Impact of cloud-convection parameterization on improving systematic bias of CFSv2

P. Mukhopadhyay

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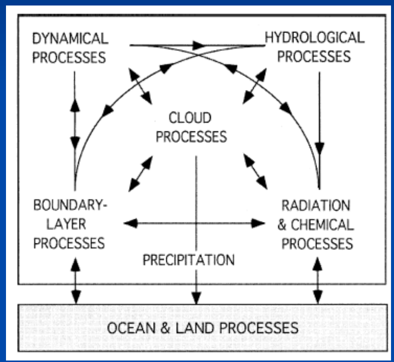
Outline

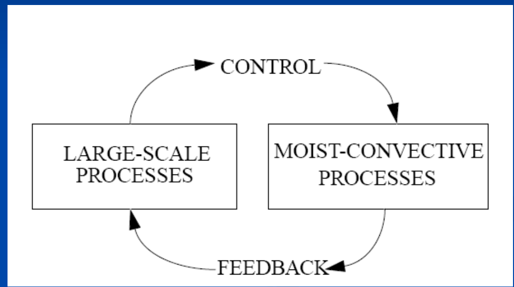
- Paradigm of Conventional Parameterization
- Issues of CFSv2 biases related to convection
- Recent New approaches in dealing convection parameterization in CFSv2
- Summary

Issues of cumulus Parameterization

The Cumulus Parameterization Problem: Past, Present, and Future
By Akio Arakawa, JOC, 2004, Arakawa et al. 2011, Arakawa and Wu 2013, Wu and Arakawa 2014

- "Major practical and conceptual problems in the conventional approach of cumulus parameterization, includes inappropriate separations of processes and scales".





$$\sum_{j=1}^{N} K_{ij} \cdot M_{Bj} + F_i = 0$$

K_{ij} = effect of cloud j on cloud i,

F_i = environmental forcing for

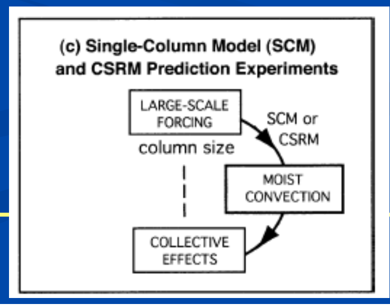
cloud i

M_{Bj} = mass flux at base of cloud j

Task of Conv. Param

To calculate the collective effects of an ensemble of convective clouds in a model column

$$Q_{1C} \equiv Q_1 - Q_R \equiv L(\bar{c} - \bar{e}) - \frac{\partial \overline{\omega' s'}}{\partial p}$$



Issues of Convective Parameterization:

- Since Arakawa, 2004, Arakawa et al. 2011, Arakawa and Wu 2013: Mainly discussed how to improve the sub-grid scale variability and unify/transform convection parameterization to unified Cloud parameterization (fractional area covered by convective updrafts in the grid cell σ: Normally σ<<1)

- As a consequence of these debates, Grell-Freitas schem evolved (Grell-Freitas, 2014) [parameterizes the convection when Δx~50 km and resolves when Δx~3km]

- A Cumulus Parameterization with State-Dependent Entrainment Rate by Chikira and Sugiyama (2010, JAS): The cumulus ensemble is spectrally represented according to the updraft velocity at cloud base. Cloud-base mass flux is determined with prognostic convective kinetic energy closure and the lateral entrainment rate vertically varies depending on buoyancy and updraft velocity; (AGU 2015, Dazlich, Moorthi and Randall, CPT)

Quantifying the limits of convective parameterizations by Jones and Randall (JGR, 2011)

Revisit the QE approximation: Quasi-equilibrium (QE) closure is an approximation that is expected to apply to a large ensemble of clouds under slowly changing weather conditions. It breaks down under rapidly changing conditions or when the domain size is too small to provide an adequate sample of the cloud field.

With time-varying forcing, a considerable range of responses is found. As expected, the more slowly the forcing varies, the better the response is approximated by QE. Errors become large when the period of the forcing is less than 30 h, suggesting that the diurnal cycle cannot be accurately simulated with a QE closure.

One of the conclusion: Cloud parameterization will be needed for the foreseeable future, because cloud resolving models will continue to be too computationally expensive with large domain sizes.

Referring to Bjerkness's concern about small scale processes impacting the representation of frictional stress; Arakawa mentioned "We see that similar problems exist for all microphysical processes. The progress of our ability to represent cloud microphysical processes in climate models has been especially slow (Randall et al., 2003)

Laura Fowler et al. (2016, June, JAS) : Analyzing the Grell–Freitas Convection Scheme from Hydrostatic to Nonhydrostatic Scales within a Global Model:

Implemented GF in MPAS where Δx~50 km to 3 km.

In addition MPAS has the cloud microphysics parameterization of Hong and Lim (2006; WSM6), the KF parameterization of convection (Kain 2004, Kain and Fritsch 1993), the Tiedtke (TD; Tiedtke 1989) the Rapid Radiative TransferModel forGCMs described by Mlawer et al. (1997) and Iacono et al. (2000).

Stochastic Approach

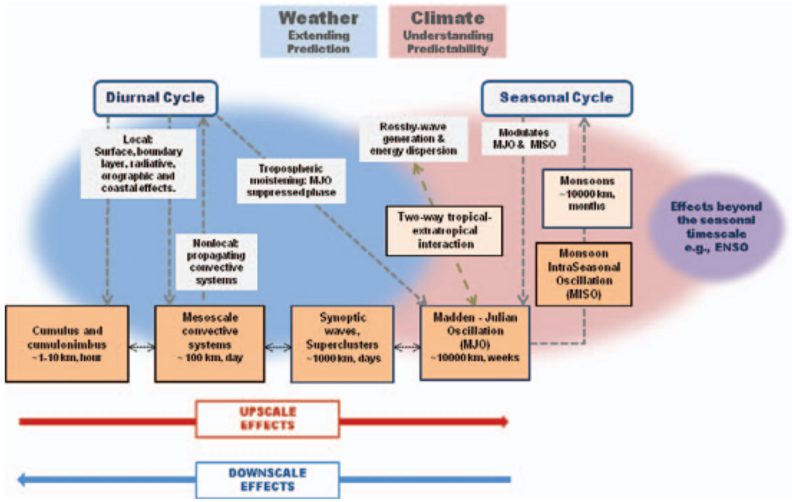
Stochastic Parameterization: Towards a new view of Weather and Climate Models by Judith Berner et al. 2015 and J. Dave Neelin etal. Phil. Trans. Roy. Soc.

It is our conviction, that basing stochastic parameterizations on sound mathematical and statistical concepts will lead to substantial improvements in our understanding of the Earth system as well as increased predictive capability in next generation weather and climate models.

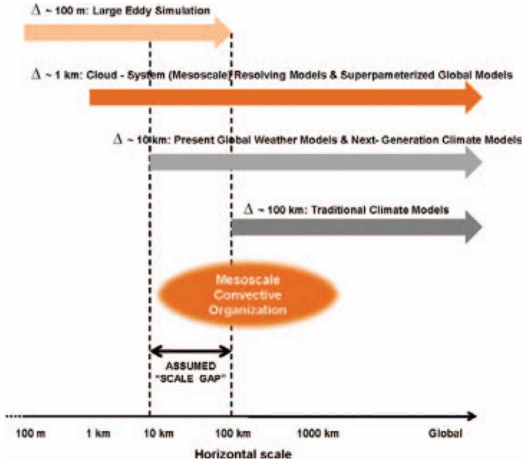
Stochastic Parameterization in 3D GCM/CGCM

Peters et al. ECHAM6 (Under Rev), Rochetin et al. LMDZ GCM (2014), Dorrestijn et al. (2016), CFS with SMCM (Under prep)

Moncrieff et al, 2012, BAMS



Scientific Basis of the study



The organized systems exhibit hierarchical coherence: (i) mesoscale systems consist of families of cumulonimbus; (ii) cumulonimbus and MCS are embedded in synoptic waves; and (iii) the MJO/MISO is an envelope of cumulonimbus, MCS, and superclusters.

The upscale effects of convective organization are not represented in traditional climate models.

The mean atmospheric state exerts a strong downscale control on convective structure, frequency, and variability. Mesoscale convective organization bridges the scale gap assumed in traditional convective parameterization.

(i) SCM/CRM resolves cumulus, cumulonimbus, mesoscale circulations, but the computational domain is small (~100 km) and simulations short (~1 day).

(ii) Two-dimensional CSRMs in superparameterized global models permit MCS-type organization and mesoscale dynamics.

(iii) High-resolution global numerical prediction models may crudely represent large MCS (superclusters). (iv) MCS, and other mesoscale dynamical systems, are absent from traditional climate models—organized convection is not parameterized.

ISSUES

- CFSv2 T126 shows colder Tropospheric temperature bias and colder SST bias

- CFSv2 T382 shows warmer Tropospheric temperature and warmer SST bias

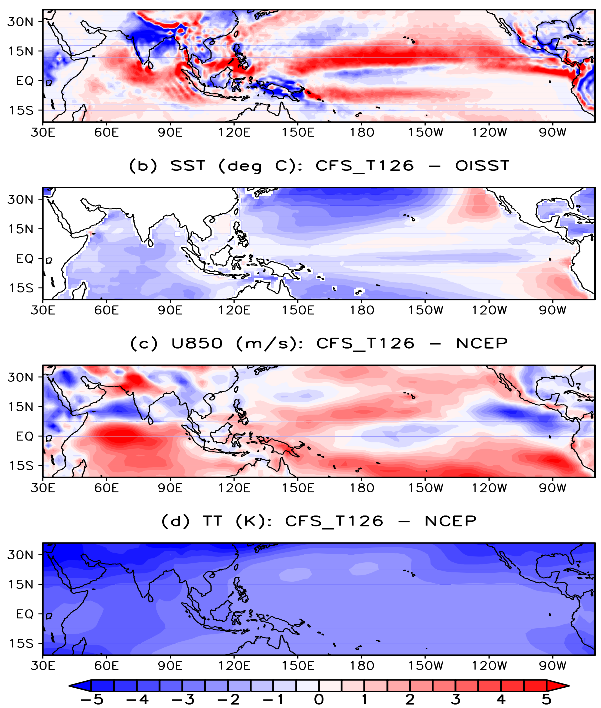
Inspite of contrasting bias, the rainfall bias in both the models are similar

- CFSv2T126 & CFSv2 T382 both produce too much frequency of lighter rainfall and shows dry bias over Indian land mass but northward propagation is reasonable in both.

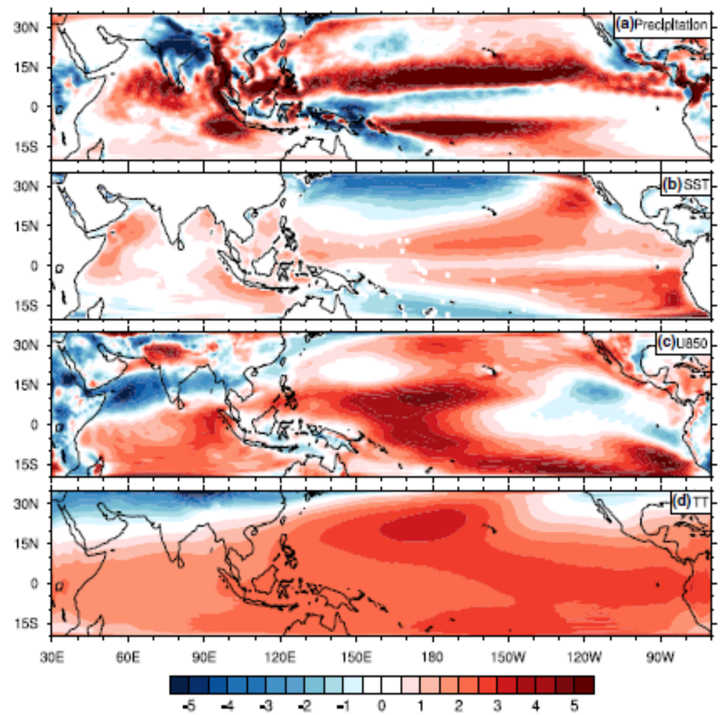
- CFSv2T126 & CFSv2 T382 both underestimates synoptic variance and overestimates ISO variance

- Diurnal Convective lifecycle is equally incorrect in CFSv2T126 & CFSv2 T382. (Deep convection is lacking)

CFSv2 T126 bias



CFSv2 T382 bias

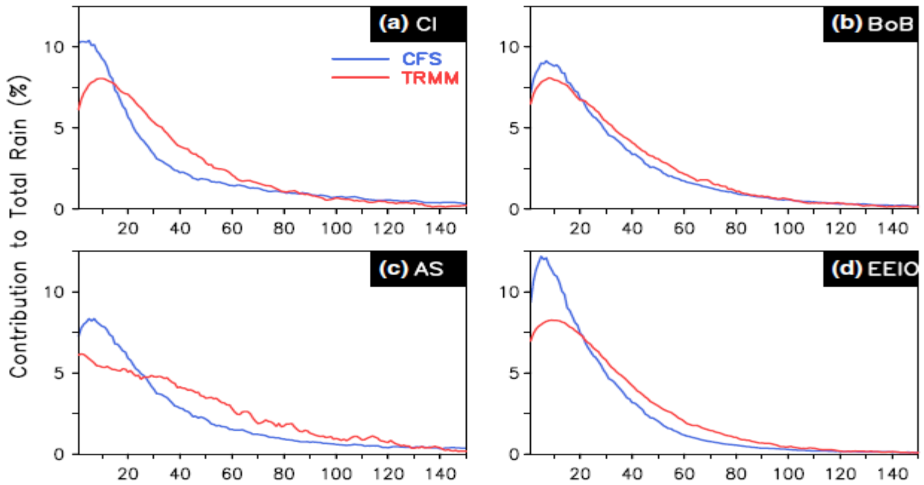


Seasonal mean bias in a) precipitation (mm day−1), b) SST (°C), c) zonal wind at 850 hPa (m s −1) and d) tropospheric temperature (TT, K) relative to TRMM, TMI and CFSR respectively

Abhik et al. Cli. Dyn. 2015, DOI 10.1007/s00382-015-2769-9

Fig. 4 Probability distribution function (PDF) of daily rainfall (mm day^{-1}) during all JJAS seasons with a bin width of 5 mm day^{-1} in percentage over a central India (CI), **b** Bay of Bengal (BoB), **c** Arabian Sea (AS) and eastern equatorial Indian Ocean (EEIO). The regions are marked by *white boxes* in Fig. 3b

CFSv2T382



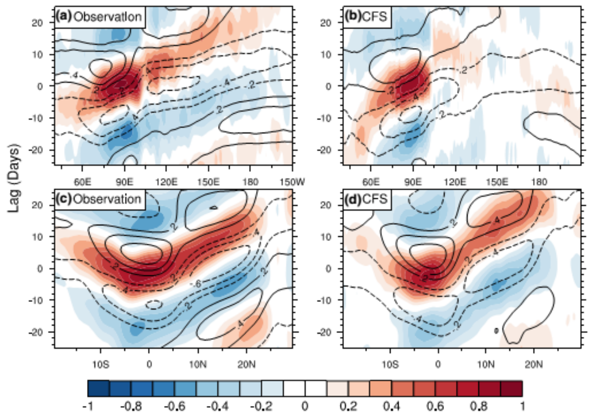
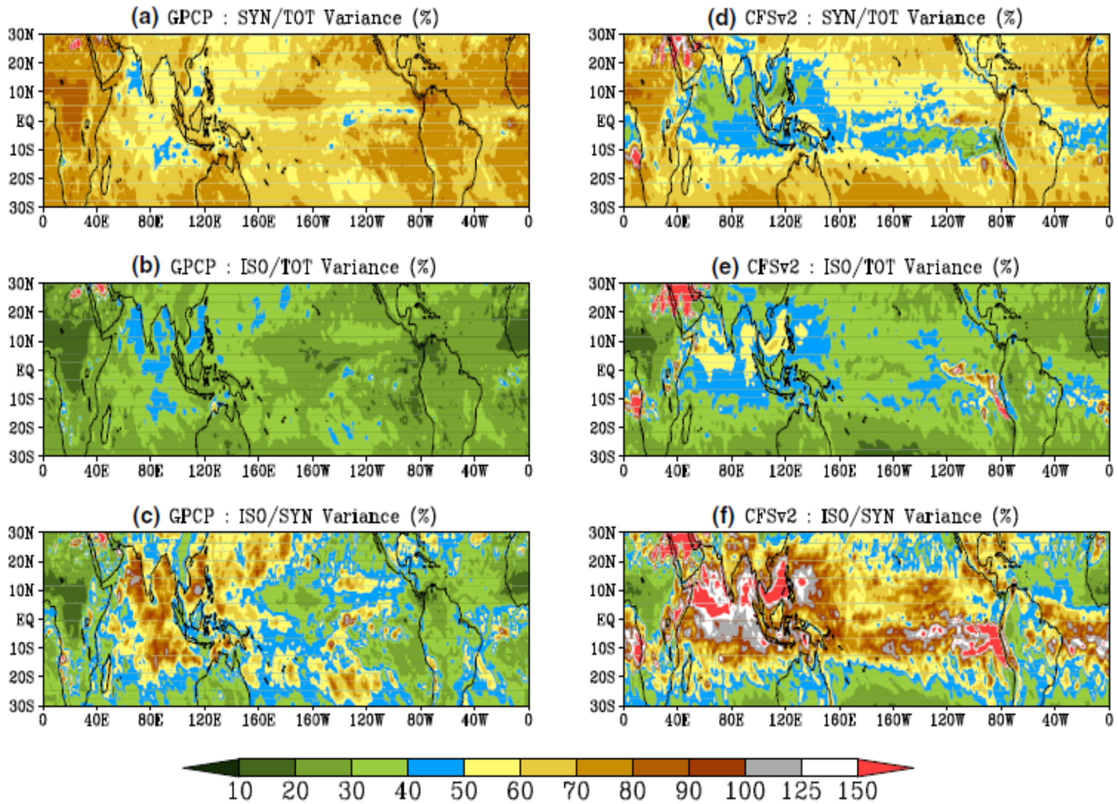


Fig. 8 **a**, **b** Longitude versus lag correlation and **c**, **d** latitude versus lag correlation of 20–100-day filtered precipitation (*shaded*) and U_{850} (*contour*) with base 20–100-day filtered precipitation time series over EEIO (10°S–5°N, 75°–100°E) for observation and CFS T382. For longitude-lag (latitude-lag) plot data are averaged between 70°E and 90°E (10°S and 10°N)

