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DEVELOPMENT OF AUTOMATIC WEATHER STATIONS IN THE JAPANESE ANTARCTIC CLIMATE RESEARCH PROGRAM (ACR)

Tokio KIKUCHI[1] and Tatsuo ENDOH[2]

[1]*Department of Information Science, Kochi University, 5–1, Akebono-cho 2-chome, Kochi 780*
[2]*Institute of Low Temperature Science, Hokkaido University, Kita-19, Nishi-8, Kita-ku, Sapporo 060*

Abstract: Automatic weather stations (AWS) were installed in East Queen Maud Land in order to obtain a multi-year climatic record since 1987. After 4 years of operation of Argos and CMOS AWS, they proved to be useful in the observation of climate parameters and associated weather phenomena. Some preliminary results are reported on the Argos AWS units which were effective in studying the cause of the "dark stream" in thermal infrared satellite images and in obtaining a long period of data.

1. Introduction

Because the Antarctic continent and the surrounding Antarctic sea areas are vast in size and remote from civilized areas, it is indispensable to develop automatic weather stations (AWS) in order to obtain climatic records of these areas. In spite of these needs, it has been a great problem to make reliable observations by AWS from the beginning of the Antarctic expeditions, until the recent development of semiconductor and satellite technologies made it possible to implement systems that work at very low temperature with low power consumption. Such new AWS systems are categorized in two types: one which records the data in complimentary metal oxide semiconductor (CMOS) memories and another which transmits the data to the NOAA weather satellites (Argos).

An Argos AWS works as a data collecting platform (DCP) which transmits 32–256 bits of data together with a unique identification number (ID) on the transmit frequency of 401.650 MHz±4 kHz. The transmitted data are received and recorded by the NOAA satellites, re-transmitted to ground stations, and subsequently processed at Argos Global Processing Centers (GPC). The data are available at the French GPC about 1–2 hours later and can be monitored via international data transmission networks, and are air-mailed on magnetic tape every month. Argos AWS units are extensively used by the United States Antarctic Program (STERNS and WEIDNER, 1983).

Here, we report on the CMOS and Argos AWS systems in the Antarctic Climate Research programs around Syowa, Mizuho and Asuka Stations. Some preliminary results from the AWS are also mentioned briefly.

2. AWS before ACR—A History

Figure 1 and Table 1 show the locations and chronological list, respectively, of AWS deployed before and during the Antarctic Climate Research (ACR) study period.

Before the ACR began, we tested two CMOS AWS and one Argos system at two stations, Asuka Camp (71°32′S, 24°08′E, 930 m) and Advance Camp (AC: 74°12′S, 34°59′E, 3198 m) in 1985 (ENDOH *et al.*, 1987; KIKUCHI and MAKINO, 1988). The CMOS memories at Asuka Camp worked well for more than a year but the data record was not complete because the temperature and wind sensors were buried in snow cover.

The other CMOS system, at AC, worked well for about 8 months except for some erroneous wind records in the very cold season. It seems that the system lost some of the wind sensor output pulses. Later AWS systems use dynamo sensors in the anemometers and are free from such trouble. It should also be noted that the CMOS memories can hold once-recorded data even in extreme temperatures lower than −60°C (KIKUCHI and MAKINO, 1988).

