Convective rain study with radiometer, radar and electric field observations at a tropical location

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Abstract **– Characterization of convective rain at tropical station Kolkata, located near the land-ocean boundary, in the eastern part of India, has been made using observations from multi-frequency radiometer, micro rain radar, disdrometer and electric field monitor. Features of convective rain in respect of liquid water content, rain rate profile, and electric field variation have been identified. Multi-frequency radiometric brightness temperatures are used to nowcast impending rain events and rain fall amount.**

Index Terms **— Convective rain, Radiometric measurements, Brightness temperature, Micro rain radar, Atmospheric electric field, Nowcasting.**

1. Introduction

In the tropical region, convective rain is an important weather phenomenon that influences the lives of the people. The atmospheric parameters associated with convective processes have distinctive features that can be revealed in terms of liquid water content, vertical profile of rain rate, rain drop size distribution and electric field variations. Radiometric measurements of brightness temperatures in the 22-31 GHz band and 51-59 GHz can provide effective tools to reveal the characteristic features of convective rain and to nowcast of an impending rain event and rainfall amount. Conventionally, spatial and temporal interpolation is used to nowcast intense convective activities using satellite, radar and radiometer data [1-4]. In the present study it has been shown that a considerable increment in liquid water before rain can be taken as a possible estimator of the rain accumulation. This increment in liquid water will have its signature on brightness temperatures (BT) at 31.4 GHz, the frequency at which strong liquid water absorption occurs. Also, the variations in atmospheric electric field recorded from an electric field sensor can predict the onset of rain.

2. Instruments and Dataset

In order to find out an effective precursor of convective precipitation, we have studied the atmospheric parameters over Kolkata (22.65ºN, 88.45ºE) using a multi frequency profiler radiometer (RPG-HATPRO) and an electric field monitor. The multi-frequency microwave radiometer measures brightness temperatures at 14 frequencies at two frequency bands, namely, 22.24-31.4 GHz and 51.3-59 GHz [5]. A micro rain radar (MRR) is used to classify the rain as convective or stratiform based on the melting layer signature in the rain rate profile. An impact type of disdrometer has been used for observing drop size distribution and rain accumulation measurements. An electric field monitor, collocated with the radiometer, measures electric field intensity simultaneously.

3. Results and Discussions

The startiform and convective rain events are classified on the basis of melting layer signature in rain rate profile obtained from MRR as shown in Fig. 1.

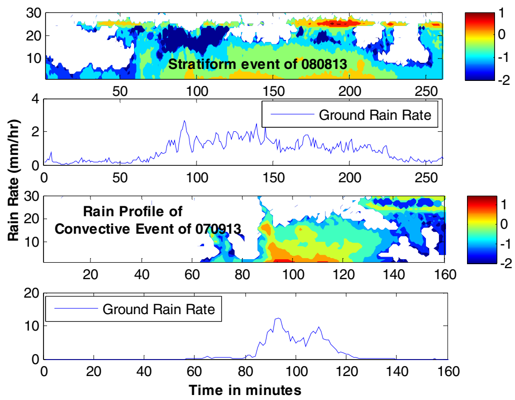

Fig. 1. The convective and startiform events as observed from MRR. Colorbars are in logarithmic scale

Prior to heavy rain events liquid water starts increases significantly due to formation of liquid drops in cloud during convective processes. As a result, it can be seen that brightness temperatures at 31.4 GHz, which is sensitive to liquid water absorption, shows a sharp increase before rain. A case study for a rain event on 15 July 2015 is shown in Fig. 2, for which a heavy rain accumulation of 53 mm was recorded. The brightness temperature at 31.4 GHz shows an increase prior to the rain event. It may be noted that BT variations for rainy and non rainy conditions are significantly different.

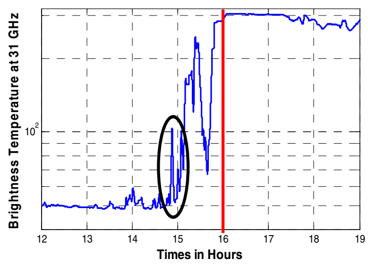

Fig. 2. Variation of BT at 31 GHz at 15/07/15. Red line shows start of rain.

The BT data are recorded for every half hour. The net BT variation is calculated in a normalized form as given below.

Net BT variation = (Max BT -Initial BT)/ (Initial BT) (1)

The net BT variation is below 0.4 in absence of rain and is above 0.5 in case of convective rain. The BT variation at 31.4 GHz can be related to the amount of impending rainfall. Fig. 3 shows the scatter plot of accumulated rain against net BT variation for 45 rain events which gives a good linear agreement between these two parameters with a correlation coefficient of 0.68. It is observed that the best correlation is obtained for a lead time of 75 min.

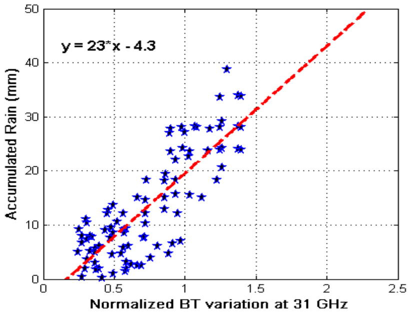

Fig. 3. Net BT variation vs rain accumulation.

3.1 Electric field observations

Intense convective activities are generally accompanied by large clouds which have an enormous source of cloud liquid water. On the eve of convective occurrence, when a large cloud is overhead the sensor, negative charges at the cloud base induce a negative electric field which can be considered as a precursor of the impending rain event [6]. The atmospheric electric field starts to diminish about half an hour before the onset of rain.

Both convective and calm days are considered during the observed period to study the variation of electric field. In the presence of convective event, the mean electric field magnitude and its standard deviation can take very large values indicating the presence of thick convective clouds. This reveals that the variation of electric field has a significant relation with impending rain. An analysis of the heavy rain events indicates that a significant electric field deviation can be seen about 40 minutes prior to the event (Fig. 5).

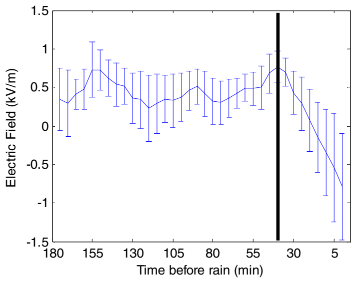

Fig. 5. variation of EF before the convective events

Since electric field variations inside the cloud mainly originate from presence of liquid water content, electric field variation and cloud liquid water must also be related. The average liquid water content (LWC) from radiometric observations has a positive relation with the electric field variations as shown in Fig. 6.

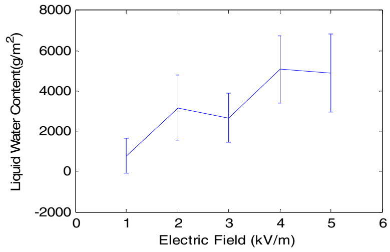

Fig. 6. Vraition of LWC vs Electric Field variation

4. Conclusions

In this study, an effort has been made to characterize convective precipitation in terms of liquid water content, rain rate profile and electric field variation. It has been observed that both the radiometric brightness temperature at 31.4 GHz and atmospheric electric field show definite behavior prior to convective rain. The analysis of these parameters indicates that the total amount of convective precipitation is directly related with cloud liquid water content which in turn is manifested in the variation of brightness temperature and electric field. A combination of these two parameters can be utilized to nowcast convective rain events and rainfall amount with a reasonable lead time and prediction accuracies at a tropical location.

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