# Electrical characteristics and environmental conditions of lightning-ignited fires in the Iberian Peninsula and Mediterranean France between 2009 and 2015

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# Abstract

About **5% of the wildfires in the Mediterranean basin are produced by lightning** [1]. Lightning-ignited fires tend to occur in remote areas and can spread significantly before suppression. The occurrence of lightning-caused fires is closely related with intense drought periods and high temperatures [2]. Therefore, **drier conditions and higher temperatures** in a changing climate are expected to lead to a future increase in lightning-ignited fires occurrence. The development of a lightning-ignited fire parameterization for Earth system models arises as a necessary tool to predict the future occurrence of these extreme events and to study their impact on atmospheric chemistry.

**Long Continuing Current lightning** (LCC-lightning), preferable taking place in **dry thunderstorms***, is believed to be the main precursor of lightning-ignited fires. This was originally proposed by McEachron and Itagenguth in 1942 [3] working with laboratory sparks, which suggested that ignition by natural lightning is usually caused by a discharge having an unusual long-continuing current phase (>10 ms). Later in 1967 this hypothesis was confirmed by Fuquay et al. [4].

In this work, we analyse three fire *databases of lightning-ignited fires* in Spain, Portugal and Southern France between 2009 and 2015. Furthermore lightning measurements from the *World Wide Lightning Location Network* (WWLLN), the *Earth Networks Total Lightning Network* (ENTLN), and the Lightning Imaging Sensor (LIS) onboard the International Space Station (ISS), and land and atmospheric variables from the new *ERA-5 reanalysis* are combined to investigate the **electrical characteristics and environmental conditions of the fires**. This preliminary data analysis will be useful to set new relationships between the characteristics of thunderstorms and the initiation of wildfires. It is the first step towards the development of a detailed lightning-ignited fire parameterization for the atmospheric chemistry-climate model *EMAC*.

**dry thunderstorm*: most of the its precipitation evaporates before reaching the ground

[1] Vázquez, A., and Moreno, J. M. (1998). Patterns of lightning-, and people-caused fires in peninsular Spain. International Journal of Wildland Fire, 8(2), 103-115.

[2] Pineda, N., and Rigo, T. (2017). The rainfall factor in lightning-ignited wildfires in Catalonia. Agricultural and Forest Meteorology, 239, 249-263.

[3] McEachron, K. B., and Itagenguth, J. It (1942), Effect of lightning on thin metal surfaces, AIEE Trans., 61, 559-564, 1942.

[4] Fuquay, D. M., Baughman R. G, Taylor, A. R. and Hawe, R. G. (1967). Characteristics of seven lightning discharges that caused forest fires. Journal of Geophysical Research, 72 (24).

# **Introduction**: Lightning-ignited fires and Long Continuing Current (LCC) lightning

# Introduction: Lightning-ignited fires as main precursors of natural wildfires

A lightning-caused wildfire burns in Alberta, Canada. Credit: The Government of Alberta.

They usually take place in remote areas

~**70%** of the total burned area in **boreal forests** worldwide (Canada, Alaska)
Flannigan & Wotton, 1990
McGuiney et al. 2005

~**5%** of fires in the **Mediterranean** basin (7.3% of burned area).
Vázquez and Moreno, 1998

~**25%** of fires in the **Alps** during summer
Cesti et al. 2005, Conedera et al. 2006

~**16%** in **US** (56% of total burned area)

Also important in **Australia**, Amazonia, Africa, ...

# Main factors for lightning-ignited fires

- **Vegetation type**: Most Lightning-ignited fires are produced in coniferous forest.

- **Fuel moisture**: Droughts cause depletion of soil and vegetation moisture, increasing the risk of wildfire.

- **Wind**: Strong winds increase the probability and rate of fire spread.

- **Precipitation**: Most lightning-ignited fires occur during a phase of a thunderstorm at which the precipitation rate is low (dry thunderstorms). Lightning-produced fires are ignited by so-called “dry lightning”.

- **Temperature**: High temperatures favor the occurrence of lightning-ignited fires.

- **Lightning properties**:
  - **Lightning polarity, multiplicity and electric peak current**: Current Lightning Location System report the polarity, multiplicity and peak current of lightning flashes. There is only a weak correlation between low values of the peak current and the occurrence of lightning-ignited fires [*Pineda et al, 2014*].

  - **Long Continuing Current in lightning**: Ignition by natural lightning is usually caused by a discharge having an unusual long-continuing current phase (> 10 ms).

