

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

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Knowledge for Tomorrow



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



~**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, ...

They usually take place in **remote areas**



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)

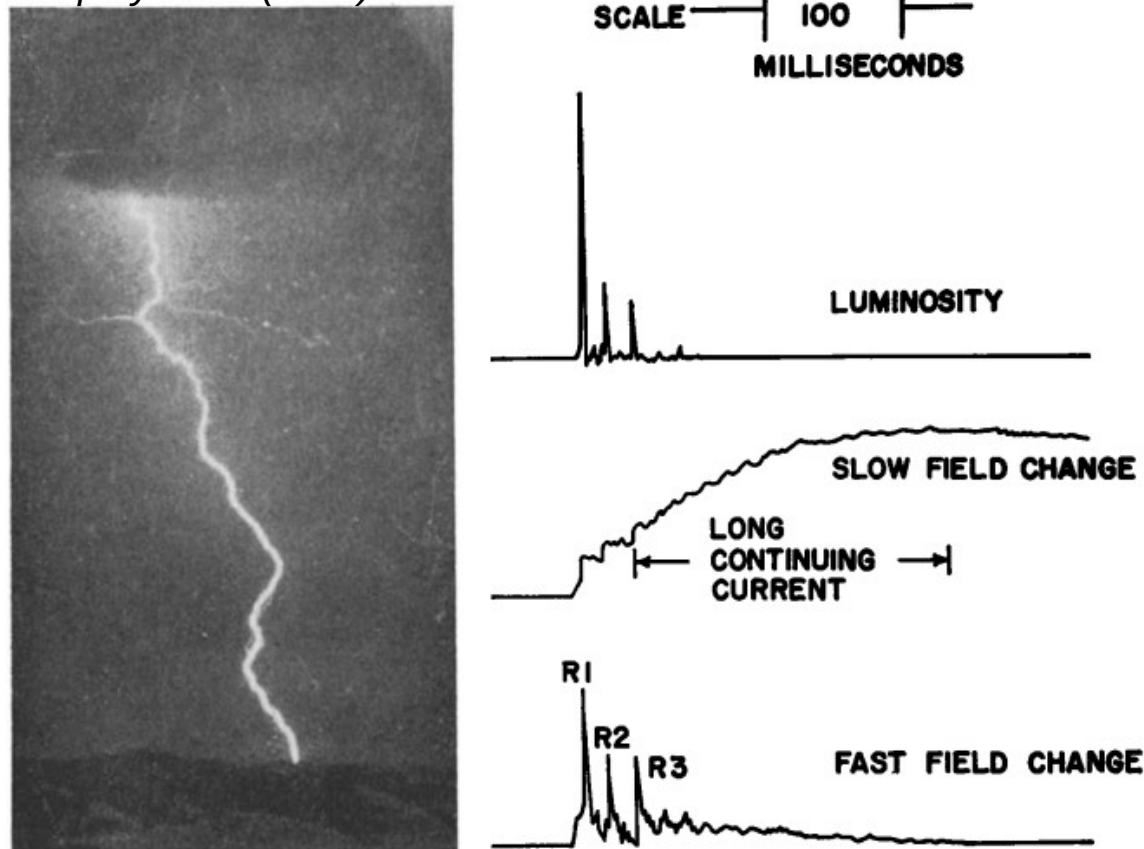


Fig. 1. Flash image, luminosity trace, and fast and slow field change traces of a discharge that caused a forest fire on September 6, 1966. Note the long-continuing current phase following the R3 stroke.

*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*

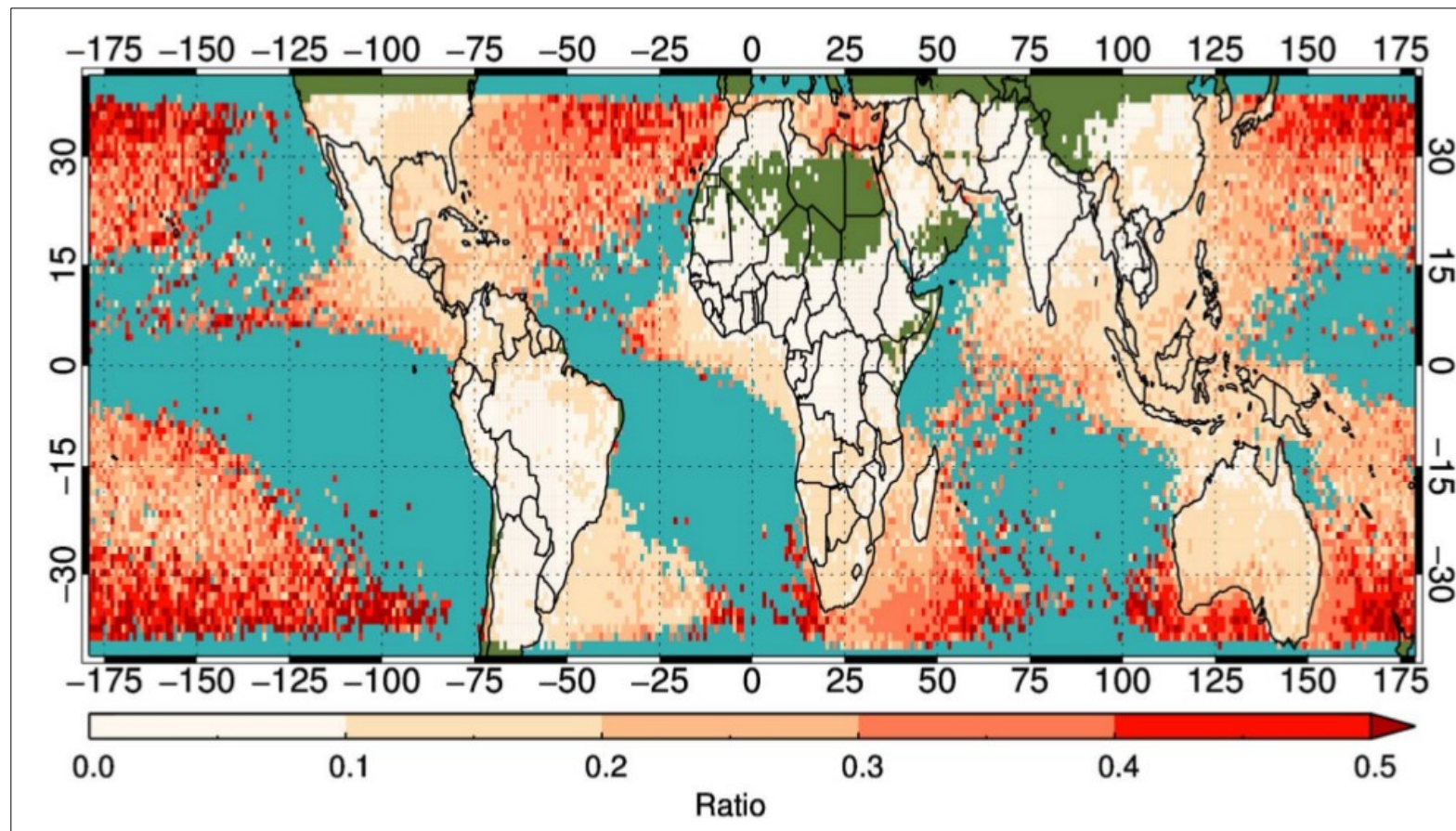
- Some lightning discharges have a long continuing current phase with a duration of tens or hundreds milliseconds.
- According to several optical and radio signals of fire-producing lightning, most lightning-ignited fires could be produced by LCC lightning.
- The long lasting phase (>10 ms) of LCC lightning 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



[Bitzer, 2017]

**Weaker
updraft**



**Smaller
charging rate**



**More extended
charge
regions before
lightning
discharges**

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].



