X-band radar coupled with a GR3H rain-flow model in mountainous areas for flood prediction.

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1. INTRODUCTION

Intense and localised rain events are commonly observed in the Mediterranean area suggesting the need for radar rainfall information. The hydrological risk is the flash flood associated with short response times of the basins. Then the need of flood forecasting with a sufficient anticipation delay has grown up.

Even if a large number of radars (20) are set up in France, some places are not covered by the French radar network ARAMIS (Météo France), in particular the Alpine area which is very mountainous. The radar rainfall measurement is more difficult in complex topography area due to ground echoes and beam attenuation effect e.g. Delrieu, (1998). Within the framework of RHYTMME (Hydro-meteorological risk in Mountainous and Mediterranean Area) project, an X-band radars network will be installed on the French Alpine. The first one is localised on the Mount Vial at 1500m altitude, close to Nice. This dual polarized X-band radar (Hydrix®) associated with a ZPHI® algorithm (Testud and al., 2000), which corrects for signal attenuation, allows to estimate rain rate without adjustment by rain gauges. In a previous study (Diss and al., 2009), a validation of rainfall accumulation by X-band radar was conducted by comparison with S-band radar (Météo France) rain product and by a dense network of rain gauges (from Météo France and Cemagref). This study shows that X-band radar vielded more accurate rain estimates than the S-band radar in comparison with the reference gauge measurements at short distance (< 60 km).

This research work aims at integrating the space time knowledge of rain rate in a rainfall runoff model adapted for flood forcasting. The model selected for this work is a spatialized version of the conceptual model GR3H (Fourmigue and al., 2005). So we want to appreciate the relevance of the use of the X band radar rainfall information, coupled with a rainfall runoff model, for flood warning

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2. METHODOLOGY

The hydrological model used in this study is the conceptual rainfall-runoff model, GR3H. The input is the hourly rainfall on the watershed and the output is the hourly flow at the outlet. This model is based on three parameters: S0/A in the production function and B and C in the transfer function (Fig.1). If past chronicle of rainfall and flow information on basin are available, this three parameters can be optimized. In case any flow information is available, the parameters have to be set to predefined values. Therefore, we used the values of the AIGA method (Lavabre and Gregoris, 2006). This operational method developed Cemagref and Météo France gives one by qualification of the rain and flow risk in every point of the study area. This method has been already calibrated and tested on more than 300 gauged catchments in the South of France. This method only needs reliable spatially distributed rainfall information as input to be applied on gauged and ungauged catchments. In case of ungauged catchment, the parameters B and C are set to a fixed and unique value on each pixel. The parameter S0/A is estimated from statistical value of soil humidity available on each pixel of our study area. At the end, the flow estimated by the model is compared to some referenced quantile of the SHYREG database (Lavabre et al., 2003) to obtain three warning levels. The first (yellow) one corresponds to the time return up to 2 years. The second (orange) and the thirst (red) one represents respectively the time return up to 10 and 50 years.



Fig.1: Diagram of the GR3H rainfall-runoff model using 1km² pixel.

The advantage of methods taking into account the spatial variability of rainfall, compared to more traditional methods, have been showed in numbers of studies e.g. Over (1995). Both X-band radar rain and rain gauges information is used as inputs in the hydrological model. First, we searched significant flood events on the basins located in the measured

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radar area i.e. to a distance of 60 km from the radar. Then, we selected basin having had a significant rainfall in order to analyse the warning or no warning from the hydrological model and compared with the flow data or observation from eye-witnesses.

3. CASE STUDY

The X-band radar Hydrix® was set up in June 2007 on the Mount Vial, in the Alpine area. This area is very mountainous and not completely covered by the French radars network and rain gauges network.

During a visit of the Réal-Tuebi basin the 29th June 2009, we observed an intense and fast rainfall event which caused one response of the Réal catchment (Fig. 2). In fact, a passage to ford was blocked by rock few minutes after rainfall event.



Fig.2: The passage of ford from the Réal basin after the rainfall event (at 14h45 GTM).

This catchment is known to be really reactive and indeed we observed the speed of the basin response. The Réal Tuebi catchment is located in the North West from the radar 30 km far. At this short distance, we can expect relevant rainfall information from the X-band radar. One rain gauge station is localised on the Tuebi catchment but unfortunately we do not have any flow information on these study catchments.

