Atmospheric Research Testbed (ART) facilities for Precipitation Process studies over different regions in India

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Acknowledgments to all my colleagues in the project at IITM

Atmospheric Research Testbeds (ARTs) Project of IITM, MoES

1

Monsoon Core Zone Testbed (3 yrs. OBS)

Established an Atmospheric Research Testbed in Central India for better understanding on processes governing monsoon convection including its diurnal variation and land-atmosphere interactions.

Measure relevant meteorological parameters using state-of-the-art observational systems.

2

Orographic Testbed (~10 yrs. OBS)

Established high altitude cloud physics laboratory (HACPL) for cloud, aerosol, rain microphysics using in-situ and radars over Western Ghats .

Better understand orographic convection and precipitation processes; aerosol-cloud-precipitation interaction processes.

3

Urban Testbed (OBS begins Aug 2024)

Establishing a small Radar network in Mumbai to provide high-resolution rainfall (both temporal and spatial) to enable flood warning and nowcasting.

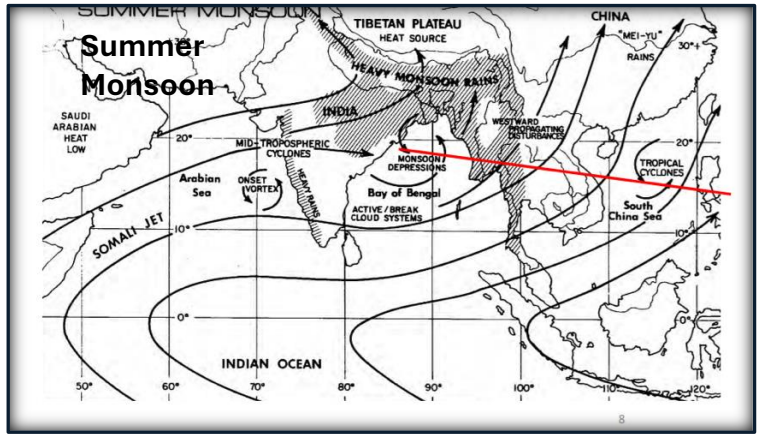
Utilize radar data sets to better understand heavy precipitation processes and to validate satellite retrievals.

Atmospheric Research Testbed- CI

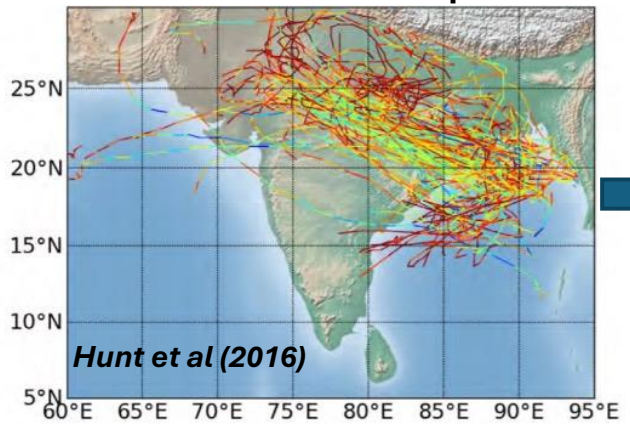
Indian Institute of Tropical Meteorology, Pune.

Ministry of Earth Sciences, Government of India

Background: Monsoon Core Zone and Need for Atmospheric Research Testbed



Tracks of monsoon depressions



- The monsoon trough over Central India, which comprises the **monsoon core zone (MCZ),** is one of the important semi-permanent systems of the regional monsoon system.
- **Detailed atmospheric measurements in MCZ** wherein synoptic-scale disturbances (monsoon lows and depressions) frequently pass during the monsoon season **were overdue**.
- It is known that **variability in all-India summer monsoon rainfall** is highly correlated with that of summer monsoon rainfall over central India (Gadgil, 2003).
- So an **improved prediction of variability in central India** should also project onto larger-scale predictability.

- Considering this importance, an **Atmospheric Research Testbed (ART) Facility in Central India** was established by IITM-MoES at Silkheda (50 km NW of Bhopal) for a better understanding of processes governing monsoon convection.
- **ART is a permanent observation facility** and have a wide set of remote-sensing and in-situ instruments that will provide continuous observations of convection, clouds, cloud microphysics, aerosols, precipitation, land surface properties, radiation (& many more).
- ART datasets will provide **key resources for validating CRM & GCMs** using both statistical & process-oriented approaches.

