Study on Radar Signatures of Hail in the Basque Country

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Abstract

Identifying the signatures of hail is one of the challenges in the Basque meteorology Agency (EUSKALMET) of the Directorate of Emergencies and Meteorology, (DAEM), Security Department of the Basque Government. The Basque Country has a complex topography not only because of its mountains, but also because its surroundings, including the Cantabrian Range and the Iberian System.

Hail storms are the reason for many accidents that cause human and economic losses. The damage depends on the intensity of hail and its trajectory. The goal of the study is to improve the understanding of the mechanism and the identification of radar signatures or radar patterns associated to hail.

The polarimetric doppler weather radar is the best observation system, available in the area of Basque Country, to follow the evolution of storms. It is located inland, which means that it covers all the convective process from the origin to the end and offers good temporal and spatial resolution.

The methodology is based on gathering the maximum number of cases of hail storms from different sources: radar observations, metar (direct sources) and traffic information, facts derived from hail impact on vegetation or other objects, and new/social media (indirect sources).

Once the information is reviewed, only those cases in which the hail is verified in time and space are used in this study. Hail size is also an important feature but it is the most subjective information. Therefore it is used as complementary information. The meteorological situation, the weather warning and real-time information delivered by EUSKALMET, were studied together for verification purposes to improve future forecasts.

The results of the study reveal that the parameters of the Zhail product have a dependency on the meteorological situation (winter versus summer signatures). Finally, combination of radar products and signatures of degradation of the quality of the radar, and other meteorological sources are verification tools for Zhail product.

1 Introduction

A hailstorm is a natural phenomenon that can cause great economic losses in rural areas (crops, trees) and urban areas (cars and property). While it is not one of the main causes of traffic accidents, a sudden hailstorm causes collisions with property damage and even injuries and fatalities (351, 2.3% of all injuries and fatalities in 2013), as reflected in the statistical yearbook of traffic accidents of the Basque Country (2013) and press releases (fatal accident-@DiarioVasco Feb, 08,2013).

Moreover, hailstorms do not spend much time in the news, their presence during a sports event, outdoor public event is described by reporters as “they carried on despite the strong hail …”, or “the beautiful landscape it leaves behind…” and the dissemination of images, comments and descriptions of the phenomenon on social networks, blogs (web pages), forum (web page) (@DiarioVasco, April, 28 2013 and May, 19 2013).

Hail can also severely damage plants. The severity of damage depends on specific parameters of the storm: length of the storm, size of hail and time of year. The later the damage is caused in the growing season, the less time the plant has to recover and gather energy for the winter (Schubert 1991).

The main observation systems that the DAEM (Emergency and Meteorology Assistance Directorate) has for monitoring storms in real time are the Kapildui polarimetric Doppler weather radar (Gaztelumendi et al 2006 and Aranda and Morais 2006), satellite images, lightning network and a dense network of automatic surface stations distributed uniformly throughout the Basque Country. But it is the radar that gives more three-dimensional information about the structure and characteristics of the storm as well as the severity and probability of hail through its effects (Ceperuelo 2008, Selex-Gematronik 2005). The DAEM has no direct observation system for hail, rather other indicators associated with storms like the concept of “probability” and real-time monitoring of combined values, which send alerts in real time (Waldogel et al

1979 and Holleman et al 2000). However, the term probability implies the study of type I errors (detecting something that is not there) and type II errors (not detecting something that is there), and therefore, a database on hail events is necessary (Web-Univ of California).

It is true that not all storms are equal, the size of the cells, the interconnection between them and the path from its origin (trigger) to where it ends. The time of year, among other factors, affects its development and severity. The study of the historical database thus indicates that a storm with a single-cell structure with little vertical development can come as a surprise with hail and cause a collision when passing over a main thoroughfare, while a multicell storm leaves no trace, no press release beyond the online status tweets made by Euskalmet (@DiarioVasco May 17,2013, @Noticias de Álava, 2013, @elcorreo May 16, 2013).

This is why the emergency directorate pressures Euskalmet with the concept "When disaster strikes is not the time to think and react, but rather the time to act as planned" (Anitua, 2014), which taken in a meteorological context is basically saying, within the limitations imposed by nature, know or define patterns of aggressiveness in advance. Knowledge obtained from the historical database allows us to better prepare for real-time monitoring in the future.

The lack of direct observations of hailstorms makes it necessary to create a hail database from other sources (press, impact, etc.), documented and detailed hail events from direct and indirect observations (Betschart and Hering 2012).

2 Objetives and methodology

The objective of this work is to identify radar images in situations of hailstorms to then study the radar products, verify effectiveness, propose improvements and define warning patterns.

For the present study, we worked with the weather base of 2013. The methodology is described in Figure 1.

