Proc. NIPR Symp. Polar Meteorol. Glaciol., **11**, 35-50, 1997

METEOROLOGICAL OBSERVATIONS ALONG A TRAVERSE ROUTE FROM COAST TO DOME FUJI STATION, ANTARCTICA, RECORDED BY AUTOMATIC WEATHER STATIONS IN 1995

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Abstract: This paper focuses on instrumentation and observational results of eight Automatic Weather Station (AWS) units in East Queen Maud Land, Antarctica 1995. The AWS units were installed at six sites on the ice sheet from coast to inland: the site nearest to the coast (H21) was located at 60 km at 1076 m altitude and a site farthest from the coast (Dome Fuji Station) was located about 920 km inland at 3810 m altitude. Two types of AWS units (CMOS and ARGOS) were employed. Air temperatures at H21 and Dome Fuji Station change from +2.3 to −44.4°C and −23.3 to −80.1°C, respectively. Monthly mean July temperatures in eight AWS data are systematically higher than June and August temperatures, respectively. During the period of temperature increase in July, atmospheric pressure also increased. Wind speed during the whole period could only be obtained at MD180 at which glazed surface was observed. Prevailing wind (south-east: SE) at Relay Point covers 40% of the total wind direction, and wind from the east north-east slightly prevails (11%) at Dome Fuji Station. Atmospheric pressure at Relay Point drops in May and September, and increases in July and December. Monthly mean lapse rates on snow surface were calculated using AWS data. Annaul mean lapse rates obtained by the AWS data were systematically lower than that obtained by 10 m snow temperatures in Mizuho Plateau. Increase of temperature difference between air and snow surface with altitude will be a reason for the phenomenon.

1. Introduction

The Japanese Antarctic Research Expeditions (JAREs) have been preparing for deep ice coring at Dome Fuji (77°19′01″S, 39°42′12″E; 3810 m asl), the highest place in Queen Maud Land, since 1992. In 1995 the 36th Japanese Antarctic Research Expedition (JARE-36) started to overwinter for deep ice coring, glaciological and meteorological observations at Dome Fuji Station (KAMEDA *et al*., 1997; YOSHIMI *et al*., 1997).

Five automatic weather station (AWS) units were newly installed along a traverse route from the coast to Dome Fuji Station from January to February in 1995. This is part of a five-year research program called "Automatic Weather Station Program during Dome Fuji Project", which has started since 1993 by JARE-34 (ENOMOTO *et al.*, 1995). AWS research before the program was summarized in KIKUCHI and ENDOH (1993). Here, we describe instruments and observational results of eight AWS units along the traverse route during 1995 in this paper.

2. Observational Sites

Figure 1 shows six observational sites (H21, Mizuho, MD180, Relay Point, MD550 and Dome Fuji Station) along a traverse route, which expand from 1076 m to 3810 m altitude. Table 1 summarizes these sites, observational period, meteorological factors and types of AWS (types of AWS are explained in Section 3). Air temperature and wind speed at Mizuho Station and Relay Point in 1993 are described in ENOMOTO *et al.* (1995). Table 2 shows sensor heights in meters from the snow surface. Sensors were raised when

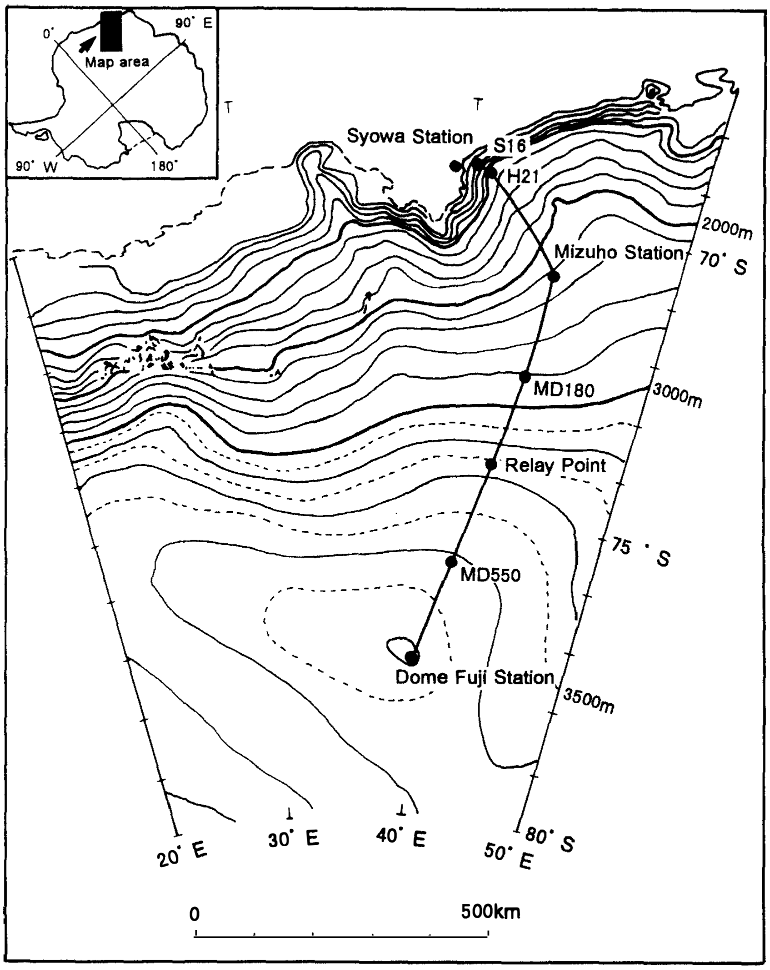

Fig. 1. Location map of Automatic Weather Station (AWS) units in East Queen Maud Land, Antarctica in 1995.

Table 1. List of observation sites by CMOS- and ARGOS-AWS units along a traverse route from coast to Dome Fuji Station.

Site name	Latitude (S)	Longitude (E)	Elevation (m)	Observation period			Factors	Type
				1993	1994	1995		
H21	69°05′32″	40°48′26″	1076	–	–	○	T_a, W_s	CMOS
Mizuho Station (IM0)	70°42′00″	44°17′21″	2250	○	○	○	T_a, W_s	CMOS
MD180	72°21′53″	43°41′33″	2833	–	–	○	T_a, W_s	CMOS
Relay Point (MD364)	74°00′29″	42°59′48″	3353	○	○	○	T_a, T_s, W_s, W_d, S	CMOS
				–	–	○	T_a, W_s, W_d, P	ARGOS
MD550	75°40′33″	41°32′13″	3663	–	–	○	T_a, W_s	CMOS
Dome Fuji Station	77°19′01″	39°42′12″	3810	–	○	○	T_a, T_s, W_s, W_d	CMOS
				–	–	○	T_a, W_s, W_d, P	ARGOS

T_a: air temperature, T_s: snow temperature, W_s: wind speed, W_d: wind direction, S: solar radiation, P: air pressure.

