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DATA-LOGGING AUTOMATIC WEATHER STATION ALONG THE TRAVERSE ROUTE FROM SYOWA STATION TO DOME FUJI

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Abstract: This paper introduces the unmanned meteorological observation system along the traverse route to Dome Fuji (3810 m a.s.l.), and summarizes the results of the low temperature test and operation in the Antarctic.

The Japanese Antarctic Research Expedition (JARE) recently extended a regular research route to Dome Fuji. From the climatological point of view, this area has one of the sparsest meteorological data networks in Antarctica. In order to obtain meteorological data in this area, automatic weather stations (AWS) using data loggers were tested in a cold box and installed at Dome Fuji, Relay Point (3300 m a.s.l.), Mizuho Station (2230 m a.s.l.) and S25 (840 m a.s.l.) in the coastal region, and A2 on the fast-ice, during JARE-34 in 1992–1994.

The observation sites between Relay Point and Syowa Station were checked in January 1994. It was confirmed that the data loggers worked successfully through the year in 1993, but there were interruptions in the wind data.

It can be concluded that the data logger is satisfactory for use in inland Antarctica, but problems remain to improve sensors and to arrange fail-safe setting of loggers and instruments.

1. Introduction

There are many manned and unmanned meteorological stations in Antarctica (STEARNS *et al.*, 1993). However, there are no meteorological observations in the Dome Fuji area (Fig. 1). RAPER *et al.* (1984) estimated the long-term temperature change in Antarctica by interpolating the data between observation sites. There are still blank areas where data are too sparse for interpolation. Few data are available to estimate the temperature over a broad area of the high plateau, especially on the ridge region in East Antarctica.

Meteorological observations between Dome Fuji and Syowa Station will provide a set of data with a large spatial scale and with a large altitudinal range; from 0 m to 3800 m. For research on katabatic wind, this area covers the uppermost part of the katabatic wind region upwind of the coast. For satellite observations of the ice sheet, surface data are also required.

A data logging system available for low temperature use was developed during the Antarctica Climate Research (ACR) Program between 1987 and 1992 (KIKUCHI and

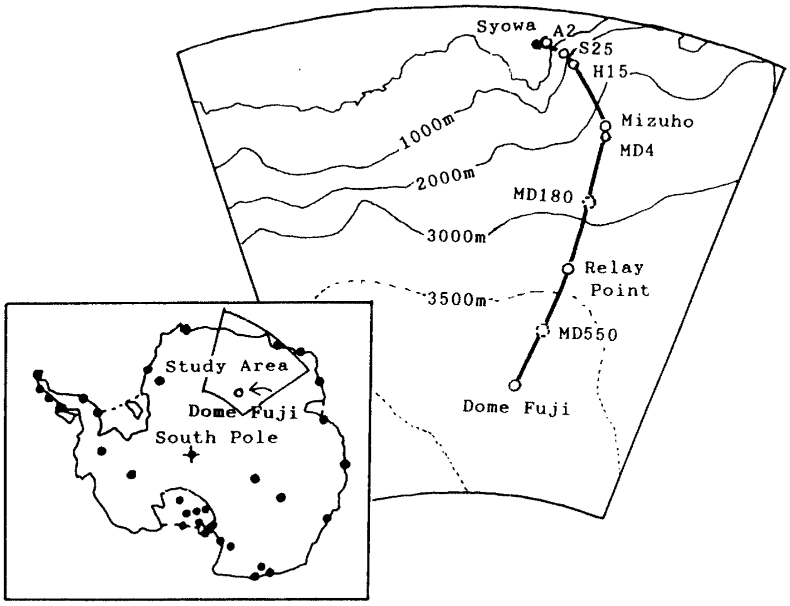

Fig. 1. Distribution of meteorological observation sites both manned and unmanned in 1993 (solid circle). The CMOS AWS both occupied and planned which are introduced in this paper are indicated with empty circles.

ENDOH, 1993). We used one such logging system in the inland plateau region after low-temperature tests.

The next section lists the new observation sites extending to the top of Dome Fuji. Section 3 describes the observation system used and results of the low temperature test. Section 4 gives the preliminary observation results and meteorological characteristics of observation sites. Although the data logger and the meteorological instruments were prepared and set carefully, we encountered some problems. Section 5 considers those problems.

2. Distribution of Observation Sites

The observation sites were located at the top of the dome at altitude 3800 m a.s.l., on the slope and in the coastal area. Table 1 summarizes the observation sites and measured quantities.