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” $A = (1 - \frac{T}{14 \text{ days}}) \times (1 - \frac{S}{10 \text{ km}})$, 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 Conservação da Natureza 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 Português 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.

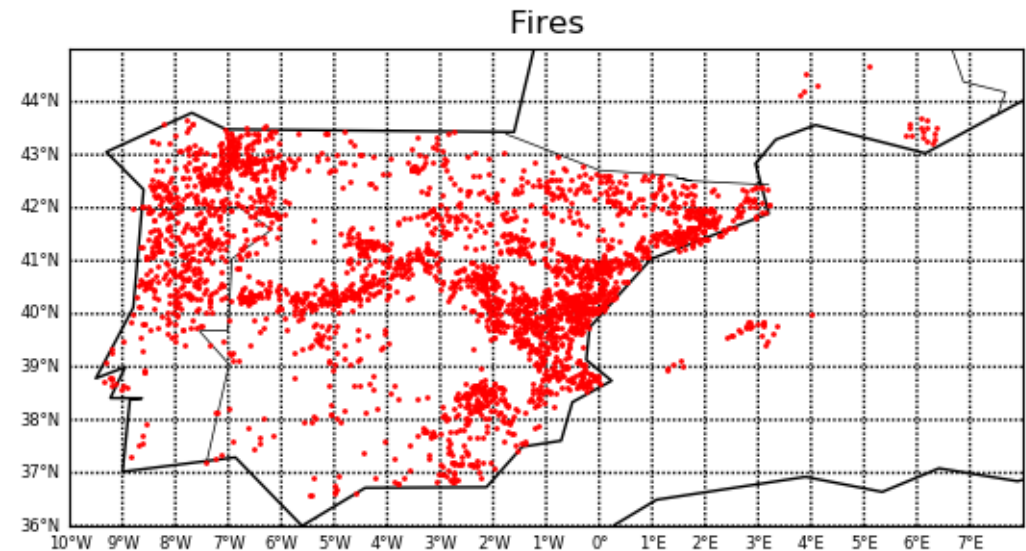


Fig. 1: Fires included in the analysis (2009-2015).

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*.

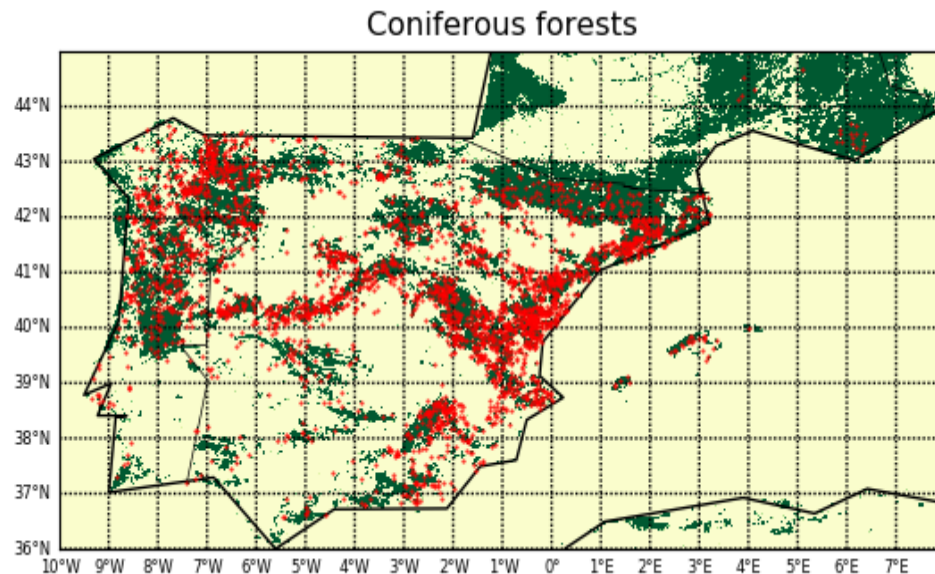


Fig. 2: Coniferous and mixed forests (green dots) derived from satellite observations produced by the ESA-CCI for 2015 and fires (red dots) included in this study. Spatial resolution is 300 m.

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) .



Results



Results: 1°x1° LIS-ISS lightning data over Europe. Preliminary analysis

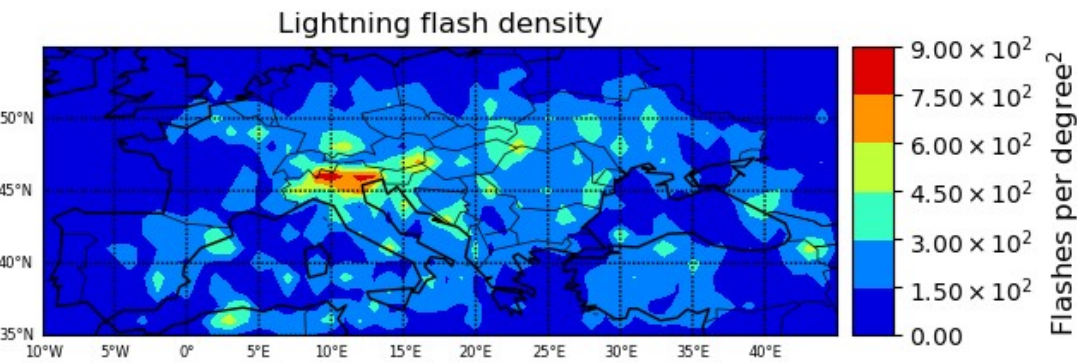


Fig. 3: Lightning flashes over Europe between 2017-2019 from LIS-ISS data.

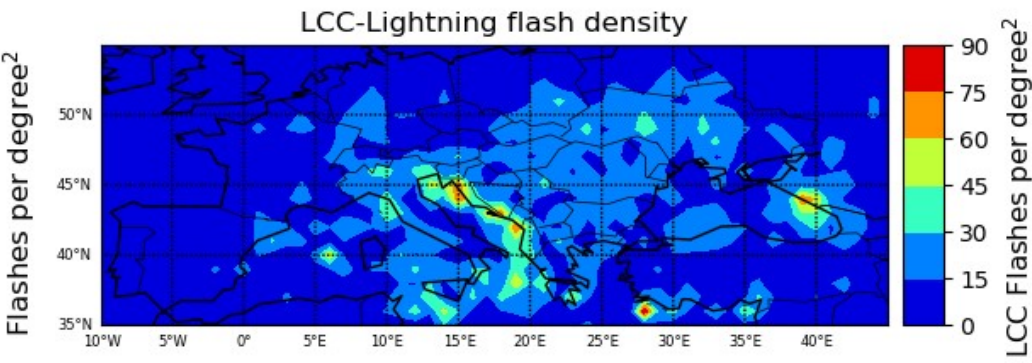


Fig. 4: LCC-lightning over Europe from LIS-ISS data following the method proposed by Bitzer, JGR (2017).

