TWILIGHT ZONES AND TROPICS: CLASSIFYING DUST WHERE IT GETS COMPLICATED

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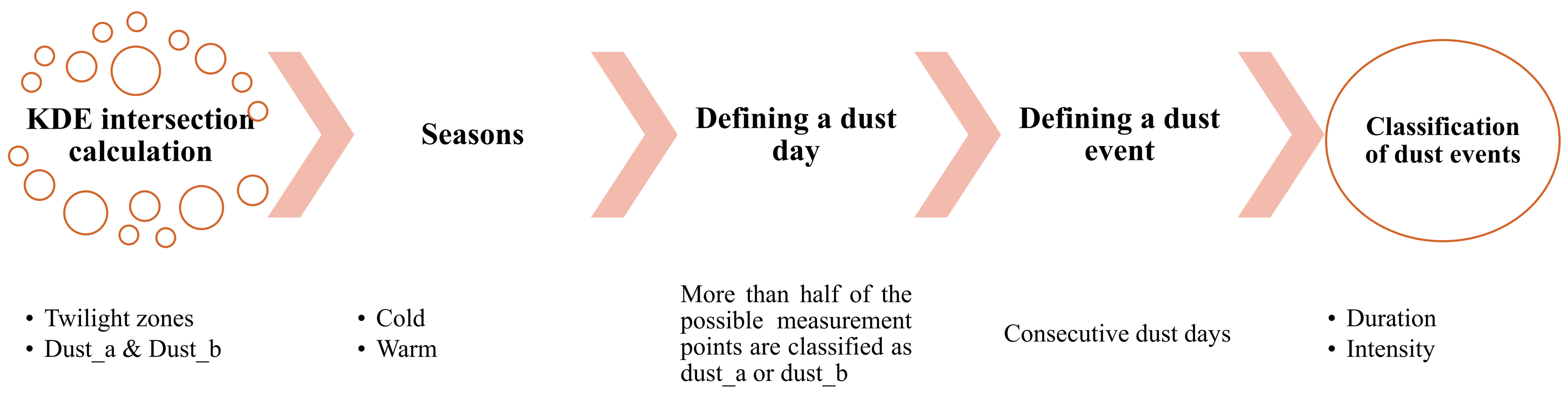
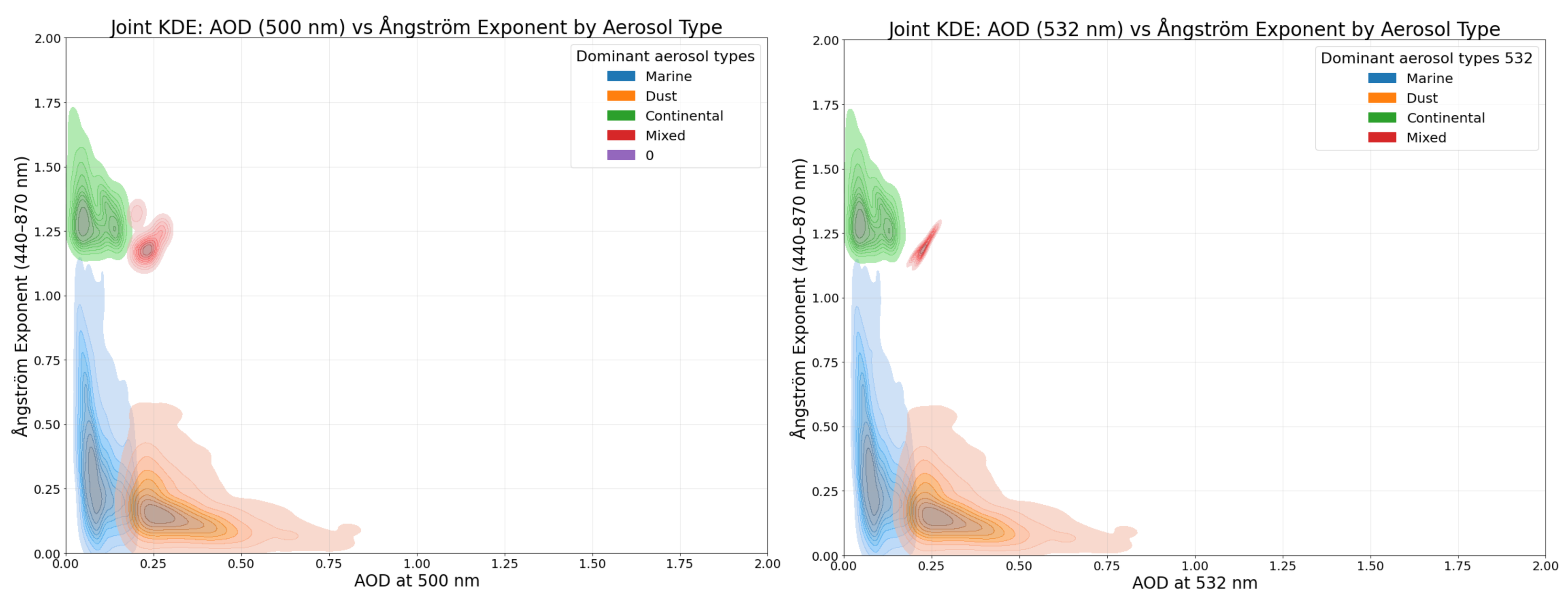
Introduction

