Wet scavenging of aerosols and surface ozone in a semi-arid region (Arizona)

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INTRODUCTION

Motivation: The semi-arid climate of Arizona, characterized by distinct seasonal precipitation, presents unique challenges in understanding how precipitation influences air pollutants such as particulate matter (PM) and surface ozone (O_3).

Science Question: What are the relationships between precipitation and $PM_{2.5}$, aerosol optical depth (AOD_{500nm}), Angstrom Exponent ($AE_{440\text{-}870nm}$), and O_3 across Tucson, Arizona's two seasons with most precipitation (winter and summer)?

METHODS

Dataset: Tucson (Children's Park)

- US EPA hourly O_3, $PM_{2.5}$, and AZMET precipitation data
- AERONET Level 2.0 AOD_{500nm} and $AE_{440\text{-}870nm}$ data (2015-2023)

Data Analysis:

- Identify rain events and calculate the means for a 48-hr averaging window before and after rain events.
- Calculate percent difference (Δ%) between $PM_{2.5}$, O_3, AOD_{500nm}, and $AE_{440\text{-}870nm}$ before and after each rain event. C = Concentration.

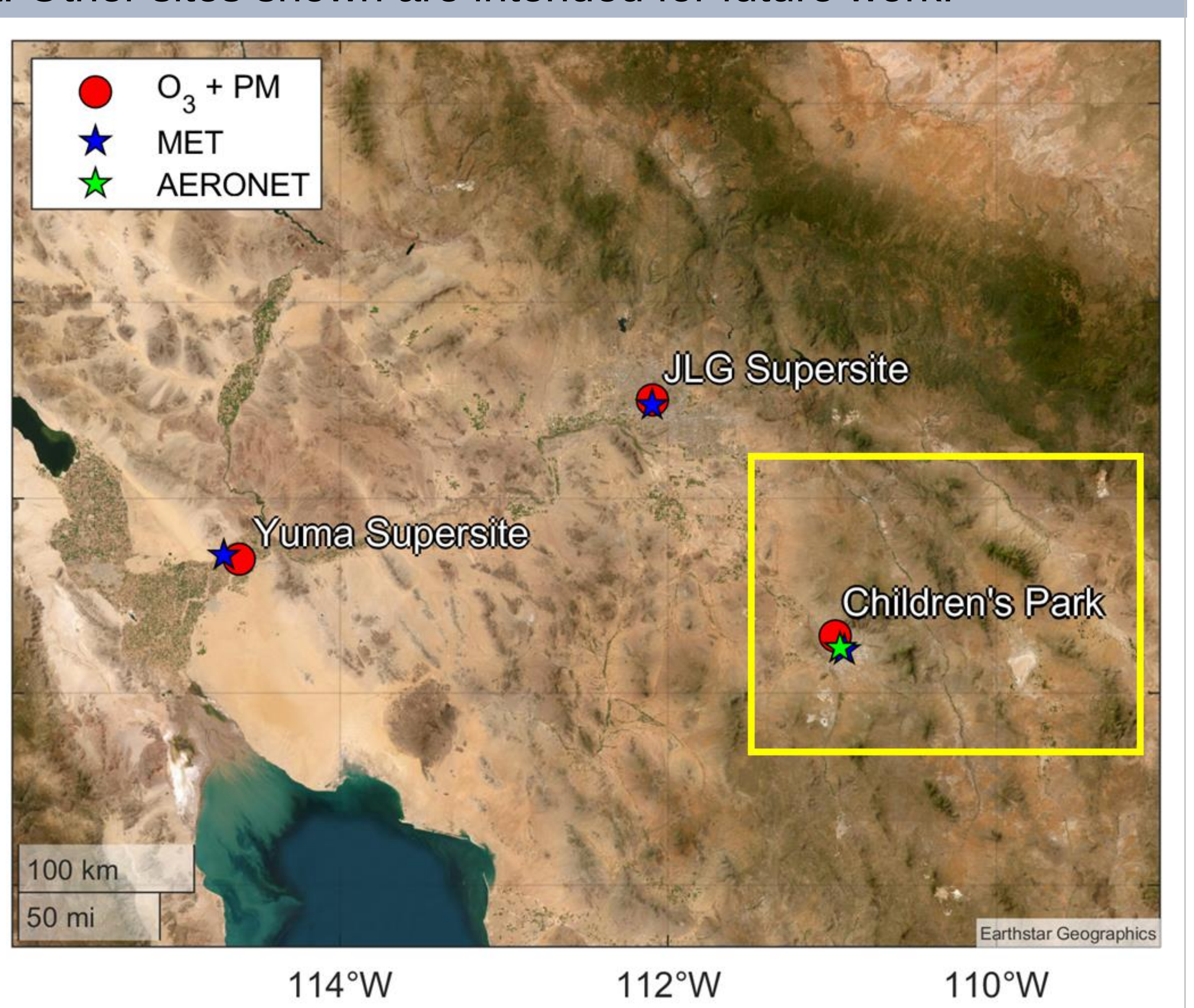
$$\Delta\% = \frac{C_{after} - C_{before}}{C_{before}} \, x \, 100\%$$