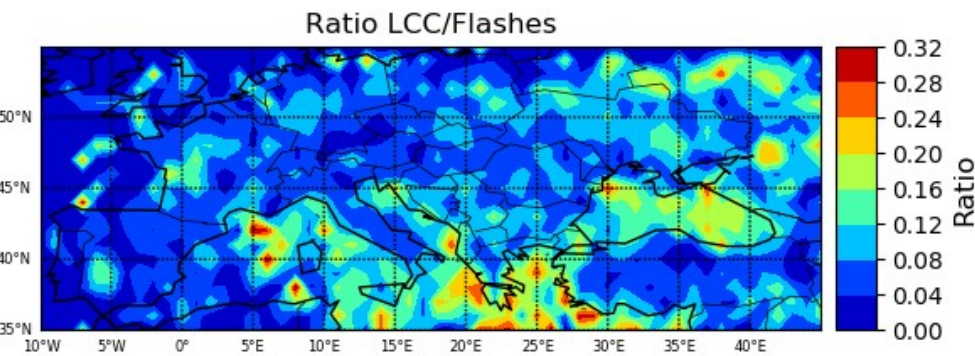


Fig. 5 : Ratio of LCC-lightning to all lightning over Europe (ratio in one cell is set to zero if there are less than 10 lightning discharges or less than 2 LCC-lightning flashes).

Normal lightning = Lightning flashes without LCC-phase

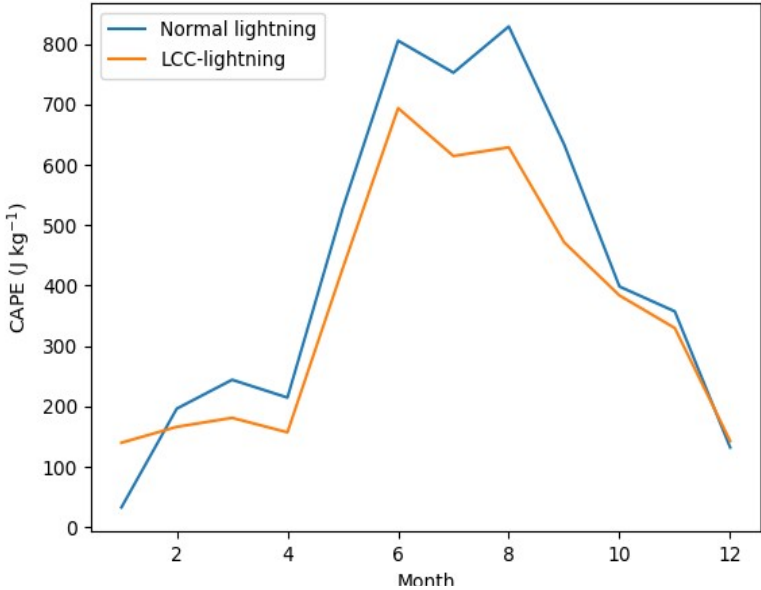


Fig.6: Monthly averaged *Convective Available Potential Energy* (CAPE) per normal lightning flash (blue) and per LCC-lightning flash (orange) during 2017-2019. We have only included lightning flashes over **land**. The CAPE has been obtained from the 0.25°x0.25° ERA5 hourly data reanalysis.

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

Results: 0.5°x0.5° LIS-ISS lightning data over Iberia. Preliminary analysis

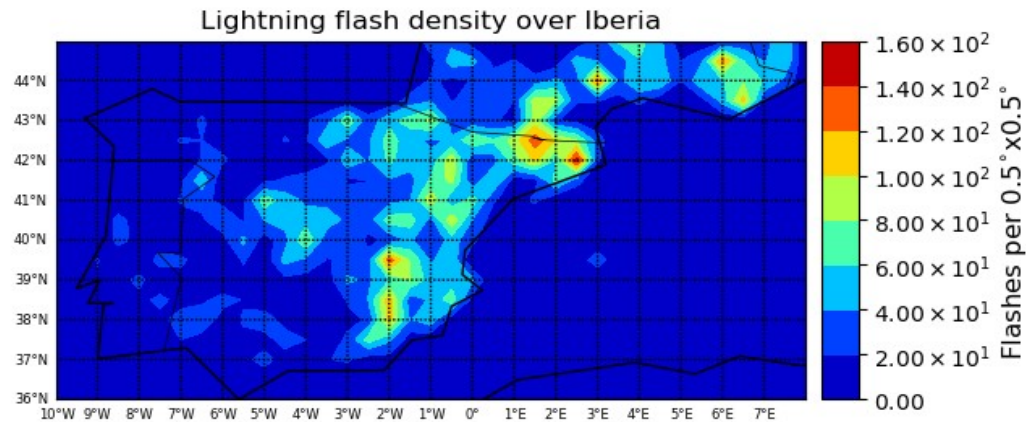


Fig. 7: Lightning flashes over Iberia between 2017-2019 from LIS-ISS data.

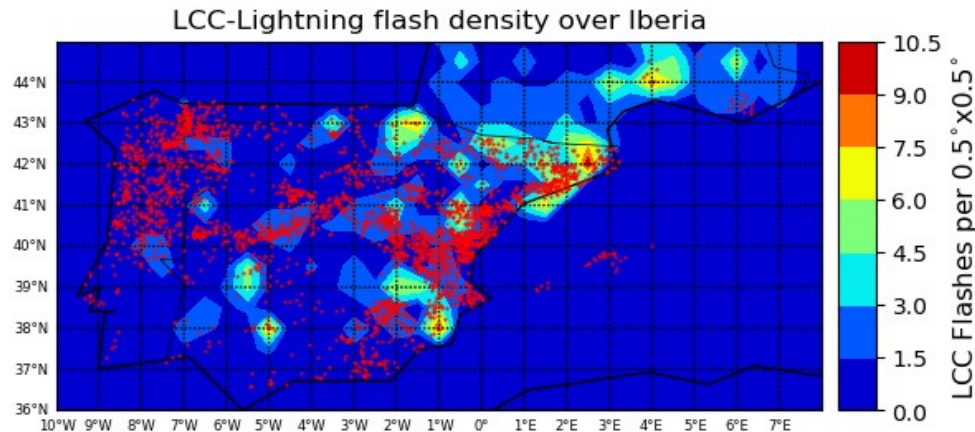


Fig. 8: LCC-lightning over Iberia from LIS-ISS data following the method proposed by Bitzer, JGR (2017) and fires (red dots).