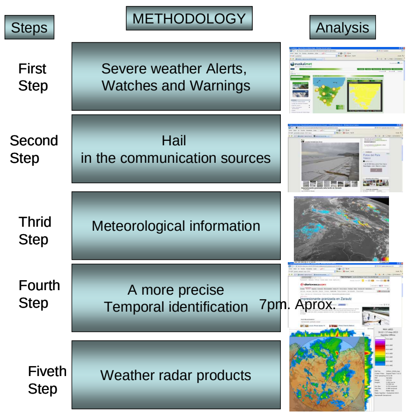

Figure 1:Methodology

1. Review and analysis of weather warning information (table 3) provided by Euskalmet (snow, heavy rainfall, persistent rainfall) where the warning for possible hailstorms appear (Web page Euskalmet). This first step identifies the main weather events of the year and verifies the warning system up to four days prior. These events are studied and classified on a meteorological level.
2. Exhaustive search for press releases with the word hail and its linguistic derivatives in the main online media sources in the Basque Country (periodicals). This information is contrasted with available information from the press office of the Basque Meteorology Agency (Orbe, 1994). This search ends with general searches through Google or Twitter, which provide visual information but do not add any event to the study and present the problem of the accuracy of the information. For this work, emails or the very press releases from our office are considered as the main information and all sources that cannot be verified are rejected. This information is supplemented by information provided by the traffic department and Neiker. All information is used to create a supply a hail database, adding identification of the origin of the information by columns and color-coding.
3. Compilation of the most relevant historical weather observations in 2013 and, in particular, the events identified. Observations of: surface area, electrical activity, satellite and METAR observations (Bilbao, San Sebastian and Vitoria).
4. More accurate information on each of the days, on the time slot of study.

5. Analysis of the radar data. Control parameters used are subdivided into three groups: a) type of cell (single-cell, multicell and supercell); b) weather conditions during the storm; c) behavior of the storm from its inception into maturity to the end. Details are described in Table 1.

Table 1:Analysis of the radar data

Type of cell Type of thunderstorm	**Meteorological Conditions**	**Evolution of Thunderstorm**
• Size and shape of the cell (PPIs 0.5º) • Type of groups (Multicells line…). Interconexión between them (PPIs 0.5º, MAX, CTR) • Maximum height of the cell (MAX and EchoTop) • Maximun reflectivity value, and vertical profile of the reflectivity inside the cell (MAX, RHIs) • Classification of the thunderstorm taking into account bibliographic revision "classification of the thunderstorms". (Cotton et al 2011, Web Univ Illinois). Not all the references are included.	• Meteorological description of the episode (other meteorological sources such as, analysis chars, aws, metar, satélite+lightning maps of europe, reports…) • Wind information. Features of the movements of the cells; velocity, trayectory. (VVP, Soundings, CTRs, PPIs radial velocity) • Interaction between the movement of the cells and the main flow of the air mases (VVP, soundings, CTRs and satellite) • Lightning activity. Combination MAX product with lightning strokes • Analysis and correlation between surface observations (AWS) and radar reflectivity	• Identification of the lifting areas associated to the episode (PPIs-300 km, satellite) *Iberian system *Basque Country mountains *Cantabrian system *Central system • Identification of impact areas. Analysis of recurrence areas • Duration of the thunderstorm • Behaviour/evolution of the Zh and ZDR during the thunderstorm. Identification of the quality issues associated to this type of events (attenuation problems) (PPIs different elevations) • Analysis of the Zhail • Verification sources of the presence of hail. Combination between Zhail and accurate sources of hail

3 Meteorological description of the storms in 2013

The synoptic conditions that cause the appearance of hail have a clear seasonality, so they can be included into two large groups, the cold season (winter) and the warm season (spring and summer-Alvarez et al 2011).

In winter, hail occurs in situations where cold air comes in at all levels of the atmosphere. Sometimes, they are pockets of cold air (cold drop) in the upper layers with temperatures below -30ºC in the 500-hPa level. These pockets usually show up on the surface in the form of low-pressure areas. This situation causes a high dynamic instability that fosters the creation of generally small or medium size hail. In this group, we can include events between November and May. The specific characteristics of the spring of 2013, when the month of May was rather cold in the Basque Country, caused the hail events in this season to be produced by typical winter situations.

