Polarforschung 58 (1): 41—46, 1988

Measurements of the Atmospheric Turbidity at D47, Adelie Land, Antarctica

A contribution to I. A. G. O.*

By Gerd Wendler and Nobuyoshi Ishikawa**

Summary: As part of a larger experiment, atmospheric turbidity measurements were carried out during the austral summer 1985/86 in Adelie Land, Eastern Antarctica at 1560 m elevation. A comparison of our measurements of the solar beam with those of other areas in the Arctic and Antarctic was carried out. Our values were higher than all measurements from the Arctic. For Antarctica, Plateau and Mizuho Stations, both higher in altitude, had somewhat higher values, while the value of the coastal stations were lower. We calculated also turbidity indexes such as Linke's turbidity factor T and Ångström's turbidity coefficient β. Mean values of T were around 2.0, which are low values indeed. Beta values were around 0.04, a rather typical value for polar regions. No trend in turbidity could be observed for the time of observation. Further, it could be shown that the decrease in intensity with increasing optical air mass was less pronounced for larger wavelengths than for shorter ones.

Zusammenfassung: Im Rahmen eines größeren Untersuchungsprogrammes wurden während des Südsommers 1985/86 in Adelie-Land, Ost-Antarktis, bei 1560 m NN atmosphärische Trübungsmessungen durchgeführt. Im Vergleich mit anderen Polarregionen lagen die hier erhaltenen Solarstrahlungswerte über allen Messungen aus der Arktis; in Antarktika wiesen die höher gelegene Plateau- sowie die Mizuho-Station etwas größere Beträge auf, während die Küstenstationen darunter blieben. Ferner wurden Trübungs-Indizes wie Linkes Trübungsfaktor T und Ångströms Trübungskoeffizient β berechnet. Die T-Werte lagen im Mittel um 2.0 und damit vergleichsweise niedrig, während β bei 0.04 einen für Polargebiete recht typischen Wert aufwies. Im Verlauf der Beobachtungszeit ergab sich bei der Trübung kein Trend; wohl aber konnte gezeigt werden, daß die Intensitäts-Abnahme mit wachsender optischer Luftmasse für größere Wellenlängen weniger ausgeprägt verlief als für kleinere.

INTRODUCTION

During the austral summer 1985/86, a large meteorological U.S.-French joint experiment was carried out in Adelie Land. The goal of the experiment was to obtain a better understanding of the boundary layer processes, especially as they relate to the katabatic wind, which is well developed in this area (MAWSON 1915). As part of this experiment the U.S. occupied one site (D47, 67° 23' S, 138° 43' E) at 1560 m altitu-

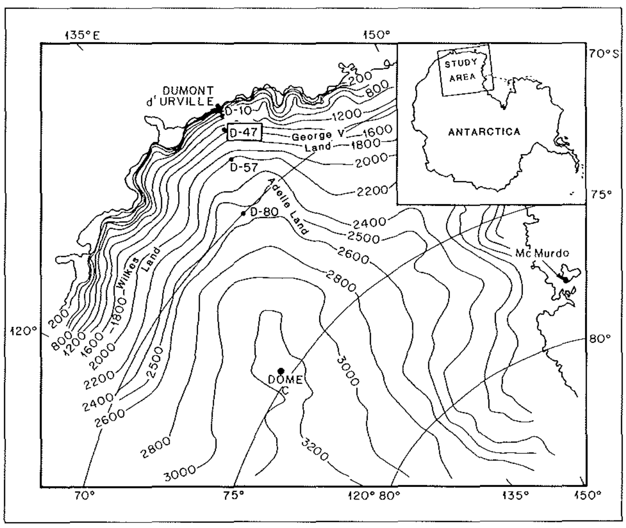

Fig. 1: Area map of Adelie Land, Antarctica.

Abb. 1: Lagekarte des Meßgebietes in Antarktika. Höhenlinien sind in m NN angegeben.

