Measurement of Meteorological Data in Northern Chile (August - October 1994)

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Abstract

Meteorological conditions in Northern Chile have been measured in August to October 1994. The data indicate that water vapor pressure is quite good (mean value is 1.2 hPa) at the altitude of 4000-m level but worse (1.9 hPa) at the 3000-m level. The wind is generally stronger at higher places, however. The water vapor pressure is best at the dawn at a place (Ollague), but nearly constant at one place at the 4000-m level and is best in the daytime at other two places at the 3000-m level. The wind is generally weak at nights (2 m/s) but becomes stronger in the daytime and until 20 hours. The wind direction is mostly west at all measured positions. The precipitation is extremely low (< 10 mm/yr) between the seashore and the Andes mountain, but become large (> 100 mm/yr) near or in the Andes mountain. Further measurement is continued

1. Introduction

The Nobeyama Radio Observatory (NRO) is planning a project of the Large Millimeter and Sub-millimeter Array (LMSA). The construction site of LMSA must be a fairly flat area of a

few km squares with very good atmospheric and meteorological conditions at millimeter and submillimeter wavelengths. At the moment, Mouna Kea in Hawaii and high places in Northern Chile are thought to be most probable candidates of the site. Atmospheric and meteorological data have been well obtained at Mouna Kea but limited in mountain sites of Northern Chile. In to compare the two candidates, therefore, the observatory started measurement of the atmospheric and meteorological data in Northern Chile in 1994 using a 220 GHz radio meter, radio seeing monitor, and meteorological equipments. Here we report the preliminary results of meteorological measurement between 1994 August and October.

2. Equipments

An anemoscope and anemometer, actinometer, thermometer and hygrometer are attached to a steel pole whose height is 3 m (figure 1). Electric power is supplied by a solar cell and a storage battery. Measured data are stored in an IC memory card every 10 minutes, which enables us to keep the data in the card for three months. Measured items are wind direction (error is $< \pm 5°$), wind speed ($\pm 5\%$), temperature ($\pm 0.5°C$), relative humidity ($\pm 5\%$), and solar radiation ($\pm 3\%$). The wind speed is the mean value in a minute. Maximum wind speed in the minute is empirically estimated to be about 1.3 to 1.5 times larger than the mean value, although depends on the character of the wind. All the items are measured every 10 minutes automatically. Water vapor pressure p is calculated using the equations of

$$p = h\ sv,$$

$$sv = 6.11 \exp[17.27\ (T - 273.16) / (T - 35.86)],$$

where h is the relative humidity, sv the saturated water vapor pressure (hPa), T the absolute temperature (K).

3. Locations of Weather Stations

Four weather stations were installed in August 1994 at sites of altitude 3100 – 4500 m in Northern Chile (A – D in figure 2). The latitude of the sites is 21.3° – 24.6°. Two positions of the 4000-m level (A and B) is located in the Andes mountain. All sites are within several hours from Antofagasta, the biggest city in Northern Chile. Weather stations at location A and B were set on hills close to the flat areas large enough for LMSA. The station at B is located in the perfectly flat area surrounded by mountains. The station at C stands on a hill in the ground of a mining company. The company has also a weather station on a hill at M that is near B (figure

2). We refer the data (only daily mean values) of April 1993 to June 1994 obtained at M. The positions of these stations are summarized in table 1.

Table 1. Positions of Weather Stations

Station	Place	Longitude	Latitude	Altitude
A	Ollague	68°25'39"	21°16'53"	4500 m
B	Pampa EL Hueso	68°27'54"	24°32'51"	4300 m
C	Bajada Colorada	68°20'46"	22°34'52"	3500 m
D	mining company	69°03'26"	24°15'11"	3100m
M	Escondida	68°37'13"	24°39'10"	4300 m

4. Results

4.1. Statistical Mean

Figures 3 to 6 shows all original data of station A to D between the middle of August and the end of October 1994 (winter to spring in Chile). The periodic variation of solar radiation, temperature, relative humidity, and wind speed indicates the daily variations. It is clear especially in humidity that weather condition was bad in the middle of August and at the end of September at the four positions that are separated by several ten km or more than 100 km. Statistical mean values calculated from these data is summarized in table 2, where the values of station M are for three months from August to October 1993.

Table 2. Mean values of meteorological data

Station	Height (m)	Temperature (°C)	Relative humidity (%)	Water vapor pressure (hPa)	Mean wind speed (m/s)
A	4500	2.9 ± 6.4	17 ± 16	1.2 ± 0.9	6.7 ± 3.6
B	4300	− 1.2 ± 7.1	25 ± 20	1.2 ± 0.8	5.0 ± 4.2
C	3500	9.7 ± 5.0	18 ± 15	1.9 ± 1.1	3.7 ± 3.0
D	3100	9.5 ± 4.9	17 ± 12	1.9 ± 1.0	4.2 ± 4.4
M	4300	− 0.5	21	1.2	

4.2. Water Vapor Pressure

Figure 7 shows the cumulative probabilities and distributions of the water vapor pressure for all data (about 75 days) and for date with good weather condition (45 days). At locations A and B, about 60 % is better than 1 hPa. Figure 7 and table 2 clearly indicate that the water vapor pressure is better at the 4000-m level that at the 3000-m level.

4.3. Wind Speed and Direction

The wind speed is very important to design telescope antennas. Figures 8 and 9 show the cumulative probabilities and distributions of mean wind speed. These figures and table 2 show a trend that the wind is stronger at higher places. Especially the wind at location A near Ollague is much stronger. At nights at B to D, the wind is fairly weak (section 4.5). The wind direction is mostly west (figures 10 and 3 – 6).

4.4. Daily Variations

Figure 11 shows daily variations of solar radiation, temperature, water vapor pressure (dew point), and wind speed averaged for all data (about 75 days) or only good data (45 days). Water vapor pressure is best at the dawn (location A) or midday (B, C, D), and worst at 17 – 22 hours. The wind becomes strong with the rising sun and strongest at 15 – 17 hours. Nights are calm at locations B, C, and D (about 2 m/s). The variation patterns of the water vapor pressure and the wind speed are very similar each other at A, so that the two items are apparently correlated (figure 12a). However, such relation cannot be seen at B, C, and D (figure 12b).

4.5. Annual Variations at Escondida

Figure 13 shows annual variations of temperature, relative humidity, water vapor pressure, and wind speed averaged in a day at the weather station M of the mining company, which is close to the station B. The water vapor pressure is best (< 1 hPa) in May to July (winter) and become twice in January (summer). This is because that both temperature and relative humidity become low in winter.

4.6. Distributions of Precipitation and Water Vapor Pressure in Northern Chile

The Chilean government have gathered meteorological data of 1976 – 1977 or older from weather stations already existing in Northern Chile ("Investigacion de Recursos Hidraulicos en el Norte Grande", Antecedentes Meteorologicos e Hidrometricos, Septiembre 1977). Figure 14 shows the distribution of the annual precipitation (mm/yr). The precipitation is high in and near the Andes mountain. Most precipitation concentrates in summer (January – March). Figure 15 shows the distribution of the water vapor pressure calculated from temperature and relative humidity. It is clear that the water vapor pressure is better at the altitude more than 4000 m.

Acknowledgements

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Figure captions

Fig. 1. Meteorological equipments attached to weather stations.

Fig. 2. Locations of four NRO weather stations (A to D) and of a stations of a mining company. Dark regions indicate the altitude higher than 4000 m.

Fig. 3 – 6. Data measured at locations A to D from the middle of August and the end of October. The periodic variations of the solar radiation to the wind speed indicate daily variations. It is clear especially in relative humidity that weather conditions were bad in the middle of August and at the end of September at all positions.

Fig. 7. Cumulative probabilities (a) and distributions (b) of water vapor pressure for all data (about 75 days) and for good data (45 days).

Fig. 8. Cumulative probabilities (upper) and distributions (lower) of wind speed averaged in a minute.

Fig. 9. Distributions of mean wind speed same as figure 8 (lower).

Fig.10. Relation between wind speed and wind direction. The wind direction is mostly west.

Fig.11. Daily variations of temperature, solar radiation, dew point and water vapor pressure calculated temperature and relative humidity, and mean wind speed from 0 to 24 hours, averaged in all days or days with good weather condition (45 days).

Fig.12. Relations between water vapor pressure and wind speed at locations A and B. The relations are shown in August to October separately.

Fig.13. Annual variations of temperature, relative humidity, water vapor pressure, and wind speed at location M (Escondida), where all original data are the values averaged in a day. Relative humidity and water vapor pressure at Paranal are also shown.

Fig.14. Distribution of annual precipitation (mm/yr) in Northern Chile.

Fig.15. Distribution of water vapor pressure (hPa) averaged in a year.

