# LONG-RANGE TRANSPORT OF FREE-TROPOSPHERIC AEROSOL: A NINE-YEAR CLIMATOLOGY

**Horst Jäger[1], Paul James[2], Andreas Stohl[2,3], Thomas Trickl[1]**

*[1]Forschungszentrum Karlsruhe, Institut für Meteorologie und Klimaforschung (IMK-IFU), Kreuzeck-bahnstr. 19, D-82467 Garmisch-Partenkirchen, Germany, e mail: thomas.trickl@imk.fzk.de*

*[2]Lehrstuhl für Ökoklimatologie, Technische Universität München, Am Hochanger 13, D-85354 Freising, Germany*

*[3]Norsk Institutt for Luftforskning, P.O. Box 100, Instituttveien 18, N-2027 Kjeller, Norway*

## ABSTRACT

The long-term aerosol measurement series with the stratospheric aerosol lidar at Garmisch-Partenkirchen has yielded information on the free troposphere since 1992. By inspecting ten-day FLEXTRA backward trajectories for two selected years the aerosol observations could be mostly attributed to long-range transport, mostly from North America, but also from Africa and the Pacific area. A pronounced seasonal cycle was found which peaks in April. The trend of the observation frequency is negative in the early 1990s and slightly positive later on. The initial negative trend is very likely associated with downward transport of Mt.-Pinatubo aerosol. The results suggest some correlation of the aerosol observations with descending air masses.

## 1. INTRODUCTION

Aerosols are excellent tracers of long-range transport. Long-range transport of trace gases such as ozone has been extensively studied in the recent past and our groups have been strongly involved in this rapidly evolving field (e.g., [1-4], see also *http://www.esi-topics.com/fmf/2005/july05-AndreasStohl.html*). Although the observation of intercontinental dust transport has a long history (e.g., [5]) comprehensive investigations of the free-tropospheric aerosol with lidar have been sparse.

Within the European project EARLINET (European Aerosol Research Lidar Network, 2000-2003) one of the work packages was devoted to the long-range transport of aerosol [6]. Co-ordinated observations were extensively made for Saharan dust leading to observations of mineral dust at all stations involved in the project [6,7]. In addition, single case studies of long-range transport were made. Here, we report on a nine-year climatology of the free tropospheric aerosol above our station. The study was limited to Garmisch-Partenkirchen because of the unique time series available which started as early as in 1976 for the stratosphere [8] and which has covered the entire free troposphere since 1992, after the system modernization. Also, the particularly high signal-to-noise ratio of our big NDSC (Network for the Detection of Stratospheric Change) lidar, used for these investigations, allows us to resolve free-tropospheric aerosol structures at a level of about 1 % of the Rayleigh contribution.

## 2. RESULTS AND CONCLUSIONS

The aerosol structures in the free-tropospheric backscatter coefficients at 532 nm rarely exceed 30 % of the Rayleigh values. Exceptions are pronounced fire plumes. However, only in the case of two Canadian fires the Rayleigh value was clearly exceeded in recent years (e.g., [9]). Our analysis is limited to clearly discernible structures above 5 % or 10 % of the Rayleigh backscatter coefficient (i.e., scattering ratio R = 1.05 or 1.10, respectively). Since aerosol is influenced by washout we have based our analysis on relating measurements exhibiting an aerosol structure above the boundary layer exceeding the respective threshold to the total number of measurements per month or year.

For the years 1996 and 2000 ten-day FLEXTRA [10] backward trajectories were calculated for times within ±3 h from the individual measurements during the early night. After discarding a few uncertain cases 71 measurements remained which are classified as follows:

- 48 cases with clear contact with a remote boundary-layer (mostly U.S.A.),
- 10 cases with contact with a remote boundary layer, but discernible structures smaller than 5 % of the Rayleigh backscatter coefficient,
- 4 cases with a North-American contribution plus some structure related to advection from the Pacific area,
- 4 cases which can only be explained by advection from the Pacific area,
- 2 cases with indirect advection from the Sahara desert via the Atlantic,
- 3 cases which could not be assigned.

We conclude a very high correlation of even tiny structures with long-range advection from some remote boundary layer.

For the nine-year climatology we excluded 83 cases from the 449 measurements between 1992 and 2000 because of potential exclusive cloud influence, leaking of Pinatubo aerosol through the tropopause, uncertainty about the boundary-layer height and other reasons. After trajectories are available for all years this analysis will be repeated and is expected to result in a reduced removal of measurements. Because of the limited number of data we calculated the monthly fractions as an average over several years. The result is shown in Fig. 1.

