Factors Influencing AOD and LCS Data Assimilation

Celime Garcia[1], Yeongkwon Son[2], W. Patrick Arnott[3]
Atmospheric Sciences, University of Nevada, Reno, Nevada[1,3]
Desert Research Institute, Reno, Nevada[1,2]

OVERVIEW

This study validates satellite aerosol optical depth (AOD) measurements by comparing them with ground-based AOD data from AERONET. Additionally, it examines the relationship between ground AOD and particulate matter (PM) measurements from low-cost sensors (LCS) to improve surface-level air quality estimates. Satellite-derived AOD is influenced by meteorology, surface land cover, topography, and aerosol transport, which can limit its accuracy in representing true surface conditions. By integrating LCS data, this work helps bridge the gap between satellite observations and ground conditions, improving the spatial resolution of air quality estimates and enhancing the applicability of satellite data for surface-level pollution monitoring.

INTRODUCTION

- Exposure to particulate matter (PM) poses significant and lasting health risks
- Current monitoring methods include Federal Equivalent Methods (FEM), LCS and satellite-based observations.
- FEM provide high accuracy but are costly and sparsely distributed, while satellite measurements are influenced by meteorology, surface land cover, and topography, limiting their reliability.
- Aerosol measurements are particularly challenging in mountainous regions, where terrain complexity affects remote sensing accuracy.
- Integrating LCS data with satellite AOD measurements improves spatial resolution and provides a more reliable representation of surface-level air quality.

METHODS

Ground AOD measurements collected from AERONET at University of Nevada, Reno

Ground PM measurements are collected from PurpleAir (Sensor ID-26057)

Gather satellite Terra (MOD) and Aqua (MYD) AOD products-Deep Blue (DB) and Dark Target (DT)- are available at 1° and 10 km resolutions, with additional 3 km product

Ground AOD is averaged using ±30min and ±60min windows and compared to satellite AOD using two methods: nearest-pixel and 27.5km averaged AOD for the 10km products, and nearest-pixel and 7.5km averaged AOD for the 3km products

Hourly averaged ground AOD is compared to hourly ground PM measurements from PurpleAir sensor (PMS5003)

Linear regression and machine learning (ML) models were used to relate ground AOD to PM measurements

Models were trained on 70% of the data, fine-tuned with validation data (15%) , and tested on remaining 15%, with the best parameters selected using 5-fold cross-validation.

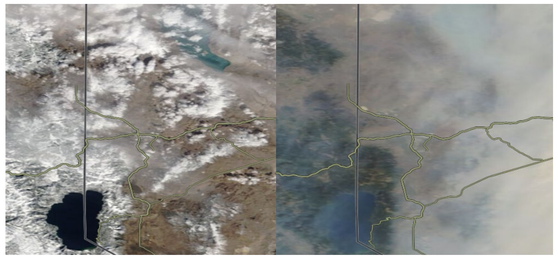

Figure 1. Clouds and snow inhibit remote sensing (February 16, 2021) (left). Smoke affecting Reno's air quality September 14, 2020 (right).

RESULTS

The R^2 values for both the 10 km and 3 km AOD products decreased from 2020 to 2023, primarily due to fewer fire-impacted days. At the 0.05 significance level, there were no significant differences in R^2 or RMSE between the comparisons of Terra AOD to AERONET and Aqua AOD to AERONET, nor between the DT and DB algorithms, with the 3 km product showing a slightly higher, though not significantly different, R^2 compared to the 10 km product.

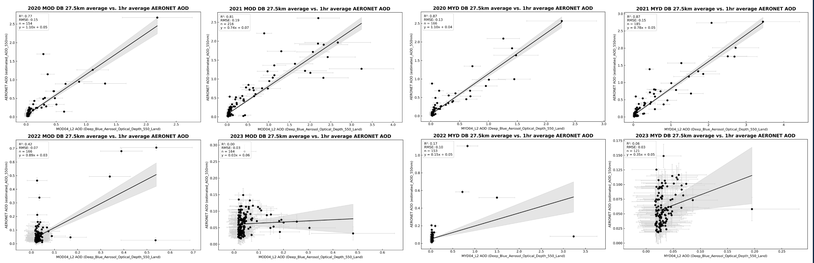

Figure 2. Terra's Deep Blue 27.5km averaged AOD product Vs. AERONET 1hr AOD average 2020-2023 (left). Aqua's Deep Blue 27.5km averaged AOD product Vs. AERONET 1hr AOD average 2020-2023 (right).

