14.2 THE DESIGN AND EVALUATION OF THE LIGHTNING IMAGING SENSOR DATA APPLICATIONS DISPLAY (LISDAD)

Robert Boldi, Earle Williams, Anne Matlin, Mark Weber,
MIT/Lincoln Laboratory, Lexington, Massachusetts.

Stephen Hodanish, David Sharp,
National Weather Service, Melbourne FL.

Steve Goodman, Ravi Raghavan,
NASA Marshall Space Flight, Huntsville, AL.

1. INTRODUCTION

The ultimate goal of the LISDAD system is to quantify the utility of total lightning information in short–term, severe–weather–forecasting operations. Secondary goals were to collect times series of various storm–cell parameters that relate to storm development and electrification and subsequently make these data available for post–facto analysis. To these ends scientists from NASA, NWS, and MIT/LL organized an effort to study the relationship of lightning and severe–weather on a storm–by–storm, and even cell–by–cell basis for as many storms as possible near Melbourne, Florida. Melbourne was chosen as it offers a unique combination of high probability of severe weather and proximity to major relevant sensors, specifically: NASA's total lightning mapping system at Kennedy Space Center (the LDAR system) at KSC [*Lennon and Maier, 1991*], a NWS / NEXRAD radar at Melbourne, and a prototype Integrated Terminal Weather System (ITWS), at Orlando. The ITWS system obtains cloud–to–ground lightning information from the National Lightning Detection Network (NLDN) via a link to Lexington, MA, and also uses NSSL's Severe Storms Analysis Package (NSSL / SSAP) to obtain information about various storm–cell parameters.

2. THE LISDAD SYSTEM

To assist in realizing this project's goal, an interactive, real–time data processing system (the LISDAD system) has been developed that supports both operational short–term weather forecasting and post–facto severe–storm research. Suggestions regarding the design of the data display and its salient behavior have been taken from both the operational users (NWS/ Melbourne) and researchers at NASA and MIT/ LL. The flows of data in the system are portrayed in Figure 1. In this figure, primary data sources are at the top, major processing systems are in boxes, and the final data outputs are at the bottom.

*The work described here was sponsored by the Federal Aviation Administration. The United States Government assumes no liability for its content or use thereof.

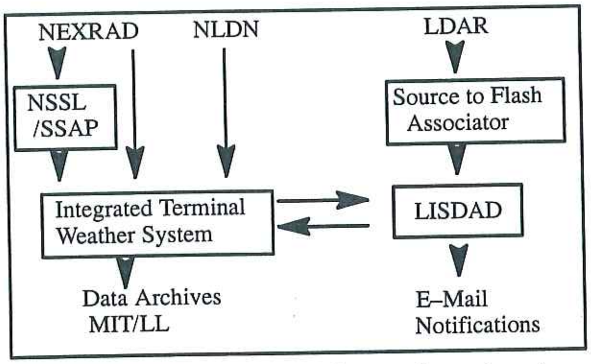

Figure 1. Data sources, flows and processing systems in the LISDAD system. See text for details.

2.1. NEXRAD data processing

The NEXRAD base data is processed by the NSSL/ SSAP, producing locations and velocities of storm–cells as well as various storm parameters such as Echo-Tops, VIL, Maximum dBZ, Height of the Maximum dBZ. This cell–based information is generated once every NEXRAD volume scan (about every 5 minutes). See *Johnson [1995]* for a more complete description of the SSAP and its use within the WSR–88D.

2.2. NLDN data processing

The NLDN data, primarily cloud–to–ground lightning data, is relayed by the ITWS to the LISDAD system where it is associated with a storm cell according to the following procedure. (1) Advect the positions of the cells detected by the NSSL/SSAP algorithm to the current time using the track vectors provided with the cells. (2) Assign the flash to ALL cells within 5 km of the flash location. (3) If no cell was found within 5 km, then assign the flash to the CLOSEST cell if it is within 35 km of the flash location. Using these rules, about 95% of the flashes are assigned to a single cell, with the remainder of the flashes being evenly split between 0 and 2 cell assignments per flash. It was also discovered that rule 1 (cell advection) has a large influence upon the computed minute–to–minute flash rates as severe–storm cells can move a distance about equal to their mean inter–cell spacing (20 – 50 km) in the time it takes for the NEXRAD to update (5 minutes).

