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CLASSIFICATION OF SMALL NEGATIVE LIGHTNING REPORTS AT THE KSC-ER

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Introduction

The NASA Kennedy Space Center (KSC) and Air Force Eastern Range (ER) use data from an extensive suite of lightning sensors because the KSC-ER is located in a region that experiences a high area density of lightning flashes. This suite consists of two cloud-to-ground (CG) lightning detection networks, the Cloud-to-Ground Lightning Surveillance System (CGLSS) that is owned and operated by the KSC-ER and the U.S. National Lightning Detection Network™ (NLDN) that is owned and operated by Vaisala Inc. It also contains a 3-dimensional lightning mapping system, the Lightning Detection and Ranging (LDAR) system, that can detect intracloud as well as cloud-to-ground lightning. These systems provide warnings for ground operations and are used to insure mission safety during space launches.

For operational applications at the KSC-ER it is important to understand the performance of each lightning detection system in considerable detail. In this report we will examine a specific subset of the CGLSS stroke reports that have low values of the negative inferred peak current, I_p, i.e. values between 0 and -7 kA, and are thought to have produced a new ground contact (NGC). When possible, the NLDN and LDAR systems were used to check the CGLSS classification and to determine how many of the reported strokes were the first stroke in a flash, a subsequent stroke that produced a new ground contact (NGC), a subsequent stroke in a pre-existing channel (PEC), or a cloud pulse that the CGLSS mis-classified as a CG stroke.

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It is of scientific interest to determine the smallest lightning current that can reach the ground either in the form of a first stroke or by way of a subsequent stroke that creates a new ground contact. In Biagi et al (2007), 52 low amplitude, negative return strokes ($|I_p| \leq 10$ kA) were evaluated in southern Arizona, northern Texas, and southern Oklahoma. These authors found that 50-87% of the small NLDN reports could be classified as CG (either first or subsequent strokes) on the basis of video and waveform recordings. Low amplitude return strokes are also interesting because they are usually difficult to detect, and because they might bypass a conventional lightning protection system that relies on a particular attractive radius to prevent "shielding failure" (Golde, 1977). Small strokes also have larger location errors compared to larger events. In this study, we will use the estimated peak current provided by the CGLSS and the results of our classification to determine the minimum I_p for each category of CG stroke and its probability of occurrence. The CGLSS data are ideally suited for this analysis because of the ability of CGLSS to detect and locate accurately low-current strokes (Ward et al., this conference). Where possible, these results will also be compared to prior findings in the literature.

Instrumentation

The CGLSS is a local network that covers the KSC-ER operations area with 6 medium gain IMPACT ESP sensors[4] located 10 to 30 km apart (see Figure 1). The CGLSS processes data in the following sequence: sensors detect an electromagnetic pulse that is characteristic of a return stroke in CG lightning; the GPS time, amplitude, polarity, and direction of the stroke

[4] Manufactured by Vaisala Inc., Tucson, AZ

are transmitted via land-line communications to a network control center at the ER; information derived from multiple sensors is used to geo-locate the event and estimate the peak current (and polarity) of each stroke; and finally lightning information is forwarded to users in real-time via terrestrial data links. The CGLSS sensor locations are shown in Figure 1 (black triangles). The flash detection efficiency of the CGLSS inside the perimeter of the network is ~98% and the median location accuracy is ~250m (Boyd, et al, 2000).

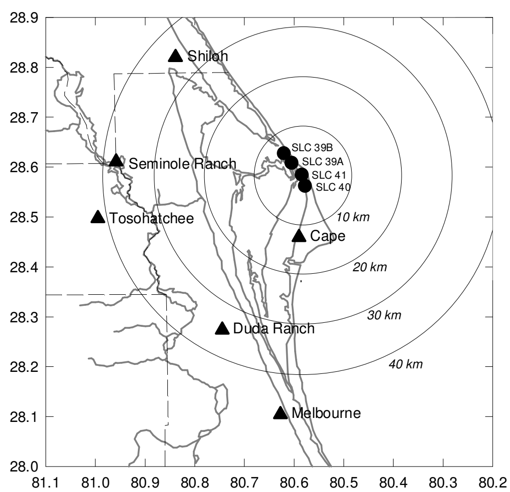

Figure 1. Locations of the CGLSS sensors (triangles) at the KSC-ER in 2006.

The NLDN is a national network of 113 IMPACT ESP sensors that are placed 200-350 km apart. Figure 2 shows the evaluation region (100 km radius) at the KSC-ER and its location relative to the 10 closest NLDN sensors (black triangles). The three closest NLDN sensors to the KSC-ER are in Palm Bay, Tampa, and Ocala, FL. The NLDN data processing steps are similar to the CGLSS, except that satellite links are used instead of land-line communications and the control center is located in Tucson, AZ. The entire process takes approximately 30-40 seconds. The NLDN flash DE is typically greater than 90%, and the median location accuracy is typically better than 500 m. Performance falls off somewhat at the boundaries of the network (Cummins et al., 2006).

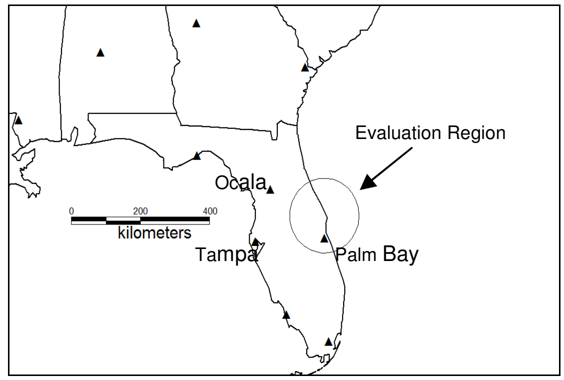

Figure 2. Evaluation region at the KSC-ER (100 km radius) and the locations of the nearest NLDN sensors.

