P7.7

A CLIMATOLOGICAL STUDY OF CLOUD TO GROUND LIGHTNING STRIKES IN THE VICINITY OF KENNEDY SPACE CENTER, FLORIDA

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1. Introduction

Lightning activity in the Kennedy Space Center (KSC) area is monitored continuously by the Cloud to Ground Lightning Surveillance System (CGLSS), which has been in operation since 1990. The system consists of six independent and geographically dispersed lightning detection and direction sensors, a centralized strike position analyzer, and a networked data display. The position analyzer and the data display are collocated in the Range Operations Command Center (ROCC) at Cape Canaveral Air Force Station. The locations of the six sensors, along with the ROCC, are shown in Figure 1. Also shown in Figure 1 is the shuttle launch pad LP39A, which is used as a convenient point of reference for KSC. The current results are then strictly applicable to Shuttle pad and launch operations. However, due to general consistency of the geographical distributions of strikes in the overall region, other areas of KSC should expect similar distributions near strikes over time. Hence the current study is also of interest to other current or future vehicles that do or will launch out of KSC. A ring of 32 km radius, centered on LP39A, is also shown in Figure 1. Only lightning strikes that occurred within this circle are considered in the following analysis. A detailed description of the CGLSS hardware, system capabilities, and operational limitations can be found in the CGLSS Instrumentation Handbook, which is available online at http://www-sdd.fsl.noaa.gov/RSA/cglss/CGLSS_inst_handbook.pdf.

The collected CGLSS data is operationally archived for the ongoing period from January 1, 1990 to the present. The data is stored in tabular ASCII format, and is available online at ftp://trmm.ksc.nasa.gov/midds/LLP/. After obtaining all data for the 10-year Period of Record (POR, January 1, 1993 to December 31, 2002), a database subset was developed consisting of all lightning strikes that occurred within 32 km of KSC. For convenience, LP39A was used as a specific positional surrogate for KSC. The original inclusive database contains in excess of 1.5 million lightning strikes. The subset database contains 173039 individual strikes.

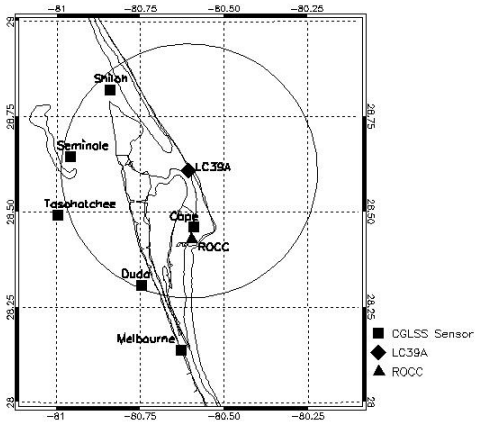

Figure 1. Map of the KSC area showing locations of the CGLSS sensors and the ROCC, along with LP39A. Also shown is a circle of 32-km radius, centered on LP39A.

2. RESULTS

A histogram of lightning strike intensities (in kA) was produced for all strikes in the subset database, for the entire POR, as shown in Figure 2. The mean magnitude of all strikes was 26.0 kA with a standard deviation of 20.2 kA. In Figure 2, the y-axis is scaled logarithmically to enhance detail at low occurrence values.

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Figures 3-12 show similar histograms of strike intensities for each individual year in the POR. Figures 13-24 show histograms of strike intensities for each month, including all strikes that occurred during that month for all years in the POR.

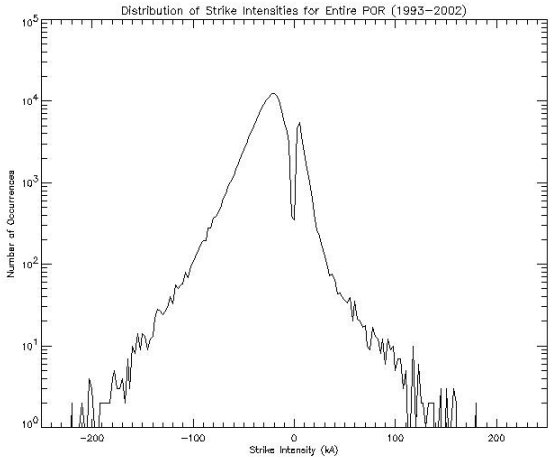

Figure 2. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for the entire POR, from January 1, 1993 to December 31, 2002.

