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Hydro-meteorological and impact characterization of floods in the Basque Country

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CONTENT

1. Motivation and context

- Severe weather phenomena affect the Basque society in many ways, from disruption in various sectors and substantial damages in infrastructure to human and economic losses.
- Flooding is, among others, one of the natural event that causes a relatively high impact in Basque Country, usually as a consequence of intense and persistent precipitation.
- A dense hydro-meteorological network is present in our territory with high temporal resolution data (10 min) covering main rivers.
- Insurance claim data from "extraordinary floods" are available.
- Previous works on flood characterization have been done for some particular catchments and temporal periods in the past.

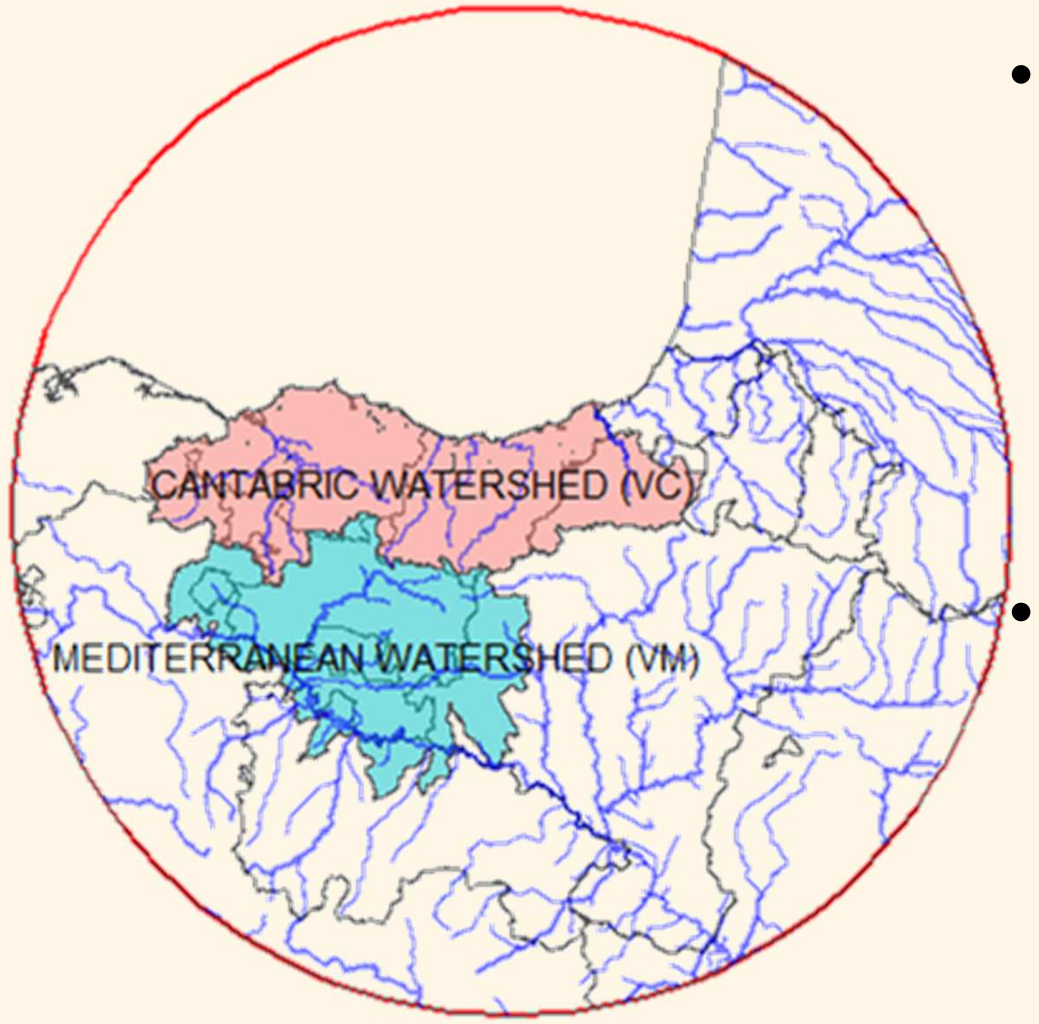
In this work we focus on the analysis of flood impacts and their hydro-meteorological characterization for all the territory, during the period 2000-2021 .

The final objective is to contribute to knowledge of impact processes, increasing awareness and preparedness during flood events.

Nov 2011

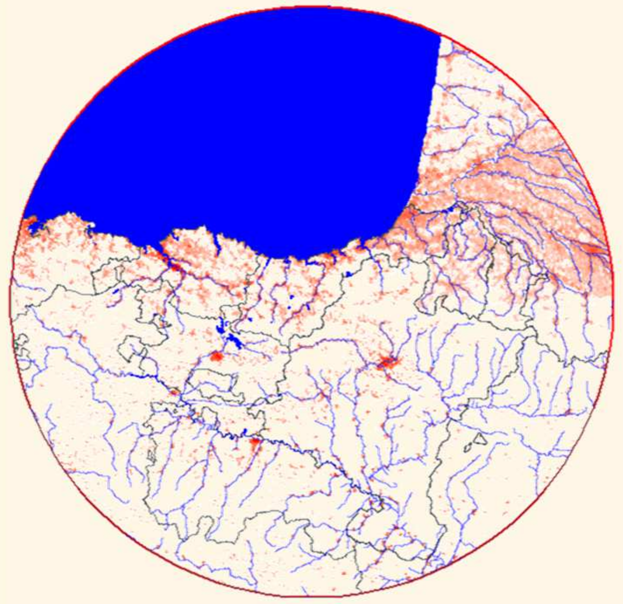
1. Motivation and context

Basque Country is located in between France and Spain at west part of Pyrenees.

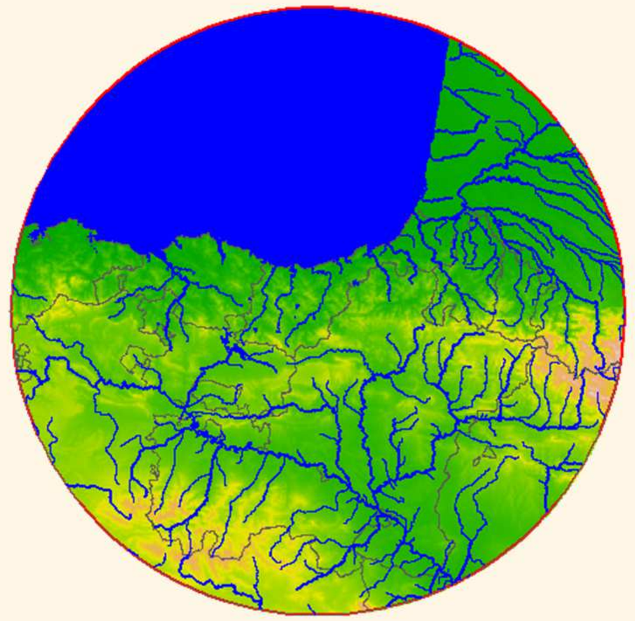


- Is important to note that Mediterranean basins cover most part of Southern part of the territory, mainly in ARABA, the largest (2,963 km²) of the three BAC territories but the less industrial, inhabited and relatively flat part of the Country.
- On the other hand BIZKAIA (2.217 km², 1.141.000 inhabitants) and GIPUZKOA (1980 km², 700.000 inhabitants) are mainly in Cantabric basin, with many relatively small river´s valleys highly populated and with industrial activities.

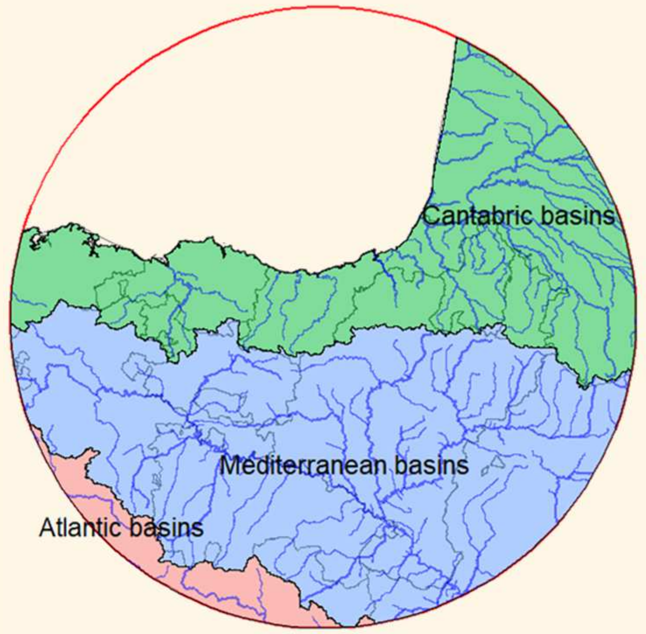
Basque Autonomous Community (BAC) is conformed by ARABA, BIZKAIA and GIPUZKOA territories.



