TRIPLE EYEWALL EXPERIMENT OF THE 2012 TYPHOON “BOLAVEN” USING CLOUD RESOLVING ENSEMBLE FORECAST

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1. Introduction

Typhoon “BOLAVEN” passed the Okinawa island about 1200 UTC 26th August 2012, while moving northwestward. Compared with the original forecast of JMA, observed surface pressure at the Nago station in the Okinawa island was high, and precipitation and wind speed were weak. The Radar Information Sharing System (RISS) of JMA showed that the typhoon had a clear structure of triple eyewall from 1800 UTC 25th to 0600 UTC 26th. We infer that this multiple eyewall structure might weaken the surface winds and suppressed precipitation insides the eyewalls. In the radar observation, the eyewall replacement wasn’t analyzed. On the other hand, JMA’s operational mesoscale model (MSM) didn’t reproduce the triple eyewall structure of the typhoon. Here, we performed a reproduction experiment with the cloud resolving ensemble forecast to see predictability of the triple eyewall.

2. Methods of experiment

At first, with the initial time at 1200 UTC 25th August, a mesoscale ensemble forecast with a horizontal resolution of 5 km and 11 members was performed up to the forecast time (FT) of 36 hrs using the JMA nonhydrostatic model (JMANHM). Next, its down-scaling (cloud resolving ensemble) forecast with a horizontal resolution of 1 km and 11 members was performed up to FT=24. Control run of the 5km ensemble forecast was conducted using the JMA 4DVAR (JNoVA) mesoscale analysis as the initial condition and the JMA global model (GSM) forecast as the boundary condition. The JMA one-week global ensemble forecast was used as the initial and boundary perturbations. The initial and boundary conditions of the 1 km ensemble forecast is given by the 5km ensemble forecast result with the initial time lag of 6 hrs. Cloud microphysics with the 2-moment 3-ice bulk method and Kain-Fritsch convective parameterization scheme were employed in the 5 km ensemble forecast, while the Kain-Fritsch scheme was switched-off in the 1 km ensemble forecast. A boundary layer model (MYNN3) was used in the 5 km ensemble forecast, while the Deardorff’s (1980) TKE scheme was employed in the 1 km ensemble forecast.

3. Reproducible criteria of multiple eyes

Since there are no objective (numerical) evaluation methods about criteria of multiple eyes, we introduce the following criteria:

●Distributions of updrafts or total water substances (Qc+Qr+Qi+Qs+Qg) in the lower troposphere (1 km to 5 km AGL) are ring-shaped structure and continue at least 6 hrs (Even if a part of ring changes spiral or it cuts off for the short time, we ignore it if the ring-shaped structure of updrafts or total water substances keeps overall).

4. Results of experiment and analysis

This section discusses the results of the 1 km ensemble forecast for the period from FT=01 to FT=06. To decide the typhoon’s geometric central position precisely, we adopt the Braun’s (2002) method, and then we measured the ring shape of multiple eyes for all forecast time. Figure 1 shows results of central position that estimated by the Braun’s method and surface minimum pressure of the model (CNTL and the member M05 only). Though the maximum difference of surface minimum pressures among the ensemble members was about 10hPa, differences between the central pressures decided by the Braun's method and surface minimum pressures for each member were less than 1 hPa (Figure not shown). Next, to analyze the triple eyewall structure, spatial averages of physical elements were calculated on the rings with radius of every 1 km (from 1 km to 600 km) and width 1 km, and temporal averages of physical elements were calculated in 6 hrs between FT=01 and FT=06 (Figure 2). Figure 3(a)(b), (c)(d) and (e)(f) show tangential velocities ([**vt**]st), updrafts ([**w**]st) and liquid water substances ([**Qc+Qr**]st) for CNTL and the member M05 respectively. Radii of the local maximum surface velocity appeared at places about 50 km and 120 km for both CNTL and the member M05, consistent with the observation. However, the inner most eyewall that located on the radius of 10 km wasn't clear in the model (Strong and weak wind shears are shown by black solid lines and broken lines, respectively). Updrafts of middle eyewall were stronger than those of other eyewalls, and the middle eyewall had abundant water substances below 6 km AGL. The regions of strong tangential velocity existed at the outer edges of the eyewalls. Though the outer eyewall wasn't clear compared with the middle eyewall, it had a similar structure. Downdrafts existed between the eyewalls. Although updrafts and liquid water substances in the lower layer appeared at the place of radius 10km, the formation of the inner most eyewall was insufficient in this simulation.

