The System of Measurements of Radiation and Micrometeorological Elements at Mizuho Station, East Antarctica: Installation and Performance

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みずほ基地での放射および微気象要素観測システム

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要旨: 1979年から3年計画で南極域観測計画 (POLEX-South) が開始された. 初年度の1979年には，第20次南極観測事業の1つとして，みずほ基地に30mの観測塔を建設，種々の観測センサーを取り付け，放射および接地気層の精密観測を実施した. 放射関係では，地吹雪が雪面を覆う斜面下降風帯の放射特性を明らかにするため，雪面上に直達日射計，4台の全天日射計，4台の雪面反射計，上下向き2台の長波長放射計，熱収支計を設置し，30m観測塔頂部には全天日射計2台，雪面反射計2台，上下向き2台の長波長放射計を設置した.

接地層関係では，30m層内の温度・風分布および雪面下10mまでの雪温分布を主として測定し，斜面下降風および低気圧接近下での接地気層の微気象的特性を観測することを目的とした. このため雪面上に放射温度計，飛雪計を設置，地上30, 16, 8, 4, 1, 0.5mに温度計，風速計を，30, 2mに風向計を，さらに雪面および雪面下10, 5, 3, 1, 0.5, 0.3, 0.1mに温度計，1, 0.5, 0.1mに熱流板を設置した.

これらセンサーからの信号は，みずほ基地内 (雪面下3m) に建設したPOLEX棟で処理し記録した. 記録方式はテープレコーダーに1分間隔でディジタルに記録する方式と打点式記録計でモニター用に記録する方式をとった.

本論文では，これら観測結果の解析に基づいて今後発表される一連の論文の基礎として，観測のシステムと問題点についてのみ記述することとした.

Abstract: The Japanese Antarctic Research Expedition operated a three-year project, Polar Experiment South (POLEX-South), from 1979 when the project was limited mainly to the meteorological program, especially the measurements of radiation and vertical profile of temperature and wind in the lowest 30 m layer at Mizuho Station (70°42′S, 44°20′E, 2230 m above sea level) where katabatic wind blew continuously at a velocity of 12–13 m/s and caused drifting snow. A 30 m tower was erected and instrumented in January 1979 and the meteorological program was operational through 1979 and will continue until 1981.

The radiation measurements of global shortwave, reflected shortwave, and outgoing and incident longwave were made at the snow surface and at the top of the tower. Direct solar radiation and net radiation were measured only at the snow surface. Temperatures were measured at 15 different levels (7 heights,

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surface, 7 subsurfaces). Wind velocities and wind directions were measured at 7 levels and 2 levels, respectively. Drifting snow flux, thermal flux in snow, dew point temperature and pressure were also measured. The recording system included a micro-computer, a data logger, transducers, magnetic tape recorders, analog recorders and printing instruments. The measured values were sampled every minute and recorded by magnetic tape recorder and analog recorders.

This paper mainly describes the installation and performance of the meteorological system set in a cold katabatic wind area such as Mizuho Station.

1. Introduction

Mizuho Station was established in July 1970 at 70°42'S and 44°20'E (Fig. 1) and three to five wintering-over personnel carried out the observations on glaciology and meteorology intermittently during 1970–1975. Since 1976 the station has been occupied continuously. The meteorological observation at Mizuho Station indicated that the katabatic wind of 12–13 m/s blew continuously and caused drifting snow.

As a subprogram, polar experiment in the Antarctic (POLEX-South), of GARP (Global Atmospheric Research Program) of Japan, a three-year project on meteorology and glaciology of the Japanese Antarctic Research Expedition (JARE) commenced in 1979 in Mizuho Plateau and in the sea ice area near Syowa Station. The main aim of this project is to investigate the radiation balance and to understand the interaction of ice sheet and sea ice with the polar atmosphere.

In the first year of the project, 1979, JARE-20 installed 12 radiometers on the snow

