Improving the Air Pollution Monitoring System in Graz, Austria by Additional DOAS Measurements

Guest contribution

D Baumgartner, A. Gobiet, M. Mayer, R. Maderbacher, H. Pietsch and E. Putz

University of Graz - Institute for Meteorology and Geophysics, Halbärthgasse 1, A-8010 Graz, Austria

Introduction

The response of air quality to air pollution, abatement strategies and changes in the emission of NO_x and VOC have to be investigated by permanent and long-term monitoring. The analysis of measurements with respect to trends is complicated by the fact of non-uniform emission and inhomogeneous distribution of pollutants. The choice of measurement sites is therefore a crucial point, especially in urban areas. Remote sensing methods produce line integrated trace gas concentrations in contrast to conventional measurements at a single site. The time average of such measurements corresponds to a mean over an area (light path × mean wind speed). With respect to trend analysis of air-quality and model validation remote sensing methods are superior to others.

From July 1996 to February 1997 DOAS (Differential Optical Absorption Spectroscopy) measurements were performed permanently in the city of Graz (300,000 inhabitants) in Austria.

The objective of the mesurement campaign was twofold (Mayer *et al.*, 1996, 1997):

* to start a long-term observation of air quality in the city of Graz based on DOAS data; and
* an intercomparison between long-path DOAS measurements and conventional measurements to deduce their relationship.

Proceedings of EUROTRAC Symposium '98
Editors: P.M. Borrell and P. Borrell

Transactions on Ecology and the Environment vol 28, © 1999 WIT Press, www.witpress.com, ISSN 1743-3541

Experimental

The light source of the DOAS system (Platt, 1983) was established at the Grazer Schloßberg, a small hill in the centre of the town. The receiver unit was placed in an air-conditioned container, also equipped with conventional ozone, NO and NO_2 instruments (Horiba), at a distance of about 3.7 km in a western district. The light beam crossed the city at an average height of 70 m above ground.

The light source, a Xenon high pressure arc lamp (Osram XBO 450 W), was placed at the focus of a parabolic mirror (30 cm diameter, 60 cm focal length) to obtain a well-collimated light beam. At the other end of the open path the light was received by a telescope, which had the same dimensions as the light-telescope to transfer the light by means of a silica fibre to the entrance slit of the spectrograph. The spectrograph has a slotted disc set-up and is equipped with a holographic flat field grating (550 grooves/mm) and a photomultiplier tube for scanning the spectra. They were taken in the spectral range from 250 nm to 380 nm with a spectral resolution of about 1 nm. After an integration time from 2–5 minutes the spectra were stored on an external hard disk.

The evaluation of the absorption spectra was performed with MFC, a programme developed at the IUP Heidelberg (Gomer *et al.*, 1993), to determine the ratio of the air pollutants ozone, NO_2, SO_2 and HCHO.

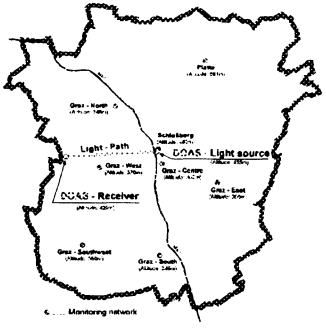
Results and discussion

The air quality monitoring network based on conventional instruments consists of six stations measuring O_3, NO, NO_2, SO_2, CO and particulate matter and two additional ozone monitoring stations (Schloßberg and Platte, 100 m and 300 m above the valley). The combination of stations at different heights with long-path DOAS measurements allowed us to gain some insight into the processes responsible for the changing vertical ozone profile.

On average the concentration along the DOAS path is, not surprisingly, higher than near ground. The difference is more pronounced in winter (day and night) and summer nights. During summer days connective mixing takes place and reduces the gradient or even changes the sign of it. As an example, the daily variation of ozone on two consecutive days from four monitoring stations and DOAS data are shown in Fig. 2. There is, more or less, not much difference between all data between 10 a.m. and 5 p.m. One station (Platte) is decoupled from the others from evening to morning and exhibits the characteristic of a

mountain station near urban areas. Schloßberg and DOAS show similar behaviour day and night.

On August 15th it was raining all day, the next day was mainly sunny and dry. Nearly the whole time DOAS concentrations exceeded ground measurements.