The NLDN and CGLSS systems differ somewhat in their processing of the lightning information. Currently, the NLDN locates all detected strokes, optionally groups them into flashes, and then estimates the peak current (I_p) of each stroke by scaling the range-normalized signal strength by a factor of 0.185 (Cummins et al., 2006). The reported time is the estimated time-of-occurrence of the stroke at the stroke location.

The CGLSS on the other hand, locates the first stroke in each flash and some of the subsequent strokes that have strike locations that are more than about 0.5 km from the first-stroke location (Maier and Wilson, 1996). In the following, we will refer to both of these types of events as "CGLSS strokes." The CGLSS estimates I_p by scaling the range-normalized signal strength by a factor of 0.23. The CGLSS event time is the time that the radiated lightning waveform exceeds a fixed detection threshold at the nearest reporting sensor. Therefore, the CGLSS times can be up to ~ 200 μs after the time-of-occurrence of the NLDN strokes in the evaluation region. When the CGLSS detects more than one stroke at the same location, it reports the highest I_p of any stroke in the flash at that location.

The LDAR system is a volumetric lightning mapping system that contains 7 time-of arrival (TOA) receivers at the locations shown in Figure 3. The LDAR system has a range of about 100 km and a location accuracy of about 100m within 3 km of the central site. The LDAR system locates the sources of VHF radio impulses with a 6 MHz bandwidth centered at 66 MHz. VHF radiation is thought to be produced by lightning stepped-leaders and other processes associated with the breakdown of virgin air. The sensor antennas are equally sensitive to both horizontally and vertically polarized signals. The LDAR system has a flash detection efficiency that is close to 100% and a false alarm rate that is less than 1% (Maier et al, 1995). For a more detailed description of the LDAR system see Lennon and Maier (1991), Maier et al. (1995), and Boccippio et al. (2000a,b).

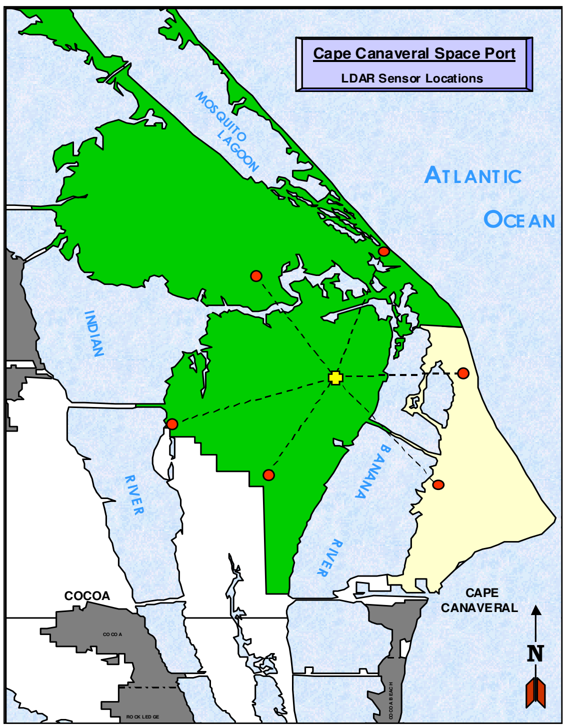

Figure 3. Location of the LDAR sensors (red) and central station (yellow) at the KSC-ER.

In addition to the LDAR data, we also examined time-correlated, electric field waveforms that were recorded by the Los Alamos Sferic Array (LASA) in central Florida. The LASA records broadband electromagnetic pulses from lightning in support of the radio frequency (RF) and optical observations of the Fast On-orbit Recording of Transient Events (FORTE) satellite (Smith et al., 2002, Shao et al., 2006)). The Florida array contains 8 stations that are connected to the internet, and the operation, data retrieval, and data processing is done via the internet at Los Alamos, NM (Shao et al., 2006). For this study, the closest LASA sensors were located at Daytona Beach, Tampa, and Jacksonville, FL. Of these three sites, only Tampa was operational during the summer of 2006, and the Tampa site is located about 200km west of the KSC-ER. Because of the large distance from the KSC-ER, many of the small CGLSS strokes were below the detection threshold (~ 0.5 V/m) of the LASA sensor in Tampa.

Methods

Data and Event Selection Process

The CGLSS data were provided by Computer Sciences Raytheon and delivered in a standard APA output format. They were then reformatted to show only the relevant stroke information that was required for the LDAR and NLDN comparisons. The data fields contained the GPS date and time in ms, latitude and longitude in degrees, multiplicity (number of strokes in the flash), the estimated peak current (in kA), the chi-square value at the optimum location, and the dimensions of the semi-major and semi-minor axes (in nm) of a 39% confidence region around the optimal location. The chi-square value is a normalized measure of "agreement" among all the reporting sensors. Ideally, the chi-square distribution has mean and median values equal to unity, but values between 0 and 3 are considered to be "good," and values between 3 and 10 are "acceptable." The semi-major and semi-minor axes characterize the dimensions of the confidence region for a given probability value, and are based on a two-dimensional (spatial) Gaussian distribution of location errors that have been inferred from knowledge of the measurement errors and the geometry of the sensor locations (see Vaisala Technical Note, 2004 for further details). The 39% confidence region used in the CGLSS corresponds to a 2-dimensional, one-standard-deviation location error (P = 0.39).