* Interaction Atmosphere-Glacier-Ocean

** Prof. Dr. Gerd Wendler, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701 (USA).
Prof. Dr. Nobuyoshi Ishikawa, Institute of Low Temperature Sciences, University of Hokkaido, Sapporo 060 (Japan).

	lat	long	alt	W/m²	Reference
Devon Ice Cap	75°30'N	83°10'W	1320 m	912	HOLMGREN 1971
McCall Glacier	69°18'N	143°48'W	1740 m	906	SHAW & WENDLER 1972
Carrefour Greenland	69°49'N	47°26'W	1850 m	905	AMBACH & MARKL 1981
Maudheim Station	71°03'S	10°56'W	37 m	954	LILJEQUIST 1956
Little America V	78°11'S	162°10'W	44 m	960	HOINKES 1961
Adelie Land	67°23'S	138°43'E	1560 m	997	present study
Mizuho Station	70°42'S	44°20'E	2230 m	1034	YAMANOUCHI 1983
Plateau Station	79°15'S	40°30'E	3265 m	1065	KUHN 1971

Tab. 1: Direct beam solar radiation measurements for the optical air mass of 2 for selected stations in Polar regions.

Tab. 1: Gemessene direkte Sonnenstrahlung, bezogen auf die optische Luftmasse 2, für ausgewählte Stationen in Polargebieten.

de (Fig. 1), while the French manned two stations. This project, which had been planned for a long time, was described by WENDLER & POGGI (1980) and POGGI et al. (1982). Besides measurements through the boundary layer by balloon and kite (ANDRÉ 1987), and of total heat balance on the ground (WENDLER et al. 1987), atmospheric turbidity measurements were carried out between 18 November and 25 December 1985. These measurements were made under clear sky conditions with a Linke Feussner actinometer (No 700 207), which was equipped with the Schott filters OG1, RG 2, and RG8. This instrument had been intercompared with the United States standards in Boulder. A digital microvoltmeter (Fluke 8060A digital multimeter) was used as a readout instrument.

At the site of the measurements, there has been an automatic weather station (RENARD & SALINAS 1977, STEARNS & SAVAGE 1981) for the last five years, hence climatological data are available. The climate of Adelie Land is relatively mild for Antarctica (WENDLER & KODAMA 1985). The mean summer temperature (December to February) at our station is —17.2° C. Positive temperatures were never observed, hence our station, some 110 km from the ocean, lies in the dry snow zone (BENSON 1962), displaying a high surface albedo (WENDLER 1986). The mean summer wind speed is high (11.3 m/s) even though the summer has the lowest wind speed of all seasons. Winds are blowing nearly always from a southeasterly direction; therefore, the directional constancy, which is the resultant wind vector divided by the sum of all winds is large with monthly values around 0.9.

RESULTS

In Fig. 2 the intensity of the direct solar beam is presented as a function of the optical air mass. Note that the y-axis has a logarithmic scale. It can be seen that the intensity of the solar radiation varies little for the same solar elevation (air mass) from day to day. A total of 79 measurements were carried out. A reason for the small variability might be found in the fact that there are no local pollution sources in Antarctica. The data have been adjusted for Earth — sun distance and atmospheric pressure. In the table, the solar intensity is given for the air mass of 2 for our site as well as for selected sites in the Arctic and Antarctic.

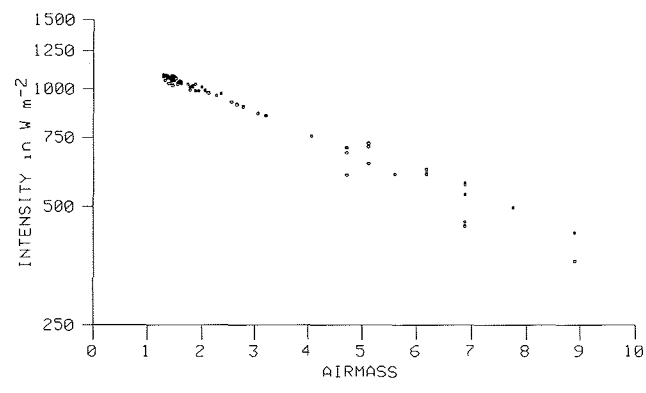

Fig. 2: Direct beam solar radiation intensities (logarithmic scale) at D57, Eastern Antarctica as function of optical air mass.

