MAUSAM, **73**, 3 (July 2022), 607-616

MAUSAM

DOI : https://doi.org/10.54302/mausam.v73i3.1322
Homepage: https://mausamjournal.imd.gov.in/index.php/MAUSAM

UDC No. 551.510.534.1 : 551.581.21 (239.9)

Analysis of stratospheric ozone and meteorological parameters observed at Bharati station, Larsemann hills, Antarctica during the 37th Indian scientific expedition to Antarctica

ROHIT THAPLIYAL

Meteorological Centre, Dehradun, Mohkampur, Haridwar Road, Dehradun, Uttarakhand – 248 005

(*Received 9 September 2021, Accepted 12 April 2022*)

e mail : rohitthapliyalimd@gmail.com

सार – **लगभग** 140 **मिलियन वर्ष पहले दक्षिण अमेरिका, अफ्रीका, अंटार्कटिका और ऑस्ट्रेलिया सहित भारत सुपरकॉन्टिनेंट गोंडवाना का हिस्सा था। जब सुपरकॉन्टिनेंट विभाजित हुआ, तो भारतीय प्लेट उत्तर-पूर्व की ओर बढ़ी, जबकि ऑस्ट्रेलियाई और अफ्रीकी प्लेट तुलनात्मक रूप से कम दूरी और बहुत कम गति से आगे बढ़ीं। अंटार्कटिका लगभग स्थिर रहा। अंटार्कटिका के लिए** 37वां **भारतीय वैज्ञानिक अभियान भारती स्टेशन, लारसेमैन हिल्स, अंटार्कटिका में भारत मौसम विज्ञान विभाग (आईएमडी) के सदस्यों का चौथा शीतकालीन अभियान था। अभियान के दौरान, सतह और ऊपरी हवा में मौसम संबंधी प्रेक्षण, ऊर्ध्वाधर ओजोन माप, मौसम की निरंतर निगरानी और पूर्वानुमान की रिकॉर्डिंग की गई। मौसम संबंधी इन सभी प्राचलों का गहन विश्लेषण और अध्ययन किया गया। तापमान विश्लेषण से पता चला है कि सबसे ठंडा महीना सितंबर का, और सबसे गर्म जनवरी का था। पूरे वर्ष तेज और लगातार उत्तर-पूर्वी अगभीर पवनें देखी गईं, मई सबसे तेज पवन वाला महीना था। इस अवधि के दौरान** 15 **दिनों की अवधि में नौ बर्फ़ीले तूफ़ान देखे गए जिनमें** 5 **अगस्त,** 2018 **को अधिकतम अस्सी समुद्री मील गति वाला पवन का झोंका था। इस अभियान के दौरान, कुल** 32 **बैलून-जनित जीपीएस-आधारित ओज़ोनसोंडे के आरोहण लिए गए और उनके विश्लेषण से पता चला कि ओजोन सांद्रता सांद्रता की न्यूनतम स्थूलता** 15 **सितंबर और** 10 **अक्टूबर के बीच प्रेक्षित की गई। साथ हीइस अध्ययन में अंतरिक्ष के मौसम, मौसम संबंधी विशेष घटनाएं और भारती स्टेशन के पास पाए जाने वाले जीवों को देखा गया और उनके दस्तावेज तैयार किए गए।**

ABSTRACT. India, along with South America, Africa, Antarctica and Australia, was part of the supercontinent Gondwana some 140 million years ago. When the supercontinent split, the Indian plate moved north-eastward while the Australian and African plates moved comparatively less distance and at much lower speeds. Antarctica remained almost stationary. The 37th Indian Scientific Expedition to Antarctica was the fourth wintering of India Meteorological Department (IMD) members at Bharati Station, Larsemann Hills, Antarctica. During the expedition, recording meteorological surface & upper-air observations, vertical ozone measurement, continuous weather monitoring and forecasting were performed. All these meteorological parameters were thoroughly analyzed and studied. Temperature analysis showed that the coldest month was September and the warmest was January. Strong and persistent north-easterly near-surface winds were observed throughout the year, with May being the windiest month. During the period, nine number of blizzards spanning a period of 15 days were observed with a maximum wind gust of eighty knots during a blizzard on 5th August, 2018. During the expedition, a total of 32 balloon-borne GPS-based ozonesonde ascents were taken and their analysis showed that the minimum thickness of ozone concentration is observed between 15th September and 10th October. Also, space weather, special meteorological phenomena and fauna found near Bharati station were observed and documented in this study.

Key words – Indian scientific expedition to Antarctica, Blizzard, Total column ozone, Weather extreme, Aurora.

1. Introduction

Antarctica is also known as a land of extremes; it is the coldest, windiest and driest continent. Almost the whole continent is covered with ice with an average thickness of around 1.9 km (Fretwell *et al*., 2013). The sea-ice cover around the polar continent of Antarctica has a strong seasonal cycle, with a maximum sea-ice cover in

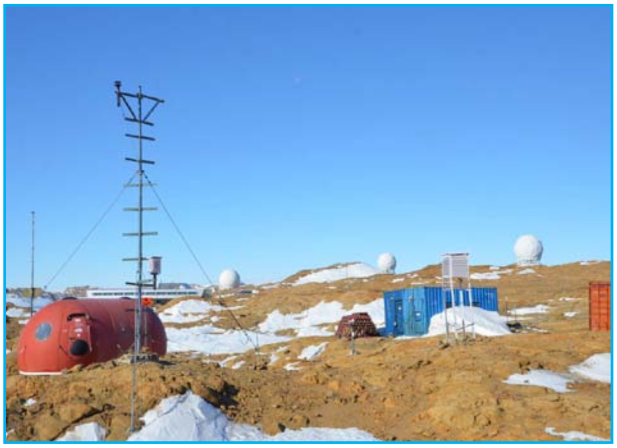


Fig. 1. Current weather instruments system, solar radiation sensors and surface observatory installed near Bharati station, Antarctica

September and a minimum in February (NASA). This cycle affects the global climate as well as global thermohaline circulation. Therefore, a meteorological programme to study atmospheric parameters in Antarctica is required.