Table 2. Sensor heights (m) at eight meteorological stations. The upper six stations are CMOS-AWS. The lower two stations are ARGOS-AWS. Arrows indicate that sensor heights were changed from the former to the latter.

Site name	Sensors	January 1995	November 1996	January 1996
H21	T_a	1.35	0.65 → 2.10	2.25
	W_s	1.75	1.05 → 2.55	2.70
Mizuho	T_a	1.85	1.75	1.85
Station	W_s	2.20	2.10	2.20
MD180	T_a	1.40	1.35	1.25 → 1.50
	W_s	1.75	1.70	1.60 → 2.00
Relay Point	T_a	–	2.25	2.20
(MD364)	W_s	–	2.80	2.75
	W_d	–	2.80	2.75
	S	–	3.30	3.25
MD550	T_a	1.50	1.26	1.25 → 1.50
	W_s	1.80	1.56	1.55 → 2.00
	W_d	–	–	2.00
Dome Fuji	T_a	2.10	2.10	2.10 → 2.15
Station	W_s	2.15	2.15	2.15 → 2.05
	W_d	2.15	2.15	2.15 → 2.05
Relay Point	T_a	2.65	2.40	2.05
(MD364)	W_s	3.20	2.95	2.60
	W_d	3.20	2.95	2.60
Dome Fuji	T_a	2.05	2.05	2.05
Station	W_s	2.60	2.60	2.60
	W_d	2.60	2.60	2.60

heights of thermometers became close to 1.2 m due to snow accumulation.

H21 (1076 m) is located nearest to the coast (about 60 km); thus air temperature and wind speed will be influenced by coastal cyclone activities. Three sites, Mizuho Station (2250 m), MD180 (2833 m) and Relay Point (3353 m) are located on a slope of the ice sheet where katabatic winds play an important role in air temperature and wind speed. MD180 was located at the glazed surface region, while other two were at sastrugi surface region. MD550 (3663 m) is located on the relatively flat terrain, where seems to be a region just beyond the influence of the katabatic wind from observations of snow surface features (FURUKAWA *et al.*, 1996) and surface snow properties (SHIRAIWA *et al.*, 1996). Dome Fuji Station (3810 m) is on the top of the ice dome in Queen Maud Land, where surface hoar grows frequently on the snow surface (KAMEDA *et al.*, 1997) and depth hoar is well developed in inner layer.

3. Instrumentation

Two types of AWS units were employed: one is data-logger system which use complimentary metal oxide semiconductor (CMOS) memories and another is the ARGOS system which transmits the data to the NOAA series of polar orbiting satellites using the ARGOS Data Collection System on board. Figure 2 shows CMOS-AWS unit at MD180, and Fig. 3 shows ARGOS AWS unit at Relay Point.

CMOS data-loggers of the "KADEC series" (by KONA System Co. Ltd., Japan) with extra additional lithium batteries were used. This type of AWS initially used at Asuka Camp in 1985 by JARE-26 (ENDOH *et al.*, 1987), and extensively used since 1993 by JARE-34 (ENOMOTO *et al.*, 1995). The data-logger was proved to operate to −82°C by low temperature test (ENOMOTO *et al.*, 1995).

Data-loggers were set in a thermal insulation box (50 cm × 40 cm × 30 cm) and were buried in snow at about 50 cm depth. Data were took out from the data-logger once a year, when an oversnow traverse party passed the sites. It took about four hours for data acquisition and restarting operations to be done by one person. A windmill generator "Windcharger 910 series" (by Marlec Engineering Co. Ltd., U.K.) was used for heating the CMOS data-logger in the insulated box at MD550. The data-logger system at Dome Fuji Station was connected to large batteries (60Ah × 4).

The anemometers (AG-860, Makino Applied Instruments Inc., Japan) has sometimes stopped due to icing, especially at H21, and due to coldness at Dome Fuji and MD550 when air temperature was below −60°C. Platinum sensors in shelters were used for air temperature measurements with 0.1°C accuracy. Since the shelters were no forced ventilation system, the air temperature tends to rise in summer season daytime owing to heated shelter by solar radiation when wind speed is below 1.2 m/s. Therefore, the temperature data when wind speed is below 1.2 m/s in summer (November to February) were eliminated from whole data.

ARGOS-AWS units have worked at Relay Point and Dome Fuji Station since February 1995. ARGOS identification numbers are 8918 and 8982, respectively. The observation factors are air temperature, atmospheric pressure, wind speed and wind direction. This unit was originally designed by Stanford University (Prof. Alan PETERSON's group) and has maintained and improved by the University of Wisconsin-

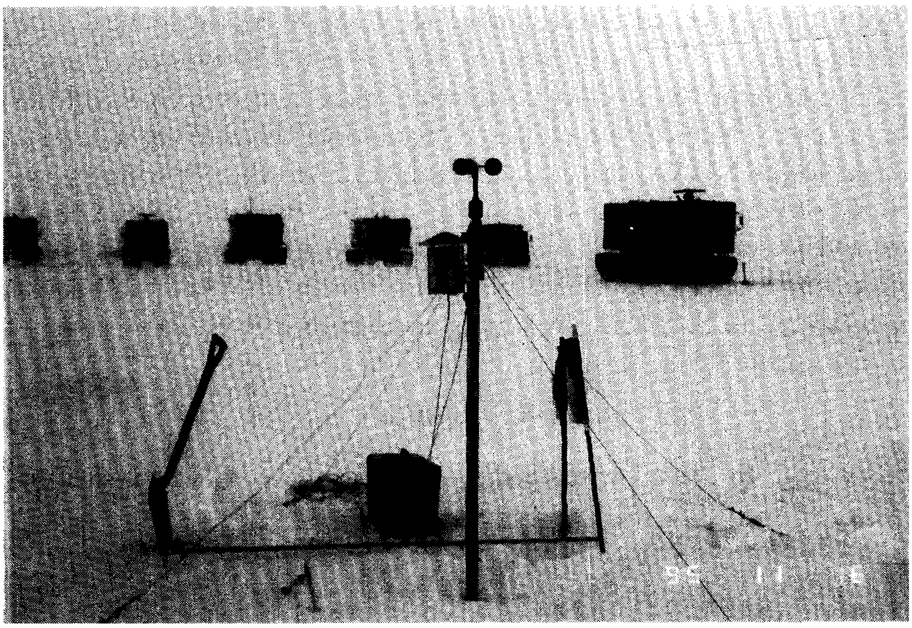

Fig. 2. CMOS-AWS at MD180 on 16 November 1995. The insulation box at the left behind was buried under snow.

