THE RONDÔNIA LIGHTNING DETECTION NETWORK: NETWORK DESCRIPTION, SCIENCE OBJECTIVES, DATA PROCESSING/ARCHIVAL METHODOLOGY, AND RESULTS

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ABSTRACT: A four station Advanced Lightning Direction Finder (ALDF) network was established in the state of Rondônia in western Brazil in 1999 through a collaboration of U.S. and Brazilian participants from NASA, INPE, INMET, and various universities. The network utilizes ALDF IMPACT (Improved Accuracy from Combined Technology) sensors to provide cloud-to-ground lightning observations (i.e., stroke/flash locations, signal amplitude, and polarity) using both time-of-arrival and magnetic direction finding techniques. The observations are collected, processed and archived at a central site in Brasilia and at the NASA/Marshall Space Flight Center in Huntsville, Alabama. Initial, non-quality assured quick-look results are made available in near real-time over the Internet.

The network, which is still operational, was deployed to provide ground truth data for the Lightning Imaging Sensor (LIS) on the Tropical Rainfall Measuring Mission (TRMM) satellite that was launched in November 1997. The measurements are also being used to investigate the relationship between the electrical, microphysical and kinematic properties of tropical convection. In addition, the long-time series observations produced by this network will help establish a regional lightning climatological database, supplementing other databases in Brazil that already exist or may soon be implemented. Analytic inversion algorithms developed at the NASA/Marshall Space Flight Center have been applied to the Rondônian ALDF lightning observations to obtain site error corrections and improved location retrievals. The data will also be corrected for the network detection efficiency. The processing methodology and the results from the analysis of four years of network operations will be presented.

INTRODUCTION

In recent years, the worldwide application of lightning detection networks for scientific research and operations has increased with the recognition of the well-established physical links of lightning with cloud dynamics, precipitation microphysics and other related phenomena (e.g., atmospheric chemistry, global electric circuit). In 1999, through a collaboration of U.S. and Brazilian participants from NASA, INPE, INMET, and various universities in both countries, a four station Advanced Lightning Direction Finder (ALDF) network was established in the state of Rondônia in western Brazil. In this paper, we briefly describe this network, outline its science objectives, review the data processing methodology, and discuss results acquired during its first four years of operation.

NETWORK DESCRIPTION

Figure 1 depicts the Rondônian ALDF network. The network employs four ALDF IMPACT (Improved Accuracy from Combined Technology) sensors in a long baseline, high gain configuration. The network provides cloud-to-ground (CG) lightning observations (i.e., stroke/flash locations, signal amplitude, and polarity) using both time-of-arrival (a distinct advantage of using the IMPACT technology) and magnetic direction finding techniques. GPS (Global Positioning System) timing enables the CG strokes to be time-tagged with better than 300 ns accuracy. The observations are collected, processed and archived at a central site in Brasilia and at the NASA/Marshall Space Flight Center in Huntsville, Alabama by using VSat satellite links to transmit data from each station (Figure 2). Initial, non-quality assured quick-look results are made available in near real-time over the Internet.

Estimates of the detection efficiency (DE) and location accuracy of the network were initially derived theoretically. These estimates have now been more accurately re-derived using actual network data [*Rompala et al.*, 2003]. Knowledge of DE will enable the data to be used with less bias over a wider region yielding more accurate results and conclusions.

SCIENCE OBJECTIVES

A primary objective of the network is to provide ground truth data for the Lightning Imaging Sensor (LIS) on the Tropical Rainfall Measuring Mission (TRMM) satellite that was launched in November 1997, as well as its predecessor, the Optical Transient Detector (OTD), launched in April 1995 [*Christian et al.*, 1992; *Christian*, 2003; *Christian et al.*, 2003; *Pinto et al.*, 2003]. Intercomparisons of observations from the network with LIS and OTD provide valuable insight on how the South Atlantic Anomaly [*Pinto*, 1993] impacts the DE of LIS and OTD measurements.

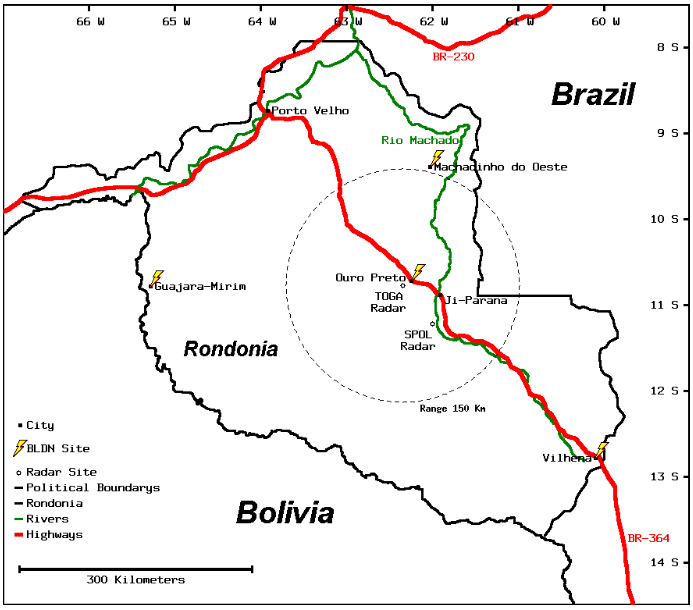

Figure 1. Brazil Lightning Detection Network (BLDN) deployed in the state of Rondônia.

