Development of Seasonal/Weather Prediction System for Predicting Extreme Events

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1. Introduction

Along with the changing climate, extreme events that cause severe damage to economics, infrastructure, and human lives, are changing. Due to such situation, demands for the seasonal prediction is also changing. Early warning for heavy rainfall is one of such demands, thus we attempted to develop (1) seasonal prediction model which can predict atmospheric river that can be a source of heavy rainfall. Until last fiscal year, the potential predictability is evaluated but we tried to extend this using ocean 3D-var in this fiscal year. Demand for (2) seasonal prediction of tropical cyclones (TCs) is also increasing recently, since this can provide early warning information regarding TCs. In addition, collaborating with Japan Meteorological Agency (JMA), (3) update of operational numerical weather prediction model, i.e., Global Spectral Model of JMA (JMA-GSM), is conducted in this study.

2. Seasonal prediction of atmospheric rivers using ocean 3D-var

In our past study, seasonal prediction of atmospheric rivers (ARs) in western North Pacific is found to be possible, using our seasonal prediction model [1]. Normally, seasonal prediction is impossible for midlatitude atmospheric variability, but it was found that source of predictability stems from the tropical variability through teleconnection patterns between tropics and midlatitude. In this teleconnection, role of subtropical region is important, i.e., air-sea coupling and anticyclonic circulation need to be correctly predicted. The air-sea coupling can be improved by ocean subsurface temperature, thus ocean 3D-var [2] can be useful for predicting seasonal AR activity. This study tried to evaluate this impact. The hindcast experiments revealed that the impact of the ocean 3D-var appeared in longer range prediction rather than in shorter range prediction. The reason and underlying mechanisms are explained especially by the improved air-sea coupling tropical variability. The details will be summarized in a research paper [3].

3. Seasonal prediction of tropical cyclones using updated SINTEX-F2 with higher resolutions

Tropical cyclone (TC) is known to cause serious impacts on human life and society. Therefore, development of numerical weather prediction models to predict TC activity has been continued even recently. The seasonal prediction of TCs is one of the strategies to respond this demand, since it enables early warning for strong TC activity. However, since the numerical models involve many uncertainties, it remains difficult to predict the activity accurately. To respond the demand and further improve the prediction accuracy, we updated seasonal prediction model SINTEX-F2 using higher resolutions and a new convection scheme [4]. In this study, we evaluated its seasonal prediction skill for TCs and revealed the underlying mechanisms influencing the prediction skill. In particular, the past studies [5] revealed that increasing resolution does not always result in improving the seasonal forecast, thus the impact of high resolution is especially focused on.

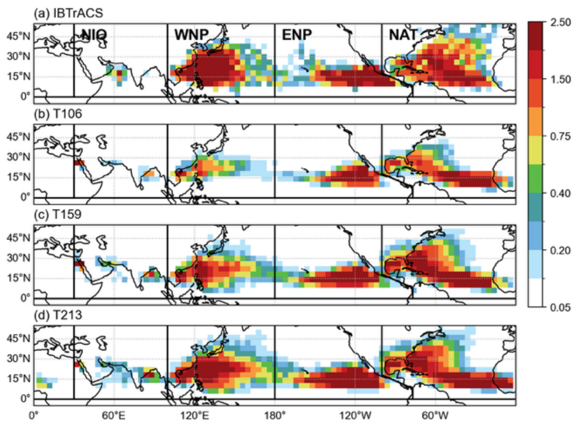

Figure 1: Comparison of horizontal distribution of TC frequency (number per day) during May-Oct, 2001-2023. WNP (western North Pacific), ENP (eastern North Pacific), NAT (North Atlantic), and NIO (North Indian ocean) represent ocean basins which are used basin-wide TC analyses. T106, T159, and T213 corresponds to resolutions of 120 km, 80 km, and 60 km, respectively.

We conducted seasonal TC prediction during 2001-2023 (23 years) using 12 ensemble members. Each prediction is initialized from 1st and 2nd day of May or June and conducted for 6 lead months. Figure 1 shows the horizontal distributions of climatological TC frequency (TCF) obtained from predictions with different resolutions. It is apparently shown that higher resolution improved climatological TCF distribution. In addition, the higher resolution improved seasonal cyclone TCF and TC intensity (not shown here), meaning that the high-resolution improved TC statistics in the seasonal prediction.