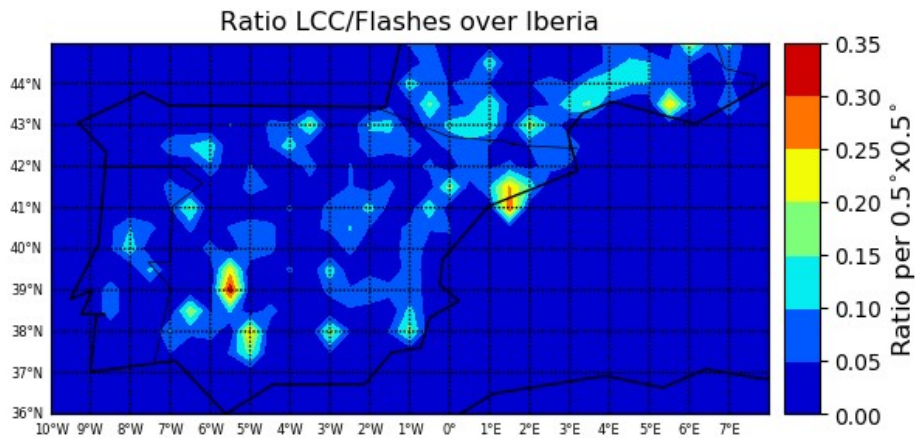


Fig. 9: Ratio of LCC-lightning to all lightning over Iberia (ratio in one cell is set to zero if there are less than 10 lightning discharges).

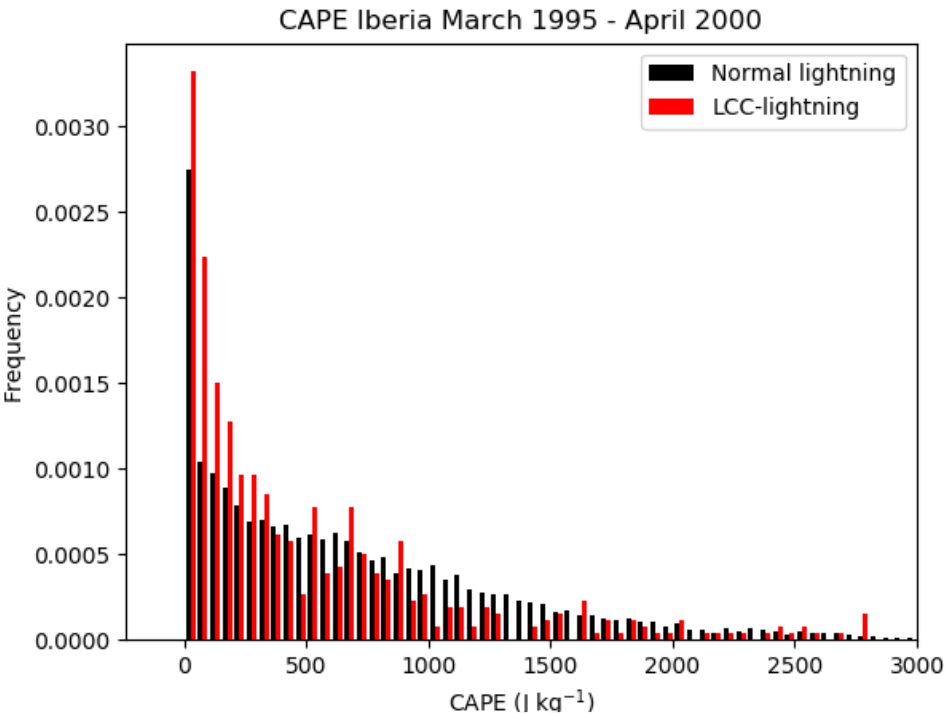


Fig. 10: Frequency distribution of CAPE per normal lightning flash and per LCC-lightning flash.



Monthly climatology of lightning-ignited fires

Monthly climatology of fires 2009-2015

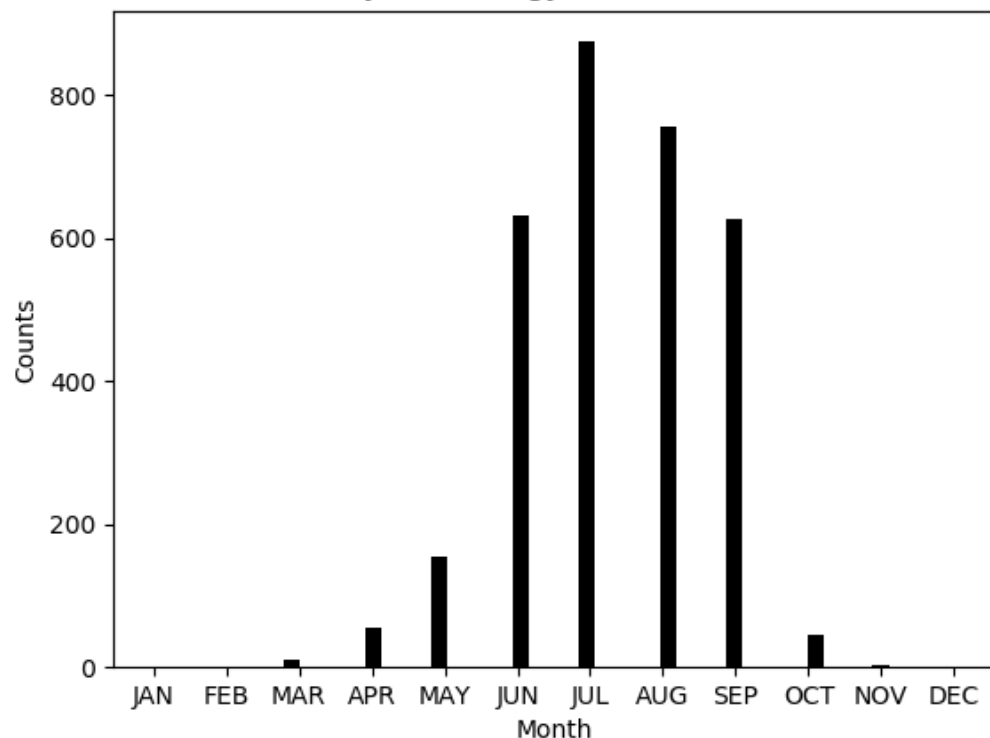


Fig. 11: Monthly climatology of lightning-ignited fires over **Spain, Portugal** and Mediterranean **France**.

