

The Wind Features associated with the Multiple Eyewall in Typhoon Bolaven

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1. Introduction

Typhoon ‘Bolaven’ passed the Okinawa Main Island at about 1200 UTC 26 August 2012, while moving northwestward. The surface observation data at Nago of Okinawa show that the rainfall intensity and surface wind speed in the typhoon’s central regions were smaller and weaker than those of the JMA’s operational forecast. Okinawa Meteorological Observatory held an unprecedented press conference before the approach of typhoon ‘Bolaven’ to take the greatest precautions for the local governments and inhabitants. However, severe damages did not actually occur. The radar images of Japan Meteorological Agency (JMA) show that the multiple eyewall structures of ‘Bolaven’ were clearly maintained for more than at least 24 hours without eyewall replacements. It is deduced that the structures of multiple eyewall affected the wind velocity and precipitation in the typhoon’s central region. In this study, the multiple eyewall structures and wind features were reproduced by the cloud-resolving ensemble simulation to investigate the relation between them.

2. Experimental settings and Multi-Eye Index

A cloud resolving ensemble simulation with a horizontal resolution of 1 km, horizontal grids of 800×800 , 60 vertical layers and 11 members was performed up to the forecast time (FT) of 24 hours from the initial time at 1800 UTC 25 August using the JMA nonhydrostatic model. The initial and boundary conditions for the cloud resolving ensemble simulation were taken from a mesoscale ensemble simulation with a horizontal resolution of 5 km. Although the triple eyewall structure was not reproduced, the typhoons with a double eyewall structure or with a single eyewall and spiral rainbands were reproduced in all members. To evaluate the degree of multiple eyewall structure objectively, the Multi-Eye Index (MEI), which indicates concentric uniformity of multiple eyewalls, was defined by formula (1):

$$\text{MEI} = \frac{1}{M} \sqrt{\frac{1}{N} \sum_{i=1}^N (Tw_i - M)^2} \quad \left(M = \frac{1}{N} \sum_{i=1}^N Tw_i \right), \quad (1)$$

where Tw are the total water substances (cloud water, rain, cloud ice, snow, graupel) within the ring area. N and M are the number of grid points in the ring area and the average of Tw , respectively. The outer edge radius of the ring area corresponds to that of the outer eyewall if the typhoon has the double eyewall structure. It shows a point of the maximum tangential wind velocity on the surface. In this study, the bottom and top heights and the width of the ring area from the outer edge radius were set to be 0.5 km, 4.0 km and 2.0 km, respectively. Because MEI is sensitive to the precision of the typhoon’s central position, the geometric central position estimated by the Braun’s method (Braun 2002) was used as the typhoon center.

3. Experimental results and analyses

Table 1 indicates the MEIs of each member at FT=04. When MEI is 0.8 or less, it is considered that double eyewall structure was produced. In concrete terms, the typhoon of P05 had a double

eyewall structure while a spiral rainband extended from a single eyewall in M01. P05 and M01 had the lowest and highest MEI values, corresponding to the highest and lowest degrees of multiple eyewall structures, respectively.

Next, the relations between the degree of multiple eyewall structure MEI and the wind velocities are confirmed by using all ensemble members. Specifically, the correlations between MEI and the average of top 5% maximum wind of wind velocity, tangential wind velocity and radial wind velocity within 60 km radius from the typhoon center were statistically analyzed by changing the altitude at FT=04. FT=04 was selected for analysis because the multiple eyewall structures were well reproduced in a number of ensemble members at FT=04. Below the altitude of 1 km, correlations between MEI and wind velocity (tangential and inward wind velocities) were larger than 0.5 (not shown). The positive strongest correlations were shown with wind velocity and tangential wind velocity at the altitude of 0.8 km (Fig. 1). The correlations between MEI and wind velocity (tangential and inward wind velocities) below the altitude of 1 km were significantly indicated by the test of correlation coefficient ($\alpha = 5\%$). These results suggest that the strong winds near the surface in the central region tend to be suppressed statistically as the degrees of multiple eyewall structure are larger.

Table 1: Multiple-Eye Index (MEI) of each member at FT=04.

