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The Basque Impact Weather Catalogue

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Abstract. This paper introduces the Basque Country impact weather catalogue, a versatile tool designed, developed, and maintained by the Basque Meteorology Agency (Euskalmet), with the primary objective of systematically recording detailed information regarding adverse weather events that generate some degree of impact in the Basque Autonomous Community (BAC). The catalogue serves as a repository where information is gathered for the comprehensive characterisation and evaluation of extreme weather events, focusing on both environmental conditions and their associated impacts. For this purpose, three key aspects are included: context, hazard and risk and impact. In the context section, we include information about the date, duration, spatial extent, measurement statistics data, synoptic/mesoscale aspects, and other metadata. The hazard and risk section includes information about hazard and risk typology according to Euskalmet severe weather criteria and warnings procedure. Regarding the impact, a range of metrics and indicators are defined to characterise critical aspects, encompassing the severity of impact including economic damages, human fatalities, and disruptions to normal life. The creation of the Catalogue involves utilising various data sources and repositories, not only from Euskalmet but also, particularly in terms of impact, from emergency interventions, newspapers, local media websites, social media, and data from the Spanish Insurance Consortium. While the volume of available material from each event description may vary from case to case, a standardised information structure and minimum content are imperative for all registered events. This ensures that qualitative analyses based on extensive reports, and quantitative analyses based on recorded or estimated metrics and indicators, are possible for events included. This paper outlines into the design and structuring of the catalogue, and the fundamental steps undertaken during its implementation.

1 Motivation and Methodology

Human-induced climate change, is causing more frequent and intense extreme events resulting in widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability in different parts of the world (e.g. IPCC, 2022). Strengthening the resilience of our societies against the impact of severe weather is a global priority (e.g. Seneviratne et al., 2021). At the Basque Country level, a plausible escalation of severe weather conditions and increasing exposure to these will likely result in a growing impact that needs to be evaluated. The initial step in this intricate process of characterising the impact of weather involves collecting, preparing, and maintaining accurate information, starting the establishment of what will hopefully become a longer term record. Our main drivers for such effort can be summarised as follows:

1. The need to continue advancing in the knowledge of local meteo-climate impact, increasing the value of weather-related warnings (Zhang et al., 2019), and improving Euskalmet's operational procedures following WMO recommendations (WMO, 2015, 2021) and other initiatives for integration of impacts into weather and climate services (e.g. Kaltenberger et al., 2020, Geiger et al., 2024; Golding, 2022).

2. The need to valorise the substantial work done in past years, generating impact-oriented warnings, severe weather reports, and other documentation related to impactful weather in the Basque Autonomous Community (BAC) within the context of Euskalmet (GV, 2023; Gaztelumendi et al., 2012, 2016a, b).

3. The necessity for reliable and homogeneous information about impactful weather suitable for monitoring the

past and future evolution of climate change at the local BAC level in the context of a formal climate emergency as declared by the Basque Government (GV, 2019).

4. The conviction that official, trustworthy and unequivocal information regarding weather and climate impact, should be made available to specific users and general public as soon as possible.

To o achieve these goals, we have undertaken a project (starting in 2021) for the implementation of a catalogue of impact events in the BAC. The project has been managed using a lean methodology, incorporating a cyclo-iterative philosophy with a focus on rapid results, value checks, and successive revisions. The main tasks undertaken in the project included the review of similar initiatives, searching and selecting appropriate data sources, designing the catalogue structure, and selecting and characterising events. A preliminary design was established and continuously improved through expert feedback in successive phases until the final solution was achieved. The main objective is to draw up and maintain a catalogue with homogeneous information to characterise events of impact that have affected the BAC during the 21st century, from the hydro-ocean-meteo-climatic point of view.

In this paper, we will present some results and discussions of principal aspects undertaken during the project, including some comments about the revision of similar initiatives, selection of local data sources, the structuring of the content of the catalogue, the event selection and strategies adopted for characterisation, and some operational aspects that could be of interest to readers. Finally, we draw some principal conclusions and comments for future improvement.

