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Understanding impact weather: insights from the Basque Country

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0. Content

1. Introduction

- A **severe weather catalogue** has recently been implemented (Gaztelumendi et al 2023), to record detailed information about severe events that have affected Basque society.
- This catalogue serves as a repository of valuable information for **characterizing and evaluating Impact** weather events and its consequences at local level.
- The main motivation of this work is to **improve the understanding of local impact weather** by leveraging the recently created catalogue
- Additionally, it aims to assess to what extent the information contained in its current structure can be systematically extracted and exploited.

1. Introduction

Catalogue of severe weather in the Basque Country.

- Impact weather events that have affected the CAE during the 21st century.
- Homogeneous information structured in three main categories:

(1) **Context.** Different information related with synoptical and local hydro-meteo-ocean conditions including date, **duration**, **spatial extension**, synoptic characteristics and other contextual information.

(2) **Hazard & Risk.** An ad-hoc classification of **hazard type** and **risk type** according to Euskalmet criteria.

(3) **Impact.** Various aspects are considered in order to categorize impact, based on four impact indicators, including general impact (**IIG**) and its three components: social (**IIS**), economic (**IIE**) and human health (**IIH**) . Among others: economic damages from insured assets, human fatalities or normal life disruptions are checked in order to stablish impact indexes.

Context

- **Identification code**
- **Temporal characterization**
  - Date
  - Duration
- **Spatial characterization**
  - Political zones
  - Watershed zones.
  - Detailed political zones
  - Temp zones.
- **General conditions**
  - Brief meso-synoptic description
  - Brief registered ocean-hydro-meteo records summary description*
  - Impact Weather Headline
  - Weather type*
- **Internal control fields**
  - Severe weather report available
  - Analysis available
  - Forecast available
  - Warning issued
  - Present in annual report
  - Press release issued
  - CCS data available*
  - Media information available (news online, press summary, etc..)
  - Social Networks (Tweeter, etc)
  - Other (general comments,..)

Hazard & Risk

- **Hazard type**
  - Summer Convection
  - Wind Storm
  - CTD (Coastal Trapped Disturbance)
  - NW Gale
  - Active Frontal System
  - Cut Off Low (Rain)
  - Swell
  - Heat Advection
  - Cold Advection
  - Winter Storm
  - Fire Weather Conditions
- **Risk type** (including colour codes)
  - MC: coastal impact
  - MC: navigation
  - MC: “Embata”
  - PREC: Intense
  - PREC: persistent
  - WIND: exposed
  - WIND: non exposed
  - TEMP: extreme high
  - TEMP: persistent high
  - TEMP: extreme low
  - SNOW
  - Forest fires
  - Others.

Impact

- **General impact Index (IIG)**
  - f(IIS,IIE,IIH)
- **Social impact Index (IIS)**
  - Minor sanitary incidents
  - Minor urban damages
  - Evictions and rescues
  - Outages (power, water, ..)
  - Transport incidents (road closures, traffic jumps, flight cancelation,..)
  - Emergencies interventions
  - 112 calls*
- **Economic impact Index (IIE)**
  - Euros paid by CCS
  - Claims accepted by CCS
  - Number Municipalities with accepted claims.
  - Number of Civil Works claims.
- **Human health impact Index (IIH)**
  - Number of injuries
  - Number of seriously injured
  - Number of deaths

1. Data and methodology

- All events recorded in the catalog (as of 25/02/2024) for the period 2001-2023 were used.
- Working with the original data structure and dealing with coexistence of both quantitative and qualitative variables.
- Various R scripts were developed for data loading, cleaning, segmentation, aggregation, transformation, and visualization.
- A “wide” data frame was prepared from the original data, with 133 columns for features and 500 rows for events, serving as a starting point for subsequent operations. The columns contain variables related to date, duration, spatial classification, hazard typology, risk typology, and impact indicators, while the rows represent the events.

- Various techniques of Exploratory Data Analysis (EDA) and Visual Data Analytics (VDA) were applied for characterization, including segmentation/aggregation processes and the implementation of summary tables, count matrices, heatmaps, histograms, density plots, bar graphs, etc.
- Each key aspect (hazard, risk, impact, spatial, and temporal features) was characterized:

  (1) individually,

  (2) in combination with the hazard-risk pair, and

  (3) for the hazard-risk-impact trio.

  In this presentation, only some of these are shown.

Diverse libraries were employed, including *tidyr* (Wickham, 2023) for data manipulation and transformation, *dplyr* (Wickham et al., 2023) for data transformation and analysis, and *ggplot2* (Wickham, 2016) for data visualization and analysis. *Facets* (Wickham, 2016) were used to generate multiple plot panels based on factors, and grouping and summarizing (Wickham et al., 2017) were extensively used to simplify complexity and extract conclusions with varying levels of aggregation.

2.1. Results and discussion: Hazard type

The hazard categorization used in the catalog is based on 12 categories derived from the hazard typology definition employed by Euskalmet related with weather systems/conditions precursors of impact.

The category H12.Other is included to encompass other types not explicitly covered in the current hazard definition.

Multiple hazards can coexist during a single event (465 events/607 hazards).