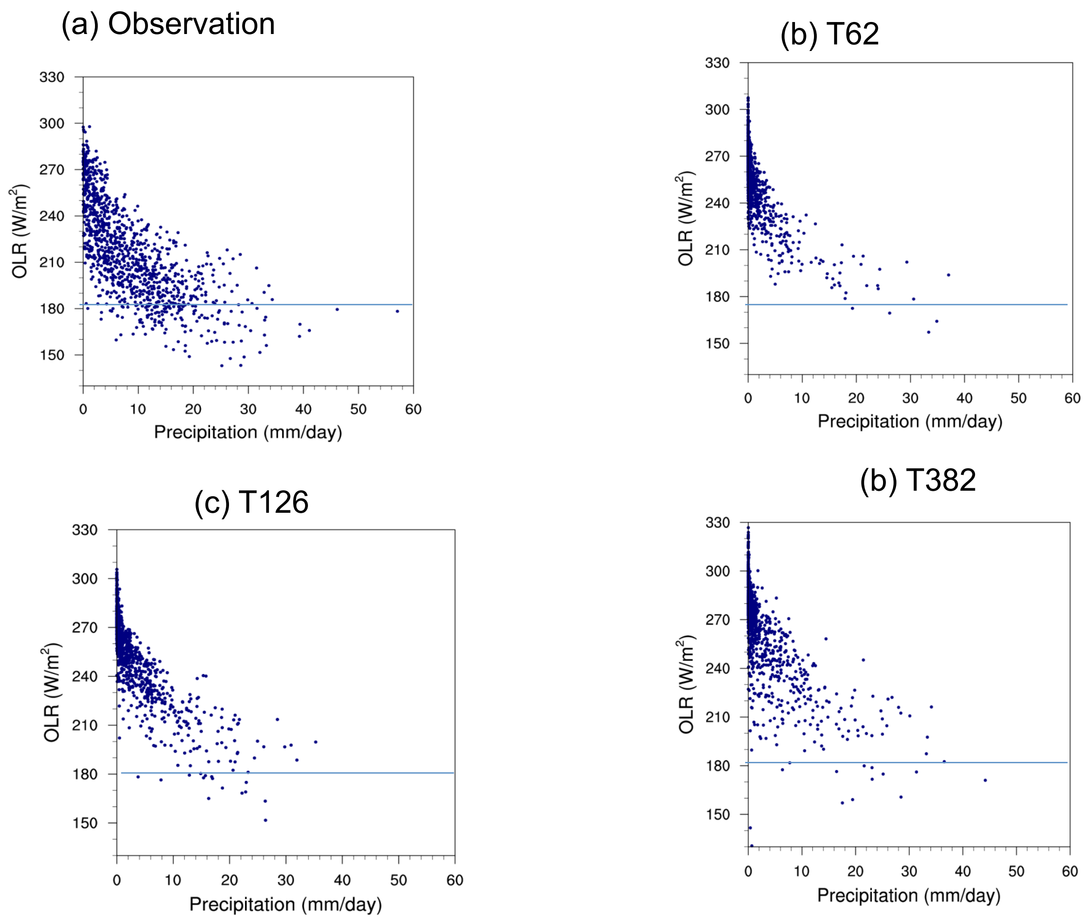
Abhik et al. 2015



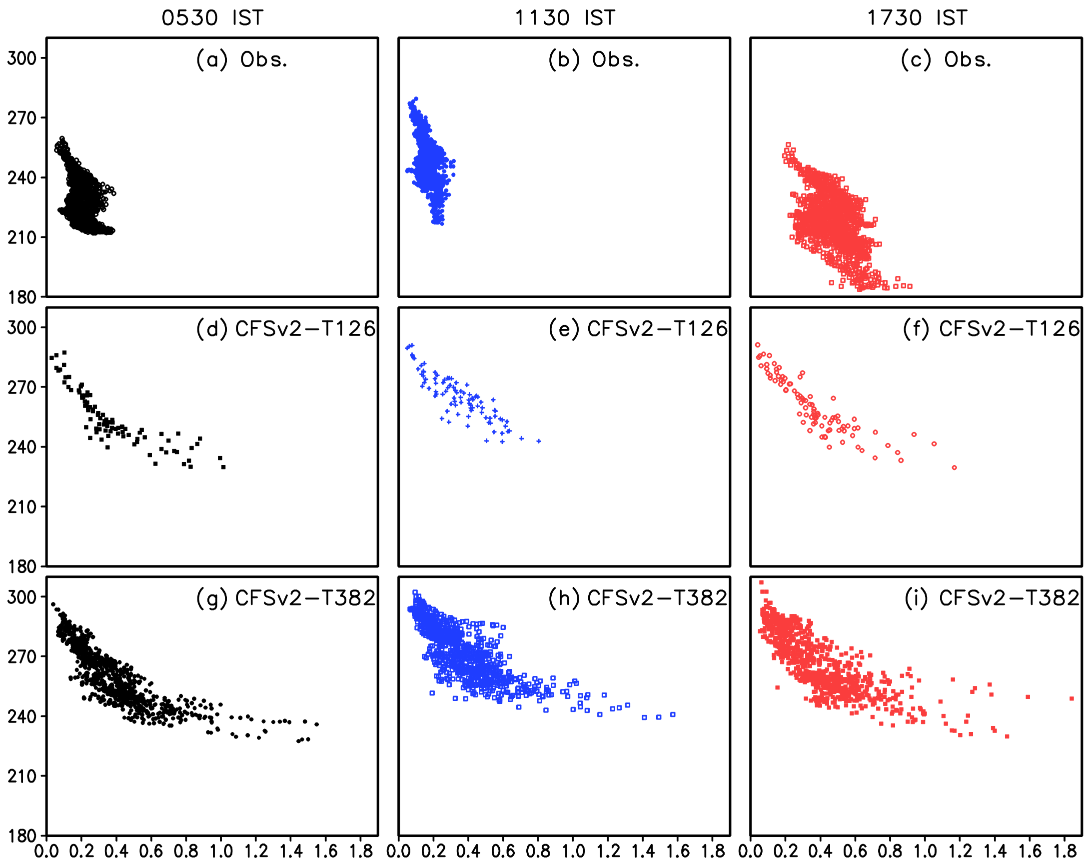
Goswami et al. 2014

CFSV2: Less synoptic variance and more ISO variance

a) Ratio of synoptic scale (2–10 day bandpassed) variance to total variance in GPCP; b) ratio of ISO scale (10–90 day bandpassed) variance to total variance in GPCP; c) ratio of ISO scale variance to synoptic scale variance in GPCP; d) ratio of synoptic scale variance to total variance inCFSv2. e) Ratio of ISO scale variance to total variance in CFSv2; f) ratio of ISO scale variance to synoptic scale variance in CFSv2 (the values are given in



Scatter plot of OLR vs Precipitation for JJAS monsoon zone India. OLR is taken from NOAA and precipitation from TRMM

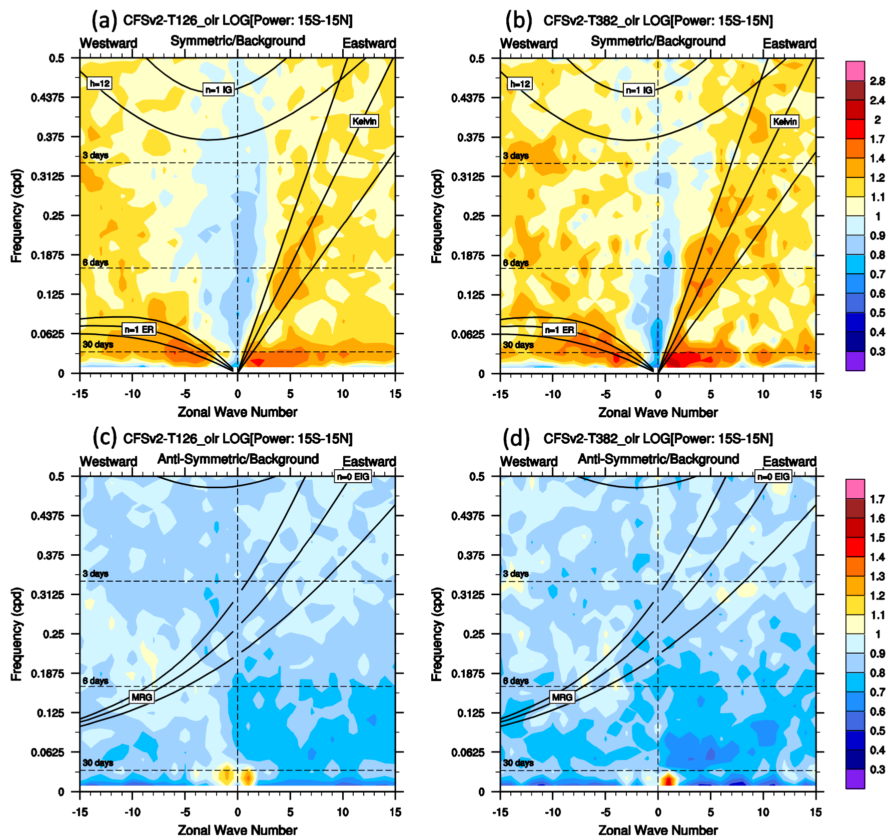


Scatter plot of OLR vs rainrate

Both the model produces shallow convection throughout the day consistent with too much of lighter precipitation

Ganai et al. 2015

T126 T382



Space-Time spectra (Wheeler-Kiladis diagram [Wheeler and Kiladis, 1999]) of OLR showing the symmetric component for (a) CFSv2-T126, (b) CFSv2-T382 and the anti-symmetric component for (c) CFSv2-T126, (d) CFSv2-T382.

Goswami et al. 2015

CFSv2 T382

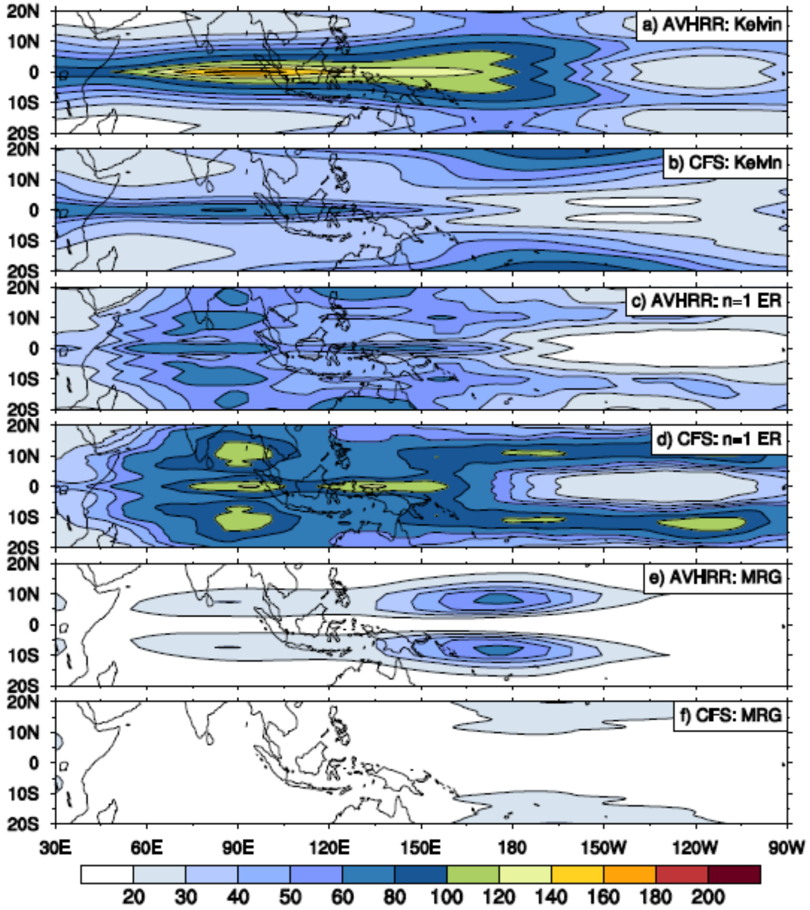


Fig. 13: Distribution of boreal summer time OLR variance ($W^2\ m^{-4}$) of (a), (b) Kelvin; (c), (d) n=1 ER and (e), (f) MRG waves for AVHRR and CFS.

Abhik et al., 2015

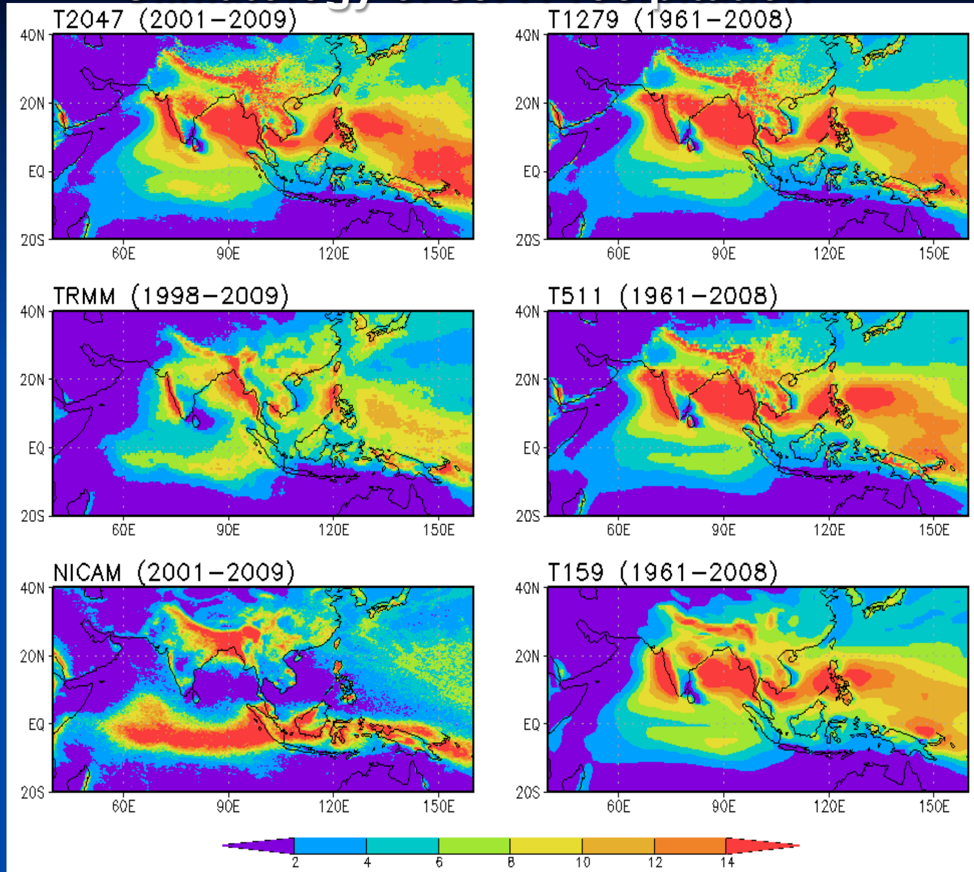
Climatology of JJA Precipitation

Kinter etal 2013

IFS T12047
10 km

TRMM
25km

NICAM
7 km



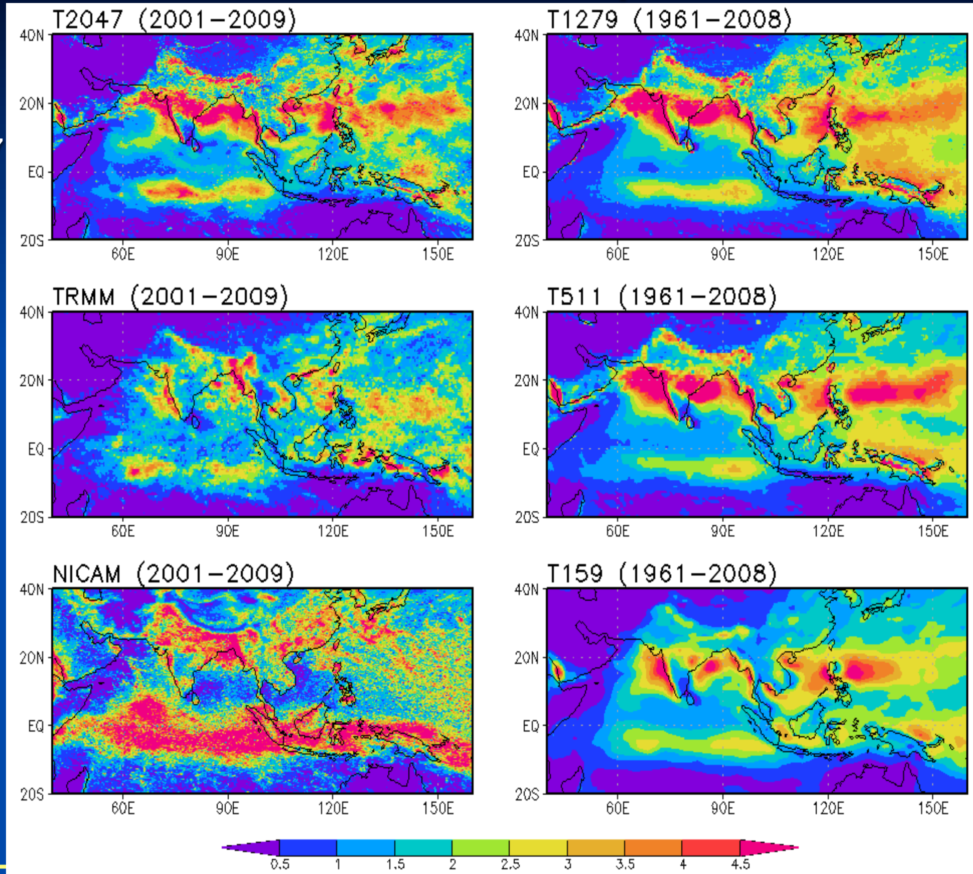
IFS T1279
15 km

IFS T1511
39km

IFS T1159
125 km

Adopted from Emilia Jin, Athena Workshop, ECMWF, 7-8 June

Standard Deviation of JJA Precipitation Anomalies



IFS T12047
10 km

IFS T1279
15 km

TRMM
25km

IFS T1511
39km

NICAM
7 km

IFS T1159
125 km

Adopted from Emilia Jin, Athena Workshop, ECMWF, 7-8 June

Arakawa and Wu, 2013

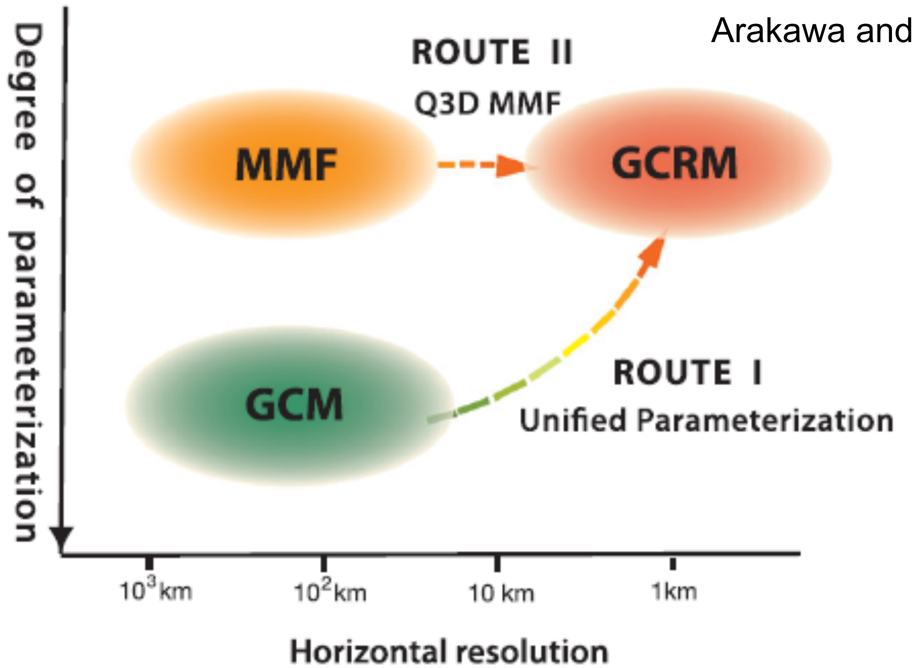


FIG. 3. Two routes for unifying the low- and high-resolution models.

Route II with 2D MMF: accomplished in IITM through development of SP-CFS

Attempts of Improving the biases of CFSv2 through Superparameterized CFS (SP-CFS)

Bidyut B. Goswami, R. P. M. Krishna, P. Mukhopadhyay, Marat Khairoutdinov, and B. N. Goswami, 2015: Simulation of the Indian Summer Monsoon in the Superparameterized Climate Forecast System Version 2: Preliminary Results. J. Climate, 28, 8988–9012

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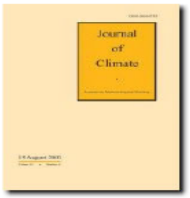

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Simulation of the Indian Summer Monsoon in the Superparameterized Climate Forecast System version 2: Preliminary Results

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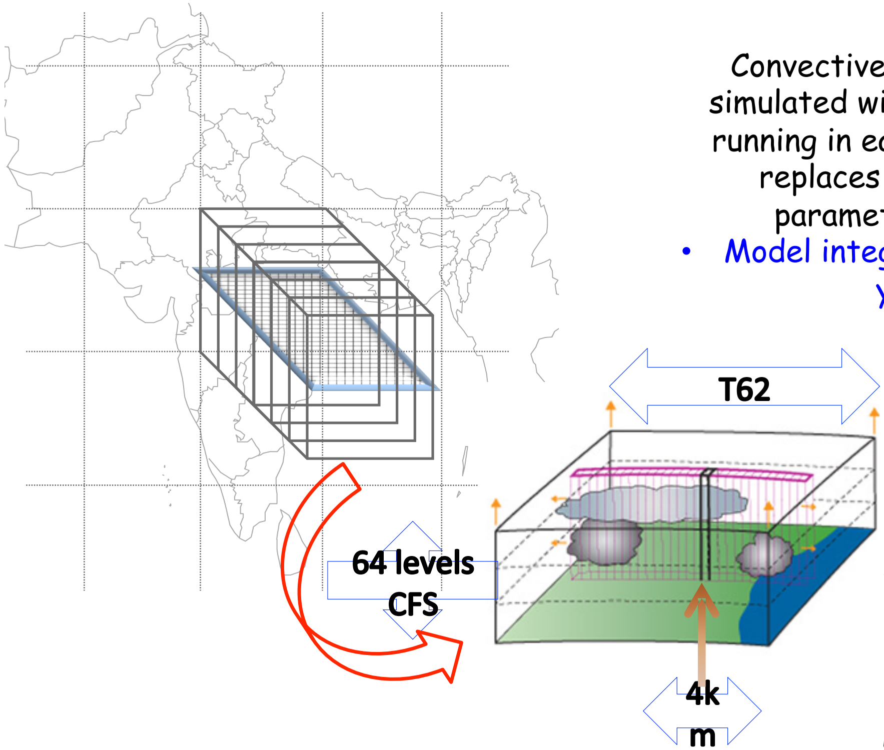
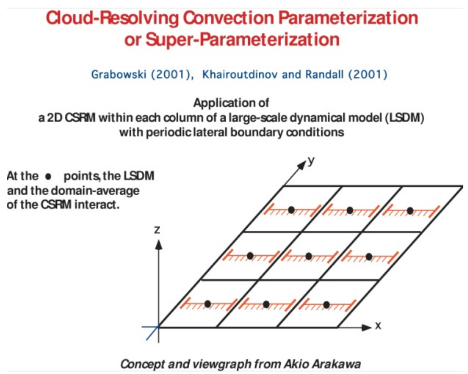
Superparameterized CFSv2-T62 (SPCFS) Analyses of 6.5 year free run

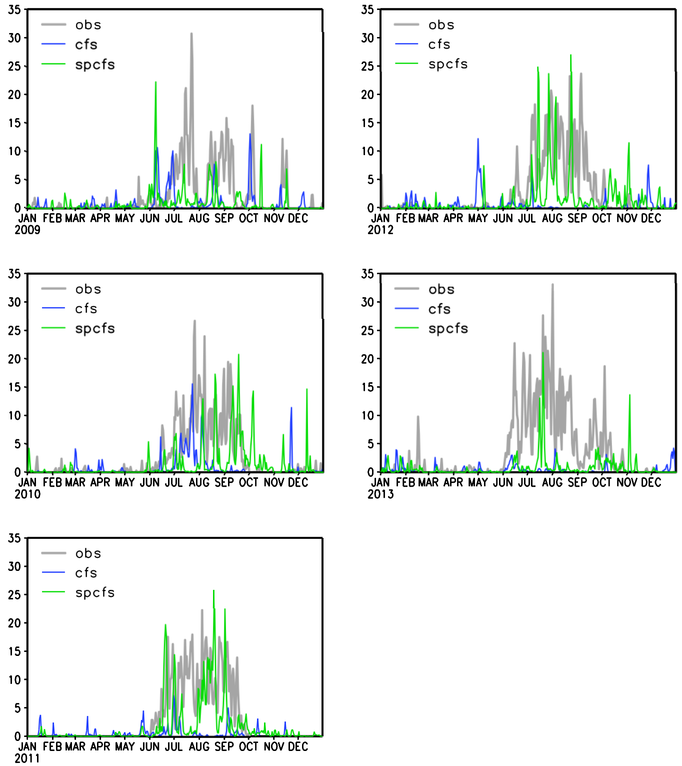


Convective tendencies are explicitly simulated with a **C**loud **R**esolving **M**odel running in each GCM grid column which replaces the traditional cumulus parameterization of the GCM.