In the context of this document, a hazard is any agent that can cause harm, risk is the probability of that harm occurring, and impact is the final effect. Risk, hazard, and impact categories are similar to those used operationally in Euskalmet. Note that this definition of risk differs with respect to the general literature, e.g., from the IPCC (Reisinger et al., 2020), where risk is defined as the product of a potential impact multiplied with its probability of occurrence.

2 Results and Discussion

2.1 Review of initiatives

At the beginning of the project, we proceeded to search for and analyse different initiatives for cataloguing impact weather to detect best practices and general guidance for our project. The need to consistently characterise and catalogue hazards related to extreme weather and climate events had been recognised by many National Meteorological and Hydrological Services (NMHS), United Nations (UN) agencies, research bodies, and the private sector (e.g. insurance companies). Many of them have independently developed databases and procedures to record extreme weather, water, and climate events and their impacts. At this initial stage of the project, we selected and analysed some of them; not only material from WMO workshops, meetings, and other publicly available documentation (e.g. WMO, 2017), but also from other heterogeneous initiatives with alignment with our aims and project goals (e.g. ESWD, 2023; EWSC, 2023; CatRaRE, 2023; ASSA, 2023; BNSWWA, 2023; NIWA, 2023; EMDAT, 2023; GLIDE, 2023; IRDR, 2023; ECMWF-SEC, 2022; EWOB, 2023; Roberts et al., 2014; Dotzek et al., 2009). Such initiatives exhibit a very different orientation, diverse data structures, and visualisation interfaces, depending on their specific focus. They may contain structured data (tabular), unstructured data, including documents, web pages, images, audio, and video, as well as data visualisations, event sheets, dashboards, and other resources that facilitate inquiries. This first project phase has enabled us to comprehend the general context in which similar initiatives are developed and to establish a methodology considering the particularities of our case (oriented towards local impact, as simple and clear as possible, based on local plausible resources, including past and present events, operational, human-based with some degree of automation, multipurpose, scalable, and easy to improve).

2.2 Local data sources

Diverse raw data sources and repositories at the Basque Country level are reviewed as potentially valuable for the elaboration of the catalogue. These sources include not only previous datasets and products available at Euskalmet but also, particularly for impact-related aspects, information from external sources such as newspapers, local media websites, social media, emergency interventions, and data from the Spanish Insurance Consortium. In Fig. 1, we illustrate the main local raw data sources that we have used for the catalogue development. A significant portion of the available information originates from previous efforts conducted over the years in various contexts, including Euskalmet's operational tasks, research and development projects, European projects, scientific papers and other internal documentation initiatives (e.g. Egaña et al., 2021; Hernandez et al., 2022, 2009; Gaztelumendi et al., 2022a, 2021a, b, 2018a).

During the analysis phase of local data sources, we recognize the significant amount of potentially valuable information that Euskalmet have already generated, but also that the level of data structuration varies significantly among different products. Some products as analysis, forecasts, shift change records, warnings, observations, etc. are structured in database (DDBB) ready for direct exploitation. In contrast, other information, such as severe events reports, monthly, seasonal, and annual bulletins, social media data, impact data, press releases, etc., is recorded in heterogeneous documents and folder structures that require considerable processing efforts.

MAIN DATA SOURCES	Severe weather report
	Euskalmet Analysis DDBB
	Euskalmet Forecast DDBB
	Euskalmet shift change tokens DDBB
	Euskalmet Warning DDBB
	Euskalmet Annual reports
	Scientific papers (Tecnalia. Euskalmet, others)
	Insurance data (CCS)
	Media information (newspapers,radio, tv, etc..)
	Social networks (twitter, etc..)
	Other sources (emergencies, 112,...)

Figure 1. Primary local raw information/data sources used for event selection and characterization.

2.3 Catalogue content structuration

After analysing local data sources, we proceeded to structure the content of the catalogue, considering the resources available for the project, and considering the catalogue as a multiple purposes space where information about environmental conditions and impact are systematically collected. We designed a flexible conceptual record structure based on three main sections: context, hazard/risk and impact.

