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Spatial and temporal homogeneity of lightning archive

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INTRODUCTION :

Different studies have already shown the relationship and sensitivity of lightning activity to changes of surface temperature or Nox production. So with the global warming debate, it is relevant to evaluate whether or not this activity should increase in correlation with global warming.
Defining climatic indicators to follow lightning activity on different scales and periods is therefore the first step.
In climate database of most weather services, only daily occurrences of storm are stored for local observations stations. On the other side, we now have more than 10 years of lightning archive produced by the lightning network, providing a continuous spatial coverage on France.
We need to define a homogeneous parameter to get an indisputable reference to compare the future values because one has to be sure that the climatic trend that may come out is due to climate and not to a measurement change. It's why we decided to perform a study on lightning database homogeneity.
As stroke density seems very sensitive to technological improvements (better sensors, change of lightning processor to locate, evolution of topology of the network), we worked with the occurrence of storm day by comparison between climate database and lightning database.

REFERENCE DATASET FROM CLIMATE DATABASE:

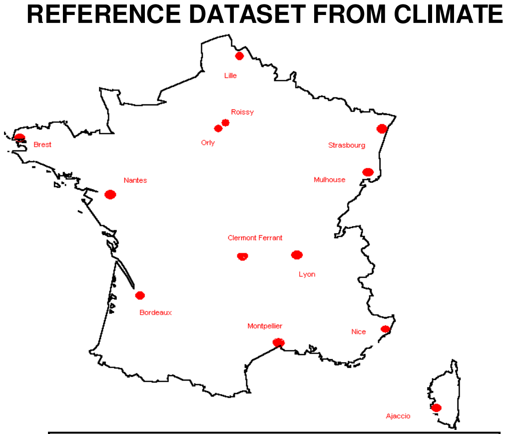

Figure 1: Selected stations from climate database

The climate database contains human observations for a large number of stations. For good reference, we only selected stations opened 24/24H and 7days a week and which have made at least 90% of possible observations with a constant level since 1994 (beginning of the lightning database).
With these criteria, we found 13 stations on France, spread throughout the country as shown by figure1.

WHAT IS A STORM DAY IN LIGHTNING DATABASE?

To be able to compare the lightning database with climate database, we have to decide how we can define a positive occurrence around the stations. How many flashes are necessary to have a storm day and to be sure that it is not due to an outlier? What is the optimal distance to check for flashes around the station?
To find the better choice to define the storm day we compared for 3 stations (Lyon, Orly, Bordeaux) the occurrence from climate database to different cases from lightning database: 1 or 2 flashes in a radius from 8 to 26 km around the station. For each case, we computed a contingency table between observer and network data:

Radius: xx km Xx flashes		Climate database: human observer	
		Storm day	Not a storm day
Lightning database	Storm day	Hit→ a	False alarm →b
	Not a storm day	Miss → c	Negative → d

The figure 2 shows results for Lyon station and different radius.

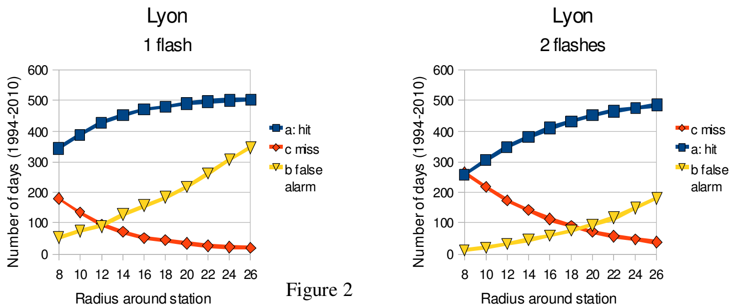

Figure 2

We can notice that good detection rate always rises with radius and miss decreases. But the false alarm rate is also rising .
To choose between these different scenarios, we use the ROC method.
With ROC method, the good detection rate H is: H=a/(a+c)
And false detection is given by: F=b/(b+d)).
We ploted H and F on the same graphic. With this theory , we are searching the nearest point from the point F=0 and H=1.
But in our case, the number of days without thunderstorm is so big that the false alarm is very small and we can't tell which is the nearest point from (0,1). The result is given by figure 3.

