

Properties of Aged Forest Fire Plumes after Intercontinental Transport across the Atlantic Ocean

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INTRODUCTION

It is widely accepted that long-range transport is one of the most important factors controlling the spatial and temporal variability of aerosol properties and atmospheric particle load. Although a large fraction of the aerosol remains in the planetary boundary layer, particularly desert dust plumes and biomass burning plumes may be lifted into the free troposphere and transported over long distances, even between continents. During long-range transport, the microphysical, optical and radiative properties of aerosols are modified which may have a large impact on their climate effects (Fiebig et al., 2003).

Information on the effects of transformation and mixing processes during long-range transport is urgently needed for the quantification of the radiative forcing due to aerosols, for the assessment of heterogeneous processes with respect to atmospheric chemical composition changes, and for the validation of aerosol products from space-borne sensors such as aerosol optical thickness.

METHODS

In summer 2004 the long-range transport of particles emitted from large forest fires in Canada and Alaska contributed significantly to the aerosol loading of the free troposphere over Europe (Damoah et al., 2006). Airborne in situ measurements on the intercontinental transport of aerosols from biogenic and anthropogenic origin were performed at the European west coast as a part of the ICARTT-ITOP study (Intercontinental Transport of Ozone and Precursors). During the study the German Falcon 20 E-5 research aircraft was operating from an airport north of Paris. The aircraft was equipped with extensive in-situ aerosol and trace gas instrumentation. Measurement flights were performed over the European west coast probing the entire tropospheric column from the boundary layer to the upper free troposphere.

Trajectory analyses were conducted for all the measurement flights and permitted the identification of the plume origin for several forest fires cases. Simultaneously to the airborne in-situ measurements, black carbon data from the high-alpine research station Jungfraujoch (JFJ; 3580 m asl) in Switzerland showed

elevated BC levels during this period. Trajectory analyses confirmed that the JFJ station was probing the same forest fire plume as the Falcon during the measurement flights at the European West coast.

RESULTS

Figure 1 shows a forest fire plume example from the period 22 – 23 July 2004. Plume #2 arrived at the JFJ station on the night from 23 to 24 July 2004. Plume #1 has mixed with air masses from the Saharan desert which is confirmed by size distribution data. Physico-chemical properties of the forest fire plumes indicated a strong absorption signal in the visible spectral range at $\lambda = 550$ nm in combination with an enhanced accumulation mode. Figure 2 summarises all absorption coefficient data measured in the troposphere during the ITOP study.

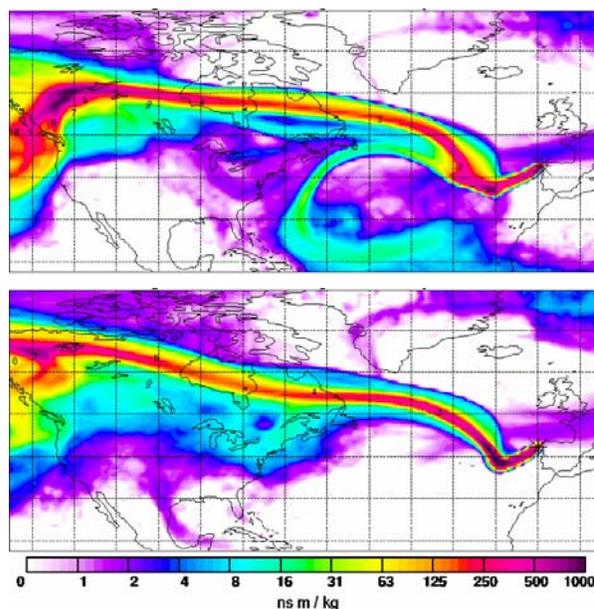


Figure 1, FLEXPART analyses of two forest fire layers on 22 July 2004, probed at the Spanish west coast; Plume #1 (top panel) was observed at an altitude of 6–8 km, Plume #2 (bottom panel) at an altitude of 3–4 km.