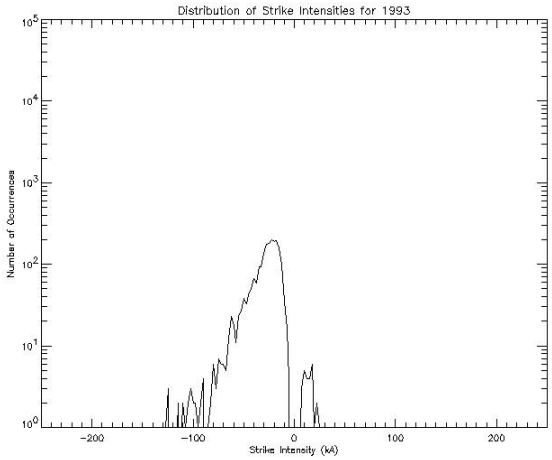

Figure 3. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1993.

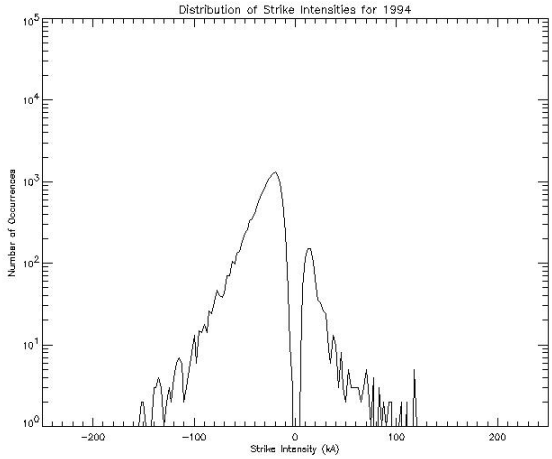

Figure 4. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1994.

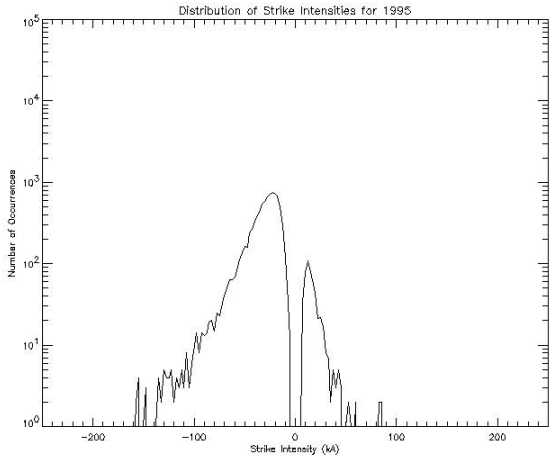

Figure 5. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1995.

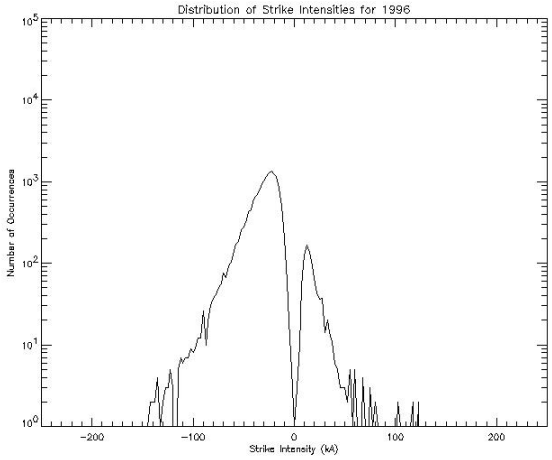

Figure 6. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1996.

