11D.4 SIMULATED TROPICAL CYCLONES IN THE NCAR COMMUNITY CLIMATE MODEL AT T170 RESOLUTION

Junichi Tsutsui*
Central Research Institute of Electric Power Industry, Abiko, Japan

1 INTRODUCTION

Observed interannual variability of tropical cyclone (TC) activity can be explained in many cases by different dynamic and thermodynamic conditions associated with tropical cyclogenesis (e.g., Nakazawa, 2001). Also, it is found that individual TC formation is affected by some large-scale forcing prior to the cyclogenesis under dynamic and thermodynamic conditions preferable to its happening (e.g., Briegel and Frank, 1997). Basically, both of these large-scale properties are being revealed from observed data.

On the other hand, climate simulation studies using atmospheric general circulation models (GCMs) have been conducted to investigate climate change influences on TC activity (e.g., Tsutsui, 2002). They examined changes in TC activity and associated large-scale fields as an impact of different climate conditions such as sea surface temperature anomalies. However, the process of simulated tropical cyclogenesis during long-term time integration of a climate model has not been examined well partly because the model's spatial resolution is usually too coarse to discuss it.

In this study, therefore, I investigate various aspects of simulated TCs, including the process of tropical cyclogenesis, for long-term integration using one of the most recent high-resolution global models. The objective of this study is mainly to examine the quality of the model as a tool for climatological studies on TCs. In addition, another objective is to research the possibility of modeling studies on large-scale forcing associated with tropical cyclogenesis, which is being revealed from observational evidences. In a GCM simulation, the origin of a TC is generated by the model itself, which is different from other types of numerical experiments with given TC origins. Since the amount and quality of observation relevant to tropical cyclogenesis are limited over tropical waters, modeling studies would be beneficial to reducing uncertainties about this issue if realistic tropical cyclogenesis was simulated.

2 BRIEF DESCRIPTION OF T170 CCM3

In this study, I use the National Center for Atmospheric Research Community Climate Model version 3 (CCM3) with a horizontal spectral resolution of T170. Although the CCM3 has marked improvement in the mean properties of climate compared to the previous version model, it has very little variability in convection in the tropics (Maloney and Hartmann, 2001). In particular, the model can produce very few TC-like disturbances. Therefore, I use a modified version of CCM3, where a boundary layer relative humidity (RH) threshold is imposed on triggering the model's deep convection scheme. The frequency of TC-like disturbances dramatically increases as the threshold value increases. In this study, a RH threshold of 85% is used. Since the standard horizontal resolution of the CCM3 is T42, some physics parameters are adjusted for the T170 model to reduce dependencies of simulated climatology on spatial resolution.

*Corresponding author address: Junichi Tsutsui, Central Research Institute of Electric Power Industry, 1646 Abiko, Abiko-city, Chiba 270-1194 Japan; e-mail: tsutsui@criepi.denken.or.jp.

3 RESULTS

3.1 Climatological Aspects

The modified T170 model has some energy imbalances in global annual mean properties. These imbalances are emerged by both the RH threshold implementation and increased resolution. In particular, global precipitation rate in the modified T170 model increases by about 9% compared to the original T42 model, and remarkable overestimated precipitation occurs in the tropics. However, geographical distributions of tropical precipitation are in good agreement with observed data. Also, the modified T170 model indicates better vertical thermodynamic profiles at some observation sites in the equatorial Pacific than the original T42 model. This improvement of tropical thermodynamic structure is resulted from the RH threshold implementation.

In this study, a simulated TC is defined as a low over the ocean between 40°N to 40°S with a significant pressure gradient at sea level and a warm-core structure in the upper troposphere. Simulated TC activity is very sensitive to threshold values, and the model with a threshold of 85% simulates TCs with a frequency comparable to that for observed TCs, where the frequency is evaluated by the number of total annual days of TC occurrence. This strong sensitivity, which basically does not depends on the spatial resolution of the model, implies that realistic simulation of moisture distribution in the lower troposphere is crucial for variability in convection.

Although the global frequency of simulated TCs is comparable to observation, simulated TCs tend to concentrate too much in particular basins. The western North Pacific is one of the TC basins where concentrated TC occurrence is simulated. One of the most important climatological aspects for tropical cyclogenesis in this basin is large-scale circulation in the lower troposphere. Figure 1 shows climatological 850-hPa wind patterns in September for the model and the NCEP/NCAR reanalysis. In the model, a strong shearline is formed between monsoon south-westerlies and trade winds, where most simulated TCs form in this season. Although general wind pattern is in good agreement with reanalysis, the magnitude of simulated south-westerlies is exaggerated, and associated cyclonic circulation dominates over a large area of the basin. This enhanced monsoon circulation possibly results in overestimated TC activity in the model.

