A STUDY OF A FLOOD EPISODE IN BASQUE COUNTRY

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I. INTRODUCTION

In this paper an analysis of a flood episode affecting San Sebastian area on 6 November 2011 is made. A heavy and persistent rainfall episode affects Basque Country along 4-7 November 2011; as a consequence some floods are produced mainly in the east part during 6 November.

During this episode a Cut-Off Low moves from south of Pyrenees towards Mediterranean Sea over Balearic Islands area. In the surface, a low is generated over the northeast of Iberian Peninsula. When the low gets stronger, northerly flow intensifies over the Bay of Biscay and different fronts fully affect the Basque Country during several days. The characteristics of the Mediterranean air mass, its posterior passage over Cantabrian Sea, and the front persistence over the Basque Country, cause high efficiency in precipitation leaving extraordinary amounts of precipitation in some parts of north-eastern Basque Country, during day 5 and 6.

II. SYNOPTIC ENVIRONMENT

In upper-level map (500 hPa) is observed a trough over the northwest of Iberian Peninsula on November 4, 2011 (FIG 1). This trough generates a closed circulation and a cut off low during November 5. The cut-off low (COL) displaces, during November 6, from Pyrenees to Balearic Isles. The air mass in 500 hPa level is cold during the 5th of November (temperature around -22 ºC) and gets warmer on November 6, although in both days there is a moderate instability degree is observed (TTI 50-52, see FIG 2).

The COL in the upper-air flow extends down to the surface (see FIG 3). During the 5th of November the formation of a low over the northeast of Iberian Peninsula is visible. Such low centres in the Mediterranean Sea along November 6 and becomes stronger generating an intense northerly flow over the Bay of Biscay. This northerly flux provides lower layers of warmer and wetter air. The sea surface temperature is about 17.5 ºC, whereas the mean temperature for the beginning of November is around 16 ºC, so this air mass can contain a higher quantity of water vapour. Different weather fronts, with characteristics of Mediterranean Sea, cross the north part of Iberian Peninsula. The fronts are nearly stationary and within northerly meteorological regimes the rainfall is strong, widespread and persistent.

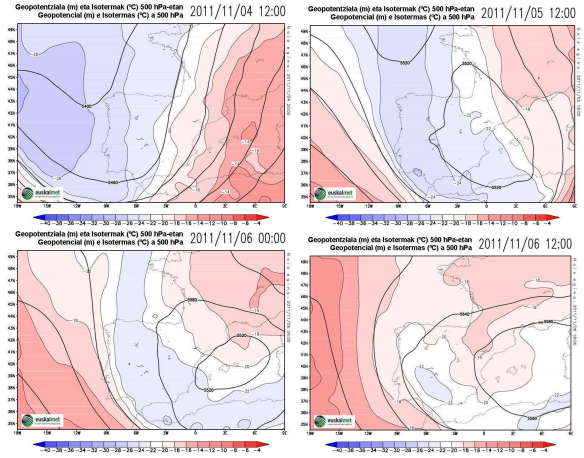

FIG. 1 500hPa charts for 12 UTC for November 4, 5 and 00 UTC y 12 UTC for November 7, 2011. Geopotential heights are in meters and isotherms are in ºC.

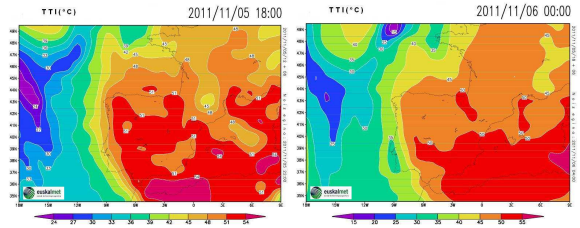

FIG. 2 Stability index TTI (Total Totals index)

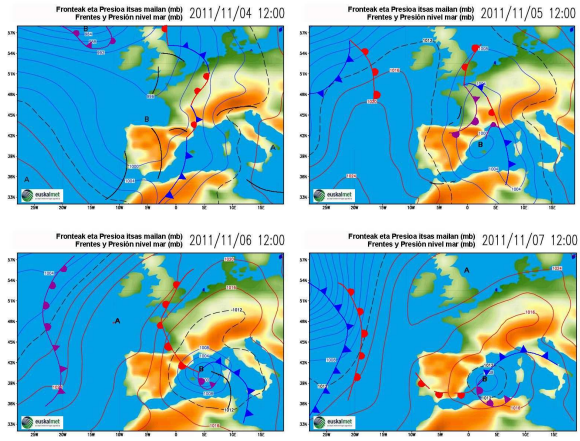

FIG. 3 Sea level pressure maps for 12 UTC November 4 -7, 2011.

