Variation of vertical structure of precipitation in wet and dry spells during the southwest and northeast monsoon seasons over Arabian Sea and Bay of Bengal

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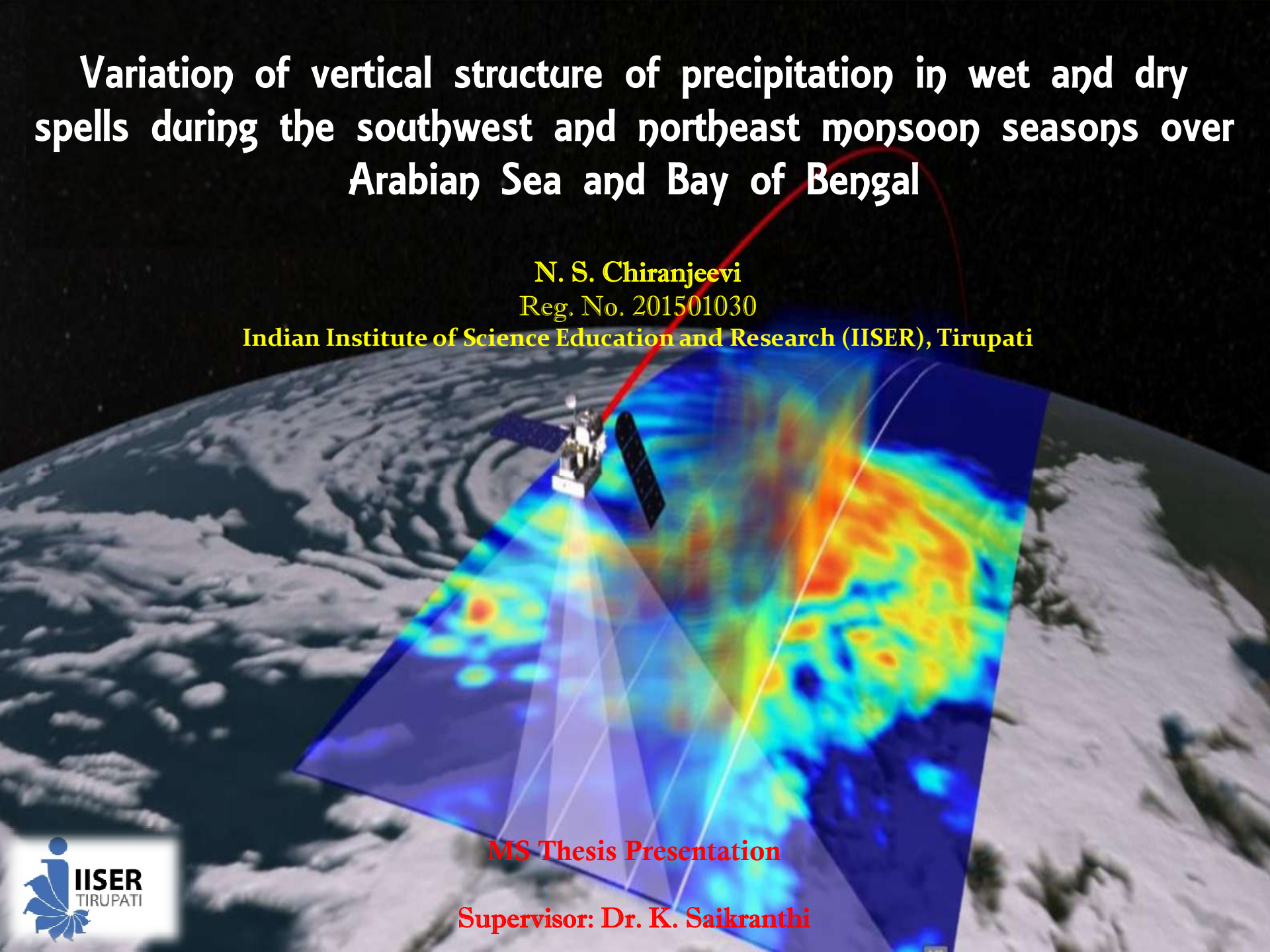

MS Thesis Presentation

Supervisor: Dr. K. Saikranthi

Outline

- Introduction and motivation
- Gap area and objectives
- Data description
- Identification of wet and dry spells
- Variation of occurrence and fraction of rain types during wet and dry spells
- Vertical structure of rainfall during wet and dry spells
- Associated background conditions
- Summary

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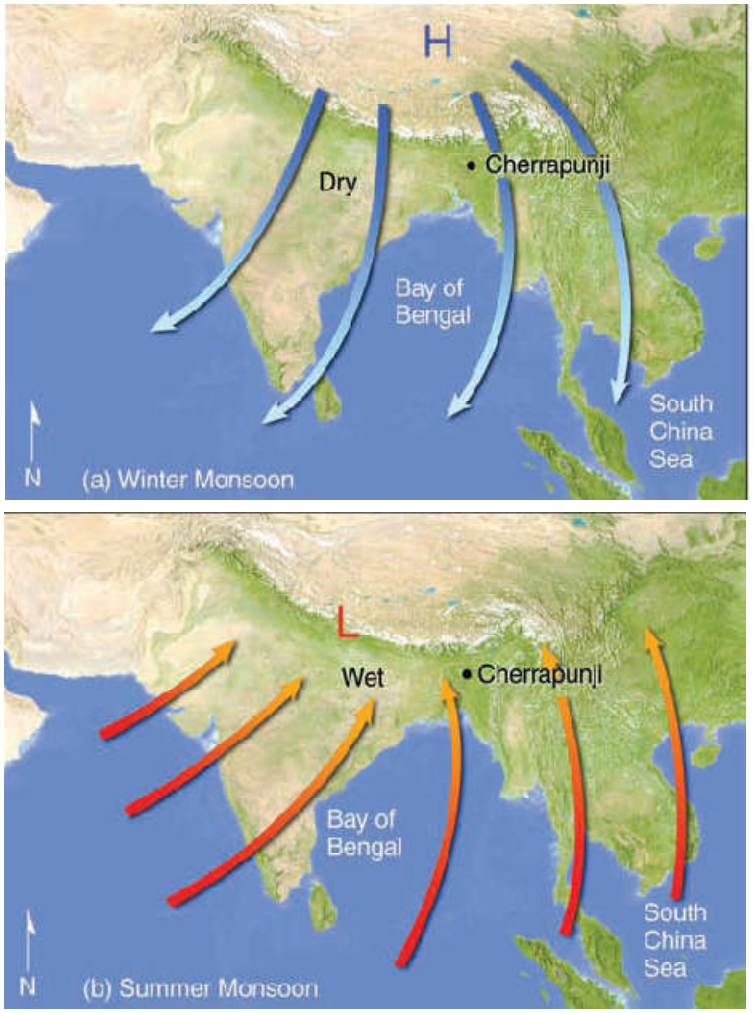
Introduction :