Between June and September, hail events have been marked by normal conditions in the seasons of spring and summer. In these seasons, it is both the dynamic and thermal instability that causes the creation of hail. Dynamic instability is due to the ripple of general circulation in the upper layers of the atmosphere with consequent formation of valleys. On these occasions, the wind at high levels often lead to storms moving from southwest to northeast. One of the events that can be included in this subgroup corresponds to the 17^{th} and 18^{th} of June. In the case of thermal instability, it is the temperature difference between the surface, which heats up throughout the day, and the highest levels of the atmosphere that cause strong updrafts that lead to the formation of storms and hail. In this case, with instability indexes exceeding the established thresholds (TTI>=55 and/or LI<=-3), the formation of hail is highly probable, even medium and large size hail. On July 12^{th} and 13^{th}, there was an example of this kind of instability. Most commonly, instability comes from a combination of both thermal and dynamic instabilities. The rest of the summer events can be included in this section. In cases where only thermal instability is present, and also, if there is an absence of wind at higher levels, storms barely move.

4 Brief description of different study cases in 2013 for classification of types of cell. Results

The days selected for presentation in results show common situations in our region: cold season storms, "storms of maritime origin", "storms of inland origin" and warm season storms.

4.1 Cold season storms: storms of maritime origin, January 23rd, 2013 and February 2nd, 2013.

January 23rd, 2013

Synoptic situation, squall in the Gulf of Lion and a northwest inflowing component on the coast with the presence of convective nuclei (single-cell). When storms come by sea, they go through an activation process moments before (topographical shot-the cantabrian coast) and they come together forming a convective line (multicell line- multicell cluster) that loses strength as they move inland. In general, the area of most impact is the first northern half of the Basque Country. The press releases reveal that on that day, there were occasional traffic problems and difficulties in the course of social events caused by weather conditions.

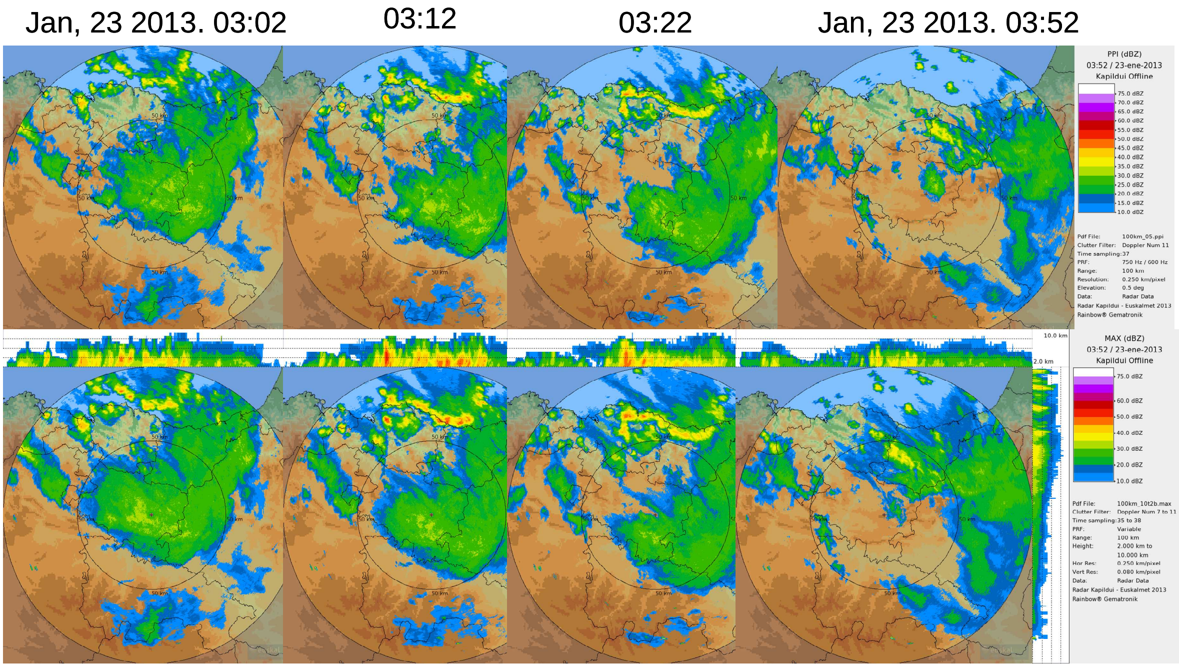

Figure 2. On Jan 23 2013.:PPIs 0.5º and MAX (2-10km). (100km)

Time life of the storms is among 1hour, 7 km height and the horizontal reflectivity is less than 55 dBZ.

Since the structure of the type of winter storms, vertical development, does not coincide with the structure in summer, Zhail parameters are altered to increase the probability of hail in the output.

Table 2:ZHail Parameters

Zhail parameters	***Winter***	***Summer***
Zh (dBZ)	40	45
Height (m)	1000	3000
H0	In 2013 the h0 was fixed using the data of Arteaga sounding (a value for the whole region). At this moment the h0 is the output of the model (a value each point.	

The ZHail parameters were fixed according to the main features found in the analysis of winter cases (figure 3). The winter Zhail, the probability of hail has a correspondence to the press observations.