Population



Orography and rivers



Main basins

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1. Motivation and context

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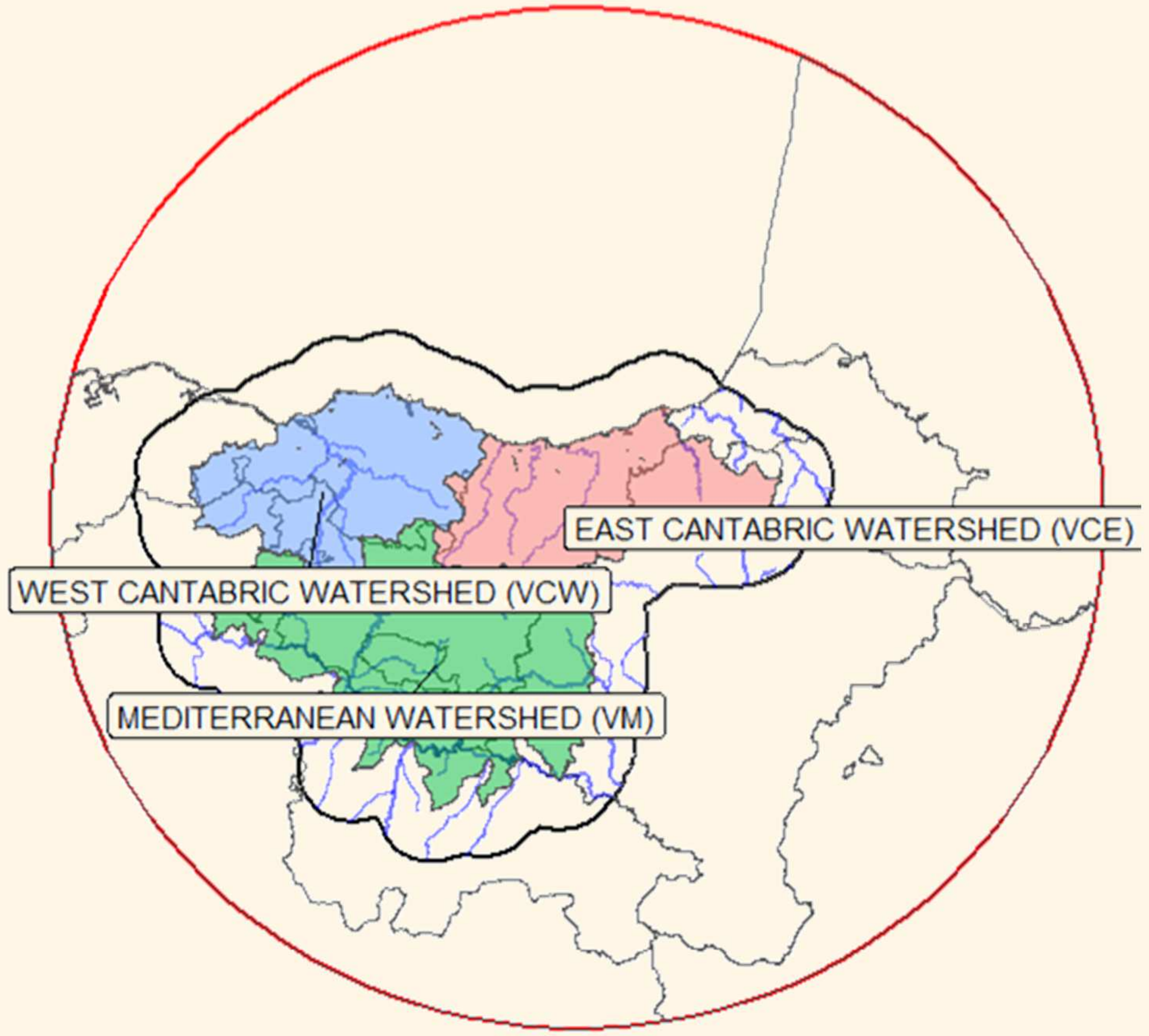
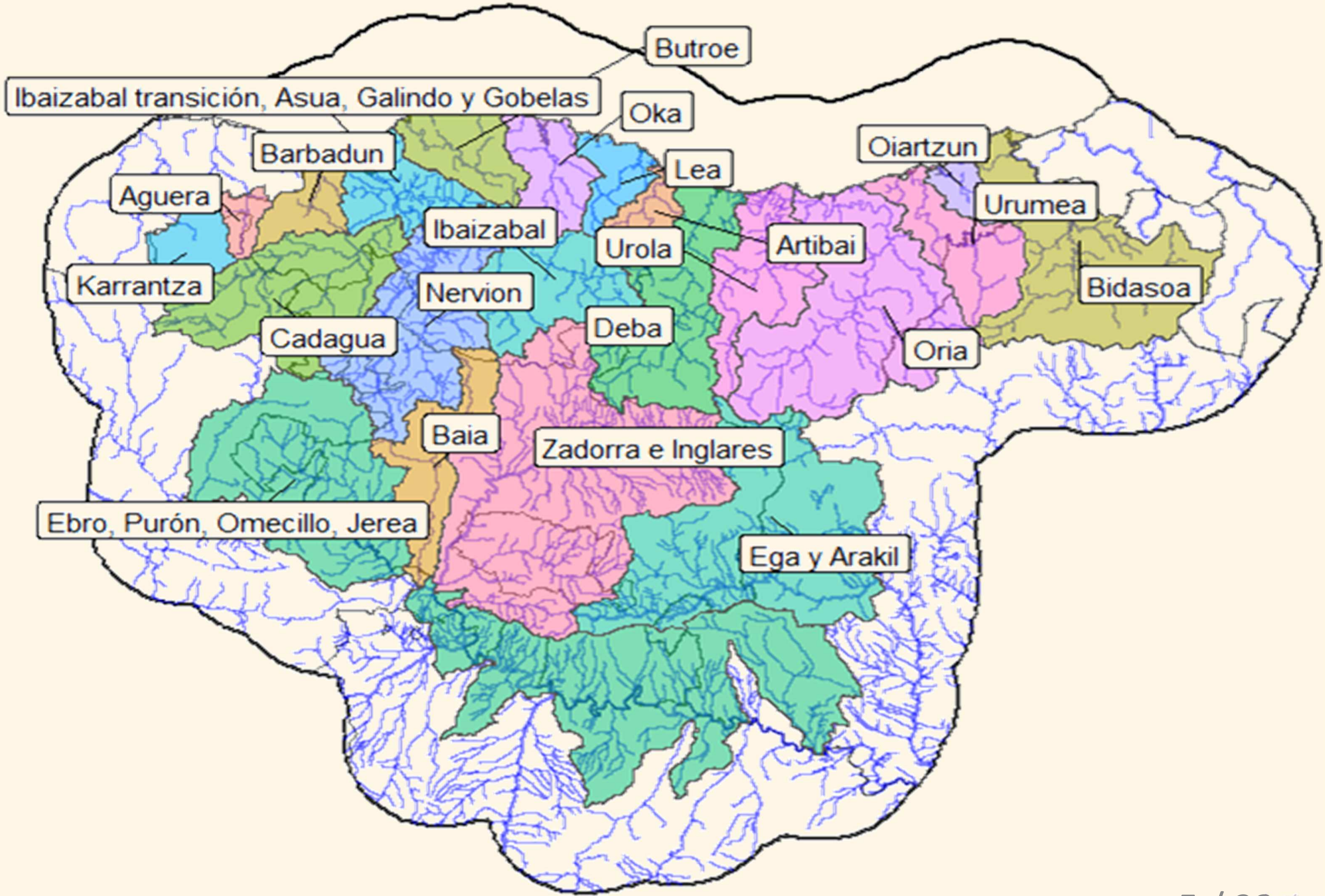
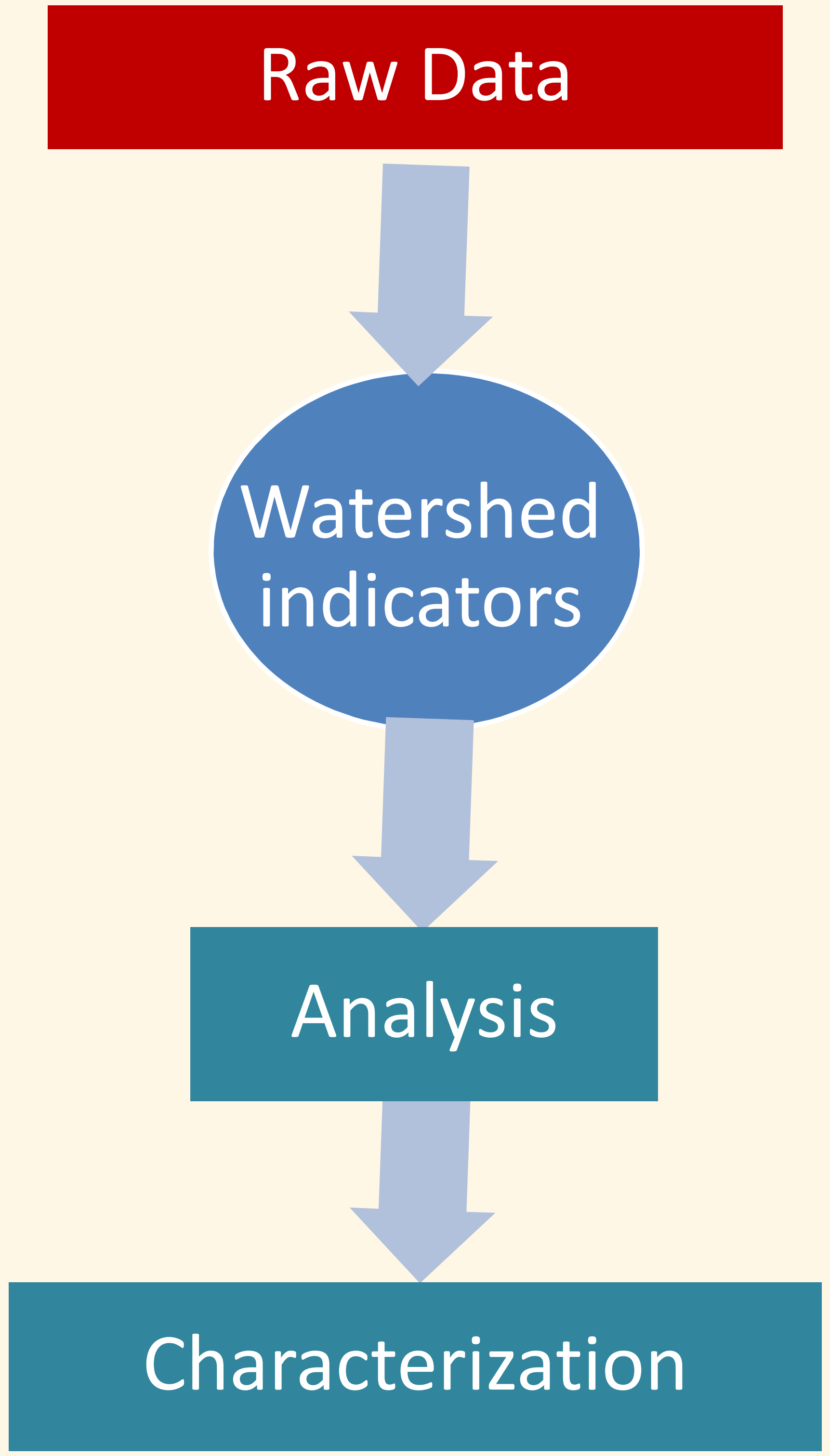
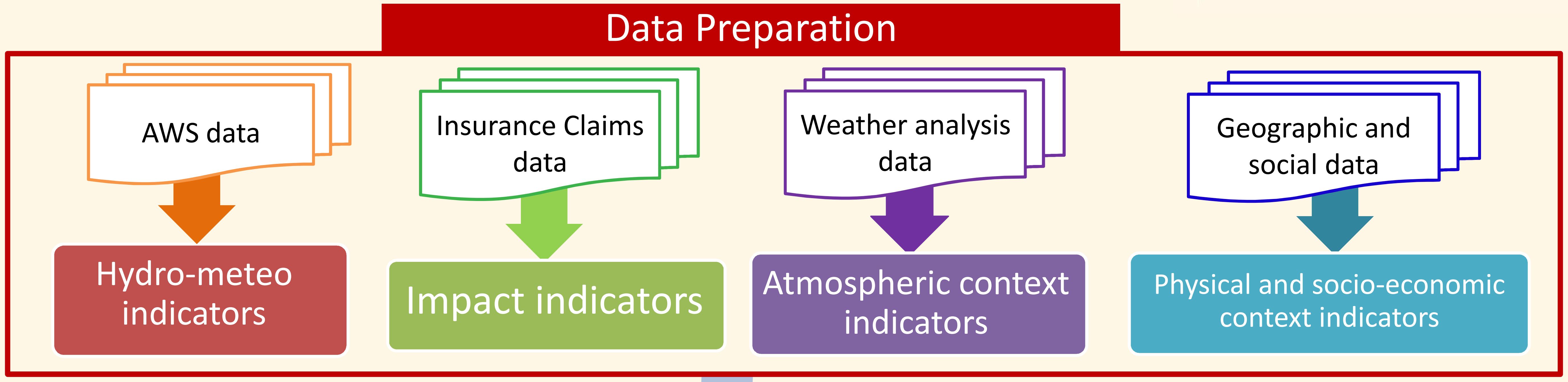
For this study the full domain is divided in 21 watersheds





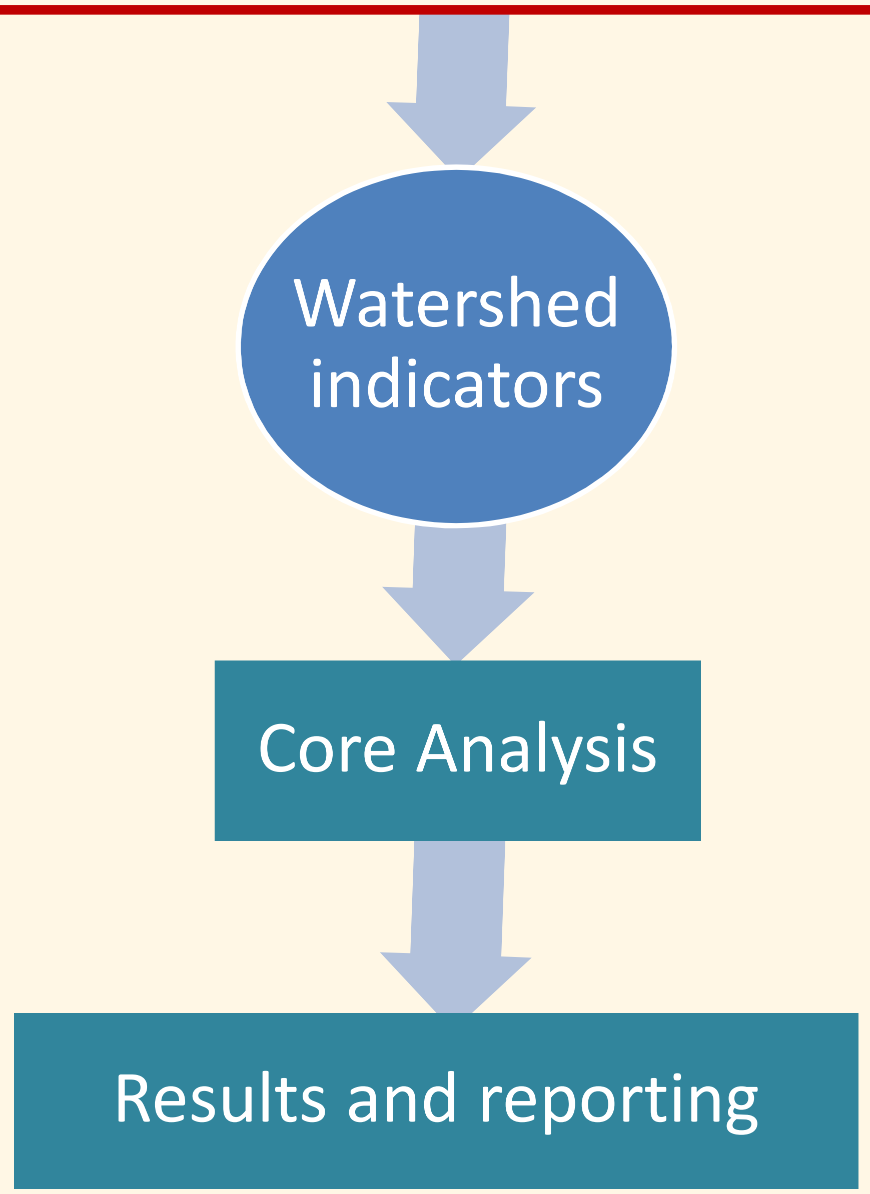
2. Methodology and data





Workflow is based on typical processes in data science.

We use extensively Exploratory Data Analysis (EDA) and Visual Data Analytics (VDA) for data preparation, core analysis and characterization



- ✓ Four data typologies are included in the study :(1) **impact**, (2) **hydro-meteo**, (3) **weather context**, (4) **physiographic and social context** at watershed level.
- ✓ A set of specific Python and R scripts have been developed for the acquisition of such heterogeneous raw data set the inspection, cleaning and transformation in a set of indicators with relevant information.

