

Design of control and analysis tools from kapildui's radar data

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1. Introduction and objectives

At the end of 2005 the MCD (Meteorology and Climatology Directorate) of the Basque Country installed a C-band Dual Doppler weather Radar, Meteor 1500C, from Selex Gematronik. It is located on the top of a mountain 1000 meters height a.s.l., named Kapildui, in an inland region in the south of the Basque Country. The Basque Country has a complex topography and basins with hydrological characteristics of high flood risk. The purpose of this radar is to complement the hydrometeorological observations, the dense network of automatic weather stations (AWS) distributed along the Basque Country [1] and other meteorological information available in Internet (satellite images), and make up for the hydrometeorological demand of the Basque Meteorology Agency.

In an attempt to achieve a better exploitation in the radar operation, comes up the aim of this work: the development of system monitoring tools based on the analysis of raw data. These tools are low cost tools able to integrate in the operational radar management easily, which are designed with the special attributes to be simple and to emphasize features hidden in raw data. For these purpose, we have explored information from an historical database of volumetric raw data (Z, ZDR, V, W) within a dimension of one year and a half, over a period of time between June 2006 and March 2008.

The results of this study are giving rise to the development and design of new tools, which provide the identification of non meteorological signals and standards associated to this identification. Both results make possible the system monitoring and the stability in the system operation. That is a direct profit incorporated to the system management.



FIG. 1. Instrumental observations of the Basque Met Service.

2. Features of raw data

This work is based on the exploitation of the historical database from the weather radar of Kapildui. These raw data have been obtained from the Meteorology and Climatology Department of the Basque Government under the ETORTEK 2007-2009 project. This database consists of raw data from the operation of Kapildui's radar [2], registered by 4 scans every ten minutes. This means that 6 cycles per hour are done, in other words, 144 per day, except in certain cases of malfunction or breakdown. Two are volumetric scans (Doppler mode and long pulse-300

km, short pulse-100 km), and two elevation scans (one at 339.0 ° and the other at 241.0 °). Data of each scan is divided in 4 variables: Z (reflectivity), V (radial velocity), W (velocity's spectral width) and ZDR (differential reflectivity).

The work is carried out for the second scan because it is a more detailed and higher resolution scan, focused on the Basque orography, and highlights the characteristics of the region. Besides, it has an azimuthal angular resolution of 1°, allowing us to work in a simple way with the tools. This scan has a range of 100 km, with a resolution in distance of 0.25 km. The number of samples taken in range, for each azimuth is 400, corresponding to one sample in each 0.25 km. Furthermore, this volumetric scan has 14 elevation angles: -1°, -0.5°, 0.5°, 1.5°, 2.7°, 4.1°, 5.8°, 7.8°, 10.1°, 12.9°, 16.2°, 20°, 24.6° y 35°.

3. Methodology

The raw data provided by the radar are in a pseudo-XML format. We must use a tool from Rainbow software [3] [4], provided by the manufacturer of the radar, "postprocessing", allowing us to transform it into ASCII format. Then, the data will be in a format that allows to develop tools for this study. To obtain the tools designed for radar scans, there are a series of steps in the scheme of Figure 2 that must follow to obtain it.

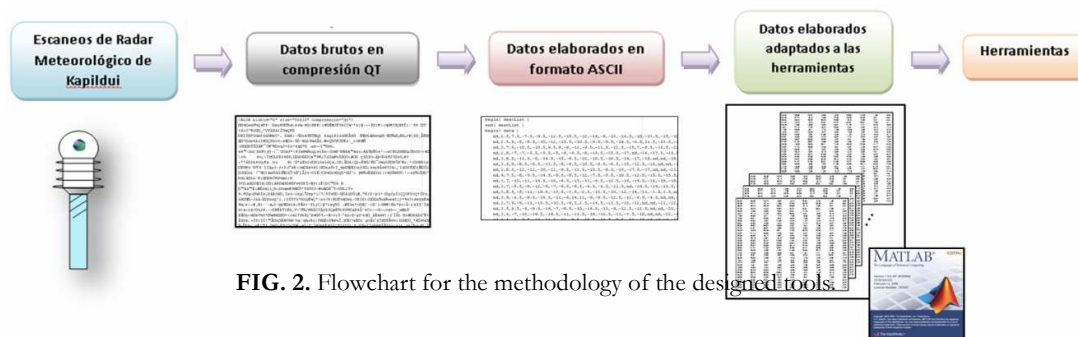


FIG. 2. Flowchart for the methodology of the designed tools.

