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三重大学大学院　生物資源学研究科

修士論文

結合系『黒潮→台風⇔大気』がもたらす台風の U ターン

A “Kuroshio-typhoon-atmosphere” couple system causes the U-turn of a typhoon

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ABSTRACT

Typhoon Ma-on landed of Tokushima prefecture on 20 July 2011, then moved southward until July 22.Focusing on the characteristic course of this typhoon, we conducted a verification using a numerical model. When the typhoon is strong, the typhoon does not go southward but goes east, but when the typhoon is weak, the typhoon goes southward. Comparing the atmospheric environment around the typhoon at this time, the result of both calculations was a place where north wind dominates as a whole, but when the typhoon was strong, there was a high pressure anomaly on the east side of the typhoon compared to the weak typhoon. It was shown that the south wind was excited. From this, it was shown that the stronger the typhoon, the more distant the effect is to the surroundings. From the results of data assimilation, the developing of disturbance and the strengthening of trough were seen on the Kuroshio Extension. In assimilation of the observation, low pressure anomaly was observed on the Kuroshio Extension compared to REF. It is thought that the disturbance captured by the observation developed on the Kuroshio Extension. From the results of the two analyzes, the remote influence of the typhoon and the development of the disturbance occurred on the Kuroshio Extension, which supported the southward movement of the typhoon.

Contents

1. Introduction

The course of typhoons is determined by two factors, large-scale flow and typhoon's own flow. Although the typhoon itself has a flow toward the northwest due to the beta effect and so on, Chan and Williams (1987) showed that the movement by his own flow is extremely slow and it is common to be flushed by the wind of the upper layer. Therefore, many studies have been made to determine the course by the influence of the surrounding atmospheric pressure field, but the contents that the typhoon itself affects the surroundings there are few studies on the influence of the typhoon itself on. Research on typhoons by remote effect, there are things that the remote influence affects the correlation magnitude atmospheric field and the one that influences the typhoon's own route.Kawamura and Ogasawara (2006) and Yamada and Kawamura (2007) showed the influence of the typhoon around the surrounding area. These studies show that a typhoon strengthens the anticyclone in remote way. However, these studies do not mention the relationship between the enhanced anticyclone and the course of the typhoon. As a previous study, Katsube and Inatsu (2016) describes the relationship between the strength of the typhoon and its course.

Typhoon Ma-on landed of Tokushima prefecture on 20 July 2011, then moved southward until July 22. Typhoons moving southwards for two days near Japan are unprecedented. This movement is different from the movement of westerly jet and Pacific Ocean anticyclone and it is also different from typhoon's own flow.

In this research, we focus on the path like U-turn of Margon. The aim in this research is to clarify whether or not the remote forcing of typhoon is involved as a reason for taking such course. In order to achieve this research purpose, we investigated the influence of typhoon intensity using a numerical weather forecast model and verified the influence of the Kuroshio Extension flow using data assimilation.

2. Data and Methods

2.1 Model configuration

We conducted a numerical experiment by using the Weather Research and Forecasting (WRF) Model Version 3.4.1 (Michalakes et al. 2001). Calculating area is shown in Fig.1. The outermost domain (d01) had horizontal resolution of 30km. The second outside domain (d02) had horizontal resolution of 6km. All domains included 50 vertical layers. Using parameters is shown table 1.

The initial and lateral boundary conditions of the atmosphere used the European Centre for Medium-Range Weather Forecasting (ECMWF) ERA-interim data(Simmons et al, 2007) with horizontal resolution 1.5° × 1.5°. The initial and lateral boundary conditions of sea surface temperature (SST) used daily National Oceanic and Atmospheric Administration (NOAA) optimum interpolation sea surface temperature (OISST,Reynolds et al. 2002) data with horizontal resolution 0.25° × 0.25°. Calculation period was 5 day, from 0000 UTC 18 July 2011 to 0000 UTC 23 July 2011.

Calculation results using the above data is referred to as control run (CTL). Calculation results to weakened the strength of the typhoon is referred to as weak run(Weak). In Weak,remove the typhoon from the initial value, inserted a weaker vortex than the actual typhoon. The actual typhoon went south while weakening. In the computation result of CTL, weakening of the actual typhoon was not expressed.

We verified by comparing the both of calculation results that difference between strength of typhoon influences course.

2.2 Data assimilation

2.2.1 Radiosonde Observations form a ship

This study uses GPS radiosondes data taken research vessel Wakatakamaru. In 2011 observation, GPS radiosondes were launched over the Sanriku conducted every other hour off from 1600 UTC 19 Jul 2011 to 0900 UTC 19 July 2011. The observation point is shown in Fig.2.

2.2.2 Ensemble Reanalysis

An observing system experiment was performed by comparing two analyses produced using ALEDAS2 (AFES-LETKF ensemble data assimilation system 2) with and without the additional radiosonde observations (hereafter referred to as CTL and OSE, respectively). ALEDAS2 is an atmospheric ensemble reanalysis data assimilation system composed of the Atmospheric General Circulation Model (AGCM) for the Earth Simulator (AFES; Ofuchi et al. 2004; Enomoto et al. 2008) and the Local Ensemble Transform Kalman Filter (LETKF; Hunt et al. 2007; Miyoshi and Yamane 2007).

ALERA2 is an experimental ensemble reanalysis produced using ALEDAS2 and includes the analysis ensemble mean and analysis ensemble spreads for wind, temperature, humidity and geopotential height for 63 ensemble members at 48 levels with a horizontal resolution 1.25° × 1.25°.

By comparing the two reanalysis data, it becomes possible to evaluate the influence of a small scale disturbance captured by observation.

