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THE CHARACTERISTICS OF SPATIO- AND TEMPORAL-VARIATION OF RAINFALL IN MATSUYAMA PLAIN

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SYNOPSIS

The diurnal rainfall variation in Matsuyama plain was analyzed by using datasets from AMeDAS, MLIT (Ministry of Land, Infrastructure, Transport and Tourism), and the local government. The late afternoon peak of precipitation is particularly noticeable around the top of alluvial fan, especially in the warm season. The absolute humidity observations indicate that the sea breeze transports the moist air along the river toward the inland regions, and thus contributes to an increase in the water vapor content around the top of alluvial fan. This is one of the reasons for the intense precipitation around the top of alluvial fan.

INTRODUCTION

The features of diurnal precipitation variation in Japan have been investigated in previous studies. Fujibe (1) showed that localized precipitation had a distinct afternoon maximum in inland regions, and a nocturnal or morning maximum over coastal regions. Kuwagata (2) and Saitoh and Kimura (3) analyzed diurnal and regional features of convective rainfalls in the Central Mountain region and pointed out the effects of thermally driven circulations. These previous studies were based on the precipitation datasets from the AMeDAS (Automated Meteorological Data Acquisition System) network, with more than a thousand stations in Japan. However, the observation network where an observatory is located each with a radius of about 17 kilometers in average is still not sufficient enough to grasp the local precipitation such as localized torrential rainfall. In this study, we focused on the relationship between the rainfall distribution and orographic effects such as the shape of plain, rivers, and elevation, by using precipitation datasets from AMeDAS, MLIT, and the local government. Such a combination enabled us to make more intensive analysis of the local rainfall. Furthermore, we analyzed the datasets from the absolute humidity observations which revealed the transportation of water vapor due to sea breeze circulation. We also investigated the relationship between the rainfall distribution and the transportation of water vapor.

STUDY AREA AND ANALYTICAL POINT OF VIEW

The Matsuyama plain has a triangular geometry and is mainly composed of an alluvial fan formed by flooding of the river. Fig. 1 shows the land use category and the precipitation observatories in the Matsuyama plain. We used 13 datasets from the observatories whose elevation ranges from 5 m a.s.l. to 460 m a.s.l. Fig. 2 shows the diurnal course of total hourly rainfall from 1976 to 2009 (34 years) at the Matsuyama meteorological observatory. Double peaks of precipitation were found in the early morning and in the late afternoon. This is already known as a general diurnal pattern of precipitation in the coastal regions in Japan (Fujibe (4)). But the diurnal change of precipitation was found to be more remarkable in the summer season (July and August). Fig. 3 shows the dependency of rainfall on elevation in August and February. Table 1 shows the relation between Observation point and Elevation. The dependency on elevation in February is more noticeable than in August: the correlation coefficient in August and February is 0.38 and 0.70, respectively. The dependency of total amount of rainfall on elevation has been reported in previous studies (e.g., Suzuki and Nakakita (5)), but the lower correlation coefficient in August indicates that precipitation in warm seasons is affected by other factors apart from elevation. In the following chapters we discuss why the summer time rainfall does not show a clear elevation dependency in Matsuyama by focusing on the spatial distribution of diurnal rainfall variation and the water vapor on the basis of the datasets in the warm season.