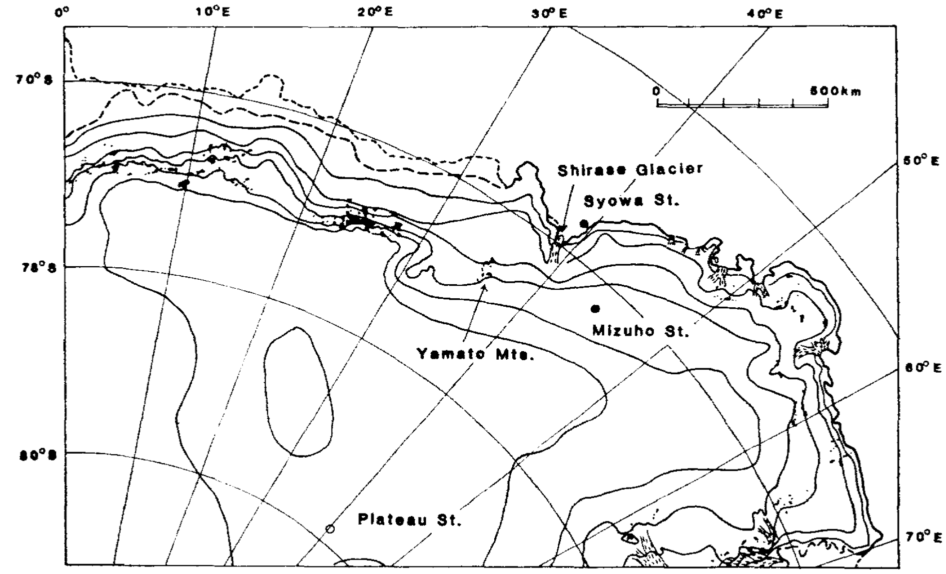

Fig. 1. Location of Mizuho Station.

surface of Mizuho Station for the investigation of radiation. A 30 m tower was erected there and 6 radiometers were installed at the top of the tower for the investigation of the effect of drifting snow to radiation. Seven thermometers, 7 anemometers and 2 wind vanes were equipped to the tower to measure the temperature and wind profile for understanding the structure of the boundary layer. Eight thermometers and 3 thermal flux meters were buried in snow to measure the heat flow in snow. A radiation thermometer was installed on the snow surface for the measurement of the surface temperature. A hygrometer and a barometer were installed to measure the dew point temperature and air pressure. A drifting snow meter was installed to measure the flux of drifting snow. A recording system using magnetic tape recorders and analog recorders were set in a room in the main camp. The data obtained were recorded every minute.

In this paper, the installation and performance of the measurement system in 1979 are described, and the result and analysis of the measurement will be reported in succeeding papers.

2. Tower Installation

Since a strong wind and intense drifting snow was expected to cause difficulty in erecting a high tower, the tower system was planned carefully by the authors and the members of the logistic section, National Institute of Polar Research.

The tower erected at Mizuho Station, as shown in Fig. 2, was the same as the tower of Plateau Station (DALRYMPLE and STROSCHEIN, 1977). Both towers consisted of 17 separates sections made of aluminum-alloy and was manufactured by Up-Right Scaffolds, U.S.A. The site of the tower at Mizuho Station is shown in Fig. 3. The system of the foundation and the anchor was designed by M. SANO, National Institute of Polar Research. Three kinds of foundation material, H-shaped iron beam, plank and timber, were placed horizontally on the snow surface as shown in Fig. 4. The base section of the tower was set on H-shaped iron beams and was leveled. As shown in Fig. 5, the anchor plates for guy cables were constructed from 2 pieces of plank, $0.05\times0.4\times2$ m, which were fixed across and attached with a 3 m wire which was connected with two guy cables by wire strainers. Eight anchors were placed in the pit holes, each $2\times2\times2$ m, which were excavated and then were filled with snow and pressed down by an over-snow vehicle, SM-50.

On 17th of January, 1979, the foundation and the base section were constructed and on the 18th the anchors were set. On the 19th, the whole tower was erected. The first four sections of the tower were pulled up by hand and then the other 13 sections were raised using the SM-50. The sections were put into place by a three-man team

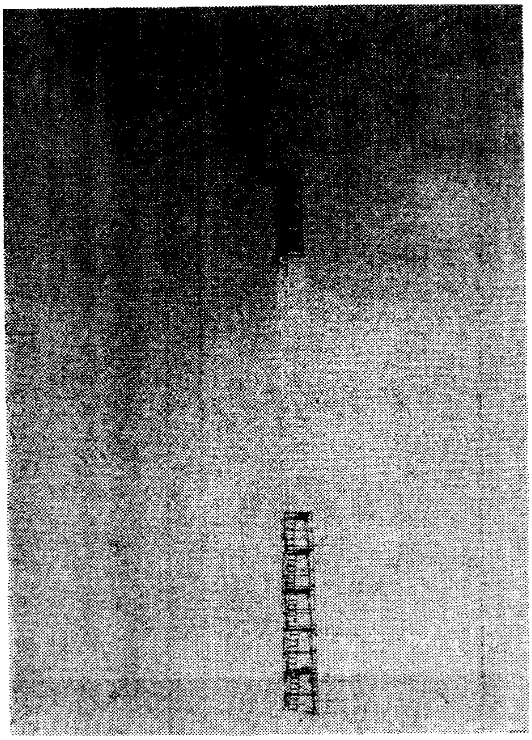

Fig. 2. 30-m tower.

