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# Hydrometeorological risks in Mediterranean mountainous areas

## *RHYTMME Project<sup>1</sup>: Risk Management based on a Radar Network*

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Samuel Westrelin

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### 1. Introduction

In most cases, natural hazards encountered in mountainous regions are largely dependent on precipitations : flash floods, debris flows, landslides, rockfalls, snow avalanches and forest fires. To better understand the occurrence of these hazards and to prevent populations from their dangers, the knowledge of rainfall quantities at high temporal and spatial resolution is crucial. While the rain-gauge network is not dense enough to capture all the variability of precipitations, especially in rugged regions, radars can be very efficient. However, to install them in mountains as well as to retrieve real-time useful information remains a big challenge. To improve this radar information to elaborate warning services useful for the management of natural risks is another one. Southeast of France is a mountainous region both very exposed to natural hazards and not well covered by radar measurements. In this context, the “RHYTMME” project (Westrelin & al, 2010 ; Mériaux & al, 2011) began in 2008 with the following main aims, both from research and operational objective:

- to provide an accurate radar rainfall information in mountainous areas ;
- to develop a real-time hazards warning system based on this information.

The present paper gives an overview of the main achievements of the project in mid 2012.

### 2. Radar network improvement

In the extreme southeast of France, a new X-band polarimetric radar (75 kW peak power, 2 microsecond pulses, 500 Hz PRF, 1.3° beamwidth) has been installed in autumn 2010 at Maurel mountain (alt. 1770 m) about 60 km away from a pre-existing polarimetric X-band radar owned by CNRS and operated by Novimet (Mont Vial, 1550 m). The amount of overlapping between the two radars is large in order to mitigate attenuation and extinction of the radar signals. There is also some overlapping with existing S-band polarimetric radar (fig. 1a). The Maurel radar is installed over a flat roof of roughly 30 m<sup>2</sup> at 7 meter height ; its antenna is protected from strong winds and adverse meteorological conditions by a radome. Below the radome, the radar electronics is kept in an adequate range of humidity and temperature conditions. The building shelters the radar computer and a generator which supplies all the equipments with electric power in case of electric shutdown ; it has a four-day charge. In the Meteo-France radar network (Champeaux & al, 2012), this is the first radar installed at such an altitude, on a site covered with snow during several months in a year. It is also the first X-band polarimetric Doppler radar within this network.

In November 2012, an identical radar will be installed at Mont Colombis (alt. 1770 m) at the top of a 19m height tower ; it will cover both previous hidden areas (fig. 1a) and new areas (fig. 1b), frequently concerned with natural hazards triggered by rainfalls : catchment basins of Bléone, Buech, Basse Durance, Ubaye, Guil.

Southeast of France is extremely rugged and high (towering above 3500 m) and prone to intense flooding and to rough mountainous hazards. Those two features are one of the main challenges of RHYTMME that aims to benefit in real-time from the X-band dual polarized radar data for better quantitative precipitation estimation (QPE) products (for example Testud & al, 2000 ; Tabary & al, 2008 ; Tabary & al, 2011) and hydrometeors discrimination (snow, hail, rain, ...). The following section gives an overview of the science included in the project.

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<sup>1</sup> RHYTMME is a R&D project supported by the Provence-Alpes-Côte d’Azur Region, the European Union, the French Ministry in charge of Ecology, Météo-France and Irstea.

### 3. Research and development on radar algorithms

Since June 2011, real-time rainfall estimates are produced with this new radar network ; the QPE algorithm is the same as the Météo-France operational one (Tabary, 2007 ; Tabary & al, 2007) based on Marshall-Palmer relationship using beam altitude correction, mask correction, fixed echoes and ground clutter filtering, multi-tilt combination, attenuation correction thanks to differential phase (with coefficients adapted to X-band) and rain gauge calibration.