- Model integrated for 6.5 years and five years are analyzed

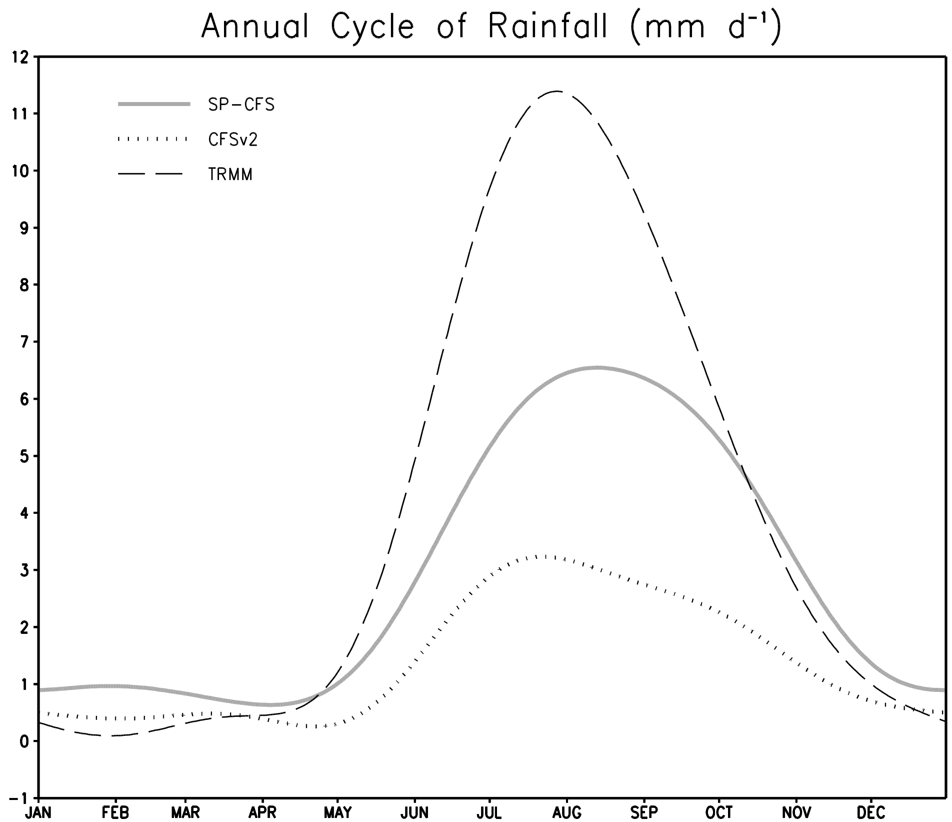


The rainfall is averaged over : 73-82E; 18-28N

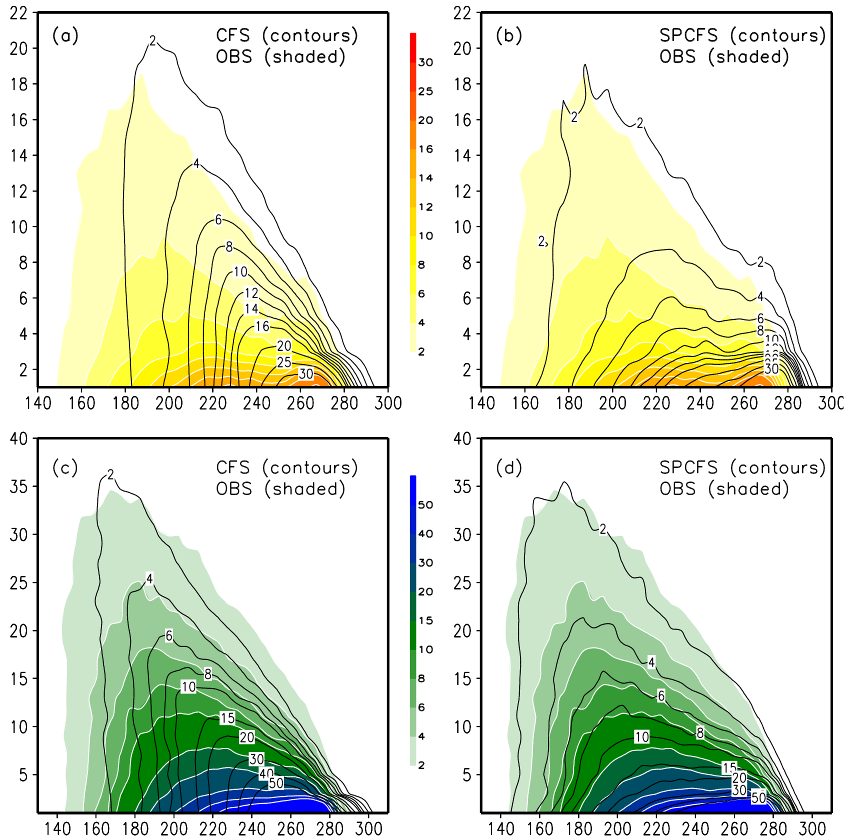


SP-CFS produces reasonable rain, CFS hardly rains

The Standard Dev for JJAS (5 years) :
IMD=5.01
SPCFS=4.33
CFS=1.8

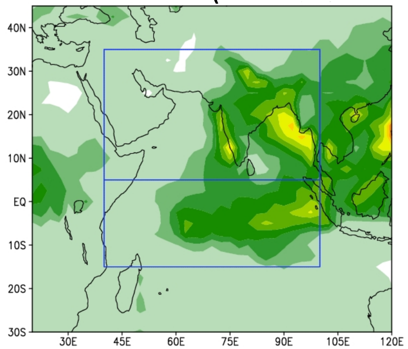


Annual cycle of the climatological mean rainfall (mm day^{-1}) averaged over the area: 15°N-25°N; 75°E-90°E.



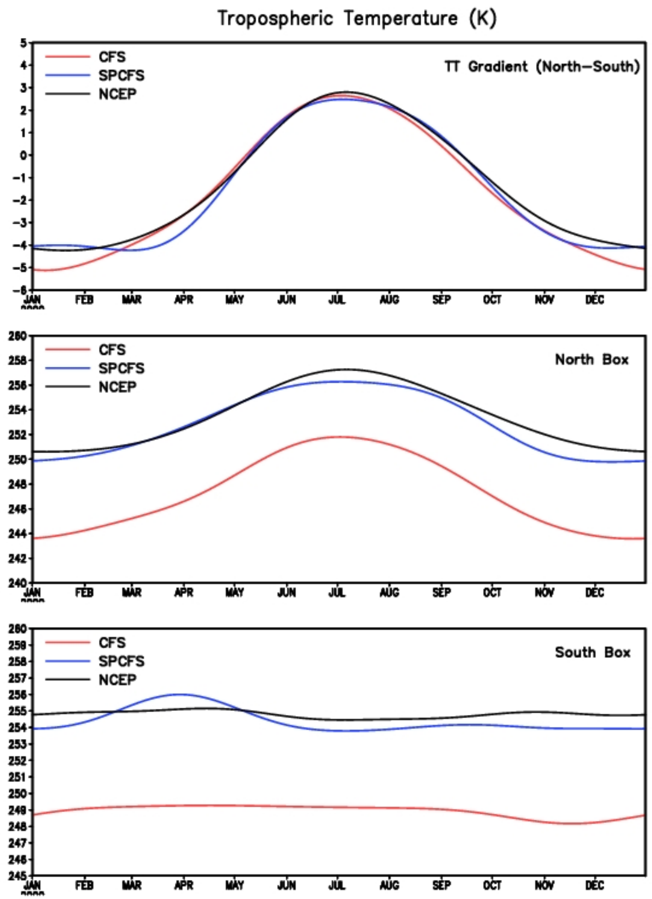
Joint distribution of rainfall (mm day^{-1}), along y-axis, and OLR (W m^{-2}), along x-axis, computed for each grid point, (a) & (b) over the monsoon domain bounded by 15°S-30°N and 50°E-110°E and (c) & (d) over the entire Tropics within 15°S-15°N, for the 5 boreal summers (JJAS). For observation we have taken TRMM rainfall and NOAA OLR. Model simulated values are contoured and overlaid on observation (in shading). The values are in multiples of 100.

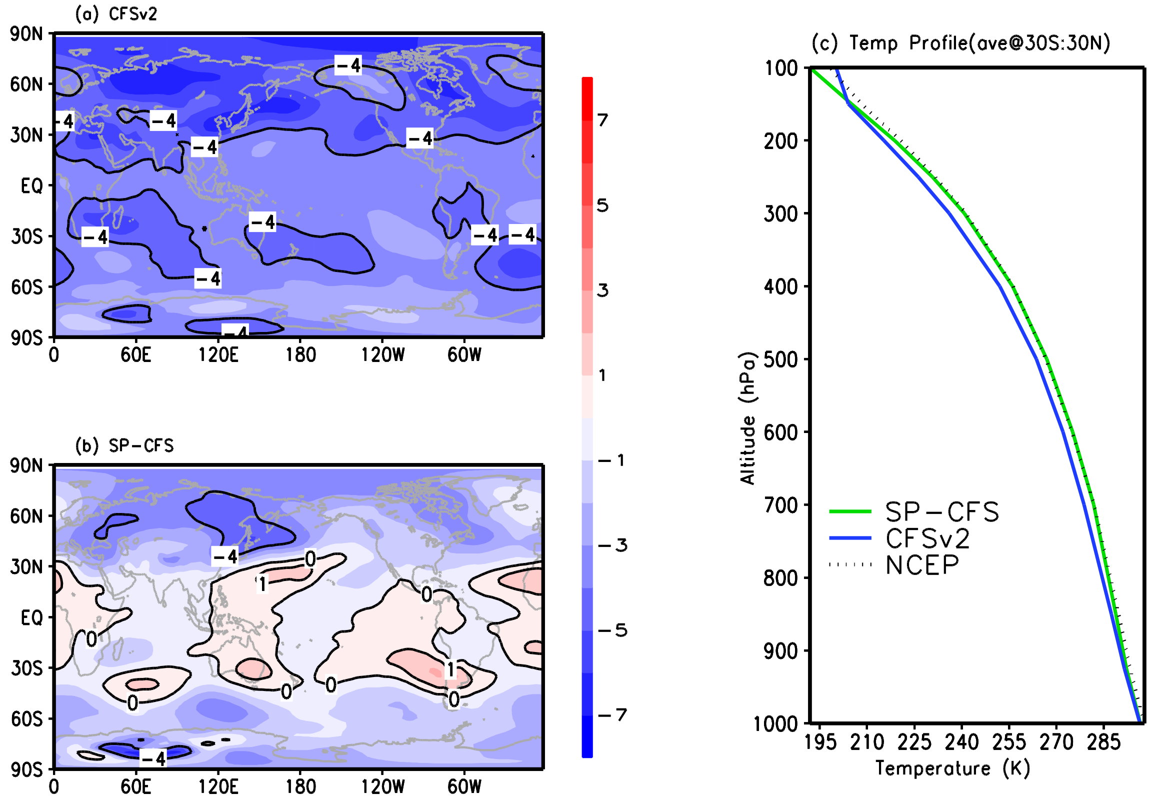
North box : 40-100E; 5-35N
South box : 40-100E;15S-5N
600-200hPa (Xavier et. al. 2007)



Improvement in tropospheric temperature bias is seen in TT gradient. Even though the Gradient looks reasonable in both CFS and SPCFS, but the bias is seen when we see the North and South boxes individually. The TT-gradient in a cooler background in CFS perhaps is consistent with reasonable circulation pattern (Fig-12 in manuscript) but deficient moisture (Fig-13b in manuscript) leading to dry monsoon.

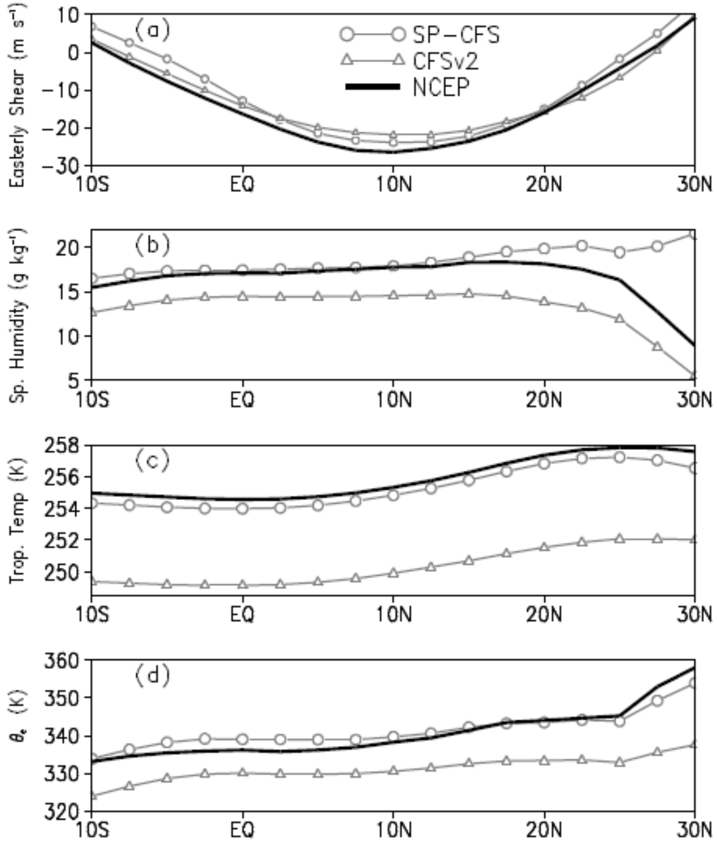
Right result due to wrong reason in CFSv2



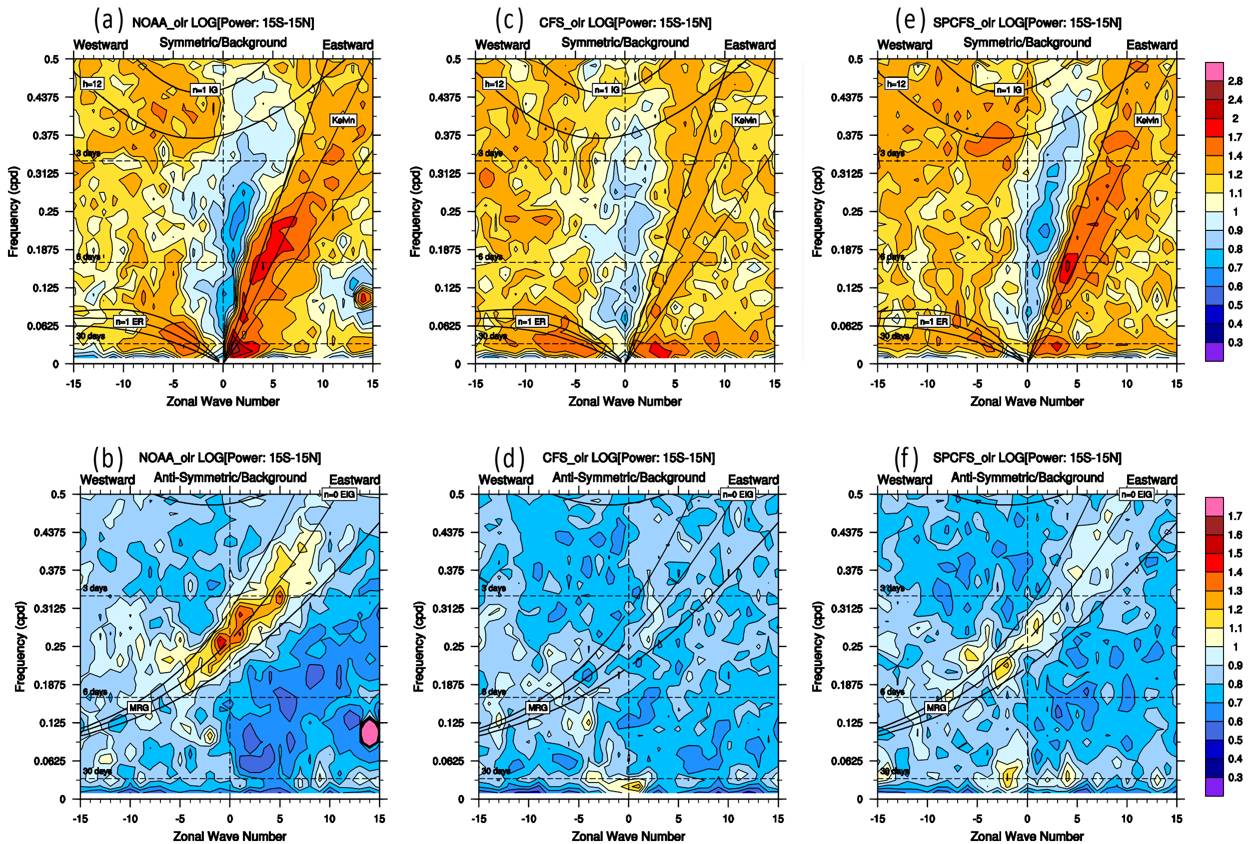


Boreal summer (JJAS) climatological Tropospheric temperature bias of (a) CFSv2 and (b) SP-CFS, relative to NCEP. (Averaged between 600hPa-300hPa). (c) Vertical profile of JJAS mean climatological temperature for tropics (30°S-30°N; 0°E-360°E).

Mean state in SP-CFS has improved due to improvement in moist instability and convective coupling as evident in the subsequent slides

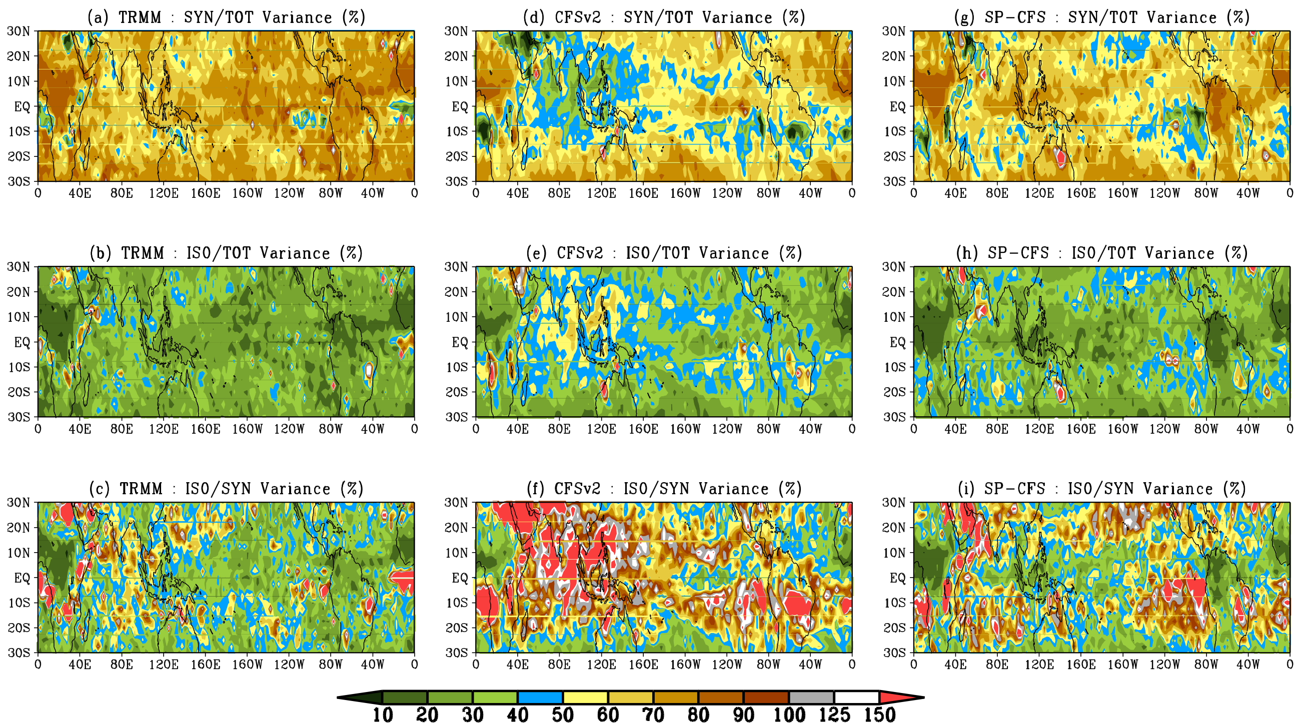


Climatological Seasonal mean meridional distribution of (a) easterly wind shear (U200-U850, m s-1), (b) surface level specific humidity (g kg-1), (c) tropospheric temperature (averaged between 200 and 600 hPa) and (d) equivalent potential temperature (averaged between 1000 to 850 hPa and 65° to 95°E.