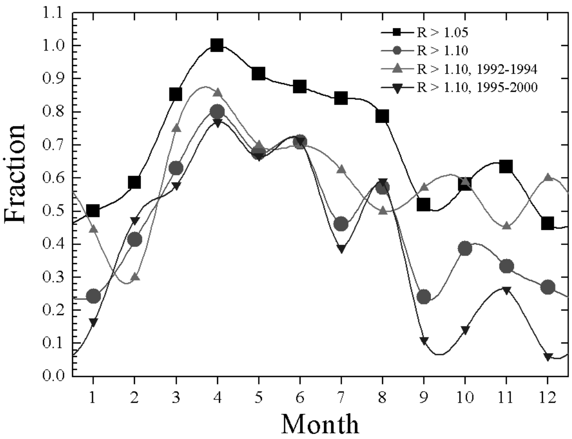


**Fig. 1:** Seasonal cyces of the monthly mean fractions for the two thresholds R = 1.05 and R = 1.10

The trend results are shown in Fig. 2. For the 5 % threshold no significant trend is obtained. For the more pronounced structures exceeding 10 %, possibly in part those less influenced by washout, a negative trend is seen during the Pinatubo period, followed by some rise.

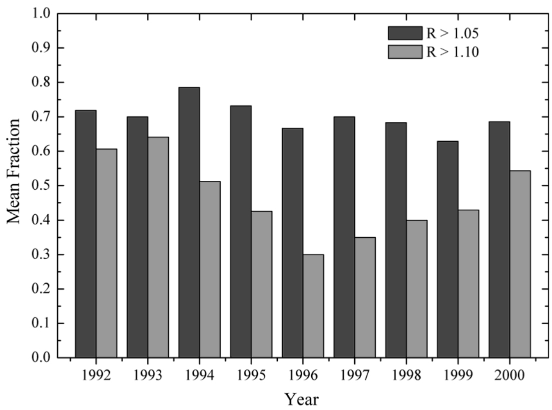


**Fig. 2:** Annual mean fractions for the two thresholds R = 1.05 and R = 1.10

The results suggest that the aerosol observations are positively correlated with subsiding air masses. On one hand, this is seen by a comparison of the trend before and after the Pinatubo period, indicating downward transport even from the stratosphere. On the other hand the low number of aerosol observations during the cold season after 1994, in absence of the volcanic aerosol, is in agreement with the lower probabilty of an export from the boundary layer expected for this part of the year. The seasonal cycle also shows some similarity to the late-winter-spring maximum of ozone [11]. We cannot exclude that some mechanisms responsible for these phenomena are the same.

**ACKNOWLEDGEMENTS**

The authors thank P. Fabian and W. Seiler for their support. This work has been funded by the European Union within the EARLINET project and by the German Bundesministerium für Bildung und Forschung within the ATMOFAST project.

**REFERENCES**

1. W. Carnuth, U. Kempfer, T. Trickl, Highlights of the Tropospheric Lidar Studies at IFU within the TOR Project, *Tellus B* **54** (2002) 163-185

2. H. Eisele, H. E. Scheel, R. Sladkovic, T. Trickl, High-resolution Lidar Measurements of Stratosphere-troposphere Exchange, *J. Atmos. Sci.* **56** (1999) 319-330

3. Stohl A. and Trickl T., A textbook example of long-range transport: Simultaneous observation of ozone maxima of stratospheric and North American origin in the free troposphere over Europe, *J. Geophys. Res.* **104** (1999) 30445-30462

4. T. Trickl, O. C. Cooper, H. Eisele, P. James, R. Mücke, A. Stohl, Intercontinental transport and its influence on the ozone concentrations over central Europe: Three case studies, *J. Geophys. Res.* **108** (2003) 8530, 10.1029/2002JD002735, STA 15, 23 pp.

5. R. Reiter, K. Pötzl, R. Sladkovic, Determination of the Concentration of Chemical Main and Trace Elements (Chemical Matrix) in the Aerosol from 1972 to 1982 at a North-Alpine Pure Air Station, Part II: Parametric Correlation Analysis of the Chemical Matrix with Consideration of Meteorological Quantities, *Arch. Met. Geoph. Biocl. B* **35** (1984) 1-30

6. T. Trickl et al., Analysis of source regions, in: *EARLINET: A European Aerosol Research Lidar Network to Establish an Aerosol Climatology*, Final Report, European Union, J. Bösenberg, V. Matthias, Eds., Max-Planck-Institut für Meteorologie (Hamburg, Germany, 2003), Report No. 348, ISSN 0937 1060, pp. 152-162

7. A. Papayannis et al., Observation of Special Events, in: *EARLINET: A European Aerosol Research Lidar Network to Establish an Aerosol Climatology*, Final Report, European Union, contract EVR1-CT1999-40003, J. Bösenberg, V. Matthias, Eds., Max-Planck-Institut für Meteorologie (Hamburg, Germany, 2003), Report No. 348, ISSN 0937 1060, pp. 60-68

8. H. Jäger, Long-term record of lidar observations of the stratospheric aerosol layer at Garmisch-Partenkirchen, *J. Geophys. Res.* **110** (2005) D08106, doi: 10.1029/2004JD005506, 9 pp.

9. C. Forster et al., Transport of boreal forest fire emissions from Canada to Europe, *J. Geophys. Res.* **106** (2001) 22887-22906

10. http://zardoz.nilu.no/~andreas/flextra+flexpart.html

11. P. Monks, A review of the observations and origins of the spring ozone maximum, *Atmos. Environ.* **34** (2000) 3545-3561