# Forest fires caused by lightning activity in Portugal

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## 1. Motivation

Wildfires in southern Europe cause extensive economic and ecological losses and, even human casualties [1]. According to the EC-JRC European Forest Fires Information System (EFFIS) for Europe, the years of 2003 and 2007 represent the most dramatic fire seasons since the beginning of the millennium, with total annual burned areas for Europe of over 600.000 ha, reaching 800.000 ha in 2003. Moreover, **Portugal holds one of the highest fire frequency densities in the Mediterranean area** (Fig. 1A) with the years of 2003 and 2005 representing the most dramatic fire seasons for the last 30 years, with total annual burned areas of 450.000 ha in 2003 and 350.000 ha in 2005 (Fig. 1B).

On the other hand, some countries have a relatively large fraction of fires caused by natural factors such as lightning, e.g. northwestern USA, Canada, Russia. In contrast, Mediterranean countries such as **Portugal has only a small percentage of fire records caused by lightning**, that has a density of occurrence over Portugal has shown in Fig. 2, with a strong daily cycle (Fig. 3). Although significant uncertainties remain for the triggering mechanism for the majority of fires registered in the catalog as they were cataloged without a likely cause.

*The main objective of this work is to evaluate and quantify the relations between the wildfires' occurrence and lightning activity*

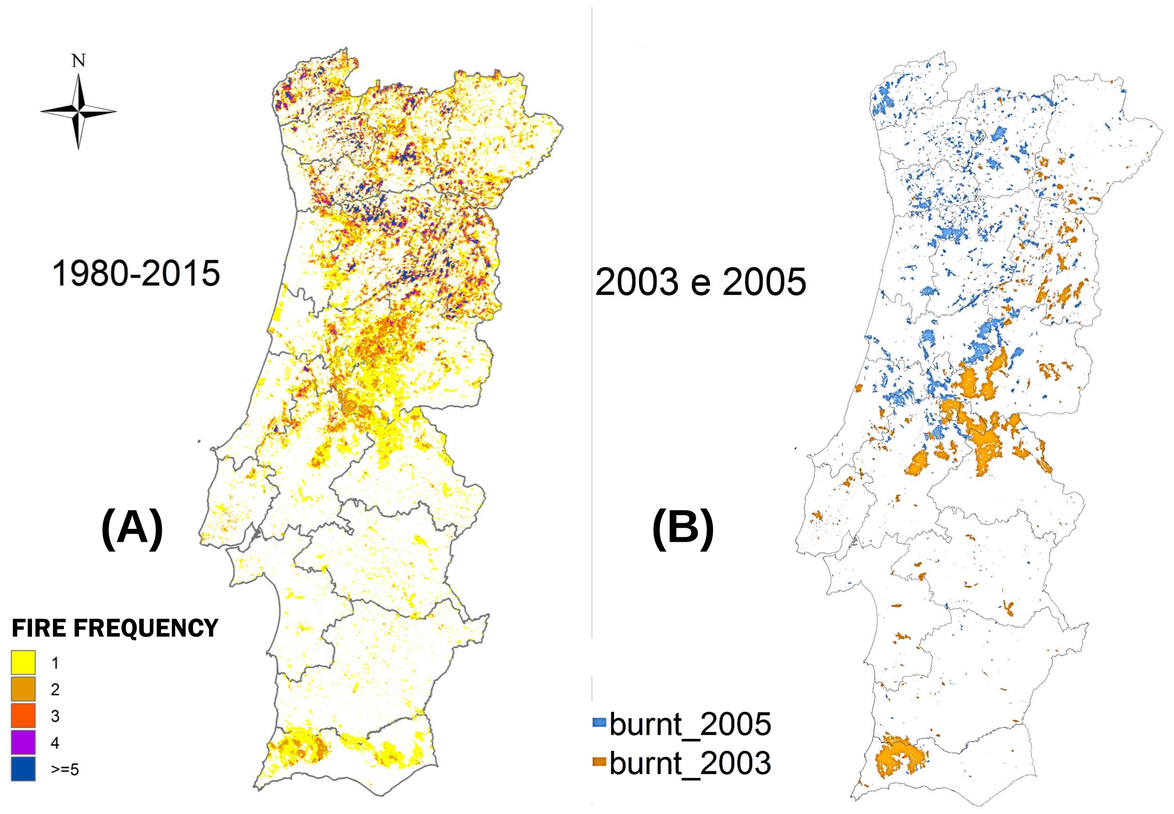



**Figure 1 –** (A) Fire frequency between 1980 and 2015; (B) Fire scars (burnt area at the end of the fire season(FS)) mapped for 2003 and 2005.

