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OBSERVATIONAL STUDY ON REGIONAL CLIMATE OF IZU OSHIMA ISLAND, TOKYO

Rika SUZUKI, Hiroshi G . TAKAHASHI and Jun MATSUMOTO

Abstract To examine the regional climate of Izu Oshima Island, Tokyo, we observed precipitation and temperature from June 2009 to September 2010 in various places across the island. Using our observational data, AMeDAS (Automated Meteorological Data Acquisition System) data from the Japan Meteorological Agency and precipitation data from the Tokyo Metropolitan Government Bureau of Construction, we analyzed the altitudinal increase of precipitation and the spatial distribution of temperature associated with the prevailing winds. The rainfall amount increased with altitude due to the altitudinal increase in rainfall frequency, although the rainfall intensity did not increase with altitude. The prevailing wind direction over Izu Oshima Island is northeast (NE) or southwest (SW). When NE-wind days and SW-wind days were selected, the mean temperature in the leeward side of the island was found to be higher than that on the windward side.

Key words: effect of prevailing wind on temperature distribution, altitudinal increase in rainfall, observation

1. Introduction

The regional climate over and around mountain regions is influenced by various factors, such as the prevailing wind, the scale of topography, and the dominant precipitation systems. In particular, the effects of topography vary over wide spatial scales. As an example of topographic influence, an altitudinal increase in precipitation amount has been observed in many regions. Yoshino (1986) showed that precipitation is most abundant at altitudes around 2,000 m above sea level (a.s.l.), with an annual rainfall amount of 2,000–3,000 mm over tropical mountains. Kuraji *et al.* (2001) examined the altitudinal increase in precipitation between 380 and 2,565 m a.s.l. in a mountain of headwater area in northern Thailand and reported that the mean rainfall intensity has no altitudinal dependence, whereas the proportion of hours with rain clearly increases with altitude in the wet season. Previous studies examined the precipitation over Yaku-shima Island (504 km^2), which has an isolated mountain peak (1,935 m a.s.l.) and is located in the south of Japan around 30°N, 131°E. Eguchi (1984) and Takahara and Matsumoto (2002) observed that precipitation over the leeward side of Yaku-shima Island was higher than that over the windward side. However, the data for these analyses were limited to stations at lower altitudes. Nakano *et al*. (2003) observed precipitation at five sites located at different altitudes on Miyake Island (55.5 km^2 with a mountain peak of 775 m), Tokyo around

34°N, 139°E in the south of central Tokyo. They reported an altitudinal increase in precipitation. However, these sites were located on different slopes.

The regional climate of Izu Oshima Island (91.06 km^2) was investigated by Kizawa and Sakamoto (1951). They found that precipitation in the southern part is more abundant than that in the northern part throughout a year, although their results were based on observations at only a few stations.

Few studies have examined the regional characteristics of a small-scale island currently as Izu Oshima Island. The Japan Meteorological Agency (JMA) maintains only two stations at Izu Oshima Island, both of which are located in the western lowland of the island. They do not provide enough information to describe the regional climate of the island. We, therefore, set up our temperature and precipitation measurement equipments in various places on Izu Oshima Island to examine the regional climate, particularly the altitudinal increase in precipitation and spatial distribution of temperature associated with the prevailing wind.

2. Observations and Data

Izu Oshima (34°44'N, 139°24'E) is a mountain island with a single peak, Mt. Mihara (764 m), and is located in the northernmost part of the Izu Islands, Tokyo. Our observation period covered 15 months, from 15 June 2009 to 13 September 2010. 0.5-mm tipping-bucket rain gauges (MW-101, EKO Instruments Co., Ltd.) with data loggers (RF-3, T & D Co.) and thermo recorders (RTR-52, T & D Co.; thermistor thermometry) were installed at various places on the island, as shown in Fig. 1 and

