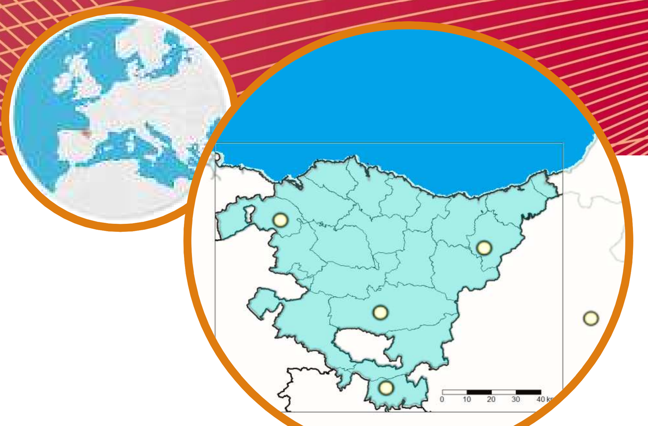


Figure 1. Location of Basque Country and LINET sensors

Evaluation of the potential use of lightning features as a storm severity indicator in Basque Country

S. Gaztelumendi [1,2], J. Egaña [1,2]

1- TECNALIA, Energy and Environment division. Meteorology Area. Parque tecnológico de Álava. Araba, Basque Country.

2- Basque Meteorology Agency (EUSKALMET). Parque tecnológico de Álava, Miñano, Araba, Basque Country.

Abstract

The main goal of the present work is to provide evidences of the potential use of lightning characteristics in order to provide the basis for an early detection system of convective storm severity in the ground. In such a way that they can be applied to surveillance tasks and for nowcasting purposes in Basque Country.

In this study we check relations between surface severity and different lightning indicators calculated each minute, and particularly on LJ during severe storm episodes. For this analysis we use several events of severe weather that take place in the Basque Country during the operational period of the LDS available in Euskalmet since 2009

Introduction

Different studies from different places all around the world indicate that rapid increases in total lightning activity, termed "lightning jumps" (LJ) (Williams et al. 1999) are produced some minutes (between 1–30 depending of thunderstorm type) prior to the occurrence of severe weather on the ground (e.g. Buechler et al. 2000, Bridenstine et al. 2005, Steiger et al. 2007; Gatlin 2006, Shultz 2009). Such phenomenon is the basis for the implementation of nowcasting tools for severe weather in different meteorological services around the world.

Lightning data, accessible in Basque Meteorology Agency (Euskalmet) today, comes from a lightning detection system (LDS) that covers our territory with 4 antennas, this system is part of LINET lightning detection network. Such a network operates in VLF/LF frequencies and provided different lightning information including cloud to ground (CG) and intra cloud (IC) strokes (Betz 2009, Holler 2009, Lopez et al 2011, Nowcast 2016, Gaztelumendi et al 2017).

Methodology and data

In this work, all strokes data available for 2010-2018 period in Basque Country area and surroundings are used. Raw data are cleared by eliminating data with inconsistencies in heights and spatial accuracy. Final data are spatially aggregated around 26 representative points coincident with the locations of some AWS available in the area (Gaztelumendi et al 2018). Later on a temporal aggregation to minute cadence has been done. Note that the real time operational availability of strokes data in Euskalmet case are one file each minute.

This strategy of spatial aggregation responds to the Eulerian strategy (as opposed to Lagrangian one) followed in this study (Wu et al 2018). The static point of view in which the question is whether from a certain fixed point on the ground, it is possible to characterize the severity based on the characteristics and temporal evolution of strokes that occur within a given radius (fixed here in 12 km). In this work no grouping of strokes to flashes have been performed.

The selection of the different parameters used in this work has been established based on a selection of the most widely used in different contexts when characterizing extreme events and particularly in the context of LJ (e.g. Pérez et al 1997, Peterson et al 1998, Schultz 2009, 2014, Gatlin et al 2010, Chronis et al 2015, Franell et al 2017, Rigo 2018).

All the parameters are calculated for the entire time period and for all locations in order to have a full data set useful for climatic perspective in order to characterize typical values in different seasons. Finally, we also analyzed their behavior during different extreme events that have affected the CAV in recent years (Egaña et al 2017, Gaztelumendi et al 2017, 2019) and during different days with very heavy rain registered in Basque AWS network.

