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DIAL Ozone Measurements at the Meteorological Observatory Hohenpeißenberg: Climatology and Trends

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1 INTRODUCTION

Since October 1987 a differential absorption lidar (DIAL) has been used at the Meteorological Observatory Hohenpeißenberg (MOHp) for routine monitoring of ozone between 15 and 50 km. Measurements are taken every clear night, on average 7 per month. Figure 1 shows the monthly distribution of the 520 measurements taken between 1987 and 1993. The gap in 1989 is due to data loss.

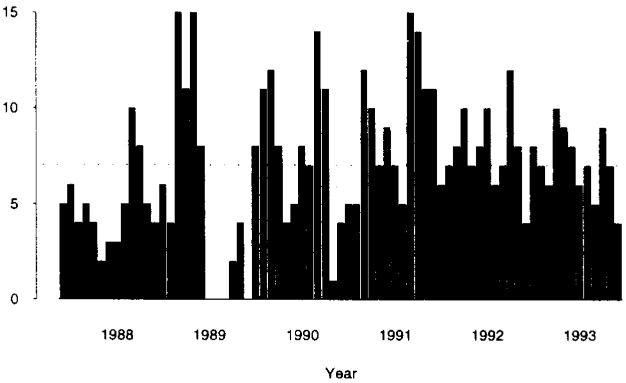

Figure 1: Number of DIAL ozone soundings taken at MOHp in each month since 1987.

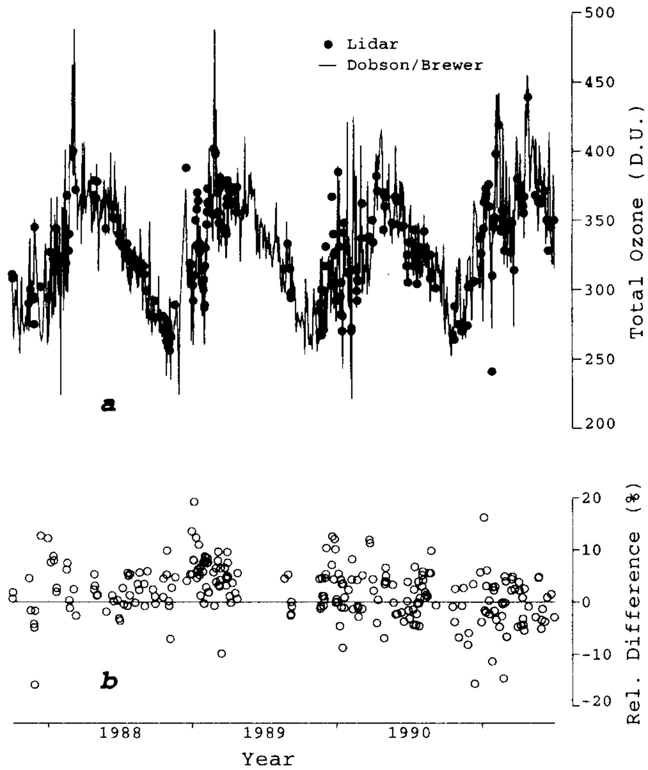

Figure 2: Comparison between total ozone values measured by Dobson and Brewer spectrometer and derived from DIAL data. The top panel shows absolute values, the bottom panel the relative difference (Lidar-Total O_3)/Total O_3.

2 COMPARISON WITH DOBSON TOTAL OZONE

MOHp lidar data have been successfully compared with data from several other instruments, e.g. balloonsondes flown at MOHp [1]. Here we report a comparison with total ozone measured by the Dobson and Brewer spectrometers at MOHp. Since the lidar measures ozone only in the stratosphere, the tropospheric part of the profile, amounting to about 10 % of total ozone, has to be supplied from other data. Long-term-mean profiles from the ozone balloon soundings at MOHp were used. The error arising from the use of the mean profile instead of the actual profile is well below 5 % in most cases. The comparison is shown in Figure 2 for the period from 1987 up to the Pinatubo eruption in June 1991. The top panel gives absolute values measured by the Dobson (solid line) and derived from the lidar data (dots). The data demonstrate the annual variation of total ozone, as well as the short term variability. (The accuracy of the Dobson measurement is about 2 %.) The lidar and Dobson data agree very well, even single peaks often coincide. In the bottom panel the relative difference is given. Typically agreement within about 10 % is found. Before 1989 the Dobson data seem to be systematically lower by about 5 %, after 1989 no bias is apparent. The data gap in 1989 is due to data loss, not a change in the lidar. The bias before 1989 is not fully understood and currently under investigation. Nevertheless the good agreement is remarkable, considering the fact that the Dobson measures during the day and the lidar at night, as well as the potential errors introduced by the use of a mean profile to account for tropospheric ozone.