3. Result

3.1 Simulated results of the numerical model

Figure 3 shows the typhoon of CTL_RUN headed east, no movement toward the south east like the actual typhoon was seen, and the traveling speed was also faster than the reality (red line in Fig. 3). The track of the Weak_RUN's typhoon resulted in a rough reproduction of the path like the actual U-turn of the typhoon (white line in Fig.3). Weak_RUN reproduces to some extent the reason why the typhoon made its way to the south.

Figure 4 shows the geopotential height at 500 hPa (Z500) in (a) CTL_Run and (b) Weak_Run at 0000 UTC 20 July 2011. The typhoon started to go southward in this time. These can be due to the synoptic-scale atmospheric pressure pattern where the north wind dominates.

Figure 5 shows the difference between CTL_RUN and Weak_RUN of sea level pressure (SLP) at 0000 UTC 20 July 2011. In order to eliminate the difference due to the strength of the typhoon, we masked out the area around the typhoon. Focusing on the typhoon surroundings, the anticyclone anomaly distributed the eastern side of the typhoon. This high pressure anomaly continued to the upper level. suggesting that the typhoon was strongly driven by the north wind to the upper level at the front of the typhoon at Weak_RUN.

Also, in the range of 30-40°N and 140-160°E where the high pressure anomaly appears on the eastern side of the typhoon, each term of the vorticity equation (1) below is area averaged. This calculation was done to investigate the origin of high pressure anomaly.The term enclosed in red is the horizontal divergence term, the term enclosed in blue is the beta term, and the term enclosed in yellow is the advection term. Horizontal divergence term 6.5×10^{-10} / s, beta term 5.6×10^{-12} / s. The advection term was -1.8×10^{-10} / s, indicating that the high pressure anomaly

$$\frac{\partial \zeta}{\partial t} = -u\frac{\partial \zeta}{\partial x} - v\frac{\partial \zeta}{\partial y} - v\frac{\partial f}{\partial y} - (\zeta + f)\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) \quad \mathbf{(1)}$$

was caused by divergence.

Figure 6 shows the precipitation at (a) CTL_RUN (b) Weak_RUN at 1200 UTC 19 July 2011. The precipitation of CTL_RUN is heavier on the east side of the typhoon itself and the upward flow accompanying the typhoon is stronger on the east side of the typhoon itself (figure not shown).

3.2 Analysis results of data assimilation

Figure 7 shows the difference between OSE and REF of (a) SLP and (b) Z500 at 0600 UTC 20 July 2011. High pressure anomaly distributed near the observation point. There are two low pressure anomalies in the east and west of the high pressure. The result of OSE reflects the development of the small-scale disturbance captured by Radiosonde observations, which is not seen in REF. Furthermore, it is suggested that the disturbance may affect the large-scale low pressure of the upper layer.

Figure 8 shows the SLP and SST at (a) REF (b) OSE at 1200 UTC 20 July 2011. In OSE, compared to REF, the low pressure section extends from the typhoon to the east along the Kuroshio Extension basin.

Figure 9 shows the difference between the OSE and the REF of the wind direction and wind speed, and absolute wind speed averaged from 925 hPa to 600 hPa at 1800 UTC 20 July 2011. In OSE, rotation of low pressure is distributed. The result of OSE is a north wind on the northeast side of the typhoon, and the typhoon becomes a peripheral field which makes it easy to go southward.

4. Discussion and conclusion

Typhoon Ma-on landed of Tokushima prefecture on 20 July 2011, then moved southward until July 22. Focusing on the characteristic course of this typhoon.

In order to verify the relationship between course and strength, we verified by numerical model.From the results of numerical model experiments, the typhoon of CTL_RUN did not go southward and that of Weak_RUN went go southward (Fig.3).The difference between the CTL_RUN and the Weak_RUN suggests that there is a high pressure anomaly in the front (east) of the typhoon from the lower level to the upper level and in the Weak_RUN it is a north wind at the front of the typhoon southward(Fig.5).Since the difference between the CTL_RUN and the Weak_RUN is only the initial typhoon intensity, we suggest that this anticyclone anomaly was excited by the difference in typhoon intensity.

The reason for the high pressure anomaly on the east side of the typhoon is believed to be related to the strong rainfall on the east side of the typhoon itself by CTL_RUN(Fig.6). In the CTL_RUN, the upward flow is strong on the east side of the typhoon itself, and there was a downward flow at the front(east) of the typhoon as a supplementary flow.

This is a result suggesting that a strong intensity typhoon may affect the course. This mechanism has been clarified in this research.

From the results of data assimilation, the developing of disturbance and the strengthening of trough were seen on the Kuroshio Extension.(Fig.7). In Ose, low pressure anomaly was observed on the Kuroshio Extension compared to REF. It is thought that the disturbance captured by the observation developed on the Kuroshio Extension.

From the results of the two analyzes, the remote influence of the typhoon and the development of the disturbance occurred on the Kuroshio Extension, which supported the southward movement of the typhoon.