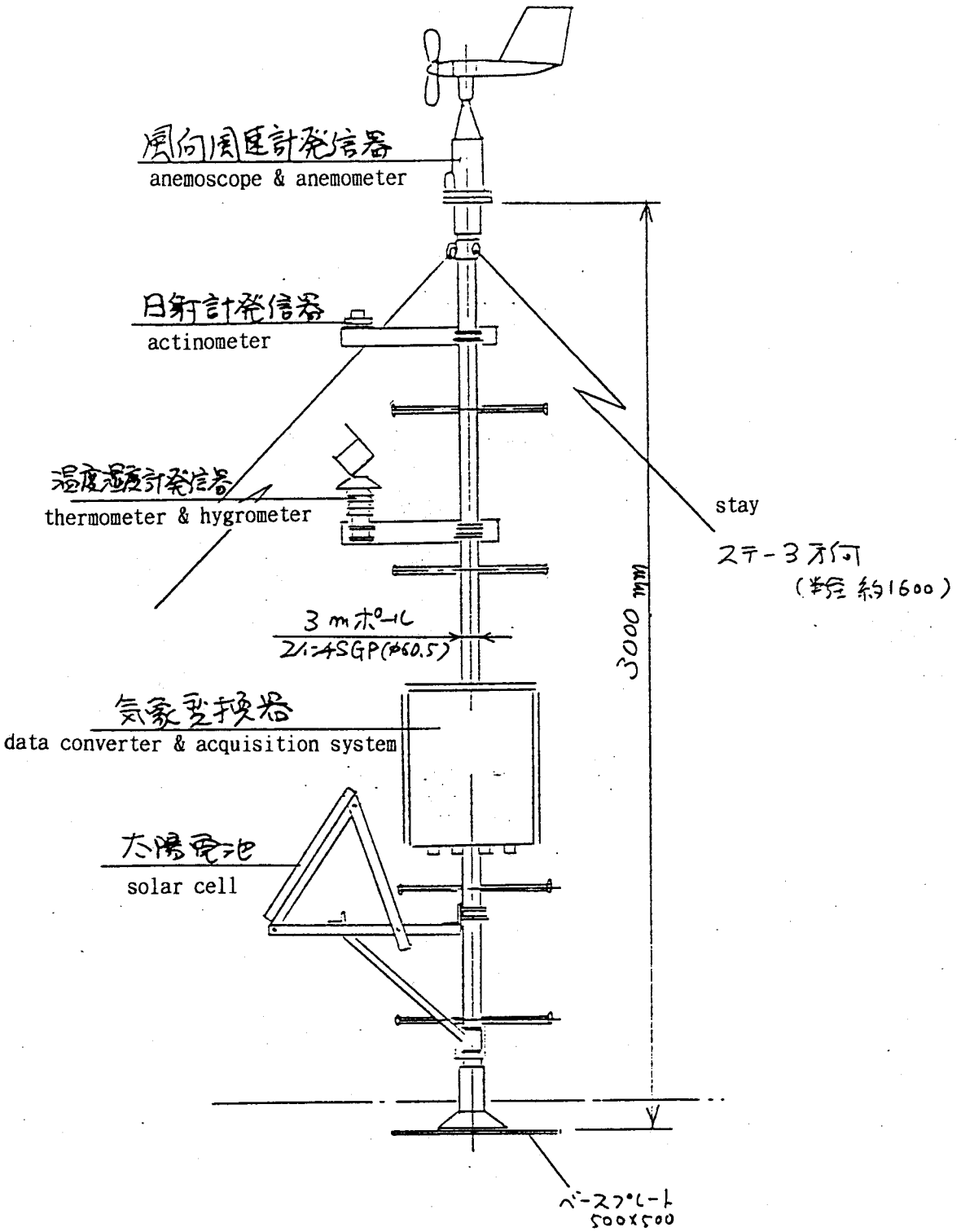


Fig-6

変更 REVISIONS		名称 TITLE	3mポール 設置参考図
作成 DRAWN BY 佐久	照査 CHECKED BY	検認 APPROVED BY	尺度 SCALE / 単位 DIM IN mm / 型式 MODEL
株式会社 小笠原計器製作所 OGASAWARA KEIKI CO., LTD. TOKYO JAPAN		図面番号 DRAWING NO. E7-5900B-33	SHEET

Fig. 1

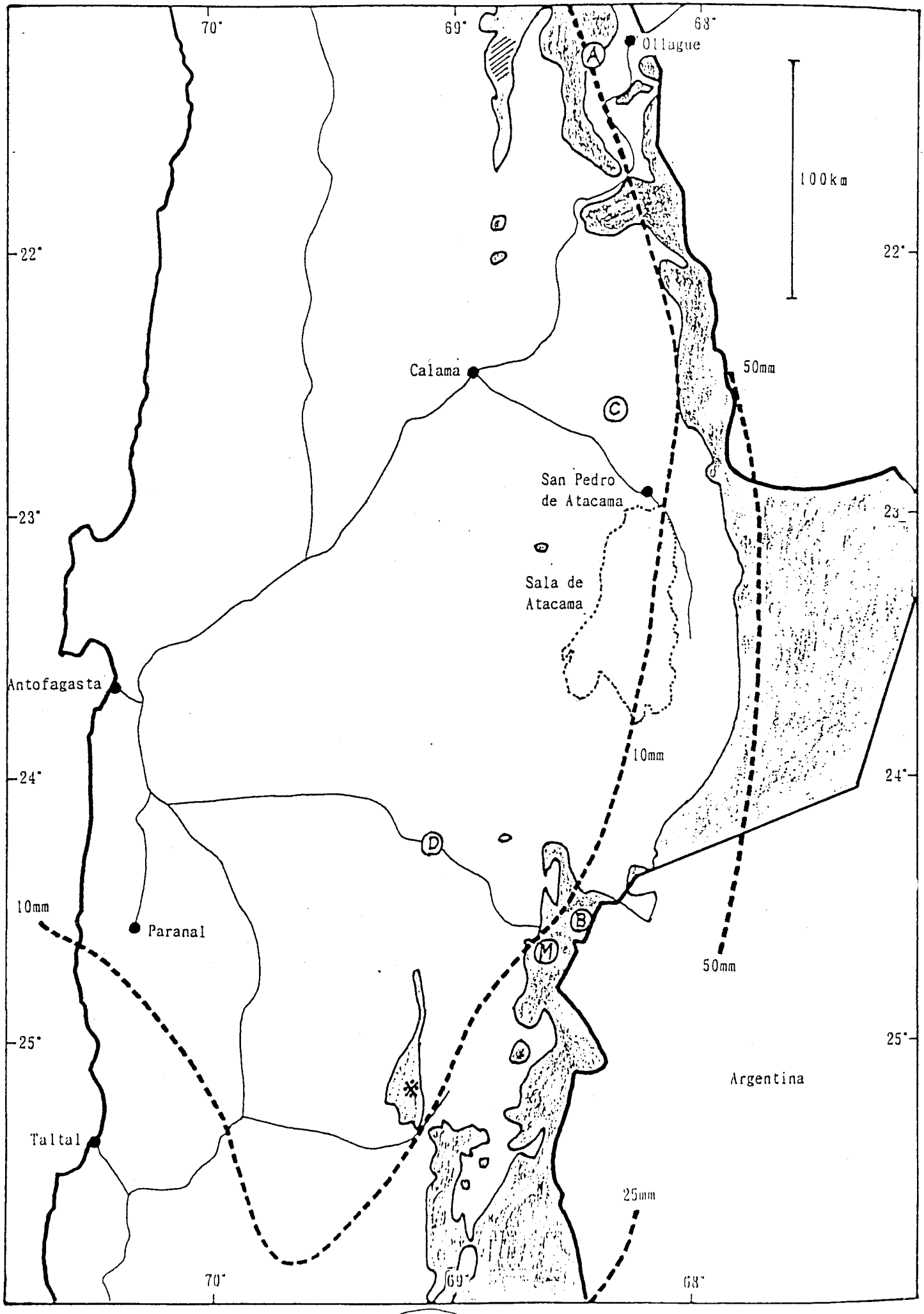

70°
69°
68°
Ollague
A
100km
22°
Calama
50mm
C
San Pedro
de Atacama
23°
Sala de
Atacama
Antofagasta
10mm
24°
D
10mm
Paranal
B
M
50mm
25°
Argentina
Taltal
25mm
70°
69°
68°

Fig. 2.

