# SPATIO-TEMPORAL VARIATION OF EXTREME WAVE HEIGHTS DUE TO THE PASSAGE OF TROPICAL CYCLONES

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## ABSTRACT

Storm-level winds transfer energy to the ocean surface and cause local wind waves that continue to propagate beyond the tropical cyclone (TC) generation area as swells. Together, the wind waves and swells may reach extreme heights that bring hazard to marine ecosystem, navigation, and coastal structures, but the TC-generated waves are less studied than TC-related rain and winds. This study thus aims to (1) identify and analyze the spatial and temporal patterns of TC-induced extreme wave heights in the Philippine region (5°-25°N and 115°-135°E) and (2) relate the extreme waves, separated into its wind wave and swell components, to either landfalling TCs or nonlandfalling TCs.

Datasets used in this study are significant wave heights from WAVERYS dataset by Copernicus Marine Environment Monitoring Service during the period 1993-2020 and TC track data in the western North Pacific from the International Best Track Archive for Climate Stewardship. The extreme case is defined with the 99th percentiles, $H_{99}$, with the 28-year data to be analyzed per quarterly periods: December-February (DJF), March-May (MAM); June-August (JJA); and September-November (SON) to account for TC track and monsoon seasonality. The Empirical Orthogonal Function analysis is employed to the extremes to identify the spatial modes of variability and its time coefficient is correlated against TCs and the Niño 3.4 index. The results indicated that the seasonal $H_{99}$, except in DJF, are associated with long-lived intense TCs (TCs with minimum central pressure less than 980 hPa). Different regions respond to the major TC track types: over the South China Sea (SCS), inland seas, and coastal areas of the Philippines for landfalling TCs; and open ocean WNP for nonlandfalling TCs. About 82% of the JJA $H_{99}$ over SCS, however, coincided with nonlandfalling TCs. These TCs are known to enhance the southwest monsoon and were identified as positive anomalies in zonal wind around 12°-18°N and 119°-120°E during TC events that occur in JJA. Most of the TCs that enhanced the southwest monsoon moved along a line segment connecting northeast of Luzon and east of Taiwan. The west of Northern Luzon, the seas west of Mindoro, and the inland seas between Mindoro and Panay are the most affected regions of the TC-enhanced southwest monsoon "outside" the TCs. In terms of the TC characteristics, the spatial gradient of the wave field depends on the TC intensity while the asymmetry depends on the track type. The wave field is asymmetric about the *y*-axis during landfalling TCs due to the TC-induced waves being attenuated as they interact with the coasts. The corresponding wave components of the TC-induced $H_{99}$ showed that the marine regions above 12°N are dominated by wind waves brought by TCs and the background monsoon while the low latitude regions are more swell dependent from the existing Pacific swell pools and the approaching TCs. Results of this study has shown that extreme wave events are caused by

landfalling and nonlandfalling TCs as well as other meteorological phenomena. Marine weather warnings can thus be improved by moving beyond Tropical Cyclone Warning for Shipping and incorporating remote TCs that enhance the southwest monsoon, cold surge events, and active MJO.