Coastal-maritime risk and early detection in Basque Country

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Abstract

The Basque Country is periodically affected by severe coastal-maritime episodes which, depending on their severity, can significantly alter human activities on the coastal strip, cause considerable material damage or even directly or indirectly result in personal injury.

In the field of coastal-maritime impact, three types of risk are currently considered in the warning/alert/alarm system operated by the Emergencies and Meteorology Directorate. The first one is associated with wind reversals along the coastline ("galernas") with a particular impact on users of beaches and coastline during the summer season. The second one, associated with bad sea conditions, with an impact on navigation in coastal sea waters (2 miles). The third one, associated with high sea-wave and tide conditions that favour overtopping and flooding in the most exposed areas of the coast.

The process of determining and communicating warnings/warnings/alarms is a complex decision making operation involving multiple actors analyzing different types of information based on a variety of available tools.(GV 2018, Gaztelumendi et al 2016b).

In this contribution we include a description of the warning system, some aspects related to communication and dissemination, and an analysis of warnings issued during the years of operation of the system. Likewise, we succinctly describe the danger indicators and the early warning system (EWS) currently operating in Euskalmet, which allows us to address surveillance and forecast by determining severe situations and their degree of potential impact days in advance (WMO 2010).

Coastal-maritime warning system overview

General aspects

In most countries, different organizations have been issuing ocean-meteo warnings based on pre-established threshold surpass for certain key variables. The World Meteorological Organization recommends the implementation of systems that incorporate risk and impact quantification (WMO 2015). The coastal-maritime risk system in Basque Country is a pioneering system strongly oriented to impact, which has evolved over the last few years (Gaztelumendi et al 2012, 2016a, 2020), including in 2009 the colour codification for different impact levels (yellow -warnings / orange - alerts / red - alarms), and incorporating in 2015 the "impact on the coast risk" (GV 2018). Currently, the DAEM (Directorate of Emergencies and Meteorology) protocol for surveillance and prediction of severe phenomena (GV 2018) considers 3 well-differentiated maritime-coastal risk categories:

"Galerna" risk or similar. Due to a sudden wind reversal with intensification that affects the Basque coastline under particular conditions. In general, it occurs during the spring-summer season affecting a relatively narrow strip of land-sea of the coastline (e.g. Gaztelumendi et al, 2011). This local phenomena can cause problems for beach users and small boats. In evaluating its impact, the characteristics of the wind field and human activity are considered.

Navigation risk. Due to a worsening in the sea conditions (waves and wind), usually due to the effect of NW storms or relatively deep storms close to the Basque Country area (Egaña et al, 2010, 2011, 2014, 2020, Gaztelumendi et al , 2014). Under these conditions, general navigation and fishing activity can be dangerous. The impact is mainly derived from the possible damage to boats and the fishing activity interruption. This type of risk is evaluated considering, among other factors, the significant wave height, the wind in the first two miles and human activity.

Coastal impact risk. It is produced by the combined effect of relatively high tides with highly energetic waves in different areas of the Basque coastal strip. The impact is produced, either by the direct effect of energetic waves, or by floods derived from the overflows. In the worst cases derived in substantial damage in the coastal area This type of risk in its most extreme manifestations can have a great impact in terms of economic losses (coastal infrastructures, …) and eventually in human lives (e.g. Gaztelumendi 2020a). For its evaluation, it is considered, the sea level and the run-up integrated in different overflow impact index (Liria et al, 2014, Stockdon et al, 2006) and some context aspects.

Communication

The communication of severe ocean-meteo conditions together with an estimate of their degree of impact, is essential when planning and executing the appropriate preventive measures to minimize damage (WMO 2018). For this purpose, at Euskalmet we develop different user-oriented products and dissemination processes through different communication channels (Gaztelumendi et al 2016b, 2015), including the Euskalmet website and email since 2004, Twitter since 2011 and an "à la carte" notification service since 2019. Among all the products, the official severe phenomena bulletin stands out, which began to be produced in 2004 and collects, clearly and succinctly, the What? When? Where? and the degree of impact plausible in a given situation (GV 2018), this bulletin is sent by e-mail to different organizations and institutions (including ports and affected municipalities).

