Web-Based Data Analysis Tools

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Mission Research Corporation (MRC) is developing software tools to assist the Atmospheric Radiation Measurement (ARM) Program and ARM-Unmanned Aviation Vehicle (UAV) in data collection and analysis. Two of these tools were demonstrated at the March 1996 ARM Science Team Meeting. They are 1) world-wide-web (WWW, i.e., Internet) based interactive codes, in which a user enters input parameters, requests that the data be processed, and gets back results; and 2) a browser such as Netscape Navigator on which these codes are used. Both tools were developed in close association with the Institute for Computational Earth System Science (ICESS) at the University of California at Santa Barbara.

These tools are reached via the address **http://arm.mrcsb.com/** on the internet. This brings up a simple home page with several options—the two presented here, and also "ARM/UAV Support." This third option highlights some of MRC's other tools for ARM/UAV. It also provides links to many other ARM related sites, including ICESS. The two new options are an atmospheric radiative transfer calculator, and a cloud optical thickness-particle size extractor.

SBDART - Atmospheric Radiative Transfer Calculator

The first tool (option "SBDART Radiative Transfer Model") is functional now. It is a WWW interface to the SBDART (Santa Barbara DISORT Atmospheric Radiative Transfer) code from ICESS. The user enters parameters for time, location, atmospheric conditions, earth's surface, sensor instrument, and clouds. These are sent to our computer, which runs SBDART. The results are then sent back, as a data table and plots of flux density, to the WWW browser for viewing.

ICESS developed SBDART by assembling a set of highly developed and reliable models previously developed by the atmospheric community. The energy transfer is calculated with the DISORT code, using discrete ordinates (Stamnes et al. 1988). The user can specify up to five cloud layers (assumed to be uniform horizontally), each with its own value of optical thickness and effective particle size. A Mie code was used to generate a database of scattering efficiency, single scatter albedo, and asymmetry factor for cloud water particles, as a function of mean particle size (using a log-normal distribution). Presently there is also data for spherical ice, of 106 micron radius, for modeling cirrus clouds. The Henyey-Greenstein approximation is used for the phase function.

SBDART uses the low resolution band models from the LOWTRAN 7 atmospheric transmission code (Pierluissi and Maragoudakis 1986) for molecular species of the earth's atmosphere. This covers the 0 to 50000 cm^{-1} range, with 20 cm^{-1} resolution (about 5 nm in visible, 200 nm in thermal infrared). This data was fit with a three term exponential fit (Wiscomb and Evans 1977).

The user can select from six standard atmospheric profiles (topical, midlatitude summer or winter, subartic summer or winter, or US62), or may use results from radiosonde profiles. Future plans include allowing the user to upload radiosonde profile data (McClatchey et al. 1972).

Boundary layer aerosols may be selected from rural, urban, or maritime, with the user setting their concentration by giving a visibility value. For upper atmosphere aerosols the choices are fresh or aged volcanic, meteoric, or climatological tropospheric. These models are derived from 5s (Tanre et al. 1988) and LOWTRAN 7.

Surface albedo may be selected from ocean, lake, clear water, vegetation, snow, or sand, all of which are wavelength dependent. Alternatively, the user may directly give a value for the albedo.

Figure 1 shows an example of results from a run. It uses defaults for all the parameters, and then puts a cloud at 3 kilometers, with optical thickness of 10, and effective particle radius of 8 microns.