# Long Continuing Current (LCC) lightning

*Fuquay et al. (1967)*

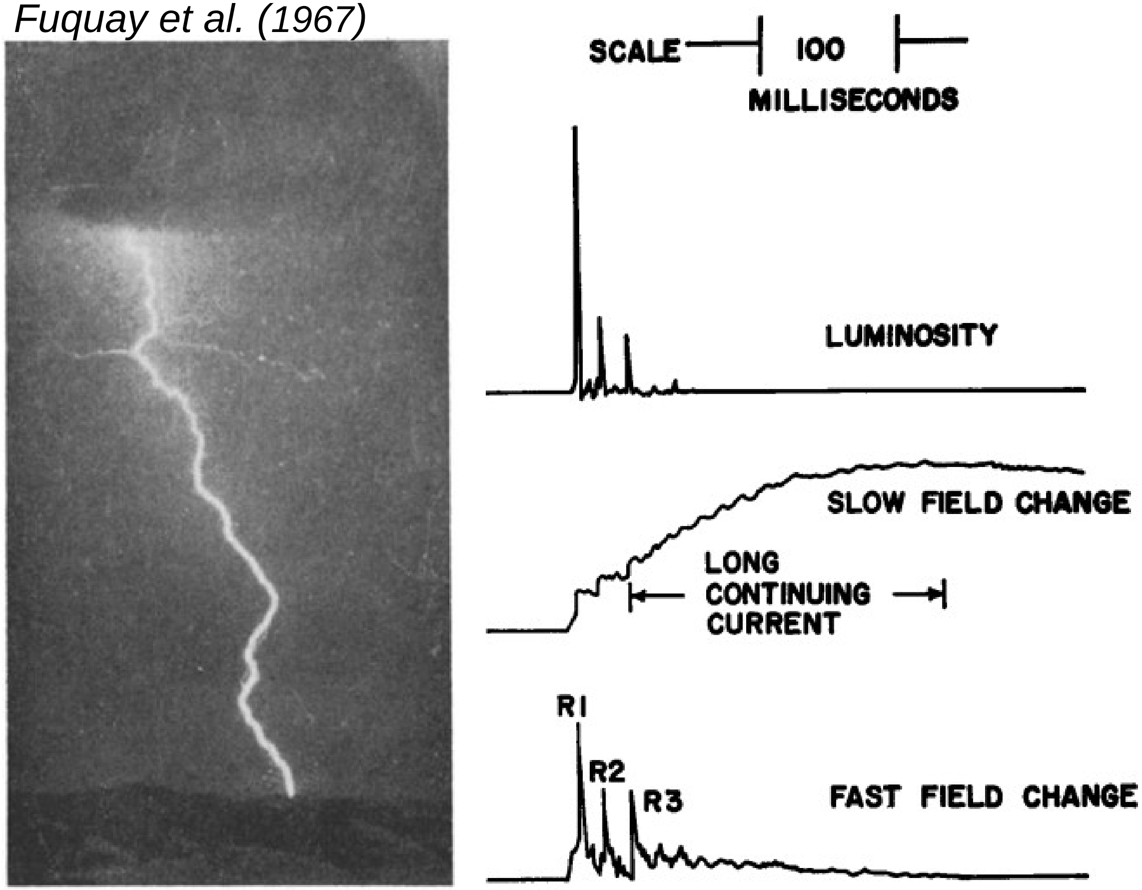


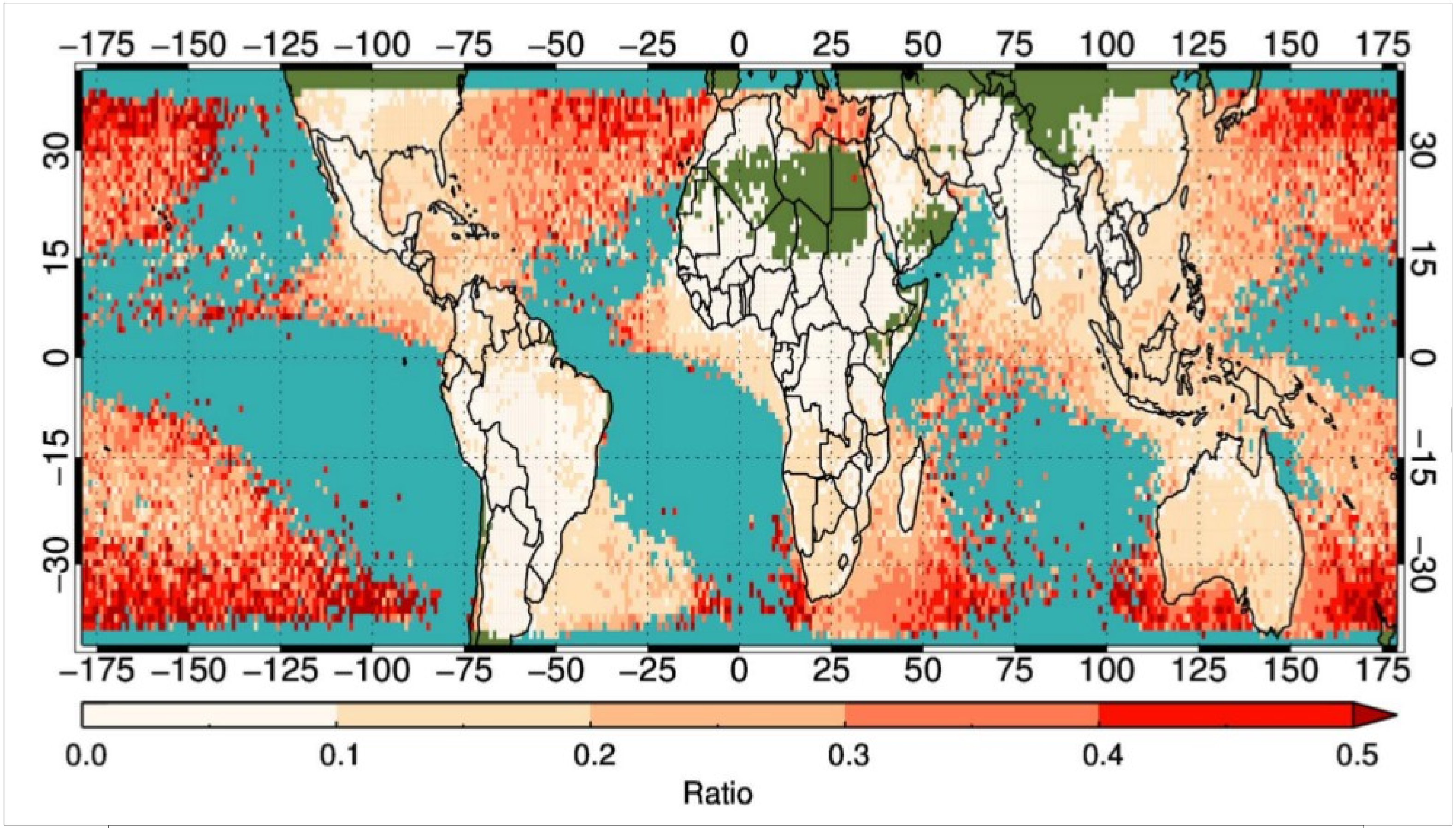

Fig. 1. Flash image, luminosity trace, and fast and slow field change traces of a discharge that caused a forest fire on September 6, 1966. Note the long-continuing current phase following the R3 stroke.

*The Flexible Combined Imager and the Lightning Imager onboard Meteosat Third Generation (**MTG**) will simultaneously detect **forest fires and LCC-lightning** over Europe and Africa from space for the first time from 2021 onwards*

- Some lightning discharges have a long continuing current phase with a duration of tens or hundreds milliseconds.
- According to several optical and radio signals of fire-producing lightning, most lightning-ignited fires could be produced by LCC lightning.
- The long lasting phase (>10 ms) of LCC lightning can be reported by optical sensors and by Extremely Low Frequency (ELF) radio sensors.
- Current Lightning Location Systems can not report the long lasting phase of LCC lightning.

**Methods**: Lightning Imaging Sensor on the International Space Station (LIS-ISS), Lightning Location Systems (LLS), Fire databases and ERA-5 reanalysis

# Methods: Long continuing current (LCC) lightning from space: LIS




Ratio of flashes with **continuing current** to all flashes detected by **LIS** [*Bitzer, 2017*]

Storms with large LCC-lightning ratio have **weaker updrafts:**
Most of LCC-lightning take place in winter and oceanic thunderstorms [*Bitzer, 2017*].

[*Bitzer, 2017*]

**Weaker updraft**

↓

**Smaller charging rate**

↓

**More extended charge regions before lightning discharges**

Are the meteorological conditions typical of LCC lightning also typical of lightning-ignited fires?

# Methods: Search of **lightning candidates** for fires in **Lightning Location Systems** (LSS)

Lightning data:

- Lightning measurements between April 2009 and Dec 2013 from the World Wide Lightning Location Network (**WWLLN**).
- Lightning measurements between Jan 2014 and Dec 2015 from the Earth Networks Total Lightning Network (**ENTLN**).

Lightning candidates are obtained by searching maximum “proximity index” $A=(1-\frac{T}{14\,days})\times(1-\frac{S}{10\,km})$ , where *T* and *S* are, respectively, the temporal and spatial separation between each lightning candidate and a fire [*Larjavaara et al. (2005)*].

# Methods: Fire databases

- Data of fires in **Spain** from *Ministerio de agricultura, Pesca y Alimentación.* The database includes fires between 1968 and 2015. Cause of fires are provided. Lightning-ignited fires are identified using lightning data from *Agencia Estatal de Meteorología* (AEMET).

- Data of fires in **Portugal** from *Instituto da Conservaçao da Naturaleza e das florestas*. The database includes fires between 1980 and 2015. Cause of fires are provided but the percentage of "unknown cause" is very high. Lightning-ignited fires are identified using lightning data from *Instituto Portugués del Mar y de la Atmósfera* (IPMA).

- Data of fires in the **Mediterranean area** in **France** from *Prométhée.* The database includes fires between 1973 and 2018. Cause of fires are provided. We only include fires with reported geographical coordinates.

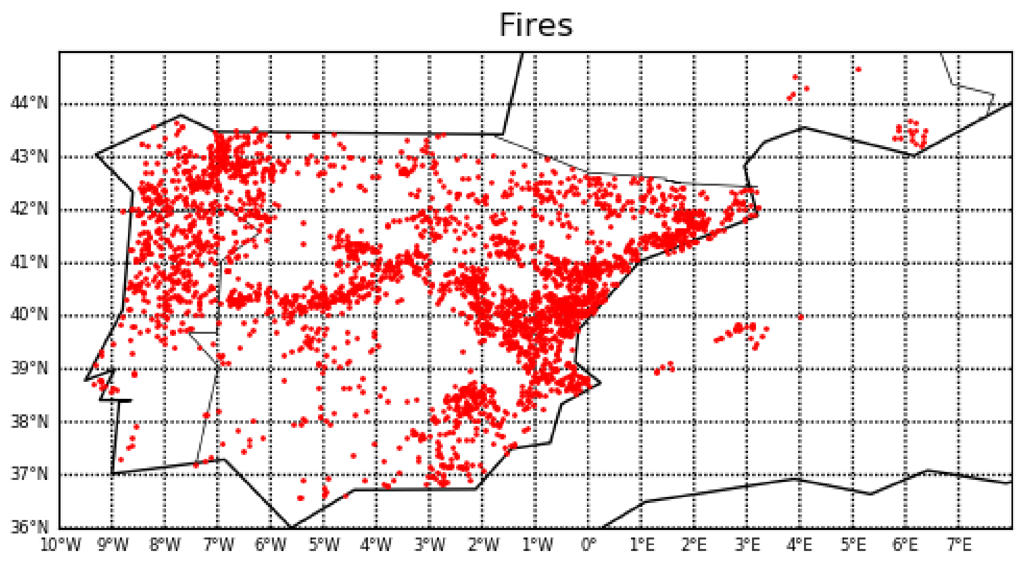



Fig. 1: Fires included in the analysis (2009-2015).