The NLDN data were provided by Vaisala Inc. in Tucson AZ, and consisted of the GPS date and time (in ms), the latitude and longitude (in degrees) of the lightning location, the estimated peak current (in kA), the semi-major axis (in km) and orientation of the error ellipse, the chi-square value of the location, and the number of sensors reporting the stroke (NSR). The confidence region for the error ellipse in the NLDN data set is for the median location error (P = 0.50).

The LDAR data were provided by the KSC in binary form and then were reprocessed into text form by Vaisala Inc. These data consisted of the GPS date and time; the latitude, longitude, and altitude (in meters) of the VHF sources.

All lightning events reported by the CGLSS in the summer of 2006 (June 1 to August 31) were examined and then all data for negative strokes within 20 km of an origin at the LDAR central site (see Figure 3) were entered into a spreadsheet. Next, all CGLSS events that had a low amplitude ($|I_p| < 7$kA) and were separated from any previous CGLSS stroke by more than 0.5 seconds in time or 2 km in space were selected for further analysis. Using these selection criteria, a total of 237 low amplitude "candidate" first strokes (and subsequent strokes producing new ground-contacts) were selected out of 4967 flashes. Within this sample of low amplitude stroke reports, 114 were detected by at least two of the three lightning detection systems (CGLSS, NLDN, and LDAR), and these events were then analyzed in more detail.

Figure 4 shows a scattergram of the relationship between the NLDN I_p values (x-axis) and the corresponding CGLSS I_p values (y-axis) for 3250 time-correlated strokes that were detected on July 23, 2006. This figure also shows the linear regression (slope = 1.13 with zero intercept) and R^2 value (0.95). Note that the I_p values from both detection systems are highly correlated over a range of - 150 kA to + 150 kA, and that the largest scatter is for extreme values of I_p (both maximum and minimum). On average, the CGLSS I_p values are slightly higher than the NLDN values. This difference was expected because each system uses a slightly different scaling factor to convert the range-normalized peak field to the estimated peak current (0.23 for the CGLSS and 0.185 for the NLDN). The scaling difference predicts a slope of 1.24 (0.23/0.185), which is within 10% of the empirically-derived slope shown in Figure 4 (1.13). The remaining difference is likely associated with limitations in the propagation models (Cummins et al, 1998), because the propagation paths to NLDN sensors are roughly 2 to 3 times larger than for the CGLSS sensors.

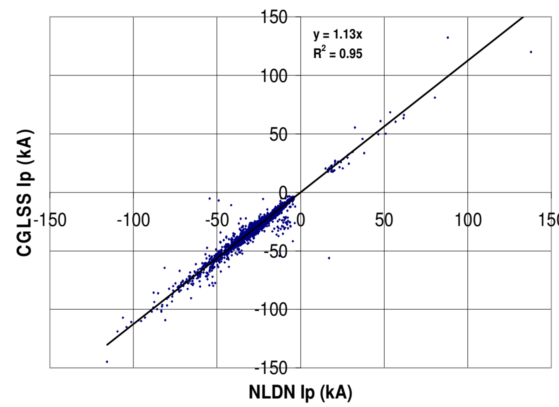

Figure 4. CGLSS I_p values vs. NLDN I_p values for 3294 lightning strokes that were reported on July 23, 2006.

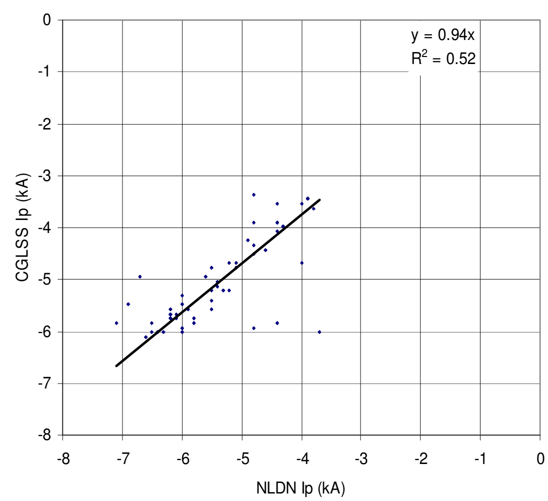

Figure 5. CGLSS I_p values vs. NLDN I_p values for the 67 time-correlated negative low amplitude strokes ($|I_p|$<7kA) that were detected by both networks.

Figure 5 shows a scattergram of the relationship between the NLDN I_p values (x-axis) and the CGLSS I_p values (y-axis) for the 67 negative low amplitude strokes (i.e. $|I_p|$<7kA) that were detected by both the CLGSS and NLDN. Here, all CGLSS I_p values have been divided by a factor of 1.13 to correct for the scaling difference. This figure also shows the slope of the linear regression is 0.94, with zero intercept, and the R^2 value is 0.52.

Data Processing

In order to identify coincident events in the CGLSS and LDAR datasets, a one-second interval of LDAR data that included each CGLSS event was plotted as a function of altitude and time as shown in Figure 6a. Here and in figures 7a to 10a to follow, the blue dots show the altitudes and times of the LDAR sources and the colored symbols show the times that the CGLSS and NLDN systems reported strokes. One second of LDAR data were plotted because the duration of a lightning flash at the KSC-ER is usually less than one second (McNamara, 2002). In the LDAR record, progression of the stepped leader toward ground is typically characterized by a "line" of LDAR sources moving from high to lower altitudes as time advances, such as the sources preceding the two CGLSS strokes in Figure 6a. Large strokes usually have a better-defined line of sources moving toward the ground, and small strokes may only have one or two sources at low altitudes. The remaining LDAR sources are produced by branches or new channel development inside the cloud. The CGLSS stroke-of-interest (SoI) in Fig. 6a is shown as a red square at a height of 0 m. Any other CGLSS or NLDN strokes in the interval of interest, and within a distance of 20 km, are also included in the plot with the labeled symbols. If the NLDN recorded the SoI, that event is plotted with an asterisk directly above the CGLSS event at a height of 2000 m. Figure 6a is an example of the LDAR, CGLSS and NLDN data associated with a -3.5 kA SoI that was a subsequent stroke that produced a new ground contact on July 7, 2006.

