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Investigation of Unusual Atmospheric Warming over the Schirmacher oasis, East Antarctica

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ABSTRACT

The weather over the Schirmacher oasis (located at the periphery of east Antarctica) experiences impact of the severe katabatic winds flowing from the interior of the continent towards the periphery and the induction of warm, moist air associated with the moving cyclones along the east coast of Antarctica. These processes at times lead to unusual atmospheric warming which need in-depth investigations. In the present paper, an unusual atmospheric warming (surface air temperature touching +12 °C) observed at the two closely located stations (Russian Antarctic station, Novolazarevskaya-70°46'S; 11°52'E and the Indian Antarctic station, Maitri-70°46'S; 11°41'E) during February 1996 has been investigated by a number of complementary atmospheric techniques. This unusually high temperature has been investigated as a wide spread warming over the east Antarctic region, which was caused by the induction of warm, humid oceanic air around the Syowa, Japan station under a blocking polar high.

Keywords: *Schirmacher oasis, Atmospheric warming, Novolazarevskaya station, Maitri station, Blocking polar high*

1. INTRODUCTION

The Russian Antarctic station, Novolazarevskaya (70°46'S; 11°52'E) and the Indian Antarctic station, Maitri (70°46'S; 11°41'E) are closely located over the Schirmacher oasis in east Antarctica[1]. Being at the periphery of the Antarctic continent, they experience atmospheric dynamics associated with the katabatic winds flowing from the interior of the continent towards the periphery of Antarctica[2,3] and the induction of warm, humid air associated with the moving cyclones along the periphery of east Antarctica[4,5]. The two closely located stations offer a great advantage to utilize measurements of the surface based meteorological parameters, radiosonde profiles taken at the Novolazarevskaya station and the complementary acoustic sounder measurements made at the Maitri station[4,6].

The surface air temperature over the Schirmacher oasis has a seasonal variation with a peak (maximum) observed during local summer and a secondary peak during the winter season[7,8]. The peak during summer is due to solar energy warming up the icy/rocky surfaces and the secondary peak is due to the induction of warm, moist air by the cyclones moving along the coast. Apart from these two peaks, there are incidences when the surface air temperature enhances due to the presence of a blocking polar high, it is observed primarily during local winter season[9]. Of course, with the passage of time, enhancement of surface air temperature associated with global warming is becoming an important issue but this change over decades is within ±0.5 °C over the Schirmacher oasis[10].

In the present paper, we investigate an unusual surface air temperature enhancement by 12 degree Celsius over a period of just 8 days. It touched +12 °C at the Maitri station during the month of February 1996, while the average surface air temperature for this month is below 0 °C. It may be noted that this type of surface air temperature has not been observed in the past two decades over the Schirmacher oasis, calling for a detailed investigation to understand the atmospheric dynamics over the eastern Antarctic region and the source of such a warming. In addition, we need to investigate the impact of this warming over the Schirmacher oasis.

2. DATA

The following data sets recorded during the period January-February, 1996 have been utilized:

1. Meteorological parameters recorded at the Novolazarevskaya and the Maitri stations.
2. Facsimile charts recorded by a Monostatic acoustic sounder operating at the Maitri station. The acoustic sounder has a probing range of 1 km in altitude[6].
3. UV-B Minimum Erythemal Dose data recorded at Maitri[11].

4. Radiosonde profiles recorded daily at the Novolazarevskaya station.
5. Synoptic data charts of surface msl pressure, temperature at 850 hPa and geopotential height at 500 hPa levels

3. VARITION OF SURFACE AIR TEMPERATURE

Figure 1 shows variation of 3-hourly surface air temperature recorded during the period January-February, 1996 at Maitri and Novolazarevskaya stations. It shows that the surface air temperature started increasing from January 25, 1996 onwards, reached at the peak on February 3 and subsided by February 5, 1996. It is important to note that close to the peak of the warming event, the diurnal variation was totally suppressed; indicating that the local heating and cooling had lost control over the warming of the atmosphere and a major event must have been responsible in suppressing the local effects. It is important to note that wide spread rainfall of light intensity continued during the night hours (for a duration of 10 hours) on February 2 over the Schirmacher oasis. The rainfall eroded so much of polar cap ice that most of the lakes and depressions in the Schirmacher oasis were full and all the rocks were wet.

4. CAUSE OF WARMING

To investigate the cause of warming, standardize values of the atmospheric height at fixed pressure levels derived from radiosonde observations have been plotted in Figure 2. In this figure, data pertains to the period January 10 to February 15. Figure 2 shows that due to the warming; the atmosphere was lifted from the mean height at all pressure levels, indicating it to be a major event. Figure 2 also indicates that the warming was not abrupt; rather it was gradual which started from January 25, 1996 onwards. However, after reaching at the peak on February 3, 1996, it ended abruptly on February 4, 1996 itself. This shows that the enhanced temperature suddenly dissipated in the atmosphere. In fact, air being the lightest medium compared to the solid ice in Antarctica, the heat dissipation in air has to be much faster, unless supported by a heating mechanism.

Further, temperature variation at various fixed pressure levels derived from the radiosonde data plotted in Figure 3 shows that the warming was prominently below the 500 hPa level and the prominence was clear between February 1 to February 4, 1996. The heating in the lower atmosphere must have lifted the upper part of the atmosphere, which led to cooling in the upper regions.

