CHARACTERISTICS OF MOUNTAIN-AIR TEMPERATURES COMPARED WITH FREE-AIR TEMPERATURES IN CENTRAL JAPAN

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Abstract In order to examine the summer thermal conditions over the mountainous regions of central Japan, observed mountain-air temperatures were compared with free-air temperatures. The average temperature differences (mountain-air minus free-air) appear positive in the central region, and negative in the outlying areas of the mountains. During the summer, especially when the Ogasawara high extends over the Japan Islands, the positive temperature difference in the central mountainous region becomes more prominent.

Key words: mountain-air temperature, free-air temperature, central Japan

1. Introduction

Presently, there are insufficient observed data to clarify the thermal conditions in the mountainous region of Japan. This report is an attempt to examine the characteristics of the mountain-air temperatures compared with free-air temperatures. Therefore, in this study, air temperatures in the mountainous region of central Japan are compared with the thermal conditions determined from upper-layer air temperatures at three stations, Tateno, Wajima and Hamamatsu.

There have been several studies of the observed air temperature profiles over mountain slopes compared with nearly free-air temperatures (*e.g.*, Makita, 1978a, b; McCutchan, 1983). According to these reports, temperature differences between mountain-air and free-air exhibit considerable variability as related to season, the type of air mass (*i.e.*, wind direction, wind speed), the time of day (*i.e.*, radiative and turbulent heat exchanges), cloud amounts, and the existence of snow-cover. In reviewing several studies, Barry (1981) concluded that the primary control of the temperature difference between free-air and summit-air appears to be the atmospheric temperature structure related to the lapse rate and adiabatic lapse rate. The reason for this temperature difference, however, has still not been conclusively determined.

Since the present data are insufficient data and the investigation is still in progress, the present report should only be regarded as preliminary.

2. Data and Method

Summer thermal conditions are examined with the use of air temperatures observed at 16 mountain stations and the upper-air temperatures over Tateno, Wajima, and Hamamatsu, at 00z during August, from 1971 to 1980. These data were obtained from the *Meteorological Data of Japanese Mountains in Summer* (Japan Weather Association) and *Aerological Data of Japan* (Japan Meteorological Agency), respectively.

Only mountain stations that had less than 3 years of missing data during the decade were chosen as subjects of this study. The study area and meteorological stations are shown in Fig. 1. Details of the data are listed in the Appendix.

