# Changes in Meteorological Environment by Development of Motooka, Fukuoka Pref. (2) : Original Situation Before Development

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# Changes in Meteorological Environment by Development of Motooka, Fukuoka Pref. (2) – Original Situation Before Development –

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Motooka district is scheduled to be a new campus for Kyushu University. We have been conducting meteorological observations to obtain the data that evaluate the environmental change over the future development since June 1994. In the present study, we compared meteorological data of Motooka (from June 1994 to December 1999) obtained with those of urban area to clarify the differences of climates between both areas. The original condition before the urbanization in Motooka was approximately 1.5 °C lower than Fukuoka the year round. While the maximum air temperature in Motooka was nearly equal to Fukuoka in winter and lower about 1 °C in summer, the minimum air temperature in Motooka was 2–4 °C lower than Fukuoka both in summer and winter. The trend of the absolute humidity in Motooka increased every year. In last 3 years, it exceeded about 4 g/m$^3$ than Fukuoka in summer season. This difference of humid condition between Motooka and Fukuoka should be brought by the differences of ground surface between both areas. The data suggests that the less conversion of solar radiation into latent heat in urban area causes the high temperature in summer daytime.

## INTRODUCTION

Motooka district about 15 km NW of Fukuoka City is scheduled to be a new campus for Kyushu University. The region of about 2,750,000 m$^2$ shall be greatly changed from the ground condition fully covered with the vegetation such as forests and farmlands into that of less vegetation and partly flat with many buildings.

We have focused to elucidate meteorological changes that will be brought by such big development. The assessment is important not only for Kyushu University but also for environmental problems. In this respect, we have been conducting meteorological observations of the Motooka site since 1994.

As we can obviously find in the process of heat island phenomenon in urban areas, urban constructions have brought special urban climates. We considered that decrease of vegetation, that is less conversion of solar energy into latent heat transfer, chiefly contributes to the climatic changes over the development.

In the present study, first we compared meteorological data obtained with those of urban area to clarify the differences of climates between both areas. Second, we exam-

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ined the meteorological improvement of vegetation on local thermal environment.

## OBSERVATION

### Observation site and Components

The Motooka district is in the middle of Itoshima Peninsula in the west end of Fukuoka City, Fukuoka Prefecture. Meteorological observations in Motooka district have been conducting since June 1994.

Figure 1 shows locations of observation points. For continuous observation, the main