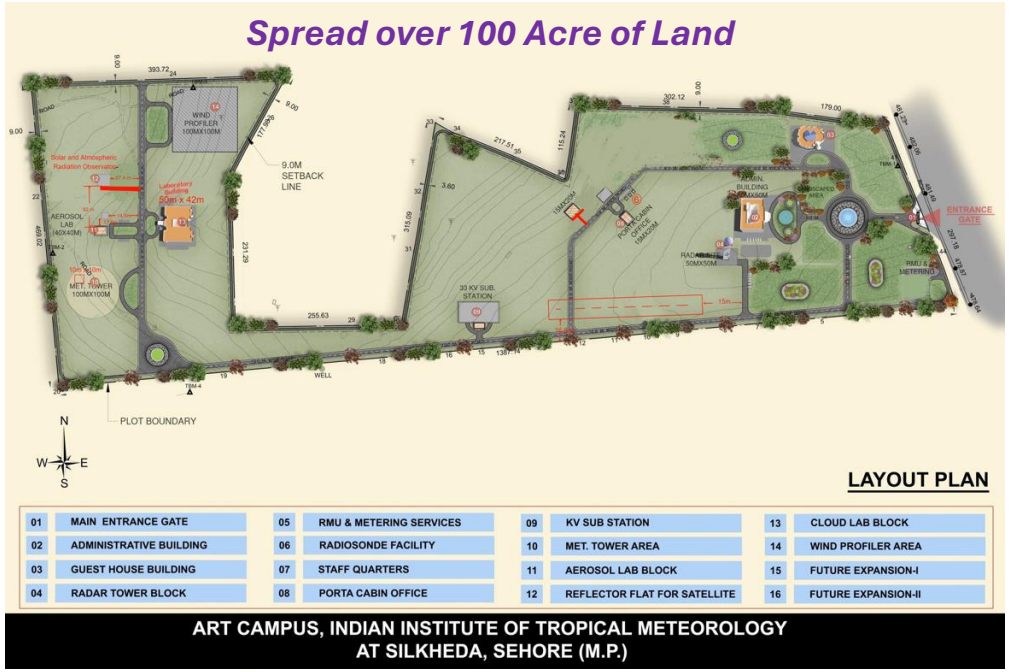
Objectives of the ART Project

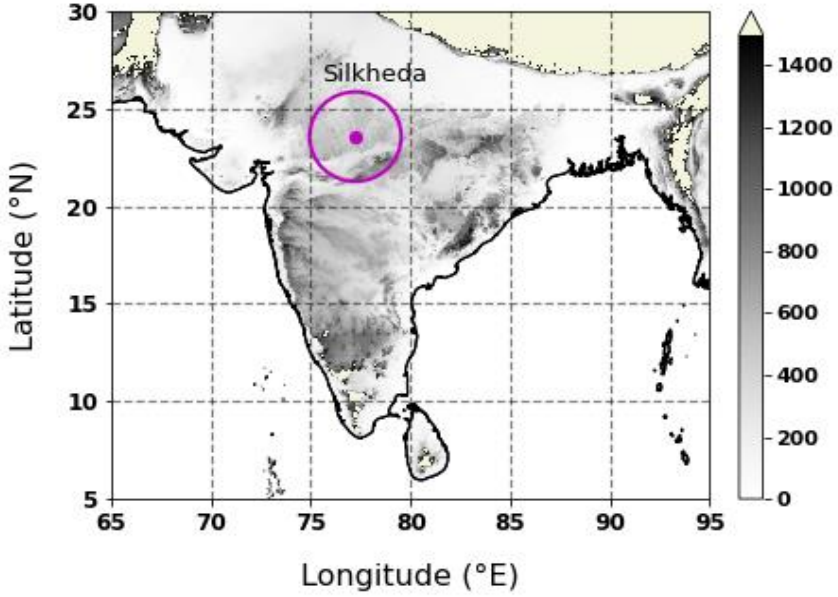
1. **To establish an Atmospheric Research Testbed in Central India (ART-CI)** for a better understanding of processes governing monsoon convection including its diurnal variation and land-atmosphere interactions over the monsoon core region using state-of-the-art observational systems.

2. **To organize intense observational campaigns along with weather prediction model runs** for testing hypotheses and to improve physical parameterizations in models related to convection and land surface processes.

3. **Outreach, Training, and Dissemination of ART-CI data sets.** The testbed will be made into an international facility for intense observational campaigns and testing physical parameterization schemes including sensitivity runs. Data will be used to test/validate/constrain numerical models in improving predictions of intense convective storms, and high-impact mesoscale weather events.

Atmospheric Research Testbed (ART) Facility of IITM at Silkheda in Sehore district of Madhya Pradesh





Progress History.....

2021

1. C-Band RADAR
2. Micro Rain Radar
3. Impact Disdrometer
4. Microwave Radiometric Profiler
5. Ceilometer

2022

1. C-Band RADAR
2. Micro Rain Radar
3. Impact Disdrometer
4. Microwave Radiometric Profiler
5. Ceilometer
6. CCN Counter
7. Aethalometer
8. Total Carbon Analyser

2023

1. C-Band RADAR
2. Micro Rain Radar
3. Impact Disdrometer
4. Microwave Radiometric Profiler
5. Ceilometer
6. CCN Counter
7. Aethalometer
8. Total Carbon Analyser
9. SMPS
10. MRR
11. Radiation Sensors
12. WSI
13. GHG 72m flux tower
14. Radiosonde
15. Lightning Location Network

Present

1. Dual Pol C-Band RADAR
2. Micro Rain Radar
3. Impact Disdrometer
4. Microwave Radiometric Profiler
5. Ceilometer
6. CCN Counter
7. Aethalometer
8. Total Carbon Analyser
9. SMPS
10. Radiation Sensors
11. WSI
12. GHG 72m flux tower
13. Radiosonde
14. Lightning Location Network
15. ACSM
16. Sunphotometer
17. SP2

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Timeline

Instruments to Monitor/Study

Radiation
Monitoring incoming SW and outgoing LW radiation.

Aerosols
Continuous monitoring of ambient aerosol physical and chemical properties.

Meteorology
To monitor the surface and upper air meteorological parameters.

Cloud Physics
To study microphysical and macro-physical properties of clouds.

Precipitation
Continuous monitoring of precipitation properties.

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Precipitation

C-band Polarimetric Doppler Weather Radar

Continuous monitoring and tracking of monsoon precipitation spatially and to understand the microphysical process involved in the precipitation.

Micro Rain Radar

To study the vertical structure of the precipitation system, falling rate of precipitation particles, and drop size distribution

Impact Disdrometer

To study raindrop size distribution, rain rate, rain intensity, etc. at the surface.

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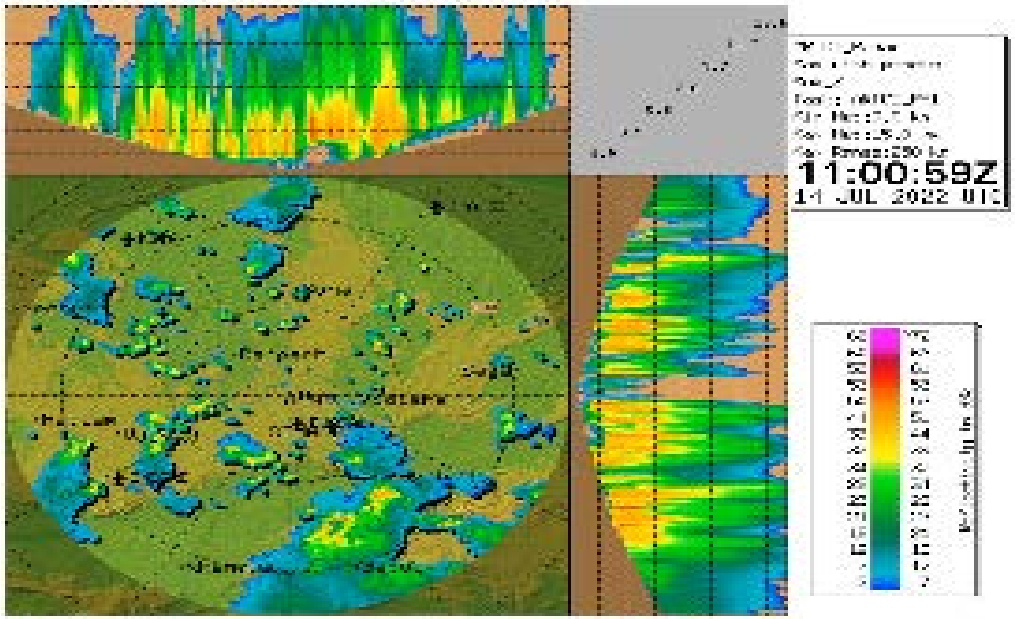
Passage of typical convective storm: Radar's view