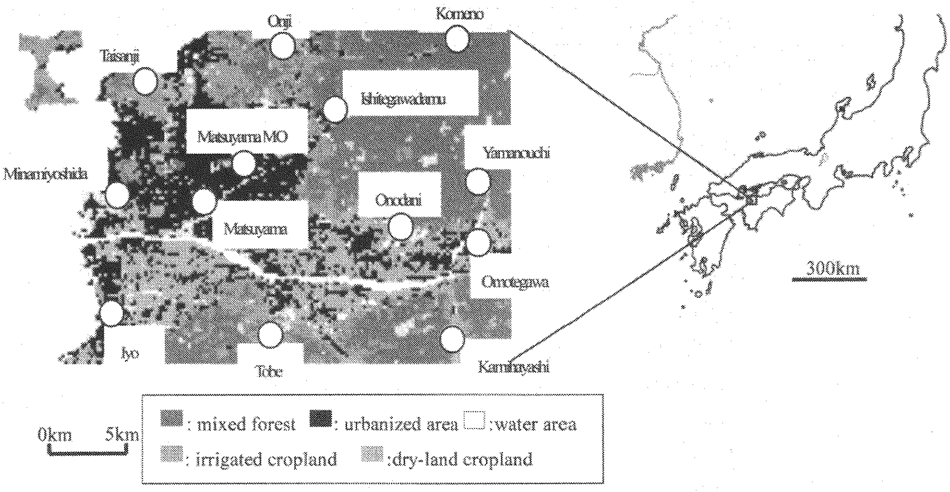

Fig. 1 Land use category and precipitation observatories in Matsuyama plain

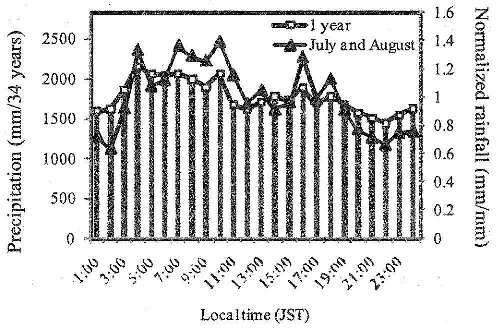

Fig. 2 Total hourly rainfall from 1976 to 2009 (34 years) at Matsuyama meteorological observatory. Plots shows the hourly rainfall normalized by the averages of total rainfall.

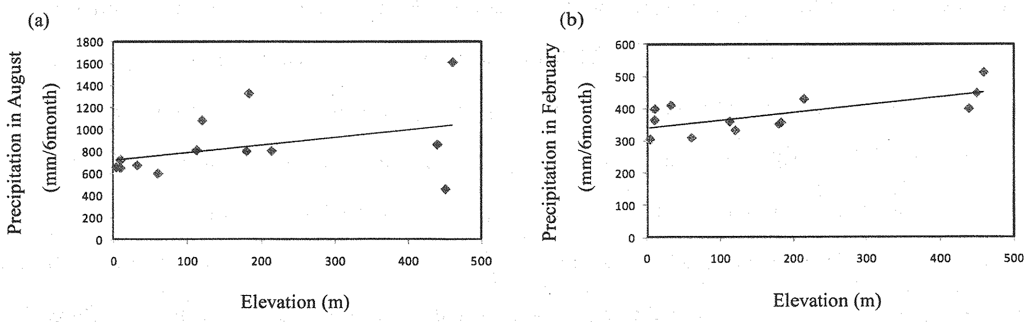

Fig. 3 Total rainfall amount in (a) August and (b) February (2003-2008) against elevation

for the 13 observation points shown in Fig. 1.

Table 1 Elevation of observatories

Observatory	Elevation (m a.s.l.)
Minamiyoshida	4
Iyo	10
Matsuyama	10
Matsuyama MO	32
Taisanji	60
Tobe	112
Omotegawa	120
Onodani	180
Yamanouchi	183
Ishitegawa	214
Onji	439
Komeno	450
Kanihayashi	460

COMPARISON OF DIURNAL RAINFALL VARIATION BETWEEN POINTS IN MATSUYAMA PLAIN

Firstly, we compared the diurnal rainfall variation at two points of called Kamihayashi and Komeno where the elevation is almost same (Kamihayashi: 460m a.s.l. and Komeno: 450m a.s.l.) in order to eliminate the dependency of rainfall on elevation (Fig. 4). Here, we classified the data into large scale rainfall events and small scale events based on the weather chart and AMeDAS data, using the method proposed by Suzuki and Nakakita (5). The large scale rainfall means that precipitation arisen from weather disturbance with meso-α or meso-β scale such as typhoon, stationary front and cyclonic rain, while the small scale means meso-γ such as convective precipitation and thunderstorms.