# Methods: **Meteorological analysis** of lightning-ignited fires

- **ERA5 reanalysis** from ECMWF: Convective available potential energy (CAPE), precipitation, temperature, moisture, etc… .

- **Land cover data** from the European Space Agency (ESA) Climate Change Initiative (CCI): Analysis of lightning and lightning-ignited fires in *coniferous forest*.

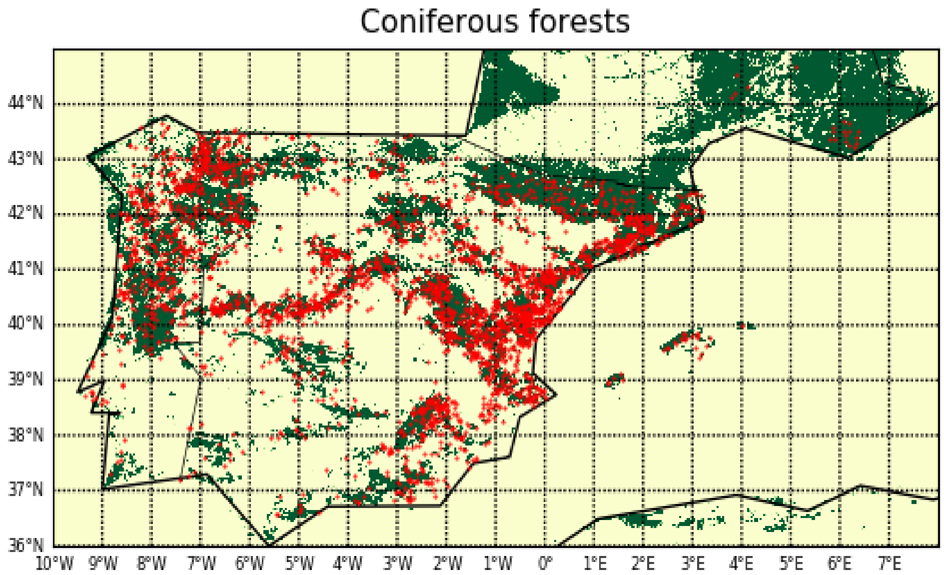



Fig. 2: Coniferous and mixed forests (green dots) derived from satellite observations produced by the ESA-CCI for 2015 and fires (red dots) included in this study.
Spatial resolution is 300 m.

We will only analyze lightning **discharges and fires over coniferous and mixed forests** to determine the characteristics of lightning discharges that produce fires. We do not include lightning discharges over forests from areas without reported data of fires (Western France and North Africa) .

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# Results

# Results: 1ºx1º LIS-ISS **lightning** data over Europe. Preliminary analysis

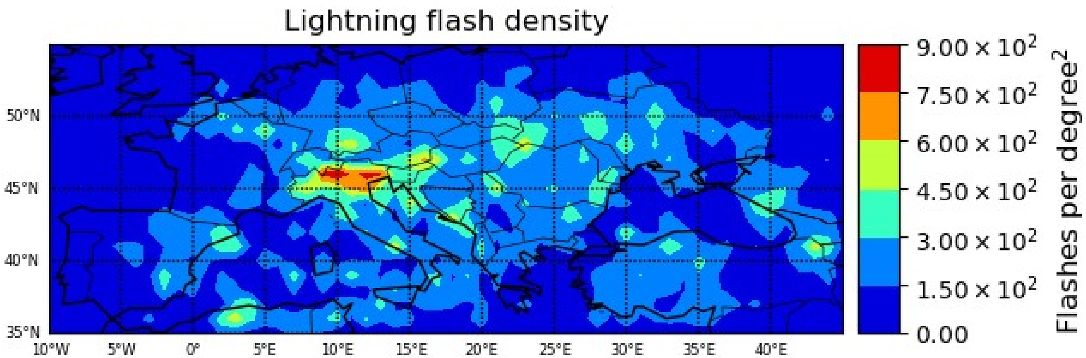


Fig. 3: Lightning flashes over Europe between 2017-2019 from LIS-ISS data.

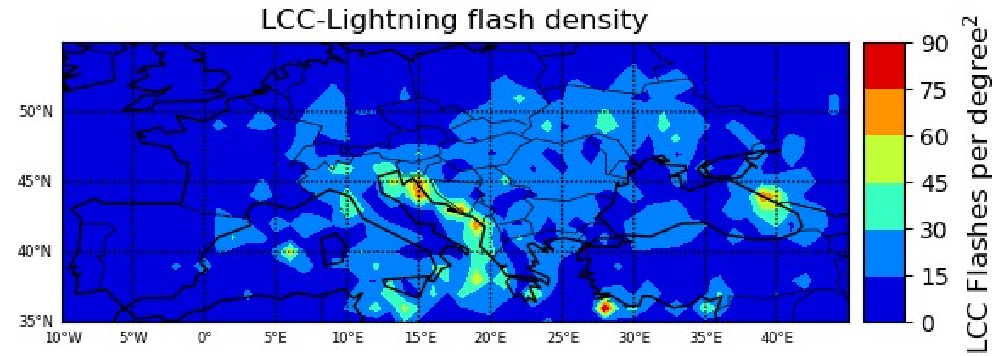


Fig. 4: LCC-lightning over Europe from LIS-ISS data following the method proposed by *Bitzer, JGR (2017).*

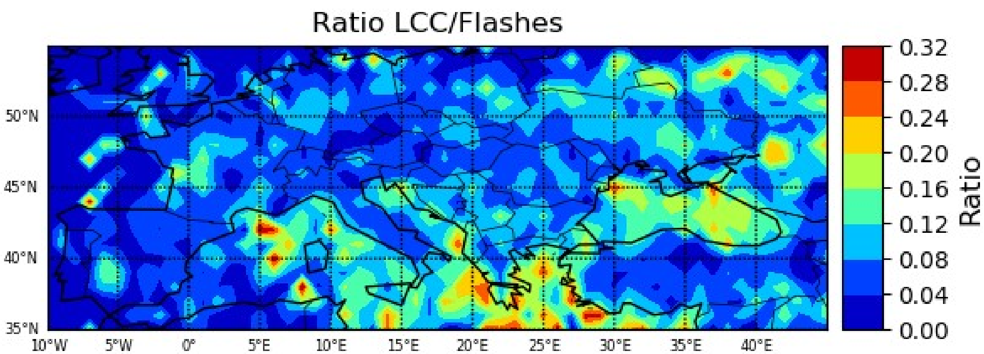


Fig. 5 : Ratio of LCC-lightning to all lightning over Europe (ratio in one cell is set to zero if there are less than 10 lightning discharges or less than 2 LCC-lightning flashes).

***Normal lightning = Lightning flashes without LCC-phase***

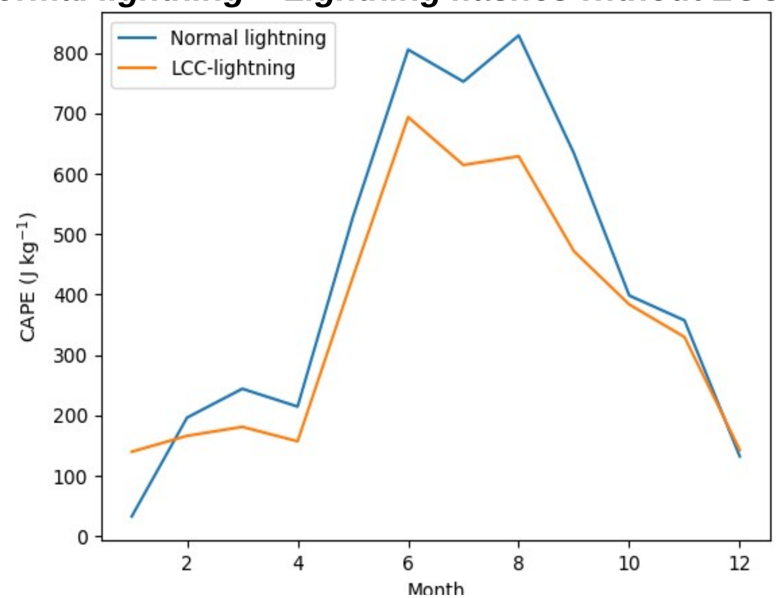


Fig.6: Monthly averaged *Convective Available Potential Energy* (CAPE) per normal lightning flash (blue) and per LCC-lightning flash (orange) during 2017-2019. We have only included lightning flashes over **land**. The CAPE has been obtained from the 0.25ºx0.25º *ERA5* hourly data reanalysis.

