Proceedings of ERAD 2006

Influences of radar rainfall uncertainties on a distributed rainfall runoff model

Yann Laborda[1], Christian Salles[2] and Luc Neppel[2]

[1]Service de Prévision des Crues du Grand Delta (SPCGD), Nîmes (France)

[2]HydroSciences (UMR 5569), Montpellier (France)

1 Introduction

In the south of France, the precipitation occurs mainly during autumn and spring. Rainfalls are usually short, intense, heavy and irregularly spatially distributed and lead locally to destructive flash floods (e.g. Senesi et al., 1996; Neppel et al., 1997, Bechtold and Bazile, 2001 and Gaume et al., 2004). Floods are the most important natural hazard in this area. Meteorological and morphological features make difficult the anticipation of flood in this zone. Particularly, high variability of rainfall exists both in time and space, and rivers basins response time is generally quick. Hydrological models taking into account the rainfall variability play an important role and become essentials in floods alert systems in the Mediterranean.

Therefore, weather radar becomes a crucial tool to predict extreme flood. The radar data are of large interest for distributed rainfall runoff models. However, radar rainfall data are subject to various sources of error that are both random and systematic in nature (Zawadski, 1984 and Smith et al., 1996). Therefore, radar rain rates are biased compared to tipping bucket rain rate (e.g. Creutin et al., 1998 and Seo, 1998).

The purpose of this study is to compare instantaneous rain rates estimated from weather radar with ground rain gauge measurements. Firstly, the spatial and temporal structure of observed differences between radar and ground measurements are analyzed. Secondly, we discuss how the radar rain rates uncertainties spread through a distributed rainfall runoff model ALTHAIR (Bressand, 2002) and how they affect the hydrograph outputs.

2 Data and procedures

Radar data are coming from the Nîmes weather radar of French meteorology forecast and are processed by the CALAMAR algorithm (RHEA, 2006). The CALAMAR algorithm provides 5 minutes time step advected images free off ground echoes with or without ground gauge adjustment. Ground data are obtained from tipping bucket rain gauges. The ground network consists of 28 rain gauges spread over an area of about 9 000 km^2. The rain gauge sampling surface is 400cm² and the bucket tips every 0.5 mm of rain depth.

Six major rain events, summarized in Table 1, have been selected from the data collected during 2003-2004 by the "Service de Prévision des Crues du Grand Delta" (SPCGD) in association with RHEA company. The six events cover various rainfall structure (convective, stratiform and orographic).

Table 1. Duration, water depth and maximum rain intensity derived from the ground network for the six selected events.

Event	duration (h)	event water depth (mm)	max rain intensity (mm/h)	event description
22/09/2003	24	62	348	Intense rainfall in the south of studied area
19/10/2003	21	44	114	Stratiform rainfall
15/11/2003	39	77	30	Cevenol event with intense and homogeneous rainfall on relief
22/11/2003	62	84	162	Cevenol event with intense rainfall in relief
02/12/2003	60	177	144	Continuous rainfall with meso-scale structures at the beginning of the event
16/08/2004	36	47	174	Summer thunderstorm with intense rainfall on relief

3 Differences between radar and ground rainfall estimates

For each time step, the five minute rainfall depth measured by the ground rain gauges (W_G) is compared with the 5 min. radar rainfall depth at the same locations obtained from the CALAMAR algorithm without ground adjustment (W_R). Considering each rainy time step of the six selected events, it results 38 383 values of W_G-W_R. The extremes values of the observed differences are –9 mm and 26 mm. The event by event distributions of the differences are plotted in figure 1.