3.1. Raw data acquisition

The raw data collected in the radar scans are stored in files. They have been organized into a database for a better access. The statistical study of data in .vol files (volumetric scan) and .ele files (elevation scan) gives information about their availability. It shows systematic problems in the operation of the radar and random problems because of other causes. This is the first important step in this work.

3.2. Data conversion

The files provided by the MDC have a pseudo-XML format, divided into a header text in XML format and a series of blocks of binary compressed data. Due to the interest in working with the MATLAB software, we have done a transformation to an ASCII format using the tool "postprocessing" of Rainbow.

All ASCII files follow the same structure: a header and a data block. The data block presents information of each elevation, followed by the corresponding reflectivity data. These are organized according to azimuth angle and distance. Each data represents the value of reflectivity in dBZ of each bin, and our statistics operations will be applied on this data.

3.3. Reading data

The development environment in which has been carried out this work is MATLAB (Matrix Laboratory) [5]. One of its basic features is the matrixes manipulation, which is well suited to the format of processed data.

We extract reflectivity information hosted in ASCII files. This is stored in a matrix of 4 dimensions: 10minutes files (m), elevation angles (14), azimuth angles (360) and distance (400), corresponding to each day. These data are organized bin to bin in Cartesian format, designing a tool in MATLAB software for it. The advantage of having the

information organized in this way is that we can control the format of the files, learning about the operation of the radar.

3.4. Tools

To emphasize the relevant information from radar data, organized into matrixes, and make decisions, a series of tools have been developed as main aim of this work. There are two kinds: statistical and visualization tools.

3.4.1. Statistical tools

The development of these tools is interesting to highlight and interpret the data characteristics. The software MATLAB provides statistical functions (mean and probability) that are used in the design of these tools. Besides, a set of accumulations in different representations are carried out.

The result of the mean operator is the average of reflectivity of each bin of the radar coverage area. The probability operator is the percentage of time that reflectivity of each bin exceeds a specific value of reflectivity. With regard to a set of accumulations, using results of previous statistical operators, these are organized in histograms of three types. They highlight certain features hidden in the data. The first one represents the data over one month, the second allows to follow the evolution of data in one day and the third provides a tool that can be used to track the evolution of the system and monitoring it, by means of each 10minutes analysis, representing the reflectivity between the angle of azimuth.

3.4.2. Visualization tools

To provide a different view of the statistical tools with a better geographic detail, we have developed a set of visualization tools. With them, we can identify the points of greatest impact on a cartographic map. For the design of these tools we have chosen the B-Scope and PPI formats, typical representations of weather radars. These tools have been used to visualize statistics related to data. To this end, we have used own functions of MATLAB.

The B-Scope format shows the input data as a Cartesian diagram, its scale goes from up to down to the azimuth and from left to right for the range. Their input data correspond to probability values. Besides this, for its implementation, we make use functions of MATLAB for image processing.

On the other hand, there are tools that have been carried out on PPI (Plan Position Indicator) representation, using as input the probability or the mean. For this, we must do another transformation, since the data are organized by bins in Cartesian format and we need a representation in polar coordinates.

This toolkit will serve as an alternative to Rainbow. They also bring added value to their visualization tools. Apart from showing the levels of reflectivity, they can be used to represent the statistics values. Consequently, the points with a specific reflectivity or probability value are stored in text files organized in range-azimuth format.

In all cases, the results of MATLAB have been compared with the software Rainbow, to verify that the system works properly.

