On the joint occurrence of wave storms and heavy rainfall events along the Catalan coast (NW Mediterranean)

...Photo by Catalan civil protection after Gloria compound event (January 2020)...

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FEDER/MICINN-AEI/CTM2017-83655-C2-2-R

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DEFINITIONS

Current definitions of compound events (*Leonard et al., 2014; IPCC SREX, 2012*) include different cases such as clustered/successive/simultaneous events happening at the same or different locations, leading or not to amplification effects

The **compound event** is defined **here** as the combination of extreme rainfall and coastal storm given at any point of the region refined by the Catalan main riverine basins and their corresponding coastal fringes.

To assess the joint impact of such events, two different cases are distinguished

SYNERGETIC COMPOUND HAZARDS. Both hazard sources (extreme rainfall and waves) happen at the same area, i.e. the riverine basin and its coastal fringe, and are simultaneous in time (or in few-days succession). This allows for potential synergetic (with possible amplification effects) interaction of hazards

CUMMULATIVE COMPOUND HAZARDS. The impact of the different hazard sources are simultaneous (or in few-days succession) but affecting different (non physically connected) parts of the territory. The stakeholder must face the potential cumulative impacts caused by extreme rainfall and coastal storms.

Note that a single event can be synergetic in one part of the territory with cumulative effects in other parts of the region.

MOTIVATION AND OBJECTIVE

Traditionally, this kind of compound events have been mis-regarded in the area as the general believe is that they are uncorrelated and infrequent.

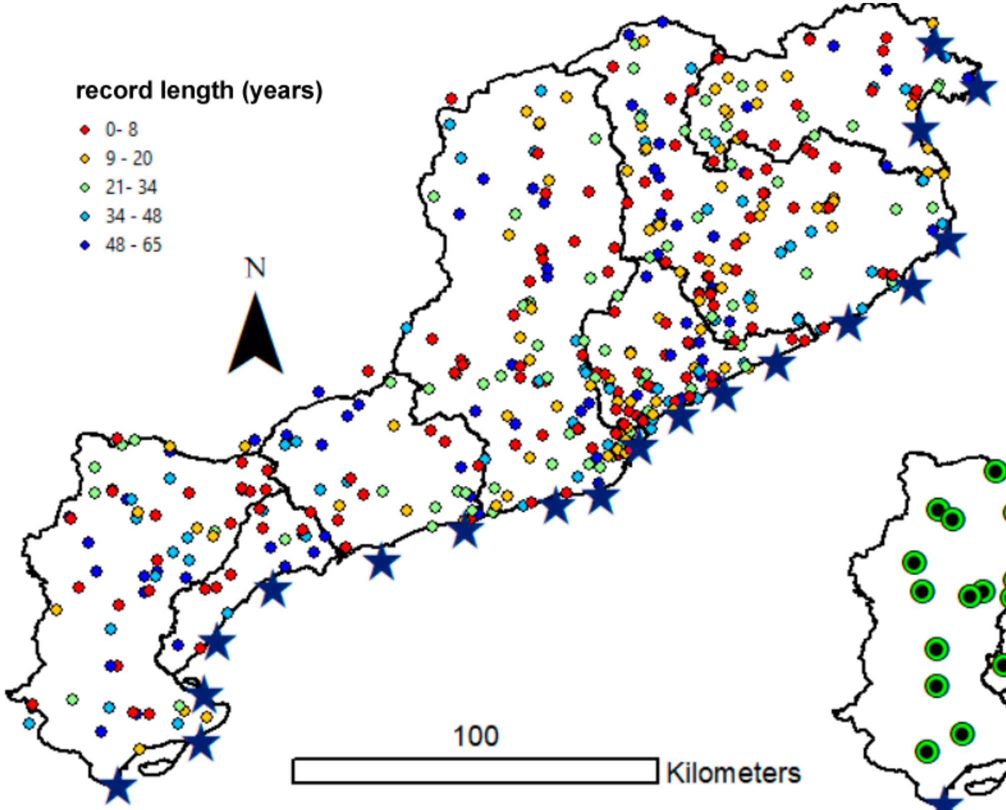
Recent events such as Gloria storm (cover photo, January, 2020) highlight the importance of studying the joint occurrence of wave storms and heavy rainfall events along the Catalan coast (NW Mediterranean)

