Satellite Monitoring of the Biomass-burning Aerosols during the Wildfires of August 2021 in Greece

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Introduction

Greece is located in the Eastern Mediterranean and exhibits favorable conditions for forest fires during the summer period. In the first two weeks of August 2021, Greece has suffered a series of wildfires that have burned a large swath of the island of Evia and several areas of the Peloponnese (50,000 hectares). The present study aims at analyzing the impact of these fire events over Greece on atmospheric aerosol load using satellite data. Satellite information for aerosol height in the free troposphere can provide value to the atmospheric modeling community by improving air quality forecasting and providing improved air quality and radiative forcing studies. Lidar profiles from the PANhellenic GEophysical observatory of Antikythera (PANGEA) can be used to verify the location of the aerosol layer in the atmospheric column and compare with the layer height retrieved by the satellite algorithms. A synergy of satellite data from TROPOMI will be used to derive the aerosol optical and geometrical properties, during biomass burning events observed over Greece in the summer fire season. The measurements allowed us to monitor the evolution of fresh smoked aerosol, in terms of their vertical distribution, as well as to analyze its optical and geometrical properties.

Data

TROPOMI/S5P satellite data (UVAI, ALH & CO)

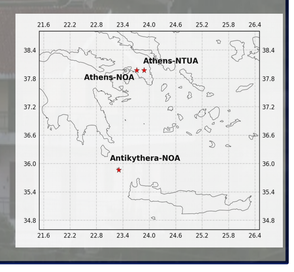
- We use the OFFL Level-2 Data for Aerosol index (UVAI), Aerosol layer height (ALH) and Total CO column products. (Data available at: **https://s5phub.copernicus.eu/dhus/#/home)**
- The S5P UV Aerosol index indicates the presence of elevated absorbing aerosols in the Earth's atmosphere. Is useful for tracking global transport of smoke aerosols and dust particles, for it is not as affected by clouds as are most other aerosol products.
- The TROPOMI Aerosol Layer Height (ALH) focuses on retrieval of vertically localized aerosol layers in the free troposphere, such as desert dust, biomass burning aerosol, or volcanic ash plumes in layers for cloud-free scenes **[1]**. Is very sensitive to clouds and the height will be strongly biased towards the cloud height for partially clouded pixels.
- The total CO columns retrievals reflect the advection of the fire emissions around the burned study areas.
- Only retrieval values that passed quality checks (QAC) are included in the analysis study.

Ground-based lidar measurements

- EARLINET **[2]** SCC Lidar backscatter coefficient profiles from the PollyXT lidar in PANGEA, Antikythera station are used.

AERONET columnar measurements

- The level-1.5 direct products of aerosol optical depth (AOD) and Angstrom Exponent (AE) data are obtained from AERONET sun-photomoeter network measurements at three Greek stations **ATHENS_NOA (37.97°N, 23.72°E), ATHENS_NTUA (38.97°N, 23.78°E)** and **Antikythera_NOA (35.86°N, 23.31°E)** during the study period (4-10 Aug 2021).



Data analysis & Results

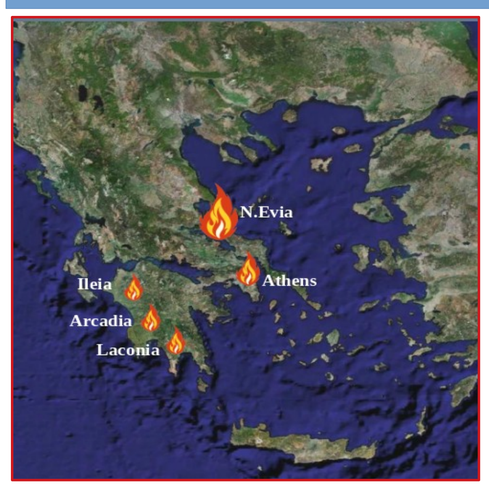


Figure 1. Location of the main summer wildfire study areas within Greece: **N.Evia, Athens**, and **Peloponnese** which saw multiple large-scale and high intensity wild land fire events during August 2021.