The cause of maritime-coastal risk ("Galernas" and wave height) has been present since the origin of the warning system, in April 2004. In November 2009 the colours codes are included. In February 2015 "wave height" is updated by "Navigation" and the overshoots and coastal floods are included as "coastal impact risk".

Warning/alert/alarm analysis

The maritime-coastal risk appears in about 50% of the total warning bulletins, issued during those last years, containing yellow and orange level, rising up to 71% for the red level. Maritime-coastal risk appears in 40% of yellow and orange days, rising to 64% in alarm events days (red level).

In figure 1 we present the annual and monthly distribution of coastal-maritime risk days. The years 2014 and 2019 stand out for their severity, during those years a very high number of risk days occurred mostly due to storms in the cold season (for details see Egaña et al, 2014, Gaztelumendi et al, 2014). Considering the monthly distribution (see figure 1), note that January and February tend to be especially risky. However, specific alarm days (red) are recorded from November to March. The days of "Galerna" are mainly produced during the summer season, just in the yellow level during the study period. Although the risk of navigation is present throughout all the seasons, its impact is very relevant from November to March and relatively low from April to October (note that during the summer the reference threshold is relaxed for better consideration of the risk associated with nautical and beach summer-holidays activities). In the case of coastal impact, during the months of May to September the impact is practically null, while the rest of the year and particularly in January and February the impact is significant due to spring tide situations coincident with energetic waves.

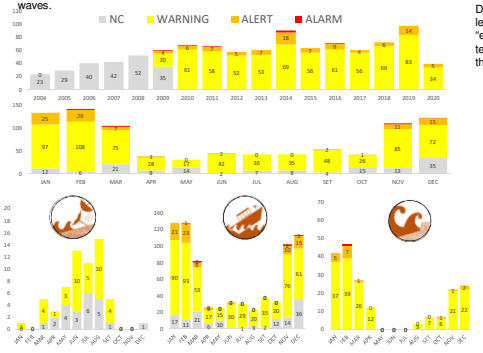

Figure 1. Annual and monthly distribution of warning/alert/alarm days for April 2004-April 2020, including all maritime-coastal risks (top), "Galerna" (bottom-left), Navigation (bottom -center) and Coastal impact (bottom-right).

Coastal-Maritime Risk Early Detection System (CMR-EDS)

Danger indicators

Each of the maritime-coastal risk causes included in our system occurs in an ocean-meteorological context that can be characterized by different physical parameters as danger indicators.

In the "Galerna" case, the key parameters are the spatio-temporal configuration of pressure and temperature field along the Cantabric coast, the detection of local sudden changes in wind intensity and direction with sudden changes in temperature with propagation from west to east along Basque coast.

In the "Navigation" case, the key parameters are the significant height, period of the swell and the wind field configuration.

In the "Coastal impact" case, the key parameters are the overtopping indexes that depend on the characteristics of the waves (significant height, peak period, wave direction) and the sea level (astronomical tide and meteorological tide or residual).

Context indicators

Each severe event occurs in a particular context of human activity in the affected maritime-coastal area that conditions the final impact. These factors or context indicators are included through context analysis and expert judgment based in different vulnerability considerations for each risk typology.

In the "Galerna" case, the key aspects are those dealing with beach activity and occupation. Including the beginning or end of summer period, hours of the day affected, weekend or holiday cases, sports or special events planned in beaches.

In the "Navigation" case, main considerations include the season and time of the year that modulates some aspects of boat activity particularly from the recreational side, the degree of abruptness of the sea conditions change and the sea-sports planned activities, among others.

In the case of the impact on the coast, the key parameters are the differential vulnerability of different Basque coastal areas due to orientation, morphological characteristics and human properties distribution (e.g. Gaztelumendi 2020).

Surveillance and Forecast

We have developed a specific early warning system for surveillance and forecast of maritime-coastal risk that provides the necessary information on the key parameters for each type of risk, considering different temporal horizons.

On the side of the surveillance of severe events, the system allows us to monitor in real time selected key real time data from the ocean-weather observation systems available in the Basque Country and its surroundings (e.g. https://www.euskoos.eus/). To facilitate the supervised monitoring process, the system allows the relevant information to be monitored in addition to emitting acoustic and visual signals according to the pre-established conditions for each key parameter (see figure 2).