The first section includes context information related to synoptical and local hydro-ocean-meteo-climatic conditions, such as date, duration, spatial extension, event typology, key observations data, and a brief summary description of the event. Other complementary contextual information is also included as internal control fields (see Fig. 2). The second section encompasses an ad-hoc classification of hazard type and risk type according to Euskalmet official criteria considering maritime coastal risk (RMC), risk derived from extreme temperatures (TEMP), risk from extreme precipitation (PREC) and risk derived from extreme wind (WIND) and others risks (see Fig. 2). The third section includes different aspects indicative of impact (economic damages, human fatalities, or disruptions to normal life, etc), and four derived indicators to categorize general impact and its social, economic and human health components (see Fig. 2).

The designed event information structure meets our current needs but is flexible enough for the incorporation of new fields in subsequent revision phases (UNDRR, 2020, 2021). General, social, economic and health impact indicators implemented are segmented into five categories (very low, low, medium, high and very high). All information of public interest are planned to be open for consultation in near future.

2.4 Events selection and characterization

After establishing the basic structure of the catalogue, the next step is to determine which events to include. In the complete version of the catalogue, we have decided to focus on cases where hydro-ocean-meteo-climatic factors directly or indirectly cause some degree of damage or alteration of human activity in the BAC during the 21st century. In other words, we are not only considering events from a high-impact perspective but also including those with low and medium impact.

The selection of events is based on the review of different aspects as; (1) official warnings issued (GV, 2023), (2) different documentation and studies available in Euskalmet (e.g. Hernandez et al., 2009), (3) potential high impact environment (e.g. Egaña et al., 2021, 2016, 2014) (4) substantial surpass of stablished thresholds in local observational network (e.g. Hernandez et al., 2022; Gaztelumendi et al., 2018b, 2022b) and (5) impact check based on the analysis of Media, Social networks, 112 or Insurance data (e.g. Gaztelumendi et al., 2021c, 2020, 2017, 2016c). As the categorization of impact in the lower zone could be somewhat subjective, we decided to include in the catalogue all potentially impactful events (including very low impact cases), considering that further selection of events by degree of impact is immediate.

Once an event has been selected, the focus shifts to complete characterization. The completion of the records in the event forms is carried out through human effort by the expert personnel in our analysis-surveillance-prediction team based on available sources (see Table 1). One of the most difficult and key issue in the process is the characterization of impact. Impact data is collected and analysed in different subsequent stages (1) in the short term including information from social network (Gaztelumendi et al., 2021c), communication media and emergency interventions (Gaztelumendi et al., 2016b) and (2) in the medium to long term with insurance data conveniently processed (e.g. Gaztelumendi et al., 2023a, b). It is important to note that in our operational procedures, forecasters and surveillance staff (working 24×7) must be aware of hydro-ocean-meteorological conditions and to the impact during the course of a particular severe event. Real time information from social networks, emergencies and communication media is included in an event folder and summarized in the shift change records. Impact data are also included into operational severe events reports that are mandatory in the case of high-impact weather.

It should be noted that the process of inclusion of events in the catalogue commenced in 2021 (with the initiation of the project), involving the retrospective incorporation of various "historical" events. Based on the experience during this early stage of the project we decided to implement new specific routines in Euskalmet operational analysis and surveillance procedures for systematically collect impact in a more organized manner than before (primarily for its inclusion in severe weather reports) with the aim of facilitating the subsequent cataloguing process.

Through our experience we observed that as an event which has the potential to be catalogued becomes more distant in time and its impact is lower and less widespread, the difficulty in the characterization process substantially increases. Note also, that as cataloguing requires a significant amount of human resources, if possible, is convenient to au-

