Poster2-36

THE MICROPHYSICAL PROPERTIES OF STRATIFORM CLOUD CLUSTER DURING INDIAN SUMMER MONSOON: A CASE STUDY USING DUAL POLARIMETRIC C-BAND RADAR AND AIRCRAFT OBSERVATIONS

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1. INTRODUCTION

Cloud clusters contribute significant amount of surface rainfall during Indian Summer Monsoon (ISM). It has been often found that several cloud clusters form over Bay of Bengal as a low pressure system or depression and propagate westward/north-westward through Indian peninsular region during ISM (Saha et al. 1981; Chen and Weng 1999; Chen and Yoon 2000; Chen et al. 2005). These westward propagating cloud systems are associated with the 10-20 days oscillation of monsoon intraseasonal oscillation and a major component of active-break phases of ISM (Krishnamurti and Ardanuy 1980; Chen and Chen 1993; Krishnan et al. 2000; Rajeevan, M., Gadgil, S., Bhate 2010). For the last several decades the dynamical properties of these cloud clusters have been explored by several studies, whereas their microphysical properties remain untouched. In the present study we have critically examined the microphysical properties of such a cloud cluster over the peninsular Indian region.

2. DATA AND METHEDOLOGY

During the monsoon of 2018, the 'Cloud Aerosol Interaction and Precipitation Enhancement EXperiment (CAIPEEX)' was underway over the rain shadow region of Western Ghats (WG) mountain range, India, which facilitated the collocated observation of several state of the art instruments; i.e. Polarimetric C-Band Doppler Weather Radar, Microwave Radiometer Profiler, Wind Profiler, Radiosonde, etc. In situ measurements of cloud and precipitation microphysical properties by aircraft observations were also conducted during the campaign. The cloud physics aircraft was equipped with Cloud Imaging Probe (CIP) and Precipitation Imaging Probe (PIP) along with other aerosol, cloud and precipitation measuring instruments.

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In this present study we have utilized the co-located observation of Radar, Radiometer and Radiosonde data along with aircraft observations. Co-located Radar and Radiometer provides detailed insight about various types of hydrometeors and the ongoing microphysical processes associated with the cloud system in different temperature regime. To extract the information about ongoing microphysical processes we have adopted the Quasi-Vertical Profiles (QVP) analysis of polarimetric radar parameters as introduced by Ryzhkov et al. (2016) and used in several studies (Schrom and Kumjian 2016; Kumjian and Lombardo 2016). Besides, we have used a fuzzy logic based Hydrometeor Identification (HID) algorithm (Dolan et al. 2013) to examine the dominant types of hydrometeor throughout the study period. This HID algorithm is able to identify ten different hydrometeor classes; i.e. Drizzle (DZ; rain rate <2.5 mm/hr.), Rain (RN), Ice Crystals (IC), Aggregates (AG), Wet Snow (WS), Vertical Ice (VI), Low-Density Graupel (LDG; density: 0.25 to 0.55 g/cm3), High-Density Graupel (HDG; density: 0.55 to 0.9 g/cm3), Hail (HL) and Big Drops(BD)/Melting Hail (>5 mm). In situ observations from CIP and PIP show the existence of different hydrometeors at different altitude.

3. RESULTS AND DISCUSSION

Earlier studies have revealed that the westward propagating cloud clusters through peninsular Indian region are associated with monsoon depression (Saha et al. 1981; Chen and Weng 1999; Chen and Yoon 2000; Chen et al. 2005) and synoptic influences play a significant role throughout their lifecycle. In the present study our main focus is to critically examine the microphysical properties associated with such a cloud cluster on case study basis.

3.1 *Case overview*

The cloud cluster which has been analyzed in the present study was a part of westward propagating cloud system over Indian peninsular region and was associated with monsoon depression. The movement of the cloud system was monitored by INSAT-3D (TIR1-BT<233K) satellite data (Fig. 1). It can be seen that the system has spent significant amount of time (from 0000 UTC 20-Aug-2018 to 1200 UTC 21-AUG-

2018) over the radar surveillance area during its westward propagation, which has provided us the unique opportunity to study the detailed microphysical evolution associated with the system.