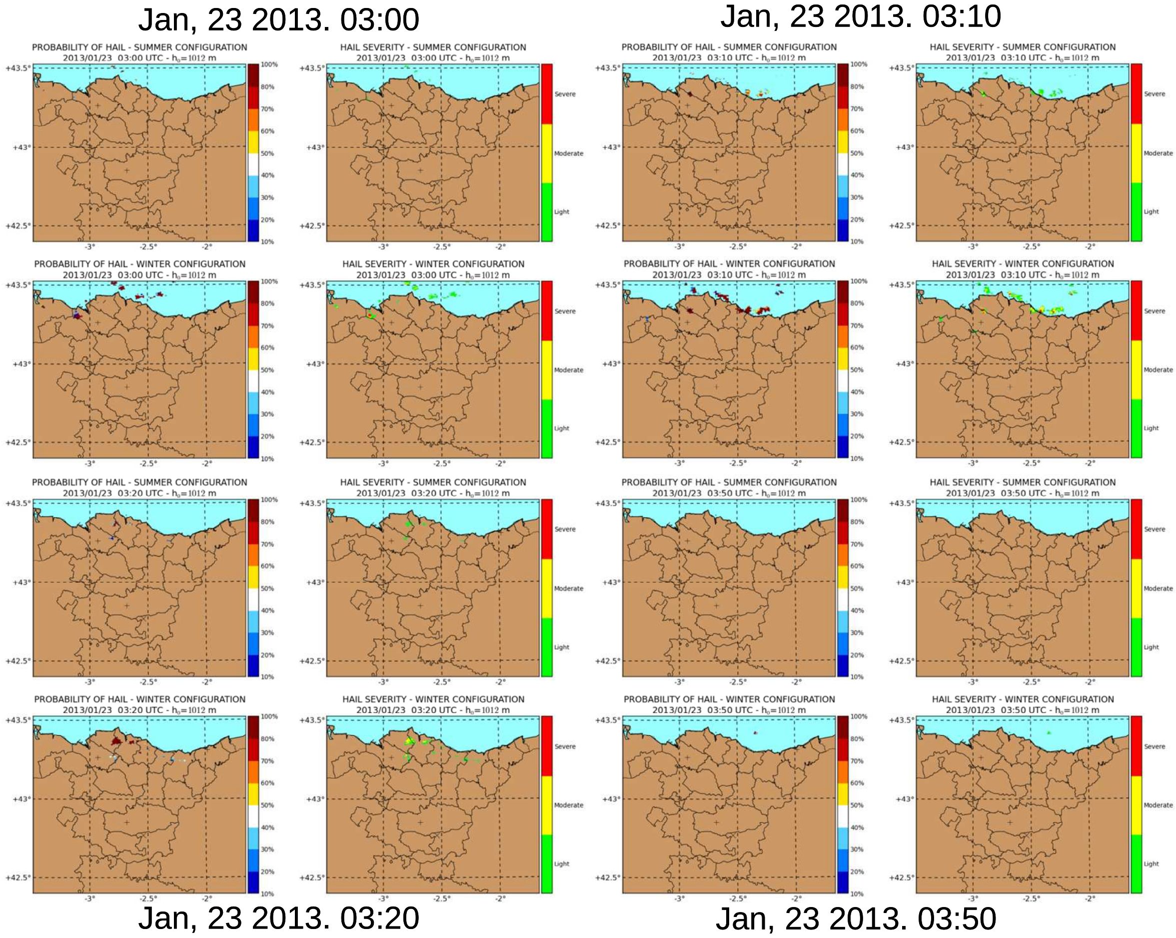

Figure 3. On Jan 23 2013. Comparison between winter(second and fourth line) and summer(first and third line) parameters

February 2nd, 2013

Frontal passage that leaves atmospheric instability. Weather situation of a persistent northern flow. As in the previous case, there was an evolution of single-cell storms that enter from the coast and evolve into a multicell behavior as they approach.