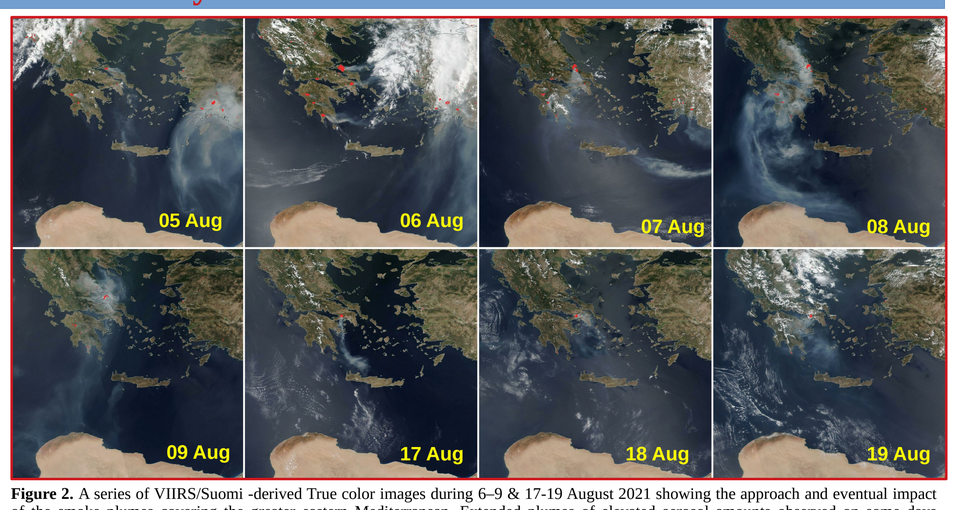


Figure 2. A series of VIIRS/Suomi -derived True color images during 6–9 & 17-19 August 2021 showing the approach and eventual impact of the smoke plumes covering the greater eastern Mediterranean. Extended plumes of elevated aerosol amounts observed on some days downwind of the fires (**https://wvs.earthdata.nasa.gov**).

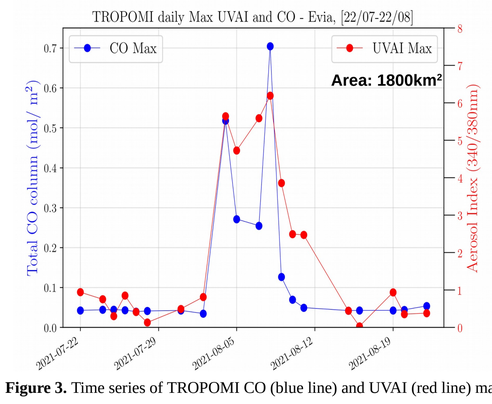
Satellite imagery Visible Infrared Imaging Radiometer Suite **(VIIRS)** on the Suomi-NPP platform sensor used to visualize the geographical distribution of the aerosol plumes.

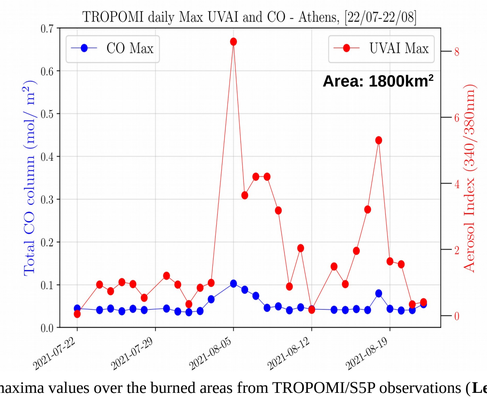
Spatio-temporal analysis for UVAI retrievals and CO emissions through the S5-P TROPOMI measurements.

High **CO** + **UVAI** retrievals ➡ Absorbing aerosols

- **Max. CO:** ~0.7 mol/m² (N.Evia), ~0.25 mol/m² (Pelop.), ~0.11 mol/m² (Athens)
- **Max. UVAI:** ~6.2 (N.Evia), ~ 4.8 (Pelop.), ~8.1 (Athens),

CO and UVAI daytime distributions show good consistency in terms of temporal and spatial patterns [22/07-22/08]