3.5. Weather characterization

In the previous study on the methodology associated with the historical database and the results obtained from the analysis of other sources (through the Internet), we have carried out a meteorological classification. In order to get a good result, we have used the Euskalmet stylebook. We highlight the days called clear air days, compared to other days with different weather patterns. These allow us to study points which present significant values. Moreover, the information provided by the AWS allows testing and debugging reflectivity data provided by the radar at all time.

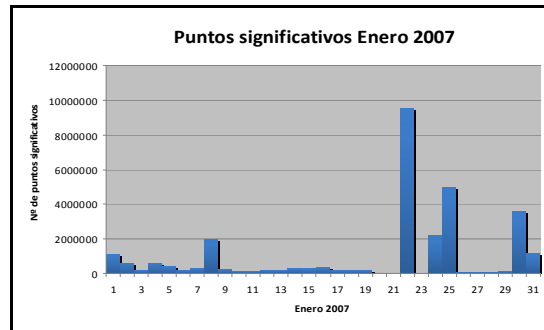


FIG. 3. Monthly volume of significant points.

4. Results

Following are the results of the analysis of historical database with the designed tools. These results will lead to patterns that will be used to identify points of clutter and system monitoring.

For a better understanding of the later results, let's define the concept of 'significant point'. It is a point, defined by its azimuth, range and elevation, where its reflectivity is above a certain value. To set this level of reflectivity limit, an extensive analysis of data has been done. The limit value is defined by 10 dBZ, since it is the reflectivity limit beyond which Euskalmet considers the existence of precipitation. **4.1. Volume of significant points for a particular month**

The graph represents the number of significant points in January 2007, within the database which we work with. It gives a first idea of weather features. We can say that 8, 22, 24, 25, 30 and 31 are not clear air days. In other cases, a more thorough analysis has to be done.

4.2. Histograms

The previous figure shows a histogram with the time evolution of significant points in all the hours in a day. It is a mixed day, which can't be noticed in a monthly view like Figure 3. This histogram is useful to observe its characteristics. The red line indicates the limit of discrimination of clear air. It is defined based on similar behaviour patterns of days with weather characteristics defined (clear air or precipitation).

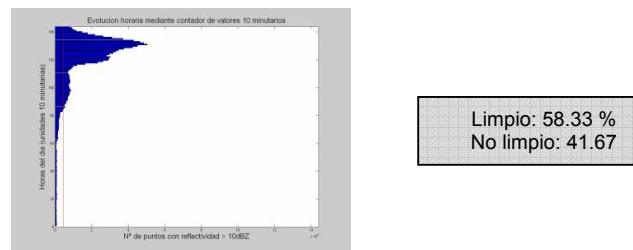


FIG. 4. Time evolution for a mixed day (per 10 minutes).

On the other hand, this tool is also used to detect irregularities in the radar operation, as shown below. In Figure 5, a current day outside the database has been analyzed, in which a radar malfunction is suspected. There are unacceptable variations of significant points in consecutive time moments. This makes no sense from the meteorological viewpoint. It does not match a pattern that would follow a day of clear air.

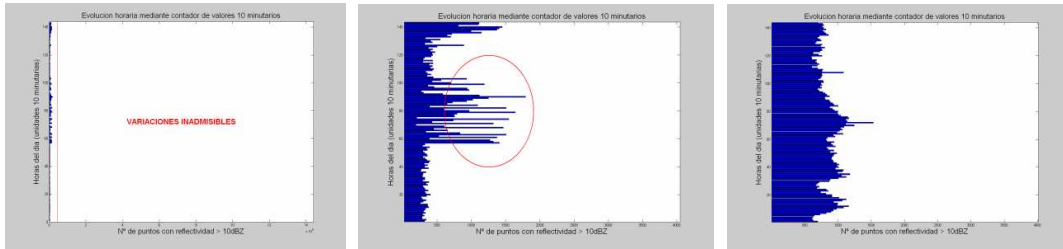


FIG. 5. a) Time evolution of 11/03/2010. b) Figure a enlarged, where an irregular behaviour is observed irregular. c) Time evolution pattern for a clear air day.