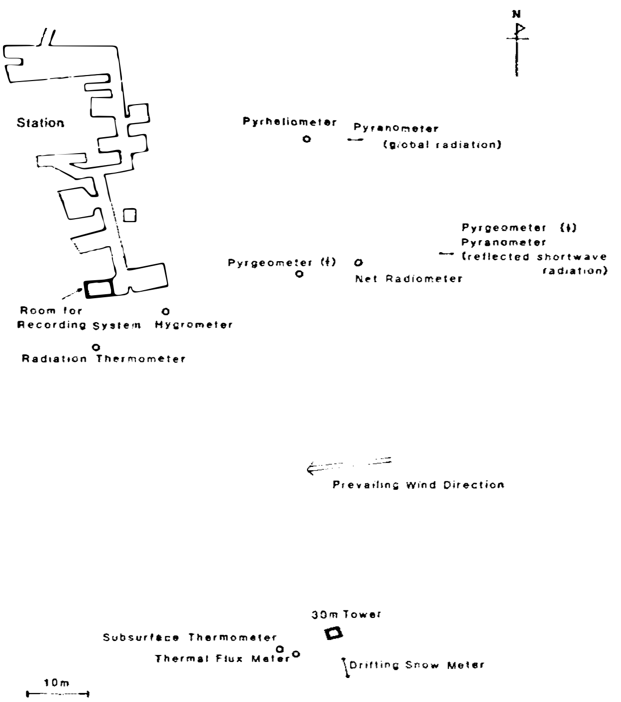

Fig. 3. Site of measurements.

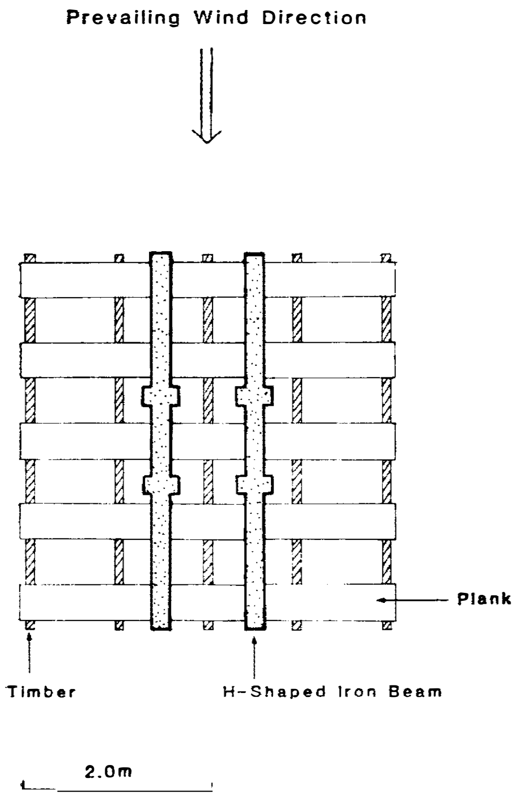

Fig. 4. Schematic diagram of base of tower.

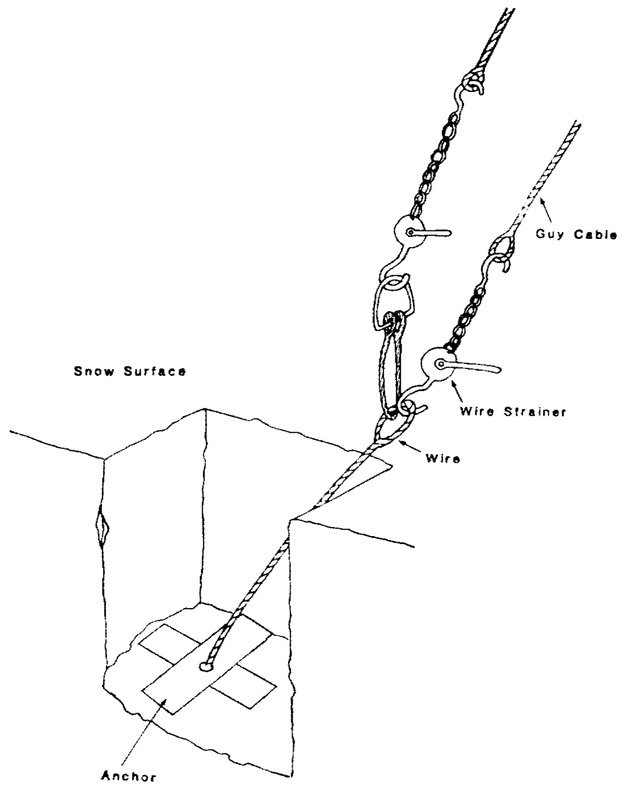

Fig. 5. Schematic diagram of anchor of tower.

and the tower was tightened by 16 guy cables at four different levels. The change of air temperature and wind velocity during the construction period is shown in Fig. 6. In January and February the guy cables were strained every two weeks but after March the straining was carried out only once a month because of hardening of snow.