Firstly we compare the hourly rainfall radar information with the rain gauge measurement on the location of the station. The result shows a correct correlation (\sim 0.9) between radar and rain gauge. Secondly, we compared (Fig. 3) the average rain on basins obtained by radar and then by the rain gauge at short timescale (5min for the radar and 6min for the rain gauge).



Fig. 3: The average rainfall on both basins from the radar and the rain gauge at short timescale. The vertical dotted line indicates the start of flood observed by eye-witnesses.

We note that the rain accumulation obtained by the radar on the Tuebi (30 km²) and the Réal (2 km²) catchments is significantly higher than the rainfall accumulation measured by the rain gauge. Moreover, no rain was measured by the rain gauge until 2pm, while the radar provides rain information from 12pm.

Looking at the hourly hydrological model outputs, we note (Fig.4) that the radar rainfall information allowed to produce a significant flow level as compared to the almost zero flow obtained from the rain gauge information.



Fig. 4: Hydrological modelling on the Réal catchment. Blue line represents the discharge estimated by radar and the red line the discharge from the rain gauge. The black lines on the top correspond to the radar rainfall information on the basin.

We observed that the Réal catchment reacted really quickly, in just 20min and by consequence that the hourly time step of the hydrological model and of the rainfall information was no short enough to represents the earlier peak (at 14h15).

The use of shorter timescale than one hour in the hydrological model could improve the time delay of the calculated flow.

4. DISCUSSION AND FORTHCOMMING

This study aims to evaluate the relevance in a mountainous area of X-band radar rain information using an operational rainfall runoff model for flood prediction. The hydrological model is the GR3H model used in the AIGA model.

This study shows the relevance of the X-band radar, which takes into account the spatial variability of the rainfall. The rain accumulation on basins (even as small as 2 km^2) can be significantly under estimated by the rain gauge compared to the radar as well as leading to a considerable time delay. These can have a great effect on the flow estimated by the hydrological model, and therefore on the warning level.

This study shows also the need to develop an hydrological model at 5 min timescale for the small catchments in mountainous area. So we would like to test the hydrological model with short timescale on gauged catchments.

We have to note that the June rain event does not measure an hourly high intensity of rain and the study catchment area is very small. Therefore, we will expect to observe other rainfall events, on gauged and ungauged basins, to test our hydrological model with several timescales (for example the recent events in Cannes/Antibes this September). In the future, four Xband radars will be set up in the Alpine area. In 2010, the second one should be installed close to the Mount Vial X-band radar.

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REFERENCE

- Delrieu, G., Serrar, S., Guardo, E., Creutin, J.D., 1998, Rain measurement in hilly terrain with X-band radar systems: Accuracy of pathintegrated attenuation estimates derived from mountain return, Journal of Atmos. and Oceanic Technology, vol. 16, pp. 405-416
- Diss, S., Testud, J., Lavabre., J., Ribstein. P., Moreau. E., Parent du Chatelet; J., 2009, Ability of a dual polarized X-band radar to estimate rainfall, Advances in Water Resources, 32 (2009), pp. 975-985
- Fourmigué, P. et Lavabre, J., 2005, Prévision de crues avec le modèle conceptuel pluie-débit GR3H. Adaptabilité aux incertitudes sur la pluie. Revue des Sciences de l'Eau. 18/1(2005), pp. 87-102.
- Lavabre, J., Gregoris, Y., 2006, AIGA : un dispositif d'alerte des crues. Application à la région méditerranéenne française. FRIEND 2006. Water Resource Variability : analyses and impacts. 27/11 au 1/12/2006. La Havane (Cuba). AISH Publications 308, pp. 214-219.
- Lavabre, J., Fouchier, C., Folton, N., Gregoris, Y., 2003, SHYREG : une méthode pour l'estimation régionale des débits de crue.Application aux régions méditerranéennes françaises. Ingénierie EAT, n° spécial Risque naturel et aménagement du territoire 2003, pp. 97-111.
- Over, T., 1995, Modelling space time rainfall of the mesoscale using random cascades, PhD thesis, University of Colorado.
- Testud, J., Le Bouar, E., Obligis, E., Ali-Mehenni, M., 2000, The rain profiling algorithm applied to polarimetric weather radar., Journal of Atmos. and Oceanic Technology, vol. 17, pp. 332-356.