Verification of Summer Thunderstorm Forecasts over the Pyrenees

Introduction

Météo-France have conducted a study of summer thunderstorm forecasts in the Pyrenees in order to evaluate the performance, the possibilities and the limitations of such forecasts mountainous area. A common criticism expressed by users is a perceived overestimation of the frequency of stormy days. The pertinence of this criticism is touched upon here.

Geographical overview

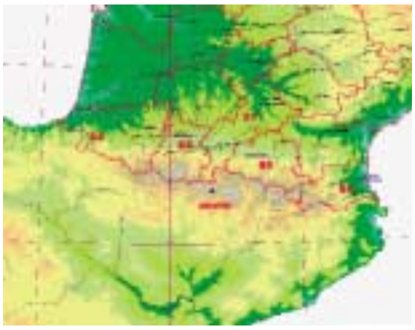


Figure 1: Pyrenean relief map with red lines showing the French départments (five of which contain a portion of the mountain chain).

The Pyrenees are a chain of mountains that extend from the Atlantic to the Mediterranean Sea. The highest relief is situated in the central part with several peaks over 3000 m, the highest one is « Pico di Aneto » in the Maladeta Massif. France is subdivided into 'départments' and each one is administered by a Prefet. Five départments contain a portion of the Pyrenees in their territory and these are from west to east: Pyrénées Atlantiques (64) with a meteorological station at Pau, Hautes-Pyrénées (65) with a meteorological station at Tarbes, Haute-Garonne (31) with a meteorological station at Toulouse, Ariège (09) with a meteorological station at Saint-Girons and Pyrénées-Orientales (66) with a meteorological station at Perpignan. The nearest station to the mountains is Saint-Girons (391 m).

Verification methods

This study verifies the occurrence of thunderstorms over high ground on the French side of the Pyrenees only between 1st June and 15th September. Comparisons have been made between the actual observations and previous forecasts for day D+0 to day D+4. Note that forecasters in this study are forced to provide a wholly deterministic forecast although some uncertainty or probability may be expressed in regular bulletins.

Forecasts issued by the National Centre in Toulouse cover the Pyrenees as a whole, so we consider observations covering the whole mountain chain (during 2002 and 2003) for verification purposes. Verification for each of the five local centres uses data covering only their respective departments. The check is based on satellite imagery and lightning network data.

Figure 2: NOAA 16 VIS image 2002/08/16 1332 UTC. The thunderstorm cells over the mountains appear clearly. The dots mark the location of lightning strikes during the previous 30 minutes.

Climatology and results

Over the mountains, there is no daily occurrence climatology available but the monthly mean density of lightning gives an idea of the thunderstorm activity over the Pyrenees (see Fig 3). Of course the maximum occurs during July and August, the hottest months. Looking at the geographical details, one can notice that the maximum of lightning is just south of the border on the southern slope. Note also the maximum over Andorra and the western part of Pyrénées-Orientales, which may be explained by local wind climatology.

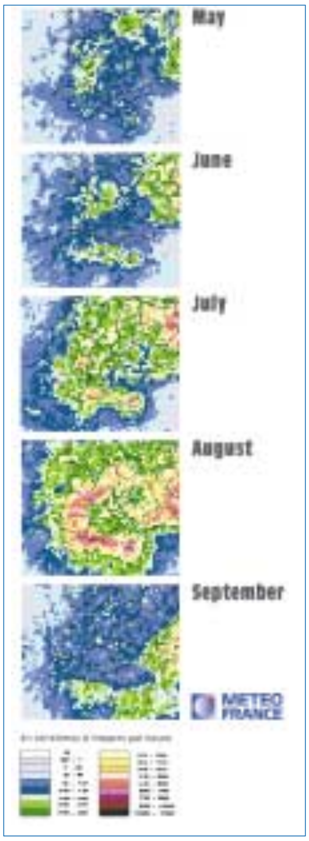


Figure 3: Monthly mean density of lightning reaching the ground from 1998-2001

The results of this study, based on two summers' data, could not be considered as climatology but some facts must be mentioned.

