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SHORT PERIOD CLIMATOLOGY OF MAITRI, SCHIRMACHER OASIS, EAST ANTARCTICA

1. Antarctica has attracted the attention of scientific community all over the world since it is one of the most important climate regimes with a potential to influence long-term global climatic patterns. The Indian Antarctic Station, Maitri (70° 45′ 57″ S, 11° 44′ 09″ E) is located in the Schirmacher Oasis of east Antarctica. Since 1990 all the meteorological observation such as pressure, temperature, wind speed and direction, total global solar radiation, surface ozone, radiometersonde, ozonesonde etc., are being taken at Maitri (WMO station index No.89514).

A broad perspective of meteorological features of the area with reference to operational requirements has been discussed by Turner and Pendlebury (2004). Although a long period meteorological data of Novolazarevskaya (70° 46′ S, 11° 50′ E) is available in archives of AARI, so far no effort has been made for climatological study of the Schirmacher Oasis, Queen Maud Land, east Antarctica. WMO has prescribed data requirement of 30 years for preparing the climatological normal of a station. Therefore, in order to fill up the gap the study the short period climatology of Maitri, Schirmacher Oasis, east Antarctica has been attempted in this paper. The present paper is intended to provide a consolidated summary and discussion of the data based on the available records for 16 years (1990-2005).

2. For the study of climatology of Schirmacher Oasis daily synoptic data was used for computation of daily and monthly mean of temperature, wind, pressure and clouding. Three hourly daily synoptic data recorded at Maitri for the year 1990 to 2005 has been used for computation of daily and monthly mean of temperature, wind, pressure and clouding. The daily mean values were derived by averaging 8 synoptic observations. Thereafter monthly and annual values were calculated. The monthly mean values for the year 2004 & 2005 were used from monthly weather reports of the station. Table 1 and Table 2 gives the climatological summary of Maitri, which is a representative meteorological station of the area.

2.1. *Surface temperature* - It is evident from the climatological table that annual cycle of temperature takes a familiar form with broad summer maximum and a minimum in July or August. Average annual temperature of Maitri is -9.5° C. Monthly average air temperature, mean maximum, mean minimum and extreme temperature recorded for each months are shown in Table 1. The lowest mean temperature and extreme daily minimum temperature are recorded in August and highest mean and extreme maximum temperatures in January & December. February 1996 had been a exceptional year when on February 3rd the Maximum temperature rose to 12.2° C. The lowest temperature of –35.3° C was recorded on 21st July 2005.

2.2. *Wind* - The surface wind regime at Maitri is characterized by alternating spells of strong wind and light wind or calm. The duration of these spells varies considerably from few hours to several days. Average annual wind speed at Maitri is 17.5 kt. Monthly average wind speed and extreme wind speed recorded for each month is given in Table 1. May and June is distinguished by the highest average wind speed 21 & 20 kt respectively. The mean daily wind speed varies between 10 and 20 kt. Wind maxima recorded in each month varies between 55 and 90 kt. Wind speed exceeding 100 kt has been recorded during winter months. There are about 178 days in a year when daily average wind speed exceeds 23 kt. Average number of days for each month is given in Table 2. Wind direction is a significant feature of weather at Maitri. The most predominant direction at Maitri is southeast.

2.3. *Surface pressure* - Maitri station lies between the high-pressure region centered around the South Pole and the circumpolar trough of low pressure roughly along 63º S. Therefore atmospheric pressure at the stations is influenced by the relative position and strength of these features. The mean sea level pressure (msl) at the station based on 16 years of observations (1990-2005) exhibits a half yearly cycle with lowest pressure being recorded in spring season and a secondary minimum in March. Similarly maximum pressure is recorded in June and January. A mean monthly variation in the latitude of the axis of the Antarctic trough also indicates similar fluctuations throughout the year.

Average annual air pressure reduced to mean sea level is 985.9 hPa. Monthly average msl pressure and extreme value recorded for each month is given in Table 1. The highest msl pressure of 1030.5 hPa was recorded on 29th April 1990 and lowest msl pressure of 930.0 hPa was recorded on 9th August 2005 during the passage of low-pressure area.

