Intercomparison of Shortwave Radiative Transfer Code and Measurements

R. N. Halthore
Brookhaven National Laboratory
Upton, New York

Abstract

A protocol and rationale for intercomparison of shortwave models and measurements is discussed. In an activity currently under way, several modeling groups around the world have brought many types of models ranging from line-by-line models to general circulation models (GCMs) to perform this intercomparison. The purpose of this report is to inform potential participants of this activity.

Introduction

Recent developments in the field of shortwave radiative transfer have raised fundamental questions on our understanding of basic processes occurring in the atmosphere. There is considerable ambiguity in the amount of shortwave energy absorbed by clouds. Our knowledge of shortwave energy absorbed by cloud-free skies appears to be in doubt. But apart from the current issues, a previous landmark model intercomparison effort showed "substantial" discrepancies among models even for the simplest case pure water vapor absorption where the models differed by as much as 6% to 11% for the total atmospheric absorption. Recognizing the need for another effort of this kind, a few of us met at the Gordon Conference on Solar Radiation and Climate held in June 1998 in Plymouth, New Hampshire. We agreed to perform model intercomparisons for specific radiation components of the earth-atmospheric system in cloud-free skies to compare models against each other and, where available, to evaluate against measurements. Model-to-model intercomparisons have value since not all models are equal—some, such as the line-by-line models, treat transmittance more accurately, whereas some broad-band models treat multiple scattering more accurately. Model-to-measurement comparisons give us a reality check if we know the accuracy of the measurements.

The atmospheric radiation components identified to calculate and report are, in order of increasing complexity: direct downward solar irradiance at the surface, diffuse-downward shortwave irradiance at the surface, diffuse-upward shortwave flux at the surface, and top of the atmosphere (TOA) upward flux. Four cases were identified as providing the necessary protocol for intercomparison: 1) standard atmosphere without aerosols, 2) standard atmosphere with prescribed aerosol optical properties, 3) actual atmosphere with measured aerosol properties and components of irradiance, and 4) standard atmosphere with a prescribed cloud and cloud properties but without aerosols. Each case involves two atmospheres and two geometrical configurations. More than 20 groups around the world are involved in this effort that encompasses most of the original and frequently used models.

Models

Spectral resolution varies from very broadband (GCMs) to moderate (MODTRAN [moderate-resolution atmospheric radiance and transmittance model] is an example) to line-by-line codes. Various methods of solving the transfer equation are employed in these models including two-stream approximation, doubling/adding codes, and discrete ordinate models. Specialized radiative transfer codes that, for example, are used normally in atmospheric correction procedures are also used. The protocol is explained below, which can be read in its entirety at http://www.ecd.bnl.gov/~halthore/intercomp/intercomparison.html

Protocol (Date: July 7, 1998; Upgraded from Draft status: February 1, 1999)

For each case listed below, the atmospheric radiation components that we will calculate and report are, in order of increasing complexity: direct downward solar irradiance at the surface, diffuse-downward shortwave irradiance at the surface, diffuse-upward shortwave flux at the surface, and TOA upward flux. It is realized that for the constant surface reflectance cases, the upward flux at the surface is just the reflectance multiplied by the total downward irradiance.

The cases to be treated are as follows:

1. **Without aerosols but with Rayleigh scattering included**. Two standard atmospheres (provided by Gail Anderson)—sub-arctic winter (low humidity), tropical atmosphere (high humidity)—at two solar zenith angles—30° and 75°. We agreed to specify a constant surface albedo of 0.2 (Lambertian) across the spectrum (0.28 μm to 5.0 μm), solar spectrum (big file!), and minor gas (H_2O, O_3) abundance as a function of height from MODTRAN with 360 ppmv for CO_2. Report calculations (as shown in Table 1) for broadband shortwave (0.28 μm to 5.0 μm), ultraviolet (0.2 μm to 0.35 μm), visible (0.35 μm to 0.7 μm), and shortwave infrared (SWIR) (0.7 μm to 5.0 μm). Input-height resolution is not specified—you do what is usual for your model. **RESULTS**: Be sure to look at the summary of the results submitted so far.

2. **With aerosols**. For the same conditions as above, run the models for two aerosol loadings: high (aerosol optical thickness [AOT] at 550 nm = 0.24, angstrom exponent (b = 1.6), and low (AOT at 550 nm = 0.08; b = 0.74). Aerosol scattering properties, single-scattering albedo (SSA) and phase function (P), are calculated from Mie theory for assumed aerosol properties. Note that aerosol extinction and scattering properties are not independent of each other, although in this treatment they appear so. Table 2 provides the format for output. Results submitted so far are summarized here.

3. **Comparison with measurements**. For two actual cases (high and low AOT) for which measurements are available, we will perform the code comparisons. Atmospheres, aerosol properties, surface reflectance, and solar zenith angle will all be specified. Results will be compared with measurements. Table 3 provides the format for output.

Table 1. Aerosol-free case with standard atmospheres.

