Shortwave Radiative Transfer in the Earth’s Atmosphere: Current Models and Validation

Jennifer Delamere, Eli Mlawer, and Tony Clough
Atmospheric & Environmental Research, Inc.
Summary

• AER builds radiative transfer models suitable for Earth’s atmosphere
  – Longwave and shortwave
  – Validated against high-resolution radiance/irradiance measurements

• RT models require:
  – Solar spectral irradiance
  – Complete spectral range
  – Sufficient spectral resolution

• Consensus data from solar community would ultimately be transferred into global climate and numerical weather prediction models
AER Products & Services

- Community Radiative Transfer Models
- Community Databases
  - Spectral line parameters (input)
  - Solar source function (input)
  - Reference RT Cases (output)
- Web-sites
  - http://www.aer.com
  - http://rtweb.aer.com
Radiative Transfer: Line-by-Line

Line-by-Line Radiative Transfer Model (LBLRTM)

- Calculations valid from ultra-violet to sub-millimeter spectral regions
- Multiple-scattering option available (CHARTS)
- Validated extensively against high-resolution measurements

MLS Profile
TOA: 1368.2
SFC: 1084.0
Required Parameters for SW RT

Spectral line and continuum parameters

- MT_CKD Continuum Model
- HITRAN database (38 molecules)
Required Parameters for SW RT

Solar Spectral Irradiance

- Kurucz (1992) provided desired resolution and spectral range for RT calculations
- Formulation based on Kitt Peak Solar Flux Atlas and solar RT calculations
Required Parameters for SW RT

Solar Spectral Irradiance

- Kurucz (1992)
- Other Options (Gueymard, Thullier, etc.)
Radiative Transfer: GCM-suitable

RRTM Longwave & Shortwave Correlated-k Models

- Accelerates calculations of fluxes
- Uses small set of absorption coefficients to represent absorption coefficients at all frequencies in the spectral band
- Achieves accuracy comparable to line-by-line method

MLS Profile
SFC: 1084.0
SFC: 1084.8
Δ SFC: -0.8
Users of RRTM Models

- **Global GCMs**
  1. ECMWF forecast model (using LW and testing SW)
  2. NCEP Global Forecast System (GFS) (using LW and testing SW)
  3. Max Planck Institute climate model (ECHAM5) (using LW)
  4. NCAR atmosphere model (CAM3) (using LW and SW at AER)
  5. GFDL climate model (testing LW and SW)

- **Mesoscale/Regional Models**
  1. Penn State/NCAR (MM5) (using LW)
  2. NCAR Weather Research and Forecasting (WRF) (using LW in NCAR/EM)
  3. UC/CIRES Arctic regional climate model (ARCSyM) (using LW)

- **Dept. of Energy ARM Program**
  1. Various Single Column Models (Scripps, LLNL, etc.) (using LW)
  2. BBHRP (using LW and SW)
  3. McICA (implemented in LW and SW)

- **NPOESS (algorithm component; clear sky only)**
  1. AER/NGST VIIRS net heat flux and ocean albedo (using LW and SW)
Welcome to the Website of AER's Radiative Transfer Working Group

Measurement/Model comparison for high water case from 22 July 2001 from ARM Southern Great Plains (SGP).

The top panel is the downwelling radiance at the surface measured by the AERI instrument (U. of Wisconsin).
Welcome to the Website of AER's Radiative Transfer Working Group

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Solar Source Function

I. Description
II. Code and Examples
III. Contact Information
IV. What's New
V. References and Publications

Anonymous FTP of extract_solar

Source Code and Makefiles:

pub/anon_downloads/aer_extract_solar/aer_extract_solar_v1.3.tar.gz

Note: To FTP directly from web browser you must have your preferences set to send email address an anonymous FTP password.