- Indian economy is termed as "Monsoon economy"
- Monsoon seasons over South Asia are considered as the world's most pronounced and unique weather phenomena
  - Southwest monsoon – June to September
  - Northeast monsoon–October to December
- Monsoon - Seasonal reversals of wind direction
- Monsoons are land-atmosphere-ocean coupled systems
- Monsoonal precipitating systems exhibit remarkable variations at intraseasonal, interannual and inter decadal time scales



From Essentials of Meteorology: An invitation to the Atmosphere

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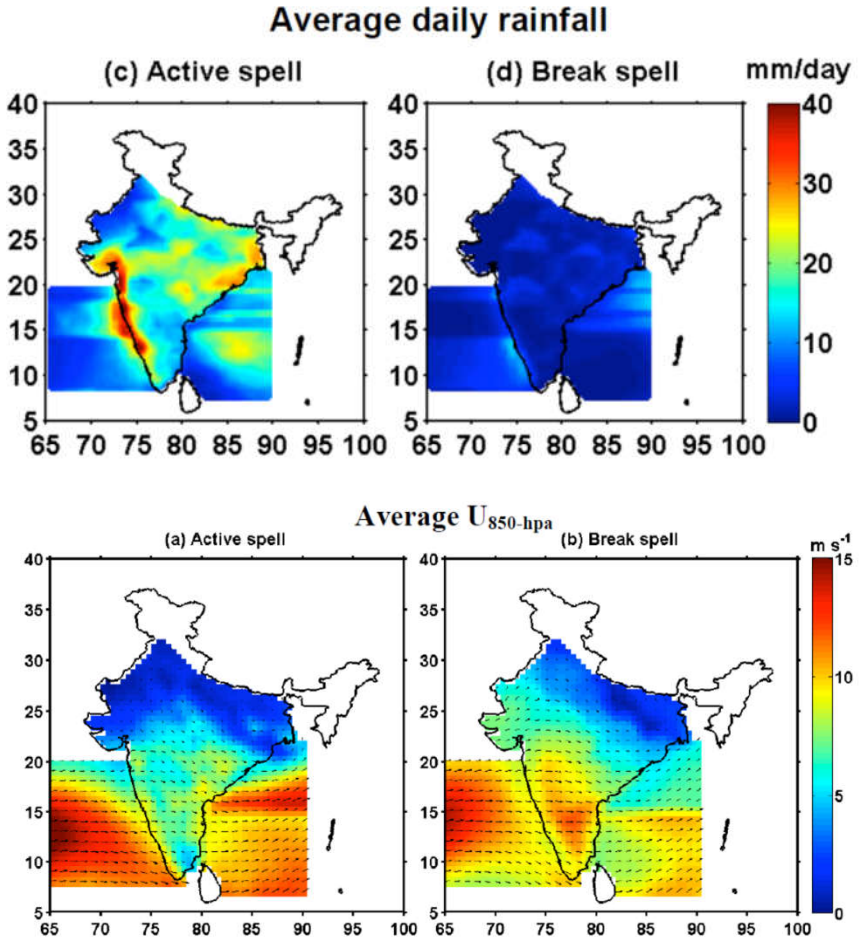
Introduction :

- In intraseasonal time scales
  - Periods of excess rainfall → wet spell
  - Periods of scanty rainfall → dry spell
- 3 modes of oscillations during monsoon rainfall over the India - (3-8 day; 10-20 day and 30-60 day)
- Small temporal scale rainfall variations
  - → synoptic scale activities

  Large temporal scale rainfall variations
  - → large-scale atmospheric and oceanic patterns (eg. MJO)
- Previous studies showed the precipitating systems propagate
  - North during 10-20 day oscillations
  - Northwest during 30-60 day oscillations



From Rao et al. 2016

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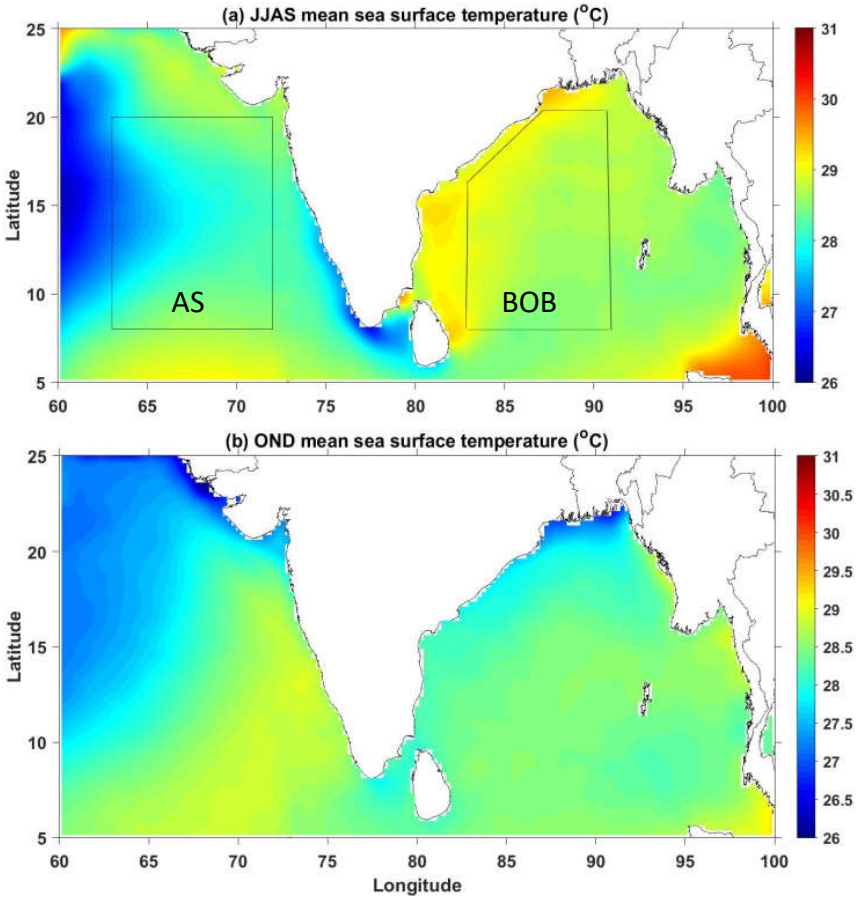
Introduction :

