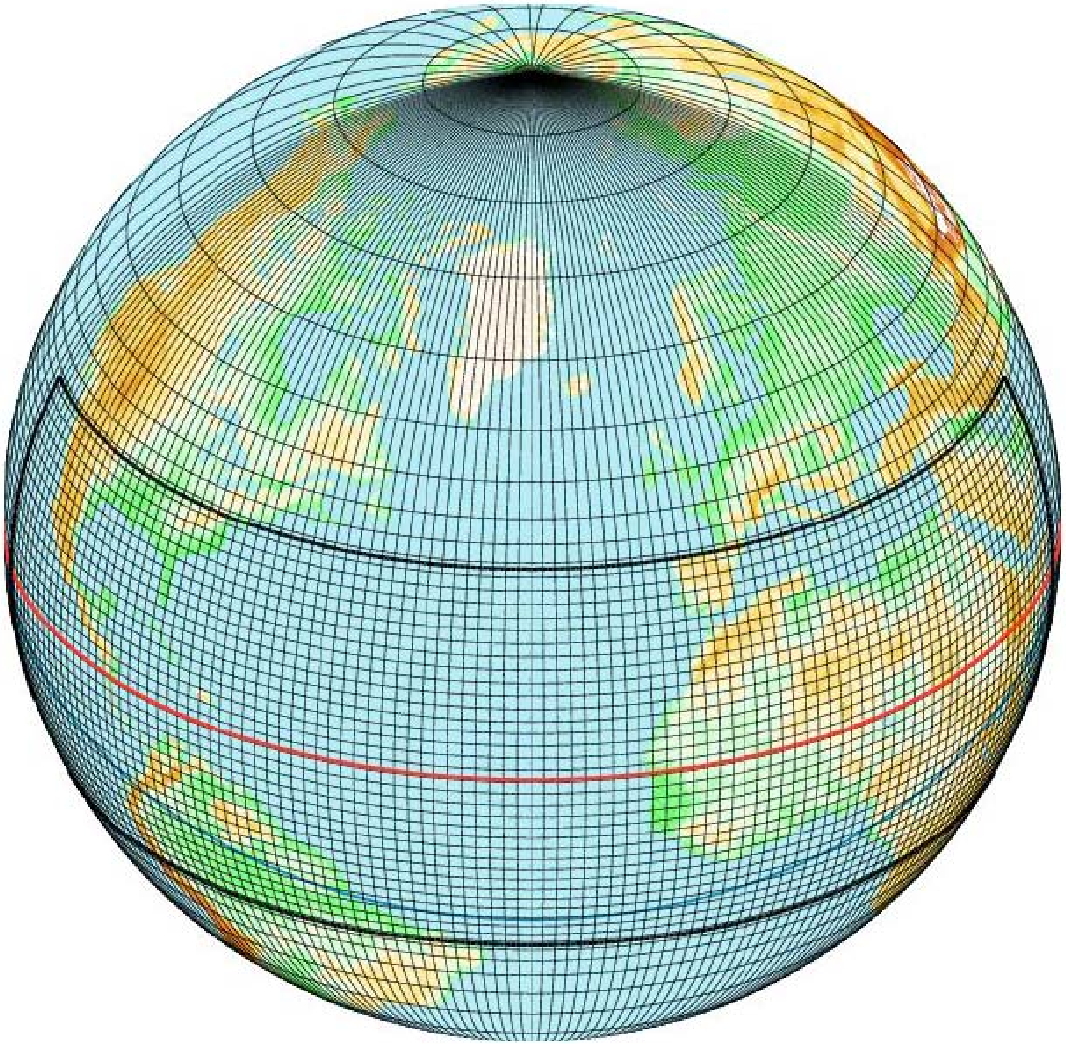
We are presently evaluating the RCAECO configuration on the other ICTS domains: Some improvements, no degradation yet !

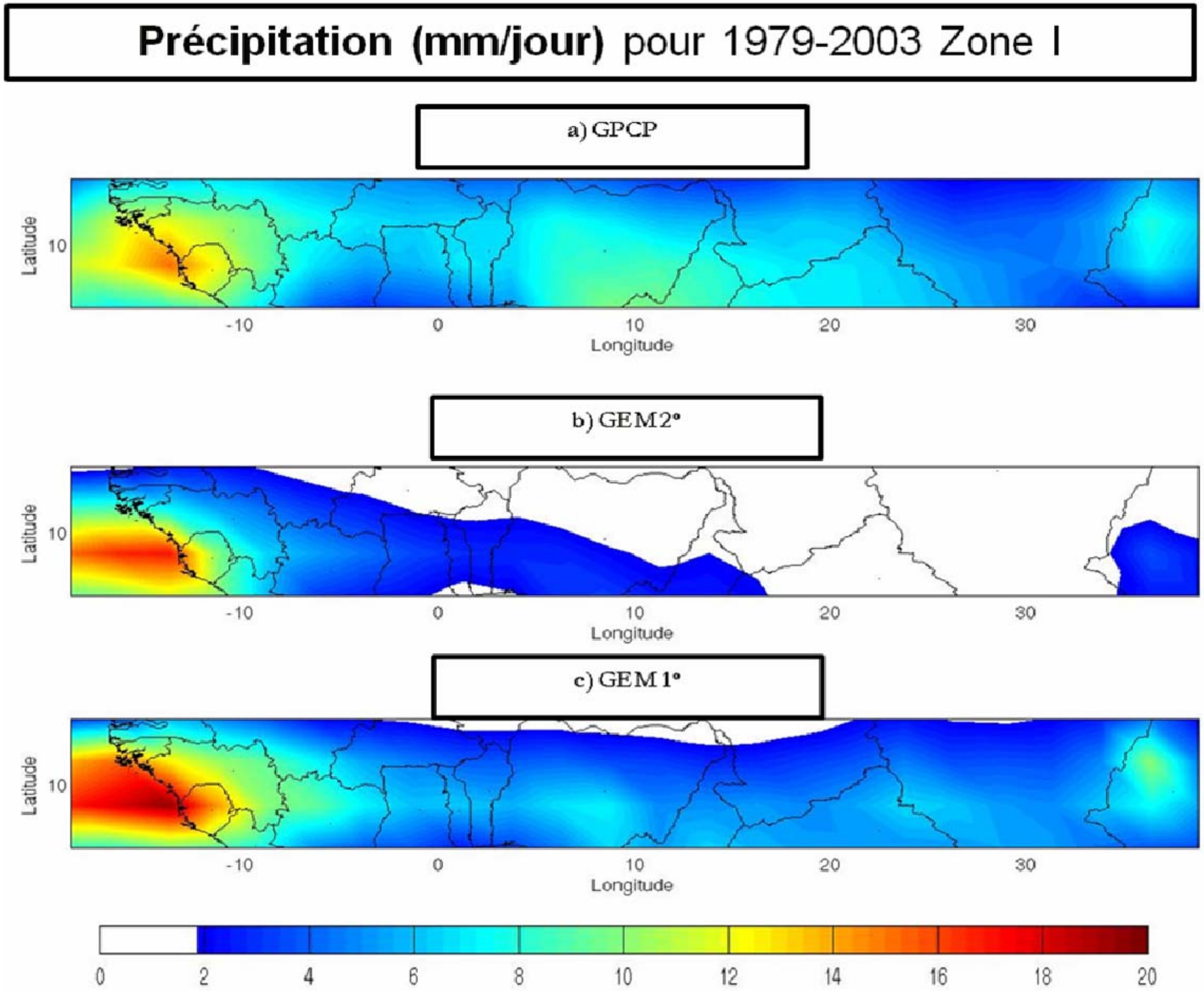
The sensitivity of African precipitation to model resolution

Studies using the Canadian Global Environmental Multiscale Model (GEM), run in Global regular mode at 2° and 1° resolution and in Global variable resolution mode, with an outer global resolution of 2° and an inner high-resolution region over Africa of 0.33°

