Developments of moist process physics parameterization in CFS/GFS (emphasis on short range forecast)

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Monsoon Mission meeting 4-5 December 2019

Outline

- Issues in moist process in CFSv2/GFS vis-à-vis convection

- Recent approaches in dealing convection in GFS/CFSv2

- Challenges

- Conclusion

GFS forecast in Retrospect

- Short range ensemble prediction with GFS T254 till 2015
- Short range Ensemble Prediction (GFS (EL) T574 with 21 member) till May 2018
- Short Range deterministic forecast GFS (SL) T1534 (~12.5km) since June 2016
- Short Range Ensemble Prediction GEFS (SL) T1534 since June 2018

Climatology of JJA Precipitation

Kinter etal 2013, BAMS

IFS T2047
10 km

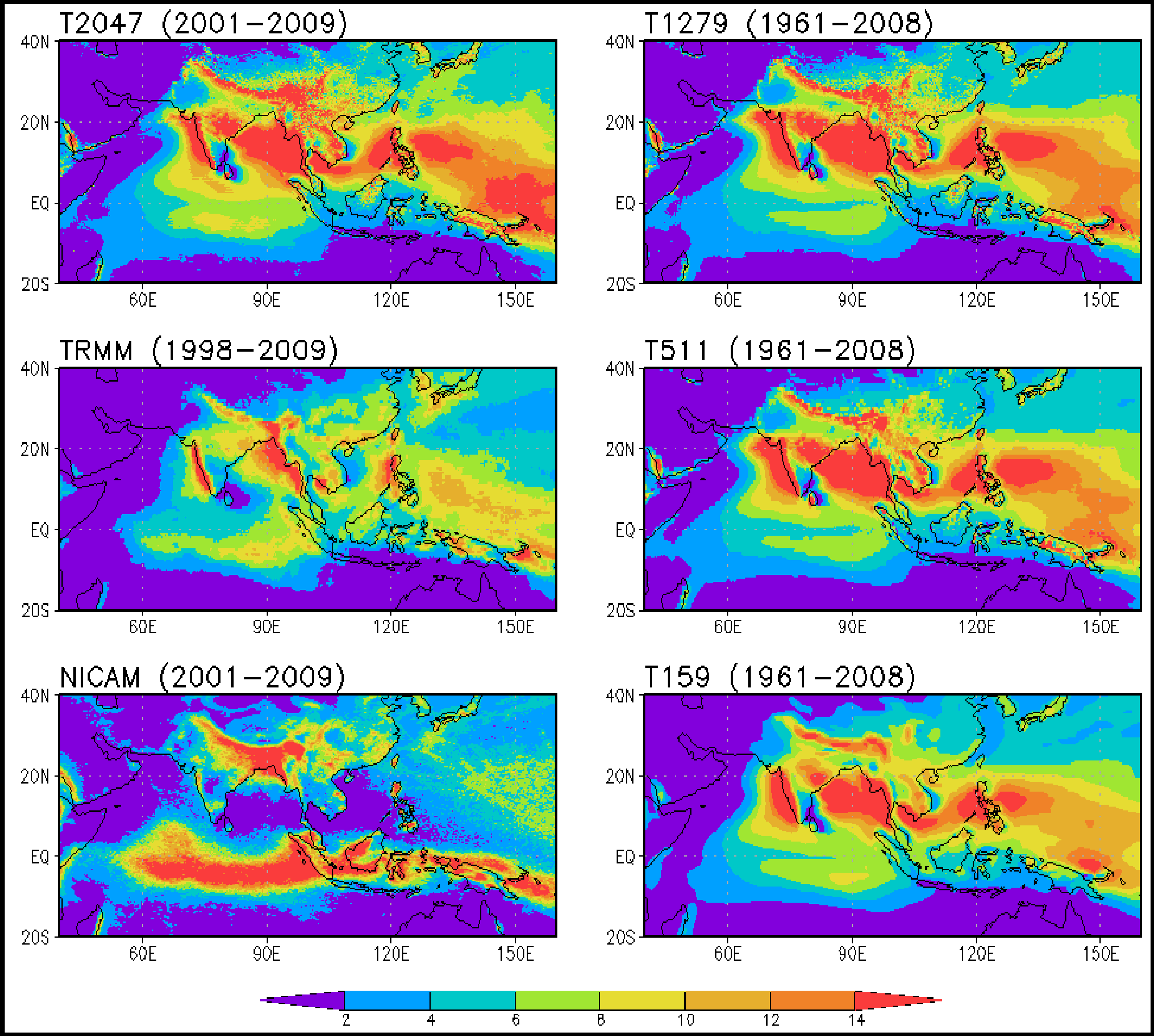
IFS T1279
15 km

TRMM
25km

IFS T1511
39km

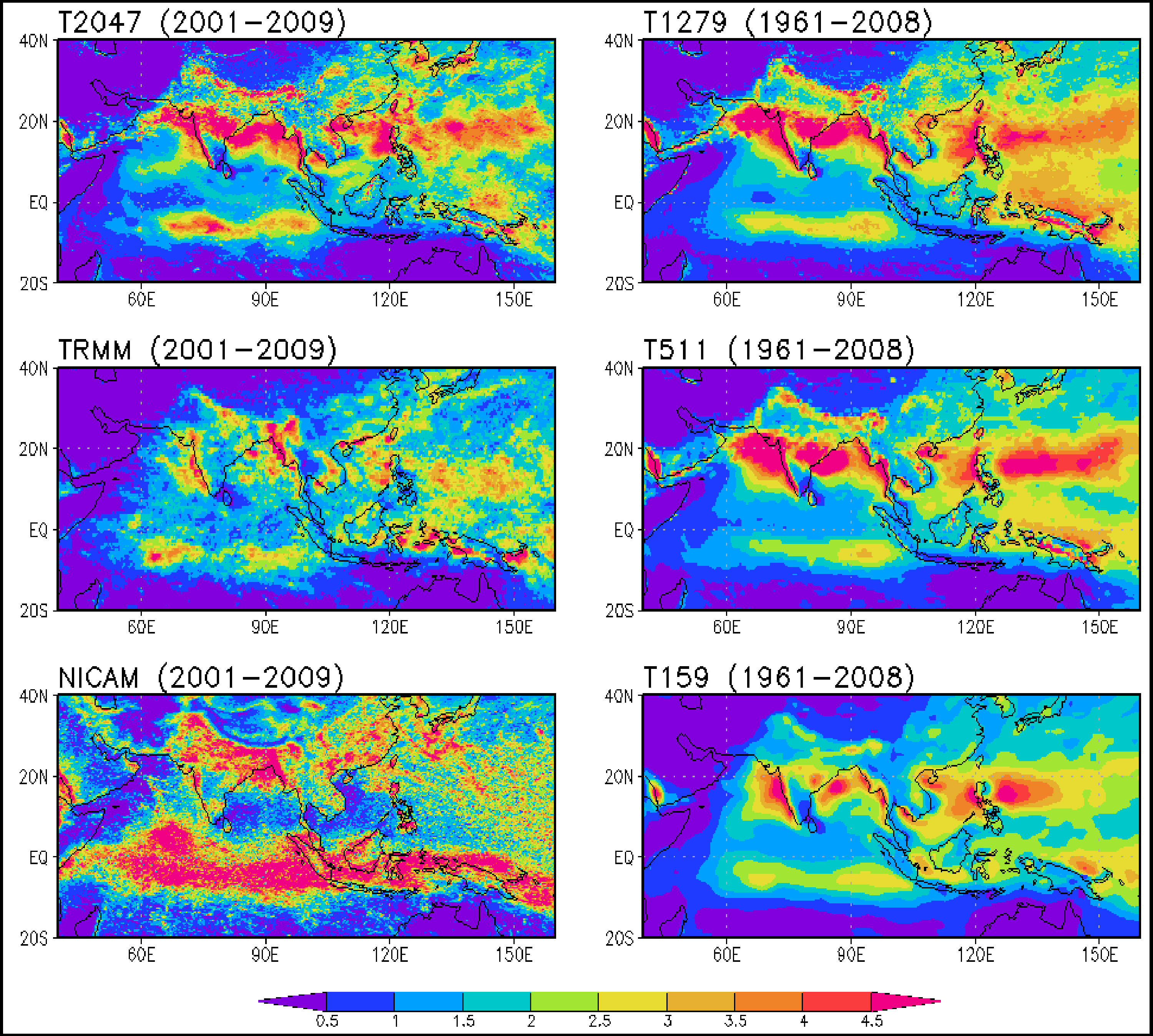
NICAM
7 km

IFS T1159
125 km



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

Standard Deviation of JJA Precipitation Anomalies



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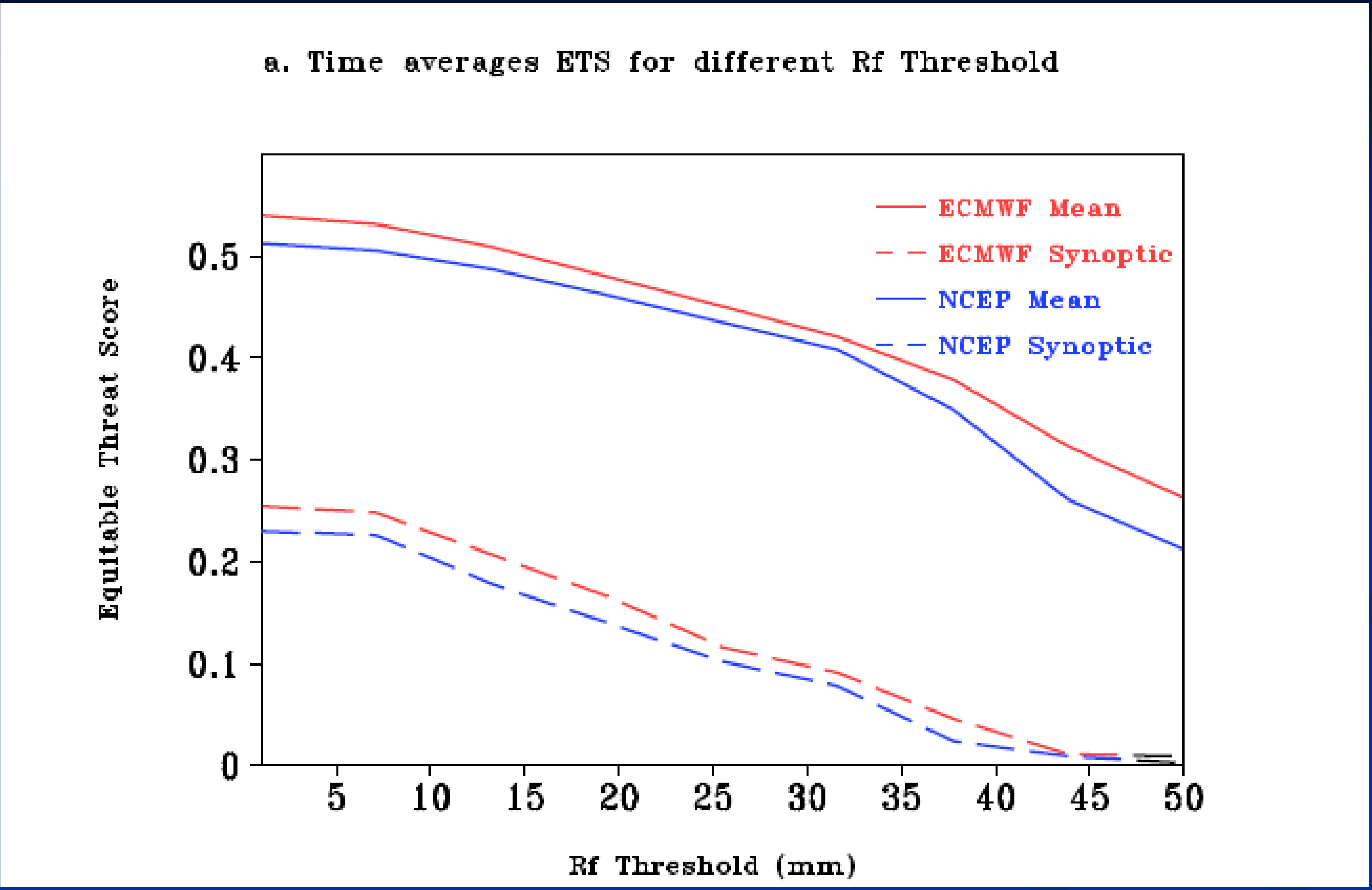
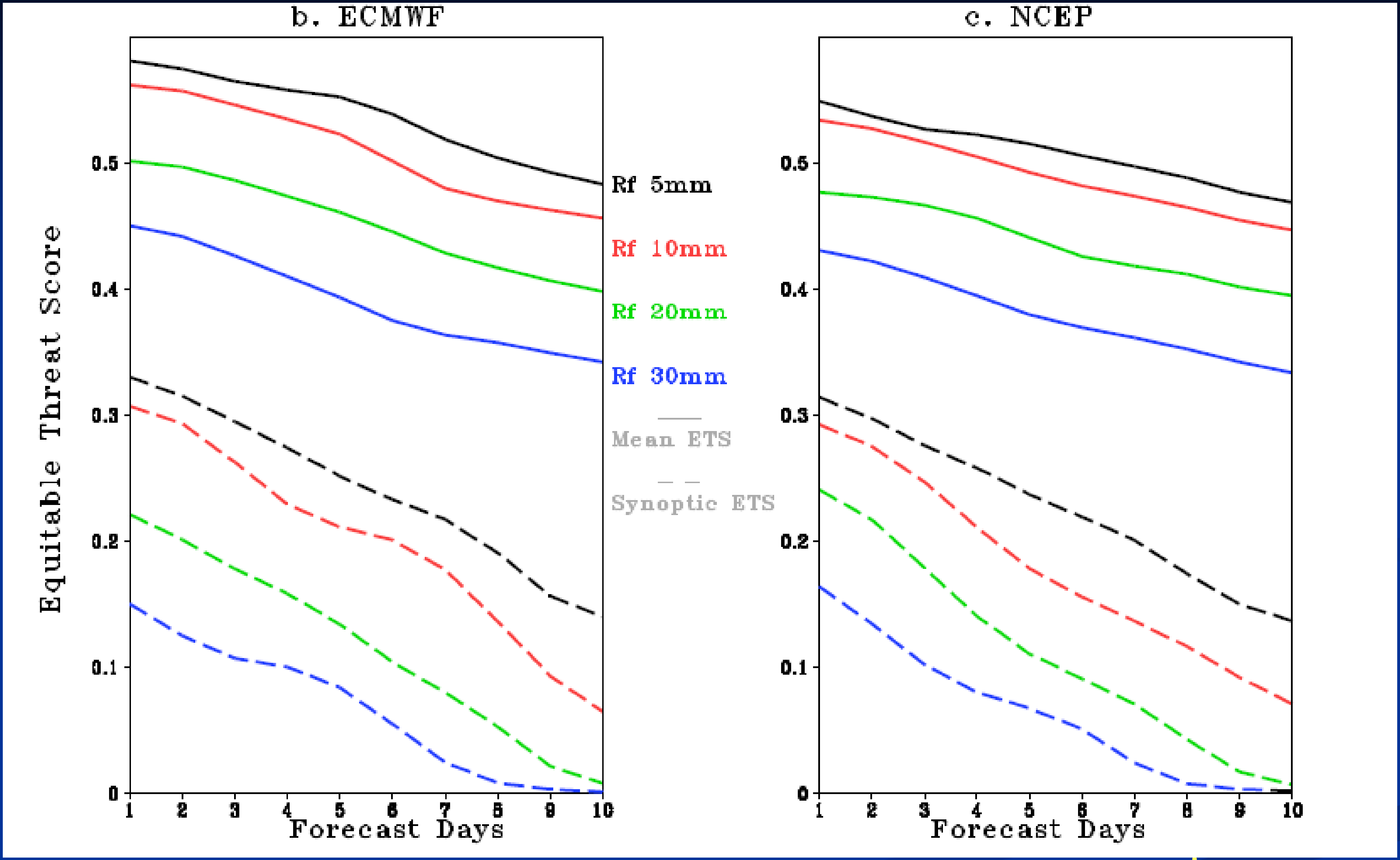
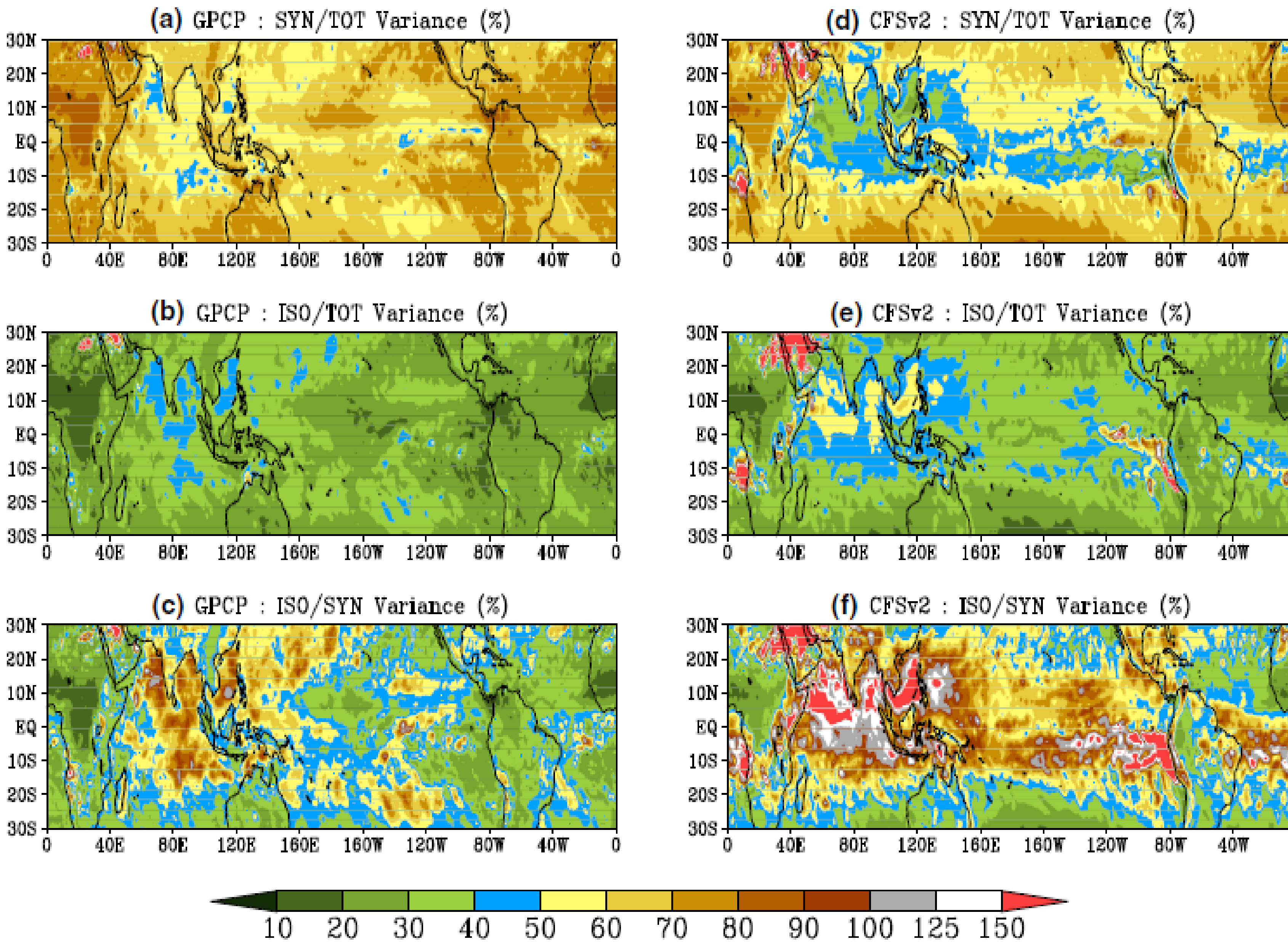


Taraphdar et al. 2016

Boreal Summer Global tropics


b. ECMWF
c. NCEP
Equitable Threat Score
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
Forecast Days
Rf 5mm
Rf 10mm
Rf 20mm
Rf 30mm
Mean ETS
Synoptic ETS



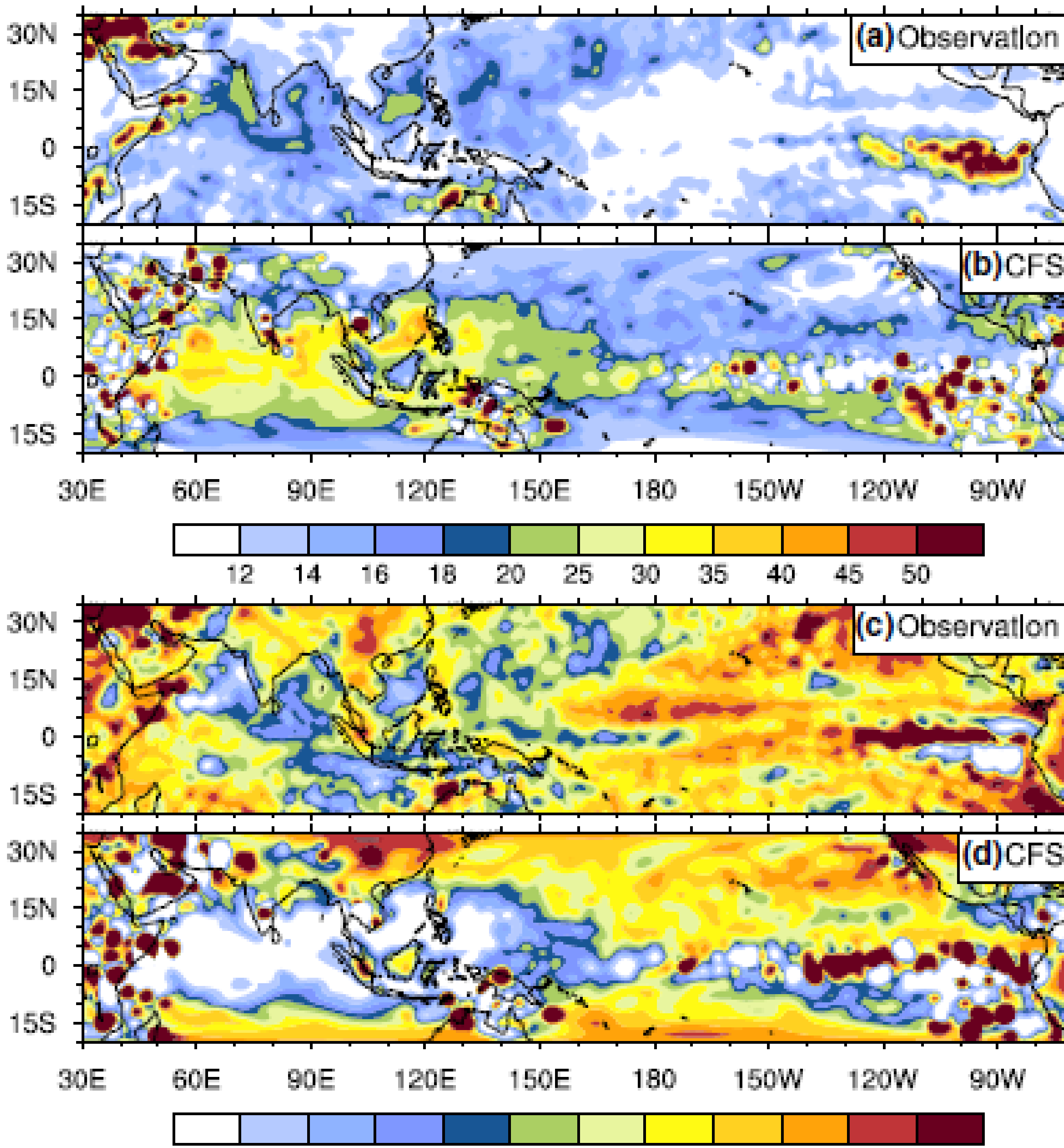
Goswami et al. 2014

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

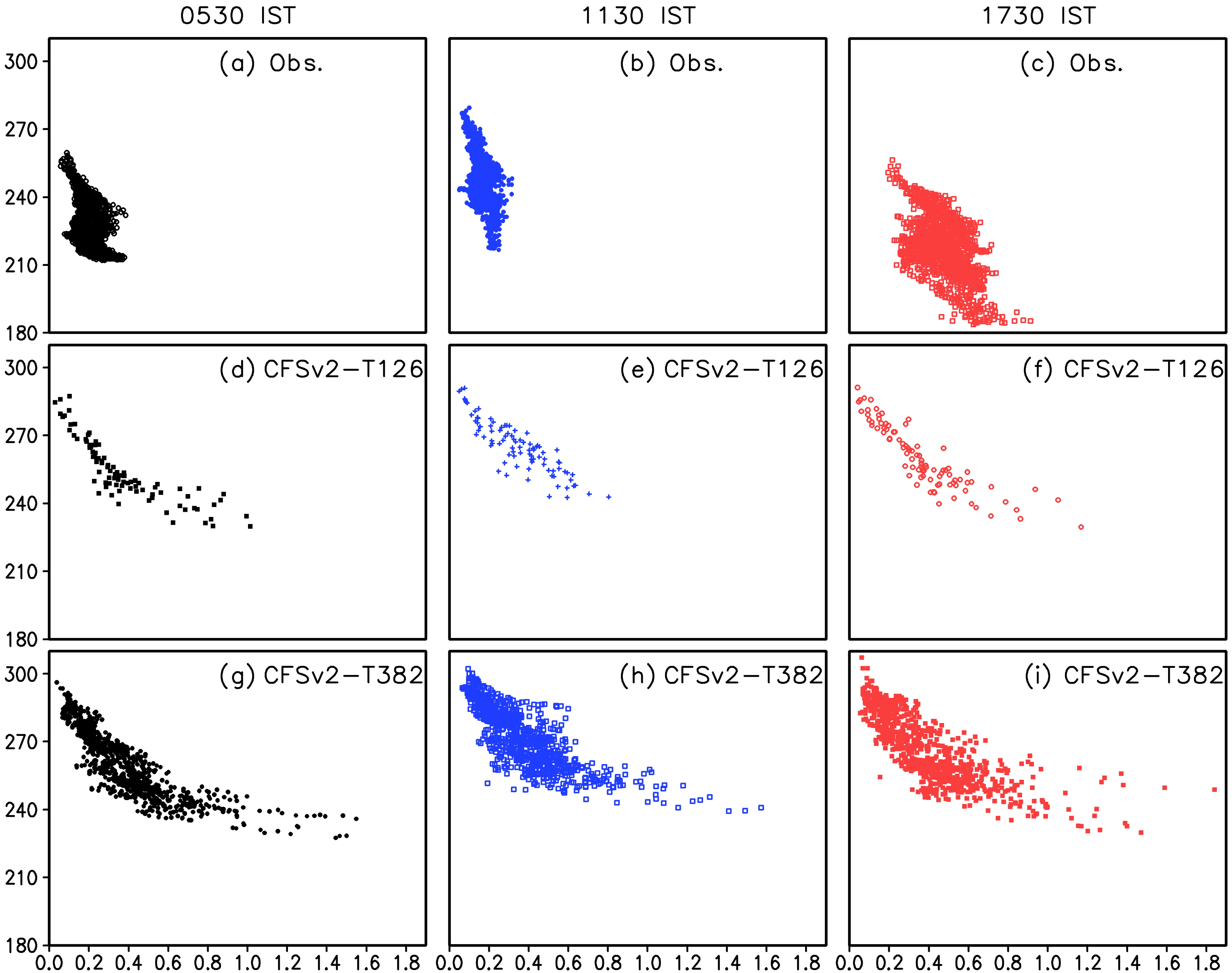
Abhik et al. 2015

CFSv2 T382 ISO 10-90 days variance



CFSv2 T382 Synoptic variance (2-10 Days)

CFSv2 T382 overestimates ISO and underestimates Synoptic variance over tropics

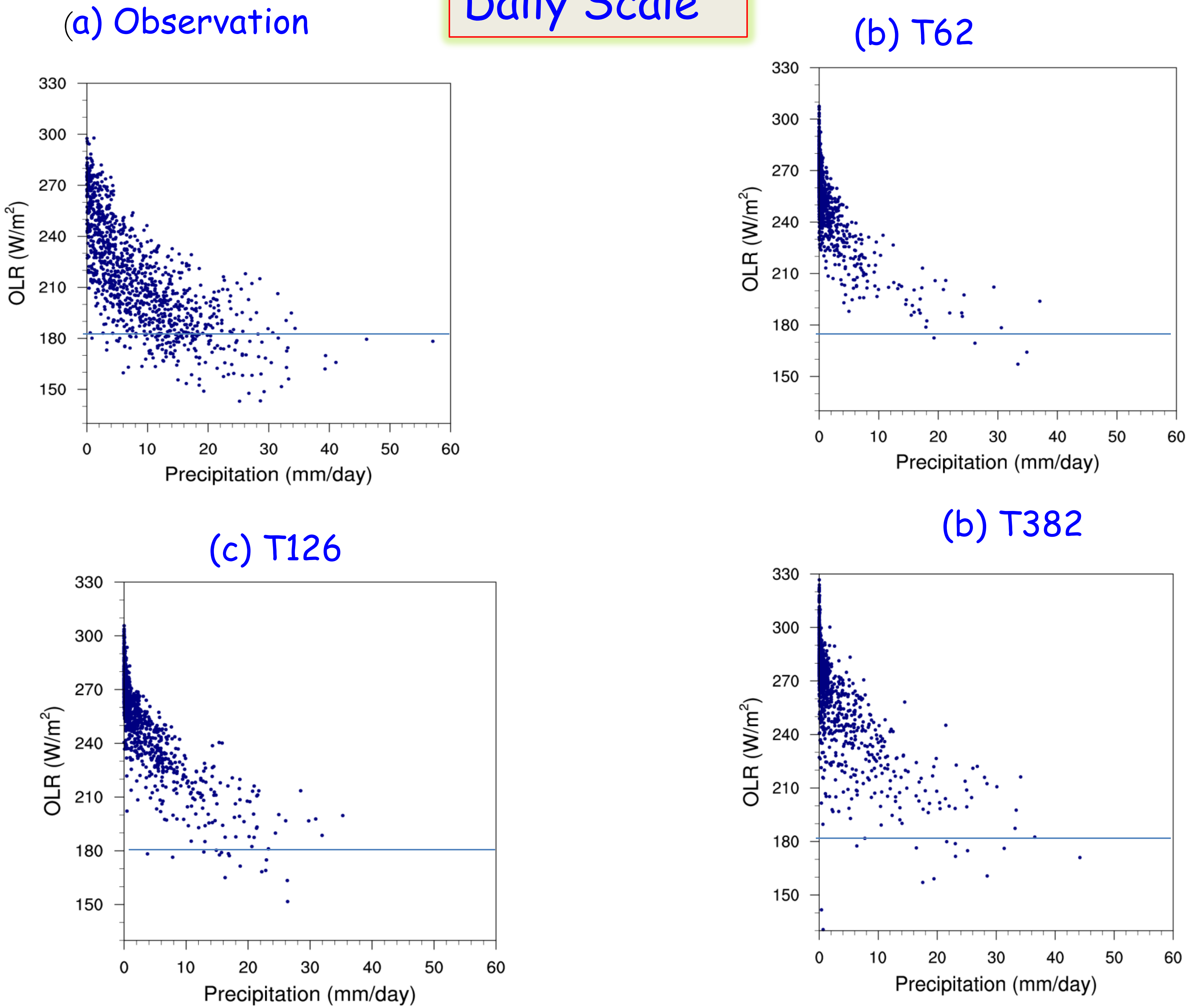


Scatter plot of OLR vs rainrate

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

Ganai et al. 2015

Daily Scale



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

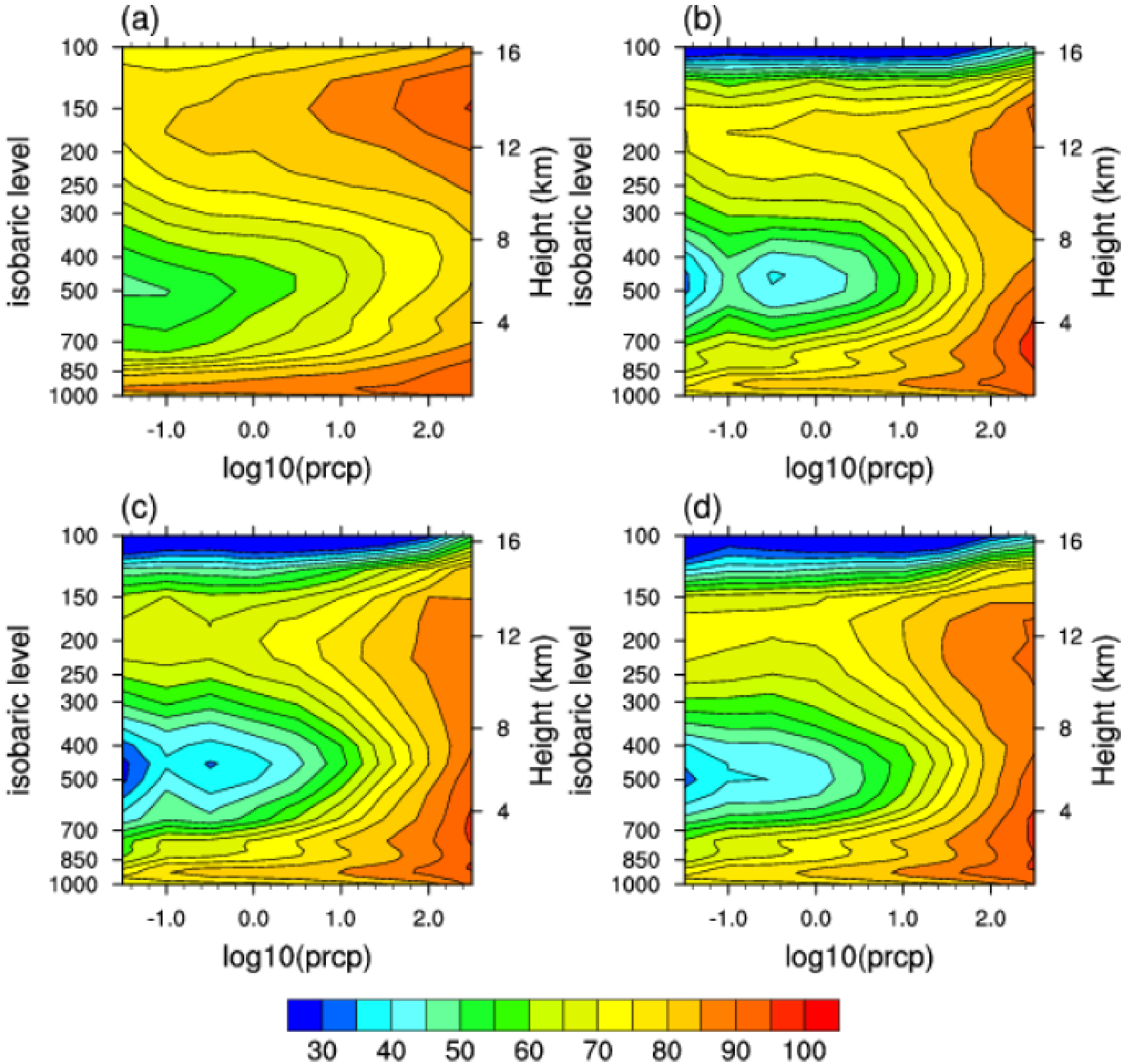


Figure 8. Composite of vertical profile of relative humidity (%, shaded) with respect to precipitation for MISO events for (a) Observation; (b) T62; (c) T126, and (d) T382.

Tirkey et al. 2019

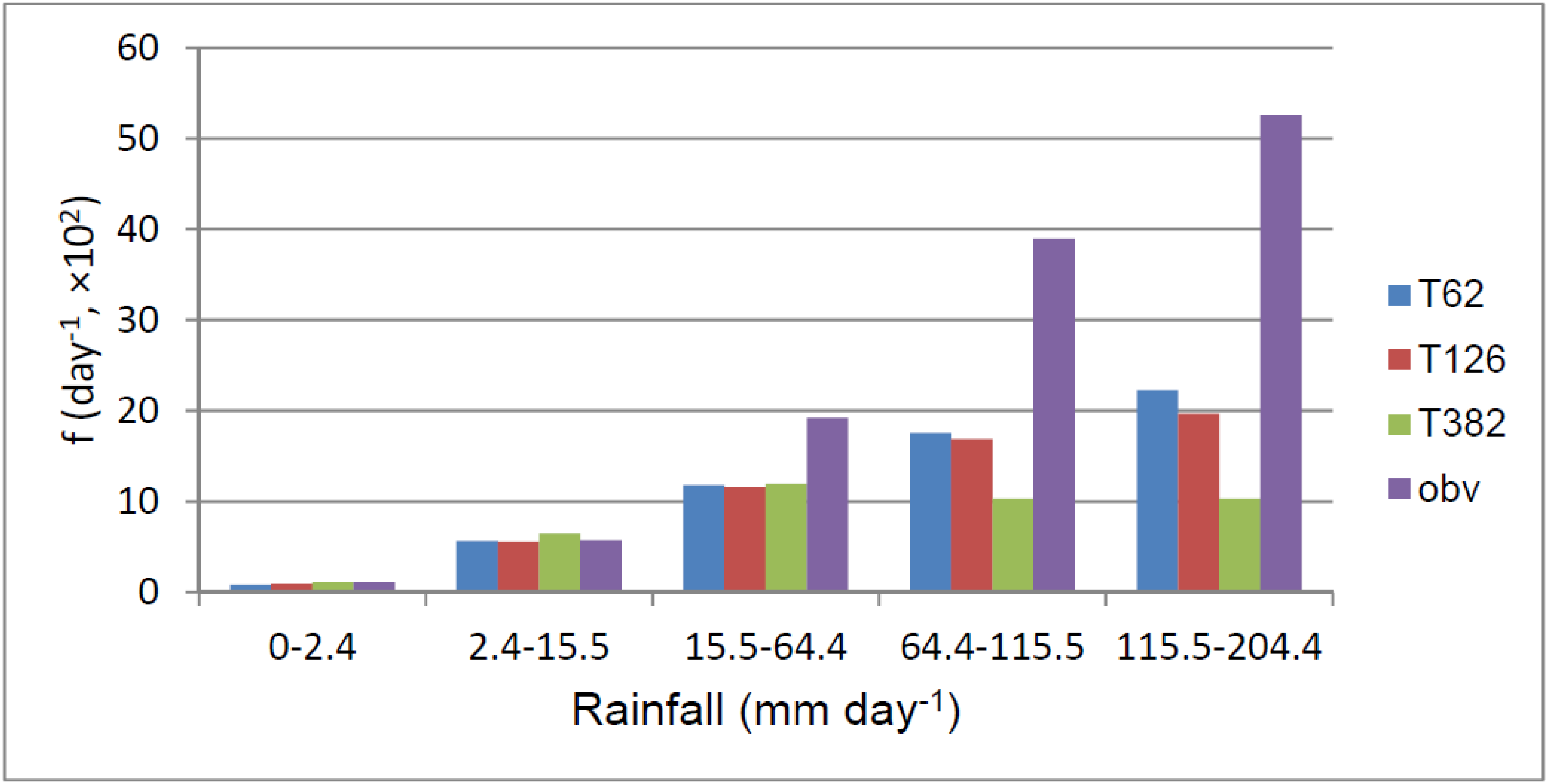


Figure 11. Precipitation efficiency (f) = precipitation rate/total grid box cloud water path of T62, T126, and T382 CFSv2 model for Indian Summer Monsoon Region (15° S–30° N, 60° E–95° E) and for MISO events.

