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HOUSTON LDAR NETWORK PERFORMANCE, DATA USAGE, AND FIRST RESULTS

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1. INTRODUCTION

The Houston LDAR II network is an array of twelve VHF time-of-arrival (TOA) sensors. The LDAR II sensors were purchased by the Texas A&M Department of Atmospheric Sciences from Vaisala Inc. to examine the total lightning structure of thunderstorms and conduct in-depth studies into the effects a large metropolitan region has on thunderstorm electrification (Orville et al. 2001; Steiger et al. 2002). The sensors are functionally similar to the New Mexico Institute of Mining and Technology's Lightning Mapping Array (LMA) described by Rison et al. (1999). These systems are based on the original Lightning Detection and Ranging (LDAR) system developed at NASA's Kennedy Space Center (Lennon and Maier, 1991).

VHF TOA systems map lightning in three dimensions by detecting short impulses of VHF radiation. By accurately measuring the time of arrival of the VHF pulses at several sensors and based on the fact that VHF signals propagate along line-of-sight, these pulses can be modeled as point sources in three dimensions. Each sensor records the time and amplitude of the largest amplitude pulse during a 100 μs interval. This gives the network the possibility of detecting a maximum of 10,000 sources every second.

2. NETWORK SETUP AND OPERATION

The Houston LDAR II network has been operational since mid July of 2005 with at least seven sensors and has been archiving lightning data since August 1, 2005. By mid-August, the number of sensors increased to the current configuration of the Houston LDAR II network (Fig. 1) with ten operational sensors. The center of the network is located at 29.79°N and 95.31°W, which is slightly northeast of downtown Houston. The network has an average sensor baseline of 25 kilometers and a network diameter of 80 kilometers. Each sensor is tuned to a 5 MHz band with a center frequency that varies between 69.0 and 71 MHz (upper edge of TV channel 4) depending on RF noise conditions at each site.

Real-time data from the sensors is transmitted to Texas A&M for thunderstorm warning, research case selection, and to monitor and fine-tune the LDAR sensors. The real-time data is transmitted to the central workstation through a wide variety of Internet connections, from DSL to T1 lines. Due to the limited data rates at several of the sites, the sensors are configured to transmit the strongest VHF pulse during every 200 ms interval, essentially decimating the data by 50%. This reduces the maximum possible number of sources per second to 5,000 and cuts the maximum data rate in half to a manageable 300 kbps.

Each LDAR II sensor has the capability of storing the non-decimated (100 μs resolution) to a hard disk at the sensor site. The raw data is physically retrieved every other month and processed to provide the highest quality dataset for research analysis. In the event that a hard disk fails and non-decimated data for a sensor is

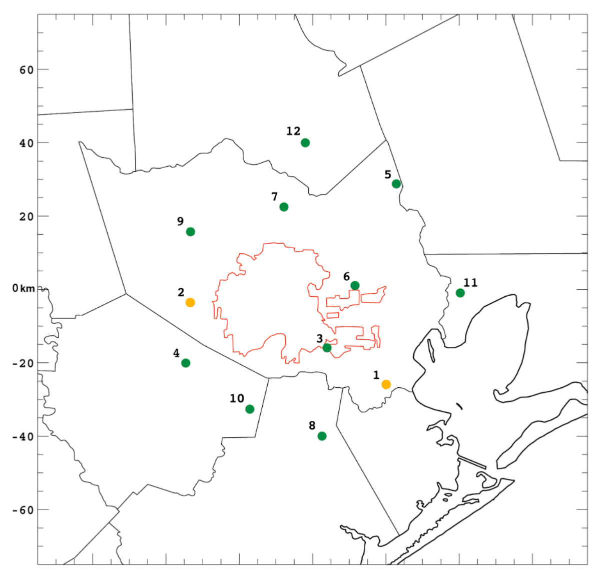

Figure 1. Map depicting the locations of the twelve Houston LDAR II sensors. The green sensors are currently installed and functioning and the orange sensors are currently offline and/or not installed. The red outline shows the Houston Urban area and industrial suburbs.

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lost, the real-time decimated data for that sensor can be incorporated into the research dataset to partially replace the data that were lost.