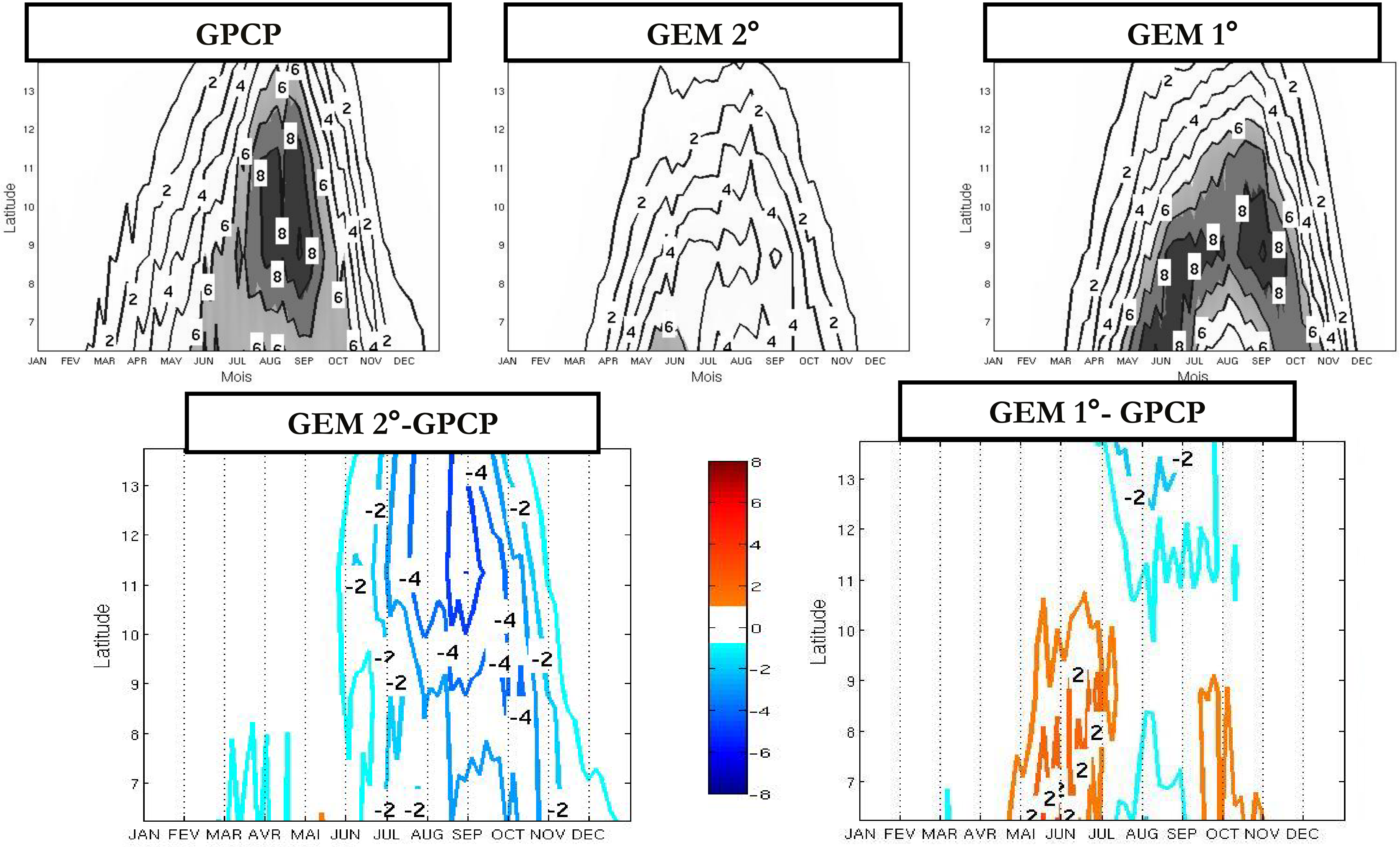


GEM variable resolution: 2° global resolution 0.33° over North Africa & the tropical Atlantic.



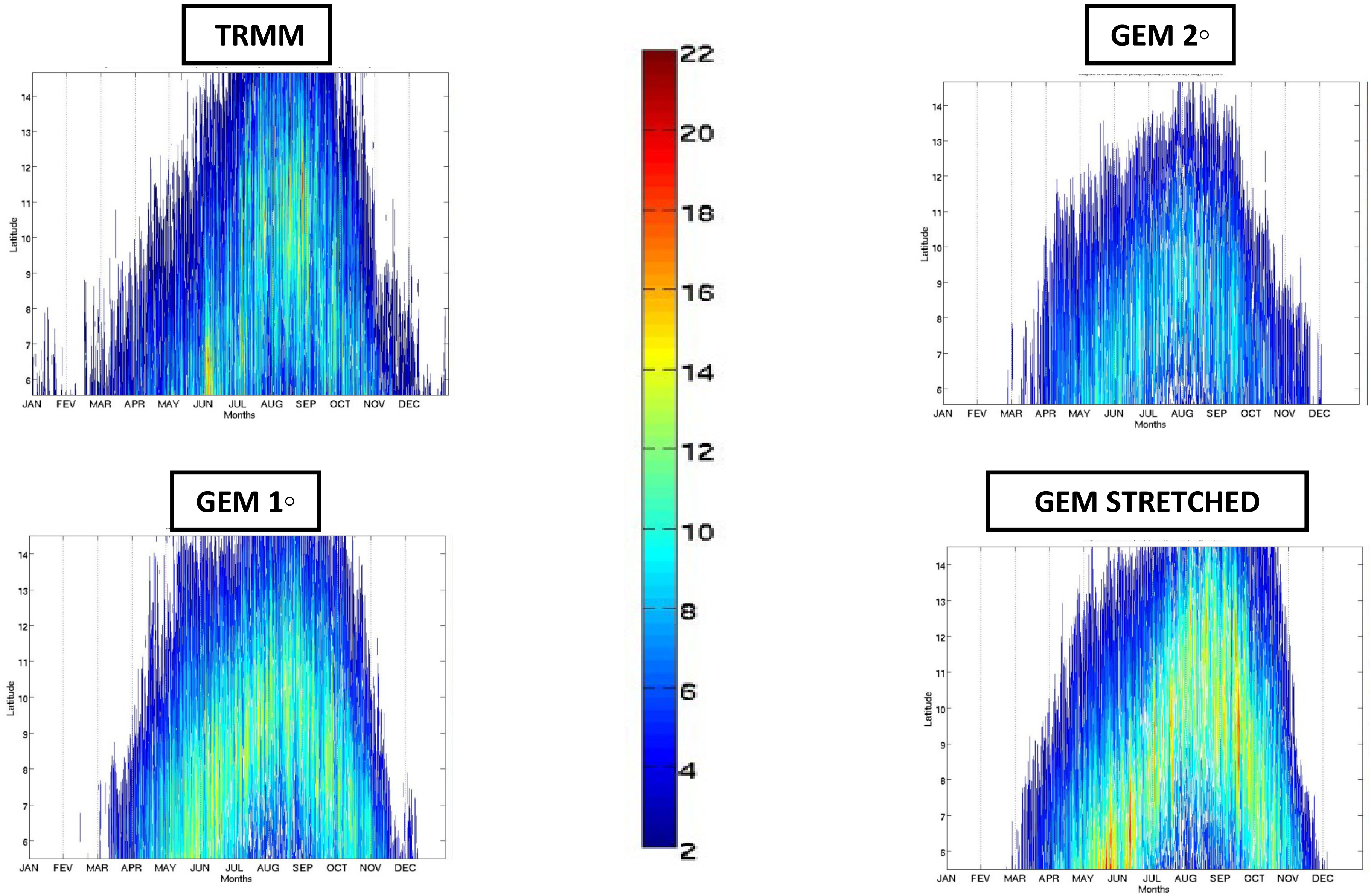

Précipitation (mm/jour) pour 1979-2003 Zone I
a) GPCP
b) GEM2°
c) GEM1°
Latitude
Longitude
10
-10
0
10
20
30
0
2
4
6
8
10
12
14
16
18
20

Mean Annual Cycle of precipitation averaged across the African ITCZ as a function of latitude.



Time-Latitude Diagrams 1998-2003 (Zone I)

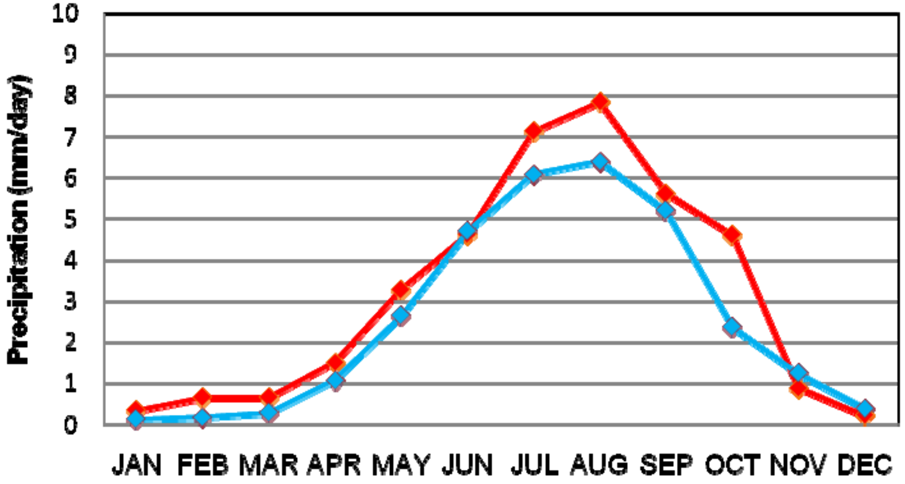
Precipitation (mm/day)