On the prediction side, the system currently operating in Euskalmet incorporates different pre-processing, modeling and post-processing modules that provide the key parameters necessary for different temporal horizons at different resolutions (see figure 2). The wave prediction system is based on different numerical models such as Wavewatch-III, WAM and SWAM (Gaztelumendi et al, 2009, 2020, Ferrer et al, 2009). The meteorological prediction system is based on the combination of different synoptic and mesoscale models (GFS, WRF) that run nested in different grids with increasing resolution up to 1km. The meteo system feeds the wave prediction system and provides detailed information on some key meteorological parameters (see figure 3).

Different statistical models and additional calculations are also included that allow considering other variables of diagnostic interest (tide level, residuals,...), as well as probabilistic aspects on certain key parameters. Part of the numerical prediction system is executed in "ensemble" mode so that, in addition to increasing the forecast horizon, it allows us to incorporate predictability. Different post-processing techniques are applied, which allow us to obtain the necessary information in the appropriate formats for its effective incorporation into the decision-making support systems.

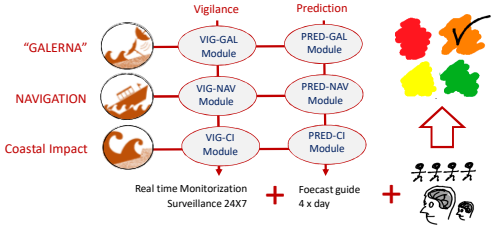

Figure 2. Schematic representation of the Maritime-Coastal Risk Early Warning System (MCR- EWS)

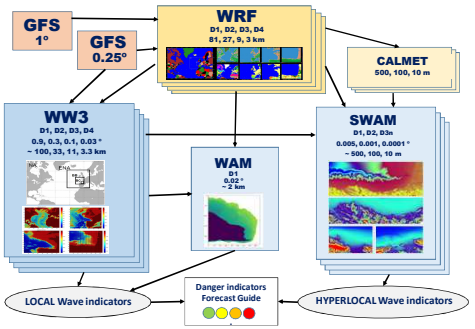

Figure 3. Schematic representation of the wave prediction system of the different modules.

Conclusions and future work

Following recommendations of WMO (WMO 2015). Meteorological services are encouraged to move from weather forecast to impact prediction. In Basque Country we are pioneers, and both aspects are integrated in the Directorate of Attention to Emergencies and Meteorology (DAEM) of the Department of Security of the Basque Government, which has specific procedures and tools for action before, during and after severe events, including maritime-coastal risk (GV 2018).

The DAEM prediction, monitoring and action procedure for severe meteorological phenomena (GV 2018) establishes which phenomena, in what context and based on which ocean-hydro-meteorological reference magnitudes, a particular event could produce an impact and to what extent. In the field of maritime-coastal risk, three types of risk are considered, the one associated with "Galerna" with a special impact on users of beaches and the coastline, the one associated with bad sea conditions with an impact on navigation in the strip closest to the coast (2 miles) and the one associated with the overflow and surge events with an impact on the most exposed areas of the on shore coast (GV 2018, Gaztelumendi et al, 2012, 2016a).

During these last 18 years of operation in Euskalmet, aspects related to maritime-coastal risk has an increasing relevance, as they are one of the risks that most frequently manifests its severity, particularly in relation to the impact on the coast, being one of the major contributions to the most damaging events that occurred in the Basque Country with large economic losses (eg Gaztelumendi 2020).

The early warning system for maritime-coastal risk operating in Euskalmet, developed and implemented by Tecnalia and Azti over recent years, allows us to carry out detailed real-time monitoring of impact events that affect the coastal area, as well as high predictive capacity on potential high impact events that may cause damages in temporal horizons of up to 10 days.

There are several improvement lines planned for near and mid future, highlighting:

- The improvement of certain aspects of integration and robustness of the different modules and hardware.
- The inclusion of sea-observations assimilation capabilities in wave prediction models.
- Improve models or include new ones with increased capabilities in particular areas of interest as ports and particular beaches.
- The coupling of oceanographic models in the system that allow integrating currents and a more accurate calculation of sea level and storm surge effects,
- Include new automatic surveillance capabilities based on the information provided by the coastal camera system (e.g. https://www.kostasystem.com/).
- The improvement of nowcasting in the side of the "Galerna" including new observation sites in west coast..
- Expansion of damage and impact characterization studies.

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