Statistics of shortwave horizontal photon transport effects

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Summary

- This poster examines the importance of horizontal photon transport effects, which are not considered in the 1-D calculations of solar radiative heating used by most atmospheric dynamical models.
- In a 2-3 year long dataset of observed 2-D atmospheric vertical cross-sections, simulated 2-D radiative effects increase 24-hour average (day + night, cloudy + clear) solar absorption by about 4.1 W/m^2, 1.2 W/m^2, and 0.3 W/m^2 at the TWP, SGP, and NSA sites, respectively.
- 2-D effects are often much larger than the average values above, especially for high sun and for convective clouds.
- Horizontal photon transport often enhances solar heating even for oblique sun.

Outlook

- Scanning radars will offer new opportunities for examining full 3-D effects, which in earlier case studies were about 30% stronger than 2-D effects.
- Early tests suggest that neural net-based corrections for 2-D effects can greatly improve the accuracy of 1-D radiation calculations for dynamical cloud simulations.

Dataset

2-D atmospheric vertical cross-sections for 3 years at NSA and SGP, 2 years at TWP

- Microbase cloud profiles (ice & water content, particle size)
- Mergesonde wind aloft (Needed to convert time to distance traveled. Resulting median resolution: NSA: 86 m, SGP: 141 m, TWP: 74 m)
- Cloud classification at SGP
- Broadband shortwave fluxes from 1-D & 2-D Monte Carlo simulations

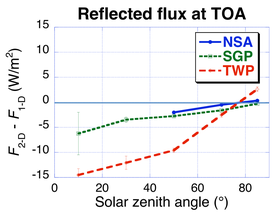
Overall average results

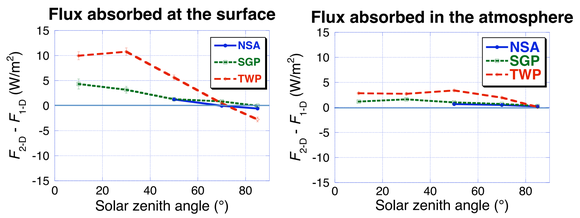
Multiyear24 hour (day+night, clear+cloudy) average difference between 2-D and 1-D calculations of solar radiative heating (W/m^2)

TOA refl.	-0.28 ± 0.04	-1.21 ± 0.05	-4.10 ± 0.21
Atm. abs.	0.25 ± 0.01	0.52 ± 0.02	1.47 ± 0.03
Sfc. abs.	0.02± 0.04	0.68 ± 0.05	2.63 ± 0.17

Uncertainty estimates are standard errors based on the spread of results when total dataset is divided into 25 subsets. Because they assume that the 25 subsets are fully independent from each other, the standard errors likely underestimate actual uncertainties.

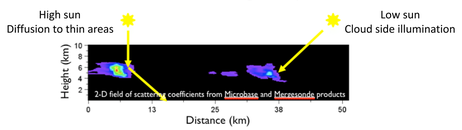
Solar elevation



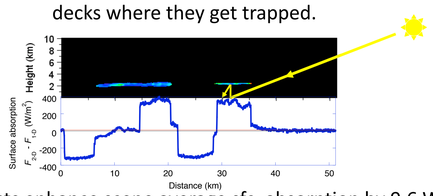


Expected result: 2-D effects are strongest for high sun
Unexpected result: They often enhance absorption even for low sun

In earlier studies, cloud side illumination dominated for low sun, enhancing reflection and reducing absorption.

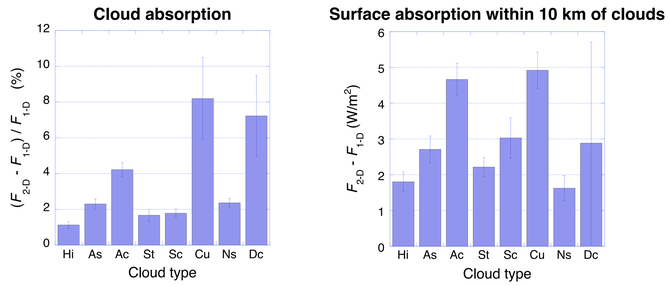


In current dataset, absorption is often enhanced by the 2-D effect of photons moving obliquely under extensive cloud decks where they get trapped.



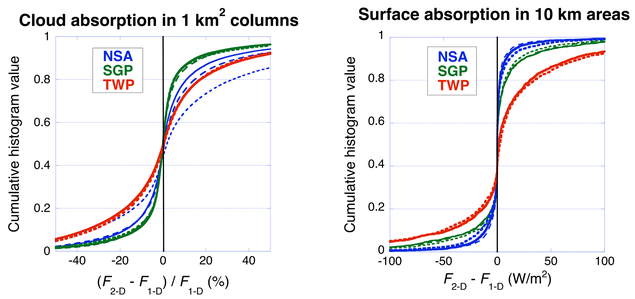
2-D effects enhance scene average sfc. absorption by 9.6 W/m^2

Cloud type



2-D effects are stronger for convective than for stratiform clouds.

Histogram of 2-D effects



Each line represents a histogram for a single year.

2-D effects are often much larger than their average values. At TWP:
- 1-D cloud absorption calculations are off by >20% in third of 1 km wide columns
- 1-D surface absorption calculations are off by >50 W/m^2 in quarter of 10 km areas