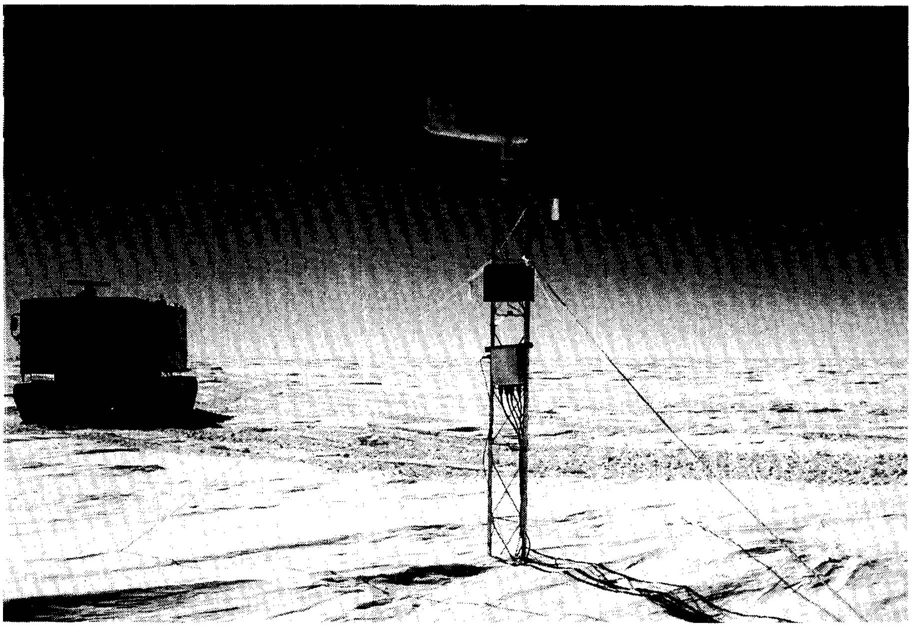

Fig. 3. ARGOS-AWS at Relay Point on 14 November 1995.

Madison (Prof. C.R. STEARNS' group). Thus, the units are the same as the ones which are widely used in the Antarctic by the U.S. Automatic Weather Station Program (BROMWICH and STEARNS, 1993).

ARGOS-AWS units are powered by twelve 40 ampere-hour gel-cell batteries charged by solar panels and require 1.3 kW hrs per year at 12 volts. The batteries were separated into four wooden boxes and were buried at about 1 m in depth. Air temperature is measured with a platinum resistance thermometer (by Weed Instrument Co., USA) at 0.125°C resolution, the atmospheric pressure with a digiquartz pressure transducer system (Model 215, Parascientific Inc., USA), and wind speed and direction with an aerovane (Bendix inc., USA). The data are update at 10 min intervals and the successive four data are transmitted to the NOAA series satellite at 200 s intervals. Assembling and installation of ARGOS-AWS unit took about six hours by two persons. ARGOS-AWS data at Relay Point and Dome Fuji Station were collected from the anonymous ftp server at the Space Science and Engineering Center of the University of Wisconsin-Madison. More detailed information on ARGOS-AWS units are described in STEARNS *et al.* (1993).