Tirkey et al. 2019

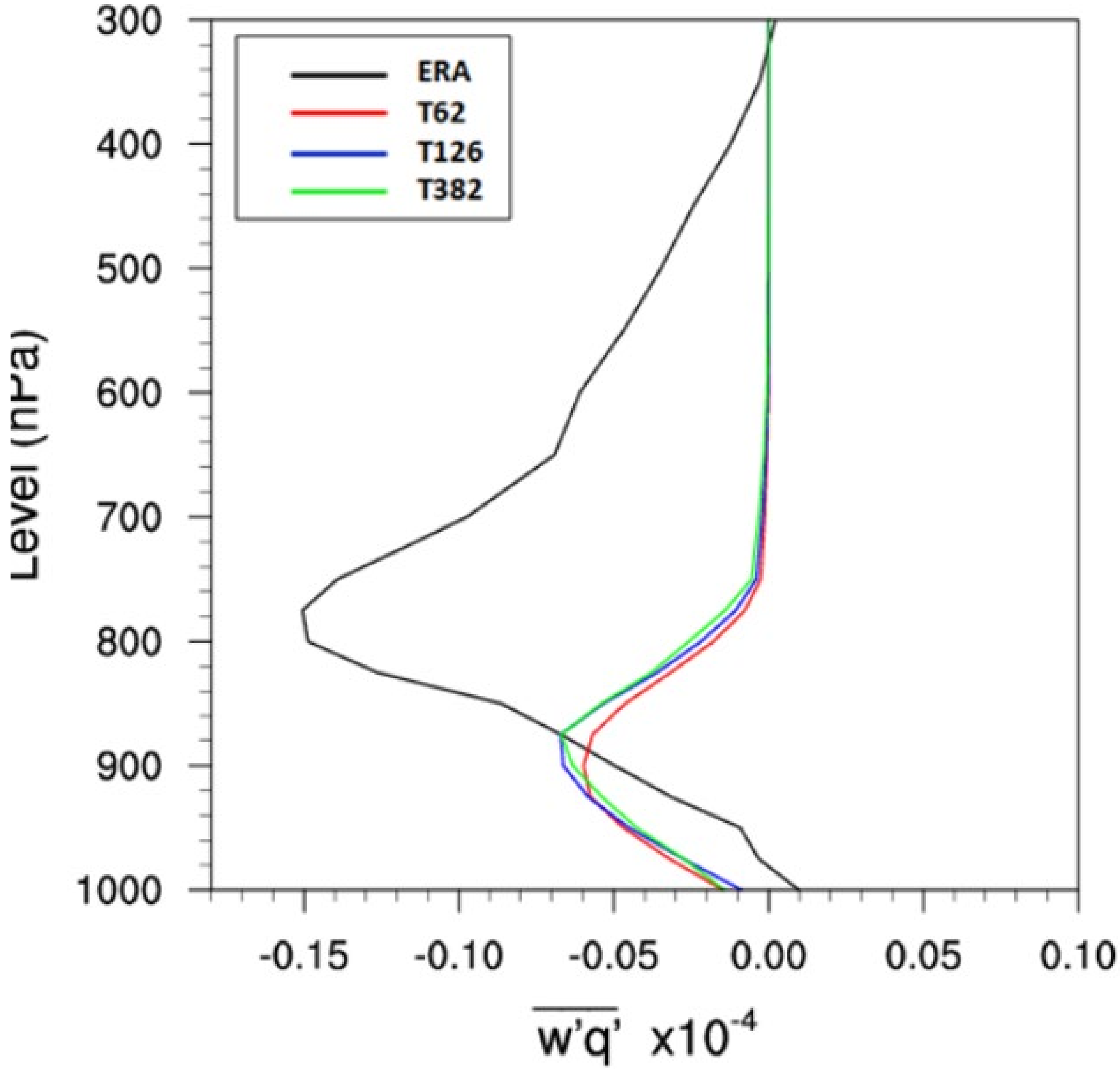


Figure 10. Vertical turbulent flux of moisture (kg m^{-2} s^{-1}) for Indian Summer Monsoon Region (15° S–30° N, 60° E–95° E) during MISO events.

Tirkey et al. 2019

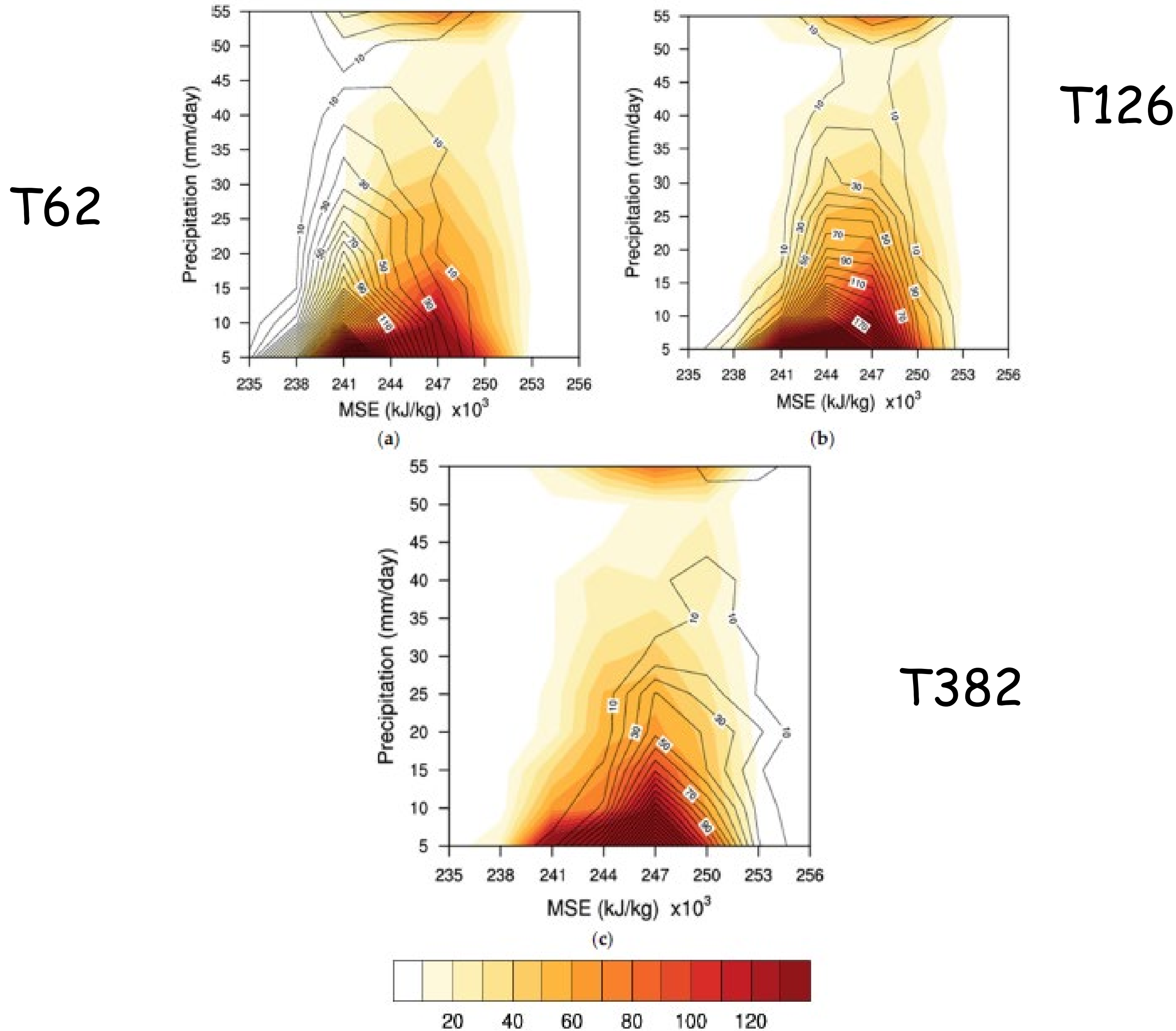
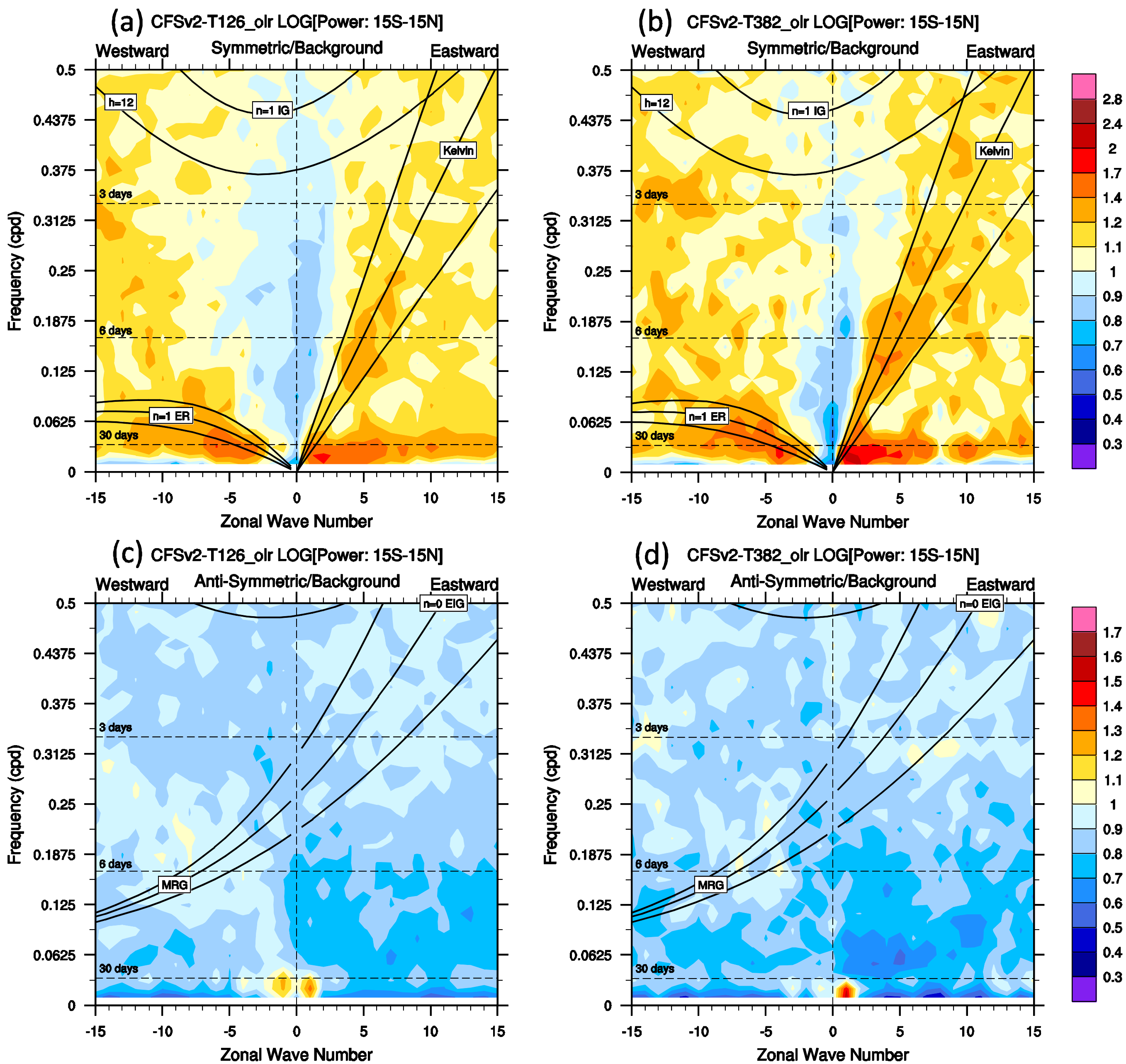


Figure 7. Joint distribution of Moist Static Energy (MSE) and rainfall for MISO events for Indian Summer Monsoon region (15° S–30° N, 60° E–95° E), shading for observation (Obs) and contour for model; (**a**) T62 and Obs; (**b**) T126 and Obs; (**c**) T382 and Obs.

Tirkey et al. 2019

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.

B. B. Goswami et al. 2015

CFSv2 T382

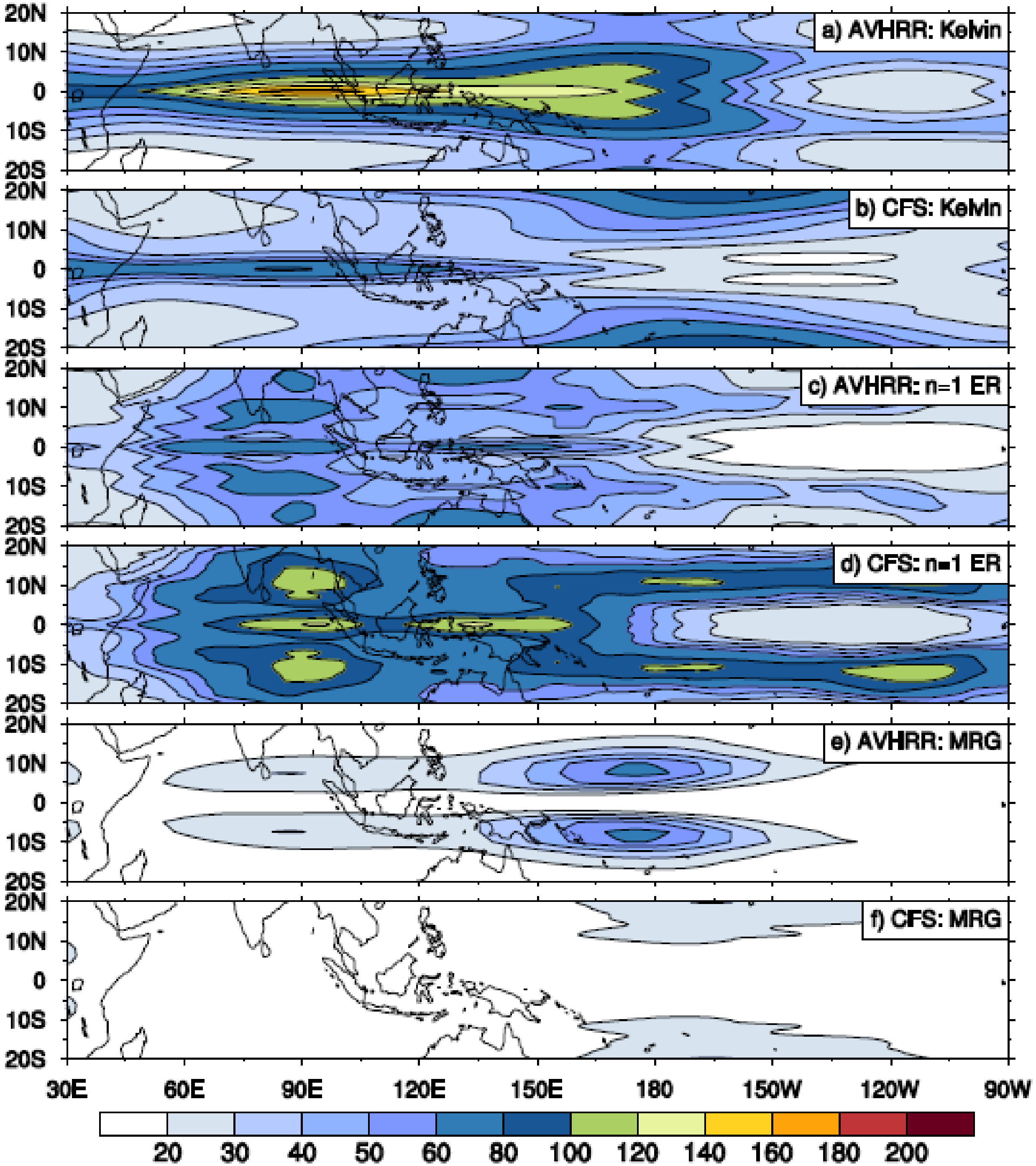


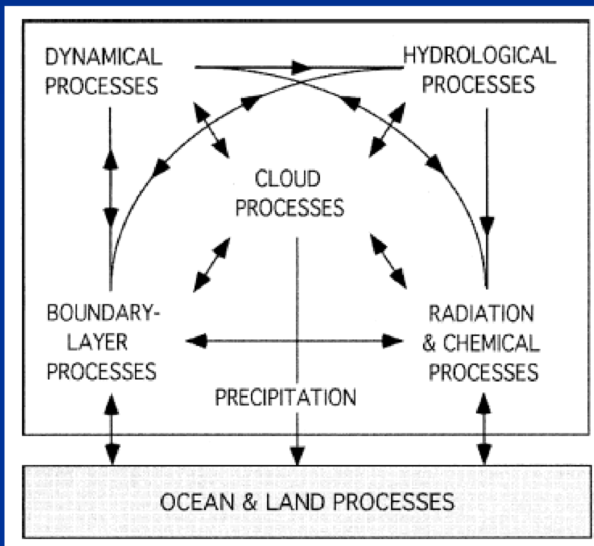
Fig. 13: Distribution of boreal summer time OLR variance ($W^2\ m^{-4}$) of (a), (b) Kelvin; (c), (d) n=1 ER and (e), (f) MRG waves for AVHRR and CFS.

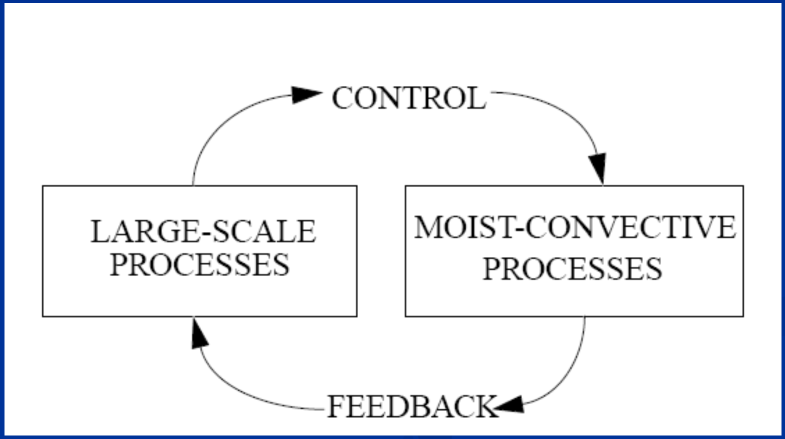
Abhik et al., 2015

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,

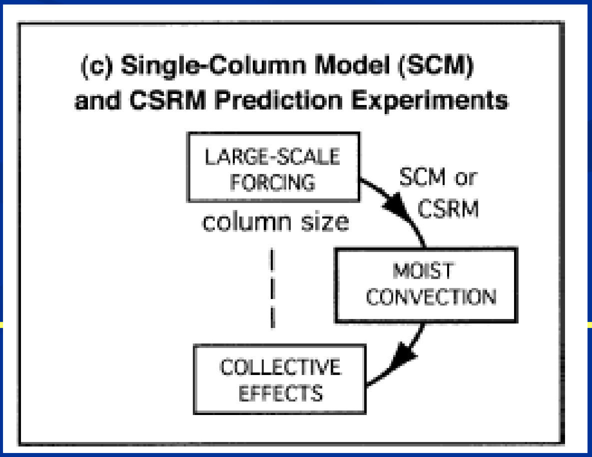
F_i = environmental forcing for cloud i

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

Task of Conv. Param

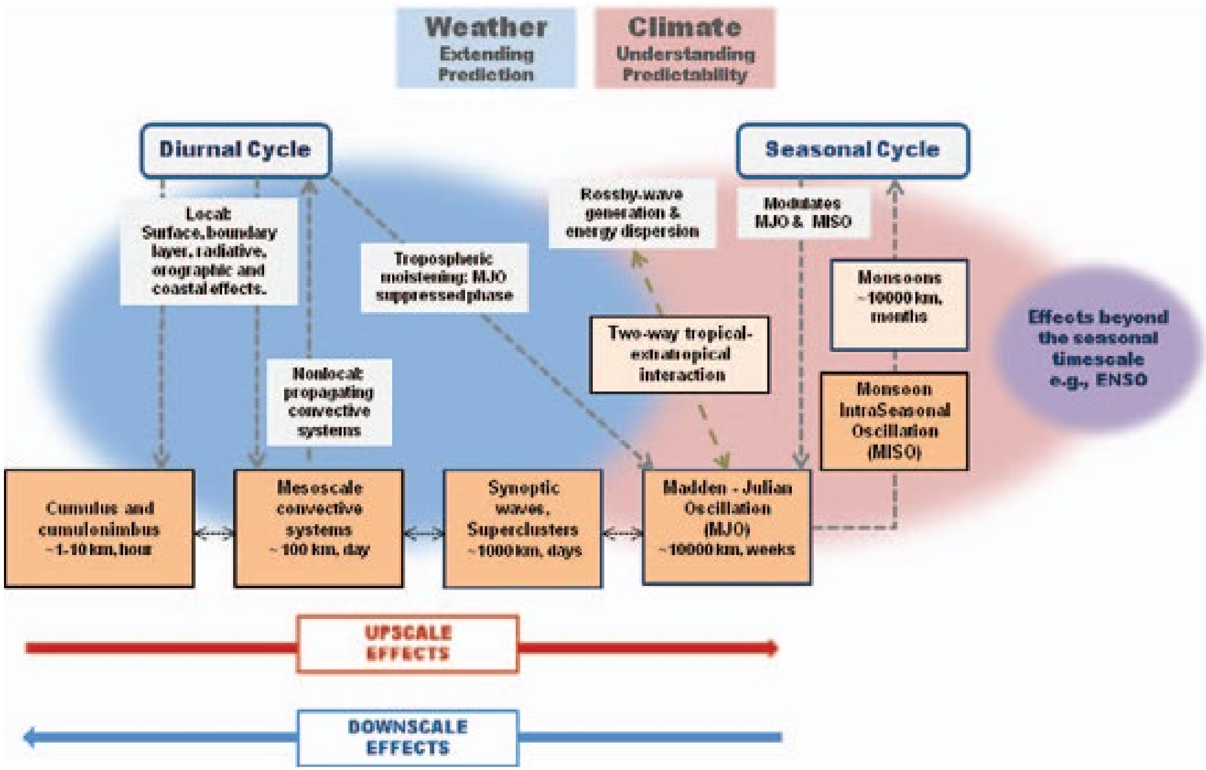
To calculate the collective effects of an ensemble of convective clouds in a model column

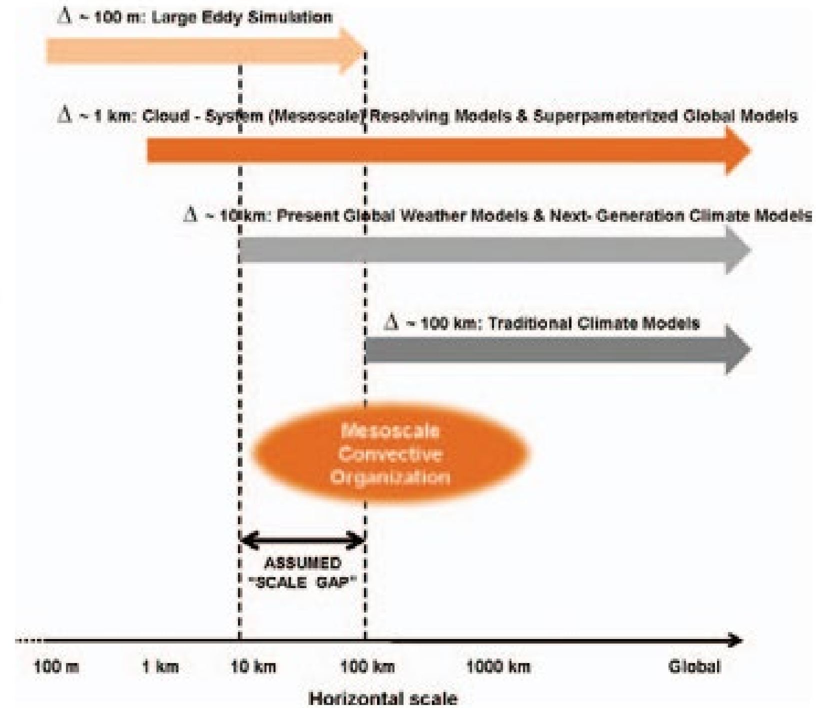
$$Q_{1C} \equiv Q_1 - Q_R \equiv L(\bar{c} - \bar{e}) - \frac{\partial \overline{\omega' s'}}{\partial p}$$



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.**

Flowchart of GEFS

The Global (Ensemble) Forecast Model

EnKF – GSI Hybrid Data Assimilation System

Analysis (Control)

Ensemble Initialization method: Ensemble Kalman Filter (EnKF) scheme.

The 6-hr forecasts from the previous cycle

20 Perturbed members

Tropical Storm Relocation (if storm is present)

Centering of the perturbations on the ensemble control analysis (Distributes the spread around analysis instead of Ensemble Mean

FORECAST: 21 members runs for 192 hrs (8 days) GFS Semi-Lagrangian T1534 (approx 12 km at equator); L64 vertical resolution.

The stochastic total tendency perturbation (STTP) to enhance model uncertainty

POST PROCESSING

240 hr (10 days) forecast

Resolution: 0.125°x0.125°

6 hr interval

Products: 21 members, Ensemble mean, Ensemble Spread

Flowchart of deterministic GFS

GDAS

EnKF – GSI Hybrid Data Assimilation System

Analysis(Control)

FORECAST: GFS Semi-Lagrangian T1534 (approx 12 km at equator)

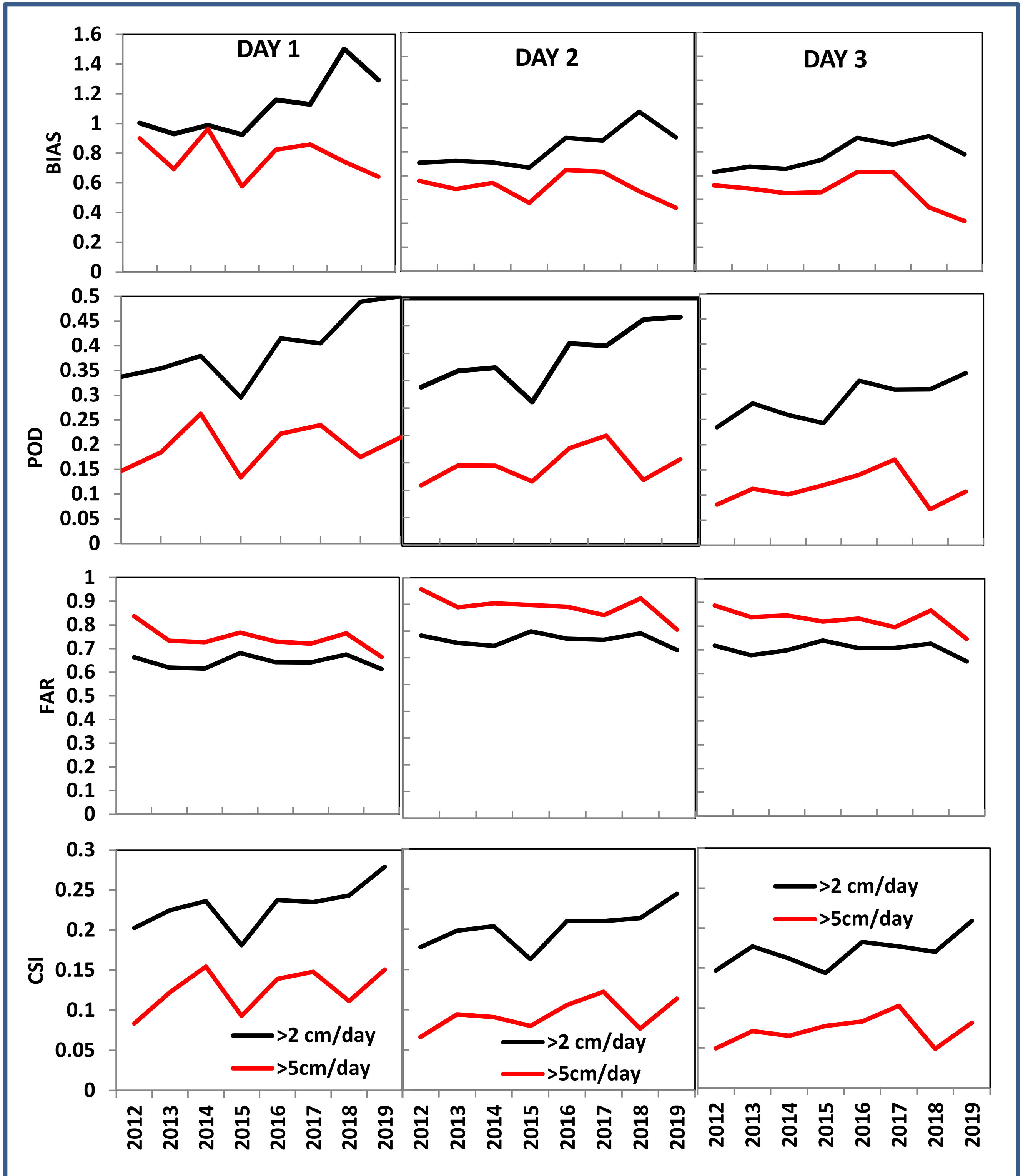
L64 vertical resolution, runs for 240 hrs (10 days)

POST PROCESSING

240hr (10 days) forecast

Resolution: Regular grid and Gaussian grid at different resolutions

0.125°x0.125°



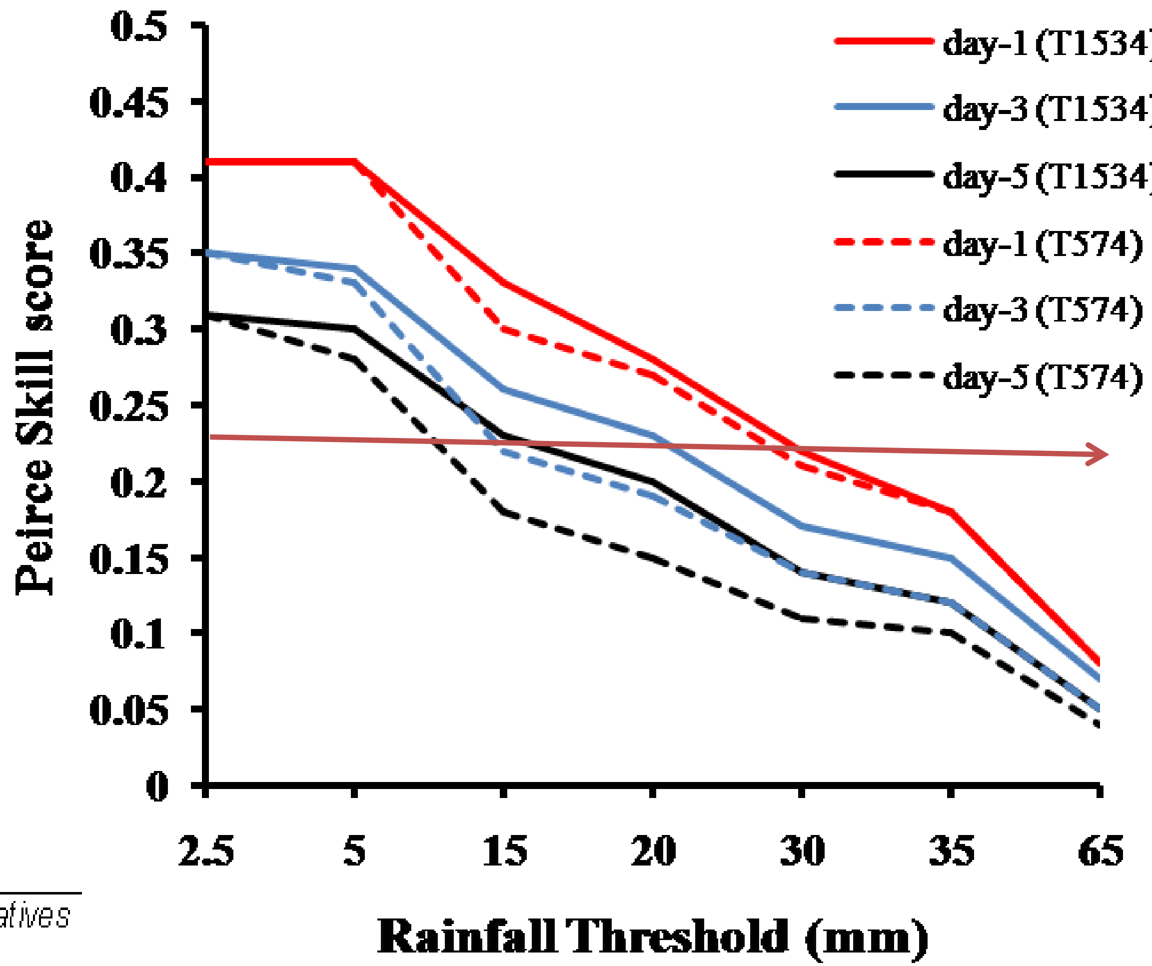
Verification of Rainfall forecasts from GFS for JJAS (2012-2019)

Monsoon Core Zone (18-28N, 66.5-88E)

- Bias Score: Frequency Bias
  - >1 implies model overestimates observed rain
  - >1 implies model underestimates observed rain
- Probability of Detection (POD): Fraction of correct forecasts
  - 0 No Skill
  - 1 Perfect Score
- False Alarm Ratio (FAR): Fraction of fals alarms
  - 1 Worst
  - 0 Best
- Critical Success Index (CSI) : Threat Scor
  - 0 No Skill
  - 1 Perfect Score

Peirce Skill Score (High Resolution global 12.5 km model gives better skill (The skill of GFS T574 with 3 day lead is now extended to 5 days with T1534 ~12.5 km global GFS

Hanssen and Kuipers discriminant (true skill statistic, Peirce's skill score) - (also denoted TSS and PSS)
Range: -1 to 1, 0 indicates no skill. **Perfect score:** 1.

