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# TIME SERIES OF OZONE VERTICAL PROFILES IN A RURAL AND AN URBAN ENVIRONMENT

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## INTRODUCTION

The presence of hydrocarbons and nitrogen oxides and intense insolation lead to the well-known photochemical smog which is characterized by high concentrations of tropospheric ozone. Differential absorption and scattering lidar is a technique ideally suited for the quantitative assessment of the development and decay of high-ozone regions in the planetary boundary layer. The present paper describes a series of such measurements in a rural and in an urban environment in Southern Bavaria, Germany.

## APPARATUS

The instrument used was the mobile DAS lidar ARGOS (Goers et al. 1993). For ozone measurements ARGOS uses two Nd:YAG-laser-pumped dye lasers fired with 50 µs time delay and tuned to one of 13 pairs of wavelengths for which $SO_2$ interference has been measured to be strictly zero (Weitkamp et al. 1992). For the measurements presented on and off-resonance wavelengths of 280.91 and 282.72 nm were used throughout. The small wavelength difference minimizes the Rayleigh scattering correction and renders the effect of backscatter-coefficient gradients on the evaluated ozone concentrations manageable except under very severe conditions.

## MEASUREMENTS AND RESULTS

Measurements were made in a rural area near Andechs, 40 km southwest of Munich, and in the Olympic Center in downtown Munich (48°08' N 11°35' E) next to a busy multilane inner-city expressway. Selected results are presented in Figs. 1, 2 and 3.

Figure 1 shows a measurement in Andechs in the evening after a clear, warm summer day, during the cloudy night, in the morning of the following day with bright sunshine until about 13:00 h, and in the afternoon when clouds began

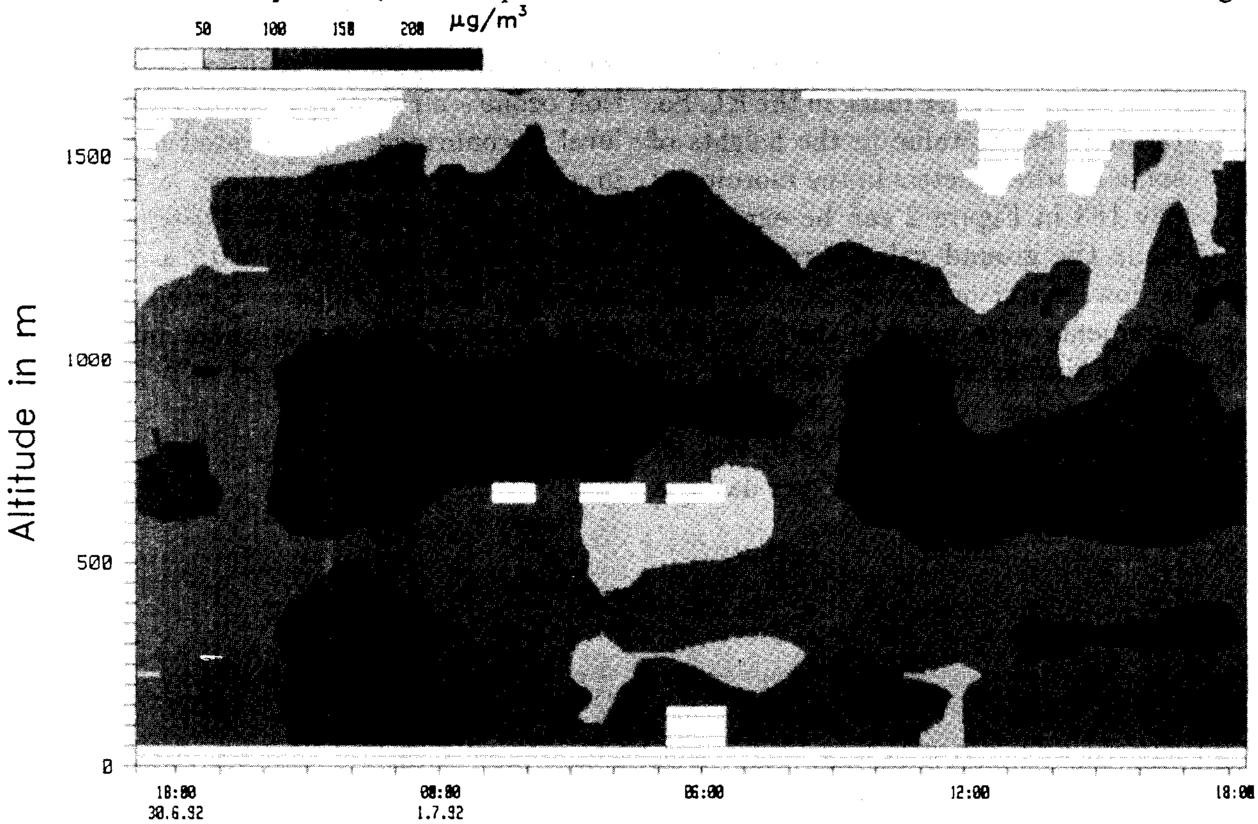


Fig. 1

Ozone concentration vertical profiles at Andechs. White areas with horizontal bars indicate regions for which data could not be evaluated.