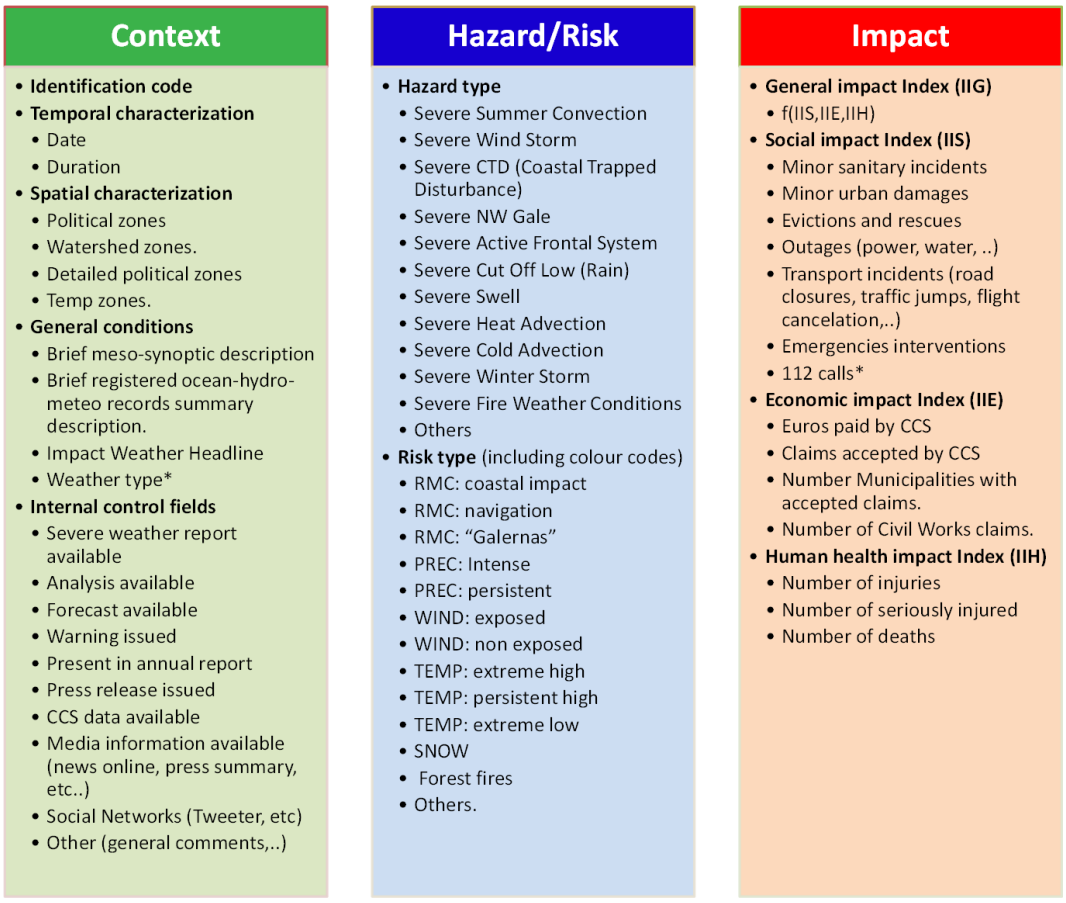

Figure 2. List of components included in the three main categories of the catalogue: context, hazard and risk, and impact.

tomate as many processes as possible, and to involve the operational staff who experienced the event to be catalogued.

2.5 Operational implementation

At an early stage of the project, we defined a field structure based on Excel, where key fields for event characterization and classification are kept in columns, and each event is represented in rows. This approach allows for the quick incorporation of information, revision of the aforementioned fields, inclusion of new ones, and a certain capacity for analysis using commonly used tools in Excel itself and different scripts implemented in R (R Core Team, 2022) for exploratory data analysis and visual data analytics (Gaztelumendi et al., 2023a, b).

After completing the development phase, a more robust solution will be implemented for operational purposes. We plan to use a relational MySQL database to store all data, which will ensure that the catalogue can be easily updated and effectively utilized. This solution appears suitable for our data structure and characteristics, supporting concurrent access, facilitating queries, and enabling the development of various analysis tools and summary dashboards.

Several basic web tools have been implemented to facilitate the loading and querying of this database. Further efforts are planned for the full exploitation of the catalogue, including case consultation, comparative analysis, statistics, and other identified tools as appropriate.

Maintenance and revision routines are formally established in order to (1) improve aspects already included in the catalogue (2) include new events from the past or (3) include new present events as soon as possible as they occur and (4) to include new fields as new hazards/risk categories. For this purpose, a series of operational work instructions are established, detailing what, how, who and when new events must be included or in which terms modification of record structure could be done. In the medium term and depending on the resources available and financial support, we are planning to extend the catalogue into the 20th century, which is a challenge considering that Euskalmet has been active since 2003.

3 Conclusions

We have designed and established a methodology to maintain a catalogue of impactful hydro-ocean-meteo-climatic events

Table 1. Relative contribution of main data sources to the various information categories present in the catalogue.

