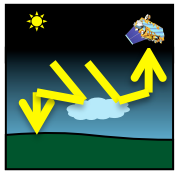
2D radiative processes near cloud edges

Tamás Várnai
Joint Center for Earth Systems Technology, University of Maryland Baltimore County and NASA GSFC

Summary

- Simulations show that horizontal photon transport typically affects radiation fields up to and beyond 5 km from cloud edges.
- 2D radiative processes increase average clear-sky zenith radiances, cloud absorption, and surface absorption in cloudy columns, but they decrease average clear-sky surface absorption near clouds.
- 2D simulations using zenith-only ARM data can capture much, but not all zenith radiance enhancements; scanning radar can help with rest.

Zenith transmittance at the surface



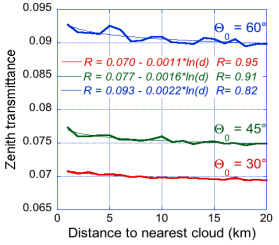
Introduction:

- Studies have shown that clouds enhance satellite radiances at nearby clear areas through horizontal photon transport.
- This part of the study examines whether the same process can significantly enhance ground-level zenith radiances too, and whether the impact quickly fades farther from cloud edges.
- Zenith radiances are observed by ARM instruments such as SWS or NFOV.

Dataset:

- One year of data over all oceans between 60° S and 60° N.
- Cloud height and optical properties from the MODIS instrument on the Aqua satellite.
- 0.47 μm zenith radiances, obtained for the entire MODIS dataset using 2D and 3D Monte Carlo simulations.

Results:

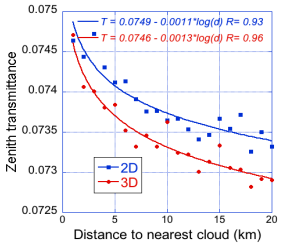


Zenith transmittance (T):

$$T = \frac{\pi I}{\mu_0 F_0}$$

I: zenith radiance
μ_0: cosine of solar zenith angle
F_0: solar irradiance

- Since aerosols and surface are not included in the simulations, clear-sky radiances depend on distance from cloud edges only because of horizontal photon transport.
- 3D simulations show that average clear-sky zenith radiance increases near clouds, and the increase extends at least 10 km from cloud edges.
- Near-cloud transmittance increases are strongest for oblique sun.



Plot combines all solar elevations in MODIS dataset.

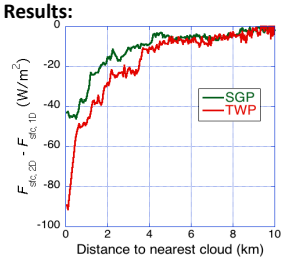
- Zenith-pointing ARM instruments provide 2D cloud information (vertical cross-sections along the wind direction).
- Results for the yearlong MODIS dataset show that 2D simulations can capture much, though not all of near-cloud enhancements.
- For improved characterizations of near-cloud enhancements, ARM scanning radars can provide 3D cloud information.

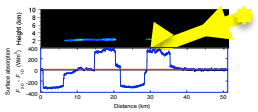
Surface absorption near clouds

Dataset:

- 3 years at SGP, 2 years at TWP
- 2D vertical cross sections of cloud ice & water content and particle size, based on Microbase profiles & Mergesonde winds
- Broadband solar fluxes from 1D and 2D Monte Carlo simulations

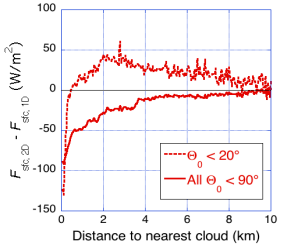
Results:

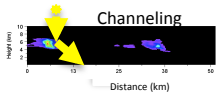




Through horizontal photon transport (shadowing), clouds reduce overall average surface absorption of clear areas within about 5 km from cloud edges.

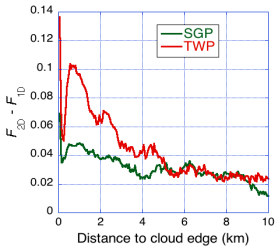
In turn, horizontal photon transport increases surface absorption below clouds by allowing sunlight to slip under the clouds from the side.





- For high sun, surface absorption is reduced only right next to cloud edges, because shadows are short.
- Beyond the shadows, clouds increase surface fluxes through horizontal photon transport (channeling).

Solar absorption inside clouds



- Broadband simulations for the same ARM dataset show that cloud absorption increases near cloud edges.
- Cloud top variability and variations in internal cloud structure result in horizontal photon transport enhancing cloud absorption even far away from cloud edges.