Fig. 4 shows that the afternoon precipitation peak at Kamihayashi, which is located near the edge of the alluvial fan, is more evident than that at Komeno, which is located in the middle of a mountainous area. In addition, this appeared more clearly in the case of small scale rainfall events (Fig. 4b). Fig. 5 shows a similar comparison between a different set of points of Omotegawa (120 m a.s.l.) and Tobe (112 m a.s.l.) where the elevation is lower than the points in Fig. 4. Again, the point near the edge of alluvial fan (Omotegawa) experienced a larger afternoon peak. These results indicate that even if the elevation is almost the same, the precipitation tends to be larger near the apex of the alluvial fan and also tends to occur in the late afternoon, especially in the case of small scale rainfall events. On the other hand, the total rainfall in February (Fig. 6) shows that there is not a significant difference between Kamihayashi and Komeno in large scale rainfall events while the small scale rainfall events much less happen (see Fig.6b). This suggests that the local thermally-induced rainfall events do not occur in winter season and that the rainfall intensity tends to depend on the elevation.

In warm seasons the apex of alluvial fan is characterized as the region where the precipitation is large and is caused by the small scale disturbance in the summer afternoon. Kanda and Tsunoi (6) analyzed the spatial wind pattern in the Kofu basin and reported that sea breeze penetrates along rivers toward the basin. They also reported that the wind pattern affects the spatial and temporal field of air temperature. The transportation of water vapor due to sea breeze is suggested by Kuwagata (2) and Shimoju et al. (7). Therefore, it can be assumed that the local intense precipitation at near the apex of alluvial fan is due to the convergence of water vapor generated by sea breeze in the daytime. This water vapor transport is examined in the next chapter.

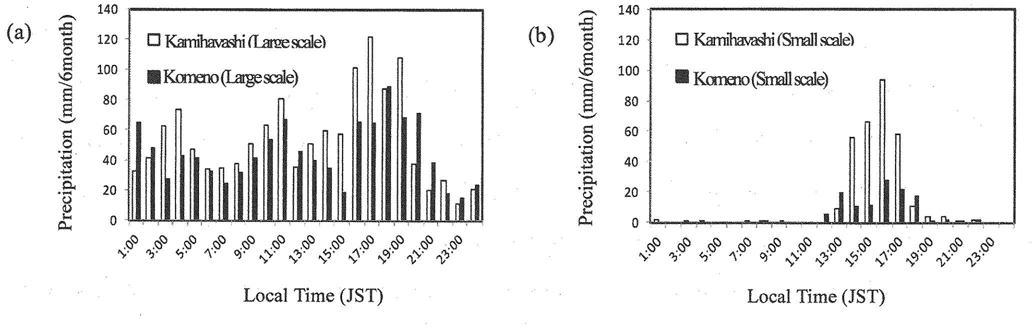

Fig. 4 Total hourly rainfall amount in August (2003-2008) at Kamihayashi (elevation: 460m a.s.l.), Komeno (450m a.s.l.) (a) large scale rainfall event, (b) small scale rainfall event. See text for the definition.

