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Los Alamos Sferic Array 1998-2003: Results, Array Status, Data Processing and Calibration

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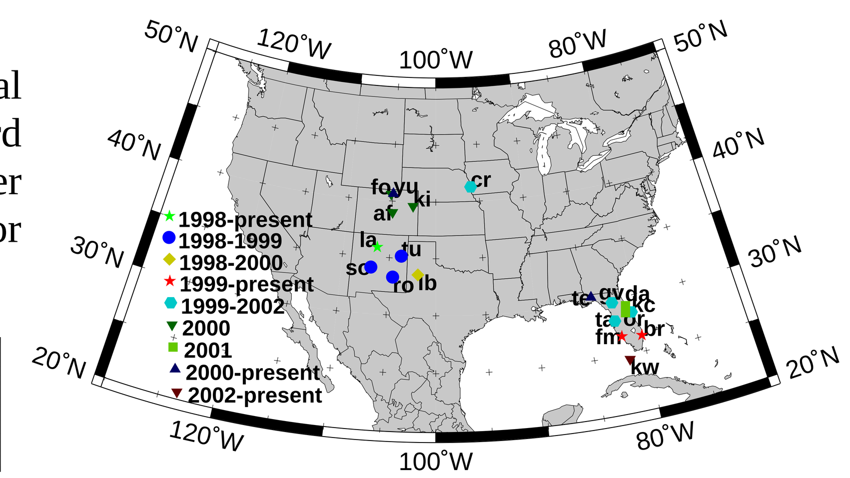
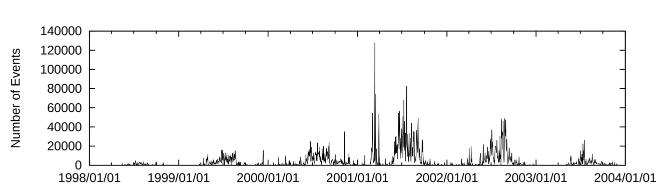
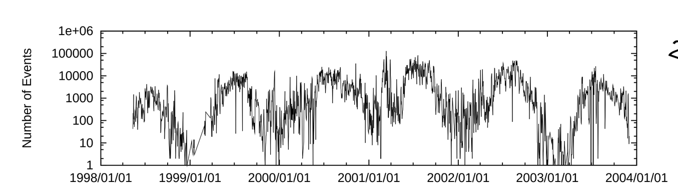
Introduction

The Los Alamos Sferic Array (LASA) network of fast electric-field-change meters has operated in several configurations during the past five years, as illustrated below. This presentation describes the array operations including calibration issues and methods. The routine processing algorithms are described. Comparison of LASA lightning observations with other detection systems has been updated to cover a period of increased station sensitivity. The changes in the array operations which have been possible due to improvements in technology are noted, and directions for future array improvements are discussed.

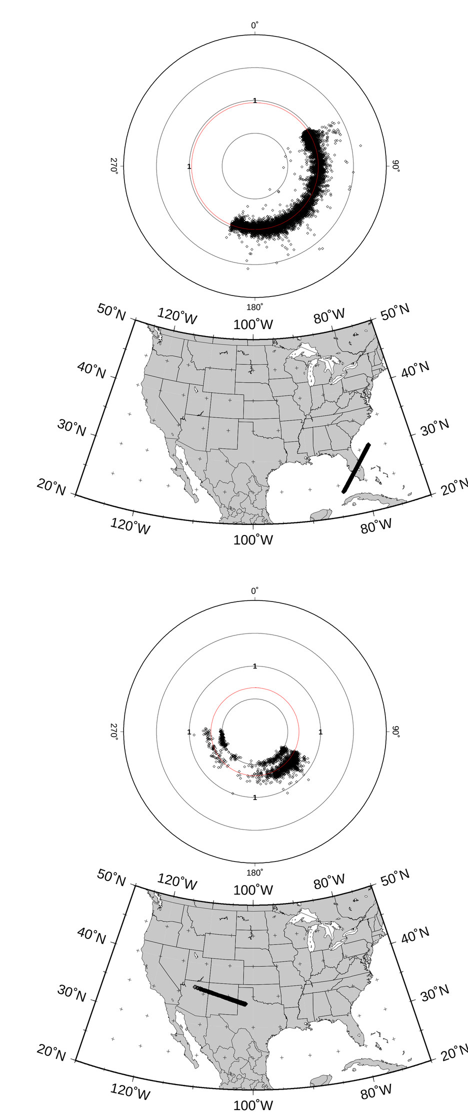
The LASA station sensors have remained the same hardware since the original 1998 design. Minor upgrades, such as the installation of larger capacity hard drives, have been made, allowing for increased data rates (as seen the number of events vs time plots below). A major upgrade is presently in development for deployment next year.







