RegCM V 4.7.0 : South East Asia Domain

Preliminary results on the Parameter Tuning and Calibration of RegCM4.7.0 with Tiedtke Cumulus parameterization over South East Asia Domain

Paolo Stocchi, Erika Coppola, Filippo Giorgi

Abdus Salam ICTP, Trieste (Italy)

Ninth RegCM Workshop, May-June 2018, ICTP

South East Asia: Introduction

- Southeast Asia has a **tropical maritime** climate featuring relatively high temperatures, high relative humidity, and abundant precipitation
- Affected by **extreme weather** events, particularly tropical cyclones, droughts and floods
- Much of the region is heavily influenced by **monsoon systems** which often bring extreme weather.
- It is also a region of the world which is expected to experience serious, **negative impacts** of **climate change** (extreme weather events are projected to increase in frequency and intensity) due to its fast growing and urbanising population, as well as the reliance of many of its people on climate-sensitive sectors such as agriculture, fisheries and natural resources

South East Asia: Introduction

S.E. Asia is annually affected by extreme weather events, particularly tropical cyclones, droughts and floods. Large areas of S.E. Asia are prone to flooding, and much of the region is heavily influenced by monsoon systems which often bring extreme weather. As the climate warms, these types of extreme weather events are projected to increase in frequency and intensity, threatening the lives and livelihoods of millions of people

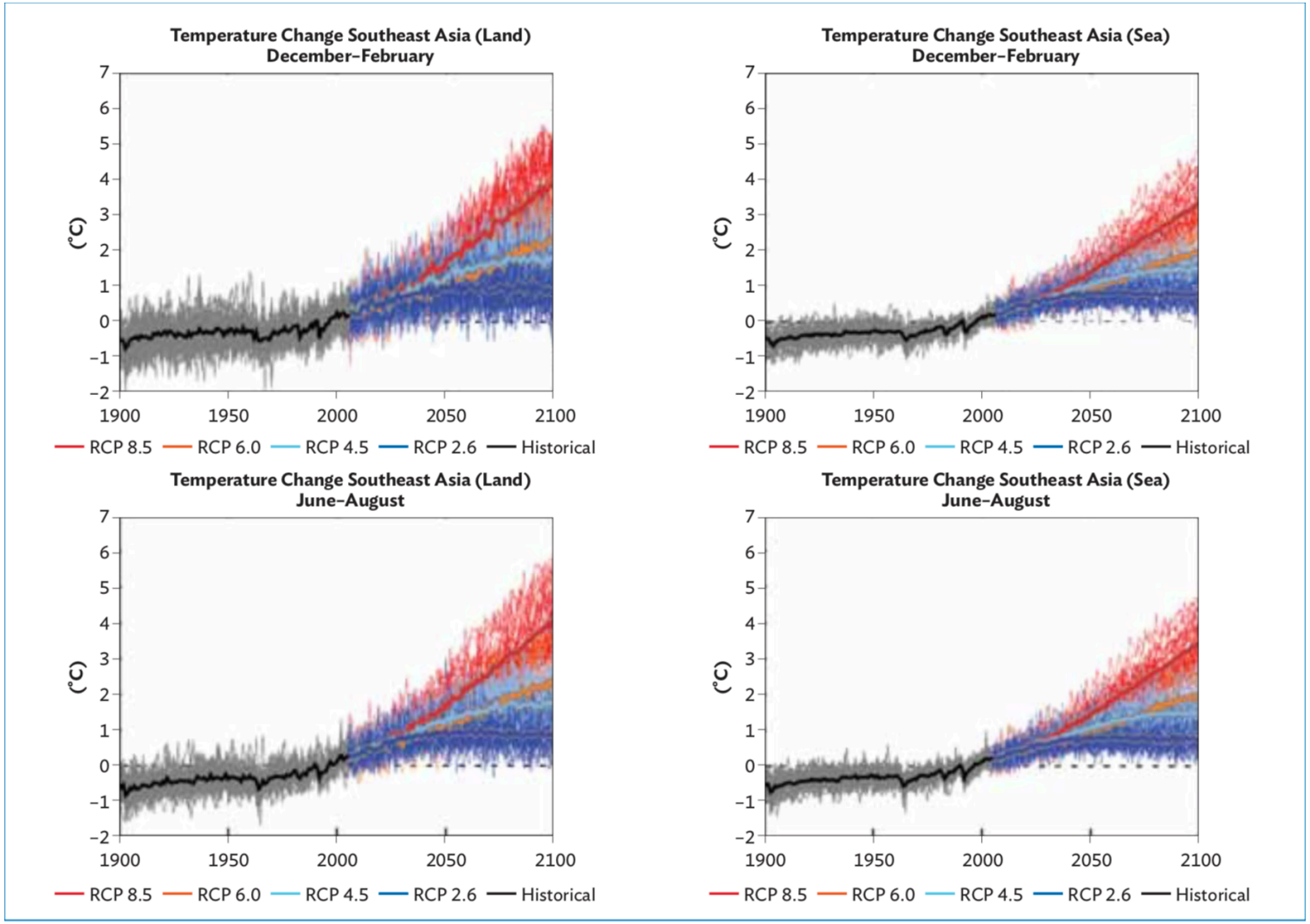
It is also a region of the world which is expected to experience serious, negative impacts of climate change due to its fastgrowing and urbanising population, as well as the reliance of many of its people on climate-sensitive sectors such as agriculture, fisheries and natural resources.

South Asia is one on the most difficult to represent by climate models because of the complex geography, formed by thousands of islands of very different forms, sizes and orographic characteristics

In this complex terrain situation, mesoscale forcing
also becomes **an important factor, and particularly sea-breeze circulation (Riehl, 1979) DA MODIFICARE PERCHE RIFERITO AL** , so that the use of high resolution regional climate models, nested in reanalysis datasets or global model output becomes
very important to reproduce climate features and to develop future climate projections with the needed
degree of detail for local applications

Climate Change Should Matter to Southeast Asia

Historical and Expected Temperature Changes in Southeast Asia under Different Scenarios



IPCC (2014)

According to the Fifth Assessment Report (AR5

- **Mean Temperatures increasing** at a rate of 0.14°C–0.20°C per decade since the 1960s
- more hot days and warm nights

- **Annual total wet-day rainfall increased** by 22 millimeters per decade while rainfall on extreme-rain days increased by 10 millimeters per decade

- **Relative sea level increase** in the Western Pacific Ocean was three times greater than the global mean during 1993–2012

- **A median increase in temperature** over land ranging from 0.8°C in RCP2.6 to 3.2°C in RCP8.5 **A review of the climate change related scientific literature reveals a lack of regional model downscaling experiments over S.E. Asia**

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has concluded that evidence of anthropogenic climate change is “unequivocal” and that “climate change will amplify existing risks and create new risks for natural and human systems.” The mean temperature of the earth has already warmed approximately 0.85°C from 1880 to 2012. The oceans are warming, polar ice sheets and glaciers are melting, and mean sea level has risen by 20 centimeters. Moreover, this warming is predicted to accelerate.

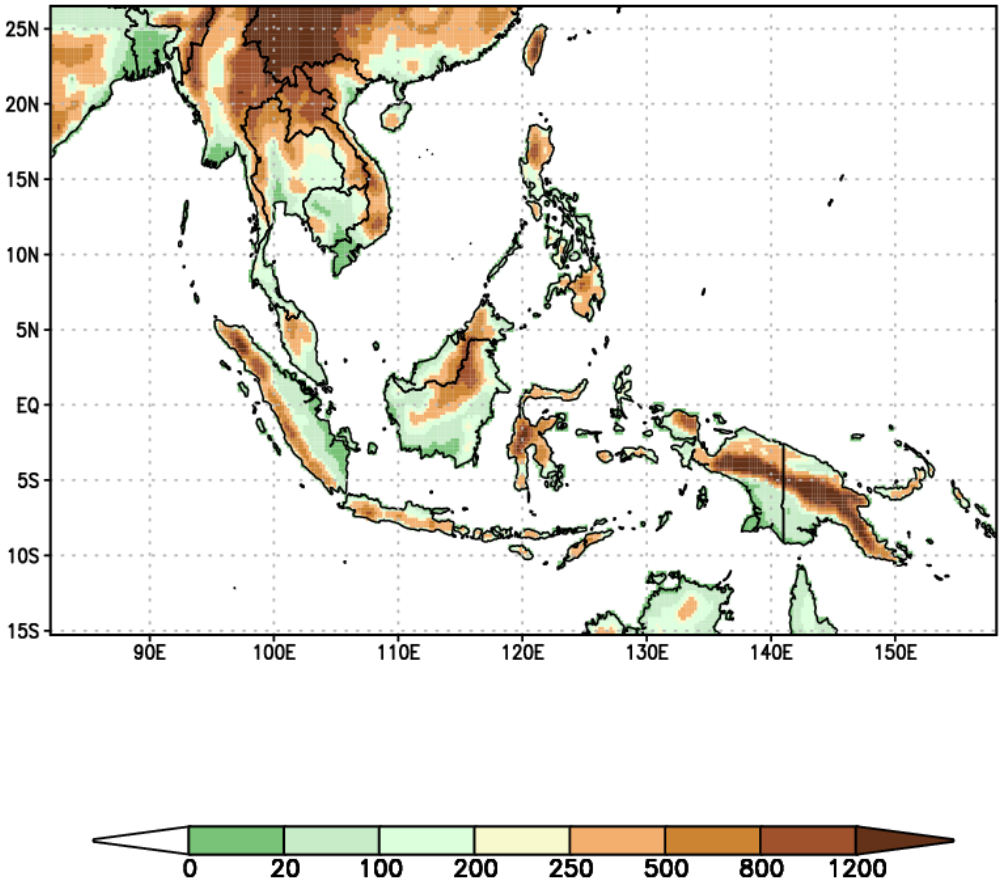
For the future, the AR5 depicts warming under four different representative concentration pathway (RCP) scenarios, each of which is named after expected radiative forcing values (in watts per square meter) by 2100. Each RCP roughly corresponds to a stabilized peak CO_2 concentration and a mean temperature rise, as shown in Table 1.

All RCPs, even those that represent drastic cuts in GHG emissions, reflect continued warming, and all but one indicate mean warming of at least several times the warming experienced to date. All but RCP2.6 reflect temperatures that continue to rise beyond 2100, such that true stabilization of climate change does not occur within several centuries. Although these scenarios are hypothetical, pathways to date are consistent with RCP6.0 or higher. This implies at least 3°C of mean warming by 2100, with a rapid rate of warming continuing thereafter

For future climate, AR5 indicates a median increase in temperature over land ranging from 0.8°C in RCP2.6 (“low” greenhouse gas concentrations) to 3.2°C in RCP8.5 (“high” greenhouse gas concentrations) by the end of this century (2081–2100). A moderate increase in precipitation is projected for S.E. Asia: 1% in RCP2.6 (“low” greenhouse gas concentrations), increasing to 8% in RCP8.5 (“high” greenhouse gas concentrations) by 2100 (see Figure 2.1 below for results for RCP4.5, “medium” greenhouse gas concentrations)

A review of the climate change related scientific literature reveals a lack of regional model downscaling experiments over S.E. Asia. In comparison to other major land areas in the world (Europe, the Americas, Africa, and more), S.E. Asia (as defined by the land areas covered by ASEAN member countries) has not been rigorously studied using an ensemble of dynamically downscaled global models over the S.E. Asian region. Most of the climate change projections for S.E. Asia have been derived from global model runs, including those which informed the Intergovernmental Panel of Climate As S.E. Asia contains very complex terrain, the region is a logical choice for regional climate model (RCM) simulations. A review of the climate change related scientific literature reveals a lack of regional model downscaling experiments over S.E. Asia. Literature Review 16 Change Fifth Assessment Report, or the IPCC AR5 (IPCC, 2013) or have involved the use of regional models over individual S.E. Asian countries

RegCMV4.7.0 : South East Asia Domain 25 Km



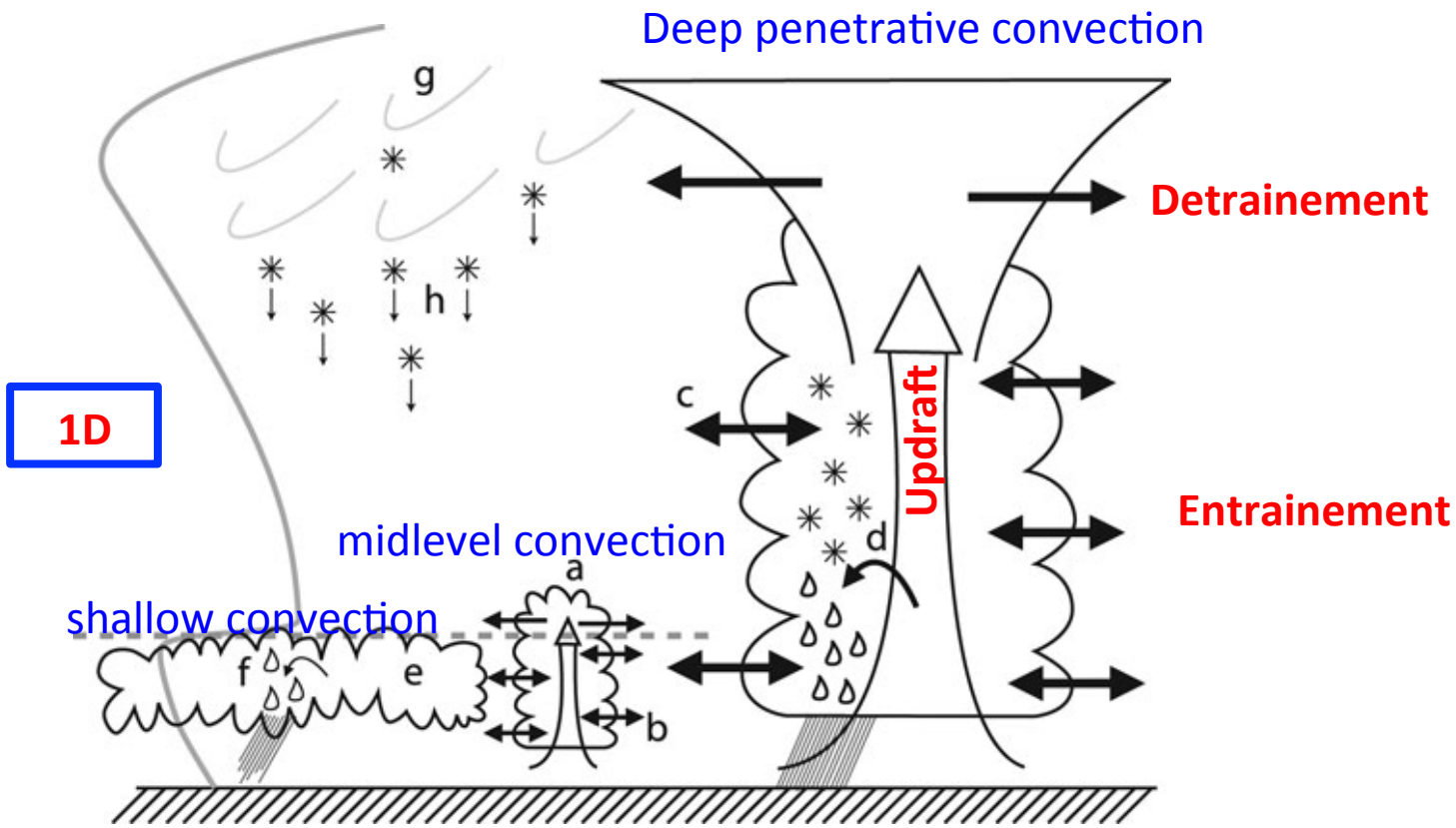
- South Asia region is one on the most difficult to represent by climate models because of the **complex geography**, formed by many islands of very different forms, sizes and **orographic characteristics**

- In this complex terrain situation the use of **high resolution regional climate models**, nested in reanalysis datasets or global model output becomes very important to reproduce climate features and to develop future climate projections with the needed degree of detail for local applications

First step: To calibrate the performance of the RegCM-4.7.0 over South East Asia domain by tuning some parameters, focusing in particular on **Tiedtke** convective parameterization scheme.

