International Conference on Hydroinformatics

8-1-2014

FloodAlert: A Simplified Radar-Based EWS For Urban Flood Warning

Xavier Llort

Rafael Sánchez-Diezma

Alvaro Rodríguez

David Sancho

Marc Berenguer

See next page for additional authors

Authors
Xavier Llort, Rafael Sánchez-Diezma, Alvaro Rodríguez, David Sancho, Marc Berenguer, and Daniel Sempere-Torres

FLOODALERT: A SIMPLIFIED RADAR-BASED EWS FOR URBAN FLOOD WARNING

XAVIER LLORT (1), RAFAEL SÁNCHEZ-DIEZMA (1), ÁLVARO RODRÍGUEZ (1), DAVID SANCHO (1), MARC BERENGUER (2), DANIEL SEMPERE-TORRES (2)
(1): Hydrometeorological Innovative Solutions, Jordi Girona 1-3, K2M-S104, 08034 Barcelona, Spain.
(2): Centre de Recerca Aplicada en Hidrometeorologia, Jordi Girona 1-3, K2M-S104, 08034 Barcelona, Spain.

In this work we present FloodAlert, a simplified flood Early Warning System [EWS] based on the use of radar observations and radar nowcasting to issue local flood warnings. It is a web-based platform and it is complemented with a flexible and powerful dissemination module.

INTRODUCTION

Urban floods can be caused by intense rainfall accumulations in short time periods that eventually exceed the capacity of the sewer networks. Despite the efforts made in the last years in all cities to increase the sewer's capacity many cities are still exposed to these heavy rainfall events.

In this work, we present a simplified flood *cloud* EWS, called FloodAlert, based on the use of radar observations to issue local flood warnings.

Although precipitation accumulation estimates based on radar observations may suffer from different sources of error, they may also be the quickest way to obtain a reliable estimate of the accumulated precipitation, and of the precipitation that may occur in the forthcoming few hours by means of radar-based nowcasting. This short-term forecasting is crucial for urban floods where the response times are usually very short.

Radar data are quality-controlled before its use and with cross-correlation techniques the motion field of the precipitation is obtained. This motion field is used to calculate the precipitation nowcasting and to define an observation region surrounding the point of interest, where it is important to be aware. This region changes dynamically with the precipitation according to its direction and speed. Accumulation values are calculated on this observation region for the next hours and warnings issued according to user-defined thresholds.

A web-based platform has been developed to display the information and manage the configuration of the product (points of interest, warning thresholds and dissemination information -SMS mobiles, emails, etc.-). The platform dynamically displays geo-referenced information, including the points of interest, present and forecasted precipitation fields and hazard warnings. The warnings issued by the platform can be spread not only through the viewer but also by email and SMS.

The proposed solution is currently running operationally under several national radar domains. The following sections give the description of the product and provide several examples.

RADAR OBSERVATIONS AND NOWCASTING

The traditional instrument to estimate precipitation has been the raingauge. Raingauges provide real measurement of the precipitation at given points, but the lack of spatial representativeness of these punctual measurement plus the fact that cannot provide a precipitation forecast make them limited for real time early warning of flood hazard situations.

On the other hand, radar precipitation estimates (which are nowadays available over many countries) suffer from different sources of errors, but they may be the quickest way to obtain a reliable estimate of the accumulated precipitation, and of the precipitation that may occur in the forthcoming few hours by means of radar-based nowcasting. Radar estimates also provide a good spatial representation of the precipitation that might help in the real time management of the potential flooding situations.

Radar rainfall observations

Due to different errors affecting radar precipitation estimates (see for reference Zawadzki [1]) before the use of the data there is the need for a quality control process.

The quality control process applied for FloodAlert (described in Sánchez-Diezma [2]) includes statistical calibration of radar reflectivity estimations, correction of non-meteorological echoes, correction for underestimation due to beam blockages (interaction of the radar measurement process with the topography and other elements) and conversion from reflectivity to instant rainfall using a climatological Z-R relationship. This process is represented in Figure 1 as the transformation from raw radar observations (white boxes) to instantaneous radar observations (grey boxes).