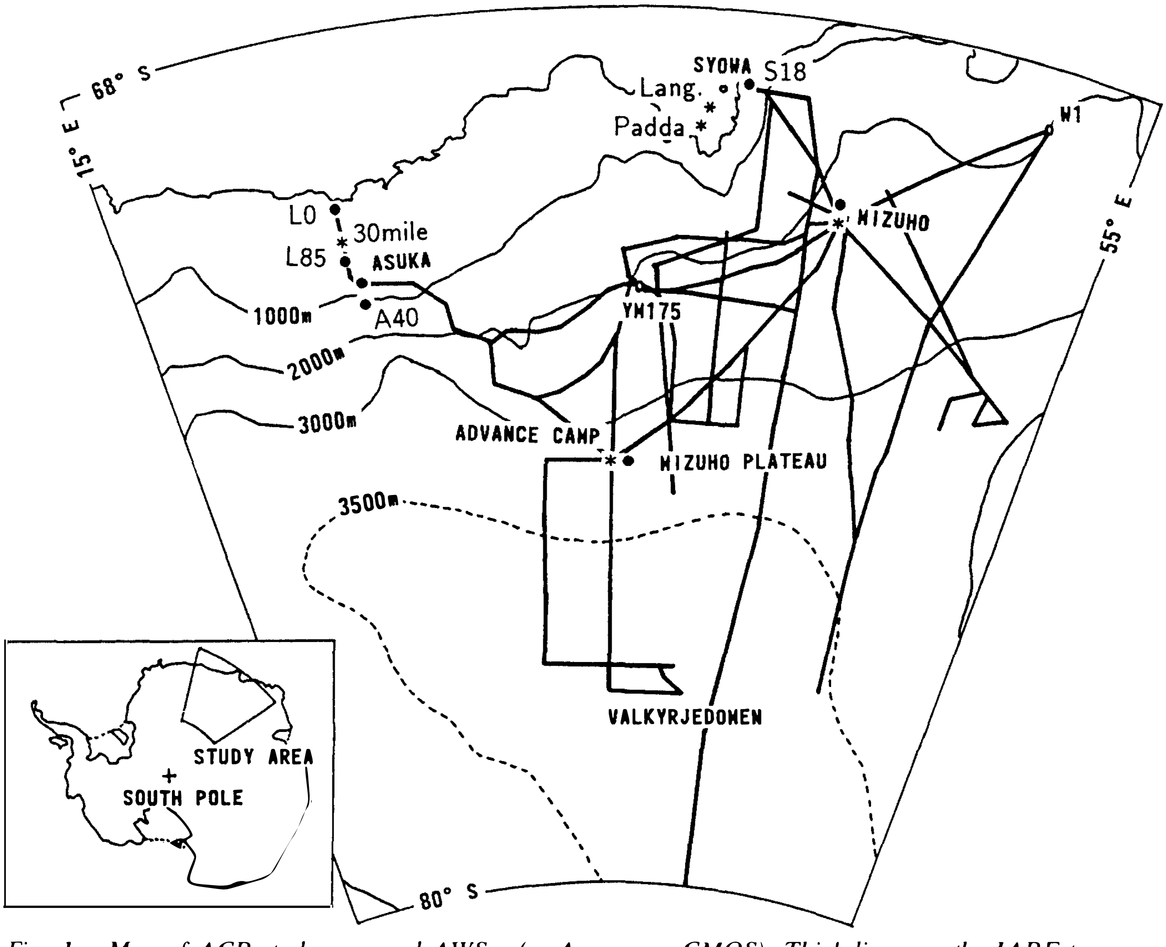


Fig. 1. Map of ACR study area and AWSes (∗: Argos, ● : CMOS). Thick lines are the JARE traverse routes, and thin curves are the coastline and the contours.

Table 1. Historical review of automatic weather stations since 1985.