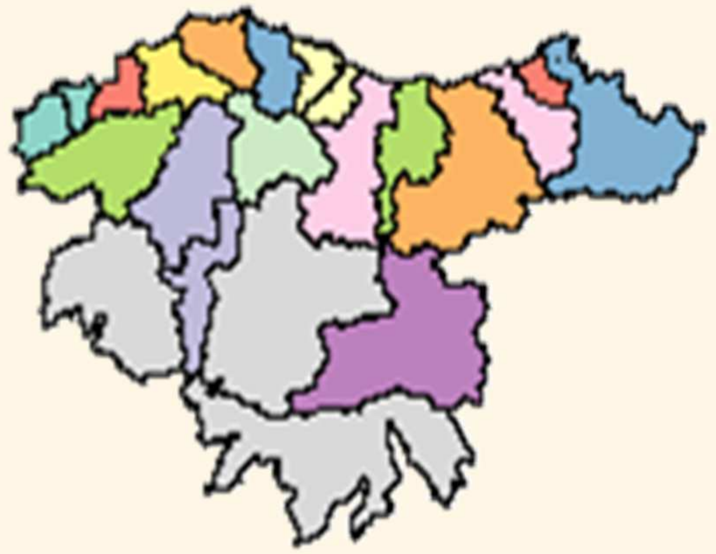
2. Methodology and data – physiographic and socio-economic context

Different data sources are used for physiographic and socio-economic context, including AWS descriptors, different rasters and shapes for rivers, watershed, municipalities, etc and tabular data for population and other social aspects.

A set of R scripts have been implemented in order to translate original data based on different tabular data at municipality level, raster files with orography and some vector files with different shapes to adequate format for analysis at watershed level.

(1) Socio-economic indicators at watershed level.
(2) Physiographic indicators for each watershed.
(3) Auxiliary vector files for spatial segmentation

Geographic and social data at different formats



(1) Physiographic and socio-economic context indicators

(2) derived shapefiles

2. Methodology and data - Impact

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Claims data used in this study come from the Spanish Insurance Compensation Consortium (CCS). Consist on a set of individual claims paid by CCS for "**extraordinary inundation**" cause during the studied period. Available information consist on an excel spreadsheet that includes day, amount paid and municipality where claim is accepted.

Different R scripts have been implemented in order to translate original claim data based on unitary claims and municipalities to a **daily data** structure based **on watersheds**. Under different spatial and temporal aggregation, different daily quantitative and qualitative impact indicators are constructed by different spatial and statistical operations (segmentation, count, sum, mean, max, sd …).

Final Impact data set, consist on **daily impact indicators** aggregated at watershed level. Such data are stored in R native tibble format for further exploitation and in .csv file with more than 50 impact indicators.

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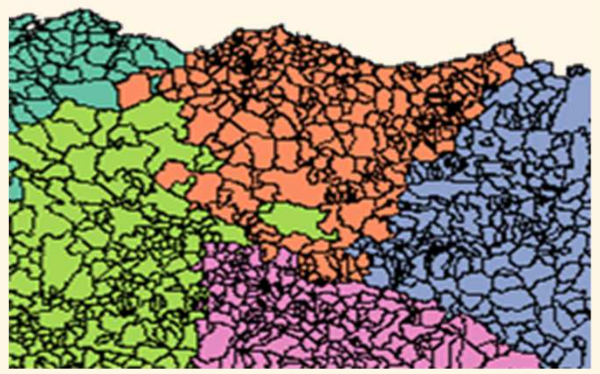


Claims CCS data.

Excel file

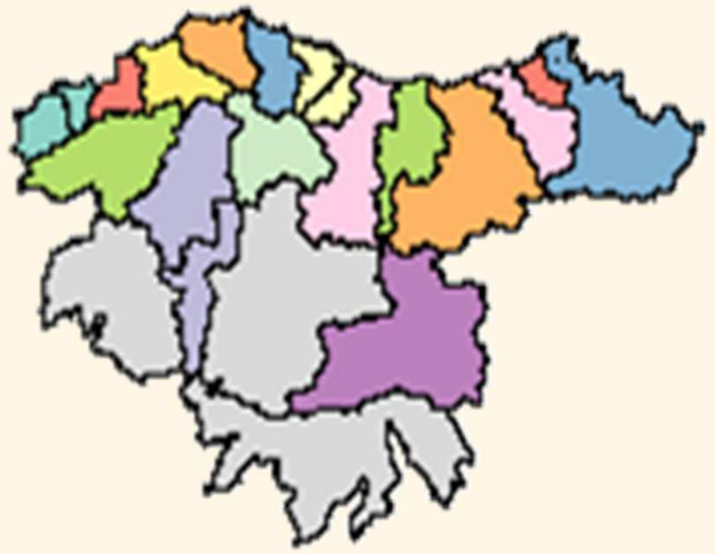
853 M

639.290.706 €

80.321 P

2007 D

sf, ggplot2, PATCHWORK, Terra, tidyr, dplyr, lubridate



Daily impact indicators data.

R tibble & .csv

21 Watershed

(317 M)

364.193.354 €

40.820 P

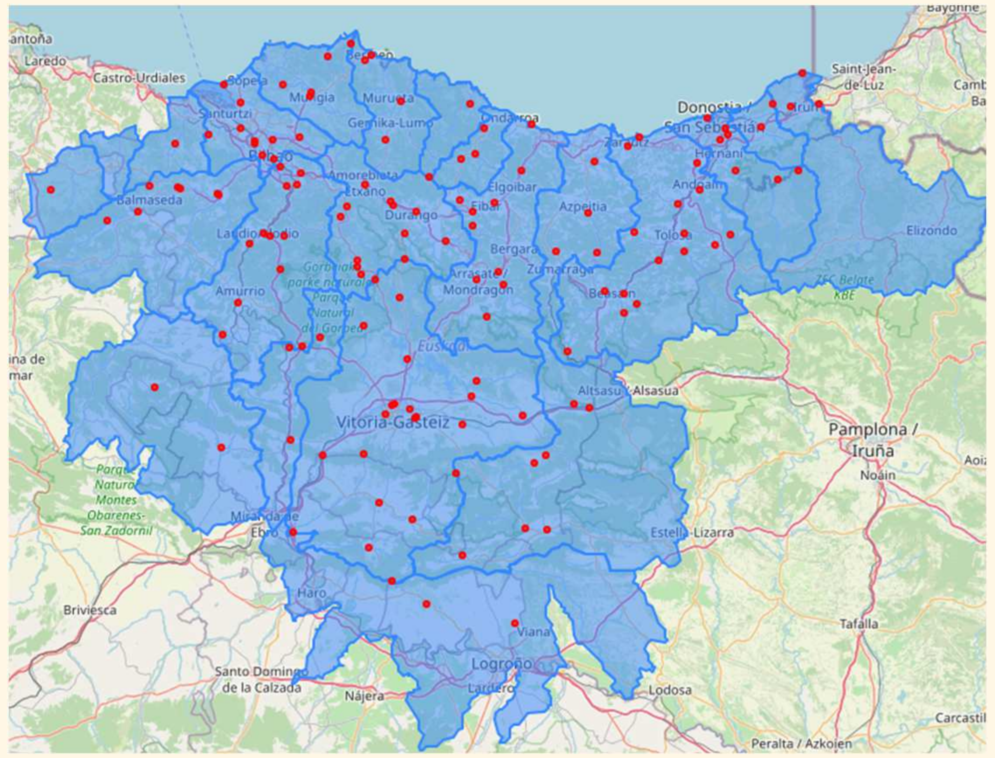
933 D

2. Methodology and data – Hydrometeo

Hydro-meteo (river level, precipitation, …) data used in this study comes from Euskalmet and URA, consist on a set of files with hydro-meteo variables registered in the Basque network during the period 2000-2021. Available data (mainly in plain text .dat files) for each location have different structures, different temporal resolution and different quality control level.

Available files:

- 119 locations with quality controled daily meteo data.
- 39 locations with 10 min river level quality controled data
- 71 locations with raw 10 min river level data.
- 103 locations with raw 10 min precipitation



Different Python scripts have been implemented in order to prepare single unique files for each watershed containing different hydro-meteo indicators at daily level. Such indicators are constructed throw different mathematical operations (count, sum, mean, max, sd …) under different spatial and temporal aggregations.

Python3 con Pandas, numpy, json, sklearn, seaborn. SQLite.

Final Hydro-meteo data set, consist on more than 100 daily hydro-meteo indicators aggregated at watershed level. Such data are stored in .csv format for further exploitation:

Hydro-meteo indicators are calculated for all the basins where raw data are available, among others, max, min and mean values of precipitation accumulated in different temporal period (p10minutes,p30min, p1hour,p3h,p6h,p12h,p24h,p48h,…p168h) and normalized river level.

17 files with more than 100 hydro-meteo indicators

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2. Methodology and data – Weather context

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SLP maps, geopotential and temperature synoptic maps (850hPa, 500hPa), precipitation analysis maps, different Radar products and AWS daily data and other products available in Euskalmet.

We apply expert analysis based on operational procedures (maps and data available in Tecnalia-Euskalmet intranet) in order to obtain the daily general weather context, based on human classification of circulation patterns, weather types, severe weather classification and other characteristics at synoptic and mesoescale level.

6 different meteorological context qualitative indicators for relevant impact days.

:

(1) Synoptic classification is based on three aspects: **type**, **circulation** and **shape**. Type refers to the prevailing wind direction in lower layers, circulation to the ratio of the component u and v wind up describing the movements that occur in middle and high levels. The shape describes the situation of different pressure systems in surface (see Table 1).

(2) Type of structure or prevailing cloud system. Based on Euskalmet classification for predominant prevailing type of cloud system that are present during event (see Table 2)

(3) Categories of severe weather. Euskalmet classification for potentially dangerous episodes. In floods context are limited to 4 options: cut-off lows, active frontal systems, northwest gale and storms (see Table 3)

(4) Type of precipitation. Established based on stratiform and/or convective nature of precipitation. Being stratiform when the intensity of rainfall is weak or moderate; convective if the precipitation dominated by strong or very strong rainfall.

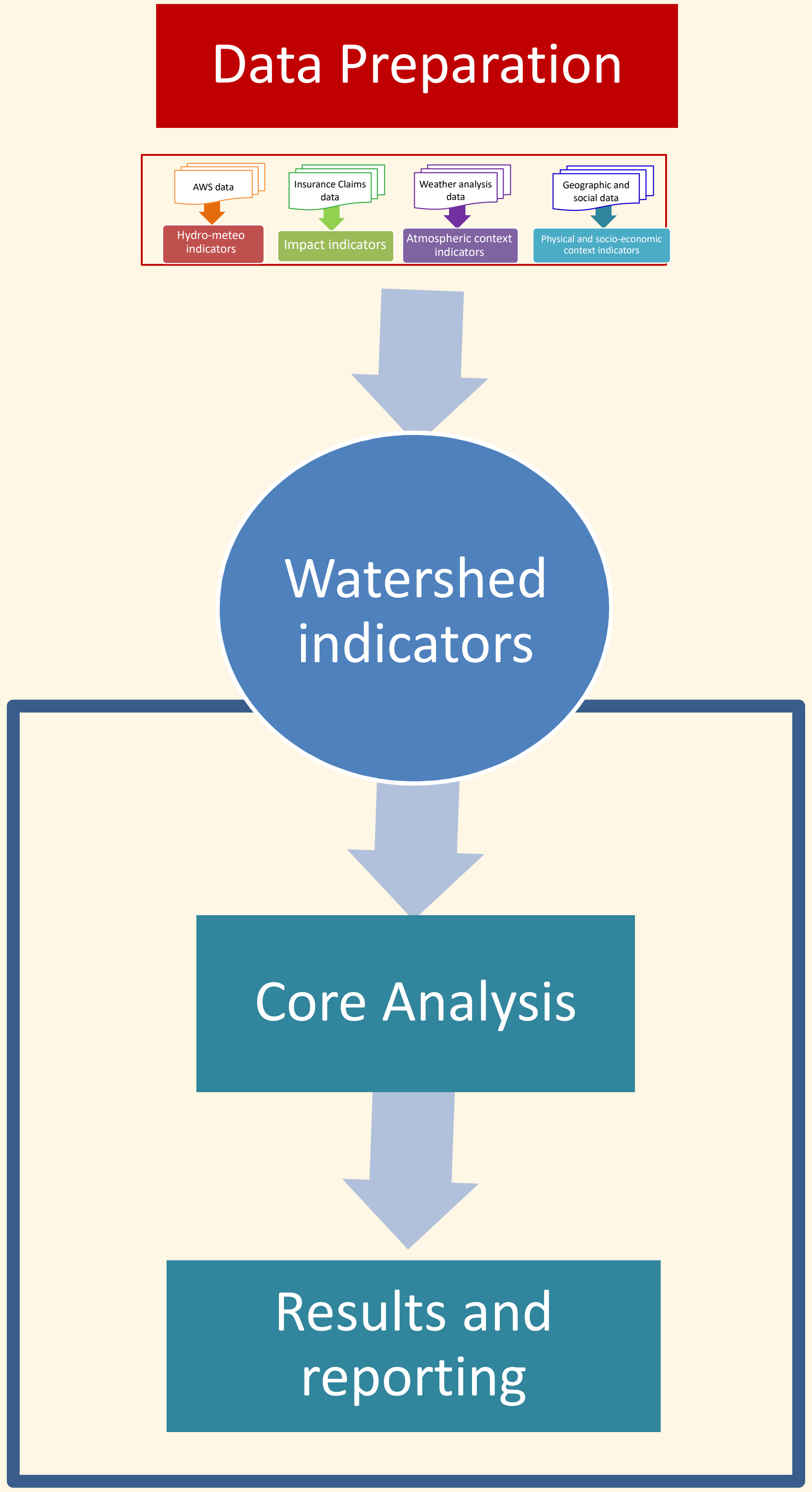
Weather analysis, and atmospheric configuration data

