Statistical Analysis of Temporal and Spatial Distribution of Cloud-to-Ground Lightning in Japan from 2002 to 2008

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1. Introduction

Today, lightning is a major cause of natural disasters to electric power facilities and transportation including aviation. In Japan, the number of the people killed by lightning is about ten per year. ¥200,000,000,000 /year (in Japan) economical losses, not include human damage. Especially, we use many digital technologies, they are extremely weak to lightning damages. (for example, computers, cell phones, etc…)

In order to figure out lightning activity, the Japan Meteorological Agency (JMA) has established a lightning location network for the past about 10 years and accumulates detailed CG lightning observation data. In this study, the temporal and spatial distributions of CG lightning in and around Japan have statistically been investigated using the lightning location data of JMA.

2. Lightning Location Data

2.1. Lightning Location System in JMA (called "LIDEN")

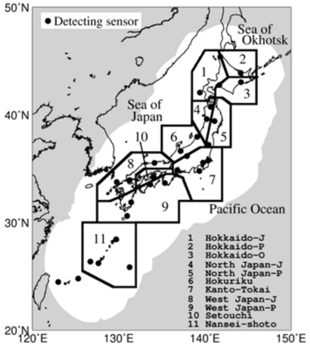

Figure 1. Detection coverage of LIDEN and sensor locations (black dot) (from 2002 to 2008).

The number [1-11] indicates each subarea. (hereafter called S-1, S-2, ..., S-10, S-11)

Observation:

Cloud-to-Ground (CG) lightning location data was observed by the Lightning Detection Network (LIDEN) operated by JMA. LIDEN consists of 30 detecting stations, covering the whole land area of Japan and the surrounding sea, and measures CG strokes in the Time of Arrival method using the LF band (LIDEN also detects Cloud-to-Cloud lightning (CC) with the VHF band, but we don't use the CC data in this study). The average distance between stations is about 200 km.

LIDEN has undergone a number of upgrades. In March 2009, lightning detection algorithm was changed to improve detection efficiency. We therefore used the CG flash data for the period from 2002 to 2008, for which data were expected to be homogeneous.

2.2. Procedure of analysis

The analysis was made after converting all the CG flash location data to grid data with a latitudinal and longitudinal spatial resolution of 0.01°, corresponding to an approximate resolution of 1km. Geographical plots are made with a spatial resolution of 0.1° due to clarify the difference of CG flash frequency. Variations of CG flash counts and positive CG flash ratio per total in land and sea area were documented. The analysis domain was divided into 11 climatological subareas (Subarea 1 is denoted by S-1), as shown in Fig.1.

3. CG density distribution

3.1. CG Spatial distribution and Seasonal variation

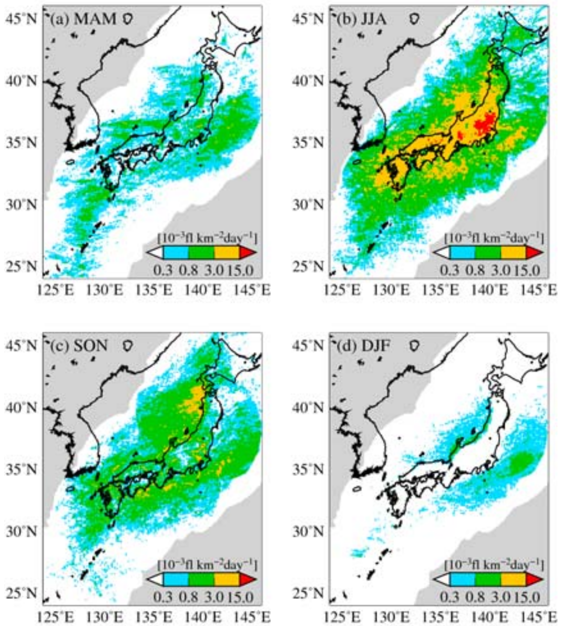

Figure 2. CG flash density distribution for 2002-2008 (0.1° × 0.1° resolution), for (a) MAM, (b) JJA, (c) SON, (d)DJF.

The seasonal variation of averaged CG flash density distribution for 2002-2008 is shown in Figure 2.

In spring (MAM), there is a region of relatively high CG flash density over the Pacific Ocean along S-5 and S-7 (Kanto-Tokai) (Figure 2a).

In summer (JJA), high CG flash density of more than 0.015 flashes km^{-2} day^{-1} is found in inland areas, especially in the eastern part of S-7 (Figure 2b). This area has the Kanto plain, which is the largest plain in Japan bounded by the Central Mountains on the western and northern sides.

In fall (SON), the frequency of CG flashes decreases over the inland area, but remains relatively high along and off the coast of S-4 (Figure 2c).

In winter (DJF), the frequency of CG flashes is high along the coast of S-6 (Hokuriku) and off the coast of S-7, whereas it is quite low in other districts of Japan (Figure 2d). It is to be noted that summertime CG flashes in inland areas of Japan are more than fifty times frequent than those in wintertime in S-6.