All the calculus presented here has been done with R (core team 2014), particularly using different R libraries and scripts for temporal and spatial data analytics

Results & Discussion

In Figure 2 we can see the 26 areas defined for spatial aggregation of strokes with 26 selected locations for this study. We define a 12km radius around a selection of AWS in order to cover the territory and to produce sufficient data for the different aggregations. Those areas are established with the intention of incorporating most part of strokes for a particular storm in the hope that poorly correlated strokes from other storms do not affect the statistics of each area.

In figure 3 we can see the distributions of one minute rates for different variables included in this study. Such variables are Total lightning (TL), Cloud to ground (CG), In-cloud (IC), The positive fraction (POS), the negative one (NEG), the CG positives (CGPOS), the CG negatives (CGNEG), the IC positives (ICPOS) and negatives (NEG), the fraction of CG POS with current > 5 kA (CGPOS5), the CG NEG < -5kA (CGNEG5) and the fraction of IC between 1 and 5 km (IC1_5), between 5 and 10 (IC5_10) and over 10 km (ICE10_15)

In figure 4 we can see the monthly distribution for TL, IC and CG one-minute rates (X) and some details for 4 selected locations. Note that monthly distribution varies responding to thunderstorms behavior in the territory, as respond to seasonality and to local geographical aspects.

In figure 5 we present box-plots for spatially aggregated 5-minutes rates (XR), and monthly details. We use 20 minutes of the thunderstorm's recent variable rate history (XTRC) to understand if the current behavior of a storm's variable rate (XR) is abnormal. In Figure 6 we present box-plots for spatially aggregated 5-minutes time rates of changes at 1-min intervals in the past 20 min (XTRC).

Note that higher values and outliers are spread during all seasons probably as a consequence of partial penetration of thunderstorms in the considered area. This behavior is indicative that different thresholds must be established in order to consider XTRC as the base for severity identification.

Sharp change rate (jumps) were objectively identified for each area during studied period using a modified σ-lightning jump algorithm from Schultz et al. (2009, 2011). If the time at which a jump occurs is correlated with severe weather, and the eulerian approximation is plausible it should be possible to detect some kind of correlation between those variables and severity at daily level in a climatic perspective including some kind of segmentation for severe weather.

In figure 7 we can see the Pearson correlation coefficients between daily precipitation (24-hour, 1-hour and 10min), variable rates and temporal rates of change of lightning variables. Correlation is poor in general, but a little bigger with derived IC variables, and particularly with IC strokes values at high levels.

In figure 8 we present for Mañaria AWS during 2018-06-03 heavy precipitation event, the temporal evolution at minute scale of the 5 minutes rates and 20 minutes time rate change for TL, CG and IC. In Figure 9 we present the same for Salvatierra during 2018-07-04 tornado event including the temporal rate of change and a plausible representation of the lighting jump threshold evolution during time, (based on standard deviation of time rate of change during the past 20 min), note that LJ occurs when this value exceeds the first. It is possible to find more details on these two events in two study cases presented in this same congress.