From the analysis executed during this study, we have developed an application of the histograms that can help to complement storm tracking tools.

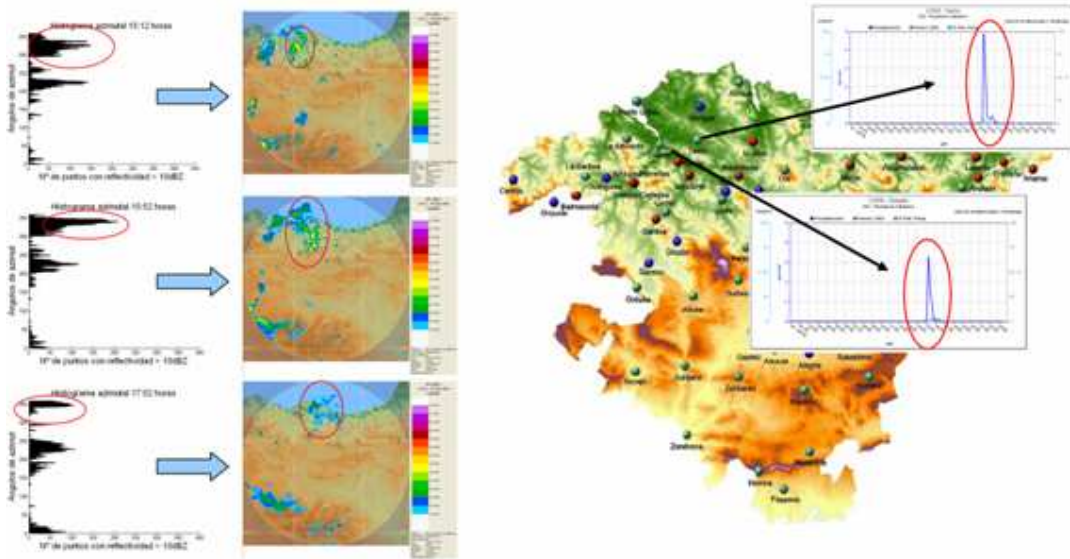


FIG. 6. a) Evolution of the storm through our tools and comparison with Rainbow. b) Evolution of the storm through the AWS.

In each of the azimuth-histograms for a specific time, shows the presence of the evolution of a storm front. This result is suitable to highlight characteristics of the data that remain hidden from observation with other tools. The passage of the storm front is also checked against information provided by the network of AWS.

4.3. Visualization tools

4.3.1. B-Scope

The figure below represents the probability that the value of reflectivity of each point exceeds 10 dBZ. The probabilities are represented by a colour bar from 0 to 100%. The figure 7.a fits to the pattern of a clear air day. Red are the most probably points and appear in both figures, they form a pattern of static clutter. These effects are also applicable to the results of probability PPIs, figure 8. Otherwise, the points whose probability value is between 40 and 70% for a day that has a pattern like in Figure 7.a, can be associated with dynamic clutter, being generated by: aeroplanes, wind turbines, flocks of birds.

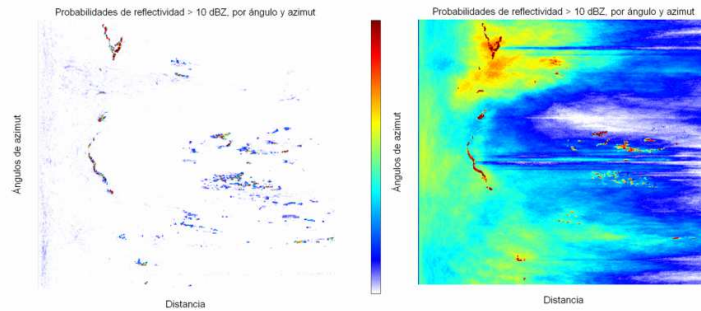


FIG. 7. B-Scope: a) Clear air day. b) Precipitation day.

