



Characterization of an intercontinental smoke transport event from America to Europe in September 2020 using Aeolus Baseline16 data and multi-platform data

Kangwen Sun^{1,2}, Guangyao Dai², Dimitri Trapon¹, Songhua Wu², Holger Baars¹, Albert Ansmann¹

1 Leibniz Institute for Tropospheric Research, Leipzig, Germany
2 College of Marine Technology, Faculty of Information Science and Engineering, Ocean University of China, Qingdao, China
contact: ksun@tropos.de



Introduction

In September 2020, **massive wildfires** in the western United States, especially in California, emitted vast quantities of **biomass burning aerosols**, including **organic carbon and black carbon**. These aerosols were lofted into the free troposphere and transported across continents. Leveraging the unique capabilities of the **high spectral resolution lidar ALADIN** onboard Aeolus satellite, combining data from multi-platform, involving, CALIOP onboard CALIPSO, MODIS onboard Aqua and Terra, and MERRA-2 reanalysis model, this study mostly focus on the **identification of the smoke transport process**, **methodology to derive smoke optical properties** from Aeolus Baseline16 products, and **characterization of the smoke plumes** via extinction coefficients and lidar ratios.

Data and models

Data source	Products
ALADIN/Aeolus	L2A product (Particle optical properties, etc.)
CALIOP/CALIPSO	L2 VFM product (Aerosol subtypes)
MODIS/Aqua&Terra	AOD@550 nm (daily)
MERRA-2	Column mass concentration (CMC) of organic carbon, black carbon and dust (hourly)

Methodology

- **Step 1-Determine the general region and period of the smoke transport:**
 - 1.1 using temporal-averaged smoke CMC from MERRA-2
 - 1.2 verified by smoke aerosol dominant examination using Aerosol subtypes statistical analysis from CALIOP
- **Step 2-Select the Aeolus tracks crossing the smoke plumes from the beginning of the transport to the end**, with the assistance of hourly CMC from MERRA-2.
- **Step 3-derive smoke data from Aeolus products:**
 - 3.1 Quality control: 1) use "bin-1-clear" flag, 2) outlier elimination (backscatter coefficient (β) > 30 Mm⁻¹sr⁻¹, extinction coefficient (α)>600 Mm⁻¹)
 - 3.2 Cloud screening: cloud flag (RH>80% or Rb= β/β_m >2.5)
 - 3.3 Smoke data selection: retain data with 1) CMC-smoke>15mg/m², 2) CMC-smoke/CMC-all>0.6
 - 3.4 β correction: with circular depolarization ratio (δ) of 0.22 derived from linear δ of 0.1 [Hu et al., 2022]
 - 3.5 Smoke α and β extension: using 1) original α and β , 2) averaged lidar ratio (LR) of one smoke cross-section (only within the range of 40 sr to 120 sr [Flousti et al., 2023])

Results

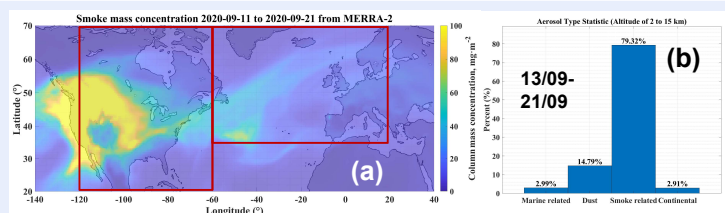


Fig. 1: (a) Integrated smoke CMC in America-Atlantic-Europe region from 11st to 21st September 2020, (b) Statistical analysis of aerosol type in the red-box region.

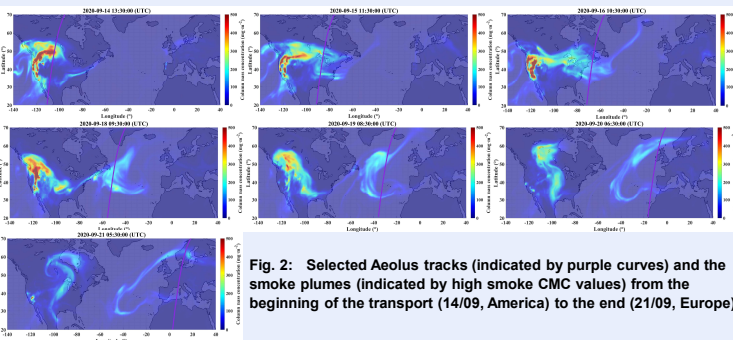


Fig. 2: Selected Aeolus tracks (indicated by purple curves) and the smoke plumes (indicated by high smoke CMC values) from the beginning of the transport (14/09, America) to the end (21/09, Europe).

- Red-box region in Fig. 1(a) is likely to be the main region of the smoke transport event, which was dominated by smoke aerosol (around 80%).
- The selected Aeolus tracks (all descending) crossed the smoke plumes, had potential to capture and observe the smoke layers.