Type	Circulation	Shape
Maritime	Zone	Undefined
		Azores High
		Britannic Low
		Low latitudes circulation
	Meridian	Undefined
		Azores High
		Atlantic High
		Britannic Low
		Bay of Biscay Low
		Euro-Mediterranean Low
	Detached	Undefined
		Bay of Biscay Low
		Mediterranean Low
		Euro-Mediterranean Low
Iberic	Zone	Undefined
		Low latitudes circulation
		Britannic Low
		Euro-Mediterranean High
	Meridian	Undefined
		Centre-European High
		Britannic Low
		Bay of Biscay Low
	Detached	Undefined
		Atlantic Low
		Bay of Biscay Low
Continental	Meridian	Undefined
		Britannic-European High
		Euro-Mediterranean Low
	Detached	Undefined
		Euro-Mediterranean Low
		Continental High
		Britannic-European High
Local	Zone	Undefined
		Barometric swamp
		Iberian Thermal Low
		Iberian High
	Meridian	Undefined
		Barometric swamp
		Iberian Thermal Low
	Detached	Undefined
		Barometric swamp
		Iberian Low
		Iberian Thermal Low
		Britannic High

Name	Type of structures and cloud system description.
Active fronts	It is the situation in which one or more fronts pass through the Basque Country, leaving persistent rainfall. They can be very active fronts or a succession of fronts that pass through the Basque Country leaving lots of rain, even a succession of fronts and instability lines. Most of the precipitation is stratiform, although occasionally can leave convective precipitation.
Instability line	Leave storm rainfall. Its shape and displacement mode can make the amount of accumulated rainfall is higher or lower. In any case, precipitation is associated with storms and precipitation is largely convective. In the worst situations in which an instability line moved slowly, convective cells can pass through the same point generating heavy rainfall.
Quasi-stationary warm front	Northwest flow situation at all levels with a warm front it moves from west to east, with a north-south elongation and having a slow-moving. Rainfall is stratiform. These situations can be accompanied by the passage of more fronts
Convective cells	Convective cells are small-scale storm systems. They have different shapes, but do not bind in a line, and generally each cell is independent and has its own movement, sometimes when the flow is strong in height the different cells are moved in the same direction. Rainfall is heavy in a short time.
Mesoscale Convective systems	They are mesoscale systems dimensions, but of significant size (usually the major axis exceeds 100 km), where more or less active areas are grouped, with a mixture of convective precipitation in the most active and stratiform rainfall in less active zones. They can make very heavy rainfall since in many cases they are systems that do not follow the synoptic scale flow, and present self-propagation, sometimes very slow.

Severe weather	Description
Storms	These are the situations that occur in the summer, with heavy showers (> 10 mm in 10 minutes or > 15 mm in 1 hour) or very strong wind gusts (> 100 km / h) or large hail (above 2 cm diameter).
Hurricane winds	Situations that generate high wind gusts (> 100-120 km / h) generated by deep depressions (could be explosive cyclogenesis, or remnants of hurricanes or ordinary cyclogenesis).
CTD-s (Coastal Trapped Disturbance)	Sharp turn to the west-northwest, with sudden drop in temperatures (> 5-10 °C in 20 minutes), and maximum gusts above 60 km / h . This disturbance is spreading from west to east along the Basque coast.
Northwest gale	Intense northwest winds situation, also it is accompanied by persistent precipitation (> 60 mm in 24 hours) and wave (significant wave height exceeding 3.5 meters).
Persistent and heavy rainfall (cut-off low)	Situations cold pool in middle and upper levels, attached to efficient frontal systems or formation of mesoscale convective systems.
Swell arrival from distant deep depressions	Waves generated in remote areas that reaches the coast and sea background with heights exceeding 4 meters.
Heatwaves	Three days or more with overcoming the maximum-minimum thresholds. Arrival of a very warm air mass (temperature in the level of 850 hPa above 20-22 ° C) of North Africa or southern Iberian Peninsula with great persistence.
Heatstroke	A day with extreme high temperatures, usually in combination with the arrival of a very warm air mass from North Africa or southern Iberian Peninsula (temperature in the level of 850 hPa above 20-22 ° C) with south flows.
Severe frost	Continental very cold air advection combined with radiation cooling due to clear skies.
Snow storm	Cold and moisture air that can leave snow at low levels. Precipitation should exceed 5 mm in 24 hours.
Active frontal systems	Situations that often leave persistent rainfall, with northerly winds and quasi-stationary frontal systems, or active fronts.
Others	Events that cannot be classified in one of the previous options.

2. Methodology and data



Core Analysis, results and reporting

For core analysis and reporting of results VDA techniques are used. Visualizing the data in graphs, charts, and maps helps identify patterns and relevant factors behind impact flooding supporting the characterization of such phenomena in the target catchments and the reporting of conclusions.

The implementation of different R scripts* allows to analyze the data directly within the visualization itself extracting results and preparing graphs and maps for reporting.
Facets are used to create multiple panels of plots based on the levels of categorical key indicators.
Grouping and summarizing is used extensible in order to simplify complexity and extract conclusions with different level of spatial and temporal aggregation.

R libraries particularly used: *

- Sf for spatial vector data manipulation and analysis
- Terra for spatial raster data manipulation and analysis.
- tidyr for data manipulation and transformation
- dplyr for data transformation and analysis.
- ggplot2 for data visualization and analysis.

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3. Results and Discussion- Impact

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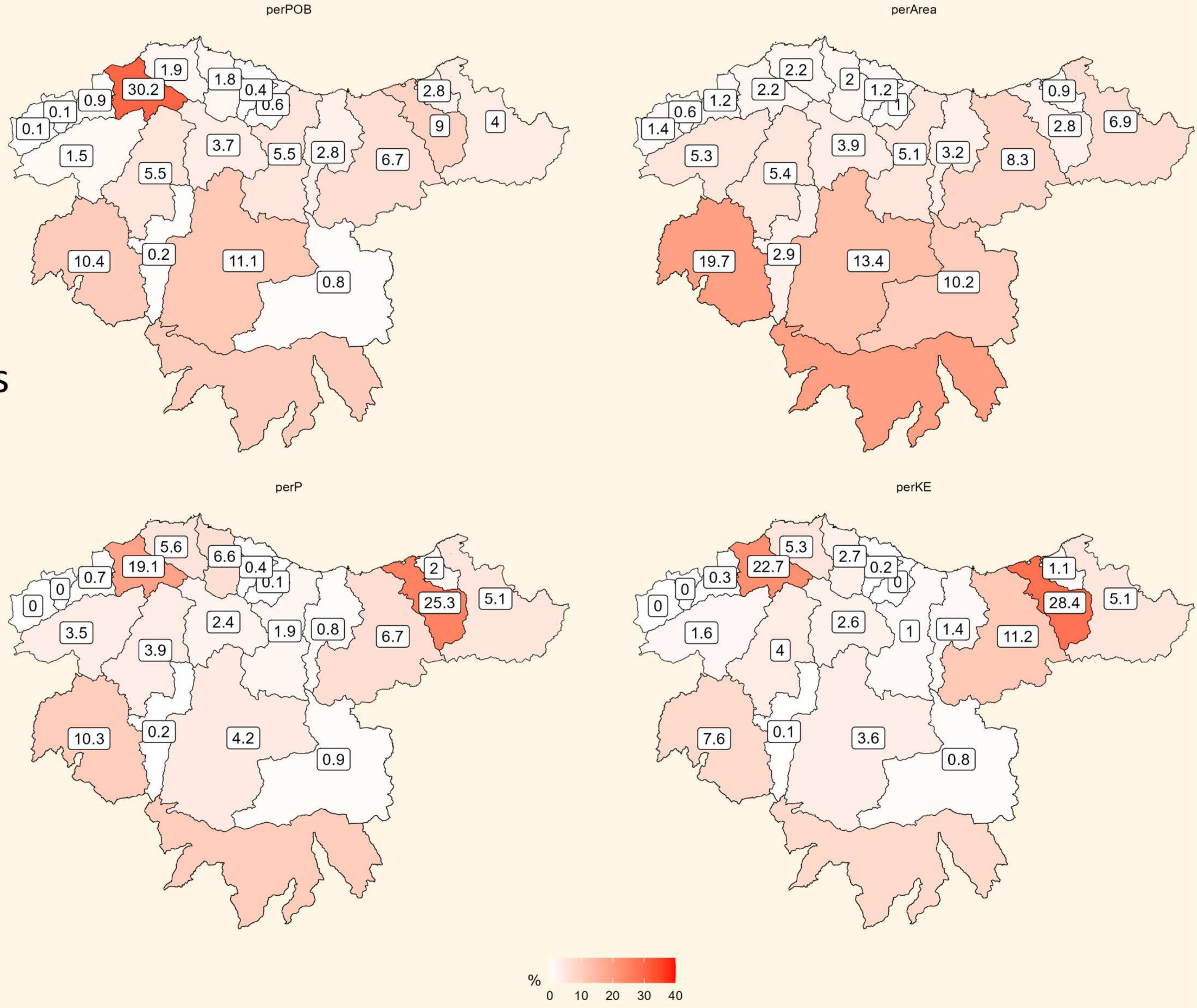
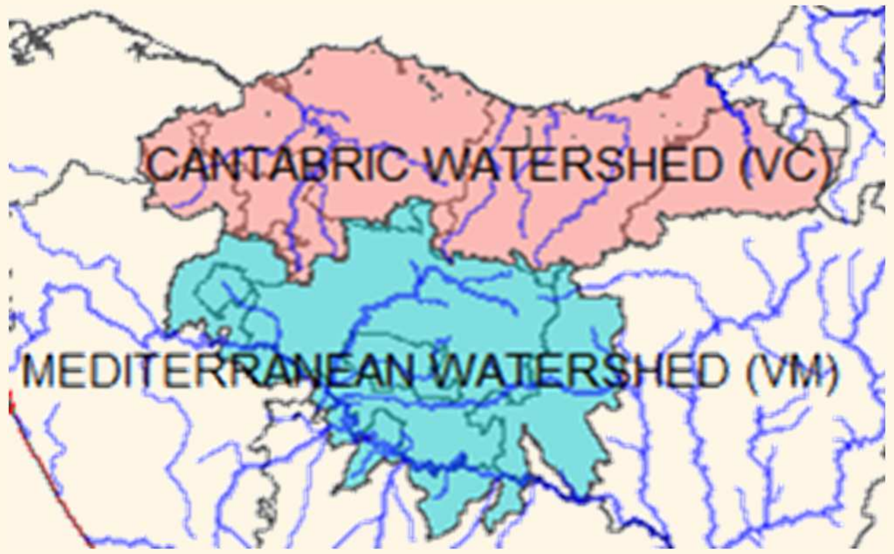
Impact at watershed level (Example of impact results for 21 watersheds analysed based on relative proportion tables and maps):

	perPOB	perArea	ND	NM	P_ND	perP	perKE	P_POB	KE_POB
Zadorra e Inglares	11.06	13.4	207	20	8.21739	4.2	3.6	6.1	47.4
Urumea	8.96	2.8	149	8	69.3557	25.3	28.4	45.7	457.8
Urola	2.77	3.2	49	11	6.65306	0.8	1.4	4.7	74.5
Oria	6.71	8.3	121	53	22.6776	6.7	11.2	16.2	241
Oka	1.77	2	54	15	50.0555	6.6	2.7	60.7	223.5
Oiartzun	2.83	0.9	38	4	21.3684	2	1.1	11.4	56.7
Nervion	5.53	5.4	108	15	14.6944	3.9	4	11.4	104.7
Lea	0.45	1.2	32	7	5.65625	0.4	0.2	16	56.3
Karrantza	0.12	1.4	8	2	2.125	0	0	5.6	21.1
, Asua, Galindo y Gobelas	30.23	2.2	239	18	32.5899	19.1	22.7	10.2	108.5
Ibaizabal	3.7	3.9	95	19	10.5157	2.4	2.6	10.7	101.8
Ega y Arakil	0.79	10.2	85	22	4.09411	0.9	0.8	17.4	144.3
ro, Purón, Omecillo, Jerea	10.37	19.7	314	51	13.4522	10.3	7.6	16.1	106.5
Deba	5.53	5.1	88	17	8.97727	1.9	1	5.7	26.3
Cadagua	1.48	5.3	103	9	13.9223	3.5	1.6	38.4	155.2
Butroe	1.86	2.2	95	16	24.1894	5.6	5.3	49	413.3
Bidasoa	4.03	6.9	114	19	18.3245	5.1	5.1	20.5	183.7
Barbadun	0.9	1.2	38	6	7.76315	0.7	0.3	13.1	52.5
Baia	0.25	2.9	42	5	2.42857	0.2	0.1	16	72.6
Artibai	0.63	1	17	5	2.41176	0.1	0	2.6	9
Aguera	0.06	0.6	7	3	1	0	0	4.7	14.6

- ✓ In two cantabric watersheds : Urumea (SS area) and Ibaizabal plus (BI area) 45% of total claims (**perP**) are produced corresponding to more than 50% of euros paid (**perKE**)
- ✓ Ratio of total claims per day (**P_ND**) are around 70 in Urumea case, 50 in Oka and 32 in Ibaizabal plus.
- ✓ Ratio of claims and euros per population (**KE_POB** and **P_POB**) are higher in Oka, Urumea, Butron and Cadagua.



