THE MEASUREMENT OF THE SURFACE TEMPERATURE AT MIZUHO STATION, EAST ANTARCTICA

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Abstract: In 1979, the measurement of the surface temperature was made at Mizuho Station (70°42′S, 44°20′E, and 2230 m above sea level), East Antarctica, by employing three different methods, a platinum resistance thermometer, a pyrgeometer and a radiation thermometer. These instruments were installed at different sites, on the drift snow, on the sastrugi and on the glazed surface.

In winter the surface temperature measured by these different methods is roughly similar, but in spring and summer the surface temperature depends upon the density of snow and the wind speed. Namely, the surface temperature on the glazed surface (multi-year eroded surface with density twice as large as that of the surface of drift snow and sastrugi) is different from that on the surface of drift snow and sastrugi.

Mizuho Station is located in the katabatic wind area where the various forms of snow surface coexist. Therefore, in this paper, it is pointed out that in order to understand the heat exchange at the surface of Antarctica, especially in the katabatic wind area, the distribution of the types of the snow surface and its variation must be studied in addition to the investigation of the micro process of heat exchange for the different types of the surface.

1. Introduction

The Japanese Antarctic Research Expedition (JARE) began in 1979 a three-year project, a polar experiment (POLEX-South), as a subprogram of GARP (Global Atmospheric Research Program) of Japan, in Mizuho Plateau and in the sea ice area near Syowa Station. The aim of the project is to investigate the radiation balance and the interaction of land and sea ice with the polar atmosphere.

In 1979, in order to study the heat exchange between snow and atmosphere, the measurement of the temperature profile in air and snow including the surface temperature and of the wind profile was made at Mizuho Station (70°42′S, 44°20′E), as one of the observations of the project (MAE *et al.*, 1981; WADA *et al.*, 1981). Compared with the measurement of air and snow temperatures, it is very difficult to measure a correct surface temperature. One of the reasons of the difficulty is the fact that an ordinary thermometer covered with a thin layer of snow absorbs solar radiation penetrating through the layer. Another reason is due to the fact that the snow surface is not homogeneous.

Mizuho Station is located in a region which is characterized by the katabatic wind of a velocity 10～13 m/s, and the drifting snow caused by the wind. The katabatic wind and the drifting snow produce various types of snow surface. WATANABE (1978) studied the surface features in Mizuho Plateau and classified them into three major types: dune as a depositional form, sastrugi or smooth surface as an erosional form, and glazed surface as a long-term hiatus form. The glazed surface has higher density, 0.7 g/cm^2, than the density of other forms of snow surface, 0.3 g/cm^2. In 1977, FUJII (1979) observed the seasonal variation of the surface form in an area of 100×100 m at Mizuho Station. From the observation he showed that in summer the glazed surface occupied 80% of the whole area, in autumn and winter deposition and erosion occurred alternately, and in spring the depositional form of snow changed successively into the stable erosional form. The variation of the surface form was explained by FUJII (1981).

It is expected that the absorption and reflection of radiation at the snow surface depends upon the feature of snow surface. In addition, the density of snow also is accounted for. This suggests that the temperature, especially in spring and summer, is possibly different between dune, sastrugi or smooth surface and glazed surface.

In the present investigation, in order to measure the surface temperature three kinds of apparatus were used; a platinum resistance thermometer, a pyrgeometer and a radiation thermometer. The pyrgeometer which detects the surface temperature by receiving long-wave radiation emitted from the surface was installed on a perturbed surface of erosional type. The radiation thermometer which detects the surface temperature by receiving radiation in the infrared region (wave length between 8 and 12 μm) was installed on the glazed surface. In this paper, we report the result of the measurement of the surface temperature using these apparatus and its analysis.

2. Apparatus

Since the pyrgeometer, the radiation thermometer, the platinum resistance type thermometer and the recording system of the observed value were previously reported in detail (MAE *et al.*, 1981), we describe simplly the apparatus including the heating system of the radiation thermometer.