About 140 million years ago, the supercontinent Gondwana split up into Africa, Antarctica, Australia and India. The Indian plate drifted north-eastward with a very high speed (18-20 cm yr^{-1} during the late Cretaceous period) subsequent to its breakup from Gondwanaland. It then slowed to ~5 cm yr^{-1} after the continental collision with Asia roughly 50Million years ago (Klootwijk *et al.*, 1992; Gaina *et al.*, 2007) resulting in the formation of the Himalayas. Tectonically and spiritually, the Larsemann Hills region is assumed to be the connection between India and Antarctica in Gondwanaland. The Bharati research station in Larsemann Hills, East Antarctica, was commissioned on 18th March, 2012 to facilitate year-round scientific research activity by the Indian Antarctic program. The Indian meteorological programme at Bharati, Larsemann Hills, East Antarctica, started on 23rd November 2014 with the 34th Indian scientific expedition to Antarctica. The meteorological programme included measuring, recording and analyzing meteorological parameters and solar radiations. Radiosonde/Ozone sonde upper air instruments are used for year-round monitoring of stratospheric ozone concentration. The data thus generated is used for weather forecasting and long-term climate studies. Fig. 1 shows the location of the installation of IMD's scientific equipment. The regular scientific activities carried out in the 37th Expedition were :

(*i*) Recording of 3 hourly synoptic observations and the transmission of main synoptic observations.

TABLE 1

Details of the extreme weather parameters observed during the 37th ISEA

1.	Lowest Temperature recorded	-29.8 °C on 29-08-2018
2.	Highest Temperature recorded	+09.9 °C on 5-01-2018
3	Maximum gust	80 knots on 5-08-2018 with (Ultrasonic wind sensor)
4	Number of Blizzards	9
5.	Lengthiest Blizzard	24 hours 5-11-2018/0201 UTC to 6-11-2018/0159 UTC
6	Total Snowfall	85.0 mm (from Dec 2017 to Nov 2018)
7.	No of snowfall days	122
8.	Number of Aurora observed	76 times
9	Lowest Station level Pressure	949.6hPa (954.7 hPa : MSLP) 05/11/2018
10	Highest Station level Pressure	1015.4 hPa (1021 hPa : MSLP) 03/06/2018

(*ii*) Continuous monitoring of weather systems by analysis of current observations and satellite imageries.

(*iii*) Weather forecast and briefing for helicopter & ship operations, outdoor construction work, field visits by scientific & logistic team members and other outdoor work.

(*iv*) Balloon-borne GPS-based radiosonde and Ozone sonde ascents were taken for the analysis of the vertical ozone profile.

(*v*) Space weather monitoring.

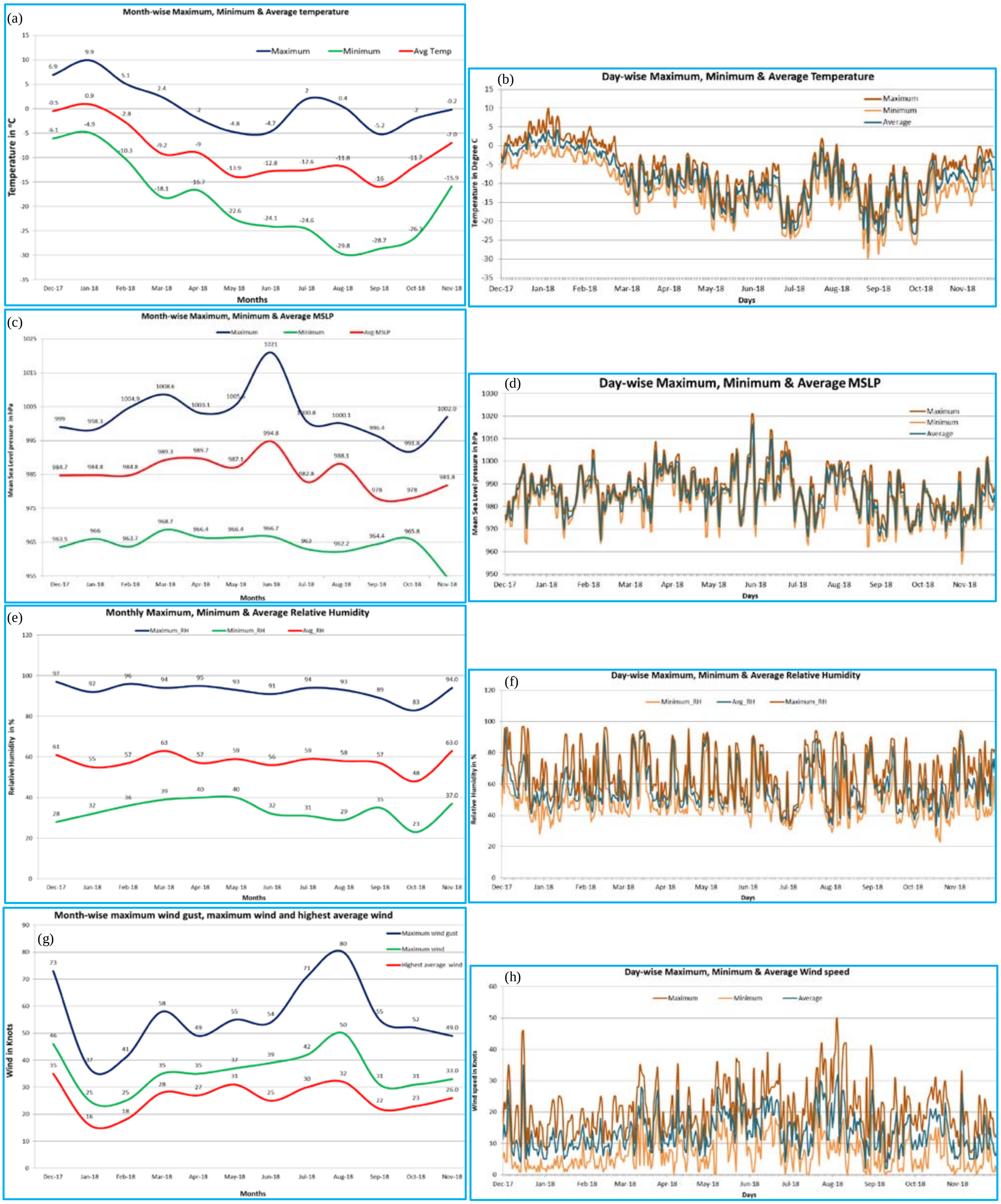
Besides the above, regular maintenance and upkeep of scientific instruments are required in the harsh Antarctic weather.

