Radiative Transfer in a Coupled Atmosphere-Water System: AccuRT User Manual for Virtual Machine (VM) version

Contents

1 Introduction

This document describes how to use a flexible and accurate tool – **AccuRT** – for radiative transfer (RT) simulations in a *coupled* system, consisting of two adjacent slabs with different refractive indices, such as a coupled atmosphere-water (liquid or solid) system. Each of the two slabs comprising the coupled system, is taken to be a stratified medium in which the inherent optical properties (**IOP**s) can vary along the direction of stratification, but in which no variation in **IOP**s is permitted in directions perpendicular to the direction of stratification. Technical details about this tool are provided in a companion document [1].

2 Salient Features

The **AccuRT** tool has a unique set of features. It provides:

- radiative quantities (irradiances and radiances) in the wavelength range between 280 nm and 4,000 nm;
- irradiances at any user-specified locations in the atmosphere and water;
- radiances in any user-specified direction (azimuth and polar angle) at any user-specified location (height in the atmosphere and depth in the water);
- easy-to-read output files;
- Matlab routines for automatic plotting of irradiances and radiances.*

The concept of **materials** is used to provide high level configuration of radiatively-significant constituents in the *coupled* system that automatically specifies wavelength dependent **IOP**s.

AccuRT has intuitive input specifications provided in the **main** configuration file (Appendix A) including:

- support for an arbitrary† number of layers (in each of the two slabs) as required to resolve vertical variations in the **IOP**s;
- solar input spectrum, as well as a user-specified (constant) input option;
- bottom albedo and emissivity boundary conditions;
- atmosphere materials: clear atmosphere **IOP** models for molecular scattering and gaseous absorption (Appendix B, **earth_atmospheric_gases** (**gasIOP**, **Air**) as well as **IOP**s for a bi-modal distribution of aerosol particles generated by a Mie code (Appendix C, **aerosols**);

*A third-party Python library is available from https://github.com/TorbjornT/pyAccuRT.

†In the current version of **AccuRT** the number of layers in each slab can be arbitrary as long as the sum does not exceed 78.

- water materials: pure water **IOP**s (Appendix D, **pure_water**) and water impurity **IOP**s (bio-optical models, Appendix E, **water_impurities_ccrr**);

- vacuum material: to allow for either of the two slabs comprising the coupled medium to be transparent (Appendix F, **vacuum**);

- two different user-specified materials, to allow for user-specified **IOP**s:

  user_specified (Appendix G). When using this option the user must provide Legendre polynomial expansion coefficients (moments) of the scattering phase function. It is important that enough moments be provided to ensure an accurate representation of the scattering phase function.

  layer_user_specified (Appendix H). When using this option the user provides absorption and scattering coefficients, refractive index and asymmetry factor for the Henyey-Greenstein scattering phase function. Other scattering phase functions will be implemented in an upcoming version of AccuRT.

The **AccuRT** tool is:

- easy-to-run, and

- well-documented including technical notes [1] in addition to this user manual.

3 Installation of VM version

The configuration of this Debian Linux w/ AccuRT Virtual Machine (VM) is as follows:
1. debian 9 with xfce4 GUI
2. AccuRT v1.0.716
3. openssh enabled
4. Firefox ESR browser
5. GNU Octave (free alternative of MATLAB) 6. FileZilla (free FTP client)

You can run AccuRT on this VM and plot the result using Octave. FileZilla allows you to transfer your results to other machines as needed and the command line sftp/scp tools are also available. (Or you can use your VM software to transfer to/from the VM to your host machine.)

To start using this VM, you need to download Oracle VirtualBox from the following website:

https://www.virtualbox.org/wiki/Downloads

Depending on the host system (Windows, Mac or Linux) you have, you need to choose the correct installation package. After the installation of VirtualBox, you can add this VM by choosing:

Machines > Add > Locate the "accurt-debian9.vbox" file included in the directory

then you should see a machine named "accurt-debian9" and you can power on it by clicking "Start"

The login user information for this machine is:

username: accurt password: AccuRTuser1234

Here are some tips:

1. There is a folder under your home folder called "AccuRT", which contains a test run case using the default setup of AccuRT. To run AccuRT, you can open a terminal window (click the terminal icon in bottom middle) and go to the AccuRT/Testcases/ folder, then type "AccuRT test01" and the program should run. You can build you own case based on this template once you get it to run.

2. To use Firefox, you can open a terminal window (click the terminal icon in bottom middle) and type "Firefox".

3. To use GNU Octave, you can open a terminal window (click the terminal icon in bottom middle) and type "octave".

Once you login you should be good to go. You can clone this machine and use it as your basic testbed for radiative transfer simulations. You can also use it to practice and get familiar with Linux systems as well as virtual machines.

3.1 Quick Installation Check-List

It is very important to have your environmental variables properly set, otherwise the program will not run. Here is a quick check list of commands to run to make sure that everything is set up properly:

```
echo $ACCURT_PATH
```

This command should return the path to the directory created by unpacking **AccuRT**. To check if it is correct do

```
ls $ACCURT_PATH
```

You should see something like:

```
lib  license  lll  main  README
```

```
echo $LD_LIBRARY_PATH
```

If there is more than one path returned they will be separated by a colon. If there is more than one path, the last path should be `$ACCURT_PATH/lib`:

```
/usr/lib:/usr/local/lib:/home/username/AccuRT/AccuRT_v1.0.716/lib
```

```
echo $PATH
```

Again, the last path should be to `$ACCURT_PATH/main`:

```
/usr/local/bin:/bin:/usr/bin:/usr/sbin:/home/username/AccuRT/
   AccuRT_v1.0.716/main
```

If for some reason there is an issue with any of your environmental variables, recheck your `$HOME/.bash_profile` file, correct the environmental variables, and update the changes with the `source $HOME/.bash_profile` command. Then run through the check list again.

4 Running AccuRT – Quick-Start

To see a help menu, run **AccuRT** from your terminal without any arguments:

```
AccuRT
```

Generate a template set of input files with

```
AccuRT -g myConfigName
```

where **myConfigName** should be replaced by a string such as **MyShinyConfig**. The main configuration file is then called **myConfigName**. Edit the main configuration file and its materials in the **myConfigNameMaterials** folder. Once done, run AccuRT with the following command:

```
AccuRT myConfigName
```

After the program finishes running, the output will appear in the folder named

```
myConfigNameOutput
```

To get an overview of the output data the user may set the tag

```
SAVE_COSINE_IRRADIANCES=true
```

in the main configuration file **myConfigName** to generate text files containing cosine weighted (planar) irradiance and the **Matlab** program **plotIrradiance.m**, which will plot irradiances at all user-requested levels in the upper slab (atmosphere) (as specified in the DETECTOR_DEPTHS_UPPER_SLAB tag) and levels in the lower slab (water) (as specified in the DETECTOR_DEPTHS_LOWER_SLAB tag). In addition to cosine weighted irradiance, AccuRT can generate sine weighted irradiance (SAVE_SINE_IRRADIANCES tag) and scalar irradiance (SAVE_SCALAR_IRRADIANCES tag).

Similarly, the user may set the tag SAVE_RADIANCES=true in the main configuration file to generate a text file containing radiances and the **Matlab** program **plotRadianceAll.m**, which will plot radiances in all user-requested directions (specified in the DETECTOR_AZIMUTH_ANGLES and DETECTOR_POLAR_ANGLES tags) at all user-requested locations specified in the DETECTOR_DEPTHS_UPPER_SLAB tag (atmosphere) and the DETECTOR_DEPTHS_LOWER_SLAB tag (water).

5 Input

To make use of **AccuRT** the user needs to specify the physical input required and the output desired. The user must specify (i) the radiative energy input at the top of the upper slab (*e.g.* at the top-of-the-atmosphere (**TOA**) for a *coupled* system), (ii) the physical properties of each of the two slabs that constitute the coupled system (*e.g.* temperature and **IOP**s), and (iii) the boundary conditions at the bottom of the lower slab (*e.g.* at the bottom of the water for a coupled system). Each of the two slabs is assumed to be a plane-parallel or stratified medium, so that the **IOP**s (*i.e.* the scattering and absorption coefficients and the scattering phase function)

vary only in the direction of the stratification (the vertical direction for a coupled atmosphere-water system), denoted by z. In order to resolve changes in the **IOP**s as a function of z, each slab is divided into a number of adjacent plane-parallel layers (that are perpendicular to the direction of stratification), such that the **IOP**s are constant within each layer, but allowed to vary from one layer to the next. The interface between the upper slab (*e.g.* the atmosphere) and the lower slab (*e.g.* the water) is assumed to be flat in the present version of **AccuRT**. A wind-roughened water interface will be included in an upcoming version.

In the main configuration file (see Appendix A) the user must specify:

1. irradiance incident at the top of the upper slab (**TOA** for a coupled atmosphere-water system) in [W m^{-2}] – a default solar spectrum is available for a coupled atmosphere-water system;

2. wavelength range, # of center wavelengths and widths in [nm] – a discrete set of wavelengths is allowed;

3. polar angle(s) of incident radiation in degrees (solar zenith angle(s) for a coupled atmosphere-water system);

4. the number of "discrete ordinate streams" used to solve the radiative transfer equation (**RTE**) (see §4 in [1]).

Specifications required for the upper slab of a coupled atmosphere-water system:

1. ground-level altitude; sea-level is default;

2. layer boundaries;

3. atmospheric type (see [1]);

4. aerosol particle type (bi-modal log-normal volume distribution is allowed) for each layer;

Specifications required for the lower slab of a coupled atmosphere-water system:

1. layer boundaries;

2. refractive index as a function of wavelength (set to "one" in the upper slab, the atmosphere), determined by the first material added to the tag named `MATERIALS_INCLUDED_LOWER_SLAB`;

3. pure water properties (see **pure_water** configuration file);

4. water impurity properties
(see **water_impurities_ccrr** or **water_impurities_gsm** configuration files);

5. water bottom albedo (current default is "loamy_sand").

6 Output

Once the input parameters specified above have been defined, **AccuRT** will solve the **RTE** as described in §4 in [1], and provide two types of output in terms of apparent optical properties (**AOPs**):

- irradiances and mean intensities (scalar irradiances) at a set of user-specified vertical locations in the coupled system;
- radiances in a number of user-specified directions at a set of user-specified vertical locations in the coupled system.

