A Study of Atmospheric Factor Affecting Tropical Cyclone Intensity Over the Mid-Latitude Region in East Asia Using the WRF Model: Focusing on the Jet Stream

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Gun-Woo Do[1], Hyeong-Seog Kim
Ocean Science and Technology School, Korea Maritime and Ocean University, Busan, South Korea

1. INTRODUCTION

Due to climate change, predicting the intensity of a Tropical Cyclone (TC) has become increasingly challenging. Marine factors like Sea Surface Temperature (SST) have been well-known so far as factors affecting the intensity of TC. However, there is still a tendency to prioritize SST for TC intensity forecasts. With the changing characteristics of TC due to climate change, there is an increasing need to consider not only SST but also other factors in a comprehensive manner for accurate TC intensity forecasts. Among the various factors that can affect TC intensity, we particularly focused on the upper-level jet stream. Generally, it is known that when the upper jet stream strengthens, the vertical wind shear increases, leading to a weakening of TC intensity. However, we can expect other results considering the secondary circulation structure of the upper jet stream. In this study, we use the WRF model to gradually strengthen the upper jet stream. And we look at how TC intensity changes. This study underscores the importance of considering not only sea surface temperatures but also other factors more extensively in assessing changes in TC intensity over mid-latitude(30°N~).

2. DATA AND METHOD

For the simulation, we use WRFV4.1.2, with TC Chaba from 2016 as our case study. Chaba caused significant damage in East Asia, including Korea and Japan. Its track closely interacted with the jet stream over 30°N, making it suitable for this study. TC best track data was sourced from the RSMC Tokyo-Typhoon Center. GFS data served as input for WRF. The model's options are detailed in Table 1. We examined the changes in TC mean wind speed and center pressure after strengthen wind speed on the jet stream core (35° N–50° N, 130° E–160° E) by 20%, 30%, and 50%.

3. RESULTS

In all experiments, simulation results showed that the TC track closely resembled the best track data (Fig. 1), indicating the successful execution of the simulations. When mean wind speed and pressure within 3 degrees of the TC center, it showed that strengthening the jet stream led to an increase in average wind speed from October 3rd to 5th. After the 5th, however, a stronger jet stream resulted in a rapid decrease in mean wind speed (Fig. 2(a)). Conversely, for central pressure, while it decreased from October 3rd to 5th as the jet stream intensified, it led to a rapid increase with stronger jet stream conditions (Fig. 2(b)). The box-whisker plots (Fig. 3) of the hourly moisture flux convergences (MFC) at the 850 hPa and 700 hPa averaged 3 degrees around the TC center for 3–5 October at 00UTC. You can see that MFC increases in x1.3, x1.5 compared to x1.0, x1.2 both. Table 2 that Correlation coefficients (r) and p-values between TC central pressure and the 850-hPa & 700-hPa MFC for each experiment. The red colors denote statistical significance at the 95% confidence level. It showed an increased correlation between MFC and jet stream strength as it intensifies at x1.3 and x1.5.

4. CONCLUSION

Following Fig. 2, the intensity of TC increases rapidly as it approaches the jet stream. After that, the intensity drops sharply. According to Fig. 3 and Table 2, MFC increased at 850 hPa and 700 hPa during TC intensification by jet forcing. And increasing of MFC has a significant correlation with TC intensification. The upper jet stream can increase approaching TC intensity by controlling around environmental factors (e.g., MFC) at the lower level. However, it can weaken the intensity of TC as strong as the upper jet stream after increasing. It has been conventionally understood that as upper-level jet streams intensify, they strengthen vertical wind shear, thereby weakening TC intensity. However, this study provides a more detailed understanding of this process. When TC approaches the jet stream over the mid-latitude, their intensity doesn't consistently decrease. Instead, we observed that as the jet stream strengthens, the TC intensity temporarily increases before sharply declining. Such unexpected temporary intensification could lead to unforeseen damages in the vicinity. Our study suggests that we need to consider other factors, not just sea surface temperatures in predicting TC intensity in mid-latitude regions. However, it's important to note that this study only examines one case. Further research with more case studies is necessary to validate this study.

