Towards an integrated index on hydrometeorological risk in coastal Mediterranean Regions

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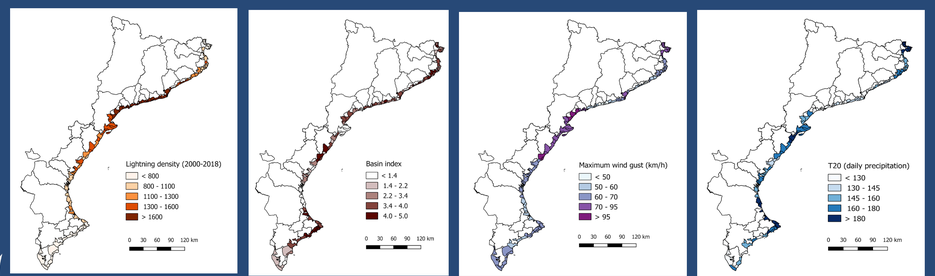
ABSTRACT: The Mediterranean region is a hot spot for climate and environmental changes (Cramer et al., 2018). Hydrometeorological hazards together with the existence of high values of exposure make the Mediterranean coastal fringe highly vulnerable and subjected to a high risk of impact of extreme events (IPCC, 2018). Long-term planning requires a proper risk and vulnerability assessment. Traditionally, this has been done by considering these hazards in an independent manner, although it is clear that a more holistic and integrated approach is needed. This work proposes an integrated hazard index to classify the Mediterranean coastal municipalities in terms of their susceptibility to be affected by multiple hydrometeorological hazards. The index is tested in a representative Mediterranean coastal area, the Catalonia and Valencia coastal zones (NE Spain). The indicators represent different system characteristics determining the expected risk: a) climatic, b) geomorphological and c) impact and perception components. The selected climatic indicators are: 20-year return period of precipitation, number of lightning strikes and maximum wind speed. Geomorphological indicators include the catchment area slope and municipality area. Socioeconomic indicators have been estimated from the compensations paid by the National insurance company (CCS), number of flood events that have affected each municipality estimated from their impact, and population awareness and social impact measured through social media response (tweets).

Building an integrated index on hydrometeorological hazard (HMHI)

1-Selection of indicators representative of the most important n hydrometeorological hazards in the region



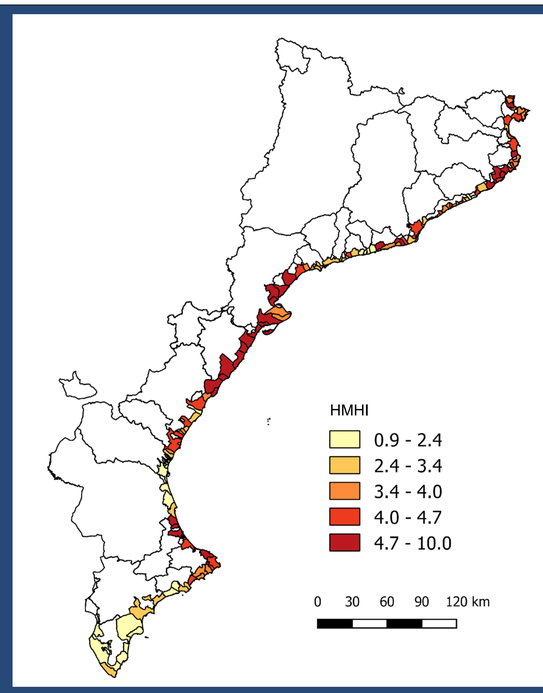
2-Quantification of the values of selected indicators, according to quantiles + expert criteria, into 5 categories.

