Deducing Locations and Charge Moment Changes of Lightning Discharges by ELF Network Observations in Japan

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ABSTRACT: Recent observations of electromagnetic radiations from lightning in the ELF frequency range so-called ELF transients are recognized as a powerful tool not only to deduce the global lightning distribution but also to obtain one of the most important properties of lightning discharges such as charge moment changes (CMCs). In this paper we demonstrate the spatio-temporal distributions of lightning discharges together with CMCs around Japan by using our newly developed domestic ELF observation network. This is the first time to obtain such type of distribution by using only ELF observations in the spatial scale of Japan (a few thousands km). We found that the obtained lightning source distributions both over the Pacific Ocean and the Sea of Japan are originated from the thunderstorm active regions confirmed by other measurements such as WWLLN. Statistical properties of the charge moment changes indicate that both number and CMC of positive CGs are superior to those of negative CGs. Moreover, considerably large CMC with both polarities are identified for the CGs over the Pacific Ocean as well as those with positive polarity over the Sea of Japan. Furthermore, we are going to present updated our lightning measurement network in Japan.

INTRODUCTION

Powerful transient radiations from intensive CGFs in the Extremely Low Frequency (ELF) range can propagate significantly long distance due to a small attenuation. One of the most important electrical properties of the lightning strokes obtained from the ELF transient is a vertical charge moment change (CMC) in contrast to the peak current (*I*p),

Recent applications of ELF transient observations include the global distribution of energetic lightning by a single locating technique using the multi-component measurement [Huang et al., 1999; Hobara et al., 2007] and a large amount of CMC as a proxy of transient luminous events (TLEs) such as red sprites.

However due to relatively large locating error expected from the single locating method (typically ~few hundreds km), no detailed spatial distribution of CGFs with CMC around Japan has been obtained. Moreover, meteorological conditions for winter and summer thunderstorm activities in relation with TLEs have not been understood well.

In this paper we use the data from the ELF observation network and deduce the detailed spatio-temporal lightning distribution with CMC around Japan and Asian region. Then we study the energetic lightning properties such as seasonal and regional dependences. Moreover deduced CMC information is useful for natural disaster monitoring and mitigation due to severe weather, and also for promoting renewable energy power plant such as wind farm and solar power.

ELF TRANSIENT OBSERVATION AND DATA ANALYSIS

UEC's ELF field sites are located in Moshiri (MSR), Hokkaido and Tarumizu (TRU), Kagoshima in Japan respectively. Both sites are in the territory of Solar Terrestrial Environment Laboratory (STE) of

Nagoya University. The two horizontal magnetic waveforms are continuously recorded by a pair of induction coils with a sampling rate of 4 kHz and upper cutoff frequency of 1 kHz with a highly accurate GPS time stamp. In MSR, the vertical electric field is observed in addition to the two horizontal magnetic field components.

ELF transient waveforms observed in the two field sites were processed to locate lightning sources and corresponding source electrical properties. The transient events from the lightning sources were identified both by occurrence time and arrival direction calculated by a Goniometric method by using 2 magnetic field components. Then the lightning source locations are obtained by a conventional triangulation technique, and corresponding CMCs and discharge polarities are calculated.

RESULTS

Figs. 1(a) and 1(b) show the spatial distributions of CGFs on March 29, 2011 for the positive and negative CGFs respectively. As is seen from the figure, two active thunderstorm centers are clearly identified over the Pacific Ocean by our ELF network observations. Both positive and negative flashes have similar spatial distributions. Other typical thunderstorm center is located over Sea of Japan in March (not shown).

