Visually and Easily Detectable Radar Information available for Judging the Evacuation from Heavy Rainfall Disasters

Izumi Yokota

Izumi Yokota[1], Koji Nishiyama[1], Kenichi Tsukahara[1], Kenji Wakimizu[2]

[1]*Fuculty of Engineering, Kyushu University, 744, Motooka, Nishi-ku, Fukuoka, 8190395, Japan*
[2] *Fuculty of Agriculture, Kyushu University, 6-10-1, Hakozaki, Higashi-ku, Fukuoka, 8128581, Japan*
(Dated: 25 April 2014)

1 Introduction

During the rainy season in Japan, many heavy rainfall events occur frequently along the stationary front called as 'BAIU', which maintains its strength and becomes stationary over the Japan Islands due to the dynamical balance between Pacific high pressure system and northern high pressure system. The supply of abundant warm and humid air continuously intruding into the BAIU front strongly enhances atmospheric instability over the Japan islands. This causes the repetition of the generation and subsequent dissipation of strong atmospheric instability, as pointed out by Ninomiya (2000). The BAIU front is basically characterized by steep gradients of water vapor in lower layers in Japan, as shown by Akiyama (1973).

In Japan, when the possibility of heavy rainfall occurrence is forecast, a local government has an authority to issue the information of evacuation advisory (recommendation and compulsory instruction) for local residents, based on real-time information (river stage, soil moisture, rainfall amount, and actual disastrous situation) as well as weather forecasting in a pre-determined specific region. However, the delay of the timing for issuing evacuation information is one of serious problems in Japan due to the shortage of well-educated staffs in a local government, and the difficulty of complicated mechanisms causing serious heavy rainfall and subsequent disasters. On the other hand, there are significant features relating to heavy rainfall such as 'band-like Back-Building (BB) systems' shown by Bluestein and Jain (1985). In Japan, The BB system frequently occurs in warm season under the influence of stationary front and the movement of typhoon, and can be clearly recognized from weather radar. The BB system seen in Japan are reported by Kato (1993), Kato and Goda (2001), Yamasaki (2008), etc.

In this study, for making suitable decision about the evacuation from a heavy rainfall event and associated disasters, it is investigated how much the BB system can be visually and easily recognized by local government staffs and local residents using JMA (Japan Meteorological Agency) radar networks (C-BAND).

2 Heavy rainfall case on July 12, 2012 in Kumamoto, Japan

Heavy rainfall and associated serious disasters occurred in Kumamoto prefecture (FIGURE 1) in Japan on July 12, 2012. The heavy rainfall event is characterized by slowly-moving quasi-stationary front, and the inflow of warm and humid moisture exceeding equivalent potential temperature > 345K into the front system, as shown in FIGURE 2. The weather situation is typical atmospheric environment suitable for causing heavy rainfall in Japan. Actually, the event brought daily rainfall of 493 mm/day at Aso Otohime on the day, as shown in FIGURE 3. 78% of the daily rainfall amount was recorded in the period (4 hours) between 0200-0600JST. The average hourly rainfall for 4 hours is 96 mm/h.