2.3. LDAR data processing

The raw, discrete LDAR radiation sources acquired from KSC are grouped into lightning flashes using a time–space association algorithm. In this procedure, any source that occurs within 300 milliseconds and a distance D(r) of a previous source is placed into the same flash as the previous source. The function D(r) reflects both the typical size of storm cells and the decreasing accuracy of the LDAR system as the range (r) from the LDAR system increases. For sources close the the LDAR network, D(r) is 5 km and reflects the size of storm cells. For sources far from the LDAR network, D(r) primarily reflects the accuracy of the LDAR system and is 30 km. A flash can remain active for up to 5 seconds. After a flash is created, it is associated to a storm cell using the procedure described above for the NLDN data.

The number of flashes generated from a set of sources is not very sensitive to the exact values of the distance window D(r) or the time window (300 milliseconds). Experiments were performed wherein these values were doubled with less then a 20% change in the number of flashes generated from a given set of sources. This indicates that the flashes are relatively compact in time–space coordinates. Many of the flashes (more than 10%) are composed of just a single source. These single–source flashes have been given the name "singletons". The percent of all flashes that are "singletons" increases from 12% to 30% as the distance from the LDAR network to the flash increases from within 25 km to greater than 50 km. The influence that the distance from the LDAR network has upon the distribution of sources per flash can be seen in Figure 2. In this figure, the solid–filled histogram is the distribution of sources per flash for all flashes detected within 25 km of KSC. The horizontally–lined histogram is for flashes detected between 25 and 50 km of KSC, and the vertically–lined histogram is for flashes detected beyond 50 km from KSC. The distance to the flash does not effect the duration of flashes however. As shown in Figure 3, the histograms of the distribution of flash durations are essentially independent of distance from the LDAR network, indicating that as the distance increases, the network randomly fails to detect sources uniformly throughout the duration of the flash. In this figure, once again, the solid–filled histogram is the distribution of flash duration for all flashes detected within 25 km of KSC. The horizontally– lined histogram is for flashes detected between 25 and 50 km of KSC, and the vertically–lined histogram is for flashes detected beyond 50 km from KSC.

2.4. Real–Time Data Display

The initial concept for the user's Graphical Situation Display (GSD) was simply to overlay radar data with lightning data and this still forms a part of the display. Specifically, the GSD presents the user with a map of the Composite Maximum Reflectivity obtained from the NEXRAD; superimposed upon this background image are placed small black circles indicating the locations of storm cells identified by the NSSL/SSAP. The circles become cyan if lightning is associated with the storm–cell. At the user's option, these cells can be advected during the inter–NEXRAD update interval. (This helps follow the movement of fast–moving cells.) If the cells are being advected, they are portrayed as squares to distinguish them from the locations of the cells as reported by the NSSL/SSAP (and change only once every 5 mins).

As the association between rapid upward trends in the total lightning rate and severe weather became evident