Study of the convective organization over the monsoon zone using radar observations

Courtesy: Sachin, Harshad Hanmante

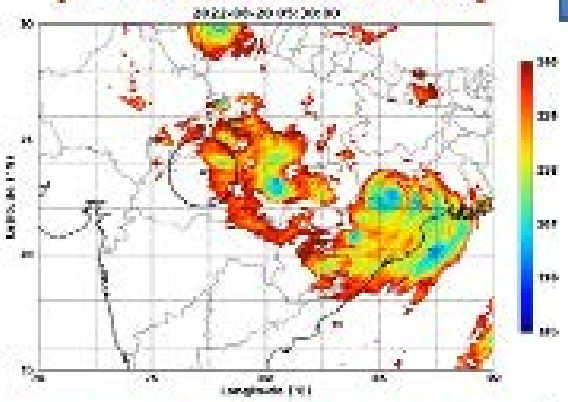
Rain-type classification and convective clustering in heavy rain events: Radar OBS Vs. Model

Harshad, Sachin et al., (in preparation)

- In core **monsoon zone**, deep moist convection produces **widespread and heavy precipitation.**
- **Proper depiction of convection features** (cloud types, spatial structure, diurnal cycle, lifetime, precipitation) is key to understand **precipitating cloud population & its organization.**
- High-resolution **CPOL radar OBS (6 min, 1 km)** in extreme rain event (293 mm: 22 Aug 2022) are used to stratify radar echoes into **different rain types** as the convective, stratiform, mixed, ISO convective core, ISO fringe and to **measure degree** of **convective clustering.**
- This radar-based clustering is used to assess how the **convective clustering is represented in convection-permitting WRF model.**

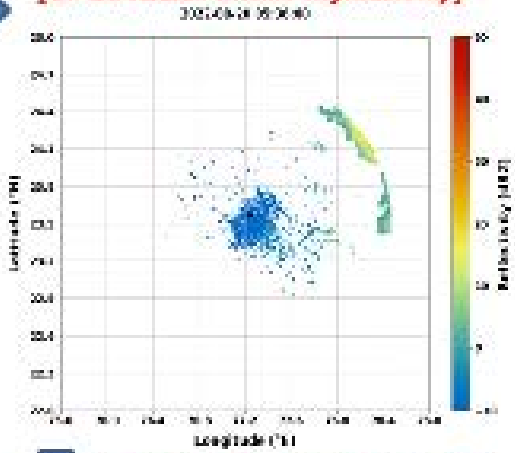
Large scale features

[30-min Satellite IR Tb < 241 K]

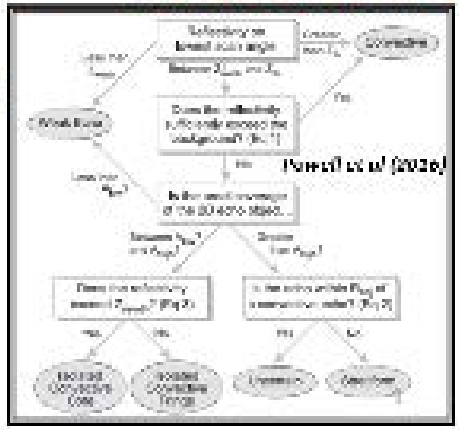


Mesoscale features

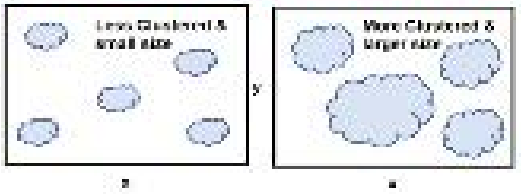
[CPOL radar 6-min reflectivity]



Intensity and texture based Rain-type classification



Simple Cloud Aggregation Index (SCAI)



- More number of smaller clouds = larger SCAI = Less Aggregated
- Less number of larger clouds = smaller SCAI = More Aggregated

Tobin et al (2012)

Example Scenes of convection: Radar OBS Vs WRF Model

Isolated Shallow cells

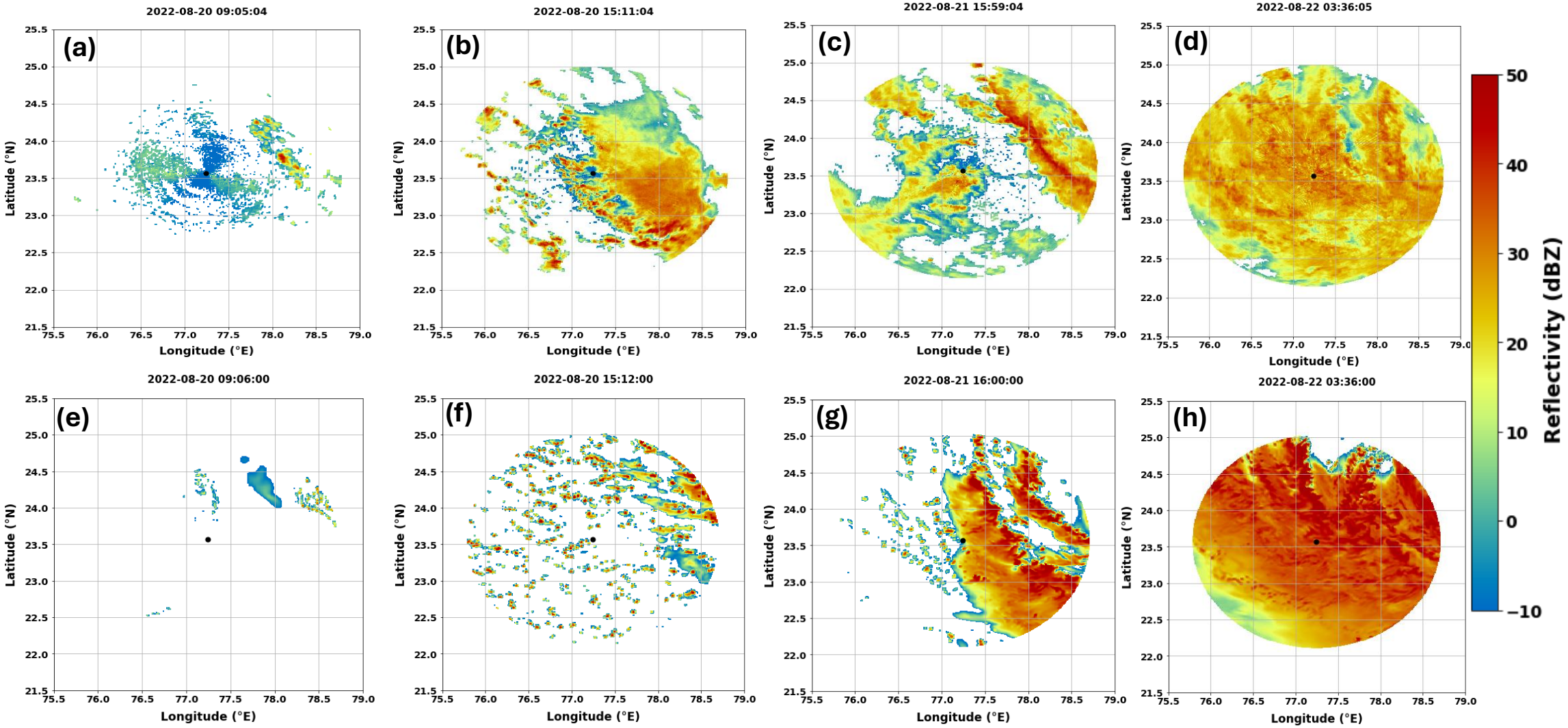
Small clusters of convection with limited stratiform