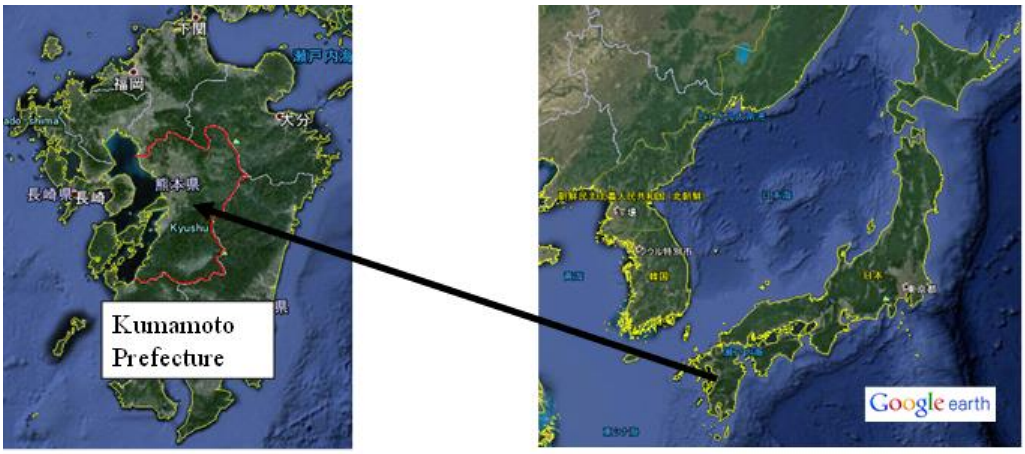

FIGURE 1: The location of Kumamoto Prefecture depicted by red line

 yokota.izumi.290@m.kyushu-u.ac.jp

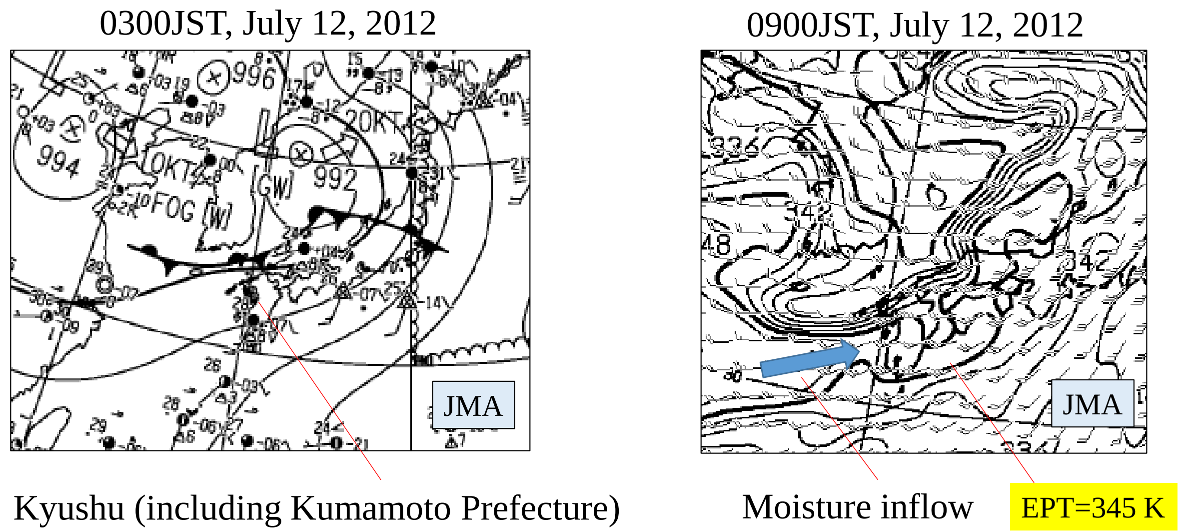

FIGURE 2: Left figure shows the distribution of atmospheric pressure on the sea surface level. Right figure shows the distribution of equivalent potential temperature on the 850 hPa level.

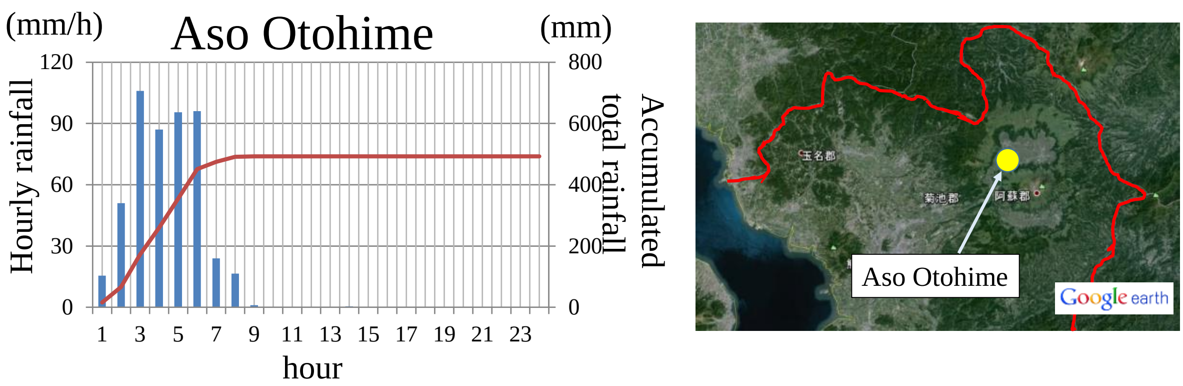

FIGURE 3: Observed rainfall amount at Aso Otohime located in the north of Kumamoto Prefecture

TABLE 1: The number of damages caused by heavy rainfall and associated disasters in Kumamoto prefecture on July 12, 2012.