4. Results

Figures 4a and 4b show air temperature and wind speed at six sites obtained by

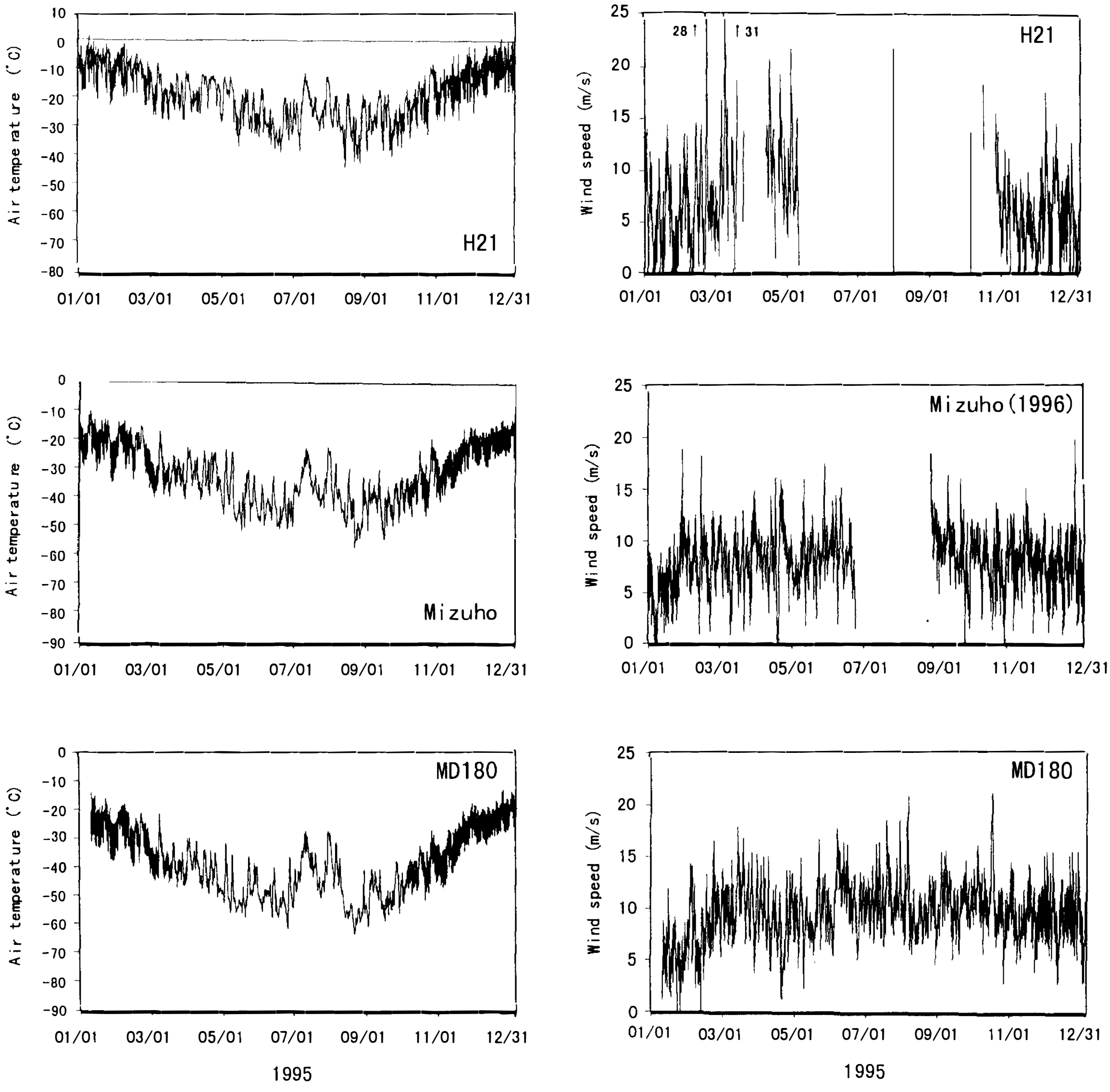

Fig. 4a. Air temperature and wind speed at H21, Mizuho and MD180 in 1995 obtained by CMOS-AWS units. Wind speed data in 1996 are shown for Muzuho Station.

CMOS-AWS units. Air temperature at H21 varied from +2.3 to −44.4°C. There was some interruption of wind data at H21. During this period the rotation of the anemometer was probably locked by icing. Air temperature at Mizuho Station varied from −10.1 to −57.2°C. From 1 February to 18 November 1995, wind speed data were not recorded because of data-logger trouble at Mizuho Station. Since the data-logger was used for 4 years in Antarctica, electronic devices in the logger probably broke down. Thus, wind speed data in 1996 are shown in Fig. 4a. Air temperature at MD180 varied from −13.5 to −64.1°C. Wind speed during the whole period could only be obtained at this site. The maximum wind speed was 21 m/s at 1500 LT on 20 October.

Air temperature at Relay Point varied from −18.8 to −70.8°C as shown in Fig. 4b. Wind speed data in 1995 at Relay Point was missed due to the same trouble that affects

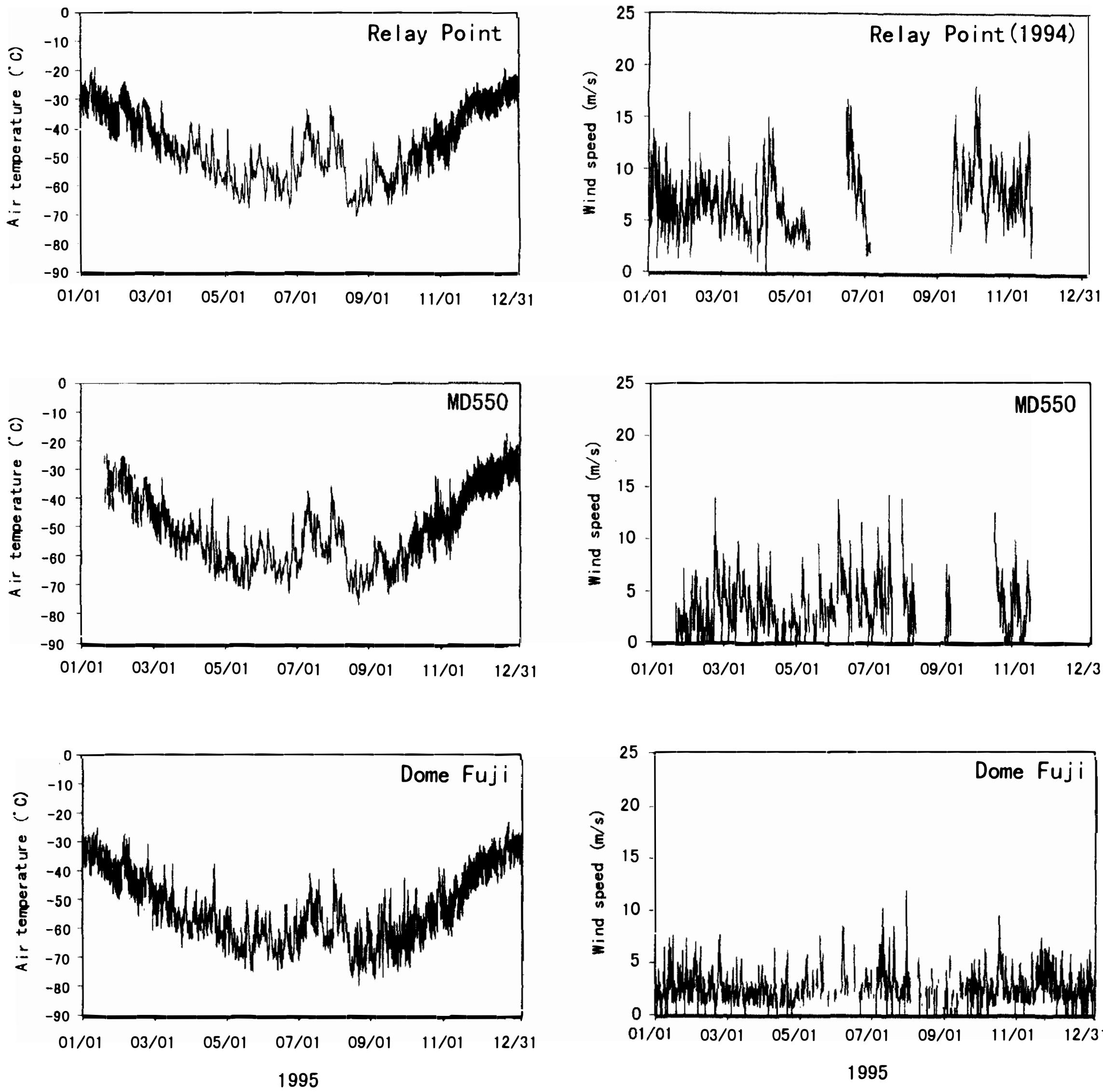

Fig. 4b. Air temperature and wind speed at Relay Point, MD550 and Dome Fuji Station in 1995 obtained by CMOS-AWS units. Wind speed data in 1994 are shown for Relay Point.