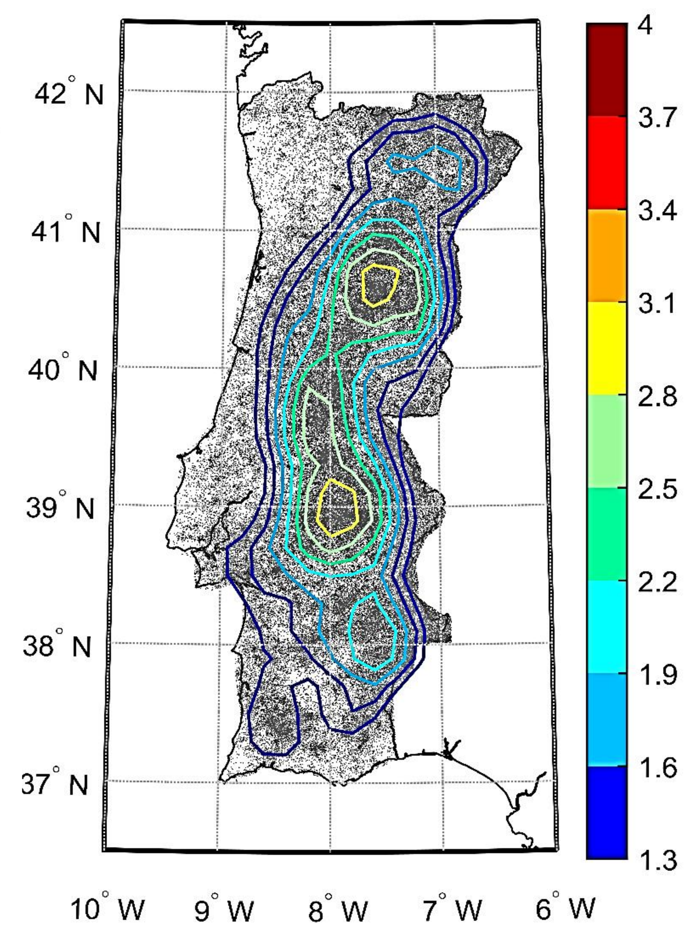



**Figure 2 –** Summer (JJAS) spatial density distribution of CG discharges in coloured contours. Values given as number of discharges/km² per year over a regular 0.2° × 0.2° grid. Geographical density distribution of CG discharges/km². All effective CG discharges for each year are represented by grey dots.