3. Results and Discussion- Impact



ind	All	VC	VM	units
sumD	796	524	429	days
sumD>5P	204	137	92	days
sumD>100P	44	34	11	days
sumD>1000P	9	6	1	days
perD	9.91	6.52	5.34	%
perD>5P	2.54	1.70	1.14	%
perD>100P	0.548	0.423	0.137	%
perD>1000P	0.11	0.07	0.01	%
sumP	33,616	27,527	6,089	claims
meanP	42.2	52.5	14.2	claims
maxP	5,639	5,595	1,092	claims
sumKE	277,806	236,583	41,223	K€
meanKE	349	451	96.1	K€
maxKE	54,896	54,661	5,264	K€
meanNM	4.42	4.66	2.52	municipalities
maxNM	120	119	32	municipalities
meanUH	2.19	2.19	1.39	watersheds
maxUH	20	17	4	watersheds

Example of impact analysis for full domain (**all**) and two principal basins (Cantabric **VC** and Mediterranean **VM**) using main impact indicators (**ind**) :

Days (D):

- ✓ During 10% of days at least one claim is paid in any part of the domain,
- ✓ During 0.5% of days more than 100 claims are paid.
- ✓ Days with any number of claims are quite similar in between VC and VM , but clear differences appear for days with increasing number of claims.

Claims (P):

- ✓ More than 80% of claims are produced in VC.
- ✓ Mean number of claims is four times higher in VC than in VM
- ✓ During a single day around 16% of total claims are produced

Euros (KE).

- ✓ More than 85% of economic losses are produced in VC.
- ✓ During a single day around 20% of economic losses are produced

Watersheds (UH) and municipalities (M):

- ✓ In a “mean event” 4 municipalities are affected (2% of total).
- ✓ During the worst event 28% municipalities are affected, 45% in the VC case and 16% in VM case.

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3. Results and discussion – Impact

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Events are categorized considering the **relevance of impact** based on the
Economic Impact Indicator (IIE indicator)

IIE values are discrete and correspond to 6 impact categories:
NIA, VERY LOW, LOW, MODERATE, HIGH and **VERY HIGH**

We include the "**NIA**" value (Not Impact Available" for a day with no claims that could be considered at first instance as No Impact.

The **IIE** indicator is a qualitative index based on three sub indexes that try to catch on a **daily basis** the three most important aspects of impact, that can be derived from insurance claims data IIE=f(IIEM, IIEP, IIEE):

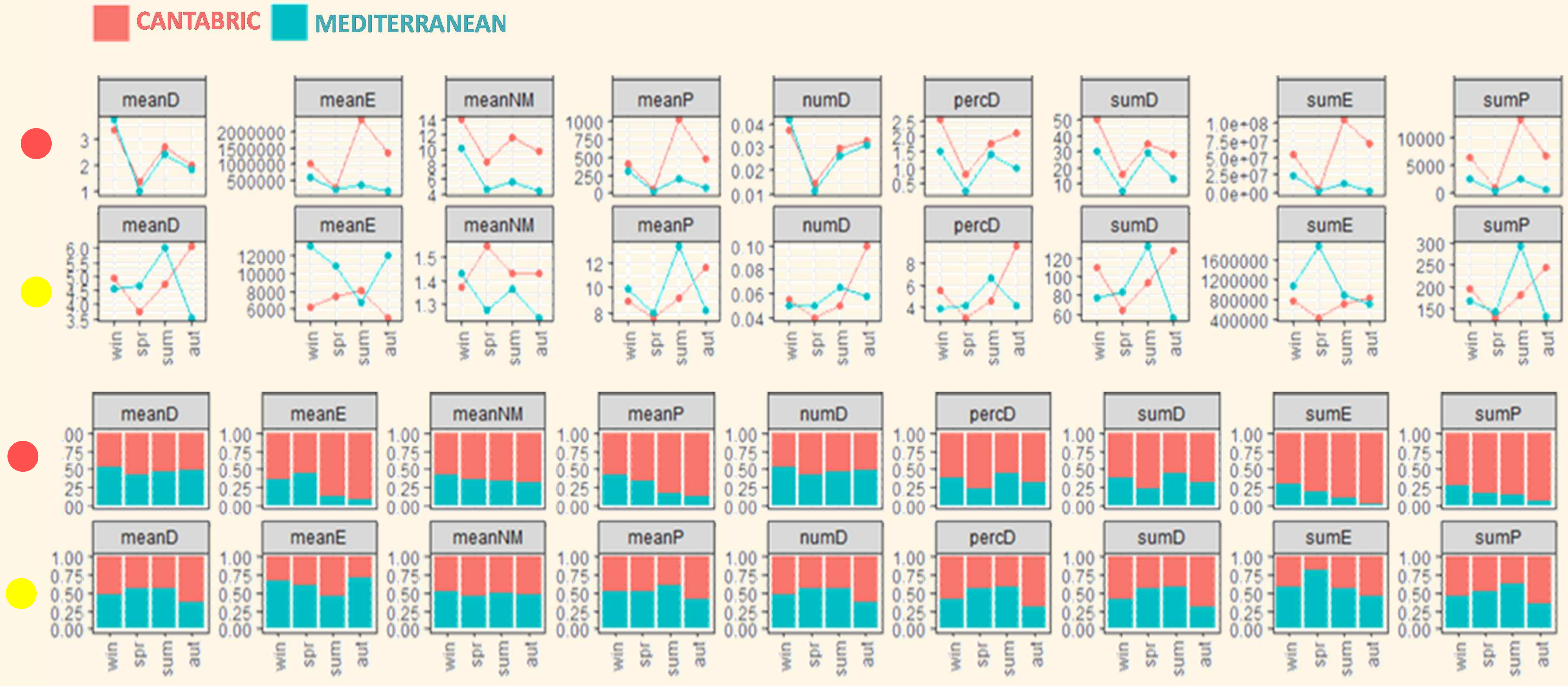
(1) Those dealing with **economic amount** paid, as a proxy of **damages importance** produced during a event.
IIEE<-cut E (0,5000,20000,100000,1000000,Inf)

(2) Those dealing with the **number of claims** as a proxy of the **generalization of affection** on properties
IIEP<-cut P (0,1,10,50,1000,Inf)

(3) Those dealing with **spatial extension** of a event using the **number of municipalities** affected IIEM<-cut M (0,1,3,10,50,Inf)

- **NO RELEVANT IMPACT** = IIE (NIA)
- **LESS RELEVANT IMPACT** = IIE (VERY LOW and LOW)
- **RELEVANT IMPACT** = IIE (MODERATE,HIGH and VERY HIGH)

In figure we present some daily **impact indicators** temporally aggregated by **seasonal mean** spatially aggregated by **main basin** (cantabric vs mediterranean) segmented by **impact relevance** for all the studied period (2000-2021)..



- ✓ Number of claims with any degree of impact are higher during summer and minimum during spring.
- ✓ Proportion of claims in less relevant impact events during summer are higher in Mediterranean basin.
- ✓ Proportion of claims in relevant impact events are much higher in Cantabric basin for any season.

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3. Results and Discussion- Hydrometeo

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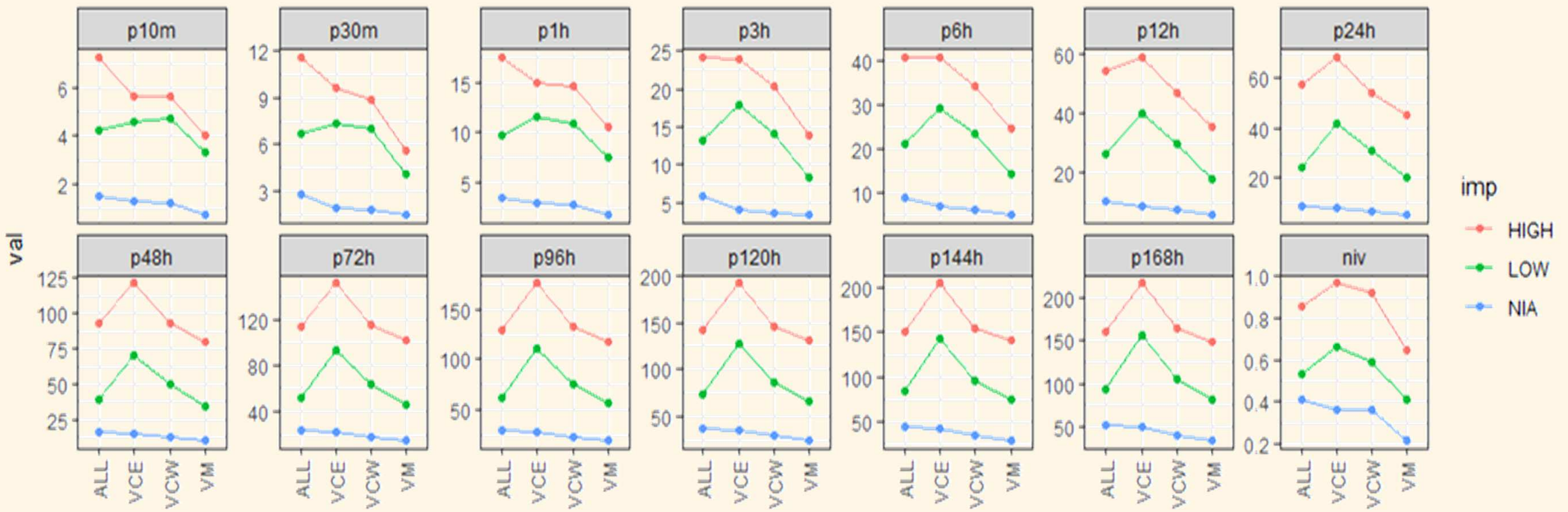
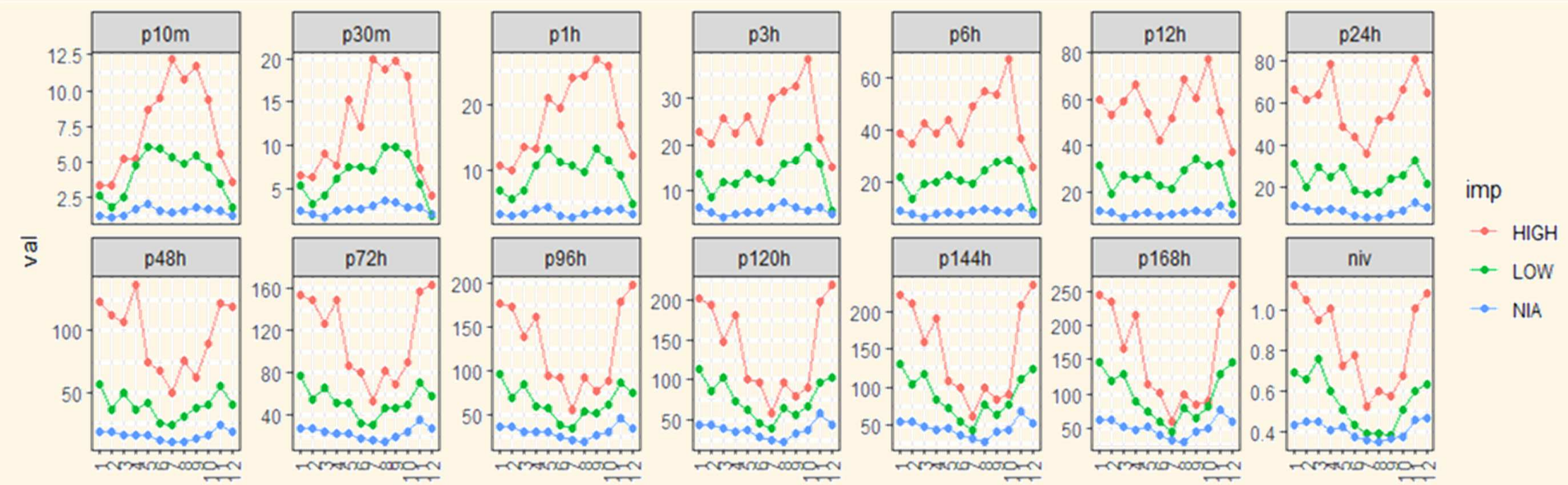
In fig 1 we present some maximum daily hydro-meteo indicators temporally aggregated by **annual mean** and spatially aggregated for all basins (**ALL**) East and West Cantabric basins (**VCE , VCW**) and Mediaterranean basins (**VM**) segmented by impact relevance (**NIA**, **HIGH** and **LOW**) for all the studied period (2000-2021).