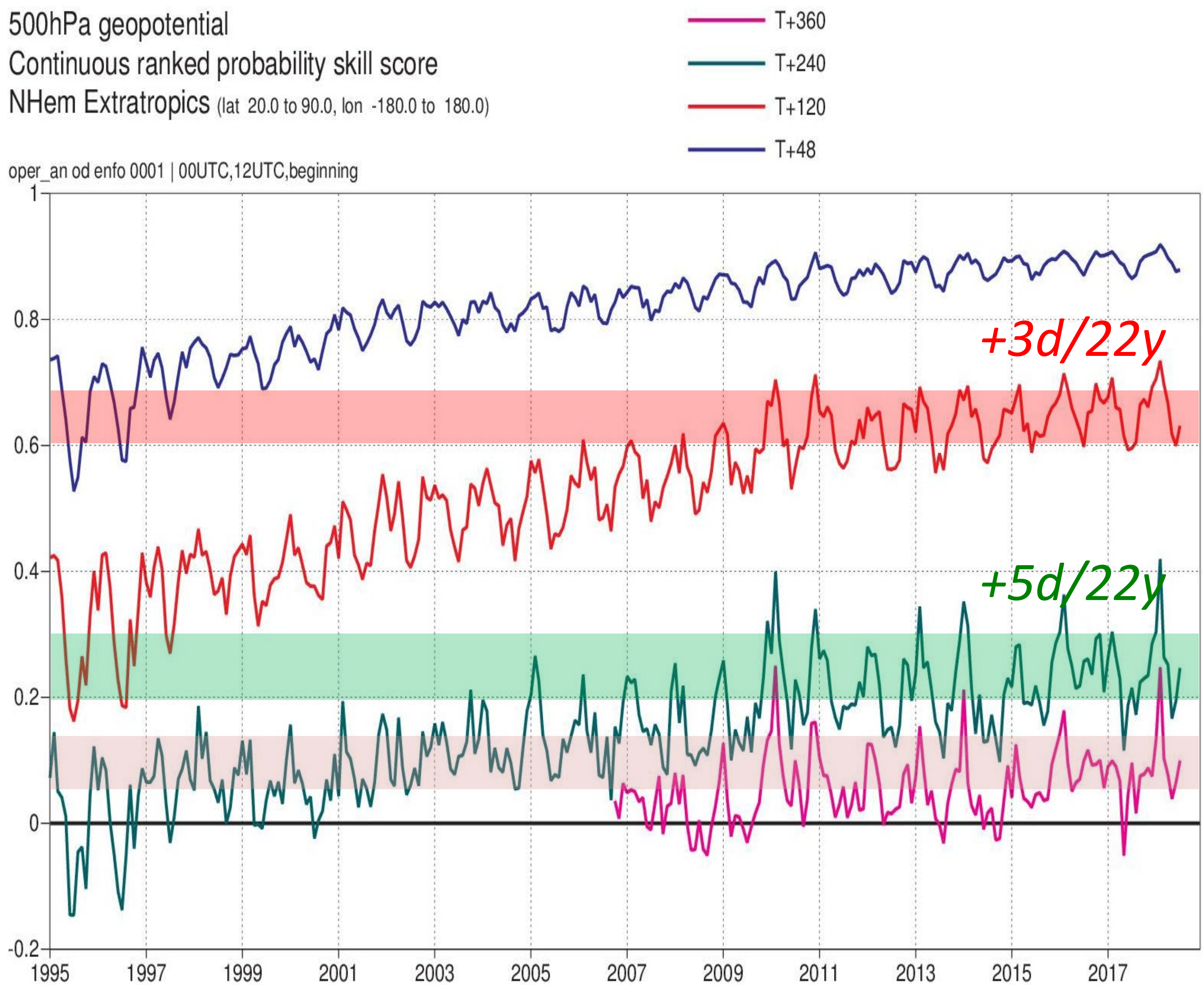


$$HK = \frac{hits}{hits + misses} - \frac{false\ alarms}{false\ alarms + correct\ \ negatives}$$

Rao et al. 2019, BAMS

NH X-TR: we have gained ~ 2+ days per decade

For the X-tropics we have been improving by ~2 days per decade



(verified against analyses)

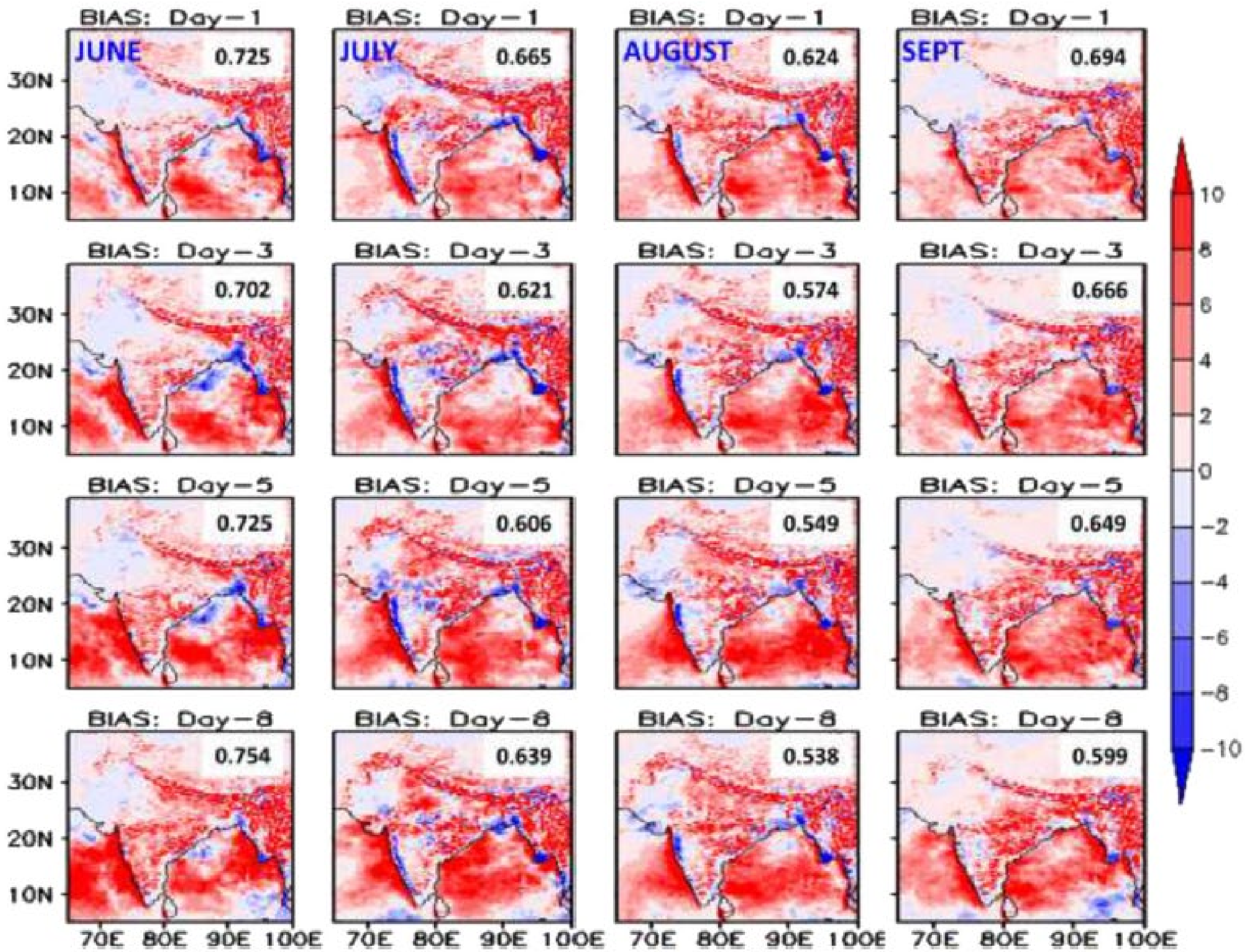
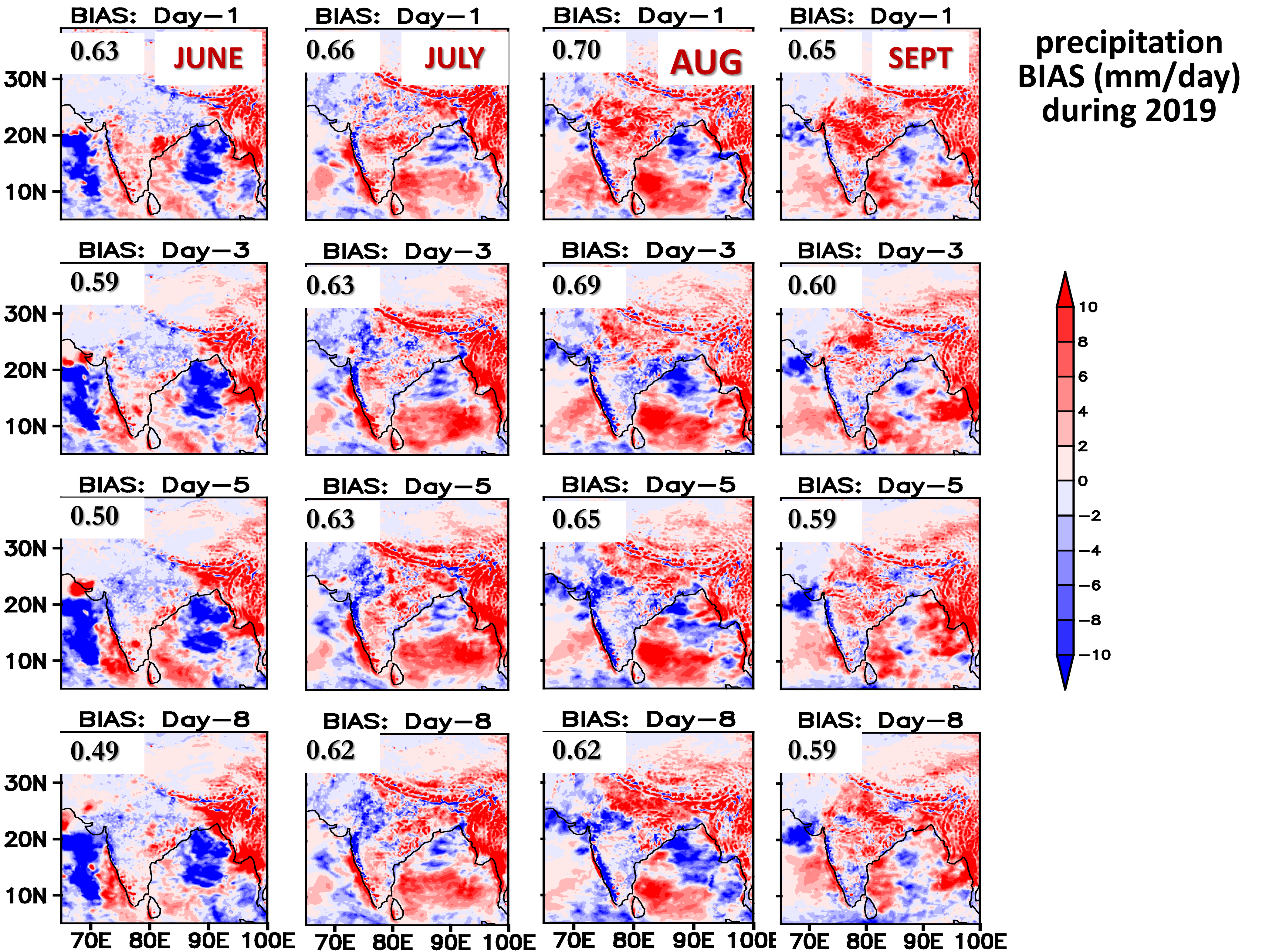
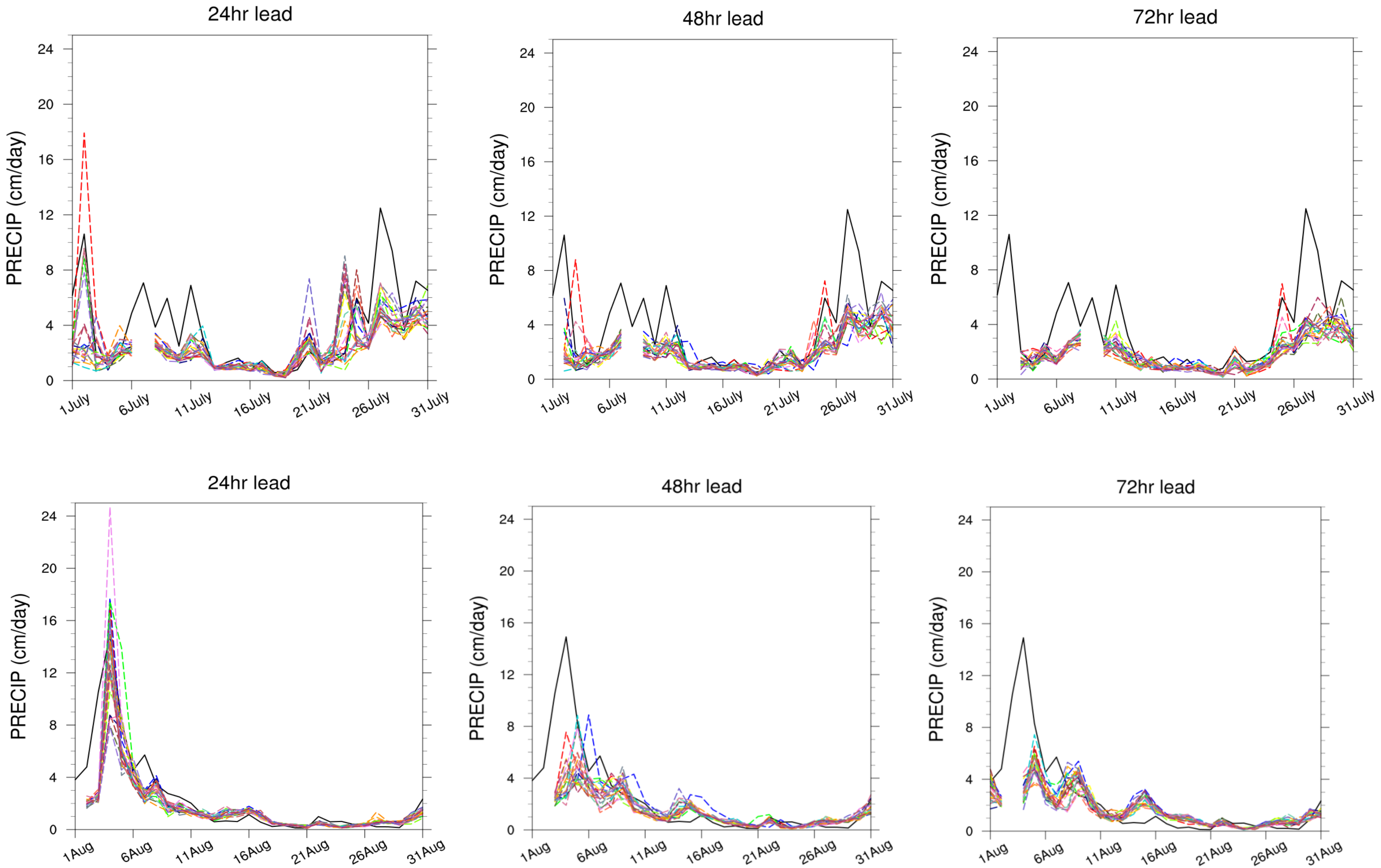


Figure 3. JJAS rainfall bias (mm day^{-1}) for day-1, day-3, day-5 and day-8 lead time from the GFS T1534 model forecast with respect to IMERG gridded data during June, July, August and September, respectively.

Mukhopadhyay et al. 2019

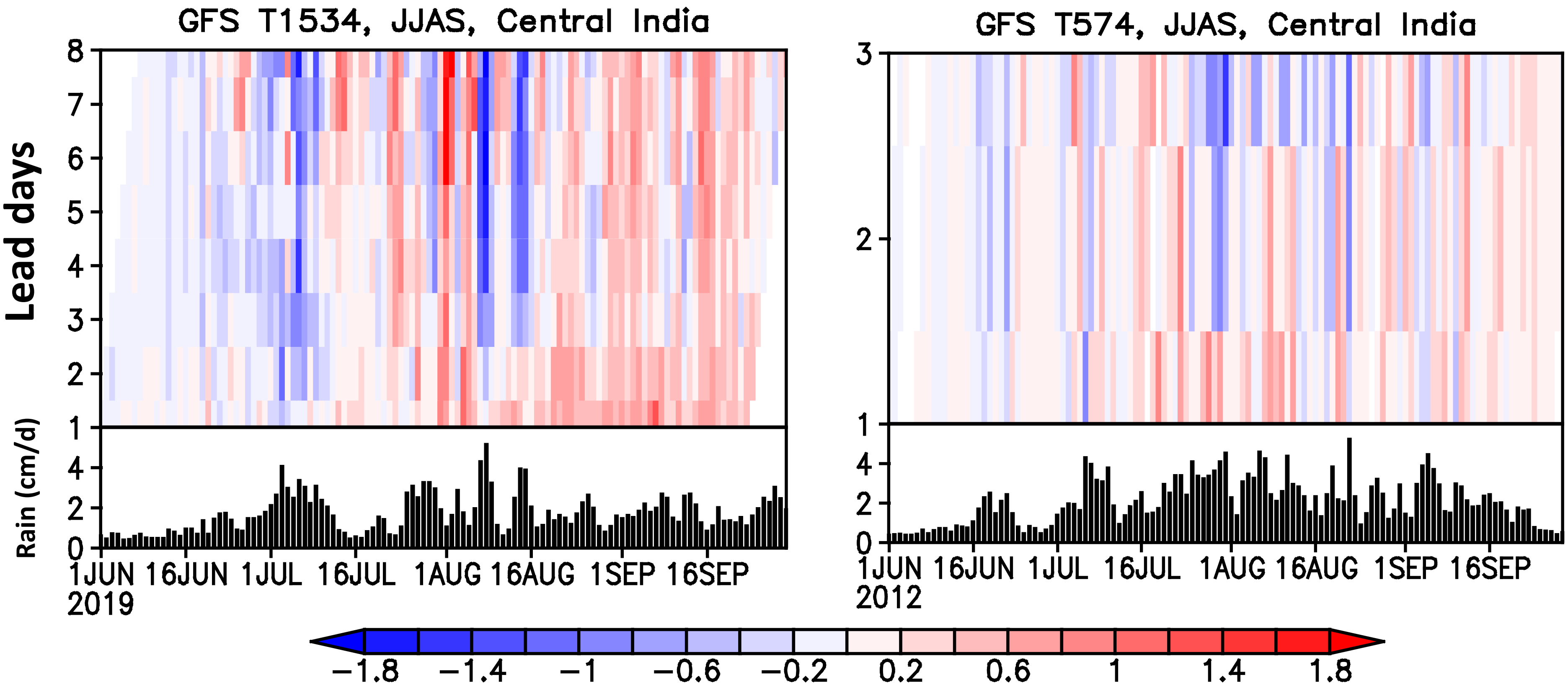

precipitation
BIAS (mm/day)
during 2019
JUNE
JULY
AUG
SEPT
BIAS: Day−1
BIAS: Day−3
BIAS: Day−5
BIAS: Day−8
0.63
0.66
0.70
0.65
0.59
0.63
0.69
0.60
0.50
0.63
0.65
0.59
0.49
0.62
0.62
0.59
30N
20N
10N
70E
80E
90E
100E
10
8
6
4
2
0
−2
−4
−6
−8
−10



Time series of rainfall for Mumbai/Pune region (18-19.5N, 72-74E) shown for observation (black line) and ensemble members (colored, dashed) from GEFS T1534 for July and Aug 2019

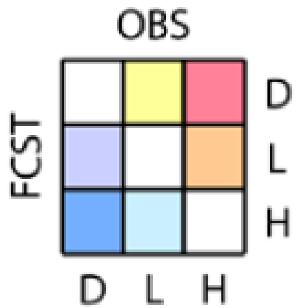
Chiclet diagram

Central India (74E-85E, 18N-27N)
JJAS – 2019, Upper panel rainfall (shaded) bias in GFS T1534 with respect to IMD-GPM merged rainfall

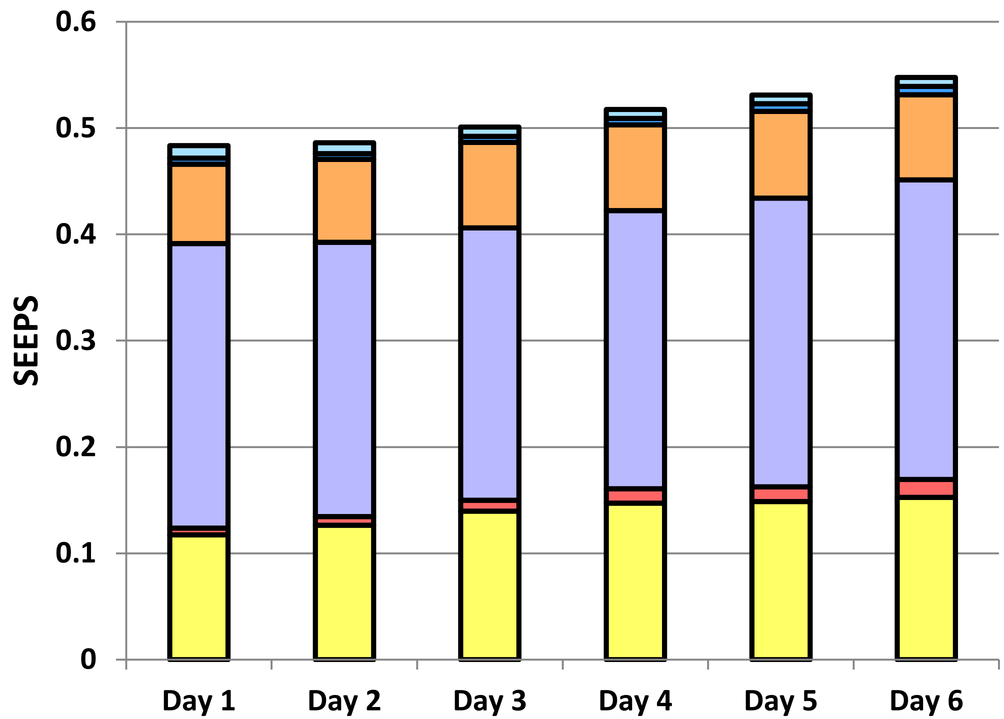


SEEPS for GFS T1534 for Indian land points only

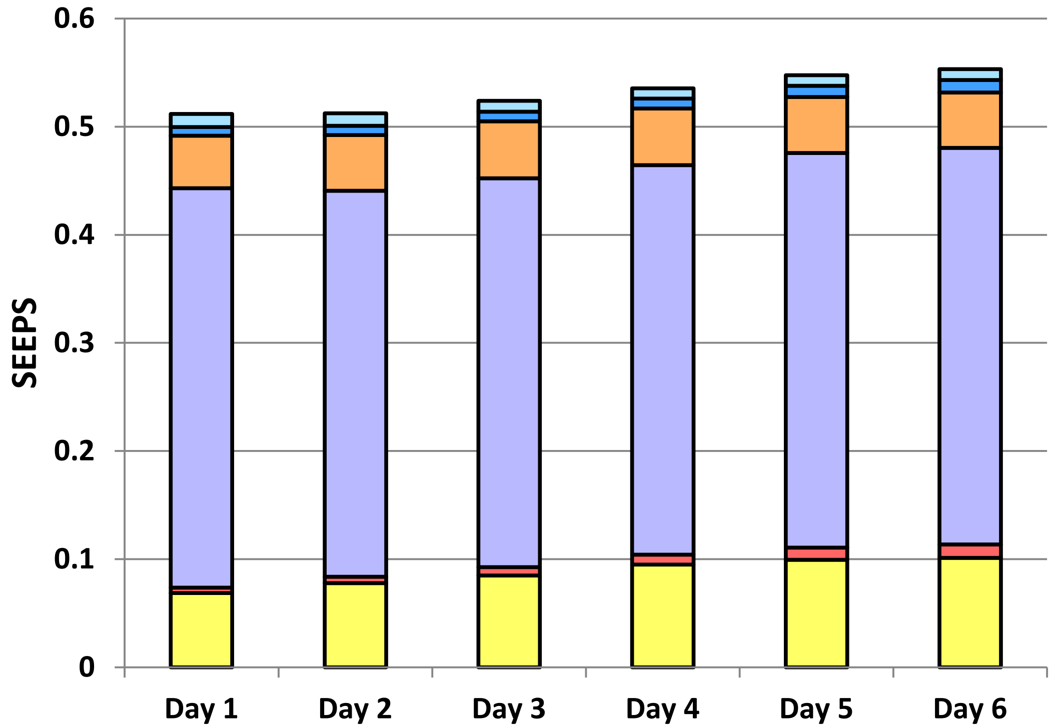
Stable Equitable Error in Probability Space (SEEPS) score for GFS T1534 JJAS 2018 and 2019 for Indian land points only. It is an error score which uses the categories 'dry (D)', 'light precipitation (L)', and 'heavy precipitation (H)' based on the climatological cumulative precipitation distribution.

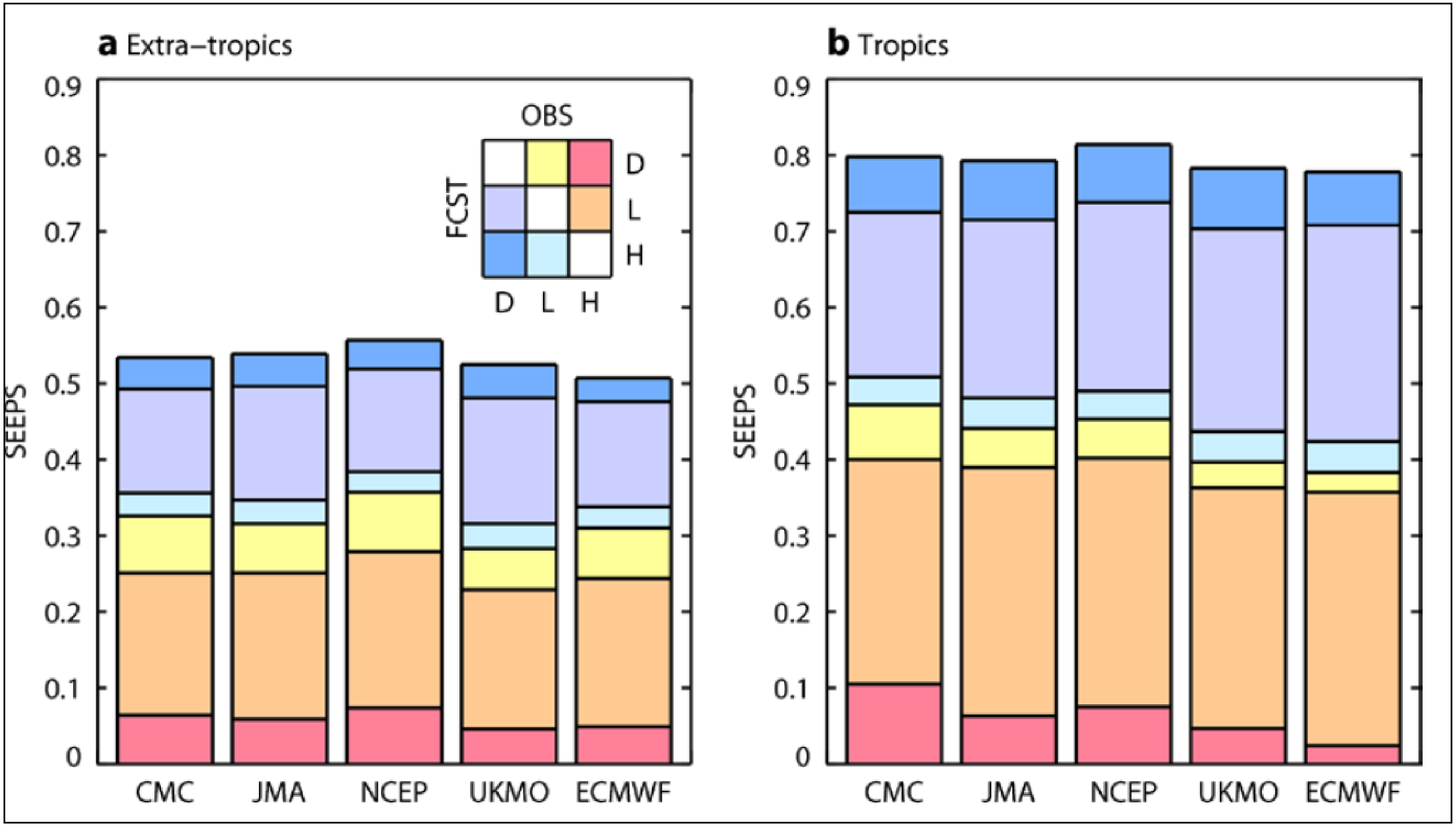


JJAS 2019



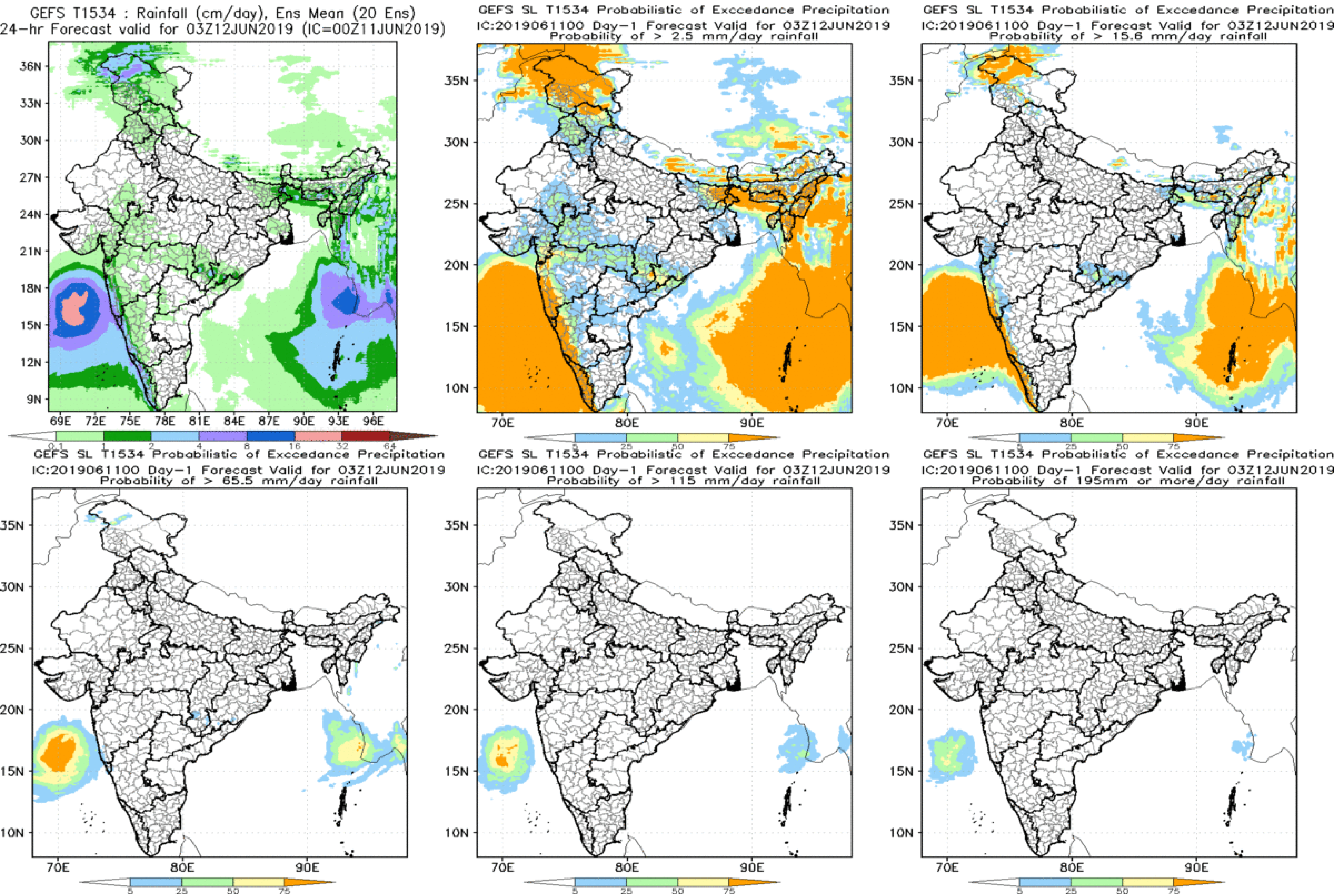
JJAS 2018

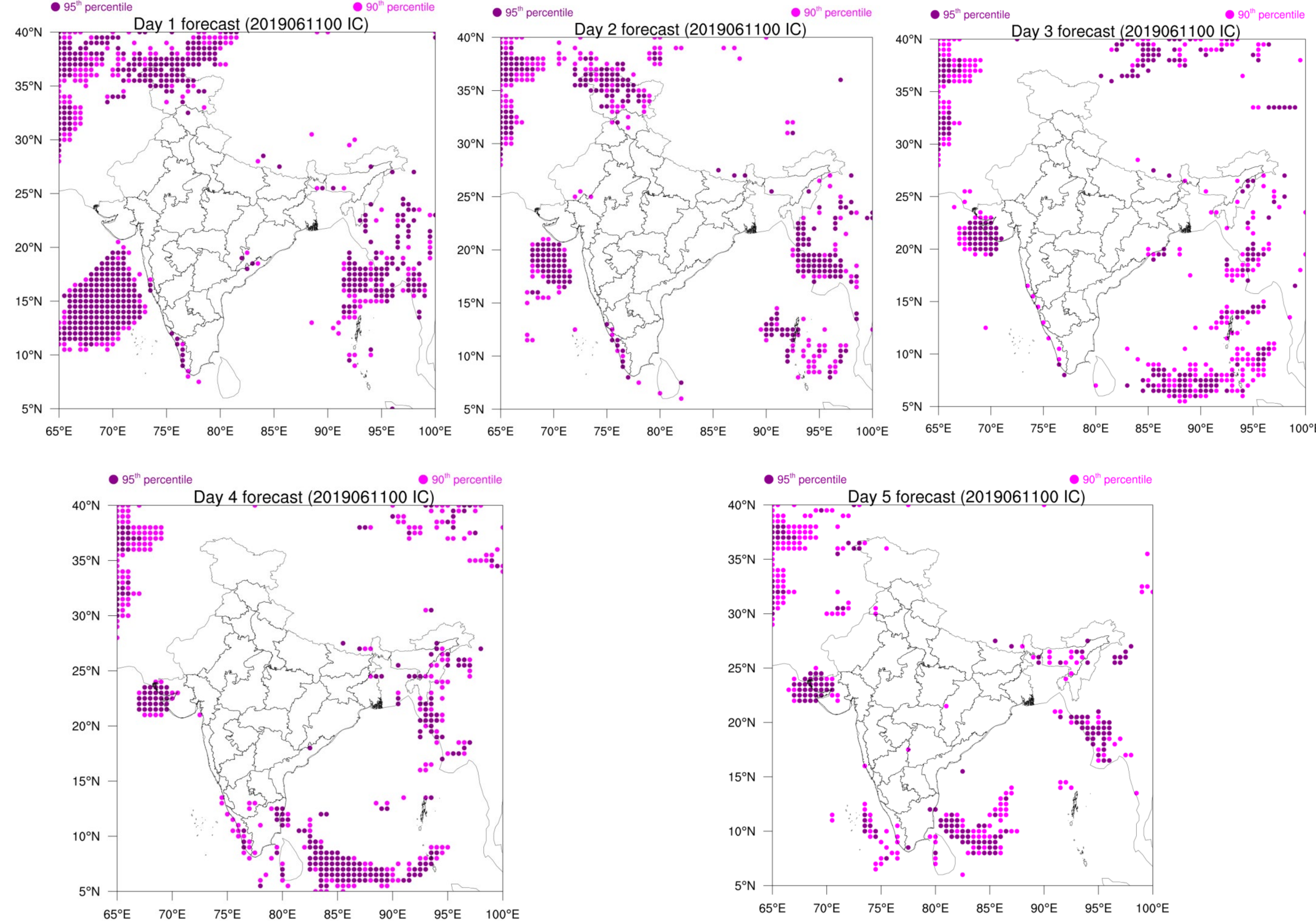




Comparison Precipitation forecast skill global model 2010/2011

Probabilistic rainfall forecast from GEFS T1534





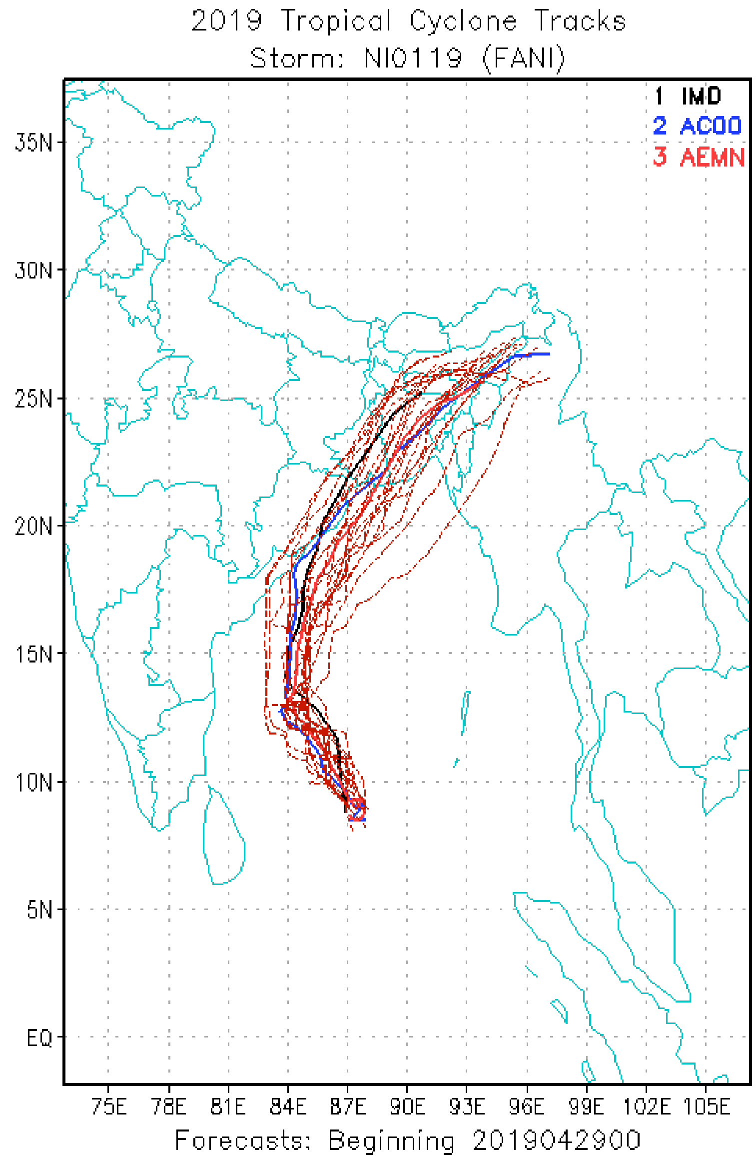
Percentile based extreme rainfall forecast from GFS T1534

