Abstract of Doctoral Dissertation

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Title of Doctoral Dissertation

Studies on Lightning IC/CG Ratio and Effects of Lightning and Rainfall Currents on Global Electric Circuit

（雷放電の IC/CG 比及びグローバルサーキットへの雷・降雨電流の影響に関する研究）

The ratio of intracloud (IC) discharges to cloud-to-ground (CG) discharges, which is denoted by *Z*-value, is one of the key parameters in the lightning physics because it has close relation to the climatological difference in the thundercloud formation and structure in the tropical, subtropical and temperature regions and because it is one of the major parameters for the quantitative evaluation of lightning contributions to the global electric circuit (GEC). However, the latitudinal, regional and seasonal dependences of *Z*-value are not fully clarified so far. In order to estimate the effects of lightning and rainfall currents on GEC, a simple 2D model was developed in the previous study. However, it only treats the extremely simplified input parameters, such as constant lightning and rainfall currents and constant atmospheric conductivity, with relatively low temporal and spatial resolutions. The purpose of this dissertation is to estimate more statistically reliable *Z*-value and its latitudinal, regional and seasonal dependences and to quantitatively evaluate the effects of lightning and rainfall currents on GEC with more appropriate input parameters and with more high temporal and spatial resolutions.

For this purpose, firstly, we have developed new methods to classify IC, positive CG (+CG) discharges, and negative CG (-CG) discharges using the lightning optical data obtained by the Global Lightning and Sprite Measurements on Japanese Experiment Module (JEM-GLIMS) mission and ground-based lightning data. Secondly, we have estimated *Z*-value and its latitudinal, regional, and seasonal dependences. Finally, we have quantitatively evaluated the contribution of lightning and rainfall currents to GEC using newly developed 3D GEC model.

In this study, a total of 8354 JEM-GLIMS lightning events detected in the period from November 2012 to August 2015 are analyzed. These lightning events are first classified into the three discharge types, *i.e.*, IC, -CG, and +CG discharges by compared to the ground-based lightning data provided by the JLDN, NLDN, WWLLN, and GEON. Then, the identified discharge events are used to estimate Z-value, and we have first estimated its latitudinal, regional and seasonal dependences. It is found that the *Z*-ratio in the continental region is slightly higher than that in the oceanic region. The average of *Z*-ratio over continental and oceanic region are 1.7 and 1.1, respectively. In addition, the averaged *Z*-value in the local summer season (1.2) is higher than that in the local winter season (0.6). The latitudinal dependence of the *Z*-value estimated in this study shows a good agreement with the results shown in the previous studies. The estimated *Z*-ratio varies in the range of 2.9 - 0.19 from the equator to 50º latitude, and the global mean value is 1.6.

As a next step, we have developed a new 3D GEC model, which can calculate atmospheric electric field with 5 min time resolution and $0.2^{\circ}\times0.2^{\circ}$ spatial resolution. In this model, lightning and rainfall activities are regarded as the electric current generator. In addition, this model uses the input parameters of time-variable lightning and rainfall activities and time-variable column resistance and associated atmospheric conductivity. First, the regional dependence of *Z*-ratio derived from this study is applied to the CG lightning data provided by the WWLLN network in order to estimate the occurrence number of IC discharges. Then, the estimated occurrence number of IC and CG discharges and the precipitation data obtained by the global precipitation measurement (GPM) project are used for the 3D GEC model. Finally, the total upward current

from thunderclouds to the ionosphere is calculated. It is found that the average lightning and precipitation currents in the GEC are estimated to be ~70 A (~6%) and ~1080 A (~94%), respectively. We have also compared the fair weather electric field predicted by the GEC model to that observed at Syowa station in Antarctica and Reading station in UK. It is found that the absolute amplitude of the fair weather electric field estimated by the model is comparable to that observed at Syowa and Reading stations. It is also found that the diurnal variation of the fair weather electric field estimated by the model is well correlated with that observed at the two stations.

We found that the regional dependence of *Z*-value obtained by the combination of the ground-based and space-based observations greatly contributes to more accurate estimation of the total lightning and rainfall currents in the GEC. It is first quantitatively presented that the upward current from thundercloud to the ionosphere generated by lightning activities is only 6% and that the rainfall activity plays a crucial role in the GEC.