

Detection Efficiency Contours for Regions Serviced by Lightning Detection Networks of Limited Scope

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ABSTRACT: Lightning Detection Networks (LDN's) are finding worldwide application. The detection site densities among these networks varies greatly. For those networks where the site density is low, range effects prompt a wide variation in the detection efficiency over the region. Knowledge of the network's efficiency profile then becomes a critical factor in meeting its operational objectives, in analyzing the local data, linking it with data for neighboring networks, and establishing local climatology. The work presented here offers a direct and versatile approach for developing such a profile. A method to survey detection efficiency over the service region is presented which is based on the region's peak stroke current distribution. The method suggests techniques for incorporating operational parameters into analysis as well as event range factors. It also forms the basis for an study of the features of peak stroke current distributions.

RONDONIAN REGIONAL PEAK CURRENT DISTRIBUTION

A network's regional detection efficiency is effectively reflected in variations in the peak current distribution (PCD). Range attenuation will preclude the detection of low current cloud to ground (CG) events occurring in its remote sectors while the PCD spectrum from central sectors will be nearly complete. The extent of this variation is illustrated using data gathered by the LDN servicing the Rondonian region of Brazil. This network consists of four stations which form an irregular grid with intersite distances varying from 150 km to 605 km. The CG lightning event data gathered at these sites includes the azimuth of the incoming electromagnetic signal source, its strength, time of arrival, and polarity. Correlating event information from these sites permits the determination of the time of occurrence and location of the discharge. These results also lead to a peak current determination of the lightning strike.

The area serviced by the Rondonian network covers more than a million square kilometers. For purposes of this study this region was taken as running from -16° to -6° latitude and -67° to -57° longitude. The distance of sites to the geographic center ranges from 120 km to 450 km. In order to gain a sense of the radial variation in the PCD, this service area was divided into four concentric sectors made up of $1.0^{\circ} \times 1.0^{\circ}$ blocks. This division is displayed in the figure 1.

The empirical data used in this initial survey included both positive and negative CG events occurring during November of 1999. The negative PCD's for the four sectors is presented in the figure 2. It clearly illustrates a significant radial reduction in the detection of low peak current events. The PCD's for positive events follow a similar overall pattern.

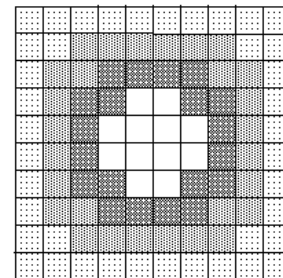


Figure 1. The four regional sectors

RONDONIAN LDN REGIONAL DETECTION EFFICIENCY

The PCD spectrum for the inner sector demonstrates nearly ideal detection efficiency. To gain a profile that was representative of the range of events over the entire region a smaller central segment of the region was considered. This sampling came from a $4^\circ \times 4^\circ$ block, quad, at the center. This sector is large enough to have accumulated enough events to be statistically significant and its location insures nearly ideal detection efficiency.

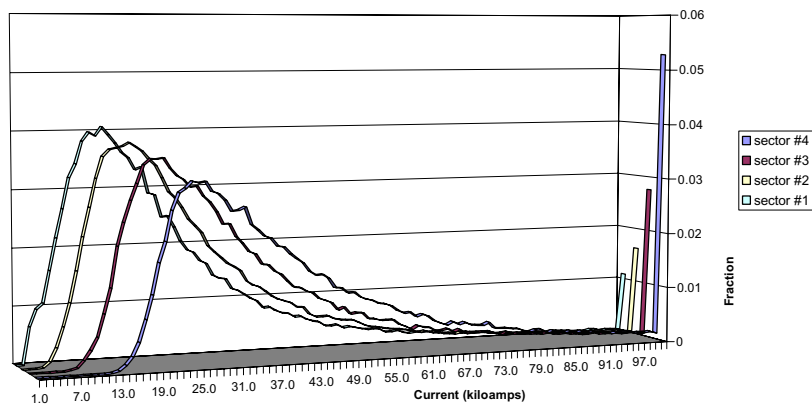


Figure 2. The PCD for negative CG events in the four regional sectors for November, 1999

The detected PCD for events within this central quad was then considered as a probability distribution representative of the event distribution experienced at any location over the region. This set of control events was then applied to locations on a $0.1^\circ \times 0.1^\circ$ grid of the region to determine what proportion of the set would be detected at each of these points. The accumulated results for locations making up the four sectors is shown in figure 3.

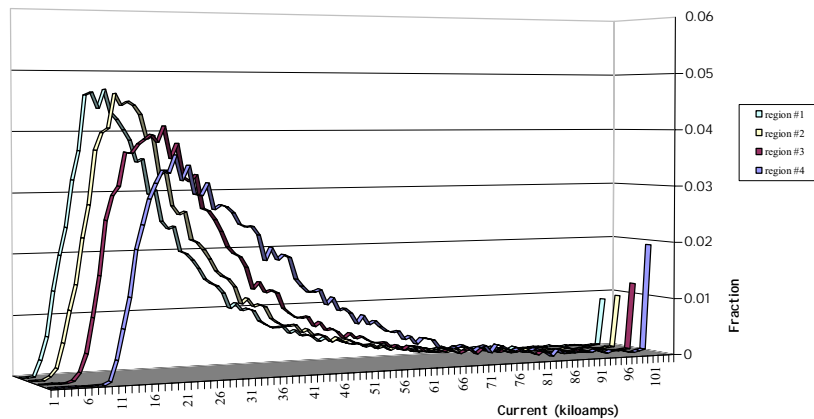


Figure 3. The central quad data applied to the four regional sectors

In all sectors the agreement between empirical and modeled PCD's was strong enough to warrant the use of the uniformity assumption in determining, at least, regional detection efficiency's first order approximation.