(A) Ollague (4500m)

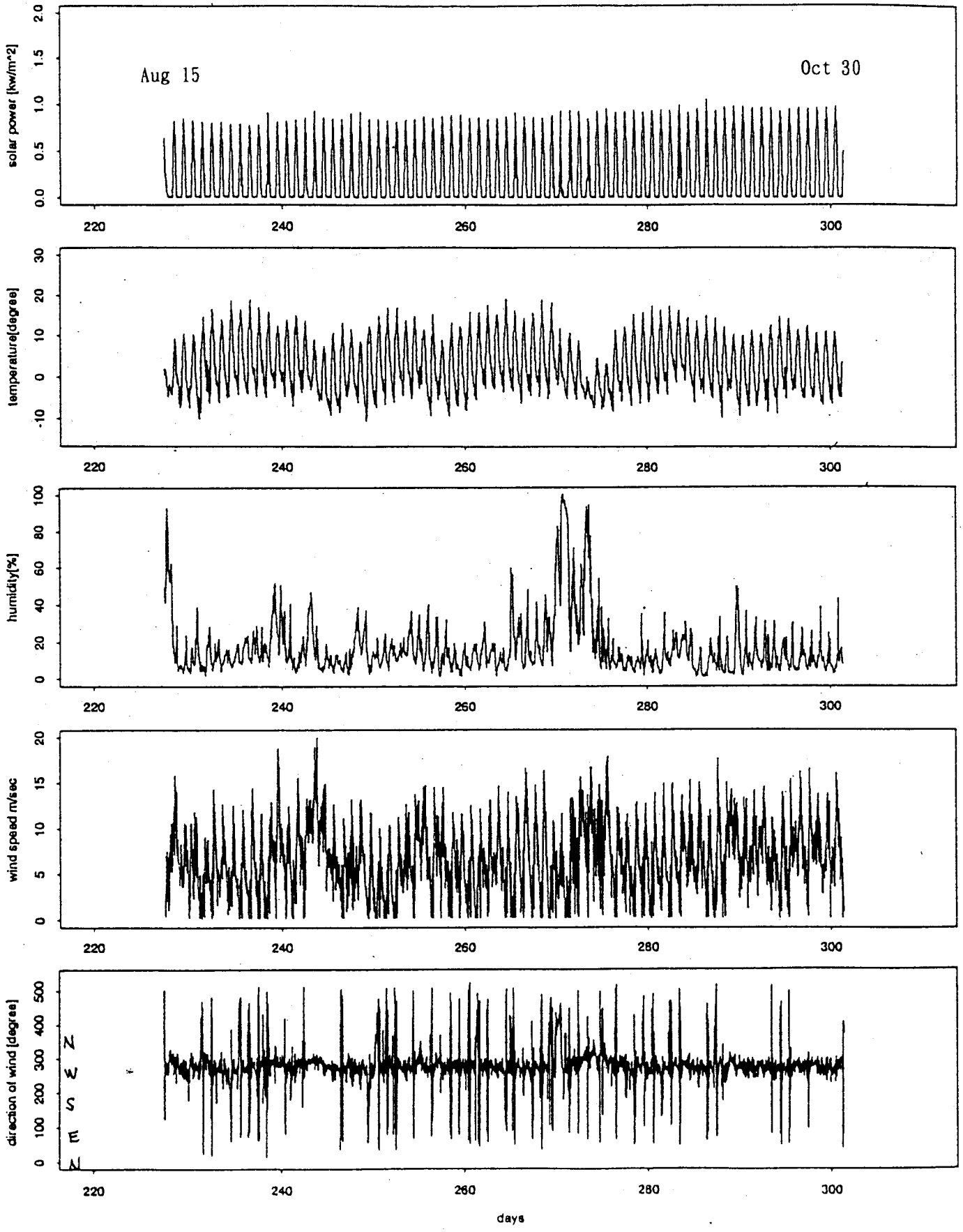


Fig. 3.

(B) Pampa EL Hueso (4300m)

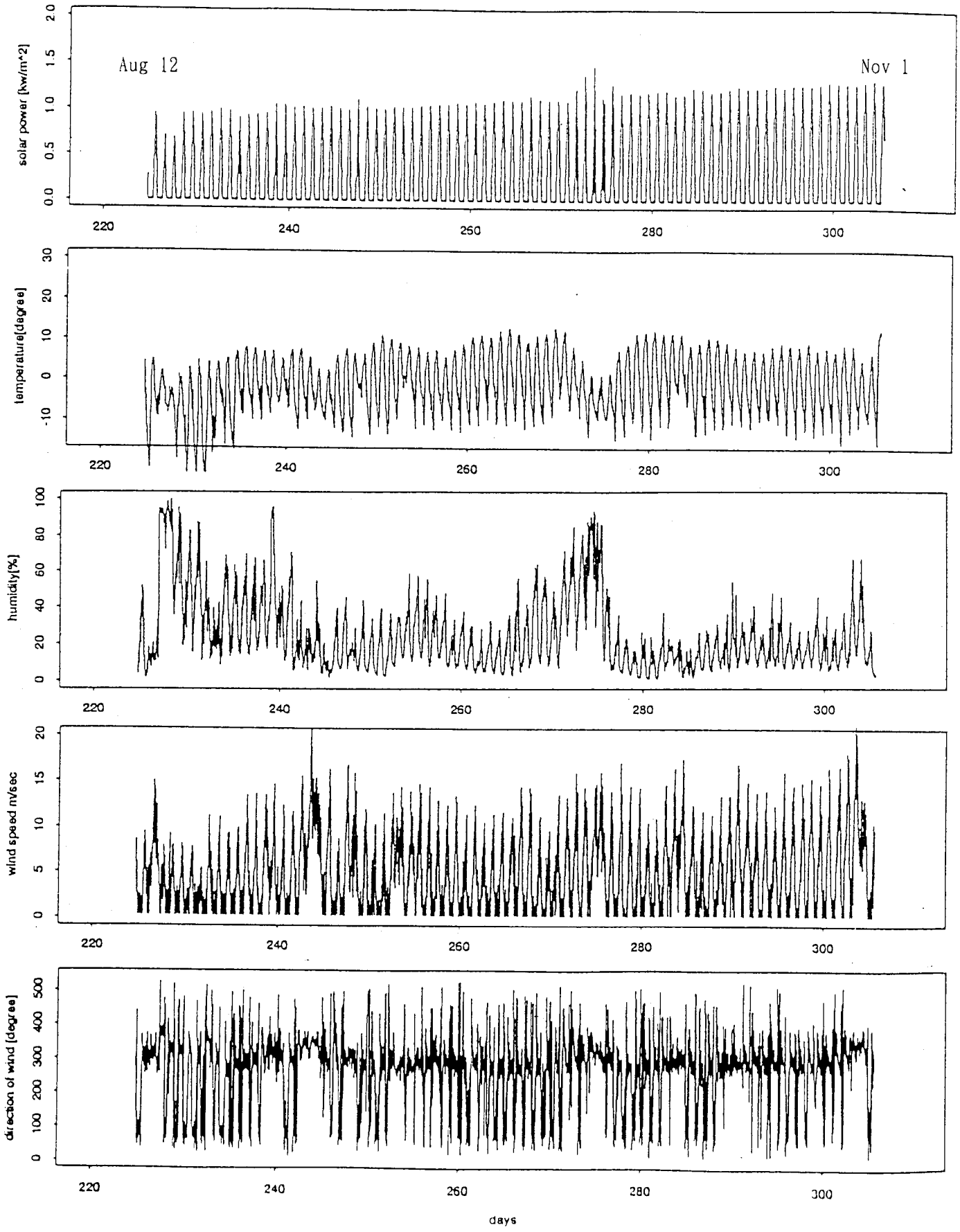


Fig. 4.

(C) Bajada Colorada (3500m)

