MAUSAM, **62**, 4 (October 2011), 547-556

551.506.2(99)

Recent trends and variations in surface meteorological parameters over Indian Antarctic station Maitri

O. P. SINGH, U. P. SINGH and R. P. LAL

India Meteorological Department, New Delhi – 110 003, India

e mail : singh.op@imd.gov.in

सार – भारतीय एंटार्कटिक अनुसंधान मैत्री में हाल ही के दो दशकों 1991–2010 के दौरान तापमान, दाब और पवन के सतही मौसम विज्ञानिक आँकड़ों का उपयोग करके सतही मौसम विज्ञान प्राचलों का विवेचन इस शोध पत्र में किया गया है। मैत्री में औसत वायु तापमान की प्रवृत्ति पिछले दो दशकों में –0.4 प्रति दशक रही जिससे पता चलता है कि मैत्री के सतही तापमान में भूमंडलीय उष्णन का कोई प्रभाव नहीं पड़ा है।

पिछले दो दशकों में मैत्री के सतही तापमान में कोई प्रवृत्ति नहीं देखी गई है। 1991–2000 के दशक में औसत सतही पवन गति की प्रवृत्ति में मामूली सी वृद्धि देखी गई है जबकि 2001 से 2010 के दशक में मामूली सी कमी की प्रवृत्ति देखी गई है। तथापि, सतही प्राचलों में बड़ी अंतर – वार्षिक विविधता देखी गई है और रैखिक प्रवृत्ति इस प्रकार की विविधताओं का ही परिणाम है। वर्ष 2009 और 2010 के दो विपरीत मानसून वर्षों में जनवरी से मार्च के दौरान मैत्री में सतही दाब में रूचिकर विसंगतियाँ देखी गई। वर्ष 2009 के सूखे में मैत्री में जनवरी से मार्च में सतही दाब असंगत रूप से कम था जबकि अत्यधिक मानसून वाले वर्ष 2010 की समान अवधि में दाब विसंगतियाँ सकारात्मक रही। मैत्री में मानसून 2009 के जनवरी–मार्च के दौरान नकारात्मक तापमान विसंगतियाँ रही और वर्ष 2010 के अच्छे मानसून से पहले इसी अवधि के दौरान सकारात्मक विसंगतियाँ देखी गई।

ABSTRACT. Utilizing surface meteorological data of temperature, pressure and wind of recent two decades, 1991-2010 over Indian Antarctic research station Maitri the trends and variabilities in surface meteorological parameters have been discussed. The trend in mean air temperature at Maitri has been -0.4/decade during past two decades showing no impact of global warming on Maitri surface temperature.

There is no trend in surface pressure at Maitri during last two decades. Mean surface wind speed has shown slight increasing trend during the decade 1991-2000 whereas it has shown slight decreasing trend during the decade 2001-2010. However, there are large interannual variations in surface parameters and the linear trends seem to be the result of such variations. During Jan-March of two contrasting monsoon years 2009 and 2010 interesting anomalies in surface pressure at Maitri have been observed. Surface pressure was anomalously lower at Matri in Jan-March of drought year 2009 whereas positive pressure anomalies prevailed during the same period of excess monsoon year 2010. Negative temperature anomalies during January-March over Maitri preceded drought monsoon 2009 and positive anomalies prevailed during the same period before good monsoon 2010.

Key words – Maitri, Trend, Interannual variation, Anomaly, Surface meteorological parameter, Southern oscillation.

1. Introduction

Antarctica is a challenging region for research because of its geographical remoteness and extreme climate. The climate change that took place at the earth in the 20th century determines the need for a quantitative study of variability of meteorological parameters influencing climatic system. The Antarctica and Arctic, being a unique component of the Earth's climatic system have a significant influence on the global climate.

The global climate models predict in what way the Antarctic climate can change during the current centennial, differing in projections. The results of most climate models point to a comparatively moderate air temperature increase in the Antarctic during the next decades. Since the duration of regular meteorological measurements exceeds 50 years only at some stations, the answer to the question whether the air temperature changes in the Antarctic reflect the global climate change remains open. For most Antarctic stations the temperature trends are small and statistically insignificant. The values of the trends depend to a great extent on the interannual variability and the period of data analysis. Therefore it cannot be definitely said at present what is typical of Antarctica in general: warming or cooling.

The climate of the Schirmacher Oasis is relatively mild for Antarctic conditions. Because of the positive radiation balance, the Schirmacher Oasis is regionally classified as a 'coastal climate zone'. The database for the Indian Antarctic Research station Maitri on the Schirmacher Oasis at East Antarctica for the period from 1990 to 2010 has been analysed in the present study. Linear trends and variabilities of three parameter, *viz*., pressure, temperature and wind have been examined in the context of the Antarctic climate change has been studied by Turner *et al*., 2005**.**

The inhomogeneous Antarctica temperature trend, little change at Antarctic coastal station and strong warming of Antarctic Peninsula has attributed strengthening of circumpolar westerlies (Thompson and Wallace, 2000). The near surface temperature and pressure have key importance for understanding the Antarctic climate. The near surface temperature is one of the important factors which has significant role in melting of sea ice surface.

