

# STORM CLUSTER IDENTIFICATION AND IMPACTS FOR SHORELINE RESILIENCE

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## INTRODUCTION

The USACE recognizes resilience as a fundamental and important characteristic of its systems and operations. (USACE, 2020) Increasing attention is being focused on understanding the effects of extratropical storms and storm clustering (Wadey, 2023). These effects will take on particular significance in regions with higher rates of sea level change. The development of a foundational understanding of the spatial and temporal characteristics of storm clusters may be found to be essential to a more comprehensive description of nonstationary hazards and risks. USACE mission areas that may be sensitive to sea level change, storm power, and threshold exceedance include Coastal Storm Risk Management (CSR), Flood Risk Management (FRM), Navigation, Water Supply, Recreation, Environmental Restoration, and Disaster Response.

The approach to the identification and evaluation of storm cluster potential impacts will analyze the range and significance of storm cluster definitions, storm and storm cluster duration and power, exceedance of wave height threshold, influence of wave direction, and water level realization and development over the storm cluster.

## APPROACH

For this paper two very different US regions are evaluated: Pacific Ocean west coast and Atlantic Ocean northeast coast. The locations are shown in figure 1 below. The west coast location utilizes the NDBC buoy 46029 (Columbia River) and the NOAA water level gage at Toke Point, WA. The NDBC buoy for this data set is located in 131 m water depth. The east coast location utilizes the NDBC buoy 44025 (Long Island) and the NOAA water level gage at The Battery, NY. The NDBC buoy for this data set is located in 36.3 m water depth.

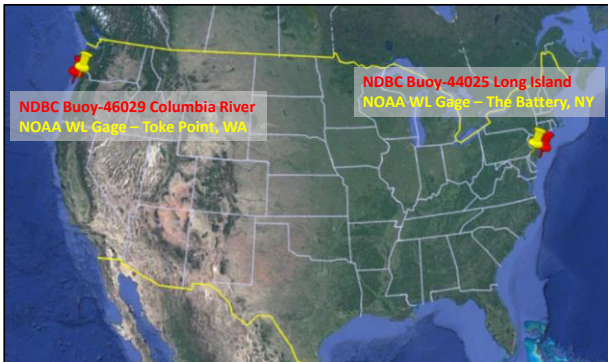


Figure 1 - Locations for analysis - (1) Pacific Ocean/West Coast of US - Columbia River and (2) Atlantic Ocean/East Coast of US - Long Island.

## EXAMPLE RESULTS

Preliminary results for just one storm season are illustrated below in figures 2 and 3 for the two locations. Each plot provides the following data over a subset for the 2012 winter season - significant wave height (pink), peak wave period (blue), mean wave direction (black) and storm power (yellow). Also included on each plot is a tentative storm wave height threshold which is based on typical wave heights over the storm season for each location. The threshold for the west coast location is 4m and the threshold for the east coast location is 2m. The west coast plot (figure 2) provides data from January 16, 2012 to March 23, 2012 and the east coast plot (figure 3) provides data from January 10, 2012 to March 17, 2012. Each subset of record was initially chosen to provide an illustration of a range of storm types from singular events to pronounced storm clusters.

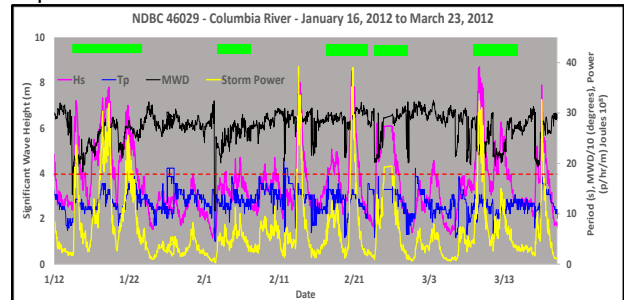


Figure 2 - Storm data for NDBC buoy 46029 (Columbia River). Data plotted includes significant wave height, peak wave period, mean wave direction, and storm power. Green bars indicate potential storm clustering periods subject to cluster definition. Tentative storm wave height threshold set at 4m.

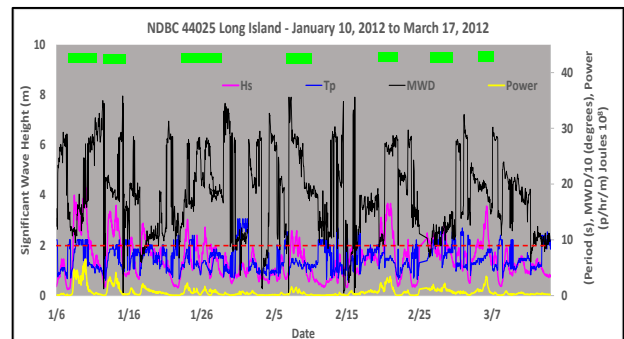


Figure 3 - Storm data for NDBC buoy 44025 (Long Island). Data plotted includes significant wave height, peak wave period, mean wave direction, and storm power. Green bars indicate potential storm clustering periods subject to cluster definition. Tentative storm wave height threshold set at 2m.

