Fourteenth Indian Expedition to Antarctica, Scientific Report, 1998
Department of Ocean Development, Technical Publication No. 12, pp. 99-107

Atmospheric Water Vapour Measurement at Maitri, Antarctica

B.C. ARYA and S.L. JAIN

National Physical Laboratory,
Dr. K.S. Krishnan Road New Delhi-110 012, India

Abstract

Atmospheric water vapour content has been measured during 14th Indian Antarctic Expedition at Maitri (70° 46'S, ll°45'E), Antarctica. The measurements were carried out on clear sunny days during Jan.-Feb. 1995. The average precipitate water vapour at zenith was in the range 1.7- 2.4 mm.

Introduction

The measurement of atmospheric water vapour plays an important role in understanding meteorology, climatology, infrared astronomy and cloud physics. The amount of atmospheric water vapour varies considerably with the temperature and relative humidity unlike other gases of the atmosphere. Water vapour is the primary absorber of thermal and near infrared radiation in the earth atmosphere and has considerable effect on radiation field, radiative albedo and the energy balance of the earth/atmospheric system.

The integrated water vapour content in the vertical column of the atmosphere can be obtained from ground with sun photometer (Volz, 1974) or microwave radiometer (Hogg *et al,* 1983). For estimation of water vapour using sun photometer the solar radiation is measured at two wave length regions; one at the centre of an absorption band and other within atmospheric window just outside the absorption band which is assumed as reference. The method has already been successfully used by Tomasi and Guzzi, 1974; Greve, 1978; Kondratyev *et al*, 1965; Robson *et al.,* 1979; Martin *et al.*, 1981; Buscher and Lemke, 1980; Symthe and Jackson, 1977. Bo-Cai Gao and Goetz, 1990 have derived high spatial resolution column atmospheric water vapour contents from spectra obtained from air borne visible-infrared imaging spectrometer.

In the present paper we report measurements of water vapour during 14th Indian Scientific Expedition in 1994-95 at Maitri (70°46'S 11°45'E) an Indian

Antarctic station. The total water vapour content was measured with sun photometer using infrared grating monochromator designed and developed. at National Physical Laboratory, New Delhi.

Experimental Set-up

The block diagram of I.R. grating spectrometer designed, developed at N.P.L., New Delhi is depicted in Fig. 1. A Polar Heliostat stationed outside the Laser Heterodyne hut at Maitri, Antarctica is used to get solar image in a fixed direction in the laboratory. The incoming chopped solar radiation is focussed by ZnSe lenses of focal lengths of 10" and 2.5" on the entrance slit of the monochromator. The signal is detected with the help of pyroelectric detector. The signal output from detector is fed to the lock-in-amplifier for synchronous detection and is directly recorded on a strip chart recorder and also stored on floppy diskette. The details of monochromator and pyroelectric detector are given below:

Specifications of high resolution grating monochromator

The monochromator used is a Czerny-Turner scanning type with focal length 240 mm having two gratings covering wavelength region from 800-3100 nm and 3500-12500 nm respectively. The resolution of monochromator is better than 0.1 nm with 600g/mm and 20 micron slit. The monochromator is controlled by an onboard microprocessor, and the connection between the control module and the monochromator body is through RS-232C serial port. Alternately it can also be controlled by PC through RS-232C serial port. The wavelength selection, slit width, scan speed etc. are controlled by microprocessor.

Characteristics of pyroelectric detector

1.	Wavelength range	0.001 to 1000 µm
2.	Maximum input average power	0.05 watt
3.	Current responsibility	0.5µA/watt
4.	NEP(632.8 nm, 15 Hz, 1Hz, BW)	15 $x10^{-9}$ $W/Hz^{1/2}$
5.	Active diameter	2 mm