Results

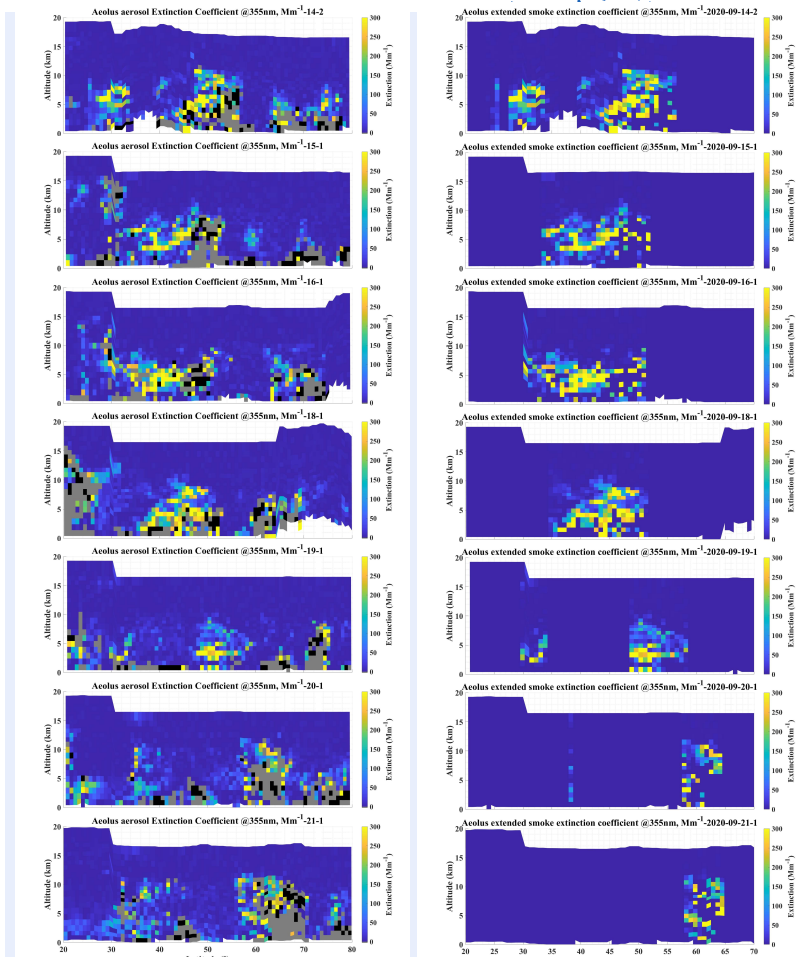


Fig. 3: Left column: Aeolus a cross-sections of the same tracks as presented in Fig. 2, have been processed with step 3.1 and step 3.2 of the methodology. The gray bins indicate the clouds while the black bins indicate the invalid data. Right column: Smoke a cross-sections of the same tracks as presented in Fig. 2, have been processed with step 3.1 to step 3.5 of the methodology. Only smoke α were plotted in these figures.

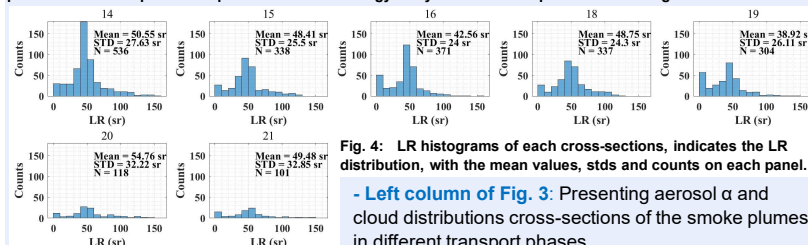


Fig. 4: LR histograms of each cross-sections, indicates the LR distribution, with the mean values, stds and counts on each panel.

- Left column of Fig. 3: Presenting aerosol α and cloud distributions cross-sections of the smoke plumes in different transport phases.
- Left column of Fig. 3: On 14th to 19th, the aerosol layers were mostly beside the clouds, while they might be elevated to be above the clouds on 20th and 21st.
- Right column of Fig. 3: Describing the characteristics of smoke layers in different transport phases. Smoke α (indicating intensity) decreased. Layers' top firstly turned down then up. Smoke plume seemed to be separated to two (strong/north and weak/south) on 19th.
- Fig. 4: Smoke LRs are within the reasonable range and expected tendency for aged smoke [Ansmann, 2021], but except for 20th and 21st (may be because the less counts).

Conclusion and outlook

- With the Aeolus observations and the methodology proposed in this study, it becomes feasible to conduct 3-D Characterization of smoke transport.
- Further verification both for smoke α and the transport trajectory should be considered.
- Potentials: Calculation of volume concentration, mass concentration, etc., based on smoke α . Quantitative analysis of the smoke transport intensity combining wind data from Aeolus

Reference

- Ansmann, A. et al.: Tropospheric and stratospheric wildfire smoke profiling with lidar: mass, surface area, CCN, and INP retrieval, Atmos. Chem. Phys., 21, 9779–9807, 2021.
- Flousti, A. A. et al.: DeLiAn – a growing collection of depolarization ratio, lidar ratio and Angström exponent for different aerosol types and mixtures from ground-based lidar observations, Atmos. Meas. Tech., 16, 2353–2379, 2023.
- Hu, Q. et al.: The characterization of long-range transported North American biomass burning plumes: what can a multi-wavelength Mie-Raman-polarization-fluorescence lidar provide?, Atmos. Chem. Phys., 22, 5399–5414, 2022.