Dead and missing persons	Inundation above floor level	Inundation below floor level	Destruction of houses and public facilities
25	1912	1748	385

The extremely heavy rainfall led to serious disasters in Aso city located in the northeast mountainous region of Kumamoto prefecture. The damages are summarized in TABLE 1, At least 22 persons died from landslides that occurred in Aso area, and floods caused serous damages to many houses and public buildings.

FIGURE 4 shows relationships of daily rainfall with maximum hourly rainfall and 3 hours rainfall observed on the same day in Kumamoto prefecture between 1979 and September, 2012. The relationships are derived using AMeDAS (Automated Meteorological Data Acquisition System), which has fine resolution of approximately 17 km and the time interval of 10 minutes. The result shows that the event (blue triangles) includes maximum records (288.5 mm/3h, 493 mm/day observed at Aso Otohime) among three hours rainfall and daily rainfall. The next section shows the behavior of radar echoes causing such extremely heavy rainfall.

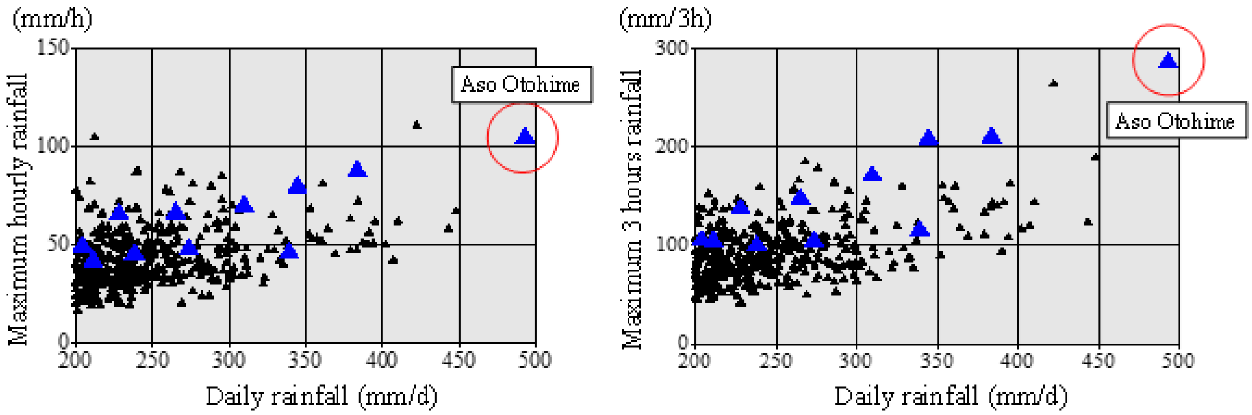

FIGURE 4: Relationships between daily rainfall and maximum hourly rainfall (left figure), 3 hours rainfall (right figure). These data show AMeDAS rainfall observed in Kumamoto Prefecture between 1979 and Sep, 2012. Blue triangles show observed rainfalls on July 12, 2012.

3 Behavior of long-lived radar echoes

In this section, the behavior of radar echoes causing extremely heavy rainfall is investigated using JMA C-band radar network with 1km mesh and 5 minutes interval. As shown by FIGURE 5, radar echoes were quasi-stationary more than 6 hours. Before 0200JST, Strong echoes were observed in the north of Aso area. Band-like Back-building system can be clearly recognized by a remarkable feature that strong echo cells formed repeatedly in the west of Kyushu and moved into the east under slow movement of the BB system into the South. After 0200JST, Aso area had been strongly affected by the BB system for 4~5 hours. In other words, the BB system continued to be stationary in the central Kyushu (especially, Kumamoto Prefecture) including Aso area.

This feature can be more clearly recognized by ‘analyzed rainfall’, which represents radar-and-rainguage analyzed rainfall product (accumulated rainfall within an hour: hourly rainfall) with 1km grid and 30 minutes interval, as shown in FIGURE 6. This rainfall product (made by JMA) can be obtained by optimum interpolation of radar-based grid rainfall using its surrounding actual rainfall data, which are measured with dense rainfall observation network. FIGURE 6 shows the BB system led to the appearance of stationary clear-cut band-like heavy rainfall distributions in the same region (central Kyushu) for long hours. Therefore, we can understand that Aso area had been strongly affected by the BB system.