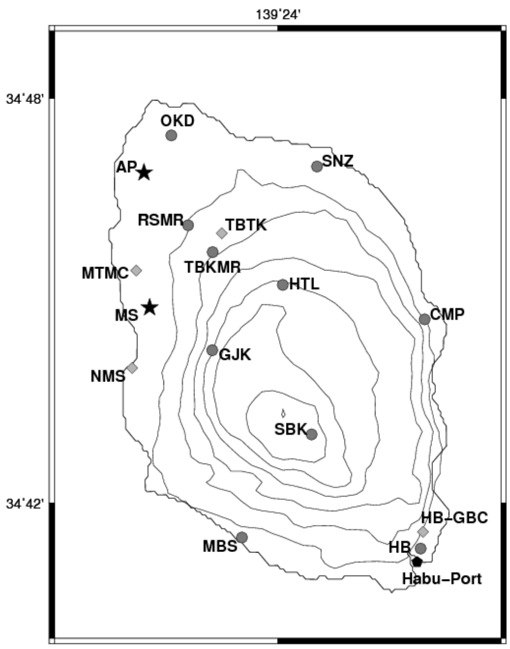

Fig. 1 Location of study area and measurement sites on Izu Oshima Island. Contour interval of topography is 100 m. Circle, star, and diamond signs indicate observational stations by Tokyo Metropolitan University, Japan Meteorological Agency, and Tokyo Metropolitan Government Bureau of Construction, respectively. The pentagon sign indicates the station used by Kizawa and Sakamoto (1951).

Table 1. To discuss the altitudinal increase in rainfall, several rain gauges were installed on a northwest-facing slope. The recording interval of this observation was 10 minutes for both precipitation and temperature. Installation environment at Camp site (CMP in Fig. 1) was not good enough to discuss the regional characteristics of temperature. Therefore, the data of temperature at this station was used only as a reference.

We used precipitation, temperature and wind data observed at AMeDAS (Automated Meteorological Data Acquisition System) stations by JMA and precipitation data by the Tokyo Metropolitan Government Bureau of Construction (TMGBC). The precipitation amount was observed using tipping-bucket rain gauges by JMA in 0.5-mm intervals while by TMGBC in 1.0-mm intervals. The stations of these observations are also indicated in Fig. 1 and Table 1. We used daily averaged wind direction and speed at Oshima Airport (AP) AMeDAS station in the fourth section of Chapter 4 to investigate the temperature distribution associated with the prevailing wind.

Table 1 Observational stations used in this study

Station	Abbreviated name	Observation institute (rainfall)	Rate of missing data (rainfall) [%]	Observation institute (temperature)	Rate of missing data (temperature) [%]	Altitude [m]
Okada	OKD	TMU	73.68	TMU	26.56	49
Senzu	SNZ	TMU	13.83	TMU	2.40	51
Risu-mura	RSMR	TMU	6.67	TMU	2.50	160
Tsubakinomori Park	TBKMR	TMU	14.33	TMU	9.85	270
Hotel	HTL	TMU	24.48	TMU	2.15	490
Camp site	CMP	TMU	0.00	TMU	26.53	68
Gojinka-chaya	GJK	TMGBC	0.23	TMU	1.97	567
Sabaku	SBK	TMU	27.56	TMU	2.60	655
Habu	HB	-	-	TMU	2.96	51
Habu (TMGBC)	HB-GBC	TMGBC	0.04	-	-	40
Mabushi	MBS	TMU	0.00	TMU	26.56	58
Air port	AP	JMA	0.16	JMA	0.25	38
Meteorological station	MS	JMA	0.23	JMA	0.25	74
Tsubaitsuki	TBTK	TMGBC	0.04	-	-	190
Motomachi	MTMC	TMGBC	0.35	-	-	46
Nomashi	NMS	TMGBC	0.04	-	-	33

Locations of these stations are shown in Fig. 1. TMU, JMA, and TMGBC indicate observation by Tokyo Metropolitan University, Japan Meteorological Agency, and Tokyo Metropolitan Government Bureau of Construction, respectively.

There is a possibility that the precipitation amount at higher altitudes was underestimated due to stronger wind because of comparatively lower tree height in the surroundings, influenced by volcanic eruptions of Mt. Mihara.