Monthly climatology of lightning flashes 2009-2015

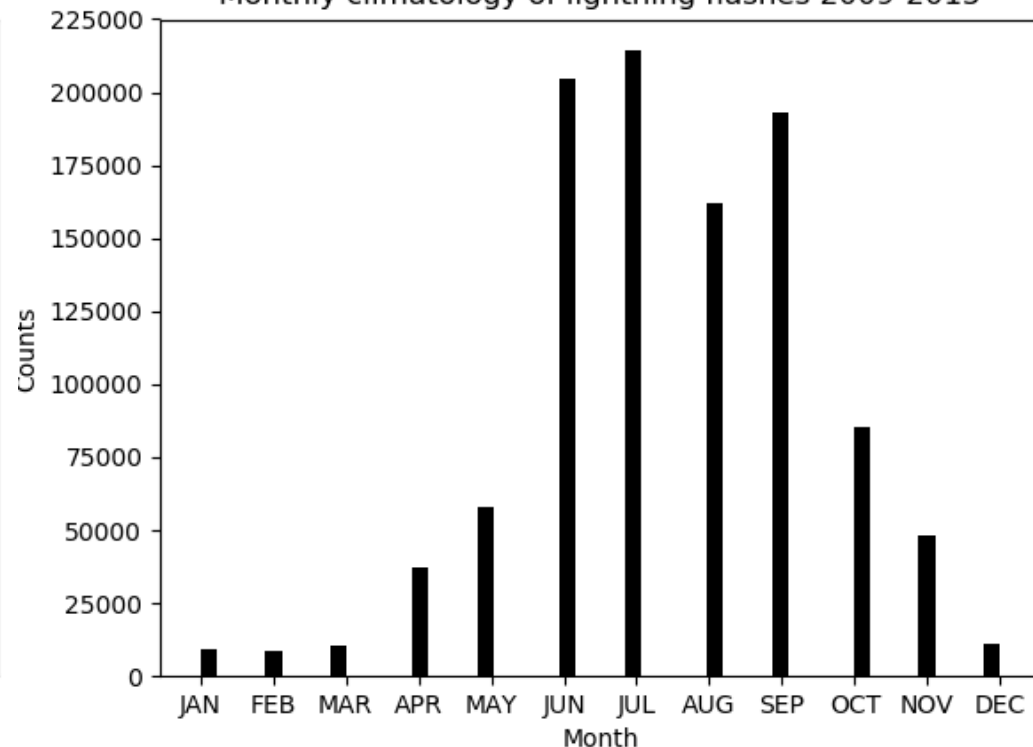


Fig. 12: Monthly climatology of lightning flashes over *coniferous and mixed forests* in **Spain, Portugal** and Mediterranean **France** derived from WWLLN and ENTNLN.



Lightning candidates: Timing and distance

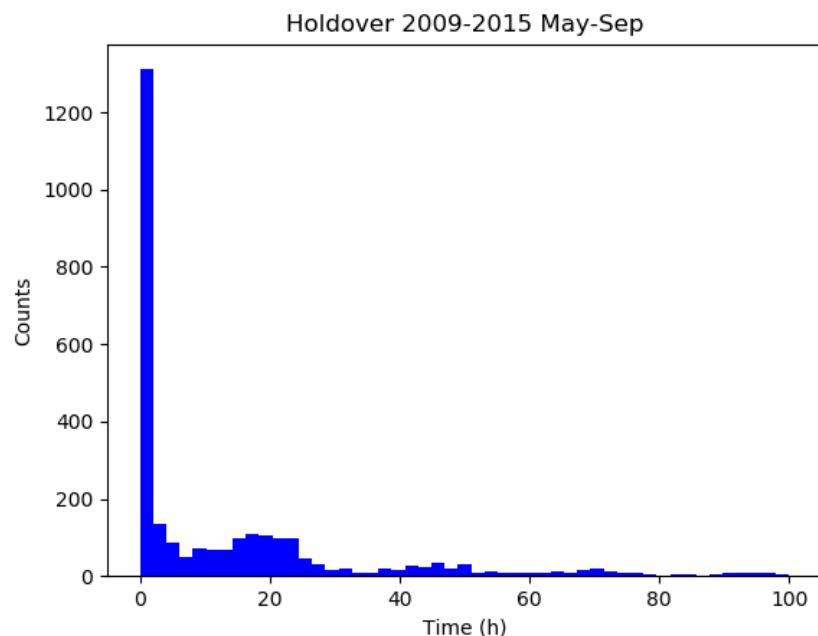


Fig. 13: Time between the lightning candidate and the declaration of the fire.

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

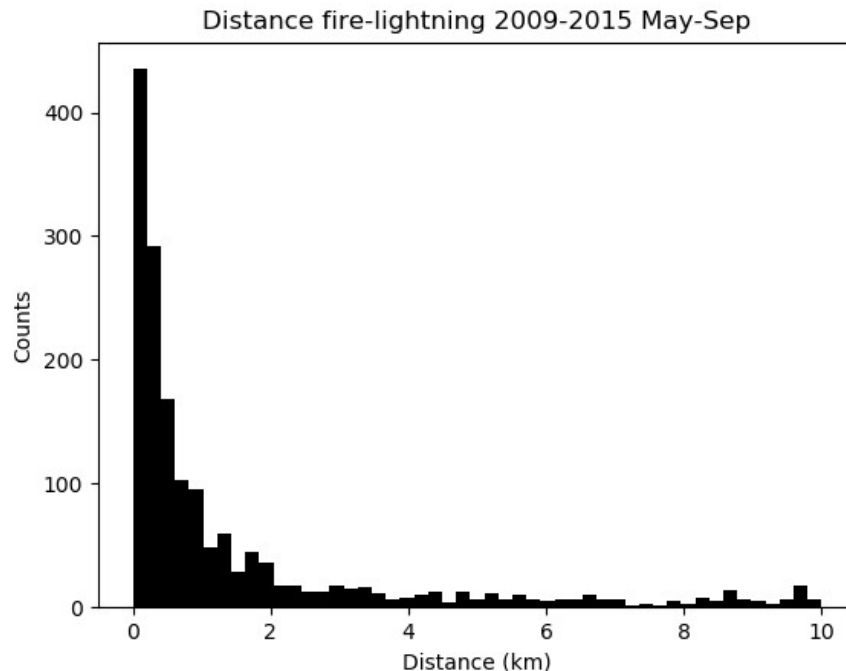


Fig. 14: Distance between fire and lightning candidate.

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.

