BALTRAD SOFTWARE SYSTEM CONTRIBUTIONS TO KAPILDUI'S RADAR.

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Introduction

One of the methods that the Directorate of Emergencies and Meteorology, Security Department of the Basque Government (DAEM) has for the observation and prediction of the meteorological events is the Doppler polarimetric weather radar, located on top of a 1221.2 m mountain (Kapildui mountain*)*, which is able to locate precipitations at a distance of 300 km around the Basque Country and can also to measure its intensity, evolution and trajectory.

Since 2007, many projects are carried out by students and teachers of the Department of Applied Mathematics and the Department of Communications (Faculty of Engineering of Bilbao - University of the Basque Country UPV/EHU) in collaboration with the Basque Meteorology Agency - EUSKALMET, in order to analyse the historical database of the Kapildui radar.

In 2012, the possibility was raised of integrating inside the DAEM system, an open source/access prototype capable of controlling the processing and distribution of the data, both online and offline. The purpose was using it as a complement of the methods used at that time and providing different clients of EUSKALMET a free and easy to use alternative to handle radar information in a simple way.

After a study of different possibilities, the idea of using the BALTRAD software was considered, due to the compatibility between the data supported by this system, and the Kapildui data and network structure of EUSKALMET. Therefore, taking the BALTRAD tool as a reference, the aim was an adaptation and configuration of the tool according to the potential customers, in order to assess the influence and contributions of the software.

Furthermore, seeking to increase the capability of the radar services, it was decided to do a study of the various filtering techniques offered in the BALTRAD bRopo package, in order to make a quality mask applicable to the radar and its historical database, by selecting the most effective search techniques and the optimal values for each of the parameters that make up each filter.

1 Aims and Methodology

The work has two main objectives directly related to each other: BALTRAD communications in a network and the distribution of quality data among this network:

To do this, a communication network is designed connecting the various tools that are used in EUSKALMET, enabling radar data to be distributed and managed by BALTRAD, with the purpose of evaluating the various improvements and contributions the tool offers when handling information, taking into account different aspects of operations of the radar and the use of it by the potential clients of the Agency. The other aim is to identify, select and evaluate the bRopo package.

The methodology used to achieve these objectives is divided into three different blocks as it is shown in figure 1: Preparing the BALTRAD node, General BALTRAD configuration and Study of bRopo.

1. After studying the BALTRAD documentation and making a proposal of the network, the first stage consists in preparing the main node, focusing on the choice of the operating system, installing and adapting BALTRAD to the Kapildui radar, according to different options, such as a complete configuration for this radar, a basic installation for users with meteorological data or users whose only purpose is to receive this data, i.e., a minimal installation.

2. Once the node is configured, the next step is the configuration of the different options that BALTRAD offers (Products generation, distribution and data exchange) according to the initial proposal of the network done in the preceding point. Another series of alternative methods of distribution are also implemented in the network to provide greater variety to the current ones.

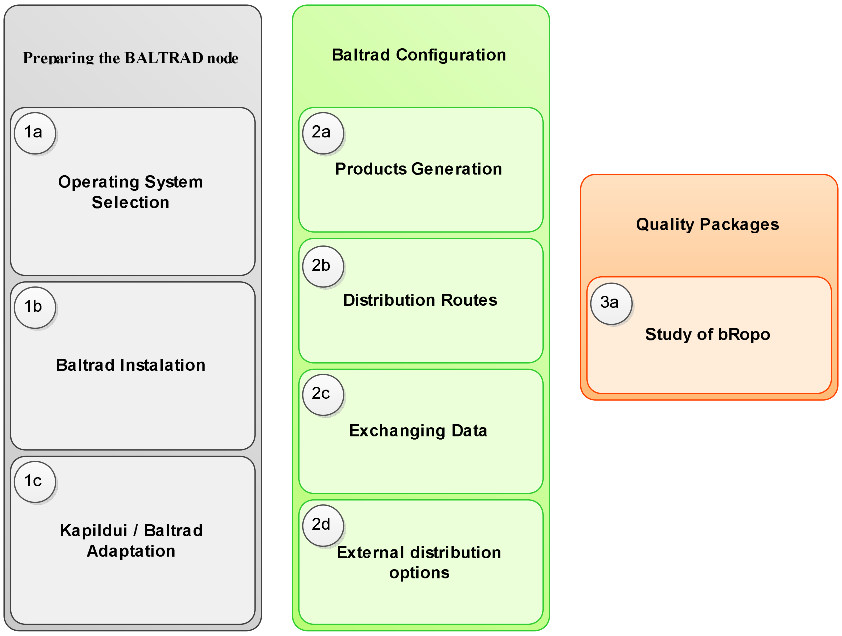


Figure 1: Methodology.

