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INTERCOMPARISON BETWEEN OZONE PROFILES MEASURED ABOVE SPITSBERGEN BY LIDAR AND SONDE TECHNIQUES

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ABSTRACT

This paper compares coincident ozone profile measurements by electrochemical sondes and lidar performed at Ny-Ålesund/ Spitsbergen. A detailed height dependent statistical analysis of the differences between these complementary methods was performed for the overlapping altitude region (13-35 km). The data set comprises ozone profile measurements conducted between Jan. 1989 and Jan. 1991. Differences up to 25 % were found above 30 km altitude.

INTRODUCTION

Since summer 1988, a differential absorption lidar (DIAL) and a sonde facility are operated in Ny-Ålesund/ Spitsbergen (79°N, 12°E) in a joint effort of Alfred Wegener Institute and University of Bremen in order to investigate the characteristics of the arctic stratospheric ozone layer at high latitude [1-4]. The data sets of these two complementary methods possess different characteristics. The balloon borne sondes provide ozone concentration profiles (and PTU/wind measurements) from ground level up to about 35 km, whereas the DIAL instrument covers the altitude range 13-45 km approximately. The lidar data offer a good temporal but a moderate height resolution, whereas sonde data reveal more structured features in the profiles because of the better height resolution (50 m), which is important when e.g. strongly laminated layers occur. The ozone sounding freqency however is 1 - 5 sondes/week, resulting in a limited temporal resolution, whereas several lidar profiles per day might be obtained at favourable weather conditions. For a combination of both sets of data a detailed comparison between the two different methods is mandatory.

EXPERIMENTAL

The in situ measurements are performed with electrochemical sondes purchased from VAISALA Corp. (Type 5A) and handled according to the standard conditioning procedure given by the manufacturer. Ozone data were calculated from the raw data by means of the 'OZONE' program, also distributed by the manufacturer. Calculation of height is done in this program by integration of the barometric equation. The DIAL instrument uses a narrow bandwidth pulsed XeCl Excimer laser (max. 40 Hz, 150 mJ per pulse) as a source for 308 nm photons, which are strongly absorbed by ozone molecules. Part of the laser output is converted to a reference wavelength of 532 nm by Raman shift in pressurized hydrogen gas. The ozone concentration may be deduced by examination of the differential dependence of the amount of backscattered photons at both wavelengths with respect to altitude, which is determined in terms of photon transition time. The ozone concentration is determined from the lidar equation

$$O3(z) = \frac{1}{2} * \left(\frac{d}{dz} \ln \frac{I(z,ref)}{I(z,abs)} - RC \right) / da$$

where I(z, abs), I(z, ref) refer to the photon signals in the absorption and reference channels and da denotes the difference in the corresponding absorption cross sections, taken from Paur and Bass [8]. RC indicates a Rayleigh scattering correction term. More details about the experimental technique can be found in [4, 6-7].

During 1989-1991, 35 ozone sonde profiles were measured while the lidar was also in operation (Table 1). All these coincident measurements took place in the win-

	1989	1990	1991
JAN	15 (6) 16 (3)	19 (0) 29 (0)	3 (10) 5 (8) 7 (7) 9 (9) 16 (6) 21 (3) 23 (6) 25 (10)
FEB	6 (4) 8 (4) 21 (3) 23 (7)	6 (1) 14 (3) 21 (4) 24 (3) 26 (10)	8 (9) 15 (0) 18 (11) 20 (11) 22 (0)
MAR		5 (7) 10 (10)	10 (11) 11 (11) 12 (10) 13 (8) 14 (8) 16 (11) 17 (9)

Table 1. Dates of 35 launches of ozonesondes in Ny-Ålesund with coincident DIAL measurements. The number of height bins (2 km width) covered by both methods is given in paranthesis. Annual sums are 27 (1989), 38 (1990) and 158 (1991) bins.

ter - to - spring transition period (Jan. - Mar.). Unfortunately, as a result of early balloon bursts, no height overlap was found in 3 of the flights. The ozone concentration data were sampled into altitude bins of 2.0 km width and subsequently averaged arithmetically for each method. The lidar algorithm produces one data point every 200 m, i.e. that 10 points are averaged in the case of lidar ozone data. On the other hand, sonde data were sampled on a 0.1 Hz basis, which corresponds to 40 points within a bin at a typical balloon ascent velocity of 5 m/ sec.