4 Consideration on the timing of evacuation and weather warning issue

This section investigates whether the timing of evacuation advisory issued by a local government and weather warning for flood, heavy rainfall, landslide issued by JMA corresponding to quasi-stationary BB system. In FIGURES 5 and 6, the times of evacuation advisory and weather warning are given with time evolution of the BB system.

Heavy rainfall and flooding warning was issued by JMA for Kumamoto prefecture at 0030JST. At the time, Aso city was not included within heavy rainfall area, which was located in the north area of Kumamoto prefecture, as shown in FIGURE 5. The heavy rainfall area had already shown the BB type echoes by 0100JST. The appearance of the BB type echoes led to the band-like heavy rainfall distribution, as shown by FIGURE 6. This feature implies a cumulonimbus generated repeatedly in the same area and moved eastward on the same route due to slow movement or stationary situation of the frontal system. Therefore, it can be expected that the appearance of ‘dangerous’ BB type echoes could be visually recognized from these radar images. Moreover, accumulated rainfall (analyzed rainfall estimated as hourly rainfall) showed intense local accumulation of heavy rainfall which has strong potential to lead to the occurrence of serious disasters in a narrow region. Actually, the heavy rainfall induced by the BB system led to landslide warnings (0240, 0310, 0350JST) for Aso city issued by JMA until evacuation advisory issued by Aso city at 0400JST. The landslide warning is issued at the time when soil moisture exceeds predetermined limitation within the area of a local government.

In spite of the fact that several warnings were issued by JMA by 0400JST, Aso city was not issued until the time. The issue of evacuation for local residents was the same timing as the occurrence (0400JST) of landslide disaster in Aso city. Although it might took several time for the preparation of disaster treatment which Aso city must conduct, the timing of the evacuation advisory issue had been delayed, consequently. If there were staffs in local government who had an ability to recognize the signal of heavy rainfall from radar images, the evacuation advisory could be issued around 0200JST. Unfortunately, many local governments do not own well-educated staffs who had an ability to understand radar images. However, the BB type echoes can be easily recognized by ordinary persons as well as staffs of a local government.