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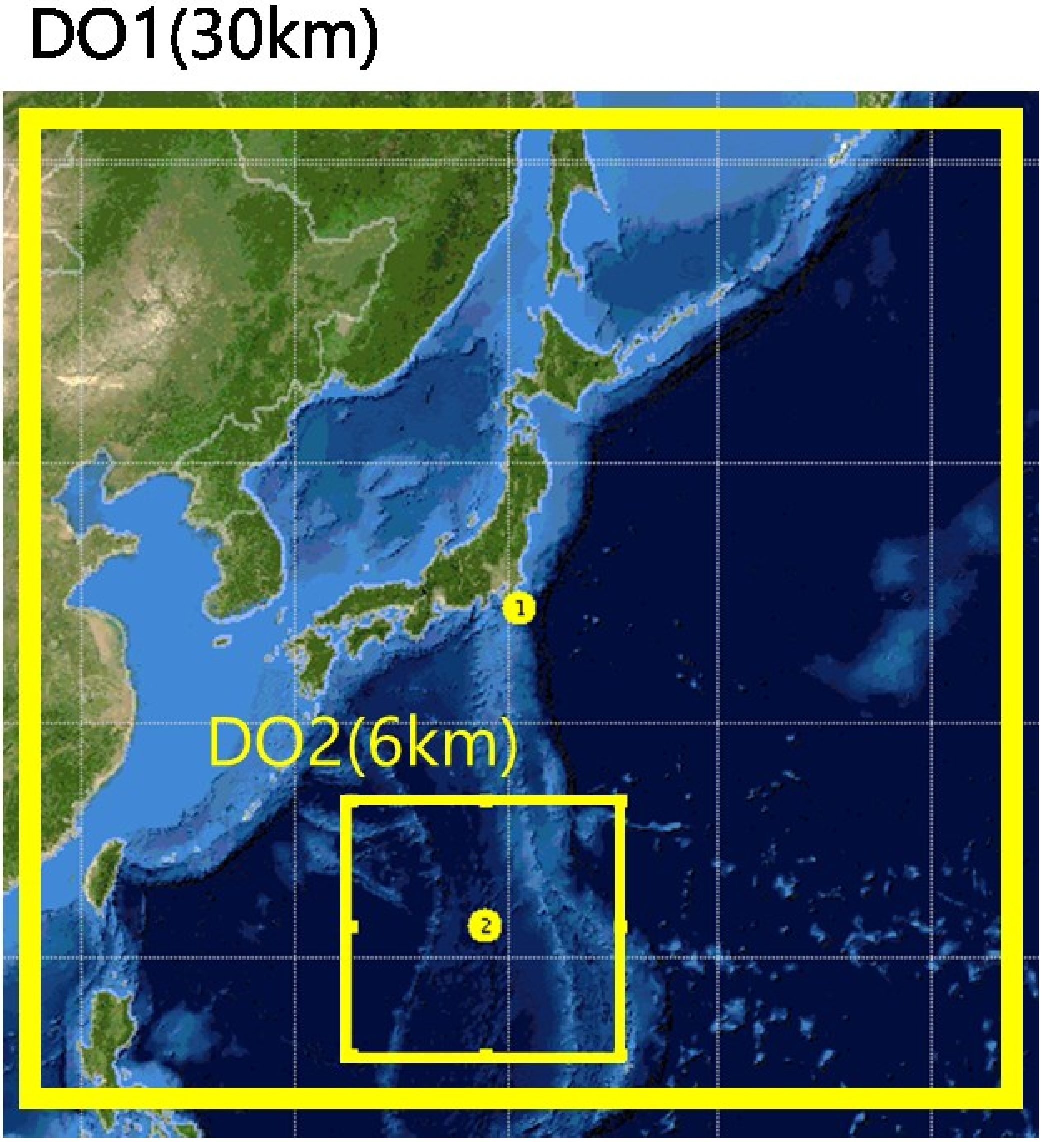

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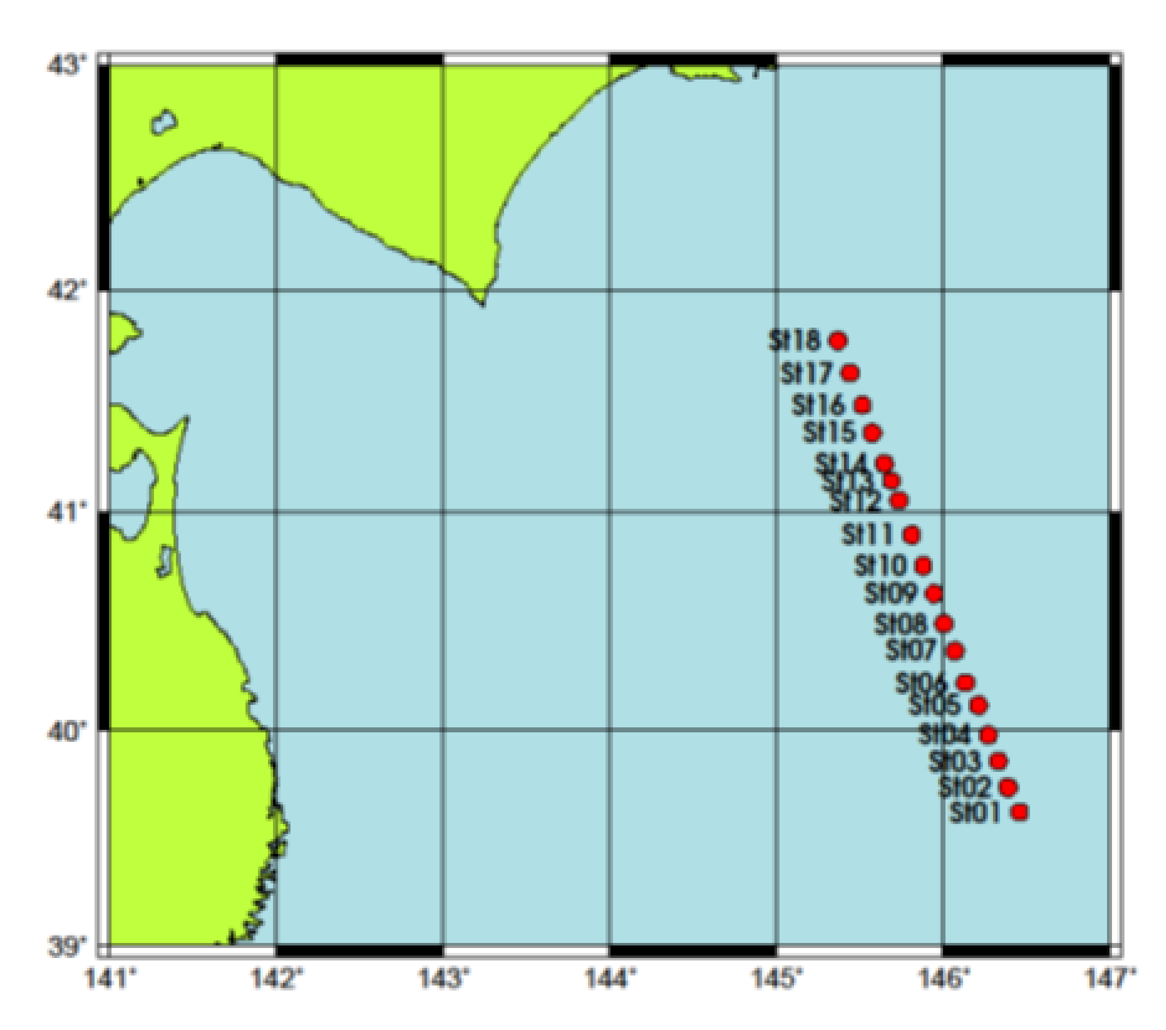