III. EPISODE DESCRIPTION

Between Friday 4th and Monday 7th, different weather fronts associated with a COL affected the Basque Country. The fronts were nearly stationary leaving strong, widespread and persistent precipitations.

The afternoon on November 4, different storm cells were formed in Basque Country area. Later, in the evening, northerly flux move, from Cantabrian Sea, convective cells producing heavy precipitation near the coast; more than 20 mm/h in the west of Basque Country. The maximum total amount of precipitation was 44.6 mm in 6 hours in Mungia AWS (see FIG 4).

During November 5, the heaviest rainfall had place in the west part, (23.4 mm/h in Punta Galea and Mungia weather stations). Along the evening, precipitation went down in the west region of the Basque Country and intensified in the east, but there were some cells with convective vertical structure in the western part. In the cantabrian slope more than 100 mm were recorded, especially in the eastern part, (125 mm in Añarbe, 122 mm in Bidania, 120 mm in Ibai Eder) (see FIG 4).

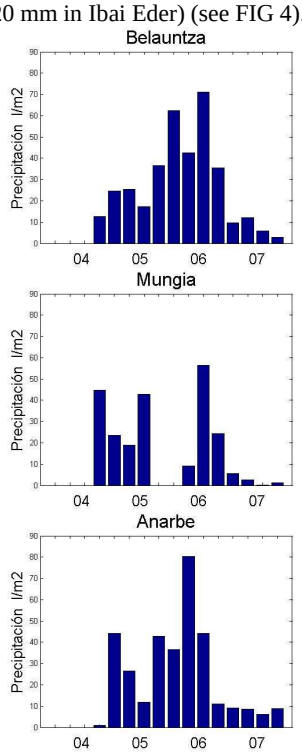

FIG. 4 Six hourly accumulated precipitations at Belauntza, Mungia and Añarbe AWS during the episode.

Along the early hours and morning on November 6 the precipitation was more intense in the east of the Basque Country; in Añarbe and Belauntza more than 100 mm were measured in just 12 hours. More intense precipitation was recorded in that region, 22.9 mm/h in Añarbe and 22.6 mm/h in Belauntza. In some automatic weather stations were measured more than 150 mm in 24 hours, we have to emphasize the amount of precipitation in Belauntza with 211.5 mm in 24 hours (see FIG 4).

During November 7, precipitations disappeared progressively, with rain accumulation minor than two days before (see FIG 5).

The worst affected place was the northeast region of the Basque Country, with a precipitation amount about 200 mm. In some regions near Donostia-San Sebastian total rain amount was around 300 mm, the highest rainfall occurred at Belauntza 358.6 mm (see FIG 5 and FIG 6)

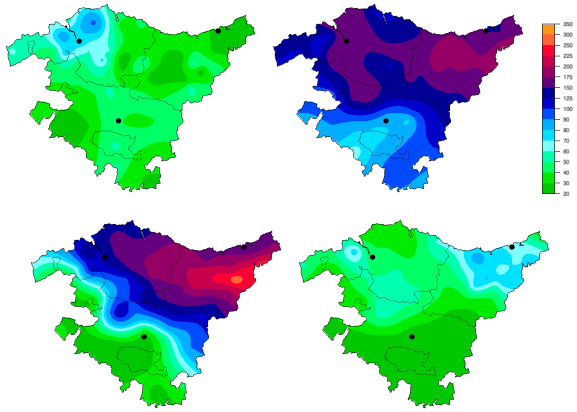

FIG. 5 Daily precipitation distribution (mm) on November 4, 5, 6 and 7.