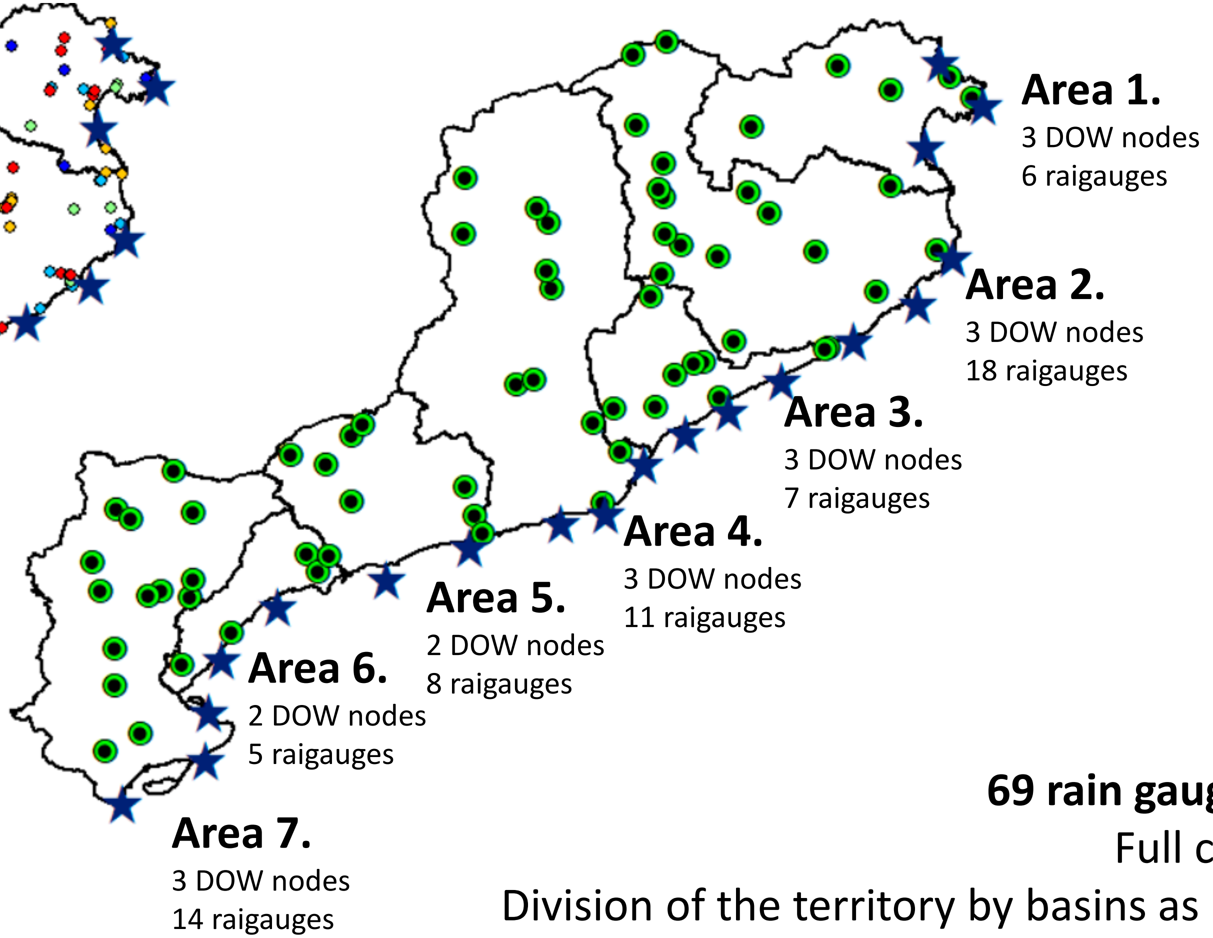
In such context, the **main objective of this work** is to assess the **occurrence** and **correlation in magnitude** of compound rainfall and coastal storms at the Catalan coast.