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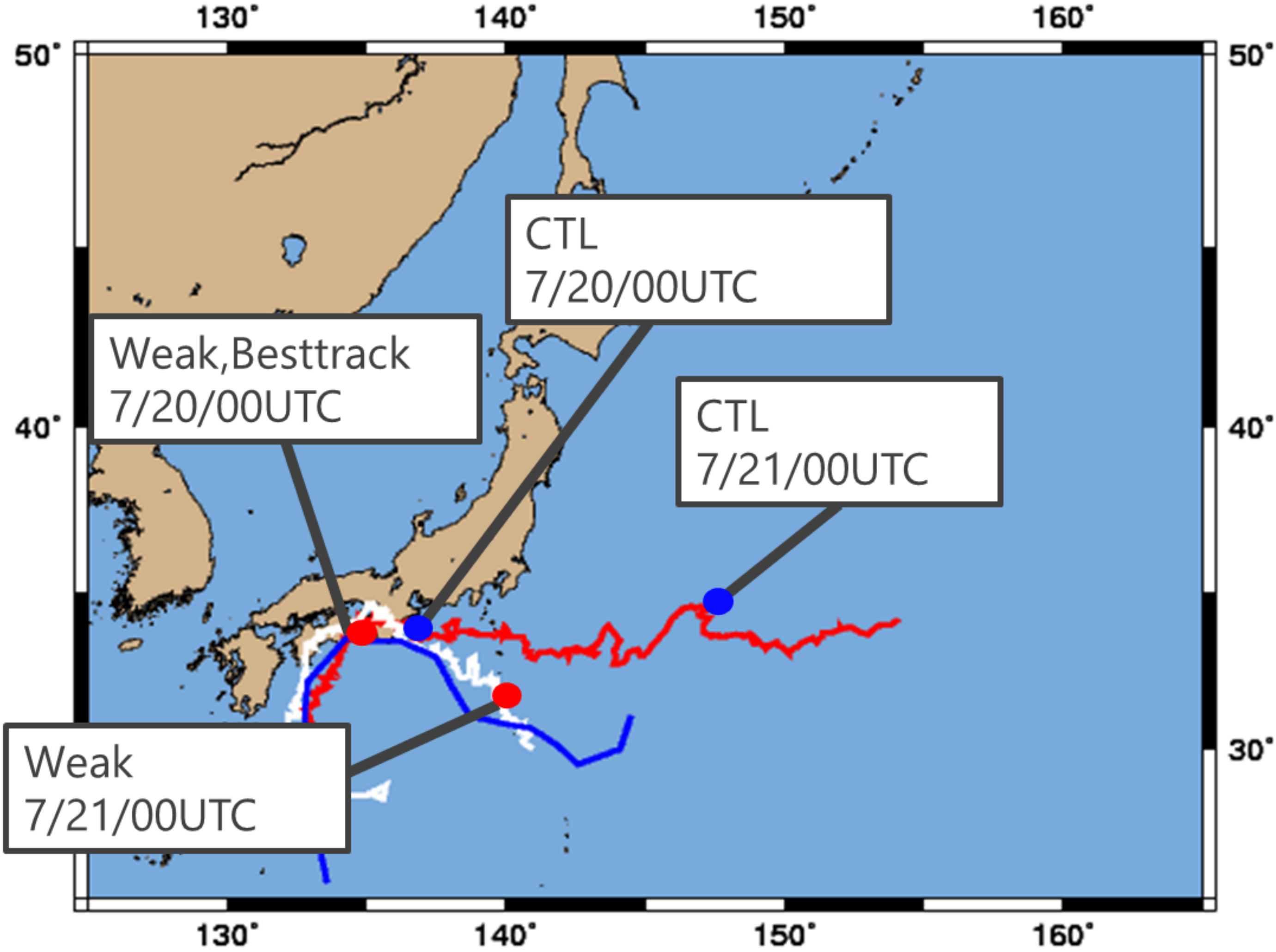

