

Precipitation-Induced Aerosol Reduction Using MPLNET Lidar and Micro-Rain radar observations

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Abstract: The role of precipitation in aerosol removal is crucial for accurate climate modelling and environmental management. The purpose of this study is to combine NASA's Micro-Pulse Lidar Network (MPLNET) lidar observations with micro-rain radar profiles to study the effects of precipitation on aerosol load in the atmosphere. The MPLNET lidar data are collected from NASA's Universitat Politècnica de Catalunya permanent observation site. Analysis of aerosol scattering before and after precipitation revealed significant changes backscattering vertical profile shape of data distribution. This study provides quantitative insights into the influence of precipitation on atmospheric aerosols and demonstrates the impact of rain by studying changes in backscatter profiles. The results of this research will make a significant contribution to the field of atmospheric science, particularly in enhancing our understanding of the interaction of aerosols, clouds and precipitation.

Introduction Aerosols, important tiny particles suspended in the atmosphere, have a considerable effect on both human health and environmental processes. These short-lived atmospheric components, originating from natural phenomena such as dust storms and sea salt, as well as human activities such as fossil fuel combustion and industrial emissions, have a transient atmospheric presence, usually ranging from days to weeks. The health implications of aerosols are deep, with particles contributing to respiratory diseases such as

asthma and bronchitis and even increasing the incidence of cardiovascular diseases. Particularly vulnerable groups, including the elderly and children, bear the brunt of these adverse health effects. In urban settings, aerosols play an essential role in modulating the effect of urban heat island, especially during heat waves [2], thus intricately linking human comfort and urban climate dynamics with their concentration and behavior. Beyond health and localized climate effects, they exert direct influences by scattering and absorbing solar

radiation, affecting photovoltaic energy production [3], Earth's energy equilibrium, and inducing cooling or warming phenomena. The impact is dichotomous: while some aerosols reflect incoming solar radiation, promoting a cooling effect, others, such as black carbon, absorb it, leading to localized warming. The complex interplay between aerosols and climate extends beyond affecting the balance of radiation. Aerosols play a crucial role in adjusting atmospheric stability, impacting large-scale atmospheric circulation, and even changing regional hydrological patterns [4]. This significant influence on the sensitivity of regional climates has become especially notable due to substantial human-induced changes in the overall radiative effects of aerosols in recent years. An essential element in comprehending aerosol dynamics involves evaluating how they interact with meteorological events, especially precipitation [5]. The way aerosols are removed or cleaned by rainfall substantially changes their levels and spread in the air. This cleansing mechanism, which plays a crucial role in the life cycle of aerosols, controls the lifespan of aerosols that remain in the atmosphere, thereby impacting their direct and indirect impacts on climate and health. Grasping this process is vital for thorough climate modeling and the development of efficient environmental management plans. Therefore, the objective of this research is to clarify the mechanisms and effects of precipitation on aerosol levels, providing information on the complex relationships between aerosols, climate, and meteorological events. Aerosol scavenging is the process of eliminating aerosols from the air through precipitation. This plays a crucial role in the aerosol life cycle in the atmosphere, impacting its levels, spread, and attributes. The methods of scavenging involve under-cloud washout and in-cloud rainout, both influenced by the aerosols' physical and chemical traits and the current weather conditions. Aerosol removal efficiency through scavenging significantly affects visibility, cloud formation, and precipitation patterns, thus influencing local and regional climate systems.

1. Methodology

The study uses light detection and range (Lidar) technology and micro-rain radars (MRR) to explore atmospheric aerosols and their scavenging by precipitation. Using data from

the NASA Micro-Pulse Lidar Network (MPLNET) [6] and colocated MRRs, we gain insights into the interaction between aerosols and various precipitation events. This comprehensive approach allows for detailed analysis of precipitation's impact on aerosol profiles, particularly through the examination of aerosol backscatter profiles (L1.5 level, version V3) before and after precipitation events at Universitat Politecnica de Catalunya (UPC). By analyzing aerosol backscatter at different altitudes and correlating them with precipitation intensity, the study reveals significant insights into how precipitation contributes to aerosol removal from the atmosphere. This methodology combines lidar data, detailed precipitation measurements, and statistical analysis to elucidate the scavenging effect of precipitation on atmospheric aerosols.

