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SOME RESULTS OF GROUND BASED AEROSOL OPTICAL DEPTH MEASUREMENTS IN ANTARCTICA IN SUMMER 1984–1985

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Abstract: Experimental results of aerosol optical thickness in East-Antarctica are presented. The observations were carried out by a GDR-team at three Soviet Antarctic stations during the polar summer of 1984–85. The nearly uniform optical thickness of $\tau_A \simeq 0.037$ was observed at the coastal stations (Mirny, Molodezhnaya) as well as at the continental station Vostok.

1. Introduction

The aim of this experiment was to collect the data of optical depth of the natural background aerosol at the "cleanest" area on the Earth, in Antarctica, which has been uninfluenced by the mankind. Because of the effect of aerosols on radiation and also on climate changes it is important to obtain typical aerosol data, their variability in time and spatial distribution over the earth.

Optical aerosol observations at different geographical locations can give a better understanding on global exchange processes between the troposphere and the stratosphere as well as on the influence of large-scale dynamical processes to the vertical and horizontal aerosol distributions.

Aerosol measurements by satellites (KENT *et al.*, 1985; MCCORMICK *et al.*, 1981) can give global information on stratospheric aerosol. Ground based optical observations also can be applied to above mentioned investigations. The man-made particle production is increasing all over the world, but only the Antarctic region has kept nearly natural background conditions up to now.

2. Locations and Periods of Observation

The ground based measurements were carried out using the spectrophotometer-system BAS-M (SCHULZ and LEITERER, 1987) at the coastal stations Molodezhnaya and Mirny as well as at the inland station Vostok.

The coordinates and the observation periods are shown in Table 1. The distance to the open water was about 50–70 km from Molodezhnaya, only about 1–10 km from Mirny and about 1400 km from Vostok. Because of the dominant wind from the inland, Antarctic continental weather conditions prevail in the boundary layer even at the coastal stations.

Table 1. Stations coordinates and observation periods.

Station	Period	Coordinates
Molodezhnaya	22. 11'84–04. 01'85	67°40'S 45°50'E
Vostok (3500 m above sea level)	23. 01'85–03. 02'85	78°27'S 106°51'E
Mirny	06. 02'85–08. 04'85	66°33'S 93°01'E

3. Method of Data Sampling and Processing

Using the spectrophotometer-system BAS-M (SCHULZ and LEITERER, 1987; LEITERER *et al.*, 1982; LEITERER and MARKGRAF, 1983; LEITERER and WELLER, 1983, 1984) the total atmospheric optical depth $\tau_{T\lambda}$ was derived from multiwavelength (42 channels for $378<\lambda<1150$ nm) transmission measurements of the direct solar-radiation, and deduced from the following equation:

$$-\tau_{T\lambda}=\sin h_{\odot} \ln \frac{U_{\odot\lambda}}{U_{E\lambda}\cdot\theta(h_{\odot})}, \tag{1}$$

where $h_{\odot}=h_{\odot m}+\Delta h_{\odot}$, and notations used in eq. (1) are as follows:

$h_{\odot m}$: solar elevation angle measured by sextant,

$\Delta h_{\odot}$: correction for the real optical air mass using the data of KASTEN (1965),

$\tau_{T\lambda}$: total optical depth for air mass $m=1$,

$U_{\odot\lambda}$: measured signal, in Volt,

$U_{E\lambda}$: extraterrestrial signal, in Volt; derived by the method with the Langley plot, *e.g.* SHAW *et al.* (1973),

$\theta_{\lambda}(h_{\odot})$: an experimentally derived correction function (obtained under constant conditions with $|\Delta\tau_{T\lambda}|\leqslant 0.001$) including all effects of the solar spectrum, filters, absorbers etc.

For simplification of presentation we omit the wavelength-index λ hereafter. In order to derive the aerosol optical depth τ_A the following relation can be used:

$$\tau_A=(\tau_T-\tau_R)-\tau_{O_3}-\tau_{O_2}-\tau_{H_2O}-\tau_C, \tag{2}$$

where

τ_R: optical depth for clean air,

τ_{O_3}: optical depth for ozone,

τ_{O_2}: optical depth for oxygen,

τ_{H_2O}: optical depth for water-vapour,

τ_C: optical depth for thin clouds.