The observation site at the top of Dome Fuji is the highest meteorological observation site in Antarctica. Meteorological conditions above 3000 m are expected to change since the katabatic wind decreases and subsidence of the troposphere is expected. The observation sites above altitude of 3000 m are Dome Fuji, MD550 and Relay Point. Mizuho Station was unmanned but an automatic weather station was installed by the ACR Program and data were transmitted by the ARGOS system. However, due to aging of some sensors, these observations were terminated in 1993. Data logging meteorological observation equipment was installed in January 1993 at Mizuho Station and is continuing to record.

A2 and S25 (later H15) were located on the fast-ice and in the coastal slope region,

Table 1. List of observation sites by CMOS AWS since 1993.

Station	Altitude (m a.s.l.)	Start	Stop	Quantities
A2*	0	Feb. 1993	Feb. 1994	T_a, T_s, T_i, V, D
S25*	840	May 1993	Dec. 1994	T_a, T_s
H15	1032	planned Jan. 1995		T_a, V
Mizuho	2230	Jan. 1993		T_a, V
MD4*	2200	Jan. 1993	Jan. 1994	V
MD180	2848	planned Jan. 1995		T_a, V
Relay Point**	3300	Jan. 1993		T_a, T_s, V, D, R
MD550	3600	planned Jan. 1995		T_a, V
Dome Fuji**	3810	Dec. 1993		T_a, T_s, V, D

T_a: air temperature, T_s: snow temperature, T_i: surface temperature, V: wind speed, D: wind direction, R: solar radiation.
*: temporal observation in JARE-34.
**: Argos AWS is to be installed in January 1995 by JARE–Wisconsin University cooperative research work.

respectively. MD180 is located between Mizuho and Relay Point and MD550 is located between Relay Point and Dome Fuji. Therefore, the area between Syowa Station and Dome Fuji was covered by unmanned meteorological stations with an interval of a few hundred kilometers. The increments of the altitudes varied from the minimum of 200 m between Dome Fuji and MD550 and maximum of 840 m between Syowa Station and H 15. The anemometer was set at MD4, 10 km from Mizuho Station, to compare the wind data between neighboring points. This system was removed in January 1994.

The logged data were collected at Mizuho, Relay Point and H25 by JARE-34 in January 1994. The data at Dome Fuji are scheduled to be collected by JARE-35 in summer season of 1994/95. The observation systems for MD180 and MD550 are scheduled to be installed in 1995.

3. Observation System and Low Temperature Test

3.1. Observation system

Data loggers with CMOS memory are used in these observations. Three types of data loggers were used. They have single channel, six channels and nine channels. These data loggers are operated on lithium batteries. The measurement interval is set to be one hour.

We used mainly the single channel type for the inland observation, since this data logger seems to be reliable for use in low temperature below −50°C (TAKAHASHI *et al.*, 1992). Therefore the inland observation points used from two to five data loggers on depending the measured quantities.

A nine-channel data logger was used at point A2 over the fast-ice. A six-channel data logger was used at point S25 in the coastal region to measure snow temperature at five levels and air temperature. Air temperature and snow temperature were measured by platinum resistance thermometer (PT100) sensor. Anemometer and wind vane were used for wind measurement. Solar radiation was measured at Relay Point. An infrared thermometer using a thermopile was set at A2 to observe surface temperature. The wind vane and the infrared thermometer needed an electric power supply, thus switching of these instruments was controlled by the data logger to save the battery.

3.2. Problems of unmanned observation system

Many unmanned observations have been carried out in JARE. Most systems worked successfully near the coast, however, many problems occurred in the inland region due to low temperature (KIKUCHI and ENDOH, 1993). These troubles due to low temperature condition may be summarized as follows:

1) Fall of battery voltage,
2) Rapid consumption of battery power,
3) Erroneous action of instrument or data logger.

The first problem causes mal-functioning of instruments as the battery does not supply the proper voltage. The second problem results in unexpected termination of the measurement or logging of a much shorter data record than the period programmed initially. There have been many such cases. In such a case, however, the logged data could be kept in the CMOS memory if battery for memory back-up were available. These problems became serious as we aimed to extend the observation area to inland.