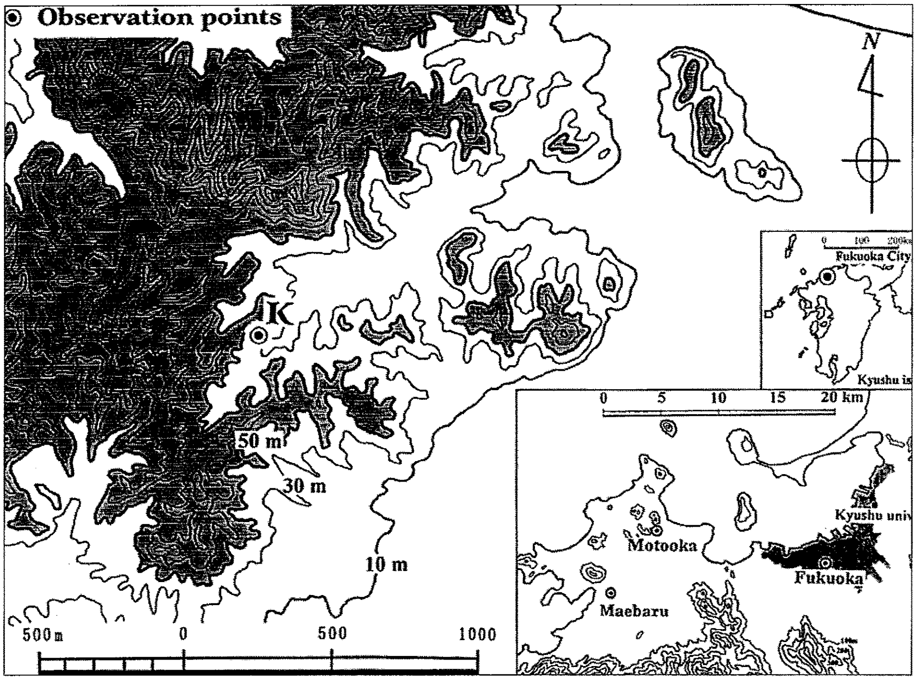


**Fig. 1.** Locations of observation points.

**Table 1.** Measuring instruments at Motooka (K–point) observation station.

| Observation Elements | Height (m) | Sensor type | Interval |
|---|---|---|---|
| Air temperature | 1.4 | Platinum resistance thermometer | 10 min |
| Relative humidity | 1.4 | Capacitive hygrometer | 10 min |
| Wind direction/Wind speed | 6 | Windmill anemometer | 60 min |
| Global solar radiation | 6 | Photodiode pyranometer | 10 min (integrated) |
| Reflectance of solar radiation | 1.2 | Photodiode pyranometer | 10 min (integrated) |
| Net radiation | 1.2 | Thermopile radiometer | 10 min (integrated) |
| Soil temperature | 0.1, 0.3 | Thermistor thermometer | 10 min |
| Precipitation | 0.45 | Tipping–bucket rainguage | Real time |

observation station was set up at point K, where is not scheduled to be changed geographically in the future development. The point K is placed on the south side of a ridge that runs along the valley in the SW–NE direction. Many weeds were rampant from summer to autumn around the observation station and they withered in winter, which is an important requirement for the heat balance of the ground. Table 1 shows a list of observation items for routine observations.

**Data collection and field measurement**

We began the meteorological observation on June 14, 1994. The data collection was conducted every four week and weed managements of point K were done 3–4 times during summer. We used the data of Fukuoka and Maebaru districts measured by Fukuoka district meteorological observatory and AMeDAS Maebaru respectively.

## RESULT AND DISCUSSIONS

We analyzed meteorological data of Motooka (from June 1994 to December 1999), mainly on air temperature and humidity taking the data of Fukuoka and Maebaru into account. From the viewpoint of urbanization, these three places may be regarded as follows; Motooka as rural, Maebaru as suburban, and Fukuoka as urban respectively.

**Basic Thermal environment of Motooka**

The annual mean climatic data are shown in Table 2. On the mean air temperature, Motooka was substantially lower than Fukuoka and Maebaru throughout the year. By averaging, air temperature in Motooka was about 1.5 °C lower than Fukuoka and about 0.7 °C lower than Maebaru.

The characteristics of thermal environment in each site could be given more expression by using general climatic index. Figure 2 and Figure 3 show the occurrence of tropical days (daily maximum air temperature exceeds 30 °C) and torrid nights (daily minimum air temperature exceeds 25 °C) respectively. The occurrence of torrid nights in Motooka was only a few days in contrast with much more frequent occurrence in Fukuoka, which is a typical heat island phenomenon.

The changes in the maximum and minimum air temperature in Motooka and Fukuoka are shown in Figure 4 and differences of both temperatures in Figure 5. The magnitude of difference of the minimum air temperature between the two sites was larger than that of the maximum air temperature. A lot of works have been made for several cities in Japan, these tendencies mostly agree with present observations. However, as for the maximum temperature, we should consider each background of observation sites, that is, in Motooka they should rise because it is set up on the slope exposed to SE where receive more solar energy in comparison with flat ground, and in Fukuoka they should drop because of the large pond near by (Katayama et al., 1987).