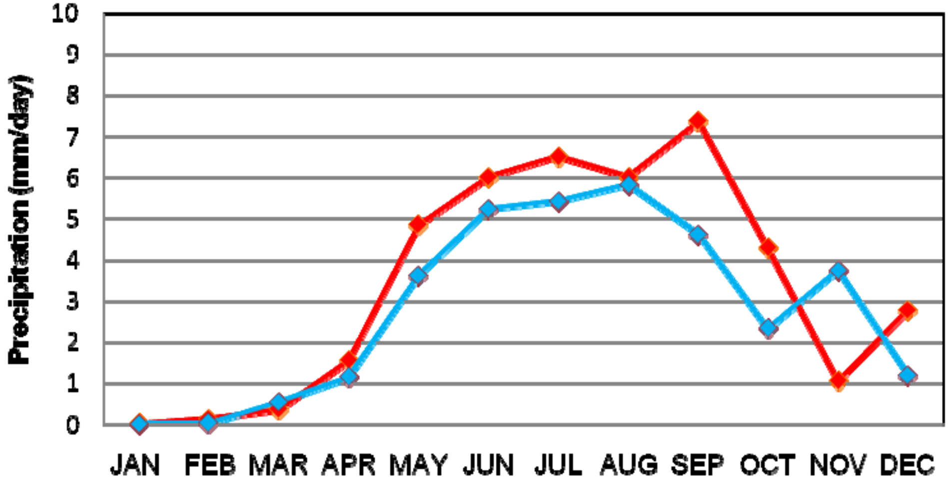
Spatially Averaged Annual Cycle of precipitation (Zone I)