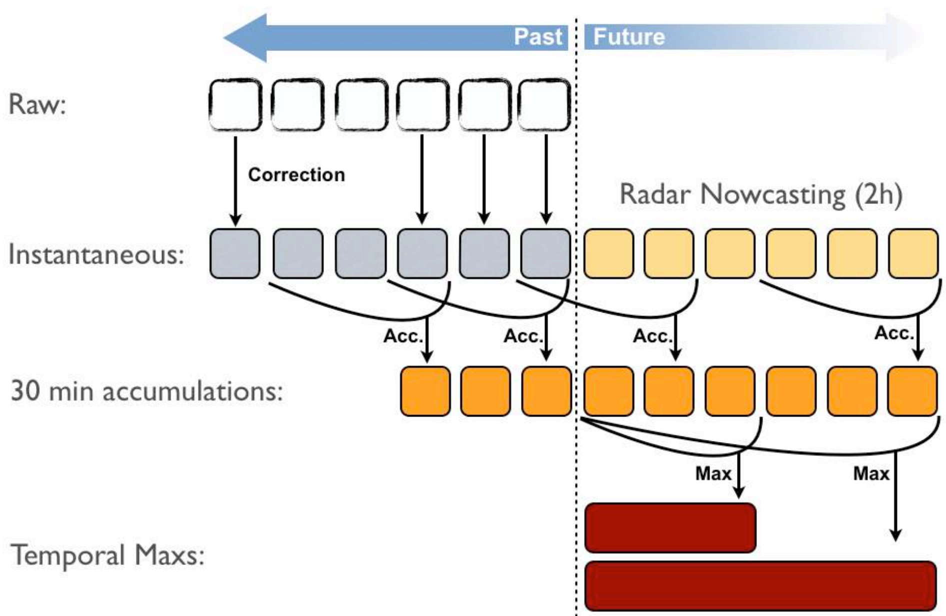

Figure 1. Data flux scheme. Vertical dashed line divides past and future. Each color box indicates a different kind of data.

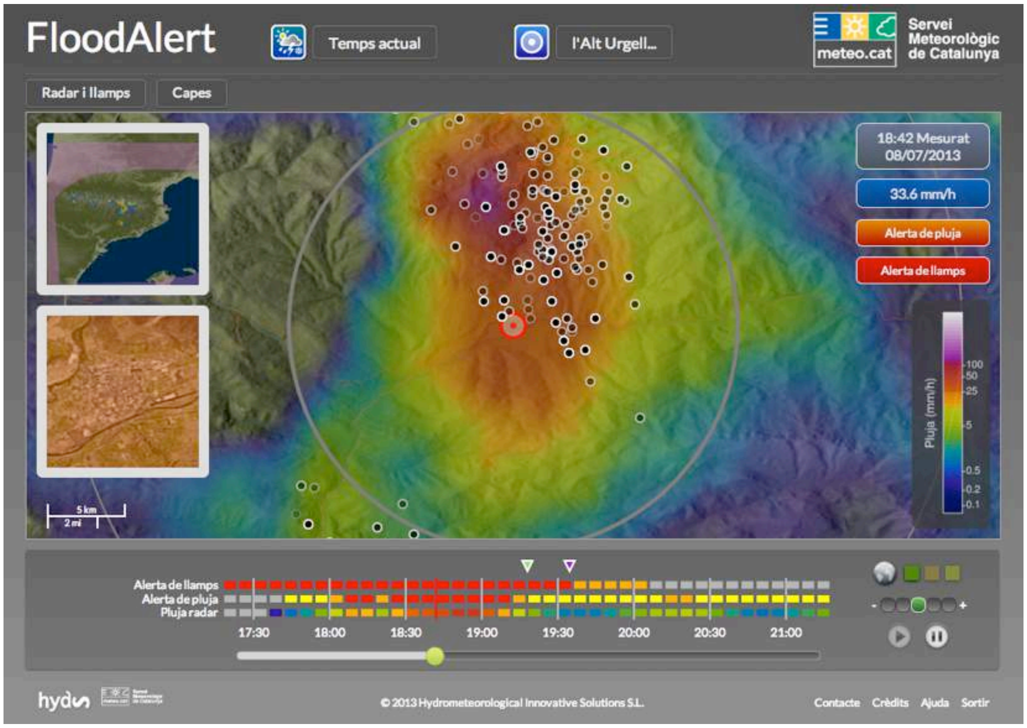

Figure 2. Viewer interface showing the radar precipitation (2h) observations and radar nowcasting (2h). Dots represent observed lighting. The alert bar at the bottom shows the levels of warning at each time step according to user defined thresholds.