Thus, the user must specify (see Appendix A):

1. the vertical locations at which output is desired;
2. the type of output:
   - hemispherical and scalar irradiances only;
   - radiances only;
   - hemispherical and scalar irradiances as well as radiances;
3. if radiances are desired, the directions in which they are requested must be specified.

7 Materials

7.1 Core materials

Core materials are supported by our Standard and Enterprise Support Contracts. The following materials are included among the core (see Table 1 for an overview):

- the **earth_atmospheric_gases** material which provides profiles of atmospheric molecular absorption and Rayleigh scattering optical depths and includes two options:
  - The **gasIOP** option which provides **IOP**s for the most important gaseous absorbers in the Earth's atmosphere
  - the **Air** option which provides **IOP**s for Rayleigh scattering, but provides ozone absorption only in the UV and visible spectral range
- the **aerosols** material which provides **IOP**s for particulate matter in the atmosphere
- the **cloud** material which provides **IOP**s for clouds consisting of liquid water droplets and ice particles in the atmosphere
- the **pure_water** material which provides **IOP**s for pure water

- the **water_impurities_ccrr** material which provides **IOP**s of dissolved and particulate matter in the water based on the CCRR bio-optical model
- the **water_impurities_gsm** material which provides **IOP**s of dissolved and particulate matter in the water based on the GSM bio-optical model
- the **vacuum** material which allows for either of the two slabs comprising the coupled medium to be transparent.

Table 1: Core materials included in AccuRT.

Core Material	options	allowed position	descriptions
earth_atmospheric_gases			
	1. gasIOP 2. air	upper slab	profiles of atmospheric molecular absorption and Rayleigh scattering optical depths.
aerosols			particulate matter in the atmosphere.
clouds	1. water cloud 2. ice cloud	upper slab	clouds consisting of liquid water droplets and ice particles in the atmosphere.
pure_water		lower slab	pure water.
water_impurities_ccrr		lower slab	dissolved and particulate matter in the water based on the CCRR bio-optical model.
water_impurities_gsm		lower slab	dissolved and particulate matter in the water based on the GSM bio-optical model.
vacuum		both slabs	synthetic material which allows for either of the two slabs comprising the coupled medium to be transparent.
Cryosphere Material	options	allowed position	descriptions
snow	1. ISIOP 2. Mie	upper slab	snow material
ice	1. ISIOP 2. Mie	lower slab	ice floating over ocean

7.2 Creating a mixture of materials

AccuRT allows one to create a mixture of materials by adding multiple materials of the same type as an existing material. To that end, one can make multiple copies of an existing material file, keep the name of the existing material, and add to the name of each copy a unique string of characters. For example, if one wishes to create a mixture consisting of a total of three aerosols materials, one can make two copies of the existing file named **aerosols**, and name the two copies **aerosols2** and **aerosols3**:

```
cd myConfigNameMaterials/
cp aerosols aerosols2
cp aerosols aerosols3
```

Next, one must edit the three files **aerosols**, **aerosols2**, and **aerosols3** to obtain the desired properties. Then in the main configuration file one can include all three materials by setting:

```
MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases aerosols
   aerosols2 aerosols3
```

Other possible names would be **aerosolsXYZ**, **aerosols_A**, etc., the syntax rule being that the new name must start with the material name, in this case "aerosols", followed by one or more (upper or lower case) characters of the English alphabet (A–z), and/or numbers 0–9, and/or the special characters "_", "-", and "." (underscore, hyphen, and period).

The same strategy for creating a mixture of materials by making copies of an existing material type, where each copy has the existing material name followed by a unique string of characters, works for every material. **AccuRT** will automatically create a mixture of the materials, thus allowing for a significant amount of flexibility.

7.3 Interpolation rules

As explained in the main configuration file, tabulated numbers, *i.e.* a list of x-values with corresponding y-values, may be assigned to a tag as follows:

```
TAG = <x_1> <y_1>
      <x_2> <y_2>
       ...   ...
      <x_n> <y_n>
```

Unless otherwise specified, y-values corresponding to x-values that lie between the tabulated values are found by linear interpolation. In some cases a table may be assigned only one y-value, which will make it constant.

Example 1: Detector band width in main configuration file

In the **main** configuration file, find the tag `DETECTOR_WAVELENGTH_BAND_WIDTHS`. Band widths of 1.0, 1.5, and 3.0 nm may be specified at the center wavelengths 400, 500, and 700 nm in this manner:

```
DETECTOR_WAVELENGTH_BAND_WIDTHS = 400 1.0
                                  500 1.5
                                  700 3.0
```

With this specification, the wavelength band width will be 1.25 nm at 450 nm, and 2.625 nm at 650 nm obtained by linear interpolation, *i.e.*, $y = y_i + \frac{\Delta y_i}{\Delta x_i}(x - x_i)$, where $x_i < x < x_{i+1}$, $\Delta x_i = x_{i+1} - x_i$, $\Delta y_i = y_{i+1} - y_i$, $x_1, x_2, x_3 = 400, 500, 700$, and $y_1, y_2, y_3 = 1.0, 1.5, 3.0$.

Details:

$$y_{450} = y_{400} + \frac{\Delta y_{500}}{\Delta x_{500}}(450 - 400) = 1.0 + \frac{0.5}{100}50 = 1.0 + 0.25 = 1.25,$$

and

$$y_{650} = y_{500} + \frac{\Delta y_{700}}{\Delta x_{700}}(650 - 500) = 1.5 + \frac{1.5}{200}150 = 1.5 + 1.125 = 2.625.$$

Also, if one were to specify:

```
DETECTOR_WAVELENGTH_BAND_WIDTHS = 270 30.0
                                  4000 30.0
```

then the bandwidth will be 30 nm everywhere in the interval between 270 and 4000 nm, so that a center wavelength of say 635 nm (as specified by the tag `DETECTOR_WAVELENGTHS`) will have a band width of 30 nm [635 ± 15 nm].

Finally, one may specify the wavelength band widths as follows:

```
DETECTOR_WAVELENGTH_BAND_WIDTHS = 270 1.0
                                  350 1.0
                                  351 5.0
                                  400 5.0
                                  401 10.0
                                  700 10.0
                                  701 30.0
                                  1200 30.0
                                  1201 100.0
                                  4000 100.0
```

which will give a bandwidth of 1 nm between 270 and 350 nm, 5 nm between 351 and 400 nm, 10 nm between 401 and 700 nm, 30 nm between 701 and 1200 nm, and 100 nm between 1201 and 4000 nm.

Example 2: aerosols material AEROSOL_PROFILE tag

Assume that we use the default depth (layer) configuration file in the atmosphere given by:

```
# layer 1: 100.0e3 - 70.0e3 (DEPTH = 30.0e3; THICKNESS = 30.0e3)
# layer 2: 70.0e3 - 50.0e3 (DEPTH = 50.0e3; THICKNESS = 20.0e3)
# layer 3: 50.0e3 - 40.0e3 (DEPTH = 60.0e3; THICKNESS = 10.0e3)
# layer 4: 40.0e3 - 30.0e3 (DEPTH = 70.0e3; THICKNESS = 10.0e3)
```

```
# layer 5: 30.0e3 - 24.0e3 (DEPTH = 76.0e3; THICKNESS = 6.0e3)
# layer 6: 24.0e3 - 20.0e3 (DEPTH = 80.0e3; THICKNESS = 4.0e3)
# layer 7: 20.0e3 - 16.0e3 (DEPTH = 84.0e3; THICKNESS = 4.0e3)
# layer 8: 16.0e3 - 12.0e3 (DEPTH = 88.0e3; THICKNESS = 4.0e3)
# layer 9: 12.0e3 - 10.0e3 (DEPTH = 90.0e3; THICKNESS = 2.0e3)
# layer 10: 10.0e3 - 8.0e3 (DEPTH = 92.0e3; THICKNESS = 2.0e3)
# layer 11: 8.0e3 - 6.0e3 (DEPTH = 94.0e3; THICKNESS = 2.0e3)
# layer 12: 6.0e3 - 4.0e3 (DEPTH = 96.0e3; THICKNESS = 2.0e3)
# layer 13: 4.0e3 - 2.0e3 (DEPTH = 98.0e3; THICKNESS = 2.0e3)
# layer 14: 2.0e3 - 0.0e3 (DEPTH = 100.0e3; THICKNESS = 2.0e3)
```

Suppose now that we have a measured profile of aerosol concentrations corresponding to the following volume fraction profile:

Depth from TUS (m)	Volume fraction ($\times 10^{11}$)	Height (m)	Layer
95800	0.001	4200	12 (partly filled)
96300	0.01	3700	13
96800	0.5	3200	13
97300	1.0	2700	13
97800	2.0	2200	13
98300	3.0	1700	14
98800	4.0	1200	14
99300	2.0	700	14
99800	1.0	200	14 (partly filled)

In the table above, 'TUS' denotes the top of the upper slab, and ÔHeightÕ the vertical distance above the bottom of the upper slab. How will the material be distributed layer-by-layer using linear interpolation? What volume fraction will be assigned to each of the layers 12, 13, and 14? Starting with layer 12, the volume fraction varies linearly from $V(4000) = V(3700) + \frac{0.001-0.01}{4200-3700}(4000-3700) = 0.01 - 0.0054 = 0.0046$ to the value $V(4200) = 0.01$. Thus, the volume fraction for layer 12 will be automatically calculated in AccuRT as:

$$V_{12} = [(0.01 + 0.0046)/2] \times \frac{200}{2000} = 0.00073.$$

Similarly, in layer 13, we have $V(2000) = V(1700) + \frac{2.0-3.0}{2200-1700}(2000-1700) = 3.0 - 0.6 = 2.4$. Thus:

$$V_{13} = \frac{1}{2} \times \Bigg[(2.4 + 2.0) \times \frac{200}{2000} + (2.0 + 1.0 + 1.0 + 0.5 + 0.5 + 0.01) \times \frac{500}{2000} + (0.01 + 0.0046) \times \frac{300}{2000} \Bigg]$$
$$= \frac{1}{2}\Big[0.44 + 1.2525 + 0.00219\Big] = 0.84735.$$

Finally, in layer 14, we get

$$V_{14} = \frac{1}{2}[(1.0+2.0+2.0+4.0+4.0+3.0)\frac{500}{2000}+(3.0+2.4)\frac{300}{2000}] = \frac{1}{2}[4+0.81] = 2.405.$$

7.4 Extrapolation rules

AccuRT always *interpolates linearly* between specified values. By contrast, AccuRT generally *extrapolates to a constant value*. Thus, outside the range of specified values AccuRT uses the nearest value, *i.e.* the value outside the range will be equal to the value at its nearest boundary. See Example 3 below.