And

$$\tau_R=0.00879\frac{p}{p_0}\lambda^{-\alpha}$$

where λ is wavelength in μm,

$\alpha=4.09$ for $\lambda>0.5$ μm,

$\alpha=(4.09-2472\exp(-25.67\lambda))$ for

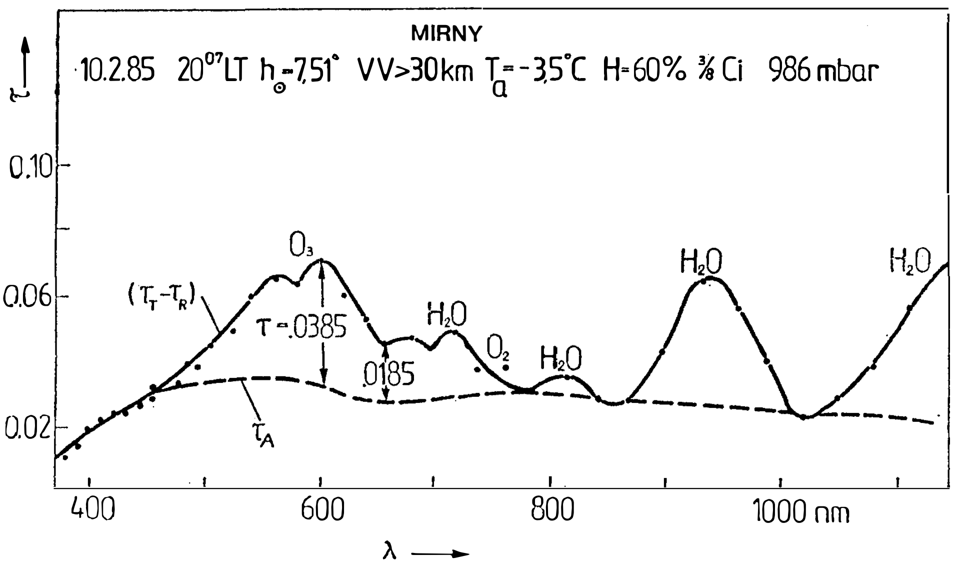

Fig. 1. Diagram showing the graphical smoothing of the ($\tau_T-\tau_R$)-curve to eliminate the optical thickness of water vapour, ozone and oxygen. VV: visibility, T_a: air temperature, H: relative humidity, Ci: Cirrus clouds.

$\lambda \leqslant 0.5\ \mu m$ (LEITERER and SCHULZ, 1986),

and p, p_0 are pressure in mbar, p measured at the altitude of the spectrophotometer, $p_0=1013$ mbar (normal pressure).

τ_{H_2O} and τ_{O_2} are eliminated by graphical smoothing of the ($\tau_T-\tau_R$)-curve as in Fig. 1.

τ_{O_3} was taken into account both by using the absorption coefficients of ozone from DUETSCH (in LINKE, 1970) and by graphical smoothing method, which was developed by the authors (LEITERER and SCHULZ, 1987).

In this way one also get data for the total ozone amount. The value $\tau_{O_3}=0.0385$ corresponds to 325 matmcm O_3 (milli-atm-cm of total ozone).

The accuracy of O_3-estimation by the BAS-M is about $\pm 5\%$. A direct comparison with the Soviet standard total ozone observation device M-83 (GUSHCHIN, 1981) for 13 days in Mirny in February 1985 has shown a mean systematic difference of $+3.5\%$ between the BAS-M and the M-83.

4. Results and Discussion

Figure 2 gives a comparison between aerosol optical depths as a function of the wavelength at the three geographical locations. The differences in aerosol optical depth are small between the two coastal stations (Mirny, Molodezhnaya) and the inland station (Vostok) which is located at a height of 3500 m above sea level. The deviations of optical depth of all measurements (three stations) from the mean value are no more than $\tau_A=0.006$. Therefore one can assume that the tropospheric and stratospheric background aerosol above the central Antarctica (Vostok) and the eastern coastal regions (Mirny, Molodezhnaya) is nearly uniform within a limit of $\Delta\tau_A=\pm 0.006$.

