Proceedings of the15 thCongress of Asia and Pacific Division of International Association for Hydraulic Research (IAHR'06),
Indian Institute of Technology, Madras, India. Aug. 7-10, 2006. pp. 1-8.

Mesoscale meteorological systems due to boulder flow disaster over South Kyushu Japan on 20 July 2003

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Abstract

A severe rainfall more than 200 mm per 3 hours in the dawn of 20 July 2003 brought the severe boulder disaster over the Minamata city and Hishikari town located in the southwest of Kyushu Island Japan, which claimed 22 people's lives.This study is aims to investigate the characteristics of the mesoscale meteorological systems bringing such sediment disasters, using various kinds of meteorological datasets. Two independent precipitation systems hit the South Kyushu: one is the mesoscale cloud cluster rapidly evolved to the south of the Gotou Islands on the East China Sea, and another is the orographical rainband evolved on the leeward of the Koshikijima Islands. The horizontal SST gradient and the momentum convergence of the lowlevel atmosphere plays an important role in the evolution of the each system.

1. INTRODUCTION

A severe rainfall more than 200 mm per 3 hours in the dawn of 20 July 2003 brought the severe boulder disaster over the Minamata city and Hishikari town located in the southwest of Kyushu Island Japan (see Figs. 2-3), which claimed 22 people's lives. Fig 1 shows the disaster by boulder flow of the Hougawachi section in the Minamata city where were lost 16 people's lives. The number of death was exceeded that of the storm surge by T9918 (BART) in Kumamoto Prefecture.

The purpose of this study is to investigate the characteristics of the mesoscale meteorological systems bringing such sediment disasters, using various kinds of meteorological datasets.

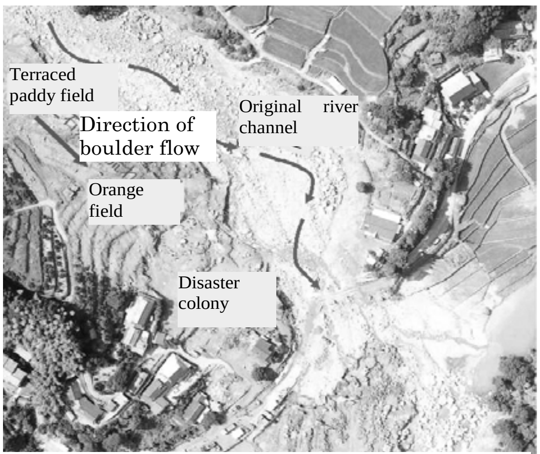

Fig. 1 Boulder flow disaster of the Hougawachi-Atsumari section in Minamata city (provided by Asia Air Survey Co. Ltd.)

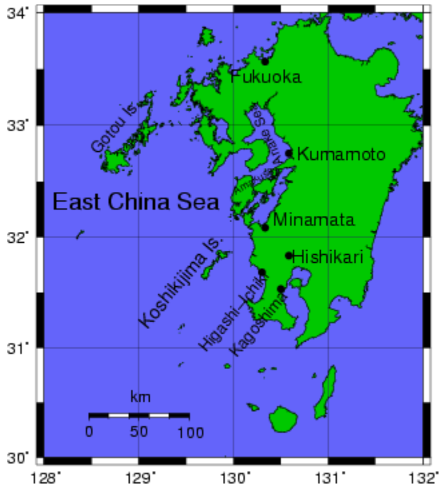

Fig. 2 Location of Minamata City in Kyushu Island

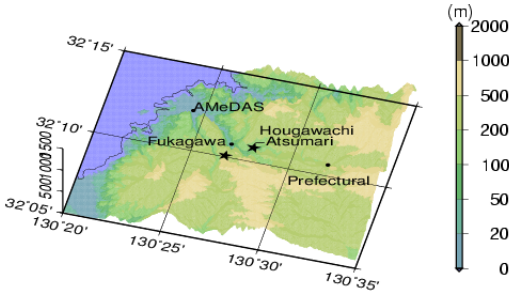

Fig.3 Map of the rainfall observation station in the Minamata City. The star-shaped symbol shows the damaged area.

2. DATASETS

Ground based observation data of precipitation were used to investigate the local characteristics of rainfall. More than 140 sites are located with the mean horizontal interval less than 7 km. Radar echo data and meteorological satellite data (GOES-9 IR image) were also used to investigate the horizontal characteristics. On the vertical or three dimensional structure and base state, the radiosonde observation data and wind profiler (Kato et al., 2003), observed by JMA, data was used.