Squall line with associated stratiform area

Widespread stratiform

Radar observed reflectivity

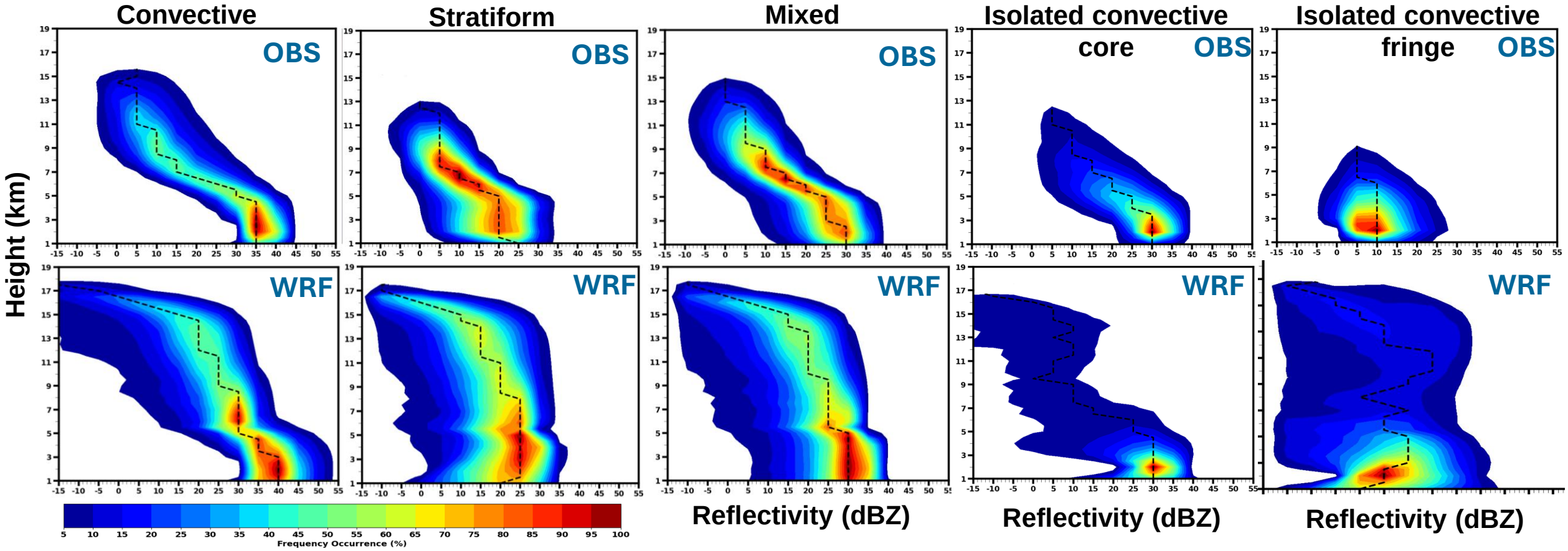
Model simulated reflectivity



Harshad, Sachin et al., (in preparation)

Spatially extended convective activity is an indication of ORGANIZATION

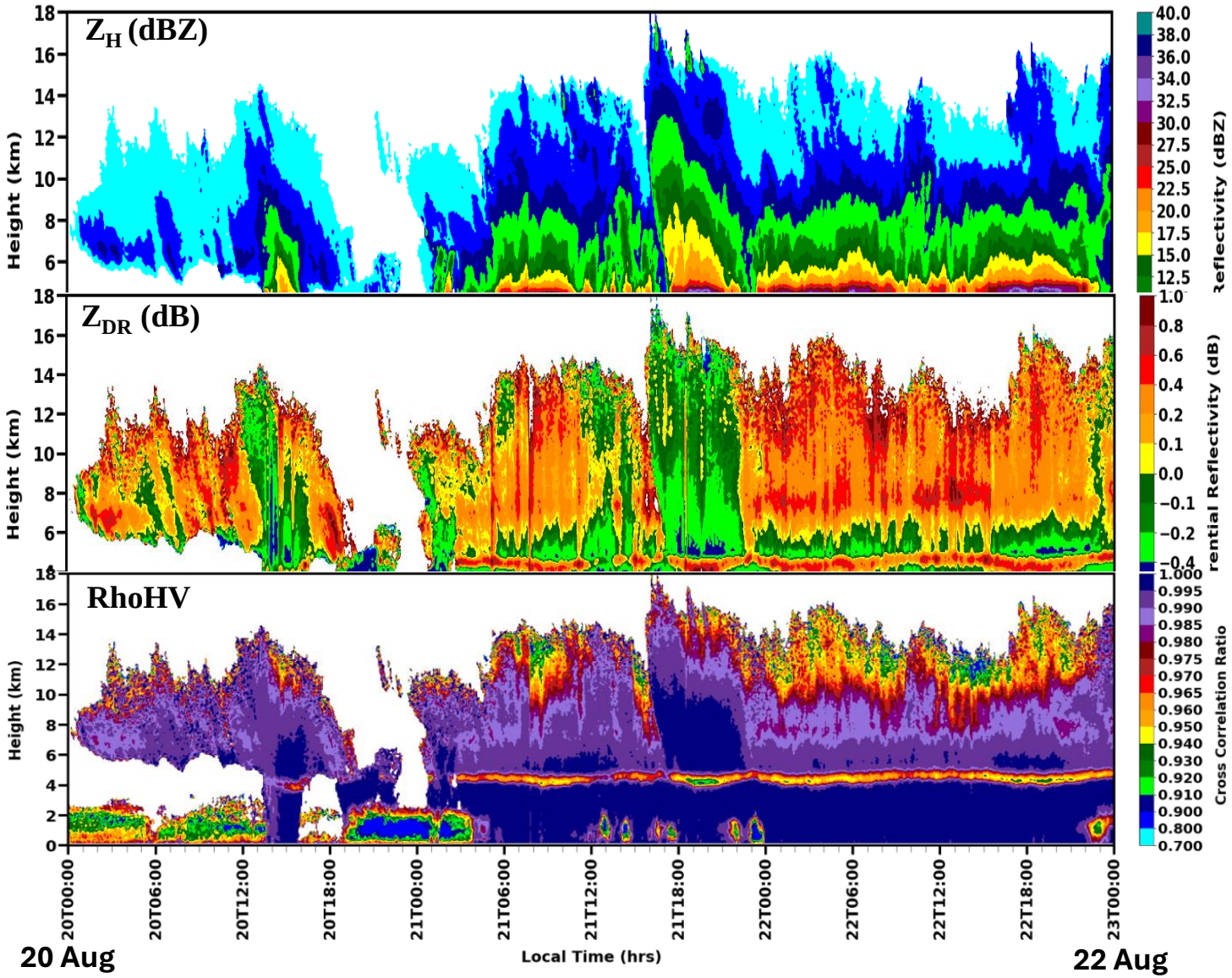
Composite CFADs of reflectivity revealing "depth & internal vertical structure" of rain types: Radar OBS Vs. Model