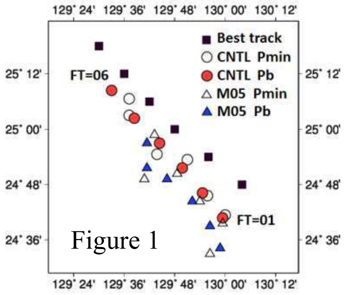
Figure 1

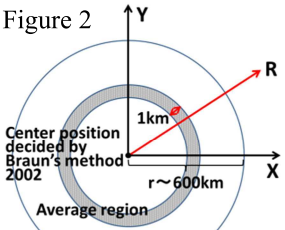
Figure 2

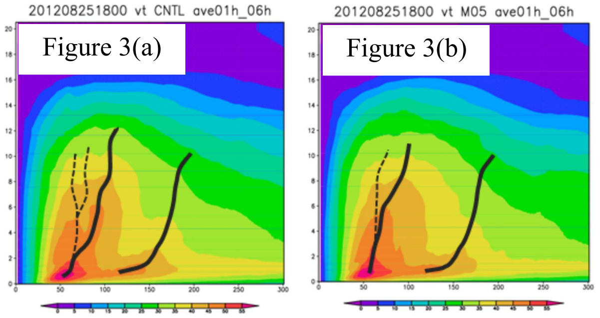
Figure 3(a)
Figure 3(b)

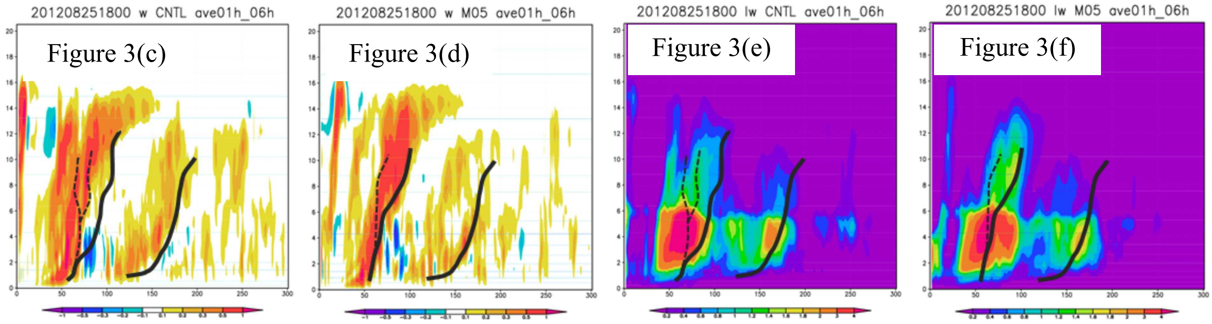
Figure 3(c)
Figure 3(d)
Figure 3(e)
Figure 3(f)

Figure 1: The estimated typhoon's central position by Braun's (2002) method and surface minimum pressure of CNTL and M05.

Figure 2: Calculation method of the averaged physical elements to analyzing the triple eyewall (Spatial average in the shaded region).

Figure 3: The averaged physical elements in 1km ensemble forecast. (a) and (b) show tangential velocities ([**vt**]st) of CNTL and M05 respectively. (c) and (d) show updrafts ([**w**]st) of CNTL and M05 respectively. (e) and (f) show liquid water substances ([**Qc+Qr**]st) of CNTL and M05 respectively.

Reference: Braun, S. A., 2002: A Cloud-Resolving Simulation of Hurricane Bob (1991): Storm Structure and Eyewall Buoyancy. *Mon. Wea. Rev.*, **130**, 1573-1592.

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