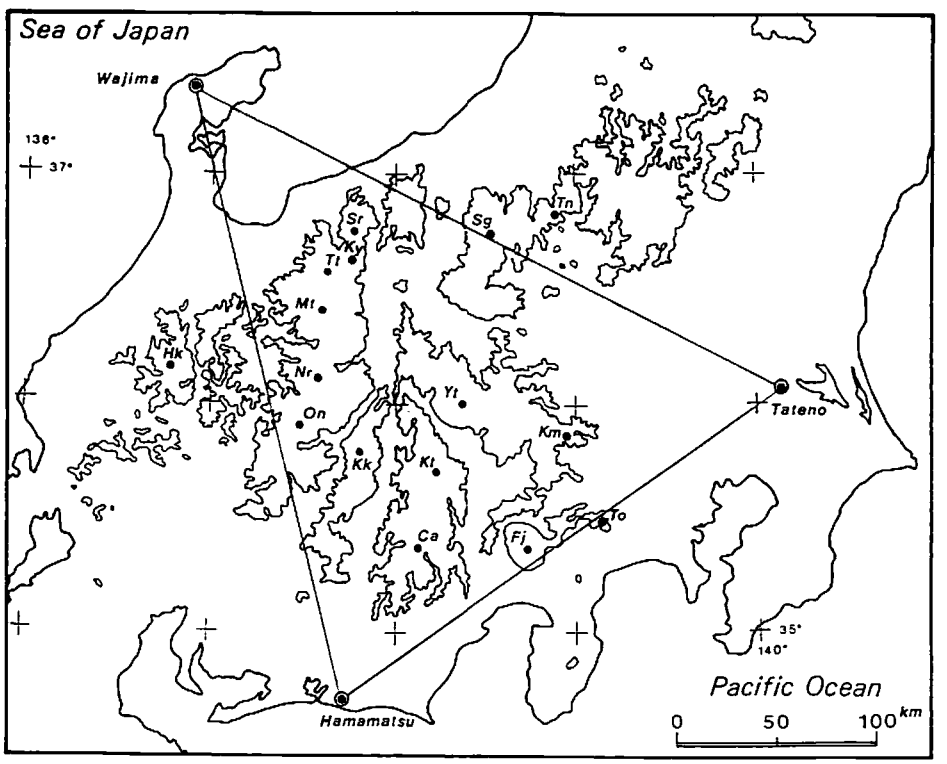

Fig. 1 Map showing the study area and the meteorological staitons employed in the present study
Here, the mountain stations are indicated by the dots, where Tn is the Tanigawadake station, Sg the Shiga-Higashitateyama, Sr the Shiroumadake, Ky the Kashima-Yarigatake, Tt the Tateyama, Mt the Mitsumatarengedake, Nr the Norikuradake, On the Ontakesan, Kk the Kiso-Komagatake, Kt the Kitadake, Ca the Chausudake, Yt the Yatsugatake, Km the Kumotoriyama, Fj the Fujisan, To Tanzawa-Tohnotake, Hk the Hakusan station. The thick solid line denotes the coast, the thin solid line the 1,000m above msl contour. The three upper air observing stations are located at the apexes of the indicated triangle.

Next, isothermal surfaces at the 16 altitudes, one for each mountain statin, were set up by using the aerological data for August 1971–1980, *i.e.*, the free-air temperatures at Tateno, Wajima and Hamamatsu. In addition, ten days when the Ogasawara high was well-developed were selected: the 8, 9, and 10 of August 1971, and the 8, 9, 10, 11, 20, 21, and 28 of August 1973. The mountain-air temperatures were then compared with the corresponding free-air temperatures.

3. Results and Discussion

Figure 2 shows the interannual temperature fluctuations of the free-air (top), mountain-air (middle) and the differences (bottom) from 1971 to 1980. Most of the mountain-air temperatures exhibit larger variations than the free-air temperatures. It is clear that both sets of temperature exhibit lower values in the years 1972, 1976, and 1980

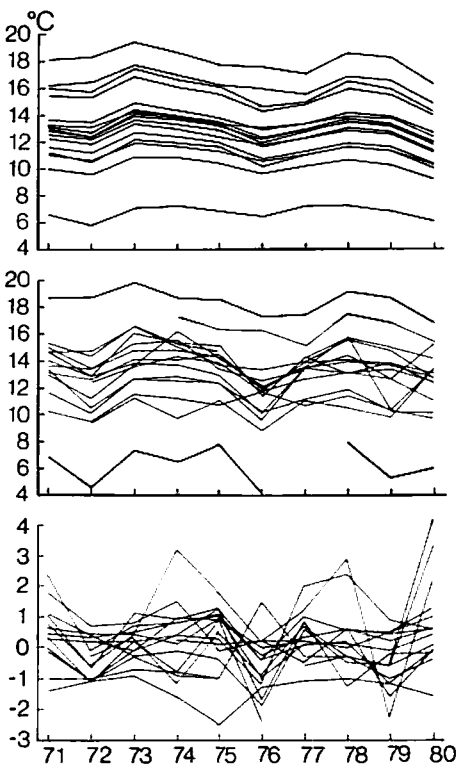

Fig. 2 Interannual fluctuations of the free-air temperature (top), mountain-air temperature (middle), and the differences (mountain-air minus free-air, bottom)
The free-air temperatures are the weighted average of the three upper-air observing stations at the heights corresponding to each mountain station.

than usual, except for Mt. Tateyama, Mt. Ontakesan, and Mt. Kiso-Komagatake in 1980 (see the Appendix). The sequence of temperature differences (mountain-air minus free-air) of each mountain can be divided into three groups which have a positive, negative and mixed sense of the temperature difference.

Latitudinal distributions of the temperature for the years 1971 through 1980 are shown in Fig. 3. Various tendencies can be seen from year to year. Positive temperature differences do not always occur during hot summers, just as negative differences are not always found in cool summers. For example, comparing the hot summer of 1973 with that of 1978, and the cool summer of 1976 with that of 1980, it can be seen that in the former, negative differences are predominant, whereas in the latter, positive differences dominate.

