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Micrometeorological Observations in the Islamabad-Rawalpindi Area, Pakistan

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ABSTRACT

Micrometeorological observations were conducted in the semiarid region of Islamabad-Rawalpindi, the capital district Pakistan. The area of open space that is planted densely in the planned city of Islamabad is far greater than that in Rawalpindi. Results showed that the temperature in Islamabad was 2°C lower and the relative humidity was 10% higher than those in Rawalpindi. It is considered that Islamabad area is cooled by a somewhat greater wind speed than Rawalpindi and the latent heat of evapotranspiration from the green spaces and bodies of water.

1. Introduction

Green space has various effects on our living environment and particularly its existence is significant in arid and semi-arid climatic region[2] . Islamabad, the capital of Pakistan, is one of those cities planned and built with an affluent amount of open space in the area of harsh environmental condition. A great number of trees planted in the area 20 years ago have created a thick layer of greenery over the urban space in a sharp contrast with landscape of the surrounding desert area [1, 3] . The objective of this micrometeorological surveys conducted in the area is to examine characteristic meteorological features due to the effects of urban greenery in this semi-arid region.

2. Observation methods

A series of movement observations operated with an automobile was conducted to investigate the relationship between temperature distribution and amount of greenery in Islamabad in 1988. Since a number of species of trees planed 20 years ago have grown in various height and density, traveling within the city area is almost like moving through a wide variety of green space, and the movement observation method is suitable for research of the effects of greenery under those conditions.

The north-western area (dotted area in Fig. 1 and

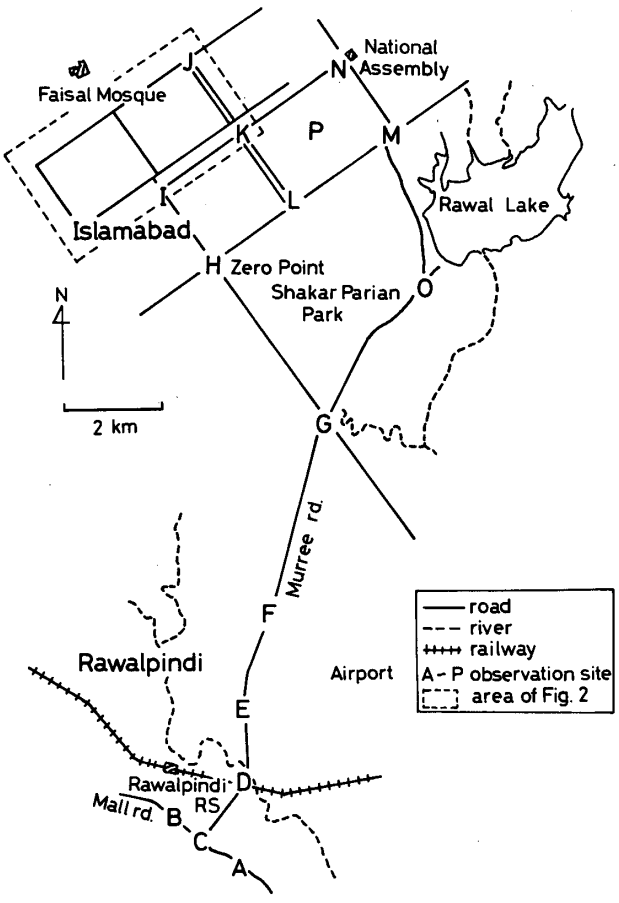

Fig. 1. Observation area of Islamabad and Rawalpindi. The area surrounded by dashed lines is the observation area in 1988. A through P indicate the observation points in 1990.

Fig. 2) of the city was selected for the observation and the distribution of temperature and humidity were measured at each point moving by an automobile. Height of the observation was approx. 1.2 m above ground level. Digital temperature and humidity sensor (SATO KEIRYOKI, SK-70TRH) was used to measure air temperature and relative humidity. The sensor was set up 10 cm out of the automobile window and average speed of the automobile was approx. 20 km/hr. The observation started at 12 : 11 and continued through 12 : 44 in August 23th, 1988. Two rounds of observation within a time interval were conducted along the course of 11 points indicated in Fig. 2. Since the day was fine and the observation time was near the midday, the error of the observed value due to time difference at each point seems to be negligile.

