THE INFLUENCE OF GLOBAL WARMING ON TROPICAL CYCLONE CHARACTERISTICS AND THEIR IMPACTS IN THE PHILIPPINES

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ABSTRACT

Tropical cyclones (TCs) are among the deadliest and most destructive natural hazards in the Philippines, primarily due to extreme winds, rainfall and storm surge. With global warming and climate change (CC), most climate models project a decrease in the frequency of TCs in the future but also an increase in the number of intense TCs as well as an increase in the TC-associated rainfall globally and in the Western North Pacific (WNP) Basin. In the Philippines, projections are generally consistent with the global studies of TCs and CC wherein a decrease in TC frequency, but an increase in the frequency of intense TCs and increase in the TC-associated rainfall are projected. These changes may lead to more damage in the future. It is therefore important to have a better understanding of how TCs might change in the future, particularly the most damaging events. This study aims to analyze how the characteristics and potential impacts of the most damaging TC events in the Philippines might change under future climate conditions using a high-resolution limited area model and the pseudo-global warming technique.

First, it is important to evaluate the ability of the Weather Research and Forecasting (WRF) Model to simulate the observed TC cases in the Philippines to provide a degree of confidence for future TC simulations under future climate conditions. For the first part of this study, the sensitivity of selected TC events to different choices of parameterization and settings in the WRF model will be examined, in particular the cumulus scheme, surface flux parameterizations and spectral nudging, initial conditions, resolution and domain settings. This will help select a combination of parameterizations and model settings that can be used in the future climate experiments i.e. the model that best reproduces the track and intensity of the TC cases under current climate conditions. This will also provide insights into the sensitivities and uncertainties associated with the use of a limited area model such as WRF in simulating TCs under different climate conditions.

Next, the response of the TC events to sea surface temperature (SST) and atmospheric temperature (ATM) warming will be investigated. As the climate changes, SSTs are projected to increase, together with other changes of atmospheric and oceanic variables, which will have an impact on TCs in the future. A set of simulations will be performed with the WRF model to investigate the response of the

same damaging TC events to increased and decreased SSTs. Different experiments per TC case will be carried out using European Centre for Medium-Range Weather Forecasts Re-analysis 5th Generation (ERA5) initial and boundary conditions as a control experiment; then experiments will be conducted with an imposed uniform SST anomalies between -4 to +4 °C across the whole domain per TC case; and an additional set of simulations will be also conducted using the monthly mean SST delta from one representative Coupled Model Inter-comparison Project Phase 6 (CMIP6) Global Climate Model (GCM) – The Community Earth System Model Version 2, which was found to have relatively good performance in simulating the spatial pattern of the climatological mean SST in the WNP Basin. Further experiments will also be performed to mimic the maintenance of atmospheric vertical stability by imposing uniform ATM profile changes.

Lastly, simulations will be performed using the WRF model, with global warming deltas derived from a selection of the latest CMIP6 GCMs using the Pseudo-Global Warming (PGW) Technique which adds a climate perturbation signal to the present day conditions during a past (pre-industrial) or future (far future or late-century) periods of interest. The novelty in this part of the study is in investigating (1) different TC cases with observed varying intensity, landfall area, & months of occurrence; (2) simulations forced with initial and boundary conditions from several GCMs; (3) WRF's simple mixed-ocean layer model will be used in order to capture the atmosphere-ocean feedback during the passage of TCs; and (4) the sensitivity to the use of different cumulus schemes, including convection-permitting model experiments, and initialization times. To improve the understanding of the potential physical mechanisms behind the changes in TC characteristics, including the differences in responses among the different experiment groups, analysis of the TC environment in the different PGW experiments will also be conducted. With the simulated projected changes in TC characteristics in the future, the TC potential damage will then be estimated using a simple Cyclone Damage Potential Index, which can help inform disaster risk management and future climate change adaptation options in the country.

Keywords: Tropical Cyclones, Philippines, Global Warming, Climate Change, Pseudo-Global Warming Technique, Cyclone Damage Potential