Space-Time spectra (Wheeler-Kiladis diagram [Wheeler and Kiladis, 1999]) of OLR showing the symmetric component for (a) NOAA OLR, (c) CFSv2 and (e) SP-CFS and the anti-symmetric component for (b) NOAA OLR, (d) CFSv2 and (f) SP-CFS.

Ratio of Synoptic to ISO variance.



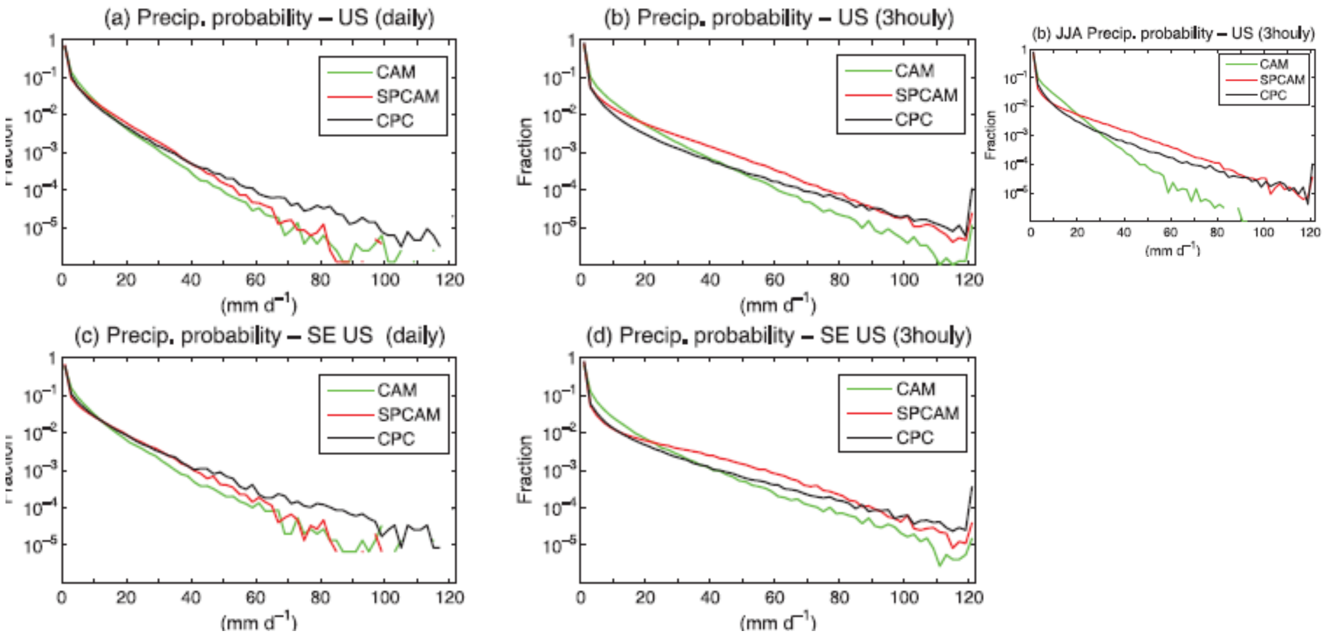
SP-CFS has improved the bias in synoptic and ISO variance

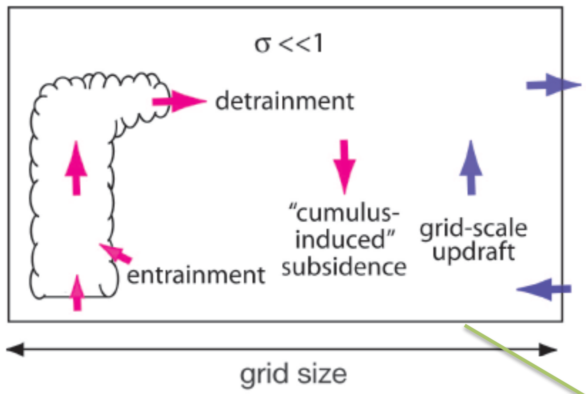
Slide Courtesy: Dr. Marat Khairoutdinov

Global status of Superparameterization

What is the use of SP framework apart from demonstrating the role of resolving the cloud processes in the GCM?

"Super-parameterization": A better way to simulate regional extreme precipitation?, by Li et al., JGR 2012



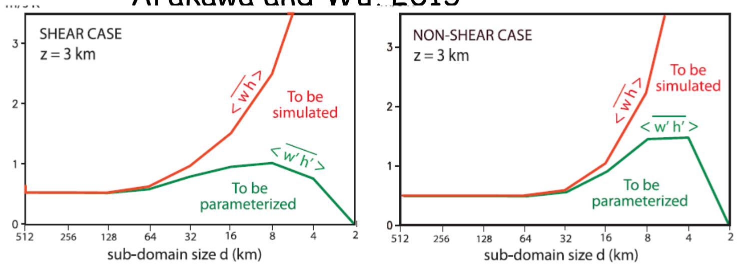


Arakawa et al. 2011, ACP

σ is the fractional area covered by all convective clouds in the grid cell

AS "Consider a horizontal area – large enough to contain an ensemble of cumulus clouds but small enough to cover a fraction of a large-scale disturbance. The existence of such an area is one of the basic assumptions of this paper." In reality, the GCM grid cells are not large enough and, at the same time, not small enough.

Arakawa and Wu, 2013



σ ~1

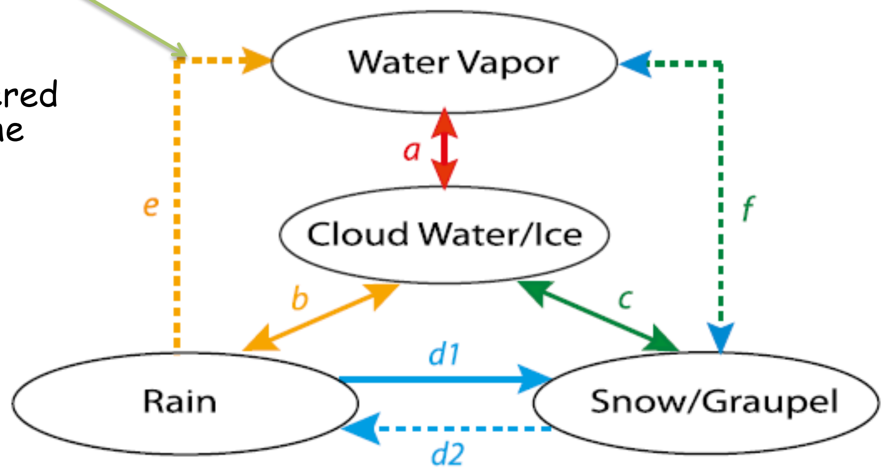


FIG. 9. A simplified view of the cloud microphysical conversions included in the CRM simulation used in this paper. See text for

Arakawa and Wu, 2014

Revised SAS

A revised version of SAS deep convection scheme following Han and Pan (2011) is tested and evaluated.

For deep convection, the scheme is revised to make cumulus convection stronger and deeper to deplete more instability in the atmospheric column.

Large eddy simulation (LES) studies by Siebesma and Cuijpers (1995) indicate that the fractional entrainment and detrainment rates are <u>one order of magnitude larger than the values used in most existing deep convection schemes</u>.

The GFS used in this test has 64 vertical sigma-pressure hybrid layers and T126 horizontal resolution (about 100 km at the equator). The CFS run was initialized at 0000 UTC 16 December 2002 and ran for 45 days. The CFS forecasts during the preceding 15 days (a spin up period) have been discarded

from the analysis, and forecast results during the remaining 1-month period are presented. An evaluation using a longer CFS run would be desirable, but will be left for a future study.

	Default SAS	Revised SAS
	SAS suffers from underestimating the entrainment/detrainment rates by one order of magnitude.	Maximum allowable cloud base mass flux (M_{bmax}) is increased by defining a criteria proposed by Jacob and Siebesma (2003).
Entrainment	Entrainment is considered to take place at levels below the cloud base only	Entrainment is allowed above the cloud base also
Detrainment	from the cloud top only	for all the levels.
Entrainment rate	uniform below the cloud base	in sub-cloud layer is inversely proportional to the height

Han and Pan (2011), Pattnaik et al (2013), W. C. de Rooy et al. (2014), Das et al. (2002)

Model Impacts of Entrainment and Detrainment Rates in Shallow Cumulus Convection

A. P. SIEBESMA AND A. A. M. HOLTSLAG*

JAS, 1996

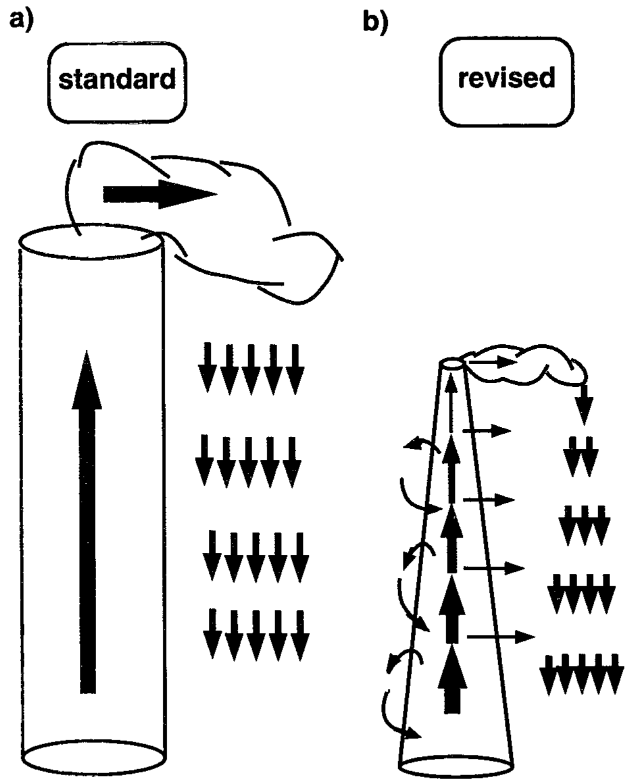
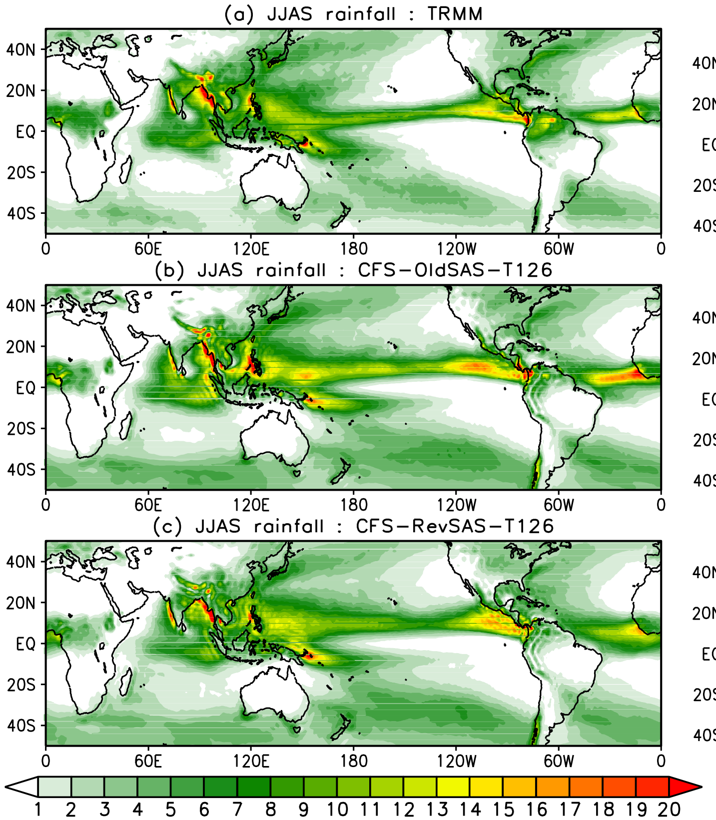


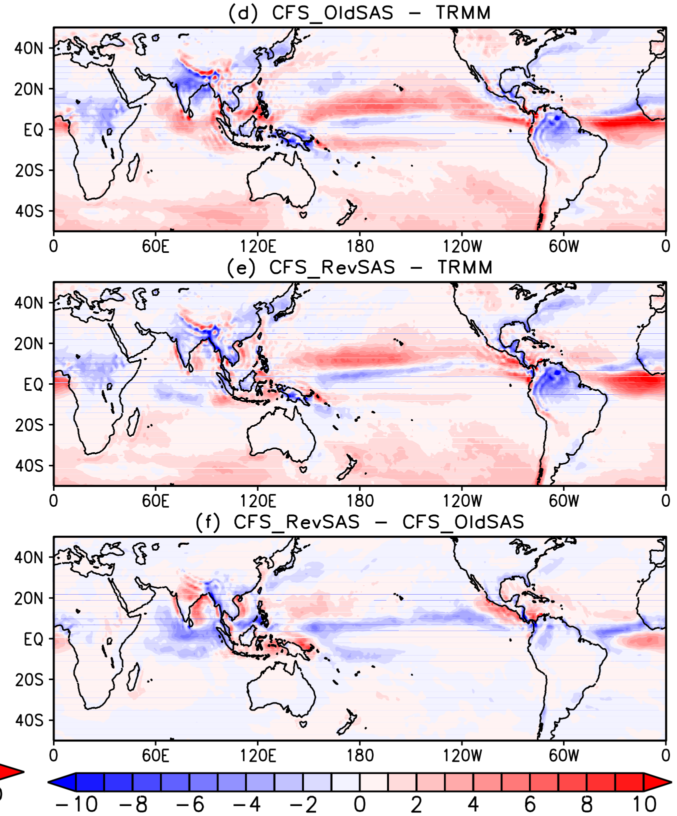
FIG. 7. Schematic picture of the turbulent mixing mechanism of a shallow cloud ensemble. In the case of the standard values of ϵ and δ, the scheme behaves approximately as a nonleaking funnel with massive detrainment at cloud top. When using the enhanced values of ϵ and δ, as suggested by the LES results, there is more intense lateral mixing and a decreasing mass flux with height due to the fact that $\delta > \epsilon$ and hence little massive detrainment at the top.

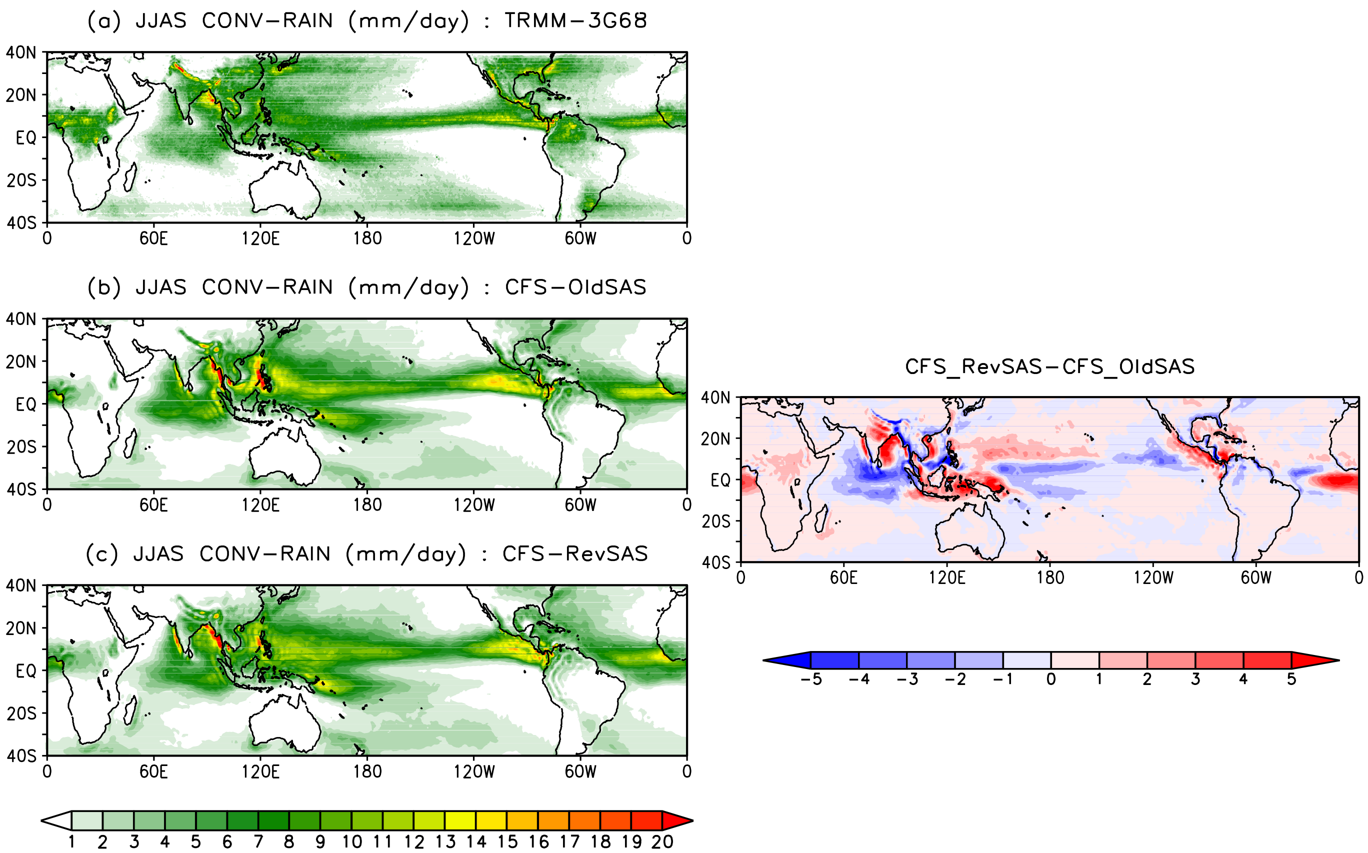
Impact of Revising Subgrid scale convection only RevSAS

JJAS Mean precip

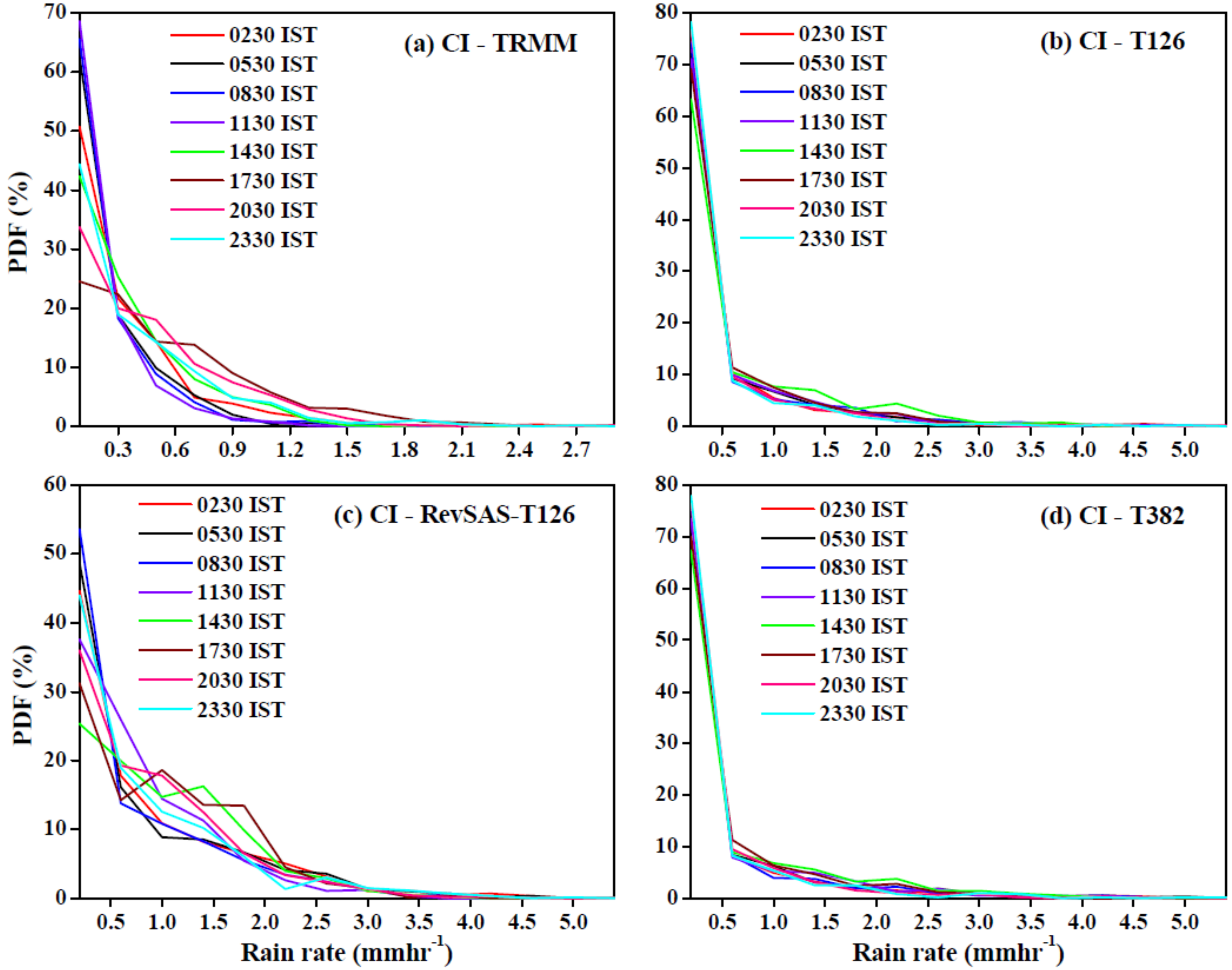


JJAS precip bias

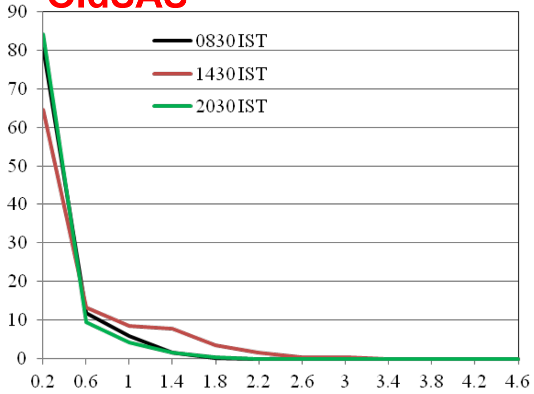




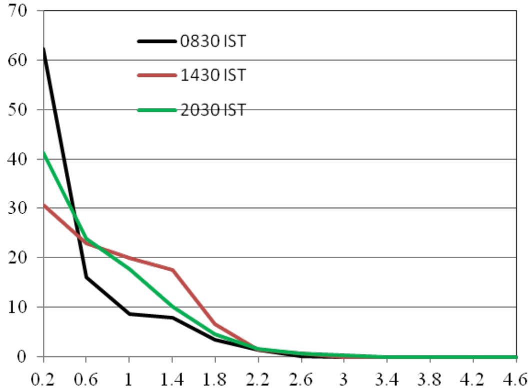
Convective Rain


(a) CI - TRMM
(b) CI - T126
(c) CI - RevSAS-T126
(d) CI - T382
0230 IST
0530 IST
0830 IST
1130 IST
1430 IST
1730 IST
2030 IST
2330 IST
PDF (%)
Rain rate (mmhr^{-1})