3.3. Results of low temperature test

To overcome the first and second problems, changes of battery capacity due to low temperature should be quantitatively investigated. For the third problem, possible errors of data logger and instruments should be investigated. Thus, the single channel data logger, the lithium battery and the infrared thermometer were tested in the cold box to the temperature of −83°C. The results of tests were:

a) the data logger could operate in the temperature as low as −82°C when the battery supplied proper range of voltage,
b) the data logger stopped at the temperature of about −83°C but the system started logging again when the temperature rose,
c) the lithium battery was consumed at a rate three times that of normal use at 20 °C,
d) delay of the data logger clock was observed,
e) the value measured by the infrared thermometer began to shift when the instrument was in a cold environment below −20°C.

In consideration of result c), extra batteries were added so the total battery capacity was three times as much as usual. A fall of voltage was observed but it was small if the battery was new or had enough capacity.

To avoid problem b), the data logger should be kept at temperature above −82°C. This problem is serious for unmanned observation at Dome Fuji since the minimum air temperature is expected to fall to about −90°C. Thus, the logger was buried in snow below 2 m depth. The annual minimum temperature becomes as much as 10°C higher than in the air, in snow of 2 m depth.

For problems d) and e), the logged data should be checked. Delay of clock as much as one hour was observed after a one-year observation period in 1993. The infrared thermometer shows a shift of the measured value below −20°C. Therefore, this infrared thermometer was installed only on the fast-ice area near the Syowa Station and was not operated during the coldest season. In order to use this instrument in the colder area, it must be heated.

4. Results of the First Year

4.1. Operation of data logger

All single channel data loggers worked successfully throughout 1993. The data logger at the Relay Point was cooled to below −50°C in the plastic box buried at 1 m depth in snow. The minimum air temperature measured at the Relay Point was −72.6 °C. The data logger with six channels which was installed at S25 was terminated in December 1993 after operation for seven months, two months shorter than programmed initially. Since S25 is a relatively warm region, rapid battery consumption seems to have caused the termination. For the multi-channel data loggers, battery consumption should be tested in a cold box.

The wind data record was interrupted in winter. The solar radiation data could not obtained due to a mistake in combining sensor cables. Almost all platinum resistance thermometers operated successfully but shift of measured value occurred with one sensor.

4.2. Observed meteorological characteristics

This section introduces preliminary results of the meteorological observations in 1993, focusing on characteristics of observation sites. Changes in wind direction with altitude and simultaneous fluctuations of wind speed over the distance of 1000 km between Syowa Station and Dome Fuji are discussed.

It was evident from the observations during the traverse from Syowa Station to Dome Fuji, in the summer of 1993/94, that the wind direction was steady in the slope area but it became variable near the top of Dome Fuji. Most of the traverse route was located in the steady katabatic wind region, and the wind direction shifts from east to north with increasing altitude. Figure 2 shows the profile of wind direction observed

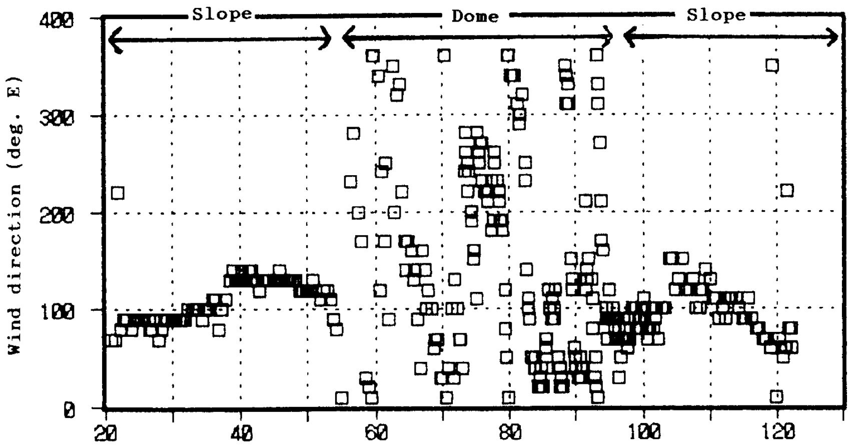

Fig. 2. Variations of wind direction along the traverse from Syowa Station to Dome Fuji. The date is given in days after October 1, 1993. The observations were carried out on the slope area and at Dome Fuji.