Station	Type	Start	Stop	Notes
S18	CMOS	Jan. 1987	~ Dec. 1987	D V Ta R P Ts Ps
Mizuho	CMOS	Oct. 1986	~ Jan. 1987	Tr Ta
	Mech.	Oct. 1986	~ Dec. 1987	Ta P
	Argos	Jan. 1987	~ June 1987	V Ta P R Tr E (05002)
	Argos	Jan. 1987	~ June 1987	V Ts Hr E1–E4 (05024)
	CMOS	Jan. 1987	~ Dec. 1987	Ta D V
	CMOS	Jan. 1987	~ Dec. 1987	Ta R RL
	Argos	Jan. 1988	~ Jan. 1989	Tr Ta V E P R (05001)
	CMOS	Jan. 1988	~ July 1988	Tr Ta V R
	Argos	Jan. 1989	~ Jan. 1990	Tr Ta V E P R (05002)
	Argos	Jan. 1990	~ *	Tr Ta V E P R (05004)
Advance Camp	Argos	Nov. 1984	~ May 1985	Tr Ta V E (05001)
	CMOS	Feb. 1985	~ Dec. 1985	Ta Ts V D
	Argos	Oct. 1988	~ Nov. 1988	Tr Ta V E P R (05005)
	CMOS	Oct. 1988	~ ?	Tr Ta V R
Sør Rondane				
L0	CMOS	Dec. 1988	~ Dec. 1989	
30-Mile Point	Argos	Dec. 1987	~ Dec. 1988	Tr Ta V E P R (05004)
	Argos	Dec. 1988	~ Dec. 1989	Tr Ta V E P R (05024)
	Argos	Dec. 1989	~ *	Tr Ta V E P R (05001)
L85	CMOS	Dec. 1988	~ Mar. 1989	
Asuka	CMOS	Dec. 1984	~ Dec. 1985	Tr Ta V
A40	CMOS	Dec. 1988	~ Jan. 1989	
Lützow-Holm Bay				
Padda	Argos	Jan. 1989	~ *	Tr Ta V E P R (05007)
	Argos	Jan. 1989	~ *	Ta Tr P Tw S (05288)
Langhovde	Argos	May 1989	~ *	Tr Ta V E P R (05024)

Abbreviations: Mech. —Mechanical recorder using strip chart. Tr—Room temperature. Ta—Air temperature. Ts—Snow temperature. V—Wind speed. D—Wind direction. P—Atmospheric pressure. R—Solar radiation. RL—Long-wave radiation. Hr—Room humidity. Ps—Snow accumulation pressure. Tw—Water temperature. S—Salinity. E, E1–E4—Battery voltage.

Note that the definition of 'room' varies from true room of a cabin to inside of case of the transmitter/recorder.

*Still transmitting at the end of February 1993.

Numbers in parentheses are Argos identification.

Another AWS at AC, with Argos system, was set in December, 1984, but did not work well perhaps because of extremely low temperature. In spite of the poor performance of the Argos system in this preliminary experiment, it has a potential advantage over the CMOS system in that the data can be retrieved on a near-real-time basis. For example, we tried to fix the system in February, 1985, after receiving erroneous data caused by memory error. Analyses of troubles including those caused by low temperature were not fully accomplished until the first year of the ACR.

3. Development of AWS in ACR

In the first year of the ACR, 1987, two Argos and two CMOS AWS systems were tested at Mizuho Station (70°42′S, 44°20′E, 2230 m) which became unmanned in December 1986. One Argos AWS measured wind speed, air temperature, atmospheric pressure, solar radiation, room (inside a cabin buried in snow) temperature and the voltage of the battery connected to the AWS itself, while the other was used to monitor the output of several batteries connected to other recorders. Both Argos systems lost contact with the satellite by June. Later analysis of the systems revealed that there was a drift in the transmitter frequency due to extremely low temperatures. Other mistakes in timer settings, which would have reduced the power consumption by transmitting the data once in 180 s, caused battery power failure by resulting in data being transmitted continuously and made recovering from the frequency drift impossible. Later the circuit constants of the oscillator were adjusted to obtain the desired frequency at about −40°C.

The CMOS systems worked well for almost a year except for some troubles which are discussed below. Figure 2 shows the record of wind and temperature measured by one of the CMOS AWS units, which was originally used at AC in 1985 (KIKUCHI and MAKINO, 1988). There are considerable interruptions of wind speed data by continuous zero output which indicate locking of the anemometer rotation. We suspect that there may have occurred icing on the anemometer, or the lubricating oil used was not appropriate for the low temperature condition. Another data interruption in all three elements occurred from day 336 to 368. This was caused by memory failure of one 1 kB memory cell in 16 kB of total memories. Similar trouble occurred in 1985; we replaced the memory after that. It may be that the circuit around the memory rather than the memory itself was the cause of the trouble.

