P4.8 New Fu-Liou Code Tested with ARM Raman Lidar Aerosols and CERES In Pre-CALIPSO Sensitivity Study

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Introduction

Raman lidar vertical profiles of aerosol optical depth are used in conjunction with Raman lidar (night) and GOES/AERI (daytime) temperature and humidity profiles to compute Shortwave (SW) flux profiles using a modified version of the Fu-Liou radiative transfer code. Comparisons to observations of surface fluxes at the ARM SGP site for a clear sky day are shown. At top of atmosphere model computed radiances and fluxes are compared to CERES (Wielicki, 1996) instantaneous measurements from the ES8 product.

Perturbations to the observed aerosol profiles are made in an error analysis. The ground based Raman lidar measures the actual extinction profile. CALIPSO, a satellite mission with a nadir pointing lidar, will measure the backscatter profile and assume values of the extinction to backscatter ratio(Sa) to estimate the extinction profile. Here we show the effect of a gross error in the assumed value of Sa on a calculated shortwave heating rate.

Fu-Liou Radiative Transfer Model

A modified version of the Fu-Liou code, a correlated-k code with a 2-stream SW and 2/4-stream LW, was run for pristine sky (no aerosol) and for clear sky using AERONET Cimel sun photometer aerosol optical depths at 7 wavelengths, measured at the ARM SGP central facility. Modifications of the code allow for multiple wavelength aerosol optical depth measurements to be input. The optical properties of wavelength dependent single scatter albedo and asymmetry parameter are determined by choosing an assumed aerosol type or external mixture of constituents. The aerosol types and properties are taken from OPAC(Hess,1998) and earlier work by d'Almedia(1991) and Tegin&Lacis(1996). Other modifications affecting the *shortwave* include improved treatment of rayleigh scattering to match the improved band resolution for aerosols, updated ozone absorption coefficients, minor absorption by H_2O in the visible and inclusion of O_2 and CO_2 absorption by means of a correction based on work by Chou(1999). This absorption correction is applied after the main body of the code produces fluxes. Shortwave energy beyond 4 microns is now treated in an approximate manner by inclusion in the existing 2.5-3.5 micron band with high absorption characteristics.

Modifications to the *longwave* portion of the code include updating the continuum absorption to CKDv2.4 motivated by SHEBA results (Tobin,1998). Significant differences from earlier versions occur in the spectral region around 500cm^{-1} allowing more transmission at low specific humidity typically found in the upper troposphere. Other modifications include updating absorption for water vapor, ozone, methane, N_2O and the addition of CFC's in the 8-12 micron window region.

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Most recently the thermal longwave was extended from 2200cm^{-1} to 2850cm^{-1} to better handle extreme daytime desert cases.

Data

Several sources of data are used in this work.

1) Raman lidar profiles of temperature, humidity and aerosol optical depth (night).
2) Combined AERI/GOES retrievals of profiles of temperature and humidity (daytime).
3) The CERES SARB group maintains a CAVE (CERES ARM Validation Experiment, Rutan, 2001,) web database [http://www-cave.larc.nasa.gov/cave] of surface fluxes, aerosol optical depth and cloud fraction (Long, 2000) derived from surface flux measurements from the ARM SGP site.
4) CERES top of atmosphere broadband shortwave and longwave fluxes.
5) SMOBA ozone mixing ratio vertical profiles.

Method

A clear sky day of September 6 2000 was chosen to analyze. Data from Raman lidar and the diffuse SW cloud fraction, as well as CERES MLE all showed clear sky for most of the day except late afternoon. Temperature and Humidity profiles from Raman lidar during the night and GOES/AERI during the day along with NCEP Smoba daily ozone profiles were averaged or sampled to ½hourly periods to match the observations from the CAVE data set of surface observations. Skin temperature is taken from a downward looking pyrgeometer assuming a surface emissivity of 0.98. Broadband surface albedo is taken as the ratio of the down looking to up looking PSP except at the time of CERES overpass. If available a CERES TOA albedo is used to retrieve a surface albedo based on an atmospheric correction from a look-up table requiring sun angle, total PW, AOT, O_3 and assumed surface albedo spectral shape.

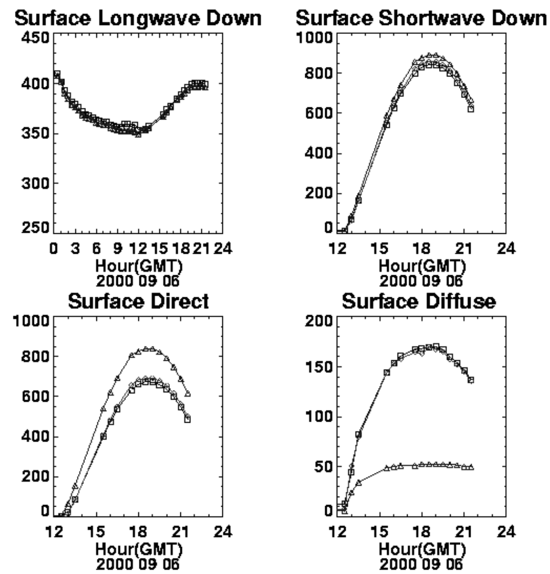

Figure 1. Comparison of observed (square) Fu-Liou model pristine (triangle) and model with observed aerosol (diamond) at ARM SGP for single day.