To inspect the synoptic condition over the entire southern hemisphere during the warming period, we have examined a series of synoptic pressure charts. It has been found that between January 25 to January 29, the mslp enhanced continuously from 1008 hPa to 1032 hPa over the interior of the Antarctic continent. At the same time, a series of low-pressure areas moved from west to east along the east Antarctic coast. Figure 4 shows the synoptic chart of mslp on January 29, 1996 at 1200 UT. The figure shows two well-defined cyclones marked as “A” and “B” which were responsible for pushing the warm, moist air from the periphery towards the main Antarctic continent. The cyclone marked as “B”, remained active until January 31 but weakened on subsequent days. However, the one marked as “A” more or less remained stationary but intensified until February 1, 1996. Under the influence of these two cyclones, the atmosphere over 40 °E experienced induction of warm and humid oceanic air towards the interior of Antarctica. As a proof of this statement, Figure 5 shows synoptic variation of TTD values at 850 hPa pressure level on February 1, 1996. It clearly indicates intrusion of warm air around 40 °E along the coast of east Antarctica. Similarly, the 500 hPa geopotential height chart (Figure 6) shows a well defined ridge coinciding with the intrusion of warm air at 850 hPa level. Under the influence of this intrusion of warm moist air and the presence of polar high, the moist air condensed over the continent, releasing latent heat and this heat warmed up the atmosphere leading to a widespread rainfall. The quantity of rain was so much that all the lakes and ponds situated over the Schirmacher oasis were full. The rainfall also created several lakes over the shelf, hampering the convoy movement. In fact, two of the authors (HND and NCD) personally experienced at the Maitri station. Unfortunately, there was no rain gauge installed to make measurements of the intensity of rainfall or the total quantity of rainwater fallen on the ground. Nevertheless, it makes this rainy warming event a rare event calling for detailed investigations.

The above results indicate that the atmospheric warming first started towards the east of the Schirmacher oasis and later on, it spread towards the Schirmacher oasis itself.

To confirm the direction of arrival of wind, 3-hourly wind direction and wind speed recorded over the Maitri station has been plotted in Figure 7. It shows that during the period of warming, wind direction was predominantly from 160 degrees, this is the direction of maximum slop/katabatic wind flow around the Maitri station[13]. Moreover, the speed of the inducted air was the maximum on February 1-2, indicating that warm, humid air was inducted along the maximum slopes around the Schirmacher oasis. The warming has not been caused by a localized phenomenon.

5. EFFECT OF WARMING

Once the cause of warming has been understood, it is important to see the impact at the local levels through acoustic sounder working at the Maitri station. Normally, in the summer months, there is a clear-cut diurnal pattern of thermal structure in which thermal convection is seen during the day and inversion/s are seen at night[13]. However, in a cloudy situation, convection may get suppressed and the inversions may become weak. Normally, as the day time temperature increases, thermal convection becomes stronger under the influence of solar heating of the ground, but during this warming spell (Figure 8), the monostatic acoustic sounder record for February 3 shows the lower atmosphere having inversion at night but no convection has been observed during the day, despite a clear sunshine. This means that there was no substantial surface heating to lead to the formation of surface convection. It is important to note that since it rained on February 2, the solar energy falling on the surface must have been utilized in evaporating water fallen on the rocks and in the ponds / lakes.

Figure 9 shows the acoustic sounder data recorded during day time on February 4-5, 1996 which clearly shows a dull convection on February 4 and a moderate thermal convection on February 5. In fact, the clear formation of convection at Maitri subsided beyond January 20 and the acoustic sounding data was seriously affected by high winds during the warming period.

During the period of warming, it was cloudy up to February 2, 1996 and suddenly, on February 3, 1996, it was a clear sky. Since, it had rained just a day before, the sky was absolutely clear and the highest dose of UV-B in the year 1996 was recorded at the Maitri station (Figure 10). Figure 10 also shows the magnitude of direct and diffused radiation recorded at the Novolazarevskaya station.

6. DISCUSSION AND CONCLUSION

It has been observed that at the Maitri station, katabatic flows have a high degree of directional constancy (0.84) as the katabatic winds follow the flow lines or the slope over the polar cap ice[3]. In this case, during the warm spell period, flow has remained unidirectional from around 160 degrees. Also, the observed relative humidity was high during the warming period, indicating that the moist and warm winds have been induced basically from the interior of the continent. This is the reason that the acoustic sounder data shows no convection during the warming period, despite being a clear sunny day.

From the investigations presented in this paper, it is clearly understood that apart from the cold, katabatic winds falling along the highest slope around the Schirmacher oasis, even warm, moist air follows this path, linking the interior of the Antarctic continent with its periphery. It also demonstrates the blocking high condition prevailing over the Antarctic continent, which predominates only in the winter season, may also prevail in other seasons, resulting in wind-spread rainfall-a rare phenomenon in Antarctica. In fact, in the winter season, atmospheric temperature is so low that it only warms up the atmosphere but in other seasons, the warming may favor formation of rainfall. The UV-B values being the maximum just after the warming are important to study the fine particulate matter loading over the Antarctic region.

In the present case, a detailed investigation has been possible due to a number of data sets available from the complementary techniques but we recommend induction of RASS over the Indian Antarctic stations, as RASS would provide temperature profiles under all weather conditions. An acoustic sounder fails under windy conditions, posing a serious limit on its usage in Antarctica[12].

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REFERENCES

[1] Stations of SCAR Nations operating in the Antarctic, Winter 2002, Scientific Committee on Antarctic Research, SCAR Bulletin 147, October 2002.

[2] N. P. M. Van Lipzig, J. Turner, S. R. Colwell and M. R. Van Den Broekethe, "Near-surface wind field over the Antarctic continent", International Journal of Climatology, Vol. 24, no. 15, PP 1973-1982, 2004.

[3] Ashok Kumar, V.B. Gupta, H.N. Dutta and Sachin D. Ghude, "Mathematical modelling of katabatic winds over Schirmacher region, East Antarctica", *Indian J Radio & Space Physics*, Vol. 36, PP. 204-212, 2007.

[4] Kh. Gajananda, H.N. Dutta and V.E. Lagun, "An episode of coastal advection fog over East Antarctica", *Current Science*, Vol. 93, no.5, PP 654-659, 2007.

[5] Roberta Massom, Michael J. Pook, Josefino C. Comiso, Neil Adams, John Turner, Tom Lachlan-Cope andTimothy T. Gibson, "Precipitation over the Interior East Antarctic Ice Sheet Related to Midlatitude Blocking-High Activity", *Journal of Climate*, Vol. 17, no. 10, PP. 1914-1928, 2004.

