Design an operational clutter map for Kapildui´s radar

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1. Introduction

Due to the exponential demand about meteorological information by users (civil protection, etc.), it is necessary to improve the observations of hydro-meteorological data (high resolution time-space). It is for this reason that the Meteorology and Climatology Department of the Basque Government (Basque Met Service-EUSKALMET) installs a C-BAND METEOR 1500 Dual Doppler Weather Radar in Kapildui, inland in the south of the Basque Country.

One of the goals of Met Service is to improve data quality, accuracy and availability. To do this, this work is focused on reducing those bins associated using ground clutter reflectivity by a conservative clutter map that could be included in the operation of the radar. This would improve the products generated from the corrected raw data. The design of this clutter map is not an easy task, because clutter presents a high variability in time with this type of raw data.

To achieve this purpose, one year and a half historical database will be used. The study of this database results in the classification of clutter data into two groups. On the one hand, data that keep more constant over time, and on the other hand, data that present a higher variability.

This work focuses on identifying the most static bins and their subsequent elimination. In this paper, the methodology and procedure to obtain the aim of improving the quality of raw data removing the ground clutter is proposed.

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

2. Aims

The main aim of the project is to design an operational clutter map. This clutter map attempts to identify reflectivity data which, being induced by the topography, are not filtered by the Doppler filter that is available on the radar and which appear with very high probability. Therefore, the work is based on analyzing the behaviour of the filtered raw data over time.

As shown in the figure, the implementation of the map is carried out using the manufacturer tools so that is not required a special adaptation.

The clutter map is designed to remove most affected points by clutter in time. This is the reason for calling it static map or conservative map. The work will mainly consist of the implementation of a clutter map associated with the high resolution volumetric scan.

From the work come up secondary objectives as the study of the feasibility of carrying out scans at elevations below 0° since these elevations there is always impact with the ground (optimization of the geometry of high
resolution volumetric scan) and whether the use of these scans with low elevations could be useful for system monitoring tasks.

Static points from which the map will be created, can serve as monitoring tools.

3. Methodology

For the design of this map, it is required, first, an exhaustive study of the historical database provided by the Department of Meteorology and Climatology of the Basque Government, and the potentials that the system currently provides.

The database consists of data registered by 4 scans every ten minutes: Two volumetric scans (short pulse-100 km, Doppler mode and long pulse-300 km) and two elevation scans (one pointing to NW (339.0°) and another pointing to SW (241.0°)). All of them operate in polarization mode.

Data from each scan and variable are stored in a separate file. The variables are Z, V, W and ZDR. Z is horizontal reflectivity from the target. V is radial velocity (it is the velocity of target parallel to radar beam). W is spectral width. ZDR is differential reflectivity. For 100 km volumetric scan there are Z, V, W and ZDR data. This scan has fourteen 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° and 35°.

### Table 1. Most relevant second scan characteristics.

<table>
<thead>
<tr>
<th>Mode Features</th>
<th>Scan Type</th>
<th>Data types</th>
<th>Execution time (s)</th>
<th>Angle Step (°)</th>
<th>Range Step (km)</th>
<th>PRF (kHz)</th>
<th>Maximum Range (km)</th>
<th>Scan Strategy</th>
<th>Number of Elevations</th>
<th>Lowest Elevation (°)</th>
<th>Highest elevation (°)</th>
<th>Filter Mode (URDopples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Scan</td>
<td>Vol</td>
<td>Z, V, W, ZDR</td>
<td>383</td>
<td>0.25</td>
<td>900/675</td>
<td>100</td>
<td>S</td>
<td>Optimised</td>
<td>14</td>
<td>-1.5</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

This paper uses essentially the variable Z. However, it will be necessary to carry out some views of the variable V to obtain the behaviour of the clutter points. Steps associated with the methodology are:

3.1 GIS tools (Geographic Information System) -> Global Mapper

In the second place, radio propagation simulations are made with a theoretical model that allows us to know how far and which elevation beam intersects with the terrain.

3.2 Manufacturer tools -> Rainbow

Next step will be check, with the tool installed on the radar, that if reflectivity values that don’t correspond with reality, appear at the points designated as static clutter. The software used in this case is Rainbow, specifically RainDART and 3DRave applications.

3.3 Internally developed tools -> tools developed with Matlab

Then, internally developed tools [8] will be used to monitor the system from another point of view and obtain additional information about it.

3.4 Implementation of the clutter map

Finally, a conservative static clutter map will be implemented for each elevation (only for the lowest elevations, since the clutter does not affect to elevation angles greater than 1°) from previous results correct interpretation, and an appropriate parameterization of the radar software that allows a more accurate estimation of hydro-meteorological phenomena.
4. Results

The results are going to be presented following the methodology applied.

4.1 Global Mapper

With this tool different results are got. First, it can be checked that a -1° elevation scan has a high impact with ground surface:

Another outcome is to get the first elevation that is not affected by clutter. Although the following elevations do not belong to any actual Kapildui radar scan, they are used in this propagation model to obtain, theoretically, the minimum elevation that is not affected by static clutter.

0.5° is an elevation that is used in the operation of Kapildui and, from this, in different weather conditions, the impact of terrain variation is shown.

New representations of radio propagation from Kapildui for different values of k (propagation constant) are made. It is noticed that under favourable conditions, with k = 5/6, the impact on ground’s surface would be lower while in adverse conditions with k = 1/6, the impact with ground increases.