Member	Radius of local maximum tangential velocity (km)	MEI
P05	133.0	0.58
P01	120.0	0.64
CNTL	140.0	0.69
P03	148.0	0.76
M05	134.0	0.79
M03	139.0	0.83
M02	114.0	0.89
P04	135.0	0.91
M04	124.0	0.96
P02	140.0	1.08
M01	132.0	1.17

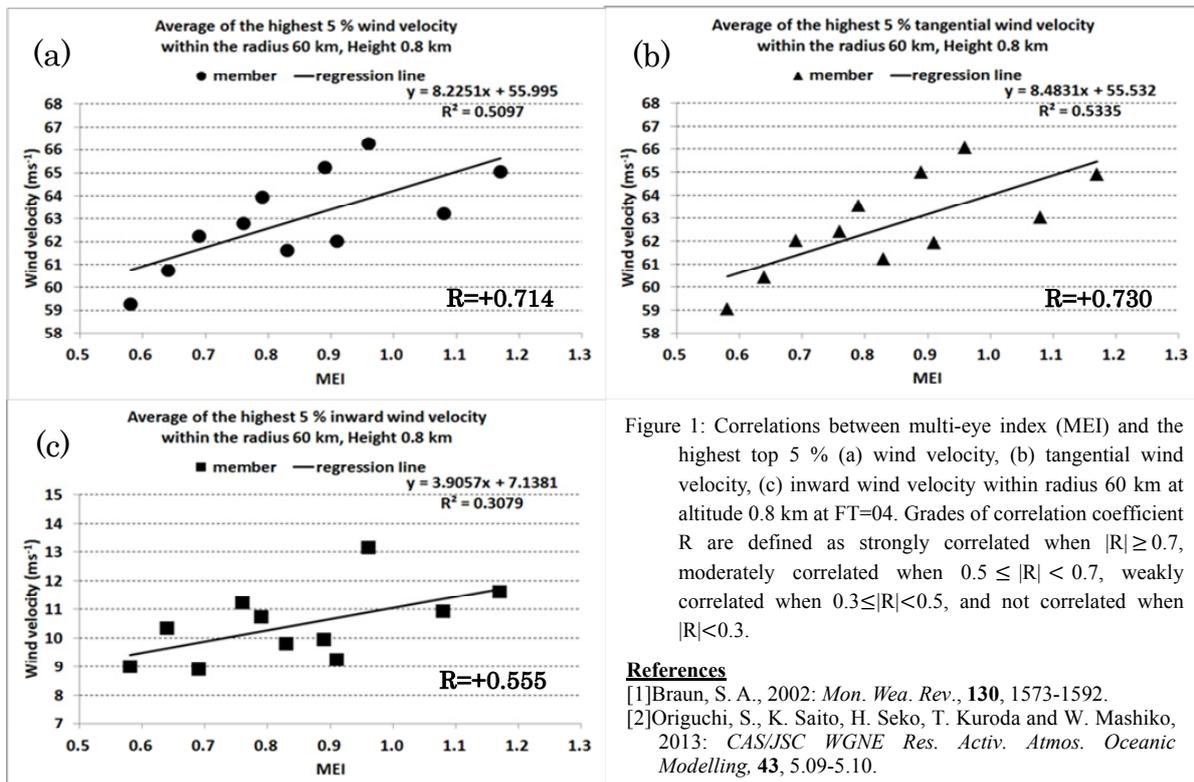
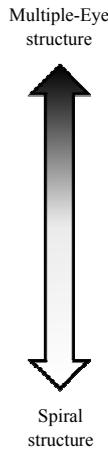


Figure 1: Correlations between multi-eye index (MEI) and the highest top 5 % (a) wind velocity, (b) tangential wind velocity, (c) inward wind velocity within radius 60 km at altitude 0.8 km at FT=04. Grades of correlation coefficient R are defined as strongly correlated when $|R| \geq 0.7$, moderately correlated when $0.5 \leq |R| < 0.7$, weakly correlated when $0.3 \leq |R| < 0.5$, and not correlated when $|R| < 0.3$.

References

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