1. Introduction

What is MCARaTS

MCARaTS is a general purpose radiative transfer model (RTM). It simulates the three-dimensional radiative transfer (3DRT) in atmosphere-ocean-land system using the Monte Carlo methods. The model can be applied to the ultraviolet to microwave spectral range. However, polarization is not taken into account. The codes can be used for simulations of radiative energy budget and quasi-observation with optical instruments.
A major purpose to use the software could be to simulate accurate radiative quantities as virtual observation data obtained with optical instrument (or human eyes) for cloud-containing atmosphere over land/ocean surface. The other objective is to investigate the three-dimensional radiative transfer within inhomogeneous media. Volume rendering is a new feature. Approximate RTE solvers are incorporated mainly for visualization of 3-D volumetric data. Thus MCARaTS can be used as a visualization tool.
Input to the RTM should be optical properties of the atmosphere and surfaces (i.e. extinction coefficients, single scattering albedos, phase functions, and sruface BRDFs).

Features of the RTM

Can be summarized as follows:
What's good : Easy to use, fast, and parallelized
Basic algorithm : Forward-propagating Monte Carlo photon transport algorithm
Radiative transfer solvers

- Fully-3-D radiative transfer (F3D)
- Partially-3-D radiative transfer (P3D)
- Independent column approximation (ICA)

Input

- Three-dimensionally inhomogeneous atmosphere
- Inhomogeneous surface modeled by BRDF models
  1. Lambertian model
  2. Diffuse-specular-mixture (DSM) model
  3. Rahman-Pinty-Verstraete (RPV) model
  4. Li-Sparse-Ross-Thick (LSRT) model

Output quantities

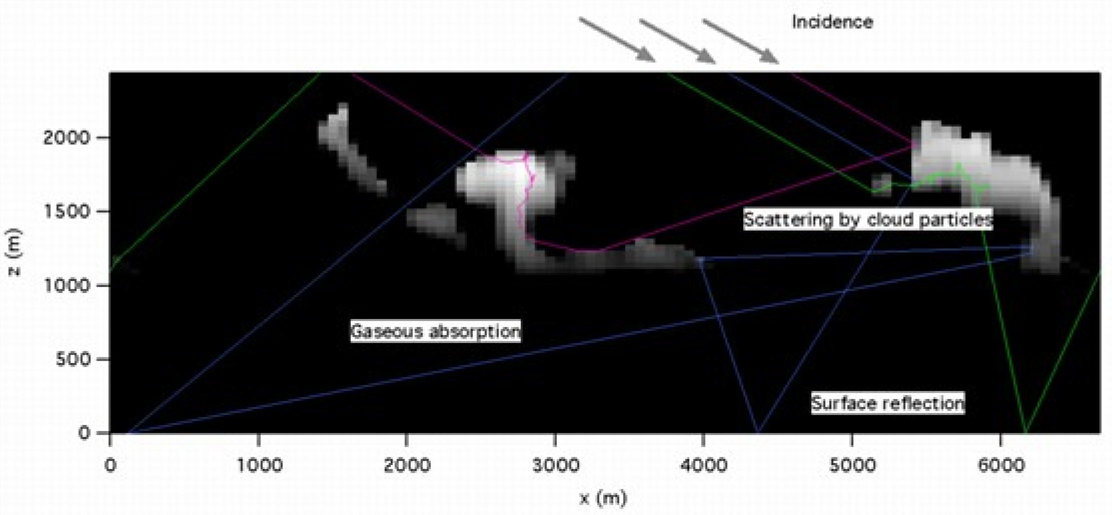
- Radiative fluxes and heating rates
- Radiances with pathlength statistics
- Pseudo-radiances for quick visualization of 3-D volumetric data

Numerical techniques

- The maximum cross section technique applied to super-cells
- The local estimation method
- Variance reduction techniques
  - Collision-forcing method for optically-thin media
  - Flexible truncation of forward peak of phase function
  - Numerical diffusion (a denoising technique)
  - The Russian roulette method
- Parallelization using MPI

Requirements

- Linux/UNIX-like operating system
- Fortran 90/95 compiler
- MPI is optionally needed for parallelization.



Output quantities from the RTM

Various types of radiative quantities can be calculated.

- Upward/downward/direct fluxes at layer interfaces (averaged over finite areas)
- Volume-averaged heating rates (averaged over finite volumes)
- Radiances possibly with pathlength statistics
  1. Radiances averaged over solid angles, at some locations
  2. Radiances averaged over horizontal areas, for some specific directions
  3. Radiances averaged over horizontal areas and solid angles

For 1 and 2, a visualization mode can be chosen.

- Pathlength statistics (optional)
  1. Layer average pathlength normalized by vertical layer depth: Layer air mass factors
  2. Pathlengths averaged with weighting by user-specified functions: Air mass factors
  3. Histogram of pathlength integrated from the source emission to the radiance detector: Time-resolved radiance distributions

The above can be calculated pixel-by-pixel for each user-specified radiance.
Local fluxes could not be output in the latest version. Instead, radiances averaged over solid angle can be calculated. If the FOV is a hemisphere, the averaged radiance can be easily converted to irradiance on any inclined plane or hemispherical actinic flux density.

3D radiative transfer

In previous studies on transfer of energy, several kinds of 3D radiative transfer (3DRT) solvers have been developed, such as finite difference and characteristics methods. We can see a variety of 3DRT codes in the I3RC project for example. The Monte Carlo method is a kind of simple and powerful solvers. Its accuracy is well known due to its physically correct basis and a number of tests. That is why the Monte Carlo method has been frequently used as reference to validate other methods.
For a study on 3DRT, an exact method and two approximations to solve 3D radiative transfer are incorporated in the MCARaTS codes:

- Fully-3-D radiative transfer (F3D)
- Partially-3-D radiative transfer (P3D)
- Independent column approximation (ICA)

ICA neglects horizontal transfer of radiation and applies 1D radiative transfer (1DRT) to atmospheric columns independently. Using the ICA mode, we can compare 3D and 1D schemes strikingly even for very complicated model atmospheres, not being affected by different property descriptions (e.g., constant or trilinear extinction in each cell), area/volume-averaging or method of phase function truncation etc.

MCARaTS softwares

The package includes softwares for the followings:

- Radiative transfer solvers,
- Processing utility tools for the I/O data.

The processing tools can process the data file output from the RT solvers. See also the corresponding manual pages for details.

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