Seasonal variations of the differences (Motooka–Fukuoka) in the maximum and minimum air temperatures are shown in Figure 6. Here, we used the mean air temperature at Fukuoka as the horizontal axis, which is assumed to be the seasonal variation of air temperature. The right and left sides of the horizontal axis in this Figure correspond to summer and winter respectively. The difference in the minimum air temperature

**Table 2.** Observed values of some climatic elements.

| Year | | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|
| Mean Temperature | (°C) | | | | | |
| Motooka | | 14.8 | 15.0 | 15.4 | 16.5 | 15.5 |
| Fukuoka | | 16.5 | 16.6 | 17.1 | 18.1 | 17.1 |
| Maebaru | | 15.4 | 15.7 | 16.2 | 17.1 | 16.2 |
| Maximum Temperature | (°C) | | | | | |
| Motooka | | 18.7 | 19.6 | 20.3 | 21.4 | 20.4 |
| Fukuoka | | 20.2 | 20.5 | 21.0 | 21.9 | 21.1 |
| Maebaru | | 19.3 | 19.7 | 20.1 | 21.1 | 20.2 |
| Minimum Temperature | (°C) | | | | | |
| Motooka | | 9.2 | 10.5 | 10.9 | 12.1 | 11.2 |
| Fukuoka | | 13.1 | 13.2 | 13.8 | 14.8 | 13.7 |
| Maebaru | | 11.3 | 11.5 | 12.1 | 13.3 | 12.2 |
| Relative Humidity | (%) | | | | | |
| Motooka | | 79 | 82 | 84 | 87 | 86 |
| Fukuoka | | 68 | 68 | 67 | 70 | 68 |
| Absolute Humidity | (g/m$^3$) | | | | | |
| Motooka | | 12.3 | 13.6 | 14.1 | 15.5 | 14.7 |
| Fukuoka | | 12.3 | 12.5 | 12.4 | 13.7 | 12.7 |
| Wind speed | (m/s) | | | | | |
| Motooka | | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| Fukuoka | | 2.7 | 2.8 | 2.8 | 2.7 | 2.8 |
| Precipitation | (m/s) | | | | | |
| Motooka | | 1826 | 1384 | 1872 | 1907 | 1777 |
| Fukuoka | | 1593 | 1276 | 2083 | 1866 | 1662 |
| Maebaru | | 1640 | 1275 | 1900 | 1706 | 1677 |