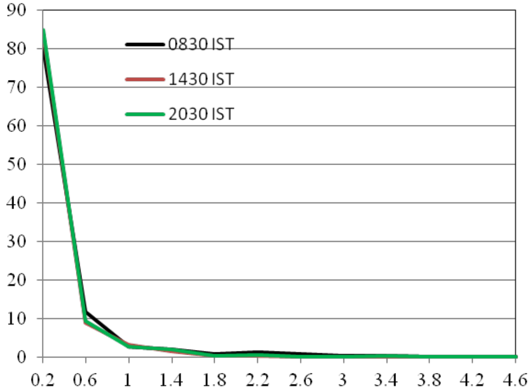
Convective-rain OldSAS



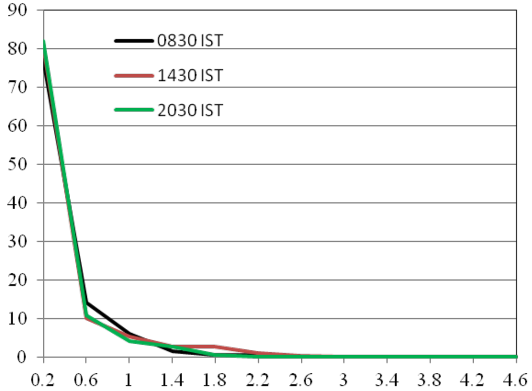
Convective-rain-RevSAS



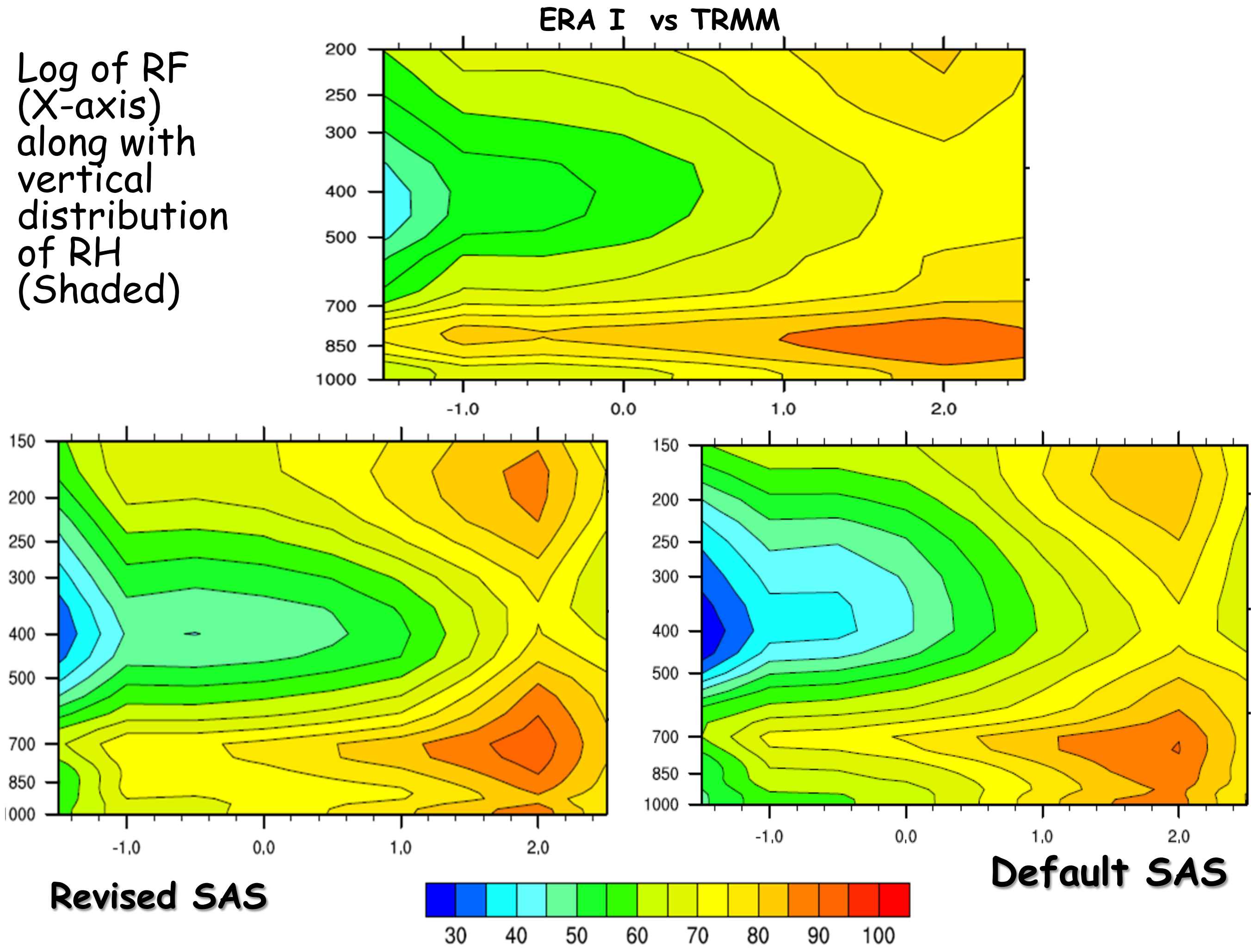
Stratiform-rain-OldSAS



Stratiform-rain RevSAS

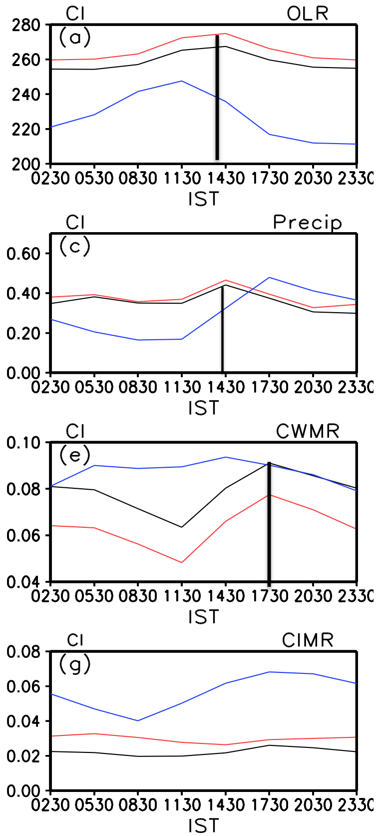


Log of RF (X-axis) along with vertical distribution of RH (Shaded)

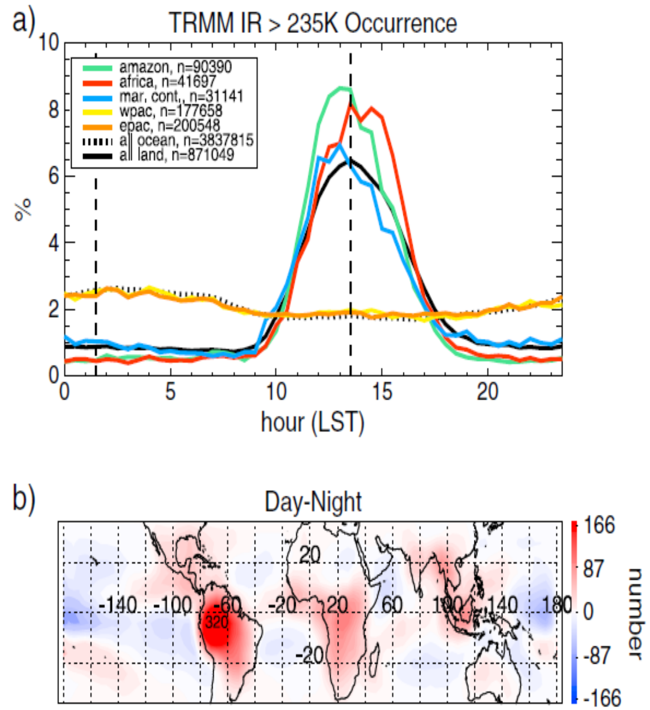


WHAT NEXT

CFST382 (RED line), CFST126 (BLACK line), TRMM & MERRA (Dotted BLUE line)
OLR (INSAT) from Mahakur et al.



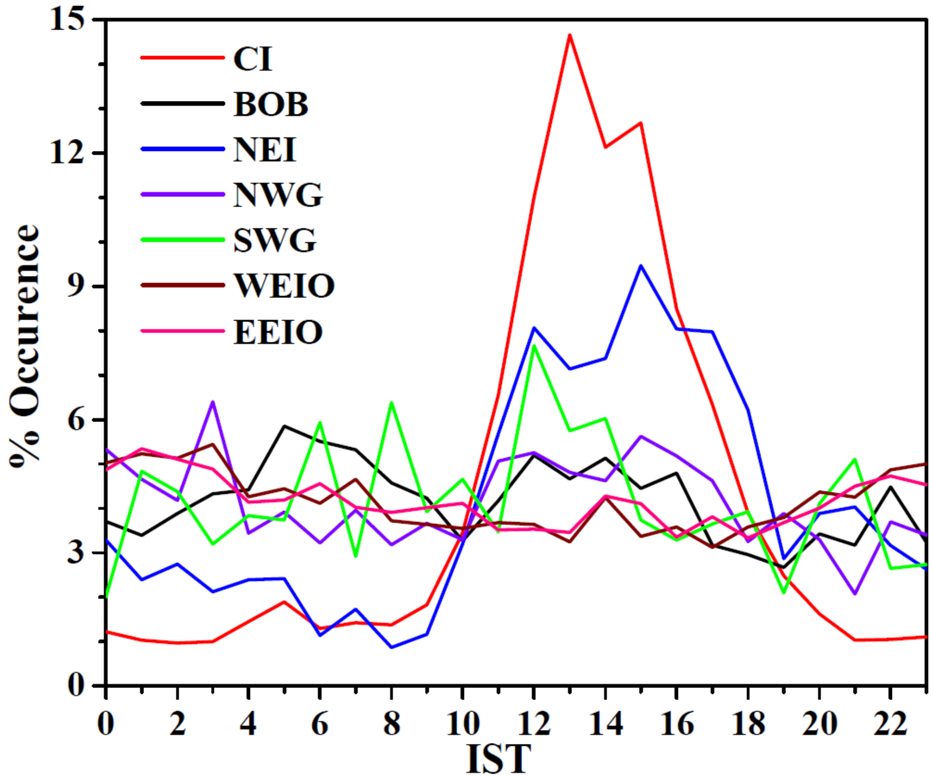
Malay et al.



Wall et al., 2013

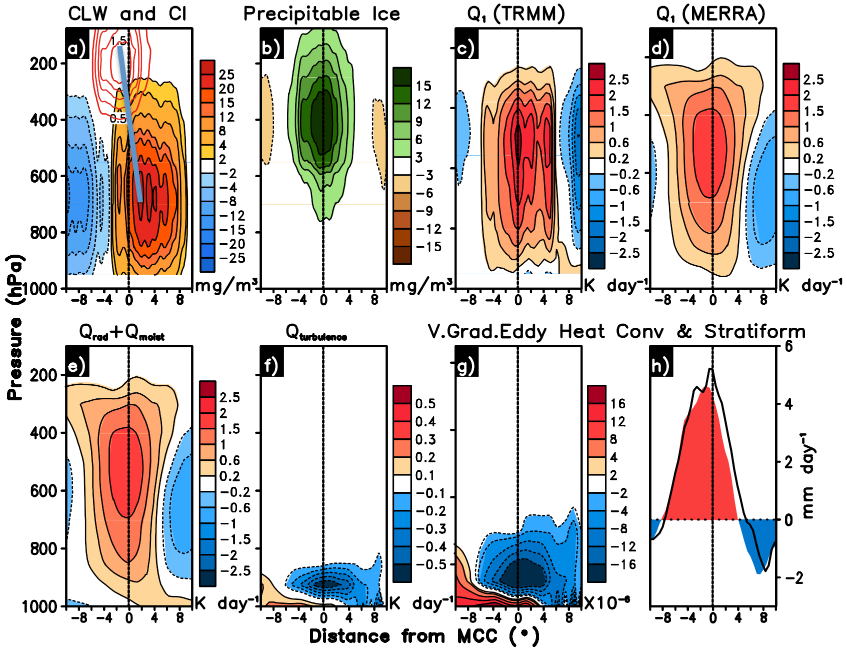
Diurnal variation of population of TRMM VIRS congestus for different regions. The black dashed lines indicate the times of CloudSat overpass.

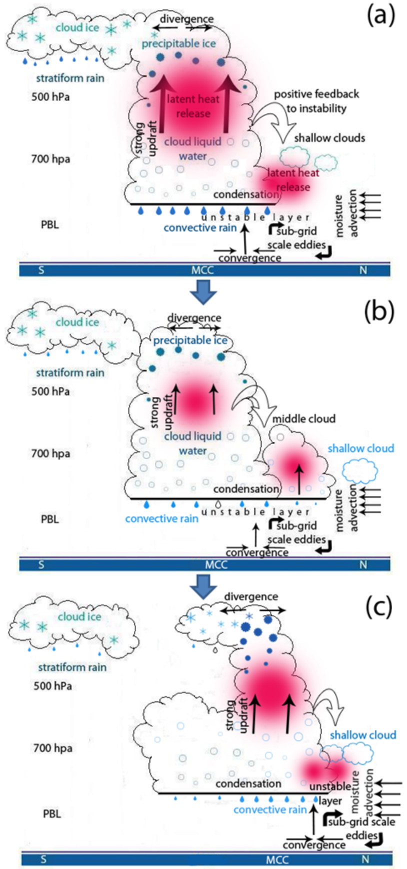
Diurnal variation of population of TRMM VIRS congestus for different regions over Indian monsoon region



Mahakur et al.

Hypothesis based on observation for northward propagation BSISO (Abhik et al, 2013)

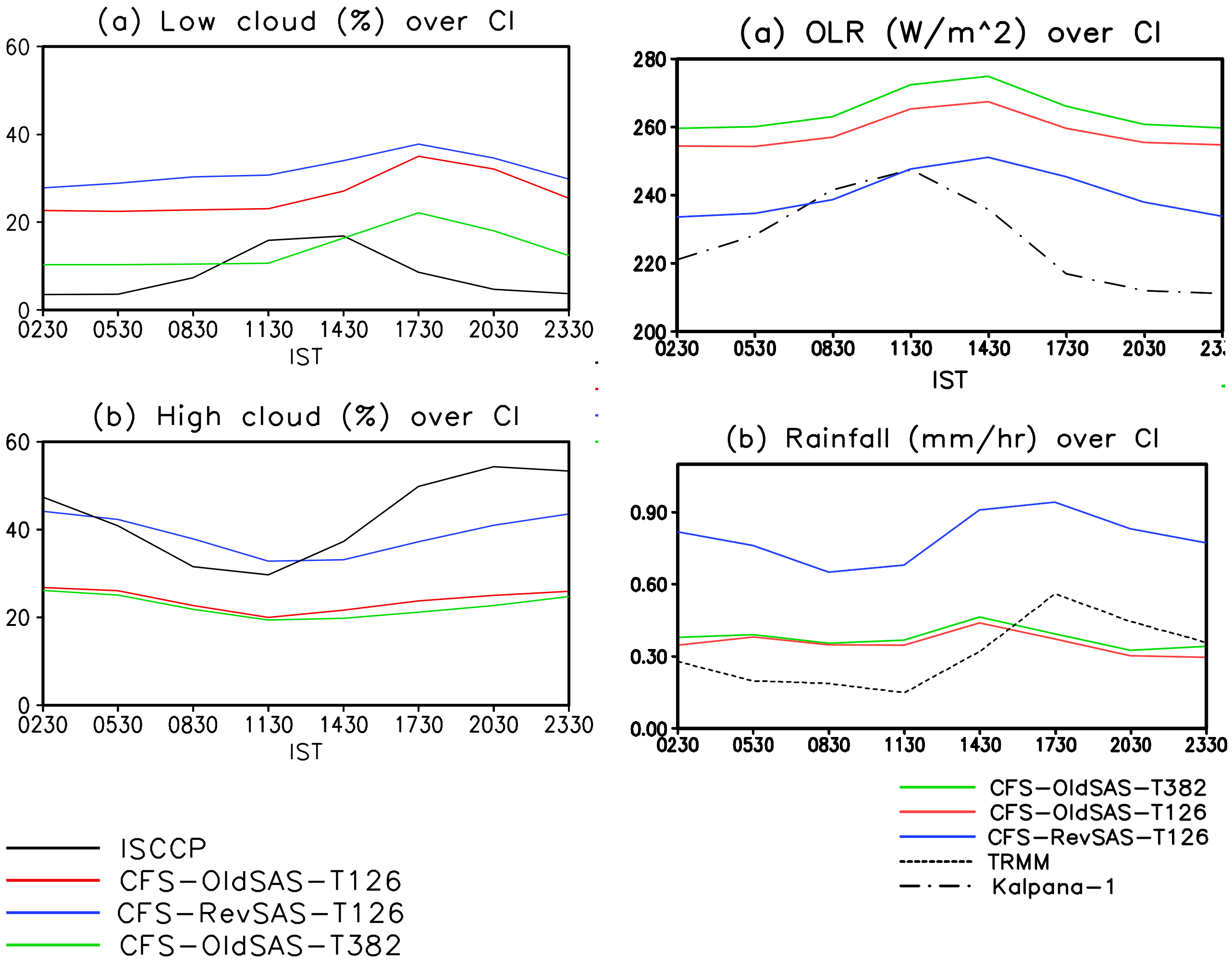




Our results are supplemented by few recent studies e. g.