Example 3: Constant extrapolation
Consider the `REFRACTIVE_INDICES_IMAG_FINE` tag in the **aerosols** material:

```
REFRACTIVE_INDICES_IMAG_FINE = 200 0.008
                               900  0.007
                               1000 0.007
```

Thus, the imaginary part of the refractive index at wavelength 2000 nm (and at any wavelength longer than 1000 nm) will also be 0.007 since extrapolation, in general, gives a constant value. However, there is one important exception to this general rule: it *does not apply* to concentration profiles. Concentration values are set to zero outside the specified boundaries, *e.g.* the `MATERIAL_PROFILE` tag in the **aerosols** material:

```
MATERIAL_PROFILE = 12 1.0e-13
                   13  2.0e-12
                   14  2.8e-11
```

Here, the volume fraction of aerosols in layers 1 through 11 is not equal to 1.0e-13, but will be set to zero.

8 Summary

AccuRT is a user-friendly tool for radiative transfer simulations in a coupled system, consisting of two adjacent slabs with different refractive indices, such as a coupled atmosphere-water system. In a main configuration file (Appendix A) the user controls the input settings including boundary conditions, desired layer depths in the atmosphere and water of a coupled atmosphere-water system, materials to be included in the atmosphere (gases and aerosol **IOP**s, Appendices B and C) and water (pure water and impurity **IOP**s, Appendices D and E). To allow the user to have full control of the input **IOP**s in both the atmosphere and the water a configuration file in which the user may specify the input **IOP**s is also available (Appendices G and H). The desired output is also controlled by the main configuration file and allows for three options:

1. irradiances (cosine weighted, sine weighted, or scalar) only – at user-specified locations in both slabs (atmosphere and water),

2. radiances only – at user-specified directions and locations in the atmosphere and water,

3. irradiances (cosine weighted, sine weighted, or scalar) – at user-specified locations in both slabs (atmosphere and water) as well as radiances at user specified directions and locations in both slabs (atmosphere and water),

4. **IOP**s – at user-specified locations in both slabs (atmosphere and water).

The user can request these radiative quantities at a single wavelength or an arbitrary number of wavelengths between 280 nm and 4000 nm.

9 Acronyms

aerosols particulate matter in the atmosphere

Air Material for absorption based on ozone cross section in the UV and visible spectral ranges

AOP Apparent Optical Property

AccuRT Accurate Radiative Transfer Tool for Coupled Systems

CCRR CoastColour Round Robin, http://www.coastolour.org/round_robin.html

earth_atmospheric_gases profiles of atmospheric molecular absorption and scattering optical depths

gasIOP Band model for absorption by atmospheric gases

IOP Inherent Optical Property

materials Radiatively-significant constituents like gases and particles in the atmosphere and dissolved and particulate matter in the water

Matlab Matrix Laboratory (MatLab)

pure_water absorption and scattering by pure water

RTE Radiative Transfer Equation

snow/ice snow/ice **IOP**s

TOA top of the atmosphere

user_specified allows the user to specify the **IOP**s

vacuum allows for the slab to be transparent if included in either of the two slabs, and if included as the first material (of possibly several materials) in the lower slab, the refractive index of the lower slab will be set to one (as in the upper slab)

water_impurities_ccrr absorption and scattering by dissolved and particulate matter in the water

water_impurities_gsm absorption and scattering by dissolved and particulate matter in the water

10 References and citations

References

[1] Radiative Transfer in the Atmosphere–Snow-Ice-Water System: Technical Description of the **AccuRT** Computational Tool, *Technical Notes*, Geminor Inc, January 2014.

Appendices

The following configuration files are the defaults in version v1.0.685 of **AccuRT**.