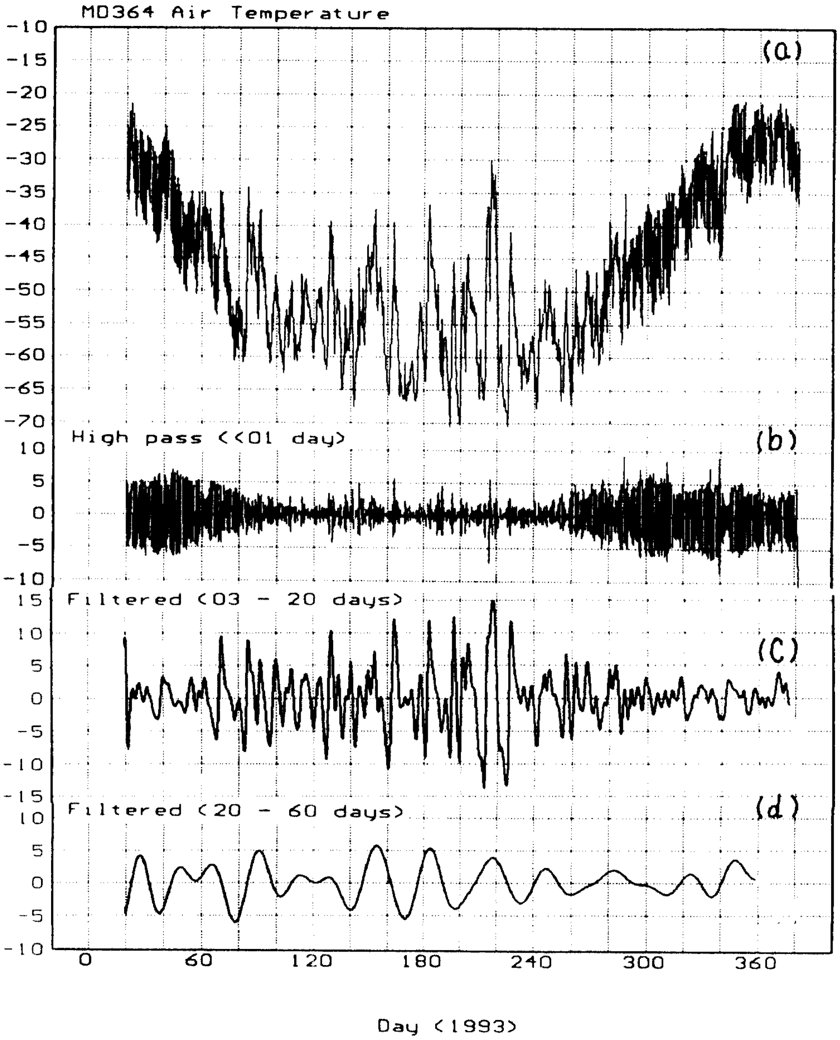

Fig. 3. Time series of air temperature at the Relay Point (3300 m a.s.l.). (a) Raw data measured at 1-hour intervals, (b) high pass filtered data (<1 day), (c) band pass filtered data with a range of 3–20 days, (d) band pass filtered data with a range of 20–60 days.

during the traverse from Syowa Station (MOTOYAMA *et al.*, 1995).

The CMOS AWS data showed a steady wind direction at Mizuho Station and Relay Point throughout 1993. At Syowa Station, wind direction was variable. The wind direction in the slope area is east (90 deg.) in the lower part and shifts slightly to east-south-east (120 deg.) in the higher part.

Temperature data at Relay Point are shown in Fig. 3. Fluctuations on various temporal scales are extracted using a band pass filter (MURAKAMI, 1979). Air temperature fluctuated greatly in winter. The abrupt increases of air temperature in winter is significant. The air temperature in winter often increases more than 30 K in only a few days. On the other hand, the diurnal component becomes dominant in summer. In the coastal area, the diurnal fluctuation appears in all seasons. Seasonal changes are insignificant (Fig. 4).