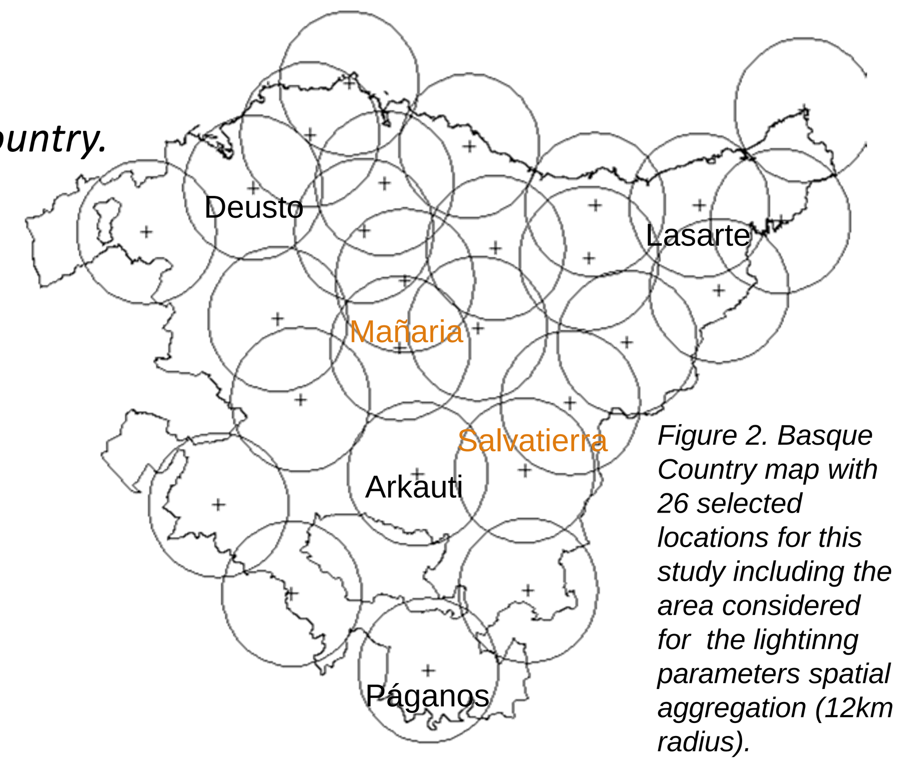


Figure 2. Basque Country map with 26 selected locations for this study including the area considered for the lightning parameters spatial aggregation (12km radius).

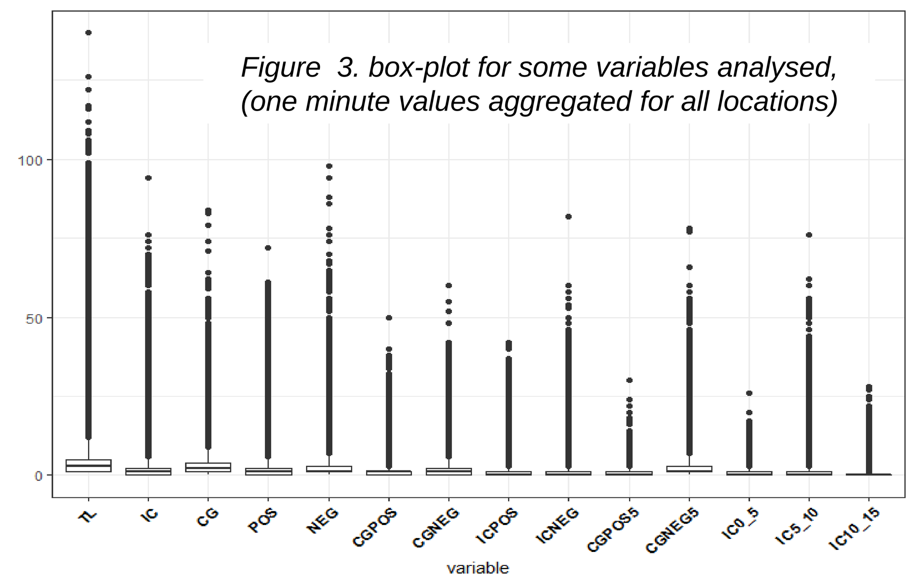


Figure 3. box-plot for some variables analysed, (one minute values aggregated for all locations)