- ✓ During more relevant impact days mean of max hydro-meteo indicators related with precipitation persistence (p24h…p168h) double the value of low impact days that double the NIA days.
- ✓ Precipitation indicators are in general higher in VCE and lower in VCM, during impact days intense precipitation indicators (p10m,p30m,p1h) shows similar behavior for VC and VM.
- ✓ Mean maximum normalized river level is over 0.8 for more relevant impact events in the case of VC and just over 0.6 in the case of VM.



In fig 2 we present some maximum daily hydro-meteo indicators temporally aggregated by **monthly mean** and spatially aggregated for all basins (**ALL**) segmented by impact relevance (**NIA**, **HIGH** and **LOW**) for all the studied period (2000-2021).

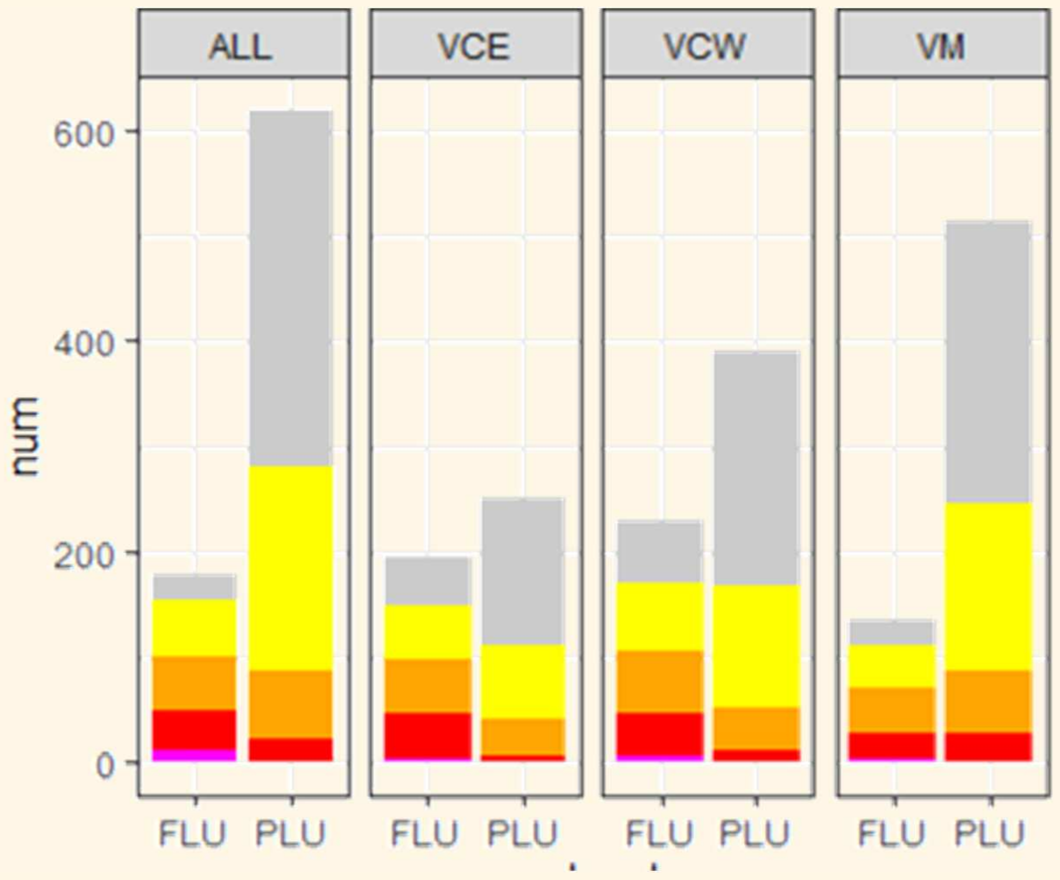
- ✓ During warm season mean of max hydro-meteo indicators of intense precipitation (p10m,p30m,p1h) are much higher than during cold season. Such differences are higher as impact is more relevant.
- ✓ During cold season mean of max hydro-meteo indicators of persistent precipitation (p24h,p48,..p168h) double warm season values.
- ✓ Mean maximum normalized river level is over 0.8 for HIGH impact events during cold season and below 0.8 during warm season.

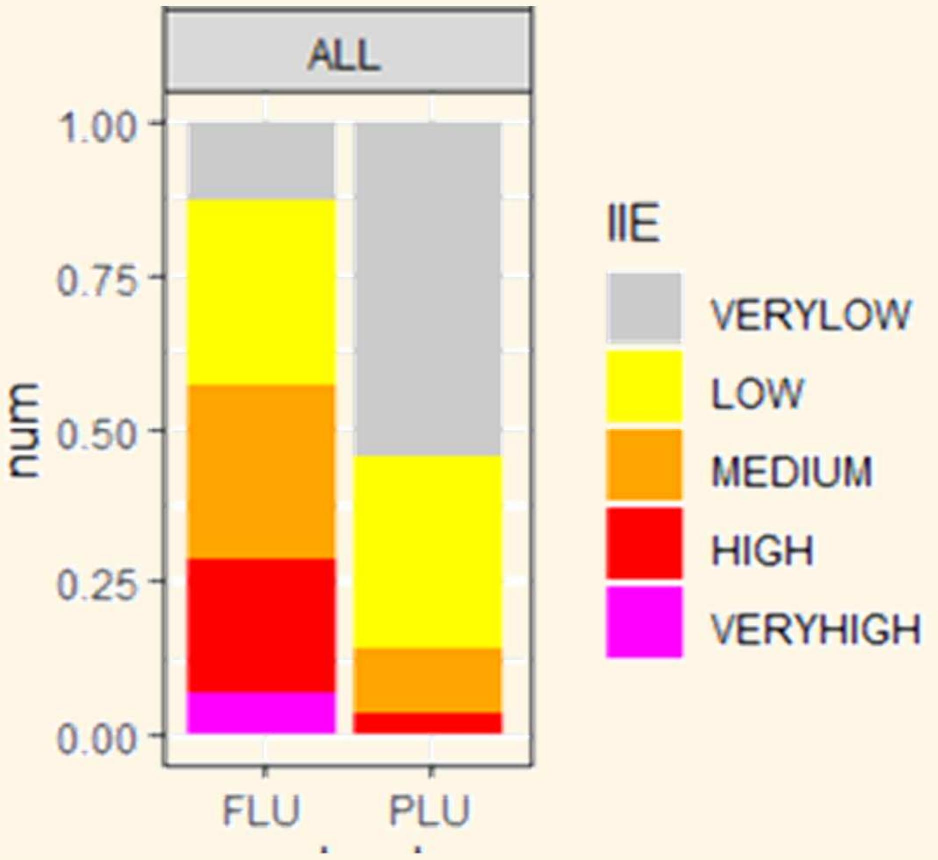


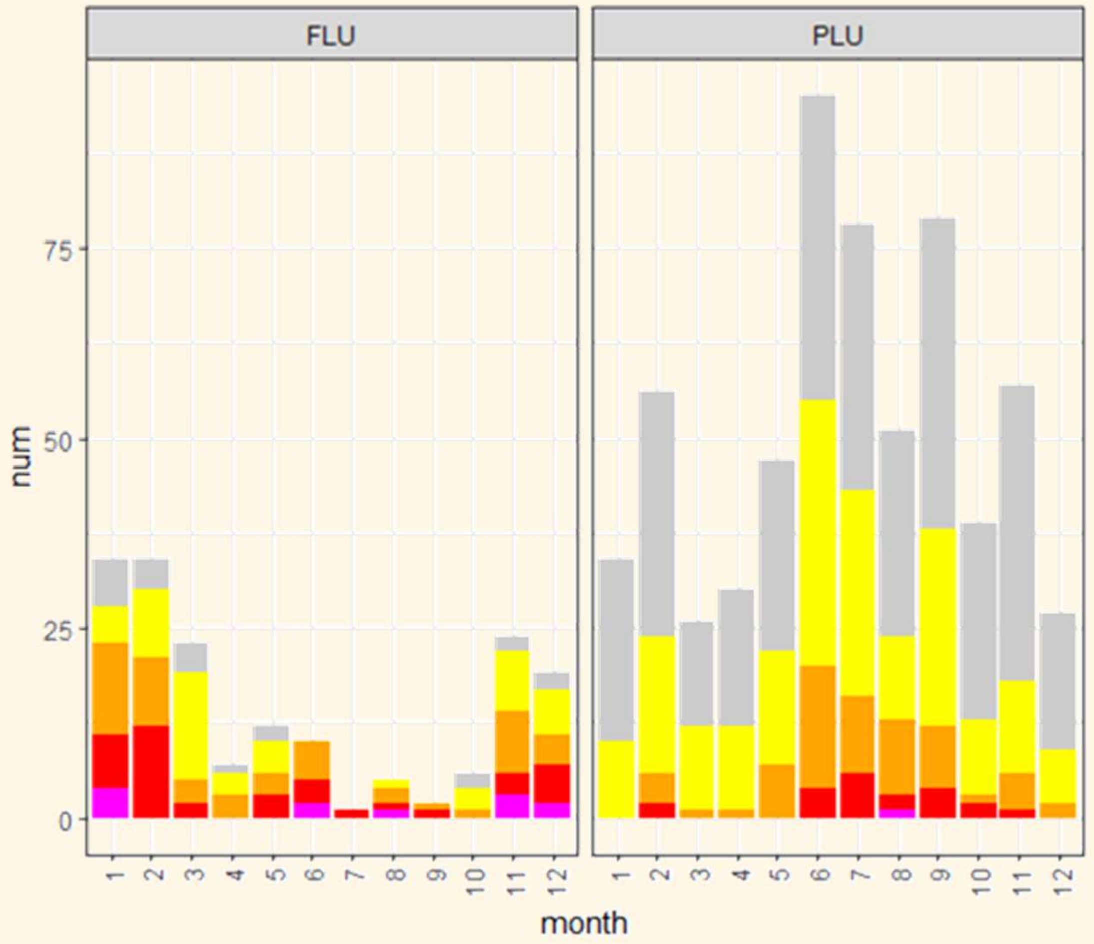
3. Results and Discussion- Hydrometeo

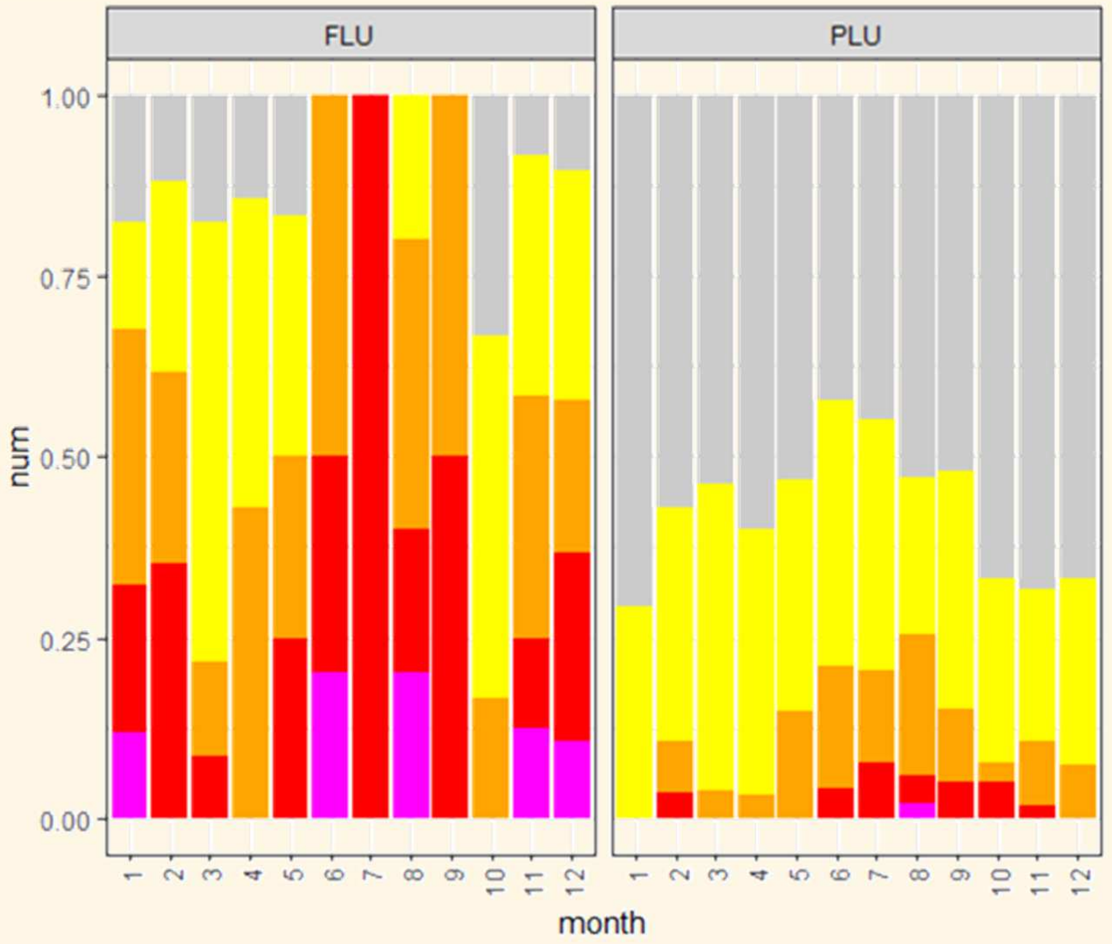
Impact events are categorized considering a **Pluvial - Fluvial Indicator (IFP)** based on the value of normalized* maximum river level. If such value is over 0.8 the event is classified as fluvial and if is down 0.8 is considered pluvial.
*River level are normalized based on available orange level for floods surveillance in URA and Euskalmet operational procedures.

