

## Numerical Experiments for Concentric Eyewalls of Typhoon Bolaven (2012)

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Eyewall is a ring of convective clouds that encircles the eye of a tropical cyclone (TC) such as typhoon and hurricane. TC occasionally has some eyewalls which are called as concentric eyewalls. Striking concentric eyewalls of some hurricanes are studied by airborne radar observations and numerical simulations. These previous studies indicate that eyewall replacement often occurs once concentric eyewalls are formed. The eyewall replacement is a process that the inner eyewall gradually decays and the outer eyewall moves into the position of the inner (old) eyewall. In addition, the wind speed of TC rapidly varies during the replacement. It is important for prediction of TC's intensity to understand the process of the eyewall replacement. However, typhoon Bolaven, which passed in main Okinawa island in 2012, had stationary concentric eyewalls for very long time. And the replacement of Bolaven's concentric eyewalls did not occur. It is clear from observation by Doppler radars of Japan Meteorological Agency (JMA). It shows that the eyewall replacement does not always occur even if concentric eyewalls are formed. As seen above, the process of the eyewall replacement are not fully known.

In this study, we investigate that Bolaven's concentric eyewalls structure and their maintaining reason, using the Cloud Resolving Storm Simulator (CReSS) which is a three-dimensional, nonhydrostatic model. According to some previous studies for concentric eyewalls of hurricanes, concentric eyewalls has horizontal scale of about 10 km. In order to simulate the concentric eyewalls of Bolaven, it suggests that we conduct numerical experiment with horizontal resolution of about 1 km. First, we perform the experiment with 5 km horizontal resolution whose initial and boundary conditions are given by the initial data of the Global Spectral Model (GSM; 0.5 degree horizontal resolution) provided by JMA. Second, we perform the experiment with 2.5 km horizontal resolution based on the output data of 5 km horizontal resolution. Finally, we perform the experiment with 1 km horizontal resolution based on the output data of 2.5 km horizontal resolution.

We could simulate the striking concentric eyewalls which were located within about 100 km radius from Bolaven's center with 1 km horizontal resolution. Simulated concentric eyewalls are stationary for over one day. It substantially exceeds the time required for the eyewall replacement. And, the simulated concentric eyewalls have the moat regions, which is very dry and weakly descending. These results almost agree with some observations.

The inner eyewall of a TC gradually decays when supply of vapor into the inner eyewall due to low level inflow from outside of TC is constrained by existence of moat region. This structure is characteristic when replacement of eyewall occurs in TC. Despite of these features, the inner eyewall of Bolaven is stationary. Thus, it suggests that vapor supplied from the periphery of the inner eyewall region is enough to maintain the inner eyewall, even if the moat regions suppress supply of vapor by inflow from outside of Bolaven.

Keywords: tropical cyclone, concentric eyewall, vortex dynamics, numerical modeling, nonhydrostatic cloud resolving model