**Preliminary conclusion:**
**CAPE/LCC < CAPE/Flash**
Is this pattern also present in **lightning-ignited fires**?

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# Results: 0.5ºx0.5º LIS-ISS **lightning** data over Iberia. Preliminary analysis

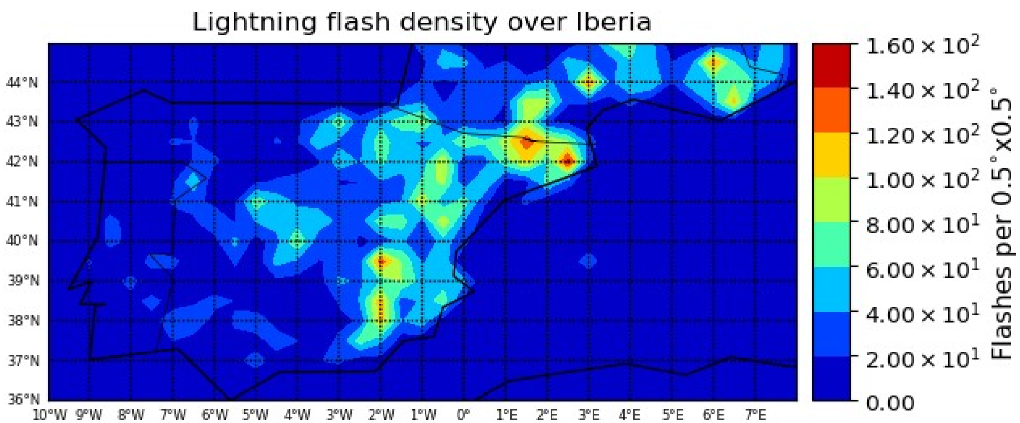


Fig. 7: Lightning flashes over Iberia between 2017-2019 from LIS-ISS data.

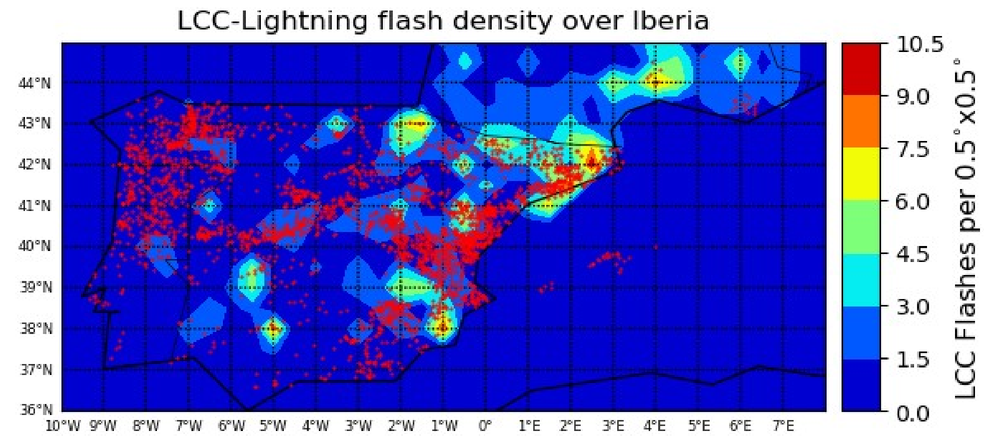


Fig. 8: LCC-lightning over Iberia from LIS-ISS data following the method proposed by *Bitzer, JGR (2017) and fires (red dots).*

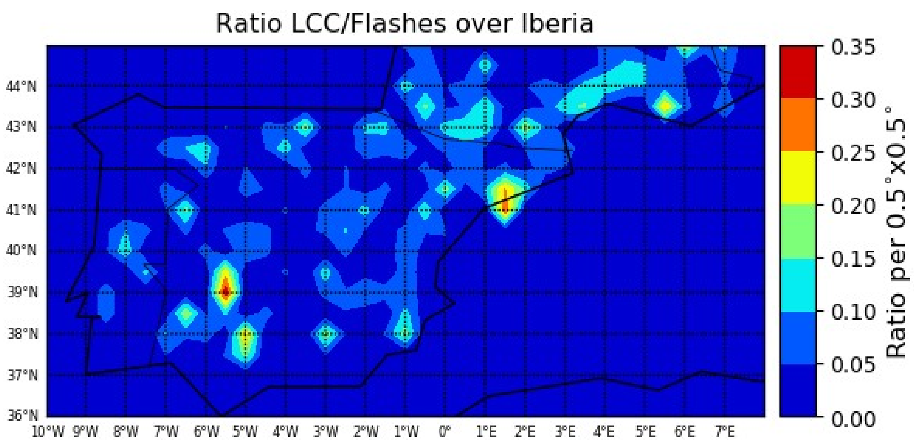


Fig. 9: Ratio of LCC-lightning to all lightning over Iberia (ratio in one cell is set to zero if there are less than 10 lightning discharges).

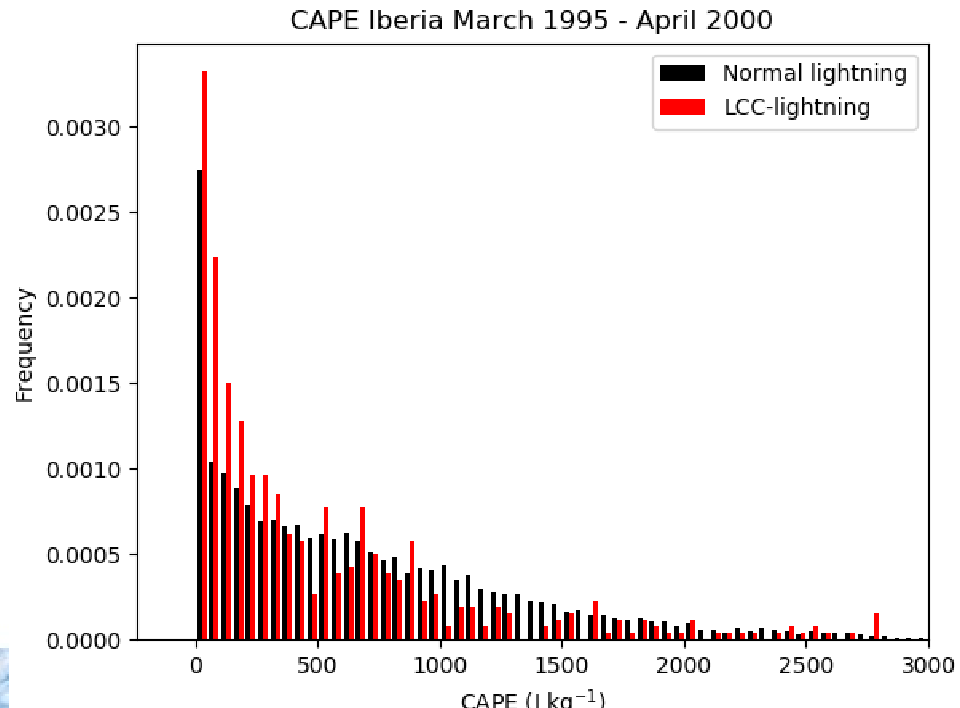


Fig. 10: Frequency distribution of CAPE per normal lightning flash and per LCC-lightning flash.