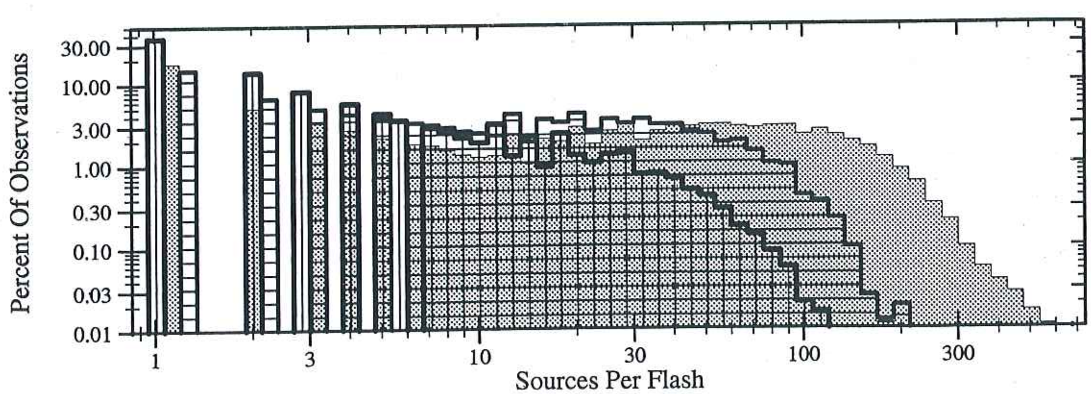

Figure 2. Distribution of the sources per flash as a function of the distance from the LDAR network. See text for details.

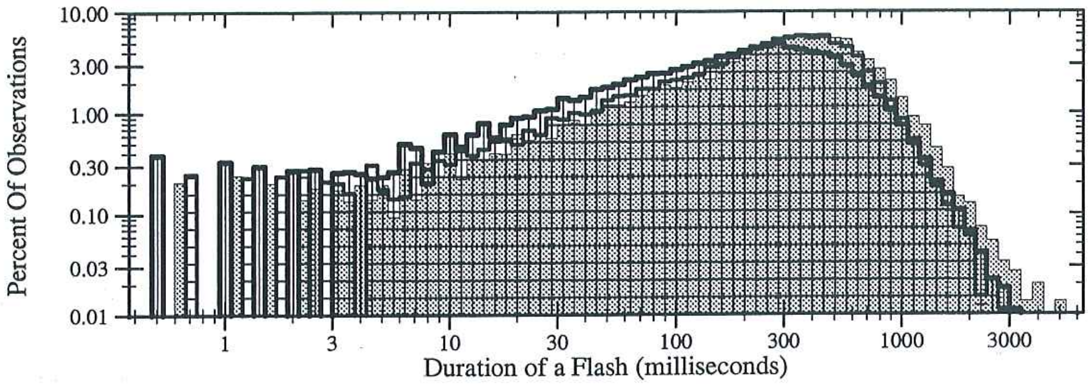

Figure 3. Distribution of flash duration as a function of distance from the LDAR network. See text for details.

to the NWS users, the display was significantly redesigned. The focus changed to support the display of time series of storm–parameter data and the automatic recognition of cells that have a high probability of being (or becoming) severe storms ("interesting cells") based on the total lightning data (LDAR). If a storm cell has lightning rates indicative of a severe storm, the cell icon (a square or circle) turns red. Figure 4 shows an example of the method used to portray "interesting" cells. In this figure there are two cells, one to the north is numbered "16" and below it one numbered "8" surrounded by a double box, indicating that it has been classified as an "interesting" cell.

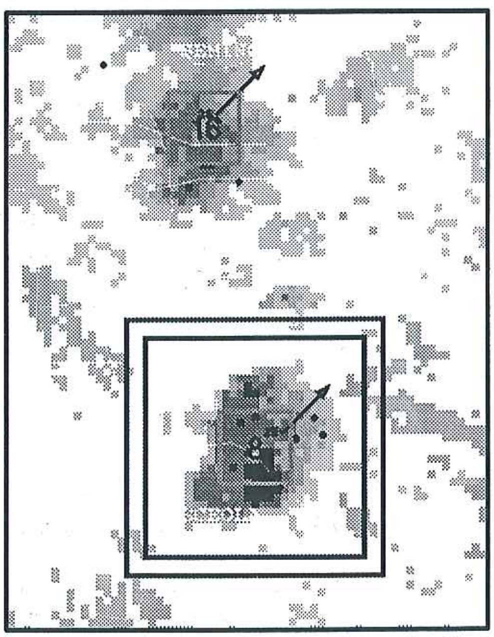

Figure 4. Example of GSD display of "interesting" cells.

