Development of Seasonal/Weather Prediction System for Predicting Extreme Events

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Keywords：Numerical weather prediction, Seasonal prediction, Coupled general circulation model, Convection scheme, Tropical cyclones

1. Introduction

Climate change along with the global warming increases occurrence of extreme weather events (e.g., heavy rainfall, strong typhoon, heat wave etc.) and intensifies their strengths in all over the world. Because of the increasing extreme events, total damage due to wind and flood is also increasing. To mitigate the damage and avoid the climate risk, more accurate weather and seasonal prediction techniques are necessary. In this project, we continued our previous works, and conducted three subjects in order to develop better prediction techniques and numerical schemes employing dynamical models. They are: (1) implementation and evaluation of a new convection scheme for simulating tropical cyclones (TC) in an operational weather forecasting model, (2) application of the convection scheme to seasonal prediction, and (3) further investigation of improved seasonal prediction using an atmospheric nudging scheme.

2. Implementation and evaluation of a new convection scheme for simulating TC in JMA-GSM

Western north Pacific is the most TC-active region in the world. This area includes Japan, so more accurate prediction method is needed for us to reduce the damage from TCs. Japan Meteorological Agency (JMA) has continued to improve the prediction accuracy of numerical weather prediction model named global spectral model (GSM), but TC prediction especially in terms of its intensity has not been much improved for a past decade. From the last fiscal year, to improve the accuracy of TC prediction in the Japan area, JAMSTEC and JMA started a collaborative work to implement a new convection scheme developed at JAMSTEC [1] into JMA-GSM.

The implementation was completed in the last fiscal year, but the actual fidelity of the convection scheme for simulating global TC activity remained unknown. Thus, we performed the evaluation experiments focusing on mean state, variability, and the global TC activity. To obtain comparable mean state of atmospheric general circulation, several tunings were performed on the convection scheme of Baba (2019) (spectral scheme hereafter). With the tuning, the spectral scheme showed comparable mean state as well as better tropical variability. In particular, intraseasonal variability represented by Madden-Julian Oscillation (MJO) has been much improved. Focusing on the TC properties, the new scheme succeeded in simulating better TC genesis frequency especially in the western north Pacific. In addition, the spectral scheme better simulated TC intensity as seen in the minimum pressure and maximum wind speed spectra (Fig. 1). Since the improvements by the new convection scheme is significant, accuracy increase of TC prediction using the scheme in JMA-GSM is expected (the results has been out in a press release from JAMSTEC) [2].

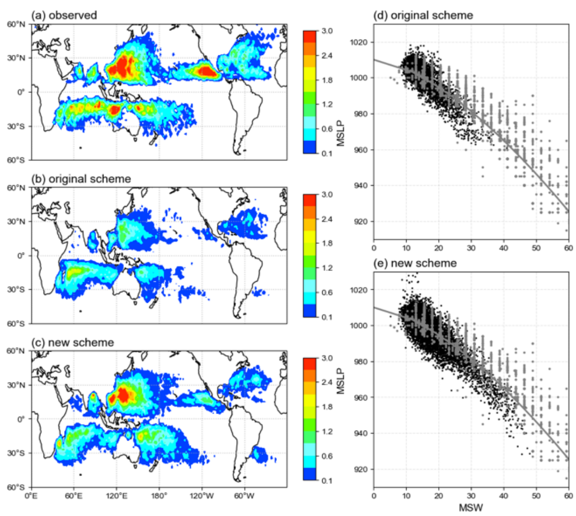

Figure 1: (a)-(c) Comparison of TC track density (number per year) between observed and model simulations. (d)-(e) Comparison of scatter plot of maximum surface wind speed (MSW) versus minimum sea level pressure (MSLP). Gray line and dots indicate empirical and observed values, respectively.

3. Application of a new convection scheme to seasonal prediction

El Nino Southern Oscillation (ENSO) is known to be the largest climate variability in the tropics and so it is import to predict the variability in the seasonal prediction. Recent coupled seasonal prediction model can capture ENSO variability well, but there still remains uncertainty in predicting ENSO, e.g., some events were not predicted well and ENSO diversity exists in a future projection. Therefore, more accurate ENSO prediction is still required. One of the possible ways to improve the dynamical model for simulating ENSO is to introduce the better convection scheme. This is because ENSO is a coupled atmosphere-ocean phenomenon in which the convective activity plays an important role for development of the ENSO.