An Eppley precession infrared radiometer (PIR) was used as a pyrgeometer and it was equipped with a hemispherical dome made of silicon to reflect the solar radiation. The pyrgeometer was installed on the lower surface of the platform, facing down to the snow surface as shown in Fig. 8b of the previous paper (MAE *et al.*, 1981). The radiation flux measured with the pyrgeometer was recorded by an analog recorder and a magnetic tape recorder. Using the law of Stefan and Boltzman and assuming that the emissivity from the snow surface was unity, the radiative temperature of the snow surface was computed from the measured radiation flux.

The radiation thermometer was manufactured by Chino Co., Japan. The wave length range detected by the thermometer was between 8 and 12 μm. The thermometer was set in a thermally insulated box in which the temperature of the thermometer was maintained above 0°C by a heater. However, the temperature in the box could not be kept constant during the period of the measurement and it seems that the reference to determine the surface temperature was influenced by the change of the temperature in the box as described in the previous paper (MAE *et al.,* 1981). Therefore, the absolute value of the measurements is reliable only for a short period such as a few weeks.

The thermometer was a platinum resistance type and was set in a metal pipe of 18 cm long and 8 mm in diameter. The thermometer was of the same type as those buried in snow for the measurement of snow temperatures (MAE *et al.,* 1981) and those installed on the 30 m tower for the measurement of the air temperature, though the latter were not set in pipes.

3. Location of Sensors

The sites of the pyrgeometer, the radiation thermometer and the thermometer are shown in Fig. 1. The pyrgeometer was installed on the glazed surface which

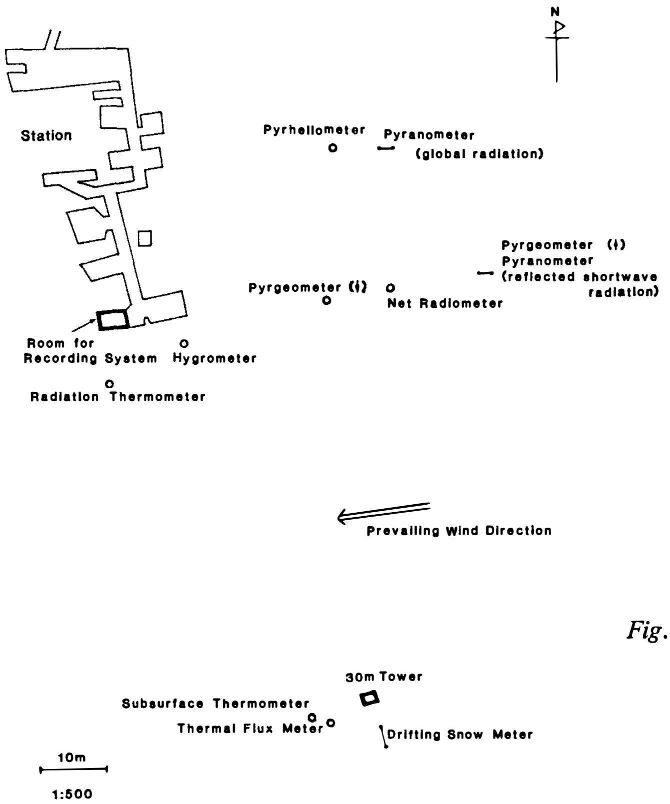

Fig. 1. Sites of the platinum resistance thermometer (subsurface thermometer in the figure), the pyrgeometer (↓ in the figure) and the radiation thermometer.

changed to the erosional surface with a small perturbation of about 10 cm height through the depositional form. The radiation thermometer was installed on the glazed surface of which the state did not change during the period of the measurement. The thermometer was buried in snow below the snow surface. When the drifting snow accumulated, the snow was removed. The feature of the snow surface over the thermometer was, therefore, very similar to the depositional form.

4. Result of Measurement

Figures 2, 3, 4, 6 and 7 show the result of measurement in July, August, October, early December and late December.

4.1. Surface temperature in winter

During the period between 25 and 27 of July, the sun does not rise above the horizon line and the effect of the sunshine to the surface temperature can be neglected. On 18, 19 and 20 of August, the elevation of sun is about 6 degrees at the culmination. In this case, the radiation effect is also negligible.