The measurements are also being used to investigate the relationship between the electrical, microphysical and kinematic properties of tropical convection [*Petersen et al.*, 2002; *Williams et al.*, 2003]. Since its installation in 1999, the network has provided critical storm observations in three field campaigns. In addition, the long-time series observations produced by this network will help establish a regional lightning climatological database, supplementing other databases in Brazil that already exist or may soon be implemented (e.g. studies requiring regional climatological statistics such as required by atmospheric chemistry modeling [*Levy et al.*, 1996]).

DATA PROCESSING/ARCHIVAL METHODOLOGY

As noted previously, observations are collected, processed and archived at a central site in Brasilia and at NASA in Huntsville, Alabama. Two approaches are employed in processing the ALDF data. An initial near real time view of the region's lightning activity is obtained using an Advanced Position Analyzer (APA). However, limitations associated with using only these APA solutions include (1) significant percentage of flashes and strokes missed – on the order of 20-40% depending on APA settings, (2) location solutions obtained without fully accounting for local site error affects primarily due to azimuth error and sensor alignment offset, and (3) processing algorithm proprietary (and requires APA) so not possible to easily validate or reproduce APA solutions, or calculate new solutions.

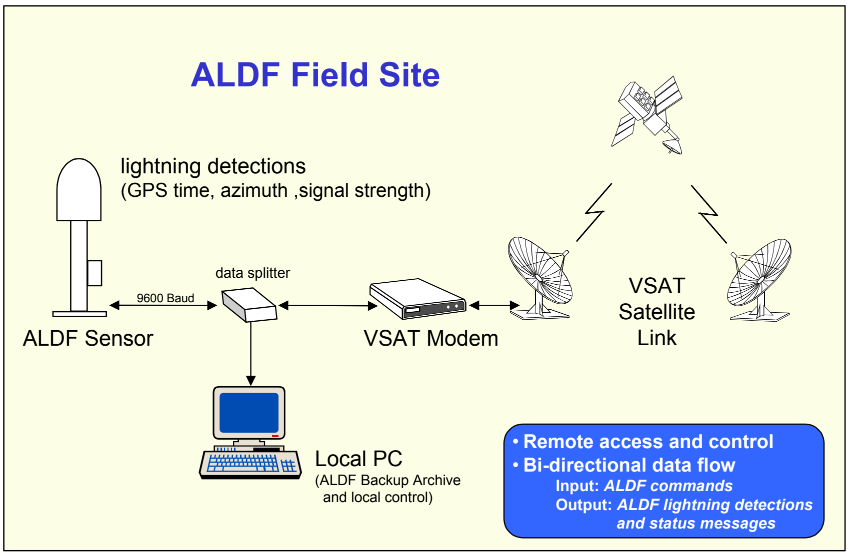

Figure 2. Operations and data flow from the ALDF field sites.

In order to overcome these limitations, analytic inversion algorithms developed at NASA have been applied to the Rondônian ALDF lightning observations to obtain site error corrections and improved location retrievals [*Koshak et al.*, 2000].

RESULTS

Lightning activity in the Rondônia region is characterized in the plots in Figure 3. The activity index used for these plots consists of averaging the raw ALDF detections from all operating sensors (i.e., we did not use flash/stroke solutions). No distance or seasonal adjustment has been made for DE variations. The daily activity plot (top) suggests a 5-10 day convective cycle that has been observed previously with Easterly waves propagating off the coast of Africa. A periodicity closer to one month is seen in the 5-day moving average plot (middle) perhaps correlating with local regime changes noted by *Petersen et al.* (2002). An even larger scale regime shift perhaps reflecting the "Green Ocean" [*Williams et al.*, 2003] is observed in 31-day moving average plot (bottom), with nearly twice the frequency of lightning in Oct-Nov compared to Jan-Feb, although both periods receive similar amounts of total precipitation.