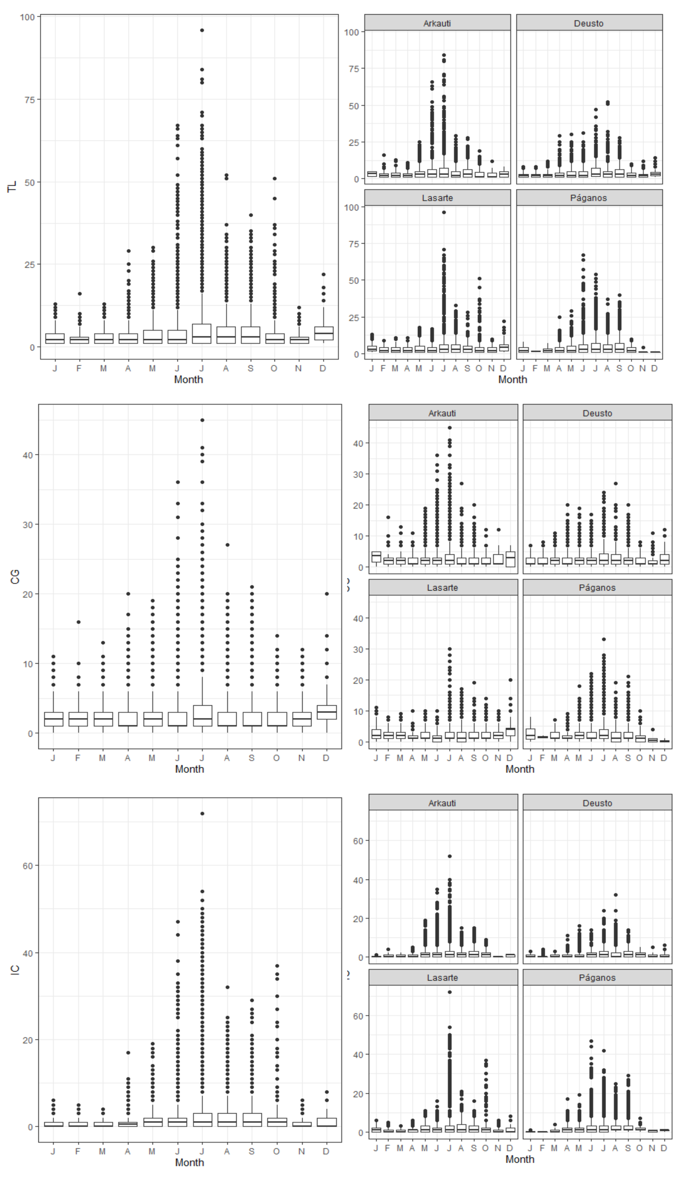


Figure 4 Monthly box-plot for one minute counts TL,CG and CC (top to down) aggregated for all locations (left) and for 4 selected areas (right).

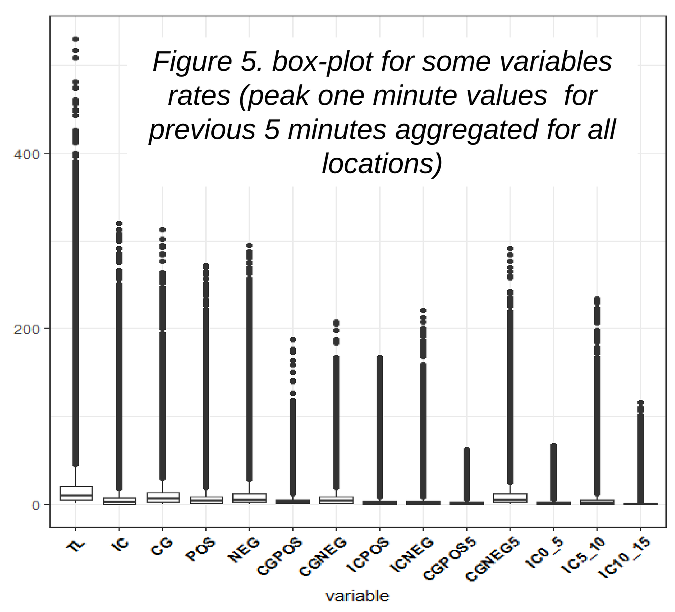
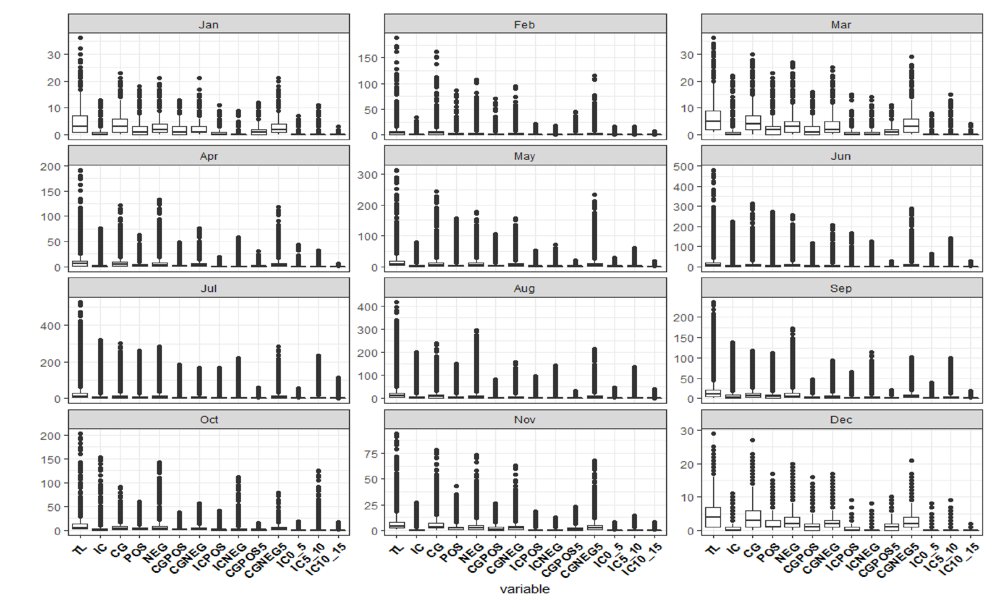