The assessment is aimed to allowing a **differentiation of potential synergetic and cumulative hazards** induced by compound events.

DATASETS– FIGURE A

A.1. Original dataset. RAIN: **491 rain gauges**, daily rain P24h (mm) ; **AEMET** (Spanish Meteorological Agency)
WAVES : **19 coastal nodes**, hourly significant wave height Hs (m): **Downscaled Ocean Waves dataset** (*Camus et al. 2013*)





A.2. Final Dataset
69 rain gauges, 19 wave nodes
Full coverage 1973-2013
Division of the territory by basins as in *Llasat et al. 2016*

METHODS 1

1) Storm identification at each node form the dataset

Coastal storm: Peak Over threshold on Hs with quantile 0,995 (*Sanuy et al., 2020*) and 3 days for independency

Extreme rainfall: Peak Over threshold on P24h with 40 mm (*Cortès et al., 2019*) and 3 days for independency

Compound event: when the date of extreme rainfall in a rain gauge placed in a coastal basin falls within 3 days before the starting date of a coastal storm and its final date

2) Characterization of the events at each basin

Records from different locations with dates falling with **5 days of difference** are regarded as the **same compound event**, to account for the propagation of the rain across the territory.

Each date with storm records is classified as Rain only, Sea only or Compound, and **the maximum value of P24h or Hs recorded inside each basin/coastal fringe** is chosen as representative of the area (See basins in FIGURE A).

METHODS 2

3) ANALYSIS OF OCCURRENCE

With all events identified and characterized per areas, occurrence of potential synergistic and cumulative hazards along the coast is analysed. Yearly number of events and 5-yr running averages are also calculated **FIGURE B**

4) HAZARD SOURCE INTENSITY CORRELATION ASSESSMENT

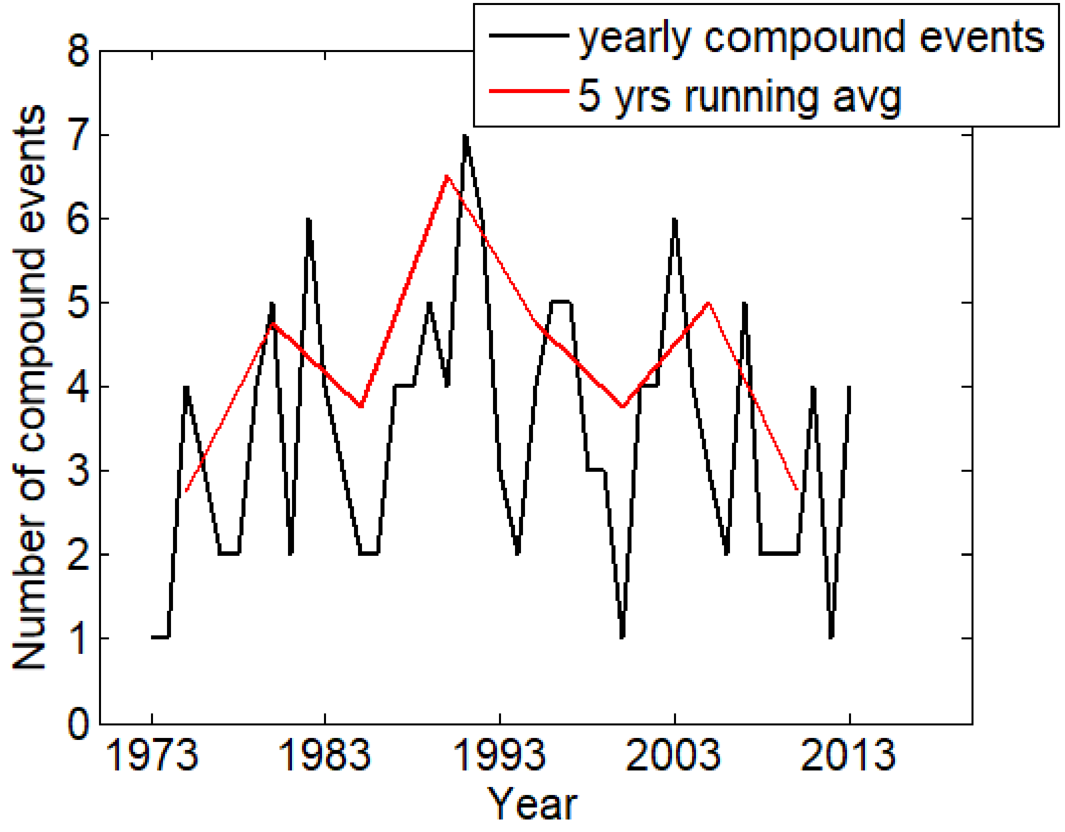
For the identified subset of compound events, the correlation of the magnitude of the Hs with the maximum P24h at each of the basins is assessed by means of the spearman rho correlation parameter. Given X=rank(Hs) and Y=rank(P24h) the parameter is calculated as