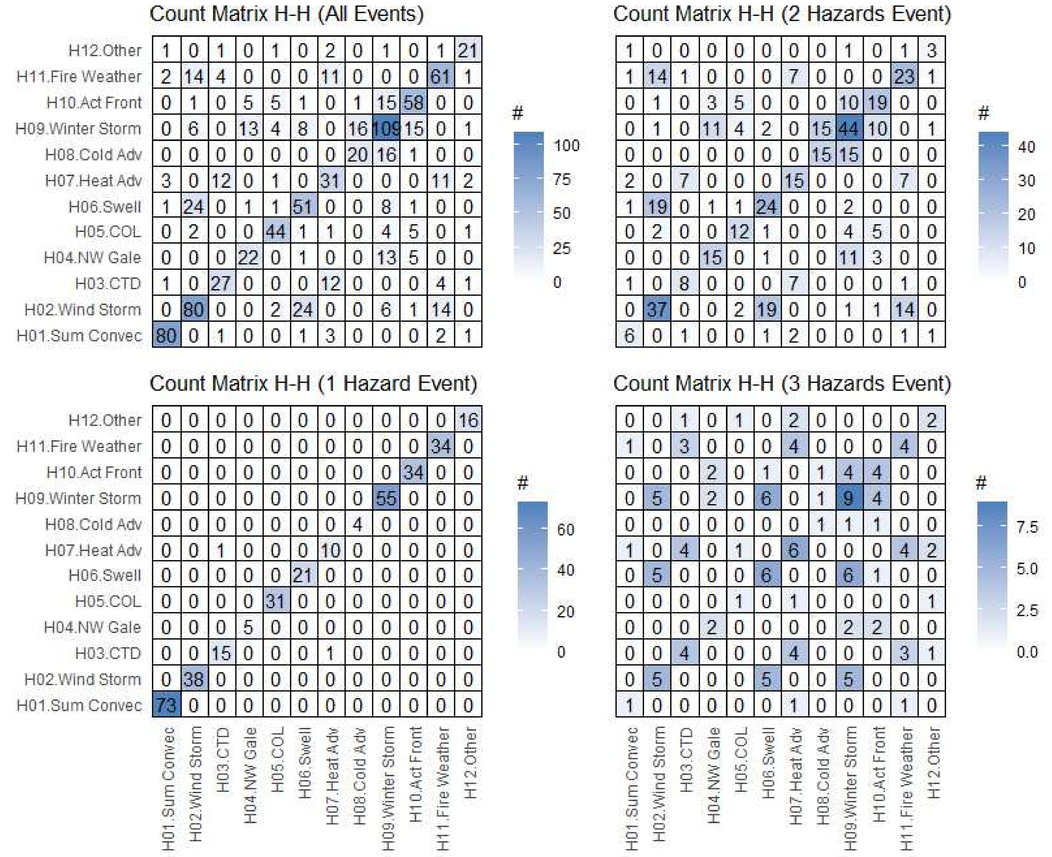
As we can see in the summary table

- 73% of events are single-hazard, 24% two-hazards, and 3% three-hazards.
- The three most frequently occurring hazard types are H09.Winter Storm (24%), H02.Wind Storm (17%), and H01.Summer Convection (17%).

Hazard summary table

HAZARD	Num Events	Mean Duration (hours)	Num Events (siingle hazard)	Mean Duration (single hazard)	Num Events (two hazards)	Num Events (three hazards)
H01.Sum Convec	80	1,4	73	1,2	6	1
H02.Wind Storm	80	2	38	1,9	37	5
H03.CTD	27	1,8	15	1,1	8	4
H04.NW Gale	22	2,8	5	1,8	15	2
H05.COL	44	2,1	31	2	12	1
H06.Swell	51	2	21	1,6	24	6
H07.Heat Adv	31	3	10	2	15	6
H08.Cold Adv	20	5	4	4,2	15	1
H09.Winter Storm	109	2,9	55	2,5	44	10
H10.Act Front	58	2,1	34	1,7	19	5
H11.Fire Weather	61	2,5	34	1,9	23	4
H12.Other	21	1,6	16	1,2	3	2

Count H-H matrixes



- The hazard types that most frequently (more than half) appear in combination with others are Cold Adv, NW Gale, Heat Adv, and Swell.
- Among the three-hazard events, 02.Wind Storm+06.Swell+09.Winter Storm and 03.CTD+07.Heat Adv+11.Fire Weather stand out.
- In absolute terms, the most common two-hazard events are Wind Storm + Swell .

In the **count matrixes H-H**, we can observe in absolute terms the **frequency a hazard typology appears in combination with others hazards** in the considered events (The diagonal shows the number of times a particular typology appears, and off-diagonal the instances where it is combined with other typologies).

2.2. Results and discussion: Risk type

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Events are characterized by 13 risk categories, matching the same risk used in the Basque system for monitoring and forecasting severe weather (GV 2018, Gaztelumendi et al. 2010, 2011, 2024).

These variables are not binary; instead, they contain risk level information based on color gradation following warnings / alerts / alarm (yellow / orange / red) levels.

The R13. Other category includes other risks like hail, lightning, landslides, etc., not explicitly covered as warning causes in the current system.

During an event, one or more risks can occur simultaneously. The 465 events contain 987 risk types.

The two most frequently occurring risk types are R02: Navigation (33%) and R07: Wind in Exposed Zones (32%).

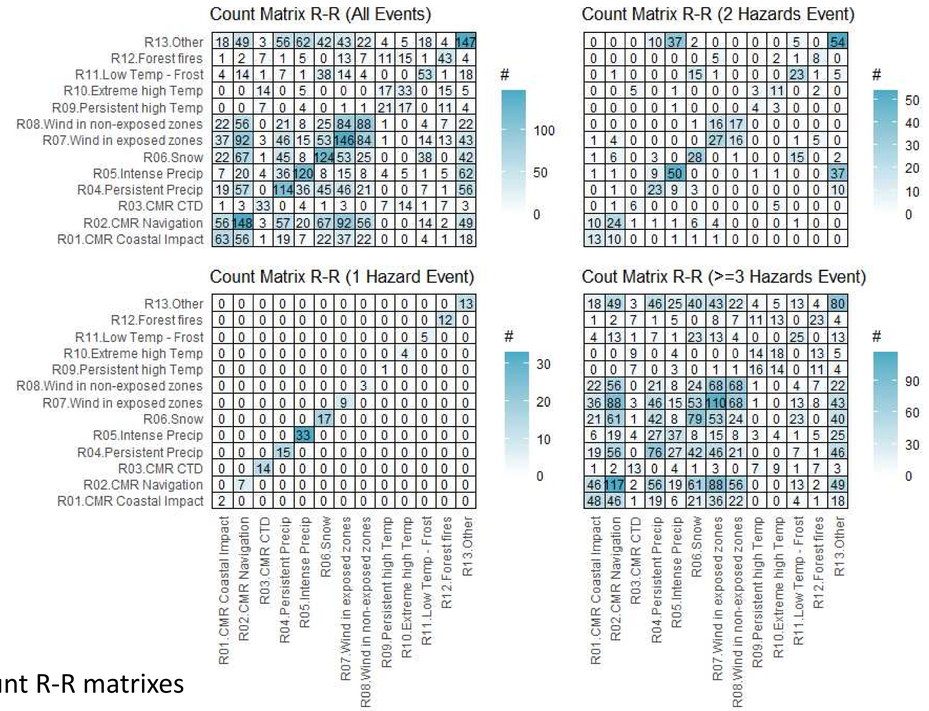
There are 173 events with a single risk, 118 with 2 risks, 70 with three risks, 42 with four, 29 with five, 8 with six, and 1 with seven.

The most repeated combinations involve the two wind typologies, Navigation and Coastal Impact, and persistent and extreme temperatures.