Abb. 2: Intensitäten der direkten Sonnenstrahlung (logarithmische Skala) bei D57, Ost-Antarktis, als Funktion der optischen Luftmasse.

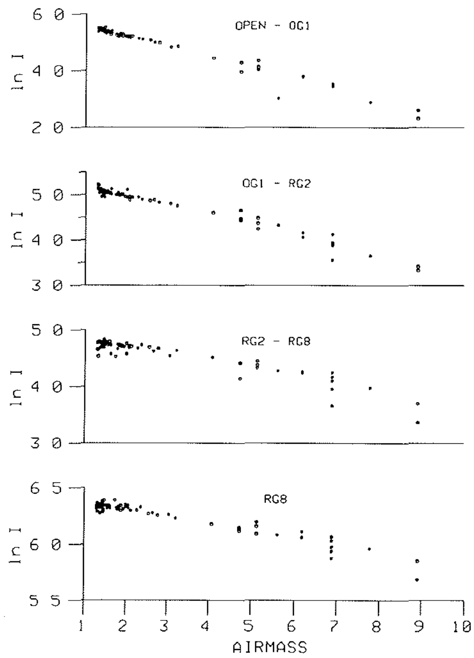

Fig. 3: Intensity (logarithmic scale) of the radiative fluxes at D57, Eastern Antarctica for different wavelength bands versus optical air mass. a) open — OG1 $<$ 525 nm, b) OG1 — RG 2 525 nm — 630 nm, c) RG 2 — RG 8 630 nm — 710 nm, d) RG 8 $>$ 710 nm

Abb. 3: Intensität (logarithmische Skala) der Strahlungsströme bei D57, Ost-Antarktis, für Banden verschiedener Wellenlängen, aufgetragen gegen die optische Luftmasse.

It can be seen that the intensity of the solar radiation is high in Adelie Land. Nowhere in the Arctic have such high values been observed. When we compare the data with Antarctica, higher values were observed in Plateau and Mizuho stations, while the present values are higher than those found at the coastal stations of Antarctica. The reason for the low turbidity might be found in the fact that the southern hemisphere is much less industrialized than the northern one. Hence, man made pollutants will be less abundant. Also, there is much more land area on the northern hemisphere, therefore natural terrestrial aerosols are also expected to be less frequent in the south. Furthermore, Antarctica is separated from any industry by the surrounding oceans, much more so than the Arctic. The data of Tab. 1 were taken over a time period of over thirty years. Our data fit well within the data previously collected, which might be taken as an indication that there was no substantial change in turbidity over Antarctica during the last three decades.

In Fig. 3 the intensity of the solar beam in different wavelength bands is plotted against the optical air mass. The decrease in intensity with air mass is less pronounced with increasing wavelength, which is, of

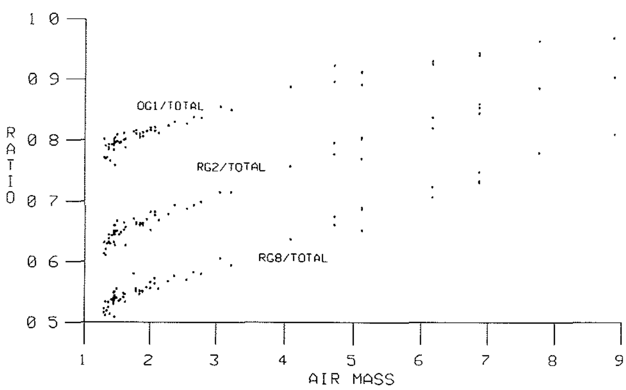

Fig. 4: The ratio of the intensity in different wavelength bands to the total intensity of the solar spectrum. a) OG1 / total, b) RG2 / total, c) RG8 / total.