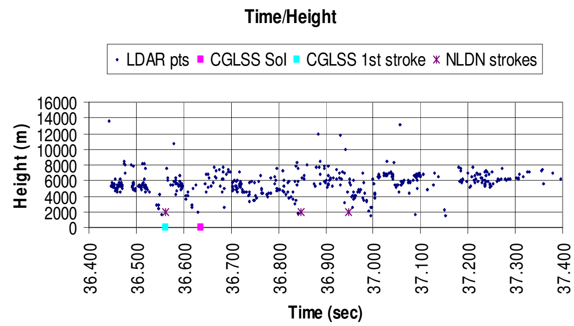

Figure 6a. Heights of LDAR sources as a function of time for a subsequent stroke that that produced a new ground contact (NGC) at 18:54:36.6370 UTC and had an I_p of -3.5 kA.

Figure 6b shows a plan view of the x-y positions of the same LDAR sources and the CGLSS and NLDN stroke locations that are shown in Figure 6a. Note that the subsequent SoI struck about 9 km southwest of the first stroke, and that the 3rd and 4th strokes (located by the NLDN) are much closer to the location of the first stroke. Therefore this was a multi-stroke negative flash, where the second stroke struck some distance from the first stroke, and the later strokes were within or close to the channel established by the first stroke (Valine and Krider, 2002).

Two aspects of Figures 6 indicate that the SoI was a subsequent stroke that produced a new ground contact. Figure 6a shows evidence of a stepped leader just prior to the SoI at 18:54:36.637 UTC. This interpretation is supported by the large spatial separation between the SoI and all other strokes in Figure 6b. In a case such as this, knowledge of the probable location errors derived from the error ellipse parameters was also used to determine if the difference in the stroke locations could be due to random errors in the lightning detection systems.

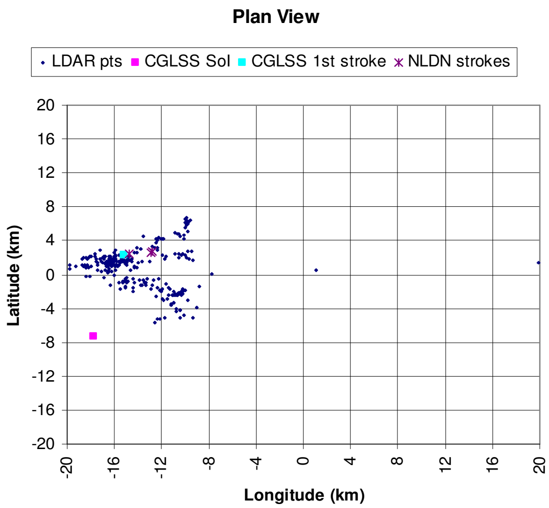

Figure 6b. Plan View of the LDAR sources and strokes shown in Figure 6a.

Figure 6c shows the LASA electric field waveform (circled) that was detected at the Tampa site and that was produced by the SoI. On careful examination, this waveform had the attributes of a return stroke that produced a new ground contact; therefore, the SoI was classified as a subsequent stroke that produced a NGC.

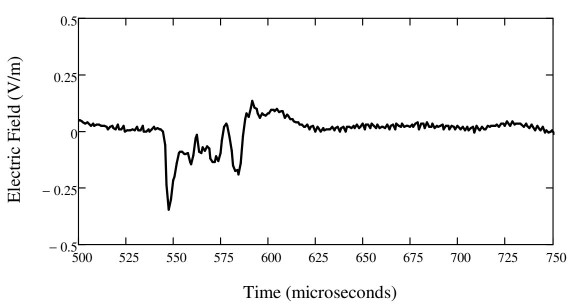

Figure 6c. The LASA waveform for a -3.5 kA subsequent stroke that produced a NGC and is shown in figures 6a and 6b. Time axis is relative to 18:54:36.637 UTC. Electric field is not calibrated.

This approach to stroke classification was refined and tested on several other flashes that had LASA waveforms, in order to gain confidence that a proper classification could be assigned without the aid of the LASA waveforms (i.e. on low-I_p events that were not detected by the LASA).

Results

Classification

A table listing all 114 small CGLSS strokes that were analyzed in detail and their final classifications can be found in the Appendix. Data for 9 of these events were too ambiguous to be classified. Representative examples of each of the four classes of events will now be discussed in detail.

21 strokes (18%) in our dataset were determined to be the first stroke in a CG flash. Characteristics of the storm cells (growing, developed, or decaying) that were associated with all 21 of these strokes were tabulated and compared to determine if there was a tendency for small storms to produce small strokes, and none was found. 10 events were associated with large, well developed storms and 11 occurred in small, developing or decaying cells.