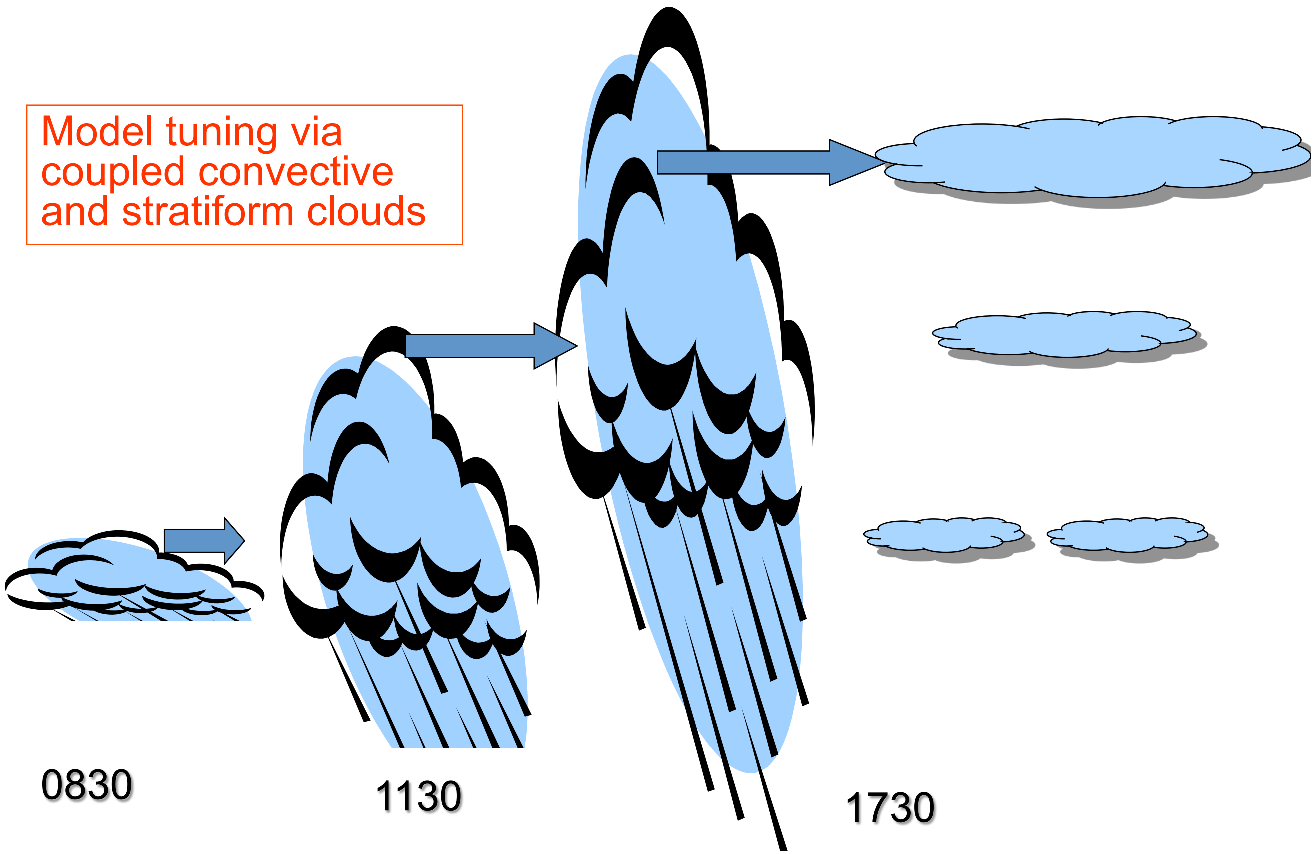
Preconditioning Deep Convection with Cumulus Congestus by Hohenegger and Steven, 2013

A climatology of tropical congestus



(a) Low cloud (%) over CI
(b) High cloud (%) over CI
IST
ISCCP
CFS−OldSAS−T126
CFS−RevSAS−T126
CFS−OldSAS−T382
(a) OLR (W/m^2) over CI
(b) Rainfall (mm/hr) over CI
TRMM
Kalpana−1

To simulate better stratiform clouds a spectrum of cumulus clouds is necessary.



Where do the present day Models Stand?

Two-moment bulk stratiform cloud microphysics in the GFDL AM3 GCM: description, evaluation, and sensitivity tests

M. Salzmann[1,*], Y. Ming[2], J.-C. Golaz[2], P. A. Ginoux[2], H. Morrison[3], A. Gettelman[3], M. Krämer[4], and L. J. Donner[2]

NCEP Initiative

Sun and Han, AGU 2014 "Zhao and Carr microphysics scheme has been implemented into the NCEP Global Forecasting System (GFS) for many years. It predicts total cloud condensate (cloud water or ice). We are testing several sophisticated microphysics schemes from the Weather Research and Forecasting Model (WRF) in the GFS. These schemes have more cloud species and more physically-based parameterized processes."

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Interactions between Cloud Microphysics and Cumulus Convection in a General Circulation Model

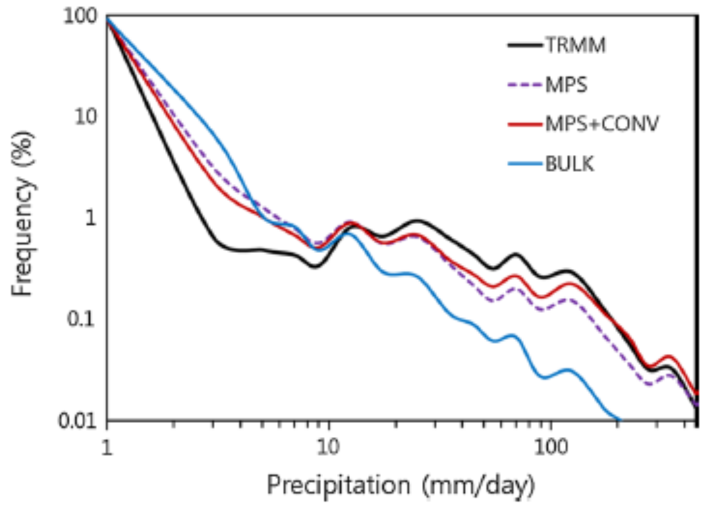
LAURA D. FOWLER AND DAVID A. RANDALL
Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado

(Manuscript received 1 May 2001, in final form 17 May 2002)

Clim Dyn
DOI 10.1007/s00382-014-2376-1

GCMs with implicit and explicit representation of cloud microphysics for simulation of extreme precipitation frequency

In-Sik Kang · Young-Min Yang · Wei-Kuo Tao



TECHNICAL MEMORANDUM

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A new prognostic bulk microphysics scheme for the IFS

Richard M. Forbes[1], Adrian M. Tompkins[2] and Agathe Untch[1]

Research Department

[1]ECMWF [2]ICTP, Italy

September 2011

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen terme

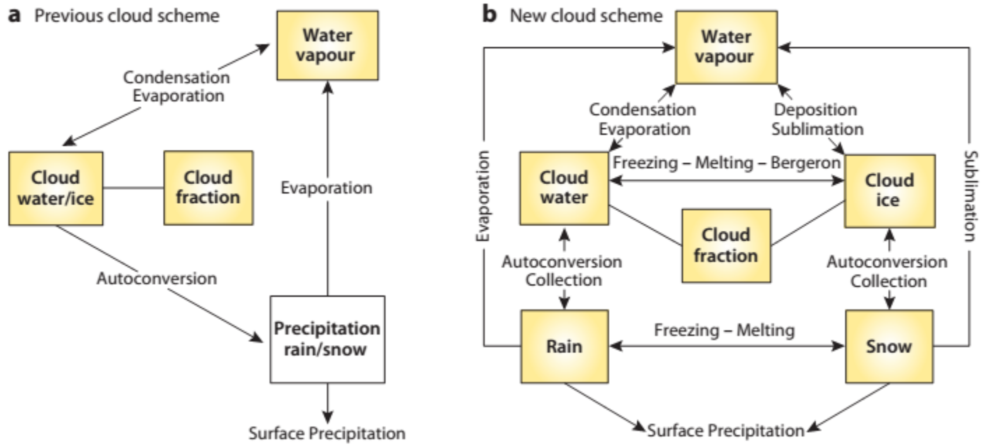


Figure 1: *Schematic of the IFS cloud scheme: (a) the Tiedtke scheme with three moisture related prognostic variables operational from 1995 to 2010 (before IFS Cy36r4) and (b) the new cloud scheme with six moisture related prognostic variables (Cy36r4 onwards). Yellow boxes indicate prognostic variables.*

2.2 Numerical framework

The new scheme is a multi-species prognostic microphysics scheme, with $m = 5$ prognostic equations for water vapour, cloud liquid water, rain, cloud ice and snow. The equation governing each prognostic cloud variable within the cloud scheme is

$$\frac{\partial q_x}{\partial t} = S_x + \frac{1}{\rho}\frac{\partial}{\partial z}(\rho V_x q_x), \tag{1}$$

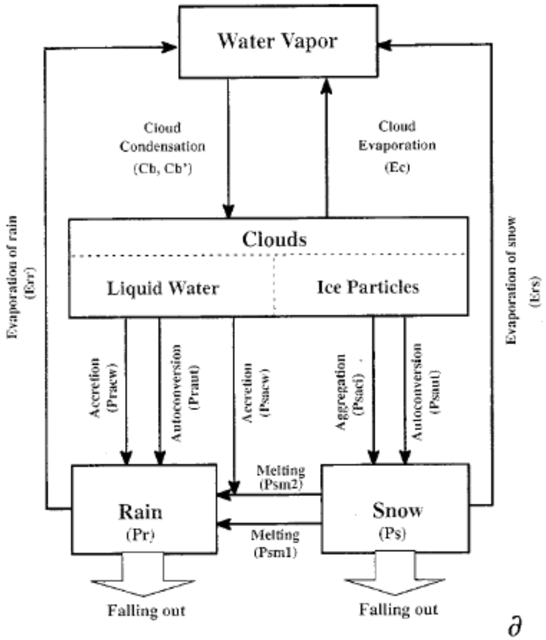
where q_x is the specific water content for category x ($x = 1$ for cloud liquid droplets, $x = 2$ for rain, and so on), S_x is the net source or sink of q_x through microphysical processes, and the last term represents the sedimentation of q_x with fall speed V_x.

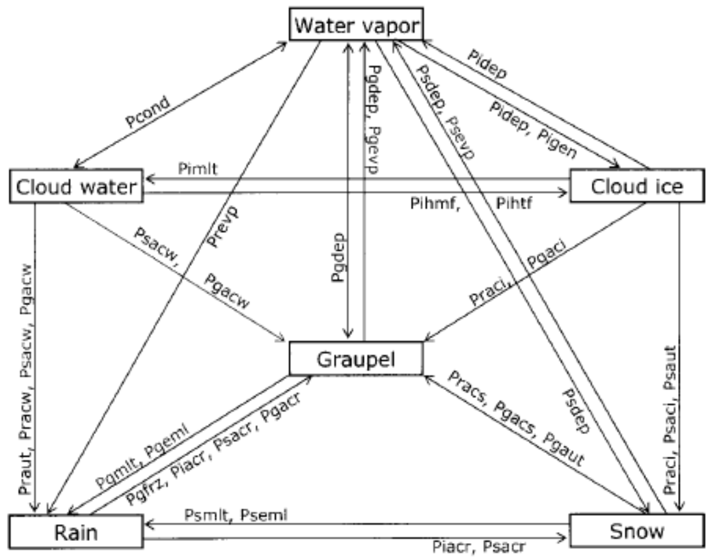
Zhao & Carr 1997

Default CFS Microphysics

Hong & Lim 2006

WSM6



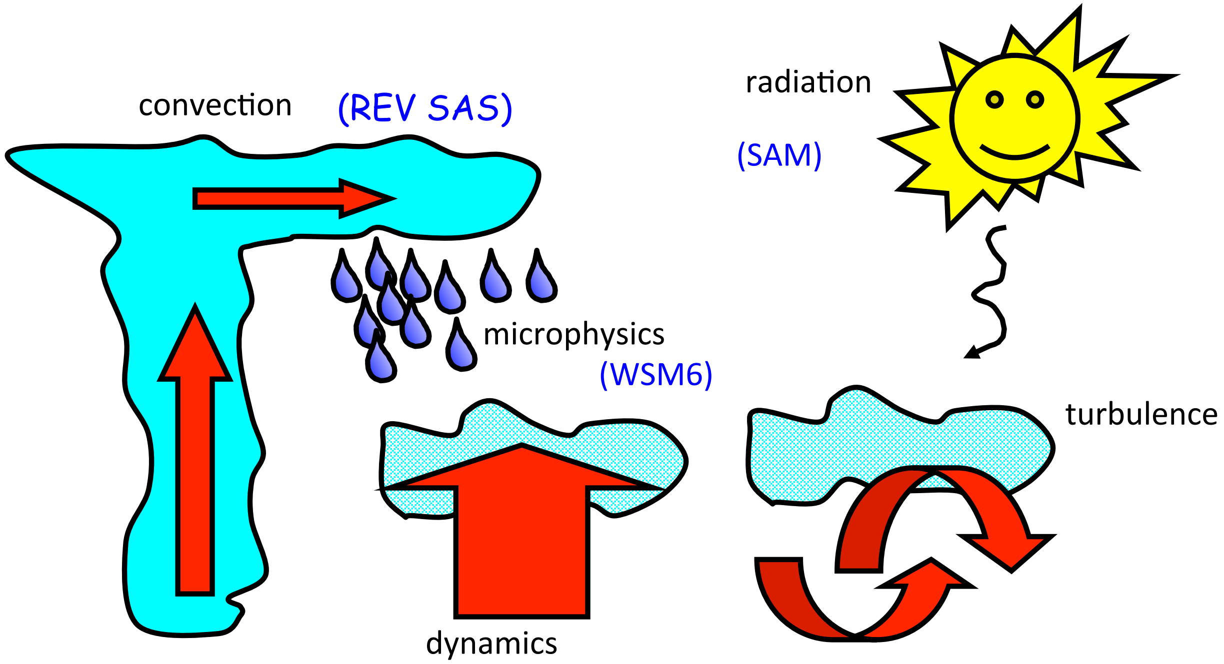


Tendencies

$$\frac{\partial}{\partial t}(n) = \mathrm{ADV}(n) + \mathrm{TURB}(n) + \mathrm{SEDIM}(n) + \mathrm{SOURCE}(n)$$

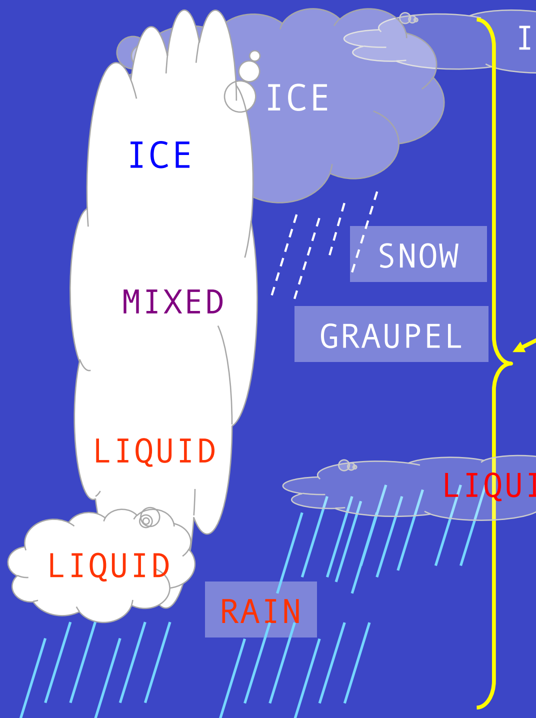
where n = *[n_r, n_i, n_s, n_{clw}, n_g, n_v] represents the concentration of rain, ice* crystals, snow, graupel, cloud water, water vap.

Revised Cloud-Convective-Radiation in CFSv2 T126



Clouds are the result of complex interactions between a large number of processes
SAM: System of Atmospheric Model

CloudSat IWC/LWC Retrieval



CloudSat measurements are sensitive to multiple particle types:

➔ cloud ice (~small particle), snow, graupel

➔ cloud liquid (~small particle), rain

Note that: The Micro Wave Limb Sounder (MLS) provides IWC estimates described as small ice particles at levels in the upper-troposphere

Slide Courtesy: Frank Li, JPL

Evaluating the Diurnal Cycle of Upper-Tropospheric Ice Clouds in Climate Models Using SMILES Observations

Jiang et al., 2015

Superconducting Submillimeter Limb Emission Sounder (SMILES) on the International Space Station (ISS)

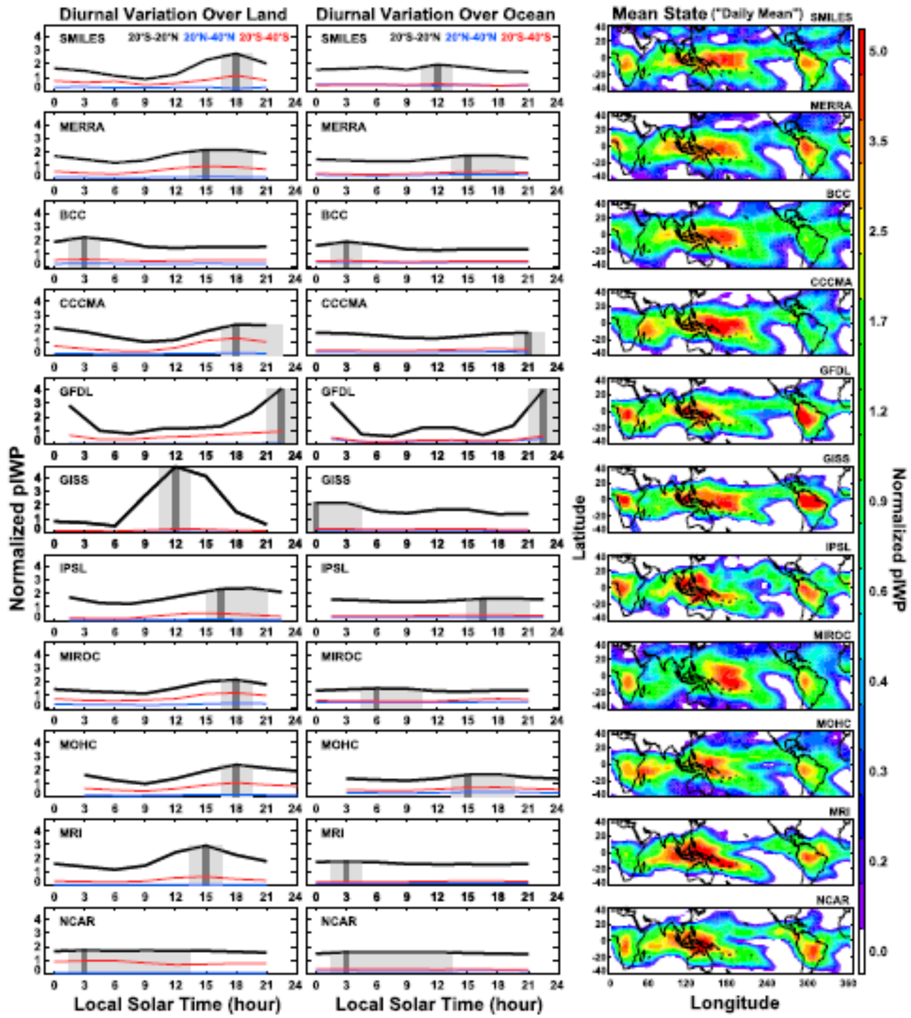
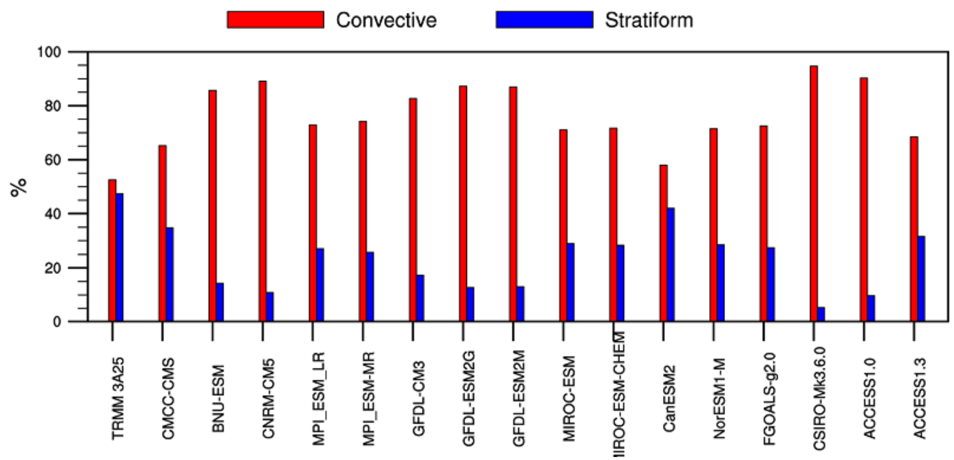


Fig. 8 Percentage of precipitation (averaged over SAM region, 10°N–30°N and 70°E–100°E) explained by convective (*red bars*) and stratiform (*blue bars*) types in the historical simulations of the 16 CMIP5 models along with that from observations (TRMM)



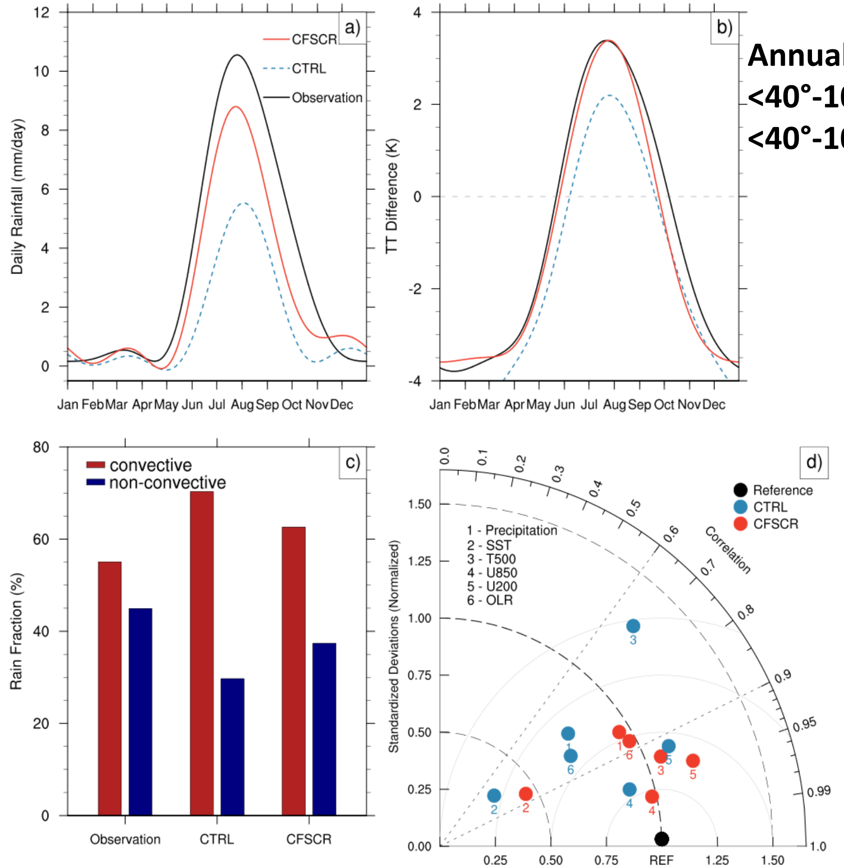
Why ensemble mean projection of south Asian monsoon rainfall by CMIP5 models is not reliable? C. T. Sabeerali · Suryachandra A. Rao · A. R. Dhakate ·K. Salunke · B. N. Goswami, Cli. Dyn. 2015

