Automatic Detection of Severe Thunderstorms to Improve Weather Warnings

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Introduction

Developing the observation and *nowcasting* of severe thunderstorms is a main issue at Météo-France. Indeed, these phenomena have a small extension and to forecast their evolution remains difficult.

Consequently, detecting and following severe thunderstorms gives the possibility to be more efficient in our safety missions.

The main purpose of this topic (which started in 2019) is to develop tools using different data sources in weather observations to discriminate severe and non-severe thunderstorms.

During summer of 2020, the first algorithm, named MIMOSA, was developed in collaboration with different Météo-France services and an internship. This algorithm under development gives the opportunity to detect all thunderstorms in France and identify each thunderstorm severity.

First, we will present the MIMOSA algorithm. Then, we will show two thunderstorm events in 2020 detected by MIMOSA. Finally, improvements about this project will be discussed.

MIMOSA algorithm:

The MIMOSA algorithm was developed by Dorian Jaubert (Météo-France) during the first semester of 2020. This tool promotes the detection of thunderstorms observed every 5 minutes in the French area and proximity. The algorithm takes into account different observation sources such as RADAR data, surface measurements and lightning strikes to determine the thunderstorm severity.

Severity thresholds were determined from different convective events in 2018 and 2019.

Data sources:

** The contour of convective cells : the **OPIC** Object **

Contours of convective cells named “special OPIC” are built using thresholds based on RADAR reflectivity (**figures 1 and 2**). This choice was validated studying several convective events in 2018 and 2019. In addition, according to weather forecasters, the 48 dBZ threshold most of the time is a good spatial representation of convective cores of thunderstorm especially in the summer. Furthermore, OPIC objects contain information about the thunderstorms, such as: size, lightning activity, speed and forecast trajectory. This last characteristic is not integrated in MIMOSA yet.

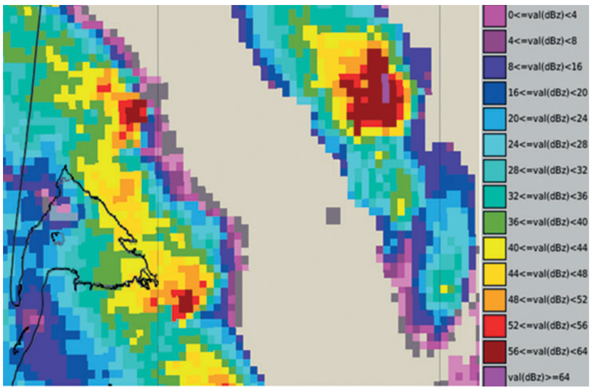


Figure 1: RADAR reflectivity observation (dBZ).

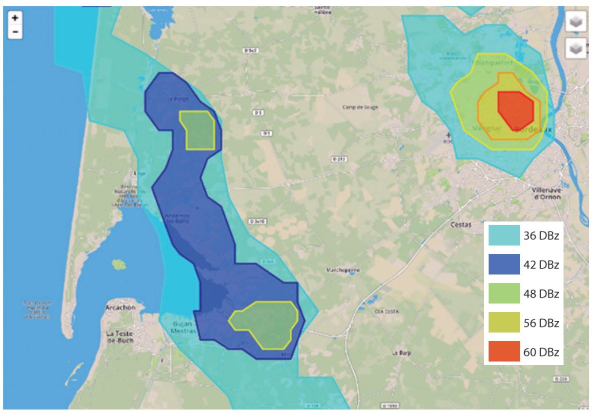


Figure 2: OPIC Objects built using different reflectivity thresholds (dBZ)

** Data observation used to set up the thunderstorm severity **

In general, only observations are used in MIMOSA, except for the hail that uses the specific parameter **POH** (probability of hail) in which the freezing level is estimated by the AROME model (a French small-scale model). The algorithm takes into account surface measurements, especially for 6-minute rainfalls and 10-minute wind gusts.