Figure 7 shows a -4.4kA first stroke that occurred at 19:46:53.9177 UTC on July 17, 2006. The time/height plot in Figure 7a showed that one or more attempted leaders developed before the leader that contacted ground at 53.917 seconds. The minimum chi-square values for the CGLSS and NLDN locations were both good (0.7 and 2.0, respectively) and the median semi-major axis (SMA) of the CGLSS and NLDN ellipses were 0.18 nm and 1.7 km, respectively. A larger SMA for the NLDN location was expected because the NLDN sensor spacing is roughly 10 times larger than in the CGLSS, and low-current strokes are typically seen by only 2 or 3 sensors. The location difference in Figure 7b is about 3.5 km, but this difference is reasonable given the large SMA of the NLDN. The nearest previous flash was 226 km away and was 3.736 seconds before the discharge shown in Figure 7.

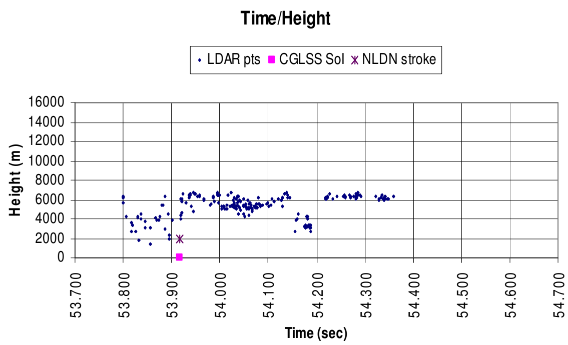

Figure 7a. Heights of LDAR sources as a function of time for a first stroke at 19:46:53.9177 UTC with an I_p of -4.4 kA.

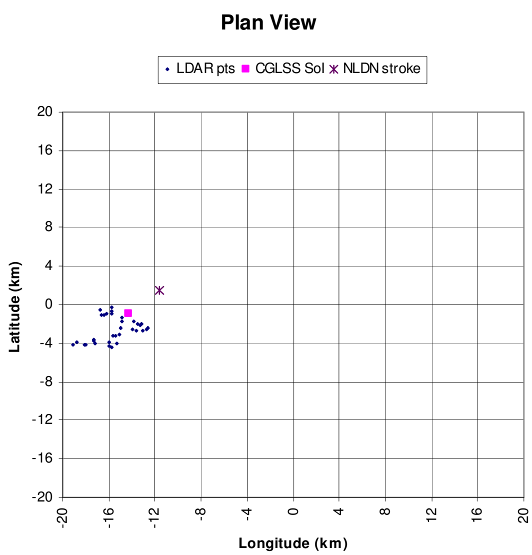

Figure 7b. Plan View of the LDAR sources and the CGLSS and NLDN stroke locations for the event shown in Figure 7a.

41 (36%) of the reports in our dataset were determined to be for subsequent strokes in a flash that produced a new ground contact (NGC). Figure 8 shows a -6.8 kA subsequent stroke that occurred at 21:18:39.4184 UTC on August 23, 2006 and produced a NCG. The LDAR time/height plot in Figure 8a shows a clear leader propagating to ground before the first stroke and before the SoI. The NLDN detected the SoI and had an I_p of -6.4 kA. The minimum chi-square values for the CGLSS and NLDN SoI locations were both good (0.3 and 1.4, respectively) and the SMA of the CGLSS and NLDN ellipses were 0.1nm and 2.8 km, respectively. The probable classification as a NGC is clear in Figure 8b because the SoI occurred 3.38 km from the first stroke, the expected location errors are small, and there are a few low-altitude LDAR sources just prior to the return stroke.

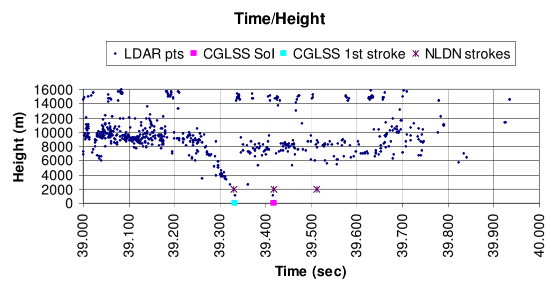

Figure 8a. Heights of LDAR sources as a function of time for a subsequent stroke that produced a NGC at 21:18:39.4184 UTC with an I_p of -6.8 kA.

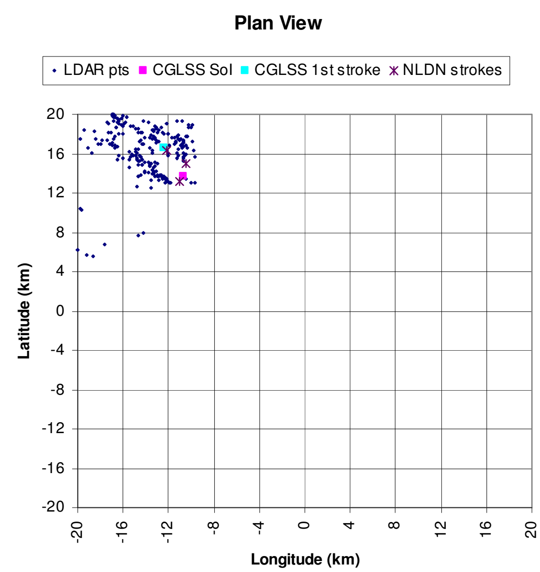

Figure 8b. Plan View of the LDAR sources and stroke locations shown in Figure 8a.

