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Evaluation of net-current by cloud-to-ground lightning discharges using global ELF network data

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Lightning discharge radiates electromagnetic energy over an extremely wide bandwidth. Measurement of electromagnetic wave in ELF range (less than 3 kHz) is especially focused on as a useful way to derive global mapping of cloud-to-ground lightning discharges (CGs). The main reason for it is that the ELF observation provides us the information about the polarities and charge moments (Qdl) of respective detected events.
In preceding ELF studies, global distribution of intense positive CG (PCG) and negative CG (NCG) [|Qdl|>1000Ckm] had already been derived with long-term ELF data (annual or several years). In these analyses, the majority of detected events was PCG although previous works with other observation methods showed that NCG occurs more than 10 times as much as PCG. It indicates that occurrence frequency of NCG are dominant in small Qdl events [|Qdl|<1000Ckm]. However, these small events had been excluded from analysis due to signal-to-noise ratio.
Here we improved the methods for the estimation of lightning position and Qdl. The time of arrival (TOA) method is applied for the geolocation to ELF network data. The averaged-error is evaluated to be 676 km based on the comparison with VLF network for 1224 events which are detected in both networks. We estimated the Qdl value from the peak amplitude of sferics. This process is based on the fact that the peak amplitude normalized with source to observer distance is highly correlated to the Qdl calculated by the classical method using FFT analysis with the coefficient of 0.85. By these improvements, the location and Qdl of CGs down to 471 Ckm can be estimated with the uniform sensitivity across the globe.
We have applied new algorithm to analyze three months data from January 2004 to March 2004. As a result, we have obtained about 1 million events. It indicates that the detection sensitivity becomes about 10-30 times bigger than that in previous studies. This progress allows us to consider day-to-day variation of global CG activities, which has been difficult to derive with previous satellite or ground-based observations.
New algorithm also makes it possible to consider the contribution of CGs to global electric circuit (GEC). GEC is considered to be a three dimensional circuit running through the atmosphere, ionosphere and magnetosphere. In this circuit, CG plays a role to carry the charges beneath thunderstorms. NCG works as upward flow and PCG works as downward one in this circuit. The estimation of upward flow by NCG had been difficult because the number of NCG whose Qdl was large enough to detect by previous methods is few rather than that of PCG. With new algorithm, we can derive the three dimensional mapping of charge movements by CGs. It shows that strong upward flow is apparent in Maritime continent, Africa, America, and the Pacific Ocean.

Keywords: lightning, thunderstorm activity, Global Electric Circuit