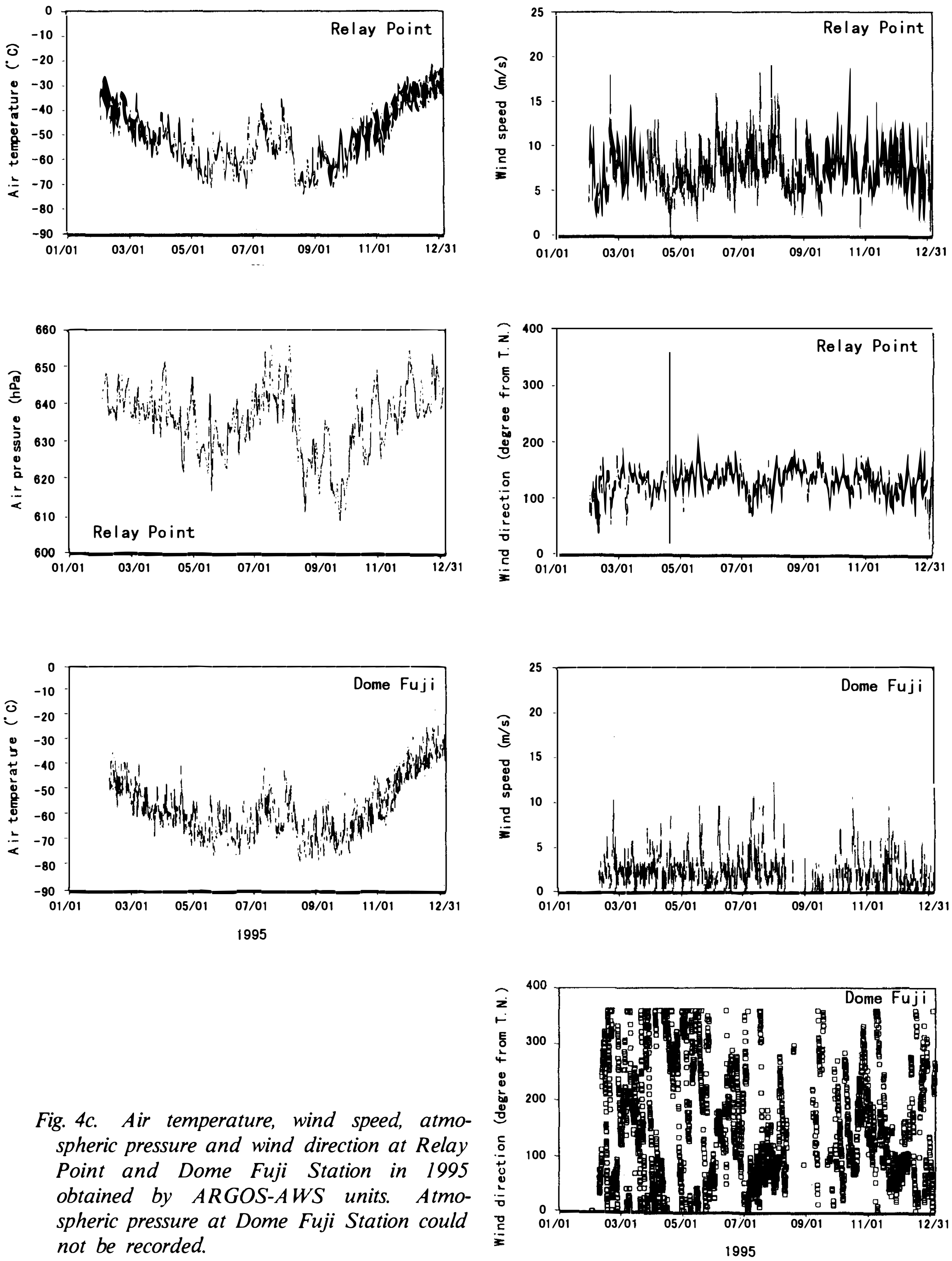

Fig. 4c. Air temperature, wind speed, atmospheric pressure and wind direction at Relay Point and Dome Fuji Station in 1995 obtained by ARGOS-AWS units. Atmospheric pressure at Dome Fuji Station could not be recorded.

the data-logger at Mizuho Station, and data in 1996 were partly affected by sensor troubles. Thus, wind speed data in 1994 are shown in Fig. 4b. Air temperature at MD550 varied from −17.0 to −77.1°C. Wind speed data indicate that the anemometer rotation was locked from July to October. This problem was also observed at CMOS- and ARGOS-AWS units at Dome Fuji Station, which was caused by hardening of the grease in the rotational part and entering of frost into the rotational parts. Air temperature at Dome Fuji Station varied from −23.3 to −80.1°C. The minimum air temperature of −80.1°C was recorded at 1300 LT on 18 August, and the maximum temperature of −23.3°C was recorded at 1100 LT on 21 December. Compared with ventilated air temperature data obtained at Dome Fuji Station by the Japan Meteorological Agency (JMA), the maximum air temperature is 0.3°C higher and the minimum air temperature is 0.8°C lower, respectively. Wind speed at Dome Fuji Station at 2.2 m height varied from 0 to 13.2 m/s. Average wind speed from February to April is 2.4 m/s and from October to December 2.8 m/s. Average wind speed data at other months are not sufficiently reliable, because the anemometer tends to be locked frequently.

Figure 4c shows air temperature, wind speed, wind direction and atmospheric pressure obtained by ARGOS-AWS units. Atmospheric pressure data at Dome Fuji were not obtained due to pressure sensor trouble. Since data were not continuously received from the ARGOS-AWS units to NOAA satellites, not all profiles in Fig. 4c are continuously. The percentages of received data were 81 and 56% for Relay point and Dome Fuji Station, respectively.

Air temperature at Relay Point varied from −21.2 to −74.2°C. Average wind speed for the observation period is 7.4 m/s, while the data ranges from 0 to 21 m/s. The prevailing wind direction is about 120°. Since the maximum slope of the ice sheet at Relay Point is close to the 0–180° line, the direction of prevailing wind is about 60° east from the maximum slope of the ice sheet. The atmospheric pressure varied from 608 to 656 hPa. It is clear that atmospheric pressure dropped in May and September, and increased in July and December. The period of the increase of atmospheric pressure in July agree with the period of temperature increase in July. Air temperature at Dome Fuji Station varied from −22.5 to −80.9°C. Wind speed changed from 0 to 17 m/s.