[6] Jaya Naithani and H.N. Dutta, "Acoustic sounder measurements of the planetary boundary layer at Maitri, Antarctica", *Boundary layer Meteorology*, Vol. 76, no.1-2, PP. 199-207, 1995.

[7] Guilhem Autret**,** Frédérique Rémy and Sylvie Roques**,** "Multiscale Analysis of Antarctic Surface Temperature Series by Empirical Mode

Decomposition", *Journal of Atmospheric and Oceanic Technology*, doi: http://dx.doi.org/10.1175/JTECH-D-11-00050.1, 2013.

[8] H. Enomoto, H. Motoyama, T. Shiraiwa, T. Saito, T. Kameda, T. Furukawa, S. Takahashi, Y. Kodama O. Watanabe, "Winter warming over Dome Fuji, East Antarctica and semiannual oscillation in the atmospheric circulation", *Journal of. Geophysical Research*, Vol. 102, no. D-18, PP. 23103-23111, 1998.

[9] Marek Kejna, "Trends of air temperature of the Antarctic during the period 1958–2000", Polish Polar Research, Vol. 24, No 2, PP. 99-126, 2003.

[10] Y. Richard, M. Rouault, B. Pohl, J. Cr´etat, I. Duclot, S. Taboulot, C. J. C. Reason, C. Macrona and D. Buirona, "Temperature changes in the mid- and high-latitudes of the Southern Hemisphere", International Journal of Climatology. Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/joc.3563, 2012.

[11] Risal Singh, Shambhu Nath, R. S. Tanwar and Sachchidanand Singh, "Study of Erythemal Dose Variation and Exposure time for different UV-B Dose levels at Indian mainland and Antarctica", Proc. URSI, New Delhi, 2005. http://www.ursi.org/Proceedings/ ProcGA05/pdf/K04a.9(01460).pdf

[12] Jaswant Singh and H.N. Dutta, "Antarctica: The Most Interactive Ice-Air-Ocean Environment", NOVA Science Publisher Inc., USA. 2011 Barcode / ISBN-13:9781611228151; ISBN:1611228158; pp 1-259.

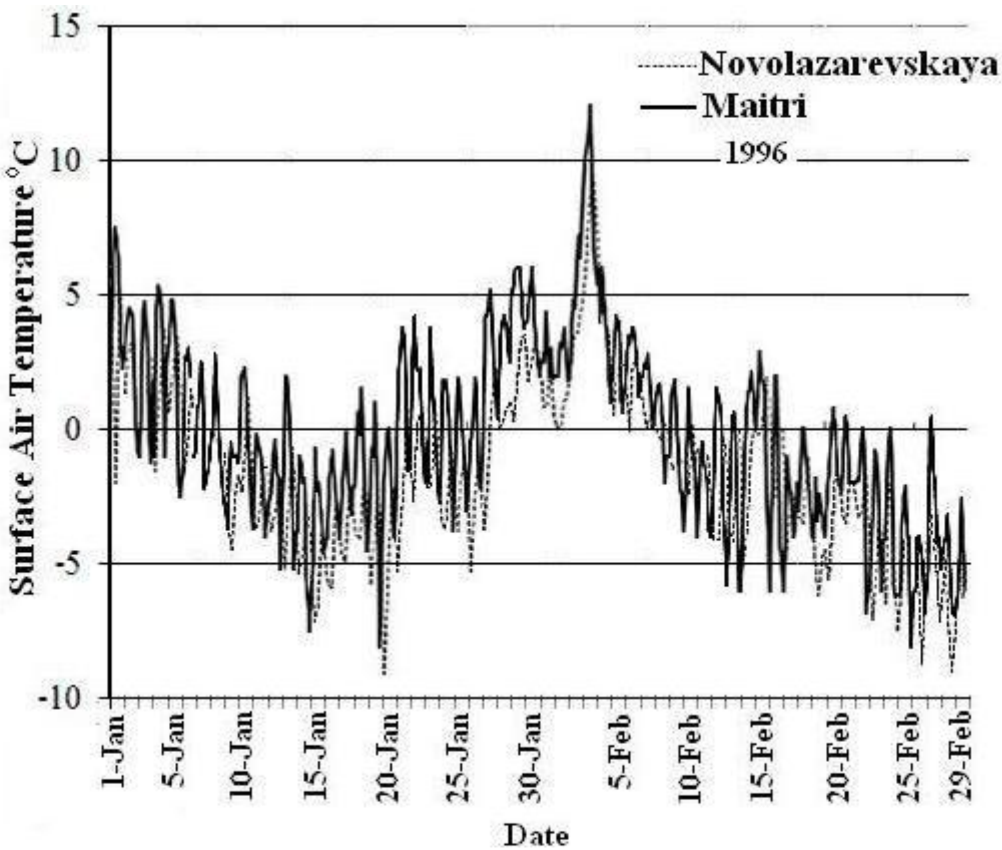


Fig. 1: Variation of 3-hourly surface air temperature over the Novolazarevskaya and the Maitri stations during January-February, 1996. It shows that there has been a gradual increase in the surface air temperature from January 25 onwards, touching a peak on February 3 and suddenly subsiding by February 5, 1996.