2.4. *Snowfall* - Snowfall was observed almost in all the months. Table 2 shows the monthly average snowfall for the period (1998-2005) along with monthly mean values of number of days with snowfall. Snowfall occurs on average on 5 days per month through the year with higher frequency from April to September. The maximum

TABLE 1

Climatological table of Maitri, Antarctica, (70° 45′ 57″ S, 11° 44′ 09″ E) for the elements temperature, pressure and wind speed for the period 1990-2005

Months	Temperature (°C)					Pressure (hPa)			Wind Speed (kt)	
	Average	Mean max	Mean min	Absolute max	Absolute min	Average	Pr. max	Pr. min	Average	Max/Gust
Jan	0.6	3.4	-2.7	9.4	-9.7	987.3	1009.8	960.0	13.3	51/80
Feb	-2.3	0.4	-5.5	12.2	-13.8	986.4	1006.0	963.3	16.3	46/84
Mar	-7.2	-4.5	-10.4	3.5	-20.7	983.8	1006.8	958.8	18.0	53/91
Apr	-11.5	-8.7	-14.6	2.5	-28.1	984.3	1030.5	945.1	18.9	60/77
May	-13.1	-10.2	-16.3	2.8	-30.8	986.3	1018.6	955.0	21.0	70/ >100
June	-13.8	-11.0	-17.1	-0.1	-32.3	989.9	1019.8	954.3	20.3	66/90
July	-16.1	-13.0	-19.5	-0.6	-35.3	985.9	1012.4	948.9	19.6	78/100
Aug	-17.4	-14.0	-20.9	0.2	-34.5	983.4	1018.6	930.0	17.7	80/106
Sep	-16.1	-12.9	-19.9	-0.8	-32.6	985.0	1024.2	943.2	17.0	94/110
Oct	-11.1	-8.4	-14.8	1.0	-28.2	983.9	1011.9	951.1	18.0	66/82
Nov	-5.4	-2.6	-8.8	6.2	-21.6	986.4	1020.4	958.1	16.4	58/81
Dec	-0.1	2.5	-3.3	10.3	-11.6	987.9	1010.5	963.0	13.5	56/86
Annual	-9.4	-6.6	-12.8	12.2	-35.3	985.9	1030.5	930	17.5	94/ >110

TABLE 2

Climatological table of Maitri, Antarctica, (70° 45′ 57″ S, 11° 44′ 09″ E) for weather phenomena for the period 1990-2005

Months	Number of days with						Average cloud octa	Average number of blizzards	Snowfall (mm)
	Average Speed >23 kt	Snow fall	Fog	Blizzard	Clear sky	Overcast sky			
Jan	8.8	5.1	0.8	0.3	4.8	9.0	4.8	0.1	4.9
Feb	12.9	4.1	0.0	0.5	4.1	11.5	4.6	0.4	2.2
Mar	16.3	4.9	0.0	3.0	5.9	9.1	4.5	1.7	4.5
Apr	17.1	5.6	0.1	5.3	5.1	11.1	4.3	3.1	17.6
May	18.6	5.3	0.3	6.3	6.6	10.5	4.3	3.4	16.8
June	17.4	5.8	0.0	4.8	7.7	10.0	4.1	2.3	27.1
July	17.7	6.1	0.1	6.1	6.6	11.9	3.8	3.1	22.7
Aug	16.3	5.3	0.1	6.6	6.2	8.4	4.6	3.2	43.3
Sep	14.0	5.1	0.0	5.1	7.0	8.2	4.5	2.8	26.8
Oct	15.7	4.4	0.0	4.0	5.8	9.9	4.5	2.6	12.1
Nov	14.0	3.1	0.1	2.1	6.2	6.3	3.8	1.1	2.0
Dec	9.3	6.4	1.1	0.9	4.0	6.6	5.1	0.5	2.1
Annual	178.1	61.1	2.6	44.9	70.0	112.5	4.4	24.3	182.1

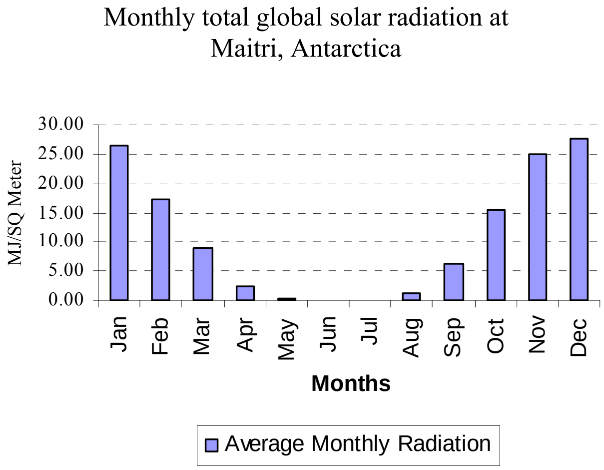

Fig. 1. Annual variation of average daily total global solar radiation (MJm^{-2}) at Maitri based on mean monthly data for the period 1990 to1997