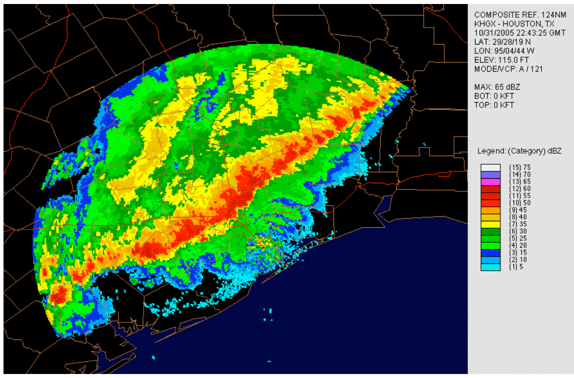

Figure 2. Composite reflectivity scan from the NWS WSR-88D at League City (KHGX) on October 31, 2005 at 22:43 UTC.

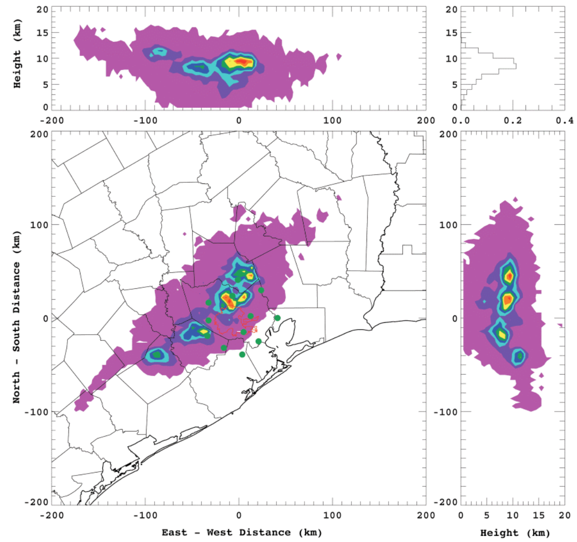

Figure 3. Lightning source density plot for the time period from 22:38 to 22:48 UTC on October 31, 2005.

3. FIRST RESULTS

The first test of the current ten sensor network configuration came on October 31, 2005. An intense squall line ahead of a strong cold front propagated from the panhandle region of Texas, through Houston, and into the Gulf of Mexico. Figure 2 shows the League City WSR 88D (KHGX) composite reflectivity as the squall line passed over the center of the LDAR network at 22:43 UTC. The system maintained this intensity throughout its traversal across the coverage area of the Houston LDAR II network.

Figure 3 is a plot of LDAR source densities for a 10 minute period centered on the time of the radar image. The LDAR source density plot clearly shows the regions of maximum sources, which correspond with the most intense regions in the convective line as seen in Figure 2. The purple shaded region depicts where there was at least one source during the 10 minute period. The purple region ahead of the main convective line is most likely associated with intracloud flashes in the forward anvil, while the shaded region behind the maximum density cores indicate the extent of the lightning activity in the trailing stratiform region.

The next feature plotted from the LDAR lightning data are the sources that compose an individual flash. Figure 4 is one of thousands of intracloud and cloud-to-ground flashes that were detected by the network. This sample intracloud flash shows a fairly well defined bi-level structure similar to the structure discussed by Shao and Krehbiel (1996). The intial upward propagation of sources, abundance of VHF activity in the upper branch, and lesser activity in the lower branch suggests the typical dipole charge structure with the positive charge layer on top. Many other intracloud flashes (not shown) exhibited a significant decrease in altitude of the sources as the flashes propagated into the trailing stratiform region. At first glance, these flashes appear to be similar to flashes observed in a leading-line, trailing-stratiform (LLTS) mesoscale convective system in Dallas by Carey et al. (2005).