Can also use anonymous FTP performing the following:

ftp ftp.aer.com:

login: anonymous
password: your email address

extract_solar:

cd pub/anon_downloads/aer_extract_solar/

Source code and makefiles are contained in the file:

get aer_extract_solar_v1.3.tar.gz

To unpack tared and compressed files on Unix:

gunzip aer_extract_solar_v1.3.tar.gz

tar -xvf aer_extract_solar_v1.3.tar

Atmospheric and Environmental Research Inc. (AER)
Radiative Closure Experiments

Specification of Atmospheric Properties

Radiative Transfer Model

Flux/Radiance Measurements

COMPARE
Longwave Example

AERI ARM/LBLRTM Validation

Radiance (W/cm² sr cm⁻¹)

AERI ARM SGP Observation 010722 (Sonde 0522 Z)
4.51 prec. cm H₂O
331.4 DU O₃

(a) AERI ARM - LBLRTM_v6.0
Line File: hitran96
CKD 2.0.1

(c) AERI ARM - LBLRTM_v7.00
Line File: aer_hitran_2000_updat_01.2
MT_CKD_1.0

Wavenumber (cm⁻¹)
RSS Validation

- Ground-based Rotating Shadowband Spectroradiometer (SUNY Albany) (Harrison et al., 1999)
- Deployed at ARM Southern Great Plains site from 1996 onward
- Spectrally resolved direct-normal, diffuse-horizontal, and total-horizontal irradiances
  - 9000-28,900 cm\(^{-1}\) (1.1 - 0.35 \(\mu\)m)
  - 512 channels (instrument now has 1024 channels)
  - Spectral resolution from 91 cm\(^{-1}\) (IR) to 65 cm\(^{-1}\) (UV)
- Model-measurement intercomparison provided means to look at clear-sky anomalous absorption issue
Solar Irradiance in RSS Validations

• Extraterrestrial irradiances implied from RSS langley regressions do not agree in all spectral regions with the Kurucz solar irradiances (Harrison et al., 1999)

• Approach: RSS irradiances adjusted to Kurucz solar irradiances

  • Implication: Measurement-model comparisons are effectively between measured and calculated transmittances
• Model LBLRTM/CHARTS calculations (Mlawer et al., 2000) include:
  - Atmospheric thermodynamic profile specified by observations
  - Spectrally dependent surface albedo derived from measurements
  - Aerosols
  - Instrument cosine response
High-Resolution ASTI Validation

- Absolute Solar Transmittance Interferometer (U. Denver)
  - Measures solar radiance from 2000 - 10,000 cm\(^{-1}\) (1 - 5 \(\mu\)m) with 0.6 cm\(^{-1}\) resolution
  - Field of View: central 16% of the solar disk

- Deployed at the Southern Great Plains ARM site
- Opportunity to look in detail at processes in the near-infrared
- Validation resulted in parameterization of collision-induced O\(_2\) continuum for RT models
Figure 1. (a) Solar radiances measured with the Absolute Solar Transmittance Interferometer (ASTI), (b) radiances calculated by the line-by-line radiative transfer model (LBLRTM), (c) differences between the ASTI measured radiances and the LBLRTM calculated radiances before formulation of the O$_2$ continuum, and (d) differences between the ASTI measured radiances and the LBLRTM calculated radiances after formulation of the O$_2$ continuum for the spectral range 7300–8300 cm$^{-1}$ and a zenith angle of 71.5°.
• Radiative Closure Studies for:
  - broadband
  - shortwave
  - cloudy skies
  - ‘grid cell’
  - TOA
  - all ARM sites

• Generate heating rate profiles based on in-situ measurements using validated radiative transfer model (for use by modelers)

• Generate dataset of measured and modeled radiation for all ARM sites

• Provide a ‘test suite’ for researchers evaluating new parameterizations and data sources
BBHPRP Project

Retrieved Cloud Microphysics

Satellite TOA Measurement

Modeled TOA Fluxes

Radiative Transfer Model (RRTM)

Modeled Surface Broadband Fluxes

Broadband Radiometers

10-km

2-km

Low Radar Sensitivity

Base

Top

Radar Echo

Emission

Laser Cloud Radar Microwave Radiometer
Wrap-Up

- Consensus data from solar community would ultimately be transferred into global climate and numerical weather prediction models
  - AER hosts a web-site with models and their associated inputs and reference output cases
    - http://rtweb.aer.com
  - Opportunity for future high-resolution radiometric measurements in Chile (proposed RHUBC-II experiment)

Line-by-Line RT Calculations
LBLRTM/CHARTS

Rapid RT Calculations
RRTM

Inclusion into GCMs/NWPs
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* Included as Minor Species
# RRTM_SW Band Data

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