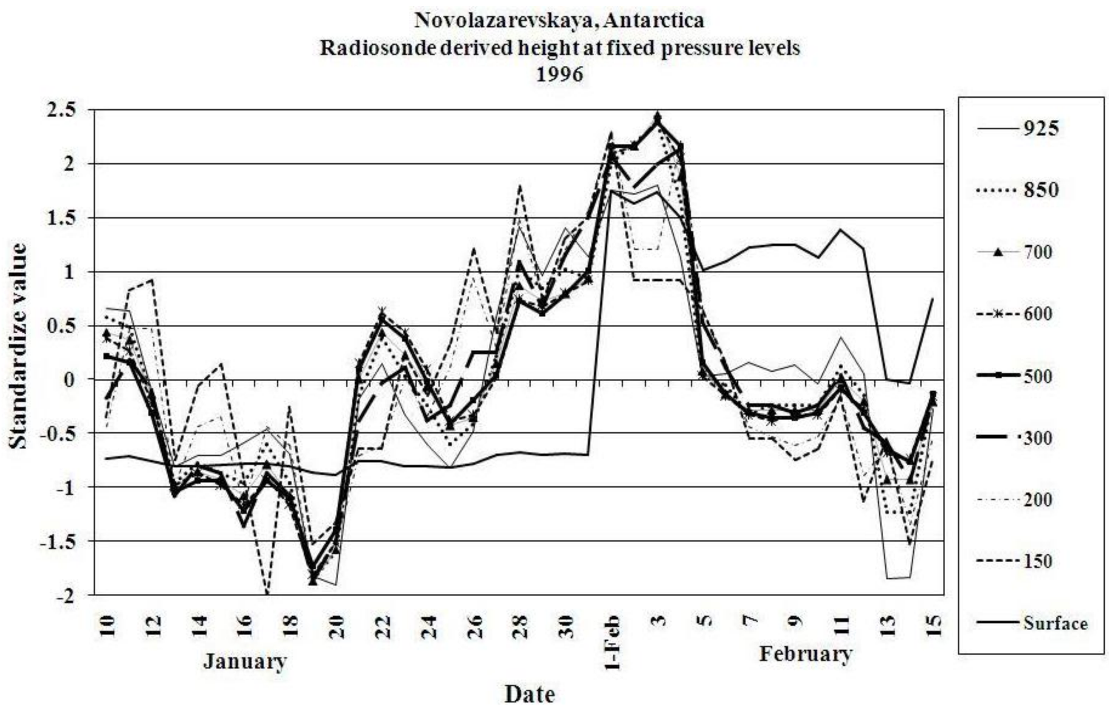


Fig. 2: Variation of the radiosonde derived Standardize values for the height of atmosphere at fixed pressure levels during the warming event. It shows that the warming started on January 25, 1996 and reached at its peak on February 3, 1996. The rise of warming was gradual while it ended abruptly from February 4, 1996 itself.

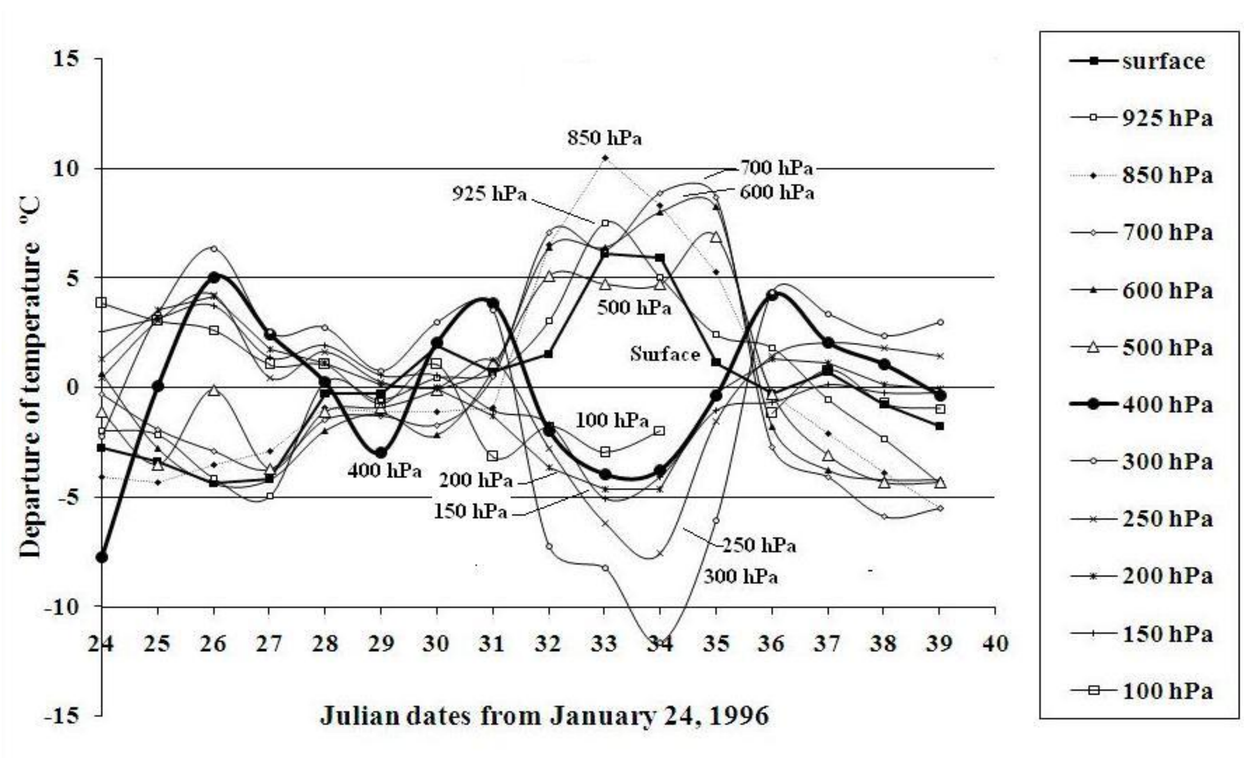


Fig. 3: Standardize departure of atmospheric temperature at fixed pressure levels during the warming event. It clearly indicates that the warming event was confined below 400 mbar level and the maximum impact can be seen at 850 hPa level. It is important to note that the temperature enhancement clearly reveals the event starting from January 31, 1996 and ending on February 4, 1996.