Radar nowcasting

The precipitation movement field can be calculated from the last radar observations by means of cross correlation techniques. This motion field represents the directions (with the same resolution of radar estimates) in which the precipitation moves. This movement field is used to extrapolate the last observations to the future in order to provide forecasted precipitation fields for the next hours (see Berenguer *et al.* [3] and Berenguer *et al.* [4] for a complete description of the technique).

Forecasting skills of radar nowcasting decay quickly, but it is the best precipitation forecasting available for the next 1-6 hours (depending on situation and radar coverage) that can be obtained. On top, rapid update of these techniques allows keeping the forecasting updated with the last observations information (usually ~10 min). This process is depicted in Figure 1 as the calculation of the radar nowcasting (yellow boxes) from the radar instantaneous observations (grey boxes).

Figure 2 shows an example of radar nowcasting as seen from FloodAlert platform. It corresponds to a convective precipitation event in the Pyrenees that hit La Seu d'Urgell town. The figure shows the strong convective cell (with associated lighting) at the point of interest (La Seu d'Urgell) and the associated warnings based on user-defined thresholds (in mm/h). The viewer has zoom capabilities and it is able to display geo-referenced information together with the rainfall and warning information.

Precipitation accumulation

Once both the radar observations as well as the radar nowcasting are available, FloodAlert calculates the 30 minutes accumulation in a moving window scheme.

The 30 min interval was chosen here because is one of the most representative for urban floods, where usually the sewer systems have been designed using this concentration time as reference. The accumulation process is done in a moving window scheme, that is, calculating the 30 min. accumulation every time that new data is available (see Figure 1 where this process is shown as the aggregation of instantaneous data -grey and yellow boxes- into accumulated fields -orange boxes-).

In order to calculate the rainfall accumulation form the radar instantaneous precipitation estimates (both observed and forecasted) the movement of the precipitation field is again taken into account (Sánchez-Diezma [1]) to provide realistic estimations of the rainfall accumulation.

FloodAlert

Once the 30 min precipitation accumulations are available (both observed and forecasted) FloodAlert calculates, for each pixel (according the radar data resolution), the maximum value in the following hour and the maximum value in the following 2 hours.

This process generates fields with the maximum accumulation (in 30 minutes) forecasted for each pixel in the next 1 or 2 hours. From these fields and according to user-predefined thresholds of accumulation in 30 min., FloodAlert delimitates and shows the areas that will be over the thresholds.

Figure 3 shows and example of the areas that will be over the different thresholds in the following hours in an event close to Barcelona. The web-viewer shows the areas using a color scheme and gives feedback on the points of interest of the user.

FloodAlert also calculates flooding warnings on the points of interest. The graph of the evolution of the 30 min precipitation accumulation (both observed and forecasted) is shown for 3 different surrounding areas (5, 10 and 15 km.). But since the motion field of the precipitation is available and in order to reduce false alarms, only the maximum over an intelligent area is calculated.

The intelligent area changes dynamically with the precipitation direction and speed, and at each time step represents the precipitation that might impact the point of interest. It is defined as the intersection of two elements:

- A parabola oriented towards the direction where the precipitation is coming (using the motion field derived with cross-correlation techniques with the last observations) and with the aperture depending on the precipitation motion field velocity. Figure 4 shows the different parabolas apertures used depending on the precipitation field velocity.
- Three circular surrounding areas: 5,10 and 15 km.

Figure 6 shows an example of the evolution of the maximum values of the 30 min. accumulation in the intelligent areas (left panel), and the corresponding accumulation field (right panel). It corresponds to an event in Palma de Mallorca on the August 30th 2012 and it can be seen how the forecast shows accumulations in 30 min over the user red level threshold.