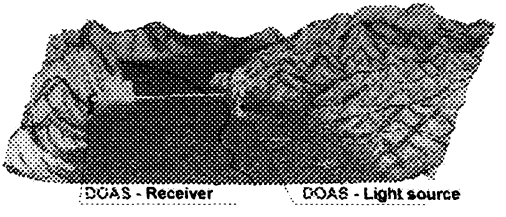


Fig. 1: Map of Graz and monitoring stations.

Table 1: Statistical parameters of ozone concentrations for all measurements of DOAS and from Graz West from July 1996 to February 1997. The difference between Graz West and DOAS is also shown. Ozone concentrations in mg/m^3.

	$[O_3]$ DOAS	$[O_3]$ Graz West	Difference
Number	5726	5726	5726
Mean	0.049	0.033	–0.016
Median	0.049	0.022	–0.018
Standard deviation	0.021	0.033	0.025
Max.	0.120	0.147	0.099

Four days later (Fig. 3), the DOAS data show a remarkable diurnal feature. Both days were dry, warm and sunny. In the evening of 21st August a thunderstorm was approaching with strong winds (7 p.m.) and rain.

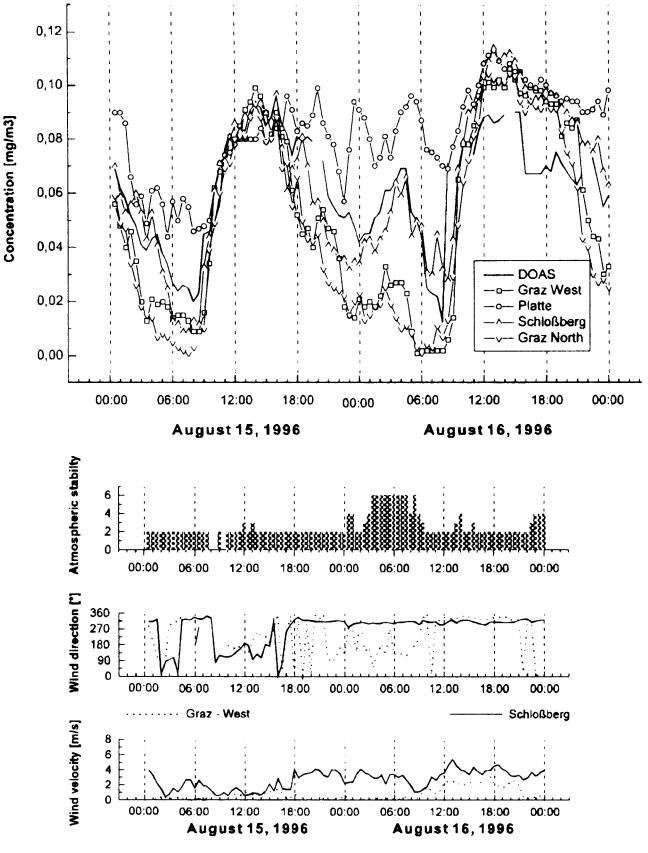


Fig. 2: Daily variation of ozone at four monitoring stations and DOAS data.

In contrast to the days before, ozone concentrations reach only half the value of the four other stations in the time from about 10 a.m. to 6 p.m. During night-time the variation of the DOAS and Schloßberg data are again quite similar. It is worth mentioning that NO_2 is strongly anti-correlated with ozone (less than 1 $\mu g/m^3$ from 10 a.m. to 6 p.m.)

How can we explain this? Ozone profiles depend on chemical processes, vertical mixing and advection. Vertical mixing strongly depends on atmospheric stability, which can be classified by *e.g.* Pasquille's or similar (ÖNorm M9440) stability categories ranging from extremely unstable (2) to very stable (7).

On August 15th it was extremely unstable to neutral (2–4 from 0 a.m. to 12 p.m.) and on the following day slightly unstable to neutral (3–4)

from 8 a.m. to 10 p.m. During the night it was slightly stable to moderately stable. On both days, August 20th and 21st, we had extremely unstable conditions (2) from 1 p.m. to 7 p.m., the rest of the days it was neutral to moderately stable (4–6).