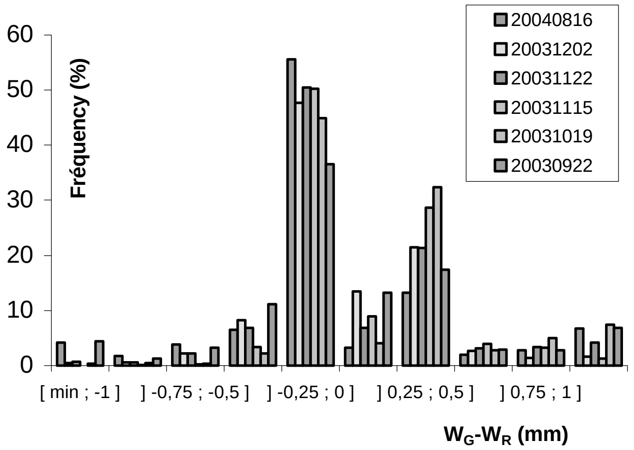

Fig 1 : Event by event distribution of W_G-W_R difference

The distribution of the difference W_G-W_R are quite similar whatever the considered rainfall event. They are all bimodal with a maximum frequency in the range] –0.25 - 0 mm] and a secondary peak in the range] 0.25 - 0.5mm]. The high frequency observed for] –0.25 - 0 mm] range is mainly due to the sensitivity of the ground rain gauges. Actually, the rain gauge can not detect rain depth lower than 0.5 mm (i.e. corresponding to a bucket tip). The radar is not affected by this limitation.

In the following, in order to get rid of rain gauge sensitivity issue we filtered by considering W_G-W_R differences only when the ground rain gauge measurement is higher or equal to 0.5mm.

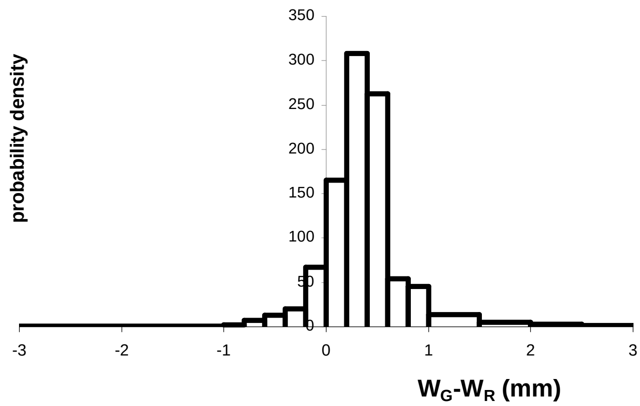

Fig 2 : Distribution of W_G-W_R difference obtained from 17982 observations.

Once the filtering is done, the resultant dataset contains 17982 values. The distribution of the differences are still independent of the rain event. Hence, the mean value of W_G-W_R seems not to depend on observed radar rainfall depth.

We ran statistical fits on the filtered dataset and the most appropriate distribution is a normal distribution (Fig. 2). The parameters of the adjusted distribution with a 80% confidence interval are (mean : 0.41mm , standard deviation: 0.68mm.). It confirms that on average rainfall radar estimates are lower than ground gauge estimates.

4 Sensibility of rainfall-runoff model outputs

The radar rain rates deviation from ground measurement are normally distributed. In this section we study how the hydrograph outputs obtained from the distributed rainfall runoff model ALTHAIR (Bressand, 2002) are affected by the radar uncertainties.

4.1 The study catchment

The ALTHAIR simulations were ran on the Anduze's Gardon catchment located inside the area covered by the rain gauge network. The catchment area extends over 524 km² and is equipped with 7 rain gauges.

The distributed ALTHAIR model, has been specifically developed for the locally observed flash runoff. The Hortonian infiltration process is used to estimate the runoff of each 1 km²elementary cell, combined with a lag and route method to obtain the cells contribution to the outlet runoff.

4.2 Monte Carlo simulations

The convective rain event of the 16th of August 2004 was selected for the first step of the simulation purpose. For each rainy pixels (i.e. higher or equal to 0.5 mm) of the radar rainfield we add a random noise. The noise is randomly chosen in the normal distribution with mean and standard deviation obtained above. Therefore, for each five minute time step of this event we obtain a noisy radar rain field. The hydrogram corresponding to the noisy event is obtained with ALTHAIR model. This operation was repeated 1000 times, the parameters and the initial conditions of ALTHAIR remain the same for all the 1000 cases. The resultant hydrograms were considered to test the ALTHAIR sensibility to radar uncertainties.

Moderate differences were observed between the 1000 simulated hydrographs. The hydrograph profile remains similar for all the simulations. The peak discharge is varying between 114 and 119 $m^3 s^{-1}$, peaks are all occurring at the same time, and the hydrograph volume is between 6320 10^3 m^3 and 6510 10^3 m^3. As an illustration, in figure 3 we plot for each time steps the mean discharge and its standard deviation obtained from the 1000 hydrographs. The standard deviation is less than 1 m^3s^{-1}, that is less than 1% of the peak discharge.