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation. The scheme has been originally developed by **Tiedtke (1989)**, and in the following has been continuously further developed and improved by **Gregory et al. (2000)**, Jakob and Siebesma (2003), and **Bechtold et al. (2004)**



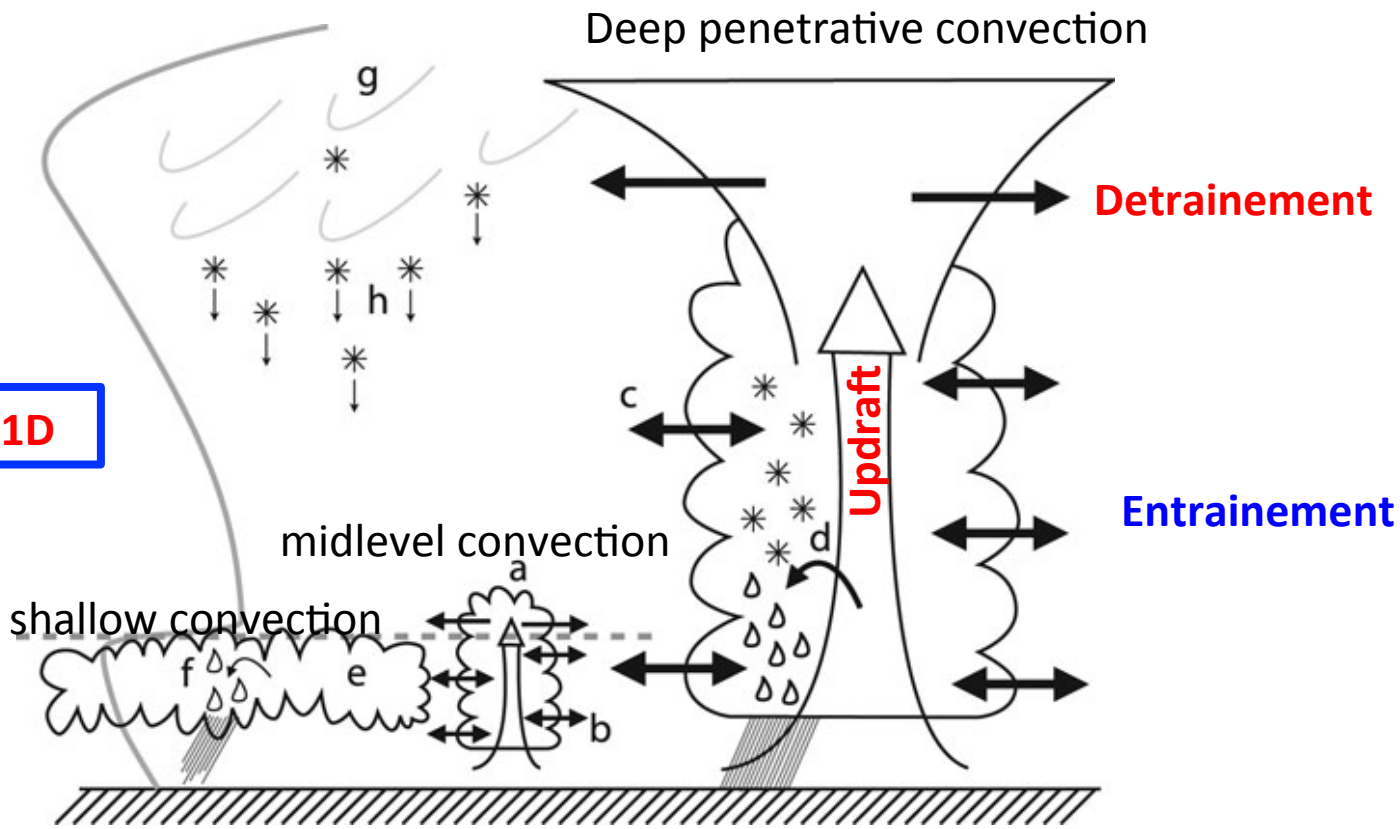
Tiedtke, 1989

Entrainment rate is a key parameter in cumulus parameterization

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation. The scheme has been originally developed by **Tiedtke (1989)**, and in the following has been continuously further developed and improved by **Gregory et al. (2000)**, Jakob and Siebesma (2003), and **Bechtold et al. (2004)**

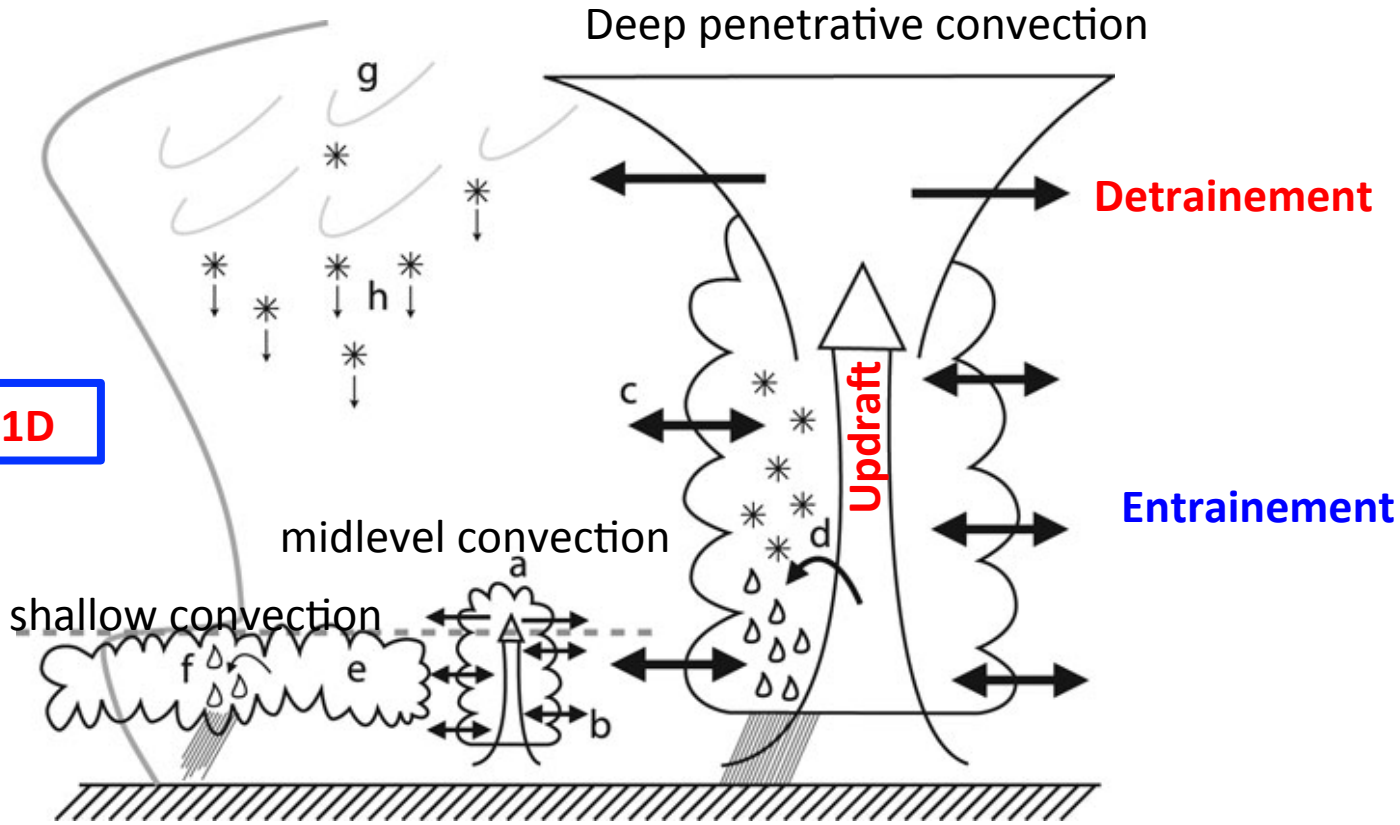
1D



Tiedtke, 1989

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation. The scheme has been originally developed by **Tiedtke (1989)**, and in the following has been continuously further developed and improved by **Gregory et al. (2000)**, Jakob and Siebesma (2003), and **Bechtold et al. (2004)**



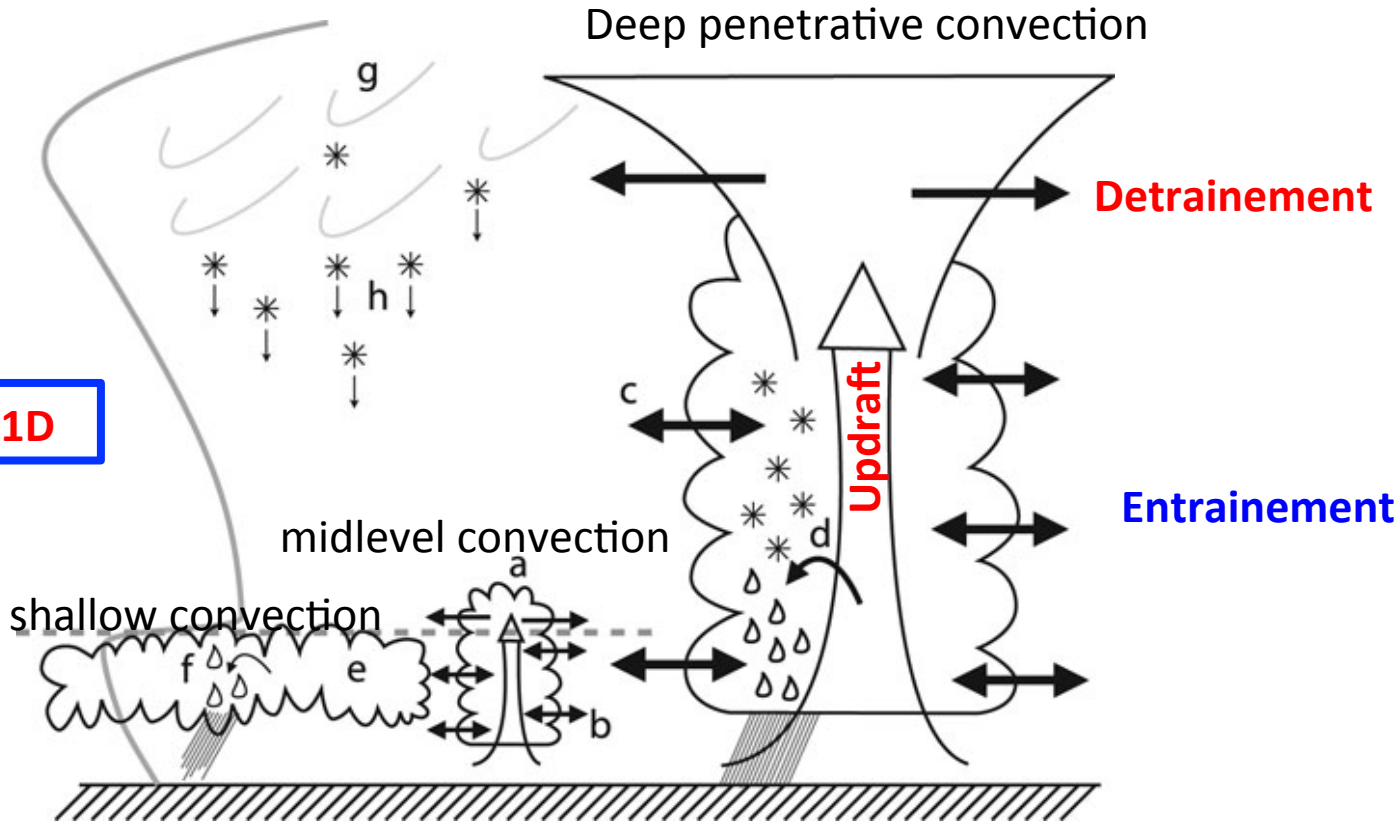
1D

Tiedtke, 1989

Entrainment rate is a key parameter in cumulus parameterization causing uncertainty in climate models

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation. The scheme has been originally developed by **Tiedtke (1989)**, and in the following has been continuously further developed and improved by **Gregory et al. (2000)**, Jakob and Siebesma (2003), and **Bechtold et al. (2004)**



1D

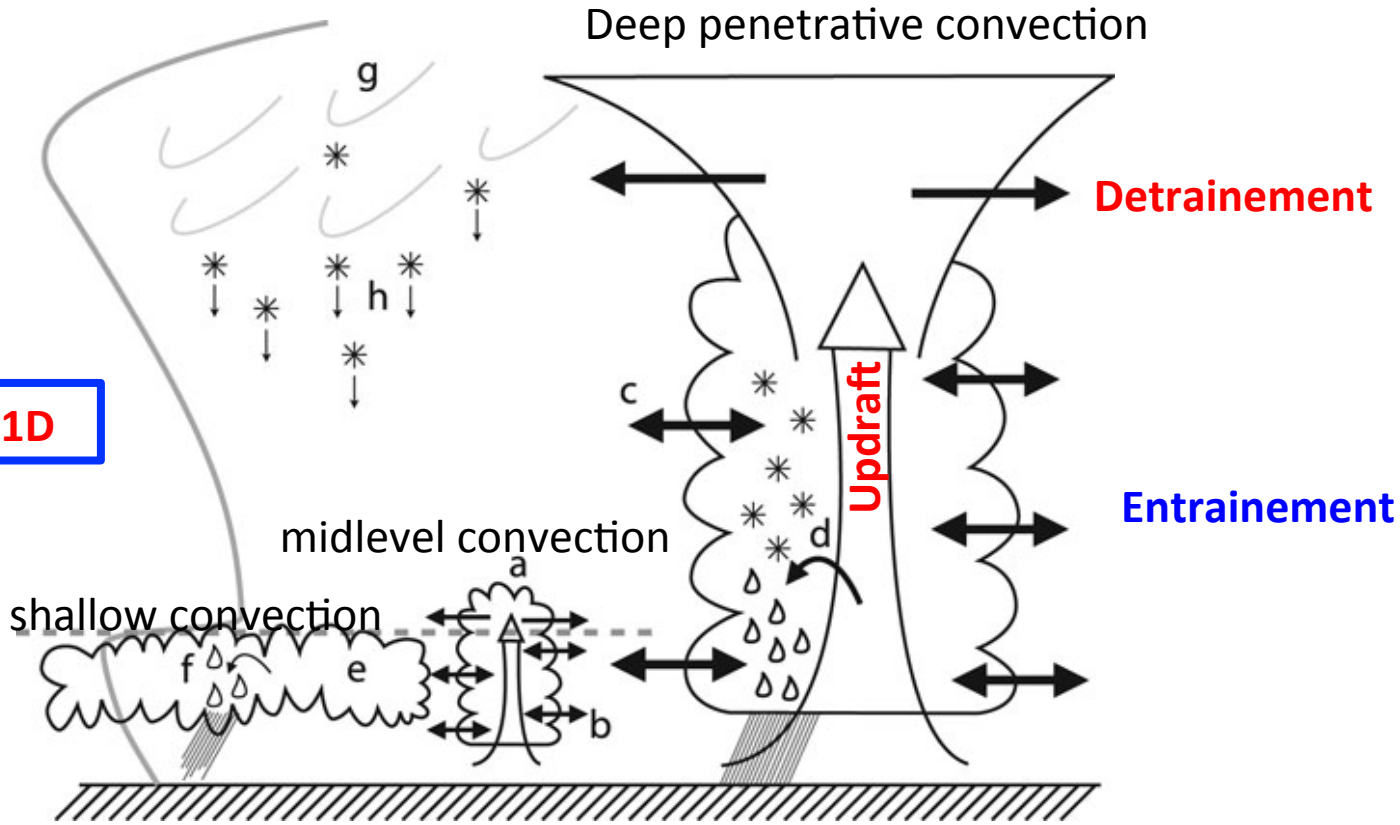
$$E_1^u = \varepsilon_1^u \frac{M^u}{\bar{\rho}}(1.3 - RH) \left(\frac{q_{sat}(\bar{T})}{q_{sat}^{base}(\bar{T})} \right)^3$$

Tiedtke, 1989

Entrainment is the single most important parameter in a mass flux convection parametrization causing uncertainty in climate models

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation. The scheme has been originally developed by **Tiedtke (1989)**, and in the following has been continuously further developed and improved by **Gregory et al. (2000)**, Jakob and Siebesma (2003), and **Bechtold et al. (2004)**



1D

Entrpern_lnd=1.75*10^{-3}

Entrpern_ocn=1.75*10^{-3}

$$E_1^u = \varepsilon_1^u \frac{M^u}{\bar{\rho}}(1.3 - RH)\left(\frac{q_{sat}(\bar{T})}{q_{sat}^{base}(\bar{T})}\right)^3$$

Tiedtke, 1989

Entrainment is the single most important parameter in a mass flux convection parametrization causing uncertainty in climate models