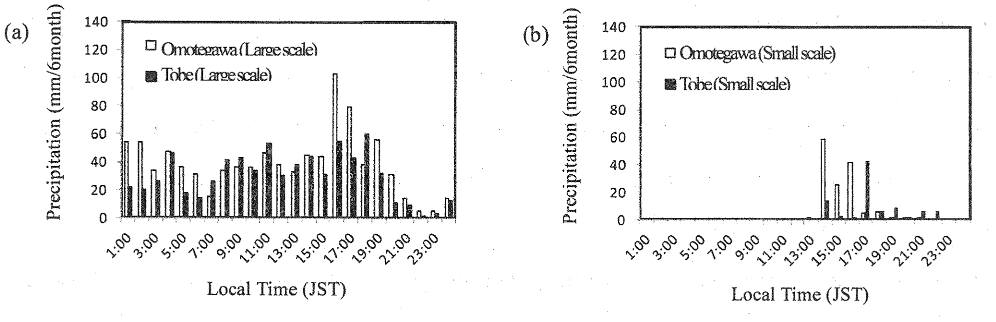

Fig. 5 Same as Fig. 4 but for Omotegawa

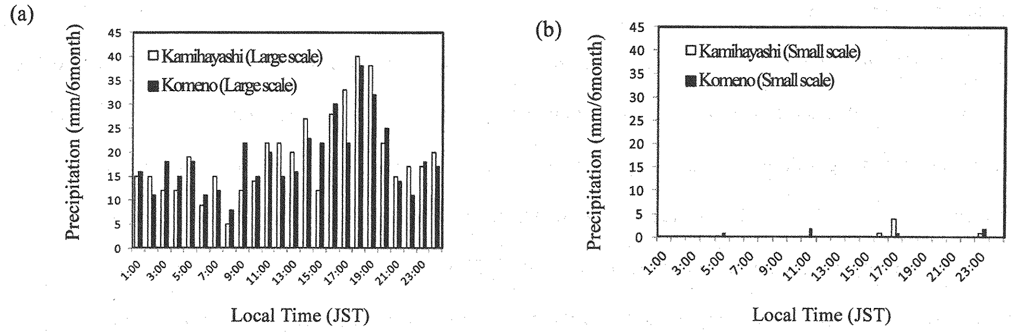

Fig. 6 Same as Fig. 4 but February (2003-2008).

WATER VAPOR DISTRIBUTION IN MATSUYAMA PLAIN

As a preceding study on the local climate in Matsuyama plain, Fujimori et al. (8) had investigated urban heat island (UHI) phenomenon on the basis of field observation network where the density of the thermo-hygrometers network is approximately one station per 3 km^2 in Matsuyama plain. The observation network is still working with 3 additional stations and the datasets of humidity are available for the present study.

Cumulative wind speed blowing from 16 quarter wind direction at (a) 11:00 and (b) 15:00 over 14 days in which the small scale rain event occurred in August 2010 is shown in Fig. 7. The analysis was based on hourly datasets of Matsuyama meteorological observatory. Northwesterly or southwesterly wind is dominant. In Matsuyama plain the local circulation is ordinarily observed especially in summer season. Due to this sea breeze (westerly wind) is dominant in the daytime usually from 9:00 to 17:00. Fig. 8 gives the spatial distribution of absolute humidity at 11:00 and 15:00 in August 2010 which was ensemble-averaged over 14 days when the small scale rain events occurred. Results of our analysis show that the humid air is transported from coastal regions to the inland especially through the southern part of plain (irrigated cropland) and along a large river (see Fig. 1 for the land use category). Another interesting finding is that the moist region appeared in the eastern edge of alluvial fan in the afternoon (Fig. 8b). This could be one of the evidence for the convergence of water vapor and could explain the reasons for the large precipitation around the apex of alluvial fan.

Fig. 9 shows the diurnal course of absolute humidity at the two points of Kitayoshii at the apex of alluvial fan and Wake in the coastal region. The difference of water vapor content of the two points is great at nighttime (time zone of land breeze from 18:00 to 08:00), and it is small in the daytime (time zone of sea breeze from 09:00 to 17:00). The difference especially tends to be small in the afternoon. These results suggest that the local sea breeze contributes to an increase in the water vapor content over inland regions through the moist air advection from coastal regions and then cause the local rainfall near the apex of alluvial fan in the late afternoon. It should be noted that the above discussion is based on the humidity datasets in August 2010, and thus further studies would be necessary to better understand the mechanism of intense precipitation around the top of alluvial fan.