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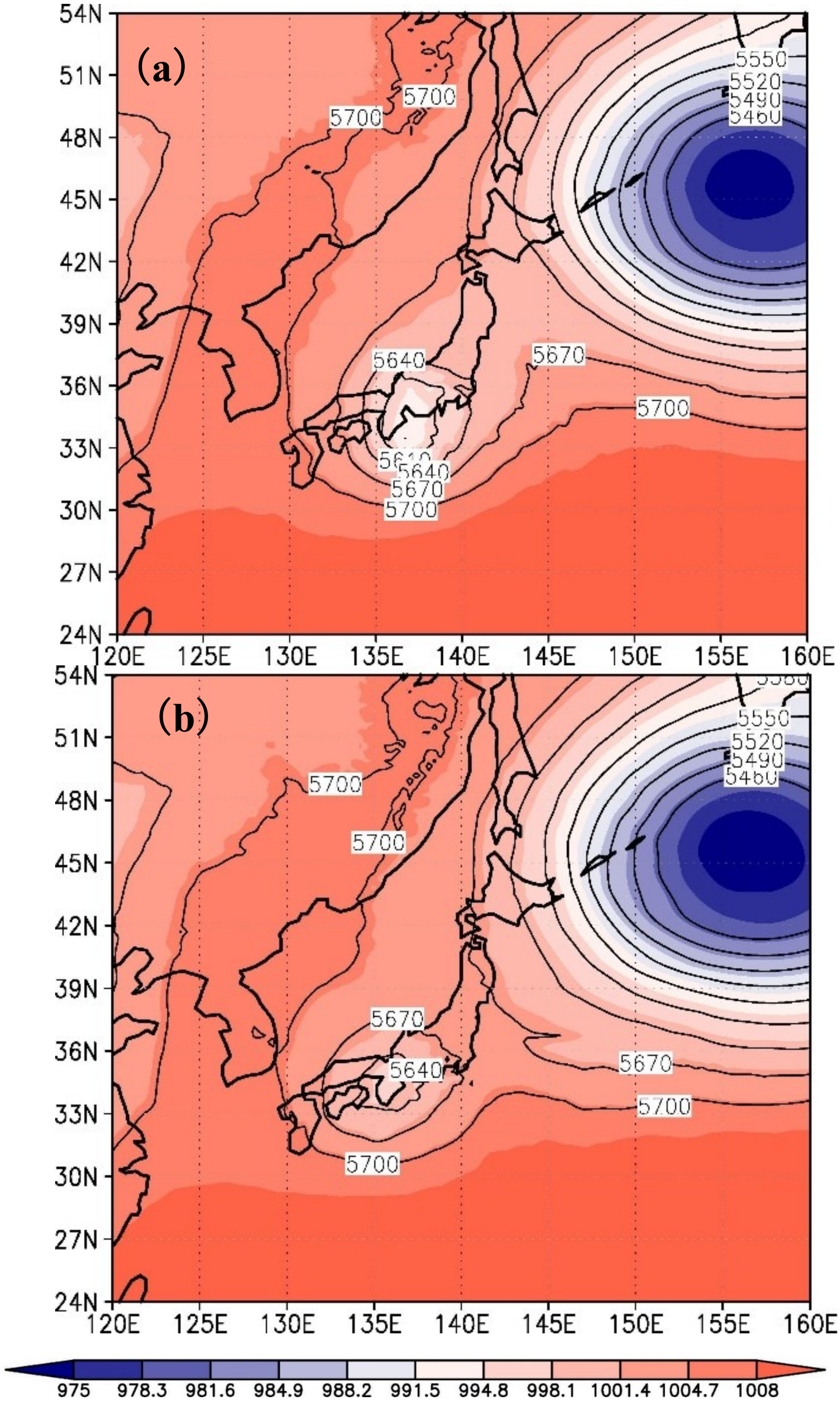

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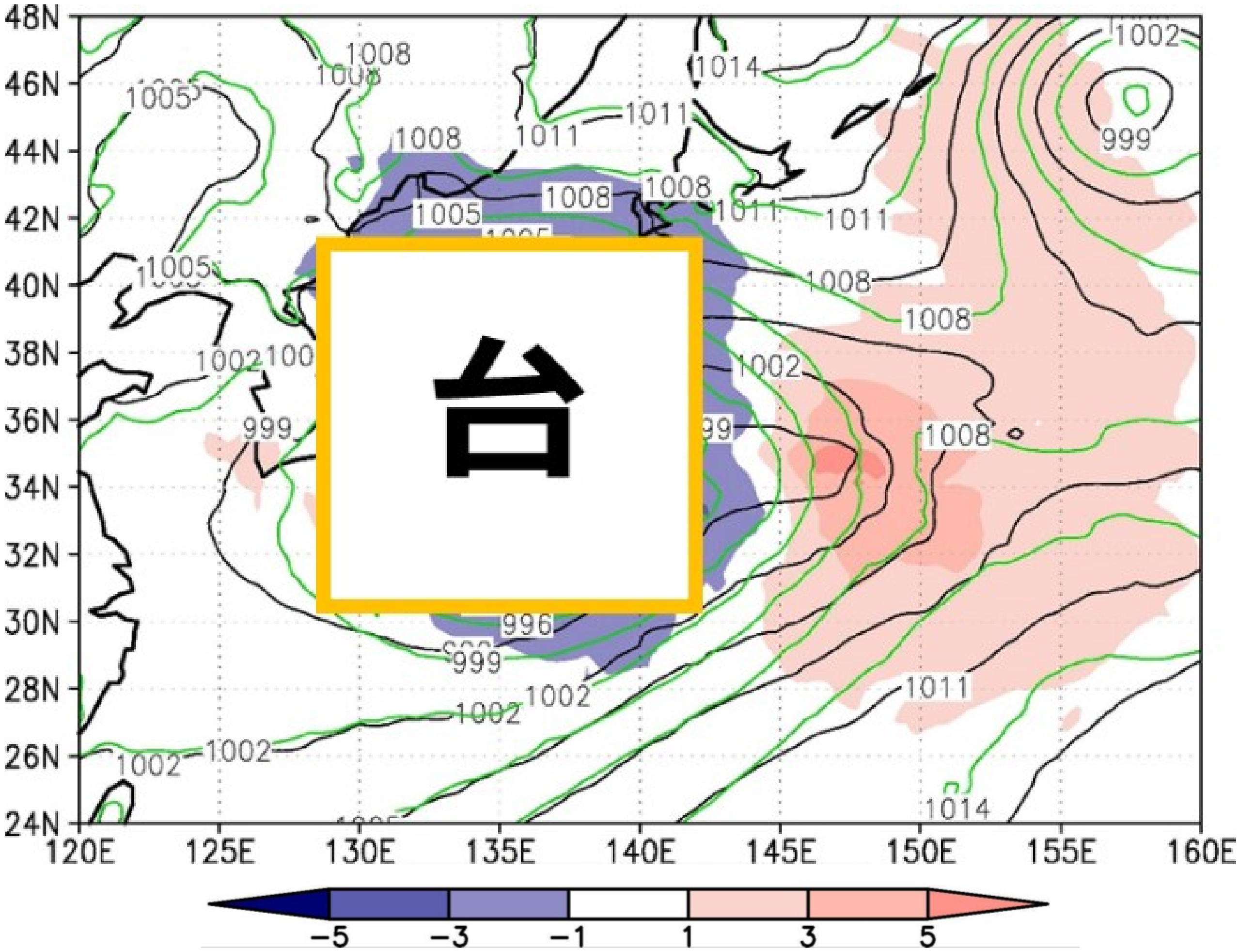

