

Abstract

Nighttime aerosol optical depth (AOD) using lunar photometry has attracted great interest 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 two events detected during the day and we confirm the presence of wildfire emissions by detecting high levels of formaldehyde, and then we monitor the Lunar AOD to analyze the behavior of fine and coarse particles since forest fires 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 (NO₂) are notable for their adverse effects on human health [1, 2].

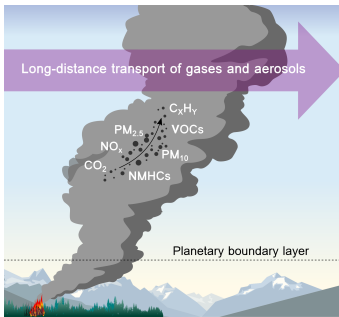


Figure 1. Typical emissions generated by a forest fire due to the combustion of leaves, branches and bark [3].

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).

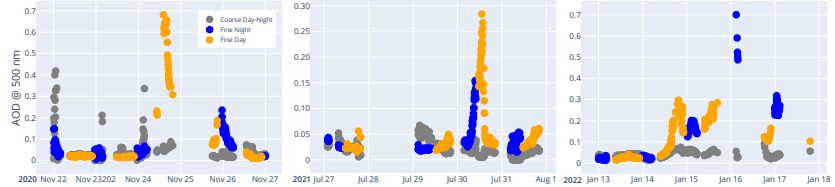


Figure 3. Aeronet Montevideo Aerosol Optical Depth Record using the 500 nm band for daytime and nighttime data. Three cases were selected in different years a) November 2020; b) July 2021; and c) January 2022.

Differential slant column densities (DSCD) were calculated using AirYX UV data for formaldehyde (HCHO) and nitrogen dioxide (NO₂), which were the molecules analyzed during the reference event. Other secondary molecules such as ozone (O₃), oxygen dimer (O₄) and water vapor (H₂O) 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

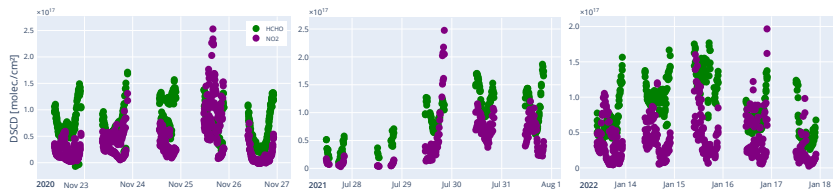


Figure 4. DSCD of HCHO and NO₂ for elevation angles of 2° and 3° for: a) November 2020; b) July 2021; and c) January 2022.

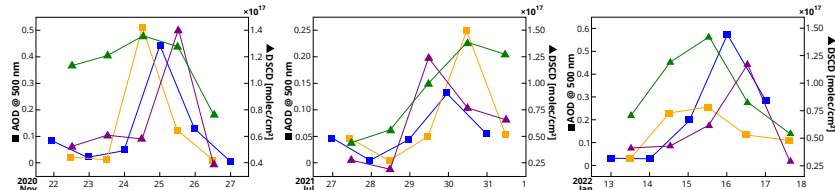


Figure 5. Average of Aeronet AOD (squares) and MAX-DOAS DSCD (triangles) per day-night period for the three selected cases: a) November 2020; b) July 2021; and c) January 2022.

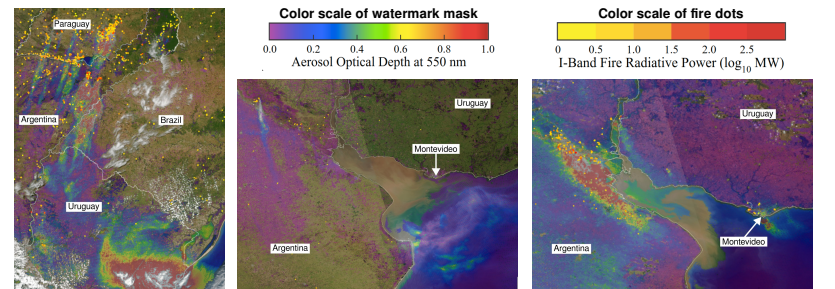


Figure 6. Forest fires points and emissions detected by NOAA-20 and Suomi NPP: a) November 24, 2020; b) July 30, 2021; and c) January 14, 2022.

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.

References

- [1] Zhang, Chunlin, et al. "Open biomass burning emissions and their contribution to ambient formaldehyde in Guangdong province, China." *Science of the Total Environment* 838 (2022): 155904.
- [2] Griffin, Debora, et al. "Biomass burning nitrogen dioxide emissions derived from space with TROPOMI: methodology and validation." *Atmospheric Measurement Techniques Discussions* 2021 (2021): 1-44.
- [3] Guo, Linfei, et al. "Emission of atmospheric pollutants during forest fire in boreal region of China." *Environmental Pollution* 264 (2020): 114709.
- [4] Osorio, M. et al. "Measurement report: Combined use of MAX-DOAS and AERONET ground-based measurements in Montevideo, Uruguay, for the detection of distant biomass burning." *Atmospheric Chemistry and Physics* 24:12 (2024): 7447-7465.