libRadtran user course, lecture # 8

Arve Kylling

NILU-Norwegian Institute for Air Research

The libRadtran radiative transfer package

The libRadtran software package is a suite of tools for radiative transfer calculations in the Earths atmosphere.

- Borne sometime in the early 90s.
- Early development A. Kylling and B. Mayer.
- First publication with uvspec in the title Mayer et al. (1997).
- Continuous development until today.
- Freely available from `www.libradtran.org`.
- Currently version 2.0.2. See `http://www.geosci-model-dev-discuss.net/8/10237/2015/gmdd-8-10237-2015.html`.
- More than 600 papers have actively used libRadtran.

libRadtran: some applications

- Analysis of **UV-radiation** measurements
- **Cloud and aerosol remote sensing** using solar and thermal measurements.
- **Volcanic ash studies**
- **Remote sensing of surface properties**
- **Trace gas remote sensing**: forward modelling
- Calculation of **actinic fluxes**
- Determination of solar direct irradiance and global irradiance distributions.
- Simulation of satellite radiances to be used for data assimilation
- Validation of radiation schemes included in **climate models**
- Simulation of heating rates in 3D
- Simulation of solar radiation during a **total eclipse**
- Rotational **Raman scattering**, which explains the filling-in of Fraunhofer lines
- Remote sensing of **planetary atmospheres**

libRadtran tools

Some libRadtran tools are:

- **uvspec** The main radiative transfer tool
- **mie** Calculation of single scattering properties
- **ssradar** Single scattering radar simulator
- **zenith** calculates solar zenith and azimuth angles and Earth eccentricity
- **angres** calculates the effective radiation given an angular response and a radiance distribution
- **vac2air** converts from vacuum to air wavelength and vice versa
- **snowalbedo** calculates diffuse and direct albedo of snow
- **make_slitfunction** generates various slit functions
- **conv** convolves an input file with a convolution function
- **integrate** integrates a file between given limits
- **spline** spline or linear interpolation between given data points

More are included in the package.

libRadtran: useful folders

Useful folders

- **bin** Contains all executeables including `uvspec`.
- **doc** The libRadtran User's guide is found here.
- **examples** Look here for examples of input and, the resulting output, files.
- **GUI** Location of the Graphical User Interface to `uvspec`.
- **src** The source code for the main tools.
- **libsrc_c** C source that is used by many tools.
- **libsrc_f** Fortran source that is used by many tools.
- **src_py** Place to start if you want to add your own input option (python).

uvspec: solar zenith angle, albedo and more

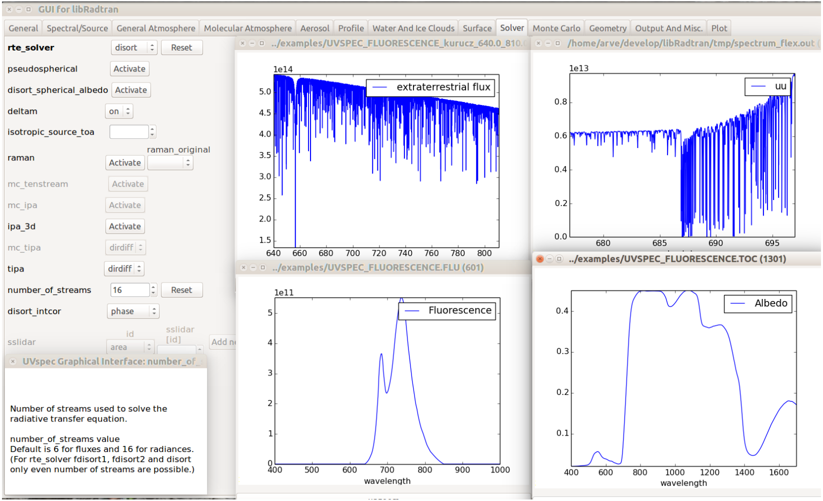
Calculate solar zenith angle:

```
zenith -q -a 60 -o -20 -e -s -15 19 1 12 00
12:00:00  60.6561    3.4746 1.009064
```

Add following to input file

```
albedo 0.2                 # Surface albedo
sza  60.6561               # Solar zenith angle
mol_modify O3 300. DU      # Set ozone column
day_of_year 19             # Correct for Earth-Sun distance
rte_solver disort          # Radiative transfer equation solver
```

Graphical User Interface (GUI)



uvspec: scripting languages

Repeated runs cumbersome. Use scripting languages to generate input file, run code and handle output:

python Powerful and easy to use.

shell Various unix shells

perl Powerful scripting language. If you find shell scripting syntax awkward you do not want to try perl

uvspec: visualization of input/output

GUI simple visualization of some input/output
gnuplot useful for quick views of data in column format
python/matplotlib Can do nearly everything
python/mayavi Powerful 3D plotting

Ozone retrieval (look-up tables)

Use Perl script: `src/Gen_o3_tab.pl`. **WARNING: options not updated to version 2.0.**

