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Assessment of Natural Hazards Due to a Category-5 Extreme Typhoon under Global Warming by Dynamical Downscaling Experiments

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1. INTRODUCTION

A typhoons is one of the disastrous natural hazards in the western North Pacific region. Every year disasters due to severe typhoons occur somewhere in the Pacific region. Therefore, weather forecasting plays a critical role in preventing and mitigating such disasters. Furthermore, the assessment of the impacts by severe typhoons under global warming is a challenging and important task for the prevention and mitigation of natural disasters in the future climate under global warming. For the future assessment, a weather forecasting technique is impossible. Therefore, numerical simulations by prescribing climate prediction data are feasible.

In the present study, we assess natural hazards due to an extreme typhoon under global warming by investigating the changes in the intensity of typhoons in the future climate conditions by conducting dynamical downscaling numerical experiments with a regional meteorological model. Worst-case typhoons in the past should be regarded as a baseline in considering disaster-spawning typhoon hazards. For this purpose, the present study deals with Typhoon Vera (1959), so called Isewan Typhoon, as a worst-case scenario. The numerical experiments are intended to simulate the Category-5 extreme typhoon and to project the behaviours of the same typhoon under assumed global warming conditions.

2. EXPERIMENTAL DESIGN

The regional meteorological model used here is the Weather Research and Forecasting (WRF) model - the Advanced Research WRF version 3.3.1 (Skamarock et al 2008). The Japanese long-term reanalysis dataset, JRA-55 (Kobayashi et al. 2015), is used as the initial and boundary conditions for the WRF model to perform simulations for the past typhoon.

The assumed warming climate conditions are created with the use of the pseudo-global warming (PGW) technique (Sato et al. 2007), which uses the climate-change increments from the present to the future climate. The climate-change increments are obtained from the present and the future climate simulations by the Japan Meteorological Agency (JMA)/Meteorological Research Institute (MRI) atmospheric general circulation model (AGCM) (Mizuta et al. 2012). Firstly, we investigate the general performance of the WRF model in representing actual Isewan Typhoon by examining the sensitivity to the initial condition. Since the typhoon occurred in September, the climate increment data are based on the monthly means of September in the present and the future climate simulations. We do not add the increment of relative humidity, because in general there is no significant change in relative humidity from the present to a future climate from the AGCM experiments. Details can be found in Mori and Takemi (2016). In addition to the control AGCM future simulation, we use the outputs from the 3 AGCM simulations with different sea surface temperature (SST) patterns (Mizuta et al. 2014). We perform a number of numerical simulations with different initial times, different added parameters for the climate increments, and different SST conditions. From these ensemble simulation sets, we examine the robustness of the change in the intensity of the simulated typhoons from the present to the future climates.

3. RESULTS

Figure 1 summarizes the maximum intensity of the simulated typhoons under the 1959 and the future conditions. The intensity is measured here with the minimum central pressure and the maximum surface wind in their lifetimes. In terms of the minimum central pressure, the intensity range is 899.5–909.0 hPa in the 1959 condition and 879.4 – 898.1 hPa in the PGW condition. If only the SST increment is added in the PGW experiments, the intensity becomes extremely strong (i.e., 859.7–876.8 hPa).

At the time of landfall, the intensity range is 926.2–932.7 hPa in the 1959 condition, while it is 912.7–929.5 hPa in the PGW condition. The cases with only SST increments added resulted in the maintenance of the extreme intensity in the range of 887.8–892.4 hPa. Thus, the intensity of the simulated typhoons under the PGW condition is projected to be maintained up to the time of landfall.

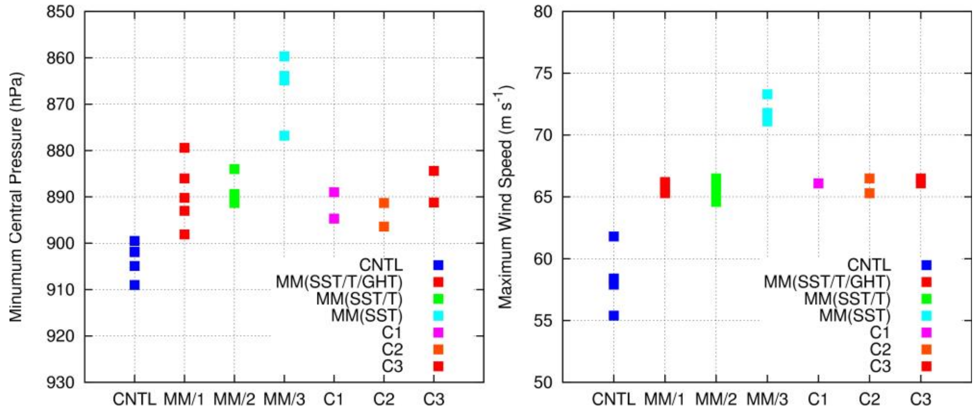

Figure 1 The maximum intensity of the simulated typhoons under the 1959 and the future conditions.

4. CONCLUSIONS

By performing dynamical downscaling PGW experiments with different SST patters, we find that the intensity of the simulated typhoons unanimously increases at their mature stages under the future climate conditions. With the September 1959 condition, the central minimum surface pressures of the simulated typhoons are 900 hPa or higher; while in the future conditions, the simulated intensities at their maxima range between 900 hPa and 880 hPa in terms of the central surface pressure. At the time of landfall, the simulated typhoons under global warming maintain its intensity and are stronger than those in the 1959 condition. The increased intensity of the typhoon affects more severely to the central part of Japan.

The change in the impact of typhoons under global warming may depend on the latitudinal location in Japan, partly because the projected change in the tropospheric temperature depends on the latitude and may affect the intensity evolution from the southern part to the northern part of Japan. More comprehensive investigations are necessary in order to assess the typhoon impacts throughout the Japanese islands.

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