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Global cloud-to-ground lightning discharge mapping with time of arrival method using ELF network data

Kozo Yamashita[1*], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hiromi Kase[1]

[1]Dept. of Geophysics, Tohoku Univ., [2]Dept. of Cosmosciences, Hokkaido Univ.

ELF (less than 3 kHz) waves radiated from lightning discharges can propagate around the world many times in the Earth-ionosphere waveguide due to its extremely low attenuation. This characteristic enables us to monitor the global activity of cloud-to-ground (CG) discharge with single or few ELF observation sites. Global observation of CGs based on ELF measurements provides essential information including polarity and charge moment (Qdl) for investigations of global scale thunderstorm activity.
The geolocating method based on direction finding of sferics, which has been used for most of the previous studies, in the frequency range of 1 - 100 Hz has rather large error, the order of 1000 km, even for the CGs with relatively large Qdl (>1000 Ckm). Also, the estimation of Qdl using the FFT analysis is sensitive for the background noise, so that meaning error becomes large for smaller events.
Here we improved the methods for the estimation of lightning position and Qdl. The time of arrival (TOA) method is applied to ELF network data for geolocation of CGs. The averaged-error is evaluated to be 676 km based on the comparison with VLF network for 1224 events, which were detected by both networks. We estimated the Qdl value from the peak amplitude of transient waveform caused by CG. This calculation 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 three months data from January 2004 to March 2004. As a result, we have obtained about 1 million events. It means 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 is difficult to derive with previous satellite or ground-based observations. This result shows that strong concentrations of CGs are apparent in not only the three main areas (Maritime continents, Africa, and America) but also the minor ones (Japan, Mediterranean, and Pacific Ocean).

Keywords: lightning, thunderstorm activity, Global Electric Circuit