[1]*Corresponding author address: Gun-Woo Do, OST, KMOU, South Korea; e-mail: rjsdn613@g.kmou.ac.kr*

WRF-ARW 4.1.2V			
Integration time	2016.10.01_00:00:00 ~ 2016.10.06_00:00:00		
Resolution of Domain 1	50km		
Resolution of Domain 2	10km		
Nested Option	Two-way Nesting		
SST input Option	SST constant		
FDDA option	Analysis Nudging	Surface	X
		Spectral Nudging	O
Micro Physics	WRF Single–moment 6–class Scheme		
PBL Physics	Yonsei University(YSU) Scheme		
Cumulus Physics	Multi–scale Kain–Fritsch Scheme		
Radiation	RRTMG Shortwave and Longwave Schemes		
Land Surface	Unified Noah Land Surface Model		
Surface Layer	Revised MM5 Scheme		

Table 1. Set up for WRF. Oct 1 ~ Oct 2 is a spin-up period for this study.

	x1.0		**x1.2**		**x1.3**		**x1.5**	
	r	p-value	r	p-value	r	p-value	r	p-value
850hPa	0.09	0.77	-0.2	0.42	-0.5	0.05	**-0.78**	<0.01
700hPa	-0.29	0.26	-0.09	0.77	**-0.68**	<0.01	**-0.81**	<0.01

Table 2. Correlation TC mean center pressure within 3 degrees with mean moisture flux convergence within 3 degrees in 850 hPa and 700 hPa. Confidence level is 95%. Red text means significant results.

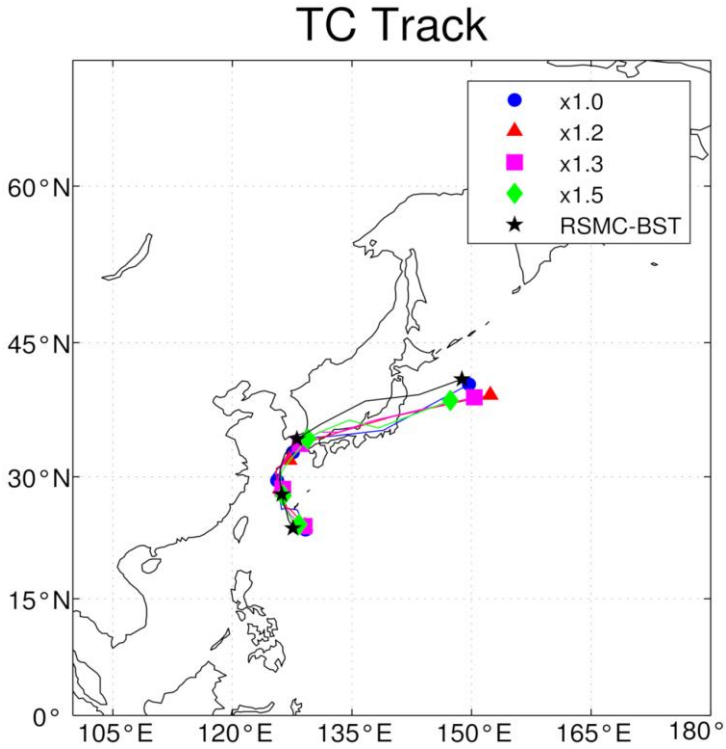

Figure 1. TC track using WRF simulation. x1.0 is a Control experiment. x1.2, x1.3, and x.15 represent experiments that jet streams are enhanced by 20%, 30%, and 50%. The four markers represent October 3rd to October 6th, excluding the spin-up period.