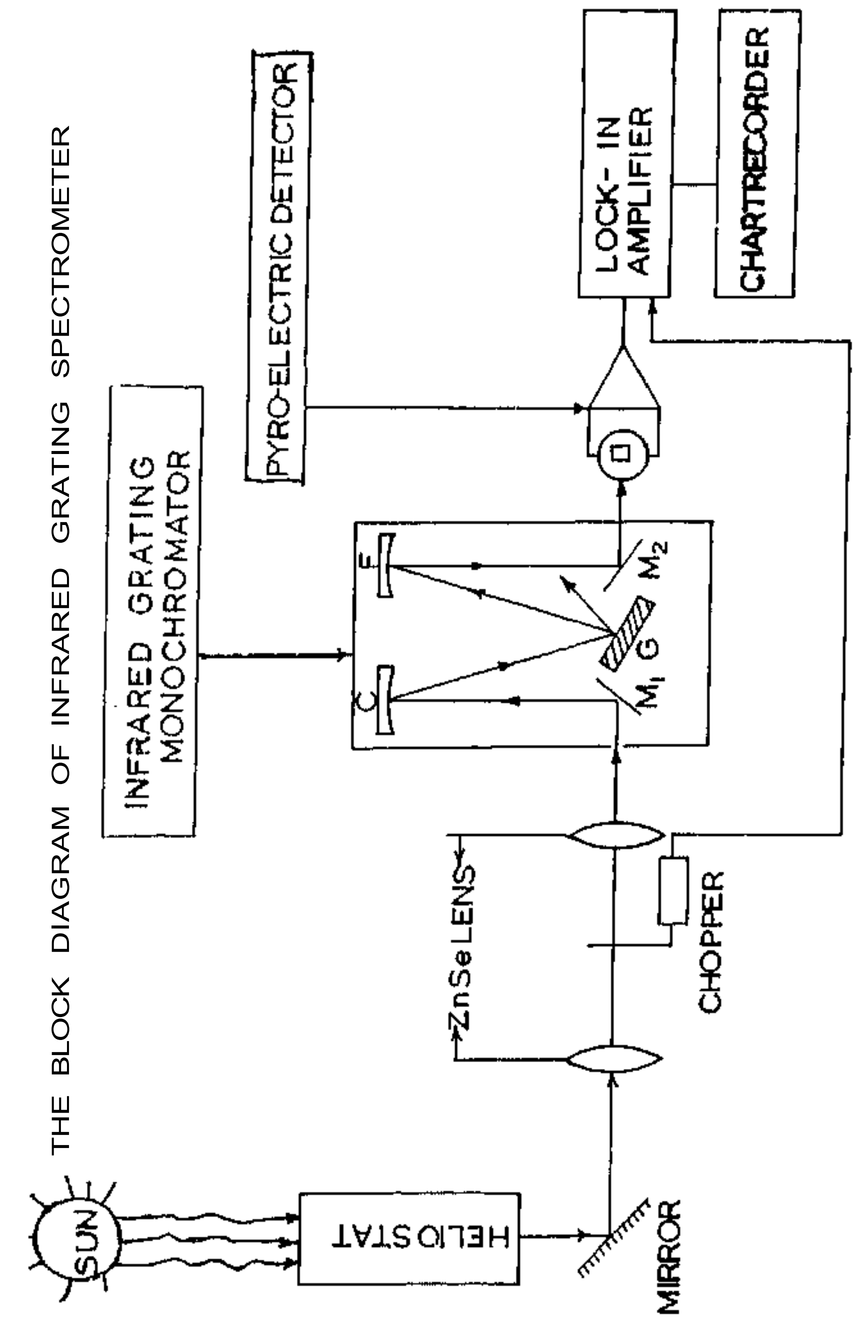

Fig. 1: Block diagram of the experiment

Discussion and Results

The solar radiation absorption spectra were monitored using IR. grating spectrometer from 0.75 am to 1.6 μm spectra range at various zenith angles of the sun. The bandwidth of the monochromator during the present work was set at 1.5 nm. Extra care was taken so that solar image was accurately focussed and aligned on the entrance slit of the monochromator. The measurements were carried out on clear sunny days of Jan 20, '95, Jan 21, '95, Jan 23, '95 and Feb 4, '95. The visibility was very good at Maitri during the time of observation. The typical solar absorption spectra taken at Maitri, Antarctica is shown in Fig. 2. The signature of absorption of water vapour bands centred at 0.94 μm, 1.14 μm and 1.38 μm are clearly seen.