A Main configuration file

```
#               [ AccuRT main configuration file ]
#
# Each tag is named with upper case letters and documented immediately
# above the specification of its default value(s).
#
# At the very end of this main configuration file is information on
# the tag syntax formats: "list" format and "table" format.
#
#              Start of main configuration tags:
#
# ------------------------------------------------------------------
#                     I. INPUT SETTINGS
# ------------------------------------------------------------------
#
#                 [ UPPER BOUNDARY SETTINGS ]
#
# The SOURCE_TYPE tag shall be assigned <earth_solar> or
# <constant_one>, depending on the type of radiation source.

SOURCE_TYPE = earth_solar

# The SOURCE_SCALING_FACTOR tag shall be assigned a number that is to
# be multiplied with the source output power. For example, such a
# factor is necessary to account for the variation in the sun-earth
# distance throughout a year. It is also possible to assign tabulated
# scaling factors [unitless] versus wavelength [nm]. See "Table
# format" documentation at the end of this main configuration file
# for details.

SOURCE_SCALING_FACTOR = 1.0

# The SOURCE_ZENITH_ANGLE tag shall be assigned the source zenith
# angle [degrees].

SOURCE_ZENITH_ANGLE = 45

#                 [ BOTTOM BOUNDARY SETTINGS ]
#
# The BOTTOM_BOUNDARY_SURFACE tag shall be assigned <white> or
# <loamy_sand>. The white surface has a wavelength independent albedo
```

```
# equal to 1.0. Spectral information about loamy_sand can be found at
# http://speclib.jpl.nasa.gov/.

BOTTOM_BOUNDARY_SURFACE = loamy_sand

# The BOTTOM_BOUNDARY_SURFACE_SCALING_FACTOR tag shall be assigned a
# number that is to be used to scale the albedo of the bottom. If this
# tag is assigned the number 0.0, it will yield a black surface. There
# is no upper limit for this scaling factor, but the resulting surface
# albedo will be set to 1.0 if the original albedo multiplied with the
# scaling factor is larger than 1.0. It is also possible to assign
# tabulated scaling factors [unitless] versus wavelength [nm]. See
# "Table format" documentation at the end of this configuration file
# for details.

BOTTOM_BOUNDARY_SURFACE_SCALING_FACTOR = 1.0

#              [ COMPUTATIONAL POLAR ANGLE SETTINGS ]
#
# The STREAM_UPPER_SLAB_SIZE tag shall be assigned the number of
# computational polar angles (streams) to be used in the upper slab.
# At a given wavelength the number of streams in the lower slab will
# be obtained from the number of streams in the upper slab as
# explained below.

STREAM_UPPER_SLAB_SIZE = 8

# The STREAM_LOWER_SLAB_PARAMETERS tag shall be assigned two
# parameters k1 and k2, which are used in the equation n = k1 *
# STREAM_UPPER_SLAB_SIZE * (refractiveIndex)^(k2) determining the
# number of streams used in the lower slab. If several wavelengths are
# assigned by the DETECTOR_WAVELENGTHS tag, then the number of streams
# in the lower slab is determined from the largest refractive index
# within the wavelength range.

STREAM_LOWER_SLAB_PARAMETERS = 1.0 2.0

#                [ INPUT LAYER DEPTH SETTINGS ]
#
# The LAYER_DEPTHS_UPPER_SLAB tag shall be assigned a list of
# depths [m] from the top of the upper slab at a height of 100 km (0
# depth) to the height of the lower boundary of each layer in the
# upper slab. 100 km is taken to be the top-of-the-upper-slab (TUS).
# There will be one layer for each specified depth as explained in
# detail below. In the upper slab all layers have refractive index
# equal to 1.0. The upper slab will be the atmosphere in a coupled
# atmosphere-water system.
```

```
LAYER_DEPTHS_UPPER_SLAB = 30.0e3 50.0e3 60.0e3 70.0e3
                          76.0e3 80.0e3 84.0e3 88.0e3
                          90.0e3 92.0e3 94.0e3 96.0e3
                          98.0e3 100.0e3

# As alluded to above, for each depth there is a corresponding
# layer number. The counting of layers begins at the top of each
# slab. For the layer depths in the upper slab, given as defaults
# above, the first layer lies between 100.0e3 and 70.0e3 and the
# second layer lies between 70.0e3 and 50.0e3. Thus, for the
# default depths given above the layers in the upper slab become:
#
# layer 1: 100.0e3 - 70.0e3 (DEPTH = 30.0e3)
# layer 2: 70.0e3 - 50.0e3 (DEPTH = 50.0e3)
# layer 3: 50.0e3 - 40.0e3 (DEPTH = 60.0e3)
# layer 4: 40.0e3 - 30.0e3 (DEPTH = 70.0e3)
# layer 5: 30.0e3 - 24.0e3 (DEPTH = 76.0e3)
# layer 6: 24.0e3 - 20.0e3 (DEPTH = 80.0e3)
# layer 7: 20.0e3 - 16.0e3 (DEPTH = 84.0e3)
# layer 8: 16.0e3 - 12.0e3 (DEPTH = 88.0e3)
# layer 9: 12.0e3 - 10.0e3 (DEPTH = 90.0e3)
# layer 10: 10.0e3 - 8.0e3 (DEPTH = 92.0e3)
# layer 11: 8.0e3 - 6.0e3 (DEPTH = 94.0e3)
# layer 12: 6.0e3 - 4.0e3 (DEPTH = 96.0e3)
# layer 13: 4.0e3 - 2.0e3 (DEPTH = 98.0e3)
# layer 14: 2.0e3 - 0.0e3 (DEPTH = 100.0e3)


# The LAYER_DEPTHS_LOWER_SLAB tag shall be assigned a list of
# depths [m] from the top of the lower slab (TLS) (bottom of
# the upper slab) at 0 m depth to the depth of the lower
# boundary of each layer in the lower slab. This slab will be
# the water in a coupled atmosphere-water system. There must
# be at least one layer in the lower slab. One depth will give
# one layer. Layer numbers will be assigned in a manner similar
# to that adopted for the upper slab counting downwards from
# the TLS.

LAYER_DEPTHS_LOWER_SLAB = 100

#                  [ LAYER MATERIAL SETTINGS ]
#
# The MATERIALS_INCLUDED_UPPER_SLAB tag shall be assigned a list of
# materials to be included in the upper slab. Only materials with
# their own configuration files contained in the material
# configuration folder can be included. The material profiles
# versus depth tag in these configuration files will determine how the
```

```
# material is distributed in the different layers specified by the
# LAYER_DEPTHS_UPPER_SLAB tag. For an atmosphere-water system, the
# following options are available:
# MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases
# if a clear sky (cloud- and aerosol-free) atmosphere is desired,
# but if aerosols are also desired, one should set (i)
# MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases aerosols
# and if a cloud is desired, one would set (ii)
# MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases cloud
# or if both aerosol and cloud materials are desired, one should set (iii)
# MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases aerosols cloud.

MATERIALS_INCLUDED_UPPER_SLAB = earth_atmospheric_gases aerosols

# The MATERIALS_INCLUDED_LOWER_SLAB tag shall be assigned a list of
# materials to be included in the lower slab. Only materials with
# their own configuration files contained in the material
# configuration folder can be included. The material profiles
# versus depth tag in these configuration files will determine
# how the material is distributed in the different layers
# specified by the LAYER_DEPTHS_LOWER_SLAB tag. For an
# atmosphere-water system, the following options are currently
# available:
# MATERIALS_INCLUDED_LOWER_SLAB = pure_water
# if clean water (with no impurities) is desired, while the setting
# MATERIALS_INCLUDED_LOWER_SLAB = pure_water water_impurity_ccrr
# should be used in the general case. At present only a single
# bio-optical model is included; other bio-optical models will be
# added later. NOTE that the refractive index for the lower slab
# will be obtained from the first listed material. If vacuum is
# listed first, the refractive index of both the lower and upper
# slab will be 1.0.

MATERIALS_INCLUDED_LOWER_SLAB = pure_water water_impurity_ccrr

# ------------------------------------------------------------------
#                    II. OUTPUT SETTINGS
# ------------------------------------------------------------------
#
#                  [ OUTPUT DEPTH SETTINGS ]
#
# The DETECTOR_DEPTHS_UPPER_SLAB tag shall be assigned a list of
# depths [m] measured from the top of the upper slab (TUS), at which
# radiative quantities (radiances and irradiances) are to be computed.
# If the earth atmospheric gases material is included (see the
# MATERIALS_INCLUDED_UPPER_SLAB tag) the atmosphere bottom will be at
# a depth of 100 km. See also the LAYER_DEPTHS_UPPER_SLAB tag.
```

```
DETECTOR_DEPTHS_UPPER_SLAB = 0 99999.999

# The DETECTOR_DEPTHS_LOWER_SLAB tag shall be assigned a list of
# depths [m] measured from the bottom of the upper slab, at which
# radiative quantities (radiances and irradiances) are to be computed.
# See also the LAYER_DEPTHS_LOWER_SLAB tag.

DETECTOR_DEPTHS_LOWER_SLAB = 0.0001 1 10 20

#                 [ DETECTOR ANGLE SETTINGS ]
#
# The DETECTOR_AZIMUTH_ANGLES tag shall be assigned a list of detector
# azimuth angles between -180 and +180 degrees. Light from the
# direction of the source will be assigned + 180.0 degree azimuth
# angle. See also the "List format" documentation at the end of this
# main configuration file. Note, however, that the radiance is
# symmetric about 0 since the difference in azimuth is what counts,
# e.g. -20 gives the same result as +20. The DETECTOR_AZIMUTH_ANGLES
# tag could also be assigned the value "nan" (not a number) to invoke
# computation of azimuth-independent irradiances and azimuthally
# averaged radiances. This choice will increase the computational
# speed significantly, because in the nadir or zenith direction the
# radiances are independent of azimuth. This choice also facilitates
# fast computation of irradiances, and hence the remote sensing
# reflectance defined as the ratio of the zenith radiance and the
# downward irradiance (just above the atmosphere-water interface).

DETECTOR_AZIMUTH_ANGLES = 0:20:180

# The DETECTOR_POLAR_ANGLES tag shall be assigned a list of detector
# polar angles between 0 and 180 degrees. Light traveling downwards
# will be detected at angles larger than 90 degrees, and light
# traveling upwards will be detected at angles smaller than 90
# degrees. See also the "List format" documentation at the end
# of this main configuration file.

DETECTOR_POLAR_ANGLES = 0:2:180

#               [ DETECTOR WAVELENGTH SETTINGS ]
#
# The DETECTOR_WAVELENGTHS tag shall be assigned a list of center
# wavelengths [nm], at which radiative quantities are to be
# computed. See also the "List format" documentation at the end
# of this main configuration file.

DETECTOR_WAVELENGTHS = 400:50:700

# The DETECTOR_WAVELENGTH_BAND_WIDTHS tag shall be assigned
```

```
# tabulated wavelength band widths [nm] versus wavelength [nm].
# In the example given below 270 [nm] is the center wavelength at
# the start of the wavelength interval and 4000 [nm] is the center
# wavelength at the end of the interval. And the total bandwidth is
# 1 nm throughout the interval, so that at 270 nm the band width is
# over the interval [269.5, 270.5] in [nm]. See also the
# "Table format" documentation at the end of this configuration file
# as well as Section 10.5 of the User's Manual.

DETECTOR_WAVELENGTH_BAND_WIDTHS = 270 1.0
                                  4000 1.0

#                 [ OUTPUT IRRADIANCE SETTINGS ]
#
# The SAVE_COSINE_IRRADIANCE tag shall be assigned <true> or <false>,
# depending on whether or not the downward and upward hemispherically-
# integrated cosine weighted radiances [W/m2/nm] for the specified
# detector wavelengths and detector depths are to be saved in the
# files cosine_irradiance_downward.txt and
# cosine_irradiance_upward.txt. Cosine irradiance is commonly
# referred to as hemispherical irradiance or plane irradiance.
# The cosine irradiance is the hemispherically-integrated energy
# incident upon a plane horizontal surface.

SAVE_COSINE_IRRADIANCE = true

# The SAVE_SINE_IRRADIANCE tag shall be assigned <true> or <false>,
# depending on whether or not the downward and upward hemispherically-
# integrated sine weighted radiances [W/m2/nm] for the specified
# detector wavelengths and detector depths are to be saved in the
# files sine_irradiance_downward.txt and sine_irradiance_upward.txt.
# The sine irradiance is the hemispherically-integrated energy
# incident upon a vertically oriented cylindrical surface.

SAVE_SINE_IRRADIANCE = false

# The SAVE_SCALAR_IRRADIANCE tag shall be assigned <true> or <false>,
# depending on whether or not the downward and upward
# hemispherically-integrated un-weighted or scalar radiances [W/m2/nm]
# for the specified detector wavelengths and detector depths are to be
# saved in the files scalar_irradiance_downward.txt and
# scalar_irradiance_upward.txt. The sum of the upward and downward
# scalar irradiances is sometimes referred to as the actinic flux, and
# the sum of downward and upward scalar irradiances divided by 4 pi is
# often referred to as the mean intensity. The scalar irradiance
# is the energy incident upon a spherical surface from all directions.

SAVE_SCALAR_IRRADIANCE = false
```

```
#                   [ OUTPUT RADIANCE SETTINGS ]
#
# The SAVE_RADIANCE tag shall be assigned <true> or <false>,
# depending on whether or not the radiance [W/m2/nm/sr] for the
# specified detector wavelengths, detector depths, polar angles,
# and azimuth angles are to be saved in the file radiance.txt.
# Note that computing radiances is considerably more computer
# demanding than computing irradiances.

SAVE_RADIANCE = false

#                    [ SAVE INPUT SETTINGS ]
#
# The SAVE_IOPS tag shall be assigned <true> or <false>, depending on
# whether or not the inherent optical properties (IOPs) should be
# saved in the file iops.txt. For each wavelength and layer, the IOPs
# are the total optical depth, the scattering coefficient, the
# absorption coefficient, and the moments of the scattering phase
# function. In addition to these IOPs, the wavelength dependent
# refractive index of the lower slab is written to a separate file
# named lower_slab_refractive_index.txt when the SAVE_IOPS tag is set
# to <true>.

SAVE_IOPS = false

# The SAVE_BOTTOM_BOUNDARY_SURFACE tag shall be assigned <true> or
# <false>, depending on whether or not the bottom boundary surface
# albedo for the wavelengths specified by the DETECTOR_WAVELENGTHS
# tag, are to be saved in the file bottom_boundary_surface.txt.

SAVE_BOTTOM_BOUNDARY_SURFACE = false

# The SAVE_MATERIAL_PROFILE tag shall be assigned <true> or <false>,
# depending on whether or not a list of included materials with
# corresponding concentrations are to be saved in the file
# material_profile.txt. Inspection of the saved material_profile.txt
# will make it easier to determine whether the layer structure is
# adequate and whether the material concentration profiles have been
# properly adjusted to the layer structure.

SAVE_MATERIAL_PROFILE = true

# The PROFILE_OUTPUT_WAVELENGTH tag shall be assigned the reference
# wavelength [nm] where the material profile IOPs should be listed.

PROFILE_OUTPUT_WAVELENGTH = 500
```

```
#                     [ VERBOSITY SETTINGS ]
#
# The PRINT_PROGRESS_TO_SCREEN tag shall be assigned <true> or
# <false>, depending on whether or not the step-by-step calculation
# progress is to be displayed.

PRINT_PROGRESS_TO_SCREEN = true

#                     [ REPEAT RUN SETTING ]
#
# The REPEATED_RUN_SIZE tag shall be assigned an integer larger than
# zero, which determines the number of times AccuRT will be run. For
# each run varying tag values may be read from a text file or drawn
# randomly as follows:
#
# File value assignment:
# Specify the name of the text file, which must end with .txt, for
# example like this:
#
# SOURCE_ZENITH_ANGLE = source_zenith_angle.txt
#
# The values in the source_zenith_angle.txt file should be in separate
# rows. A new row will then be read for each run. The reading will
# continue from the top of the file if the repeated run size is larger
# than the number of rows. The input text files should be stored in
# the same folder as the configuration files.
#
# Random assignment:
# A randomly drawn number can be assigned by specifying the distribution
# and limits enclosed in square brackets. For example:
#
# SOURCE_SCALING_FACTOR = [uniformly distributed from 0.9 to 1.1]
# or
# SOURCE_SCALING_FACTOR = [loguniformly distributed from 0.9 to 1.1]
#
# It is also possible to have randomly drawn numbers in a list, e.g.
#
# DETECTOR_WAVELENGTHS = 400 [uniformly distributed from 500 to 600] 700
#
# New values will be drawn for each repeated run, in accordance with
# the given probability distribution. Currently, "uniformly" and
# "loguniformly" are the only distributions implemented.
#
# The output radiometric quantities are appended to their output
# files at each run. And for random assignment the drawn values are
# also saved in separate files named with the tag name.
#
# The repeated run size option is particularly useful when making
```

```
# look-up tables and training ensembles for neural networks.

REPEATED_RUN_SIZE = 1

#                 End of main configuration tags
#_____________________________________________________________________


########################## TAG syntax formats ##########################
#
#---------------------------------------------------------------------
#                          List format
#---------------------------------------------------------------------
# A list of numbers may be assigned to a tag in two different ways:
#
# 1) TAG = <value_1> <value_2> ... <value_n>
#
# Example:
#
# DETECTOR_DEPTHS = 0 50e3 90e3 99999
#
# 2) TAG = <value_1>:<step>:<value_n>
#
# Here the list starts with the number <value_1>, and the other numbers
# are <value_1> + <step>, <value_1> + 2*<step>, ... , <value_1> + n*<step>
#
# Example:
#
# DETECTOR_AZIMUTH_ANGLES = -180:20:180
#
# A list may contain only one element.
#
#---------------------------------------------------------------------
#                          Table format
#---------------------------------------------------------------------
# Tabulated numbers, i.e. a list of x-values with corresponding
# y-values, may be assigned to a tag in this manner:
#
# TAG = <x1> <y1>
#       <x2> <y2>
#        ...
#       <xn> <yn>
#
# Unless otherwise specified, y-values corresponding to x-values in
# between the tabulated points are found by linear interpolation.
# A table may be assigned only one y-value, which will make it
# constant.
#
```

```
# Example:
#
# Band widths of 1.0, 1.5, and 3.0 nm may be specified at the center
# wavelengths 400, 500, and 700 nm in this manner:
#
# DETECTOR_WAVELENGTH_BAND_WIDTHS = 400 1.0
#                                   500 1.5
#                                   700 3.0
#
# With this table, the wavelength band width at, say 450 nm, will
# be 1.25, obtained by linear interpolation.
#-----------------------------------------------------------------------
```