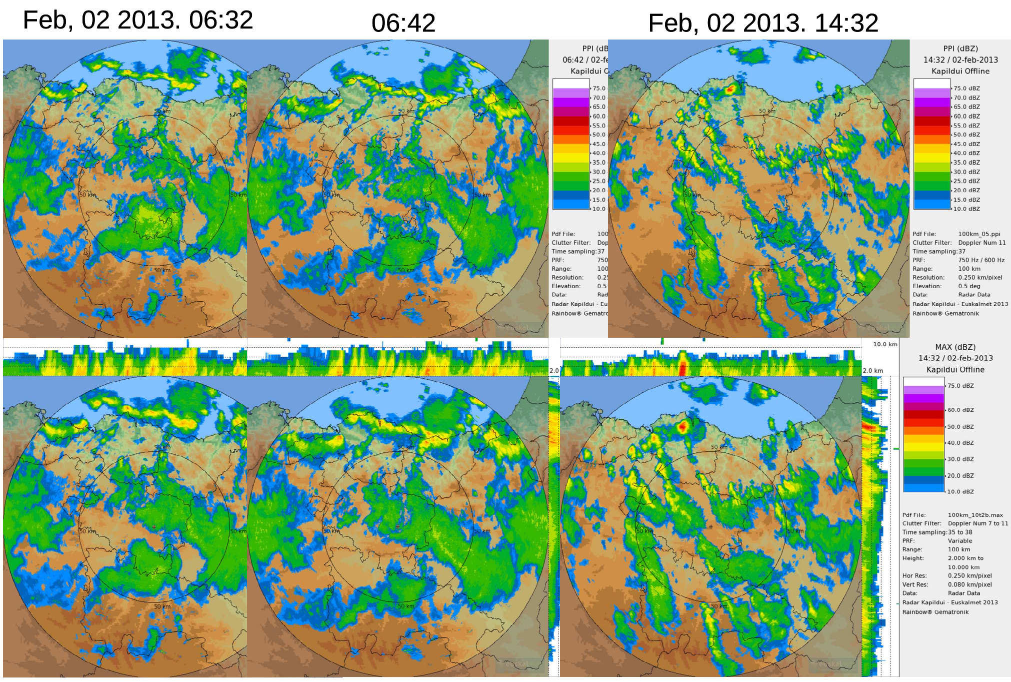

Figure 4. On Feb 2 2013. 0.5° and MAX (2-10km). (100km)

The structure of the cell is similar to the first episode (Jan 23, 2013). More electrical activity was registered on Feb 2 (617 strokes) than Jan, 23 (252 strokes). The number of strokes registered in winter is always lower than in summer. Throughout a day, the direction of the multicell lines is changing (from parallel to perpendicular to the coast). These maritime street lines (northwest direction) are also a typical winter storm pattern of the Basque Country.

In February was found a maximum relationship between warning/alerts and number of news published of hail.

Table 3 Weather warning information

Month/NºDays	01	02	03	04	05	06	07	08	09	10	11	12
Orange A.	0	6	2	0	1	1	0	0	0	0	1	0
Yellow W.	6	5	1	2	1	3	8	2	3	0	5	2
Total	6	11	3	2	2	4	8	2	3	0	6	2
Nº News (Relevant)	3	36	1	12	5	1	1	0	1	0	1	2

4.2 Cold season storms. Inland storms. May 16th, 2013

May 16^{th}, 2013

Two traffic accidents in Araba during a hailstorm early in the afternoon left 12 injured and involved 15 vehicles (@diariovasco, @elcorreo). The presence of dynamic instability by the presence of two low pressure centers to the north of the British Isles with associated fronts that pass by the coast, leaving an unstable environment and thus, storms that affect the south of the region most of all.

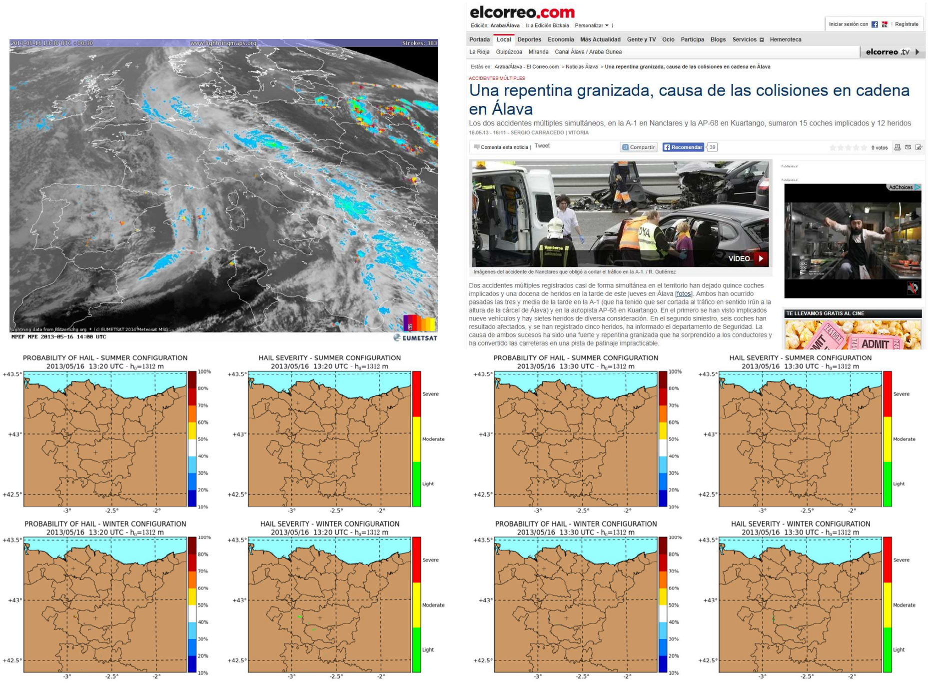

Figure 5. On May 16 2013. Satellite image, summer versus winter Zhail parameters and digital press documentation of the accident.