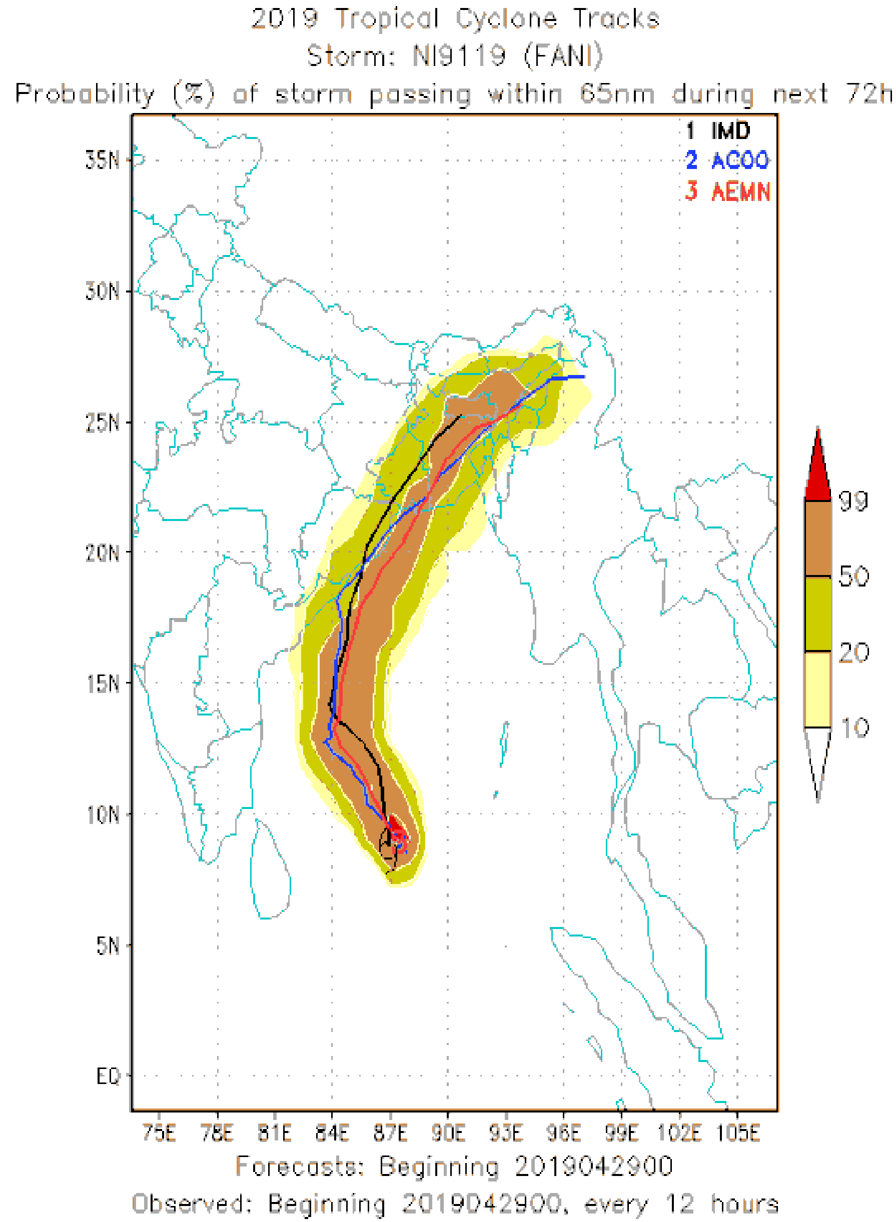
IMD - Observation

AC00 - control run

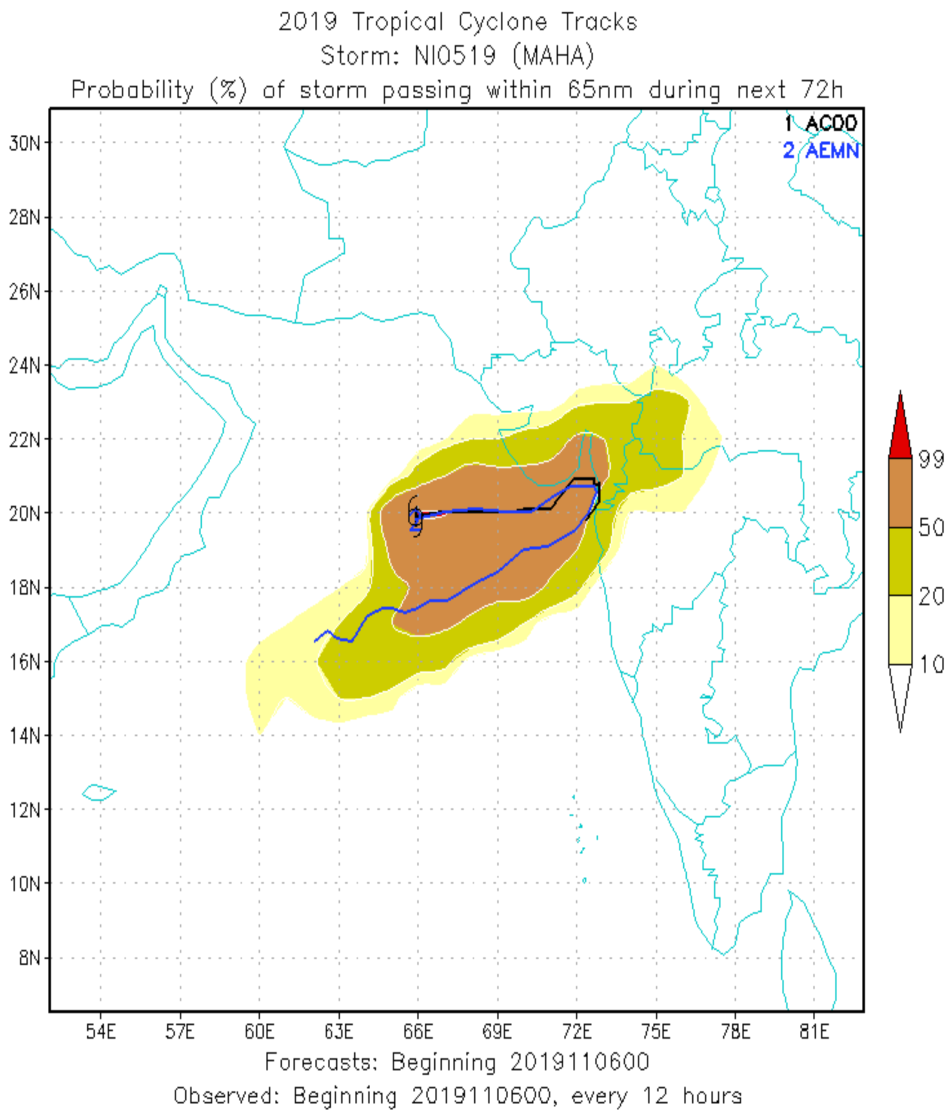
AEMN-Ensemble Mean

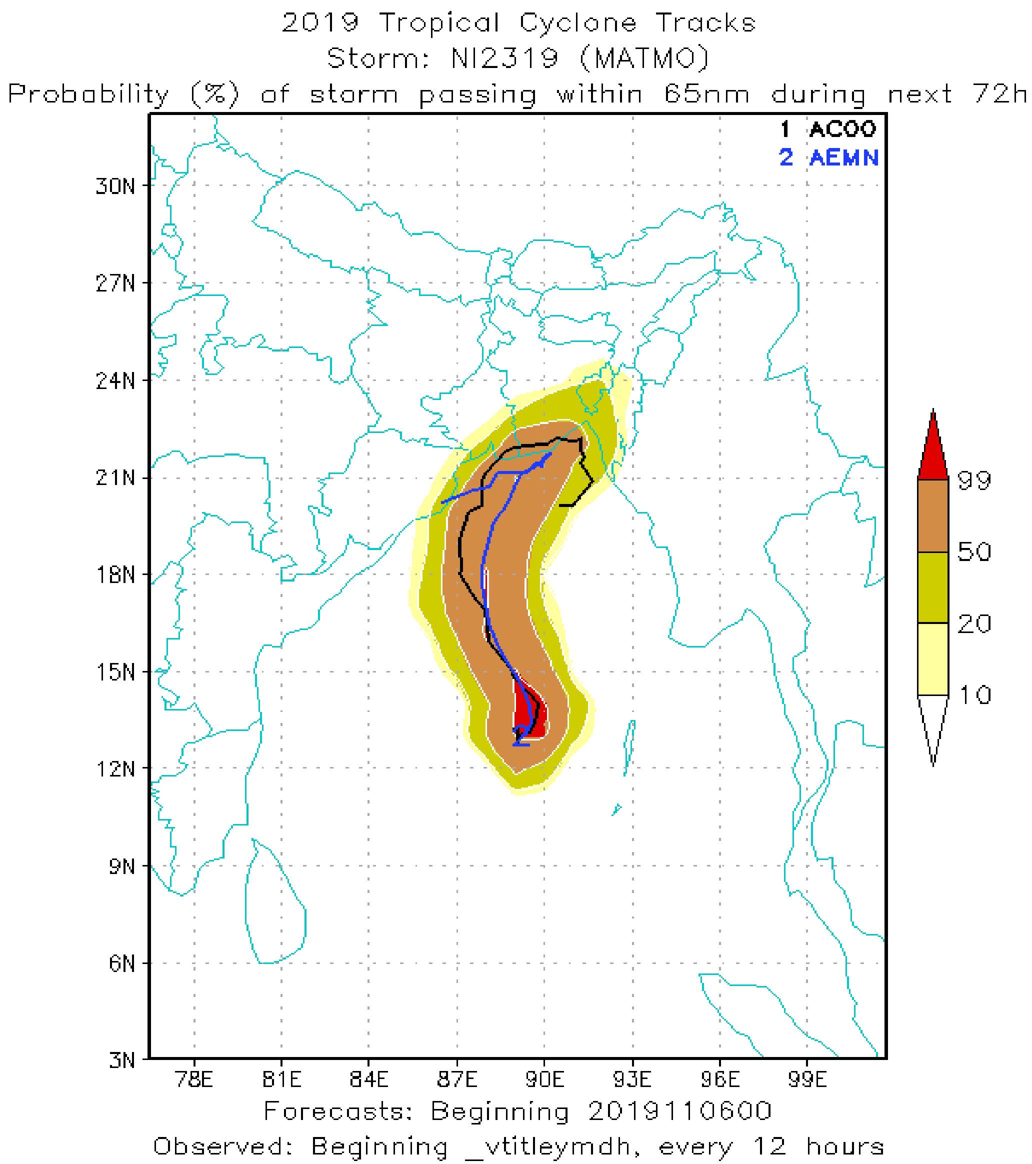
---- Ensemble members



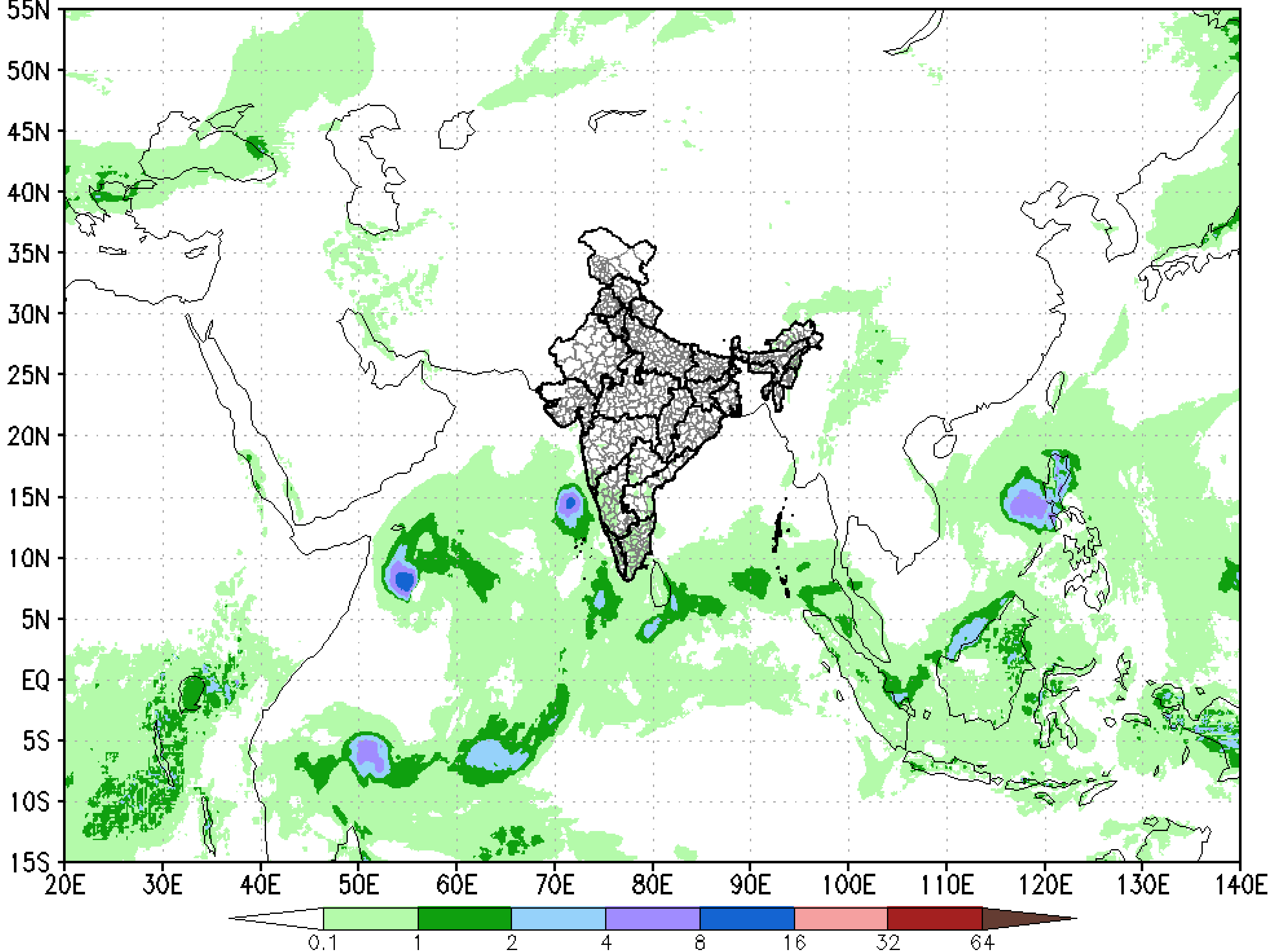


Medha et al.


2019 Tropical Cyclone Tracks
Storm: NI0519 (MAHA)
Probability (%) of storm passing within 65nm during next 72h
1 AC00
2 AEMN
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
10N
8N
54E
57E
60E
63E
66E
69E
72E
75E
78E
81E
99
50
20
10
Forecasts: Beginning 2019110600
Observed: Beginning 2019110600, every 12 hours

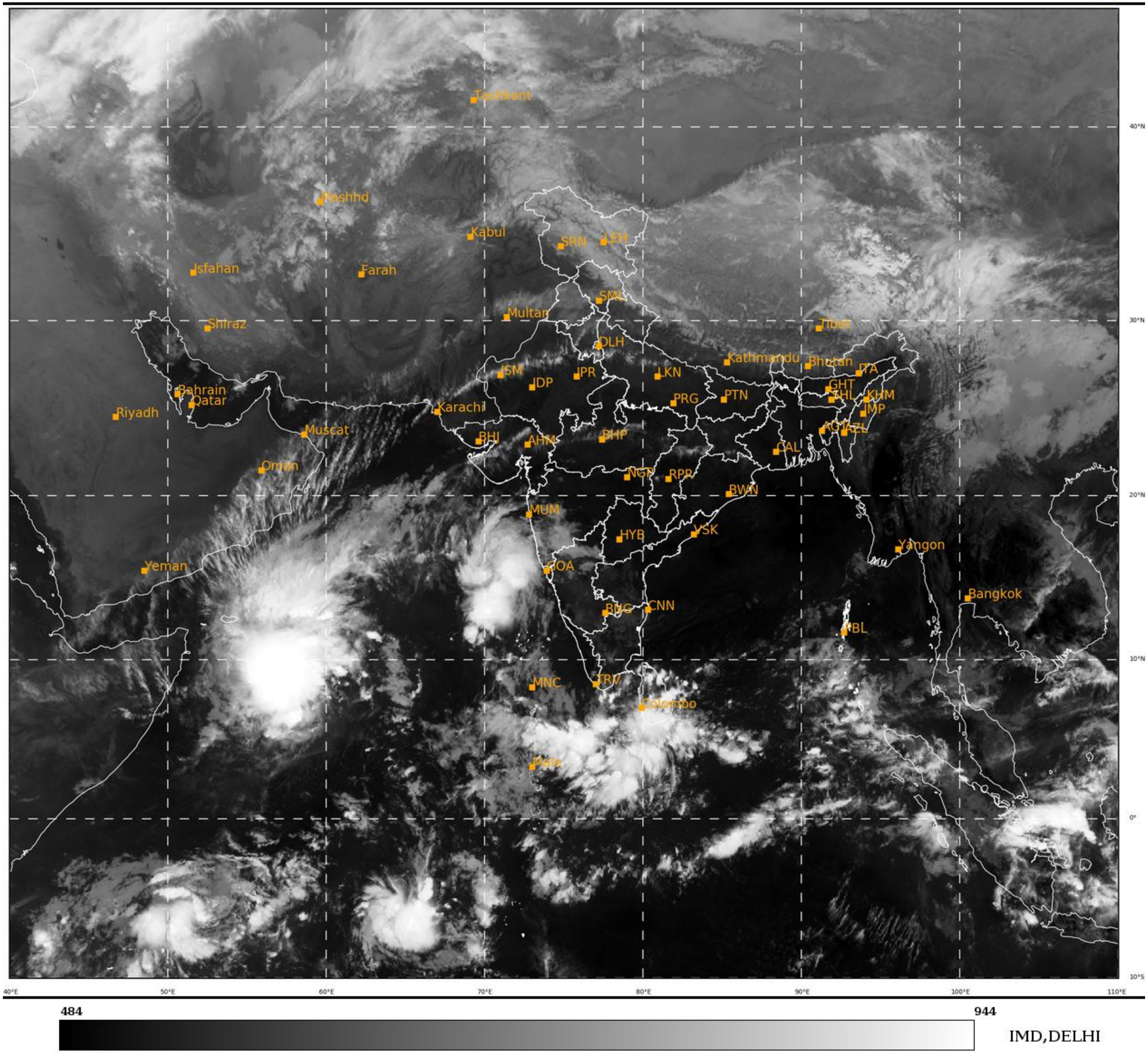

2019 Tropical Cyclone Tracks
Storm: NI2319 (MATMO)
Probability (%) of storm passing within 65nm during next 72h
1 AC00
2 AEMN
30N
27N
24N
21N
18N
15N
12N
9N
6N
3N
78E
81E
84E
87E
90E
93E
96E
99E
99
50
20
10
Forecasts: Beginning 2019110600
Observed: Beginning _vtitleymdh, every 12 hours

GEFS T1534 : Rainfall (cm/day), Ens Mean (20 Ens)
24-hr Forecast valid for 03Z04DEC2019 (IC=00Z03DEC2019)



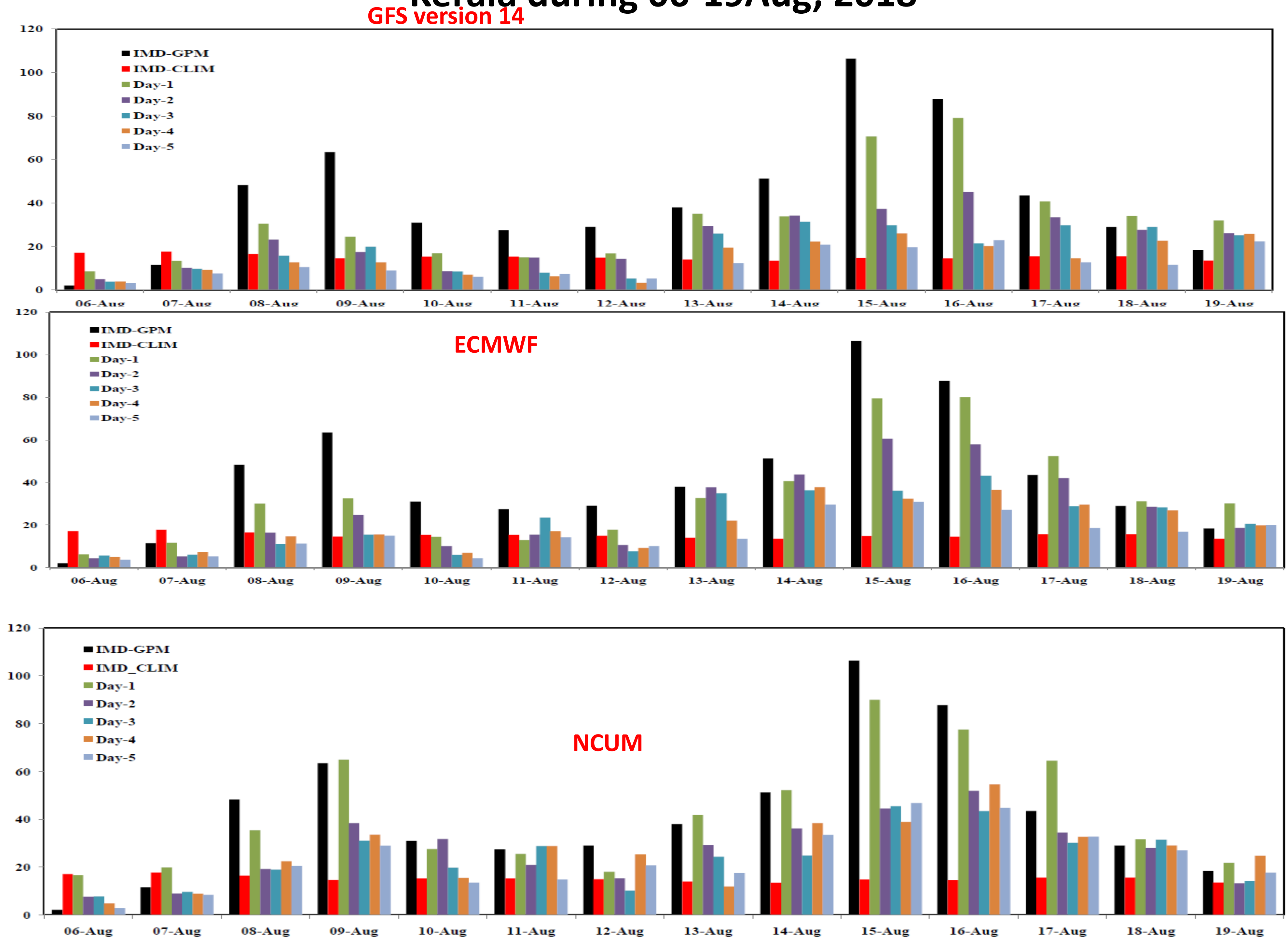
SAT : INSAT-3D IMG
IMG_TIR1 10.8 um
L1C Mercator

04-12-2019/(0400 to 0427) GMT
04-12-2019/(0930 to 0957) IST

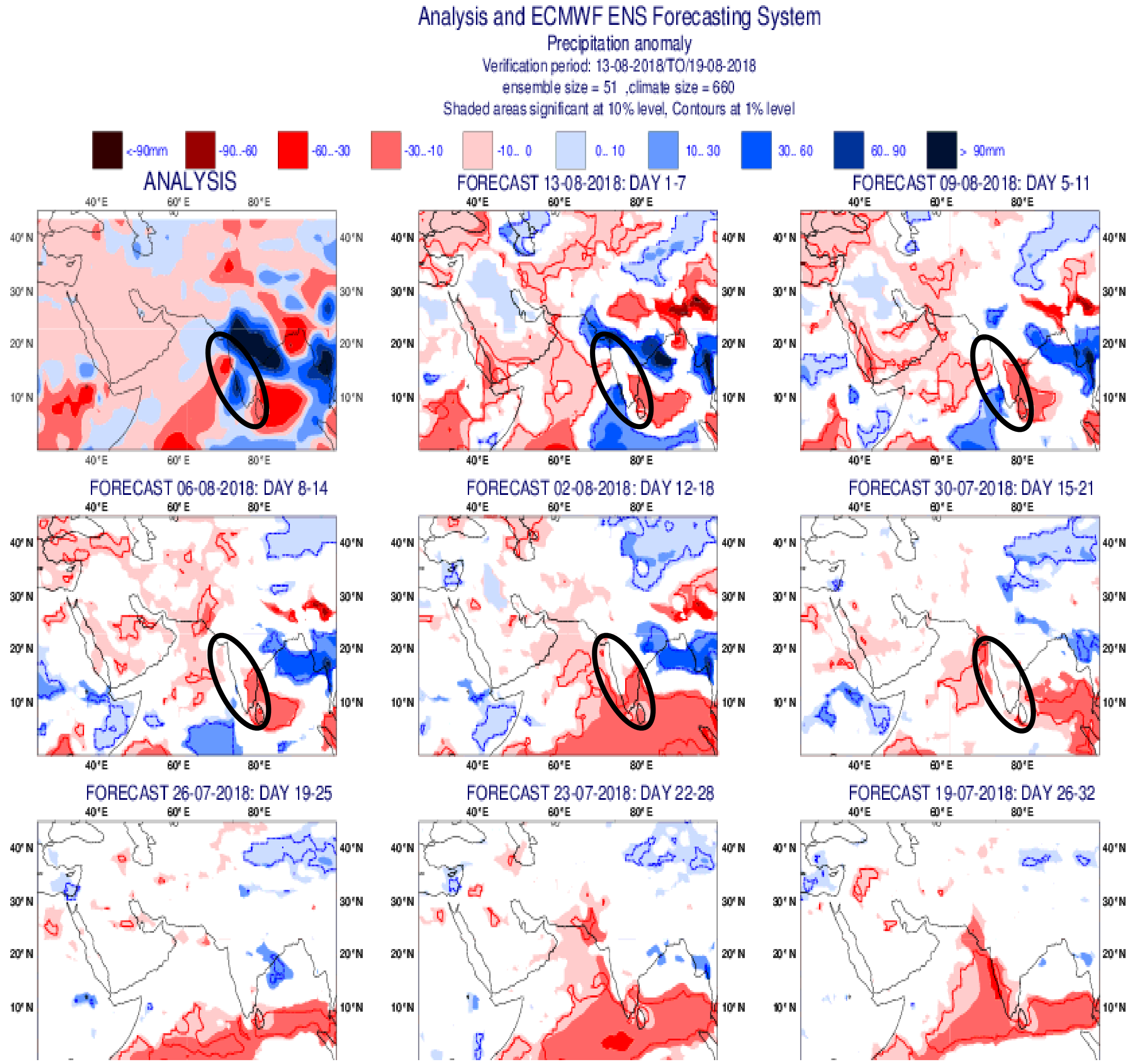


IMD,DELHI

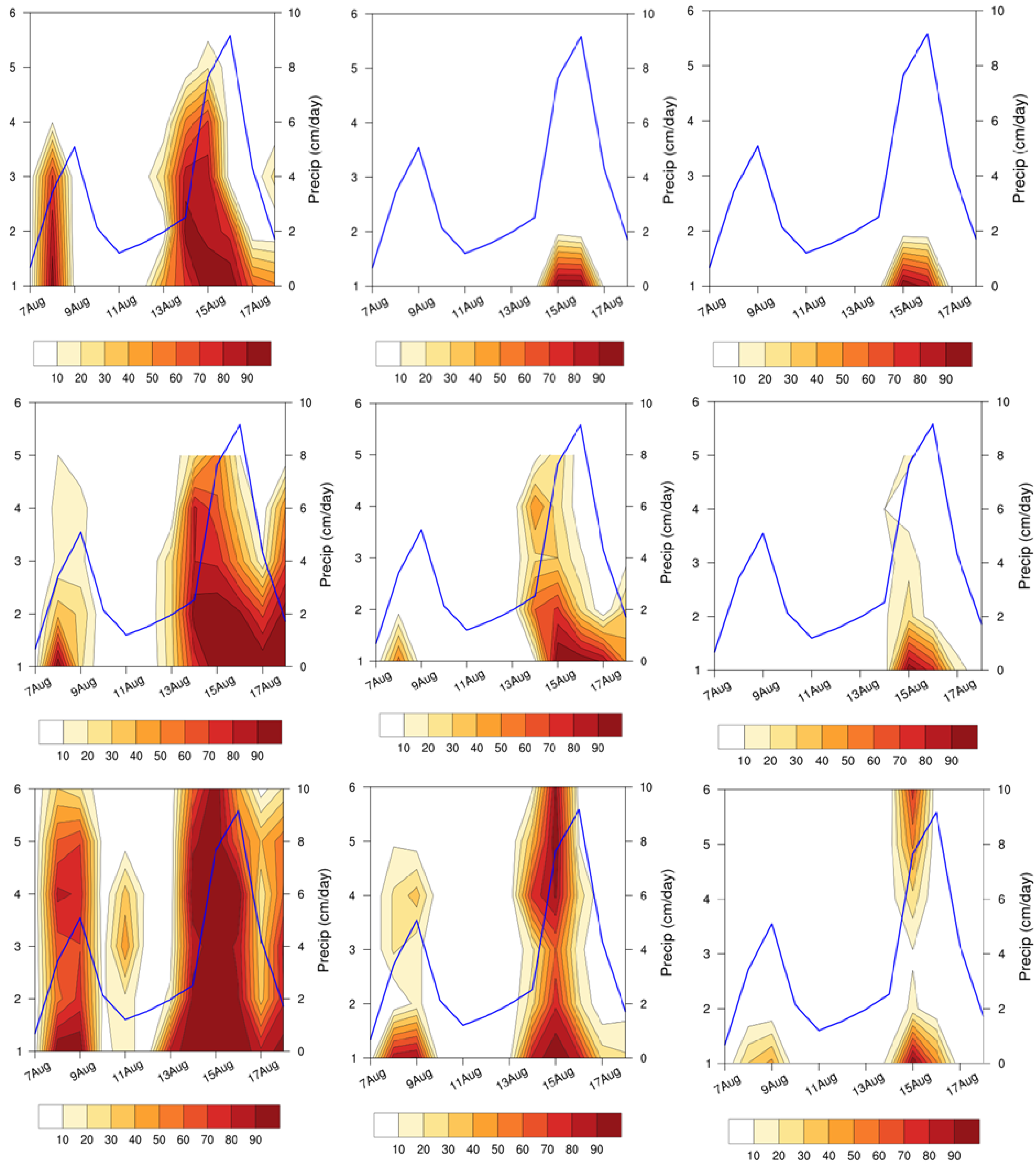
Deterministic Forecast Rainfall (mm/day) time series over Kerala during 06-19Aug, 2018



ENS weekly TP fc over India for 20180813-0819



Slide borrowed from Roberto Buizza, ECMWF



Forecast lead time diagram of the probability that the GEFS forecast (top row), ECMWF (middle row) and NCUM (bottom row) for the daily accumulated rain over Kerala (9.5-11.5°N, 76-77.5°E) exceeding the observed daily climatology plus 1 standard deviation (first column), 2SD (middle column) and 3SD (third column). The blue line represents the IMD-GPM rainfall (cm/day) averaged for the same region.

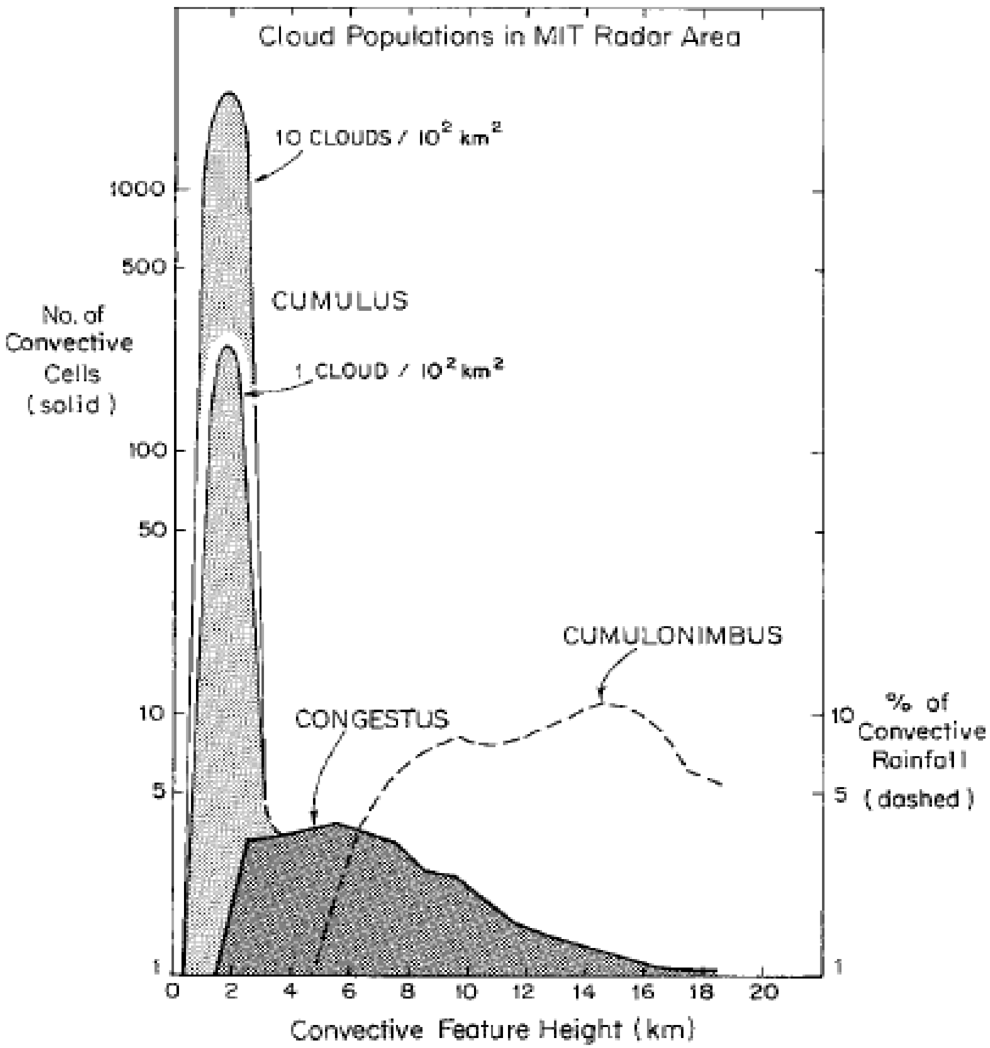


FIG. 4. Average number of clouds in the MIT radar area (solid curves) and percent of convective rainfall (dashed curve) as a function of convective feature height. The frequency distribution of precipitating convective features, containing a congestus peak (marked CONGESTUS), is from Fig. 2. The percent contribution to convective rainfall, with a peak at the cumulonimbus end (marked CUMULONIMBUS) is from Fig. 3. Two cumulus distributions (marked CUMULUS), based on shallow cloud densities of 1 and 10 $(10^2\ km^2)^{-1}$, are estimated from information and data in Williams et al. (1996) and Nicholls and LeMone (1980).

Johnson et al. (1999), J. Clim

Tropical clouds mainly consists of shallow cumulus, congestus, and cumulonimbus.

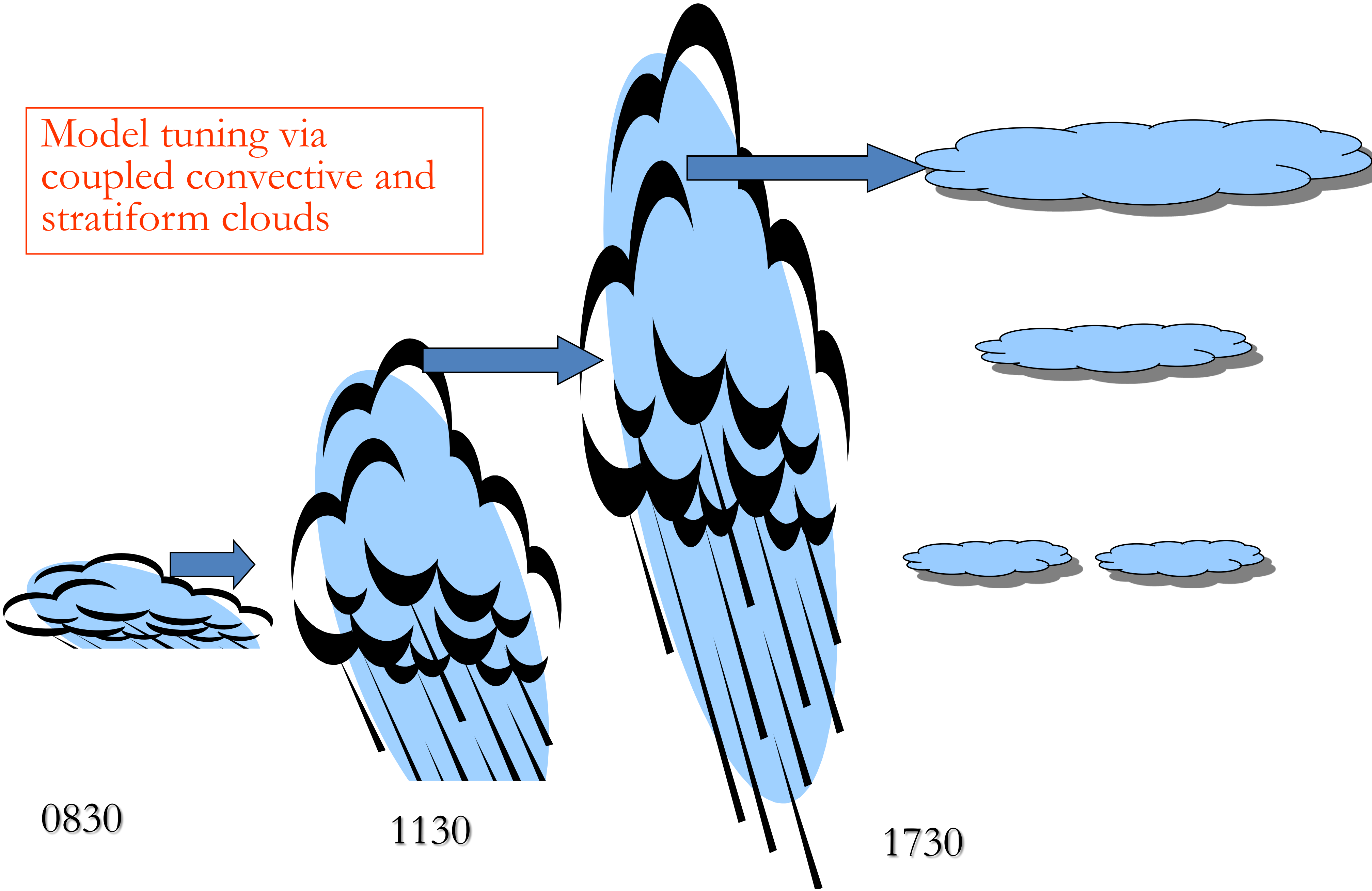
- The specific roles of clouds of the congestus

- The shallower clouds contribute to moistening and preconditioning the atmosphere for deep Convection

- The deeper clouds contribute an important fraction of the total tropical rainfall

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

Model tuning via coupled convective and stratiform clouds



Revision of Convection and Vertical Diffusion Schemes in the NCEP Global Forecast System

JONGIL HAN

Wyle Information Systems LLC, and National Centers for Environmental Prediction/Environmental Modeling Center, Camp Springs, Maryland

HUA-LU PAN

National Centers for Environmental Prediction/Environmental Modeling Center, Camp Springs, Maryland

(Manuscript received 12 October 2010, in final form 14 February 2011)

$$\mathrm{Pr} = 1 + 2.1\mathrm{Ri}. \tag{23}$$

For unstable conditions (Ri < 0),

$$f_h(\mathrm{Ri}) = 1 + \frac{8|\mathrm{Ri}|}{1 + 1.286|\mathrm{Ri}|^{1/2}} \quad \text{and} \tag{24}$$

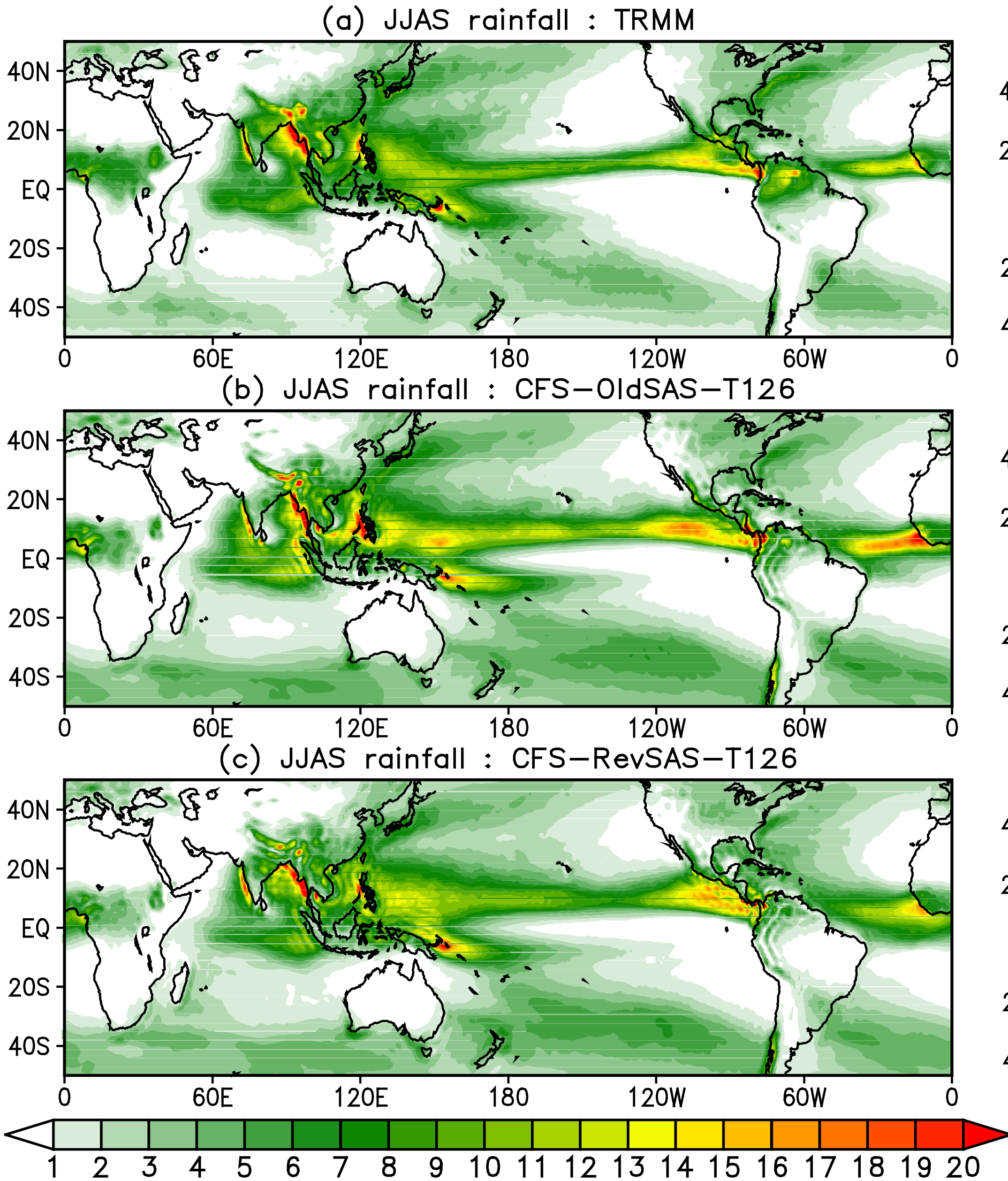
$$f_m(\mathrm{Ri}) = 1 + \frac{8|\mathrm{Ri}|}{1 + 1.746|\mathrm{Ri}|^{1/2}}. \tag{25}$$

The background diffusivity in the GFS for heat and

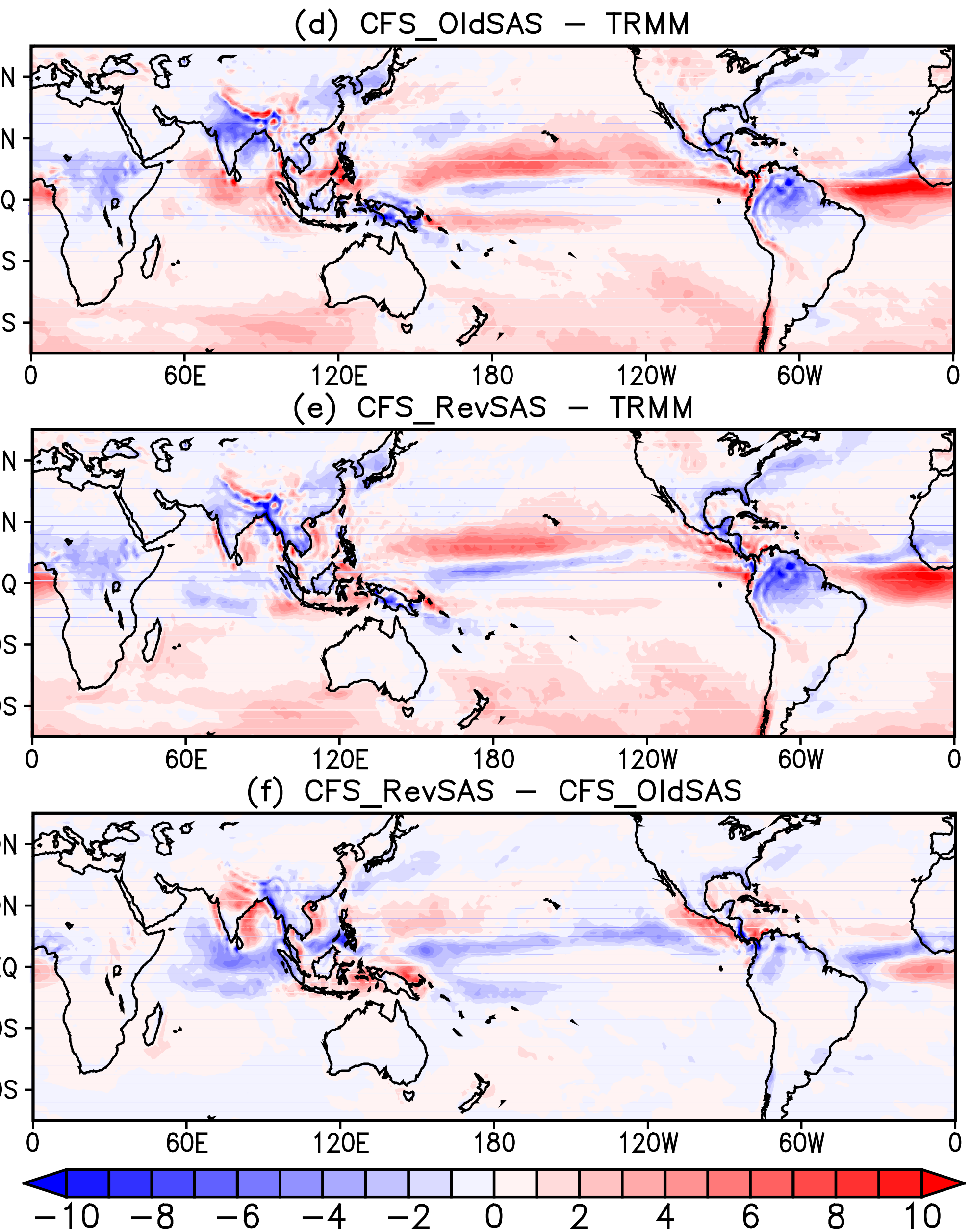
Laboratory Modular Ocean Model version 3 (Pacanowski and Griffies 1998). The GFS used in this test has 64 vertical sigma-pressure hybrid layers and T126 horizontal resolution (about 100 km at the equator). The CFS run was initialized at 0000 UTC 16 December 2002 and ran for 45 days. The CFS forecasts during the preceding 15 days (a spinup 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.