	Severe weather report	Euskalmet Analysis DDBB	Euskalmet Forecast DDBB	Euskalmet shift change tokens DDBB	Euskalmet Warning DDBB	Euskalmet Annual report	Scientific papers (Tecnalia. Euskalmet, others)	Insurance data (CCS)	Media information (newspapers, radio, tv, etc.)	Social networks (Twitter, etc.)	Other sources (Emergencies, 112, ...)
Temporal characterization	X	X	X	X	X		X				
Spatial characterization	X	X	X	X	X		X				
General conditions	X	X	X	X		X	X				
Internal control fields	X	X	X	X	X	X	X	X	X	X	X
Hazard type	X	X	X	X							
Risk type (including colour codes)					X			X	X	X	X
General impact Index (IIG)								X	X	X	X
Social impact Index (IIS)								X	X	X	X
Economic impact Index (IIE)								X			
Human health impact Index (IIH)									X	X	X

focusing on the Basque Country. During the project, introduced in this paper, a first version of the catalogue has been produced, encompassing over 450 events that affect Basque Country during the 21st century. The selection, characterization and loading process in the catalogue of the past events has required more than 1000 h.

Throughout the course of this work, the utility of the catalogue as a tool for valorizing previous reports and internal documentation related to adverse meteorology is evident. While compiling the catalogue, we have found it difficult to determine the impact of events from the distant past, especially those with medium-low impact, as publicly accessible data becomes scarcer the smaller the incidents are. This highlights the need to record conveniently the impact of present events as soon as information becomes available.

The process of selecting events based on a gradation of impact is complex; therefore, we decided to include events with very low or low impact in the catalogue, using a general impact index estimated for each event. All the events have a common information structure, allowing for the establishment of quantitative analyses based on the various metrics included in the catalogue. It also facilitates qualitative analyses based on the texts fields and links to complementary materials.

It is important to note, that when we started the project (2021), although there were multiple precedents for the collection and characterization of severe events (with more or less presence of impact information) and although various meteorological centers and the WMO have maintained initiatives (workshops, meetings, pilot projects, etc.) in the field of cataloguing, there was no definitive public guidance for hazardous weather cataloguing. As a result from some of these initiatives in 2023, WMO Resolution 12 includes methodology and guidance for cataloguing hazardous weather events (WMO, 2023). In near future, we planned to standardize our catalogue including the recommendations that are applicable in our particular context.

The catalogue is expected to become a future data source for monitoring the effects of climate change and providing a homogeneous and consistent dataset for studies in different fields. The compilation of qualitative and quantitative indicators included in the catalogue constitutes an essential database for subsequent correlation studies on impact and for implementing data-driven models based on machine learning techniques.

Based on our experience with the implementation of our catalogue, we list some practical recommendations for similar activities:

- Review other similar initiatives and tailor different practices to meet your local needs and capabilities.

- Don't wait until everything is perfectly defined before beginning work.

- Design a flexible structure that can be gradually completed and enhanced.
- Establish internal procedures and resources to ensure the ongoing continuity of the work.
- We believe that gathering impact information should be viewed as a routine responsibility for operational staff.
- Give careful consideration to areas beyond your comfort zone, such as assessing impact.
- Develop a redundant system to guarantee that impact indicators, which may be somewhat subjective, remain unbiased.
- Automate the collection of data from instrumentation and modeling as much as possible, saving man-hours for essential tasks.

Code and data availability. Although the code, as well as the derived datasets, are not publicly accessible because they are intended for internal use, details about their implementation can be obtained by contacting the authors.

Author contributions. SG conceived and conducted the project, set methodology, wrote the article and contributed to conceptualization, catalogue design and impact data acquisition. JE contributed to conceptualization, catalogue design, events selection and data acquisition, MR contributed to catalogue design, event selection and did most of data acquisition, EI contributed to catalogue design and data acquisition.

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References

ASSA (Australian Severe Storm Archive): Severe Storm Archive, http://www.bom.gov.au/australia/stormarchive/, last access: 21 October 2023.

BNSWWA (British National Severe Weather Warnings Archive): National Severe Weather Warnings Archive, https://www.metoffice.gov.uk/research/library-and-archive/publications/national-severe-weather-warning-service, last access: 21 October 2023.