- At intraseasonal timescales, when compared to Arabian Sea, the speed of propagation of rainfall is slower over Bay of Bengal at intraseasonal time scales.
- The northward propagation from Indian Ocean influences the consecutive spells over central India.
- Also, rain types (like convective and stratiform rain) alters this northward propagation.
- Hence, these studies portray the need to understand the morphology of precipitating systems over AS and BOB during intraseasonal time scales.



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Gap area and objectives:

- All the previous studies, dealt with understanding the seasonal differences of rain types (in terms of their occurrence and vertical structure).

- However, the information on vertical structure and their association with the background atmosphere at intraseasonal time scales is less known over AS and BOB, especially during northeast monsoon is least explored.

Hence the objective of the present study is to understand the

- **The differences in occurrence of various rain types during wet and dry spells and also to understand the variations in the vertical structure of precipitation (in terms of vertical profiles of reflectivity and storm height) over the AS and BOB during the SWM and NEM.**
- **The association of variation of precipitating systems with the background atmospheric conditions prevailing over the two seas.**

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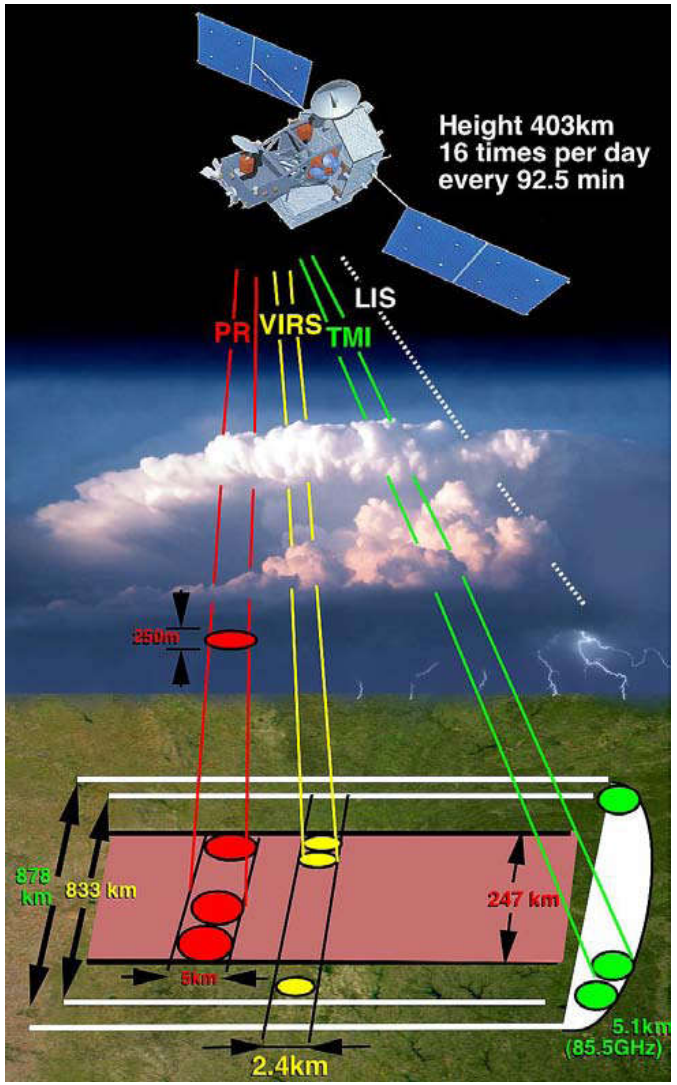
Data used:

- 16 years of (1998-2013)
  - **TRMM PR 2A25** (spatial resolution – 0.05° x 0.05°, vertical resolution – 0.25km) and **3B42** (spatial resolution – 0.25° x 0.25°, temporal resolution -3hr) version 7 rainfall data.
  - **ERA5 reanalysis data** (spatial resolution – 0.25° x 0.25°, temporal resolution -1hr) (Total column water vapor, temperature, relative humidity, vertical wind velocity)
  - **Optimum Interpolation sea surface temperature** (OISST) dataset (spatial resolution – 0.25° x 0.25°, temporal resolution -1day)
  - Domain of interest:
    Arabian Sea (AS) – (8-20°N and 63-72°E)
    Bay of Bengal (BOB) – (8-21°N and 83-92°E)
  - SWM (June to September) and NEM (October to December) seasons

Tropical rainfall measuring mission precipitation radar (TRMM PR) – Scan strategy



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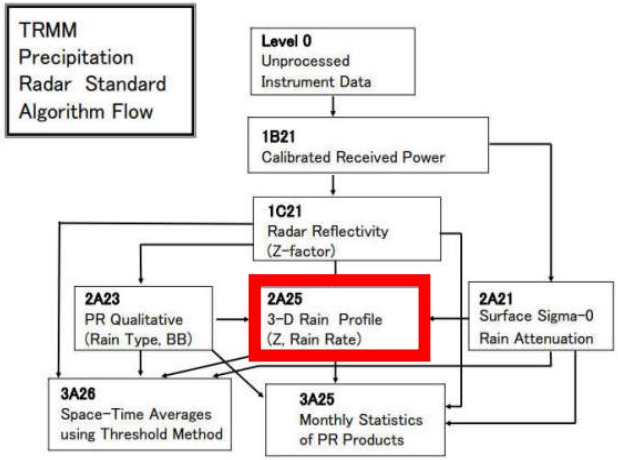
TRMM PR Specifications and algorithm flow:

Item	Specification
Frequency	13.796, 13.802 GHz
Sensitivity	≤ ≈ 0.7 mm/h (S/N/pulse ≈ 0 dB)
Swath width	220 km (from end to end)
Observable Range	Surface to 15 km altitude
Horizontal resolution	4.3 km (nadir)
Vertical resolution	0.25 km (nadir)
Antenna	
Type	128-element WG Planar array
Beam width	0.71° x 0.71°
Aperture	2.0 m x 2. 0 m
Scan angle	± 17° (Cross track scan)
Transmitter/receiver	
Type	SSPA & LNA (128 channels)
Peak power	≥ 500 W (at antenna input)
Pulse width	1.6 μs x 2 ch. (Transmitted pulse)
PRF	2776 Hz
Dynamic range	≥ 70 dB
Number of independent samples	64
Data rate	93.2 kbps
Mass	465 kg
Power	250 W



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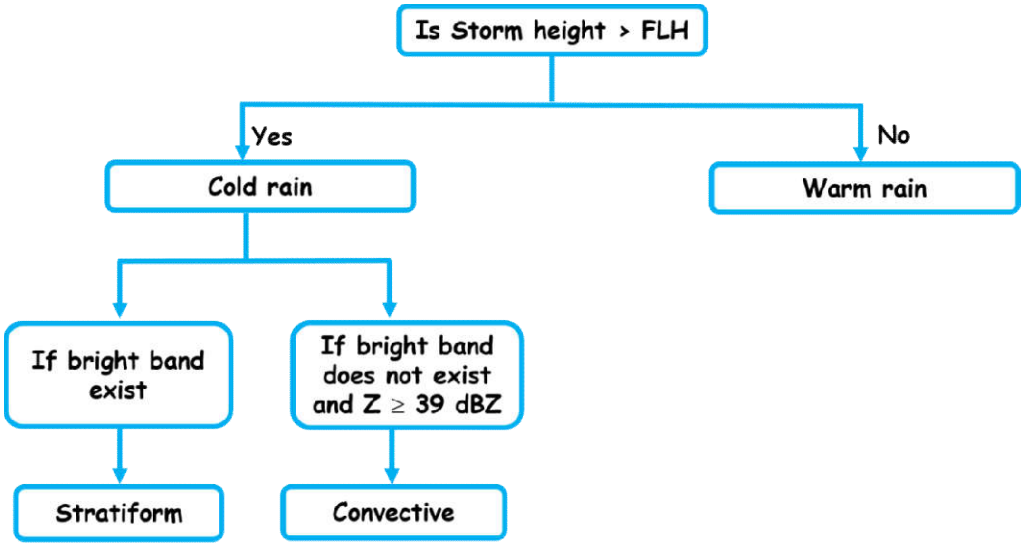
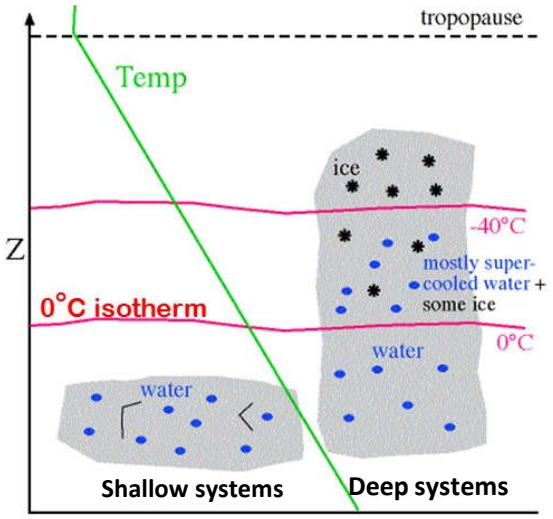
Rain type classification:



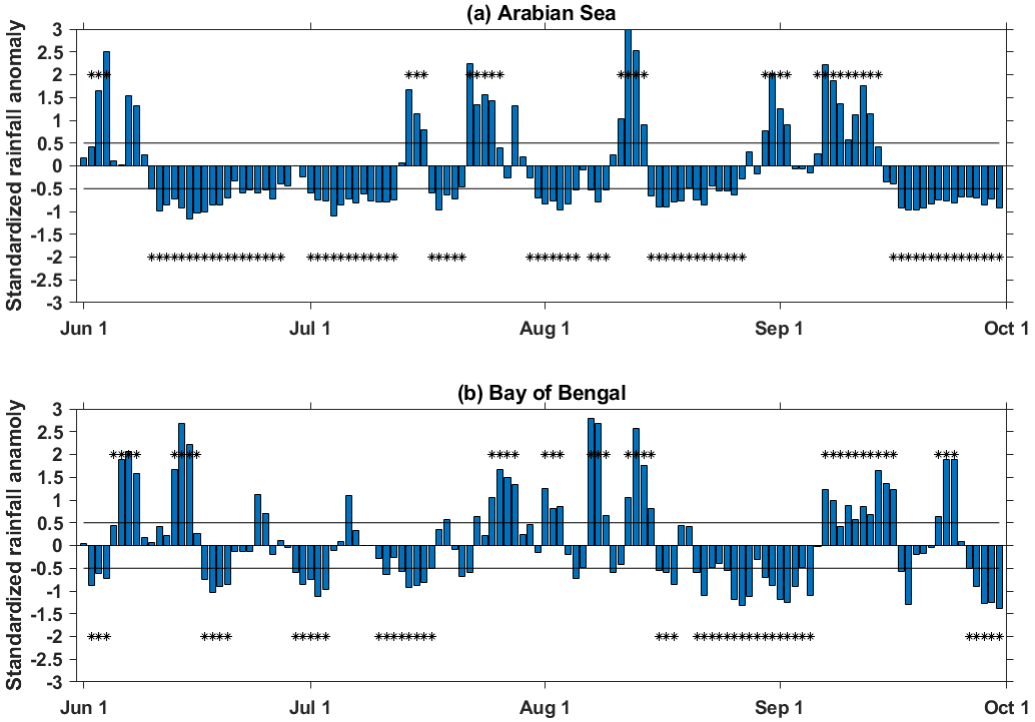
Deep and shallow systems



Following Houze et al. 2015, Saikranthi et al. 2017 the precipitating systems are segregated to