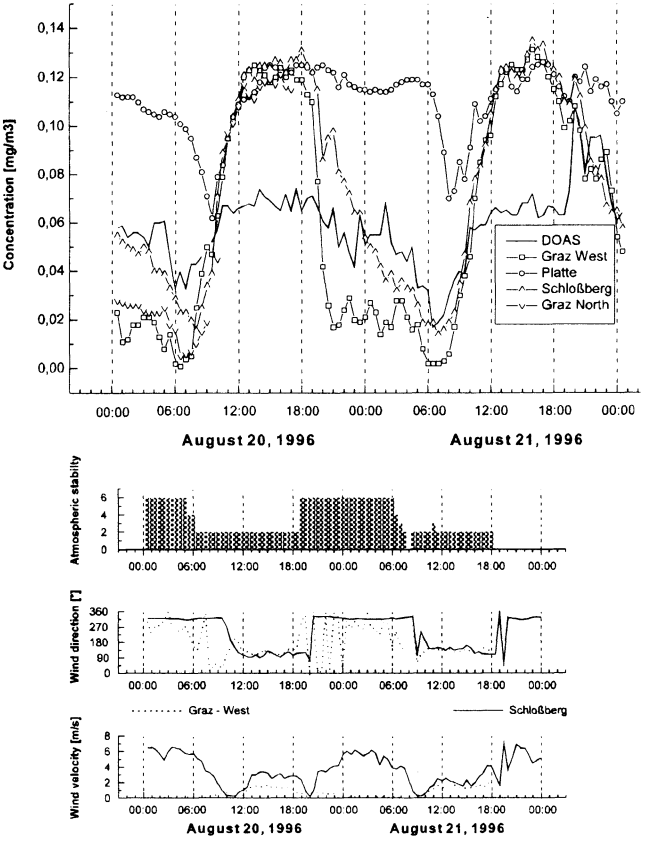


Fig 3: Daily variation of ozone at four monitoring stations and DOAS data.

One can conclude that stability is important but not the only essential parameter. As already mentioned, advection is vital. The local wind system is strongly pronounced on 20th and 21st with SE winds during the day (10 a.m. to 8 p.m.) and later NE winds (8 p.m. to 10 am), but not on the 15th and 16th. So we have an indication that unpolluted air is advected by the local wind system in the height range of about 60 to 100 m above ground if this wind system is really pronounced. High ozone values at the Schloßberg station can

be explained by upslope winds transporting ozone-rich air from the city up the hill.

A statistical analysis (Table 2) of stability classes (extremely unstable to very stable) revealed, that during stable or very stable conditions nearly always higher ozone concentrations can be observed in layers along the DOAS light-path (70 m above ground).

Table 2: Statistical parameters of the difference between Graz West and DOAS measurements for different stability categories.

	Class 2 extremely unstable	Class 3 slightly unstable	Class 4 neutral	Class 5 slightly stable	Class 6 moderately stable	Class 7 very stable
Number	810	491	1595	249	975	627
Mean	–0.002	–0.010	–0.016	–0.026	–0.029	–0.028
Median	–0.009	–0.014	–0.018	–0.026	–0.027	–0.024
Std. deviation	0.028	0.021	0.020	0.022	0.020	0.020
Min.	–0.077	–0.064	–0.093	–0.083	–0.106	–0.097
Max.	0.086	0.075	0.065	0.043	0.034	0.048

During extremely or slightly unstable conditions we observe cases with higher or lower concentrations compared to ground measurements, most probably caused by advection of ozone-poor air from rural areas by the local wind-system. So far we found no simple relation using common meteorological parameters which indicates when advection is important and which could serve to predict ozone (or NO_2) concentrations at ground level by means of DOAS measurements.

Acknowledgments

The project was supported by the Styrian Government and the City Council of Graz.

References

Gomer, T., F. Heintz, J. Stutz, U. Platt; *MFC Version 1.98, User Manual* 1993.

Mayer, M., H. Pietsch, D. Baumgartner, R. Maderbacher, E. Putz; Measurement report to Styrian Government and City Council of Graz, 1996 and 1997.

Platt, U.; Differential Optical Absorption Spectroscopy, in: D.K. Killinger, A. Mooradian (eds), *Optical and Laser Remote Sensing*. Springer-Verlag, Berlin 1983, pp. 97–105.