From Fig. 2 it can be seen that the surface temperatures, T_t and T_p, measured with the thermometer and the pyrgeometer are approximately equal to each other but the surface temperature, T_r, measured with the radiation thermometer is lower than T_t and T_p. As described in the previous section, the absolute value of T_r is not reliable. However, when T_r increases by 2°C, T_r becomes very similar to T_t and T_p as shown in Figs. 2 and 3. This means that, although the absolute value of T_r is not

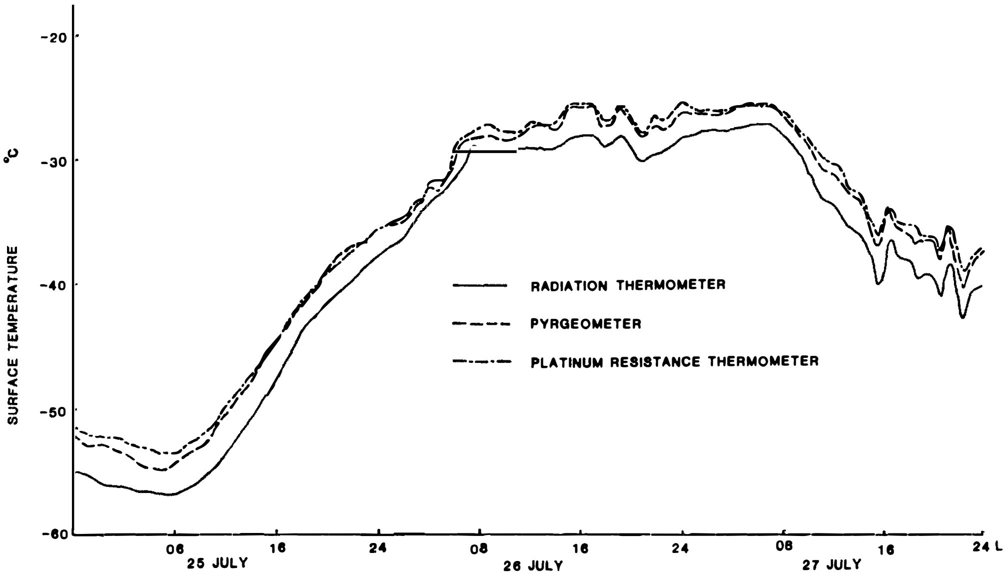

Fig. 2. The surface temperature measured with the three instruments in July.

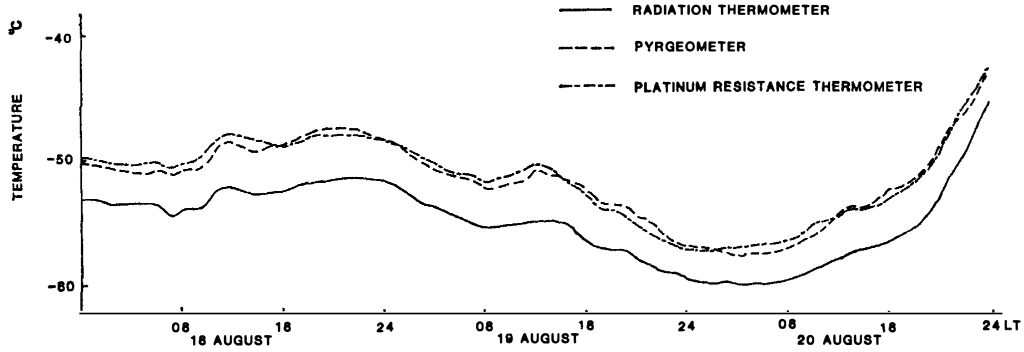

Fig. 3. The surface temperature measured with the three instruments in August.

correct, the relative value of T_r is reliable.

