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Study of Verticle Distribution of Aerosols during Central Portugal Forest Fire Event using Remote Sensing Data

Arka Ghosh[1], Manu Mehta[2] and Soubhik Biswas[3]

[1]Pondicherry University Pondicherry, India
[2]Indian Institute of Remote Sensing, ISRO Dehradun, Uttarakhand, India
[3]Pondicherry University Pondicherry, India
E-mail: [1]aghoshpro@gmail.com, [2]manu@iirs.gov.in, [3]gozkid@gmail.com

Abstract—*On 18th June, 2017 an ample amount of smoke plume had been dispersed into the atmosphere during the raging forest fire event which had taken place in Central Portugal, thereby affecting the air quality, vegetation, socioeconomic life of the surrounding regions. This study deals with the vertical profile of aerosols during forest fire. The vertical profile data is taken from CALIOP on board CALIPSO satellite. We have presented the aerosol vertical distribution before and after the fire event happened in the study area also the smoke aerosol detection of that area has been carried away with CALIPSO vertical feature mask data.*

1. INTRODUCTION

In this study we are using NASA's CALIPSO satellite data to observe a forest fire event. Every year an ample amount of aerosols released from wildfires and dust storms into the earth's atmosphere that may have potential impacts on the earth's climate, environment, and air quality. Detecting smoke aerosols and monitoring their movements and evolutions in a daily manner may have serious implication in climate and health.

2. STUDY AREA

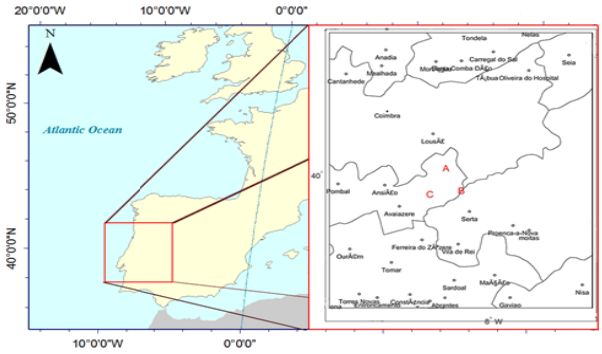


Figure 1: This map has been created with ArcMap 10.3 and MATLAB with the WGC_1984 Geographic Coordinate System Map of Central Portugal showing three places A, B, C affected by the forest fire

We choose this study area as many fire events are getting reported in the whole Mediterranean region [1] from past few years and this area has recently been suffered a raging forest fire as described in *Fig 3* in the RESULTS AND DISSCUSSION section. This area is a prime study area where a raging forest fire incident had taken place on 18th June 2017 and continued to the date 24th 7une, 2017. Because of fire event there is a huge probability that traces of smoke plume may be found in this area. So we defined this area as "source". More precisely 3 local places as shown in Fig 1 marked as A, B, C in District of Leiria, Central Portugal has been chosen for this study as these places had been mostly affected due to the forest fire.

A. Castanheira de Pêra (40°0'21.05"N, 8°12'45.14"W)
- Area Coordinates: 39.9459469, -8.2414562 40.0622570, -8.1654847
- Elevation: 478.73 Meters above sea level

B. Pedrógão Grande (39°55'4.21"N, 8°8'44.92"W**)**
- Area Coordinates: 39.8502554, -8.2614076 40.0364608, -8.1080376
- Elevation: 395.15 Meters (1296.43 Feet) above sea level

C. Figueiró dos Vinhos (39°54'9.66"N, 8°16'33.9"W)
- Area Coordinates: 39.7932137, -8.3639753 40.0673376, -8.2097490
- Elevation: 445 Meters (1,460 feet) above sea level

3. DATA USED

3.1 Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

CALIPSO provides, from space, the first global survey of cloud and aerosol profiles and physical properties, with seasonal and geographical variations. CALIPSO is known for

its unique capability to gather information about the vertical profiles of clouds and aerosols and their over-lap which is not available from other EOSs. These observations, when combined with coincident data from other missions, will greatly enhance our understanding of how aerosols and clouds interact, the quantity of aerosols produced worldwide, how aerosols are transported and how long they remain in the atmosphere. We have used CALIPSO L2 5 km Aerosol Profile Standard Products at night time as daytime CALIPSO observations are affected by solar background illumination, which decreases the signal-to-noise ratio, making the daytime measurements more challenging to interpret [2]. CALIPSO satellite provides backscatter coefficients, Depolarization Ratio, Color Ratio. A set of CALIPSO L2 data parameters and equations are given in the Table 1.