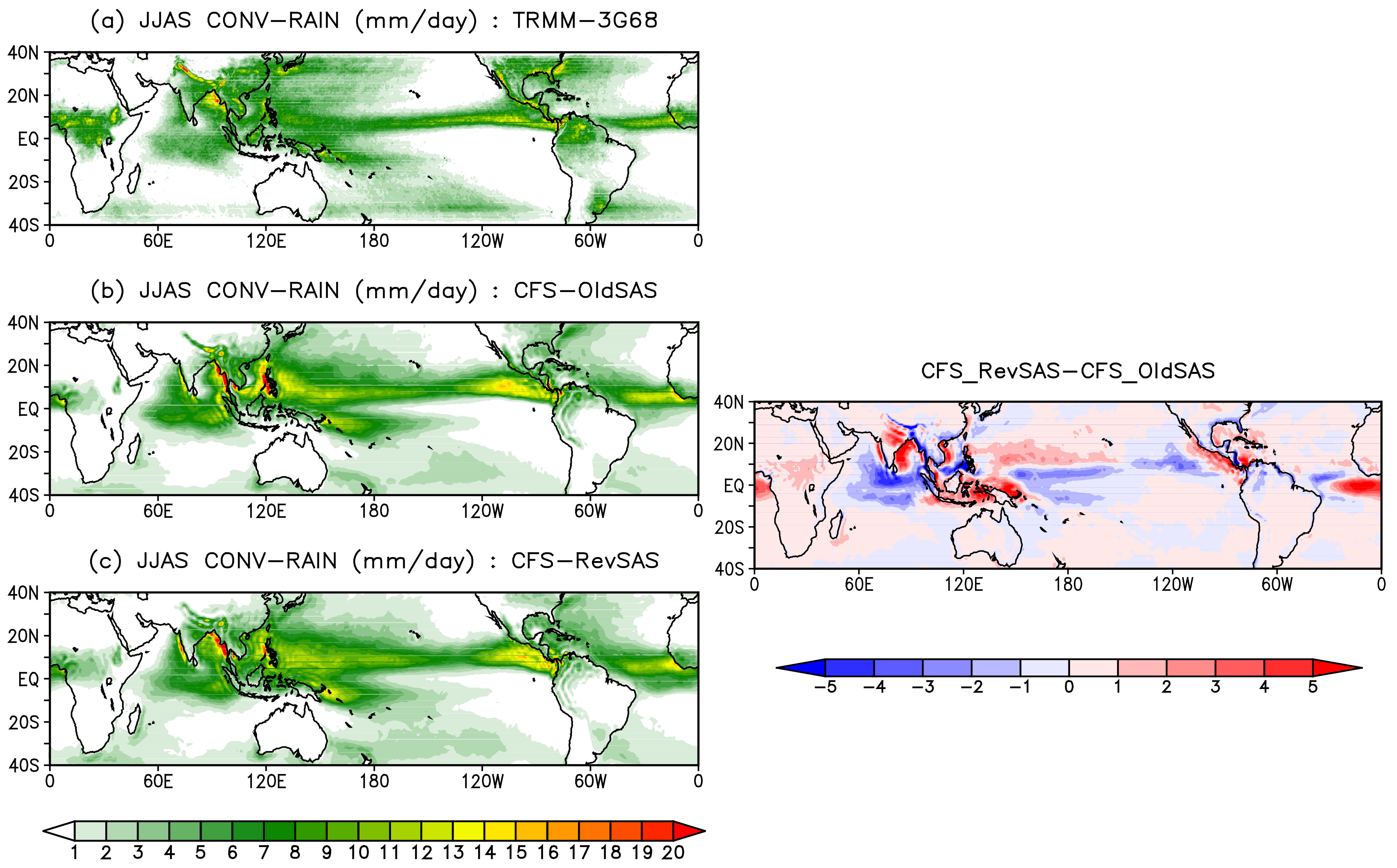
Impact of Revising Subgrid scale convection only RevSAS (Ganai et al. 2015, 2016)

JJAS Mean precip

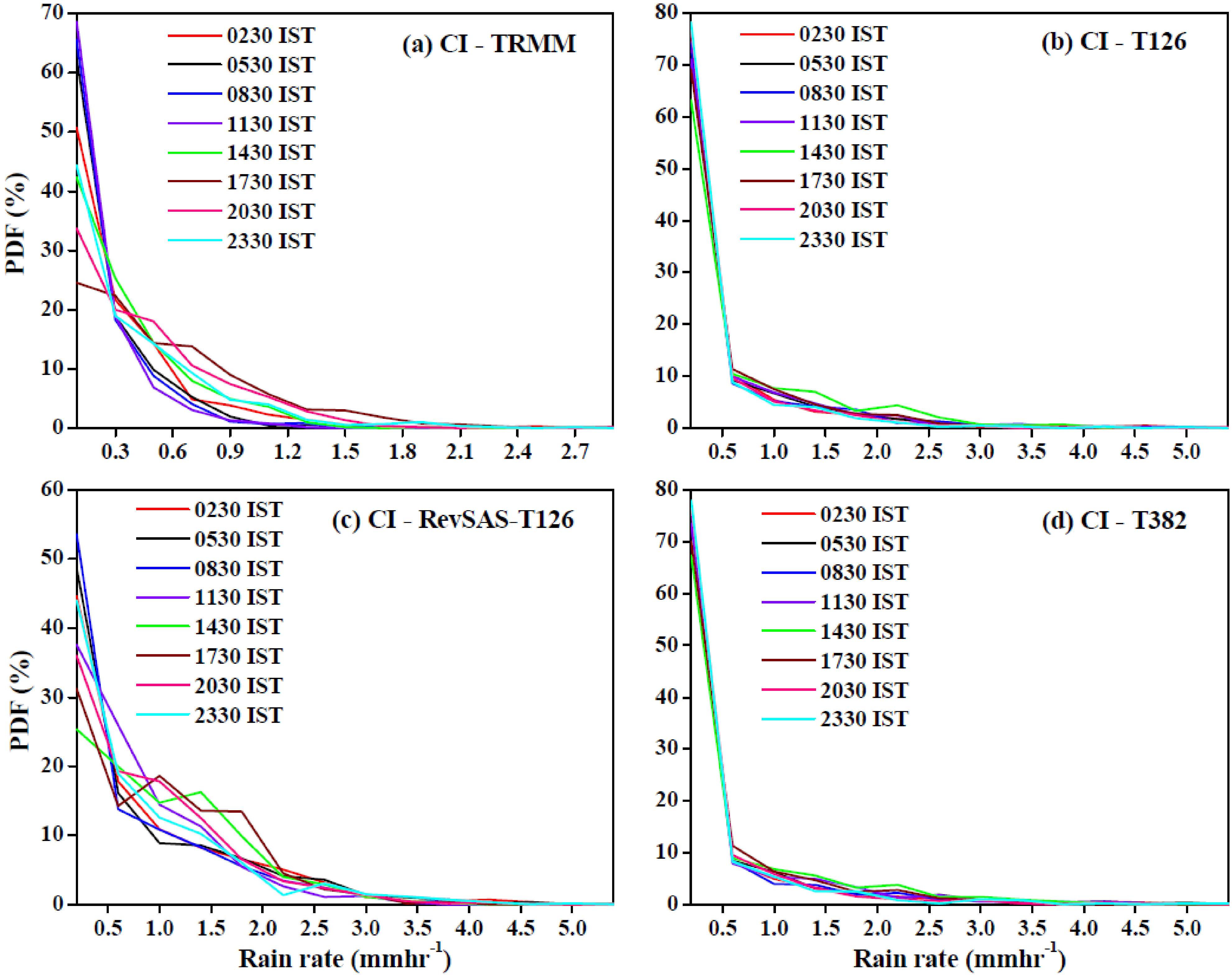


JJAS precip bias

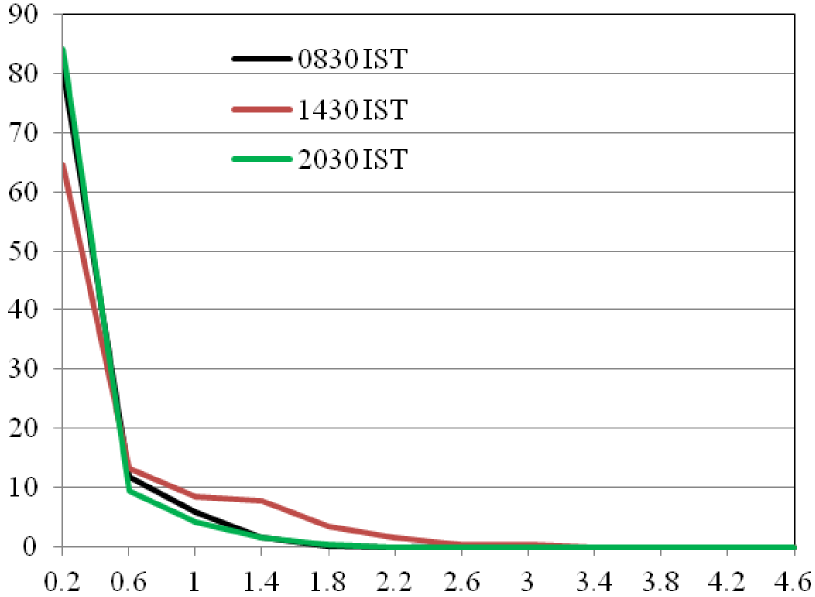




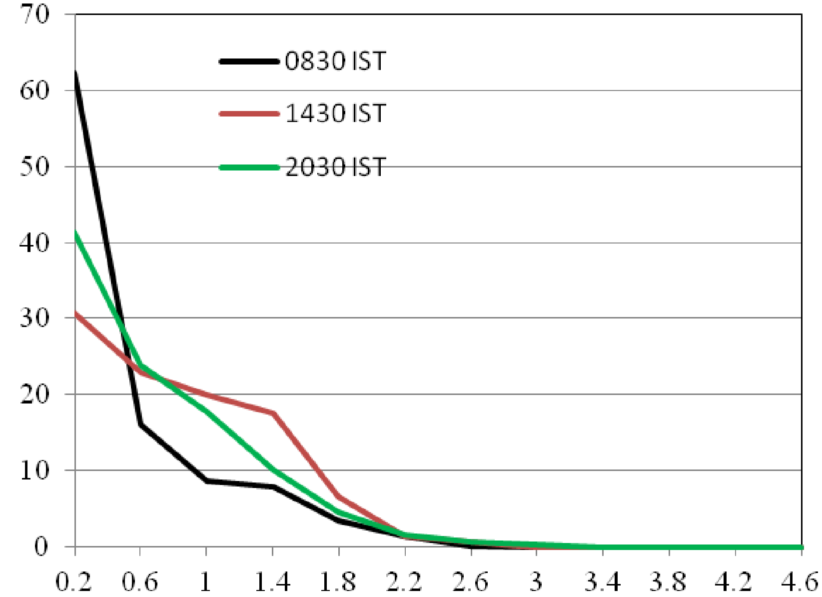
Convective Rain


(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)

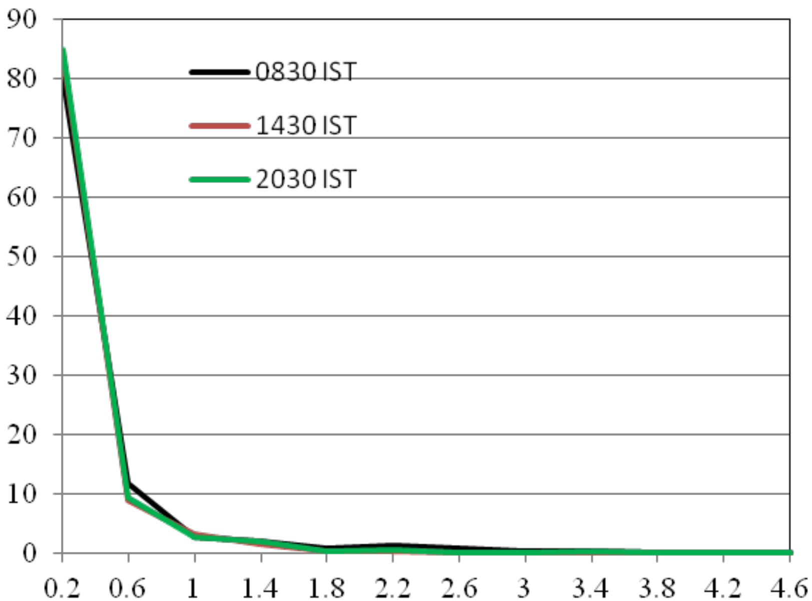
Convective-rain-OldSAS



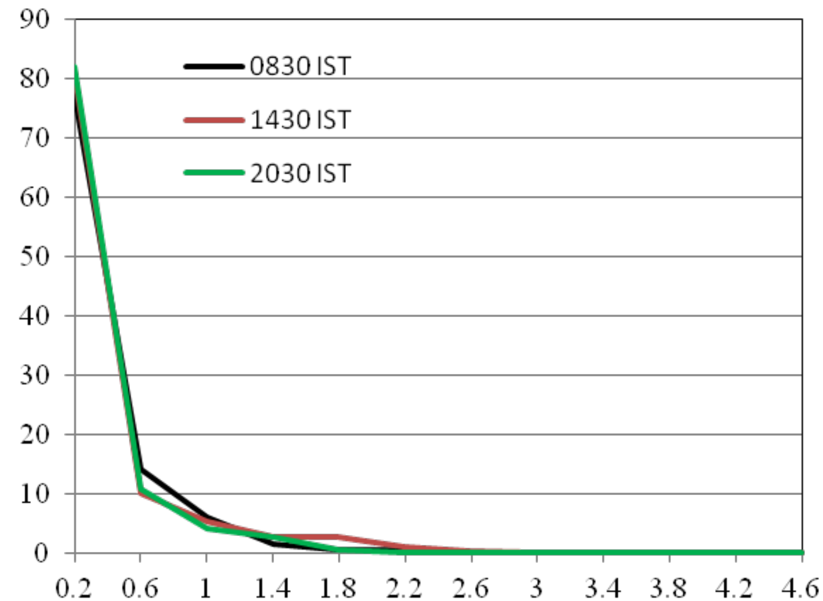
Convective-rain-RevSAS



Stratiform-rain-OldSAS



Stratiform-rain-RevSAS



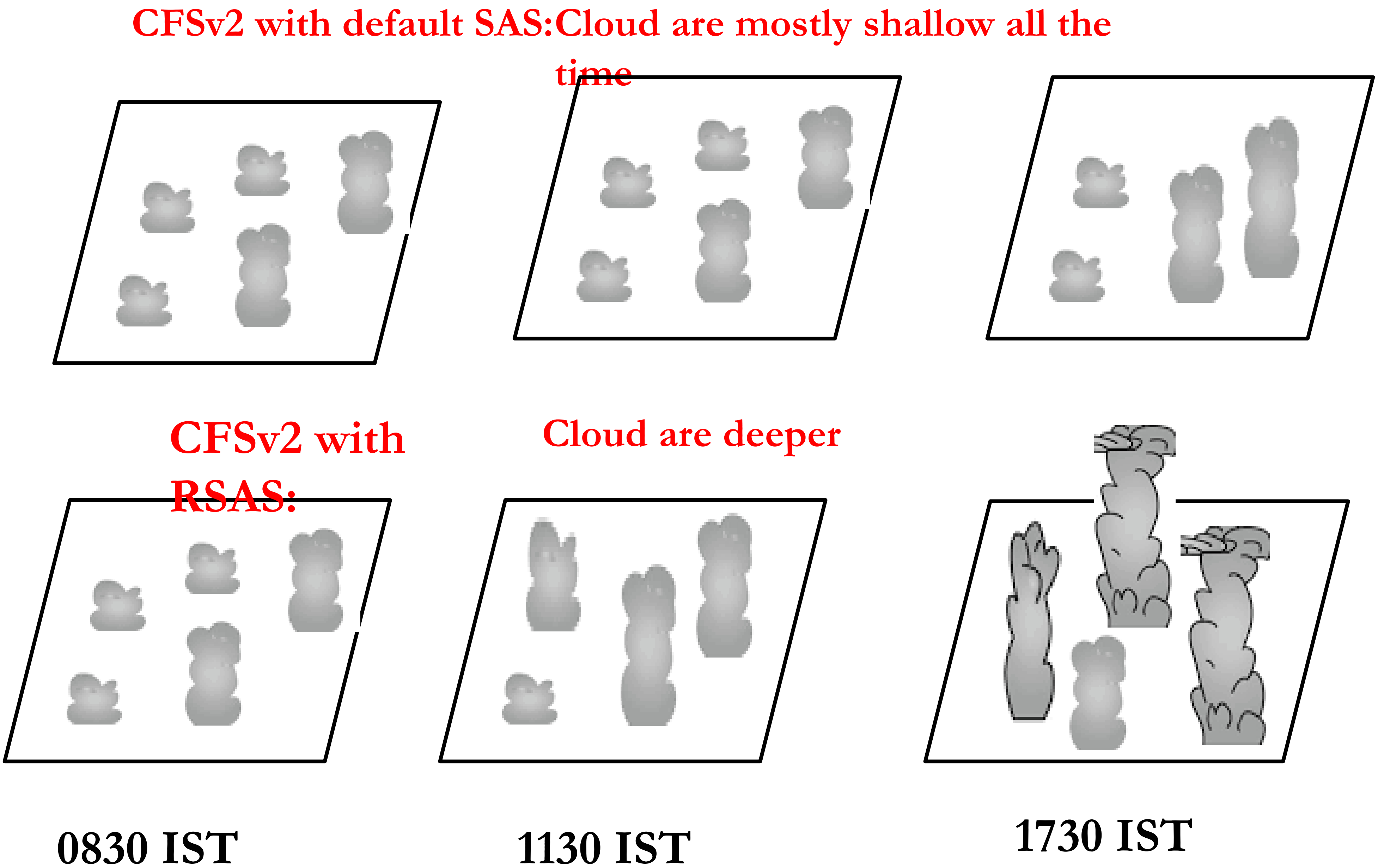
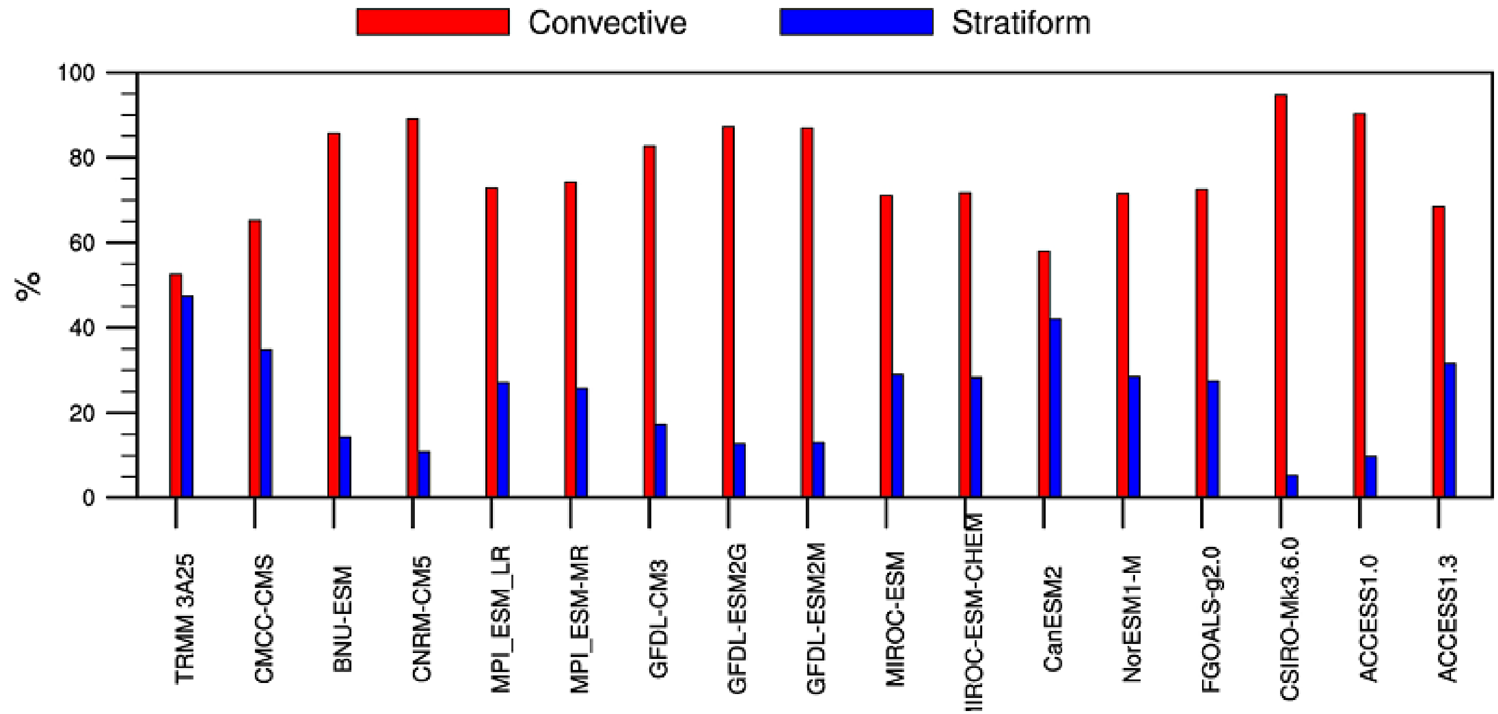

CFSv2 with default SAS:Cloud are mostly shallow all the time
CFSv2 with RSAS:
Cloud are deeper
0830 IST
1130 IST
1730 IST

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)



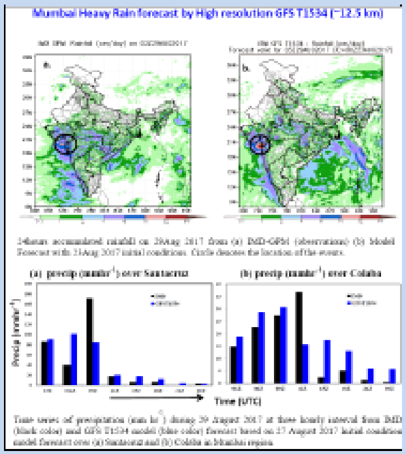
Sabeerali et al. 2015, Clim Dyn

Too much convective rainfall and less stratiform rainfall

"This may be presumably due to the wrong representation of the parameterization of physical processes…"

ISSN 0252-1075
Contribution from IITM
Research Report No. RR-146
ESSO/IITM/MM/SR/02(2019)/197

Performance of Very High Resolution Global Forecast System Model (GFS T1534) at 12.5km over Indian Region during 2016-2017 Monsoon Seasons



P. Mukhopadhyay, V.S. Prasad, R. Phani Murali Krishna, Medha Deshpande, Malay Ganai, Snehlata Tirkey, Sahadat Sarkar, Tanmoy Goswami, C.J. Johny, Kumar Roy, M. Mahakur, V.R. Durai and M. Rajeevan

Indian Institute of Tropical Meteorology (IITM)
Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2019JD030278

Key Point:
- Modification of cloud condensate to precipitation conversion parameter reduces the convective rain and improves the large scale rain

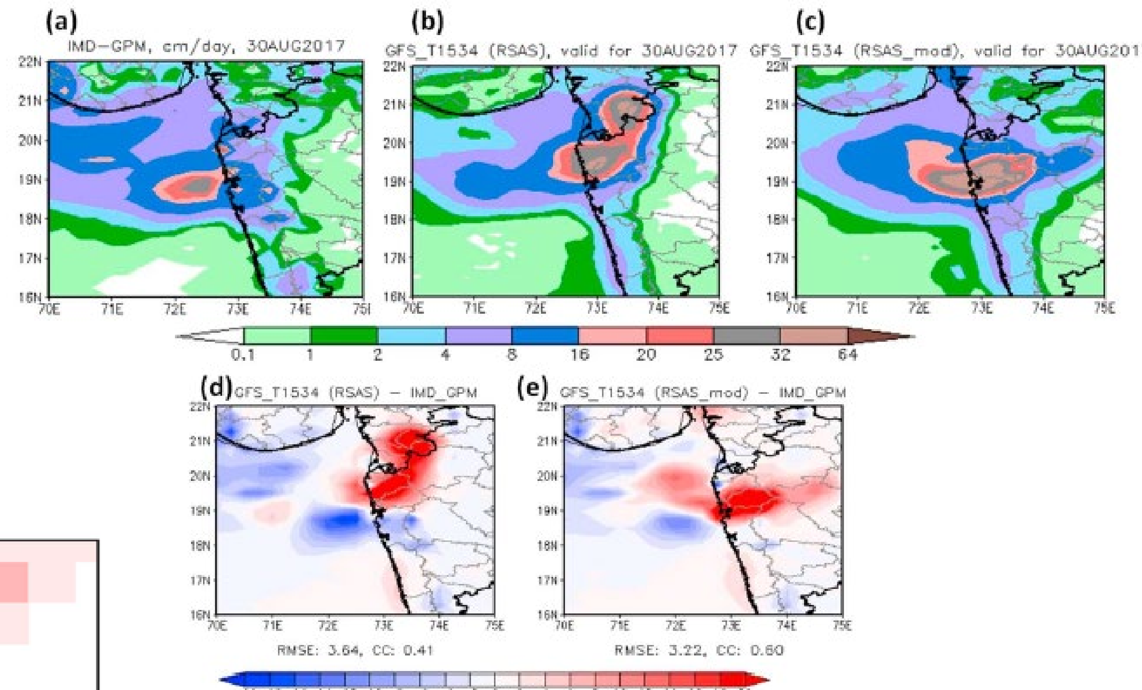
Correspondence to:
P. Mukhopadhyay,
mpartha@tropmet.res.in

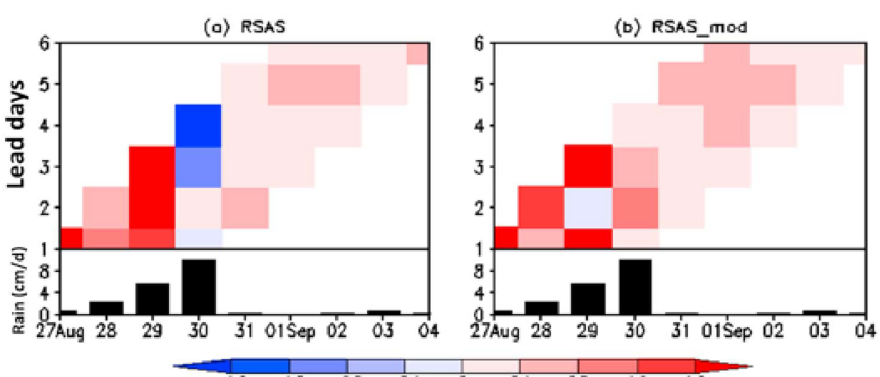
Citation:

The Impact of Modified Fractional Cloud Condensate to Precipitation Conversion Parameter in Revised Simplified Arakawa-Schubert Convection Parameterization Scheme on the Simulation of Indian Summer Monsoon and Its Forecast Application on an Extreme Rainfall Event Over Mumbai

Malay Ganai[1,2], R. P. M. Krishna[1], Snehlata Tirkey[1], P. Mukhopadhyay[1], M. Mahakur[1], and Ji-Young Han[3]

[1]Indian Institute of Tropical Meteorology, Pune, India, [2]Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune, India, [3]Korea Institute of Atmospheric Prediction Systems, Seoul, South Korea





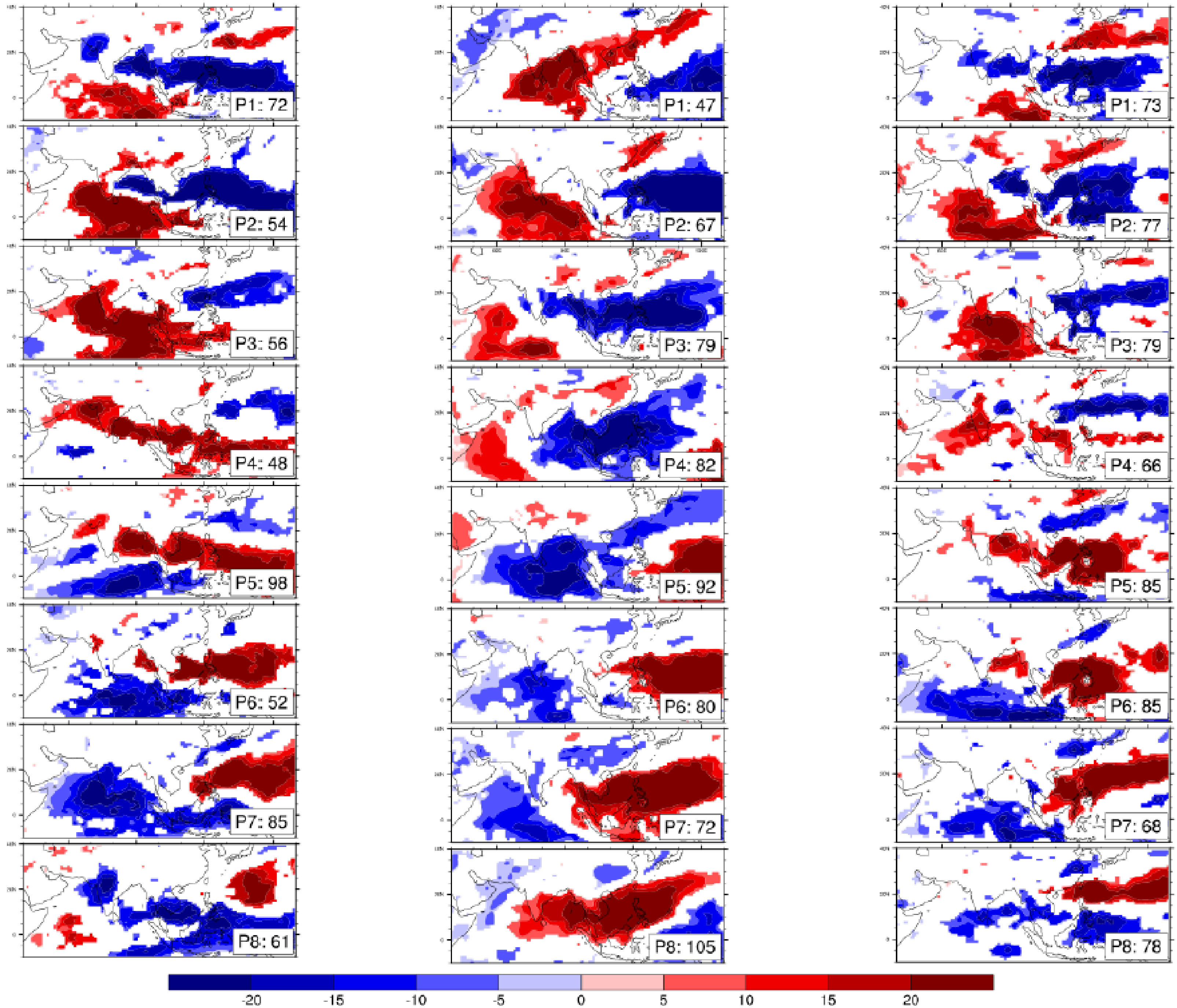
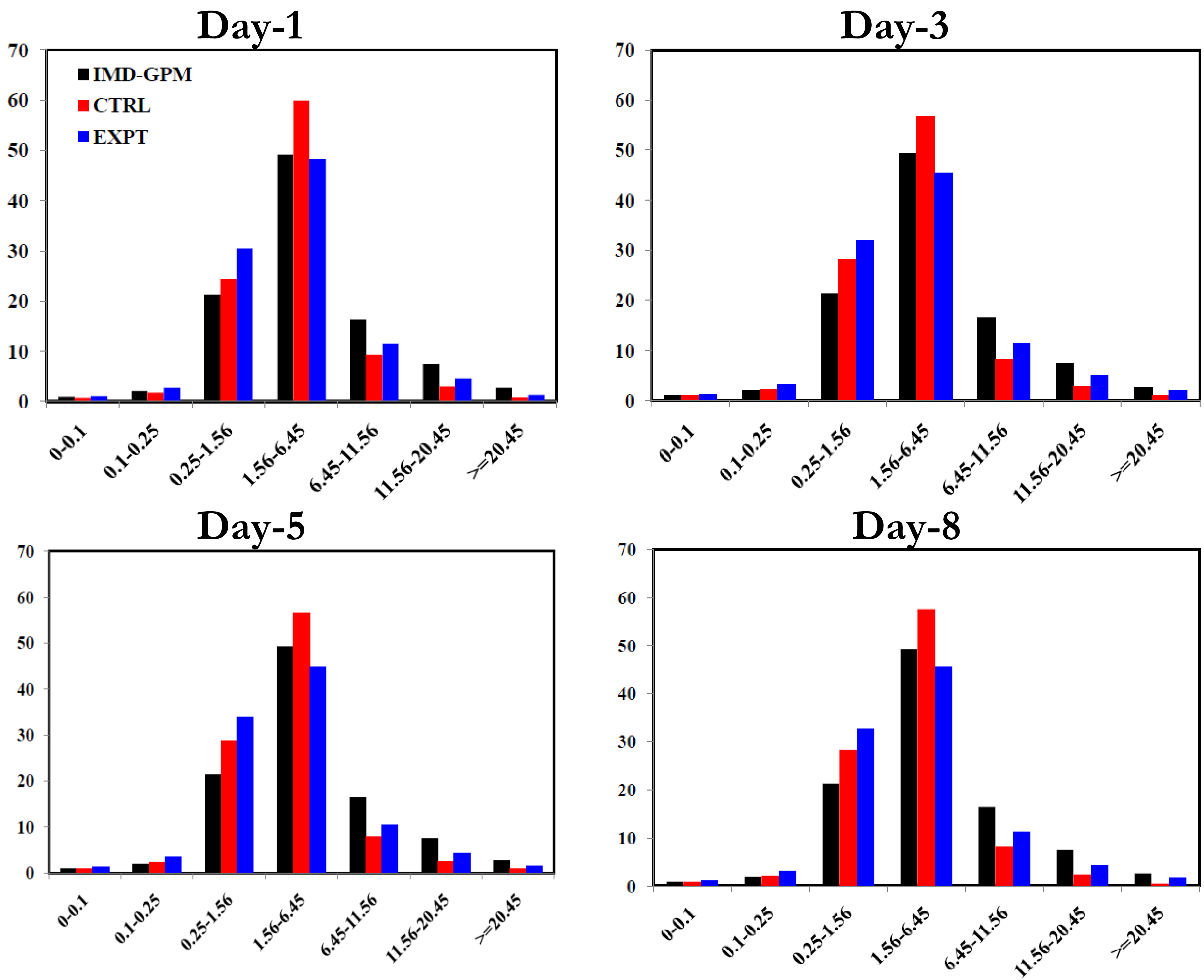
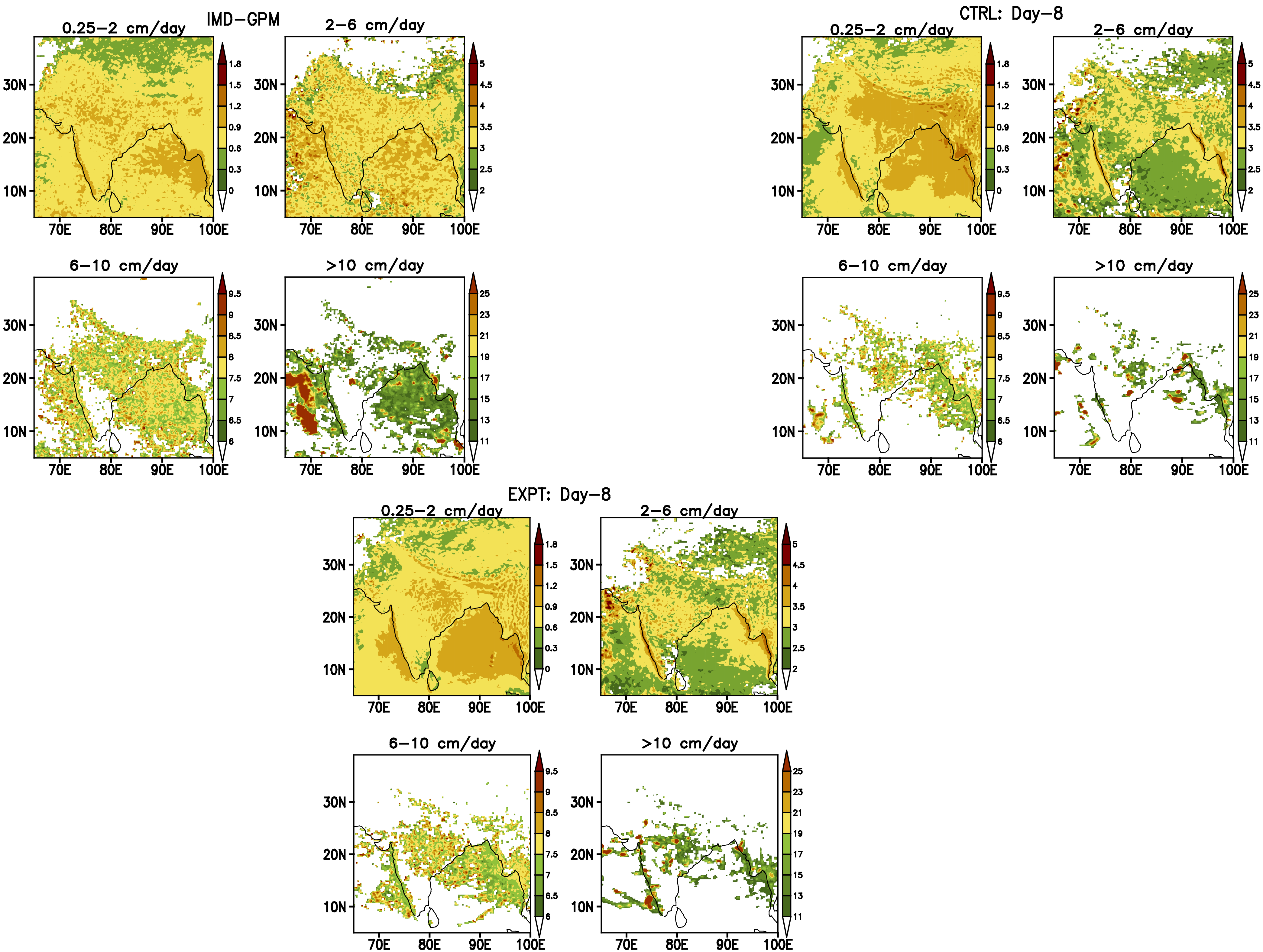


Figure 6 Composite of longwave radiative forcing anomaly corresponds to the eight phases of BSISO, constructed based on the PC1 and PC2 of MV-EOF of outgoing longwave radiation and zonal wind at 850hPa. First , second and third column represents the observation, RSAS and RSAS-mod results respectively.