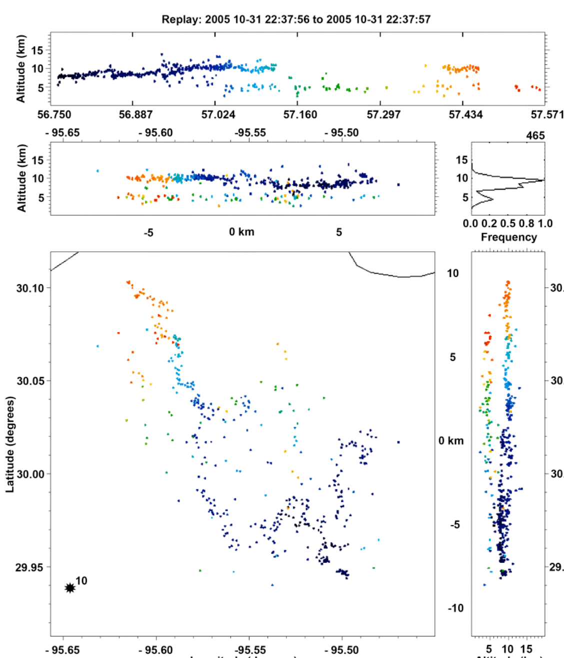

Figure 4. Example of a bi-level flash detected by the Houston LDAR network during the Oct. 31, 2005 squall line.

LDAR II Sensor Sensitivity on 10/31/2005

Sensor #	1	2	3	4	5	6	7	8	9	10	11	12
Sensitivity	N/A	N/A	-57	-60	-60	-62	-60	-62	-58	-56	-59	-56

Table 1. Approximate values of the individual LDAR sensor detection sensitivities in dBm. Sensor numbers correspond to the sensor numbers found in Figure 1. N/A indicates that the sensor was non-functional during on this day.

4. NETWORK PERFORMANCE

Since the network became operational in mid July, several noise surveys have been conducted at the various sites in order to improve the networks overall sensitivity to weaker amplitude and/or more distant VHF sources. The first seven sensors were originally tuned to a center frequency near 74 MHz in an attempt to avoid television channels. This produced an average sensor sensitivity of approximately -57 dBm. After continuous monitoring of the sensors, it became clear that the amount of noise during the daytime was much greater than the noise surveys suggested which caused the average sensitivity to be reduced to -55 dBm. In early October, when the nearly constant thunderstorm activity subsided, a new round of noise surveys was conducted for the current ten sensors. From these noise surveys, it was found that tuning the sensors to a frequency between 69 and 71 MHz would improve sensor sensitivity to the values shown in Table 1. Along with the increased sensitivity, came a decrease in the daily fluctuation in noise levels that had been previously observed at several of the sites. It should be noted that the sensors' noise levels are regularly monitored and their gains are adjusted as required and thus sensor sensitivity may vary from day to day.

An important performance feature of the Houston LDAR network that both researchers and average users need is the networks effective range. The squall line discussed in Section 3 was a likely candidate to demonstrate the networks detectable range for several reasons. As the convective line traversed the Houston LDAR coverage area, the intensity of the convective activity remained rather constant and extended well past the anticipated range of the network. In addition, the squall line was traveling through a fairly uniform environment, which suggested the electrical activity of the system would not change drastically during its lifetime.

A plot of source altitudes versus their radial distance gives insight to the networks range. Figure 5 shows a 1 km thick slice of all LDAR sources detected during the 8 hour period when the LDAR network detected any lightning