Table 1

Symbol	CALIPSO Parameter Name
$\beta_{512,Total}$	Total Particle backscatter coefficient in 532nm
$\beta_{532,\perp}$	Perpendicular particle backscatter coefficient in 532nm
$\beta_{532,\parallel}$	Parallel particle backscatter coefficient in 532nm
β_{1064}	Particle backscatter coefficient in 1064nm
$\delta_v(z)$	Particulate Depolarization Ratio 532 nm
χ_{color}	Color Ratio

3.2 Equations

- Total Particle backscatter coefficient in 532nm

$$\beta_{532,Total} = \beta_{532,\perp} + \beta_{532,\parallel}$$

- *Particulate Depolarization Ratio 532 nm*

$$\delta_v = \frac{\beta_{532,\perp}}{\beta_{532,\parallel}}$$

- Color Ratio is ratio of the particle backscatter at 1064 to 532 nm

$$\chi_{color} = \beta_{1064} / \beta_{532,Total}$$

3.3 CALIPSO Vertical Feature Mask

The CALIPSO Level 2 Lidar Vertical Feature Mask (VFM) consists of a sequence of bit-mapped integers, with one 16-bit integer being recorded for each range resolution element in the Level 0 Lidar data downlinked from the satellite [8]. Decoding the bits in the individual integers yields information on feature type (e.g., cloud, aerosol, or clear air) and subtype (e.g., water cloud or ice cloud) at each cross points of latitude and longitude. For our analysis we use CALIPSO Level 2 Lidar vertical feature mask (VFM) standard data product describes the vertical and horizontal distribution of cloud and aerosol layers observed by the CALIOP sensor [3,5,9,10].We use the data product Feature Classification Flags (FCF) For each layer detected in the CALIPSO backscatter data, we derive a set of feature classification flags that report (a) feature type (e.g., cloud, aerosol, stratospheric layer, surface); (b) feature subtype - aerosol type(dust marines, elevated smoke, polluted dust) shown in *Fig 6*. For further information, including instrument specifications, we refer to [8].

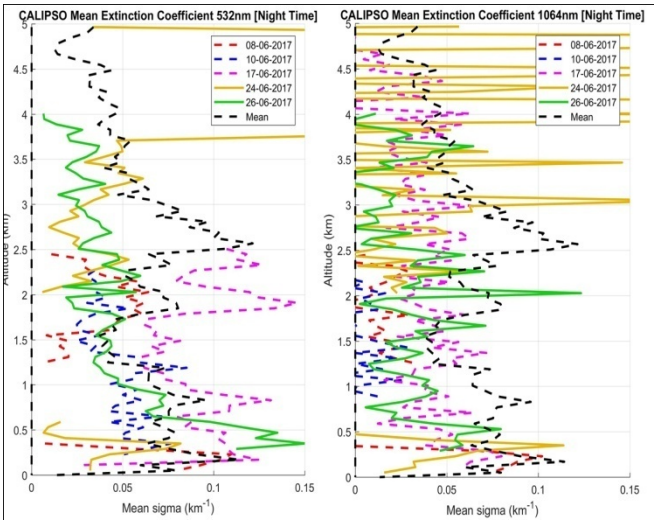
4. RESULT AND DISCUSSION

Observation of The Forest Fire Event at Central Portugal from satellite data

Central Portugal Forest Fire

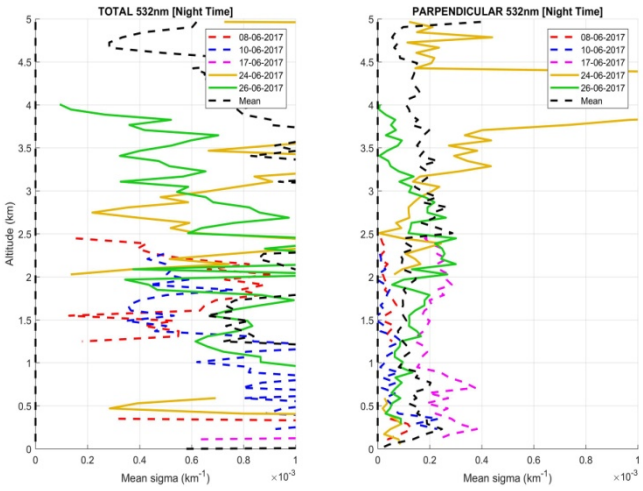
Figure 2: MODIS/NASA **satellite true color image of the fires of Central Portugal and associated smoke plumes drifting into Northern Portugal and Spain on 18 June, Image courtesy: Jeff Schmaltz LANCE/EOSDIS MODIS Rapid Response Team, GSFCASA [4]**