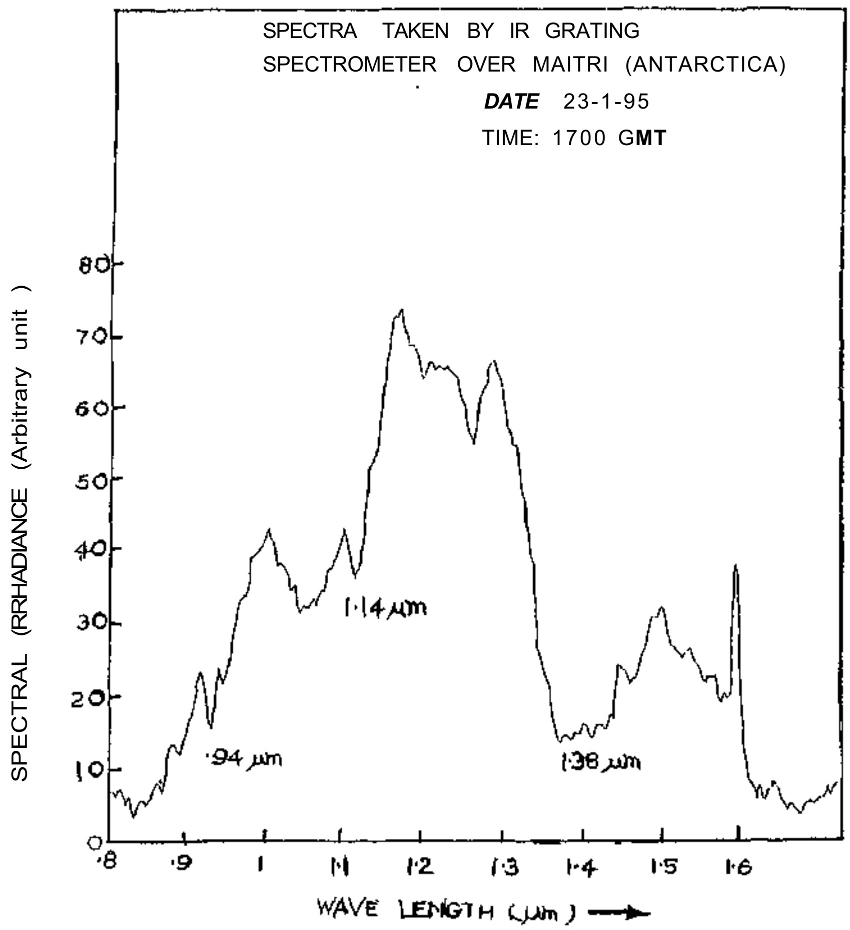

Fig. 2: Typical solar absorption spectra taken at Maitri

In order to derive total vapour content in the atmosphere with high precision from absorption band, the transmittance of the band must be sensitive to the change in water vapour molecules in the line of sight. In the present work 1.14 µm absorption band has been used for the deduction of total water vapour content of the atmosphere. The 1.38 µrn band is stronger than 1.14 µm and 0.94 µm bands. The integrated absorption at 1.38 µm band tends to saturate for low values of water vapour amount (Emery *et al,* 1979). The 1.14 µm and 0.94 urn absorption bands more or less retain their shape even under the conditions of long optical path. In the view of above discussion, the observations at 0.94 µm and 1.14 µm bands are most useful to measure water vapour content in the long optical path of the atmosphere.

The total water vapour content in the zenith was calculated by comparing the irradiance readings at 1.14 µm i.e. the centre of the absorption band and 1.23 µm window region lying between 1.14 µm band and O_2 band centred at 1.264 µm. The aerosol extinction is usually a slowly varying function of wavelength in the visible and near infrared. Due to close proximity of two selected spectral channels, one at water vapour absorption region and other nearby region in which water vapour absorption is absent, the Rayleigh and aerosol optical depths are approximately the same. The ratioing of spectral irradiance at two wavelengths effectively eliminates the aerosol and Rayleigh scattering leaving only the water vapour absorption effect. The total water vapour content (w in mm) was computed using following expression given by Guzzi *et al.*, 1972.

$$w(mm) = \frac{p}{mp_o k^2}\left(\ln \frac{D_o(\lambda_1)\, D(\lambda_2)}{D(\lambda_1)\, D_o(\lambda_2)}\right)^2 \qquad \text{...(1)}$$

where

p is pressure in mb

p_0 is pressure at sea level

k is absorption coefficient of water vapour in $mm^{-1/2}$

$D(\lambda_1)$ is signal strength at the centre of absorption band at wavelength λ_1

$D_o(\lambda_1)$ is the extrapolated signal strength for zero air mass at wavelength λ_1

$D(\lambda_2)$ is signal strength at wavelength λ_2 (window region)