In addition to the AWS at Mizuho Station, another CMOS AWS was used at S18 (69°00′S, 40°15′E, 650 m) in 1987. It measured wind speed and direction, solar radiation, air temperature and atmospheric pressure.

In 1988, three Argos and two CMOS AWS systems were set up in the wider area of ACR studies. An Argos AWS was set up at Mizuho Station for the purpose of climatic recording with a CMOS back-up system. Another Argos system was placed at 30-Mile Point (70°50′S, 24°00′E, 350 m) which is a transportation camp between Breid Bay and Asuka Station. An example of

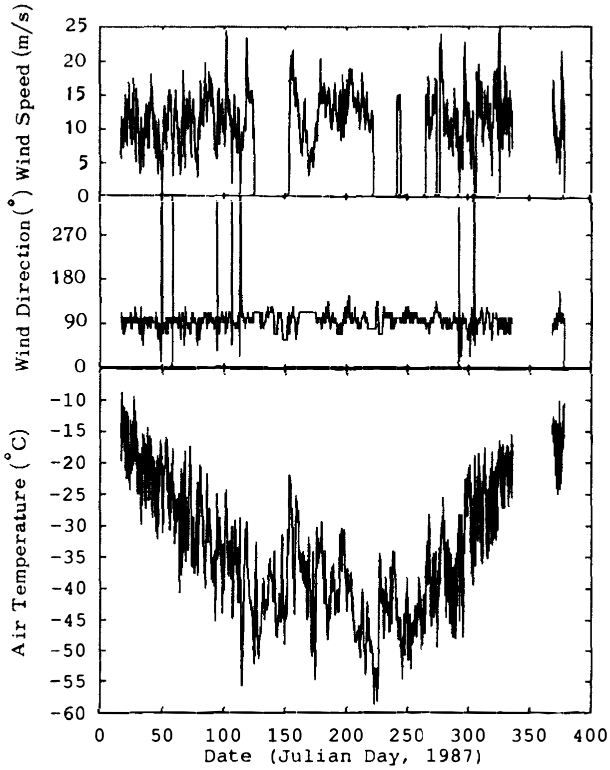


Fig. 2. CMOS record of 3-hourly weather data (wind speed, wind direction and air temperature) at Mizuho Station.

Argos data obtained in the second year of ACR is shown in Fig. 3, which shows wind and temperature only.

Some of the troubles associated with these Argos AWS are:

1) Temperature measuring circuit of Mizuho AWS had significant drift. Some of the errors are effectively compensated for by the simultaneous record of CMOS AWS and on-site measurement of air temperature by maintenance personnel.