To understand the rainfall characteristics, we defined the following components. The rainfall amount (RA) was the total amount for the observation period divided by the total number of observation hours. The rainfall frequency (RF) was the number of rainfall hours divided by the total number of observation hours, and the rainfall intensity (RI) was the total amount for the observation period divided by the number of rainfall hours.

3. Climate of Izu Oshima Island

The regional climate of Izu Oshima Island was described by Oshima Meteorological Station (2007; personal communication) as having higher temperature, more precipitation, and stronger winds compared with central Tokyo. The mean annual precipitation is 2,838 mm, which is about twice as high as in central Tokyo (1,467 mm). The prevailing wind directions are northeast (NE) and southwest (SW). More specifically, the prevailing wind directions are SW and WSW in January, NE in February and March, SW in a warm period from April to August, SW and NE in September, NE in October and November, and NE and SW in December. The annual mean wind speed is 4.8 m/s.

4. Results

Measurement accuracy

Figure 2 shows a time-series of precipitation and temperature in the summer of 2009 at our station Okada (OKD) and at AP operated by JMA. Our observations were in close agreement with those by JMA. Compared with the precipitation data from TMGBC, our observations were also quantitatively close (not shown). Thus, our observation data had enough accuracy to be used for understanding the regional climate.

Spatial precipitation distribution

We analyzed the spatial distribution of mean RA (Fig. 3). Precipitation in mountainous area was more abundant than that in lowlands. In addition, precipitation in the western and eastern areas was greater than that in the northern and southern areas. This tendency was different from that obtained in the previous study (Kizawa and Sakamoto 1951), which reported precipitation in the Habu Port (location is shown in Fig. 1) was higher than that in the former meteorological station (same as Tsubaitsuki, TBTK in this study) throughout the year.

Altitudinal dependence of rainfall

Figure 4 shows a scatter diagram of the relationships between altitude and RA (a), RF (b), and RI (c) plotted by different signs for each type of tipping bucket (0.5 mm or 1.0 mm). RA increased with altitude, although Mt. Mihara is a comparatively low peak. RF increased with altitude, whereas