- Perform curve-fitting based on simple exponential decay function:

$$y = be^{-ax}$$

where x is the meteorological variable, y is the aerosol variable, and a and b depend on aerosol characteristics which can be linearized such that a and ln$b$ are interpretable as slope and intercept, respectively.

Figure 1. Map showing Tucson, Arizona, and sites collecting data. Other sites shown are intended for future work.



RESULTS: Monthly and diurnal profiles

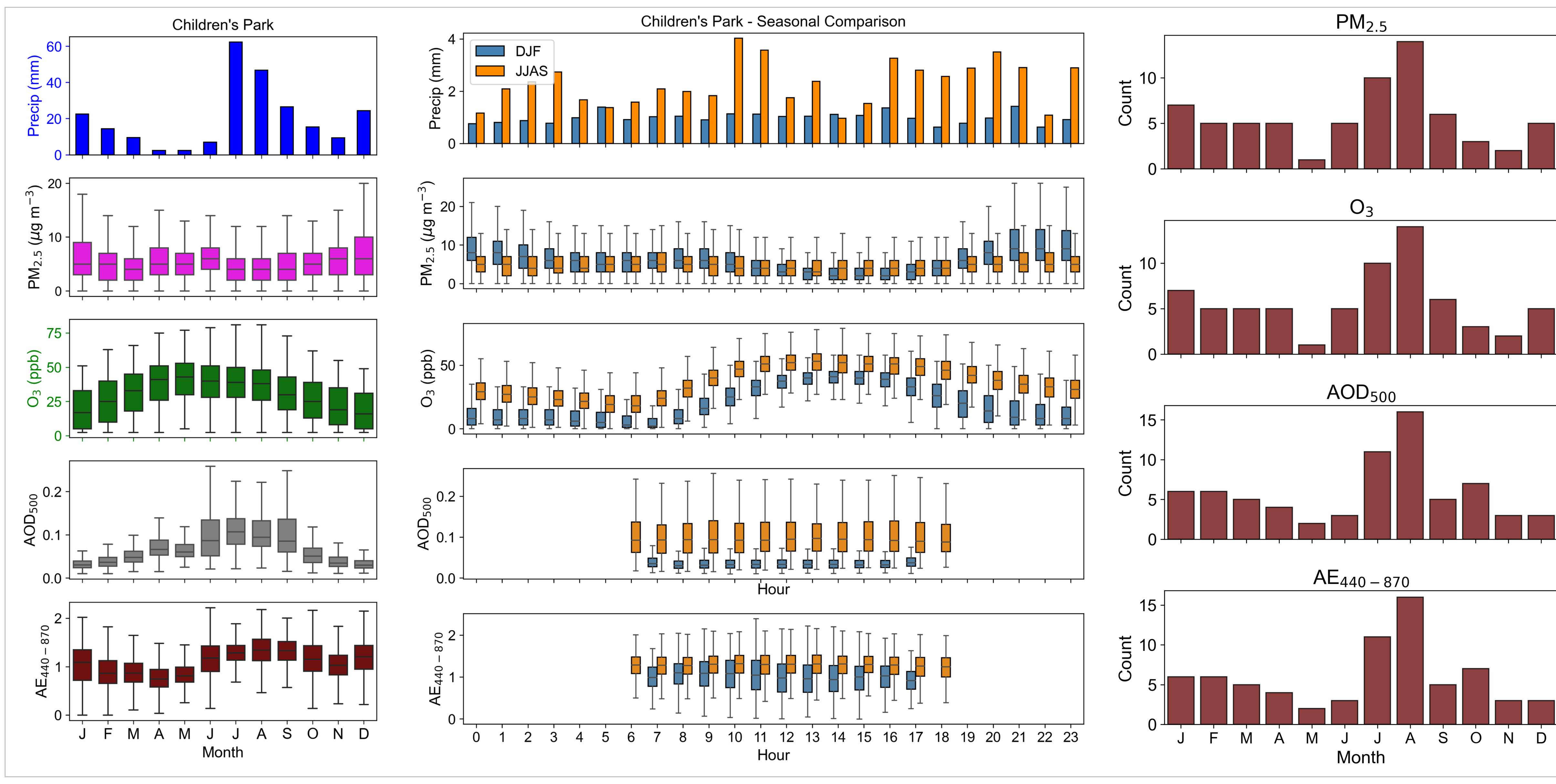


Figure 2. (left) Monthly profiles of precipitation, $PM_{2.5}$, O_3, AOD_{500nm}, and $AE_{440\text{-}870nm}$ in Tucson. **(middle)** Diurnal comparison during the winter (DJF) and monsoon summer (JJAS) seasons. **(right)** Number of valid rain event cases for a 48-hr averaging window before and after rain.