		Sub-Arctic Winter		Tropical	
	Solar Zenith Angle	**30**	**75**	**30**	**75**
Direct Down	Broadband				
Direct Down	0.2 µm to 0.35 µm				
Direct Down	0.35 µm to 0.7 µm				
Direct Down	0.7 µm to 5.0 µm				
Diffuse Down	Broadband				
Diffuse Down	0.2 µm to 0.35 µm				
Diffuse Down	0.35 µm to 0.7 µm				
Diffuse Down	0.7 µm to 5.0 µm				
Diffuse Up	Broadband				
Diffuse Up	0.2 µm to 0.35 µm				
Diffuse Up	0.35 µm to 0.7 µm				
Diffuse Up	0.7 µm to 5.0 µm				
Diffuse Up TOA	Broadband				
Diffuse Up TOA	0.2 µm to 0.35 µm				
Diffuse Up TOA	0.35 µm to 0.7 µm				
Diffuse Up TOA	0.7 µm to 5.0 µm				
Without aerosols, this case highlights the transmittance part of the codes, with the line-by-lines acting as benchmarks for the direct.					

Table 2. Aerosol case with standard atmospheres.

		Low AOT	High AOT
	Solar Zenith Angle	**27.08°**	**51.39°**
Direct Down	Broadband		
Direct Down	0.2 µm to 0.35 µm		
Direct Down	0.35 µm to 0.7 µm		
Direct Down	0.7 µm to 5.0 µm		
Diffuse Down	Broadband		
Diffuse Down	0.2 µm to 0.35 µm		
Diffuse Down	0.35 µm to 0.7 µm		
Diffuse Down	0.7 µm to 5.0 µm		
Diffuse Up	Broadband		
Diffuse Up	0.2 µm to 0.35 µm		
Diffuse Up	0.35 µm to 0.7 µm		
Diffuse Up	0.7 µm to 5.0 µm		
Diffuse Up TOA	Broadband		
Diffuse Up TOA	0.2 µm to 0.35 µm		
Diffuse Up TOA	0.35 µm to 0.7 µm		
Diffuse Up TOA	0.7 µm to 5.0 µm		
(a) This case highlights the accuracy of models in handling multiple scattering.			

Table 3. Case with measured aerosol and atmospheric properties.

		Sub-Arctic Winter				Tropical			
		Low AOT		High AOT		Low AOT		High AOT	
	Solar Zenith Angle	**30**	**75**	**30**	**75**	**30**	**75**	**30**	**75**
Direct Down	Broadband								
Direct Down	0.2 µm to 0.35 µm								
Direct Down	0.35 µm to 0.7 µm								
Direct Down	0.7 µm to 5.0 µm								
Diffuse Down	Broadband								
Diffuse Down	0.2 µm to 0.35 µm								
Diffuse Down	0.35 µm to 0.7 µm								
Diffuse Down	0.7 µm to 5.0 µm								
Diffuse Up	Broadband								
Diffuse Up	0.2 µm to 0.35 µm								
Diffuse Up	0.35 µm to 0.7 µm								
Diffuse Up	0.7 µm to 5.0 µm								
Diffuse Up TOA	Broadband								
Diffuse Up TOA	0.2 µm to 0.35 µm								
Diffuse Up TOA	0.35 µm to 0.7 µm								
Diffuse Up TOA	0.7 µm to 5.0 µm								
This case represents the reality check. Some components of the atmospheric radiation such as the direct normal solar irradiance can be measured accurately; others such as diffuse downward irradiance have relatively larger errors.									

4. **Cloud case**. A continental boundary layer stratiform cloud is defined (Dong et al. 1997) to have an integrated optical depth of 60 at 550 nm, and is located between 1 km and 2 km (904 mbar and 805 mbar) in the tropical model atmosphere devoid of aerosols. This corresponds to a uniform mixing ratio of about 146 particles/cc. The wavelength dependent optical properties are defined corresponding to a log normal size distribution with a modal radius of 7 microns, and a logarithmic width of 0.35. Broadband modelers are requested to use their own method of creating broadband result from high-resolution data. Phase function (2.6 Mbytes) is defined at 181 angles at each of the 188 wavelengths (0.2 µm to 8.1 µm). For those who prefer it, Legendre polynomial moments of the phase function are also provided. Surface albedo is to be assumed as 0.2 (constant). The output should be as in Table 1 above, but only for the tropical atmosphere (30° and 75° solar zenith angle).

Acknowledgments

Those who helped draft the protocol are: Gail A. Anderson, Bernard Bonnel, Fu Lung Chang, Ming-Dah Chou, David Crisp, Philippe Dubuisson, Stuart Freidenreich, Qiang Fu, Catherine Gautier, Stephan Kinne, Istvan Laszlo, Zhanqing Li, V. Ramaswamy, Paul Ricchiazzi, Stephen E. Schwartz, and Alexander Trichtchenko.

Reference

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