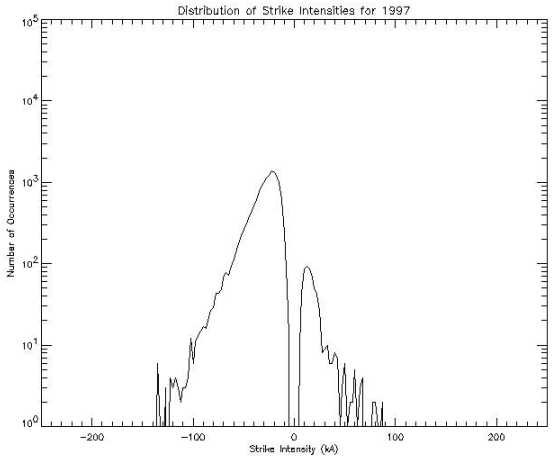

Figure 7. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1997.

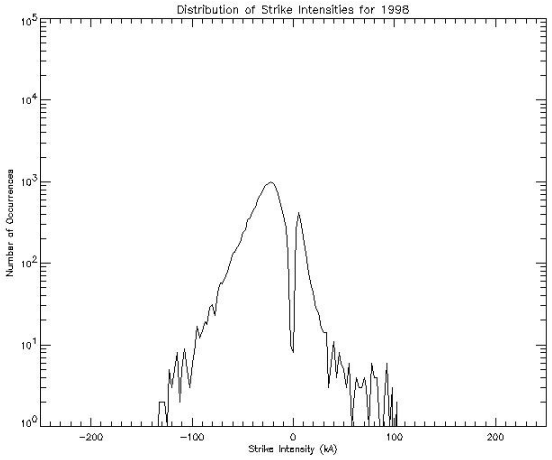

Figure 8. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1998.

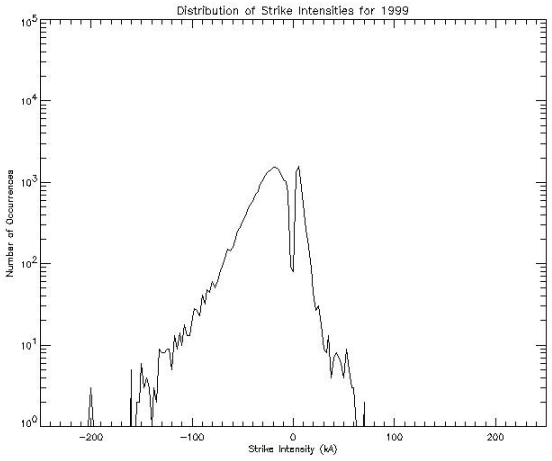

Figure 9. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 1999.

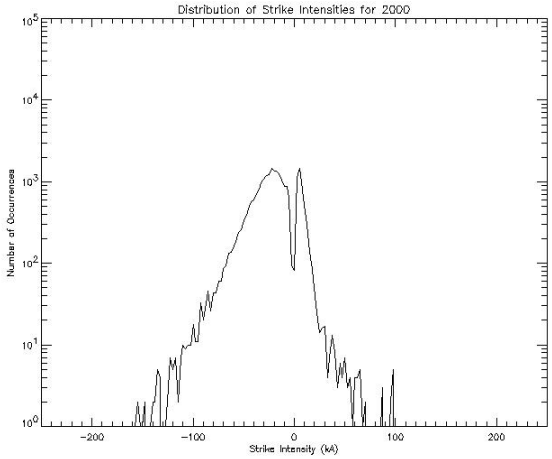

Figure 10. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 2000.

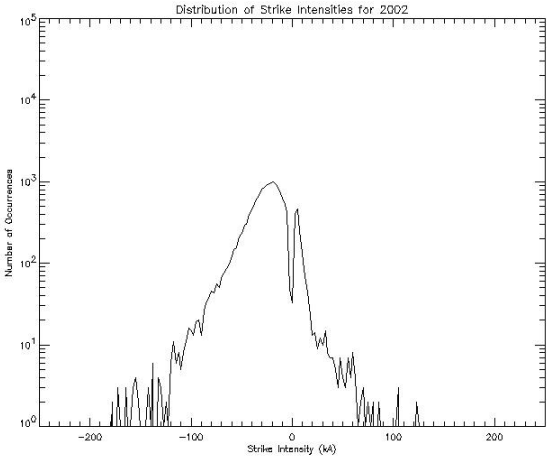

Figure 12. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 2002.