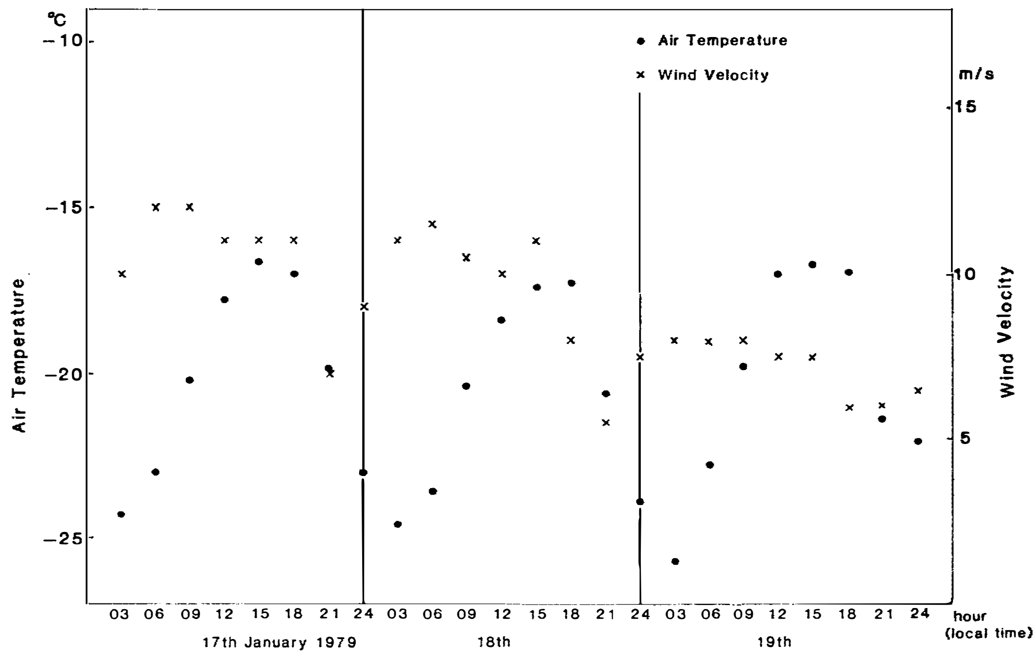

Fig. 6. Temperature and wind velocity during a period of tower installation.

3. Sensors

3.1. Radiometer

The radiometers used for the radiation measurement of global shortwave, reflected shortwave and outgoing and incident longwave are listed in Fig. 7. Eight pyranometers, 2 pyrgeometers, 1 pyrheliometer and 1 net radiometer were installed on the snow surface. The location of the radiometers is shown in Fig. 3. As an example, the installed pyranometers are shown in Figs. 8a and 8b.

In order to investigate the effect of the lowest 30 m air layer and drifting snow to radiation flux by comparing the measurement of radiation flux at the top of the tower with the measurement of radiation flux at the surface, 2 pyranometers and 2 pyrgeometers were set on the platform fixed to the top of the tower as shown in Figs. 9a and 9b.

3.1.1. Pyranometer

Pyranometers (MS-800) manufactured by Eko Instruments Co., Japan, were used to measure the global and reflected shortwaves from the snow surface. The sensor

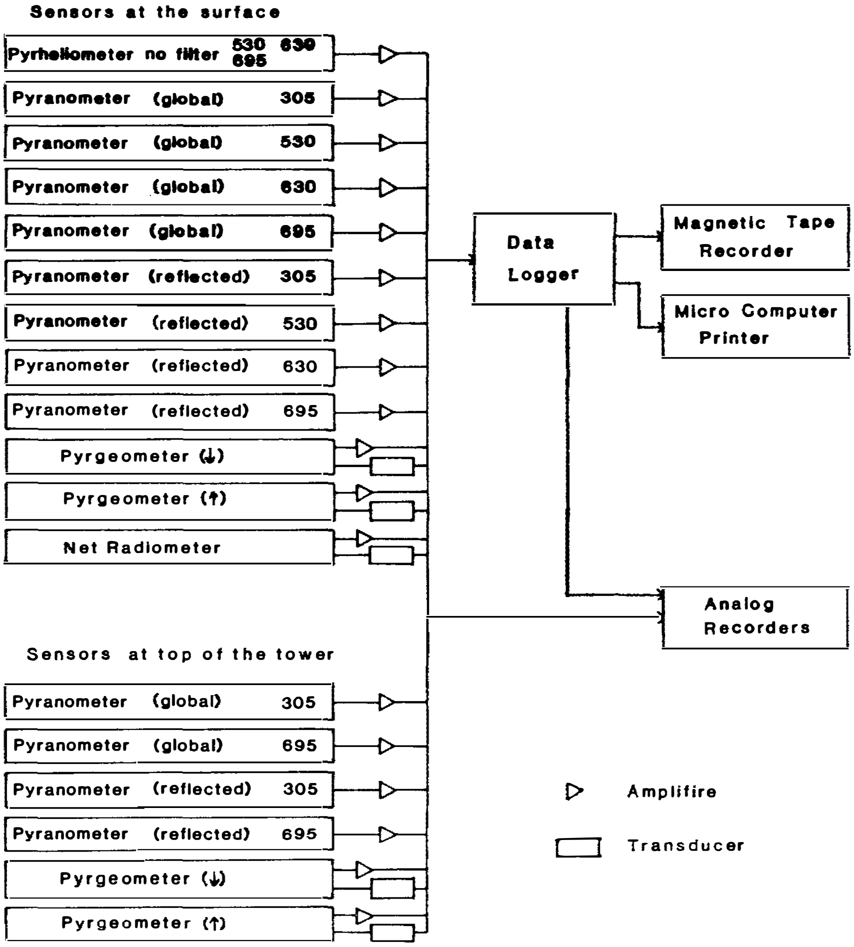

Fig. 7. Measurement system of radiation. Numbers indicate wave length with its unit in μm.