Model reflectivity values (for all rain types) below 5 km are similar to OBS, while above 5 km they exhibit greater ranges. Vertical extents of all rain types in model are higher as compared to OBS.

- **Convective:** Deep convection with reflectivity between 35-40 dBZ near 5 km and below. **Stratiform:** Bright band present near 0°C level.
- **Mixed:** have convection features of either convective or stratiform. **ISO convective core:** cores of developing shallow & isolated convection. Model overvalued upper level reflectivity structures. **ISO convective fringe:** Echoes associated with decaying convection.

Quasi Vertical Profiles (QVPs) of Polarimetric Data Revealing Temporal Dynamics of Microphysical Processes

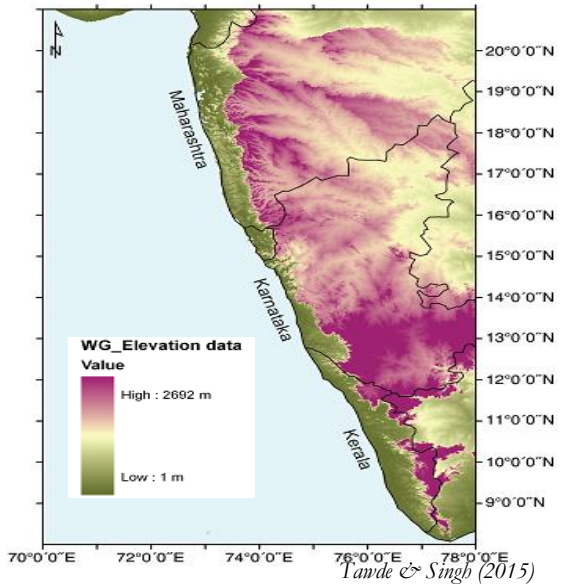


- Each figure shows **time-height evolution of QVPs during 72 h (432 profiles)**.
- Well defined **signature of melting layer** (at ~ 5 km) in stratiform cloud is characterized by **elevated Z_H, Z_{DR}, and depressed RhoHV.**
- High-resolution representations of the melting-layer with some undulations is seen.

High-Altitude Cloud Physics Laboratory, Mahabaleshwar (Orographic Research Testb

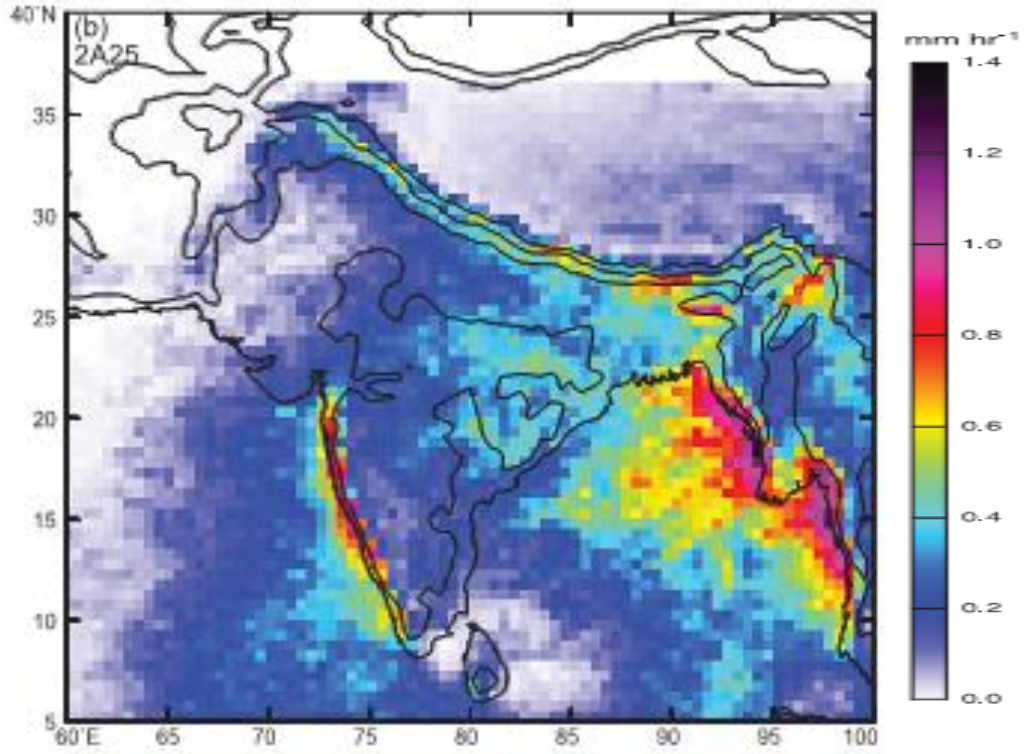
- Observing cloud, aerosol, rain microphysics using in-situ, profiling and remote sensing over Western Ghats .
- Better understand orographic convection and precipitation processes; aerosol-cloud-precipitation interaction proc

Western Ghats of India



Tawde & Singh (2015)