The 5-day mean sea surface temperature (SST) was provided by the the New Generation Sea Surface Temperature (NGSST) Development Group (Leader: Hiroshi Kawamura, Tohoku Univ., Japan). Wind profiler and rawinsonde data were used to analyze the atmospheric vertical structure. For three-dimensional structure of the mesoscale system, the reanalysis data (MAMAL) were used. All of data were provided by Japan Meteorological Agency and Kumamoto Prefecture also provided the ground based observation data.

3. SATELLITE DATA

3.1. INFRARED IMAGE OF GEOSTATIONARY METEOROLOGICAL SATELLITE

Fig. 4 shows the GOES-9 Infrared image over the East Asia at 1800 UTC on 19 Jul 2003. Mesoscale Cloud Cluster (MCC) was evolved around the 30º N over the East China Sea (120º-130ºE), in which the Equivalent Blackbody Temperature (TBB) lower than 250 K. Fig. 5 shows the GOES-9 IR image over the west Kyushu area. A mesoscale disturbance began to evolve at 1400 UTC on 19 Jul 2003 and rapidly evolved within several hours to the south of the Gotou Islands (129ºE, 32º N). This cloud system began to move eastward and hit the south of the Kyushu Island.

3.2. SEA SURFACE TEMPERATURE

The New Generation Sea Surface Temperature (NGSST) data is the reanalysis dataset mainly obtained from the satellites such as ADEOS-II, TRMM etc. Satellite SST observations from infrared radiometers (AVHRR, MODIS) and a microwave radiometer (AMSR-E) are objectively merged to generate the SST product, which is quality-controlled, cloud-free, high-spatial resolution (0.05 degree-grided), wide-covering, and daily SST digital map. (Sakaida et al., 1998, Tanahashi et al., 2000). The analyzed area of new SST (13º-63ºN, 116º-166ºE) covers the whole areas of the Okhotk Sea, Bohai/Yellow Sea and East China Sea as well as the western North Pacific Ocean.

To compute the SST anomaly, the 5 days climatology sea surface temperature (SST) data using the V4, V4.1, and interim V4.1 NOAA/NASA AVHRR Oceans Pathfinder data (Armstrong et al., 2001: Casey et al., 1999). The climatologies were created by spatially and temporally gaussian interpolating the highest quality SST data to pentad periods on a 9.28 km grid.

Fig. 6 shows the sea surface temperature distribution obtained from NGSST and its anomaly from the 5 days climatology. The gradient of the SST in the meridional direction can be seen. In the south of the East China Sea (lat. < 29°N), the SST was higher than 28 degC, while the SST was lower than 24 degC around the 33ºN. According to the distribution of the SST anomaly, the low temperature anomaly was extended from the north of the East China Sea to the coastal area of the south China. However, the high temperature anomaly existed around Okinawa and Taiwan. Such SST contrast zone corresponds the evolution area of MCC (or meiyu front) very well.

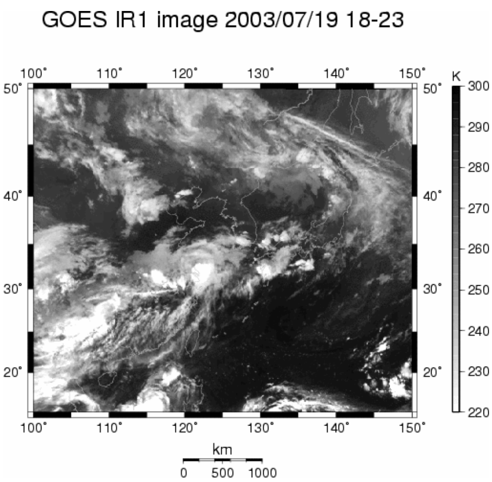

Fig. 4 : Black Body Temperature distribution of the GOES-9 IR-1 channel over the East Asia. (1823 UTC, 19 Jul. 2003)