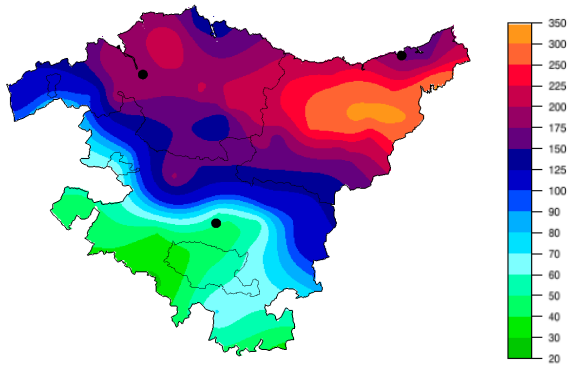

FIG. 6 Total precipitation distribution (mm) from November 4th to November 7th.

An analysis of the vertical profile of reflectivity for the event is shown in FIG 7. Can be seen the vertical scan in 339º direction at 15:27 UTC on 5 November 2011. There, can be seen the stratiform and convective structures of the event. Stratiform precipitation is characterized by a pronounced maximum of reflectivity just below the zero degree isotherm, the so-called radar bright band. The bright band seems to gradually disappear at longer ranges due to the increasing height and averaging volume of the radar at those ranges. Whereas the convective event exhibits much more uniform vertical reflectivity profile. The convective cell has 6 km vertical extension.

Precipitations were persistent with great extension, due its synoptic characteristics, with very active frontal systems. These patterns generate more widespread and prolonged rainfall over time, than other events which local characteristics, affecting whole Basque Country, so all the Cantabrian river basins were affected, resulting generalized river floods. In November, 6 water levels, exceeding flood

level, were registered from Lea basin to Bidasoa basin, causing flooding in a wide areas, although most important occurred in eastern locations, as discussed above (see FIG 8).

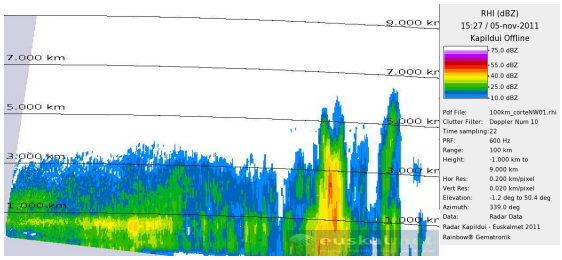

FIG. 7 RHI product NW azimuth cut at 15:27 UTC on 5 November, 2011

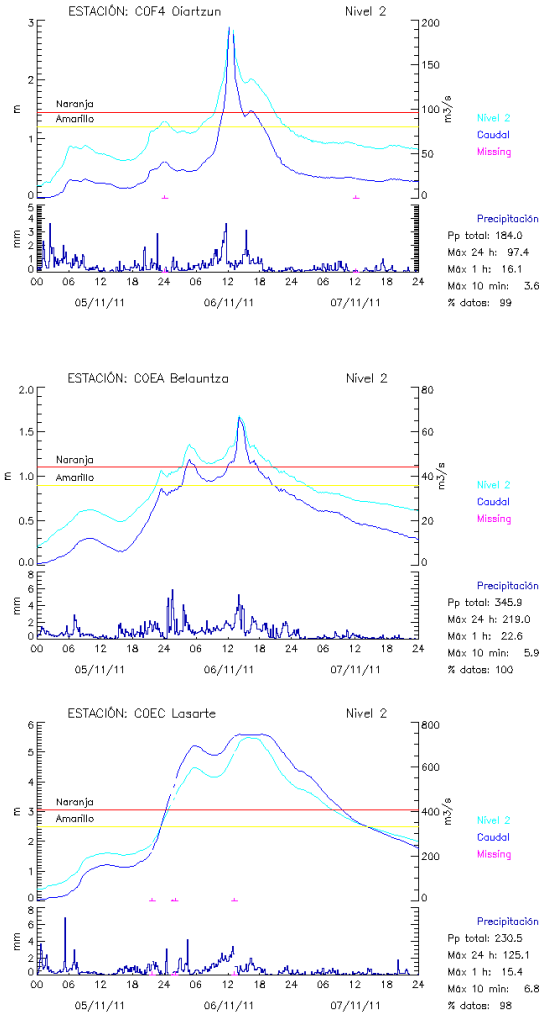

FIG. 8 Precipitation and water level time series evolution in Oiartzun, Belauntza and Lasarte stations. Oorange line is the level flooding level.