On the scale of the whole mountain chain, the daily observed frequencies reached 50% in 2002 and 64% in 2003 (see figure 4). "Isolated" thunderstorm days – those lying between two days without thunderstorms - are very few; they represent only 10% of the thunderstorm days. On the other hand, series of consecutive thunderstorm days can be very long; the longest reaches 20 days from 5th to 24th August 2003. In comparison, the longest series of consecutive days without thunderstorms was only 8 days, from 30th June to 7th July 2002.

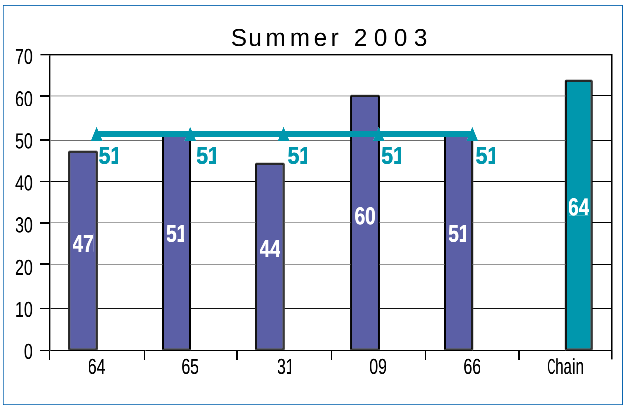


Figure 4: Observed frequencies of thunderstorm days in 2003 (%) for each department.

Within individual departments,the observed frequencies are logically lower than for the chain as a whole, with a mean of 51% of thunderstorm days.

It is interesting to compare these frequencies to those observed at a particular point like Saint-Girons in Ariege (09) at an altitude of 391m at the transition between plain and mountain.

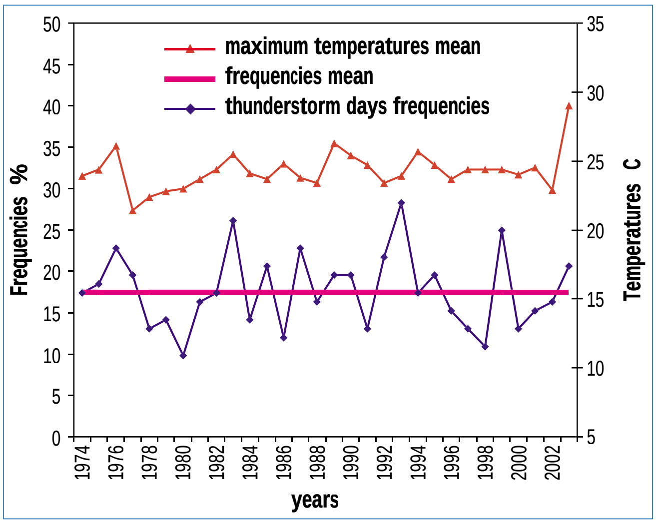


Figure 5: Frequency of thunderstorm days and mean maximum temperatures at Saint-Girons (09) from 1974 to 2003 during the summer months.

One can notice the fact that the daily thunderstorm frequencies are very different from year to year ranging from 10% in 1980 to 28% in 1993 with a mean of 17% (a bit less than 1 day in 5). Note also that there is no clear correlation with the mean maximum temperature. For instance, the very hot summer in 2003 wasn't particularly stormy at Saint-Girons, in contrast to the whole chain of the Pyrenees.

Regarding the area extent of thunderstorms during summer 2003, the cells were often spread over a large area of the chain and affected at least three departments in five. In only 5% of cases were thunderstorms limited to only one départment.

Are thunderstorm days predicted too frequently?

The simplest way to answer this question is to compare the forecast and observed frequencies for each date over the whole chain (see figure 6 below).

