A first step in the integration of radar information on a operational tool for monitoring and surveillance in potential flash flood events

R. Hernández[1,2 *], J. Moreno[1,2], K. Otxoa de Alda[1,2], M. Maruri[1,2], J. Egaña[1,2], S. Gaztelumendi[1,2]

[1] *Basque Meteorology Agency (Euskalmet). Vitoria-Gasteiz, Spain.*
[2] *Tecnalia, Meteo Unit. Vitoria-Gasteiz, Spain.*
* *roberto.hernandez@tecnalia.com*

(Dated: 31 May 2012)

Presenting author name:
Santiago Gaztelumendi

1. Introduction

In 1991 the Basque Service of Meteorology (Basque Government) began the deployment of an automatic weather station (AWS) network. Priority was given to the real time observation of water surface level of the rivers. It is noted that flood return periods are quite small in most of the short length hydrologic basins of the Basque Country, especially those oriented to the Cantabrian sea (Egaña et al 2009, 2010). Since then, technological innovations and meteorological infrastructure have undergone tremendous transformations in the Basque Country area. Different actions in Basque Government had focused in improving hydrometeorological instrumentation and observation capabilities and also to incorporate operational surveillance and forecast capabilities. In 2003 the Basque Meteorology Agency (Euskalmet) was founded in order to act as a regional hydrometeorological service, dealing among others with early detection of flash flood event and the issuance of warnings (Gaztelumendi et al 2003, Hernández et al 2003, Oxoa de Alda et al 2003). The installation of Kapildui radar is an important step in this process (Aranda et al 2006, Gaztelumendi et al 2006a). This radar is a METEOR 1500 Doppler Weather Radar with Dual polarization capabilities. Based on a Klystron transmitter system, it operates in C-band frequency and uses the advanced signal processing environment.

In this context and during those years we have developed different protocols, procedures and tools for Euskalmet operations, including monitoring and surveillance in severe weather scenarios (Egaña et al 2008, 2009, Gaztelumendi et al 2006 b, c, Hernández et al 2010, Maruri et al 2008, Orue et al 2011). Recently, we have developed a new system that considers real-time weather data coming from AWS network and other sources, helping us in the warning process. Furthermore, the software has a module that integrates radar data for different purposes. The aim of this paper is to describe the methodological aspects involved in the generation of such radar based warning product.

2. System description

The system is developed with the final objective of become fully operational rainfall/flash-floods early warning system. By now, we are focusing on storm environment and surveillance of heavy rainfall and strong wind gusts. This system presents a friendly graphical user interface, it is based on real time check and continuous monitorization of available information (fig 1). Some functions are included in order to consider thresholds or criteria surpass efficiently, tools for validation and report elaboration are also integrated. This application is developed in C #, Microsoft. NET (OOP) using the development tool Visual Studio 2010 SP1, and by now runs on Windows environment.

Screen displays are map-based and use colour codes and patterns to focus on real time rain location and intensity information (fig 2). Continuous monitoring is based on the analysis of different meteorological data received in real time from different available sources in Basque Country. In particular, Radar, Meteosat and Automatic Weather Stations network are widely used. Automatic checks for the predefined criteria are done in real time for precipitation, wind or reflectivity. Once detected a risky region, the program beeps to warn Euskalmet staff on duty in order to proceed according to established procedures in potential severe weather scenario. This information can be validated by an expert relying on a series of graphical tools that include, among others, different radar information (figs. 2). In particular, in precipitation chart, a visualization of reflectivity value for nearest pixel is included (fig 2). All the generated information is stored for later analysis. The system operates in a pre-operative mode in Euskalmet office.

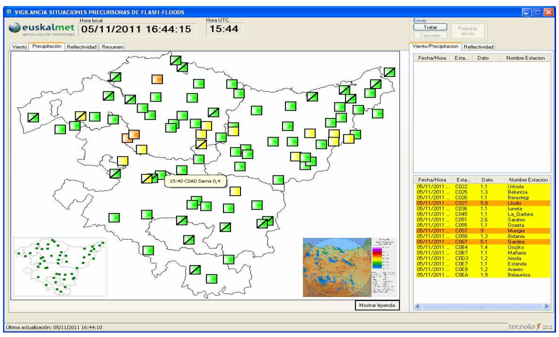

Fig. 1: System GUI example.