CatRaRE: German catalogue of heavy precipitation events, https://www.dwd.de/EN/ourservices/catrare/catrare.html, last access: 21 October 2023.

Dotzek, N., Groenemeijer, P., Feuerstein, B., and Holzer, A. M.: Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD, Atmos. Res., 93, 575–586, 2009.

ECMWF-SEC: ECMWF Severe Event Catalogue, https://confluence.ecmwf.int/display/FCST/Severe+Event+Catalogue (last access: 21 October 2023), 2022.

Egaña, J., Gaztelumendi, S., and Hernández, R.: Analysis of 2014 winter patterns and its effects in Basque Country coastal area, 14th EMS/10th ECAC, https://doi.org/10.13140/RG.2.2.17759.74402, 2014.

Egaña, J., Gaztelumendi, S., and Aranda, J. A.: Meteorological characterization of events that generate floods impact in north part of Basque Country, 16th EMS Annual Meeting, 11th European Conference on Applied Climatology (ECAC), 12–16 September 2016, Trieste, Italy, https://doi.org/10.13140/RG.2.2.23209.72803, 2016.

Egaña, J., Gaztelumendi, S., Hernandez, R., and Otxoa de Alda, K.: Synoptic and local characteristics of severe wind episodes in the Basque Country., EMS Annual Meeting 2021, online, 6–10 Sep 2021, EMS2021-230, https://doi.org/10.5194/ems2021-230, 2021.

EMDAT:The international Disaster database, https://www.emdat.be/, last access: 12 December 2023.

EWOB: European Weather OBserver (EWOB) | European Severe Storms Laboratory, https://www.essl.org/cms/european-severe-weather-database/ewob, last access: 12 December 2023.

ESWD (European Severe Weather Database): European Severe Weather Database (ESWD) | European Severe Storms Laboratory, https://www.essl.org/cms/european-severe-weather-database, last access: 12 December 2023.

EWSC: Extreme wind storms catalogue, http://www.europeanwindstorms.org/cgi-bin/storms/storms.cgi, last access: 12 December 2023.

Gaztelumendi, S., Egaña, J., Otxoa-de-Alda, K., Hernandez, R., Aranda, J., and Anitua, P.: An overview of a regional meteorology warning system, Adv. Sci. Res., 8, 157–166, https://doi.org/10.5194/asr-8-157-2012, 2012.

Gaztelumendi, S., Egaña, J., Liria, P., Gonzalez, M., Aranda, J. A., and Anitua, P.: The new Euskalmet coastal–maritime warning system, Adv. Sci. Res., 13, 91–96, https://doi.org/10.5194/asr-13-91-2016, 2016a.

Gaztelumendi, S., Orbe, I., Salazar, O., Lopez, A., Aranda, J. A., and Anitua, P.: Delivery and communication of severe weather events in Basque Country: the Euskalmet case, Adv. Sci. Res., 13, 87–90, https://doi.org/10.5194/asr-13-87-2016, 2016b.

Gaztelumendi, S., Egaña, J., and Aranda, J. A.: An analysis of flooding economic impact in Urumea area, 16th EMS Annual Meeting, 11th European Conference on Applied Climatology (ECAC), 12–16 September 2016, Trieste, Italy, https://doi.org/10.13140/RG.2.2.32227.48161, 2016c.

Gaztelumendi, S., Egaña, J., and Aranda, J. A.: Floods in Vitoria-Gasteiz: economic impact and meteorological causes, EMS Annual Meeting 2017, European Conference for Applied Meteorology and Climatology, 4–8 September 2017, Dublin, Ireland, https://doi.org/10.13140/RG.2.2.21429.76005, 2017.

Gaztelumendi, S., Egaña, J., Liria, P., and Aranda, J. A.: Description of a coastal impact event in Basque Country: the 9 February 2016 case, Adv. Sci. Res., 15, 137–143, https://doi.org/10.5194/asr-15-137-2018, 2018a.

Gaztelumendi, S., Otxoa de Alda, K., Hernández, R., Maruri, M., Aranda, J. A., and Anitua, P.: The Basque Automatic Weather Station Mesonetwork in perspective, Proceedings 2018 WMO/CIMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (CIMO TECO-2018), https://doi.org/10.25607/OBP-125, 2018b.

