Enhanced Water Vapor Absorption Within Tropospheric Clouds: A Partial Explanation for Anomalous Absorption.

David Crisp and Cinzia Zuffada

Jet Propulsion Laboratory California Institute of Technology, Pasadena, CA 91109

Recent Earth Radiation Budget Experiment (ERBE) and ground-based solar flux observations indicate that tropospheric clouds absorb . 25 W m^{-2} more solar radiation than climate models predict (Cess *et* (d., *Science*. 267 496.J95; Ramanathan *et al Science*, **267, 499,** 1995). This *anomalous ab sortion* has raised concerns about our understanding of the role of clouds in Earth's present climate. To study the origin of this anomalous absorption, we 11s('(1 a sophisticated atmospheric radiative t IIIsJ"('l' 1110(1 ('1 to compute solar fluxes and heating rates for clear-sky and cloudy conditions. This model provides a monochromatic description of solar and thermal radiance wit 1 in absorbing, emitting, scattering, planetary 2111110 ospheres. Monochromatic gas absorption coefficients are derived from an efficient, multi-grid, line-by-line model that resolve 1 heores of gas absorption lines at **ill]** atmospheric levels, and includes their contributions at large distances (>500 cm^{-1}) from the line centers. Line parameters were 01)1:1 med from the HITRAN 92 and HITEMP **(1{.** Wattson, personal communication, 1995) databases 1'111': ingle scattering optical properties of liquid water droplets were computed wit Ir a Mie scattering model, but rigorous surface- integral and finite-element methods are IIS((I for non-spher1cal water ice and aerosol particles (Zuffada and Crisp, this meeting). The multiple scattering model incorporates a multi-level. multi-stream, discrete ordinate algorithm (Stamnes et al. *Appl. Opt.* 27, 2502, 1988) and high-resolution spectral mapping methods (Cf. Meadows and Crisp, *J. Geophys Res.* 101 1996) to solve the equation of transfer. This model accounts for a large fraction of the anomalous absorption. For example, a standard, mid latitude summer model atmosphere with a single, horizontally-uniform, strato-cumulus cloud absorbs 20 to 30 W m^{-2} more sunlight at altitudes within the cloud (1 to 1.5 km) than the associated clear-sky case. However, the cloudy atmosphere absorbs about **12 w m "** less than the clear atmosphere at altitudes below the cloud base because the cloud reduces the amount of solar radiation available at these levels. The column-integrated absorption by the cloudy atmosphere was therefore ~13 W m^{-2} greater than that for the clear sky. Water vapor absorption above t 11(' cloud base accounts for most of the additional flux divergence associated with the cloud. This contribution to the anomalous absorption is proportional to the water vapor abundance and the photon path lengths within the cloud, and inversely proportional to the solar zenith angle. It SI101II(I therefore produce its largest effects at low latitudes, where the water vapor mixing ratios are greatest. '1'11(! apparent absence of a strong latitude dependence in the observed anomalous absorption (Cess et al. 199[)) suggests that other factors including the poorly constrained horizontal inhomogeneity of clouds abundance might be needed 10 explain this])1I(')10III(UIOII.