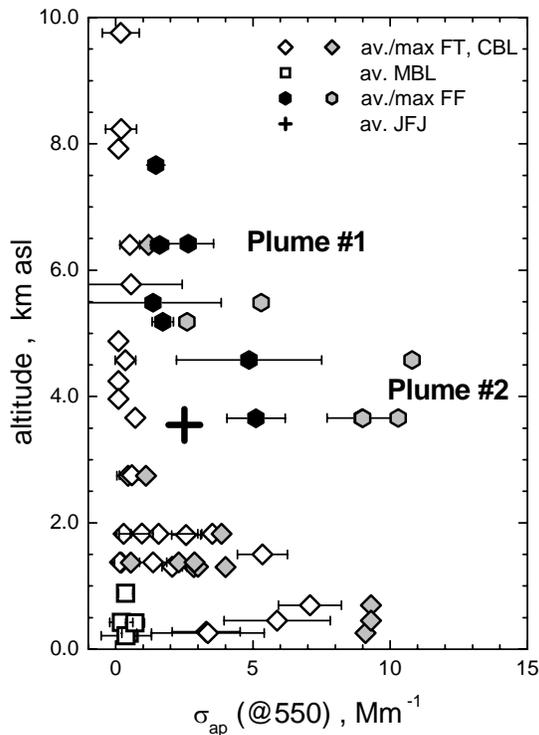


Figure 2. Vertical profile of the aerosol absorption coefficient σ_{ap} at $\lambda = 550$ nm; symbols refer to free troposphere data FT, continental boundary layer data CBL, marine boundary layer data MBL, forest fire plumes FF, and Jungfrauoch data JFJ.

Absorption coefficient values originate from PSAP data which imply that only flight sequences at constant pressure levels could be analysed. The maximum observed absorption coefficient values found in forest fire Plume #2 reached up to 10 Mm^{-1} , corresponding to values observed in the continental BL. The values measured at the JFJ station fit well into the scheme and agreed with the absorption coefficient data measured at the base of the forest fire layer. Marine boundary layer data were generally below 1 Mm^{-1} .

Figure 3 shows an example of a size distribution measured inside Plume #2, which was the densest forest fire layer encountered during ITOP. The size distribution in Figure 3 corresponds to the maximum σ_{ap} value for forest fire layers in Figure 2. Key features of the size distribution are the complete absence of nucleation mode particles, an almost depleted Aitken mode and an enhanced accumulation mode compared to the undisturbed background aerosol. This finding is in excellent agreement with results from earlier forest fire plume observations (e.g., Petzold et al., 2002) and with vertical profiles of aerosol size distributions inverted from DMA data.

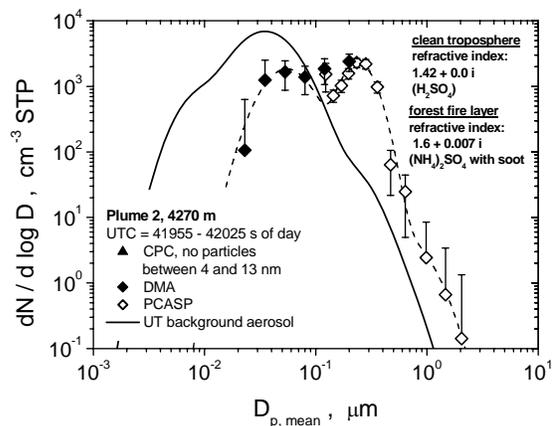


Figure 3. Composite size distribution in Plume #2 (Condensation Particle Counters CPC, DMA, Passive Cavity Aerosol Spectrometer Probe PCASP and Forward Scattering Spectrometer Probe FSSP 300); the solid line represents a size distribution in the clean UT.

Volatility analyses of Aitken and accumulation mode particles indicated that the accumulation mode aerosol inside these forest fire plumes was completely internally mixed with all particles containing nonvolatile cores, while in the clean background aerosol at higher altitudes a considerable fraction of entirely volatile particles was found even in the accumulation mode. The forest fire plumes also showed enhanced CO mixing ratios.

An overview over the aerosol properties as a function of the plume age will be given based on a large set of investigated plume events. Consequences for the impact of forest fire layers on the atmospheric radiation budget and air quality will be discussed.

Keywords: biomass burning aerosol, forest fire aerosol, black carbon, long-range transport

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Part of this work was supported by the Deutsche Forschungsgemeinschaft within the project SAMUM under Contract No. Pe 632/2-1.