3. Finally, the work focuses on the study of bRopo module applied to the Kapildui database. This module provides filtering techniques that are attractive for a radar located in complex terrain.

The database used for the study consists of days selected from a historical database between 2011 and 2013. The criterion takes into account the type of unwanted echo that is necessary to filter, based on their seasonal variability and/or weather. To sum up, days of clean air and days with precipitations are analyzed, and these days are classified in two blocks: in warm seasons (spring and summer) and seasons with bad weather (autumn and winter).

The anomalies or unwanted echoes processed in the bRopo package are static and dynamic clutter, speckle noise, biometeors, second trips and solar and electromagnetic interferences. In total, the number of simulations that have been included for each filtering technique in this study has been 340, as shown in the following figure.

FILTRO	Nº de simulaciones incluidas en los anexos
Sun	33
Speck	26
SpecknormOld	56
Biomet	45
Softcut	45
Clutter	35
Clutter 2	20
Emitter	36
Emitter 2	44

Figure 2: Number of simulations for each filter.

The test begins with the selection of a filter and its associated study days. Then, the default parameters recommended by the manufacturer are tested. In a second step, the topography in which the radar is located is considered and the behaviour of the filter is analyzed by varying each parameter separately. This is the first phase, called "Evaluation of the parameters".

Once enough tests are done to understand the behaviour of the parameter, a range of optimal values for each one are selected and a wide number of combinations are performed to obtain the most appropriate combination. This is the second phase: “Parameter combination”.