# Monthly climatology of lightning-ignited fires

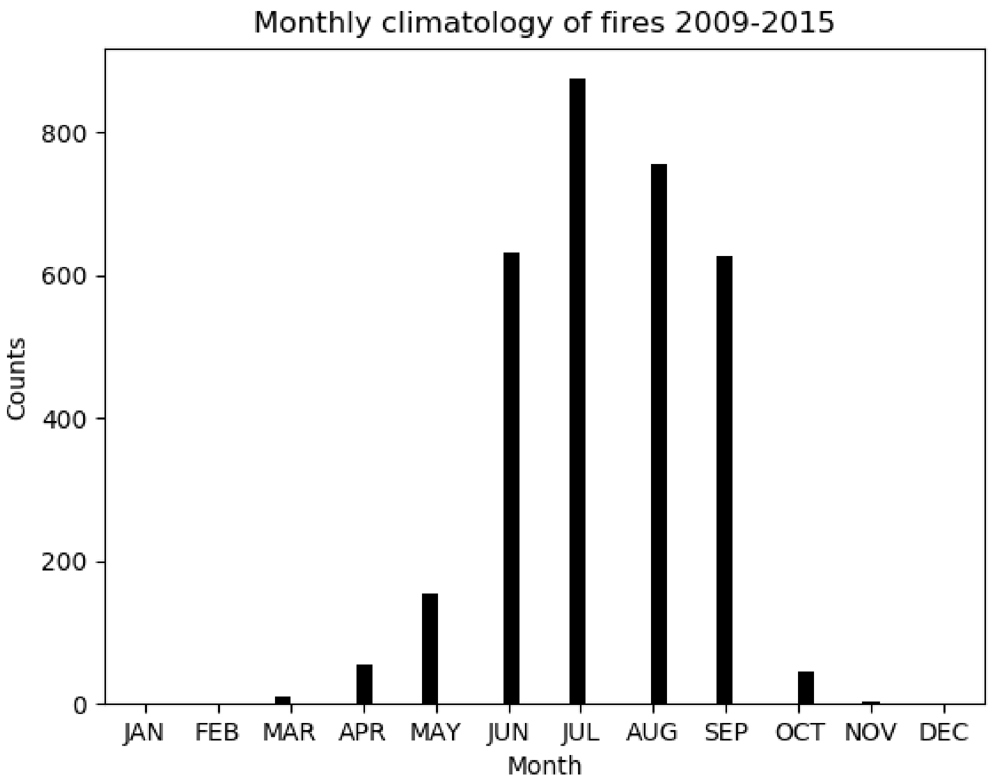


Fig. 11: Monthly climatology of lightning-ignited fires over **Spain**, **Portugal** and Mediterranean **France**.

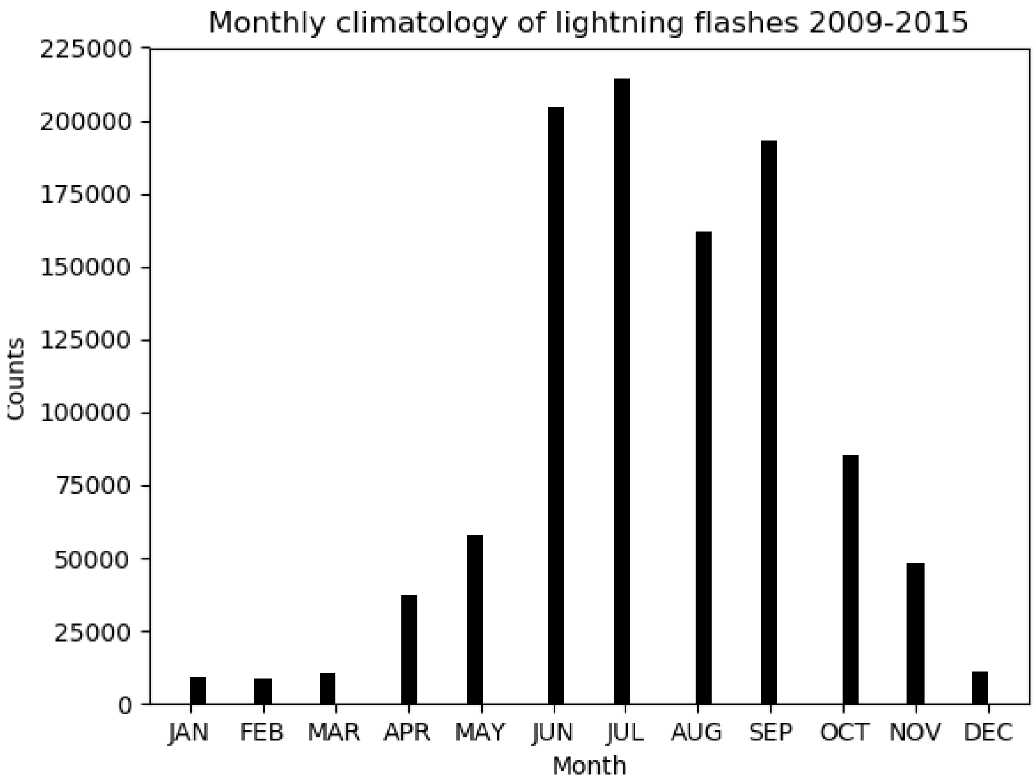


Fig. 12: Monthly climatology of lightning flashes *over coniferous and mixed forests* in **Spain**, **Portugal** and Mediterranean **France** derived from WWLLN and ENTLN.

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# Lightning candidates: Timing and distance

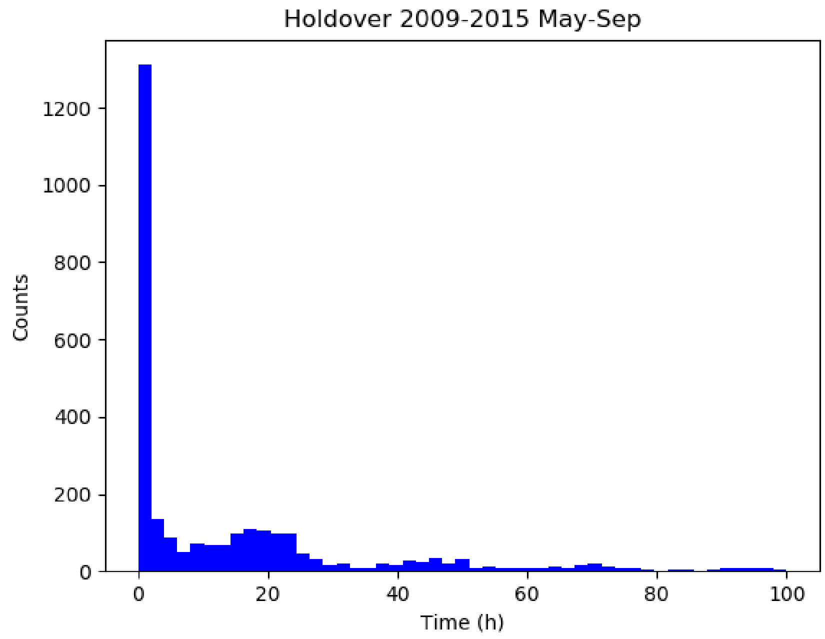


Fig. 13: Time between the lightning candidate and the declaration of the fire.

Most of lightning candidates occur between 0 hours and 60 hours before detection of the fire.