1999 = Wet Year and 2001 = Dry Year **Precipitation (mm/day)**

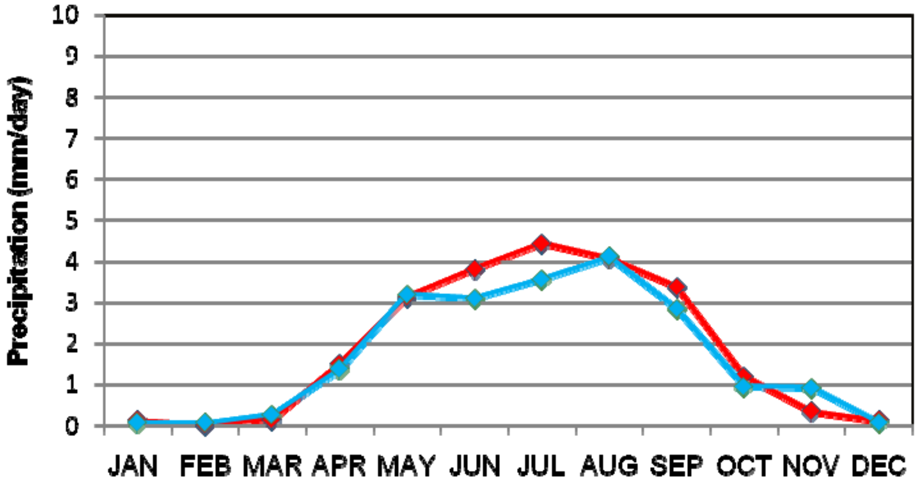
TRMM



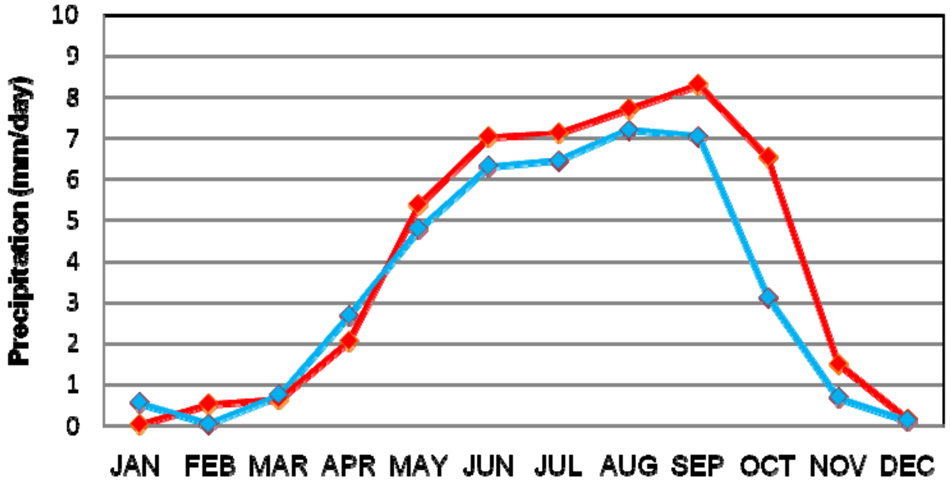
GEM 1◦



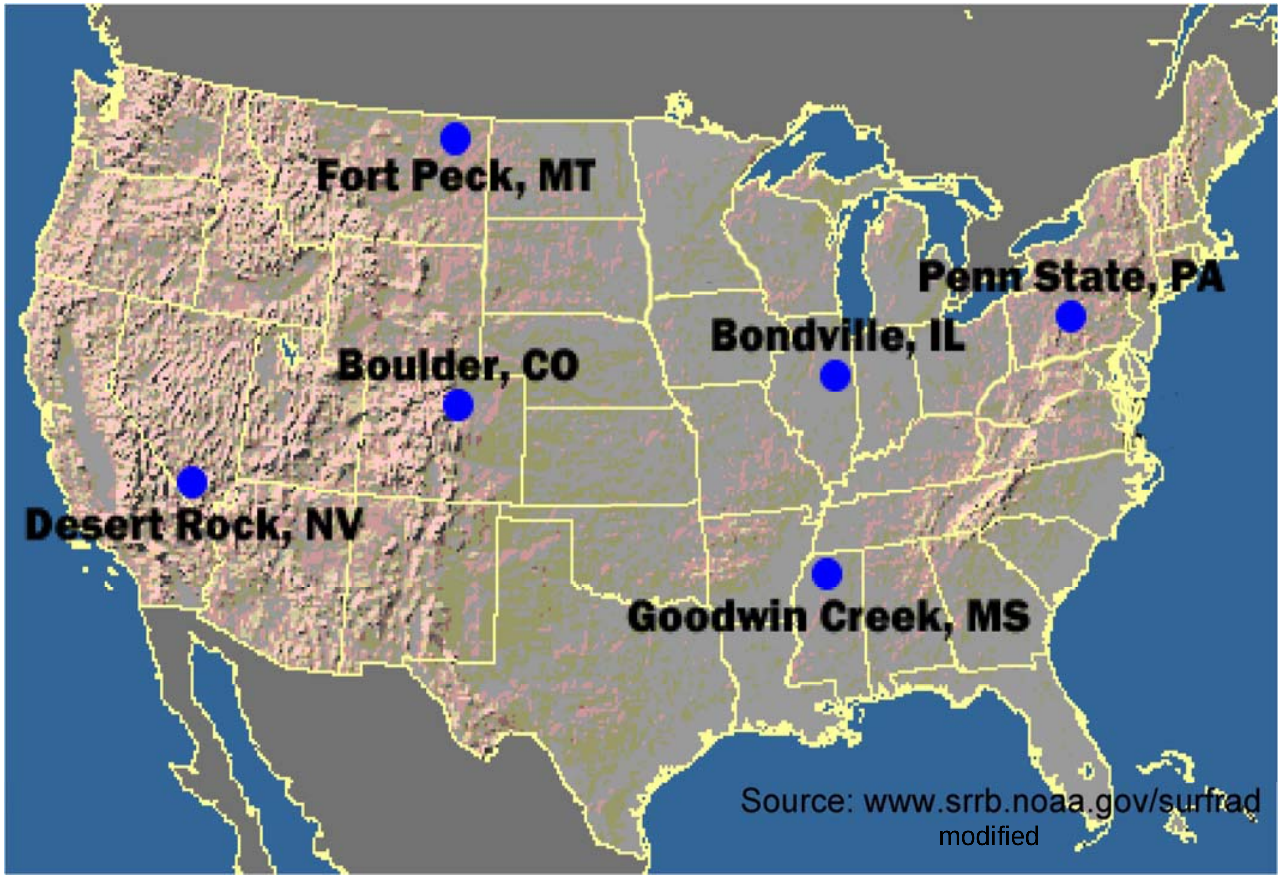
GEM 2◦



GEM STRECHED



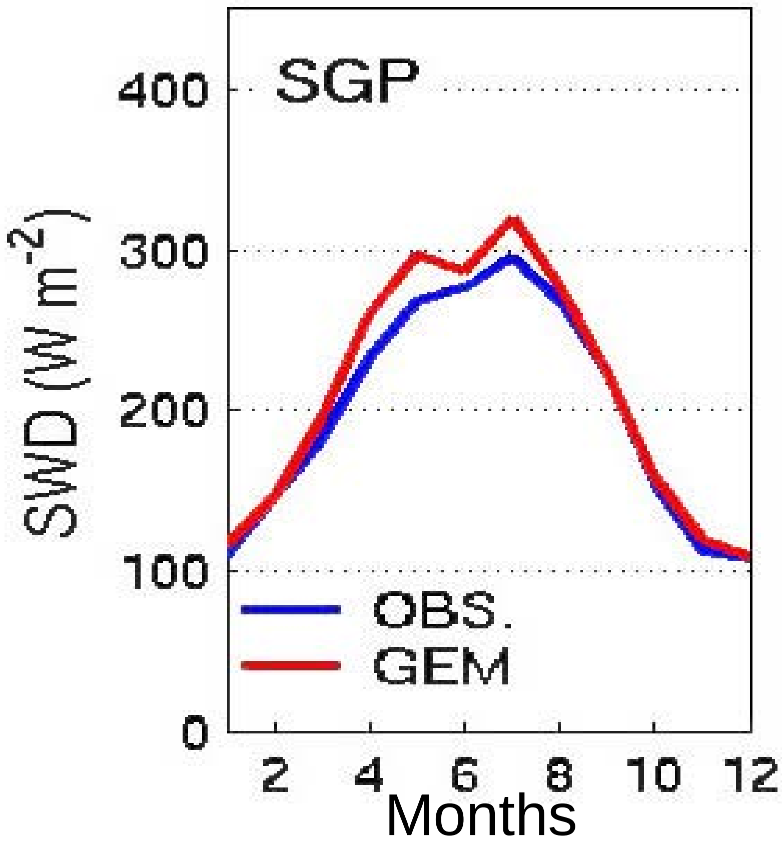
Understanding and evaluating cloud-radiation errors in RCMs

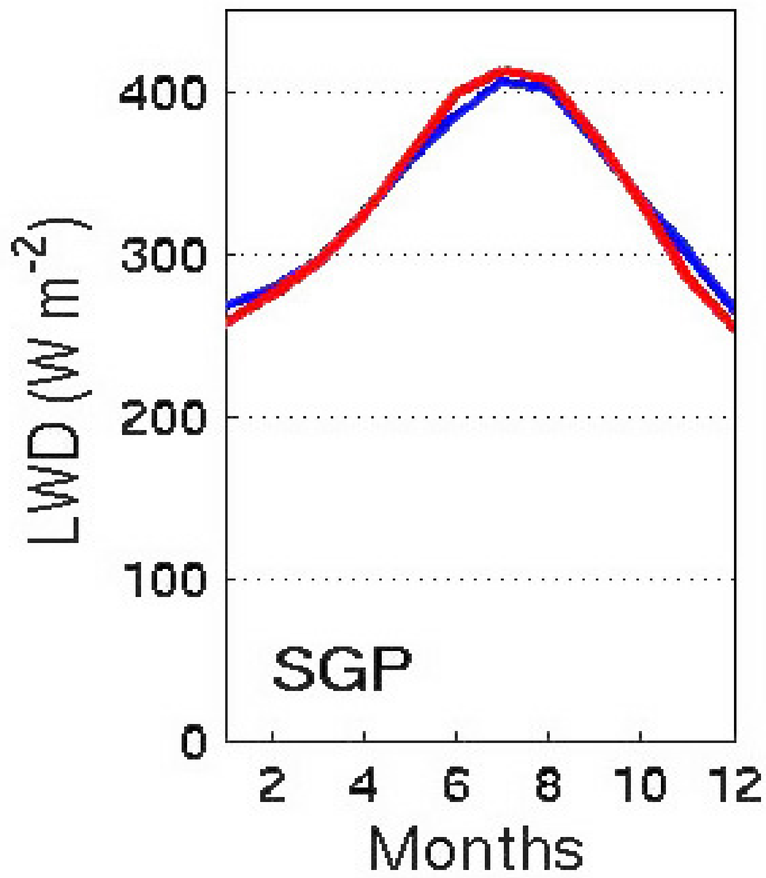


With suitable averaging (point) surface observations (e.g. of clouds and radiation) can be used in RCM evaluation

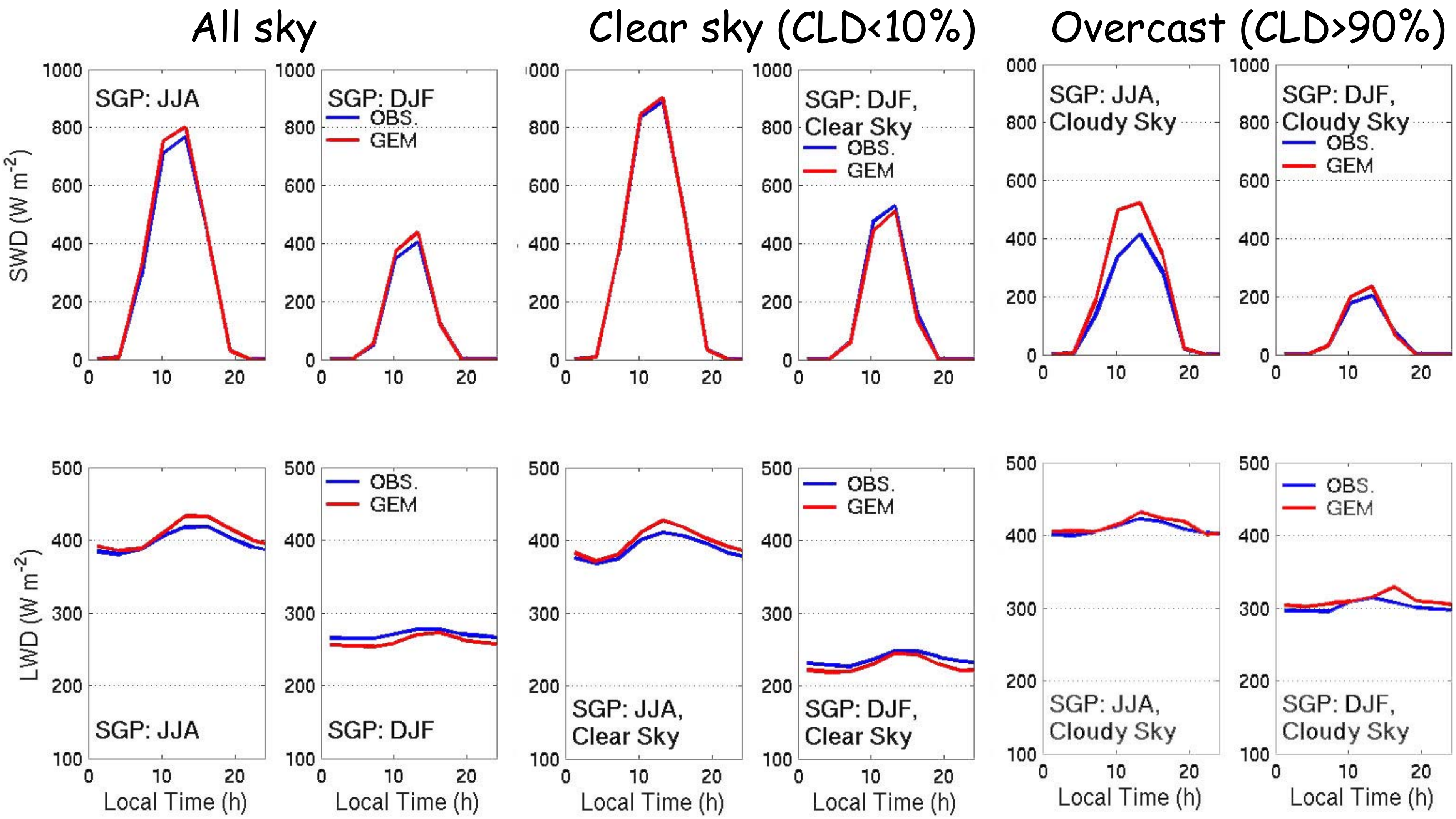
Annual Cycle of surface shortwave (SWD) and longwave (LWD) radiation at the ARM SGP site in Oklahoma (1996-2002):

