Lightning strokes frequency homogenization for climatological analysis: application to LINET data records over Europe

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In any lightning location network the detection efficiency is variable in space and time. This circumstance inherently limits the quantitative validity of studies relying on the uniformity of the threshold of the minimum detectable stroke current among different areas of the network and/or at different times. This difficulty is addressed here by studying the characteristics of the PDF (probability density function) of the stroke current registered by LINET. These distributions have shown the same shape for current values higher than the threshold defined by the mode of the distribution. For this reason, the PDF of the current becomes suited to correct the total amount of strokes detected in different network areas (having different detection efficiency). As a result we produce adjusted climatological maps of the total number of strokes over large geographical areas.

1. Introduction

The study of lightning spatial distribution is of great interest, especially for energy-management and safety purposes. Moreover, the knowledge of lightning distribution may be used as a predictor for very complex weather nowcasting systems, and lightning climatology expressed in terms of thunderstorm probability distribution may be used in warning systems in case of severe weather events, such as strong thunderstorms. The number of detected lightning strokes recorded by the network is affected by the local detection efficiency. The detection efficiency cannot be the same over the entire monitored area in spite of any attention being placed in positioning the sensors. The result is an objective difficulty in using lightning data in applications where the number of lightning is related to other variables that vary over time and space, such as most of the possible applications in weather and climate, or comparisons among different lightning networks [2]. Starting from these considerations the objective of this study is to analyze the spatial characteristics of the detection efficiency of the LINET network especially in the Mediterranean area, and to propose a method to calibrate the LINET stroke counts by correcting the detection efficiency variability.

2. Dataset

The lightning data used in this work were provided by an European ground-based Lightning Detection Network for high-precision detection of total lightning, ground strokes (CG, cloud-to-ground) and cloud lightning (IC, in-cloud), with utilization of VLF/LF techniques (in the range between 1 and 200 KHz) [1]. The network consists of about 120 sensors (as of 2010) in some 25 European countries with a good coverage of the central and western Mediterranean (from 10° W to 35° E in longitude and from 30° N to 65° N in latitude). Lightning locations are determined in 3D, using a time of arrival (TOA) difference triangulation technique. VLFLF strokes are detected with high temporal resolution and a spatial accuracy of 150 – 250 m, depending on the area and correction of systematic errors.

The period selected for the present study covers two years (from October 2010 to November 2012) and is limited mainly to Italy and the surrounding Mediterranean area. The dataset contains about 1 million of records containing all relevant lightning parameters for each single stroke, such as latitude, longitude, emission altitude (for IC strokes), and the range-normalized discharge current (in kA).

3. Methodology

The LINET data have been sampled over a regular grid of 20x20 km^2 box size. For each grid box the Probability Density Functions (PDFs) of the current intensity measured over the whole period has been calculated. In Figure 1 some examples are shown for PDFs of current distributions sampled at 1 kA in different grid boxes. The methodology applied to estimate the correct number of strokes in the Mediterranean area is described below.

Observing Figure 1 it is evident that the PDFs have similar behavior for current intensity values

higher than the mode of the distribution. The behavior among the PDFs changes for current intensity lower than the mode.

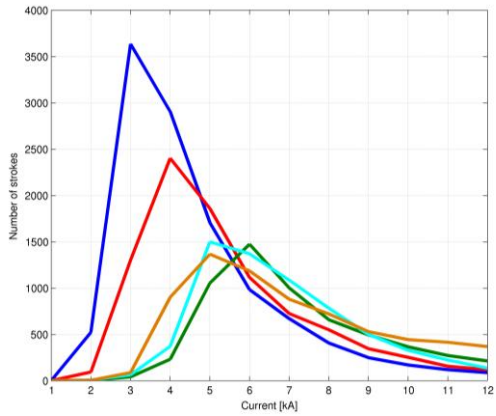

Figure 1: Example of PDFs of current distributions for spatially distant different grid boxes of size 20 x 20 km^2.

It is reasonable to assume that the real number of strokes is underestimated as the mode of the PDFs moves to higher values (detection efficiency decreases). Therefore, the maximum in the PDFs indicates the lowest current value of the strokes correctly detected, and a certain number of strokes with current intensity lower than the mode are most likely missed. The mode of the PDF represents the *current detection threshold* (CDT) for each specific grid box and is directly related to the concept of detection efficiency. It follows that we can obtain a spatial representation of the detection efficiency of the network by simply mapping the above-mentioned threshold values (without discriminating between positive and negative stroke polarity). Thus, we compute the most frequent value of the current distribution (i.e. the mode of the PDF) of the detected strokes for each grid box. The result for a selected area is shown in Figure 2, and the map can be interpreted as an efficiency map of the network. The map in Figure 2 highlights areas where the detection efficiency is higher (blue, even weakest strokes are detected) and areas where the detection efficiency is lower (more intense strokes are detected). In particular, it can be observed that in the best-covered areas the values of most frequent current values vary between 1.5 kA and 5 kA. Our methodology consists in selecting the grid boxes having CDT less or equal than 5 kA, which are assumed to have optimum efficidency, to build up a reference PDF. This PDF is used to adjust the PDFs of all grid boxes where the CDT is higher than 5 kA. The total stroke number detected in each grid box is therefore recomputed.

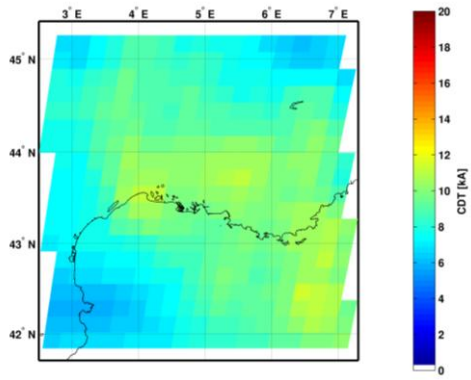

Figure 2: Example for the distribution of most frequent current intensity value (kA) of the strokes detected in each 20x20 km^2 grid box, using a reduced subset of the data.

4. Results and conclusions

By using the reference PDF we have computed the correction factor for each grid box, which corrects the total number of actually detected strokes to yield the expected number of true strokes, independent of the detection efficiency differences among the different areas. The result is shown in Figure 3. The methodology can be used to generate climatological maps of calibrated LINET stroke counts/frequency independent of the spatial detection efficiency variability.

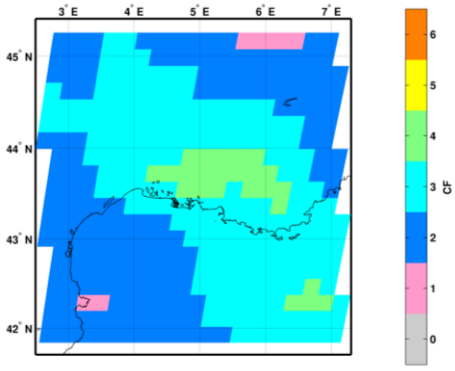

Figure 3: Correction factor values obtained for the area shown in Figure 2.

5. References

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[2] Lagouvardos, K., et al., 2009: A comparison of lightning data provided by ZEUS and LINET networks over Western Europe. Nat. Hazards Earth Syst. Sci., 9, 1713–1717.