The paper will explore the range of storm cluster definitions and relate the definition applicability to the two separate US regions. The green bars shown in figures 2 and 3 are tentative storm cluster time periods and were assessed based on the significant wave height exceedance of the storm wave threshold as well as the degree of separation of the peaks. Several distinctions can be drawn from the comparison of the two plots. Obviously, the west coast location has significantly larger wave heights and periods which translates into greater storm power. Both plots have a range of storm types from single peak events to extended events with multiple storm peaks. The mean wave direction at the east coast location shows much more variability than the west coast location. The east coast plot appears to exhibit more shorter duration storm clusters (approximately 7 over a 66 day time period) while the west coast plot exhibits about 5 longer duration events over a similar time period. An additional exploration of the data sets will evaluate how the extreme water level may be affected by the duration and clustering of storm peaks. Figure 4 provides a preliminary look at the maximum daily water level measured at the NOAA gage for the west coast example. The blue line provides the significant wave height and the white line tracks the maximum daily water level. The two time periods noted by the green bars indicate progressively increasing water levels during the storm cluster event, which could be important to total impacts and threshold exceedance.

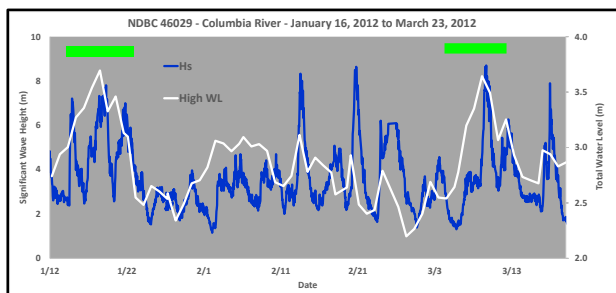


Figure 4 - Daily High Water Level plotted against significant wave height - Columbia River location.

## CONCLUSIONS

Storm intensity and its effect on coastal infrastructure and shorelines is clearly not just a function of maximum wave height or maximum storm surge for a single event, although it is not uncommon to use those values to classify the annual exceedance probability (AEP) of an event. This paper will explore the identification and description of storm clusters for a US west coast and a US east coast location. Storm wave power, combined with duration, is an improved metric that should be considered in extremal and cumulative impact/risk analyses. Since total storm power is strongly controlled by wave height, wave period, and duration, with the correlation to duration being the strongest, (Moritz 2009) the use of storm power in conjunction with analysis of storm clusters holds significant potential to understanding total impacts and possible threshold exceedance. Once a reasonable identification of storm clusters is determined for each location, the next logical steps would include determining how might the likelihood of experiencing multiple storm events at a shoreline

location or tributary within a set time period impact project function or long-term resilience. In addition, coincidence of these storm clusters with high precipitation events will exacerbate coastal risk as experienced by extreme flooding events that have exceeded any single storm definition.

## REFERENCES

Bjerknes (1919): On the structure of moving cyclones, *Geophys. Publ.*, 1(2), 1-8

Dissanayake et al, (2015): Comparison of storm cluster vs isolated event impacts on beach/dune morphodynamics, NERC Open Research Archive

Jenkins et al, (2023): The temporal clustering of storm surge, wave height, and high sea level exceedances around the UK coastline, *Natural Hazards* 115:1761-1797.

Moritz et al (2009): Evaluating potential implications of cumulative storm power on coastal infrastructure damage and shoreline erosion, *ICE Coasts Marine Structures, and Breakwaters*.

Moritz et al (2023): Understanding future nonstationary exposure climate for U.S. regions: storm power, sea level change, and topographic thresholds, *ICE Coasts, Marine Structures, and Breakwaters Conference Proceedings*.

Senechal, Castelle, Bryan (2017): Storm clustering and beach response, coastal storms: processes and impacts, First Edition, Edited by Ciavola and Coco, John Wiley & Sons Ltd., pp. 151-174.

USACE, 2020. USACE Guide to Resilience Practices, Engineering Pamphlet 1100-1-5, U.S. Army Corps of Engineers, Washington, D.C.

Wadey (2023): Coastal storms: analysis of observed sea level and wave events in the SCOPAC region (Southern England) following winter 2013/14, *ICE Coasts, Marine Structures, and Breakwaters Conference Proceedings*.