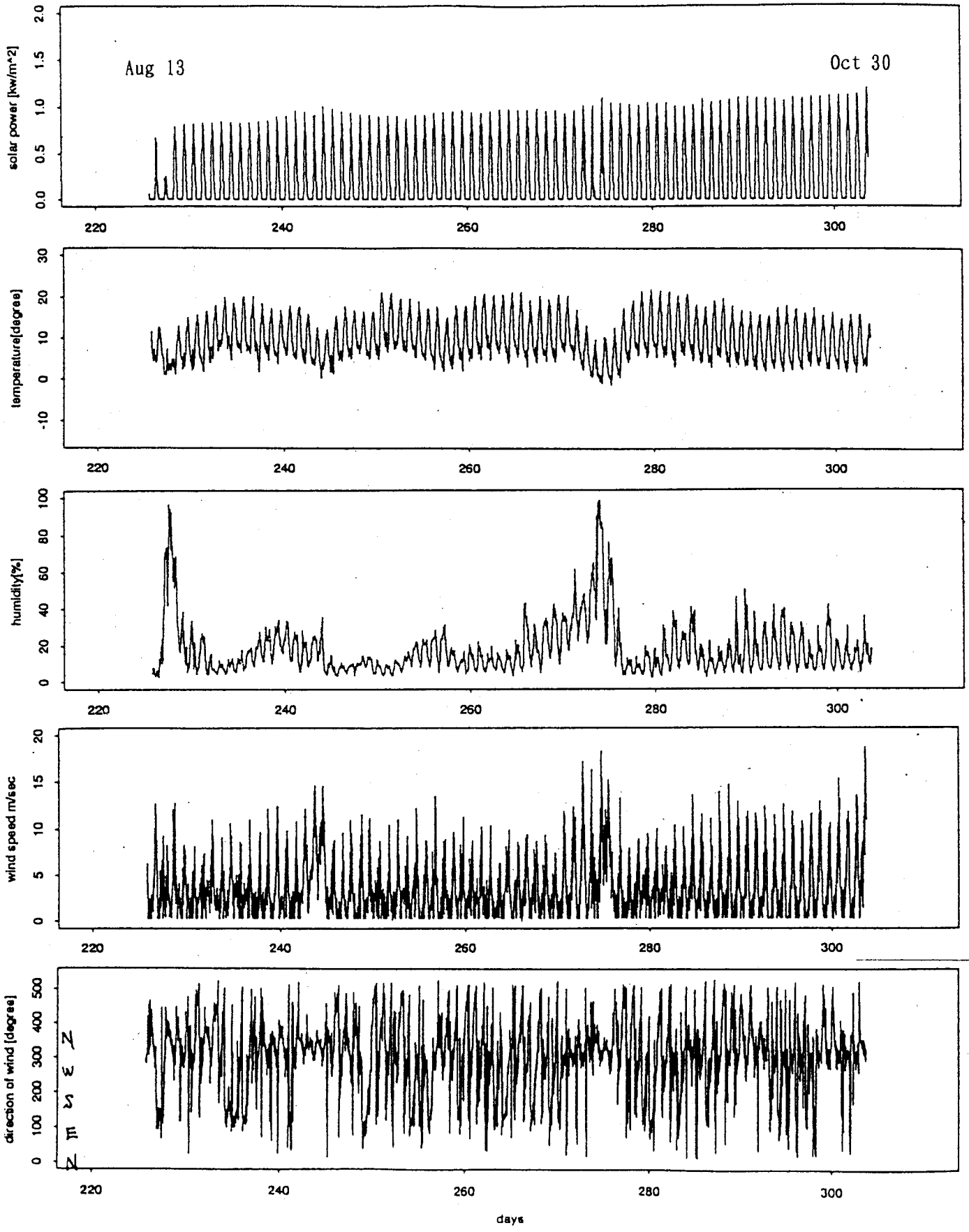


Fig. 5

(D) Mining company (3100m)

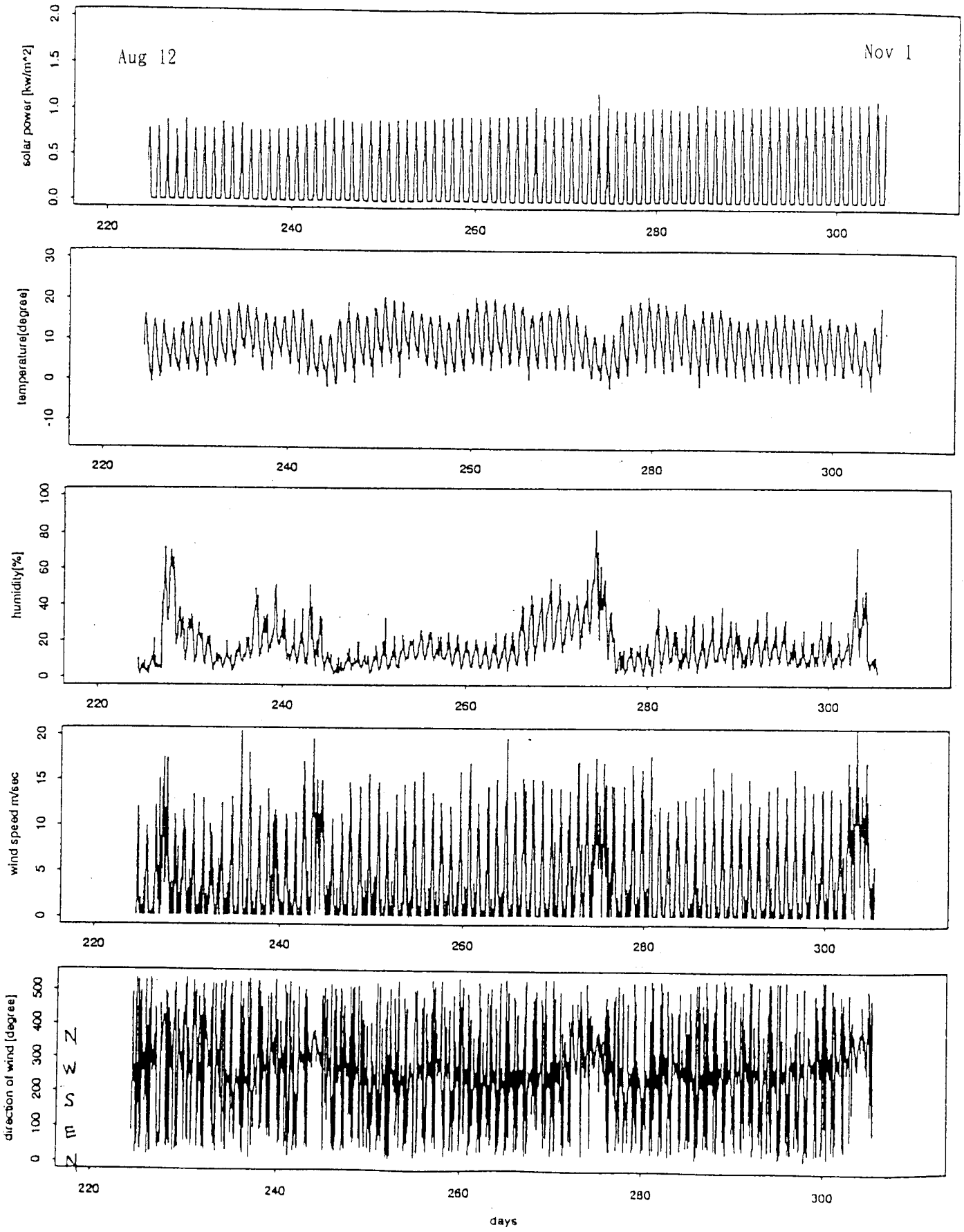


Fig. 6.

