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Linking storm surge activity and circulation variability along the Spanish coast through a synoptic pattern classification

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The potentially negative consequences resulting from the estimations of global sea level rising along the current century are a matter of serious concern in many coastal areas worldwide. Most of the negative consequences of the sea level variability, such as flooding or erosion, are linked to episodic events of strong atmospheric forcing represented by deep atmospheric disturbances, especially if they combine with extreme astronomical high tides. Moreover, the interaction between the prevailing flows during such events and the actual orientation of the coast line might accelerate or mitigate such impacts.

This contribution analyses sea surge variations measured at five tide-gauge stations located around the Iberian Peninsula and their relationships with regional scale circulation patterns with local-scale winds. Its aim is to improve the knowledge of surge related-coastal-risks by analysing the relationship between surges and their atmospheric forcing factors at different spatial scales. The oceanographic data set consists of hourly data from 5 tide gauge stations (Santander, Vigo, Bonanza, Málaga, Valencia and Barcelona) disseminated along the Spanish coastline, provided by Puertos del Estado. To explore the atmospheric mechanisms responsible for the sign and magnitude of sea surges, a regional Eulerian approach (a synoptic typing) were combined with a larger-scale Lagrangian method, based on the analysis of storm-tracks over the Atlantic and local information (synop reports) obtained from the closest meteorological stations to the tide gauges. The synoptic catalogue was obtained following a procedure that combines Principal Component Analysis (PCA) for reduction purposes and clustering (Ward plus K-means) to define the circulation types. Sea level pressure, surface 10m U and V wind components gridded data were obtained from NCEP Reanalysis, while storm tracks and cyclone statistics were extracted from the CDC Map Room Climate Products Storm Track Data (http://www.cdc.noaa.gov/map/clim/st_data.html). The second task was to evaluate the performance of each circulation type on the spatial patterns of a daily fire danger risk index (Canadian Fire Weather Index, FWI). Finally, anomaly maps of several surface and low level climate variables, corresponding to the dates of ignition of the very large forest fires within each synoptic pattern, were calculated to provide insight of the specific conditions associated to those extreme events.

A principal component analysis upon 6 hourly residuals highlighted the homogeneous behaviour of the tide gauges and provided a regional quantitative index to identify the largest storm surges. The leading PCA displayed a homogeneous spatial pattern, describing the low frequency variability along the entire coast, in spite of different orientations of the coast, accounting for more than 80% of the total variability. The second PCA displayed opposite phases between the Atlantic and the Mediterranean. Furthermore, the results suggest that surges are a regional rather than local phenomenon, probably related to the same single physical forcing. The comparison between extreme surge events and circulation patterns highlighted that single physical mechanism is represented by extratropical cyclonic disturbances located at the north-western corner of the Iberian Peninsula, responsible for an environment characterized by low pressure readings and westerly-southwesterly winds. That wind pattern acquires an onshore component in the Atlantic coast, but becomes offshore in the Mediterranean. So, the main mechanism responsible for those storm surges is the inverse barometer effect, being the wind dragging secondary. The main physical forcing of the storm surges, the extratropical cyclones, have experience a reduction of this frequency and a marked reduction in their strength since 1950, replaced by stable circulations. Both conditions suggest a long term reduction of the frequency and the magnitude of storm surges.