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# Evidence for the influence of land uses and soil types on cloud-to-ground lightning activity in Asturias (Spain)

David Prieto Sisniega[a], Manuel Mora García[b], Susana Fernández Menéndez[a], Luís Rivas Soriano[c], Fernando de Pablo Dávila[c,*]

[a] Department of Geology, University of Oviedo, Oviedo, Spain
[b] Spanish Meteorological Agency (AEMET), Oviedo, Spain
[c] Department of Fundamental Physics, University of Salamanca, Salamanca, Spain

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ABSTRACT

The present study analyses the impact of the different categories of land use and types of soils on cloud-to-ground (CG) lightning activity in the region of Asturias (Spain). Thirteen (fifteen) land uses (types of soils) and a range of fourteen years (2000 to 2013) of CG-lightning flash data were considered to complete the study. Some areas that have suffered the strong impact of human activity (urban, mining, and industrial) were associated with the increase of CG-lightning activity. When considering vegetated areas, areas with non-agricultural vegetation, arable land and permanent crops, it was showed a greater CG activity. With reference to the types of soils, Fluvisols, Regosols/Cambic-Arenosols, and Luvisols, these seemed to be associated to the increase of CG-lightning activity. The results found for the region of Asturias are different from those reported by Mora et al. (2015) for the region of Castilla y Leon (Spain).

## 1. Introduction

Lightning activity is a natural phenomenon effect associated with thunderstorms, which are one of the major causes of weather-related economic losses and damages due to hail, high rainfall, etc. There are many factors associated with the development of convection. In particular, it has been reported that the lack of homogeneity of the surface plays a role in the forcing and development of convection through heat, moisture and momentum fluxes (i.e. Pielke et al., 2011; Hirota et al., 2011). Discontinuity in the types of soils, soil moisture, and types of vegetation are factors which determine the size and strength of the fluxes (i.e. Pielke and Zeng, 1989; Brown and Arnold, 1998).

Despite the considerable number of studies about the impact of surface characteristics on convection, the studies analysing their effects on lightning are limited and they focus specifically on vegetation (e.g. Kilinc and Beringer, 2007 for Australia; Kotroni and Lagouvardos, 2008 for Greece). Mora et al. (2015) analysed the impact of land uses and types of soils on cloud-to-ground (CG) lightning activity in the Spanish territory of Castilla y Leon (CL). In the aforementioned study, it was reported that forested and wooded areas, and rendzinas, podzoles and phaeozems were associated with a greater number of CG-lightning flashes and it was speculated on that humidity was the main factor that explains these observations.

The main objective of the present study is to check if the results reported by Mora et al. (2015) are also observed in other areas with different weather and orographic characteristics in which its main land cover and types of soils are different.

## 2. Area of the study and data

The area chosen was the Spanish region of Asturias, since its characteristics are very different from those of Castilla y Leon (CL), which was considered in the previous work of Mora et al. (2015). Asturias is located in the Northern Iberian Peninsula from 42°53′N/6°48′W to 43°34′N/4°30′W, occupying a total area of 10,602 $km^2$. Different from CL (which is an inner plateau separated from the sea by surrounding mountains), Asturias is a narrow coastal Atlantic region with mountains close to the coastline (Fig. 1). The climate in Asturias is maritime humid (by contrast CL is continental dry, especially in the summer season).

The period of time considered in the present study is that from the year 2000 to 2013. The lightning data were provided by the Lightning Detection Network belonging to the Spanish Meteorological Service (AEMET). This detection network has 14 sensors in the Spanish territory of the Iberian Peninsula. Also 4 sensors from the Portuguese Lightning Detection Network (belonging to the Portuguese Meteorological Service) were used since the year 2003 (Pérez Puebla,

* Corresponding author at: Departamento de Física Fundamental, Facultad de Ciencias, Universidad de Salamanca, Pl. de la Merced s/n, 37008 Salamanca, Spain.
*E-mail address:* fpd123@usal.es (F. de Pablo Dávila).