Figure 5. box-plot for some variables rates (peak one minute values for previous 5 minutes aggregated for all locations)

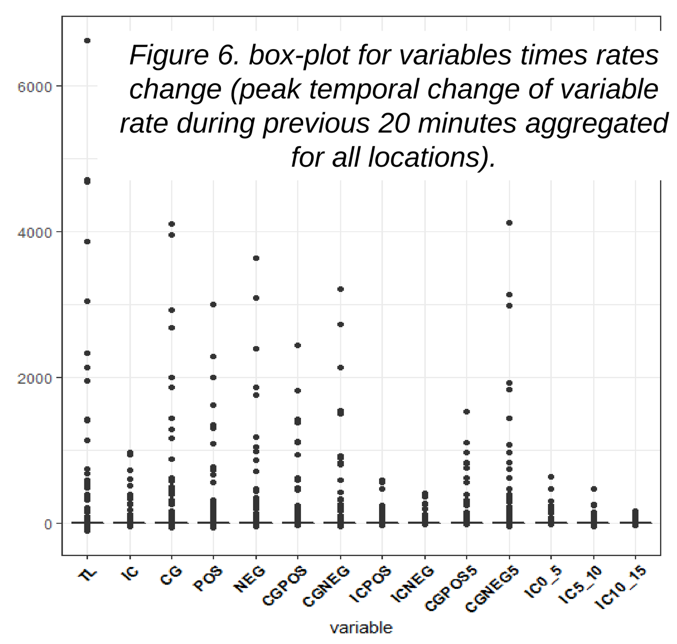
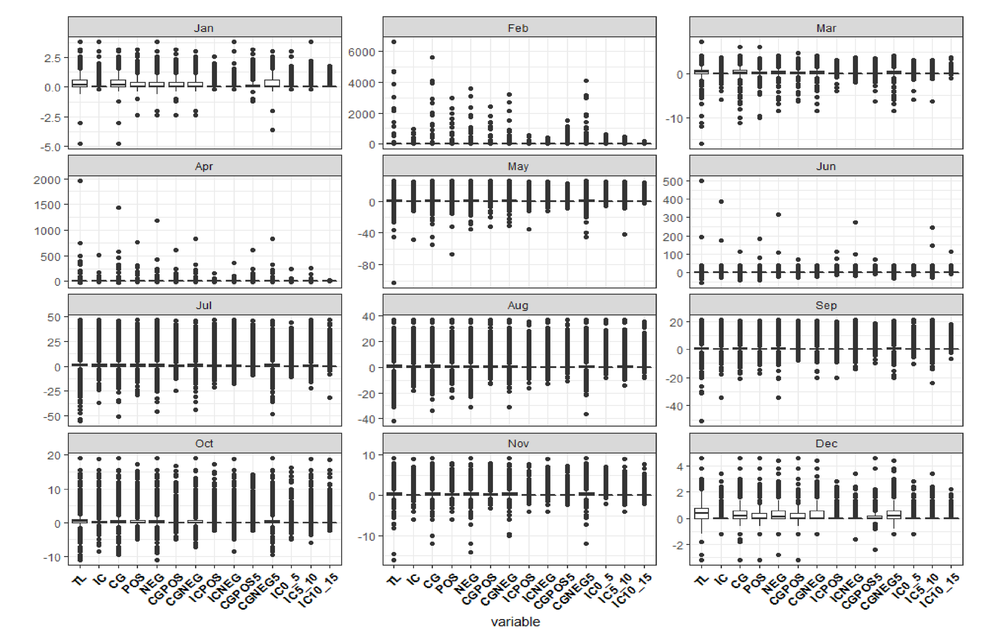