Wildfires have been identified as the most important threat to forests in Mediterranean Region especially in Europe which is regularly affected by large and destructive fire events [6-7]. These weather-based hazards represent a serious problem to modern societies, with great negative impacts at social, economic and ecological levels and causing significant human casualties [8]. In this context we have found a striking illustration of raging forest fire event of huge magnitude has been observed as a recent tragic episode of June 18, 2017 that took place in central Portugal at Castanheira de Pêra, Pedrógão Grande, Figueiró dos Vinhos with an official death toll of 64 people and 220 injuries. In *Fig 3* a true-color image is being shown that is captured and processed by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board NASA's Terra satellite on June 18, 2017. The actively burning regions, detected by MODIS's thermal bands, are outlined in red. We can easily observe lots of smoke plumes were there in the study area due to forest fire event and they were also seen drifting into Spain as well [4].



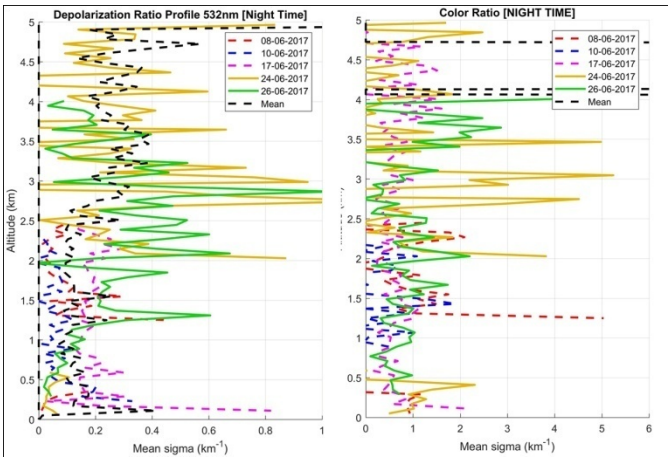
(a) **(b)**

Figure 3(a - b) shows the comparison between CALIPSO Mean Extinction Coefficient at 532nm and 1064nm of five different dates over our study area. We have calculated the Mean of the clean day (Before the Fire event) values. The forest fire incident had taken place on 18.06.2017.



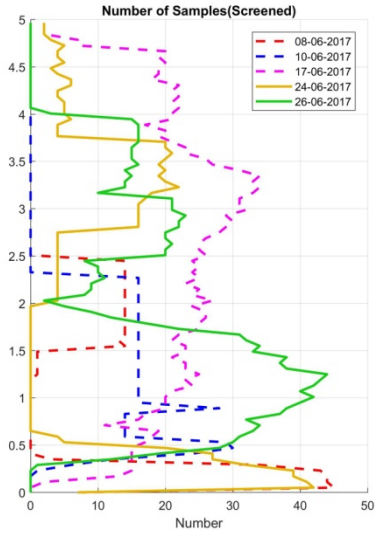
(c) **(d)**

Figure 3(c - d) shows the comparison between CALIPSO Total and Perpendicular Backscatter Coefficient at 532nm of five different dates over our study area. We have calculated the Mean of the clean day (Before the Fire event) values. The forest fire incident had taken place on 18.06.2017



(e) **(f)**

Figure 3(e - f) shows the comparison between CALIPSO Particulate Depolarization Ratio 532 nm and Color Ratio of five different dates over our study area. We have calculated the Mean of the clean day (Before Fire event) values showing in black. The forest fire incident had taken place on 18.06.2017



(g)

Figure 3(g) shows the number of samples collected by the CALIPSO satellite of five different dates over our study area at night time. The forest fire incident had taken place on 18.06.2017