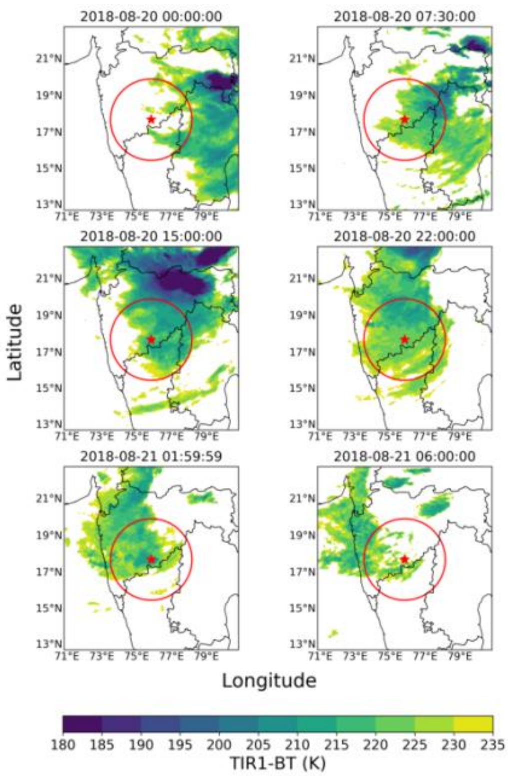


FIG-1. Evolution of the cloud cluster (TIR1-BT <233K) as observed by INSAT-3D satellite. Red circle shows the radar surveillance area.

3.2 *Thermodynamical structure*

The evolution of temperature, vapor density and liquid water profile as observed by radiometer, from 0000 UTC 20-Aug-2018 to 1800 UTC 21-AUG-2018 are presented in Fig. 2a-b. The temperature gradually decreased upward and the 0^{o}C isotherm meandered near ~4km. The moisture content in the lower troposphere (below ~3km) was consistently high (~12 $g.m^{-3}$) throughout the study period and gradually decreased upward. The liquid water content shows the presence of significant amount of mixed-phase clouds.

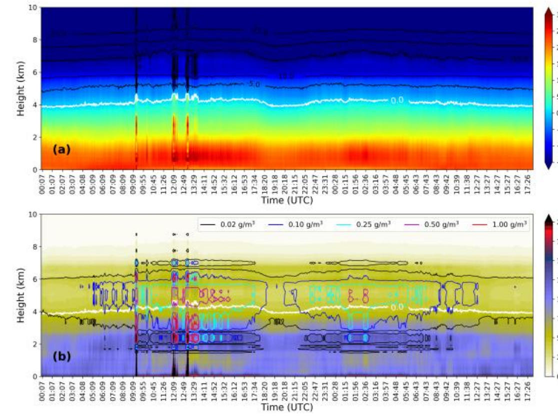
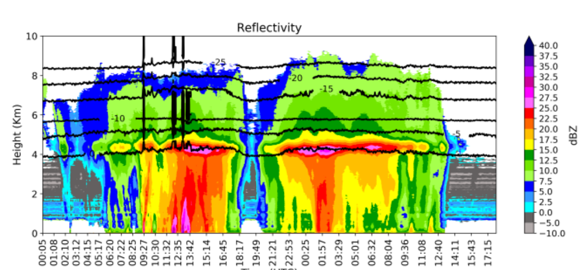


FIG-2. Radiometer observed (a) temperature, (b) vapour density (color shading) and liquid (contour) profile between 0000 UTC, 20-Aug-2018 and 1800 UTC, 21-Aug-2018. The white line represents the 0^{o}C isotherm and the black lines (in (a)) represent (from bottom to top) the -5^{o}C, -10^{o}C, -15^{o}C, -20^{o}C, and -25^{o}C isotherms respectively as recorded by Radiometer.

3.3 *Microphysical evolution*

The existence of different types of hydrometeors and the ongoing microphysical processes associated with the cloud clusters have been studied using QVP and HID algorithm. QVP provides the evolution of polarimetric radar parameters throughout the study period and indicates the presence of different types of hydrometeors in various temperature regimes. HID algorithm is able to identify ten different hydrometeor species and help to attribute the ongoing microphysical processes.

The QVPs of Z_H, Z_{DR}, K_{DP} and ρ_{HV} along with temperature profile from radiometer are presented in Fig. 3. The cloud top was ~8 km to ~9 km throughout the study period. The presence of melting layer is evident near 0^{o}C isotherm (~4 km) throughout the study period and was associated with relatively high Z_H, Z_{DR}, K_{DP} value and low ρ_{HV} value which is consistent with previous studies (Ryzhkov et al. 2016). Significant amount of dry aggregated snow can be seen above the melting layer. High value of Z_{DR} and K_{DP}, moderate ρ_{HV} and low Z_H value near the cloud top indicates the presence of pristine ice crystals. Below the melting layer moderate Z_H, low Z_{DR} and K_{DP} indicates that the surface precipitation was primary in the form of drizzle.