To see the variability in factor k, a sequence of representations is attached then (from k = 2/3 to k = 1.6) for the same elevation (0.5°).
4.2 Rainbow

Real data from clear air conditions and precipitation days are used in this task. With clear air days data, the outcomes obtained from Global Mapper are verified, while with precipitation days data, blockades are determined.

Example of clear air day:

a) ![Clear Air Day Global Mapper](image1.png)

b) ![Clear Air Day Rainbow](image2.png)

FIG. 6. 100 km scan with 0.5º elevation with a) Global Mapper y b) Rainbow

Under precipitation conditions:

a) ![Precipitation Day PPI](image3.png)

b) ![Precipitation Day Range-Azimuth](image4.png)

FIG. 7. 100 km scan with 0.5º elevation a) PPI, b) rango-azimut

The distances from the field to each of the scans, from which no data is obtained due to a total beam blockage, are summarized in the following table:

<table>
<thead>
<tr>
<th>Scan</th>
<th>Elevation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric</td>
<td>-1</td>
<td>8.6 at</td>
<td>34 between 253º and 255º</td>
<td>Most azimuth reach a circumference of about 20 km of radius</td>
</tr>
<tr>
<td>with 100 km range</td>
<td>-0.5</td>
<td>9.5 at</td>
<td>100 between 333º and 339.5 except to 339º</td>
<td>Many azimuths reach a circle whose mean radius would be about 22 km. In the SE and NW directions the scope of vision is about 70 km.</td>
</tr>
<tr>
<td>0.5</td>
<td>19 at 200º</td>
<td>100</td>
<td>Almost azimuths will reach 100 km without any impact with ground. However, beam only reaches 35 km at 326º, 26 km in azimuth between 30º and 41º, 25 km at 48º, 20 km at 134º and in the sector between 172º and 226.5º, the vision is 50%</td>
<td></td>
</tr>
</tbody>
</table>

This software is also used for the implementation of the clutter map.

4.3 Tools internally developed with Matlab

Monitoring and analysis Tools developed in Matlab are used to obtain PPIs of probabilities and PPIs of means, and from this, to know with accuracy what are the points that present a high impact of ground clutter. With PPIs of probabilities, the bins that with a probability of 100% (IN white in figure a) are higher than 10 dBZ (value at which it is considered that competes with precipitation) are obtained. In addition, those bins must match in all analyzed PPIs to be considered static ground clutter.
Otherwise, the PPIs of means, show the points that have very high average on their reflectivity values (average between 55 and 60 dBZ -> dark magenta).

Most of the points that form the clutter map present high reflectivity values and they are kept static over time. Also, these points should match to the PPIs of means analyzed.

To obtain a conservative static clutter map that eliminates, exclusively, information that is not due to weather phenomenon but to the mountains or relief areas where the radar beam intercepts, it is required to carefully choose bins with a high probability of being ground clutter as well as having reflectivity values with very high mean and very low variance. Taking the example of the day June 2, 2006, a clear air day:

![Image](image1.png)  
**FIG. 8.** PPI 0.5° elevation a) of probabilities, b) of means

### 4.4 Clutter map

Based on the information provided by the preceding sections and changing the parameters of the software available on the radar, it will be got a clutter map that will remove only the echoes caused by the terrain, keeping the reflectivity due to weather phenomena.

The radar of Kapildui implements a Doppler filter so that the data found in the historical database has already been pre-processed. Then, these data will create a clutter map. To create this file with .cmap extension, it will be necessary to work with clear air day data, in which all reflectivities are due to beam impact with the ground. On the other hand, a new task from 3D clutter map and data processing (.3dcdp) will be created. This pre-processing needs previous clutter map and a terrain file with elevation data. In this case the file will have Kapildui as a centre and 100 km of radius.

### 5. Conclusions

It is analyzed one of the errors that causes a high impact in the exploitation of weather radar; the error due to ground clutter. The clutter map removes ground clutter like conservative form to not ignore interesting hydro-meteorological data. A radar rainfall retrieval in complex orography should basically try to solve the problem of beam blockage in order to provide a useful hidrometeorological product. In designing the static clutter map, not all bins that are seen appear constantly in time but with high variability, and this effect is accentuated because it is applied to previously filtered data. The clutter map must contain only those points that have high probability and mean and low variance.

This map is useful in the operation of the radar. Clutter maps are made for 100 km range volumetric scan. This was decided because this is the scan with higher range resolution and the azimuth resolution of 1 ° facilitates programming tasks. However, the outcome achieved with this work may be extended to the 300 km scan and / or other weather radars.

In a complex orography, like in the País Vasco, surface rainfall might be even not observed at all for a large portion of the radar volume scan. Indeed the blockage of the radar beam (and the inability to use very low elevation scans except in some parts of the domain) can arise at any radar site, even at low levels, if it is badly chosen. With such comprehensive study, the optimization of the operation of the radar has been achieved. It states that the minimum elevation angle for which the beam does not impact with the ground is 1°.

Therefore, implemented clutter maps will be in any case for elevation angles below 1 °. The geometry of 100 km scan is improved. It is not interesting to have many scans below 0° and, if possible, it is interesting that these elevations coincide with those of the 300 km scan.

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