Role of Cloud Processes Behind the Indian Summer Monsoon Rainfall And its Prediction

Ushnanshu Dutta[1,2], Anupam Hazra[1], Hemantkumar S. Chaudhari[1], Subodh Kumar Saha[1], and Samir Pokhrel[1].

[1]Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, India.
[2]Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune, India.

ushnanshu.jrf@tropmet.res.in

Introduction

Why is the study of the detailed microphysical process rates important? Cloud and its propagation is important for monsoon (Sikka and Gadgil, 1990) and cloud microphysics in particular, which includes microphysical processes (viz. autoconversion, accretion, freezing and evaporation) are crucial in seasonal and intraseasonal scales scale (Hazra et al. 2016, Dutta et al., 2020, 2021). Kumar et al., (2017) have pointed out that, better understanding of various multi scale processes which drive the MISOs, are the key to achieve better fidelity in coupled climate models. The parameterizations of condensation, freezing, sublimation, evaporation, autoconversion, accretion, and sedimentation of liquid and ice (Bacmeister et al., 2006) are important for sustaining monsoon dynamics through latent heating and rainfall formation (Tao et al., 1990, 2001). Therefore, understanding of the detailed microphysical process rates may help to target the improvement of the particular processes in climate model.

Objectives

To find

i) Role of cloud microphysical process in governing the seasonal mean rainfall and its interannual variability.

ii) Possible linkage of microphysical processes with ENSO.

iii) Cloud microphysical processes in synoptic (3-7 days), Quasi-Biweekly Mode (QBM: 10-20 day) and in MISO (30-60 day) scales.

iv) Linkage between ISMR and cloud microphysical processes in the subseasonal (synoptic, QBM and MISO) scales.

Data and Methodology

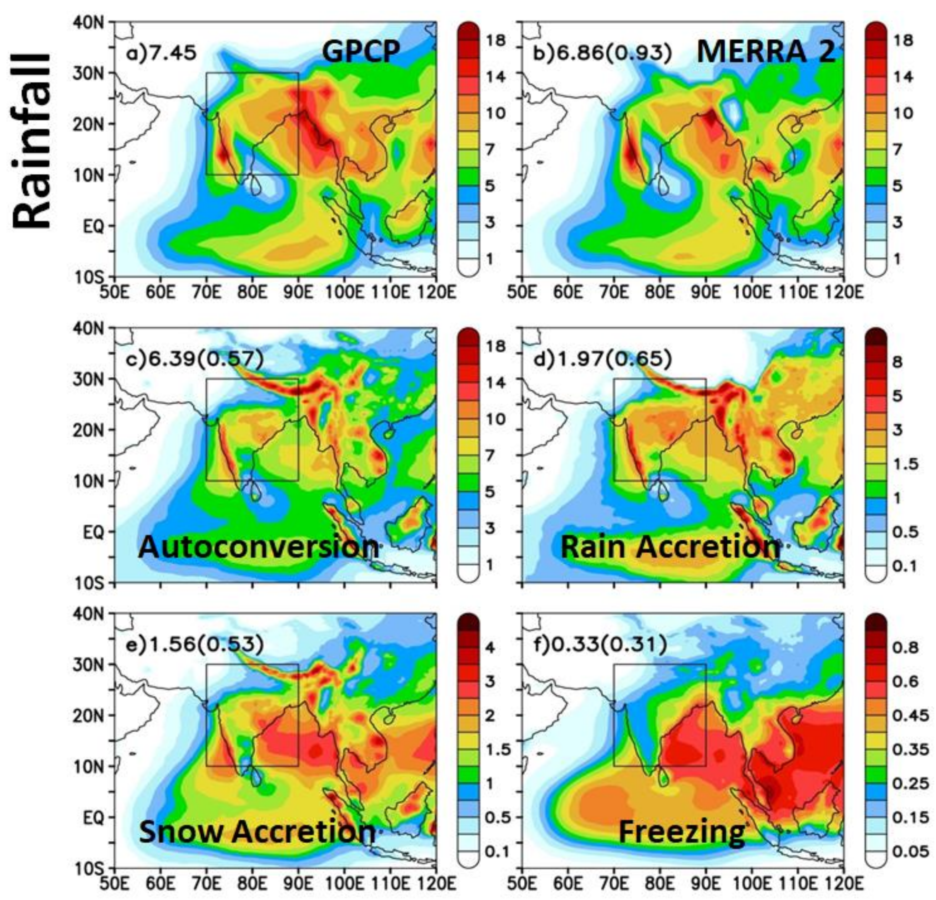
- These analyses are based on Modern Era Retrospective-analysis for Research and Applications - version 2 (MERRA2, Gelaro, et al., 2017) reanalysis data.
- The cloud microphysical tendency terms taken from MERRA2 data are Autoconversion of Cloud water to Rain (RAUT), Accretion of Cloud water to Rain (RACR), Accretion of cloud water to snow (SACR) and net freezing of cloud condensate into ice (FCI).
- The daily and monthly rainfall data are taken from Global Precipitation Climatology Product (GPCP; Adler et al. 2003). These data are in the range 1980-2019 except for daily rainfall data from GPCP, which is in the range 1997-2019.
- The normal monsoon years (NY), Excess (formerly Flood) years (EY), Deficient (formerly Drought) years (DY), and El-Nino/La-Nina years are obtained from 'Monsoon On Line' site maintained by Indian Institute of Tropical Meteorology, Pune, India (https://mol.tropmet.res.in/).

