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Atmospheric Pillar: Active remote sensing perspective

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Abstract

Rainfall (mm d^{-1} > mm h^{-1}) measurement is a vital meteorological surface parameter that caters to a vast amount of tropical monsoon research progress in India and elsewhere. This surface observation mainly recognizes/perceives its importance after extreme weather events (EWEs) happen [1]. Rainfall observations have complemented details such as location, intensity, and time duration, which decide the type of weather/precipitation system (convection and stratiform; a remote sensing perspective) and its impact/severity. The high-resolution areal rainfall maps (radar inferred quantitative precipitation estimate, QPE) provide a firm grip on EWEs evolution. However, taping the prospective remote sensing-based vertical structure of dynamics and thermodynamics pertinent to the atmospheric convection/precipitation systems is vital. This summary paper for the URSI provides a way forward for building a remote sensing-driven Atmosphere's weather pillar (vertical structure of cloud/convection and dynamics; VSC/VSD, etc.) to further extend the tropical monsoon research advancements.

1. Introduction

Remote sensing observations' enabled the vertical structure of Atmosphere/Boundary-layer Convection, Cloud, and Dynamics (VSA: VSB, VSC, & VSD) to be a potential resource pillar in unraveling the macro- and micro-physical aspects of tri-model convection/clouds to explain/evaluate the surface precipitation-/rain-rate [1-4]. The radar's Doppler (polarimetry) capability complements it in completing the cloud dynamics (hydrometeor/particle classification). These remote sensing retrieved product/parameter profiles aid in deciphering the intriguing role of low-mid-high (warm-mixed-ice) cloud dynamics [2,3].

2. Layout

The URSI Summary Paper provides possible radar and in-situ complemented/supplemented profile measurements mostly through the observational (orographic / monsoon) testbeds (HACPL/ART-CI) of IITM. All atmospheric state variables (T, RH, P, wind and rain) are used either radiosonde/GPS-RS or Reanalysis data and atmospheric dynamics and structure profile are done through radar/wind profiler [4]. Asserted vertical wind measurement keeps the Wind profiling radar (WPR) unique and priority hydrological/water cycle research advancements through convection-cloud-precipitation process study [5]. WPR's clear-air Bragg scattering from turbulent eddies in the atmosphere allows for monitoring the convective coupling between the planetary boundary layer (ABL/PBL) to free atmosphere that extends to the lower stratosphere and above [6]. These all atmospheric vertical profiles are composed basis to construct the atmosphere/weather pillar. ABCDs of the weather pillar can be versatile enough to meticulously unravel surface rain processes, which will be discussed in the URSI.

3. Paper Content

Besides using the standard/conventional tower and GPS-RS profiles, the weather and wind radars (DWR & WPR) should be used in coordinated/complemented manner to endeavor for versatile weather pillar.

4. Equations

The unique volume distributed soft atmospheric targets mainly differ by particle or ensemble scattering (Raleigh and Bragg) mechanisms with the radar equation of concern as below:

$$\overline{P_r} = \frac{\pi^2 P_t G\ c\tau}{1024(ln2)R^2\lambda^2}|K|^2 \sum {D_i}^6 \qquad (1).$$

$$P_r = \frac{P_t \lambda^2 L_{sys}\,(C_s^2 + C_r^2)}{16\pi^2 R^2} \qquad (2).$$

where $C_s^2 = \Delta r G\eta$; $C_r^2 = \left(\frac{2\pi A_e}{\lambda^2}\right)^2 |\rho|^2$

5. Results and Discussion

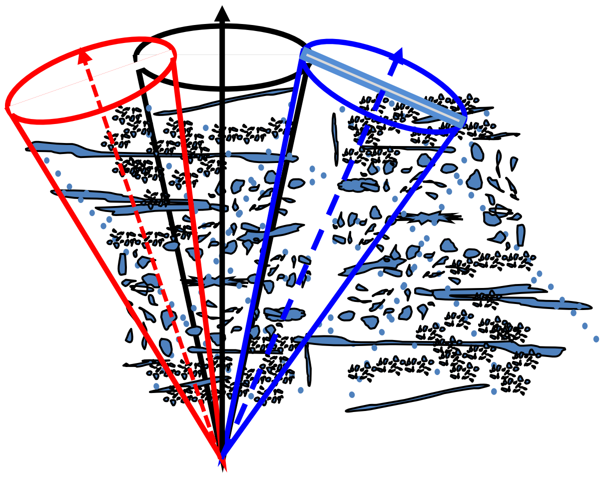

Figure 2. WPR's zenith (oblique) beam shown in black (red & blue), filling with a variety of scatter agents in the atmosphere passes through that causes echo profile as per actual backscattered or partial reflection intensity (see Eq.2), can be used for aspect sensitivity applications to explore the tilted layer in the atmosphere.