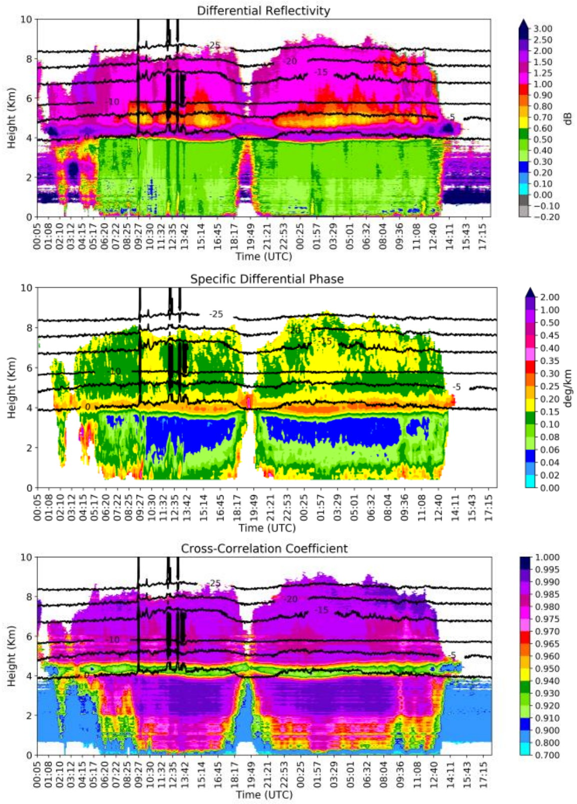


FIG-3. Quasi-Vertical Profile of Z_H, Z_{DR}, K_{DP} and ρ_{HV}. The black lines show the radiometer recorded (from bottom to top) 0^{o}C, -5^{o}C, -10^{o}C, -15^{o}C, -20^{o}C, and -25^{o}C isotherms.

The evolution of different types of hydrometeor are presented as the normalized count of each hydrometeor species (Fig. 4), which has been used as a proxy of hydrometeor amount and provides information about the ongoing microphysical processes associated with the cloud cluster throughout the study period. Wu et al. (2018) have attributed several microphysical processes based on the presence of different hydrometeor species as identified by HID algorithm.

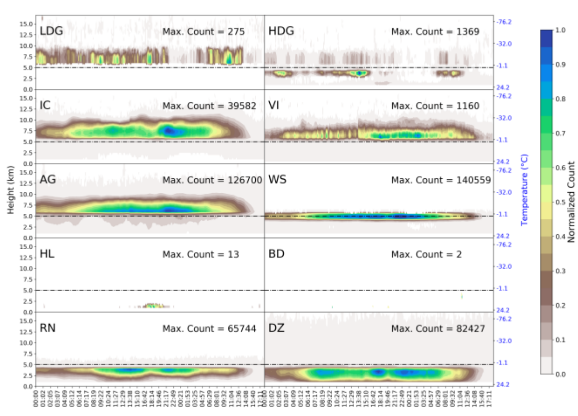


FIG-4. Evolution of different types of hydrometeor as identified by HID Algorithm. 'Colorbar' and the term 'Max. Count' represents the normalized count and the maximum count respectively of a particular hydrometeor type throughout the study period. Black dashed line represents the 0^{o}C isotherm.

In the present study, the pristine ice crystals within the cloud cluster are identified as IC by the HID algorithm and indicate the ongoing 'vapour deposition' process. In presence of electric field these IC align in vertical direction and are identified as VI. AG are formed due to 'aggregation' process of ice crystal. Presence of LDG and HDG indicates the ongoing 'riming' process with in the cloud cluster. The hydrometeors falling from above 'melt' near 0^{o}C isotherm and give rise to WS. It can be seen that the surface precipitation associated with the cloud clusters were primarily in form of drizzle. It can also be noted that HL and BD were hardly associated with the cloud cluster.

4. CONCLUSION

The present study provides a detailed insight about the dominant types of hydrometeor and the ongoing microphysical processes within a cloud cluster associated with monsoon depression during ISM. It can be seen that mixed-phase cloud processes are important in such cloud system. Vapor deposition, aggregation and melting are the dominant microphysical processes. Surface precipitation is mainly in the form of drizzle associated with the cloud cluster.

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