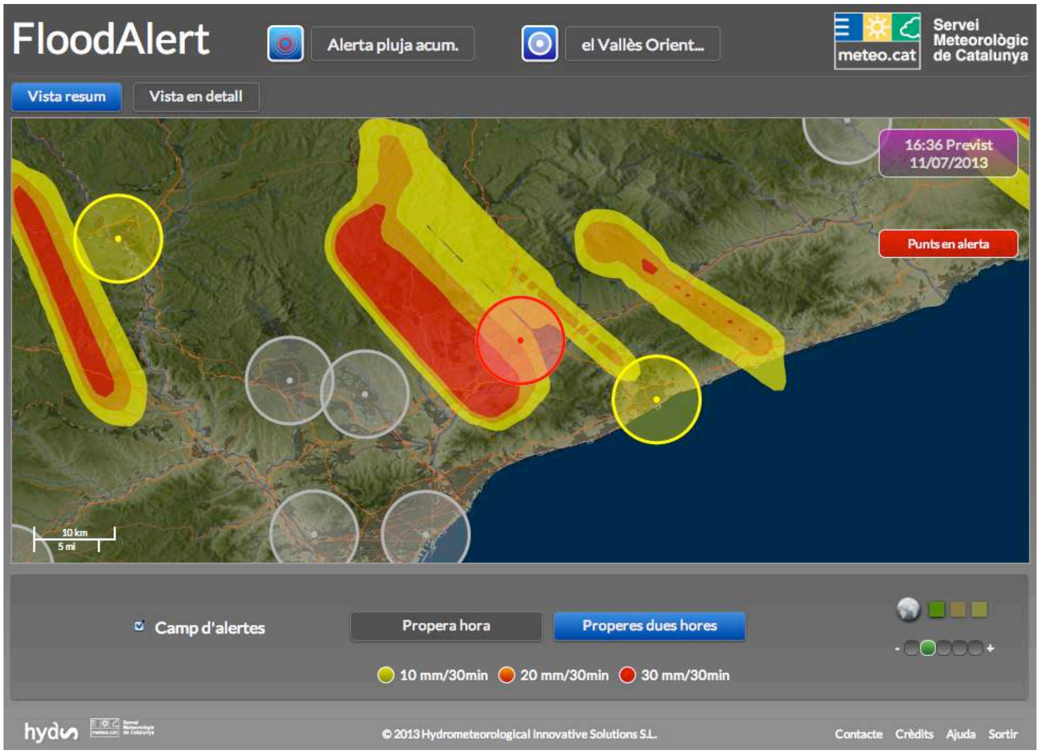

Figure 3. Example of the viewer interface showing the areas that are forecasted to be over the predefined thresholds in the following 2h. The image corresponds to the July 11th, 2013 at 14:36 in a town close to Barcelona. The user thresholds where for this case 10mm/30 min (yellow), 20mm/30 min (orange) and 30mm/30 min (red). The points are the user points of interest and the color indicates the maximum level that they will reach in the following 2h.

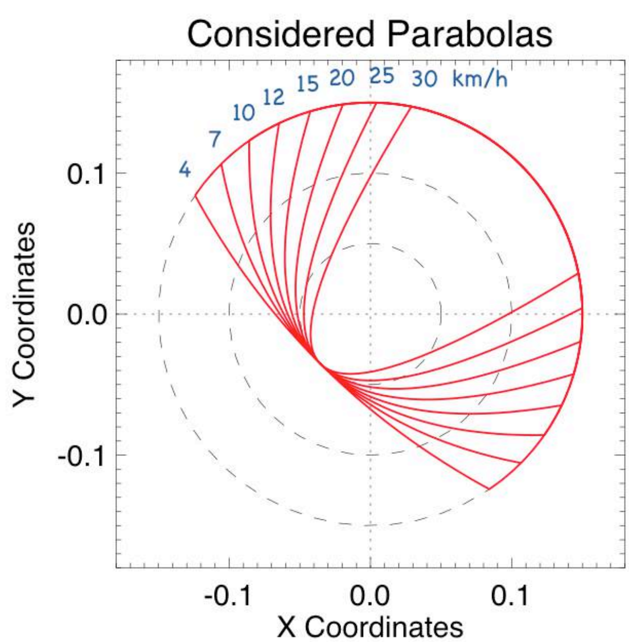

Figure 4. Considered parabolas according to the precipitation's motion field velocity.

WEB-BASED PLATFORM

FloodAlert runs in *cloud*, that is, the users do not have any hardware or software installed. The access to the platform is through any device connected to the Internet using a web browser, both to retrieve information and to configure the different parameters.

Viewer

The platform dynamically displays geo-referenced information, including the points of interest, present and forecasted precipitation fields and hazard warnings, and it is split into 4 areas:

- Real time radar observations and nowcasting. Showing the radar precipitation estimates, both measured and forecasted through the nowcasting technique. Figure 2 shows an example of that part.
- Areas that will be potentially affected by rainfall accumulation in 30 min exceeding the user-defined thresholds. Figure 3 shows an example of the representation of that product within FloodAlert platform.
- Evolution of the maximums of the 30 min accumulation in the intelligent area surrounding the point of interest. Figure 6 shows an example or that part depicting the evolution of the 30 min accumulation values and time series of accumulation fields.
- Administration area. Where the user can manage the information and parameters of the account: account information, individual thresholds for the different products at the different points of interest, devices, profiles of users, actions to be triggered when reaching the warning levels, etc.