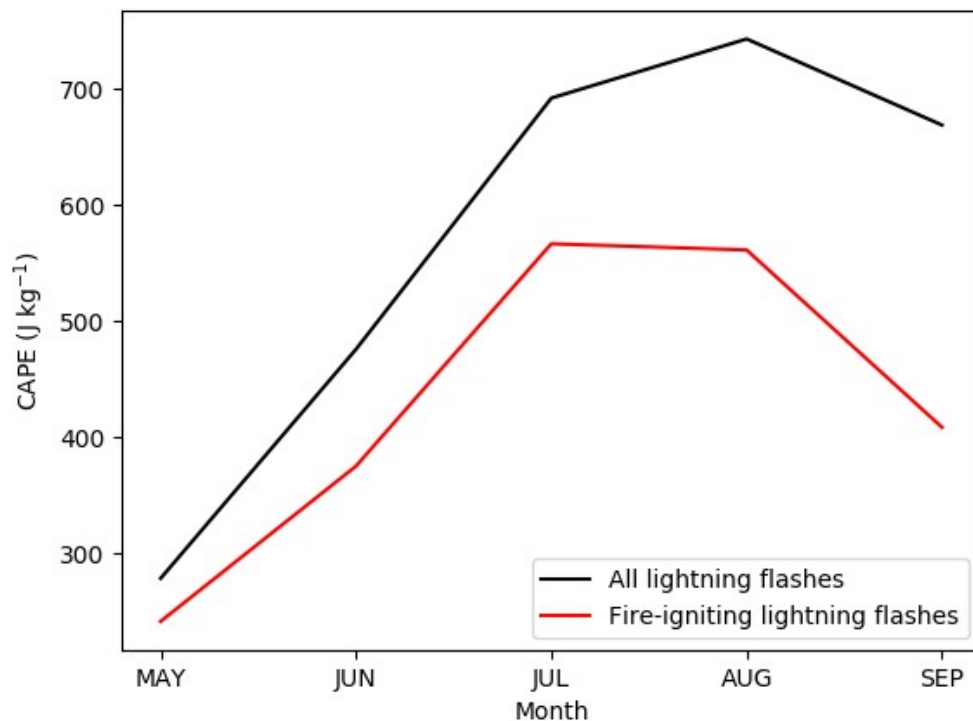


Fig. 15: Monthly averaged CAPE per normal lightning flash (black) and per fire-igniting lightning flash (red).

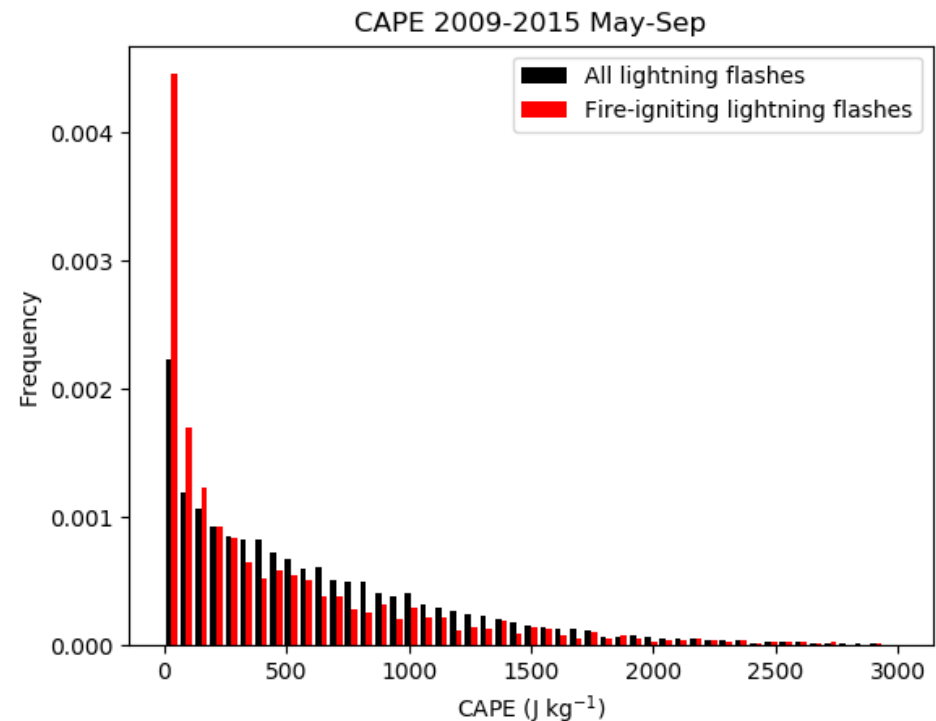


Fig. 16: Frequency distribution of CAPE per normal lightning flash (black) and per fire-igniting lightning flash (red).



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

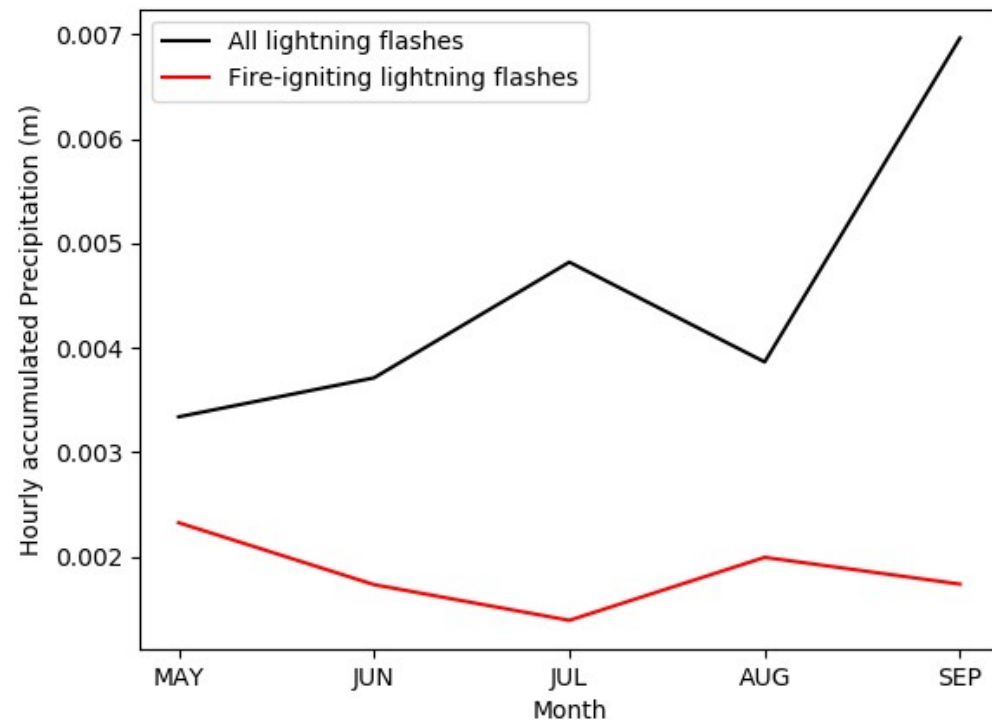


Fig.17: Monthly averaged 1-h accumulated precipitation per normal lightning flash (black) and per fire-igniting lightning flash (red).