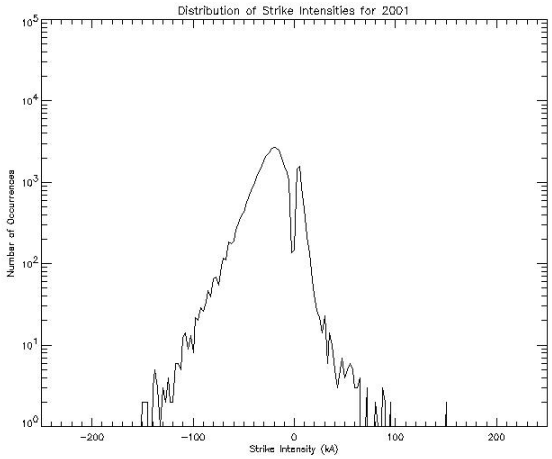

Figure 11. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A during the year 2001.

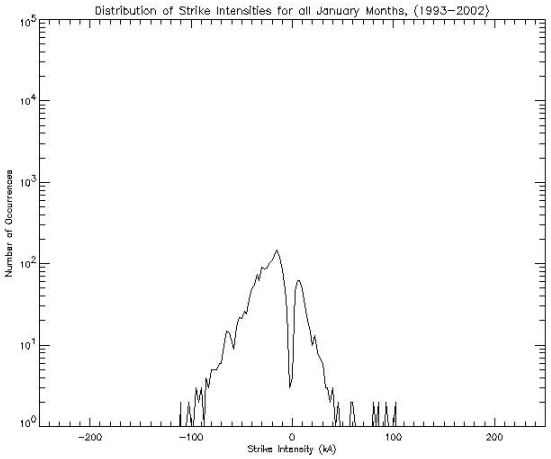

Figure 13. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all January months in the POR.

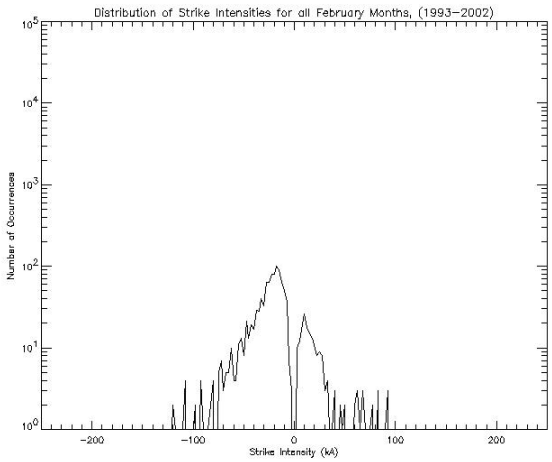

Figure 14. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all February months in the POR.

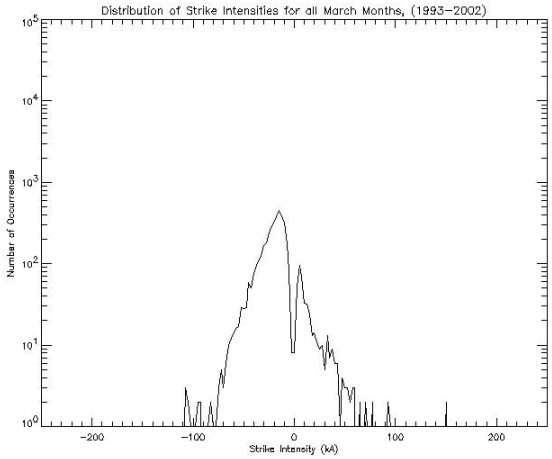

Figure 15. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all March months in the POR.