We implemented a new convection scheme (Baba 2019) in our seasonal prediction model named SINTEX-F2, and investigated the skill improvements. When the convection scheme of the model was replaced, its deterministic prediction skill was improved (Fig. 2). Further investigation revealed that this improvement is primarily originated from the improved convection response to the sea surface temperature (SST) of ENSO. The better response generates better Walker circulation anomaly due to the ENSO in the tropics, leading to lower phase error of ENSO. In addition to the difference, ocean circulation varies depending on the tropical convection which can explain the amplitude error of ENSO in the prediction system [3].

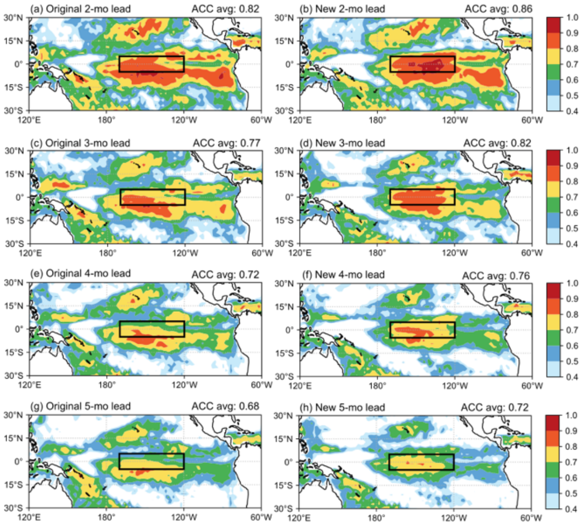

Figure 2: Comparison of seasonally averaged (Aug-Oct) anomaly correlation coefficients for SST anomaly in terms of Nino 3.4 index (the area is marked by black line boxes). “Original” and “New” mean that the prediction runs using original (Tiedtke 1989) and new (Baba 2019) convection schemes, respectively.

4. Further investigation on the skill improvement of seasonal prediction system using an atmospheric nudging scheme

Our seasonal prediction system named SINTEX-F2 did not employ atmospheric initialisation for a long time, so the atmospheric initialisation was implemented using an atmospheric nudging scheme in the last fiscal year. The atmospheric nudging was found to improve seasonal prediction skill of SINTEX-F2 especially in the midlatitude. This was considered that atmospheric forcing given by the nudging improved ocean variability, however, the atmospheric variability was also improved. In this improvement, the prediction skill was extended over the one-season (three months) which skill generally cannot be obtained for the midlatitude using ordinary seasonal prediction models. This is because atmospheric variability has much shorter timescale than ocean, and the initialization effect no longer remains in the prediction. Therefore, there was a need to investigate the reason why such extended prediction skill was obtained.

We conducted analyses regarding with the prediction skill for subsurface ocean properties, and found that the influence of atmospheric initialisation remained within the subsurface ocean. This is because the atmospheric variability given by the nudging scheme acts to force the ocean circulation which role is different from those in the tropics. Then, the atmospheric forcing changes deeper ocean properties (Fig. 3), in turn, the improved ocean properties provided better air-sea interaction in the midlatitude. These are the mechanisms why atmospheric nudging scheme improved atmospheric prediction skill over one-season [4]. These results imply that our seasonal prediction system can predict seasonal variability in the midlatitude including climate and weather extremes. We are now conducting hindcast experiments with and without the atmospheric nudging scheme, to evaluate its impact on the heavy rainfall prediction over Japan and North America. The results of the hindcast experiments will be presented as a part of ES project in the next fiscal year.

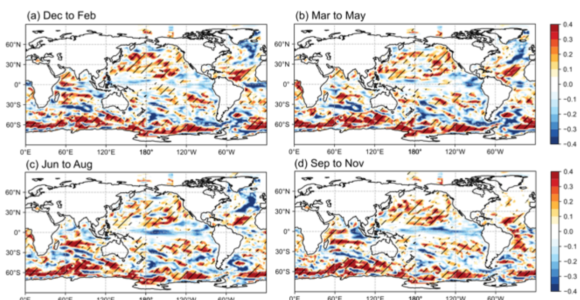

Figure 3: Difference of seasonally averaged anomaly correlation coefficients for subsurface ocean temperature anomaly at 150 m depth (defined subsurface ocean depth). The difference of the correlation is given by the run with the atmospheric nudging minus run without the nudging. The higher correlation means the improvement of ocean temperature prediction.

Acknowledgements

The author thanks to ES support desk for their helps with the

trouble-shooting for disk access and sequential job submission.

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