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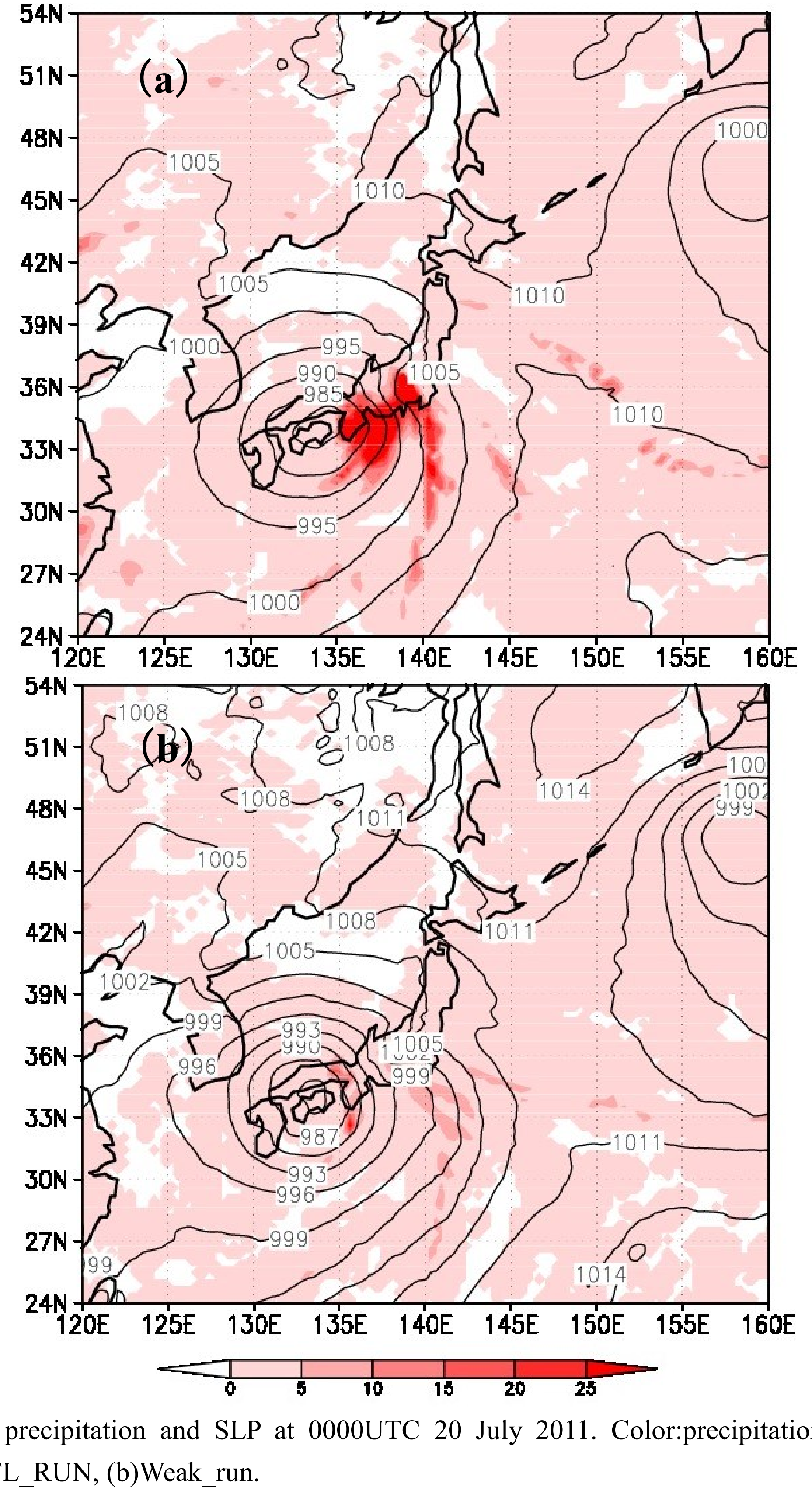