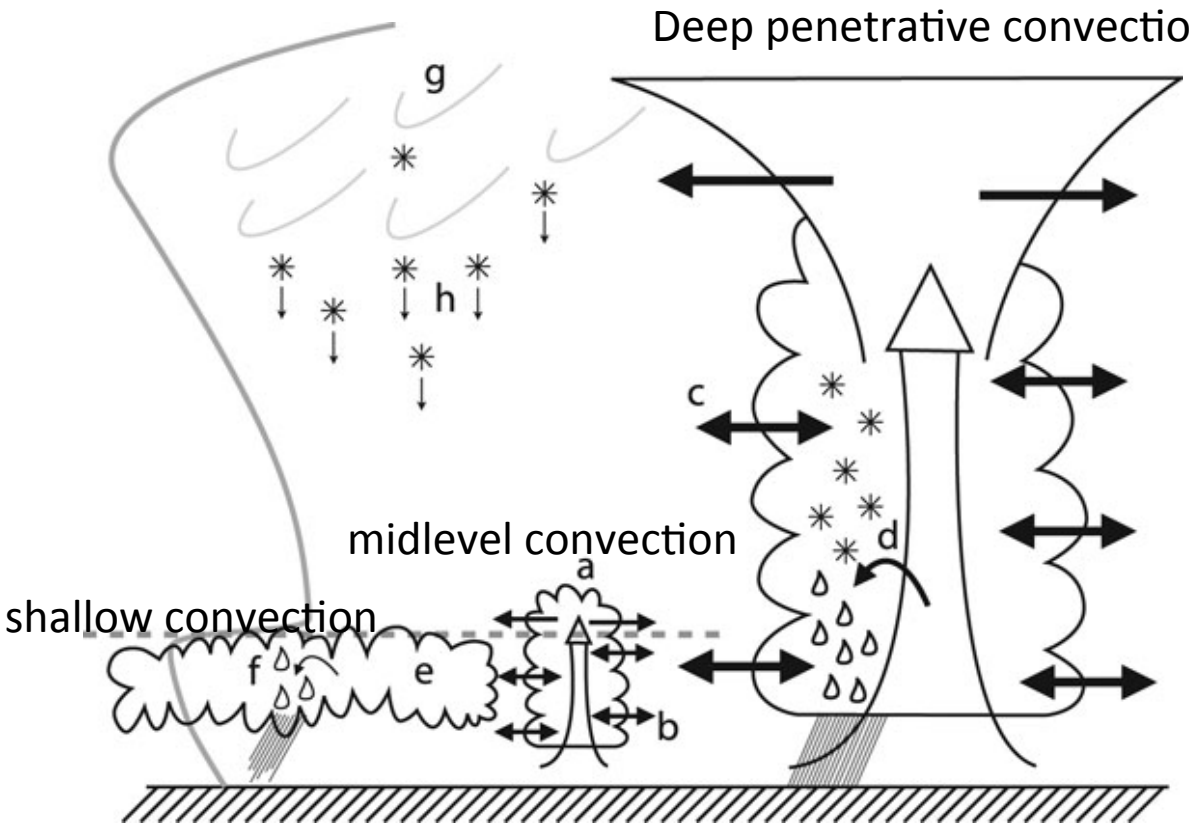
Entrainment is the mixing of environmental air into a preexisting air current or cloud so that the environmental air becomes part of the current or cloud. **The entrainment coefficient** in clouds is one of the most sensitive variables causing uncertainty in climate models.[1]

Entrainment is the single most important parameter in a mass flux convection parametrization

Entrainment rate is a key parameter in cumulus parameterization. Henry Stommel was the first to study entrainment rate in cumulus clouds

Convective parameterization Schemes:(Tiedtke)

Convective processes are extremely important for the development of deep clouds and precipitation



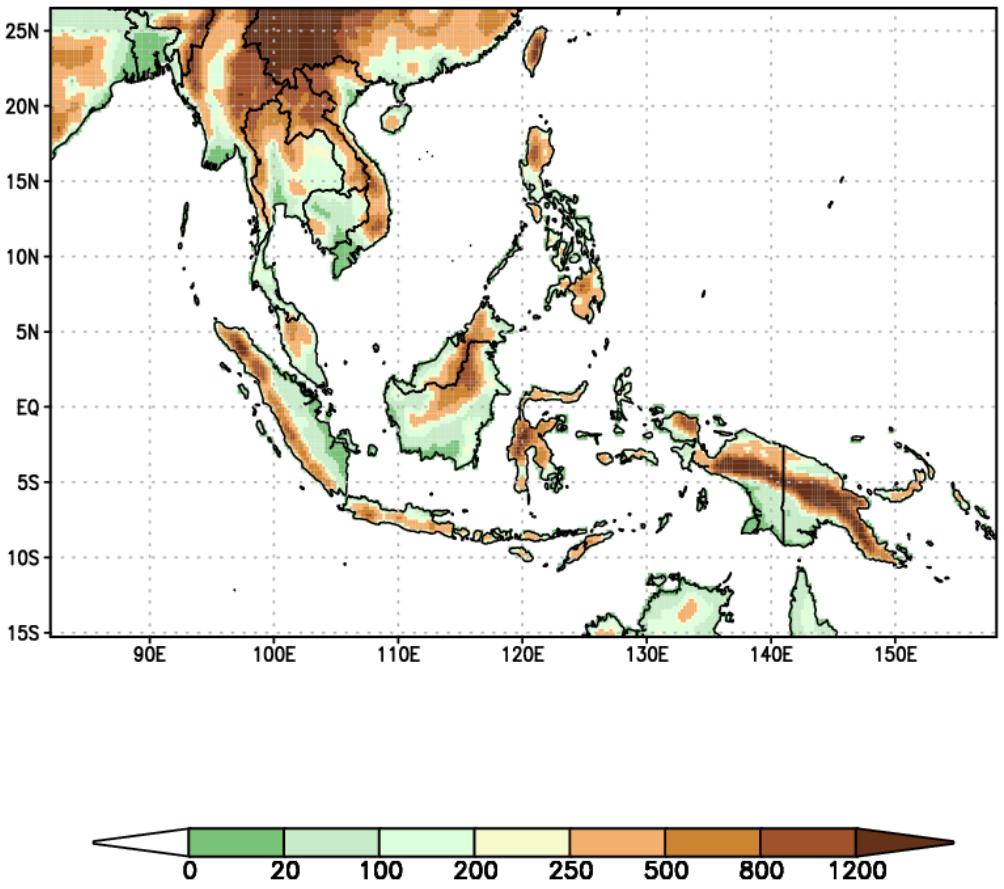
RegSome parameters of the Tiedtke convective scheme

Entrpern_lnd=1.75*10^{-3} entrainement rate for penetrative convection over land

Entrpern_ocn=1.75*10^{-3} entrainement rate for penetrative convection over sea

Tiedtke, 1989

RegCM 4.7.0 : South East Asia Setup



Model Setup :
Domain Number points: iy= 192, jx=338
Vertical levels (kz) =23
Resolution= 25 km
Projection (iproj)= Normal Mercator
Boundary Condition (ICBC)=ERA INTERIM
Period : 1999-2004

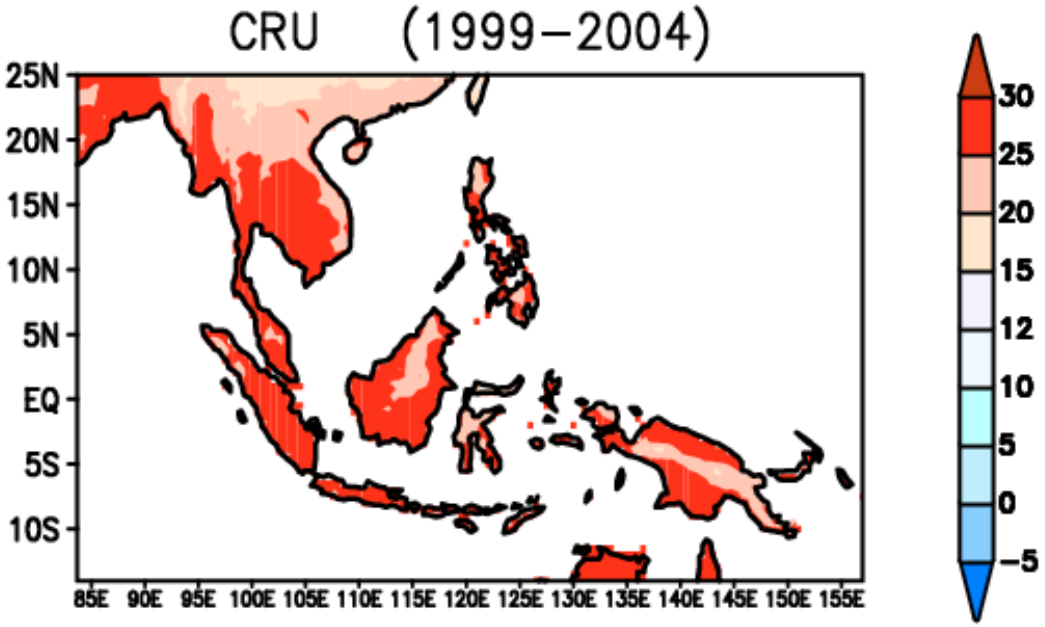
Model Physics:
PBL: Holstag PBL
Cumulus Convection : Tiedtke (ocean and Land)
Moisture Scheme: SUBEX
Ocean Flux scheme: Zeng
Soil vegetation atmosphere interaction processes : Comunity Land Model (CLM)

Tuning Experiments (Tiedtke)

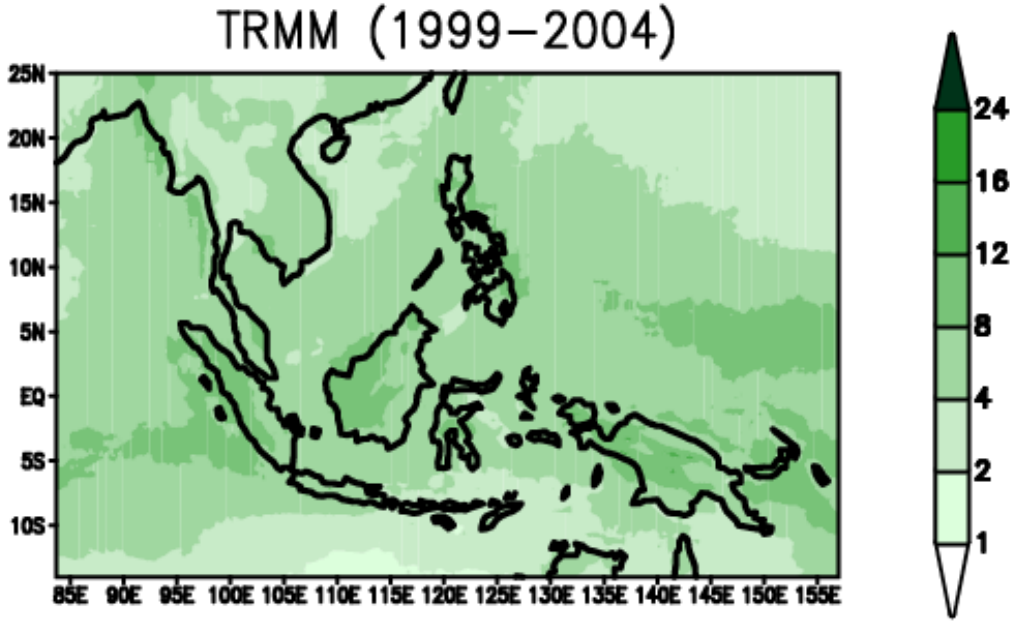
EXPERIMENT	Entrpen_lnd	Entrpen_oc
STD	1.75e-3	1.75e-3
T3	1.75e-4	1.75e-3
T4	**1.75e-2**	1.75e-3
T5	**8.75e-3**	1.75e-3
T6	**4.75e-3**	1.75e-3
T7	4.75e-3	**1.75e-4**
T8	4.75e-3	**0.75e-2**
T9	4.75e-3	**1.0e-3**

The data sets

Temperature °C



Precipitation mm d^{-1}



Climate is generally wetter over the equatorial region, while a drier climate is observed over the Indo-China region, creating a north to south dry to wet gradient over land

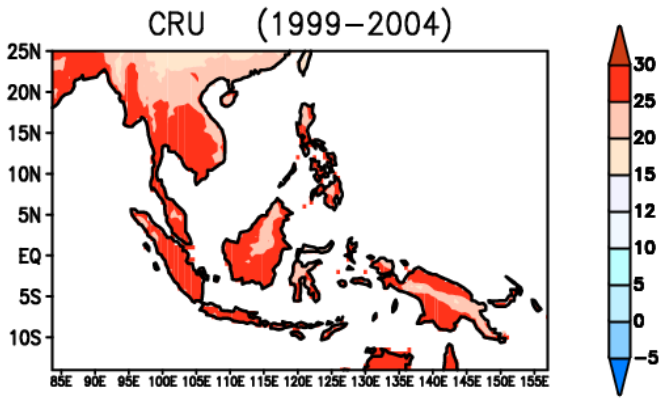
The data sets

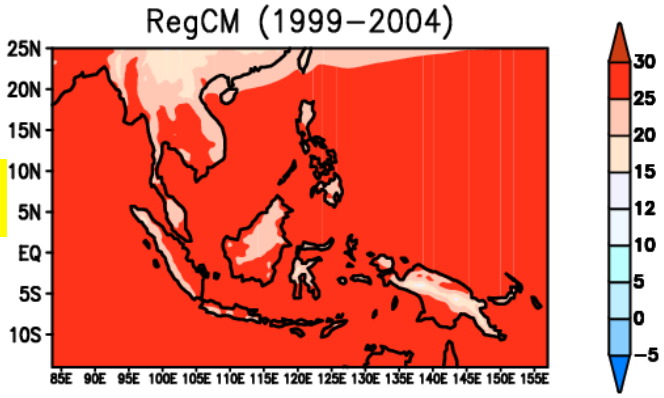
OBS

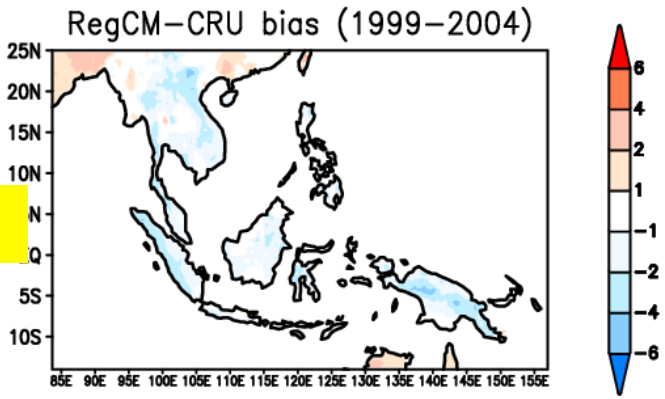
RegCMV470

BIAS : RegCM (T9)-OBS

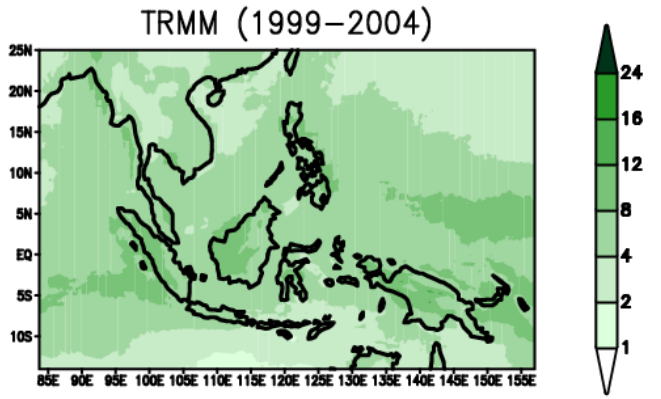
Temperature °C

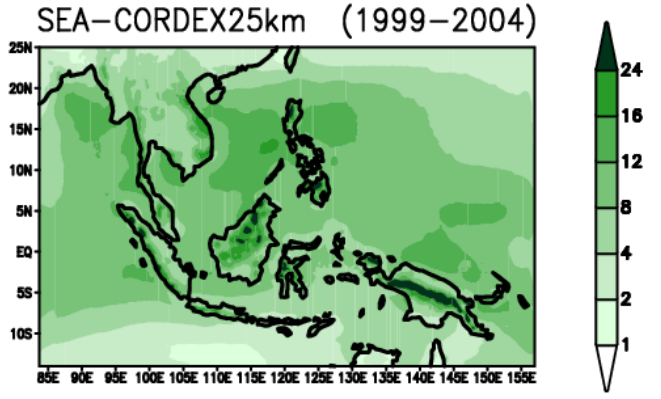


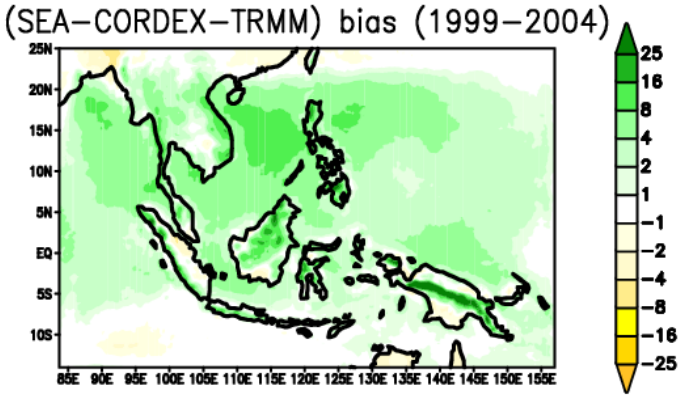




Precipitation mm d^{-1}

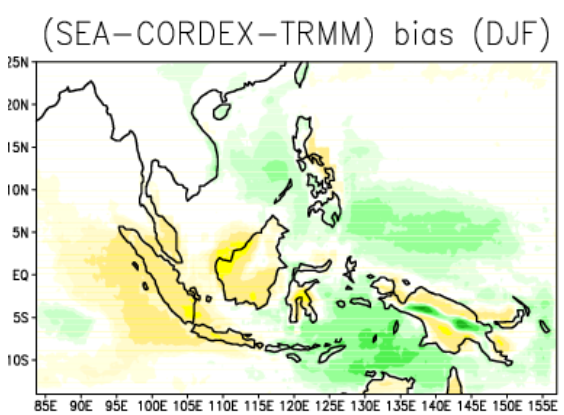




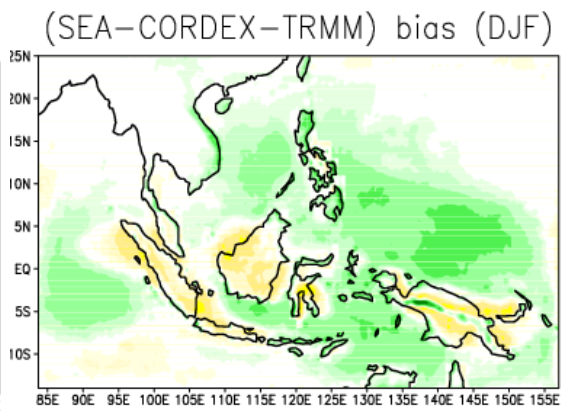


Precipitation BIAS (DJF)