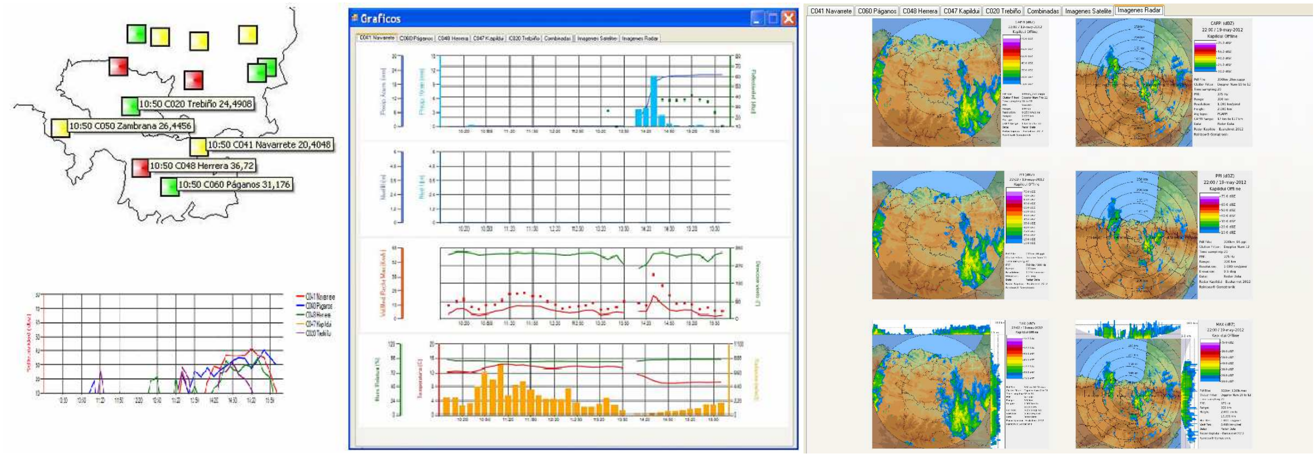

Fig. 2: Example of system software graphic tools, including pixel reflectivity plots and common radar maps for validation.

3. Radar module.

Radar information is used in the system in different ways. On the one hand, radar products are available in the system for consistency and validation purposes. On the other hand, for real time surveillance we have developed a module in order to improve the detection and monitoring of risky situations associated with convection.

The input of the detection and warning function is a PCAPPI image (2 km, 100 km range). Specifically, it is a Rainbow® (GEMATRONIK) file corresponding to the decompressed binary part of the product. In order to avoid assigning erroneous warning areas, the image is processed by applying a static mask of the ground clutter (Maruri et al 2010).

The output product is a second-level product which is applied on the PCAPPI 2 km (dBZ). The identification of risk regions, potentially flash flood precursors, is based on a series of predetermined criteria. It has been established as a potential warning an area with a minimum diameter of 5 km, with 50% of its pixels exceeding 45 dBZ (Table 1). It is a common procedure widely used for the identification of convective cells (e.g. Rainbow® by Gematronik).

Threshold	Reflectivity to be exceeded	45 dBZ
Fill Factor	Minimum fill factor for warning area	50 %
Diameter	Minimum diameter of the warning area	5 km

Table 1: Warning parameters.

3.1. The identification function

The identification function creates a mask from the original image, detecting those convective systems that meet the requirements detailed above. The body of this function is composed by a routine written in IDL® language (Exelis Visual Information Solutions) named "blob_analyzer_routine" (Fanning Software Consulting, Inc.), with the appropriate modifications to adapt it to our needs. The purpose of this routine is to create a system for analyzing regions of interest inside images (ROIs), also known as "blobs". In particular, given a radar image, the program will automatically select blobs and capture their properties (Table 2).

Methods	Purpose
NumberOfBlobs	Returns the number of blob identified in the image
GetIndices	Returns the indices of a particular blob
GetStat	Returns a data structure with the statistics of a particular blob
FitEllipse	Fits an ellipse to the blob
ReportStats	Reports the statistics of each blob found in the image

Table 2. Blob analyzer methods

The first step in detecting blobs is to prepare a binary image, in which pixels that meet the first condition (reflectivity to be exceeded) are selected. Then, "label_region" function consecutively labels all regions or blobs of two-dimensional image with a unique index, obtained by the density function. The latter is returned by the "histogram" function, that is, the function returns an array containing a list of the original array subscripts that contributed to each histogram bin. This list, commonly called the reverse index list, efficiently determines which array elements are accumulated in a set of histogram bin. All this process is known as *blob coloring*. The process continues by analyzing the other parameters for warning: diameter parameter control and fill factor parameter control (Fig 3). For that purpose, some statistics of each blob are used (Table 3).

Fig. 3: Original data (PCAPPI >10 dBZ) (upper left); mask image with pixels greater than threshold (upper right); image of unique regions from "Label_Region" function (bottom left); ellipse mask for minimum diameter and fill factor (bottom right). Date: 2009/07/01 14:50.