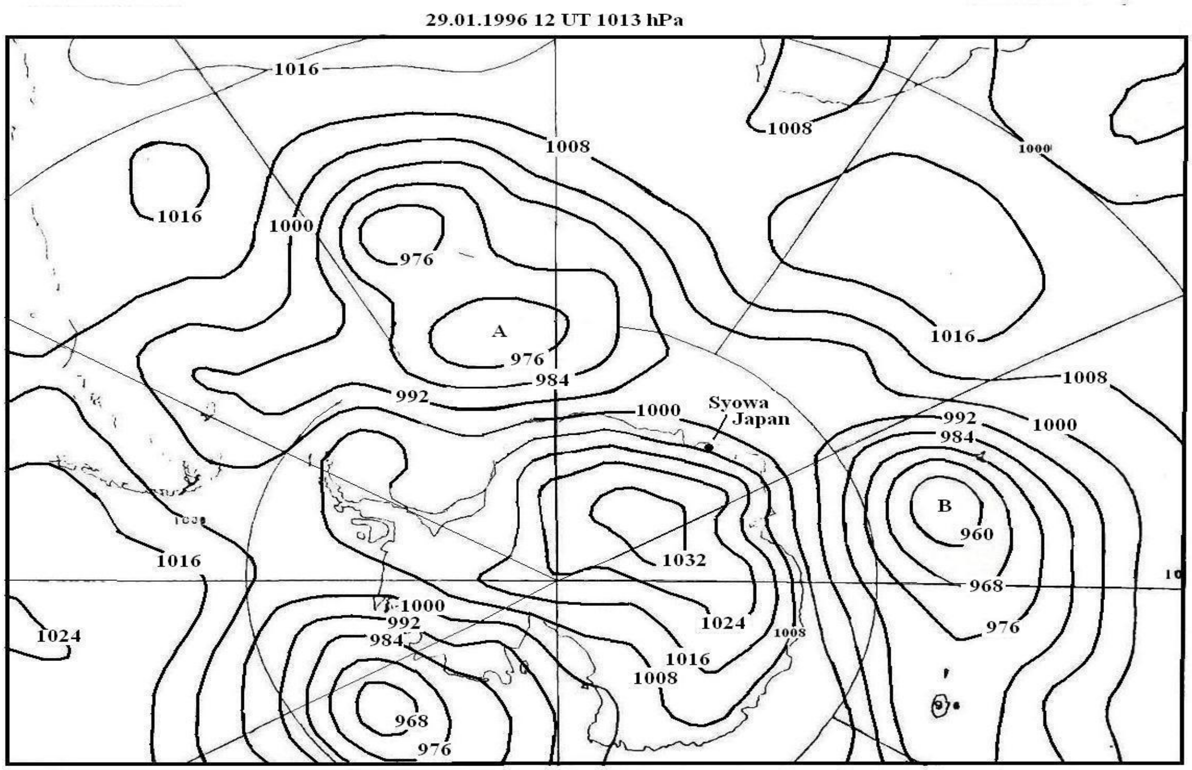


Fig. 4: The synoptic mslp chart over Antarctica for January 29, 1996. It shows that the mslp is enhancing from 1008 hPa at the periphery to 1032 hPa in the interior of the continent. It may be noted that the pressure in the interior of the east Antarctic region enhanced from 1008 to 1032 mb in the past 4 days. It also shows position and intensity of a well developed cyclone marked as "B" towards east of the Maitri station while another cyclone marked as "A" is developing towards west of the Maitri station

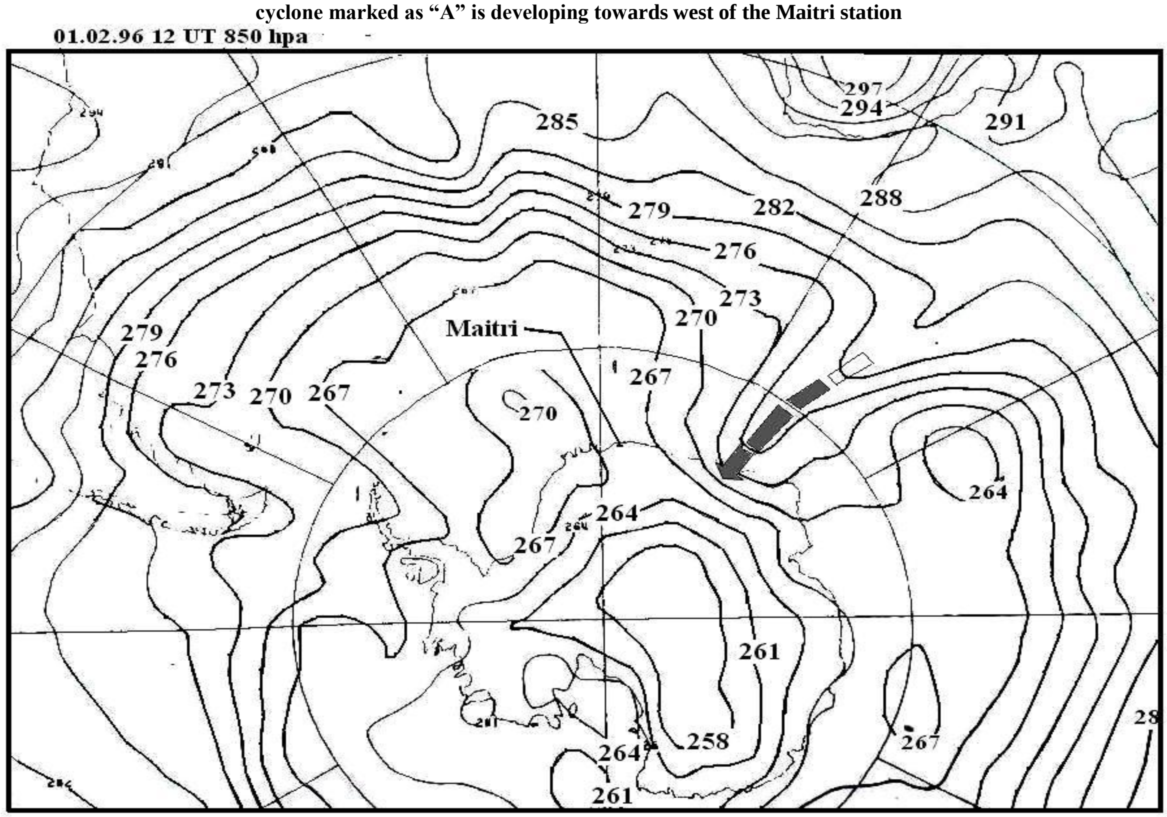


Fig. 5: Synoptic variation of TTD values at 850 hPa level indicate intrusion of warm air around 40 °E on February 1, 1996.