The observation in 1990 was conducted to investigate the differences of the micrometeorological features between Islamabad and Rawalpindi. Observation terms are as follows: instantaneous solar radiation (IIODENKI, S-SR2) ; mean wind speed, mean air temperature, and mean relative humidity for 10 seconds (KANOMAX CLIMOMASTER model-6511) ; instantaneous temperature of sky, ground surface, dry black surface, and wet black surface by radiation thermometer (TASCO THI-300). Objective emissivity was assumed to be unity. The temperatures of the dry and wet black surfaces were measured on both sides of two aluminum disks 0.12 mm of thickness and 70 mm of radius adhered by black gauzes. The wet disk was damped by a water spray. Wind direction and weather were observed with the eyes. All the instruments were equipped on a tripod set at the observation point on sidewalks of streets. The height of instruments is about 1.5 m above the ground level. The movement from a point to the other was by an automobile.

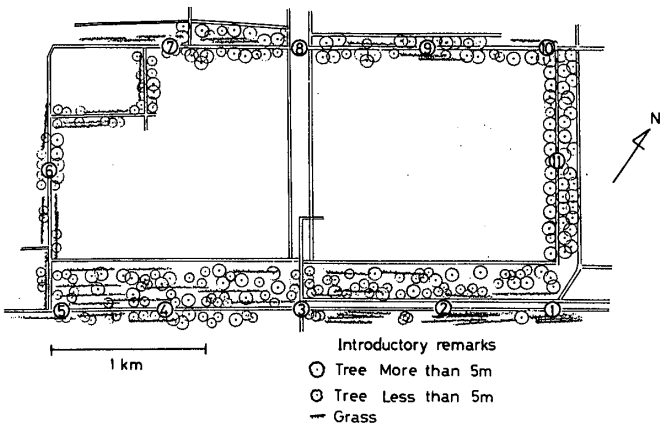

Fig. 2. Observation area in north-western part of Islamabad with vegetation features (The area surrounded by dashed lines in Fig. 1). The number indicates observation point.

The observation point in Islamabad and Rawalpindi area are shown in Fig. 1. After the initial observation in front of Hotel Holidy (point A) in Rawalpindi until 10 : 30, a series of observation started with point B and continues through O in alphabetical order. Thereafter, it continued from point G through E, C and E in Rawalpindi and point M, L, K and J in Islamabad. After 14 : 00, observations in Argentina Park (point P in Fig. 1) were conducted at five points moving on foot. The point indicated in Fig. 4 to Fig. 7 follows this order of the observation. Point A through F belong to Rawalpindi, point I through P belong to Islamabad, and point G and O do not belong to any of those. Point H was excepted because the value was largely deviated from others observed in Islamabad area.

The north-western side of the city area of Islamabad is edged by mountains higher than 1,000 m above sea level and the area surrounded by point G, H, L, M, O and G is forested on the altitude lower than 600 m. Rawal Lake is located in the eastern side of the point M and O. Point D, E, F, G, O and M are along Murree Road which is a main trunk road in the region. Point D is at the crossing point of the trunk of Pakistan Railroad and Murree Road. Point A, B, C belong to the newly developed area of Rawalpindi. Point F ("Committee Chauk") and F ("Chandni Chauk") along Murree Road were selected as representing the old town district of Rawalpindi. The observation was conducted on November lst, 1990. The day was a fine and calm, and cloud amount was zero throughout the day.

3. Results and considerations

(1) Temperature distribution and greenery in Islamabad (observation in 1988).

The vegetation along the course observation is

shown in Fig. 2. The number in the figure shows the location of the observation point. The observed values of air temperature and relative humidity at each point are indicated in Fig. 3. The inclinations among the each point are almost same between two times of observation, though there shows a little difference between two sets of observed values. Relationship between the temperature and the humidity is reversed as observed in general.

Temperature range in the area was 30.4°C to 31.9°C and a significant difference of 1.5°C was found in such a small area. The lowest temperature was observed at the point No. 11. Points No. 3 and No. 4 showed a relatively high temperature. It is considered that the temperature on the road becomes mild as the street trees grew thick overcasting shadows on the point No. 11. Also, it is considered that temperature increase was caused by heat absorption on the road at point No. 3 and No. 4 where no large street tree exist. However, it is necessary to discuss through the detail observations on the relationship between existence of street trees and the difference of air temperature.

(2) Meteorological difference between Islamabad and Rawalpindi (observation in 1990)

The observed results of the air temperature in Islamabad and Rawalpindi are shown in Fig. 4a. The points along the street in Islamabad are indicated by white circles, those of Rawalpindi are by black, and the values of point G and O located in the middle of two cities are by triangles in the figure. Point H is located on a street in Islamabad, but observed values of air temperature, shown in parenthesis, was largely apart from those of the near points, so that it was excepted from the following analysis. Area of Islamabad and Rawalpindi is indicated by "I" and "R" at the top of the figure respectively.