- Deep systems
  - Deep convective cores - DCC
  - Deep wide convective cores - DWC
  - Wide convective cores - WCC
  - Broad stratiform regions - BSR
- Shallow systems
  - Isolated shallow echoes - ISE

Identification of wet and dry spells:



Wet and Dry spells were determined by calculating the Standardised Rainfall Anomaly (SRA)

$$SRA = \frac{r - \mu}{\sigma}$$

r = Spatially averaged rainfall per day for one year

μ = Mean rainfall per day spatially and temporally averaged

σ = Standard deviation per day of rainfall spatially and temporally averaged

- If SRA > 0.5 for 3 consecutive days → Wet Spell
  If SRA < 0.5 for 3 consecutive days → Dry Spell

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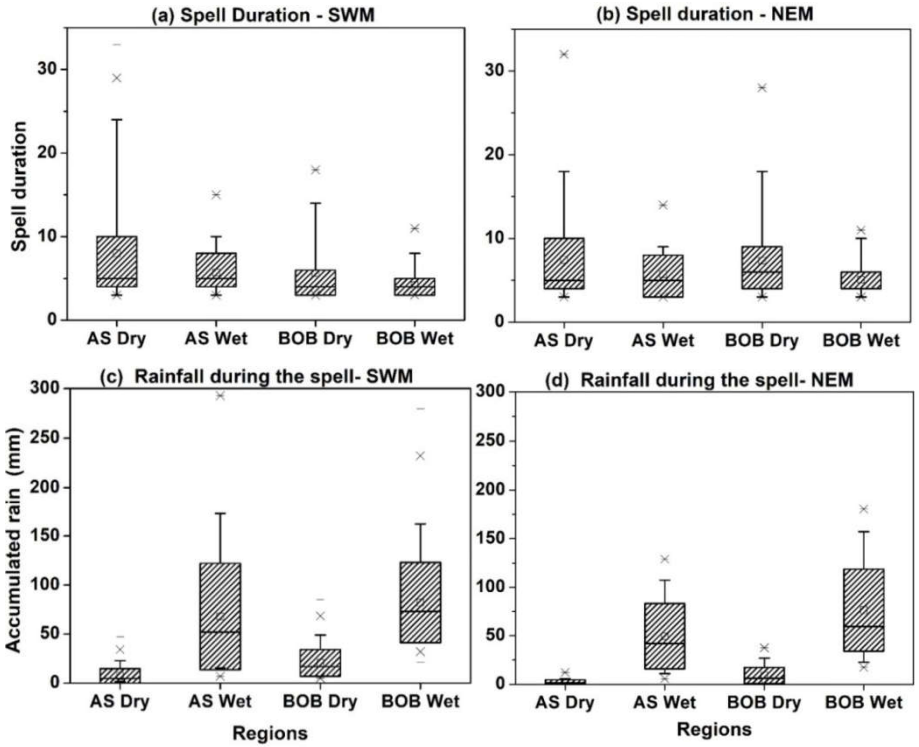
Spell duration and rainfall over AS and BOB:



- In both the seasons, the rainfall in wet spells is more than dry spells over AS and BOB.
- Even though the duration of spells is more in AS than BOB, accumulated rainfall is more in BOB compared to AS.
- Duration of dry spells over BOB is more in NEM than SWM

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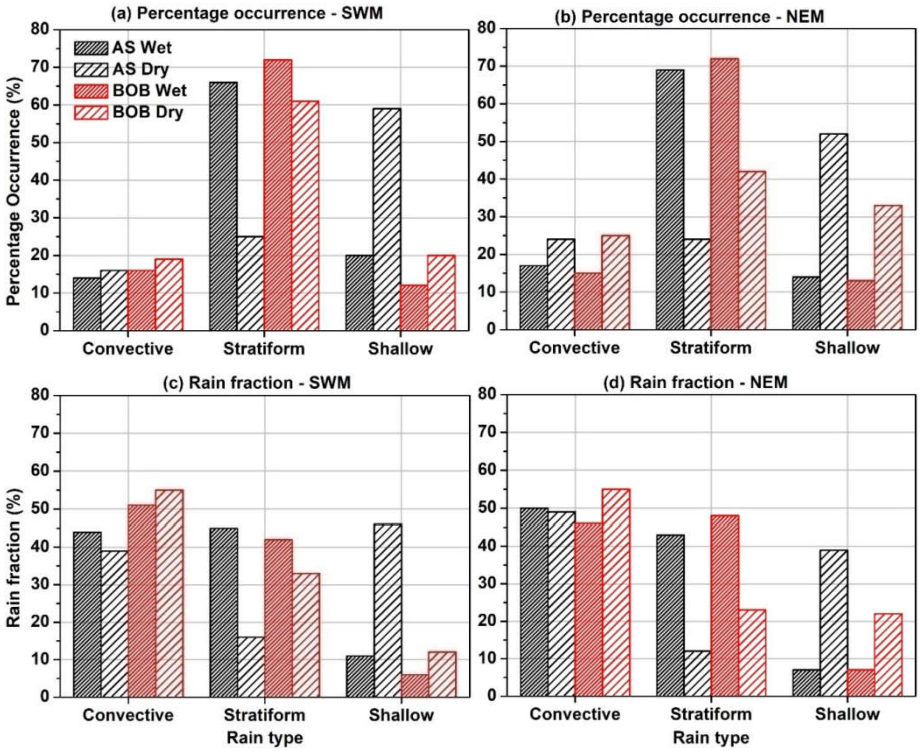
Percentage occurrence and rain fraction:



- Irrespective of season, the occurrence and rainfraction of stratiform rain is more in wet spells whereas the occurrence of convective and shallow rain is more in dry spells over AS and BOB.