Abb. 4: Das Verhältnis der Intensität für Banden verschiedener Wellenlängen zur Gesamtintensität des Sonnenspektrums.

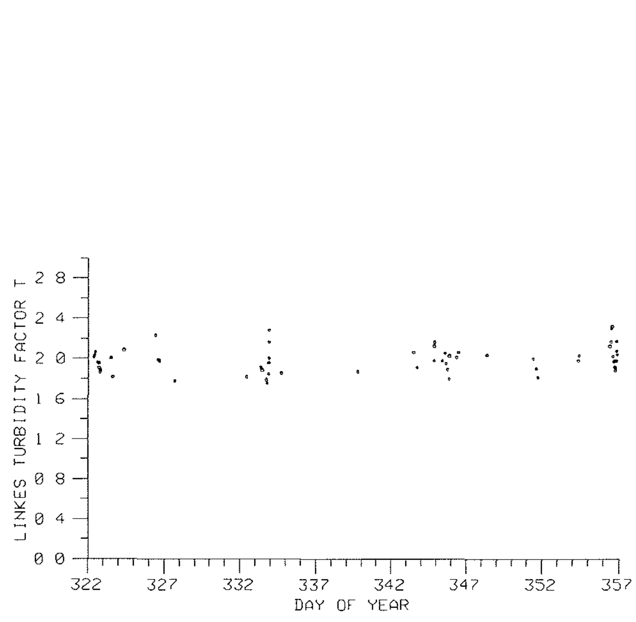

Fig. 5: Time series of the Linke turbidity factor at D57, Eastern Antarctica.

Abb. 5: Zeitreihe von Linkes Trübungsfaktor T bei D57, Ost-Antarktis.

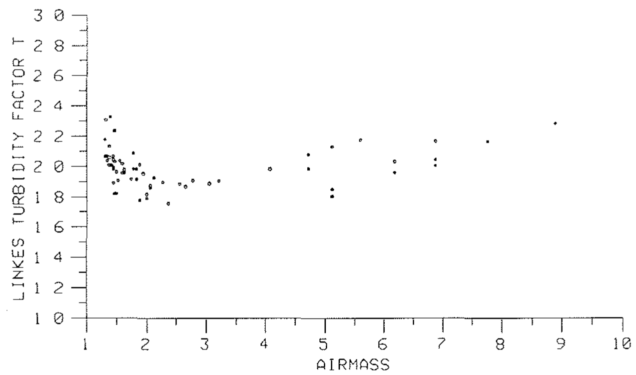

Fig. 6: Linke's turbidity factor as function of optical air mass at D57, Eastern Antarctica.

Abb. 6: Linkes Trübungsfaktor T als Funktion der optischen Luftmasse bei D57, Ost-Antarktis.

course, also the reason why during sun set or rise the reddish colors are dominant. In Fig. 4 the ratio of the radiation in the three filter bands (OG1, RG2, RG8) against the total radiation is presented. The ratio increases with air mass, which shows in another way that the red radiation is less absorbed than the shorter wavelengths of the solar spectrum. The gradient of the curves becomes steeper when going from OG1 over RG2 to RG8, as red represents a larger and larger portion of the filter measurements.

In Fig. 5, a time series of the turbidity factor T is presented. LINKE (1922) proposed this measure of turbidity first, and it is the oldest measure of turbidity. The quantity T is a simple measure of the haze and water vapor content of the atmosphere and is equivalent to the number of atmospheres of pure air that would produce the same depletion of direct solar radiation as actually measured. It is a useful measure of atmospheric turbidity, and the values we found were low (around 2); in contrast to our measurements, MARKL & AMBACH (1983) found values around 2.5 for Greenland. The turbidity factor has, however, its limitations, as it varies slightly with air mass. This fictitious variation of turbidity for unchanged atmospheric conditions can be seen in Fig. 6. The reason for this is that the wavelength dependencies of water vapor absorption and aerosol absorption and scattering are quite different from Rayleigh scattering. By using the shorter region of the solar spectrum (Open — OG1 or Open — RG2), the main water vapor bands of the solar spectrum can be avoided, but do not give real satisfactory results, either. As COULSON (1975) pointed out, the latter method does not only double the measurements necessary, but also the transmission characteristics of the filters are usually temperature dependent.