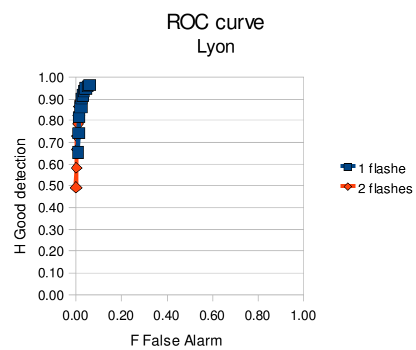

Figure 3

To face up to this difficulty, we then used the Pseudo Roc Method for rare events referring to Stevie. Roquelaure,Thesis. This calculation removes the impact of the "no-no good forecasts", which mostly dominates the data sample for rare events. We computed the same H rate and a pseudo F' rate given by: F'=b/(a+b).

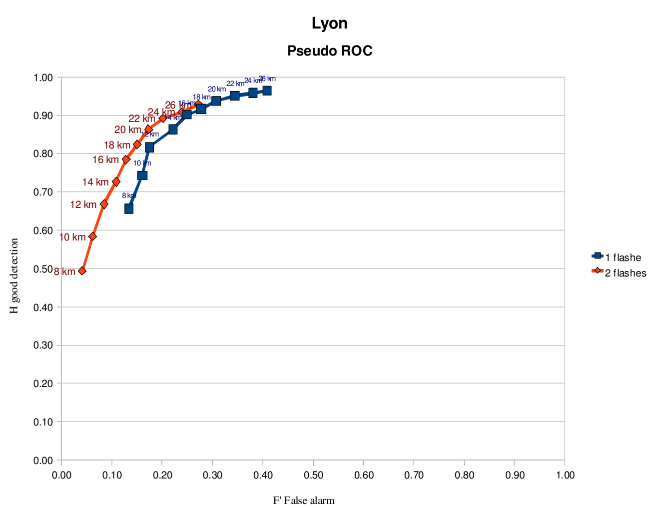

Figure 4

The figure 4 shows result for Lyon by pseudo ROC method. For the 3 stations, the better choice corresponds to 2 flashes and 20 km.
It is the definition we adopt to define a storm day around a point in the lightning database.

HOMOGENEITY OF LIGHTNING DATABASE:

We computed storm days in lightning database for the 13 stations checking 2 flashes in 20 km around the stations. Then, we compared to climate database by year using again contingency table and computing annual rates of good detection and pseudo false alarm. The figure 5 gives example of results for Lyon, Bordeaux and Nantes:

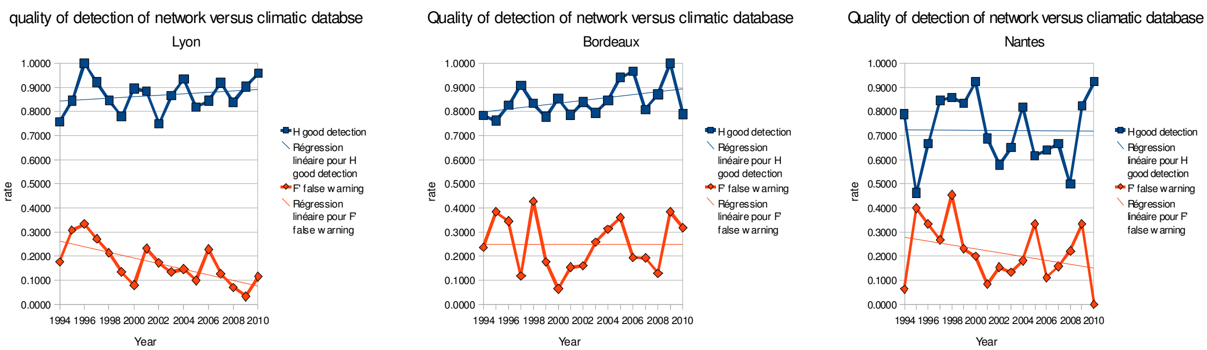

Figure 5

In general, for the 13 Stations, we can notice good detection rate is rising and false detection rate is decreasing. Most of breaks seems to appear on the same years but it's still difficult to tell if there are some breaks in lightning archive. To smooth these results and try to point out breaks, we calculated the average by year for the 13 stations. The figure 6 shows the result. The green curve represents the difference between good detect rate for the current year and previous one as given by table 1.

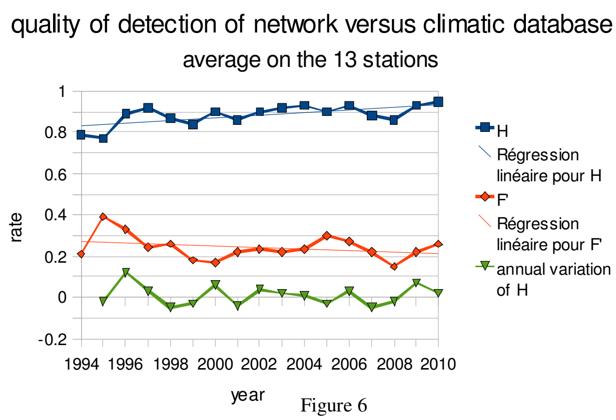

Figure 6

year	annual variation of H
1994	
1995	-0,02
1996	0,12
1997	0,03
1998	-0,05
1999	-0,03
2000	0,06
2001	-0,04
2002	0,04
2003	0,02
2004	0,01
2005	-0,03
2006	0,03
2007	-0,05
2008	-0,02
2009	0,07
2010	0.02

Table 1 : H(YY)-H(YY-1)

The average rate for good detection is of 87% and 24 % for false alarms. We can notice that in 2010, we got 94% of good detection.
It appears some breaks in 1996, 2000,2002,2006 and 2009. We then compare these years to the network history .
1996: update of network: all French sensors were updated by impact 141T sensors from Vaisala. It was the beginning of Time Of Arrival technology.

2000: Acquisition of Italian sensors (none before) .Detection in South East of France has probably increased.
2002: Acquisition of Belgian sensors and one more sensor in France at Quimper, in west of France
2006: Acquisition of German sensors. One more sensor in Corsica.
2009: Update of Meteorage network on France, all impact sensors are updated by LS7001.
On all the period, we also checked if some sensors have been out of order for a long time but nothing of significant interest was found.
Our analysis is that some noise can explain minor fluctuations of good detection rate and for us we think that the main break corresponds to the beginning of TOA technology in 1996. The second one is 2009 with LS7001 sensors but it's less important than 1996.
The average rate of good detection for the 1996-2010 period is 89% and superior to 90% after 2009.

Then to confirm theses results, we compare the good detection rate to others parameters. There is no correlation with the observed number of storm days but there is a positive correlation with the number of sensors which have participated to locate the flash. The rate of good detection increases with the number of participating sensors. In 1996 we had between 2 and 6 sensors, but in 2009 we had between 8 and 12 sensors. This result confirms the slow increase of good detection rate on the period with the improvement of network.

CONCLUSION:

To be able to compare climatic database an lightning database to check homogeneity, we had to define a storm day around a point for a lightning network. This study shows that for each day, we have to search for two flashes within 20 km around the point.

The homogeneity study points out that the main break is due to the beginning of Time of Arrival technology in 1996.

To define future climatic indicators to follow the lightning activity, we could work with storms days keeping in mind that the level of detection has slowly risen since 1996.

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