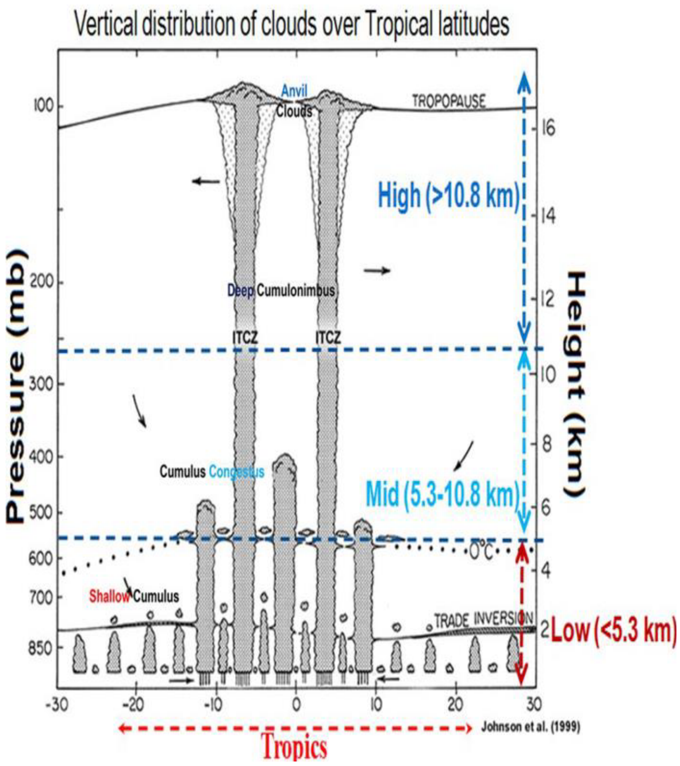

Figure 1. Vertical distribution of convective clouds over tropical latitudes for the meridional distribution of shallow cumulus, cumulus congestus, and deep cumulonimbus across the tropics. Source Fig.:Johnson et al. (1999). Further, the macro- (micro-)physical subdivision elevated estates are namely low-mid-high (warm-mixed-ice) cloud regions. Two overlay dashed lines are altitude of the 0 and -40 ºC over the Western Ghats.

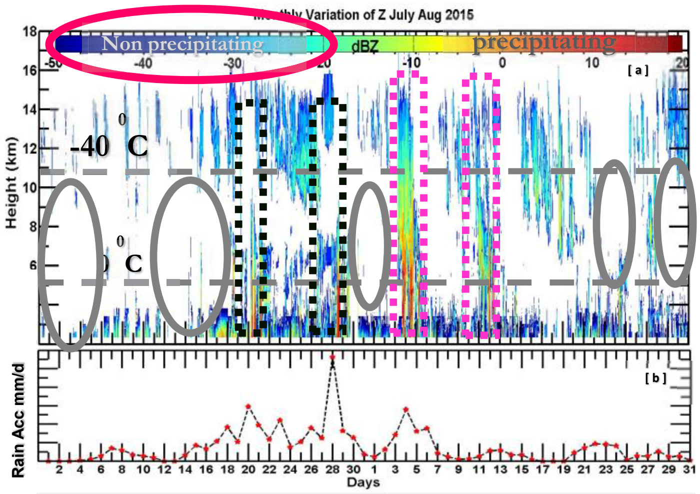

Figure 3. (a) Half-hourly mean vertical structure of cloud (VSC) measurements from the cloud radar at Mandardev in the Western Ghats during Monsoon-2015. Non-precipitating (blue) and cloud void (gray rings show white) regions are closely associated during break monsoon conditions. (b) a significant contrast between active and break monsoon rain accumulation connected to the continuous or break/gap in VSC with descending cirrus from high levels causes mid-tropospheric moistening favors cold rain processes.

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7. References

1. Kumar, K. Sunil, Sukanya Patra, Meenu R. Nair, G. Pandithurai, and M. C. R. Kalapureddy. "Indian West Coast's Extreme Rainfall: Sub-daily scale variability." *Atmospheric Research* (2024): 107518.

2. Kalapureddy, M.C.R., Sukanya Patra, Vipul Dhavale, and Meenu R. Nair. "CloudSat inferred contrasting monsoon intra-seasonal variation in the cloud vertical structure over Indian regions." *Climate Dynamics* 61, no. 3 (2023): 1567-1589.

3. Sukanya, Patra, and M. C. R. Kalapureddy. "Cloud radar observations of multi-scale variability of cloud vertical structure associated with Indian summer monsoon over a tropical location." *Climate Dynamics* 56, no. 3 (2021): 1055-1081.

4. Kalapureddy, M.C.R., K. Kishore Kumar, V. Sivakumar, A. K. Ghosh, A. R. Jain, and K. Krishna Reddy. "Diurnal and seasonal variability of TKE dissipation rate in the ABL over a tropical station using UHF wind profiler." *Journal of atmospheric and solar-terrestrial physics* 69, no. 4-5 (2007): 419-430.