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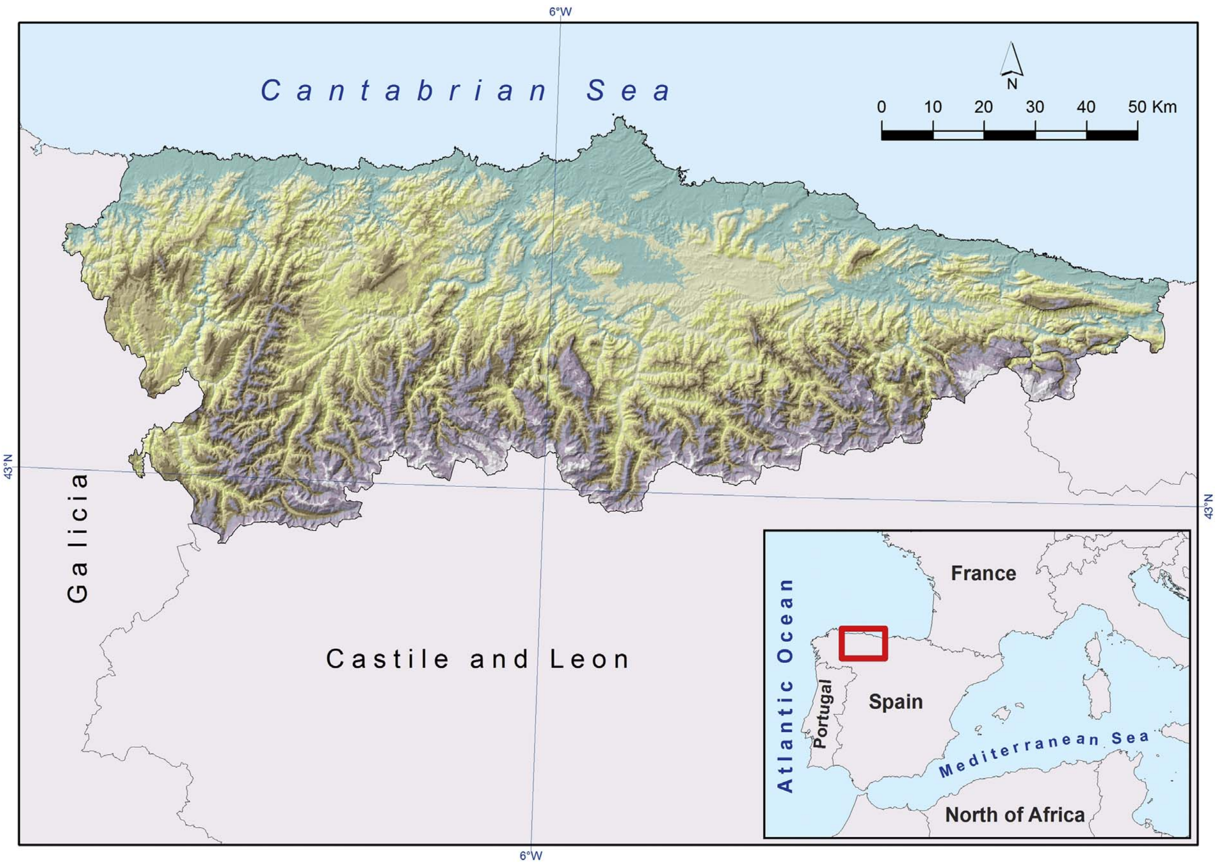


**Fig. 1.** Study area and orography in Asturias.

2004).

In addition, since 2005, the oldest sensors have been updated and 10 sensors from the French Detection Network have been incorporated. The efficiency of the detection and the accuracy of the location area are different in different years and regions, but for the purpose of this study, this influence will not be important. This is a consequence of the fact that although the efficiency of the detection of the strokes changes, the efficiency of the flash detection remains fairly stable, since detecting a flash is sufficient to detect only one stroke of the several that make up a flash (for a further explanation of these concepts, see Poelman et al., 2016). One individual stroke has been grouped into a CG-flash if the temporal separation and distance in relation to the time and position of the first stroke are, respectively, < 1.5 s and 10 km. Moreover, it is used a temporal inter-stroke interval of 0.5 s. It should be noted that these grouping criteria overlap well with those used in other studies (for example Cummins et al., 1998; Rivas Soriano et al., 2005; Kuk et al., 2011). The first stroke was selected from the flash data (if multiplicity was > 1) and only the cases that meet the requirements of a) $\chi^2 < 3$, and b) major/minor semi-axes of error < 1/0.5 km were used in this study, which guarantee lightning data of the highest quality. This procedure retains 56,020 CG-lightning flashes from the 94,749 detected by the network in the considered period.

Data on land uses came from the CORINE land cover raster data (CLC 2007 release, which are available at the next link: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster) (Büttner et al., 2002). Fig. 2 shows the distribution of land use types in Asturias. The present study has considered the 13 categories indicated in Fig. 2. The major soils were obtained from the digital soil map at 50 m pixel elaborated with the georeferenced database of Asturias (Fernández et al., 2005). In this case, the 15 soil types indicated in Fig. 3 were considered (see for example Driessen et al., 2001 to obtain information about the soil type characteristics).

## 3. Results and discussion

The spatial distribution of the CG-flash density in Asturias is shown in Fig. 4a. Maximum/minimum/mean values are 3.0/0.1/0.64 fl $km^{-2}$ $yr^{-1}$. As expected, CG-lightning activity tends to be concentrated over the mountainous Southern Asturias. In fact, there is a nearly linear increase of CG-lightning flashes with altitude between about 400 y 1900 m (Fig. 4b). This result has been found in many studies (e.g. Santos et al., 2012; Mora et al., 2015) and implies that the impact of the altitude on the spatial distribution on CG-lightning activity masks the possible effect of the surface characteristics on CG-lightning, because land uses and types of soils are not equally distributed with altitude (compare Fig. 1 with Figs. 2 and 3). It must also be taken into account that the area covered by each land use and type of soils is different (see Figs. 2 and 3). In the present study we followed the procedure adopted by Mora et al. (2015). They defined the index *LLI* as:

$$LLI_j = \frac{F_j / A_j h_j}{F_T / A_T h_T}$$

The subscripts *j* and *T* indicate one land use or soil type and the total spatial domain respectively. *F*, *A*, and *h* denote number of CG-flashes, area, and altitude respectively. If $LLI_j \sim 1$, therefore the percentage of CG-flashes over each land use or soil type *j* would be equal to the percentage of area occupied by the land use or soil type *j* if the altitude were the same. This means that values of $LLI_j > (<) 1$ imply that CG-lightning activity would be enhanced (suppressed) by the land use or soil type *j*. The relation between flash density and altitude (Fig. 4b) shows that the lines intersect at flash density 0.4, but the difference is a constant and therefore the final conclusions (maximum values of the land cover and soil types) of the LLI index do not change if the values of LLI-0.4 were taken instead.

Values of *LLI* for each land use are shown in Table 1a. Values of *LLI*,

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