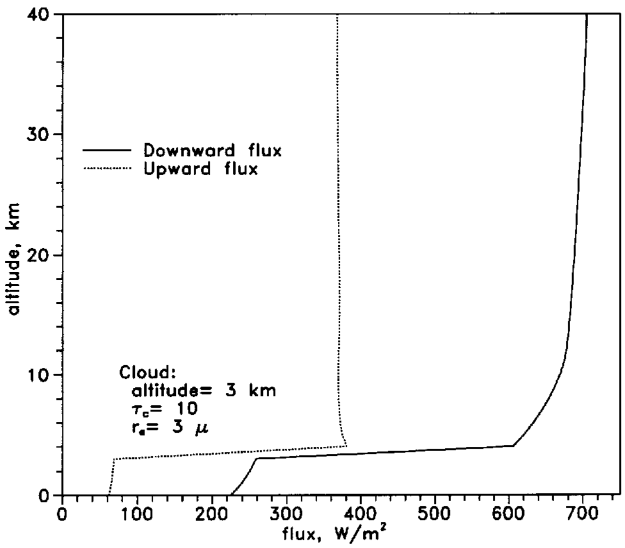

Figure 1. Sample SBDART results.

Cloud Optical Thickness - Particle Size Extractor

The last option, "Cloud Optical Thickness and Particle Size Extraction Demonstration," is, in a sense, the opposite of the SBDART calculator. The user specifies radiance measurement values, and asks "What are the cloud properties?" This uses the approach suggested by Nakajima and King (1990). To show the method we applied it to four datasets from NASA's MAS system. This presently is only a demonstration, it does not accept user data yet.

The extraction procedure's input is clouds' solar reflectance measurements from two channels, and the outputs are estimates for the cloud optical thickness (τ_c) and effective water droplet radius (r_e). The SBDART code is used to model the atmospheric radiation transfer, and, essentially, the code's parameter values for τ_c and r_e are varied until the predicted and measured reflectances match. A table-interpolation method is used, with a precalculated database of SBDART results, to find a match between calculated and measured reflectances. This approach is fast enough to handle large numbers of measurement pixels, such as the millions of pixels in each MAS dataset.

The Nakajima-King Diagram and Channel Selection

The extraction is essentially the solving of two nonlinear equations for two unknowns. For best results the τ_c-r_e behaviors should be different between the two channels. Nakajima and King suggest one channel in the visible region, where there is little absorption (called the nonabsorbing channel, with reflectance R^N) and the other a near-infrared channel with considerable absorption (the absorbing channel, with reflectance R^A). Nakajima and King used 0.75 µm for the R^N channel and 2.16 µm for the R^A channel; here we will use the 0.664 µm and 2.142 µm MAS channels.

Nakajima and King diagrams, such as shown in Figure 2, show plots of the reflectance values, with R^N along the horizontal axis and R^A along the vertical, using a matrix of τ_c and r_e values. In the figure constant r_e lines (solid) are mostly horizontal and the constant τ_c lines (dashed) are mostly vertical.

We see that for much of the plotted region there is an almost orthogonal relation between constant τ_c and constant r_e lines, which means the τ_c can be found from the R^N value, and the r_e from R^A. (And that noise in one channel does not affect determination of the parameter associated with the other channel.) The orthogonality results from the different behaviors for the two channels. For the R^A channel the cloud "saturates" (becomes essentially infinitely thick) at small thicknesses, and so for thicker clouds its reflectance is independent of thickness; instead reflectance depends on planar albedo, and is strongly dependent on particle size. For the R^N channel, however, except for small particles, the scattering does not depend strongly on particle size, and it does not saturate until the cloud is very thick; thus, the reflectance depends strongly on optical thickness. This orthogonality, however, is not actually required, and τ_c-r_e may, ideally, be retrieved for any

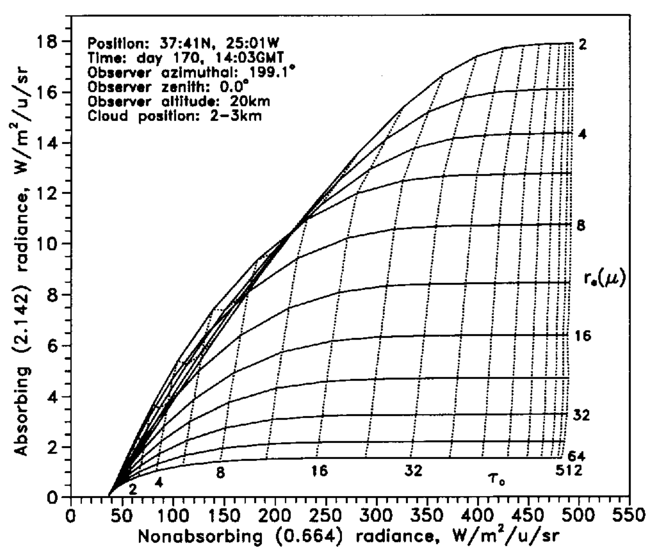

Figure 2. Sample Nakajima-King diagram.