The main goal of the study of this episode is to find severity features. The timestamp selected is from 13:20 to 13:40. The accident was around 13:30. In the real time monitoring, never thought that this storm could be accompanied by hail.

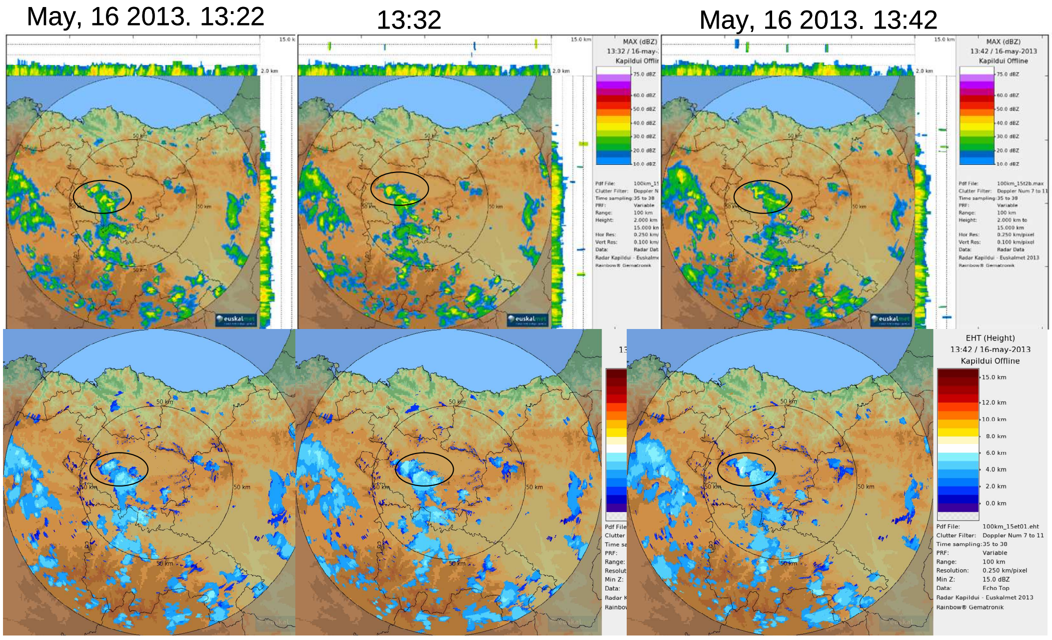

Figure 6. On May 16 2013. MAX (2-10km) and EchoTop. (100km)

The hook echo is a pendant-shaped echo that it indicates a rotation and it was found in the area of the accident. This is identified as a severity feature. Strong winds were registered in the same area and a storm height of 6 km. This is the highest values if you compare with the surroundings. The quality of the data due to the small size of the cell is considered as well.

4.3 Warm season storms. Situations of high atmospheric instability. July 2013

July 16th, 2013

The Iberian Peninsula is in a barometric swamp with a center of high pressure located in the British Isles, which block the passing of fronts. Under these conditions, the thermal low (Hoinka and Castro, 2003) affects the peninsula and the instability index is high, so the evolution of storms can be foreseen throughout the day.