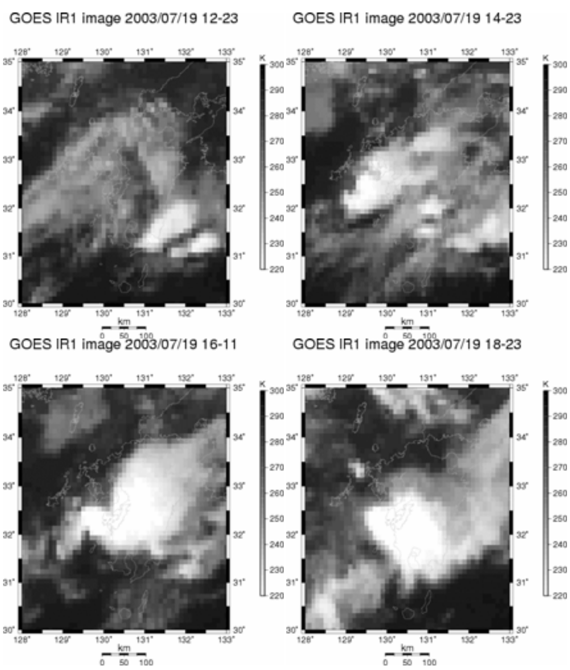

Fig. 5: Similar as Fig. 2, except over the west of the Kyushu Iskand, Japan.

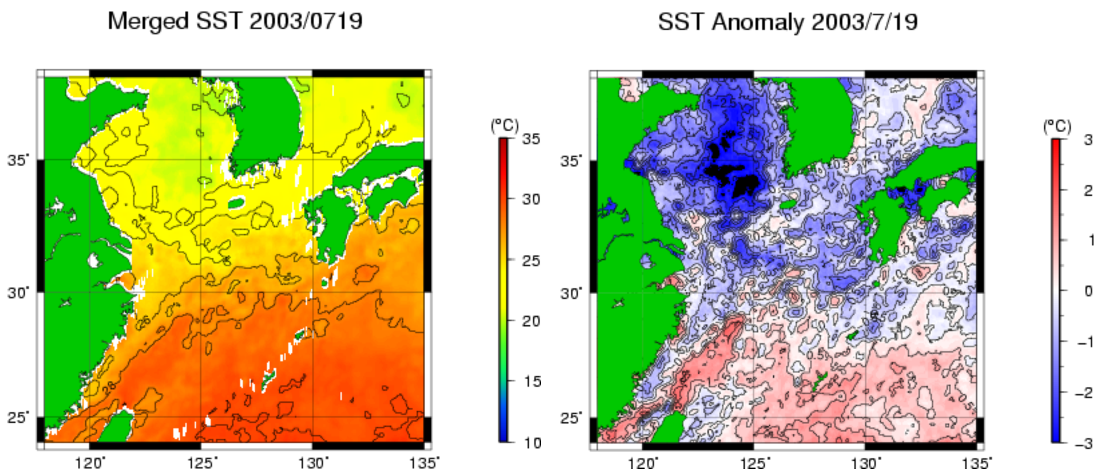

Fig. 6 Sea surface temperature (SST) provided by NGSST(Left) and its anomaly (right).

4. GROUND BASED OBSERVATION

4.1. PRECIPITATION OF THE GROUND LEVEL

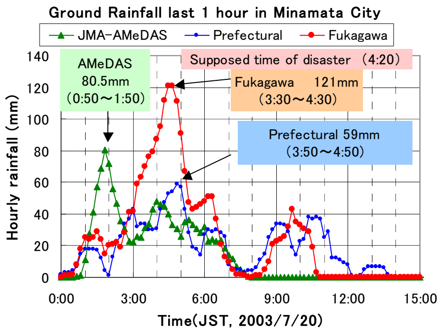

Fig. 7. Rainfall past 1 hour observed at three sites in Minamata city

Fig. 7 shows the rainfall past 1 hour observed at three sites in Minamata. AMeDAS is the meteorological station of Japan Meteorological Agency in the coastal area. Fukagawa and Prefectural station located in the valley as shown in the map of Fig. 3. All of these stations observed heavy rainfall with the rate higher than 20 mm hr^{-1} continuously during the predawn on 20 July 2003 (JST). In the coastal area, the maximum 1 hr rainfall was 80.5 mm from 0050 to 0150 JST. At Fukagawa, the nearest station of the boulder flow disaster (Fig.1), a severe squall over 100 mm hr^{-1} was observed from 0330 to 0430 JST, corresponding to the supposed time of the boulder flow disaster (Joint research group of the severe squall disaster in Kyushu, 2003). The accumulated rainfall became higher than 300 mm between 0000 and 0800 JST. Note that the AMeDAS and Prefectural station is located within 10 km distance from Fukagawa station.

4.2. RADAR OBSERVATION

Fig. 8 shows the snapshot of the rainfall rate observed by the JMA-Radar. A squall line (A) was seen to the south of the Gotou Islands, corresponding to the south east end of the mesoscale disturbance seen in the GOES IR1 image Fig. 5. Such kind of squall line occasionally evolved in the south of the meiyu front and brought the severe sqall in the west Kyushu in the last phase of Bai-u (e.g., Ogura et al., 1985).