The potential impact of atmospheric warming over Maitri may be insignificant during summer, winter and spring of 2010 as compared to 21 year short period normal being statistically significant temperature increases during previous decade 1991-2000 but insignificant warming during 2001-2010.

2. Data and methodology

All surface meteorological parameters, *i.e*., pressure, temperature, wind and associated weather over Maitri for the period 1990-2010 have been analyzed. The statistical mean value the long term mean, standard deviation and least square linear trend in respect of all parameters over Maitri for the above mentioned period have been computed. The derived product has been critically examined for interannual and inter seasonal variability of weather system and weather phenomena. The methodology is based upon Santer *et al*. (2000) who examined trend uncertainty of temperature. In this study effective samples of parameters have been examined for trends and variabilities during 1991-2010. Considering the geological location of Schirmachar oasis four seasons have been defined as follows: summer [November-December-January (NDJ)], autumn [February & March (FM)], Winter [April to August through June (AMJJA)] and spring (September-October) (Koppar, 1991). The seasonal variability of weather phenomena during the years 2009 and 2010 have been examined. The characteristics and effect of derived anomaly of various parameters over long period average have also been studied.

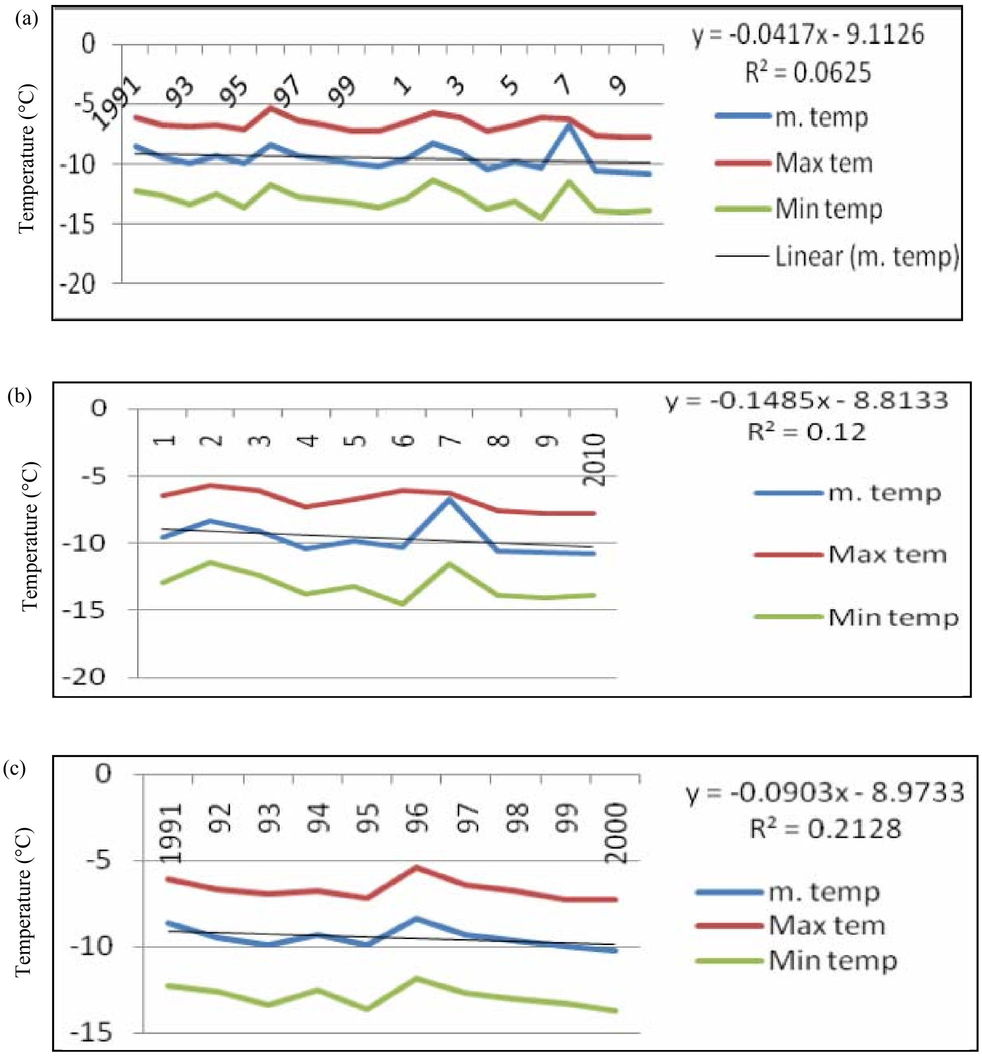
3 Results & discussion

3.1. *Temperature trend*

The temperature variation over east Antarctica is governed by two mechanisms. There may be alteration of energy balance due to increase or decrease of cloudiness/albedo and (or) advection of warm or cold air masses. Due to variation in number of penetrating low pressure system less number of blizzard have occurred during last decade which is related to cooling trend during the decade. On the interannual scale negative correlation found between temperature and strength of circumpolar westerlies. The interannual variability of synoptic activity over southern hemisphere largely affects precipitation and temperature. The latitudinal position of circumpolar trough also reflects variability of meteorological parameters to a larger extent. During last fifty years of past century rising trends of temperature has been observed at western side of Antarctic peninsular (Vaughan *et al*., 2003).