The height difference of 3500 m between coastal and inland measurements does

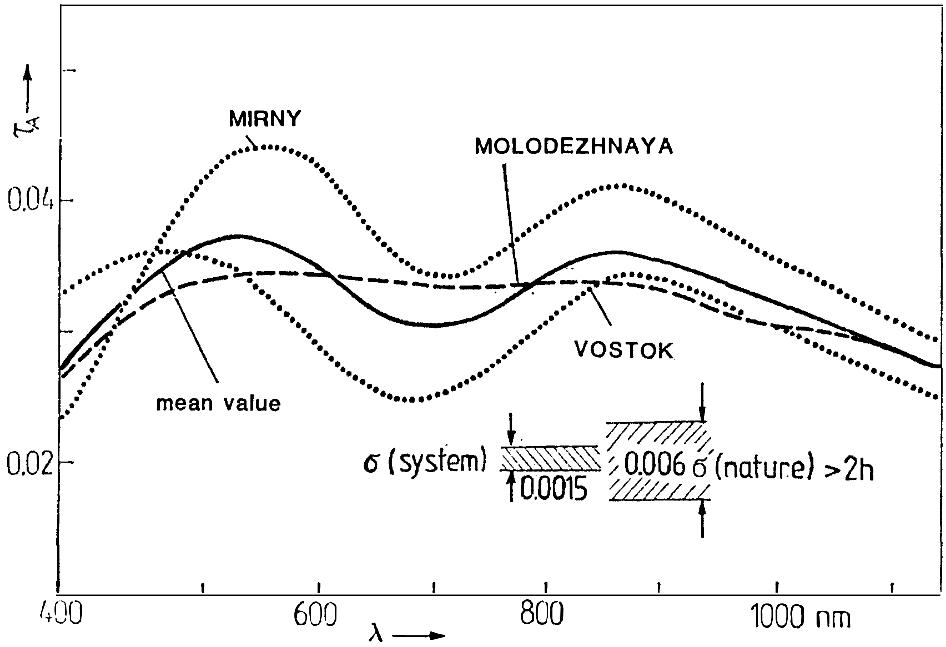

Fig. 2. Mean values of the aerosol optical thickness τ_A at 3 Antarctic stations, Molodezhnaya, Vostok, Mirny in the summer of 1984/85.

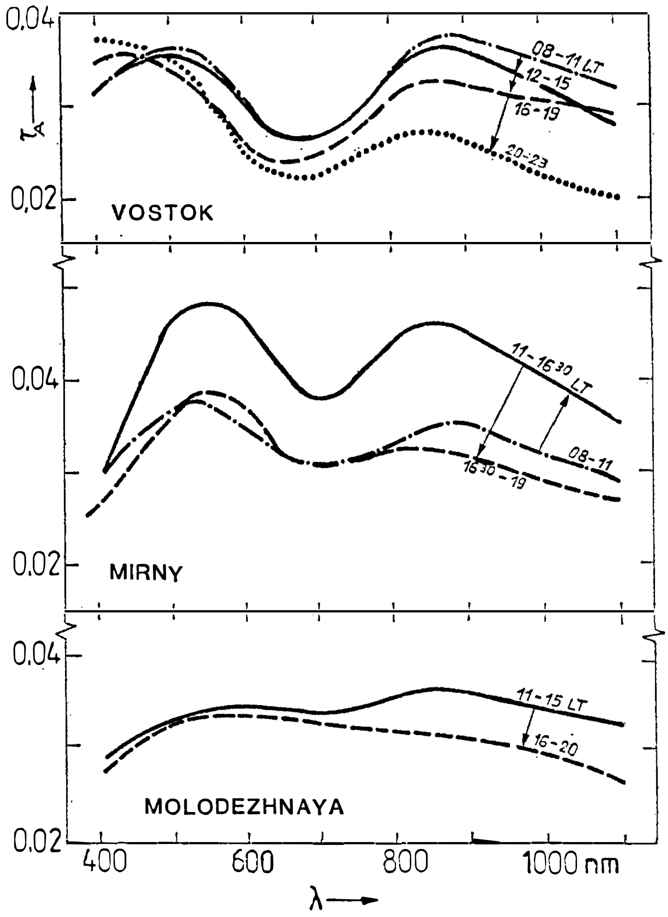

Fig. 3. Mean variation of τ_A at different time of day at the same stations as shown in Fig. 2.

not essentially influence the measured τ_A-values. Similar results were published by YAMANOUCHI (1982). This could be some evidence for small contributions of the lowest troposphere to the total optical depth of aerosol. Our aerosol observations were performed during summer conditions in regard to the tropospheric and stratospheric circulation patterns.