RESULTS

The intercomparison of both methods clearly demonstrates that ozone lidar data are systematically lower than the corresponding sonde results between 13-25 km (Figure 1 A). Above 25 km, a systematic difference is not that obvious (Figure 1 B). A histogram of the relative difference D (normalized to sonde results)

D := (lidar - sonde) / sonde

also shows clearly the overall predominance of negative D values (Figure 2).

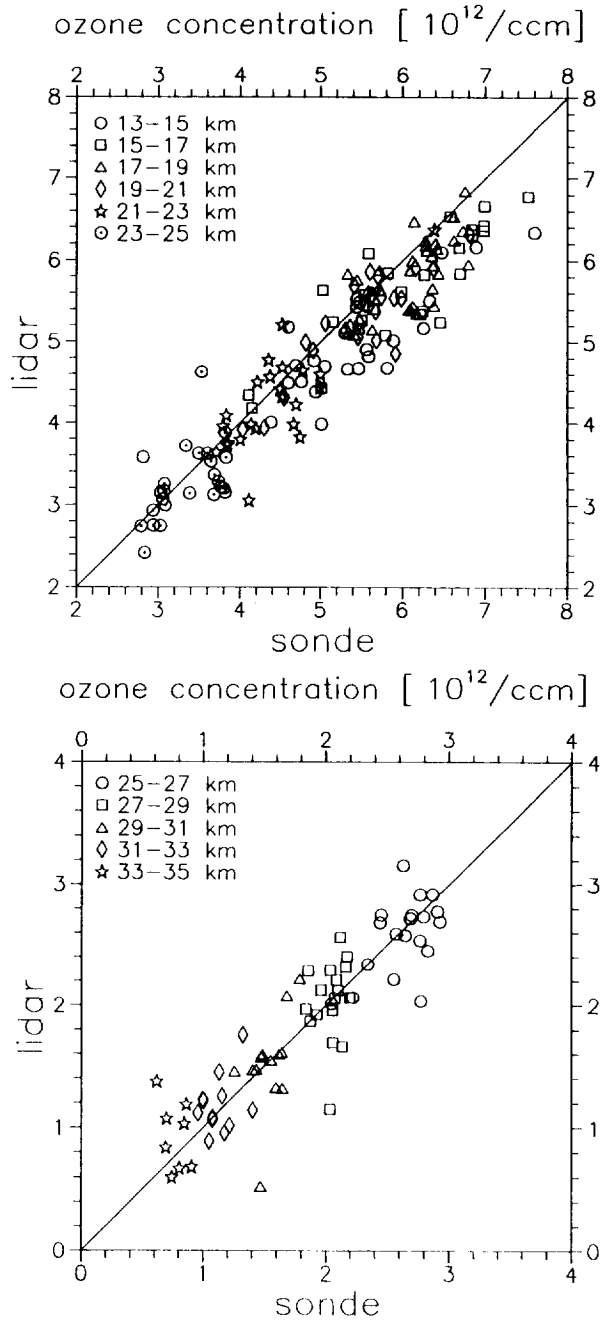

Figure 1.
Scatterogram of ozone concentrations measured by lidar versus sonde data for 13-25 km (A) and above 25 km (B).