The high resolution also improved the prediction skill for seasonal TC activity, especially in WNP. Figure 2 shows the comparison of linear correlation of seasonal TCF and accumulated cyclone energy (ACE) in each basin. Although the resolution increase does not change the prediction skill so much, it increases linear correlations for TCF and ACE compared to the lowest resolution. In addition, the correlations indicate that the present model can simulated basin-wide TC activity comparable or better than existing models [5]. Further investigation revealed that the improved prediction skill is derived from the improved organized convection in the tropics, leading to the improved sea surface temperature (SST) over the most frequent TC genesis area. Eventually, this finding means that resolution increase with recent advanced convection scheme has a potential to improve seasonal TC prediction through improving global circulation [6].

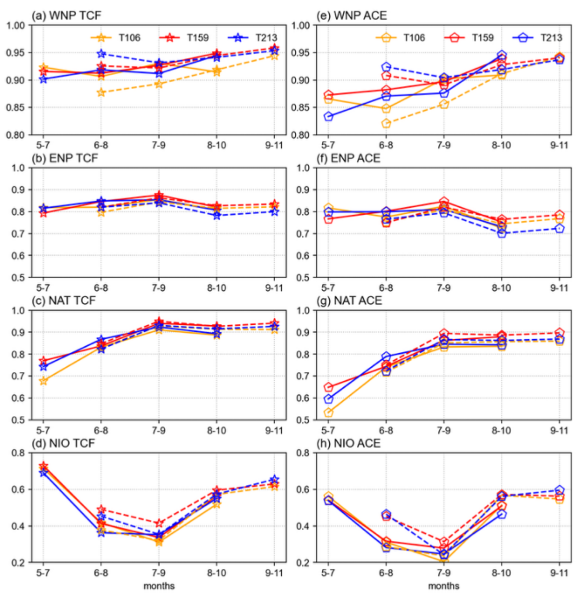

Figure 2: Comparison of linear correlation for (a-d) TCF and (e-h) accumulated cyclone energy (ACE) between different resolutions in each ocean basin. The solid and dashed line indicate May and June initialized predictions, respectively.

4. Update in JMA-GSM

In the past collaborative work with JMA, we implemented a new convection scheme in JMA-GSM (simply referred to as GSM) and showed the scheme can improve the climatological properties of TC in global model and improved the TC hindcast in realistic TC events [7].

Next (last) fiscal year, we evaluated the model's prediction skill for actual two typhoon cases. In this fiscal year, we conducted additional analyses which were needed for publication of the research, and we revealed that the GSM using a new convection scheme improved typhoon forecast in terms of track and intensity. However, if the initial condition is not realistic, the scheme shows increase of track error, due to the compensation for the typhoon's minimum pressure [8].

In recent years, JMA updated GSM to have higher resolution up to 13 km. This means that the resolution approaches to the limit where the approximation of convection scheme will be invalid, and the model accuracy may be degraded. To overcome this problem, we started research to update the convection scheme to be valid such high-resolution model. Such modification to the convection scheme is known as gray zone parameterization. Series of higher-resolution GSM simulations (Tl959, ~20km and TQ959, ~13 km resolutions) focusing on the past typhoon events are conducted (Figure 3).

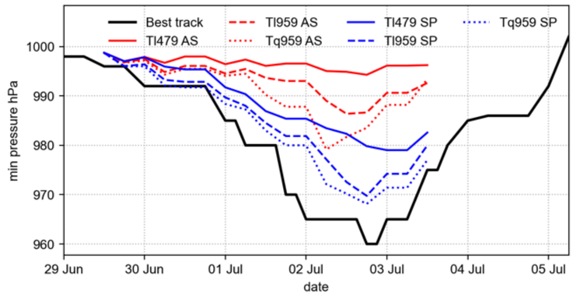

Figure 3: Time evolutions of minimum pressure of typhoon Prapiroon (2018) predicted by different GSM resolutions and convection schemes. Tl479, Tl959, Tq959 correspond to resolutions of 40 km, 20 km, and 13 km. Red and blue colored lines correspond to the original and new convection schemes, respectively.

Current results indicate that higher resolution can improve the typhoon properties greatly, but it is still insufficient and cannot be a solution to exactly predict the minimum pressure. A seamless parameterization that can archive the automatic tuning for typhoon prediction even for different model resolutions is required. Investigation for such parameterization is now being conducted.

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