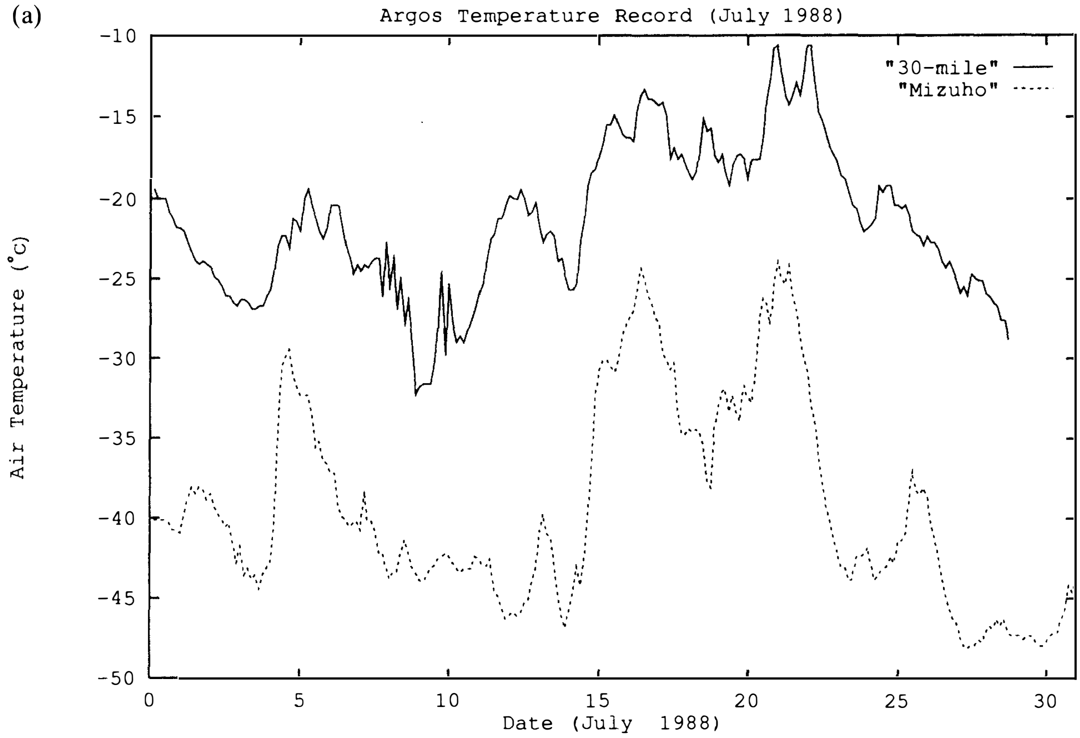
2) The designed temperature range was a little higher for 30-Mile, so we had to replace the unit in December, 1988. Techniques like folding the data range (not recording/transmitting the higher bits) may be required to expand the dynamic range while maintaining the resolution.

3) The antenna feed line of the 30-Mile AWS was exposed to strong tension by snow accumulation and the system stopped sending data repeatedly. We did not realize the cause until November 1990.

4) The record of pressure was significantly lower than the climatic value at Mizuho Station. Further, the output range decreased significantly after a year of operation. We suspect that the strain gauge attached to the pressure sensor was peeled off by low temperature.

The last Argos in AC (ID: 05005) was set up at the end of October 1988, only to stop sending data after transmitting data for only one week. Another CMOS back-up system at AC is yet to be checked, thus we have no means to

(a)



(b)