A couple of line-shaped rainband was also seen in the region of the 32ºN, 130º-131ºE. According to the zoomed image of the southeast Kyushu in Fig. 9, one of them was extended from the Koshikijima

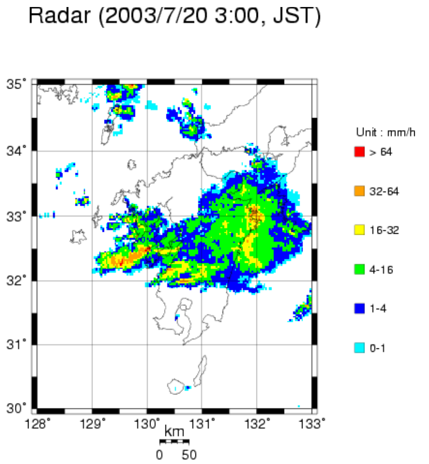

Fig. 8 Snapshot of the Radar echo intensity at 1800 UTC on 19 Jul 2003 around the Kyushu Island.

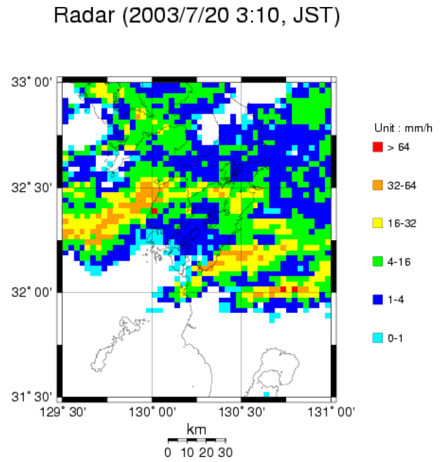

Fig. 9 Similar as Fig. 7 but over the south east Kyushu Island

Islands. Fig. 10 shows the number of times with the precipitation rate higher than 30 mm hr^{-1} from 2100 JST 19 Jul and 0900 JST 20 Jul. The area with the count larger than 15 times corresponded the rainband snapshot in Fig. 10 well. These two rainbands evolved with the orographical effect of the Koshikijima Islands and the Mt. Benzaiten. Since there are a lot of lone mountains and Islands in the west Kyushu coastal area, the orographical rainband system (ORBS) often occurred under the condition of the south or southeast wind in the lowlevel atmosphere and the lifting condensation level as high as the top of the mountains (e.g., Yoshizaki et al., 2000).

The ORBS usually brings with the rate several tens of mm hr^{-1}, however, it is hard to bring a severe squall with the rate over 100 mm hr^{-1} only by itself (Morita, 2003). The meso-β scale disturbance (A) stimulated the convection of ORBS (B) in moving eastward to join together.

5. VERTICAL AND THREE DIMENSIONAL STRUCTURE

5.1 SONDE OBSERVATION AND WIND PROFILER

Fig. 11 shows the vertical profile of wind observed at Kumamoto and Higashi-Ichiki (see. Fig. 2). The vector shows the horizontal wind and the contour shows the vertical wind, respectively. In the rainy condition, the electromagnetic wave from the profiler might be scattered by the rain drop and the vertical

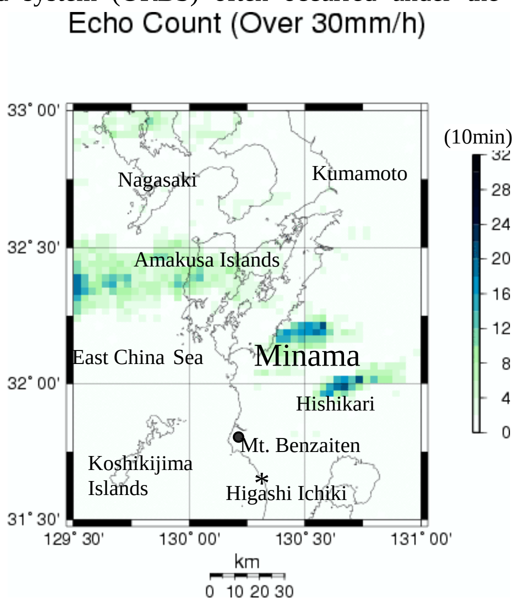

Fig. 10 Count distribution of rader echo higher than 30 mm h^{-1} obtained from Radar-GPV (JMA)

wind component might be equivalent to the drop rate.