4.2. Surface temperature in spring

In spring the elevation of sun increases and the radiation effect on the measurement of the surface temperature must be taken into account. In Fig. 4 it is shown that T_t is higher than T_r and T_p except at night, but at about 0900 T_t decreases suddenly when the platinum resistance thermometer enters into the shadow area of the 30 m tower. This phenomenon is explained by the heating of the thermometer by the solar radiation, when the snow cover above the thermometer has been removed by wind erosion. Therefore, T_t in daytime may be higher than the correct surface temperature. On the other hand, when the thermometer is buried deep in snow, the variation of T_t is delayed from that of T_r and T_p as shown by YAMANOUCHI *et al.* (1981).

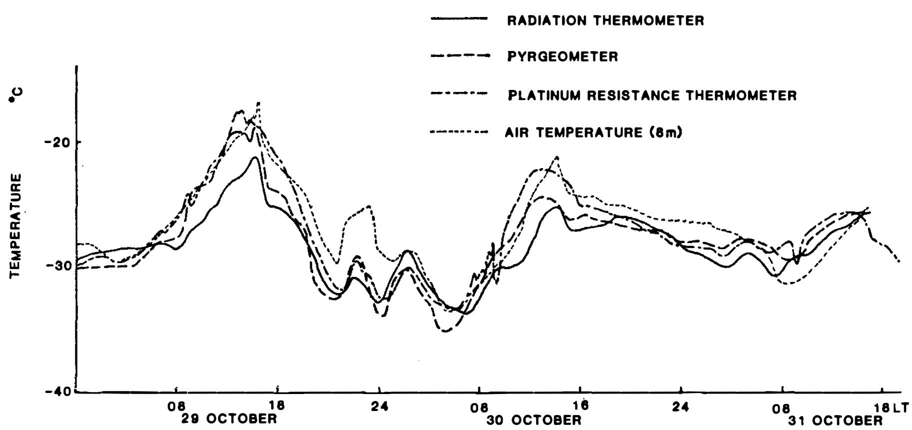

Fig. 4. The surface temperature measured with the three instruments and the air temperature at a height of 8 m in late October.

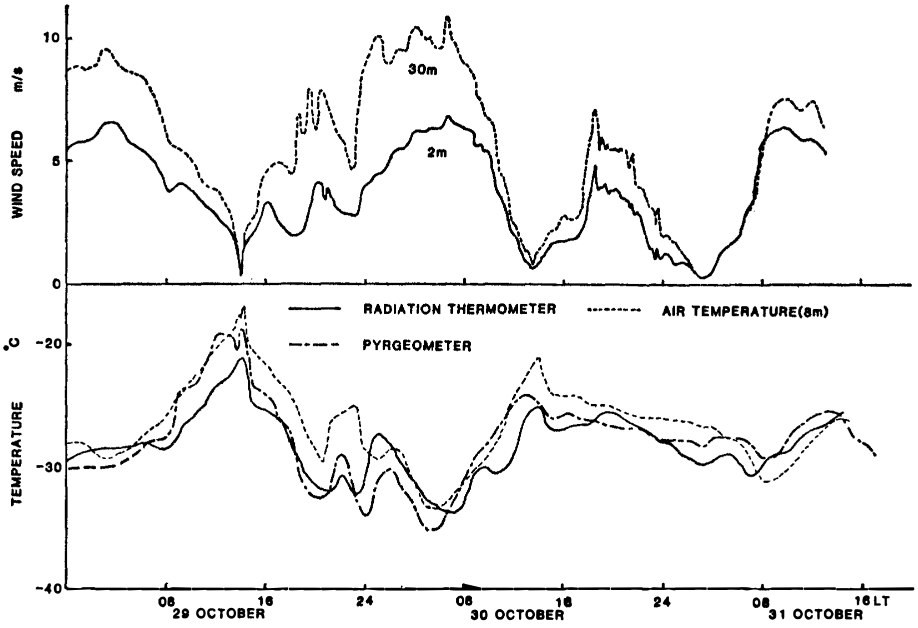

Fig. 5. The surface temperature measured with the radiation thermometer and the pyrgeometer and the air temperature at height of 8 m. The wind speed at the heights of 2 m and 30 m is illustrated.