RESULTS: Comparisons before versus after rain using 48-hr averaging window

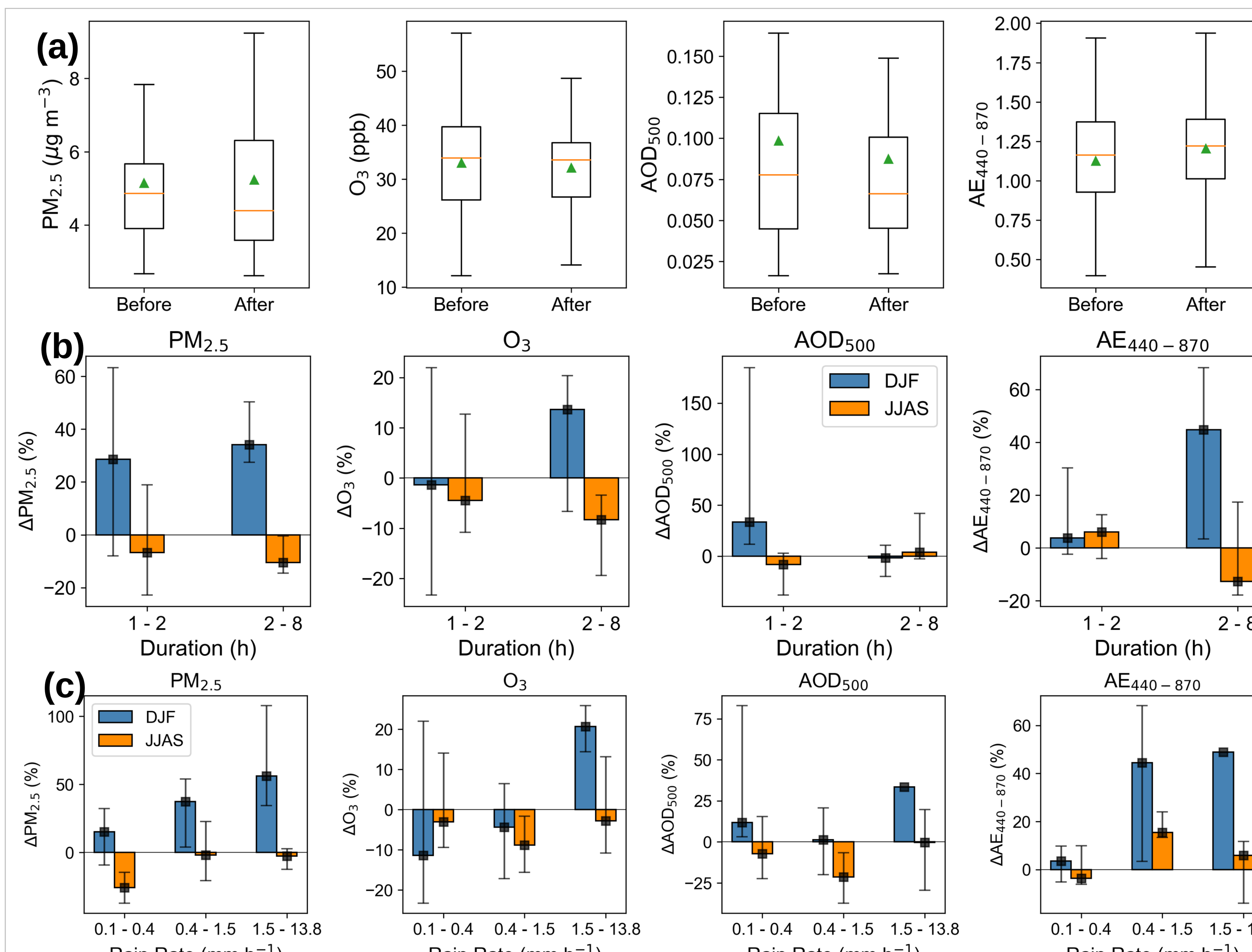


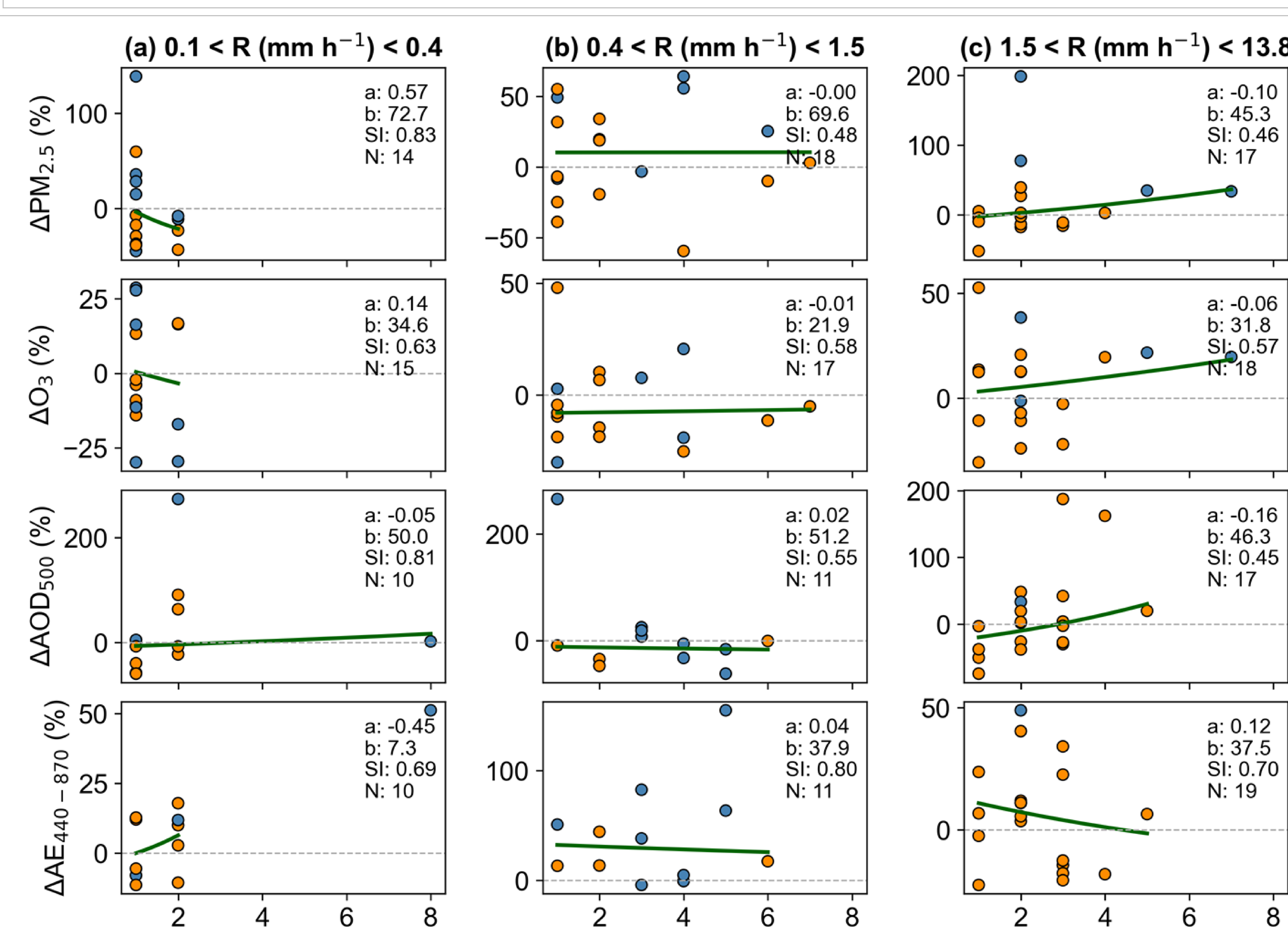
Figure 3
(a). Comparison of values before and after rainfall events.

(b). Percent difference (Δ%) as a function of rain duration across two seasons (winter and monsoon summer).

(c). Same as middle panel but as a function of rain rate.

Figure 3a. Median values are generally higher pre-rain compared to after (except for $AE_{440\text{-}870nm}$). However, dividing the data into winter and summer seasons reveal contrasting results.
Figure 3b. Increase in $PM_{2.5}$, O_3, AOD_{500nm}, and $AE_{440\text{-}870nm}$ post-rain during the winter possibly due to resuspension or local pollution sources.