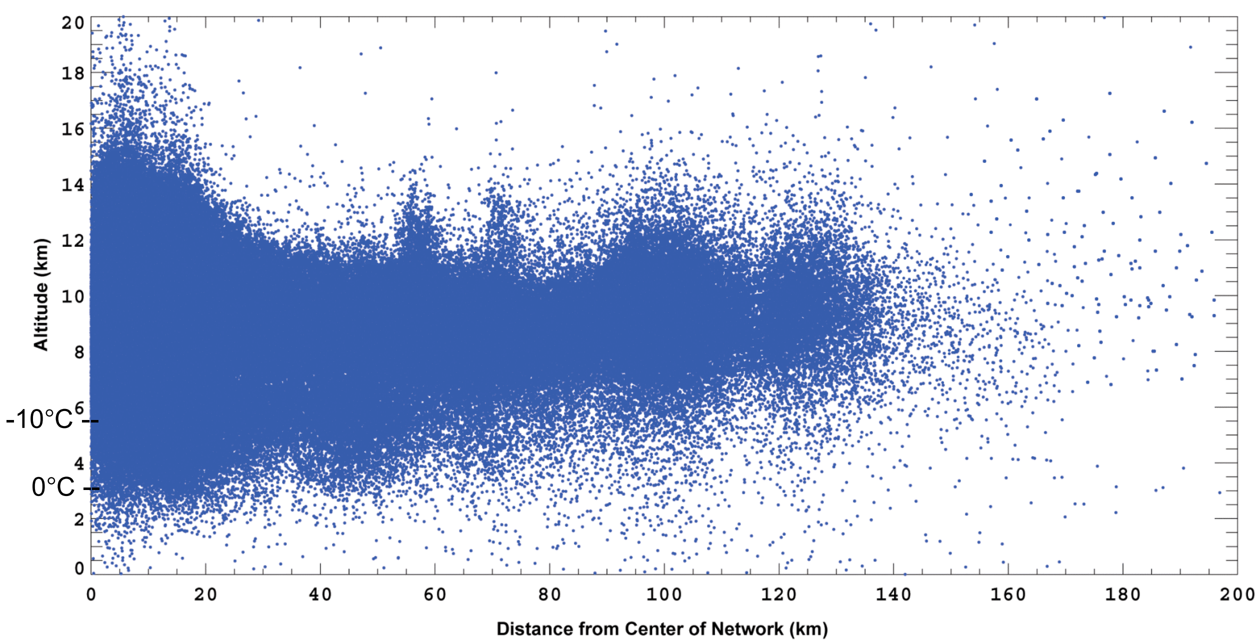

Figure 5. Altitude versus radial distance from the center of the network of sources detected in a 1 km thick slice in a line normal to the squall line propagation and for the time period of 19Z on 10/31/05 to 03Z 11/01/05.

sources that correspond to the squall line. The feature that stands out the most is the fairly dramatic drop off in the number of sources beyond 135 kilometers. This decrease in the number of sources did not appear to correspond with a change in the intensity of the squall line. Also, additional plots (not shown) were made for several other radial directions. In all cases, there was a significant decrease in the number of sources around 135 kilometers.

The other prominent feature in Figure 5 is the general upward slope of the lower edge of the region of concentrated sources the further the storm is from the center of the network. This feature is directly attributable to the line-of-sight propagation of VHF frequencies. Obstructions near the sensor antenna combined with the curvature effect of the Earth cause the sensors to detect less lower elevation lightning sources the further a storm is from the sensors, essentially blocking the sensor sight at low elevation angles. In the case of the October 31st squall line, this means lightning sources in the negative charge layer around 5.5 kilometers are significantly reduced at a range of 100 kilometers.

5. DATA DISSEMINATION

One main use of the real-time data produced by the Houston LDAR network is for advanced warning of developing thunderstorms in Houston. Organizations that are participating in the operation of the Houston network are able to monitor local lightning activity via a website interface. Plots of the LDAR source data for the last 6 minutes are displayed for each sensor location and the displays are automatically updated every 2 minutes. These images can then be looped to show the change in intensity and direction of motion of the lightning activity. Future goals are to convert the plots to show the Flash Extent Density (FED), which gives a better representation of the extent of electrical activity. In addition, Texas A&M, Vaisala, and the NWS offices in League City and Johnson Space Center will work to incorporate the LDAR lightning data into the AWIPS display used by forecasters.

6. CONCLUSIONS

The Houston LDAR II network has been operational since mid-July with at least seven functioning sensors, with ten sensors operational as of mid-August. The operating frequencies of the sensors are in the upper end of TV channel 4 in the 69 to 71 MHz range. After several VHF noise surveys at the sites, the sensors have sensitivity values between -56 to -62 dBm. The maximum range at which lightning source plots do not resemble storm features is approximately 135 kilometers with a dramatic decrease in the number of soources. As was expected, plots of lightning source densities reveal lightning cores that match fairly well with the most intense convective activity. In addition, plots of sources that compose a single intracloud flash reveal a bi-level flash structure similar to observations seen by Rison et al (1999) in central New Mexico.

6. REFERENCES

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