B Atmospheric Gases Configuration file

```
## AccuRT configuration file for earth_atmospheric_gases material ##

# See end of the main configuration file for documentation on
# how to assign values to list and table tags.

#-----------------------------------------------------------------------
# Configuration options:
#-----------------------------------------------------------------------

# The ATMOSPHERE_TYPE tag shall be assigned <tropical>,
# <mid_latitude_summer>, <mid_latitude_winter>, <sub_arctic_summer>,
# <sub_arctic_winter>, or <us_standard>.

ATMOSPHERE_TYPE = us_standard

# The GROUND_ALTITUDE tag shall be assigned the ground surface height
# [m] above sea level.

GROUND_ALTITUDE = 0.0

# The SAVE_ATMOSPHERIC_PROFILES tag shall be assigned <true> or
# <false>, depending on whether or not the atmospheric profiles and
# equivalent depths are to be saved to atmospheric_profiles.txt in the
# material folder. This file will for example contain the default
# ozone column amount, which is needed when scaling to a given amount,
# i.e.
# F_O3=userSpecifiedEquivalentDepth/
    outputEquivalentDeptAtUnitScalingFactor.
# More documentation is given in the header of the saved file. Note
# that this tag is effective only when IOP_MODEL = air.

SAVE_ATMOSPHERIC_PROFILES = false
```

```
# The SEA_LEVEL_PRESSURE tag shall be assigned the atmospheric
# pressure at sea level [mbar]. Note that 1 atm pressure = 1013.25
# mbar = 1.01325 x 10^5 Pa = 1.01325 x 10^5 N/m^2. This tag is effective
# only when IOP_MODEL = air.

SEA_LEVEL_PRESSURE = 1013

# The IOP_MODEL tag shall be assigned <gasIop> or <air>, depending on
# the type of inherent optical properties model to be used. Note that
# with the air option only ozone will be included among the absorbing
# gases. Thus changing parameters for other gases when using the air
# model will not have any effect on the output.

IOP_MODEL = gasIop

# The F tags shall be assigned scaling factors for the atmospheric
# gases.

F_H2O    = 1.0 # Only for gasIop
F_CO2    = 1.0 # Only for gasIop
F_O3     = 1.0 # Both for gasIop and air
F_N2O    = 1.0 # Only for gasIop
F_CO     = 1.0 # Only for gasIop
F_CH4    = 1.0 # Only for gasIop
F_O2     = 1.0 # Only for gasIop
F_NO     = 1.0 # Only for gasIop
F_SO2    = 1.0 # Only for gasIop
F_NO2    = 1.0 # Only for gasIop
F_NH3    = 1.0 # Only for gasIop
F_HNO3   = 1.0 # Only for gasIop
F_N2     = 1.0 # Only for gasIop
F_H2O_CON = 1.0 # Only for gasIop
F_RAY_SCA = 1.0 # Both for gasIop and air

# End of earth_atmospheric_gases material configuration file
```

C Aerosol Configuration file

```
## AccuRT configuration file for aerosol material ##

# Aerosols are assumed to consist of a collection of homogeneous
# spheres having a bi-modal log-normal volume size distribution
# with a specified volume mode radius (also called the mean radius
# below) and width for each mode (fine or coarse). A Mie code
# is used to compute the inherent optical properties of aerosols.
```

```
# See end of the main configuration file for documentation on
# how to assign values to list and table tags.

#------------------------------------------------------------------
# Configuration options:
#------------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from the top-of-the-upper-slab (TUS)) or
# depths in meters (counting downward from the TUS) in the
# MATERIAL_PROFILE tag below. The layer numbering is explained
# in detail in the main configuration file below the default
# values for the LAYER_DEPTHS_UPPER_SLAB tag.

PROFILE_LABEL = layer_numbering

# The REFERENCE_WAVELENGTH [nm] tag is used only if
# PROFILE_TYPE = extinction_coefficient (not yet implemented).
# The reference wavelength is the wavelength at which we calculate
# the extinction coefficient (see PROFILE_LABEL and PROFILE_TYPE).

REFERENCE_WAVELENGTH = 865

# The MATERIAL_PROFILE tag shall be used to specify the layers
# containing aerosols and the corresponding volume fractions or
# extinction coefficients (not yet implemented), if
# <layer_numbering> is used.
# Alternatively, if <depth_numbering> is used, then the depths
# and the corresponding volume fractions or extinction coefficients
# must be specified as illustrated in Example 1 below. Note that
# the depths specified in the MATERIAL_PROFILE tag do not have
# to coincide with the depths in the LAYER_DEPTHS_UPPER_SLAB tag
# (although they do in Example 1 below).
# Linear interpolation will be used to distribute the material
# appropriately in the layers specified in the
# LAYER_DEPTHS_UPPER_SLAB tag in the main configuration file
# (see Example 1 below and the user manual for detailed
# explanations of the linear interpolation scheme).
# The PROFILE_TYPE tag shall be assigned <volume_fraction>
# [unitless] or <extinction_coefficient> [1/m] (not yet
# implemented) depending on whether to use extinction
# coefficients or volume fractions in the MATERIAL_PROFILE
# tag below.

PROFILE_TYPE = volume_fraction

#
```

```
MATERIAL_PROFILE = 14 2.8e-11

# Aerosols are normally found in layers 12, 13, and 14, which
# are located in accordance with the default values of the
# LAYER_DEPTHS_UPPER_SLAB tag in the main configuration file,
# unless specified differently by the user. According to the
# default values above, only layer 14 contains aerosols, and
# the number in the second column corresponds to
# PROFILE_TYPE = volume fraction.

# The REFRACTIVE_INDICES_REAL_FINE tag shall be assigned values for
# the real part of the refractive index versus wavelength [nm]
# for the volume size distribution of the fine mode.
# Based on Ahmad et al. (2010, private communication, 2013):

REFRACTIVE_INDICES_REAL_FINE = 200 1.52985
                               337.1 1.53110
                               412   1.53110
                               443   1.53110
                               490   1.53110
                               514.5 1.53110
                               555   1.53110
                               632.8 1.53110
                               670   1.53110
                               860   1.52115
                               869   1.52110
                               1060  1.52115
                               1300  1.46150
                               1536  1.40185
                               1800  1.33230
                               2000  1.26270
                               2250  1.22295
                               2500  1.18320

# The REFRACTIVE_INDICES_IMAG_FINE tag shall be assigned values for
# the imaginary part of the refractive index versus wavelength [nm]
# for the volume size distribution of the fine mode.
# Based on Ahmad et al. (2010, private communication, 2013):

REFRACTIVE_INDICES_IMAG_FINE = 200 0.008715
                               337.1 0.008715
                               412   0.010253
                               443   0.010236
                               490   0.010210
                               514.5 0.010210
                               555   0.010157
                               632.8 0.010110
```

```
                                670   0.010110
                                860   0.010110
                                869   0.010112
                                1060  0.010160
                                1300  0.010210
                                1536  0.010260
                                1800  0.010360
                                2000  0.010410
                                2250  0.011455
                                2500  0.011505

# The REFRACTIVE_INDICES_REAL_COARSE tag shall be assigned values of
# the real part of the refractive index versus wavelength [nm]
# for the volume size distribution of the coarse mode.
# Based on Ahmad et al. (2010, private communication, 2013):

REFRACTIVE_INDICES_REAL_COARSE = 200 1.510
                                 337.1 1.510
                                 412   1.500
                                 443   1.500
                                 490   1.500
                                 514.5 1.500
                                 555   1.499
                                 632.8 1.500
                                 670   1.490
                                 860   1.480
                                 869   1.480
                                 1060  1.470
                                 1300  1.470
                                 1536  1.460
                                 1800  1.450
                                 2000  1.450
                                 2250  1.440
                                 2500  1.430

# The REFRACTIVE_INDICES_IMAG_COARSE tag shall be assigned values for
# the imaginary part of the refractive index versus wavelength [nm]
# for the volume size distribution of the coarse mode.
# Based on Ahmad et al. (2010, private communication, 2013):

REFRACTIVE_INDICES_IMAG_COARSE = 200 1e-4
                                 337.1 4e-7
                                 412   1e-7
                                 443   1e-7
                                 490   1e-7
                                 514.5 1e-8
                                 555   1e-7
                                 632.8 2e-8
```

```
670   1e-7
860   3e-6
869   3e-6
1060  2e-4
1300  4e-4
1536  6e-4
1800  8e-4
2000  1e-3
2250  2e-3
2500  4e-3

# The SIZE_DISTRIBUTION_MEAN_RADII tag shall be assigned values of
# the volume mode radii [microns] of the fine and coarse volume
# size distribution modes. The most probable radius of each mode is
# defined as the radius at which the log-normal volume size distribution
# of that mode has its maximum. Using average values for aerosols over
# open-ocean water from Ahmad et al. (2010), Table 2, we have:

SIZE_DISTRIBUTION_MEAN_RADII = 0.1499 2.1786

# The FINE_MODE_FRACTION tag shall be assigned values for the fraction
# of the total volume of the particles contained in the fine mode,
# denoted f_v so that f_v = V_f/(V_f+V_c) = V_f/V where V_f is the
# volume of the fine mode particles, V_c is the volume of
# the coarse mode particles, and V is the total volume of both modes.
# If PROFILE_TYPE = volume_fraction then the number in the second column
# of the MATERIAL_PROFILE will be equal to V. The FINE_MODE_FRACTION,
# f_v, in volume-space may also be related to the fine mode fraction
# in terms of number density, f_n, where f_n = N_f/(N_f+N_c), where
# N_f is the number of fine mode particles and N_c is the number of
# coarse mode particles, although this relationship is approximate and
# depends upon the mean size and width of the particles in each mode:
# f_v         f_n
# 0           0
# 0.01        0.9
# 0.02        0.95
# 0.50        0.999
# 0.95        0.9999
#
# Thus FINE_MODE_FRACTION (f_v) is a number between 0 and 1. If it is 0
# then there are no fine mode particles, and if it is 1 there are no
# coarse mode particles.

FINE_MODE_FRACTION = 0.5

# The RELATIVE_HUMIDITY tag controls the way the aerosol particle
# coarse and fine modes grow (increasing the mean radii) and the
# refractive indices change (become more like water) as the relative
```

```
# humidity increases. The mean radii and the refractive indices
# for the fine and coarse modes as specified by the tags above
# will be used if RELATIVE_HUMIDITY = 0. Otherwise, setting
# RELATIVE_HUMIDITY to a value between 0 and 0.95 will modify
# these values, as appropriate, where the values specified by the
# tags above are taken to be the dry aerosol values.
# See the aerosols material in the Technical Notes for details.

RELATIVE_HUMIDITY = 0.3

# The SIZE_DISTRIBUTION_WIDTHS tag shall be assigned a value for the
# width of each of the two volume size distribution modes. The width
# is defined as the standard deviation.
# For a given mode with total volume V_i and mean radius r_i,let
# r_small and r_large denote the radii at which dV_i/d(ln(r_i))
# has values that are respectively half a standard deviation below
# and above the mean radius r_i. Then the standard deviation
# sigma_i (and thus the value of the SIZE_DISTRIBUTION_WIDTHS tag
# for that mode) is given as sigma_i =log(r_large/r_small).
# Using average values for aerosols over open-ocean water from
# Ahmad et al. (2010), Table 2, we have:

SIZE_DISTRIBUTION_WIDTHS = 0.437 0.672

# The QUADRATURE_POINTS tag shall be assigned the number of
# quadrature points to be used in the numerical integration of
# absorption and scattering coefficients over the particle size
# distribution.
# The number of quadrature points should be an integer greater
# than 1, and should be set high enough to yield an accurate
# answer, but not too high to avoid waste of computer time.
# It is not recommended to use less than 50 quadrature points.

QUADRATURE_POINTS = 100

################## EXAMPLES #################

# EXAMPLE 1:
# If the user wants aerosols to be included in the lower 6 km of the
# atmosphere, and wants to use volume fractions having the values of e.g.
# 1e-12 between heights of 4000 m and 6000 m
# 3e-12 between heights of 2000 m and 4000 m
# 2e-12 between heights of 0 m and 2000 m,
# then the tags should be assigned the following values:
# PROFILE_LABEL = layer_numbering
# PROFILE_TYPE = volume_fraction
# MATERIAL_PROFILE = 12 1e-12
#                    13 3e-12
```

```
#                   14 2e-12
# where, in accordance with the default values of the
# LAYER_DEPTHS_UPPER_SLAB tag in the main configuration
# file, "layer 12" is the layer between 4 and 6 km height,
# "layer 13" is the layer between 2 and 4 km height, and
# "layer 14" is the layer between 0 and 2 km height, each
# of which include aerosols.
#
# Alternatively, if the user wishes to use <depth_numbering>
# instead of <layer_numbering>, she/he could use tags with
# the following assigned values:
# PROFILE_LABEL = depth_numbering
# PROFILE_TYPE = volume_fraction
# MATERIAL_PROFILE = 94.0e3  1e-12
#                   95.999e3  1e-12
#                   96.000e3  3e-12
#                   97.999e3  3e-12
#                   98.000e3  2e-12
#                   100.000e3  2e-12

# End of aerosols configuration file
```