2. Results

Figure 1 provides an in-depth analysis of precipitation's impact on aerosol concentrations across different altitude levels, showcasing a general decline in aerosols post-rainfall. This study, highlights the atmosphere's cleansing effect through precipitation. In particular, a significant reduction in aerosol levels is observed from ground to 800m, suggesting complex dynamics between the rain and aerosol distribution.

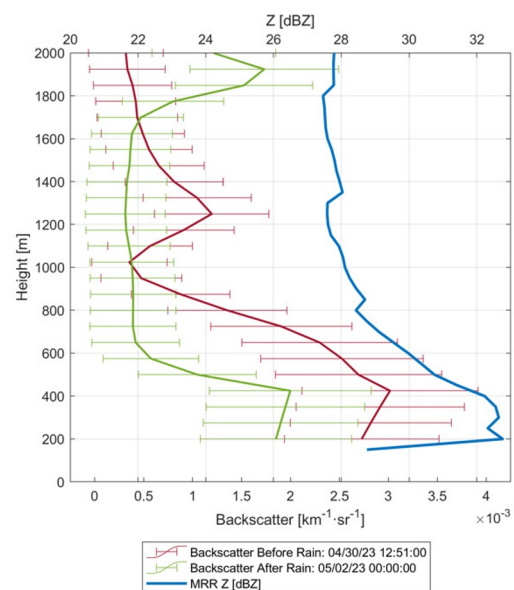


Figure 1 The backscatter coefficient with relative error, which indicates aerosol loading in units of $\text{km}^{-1}\text{sr}^{-1}$, is analyzed before (red curve) and after rain (green curve) at altitudes of 0m to 2000m, alongside

rainfall rates in dBZ¹. This analysis provides insight into how precipitation affects aerosol distribution and the cleansing effect of the atmosphere at different altitudes.

The analysis also reveals a link between higher precipitation rates and greater decreases in aerosol concentrations, particularly at 5-600m (44% of reduction). This research illustrates the nuanced relationship between precipitation patterns and aerosol distribution, further exemplified by a detailed case study of a precipitation event on 30 April 2023, with analyses of backscatter coefficients before and after the event.

In Figure 2 are represented the effects of precipitation in modulating the backscatter coefficient. A consistent reduction of the aerosol loading can be observed.

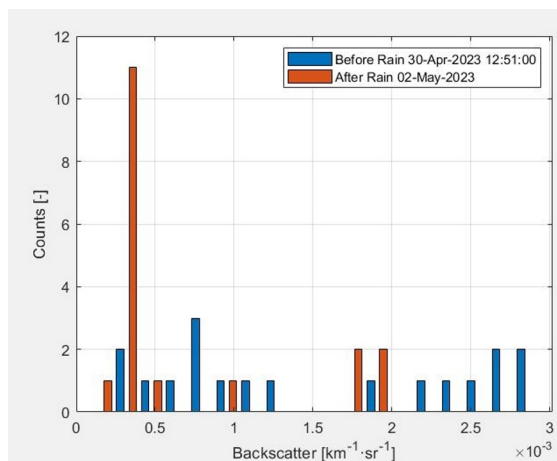


Figure 2 Backscatter coefficient before and after precipitation on 30 April 2023 and 02 May 2023. A total of 28 mm of rain has been recorded before and after precipitation.

Conclusions

Analysis of atmospheric backscatter coefficients before and after precipitation, alongside rainfall data aggregated into 300-meter bins, reveals significant atmospheric dynamics. Before precipitation, backscatter coefficients are generally higher, especially above 900m, where decreases can exceed 50%, peaking at around 90% at 1500m, likely due to the scavenging effect of rain. In particular, an increase in backscatter coefficients at 300m-600m suggests localized atmospheric

influences, possibly from ground activities or topography.

Rain rates increase with altitude, aligning with the reduction in backscatter coefficients in the evening, suggesting a link between precipitation intensity and aerosol scattering. These data illustrate the complex daily atmospheric changes, emphasizing the interplay between precipitation and aerosol distribution, and highlight the need for further research into these atmospheric dynamics.

3. References

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