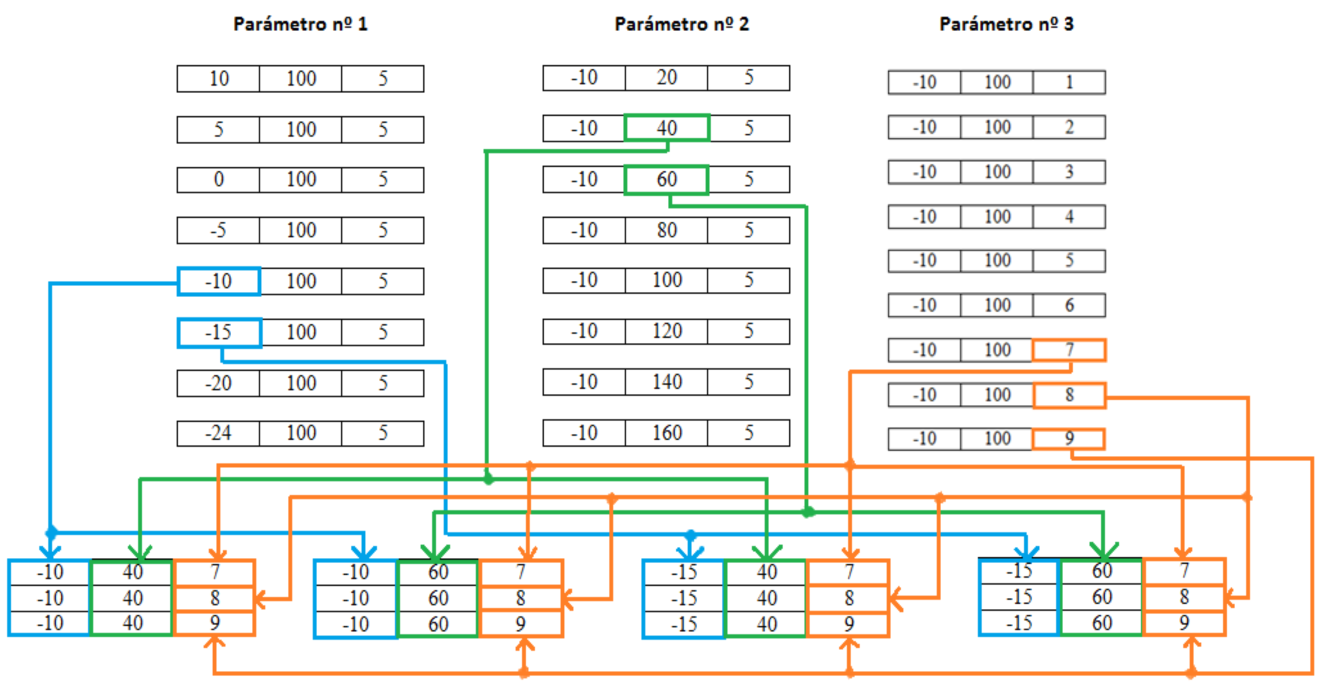


Figure 3: bRopo Methodology , Phase 1 & 2.

For example, in the Fig. 3, were selected as effective values, two values from the parameter #1 (blue squares), two from parameter #2 (green squares), and three values from the parameter #3 (orange boxes). After that, these values are combined between them seeking a higher precision result.

In order to analyze the results and define the efficiency of each filters, some visual and quantification tools have been developed. To know which proof is more accurate, is performed a subtraction of the filtered images from the original, quantifying in this way the amount of anomalies eliminated. In the bottom of the last column of Fig. 4 it can be seen a summation with the exact results, which allows to control the filter efficiency objectively. Third phase: “anomalies quantification”

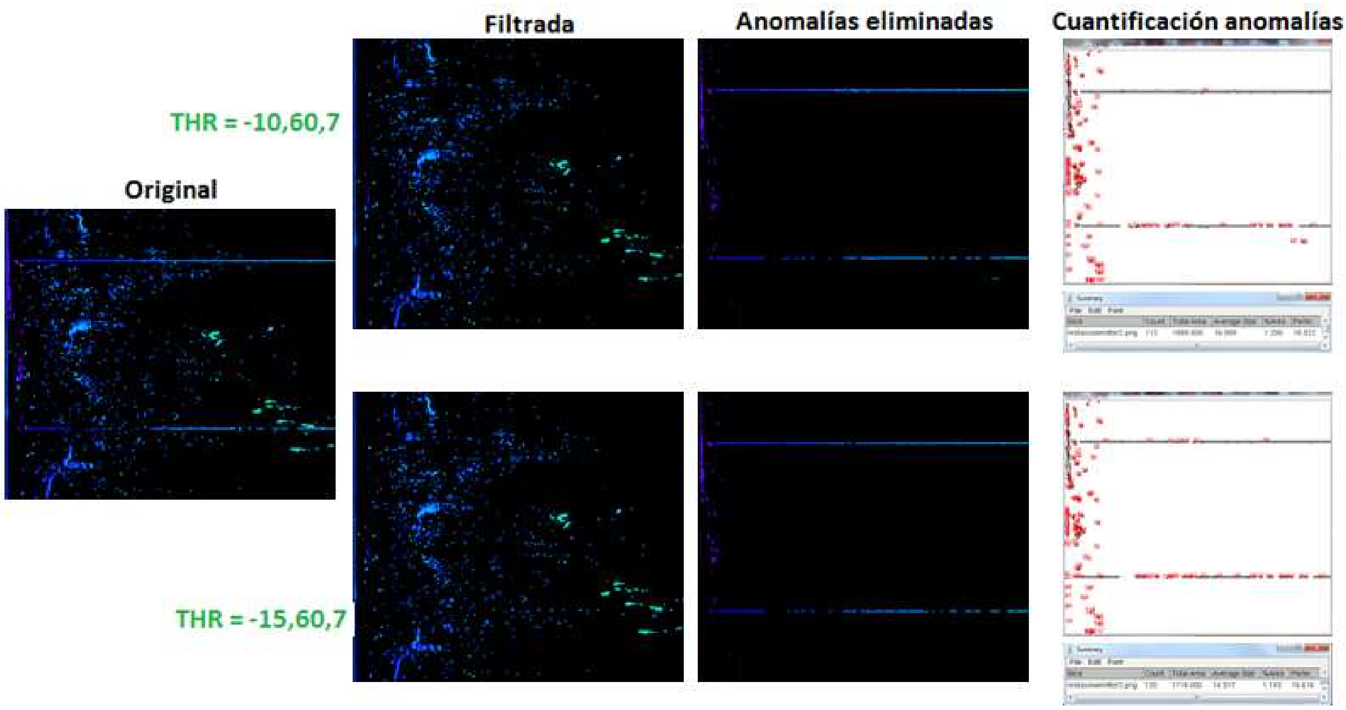


Figure 4: bRopo Methodology, anomalies quantification.