RISK	Num Events	Mean Duration (hours)	Num Events (siingle risk	Mean Duration (single risk	Num Events (two risks	Num Events (threeor more risks)	Num of Significant Risk Events	Num of Significant Impact Events	Mean Num of Risks	Mean Num of Hazards
R01.CMR Coastal Impact	63	2,1	2	1	13	48	43	38	4,1	1,8
R02.CMR Navigation	148	2,2	7	1,6	24	117	85	98	3,9	1,6
R03.CMR CTD	33	1,9	14	1	6	13	14	11	2,3	1,5
R04.Persistent Precip	114	2,3	15	1,5	23	76	60	85	3,6	1,5
R05.Intense Precip	120	1,7	33	1,5	50	37	36	70	2,5	1,2
R06.Snow	124	2,8	17	2,4	28	79	68	72	3,5	1,6
R07.Wind in exposed zones	146	2,3	9	1,6	27	110	93	112	3,7	1,6
R08.Wind in non-exposed zones	88	2,2	3	1,7	17	68	64	76	3,8	1,6
R09.Persistent high Temp	21	4	1	1	4	16	14	15	3,1	1,8
R10.Extreme high Temp	33	2,7	4	1	11	18	19	16	2,7	1,7
R11.Low Temp - Frost	53	3,3	5	2,4	23	25	22	24	2,9	1,4
R12.Forest fires	43	2,7	12	2	8	23	18	23	2,6	1,7
R13.Other	147	2,3	13	1,2	54	80	70	109	3,2	1,4

The only risk type that mostly (more than half) appears unaccompanied by other risks is R08.Intense Precip.

Focusing on Relevant Risk events (defined as those with an orange or red risk value), Navigation, Wind in Exposed Zones, Snow, and Persistent Precip are the most common, while CTD is the least.



Risk Summary table and count R-R matrixes

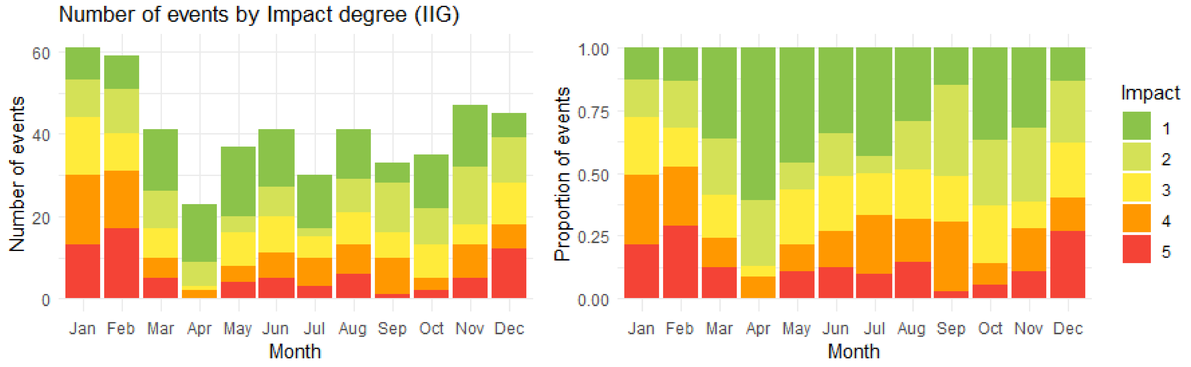
2.3. Results and discussion: Impact

The impact for each event is determined from the General Impact Index (IIG) and its components: Human (IIH), Social (IIS), and Economic (IIE).

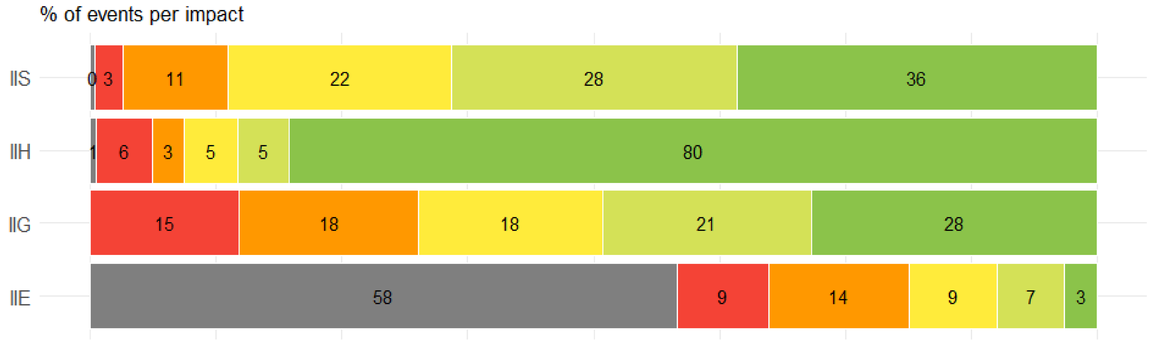
The impact indices can take values of 1, 2, 3, 4, or 5 (very low, low, moderate, high, very high) or NA if it is not available for a particular event.

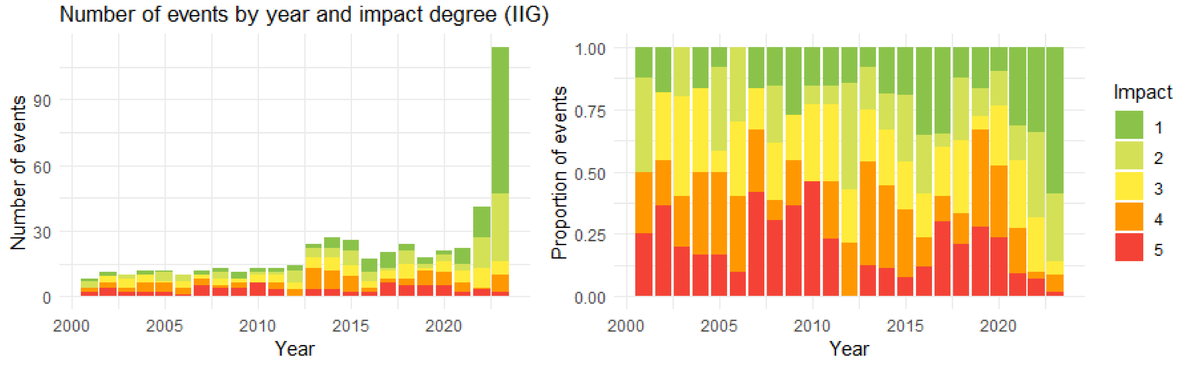
- 51% of events with relevant general impact level (IIG>2).
- 14% of events with relevant human impact (IIH>2).
- 36% of events with relevant social impact (IIS>2).
- 32% of events with relevant economic impact (IIE>2).
- 58% of events without economic impact (IIE=NA) (nowdays calculation involves insurance data, which is not available for all events).

The monthly event-impact distribution shows that the proportion of high-impact events is concentrated in the winter period, particularly in January and February (Also proportionally relevant during summer)



The annual event-impact distribution shows the effect of the event catalog loading process (Gaztelumendi et al. 2024), which results in a drastic increase in the number of events in last year once real-time recording begins. This fact affects the proportion of significant events in recent years and apparent trends.