Gaztelumendi, S.: Caracterización de daños por embate de mar en las costas de Bizkaia y Gipuzkoa, Revista de Investigación Marina, AZTI-RIM 2020, 27, 62–65, 2020.

Gaztelumendi, S., Egaña, J., R. Gelpi, I., Gomez de Segura, J. D., and Aranda, J. A.: Coastal-maritime risk and early detection in Basque Country, EMS Annual Meeting 2021, online, 6–10 Sep 2021, EMS2021-250, https://doi.org/10.5194/ems2021-250, 2021a.

Gaztelumendi, S.: Analysis of wind damages during 2009–2018 period in Basque Country, EMS Annual Meeting 2021, online, 6–10 Sep 2021, EMS2021-226, https://doi.org/10.5194/ems2021-226, 2021b.

Gaztelumendi, S.: Towards the operational use of tweets data in high impact weather scenarios: data mining and analytics in Basque Country., EMS Annual Meeting 2021, online, 6–10 Sep 2021, EMS2021-245, https://doi.org/10.5194/ems2021-245, 2021c.

Gaztelumendi, S., Gomez de Segura, J. D., Hernandez, R., Martija-DIez, M., and Aranda, J. A.: Climate change monitoring and atmospheric indices in Basque Country: experiences from URBANKLIMA2050 LIFE project., EMS Annual Meeting 2022, Bonn, Germany, 5–9 Sep 2022, EMS2022-596, https://doi.org/10.5194/ems2022-596, 2022a.

Gaztelumendi, S., Otxoa de Alda, K., Ruiz, R., Orue, J., Egaña, J., Maruri, M., and Aranda, J. A.: High temporal resolution monitoring of precipitation in the Basque Country, EMS Annual Meeting 2022, Bonn, Germany, 5–9 Sep 2022, EMS2022-584, https://doi.org/10.5194/ems2022-584, 2022b.

Gaztelumendi, S., Egaña, J., Ruiz, M., and Iturrioz, E.: Diseño e implementación del catálogo de eventos meteo-climáticos adversos de la CAE, Nota técnica 2023.01, Serie Impacto DAEM-Euskalmet, Euskalmet internal documentation, 2023a.

Gaztelumendi, S., Egaña, J., Otxoa de Alda, K., Solsona, F., Santos Alonso, R., and Stocker, C.: Hydro-meteorological and impact characterization of floods in the Basque Country, EMS Annual Meeting 2023, Bratislava, Slovakia, 4–8 Sep 2023, EMS2023-245, https://doi.org/10.5194/ems2023-245, 2023b.

Geiger, T., Röösli, T., Bresch, D. N., Erhardt, B., Fischer, A. M., Imgrüth, D., Kienberger, S., Mainetti, L., Mühlbacher, G., and Spiekermann, R.: How to provide actionable information on weather and climate impacts? – A summary of strategic, methodological, and technical perspectives, Front. Clim., 6, 1343993, https://doi.org/10.3389/fclim.2024.1343993, 2024.

Golding B. (Ed.): Towards the "Perfect" Weather Warning, Springer, https://doi.org/10.1007/978-3-030-98989-7_1, 2022.

GLIDE: Global Identifier number, https://glidenumber.net/glide/public/about.jsp, last access: 12 December 2023.

GV: Declaración institucional del gobierno vasco de emergencia climática, https://bideoak2.euskadi.eus/2019/07/30/news_56172/Declaracion_Emergencia_Clim_tica.pdf (last access: 21 October 2023), 2019.

GV: Protocolo de predicción, vigilancia y actuación ante fenómenos meteorológicos adversos. Procedimieto DAEM P005 v-11, Gobierno Vasco, https://www.euskadi.eus/contenidos/informacion/proto_meteo/es_proto/adjuntos/PE-005-Avisos-de-Meteorologia-Adversa-V11-es.pdf (last access: 12 December 2023), 2023.

Hernández, R., Gaztelumendi, S., Otxoa de Alda, K., Egaña, J., and Gelpi, I. R.: Basque meteorology monthly meteorological bulletins. P144: EMS2009-360, 9th EMS Annual Meeting & 9thECAM: Applications of Meteorology, https://www.researchgate.net/publication/253885020_Basque_meteorology_monthly_meteorological_bulletins (last access: 21 October 2023), 2009.

