Cloud Detection and Attenuation Modelling in Tropical Region

Feng Yuan, Yee Hui Lee & Yu Song Meng

Cloud plays a significant role in both the Earth's climate system and ground-to-space radio communication system. In this thesis, various types of data are collected from different kinds of instruments including radiosonde, ceilometer, dual-polarization weather radar, Ka-band beacon receiver, weather stations and whole sky imagers. By processing and analyzing the data collected from these instruments, the study of various aspects of the cloud including cloud vertical structure, melting layer of rain clouds, and the impact of cloud on the satellite communication for tropical region is performed.

In this research, a new method for the detection of cloud vertical structure and cloud occurrence for tropical region is proposed. This proposed model [1] is based on the fact that the measured water vapor pressure is larger than the derived critical water vapor pressure at the same level for cloud to be present. The estimated cloud vertical structure using the proposed method is compared with the Salonen and Uppala model, the ceilometer data and two kinds of meteorological observation. The proposed model shows a higher accuracy of prediction of the cloud vertical structure as compared to the existing SU model for tropical region.

Next, a method [2] for the detection of the melting layers for the stratiform and convective rain clouds using dual-polarization radar data is proposed. By studying the difference between these two types of rain events, it is found out that among the three radar measurements; reflectivity; differential reflectivity; and cross-correlation coefficient; the cross-correlation coefficient is the best indicator for convective rain melting layer detection in the tropical region, whereas the reflectivity is sufficient for the detection of stratiform rain melting layer. In addition, it has been observed that due to the nature of convective rain events, their raindrops can move upwards to above 6 km as recorded by the radar data. This height is even higher than the top boundary of the melting layer.

For satellite communication applications, it is important to be able to differentiate cloud events from rain events along the link. Several cloud detection methods are applied in order to accurately detect the clouds for cloud attenuation estimation [3]. In this research, beacon data are collected and processed to differentiate clouds from rain and then to study cloud attenuation in the tropical region. The cloud attenuation results are compared to the ITU-R model for Ka band frequency. It was concluded that at Ka band, the maximum cloud attenuation is about 4 dB. This shows that the ITU-R model is derived for temperate regions and tends to underestimate the cloud attenuation in the tropical region.

Therefore, in this research work, a new cloud attenuation model [4] is proposed for the tropical region. This model incorporates precipitable water vapor (PWV) value to estimate integrated liquid water content, and then determine the cloud attenuation. The estimated cloud attenuation using this new model is compared with the ITU-R model and the cloud attenuation derived from Ka-band beacon data. One of the main advantages of using PWV data from GPS for cloud attenuation modelling is its increase in temporal resolution as compared to the use of radiosonde data.

In this thesis, we have proposed a model to detect cloud vertical structure for tropical region, studied the melting layer for both stratiform and convective rain clouds, done statistical analysis of cloud attenuation on a Ka-band satellite link and also proposed a high temporal resolution method for cloud attenuation calculation in tropical region. We believe that the algorithms and techniques developed in this thesis will assist the remote sensing and satellite communication community with a better understanding of clouds.

References

[1] F. Yuan, Y. H. Lee, Y. S. Meng and J. T. Ong, "Water Vapor Pressure Model for Cloud Vertical Structure Detection in Tropical Region," in IEEE Transactions on Geoscience and Remote Sensing, vol. 54, no. 10, pp. 5875-5883, Oct. 2016.

[2] F. Yuan, Y. H. Lee, Y. S. Meng and J. T. Ong, "Characterization of Dual-polarization Radar Data for Stratiform and Convective Melting Layer Detection in Tropical Region," submitted in IEEE Transactions on Geoscience and Remote Sensing.

[3] F. Yuan, Y. H. Lee, Y. S. Meng, J. X. Yeo and J. T. Ong, "Statistical Study of Cloud Attenuation on Ka-Band Satellite Signal in Tropical Region," in IEEE Antennas and Wireless Propagation Letters, vol. 16, no., pp. 2018-2021, 2017.

[4] F. Yuan, Y. H. Lee, Y. S. Meng and J. T. Ong, "High resolution ITU-R Cloud Attenuation Model for Satellite Communications in Tropical Region," submitted in IEEE Transactions on Antenna and Propagation.