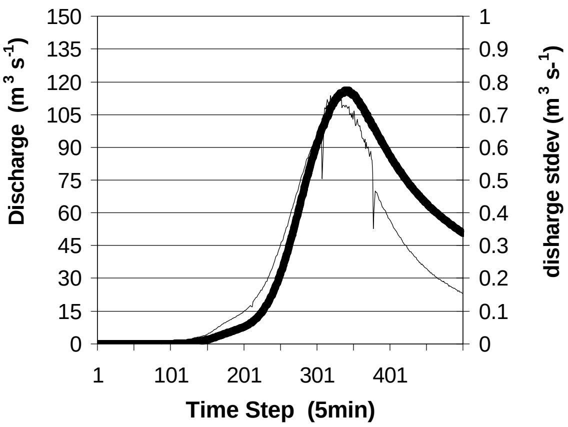

Fig 3 : Mean hydrograph output (bold line) and hydrograph standard deviation (thin line) obtained from the 1000 Monte Carlo simulations

4.3 Simulations on the lasting 4 events

In the following, for the four lasting rain events, we directly evaluate the impact mean noise (i.e. 0.41 mm) on the ALTHAIR hydrograph output.

We have compared the peak discharge obtained with the initial radar rain depth with the one obtained with the noisy radar rain depth. The differences between the radar rain depth are near 20%. In the table 2, we can see that it leads to a difference of 40 to 60 % between the peaks discharge. Thus a relative uncertainty on the radar rain depth implies twice to third uncertainties on the peak discharge. We can also note that the differences between peak discharges obtained with non calibrated radar rain depths and RHEA ground calibrated radar rain depths can be up to 265%.

Table 2. Results of simulations on 4 events with 3 different rain structure

	Error (%) on peak discharge with mean radar noisy data	Error (%) on peak discharge with radar ground adjusted data
15/11/2003	58	265
22/11/2003	36	142
02/12/2003	38	55
16/08/2004	65	75

5 Conclusion

The five minutes rainfall measured at ground by tipping bucket rain gauges differs from rainfall measured at the same location with a weather radar. From the six selected events the deviation between gauge and radar is distributed according to a normal law which parameters are time, space and rain intensity independent. The mean difference between rain gauge and radar equals 0.41 mm. It is less than a rain gauge bucket tip.

The impact of the radar uncertainties on the hydrograph output of the distributed rainfall runoff model ALTHAIR has been studied. The uncertainties at the pixel scale of the radar estimation does not significantly affect the hydrograph profile. But the peak flow can be increased by 60% when the observed bias is uniformly reported on all the rainy pixels.

Acknowledgements: The authors are indebted to the Service de Prévision des Crues du Grand Delta in Nimes for providing the rain gauge and the radar data.

Bechtold, P. and Bazile, E., 2001. The 12-13 November 1999 flash flood in southern France. Atmospheric Research, 56(1-4): 171-189.

Bressand, F., 2002, Le projet ALHTAÏ R du service d'annonce des crues du Gard. La Houille Blanche n°2, 64-68.

Creutin, J.D., Delrieu, G., Lebel, T., 1988. Rain measurement by raingage-radar combination: a geostatistical approach, J. Atmos. Oceanic Technol., 5 (1), 102-115.

Gaume, E., Livet, M., Desbordes, M. and Villeneuve, J.-P., 2004. Hydrological analysis of the river Aude, France, flash flood on 12 and 13 November 1999. Journal of Hydrology, 286(1-4): 135-154.

Neppel, L., Desbordes, M. and Masson, J.M., 1997. Spatial extension of extreme rainfall events: return period of isohyets area and influence of rain gauges network evolution. Atmospheric Research, **45**(3): 183-199.

RHEA, 2006: Mesure et prévision des crues / utilisation d'un radar hydrologique, Internal Techincal Document. 250 p.

Senesi, S., Bougeault, P., Cheze, J.-L., Cosentino, P. and Thepenier, R.M., 1996. The Vaison-La-Romaine flash flood: mesoscale analysis and predictability issues. Weather and Forecasting, 11(4): 417-442.

Seo, D.-J., 1998. Real-time estimation of rainfall fields using radar rainfall and rain gage data. Journal of Hydrology, 208(1-2): 37-52.

Smith, J.A., Seo, D.-J., Baeck, M., Hudlow, M.D., 1996. An intercomparison study of NEXRAD precipitation estimates. Water Resour. Res. 32, 2035–2045.

Zawadski, I., 1984. Factors affecting the precision of radar measurements of rain, Preprints of 22 nd Conf. Radar Meteorology. Am. Meteorol. Soc., Zurich, CH, pp. 251-256.