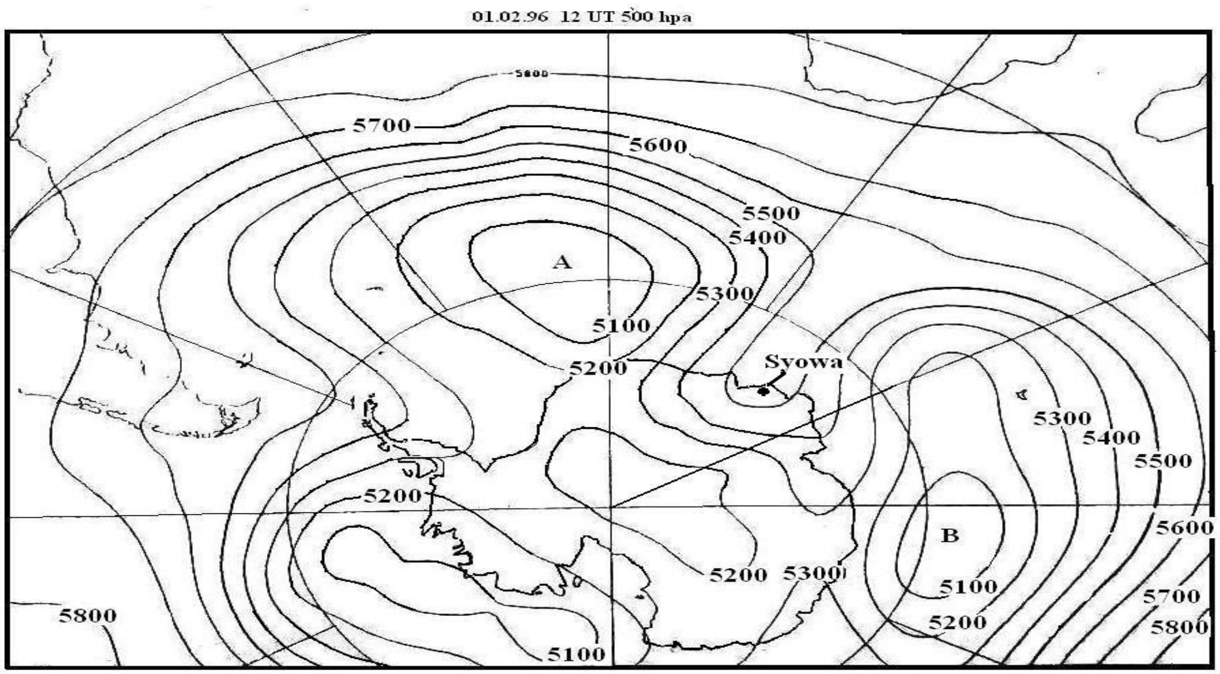


Fig. 6: Variation of geopotential height at 500 hPa level coincides induction of warm air in the same region as indicated by the 850 hPa level.

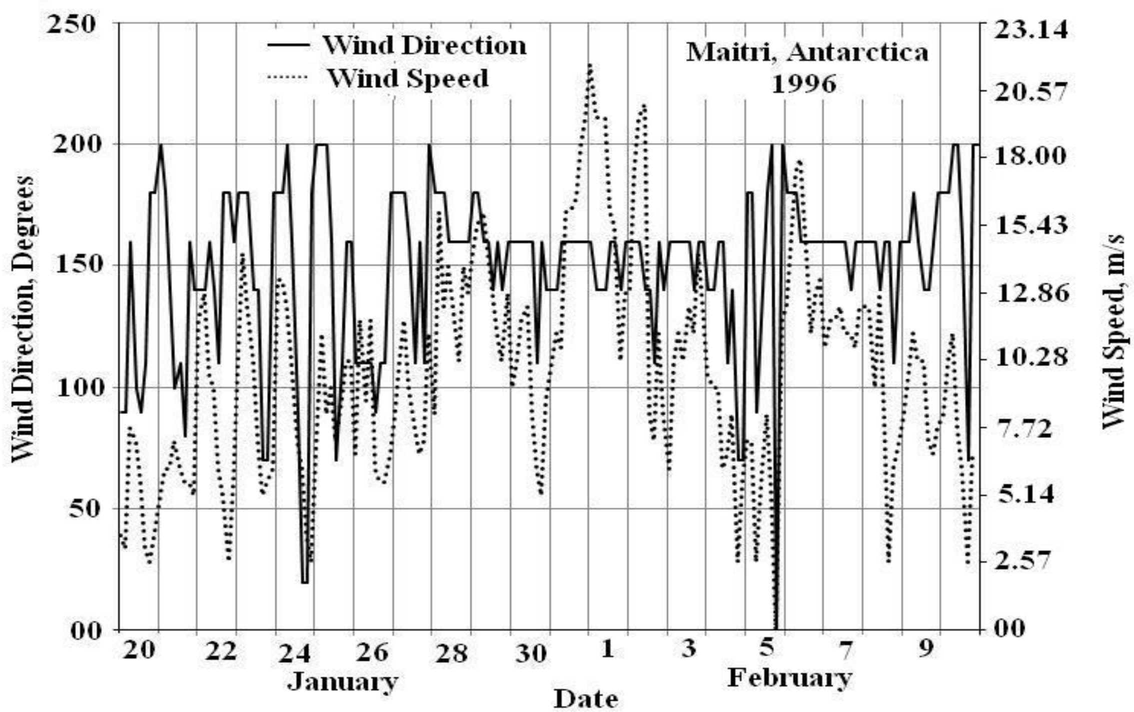


Fig. 7: Wind speed and direction recorded at Maitri, Antarctica around the warming period. It indicates that during the warming event period, wind was confined to 160°. This is the direction from where katabatic winds are inducted over the Schirmacher oasis. The direction chart clearly rules out induction of warm air from the oceanic side. Moreover, wind speed was also the highest during the event, it means the warming was created in the interior of the continent and then pushed towards the periphery along the lines of maximum slope around the Schirmacher oasis.