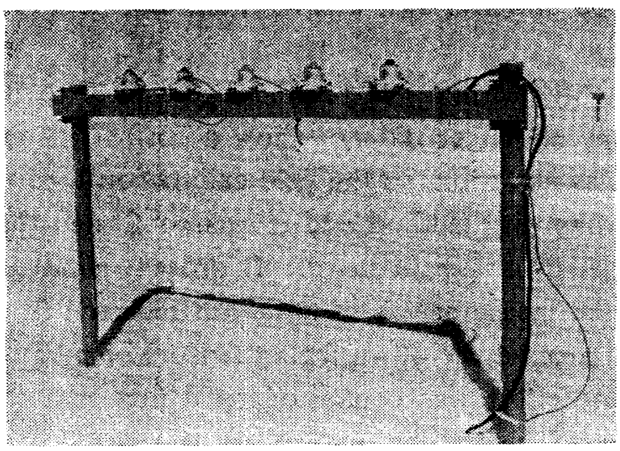

Fig. 8a. Radiometers on snow surface for incident radiation measurements.

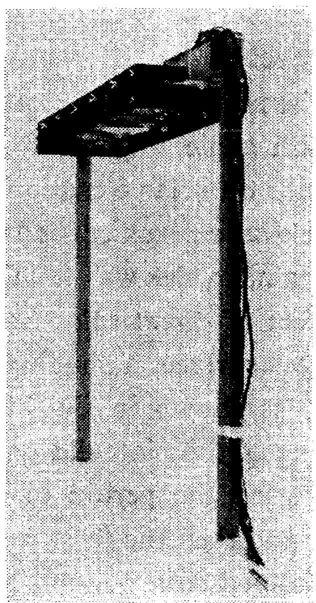

Fig. 8b. Radiometers on snow surface for measurements of radiation from the snow surface.

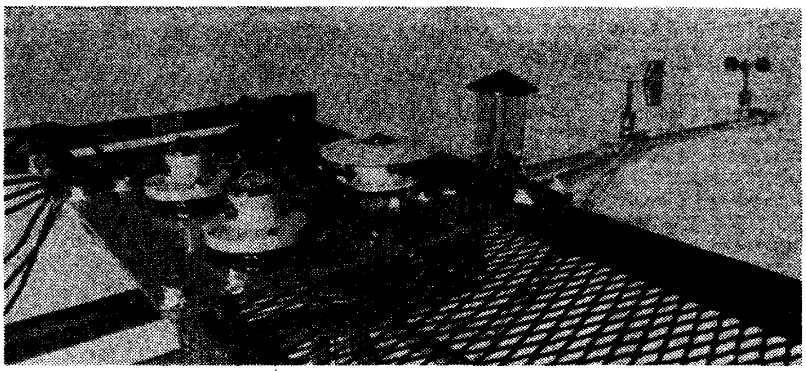

Fig. 9a. Radiometers installed at the top of tower for incident radiation measurements.

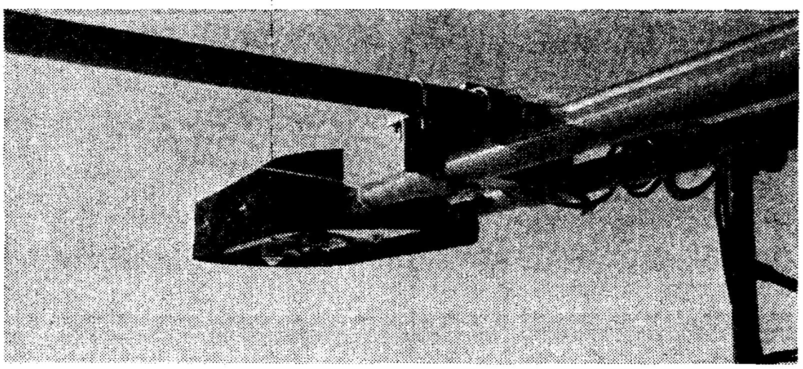

Fig. 9b. Radiometers installed at the top of tower for measurements of radiation from the snow surface.

surface was blackened with Person's black lacer and was covered with double hemispherical cut-off filter domes, one of fused quartz and the other of a colored glass. The pyranometers set on the surface and at the top of the tower were equipped with filters of Schott WG 305, OG 530, RG 630 and RG 695, and WG 305 and RG 695, respectively.