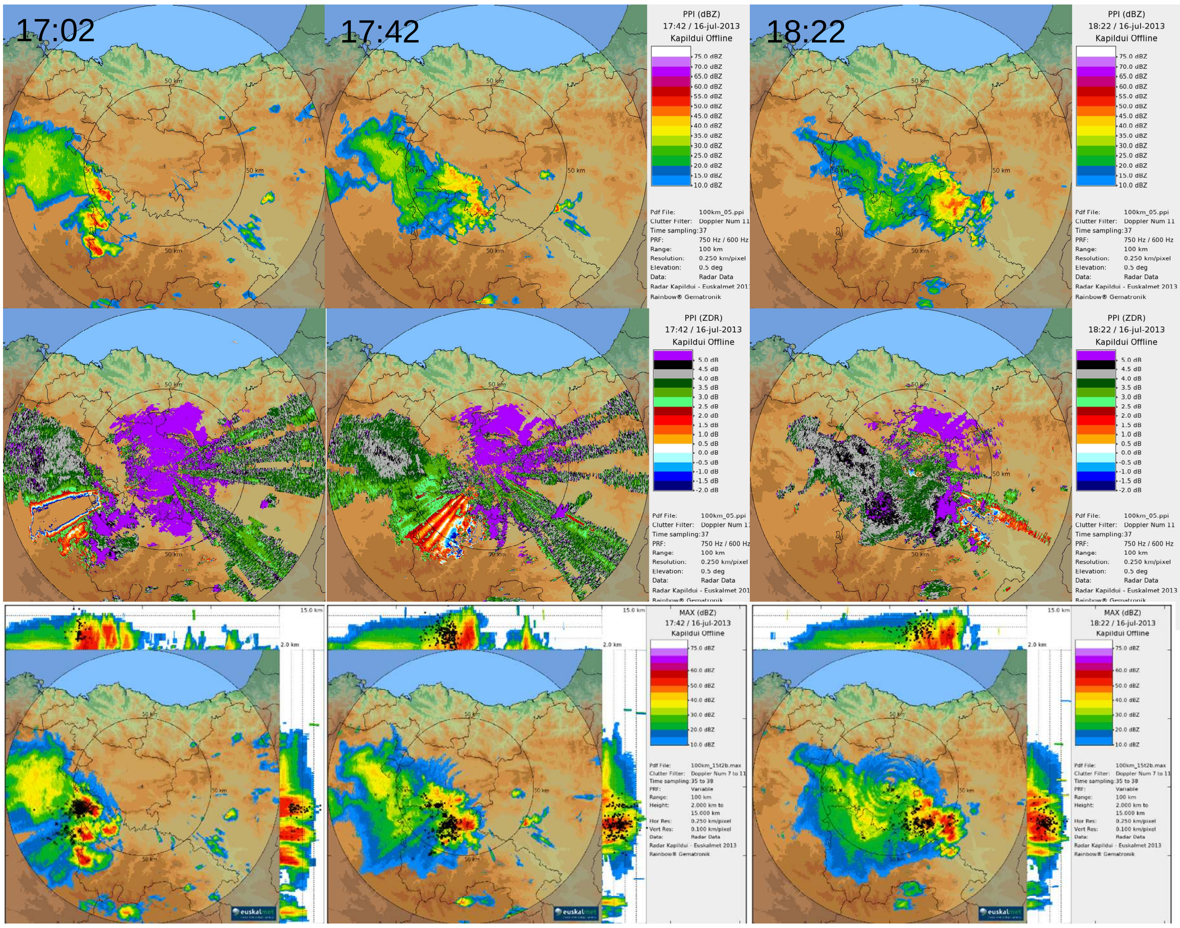

Figure 7. On Jul 16 2013.PPIs(Zh, ZDR) 0.5° and MAX+Strokes (2-10km). (100km)

The general radar features of the summer thunderstorms are; high values of reflectivity more than 50 dBZ, the size of the cell is bigger in summer than in winter, it is often to see stronger attenuation of the horizontal reflectivity (minus values of ZDR), high electrical activity 100-2600 strokes (from 13:00-19:00), the duration of the thunderstorm is longer and the thunderstorms show random spatial movements.

July 19th and 20th, 2013

A more detailed description of the event is found in Gaztelumendi et al 2014.

This episode shows the surprise factor of the summer thunderstorm. In ten minutes a big cell is registered by the radar. The slow movement and the high electrical activity are factors that were considered. Besides the area affected is a recurrent place and all the products show severity features. The automatic weather stations registered values of precipitation around 14.1 mm, in ten minutes, in many points of the AWS network.

