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# Signature of increasing total column water vapour and surface temperature at Maitri, Antarctica

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**Measurement of total column water vapour has been carried out at Maitri (70°45′S, 11°44′E), Antarctica using Microtop sun-photometer during the 16th, 21st, 22nd and 23rd Indian Antarctic Scientific Expedition. The annual mean water vapour was found out to be 0.24 cm in 1997, while it was 0.42 cm in 2002 and 0.45 cm in 2003. Monthly mean water vapour was maximum during January in all years studied and increased by 48.8% in 2002, 57.7% in 2003 and 66.6% in 2004, compared to 1997. Total column water vapour corresponding to surface temperature has also been studied. Years 2002 and 2003 were found to be warmer by 11.72 and 4.1% respectively compared to the year 1997. The observation showed signature of increasing total column water vapour at Maitri. Measurement also showed increase in surface temperature and was especially pronounced in the month of January at Maitri. In the present communication, a comparative study of water vapour and surface temperature is discussed in detail.**

**Keywords:** Antarctica, regional warming, surface temperature, water vapour.

WATER in its various phases constitutes the critical link between the chemical component of global change and the dynamics, radiation and climate components. In the upper troposphere and lower stratosphere, the radiative[1] and chemical[2] effects of water vapour are large and atmospheric concentration varies considerably with temperature and relative humidity. In global climate models, almost half of the projected increase in temperature due to a doubling of carbon dioxide in the atmosphere results from the effects of increased water vapour[3]. Increase in water vapour in the stratosphere has resulted in considerable cooling, similar to that due to ozone depletion. Recent studies have shown a stratospheric cooling in regions of $H_2O$ increase, of magnitude similar to that due to stratospheric ozone loss indicating a significant additional cause for the observed decrease in stratospheric temperature. However, doubling of water vapour in the stratosphere could lead to a 1°C rise in surface temperature[4]. Total column water vapour (very low amounts in Antarctica), however, plays a significant

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role in ozone depletion[5,6]. A recent study has shown that water vapour concentration determines the effectiveness of the heterogeneous reaction and under stratospheric conditions affects the ozone chemistry and plays a significant role in Antarctic ozone depletion by providing reaction sites as polar stratospheric clouds in the form of $H_2O$ ice[7,8].

A simulation of recent southern hemisphere (SH) climate change[9] suggests that ozone depletion plays a critical role in the SH stratosphere as well as in the SH troposphere, driving climate variability at the surface of the earth[10]. The trend in mean annual temperature from Antarctic stations shows a rapid regional warming on the Antarctic Peninsula[11,12] and probable warming in the sector from the west coast of the Antarctic Peninsula to Novolazarevskaya (065°W-011°E)[13]. The importance of this warming is due to its impact on the local environment, such as increase in atmospheric water vapour. As water vapour is the major absorber of infrared and thermal radiation in the earth atmosphere and is the strongest contributor to greenhouse effect[14], it will further enhance the temperature by its positive feedback. This will lead to local greenhouse warming and can affect the local climate. If the recent past is a guide to the future, regional climate change will have a more profound effect.

Measurements have been done at low and mid-latitudes[15,16], but at polar latitudes and high altitudes, little is known about water vapour content and its seasonal variation. Also, surface measurement database for water vapour is scarce and therefore, regular monitoring is of great importance for in-depth understanding of the hydrological cycle for global-change studies[17]. Thus measurement on total columnar water vapour has been made during the 16th, 21st, 22nd and 23rd Indian Antarctic Scientific Expeditions (IASEs). In this communication the results obtained are discussed in detail.