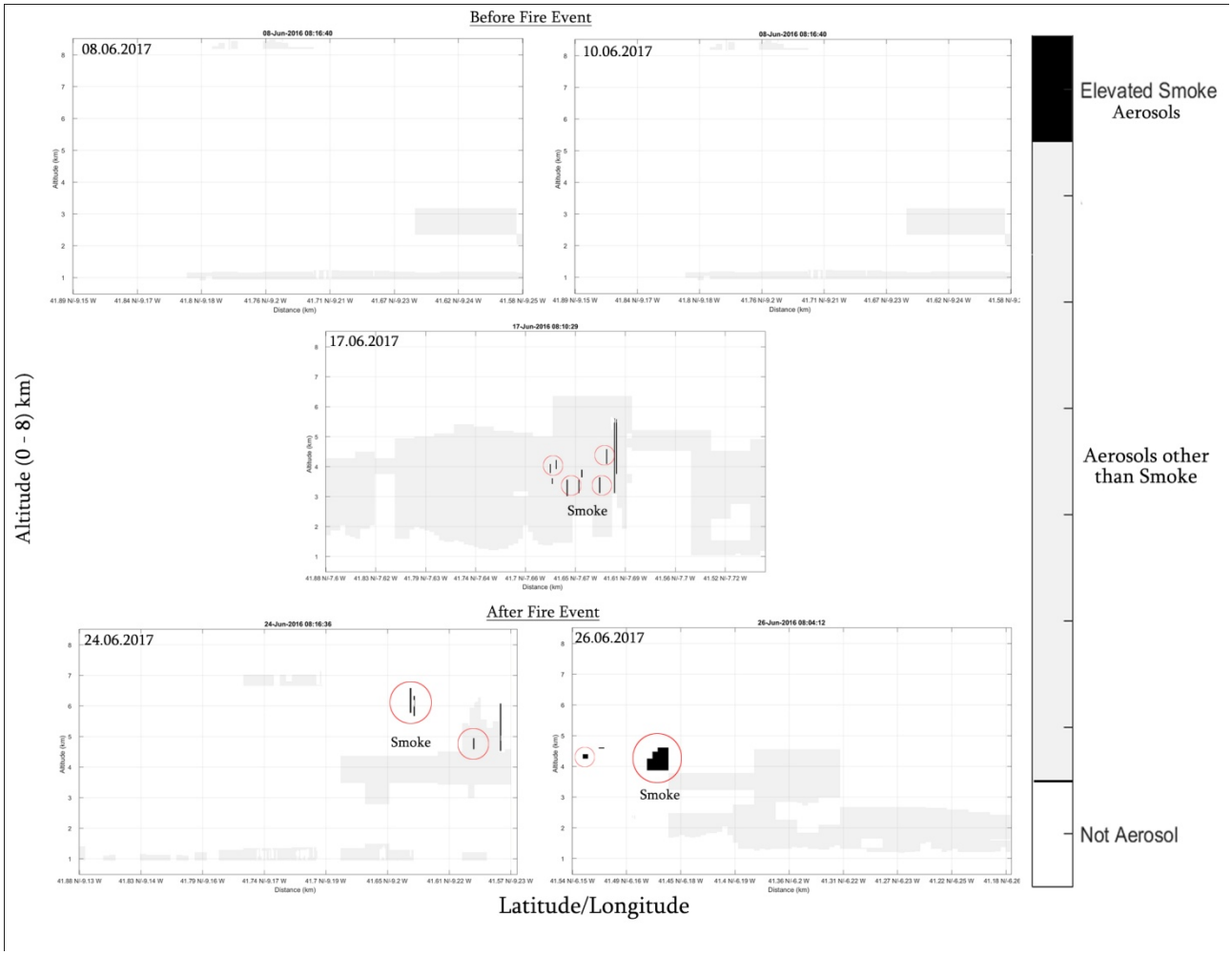


Figure 4: Comparison of Aerosol type derived from CALIPSO Vertical Feature Mask L2 product over the Study Area. The first two figure depict the condition before the fire event and last two depicts the situation after the fire event. The detection of smoke is displayed here as we can see smoke, encircled in red is found in between 4 – 6 km altitude and over a large geographical span.

5. CONCLUSION

The study gives an insight into the quantification of aerosol vertical profiles before and during the fire event took place in the study region. Further study can be made on the transport of air parcels containing smoke aerosols which might have impacts on the other regions in the Europe. Hence, the further efforts would be made to find out the potential sink areas where the transported smoke might be accumulated and effecting vegetation, health, social life.

6. ACKNOWLEDGEMENTS

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