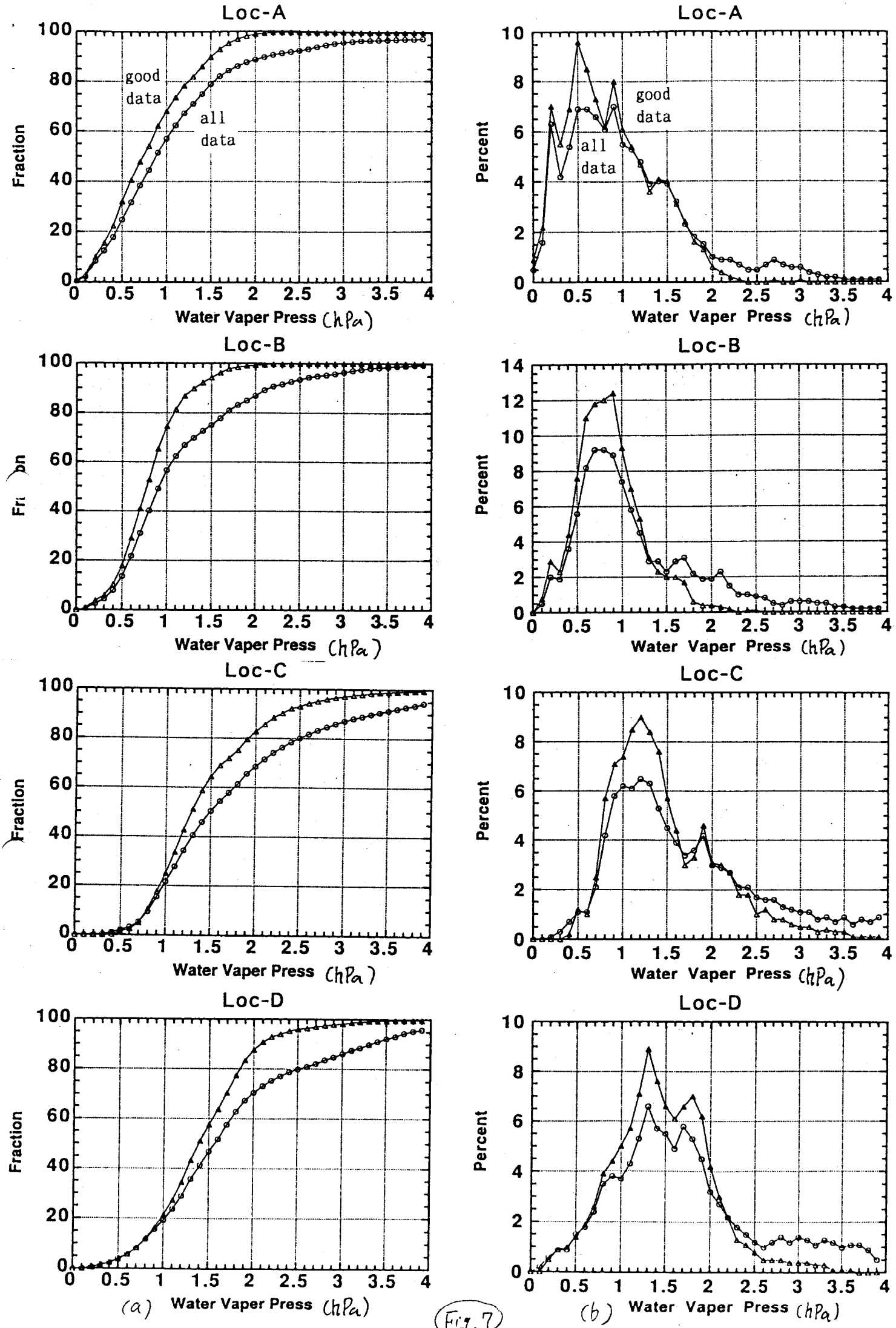
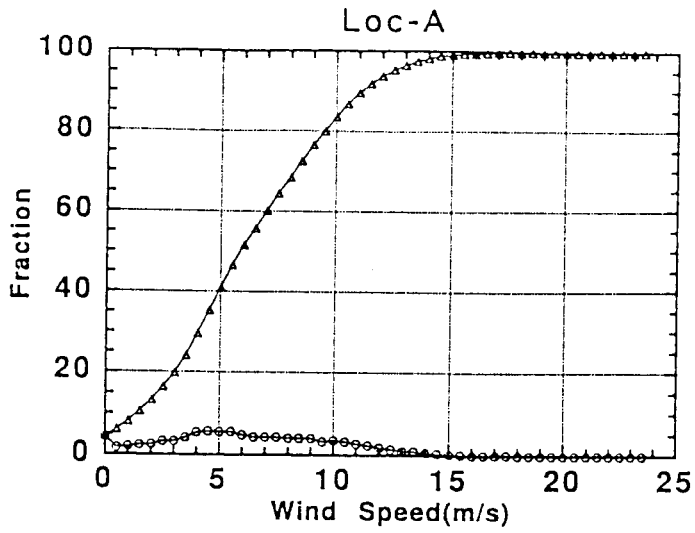
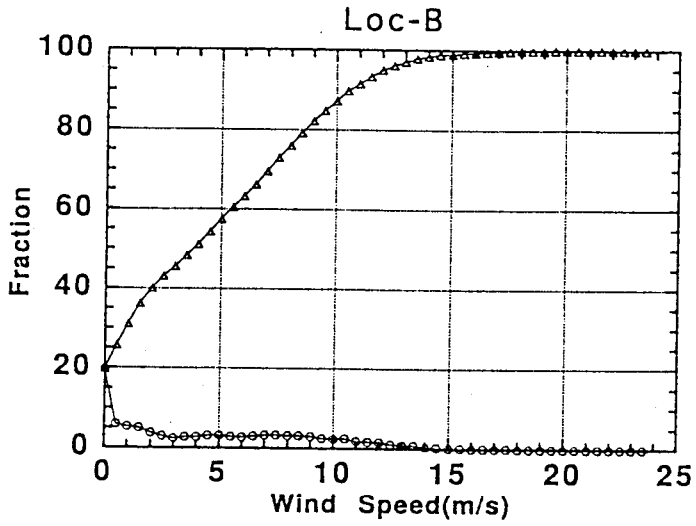
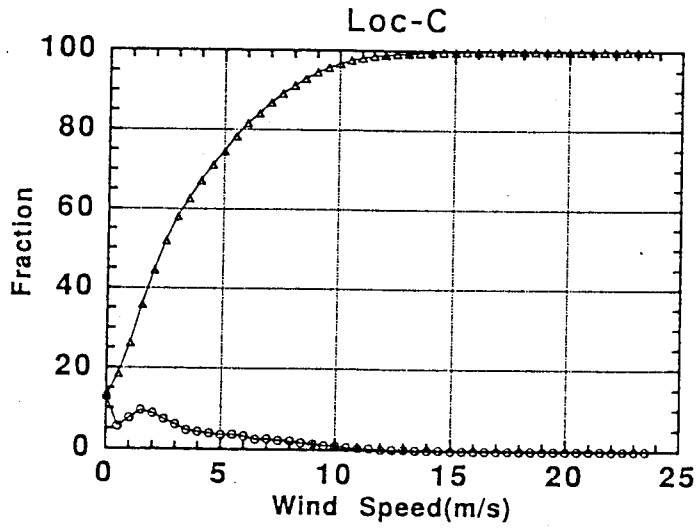

Loc-A
Fraction
good data
all data
Water Vaper Press (hPa)
Loc-A
Percent
good data
all data
Water Vaper Press (hPa)
Loc-B
Fraction
Water Vaper Press (hPa)
Loc-B
Percent
Water Vaper Press (hPa)
Loc-C
Fraction
Water Vaper Press (hPa)
Loc-C
Percent
Water Vaper Press (hPa)
Loc-D
Fraction
(a) Water Vaper Press (hPa)
Loc-D
Percent
(b) Water Vaper Press (hPa)

Fig. 7


Loc-A
Fraction
100
80
60
40
20
0
0
5
10
15
20
25
Wind Speed(m/s)


Loc-B
Fraction
100
80
60
40
20
0
0
5
10
15
20
25
Wind Speed(m/s)


Loc-C
Fraction
100
80
60
40
20
0
0
5
10
15
20
25
Wind Speed(m/s)

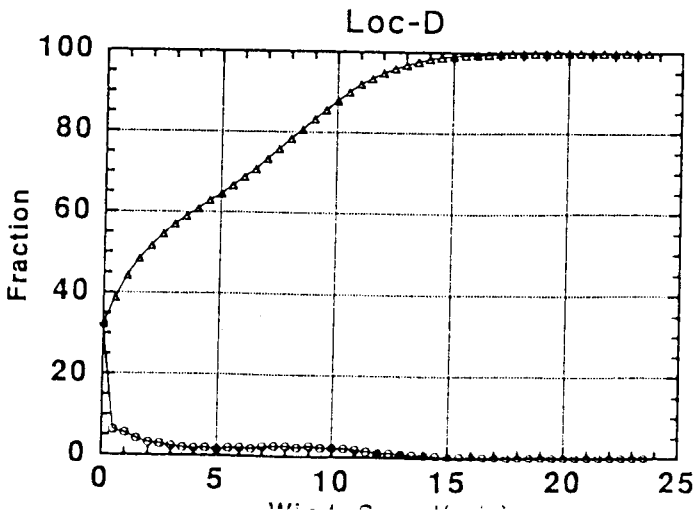

Loc-D
Fraction
100
80
60
40
20
0
0
5
10
15
20
25

Fig. 8.