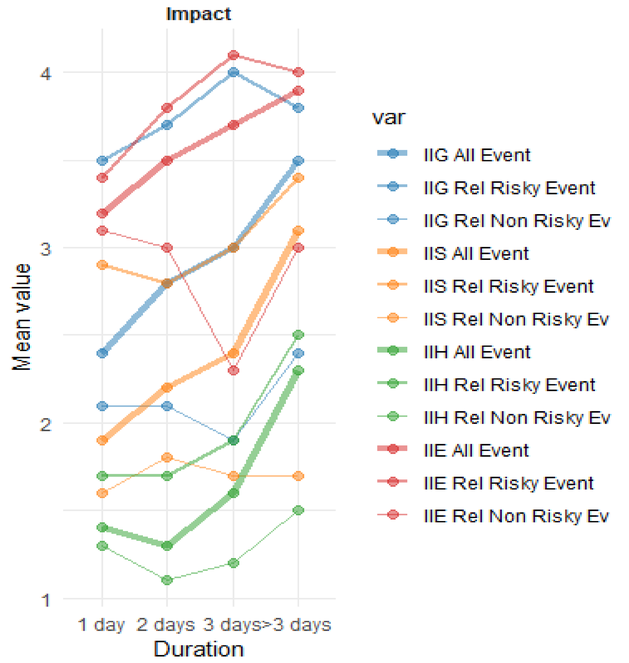


2.4. Results and discussion: Duration

- 45% of all events last 1 day, 31% two days and 24% more than 2 days.
- 38% of relevant impact events last 1 day, 32% two days, 30% more than 2 days.
- 18% 1-day events has relevant risk, this proportion increases to 42%, 51% and 80% for 2-days, 3-days and over 3 days duration.
- 43% 1-day events has relevant general impact, this proportion increases to 52%, 57% and 70% for 2-days, 3-days and over 3 days duration.
- The mean number of hazards and risks per event increases with duration.
- The number of events decreases with duration.
- This trend is influenced by the behavior of single-hazard events since multi-hazard events do not show this downward trend.
- The duration trend behaviour when segmented by Risk is similar.
- The mean value of impact indices increase as event duration increases.

Duration summary table

Dur	Max(Duration in hours)	Mean(Duration in hours)	Count (All Event)	Count(IIG=c(1,2))	Count(IIG=c(3,4,5))	Mean(Number of Hazards)	Mean(Number of Risks)	Mean(IIG)	Mean(IIS)	Mean(IIH)	Mean(IIE)	Count(Single Hazard Event)	Mean(IIG) Sing Haz	Count(Relevant Risk Event)	Mean(IIG) Non Rel Risk Event	Mean(IIG) Rel Risk Event
1day	1	1	222	126	96	1,2	1,9	2,4	1,9	1,4	3,2	174	2,4	41	2,1	3,5
2days	2	2	155	75	80	1,3	2,7	2,8	2,2	1,3	3,5	105	2,7	65	2,1	3,7
3days	3	3	61	26	35	1,5	3	3	2,4	1,6	3,7	33	2,6	31	1,9	4
>3days	12	5,4	55	15	40	1,7	3,3	3,5	3,1	2,3	3,9	23	3,3	44	2,4	3,8



2.5. Results and discussion: Spatial distribution

The spatial categorization used in the catalog is not univocal. For the same event, there can be multiple spatial descriptors of the affected territory)

Spatial descriptors can be of 24 types, which we grouped into 6 different categories for analysis.

- (SD0) The entire territory (CAV).
- (SD1.0) Political territorial division (BIZKAIA, GIPUZKOA, or ARABA).
- (SD1.1) More detailed subdivisions along the north-south and east-west axes within each political division.
- (SD2) Division by zones according to the north-south axis (zones 1, 2, 3, and 4).
- (SD3) Division by main basins (Cantabrian/Mediterranean slope).
- (SD4) Division between sea and coastal strip.

S-R, SD-R and S-S Count matrixes

Count Matrix S-R (All Events)

S24.ZONE.4	0	0	8	0	3	0	0	0	14	18	0	12	5
S23.ZONE.3	0	0	8	0	3	0	0	0	14	19	0	13	5
S22.ZONE.2	0	0	11	0	5	0	1	1	16	21	0	11	6
S21.ZONE.1	0	0	11	0	5	0	1	1	15	20	0	11	6
S20.GI.EAST	2	7	1	12	8	0	4	2	0	1	0	1	6
S19.GI.WEST	0	1	1	0	8	2	5	3	0	0	1	2	9
S18.GI.INTERIOR	5	8	1	5	5	23	4	1	0	0	7	2	9
S17.GI.LITORAL	5	9	0	1	5	4	4	3	1	1	3	1	9
S16.BI.EAST	1	1	0	1	7	0	2	1	0	0	0	0	5
S15.BI.WEST	3	6	0	2	3	1	6	5	3	4	0	6	6
S14.BI.INTERIOR	3	6	1	3	2	19	4	0	0	0	6	0	7
S13.BI.LITORAL	2	4	2	0	1	2	4	1	0	0	1	1	5
S12.AR.WEST	1	1	0	2	5	0	0	0	1	0	0	0	5
S11.AR.EAST	1	1	0	3	7	3	1	0	0	1	0	0	5
S10.AR.LLANADA	0	0	0	0	2	0	0	0	0	0	1	0	4
S09.AR.RIOJA	0	1	0	0	4	2	1	1	0	0	0	1	3
S08.GIPUZKOA	4	16	0	24	18	10	18	10	0	1	5	2	23
S07.BIZKAIA	8	20	2	17	22	6	35	21	2	0	3	8	22
S06.ARABA	9	20	3	13	17	45	18	9	5	3	18	6	22
S05.COASTAL.AREA	33	41	22	14	7	15	28	19	2	8	1	5	13
S04.SEA	33	53	1	18	3	23	42	31	0	0	4	0	14
S03.MEDITERRANEAN.SLOPE	0	0	0	0	0	0	0	0	0	0	0	0	0
S02.CANTABRIC.SLOPE	4	8	0	10	11	3	7	3	0	0	0	3	11
S01.CAV	20	50	3	34	11	52	59	38	4	5	19	9	38

Compound Matrix S-S (All Events)

SD4	27	12	11	7	3	90
SD3	0	1	1	0	22	3
SD2	4	3	4	28	0	7
SD1.1	0	57	175	4	1	11
SD1.0	1	167	57	3	1	12
SD0	94	1	0	4	0	27
	SD0	SD1.0	SD1.1	SD2	SD3	SD4

Count Matrix SD-R (All Events)