The surface temperature at Maitri is linked with transport of air masses towards interior of the Oasis. The question is whether Schirmachar oasis has cooled/ warmed during recent/previous decades. The attempt has been made to study trend over Maitri by calculating mean annual temperature. Comiso, 2000 observed small cooling in surface skin temperature across the continent on the basis of infrared satellite imagery. The spatial variation of monthly surface temperature is strongly depend upon seasons and time period. Steig *et al.* (2009) have reported significant warming in East Antarctica at the rate of 0.1°C / decade for the period 1957-2006 and a continent-wide warming trend of 0.12°C/decade.

The mean year temperature has shown a falling trend during both the decades 1991-2000 and 2001-2010. Overall trend during 20 year period shows decrease of mean air temperature by -0.4 °C per decade [Figs. 1 (a-c)]. The small temperature trend over Maitri corresponds to small changes in moisture holding capacity of the air leading to less precipitation which further corresponds to decrease in number of pressure system affecting Maitri during recent decade. The analysis also shows maximum temperature has decreased faster as compared to minimum temperature. The minimum temperature rose more than maximum temperature over Antarctic during 1950-1993 (Jones *et al.*, 1999). The falling trend of maximum, minimum and mean temp. for both the decade as well as for whole period 1991-2010 has been observed. However,



Figs. 1 (a-c). Maitri temperature (a) 1991-2010, (b) 2001-2010 and (c) 1991-2000

the highest mean maximum and mean temperature was observed in 1996 with lowest temperature in the year of 2010. In winter, the average temp. are of -14.6° C, a lowest of all seasons with highest in summer. A comparison of mean temp. of 2010 shows that temp. in winter 2010 over Maitri was colder by nearly 2.5 degree while not much change in other seasons. As per average seasonal mean temperature of 1990-2010 shows cooler winter. The comparison of seasonal temperature record for the year 2010 and long period average 1990-2010 shows seasons of 2010 are colder except autumn which is warmer. The solar insolation increases during summer which indicative of more clear sky. The less cloudy in summer gives more effective energy loss which contribute increased mean range of temperature The SAM remain negative phase during 2010 except during summer, could have lead strong circumpolar westerlies that contributed cooler seasons (Fig. 2). The same period data analysis of Novalazarevskya data shows cooling trend 1.3 °C per decade and 0.9 °C, during previous and recent decade respectively.

Sea-ice-air surface is most effective to regulate warming or cooling trend over coastal Antarctica. A vey small increase Sea-ice-air surface have a large impact on surface air temperature (Turner *et al.*, 2005.). The extent of sea ice surface area reported to be more than average during winter 2010 (Fig. 3), which possibly contributed to cooling. The coupling of ocean and air surface causes advection of warm oceanic air towards the coast and under influence of strong westerlies over the station provides warmer temperature during 2009 as compared to 2010.