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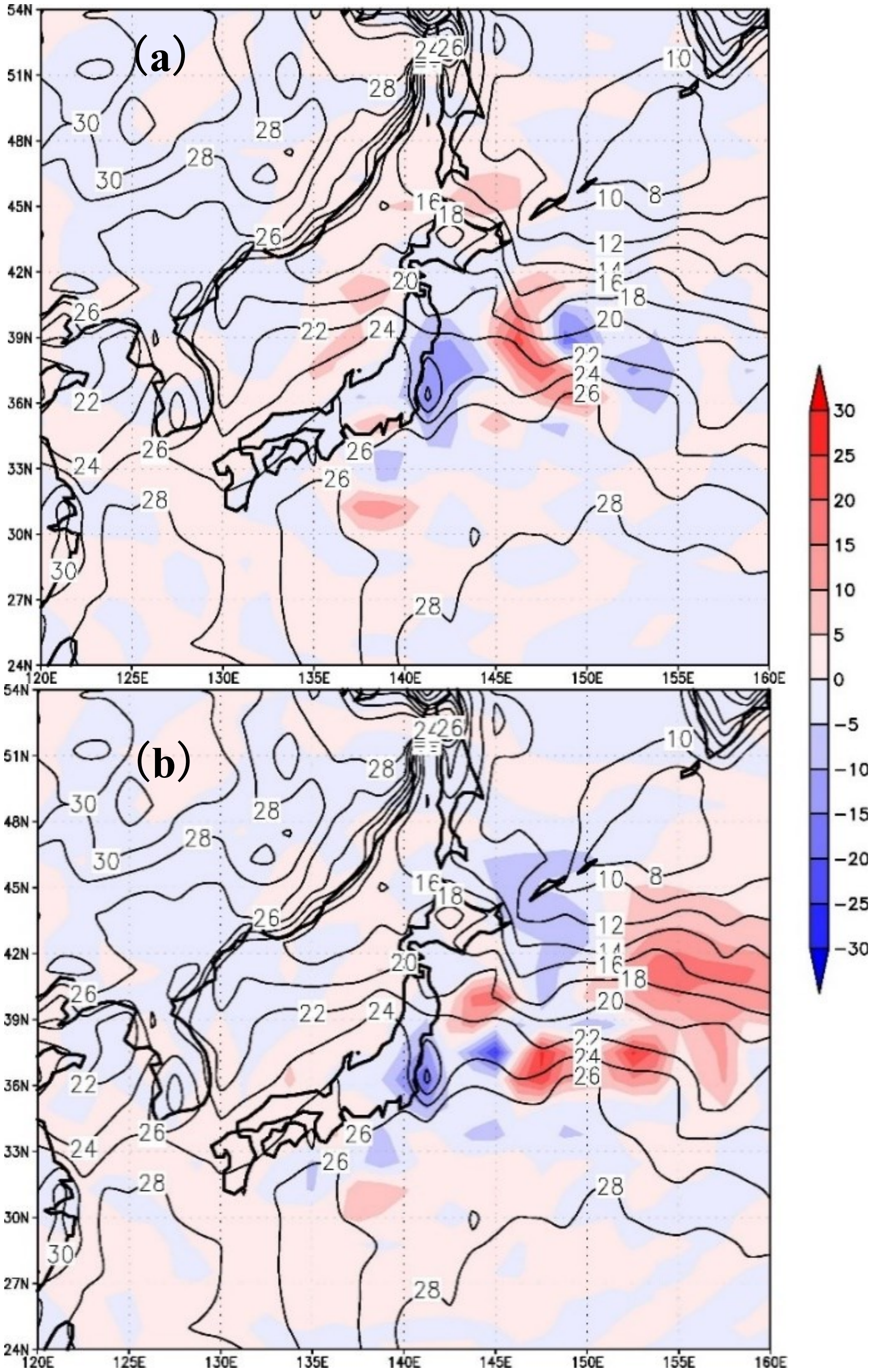

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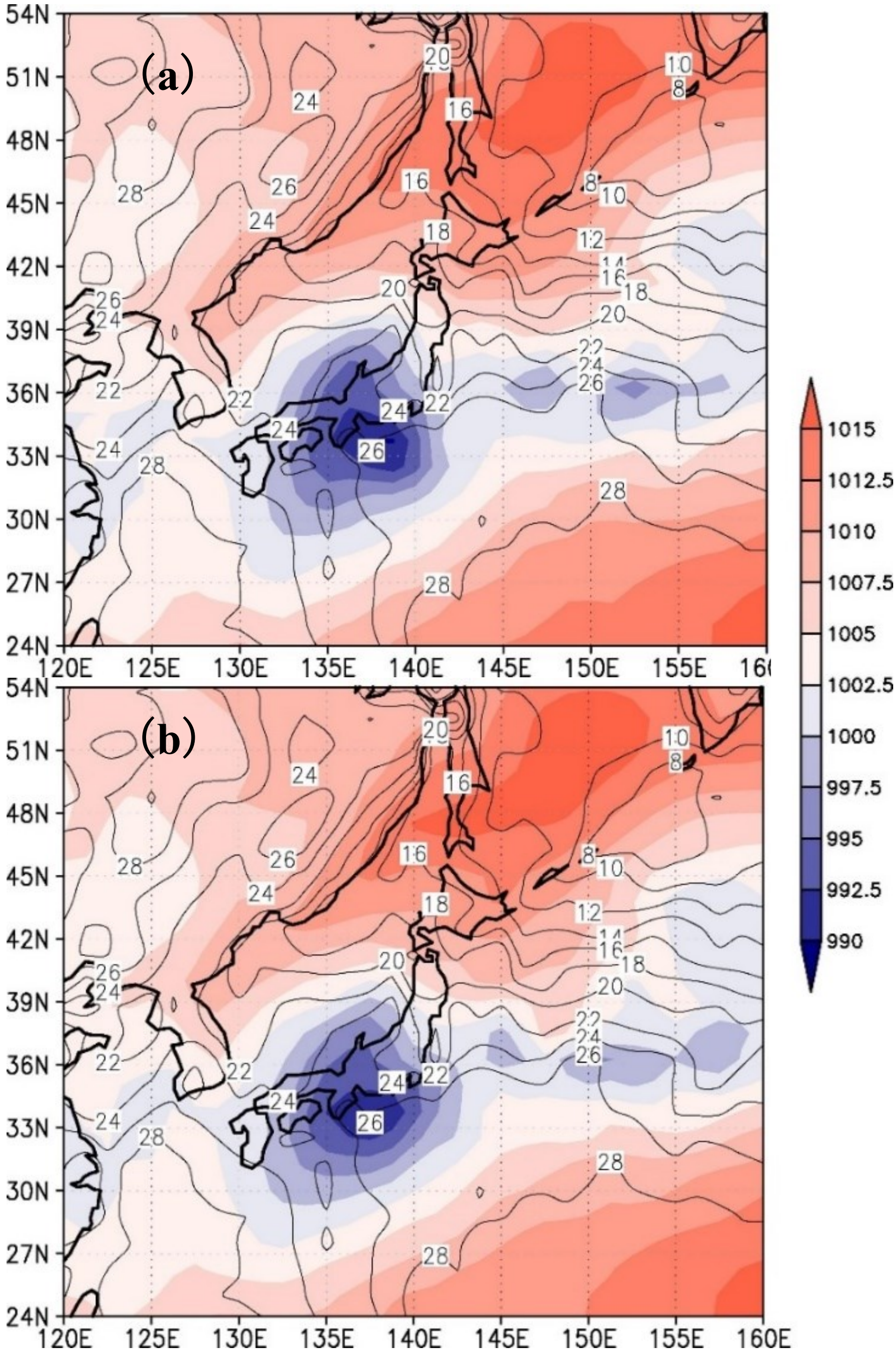