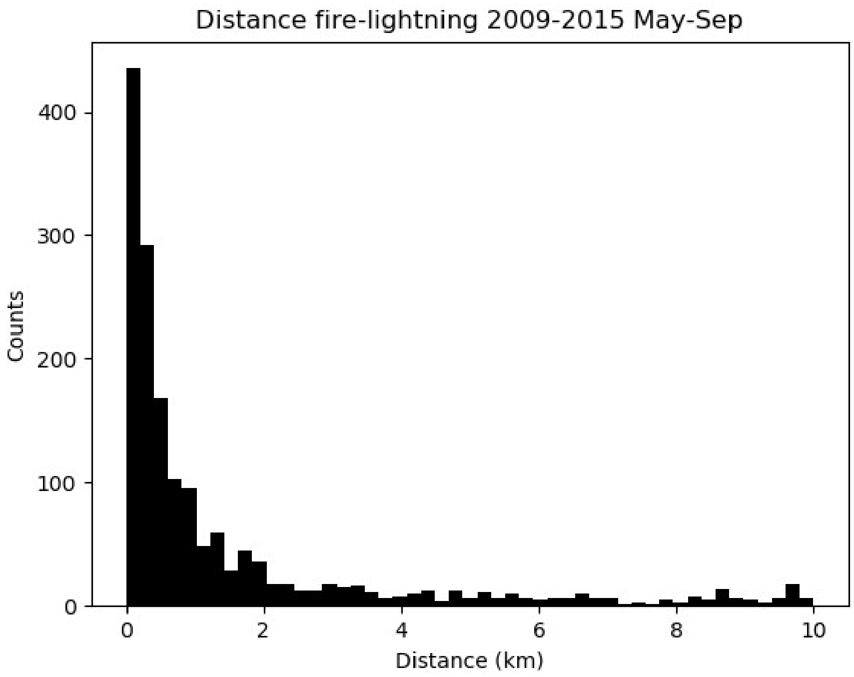


Fig. 14: Distance between fire and lightning candidate.

Most lightning candidates occur in an area less than 2 km radius around the position of the fire.

# Analysis of the convective available potential energy (CAPE)

Note: We define "**All lightning**" as all lightning flashes not igniting a fire over coniferous and mixed forests in the Iberian Peninsula and Mediterranean France between May 2009 and September 2015.

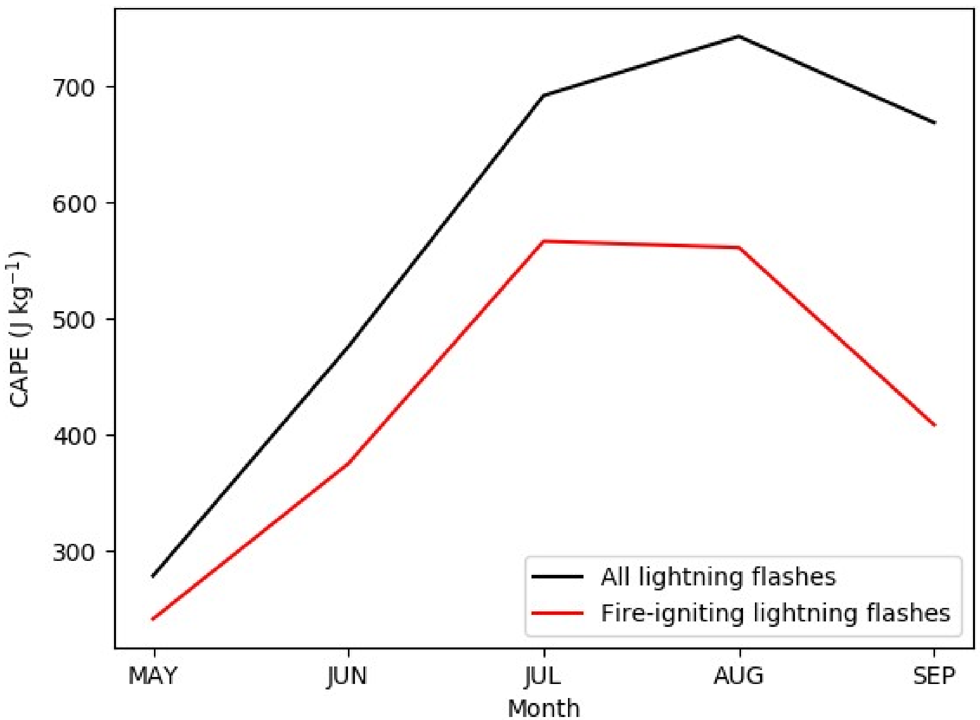


Fig. 15: Monthly averaged CAPE per normal lightning flash (black) and per fire-igniting lightning flash (red).

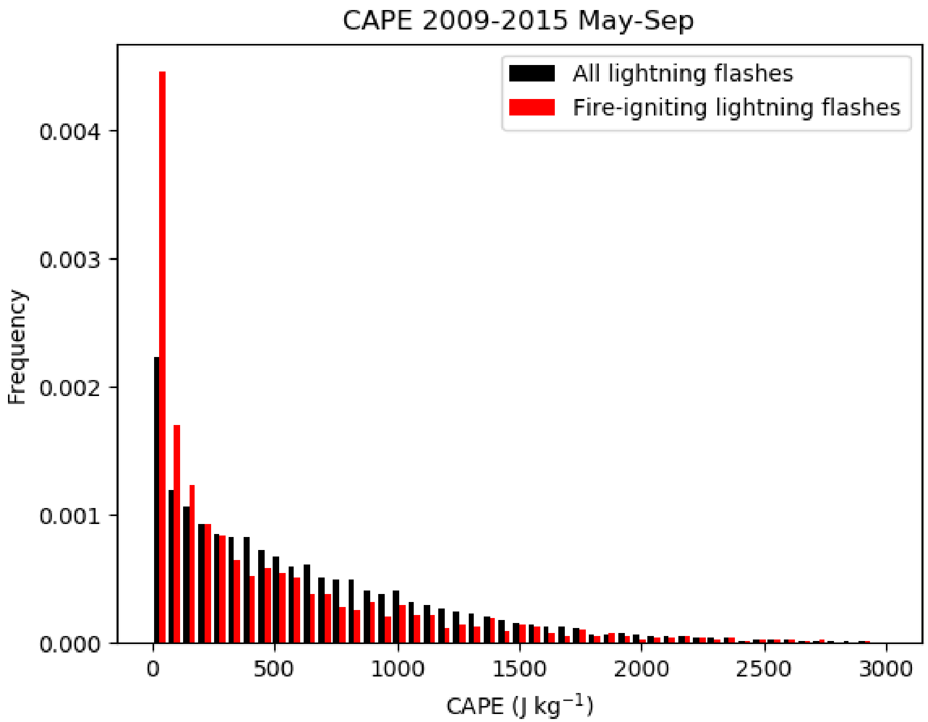


Fig. 16: Frequency distribution of CAPE per normal lightning flash (black) and per fire-igniting lightning flash (red).

CAPE is lower for lightning-produced fires than for fires not produced by lightning.
CAPE is also lower for LCC-lightning than for all lightning. This result suggests that thunderstorms with weak convection (low CAPE) could produce LCC-lightning and lightning-ignited fires.

# Analysis of the hourly accumulated precipitation

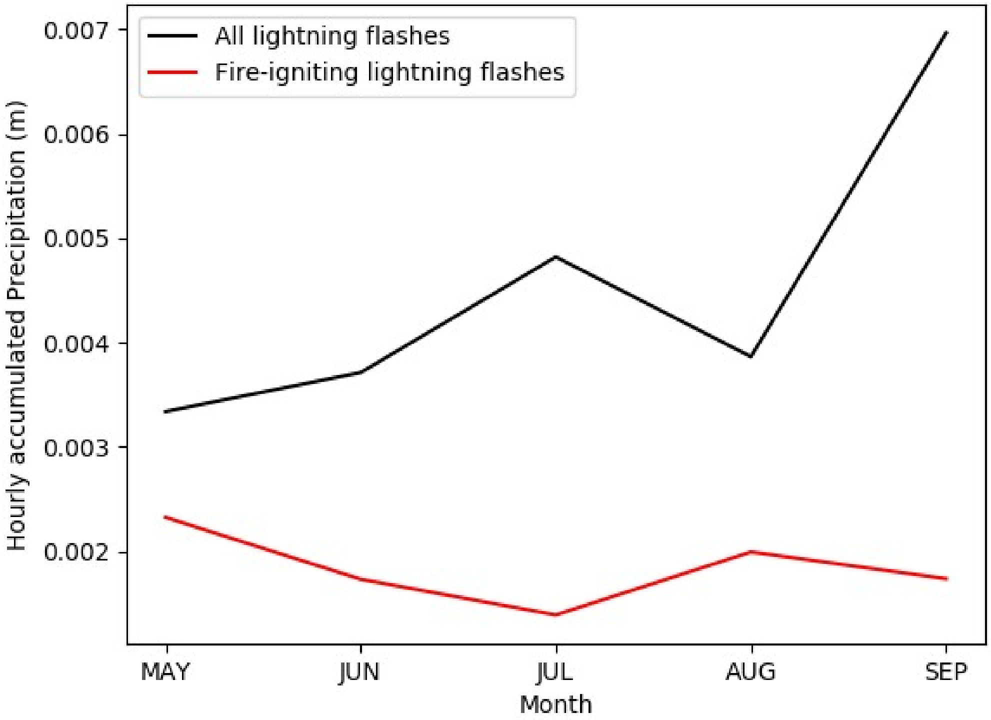


Fig.17: Monthly averaged 1-h accumulated precipitation per normal lightning flash (black) and per fire-igniting lightning flash (red).

