Chapter 8

Summary, Conclusions and Future Plan of Work
8.1. Summary and Concluding Remarks

Convective rain is a dominant climatic feature in the Indian Subcontinent especially in the pre-monsoon (March–May) and monsoon season (June–September). These activities are generally accompanied by thunder, lightning and rain and hence cause severe damage to aviation, agriculture and defence. Microwave communication links in various frequency bands are also affected by these types of activities. Hence, it is important to study the atmospheric processes behind the genesis of intense convective events to predict the occurrence of such activities in advance. Also, the effects of intense rain on communication need to be studied in detail. The present thesis deals with convective activities from multi-technique observations at Kolkata and attempts have been to develop an empirical model to predict rain occurrences and magnitude with good efficiencies and lead times. Also, an efficient rain attenuation estimation technique has been developed to obtain signal attenuation over earth-space path at frequencies above 10 GHz.

Ground based microwave radiometers operate continuously and measures atmospheric profiles up to 10 km with high accuracy irrespective of weather conditions and hence can be used as a good atmospheric monitoring tool. However, the retrieval methodology used by the radiometer has to be dynamic with respect to changing climatic and location. Three different retrieval techniques namely, regression, neural network and neural network with memory have been utilized to retrieve reliable profiles of atmospheric parameters (temperature and relative humidity) from brightness temperatures at various frequencies as observed by radiometer. To check the efficacy of the retrieval techniques a number of comparison techniques have been adopted such as daily observation, error histogram, data correlation and error significance analysis. From the analysis, it is seen that for both humidity and temperature retrievals, the application of neural networks with back
propagation (with a data memory of 45 minutes) is the best retrieval technique among the three techniques as mentioned in the study.

Radiometer provides real time profiles of temperature and moisture along with a series of instability indices which can be useful in qualitative prediction of rain. It has been seen the temperature and humidity profiles show marked changes before rain occurrence. Hence, an application of BT at 22 and 58 GHz (sensitive to water vapour and temperature absorption respectively) can be used to predict rain. BT time derivatives are used to develop a prediction model which predicts successfully 90% of rain events with over prediction efficiency of 10%. However, the prediction lead time is small (25 minutes). Hence, to increase the lead time, another attempt has been made to predict heavy rain occurrence using four parameters like KI, LI, HI and the standard deviation of BT at 22 GHz from radiometer measurements. It is seen that that a combination of LI and standard deviation of BT at 22 GHz can be most effective to nowcast convective activities with prediction efficiencies of about 80% and an over prediction rate of 18%. The proposed model performs reasonably well when tested for a number of convective events of 2012 and 2013 with a lead time of 70–75 minutes. However, the present technique can predict rain occurrence and not its magnitude.

To address this shortcoming, brightness temperatures at channels close to liquid absorption have been studied. It has been observed that the normalized variation of brightness temperature (BT) at 31 GHz (close to liquid water absorption peak) can be used to predict the impending rain accumulation about 75 minutes before start of rain. It is seen that the sudden liquid water growth about 70-75 minutes before the commencement of the actual rain event acts as a proportionate trigger to develop instability which stimulates convective growth. Hence, a combination of this technique with the preceding prediction technique (employing BT standard deviation at 22 GHz and LI) is employed to predict rain qualitatively and quantitatively with a good lead time. The composite prediction model developed from these
three parameters namely, the brightness temperatures at 22 and 31 GHz with an instability index LI predicts intense convective rain about 70-75 minutes in advance with a hit ratio of 80% and a rain amount estimation error of 30% and hence can be useful in real time prediction of rain in various fields of life. The present nowcasting technique thus provides a continuous, reasonably efficient and less involved way of predicting extreme weather compared to the techniques already reported using RADAR and satellite measurements.

Rain causes a series of propagation effects, the most dominant of which is rain attenuation, particularly above 10 GHz frequencies. To obtain attenuation over earth-space paths, an effective rain rate in terms of ground rain rate has been calculated from TRMM rain profiles. It has been found that the estimated attenuation from surface rain rate measurements matches quite well with the attenuation results at frequencies 20.2 and 30.5 GHz observed with Ka band beacon transmission from GSAT-14 satellite. It is also found that the attenuation values from the present technique provide much more realistic estimates than the same predicted form ITU-R. A detailed study on the model parameters \( \frac{R_{\text{eff}}}{R_g} \) has also been made on nine locations of the Indian subcontinent which depict a major diversity in seasons and rain types. Using these model parameters the technique estimates attenuation using ground rain rate at different frequencies, locations, and rain types.

The above studies reveal that ground based radiometric observations supported by MRR and rain rate measurements can be used to analyze, monitor and predict the occurrence of convective activities and associated rainfall amount with good efficiencies and lead times. The retrieval of atmospheric parameters from radiometric measurements can be a major issue in this study and needs attention for the betterment of the predicted profiles. Additionally, propagation effects like rain attenuation can be studied both with localized ground based measurements for real time investigation and with satellite observations for evolving a regional estimation model that work better than conventional models.
8.2. Future Plan of Work

In view of the adverse effects caused by convective activities in a tropical location, an integrated approach needs to be undertaken to study the convective processes and its life stages using a combination of ground based and satellite measurements for better predictability and understanding of this type of events. Also, extensive measurements and atmospheric modelling is required for investigation of long term variation of precipitation with respect to changing climate in the tropical region. The proposed future study may mainly focus on the following aspects:

1. Use of multi-technique observations involving electric field mill, lightning detector and radars to build a more effective nowcasting technique.
2. Implementation of rainfall prediction with satellite based measurements over the Indian region.
3. Study of the long term pattern of convective rain that might have implication in the changing scenario of regional climate over India.