Observations were made using the solar light total ozone portable spectrophotometer (MICROTOP II) instrument. MICROTOP II is a five-channel, hand microprocessor-controlled sun-photometer. The instrument is equipped with five optical collimators having a full field of view of 2.5°. All the channels are integrated with a narrow-band interference filter and a photodiode appropriate for the particular wavelength range. Each channel faces directly the solar disc once when the image of the sun is centred at the cross-hairs of the sun target. When the radiation falls on the photodiode through the collimators, it gives an electrical current proportional to radiant power cut-off by the photodiode, which is then amplified and converted into digital form in a high resolution A/D converter. Signals are processed in a series of 20 conversions per second. Out of the five channels at 300, 305, 312, 940 and 1020 nm, the first three filter channels are used to derive atmospheric total column ozone[19] and the remaining two for water vapour. The accuracy of the instrument for measurement of total ozone and water vapour is approximately 2%.

This sun-photometer was purchased from the Solar Light Company, USA in September 1996. Measurements of total column water vapour during 1997, 2002–03 and (January–February) 2004 have been carried out using the same MICROTOP instrument. The instrument was received after proper calibration at Solar Light Company and sent to Antarctica during December 1996. It was later taken back to India in 1998 and sent to Solar Light Company for the calibration. The instrument was again calibrated immediately before sending it to Antarctica during 2002 (21st IASE) and operated there January 2002 to February 2004, and taken back to Indian in April 2004.

Measurements of total column water vapour during 1997, 2002, 2003 and (January–February) 2004 have been made using MICROTOP II sun-photometer. It is a sun-dependent instrument. Therefore, measurements could not be made during polar night period (May–July) in 1997, 2002 and 2003. The 21st IASE was launched on 6 January 2002 and the team reached Antarctica on 20 January 2002. Therefore, there were hardly any observations during the first 20 days of 2002. We also had some technical problem in the memory block of the instrument and therefore could not recover the stored data for days 60 to 130 during 2003. Three consecutive observations were taken every hour to get one mean hourly value. Finally, hourly values were averaged to get daily mean value. We have also received the daily mean surface temperature data for the same location from India Meteorology Department for the same period of observation. Scattered plot of daily mean total column water vapour during the study period is depicted in Figure 1.

Day-to-day water vapour was found to be highly variable at Maitri. However, the general trend showed a maximum during polar summer and minimum during polar winter. Minimum water vapour was observed to be less than 0.1 cm during polar winter period in 1997, 2002 and 2003. However, during polar summer period, average water vapour was found to be 0.3 cm in 1997 and about 0.5 cm in 2002–03. Maximum total column water vapour was observed to be 0.51, 0.96, 0.90 and 0.95 cm in January 1997, 2002, 2003 and 2004 respectively. This observation indicates that total column water vapour increased in January 2002–04 compared to January 1997.

Correlation between daily mean water vapour and daily mean surface temperature during 2003 is depicted in Figure 2 *a* and *b*. It has been observed that both daily mean water vapour and daily mean surface temperature follow similar trend. Water vapour was found to be higher at higher surface temperature and vice versa (Figure 2 *a* and *b*). The correlation coefficient between water vapour and surface temperature was found out to be 0.81, which indicates that the water vapour and surface temperature is highly correlated. This correlation reveals that the day-to-day variation of water vapour is highly related to local metrological conditions at Antarctica.