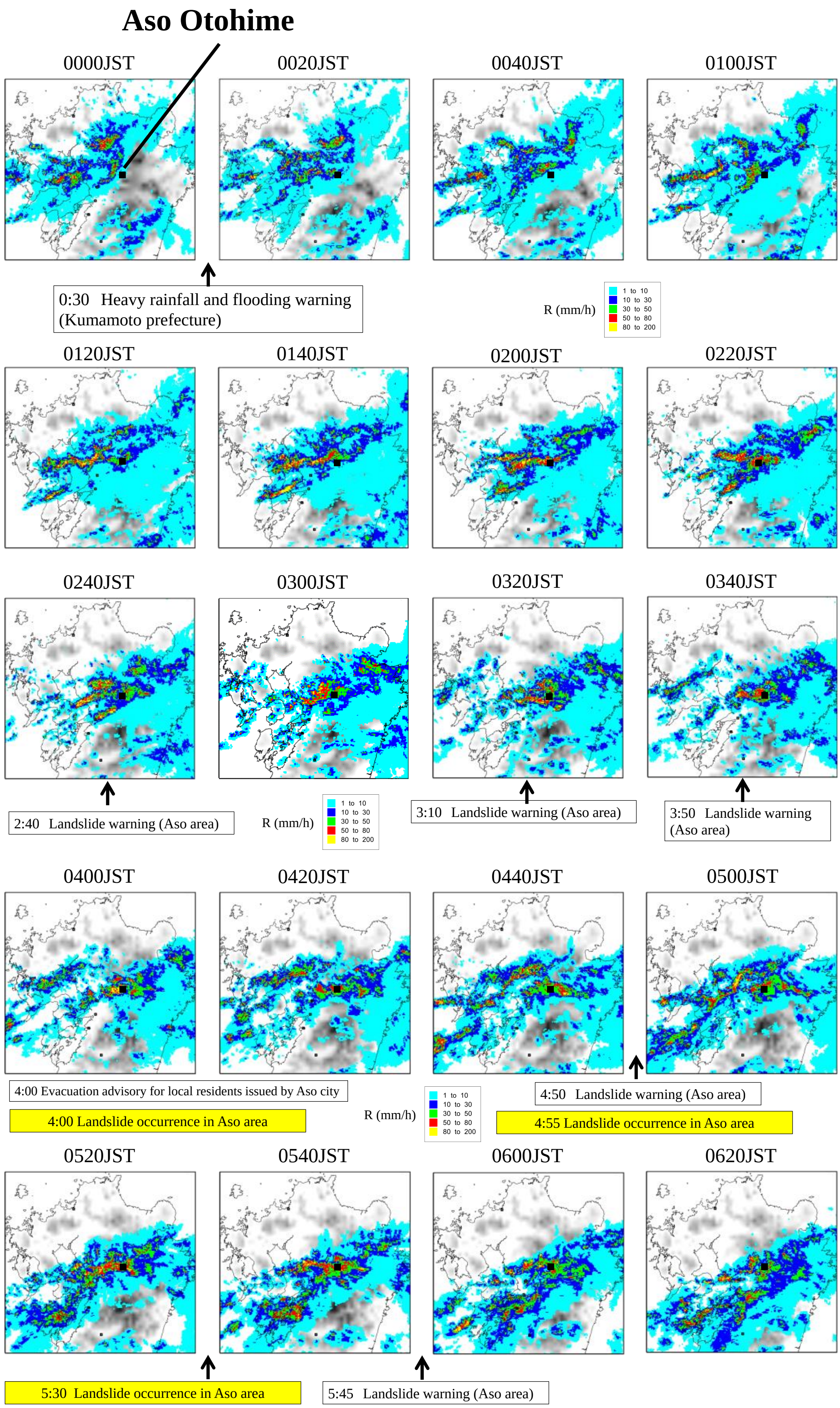

FIGURE 5: Time series of JMA radar echo, JMA weather warnings, evacuation advisory issued by Aso city and the occurrence of landslide disaster together

