Broadband Radiative Fluxes Measured by Stacked Aircraft During ARESE: Absorption of Solar Radiation by Clouds

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Introduction

In the fall of 1995 the Atmospheric Radiation Measurement Enhanced Shortwave Experiment (ARESE) was conducted to address fundamental questions about the amount of solar radiation absorption occurring in clear and cloudy skies. We present data from instruments flown on stacked aircraft as part of this experiment.

Figure 1 shows a sample of the ARESE measurements. Data analyzed here are from the following RAMS instruments (Valero et al. 1997b):

- total solar broadband radiometers measuring flux from 0.2 to 3.9 µm
- near-infrared broadband radiometers measuring flux from 0.7 to 3.3 µm
- multi-channel narrowband radiometers with, in particular for this analysis, a 10-nm-wide channel centered at 500 nm

Identical uplooking and downlooking radiometers were used on an Egrett aircraft flying at 13 km altitude, and a Twin Otter aircraft flying at 2 km altitude.

The data yield measurements of the following quantities:

net flux at 13 km = Egrett downwelling flux - Egrett upwelling flux

net flux at 2 km = Twin Otter downwelling flux - Twin Otter upwelling flux

column absorption = net flux at 13 km - net flux at 2 km

column absorptance = (column absorption)/(column insolation)

column transmittance = (Twin Otter down. flux)/(column insolation) *where column insolation is simply the downwelling flux measured at the Egrett altitude*

Analysis

In contrast to Valero et al. (1997a), in which data from only four of the ten dual-aircraft ARESE flights were examined, this analysis includes the entire ARESE data set—over 13 hours of simultaneous and collocated flux measurements. The data have been put into one of three bins: clear sky, scattered clouds, or overcast conditions. Figure 2 shows column absorptance as a function of column transmittance for the total solar, near-infrared, and (narrowband) 500-nm bandpasses. Each point on this plot is the average of a bin, i.e., of several hours of data. Linear fits to the points are shown to facilitate comparisons.

The solar and near-infrared data show a strong increase in absorptance with decreasing transmittance, i.e., with increasing cloudiness. In contrast, the 500-nm absorptance remains essentially constant.

The behavior of the 500-nm absorptance is significant because it allows us to rule out the possibility that we are measuring an apparent absorption due to a sampling bias in the data rather than a true absorption by clouds. The idea was that photons could be scattered out the sides of clouds and go undetected by the radiometers above and below. If the cloud-associated increase in broadband absorptance were due to this apparent absorption, then the same increase would have to be seen (in fact, would be especially evident) at 500 nm, a wavelength with little true absorption. Such an increase is not seen, however.

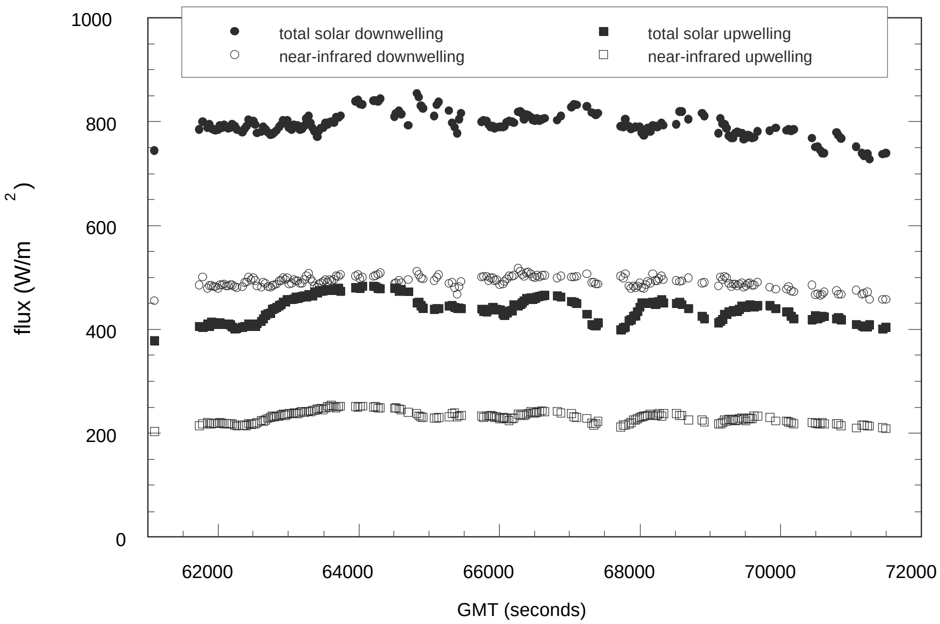

Figure 1. Broadband fluxes as a function of time, measured at 13 km altitude on October 30, 1995

