The Houston LDAR* Network
*(Lightning Detection and Ranging)

Richard E. Orville, Lawrence D. Carey, Brandon L. Ely, John Nielsen-Gammon, Renyi Zhang, and Don Collins

Department of Atmospheric Sciences and Cooperative Institute for Applied Meteorological Studies, Texas A&M University, College Station, TX 77843-3150 (rorville@tamu.edu)

1. Network Overview

- The Houston Lightning Detection and Ranging (LDAR II) network is an array of twelve VHF time-of-arrival (TOA) sensors (Fig. 1) from Vaisala Inc. based on the New Mexico Tech LMA.
- 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.
- Goal is to examine the total lightning structure of thunderstorms and conduct in-depth studies into the effects a large metropolitan has on thunderstorm electrification (Orville et al. 2001; Steiger et al. 2002).
- Operation of the Houston LDAR II network began in mid July of 2005.
- Average sensor baseline of 25 kilometers with a network diameter of ~80 km.
- Sensors operate at a frequency of 69.5 MHz. (TV Channel 4)
- 100µs data resolution gives a maximum data rate of 10,000 VHF sources per second.

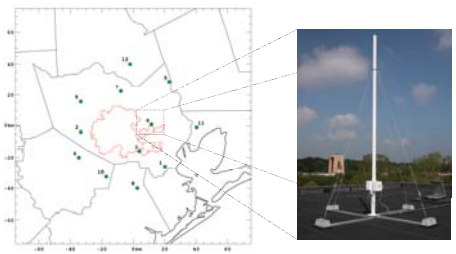


Fig. 1. Map depicting the locations of the twelve Houston LDAR II sensors (green circles). The red outline shows the Houston Urban area and industrial suburbs.

2. Houston Cloud-to-Ground Lightning Anomaly

- From the National Lightning Detection Network (NLDN) data set (1989-current), areas of enhanced cloud-to-ground lightning flashes or 'hot spots' have been observed.
- The observed hot spot near the city of Houston, Texas (Fig. 2) has been studied with the previously available NLDN data and hypotheses made as to the reason for the lightning hot spot (Orville et al., 2001; Steiger et al. 2002; Steiger and Orville 2003).
- The elevated flash densities could result from several factors, including:
  1. the convergence due to the urban heat island effect and complex sea breeze
  2. the increasing levels of air pollution from anthropogenic sources producing numerous small cloud droplets and thereby suppressing mean droplet size. The latter effect would enable more cloud water to reach the mixed phase region where it is involved in the formation of precipitation and the separation of electric charge, leading to an enhancement of lightning.
- More comprehensive data sets including the total lightning data from the Houston LDAR network will be used in order to further examine this occurrence.

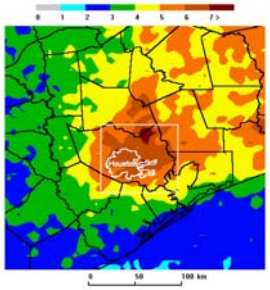


Figure 2. This map depicts the mean annual flash density (flashes km-2 year-1) for the years of 1989-2000. The Houston metro area is outlined in white, while the white box represents the urban enhancement region (coordinates of lower left and upper right corners: 29.5° N, 95.7° W; 30.2° N, 94.85° W).

3. Network Performance

- Location accuracy determined from the network's RMS time error of 70ns using method described in Thomas et al. 2004.
- Median 3D location accuracy VHF LDAR sources (Fig. 3) are estimated to be 100 m or better over the center of the network and 500 meters at a horizontal distance of 1 km.
- Network Range was estimated using LDAR data obtained from a quasi-steady storm system that began at a range of well over 400 km from the network and passed over the center of the network.
- The VHF sources during the entire duration of the storm were binned by specific range rings.
- Plotting the # of VHF sources in each range ring along with the range ring area reveals a sharp decrease in detection beyond a range of 100 km.
- Preliminary analysis of recent network modifications suggest the network range has been expanded to 150 km or greater.

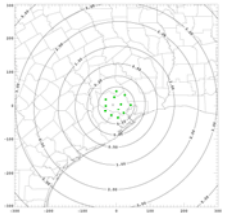


Figure 3. Median 3D location accuracy for VHF sources at altitudes of 3 km and higher (contours are in kilometers).

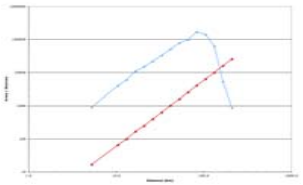


Figure 4. Log-log plot of the number of VHF sources in each range ring (blue line) along with the range ring area (red line).