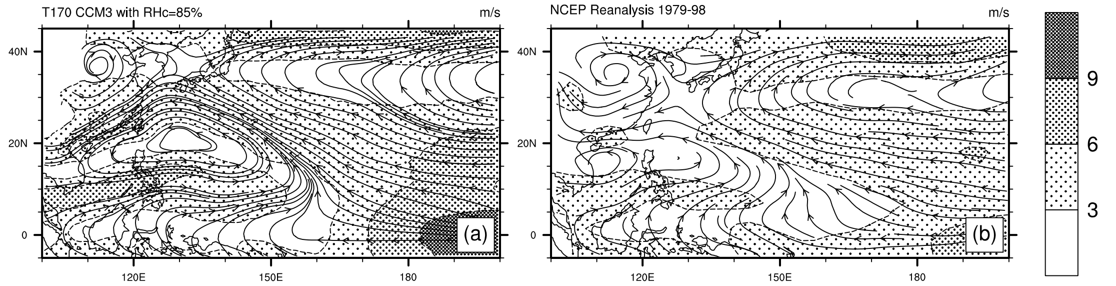

Figure 1: Climatological 850-hPa wind patterns in the western North Pacific in September for (a) the modified T170 CCM3 and (b) NCEP/NCAR reanalysis 1979-1998. Filled areas with different stippling represent wind magnitudes.

3.2 Example of Simulated TC Evolution

The high-resolution model has the most advantage in simulating individual TCs realistically. Simulated TCs by the model show some characteristic behaviors such as the organization of meso-scale convection systems in a development stage, a recurved or westward motion in a mature stage depending on large-scale wind patterns, and transition to a extratropical cyclone in mid-latitudes. Figure 2 shows a sea level pressure (SLP) map of a typical simulated TC at the maximum development stage with its recurved trajectory. The minimum central SLP is 966 hPa, which is categorized as a very intense storm in the model. This storm makes landfall in the eastern part of Japan, although it is judged as an extratropical storm at that time.

Figure 3 shows 850-hPa streamlines and areas of intense precipitation (a) when a cyclonic circulation as an origin of TC can be first recognized around (8°N, 165°E), and (b) when the disturbance is first identified as a TC around (8°N, 150°E). At the time shown in Figure 3a and during the previous several days, southerlies dominate in a broad area to the east of the cyclonic circulation. The southerlies accompany a large amount of moisture that migrates from the eastern Pacific. This sequence of events implies that a easterly wave may affect the process of the cyclogenesis.

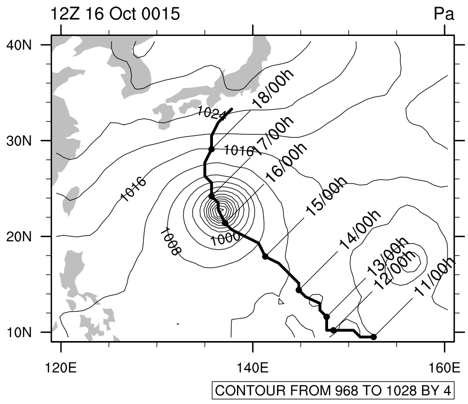

Figure 2: Sea level pressure map of a simulated TC example with its trajectory.

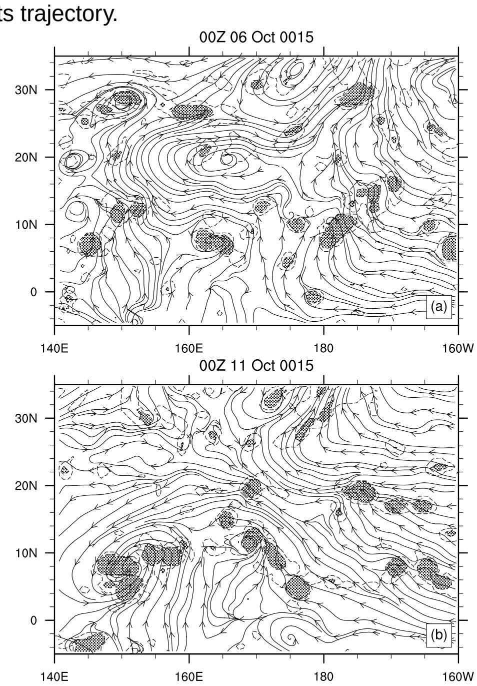

Figure 3: Streamlines at the 850-hPa level during the genesis period for the TC shown in Figure 2. Dashed contours denote precipitation rates at 0.1 and 1 mm h^{-1}, and stippled areas indicate 1 mm h^{-1} or greater of precipitation rate.

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