Hernandez, R., Otxoa de Alda, K., Gomez de Segura, J. D., and Gaztelumendi, S.: Processing of historical data from the Basque AWS network. WMO/CIMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (CIMO TECO-2022) 10–13 October 2022, Paris, France, CIMO TECO-2022 proceedings, https://www.researchgate.net/publication/378004029_Processing_of_historical_data_from_the_Basque_AWS_network (last access: 12 December 2023), 2022.

IPCC: Climate Change 2022: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., https://doi.org/10.1017/9781009325844, 2022.

IRDR (Integrated Research on Disaster Risk): IRDR – Addressing the challenges of natural & human-induced environmental hazards, https://www.irdrinternational.org/, last access: 21 October 2023.

Kaltenberger, R., Schaffhauser, A., and Staudinger, M.: "What the weather will do" – results of a survey on impact-oriented and impact-based warnings in European NMHSs, Adv. Sci. Res., 17, 29–38, https://doi.org/10.5194/asr-17-29-2020, 2020.

NIWA (New Zealand Historic Weather Events Catalogue): https://hwe.niwa.co.nz/, last access: 12 December 2023.

R Core Team: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/ (last access: 21 October 2023), 2022.

Reisinger, A., Howden, M., Vera, C., Garschagen, M., Hurlbert, M., Kreibiehl, S., Mach, K. J., Mintenbeck, K., O'Neill, B., Pathak, M., Pedace, R., Pörtner, H. O., Poloczanska, E., Corradi, M. R., Sillmann, J., Aalst, M., Viner, D., Jones, R., Ruane, A. C., and Ranasinghe, R.: The Concept of Risk in the IPCC Sixth Assessment Report: A Summary of Cross-Working Group Discussions, Intergovernmental Panel on Climate Change, Geneva, Switzerland, https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf (last access: 12 December 2023), 15 pp., 2020.

Roberts, J. F., Champion, A. J., Dawkins, L. C., Hodges, K. I., Shaffrey, L. C., Stephenson, D. B., Stringer, M. A., Thornton, H. E., and Youngman, B. D.: The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci., 14, 2487–2501, https://doi.org/10.5194/nhess-14-2487-2014, 2014.

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S. M., Wehner, M., and Zhou, B.: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1513–1766, https://doi.org/10.1017/9781009157896.013, 2021.

UNDRR: Sendai Hazard Definition and Classification Review TECHNICAL REPORT, United Nations Office for Disaster Risk Reduction (UNDRR), https://doi.org/10.24948/2020.03, 2020.

UNDRR: Hazard Information profiles: supplement to UNDRR-ISC Hazard Definition & Classification Review – Technical Report, United Nations Office for Disaster Risk Reduction (UNDRR), https://www.undrr.org/media/73913/download?startDownload=20241002 (last access: 12 January 2024), 2021.

WMO: Guidelines on Multi-hazard Impact-based Forecast and Warning Services, WMO-No. 1150, ISBN 978-92-63-11150-0, 2015.

WMO: International workshop on cataloguing and managing information on extreme weather, water and climate events. World Meteorological Organization Headquarters, 20–23 November 2017, https://community.wmo.int/en/meetings/international-workshop-cataloguing-and-managing-information-extreme-weather-water-and-climate-events (last access: 21 October 2023), 2017.

WMO: Guidelines on Multi-hazard Impact-based Forecast and Warning Services (WMO-No. 1150), Part II: Putting Multi-Hazard IBFWS into Practice, ISBN 978-92-63-11150-0, 2021.

WMO: Methodology for cataloguing hazardous weather, climate, water and space weather events, Resolution 12 (Cg-18), EC-76: Executive Council (WMO-No. 1314), ISBN 978-92-63-11314-6, 2023.

Zhang, Q., Li, L., Ebert, B., Golding, B., Johnston, D., Mills, B., Panchuk, S., Potter, S., Riemer, M., Sun, J., Taylor, A., Jones, S., Ruti, P., and Keller, J.: Increasing the value of weather-related warnings, Sci. Bull., 64, 647–649, https://doi.org/10.1016/j.scib.2019.04.003, 2019.