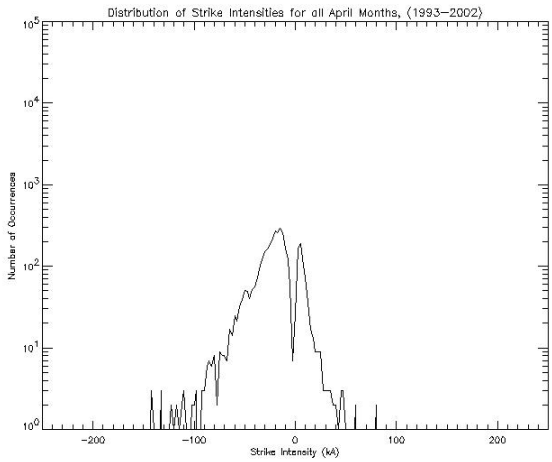

Figure 16. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all April months in the POR.

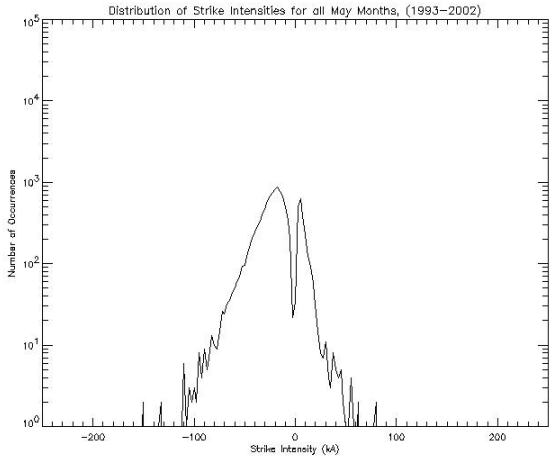

Figure 17. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all May months in the POR.

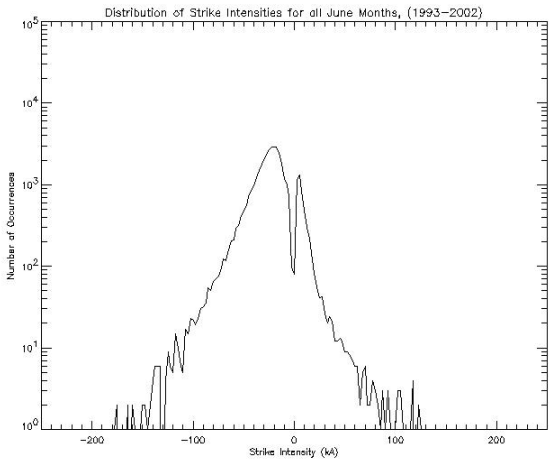

Figure 18. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all June months in the POR.

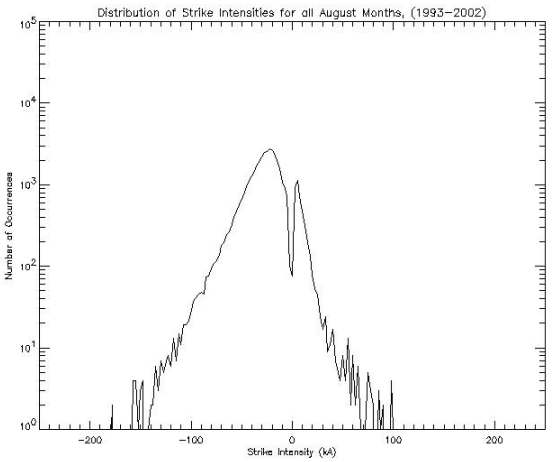

Figure 20. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all August months in the POR.

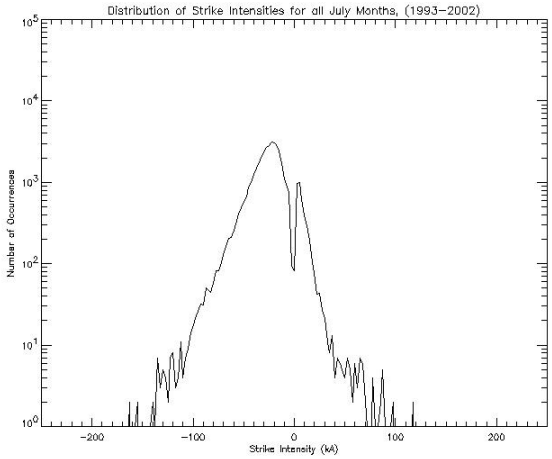

Figure 19. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all July months in the POR.