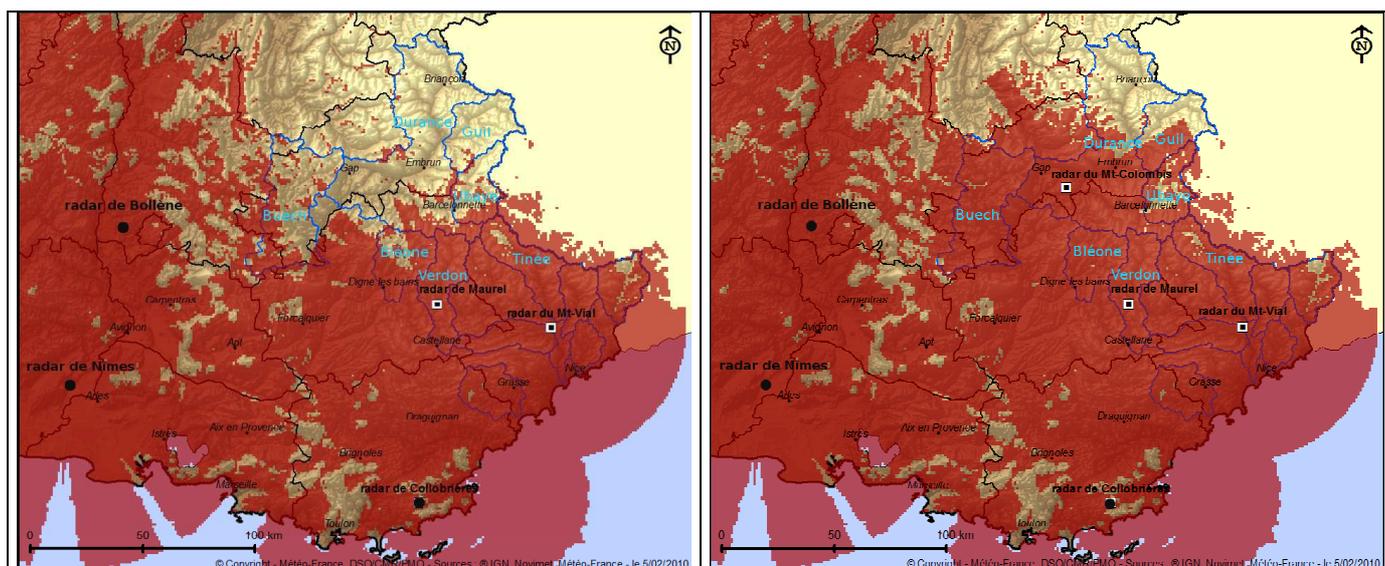
Between June 2011 and June 2012, a new QPE algorithm, mixing reflectivity and specific differential phase (“Z-KDP”) has been developed and is ready to be tested in real-time ; Z-K<sub>DP</sub> uses, for moderate and high rain rates, a relationship between rain rate and specific differential phase, which is immune to partial beam blocking. Z-K<sub>DP</sub> has given promising research results in heavy rain cases (Kabeche & al, 2012 ; Figueras i Ventura & al, 2012). This algorithm also uses a new hydrometeor classification based on polarimetry (Al-sakka & al, 2012).

Other works are ongoing such as the quantification of the effect of wet radome on rainfall estimates (Frasier & al, 2012) and the development of smart ways to mix S-band and X-band data in the overlapping areas.

In this mountainous region where the snow falls several months per year, it is critical to properly process radar measurements made in the snow region. A polarimetric algorithm for the quantitative retrieval of snow characteristics has been tested and evaluated against ground stations (Moreau & al, 2012) ; the comparison is quite encouraging.

This dense radar network is also an opportunity to retrieve accurate 3D wind field analyses by combining Doppler measurements in overlapping areas (Beck & Bousquet, 2012). These radar data, both Doppler and reflectivity measurements, have shown to benefit to weather models when correctly assimilated, especially for nowcasting ranges (Wattrelot, 2012).

A last topic dealt within Rhythmme research program is the retrieval of refractivity measurements, which required to adapt existing algorithm to X-band (Besson & Parent-du-Chatelet, 2012). Refractivity measurements at X-band are challenging but could also benefit to model assimilation by adding valuable information on the low level humidity field (Besson & al, 2012 ; Caumont & al, 2012).



**Fig. 1 :** Simulated coverage of the RHYTMME radar network over southeast of France. In red, quality indexes of the radar measurements have been represented (only indexes above 84 on a scale going from 0 to 100) ; the main catchment basins to be covered have been outlined in blue. Black circles mark S-band radars of Météo-France operational network, white and black squares mark X-band radars. (a) The left panel represents the current coverage with Météo-France operational network plus two X-band polarimetric radars (Mont Vial and Maurel) ; (b) the right panel is the same as the left one plus the third radar (Mont Colombis).