- The occurrence of shallow rain increases from SWM to NEM during dry spells over BOB.

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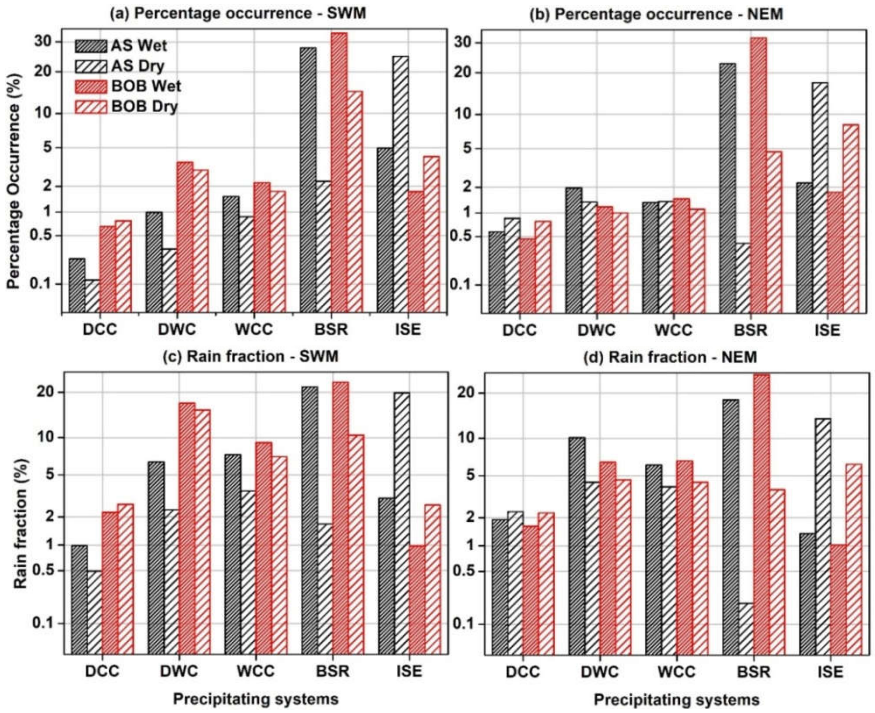
Saikranthi and Chiranjeevi 2020, Under review Atmos. Res.

Percentage occurrence and rain fraction:



- Occurrence and rainfraction of DCC, DWC, WCC and BSR > ISE in the BOB than in the AS during SWM
- During NEM, occurrence and rainfraction of DCC, DWC and ISE > BSR in AS than over the BOB.
- Overall occurrence and rain fraction of BSR and DWC > ISE during wet spells than the dry spells
- **Large scale systems → wet spells**
  Isolated shallow systems → dry spells

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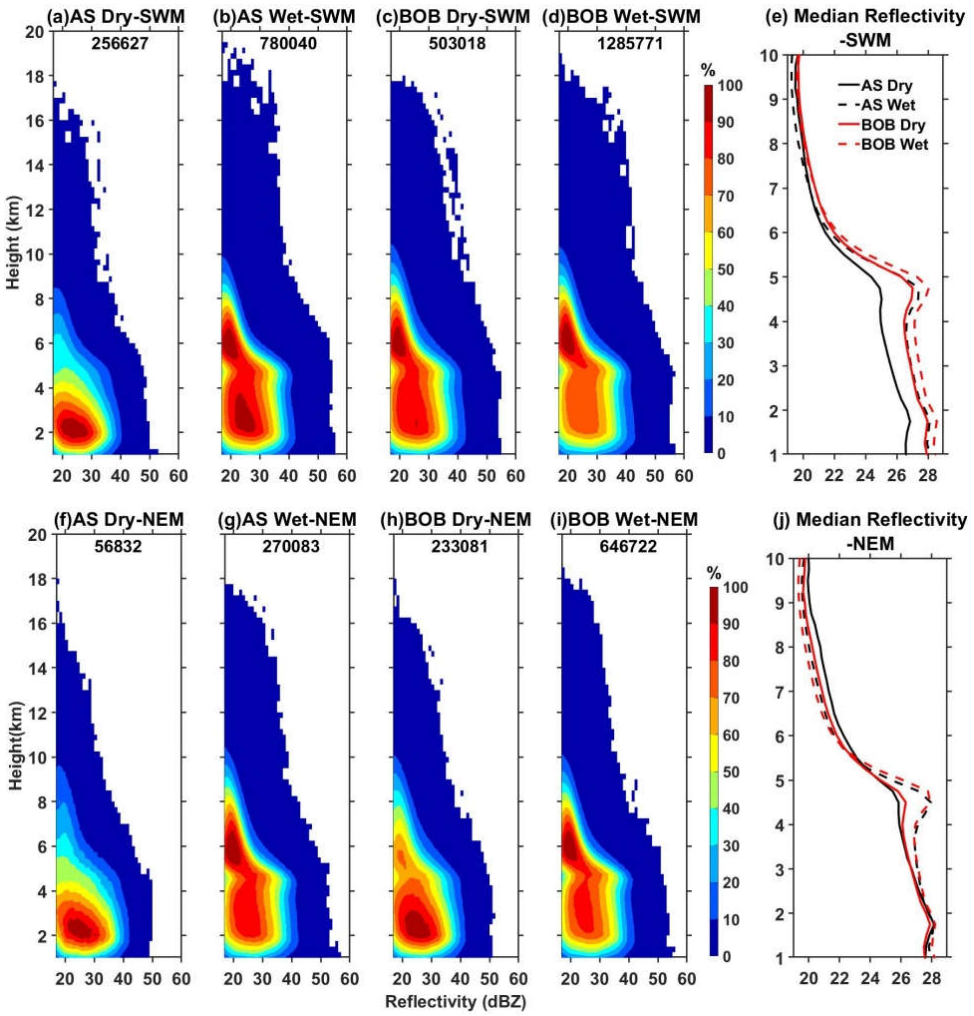
Vertical structure of precipitation:

- Large occurrence of reflectivity below 4 km in dry spells over the AS (and BOB in NEM) indicates the high occurrence of shallow rain.
- The occurrence of reflectivity shows unimodal in NEM and bimodal in SWM indicating the increase of occurrence of shallow rain in dry spells from SWM to NEM over BOB
- CFADs of reflectivity also show broader distributions in the wet spells in SWM and NEM



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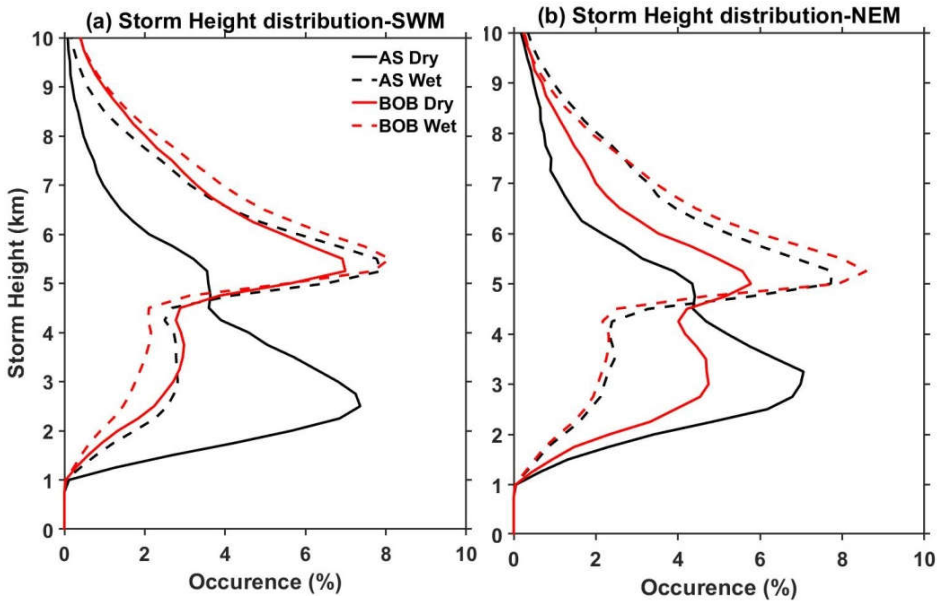
Storm height distribution:



- Peak at 3 km altitude over the AS shows predominance of shallow rain
- Peak at 6 km altitude is due to stratiform rain occurrence
- SH over the BOB during the SWM is same for both spells different in NEM
- Deep systems occurrence is more in the wet spells over both seas

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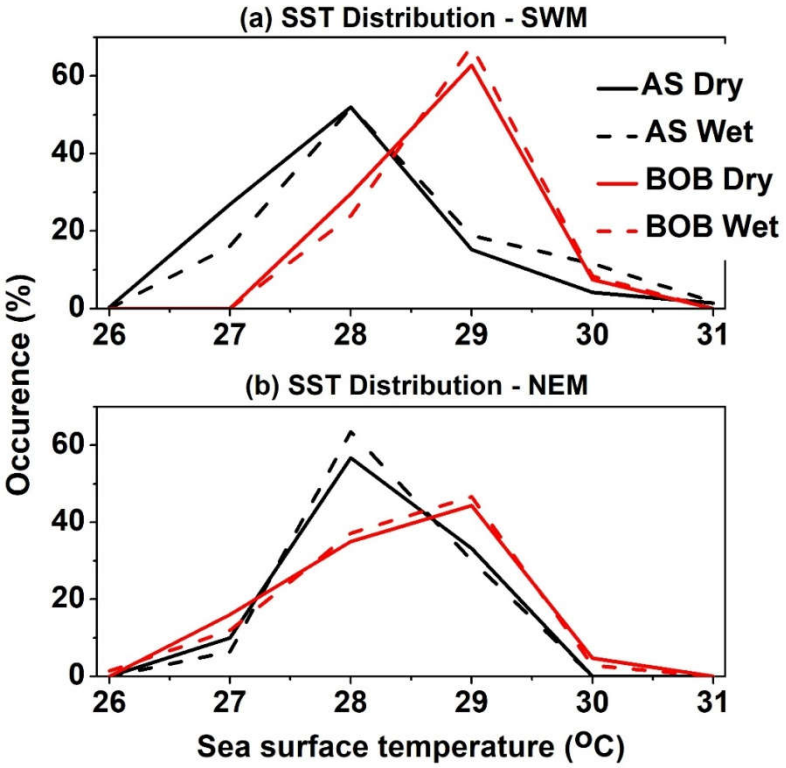
Associated background conditions

Sea surface temperature (SST) distribution:

- Distributions are same in both spells in BOB during SWM and NEM and in AS during NEM
- Larger SSTs are more and smaller SSTs are less in the wet spells over the AS during SWM
- SSTs are larger over the BOB than over the AS
- Surface forcing is larger over the BOB



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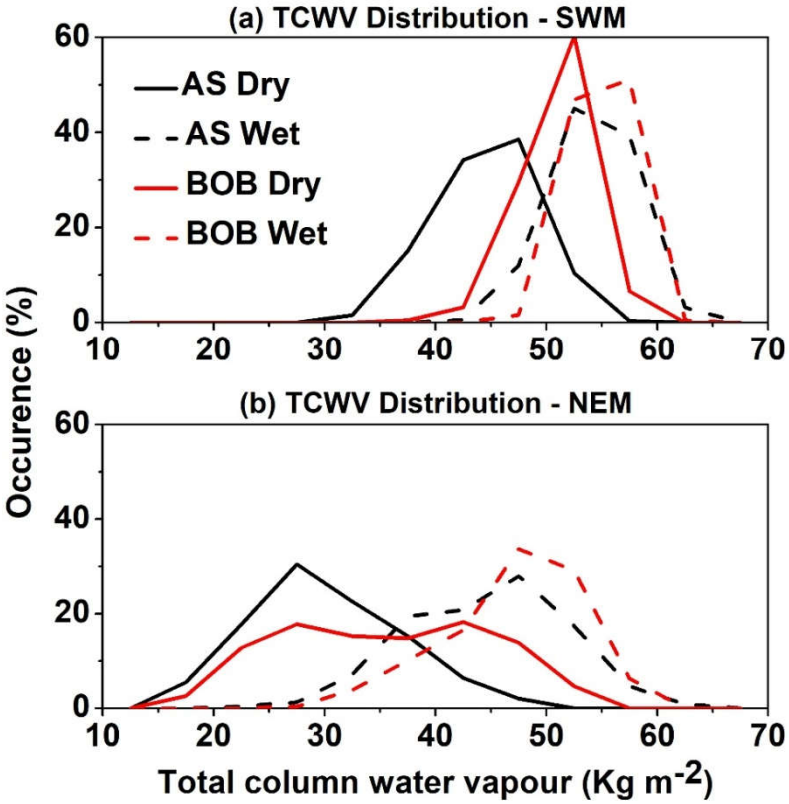
Associated background conditions