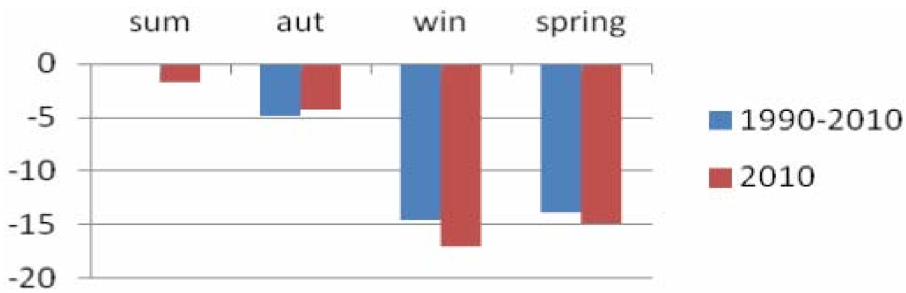


Fig. 2. Seasonal variation of temperature

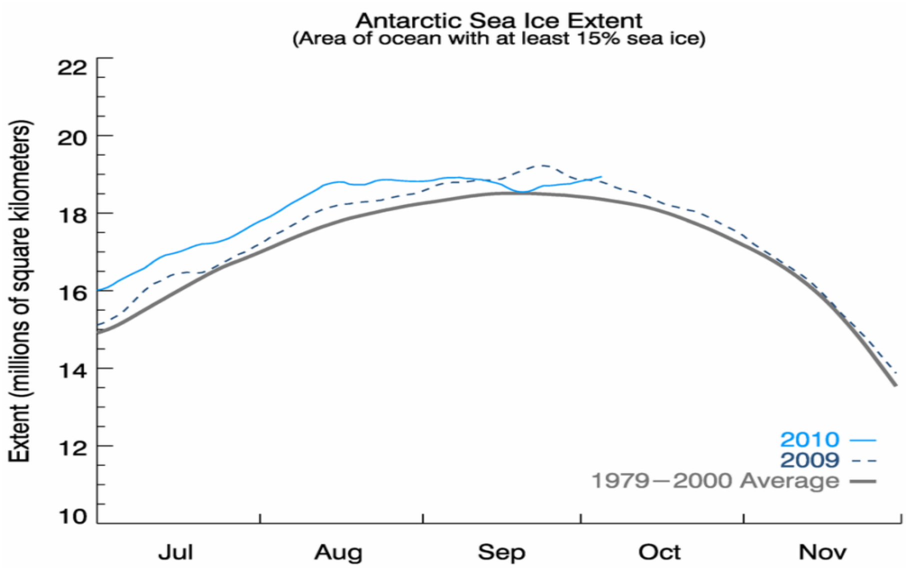


Fig. 3. Antarctica Sea ice extent (National Snow and ice data centre, Boulder Co)

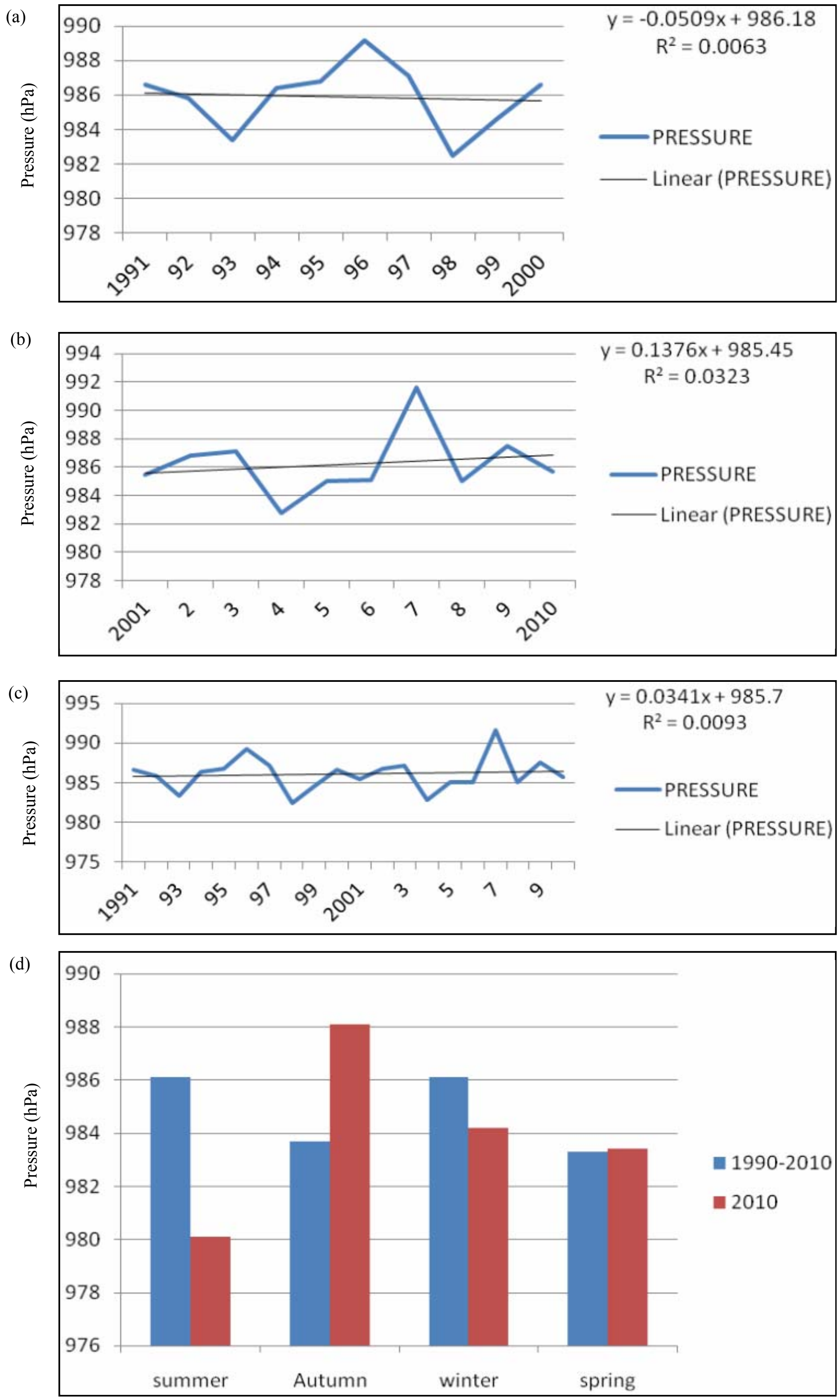
The semi annual oscillation is important for southern hemisphere climate. It allows contraction and extension of pressure trough along Antarctica and surrounding ocean. Due to the semi annual oscillation the pressure at Maitri, Schirmachar Oasis shows half yearly wave pattern. A significant coupling between half year cycle in surface pressure and temperature occurs over coastal Antarctica. The coupling of temperature to meridional circulation not only effect on seasonal time scale but also effect on daily and inter annual time scale (Michiel, 1998a).