Figure 6. box-plot for variables times rates change (peak temporal change of variable rate during previous 20 minutes aggregated for all locations).

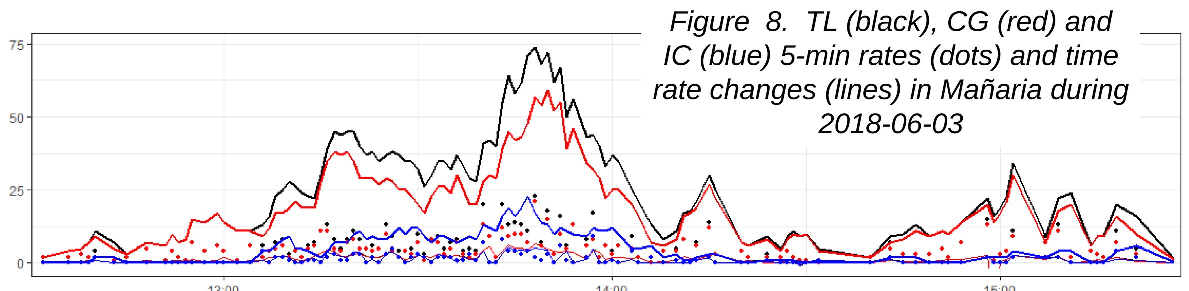


Figure 8. TL (black), CG (red) and IC (blue) 5-min rates (dots) and time rate changes (lines) in Mañaria during 2018-06-03

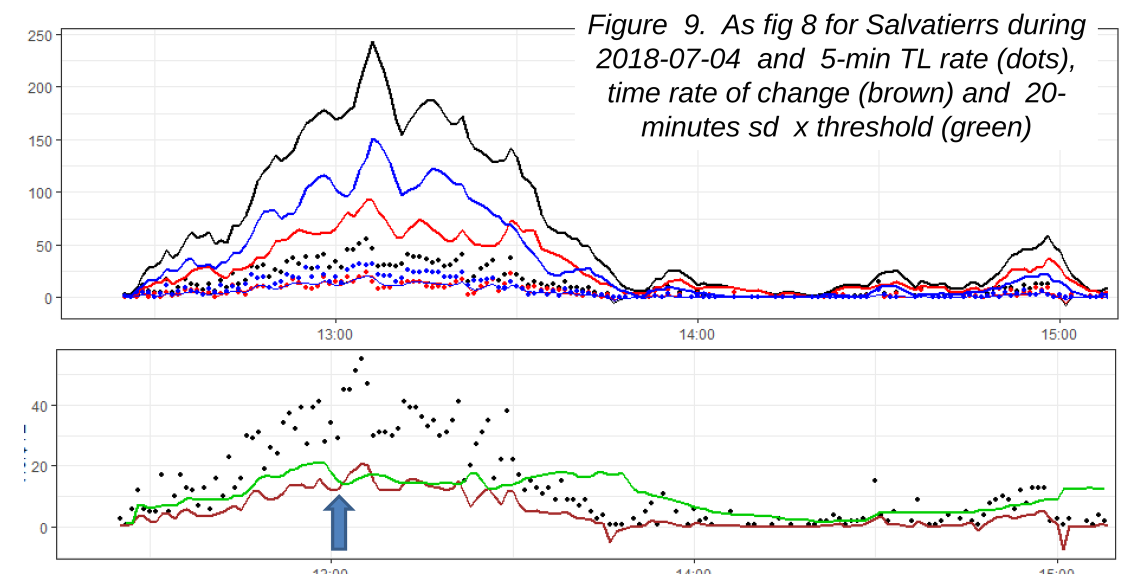
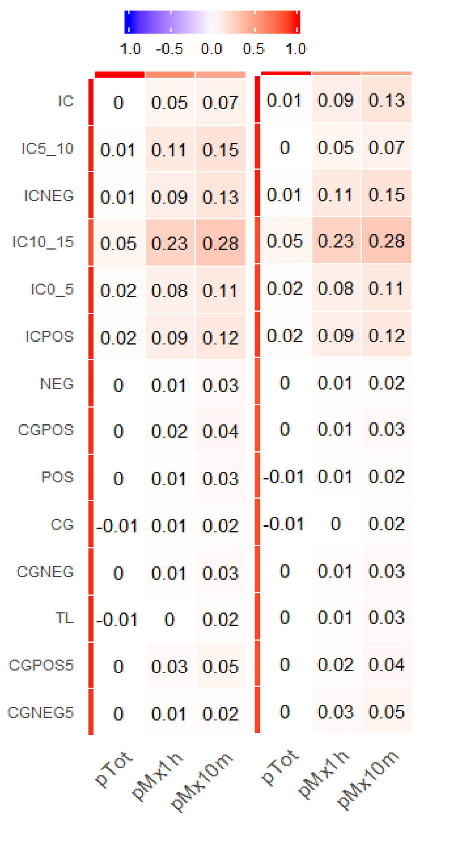