Figure 5 shows wind rose profiles for Relay Point and Dome Fuji Station. It was found that the prevailing wind (south-east: SE) at Relay Point covers 40% of the total wind

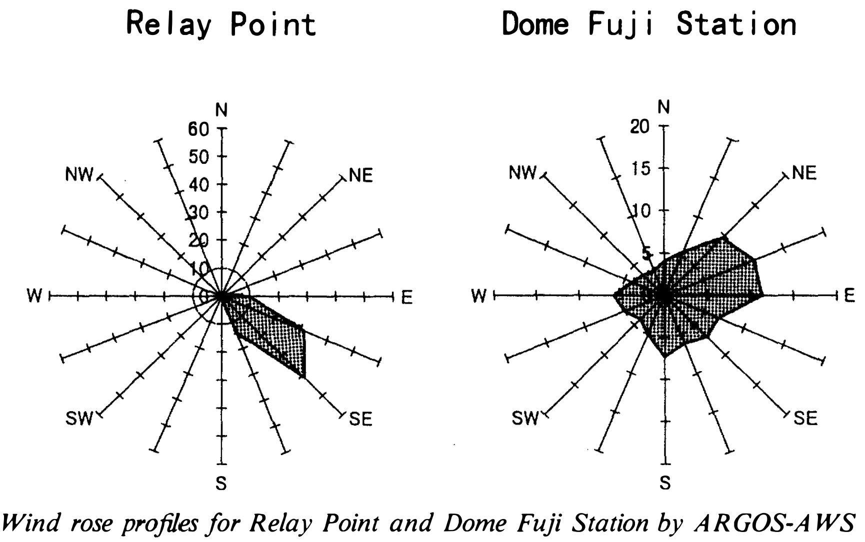

Fig. 5. Wind rose profiles for Relay Point and Dome Fuji Station by ARGOS-AWS units from February 1995 to January 1996.

dir•ction, and wind from SSE to ESE covers 84%. Wind from the east north-east slightly prevails (11%) at Dome Fuji Station, and wind from NE to E covers 32% of the total wind direction. Because Dome Fuji Station is located on top of the ice dome, there is no strong prevailing wind direction.

Figure 6 shows solar radiation (kW/m^2) at Relay Point, which was measured by a type H201 solar radiation sensor (Eiko Seiki Co. Ltd). Since the sensor surface was often covered by frost and incident light were probably enhanced in the sensor, the absolute values are only for reference. From Fig. 6 the sun was probably seen until 17 May, and came out again on 1 August 1995. The sun was seen for 24 hours from 29 October to 9 February at Relay Point.

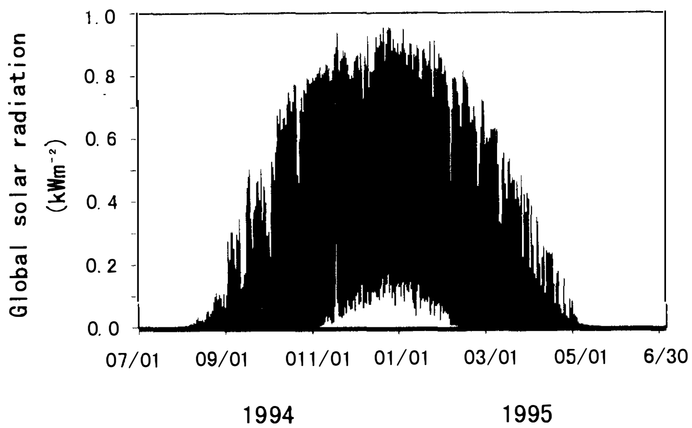

Fig. 6. Solar radiation (kW/m^2) at Relay Point in 1995 obtained by CMOS-AWS unit.

5. Discussion

5.1. Temperature increase in winter

Tables 3 and 4 show monthly mean temperatures and wind speeds at seven meteorological stations in 1995. Monthly mean wind speed at Mizuho Station and Relay Point are data in 1996 and 1994, respectively. Data at Syowa Station (JMA) and Dome Fuji Station (JMA) come from the JAPAN METEOROLOGICAL AGENCY (1996); sensor heights of air temperature and wind speed are 1.5 m and 10 m, respectively. Monthly mean temperature and wind speed in which the amount of missing data do not exceed 33.3% are shown in Tables 3 and 4. Data at hourly intervals were used for CMOS-AWS, and 10 min intervals data for ARGOS-AWS. Data in parenthesis indicate that the amount of missing data are in the range between 33.3 to 66.6%. If the number of missing data exceeds 66.6% in total, the mean values were not calculated and are indicated by dash (-).

Figure 7 illustrates monthly mean air temperatures for seven stations in 1995. CMOS-AWS data were used except for Syowa Station. This shows that air temperature decreases with increasing altitude. July temperatures are systematically higher than June and August temperatures. This phenomenon is known as "warm-core" (RUBINSHTEYN, 1962) and is caused by a warm spell observed at the middle and the end of July, which are clearly seen in Fig. 4a, 4b and 4c. The warm spell seems to be caused by an approach of cyclones into inland of the ice sheet.

Table 3. Monthly mean air temperatures (°C) in 1995 along a traverse route from coast to Dome Fuji Station. Monthly mean air temperatures in which the amount of missing data does not exceed 33.3% are shown. Data in parenthesis indicate that the amount of missing data is in the range between 33.3 and 66.6%. Data "-" indicates that the amount of missing data exceeds 66.6%.

	H21	Mizuho	MD180	Relay Point (CMOS)	Relay Point (ARGOS)	MD550	Dome Fuji (CMOS)	Dome Fuji (ARGOS)	Dome Fuji (JMA)	Syowa (JMA)
January	-9.9	-21.0	-26.4	-31.7	-	-	-36.6	-	-	-2.3
February	-11.4	-22.5	-28.5	-35.9	-38.2	(-36.8)	-42.5	(-46.7)	-45.5	-2.9
March	-19.0	-32.5	-39.2	-46.7	-49.5	-50.9	-54.1	(-56.1)	-55.4	-8.9
April	-17.7	-31.8	-41.3	-50.7	-53.4	-57.3	-57.8	(-60.0)	-58.6	-8.9
May	-23.2	-40.1	-48.8	-57.5	-60.7	-62.5	-64.1	(-65.4)	-64.4	-15.0
June	-28.9	-43.9	-51.2	-58.0	-61.4	-62.3	-65.3	(-66.8)	-65.7	-20.9
July	-22.9	-33.6	-39.7	-47.0	-50.2	-52.2	-56.4	(-58.0)	-56.5	-14.1
August	-29.4	-43.6	-52.7	-59.9	-63.5	-64.2	-66.3	(-67.2)	-66.4	-22.6
September	-27.9	-41.2	-49.3	-56.6	-60.6	-62.3	-64.5	(-67.2)	-66.4	-21.7
October	-20.5	-34.3	-40.9	-47.5	-50.7	-52.0	-56.0	(-58.8)	-56.8	-12.2
November	-15.3	-25.9	-30.9	-36.9	-39.3	-40.7	-45.0	(-46.1)	-45.1	-7.5
December	-9.7	-19.8	-23.1	-28.9	-31.0	-30.0	-34.3	(-33.8)	-34.6	-2.3
Year	-19.7	-32.5	-39.3	-46.4	-	-	-53.6	-	-	-11.6

Table 4. Same as Table 3 but for monthly mean wind speed (m/s).

