On the Relationships between TRMM-observed Quantities and Lightning Frequency

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1. Introduction

Definable relationships between lightning frequency and thunderstorm parameters, if established quantitatively, can have important applications in estimating or forecasting convective intensity and rainfall via incorporation of lightning data, and vice versa. This has been probed by many authors (summary in Latham et al., 2007). However, an important unresolved question concerns the variability of the lightning-thundercloud properties relationships for different weather regimes.

In this study, relationships between a set of TRMM-observed parameters and Lightning Imager Sensor (LIS) lightning frequency over southern China and adjacent ocean during different seasons are examined. Furthermore, this study tries to determine temperatures where radar reflectivity parameters such as maximum radar reflectivity and area with high radar reflectivities are most highly correlated with lightning flash rate. Another goal is to test the variability of those relationships between the pre-season and Mei-Yu season regime, as well as between land and nearby oceanic systems.

2. Methodology

This study is based on precipitating features (storm scale), using the 11 years-long TRMM Precipitation Feature (PF) database (Nesbitt et al., 2000). Lightning data are from observations by the TRMM LIS, while thunderstorm parameters are based on measurements from the TRMM Precipitation Radar (PR) and Microwave Imager (TMI). Thundercloud parameters include minimum 85-GHz PCT, minimum 37-GHz PCT, maximum radar reflectivity at specific temperature, convective rain rate, area of 35-dBZ and 20-dBZ echo at different temperatures, and retrievals of ice water mass (Petersen et al., 2005).

3. Results

3.1 Correlations between Lightning and Thundercloud Parameters

The IWM at 8-km is closely correlated (R=0.80-0.94) with lightning frequency as expected from the literature (Petersen et al., 2005). Of all the TRMM-observed parameters, 35-dBZ area at -15 ^{o}C has the best positive relationships (R=0.78-0.94) with lightning flash rate. The correlation between lightning frequency and 35/20 dBZ area is quite consistent within different regimes over land but varies slightly from continental to oceanic regime.

There is no correlation between lightning frequency and convective rain rate in this East Asian regime. The ice scattering signature at both 37 and 85 GHz shows significant negative relationship with lightning frequency. In this study, minimum 37-GHz PCT is more highly correlated (R=-0.66- -0.70) with lightning than minimum 85-GHz PCT (R=-0.45- -0.56).

3.2 Temperature of the best correlation and its variability

Because the charging zone may involve a temperature range from -5 ^{o}C- -30 ^{o}C (Takahashi, 1978). The 11-year TRMM database can be used to narrow the range of possibilities. Generally, for continental lightning features, area of high radar reflectivity, e.g. echo > 35-dBZ, show their best correlations with lightning frequency at -5- -15 ^{o}C while area of weaker echo, e.g. 20 dBZ, area is most closely correlated with flash rate at -30- -40^{o}C. Note that this feature does not vary much with storms over land during different regimes. However, this relationship pattern shifts to lower temperatures for the oceanic lightning systems.

4. Summary

The major findings in this study include:

1. Of all the examined parameters, area of 35-dBZ at the mixed-phase region and area of 20-dBZ at upper level, as well as roughly estimated mid-level ice water mass, are most highly correlated with lightning flash rate.
2. Temperatures of maximum correlation between area of specific radar reflectivity

and flash rate differ considerably between land and oceanic lightning storms. The area of high radar reflectivity, e.g. 35-dBZ, has its highest correlation with lightning frequency at -5- -15 ^{o}C over land but at -15- -30 ^{o}C over ocean.

This study not only adds details to the knowledge of the behavior of weather systems in the East Asian monsoon region, but also provides clues to a broader context.

References

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