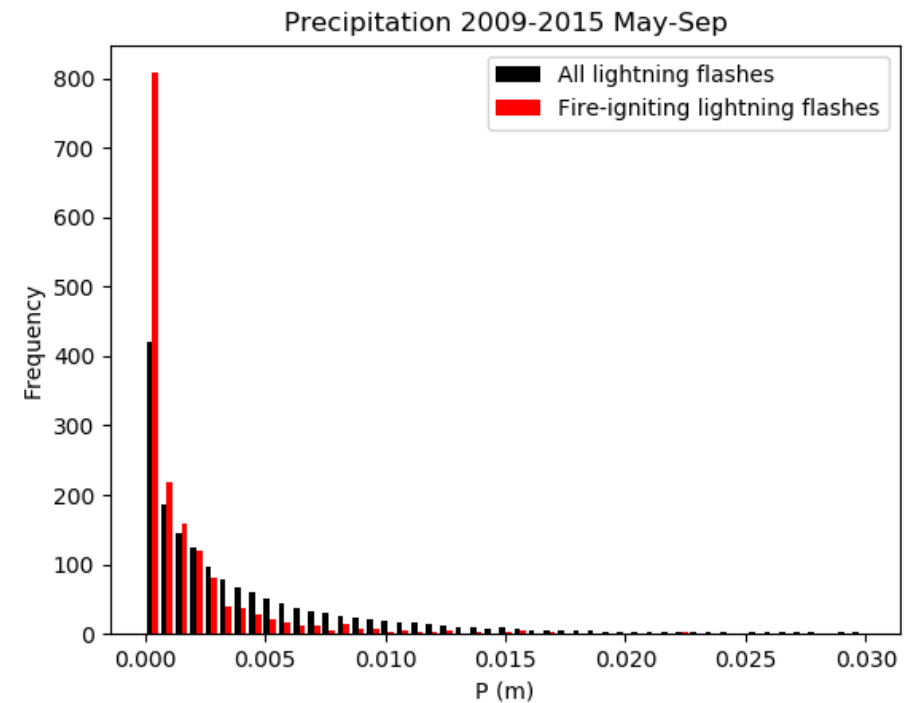


Fig. 18: Frequency distribution of 1-h accumulated precipitation per normal lightning flash (black) and per fire-igniting lightning flash (red).

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

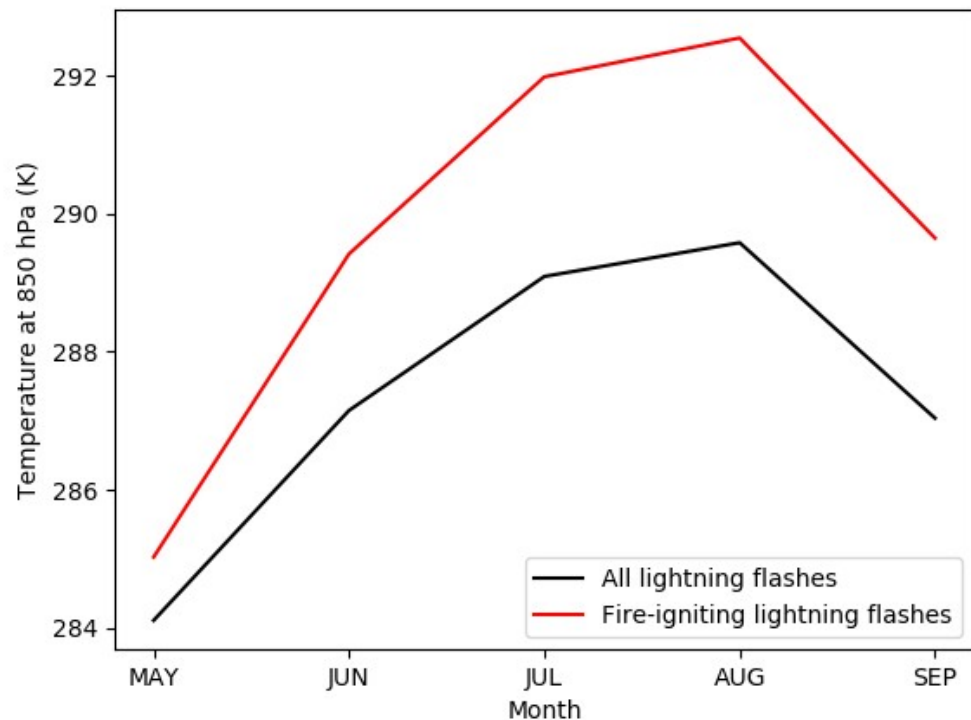


Fig. 19: Monthly averaged T (850 hPa) per normal lightning flash (black) and per fire-igniting lightning flash (red).

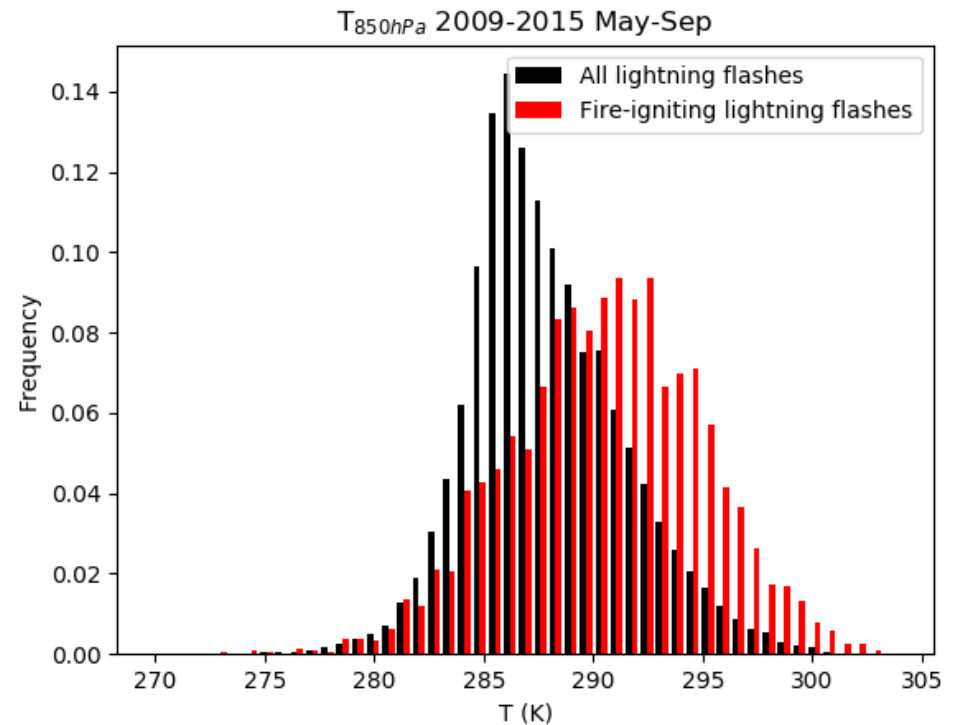


Fig. 20: Frequency distribution of T (850 hPa) per normal lightning flash (black) and per fire-igniting lightning flash (red).