Output keyword	Description
Index	the index number of this blob
Count	the number of indices in this blob
Perimeter_Pts	a [2,n] array of points that describe the blob perimeter
Pixel_Area	the area as calculated by pixels in the blob
Perimeter_Area	the area as calculated by the blob perimeter
Center	the [x,y] array that identifies the centroid of the blob
Perimeter_Length	the perimeter length
Scale	the [xscale, yscale] array used in scaling
Mincol	the minimum column index in the blob
Maxcol	the maximum column index in the blob
Minrow	the minimum row index in the blob
Maxrow	the maximum row index in the blob

Table 3. Data structure with the statistics of a particular blob

3.2. Reports and Visualization.

The blob analyzer contains a method responsible for reporting the statistics of each blob found in the image. This information is dumped to a text file, with different fields (Table 4).

Index	ID number
LON/LAT	Geographical coordinates of the centroid
Nº pixels	Number of cells that are part of the blob
Area	Blob surface calculated from the number of cells
Perimeter	Lenght of the perimeter
dBZ_Med	Average of the reflectivities
dBZ_Max	Maximum reflectivity
dBZ_vza	Variance of the reflectivity
Max axis	Length of the mayor axis of the ellipse fitted to the blob
Min axis	Length of the minor axis of the ellipse fitted to the blob
Angle	Orientation of the ellipse fitted to the blob
Comarca	Name of the region where is located the centroid of the blob

Table 4: blob statistics fields

The application results are shown as a PCAPPI image, including colour palette, background image and limit boundaries. The image fusion, with original PCAPPI product, is performed using RGBA space, adding the alpha channel (transparency) to the original RGB space. The detected blobs are represented on the image with their fitted ellipses (Fig 4). The centroid index is also included in its position. The final composition is stored in a graphics file format.

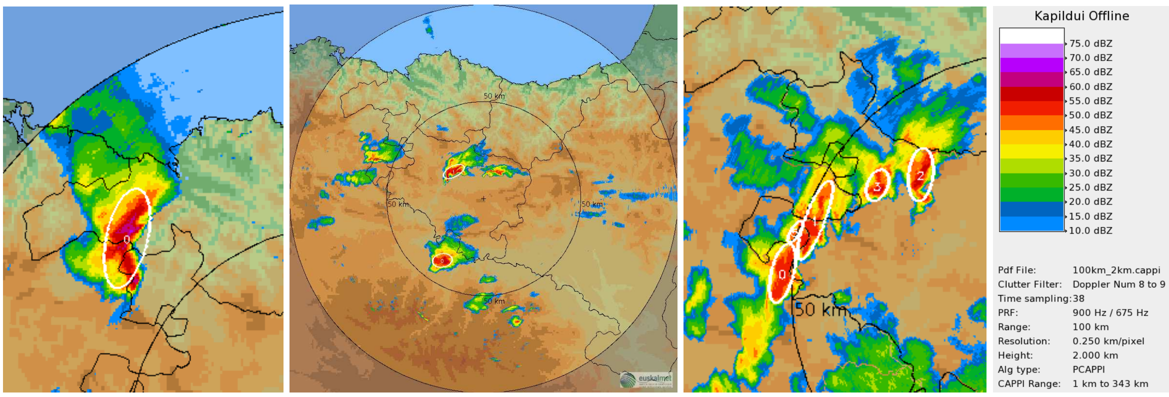

Fig. 4: Example images of warning product. Images correspond to hail storms. Dates: 2006/07/04 14:22 (left), 2009/07/01 14:50 (centre), 2011/05/30 14:00 (right) (note that the static mask of the ground clutter was not operative yet).

4. Summary and conclusions

Basque Meteorology Agency (Euskalmet) responsibilities include issuing severe weather warnings (Gaztelumendi et al 2011). In this sense, the project first establishes internal criteria and thresholds for detection of heavy rain episodes based on data from Kapildui radar reflectivity. The warnings are visible to the user at two different levels: i) the risky areas are displayed together with the PCAPPI product; ii) a summary of risky areas properties are written in a text file.

The module of identification of risky regions from radar data, potentially flash flood precursors, is written in a fourth generation programming language, well suited to digital processing of images. This allows some flexibility to develop operational software for monitoring and nowcasting.

Pre-operational system is a first step in the development of a rainfall early warning system. All the system, including the radar module, must be checked with more detailed studies on severe weather scenarios. In the future we will define other criteria based on different radar products in order to improve the system and complement the information obtained in real-time from the AWS network.

Acknowledgment

The authors would like to thank the Emergencies and Meteorology Directorate (Basque Government) for public provision of data, and Íñigo Hernáez (Adasa Sistemas) for Kapildui radar data processing. Special mention also to David Fanning for his disinterested contribution to IDL open source. We also would like to thank all our colleagues from EUSKALMET for their daily effort in promoting valuable services for the Basque community.