The accuracy of the calibration factor was within $\pm 1\%$ in the region of 0° to 70° in zenith angle. It was found that the pyranometer did not show a cosine law dependence on solar elevation at a small solar elevation, so the field calibration for low solar elevation was carried out by a shading disc method and it was confirmed that the obtained value was equal to that obtained by a pyrheliometer. In order to eliminate the effect of direct solar radiation from the measurement of radiation reflected from the snow surface, a shading plate was set around the down facing sensors of pyranometers as shown in Fig. 8b. The shading effect was confirmed by a fact that the lowering of the plate did not influence the reflected radiation.

During the period of the investigation, sometimes frost deposited on the filter dome, and then the frost was removed by means of cloth or a wood strip. Of course, the obtained data was not reliable before defrosting.

3.1.2. Pyrheliometer

Direct solar radiation was measured with a Eko-MS 52 F pyrheliometer which had an aperture angle of 4 degrees and was equipped with a rotating filter disc which had six windows: two windows without filter, three for Schott OG 530, RG 630 and RG 695 filters standardized by WMO, and one for blind. A controlling motor rotated the disc once a minute. The sensor and filter disc unit was mounted on an equatorial which was worked by a puls motor controlled by a clock which was set in a data logger. The diclination of the sensor was adjusted manually once a few days using sun spot.

A laboratory calibration of the pyrheliometer was made in 1978 by the Japan Meteorological Agency at 20°C and its field calibration was made occasionally at Mizuho Station during a period of the observation against Eppley Angstrom pyrheliometer standardized by IPS-56. These calibrations showed that the temperature coefficient of sensitivity was $-0.13\%/°C$ and the linearity of the sensitivity was $\pm 1.0\%$ for 0–2 ly/min.

3.1.3. Pyrgeometer

An Eppley precision infrared radiometer was used as a pyrgeometer. It was equipped with a hemispherical dome made of silicon. On the inner surface of the dome an interference filter was vacuum-deposited and on its outer surface a weather protective coating was made. This improved the efficiency of reflection of solar radiation compared with the old type radiometer which was reported by ALBRECHT and COX (1977). The temperature dependence of sensitivity of pyrgeometer was $\pm 2\%$ within -20 to 40°C, and the linearity of the sensitivity was $\pm 1\%$ for 0–2 ly/min.

A thermistor-battery-resistance circuit was incorporated in the pyrgeometer to compensate for detector temperature. But the field observation indicated that the efficiency of the battery decreased at low temperatures and if we use this circuit it was unable to obtain the correct radiation flux. The detector temperature and the thermopile output were measured directly and on the basis of the measured values the radiation flux was calculated.

Though the coated dome of the pyrgeometer reflects the solar radiation efficiently, heating due to the absorption of solar radiation still caused the rise in the temperature of the hemisphere dome. A chrome plate ring was equipped to eliminate such heating effect, and it was found that the dome temperature was reduced to that of environmental air.

3.1.4. Net pyrradiometer

The net radiation measurement was made by using an Eko-CN-11 Funke-type net pyrradiometer of which the detector surface was covered with a polyethylene hemispherical dome. A motor-driven fan was equipped to the pyrradiometer in order to inflate the dome by the circulation of air dried by Peltier cooler. Occasionally a black body with a platinum resistance type thermometer was covered over the sensor surface to measure the radiation of upward and downward directions.

The value of radiation measured with the net pyrradiometer was compared with the calculation of net radiation using the result of the measurement of pyranometers and pyrgeometer described in 3.1.1 and 3.1.3. The difference of the radiation flux obtained by both methods was so complicated that the details will be published in other papers on the analysis of radiation measurements.

3. 2. Sensors for measurements of micrometeorological elements

The sensors used and their position are shown in Figs. 3 and 10.

3.2.1. Thermometers

Platinum resistance type thermometers shown in Fig. 10 were used with a Wheatstone bridge to the air temperatures, at heights of 30, 16, 8, 4, 2, 1 and 0.5 m for the investigation of the boundary layer, the surface temperature, and the snow temperatures at depths of 0.1, 0.3, 0.5, 1, 3, 5, and 10 m for the investigation of heat flux in snow. The accuracy of the thermometers was ±0.3°C in the range from 0°C to −40°C and ±0.5°C in the range from −40°C to −70°C. The air temperature thermometers were set in a stainless steel barreled shield with roof as shown in Fig. 11. The shield was not artificially ventilated because the past observation of temperature made at Mizuho Station until 1978 indicated that a strong stationary wind ventilated the shield and the artificial ventilation was unnecessary. The snow temperature thermometers were set in a metal pipe.