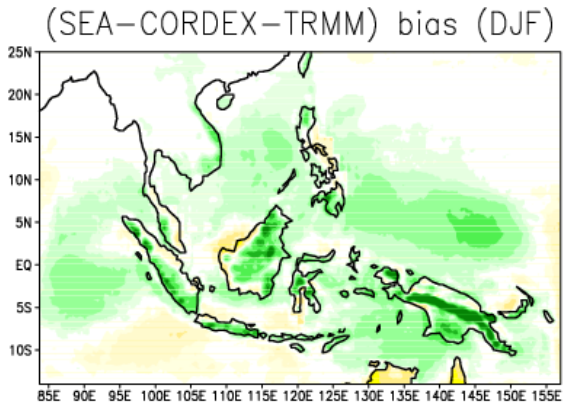
TEST: STD



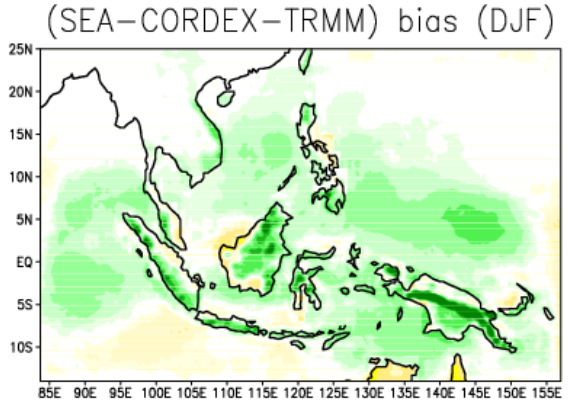
TEST: T3

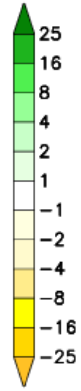


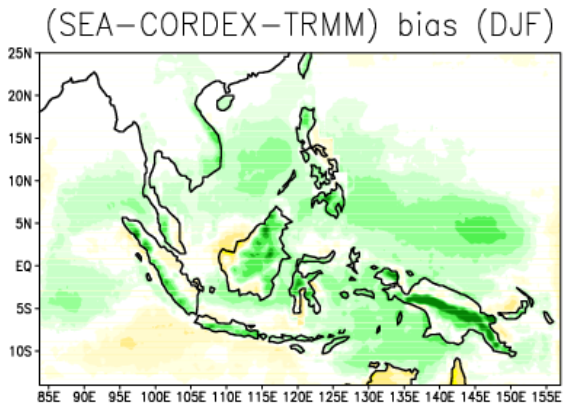
TEST: T4

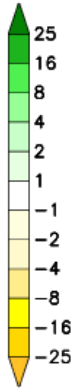


TEST: T5









Precipitation BIAS: TUNING OF **Entrpen_Ind** PARAMETER

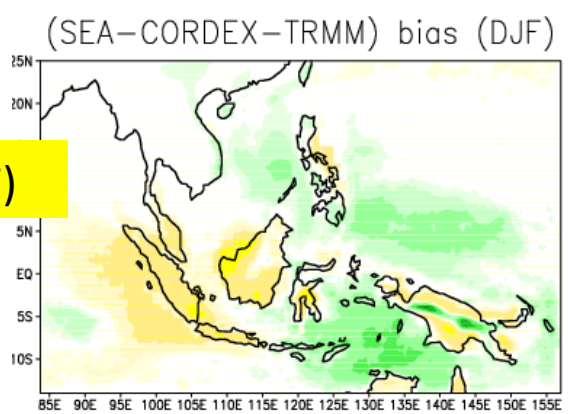
TEST: STD

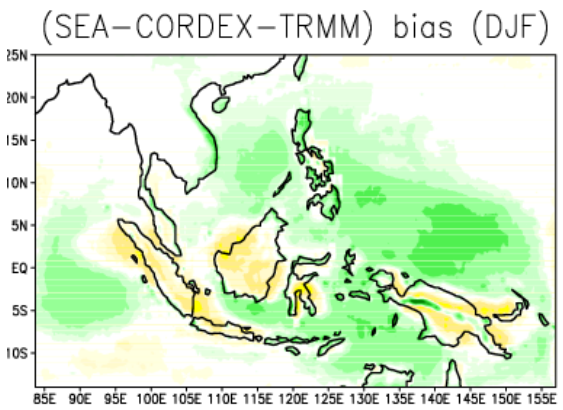
TEST: T3

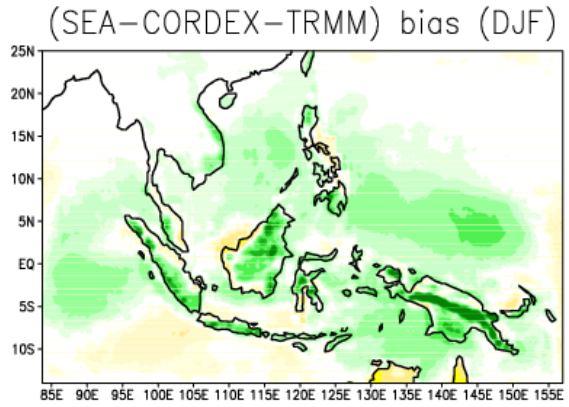
TEST: T4

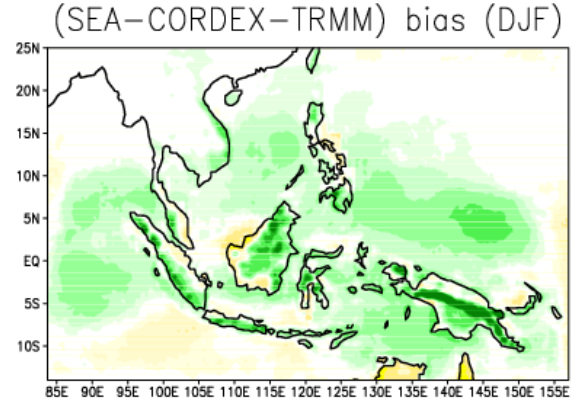
TEST: T5

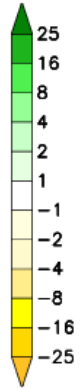
(DJF)



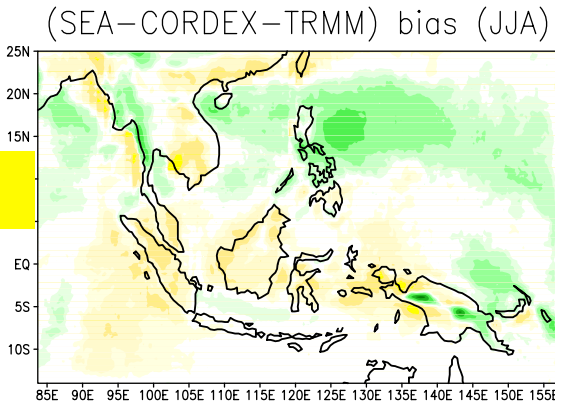


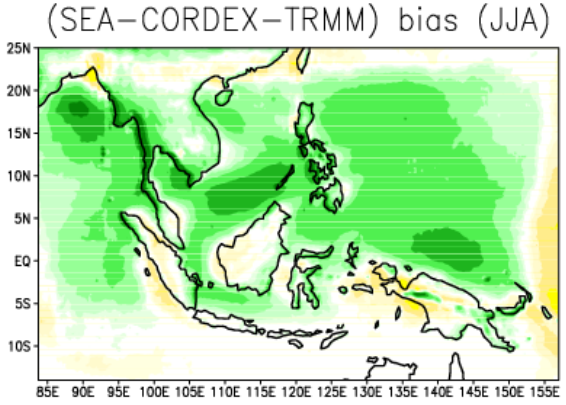


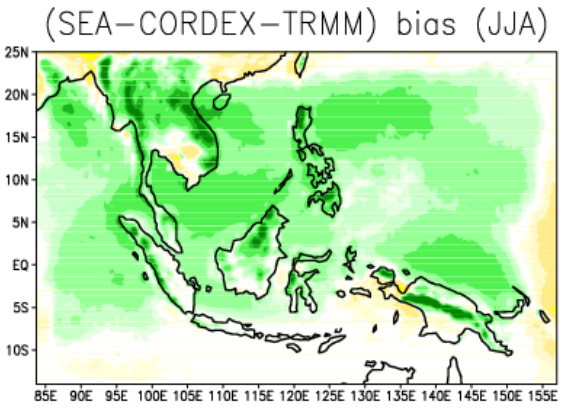


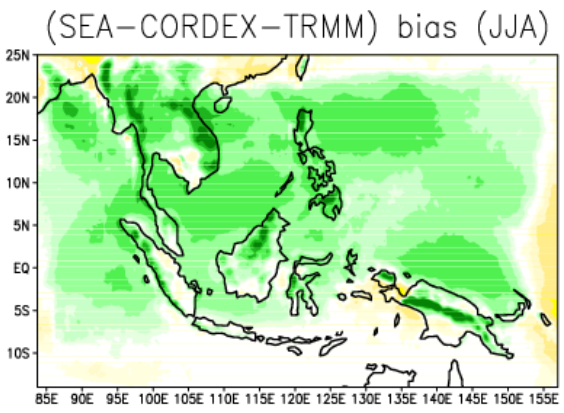


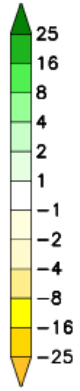
(JJA)











Entrpen_Ind=**1.75e-3**

Entrpen_Ind=**1.75e-4**

Entrpen_Ind=**1.75e-2**

Entrpen_Ind=**8.75e-3**

INCREASING standard value of Entrpen_Ind INCREASE precipitation over Land

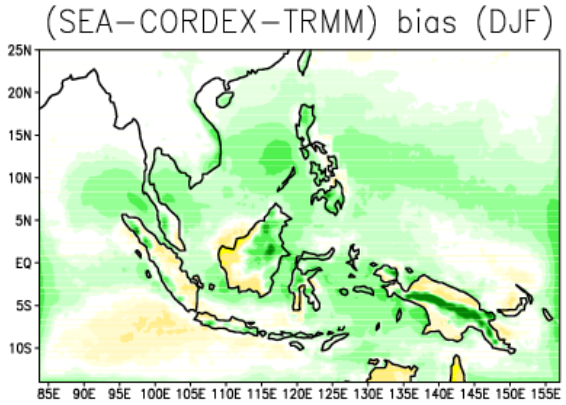
Precipitation BIAS :TUNING OF **Entrpen_ocn** PARAMETER

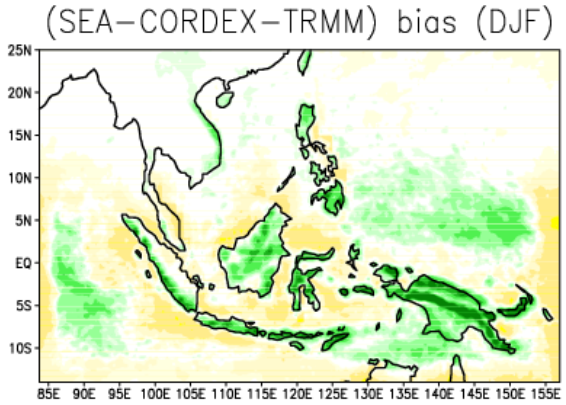
TEST: T7

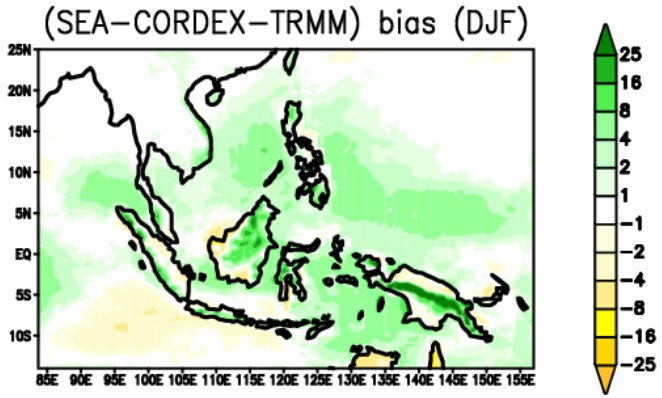
TEST: T8

TEST: T9

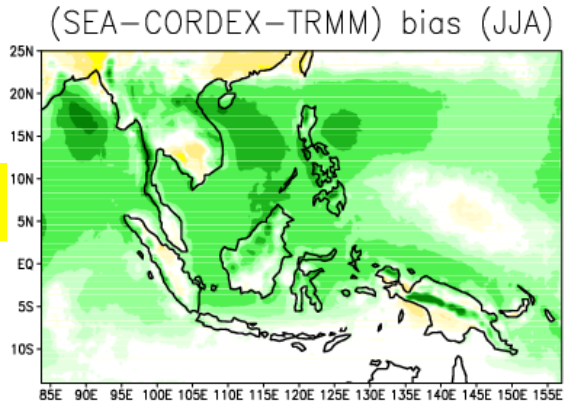
(DJF)

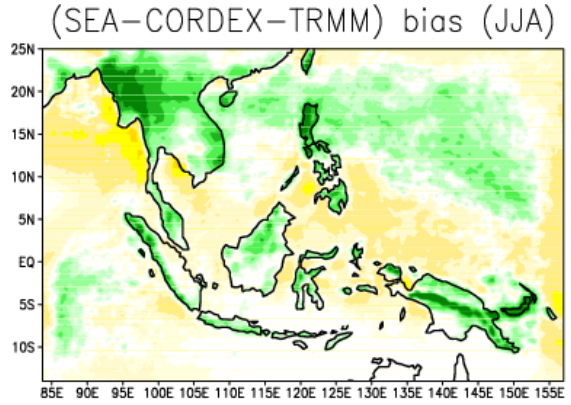


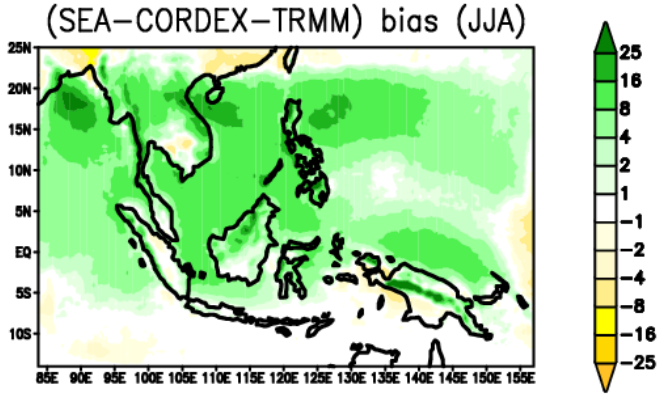




(JJA)







Entrpen_ocn=**1.75e-4**

Entrpen_ocn=**0.75e-2**

Entrpen_ocn=**1e-3**

INCREASING the Standard vaue of Entrpen_ocn REDUCE precipitation over OCEAN (really sensitive)

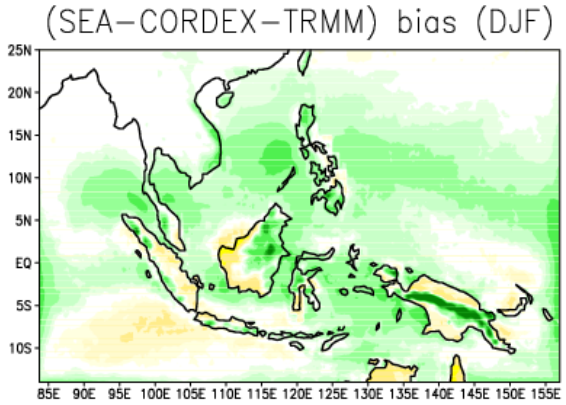
Precipitation BIAS :TUNING OF **Entrpen_ocn** PARAMETER