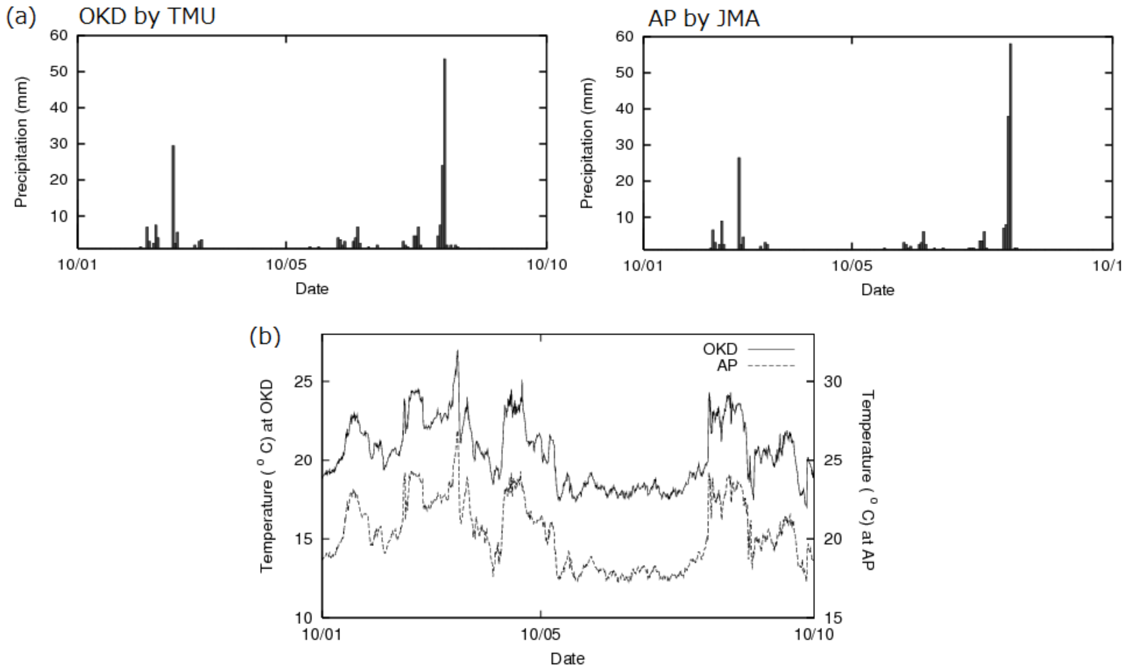

Fig. 2 (a) Time series of precipitation in the summer of 2009 at Okada (OKD, our station, upper left panel) and Oshima Airport (AP, operated by JMA, upper right panel). (b) Time series of temperature in the summer of 2009 at OKD (solid line) and AP (dashed line) (lower panel).

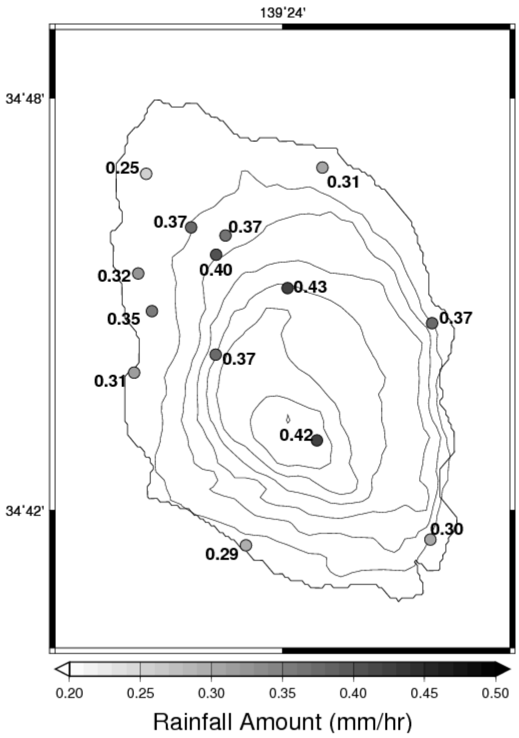

Fig. 3 Spatial distribution of mean hourly rainfall amount (RA). Topographic contours are the same as in Fig. 1.

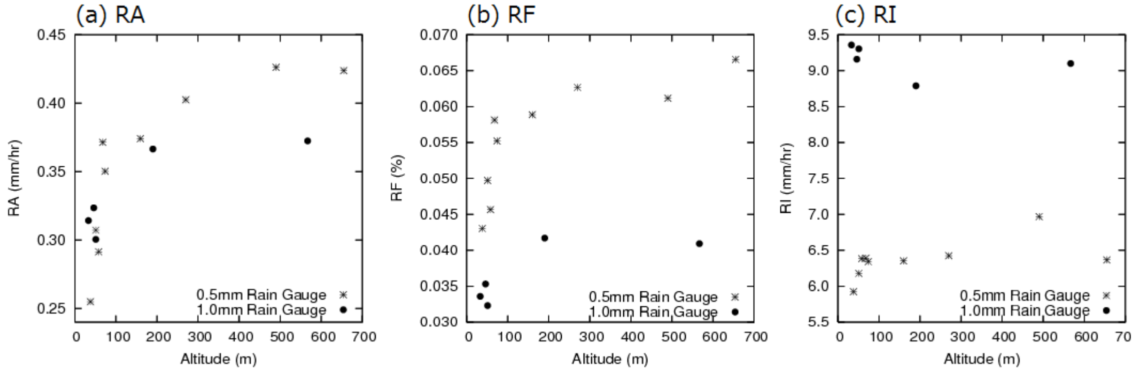

Fig. 4 Relationship between altitude and rainfall amount: RA (a), rainfall frequency: RF (b), and rainfall intensity: RI (c). In the stations shown with asterisk and filled circle signs, the precipitation amount was observed in 0.5 mm and 1.0 mm intervals, respectively.

RI did not. The seasonal differences in these tendencies for RA, RF, and RI were not obvious (not shown). Some previous studies reported that the proportion of hours with rain tended to increase with altitude (Kuraji *et al.* 2001), whereas Yoshino (1986) suggested a higher intensity of rainfall in mountains than in the lowlands. Our study suggested that the increase in RF with altitude is responsible for the increase in RA over Izu Oshima Island, which is similar to the results by Kuraji *et al.* (2001).