$$\frac{\partial q_c}{\partial t} = -Advection + TurbulentTerm + C_{cov,grid-scale} - E_{c,r} - P$$

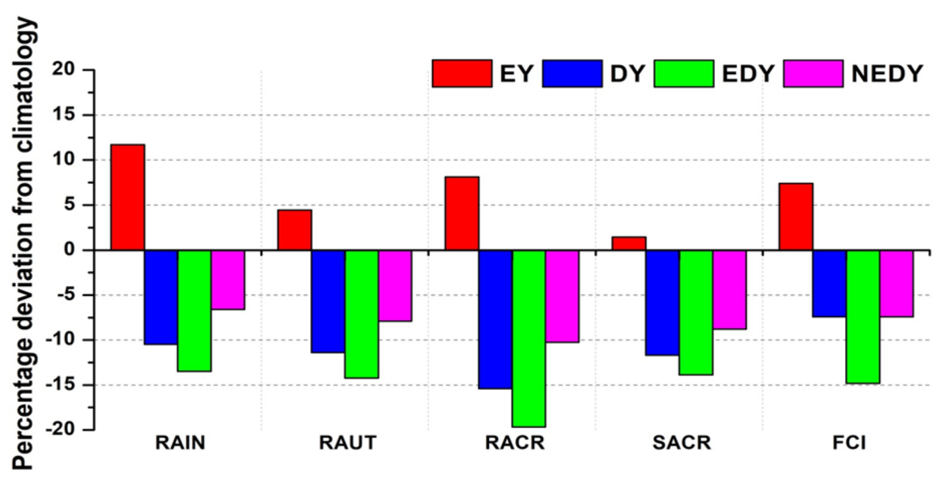
$$P = AUT + ACR + AGG$$

$$ACR = RACR + SACR$$

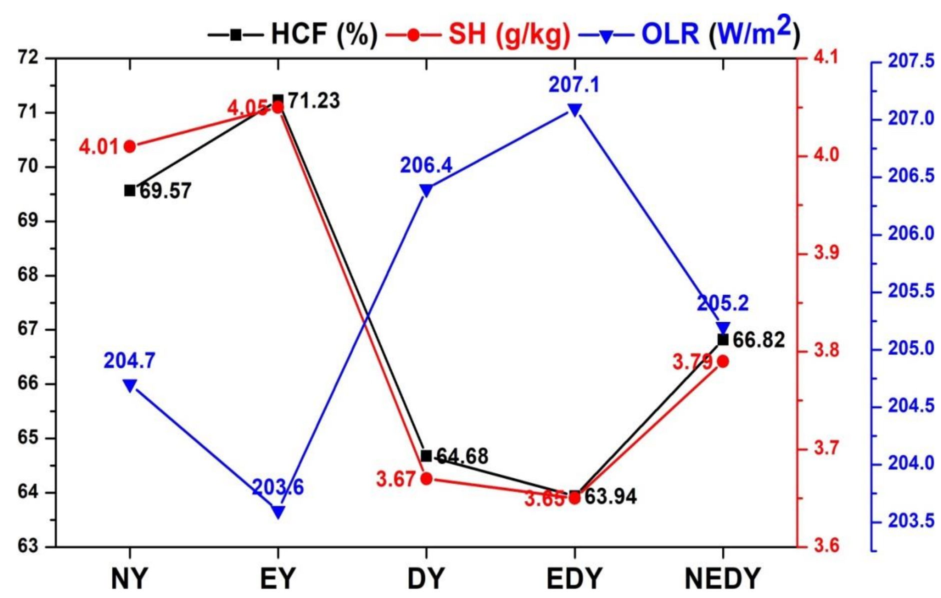
Results & Discussion



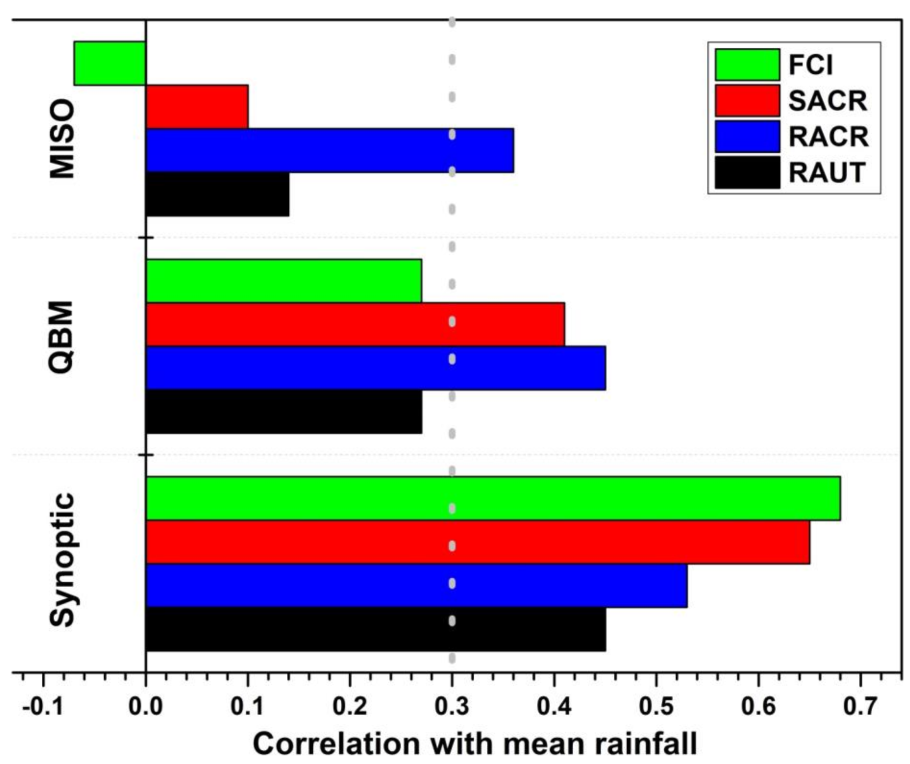
JJAS Climatology of rainfall and different microphysical processes. Mean value and (Pattern correlation) over ISM box are written in top-left panel.



EY: Excess Years, **DY:** Deficient Years, **EDY:** El-Nino+ Deficient Years, **NEDY:** Non-El-Nino+ Deficient years