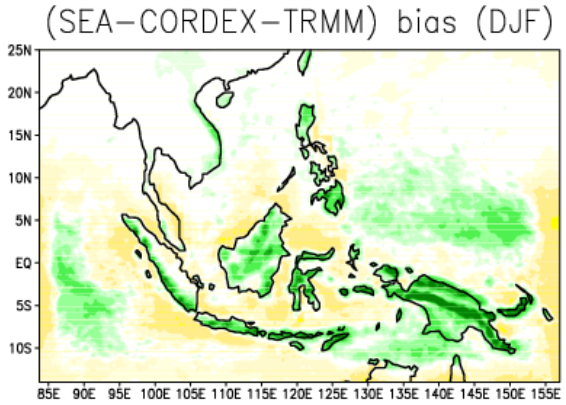
TEST: T7

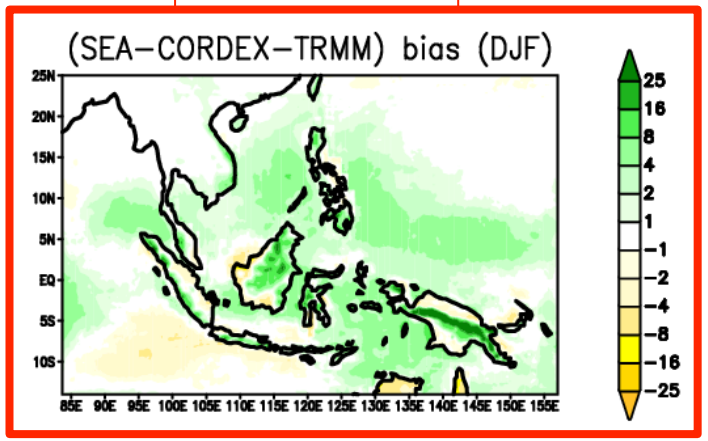
TEST: T8

TEST: T9

(DJF)

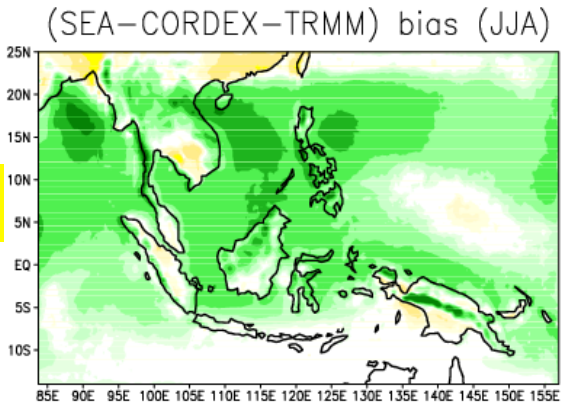


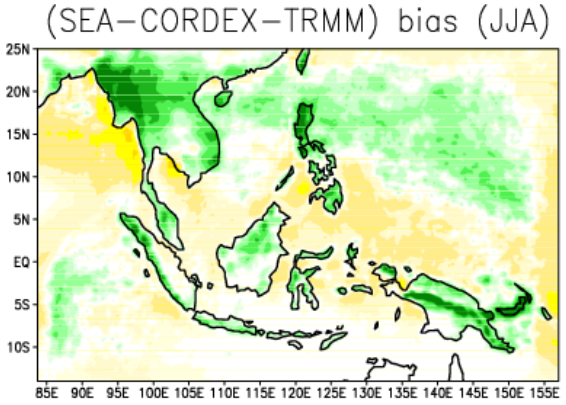


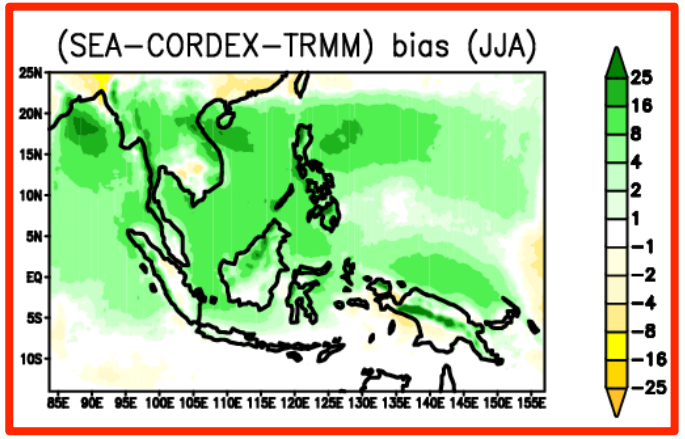


WET BIAS

(JJA)







Entrpen_ocn=**1.75e-4**

Entrpen_ocn=**0.75e-2**

Entrpen_ocn=**1e-3**

INCREASING the Standard vaue of Entrpen_ocn REDUCE precipitation over OCEAN (really sensitive)

Temperature BIAS :TUNING OF **Entrpen_lnd/Entrpen_ocn** PARAMETER

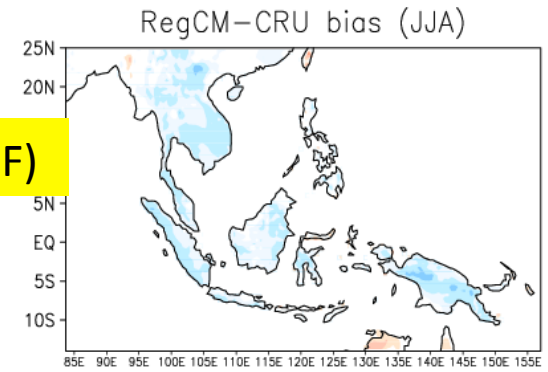
TEST: STD

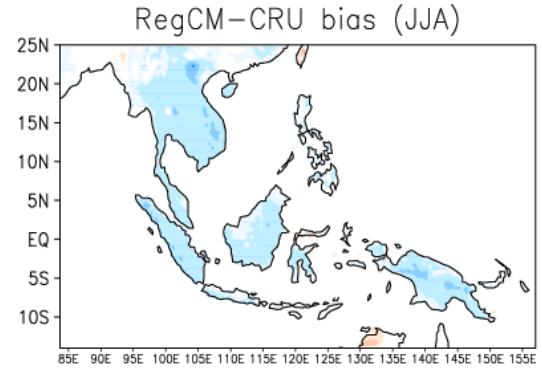
TEST: T3

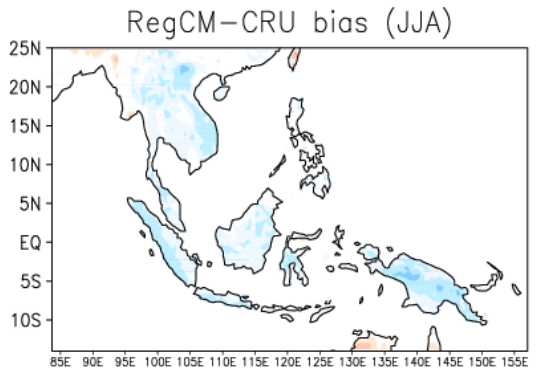
TEST: T8

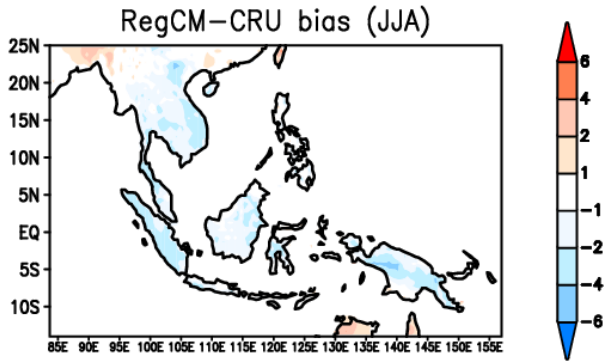
TEST: T9

(DJF)

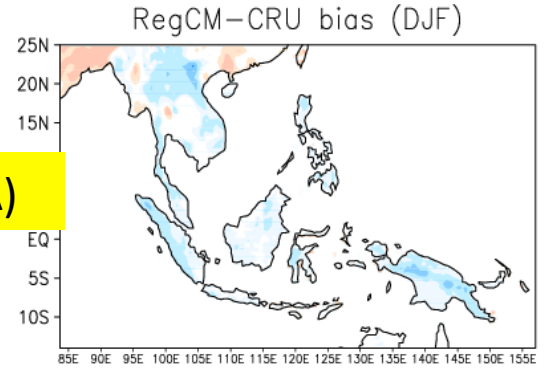


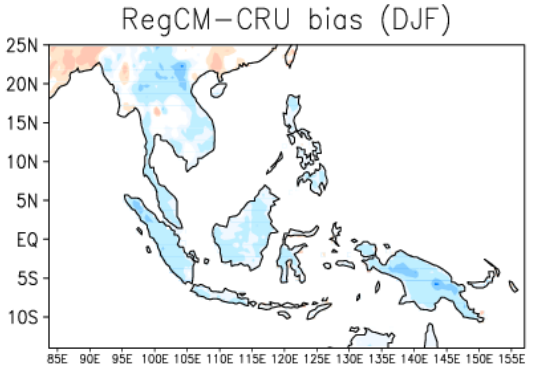


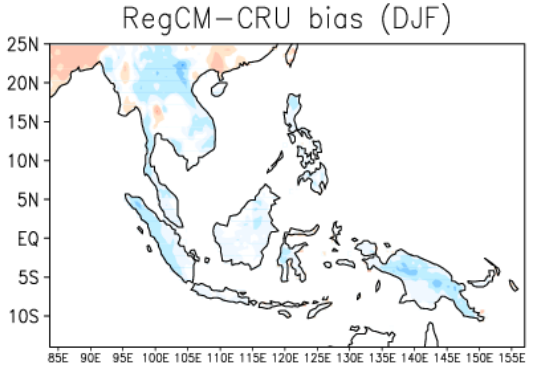


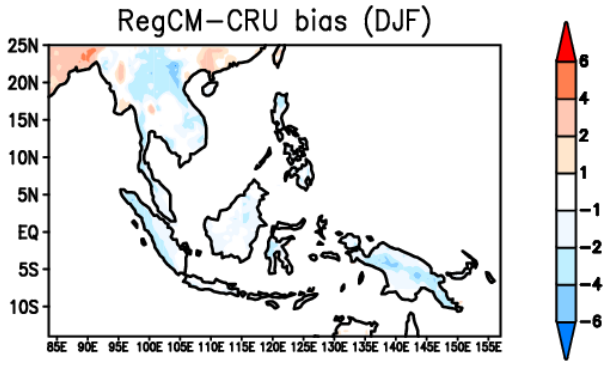


(JJA)









Entrpen_lnd=**1.75e-3**

Entrpen_lnd=**1.75e-4**

Entrpen_ocn=**0.75e-2**

Entrpen_ocn=**1e-3**

Temperature does not seem sensitive to Entrpen_lnd and Entr_pen_ocn

Temperature BIAS :TUNING OF **Entrpen_lnd/Entrpen_ocn** PARAMETER

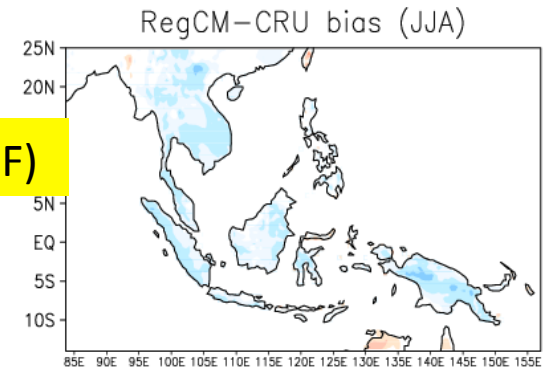
TEST: STD

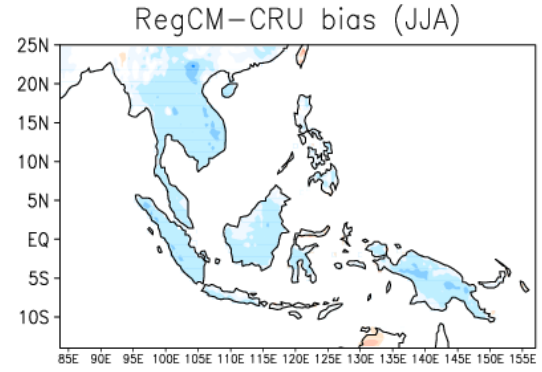
TEST: T3

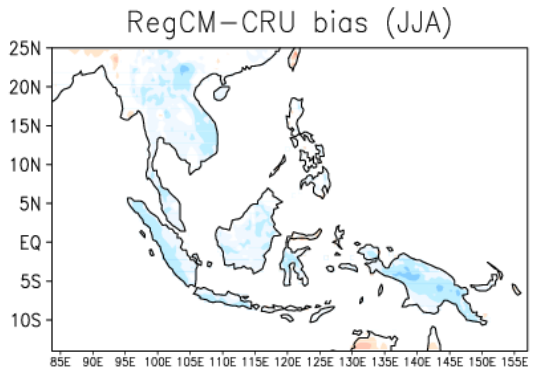
TEST: T8

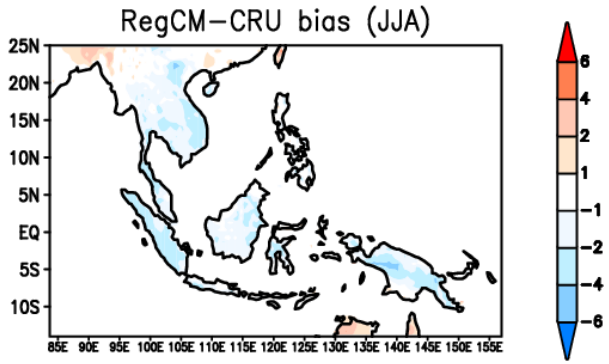
TEST: T9

(DJF)

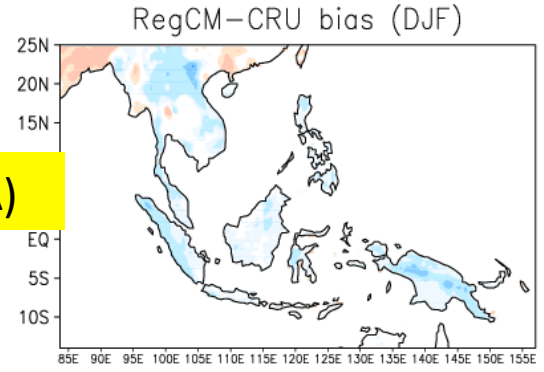


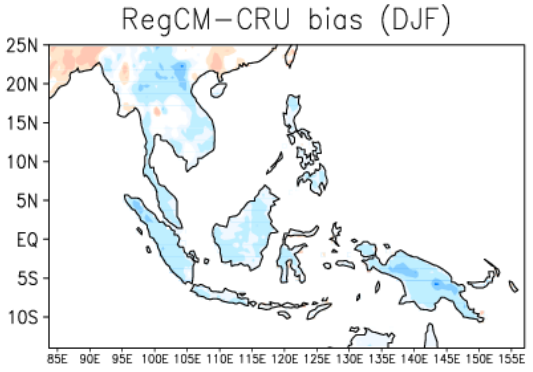


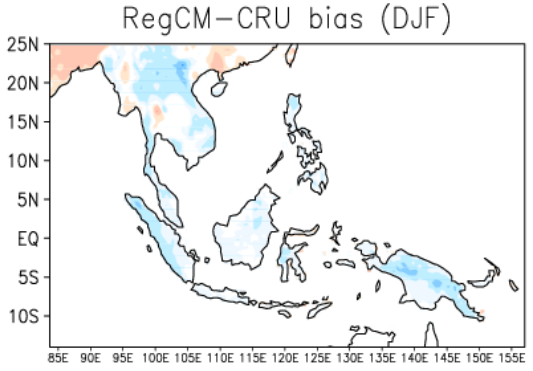


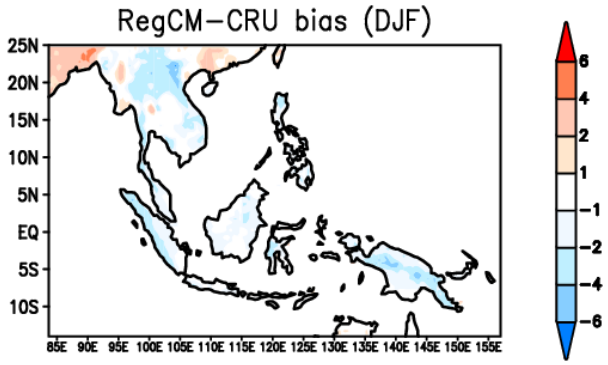


(JJA)









