libRadtran user course, lecture # 5

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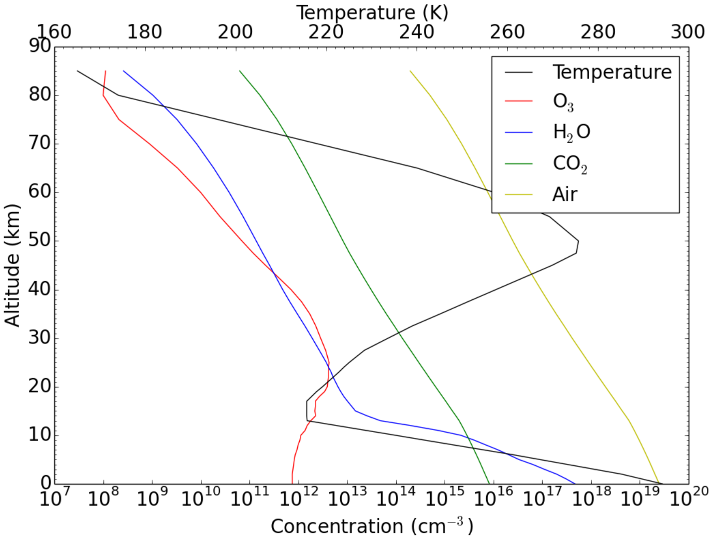
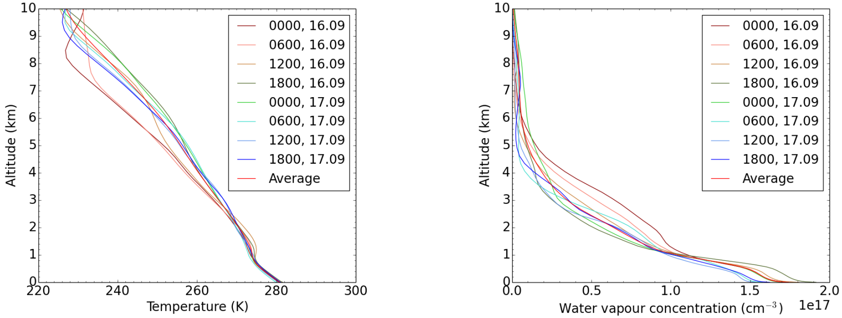
Input to RT models: Overview

- Atmospheric profiles/distributions (gases, clouds, pressure, T)
- Absorption and scattering cross sections
- Single scattering properties, phase function (ice and water clouds, aerosol)
- Surface albedo or bidirectional reflectance distribution function, temperature, emissivity

Input to RT models: the atmosphere

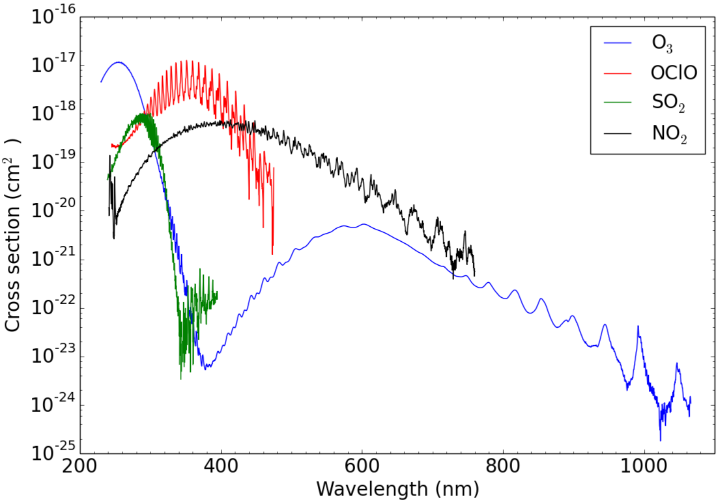


Input to RT models: the atmosphere

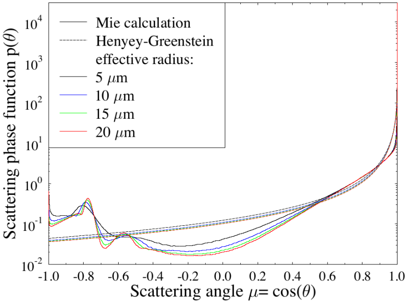


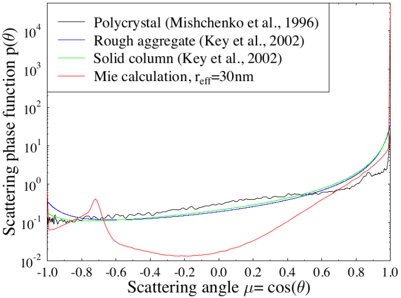
Data from ECMWF analysis, Iceland 2013.