16 (14%) strokes in our dataset were determined to be subsequent strokes that remained in or close to a pre-existing channel (PEC). Figure 9 shows the LDAR sources and location of a -4.3 kA stroke that occurred at 19:11:53.6763 UTC on July 7, 2006 that we classified as a PEC. Like Figure 8a, the

time/height plot in Figure 9a shows a clear leader propagating to ground before the first stroke and no new leader pulses before the SoI. Although the NLDN detected the first stroke, it did not detect the SoI. The CGLSS chi-square value was high but still acceptable (9.3), and the CGLSS SMA was only 0.60 nm. The classification as a PEC is supported by the lack of leader pulses, high chi-square, and the short time-interval between the first stroke and SoI. The first stroke occurred 27 ms beforehand and had an I_p of -10.1 kA.

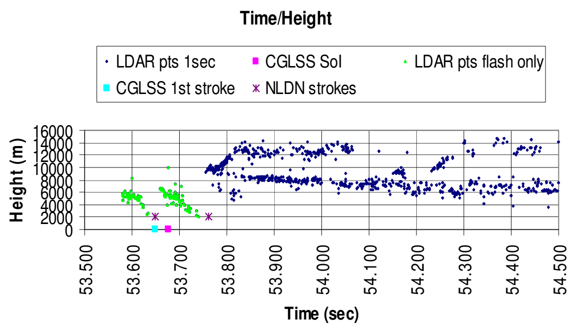

Figure 9a. Heights of LDAR sources as a function of time for a subsequent stroke in a flash that remained in a pre-existing channel (PEC) at 19:11:53.6763 UTC with an I_p of -4.3 kA.

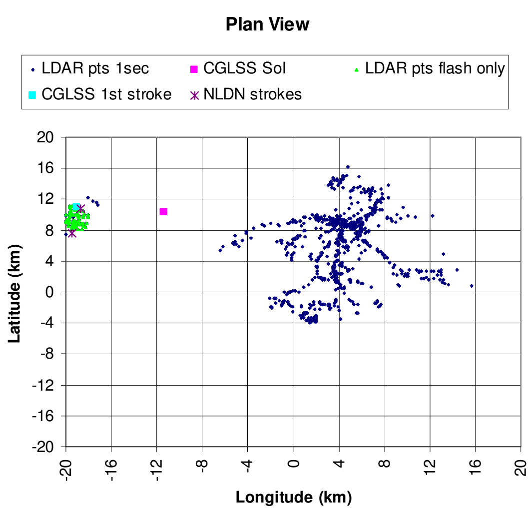

Figure 9b. Plan View of the LDAR sources and strokes shown in Figure 9a.

27 (24%) of the stroke reports in our dataset were determined to be from pulses in cloud discharges. Figure 10 shows a -4.8 kA cloud pulse (equivalent estimated peak current) that occurred at 18:46:39.5329 UTC on July 7, 2006. The time/height plot in Figure 10a shows that the LDAR sources have the characteristics of a cloud pulse. A cloud discharge often occurs at the same time as a rapid upward leader forms in the cloud. This is evident in Figure 10 when the LDAR sources jump between 8,000m and 14,000m at the time of the CGLSS report. In this case, the CGLSS could not determine a chi-square value because the location was determined by two angles, and the SMA was 0.37 nm. The NLDN network did not report this event and the nearest CGLSS stroke was 40.4 km away and occurred 06.641 sec beforehand.

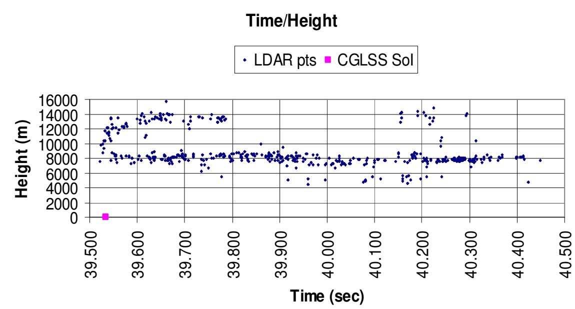

Figure 10a. Heights of LDAR sources as a function of time for a cloud pulse that occurred at 18:46:39.5329 UTC and had an I_p of -4.8 kA.

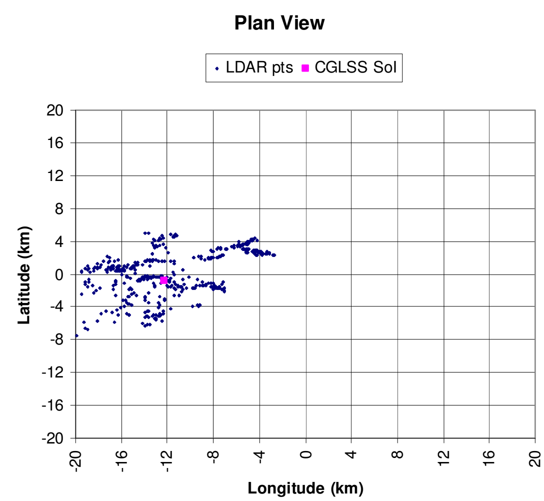

Figure 10b. Plan View of the LDAR sources shown in Figure 10a.

Minimum Inferred Peak Current

Of the 95 small strokes that were reported by the CGLSS (and LDAR) and could be classified, -3.3 kA was the lowest I_p value for a first stroke and -2.2 kA was the lowest I_p value for a subsequent stroke that produced a new ground contact. Table 1 in the Appendix shows a complete listing of all results.

Figure 11 shows histograms of the I_p values for each type of ground stroke. The maroon bars are values for first strokes, the yellow bars are strokes producing a NGC, and the green bars are strokes that remained in a PEC. It is important to note that 15 (19%) of the 78 CG strokes in our dataset had an $|I_p|$ less than 4.0 kA and, of these, 9 were new ground contacts, and only one, with an I_p of -3.3 kA, was a first stroke. 19 strokes were between -4.0 kA and -5.0 kA and of these 5 were first strokes.