Monsoon precipitation climatology- TRMM

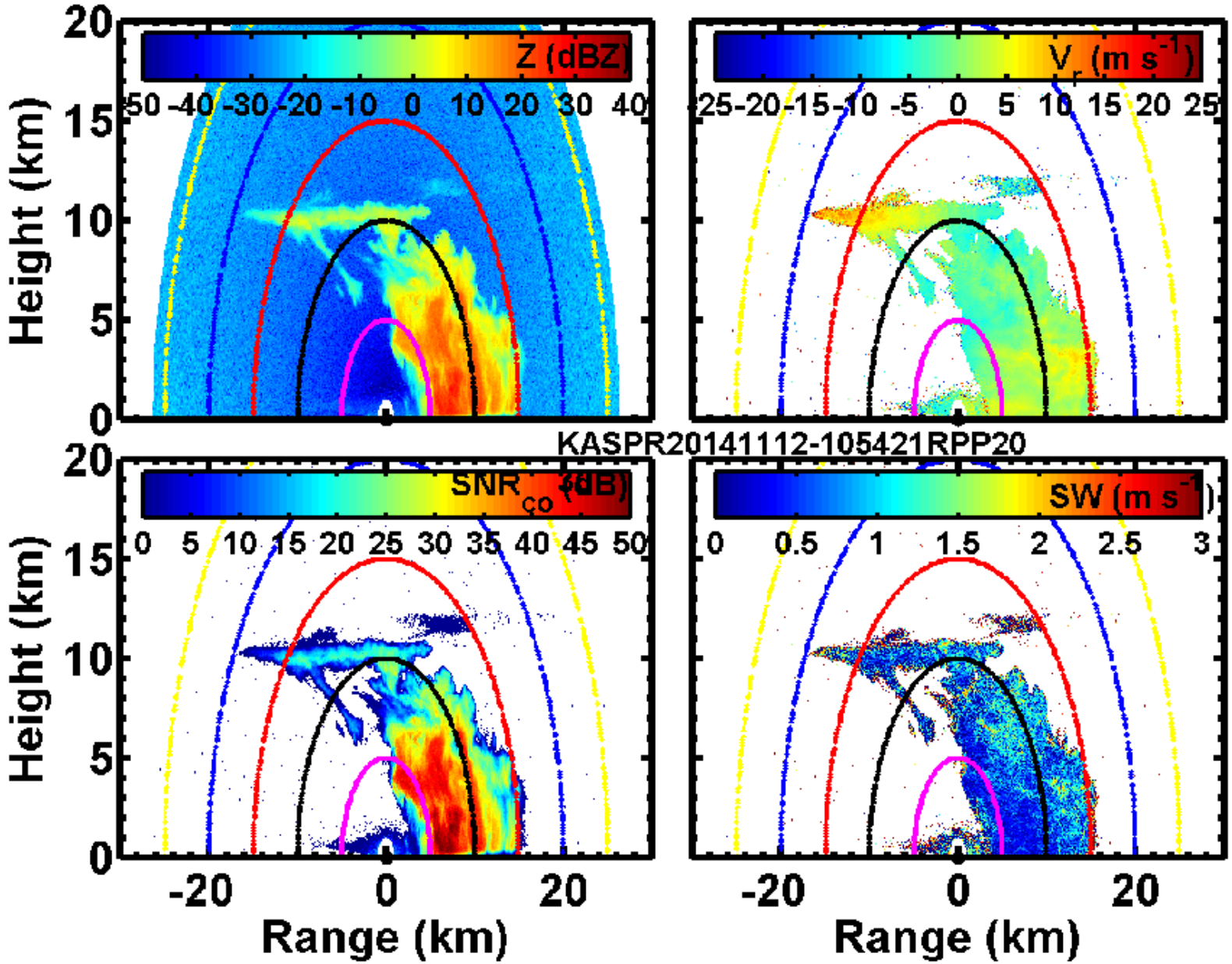


Objectives

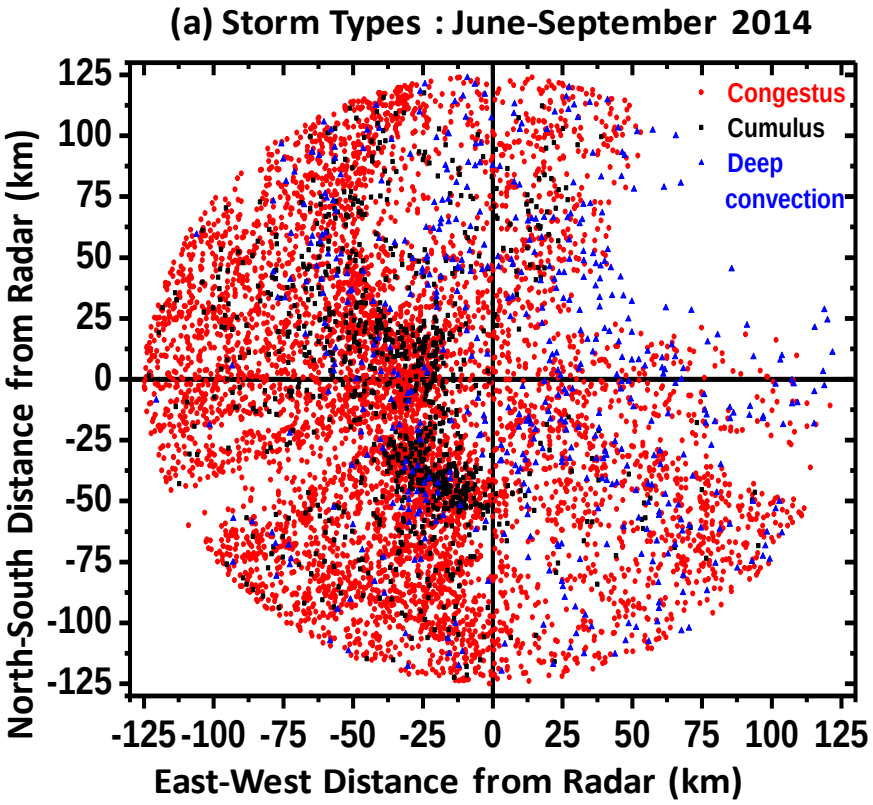
- **Orographic clouds, convection and precipitation process studies**
- **How aerosols influence the microphysics of clouds and develop parameterization for CCN and IN activity relevant to tropical region.**