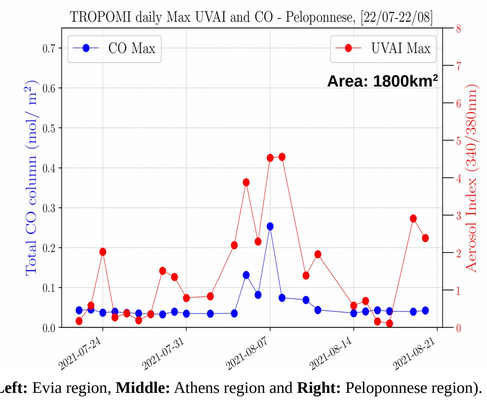
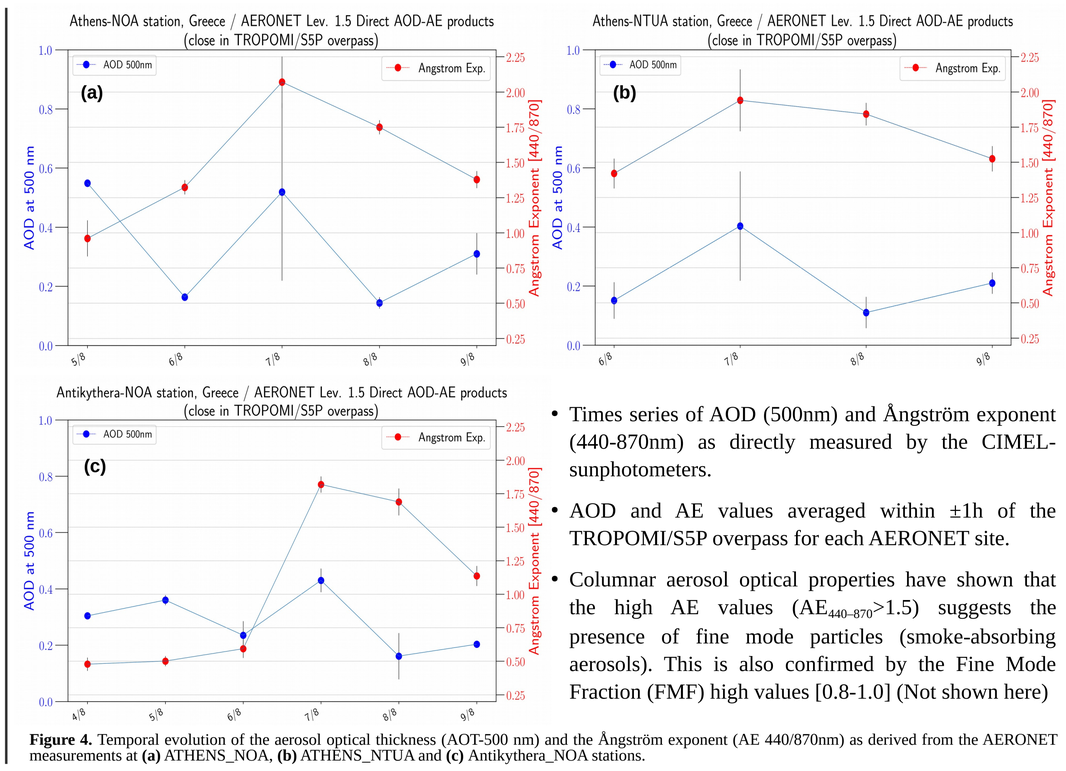


Figure 3. Time series of TROPOMI CO (blue line) and UVAI (red line) maxima values over the burned areas from TROPOMI/S5P observations (**Left:** Evia region, **Middle:** Athens region and **Right:** Peloponnese region).



- Times series of AOD (500nm) and Ångström exponent (440-870nm) as directly measured by the CIMEL-sunphotometers.
- AOD and AE values averaged within ±1h of the TROPOMI/S5P overpass for each AERONET site.
- Columnar aerosol optical properties have shown that the high AE values ($AE_{440-870}$>1.5) suggests the presence of fine mode particles (smoke-absorbing aerosols). This is also confirmed by the Fine Mode Fraction (FMF) high values [0.8-1.0] (Not shown here)

Figure 4. Temporal evolution of the aerosol optical thickness (AOT-500 nm) and the Ångström exponent (AE 440/870nm) as derived from the AERONET measurements at **(a)** ATHENS_NOA, **(b)** ATHENS_NTUA and **(c)** Antikythera_NOA stations.