Distribution of temperature

Previous studies reported that NE and SW winds prevail over Izu Oshima Island at the JMA stations (e.g., Kizawa and Sakamoto 1951). On sunny days, the temperature in the leeward area was found to be higher than that in the windward area in many cases. For example, Figure 5(a) shows that the temperature at Mabushi (MBS) was about 2 °C higher than that at Senzu (SNZ) at 12:00 on September 6 in 2009. Northeast wind prevailed on that day. On the other hand, at 12:00 on August 29 in 2010, the temperature at SNZ (in the leeward of Izu Oshima Island) was 4 °C higher than that at MBS (in the windward of the island), as shown in Fig. 5(b).

These cases suggest that temperature on the leeward was often higher than that on the windward side. To examine this phenomenon, we conducted a composite analysis of temperature based on the daily-mean surface wind observed at AP. First, we selected the days when the prevailing wind direction (θ) was NE or SW. Northeast and southwest wind days were defined as $0° < \theta < 90°$ and $180° < \theta < 270°$, respectively based on AMeDAS data at AP. Of 456 days, 30.7% were classified as NE-wind days, and 41.0% were SW-wind days. Excluding missing temperature data (from November 2009 to March 2010), we used 97 NE days (21.3%) and 147 SW days (32.2%) for the composite analysis. As the prevailing wind direction in Izu Oshima Island varies seasonally, most of the SW-wind days were in warm season, whereas most of the NE-wind days were in spring and fall. Second, mean diurnal changes in temperature for NE- and SW-wind days were examined. Figure 6(a) shows diurnal changes in temperature at SNZ and MBS on NE-wind days. The temperature in