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



Analysis of the relative humidity

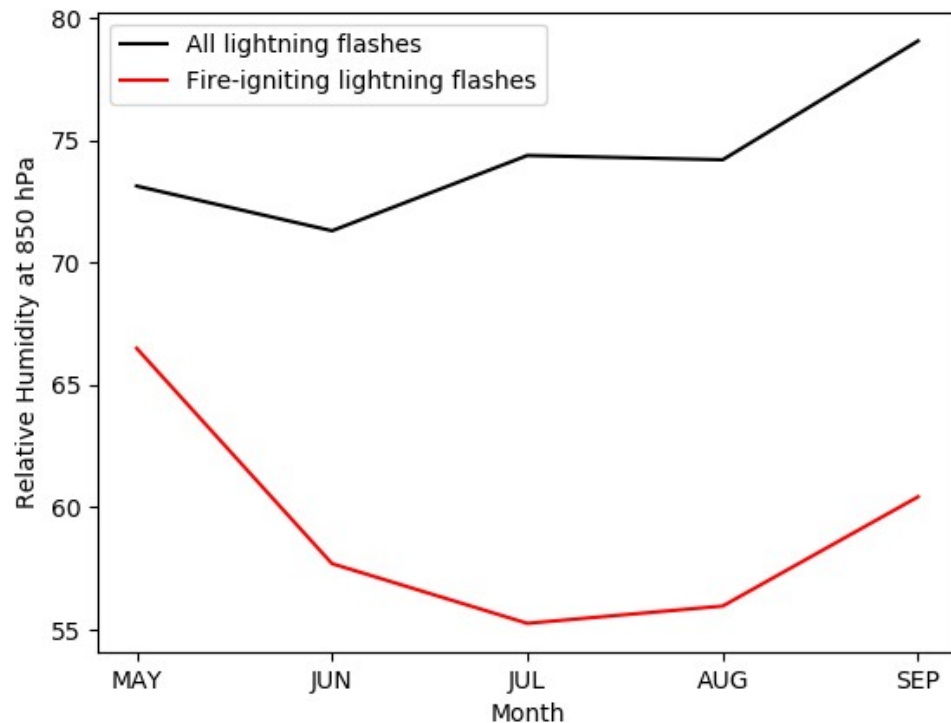


Fig. 21: Monthly averaged RH (850 hPa) per normal lightning flash (black) and per fire-igniting lightning flash (red).

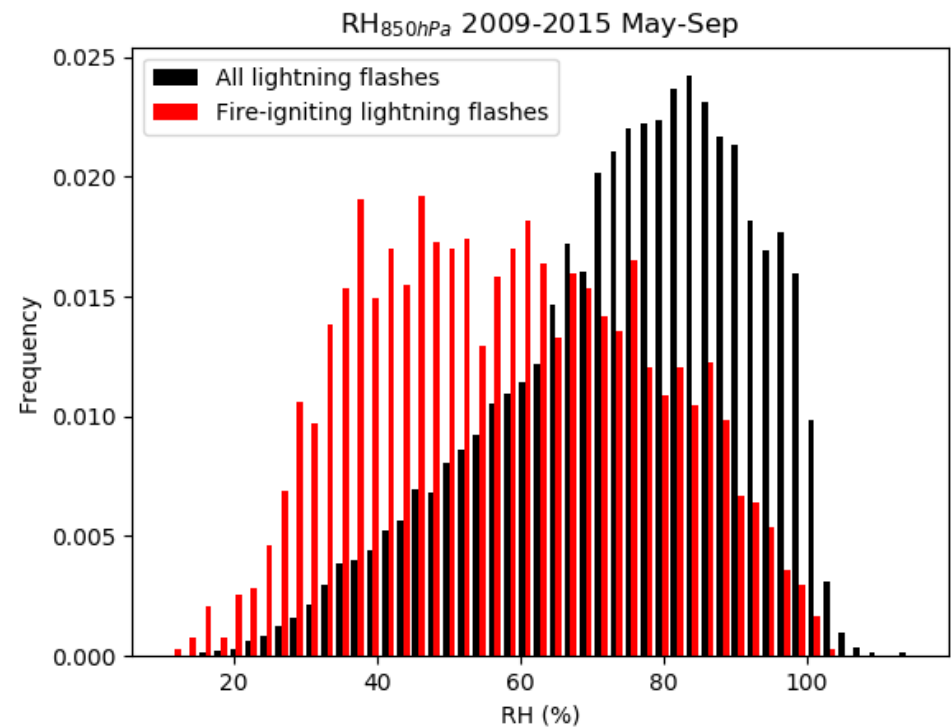
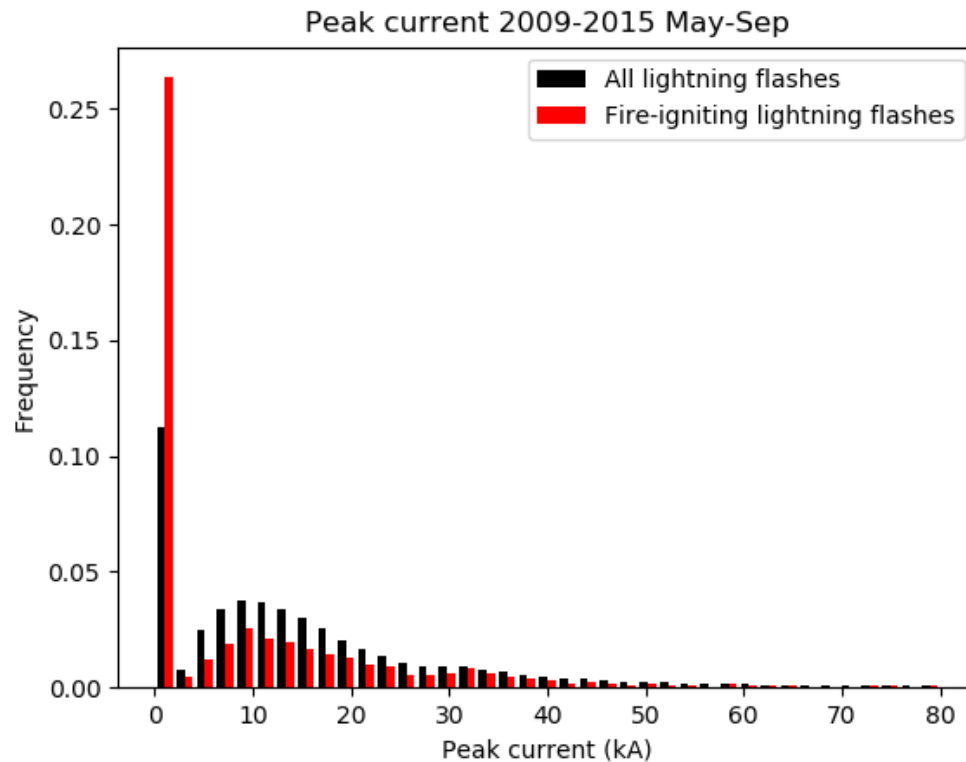


Fig. 22: Frequency distribution of RH (850 hPa) normal lightning flash (black) and per fire-igniting lightning flash (red).

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



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

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



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**



References

- Bitzer, P. M. (2017). Global distribution and properties of continuing current in lightning. *Journal of Geophysical Research: Atmospheres*, 122(2), 1033-1041.
- 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).
- McEachron, K. B., and Itagenguth, J. It (1942), Effect of lightning on thin metal surfaces, *AIEE Trans.*, 61, 559-564, 1942.
- Pineda, N., Montanyà, J., & Van der Velde, O. A. (2014). Characteristics of lightning related to wildfire ignitions in Catalonia. *Atmospheric research*, 135, 380-387.
- Pineda, N., and Rigo, T. (2017). The rainfall factor in lightning-ignited wildfires in Catalonia. *Agricultural and Forest Meteorology*, 239, 249-263.
- 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.

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