Entrpen_lnd=**1.75e-3**

Entrpen_lnd=**1.75e-4**

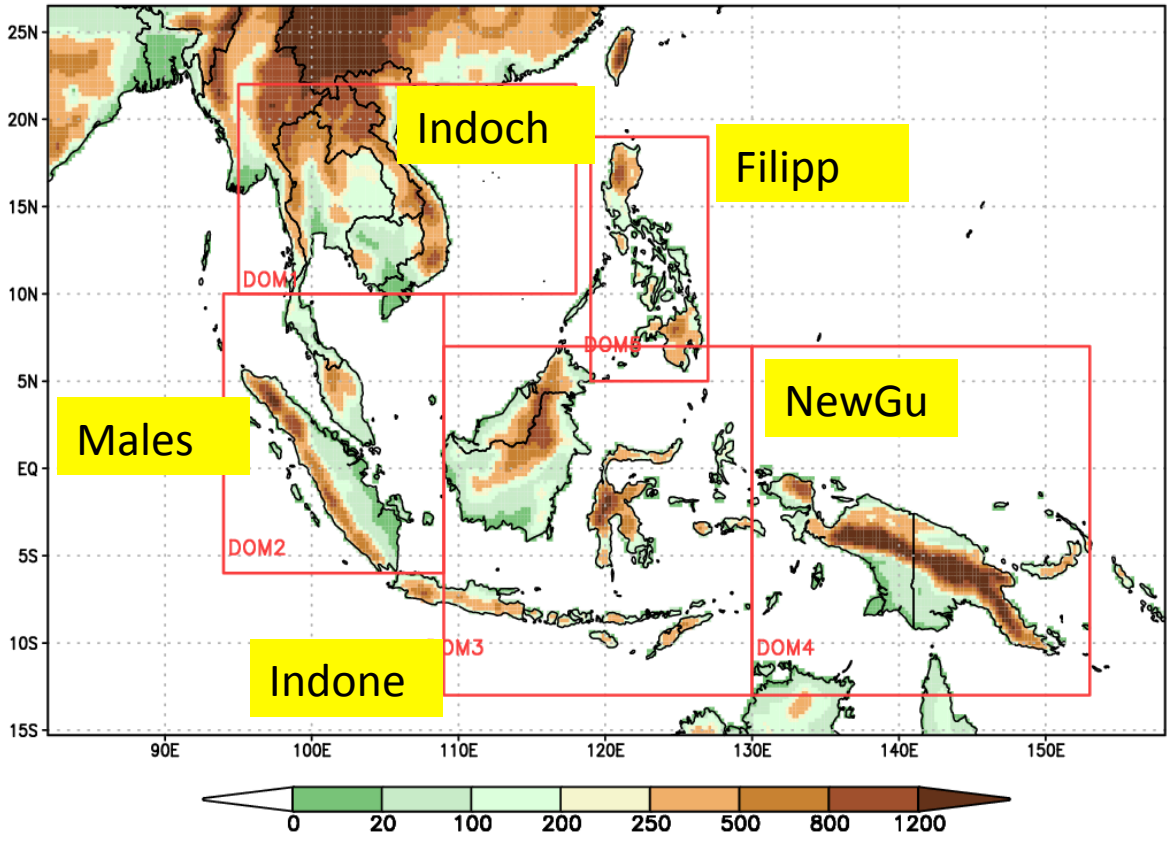
Entrpen_ocn=**0.75e-2**

Entrpen_ocn=**1e-3**

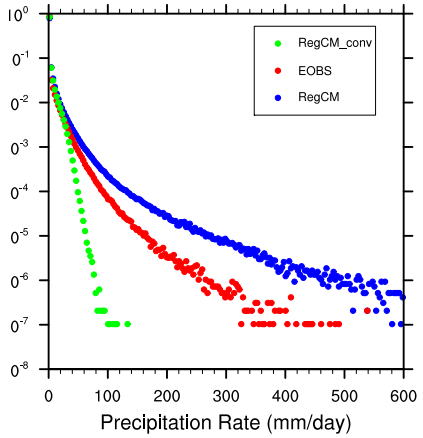
Temperature does not seem sensitive to Entrpen_lnd and Entr_pen_ocn

PDF: LAST CONFIGURATION T9

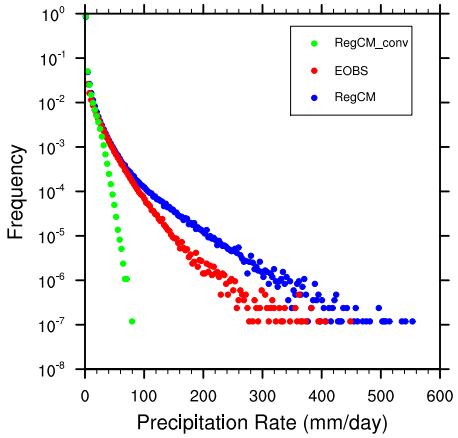
TEST: T9



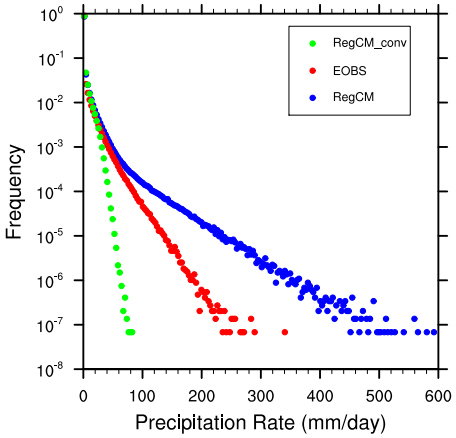
Indoch

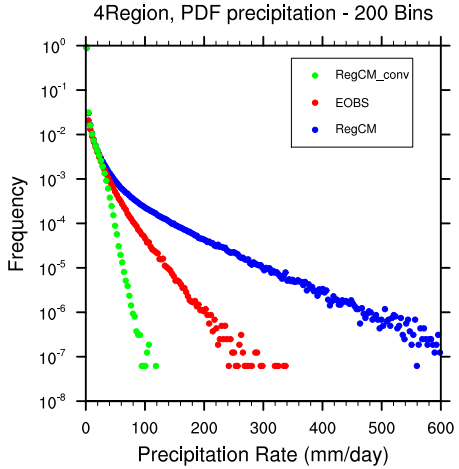


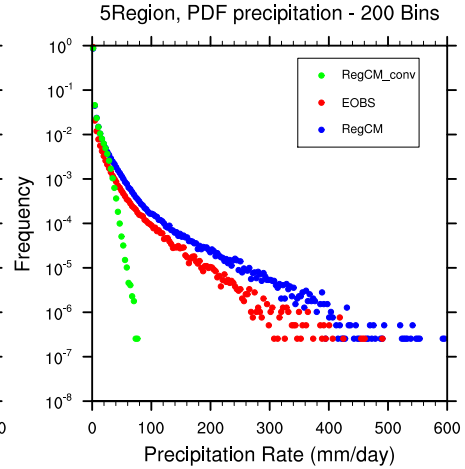
Males



Indone



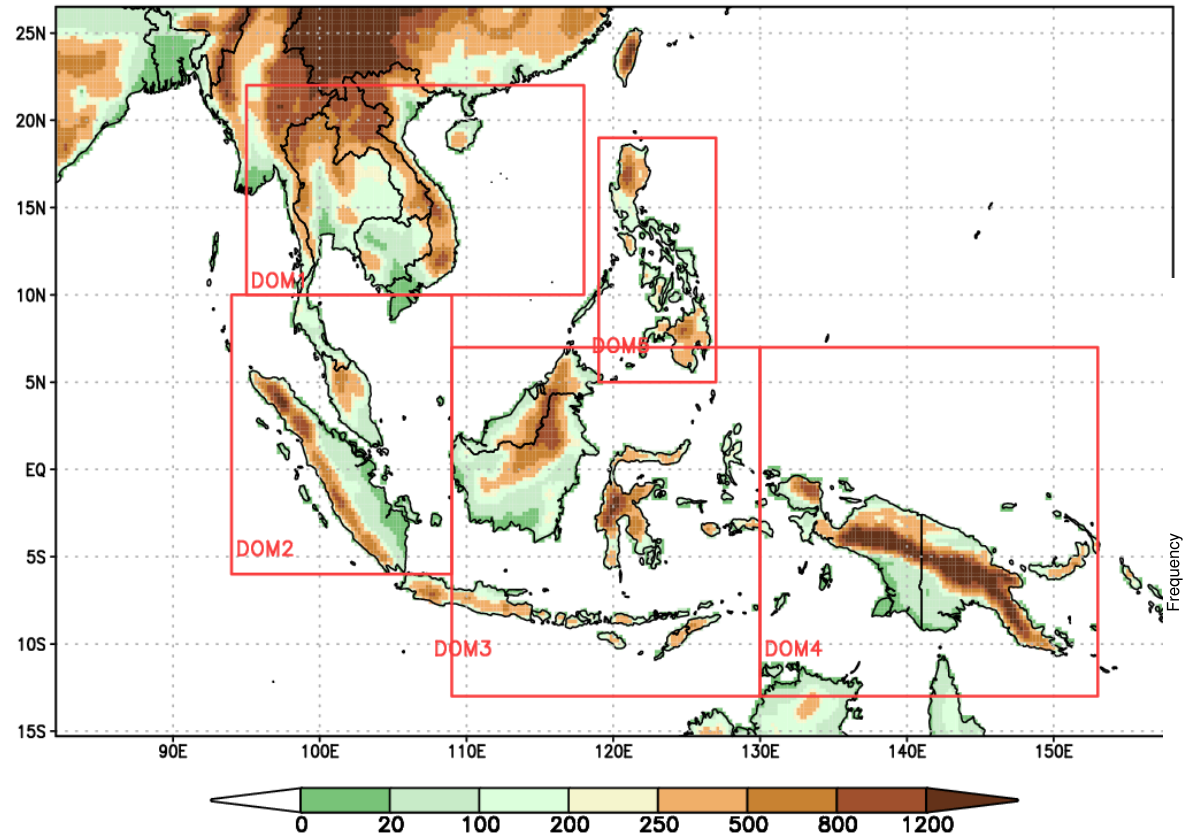


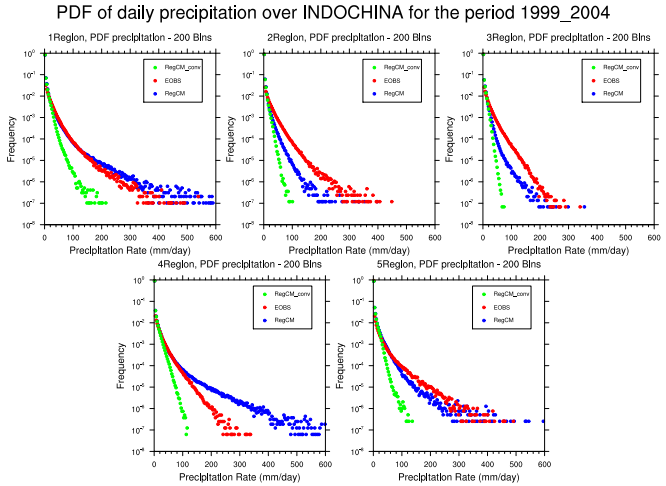


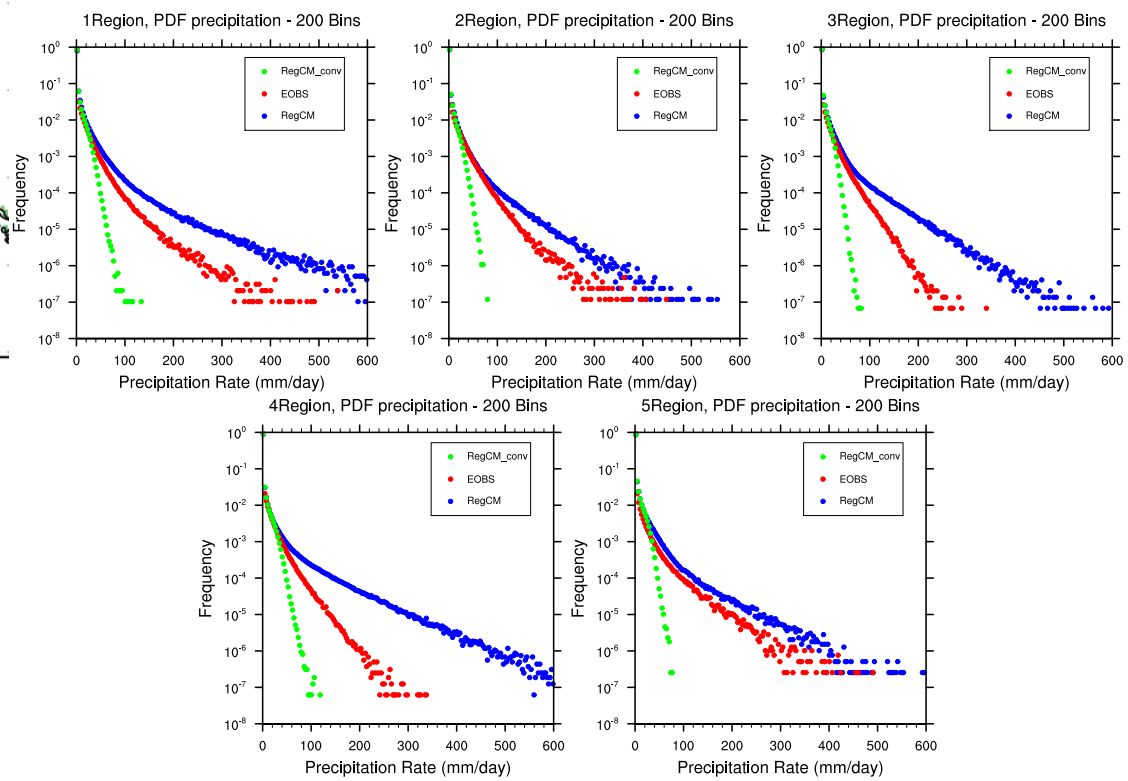
NewGu

Filipp

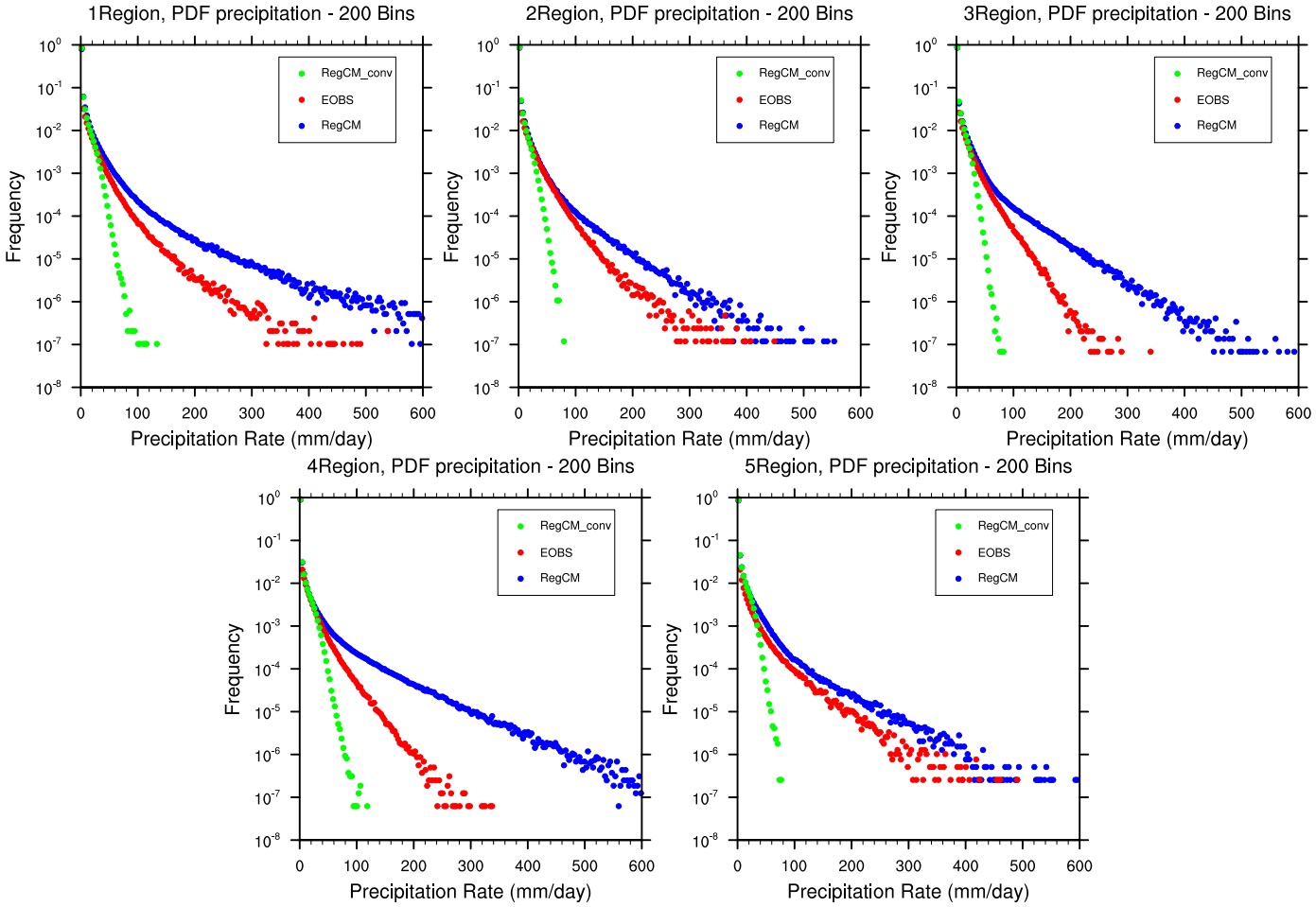
The model overstimates the frequencies of rain rates above 100 mm day^{-1}