Case study over PANGEA (Antikythera) station

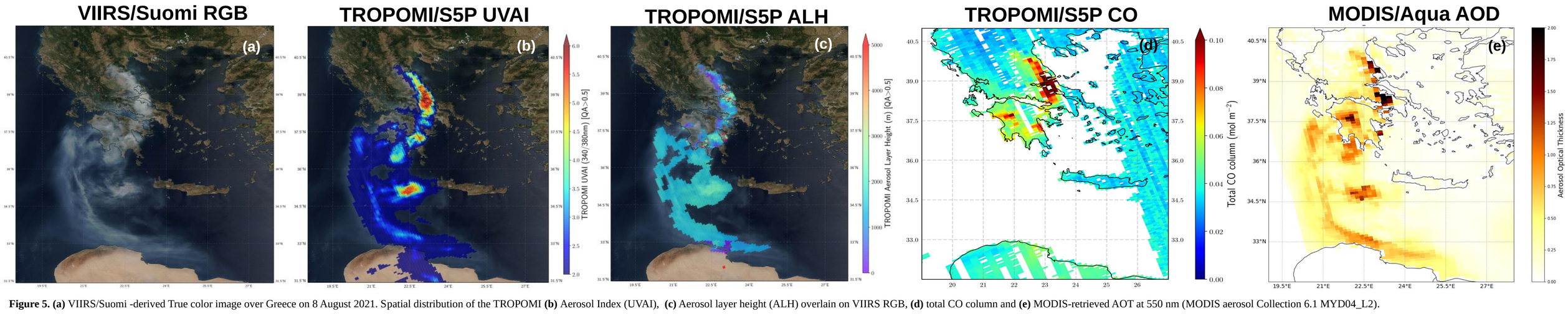
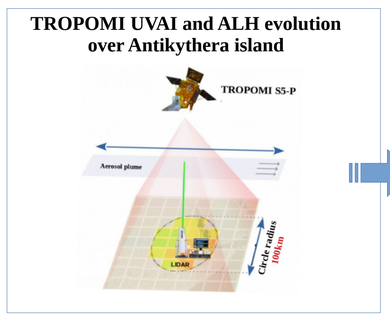


Figure 5. (a) VIIRS/Suomi -derived True color image over Greece on 8 August 2021. Spatial distribution of the TROPOMI **(b)** Aerosol Index (UVAI), **(c)** Aerosol layer height (ALH) overlain on VIIRS RGB, **(d)** total CO column and **(e)** MODIS-retrieved AOT at 550 nm (MODIS aerosol Collection 6.1 MYD04_L2).

Antikythera site

Antikythera site is considered as reference for the extended eastern Mediterranean area (PANGEA observatory). Details about the Antikythera area morphology and meteorological conditions are provided by **[3]**. The station is considered as a remote background site, established and operated by the National observatory of Athens (NOA).

Polly^{XT}_NOA lidar is a fully automated instrument capable of 24/7 operation equipped with three elastic backscatter channels, at 355nm, 532nm and 1064nm, two rotational-vibrational Raman channels, at 387nm and 607nm and two linear depolarization channels at 355nm and 532nm. Is located at Antikythera island **(23.31°E, 35.86°N)**