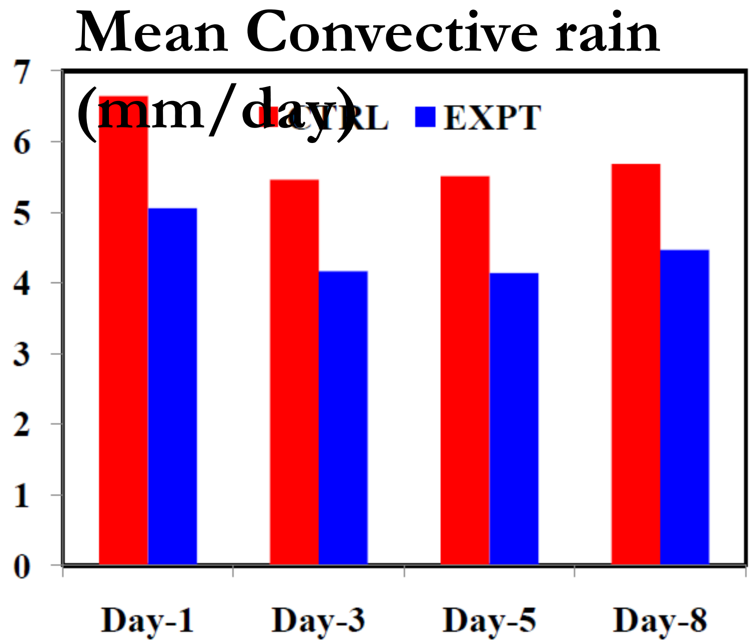
JJAS rainfall PDF over continental India

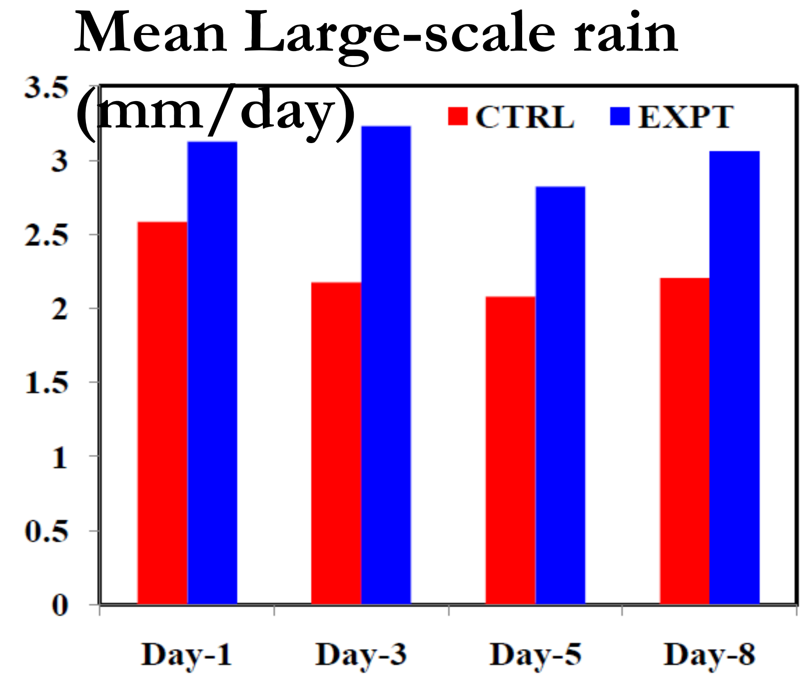


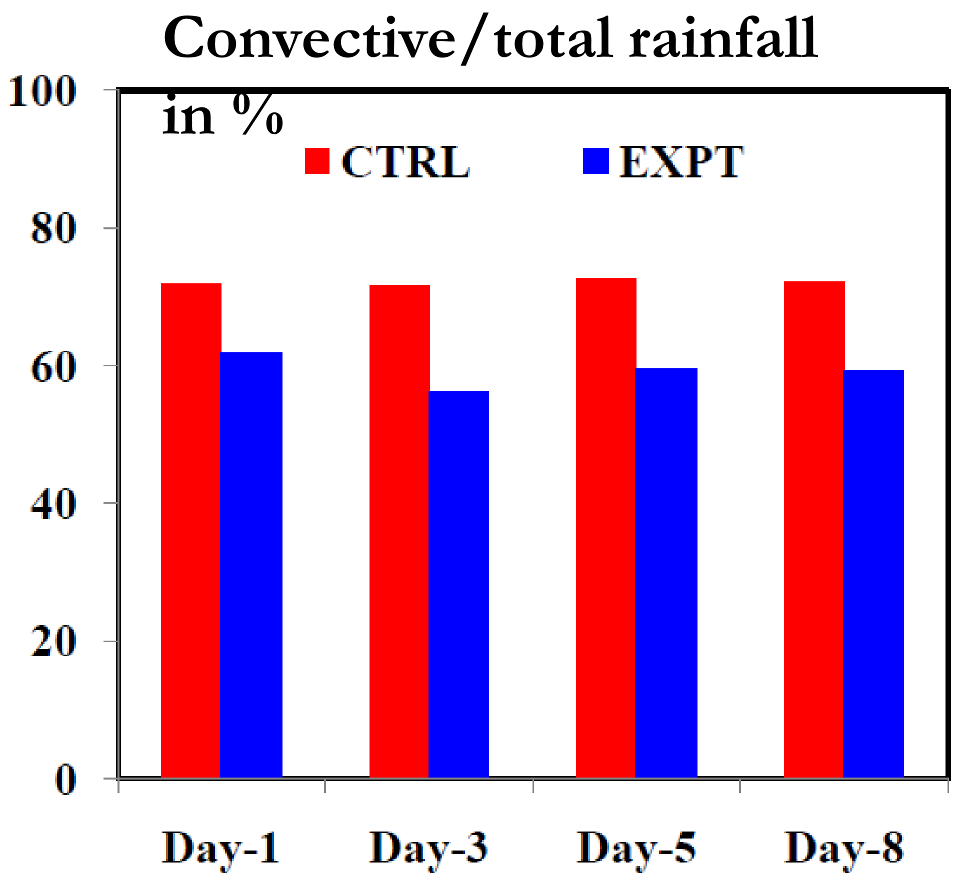


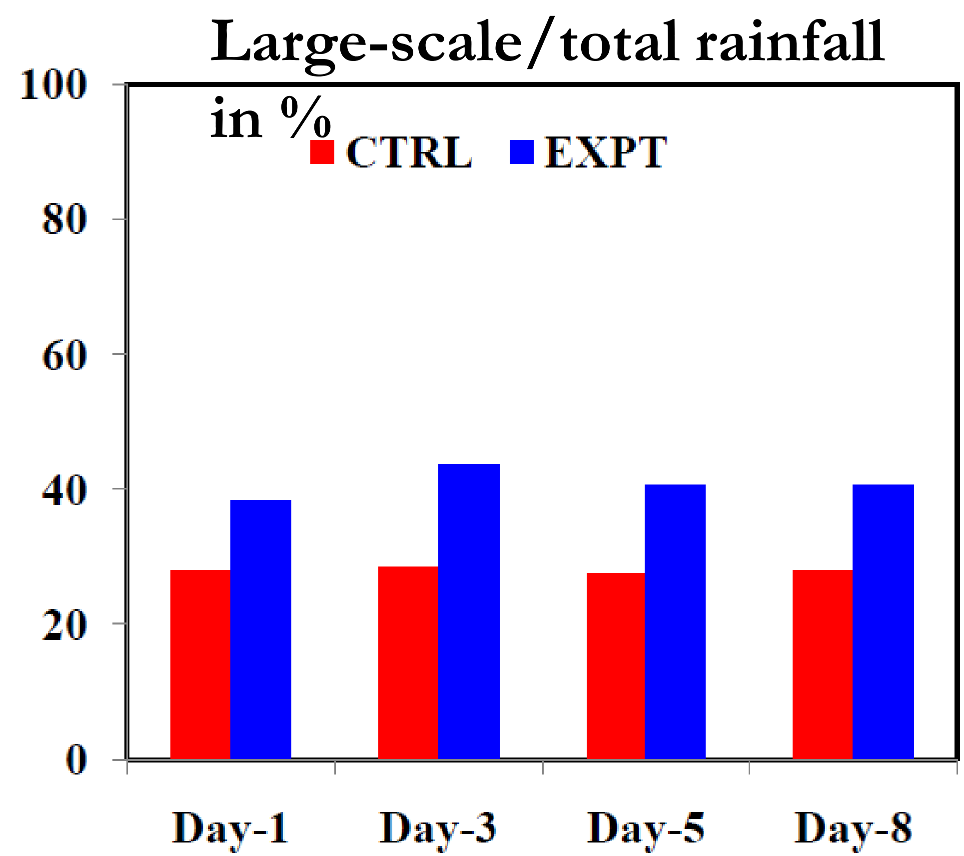
IMD−GPM
0.25−2 cm/day
2−6 cm/day
6−10 cm/day
>10 cm/day
CTRL: Day−8
0.25−2 cm/day
2−6 cm/day
6−10 cm/day
>10 cm/day
EXPT: Day−8
0.25−2 cm/day
2−6 cm/day
6−10 cm/day
>10 cm/day
10N
20N
30N
70E
80E
90E
100E
0
0.3
0.6
0.9
1.2
1.5
1.8
2
2.5
3
3.5
4
4.5
5
6
6.5
7
7.5
8
8.5
9
9.5
11
13
15
17
19
21
23
25

JJAS, 2018-2019 over All India land points

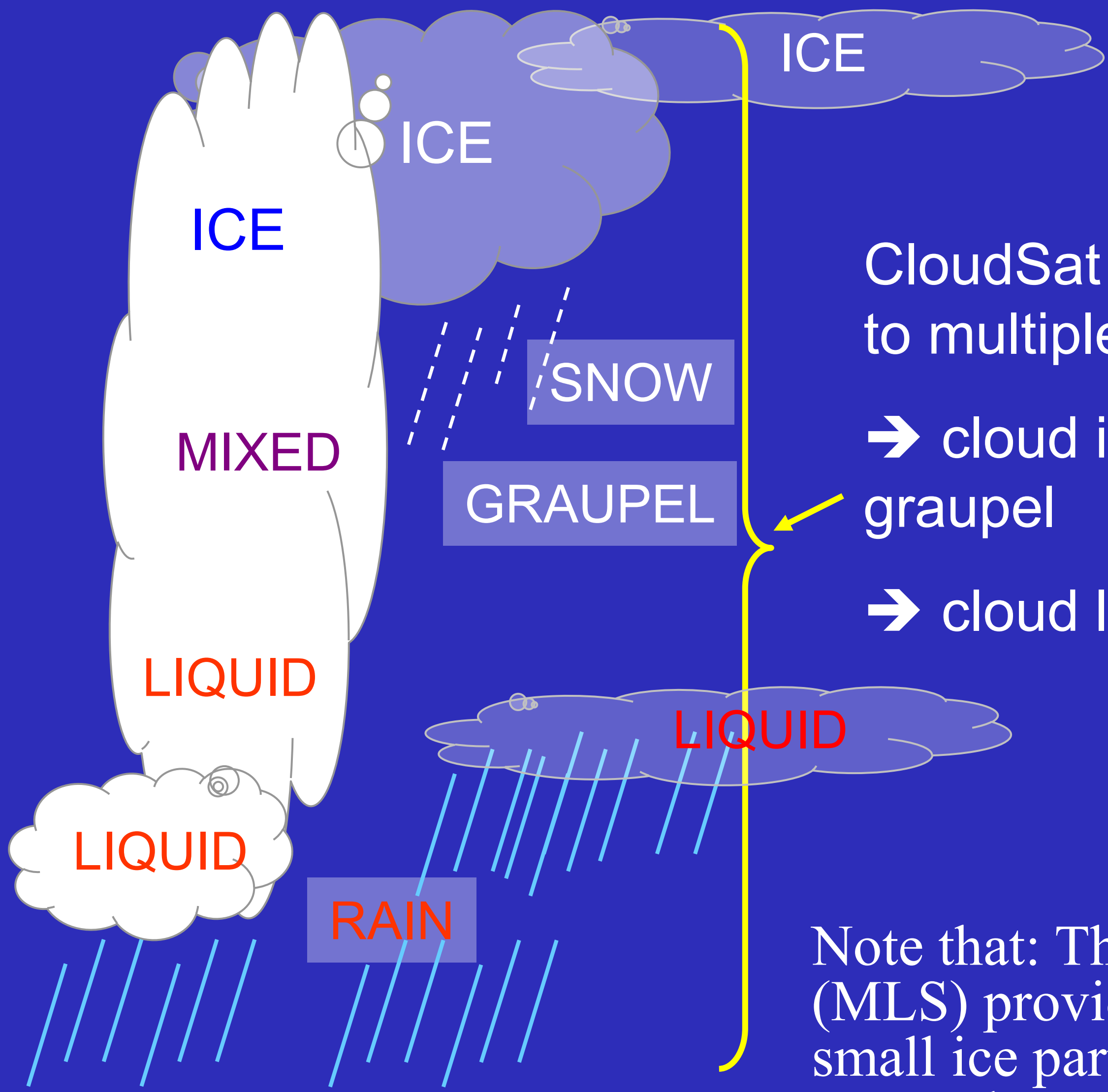








CloudSat IWC/LWC Retrieval



CloudSat measurements are sensitive to multiple particle types:

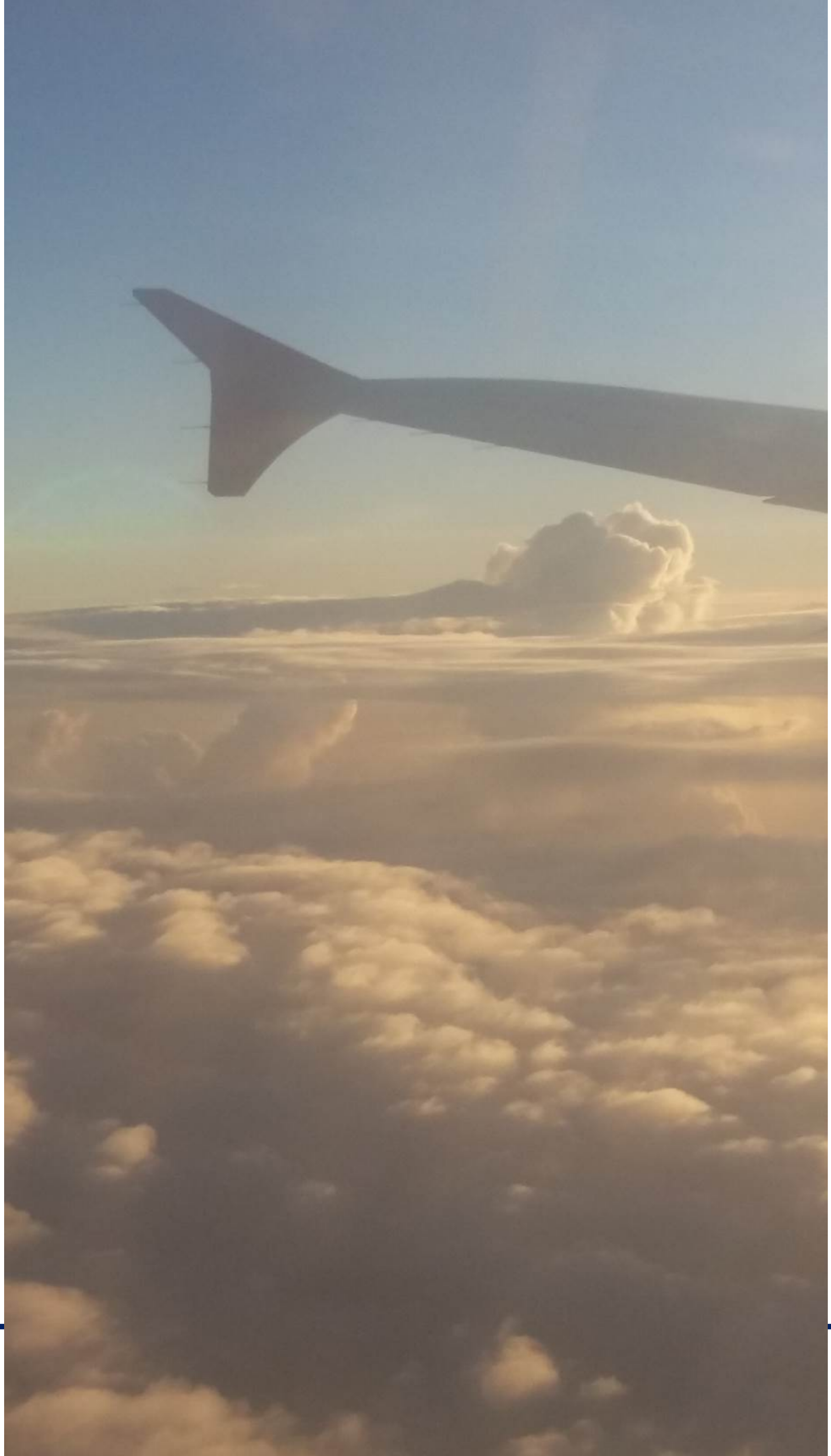
➔ cloud ice (~small particle), snow, graupel

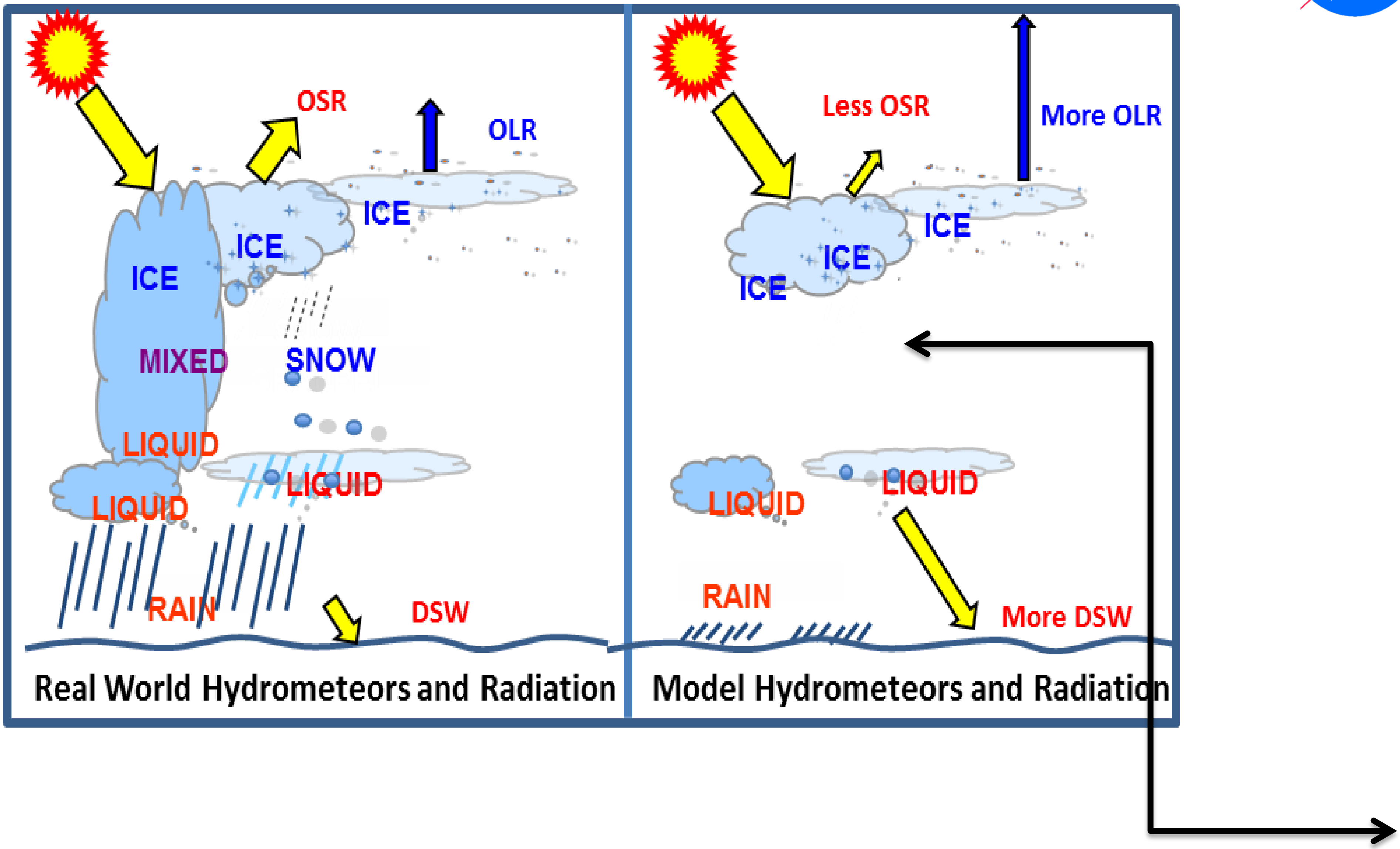
➔ cloud liquid (~small particle), rain

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

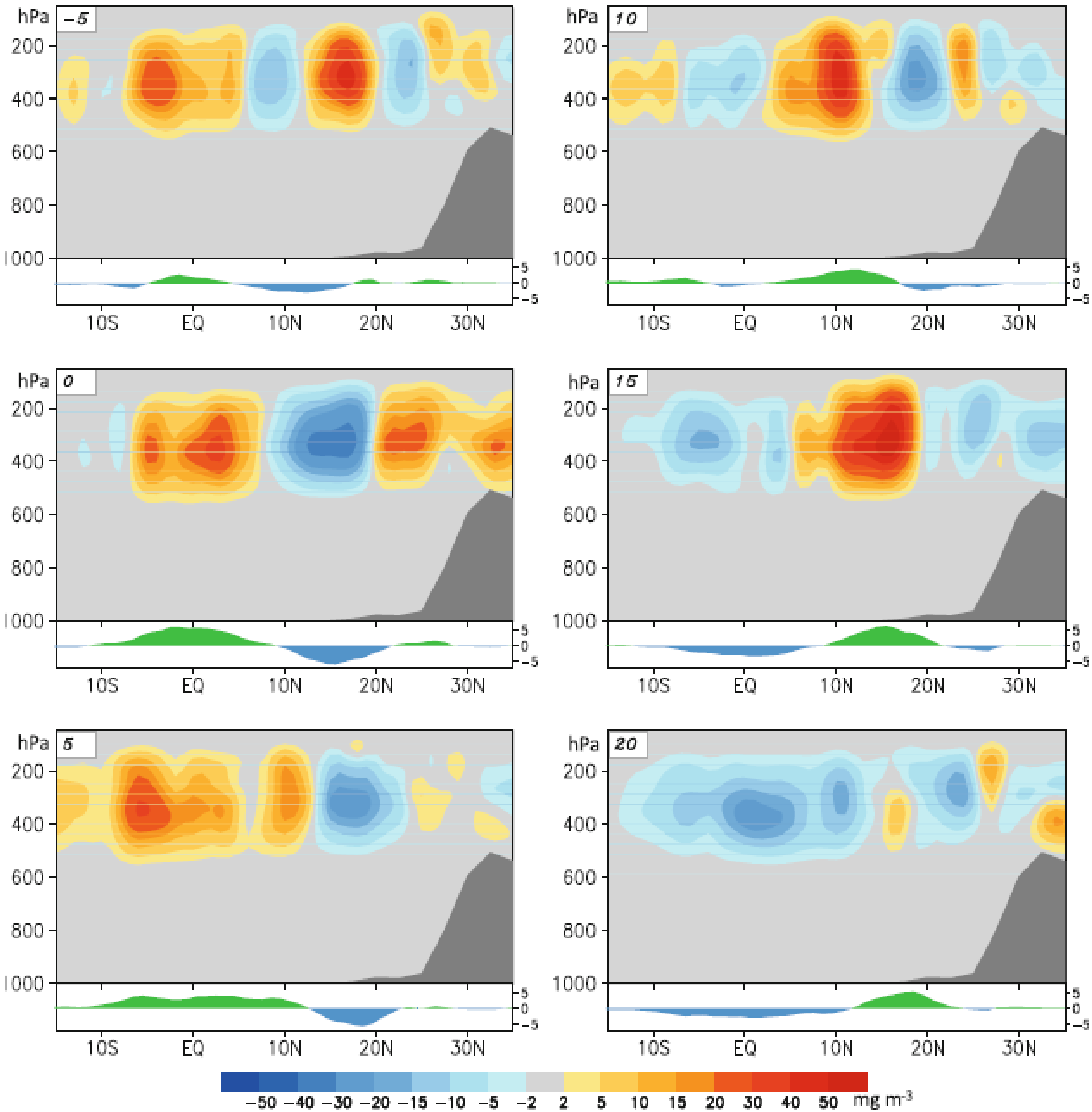
Slide Courtesy: Frank Li, JPL

Multi-scale clouds





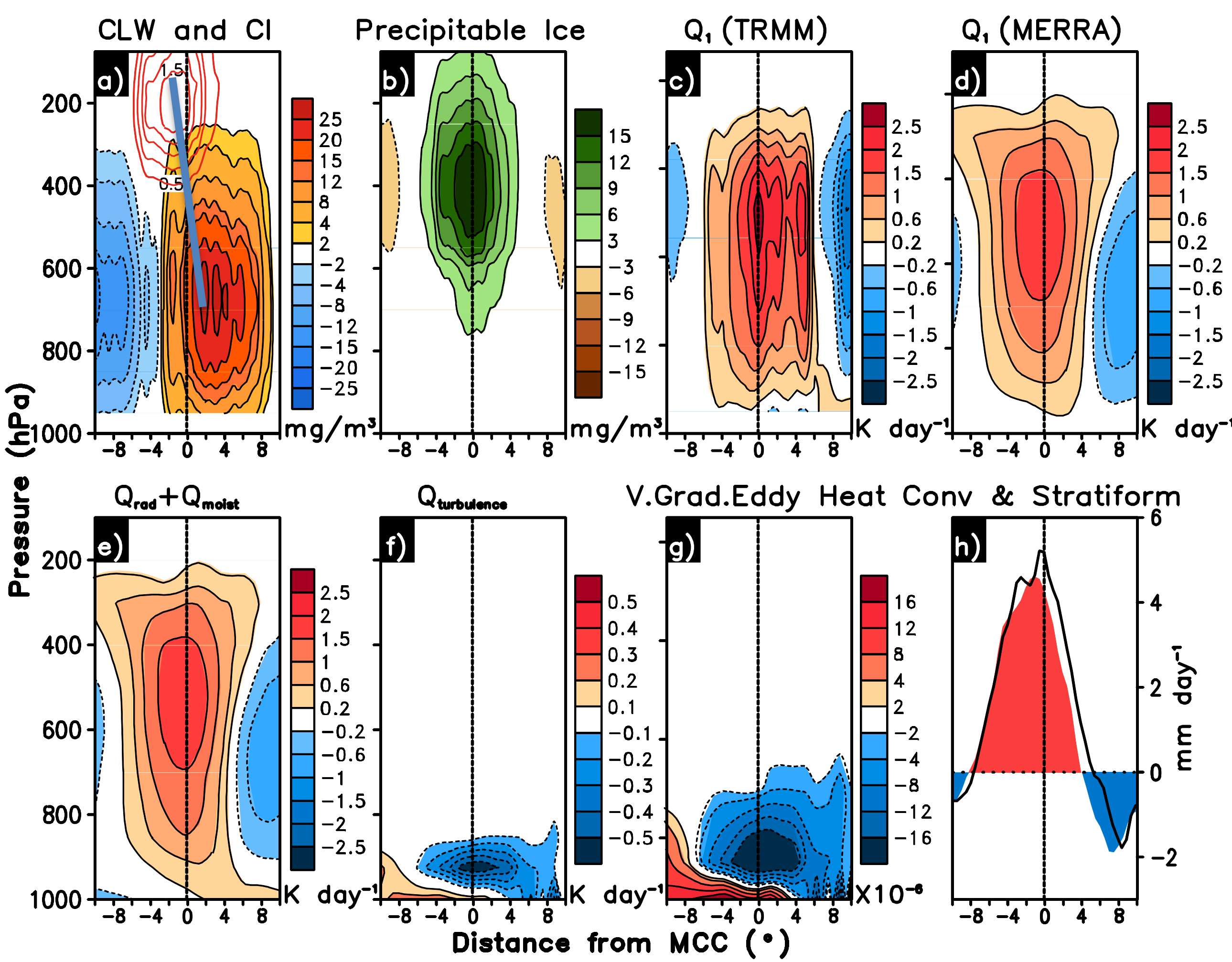
Bridging the Gap in GFS/CFSv2 using modified Microphysics: WSM6

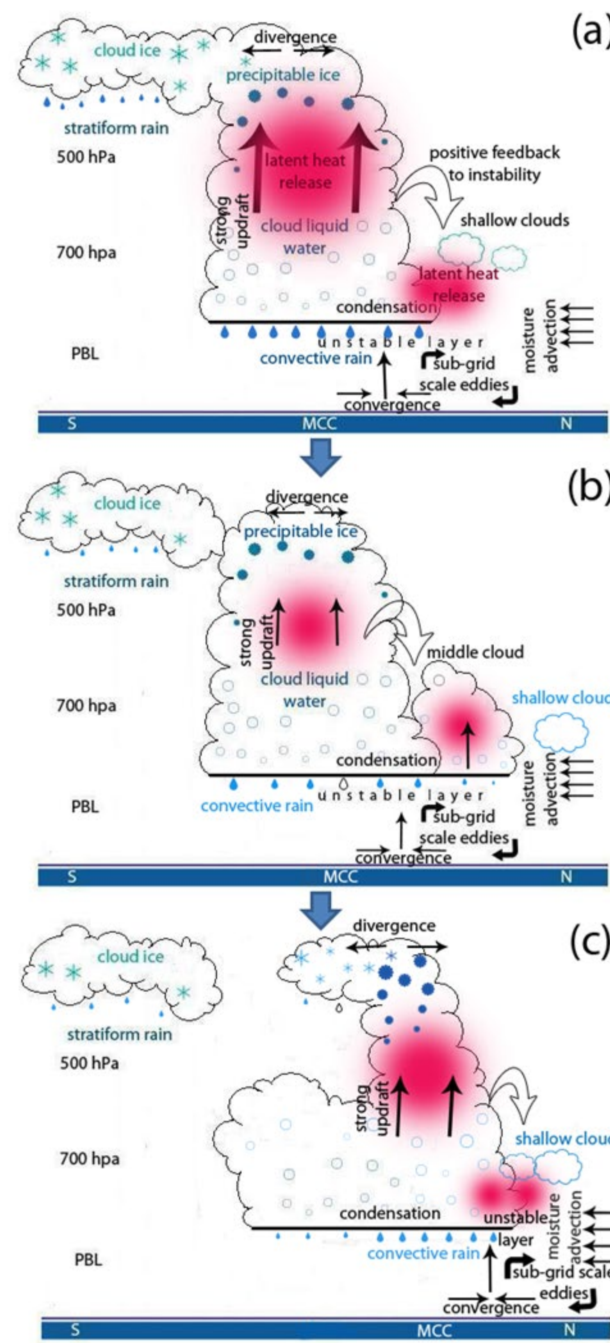


Cloudsat IWC

Jiang et al. 2011

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



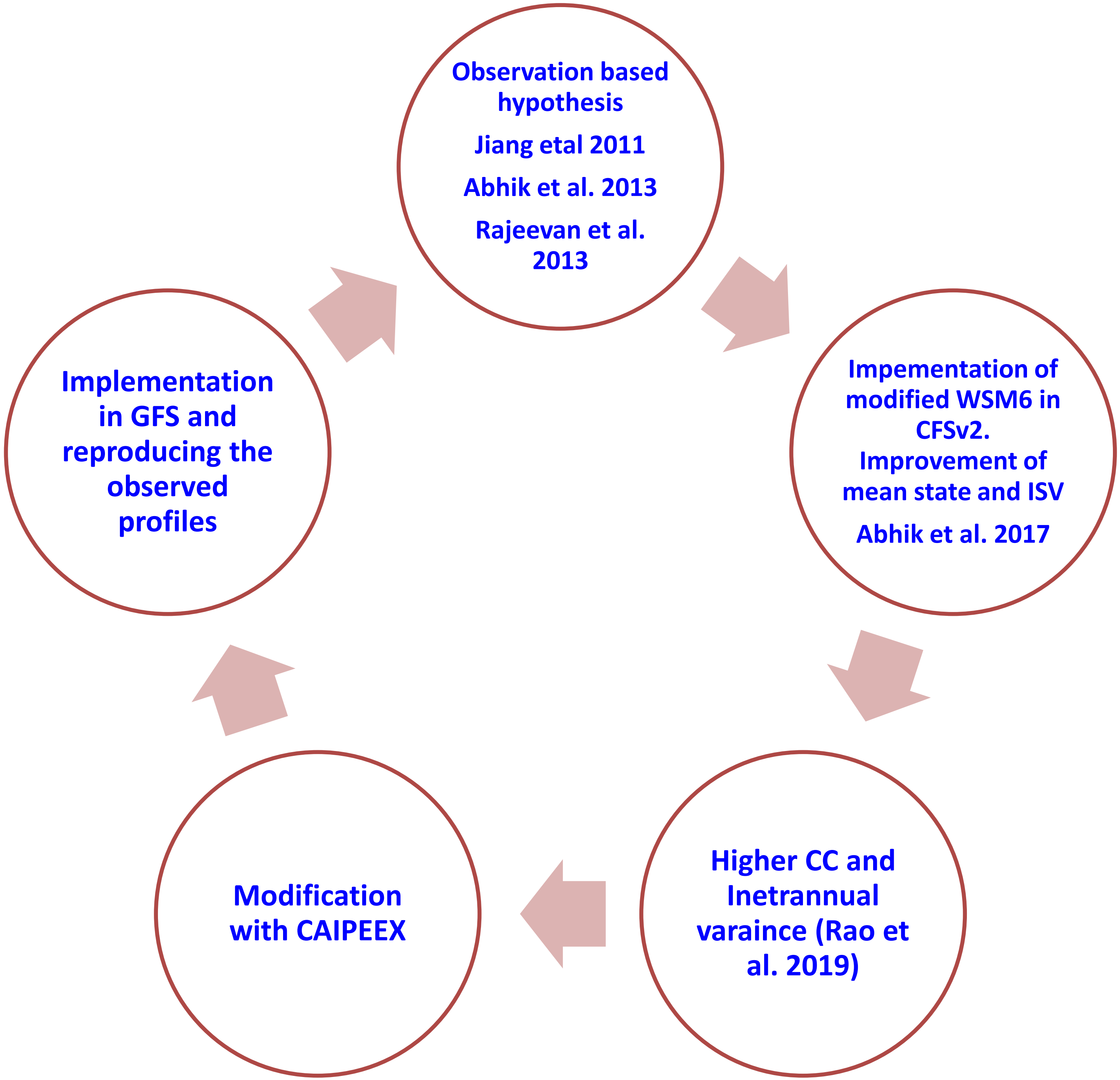


Our results are supplemented by few recent studies e. g.