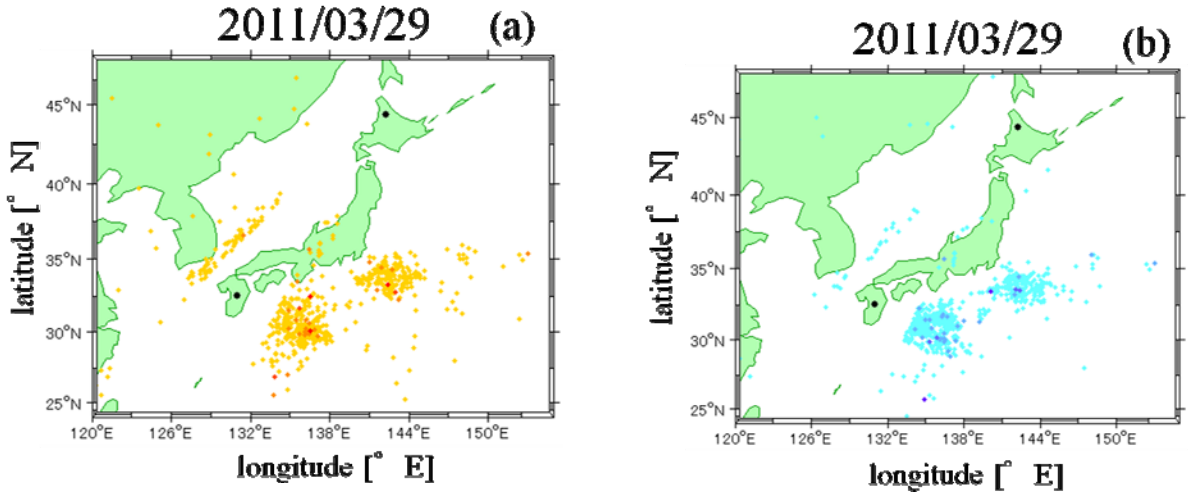
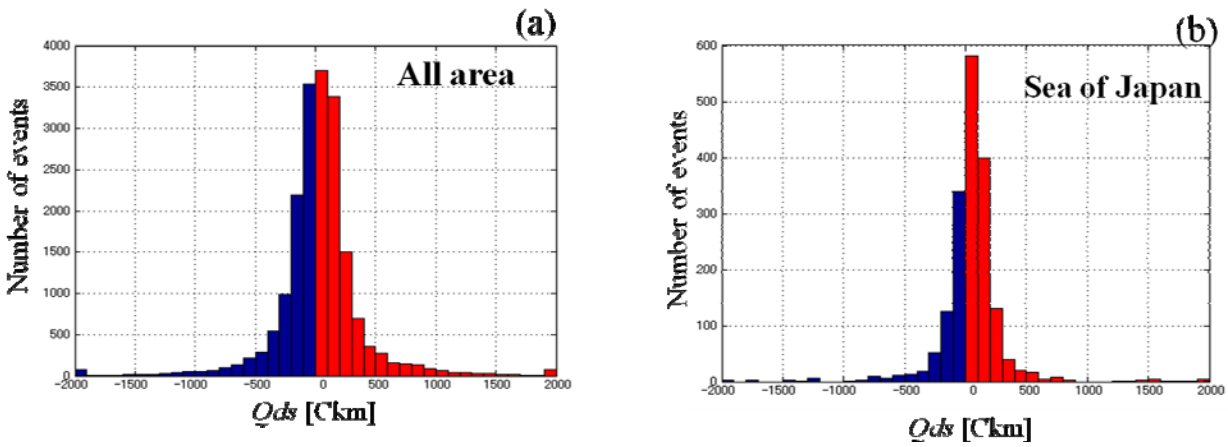


Fig. 1. CGF distributions with CMC calculated from ELF transients (1(a) : positive CGF, and 1(b) : Negative CGF).

Figs. 2 (a) to 2(c) show the histograms indicating the regional dependence of the CMC. The median value of the charge moment change from Pacific CGFs is considerably larger than that of Sea of Japan for both polarities. The number of positive GCFs is much larger than negatives over the Sea of Japan indicating typical nature of winter thunderstorm activity in Hokuriku, whilst the number of positives and negatives are comparable for CGFs over the Pacific Ocean. CMC between two regions can be due to the different meteorological conditions of thunderstorm activities (Pacific Ocean and Sea of Japan) during the early spring season.



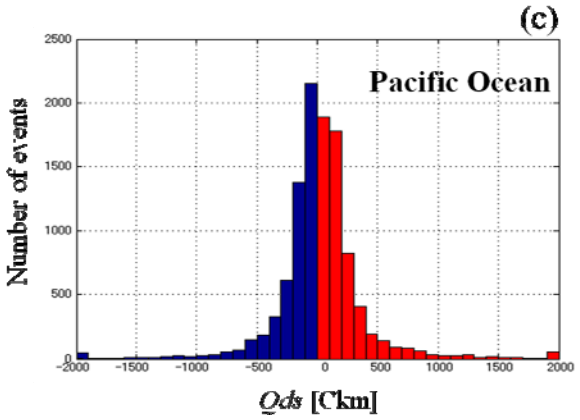


Fig. 2. Histograms indicating the number of CGF events as a function of CMC for all (2(a)), over Sea of Japan (2(b)), and over Pacific Ocean (2(c))

CONCLUSIONS

Lightning locations and associated electric charge moment change around Japan are successfully derived by our new ELF observation network (March 2011). We found that (1) most thunderstorm activities are identified over the Pacific Ocean and Sea of Japan, (2) CMC for positive strokes is much larger than negatives, (3) large numbers of positive strokes are observed over the Sea of Japan, (4) CGFs with larger CMC are predominant over the Pacific Ocean.

REFERENCES

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