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Tail fitting the intensity distribution of selected Saturnian lightning storm episodes

Joseph Ambrose Pagaran and Georg Fischer
Space Research Institute, Austrian Academy of Sciences, Graz, Austria (joseph.pagaran@oeaw.ac.at / Fax: +43 (316) 4120-690)

Abstract

Saturn Electrostatic Discharges or SEDs are measured by Cassini/RPWS (Radio and Plasma Wave Science) instrument at all intensities. They occur in episodes of storms with periodicity lasting close to one Saturn rotation (about 10 hours and 40 minutes). Using a computer algorithm, they are identified as events having intensities above a threshold value close to the galactic background fluctuation. SEDs, therefore, can be seen as extreme events above a threshold. In this perspective, through selected episodes that fulfill a set of criteria, we illustrate how generalized extreme-value distribution (EVD) functions can be used to find the best-fit EVD to intensity distribution of these SED episodes, and from this model EVD to deduce the total number of SEDs per episode, and to estimate the number of undetected SEDs.

1. Introduction

Most probably modulated by seasonal effects, lightning storms in Saturn's atmosphere have reached their peak towards the spring (autumn) equinox in northern (southern) hemisphere. These storms consists of several episodes. As detected by Cassini RPWS (Radio and Plasma Wave Science), each episode is a series of Saturn Electrostatic Discharges or SEDs. A computer algorithm [1] identifies an SED if its intensity is above a certain threshold with respect to the background intensity. A plot of intensity distribution of storm episodes [2] shows only the (right) tail of the distribution.

In this contribution, we illustrate how to use generalized extreme value distribution (EVD) functions to compute the whole intensity distribution for each selected episode knowing only its tail (extreme values). From this best fit EVD, we can estimate the number of undetected (low intensity) SEDs the algorithm failed to distinguish them from cosmic galactic background.

2. Theory

To deduce the complete intensity SED distribution from its tail, the peak above a threshold, we use the generalized extreme value distribution [3] (in the case when the shape parameter ξ is set to zero),

$$\begin{aligned} y &= f(x|\mu,\sigma) \\ &= \sigma^{-1}\exp\left(\frac{x-\mu}{\sigma}\right)\exp\left(-\exp\left(\frac{x-\mu}{\sigma}\right)\right) \quad (1) \end{aligned}$$

whose location μ and scale σ parameters translate along the horizontal direction and expands/contracts the distribution, respectively.

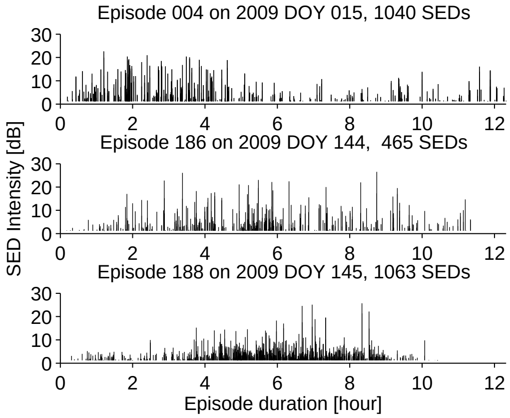

Figure 1: SED intensity as a function of time from the start to the end of the episode. Shown from top to bottom panels are episodes No. 004, 186, and 188, their corresponding DOY in 2009, and number of observed SEDs above 1.2 dB threshold.

3. Data

To achieve statistical robustness, only SED records from Cassini/RPWS that fulfill the following criteria are selected for the analysis. Those records in a storm episode having

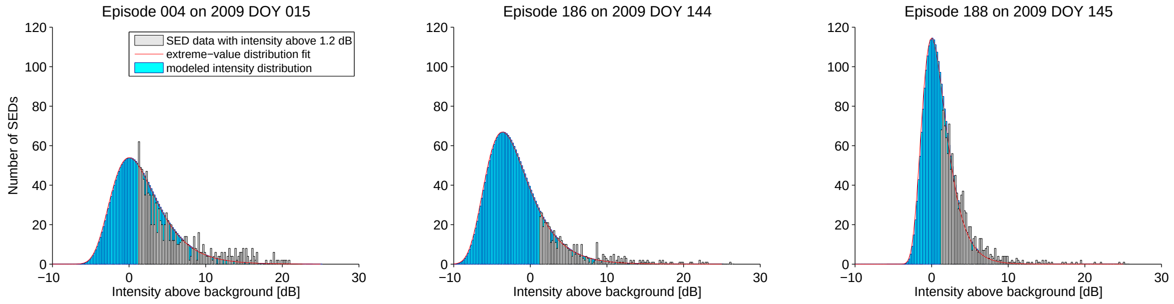

Figure 2: Tail fitting the intensity distribution of selected lightning storm episodes with extreme value distribution (EVD) function (cf. Eqn. (1)). Shown is a histogram (shaded gray) with bin size of 0.2 dB, its modeled EVD fit (red) and the complete histogram (cyan) of the same bin size.

- observed at almost constant Cassini distance throughout the duration of the episode, and between one episode to another.
- an intensity above background threshold of 1.2 dB.
- an SED number greater than 400.
- no data gap.

Among several episodes categorized in the year 2009, only episodes No. 004, 186, and 188 satisfy the above criteria. Simplified temporal plots of these selected episode are shown in Fig. 1. Some of their characteristics are provided in Table 1.

Table 1: Characteristics of selected episodes of storms in 2009, cf. Fig. 1. The last two columns are computed from histograms shown in Fig. 2.

Episode	DOY	Duration	Mean	Number of SEDs		
No.	center	[hr]	dist.	(obs)	(fit)	(rejected)
			[R_S]	≥ 1.2 dB		< 1.2 dB
004	015.6	12.3	11.3	1040	1120	1119
186	144.4	11.3	11.9	465	413	2127
188	145.4	10.4	11.4	1063	937	1523

4. Results and Discussion

The best-fit EVD to intensity distribution for each SED episode is shown in Fig. 2.

For the sum of all SEDs above a threshold value of 1.2 dB, we can compare the sum of observed to modeled total number of SEDs to be in near agreement. (See Table 1). The last column of the table shows how many SEDs remain unaccounted. These SEDs can have intensities as low as -10 dB with respect to the background intensity.

5. Conclusion

SEDs are identified as flashes having intensity above a threshold value. For a storm episode, a plot of their intensity distribution shows only the tail, i.e. SEDs can be seen as extreme events. We have illustrated how this tail can be fitted using generalized EVD functions (whose shape parameter was set to zero) to calculate the entire intensity distribution of selected SED episodes. For statistical robustness a set of criteria has to be satisfied in the selection of SED episodes. To validate our modeled distribution, we compare the SED number above the threshold to the observed value and found near agreement. From the modeled SED intensity distribution, we estimate the number of undetected SEDs, which was found to be dependent on the episodal nature of the tail.

Acknowledgements

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