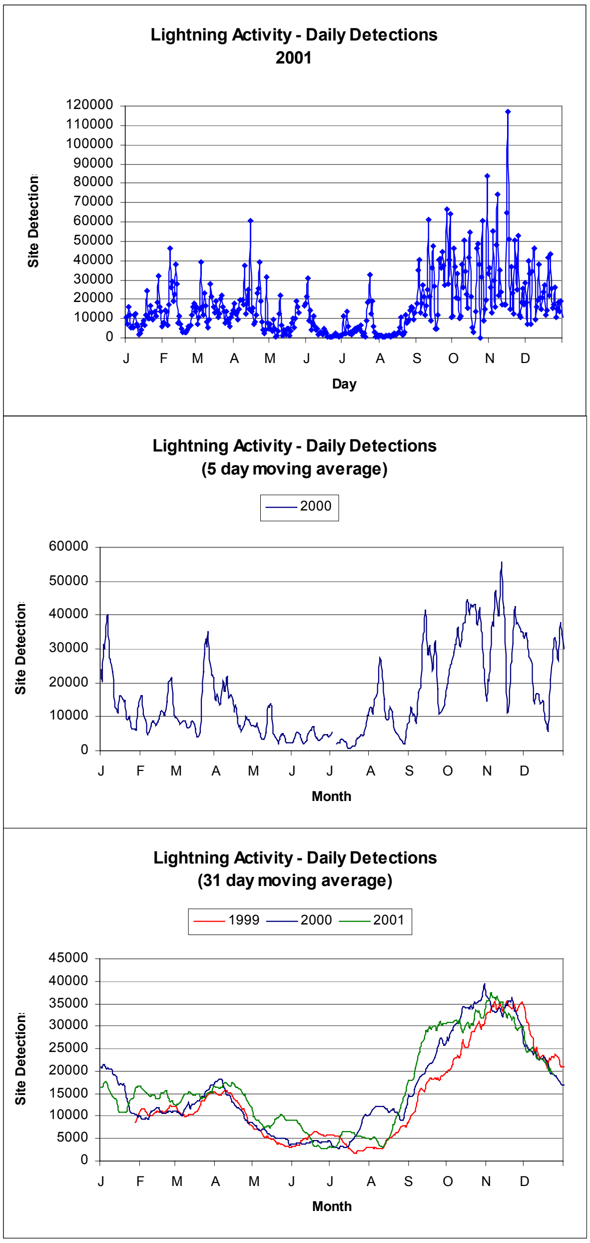

Figure 3. Observed Rondônian lightning activity (top – daily variation, middle – 5-day moving average, bottom – 31 day moving average).

The diurnal variation is shown in Figure 4. The negative peak occurs around 18-19 UTC with the positive peak generally occurring later, around 19-21 UTC. Initial lightning discharge statistics are summarized in the histograms shown in Figure 5. Note that the positive flashes are dominated by small current events. There is evidence that suggests that a large percentage of these events are actually intracloud discharges and not CG events. The percentage of positives ranged from about 15-25% depending on the season (no DE corrections have been applied to the results shown in Figures 4 and 5). Applying regional DE corrections will raise this percentage further but, as previously noted, most of these events actually correspond to ICs (we now believe the true positive CG percentage to be much smaller than indicated by these results).

CONCLUDING REMARKS

The Rondônian lightning detection network has provided the first detailed, continuous lightning climatology in the Amazon region. It has served to provide important ground truth validation for the LIS and OTD satellites. In addition, the network has provided critical observations of convection in support of three field campaigns since its installation in 1999. Plans are to continue network operations at least until the end of the TRMM mission now estimated to occur in 2004.

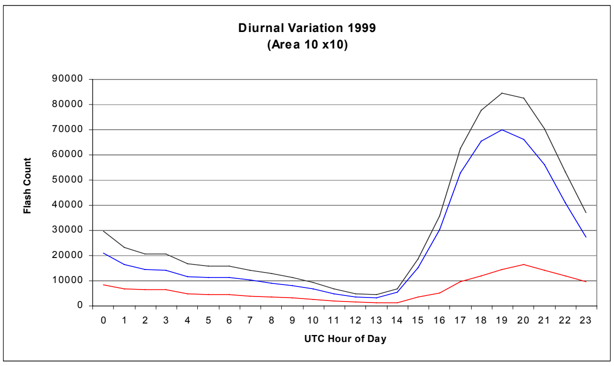

Figure 4. Diurnal variation of lightning activity in the Rondônia region of Brazil.