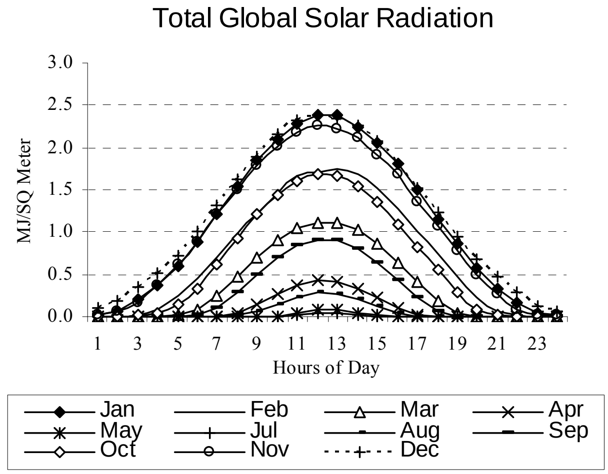

Fig. 2. Monthly variation of average hourly total global solar radiation (MJm^{-2})

snowfall is recorded in the month of August followed by June and September.

A few very rare cases of rainfall have occurred at Maitri resulting in a usually short-lived glaze or rime covering exposed rocks. On 17 January 1991 Maitri had experienced light rain and drizzle around 1930 to 2030 hrs local time. Similarly during 1996 on 2nd February Maitri experienced light rain equivalent to about 2mm.

2.5. *Blizzards, blowing and drifting snow* - Weather in Antarctica is subject to frequent and sudden changes. Strong winds and blizzards dominate Antarctic weather. A combination of blowing snow, gale force wind and very low visibility is normally defined as blizzard. At Maitri the blizzard is mostly associated with extra-tropical storms and is normally preceded by precipitation. On average during the year about 23 blizzards affects the station for 47 days during the year. During the month of April to August 3 to 4 blizzards affects the station. Average value of number of blizzards and days with blizzards for each month are shown in Table 2.

Maximum number of blizzards occurs in the month of August with about 7 blizzard days. Average wind speed recorded during the blizzard is about 52 kt but it exceeded 100 kt on several occasions. The duration may vary from hours to days with average of 25 hours. Longest duration of 168 hours was recorded in June 1997. During this period pressure dropped by 53 hPa and temperature rose by 17° C wind reaching 87 kt during the blizzard. There are about 12 such occasions when blizzard lasted more than 72 hours.

2.6. *Clouds* - The mean cloudiness throughout the year averages 4.4 octas, being highest in summer. The frequency of clear days is some what higher in winter than in mid-summer when the retreat of sea ice brings the station under more maritime conditions. Most cloud forms are a variation of stratus, although stratocumulus is often seen in summer time. Cumulus cloud is very rare but cirrus cloud is often widespread and forms at much lower levels than in temperate regions. Reliable cloud observations are very difficult during blizzard since the sky invariably remains obscured. Monthly average clouding along with number of days with clear sky and overcast sky are given in Table 2.

Fog is rare at Maitri. It occurs under the synoptic situations when warmer and moist air is rapidly advected from lower latitudes toward the continent. On average 1 day of fog is recorded during the month of December and January. During other months its frequency is almost zero. Average frequency of fog days is shown in Table 2.

2.7. *Radiation studies : Total global solar radiation measurement* - The local radiation regime is fundamental in the determination of overall climatic characteristics of the polar stations. Total global solar radiation was continuously recorded at the Maitri station using thermo-electric Pyranometer installed on the roof of the station. Radiation measurements were taken throughout the year. Daily total global solar radiation values for each month are given in Fig. 1. The total global solar radiation was found maximum in the month of January, November and December during the year due to long period of cloud free sky, insolation, and high solar elevation. As the solar elevation and duration of

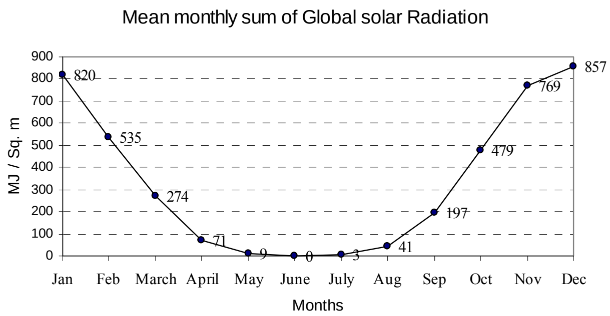

Fig. 3. Mean monthly sum of global solar radiation (MJm^{-2}) for Maitri (1990-97) (Annual total Global solar radiation = 4084 MJm^{-2})