As mentioned before, the observation was started at the points in Rawalpindi. The temperature increased as time went on. It is seen from the points in the figure that the temperature drifted the lower side by about 2°C on the street in Islamabad after 11 : 16. The trend of temperature change differs clearly from that in Rawalpindi. After the first round of observation on the street in Islamabad, it was observed at point E (sec-

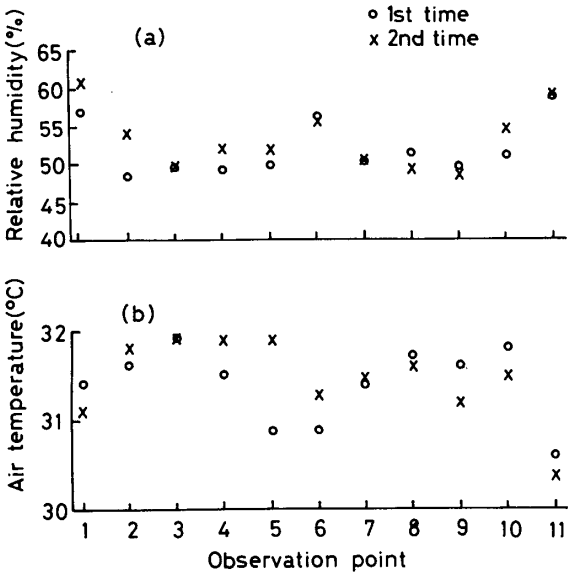

Fig. 3. Relative humidity (a) and air temperature (b) at the observation point indicated in Fig. 2. ○ indicates the first round of observation and × indicates the second.

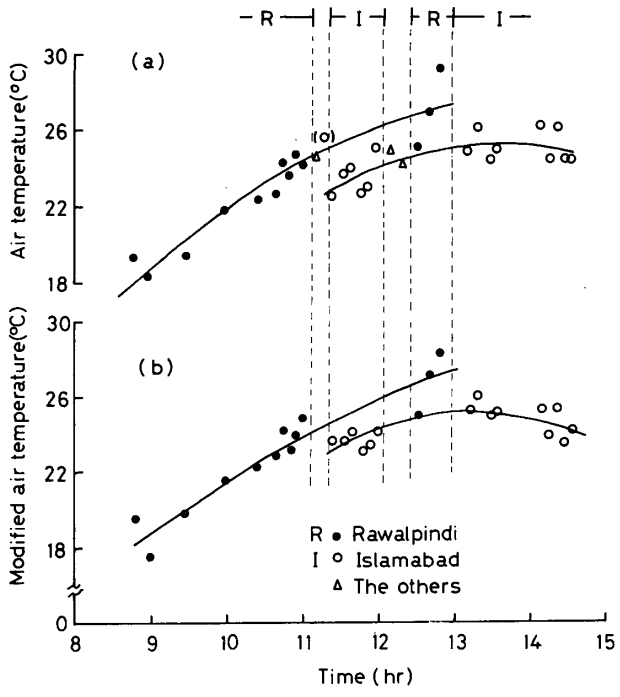

Fig. 4. Temperature distribution in Islamabad and Rawalpinidi. (a) is raw value of air temperature, (b) is air temperature corrected with wind speed. ● within the range of "R" divided by dashed lines indicates values in Rawalpindi, ○ within "I" is Islamabad, and △ is the point in the middle. These symbols are same in the following figures.

ond), C, and E (third) in Rawalpindi. Those values are shown by three black circles in the figure. Point E of the first observation and the third were exactly same spot, however point of the second observation was located across the road. Also, in spite of only 19 minutes of time difference between the second observation and the third at the point E, a large temperature difference was observed. The causes of this temperature difference would be considered that the wind speed at the third point was very weak (see Fig. 5) and ray of the sun was much stronger on the northern side of the road, though the second point, the southern side, was also full of sunshine. After the third observation at the point E, the observation continued through point M, L, K, and G in Islamabad. The last five points were in Argentina Park.

