Complementary analysis of lunar photometry to detect wildfire emissions in Montevideo

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Abstract

Nighttime aerosol optical depth (AOD) using lunar photometry has attracted great attention in recent years due to improved ground-based lunar irradiance measurements. The night is a large window of time that is not frequently used and during which aerosol dynamics evolve under conditions different from daytime. This work shows a first approximation of a night-time analysis that complements the day-time detection of emissions from wildfires that are transported from long distances. We based on three events detected during the day and we confirm the presence of wildfire emissions by detecting high levels of formaldehyde, and then we monitor the nighttime AOD to analyze the behavior of fine particles since wildfires have a high proportion of fine particles.

Wildfires emissions

Forest fires are a critical environmental concern, particularly due to their role in aerosol emissions. The combustion of biomass releases a variety of gases and particulate matter, which undergo transformations in the atmosphere, leading to secondary pollutants. Among these, formaldehyde (HCHO) and nitrogen dioxide (NO_2) are notable for their adverse effects on human health [1, 2].

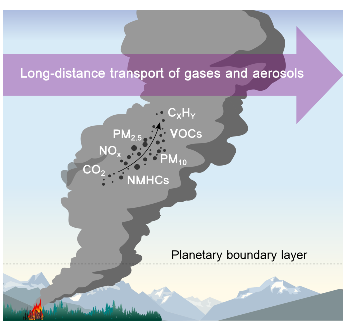

Figure 1. Typical emissions generated by a forest fire due to the combustion of leaves, branches and bark [3].

Instruments and methods

Level 1.5 and 2.0 data were used for the nighttime and daytime analyses of Aeronet, respectively. Fine and coarse mode AODs were plotted from 2020 to 2022 to identify representative cases where fine particles are elevated. A reference case from 2021 was selected, it is a confirmed event based on monitoring air mass flows to identify the origin of the emissions [4].

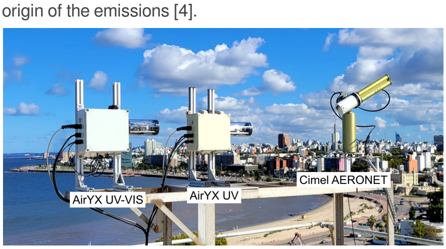

Figure 2. Instruments are installed on the roof of the Faculty of Engineering building located in Montevideo, Uruguay (34.9175° S, 56.1669° W). AirYX equipments are Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS).

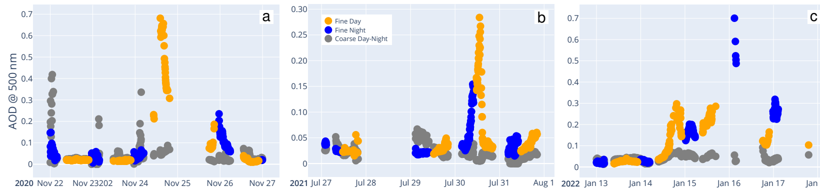

Figure 3. Aeronet Montevideo Aerosol Optical Depth Record using the 500 nm band for daytime and nighttime data. Three cases were selected in different years a) November 2020; b) July 2021; and c) January 2022.

Differential slant column densities (DSCD) were calculated using AirYX UV data for formaldehyde (HCHO) and nitrogen dioxide (NO_2), which were the molecules analyzed during the reference event. Other secondary molecules such as ozone (O_3), oxygen dimer (O_4) and water vapor (H_2O) need to be calculated to improve the DSCD approximation. Finally, the NOAA JSTAR Mapper platform was used to identify the forest fires and to determine the possible path of the emissions, including particulate matter and gases. In addition, the events were confirmed through news and government reports from different countries.

Results

Figure 4. DSCD of HCHO and NO2 for elevation angles of 2° and 3° for: a) November 2020; b) July 2021; and c) January 2022.

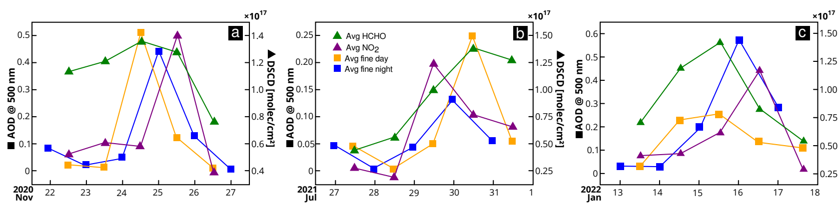

Figure 5. Average of Aeronet AOD (squares) and MAX-DOAS DSCD (triangles) per day-night period for the three selected cases: a) November 2020; b) July 2021; and c) January 2022.

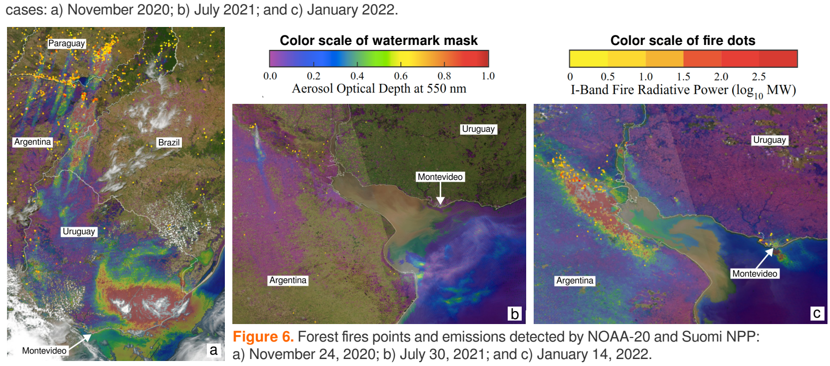

Figure 6. Forest fires points and emissions detected by NOAA-20 and Suomi NPP: a) November 24, 2020; b) July 30, 2021; and c) January 14, 2022.

Conclusions

The detection of emissions through lunar photometry, despite its limited temporal resolution, serves as a valuable tool for identifying fine particles generated by forest fires. As illustrated in Fig. 3b, a notable increase in fine particles was recorded on July 30, 2021, beginning at midnight and persisting throughout the day. This increase coincided with elevated Differential Slant Column Densities (DSCD) of NO2 and HCHO, demonstrating consistency between daytime and nighttime observations.

The relationship between fine particle presence and the increases in DSCD of NO2 and HCHO appears to be influenced by the transport speed of these substances. Further characterization is necessary to determine whether these gases arrive before or after the fine particles.

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References

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