$$rho = \frac{cov(X,Y)}{\sigma_X \sigma_y}$$

FIGURE C

RESULTS 1 – FIGURE B

B.1. 140 identified **coumpound events** in the territory (~3,5 events/year) :



This represents a **62,2%** of the coastal storms and a **18,8%** of the rainfalls

B.2. Given a compound event, all basins along the coast have around ~40% of probability of being affected by extreme waves. The table shows the total count of extreme coastal storms per area (percentages relative to the 140 compound events)

		Wave storms per area (compound events)	% relative to compound events
Area	1	92	41%
	2	93	41%
	3	86	38%
	4	91	40%
	5	82	36%
	6	89	40%
	7	85	38%

B.3. Each time a coastal storm presents at location *i* (Table B.2), the occurrence of extreme rainfall at location *j* is displayed in the following matrix as the element (*i,j*). Elements at the diagonal (*i=j*) indicate the frequency of **potential synergetic hazard**, relative to the presence of extreme waves at Area *i* (Table B.2).

		Area rain						
		1	2	3	4	5	6	7
Area waves	1	74%	85%	54%	51%	46%	38%	64%
	2	70%	81%	53%	56%	45%	39%	63%
	3	60%	76%	50%	53%	41%	38%	60%
	4	59%	77%	52%	53%	43%	38%	64%
	5	57%	78%	52%	50%	41%	44%	67%
	6	61%	80%	55%	54%	45%	42%	70%
	7	58%	78%	55%	56%	46%	41%	69%

RESULTS 2 – FIGURE C

C.1. The Spearman Rho parameter indicates the **correlation between the magnitude** of the extreme waves (Hs) and the extreme rainfall (P24h). Each map shows the correlation between Hs at the area marked with diamond and P24h at the different basins. The colour indicates de correlation level and the absence of colour indicates uncorrelation between the variables for that combination of locations (at level of confidence 0.05).

Northern basins (Areas 1 and 2)