Calibrations



Station deployment includes an absolute system calibration. The relative calibration between stations is monitored for azimuthal dependence or time dependent changes of the calibration. All pairwise station comibnations are considered and equidistant events (within 5 km) are considered. The event waveforms at the two stations are bandpass filtered between 1-50 kHz (primarily to reduce any local noise). If the waveforms had a cross correlation greater than .9, the ratio of the power is considered. The ratio is plotted for two pairs of stations at left. In the upper plots, the 1998-2003 Boca Raton / Tampa stations are compared. The relative calibration between the two stations is constant and shows no azimuthal dependence. The power ratio of the two stations is 0.965. The lower plots show the Los Alamos/Socorro station pair for 1999. The Socorro station sensitivity changed dramatically on July 24, 1999. The stored calibration values used for array processing includes a mechanism for tracking such an abrupt change in station calibration factors. By checking multiple station pairs, the individual station which had a sensitivity change can be identified and recalibrated. The table below summarizes the average calibration values for the 1998-2003 array operations.

	kc	ta	lb	gv	br	fm	fo	af	ki	la	cr	so	ro	tu	da	or	te	kw	fy	yu
kc		0.91		1.04	0.90	0.24									1.07	1.50	1.78			
ta	1.11			1.05	1.04	0.26									1.12	1.52	1.45		1.30	
lb							1.93	0.54	1.07	0.68	1.28	1.05								
gv	0.97	0.96			0.98	0.32									1.10	1.54	1.53			
br	1.11	0.97		1.03		0.21									1.16	1.52	1.40			
fm	4.20	3.79		3.11	4.73															
fo			0.52					0.22	0.35	0.36	0.50									
af			1.85				4.46		1.22	1.39	2.21									
ki			0.94				2.88	0.82		0.87	1.88									
la			1.47				2.81	0.72	1.15			1.47	0.99	1.18						2.60
cr			0.78				1.99	0.45	0.53					0.58						1.61
so			0.96							0.68			0.68	0.80						
ro			1.86							1.01		1.47		1.21						
tu			1.25							0.85	1.71	1.26	0.83							
da	0.93	0.89		0.91	0.87											1.40	1.39			
or	0.67	0.66		0.65	0.66										0.72		1.05			
te	0.56	0.69		0.66	0.71										0.72	0.95				
kw																				
fy		0.77																		
yu										0.38	0.62									

Operations

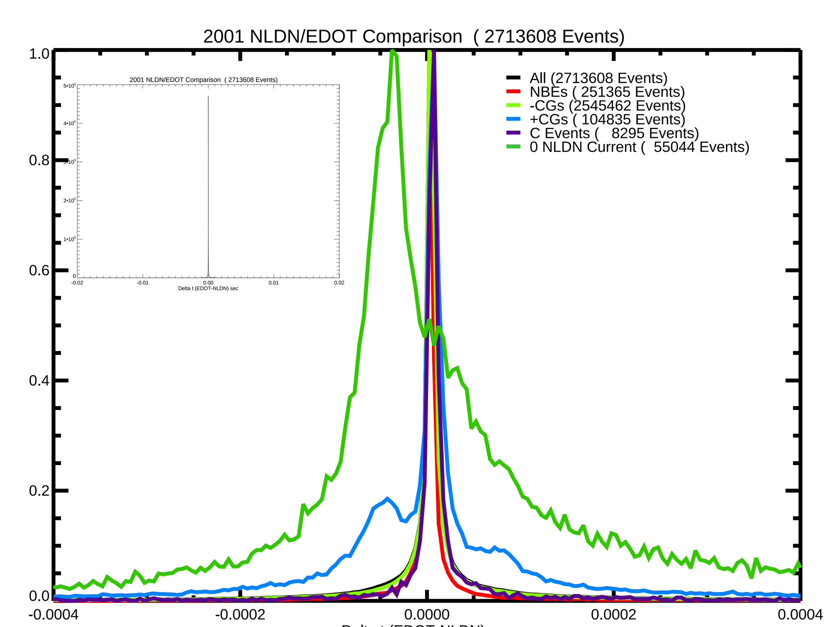
LASA operations during 1998-1999 are described by [3]. This poster is intended as an update through 2003 operations. The geolocation and automatic Narrow Bipolar Events (NBEs) identification software has been reported [3], and some subsequent updates to event classification have also been reported [2]. Currently, the processing software attempts to identify NBEs, cloud to ground discharges (CGs), intense leader events, and non-NBE intracloud events, determining polarity for all events. For NBE events, event and ionospheric heights are determined [4].