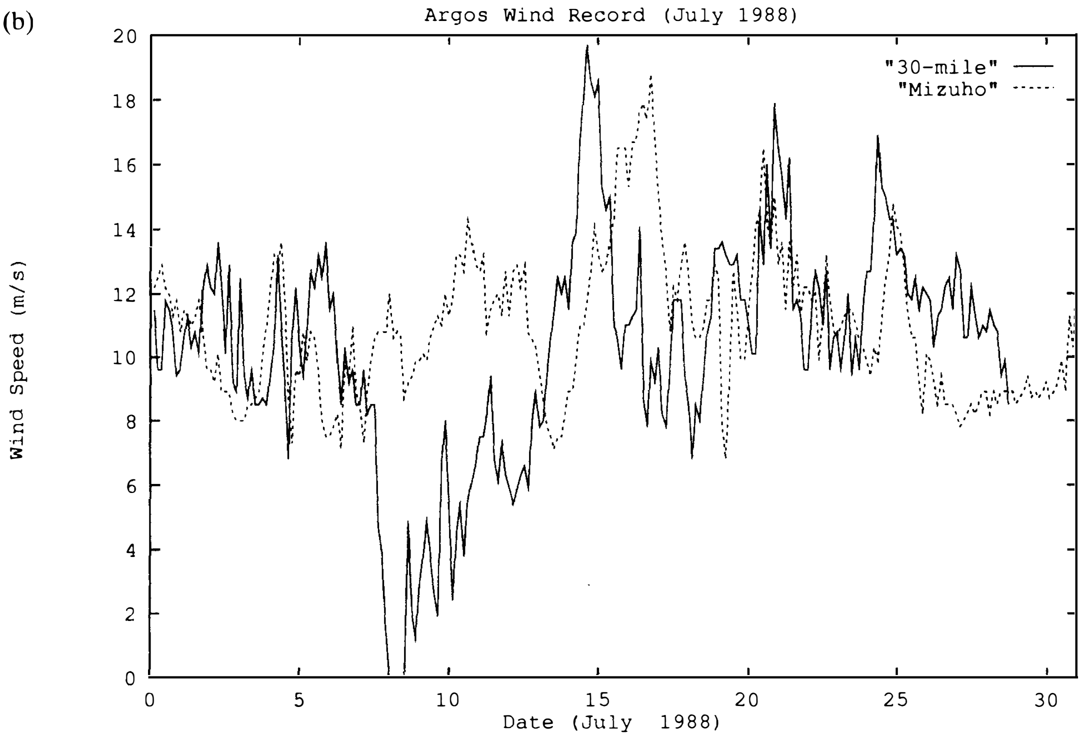


Fig. 3. (a) Temperature and (b) wind speed data obtained by Argos systems. Data shown are for the month of July 1988.

know whether it is working well or not, although it was designed to record three years of data.

In 1989, three other CMOS recorders were deployed in the Sør Rondane area in order to study the strong katabatic air stream which was found in a preliminary study of satellite images. The stream is represented by high brightness temperature in infrared images, thus it is called a dark stream.

The ACR study entered its "sea ice phase" in 1990 and meteorological and oceanographical buoys were deployed. A meteorological buoy is essentially an Argos AWS on a float. One such buoy was placed near Padda (69°35′S, 38°36′E) where another Argos oceanographical buoy was put through a hole which was dug through multi-year fast ice in January, 1990, in order to measure water temperature and salinity profiles down to 300-m depth. Another meteorological buoy was set up at L3 Point near Langhovde (69°16′S, 38°52′E) in May 1990. Detailed reports from these systems will appear from the principal investigators (Takizawa *et al.*, 1991).

The four Argos AWS units which are still working (indicated by asterisks in Table 1) will not be checked again but the receiving of data (via Service Argos) will be continued until the batteries fail.

4. Results from AWS Data

Parish and Bromwich (1987) showed that Antarctic katabatic winds tend to merge in a number of clearly defined zones, rather than to follow a radially outward pattern off the high plateau region, and cause extremely strong winds near the coast. A thermal infrared image by NOAA weather satellite shown in Fig. 4a depicts a high brightness temperature strip near 30-Mile Point west of a low temperature ice shelf (see Fig. 4d). The wind speed observed at 30-Mile Point was steady and strong (at about 10 m s^{-1}) on July 5, when Fig. 4a was taken. Such a high temperature strip of strong wind may be called a "dark stream" (Endoh, 1992) since high temperature areas are dark in conventional thermal infrared images. The wind at 30-Mile gradually decreased to zero on July 8 and relatively low wind (around 6 m s^{-1}) prevailed from July 9 to 10. Figure 4b, representing the thermal infrared image on July 9, shows that the low temperature area of the ice shelf apparently intrudes westward and covers 30-Mile Point. Consequently, the dark stream is not apparent although there still are dark areas around the slope between Asuka and 30-Mile. It should be noted that the air temperature in this period was around −30°C and lower than that on July 5. Therefore, the dark stream possibly reflects the higher air temperature which may be caused by vertical mixing of the inversion layer due to the strong katabatic wind.