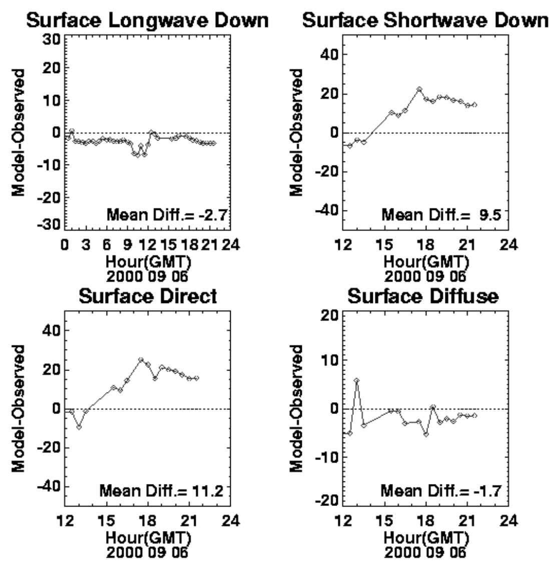

Figure 2. Difference of Fu-Liou model minus observed surface fluxes.

Results

Model calculations show good agreement for downwelling longwave at the surface with a daily mean bias of –2.7 Wm^{-2}. Longwave surface flux is highly dependent on the lower atmosphere temperature and humidity which is captured well with the measured profiles from Raman lidar and AERI. Relative measurements of water vapor profile by AERI are adjusted to match the total PW measured by the microwave radiometer.

Model shortwave reveals a 9.5 Wm^{-2} overestimate of total SW flux. Most of the discrepancy occurs in the direct beam, approaching 20 Wm^{-2} near noon. Direct SW for clear sky is mainly dependent on aerosol optical depth, and gas absorption by O_3, H_2O, CO_2, O_2, and CH4. Data from multiple wavelength CIMEL measurements are used and have accuracy to 0.01 in optical depth. The version of the Fu-Liou code used in this study used correlated-k's based on the 1982 version of the AFGL line parameter database. Future work will update the correlated-k's according to HITRAN2000. It is expected that much of this absorption discrepancy will be alleviated with this update.

Aerosol Profile Sensitivity Results

The upcoming satellite mission CALIPSO will have a lidar and will measure backscattered return due to scattering by gas molecules and aerosols. One uncertainty in retrieving the profile of extinction from space is the assumption of extinction to backscatter ratio Sa. Values can vary by a factor of 2, from 25 for clean maritime to 55 for dust aerosol (Omar, 2002).

Figure 4 shows what a gross error (2x) in the assumed value of Sa would do to shortwave heating rate using perturbed profiles of aerosol optical depth (Fig 3) consistent with a 2x error in Sa. In this case with an elevated aerosol layer, heating rates can be perturbed by nearly 0.5 (K day^{-1}).

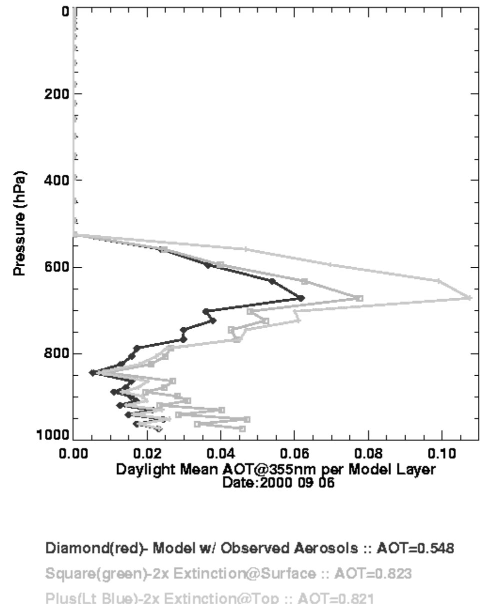

Figure 3. Daily mean aerosol optical depth as a function of pressure for the retrieved Raman lidar profile (diamond), Assuming a 2x profile at the surface normal at the top (square), Assuming a 2x profile at the top normal at the surface (plus)

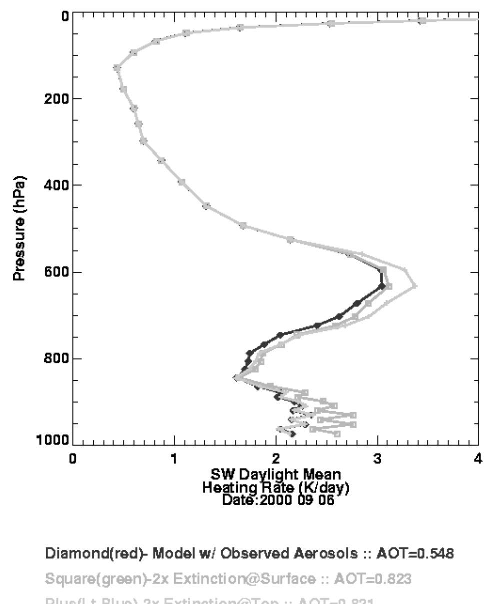

Figure 4. Daily mean model calculated shortwave heating rate as a function of pressure for the retrieved Raman lidar profile (diamond), Assuming a 2x profile at the surface normal at the top (square), Assuming a 2x profile at the top normal at the surface (plus)

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