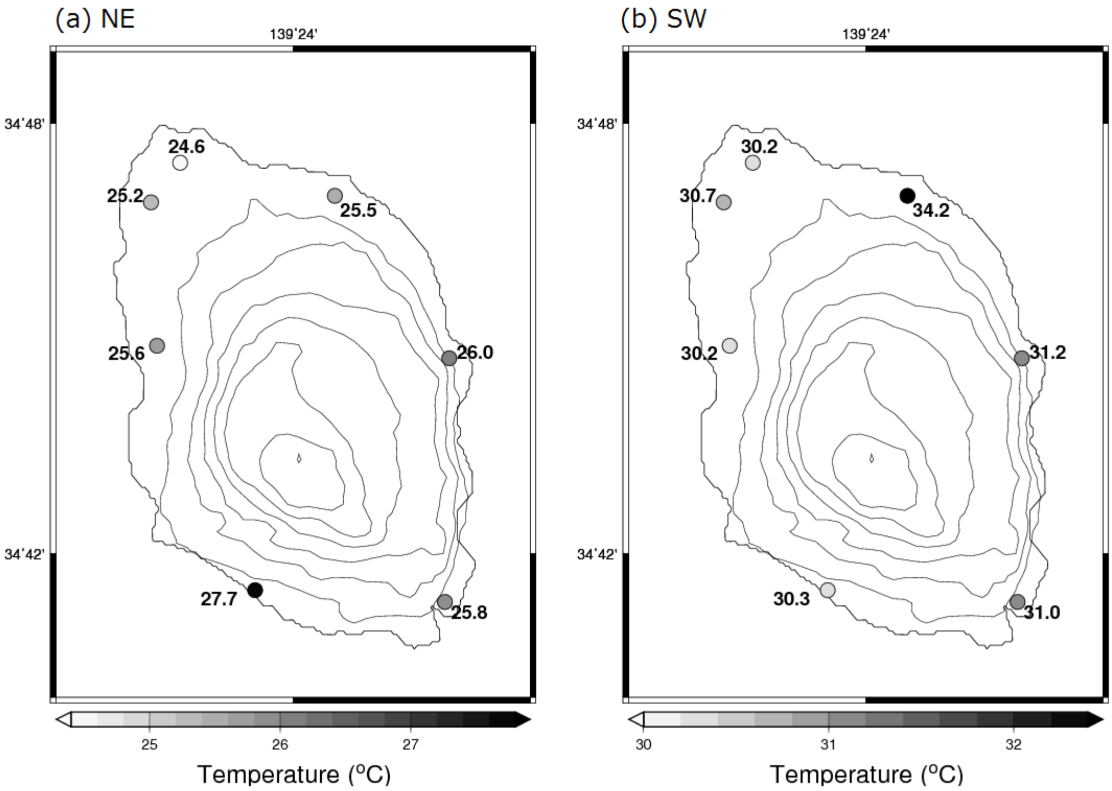

Fig. 5 Spatial distribution of temperature at the lowland stations at 12:00 JST, September 6, 2009 (a) and at 12:00 JST, August 29, 2010 (b). Topographic contours are the same as in Fig. 1.

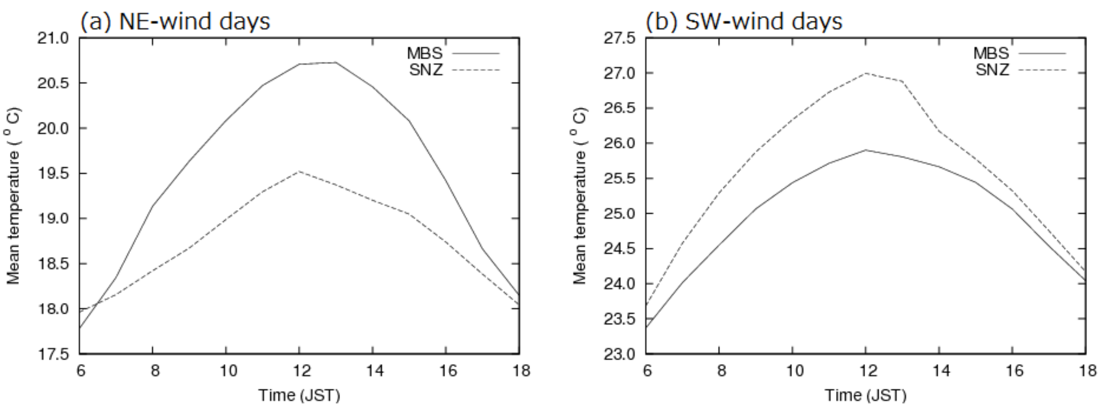

Fig. 6 Diurnal variations in temperature at Senzu (SNZ) and Mabushi (MBS) on NE-wind days (a) and on SW-wind days (b). The solid line shows the temperature at MBS, and the dashed line shows the temperature at SNZ.

early morning and early evening at each station was almost same. The increase in temperature from 6 JST to 12 JST at MBS (on the leeward side) was larger than that at SNZ (windward), which resulted in higher temperatures on the leeward side than on the windward side. On the other hand, on SW-wind days, the increase in temperature from 6 JST to 12 JST at SNZ was larger than that at MBS (Fig. 6b). Thus, the daytime increase in temperature on the leeward side was greater than that on the windward side.

The spatial distribution of mean temperature in Fig. 7 is similar to that in Fig. 5, which indicates that this tendency was frequently observed. Around noon, temperature at the leeward station (MBS or SNZ) was higher compared with that at other stations. However, the mean values at CMP may not be credible because the installation environment was not good.

5. Summary and Discussion

We examined the regional climate over Izu Oshima Island using our observations of precipitation and temperature for 15 months from 15 June 2009 to 13 September 2010. Our observations revealed regional differences of precipitation and temperature within the island that could not be covered by the JMA operational observations.