Observed and simulated by the GEM-LAM forced by ERA40

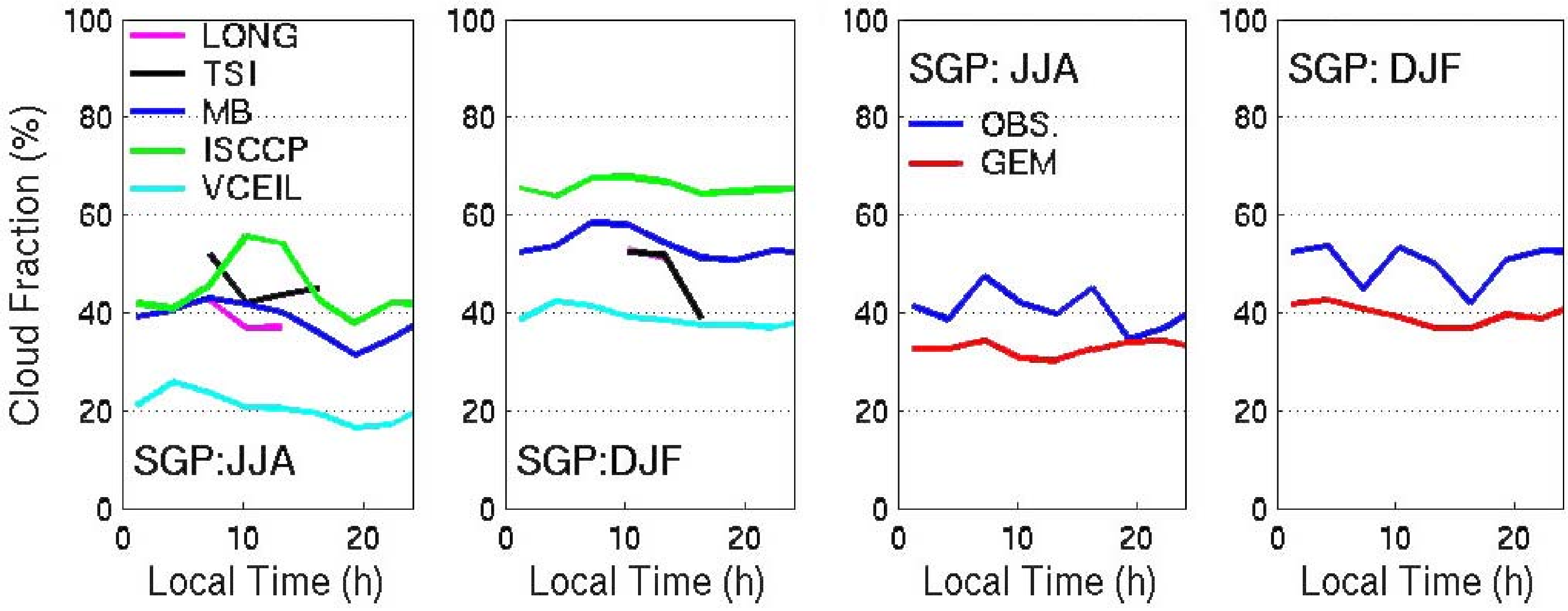




Separating model and observations into clear sky and overcast conditions helps in evaluating the individual components of the simulated cloud-radiation

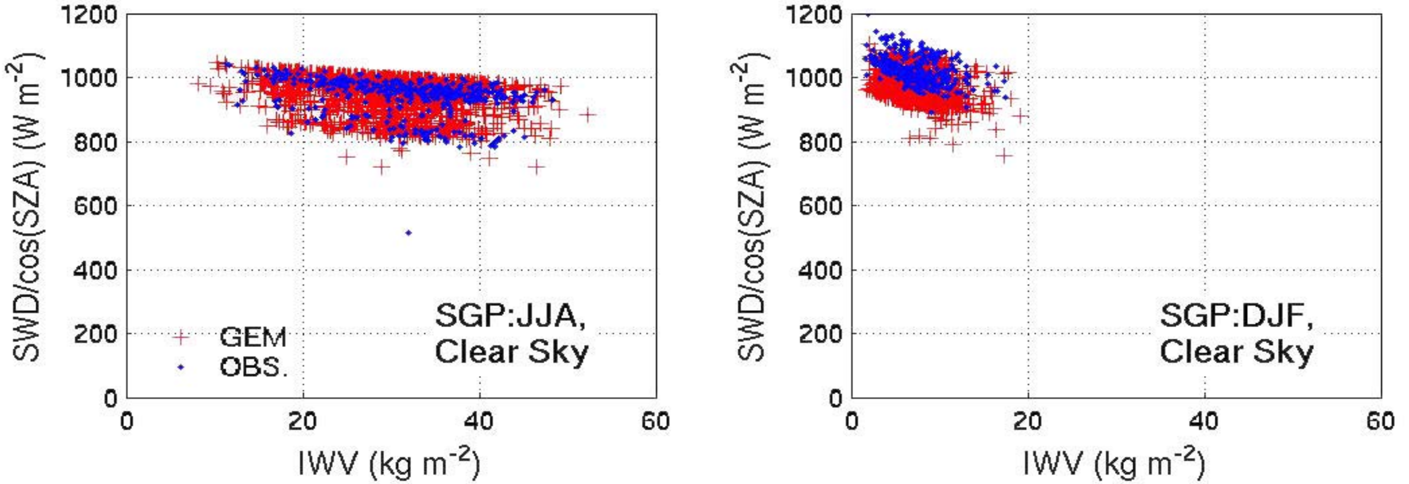


Cloud Fraction, while difficult to observe accurately, plays a key role in determining surface radiation errors

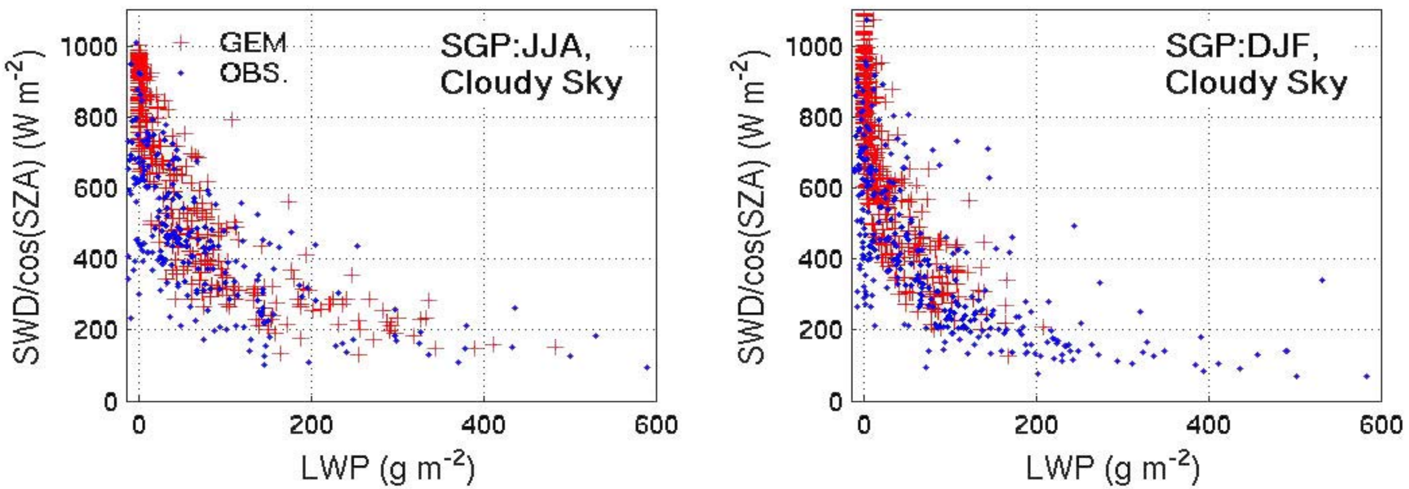


Separation into clear and overcast conditions allows an analysis of the covariability of terms controlling the surface radiation fluxes

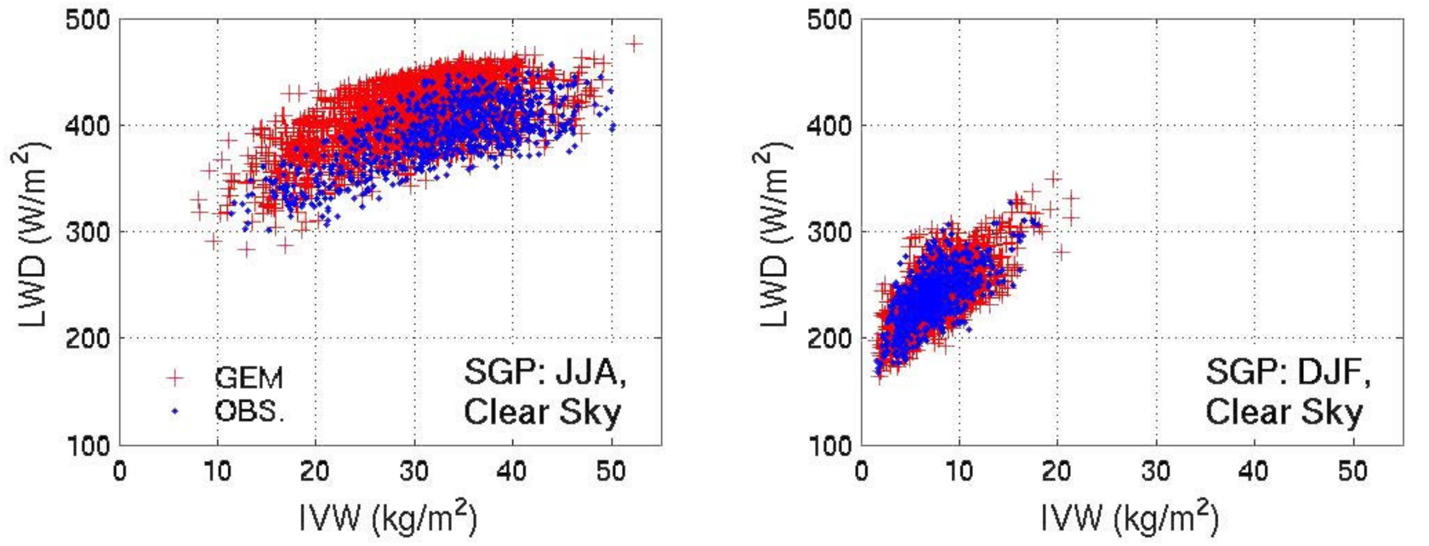
Clear-sky Solar Radiation flux against Integrated Water Vapour



