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Clear-sky remote sensing in the vicinity of clouds: what can be learned about aerosol changes?

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Studies on aerosol direct and indirect effects require a precise separation of cloud-free and cloudy air. However, separation between cloud-free and cloudy areas from remotely-sensed measurements is ambiguous. The transition zone in the regions around clouds often stretches out tens of km, which are neither precisely clear nor precisely cloudy. We study the transition zone between cloud-free and cloudy air using MODerate-resolution Imaging Spectroradiometer (MODIS) and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) measurements. Both instruments show enhanced clear-sky reflectance (MODIS) and clear-sky backscatterer (CALIPSO) near clouds. Analyzing a large dataset of MODIS observations we examine the effect of three-dimensional (3D) radiative interactions between clouds and cloud-free areas, also known as a cloud adjacency effect. Comparing with CALIPSO clear-sky backscatterer measurements, we show that the cloud adjacency effect may be responsible for a large portion of the enhanced clear sky reflectance observed by MODIS. While aerosol particles are responsible for a large part of the near-cloud enhancements in CALIPSO observations, misidentified or undetected cloud particles are also likely to contribute. As a result, both the nature of these particles (cloud vs. aerosol) and the processes creating them need to be clarified using a quantitative assessment of remote sensing limitations in particle detection and identification.

The width and ubiquity of the transition zone near clouds imply that studies of aerosol-cloud interactions and aerosol direct radiative effects need to account for aerosol changes near clouds. Not accounted, these changes can cause systematic biases toward smaller aerosol radiative forcing. On the other hand, including aerosol products near clouds despite their uncertainties may overestimate aerosol radiative forcing. Therefore, there is an urgent need for developing methods that can assess and account for remote sensing challenges and thus allow for including the transition zone into the study. We describe a simple model that estimates the cloud-induced enhanced reflectances of cloud-free areas in the vicinity of clouds. The model assumes that the enhancement is due entirely to Rayleigh scattering and is therefore bigger at shorter wavelengths, thus creating a so-called apparent "bluing" of aerosols in remote sensing retrievals.