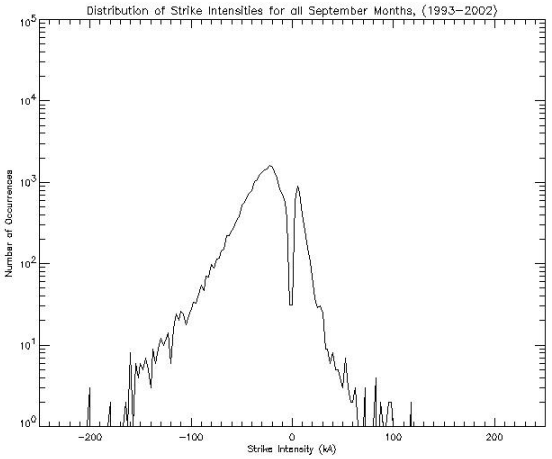

Figure 21. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all September months in the POR.

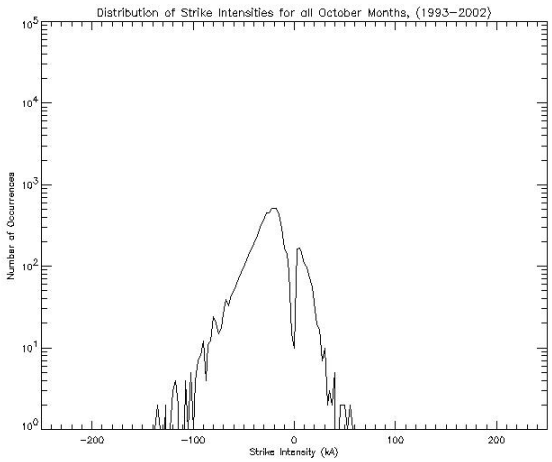

Figure 22. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all October months in the POR.

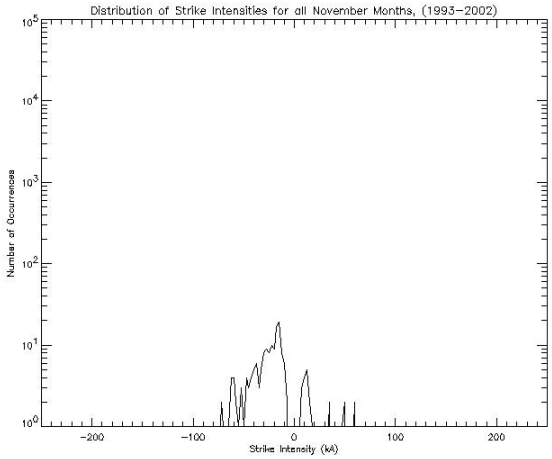

Figure 23. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all November months in the POR.

As is evident from the figures, there is significant variability in both the monthly and interannual strike distributions. It was expected to find such variability in the monthly values, as the general weather patterns at KSC are known to follow fairly ordered cycles with large seasonal amplitudes. However, the degree of interannual variability was unexpected. Table 1 presents the total number of strikes for each month and each year in the POR. The table also gives the annual, and monthly mean strike counts, as well as the standard deviations.

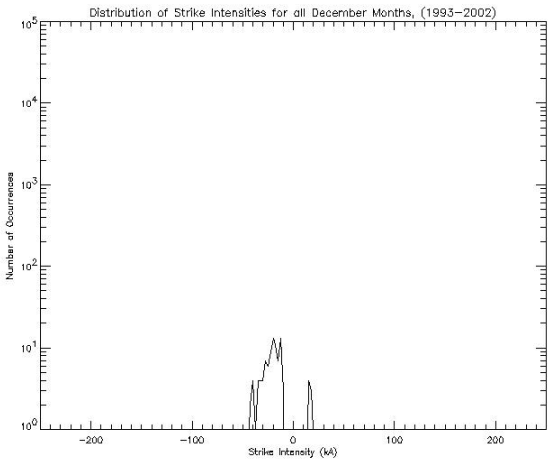

Figure 24. Histogram of lightning strike intensities for all strikes occurring within 32 km of LP39A for all December months in the POR.