2. Analysis of meteorological parameters

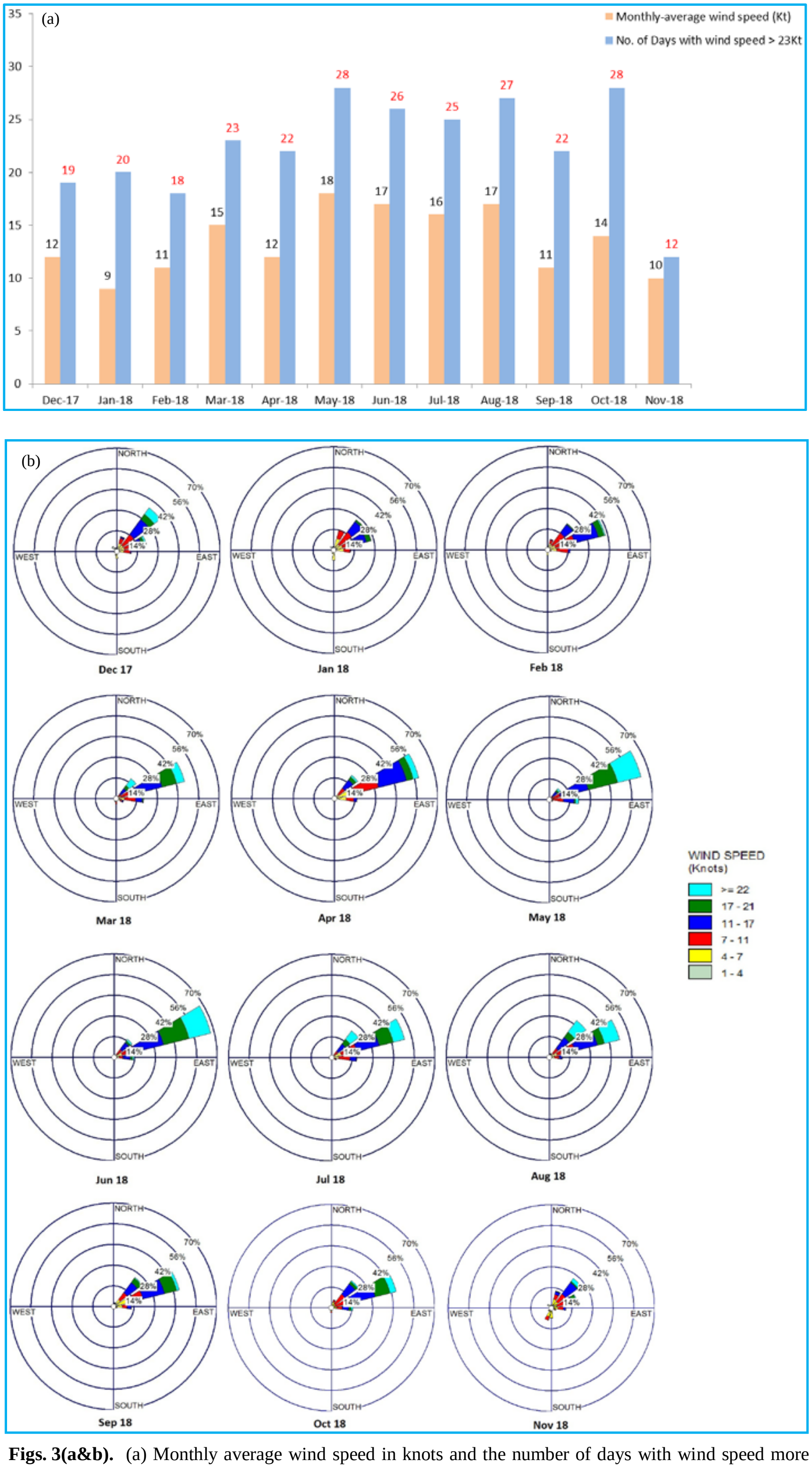
Details of the extreme meteorological observations and salient weather features observed from 1st December, 2017 to 30th November, 2018 at Bharati station are shown in Table 1. The analysis and variations in the meteorological parameters recorded during 37th ISEA are discussed below:

2.1. *Temperature*

During the expedition, which started from 1st December, 2017, the highest Maximum & Lowest



Figs. 2(a-h). Observed month-wise and day-wise variation of different meteorological parameters. (a) month-wise & (b) day-wise maximum, minimum & average temperature; (c) month-wise & (d) day-wise maximum, minimum & average MSLP; (e) month-wise & (f) day-wise maximum, minimum & average relative humidity; (g) month-wise maximum wind gust, maximum wind and highest average wind and (h) day-wise maximum, minimum & average wind speed



Figs. 3(a&b). (a) Monthly average wind speed in knots and the number of days with wind speed more than 23 knots and (b) Wind rose diagram of surface wind at Bharati station

Minimum temperatures were recorded as +09.9 °C (5th January, 2018) and -29.8 °C (29th August, 2018), respectively. The highest average of daily maximum temperature was recorded as +03.7 °C in the month of January. However, the lowest average of daily minimum temperature was recorded as −19.1 °C in the month of September. Thus, January was the warmest and September was the coldest month during the expedition. Fig. 2 (a) shows the monthly average, highest maximum and lowest minimum temperatures recorded in each month and Fig. 2(b) shows the daily maximum, minimum and average temperatures. During austral winter, July and August were relatively warmer than other months of the winter (May, June and September) period. The diurnal variation of temperature was higher during the austral summers as compared to the austral winter months.

2.2. *Pressure*

The average Mean Sea Level Pressure (MSLP) fluctuated at its peak of 994.8 hPa and a low of 978.0 hPa. The highest and lowest MSLP of the expedition were recorded as 1021.0 hPa on 3rd June, 2018 & 954.7 hPa on 5th November, 2018, respectively. The month of June experienced the highest and November experienced the lowest average monthly MSLP. Fig. 2 (c) shows the monthly average, highest maximum and lowest minimum MSLP recorded in each month and Fig. 2(d) shows the daily maximum, minimum and average MSLP.

2.3. *Relative humidity*

The climate of Antarctica is arid and does not show much fluctuation in average monthly relative humidity (RH). The highest maximum (97%) and lowest minimum (28%) RH was observed in the month of January. The increase in humidity is mainly due to the passing weather system and on rare occasions of advection fog. Fig. 2 (e) shows the variation of monthly average, highest maximum and lowest minimum RH recorded in each month and Fig. 2(f) shows the daily maximum, minimum and average RH observed at Bharati station.

2.4. *Wind*

Antarctica is the windiest continent on Earth. Many of the early explorers (Mawson, 1915) noted the presence of strong and persistent near-surface winds, which was later studied by many (Dare and Budd, 2001; King, 1989; Parish, 1982; Parish and Waight, 1987; Murphy and Simmonds, 1993) in detail. The two main forces that drive winds in the coastal region of East Antarctica are mesoscale katabatic winds and synoptic-scale cyclonic systems (Schwerdtfeger, 1984; Streten, 1963; Phillpot, 1997) that superimpose gradient winds over the low-level mesoscale flow.

Wind gust is defined as a sudden and brief increase in speed of the wind which usually lasts for less than 20 seconds (NOAA). However, for synoptic observations the surface wind is reported as the average wind direction and speed of the wind over the 10-minute period (World Meteorological Organization, 1995). The monthly maximum wind gust, maximum surface wind and highest daily average wind of each month are shown in Fig. 2(g). The daily maximum, minimum and average surface wind are shown in Fig. 2(h).

The month of May was the windiest month of the expedition, with the average monthly surface wind of 18.0 knots and the wind gust of more than 23 knots was recorded on 28 days in the month. However, the maximum wind gust of 80 knots was recorded on 5th August, 2018. The highest daily average wind of 35 knots was recorded on 17th December, 2017. During the expedition, the recorded wind gust of more than 23 knots was observed on 270 days. Fig. 3(a) shows the monthly average wind speed and the number of days with wind speed more than 23 knots. Fig. 3(b) shows the month-wise windrose of surface winds and it can be seen that the north-easterly surface winds prevailed throughout the year in Bharati station, Larsemann Hills region of East Antarctica.