3.2. *Pressure trend*

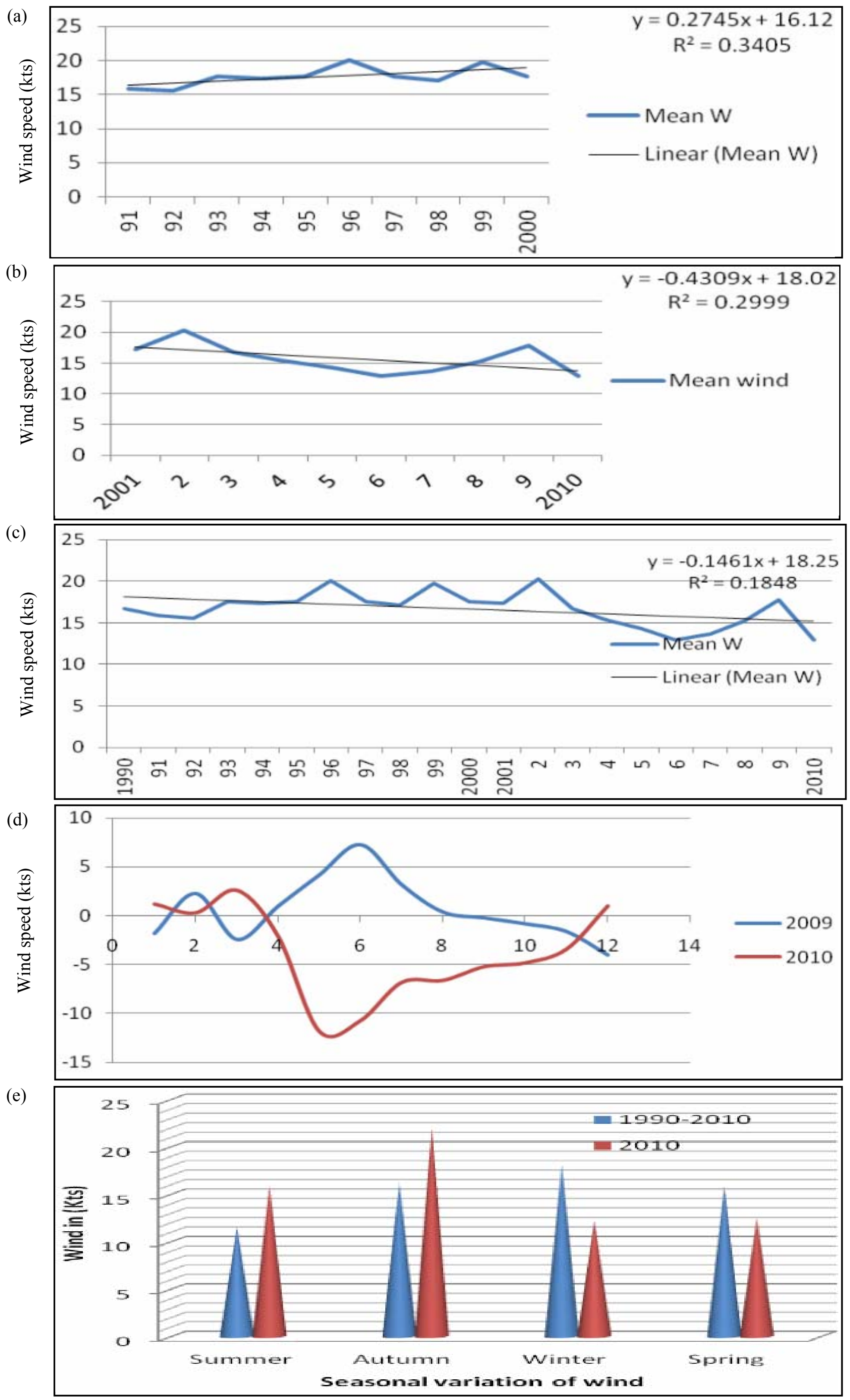
Annual mean pressure variation is shown in Figs. 4(a-c). The trend is insignificant during last twenty years period (1991-2010) whereas decadal variability shows 1.3 hPa per decade rising tendency during recent decade 2001-2010 and negative tendency of 0.5 hPa decade during 1991-2000. Turner 2005 observed a negative tendency of pressure for the period 1971-2000 for most of the Antarctic stations. The long period 1990-2000 average pressure is highest in summer with secondary maxima in winter with 987.2 hPa and 986.5 hPa respectively with lowest in spring as 985.4 hPa. In 2010, mean pressure during autumn is highest 988.1 hPa higher than the long period mean while in other seasons the mean pressure are lower than mean pressure of 1991-2010 [Fig. 4 (d)]. The lowest mean pressure during summer are associated with smallest number of low pressure system in circumpolar trough (Jones and Simmonds, 1993). Lowest mean temperature during spring season is consistence with secondary minima of cyclonic activity, as the circumpolar trough move northward as a result of semi annual oscillation. The rising trend of pressure during recent decade is indicative of decreasing number of cyclone and less intense blizzard.