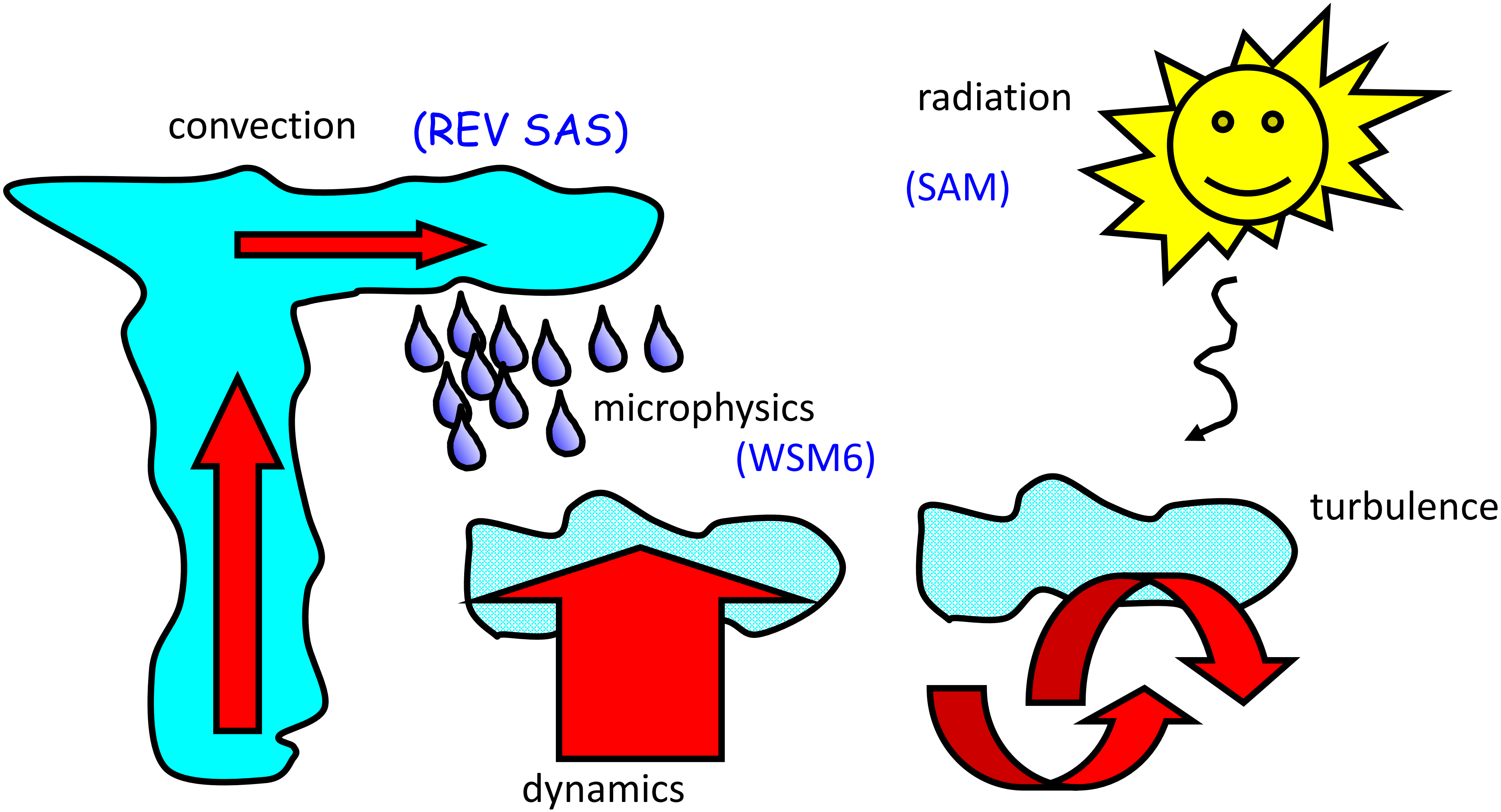
Preconditioning Deep Convection with Cumulus Congestus by Hohenegger and Steven, 2013

A climatology of tropical congestus using CloudSat by Wall et al. 2013

Improving Cloud Microphysics constrained with Indian data

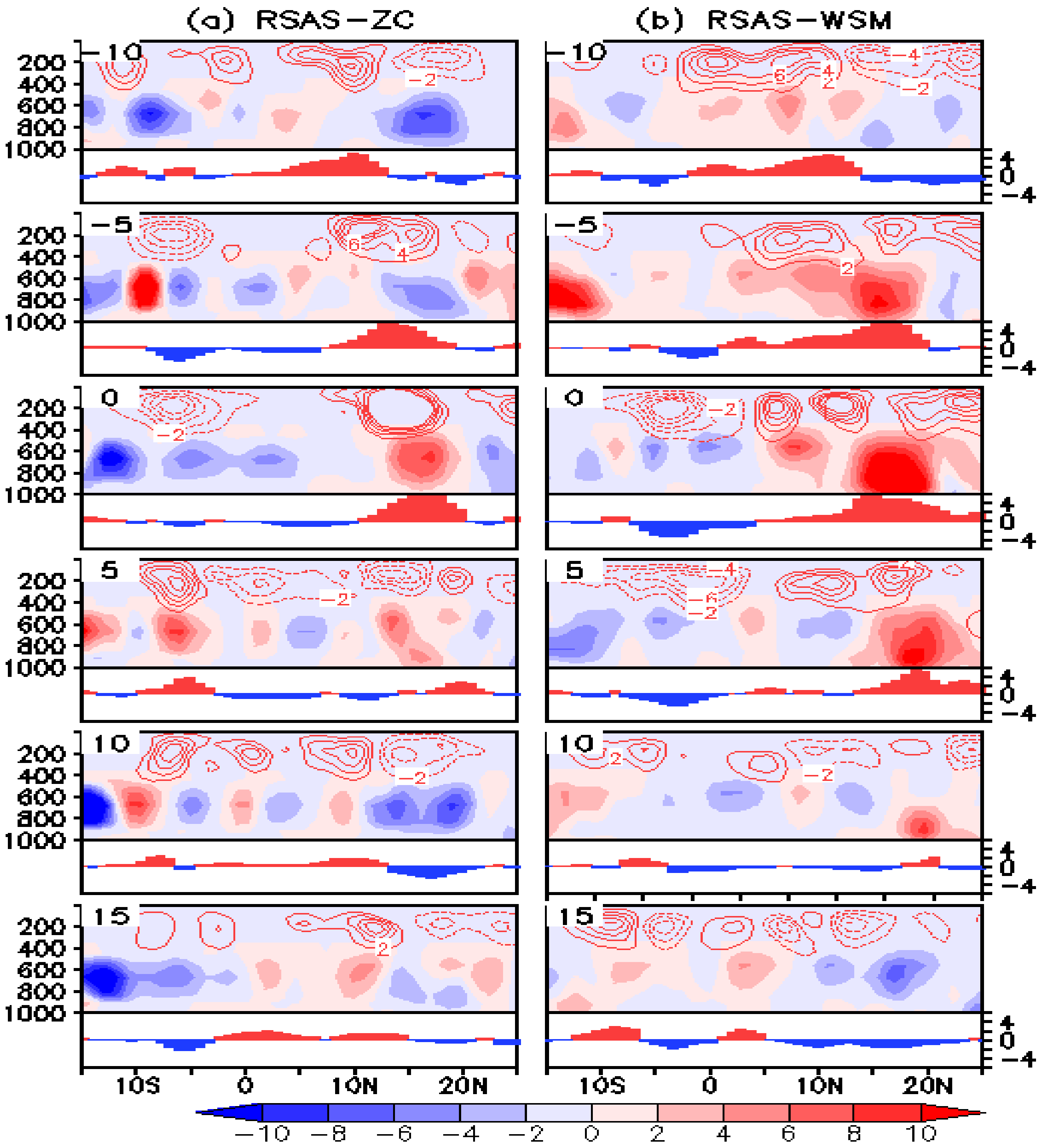


Revised Cloud-Convective-Radiation in CFSv2 T126



Clouds are the result of complex interactions between a large number of processes

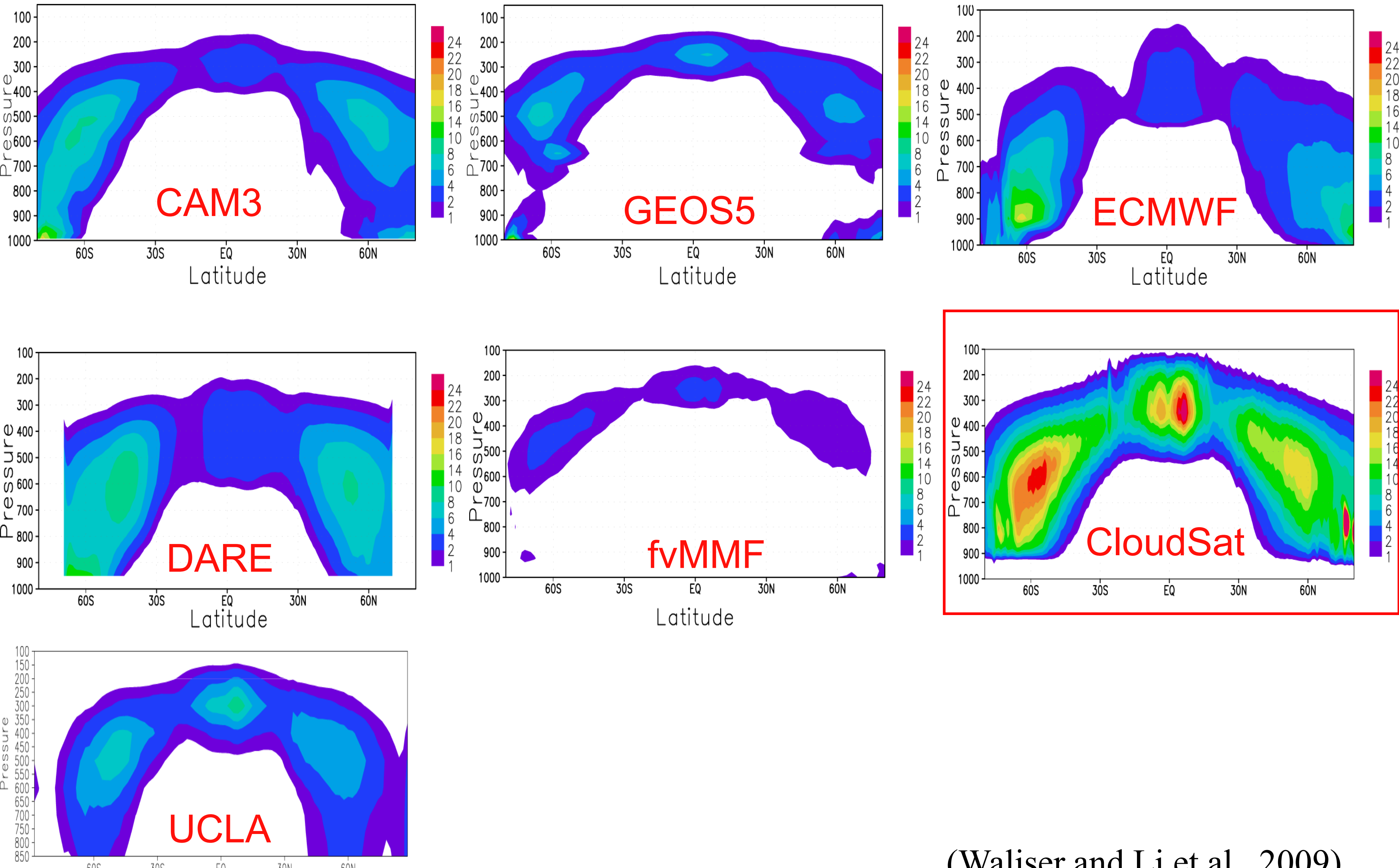
SAM: System of Atmospheric Model



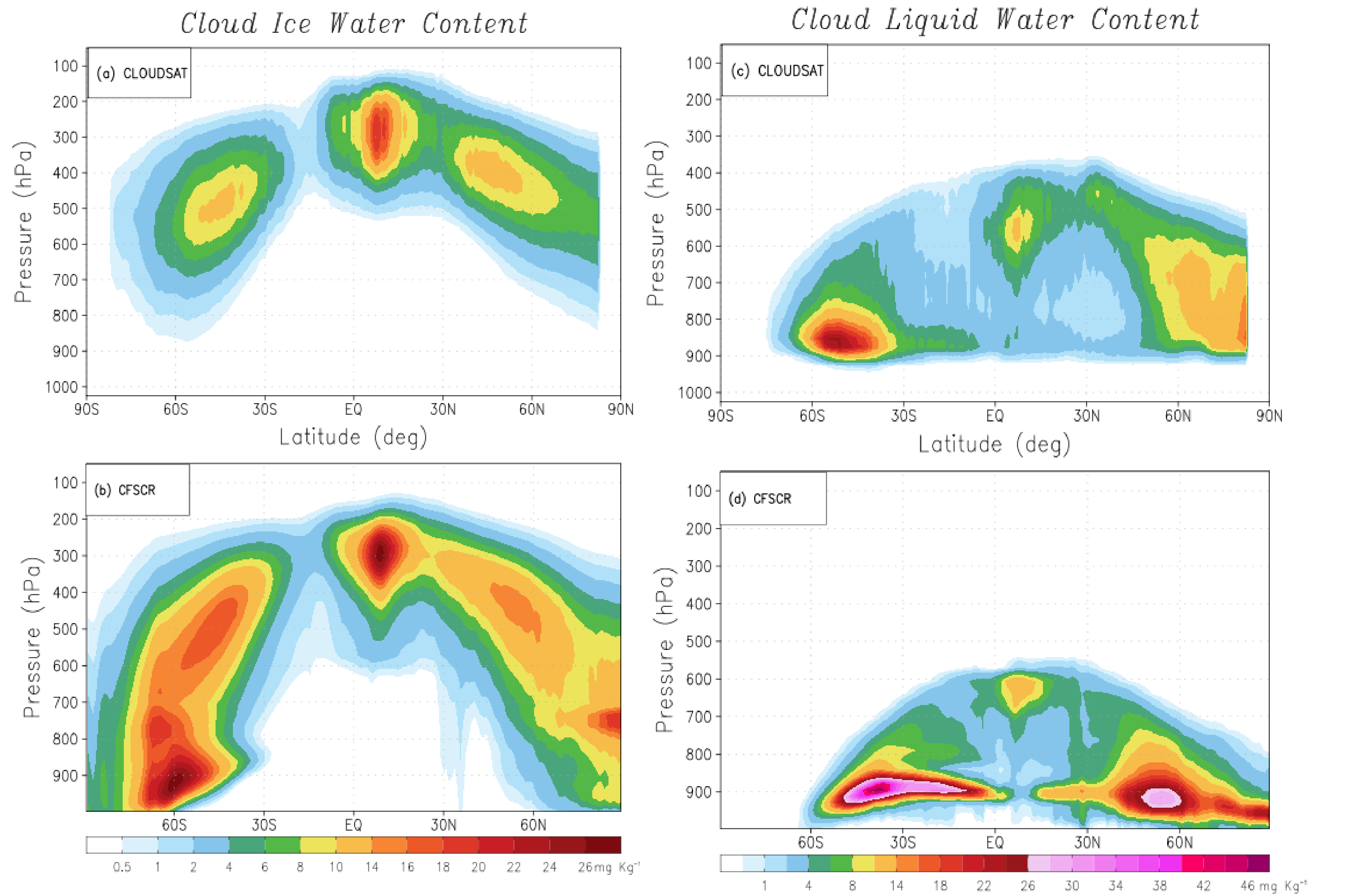
Lag composite of CLW (shaded) and CLI (red contour, solid (+ve) and dashed (-ve)) during strong event averaged over 70E-90E, corresponding rainfall anomalies plotted in the bottom in each plot.

Ganai et al. 2019, Clim. Dyn.

GCM Cloud Ice Water Content (IWC)
Annual Mean Values

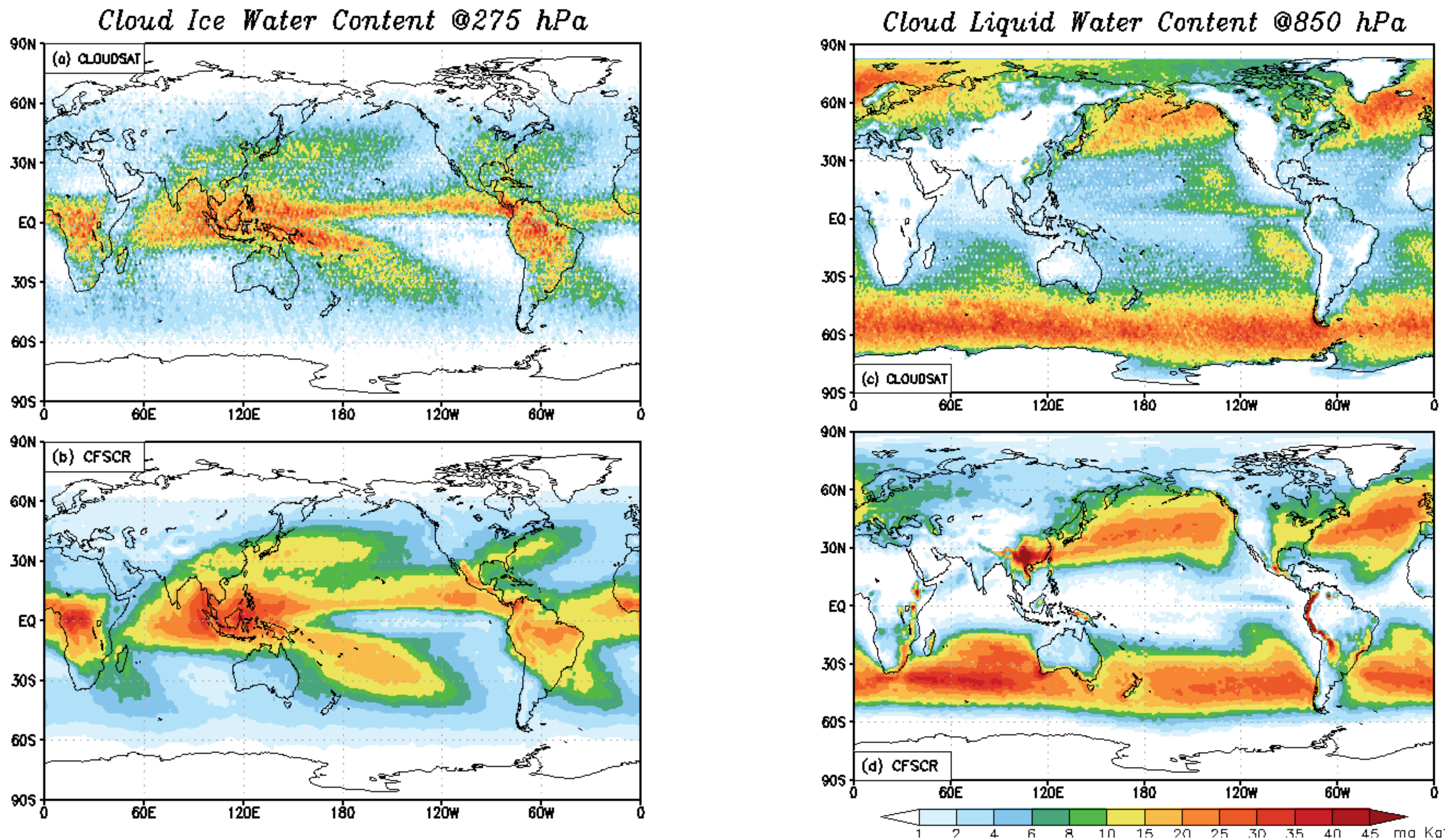


(Waliser and Li et al., 2009)



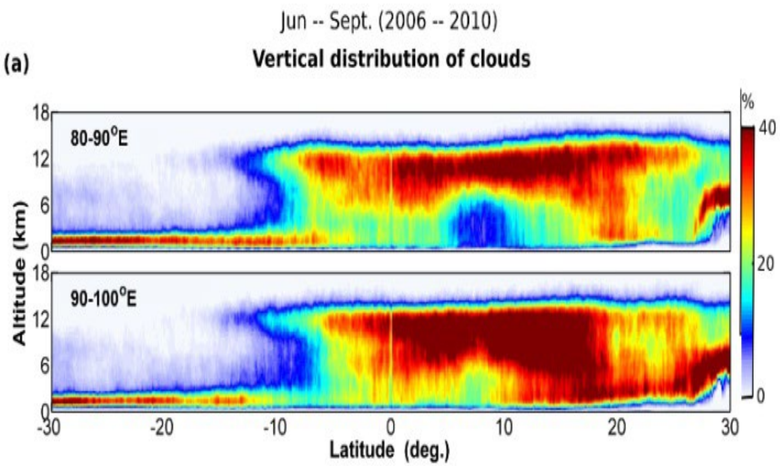
Zonally averaged annual mean vertical distribution of cloud ice water content (mg kg^{-1}) obtained from (a) CFSCR; and cloud liquid water content (mg kg^{-1}) from (b) CFSCR model.

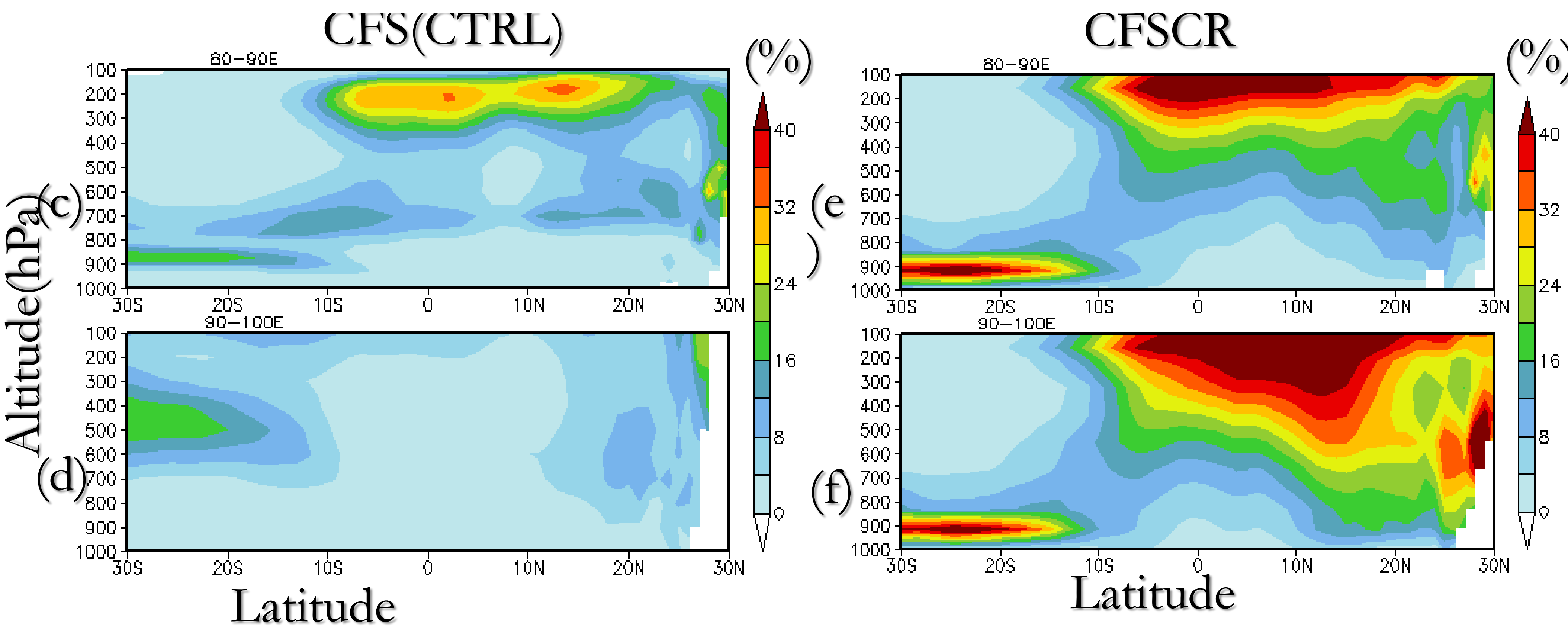
CFSCR: Modified CFSv2 with revised Cloud Microphysics, Convection and radiation



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).

vertical distribution of clouds for the meridional cross-sections (a)80-90 and (b)90-100°E for Cloudsat obs , (c) & (d) ,(e) & (f) for CFS(CTRL) and CFSCR respectively





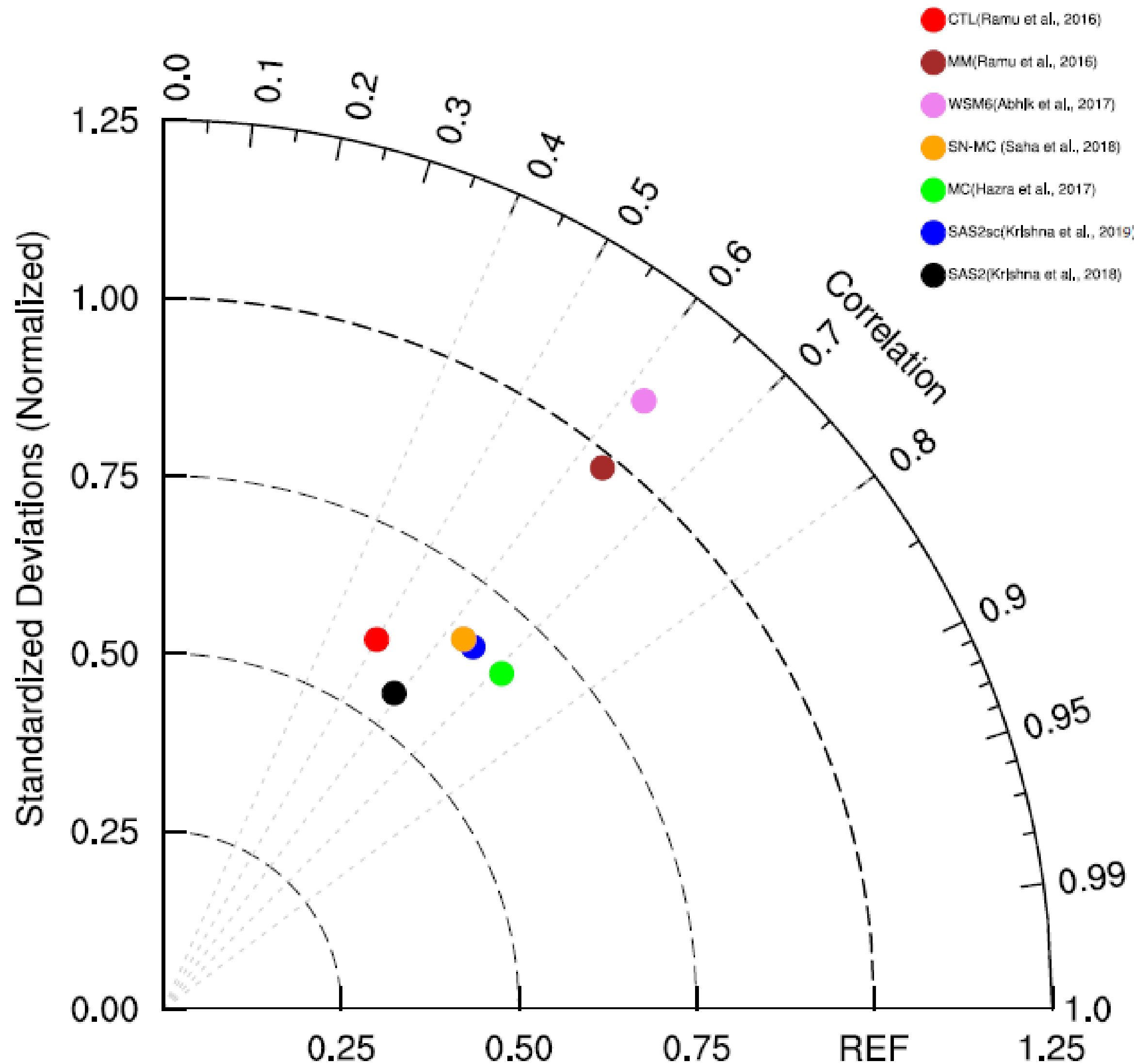
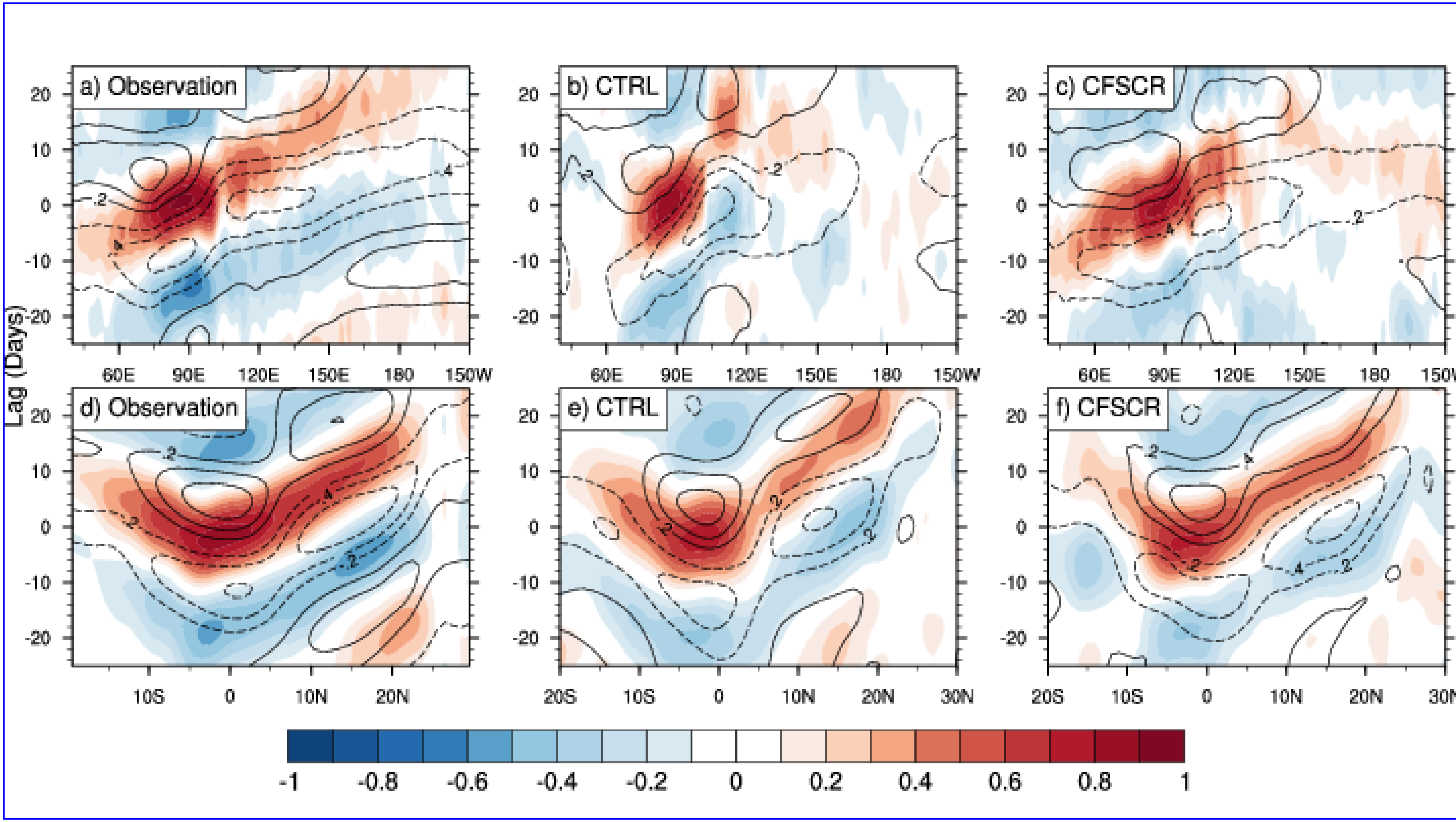
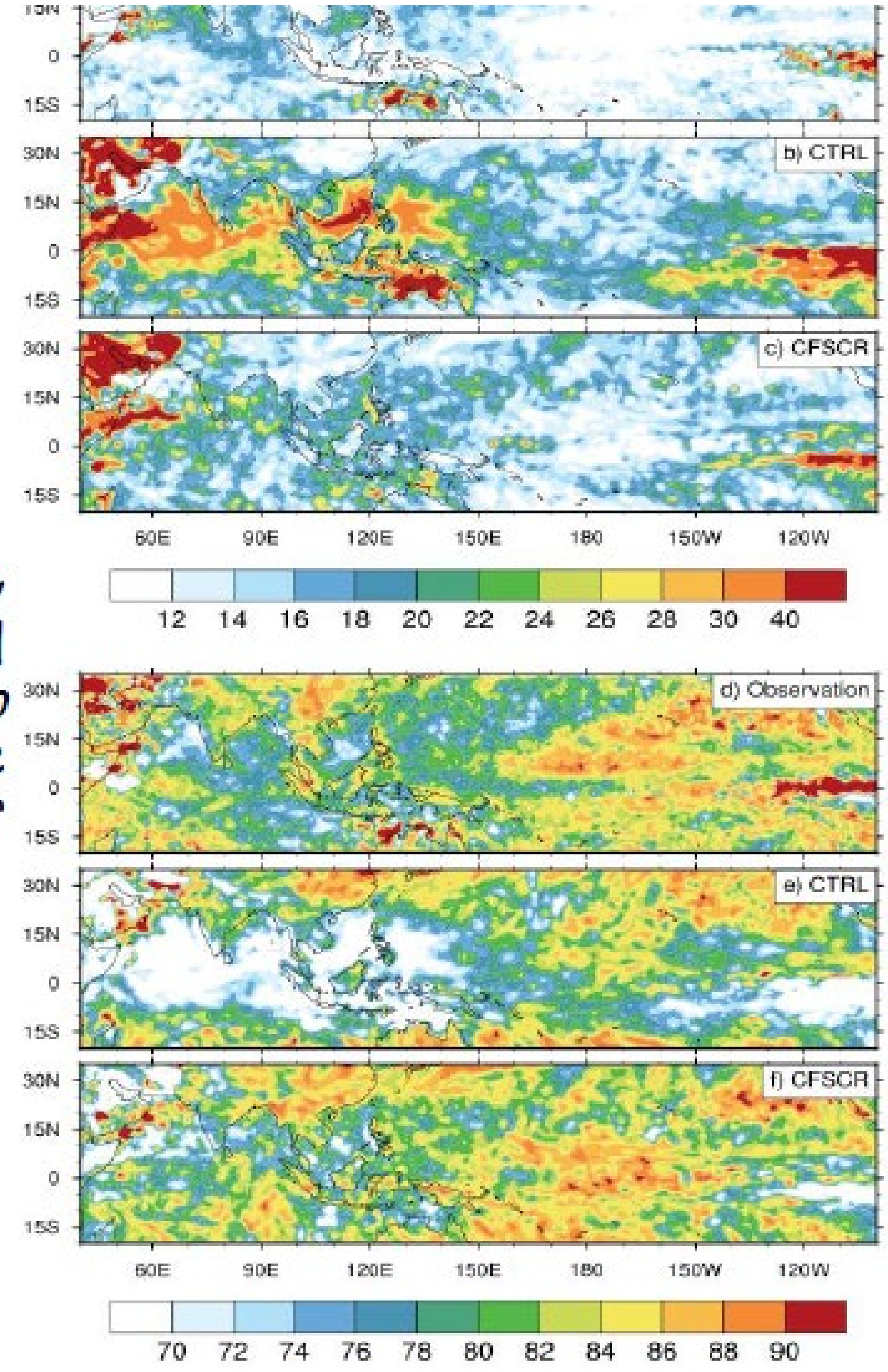


Figure 6 Taylor diagram showing the skill of ISMR prediction using reforecasts from control run (CTL) and the developmental activities under MM, namely the revised microphysics (WSM6) along with revised convection (SAS2) and a modified radiation scheme, new cloud physics parameterization (MC), the new snow model (SN) and MC together (SN-MC), the revised convection parameterization scheme (SAS2) and SAS2 with revised shallow convection scheme (SAS2sc). The improvement in skill over the CTL run is notable in the experiments. The period of the hindcast is 1981-2010. The axes denote the ratio of standard deviation of the simulated ISMR to the observed.



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).

Abhik et al. 2017, JAMES



Percentage of total daily precipitation variance explained by 20–100-day mode (*top panels*, **a–c**) and 2–20- day mode (*bottom panels*, **d–f**) for observation, CTRL and CFSCR.