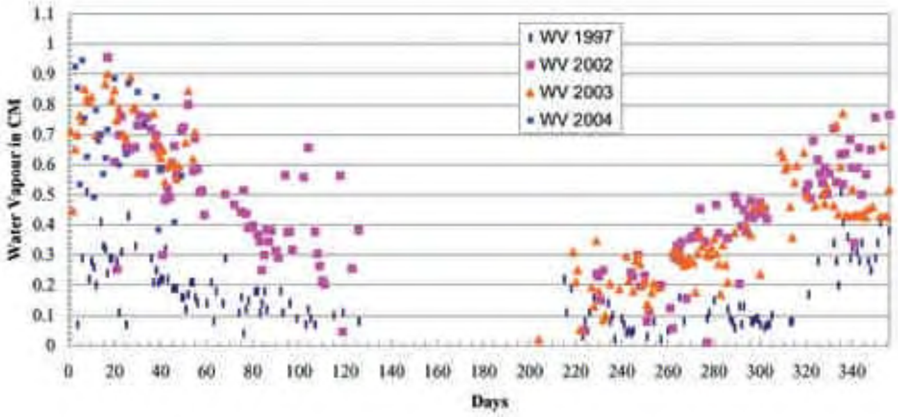


**Figure 1.** Water vapour variation at Maitri, Antarctica during 1997, 2002, 2003 and (January–February) 2004.

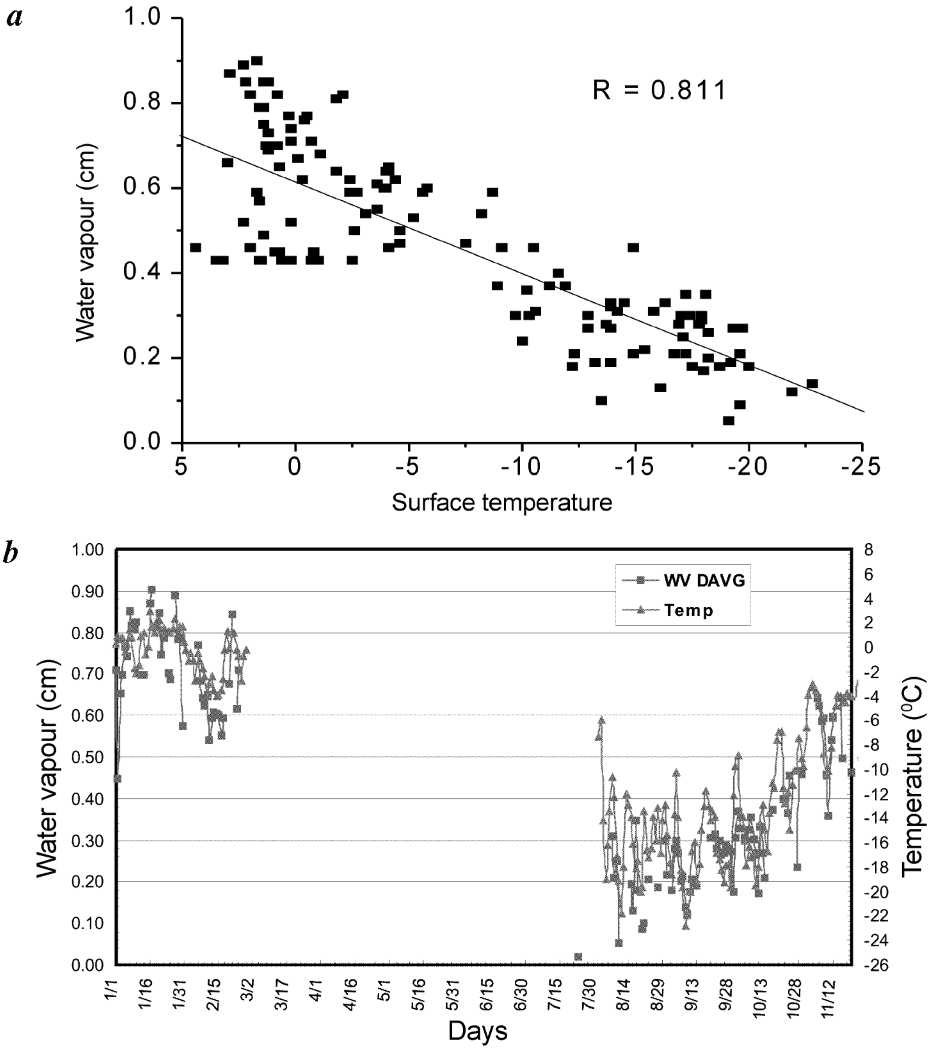


**Figure 2.** ***a***, Correlation between surface temperature and water vapour; ***b***, Comparison of water vapour with surface temperature at Maitri, Antarctica during 2003.