Input to RT models: cross sections



Input to RT models: phase functions





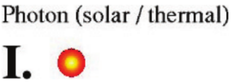
Monte Carlo solution to radiation transport

- Monte Carlo radiative transfer traces individual photons on their way through the atmosphere
- Allows all physical processes to be included $\rightarrow$ No approximations (?)
- Sort of brute force.
- May be used to solve the radiative transfer equation without knowing the equation.
- Need to understand the individual processes!
- Statistical method, hence noisy.

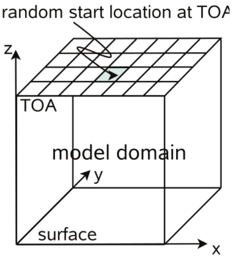
libRadtran includes the MYSTIC solver. 1D version freely available. 3D version please contact B. Mayer.

Below a step by step explanation of Monte Carlo radiative transfer is given following Mayer (2009).

Monte Carlo solution step by step

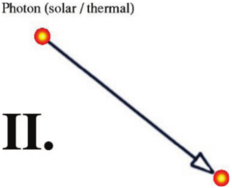


Create photon and assign location, direction and wavelength.



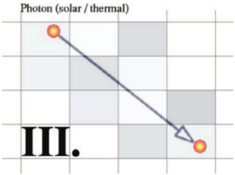
Solar radiation: start at top of the atmosphere (TOA).
Thermal radiation: start somewhere in the atmosphere or the surface.

Monte Carlo solution step by step



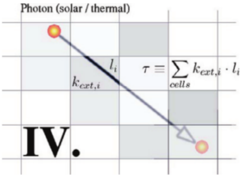
How far does the photon travel?

$$p_{\text{sur}}(\tau) = \exp(-\tau)$$

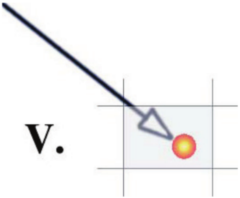


Photons travel in physical space: here a rectangular grid where the optical properties are constant within each grid cell.

Monte Carlo solution step by step



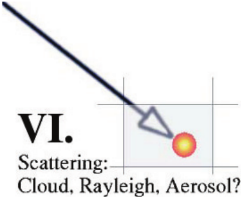
Determine where in cell (x, y, z) the photon stops.



Is the photon absorbed or scattered?
Determined by the single scattering albedo:

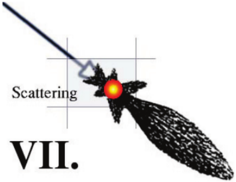
$$\omega = \frac{\beta^{\text{sca}}}{\beta^{\text{abs}} + \beta^{\text{sca}}}$$

Monte Carlo solution step by step



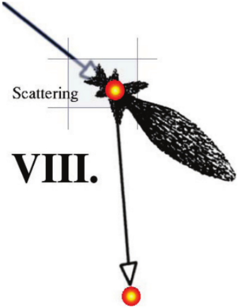
What type of scattering event?

$$\frac{\beta^{\text{sca,aer}}}{\beta^{\text{sca}}};\ \frac{\beta^{\text{sca,cloud}}}{\beta^{\text{sca}}};\ \frac{\beta^{\text{sca,Ray}}}{\beta^{\text{sca}}}$$

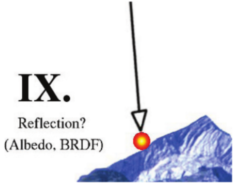


Select appropriate phase function. Here aerosol.

Monte Carlo solution step by step

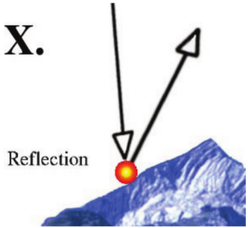


Determine scattering direction.

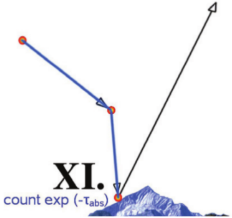


At surface photon either gets absorbed or scattered.

Monte Carlo solution step by step

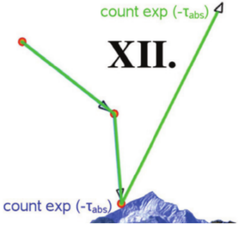


Direction determined by albedo/BRDF.



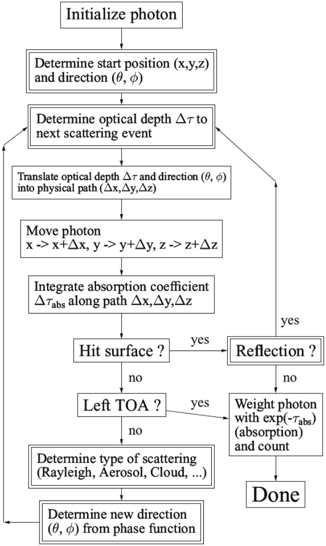
Keep on going until photon leaves the model domain at top of the atmosphere.