In Higashi-Ichiki station, the south of the ORBS, the strong south wind began to flow at 1200 UTC (2100 JST), and updraft observed during the night after the rainfall (1500-2400 UTC). A strong wind shear was constructed between 3 km and 5 km above sea level. The direction of lowlevel atmosphere (around 220-260 deg.) corresponds well as the Koshikijima ORBS shown in Fig. 9.

Fig. 12 shows the vertical profile of temperature (T) and dew point temperature (T_d) observed by radiosonde at Fukuoka and Kagoshima meteorological bureau. Dry air parcel in the middle troposphere (~500 hPa) was observed both at Fukuoka (1200 UTC 19 Jul) and at Kagoshima (0000 UTC 20 Jul), in which the T-T_d was as large as 20 degC. The Convective Available Potential Energy (CAPE) at Kagoshima became higher than 2100 m^2 s^{-2}, which is large enough to the production of the severe squall line (e.g., Bluestein et al. 1985).

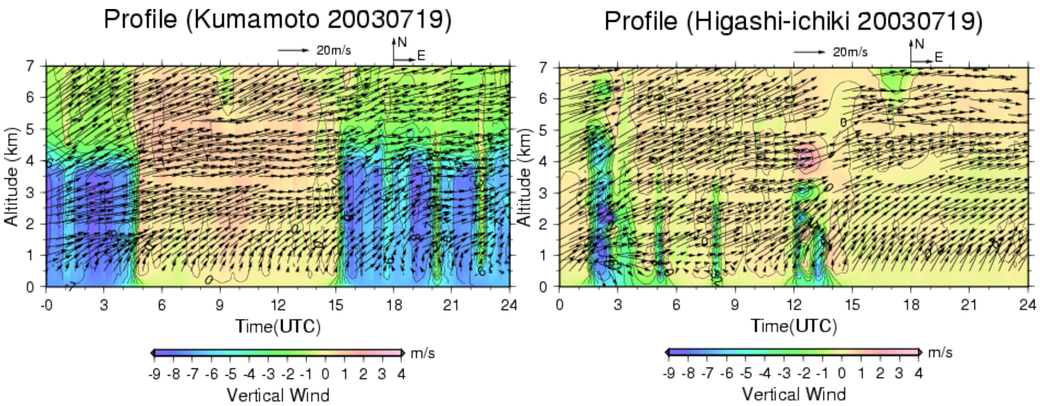

Fig. 11 Vertical profile of wind obtained by WINDAS (JMA) at Kumamoto (left) and Higashi-Ichiki (right)

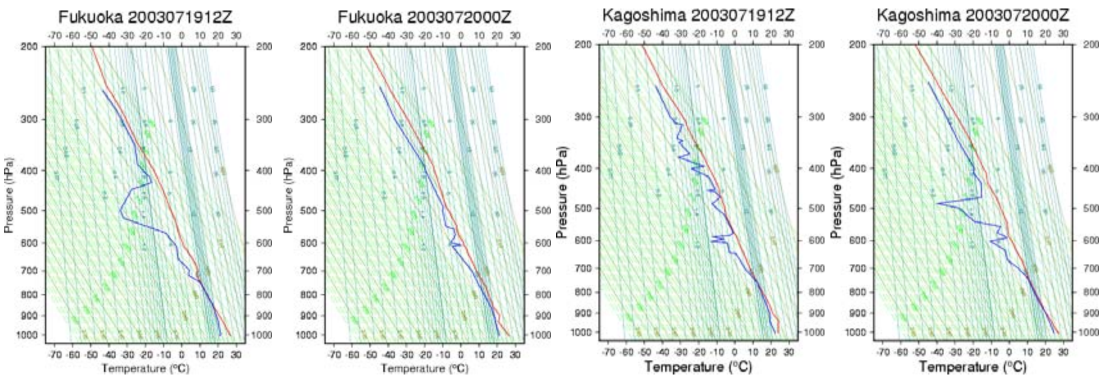

Fig. 12 Vertical profile of the atmospheric temperature and the dew point temperature from the sonde observation at Fukuoka and Kagoshima meteorological bureau

5.2 JMA REANALYSIS

Three dimensional structure of the mesoscale system was investigated using the reanalysis data provided by JMA. Fig. 13 shows the snapshot of the atmospheric structure at 1800 UTC 20 Jul 2003. The white isosurface shows the wet air particle with the relative humidity higher than 90%. The streamline on the 925 hPa isobaric surface is also shown in the same figure.