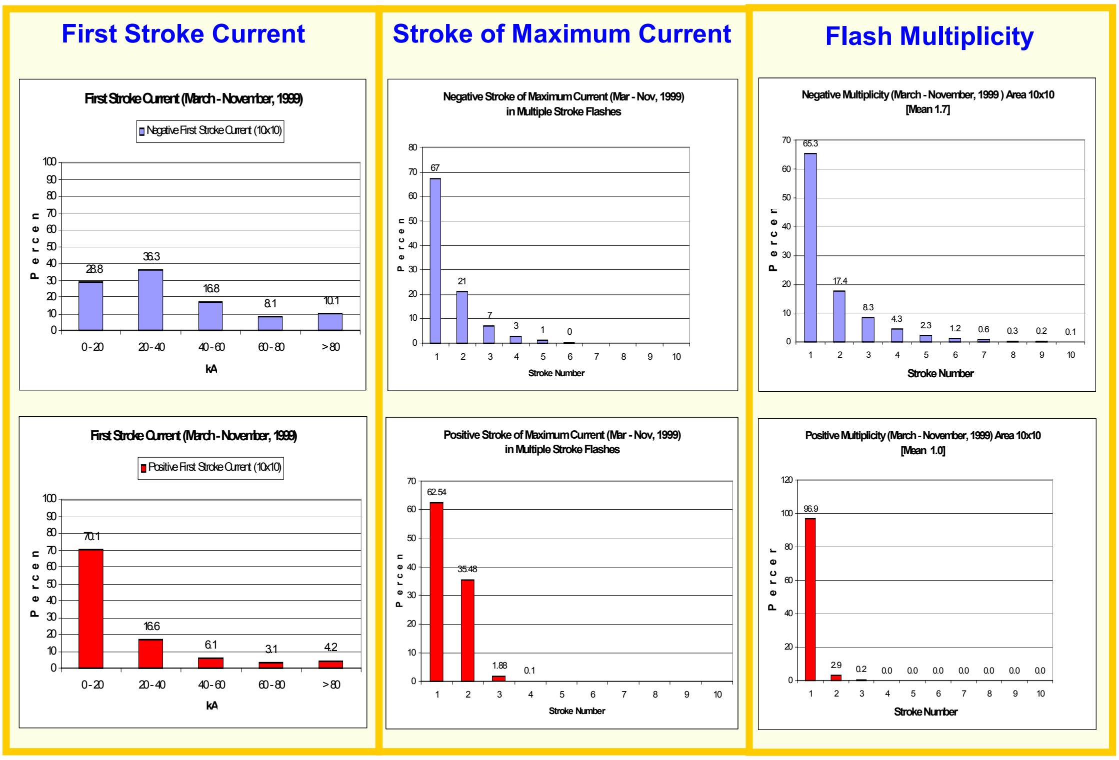

Figure 5. Flash/stroke statistics from the Rondônia region in Brazil.

REFERENCES

Christian, H. J., Blakeslee, R. J., and Goodman, S. J., Lightning Imaging Sensor (LIS) for the Earth Observing System, *NASA TM-4350*, Available from Center for Aerospace Information, P.O. Box 8757, Baltimore Washington International Airport, Baltimore, MD 21240, 44 pp., 1992.

Christian, H. J., R. J. Blakeslee, D. J. Boccippio, W. L. Boeck, D. E. Buechler, K. T. Driscoll, S. J. Goodman, J. M. Hall, W. J. Koshak, D. M. Mach, and M. F. Stewart, Global frequency and distribution of lightning as observed from space by the Optical Transient Detector, *J. Geophys. Res.*, *108 (D1)*, 4005, 10.1029/2002JD002347, 2003.

Koshak, W. J., R. J. Blakeslee, and J. C. Bailey, ALDF data retrieval algorithms for validating the Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS), *J. Atmos. Ocean Tech., 17*, 279-297, 2000.

Levy. H., W. J. Moxon, and P. S. Kasibhatla, A global three-dimensional time-dependent llightning source of tropospheric NO_X, *J. Geophys. Res.*, *107*, 22,911-22,922, 1996.

Petersen, W.A., S. W. Nesbitt, R. J. Blakeslee, R. Cifelli, P. Hein and S. A. Rutledge, TRMM observations of intraseasonal variability in convective regimes over the Amazon. *J. Climate*, *15*, 1278-1294, 2002.

Pinto, O., Jr., I. R. C. A. Pinto, and H. H. De Faria, A comparative analysis of lightning data from lightning networks and LIS sensor in the North and Southeast of Brazil, *Geophys. Res. Lettr.*, *30 (2)*, 1073, 10.1029/2002GL016009, 2003.

Pinto, O., Jr., “Recent research on the South Atlantic Magnetic Anomaly,” in *Trends in Geophysical Research*, *2*, 45-54, 1993.

Rompala, J. T., R. J. Blakeslee, J. C. Bailey, Detection efficiency contours for regions serviced by lightning detection networks of limited scope, *Preprints, 12th Int. Conf. on Atmos. Electr.*, June 2003, this issue.

Williams, E., *et al.*, Contrasting convective regimes over the Amazon: Implications for cloud electrification, *J. Geophys. Res.*, *107*, 10.1029/2001JD000380, 10 October 2002.