3.2. Regional variability in CG density and Polarity

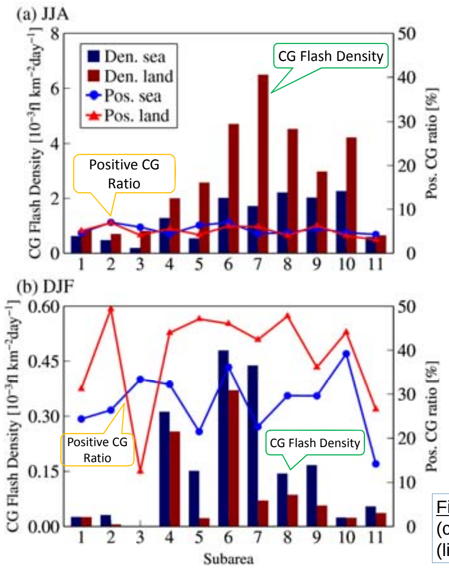

Figure 3. Regional variability of the CG flash density (columns) and the positive CG flash ratio to total CG (line) for land (red) and sea (blue), in (a) JJA and (b) DJF.

Figure 3 shows the CG flash density and the ratio of positive CG flashes to total CG flashes for over the land and sea in each area, for (a) summer and (b) winter.

For summer (Fig. 3a), CG flash density is higher over the land than over the sea in all subareas, especially highest over the land of S-7 with a value over 0.006 flashes km^{-2} day^{-1}. The ratio of positive CG flashes is less than 7% both over the land and sea.

On the other hand, wintertime CG flashes occur more over the sea than over the land in every subarea (Fig. 3b). The CG flash density over the sea is higher in S-6 and S-7 than other subareas. The frequency of CG flashes over the land is higher in regions facing the Sea of Japan (e.g., S-4; S-6) than those facing the Pacific Ocean (e.g., S-5; S-7). The ratio of positive CG flash is about 30% over the sea and about 40% over the land. A comparison of S-4 and S-5 shows that the ratio of positive CG flashes over the sea is higher in the Sea of Japan side than in the Pacific Ocean side. The same relationship is found in S-6 and S-7.

3.3. Diurnal variation, categorized by distance from the coastline

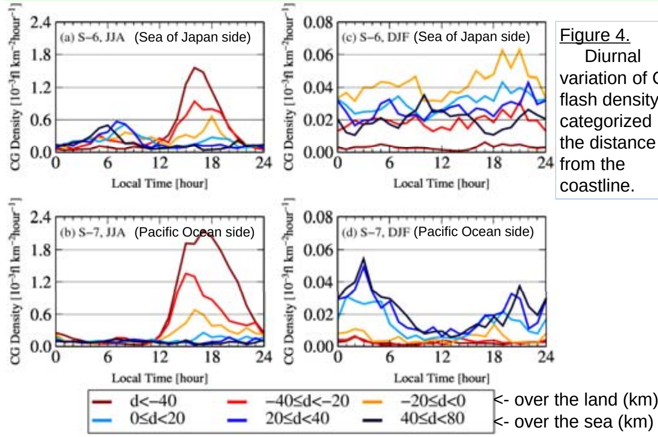

Figure 4. Diurnal variation of CG flash density categorized by the distance from the coastline.

The relationships between CG flash frequency and the distance from the coastline was examined for S-6 and S-7, where the CG flash frequency is higher than in other areas, for winter and summer. Figure 4 shows the diurnal variations of CG flash density in S-6 and S-7, divided into six categories by the distance from the coastline (d, with a positive sign for the offshore direction).

In summer (Fig. 4a and 4b), the CG flash density in the inland area (d < -40 km) has a distinct afternoon peak (15 – 18LT: UTC +9), which decreases toward the coastline. On the other hand, CG flash counts in coastal and offshore areas of S-6 have a maximum in the morning (05 - 08 LT), with a peak at earlier in offshore areas farther from the coast (Fig. 4a).

For winter (Fig. 4c and 4d), many of CG flashes in S-6 occur within 20 km from the coastline, with higher frequency over the land than over the sea, without a distinct diurnal variation. The frequency of CG flashes decreases toward inland, and is very low in the area over 40 km from the coastline. For S-7 (Fig. 4d), most of CG flashes occur over the sea, with a diurnal variation having a peak in the early morning (00 - 05 LT), while there are few CG flashes in the inland area (d < -20 km).

4. Summary and remarks

- Using lightning location data for seven years, we have captured detailed temporal and spatial features of CG flash in and around Japan, including those over the offshore area that have been outside the reach of the previous studies based on visual observation data.

- Our result for summertime CG flashes is consistent with that of previous studies on the point that CG flashes occur dominantly over the inland areas with a maximum in the afternoon [e.g., Fujibe, 1988; Kitagawa, 1989]. On the other hand, the diurnal variation over the Sea of Japan has a morning peak. It remains a challenge for future research to determine the cause of the morning maximum.
- For winter, we have revealed that the CG flashes in S-6 occur with greater frequency within 20 km the coast, especially on the land area than on the sea. Fujisawa and Kawamura (2005) found that wintertime lightning activity in the western part of S-6 area was confined within 30 km inland and 100 km offshore of the coastline, using the limited area observation in the western part of S-6 only. The distribution of the wintertime CG flash in this study is consistent with their result. The high lightning activity near the coastline may be related to the convergence of the northwest monsoon wind and land breeze causing the development of deep convection, but there is not sufficient evidence for this hypothesis.
- This study also has shown an area of high frequency in wintertime CG flashes, off the coast of S-7, for which the lightning activity has not been adequately studied yet. The effect of the warm current Kuroshio or the leeward of the Central Mountains of the Honshu Island??? Further studies are needed.