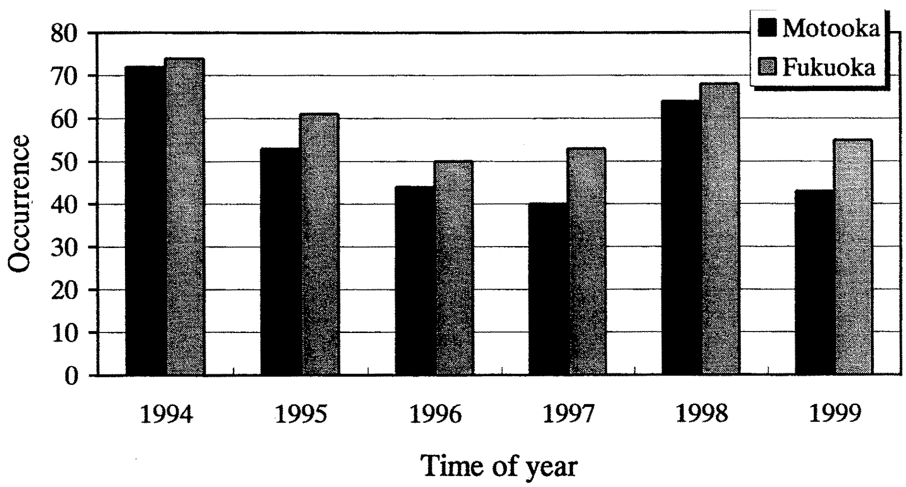


**Fig. 2.** Annual occurrence of tropical days at Motooka and Fukuoka.

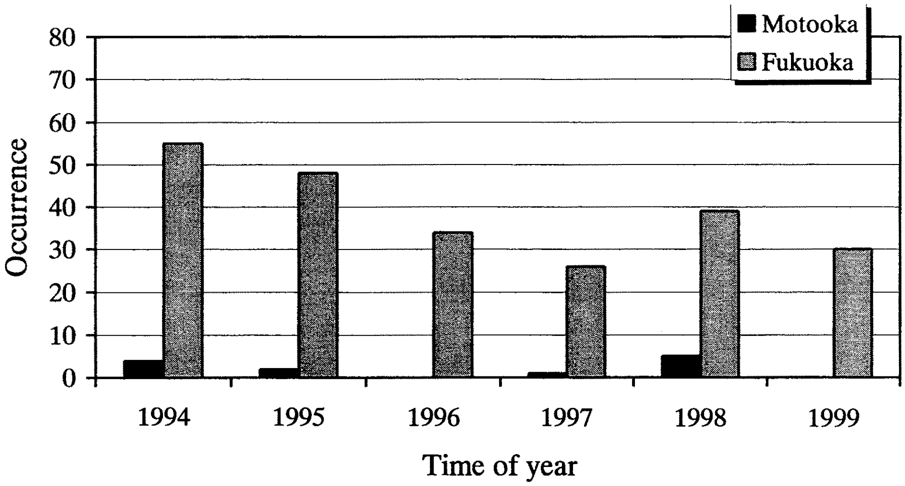


**Fig. 3.** Annual occurrence of torrid nights at Motooka and Fukuoka.

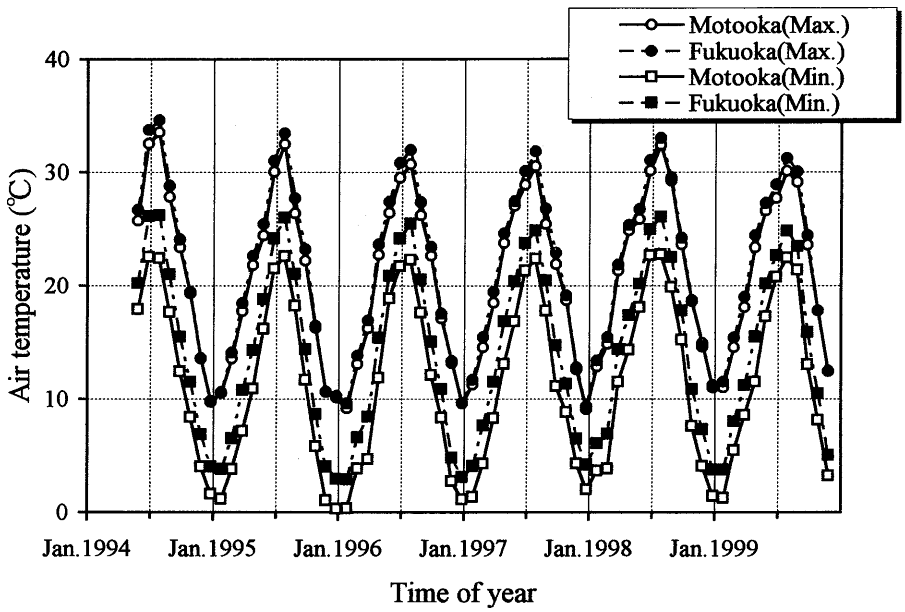


**Fig. 4.** Annual variations of the maximum and minimum air temperature at Motooka and Fukuoka.

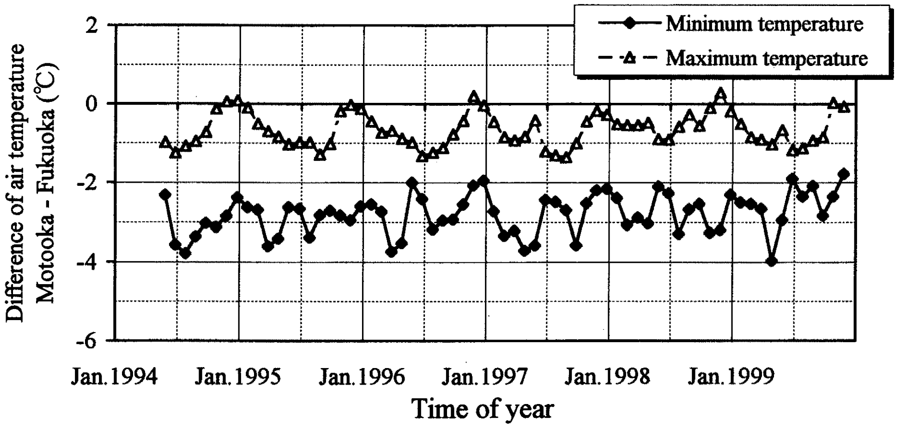


**Fig. 5.** Annual variations of difference in each maximum and minimum air temperature between Motooka and Fukuoka.

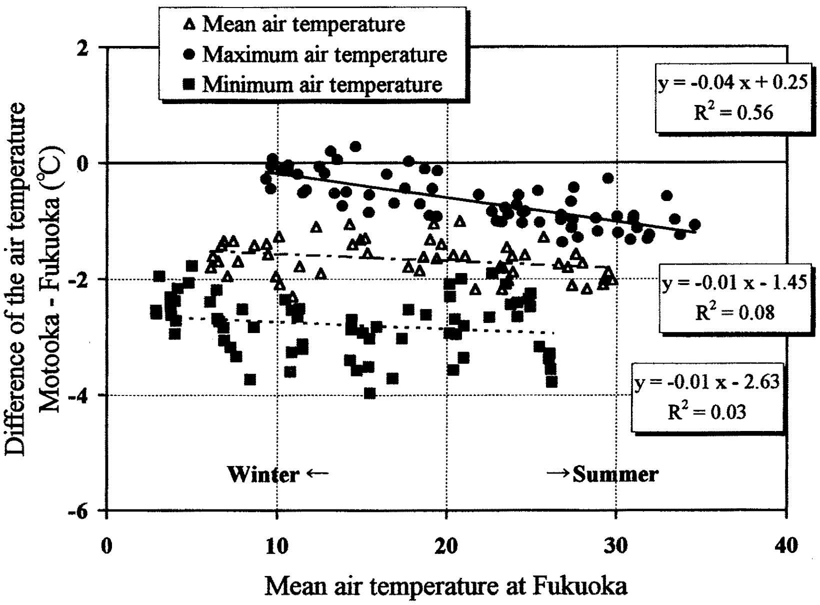


**Fig. 6.** Seasonal variations of difference in the monthly mean air temperatures between Motooka and Fukuoka (June 1994–December 1999).

between Motooka and Fukuoka fluctuated throughout the year from -2 °C to -4 °C. On the other hand those in the maximum air temperature varied from near zero during winter to almost -1 °C during summer. These tendencies of daytime air temperature suggested the meteorological improvement by vegetation during summer.