It should, however, be noted that the dark stream is not always present when the wind is strong. The wind became extreme on July 15 when the satellite image, Fig. 4c, was rather chaotic and showed no dark stream. The topographic patterns which are seen in Figs. 4a and b are obscured except for part of the coastline. It appears that the chaotic image represents clouds and the strong wind

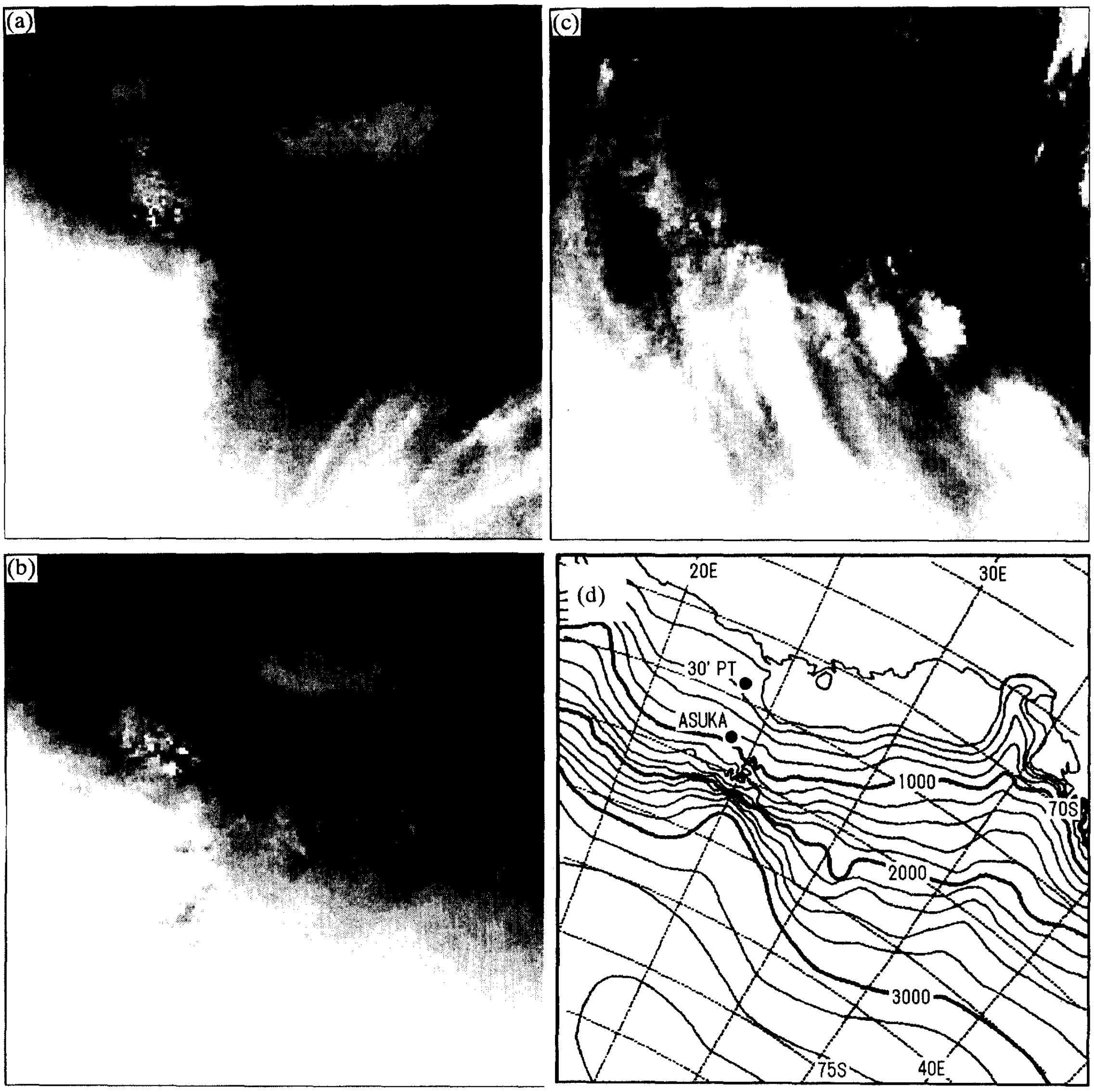


Fig. 4. Thermal infrared images on (a) July 5, (b) July 9 and (c) July 15, 1988, by NOAA weather satellite Advanced Very High Resolution Radiometer (AVHRR) ch 4 (10.3–11.3 m), and (d) topography of the image area.

was caused by a synoptic disturbance considering that if the cloud is present then radiative cooling, which is neccesary to cause the katabatic wind, is not predominant.