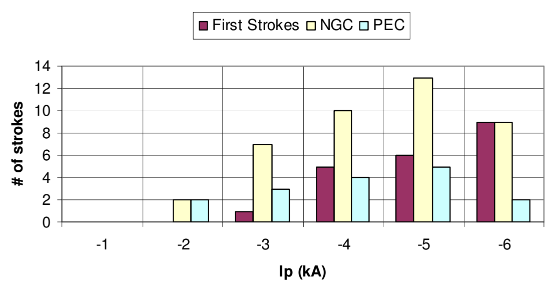

Figure 11. Distributions of the I_p values for low amplitude first strokes, strokes that produced a NGC, and strokes that remained in a PEC.

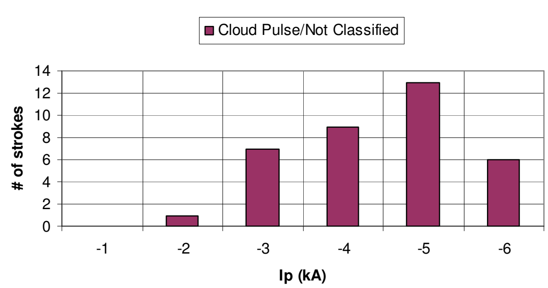

Figure 12. Distribution of I_p values for 27 misclassified cloud pulses and 9 events that could not be classified.

Figure 12 shows a distribution similar to Figure 11, but for the 27 cloud pulses that the CGLSS misclassified as a CG stroke and the 9 events that we were not able to classify at all.

From these results, we conclude that the CGLSS system at the KSC-ER can and does detect I_p values as small as -4 kA in first strokes and as small as -3 kA in subsequent strokes that produce a new ground contact, although the frequency-of-occurrence is quite low.

Discussion and Conclusions

Using the CGLSS network at the KSC-ER as the reference and the NLDN, LDAR, and LASA systems for comparison, we have analyzed 114 small negative stroke reports (i.e. strokes with an $|I_p| < 7$ kA) that were within 20 km of the LDAR central site to determine the type of lightning process that produced these reports during the summer of 2006. 21 (18%) of the 114 reports were determined to be for first strokes with no preference for production during small, large, or decaying storms. 57 (50%) of the stroke reports were produced by subsequent strokes that either created a new ground contact or remained in a preexisting channel. Overall, we found that 78 (68%) of the small negative reports at the KSC-ER were produced by cloud-to-ground strokes. These findings are in good agreement with the results of Biagi et al. (2007) in AZ-TX-OK, except that Biagi et al. used a criterion of an $|I_p| \leq 10$ kA and found that 50-87% of the small NLDN reports could be classified as CG (either first or subsequent strokes) on the basis of video and waveform recordings. The remaining 36 reports (32%) in our dataset were likely cloud pulses or events that we were simply unable to classify. This work shows that the current method used by the CGLSS to identify new ground strike points is somewhat flawed, and that about 1 out of 7 reports of new ground contacts actually occurred in pre-existing channels. A new CGLSS data processing system (the sensors will remain the same) is currently being certified for operational us at KSC-ER and should be operational by late January. This system is expected to address the strike-point problem by computing locations for all reported strokes.

The lowest I_p value for a first stroke was -3.2 kA, and the lowest value for a subsequent stroke was -2.2 kA. These I_p values agree with the findings of Rakov (1985) who found a minimum I_p threshold of 2 kA for all negative CG strokes. When grouped into 1 kA bins (Figure 11), the number of low amplitude first strokes increased steadily between -3.2 kA and -7kA. These findings are in agreement with existing literature which states that first strokes initiated by downward-propagating leaders tend to have larger peak currents than subsequent strokes (Berger et al., 1975). Only one first stroke had an $|I_p| < 4$ kA but the number increased to 5 for $|I_p| < 5$ kA. This finding is generally consistent with direct measurements of currents during (downward) strikes to instrumented towers that show a minimum current of -5kA during first strokes (Berger et al., 1975).

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Appendix

Table 1.