- ✓ For all watersheds Pluvial (PLU) event with any kind of impact are 3 times greater than Fluvials (FLU), quite similar for East Cantabric basins (VCE), nearly double for Western Cantabric basins (VCW) and more than three times in Mediterranean basins (VM) case.
- ✓ All very high impact cases are fluvial (FLU).
- ✓ Proportion of higher impact events are much relevant for Fluvial (FLU) event and in Cantabric basins (VCE and VCW).
- ✓ Unless fluvials events are predominant during cold season are plausible at any time.
- ✓ Unless Pluvials events are predominant during warm season are plausible at any time.









3. Results and Discussion - Weather context

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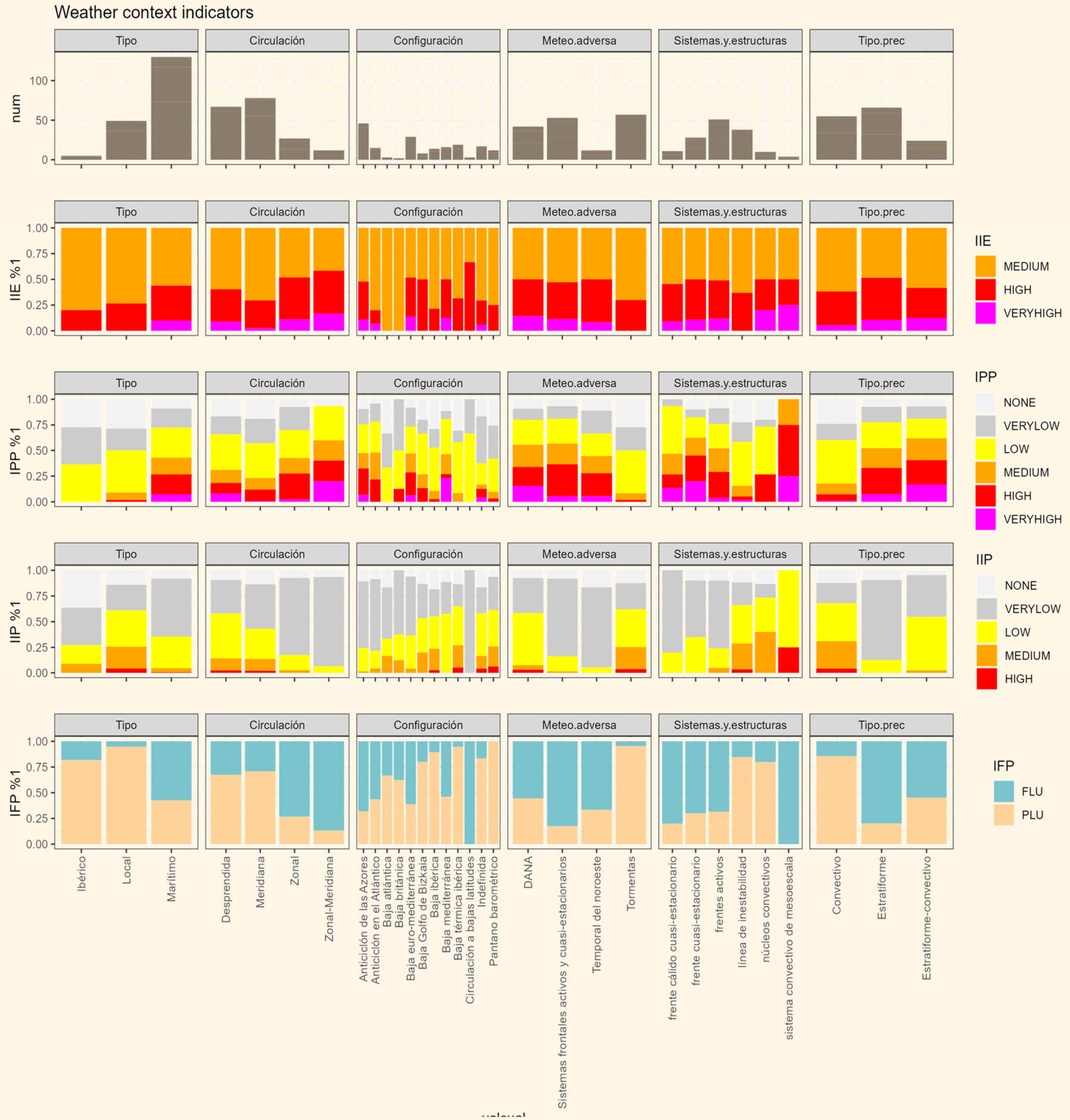


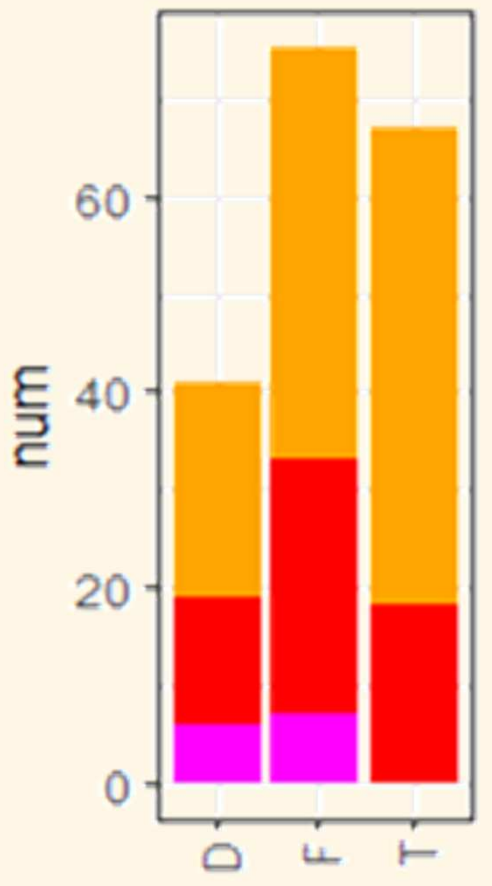
Number of events with relevant impact categorized by weather context qualitative indicators segmented by impact degree (IEE), Indicator of precipitation persistence (IPP) intensity (IIP) and Fluvial/Pluvial indicator (IFP)

Based on weather context indicators and focusing on severe weather context, we can group flood impact events in three main categories: **Cut-Off-Lows configuration (D), Winter Frontal Systems (F) and Local Storms (S)**

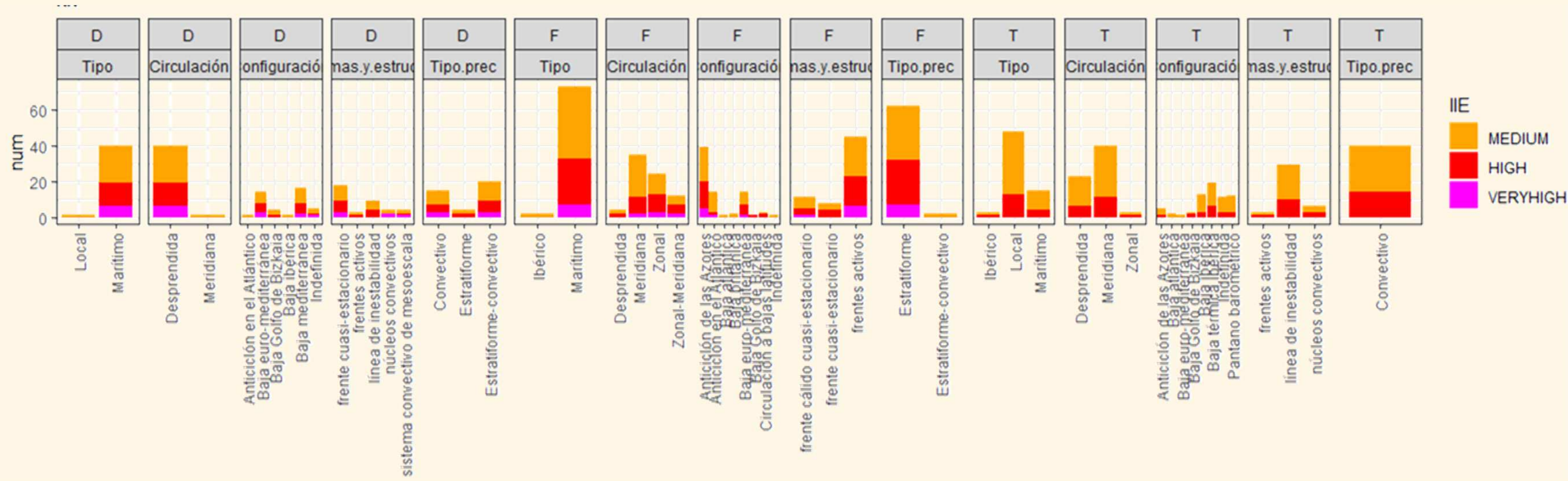
Those categories are included in the

Flood Weather Indicator (ITPI)

as a specific subclass of general severe weather classification used operationally in Euskalmet.



Number of events corresponding with each category of the weather context qualitative indicators segmented by impact and by the new flood weather indicator .