Regression equation calculated with black circles in the figure is;

$$Y_1 = -0.16x^2 + 5.85x - 20.45$$

and with white circles

$$Y_2 = -0.49x^2 + 13.32x - 65.47$$

where Y_1 and Y_2 are air temperatures of Rawalpindi and Islamabad, respectively. x is time. Two regression curves obtained above are shown by solid lines in the figure. The equations indicated that the temperature in Islamabad was lower than that in Rawalpindi by 2.0°C at 12 : 00.

As shown in Fig. 5, the wind speed was weak throughout the observation day. It will be supposed generally that higher the wind speed lower the air temperature. If it was assumed that the temperature

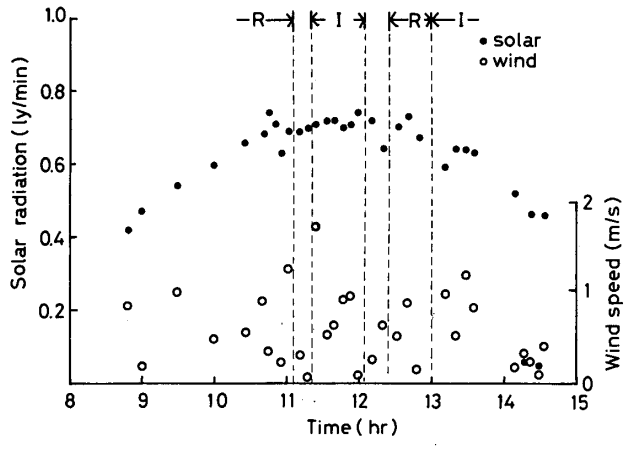

Fig. 5. Observation values of solar radiation and wind speed. Symbols are same as Fig. 4.

difference between the second and the third observation at the point E with negligible time difference depended on wind speed only, temperature difference 4°C would be caused by the difference of wind speed of 0.4 m/s. This is an extremely large difference. However, the observed values of temperature were corrected assuming that the temperature difference of 2°C would be arisen from the wind speed difference of 1 m/s on the basis of mean wind speed of 0.6 m/s. The results are shown in Fig. 4b where the solid lines are the regression curves of Islamabad and Rawalpindi respectively. The equation for Rawalpindi is

$$Y_1' = -0.19x^2 + 6.29x - 22.66$$

and for Islamabad

$$Y_2' = -0.64x^2 + 17.01x - 87.50,$$

where Y_1' and Y_2' are modified temperatures of Rawalpindi and Islamabad, respectively. It is observed that scattering pattern of the values reduced in comparison with that of the raw observed values. The temperature difference between Islamabad and Rawalpindi reduced more or less compared with those in Fig. 4a. It means that the wind speed in Islamabad is larger than Rawalpindi and mixing of air near the ground surface is active. However, it is considered that residual temperature difference depends on other factors which will be discussed later.

The wind speed and solar radiation are shown by white and black circles in Fig. 5, respectively. The mean wind speed in Islamabad was 0.3 m/s larger than that in Rawalpindi, though it is obscure in the figure. In spite of zero cloud amount, there were considerable fluctuations of the solar radiation value which will not be explained by observation errors only. It seems that the solar radiation in Islamabad was less than that in Rwalpindi throughout the day due mostly to water amount in air mass. Extremely small amount of solar radiation value was observed at two points after 14 : 00 in tree shades of Argentina Park.

The relative humidity is shown in Fig. 6a. The humidity decreased drastically with passage of time. It is observed in the figure that the relative humidity in Islamabad is roughly 10% higher than that in Rawalpindi. Since the relative humidity depends on air temperature and it is not suitable for comparing the water vapor content in the air, absolute humidity was shown in Fig. 6b for a substitution. Although time