Between November 4 and 6, Basque Country Lightning Detection Network detected 71 cloud-to-ground (CG) lightning strokes (11 were positive). Most impacts occurred on day 4 evening, affecting mainly the west part of Basque Country (Biscay). Most intense positive lightning (88 kA) was detected near La Arboleda (west of Biscay), and more intense negative (-61 kA) was measured in the sea facing Bakio (coast of Biscay). The two strokes are of November 4. On November 6 is not detected a single electric strokes (see FIG 9).

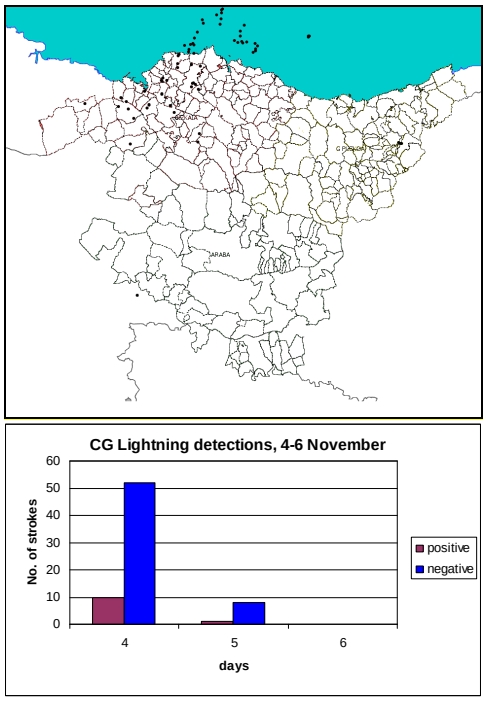

FIG. 9 CG impacts as detected by the LF/VHF network of Euskalmet. 4-6 November

IV. DAMAGES

The worst affected area was the east part of Basque Country where a person was dead. During the event, thousand people were affected by persistent and heavy rainfall. On 5th, Bilbao's tube was closed due to flooding in several stations (in the west part of Basque Country; Bilbao, rainfall was less, but the accumulated precipitation was significant).

FIG.10 Photographs of damages

On 6 November 2011, the east of Basque Country was badly hit: a hundred people was evacuated, a power cut affected 5400 people, a lot of properties were flooded with significant damage to houses and garages and several roads were closed due to flooding and landslides. These floods can be considered the worst in the eastern part of the Cantabrian slope since 1983.

V. SUMMARY AND CONCLUSIONS

These meteorological situations generate persistent and widespread precipitations over a long period of time, so that floods are caused by the growth of river flow and subsequent overflow. Although exist convective structures, most of the precipitation was stratiform type.

These events have higher predictability than warm season convective events, in which, can be generated mesoscale convective systems that discharge large amounts of water in a short time causing less predictable floods.

However, in similar situations to this event, accurate estimations of total precipitation amount are still complicated. Euskalmet forecasts near to the event show rainfall amounts that could exceed 100 mm in both November 5 and 6, i.e. it was expected accumulate more than 200 mm in 48h (considering 5 and 6), as it was, even amply exceeding in some stations.

Near Donostia-San Sebastian total rain amounts is about 300 mm, the highest rainfall occurred at Belauntza 358.6 mm, Bidania 316.9 mm and Añarbe 310.3 mm. In some areas in the northeast of the Basque Country, these quantities double the average November rainfall and have an estimated average frequency of occurrence (return period) over 100 years.

The event shows stratiform and convective structure. The stratiform precipitation has a homogeneous reflectivity in the horizontal plane. Sometimes during the event the precipitation also has convective structure, although the vertical development is quite low. Inside the storm cells, the maximum of reflectivity, around 50 dBZ, is always below 4 km.

The lightning activity is not significant along the episode; most of the strokes are registered on November 4, which is not particularly sensitive. On November 5 and 6 electric discharges tend to disappear. This coincides with a shallow vertical development typical of warm-type maritime situations, where reflectivity vertical profile shows a sharp decrease in height.

The highest values are concentrated near surface, so the amount of precipitation is high. These situations occur in areas located close to warm seas. In this case, sea temperature was 1-2 ° C above normal for this time of year, with values of 17-18 º C, relatively warm, in addition the air mass had Mediterranean characteristics and the slow moving of the fronts result in extraordinary amounts of precipitation in the cantabrian slope during the episode.

VI. ACKNOWLEDGMENT

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