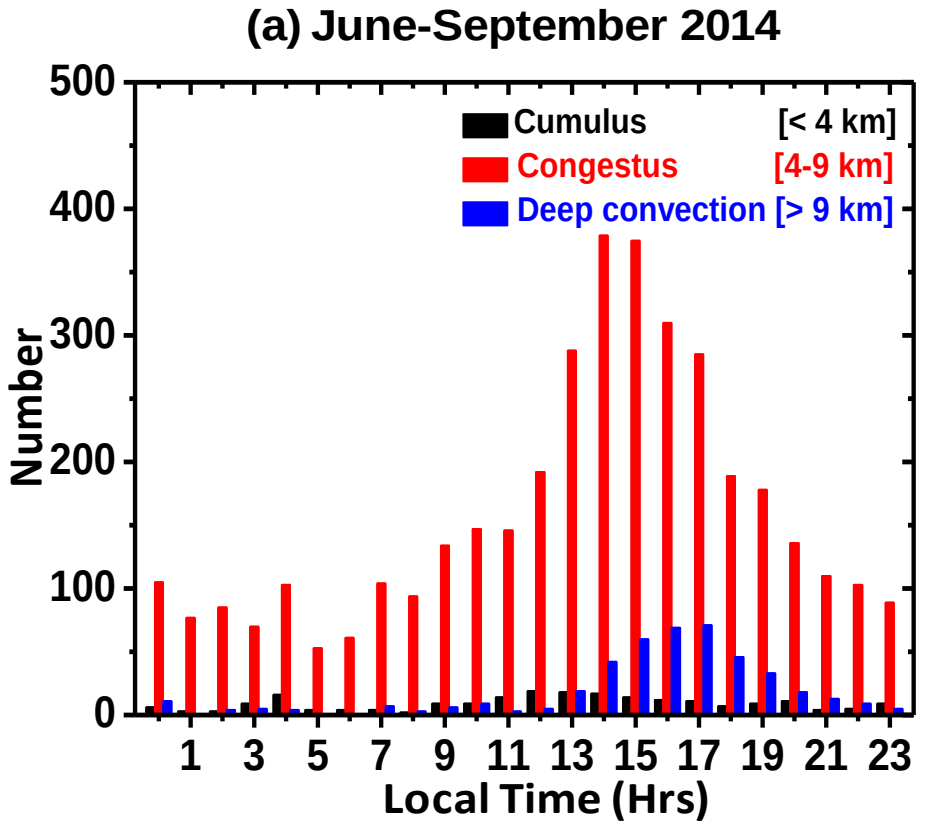
- **At high-altitude regions, clouds float close to surface and interact with aerosols** which can be observed to better understand the aerosol physical/chemical processes influencing the microphysics of clouds and precipitation.

Ka-band radar observations over Mahabaleshwar



Classification of convective cell types and their variability





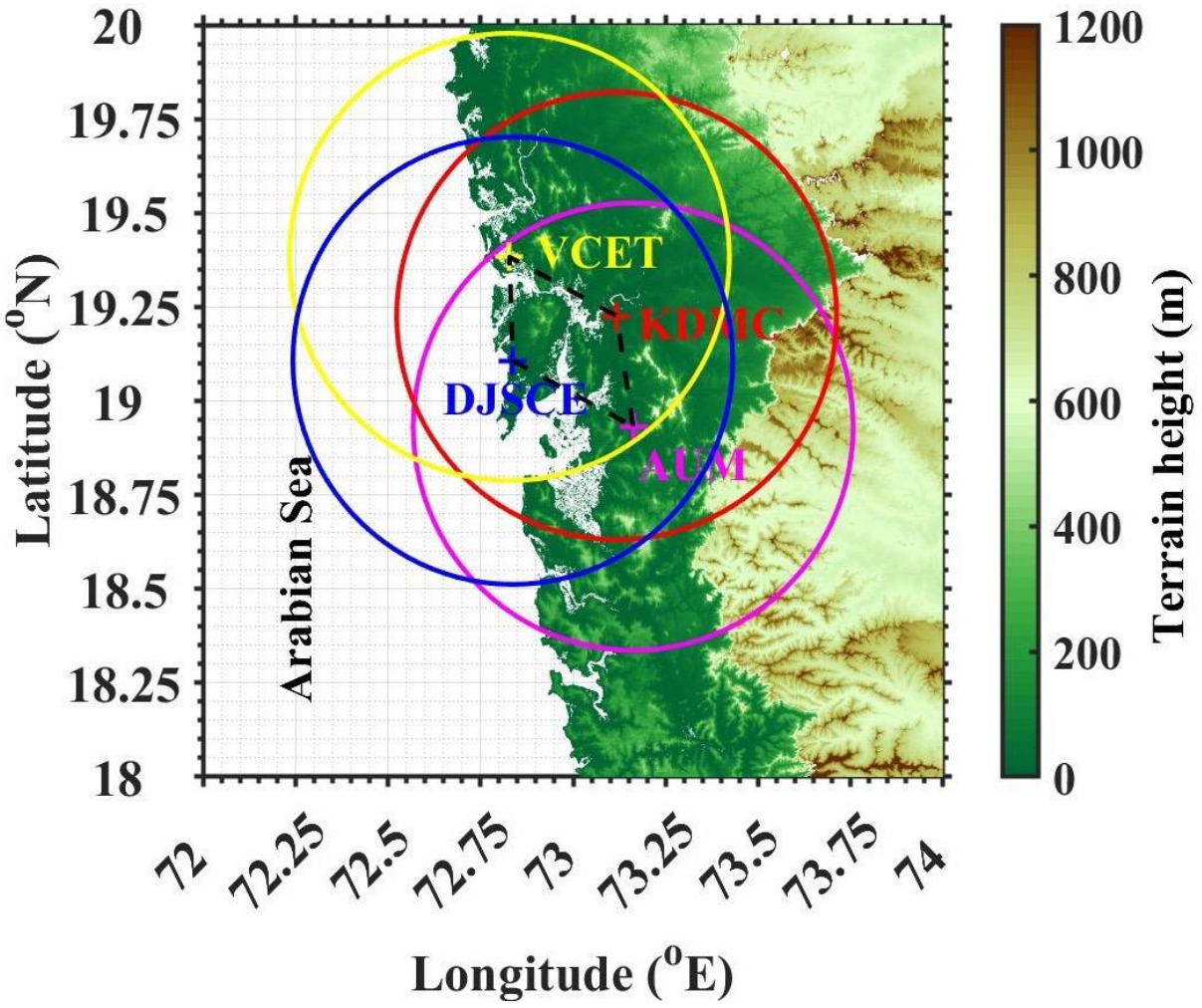
Congestus (Deep) cells are most abundant in windward (leeward) side

Lead-lag relationship between Congestus and Deep cells indicative of shallow to deep cloud transition.

