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FRAMEA: an experimental campaign for severe storm survey and flood warning, associating an X-band weather radar and a discharge hydrological model.

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1 Introduction

Severe flooding events recorded in autumn in the French Mediterranean are generally associated with moist southerly flow from the sea hitting the mountainous regions of the Côte d'Azur or Languedoc. Forecasting such events requires, especially for flood forecasting services (i.e. SPC, Service de Prévision de Crue in France), some operational product based on hydrological "rainfall-runoff" models, able to calculate and forecast the discharge at the outlet of the catchment, from the catchment characteristics and from rainfall measurements.

Since rainfall spatial variability may be strong in those precipitation conditions, quantitative knowledge of rainfall must be provided by radar measurements. However, monitoring such events implies optimum technical requirements not always fulfilled by the regular weather radars of the Météo France ARAMIS network (operating at S- and C-bands). Besides classical errors affecting the rainfall estimate (along-path attenuation, variability of raindrop size distribution, uncertainty in radar calibration…), the regular network suffers for visibility. Beam blocking in mountainous context necessarily limits the actual range of radars, thus it is not cost effective to install "big" C-band or S-band radars requiring a costly infrastructure. In this context, using compact and low-cost X-band radars could be used to complete the French weather radar network in focusing on sensible areas where the ARAMIS visibility could be insufficient, provided X-band attenuation correction scheme be applied. This is the ambition of the X-band polarimetric radar HYDRIX which, associated with algorithm ZPHI (developed by CETP and patented by CNRS), may provide accurate rainfall rate measurements, as far as its local extinction is not reached.

Recently, a two-years experimental campaign called FRAMEA (Flood forecasting using Radars in Alpine and MEditerranean Areas) has been set up, with the deployment of a prototype of HYDRIX in February, 2006, on the catchment of Réal-Collobrier (80 km^2), near Marseille (France), in conditions of Mediterranean precipitation (i.e. heavy rain inducing flash flood). This campaign ambitions to assemble some advanced techniques in rainfall observation by radar, radar data processing, and discharge modeling to develop an operational forecast module of the discharge useful for flash flood warning. Thus, the purpose of the experiment is the validation of a product based on hydrological "rainfall-runoff" models from Cemagref (e.g. the GR3H model), already extensively validated, and already operating in discharge prediction (Mimouni et al., 2001), coupled with a HYDRIX radar.

Fig. 1. HYDRIX radar at the experimental site near Collobrières.

2 Instrumental setting overview

The basin of Réal-Collobrièr (~80 km^2) is located on the Mediterranean coast, in the department of Var (south east of France), and is neighbored by the Alpine mountainous channel on the East (Fig. 2). Besides the harsh climatic and topographic context, this site is unique in France, due to the very dense instrumentation network deployed on the catchment for research purpose.

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In particular, for rain validation, this site is equipped with 17 typing-bucket rain gauges (CEMAGREF). For a larger extend, rain gauge measurements from Météo France operational network (99 parsed within a 120 km radius around HYDRIX) are also available.

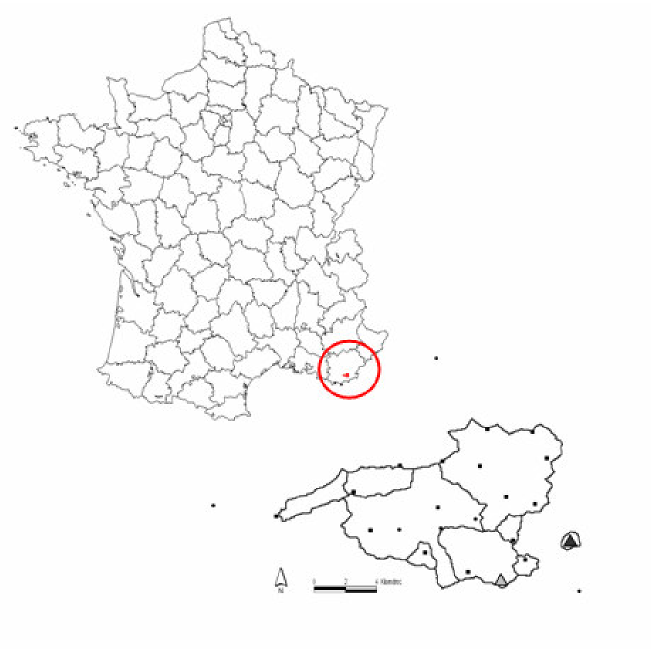

Fig.2. Location of the Real Collobrier basin in France, and the instrumental sites (black points for rain gauges, grey triangle for HYDRIX, and black triangle for the Météo France S-band radar.

Additionally, two collocated optical spectro-pluviometers (one from CETP, and one from Météo France) are used for radar calibration checking, through micro-physic parameter statistics (as in Le Bouar et al., 2001).

Finally the Météo-France S-Band radar is located about 10km far from Hydrix radar, allowing a spatial comparison between both radars.

3 HYDRIX radar

A specific advantage of HYDRIX, particularly appreciated in a mountainous context, is that the frequency of operation (X-band), combined with the antenna technology (offset feed) leads to a drastic reduction of ground clutter, and thus to an improved visibility of the radar. The moderate price of this radar (whose effective range is shorter than those of C- and S-band radars) and their simplified installation/maintenance (no radome) allows its valorization for coverage of small catchments (of a few hundredths of km^2) hidden to the ARAMIS network and nevertheless vulnerable to flash flooding events. Moreover, owing to its polarimetric capability associated with the rain profiling algorithm ZPHI (Testud et al., 2000), drawbacks that has limited the use of classical X-band radars are overcome, essentially correction for along-path attenuation, even in operational context. Table 1 summarizes some technical characteristics of this radar.