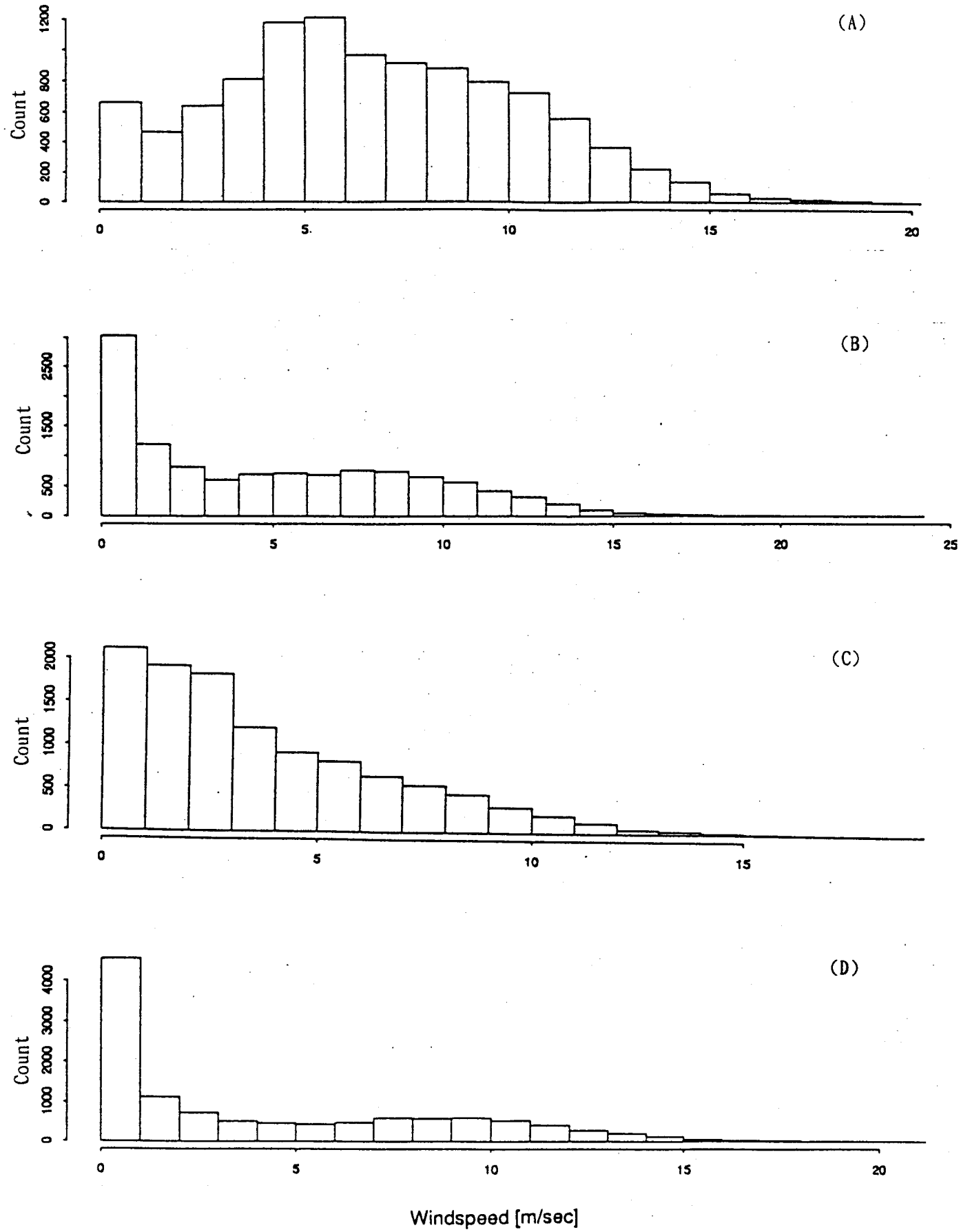

(A)
Count
0
200
400
600
800
1200
0
5
10
15
20
(B)
Count
0
500
1500
2500
0
5
10
15
20
25
(C)
Count
0
500
1000
1500
2000
0
5
10
15
(D)
Count
0
1000
2000
3000
4000
0
5
10
15
20
Windspeed [m/sec]

Fig. 9.

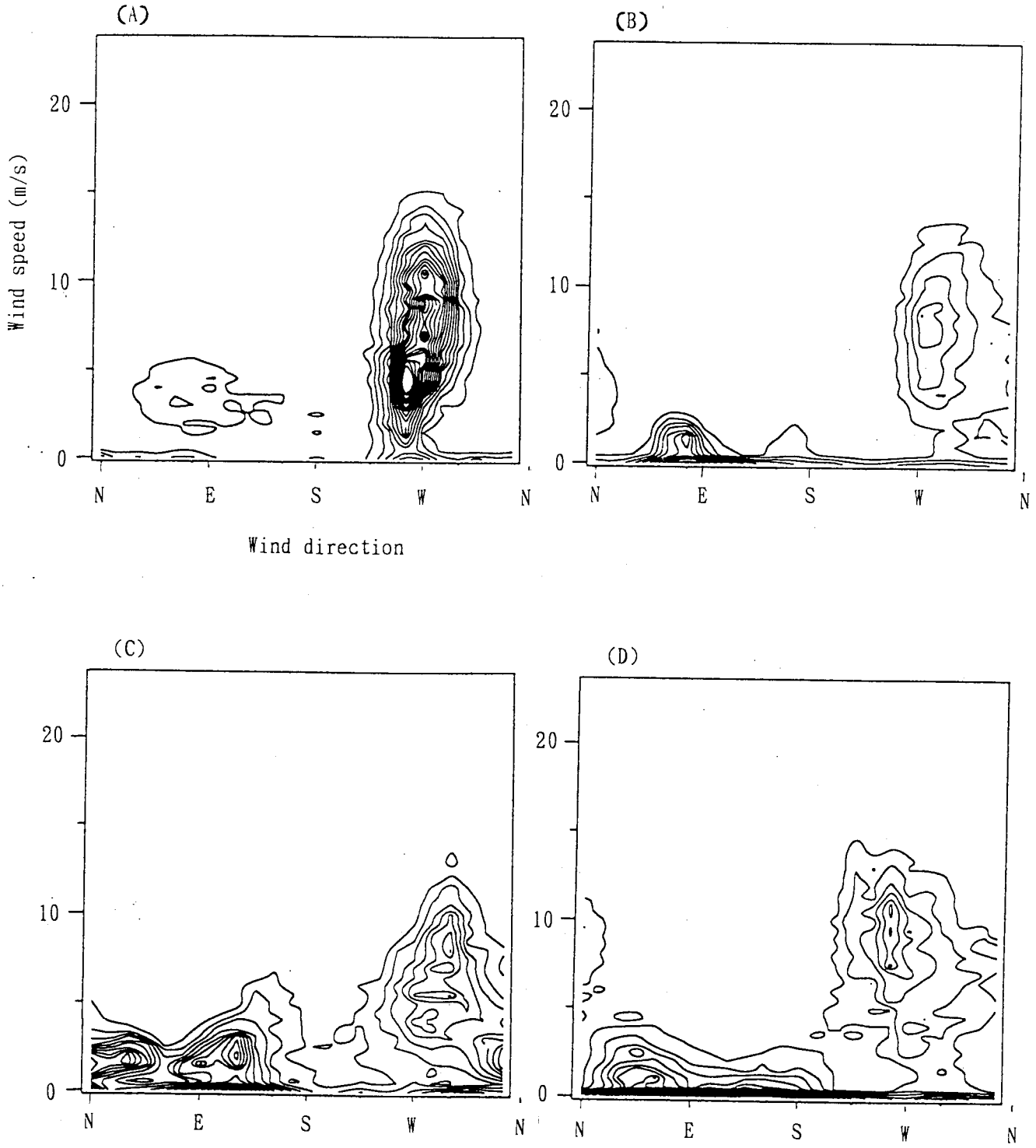


Fig. 10.

