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Effect of cloud inhomogeneities on the solar zenith angle dependence of nadir reflectance

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Abstract. A significant discrepancy has been noted between satellite measurements of shortwave reflectance at nadir and the results of plane-parallel model calculations: For moderate to large solar zenith angles, observed nadir reflectances increase with solar zenith angle, whereas plane-parallel values decrease. Consequently, cloud optical depths retrieved using one-dimensional (1-D) theory have a bias which increases systematically with solar zenith angle. Using Monte Carlo model simulations of photon transport through stochastic, isotropic, scale-invariant cloud fields with variable cloud top heights and volume extinction coefficients, we show that nadir reflectances from three-dimensional cloud fields increase with solar zenith angle, consistent with the observations. The difference from the 1-D case is shown to be explainable by cloudside illumination as well as by the presence of structured (i.e., non-flat) cloud tops. Cloud sides enhance the amount of incident solar radiation intercepted by cloud, allowing more radiation to be scattered upward