Once all the tests are done, all the result are collected and put together, grouping them in a table as can be seen in Fig. 5. Fourth phase: “Grouping results”

Nº DE PRUEBA	THRESHOLD	NIVEL DE EFICACIA	OBSERVACIONES	Nº DE ANOMALIAS ELIMINADAS
1	-20,3,3	Bajo	No funciona	103
2	-24,3,3	Alto	Elimina tanto el segmento de línea producido por el sol como la línea procedente del emisor externo	112
3	-24,1,3	Bajo	No funciona	98
4	-24,2,3	Alto	Elimina tanto el segmento de línea producido por el sol como la línea procedente del emisor externo	112
5	-24,4,3	Medio	No elimina completamente la línea procedente de otro emisor. Por otro lado el segmento de línea solar es eliminado correctamente.	107
6	-24,10,3	Bajo	No funciona	98
7	-24,3,1	Alto	Elimina tanto el segmento de línea producido por el sol como la línea procedente del emisor externo	120
8	-24,3,2	Alto	Elimina tanto el segmento de línea producido por el sol como la línea procedente del emisor externo	111
9	-24,3,5	Alto	Elimina tanto el segmento de línea producido por el sol como la línea procedente del emisor externo	114
10	-24,3,30	Alto	Funciona muy bien, en aire limpio se puede subir este parámetro, ya que no existe precipitación que compita con la radiación solar, ni la emisión electromagnética.	112

Figure 5: bRopo Methodology, grouping results.

The fact of grouping the filters, is carried out to offer the possibility to compare and examine more easily and quickly the differences between all the results. In the fourth column, we can see a few comments about the processed data and the comparison of images, and a note about how each parameter affects the filtering of the image or the visual features that a image have when comparing to another example.

Thanks to the comments, each test can be catalogued with an efficiency value. The level of effectiveness is chosen objectively (numerically, as seen in Fig. 4) and in a subjective way, based on the knowledge gained during the study. It can be categorized as low, medium and high. It will be low when the filter does not work as it should, medium when the result is close to what is expected but the quality is not good enough, and high when the result is optimum.

All those tests that have a high level of efficiency, and have a gray background to differentiate them from the rest.

Summarizing, with this methodology, we wanted to analyze the effectiveness of all filtering techniques, studying a great variety of different situations, in order to observe their behaviour and to understand the operation of each filter.

2 Results

The results of the evaluation are presented at two levels, related to the objectives.

Regarding the radar and the network, the following assumption has been made:

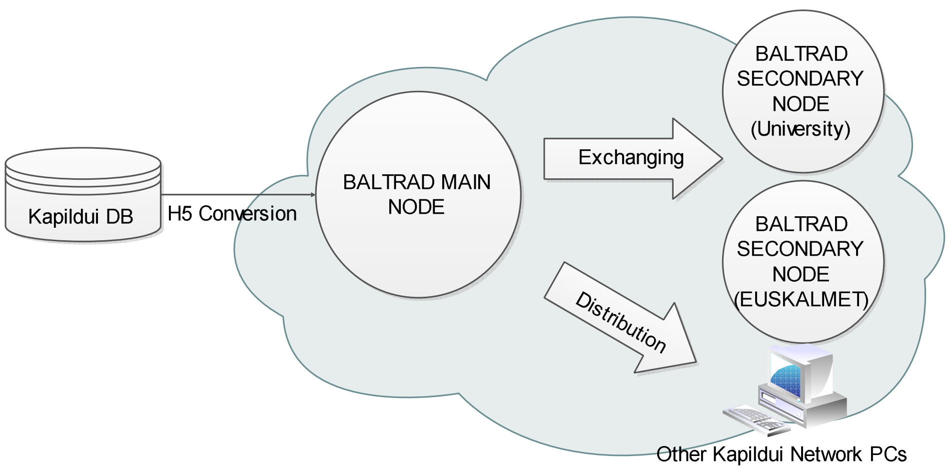


Figure 6: Kapildui Network..