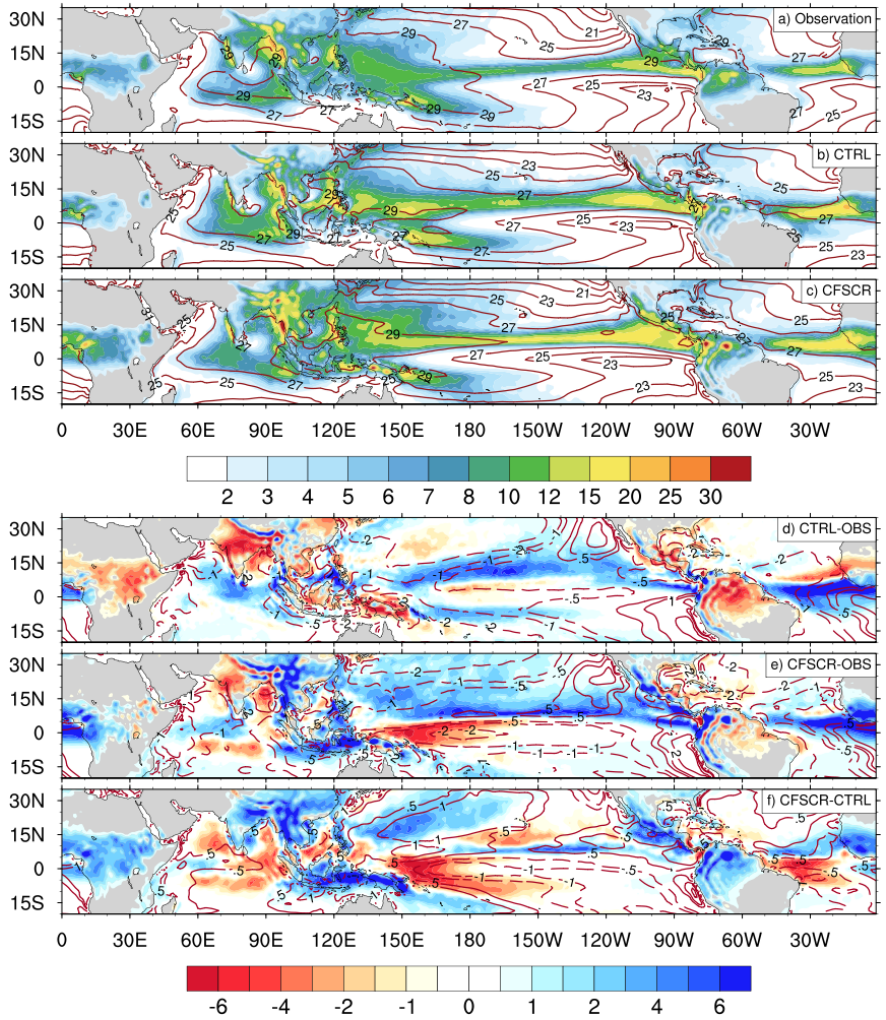
Revised convection, modified microphysics and radiation is able to improve the mean state and Intraseasonal variability of CFSv2T126

Annual Rainfall Cycle
<73°-85°E, 15°-25°N>

Annual TT Difference
<40°-100°E,5°-35°N> - <40°-100°E,15°S-5°N>

<40°-120°E, 15°S-30°N>

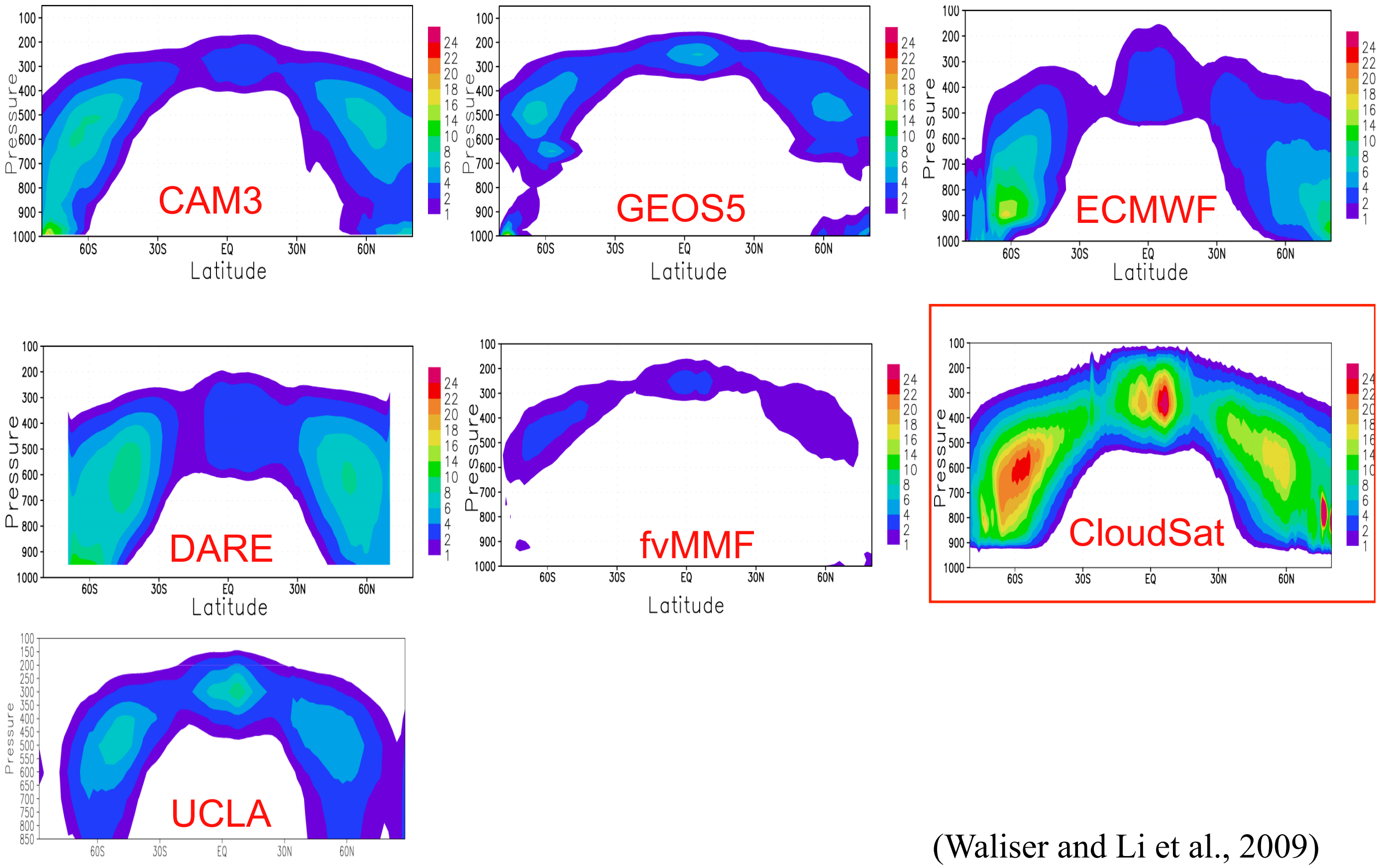




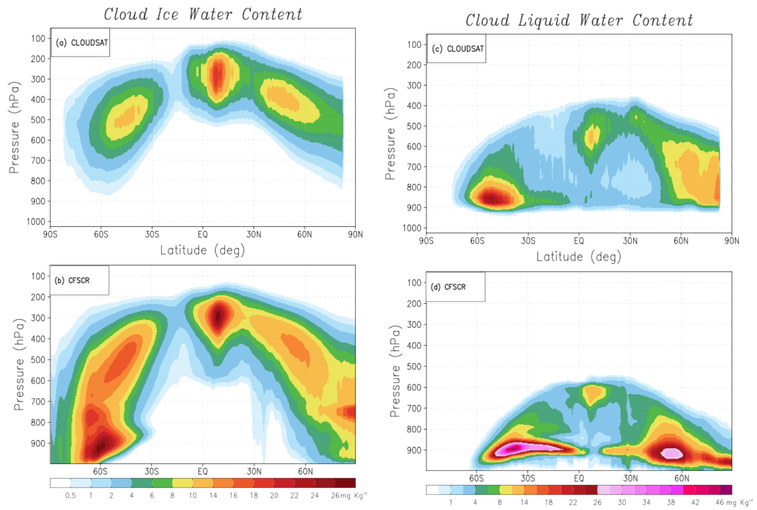
a) Observation
b) CTRL
c) CFSCR
d) CTRL-OBS
e) CFSCR-OBS
f) CFSCR-CTRL
30N
15N
0
15S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
2 3 4 5 6 7 8 10 12 15 20 25 30
-6 -4 -2 -1 0 1 2 4 6

GCM Cloud Ice Water Content (IWC)

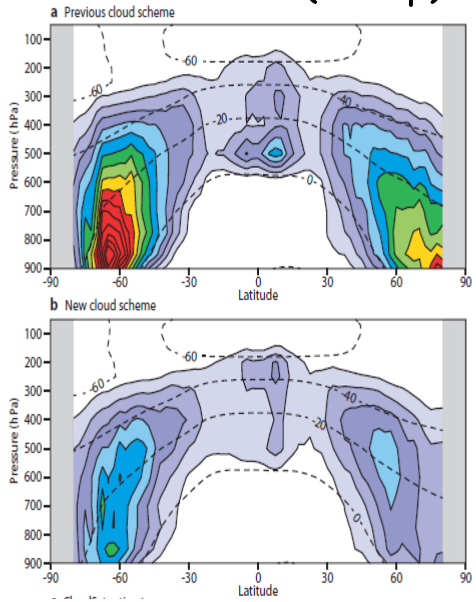
Annual Mean Values



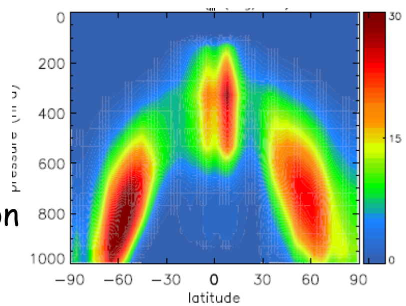
(Waliser and Li et al., 2009)



ECMWF IFS cloud ice Betchold+Bulk (comp)

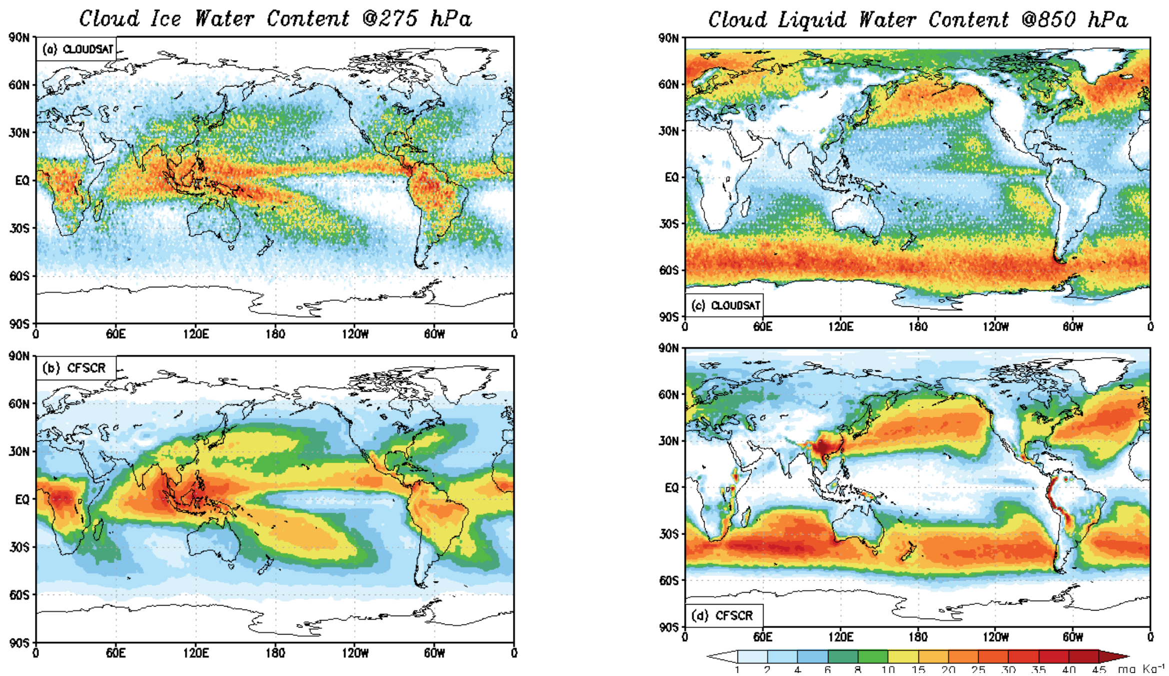


GFDL AM3+Morrisson

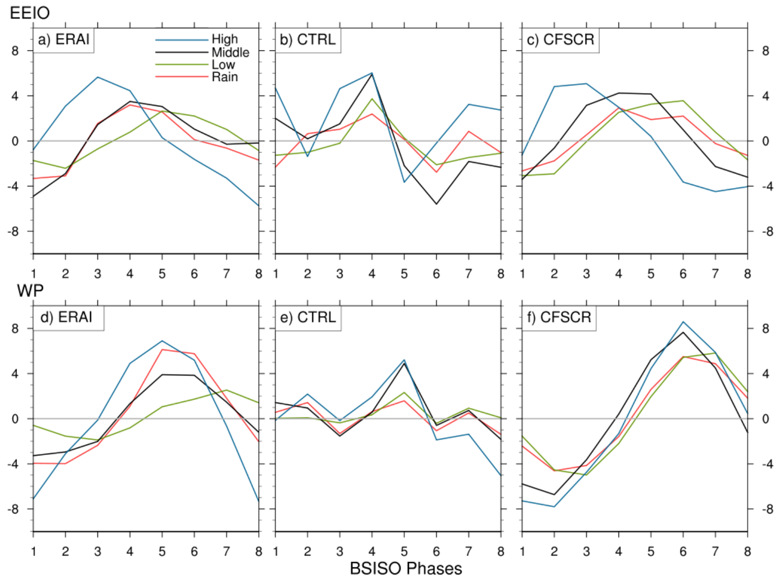


Zonally averaged annual mean vertical distribution of cloud ice water content (mg kg^{-1}) obtained from (a) CFSCR; and cloud liquid water content (mg kg^{-1}) from (b) CFSCR model.

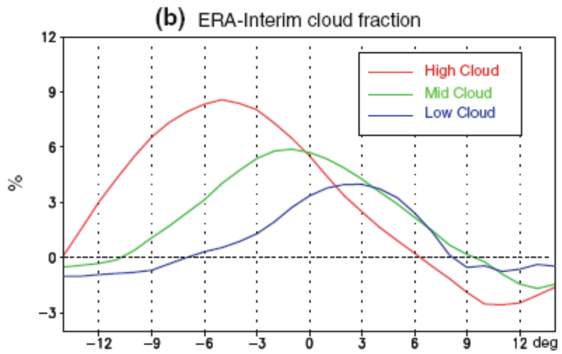
CFSCR: Modified CFSv2 with revised Cloud Microphysics, Convection and radiation



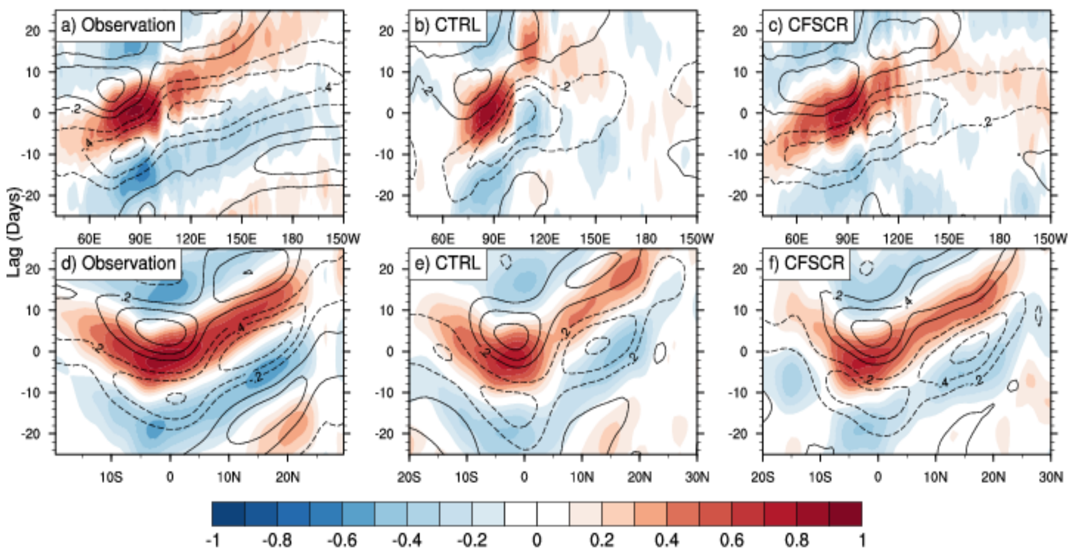
Annual mean isobaric distribution of cloud ice water content (mg kg^{-1}) obtained from (a) CloudSat 2B-CWC-RO, (b) CFSCR (at 271 hPa model level); and cloud liquid water content (mg kg^{-1}) from (c) CloudSat, (d) CFSCR (858 hPa).



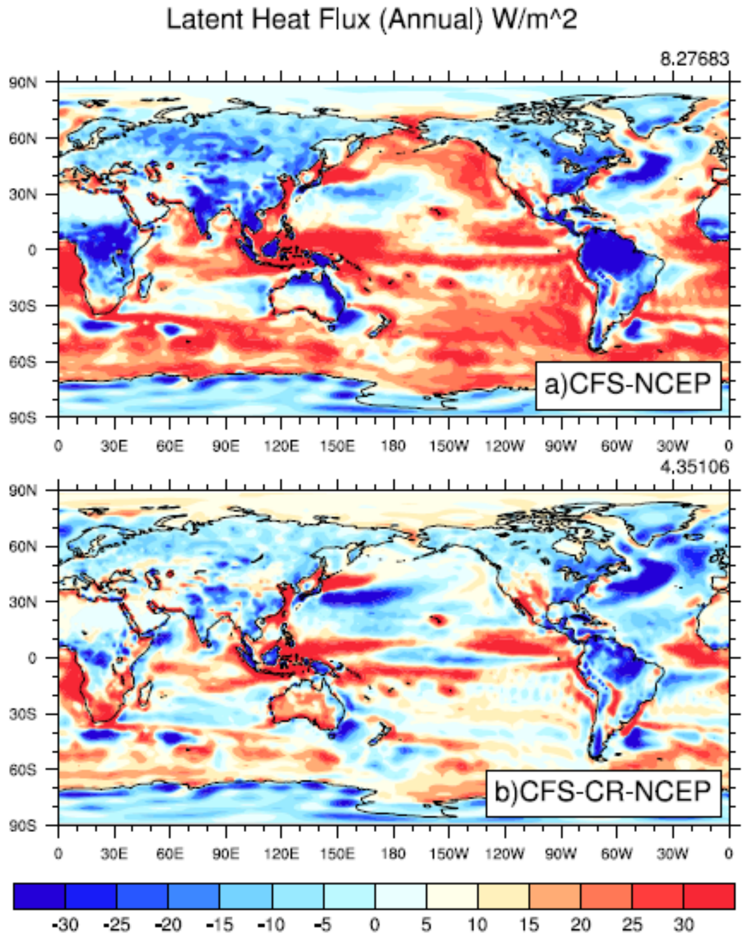
Evolution of anomalous low, middle and high cloud fractions (%, left axis) and rainfall anomalies (mm day-1, right axis) associated with BSISO1 convection over EEIO (top panels) and WP (bottom panels) for (a-b) observation, (c-d) CTRL and (e-f) CFSCR.