	H21	Mizuho*	MD180	Relay Point		MD550	Dome Fuji			Syowa (JMA)
				(COMOS)**	(ARGOS)		(CMOS)	(ARGOS)	(JMA)	
January	5.4	6.0	5.3	6.8	-	(1.4)	2.7	-	-	4.8
February	6.8	8.3	8.3	6.8	6.7	3.2	2.8	(2.8)	-	6.0
March	(9.8)	8.1	10.5	6.0	8.0	3.9	2.2	(2.6)	5.5	7.6
April	(10.6)	8.6	8.5	6.4	6.4	2.5	1.9	(2.7)	6.9	10.0
May	-	8.2	9.3	(4.0)	6.5	(3.2)	-	(2.7)	6.2	7.1
June	-	8.9	11.1	(8.8)	8.3	5.6	-	(2.9)***	6.1	4.2
July	-	-	11.0	-	8.9	(4.9)	3.7***	(3.7)***	7.1	7.4
August	-	-	9.6	-	6.7	-	-	(0.9)***	5.8	4.0
September	-	9.0	10.8	9.7	7.3	-	(2.9)***	(0.8)***	5.8	4.6
October	-	8.0	10.7	8.0	8.2	(4.2)	3.0	(3.0)	6.4	7.2
November	5.2	8.5	9.1	(8.1)	7.6	(2.9)	3.0	(2.7)	5.7	4.8
December	6.6	7.5	9.1	-	6.5		2.3	(1.5)	3.8	4.8
Year	-	-	9.4	-	-	-	-	-	-	6.0

*Data in 1996.
**Data in 1994.
***Rotation of anemometer in CMOS- and ARGOS-AWS at Dome Fuji Station was not good from June to September due to hardening of grease and entering of frost into rotational parts.

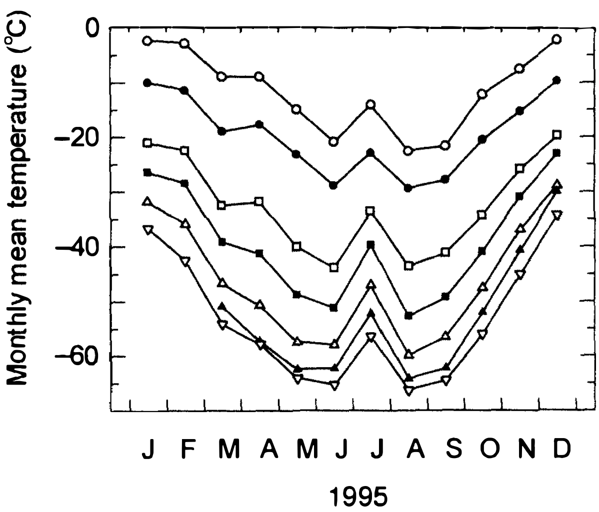

Fig. 7. Monthly mean temperatures at seven meteorological stations in 1995.
—○—Syowa: —●—H21: —□—Mizuho: —■—MD180:
—△—Relay Point: —▲—MD550: —▽—Dome Fuji.

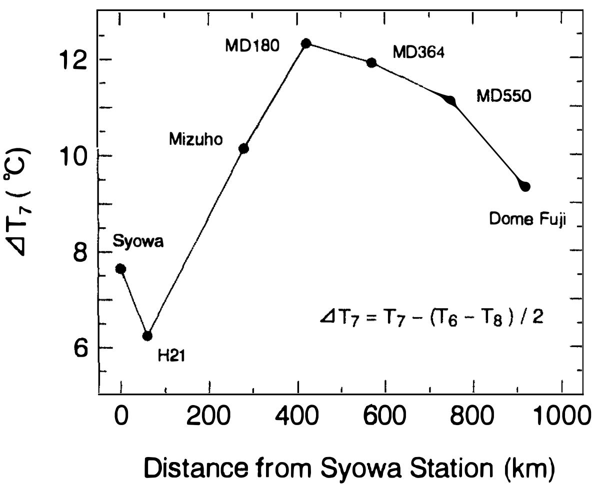

Fig. 8. Relation between July temperature increase (ΔT_7) and the distance from Syowa Station.

Here, increase of July temperature (ΔT_7) is defined as follows:

$$\Delta T_7 = T_7 - (T_6 + T_8)/2,$$

where T_6, T_7 and T_8 are monthly mean temperatures in June, July and August, respectively. Figure 8 shows ΔT_7 versus distance from Syowa Station. It was found that ΔT_7 is the maximum (12.3°C) at MD180 where the distance from the coast is about 430 km and elevation is 2833 m. Since surface elevation increases with distance from the coast, a similar relation is obtained between ΔT_7 and surface elevations. The reason for the existence of the maximum value at MD180 is beyond the scope of this paper and the problem remains to be solved in the future.