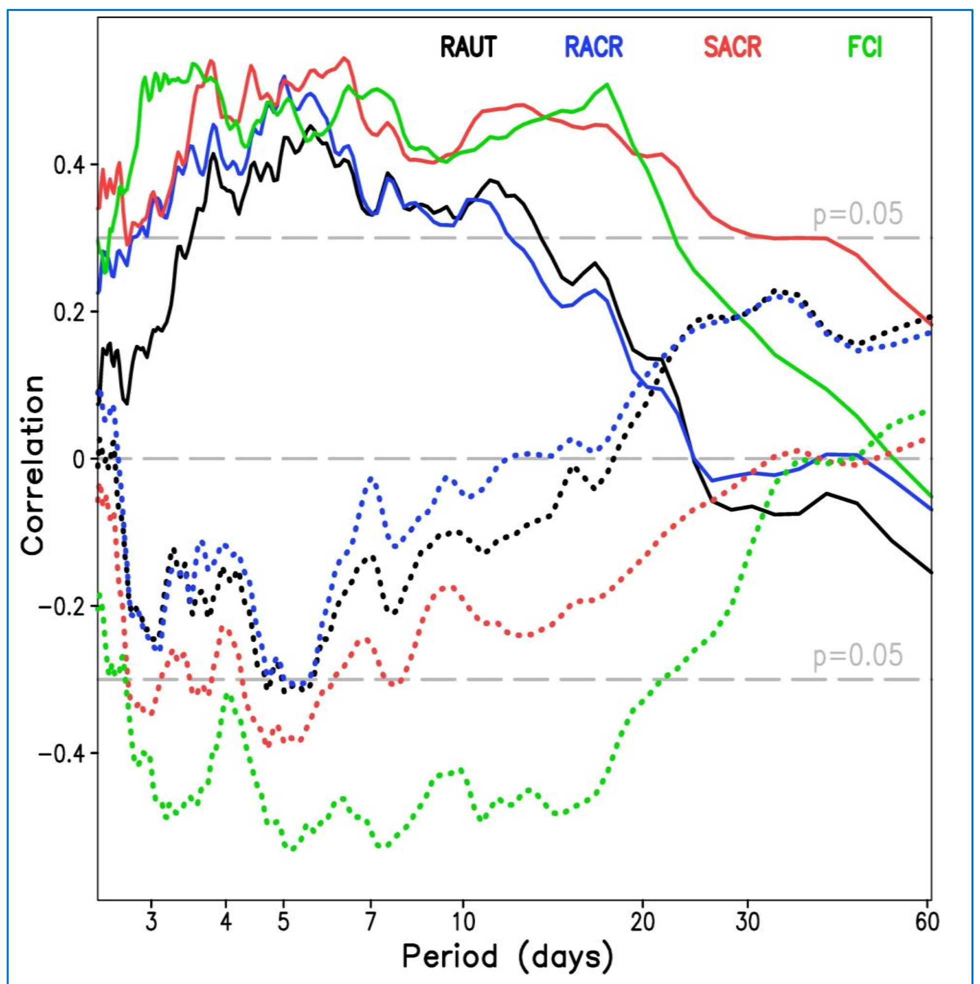
High cloud fraction and Mid-tropospheric (300-700hpa) specific humidity averaged over ISM region is shown in black and red line. OLR averaged over Bay of Bengal region is shown in blue line.



Correlation between June to September (JJAS) variance of the microphysical process and the mean ISMR

Interannual correlation between cloud process and mean ISMR

Cloud Microphysical Process	R value
Autoconversion (RAUT)	0.8
Rain Accretion (RACR)	0.8
Snow Accretion (SACR)	0.6
Freezing (FCI)	0.6



Correlation of the seasonal (June to September average) mean ISMR (Niño3.4 SST) with the cumulative variance of different microphysical processes at various time bands (or period, i.e. 2.4 - 60 days) are shown in solid (dotted) lines. Significant correlation 95% (p=0.05) are also shown.

Summary/Conclusion

i) The microphysical processes are well associated with the seasonal mean rainfall.

ii) The microphysical processes play a significant role in the interannual variability of the monsoon. During excess (deficient) years they increase (decrease) significantly.

iii) The microphysical processes are found to be linked with large scale phenomena i.e., ENSO. The difference of composites between EDY and NEDY demonstrates that during deficient years accompanied with El-Nino, these processes are weakened even more.

v) The microphysical processes also have significant subseasonal variability. The variance in more in synoptic scale compared to QBM and MISO.

vi) The subseasonal variances of the microphysical processes are well correlated with the mean rainfall. Correlation is stronger in synoptic scale.

vii) The synoptic scale variances of these processes are also well correlated with Nino 3.4 SST which may imply the remote influence of ENSO on them.

This study concludes that, microphysical processes play a seminal role in governing the interannual and subseasonal variation of rainfall, backed by thermodynamical and dynamical features.

Acknowledgements & References

We acknowledge the Director, IITM Pune, MoES, Govt. of India, for his encouragement

Dutta U, Chaudhari HS, Hazra A, et al (2020) Role of convective and microphysical processes on the simulation of monsoon intraseasonal oscillation. *Clim Dyn* 55:2377–2403. https://doi.org/10.1007/s00382-020-05387-z

Dutta U, Hazra A, Chaudhari HS, et al (2021) Role of Microphysics and Convective Autoconversion for the Better Simulation of Tropical Intraseasonal Oscillations (MISO and MJO). *J Adv Model Earth Syst* 13:. https://doi.org/10.1029/2021MS002540

IWM-7 (22-26 March 2022)
IMD, MoES, NEW DELHI, INDIA