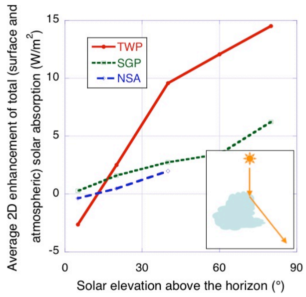
Multiyear Statistics of 2D Shortwave Radiative Effects at Three ARM Sites

Research Highlight

Because of the prohibitive computational demands of three-dimensional (3D) radiative calculations, most current models of atmospheric circulation and cloud development calculate solar heating using one-dimensional (1D) radiation models. These 1D models obtain solar radiative heating separately for each atmospheric column and don't consider that sunlight can travel from one column to the next. Several studies have indicated that this simplification can cause significant errors in solar heating calculations, but it remains unclear how important the multidimensional nature of solar radiative processes is for atmospheric dynamical simulations.

In a new study, researchers addressed this question by taking advantage of cloud observations at three sites Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility sites. For many years now, vertically pointing ARM instruments in Oklahoma, Alaska, and Manus Island in the Pacific Ocean (in Papua New Guinea) have provided 2D vertical cross-sections of clouds drifting aloft with the wind. Comparing the results of 1D and 2D radiation calculations for 2–3 year long data sets of observed cloud structures allowed researchers to assess the typical accuracy of the 1D radiation approximation used in most dynamical models of the atmosphere. The results show that 1D calculations underestimate multiyear, 24-hour average total (surface plus atmospheric) solar absorption by about 4.1 W/m2, 1.2 W/m2, and 0.3 W/m2 at the tropical, mid-latitude, and arctic site, respectively. One should note that these average values include long cloud-free periods and nighttime as well, when 1D calculations give accurate results. 2D radiative processes (not included in 1D models) often have much larger local effects than these average values suggest, especially for high sun and for convective clouds (Figure 1). The inset in Figure 1 illustrates channeling, the most important 2D process that makes 1D calculations underestimate solar heating. In this process, a portion of the sunlight scattered at the highly opaque regions of thick clouds moves to thinner regions, where sunlight can reach the surface much easier.

The results underscore the need for fast radiation models that can allow atmospheric dynamical simulations to consider the inherently multidimensional nature of solar radiative processes.



Multiyear average influence of 2D radiative processes on total (surface and atmospheric) absorption at the TWP (Manus Island), SGP (Oklahoma), and NSA (Alaska) sites. The inset illustrates the channeling process that enhances solar absorption by scattering sunlight from highly opaque regions of thick clouds to thin areas, where sunlight can reach the surface much more easily.

Reference(s)

Varnai T. 2010. "Multiyear statistics of 2D shortwave radiative effects at three ARM sites." Journal of the Atmospheric Sciences, 67, 3757-3762.

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Working Group(s)

Cloud Life Cycle