Towards a Generic Radiative Transfer Model for the Earth's Surface-Atmosphere System: ESAS-Light, Contract No AO/1-5433/07/NL/HE

Abstract

Claudia Emde[1], Arve Kylling[3], Robert Buras[1], Bernhard Mayer[1,2], Franz Schreier[2], and Ulrich Hamann[2]

[1]Ludwig-Maximilians-Universität, Munich, Germany
[2]Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany
[3]Contractor, Ålesund, Norway
March 22, 2010

The objective of the ESAS-Light project was to give actors in the field of remote sensing of planetary environments full access to a user friendly, well documented, and free of charge radiative transfer toolbox. Radiative transfer modeling plays a key role for remote sensing because it is central for the development and testing of inversion algorithms as well as for the design of new remote sensing instruments: Remote sensing of planetary atmospheres and surfaces uses radiation covering a wide range of wavelengths, coming either from the sun or from the atmosphere (passive remote sensing), or from an artificial radiation source (active remote sensing). Radiation is affected by interaction between radiation and atmosphere or surface - the observed radiation therefore contains information about the atmosphere and surface which can be retrieved. ESASLight addressed the complete solar and thermal spectral range, concentrating but not necessarily restricting itself on the Earth's specific requirements.

The *libRadtran* software package (Mayer and Kylling, 2005) has been identified to be an ideal basis for the study. *libRadtran*, developed by the authors of this study, is a suite of tools for radiative transfer calculations which is freely available at `http://www.libradtran.org`. It provides radiances, irradiances, actinic fluxes and heating rates in the solar and the terrestrial part of the spectrum. The design of *libRadtran* allows simple problems to be easily solved using defaults and included data, hence making it suitable for educational purposes. At the same time its flexibility makes it a powerful and versatile tool for research tasks. *libRadtran* has been verified in several model intercomparison studies, and validated by direct comparison with observations. One of the most relevant features of *libRadtran* is that it includes a selection of about ten different RT solvers, including the widely-used DISORT code by Stamnes et al. (1988), a fast two-stream code (Kylling et al., 1995), a polarization-dependent code (Evans and Stephens, 1991), and the fully three-dimensional Monte Carlo code for the physically correct tracing of photons in cloudy atmospheres, MYSTIC (Mayer, 2009; Emde and Mayer, 2007; Emde et al., 2010).

During the ESASLight project the *libRadtran* software package has been greatly extended to a fully vectorized (polarization-dependent) one- and three-dimensional radiatiative transfer code. Inelastic rotational Raman scattering has been added which is an issue for a variety of passive retrieval schemes. The treatment of water and ice cloud scattering has been completely redesigned and a large database of optical properties of water droplets and various ice particle shapes has been added. Aerosol modeling has been made more flexible, and a database of aerosol optical properties has been added. For the simulation of surface reflection more BRDF (Bi-directional Reflectance Distribution Function) models have been included. User friendly line-by-line tools

(Schreier and Schimpf, 2001) to compute layer optical thicknesses which are required for high spectral resolution calculations using *libRadtran* have been provided. All new algorithms have been carefully validated by comparison against benchmark results and analytical solutions. In order to make *libRadtran* more user friendly the documentation has been completely rewritten. Various new examples, a chapter on the theoretical background of the radiative transfer solvers, and a "quick starting guide" have been added. Finally a first version of a graphical user interface has been developed which makes it easier for the user to generate input files, to run the RT solvers, and to visualize the results.

The thus developed radiative transfer toolbox shall strengthen the modeling capability of ESA for internal purposes (instrument and prototyping of inversion algorithms) and provide a set of standard radiative transfer tools for the development of ESA commissioned inversion schemes and calibration/validation activities.

References

Emde, C. and Mayer, B.: Simulation of solar radiation during a total solar eclipse: A challenge for radiative transfer, Atmos. Chem. Phys., 7, 2259–2270, 2007.

Emde, C., Buras, R., Mayer, B., and Blumthaler, M.: The impact of aerosols on polarized sky radiance: model development, validation, and applications, Atmospheric Chemistry and Physics, 10, 383–396, http://www.atmos-chem-phys.net/10/383/2010/, 2010.

Evans, K. F. and Stephens, G. L.: A new polarized atmospheric radiative transfer model, J. Quant. Spectrosc. Radiat. Transfer, 46, 413–423, 1991.

Kylling, A., Stamnes, K., and Tsay, S.-C.: A reliable and efficient two-stream algorithm for spherical radiative transfer: documentation of accuracy in realistic layered media, Journal of Atmospheric Chemistry, 21, 115–150, 1995.

Mayer, B.: Radiative transfer in the cloudy atmosphere, European Physical Journal Conferences, 1, 75–99, 2009.

Mayer, B. and Kylling, A.: Technical note: The libRadtran software package for radiative transfer calclations – description and examples of use, Atmos. Chem. Phys., 5, 1855–1877, 2005.

Schreier, F. and Schimpf, B.: A New Efficient Line–By–Line Code for High Resolution Atmospheric Radiation Computations incl. Derivatives, in: IRS 2000: Current Problems in Atmospheric Radiation, edited by Smith, W. and Timofeyev, Y., pp. 381–384, A. Deepak Publishing, 2001.

Stamnes, K., Tsay, S., Wiscombe, W., and Jayaweera, K.: A numerically stable algorithm for discrete-ordinate-method radiative transfer in multiple scattering and emitting layered media, Applied Optics, 27, 2502–2509, 1988.