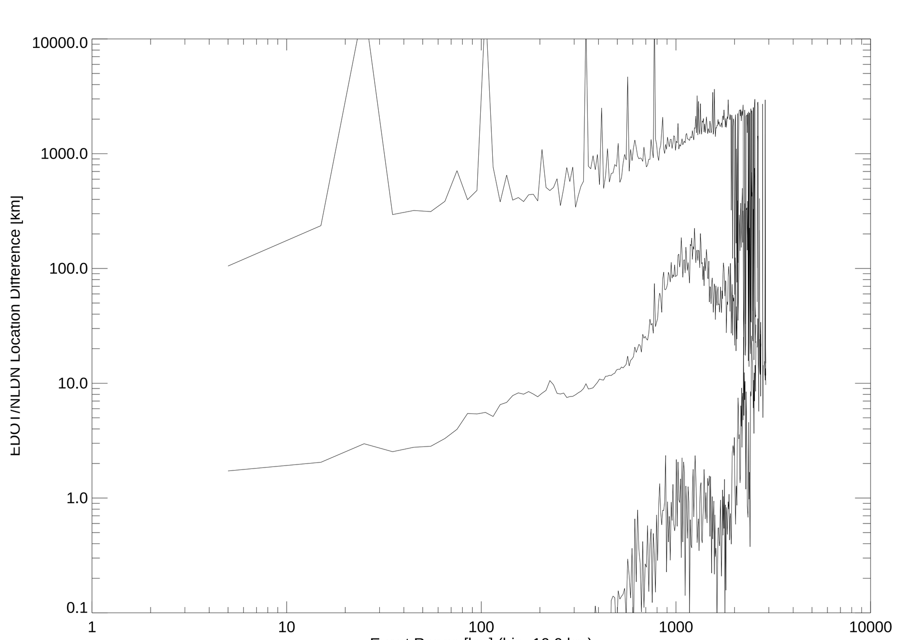
LASA has operated in an 'experimental' mode as opposed to the 'production' mode of other systems (such as NLDN). This has allowed great flexibility for reprogramming or relocation of sensors to support other studies, such as the FORTE satellite (which LASA was originally designed to support) with variable station trigger thresholds which were lowered for satellite overpasses. The LASA ground truth campaigns have been expanded to include GPS and NASA's TRMM satellite. LASA stations have been redeployed to support STEPS, ACES, and BLDN studies. One sacrifice of operating in 'experimental' mode is issues of non-uniform geographic coverage and instrument sensitive must be strictly controlled for in multi-year studies with the LASA data set. The relative calibrations and comparison with other 'production' systems outlined in this paper allow for monitoring such conditions.