On the other hand, it can be determined when the differences are negative in the higher-latitude mountains. In the latitudinal distribution of the averaged temperature differences (Fig. 4), it is clear that smaller temperature differences occur on the side

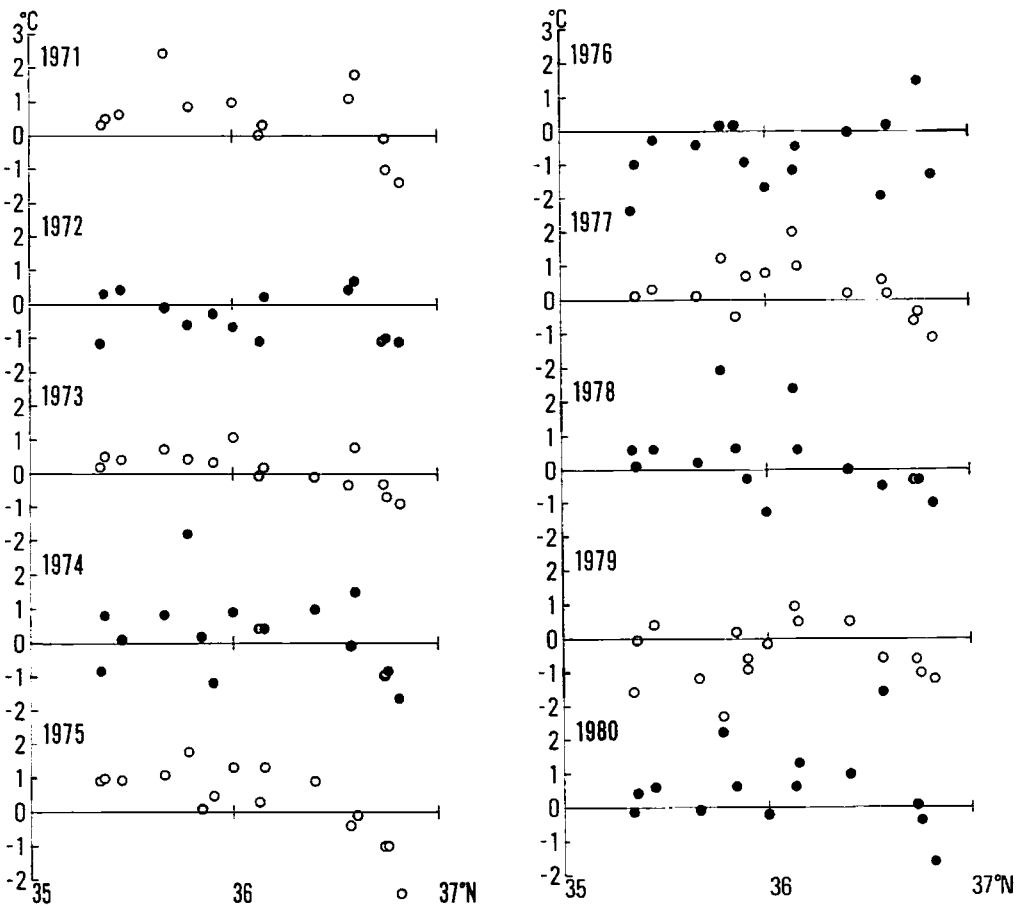

Fig. 3 Temporal changes in the latitudinal distribution of the temperature differences, where the odd numbered years are denoted by open circles, the even years by solid circles.