Database of monthly mean water vapour and corresponding monthly mean surface temperature for the observation period of January–December 1997 and January 2002–February 2004 is given in Table 1. Also, variation of monthly mean water vapour and surface temperature for the same period is depicted in Figures 3 and 4. The annual

**Table 1.** Average total column water vapour and surface temperature at Maitri, Antarctica

| | 1997 | | 2002 | | 2003 | | 2004 | |
|---|---|---|---|---|---|---|---|---|
| Month | WV (cm) | TEM | WV (cm) | TEM | WV (cm) | TEM | WV (cm) | TEM |
| Jan. | 0.45 | 0.4 | 0.64 | 0.67 | 0.71 | 0.85 | 0.75 | 1.43 |
| Feb. | 0.29 | –2.6 | 0.58 | –3.18 | 0.63 | –1.50 | 0.58 | –1.22 |
| Mar. | 0.25 | –7.2 | 0.39 | –6.96 | – | –5.64 | | |
| Apr. | 0.13 | –7.9 | 0.27 | –8.31 | – | –9.81 | | |
| May | – | –13.2 | – | –9.30 | – | –13.16 | | |
| Jun. | – | –12.5 | – | –11.80 | – | –14.04 | | |
| Jul. | – | –18.2 | – | –12.60 | – | –17.61 | | |
| Aug. | 0.08 | –16.3 | 0.18 | –16.00 | 0.23 | –15.21 | | |
| Sep. | 0.09 | –17.1 | 0.25 | –15.50 | 0.24 | –16.32 | | |
| Oct. | 0.1 | –13.7 | 0.40 | –8.61 | 0.33 | –12.61 | | |
| Nov. | 0.19 | –4.9 | 0.49 | –6.80 | 0.55 | –4.15 | | |
| Dec. | 0.35 | 0.25 | 0.61 | –1.29 | 0.48 | 1.41 | | |
| AVG | 0.241 | –9.41 | 0.42 | –8.30 | 0.45 | –8.98 | | |

WV, Mean water vapour; TEM, Mean surface temperature.