Figure 3c. $PM_{2.5}$, O_3, and AOD_{500nm} tend to decrease post-rain at lower rain rate during the monsoon summer.

Figure 4 (right). Scatterplots of the percent difference (Δ%) as a function of rain duration (h) and colored by season. Data are stratified by rain rate (R; mm h^{-1}). Number of data points (N) and scatter index (SI) is provided.



- At lower rain rates, $PM_{2.5}$ and O_3 tend to decrease after the rain event, while an increase is observed for AE post-rain.
- At higher rain rates, we observe an increase in $PM_{2.5}$, O_3, and AOD_{500nm} post-rain which could indicate secondary processes and other influencing factors, warranting further investigation.

Future Work:

- Investigate other meteorological variables that could affect the removal of air pollutants during rain periods
- Look at different averaging time windows
- Present case studies for summer and winter
- Perform similar analyses for other sites in Arizona

Acknowledgments:

- NASA grant 80NSSC22K1789 and the NASA program for Increasing Participation of Minority Serving Institutions in Earth Science Division Surface-Based Measurement Networks.
- Arizona Board of Regents (ABOR) Regent's Grant from the Technology and Research Initiative Fund (TRIF)
- GSFC for the travel grant
- US Environmental Protection Agency (EPA) Air Quality Systems (AQS)