Spectral analysis was applied to these data. Fluctuations show dominant temporal

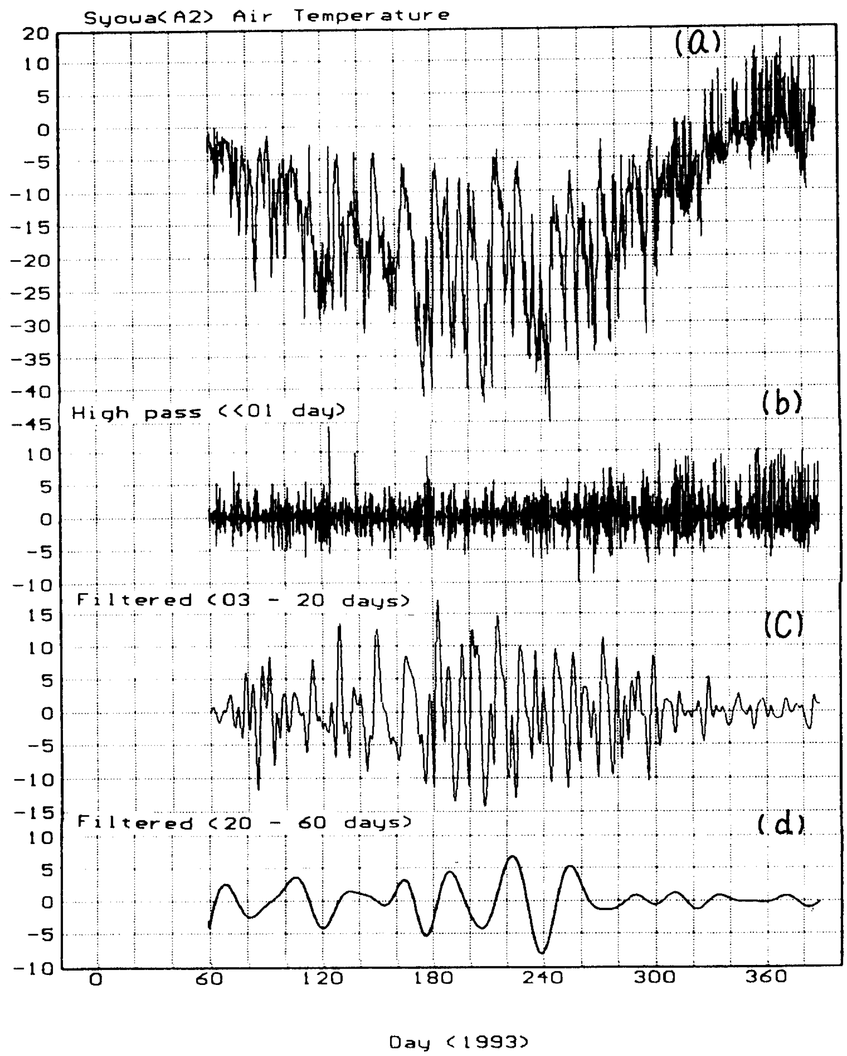

Fig. 4. Same as Fig. 3 but for point A2 on the fast-ice near Syowa Station. (a) raw data, (b) high pass filtered data (<1 day), (c) band pass filtered data with a range of 3–20 days, (d) band pass filtered data with a range of 20–60 days.

scales of 5-days and 11-days in the whole year data, and 30-days in the winter data. Fluctuations with 5-day and 10-day scales were in-phase between the dome and coastal region. Since these fluctuations were in-phase with the pressure fluctuation at Syowa Station, synoptic disturbances seems to affect these temperature fluctuations.

5. Instrumentation Problems

5.1. Anemometer

The three-cup anemometers stopped in the cold season (Fig. 5). Similar problems have occurred with anemometers used in the ACR Program (KIKUCHI and ENDOH, 1993). The trouble occurred in a strong blizzard. Small ice particles seem to intrude in the narrow space in the instrument during a blizzard and they fix the rotor when wind speed decreases. Thus, small ice particles seems make microscale bonds in the narrow