D Water Configuration file

```
## AccuRT configuration file for pure_water material ##

# See end of the main configuration file for documentation on
# how to assign values to list and table tags.

#-------------------------------------------------------------------
# Configuration options:
#-------------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from the top-of-the-lower-slab (TLS)) or
# depths in meters (measured downward from the TLS) in the
# MATERIAL_PROFILE tag below. The layer numbering is
# explained in detail in the main configuration file.

PROFILE_LABEL = layer_numbering

# The MATERIAL_PROFILE tag is needed for the water material if
# materials other than pure water with significant volume fractions
# are included. For example, the layer number for water should be
# MATERIAL_PROFILE = 1 0.0
#                    2 1.0
```

```
# if a layer of ice is included at the top of the lower slab.
# A single value will give a constant volume fraction of water
# with depth.

MATERIAL_PROFILE = 1

# *** The SALINITY tag is scheduled to be implemented in version
# 2.0. Currently it has no effect. *** The SALINITY tag shall be
# assigned tabulated salinity [psu] versus depth [m] measured from
# bottom of upper slab. A single value gives constant salinity
# with depth.

SALINITY = 35

# *** The TEMPERATURE tag is scheduled to be implemented in version
# 2.0. Currently it has no effect. ***
# The TEMPERATURE tag shall be assigned tabulated temperature [K]
# versus depth [m] measured from bottom of upper slab. A single
# value gives constant temperature with depth.

TEMPERATURE = 290

# *** The PRESSURE tag is scheduled to be implemented in version
# 2.0. Currently it has no effect. ***
# The PRESSURE tag shall be assigned tabulated pressures
# [Pa] versus depth [m] measured from the TLS.
# A single value gives constant pressure with depth.

PRESSURE = 1.0e5

# End of pure_water configuration file
```

E Water Impurities Configuration file

```
## AccuRT configuration file for water_impurity_ccrr material ##

# This material can only be included in the lower slab.

#-----------------------------------------------------------------
# Configuration options:
#-----------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from the top-of-the-lower-slab (TLS)) or
# depths in meters (measured downward from the TLS) in the
# CHLOROPHYLL_CONCENTRATION, MINERAL_CONCENTRATION and
```

```
# CDOM_ABSORPTION_443 tags below. The layer numbering is
# explained in detail in the main configuration file.

PROFILE_LABEL = layer_numbering

# The CHLOROPHYLL_CONCENTRATION tag shall be assigned the mass
# concentration [mg/m^3] of chlorophyll-a versus water depth [m].
# A single value will give a constant concentration with depth.

CHLOROPHYLL_CONCENTRATION = 1 0.5

# The MINERAL_CONCENTRATION tag shall be assigned the mass
# concentration [g/m^3] of mineral particles versus water depth [m].

MINERAL_CONCENTRATION = 1 0.2

# The CDOM_ABSORPTION_443 tag shall be assigned the absorption
# coefficient [1/m] versus water depth [m] of colored dissolved
# organic matter at wavelength 443 nm.

CDOM_ABSORPTION_443 = 1 0.05

# The CDOM_ABSORPTION_SLOPE tag shall be assigned a value that
# determines the wavelength dependence of the absorption by
# color dissolved organic matter (CDOM). The default value is
# 0.0176. The wavelength dependence of CDOM goes like
# exp(-CDOMS*(wv(i)-443)) where CDOMS is the assigned
# CDOM_ABSORPTION_SLOPE and wv(i) is the wavelength in nm.
# See water_impurity_ccrr material in the Technical Notes
# for details.

CDOM_ABSORPTION_SLOPE = 0.0176

# The MINERAL_ABSORPTION_SLOPE tag shall be assigned a value that
# determines the wavelength dependence of the absorption by
# mineral particles. The default value is 0.0123.
# The wavelength dependence of the mineral absorption goes like
# exp(-MINS*(wv(i)-443)) where MINS is the assigned
# MINERAL_ABSORPTION_SLOPE and wv(i) is the wavelength in nm.
# See water_impurity_ccrr material in the Technical Notes
# for details.

MINERAL_ABSORPTION_SLOPE = 0.0123

# *** The HG_OVERRIDE_VALUE tag is scheduled to be implemented in
# a later version. Currently it has no effect. ***
# The HG_OVERRIDE_VALUE tag shall be assigned a default value
# of "nan" (do nothing). If this tag is set to a value between
```

```
# -1 and 1, then the scattering phase function normally used for
# the water_impurity_ccrr material will be switched off, and
# "overriden" by the Henyey-Greenstein scattering phase function.
# The value specified refers to the asymmetry parameter, "g".
# For example if HG_OVERRIDE_VALUE = 0.9, then g = 0.9.
# (Recall that g = -1 for complete backscattering, g = 1 for
# complete forward scattering, and g = 0 for isotropic scattering.)
# This option may be useful for determining if the actual water
# impurities provides more or less forward scattering than
# specified by the water_impurity_ccrr model, which uses a
# combination of the Petzold (for pigmented particles) and
# Fournier-Forand (for nonalgal particles) scattering phase
# functions. See the Technical Notes for a full description of
# scattering phase functions including the Henyey-Greenstein
# scattering phase function.

HG_OVERRIDE_VALUE = nan

# Experimental option for adjusting UV chlorophyll absorption.
# Range: [0, 1]

CHLOROPHYLL_ABSORPTION_FACTOR = 0.5

# End of water_impurity_ccrr material configuration file
```