On the scale of the whole chain, this figure shows a similar behaviour in 2002 and 2003: the National Centre underestimates the thunderstorm frequencies especially for D+3 and D+4. The explanation for this decreasing trend with forecast lead time can be found in the "forecaster's strategy". In the short range, a missed thunderstorm situation is not acceptable considering the potential danger, so in case of doubt, a thunderstorm event is more likely to be forecast. In the medium range, the forecasters tends to keep in mind the increased uncertainty in numerical models and customer criticism, and therefore prefer no warning because they know that they have enough time over subsequent days to modify the forecast if necessary.

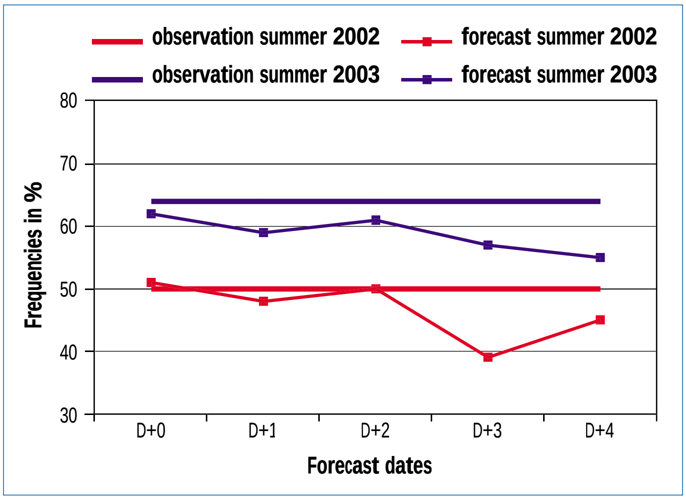


Figure 6: Daily thunderstorm frequencies observed and forecast by the National Centre for the whole chain during the summers of 2002 and 2003 from day D+0 to day D+4

The next figure shows the same comparison between forecast and observed thunderstorm frequencies on a départmental scale. The results are similar for each local meteorological station so only the means are presented.

Figure 7 implies an overestimation at the very short-range (D+0 and D+1) but forecast accuracy is then at a reasonable level around D+2 followed by an underestimation for longer-range forecasts reaching 15% at D+4. Note the quasi-linear decrease of forecast frequencies with time. The above proposed explanation at the National Centre for this forecast decrease is even more noticeable on a local scale.

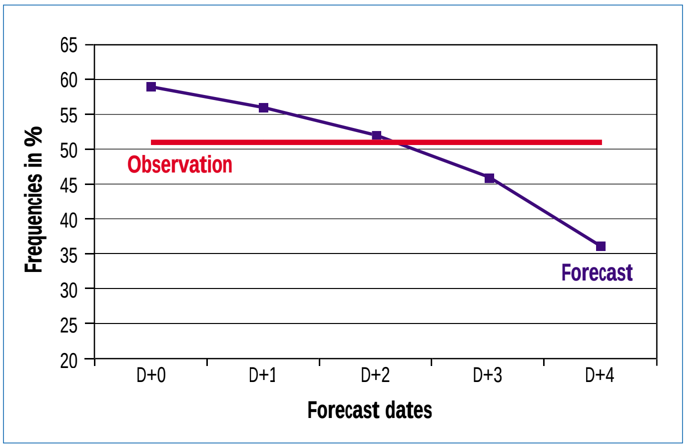


Figure 7: Comparison of observed and forecast thunderstorm days frequencies on a départmental scale (mean of five local meteorological stations)

Forecast quality verification

Definitions of scores

For each forecast series, the following contingency table is established.