Figure 7 is a plot of the minimum versus the maximum air temperature on each site. These two plots are substantially in parallel and seemed to vary their slope with temperature in detail. The shape of these plots would show their meteorological characteristics. They naturally ought to be projected on the same line as these two sites are close to each other. Thus, it means that there exists a difference in features of ground surface affecting the thermal environment between Motooka and Fukuoka. Moreover, the plot of Motooka seems to vary its slope with temperature in detail. We consider there is something affecting the thermal environment in Motooka not in Fukuoka especially during summer.

As the ridge surrounding observation site in Motooka significantly reduces the wind speed (Suzuki *et al.*, 1996), we should take the exchange rate of atmosphere that relates to accumulation of heat into consideration. We examined the relation between the differences in the maximum air temperature of two places and wind speed on fair day

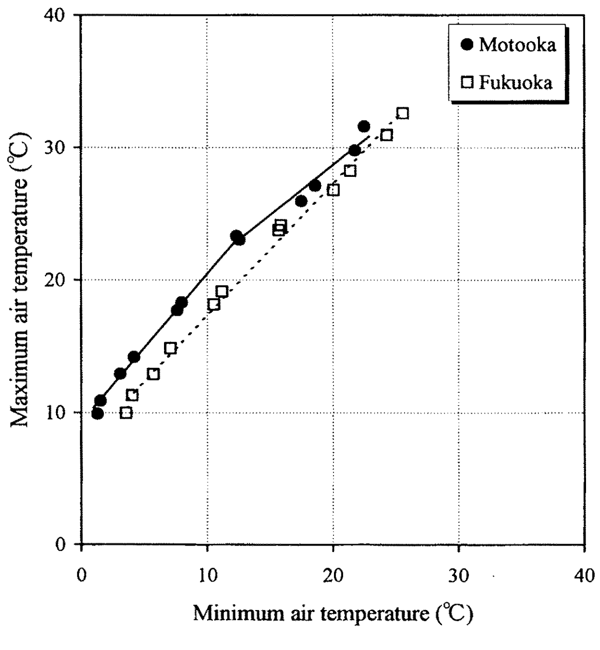


**Fig. 7.** Relations between maximum and minimum air temperature at Motooka and Fukuoka.
The plot is average value of 1995–99 for each month.