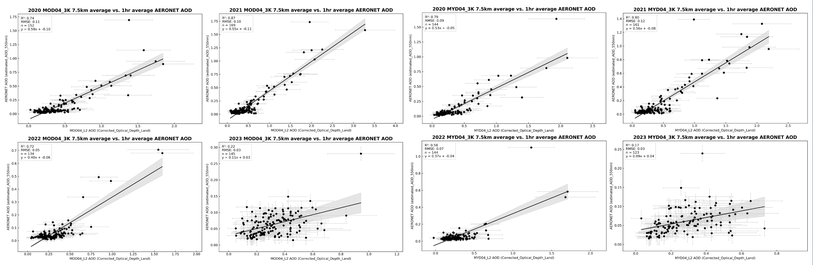

Figure 3. Terra's 3km AOD product with 7.5km averaging Vs. AERONET 1hr AOD average 2020-2023 (left). Aqua's 3km AOD product with 7.5km averaging Vs. AERONET 1hr AOD average 2020-2023 (right).

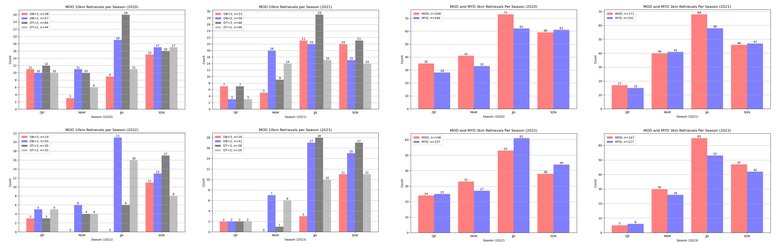

Figure 4. Count of quality assurance flags (QAF) of 2 and 3 for the DB and DT products for MOD by season (left). Count of QAF 3 for the MOD and MYD 3km product by season (right).

RESULTS (continued)

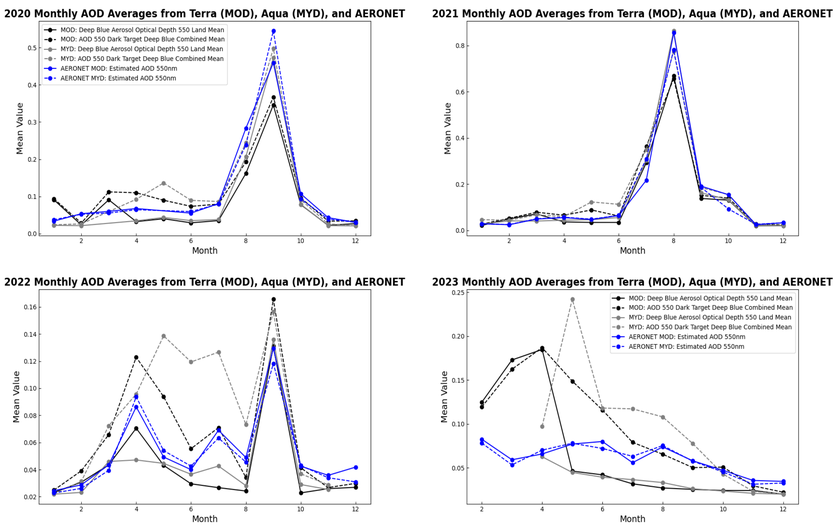

Figure 5. Average monthly AOD from 2020 to 2023 for MOD and MYD DB and DT products, alongside AERONET's estimated 550 nm AOD.

Model	Explained Variance	MAE	RMSE
Linear Regression	65.54%	6.4	16.33
Weighted Least Squares	62.34%	7.2	17.07
Random Forest	73.80%	5.44	14.21
Gradient Boost	70.90%	5.75	15.01
XG Boost	72.12%	5.78	14.66

Figure 6. Explained Variance, mean absolute error (MAE), and root mean square error (RMSE) for two traditional linear regression and three machine learning models, with the best model highlighted in green.

CONCLUSION

In future studies, 3km products from either Aqua or Terra should be used in regions with rapid surface albedo changes. Future work will focus on developing a model to estimate the planetary boundary layer (PBL), investigating its impact on AOD agreements between ground and satellite measurements, creating a PM map using machine learning, comparing it to actual PM data in western Nevada, and examining outliers in the satellite-ground AOD comparison.

ACKNOWLEDGEMENT

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