Different softwares use the outputs of these new radar algorithms to produce other informations described below and potentially useful for risk management.

### 4. The end-user platform and its pre-operational warning services

A first set of information is retrieved from softwares that run after the radar algorithms. They are of two types :

- maps of rainfall cumulated over periods from 5 minutes to 3 days at one square kilometer resolution ;
- rain and flash flood hazard warning maps at the same spatial resolution, estimated by the AIGA method (Fouchier & al, 2007), reevaluated every 15 minutes with 4 severity levels based on return period.

These products are dedicated to warn risk managers from potential danger. For this, they can be displayed in real-time by connecting to a Web address securised with login and password ; this constitutes the so-called Rhythmme platform. By

accessing to it, the user can zoom in and out, play and control animations, change the color scale of meteorological and hydrological data, control the display of geographical layers. This platform makes also available rain gauge data measurements. A neighbouring country, Switzerland, also much concerned with natural hazards experience the same kind of platform (Heil & al, 2010 ; Petzold & al, 2012).

Rhythmme platform has been tested by an end-user group for November 2011. The group is representative of mountain risk managers and is composed of about 40 members from Government agencies, Forest agencies, departmental councils, communes, river associations, nature reserves and industry (national electric power enterprise, train transportation national society, ...). The experimenters are supposed to:

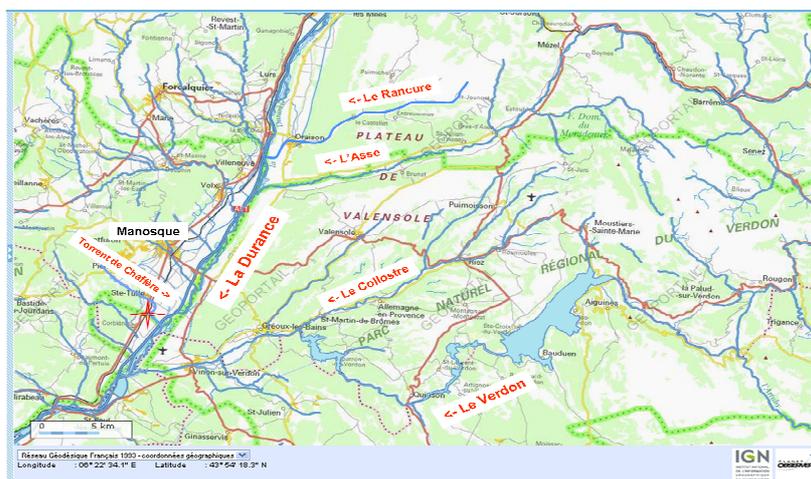
- connect as often as possible to the platform when rainy events take care on their region of interest ;
- evaluate in real-time the relevance and ergonomics of the platform ;
- a posteriori evaluate the information in regards to the observed damages.

Experimenters and hazard researchers exchange information by forms that document each event.

In what follows, two recent stormy meteorological situations over southern Alps captured by the platform are described.

## 5. Stormy situation in the beginning of November 2011.

From the 2<sup>nd</sup> to the 9<sup>th</sup> of November 2011, an exceptionally long and extended meteorological event has occurred in the southeast of France. Rhythmme platform displayed hydrological warnings indicating return periods above 50 years for river flows in Manosque region. The figure 2 gives an overview of the geography and the hydrography of this region ; the figure 3 shows a few maps the platform displayed. In parallel we could find pieces of information on what happened on the spot by the meaning of internet. Around 8 o'clock in the evening on the 5 November, the Web site of a local newspaper reported a collision between a train and a car carried along by the floods which took place in the south of Manosque.



**Fig. 2 :** Hydrological network in Manosque region (department of Alpes-de-Haute-Provence), labelled in red (source : géoportail IGN).