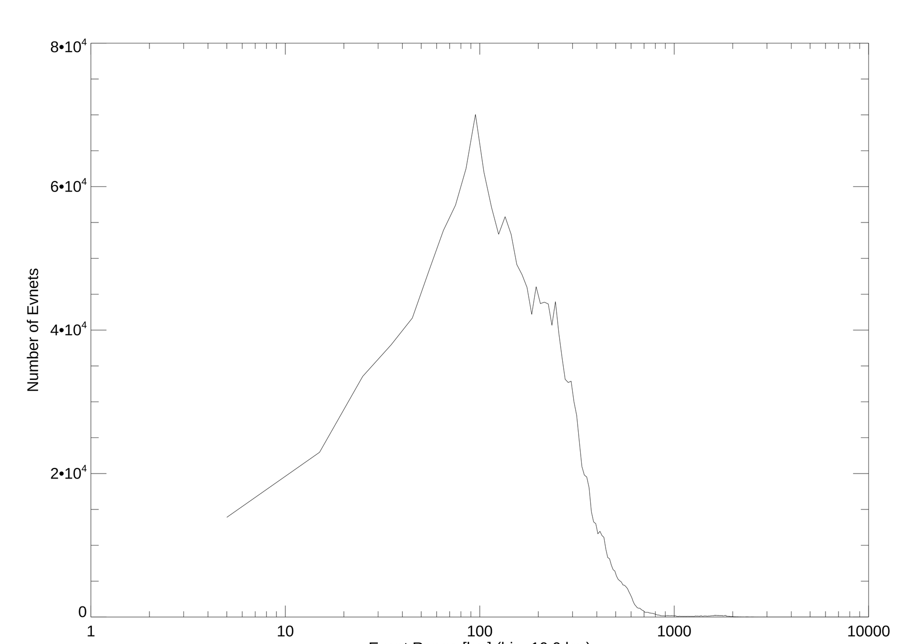
One benefit of LASA is that the data processing keeps the raw waveforms recorded by all stations. This means that although data storage and processing capabilities limit both the sampling and data rate as well as the record size, new processing algorithms can be tested against a large, and continuously growing, database of events.

National Lightning Detection Network Comparison

The National Lightning Detection Network (NLDN) consists of over 100 remote, ground-based sensing stations located across the United States that detect the electromagnetic signals from lightning [1]. The NLDN system is similar to the Los Alamos Sferic Array (LASA) in some aspects, and represents a well-calibrated and documented system to compare LASA performance against. Such a comparison for 1998 and 1999 data was used to test LASA performance shortly after the array was setup [3]. Beginning in 2000, the LASA was operated with drastically reduced thresholds, enabling each LASA station to detect both weak and more distant events. The plots in this panel address the questions of LASA geolocation accuracy for NLDN coincident events.







First, the NLDN and LASA event times are compared to find events detected by both systems. The figure above illustrates that, in general, temporal coincidence between the time stamps of the two systems is better than $\pm 20\ \mu s$. The 0 NLDN current events are distant events (discarded in the standard NLDN products) for which the peak current of the event can not be determined. Also note the broadening of the +CG histogram and the coincident identification of NBEs by NLDN (almost 10% of the total NLDN/LASA coincident events). Most significantly, NLDN/LASA temporal coincidence identifies the same event with very little residual background events.

The upper figure to the left is a plot of curves showing the minimum, maximum, and mean values of the difference in NLDN/LASA location as a function of distance from the center of LASA stations in Florida. The main conclusion is that within 1000 km of the LASA stations, the NLDN/LASA location disagreement is better than 10 km. The lower plot shows the number of events contributing to each bin in the upper plot. The decreased station thresholds (compared to 1998-1999) increased the number of events (by more than a factor of 4) and improved geolocation accuracy (because more stations per event constrained the geolocation solution.

Summary/Future

The Los Alamos Sferic Array has recorded over 8,000,000 multi-station, geo-located events during its operation between 1998-2003. The array has provided event classification information in support of GPS and FORTE satellite lightning observations. LASA stations have provided support for both the STEPS and ACES programs. One LASA station was deployed to Brazil to support BLDN development, to address the "small +CG" issue, and to study NBEs in a meteorological context outside of the US. LASA data has been used to study NLDN performance in regard to both NBE and leader event detection.

A major upgrade of LASA is currently underway. Computer hardware, electronics, and software upgrades are all being developed. The majority of current LASA hardware is running on 200 MHz computers with a 1 MHz digitizer and requires external hardware triggering. An upgrade to modern computer system allows for 20 MHz sampling with computer controlled (software) triggering.

The most critical issues we have found during operations of LASA during the past six years are data management, station reliability, and modularity of software. The current array software is a mixture of perl (primarily for networking and data transfer) and idl (for waveform analysis, geolocation, classification, and height determination). The program modularity allows for reasonably graceful recovery from a 'hiccup' in the processing, as well as incremental improvements in the software. With the larger bandwidth data records of the upgrade, we may need to move from idl to C for the analysis routines in order to improve processing speeds.

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References

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