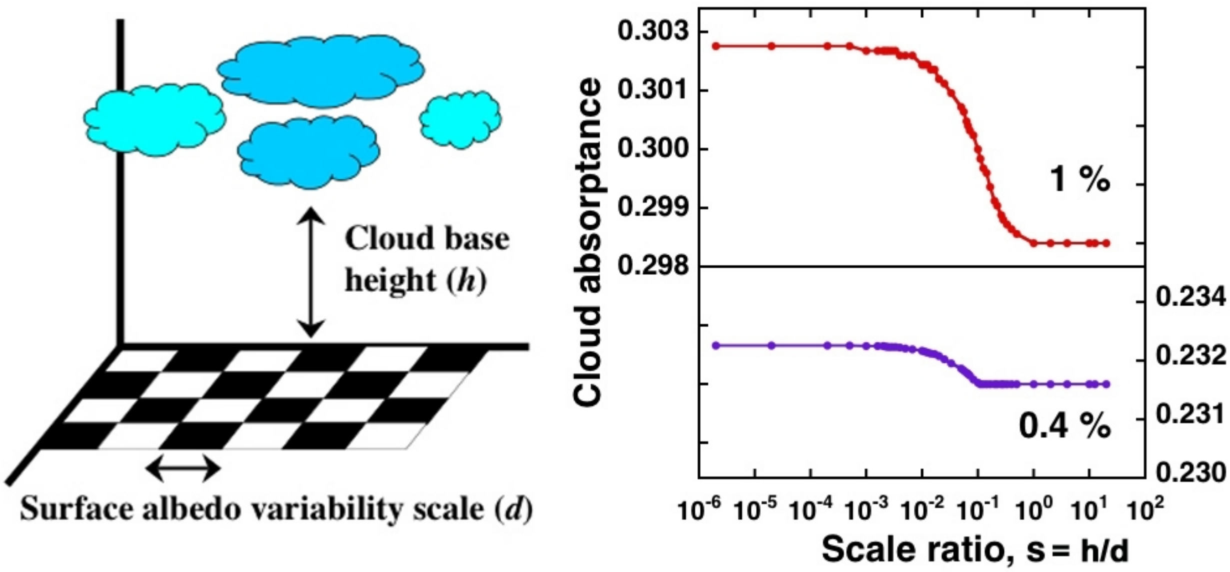
Can patchiness in the surface reflection underneath clouds explain the discrepancy between observed and calculated cloud absorption of sunlight?



One of the major concerns in the atmospheric community has been a discrepancy between measured and model-calculated sunlight absorbed by clouds. It is often referred to as the Òenhanced cloud absorptionÓ anomaly. This anomaly could have a significant impact on climate modeling and remote sensing applications. Various explanations have been offered, but, upon close examination, have failed to account for it. It has been suggested that some of the anomaly may be due to a failure to model the patchiness of surface reflection beneath clouds, which can indirectly affect cloud absorption through multiple cloud-to-ground reflections. But a careful analysis of this effect was lacking. Therefore, a three-dimensional radiative transfer model was used to calculate cloud absorption in the presence of the simplest possible surface inhomogeneity Ð a checkerboard, as depicted in the left panel. The checkerboard surface is a black and gray pattern approximating the actual variability observed at an Oklahoma field site of the Atmospheric Radiation Measurement (ARM) program. The right panel shows cloud absorptance as a function of the scale ratio s = h/d , defined as the ratio of the height of the cloud base above the surface to the horizontal scale of surface variation. A fairly simple case was first examined (upper right panel) for a single wavelength of sunlight and for the Sun directly overhead. When the cloud base is far from the ground (large s), the model predicts that the cloud absorptance is the same as it would be if the surface were replaced with a uniformly-reflecting surface with albedo equal to the average albedo of the checkerboard. As the cloud base approaches the ground (small s) the absorptance increases, and each portion of the cloud interacts radiatively only with the part of the checkerboard immediately below it. The change in absorptance between these two extremes is only about 1 percent, however, for this simple case. The change is even less when averaged over cloud inhomogeneities, over all wavelengths of sunlight and over all illumination angles (lower right panel). The average effect of surface heterogeneity on cloud absorption thus appears to be less than 0.5%, equivalent to a change in surface heating of about ~ 1 W/m2. This 1 W/m2 difference is not only less than uncertainties due to water vapor and aerosol effects, but also much less than the discrepancy (order of 10 W/m2) between measured and model-calculated cloud absorption. These results therefore strongly suggest that accounting for surface heterogeneity in radiative transfer models cannot explain anomalous cloud absorption. The results of this research were recently published in Geophysical Research Letters.

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