High-Resolution Simulation Experiments of Typhoons Using the Cloud-Resolving Model on the Earth Simulator

Kazuhisa Tsuboki
Hydrospheric Atmospheric Research Center (HyARC), Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464-8601, JAPAN
e-mail: tsuboki@rain.hyarc.nagoya-u.ac.jp

1 Introduction

Typhoons develop by close interaction between the large-scale disturbance and the embedded intense cumulonimbus clouds. The horizontal scale of a typhoon ranges from several 100 km to a few 1000 km while that of the cumulonimbus clouds is an order of 10 km. A typhoon often brings a heavy rain and an intense wind. The heavy rain is usually localized in the eye wall and spiral rainbands which develop within the typhoon. Since cumulonimbus clouds are essentially important for typhoon development, a cloud resolving model is necessary for a detailed numerical simulation.

Some typhoons usually attack Japan and its surroundings and causes, severe disaster. In particular, ten typhoons landed over the main lands of Japan in 2004. In the present paper, we show two simulation experiments of typhoons. One is the typhoon T0418 which brought a very intense wind and caused huge disaster due to the strong wind. The other is the typhoon T0423 which brought a heavy rainfall and caused severe floods.

In this research, we have utilized the Cloud Resolving Storm Simulator (CReSS) which is a cloud resolving numerical model developed for parallel computers such as the Earth Simulator. The characteristics of CReSS and evaluation of the performance of CReSS on the Earth Simulator are summarized by Tsuboki (2004)[1]. Detailed description of CReSS is found in Tsuboki and Sakakibara (2001)[2] or Tsuboki and Sakakibara (2002)[3].

2 Typhoon SONGDA (T0418)

Typhoon T0418 moved northwestward over the northwest Pacific Ocean and passed Okinawa Island on 5 September 2004. Its center passed Nago City around 0930 UTC, 5 September with the minimum sea level presser of 924.4 hPa. When T0418 pass over Okinawa Island, double eye walls were observed. This is a distinctive feature of the typhoon. T0418 was characterized by strong winds and caused a large amount of disaster due to the strong winds over Japan.

The main objectives of the simulation experiment of T0418 are to study the eye wall as well as spiral rainbands, and to examine structure of the strong wind associated with the typhoon around Okinawa Island. The simulation experiments of T0418 started from 0000 UTC, 5 September 2004. The experimental designs of T0418 are summarized in Table 1.

The simulation experiment shows very detailed structure of the eye and the spiral rainbands (Fig.1). Individual cumulus clouds are resolved. They are simulated within the eye and along the spiral rainband. The high resolution experiment provides detailed data of the cloud and precipitation systems associated with the typhoon. A weak precipitation forms around the central part of the eye. The maximum tangential velocity is located along the eye wall and at a height of 1 km. It is larger than 70 m s^{-1}.

Table 1: **Experimental design of Typhoon T0418.**

domain	x 1536 km, y 1280 km, z 18 km
grid number	x 1539, y 1283, z 63
grid size	H 1000m, V 150 $\sim$300m
integration time	18 hrs
ES node numbers	128 nodes (1024 CPUs)

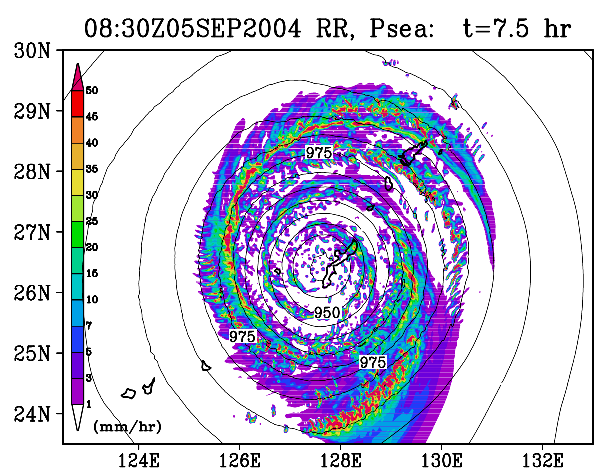

Figure 1: **Surface pressure (contour lines; hPa) and rainfall intensity (color levels; mm hr^{-1}) of the simulated Typhoon T0418 at 0830 UTC, 5 September 2004.**

3 Typhoon TOKAGE (T0423)

Typhoon T0423 moved along the Okinawa-Amami Islands on 19 October 2004 and landed over Shikoku Island on 20 October. In contrast to T0418, T0423 is characterized by heavy rainfall over Japan. Heavy rainfalls associated with T0423 occurred in the eastern part of Kyushu, Shikoku, the east coast of the Kii Peninsula and Japan Sea side of the Kinki District. They caused severe floods and disasters in these region.