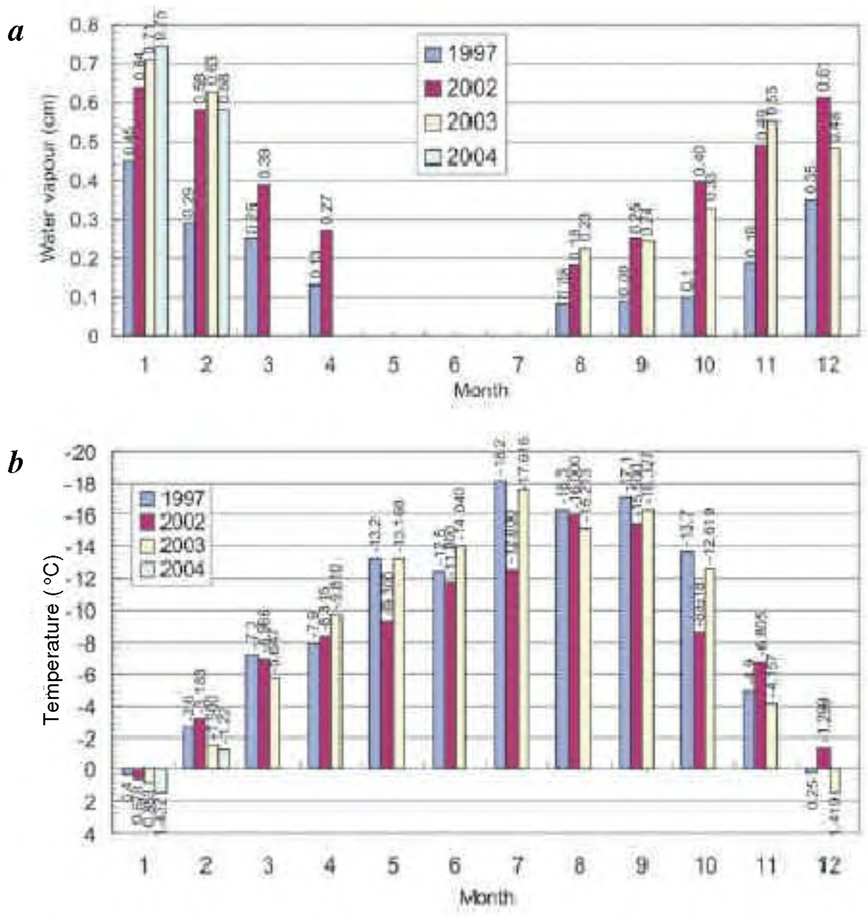


**Figure 3.** Comparison of monthly mean total column water vapour and surface temperature at Maitri, Antarctica during 1997, 2002–03 and 2004.

mean water vapour was found out to be 0.24 cm in 1997, while 0.42 cm in 2002 and 0.45 cm in 2003.

Similarly, surface temperature in 2002 and 2003 was found to be increased by 11.72 and 4.1% respectively, compared to 1997. The observations also showed that the increase in surface temperature and water vapour is quite prominent during January. An increase in monthly mean surface temperature during January has been observed as 0.24°C in 2002, 0.45°C in 2003 and 1.03°C in 2004 compared to January 1997.

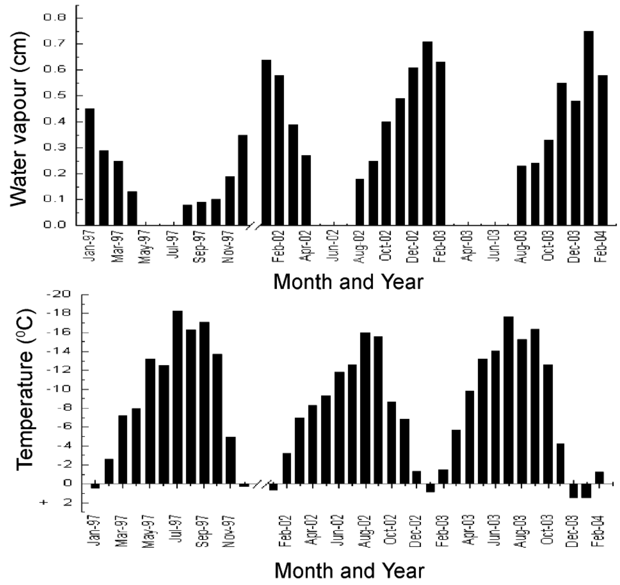


**Figure 4.** Variation of monthly mean water vapour and surface temperature at Maitri, Antarctica during 1997, 2002–03 and (January–February) 2004.

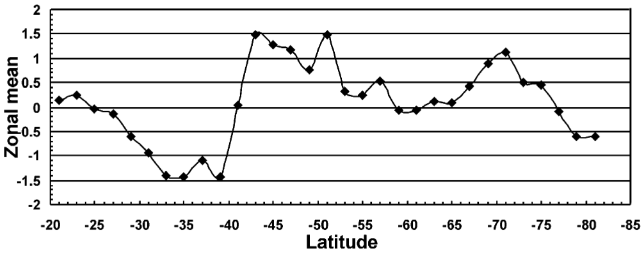


**Figure 5.** Latitudinal zonal mean surface temperature trend for mean period of January 2001–04 relative to base period of 1996–98.

Figure 5 shows the latitudinal zonal mean surface temperature trend for December and January 2001–04 relative to base period of December and January 1996–98. The figure for the region of 20 to 80°S (smoothing radius of 250 km) was drawn using data and tools available at http://www.giss.nasa.gov/gistemp/maps/. It uses the surface temperature records directly available from Goddard Institute for Space Physics (GISS) new analysis[21]. Rapid increase in zonal mean surface temperature has been observed in the region of 40 to 55°S and 65 to 75°S in the mean period of 2001–04 relative to base period of 1996–98. The observed trend in surface temperature during January at Maitri is found to be in good agreement with that of zonal mean temperature as seen in Figure 5. Variation of Antarctic temperature trends calculated for stations where records of 33 years or longer are available, also shows probable warming in the sector from 065°W to 011°E and probably attributed (based on analysis of Vaghuan *et al.*[13]) to any combination of three distinct candidate-mechanisms; changing oceanographic circulation, changing atmospheric circulation or local greenhouse warming amplified by sea-ice processes.