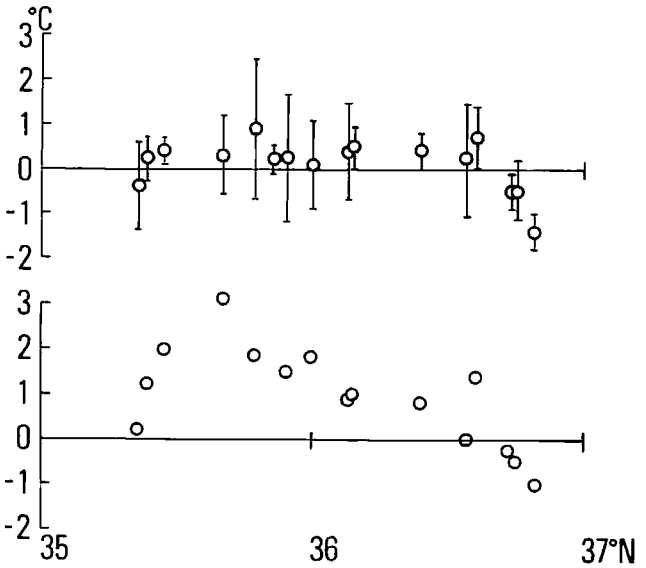

Fig. 4 Latitudinal distributions of the temperature differences for the average during 1971-1980 (upper) and the average on days when the study area was under the influence of the Ogasawara high (lower)
The bars denote ±one standard deviation.

of the Japan Sea, and at Mount Fuji, than in the central part. When the Ogasawara high extends over Japan, large positive temperature differences are found in the central part of the mountainous region. Stations which exhibit negative temperature differences are Mt. Tanigawadake (-1.0°C), Mt. Shiga-Higashitateyama (-0.2°C), and Mt. Shiroumadake (-0.4°C). Those which show positive differences of more than 1.0°C are Mt. Kitadake (+3.1°C), Mt. Tanzawa-Tohnotake (+2.0°C), Mt. Kiso-Komagatake (+1.9°C), Mt. Yatsugatake (+1.8°C), Mt. Ontakesan (+1.5°C), Mt. Kashima-Yarigatake (+1.4 C), Mt. Chausudake (+1.2°C), and Mt. Hakusan (+1.0°C).

Figure 5 displays vertical profiles of the averaged mountain- and free-air temperatures. It can be seen that the positive differences in which the mountain-air temperatures are greater than the free air temperatures are concentrated around an altitude of 2500-meters, although significant scatter exists in the data.

Mountain-air temperatures exhibit greater fluctuations than free-air temperatures. In general, temperature difference is in the negative sense during cool summers, and positive for hot summers. When comparing the cool summers of 1976 and 1980, however, negative differences prevail in the former year, while positive differences are found for the latter year. The sense of the difference is not always the same for every cool summer. This fact may mean that there is a discrepancy between the change in temperatures at the mountain-top and mounatin-base. During these years, a disparity was also observed between the upper and the ground-surface air temperatures based on meteorological data from the station at Tateno (Oka, 1992). Accordingly, the

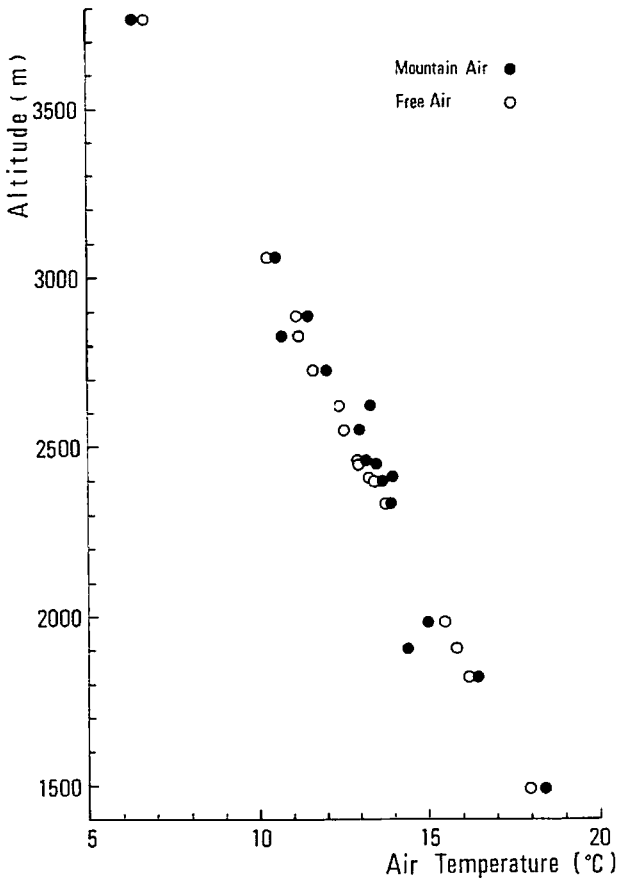

Fig. 5 Vertical profiles of the averaged mountain-air (solid circles) and free-air (open circles) temperatures

disparity between the two temperatures may be due to the vertical transport of cold air that results in cool summers. In other words, it may be that cool air had extended to the elevations of the mountain stations in 1976, whereas this did not occur in 1980.