- Atmospheric dust plays a critical role in Earth's climate system, influencing radiation budgets, cloud microphysics, and air quality. Accurate detection and classification of dust events are essential for understanding these impacts, yet methodologies often remain region-specific and dependent on particular measurement platforms.
- Recently, a clustering-based dust event classification method was developed for Romania, using Aerosol Optical Depth (AOD) at 440 nm and the Ångström Exponent (AE, 440–870 nm) derived from AERONET sun photometer data. This approach applies Kernel Density Estimation (KDE) in the AOD–AE space to identify dominant aerosol types, mixed regimes, and transitional "twilight zones."
- In this study, we assess the transferability of this method to a tropical environment by applying it to AERONET sun-photometer measurements from Barbados.
- Furthermore, to improve compatibility with lidar observations, we adapt the method by substituting the 500 nm AOD with AOD at 532 nm—a wavelength commonly used in lidar remote sensing. We compare the clustering results from both spectral configurations to evaluate the sensitivity and robustness of the classification framework under this spectral shift.

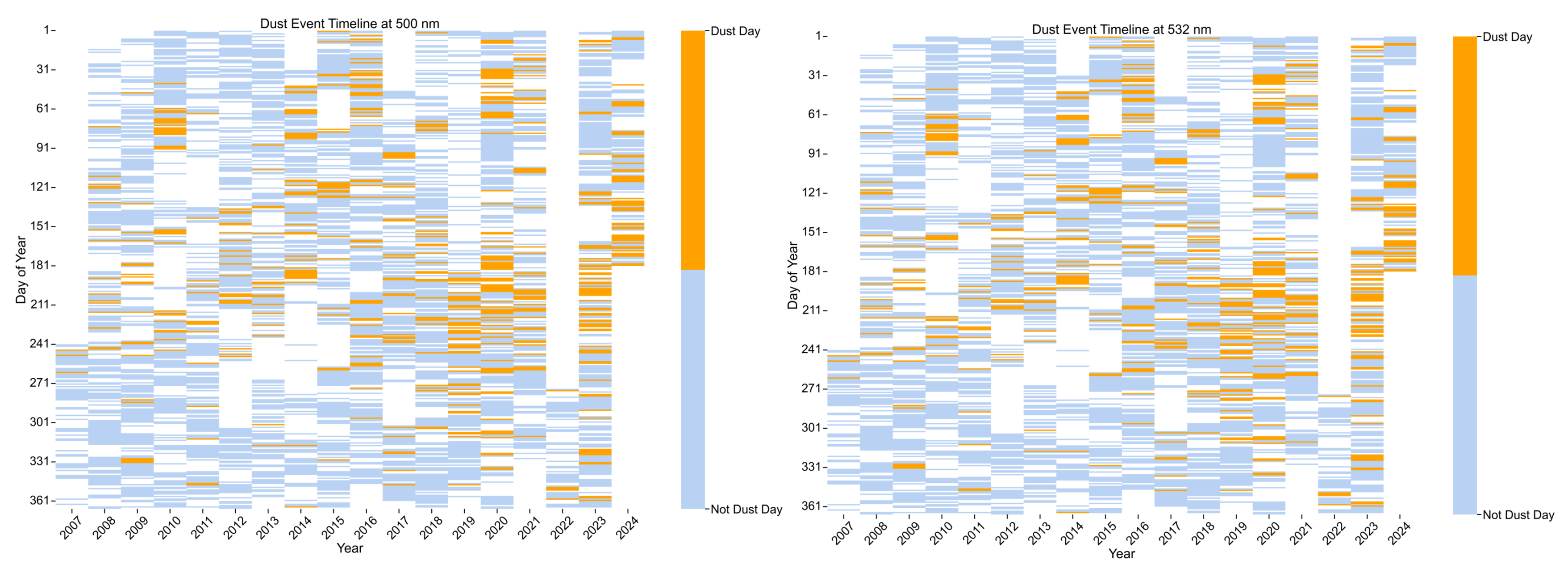
Methodology



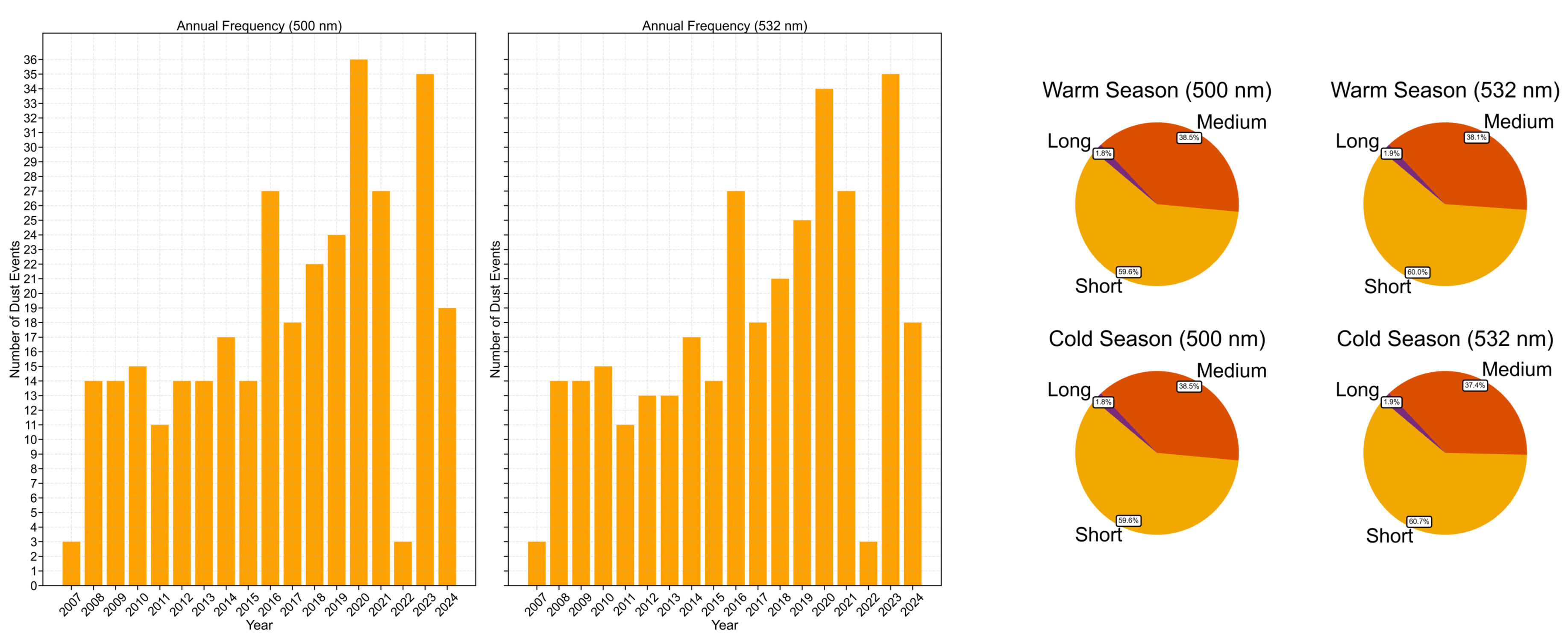
KDE distributions