Figure 9. As fig 8 for Salvatierrs during 2018-07-04 and 5-min TL rate (dots), time rate of change (brown) and 20-minutes sd x threshold (green)

Figure 7. Precipitation and lightning features correlation (rates and temporal rate of change)



	pTot	pMx1h	pMx10m	pTot	pMx1h	pMx10m
IC	0	0.05	0.07	0.01	0.09	0.13
IC5_10	0.01	0.11	0.15	0	0.05	0.07
ICNEG	0.01	0.09	0.13	0.01	0.11	0.15
IC10_15	0.05	0.23	0.28	0.05	0.23	0.28
IC0_5	0.02	0.08	0.11	0.02	0.08	0.11
ICPOS	0.02	0.09	0.12	0.02	0.09	0.12
NEG	0	0.01	0.03	0	0.01	0.02
CGPOS	0	0.02	0.04	0	0.01	0.03
POS	0	0.01	0.03	-0.01	0.01	0.02
CG	-0.01	0.01	0.02	-0.01	0	0.02
CGNEG	0	0.01	0.03	0	0.01	0.03
TL	-0.01	0	0.02	0	0.01	0.03
CGPOS5	0	0.03	0.05	0	0.02	0.04
CGNEG5	0	0.01	0.02	0	0.03	0.05

Summary and concluding remarks

Independently of the controversy about some aspects related with LINET lightning data system (e.g. very weak strokes detection, IC-CG discrimination, ..), here we present a very preliminary check of its potential utility and usability in order to extract some parameters that could be used as early identification of severity.

Although the correlation between different parameters and the severity of the storms is beyond doubt in particular case studies, we have not found general and conclusive results from the whole period. Mostly due to the used methodology and the Eulerian perspective.

In the future we will repeat this study applying the Lagrangian paradigm, that is, considering each storm individually applying grouping techniques so that we have guarantees that the strokes considered are fully correlated and from the same convective cell.

Although profusely adverse episodes studies are available for our territory, a complete and homogeneous severe storms database with complete characterization of their surface effects is needed in order to correlate lightning features and real severity.

Although this is a very preliminary work that we will complete in the future, we are optimistic in relation to the operational application of LJ algorithms based on the available information in real time.

In future work we are going to check the effect of grouping strokes into flashes previous to applying jump algorithms.

In any case, as observed in other countries and based on other lightning acquisitions systems, during severe thunderstorms events, the increasing ratio of more CC than CG strokes, the sudden rise of total strokes ratio (CG+IC) or the maintenance of a large stroke rate during a relatively large period are observed in some studied cases.

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Contact info:
santiago.gaztelumendi@tecnalia.com

TECNALIA
Parque Tecnológico de Bizkaia
C/ Geldo Edificio 700
E-48160 DERIO (Bizkaia) Spain
www.tecnalia.com

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