ANALYTIC FORM OF THE PEAK CURRENT DISTRIBUTION

In order to facilitate the development of such algorithms and to foster investigation of the character of the strike peak current distribution, the empirical central quad data set was also modeled as a gamma probability distribution function (GPDF). This type of distribution is typically used to model events which are made up of a series of exponential decay steps. Parameters for the GPDF are; the number of steps making up an event (α) and the decay factor (β).

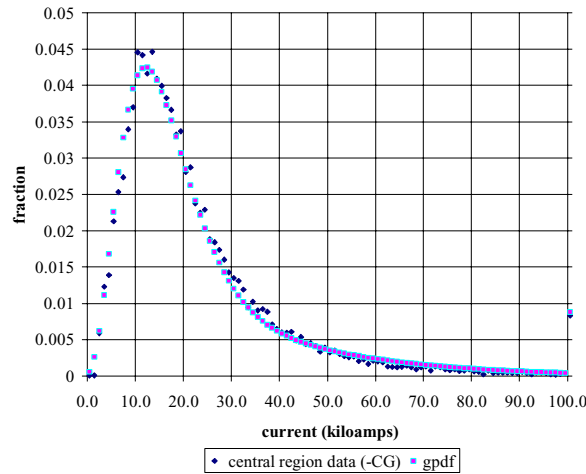


Figure 4. Negative Peak Current Distribution and its modeled bi-GPDF

In order to achieve a good fit to the empirical data in the high peak current portion of the data, the modeling was extended to include a second GPDF yielding a compound or bi-GPDF. This weighted sum of two GPDF's is shown in figure 4 along with the modeled empirical data for the central quad of the region. The method for selecting the best set of parameters for this modeling technique is yet to be determined. As the figure illustrates, even with approximate methods, a workable set of parameters can be arrived at.

ANALYTICAL ANALYSIS AND GRAPHICS REPRESENTATION

This central quad data set's bi-GPDF model was applied to the same $0.1^\circ \times 0.1^\circ$ regional grid used in the analysis of sector PCD's. The application algorithm parameters included in that analysis were the detection characteristics for each site and the combination of sites used in the 'solution' determination. The detection efficiency is taken as a simple ratio of the events detected and yielding solutions to the total number of events. Results are conveniently summarized in a contour map of the region. The contour shown in figure 5 illustrates the result of the application of the bi-GPDF model of negative peak currents to the full regional grid. In that illustration the threshold for detection at all sites was set higher than ordinary to emphasize the impact of that parameter on detection efficiency.

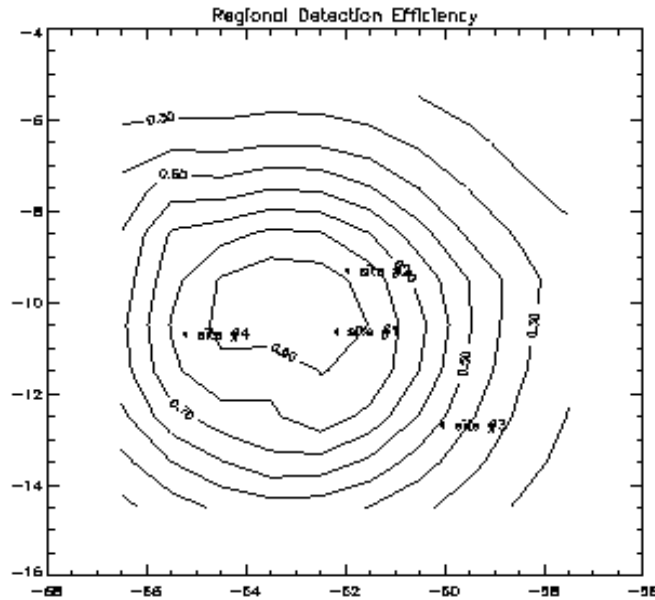


Figure 5. Regional Detection Efficiency for Negative CG

CONCLUSION

The approach presented offers a direct yet functional method of arriving at a survey of a LDN's detection efficiency. As an operational tool, its application enhances the network's reliability and compatibility with data sets from neighboring networks. The impact of variations in detection site parameters and configuration can be estimated. As a research tool, it provides basis for investigating CG events and their peak current patterns within the region. The resulting regional profile makes it possible to return to the empirical data and gain an estimate of the number of events going undetected in any sector of interest. The analytical feature of the method provides information about the distribution of peak current values among those events and the character of the full peak current spectrum.

ACKNOWLEDGEMENT

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