Total column water vapour (TCWV) distribution:

- TCWV values are larger in the wet spells over both the seas in SWM and NEM
- TCWV distributions are alike over the AS and the BOB in the wet spells in SWM
- TCWV distributions are larger values over the BOB than the AS in the dry spells in SWM
- TCWV values of wet and dry spells in BOB are larger than the respective spells over AS in NEM



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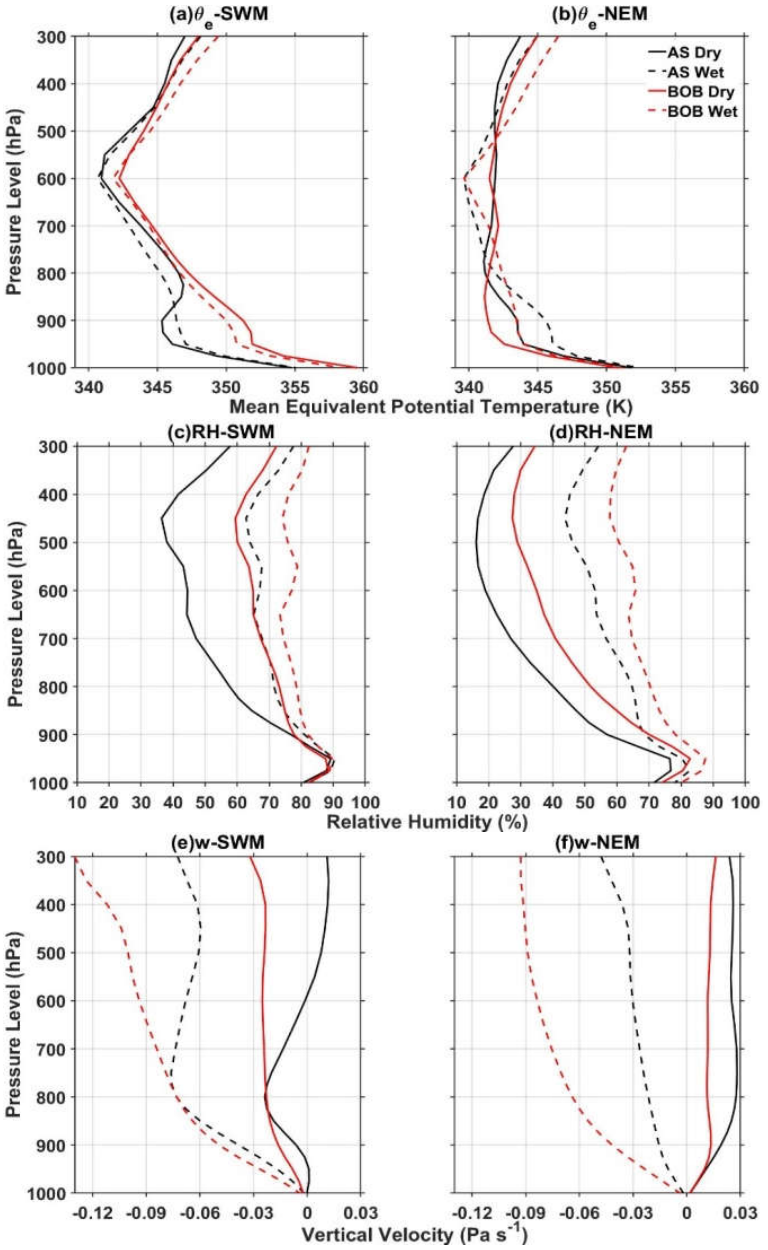
Associated background conditions

- Surface θ_e is same for both spells over the AS and BOB however values are larger in BOB in SWM.
- Stable layers seen between 900 and 800 hPa levels in the dry spells over the AS
- The lower- and mid-troposphere are drier in the dry spells than in the wet spells
- RH is larger over the BOB than over the AS in all spells
- Upward motion at all levels during wet spells in both regions in SWM and NEM, and during dry spells over BOB in SWM.
- Downward motion in the middle troposphere in dry spells over AS in SWM and at all levels in both seas in dry spells of NEM



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Summary

- In both spells the Occurrence and rainfraction of deep systems (DCC, WCC, DWC, and BSR) are more and shallow systems are less in BOB than AS during the SWM

- During Wet spells there is a higher prevalence of deeper systems due to
  - moist mid-troposphere
  - updrafts in the lower and middle troposphere
  - absence of lower tropospheric stable layers
  - higher TCWV

- During Dry spells there is a higher prevalence of isolated shallow systems due to
  - dry mid troposphere
  - downdrafts in the lower and mid-troposphere
  - presence of stable layers in lower troposphere
  - lower TCWV

- Higher occurrence of shallow systems than the deep systems in the dry spells over BOB during the NEM

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Acknowledgement

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- Dr. Aniket Chakrabarty
- Dr. Chitrasen Jena
- Prof. G Ambika
- All the faculty and administrative staff
- My friends and family

Future work

Variation of vertical structure of rainfall during El Nino and La Nina in wet and dry spells over the Indian Ocean

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