Interesting cells are those that have 1 minute lightning flash rates greater than 200 flashes per min, or a 5–minute average rate of increase of 20 flashes/min/min (i.e. an increase of 100 flashes per minute over a 5 minute period.)

Subsequent to the classification of a cell as "interesting", a "pop–up–box" appears automatically on the screen that graphs the time history of radar–based and lightning–based cell parameters (Users may also manually select any cell for a similar display). An example, Figure 5 shows the "pop–up–box" for Cell 8 of Figure 1. This Figure shows the EchoTop (□), Maximum Reflectivity (X), and the Height of the Maximum Reflectivity (Δ). Also shown is the 1 minute NLDN flash rate (■) and the LDAR flash rate (▩). This cell has been classified as "interesting" because of the very rapid rise in the LDAR–lightning flash rate. Note that this surge in the lightning rate has occurred since the most recent NEXRAD update.

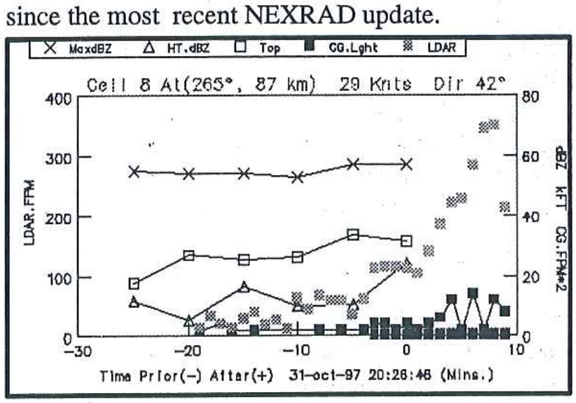

Figure 5. Pop–up–box generated for Cell 8 of Figure 2. Note that the LDAR flash rate uses the left–hand scale, 400 max, and the NLDN flash rate uses the right–hand scale, 40 max (80 max / 2). Time 0 is the time of the most recent NEXRAD update.

2.5. Post–processing procedures

To assist in the post–facto severe–storm research, the data from the LISDAD system are automatically analyzed and archived. Daily reports and graphs of interesting cells are sent (via E–Mail) from the LISDAD system to all users. Figure 6 shows a typical