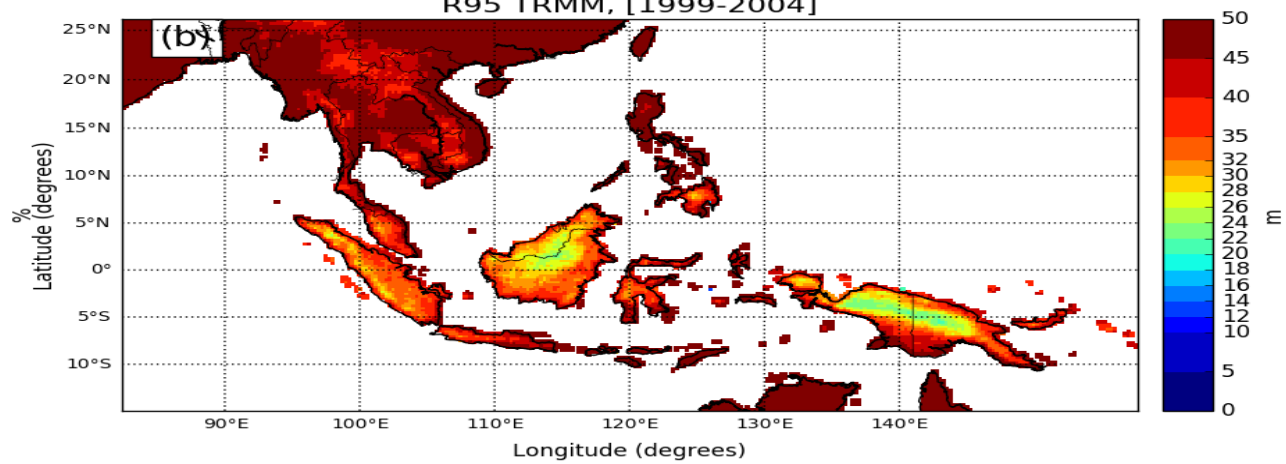

25N
20N
15N
10N
5N
EQ
5S
10S
15S
90E
100E
110E
120E
130E
140E
150E
DOM1
DOM2
DOM3
DOM4
DOM5
0
20
100
200
250
500
800
1200

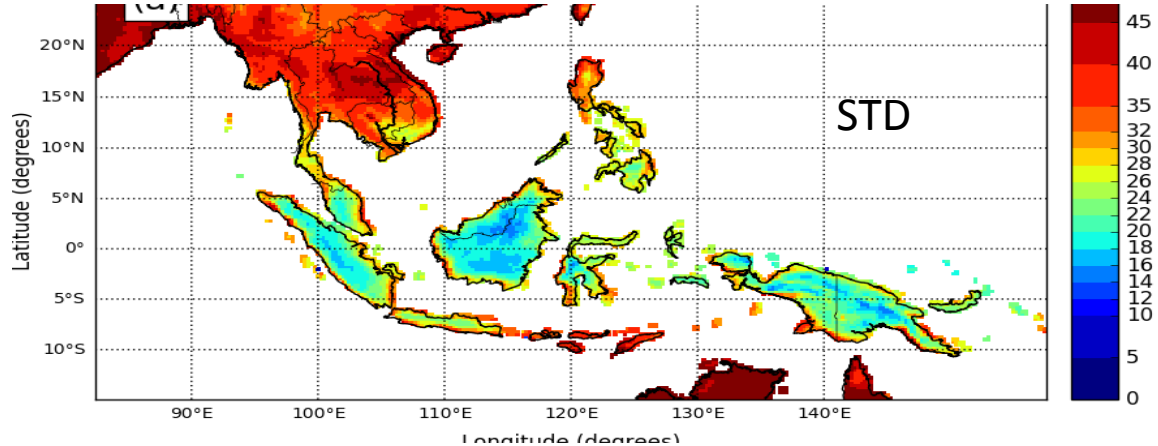

PDF of daily precipitation over INDOCHINA for the period 1999_2004
1Region, PDF precipitation - 200 Bins
2Region, PDF precipitation - 200 Bins
3Region, PDF precipitation - 200 Bins
4Region, PDF precipitation - 200 Bins
5Region, PDF precipitation - 200 Bins
RegCM_conv
EOBS
RegCM
Frequency
Precipitation Rate (mm/day)

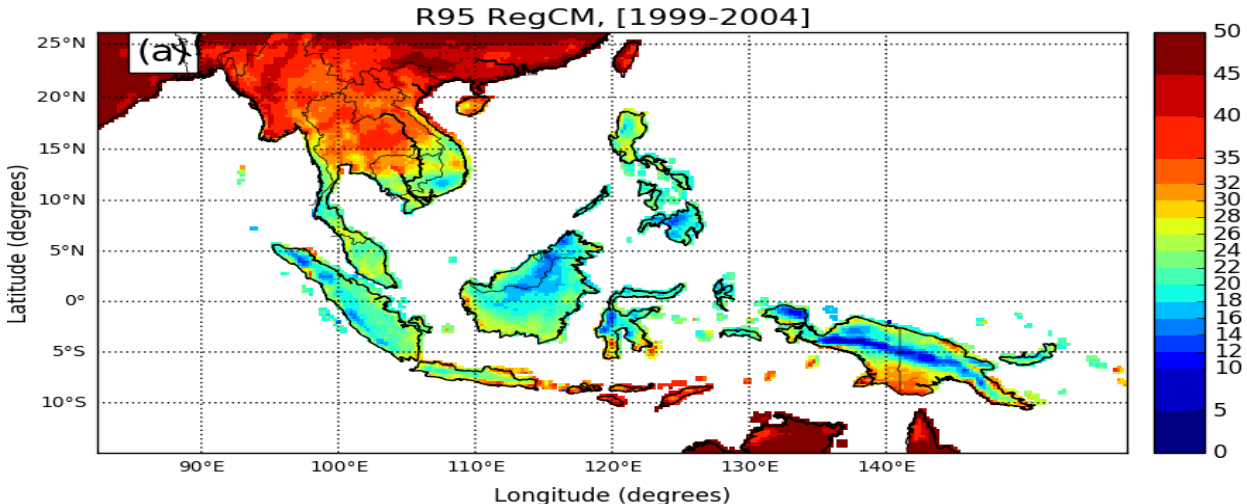

PDF of daily precipitation over INDOCHINA for the period 1999_2004
1Region, PDF precipitation - 200 Bins
2Region, PDF precipitation - 200 Bins
3Region, PDF precipitation - 200 Bins
4Region, PDF precipitation - 200 Bins
5Region, PDF precipitation - 200 Bins
RegCM_conv
EOBS
RegCM
Frequency
Precipitation Rate (mm/day)

PDF of daily precipitation over INDOCHINA for the period 1999_2004

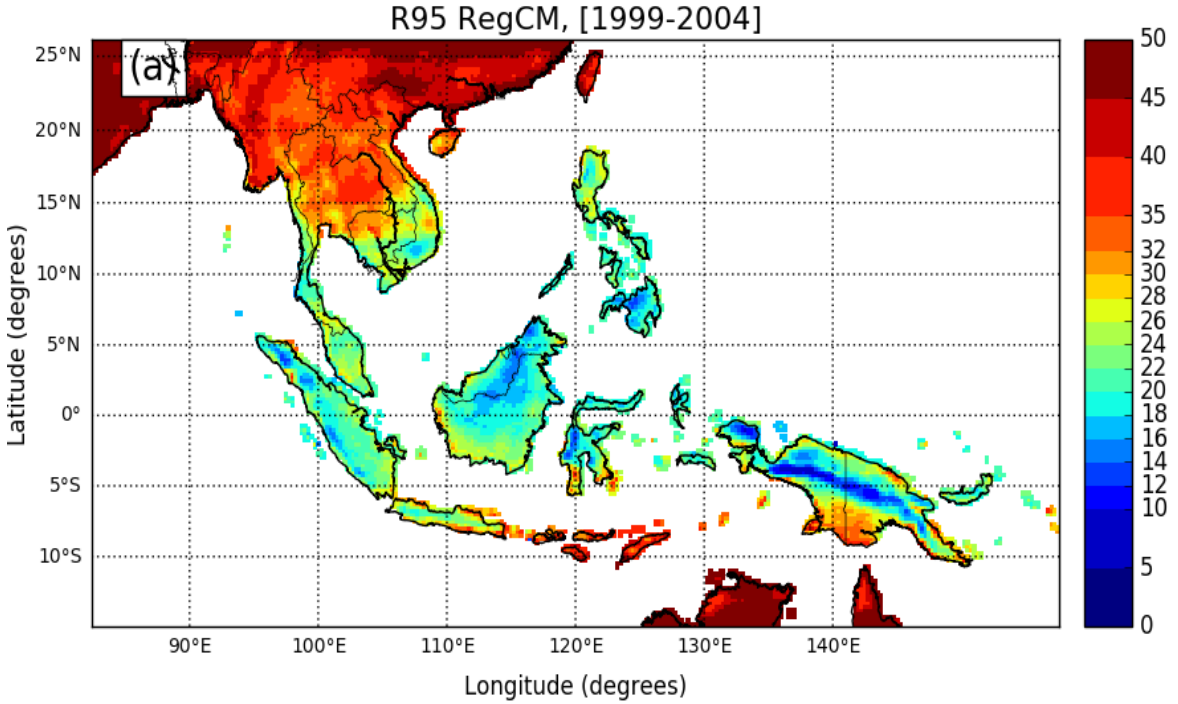


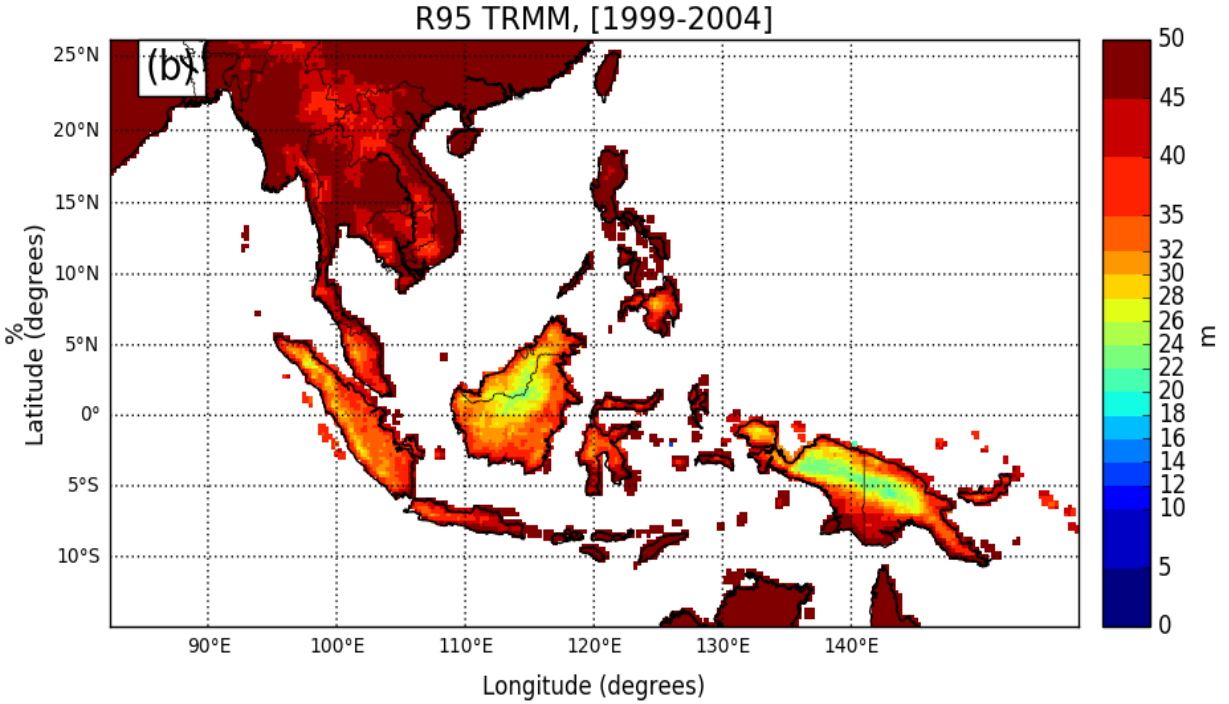

R95 TRMM, [1999-2004]
(b)
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
Latitude (degrees)
90°E
100°E
110°E
120°E
130°E
140°E
Longitude (degrees)
50
45
40
35
32
30
28
26
24
22
20
18
16
14
12
10
5
0
m


STD
20°N
15°N
10°N
5°N
0°
5°S
10°S
Latitude (degrees)
90°E
100°E
110°E
120°E
130°E
140°E
45
40
35
32
30
28
26
24
22
20
18
16
14
12
10
5
0


R95 RegCM, [1999-2004]
(a)
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
Latitude (degrees)
90°E
100°E
110°E
120°E
130°E
140°E
Longitude (degrees)
50
45
40
35
32
30
28
26
24
22
20
18
16
14
12
10
5
0

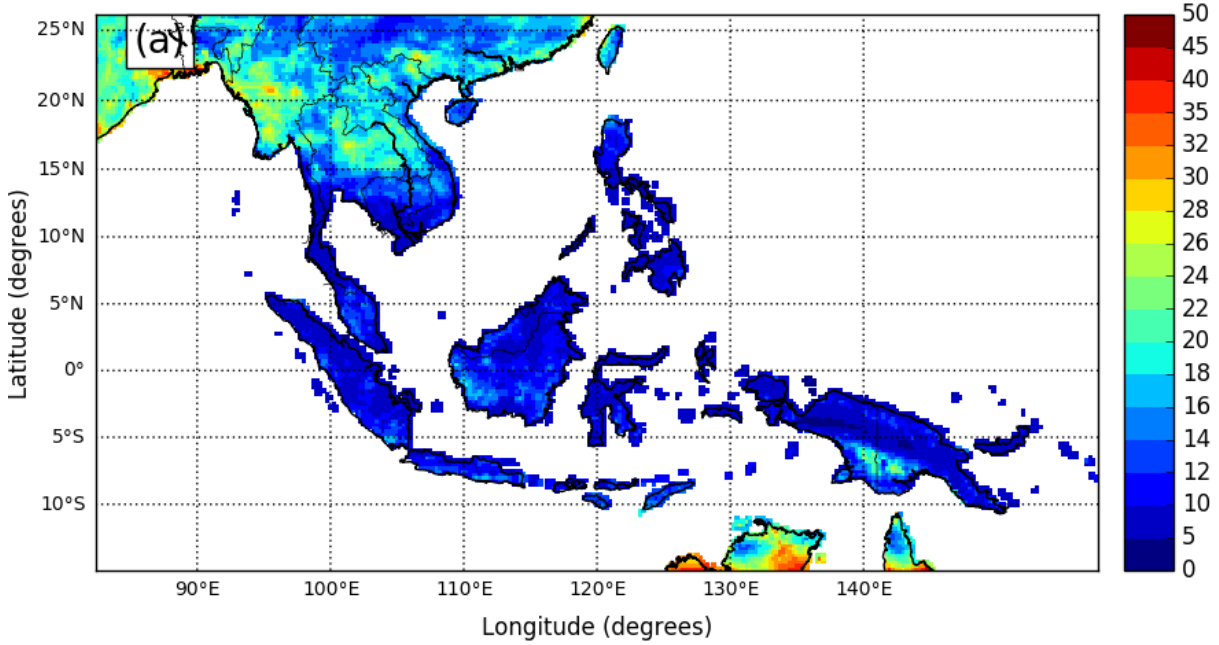
Precipitation percent due to the R95p days