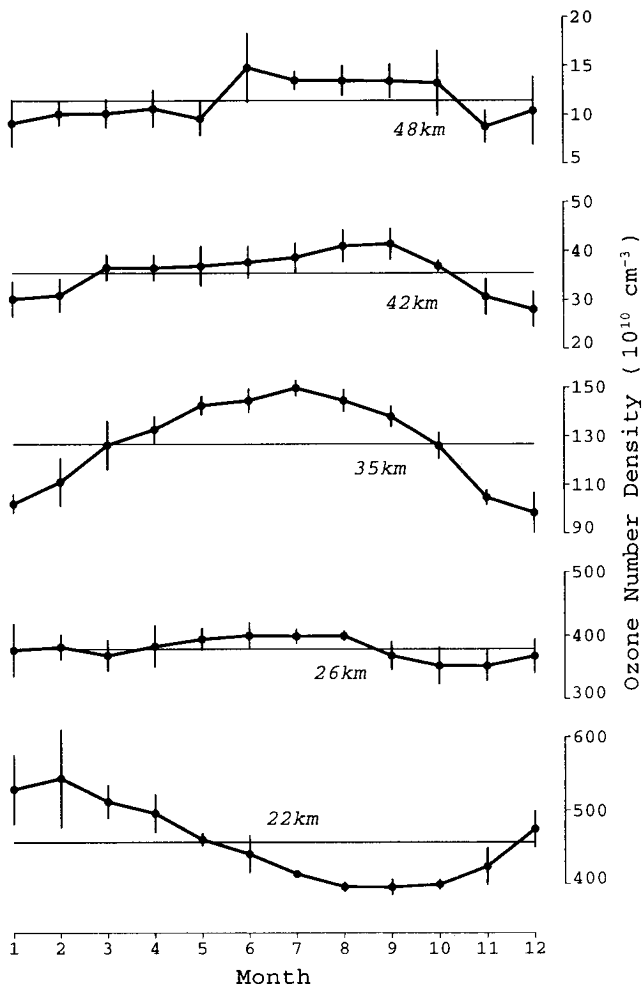

Figure 3: Annual variation of ozone concentration at various altitudes. Shown are mean values and standard deviations derived from data between 1987 and 1993. The horizontal line gives the annual mean.

3 CLIMATOLOGY

Six years of DIAL measurements are a basis for establishing a climatology for the annual variation of ozone at MOHp at various altitudes. Figure 3 shows the results for several altitude ranges, derived from lidar data between 1987 and 1993 (above 35 km) and 1987 to 1991 (below 35 km; in this way interference due to the differential backscatter term after the Pinatubo eruption is avoided). At 22 km, the altitude of the ozone maximum, an annual oscillation dominates. The maximum is observed in spring, the minimum in late summer/fall. This behaviour results from atmospheric exchange processes [2], and often this altitude region is called the dynamical region. At 35 km the ozone shows a different behaviour: again the annual component dominates, but now the maximum is found in summer. This region is controlled photochemically. It is interesting that the dynamical and photochemical regime are clearly separated, as shown by the curve for 26 km. Here hardly any annual variation is noticeable, a "dynamopause" seems to separate the two regimes.

The annual cycle at different altitudes and the variation with altitude at MOHp (47.8° N, 11.0° E) are very similar to results from Table Mountain, California (34.4° N, 117.7° W) [3]. However, at least at 35 km the amplitude of the seasonal variability is larger at MOHp (42 % compared to 30 %), probably due to the higher latitude.

4 TRENDS

DIAL measurements offer high precision in the 30 to 45 km altitude range, which cannot be reached by traditional electrochemical balloon-sondes. This makes DIAL an excellent tool for the recognition of ozone trends in the upper stratosphere. Figure 4 shows that the lidar at MOHp has recorded a statistically significant decrease of ozone in the 32 to 42 km range for the observation period 1987 to 1993 (thick line). For comparison the trends as derived from SAGE II observations from 1984 to 1991 [4] (thin line) and as predicted by photochemical models [5] (dashed line) are shown as well. The trend in the MOHp lidar data is larger than for the SAGE II data and than predicted by photochemical models. However, within their respective uncertainties all results agree quite well, both in size and in altitude dependence. To our knowledge this is the first report of a DIAL data set confirming model predictions as well as SAGE observations of an ozone decrease in the upper stratosphere. This clearly demonstrates the value of DIAL for long term monitoring. Even after a comparatively short time series of 6 years a statistically significant ozone decrease has been observed.

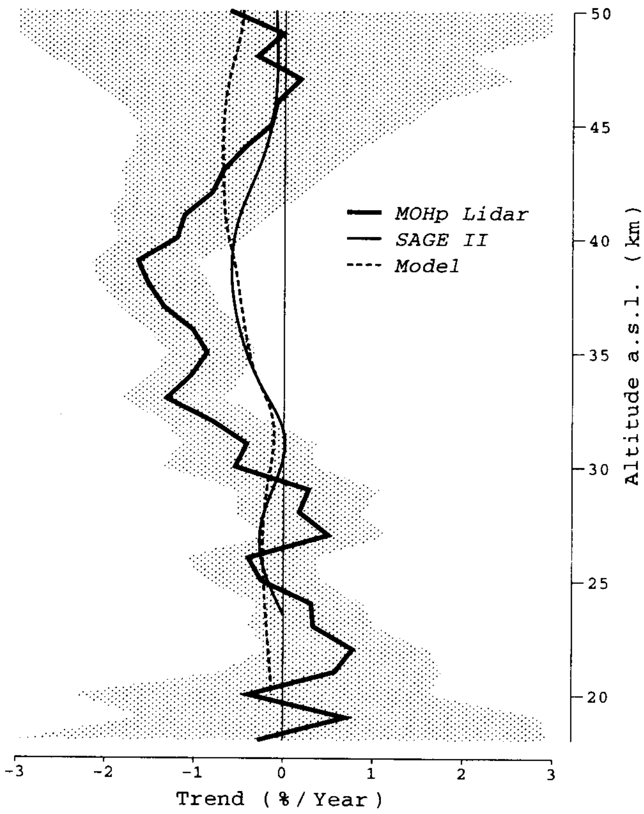

Figure 4: Ozone trend observed at MOHp as a function of altitude for the period 1987 to 1993 (above 30 km) and 1987 to 1991 (below 30 km). The thick solid line shows the slope of the linear trend line with the shaded region indicating the 95 % confidence limits. The thin line and the dashed line show results derived from SAGE II data and predicted by photochemical models, respectively.

References

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