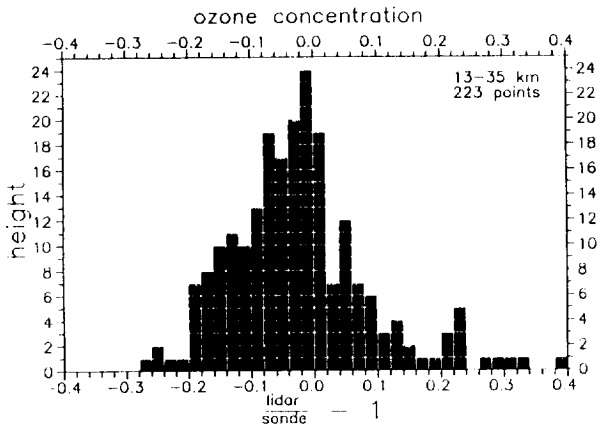

Figure 2.
Histogram of the differences between lidar and sonde data (normalized to sonde).

h/km	<D> /%	N
14	- 7.2	27
16	- 5.2	26
18	- 4.4	29
20	- 3.6	25
22	- 3.0	23
24	- 2.4	22
26	- 1.2	20
28	0.0	17
30	- 1.0	14
32	+ 5.0	12
34	+24.8	8

Table 2: Mean differences between lidar and sonde data (normalized to sonde) for all examined height levels. Last column gives the number of averaged data per level.

Furthermore, the observed strong deviation of D from a gaussian distribution indicates a dependence of D with height. As seen in a corresponding height dependent analysis, the average differences <D>, calculated for each altitude level show a systematic variation with height (Table 2). A linear regression analysis for the levels below 30 km results in

$$<D>/\% = -0.40*(30 - h)/km$$

with a correlation coefficient of r = 0.966. Strong deviation from this empirical relationship occurs for the two levels above 30 km, where the sonde data are found to be considerably lower than the corresponding lidar measurements (see Table 2).

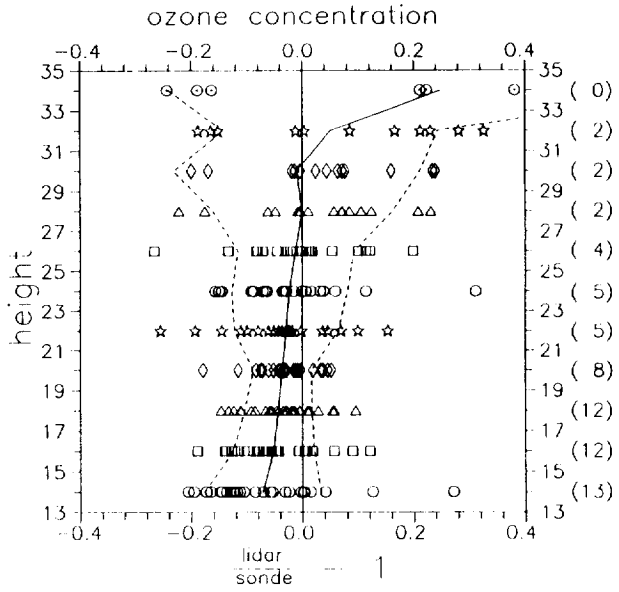

Figure 3.
Analysis of the height variation of the relative differences between lidar and sonde data. The arithmetic means <D> for each altitude level are connected by the solid curve. The dashed curves include ± 1 standard deviation. Numbers given in parentheses indicate the total number of averaged data in each level.

DISCUSSION

The systematical lower lidar data below 30 km might most probably result from the presence of stratospheric aerosols. While Rayleigh scattering effects of air molecules are corrected in our current lidar algorithm, Mie scattering of aerosol particles has not been included in the data analysis yet. A crude estimate expects the Mie correction for stratospheric background aerosols to be of the same order of magnitude around 20 km as the differences observed in the present analysis. In the beginning of 1991, the lidar apparatus in Ny-Ålesund has been modified to allow for aerosol detection including depolarization measurements [3, 5]. This will be of great value for the implementation of an aerosol correction formalism into the lidar algorithm.

SUMMARY

An intercomparison of the two methods to measure stratospheric ozone concentration showed that lidar data differ systematically from sonde results by about -(7-2) % in the lower part of the stratosphere (13-25 km) and up to +25 % in the upper part (30-35 km). In the intermediate range (25 - 30 km), the agreement is quite satisfactory, because the mean differences are found to be <1%. The reasons for the relatively large differences of opposit sign for altitudes above 30 km are unknown. Because the data base in this height range is relatively poor in the present analysis, further coincident measurements have to be performed in order to get a better insight into this detail.

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