	Observed thunderstorm	No thunderstorm
Thunderstorm forecast	a	b
No thunderstorm foreca	c	d

The good forecast rate (GF) is given by $GF = \dfrac{a+d}{a+b+c+d}$

The false alarm rate (FA) represents the ratio of bad forecasts when thunderstorms are forecast $FA = \dfrac{b}{a+b}$

The missed events rate (ME) represents the ratio of bad forecasts when no thunderstorms are forecast $ME = \dfrac{c}{c+d}$

It is clear that the lower FA and ME are, the better the forecasts are. In the next figures, FA and ME are expressed in terms of a percentage.

Scores

The level of 2/3 (66,66%) is considered as a threshold for the forecast quality.

On the scale of the whole chain, the rates of good forecasts are similar for both summers from D+0 to D+3. There is a steady drop with time but this is correlated with the drop in the quality of numerical weather products. For D+4, the scores are worse in 2003 compared to 2002. The explanation might be due to the unusually stormy character of the weather in the summer of 2003.

From D+0 to D+3, the forecast is reliable but at the expense of too many missed events.

On the scale of a department, the scores are very homogeneous and this is why only the means are shown. Note the high rates of good forecasts for D+0 and D+1. They show the value of local scale forecasts for these lead-times and even until D+2. The foreseeable limit of the phenomena is reached at D+3 when the good forecast rate becomes less than 2/3. The false alarm rate remains acceptable (less than 30% at D+1).

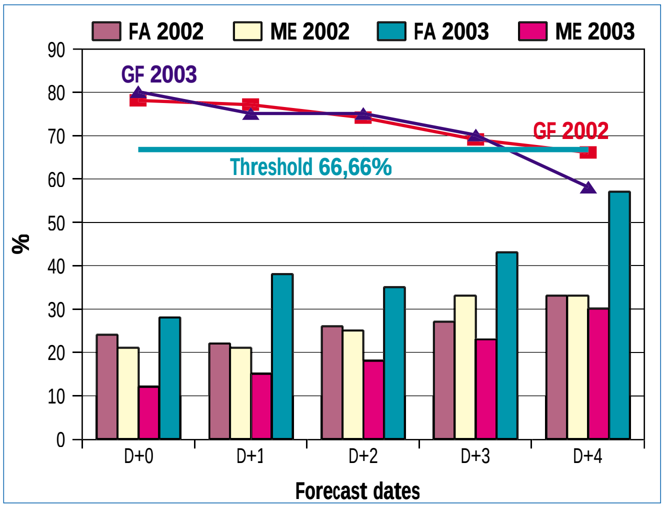


Figure 8: scores of the national centre in 2002 and 2003

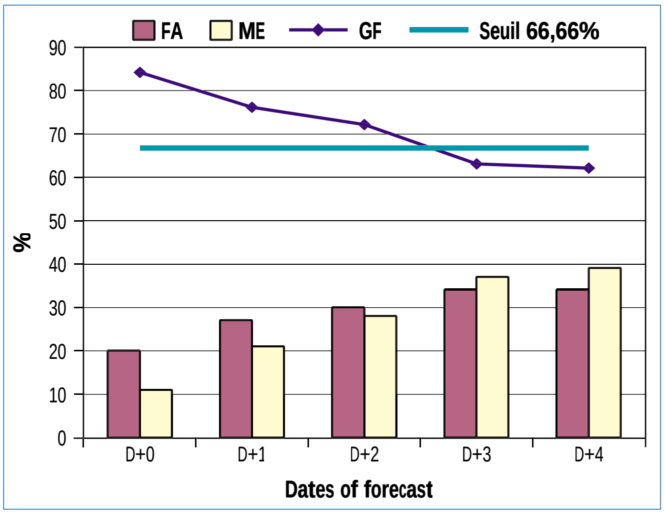
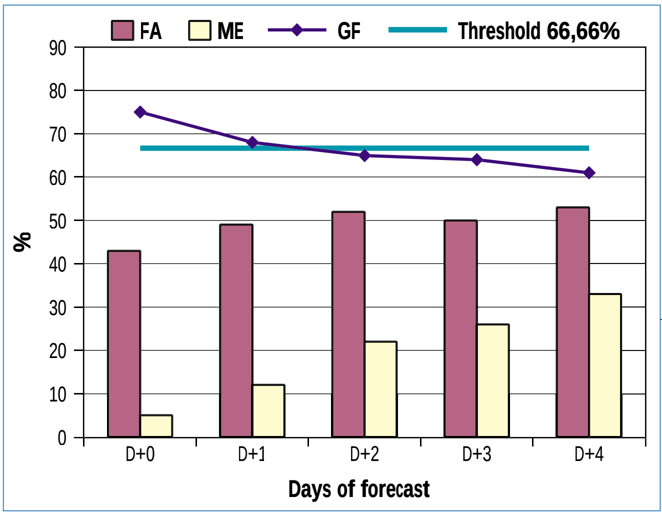