At night T_r is approximately equal to T_p and T_t as shown in Fig. 4. This means that in this period it is unnecessary that T_r shifts relatively as described in Subsection 4.1. T_p is higher than T_r in daytime, especially around 1200 when the wind speed is extremely low as shown in Fig. 5. At 0300 of 31 October, the wind speed becomes low and T_p is higher than T_r. This phenomenon may occur when the heat exchange due to wind becomes weak.

Since the density of the glazed snow surface is about twice as large as that of the snow surface where the pyrgeometer was set, the heat capacity at the glazed surface is larger than that of the snow surface. This is one of the reasons why T_r is lower than T_p.

4.3. Surface temperature in summer

Figures 6 and 7 show T_t, T_p and T_r in December. From these figures the radiation effect on T_t can be seen. T_r is much higher than T_t and T_p. As described in Subsection 4.1, the absolute value of T_r is not correct but only the relative change of T_r is reliable. Figures 6 and 7 indicate that the curve of T_r between 1200 and 1800 is flat compared with T_t and T_p and it is similar to the air temperature at a height of 8 m. This phenomenon may be explained as follows: Since the heat capacity of the glazed surface is large and the wind speed is minimum at 1800 as

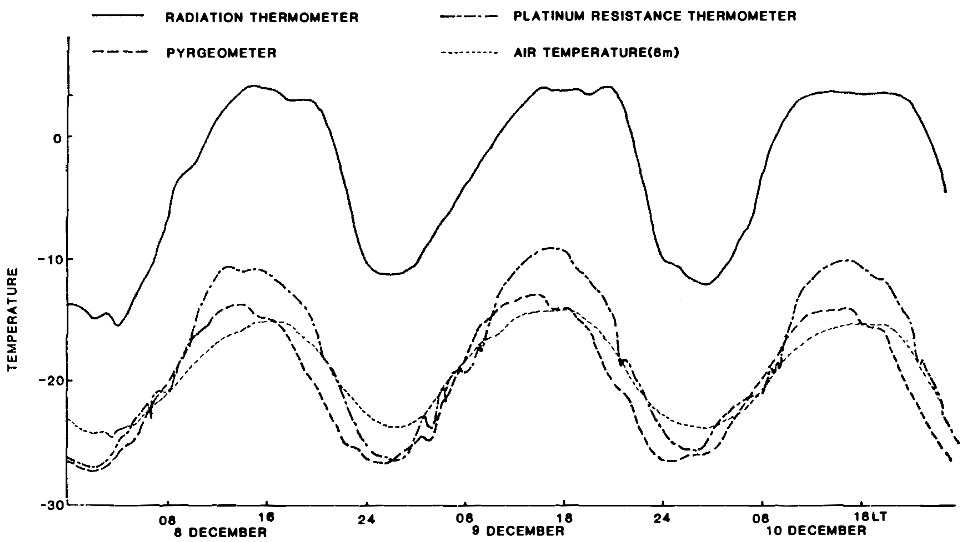

Fig. 6. The surface temperature measured with the three instruments and the air temperature at a height of 8 m in early December.