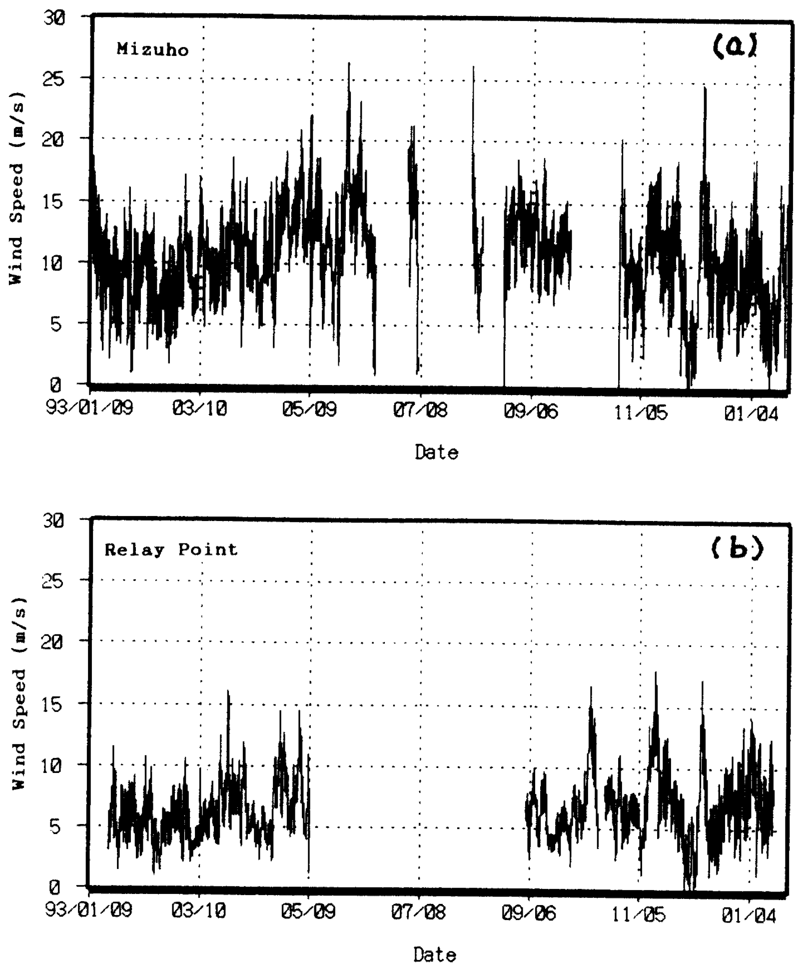

Fig. 5. Wind Speed data obtained at (a) Mizuho Station and (b) Relay Point.

apace in the instrument. There have not been any previous reports on this problem in the field in Japan. This problem seems to be a specific one in very cold and windy regions.

Icing of an aerovane tachometer was reported by STEARNS *et al.* (1993). The three-cup anemometer was frozen near Syowa Station (K. NAKAGAWA in Joetsu University of Education, pers. comm., 1992). The troubles which occurred in JARE-34 seem to be different since the outside of the instrument did not show any icing when it was stopped.

5.2. Thermometer

Measurement of air temperature shows higher value if prevailing wind speed is low since there is no forced ventilation in the screen. This increase of temperature occurs with weak wind below 4 m s^{-1}. The data were checked when the wind speed was small.

A mal-function of temperature sensor was observed. The platinum resistance thermometers were calibrated at 0°C but the measured value shifted below -30°C in some sensors. This kind of error cannot be detected by calibration at 0°C, thus, the calibration should be done at points in the anticipated range of temperature observation.

5.3. Man-made errors

There have been many mechanical and electrical troubles, however, it should be noticed that there were many mistakes in setting the system up. The single channel data logger which we used was advantageous for use in cold conditions but also had disadvantages due to the increased work and complexity of setting up since each instrument needs one data logger.

Further, much of the instrument was set up in cold and windy conditions, and even in a blizzard due to the limited schedule. Only a few persons were available to set up many kinds of instruments and data loggers in the field. We also made also some mistakes in setting switches and combining sensor cables. A fail-safe equipment setting up procedure is needed.

Problems occurred with the portable computer and floppy disks in collecting the data from loggers. The floppy disks were damaged when we used the portable computer below −20°C. Collected data were stored on two or three duplicate diskettes to prevent data loss.

6. Summaries and Future Plan

a) CMOS AWS

Observation using data loggers is economical and easy if traverse operations are frequent. Recent improvements of the CMOS AWS unit are remarkable and the observation area is expanding.

The CMOS-memory data logger was used in the cold environment below −70°C in the inland of Antarctica. It can be used below −80°C if there is enough battery capacity. Thus, new batteries usable in cold temperature or development of an energy supply system are required for the dependable use of logging systems.

b) ARGOS AWS

The ARGOS AWS (STEARNS et al., 1993; KIKUCHI and ENDOH, 1993) is required for remote observation sites where frequent visiting is impossible. It is useful for operational use as it provides the data in almost real time. ARGOS AWS units are to be installed at Relay Point and Dome Fuji in January 1995 by JARE–Wisconsin University cooperative research work.

c) Energy supply

One of the most fundamental points for developing unmanned observation systems is supplying enough electric power. Since some instruments require much electric power, there is a limit to the number of quantities that can be observed by AWS. Therefore, a stable power supply such as a solar panel or wind generator combined with a rechargeable battery for cold environment must be developed. Wind generator and solar battery were operated at the Relay Point in order to collect basic data for the future energy supply system. These systems are planned to be in operation at Dome Fuji by JARE-36.

d) Anemometer

Wind measurements require more testing in the field. To prevent ice particles from entering the instrument, the form of the anemometer was modified; a new type anemometer is planned to be installed in JARE-36.

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