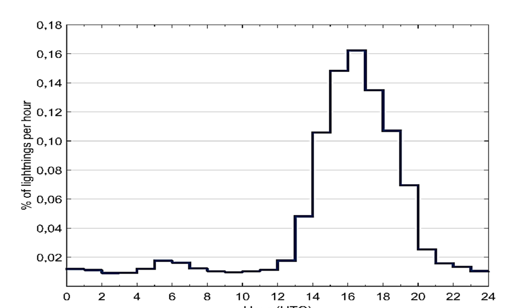


**Figure 3 –** Summer (JJAS) percentage of lightning per hour.

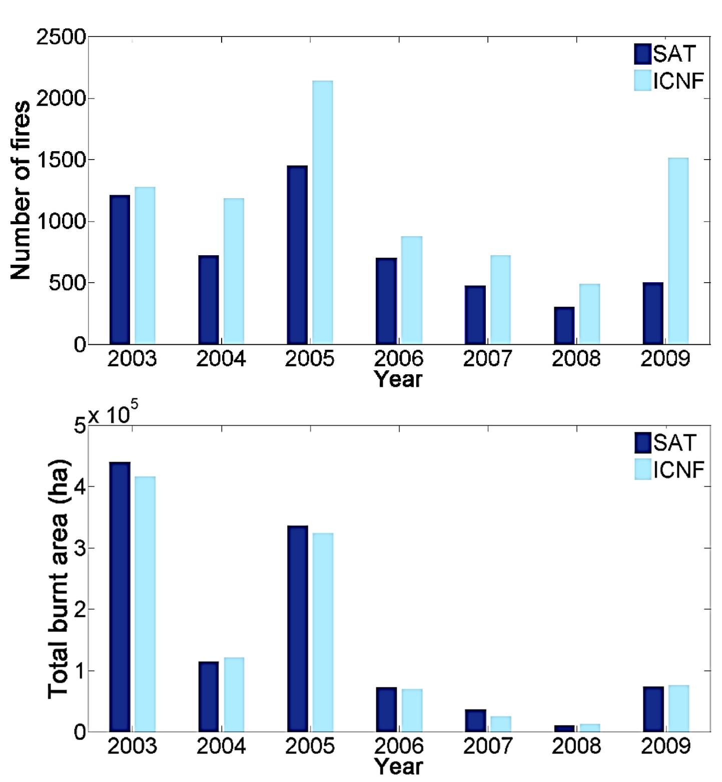



**Figure 4 –** Number of registered fires (top) and total burnt area (bottom) between 2003 and 2009.

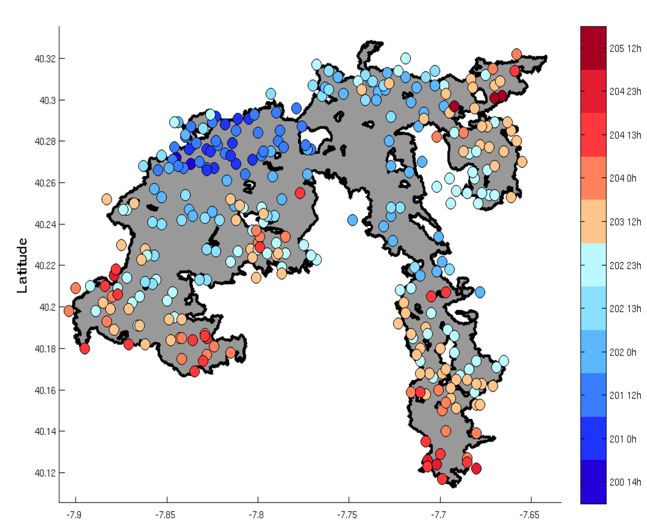


**Figure 5 –** Example of burned area, identified by satellite and dated by the method by Benali et al. [4]

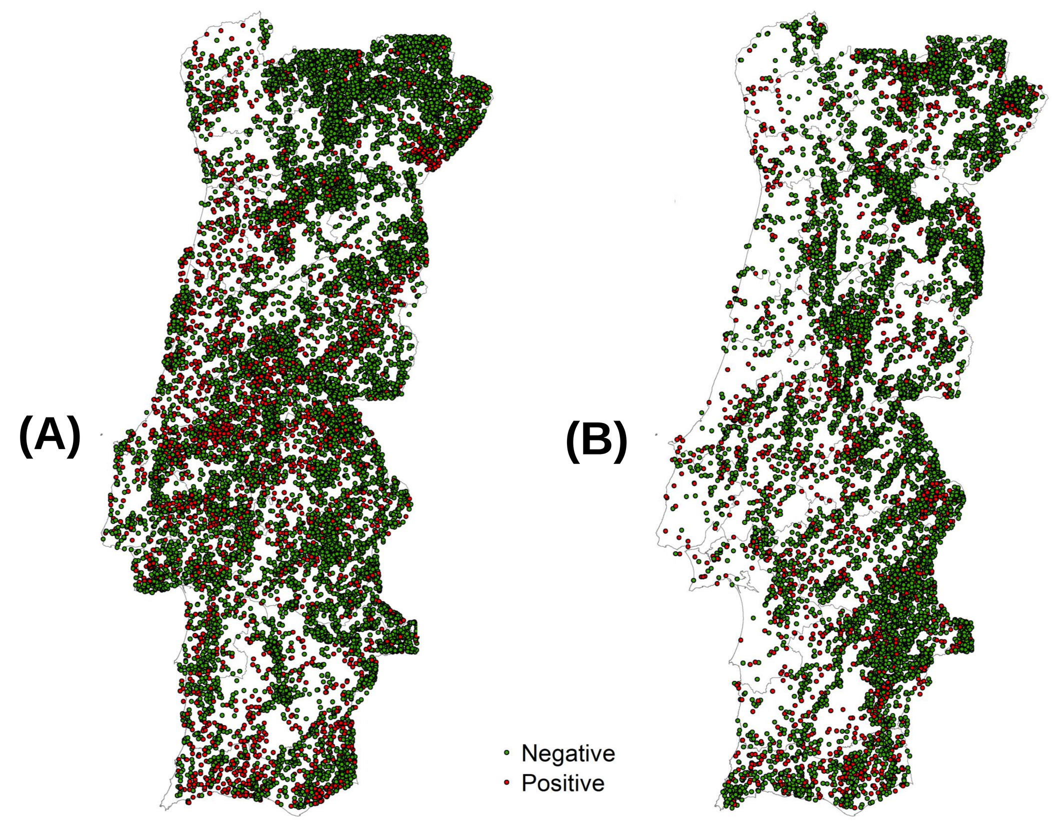



**Figure 6 –**Lightning discharges registered during (A) 2003 and (B) 2005

## 2. Data and Methodology

### FIRES

The fire database consists of relevant information about all fires that occurred in continental Portugal between 2003 and 2009, including ignition date, fire duration, location of fire start, and total burnt area (TBA). This data set was provided by the *Instituto da Conservação da Natureza e das Florestas (ICNF) (Fig.4).* Additionally, data derived using satellite data (SAT), including TBA, fire perimeters and ignition dates was also used, as provided by ISA. An example of a burned area dated following Benali et al. [4] is shown in Fig. 5.