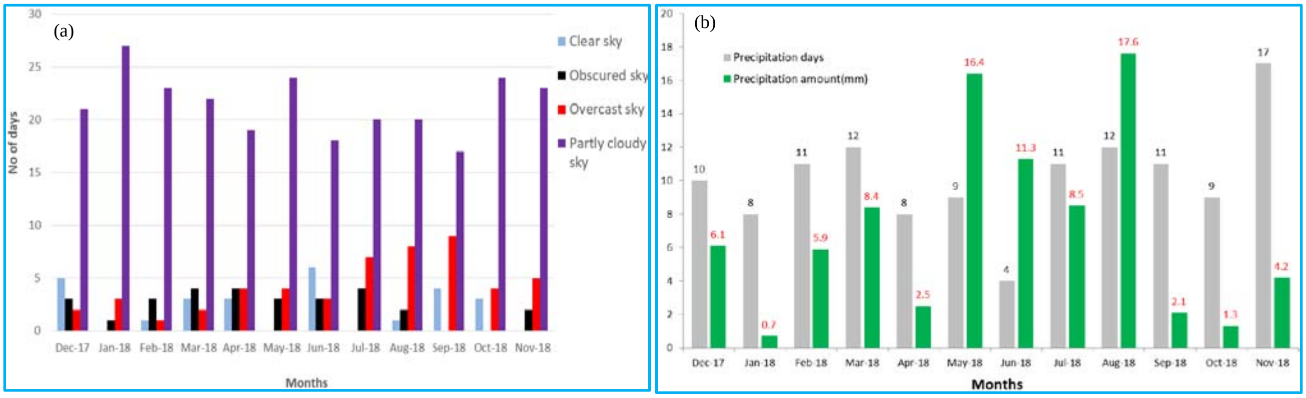
2.5. *Precipitation and cloud coverage*

The daily average sky condition is categorized as (*i*) obscured when the sky is not visible for more than 12 hours in a day due to any reason like blizzard, snowfall, fog etc; (*ii*) clear when sky has 0-1 Okta average cloud cover; (*iii*) partly-cloudy when sky has 2-6 Okta average cloud cover and (*iv*) overcast when sky has 7-8 Okta average cloud cover. Analysis of the number of cloudy days showed that cloudy sky days were maximum in the month of January, followed by May, August, September and November [Fig. 4(a)]. However, the overcast sky days were highest in the month of September, followed by August and July.

During the expedition, the precipitation in the form of only snow was observed over Bharati station. The total monthly precipitation was highest in August, followed by May. However, the number of precipitation days was highest in the month of November, followed by August and March [Fig. 4(b)]. During the 37th expedition, snowfall was recorded on 122 days at Bharati station with a maximum and minimum monthly precipitation of 17.6mm in August and 0.7mm in January, respectively.

2.6. *Solar radiation*

Polar days in the Larsemann Hills region started on 20th November, 2017 and the first sunset of the year 2018

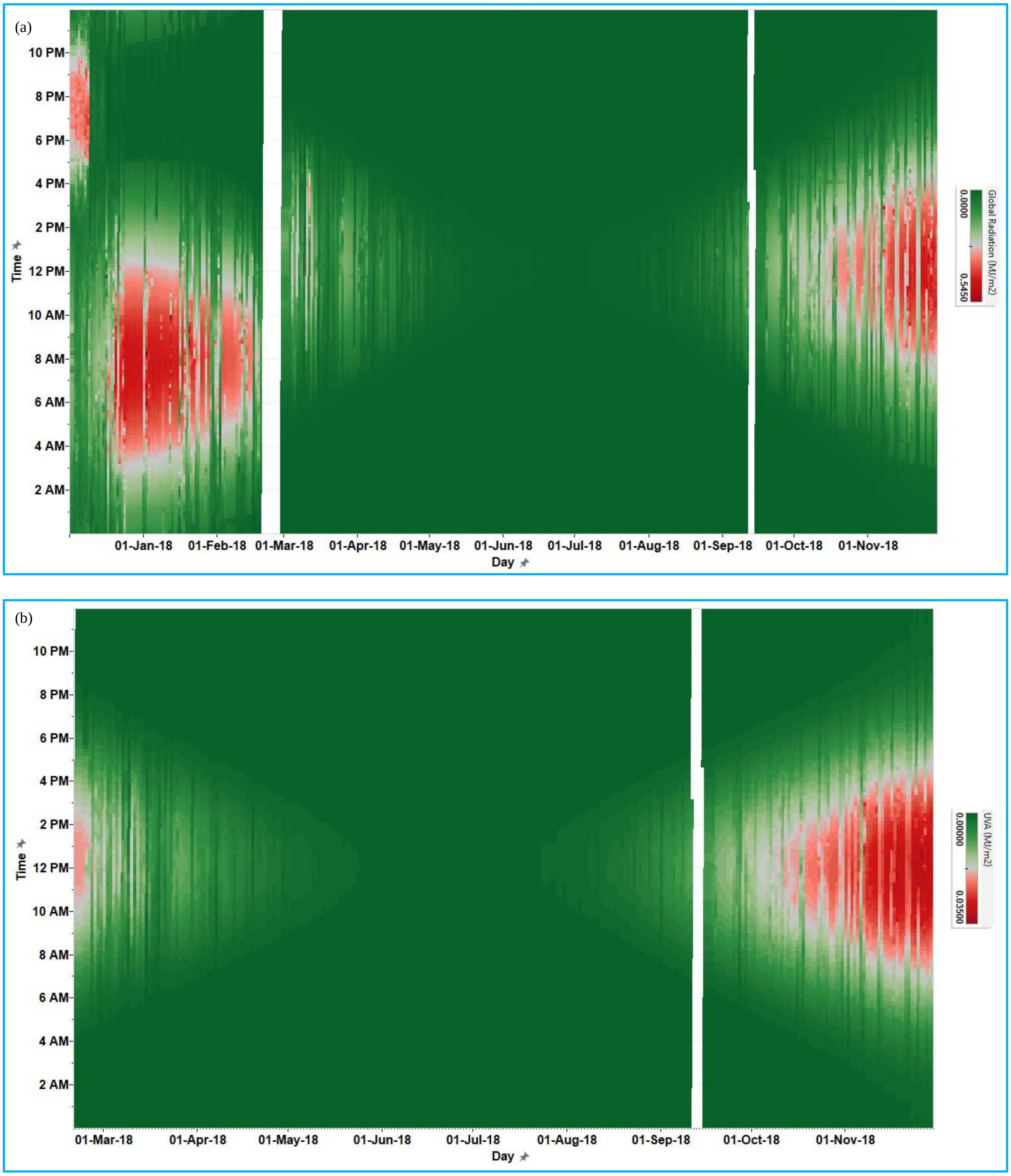


Figs. 4(a&b). Observed month-wise (a) cloud coverage and (b) precipitation over Bharati station