Table 2 gives the magnitude of the strike intensities that correspond to various cumulative probability limits. For example, from the table, on an annual basis, there is a 95% probability that a given strike will have an intensity magnitude less than or equal to 58.4 kA.

3. SUMMARY

The distribution of cloud to ground lightning strikes at KSC shows significant variability on both a monthly and interannual basis. For the POR, the greatest monthly strike count occurred in June 2001. Many individual months had no recorded strikes within a 20-mile radius of LP39A, with these occurring typically in the winter months. On a monthly strike rate basis, July had the greatest average number of strikes with 4042per month, while December had the lowest average with only 12 strikes per month. On an interannual basis, 2001 had the greatest average strike rate with an average of 3142 strikes per month, while 1993 had the lowest average strike rate with only 173 strikes per month.

Cumulative probabilities values have been calculated to show what limiting strike magnitudes correspond to various probability limits. These values have implications for various engineering and design applications where knowledge of expected strike magnitudes, given that a strike has occurred, is relevant.

Table 1. Strike count statistics for both monthly and yearly time periods.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Totals	μ	σ
jan	0	2	131	164	594	99	869	0	8	39	1906	191	298
feb	0	1	1	0	0	672	341	24	1	113	1153	115	223
mar	0	132	98	30	0	423	268	365	1594	1302	4212	421	565
apr	0	753	0	79	157	2	650	877	857	267	3642	364	375
may	0	956	0	0	1197	675	6623	658	1073	102	11284	1128	1987
jun	1580	2518	600	5864	2034	1538	4120	3218	13761	3197	38430	3843	3791
jul	17	3083	6011	1200	5051	3204	2643	8363	8510	2337	40419	4042	2873
aug	0	1847	1898	4015	5538	4588	5829	2858	6950	5711	39234	3923	2211
sep	317	1904	290	4218	292	2373	4053	7590	3367	1026	25430	2543	2335
oct	160	2967	0	22	228	380	510	7	1509	1226	7009	701	952
nov	0	0	1	0	50	0	8	32	77	13	181	18	27
dec	0	2	0	0	107	0	0	0	0	7	116	12	34
Totals	2074	14165	9030	15592	15248	13954	25914	23992	37707	15340	173016		

μ	173	1180	753	1299	1271	1163	2160	1999	3142	1278
σ	454	1223	1743	2122	1975	1487	2410	3007	4366	1733

Table 2. Strike Intensity Magnitudes in kA for Various Cumulative Probability Limits.

		Time Period												
		Annual	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	0.999	**152.2**	**203.6**	**591.9**	**594.1**	**142.4**	**121.9**	**138.6**	**126.3**	**138.8**	**158.8**	**151.0**	**144.3**	**145.9**
	0.99	**88.4**	**98.9**	**493.4**	**105.3**	**88.8**	**73.7**	**84.0**	**80.0**	**88.1**	**106.1**	**87.5**	**104.2**	**98.8**
Cum.	**0.98**	**74.5**	**83.6**	**125.9**	**66.4**	**73.7**	**63.6**	**70.6**	**68.5**	**75.7**	**87.0**	**75.1**	**89.3**	**91.7**
Prob.	**0.95**	**58.4**	**62.9**	**78.9**	**49.2**	**55.0**	**49.9**	**55.1**	**55.3**	**60.2**	**67.3**	**58.5**	**68.0**	**74.2**
	0.9	**47.4**	**48.4**	**55.9**	**38.9**	**44.9**	**40.7**	**40.7**	**45.8**	**49.5**	**54.1**	**47.5**	**59.9**	**53.4**
	0.5	**22.4**	**50.0**	**20.8**	**17.4**	**17.8**	**18.3**	**21.4**	**22.9**	**24.0**	**24.8**	**22.5**	**22.8**	**20.2**

4. REFERENCE

CSR Corporation, Systems Analysis Department, 2002: *Eastern Range Instrumentation Handbook*. CSR Corporation, Orlando, FL