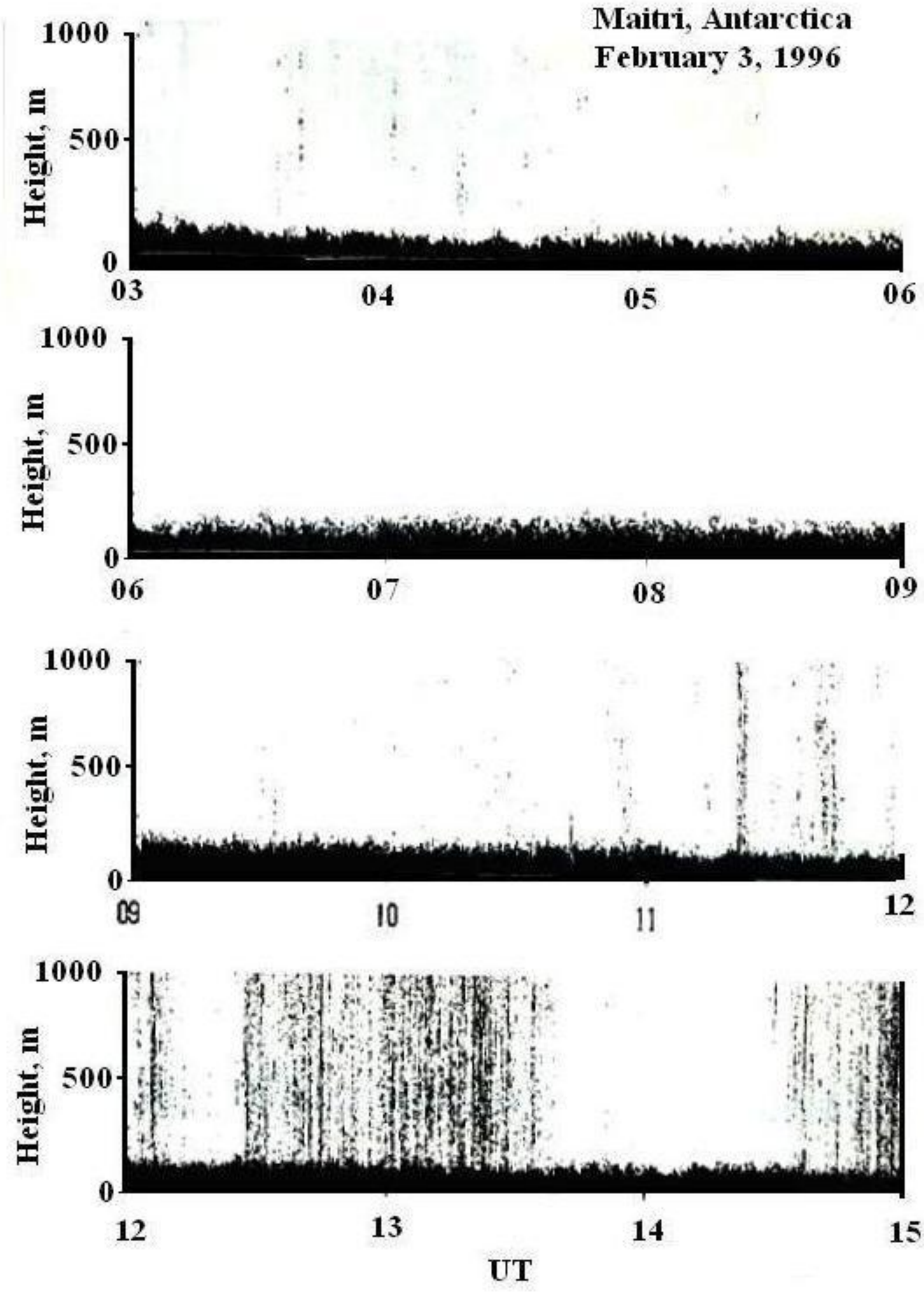


Fig. 8: Facsimile chart of the Acoustic sounder recorded on February 3 indicates that despite clear sunny weather, there is no thermal convection during the day

