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3D radiative processes in satellite measurements of aerosol properties

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Current methods for satellite measurements of aerosol properties are based on 1D radiative transfer theory, which assumes that observed solar reflectances are fully determined by local atmospheric and surface properties. However, both theoretical and observational studies have established that nearby areas can influence each other's reflectances through 3D radiative interactions. Most importantly for aerosol remote sensing, clouds were shown to enhance the brightness of nearby clear areas by scattering extra sunlight toward them. Not considering this enhancement in the interpretation of satellite data runs the risk of systematically overestimating aerosol optical thickness and underestimating particle size near clouds.

Satellite measurements have shown that clear-sky solar reflectances do indeed systematically increase near clouds, but also that the increase doesn't come only from 3D effects: Aerosol swelling, undetected cloud particles, and instrument blurring also play a role. While 3D processes were shown to be significant, their typical contribution to the observed near-cloud reflectance enhancements is yet to be determined.

This study combines satellite data analysis with radiation simulations in order to estimate the magnitude of 3D processes in a yearlong global dataset covering all ice-free oceans. The impact of 3D processes is estimated through Monte Carlo radiative transfer simulations for scenes specified by MODIS cloud products. The simulated near-cloud reflectance enhancements are then interpreted by considering co-located MODIS solar reflectances and CALIOP lidar data. This combination is helpful because the two instruments' capabilities complement each other, and while MODIS data is affected by 3D radiative processes, CALIOP data is not. The statistical analysis of this multi-instrument dataset offers insights both into 3D radiative processes and into near-cloud changes in atmospheric particles, with special focus on Saharan dust.

The results include the finding that while other processes explain more than half of the near-cloud increases in solar reflectance, the typical magnitude of 3D effects is also quite significant. Given the large extent of near-cloud areas influenced by 3D effects, the results imply that accurate and representative measurements of oceanic aerosol populations need to consider the impact of 3D radiative processes.