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落雷規模と雷雨活動の関係
Relationship between lightning magnitudes and thunderstorm activity

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Previous studies have suggested that there is correlation between occurrence frequency of lightning and meteorological parameters, such as precipitation, radar reflectivity, and updraft of thunderstorms. However, previous studies used only the information of lightning occurrence frequency, nevertheless each lightning has a different electrical properties, such as charge moment change (CMC). CMC is a physical quantity which neutralized charge amount of lightning discharge times vertical discharge length. The negative cloud-to-ground lightning discharge (-CG) account for 90 % or more of CGs expect in winter in Japan. The CMC of most of the -CG is smaller than 100 C·km. In order to estimate the smaller CMC than 100 C·km, observation of the radiowaves in Very Low Frequency (VLF) range radiated by return stroke is required. In addition, in order to link short-term meteorological forecast and the lightning data in the future, the method of estimation of CMC in a short time with high detection efficiency is important. However, by the current lightning detection systems, which use radiowaves at a higher frequency over 100 kHz, only the peak current of stroke is estimated and the CMC cannot be derived. The purpose of this study is to establish the methods of analysis to estimate small CMC of -CG and to investigate the relationship between developing process of thunderstorm and lightning activity with information of magnitudes (CMC) of each lightning stroke. A continuous monitoring of VLF waveform in frequency range of 2 kHz — 35 kHz at three stations in Kanto region located in the range of 150 km from Tokyo, Japan, has been carried out since May 15, 2013.

The methodology to estimate peak current using waveform in VLF band, which is detectable at far distance than that in LF band was established. A new method of estimation of impulsive CMC (iCMC) with a duration of 1 ms or less without use of frequency analysis nor VLF propagation model was established. The iCMC is estimated using the duration time of electric field of groundwave identified from the VLF waveform and peak current. The detection efficiency (DE) of iCMC estimation of -CG in this study is about 72 %. The DE of VLF lightning observation system for estimation of iCMC is the highest level in the world. The relationship between iCMC and the peak current estimated from VLF data was examined. It is shown that correlation between iCMC over 20 C·km and the peak current is small (R^2 = 0.21), and correlation between iCMC less than 20 C·km and the peak current is high (R^2 = 0.69). These results suggest that iCMC cannot be estimated from the peak current for the event over 20 C·km.

Using the estimated iCMC, the relationship among a time variation of rain volume, the area size of radar echo height (nearly cloud top) more than 12 km and lightning parameters for the 3 cases was examined. The rain volume and the area size of echo height more than 12 km were calculated using the Japan Meteorological Agency (JMA) C-band radar data every 10 minutes. It is found that the absolute value of iCMC of -CG increases as occurrence frequency of -CG, the area size of the radar echo height more than 12 km and rain volume increase (i.e., with the development of thunderstorm) for the first time. It is shown that occurrence frequency of -CG shows temporal decrease in advance of the occurrence of downburst on the ground by ∼15 minutes, while the area size of radar echo height more than 12 km is continuously increasing for the first time in Japan. In addition, it is shown that -CG with iCMC smaller than 5 C·km in absolute value is dominant in the occurrence time period of the downburst. Comparing the distribution of the estimated lightning magnitudes with meteorological radar data, examples of the electrical properties of CG change according to the developing process of thunderstorm in some cases were suggested for the first time.
Keywords: lightning, charge moment change