The engine of the network is a main node in which the data from Kapildui is added. First of all, it is necessary to convert the raw data generated by the radar, in XML format, into ODIM_H5 format which is supported by the BALTRAD system. This node distributes the converted data to the secondary nodes, such as the workplace of the University of the Basque Country or EUSKALMET, as well as to other machines located at these sites or other machines using the current tools. As it will be seen later, thanks to the distribution methods offered by BALTRAD, there will be a large variety of possibilities to share and exchange the data.

Regarding the BALTRAD tool, after its installation on multiple Linux-based operating systems and their respective versions of 32 & 64 bits, the most stable system for our needs was CentOS 6.4 64-bit version was determined. Therefore, the final installation of the software is made on this operating system. Concerning the hardware requirements, the only main need was installing it in a 64-bit machine, because it is only handled a single radar and the amount of the distributed data is not high, so a system with big features is not required.

To facilitate both the installation and configuration of BALTRAD, some shell-script executables have been created, making this process automatically, depending on who the final user of the system is.

For data distribution, all the distribution methods offered by BALTRAD have been properly configured, such as the exchange between nodes, Apache Server with Google maps plugin, FTP, SCP, Local Copy and the optional methods, SSH and SAMBA in order to facilitate the access between computers with different operating systems.

The volumetric files of the Kapildui radar, both the short pulse of 100km, as the 300km long pulse, in the Z, ZDR, V and W variables, are compatible with BALTRAD. With regard to the products, PPIs from the “PVOL Route” have been successfully generated for each of these variables. Moreover, some different products have been generated with the “Composite Route” for the ZDR Variable: PPI, CAPPI, PCAPPI and MAX. We can see in the next pictures some examples of the “Composite Route” for the Kapildui radar, represented in the Apache Server.

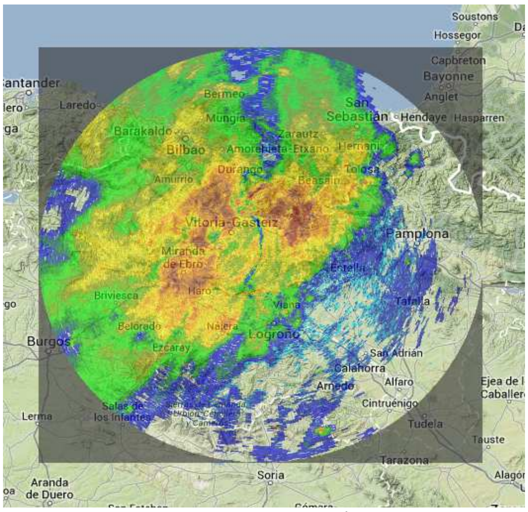


Figure 7: PPI 0.5º Google Maps.

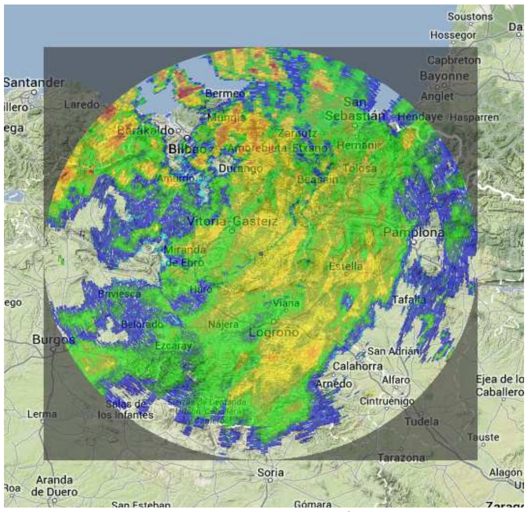
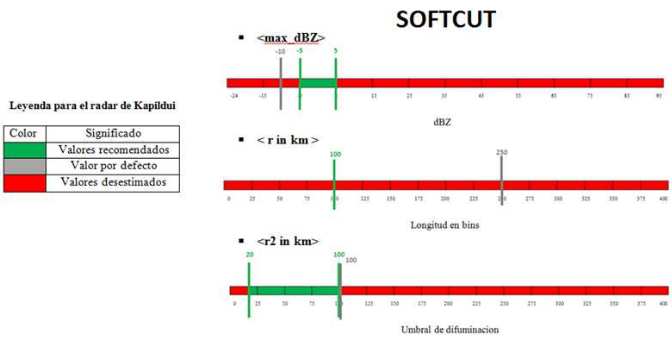


Figure 8: CAPPI Google Maps.

