1. INTRODUCTION

Presently, it is not well understood how to best model nitrogen oxides (NOx) emissions from lightning because lightning is highly variable. Peak current, channel length, channel altitude, stroke multiplicity, and the number of flashes that occur in a particular region (i.e., flash density) all influence the amount of lightning NOx produced. Moreover, these 5 variables are not the same for ground and cloud flashes; e.g., cloud flashes normally have lower peak currents, higher altitudes, and higher flash densities than ground flashes [see (Koshak, 2009) for additional details]. Because the existing satellite observations of lightning (Fig. 1) from the Lightning Imaging Sensor-Optical Transient Detector (LIS/OTD) do not distinguish between ground and cloud flashes, which produce different amounts of NOx, it is very difficult to accurately account for the regional/global production of lightning NOx. Hence, the ability to partition the LIS/OTD lightning climatology into separate ground and cloud flash distributions would substantially benefit the atmospheric chemistry modeling community. NOx indirectly influences climate because it controls the concentration of ozone and hydroxyl radicals in the atmosphere. The importance of lightning-produced NOx is emphasized throughout the scientific literature (see for example, Hunter and others, 1998). In fact, lightning is the most important NOx source in the upper troposphere with a global production rate estimated to vary between 2 and 20 TgN/yr (Lee and others, 1997), with more recent estimates of about 6 TgN/yr (Martin and others, 2007). In this study, we introduce a new technique for retrieving the ground flash fraction in a set of N lightning observed from space and that occur within a specific altitude/longitude bin. The method is briefly described and applied to CONUS lightning that have already been partitioned into ground and cloud flashes using independent ground-based observations, in order to assess the accuracy of the retrieval method. The retrieval errors are encouragingly small.

2. LIGHTNING OPTICAL PROPERTIES

In the study by Koshak (2007) the frequency distributions of several optical properties of lightning (i.e, flash radius, flash area, flash duration, Ø of optical groups in a flash, Ø of events in a flash) as observed from space and ground observations was determined; it was found that the distributions overlapped considerably thereby making it difficult to use the space-based optical measurements to discriminate between ground and cloud flashes. However, it was also shown that these distributions are different for different ground and cloud flashes. We need to analyze the means has motivated the flash discrimination process discussed in section 3. Fig. 2 shows a sample of the flash area distribution for both ground and cloud flashes. We have extended the Koshak (2007) investigation by obtaining the distributions of the maximum Ø events in a group (MNEG) and the maximum group area (MGA). The distributions of MNEG for ground and cloud flashes are shown in Fig. 3.

3. THEORY FOR RETRIEVING GROUND FLASH FRACTION (a very brief discussion)

Consider a set of k = 1, …, n characteristics, given by (x1, x2, …, xk) for the ith observed flash from space; such a characteristic could for example be flash area, or flash radius, or MNEG. The average of the Ø characteristic for N flashes in a latitude/longitude bin is

\[ \bar{x}_N = \frac{\sum_{i=1}^{N} x_i}{N} \]

\[ \bar{x}_N = \frac{\sum_{i=1}^{N} x_i}{N} \]

\[ \bar{x}_N = \frac{\sum_{i=1}^{N} x_i}{N} \]

\[ \bar{x}_N = \frac{\sum_{i=1}^{N} x_i}{N} \]

where,

\[ \bar{x}_N = \frac{\sum_{i=1}^{N} x_i}{N} \]

We don’t know N, (the Ø of ground flashes in the bin), but one can obtain solutions in terms of the means (which are estimated using the population mean estimates in obtained from distributions like those in figures 2 & 3; i.e., we invoke the Central Limit Theorem of statistics):

\[ \alpha = \frac{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2}{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2} \]

\[ \alpha = \frac{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2}{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2} \]

\[ \alpha = \frac{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2}{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2} \]

\[ \alpha = \frac{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2}{\sum_{i=1}^{n} (x_i - \bar{x}_N)^2} \]

4. APPLICATION, RESULTS, & SUMMARY

We used National Lightning Detection Network (NLDN) data to partition 5 years of CONUS-only OTD flashes into ground and cloud flashes. We then picked 52 locations across CONUS. At each location we picked the radius of a circle that enclosed 1000 OTD flashes (see Fig. 5). The circles are colored only to help distinguish the circles for plot clarity. We then applied the retrieval equations in (4). For n > 1 we obtained good results (i.e., small retrieval errors in Ø when characteristics like flash duration and flash Ø groups were not included. Overall, our best results were obtained when we used the simple retrieval equation (α = 1) with the MNEG characteristic. The results for retrieval error % in Ø over the 52 regions averaged 0.086, or just 8.6% of the full range 0-1% of Ø (see Fig. 5 for specific values of Ø). Note in figure 5 that the value of Ø shown is the true mean value across the 52 regions; this mean value increases from left (figure 5a) to right (figure 5c) since the number of cloud flashes is intentionally depleted from left to right. In summary, the results shown here clearly indicate that reasonable retrievals of ground flash flash fraction can be obtained using CONUS when the population mean estimate of MNEG (the maximum Ø of optical events in an optical group) is used. Since MNEG is a “peak return stroke detector” parameter that does not vary significantly over CONUS, then it may not vary significantly over the globe, in which case this retrieval process would work globally.

5. REFERENCES


Koshak, W. J., OTD observations of continental US ground and cloud flashes, 15th International Conference on Atmospheric Electricity, Beijing, China, August 15-17, 2007.


Figure 1. Sample LIS/OTD lightning climatology.

Figure 2. Distributions of flash area.

Figure 3. Sample ground flash showing optical events in space and time.

Figure 4. Sample ground flash showing optical events in space and time.

Figure 5a Number of flash events (1990–1999) for all available channels (10 MHz). Figure 5b Number of flash events (2000–2008) for all available channels (10 MHz). Figure 5c Number of flash events (2000–2008) for all available channels (10 MHz).