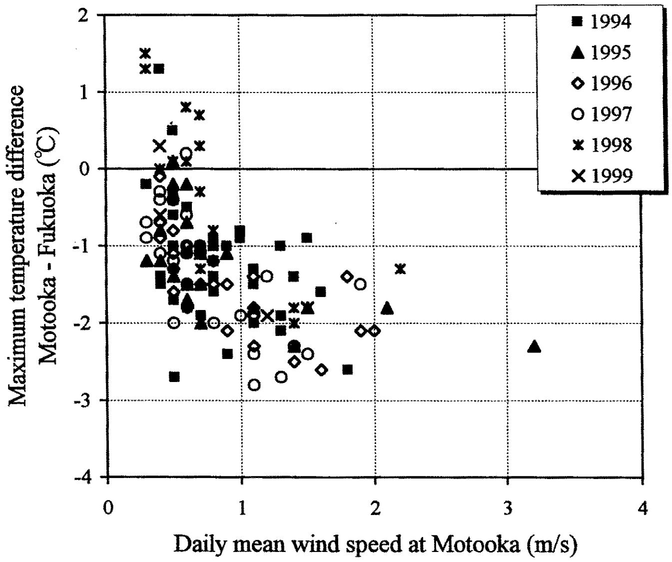


**Fig. 8.** Relations between differences in the maximum air temperature based on Fukuoka and wind speed at Motooka.
Each plot is sampled on fair day without rainfall during summer (>20MJ/m², July to September).

(daily integrated solar radiation exceed 20 MJ/m²) during summer (July to September) (Figure 8). Certainly the differences in the maximum air temperature magnified with increase in wind speed. As the strong wind interrupts the interior air of the valley forming the boundary layer in Motooka, simultaneous occurrence of the mixing of air with comparatively cooler air above and the acceleration of the evapotranspiration on the ground should bring this tendency.

## Humidity

Many studies on the humidity of the city agree with the point that relative humidity in urban areas is lower than that of rural because of the urban thermal (Oke, 1978). Relative humidity in Motooka changes about 10% higher than Fukuoka annually. The changes in absolute humidity in each site and difference between them are shown in Figure 9 and 10 respectively. These higher relative humidities in Motooka do not depend only on lower temperatures but also on more water vapor in the atmosphere than Fukuoka. Moreover, the absolute humidities in Motooka are increasing year after year, while those in Fukuoka change very little from 1994 to 1999. In last three years, the difference between them exceeded 5 g/m³ during summer, and annual mean value was about 2 g/m³ in 1999. This difference in absolute humidity is much larger in comparison with the measurements in London about 0.3 g/m³ (Chandler, 1967) and also larger than in Edmonton, Alberta about 1.5 g/m³ (Hage, 1975), which is the largest value of a day. Taking that they are the data