4.3.2. PPIs

The study of the database using these tools, provides a result that gives rise to an idea of the location and level of the most significant points, in a cartographic representation. This provides an observation of a serial of areas with high probability values, 70-100%, and also high mean values, 40-60 dBZ, forming a pattern of static clutter, which is always repeated. This is emphasized with red circles in Figure 8, and you can see the pattern that follows the clutter. With this result we can watch areas where you can find ground clutter that can be eliminated with the implementation of a clutter map in Rainbow software. [8]

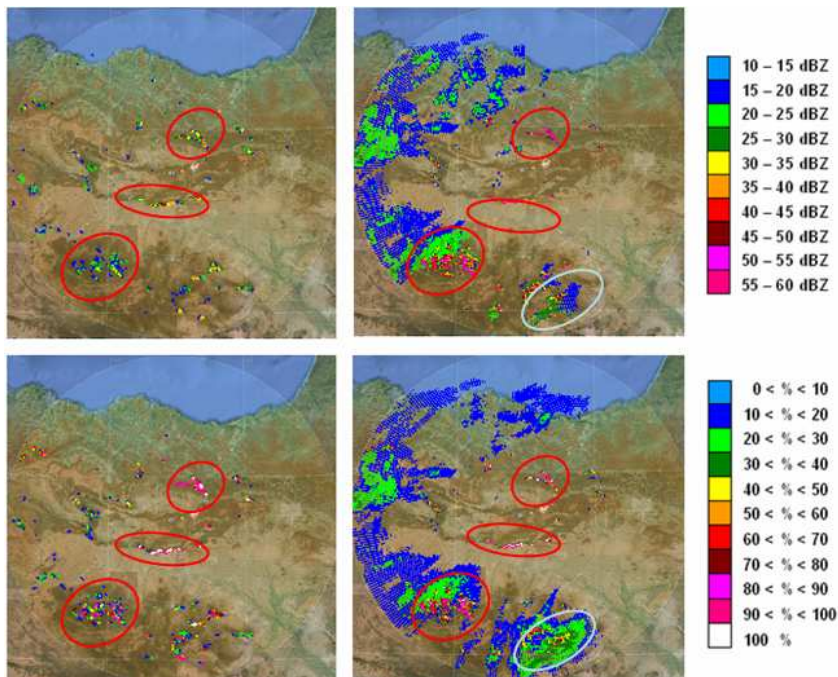


FIG. 8. Top left: Mean PPI for a clear air day. Top right: Mean PPI for a day of precipitation. Bottom left: Probability PPI for a clear air day. Bottom right: Probability PPI for a day of precipitation.

Other finding in this work is the diurnal evolution of clutter, as shown in Figure 8 top right. Significant reflectivity values appear in those points where it has been a storm front.

Based on the results of these two types of visualization for both statistics operations, reflectivity points to points of particular probability (not high) can be associated. These have a value of reflectivity between 20-40 dBZ and a probability value between 40-70%. These points are associated with a dynamic variation of the clutter. This effect is emphasized with blue circles in the figure above. This type of clutter is difficult to correct, because a map can not be implemented in the software Rainbow, so will give rise to the development of future tools based on

other parameters of the radar scan.

An application of these visualization tools is to obtain files that store the points corresponding for a particular and pre-selected reflectivity or probability value. They are stored in a range-azimuth format and will be used for more specific studies like cartographic applications or analysis of clutter.

5. Conclusions

In this work, design of control and analysis tools from Kapildui's radar data, a set of tools have been designed. These allow us to obtain different results: a pattern of static clutter areas, patterns associated with a similar meteorological behaviour and a monitoring of system performance.

The result of these tools provides patterns with similar meteorological characteristics. According to this, we performed a characterization, with the supporting of information provided by other existing sources on the Internet that have been used in this study. Statistical studies serve to highlight irregularities associated with the error detection in the radar operation. These allow continuous monitoring of the system.

Acknowledgements

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