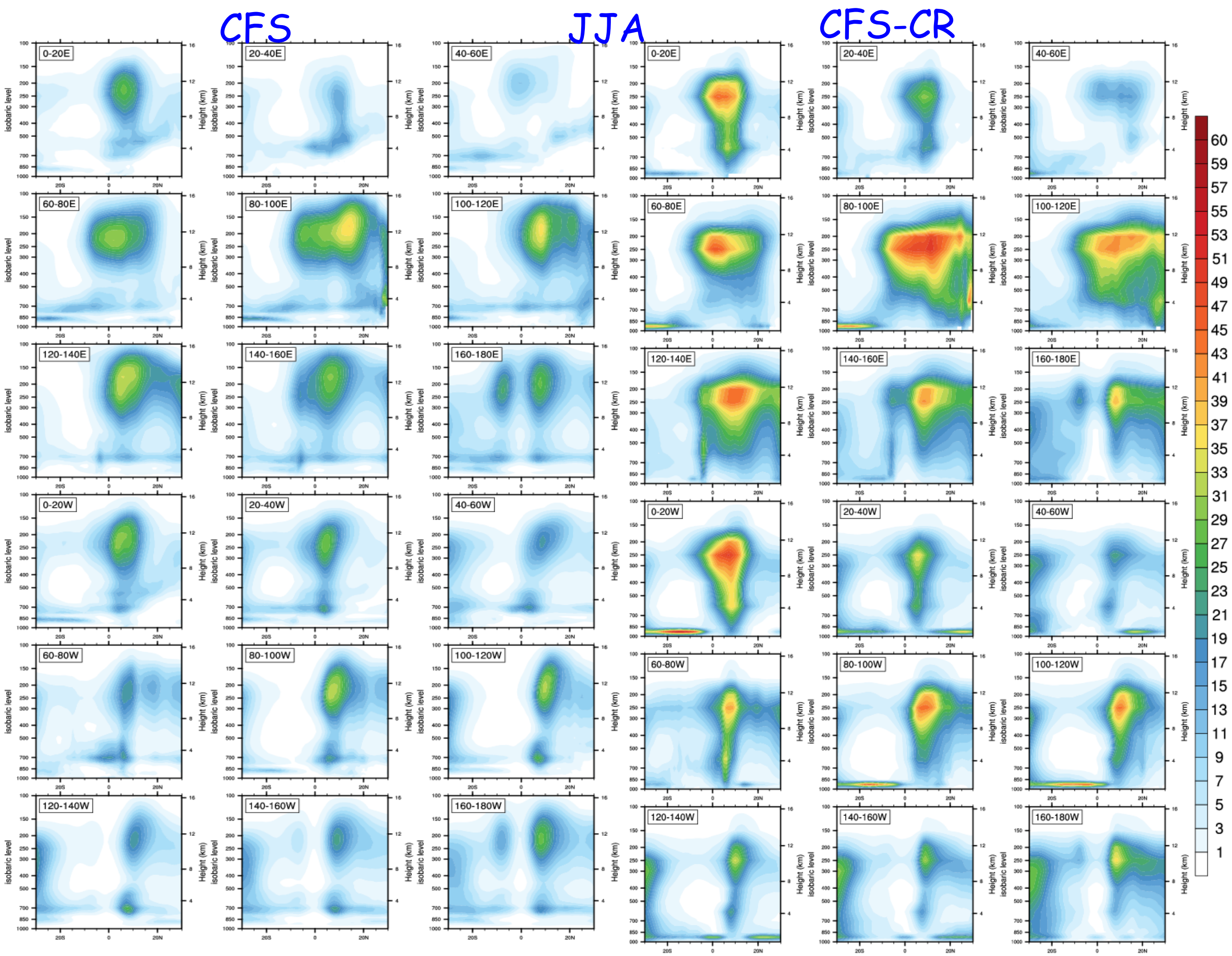
Jiang et al. 2011



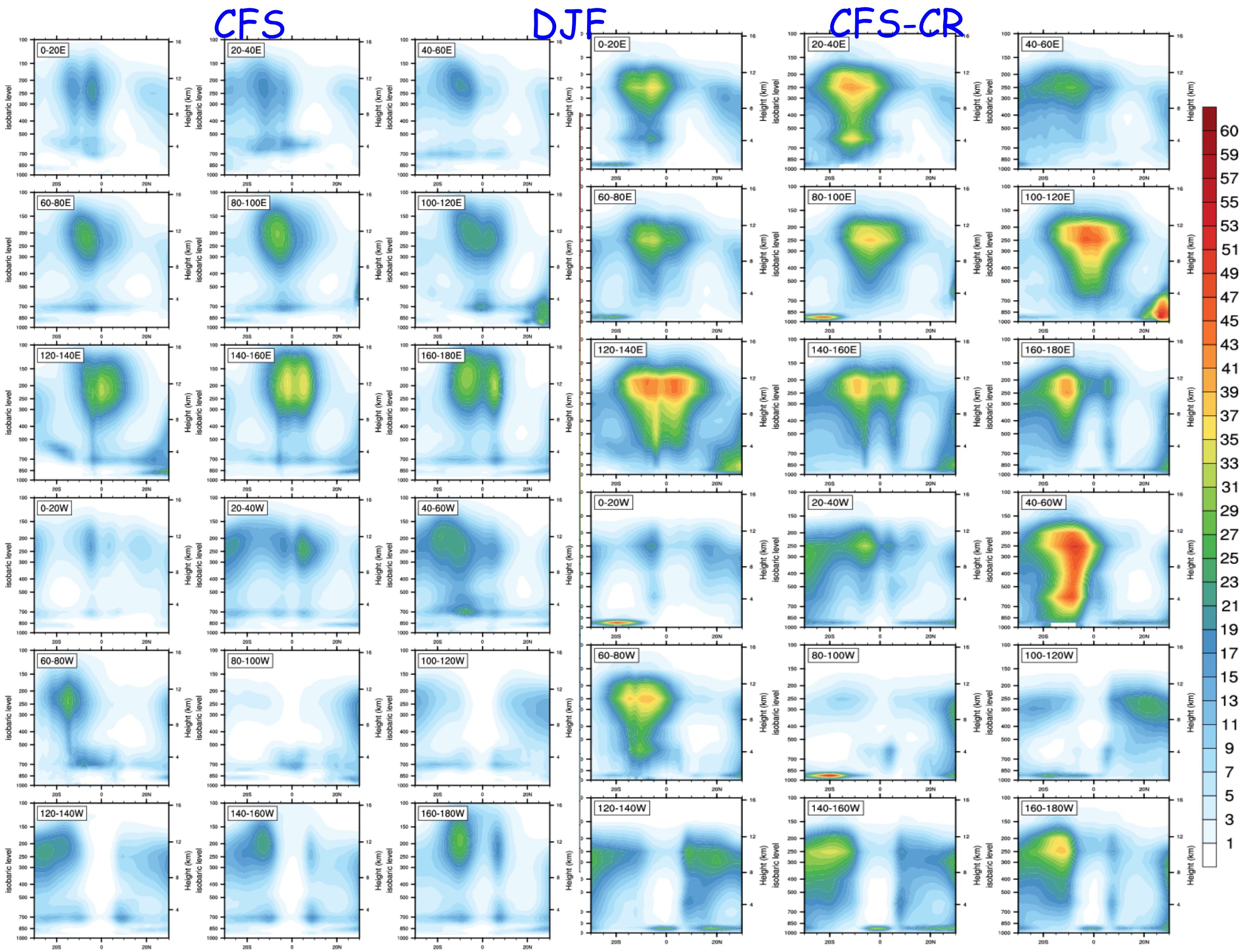
Longitude (Latitude) vs lag correlation of 20–100-day filtered precipitation (shaded) and U_{850} (contour) with base 20-100-day filtered precipitation time series over EEIO (10°S–5°N, 75°–100°E).



Latent Heat Flux (Annual) W/m^2
8.27683
a)CFS-NCEP
4.35106
b)CFS-CR-NCEP
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30



CFS
JJA
CFS-CR
0-20E
20-40E
40-60E
60-80E
80-100E
100-120E
120-140E
140-160E
160-180E
0-20W
20-40W
40-60W
60-80W
80-100W
100-120W
120-140W
140-160W
160-180W
isobaric level
Height (km)
20S
0
20N


CFS
DJF
CFS-CR
0-20E
20-40E
40-60E
60-80E
80-100E
100-120E
120-140E
140-160E
160-180E
0-20W
20-40W
40-60W
60-80W
80-100W
100-120W
120-140W
140-160W
160-180W
isobaric level
Height (km)
20S
0
20N
60
59
57
55
53
51
49
47
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
13
11
9
7
5
3
1

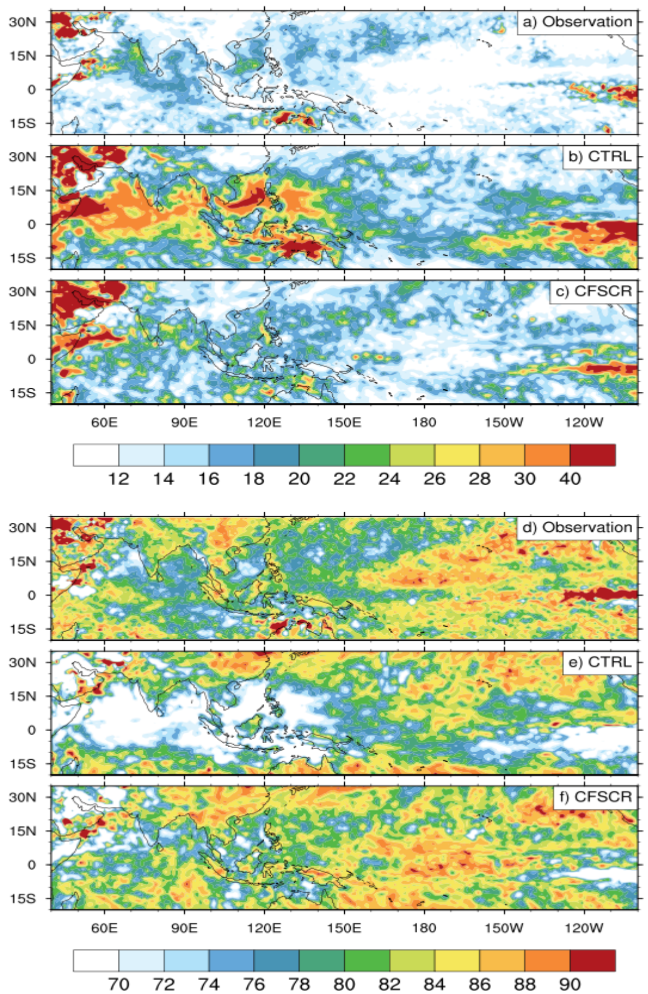
Spatial distribution of ISO scale (20-90 day bandpassed) variance for (a) TRMM,

(b) CTRL, and

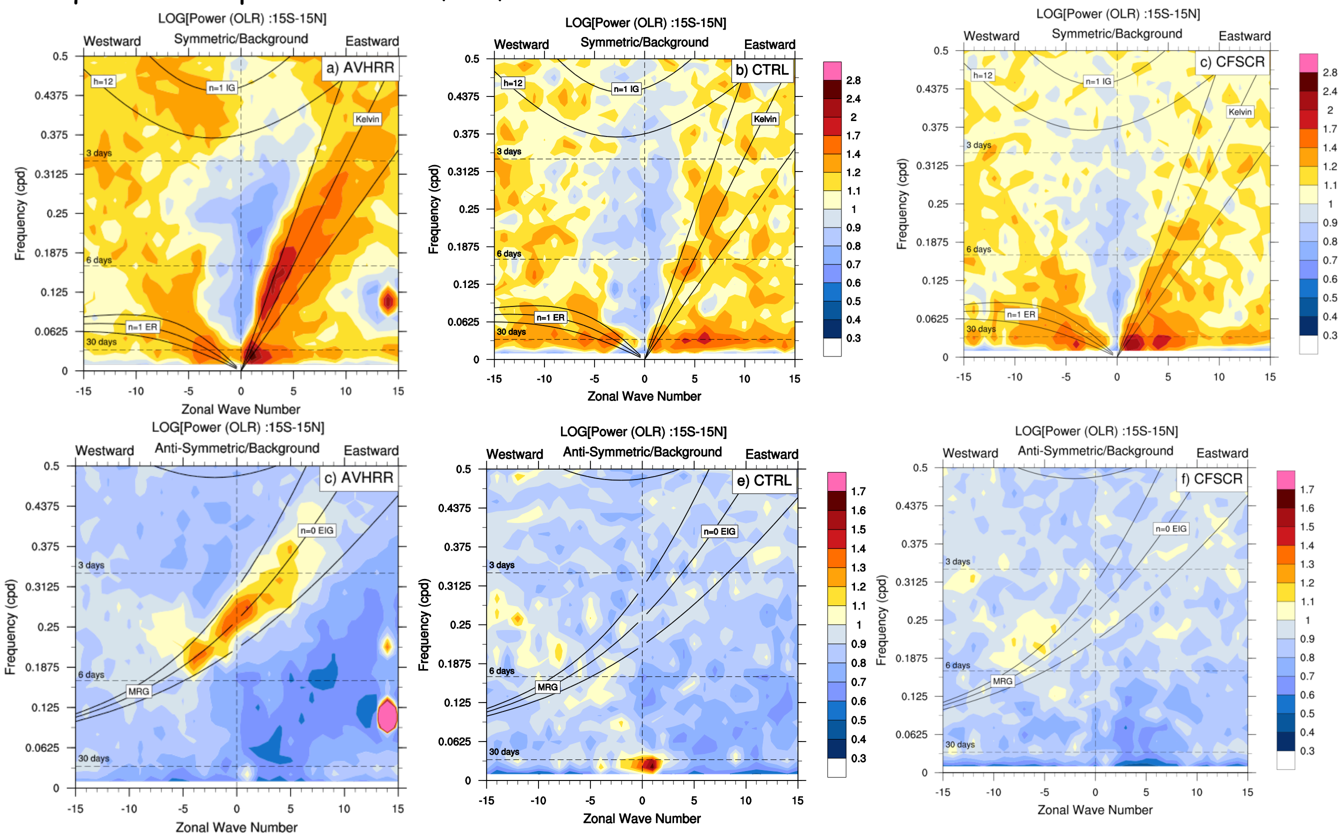
(c) CFSCR;

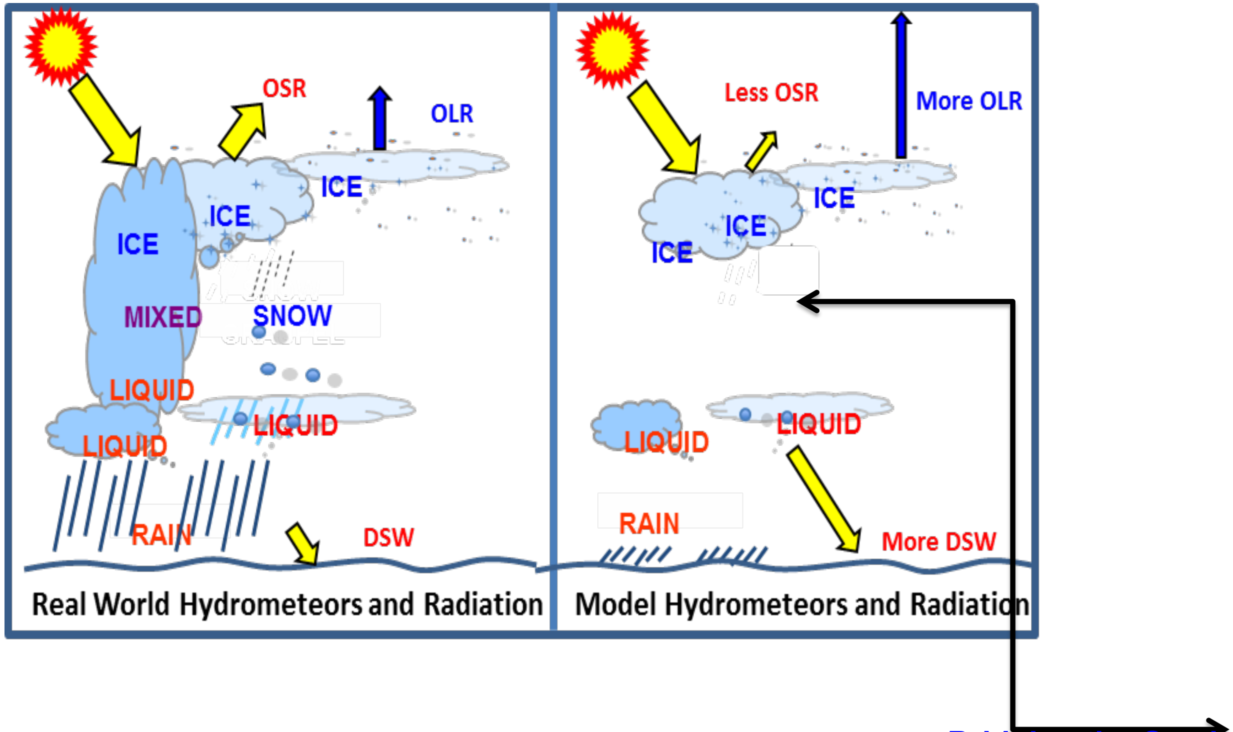
Spatial distribution synoptic scale (2-20 day bandpassed) variance for (d) TRMM, (e) CTRL, and (f) CFSCR.

All of the variances are computed for JJAS daily rainfall anomalies (mm day^{-1}).



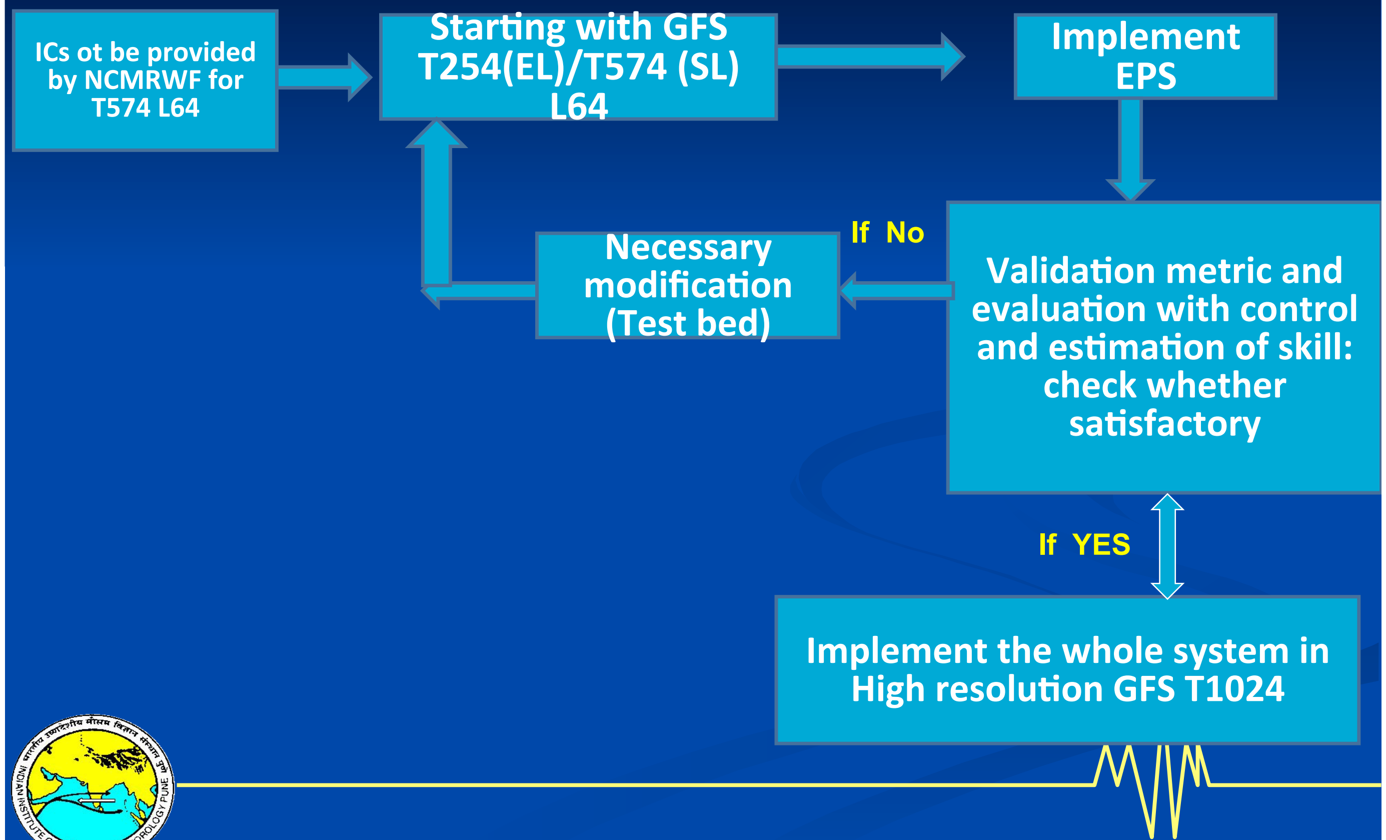
Wavenumber vs frequency distribution of spectral-power divided by estimate background spectra for equatorially symmetric (a-c) and anti-symmetric (d-f) OLR anomalies for observation, CTRL and CFSCR. Shallow water dispersion relationships for equivalent depths of h = 12, 25, and 50 m are shown in black lines.





Bridging the Gap in CFSv2 using modified Microphysics: WSM6

MoES Initiative on Short range weather scale forecast using GEFS



Summary

- Superparameterization is promising in improving sub-grid scale variability and could be explored for high spatio-temporal ranfall variabiltiy.

- Improving the convective closures with better observational constraint.

- Robust microphysical schemes help improving the mean and intraseasonal variablity of the model.

- Attempts to unify/stochastic approaches

Thank You !

The Convective and Microphysical Scheme Communication