With respect to the spatial variations of the differences, they appear to clearly change with latitude. Negative or small differences are predominant in the higher latitudes, near the coast of the Japan Sea, and in the lower latitudes, close to the Pacific Ocean. In the central mountainous region, however, the sense of the difference is positive. It appears that heating of the mountain surface plays an important role in this temperature distribution pattern, since this pattern becomes sharper under the conditions of the well-developed Ogasawara high.

It is necessary in future studies to analyze more long-term data, including an examination of the local characteristics associated with the mountain stations. It should also be considered whether the phenomenon examined in this report is related to the so-called "mass-elevation (Massenerhubung) effect".

This paper is dedicated to Professor Hiroshi Kadomura in commemoration of his retirement from Tokyo Metropolitan University.

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Appendix
Mountain Air Temperature (1971-1980, 00Z, AUG)
Mountain

LAT (° ')	LONG (° ')	ALT (m)		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	AVG1	AVG2
TANIGAWADAKE			MTN	14.6	14.6	16.5	15.0	13.6	13.3	13.9	15.5	14.7	12.6	14.4	16.7
36 49	138 56	1905	FRE	16.0	15.7	17.4	16.6	16.1	14.6	15.0	16.5	15.9	14.2	15.8	17.7
			DRC	-1.4	-1.1	-0.9	-1.6	-2.5	-1.3	-1.1	-1.0	-1.2	-1.6	-1.4	-1.0
SHIGA-HIGASHITATEYAMA				15.3	14.2	16.5	15.2	14.6	—	14.2	15.7	14.9	14.1	15.0	17.0
36 44	138 31	1985		15.4	15.3	16.8	16.1	15.6	14.3	14.8	16.0	15.5	14.0	15.5	17.2
				-0.1	-1.1	-0.3	-0.9	-1.0		-0.6	-0.3	-0.6	0.1	-0.5	-0.2
SHIROUMADAKE				10.2	9.5	11.5	11.2	10.7	11.7	10.7	11.4	10.3	9.7	10.7	12.3
36 45	137 45	2830		11.2	10.5	12.2	12.0	11.7	10.2	11.0	11.7	11.3	10.1	11.2	12.7
				-1.0	-1.0	-0.7	-0.8	-1.0	1.5	-0.3	-0.3	-1.0	-0.4	-0.5	-0.4
KASHIMA-YARIGATAKE				14.9	13.4	15.2	15.5	13.4	12.5	13.2	—	—	—	14.0	16.3
36 36	137 45	2410		13.1	12.7	14.4	14.0	13.5	12.3	13.0	13.8	13.4	12.0	13.3	14.9
				1.8	0.7	0.8	1.5	-0.1	0.2	0.2				0.7	1.4
TATEYAMA-MURODO				14.0	12.8	13.8	13.7	12.9	10.1	13.4	13.1	12.6	15.2	13.2	14.7
36 34	137 36	2454		12.9	12.4	14.1	13.8	13.3	12.0	12.8	13.6	13.2	11.8	13.0	14.7
				1.1	0.4	-0.3	-0.1	-0.4	-1.9	0.6	-0.5	-0.6	3.4	0.2	0.0
MITSUMATARENGEDAKE				—	12.4	13.5	14.3	13.8	11.7	12.6	13.1	13.3	12.4	13.0	15.0