Indicators	1	2	3	4	5
Lightning density (LD, Nº/km²) Total number of lightning for the period 2000-2018	≤ 800	800 - 1100	1100 - 1300	1300 - 1600	> 1600
Maximum wind gust (W, km/h) Quantile 97.5th of the maximum wind gust AEMET series 1981-2015	≤ 50	50 - 60	60 - 70	70 - 95	> 95
Basin index (I_B) Index combining streams order and mean slope	≤ 1.4	1.4 - 2.2	2.2 - 3.4	3.4 - 4	4 - 5
Return Period 20 (T20, mm) Return period of 20 years of the maximum daily precipitation AEMET series 1981-2015	≤ 130	130 - 145	145 - 160	160 - 180	> 180
HMHI	0.9 - 2.4	2.4 - 3.4	3.4 - 4	4 - 4.7	4.7 - 10

Thresholds used per indicator and category. HMHI refers to the value of the hydrometeorological hazard Index

3-Aggregation of the indicators in the index to characterize each municipality:

$$HMHI = \sqrt{\frac{LD * W * Ic * T20}{4}}$$



Hydrometeorological hazard Index (HMHI) per municipality

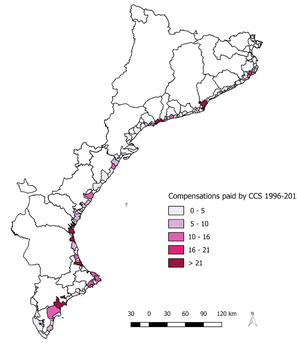
Data and context

Study area

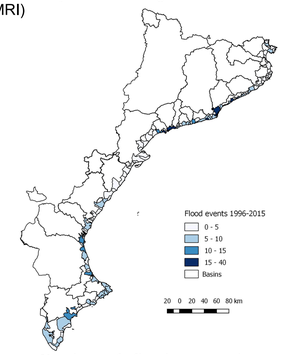
INUNGAMA: flood events database in Catalonia (1900-2015) (Llasat et al., 2016)
PRESSGAMA: press news database of natural hazards and climate change. (Llasat et al, 2009)
Daily precipitation, lightning and wind data: provided by the State Meteorological Agency of Spain (AEMET).
Slope and basins: National Geographic Institute (IGN) and Catalan Water Agency (ACA).
IMPACT DATA: News, Twitter and "Insurance Compensation Consortium" (CCS)
Population data: INE and IDESCAT.

Socioeconomic indicators

The following indicators will be used to built an integrated Hydrometeorological Risk Index (HMRI)

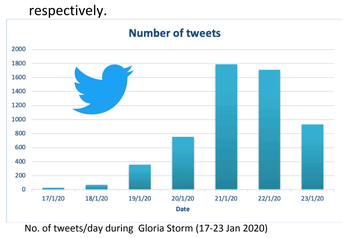


Compensations paid by the Insurance Compensation Consortium (CCS) **for floods damages** between 1996 and 2015 (in M€) at municipal scale. CCS paid a total of 713.75 M€ and 436.40 M€ in the Valencian Community and Catalonia, respectively (Cortès et al., 2019)



Number of flood events by municipalities 1996-2015. For this period, Catalonia and Valencian Community recorded 166 and 69 flood events, respectively.

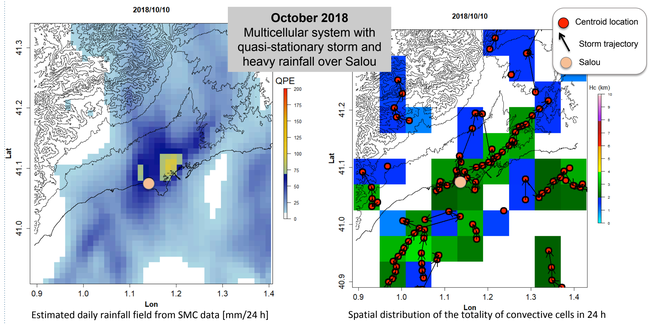
- **Twitter** is a good indicator of social awareness and meteorological phenomena impact on society.
- A methodology was developed to **extract** the **most relevant tweets** on floods, sea storms and climate change.
- It constitutes a tool for analysing the social **awareness** and the role of each agent in transmitting the message.



