Uncertainty Analysis of Satellite Retrieved Aerosol Optical Properties: Implications for Semi-arid Regions

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Satellite Aerosol Optical Depth (AOD) products face challenges over bright and semi-arid regions due to retrieval artifacts or real physical processes. This study develops a conceptual 1-D radiative transfer model (RTM) to understand the physical processes affecting satellite AOD uncertainties. We estimate uncertainties in satellite AOD based upon a traditional error propagation approach by identifying critical values associated with surface albedo and aerosol properties. The top-of-atmosphere (TOA) reflectance remains constant at the critical surface albedo (CSA), critical single scattering albedo (CSSA), or critical asymmetry parameter (CAP) despite significant variability in AOD; therefore, satellite sensors are unable to retrieve the correct aerosol signal.

The results show that large retrieval-level AOD errors arise from a constant assumed error (±5%) in the surface albedo (A), single scattering albedo (SSA), or asymmetry parameter (g), especially when the actual values of A, SSA, and g approach their critical values. Additionally, interesting findings over the Black Rock Desert (BRD) region include: (1) when the actual desert albedo is smaller than CSA at shorter wavelengths (e.g., 550nm), underestimated satellite-retrieved surface albedo leads to high AOD values; (2) when the actual desert albedo is larger than CSA at higher wavelength bands (e.g., 770 - 900 nm), satellite AOD is underestimated in spite of an underestimation of satellite surface albedo retrieval; (3) AOD errors are trivial when it comes to absorbing aerosols with high surface reflectance as the CSA becomes far away from the real albedo value; (4) an inappropriate choice of aerosol model schemes in the look-up tables is related to unexpectedly high AOD uncertainties over deserts.

This theoretical approach sheds light on the uncertainty estimates in satellite AOD products with physical processes quantitatively. Future satellite algorithm development can use our analytical framework to resolve unrealistic AOD issues over bright and semi-arid environments worldwide.