### LIGTHNING

The lightning database [2] includes cloud-ground (CG) lightning discharges extracted from the Portuguese Lightning Location System (operated by the national weather service - *Instituto Português do Mar e da Atmosfera)*. Figure 6 shows the lightning discharges for the two most dramatic fire seasons in Portugal (2003 and 2005).

### METHOD

In order to examine if a certain fire was ignited by CG lightning, the probability that a stroke had ignited a particular fire was computed based on the distance between the two in time and space and following the approach developed for Finland by Larjavaara et al. [3].

$$A = \left(1 - \frac{T}{60}\right)\left(1 - \frac{S}{10}\right) \quad (1)$$

$$B = 1 - \prod_{i=1}^{n} (1 - A_i) \quad (2)$$

*The proximity index (A) was calculated following (1) for all strokes, being considered null if either the delay in hours from a stroke to the time of ignition,* ***T****, was over* ***60 hours*** *or the spatial distance between the stroke and the nearest fire,* ***S****, was over* ***10 km****.* ***The estimated probability that a certain fire was ignited by lightning*** *(B)* ***was obtained*** *based on (2), where $A_i$ is the proximity index of a stroke surrounding a fire in question and n is the number of strokes with positive proximity index surrounding the fire. The method was applied* ***for fires with TBA > 200 ha.***