F Vacuum Configuration file

```
## AccuRT configuration file for vacuum material ##

# Vacuum has refractive index equal to one and no absorption and no
# scattering.

#-----------------------------------------------------------------
# Configuration options:
#-----------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from top of slab) or depths in meters (counting
   downward
# from top of slab) in the MATERIAL_PROFILE tag below. The layer numbering
# is explained in detail in the main configuration file.

PROFILE_LABEL = depth_numbering

# The MATERIAL_PROFILE tag shall be used to specify the layer number
# (or depth) and corresponding volume fraction filled by vacuum. A
```

```
# single value will give a constant volume fraction with depth.

MATERIAL_PROFILE = 1

# End of vacuum configuration file
```

G User Specified Configuration file

```
# AccuRT configuration file for user_specified material

# This material can be included in both the upper and lower slab.

#---------------------------------------------------------------------
# Configuration options:
#---------------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from top-of-the-slab (TOS)) or depths in
# meters (counting downward from TOS) in the MATERIAL_PROFILE
# tag below. The layer numbering is explained in detail in the
# main configuration file.

PROFILE_LABEL = layer_numbering

# The MATERIAL_PROFILE tag shall be used to specify the layer number
# (or depth) and the volume fraction occupied by the user specified
# material.

MATERIAL_PROFILE = 1 1
                   2 1

# The WAVELENGTHS tag should be assigned all user specified centre
# wavelengths [nm].

WAVELENGTHS = 400 600

# Absorption coefficient (A_i_j) [1/m], scattering coefficient (S_i_j)
# [1/m], and phase moments (P_i_j) for each layer (or depth) i and
# each wavelength j. Trailing zero valued phase moments do not need to
# be listed. Note that i and j should begin with one, not zero.

A_1_1 = 0.50 #
S_1_1 = 0.50 #
P_1_1 = 1.0 0.0 0.1 #

A_1_2 = 0.50 #
```

```
S_1_2 = 0.50 #
P_1_2 = 1.0 0.0 0.1 #

A_2_1 = 0.60 #
S_2_1 = 0.60 #
P_2_1 = 1.0 0.1 0.0 #

A_2_2 = 0.60 #
S_2_2 = 0.60 #
P_2_2 = 1.0 0.1 0.0 #

# The REFRACTIVE_INDICES tag shall be assigned a list of the real part
# of the bulk refractive index for each wavelength. Note that the
# refractive index will have no effect if this material is included in
# the upper slab.

REFRACTIVE_INDICES = 1.0 1.0

# The TURN_OFF_DELTA_FIT tag shall be assigned <true> or <false>
# depending on whether the delta-fit method should be used to make the
# scattering phase function less forward peaked.

TURN_OFF_DELTA_FIT = false

# End of user_specified material configuration file
```

H Layer User Specified Configuration file

```
# AccuRT configuration file for user_specified_layer material

# This material can be included in both the upper and lower slab.

#-------------------------------------------------------------------
# Configuration options:
#-------------------------------------------------------------------

# The INCLUDE_IN_LAYER_NUMBER tag shall be assigned one or more
# integers defining in what layer(s) the material should be included.
# The layer numbers are counted from one at the top of the slab where
# the material is included. For example, if the material is included
# in the lower slab, INCLUDE_IN_LAYER_NUMBER = 1 2, will fill the two
# uppermost layers in the lower slab with the layer user specified
# material.

INCLUDE_IN_LAYER_NUMBER = 1

# The ABSORPTION_COEFFICIENT tag shall be assigned the absorption
```

```
# coefficient [1/m] versus wavelength [nm].

ABSORPTION_COEFFICIENT =
   412  1.963e-01
   440  1.246e-01
   488  8.773e-02
   510  6.551e-02
   532  5.369e-02
   555  4.234e-02
   650  2.824e-02
   676  2.780e-02
   715  1.206e-02

# The SCATTERING_COEFFICIENT tag shall be assigned the scattering
# coefficient [1/m] versus wavelength [nm].

SCATTERING_COEFFICIENT =
   412   1.007e+00
   440   9.965e-01
   488   8.411e-01
   510   7.972e-01
   532   7.719e-01
   555   7.194e-01
   650   5.994e-01
   676   5.750e-01
   715   5.248e-01

# The REFRACTIVE_INDEX tag shall be assigned the real part of the bulk
# refractive index relative to vacuum [unitless] versus wavelength
# [nm]. Note that the refractive index will only have an effect if the
# material is included as the first material in the lower slab.

REFRACTIVE_INDEX = 1.34

# The APPLY_DELTA_FIT tag shall be assigned <true> or <false> depending
# on whether the delta-fit method should be applied to make the
# scattering phase function less forward peaked.

APPLY_DELTA_FIT = true

# [**** HENYEY_GREENSTEIN_PHASE_FUNCTION ****]
# The USE_HENYEY_GREENSTEIN_PHASE_FUNCTION tag shall be assigned
# <true> or <false> depending on whether to use a Heney-Greenstein
# scattering phase function.

USE_HENYEY_GREENSTEIN_PHASE_FUNCTION = true

   # The ASYMMETRY_FACTOR tag [unitless] shall be assigned the
```

```
   # asymmetry factor [unitless] versus wavelength [nm] for the
   # Henyey-Greenstein scattering phase function. A single
   # value will give a constant asymmetry factor.

   ASYMMETRY_FACTOR = 0.94

   # The USE_HALTRIN_TYPE tag shall be assigned <true> or <false>
   # depending on whether to use the one-parameter two-term
   # Henyey-Greenstein scattering phase function proposed by
   # Haltrin (2002).

   USE_HALTRIN_TYPE = false


# [**** FOURNIER-FORAND_PHASE_FUNCTION ****]
# TO BE IMPLEMENTED!
# The USE_FOURNIER-FORAND_PHASE_FUNCTION tag should be assigned <true>
# or <false> depending on whether to use the scattering phase functions
# derived by Fournier and Forand (1994).

USE_FOURNIER-FORAND_PHASE_FUNCTION = false

   # The SIZE_DISTRIBUTION_SLOPE tag [unitless] shall be assigned the
   # slope of the hyperbolic size distribution.

   SIZE_DISTRIBUTION_SLOPE = 3.6

   # The PARTICLE_REFRACTIVE_INDEX tag [unitless] shall be assigned
   # the real part of the effective particle refractive index relative
   # to its surrounding medium.

   PARTICLE_REFRACTIVE_INDEX = 1.1


# [**** PETZOLD_PHASE_FUNCTION ****]
# TO BE IMPLEMENTED!
# The USE_PETZOLD_PHASE_FUNCTION tag shall be assigned <true> or
# <false> depending on whether to use one of the scattering phase
# functions measured by Petzold (1972).

USE_PETZOLD_PHASE_FUNCTION = false

   # The PETZOLD_WATER_TYPE tag shall be assigned <average>, <turbid
   # harbor>, <coastal_ocean>, or <clear ocean>.

   PETZOLD_WATER_TYPE = average
```

```
# [**** TABULATED_PHASE_FUNCTION ****]
# TO BE IMPLEMENTED!
# The USE_TABULATED_PHASE_FUNCTION tag shall be assigned <true> or
# <false> depending on whether to use the user tabulated function
# specified below.

USE_TABULATED_PHASE_FUNCTION = false

   # The TABULATED_PHASE_FUNCTION tag shall be assigned scattering phase
   # function values [1/steradian] versus angles [degrees]. The tabulated
   # scattering phase function will be normalized to 1/(4*pi), and it can
   # not be wavelength dependent. Assigning a single value will give
   # isotropic scattering.

   TABULATED_PHASE_FUNCTION = 1


# End of user_specified material configuration file
```