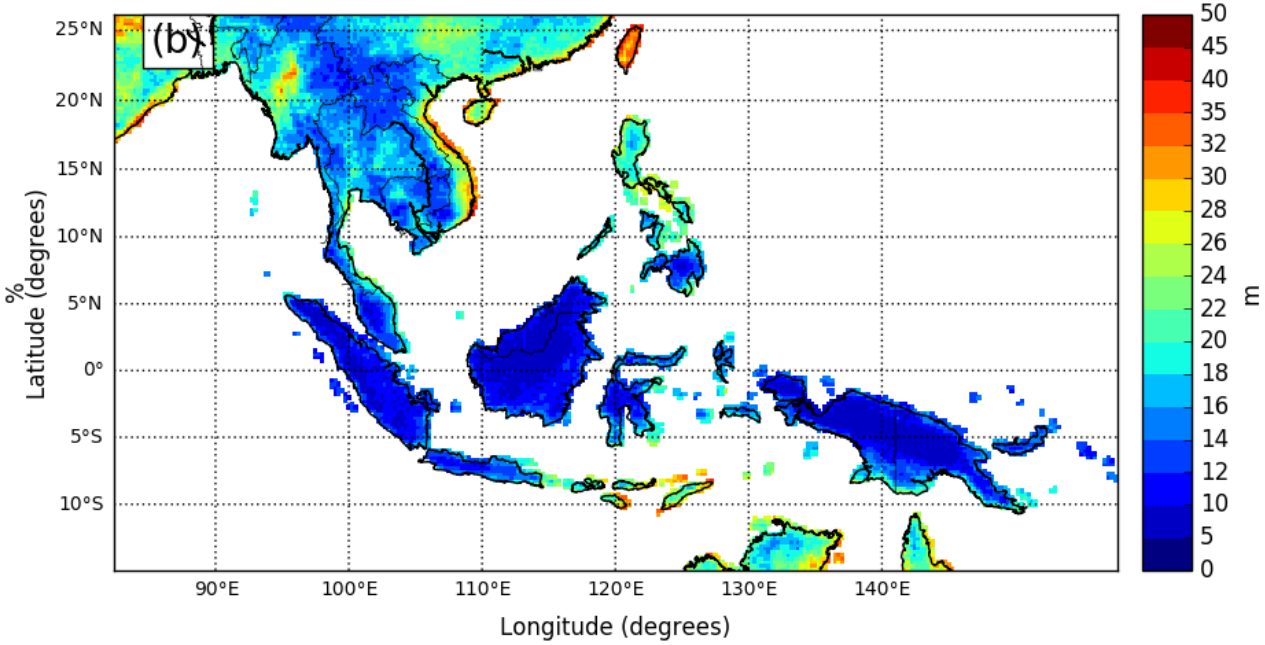


Precipitation percent due to the R99p days

R99 RegCM 1999 - 2004

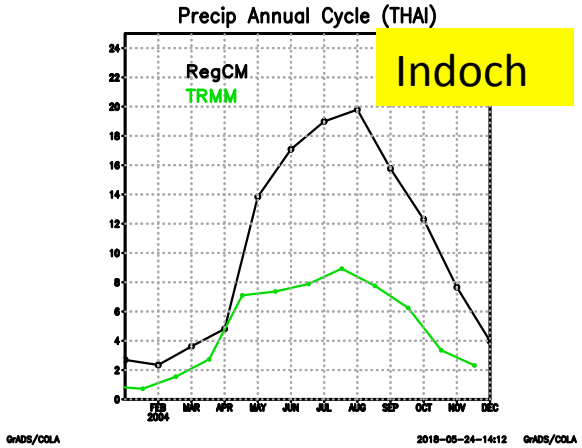


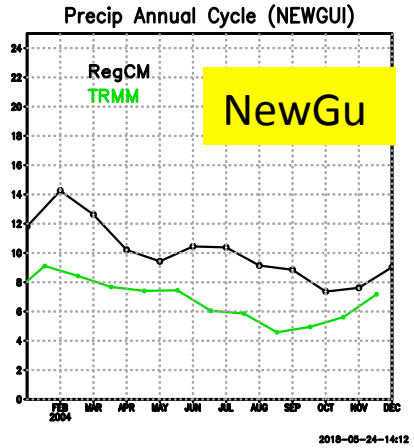
R99 TRMM 1999 - 2004

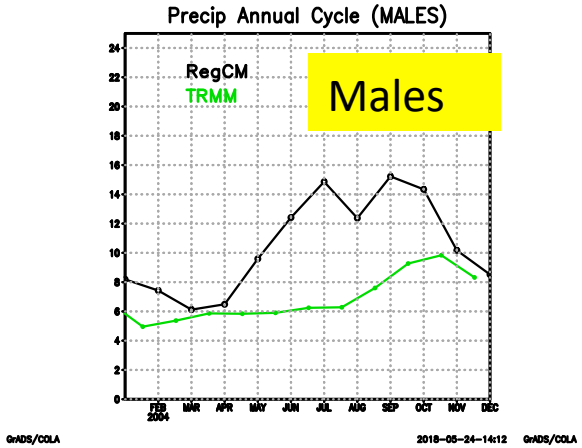


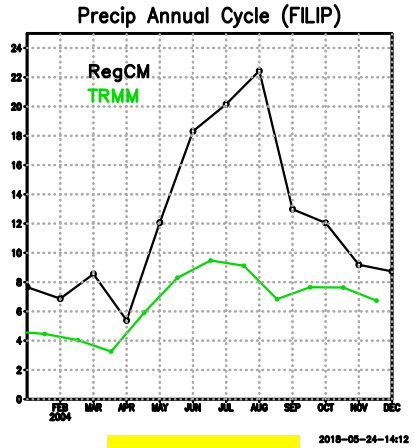
Annual Cycle - Period : 1999-2004

TEST: T9

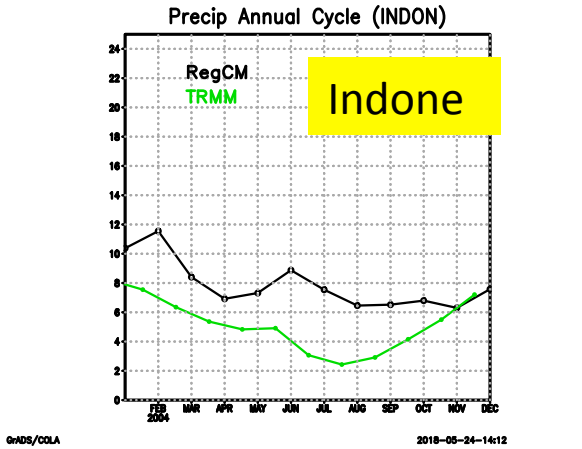


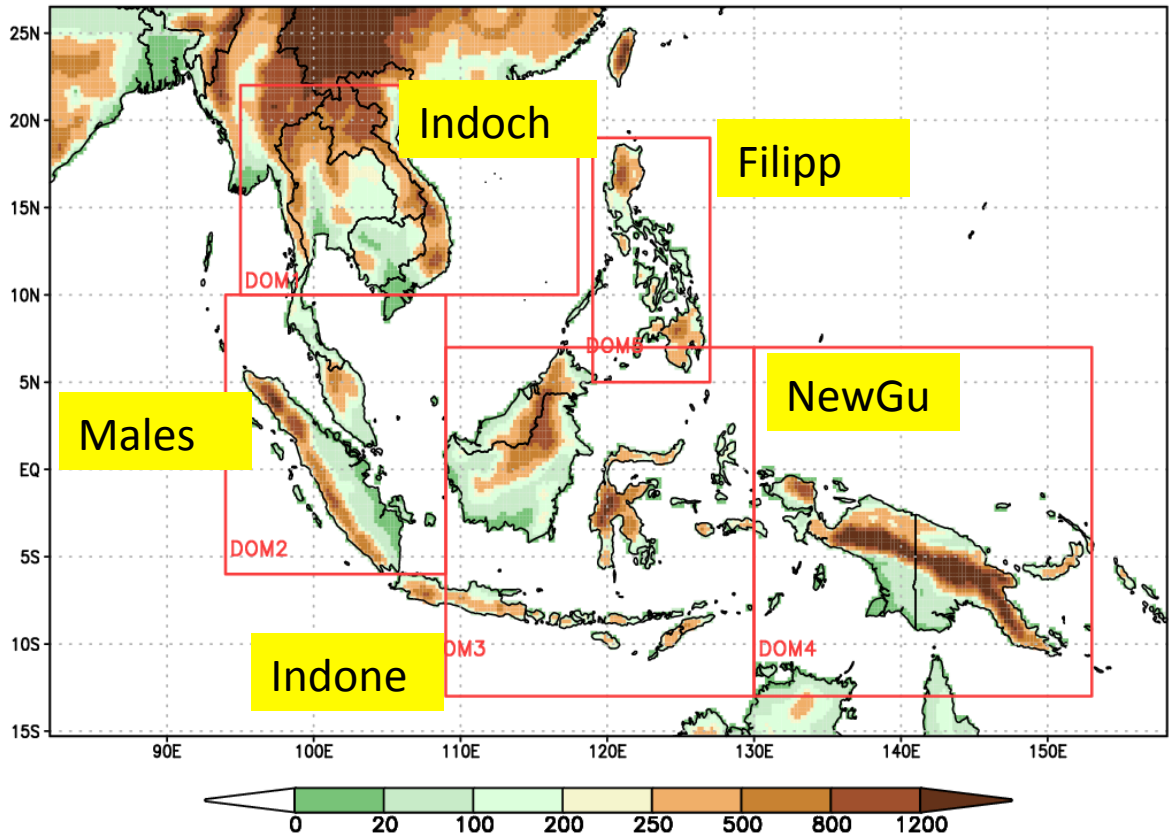






Filipp





The model reproduce well the phase of the annual cycle but confirm the wet bias

Conclusion:

Preliminary results about the calibration of RegCMV4.7.0 over South East Asia, with orizontal resolution of 25 Km, using TiedTke convective parameterization scheme, was presented.

We tuned two parameter (**Entrpen_lnd**, **Entrpen_oc**) of Tiedke scheme for optimization of performance over South East Asia domain.

Results indicates that precipitation is sensitive to this parameter

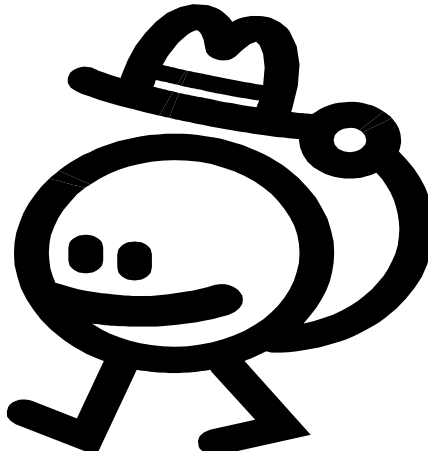
In particular:

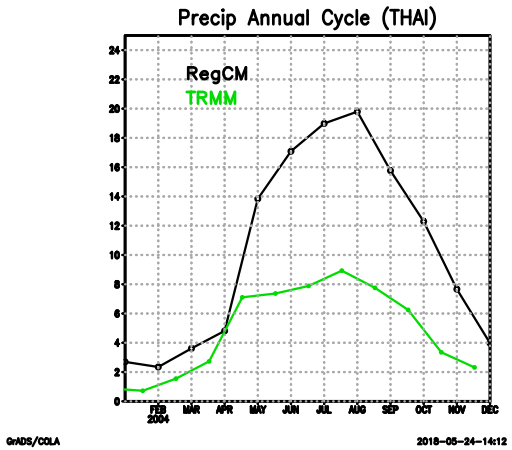
An increase of Entrpen_lnd parameter determines increment of rainfall over land

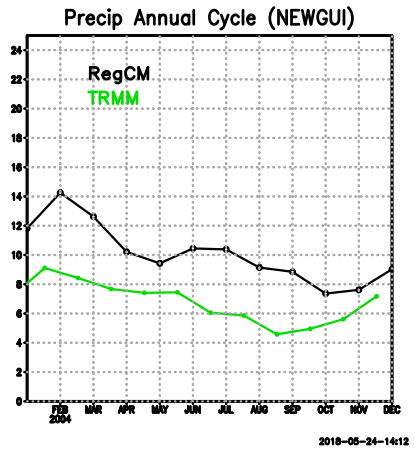
An increase of **Entrpen_oc** parameter determines a reduction of rainfall over ocean

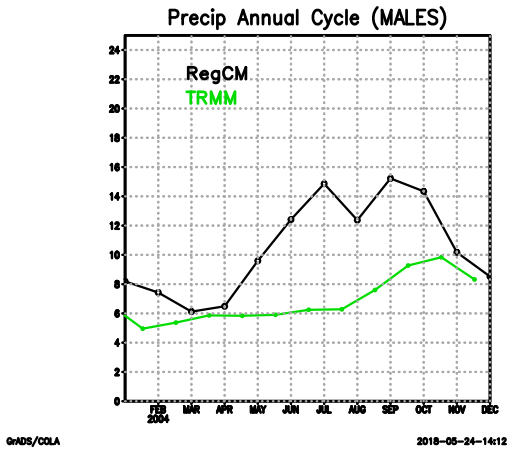
The preliminary character results of current study should be considered. The simulation with the identified parameters is not perfect and still exhibits a wet bias

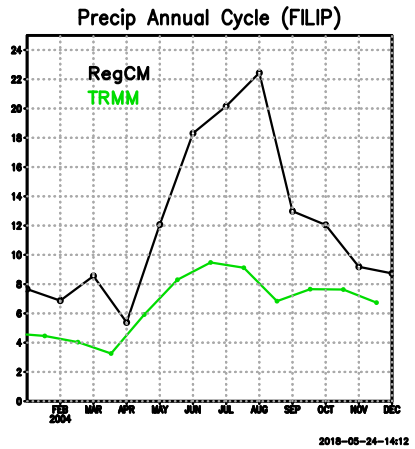
THANK YOU FOR YOUR ATTENTION

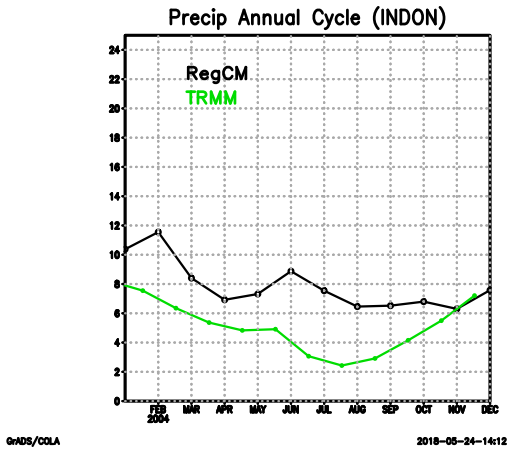


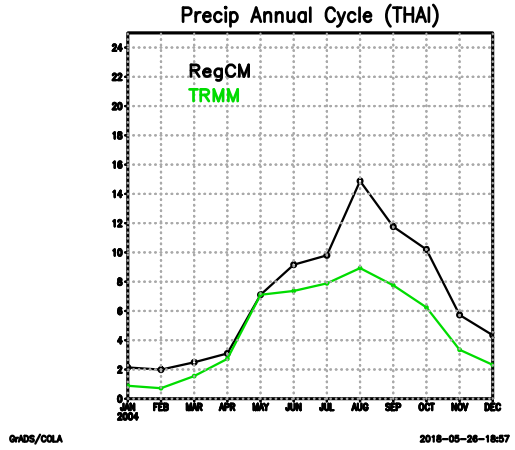

Precip Annual Cycle (THAI)
RegCM
TRMM
GrADS/COLA
2018-05-24-14:12

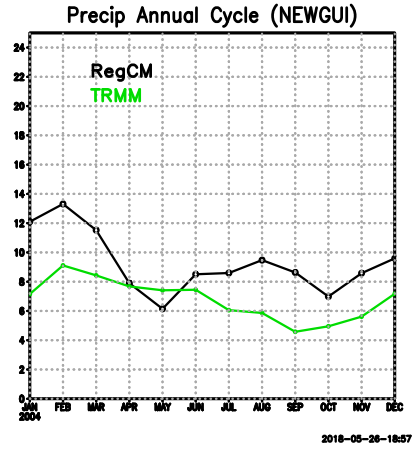

Precip Annual Cycle (NEWGUI)
RegCM
TRMM
GrADS/COLA
2018-05-24-14:12

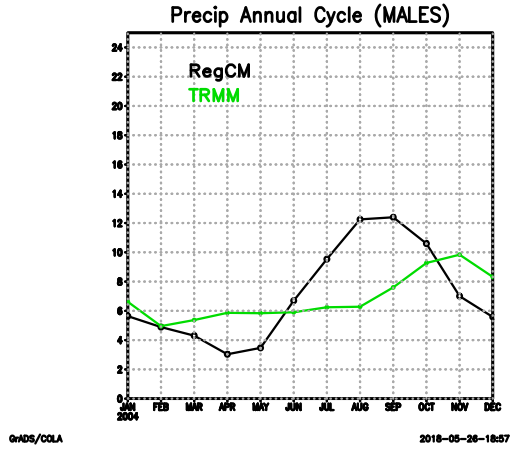

Precip Annual Cycle (MALES)
RegCM
TRMM
GrADS/COLA
2018-05-24-14:12

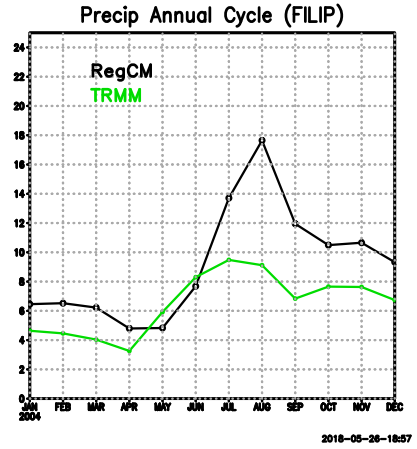

Precip Annual Cycle (FILIP)
RegCM
TRMM
GrADS/COLA
2018-05-24-14:12

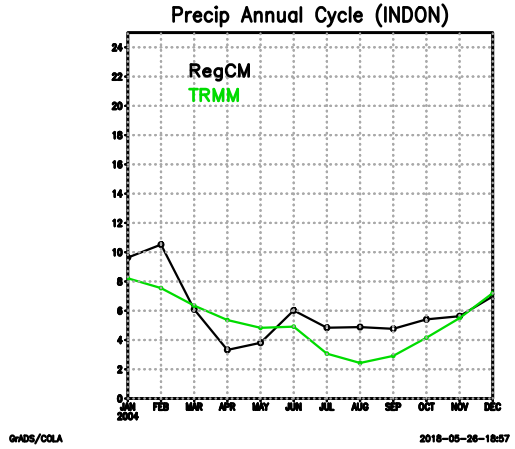

Precip Annual Cycle (INDON)
RegCM
TRMM
GrADS/COLA
2018-05-24-14:12


Precip Annual Cycle (THAI)
RegCM
TRMM
GrADS/COLA
2018-05-26-18:57


Precip Annual Cycle (NEWGUI)
RegCM
TRMM
GrADS/COLA
2018-05-26-18:57


Precip Annual Cycle (MALES)
RegCM
TRMM
GrADS/COLA
2018-05-26-18:57


Precip Annual Cycle (FILIP)
RegCM
TRMM
GrADS/COLA
2018-05-26-18:57


Precip Annual Cycle (INDON)
RegCM
TRMM
GrADS/COLA
2018-05-26-18:57

std