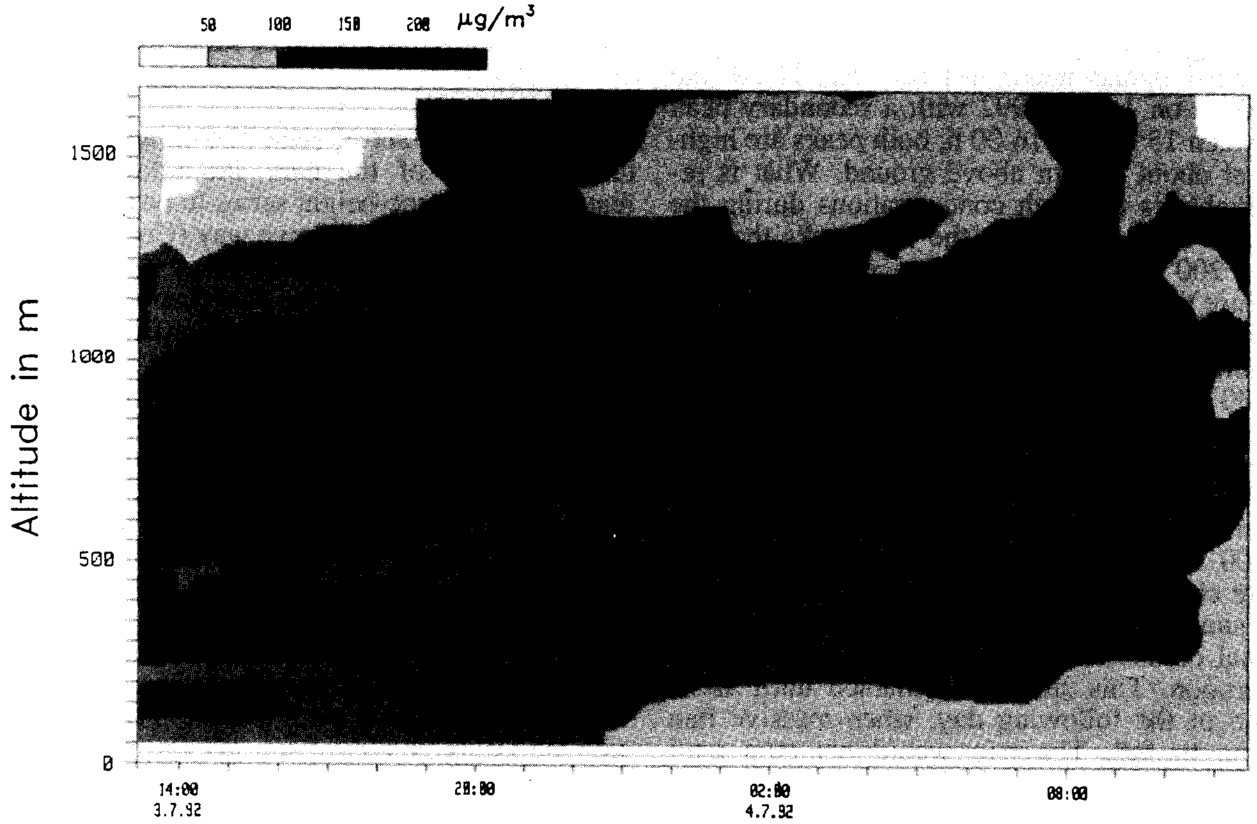


Fig.2

Ozone concentration vertical profiles at Munich. White areas with horizontal bars indicate regions for which data could not be evaluated.