Dissemination

A flexible and powerful dissemination module has been integrated into FloodAlert. It allows configuring devices (emails, SMSs, FTP servers, etc.) under different profiles (e.g standard, 24h, weekends, emergency, etc.) and the actions to be triggered when reaching the different levels.

Figure 5 shows an example of an email received for the Palma de Mallorca point on the October 29th, 2013 forecasting accumulation values (30 min accumulation) exceeding the user-defined red threshold. The email was issued 90 minutes before the flooding at the city caused problems in traffic, basements and more than 200 fireman interventions. In the email it can be seen in the top panel the areas forecasted to be over the thresholds (5, 10 and 20 mm/30 min in this case) and how those affect the point centered in the city. In the center panel, the accumulation values evolution shows how FloodAlert forecasted accumulation values over the red threshold (up to ~40mm/30 min.) and at the bottom panel if can be seen how the radar observed the storm in its last observation.

Users can connect directly to the application from the email and SMSs link, but the both are tailored to provide all available the information that might be needed for the situation management.

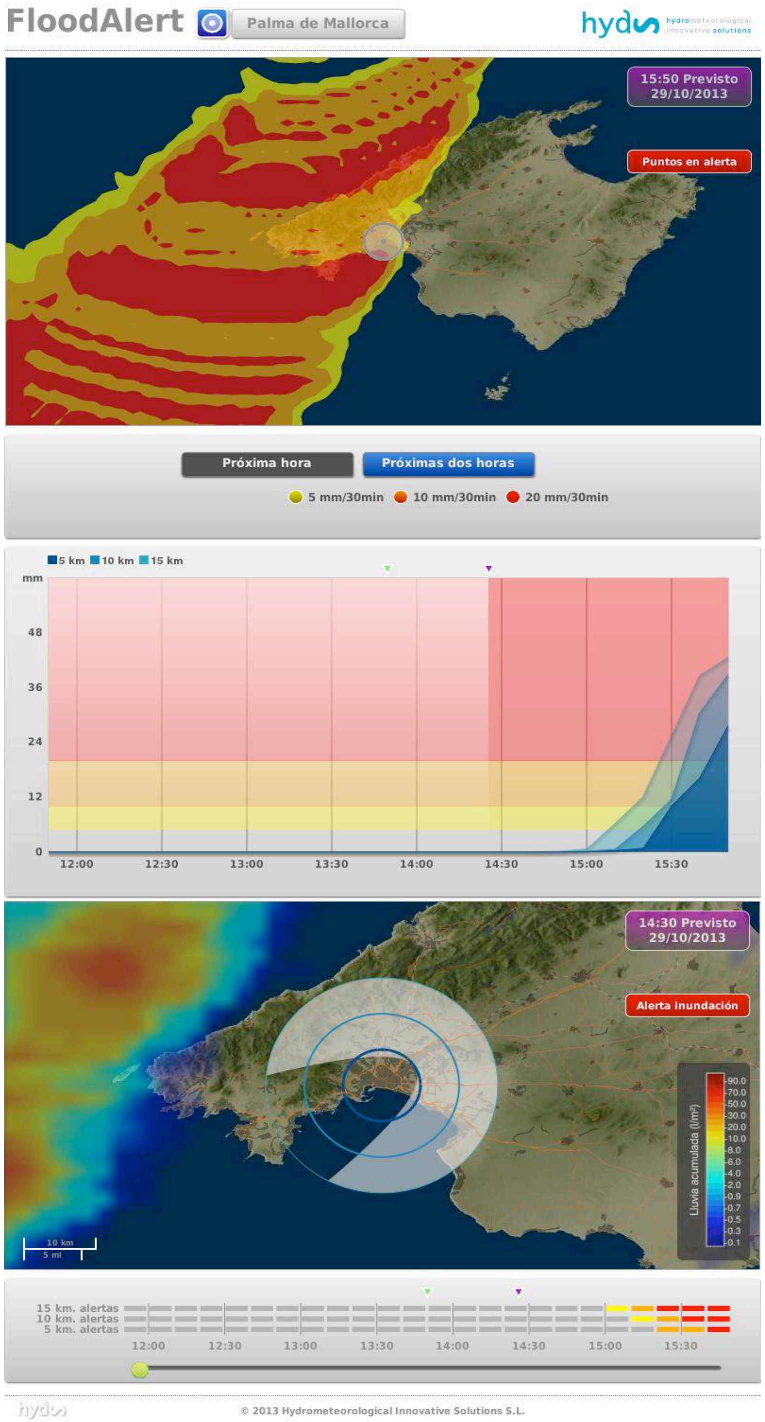

Figure 5. Example of warning email received the October 29th 2013 for the Palma de Mallorca point 90 minutes before a real flooding at the city occurred. The top panel shows the areas forecasted to be over the thresholds (5, 10 and 20 mm/30 min in this case), the central panel shows the evolution of the 30 min accumulation for the three intelligent areas, and the bottom panel shows the rainfall field in the moment that the email was issued.