I Snow Configuration file

```
## AccuRT configuration file for snow material ##

# Snow grains are assumed to consist of a collection of homogeneous
# spheres with a single-mode log-normal volume size distribution
# with a specified volume mode radius (also called the mean radius
# below) and width. The refractive index is based on the
# compilation by Warren and Brandt (2008).
# Two options are available: (i) a fast parameterization based on
# Mie computations (default), and (ii) a complete Mie computation.

# See end of the main configuration file for documentation on
# how to tabulate data.

# NOTES: This snow material shall be included at
# the bottom of the upper slab. An important parameter is the
# snow layer geometrical thickness, which is controlled by the
# LAYER_DEPTHS_UPPER_SLAB tag in the main configuration file.
# (All layer geometrical thicknesses are controlled in the main
# configuration file by the two LAYER_DEPTHS tags.) Note that by
# default there are 14 layers in the upper slab (atmosphere).
# Additional layers must be allocated at the bottom of the
# upper slab to accommodate the snow layers.

#-------------------------------------------------------------------
# Configuration options:
#-------------------------------------------------------------------
```

```
# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from top-of-the-upper-slab (TUS)) or depths
# in meters (measured downward from TUS) in the SNOW_PROFILE and
# IMPURITY_PROFILE tags below. The layer numbering is explained
# in detail in the main configuration file below the default
# values for the LAYER_DEPTHS_UPPER_SLAB tag. For example, if a
# total snow depth of 0.2 m is desired, and if layer boundaries
# 99999.8 and 99999.9 have been added to the default layer
# settings in the main configuration file so that layers 15 and
# 16 (counting downward from TUS) contain snow, then snow densities
# of 200 and and 260 kg/m^3 can be assigned to the two lowermost
# layers in the upper slab as follows:
# SNOW_PROFILE = 15 200
#                16 260

PROFILE_LABEL = layer_numbering

# The SNOW_PROFILE tag shall be assigned tabulated snow densities
# [kg/m^3] versus depth [m] measured from the TUS or layer
# number, counting from the TUS.

SNOW_PROFILE = 15 200
               16 260

# The GRAIN_EFFECTIVE_RADIUS tag shall be assigned an effective
# radius [microns] versus depth [m] measured from the TUS or
# layer number, counting from the TUS.

GRAIN_EFFECTIVE_RADIUS = 15 100
                         16 300

# The IMPURITY_PROFILE tag shall be assigned tabulated snow impurity
# fractions [unitless] versus depth [m] measured from the TUS or layer
# number, counting from the TUS. The snow impurity fraction is the
# volume fraction of the snow occupied by impurities.
# Snow impurities are assumed to be absorbing, but non-scattering.
# A single value will give a constant value of the impurity fraction
# versus depth.

IMPURITY_PROFILE = 15 1e-6
                   16 1e-7

# The IMPURITY_IMAG tag shall be assigned the imaginary part of
# the impurity refractive index [unitless] versus wavelength [nm]
# measured from the TUS or layer number, counting from the TUS.
# A single value will give a constant value versus wavelength.
```

```
IMPURITY_IMAG = 0.4

# The INTERNAL_MIXING tag shall be set to <true> or <false>
# depending on whether the snow impurities should be distributed
# inside or outside the snow grains, respectively.

INTERNAL_MIXING = false

# The USE_HG_PHASE_FUNCTION_OVERRIDE tag shall be set to <true>
# or <false> depending on whether the Henyey-Greenstein (HG)
# scattering phase function will be used instead of the full Mie
# scattering phase function. If the tag is set to <true>, the
# asymmetry factor of the HG scattering phase function will be
# set equal to the first moment of the Mie scattering phase
# function, and the HG scattering phase function will be used.

USE_HG_PHASE_FUNCTION_OVERRIDE = false

# The USE_PARAMETERIZED_MIE_CODE tag shall be assigned <true> or
# <false> depending on whether to use the parameterizations of the
# inherent optical properties described in Stamnes et al. JQSRT
# 2011, or a complete Mie calculation. Note that the parameterized
# Mie version uses a Henyey-Greenstein scattering phase function.

USE_PARAMETERIZED_MIE_CODE = true

# The SIZE_DISTRIBUTION_WIDTH tag shall be assigned tabulated
# size distribution widths [unitless] versus depth [m] measured
# from the TUS or layer number, counting from the TUS. The size
# distribution width is defined as the standard deviation sigma
# of the log transformed size distribution. A single value will
# give a constant width of the grain size distribution with depth.
# This width is irrelevant if USE_PARAMETERIZED_MIE_CODE = true.
# If USE_PARAMETERIZED_MIE_CODE = false, then the mode radius
# r_{n} (in number density space) of the lognormal size
# distribution will be calculated from the effective grain radius
# using the relationship: r_{n} = r_{eff} exp{-2.5 sigma^2},
# between the effective grain radius r_{eff} and the mode
# radius r_{n} (see Eq. (25) in Technical notes).

SIZE_DISTRIBUTION_WIDTH = 0.1

# The QUADRATURE_POINTS tag shall be assigned the number of
# quadrature points to be used in the numerical integration of
# absorption and scattering coefficients over the particle size
# distribution.
# The number of quadrature points should be an integer greater
```

```
# than 1, and should be set high enough to yield an accurate
# answer, but not too high to avoid waste of computer time.
# It is not recommended to use less than 50 quadrature points.
# This tag is only used when USE_PARAMETRIZED_MIE_CODE = false

QUADRATURE_POINTS = 50

# End of snow configuration file
```

J Ice Configuration file

```
## AccuRT configuration file for ice material ##

# Ice inclusions (brine pockets and air bubbles) are assumed
# to consist of a collection of homogeneous spheres with a
# single-mode log-normal volume size distribution with a
# specified volume mode radius (also called the mean radius
# below) and width. The refractive index is based on the
# compilation by Warren and Brandt (2008).
# Two options are available: (i) a fast parameterization
# based on Mie computations (default), and (ii) a complete
# Mie computation. Additional absorption is introduced by
# adding impurities.

# See end of the main configuration file for documentation on
# how to tabulate data.

# NOTES: This ice material shall be included at the top of
# the lower slab and listed first in the tag, for example
# MATERIALS_INCLUDED_LOWER_SLAB = ice pure_water
# so that it controls the spectral variation of the refractive
# index of the lower slab. The geometrical thickness of the
# ice is an important parameter, which is controlled in the
# main configuration file by the LAYER_DEPTHS_LOWER_SLAB tag.
# All layer geometrical thicknesses are described by the
# two LAYER_DEPTHS tags in the main configuration file.

#-----------------------------------------------------------------
# Configuration options:
#-----------------------------------------------------------------

# The PROFILE_LABEL tag shall be assigned <layer_numbering> or
# <depth_numbering> depending on whether to use layer numbering
# (counting downward from the top-of-the-lower-slab (TLS)) or
# depths in meters (measured downward from the TLS) in the
# BRINE_PROFILE, BUBBLE_PROFILE, or IMPURITY_PROFILE tags
# defined below. The layer numbering is explained in detail
```

```
# in the main configuration file below the default values
# for the LAYER_DEPTHS_UPPER_SLAB tag.
# For example, suppose we wish layers 1 and 2 (counting
# downward from the TLS) to contain ice of thickness 0.25
# in each layer with brine volume fractions of 0.05 in
# layer 1 and 0.01 in layer 2. Then if layer boundaries of
# 0.25 and 0.5 have been added to the default layer settings
# in the main configuration file by setting
# LAYER_DEPTHS_LOWER_SLAB = 0.25 0.5 100, we should specify
# the two uppermost layers in the lower slab as follows:
# PROFILE_LABEL = layer_numbering
# BRINE_PROFILE = 1 0.05
#                 2 0.01

PROFILE_LABEL = layer_numbering

# The BRINE_PROFILE tag shall be assigned the volume fraction of
# brines pockets [unitless] versus depth [m], measured downward
# from the TLS, or layer number, counting downward from the TLS.
# A single value will give a constant volume fraction with depth.

BRINE_PROFILE = 1 0.05
                2 0.01

# The BUBBLE_PROFILE tag shall be assigned the volume fraction of
# bubbles [unitless] versus depth [m], measured downward from the
# TLS, or layer number, counting downward from the TLS. A single
# value will give a constant volume fraction with depth.

BUBBLE_PROFILE = 1 0.01
                 2 0.005

# The BRINE_EFFECTIVE_RADIUS tag shall be assigned brine effective
# radius [microns] versus depth [m] measured downward from the TLS
# or layer number, counting downward from the TLS. A single value
# will give a constant radius with depth.

BRINE_EFFECTIVE_RADIUS = 1 100
                         2 150

# The BUBBLE_EFFECTIVE_RADIUS tag shall be assigned bubble effective
# radius [microns] versus depth [m] measured downward from the TLOS
# or layer number, counting downward from the TLS. A single value
# will give a constant radius with depth.

BUBBLE_EFFECTIVE_RADIUS = 1 100
                          2 200
```

```
# The IMPURITY_PROFILE tag shall be assigned tabulated ice impurity
# fractions [unitless] versus depth [m] measured from downward the
# TLS or layer number, counting downward from the TOS. The
# IMPURITY_PROFILE is the volume fraction of the ice impurities.
# A single value will give a constant impurity fraction width with
# depth.

IMPURITY_PROFILE = 1 1e-8
                   2 1e-7

# The IMPURITY_IMAG tag should be assigned the imaginary part of
# the impurity refractive index [unitless] versus wavelength [nm].
# A single value will give a constant index with wavelength.

IMPURITY_IMAG = 0.4

# The INTERNAL_MIXING tag shall be set to <true> or <false> depending
# on whether the ice impurities should be distributed inside or
# outside brines and bubbles, respectively. The surrounding ice will
# always have external impurity mixing.

INTERNAL_MIXING = false

# The USE_HG_PHASE_FUNCTION_OVERRIDE tag shall be set to
# <true> or <false> depending on whether the Henyey-Greenstein
# (HG) phase function will be used instead of the full Mie phase
# function. If the tag is set to <true>, the asymmetry factor
# of the HG phase function will be set equal to the first moment
# of the Mie phase function, and the HG phase function will be used.

USE_HG_PHASE_FUNCTION_OVERRIDE = false

# The USE_PARAMETERIZED_MIE_CODE tag shall be assigned <true> or
# <false> depending on whether to use the parameterizations
# of the inherent optical properties described in Stamnes
# et al. JQSRT 2011, or a complete Mie code. Note that the
# parameterized version uses a Henyey-Greenstein phase function.

USE_PARAMETERIZED_MIE_CODE = true

# The BRINE_SIZE_DISTRIBUTION_WIDTH tag shall be assigned
# tabulated brine size distribution widths [unitless] versus
# depth [m] measured from the TLS or layer number, counting
# from the TLS. A size distribution width is defined as the
# standard deviation sigma of the log transformed size
# distribution. A single value will give a constant width
# with depth.
# This width is irrelevant if USE_PARAMETERIZED_MIE_CODE = true.
```

```
# If USE_PARAMETERIZED_MIE_CODE = false, then the mode radius
# r_{n} (in number density space) of the lognormal size
# distribution will be calculated from the effective grain radius
# using the relationship: r_{n} = r_{eff} exp{-2.5 sigma^2},
# between the effective grain radius r_{eff} and the mode
# radius r_{n} (see Eq. (25) in Technical notes).

BRINE_SIZE_DISTRIBUTION_WIDTH = 1 0.1
                              2 0.2

# The BUBBLE_SIZE_DISTRIBUTION_WIDTH tag shall be assigned
# tabulated bubble size distribution widths [unitless] versus
# depth [m] measured from the TLS or layer number, counting
# from the TLS. The size distribution width is defined as the
# standard deviation sigma of the log transformed size
# distribution. A single value will give a constant width
# with depth.
# This width is irrelevant if USE_PARAMETERIZED_MIE_CODE = true.
# If USE_PARAMETERIZED_MIE_CODE = false, then the mode radius
# r_{n} (in number density space) of the lognormal size
# distribution will be calculated from the effective grain radius
# using the relationship: r_{n} = r_{eff} exp{-2.5 sigma^2},
# between the effective grain radius r_{eff} and the mode
# radius r_{n} (see Eq. (25) in Technical notes).

BUBBLE_SIZE_DISTRIBUTION_WIDTH = 1 0.1
                               2 0.1

# The QUADRATURE_POINTS tag shall be assigned the number of
# quadrature points to be used in the numerical integration of
# absorption and scattering coefficients over the particle size
# distribution.
# The number of quadrature points should be an integer greater
# than 1, and should be set high enough to yield an accurate
# answer, but not too high to waste computer time.
# It is not recommended to use less than 50 quadrature points.
# This tag is only used when USE_PARAMETRIZED_MIE_CODE = false

QUADRATURE_POINTS = 50

# End of ice configuration file
```