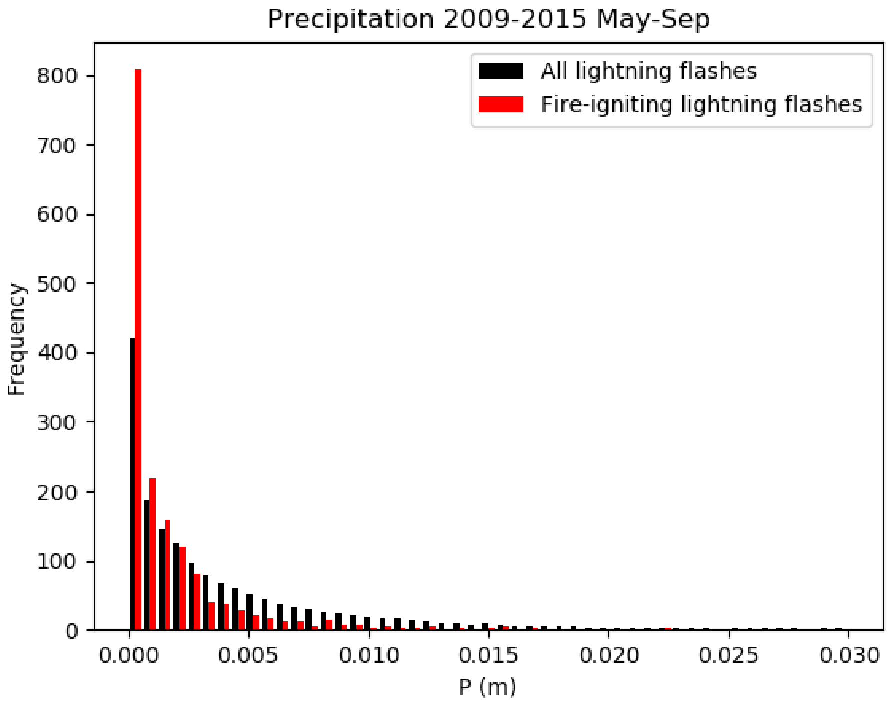


Fig. 18: Frequency distribution of 1-h accumulated precipitation per normal lightning flash (black) and per fire-igniting lightning flash (red).

1-h accumulated precipitation is lower for lightning-ignited fire cases compared to lightning not producing fire: *Dry thunderstorms favors the production of lightning-ignited fires*

# Analysis of the influence of the temperature

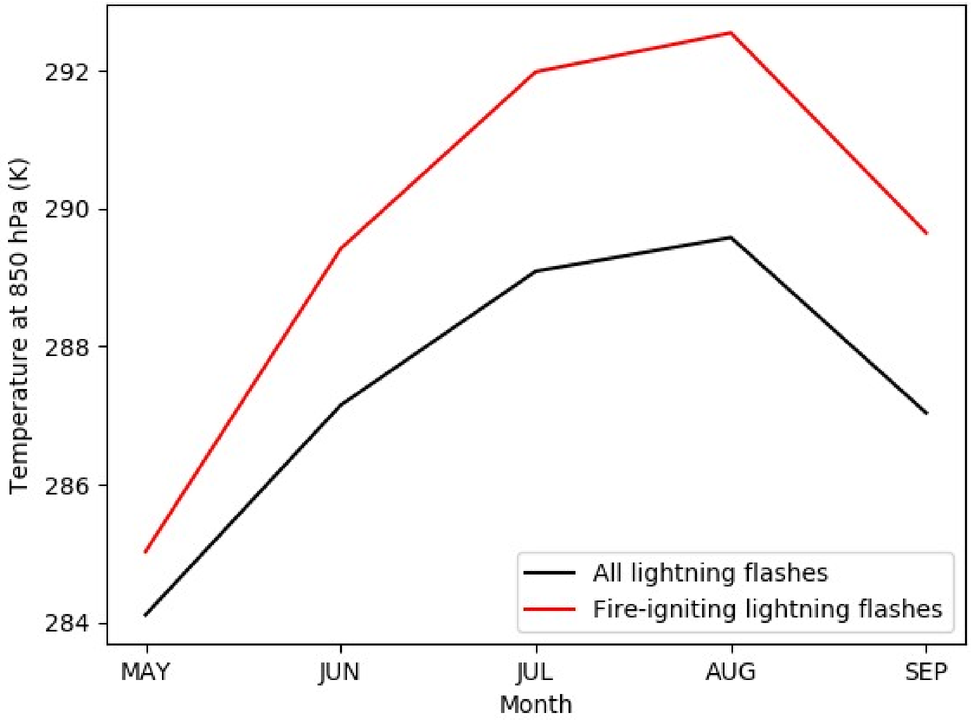


Fig. 19: Monthly averaged *T (850 hPa* per normal lightning flash (black) and per fire-igniting lightning flash (red).

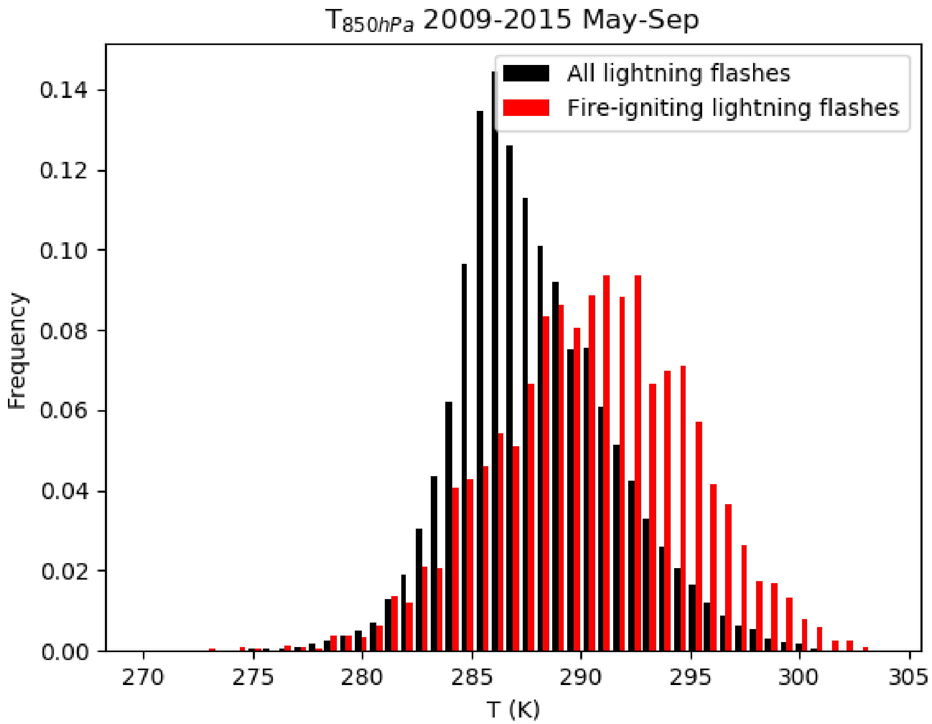


Fig. 20: Frequency distribution of *T (850 hPa)* per normal lightning flash (black) and per fire-igniting lightning flash (red).

*T (850 hPa)* is higher in thunderstorms producing fires: Dry thunderstorms (precipitation can be evaporated before reaching the ground).