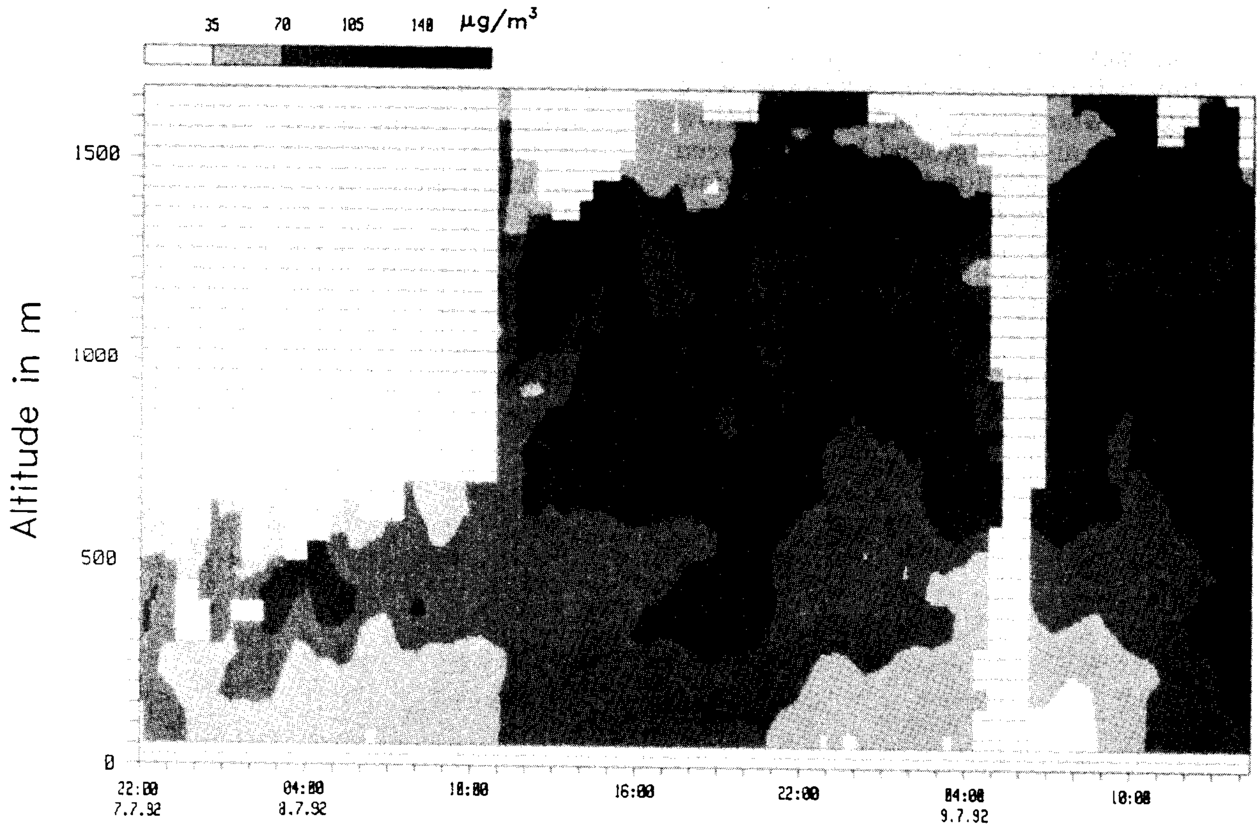


Fig. 3

Ozone concentration vertical profiles at Munich. White areas with horizontal bars indicate regions for which data could not be evaluated.

to form and to come down to about 1200 m above ground by 18:00 h. We notice the pronounced ozone maximum between 11:00 and 13:00 h on 1 July 1992 with a secondary peak between 15:00 and 16:00 h; both peaks are highest at about 650 m above ground. What is remarkable is the high concentrations during the night which, except for the two peaks that exceed 200 $\mu g/m^3$, are on average not much less intense than the daytime maximum.

Figure 2 shows the distributions measured at Munich between 13:00 h on 3 July 1992 and 11:30 h on 4 July 1992. Again > 200 $\mu g/m^3$ are observed between 13:00 and 18:00 h. The concentration goes through a minimum around midnight, and then again increases to reach a maximum by 04:00 h which persists until about 06:00 h. Weather conditions on 3 July 1992 were characterized by rain in the morning, with the sun appearing around 12:00 noon, and occasional clouds reaching down to 1150 m in the afternoon. This situation remained until about noon of the following day, when massive rain began to fall. The rain would not stop until about 18:00 h on 8 July 1992, the cloud layer was at 350 m, and no lidar measurements were possible beyond that height. After that the cloud deck began to rise to 1000 m in the early afternoon, and the night was almost clear.

Figure 3 shows the ozone behavior between 7 July 1992 22:00 h and 9 July 1992 14:30 h. Even in the rain lidar measurements were made up to about 500 m. Ozone concentrations were low during the whole period, and dropped below 35 $\mu g/m^3$ in the night at ground level. Between 04:00 and 06:00 h radiation frost on the window of the lidar beam steering unit reduced the window transmission temporarily so that the computer program data validity check module eliminated part or all of the profiles from the evaluation process. Even so an early-morning maximum with > 140 $\mu g/m^3$ can be seen to appear. It is only after 11:00 h of the following morning, when the sun comes out, that the usual high ozone concentrations begin again to form.

## DISCUSSION

The complete set of data allows a more detailed analysis of the data and allows many features of the time-height series to be explained at least in a semi-quantitative way (Goers 1994). The consequence is in essence that weather has a larger influence on ozone data than short-term and small-scale differences in human behavior (weekday-weekend differences, rural-urban environment). What remains unclear from these measurements is the question whether the observed nighttime maxima which not always appear at ground level, but are clearly present aloft, must be explained by ozone advection from areas of low $NO_x$ production, or originate from some ozone formation process hitherto not duely considered.

## ACKNOWLEDGEMENT

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