Jul, 19 2013. 17:22, 17:32, 17:42, 17:52, 18:50, 19:00

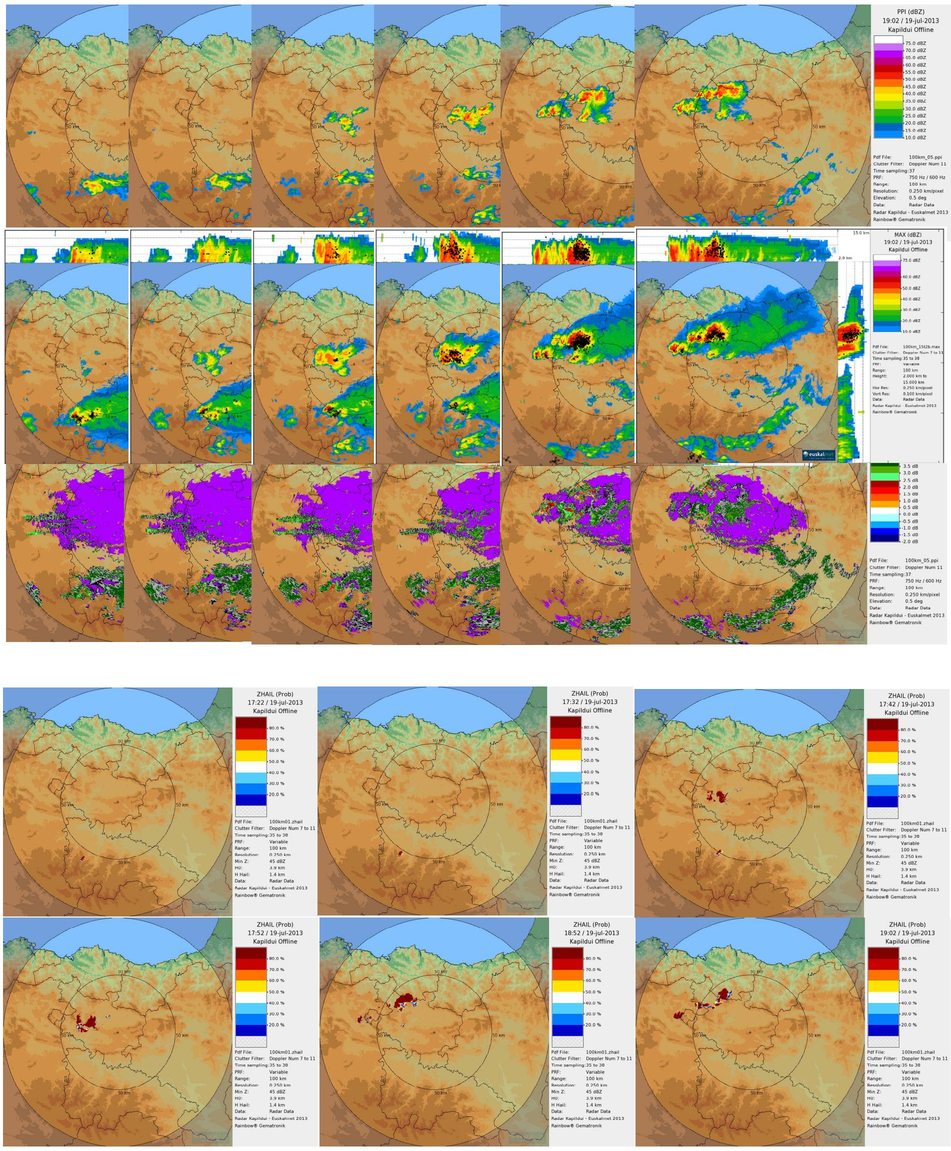

Figure 7. On Jul 16 2013.PPIs(Zh, ZDR) 0.5°, MAX+Strokes (2-10km). (100km) and Zhail

4.4 Other situations

The case of August 28th, 2013 is not included because despite its severity (Egaña et al 2014), there is no observation/information that indicates the presence of hail. It is mentioned because these are storms of maritime origin with a distinct behavior to those presented in winter and the affected area is one of the highest population centers in the region.

5 Findings

The findings will be presented, considering the multidisciplinary nature of the study.

The traffic department considers hail as an atmospheric phenomenon that causes accidents. The associated percentage of people affected is not among the highest compared to others. Most accidents are cases of multiple collisions that do not cause fatalities. In 2013, there were two fatalities and one of them was entering Bilbao. Collisions are more frequent in winter storms and more so when accompanied by snow. Another significant effect is road congestion at points of incidence.

There is a lot of information associated with hail in the press, social networks, forums, blogs, etc. The main complication encountered was the verification of the information for the lack of accuracy in the media. The definition of a filtering methodology, previous filters can be helpful for future works that use this kind of information.

Information from impacts on vegetation shows a great temporal imprecision on the moment of the hailstorm and a great spatial precision on its presence. The combined work between Euskalmet and Neiker may be of great benefit for both parties in the future. Many press releases were found that talked about economic losses due to the loss of crops.

The study on effectiveness of warnings in 2013 indicates that winter storms are more predictable. Forecasts in winter were successful 100% of case 3 and even 4 days before the event, while in the summer, variability in movement and storms' impact zones make it difficult to predict is path through the Basque Country. Summer storm systems have a component of randomness, which is not yet controlled and makes it difficult to foresee the path of storms an hour ahead of time, as shown in the results presented.

Tracking storms through radar data is essential, not only in real time to warn people and competent agencies, but also for the very knowledge gathered from the study on the historical database from storm structures that occur in our region. The more prior knowledge we have, the better the situation in real-time tracking. Real time is not the time to study, but rather the time to apply what you have studied.

Crossing data with other sources has been positive and highly recommended to have a base as complete as possible for the study, which has identified patterns and improved parameter settings for products like Zhail, in operational use. Ideas have also emerged to define new lines of work associated with storm tracking, which take the type of cell and its evolution into account when predicting the future situation.

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