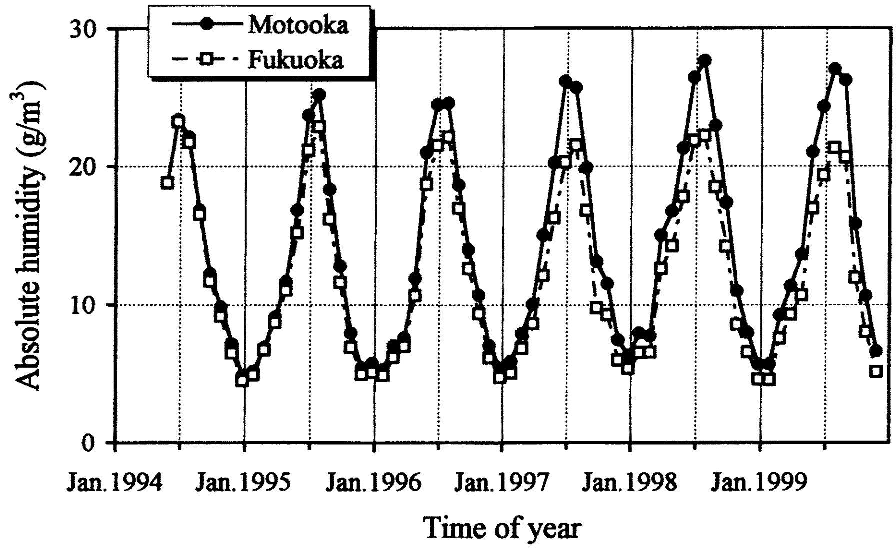


**Fig. 9.** Annual trends of absolute humidity at Motooka and Fukuoka.

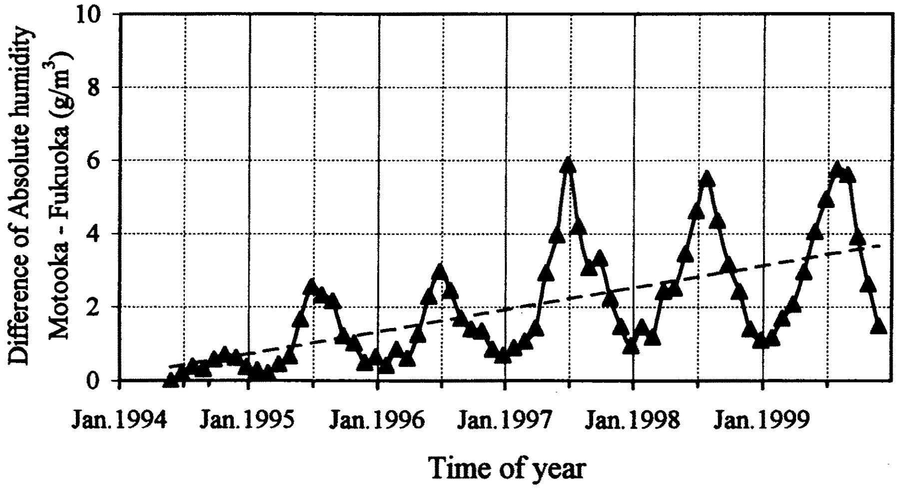


**Fig. 10.** Annual trends of difference in absolute humidity between Motooka and Fukuoka.

obtained in foreign countries into account, the value should be comparatively smaller than hot and humid country such as Kyushu Island, Japan.

We studied the effect of precipitation for these increase in absolute humidity considering the difference of the ground condition between rural and urban areas. Figure 11 shows the relation between the differences in absolute humidity and totalized–rainfall amount during summer (from June to September). Here we use the neglected amount over 30 mm/day in daily precipitation referring to the observation by Suzuki (1973) on the volcanic ash soil in Southern Kyushu Island as it should not contribute to the soil moisture. In the last 6 years, increase in absolute humidity corresponds to the precipitation. The water vapor in urban area seemed not to depend on rainfall because of rapid runoff over the ground surface.

Moreover, we recognized that many weeds have grown thickly and covered the whole secured area for new campus, where had been cultivated before in Motooka. Such change in the surface conditions of the ground around the observation site should cause the increase in absolute humidity.

Absolute humidity dependent on the maximum air temperature is shown in Figure 12. Although this humid condition should be partially brought by geographical feature in