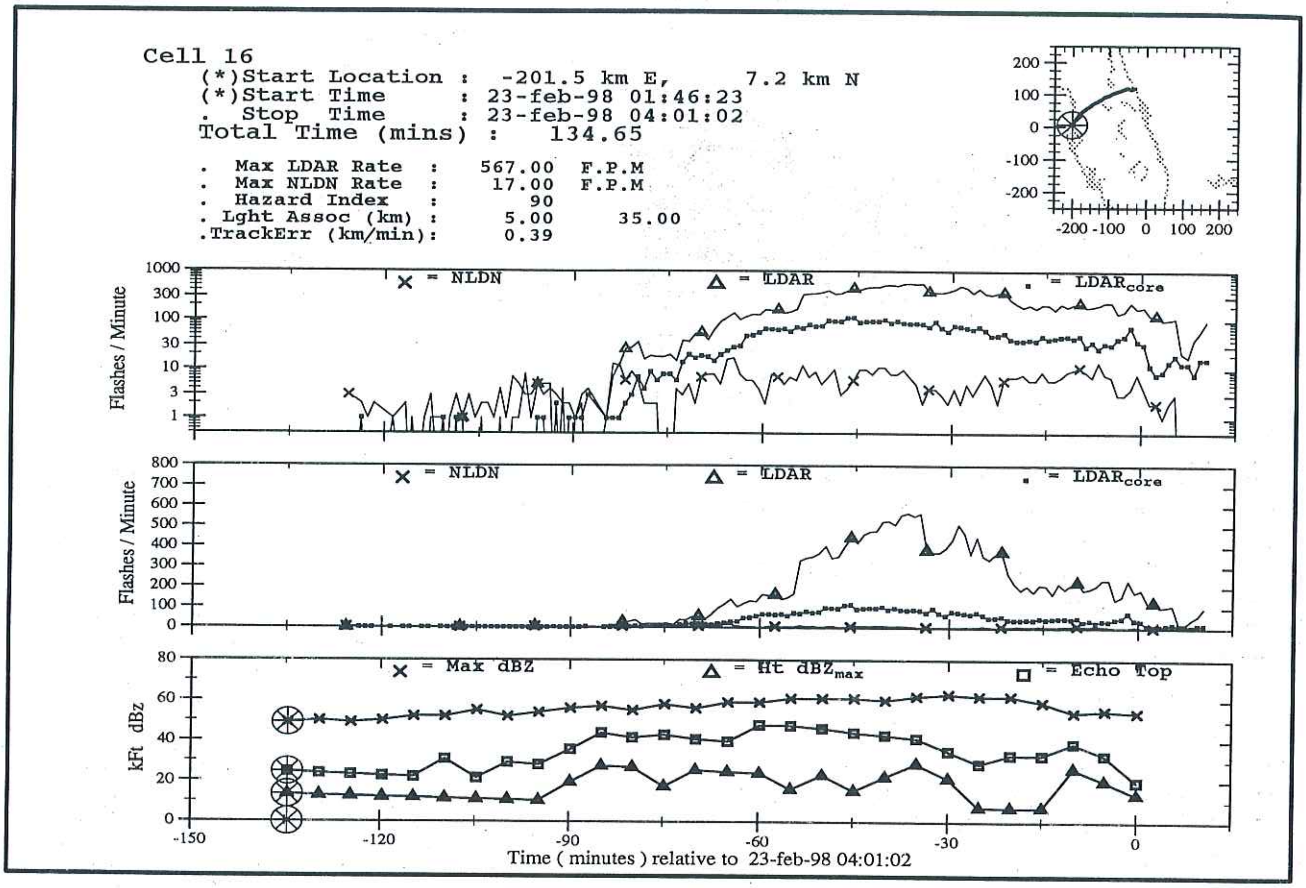

Figure 6. Example of graphical cell–summary E–Mailed to users at the end of the day.

graph of a severe–storm cell that was sent to all users. In this figure the NSSL/SSAP–generated parameters are shown in the lower graph, the NLDN and LDAR data are shown on linear and logarithmic scales in the middle and top graph, and a text summary of the storm and a plan–view of its path are presented at the top.

In addition, the NWS operational forecasters often E–Mail daily summaries of interesting storms to the other users. These two daily notifications permit researchers at NASA and MIT to review the cases and discuss them with the operational forecasters within a day of the event. This synergism has lead to the development of new total–lightning based severe–storm prediction algorithms that were evaluated in the summer of 1998, and will be discussed in following papers.

3. SUMMARY / FUTURE PLANS

The LDAR system has proven to be a convenient tool for both operational forecasters and research scientists. Its highly automated operation permits the daily monitoring of interesting weather with little effort. It has also helped segregate data derived from interesting cases from the bulk of routine, uninteresting data, thereby speeding up post–facto case regeneration and analysis.

Because most of the GSD's appearance and behaviors are controlled by a high level scripting language (much like Tck/Tk), this platform allows us to also explore future AWIPS integrated data display and algorithm concepts.

4. REFERENCES

Johnson, J. T. , M. D. Eilts, E. D. Mitchell, P. Spencer, G. J. Stumpf, and A. Witt, 1995: Operational Testing of Enhanced WSR–88D Algorithms and Display Concepts in National Weather Service Offices, p170–172, 27th Conference on Radar Meteorology, Vail, Colorado, October 1995, Amer. Meteor. Soc.

Lennon, C. and L. Maier, Lightning mapping system, NASA CP–3106 Vol II, International Aerospace and Ground Conference on Lightning and Static Electricity, 89–1 to 89–10, 1991.