No. of tweets/day during Gloria Storm (17-23 Jan 2020)

The case of Salou, a highly touristic area (Lightning density=2264,7 light/km²; Maximum wind gust: 76 m/s; PT20=123,5 mm; Basin Index=1,4; HMHI=3,16)

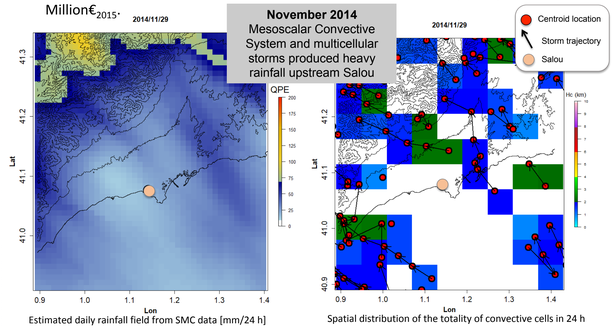
- Typical example of surface water floods by precipitation *in situ* (del Moral et al., 2020). Orange dot represents Salou village. Maximum precipitation in Catalonia was 98.4 mm. Flash floods and storm surge caused 3 deaths
- Premiums paid by CCS>2.1 Million€$_{2015}$
- Large pixels (5 × ; 5 km²) and red dots represent the height and location of the centroid, respectively; lines and arrows represent the storm trajectory, indicating bearing direction. Convective activity started over the Sea and the coast; thunderstorms moved parallelly to the coast from SW to NE. 5 lightning over Salou.



Estimated daily rainfall field from SMC data [mm/24 h]

Spatial distribution of the totality of convective cells in 24 h

- This event affected the entire Catalan coast over three days. Maximum precipitation was 336.1 mm/24 h.
- 100 km south of Salou. The effects of the episode was also aggravated by the coastal storm with wave heights larger than 2 m. 1 death was recorded and the CCS paid >12.4 Million€$_{2015}$.
- Prelitoral Mountain chain triggered the instability of the Mediterranean wet air mass. Cells moved from SE to NW and impinged perpendicularly over the mountain. As the 2010 case low tops showed shallow and efficient convection. No lightning over Salou

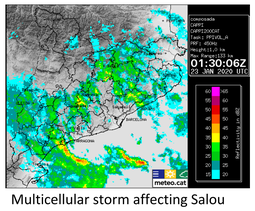


Estimated daily rainfall field from SMC data [mm/24 h]

Spatial distribution of the totality of convective cells in 24 h

The case of January 2020 – Gloria, Catalonia

- 19-23 January 2020
- Total max. precipitation: 516 mm
- 1364 lightning (2 over Salou on 23 January)
- Maximum wind speed (Puig Sesolles): 144,4 km/h;
- Largest ever recorded waves. Hs > 6 m everywhere. Massive overwash and overtopping events along the coas
- Over 500 affected municipalities, mainly coastal
- Overflow of multiple rivers and Ebro Delta
- Over 8400 emergency responses
- Opening of reservoir gates
- 4 deaths and 1 missing person
- Economic valuation >50M€ in Catalonia, 76 M€ in all Spain (Source CCS 29/1).
- Decree approval and urgent aids release



Accumulated precipitation (SMC)

Multicellular storm affecting Salou

Damages (Source: La Vanguardia)

◀ Radar image of Ebro Delta (Sentinel1, Source: Copernicus EMS)

Conclusions

An index to characterize the risk of Mediterranean coastal regions to extreme hydrometeorological hazards, HMHI, is proposed. Selected hazards are extreme precipitation (T=20y), lightning density and speed of wind gusts. Geomorphological features are also included due to their role in flash-floods generation. To reinforce the value of the index from the disaster risk management standpoint, it is integrated with relevant socioeconomic variables to built a Hydrometeorological Risk Index (HMRI). The case study of Salou has been selected to illustrate the behaviour of a municipality characterized by a high HMHI.

References

Cortès, M. et al., 2019. Changes in flood damage with global warming in the east coast of Spain. Nat. Hazards Earth Syst. Sci., 19, 2855–2877.
Llasat, M.C. et al., 2009. A press database on natural risks and its application in the study of floods in northeastern Spain. Nat. Hazards Earth Syst. Sci., Sci., 9, 2049–2061
Llasat, M.C., et al., 2016. Trends in flash flood events versus convective precipitation in the mediterranean region: the case of Catalonia. Journal of Hydrology, 541, 24-37
Del Moral, A., et al., 2020. Connecting flash flood events with radar-derived convective storm characteristics on the Northwestern Mediterranean coast: knowing the present for better future scenarios adaptation. Atmospheric Research. 238, 1 July 2020,

Acknowledgements

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