

EFFECT OF BIAS CORRECTION METHOD TO FUTURE PREDICTION OF TROPICAL CYCLONE PROPERTIES SIMULATED BY GLOBAL STOCHASTIC MODEL

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BACKGROUND AND MOTIVATION

The changes in future tropical cyclones due to climate change are of significant concern in coastal disaster prevention and environmental issues. Predicting extreme phenomena like tropical cyclones using global climate models (GCMs) requires high resolution and long-term numerical analysis. However, even with the use of supercomputers, balancing these requirements can be challenging from a computational load perspective. In IPCC AR6, the utility of statistical modeling is also advocated.

The methodology for predicting future tropical cyclones and storm surges based on the result of a stochastic tropical cyclone model using Monte-Carlo method has been proposed previously. (Nakajo et al., 2014, and Nakajo et al., 2022) In the previous studies, bias correction of tropical cyclone data of GCMs was performed under the assumption that tropical cyclone characteristics followed a normal distribution. However, frequency distributions often do not follow a normal distribution, and it is crucial to understand the impact of changes in bias correction methods on future predictions. In addition, previous research has only presented future predictions for a 4-degree temperature rise, but considering the uncertainty of future predictions, results for a 2-degree temperature rise are also necessary.

PURPOSE

Given this context, the purpose of this study is to conduct bias correction based on quantile-quantile plots, compare it with the results of normal distribution type correction, and clarify its impact on future predictions. We also conducted future prediction for a 2-degree temperature rise condition to elucidate the gradual changes in the impact of global warming.

METHODS AND DATA

The configuration of the stochastic tropical cyclone model used in this study is the same as in previous research (Nakajo et al., 2014). We calibrated the model based on tropical cyclone track data from d4PDF/d2PDF, a large ensemble GCM dataset. Model biases of GCM in the d4PDF/d2PDF were corrected by comparison with observation data, IBTrACS. In addition to the stochastic model PTC calibrated with GCM results of past reproductions, 6 models (CC, GF, HA, MI, MP, MR), FTCs of future projections were also constructed.

Quantile-quantile plots are often used to examine the similarity of statistical distribution. In this study, new bias correction was made to the tropical cyclone characteristics to ensure that the q-q plot between the observed values and d4PDF/d2PDF values conforms to the $y=x$ linear relationship. The correction values are estimated as a function of typhoon characteristics ϕ , and a 3rd-degree polynomial is used for the function estimation (Figure 1). At this time, considering that the observational data is limited to around 60 years of

information, a threshold was set for the quantiles used in the function estimation.

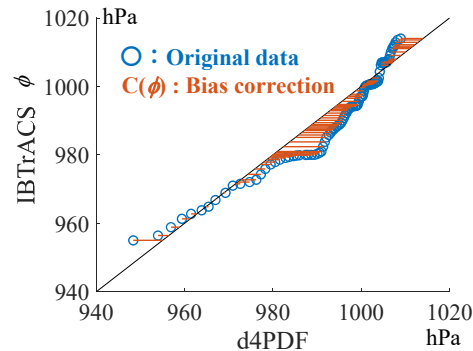


Figure 1 - Conceptual image of bias correction based on q-q plot at local region.

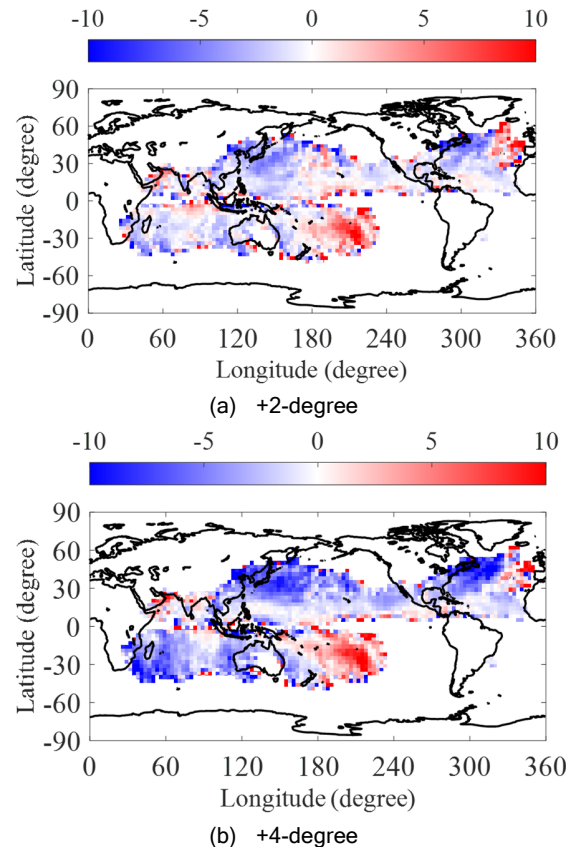


Figure 2 - Ensemble averaged future change of central pressure of tropical cyclone at +2/+4-degree in future.