point on the Nakajima and King diagram, even where the effects of τ_c and r_e are far from orthogonal.

MAS Data

The MAS (MODIS Airborne Simulator) is an airborne scanning spectrometer flown on a NASA ER-2 high-altitude aircraft. (MODIS - Moderate Resolution Imaging Spectrometer - will be part of NASA's Earth Observing System - EOS.) It provides narrow band measurements similar to those the ARM Program's MPIR (Multispectral Pushbroom Imaging Radiometer) will provide. MAS scans sideways through 85.93 degrees, from right to left, in 716 pixels, from an altitude of about 20 kilometers. Each image pixel is about 50 meters in size, and it records a new scan line about every 30 meters along its flight.

MAS data from ASTEX (Atlantic Stratocumulus Transition Experiment) was browsed, and selected datasets downloaded from NASA's Langley DAAC. Channel 2 (0.664 µm) was used for R^N, and channel 6 (2.142 µm) for R^A. The MAS data has radiance values, in units of Watts/meter^2/micron/steradian. Corresponding τ_c-r_e values for these cases are shown in the web pages.

Data Table Preparation

Each flight line (a unit of recorded data, from several minutes of flight in a straight line) is short enough that we will assume that the only variation in solar geometry is the observer zenith angle (which varies with the scan). Values for the center of the flight line were used for the other solar geometry parameters. Guesses were selected for the other SBDART parameters. Nakajima and King diagrams where then generated and compared with the measured data.

Cloudless pixels provide a test of the parameter values used, since the Nakajima and King diagram narrows down to a single point. By adjusting (for example) surface albedo and aerosol values, model predictions for this point can be moved about to try to get a good match to the measured reflectance. Also, the Nakajima and King diagram has a firm outer boundary, along the r_e=5.66 µm line, and, if clouds with this particle size are present, this can provide another good check on the choice of parameter values.

Extraction of τ_c and r_e

Values were selected for all the model parameters, initially using generic values. These values were then adjusted to get good agreement between the data and the Nakajima and King diagram. (In the future we plan to look through the vast array of data available from the ASTEX program, such as radiosonde atmosphere profiles, to help better set some of the parameter values.) After selecting a final set of parameters for a dataset (as listed on each dataset submittal screen), five Nakajima and King diagrams where generated, at the zenith angles Θ= 0.0°, ±21.4825°, and ±42.96°, by running SBDART for 232 τ_c-r_e pairs: 11 r_e values from 2 to 64 in half powers of 2, and 21 τ_c values from 0.5 to 512 in half powers of 2, plus a pair at τ_c=0 (with r_e immaterial). Each pair consisted of two SBDART runs, for the two channels. This data was then used for table-lookup; any R^N-R^A value pair can be found for given Θ,τ_c,r_e values by linear interpolation.

To retrieve τ_c-r_e values for a given pixel, this data table was searched to find the correct table cell, and linear interpolation used to get the τ_c-r_e values. The search would start in the cell found for the previous neighboring cell, as an initial guess. The cell would be checked to see if it contain the measured R^N-R^A values. If it was not the right cell, then the position would move to one of the four immediately neighboring cells, which would again be checked to see if it was the right cell. The general form of the Nakajima and King diagram was used to decide which way to move, using differences between the measured R^N and R^A values and the calculated values in the present cell. Once the correct cell was found, linear interpolation was used to find the τ_c-r_e values.

References

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