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Master of Science in Meteorology

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Rapidly Weakening Tropical Cyclones: Analysis and Impacts in the Philippines

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Abstract

Rapidly weakening (RW) tropical cyclones (TCs), in this study, is defined as the 90th percentile of all 24-hour over-water weakening periods in the Western North Pacific (WNP) basin, corresponding to a decrease of at least 20 kt in the JMA dataset and 25 kt in the JTWC dataset. Over the study period from 1951-2020, a total of 468 and 563 WNP RW TCs, and 17 and 19 landfalling RW TCs were identified from the JMA and JTWC datasets, respectively. RW tends to occur along $20^\circ - 30^\circ N$ latitude of the WNP, compared to rapid intensification (RI) where it typically occurs inside the Philippine Area of Responsibility (PAR). The frequency of RW is also fewer than that of RI TC cases. A significant decreasing trend in the number of RW TCs and ratio of RW TCs to total WNP TCs were observed from 1979 to 2020 using the JMA data at a rate of $-0.100\,yr^{-1}$ and $-0.286\,yr^{-1}$, respectively. Analysis of potential impacts due to wind of TCs undergoing RW shows significantly lower threats than non-RW TCs, except for those that made landfall on Northern Luzon. Despite the small occurrence frequency of RW TCs, inaccurate intensity forecast of these TCs can lead to over-forecasting or false alarms which can inflict warning fatigue. Indeed, analysis of archive forecasts reveal that forecast accuracy of RW (and RI) TCs at 24-hr lead time is low with a value of 0.52 (0.58) for JMA, and 0.51 (0.58) for JTWC. Hence, the need to further understand RW TCs and its possible causes.

Three landfalling RW TCs were simulated using the Weather Research and Forecasting (WRF) model to characterize TCs undergoing RW and determine how environmental conditions such as sea surface temperature (SST), vertical wind shear (VWS), and relative humidity (RH) result in an RW

event. The RW periods of Typhoon (TY) Maysak (2015) and TY Yutu (2018) were affected by an intrusion of dry air near the TC center and by decreasing SST around the vicinity. While the RW period of TY Parma (2009) was mostly caused by the changes in the underlying SST. It was found that when the equivalent potential temperature ($\theta_{e,max}$) in the TC inner core, which describes the amount of heat and moisture present, drops below 380 K, TCs will start to weaken. At RW, the $\theta_{e,max}$ of Maysak, Yutu, and Parma have decreased to 367.0 K, 375.7 K, and 384.8 K, respectively, while their zonal VWS were 8.53 m/s, 1.60 m/s, and 1.17 m/s. Thus, zonal VWS only played a minor role in the weakening of Yutu and Parma.

Many RW onsets of non-landfalling RW TCs were located to the northeast of the Philippines which can affect the Southwest Monsoon or Habagat winds and rainfall. In many cases during boreal summer, TCs located northeast of the country enhance the southwesterlies that leads to heavy rainfall in Western Luzon. For TCs that have undergone RW while enhancing the monsoon flow, the location of intense monsoon rainfall was shifted to Southwestern Luzon. The weakening of the TC resulted to a weaker influence on Habagat winds which results in weaker southwest monsoon flow.

Keywords: tropical cyclones, rapid weakening, warning fatigue, Weather Research and Forecasting model