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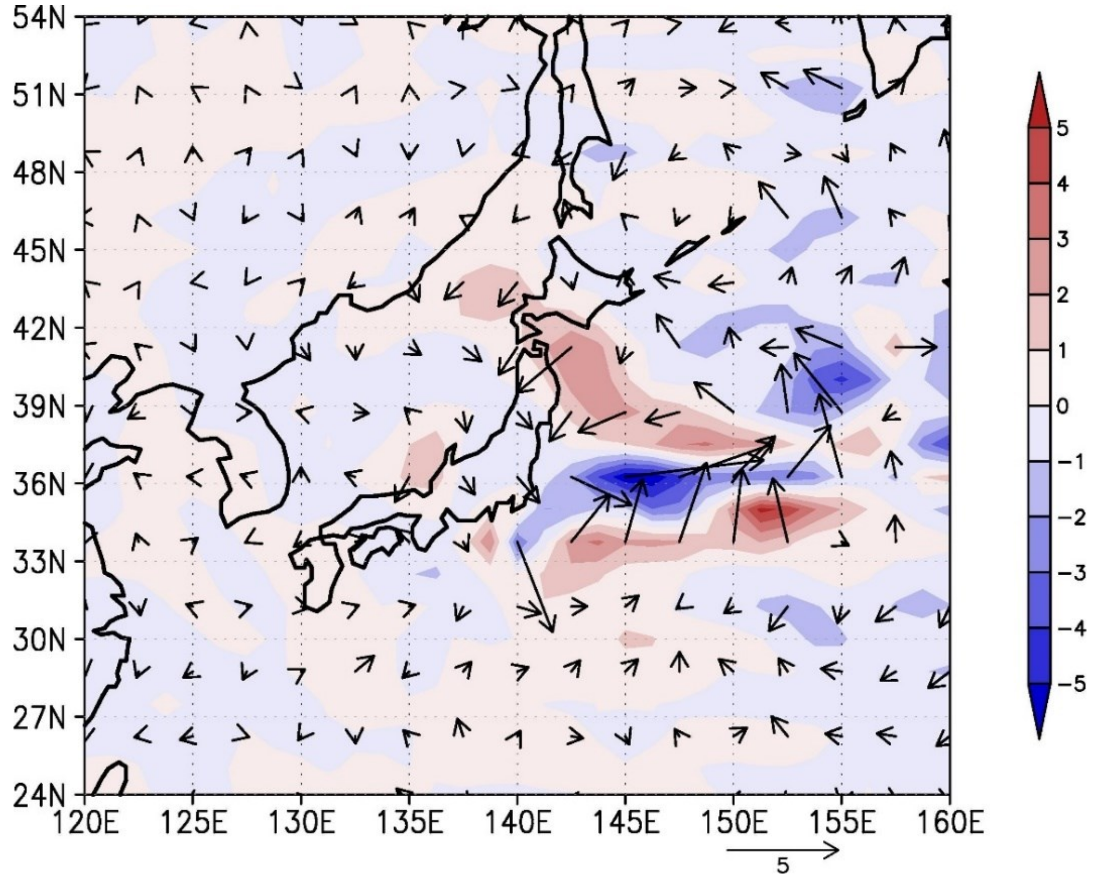

Figure 9. The difference between the OSE and the REF of the average wind direction wind speed and absolute wind speed at 925 hPa to 600 hPa at 1800 UTC 20 July 2011.

Table 1 Using parameters of regional meteorological model

	CTL_Run,Weak_Run
Domain	2
Horizontal Resolution	30km,6km
Vertical Layers	50Layers
Nesting	1way
The initial and lateral boundary conditions	ERA-Interim OISST
Initial time	2011/07/18 00:00
Microphysics	WDM6
Cumulus Parameterization	Kain-Fritsch
Planetary Boundary Layer	MYNN2