# Analysis of the relative humidity

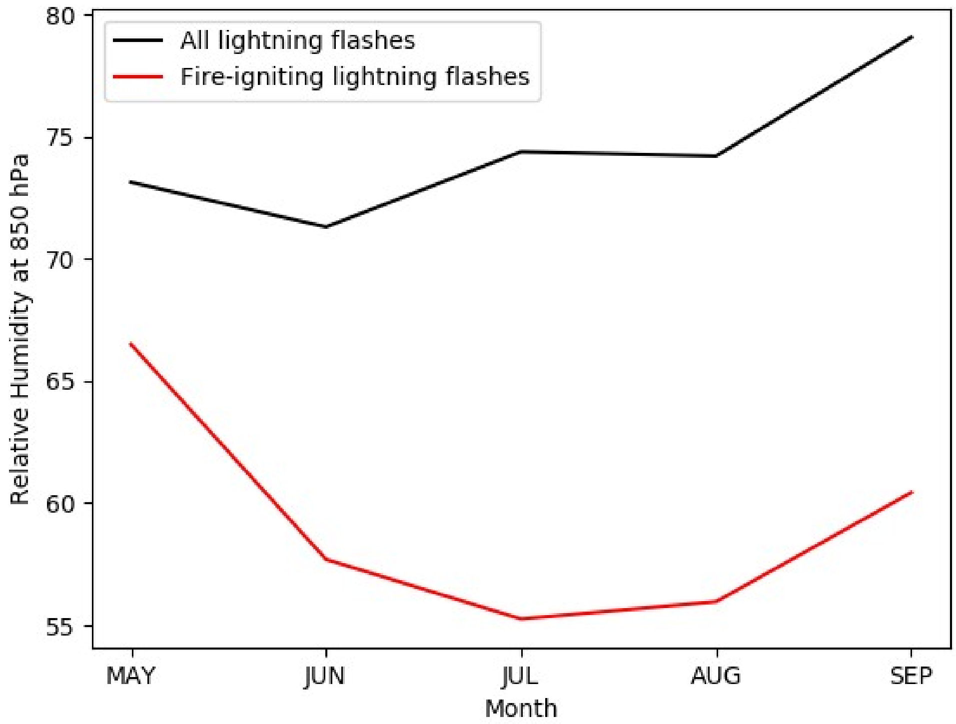


Fig. 21: Monthly averaged RH *(850 hPa)* per normal lightning flash (black) and per fire-igniting lightning flash (red).

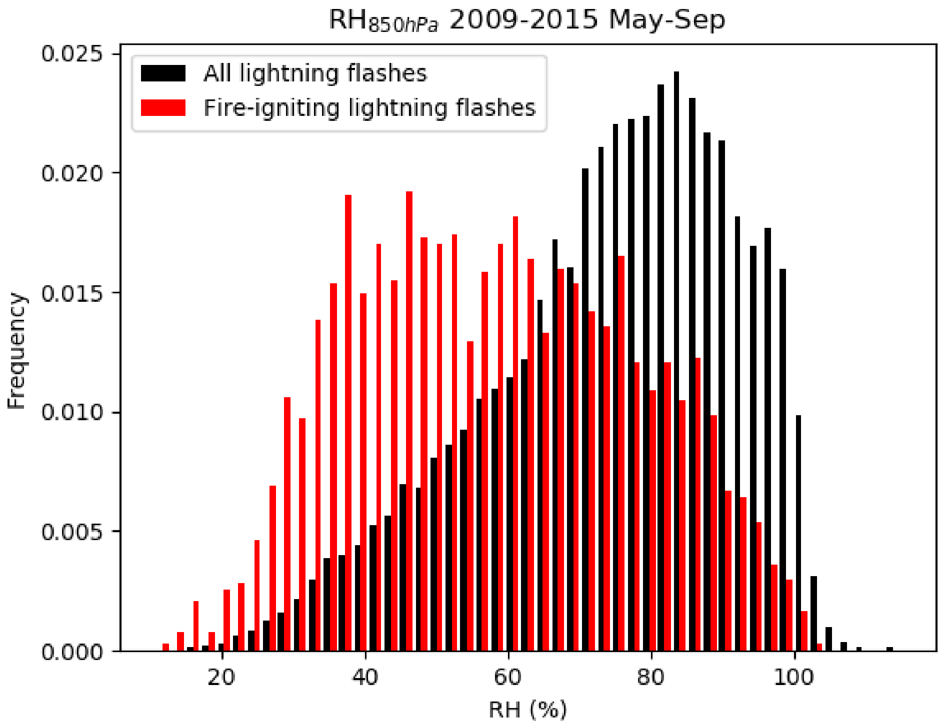


Fig. 22: Frequency distribution of RH *(850 hPa)* normal lightning flash (black) and per fire-igniting lightning flash (red).

*RH (850 hPa)* is lower in thunderstorms producing fires: Dry thunderstorms (precipitation can be evaporated before reaching the ground).

# Analysis of the lightning peak current

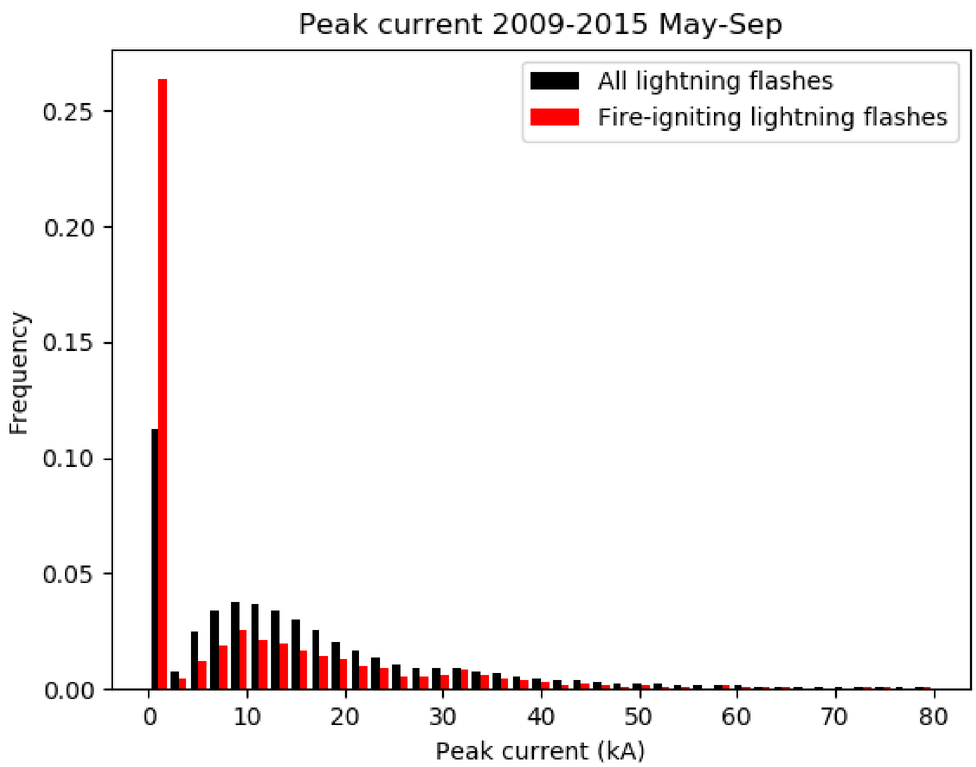


Fig. 23: Frequency distribution of the lightning peak current per normal lightning flash (black) and per fire-igniting lightning flash (red).

The frequency of small peak currents is higher in lightning-ignited fires, as previously reported by *Pineda et al. (2014)*.

# Main conclusions

- *Long Continuing Current* (**LCC**) lightning flashes have been proposed as the main precursors of lightning-ignited fires. The analysis of LIS lightning data over continental Europe suggests that LCC lightning flashes tend to occur in thunderstorms with **low values of CAPE**.

- Lightning-candidates of **lightning-ignited fires** over Iberian Peninsula and Southern France tend to occur in thunderstorms with:

  - weak convection (low CAPE)
  - high temperature at lower levels (850 hPa, ~1.5 km)
  - low moisture at lower levels (850 hPa, ~1.5 km)
  - low hourly accumulated precipitation

**LCC lightning in dry thunderstorms**

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