TABLE 2

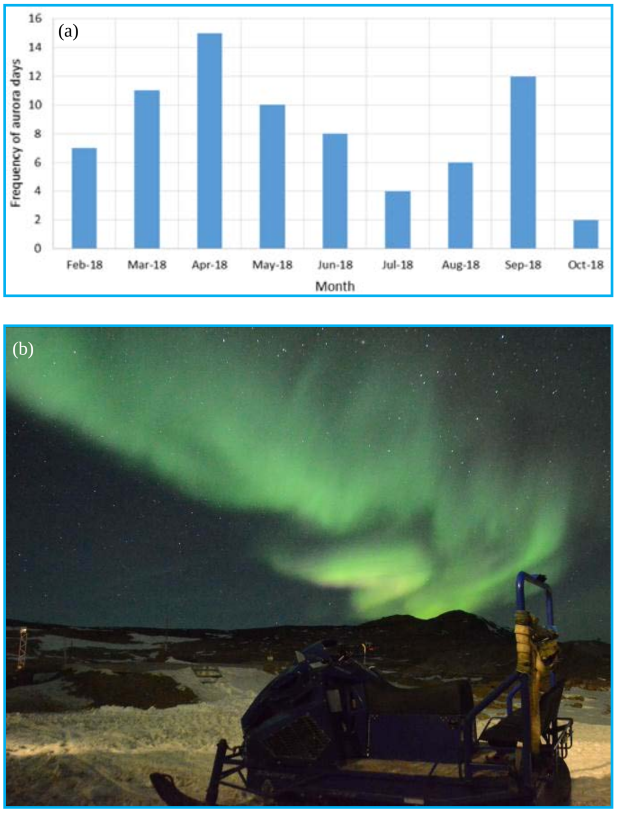
Details of the blizzards observed during the 37th ISEA

Date/Time		Extreme Values during a blizzard					
Commencement	Cessation	MSL Pressure (hPa)		Temperature (°C)		Wind (knots)	Duration Hr : Min
		Max	Min	Max	Min	Max	
December 2017 (One)							
16/1936 UTC	17/0730 UTC	973.8	963.4	-0.8	-1.9	73	11:54
January 2018 (NIL)							
February 2018 (NIL)							
March 2018 (NIL)							
April 2018 (NIL)							
May 2018 (Two)							
08/1630 UTC	08/2000 UTC	980.2	976.8	-13.1	-15.6	47	03:30
23/2015 UTC	24/0230 UTC	980.6	979.1	-8.8	-12.5	48	06:15
June 2018 (One)							
05/0230 UTC	05/1915 UTC	975.8	966.4	-6.8	-8.5	50	16:45
July 2018 (One)							
21/1130 UTC	22/0530 UTC	982.4	974.3	-3.6	-6.2	52	18:00
August 2018 (Three)							
09/0950 UTC	10/0030 UTC	987.8	985.7	-5.1	-10.1	57	14:40
27/1345 UTC	27/1915 UTC	968.1	961.9	-10.2	-12.8	46	05:30
30/1815 UTC	31/1215 UTC	978.9	970.8	-7.6	-10.7	63	18:00
September 2018 (NIL)							
October 2018 (NIL)							
November 2018 (One)							
05/0201 UTC	06/0159 UTC	969.9	954.4	-4.0	-8.6	49	24:00



Figs. 5(a&b). (a) Global solar radiation and (b) UV-A radiation in MJ/m2 recorded at Bharati station

was observed on 22nd January, 2018 (63 days of continuous sunshine). Polar nights started on 28th May, 2018 and the first sunrise, which marked the end of polar nights, was observed on 16th July, 2018 (49 days of darkness). The Pyranometer and UV-A sensors are used to measure the global solar irradiance and UV-A irradiance. The global solar irradiance and UV-A irradiance were maximum in the month of November and December when there is 24 hours of sunlight and the plot with received power in terms of Megajoules per square meter is depicted



Figs. 6 (a&b). (a) Monthly frequency of aurora days during 37th ISEA and (b) image of Aurora captured on 9th July, 2018

Fig. 7. Image of thick fog approaching from northwest direction over Bharati station on 9th March, 2018

in Fig. 5. The UV-A and global radiation values shows typical dumbbell-shaped graphs with maximum values in November and December

2.7. *Blizzards statistics*

A blizzard is a violent weather phenomenon in which horizontal visibility is reduced to less than 1000 m due to heavy drifting and blowing of snow by strong near-surface winds. Generally, winds with a speed of more than 23 knots are sufficient to blow falling snow or loose snow, thus reducing the horizontal visibility. The blizzard can last as long as a week or even more; the longest and strongest blizzard observed during 37th ISEA was in November 2018, lasting for 24 hours. In 37th Expedition (Dec 2017-Nov 2018), a total of 9 Blizzards occurred with a maximum number of 3 blizzards in the month of August and no blizzard in six months (Jan, Feb, Mar, Apr, Sep and Oct). The total number of blizzard days was fifteen (15) during the expedition. The details of the individual blizzards are given in Table 2. The 24 hour heaviest snowfall of 8.1 mm was recorded during the blizzard dated 31st August, 2018 with a maximum wind gust of 63 knots. The lowest MSLP during the expedition was 954.4 hPa and it was observed during the blizzard on 5th November, 2018.