	R01.CMR Coastal Impact	R02.CMR Navigation	R03.CMR CTD	R04.Persistent Precip	R05.Intense Precip	R06.Snow	R07.Wind in exposed zones	R08.Wind in non-exposed zones	R09.Persistent high Temp	R10.Extreme high Temp	R11.Low Temp - Frost	R12.Forest fires	R13.Other
SD4	42	63	22	22	9	25	49	35	2	8	4	5	18
SD3	4	8	0	10	11	3	7	3	0	0	0	3	11
SD2	0	0	11	0	5	0	1	1	16	23	0	13	6
SD1.1	16	35	5	27	48	37	30	16	5	6	13	12	61
SD1.0	17	46	4	43	48	52	51	29	6	4	22	13	55
SD0	20	50	3	34	11	52	59	38	4	5	19	9	38

Compound Matrix S-S (Single Risk Events)

SD4	0	0	2	0	0	17
SD3	0	0	0	0	8	0
SD2	0	0	0	3	0	0
SD1.1	0	11	57	0	0	2
SD1.0	0	39	11	0	0	0
SD0	5	0	0	0	0	0
	SD0	SD1.0	SD1.1	SD2	SD3	SD4

- SD0: 20% events and 18% of significant impact events affect the entire Basque Country.
- SD1: 48%/32% in ARABA, 75%/41% in BIZKAIA, and 70%/42% in GIPUZKOA.
- SD4: 14% affect the coastal strip, and 12% affect the sea.
- The presence of each spatial category (Sxx) is usually a consequence of to the risk typology. For example, the SD2 category is common in extreme temperature risks, SD4 in maritime coastal risks, and SD3 in precipitation-related risks.

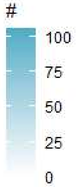
2.6. Results and discussion: Hazard and Risk

When establishing relationships between hazard typology and associated risk, it's important to consider that multiple hazards and risks may coexist in a given event.

Based on frequency analysis (we present count matrices for "all events" and "single hazard events"), we observe that associations between hazards and risks follow the inherent logic of hazard and risk definitions.

Count Matrix H-R (All Events)

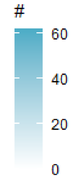
	R01.CMR Coastal Impact	R02.CMR Navigation	R03.CMR CTD	R04.Persistent Precip	R05.Intense Precip	R06.Snow	R07.Wind in exposed zones	R08.Wind in non-exposed zones	R09.Persistent high Temp	R10.Extreme high Temp	R11.Low Temp - Frost	R12.Forest fires	R13.Other
H12.Other	0	0	1	0	4	1	2	3	1	1	4	2	16
H11.Fire Weather	0	3	6	1	4	0	15	7	10	13	2	35	5
H10.Act Front	9	33	1	51	17	21	21	6	0	0	3	0	30
H09.Winter Storm	21	55	1	38	8	106	39	16	0	0	37	0	34
H08.Cold Adv	0	1	0	3	0	17	4	2	0	0	17	0	8
H07.Heat Adv	0	0	13	0	5	0	1	1	18	28	0	13	6
H06.Swell	33	47	0	6	3	13	31	23	0	0	4	0	9
H05.COL	1	6	0	33	28	4	6	5	1	0	1	0	21
H04.NW Gale	9	21	0	19	4	14	21	13	0	0	2	0	15
H03.CTD	0	2	27	0	4	0	0	0	6	13	0	6	3
H02.Wind Storm	20	45	0	8	5	14	77	59	0	0	3	12	10
H01.Sum Convec	2	4	2	4	67	0	4	3	4	4	0	3	41



- Summer Convection Hazard (H01) is primarily associated with the risk of Intense Precipitation (R05) and R13.Others (mainly hail and lightning).
- H02.Wind Storm is mostly associated with R08 and R09 (Wind Risk).
- H03.CTD hazard type is mostly associated with R04.CMR: CTD. Risk.
- NW Gale Hazard (H04) is mostly associated with Coastal Maritime Risk (R01,R02), Wind Risk (R08,R09), and Precipitation Risk (R05 and R06).
- H05 is associated with Precipitation Risk (R05 and R06).
- H06 Swell hazard type is associated with maritime-coastal and wind type risk.
- Heat Advection (H07) is mainly associated with Temperature Risk and secondarily with R12.Forest Fires and R02.CMR.CTD Risk.
- H08.Cold Advection is associated with R06.Snow and R11.Low Temp – Frost.
- H09.Winter Storm is associated with R06.Snow and R02.CMR Navigation.
- H10.Active Front is associated with R04.Persistent Precipitation and R02.CMR Navigation.
- H11.Fire Weather Hazard is associated with R12.Forest Fires.

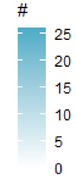
Count Matrix H-R (Single Event)

	R01.CMR Coastal Impact	R02.CMR Navigation	R03.CMR CTD	R04.Persistent Precip	R05.Intense Precip	R06.Snow	R07.Wind in exposed zones	R08.Wind in non-exposed zones	R09.Persistent high Temp	R10.Extreme high Temp	R11.Low Temp - Frost	R12.Forest fires	R13.Other
H12.Other	0	0	0	0	1	0	1	1	0	0	4	0	14
H11.Fire Weather	0	0	1	0	1	0	2	0	0	2	2	14	1
H10.Act Front	3	14	1	30	7	6	7	0	0	0	1	0	18
H09.Winter Storm	6	19	1	8	0	53	9	0	0	0	18	0	9
H08.Cold Adv	0	0	0	0	0	1	1	1	0	0	3	0	2
H07.Heat Adv	0	0	1	0	0	0	0	0	5	9	0	3	0
H06.Swell	14	20	0	1	1	1	5	2	0	0	2	0	1
H05.COL	0	0	0	22	20	0	0	0	0	0	0	0	14
H04.NW Gale	2	4	0	5	1	1	5	2	0	0	0	0	5
H03.CTD	0	1	15	0	1	0	0	0	1	2	0	0	0
H02.Wind Storm	5	17	0	0	1	3	37	29	0	0	1	1	2
H01.Sum Convec	1	2	1	4	62	0	3	2	3	2	0	1	38



Count Matrix H-R (Single Risk)

