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1. Introduction

What is MCARaTS

MCARaTS is an open-source software package to simulate the three-dimensional radiative transfer (3DRT) in atmosphere-ocean-land system using the Monte Carlo methods. The codes can be applied to simulations of solar energy budget and quasi-observation with optical instruments.
A major purpose to use the software is 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.
MCARaTS is a general-purpose radiative transfer model (RTM), which means that input should be optical properties of the atmosphere and surfaces (i.e. extinction coefficients, single scattering albedos, phase functions, and sruface BRDFs). Polarization is not taken into account.

Features of the radiative transfer code 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

- Upward/downward/direct fluxes at layer interfaces (area-averaged fluxes)
- Volume-averaged heating rates
- Radiances possibly with pathlength statistics
  1. Area-averaged radiances at arbitrary layer interfaces
  2. Camera images (angle-average radiances looking from arbitrary points)
- Local fluxes at arbitrary points (pathlength-resolved)

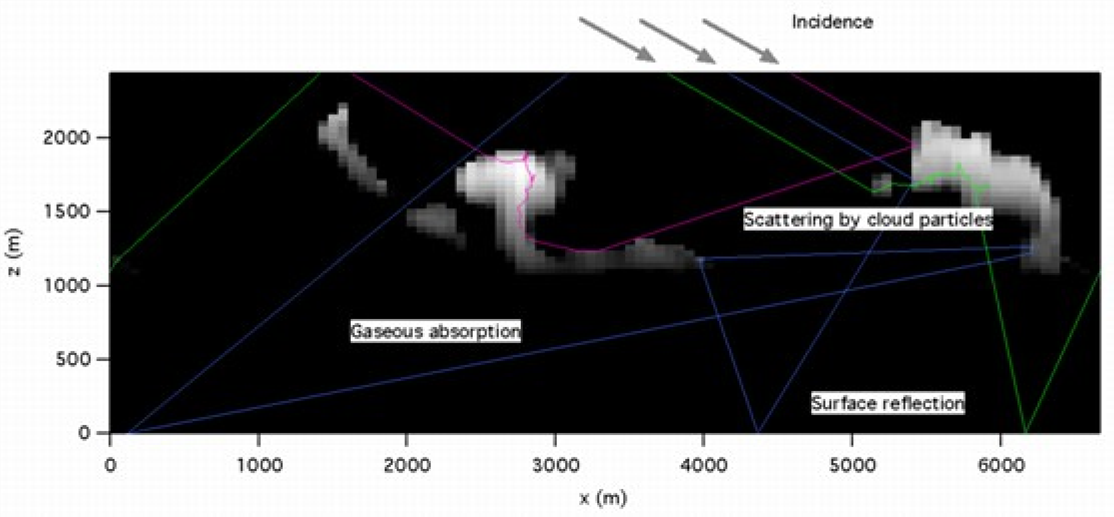
Numerical techniques

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

Requirements

- Linux/UNIX-like operating system
- Fortran 77 compiler compatible with GCC (GNU's compiler collection)
- MPI is optionally needed for parallelization.

References : Several methods and algorithms used is described in a scientific paper:
Iwabuchi, H., 2006: Efficient Monte Carlo methods for radiative transfer modeling. Journal of the Atmospheric Sciences, 63, 2324-2339.



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 spherical harmonics 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,
- Post-processing the output data.

The post-processing tools process the data file output from the RT solvers. The RT output file is in a unique format, as described later. The processing tools can convert the output data and calculate the basic statistics. See also the corresponding manual pages for details.

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