The MIMOSA algorithm steps:

When a cell is detected, the algorithm evaluates its severity in a four-level scale (**0: moderate, 1: strong, 2: severe, 3: extreme**). The thunderstorm severity takes into account the maximum of severity through three parameters : **RAIN**, **WIND**, **HAIL** using a "fuzzy logic" for each parameter (**figure 3**): Instead of assigning "True" (=1) or "False" (=0) to a variable, the fuzzy logic assigns a real number between 0 and 1. This is a way to handle the concept of "partial truth". Indeed, people usually make decisions on imprecise information.

For instance, the algorithm combines the observed rainfall rate, the cell speed, and the cell surface above 56 dBZ to estimate the rainfall severity under the fuzzy logic method.

Finally, if a lightning jump (increase of flashes in a short period of time) is detected, cell severity goes up (or stays) to level 3 out of 4 for the next 30 minutes. It stays at level 4 if the last severity was level 4.

Cases study:

** *Mesoscale* Convective System (MCS), June 26th, 2020:

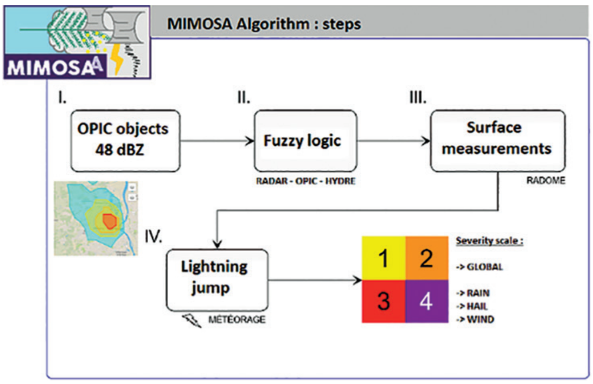


*Figure 3: **MIMOSA** steps. **RADOME** is the type of surface-based stations. **Météorage** is a Météo-France subsidiary dedicated to the lightning observation. **HYDRE** is a specific product used at Météo-France capable of detecting hail (in particular).*

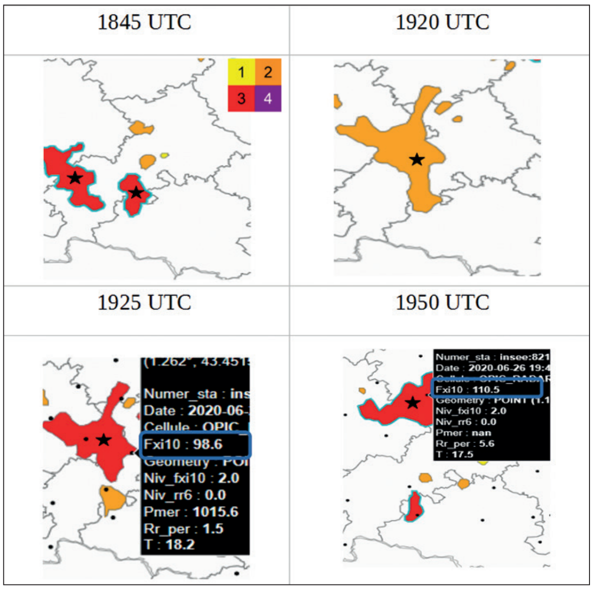


Figure 4: Evolution of cells detected by MIMOSA and their severities. Black dots represent the surface-based stations. Black stars represent the MCS convective cells.

A MCS crossed over the west of the Toulouse region. This thunderstorm caused a lot of damage due to severe wind gusts (>=25 m/s) and significant rainfalls during a short period.

According to these pictures (**Figure 4**), MIMOSA is able to follow cells and assess their severities.

At the beginning (1845 UTC), two cells were detected with a severity of 3/4 due to a lightning jump. The global severity increased for the following 30 minutes (cells surrounded in blue lines). The lightning intensity allows to identify mature and strong or severe thunderstorms according to our study.

At 1920UTC, the lightning jump ended and the severity cell decreased to level 2/4. In reality, the thunderstorm remained severe and caused wind gusts (> 25 m/s) according to radial velocity detected by Toulouse RADAR (not shown here).