## 3. Results and Conclusions

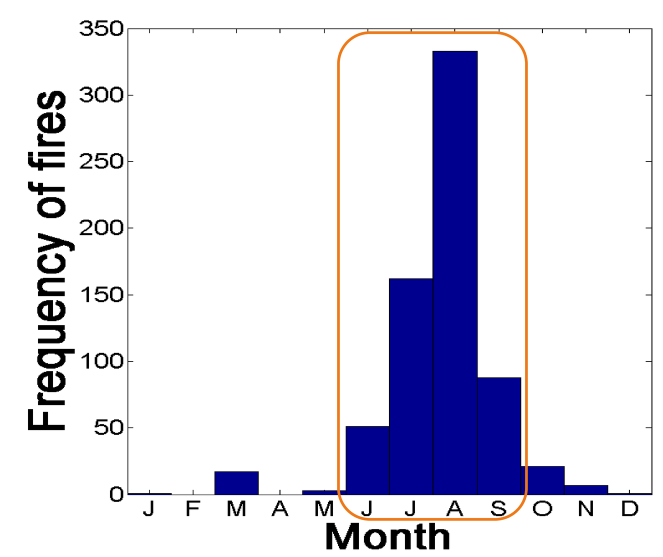



**Figure 7 –** Monthly frequency of registered ICNF fires between 2003 and 2009.

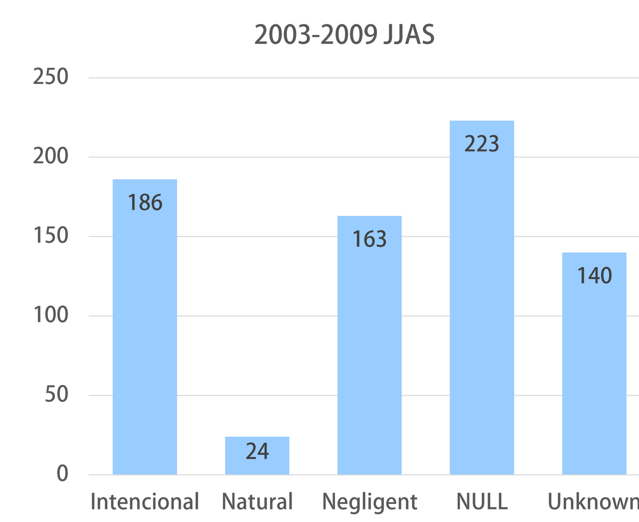



**Figure 8 –** Attributed cause of registered summer (JJAS) fires between 2003 and 2009.

The probability that a stroke had ignited a particular fire was computed for summer months as most fires in Portugal occur during June, July, August and September (Fig. 7) and approximately 50% of the registered fires during that period have no attributed cause (Fig. 8).