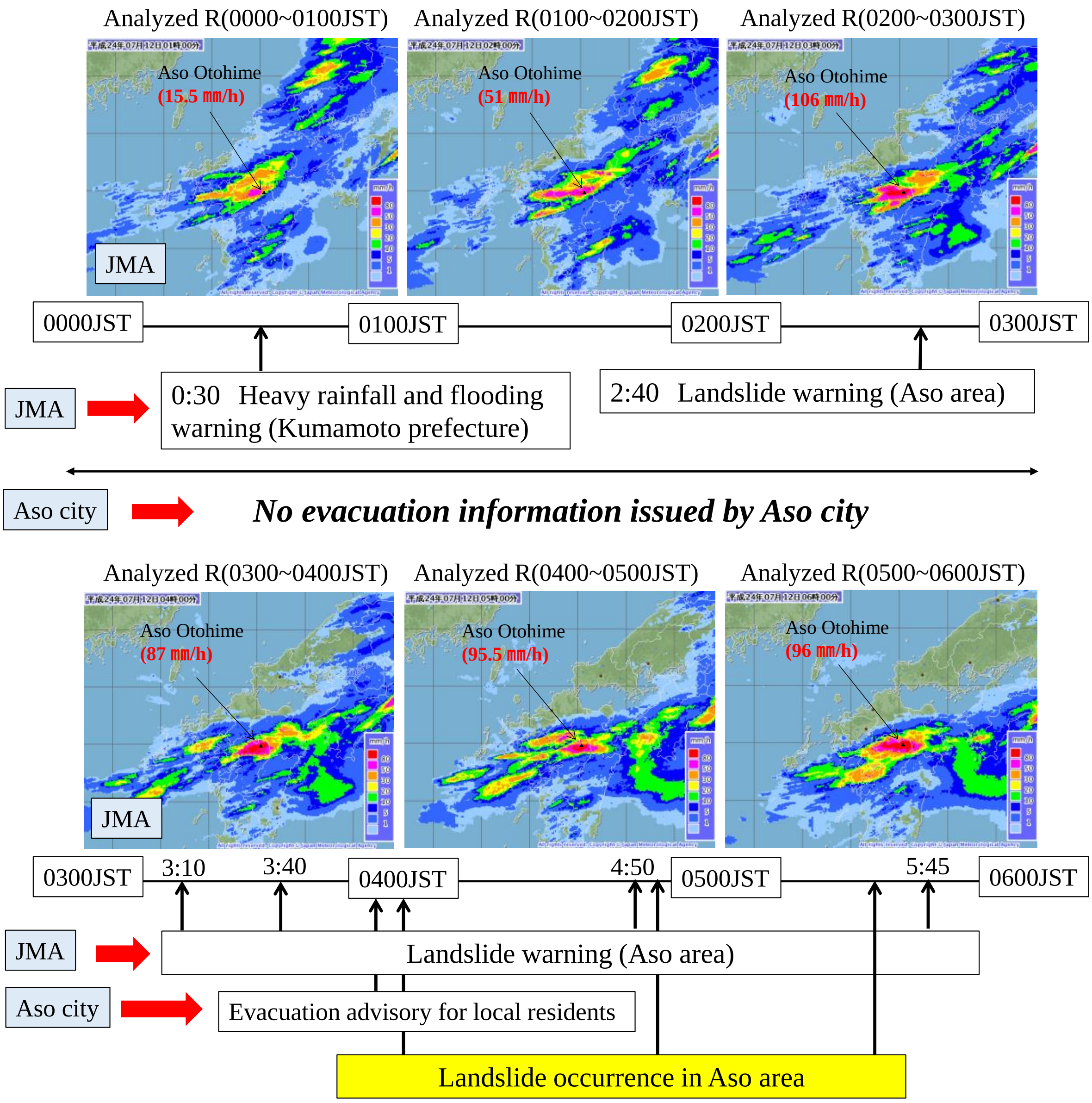

FIGURE 6: Time series of analyzed rainfall distributions (accumulated hourly rainfall), JMA warnings, evacuation advisory issued by Aso city and the occurrence of landslide disasters

5 Conclusions

The heavy rainfall case that occurred on July 12, 2012 show that the judgment of the issue by a local government for local residents was conducted after heavy rainfall had already intensified and many weather warning had been already issued by JMA. This implies that the judgment of the evacuation for local residents was conducted based on meteorological and hydrological information in a specific ‘narrow’ region under the control of the local government regardless of the existence of long-lived stationary heavy rainfall distribution in the surrounding region. Actually, before the onset of heavy rainfall, real-time radar images showed stationary BB type rainfall distribution like a smoke flowing from the upwind to the downwind region using radar images. In addition, the accumulation of rainfall around the BB region could be clearly recognized by analyzed rainfall images. These features are common among disastrous heavy rainfall cases, and are visually and easily detectable for ordinary persons who have no meteorologically-technical knowledge. Therefore, it is expected that these significant features are effectively available for the evacuation of local residents. In order to achieve it, many chances to educate staffs belonging to a local government and local residents are required.

Acknowledgement

This work was supported by JSPS Grant-in-Aid for Scientific Research (C): Grant Number: HAG5350507

References

Akiyama, T. The large-scale aspects of the characteristic features of the Baiu front. *Papers in Meteor and Geophys*., Vol. 24, pp. 157-188, 1973.

Bluestein HB. and Jain, MH. Formation of mesoscale lines of Precipitation : Severe squall lines in Oklahoma during the spring . *J. Atmos. Sci*., Vol. 42, pp.1711-1732, 1985.

Kato, T. and Goda, H. Formation and maintenance processes of a stationary band-shaped heavy rainfall observed in Niigata on 4 August 1998. *J. Meteor. Soc, Japan*., Vol. 79, pp. 899-924, 2001.

Kato, T. Numerical Simulation of the Band-shaped Torrential Rain Observed over Southern Kyushu, Japan *on* 1 August 1993. *J. Meteor. Soc, Japan.,* ol. Vol. 76, pp. 97-128, 1998.

Ninomiya, K. Large- and meso-α-scale characteristics of Meiyu and Baiu front associated with intense rainfalls in 1-10 July 1991. *J. Met. Soc. Japan*., Vol. 78, pp. 141-157, 2000.

Yamasaki, M. Study of Fukui Heavy Rainfall in 2004, *J. Meteor. Soc, Japan.*, Vol. 86, pp.369-376, 2008.