In addition to increasing trend in total column water vapour observed at Maitri, monthly mean water vapour was also found higher during ozone hole period in 2002 than in 2003, as seen in Figure 3. This may be attributed to planetary waves of extremely large amplitude observed in 2002. These waves transported warm air mass in the troposphere as well as in the stratosphere, leading to a major, sudden stratospheric warming (SSW). Varotsos and Kondratyev performed Fourier analysis of 10 and 100 hPa temperature fields and confirmed that sudden warming occurred in the stratosphere in September and also extended into the upper troposphere that vanished ozone hole earlier than usual[22,23]. Thompson *et al.*[24] argued that the major SSW of 2002 provoked large amplitude variation in the strength of SH polar vortex and induced anomalies in the tropospheric circulation, which can be followed by coherent changes in Antarctic surface temperature. Manney *et al.*[25] found that anomalous strong tropospheric transport of air from the subtropic to the polar region could be a direct cause of SSW. This evolution was found to coincide with observed surface warming and corresponding relatively higher water vapour concentration in 2002 than in 2003 at Maitri, Antarctica.

Finally, higher water vapour concentration during polar summer compared to winter period may be attributed to higher surface temperature during summer period. Also, it may probably be attributed to advection of warm, moist air from the subtropics because of reduced strength of the polar vortex during the polar summer. The low temperatures during winter over Antarctica led to the formation of a region with high-velocity circumpolar winds in winter and spring season, generally called as polar vortex. This vortex is stretched from the ground to the stratosphere and limits the exchange of air between its interior and its exterior, subsequently leading to extremely low temperatures. The very low water vapour concentration observed during polar winter may be attributed to very low temperature during polar winter, which reduces the water-holding capacity of air and makes it dry.

The aforementioned analysis reveals the signature of steady increase in total column water vapour at the Indian research base Maitri, Antarctica. The correlation between surface temperature and water vapour also reveals that most of the variation in water vapour concentration is attributed to variation in surface temperature. Besides increasing trend in total column water vapour observed at Maitri, the higher monthly mean water vapour observed during ozone hole period in 2002 than in 2003 reveals anomalous, strong tropospheric transport of air from the subtropics to the polar region followed by coherent changes in surface temperature and water vapour.

Measurements also showed increase in surface temperature, especially prominent during January at Maitri. It has also been observed that positive correlation exists between surface temperature and water vapour concentration, and day-to-day variation of water vapour is highly related to local metrological conditions. At higher surface temperature, water vapour concentration is higher. Although few records are available at Maitri, the trend observed is an important indicator of climate change. These changes in a small region in Antarctica demonstrate that the future of regional climate change may probably be one dominated by regional stimulation and feedback processes. The same may be true for more populated and polluted areas of the globe.


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# Variations in hosting beneficial plant-associated microorganisms by root (wilt)-diseased and field-tolerant coconut palms of West Coast Tall variety

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**Coconut palms (*Cocos nucifera*) in Kerala, India are affected by root (wilt), a debilitative disease caused by phytoplasma, resulting in substantial yield loss. One of the strategies to combat this problem involves breeding for root (wilt)-resistant/tolerant palms by exploiting the genetics of disease escapees identified in the heavily diseased tracts. A preliminary study on the rhizosphere microflora of these disease escapees and diseased coconut palms revealed that the bacterial population ranged from 6.2 to 12.4 × $10^5$ cfu/g dry soil in rhizosphere**

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