Mid-tropospheric moistening by congestus prior to deep convection is crucial (Johnson et al., 1999)

Mumbai Urban Radar Network

X-band Polarimetric Scanning Radar Network



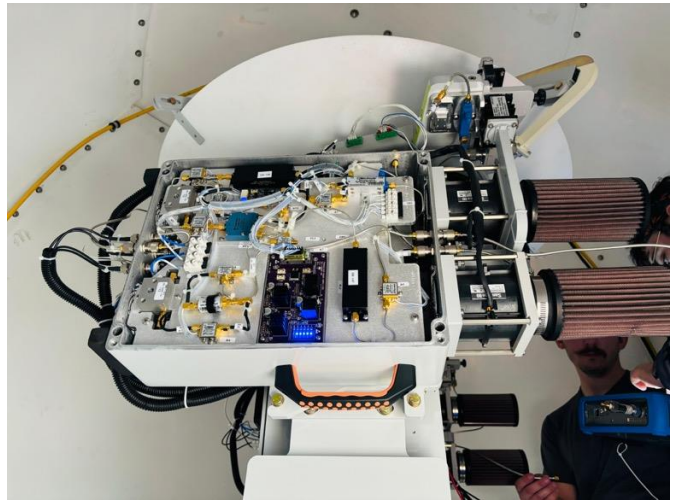
Circle indicate 60 km radar coverage. Radars are separated at distance of 30 km apart.

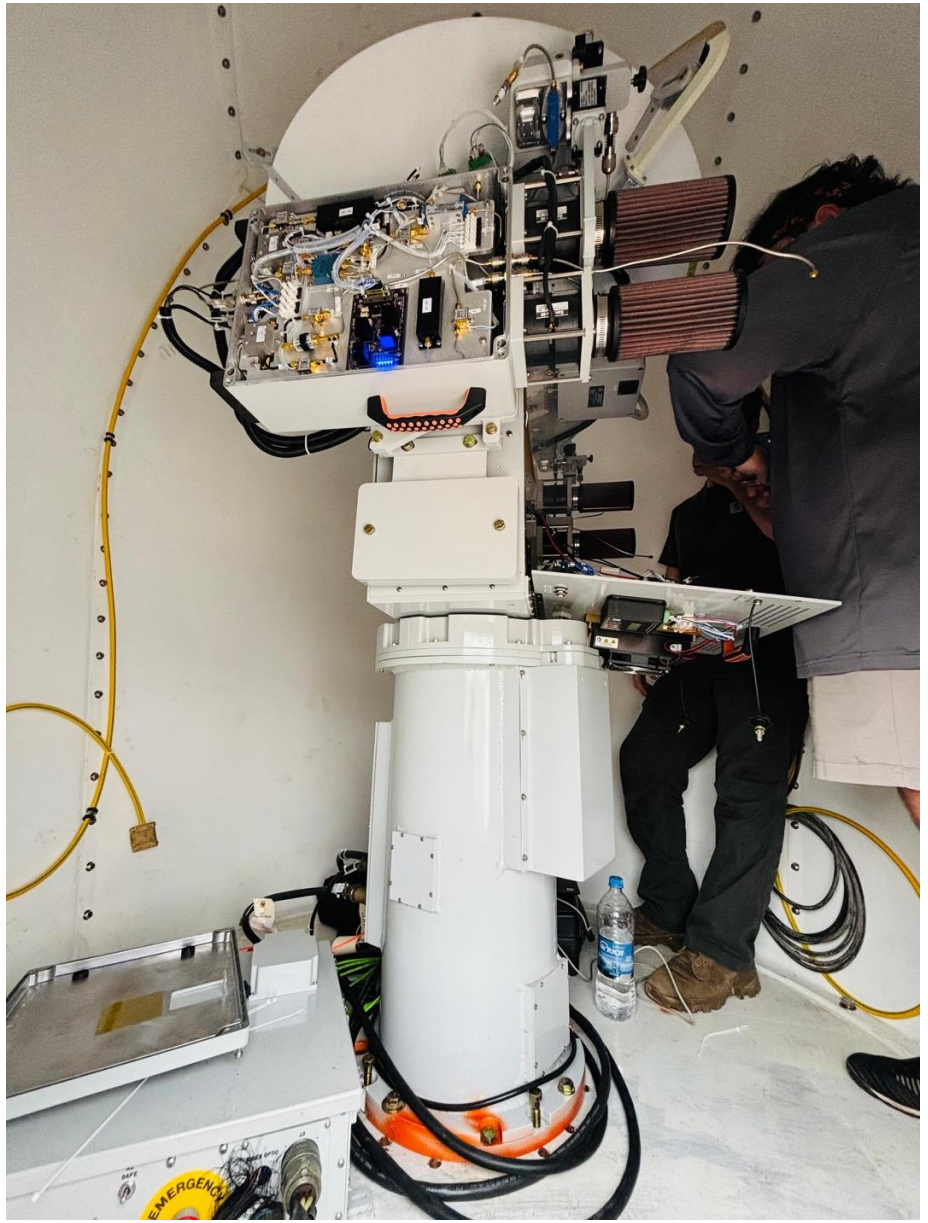
Four radar locations are:

I. Amity University (**AUM**), **Panvel**
II. Water Filtration Plant, (**KDMC**) **Kalyan-Dombivili**
III. Vidyavardhini College of Engineering and Technology (**VCET**), **Vasai Virar**
IV. Dwarkadas Jivanlal Sanghvi College of Engineering (**DJSCE**), **Ville Parle**

- ❑ Radar Mechanical Installation: **Completed** at AUM, Panvel, DJSCE, Vile Parle and VCET, Vasai Virar.
- ❑ KDMC installation is to begin next week.
- ❑ Radars will be commissioned and operational by end of July 2024.

X-band Radar Tests and Calibrations





Disdrometer network for studying the Rainfall Microphysics

IITM has established the network of Disdrometers over 10 stations of India which differ widely with respect to their geographical and climatic variations . The stations are :

1. New Delhi
2. Mumbai
3. Kolkata
4. Chennai
5. Pune
6. Mahabaleshwar
7. Kochi
8. Bhopal
9. Silkheda
10. Lakshadweep Island

Installation for 4 more stations are going on. Those are

1. Agumbe 2. Port Blair
2. Itanagar 4. Dharamshala

To study the microphysics of rainfall (rain rate, raindrop size distribution).

Also act as an important tool for calibration of Doppler weather radar.

Summary

- **Atmospheric Research Testbed facility in the Central India (core monsoon zone) is an ideal site for precipitation process studies.**

- **High-Altitude Cloud Physics Laboratory in the Western Ghats where orographic clouds and precipitation is dominant.**

- **Urban MESONET of rain gauges and X-band radar network which is currently underway will provide large data sets for understanding extreme precipitation leads to urban flood events.**

- **Disdrometer Network set up in different regions of India is being used for radar calibration and rain drop size distribution variability.**

- **All the above data sets can help better understanding the precipitation processes in different regions and Ground truth for satellite data retrievals.**

- **We invite collaborations for joint studies on Precipitation processes.**