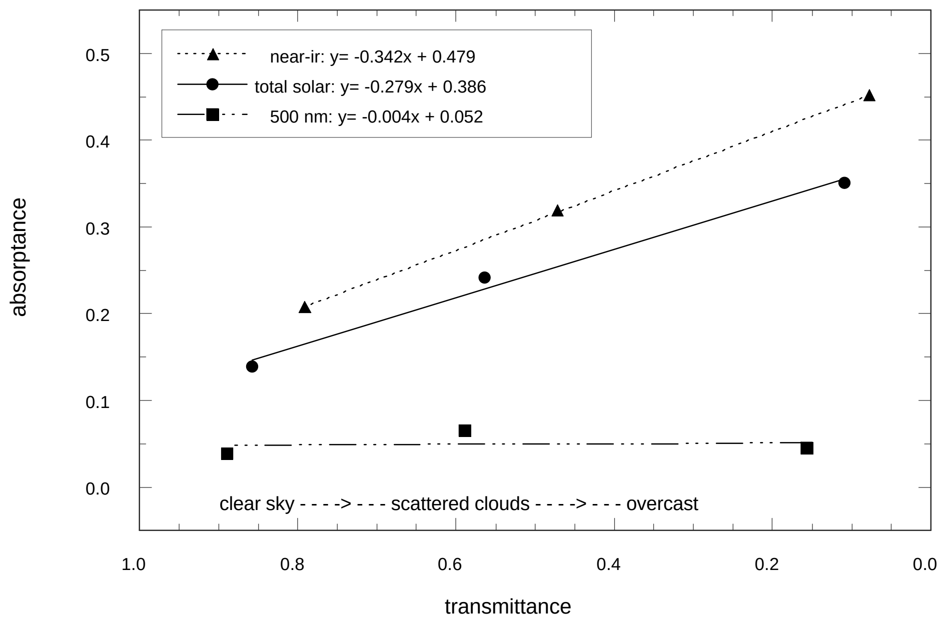

Figure 2. Column absorptance as a function of column transmittance (as defined in text) for each of three bandpasses as labeled.

The flux in the visible portion of the solar spectrum can be determined by subtracting the near-infrared flux from the total solar flux:

VISIBLE flux = (total solar flux) - (near-infrared flux)

The visible net flux and column absorption are then obtained following the definitions given earlier. By carrying this through to the absorptance calculations we can see how the total solar absorptance is distributed between the visible half, 0.2 to 0.7 µm, and the near-infrared half, 0.7 to 3.9 µm, of the total solar bandpass.

We define the following relative column absorptances:

VISIBLE relative column absorptance =
(VISIBLE column absorption) / (total solar column insolation)

NEAR-IR relative column absorptance =
(NEAR-IR column absorption) / (total solar column insolation)

The sum of the two is simply the total solar column absorptance:

VISIBLE relative column absorptance +
NEAR-IR relative column absorptance =
column absorptance in the total solar bandpass

Figure 3 shows the same binned data that appear in the previous figure with the visible and near-infrared relative column absorptances plotted as a function of transmittance in the total solar bandpass. Again, simple linear fits to the points are included on the plot. We see that the increasing absorptance associated with increasing cloudiness occurs in both halves of the total solar bandpass.

For example, on October 30, an overcast day, an average of 220 W/m^2 were absorbed in the near-infrared and 60 W/m^2 were absorbed in the visible to give a total solar column absorption of 280 W/m^2.

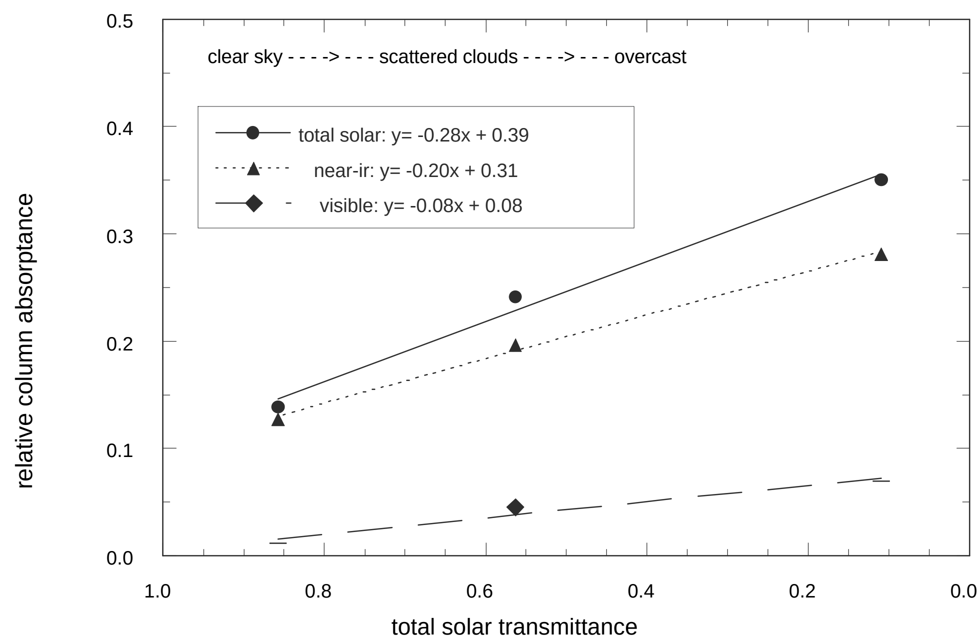

Figure 3. Relative column absorptance vs. total solar transmittance, for the total solar bandpass and its near-infrared and visible halves.

Significant Findings

- The absorption measured in the column between the two aircraft (from about 2 to 13 km above sea level) varies strongly with cloud amount, providing strong evidence for excess cloudy-sky absorption relative to clear skies.

- The 500-nm absorptance shows no increase with cloud amount, ruling out the possibility that the absorption measured is an apparent absorption (due to scattering out the sides of clouds) rather than a true absorption.

- This absorption occurs in both the visible and near-infrared portions of the solar spectrum and is not predicted by models.

References

Valero, F.P.J., A. Bucholtz, B. C. Bush, S. K. Pope, W. D. Collins, P. Flatau, A. Strawa, and W.J.Y. Gore, 1997b: The Atmospheric Radiation Measurements Enhanced Shortwave Experiment (ARESE): Experimental and Data Details. Submitted to *J. Geophys. Res.*

Valero, F.P.J., R. D. Cess, M. Zhang, S. K. Pope, A. Bucholtz, B. Bush, and J. Vitko, 1997a: Absorption of solar radiation by clouds: Interpretations of collocated aircraft measurements. Submitted to *J. Geophys. Res.*