RESULTS

In the case of not setting a threshold in the quantile-quantile plot correction method, there was a potential for "overfitting," where the distribution became narrower than that of the observation data. Setting an appropriate threshold of quantile value was found to result in a more natural distribution range of corrected tropical cyclone characteristics.

We analyzed the changes in tropical cyclone characteristics under 2-degree and 4-degree warming scenarios based on the results of the stochastic tropical cyclone model (FTCs, 6 models). Figure 2 shows an example of result. In many regions, the future average central pressure is projected to decrease (tropical cyclone will strengthen). This trend becomes more significant as latitude increases. In the South Pacific, on the other hand, there was an increase in the average central pressure. The trends in change are quite similar between +2-degree and +4-degree conditions.

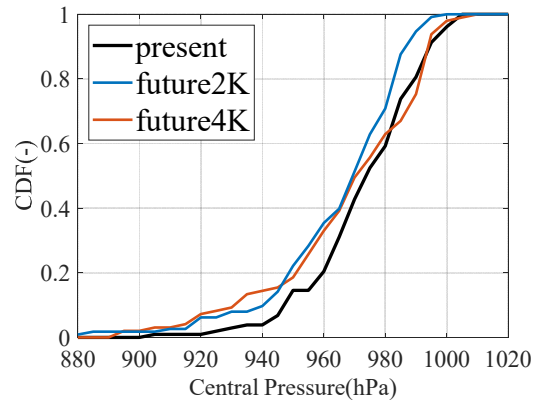
The changes in the correction method had little impact on the statistical characteristics of tropical cyclones passing through the large region (N30-60°, E120-150°), and especially the results of the present climate were well-matched between different methods. On the other hand, it has an impact on the assessment of future changes in localized regions, such as around Osaka (N34.2-35.0°, E134.8-135.6°). With the normal distribution-type bias correction, there was no significant difference in the frequency of strong tropical cyclone occurrences between the +2°C and +4°C warming scenarios, while with the q-q plot-type bias correction, the frequency of strong tropical cyclone occurrences increased significantly under the +4°C warming scenario (Figure 3). As a supplementary note, in Figure 2, we are plotting the cumulative density functions, so we are not evaluating the actual changes in the number of passages. When considering frequency changes considering the number of passages, the count of weak tropical cyclones decreases significantly. In the presentation, we also plan to provide detailed information on the changing trends of other tropical cyclone characteristics (such as frequency, translation speed, and so on) and the results of other future prediction models (6 models).

CONCLUSION

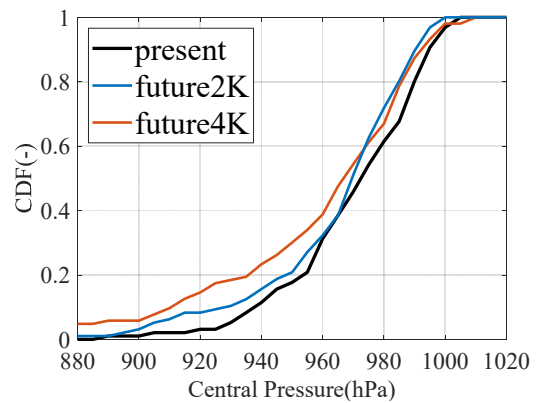
The changes in the correction method had only a minimal impact on the macro-level predictions of typhoon characteristics. When comparing future changes at smaller regional scales, the differences due to bias correction methods became significantly apparent. Around Osaka, future typhoons are projected to become both the average and extreme values stronger, and this trend is more pronounced at 4-degree compared to 2-degree of temperature rise. However, this trend difference caused by temperature condition was somewhat reduced when using the normal distribution type correction.

REFERENCES

S. Nakajo, N. Mori, T. Yasuda, H. Mase. (2014), Global Stochastic Tropical Cyclone Model Based on Principal Component Analysis and Cluster Analysis, J. Appl. Meteo.



(a) Normal distribution assumption based bias correction



(b) q-q plot based bias correction

Figure 3 - An example of future change of cumulative distribution function of central pressure around Osaka area (GF based model).

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S. Nakajo, K. Sooyoul, N. Mori, W. Adrean, T. Yasuda (2022), Assessment of uncertainty in estimating future extreme storm surge events in Osaka Bay using large ensemble typhoon data, Abstract of International Conference on Coastal Engineering, Sydney 2022.