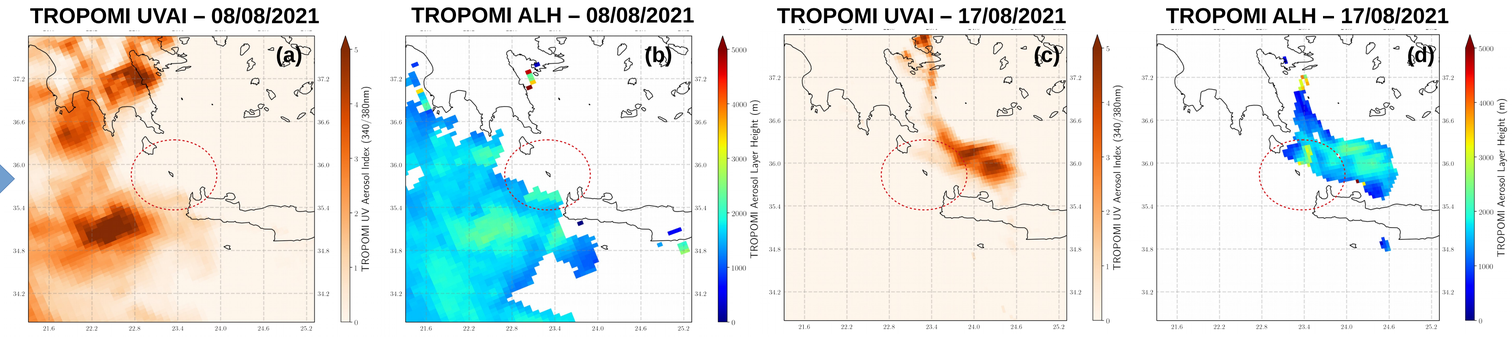


Figure 6. (a,c) Retrieved UV absorbing aerosol index (340/380nm) and **(b,d)** aerosol layer height from TROPOMI measurements around Antikythera island on 8th and 17th of August 2021.

- During the biomass burning events of August 4-9, 17-19 August 2021, continuous lidar measurements at PANGEA (Antikythera) station have been performed to observe the optical and microphysical properties of the fresh-smoke emitted particles in the PBL and the lower free troposphere.

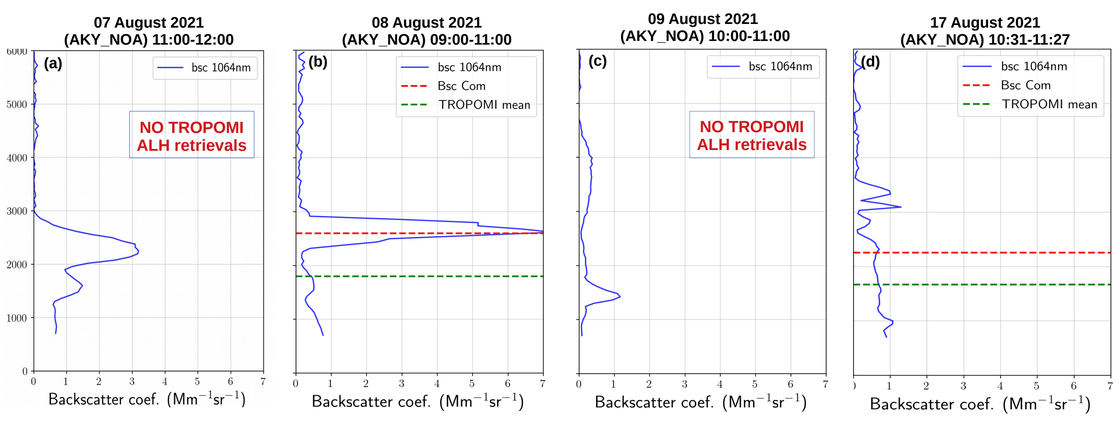


Figure 8. Backscatter coefficient profiles at 1064 nm on 7th, 8th , 9th **(a-c)** and 17th **(c)** of Aug 2021 by PollyXT lidar system at PANGEA site (close in TROPOMI overpass time). For 8 and **(b)** and 17 Aug **(d)** green dashed line represent TROPOMI ALH, and blue line represent the calculated lidar ALHbsc **[5]** (Products and analysis are provided by *NOA React team*).

Backscatter profiles (1064nm) analyzed to determine the ALH_{bsc} **[5]**

8 Aug 2021	17 Aug 2021
ALHbsc = 2590m	ALHbsc = 2252m

Difference (TROPOMI ALH – Lidar ALH_{bsc}) < 1km

Table 1. TROPOMI ALH observations co-located with the Antikythera site by averaging all TROPOMI retrievals within a radius of 100 km around lidar site on 8 and 17 August 2021.

Date	Orbit	R (km)	Mean±STD (m)	Min (m)	Max (m)
8 August	19792	100	1790±237	1355	2355
17 August	19920	100	1665±442	554	3317

✔ The ALH retrieval is performed **only** for positive AI values absorbing aerosols **[4]**

Summary

- Smoke plumes were emitted from the N.Evia, Athens and Peloponnese and highly impacted the South Greece for about 5-10 days.
- Results from three AERONET sites during the August 2021, combining TROPOMI/S5P overpasses with detailed lidar measurements have been presented.
- TROPOMI retrievals reveal that UVAI and CO values during summer wildfires are significantly increased in comparison to other days without fire events.
- A direct comparison of the PollyXT bsc profiles & TROPOMI ALH for selected co-located cases is presented for scenes containing aerosols.

References & Acknowledgments

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