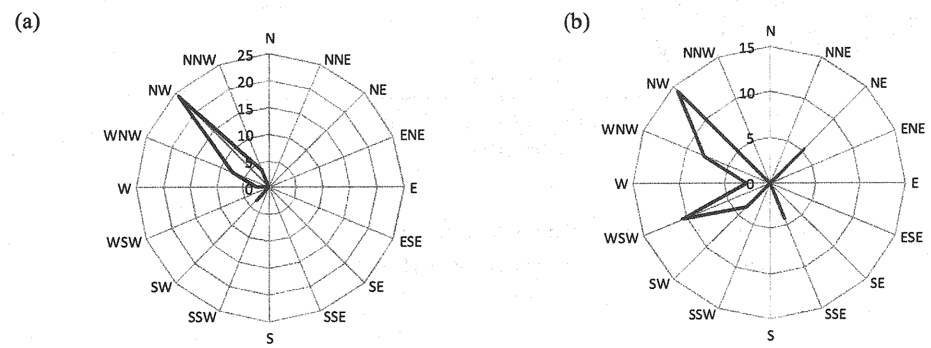

Fig. 7 Cumulative wind speed (m s^{-1} h) blowing from 16 quarter wind direction at (a) 11:00 and (b) 15:00 over 14 days in which the small scale rain event (see text) occurred in August 2010. The analysis was based on hourly datasets of Matsuyama meteorological observatory.

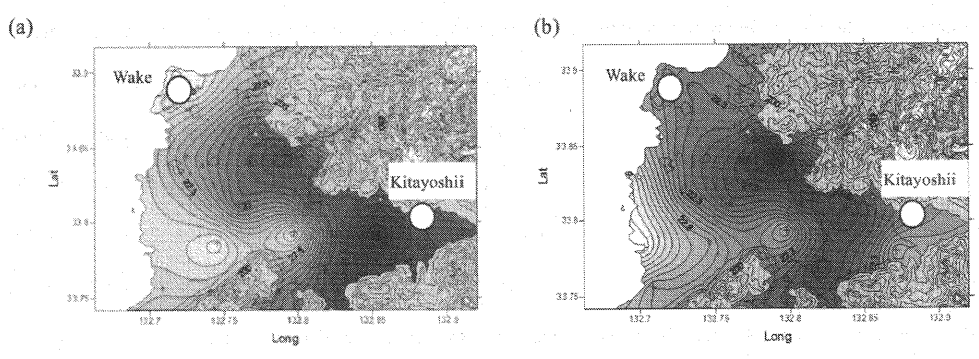

Fig. 8 Spatial distribution of absolute humidity (g m^{-3}) at (a) 11:00 and (b) 15:00 in August 2010 which was ensemble-averaged over 14 days when the small scale rain event occurred. Grayscale color displays the contour map of absolute humidity, except for the mountainous terrain where the elevation is larger than 150 m T. P.

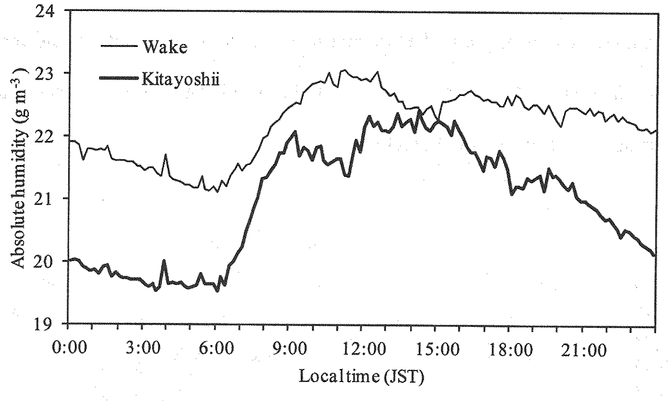

Fig. 9 Diurnal course of absolute humidity at Kitayoshii and Wake in August 2010 which was ensemble-averaged over 14 days when the small scale rain event occurred.

CONCLUSIONS

The spatio- and temporal-variation of rainfall in Matsuyama plain was investigated in this study. We used the rainfall datasets from AMeDAS, MLIT, and the local government and the humidity datasets from the observation where the density of the thermo-hygrometers network is approximately one station per 3 km^2 in Matsuyama plain. This enables us to analyze the local rainfall distribution and orographic effects such as the shape of plain, rivers, and elevation. The following are major finding of this study. 1) Double peaks of precipitation were found in the early morning and in the late afternoon, and the latter peak tends to be observed around the top of alluvial fan especially in the warm season. 2) The absolute humidity observations indicate that the sea breeze transports moist air along the river toward the inland regions and that it contributes to an increase of the water vapor content around the top of alluvial fan. This could be one of the reasons why there is intense precipitation around the top of alluvial fan.

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