Figure 5 shows the monthly mean data of wind velocity at three sites of Argos AWS, Mizuho, 30-Mile and L3. Some interesting features are:

1) Both Mizuho and 30-Mile winds are significantly stronger than that on sea ice in Lützow-Holm Bay.

2) Wind becomes weaker in summer (November to January) both at Mizuho and 30-Mile.

3) Mizuho wind is stronger than that at 30-Mile except in autumn (February to May).

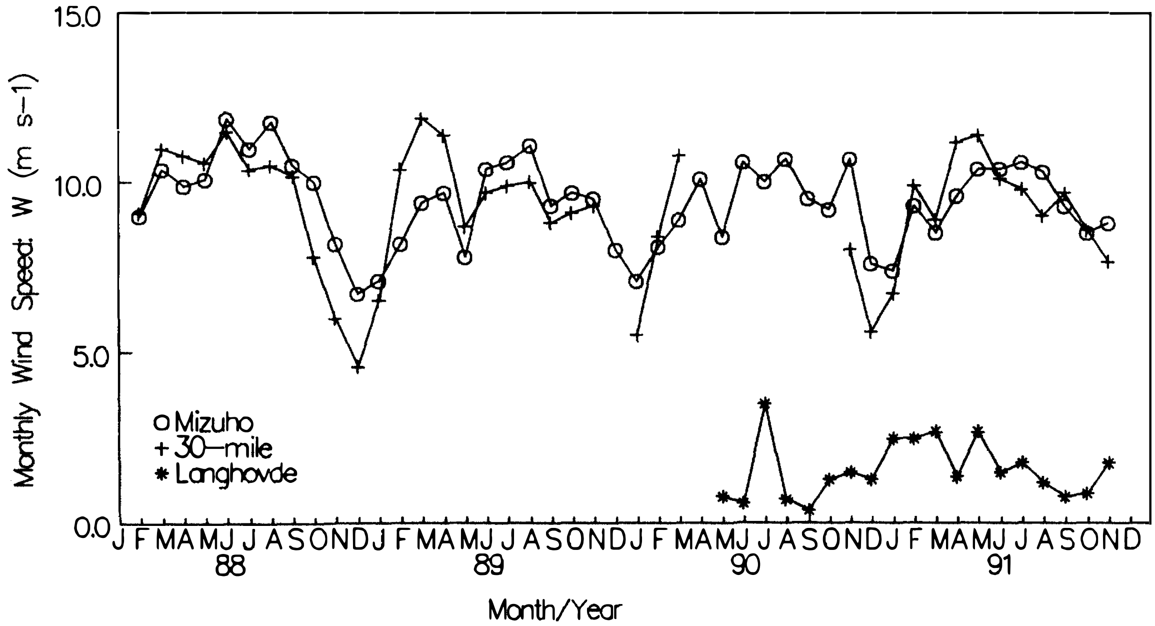


Fig. 5. Monthly mean wind speed calculated from the data by Argos systems.

The last feature is most significant in 1989 when the 30-Mile wind exceeded that at Mizuho by about 2 m s^{-1} , and less significant but observable in other years. Synoptic conditions such as approaching of cyclones may be related to this feature although more precise data would be needed.

5. Concluding Remarks

In conclusion, Argos and CMOS AWS are useful in the observation of climate parameters and associated weather phenomena. Although we must be careful in interpreting the raw output of the AWS at this stage of development of the instruments, we expect that they will become more useful by continuous effort of development and maintenance.

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