3.3. *Wind speed trend*

The wind at Maitri is generally katabatic in nature which prevails from south-east sector. Maitri remained



Figs. 4(a-d). Annual variability of mean pressure (hPa) during (a) 1991-2000, (b) 2001-2010, (c) 1991-2010 and (d) mean seasonal pressure



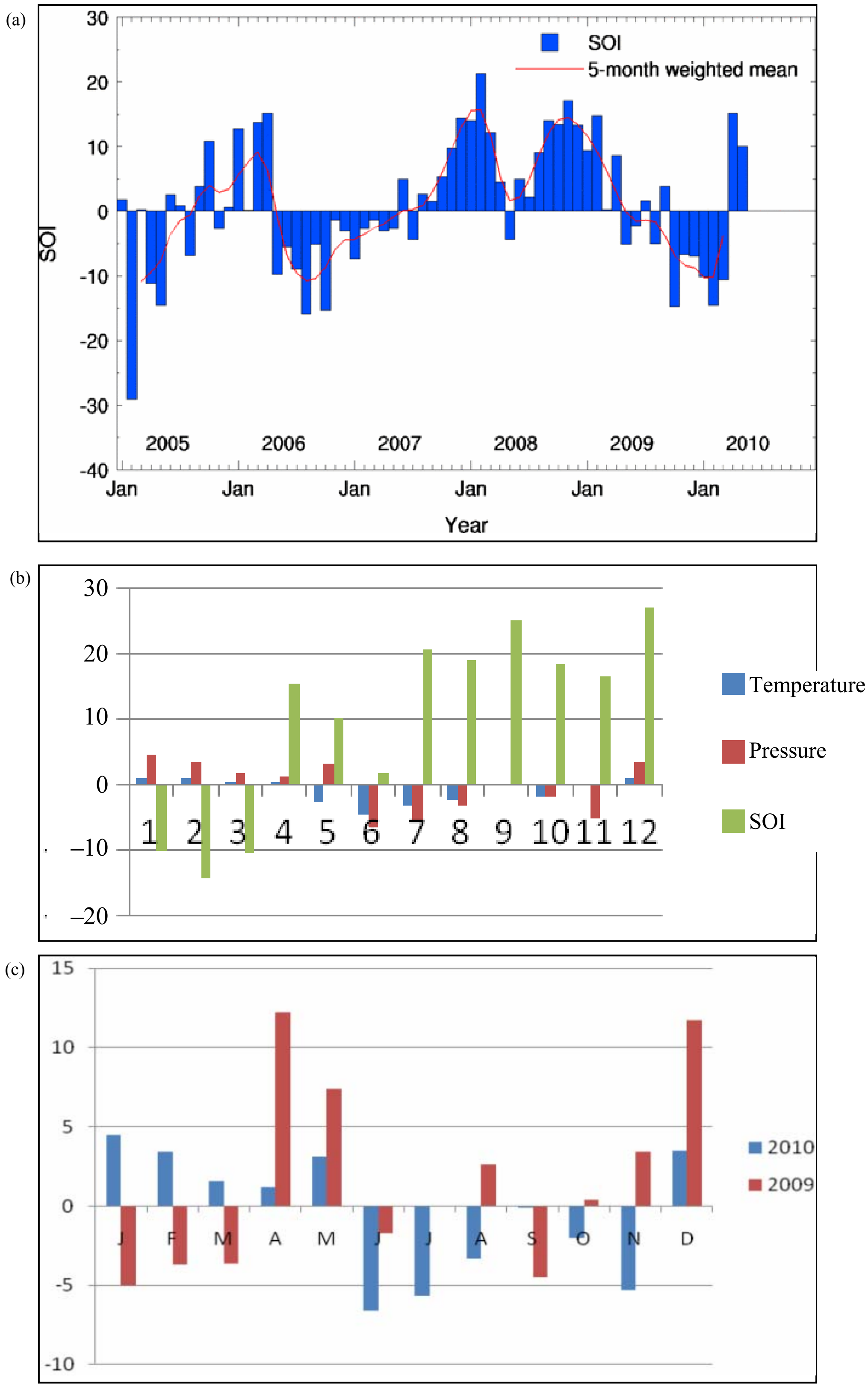
Figs. 5(a-e). Annual variability of mean wind speed (kts) during (a) 1991-2000, (b) 2001-2010, (c) 1991-2010, (d) mean wind anomalies during 2009 and 2010 and (e) seasonal mean wind 1990-2010 and 2010 windy during previous decade as compared to recent decade. The tendency of wind speed was increasing at the rate of 0.27 kts per decade during 1991-2000 but decreasing tendency -0.43 kts per decade has been observed during 2001-2010.The decreasing trend by -0.14 kts per decade is observed during over all period [Figs. 5 (a-c)]. The decreases of wind speed during recent decade corresponds to less number of cyclone disturbances affecting Maitri. The wind anomaly for the year 2009-10 shows that the year 2009 was more windy as compared to 2010 [Fig. 5 (d)], which corresponds to number of cyclonic disturbances affecting the station during the year 2009. The long period mean annual wind is 18 kts. The winter season is most windy and summer is less windy. But in 2010, wind was strongest in autumn with mean wind speed of 22 kts and lowest in spring with mean wind speed 12.5 kts [Fig. 5 (e)]. It shows there have been large variability over these mean patterns at this polar region. The increase in wind speed during 2009 corresponds to change in nature of polarity of SAM during the year in Fig. 5 (d). As far as mean seasonal wind is concerned the variation in surface wind does not confirm always changes of synoptic situation, *i.e.*, passage of low pressure system (Thomas and John, 2003). The wind at Maitri is pronounce with seasonal/annual cycle in association with movement of circumpolar trough. During the summer season the winds are weaker-speed in association with weak cyclone activity. The katabatic wind dominate in summer under clear sky conditions accompanied with weak system (Bintanja, 2000). It is not only cyclonic activity that plays a role in wind mechanism over Maitri but potential gradient is also an important factor for wind over Maitri. At the, surface, air temperature starts cooling since autumn but maximum cooling occurs during winter. The katabatic wind intensifies during the winter which starts weakening during spring.