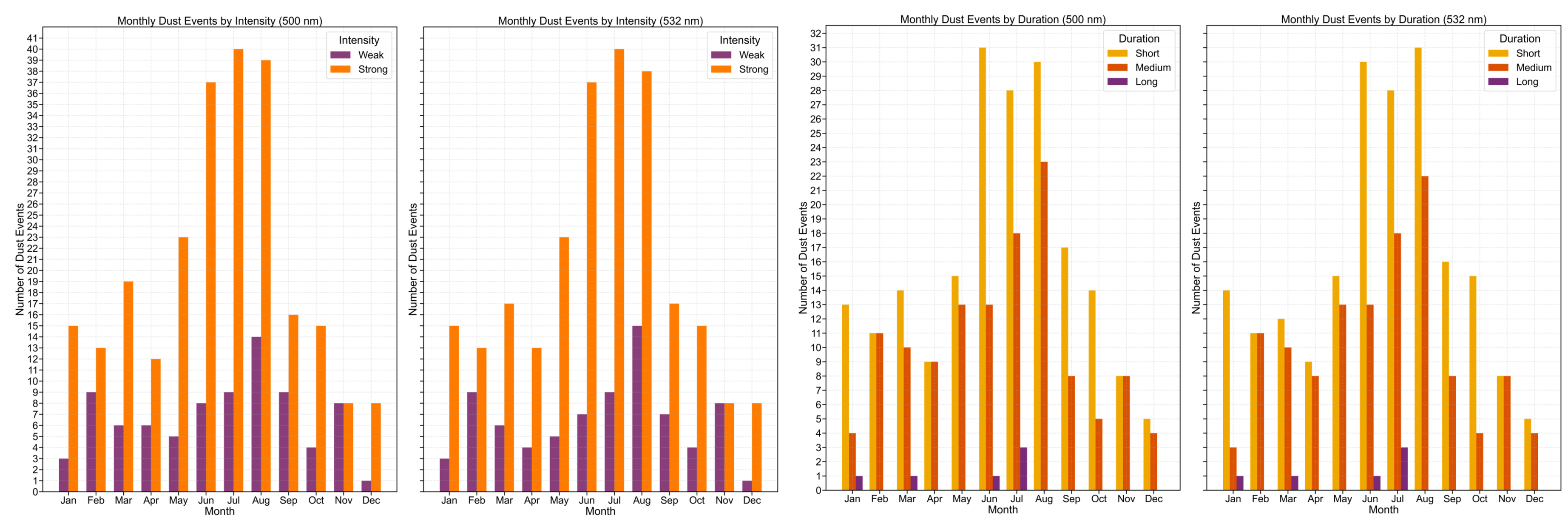
Dust Days



Dust Events Frequency



Dust Events Types



Key Results

1. Strong Spectral Agreement in Dust Event Detection

Across all diagnostic panels, the overall number and timing of detected dust events remain highly consistent between the 500 nm and 532 nm AOD configurations. Both wavelengths capture the same key features of dust seasonality, interannual variability, and event distribution patterns.

2. Expected Spectral Shift in AOD–AE Space

A systematic rightward shift in the AOD–AE joint distribution appears when using 532 nm AOD (visible in the KDE plots). This reflects the known spectral dependence of aerosol optical properties, where AOD generally decreases with increasing wavelength for coarse-mode aerosols like dust. Despite this, the dominant aerosol type classification (dust vs. others) remains stable, with a tightening of the mixed aerosol population and a reduction in non-classified cases.

3. Minimal Impact on Annual and Seasonal Statistics

The **annual frequency of dust events** shows almost identical year-to-year patterns for both configurations, including the magnitude and interannual variability. The **seasonal cycle** (monthly breakdown) is nearly unchanged, with both setups showing a summer peak dominated by strong, high-intensity events.

4. Small Shifts in Duration Distribution

A subtle increase in **medium-duration events** is visible with the 532 nm configuration, especially during the **warm season**, as reflected in both the monthly bars and seasonal pie charts. This shift likely stems from the AOD–AE space repositioning but does not affect the dominant seasonal structure.

5. Classification Framework Remains Robust

Despite the change in AOD input wavelength, the **dust event classification system (based on duration and intensity thresholds) remains fully applicable** and shows **spectral flexibility**. The overall interpretation of long-term dust event climatology stays robust and reliable, independent of the spectral choice between 500 nm and 532 nm.

Conclusions

The comparison between 500 nm and 532 nm AOD-based dust event classifications demonstrates strong spectral consistency in detecting event frequency, seasonality, and interannual variability. While a small, systematic spectral shift in the AOD–Ångström Exponent space was observed—leading to minor changes in aerosol typing and event duration distributions—the overall dust event statistics remained stable. These results highlight the robustness and spectral flexibility of the classification framework, ensuring its reliability for long-term dust climatology studies regardless of the input wavelength.

Acknowledgements

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