	R01.CMR Coastal Impact	R02.CMR Navigation	R03.CMR CTD	R04.Persistent Precip	R05.Intense Precip	R06.Snow	R07.Wind in exposed zones	R08.Wind in non-exposed zones	R09.Persistent high Temp	R10.Extreme high Temp	R11.Low Temp - Frost	R12.Forest fires	R13.Other
H12.Other	0	0	0	0	1	0	0	0	0	0	0	1	8
H11.Fire Weather	0	1	0	0	1	0	1	0	0	1	1	11	1
H10.Act Front	0	0	0	7	0	1	0	0	0	0	0	0	0
H09.Winter Storm	0	0	0	0	0	17	0	0	0	0	0	0	0
H08.Cold Adv	0	0	0	0	0	0	0	0	0	0	2	0	0
H07.Heat Adv	0	0	0	0	0	0	0	0	0	3	0	0	0
H06.Swell	1	4	0	0	0	0	0	0	0	0	0	0	0
H05.COL	0	0	0	6	6	0	0	0	0	0	0	0	0
H04.NW Gale	0	0	0	0	0	0	0	0	0	0	0	0	0
H03.CTD	0	0	12	0	0	0	0	0	0	0	0	0	0
H02.Wind Storm	0	1	0	0	0	0	6	0	0	0	0	0	0
H01.Sum Convec	0	0	1	2	26	0	0	0	1	0	0	0	4



2.7. Results and discussion: Hazard, Risk and Impact

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Considering Hazard , risk and impact relationships, in the summary table we shows **mean values** of impact indexes (among others)

- The mean IIG is 3 / 3.7 / 2.3 (all events / relevant risk events / non-relevant risk events). The mean IIS is 2.2 / 3 / 1.7. The mean IIH is 1.5 / 1.9 / 1.2. The mean IIE is 1.4 / 2.4 / 0.8 (considering NA=0) and 3.4 / 3.7 / 3.0 (considering just non-NA).
- The most impactful Hazard: H04.NW Gale (Mean(IIG=4)).
- The least impactful Hazards: H03.CTD (Mean(IIG=2.2)) and H11.Fire Weather (Mean(IIG=2.2)).
- The most impactful Risk: R08.Wind in Non-Exposed Zones (Mean(IIG=3.8)).
- The least impactful Risks: R10.Extreme High Temp (Mean(IIG=2.6)) and R11.Low Temp - Frost (Mean(IIG=2.6)).
- Hazard with higher/lower Mean(IIS): H04.NW Gale (3.2), / H11.Fire Weather (1.4).
- Hazard with higher/lower Mean(IIH): H09.Winter Storm (2) / H03.CTD (1.2).
- Hazard with higher/lower Mean(IIE): H02.Wind Storm (2.5), H03.CTD (0.8) / H11.Fire Weather (0.8).
- Risk with higher/lower Mean(IIS): R07.Wind in Non-Exposed Zones (2.8) / R11.Low Temp - Frost (1.6).
- Risk with higher/lower Mean(IIH): R08.Wind in Non-Exposed Zones (2.2) / R10.Extreme High Temp (1.2).
- Risk with higher/lower Mean(IIE): R07.Wind in Non-Exposed Zones (2.1) / R11.Low Temp - Frost (0.8).

	H-R-I summary table	Num Events	Num Events (single hazard)	Num Events (Rel Risk Events)	Total Duration (days	Mean Duration days	Mean Duration (Single Hazard)	Mean Number of Hazards	Mean Numbre of Risks	Mean(IIG)	Mean(IIS)	Mean(IIH)	Mean(NIIE)	Mean(IIP)	Mean(IIG) (Single Hazard)	Mean (IIG) (Rel Risk Events)	Mean IIG (Rel Non Risk Events)
HAZARDS	H01.Sum Convec	80	73	17	108	1,4	1,2	1,1	1,7	2,7	2,1	1,3	3,1	1,6	2,7	3,6	2,4
	H02.Wind Storm	80	38	49	157	2	1,9	1,6	3,2	3,7	2,8	1,5	4	2,2	3,5	4,1	2,9
	H03.CTD	27	15	12	48	1,8	1,1	1,6	2,3	2,2	1,9	1,8	2	1,8	1,9	3,2	1,3
	H04.NW Gale	22	5	21	62	2,8	1,8	1,9	5,4	4	3,1	2,1	3,8	2,7	3,8	4,1	2
	H05.COL	44	31	18	94	2,1	2	1,3	2,4	3,2	2,6	1,3	3,4	1,9	3	4,1	2,6
	H06.Swell	51	21	42	102	2	1,6	1,7	3,3	3,2	2,4	1,7	3,7	2,4	2,2	3,6	1,3
	H07.Heat Adv	31	10	20	93	3	2	1,9	2,8	2,7	2,1	2,4	1,5	2,2	2,8	3,2	1,8
	H08.Cold Adv	20	4	12	101	5	4,2	1,9	2,6	3,1	2,8	3	3,2	2,5	3	3,9	2
	H09.Winter Storm	109	55	56	317	2,9	2,5	1,7	3,4	2,9	2,4	1,6	3,5	2,4	2,1	3,8	1,8
	H10.Act Front	58	34	20	122	2,1	1,7	1,7	3,5	3,2	2,7	1,2	3,7	2,3	3	4	2,9
	H11.Fire Weather	61	34	15	128	2,5	1,9	1,7	2,2	2,2	2	1,4	3,7	1,8	1,6	3,3	2,2
RISKS	R01.CMR Coastal Impact	63	32	43	128	2,1	1,8	1,8	4,2	3,1	2,4	1,5	3,7	2,5	2,3	3,7	1,6
	R02.CMR Navigation	148	78	85	315	2,2	2	1,6	3,9	3,2	2,4	1,5	3,7	2,5	2,7	3,9	2,3
	R03.CMR CTD	33	20	14	62	1,9	1,4	1,5	2,4	2,2	1,9	1,7	2	1,8	1,9	3,1	1,4
	R04.Persistent Precip	114	70	60	262	2,3	2	1,5	3,6	3,4	2,7	1,4	3,6	2,3	3	4	2,7
	R05.Intense Precip	120	95	36	207	1,7	1,5	1,2	2,5	2,9	2,3	1,3	3,3	1,8	2,8	3,9	2,5
	R06.Snow	124	66	68	346	2,8	2,4	1,6	3,5	3	2,5	1,6	3,7	2,4	2,4	4	1,9
	R07.Wind in exposed zones	146	71	93	325	2,3	2,1	1,6	3,8	3,5	2,7	1,6	3,9	2,4	3,3	4,1	2,7
	R08.Wind in non-exposed zones	88	38	64	190	2,2	2	1,6	3,9	3,8	2,9	1,7	4	2,4	3,7	4,2	3,1
	R09.Persistent high Temp	21	8	14	83	4	2,4	1,8	3,1	3,3	2,7	2,8	2,5	2,1	3,6	3,4	3,1
	R10.Extreme high Temp	33	14	19	89	2,7	1,7	1,7	2,7	2,6	2,1	2,3	1	2,2	2,7	3,2	1,9
	R11.Low Temp - Frost	53	32	22	170	3,3	2,6	1,4	3	2,6	2,1	1,7	3,2	2,3	2,3	3,6	1,9
	R12.Forest fires	43	20	18	115	2,7	2,2	1,7	2,6	2,8	2,4	1,8	3,7	2,1	2,2	3,6	2,2