Another value of turbidity was developed by ÅNGSTRÖM (1929, 1930) namely the turbidity coefficient β and the wavelength exponent α. For the wavelength exponent, a value of about 1.3 is found. Assuming that value, a time series of the β values is presented in Fig. 7. Values between 0.02 and 0.06 are found. Both Figs. 5 and 7 show that there is no systematic variation in turbidity during the time of observation,

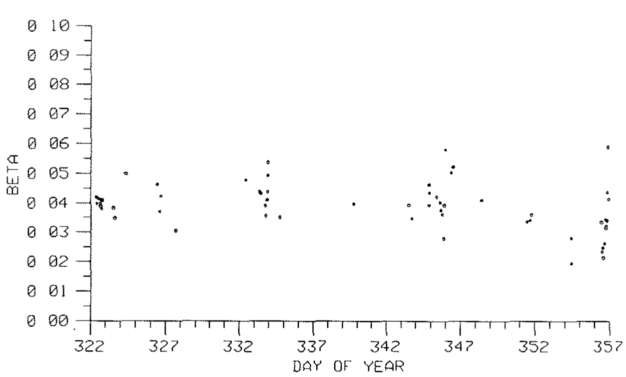

Fig. 7: Time series of Ångström's turbidity coefficient β at D57, Eastern Antarctica.

Abb. 7: Zeitreihe von Ångströms Trübungskoeffizient β bei D57, Ost-Antarktis.

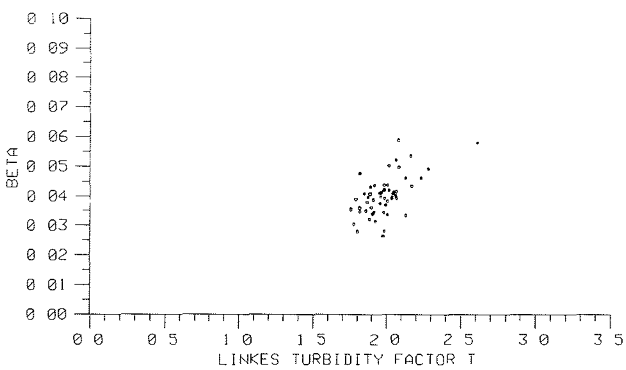

Fig. 8: Linke's turbidity factor T is plotted against Ångström's turbidity coefficient β for measurements at D57, Eastern Antarctica.

Abb. 8: Linkes Trübungsfaktor T, aufgetragen gegen Ångströms Trübungskoeffizient β bei D57, Ost-Antarktis.

as often observed in the Arctic, where in spring/early summer, higher values are found than in mid-summer (SHAW & WENDLER 1972).

In Fig. 8, Linke's turbidity factor is plotted against Ångström's turbidity coefficient β. The relationship is not very good, however, the scatter is somewhat similar to the one found by AMBACH & MARKL (1981) for Greenland.

CONCLUSION

The atmosphere is very clear in Adelie Land, Eastern Antarctica. This could be demonstrated by the comparison of direct beam measurements with other stations in polar regions. Turbidity indicators were also calculated; which verified the cleanness of the atmosphere. Further, the decrease in intensity with optical air mass was found to be less pronounced with increasing wavelength, a result to be expected. Also, no trend in turbidity over more than three decades could be observed with the data available from several Antarctic stations.

ACKNOWLEDGEMENT

This study was supported by NSF Grant DPP 8100161. My thanks go to the many people from the U.S. Antarctic Research Program and Expéditions Polaires Françaises who made this program possible. Further, my thanks go to F. Brill, who carried out with great dedication all the computer work, including drafting.