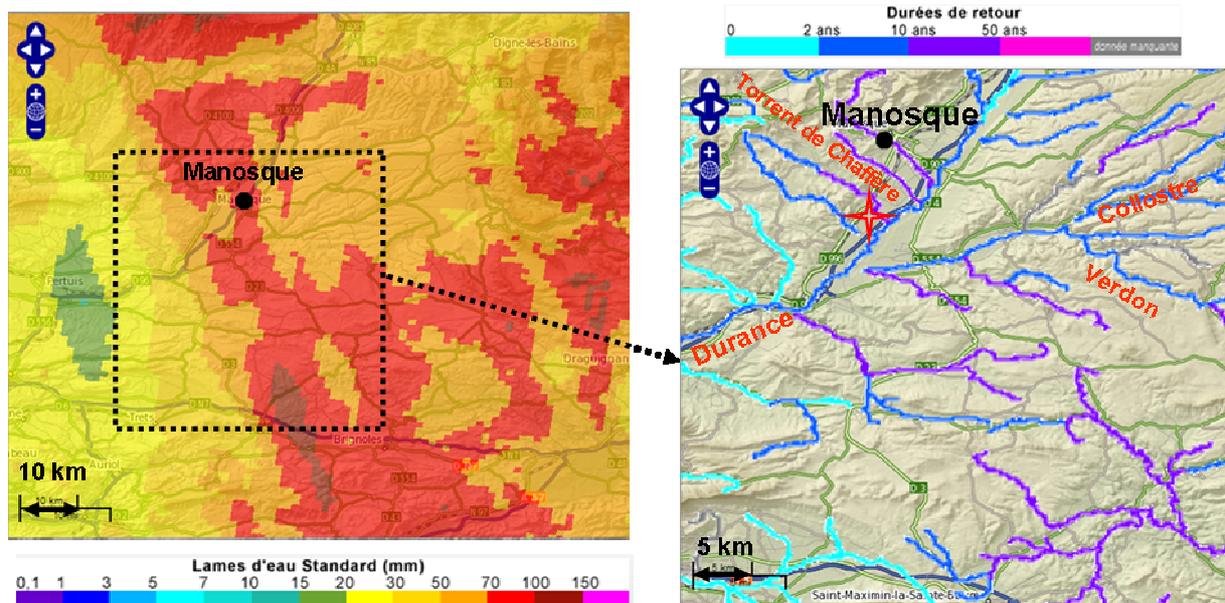
A few days later, Irstea hydrologists visited the place to estimate the flow of three rivers (fig. 2) : the Collostre (catchment basin of 209 km<sup>2</sup>), the Asse (catchment basin of 681 km<sup>2</sup>) and the Rancure (catchment basin of 116 km<sup>2</sup>). These measurements have been compared to flow discharges modelled in the Rhythmme platform.

These terrain observations showed that only one over the three rivers had reached a significant flood level : the Asse. Its peak flow has been estimated between 400 and 500 m<sup>3</sup>/s. The AIGA method applied to flow modelling in the Rhythmme platform indicated a 50 years return period (fig. 3). Witnesses assess that this flood was the third most important one since last events of October 1999 and February 1969. On the contrary, for both other rivers, the Collostre and the Rancure, estimated flows were far below 2 years return period whereas modelling indicated a 50 years return period as well.

For very close catchment basins, the performance of the platform flood warning maps could then be extremely different. Whereas the Asse situation has been correctly modelled by the platform, for both other basins it has been strongly overestimated.

Similarly, in Manosque region over three ravines on the Durance right riverside, the platform indicated flows of 10 to 50 years return period (fig. 3) whereas significant flooding only happened over the Chaffère torrent where the train collision took place.

As a partial conclusion, we can say that tools provided on the platform give some clues on the sensitive areas where events could occur but they need to be analyzed by people who have a very good knowledge of the place and who can follow the evolution of the situation in real-time to take the appropriate decisions. Moreover, we have to improve the efficiency of the real-time flow model for the small catchments.



**Fig. 3 :** Maps displayed in real-time on Rhythme platform. Left panel: 1-day rainfall on the 05/11/2011 at 14h localtime in Manosque Region (Southern Alps). Right panel: return period of river flows at 15h localtime in the same region. Blue sky color indicates a return period below 2 years, dark blue means below 10 years and violet below 50 years. The red cross indicates the place of the train collision.

## 6. Spring thunderstorms in the end of May 2012

This mid-spring has been characterised by a strong stormy activity developing in the evening in the southern Pre-Alps.