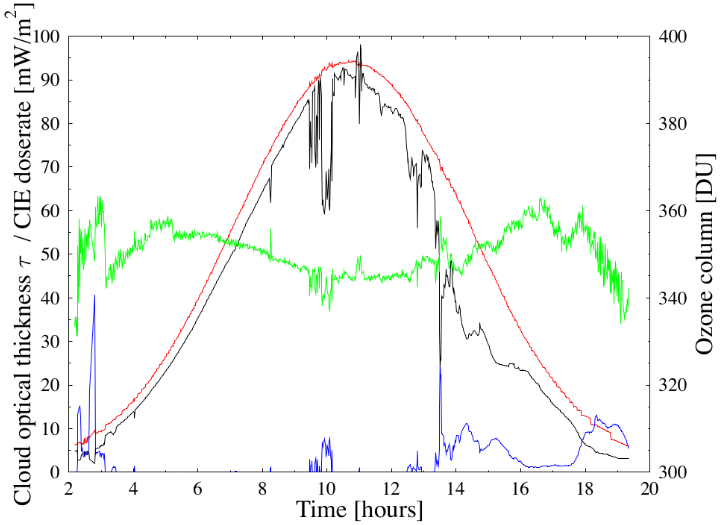
```
Gen_o3_tab generates a table of some wavelength ratio versus
solar zenith angles for different ozone amounts. The table is
read and ozone columns derived by the read_o3_tab program.

The following wavelength ratios are supported:
(See the libRadtran documentation for examples.)

    * Ratios between two wavelengths where each is
      calculated from single wavelength measurements.
    * Ratios between two wavelengths where each is
      calculated from wavelength measurements multiplied by
      a bandpass function and integrated over the bandpass.

Gen_o3_tab understands the following options:

--absolute                 : The wavelengths of the bandpass files are in
                             absolute units. Default is relative units.
--albedo <value>           : Lambertian surface albedo. Default is 0.0.
--alpha <value>            : Angstrom alpha coefficient. Default is 0.0.
--altitude <value>         : Altitude above sea level [km]. Default is 0.0.
--atmmod <name>            : Name of atmosphere file. Default atmmod/afglus.dat.
--beta <value>             : Angstrom beta coefficient. Default is 0.0.
--help                     : Prints this message.
--o3_crs <name>            : Name of o3 cross section to use. Default is Molina.
                             See libRadtran documentation for other options.
--slitfunction <name>      : Name of slitfunction file.
--bandpasslower <name>     : Name of file holding bandpass for lower wavelength.
--bandpassupper <name>     : Name of file holding bandpass for upper wavelength.
--file <name>              : Name of file where the table will be stored.
--lower_lambda <value>     : Value for lower wavelength, in nm.
--upper_lambda <value>     : Value for upper wavelength, in nm.
--zenith                   : Calculate zenith sky radiance table.
```



From Mayer and Kylling (2005).

Global radiation (SW+LW)

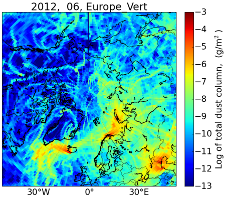
1. Compare “accurate” radiative transfer with met & climate models.
2. Radiative forcing (aerosol direct effect)

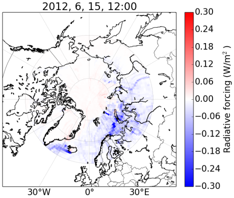
- Calculate irradiances with and without forcing (aerosol).
- Include water and ice clouds
- Aerosol from dispersion model
- Assume independent pixels
- Calculate solar and thermal radiation separately
- Computationally expensive if done for many pixels and long time periods.

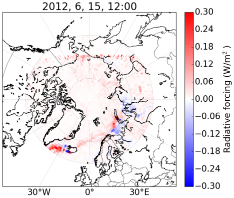
Useful options:

```
wc_file 1D filename
ic_file 1D filename
output_user .....
mol_file o3, co2, h2o .....
zout ....
output_process sum
pseudospherical
cloud_fraction_file .....
mol_abs_param fu
rte_solver disort
day_of_year ...
albedo_file ....
sur_temperature ....
sza ....
profile_file ...
profile_properties ...
```

Radiative forcing (aerosol direct effect)







Dust column

Cloudless

Cloudy

RF simulations only made north of 60°N.

Photolysis rates (aerosol)

Photolysis rate for reaction *i* given by

$$J_i(\tau) = 4\pi \int d\lambda q_i(\lambda)\sigma_i(\lambda)\overline{I(\tau,\lambda)}$$

where the mean intensity

$$\overline{I(\tau)} = \frac{1}{2\pi}\left[I_0 e^{-\tau/\mu_0} + \int_0^{2\pi} d\phi \int_0^1 I(\tau,-\mu,\phi)d\mu + \int_0^{2\pi} d\phi \int_0^1 I(\tau,\mu,\phi)d\mu\right]$$

uvspec may calculate the mean intensity.

`src/Calc_J.pl` may calculate some photolysis rates. **WARNING: options not updated to version 2.0.**

Final remarks

- Latest version always at `www.libradtran.org`.
- Missing something for your research?
  - Code is available so you may add yourself. If so please send modified code to us so we can include in future releases.
  - We may include it, but funding is needed.
- We are always interested in joining projects related to radiative transfer (modelling, measurement, data interpretation and analysis).

References I

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

Mayer, B., Seckmeyer, G., and Kylling, A.: Systematic long–term comparison of spectral UV measurements and UVSPEC modeling results, J. Geophys. Res., 102, 8755–8767, 1997.