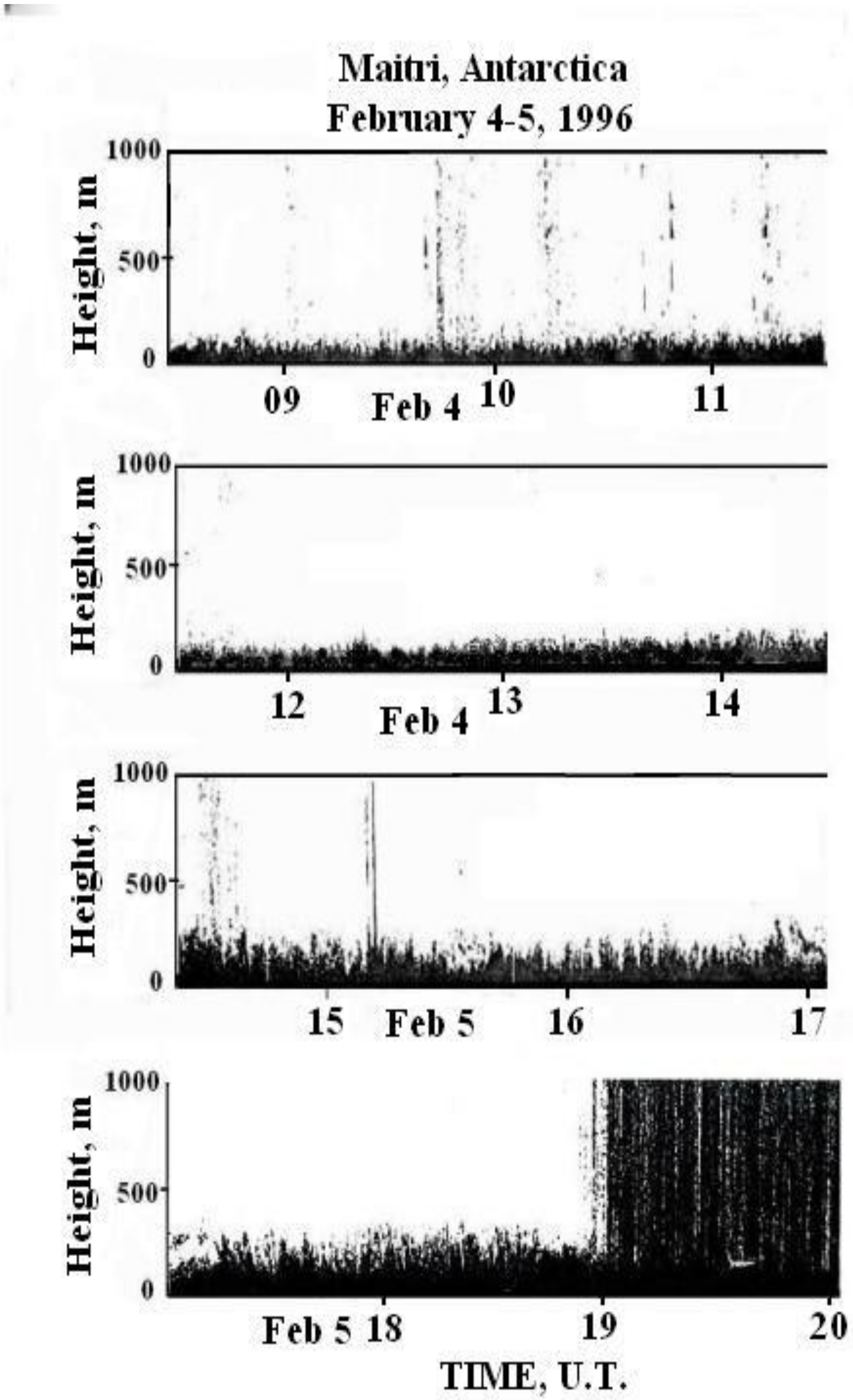
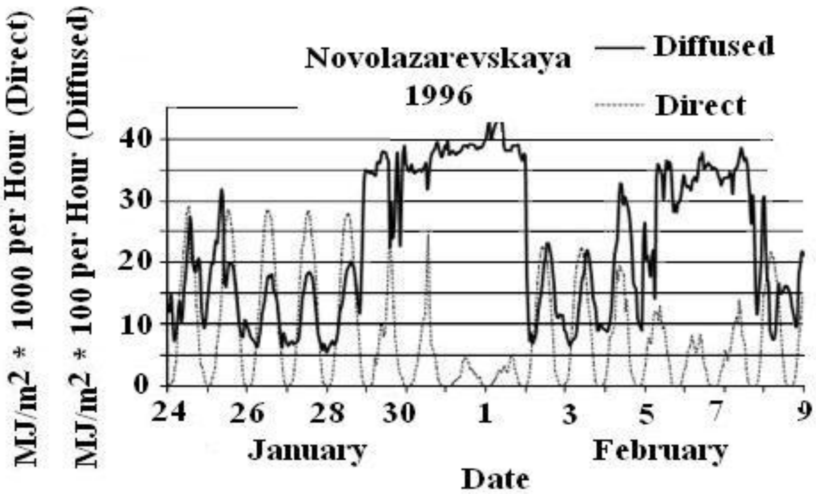


Fig. 9: Facsimile chart on February 4 shows dull thermal convection and a moderate convection on February 5. It indicates return of localized heating of the atmosphere.



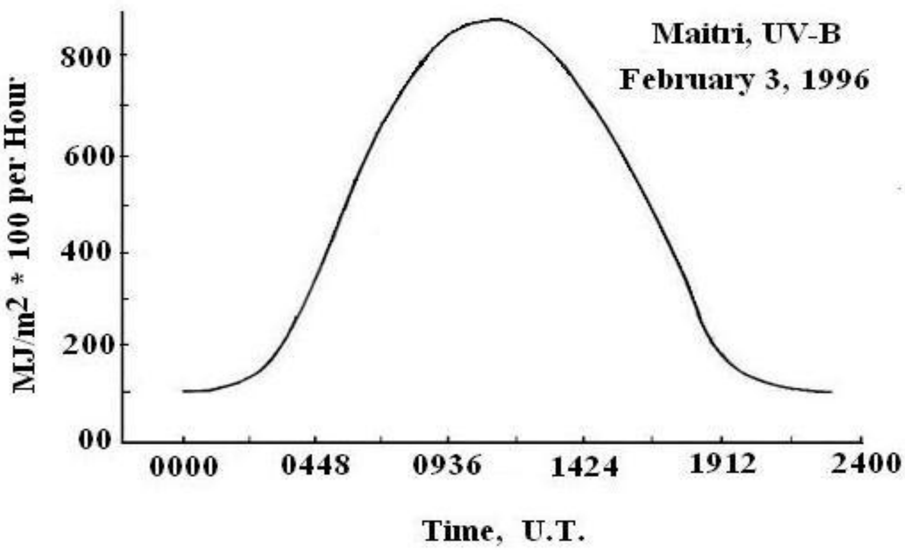


Fig. 10: Variation of direct and diffused radiation indicates that the weather was cloudy up to February 2 and suddenly cleared on February 3. Since it rained over the east Antarctic region, maximum UV-B radiation values were recorded on February 3 in the whole of 1996 year. This is the impact of warming on the Antarctic weather and the values can be used to compute the fine particulate matter loading