References

André, J. C. (1987): Vent catabatique et analogie hydraulique en Antarctique — La Recherche in press.

Ångström, A. K. (1929): On the atmospheric transmission of sun radiation and on dust in the air. — Geogr. Ann. 11: 156—166.

Ångström, A. K. (1930): On the atmospheric transmission of sun radiation II — Geogr. Ann. 12: 130—159.

Ambach, W. & G. Markl (1981): Messungen der atmosphärischen Trübung am Grönländischen Inlandeis während der Internationalen Glaziologischen Grönlandexpedition 1959 and 1967. — Polarforschung 51 (2): 129—137.

Benson, C. S. (1962): Stratigraphic Studies in the Snow and Firn of the Greenland Ice Sheet. — U.S. Army Snow Ice and Permafrost Res. Establishment, Res. Report 70, 93p.

Carroll, J. J. & B. W. Fitch (1981): Effect of solar elevation and cloudiness on snow albedo at the South Pole. — J. Geophys. Res. 86 (c6): 521—76.

Coulson, K. L. (1975): Solar and terrestrial radiation, methods and measurements. — New York.

Hoinkes, H. (1961): Studies of solar radiation and albedo in the Antarctic (Little America V and South Pole, 1957/58). — Arch. Met. Geoph. Bioklim. Ser. B, 10: 175—181.

Holmgren, B., Shaw, G. & G. Weller (1974): Turbidity in the Arctic atmosphere. — AIDJEX Bull. 27: 135—148.

Kuhn, M. (1971): Messung und Analyse der spektralen Transparenz der Ostantarktischen Atmosphäre. — Unveröff. Diss., Univ. Innsbruck.

Liljequist, G. H. (1956): Energy exchange of an Antarctic snow-field. Norwegian-British-Swedish Antarctic Expedition 1949—1952. — Scientific Res. II (1): Short wave radiation, Norsk Polarinst., Oslo.

Linke, F. (1922): Transmissionkoeffizient und Trübungsfaktor. — Beitr. Phys. frei. Atmos. 10: 91.

Markl, V. G. & W. Ambach (1983): Messungen der direkten Sonnenstrahlung und der atmosphärischen Trübung am Grönländischen Inlandeis, Station Carrefour, 1850 m. — Polarforschung 53 (1): 11—16.

Mawson, D. (1915): The home of the blizzard, Being the story of the Australian Antarctic Expedition 1911—1914. — London.

Poggi, A., André, J., Blaix, P., Delaunay, D., Gosink, J., Kodama, J. & G. Wendler (1982): Interaction atmosphère-glace-ocean en Antarctique. — La Météorologie, Juin-Septembre 1982, 163—171.

Shaw, G. & G. Wendler (1972): Atmospheric turbidity measurements at McCall Glacier in Northeast Alaska. — Conference on Atmospheric Radiation, Aug. 1972, Fort Collins, Col., 181—187. Boston, Mass.

Wendler, G., Ishikawa, N. & Y. Kodama (1988): On the heat balance of the icy slope of Adelie Land, Eastern Antarctica. — J. Applied Met. 27 (1). 52—65.

Wendler, G. (1986): The "radiation paradox" on the slopes of the Antarctic continent. — Polarforschung 56 (1/2): 33—41.

Wendler, G. & Y. Kodama (1985): Some results of climatic investigations on Adelie Land, Eastern Antarctica. — Z. Gletscherkde. Glazialgeol. 21: 319—327.

Wendler, G. & A. Poggi (1980): Measurement of the katabatic wind in Antarctica. — Antarctic J., 1980 Review, 193—195.

Yamanouchi, T. (1983): Variations of incident solar flux and snow albedo on the solar zenith angle and cloud cover, at Mizuho Station, Antarctica. — J. Met. Soc. Japan 61 (6): 879—893.