2.7. Results and discussion: Hazard, Risk and Impact

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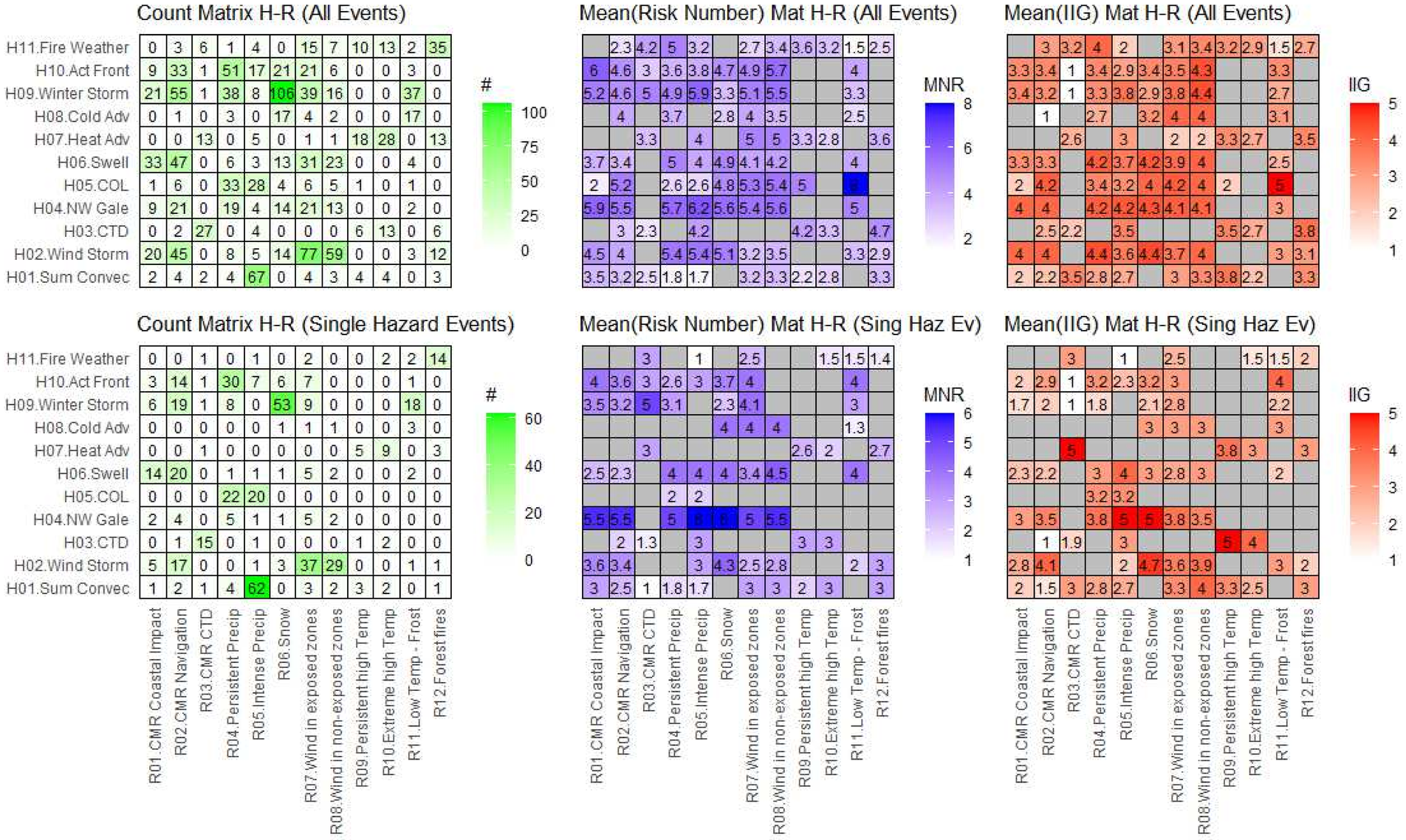
Caution must be exercised when interpreting impact values in H-R Matrixes , considering that:

- Impact is assigned univocally to a particular event (not possible to assign directly to hazrd/risk)
- The majority of events are multi-hazard and/or multi-risk, which implies cross-interactions.
- The general risk index is calculated as the maximum of its components:

IIG = max(IIS, IIH, IIE).



2.7. Results and discussion: Hazard, Risk and Impact

For example:

If we analyze the intersection of H07.Heat.Adv with R03.CMR.CTD, we have:

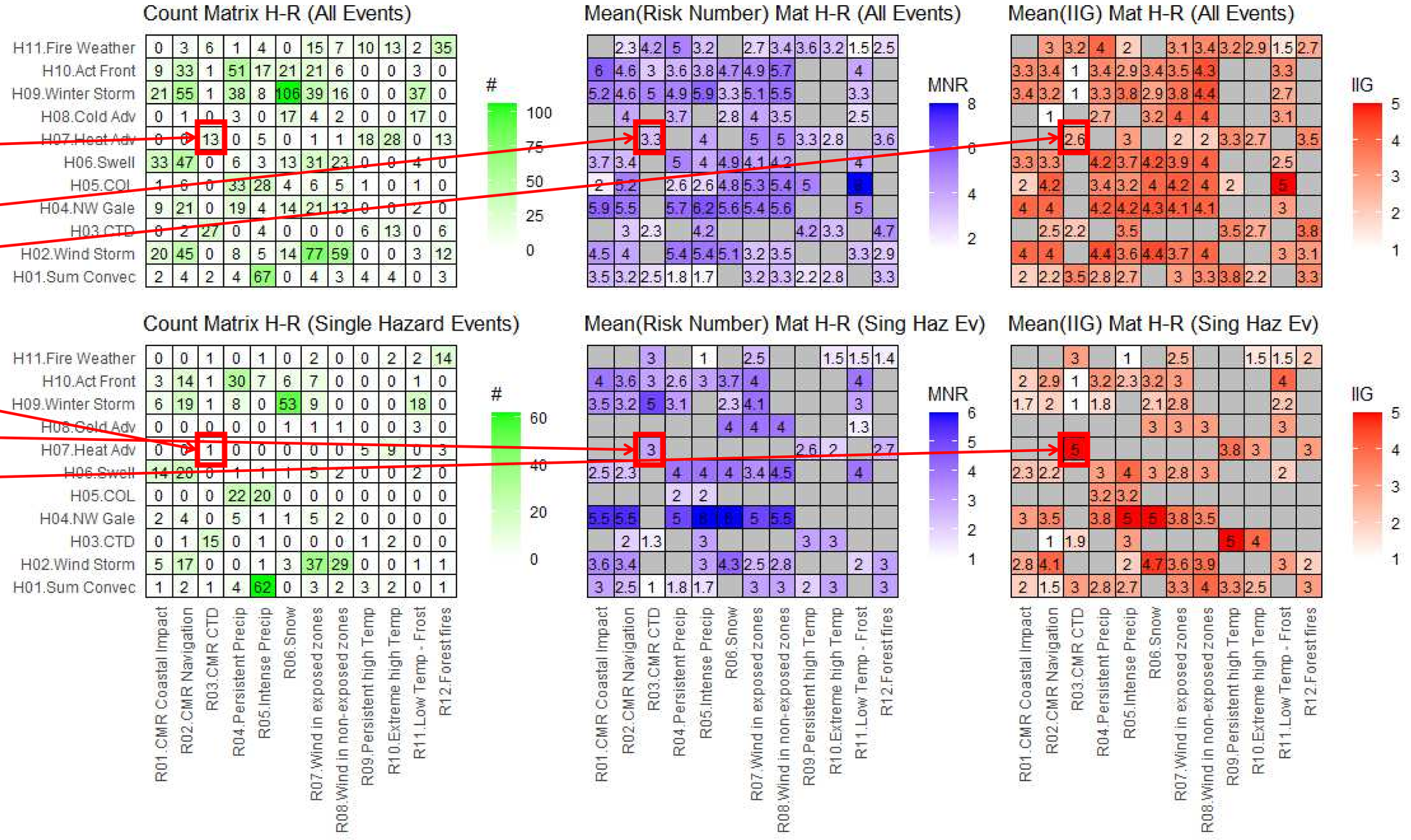
For all events:

- There are 13 events where both concepts appear in a single event, with an average number of risks of 3.3 and an average impact value of 2.6.

For single-hazard events:

- There is only one occasion where this Hazard and Risk appear together. In that event, we have 3 risks (2 additional to R03) with an average impact value of 5.

Obviously, this high impact value is not driven by R03 but is associated with the two additional risks, which in this case are linked to extreme heat (R09 and R10). In this event, the general impact is very high (5) with the IIS and IIE being low, but IIH very high, driven by the fact that during this event (2011-06-26), an 11-year-old child died from heatstroke.



3. Remarks and future work

Remarks

- Despite some shortcomings, the severe weather catalog appears to be a valuable tool for understanding key aspects of severe weather in our region
- However, the non-unique nature of many nominal categories (hazard, risk, spatial) complicates drawing clear conclusions.
- Isolating the impact of each risk and/or hazard category is challenging, as the catalog only provides univocal impact indexes at the event level.
- Unsurprisingly, impacts increase in multi-hazard, multi-risk, multi-location, and multi-day events.

- We are aware that the terminology of hazard/risk/impact used in this work could be confusing. It responds to the historical context of Euskalmet, where:

  - "hazard" refers to the weather/environmental conditions or severe weather typology,

  - "risk" is the cause of severe weather warnings issued by the Basque government, which indicates the risk of impact due to some local environmental variable (or combination) effect in a particular exposure context, and

  - "impact" refers to the realization of that risk through the quantification of the damage or perturbation of normal life.

  These are all complex concepts that can be misinterpreted, among others, due to translation into languages different from the native context.

Future work

- Review/expand the hazard and risk categories existing in the catalog.
- Review/expand the factors considered in the calculation of impact indicators.
- Use available observational data to quantify the spatial extent of risk and other key contextual parameters.
- Conduct comparative studies with events in other available catalogs (e.g., DesInventar).
- Employ more complex visual data analytics techniques (initial results with alluvial plots are particularly interesting).
- Deepen the understanding of the complex hazard/risk/impact interrelationships through modeling with AI-ML (initial results with Random Forest are particularly promising).

4. References

- Gaztelumendi, S., Egaña, J., Ruiz, M., and Iturrioz, E. (2023) The Basque Impact Weather Catalogue, EMS Annual Meeting 2023, Bratislava, Slovakia, 4–8 Sep 2023, EMS2023-237, https://doi.org/10.5194/ems2023-237,
- Gaztelumendi, S., Egaña, J., Liria, P., Gonzalez, M., Aranda, J. A., and Anitua, P. 2016 The new Euskalmet coastal–maritime warning system, Adv. Sci. Res., 13, 91–96, https://doi.org/10.5194/asr-13-91-2016.
- Gaztelumendi, S., Orbe, I., Salazar, O., Lopez, A., Aranda, J. A., and Anitua, P. 2016. Delivery and communication of severe weather events in Basque Country: the Euskalmet case, Adv. Sci. Res., 13, 87–90,
- Gaztelumendi, S., Egaña, J., Hernandez, R., Otxoa de Alda, K., Aranda, J. A., and Anitua, P., 2012. An overview of a regional meteorology warning system, Adv. Sci. Res., 8, 157–166.
- Gaztelumendi, S., Egaña, J., Ruiz, M., Pierna, D., Otxoa De Alda, K., and Gelpi, I. R., 2011. An analysis of Cantabric coastal trapped disturbances, 6th EuroGOOS.
- GV. 2018. Protocolo de predicción, vigilancia y actuación ante fenómenos meteorológicos adversos. Procedimiento DAEM P005 v-10. Gobierno Vasco.
- GV. 2023. Protocolo de predicción, vigilancia y actuación ante fenómenos meteorológicos adversos. Procedimieto DAEM P005 v-11. Gobierno Vasco.
- R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/. 2022.
- Tukey, J.W. Exploratory Data Analysis, Addison-Wesley, 978-0201076165, 1977.
- Wickham H, Vaughan D, Girlich M. tidyr: Tidy Messy Data. R package version 1.3.1, https://github.com/tidyverse/tidyr, https://tidyr.tidyverse.org. 2024.
- Wickham H, François R, Henry L, Müller K, Vaughan D. dplyr: A Grammar of Data Manipulation. https://dplyr.tidyverse.org, https://github.com/tidyverse/dplyr. 2023.
- Wickham H., Grolemund, G. R for data science. O'Reilly Media. ISBN-13: 978-1491910399. 2017.
- Wickham H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. ISBN 978-3-319-24277-4, https://ggplot2.tidyverse.org. 2016.
- WMO. 2015. Guidelines on Multi-hazard Impact-based Forecast and Warning Services. WMO-No. 1150.
- WMO. 2021. Guidelines on Multi-hazard Impact-based Forecast and Warning Services (WMO-No. 1150), Part II: Putting Multi-Hazard IBFWS into Practice (2021)

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QUESTIONS ?

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