36 24	137 37	2552		12.5	12.2	13.6	13.3	12.9	11.7	12.4	13.1	12.8	11.4	12.6	14.2
					0.2	-0.1	1.0	0.9	0.0	0.2	0.0	0.5	1.0	0.4	0.8
NORIKURADAKE				11.6	10.1	12.6	12.8	12.3	9.6	13.4	14.4	12.6	11.0	12.0	14.2
36 08	137 33	2730		11.6	11.2	12.7	12.4	12.0	10.8	11.4	12.0	11.7	10.4	11.6	13.3
				0.0	-1.1	-0.1	0.4	0.3	-1.2	2.0	2.4	0.9	0.6	0.4	0.9
ONTAKESAN				—	9.3	11.2	9.7	11.0	8.8	11.0	10.5	9.8	13.4	10.5	12.9
35 54	137 31	3060		10.0	9.6	10.9	10.9	10.5	9.7	10.3	10.8	10.4	9.3	10.3	11.4
					-0.3	0.3	-1.2	0.5	-0.9	0.7	-0.3	-0.6	4.1	0.2	1.5
HAKUSAN-MURODO				13.1	12.6	14.1	14.1	14.5	11.8	13.9	14.1	13.8	13.1	13.5	15.7
36 09	136 46	2450		12.8	12.4	13.9	13.7	13.2	12.2	12.9	13.5	13.3	11.8	13.0	14.7
				0.3	0.2	0.2	0.4	1.3	-0.4	1.0	0.6	0.5	1.3	0.5	1.0
KISO-KOMAGATAKE				13.0	11.2	13.7	16.2	14.2	12.0	13.5	15.8	10.3	13.5	13.3	15.7
35 47	137 49	2623		12.2	11.8	13.3	13.0	12.4	11.8	12.3	12.9	12.6	11.3	12.4	13.8
				0.8	-0.6	0.4	3.2	1.8	0.2	1.2	2.9	-2.3	2.2	0.9	1.9
KITADAKE				13.4	10.5	12.6	12.5	12.4	10.2	11.2	11.9	10.2	10.2	11.5	15.4
35 40	138 14	2890		11.0	10.6	11.9	11.7	11.3	10.6	11.1	11.7	11.4	10.3	11.2	12.3
				2.4	-0.1	0.7	0.8	1.1	-0.4	0.1	0.2	-1.2	-0.1	0.3	3.1
CHAUSUDAKE				13.6	13.4	14.8	14.8	14.3	12.1	13.5	14.0	13.7	12.8	13.7	16.2
35 22	138 09	2400		13.2	13.1	14.3	14.0	13.3	13.1	13.4	13.9	13.8	12.4	13.5	15.0
				0.4	0.3	0.5	0.8	1.0	-1.0	0.1	0.1	-0.1	0.4	0.2	1.2
YATSUGATAKE				14.6	12.8	16.0	15.3	15.1	11.3	14.2	13.0	13.8	12.4	13.9	17.2
36 00	138 22	2330		13.6	13.5	14.9	14.4	13.8	13.0	13.4	14.3	14.0	12.6	13.8	15.4
				1.0	-0.7	1.1	0.9	1.3	-1.7	0.8	-1.3	-0.2	-0.2	0.1	1.8
KUMOTORIYAMA				—	—	—	17.2	16.3	16.2	15.1	17.5	16.8	15.4	16.4	—
35 51	138 57	1820		16.2	16.4	17.7	17.0	16.2	16.0	15.6	16.9	16.6	14.8	16.2	18.2
							0.2	0.1	0.2	-0.5	0.6	0.2	0.6	0.2	
TANZAWA-TOHNOTAKE				18.7	18.7	19.8	18.7	18.6	17.3	17.4	19.2	18.7	16.8	18.4	21.8
35 27	139 09	1491		18.1	18.3	19.4	18.6	17.7	17.6	17.1	18.6	18.3	16.2	18.0	19.8
				0.6	0.4	0.4	0.1	0.9	-0.3	0.3	0.6	0.4	0.6	0.4	2.0
FUJISAN				6.9	4.6	7.3	6.5	7.8	4.1	—	7.9	5.3	6.0	6.3	7.3
35 21	138 44	3775		6.6	5.8	7.1	7.3	6.9	6.5	7.3	7.3	6.9	6.1	6.7	7.1
				0.3	-1.2	0.2	-0.8	0.9	-2.4		0.6	-1.6	-0.1	-0.4	0.2

MTN: mountain air temperature, FRE: free-air temperature, DRC: temperature difference between mountain air and free air, AVG1: average during 1971-1980, AVG2: average on days when the Ogasawara high is extended, —: missing