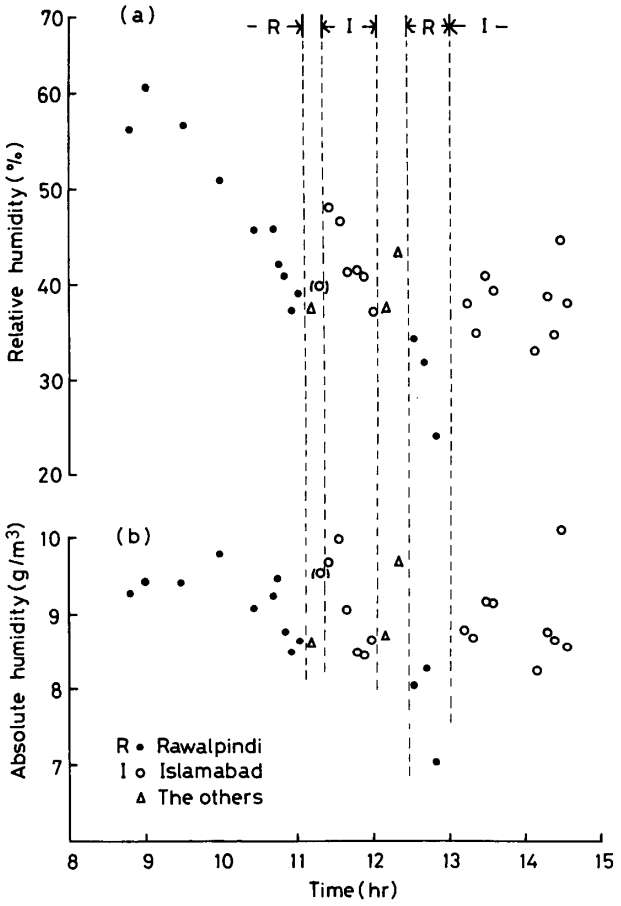

Fig. 6. Observation values of relative humidity (a) and absolute humidity (b). Symbols are same as Fig. 4.

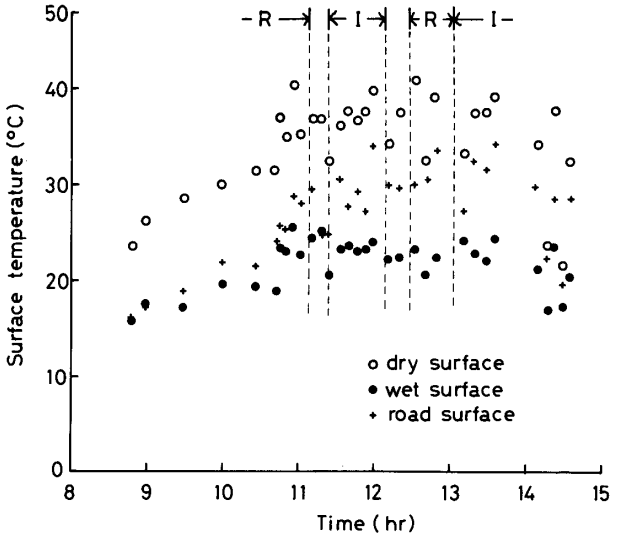

Fig. 7. Observation values of temperature on dry black surface, wet black surface, and ground surface. Symbols R and I are same as Fig. 4.

variation of the absolute humidity is not clear in comparison with that of the relative humidity, it is observed that water vapor amount differ from 0.5 g to 1.0 g per 1 m³ of air mass. If it is considered that the water amount of 1 g was supplied by evaporation, the latent heat decreases the air temperature by 1°C. It may explain the temperature difference between Islamabad and Rawalpindi. Much large number of street tree were planted and grown in Islamabad. Also, wind direction was south to south-east where Rawal Lake and Shakar Parian Park are located. It is considered that such environmental conditions supplied the water by evapotranspiration and contributed to the decreases of the air temperature in Islamabad.

The temperatures of dry black, wet black, and ground surface are shown in Fig. 7. While the dry surface temperature increased in midday, the wet surface temperature was kept low. The temperature difference on the dry and wet surfaces reached 20°C. Since the humidity was low as shown in Fig. 6, cooling effect due to evaporation on the wet surface was large. The road surface temperature was close to that on the wet surface in the morning, but it shifted close to that on the dry surface temperature in the afternoon.

4. Summary

A meteorological observation was conducted in semi-arid region of Islamabad-Rawalpindi capital district of Pakistan. The results showed that the temperature in Islamabad was 2°C lower and the relative humidity was 10% higher than those in Rawalpindi. It is considered that Islamabad area is cooled by a little larger wind speed than Rawalpindi, that is, mixing of upper air and by latent heat of evapotranspiration in the green spaces and bodies of water.

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パキスタンのイスラマバード・ラワルピンディ首都圏地域における微気象観測

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摘　要

半乾燥地帯における緑地の微気象に与える影響を調査するため，パキスタンのイスラマバードとラワルピンディ地域において気象観測を行った．ラワルピンディに対して，計画的に作られたイスラマバードには非常に多くの植物が繁茂している．観測結果は，ラワルピンディに対してイスラマバードの気温が約2度低く，相対湿度は約10%高いことを示した．イスラマバードはラワルピンディより多少風が強く，空気の上下の混合が活発で，そのうえ緑地や近くの湖からの蒸発散の潜熱による冷却効果が働いているものと考えられる．