Table 1. Main specifications of HYDRIX.

Frequency	9.3 GHz
Peak Transmit Power	35 kW per channel
Antenna	1.5 m ∅ (offset feed)
Antenna gain	41 dB
Scan velocity	13 deg./s in azimuth
Beam Width	1.5 deg.
Pulse Length	0,5 to 2 µs
Pulse repetition frequency	1000 Hz and 500 Hz
Sensitivity	0 dBZ at 55 km or 100 km
Polarization mode	Simultaneous H and V

The scanning strategy consists of a series of four PPI sweeps at low elevations (0.5°, 1.0°, 1.7° and 2.5° respectively) with a scan rate of 13 deg/s, providing a revisit time of 2.5 min.

4 The GR3H discharge model

The rainfall-runoff GR3H model, developed by Cemagref, has been designed to obtain a flood forecasting in small watersheds (some hundreds of km^2), using measured hourly rainfall as input, and the hourly flow at the outlet as output.

This model (Fig. 3) is a conceptual model associating a one-parameter production function (A: maximum level of the “soil reservoir”) that converts the input rainfall P into a discharge rainfall Pr, and a two-parameter transfer function (B: maximum capacity of the transfer reservoir, and C: base time of unit hydrographs HU1 and HU2) that converts the discharge rainfall Pr into the flow at the outlet with a delay given by C. The discontinuous event mode requires an additional parameter S_0/A, initial level rate of reservoir A.

When used as a forecasting model, A, B and C values are fixed. Thus, to adapt the GR3H model for operational forecasting, an optimization process to select S_0/A is used.

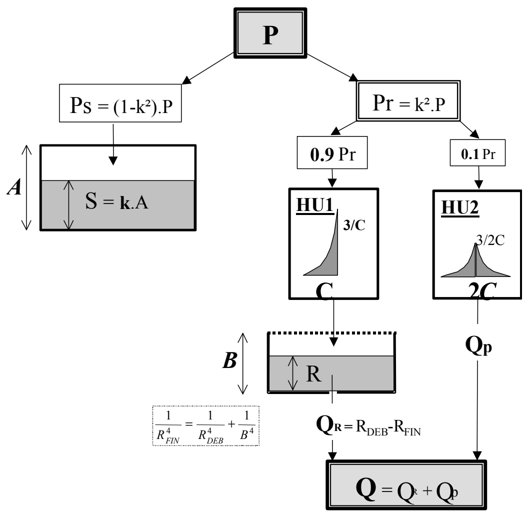

Fig. 3. Diagram of the GR3H rainfall-runoff model by Cemagref

Further developments have to be done to adapt such model to real-time constraint (for instance, the need of the whole discharge calculation to be performed and made available within each 3 minute, while using the current computing facility available in the SPC). For this reason, the operational “rainfall-discharge” model should be able to assimilate the spatial distribution of the rainfall delivered by the radar, and to determine in real time a flood hydrograph at the outlet of the catchment, with a sufficient accuracy in the context of a SPC.

5 Validation procedure

The procedure for validation of HYDRIX follows two separate approaches. First, the radar reflectivity measured by the S-band (un-attenuated) radar installed nearby at Collobrières will be compared with that delivered by radar HYDRIX at the output of algorithm ZPHI. Such a comparison will help to validate the attenuation correction scheme of ZPHI and also to appreciate the “visibility” of HYDRIX through the most intense precipitation. Second, the comparison of the rain rate fields delivered by HYDRIX with the measurements of the rain gauge will allow the HYDRIX rain rate product to be validated.

In terms of flood forecasting performance, the operational GR3H model will be validated (with an expected anticipation of 45 min in average). The capability of the radar to dynamically follow up the rain cells as a function of time may extend the anticipation time by about 1 or 2 hours. Validation will mainly be performed by comparing forecasted flows with those measured by limnigraphs.

6 User product

Since user-products are expected to be available in (quasi) real-time, data broadcast is also operationally tested. This includes the transmission of rainfall rate (projected on a Cartesian grid of 1kmx1km resolution), locally computed, and then sent to a remote server via satellite link. For demonstration purpose, these data are displayed on the web (www.novimet.com), with a refresh time of 2.5 min.

Once converted into watershed, this product can be directly available for users.

On the other hand, rainfall measurements from the radar are also ingested by the GR3H model, to provide a forecasted hydrograph at the outlet of the targeted basin.

7 Summary

An experiment project was described, aiming at assembling some advanced technique in rainfall observation by radar and discharge modeling in the framework of some operational flash flood survey in mountainous zones. For this purpose, the catchment of Réal-Collobier turns out to be ideal, because of the dense instrumental network deployed in. The experiment involves the test and validation of using an X-band polarimetric radar like HYDRIX in such a context. Evaluation will also be performed on the possible improvements provided by the deployment of X-band polarimetric radars when conventional C- or S-band radar visibility is limited by the local topography.

HYDRIX should be appreciated in such a context, not only because of its particular technical specifications, but also because of its coupling with algorithm ZPHI, initially developed to avoid attenuation effects.

This validation could lead to integrate a module coupling the rainfall-runoff model (GR3H) with HYDRIX data, without major modification or development, in the operational chain for flood forecast of a specialized service for civil protection.

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