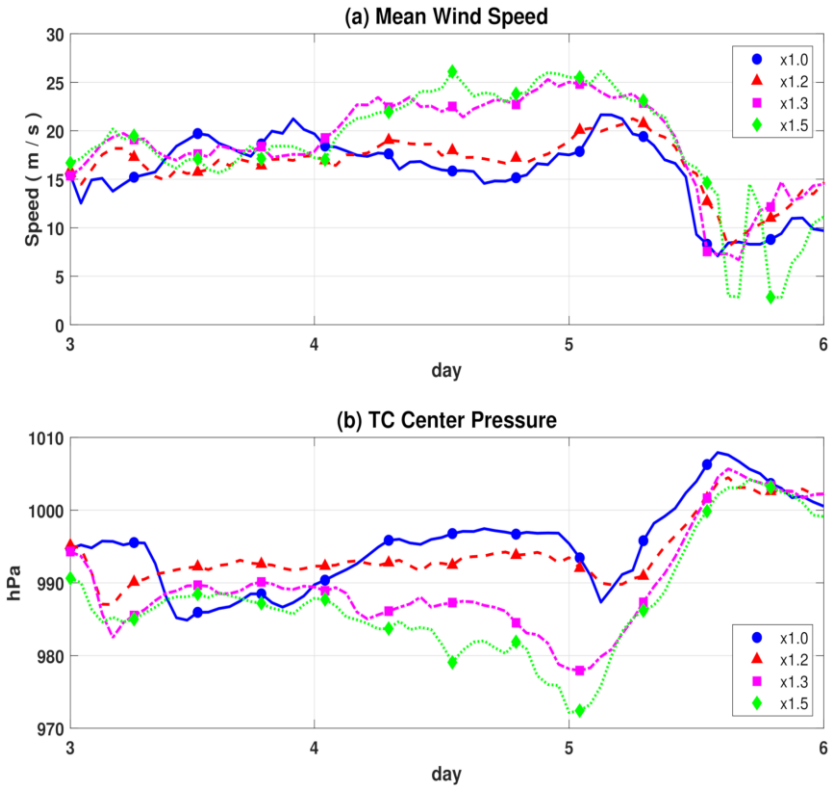

Figure 2. (a) is the Mean wind speed calculated within 3 degrees of TC center. Legend is the same as Fig. 1. (b) is the same as (a) but pressure.

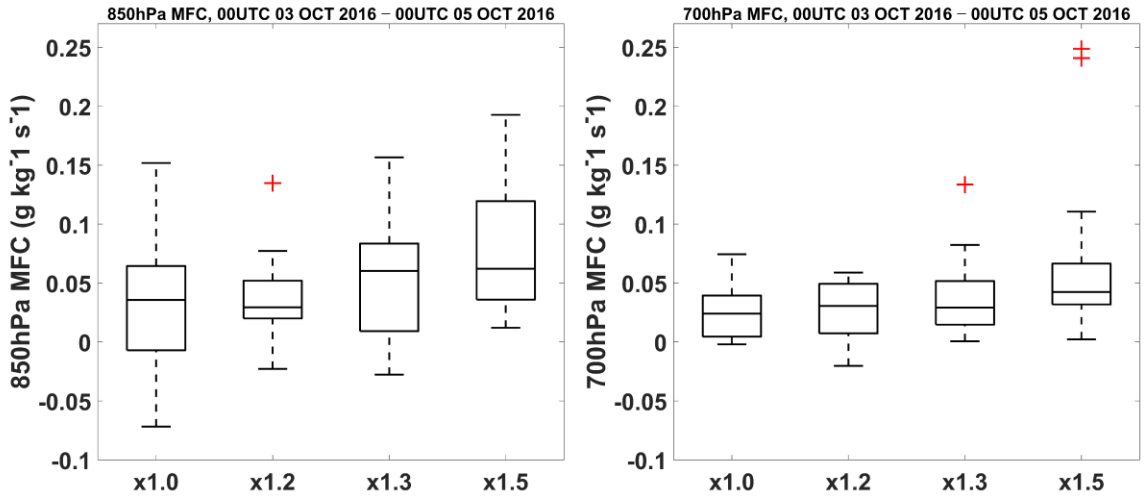

Figure 3. The box-whisker plots of the hourly moisture flux convergences (MFC) at the 850 hPa and 700 hPa averaged 3 degrees around the TC center for 3–5 October at 00UTC. Red Cross is an outlier.