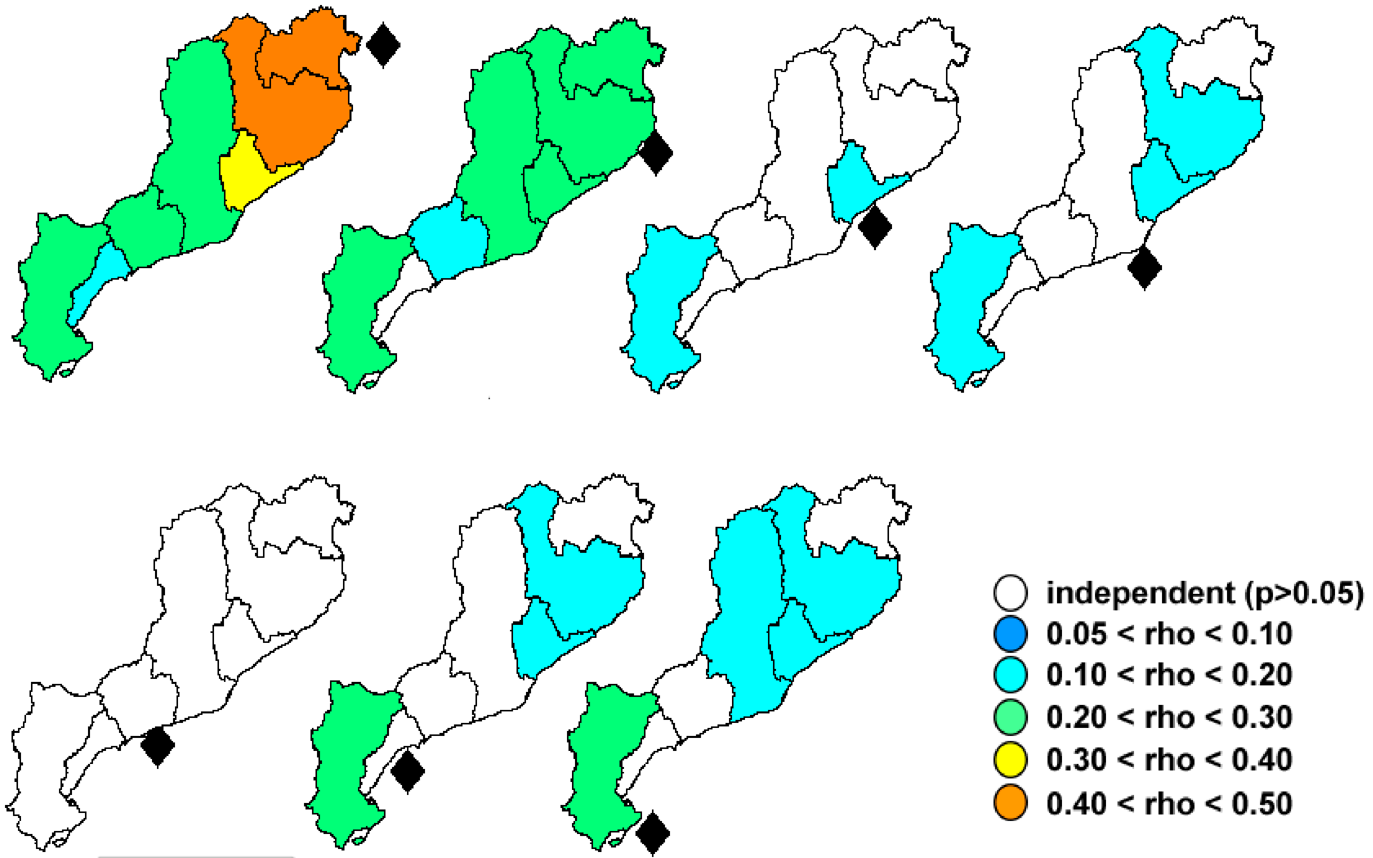
- Hs shows highest correlations with P24h
- These are mainly with P24h at Areas 1 to 3
- Highest synergetic hazard potential

Central basins (Areas 3, 4 and 5)

- Lowest correlations or independency
- Contribution to cumulative impacts (intense rain while coastal storm present in Areas 1 and/or 2)

Southern basins (Areas 6 and 7)

- Some correlation of Hs with P24h at Area 7
- Contribution to cumulative impacts (intense rain while coastal storm present in Areas 1 and/or 2)



CONCLUSIONS

- **Compund events** with extreme rainfall and waves **are not unfrequent at the Catalan Coast** (62% of coastal storms, i.e., 3-5 events/year)

- **Synergetic hazards** are more frequent and be intense **in northern basins** and secondarily at the Ebro delta.

- **Cumulative hazards** are frequently caused by events **generating extreme waves at the north with rain at any part** of the territory, specially the north itself and the southern end.

- The **central basins** show the lowest frequency of synergetic impacts, **lowest correlation** (or directly incorrelation) between variable magnitudes.

- The **central basins** mainly contribute to **cumulative hazards,** as heavy rainfall shows there some correlation with coastal storms affecting the northen part of the region.

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THANK YOU !

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