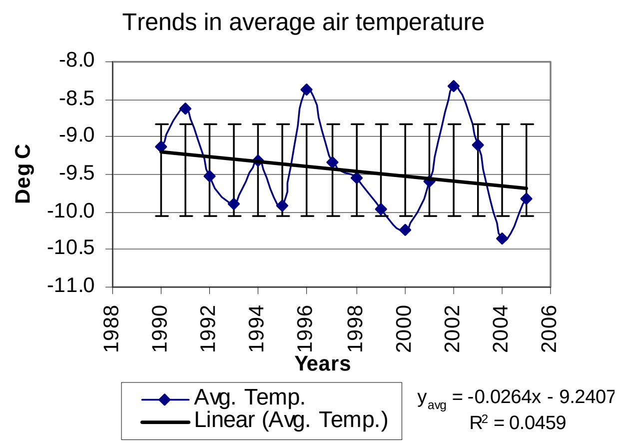

Fig. 4. Time series of annual mean surface temperature at Maitri Antarctica. Vertical bars indicate standard deviation of order 1.

sunshine started reducing total global solar radiation also reduced to zero by the end of the month of May. Solar radiation again started from the last week of July and reached to the highest value by the beginning of polar day.

The distribution of mean hourly global solar radiation with hours in Local Apparent Time (LAT) is shown in Fig. 2. The irradiance received is in direct correspondence with the duration of sunshine and solar elevation. The highest value of 2.39 MJm^{-2} occurs around noon in January & December obviously because the solar elevation reaches maximum angle of 45 degree in the second fortnight of December. Noon time lowest values of 0.04 MJm^{-2} occurs in the month of July when radiation intensity is weakest, the solar elevation being less than 0.5 degree, since annual sunrise occurs in the 3rd week of this month.

Mean monthly total radiation received at the station is shown in Fig. 3. The mean total of 4054 MJm^{-2} is somewhat lower than the data given by Schwerdtfeger (1984) for Mirny and Molodezhnya (4316 MJm^{-2} and 4228 MJm^{-2} respectively), which occupy similar locations to Maitri in east Antarctica.

2.8. *Trends in surface observations* - The relatively short length of many of the series of observations from the Antarctic research stations makes the assessment of trends in the meteorological conditions across the continent very difficult and it is not usually possible to find trends that are statistically significant. Jones *et al.* (1986) indicated the general rise of around 0.5° C in mean temperature in the southern hemisphere during the 20th century. Time series of annual mean surface air temperature of coastal stations Mirny, Mawson and Halley as reported by Turner and Pendlebury (2004) has shown a negative trend. Antarctic–wide temperature trends were considered in an earlier investigation (Raper *et al.*, 1984) within which seasonal and annual average temperatures for Antarctica were calculated by computing areally weighted means of all available station data. The annual mean Antarctic temperature showed a warming trend of 0.029° C per year for the period 1957-82, which was significant at the 95% level. However, the greatest contribution from this temperature rise came from the stations on the western side of the Antarctic Peninsula.

The records of Maitri are very short for investigation of temperature trends. The series of annual mean surface air temperature values Maitri station, along with trend lines determined from least–squares regression is shown in Fig. 4. It can be seen that the station shows a high degree of inter–annual variability, which is a feature of stations in both polar region. The coefficient $a = (-)\ 0.0264$ of a regression function $y = at + b$ is statistically significant and corresponds to a mean decadal cooling trend of 0.26° C over the period.

In parallel with the warming trend there has also been a statistically significant increase in the number of precipitation reports at the stations on the western side of the Peninsula (Turner *et al.*, 1997). A similar trend analysis of observed data, such as msl pressure, wind, number of days with precipitation and number of blizzard days, Maitri, was performed. It was found that significant negative trend has been observed in these meteorological parameters also. However conclusive results can be drawn only from long series of data.

3. *Conclusion* - The climatology of the station, Maitri, gives several interesting indications concerning

the climate of Schirmacher Oasis. The study of temperature has shown a cooling trend of 0.26° C per decade. A similar significant negative trend has been observed in other meteorological parameters such as msl pressure, wind, number of days with precipitation and number of blizzard days. These observations are just opposite to the fact being reported from west Antarctic and Peninsular region stations. In view of these facts it is apparent that continuing polar records of unchanging environment of Maitri will be extremely valuable in monitoring of the global climate in foreseeable future.

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