Update in Dynamic Core: Spectral Cubic Octahedral grid

Conventional Spectral grid:

- **Not scalable**
- **I/O**
- **Artificial diffusi damping**
- **Negative tracer**

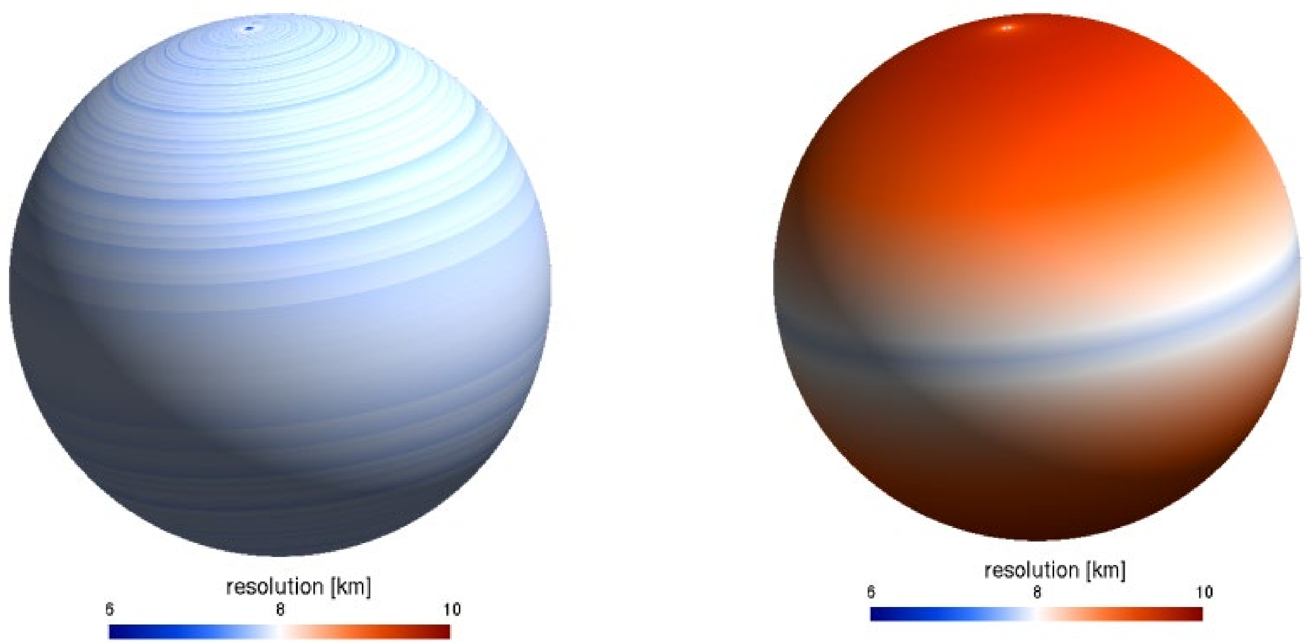
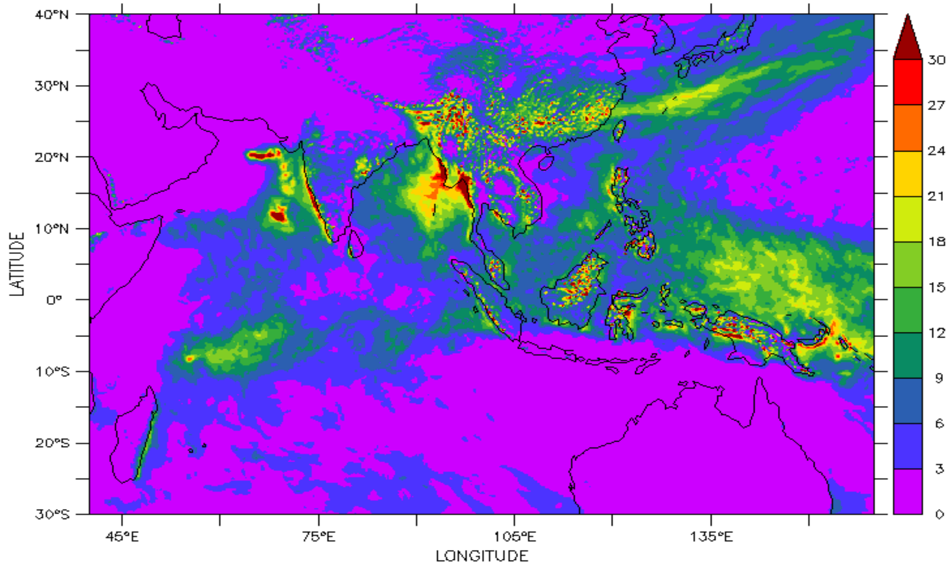


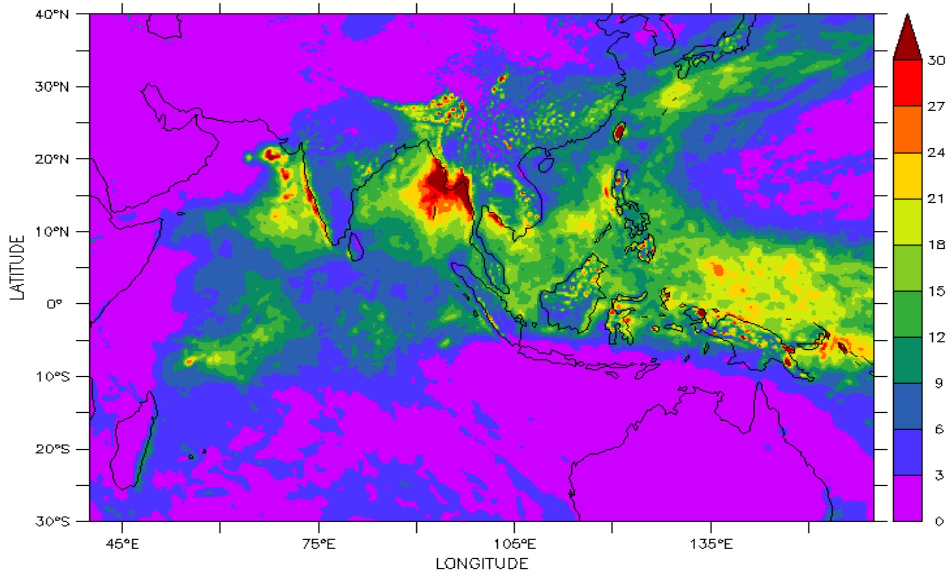
Figure (adopted from ECMWF News Letter 146) demonstrates that the octahedral mesh (right) has a locally more uniform dual-mesh resolution than the mesh (left).

Numerical simulation of an idelaised baroclinic instability, conducted using IFS model on both the mesh showed the octahedral grid results in higher accuracy and substantially reduced unphysical flow distortions accuracy mainly as the approach depends on the underlying mesh which defines the shape of the elementary volumes around which the computations are made (ECMWF New Letter, No. 146, 2015).

Day1 forecast monthly mean June 2019

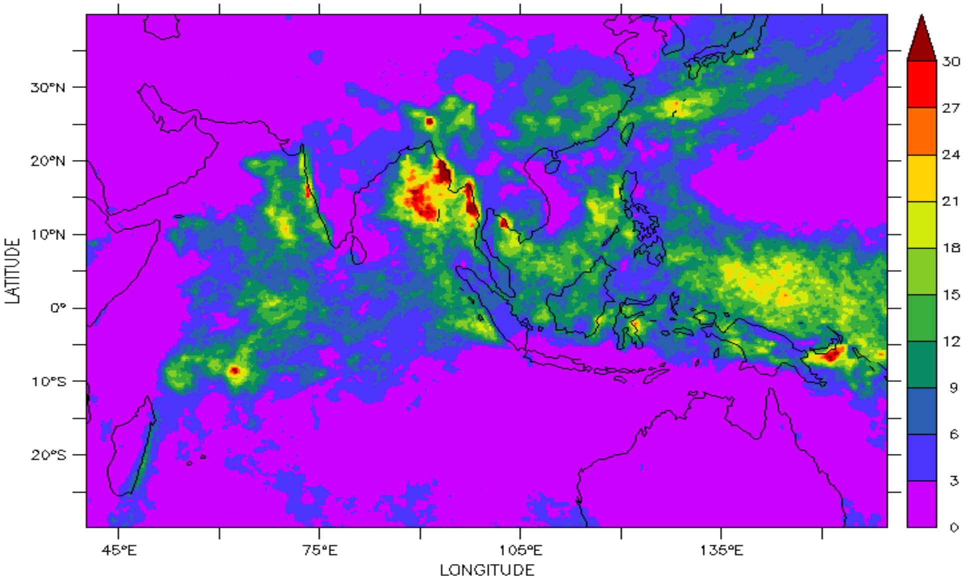


GFS1534

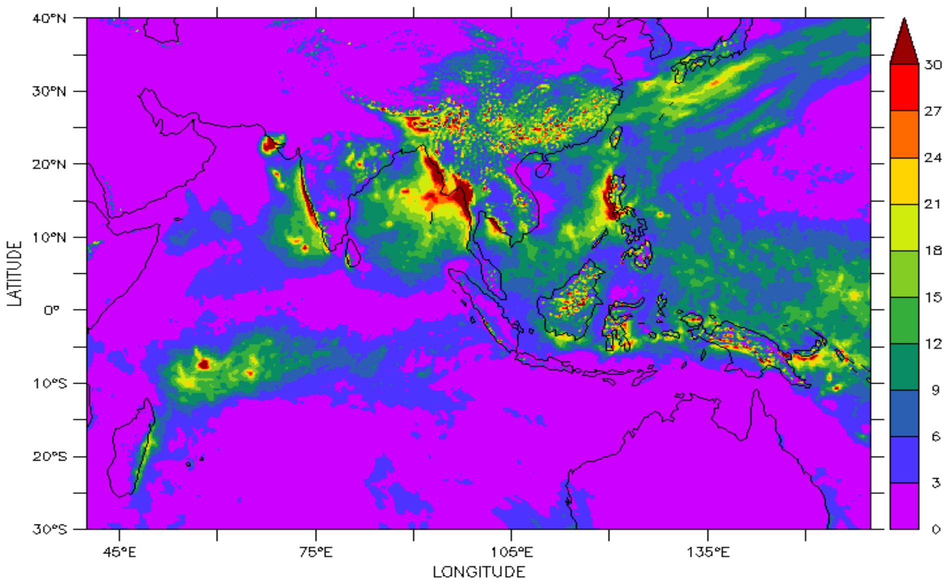


TCO 765

Observation

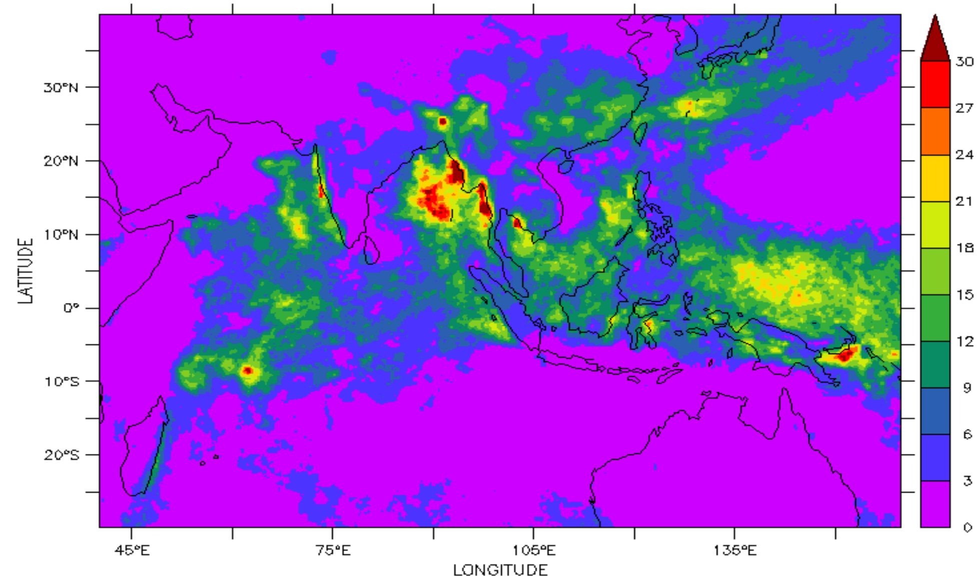


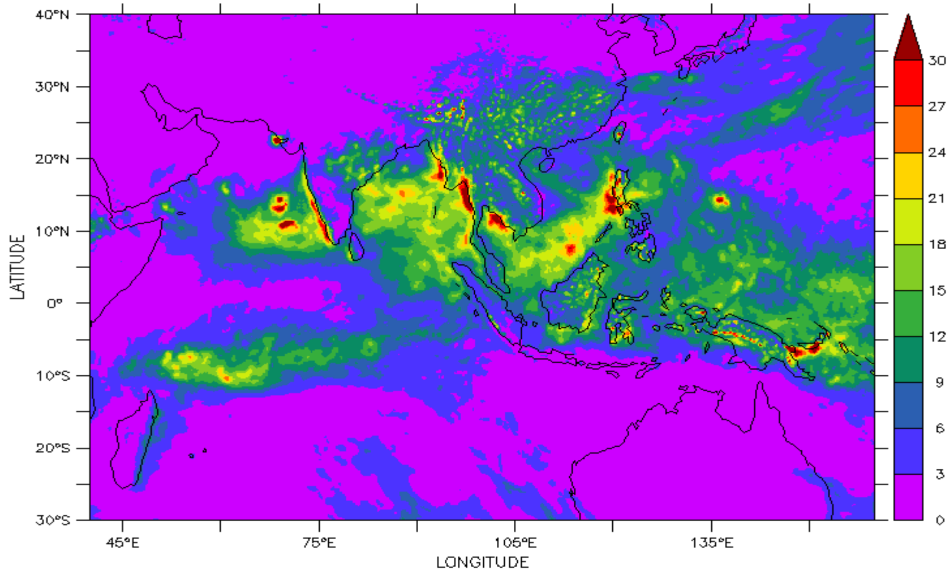
Day5 forecast monthly mean June 2019



GFS1534

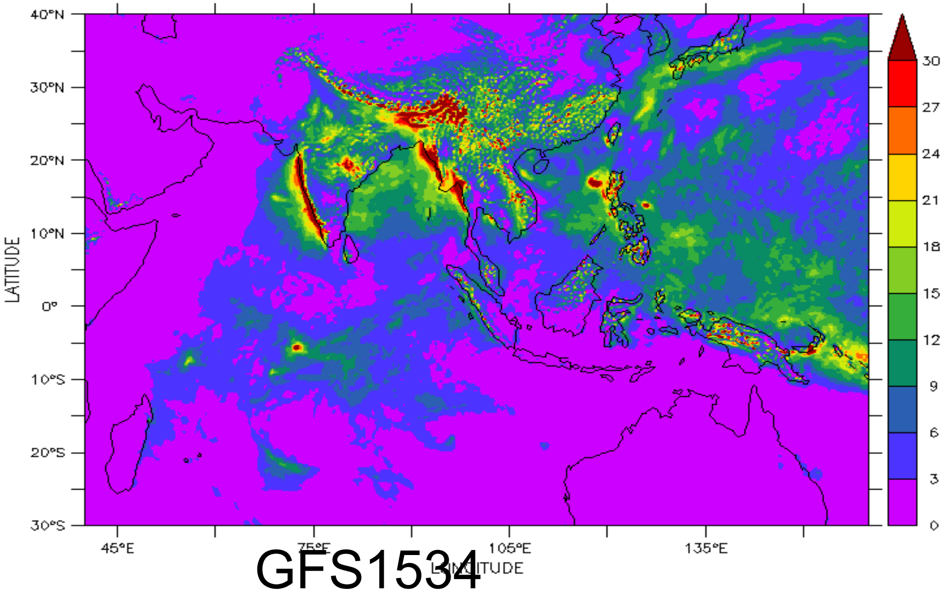
Observation



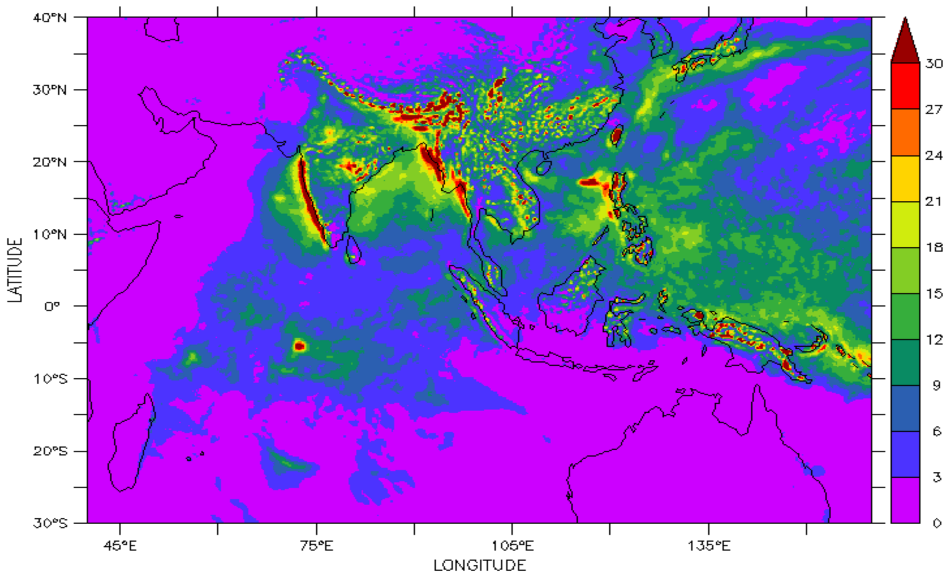


TCO 765

Day1 forecast monthly mean July 2019

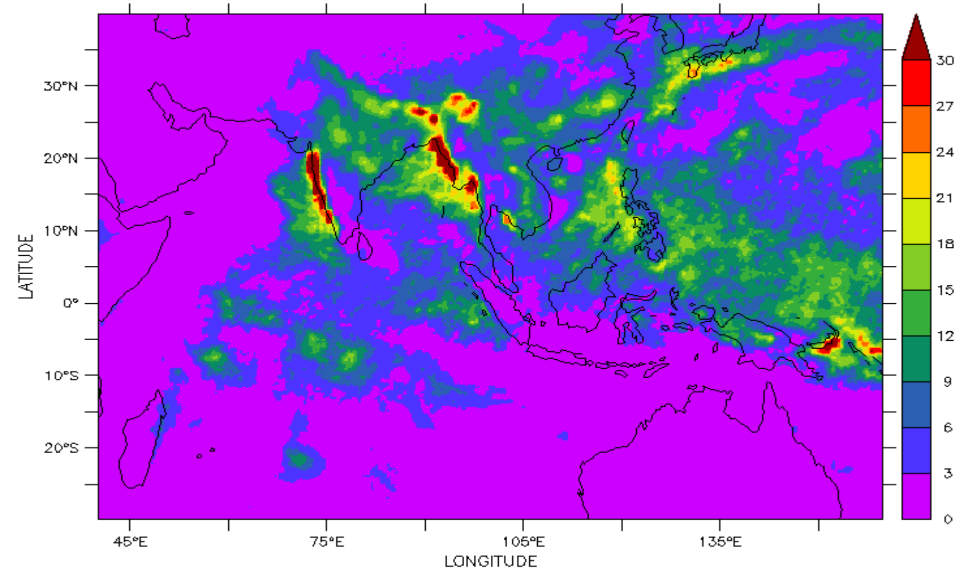


GFS1534

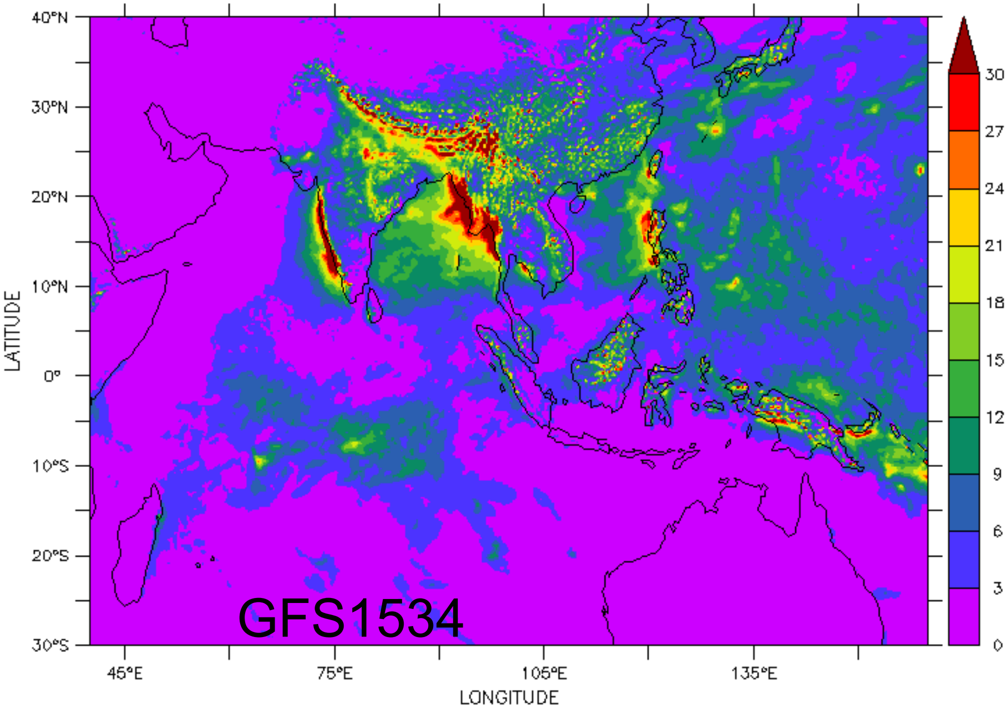


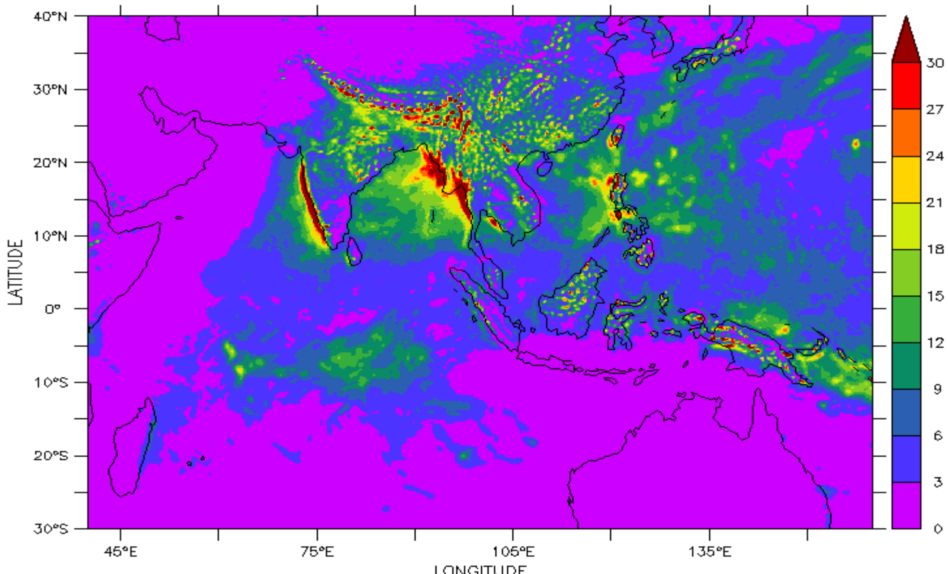
TCO 765

Observation



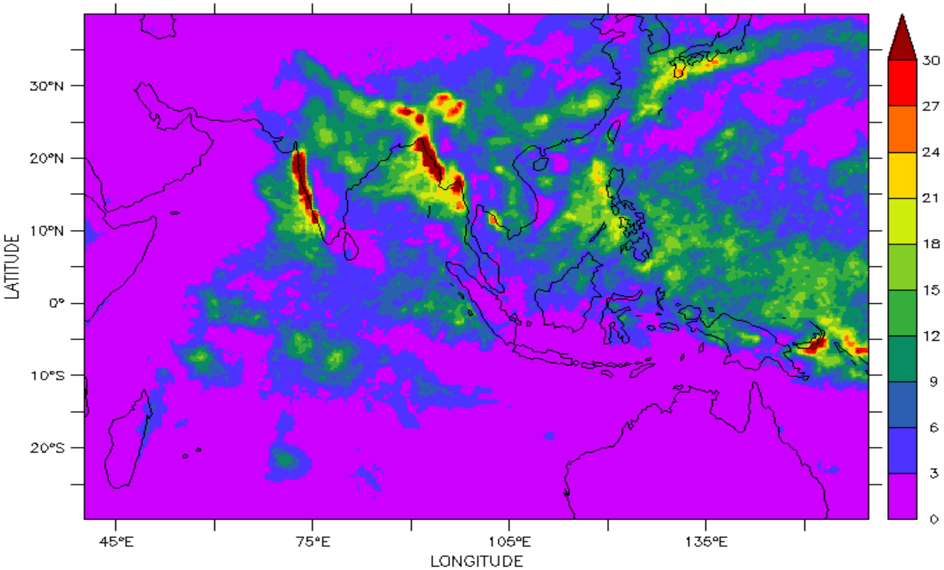
Day5 forecast monthly mean July 2019





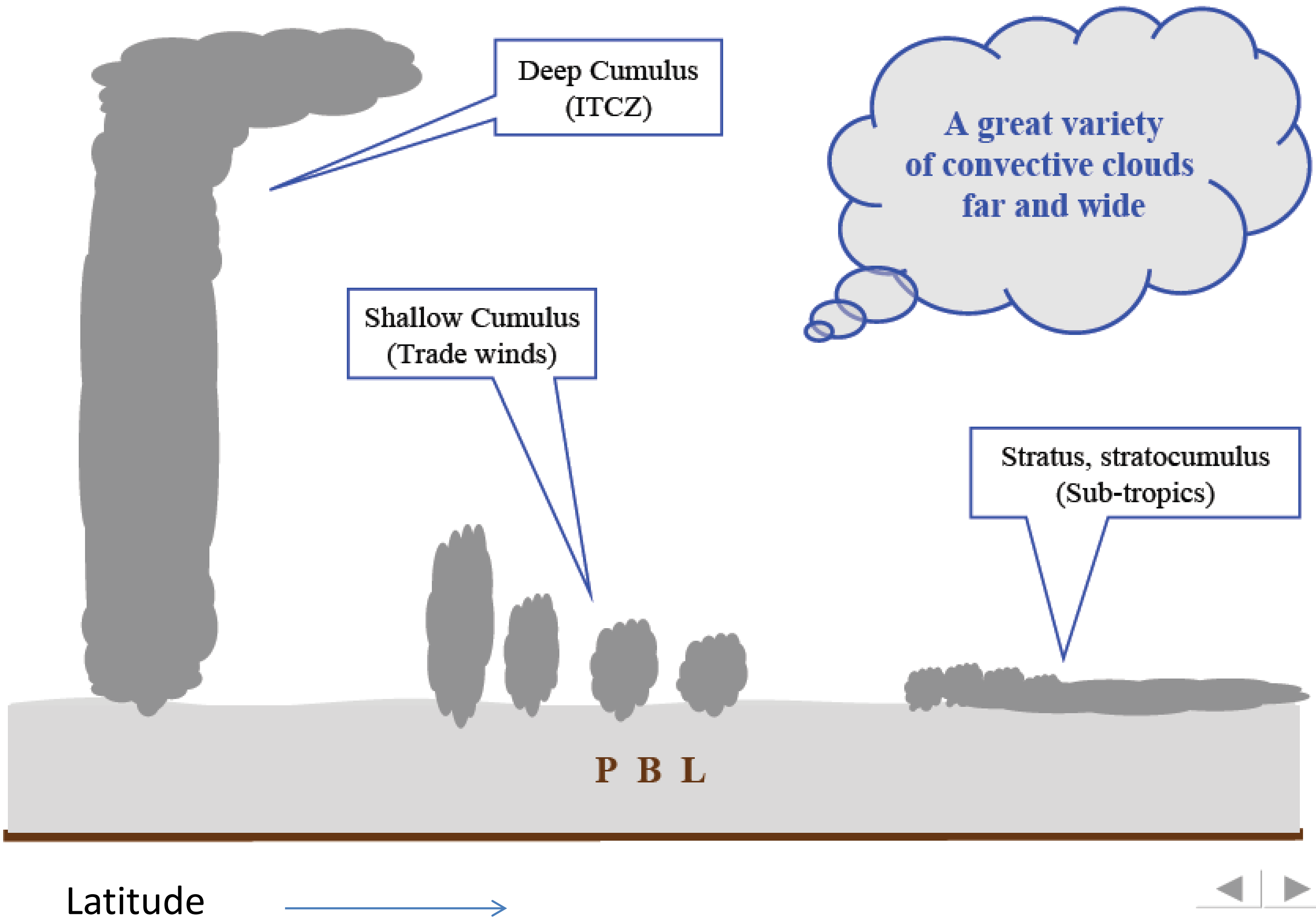
TCO 765

Observation



Grand Challenge: Represent Physically Multiscale interactive process

Phenomenology



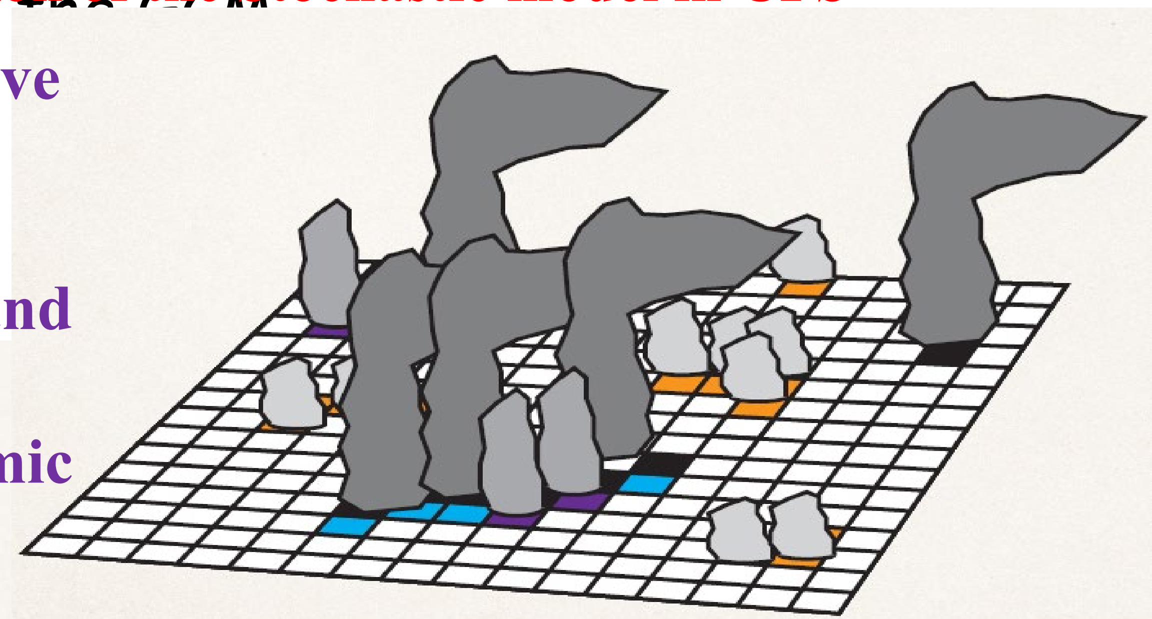
New Paradigm

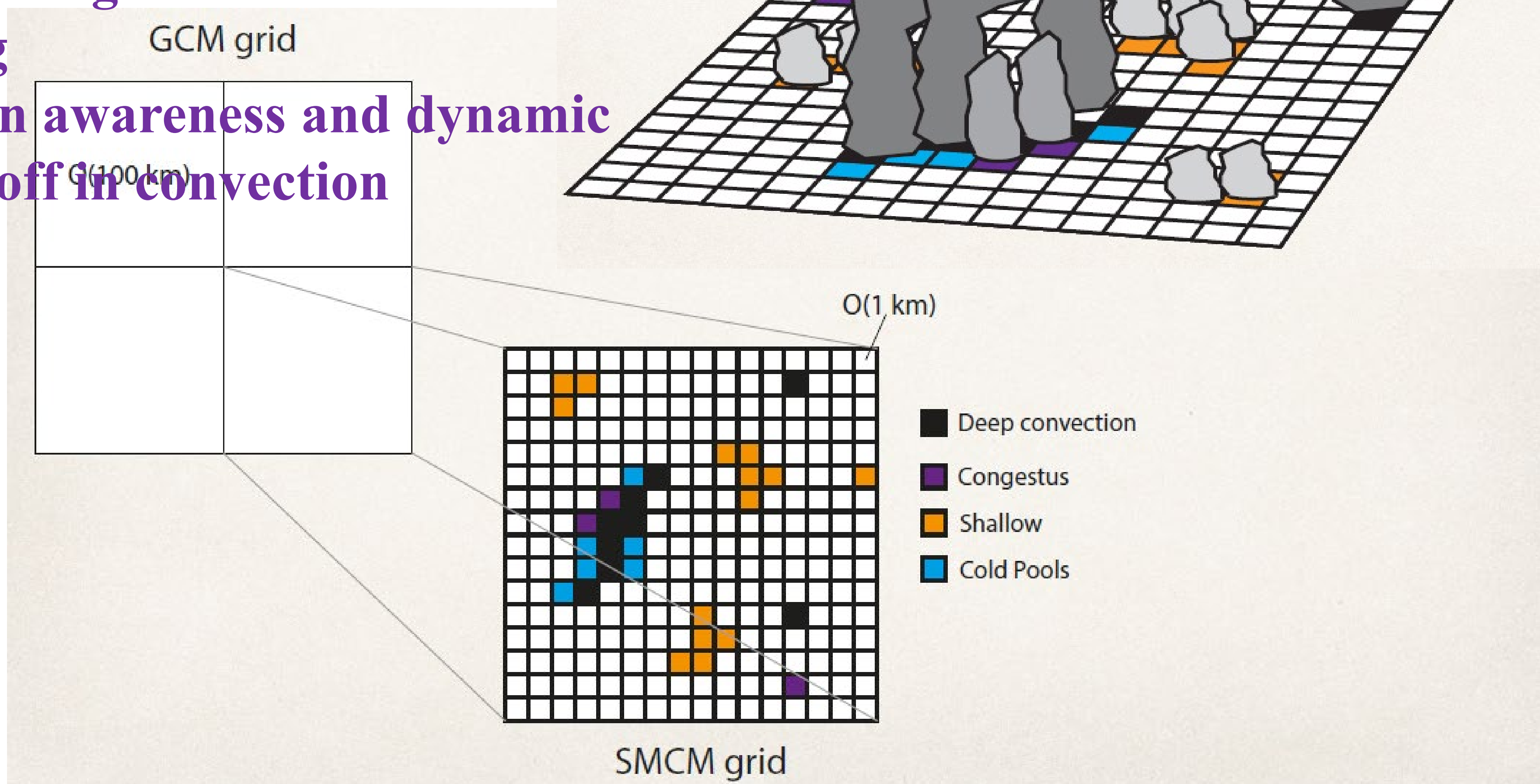
Stochastic modelling in Climate Forecast System (CFSsmcm) Model

Convective tendencies are explicitly simulated in each GCM grid column which replaces the traditional cumulus parameterization of the GCM

A Framework for the implementation of the Stochastic model in CFS

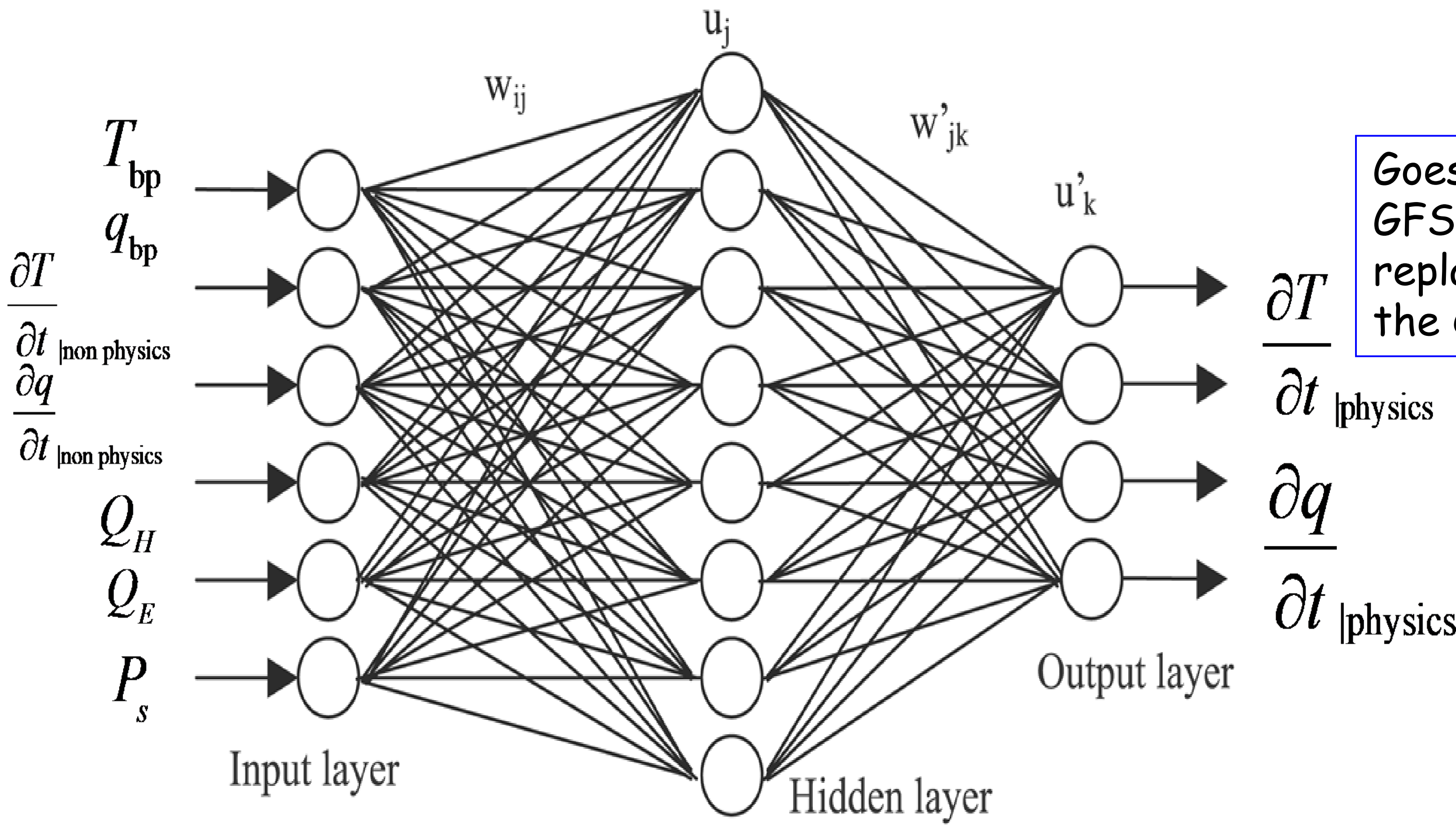
- Stochastic nature in the convective process
- Existence of different clouds
- Distinguishing different clouds and organizing
- Resolution awareness and dynamic switching off in convection





Presentation of a feed forward neural network architecture and the inputs used as well as the predicted tendencies

SP_CFS CRM



Goes into GFS/CFS replacing the CPS

Where we are (short range)?

- GFS and GEFS

Resolution T1534 (SL)~12km

Presently T1534 is uncoupled (Tested coupled GFS T574 for cyclone forecast (paper under rev)

Vertical Levels 64

Convection: RSAS_mod
RSAS Scale aware

Micro: Zhao and Carr, WSM6

Present skill of 3 to 5 days

Where we want to reach?

Resolution: 5 to 6 km (Cubic Spectral Octahedral Tco 1534)
From coupled T574 to coupled T1534

Vertical levels: 91

Convection: Stochastic scale aware
Unified param: Convection+Micro
WSM6+PBL+Rad: Unified
CLUBB/ Deep Learning

Skill extend for short range to 7~10 days
Seamless

Thank You !