4. LDAR Sample Data

- Figure 5 is a plot of LDAR source densities for a 10 minute period centered on the time of the radar image (Fig. 6) .
- 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 6.
- Figure 5 is one example of thousands of intracloud and cloud-to-ground flashes that were detected by the network on October 31, 2005.

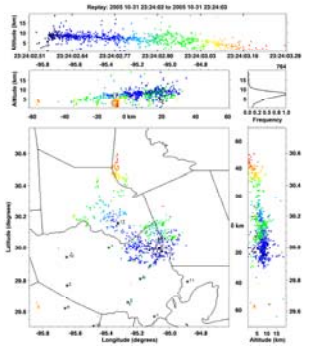


Fig 7. Example of a lightning flash detected by the Houston LDAR network on October 31, 2005. Color of points denote time from oldest (blue) to newest (red).

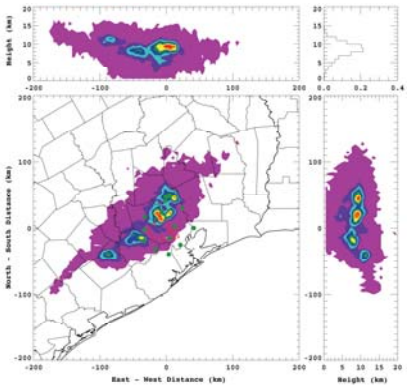


Fig 5. Lightning source density plot for the time period from 22:38 to 22:48 UTC on October 31, 2005. Green dots depict the locations of the LDAR II sensors. Purple shading depicts region containing at least 1 LDAR source / km^2.

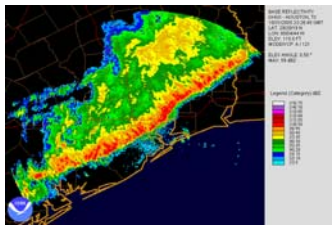
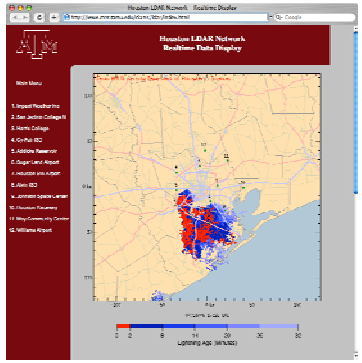


Fig 6. Base reflectivity scan of an MCS over downtown Houston from the NWS WSR-88D at League City (KHGX) on October 31, 2005.

5. Continuing Work

- Test network performance changes due to new operating frequency of 40 MHz since March 29, 2007.
- Research into the three dimensional charge structure and evolution of a leading-line trailing-stratiform MCS inferred from LDAR VHF sources.
- Continued research in to the LDAR characteristics for severe hail and/or tornadoes and possible use for advanced warnings.
- Prediction of total lightning onset using storm radar reflectivity characteristics.



Visit the Houston LDAR II Network Realtime Webpage at:

www.met.tamu.edu/ciams/ldar/index.html

6. References

Boccippio, D. J., S. J. Heckman, and S. J. Goodman , 2001, A diagnostic analysis of the Kennedy Space Center LDAR network: 1. Data characteristics, *J. Geophys. Res.*, 106, 4769– 4786.

Orville, R. E., G. Huffines, J. Nielsen-Gammon, R. Zhang, B. Ely, S. Steiger, S. Phillips, S. Allen, W. Read, 2001: Enhancement of cloud-to-ground lightning over Houston, Texas. *Geophys. Res. Lett.*, 28, 2597-2600, doi:10.1029/2001GL012990.

Steiger S. M., R. E. Orville, and G. Huffines, 2002: Cloud-to-ground lightning characteristics over Houston, Texas: 1989–2000. *J. Geophys. Res.*, 107, doi:10.1029/2001JD001142.

Steiger, S. M., and R. E. Orville, 2003, Cloud-to-ground lightning enhancement over Southern Louisiana, *Geophys. Res. Lett.*, 30, 1975, doi:10.1029/2003GL017923.

Thomas, R.J., P.R. Krehbiel, W. Rison, T. Hamlin, J. Harlin, and D. Shown, Observations of VHF source powers radiated by lightning, *Geophys. Res. Lett.*, 28, 143-146, 2001.

Thomas, R., W. Winn, S. Hunyady, W. Rison, P. Krehbiel, T. Hamlin, J. Harlin, 2004: Accuracy of the lightning mapping array, *J. Geophys. Res.*,109, doi:10.1029/2004JD004549.

Acknowledgements: We gratefully acknowledge that the scientific research and operation of the Houston network are supported by the National Science Foundation (ATM-0442011 and ATM-0321052). In addition we would like to thank the generosity of the airports, school districts, and colleges around Houston who have donated land, electricity, and internet connections to enable real-time operation of the network.