3.2.2. Anemometer

Three-cup anemometers (Fig. 11) were set at heights of 30, 16, 8, 4, 2, 1 and 0.5 m for the investigation of boundary layer. The DC-voltage generated by wind was transferred to a tape recording system. The accuracy was within ±0.5 m/s in the range of wind velocity from 0 to 5 m/s and within ±3% in the range of wind velocity from 5 m/s to 40 m/s. The range of the measurement of wind velocity was limited to 40 m/s, because the past record of wind velocity at Mizuho Station indicated that the wind velocity did not exceed 30 m/s.

DALRYMPLE and STROSCHEIN (1977) reported that at Plateau Station the cups of anemometers were checked and cleaned at least once a day because accumulation of snow or frost on the cups changed the momentum of the anemometer. However, at Mizuho Station such checking or cleaning of the cups was almost unnecessary because a stationary strong wind prevented snow accumulation or frost on the cups.

3.2.3. Wind vane

Wind vanes were mounted on the tower at heights of 30 and 2 m, as shown in Fig. 11 and their measurement range was from 0° to 540°. The accuracy of wind direc-

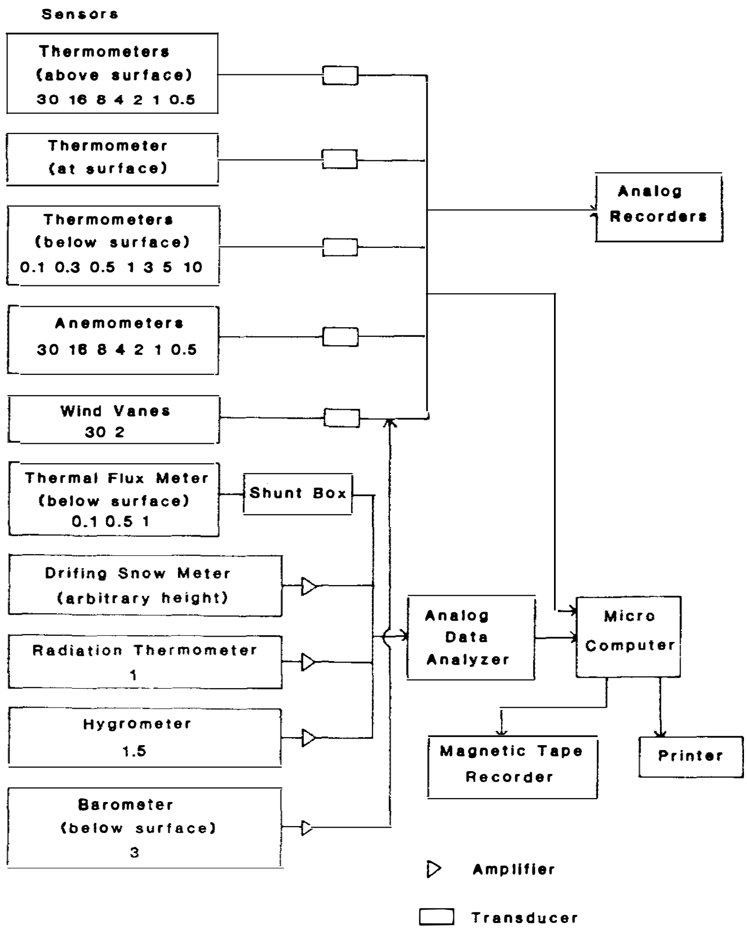

Fig. 10. Measurement system of micrometeorological elements. Numbers indicate height and depth.

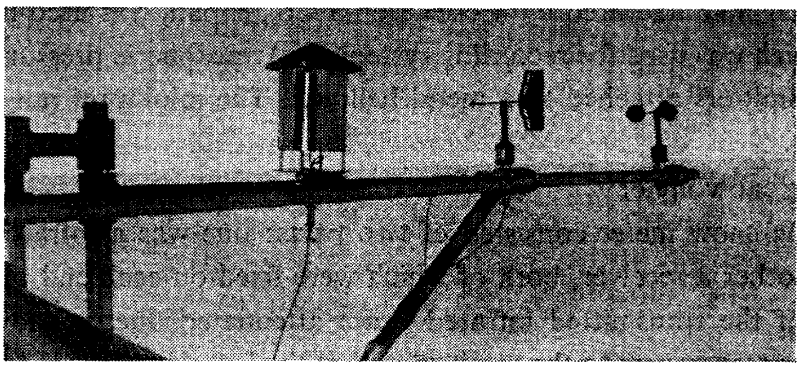

Fig. 11. Instruments for measurements of air temperature, wind velocity and wind direction.

tion was within ±3°. Snow accumulation or frost occurred rarely. True north was determined with a magnetic compass and the error was within ±2°.

3.2.4. Radiation thermometer

A radiation thermometer manufactured by Chino Co., Japan, was set at a height of 1 m in order to measure the surface temperature. The measured area of snow surface was approximately flat and about 80 cm^2 (a circle of 10 cm diameter). The wavelength used was 8–12 μm in an infrared region. The temperature range of the instrument was between 30°C and −70°C. The result of the measurement indicated that the surface temperature measured by this method was approximately equal to that measured by a platinum resistance type thermometer in winter. However, in the summer season, the surface temperature measured with the radiation thermometer became different from the temperature measured using the thermometer. For example, on 25th December 1979 the temperature measured by the radiation thermometer was 15°C higher than that measured by the thermometer. The investigation of the cause of the difference in the measured temperature is under way.