Regarding the results obtained from bRopo, after completing the test phase with each of the parameters, in the next point the most effective values will be presented for all the filtering techniques under Kapildui’s radar conditions.

In figure 9, there is an example of the SoftCut filter. As can be seen in the legend values, the ones in green are optimal for Kapildui, while those in red are discarded. The default value given by BALTRAD is marked in gray.



Figuge 9: effective values of the SoftCut filter.

In the next picture it can be seen the level of efficiency obtained with the SoftCut filter for Kapildui. (On the left, the default parameters recommended by bRopo and on the right the recommended parameters by this study)

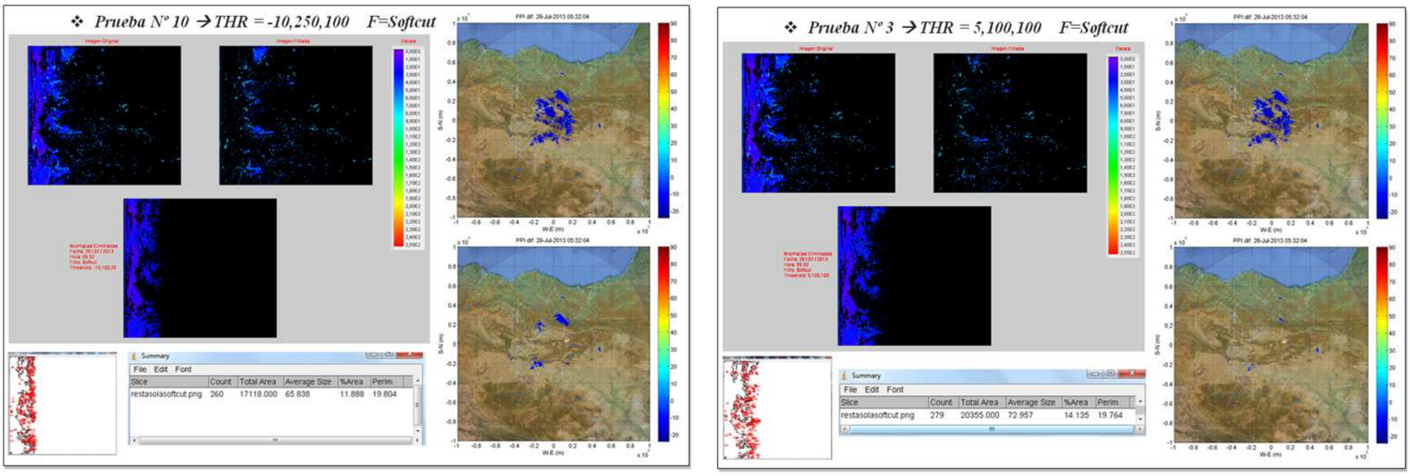


Figure 10: b-scope, PPI & anomalies quantification of the SoftCut filter.

Below there are more examples, demonstrating the importance of selecting an ideal parameter sequence to deal with the errors that appear on the Kapildui radar.

Located in the left column are the simulations with those parameters recommended by default and on the right simulations with those recommended by this study for our radar