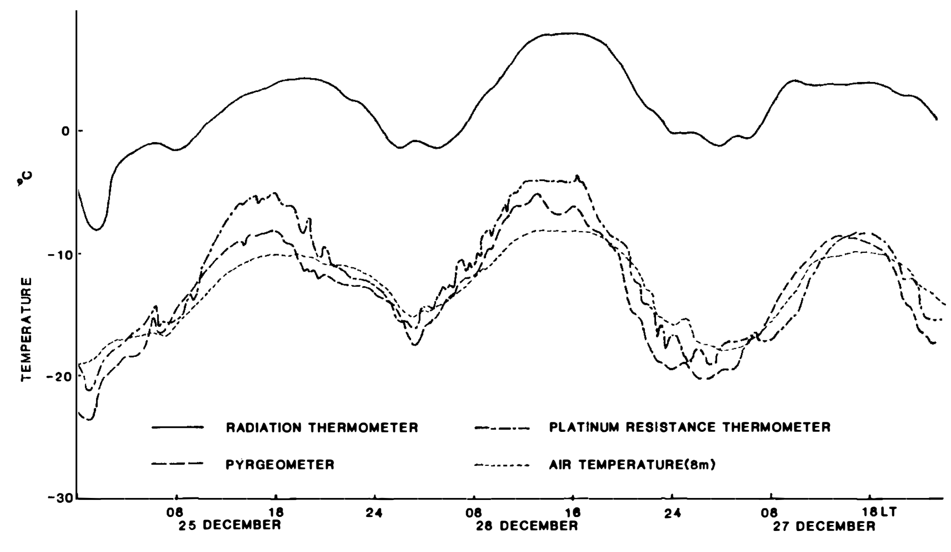

Fig. 7. The surface temperature measured with the three instruments and the air temperature at a height of 8 m in late December.

shown in Fig. 8, the temperature does not decrease until the wind speed increases and the cooling of the snow surface due to wind starts after 1800.

5. Discussion

The measurement of the surface temperature indicates that the surface tem-

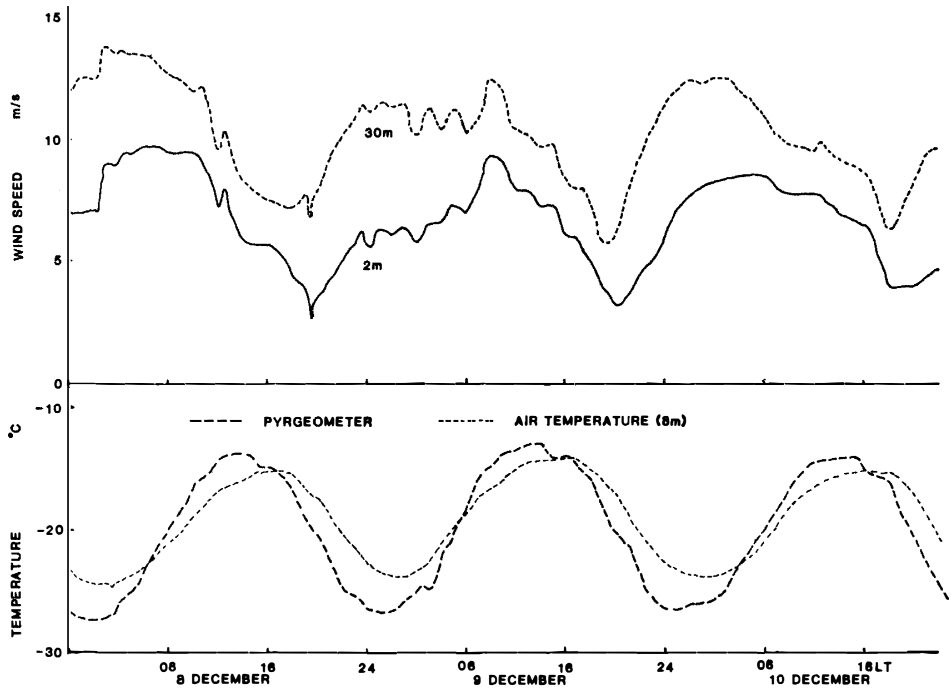

Fig. 8. The surface temperature measured with the pyrgeometer and the air temperature at a height of 8 m. The wind speed at heights of 2 m and 30 m is illustrated.

perature depends upon the property of the surface, glazed surface or other snow surfaces, and also upon the wind speed. However, this measurement is only preliminary so that a more systematic and elucidate measurement must be carried out. For example, we propose that the surface temperature in the area where various kind of the forms of snow surface coexist should be measured by the same type of thermometer.

Though the present study is preliminary, it suggests a very interesting and important fact that the thermal property of snow and the heat exchange at the surface are not homogeneous. Therefore, in order to understand the heat exchange in Antarctica, we must improve and push forward the survey of the distribution and variation of the surface forms, including the study of the micro-process of heat flow at the snow surface.

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