3.2.5. Hygrometer

A hygrometer manufactured by Panametric Co., U.S.A. was used to measure a dew point temperature at a height of 1.5 m. The accuracy and range of the measurement were ±2°C and between −110°C and +20°C respectively. In Antarctica, especially in the inland area, it was very difficult to measure the correct value of dew point temperature because of a very low vapor pressure. Therefore, a laboratory calibration was carried out carefully in 1978 in a cold room at the National Institute of Polar Research.

3.2.6. Barometer

A barometer manufactured by Meisei Denki Co., Japan, was used in a subsurface warm room which was used for recording systems. Atmospheric pressure was detected by quartz transmitters attached to a metal bellow. The minimum range of measurement was 1 mb.

3.2.7. Drifting snow meter

The drifting snow meter consisted of two parts: one was a infrared beam transmitter and the other a receiver, both of which were fixed on each end of a 2.2 m pipe. The intensity of the transmitted infrared beam attenuated due to snow particles on its pass from the transmitter to the receiver so that the intensity detected by the receiver was transferred to the flux of drifting snow. This meter was manufactured by Keiden Co., Japan. The same meter of drifting snow was used to measure the flux of flowing snow in Hokkaido, Japan, before the present observation and the empirical relation between the drifting snow flux and the attenuation of infrared beam was obtained (TAKEUCHI and FUKUZAWA, 1976).

At first the meter was installed at a height of 2 m above snow surface, but the attenuation was not detected because of a dilute flux of drifting snow. Then the meter was reinstalled at a height of 20 cm. In this case, the attenuation was detected but the meter was often buried by snow drift. The details of the result will be reported in the other paper on drifting snow in the near future.

3.2.8. Thermal flux meter

Three thermal flux meters manufactured by International Thermal Instrument Co., U.S.A. were set at depths of 0.1, 0.5 and 1 m. The thermal flux was obtained by the measurement of the temperature difference between the surfaces of a thin polymide-glass plate of which size was $5 \times 5 \times 0.15$ cm.

4. Recording System

4. 1. Recording system of radiometer measurement

The recording system for the radiation measurement (Fig. 7) was designed and manufactured by Eko Instruments Co., Japan. The instrument of the system is shown in Fig. 12. The emf output of the radiometers was amplified to the range of 0–1 V. The outputs of a thermistor in the pyrgeometer and a platinum resistance type thermometer in the net pyrradiometer were modified to 0–1 V range by a transducer. The data were sampled once a minute by a data logger which included a digital clock, an A/D converter, a scanner, a digital display and a central processing unit. Each scan of the data logger was synchronized to the rotation of the filter disc of the pyrheliometer.

Digital data were recorded in magnetic tapes which were used to be analyzed the data using a Hitachi Hitac M 160 II computer at the National Institute of Polar Research. A correct recording in the magnetic tapes was confirmed every day using the digital display system of the data logger. Digital data were also put into a microcomputer and integrated to print out their mean values of every 30 minutes. For the field calibration the data were printed out every minute.

The amplified output from the radiometer was passed through a transducer and recorded in analog recorders (0–10 mV). The analog data were obtained mainly as monitor data.

4. 2. Recording system of micrometeorological data

The recording system (Figs. 10 and 13) of micrometeorological elements was desinged and manufactured by Kaijo Denki Co., Japan, as well as the sensor. The emf output of temperature and one minute average of wind velocity and wind direction were converted by transducers to 0–1 V range. The thermal flux, surface temperature measured by the radiation thermometer, dew point temperature, atmospheric pressure and two minutes running mean of drifting snow flux were amplified and analyzed by an Analog Data Analizer into 0–1 V range.

The data were sampled once a minute by a micro-computer (GP-1000, CPU) which worked like the data logger for the radiometer measurement and then they were recorded in magnetic tapes. The obtained data were printed out a few times a day by a printer attached to the computer to comfirm whether correct data were recorded or not. Analog recorders were operated as a monitoring indicator.

Fig. 12. Recording instruments of radiation measurement.

Fig. 13. Recording instruments of measurements of micrometeorological elements.

4. 3. Effect of noise on data recording

Since Mizuho Station is located in the katabatic wind area where the wind of 12 or 13 m/s blows continuously, drifting snow due to such a strong wind generates the electric charge which causes a serious noise against the correct recording. Our empirical result of the measurement indicated that the wind of which velocity exceeded 18 m/s disturbed the correct recording of the magnetic tape recorder. However, such a strong wind did not disturb the analog recording so that the electric noise caused by drifting snow did not influence the collection of data.

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