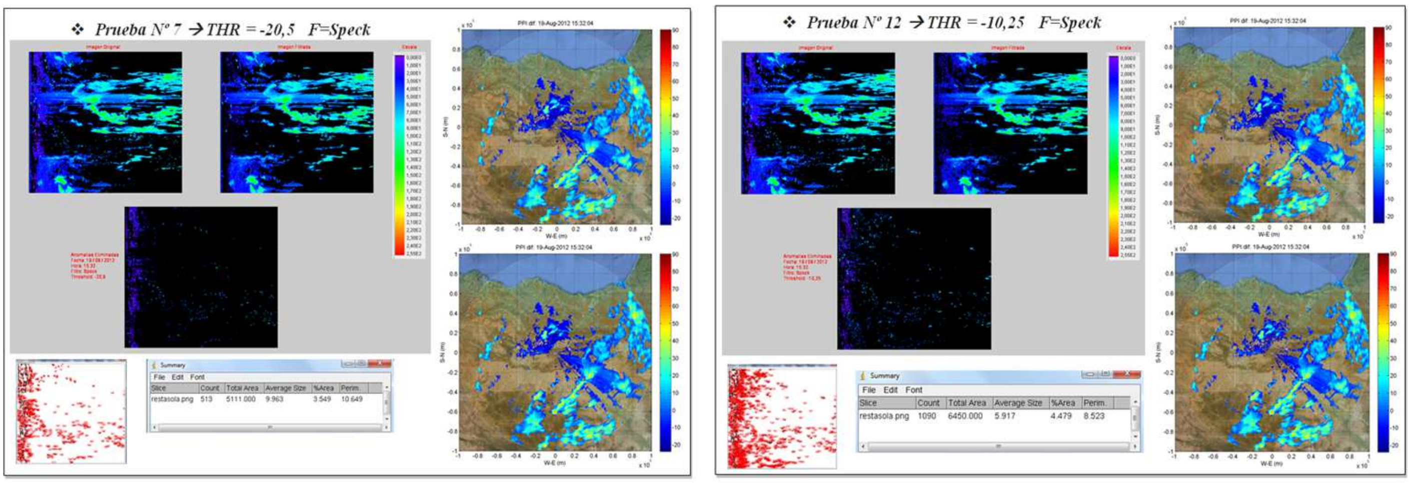


Figure 11: b-scope, PPI & anomalies quantification of the Speck filter.

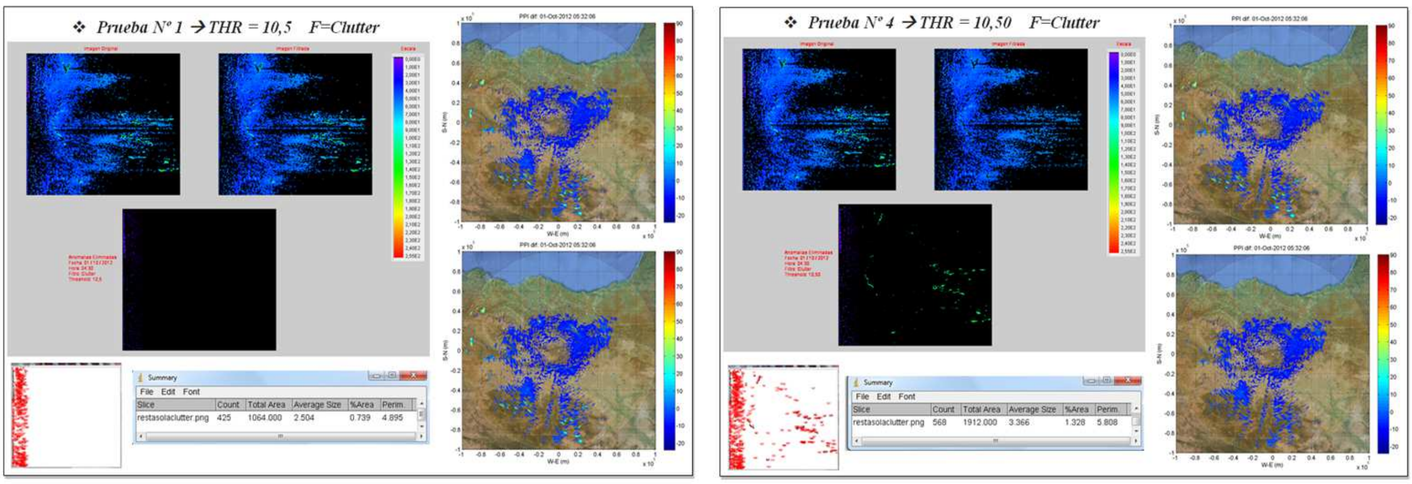


Figure 12: b-scope, PPI & anomalies quantification of the Clutter filter.