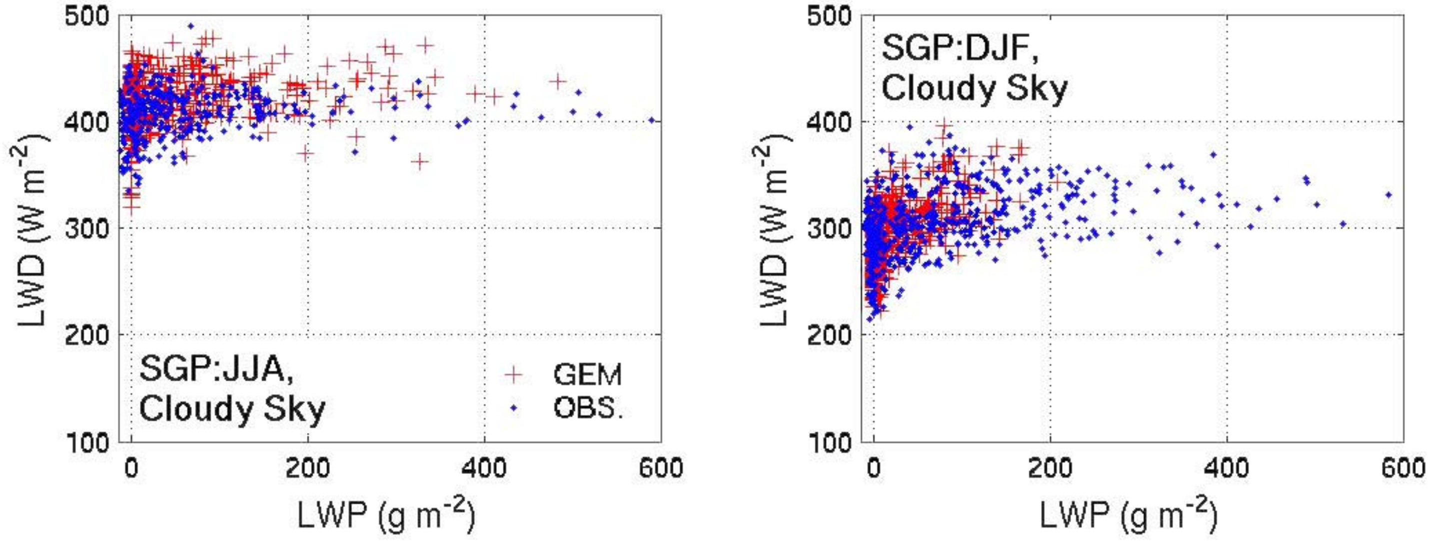
Cloudy-sky Solar Radiation flux against Liquid Water Path



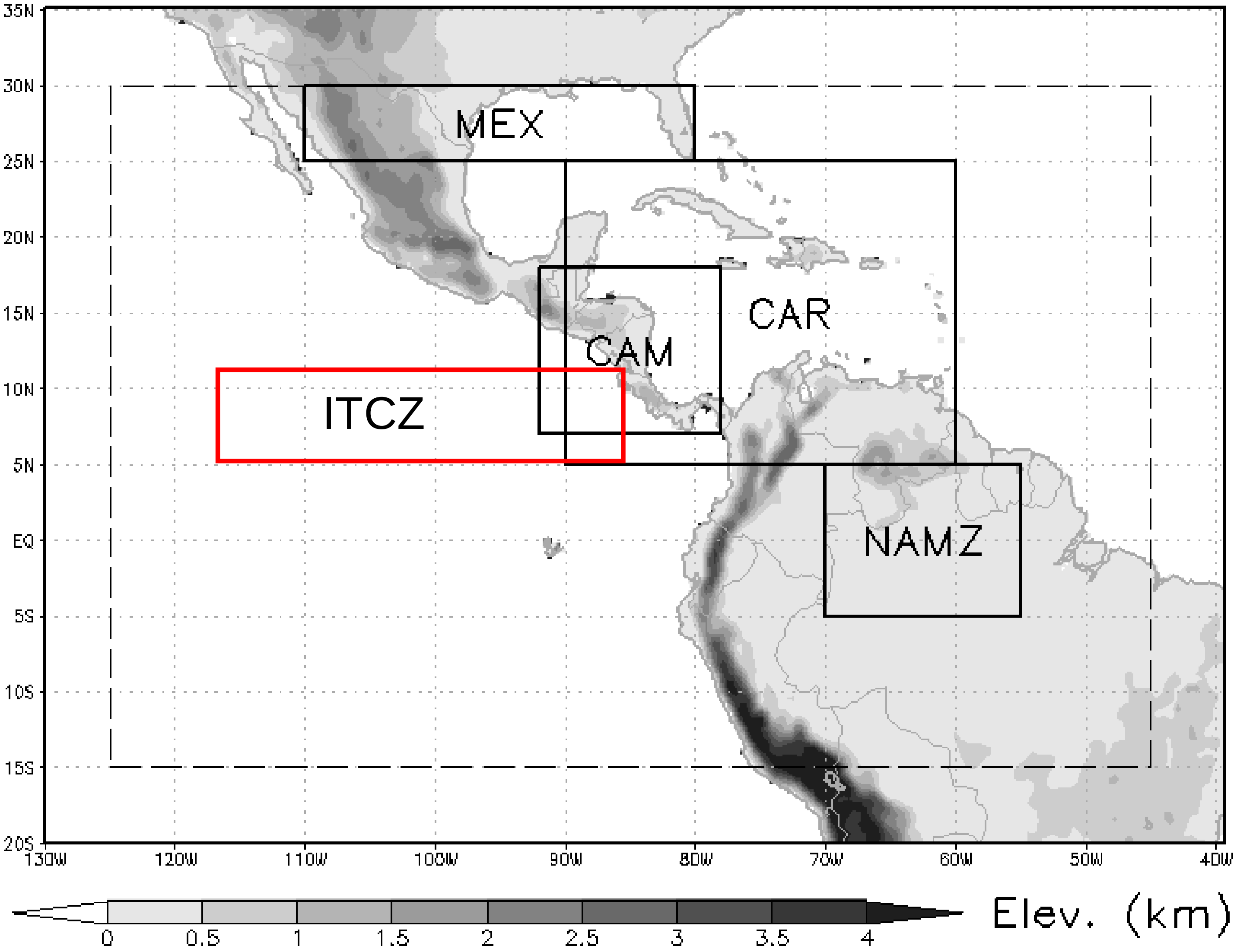
Clear-sky longwave radiation flux against Integrated Water Vapour