References

Aranda, J.A., Morais, A., 2006: The new Radar of Basque Meteorology Agency: site selection, construction and installation. ERAD 2006, Barcelona, Spain.

Egaña, J., Gaztelumendi, S., Gelpi, I.R., Otxoa de Alda, K., Maruri, M., Hernández, R., 2008: Radar Analysis of Different Meteorological Situations in the Basque Country Area. 5th European Conference on Radar in Meteorology and Hydrology. ERAD 2008. Helsinki, 30 June-4 July 2008.

Egaña, J., Gaztelumendi, S., Pierna, D., Gelpi, I.R., Hernández, R. and Otxoa de Alda, K., 2009: Flash-floods and heavy rain over Bilbao: the first June 2008 case. 9th Annual Meeting of EMS 9th European Conference on Applications of Meteorology (ECAM) Toulouse,, 28 Sep - 2 Oct 2009.

Egaña, J., Gaztelumendi, S., Pierna, D., Gelpi, I.R., Hernández, R. and Otxoa de Alda, K., 2010: Flash-floods on Basque Country at the end of January 2009. 10th Annual Meeting EMS 8th ECAC Zurich, (Switzerland), 13-17 September 2010.

Gaztelumendi, S., Otxoa de Alda, K., Hernández, R., 2003: Some aspects on the operative use of the automatic stations network of the basque country, III International Conference of Experiences with Automatic Weather Stations, Malaga Feb 2003

Gaztelumendi, S., Egaña, J., Gelpi, I.R., Otxoa de Alda, K., Maruri, M., Hernández, R., 2006a: The new Radar of Basque Meteorology Agency : configuration and some considerations for its operative use. ERAD 2006, Barcelona, Spain.

Gaztelumendi, S., Otxoa de Alda, K., Egaña, J., Gelpi, I.R., 2006b: Inclusion of Radar information in the surveillance panel of the Basque Meteorology Agency. ERAD 2006. Fourth European Conference on Radar in Meteorology and Hydrology. Barcelona 18 – 22 Sep 2006.

Gaztelumendi S., Otxoa de Alda K., Gelpi I.R., Egaña J., 2006c: An Automatic Surveillance System for Severe Weather Real Time Control in Basque Country Area. 4th International Conference on Experiences with Automatic Weather Stations. Lisbon –May 2006.

Gaztelumendi S., Egaña, J., Otxoa de Alda, K., Hernández, R., Aranda, J.A. and Anitua, P., 2011: An Overview of a regional meteorology warning system. 11th EMS Annual Meeting 10th ECAM Berlin, (Germany), 12 – 16 Sep 2011

Hernáez, I., Maruri, M., López, J., 2008: Adaptative clutter filtering using statistical radar data and atmospheric propagation conditions. 7th European Conference on Radar in Meteorology and Hydrology, Helsinki.

Hernández, R., Gaztelumendi, S., Otxoa de Alda, K., 2003: Geostatistical estimation of meteorological fields in real-time. III International Conference of Experiences with Automatic Weather Stations , Malaga Feb 2003

Hernández, R., Gaztelumendi, S., Otxoa de Alda, K., Gelpi, I.R. and Egaña, J., 2010: Combining Meteosat data and weather radar products to improve the meteorological surveillance and nowcasting, Proceedings 2010 EUMETSAT Conference. P.57, 6pp.

Maruri, M., Gaztelumendi, S., Egaña, J., Otxoa de Alda, K., Hernández, R., Gelpi, I.R., 2008: Product quality monitoring of Kapildui weather radar during critical meteorological events. 5th European Conference on Radar in Meteorology and Hydrology, Helsinki.

Maruri, M. López, J., Aranda, J.A., and Gaztelumendi, S., 2010: Effects of the Meteorological Conditions Over the Radome of Kapildui Weather Radar and Studies of their Quality Impacts. 6th ERAD, September 2010, Sibiu.

Maruri, M., Abad, V., Alvarez, J., Velasco, J., Romo, J.A., 2010: Design a clutter map and development of control and analysis tools for Kapildui's radar. WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation, Helsinki, Finland.

Orúe, J., López, J., Gaztelumendi, S., Otxoa de Alda, K., García de Andoin, R., Aranda, J.A. and Anitua, P., 2011: Online tool for severe weather real time monitoring and decision making support. 11th EMS Annual Meeting 10th ECAM Berlin, 12 – 16 Sep 2011

Otxoa de Alda, K., Gaztelumendi, S., Gelpi, I.R., Egaña, J., 2006: Use of Automatic Weather Station Data for Daily Weather Analysis. 4th International

Conference on Experiences with Automatic Weather Stations. Lisbon – 24-26 May 2006.