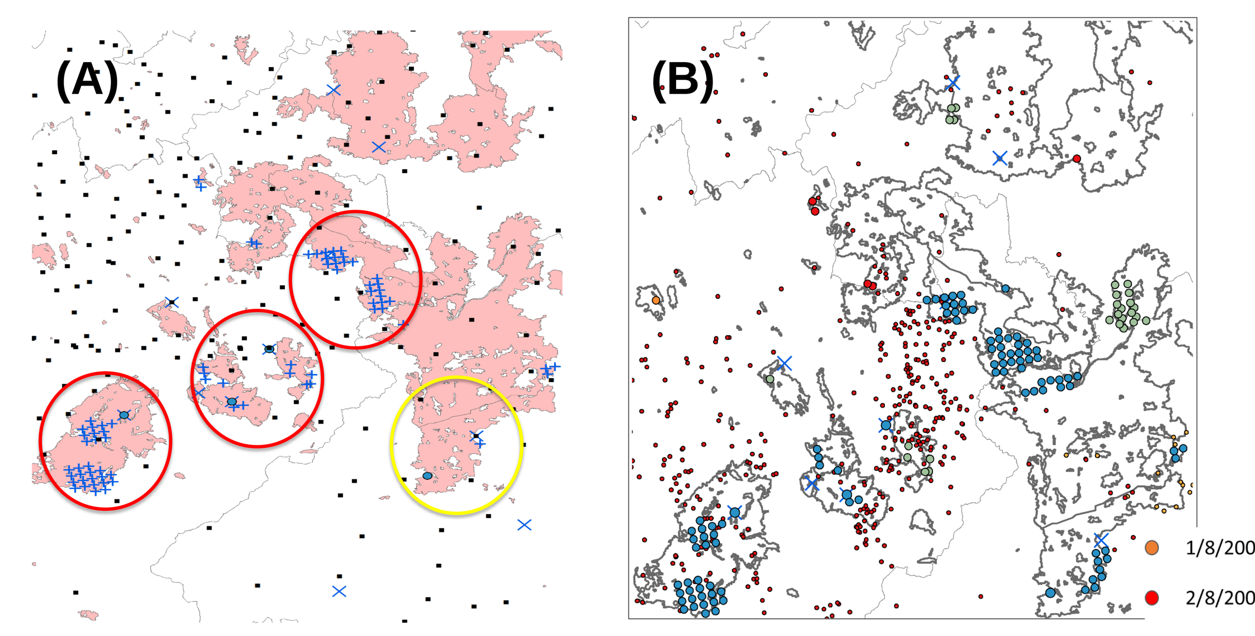
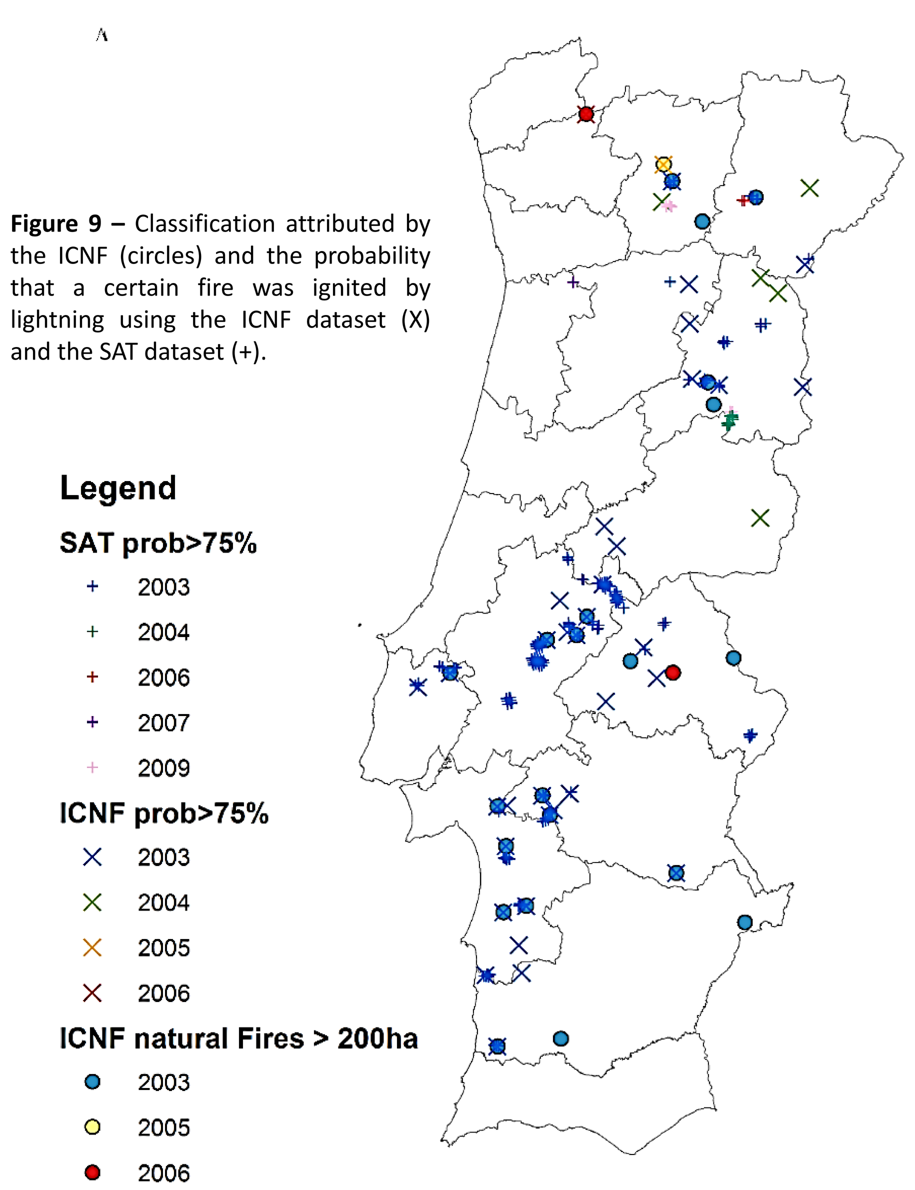



**Figure 10 –** **(A)** Examples of fires correctly (red circle) and incorrectly (yellow circle) identified because of local incorrectness. Black squares represent the parish locations; **(B)** Delay of fire ignition (large circles) relatively to lightning (small circles).

**Figure 9 –** Classification attributed by the ICNF (circles) and the probability that a certain fire was ignited by lightning using the ICNF dataset (X) and the SAT dataset (+).




- Although only a **small percentage of fires is caused by lightning**, the number of forest fires with no probable cause attributed is big enough (Fig.8) to make us believe that some of them where caused by lightning.
- Based on this approach It was **possible to validate the classification assigned by ICNF** and calculate the probability of a given fire have been caused by lightning (Figs. 9 and 10).
- Most fires were correctly classified and a significant number of previously unclassified fires were identified has having high probability of being caused by lightning.
- The combined use of the two databases (ICNF and SAT) is an asset in confirming if a certain fire has high probability of being caused by lightning.

### FUTURE WORK

- **Testing the influence of type of vegetation cover and precipitation**
- **Testing the influence of uncertainty in dating of the fires**

**References**

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