Figure 9: Mean scores of the local forecast centres in 2003 on a departmental scale.

Use of site specific thunderstorm forecasts

For a hill-walker on a one-day trip, interest is often limited to a geographical scale of just a few kilometres. The following section will try to understand a customer's point of view if he/she uses the départmental forecast as a site specific forecast. However, keep in mind that the forecasts sometimes try to

distinguish the location of thunderstorms more precisely, for example between border crests or Piedmont. Verification of forecasts at this level of accuracy is beyond the scope of the study.
Some mountain refuge guardians in the High Pyrenees have made daily observations during 2003. This allows calculation of daily thunderstorm frequencies at the precise point of each refuge. Frequencies of between 30 to 35% were derived – one day in three has thunderstorms. Scores similar to those shown previously in this article have been calculated. Again, they are very homogeneous with the same characteristics from one refuge to another. Figure 10 show an example. The false alarm rates appear high whatever the lead-time and this is the reason for customers' claim. Refuge guardians also argue that these false alarms can badly affect tourism.



However the rate of good forecasts at D+0 and D+1 must be emphasized and one must also keep in mind the very low level of missed events. This last result is probably the most interesting because it indicates that a site specific forecast of no thunderstorms is particularly reliable for short range forecasts and this is important for public safety.

Figure 10: scores calculated in 2003 when comparing the department forecast of "Hautes-Pyrénées" to the observations at the "Espugettes" refuge situated at an altitude of 2007 metres, near the famous "Garvanie Cirque"

Conclusion and further work

This study only examines the accuracy of summer thunderstorm forecasts in the Pyrenees in the simplest possible way, but has yielded some interesting results. Firstly, it highlights the great variability of the frequency of thunderstorm days with geographical scale. Additionally, a very important year-to-year variability must be considered.

These results also allow us to counter, if not to entirely refute, the common criticism of too many thunderstorms forecast. On the scale of the whole Pyrenean chain, there is no tendency to overestimate the frequency of thunderstorm days. However, on the lower scale of a French department, there is a slight overestimation tendency in the short-range forecasts. This is probably due to the fact that forecasters are very careful not to miss these dangerous phenomena.

The calculated scores establish the relevance of a local forecast with good forecast rates until D+2. On the scale of the whole chain, the reliability is acceptable until D+3.

Further study could examine these ideas more deeply and thoroughly. Many other aspects beyond the scope of the current study could be explored. Firstly, the location of thunderstorms could be investigated at smaller scales, for example at the scale of valleys or mountain ridges. Then, once a thunderstorm has started, one could speculate as to whether the forecast succeeds in determining the growth of convection during the day. Many questions about the intensity, length and the spread of thunderstorms could also be addressed. Finally, it could be interesting to investigate the reasons for bad forecasts; are they similar at all lead times and are they linked to weather situations or numerical weather prediction model resolution? It could perhaps contribute to more objective formulation of uncertainty in order to improve the quality of forecasts.

Bruno **Gillet**,
Christian **Viel**, Bernard **Roulet**,
Météo-France