3. Space weather and special phenomenon

Aurora : Manual observation of Auroras was done and it was observed 76 times during the expedition. The phenomenon is clearly visible during the nighttime and it was first visible on 19th February, 2018 after the end of polar days. The frequency of auroras is highest in April, followed by September, March and May (Fig. 6), which suggests enhanced solar activities during these months.

Fog : Fog is a very rare phenomenon in the cold and dry climate of Antarctica, but it was observed on 9th March, 2018. Fig. 7 shows the fog line approaching the Bharati station on a clear sky day.

High-speed winds : Strong surface winds are common in Antarctica and a maximum wind gust of 80 knots was recorded on 5th August, 2018. The maximum wind gust during a blizzard was 73 knots, recorded on 17th December, 2017. These hurricane winds have the potential to cause severe damage to scientific installations.

Fig. 8. A halo with colored arcs was observed on 9th September, 2018

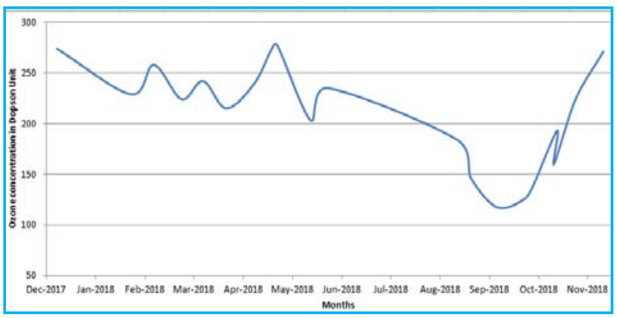


Fig. 9. Vertical total column ozone values in Dobson Unit observed over Bharati station

Halo : This optical phenomenon is produced when sunlight interacts with ice crystals suspended in the atmosphere. They can have many forms, ranging from colored or white rings to arcs and spots in the sky. A halo with colored arcs was observed on 9th September, 2018.

4. Stratospheric ozone observations

Balloon-Borne GPS-based Radio sonde & Ozone sonde ascents were used to measure the total column ozone concentration during this expedition. The operating principle of ozone detection from Electrochemical Concentration Cell (ECC) Ozone sonde is based on iodine-iodide redox reaction. The instrument consists of an ozone sensing cell and a battery-driven pump to suck ambient air into the ozone sensing cell.

When a certain volume of air containing ozone is drawn through the pump into the sensor cell, ozone reacts with the potassium iodide (KI) solution in the cell; as a result, the free iodine is liberated from the solution:

$$2KI + O_3 + H_2O \rightarrow I_2 + O_2 + 2KOH \qquad (1)$$

TABLE 3

First and last sighting of the flying birds near Bharati station

Birds	Last seen before Winter	First seen after Winter
Snow Petrel	5 May 2018	06 November 2018
Skua	10 April 2018	12 October 2018
Storm Petrel	30 April 2018	09 October 2018

The ozonesonde instrument contains different concentrations of the KI solution in the cathode and anode chamber, 1% KI and saturated KI, respectively. The ozone in the ambient air flows through the cathode cell with the lower concentration of KI solution, causing an increase of free iodine (I_2) according to the redox reaction (1).

$$I_2 + 2e \rightarrow 2I^- \qquad (2)$$

At the surface of the cathode, I_2 is converted to I^- through the uptake of two electrons (2), while at the anode surface, I^- is converted to I_2 through the release of two electrons. Thus, one ozone molecule causes two electrons to flow into the external circuit. This electrical current is directly related to the uptake rate of ozone in the cathode chamber (Komhyr, 1986; Komhyr *et al.*, 1995). The instrument calculates the vertical total column ozone in the Dobson Unit (DU).

A total of 32 ozonesonde ascents were taken during the expedition. Fig. 9 shows the fluctuation in the vertical total column ozone values. The total column ozone concentration is more than 200 DU in austral summers and it starts decreasing at the start of austral winters. The ozone concentration is found lowest during the second fortnight of September and the first week of October when it is lower than 125 DU. Thereafter, it starts increasing from the second week of October and reaches more than 200 DU by the first week of November.

5. Wildlife in Antarctica

Antarctica is home to very few species of fauna. A few wildlife species observed in and around Bharati station were Weddell Seals, Adélie Penguins, Emperor Penguins, Snow Petrels, Skuas and Strom Petrels. Three species of flying birds are found near Bharati station. These birds migrate away from Bharati Island at the start of austral winters and come back at the beginning of austral summers. Table 3 shows the date of their first and last sighting at Bharati station.

6. Conclusions

During the 37th ISEA, which started in December 2017 and ended in November 2018 for the IMD team at

Bharati station, a total of 32 balloon-borne GPS-based ozonesonde ascents were taken and meteorological surface observations, continuous weather monitoring & forecasting for 365 days were performed. The temperature analysis showed that the highest Maximum & lowest Minimum temperatures of the expedition were recorded as +09.9 °C on 5th January, 2018 and -29.8 °C on 29th August, 2018, respectively. However, the month-wise analysis showed that the coldest month was September and the warmest was January. The diurnal temperature fluctuations were higher during austral summers as compared to the austral winters. Surface wind analysis showed that the month of May was the windiest month with the average monthly surface wind of 18.0 knots and the wind gust of more than 23 knots was recorded on 28 days of the month. North-easterly winds prevailed during all the months. During the expedition, a total of 9 blizzards spanning a period of 15 days were observed with a maximum wind gust of 80 knots during a blizzard on 5th August, 2018. The UV-A and global radiation values showed typical dumbbell-shaped graphs with maximum values in November and December. The analysis of the vertical columnar ozone profile shows that the minimum thickness of ozone concentration is found between 15th September and 10th October.