Date	Time	Ip	First Stroke	NGC	PEC	Cloud Pulse	unknown
7/7/2006	18:15:55.6837	-5				1	
7/7/2006	18:24:19.1153	-5.5				1	
7/7/2006	18:35:14.6537	-6.6	1				
7/7/2006	18:46:39.5329	-4.8				1	
7/7/2006	18:48:41.2102	-5.3		1			
7/7/2006	18:50:19.6226	-5				1	
7/7/2006	18:50:35.4982	-3.2					1
7/7/2006	18:54:36.6370	-3.5		1			
7/7/2006	18:54:48.6451	-5.7			1		
7/7/2006	18:56:35.3076	-5.6		1			
7/7/2006	18:59:51.3075	-4.5				1	
7/7/2006	19:03:13.1047	-6.4				1	
7/7/2006	19:03:27.8055	-3.5				1	
7/7/2006	19:03:56.2040	-6.3				1	
7/7/2006	19:05:17.0353	-4.7					1
7/7/2006	19:09:33.6853	-5.4				1	
7/7/2006	19:10:54.6326	-5.2		1			
7/7/2006	19:11:53.6763	-4.3			1		
7/7/2006	19:14:20.6099	-6.4				1	
7/7/2006	19:16:03.1608	-3.6		1			
7/7/2006	19:20:49.0701	-4.3	1				
7/7/2006	19:23:47.8382	-5.7	1				
7/7/2006	19:28:41.1213	-4.5				1	
7/7/2006	19:31:28.6916	-5			1		
7/7/2006	19:31:28.9872	-5.9	1				
7/7/2006	19:39:59.7074	-6.1				1	
7/7/2006	20:38:21.8335	-5.1				1	
7/17/2006	19:34:30.4315	-4.4		1			
7/17/2006	19:35:56.0584	-5			1		
7/17/2006	19:46:53.9177	-4.4	1				
7/17/2006	20:37:16.6092	-4.3	1				
7/17/2006	20:47:09.7348	-4.5	1				
7/17/2006	20:57:38.4864	-6.6	1				
7/18/2006	17:18:39.2573	-3.7			1		
7/18/2006	17:25:01.3361	-6.2		1			
7/18/2006	18:37:35.4248	-6.5	1				
7/18/2006	18:37:35.4642	-5.3	1				
7/23/2006	21:03:06.3785	-5.6		1			
7/23/2006	21:03:29.4811	-4.7		1			
7/23/2006	21:09:57.0712	-6.8			1		
7/23/2006	21:13:10.0538	-4.7		1			
7/23/2006	21:13:39.1120	-3.9		1			
7/23/2006	21:16:48.4687	-3.2					1
7/23/2006	21:21:23.4781	-4.6				1	
7/23/2006	21:21:42.6290	-6.2		1			
7/23/2006	21:21:53.0946	-5.7					1
7/23/2006	21:23:10.9802	-3.1			1		
7/23/2006	21:25:37.8282	-6.5			1		
7/23/2006	21:32:35.6353	-3.3	1				
7/23/2006	21:36:08.1579	-4.2			1		
7/23/2006	21:38:56.8712	-5.1					1
7/23/2006	21:46:12.3028	-4				1	
7/23/2006	21:59:26.1814	-6	1				
7/24/2006	19:51:47.6298	-6.6	1				
7/24/2006	19:54:34.3563	-4.7		1			
7/24/2006	19:59:43.6290	-4.3					1
7/24/2006	20:02:32.5285	-6.6		1			

Table 1 cont.

7/24/2006	20:05:49.0640	-5.7	1				
7/24/2006	20:12:44.0091	-5.8		1			
7/24/2006	20:14:58.0477	-3.7					1
7/24/2006	20:21:09.4709	-3.6		1			
7/24/2006	20:22:38.2109	-2.7			1		
7/24/2006	20:27:51.6043	-6.6		1			
7/31/2006	03:36:46.9772	-4.6			1		
7/31/2006	03:38:07.0818	-3.1				1	
7/31/2006	03:53:52.2343	-5				1	
7/31/2006	03:58:36.1581	-4.6		1			
7/31/2006	04:00:02.2818	-5.7	1				
7/31/2006	04:02:55.4583	-5.4			1		
7/31/2006	04:11:47.9123	-5.3			1		
7/31/2006	04:22:22.7304	-5.8		1			
8/23/2006	21:00:35.4450	-5.7		1			
8/23/2006	21:04:54.6026	-5.1		1			
8/23/2006	21:06:07.7543	-5.4		1			
8/23/2006	21:07:08.8205	-3.7			1		
8/23/2006	21:09:01.4893	-6.3				1	
8/23/2006	21:11:50.2856	-2.5			1		
8/23/2006	21:13:24.3781	-4		1			
8/23/2006	21:14:52.0391	-6.8		1			
8/23/2006	21:18:39.4184	-6.8		1			
8/23/2006	21:24:29.6247	-3.3		1			
8/23/2006	21:27:26.9475	-2.2		1			
8/23/2006	21:30:18.8479	-5.7		1			
8/23/2006	21:32:17.8209	-3.4				1	
8/23/2006	21:32:23.7410	-3.3		1			
8/23/2006	21:33:51.2705	-2.9				1	
8/23/2006	21:34:48.6330	-6.2				1	
8/23/2006	21:35:47.3809	-5.8				1	
8/23/2006	21:37:04.1037	-5.4		1			
8/23/2006	21:38:50.5521	-6.4		1			
8/23/2006	21:39:20.8081	-4.9				1	
8/23/2006	21:42:39.9120	-6.6		1			
8/23/2006	21:46:14.9026	-4.5				1	
8/23/2006	21:57:23.3923	-3.3		1			
8/23/2006	21:59:51.8961	-3.6				1	
8/23/2006	21:59:58.4188	-4.6			1		
8/23/2006	22:00:31.1009	-2.9		1			
8/23/2006	22:05:41.5598	-4.5		1			
8/23/2006	22:08:22.5453	-4.2		1			
8/23/2006	22:09:22.7297	-5.4					1
8/23/2006	22:11:26.1130	-5.5		1			
8/23/2006	22:13:17.5709	-4.8		1			
8/23/2006	22:20:36.2522	-6.6	1				
8/23/2006	22:20:36.3703	-6	1				
8/23/2006	22:25:23.0534	-4.2		1			
8/23/2006	21:34:24.3374	-5.2					1
8/26/2006	19:17:25.5023	-6.6	1				
8/26/2006	19:19:07.7613	-5.5				1	
8/26/2006	19:21:55.3174	-6.8	1				
8/26/2006	19:22:40.0868	-6.7		1			
8/26/2006	19:30:08.6249	-5				1	
8/26/2006	19:52:39.2567	-5.1	1				
8/26/2006	19:54:07.8857	-5.8		1			
8/26/2006	20:57:38.7088	-4.8	1				
totals			21	41	16	27	9