Monte Carlo solution step by step

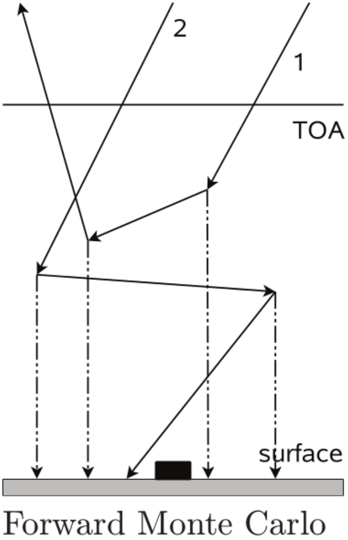


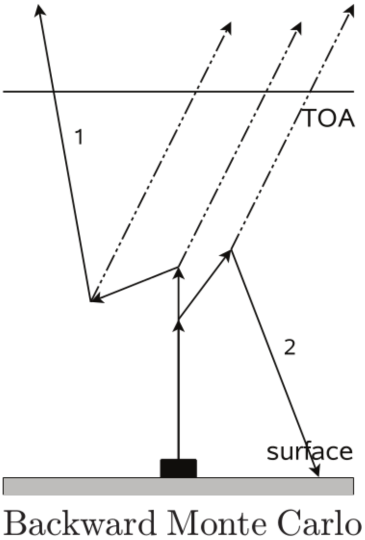
Trace many photons and count the photon whenever it hits the desired location at which we want the result.

Monte Carlo solution step by step: summary

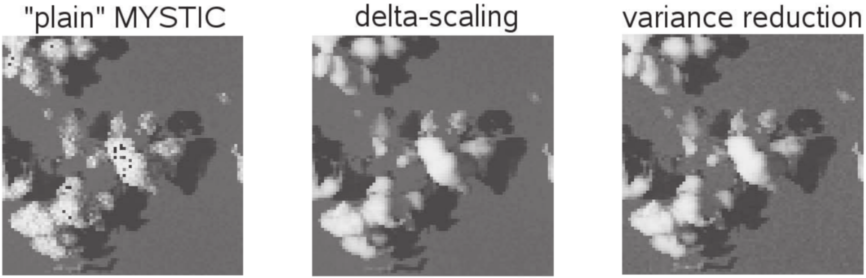


Monte Carlo; forward versus backward





Monte Carlo; variance reduction



Sample MYSTIC input file

```
                                # Location of atmospheric profile file.
atmosphere_file ../examples/UVSPEC_MC_ATM.DAT
                                # Location of the extraterrestrial spectrum
source solar ../data/solar_flux/atlas_plus_modtran
mol_modify O3 300. DU
day_of_year 170                 # Correct for Earth-Sun distance
albedo 0.2                      # Surface albedo
sza 32.0                        # Solar zenith angle
phi0 180.0                      # Sun in the North

rte_solver montecarlo           # Radiative transfer equation solver MYSTIC
mc_photons 100000               # MYSTIC number of photons

mc_sample_grid 201 201 1 1   # sample grid, 201 x 201 grid boxes

# MYSTIC input files
wc_file 3D     ../examples/UVSPEC_MC_WC.DAT
mc_elevation_file ../examples/UVSPEC_MC_ELEV.DAT
mc_albedo_file    ../examples/UVSPEC_MC_ALB.DAT

wavelength 310.0 310.0                 # Wavelengths considered

quiet
```

Sample MYSTIC input file cont'd

```
wc_file 3D    ../examples/UVSPEC_MC_WC.DAT

  2 2 35 1
100.5 100.5 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14
1 1 3 10 0.75 1.0
2 2 3 10 0.75 1.0

mc_elevation_file ../examples/UVSPEC_MC_ELEV.DAT
202 202 1 1
1 202 0
2 202 0
3 202 0
4 202 0
......

mc_albedo_file    ../examples/UVSPEC_MC_ALB.DAT
201 201 1 1
1 201 0.07
2 201 0.07
3 201 0.07
4 201 0.07
........
```

Today's exercises:

- Get familiar with the various input and output files for MYSTIC
- Increase and decrease `mc_photons` to see how result changes
- Include `mc_std`
- Increase albedo and see what happens with CPU time
- For a 1D water cloud: compare Monte Carlo and DISORT (results and CPU time)

Hints:

- example input files: `UVSPEC_MC*.INP`
- options `mc_*`

References I

Mayer, B.: Radiative transfer in the cloudy atmosphere, Eur. Phys. J. Conferences, 1, 75–99, 2009.