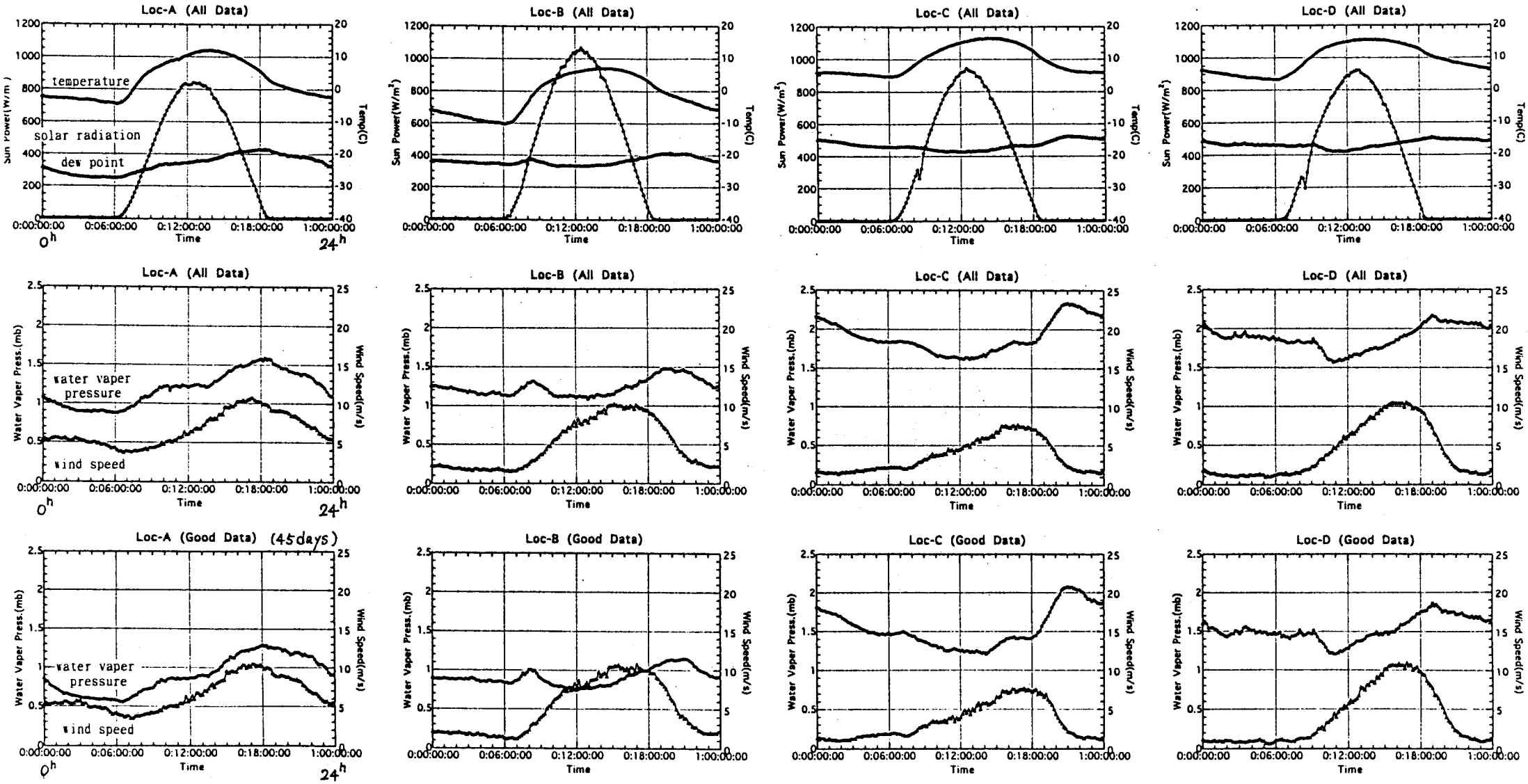
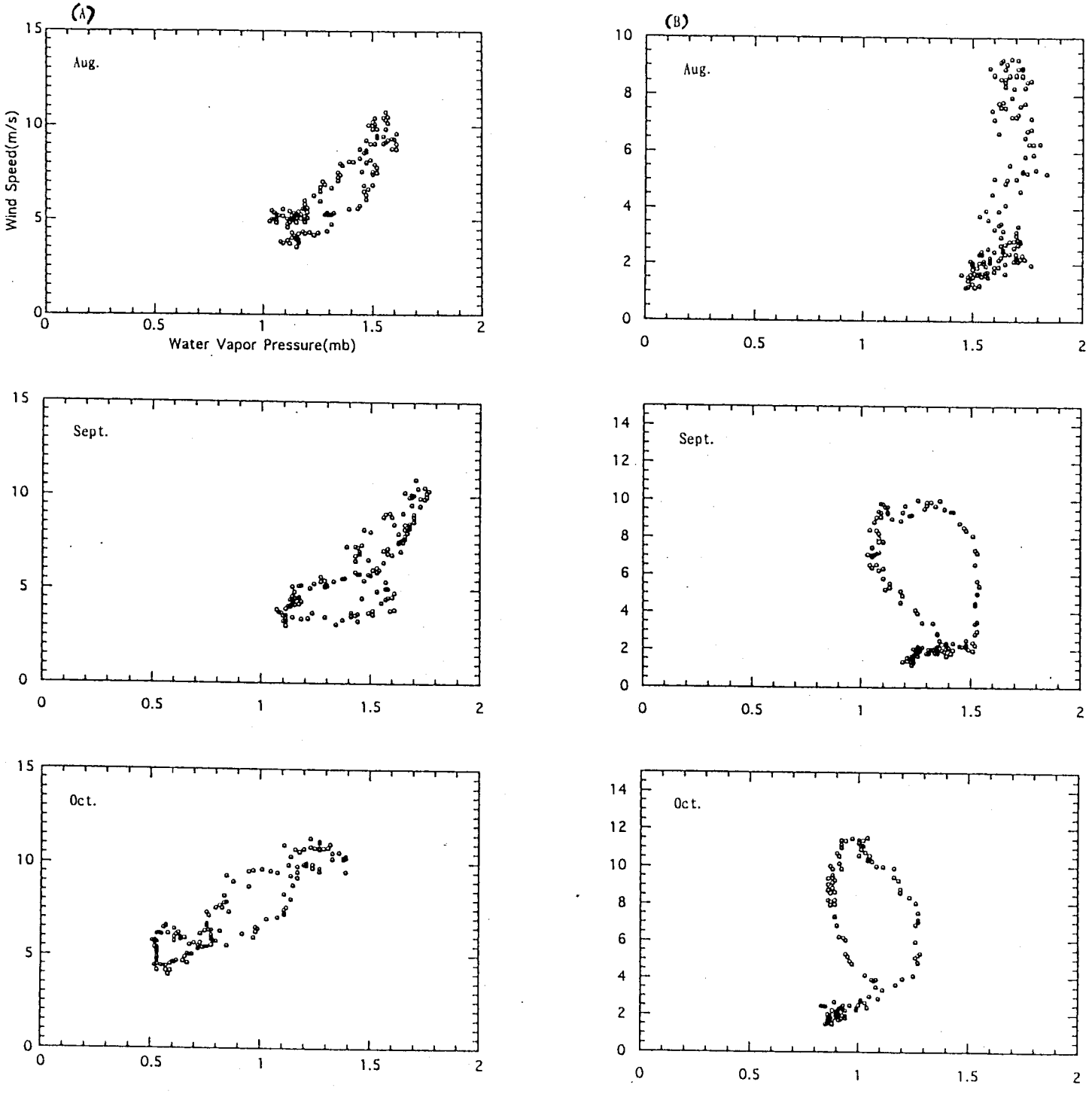

Loc-A (All Data)
Loc-B (All Data)
Loc-C (All Data)
Loc-D (All Data)
temperature
solar radiation
dew point
Sun Power(W/m²)
Temp(C)
Time
0h
24h
Loc-A (All Data)
Loc-B (All Data)
Loc-C (All Data)
Loc-D (All Data)
water vaper pressure
wind speed
Water Vaper Press.(mb)
Wind Speed(m/s)
Time
0h
24h
Loc-A (Good Data) (45days)
Loc-B (Good Data)
Loc-C (Good Data)
Loc-D (Good Data)
water vaper pressure
wind speed
Water Vaper Press.(mb)
Wind Speed(m/s)
Time
0h
24h

Fig. 11

Fig. 12


(A)
Aug.
Wind Speed(m/s)
Water Vapor Pressure(mb)
Sept.
Oct.
(B)
Aug.
Sept.
Oct.