The purpose of the simulation experiment of T0423 is to study process of the heavy rainfall. Experimental design of T0423 is summarized in Table 2. At the initial time of 1200 UTC, 19 October 2004, T0423 was located to the SSW of Amami Island.

Table 2: **Experimental design of Typhoon T0423.**

domain	x 1536 km, y 1408 km, z 18 km
grid number	x 1539, y 1411, z 63
grid size	H 1000m, V 200 $\sim$300m
integration time	30 hrs
ES node numbers	128 nodes (1024 CPUs)

The movement of T0423 and the rainfall were successfully simulated. In the simulation, a northward moisture flux is large in the east side of the typhoon center. When the large moisture flux reaches to the Japan Islands, heavy rainfalls occur along the Pacific Ocean side. The heavy rainfall moves with the movement of the typhoon from Kyushu to Shikoku. When the typhoon reaches to the south of Shikoku, heavy rainfall begins in the Kinki District and intensifies at 0630 UTC, 20 October (Fig.2). The distribution well corresponds to the radar observation.

The close view of Northern Kinki shows that a large amount of precipitation are accumulated around a height of 6 km and intense convective clouds are embedded within the precipitation region (Fig.3). The heavy rainfall along the Pacific Ocean sides moved eastward, while that in the Kinki District lasted until 12 UTC, 20 October. After the typhoon moved to the east of the Kinki District, the northeasterly intensified significantly. Consequently, orographic rainfall forms in the norther part of the Kinki District. As a result, the accumulated rainfall was large and the severe flood occurred.

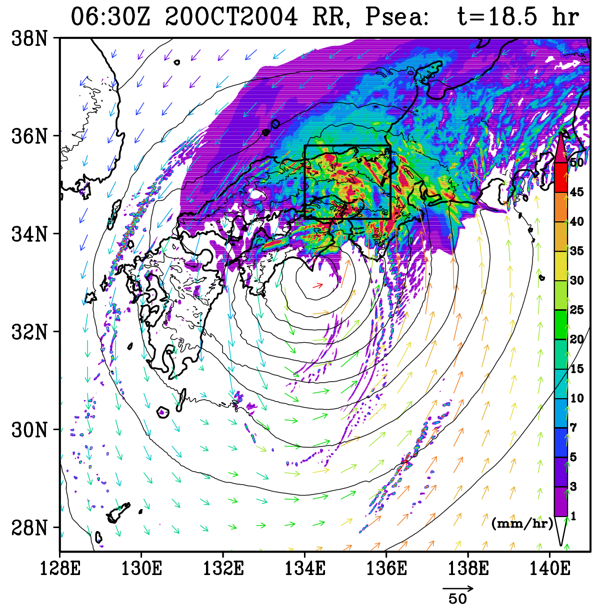

Figure 2: **Same as Fig.1 but for the Typhoon T0423 at 0630 UTC, 20 September 2004. Arrows are horizontal wind velocity at a height of 974 m and warmer colored arrows means moister air. The rectangle indicates the region of Fig.3.**

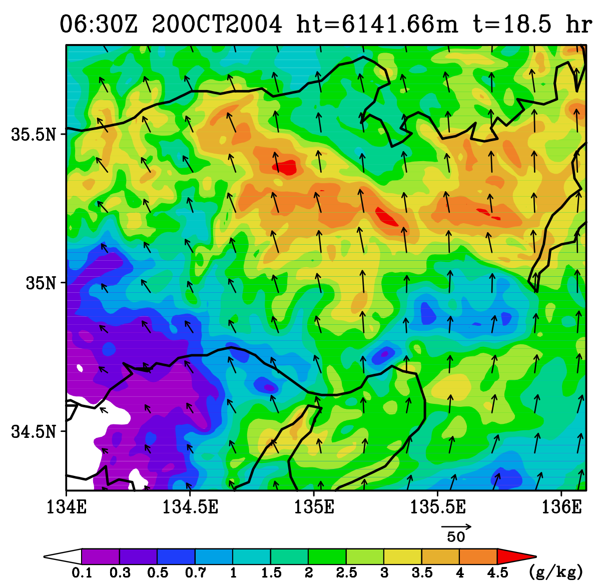

Figure 3: **Mixing ratio of precipitation (color levels; g kg^{-1}) and horizontal velocity (arrows) at a height of 6142 m at 0630 UTC, 20 September 2004.**

References

1) Tsuboki, K., High resolution modeling of multi-scale cloud and precipitation systems using a cloud-resolving model. **Annual report of the Earth Simulator Center, April 2003–March 2004**, 21–26, 2004.

2) Tsuboki, K. and A. Sakakibara, CReSS User's Guide 2nd Edition, 2001.

3) Tsuboki, K. and A. Sakakibara, Large-scale parallel computing of Cloud Resolving Storm Simulator. *High Performance Computing, Springer*, H. P. Zima et al. Eds, 243–259, 2002.