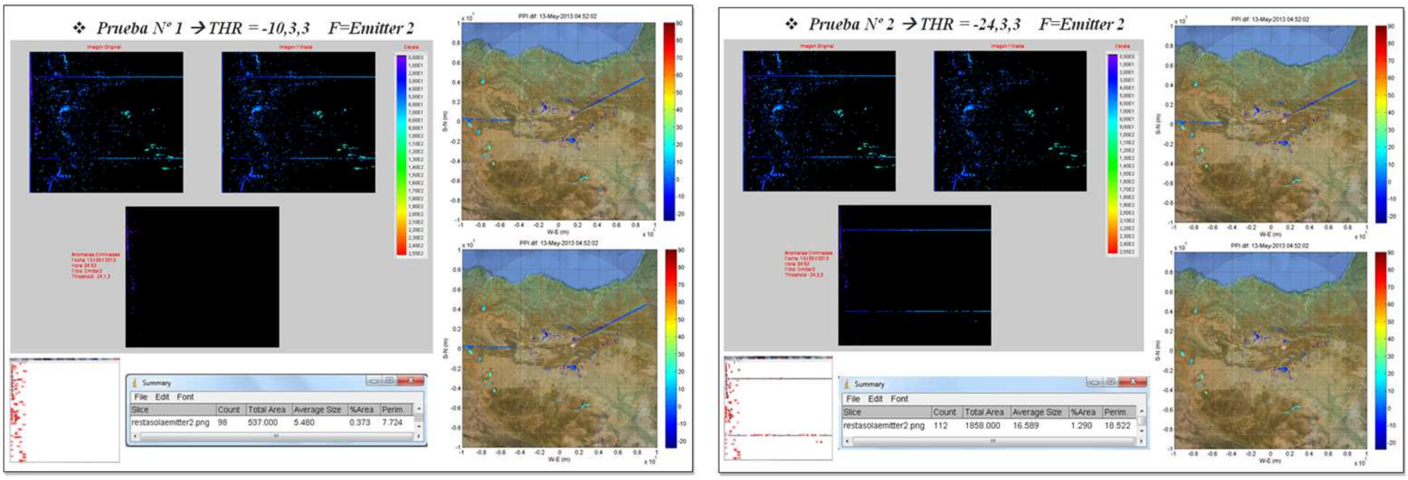


Figure 13: b-scope, PPI & anomalies quantification of the Emitter filter.

Finally, after analysing all the results obtained with each filter technique and assessing the reached conclusions, it was decided to set up a quality mask listing the filters sequence better suited for the processed data from Kapildui. The sequence depends on the strength and effectiveness of each filter. It also includes the exact value for each parameter for improving the original database of Kapildui.

1. → **SPECK - THR = -5, 9**
2. → **SOFTCUT - THR = -5, 100, 50**
3. → **EMMITER 2 - THR = -24, 2, 5**
4. → **CLUTTER (only for situations without heavy precipitations) - THR = 10, 50**
5. → **SUN - THR = -24, 100, 3**

3 Conclusions

After deploying the BALTRAD prototype, it is concluded that the main objective has been achieved successfully. From the files generated by the radar, the BALTRAD software is able to process many of the products used nowadays and distribute them properly according to the needs.

The volumetric files currently generated by the software of Kapildui are supported by BALTRAD, and the most common products generated by the current tools, have been successfully processed. The two elevation scans performed by Kapildui have not been studied in the work. BALTRAD offers a wide variety of distribution methods and new alternatives for the availability of the data generated by Kapildui.

As mentioned in the introduction, due to the characteristics of BALTRAD, it could not be used as a main software, but it would be a great complement of the current tools. In addition, due to its open source and open access, plus the previous good documentation available, (user guides and BALTRAD TRAC) and the extra information added with this work (manuals and scripts), it is considered a good free tool for potential users of the radar and EUSKALMET.

Looking ahead, several aspects that have not been treated in this work could be studied. On the one hand evaluating the possibility of integrating the other radar located in the Basque Country, inside the “Composite Route”, in order to improve the display of weather events across the region. On the other hand, studying BALTRAD Cookbook and all the different algorithms available there, with the aim of improving the data obtained from the radar, and offering our own inputs to the system.

On the other hand, it is considered that the quality module bRopo is a useful tool for anyone involved in the field of meteorology as it offers a wide and diverse collection of filtering techniques.

Due to the complex topography of the area covered by the radar, as previously mentioned, it is possible that the default values recommended by the bRopo package cannot fit the analyzed radar, so it is suggested a previous study of the topography problems to avoid filtering mistakes. According to our experience, each filter should be tested with a large database with the aim of achieving the best possible performance.

Moreover, the filters have detected all the anomalies in a satisfactory way and they usually fulfil the task for which they are designed. However, when removing such anomalies, in a few cases these filters show some limitations.

Thinking of future works, a more extended study could be done with the obtained results using a larger database, doing further investigation and trying a combination of the filtering techniques in a single simulation. It was decided not to mix filters for this study, avoiding in this way misinterpreting the individual behaviour of each one.

Acknowledgement

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