$D_o(\lambda_2)$ is the extrapolated signal strength for zero air mass at wavelength λ_2

The air mass 'm' is defined as the ratio of the slant path length for solar ray through the atmosphere to the path length if the sun was at zenith. When the sun is overhead (the solar zenith angle is zero) the air mass is 1.00. The relative air mass at a given location changes with both time of day and year. For zenith angle $X<60°$ the relative air mass is accurately represented by sec X. Due to the refraction of the atmosphere and earth's curvature, the calculation of air mass by sec X gives an error in computing air mass values at zenith angle greater than 60°. Therefore Kasten expression (Iqbal, 1983) was used for calculation at air mass at Maitri, Antarctica for the days of observation. Kasten expression is quite accurate and gives results within 1% accuracy up to the zenith angle less than 89° and also accounts for earth's curvature and atmospheric refraction of light. The values of relative air mass computed by Kasten's formula as per equation (2) is given in Table 1.

Table 1: Relative Air Mass Over Maitri, Antarctica

Time	20th Jan'95	21st Jan'95	23rd Jan'95	4th Feb '95
11.00	1.5732	1.5840	1.5958	1.7176
12.00	1.5884	1.5924	1.6116	1.7366
13.00	1.6583	1.6666	1.6843	1.822
14.00	1.7932	1.8033	1.8241	1.9917
15.00	2.0129	2.0262	2.0536	2.2741
16.00	2.3582	2.3758	2.4150	2.7549
17.00	2.8953	2.9252	2.9844	3.4789
18.00	3.7644	3.8161	3.9197	4.8959
19.00	5.2158	5.3478	5.5630	7.7773
20.00	7.8610	8.1593	8.6600	15.1611

$$m = [\cos X + 0.15(93.885 - X)^{-1.253}]^{-1} \qquad ...(2)$$

where X is zenith angle.

The zenith angie on observational days were computed using the following expression:

$$\cos X = \sin \Phi \sin \delta + \cos \Phi \cos \delta \cos \Omega$$

where δ is angle of declination of the Sun

Ω is hour angle and

Φ is the latitude of the place of observation.

The values of declination and hour angle are taken from Star Almanac for land surveyor 1995.

Table 2

Day	Average water vapour value at zenith (mm)	Average value of pressure (mb)	Average value of temperature (°C)
Jan 20, 95	2.4	985.3	+1.4
Jan 21, 95	1.72	983.8	+0.3
Jan 23, 95	2.00	984.8	+1.1
Feb 4, 95	2.1	982.3	+0.7

The measurements for water vapour were carried out on clear days using IR grating spetrometer at Maitri, Antarctica and estimated water vapour is shown in Table 2. The diurnal variation of water vapour is also depicted in Fig.3.