At 1925UTC, strong wind gusts were detected on different surface-based stations and the severity increased again to level 3/4 (Fxi10 framed in blue: maximum wind gust for the last 10 minutes at the station in kilometres/hour).

The lack of wind observations remains a weak point of the algorithm and will probably be improved later using other data observations.

Strong/weak points (+/-)

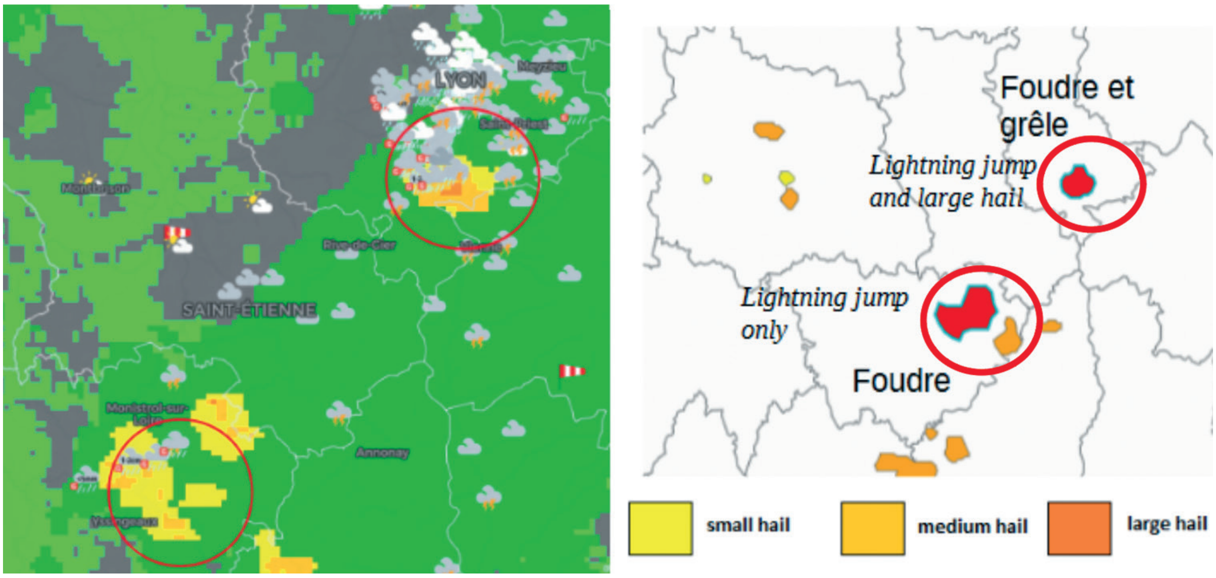
+ Early detection due to the increase in flashes (lightning jump)

+ Risk of severe wind gusts and heavy rainfalls correctly identified by the algorithm

- The severity due to wind gusts is currently underestimated due to the lack of spatial wind gust data.

** Large hail event on July 21, 2020:

Figure 5: On the left, surface observations from volunteers and type of precipitation from HYDRE (in yellow and orange). On the right, MIMOSA cells at the same time. Both cells severity 3/4 are surrounded in red.



In this event (**figure 5**), two cells were detected in severity 3/4. The one near the upper right corner due to a detected lightning jump and large hail and the other one due to a lightning jump only. These observations are consistent with HYDRE and surface observations.

Improvements/future works:

New sources of observations are being studied, especially to estimate more precisely the risk of large hail and wind gusts. These data are issued from Radars such as **VIL** (Vertically Integrated Liquid), TOP 18 dBZ and TOP 45 dBZ parameters. Today, they have already been used in some countries to determine the severity of thunderstorms.

Concerning wind gusts and other wind phenomena, new tools will be studied, such as: the mesocyclones detection algorithm (summer 2021), and the development of an algorithm to estimate wind gusts using the radial velocities from Radar (2022/2023)

At the same time, thresholds used to confirm the occurrence of lightning jumps will be adapted.

Finally, results of the current version of MIMOSA will be evaluated by forecasters during this summer 2021.