3. Results and Discussion – Indicators by watershed

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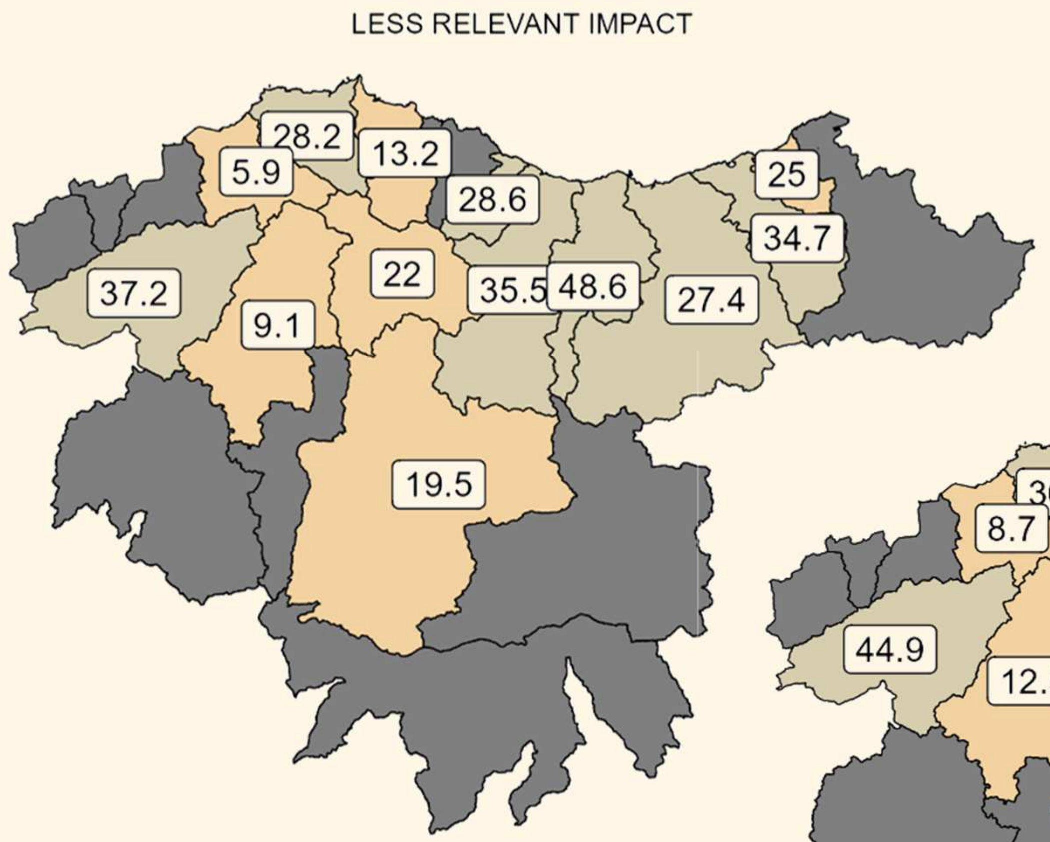
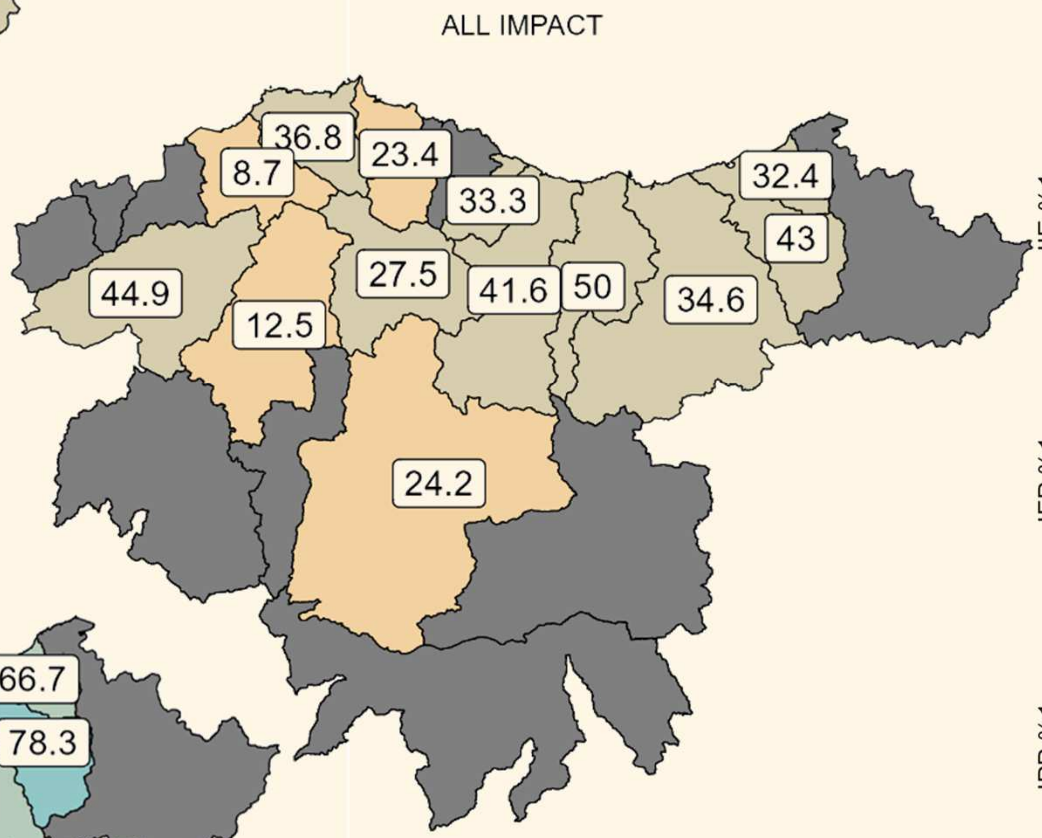
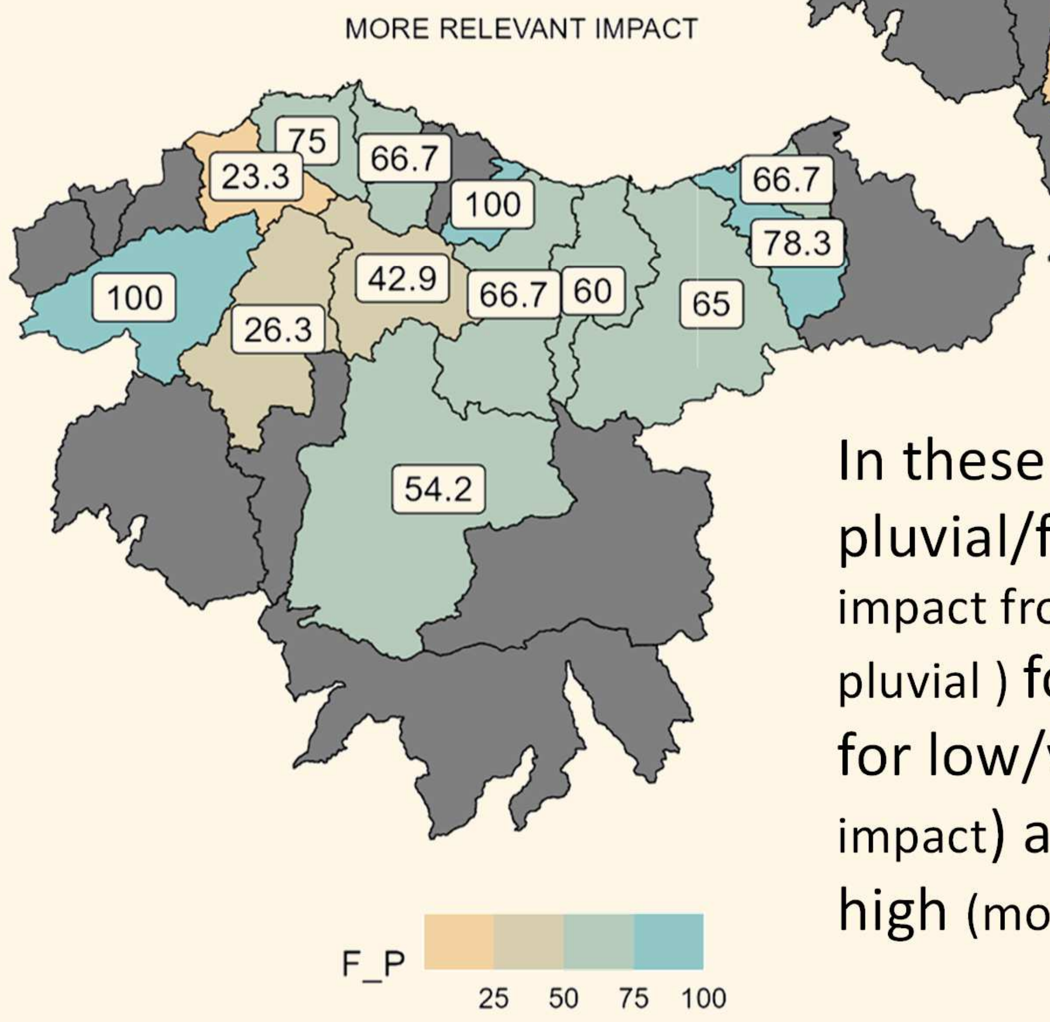
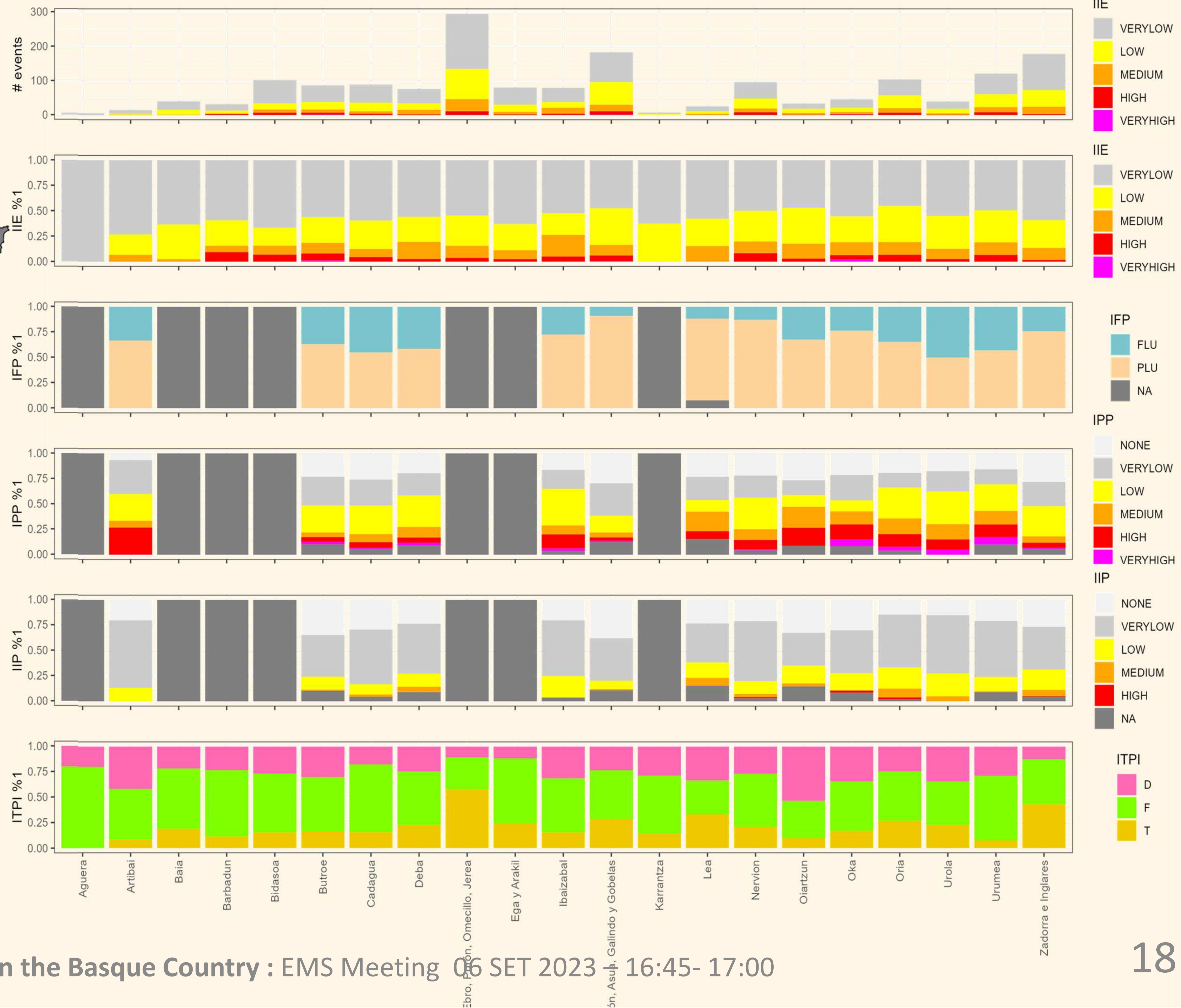
In the figure we show number of flood impact events with values of some indicators (IIE, IFP, IIP, IPP, ITPI) for studied watersheds.









In these maps we can see pluvial/fluvial percentage (100% = all impact from fluvial, 0% = all impact from pluvial) for all impacts events, and for low/very low (lees relevant impact) and moderate/high/very high (more relevant impact).

3. Main conclusions and future work

MAIN CONCLUSIONS

- ✓ In this work we have used, as a proxy for flood impact, claims paid by Spanish Insurance Compensation Consortium in the Basque territory during a twenty one years period (2000-2021). Such data together with those that characterize the geophysical and social context (characteristics of the basins, population, etc...) and hydro-meteo-climatic (river levels, rainfall,...) are conveniently prepared with different spatial and temporal aggregation level in order to draw analysis and characterization for the 21 (17) watershed areas objective of this study.
- ✓ The definition of different specific indicators (some shown in this presentation) seems to be an effective methodology for characterizing floods in the Basque Country, as well as a new way of effective communication of the impact and to explain the local context in which damages are produced.
- ✓ Unless all data claims from CCS has common cause “extraordinary inundation” plenty of minor impact events are present corresponding to less impact pluvial floods during stormy intense precipitation events.
- ✓ More relevant impact events are of fluvial nature and predominant in eastern Cantabric basin.
- ✓ The proportion of less impact pluvial nature event are higher in Mediterranean basins.
- ✓ …………

FUTURE WORK

- Detailed information about insurance penetration seems to be necessary for better characterization, as insurance penetration are different among territory and number of claims and economic amount paid depends on exposed insured assets.
- Improve resolution by exploiting claims raw postal code information (quality check needed) and determine pluvial impact contribution during fluvial event
- Complete the data series of the basins not covered at the moment (in grey on the previous slide) and improve spatial representation of data (filling gaps, kriging, etc.)
- Some aspects of the meteo context classification (weather types, etc) are going to be automatized.
- In near future we are going to implement data driven (ML) impact prediction models.
- …..

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- ✓ Our thanks for data provision to URA (hydro data), DAEM (meteo data), CCS (claims data) and geoeuskadi (geo-layers).
- ✓ Our recognition to the open-data and open-software community and particularly to Python and R contributors.

* some aspects presented here are based on preliminary results of Project URA/009A/2022 “Characterization and analysis of flood risk in the Euskadi basins” (Particularly from phase I and phase II-a) as well as results from different Euskalmet internal projects for the treatment and depuration of historical high temporal resolution data series and the characterization of impact supported by DAEM.

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Thank you for your attention : QUESTIONS ???

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