Cloudy-sky longwave radiation flux against Liquid Water Path

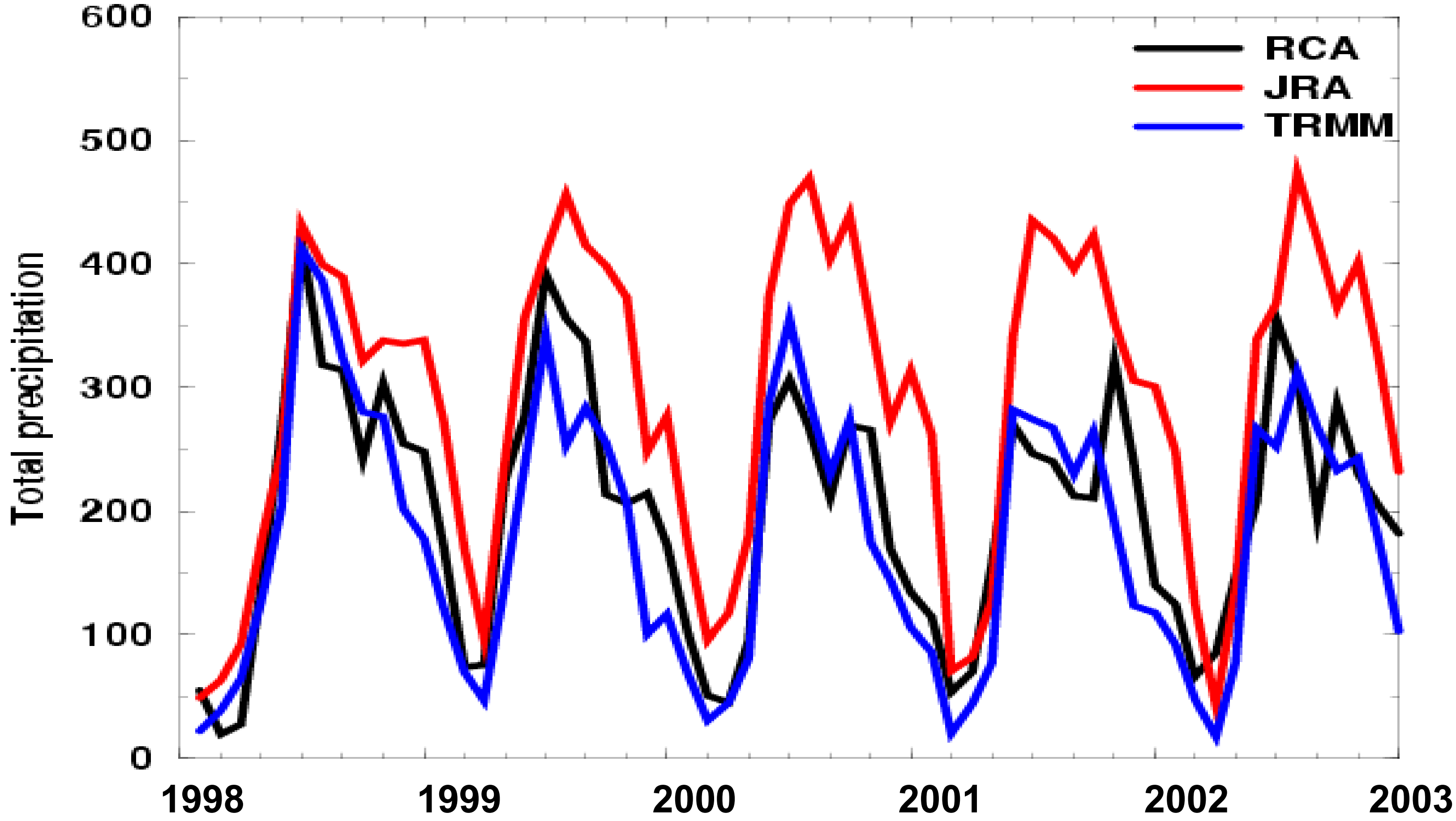


Using RCMs to simulate convection over the East Pacific and South America : RCA at 0.3°with ERA40 LBCs

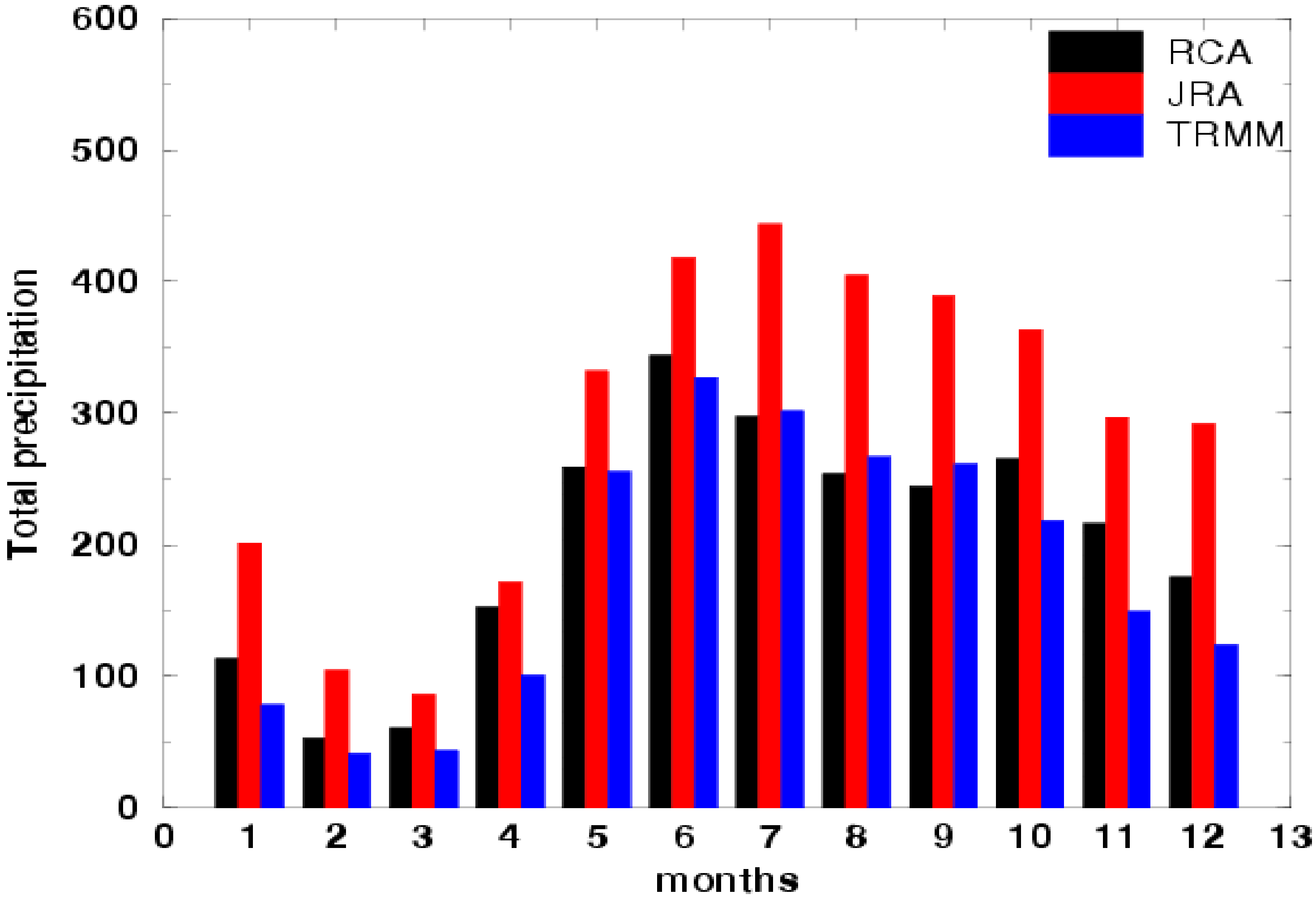


RCMs sometimes improve on reanalysis products in data sparse regions, when run at high-resolution forced by analysed LBCs

RCA-Simulated, Japanese Reanalysis and TRMM observed monthly mean rainfall averaged over the East Pacific ITCZ