4. SAM and temperature, pressure variability

The Southern Annual Mode (SAM) is major contributors for variance in sea level pressure. It plays an important role in driving decadal temperature changes. The SAM has shifted into its positive phase especially during summer and autumn, resulting in strengthening of the circumpolar westerlies and has significant. contribution to the spatial variability in Antarctic temperature change (Marshall, 2003). It is barotropic in nature a leading imperical orthogonal function in many atmospheric parameters, *viz*., surface pressure, temperature and geopotential height (Thompson and Walliac, 2000). In East Antarctica, high polarity of SAM is known to correspond to lower temperatures. The combined influence of ENSO and SAM was seen on surface air temperatures in East Antarctica mainly during the austral summer season from 1989 to 2005. However SAM is a dominant mode of climatic variability in the coastal region of central Dronning Maud Land on a decadal scale. [Naik *et al.* (2010)]. When SAM strengthen the temperature decreases over East Antarctica. Significant increase of temperature since 1990 as per data record 1970-2005 over East Antarctica was observed. [Monaghan *et al.* (2008)].

The teleconnection of ENSO to the central DML occurs through the combined influence of SAM and ENSO. This negative relationship indicates negative polarity of SAM that leads warmer temperatures in the central Dronning Maud land which is similar to the records from the East Antarctic region. On a decadal scale, the SAM was seen to override the influence of ENSO. The Southern Oscillation Index (SOI) indices showed a significant negative relationship with surface air temperatures during the austral summer. This relationship between SOI and surface air temperature suggests that during an El Niño year within the period of 1989-2005, warmer air temperatures prevailed over the central Drounning Muad land. These evidences support the finding that both the SAM and ENSO cause a combined influence on surface temperatures during austral summer in the central Drounning Maud land. The combined effects of ENSO-Antarctic Oscillation for McMurdo Dry Valleys has been studied by Bertler *et al.* (2006). The SAO dominates seasonal variation at coastal Antarctica [Van (1972)]. There are indications that the strength of the SAO is linked to the Southern Oscillation, in the sense that warm phases of the Southern Oscillation coincide with strong westerlies a weakly developed Semi Annual Oscillation (SAO) and below-average temperatures in East Antarctica (Michiel, 1998b).

The monthly values of SOI index and mean air temperature anomalies of Maitri during winter show a negative correlation 0.272 during 2009 and positive insignificant correlation 0.06 during 2010 which further gives strength to the findings of lower temperature during winter season 2010 as compared to 2009. Although SAM has an important influence on observed surface temperature variability over Antarctica but other factors also played a key role such as regional ocean circulation, sea-air feedback (Vaughan *et al*., 2003) and El-Nino-Southern oscillation. The weakly negative tendency during 1991-2010 is consistence with positive trend of southern hemisphere annular mode during summer and autumn [Fig. 6 (a)]. The year 2008-09 was dominated by positive phase of SAM. The combined contribution of SAM and La-Nina positive anomaly of mean temperature during year 2009 shows a warmer year. The positive SOI index during 2009 lead to weaker westerlies thus also contributes low level warming.



Figs. 6 (a-c). (a) Southern oscillation index during 2005-2010, (b) monthly SOI index, temperature and pressure anomaly year 2010 and (c) pressure anomaly year 2009, 2010

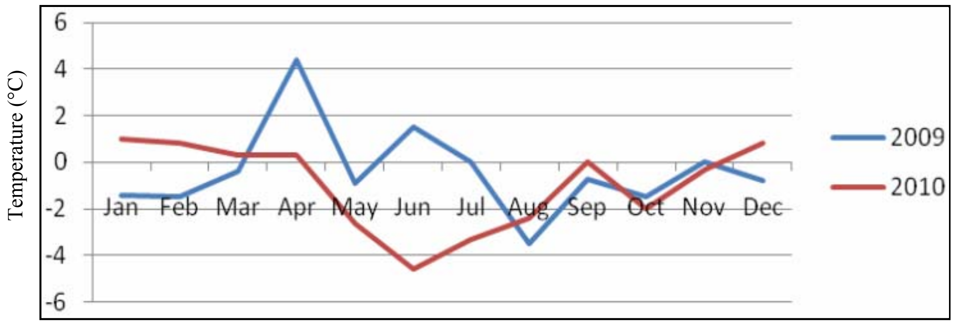


Fig. 7. Temperature anomaly during 2009 & 2010

A reverse trend is observed between monthly SOI index *w.r.t.* temperature and pressure at Maitri during 2010 [Fig. 6 (b)]. The annual correlation between pressure and SOI index are -0.277 for year 2009 and -0.08 for year 2010. The correlation during winter month of 2009 is 0.272 although very small insignificant correlation 0.06 exists during 2010. The SOI index confirms the reverse trend of atmospheric pressure over Maitri in relation to southern oscillation index.