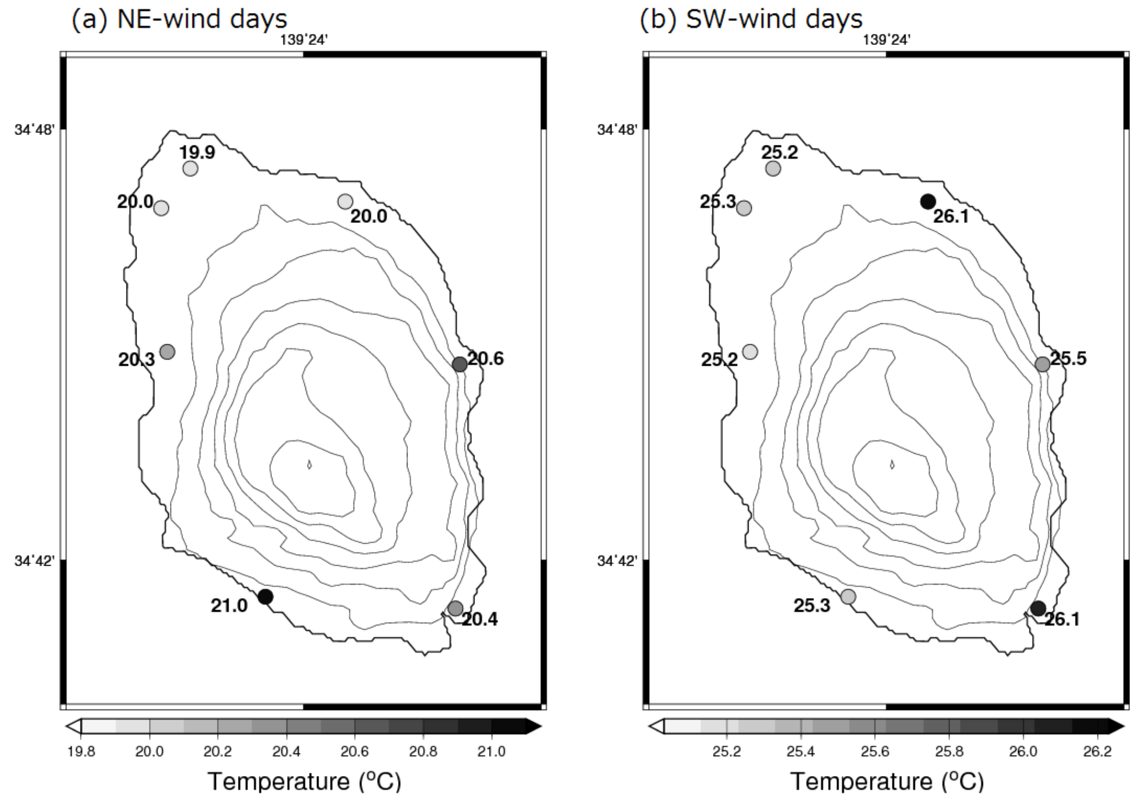

Fig. 7 Spatial distribution of mean temperature at 12:00 JST (a) on NE-wind days, and (b) on SW-wind days. Topographic contours are the same as in Fig. 1.

Precipitation in the western and eastern areas was greater than that in the northern and southern areas although Kizawa and Sakamoto (1951) reported that precipitation at the Habu Port was higher than that in Tsubaitsuki throughout the year.

The altitudinal increase in rainfall amount was clear, although spatial scale of Mt. Mihara is comparatively small (approximately 8 km in the horizontal scale and 764 m in the vertical scale). This was caused by a higher RF in mountain areas than in lowlands, although RI did not systematically change with altitude. From lower areas, we often observed clouds around the top of Mt. Mihara. The frequent appearance of clouds around the mountain may result in an increase in rainfall amount with altitude. It is possible that the clouds over Mt. Mihara are orographically induced.

The predominant wind direction over Izu Oshima Island is NE or SW at the JMA stations. During our observational period, the temperature on the leeward side of the island was often higher than that on the windward side. The composite analysis of temperature based on the daily mean prevailing wind suggested that the regional differences in temperature were associated with the prevailing wind. This probably indicates that the regional differences in temperature occurred at the island scale, which may be partly explained by sensible heating from the ground of the island and foehn phenomena. In addition, more frequent clouds on the windward side could also contribute to these regional differences.

This paper described the regional characteristics of Izu Oshima Island. In this study, an altitudinal increase in precipitation was clearly shown even though Mt. Mihara is relatively small isolated mountains. More detailed investigations of altitudinal changes in precipitation for various mountain scales are required.

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