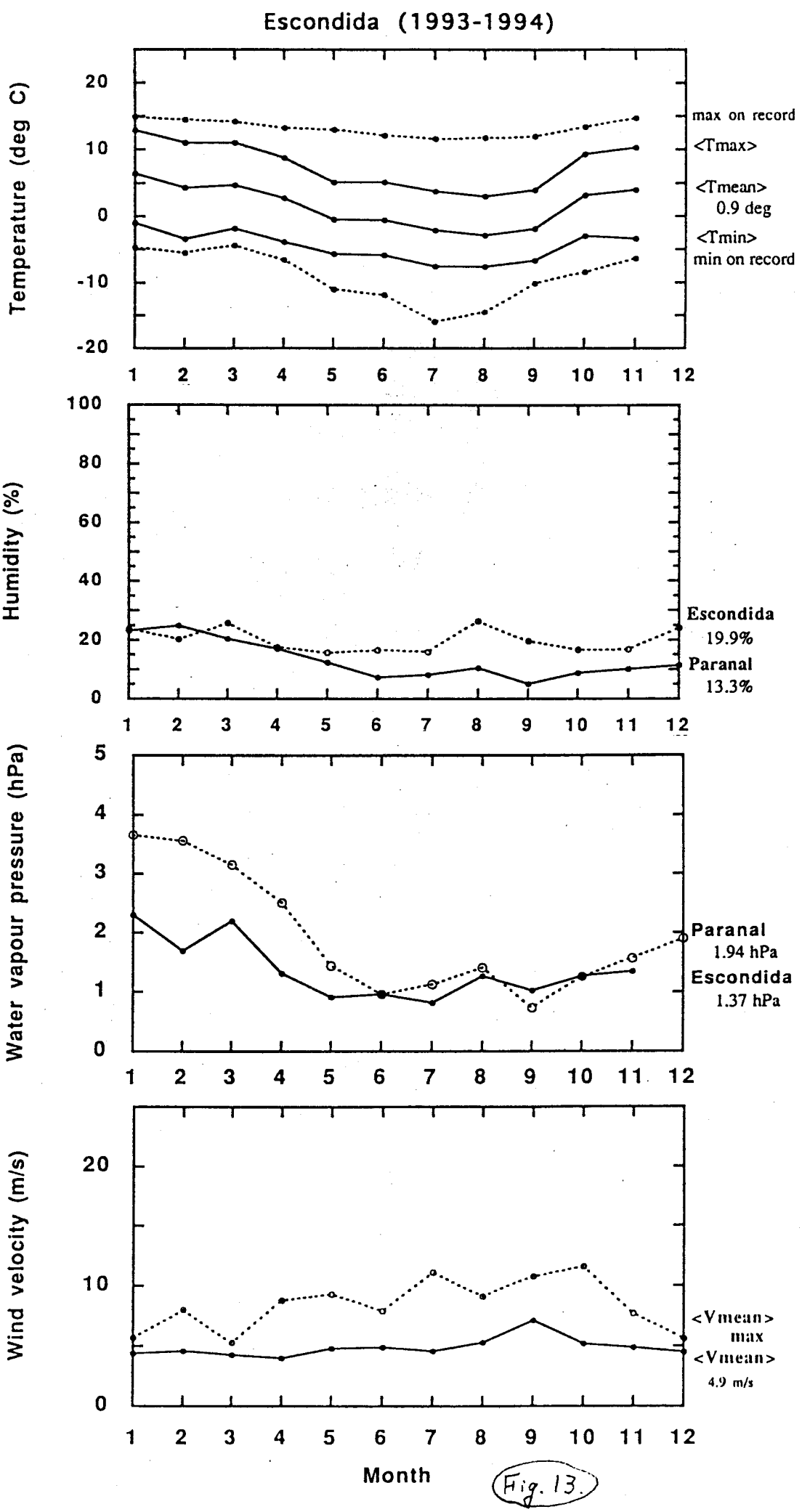
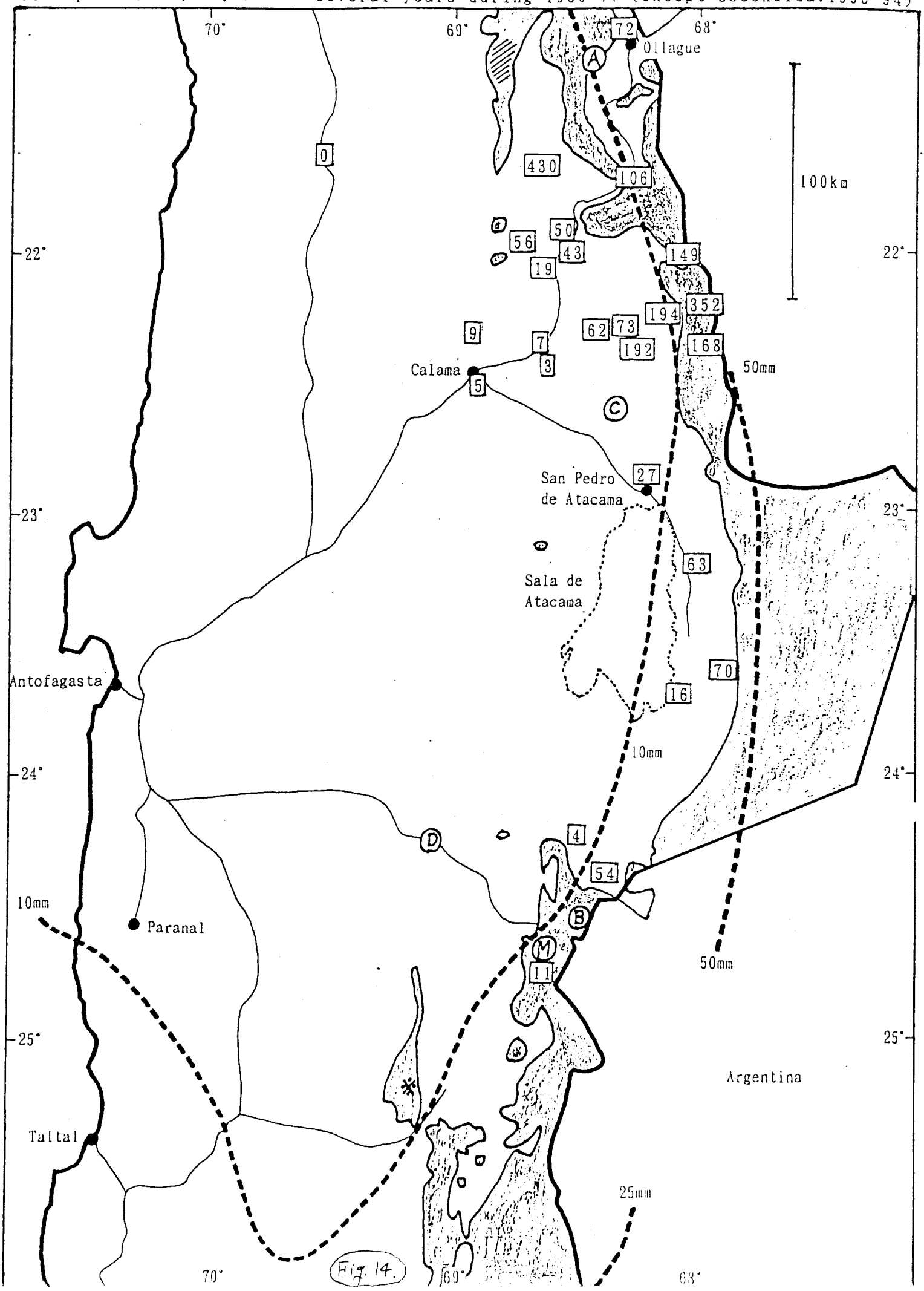
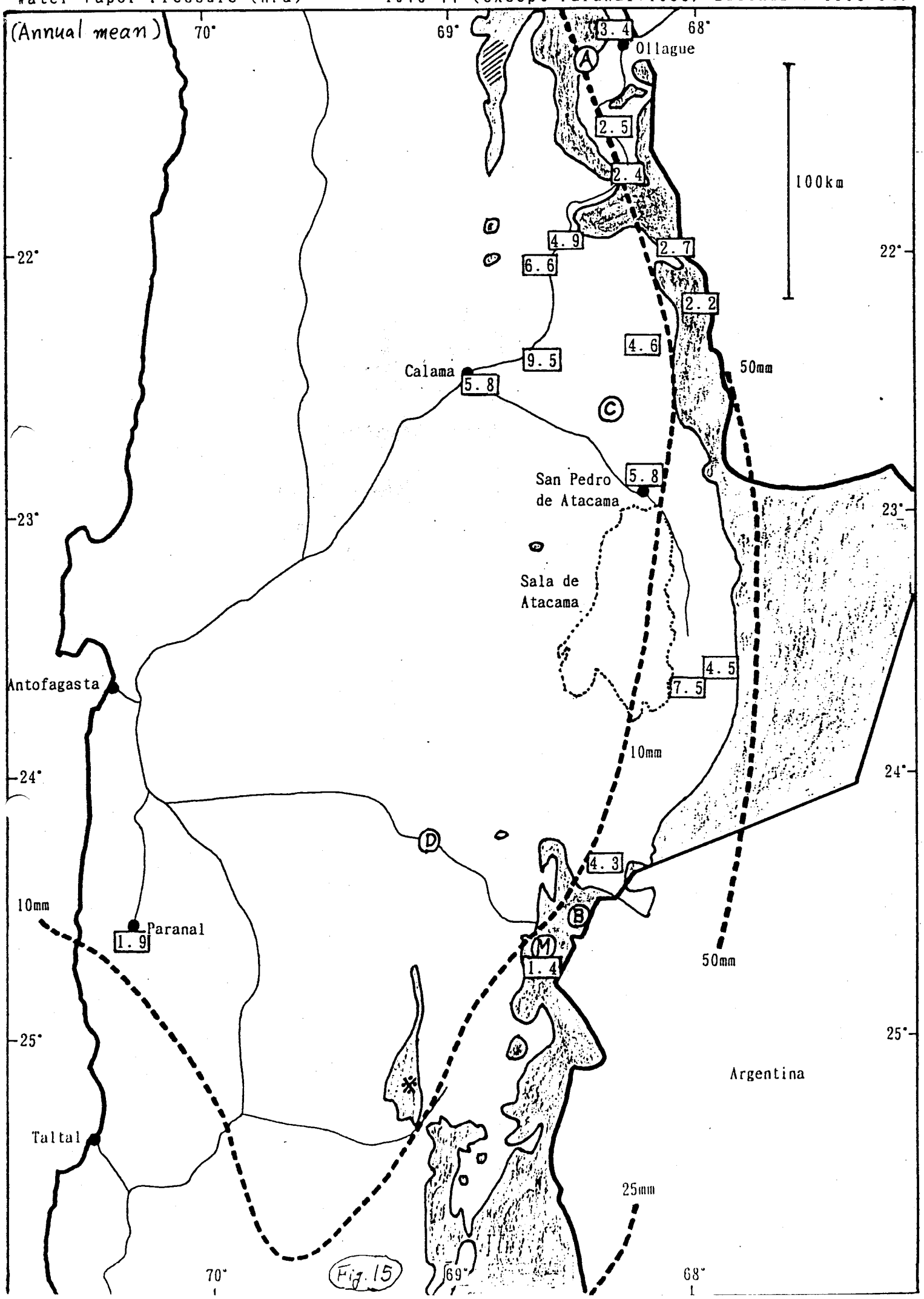

Escondida (1993-1994)
Temperature (deg C)
20
10
0
-10
-20
max on record
<Tmax>
<Tmean>
0.9 deg
<Tmin>
min on record
Humidity (%)
100
80
60
40
20
0
Escondida
19.9%
Paranal
13.3%
Water vapour pressure (hPa)
5
4
3
2
1
0
Paranal
1.94 hPa
Escondida
1.37 hPa
Wind velocity (m/s)
20
10
0
<Vmean>
max
<Vmean>
4.9 m/s
1 2 3 4 5 6 7 8 9 10 11 12
Month

Fig. 13.


Precipitation (mm/yr) several years during 1960-77 (except Escondida:1993-94)
70°
69°
68°
72
Ollague
A
0
430
106
100km
50
56
43
19
149
22°
352
194
62
73
192
168
9
7
3
Calama
5
50mm
C
27
San Pedro
de Atacama
23°
63
Sala de
Atacama
70
Antofagasta
16
10mm
24°
D
4
54
10mm
Paranal
B
M
11
50mm
25°
Argentina
Taltal
25mm
Fig. 14.


Water Vapor Pressure (hPa) 1976-77 (except Paranal:1986, Escondida:1993-94)
(Annual mean)
70°
69°
68°
22°
23°
24°
25°
3.4
Ollague
A
2.5
2.4
100km
4.9
6.6
2.7
2.2
4.6
9.5
Calama
5.8
50mm
C
5.8
San Pedro
de Atacama
Sala de
Atacama
4.5
7.5
Antofagasta
10mm
D
4.3
B
M
1.4
10mm
Paranal
1.9
50mm
Argentina
Taltal
25mm
Fig. 15