According to the streamline in this figure, a horizontal convergence zone in the lowlevel atmosphere with moist air can be seen over the south Kyushu coastal area. High pressure anomalies was existed on the 500 hPa isobaric surface to the west of Kyushu Island, one of which the moist air parcel was penetrated to the top of troposphere. Over the mid-troposphere, the dry air was covered around the meso b system and wedged moist airs between the lowlevel and the top of troposphere.

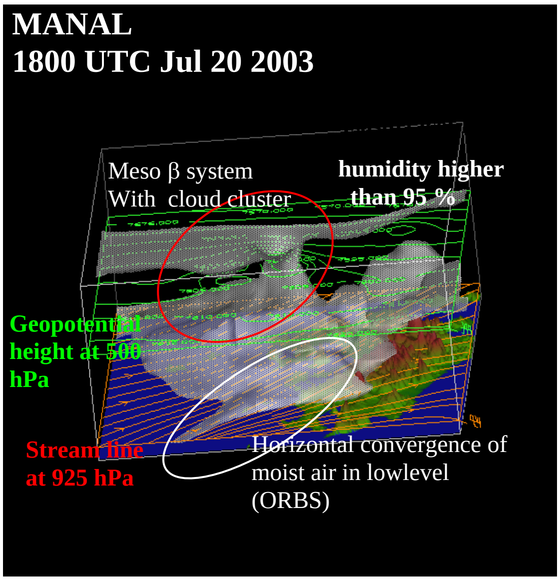

Fig. 13 Three-dimensional atmospheric structure of the mesoscale meteorological systems obtained from reanalysis data (MANAL, JMA)

6. DISCUSSION

A schematic image of the precipitation systems in the present case is shown as Fig. 14. The front was evolved on the sharp gradient zone of the SST as shown in Fig. 6. The evaporation from the sea surface was more active to the south of the front with warm sea surface area than that to the north of the front with the cold sea surface area. The entry of the dry air in the mid-troposphere intenced the convective instability of the atmosphere, and hence the b scale disturbance with the severe squall line was evolved.

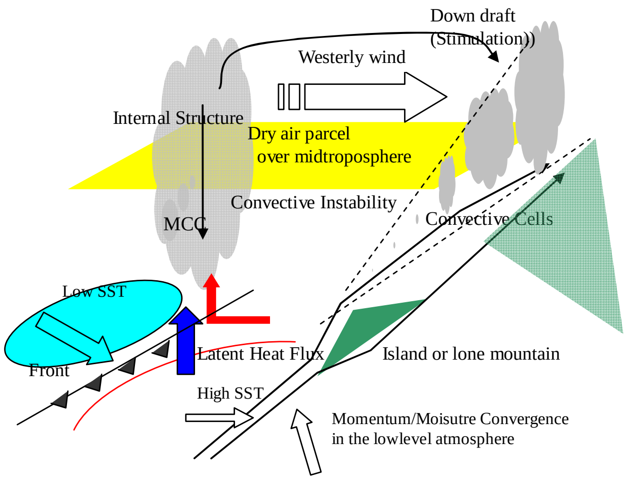

Fig. 14 Schematic of the precipitation system in the present case

The ORBS was occurred independently of the b scale disturbance. The momentum and the moisture was converged horizontally in the lowlevel troposphere (surface ~ 900 hPa) to the southwest of the Koshikijima Islands. The moist air parcel was forced to be lifted orographically over the Koshikijima Islands and Mt. Benzaiten and the convective cells were evolved leeward.

On the top of the β scale disturbance, the covected air was diverged horizontally and the downdraft in the surrounding region. The convective cells in the ORBS were stimulated locally during the movement eastward of the β-scale system.

7. CONCLUSION

Two independent precipitation systems hit the South Kyushu: one is the mesoscale cloud cluster rapidly evolved to the south of the Gotou Islands on the East China Sea, and another is the orographical rainband evolved on the leeward of the Koshikijima Islands. The horizontal SST gradient and the momentum convergence of the lowlevel atmosphere plays an important role in the evolution of the each system.

8. ACKNOWLEDEGMENT

The authors would like to acknowledge to the Kumamoto and Kagoshima Prefectural Office for providing the rainfall dataset. The authors would like to thank Prof. Osamu Morita of Kyushu University, and Hirohiko Ishikawa of Kyoto University. The NGSST data was provided by the the New Generation Sea Surface Temperature (NGSST) Development Group (Leader: Hiroshi Kawamura, Tohoku Univ., Japan). The present study was supported by Kumamoto Natural Disaster Research Association.

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