The curves in Figs. 2 and 3 were obtained on the basis of 130 spectral series. The τ_A-value of each series was the mean value of 5 to 7 spectral curves measured during about 30 s. Statistical evaluation showed that the magnitude of standard deviation was about $\sigma(\tau_A)=0.006$ for each of the curves, presented in Fig. 3. The mean deviation (at the same time of day) from day to day was in the magnitude of $\sigma(\tau_A)=0.006$. In Fig. 3 one can also see the decreasing of τ_A at wavelengths $\lambda>800$ nm from midday to evening. That means we have typical daily variations of τ_A at longer wavelengths and differences between the three stations. After a minimum in the night the solar radiation in the morning causes the particles to grow and the aerosol optical depth to increase. We also observe in the cold Vostok region (temperatures below $-30°$C) how the particles grow with the increase of the water vapour content in the air. The increasing solar radiation from night to morning is coupled with an increasing of the evaporation from the snow surface.

References

GUSHCHIN, G. P. (1981): Metodicheskaya ukazaniya po proizvodstvu i o obrabotke nablyudenii za obshchim soderzhaniem atmosfernogo ozona. Glavnaya Geofizicheskaya Observatoria, im. A. I. VOEJKOVA. Leningrad, Gidrometeoizdat.

KASTEN, F. (1965): A new table and approximation formula for the relative optical air mass. Arch. Meteorol., Geophys. Bioklimatol., Ser. B, **14** (2).

KENT, G. S., TREPTE, C. R., FARRUKH, U. O. and MCCORMICK, M. P. (1985): Variation in the stratospheric aerosol associated with the north cyclonic polar vortex as measured by the SAM II satellite sensor. J. Atmos. Sci., **42**, 1536–1551.

LEITERER, U. and MARKGRAF, H. (1983): Zur Strahldichtekalibrierung des Spektralfotometers BAS. Feingerätetechnik, **32** (4).

LEITERER, U. and WELLER, M. (1983): Probleme und Lösungswege bei der Kalibrierung von Strahlungsmeßgeräten für Meßaufgaben der Fernerkundung der Erde. Z. Meteorol., **33** (3).

LEITERER, U. and WELLER, M. (1984): Weißscheibe AOL-BAS- ein Arbeitsetalon für Reflexionsgrade und Strahldichten. Feingerätetechnik, **33** (4).

LEITERER, U. and SCHULZ, K.-H. (1986): Zur Abweichung des realen von dem nach der Rayleigh'schen Theorie berechneten Luftstreukoeffizienten. Gerlands Beitr. Geophys., **93**, 262–266.

LEITERER, U. and SCHULZ, K.-H. (1987): Experimental data on aerosol optical thickness in Antarctica in Summer 1984/85. (in press).

LEITERER, U., WELLER, M. HÄNDEL, H. and BISCHOFF, K.-H. (1982): Spektralfotometer BAS zur Fernerkundung der Erde. Feingerätetechnik, **31** (7).

LINKE, (1970): Meteorologisches Taschenbuch II. Band, Leipzig, S. 555, Tab. 555.

MCCORMICK, M. P., CHU, W. P., GRAMS, G. W., HAMILL, P., HERMAN, B. M., MCMASTER, L. R., PEPIN, T. J., RUSSELL, P. B., STEELE, H. M. and SWISSLER, T. J. (1981): High latitude stratospheric aerosols measured by the SAM II satellite system in 1978 and 1979. Science, **214**, 328–331.

SCHULZ, K.-H. and LEITERER, U. (1987): Spektralfotometer BAS-M mit Mikrorechner und dessen Erprobung unter arktischen und tropischen Bedingungen, Feingerätetechnik, **36** (3).

SHAW, G. E., REAGAN, J. A. and HEIMAN, B. M. (1973): Investigations of atmospheric extinction using direct solar radiation measurements made with a multiple wavelength radiometer. J. Appl. Meteorol., **12**, 374–380.

YAMANOUCHI, T. (1982): Derivation of atmospheric turbidity at Mizuho Station, Antarctica from the broadband solar radiation measurements. Mem. Natl Inst. Polar Res., Spec. Issue, **24**, 1–12.

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