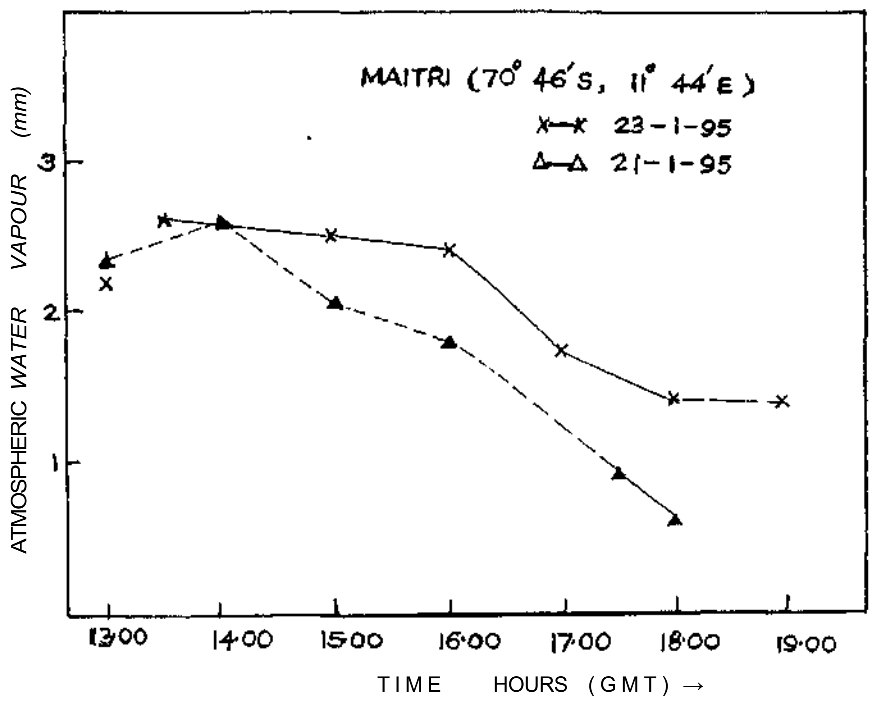

Fig. 3: Diurnal variation of water vapour

Conclusion

The average precipitable water vapour at the zenith was found to be in the range 1.7 mm to 2.4 mm at Maitri, Antarctica during the period of observation. The measurements are in good agreement with those carried out at Terra Nova Bay (74° **41.61'** S, 164° 6.89'E) Antarctica(Dall'Oglio *et al,* 1988) during Jan 4-12,1987 by Italian Antarctica summer expedition. The precipitable water vapour measured by them was in the range 1.7 mm to 3.5 mm at zenith. The low water vapour values observed over Antarctica compared to those at low latitude locations suggest that the Antarctica is a very good site for Astronomical observations in Infrared region.

Acknowledgement

The authors are grateful to Prof. E.S.R. Gopal, Director, NPL, Dr. B.M. Reddy andDr. K.K. Mahajanfor their keen interest and encouragement during the progress of the work. They also express their thanks to Department of Ocean Development, Govt. of India, New Delhi for financial and logistic support.

References

Bo-cai Gao and Alexander F.H. Goetz, 1990. Column Atmospheric Water Vapour and Vegetation liquid Water Retrievals from Airborne Imaging Spectrometer Data, *J. Geophy. Res.* (USA) 95,3549-3564.

Buscher E. and D. Lemke, 1980. An Infrared Hygrometer for Astronomical Site Testing, *Infrared Phys.* (UK) 20,321-325.

Dall'Oglio, G., P.DE Bernardis, S. Masi, B. Melchiorri, A. Moleti, W. Pecorella and L. Pizzo, 1988. Atmospheric Transmission and Noise Measurements in Antarctica, *Infra-red Physics,* 28,155-161.

Emery,R.J., P.H.Moffat, L.D.J.Harris and H.A. Gebbie, 1979. *J. Quant. Spectrosc.Radiat. Transfer* (UK) 22,401.

Greve A., 1978. The Water vapour content in the western European atmosphere obtained from infrared measurements, *Infrared Physics* (UK) 18,127-132.

Guzzi, R., C. Tomasi and 0. Vittori, 1972. Evidence of Particulate Extinction in the Near Infrared Spectram of the Sun,*Journal of the Atmosheric Sciences* (USA),29,517-525.

Hogg, D.C., F.O. Guiraud, J.B. Snider, M.T. Decker and E.R. Westwater, 1983. A steerable dual-channel microwave radiometer for measurement of water vapour and liquid in the troposphere, J. *Appl. Meteorol,* 22, 789-806.

Iqbal, M,, 1983. An Introduction of Solar Radiation, Academic, San Deigo, Calif 100

Kondratyev, K.Y. S.D. Andreev, I.Y. Badinov, V.S. Grishechkin and L.V. Popova 1965. Atmospheric Optics Investigations on Mt. Elbrus, *Appl. opt.* (USA) 4,1069-1076.

Martin J., J. Gomez-Gonzalez and A. Barcia, 1981. Simultaneous infrared spectral hygrometer and radio sonde measuremrements of the Precipitable water vapour content in the atmosphere, *Infrared Physics,* (UK) 21, 117-122.

Robson, E.I. and M. Rowan-Robinson, 1979. Measurements of atmospheric attenuation by water vapour, *Infrared Physics* (UK) 19, 115-120.

Symthe, W.D. and Jockson B.V., 1977. Atmospheric water vapour at south pole, *Appl Opt.* (USA) 16, 2041-2042.

Tomasi, C. and Guzzi R., 1974. High precision atmospheric hygrometry using the solar infrared spectrum, *J. Phys. E. Scient. lustrum* (USA) 7, 647-649.

Volz, F.E., 1974. Economical multi spectral sun photometer for measurements of aerosol extinction from 0.44 μm to 1.6 μm and precipitable water, *Appl. Opt.* (USA) 13, 1732-1733.