Acknowledgement

We are very grateful to the Director General of Meteorology, India Meteorological Department, for providing us with the opportunity to work in Antarctica. We are also thankful the Head, Polar Meteorological Research Division (PMRD) and all officers & staff members working in the PMRD for extending extreme cooperation and guidance.

We take this opportunity to extend our sincere thanks to Leader and Deputy Leader of 37th ISEA, whose support helped us achieve the desired valuable task. We especially thank Mr. Sudhanshu, Lab technician, for extending his support for balloon launches. We are also grateful to all the Scientific & Logistic members for their cooperation that helped us from time to time with ozone ascents in adverse weather conditions of Antarctica.

Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

Dare, R. A. and Budd, W. F., 2001, “Analysis of surface winds at Mawson, Antarctica”, *Weather and forecasting*, **16**, 4, 416-431.

Fretwell, P., Pritchard, H. D., Vaughan, D. G., Bamber, J. L., Barrand, N. E., Bell, R., Bianchi, C., Bingham, R. G., Blankenship, D. D., Casassa, G., Catania, G., Callens, D., Conway, H., Cook, A. J., Corr, H. F. J., Damaske, D., Damm, V., Ferraccioli, F., Forsberg, R., Fujita, S., Gogineni, P., Griggs, J. A., Hindmarsh, R. C. A., Holmlund, P., Holt, J. W., Jacobel, R. W., Jenkins, A., Jokat, W., Jordan, T., King, E. C., Kohler, J., Krabill, W., Riger-Kusk, M., Langley, K. A., Leitchenkov, G., Leuschen, C., Luyendyk, B. P., Matsuoka, K., Nogi, Y., Nost, O. A., Popov, S. V., Rignot, E., Rippin, D. M., Riviera, A., Roberts, J., Ross, N., Siegert, M. J., Smith, A. M., Steinhage, D., Studinger, M., Sun, B., Tinto, B. K., Welch, B. C., Young, D. A., Xiangbin, C. and Zirizzotti, A., 2013, “Bedmap2: improved ice bed, surface and thickness datasets for Antarctica”.

Gaina, C., Müller, R. D., Brown, B. and Ishihara, T., 2007, “Breakup and early seafloor spreading between India and Antarctica”, *Geophys. J. Int*., **170**, 151-169.

King, J. C., 1989, “Low-level wind profiles at an Antarctic coastal station”, *Antarctic Science*, **1**, 2, 169-178.

Klootwijk, C. T., Gee, J. S., Peirce, J. W. and Smith, G. M., 1992, “An early India - Asia contact : Paleomagnetic constraints from Ninetyeast Ridge, ODP Leg 121”, *Geology*, **20**, 395-398.

Komhyr, W. D., 1986, “Operations handbook-ozone measurements to 40-km altitude with Model 4A Electrochemical Concentration Cell (ECC) ozonesondes (used with 1680-MHz radiosondes)”, NOAA Tech. Memo. ERL ARL-149, Air Resources. Lab., Boulder, Colo.

Komhyr, W. D., Barnes, R. A., Brothers, G. B., Lathrop, J. A. and Opperman, D. P., 1995, “Electrochemical concentration cell Ozone sonde performance evaluation during STOIC 1989”, *Journal of Geophysical Research : Atmospheres*, 100(D5), 9231-9244.

Mawson, D., 1915, “The Home of the Blizzard, Being the Story of the Australasian Antarctic Expedition”, 1911-1914, 2, W. Heinemann, London.

Murphy, B. F. and Simmonds, I., 1993, “An analysis of strong wind events simulated in a GCM near Casey in the Antarctic”, *Monthly weather review*, **121**, 2, 522-534.

NASA, World of Change: Antarctic Sea Ice. [online] Available at: https://earthobservatory.nasa.gov/world-of-change/sea_ice_ south.php.

NOAA, Definitions : Wind Gust. Accessed 8 Dec., 2016. [online] Available at: http://graphical.weather.gov/definitions/ defineWindGust.html.

Parish, T. R. and Waight III, K. T., 1987, “The forcing of Antarctic katabatic winds”, *Monthly Weather Review*, **115**, 10, 2214-2226.

Parish, T. R., 1982, “Surface airflow over east Antarctica”, *Monthly weather review*, **110**, 2, 84-90.

Phillpot, H. R., 1997, “Some observationally identified meteorological features of East Antarctica”, Meteorological Study 42, Bureau of Meteorology, Melbourne, Australia, p275.

Schwerdtfeger, W., 1984, “Weather and Climate of the Antarctic. Amsterdam : Elsevier”,| c1984.

Streten, N. A., 1963, “Some observations of Antarctic katabatic winds”, *Aust. Meteor. Mag*., **42**, 1-23.

World Meteorological Organization, 1995, Manual on Codes, International Codes, vol. I. 1 (Annex II to WMO Technical Regulations), part A, Alphanumeric Codes.