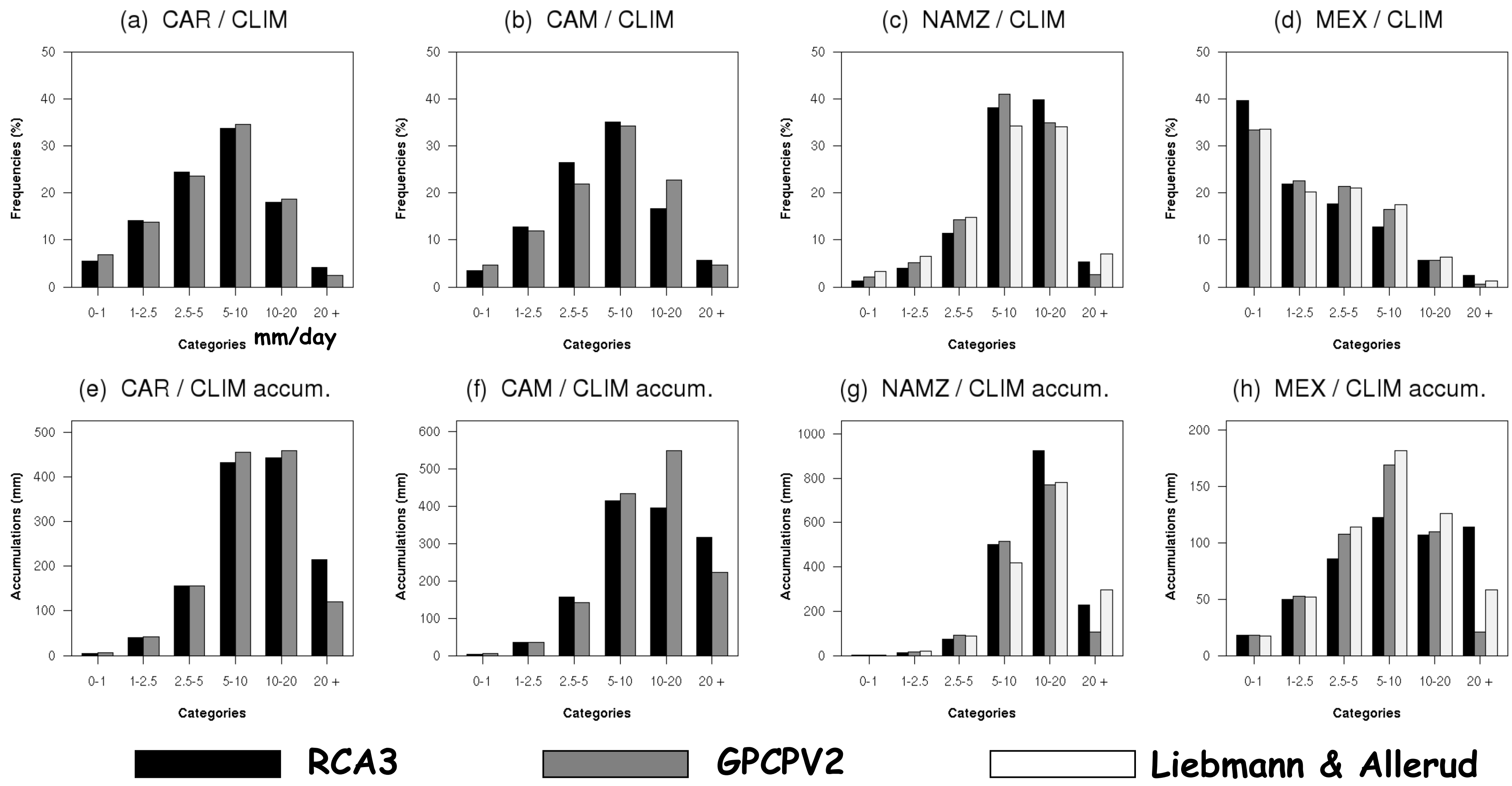


Mean Annual Cycle of precipitation averaged over the East Pacific ITCZ (1998-2003)



(a-d) Normalized intensity distribution for pentad rainfall in mm/day (1979-2005) for 4 regions of central/south America

(e-h) Contribution of each pentad-mean intensity bin to the total precipitation in each spatially meaned region (1979-2005)

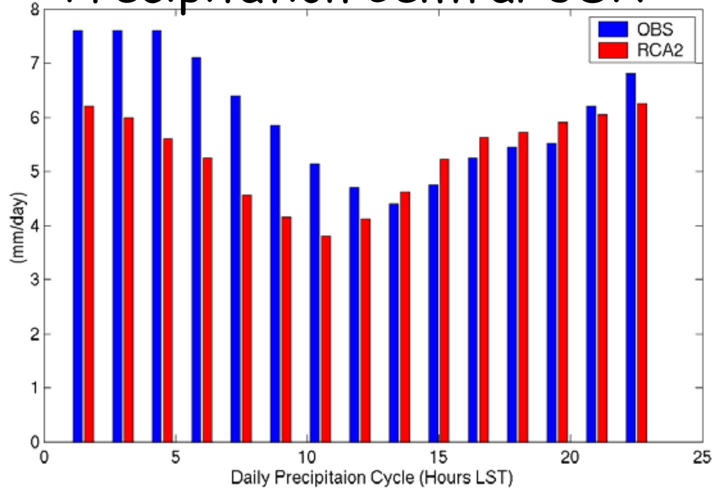


RCMs allow an indepth evaluation of key interacting parameterisation schemes required to accurately simulate important regional processes:

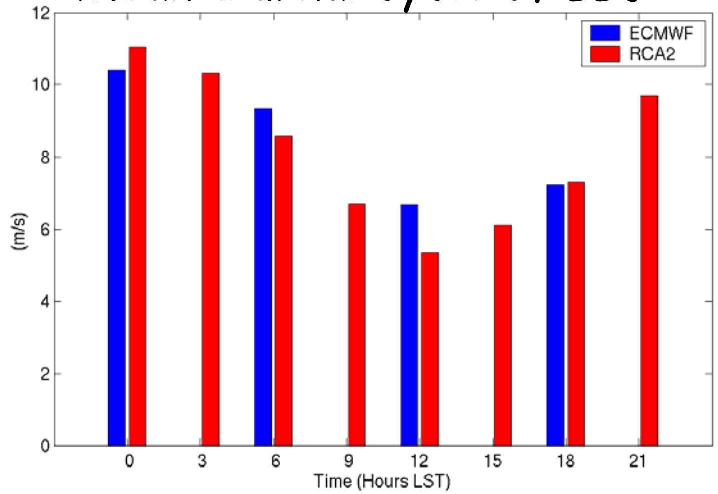
The Low Level Jet (LLJ) and the diurnal cycle of precipitation in the Central United States

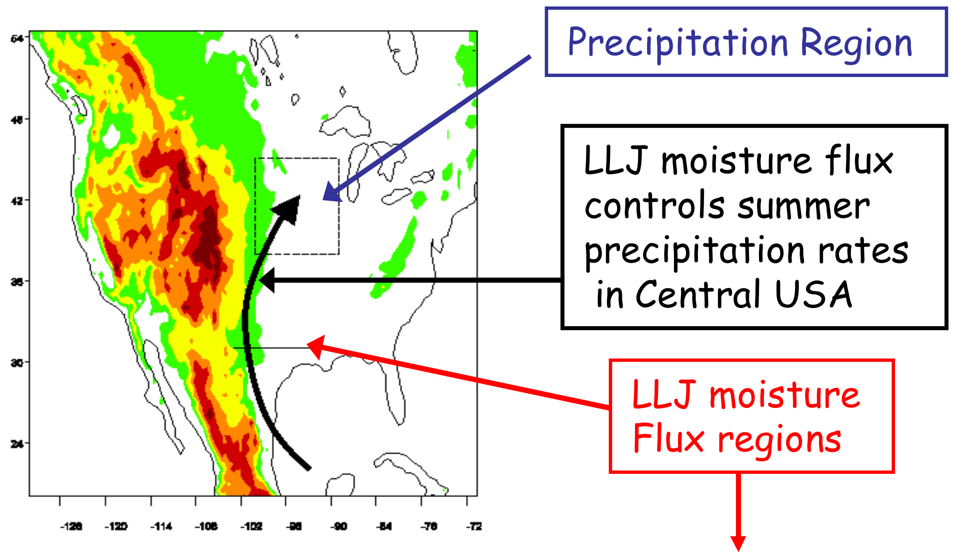
Seasonal & Diurnal Precipitation Variability over North America

Mean diurnal cycle of Precipitation Central USA



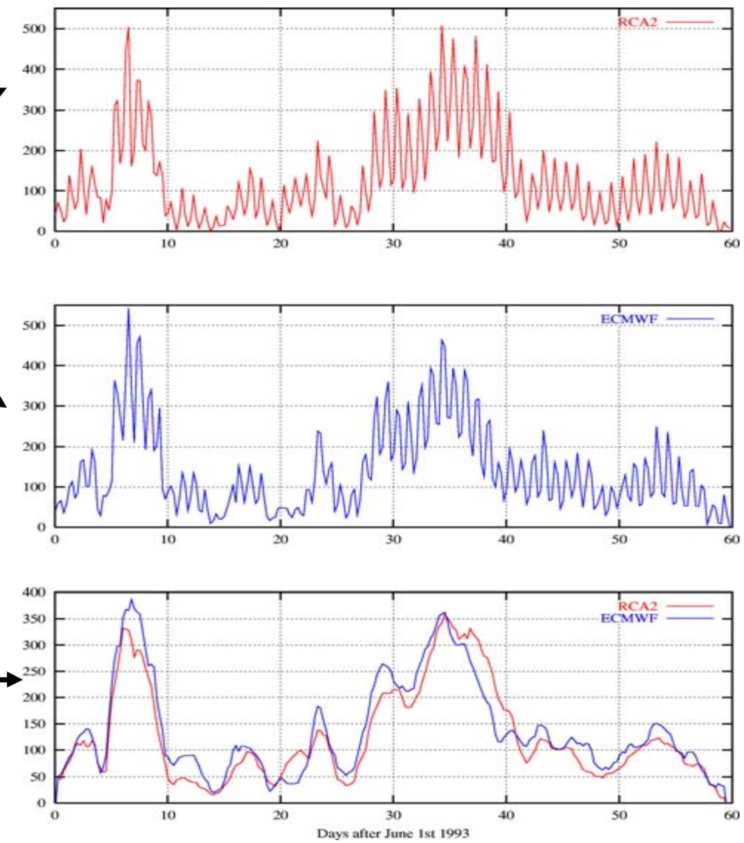
Mean diurnal cycle of LLJ





$$6hr \int_{sfc}^{1000m} v.qdz$$

$$1\ day\ mean \int_{sfc}^{1000m} v.qdz$$



Summary

RCMs can be used productively for developing and evaluating parameterization schemes at high resolution (10-100km)

To benefit most from this, it is important that the RCM performance is evaluated across a wide range of climate regimes.

It is important to evaluate RCM performance at the process level whenever possible

Increased resolution does appear beneficial in many instances. This does not come automatically but often requires effort with model physics/dynamics to fully realize the benefits.