Two noteworthy events can be quoted:

- the 23 May around 18h local time in Digne area (department of Alpes-de-Haute-Provence, 40 km north east from Manosque (fig. 2)): the hail and the flood of a small torrent in Mallemoisson made a lot of damages ;
- the 24 May in Serres (department of Hautes-Alpes, 70 km north to Manosque): a railway embankment slid between Aix-en-Provence and Gap and led to a 1-month traffic cut around 18h30 local time.

During both events, hail was observed ; on 23 May, up to 20 cm hail thickness has been reported around Digne in the local newspaper ; it seems it has had a strong erosive action on sediments enhancing mudflows and landslides (personal communication). This hail could explain the rainfall overestimation of radars (fig 4), at least on some spots: investigations on radar algorithms are being led. No river (catchment basins greater than 20 km<sup>2</sup>) has risen a critical level in the Rhythme platform though, which is coherent with terrain observations and which can be explained by very localised and short precipitations (less than 1 hour).

## 7. Conclusion-Prospects

Three years after its beginning, Rhythme project has come to the following achievements:

- installation of an X-band Doppler polarimetric radar at Maurel mountain (alt. 1770m) ;
- development of radar algorithms to deal with X-band data and correct for attenuation ;
- deployment of a first version of the platform delivering a set of real-time warning services useful for risk management ;
- test of this platform by an end-user group representative of risk managers.

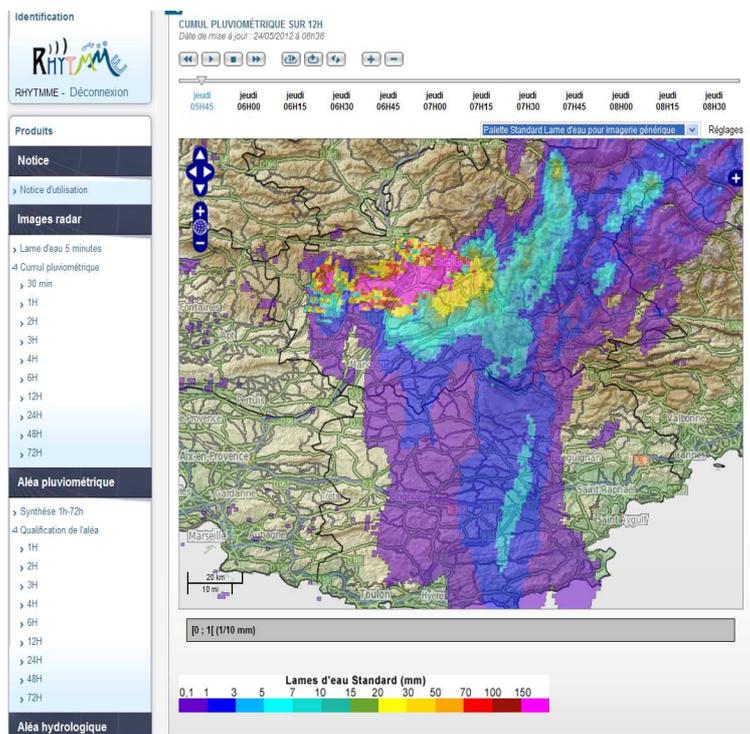
Rhythme has gone on for two years by aiming what is listed below.

The hydrological coverage of southern Alps keeps on extending to the north with the installation of X-band polarimetric radars and the development of new algorithms, polarimetric ones, to better estimate crucial data as rainfall amounts. Scientific work on snowfall estimates, radar data assimilation in weather models, Doppler wind and refractivity retrieval is also going on.

Meanwhile, Rhythme platform will improve on the following aspects:

- sending e-mails, and possibly SMS, when flooding indexes exceed certain thresholds ;
- 1-hour leadtime precipitation ;
- end-user feedback ;
- more available options: higher time depth, more informative base maps and hydrological network, etc. ;
- specific maps and services for debris flow (Bertrand & al, 2012) and landslide hazards.

At project completion, an economic model should be proposed to sustain the main achievements in regards to their usefulness.



**Fig. 4 :** Radar estimated rainfalls (in mm) over 12h on 23 May 2012 at 5h45 local time in the area of Digne. Pink pixels indicate abnormal rain quantities (above 150 mm) that do not fit to observations ; some of these pixels – but not necessary all - correspond to the place where hail has been observed.

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