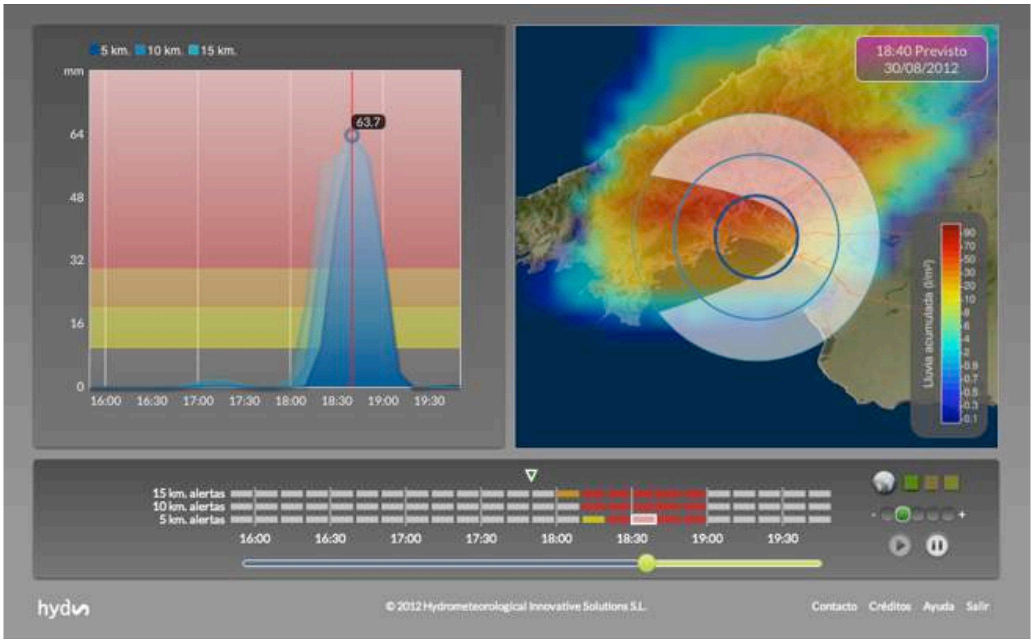

Figure 6. Example of the viewer interface for the Palma de Mallorca point 50 minutes before the storm hit the city (18:40h August 30th, 2012). The left panel shows the evolution of the 30 min. accumulation for the three intelligent areas surrounding the point and the right panel shows the accumulation field and the intelligent area. Bottom bar shows the warnings according to defined thresholds.

ACKNOWLEDGEMENTS

This study has been partly carried out in the framework of the EU FP7-Projects CORFU (Collaborative Research on Flood Resilience in Urban areas; FP7-ENV-2009-244047) and PEARL (Preparing for Extreme And Rare events in coastal regions; FP7-ENV-2013-603663). Thanks are due to the Spanish National Meteorological Agency (AEMET) and the Catalan Meteorological Service (SMC) for providing radar data.

REFERENCES

[1] Zawadzki, I., 1984: Factors affecting the precision of radar measurement of rain. *Preprints, 22th Conference on Radar Meteorology*, Zurich, Switzerland, 251-256.

[2] Sánchez-Diezma, R., 2001: Optimización de la medida de lluvia por radar meteorológico para su aplicación hidrológica., *PhD Theses*. Universitat Politècnica de Catalunya, 313 pp.

[3] Berenguer, M., C. Corral, R. Sánchez-Diezma, and D. Sempere-Torres, 2005: Hydrological Validation of a Radar-Based Nowcasting Technique. *Journal of Hydrometeorology*, 6, 532–549.

[4] Berenguer, D. Sempere-Torres and G.G.S Pegram, 2011: SBMcast–An ensemble nowcasting technique to assess the uncertainty in rainfall forecasts by Lagrangian extrapolation. *Journal of Hydrology*, 404, 226-240.