5. Teleconnection between Antarctic and Indian summer monsoon

It was Walker 1924, observed Southern Oscillations (SO), North Pacific Oscillations (NPO) and North Atlantic Ocean (NAO), the important dominating circulations which gives foreshadowing of Indian summer monsoon. Das and Datta (1985) made preliminary investigation of weather over these regions. The El-Niño propagates westward in association with contrasting weather pattern various part of the Globe. Large sale drought over Sahel and Indian sub continent during 1972, 1979 and current drought (2009) in the country occurred during intense El-Niño period. The combined effect of El-Niño and SO is ENSO which is very important signal for foreshowing the variability over the Indian monsoon. Sir Gilbert Walker considered seasonal pressure over Antarctic, it was observed that December to February pressure of MC Murdu Sound, Antarctica, (166.4° E and 77.5° S) has positive correlation of 0.8 with pressure over northeast India during following March to May and correlation of 0.6 with rainfall over Peninsular India during subsequent June to August. Interannual variations of ice cover and circulation over southern hemisphere could largely influence mascrene high which contribute significantly over Indian summer monsoon. Das and Datta (1985) studied temperature variation over SANE (2.2° W, 70.1° S) in Antarctica and compared monsoon index. There was a strong tendency for performance of monsoon to be good following cold over Antarctica reverse case occurred in case of warm episode.

Johri and Prasad (1990) studied relationship between southern hemisphere equatorial trough with southwest monsoon circulation pattern during drought year using satellite data. An inverse relationship exists between the SHET and SM over India. Southern SHET was very active during delayed onset of monsoon during 1987 over central and northeast India, weak rainfall during July and its rapid withdrawal from northeast and central part of India. In every cycle during weak SHET, southwest monsoon was active.

Southwest monsoons of 2009 and 2010 were contrasting in nature. During 2009 drought situation prevailed with cumulative rainfall 78% of long period average. During summer monsoon of 2010 country received normal rainfall with 102% long period average. During post monsoon season all five divisions of south peninsula received excess rainfall almost one and half times the normal during 2010 which was normal during 2009. The correlation coefficient of mean monthly temperature anomaly of Maitri and monthly rainfall departure of country as a whole for the year 2009 and 2010 has been derived. There is strong positive correlation coefficient 0.5591 and a negative correlation -0.2547 during monsoon season for year 2010 and 2009 respectively. During post monsoon season of 2010 and 2009 the correlation coefficient found to be +0.7239 and +0.752 respectively. The strong positive correlation coefficient is confirmative with normal rainfall in country whereas strong negative correlation coefficient is suggestive of drought like situation in the country during 2009. Further temperature anomaly as per long period mean average temperature of Matri shows 2009 warmer than 2010 (Fig. 7). The year 2010 was cooler even than long period average which further confirm strong tendency for performance of monsoon to be good following cold over the area and reverse case of monsoon in case of warm episode. There is a scope of further study on teleconnection between Antarctica and summer monsoon.

6. Conclusions

Discussion of various surface meteorological parameters, weather systems and other global phenomena like SAM, SOI leads to draw the following conclusions.

(*i*) Surface temperature analysis during last two decades over Maitri shows cooling trend. Therefore, the temperature trend does not indicate any global warming. The available solar insolation, cloud coverage, intruding low and high pressure systems over Schirmacher Oasis, all together contribute to seasonal variability.

(*ii*) Lowest seasonal mean temperature is consistent with secondary minima of cirumpolar trough moving northward as a result of Southern Annual Oscillation.

(*iii*) Sea-ice surface extent during winter, polarity of SAM and Southern Oscillation Index are major contributors affecting variability of various meteorological parameters over the station. The positive phase of SOI caused weaker westerly which leads to low level warming during 2009. The extent of sea-ice surface and weak positive correlation between SOI and temperature may be one of the reason for lowest mean seasonal temperature during 2010 as compared to long period average.

(*iv*) The positive correlation coefficient between temperature anomaly at Maitri and rainfall departure of summer monsoon over India is associated with normal rainfall in country whereas negative correlation coefficient could have lead drought like situation in the country during 2009. A negative temperature anomalies during January-March over Maitri preceded drought monsoon 2009 and positive anomalies prevailed during the same period before good monsoon 2010.

Acknowledgement

The authors are thankful to AVM (Dr.) Ajit Tyagi, Director General of Meteorology, for his inspiration and encouragement. The authors are also thankful to Shri Gopi Chand, UDC, Publication Section for neatly typing the manuscript.

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