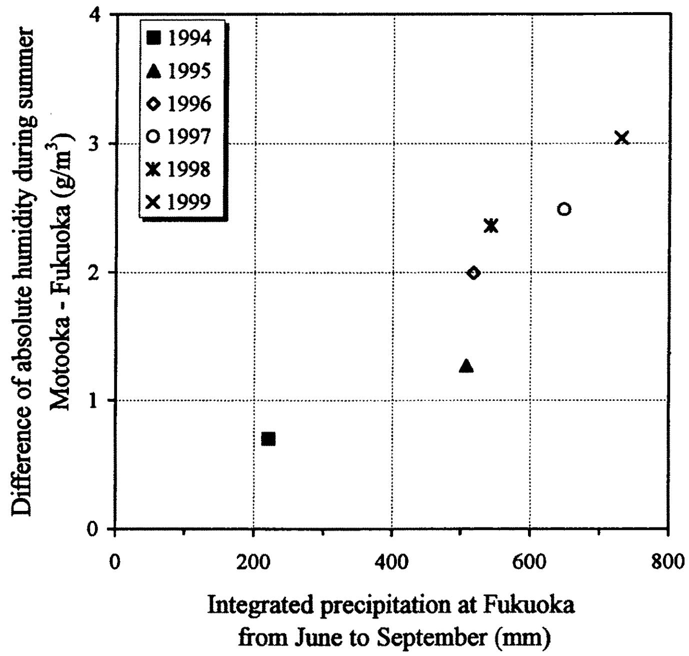


**Fig. 11.** Relationship between difference of absolute humidity (Motooka–Fukuoka) and integrated precipitation.
The precipitation was integrated for the value below 30 mm/day of daily value

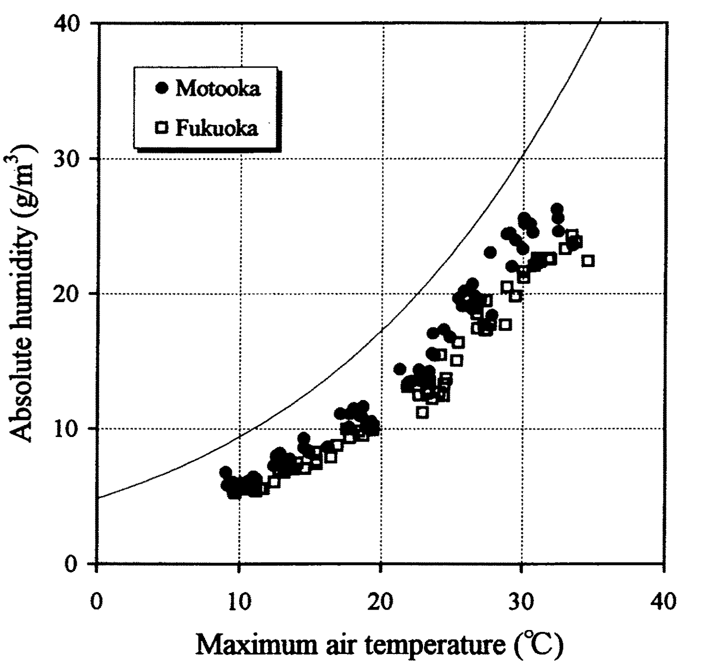


**Fig. 12.** Difference of combinations of the absolute humidity and the maximum air temperature on each month between Motooka and Fukuoka.
The data were sampled from June 1994 to December 1999, and the curve shows the saturated water vapor.

Motooka, the source of the water vapor is undoubtedly ground surface, which is evapotranspiration. We consider these differences in humidity between Motooka and Fukuoka could show the abundance of vegetations in Motooka and dryness of Fukuoka simultaneously.

## CONCLUSION

Some of the conclusions drawn from these results are as follows:

1. On the mean air temperature, Motooka was about 1.5 °C lower than Fukuoka all the day and the year round.
2. On the maximum air temperature, Motooka was nearly equal to Fukuoka in winter, and lower about 1 °C in summer.
3. On the minimum air temperature, Motooka was 2–4 °C lower than Fukuoka both in summer and winter.
4. The difference of maximum air temperature between Motooka and Fukuoka expanded with increase in the solar radiation and the wind velocity.

5. On the relative humidity, Motooka was about 10% higher than Fukuoka.
6. On the absolute humidity, Motooka increased every year, and about 2 $g/m^3$ moister than Fukuoka. This increase could be related to soil water capacity.

Although these results mostly agree with widely accepted opinions, the magnitudes of difference in absolute humidity between Motooka and Fukuoka is quite large, which may be attributed to the greater evapotranspiration in Motooka than Fukuoka.

## THANKS

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