5.2. Lapse rate of air temperature

According to 10 m snow temperature analysis in Mizuho Plateau (SATOW, 1978), an average lapse rate of mean surface temperature changed around 3000 m; 1.3°C/100 m was obtained between 1000 m and 3000 m, and 2.0°C/100 m between 3000 m and 3800 m. Figure 9 shows monthly lapse rates between H21 (1076 m) and MD180 (2833 m), and Relay Point (3353 m) and Dome Fuji Station (3810 m), which correspond to region between 1000 m and 3000 m, and 3000 m and 3800 m in SATOW (1978). The lapse rates were calculated from regression analysis using monthly mean air temperature at H21,

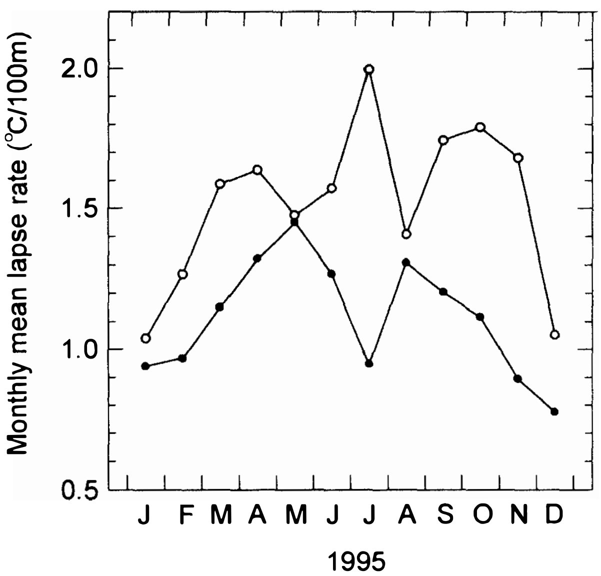

Fig. 9. Monthly mean lapse rates for H21 to MD180 (solid circle) and MD180 to Dome Fuji Station (open circle). —●—: H21-MD180, —○—: Relay Point-Dome Fuji.

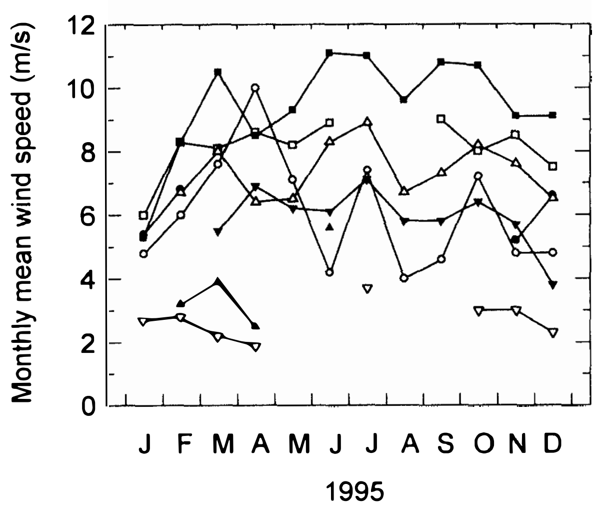

Fig. 10. Monthly mean wind speed (m/s) at seven meteorological stations. For Dome Fuji Station, the monthly mean wind speed at 2.2 m and 10 m are both shown. —○—Syowa: —●—H21: —□—Mizuho: —■—MD180: —△—Relay Point: —▲— MD550: —▽—Dome Fuji (2.2 m), —▼—Dome Fuji (10.0 m).

Mizuho and MD180 (solid circles), and at Relay Point, MD550 and Dome Fuji (open circles). In summer (December to January), the lapse rates below MD180 was 0.8 to 0.9°C/100 m, and was 1.0°C/100 m between Relay Point and Dome Fuji. The former is slightly smaller than adiabatic lapse rate (0.976°C/100 m) and the latter is nearly identical with the adiabatic lapse rate. In winter from April to September except July, lapse rates below MD180 was 1.2 to 1.5°C/100 m, and was 1.4 to 2.0°C/100 m between Relay Point and Dome Fuji. Strong inversion layer near the ice sheet surface at inland plateau during winter (KAWAGUCHI *et al.*, 1985) is one reason for the large lapse rate. Because monthly mean air temperature in July was affected by cyclone activities, the lapse rate in July is different from the rates in June and August.

Annual mean lapse rate below MD180 was 1.11°C/100 m, and was 1.52°C/100 m between Relay Point and Dome Fuji. Compared with the results of the 10 m snow temperature analysis, the annual mean lapse rates are 0.2 and 0.6°C/100 m lower, respectively. Increase of temperature difference between air and snow surface with altitude (LOEWE, 1970; KAMEDA *et al.*, 1997) will be a reason for the phenomenon.

5.3. *Wind speed*

Figure 10 illustrates monthly mean wind speed for seven stations in 1995. The data at Dome Fuji Station are shown for wind speed measured at 2.2 m (CMOS-AWS) and 10 m (JMA) heights. Wind speed at MD180 was highest at the seven stations in 1995 except April. The glazed snow surface at MD180 will be maintained by the strong wind.

6. Future Problems to be Solved in AWS Instrumentation

Because meteorological conditions are severe on the highland plateau in the Antarctic, several AWS instrumentation problems remain to be solved:

a) The ventilation system which is run by solar panels in the thermometer shelter should be used for air temperature measurements since wind speed on the highland plateau is weak (normally 2 to 4 m/s at Dome Fuji Station).

b) During winter, air temperature decreases to about −80°C. Anemometers which run under this temperature condition must be developed.

c) AWS units are sometimes covered with frost. It is important to remove the frost from the sensors, in particular the solar radiation sensor.

d) Other meteorological factors such as radiative temperature of snow surface and humidity should be measured by AWS units for understanding meteorological conditions in the Antarctic.

Acknowledgments

We would like to express our sincere thanks to all members of JARE-36 who extended generous support in the field work. Our special thanks are due to Messrs. Y. TANAKA, M. TAKEKAWA, H. SATO, K. ISHIZAWA, T. ARISAWA, K. MARUYAMA, T. NAKAMURA, T. TERADA, F. NAGAHARA and K. TAKAHASHI of JARE-36, S. FUJITA, A. TAKAHASHI, M. NAKAMURA and T. INABA of JARE-37, who kindly took part in the installation and maintenance of AWS units along the route from the coast to Dome Fuji Station. Mr. M. ITOH of JARE-35 helped to repair the ARGOS-AWS unit at Dome Fuji Station. Dr. T. UMEMOTO of Meiji University introduced the RUBINSHTEYN's paper to authors. An oversnow traverse from S16 to Dome Fuji in January 1995 was led by Mr. T. FURUKAWA of NIPR, and an oversnow traverse from Dome Fuji to S16 at November 1995 was led by Mr. K. ISHIZAWA of NIPR. The Automatic Weather Station Program in the US is funded by the National Science Foundation's Office of Polar Programs. Comments by Dr. T. YAMADA and an anonymous reviewer greatly helped to improve the manuscript. This paper is a contribution from the "Deep Ice Coring Project at Dome Fuji Station, East Antarctica".

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(Received January 10, 1997; Revised manuscript accepted June 30, 1997)