ARTS Microwave Single Scattering Properties Database
Version: 1.0.0

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Version	Date	Changes
0.9.0	2017-10-01	Beta version released
0.9.1	2017-10-01	Database and readme document updated
0.9.2	2017-12-07	Database, technical report and readme document updated
1.0.0	2018-02-19	First official version released.

Contents

1 Overview

This document provides an overview of the ARTS microwave single scattering properties database in terms of content, structure and interface. The intention of this document is to serve as an introduction, it does not provide detailed technical documentation. Detailed documentation can be found in the technical report (located in the top folder).

The database contains mainly single scattering data of ice particles that have been calculated using the *discrete dipole approximation* method (DDA). Liquid droplets are also included in the form of spheres. The intention is to include melting particles to some degree in the future. For completely spherical habits, Mie code was used. Also, the only orientation currently provided is totally random (TRO) (i.e. each orientation is equally probable). The database is also designed to hold azimuthally random orientation, however this is left out for future versions.

More habits (melting ice hydrometeors, for instance) will be added in the future, the provided meta data expanded upon, and more detailed documentation will be made available. An article describing the database in detail will also be published in the near future.

Section 3 describes the installation and software requirements of the database. Section 4 gives an overview of the database specifications. Section 5 introduces the interfaces and provides a direction to get started. Finally, in Appendix A all habit report documents been attached.

2 Usage conditions and licence

An article is currently in writing and will in the future used for citation of the database. In the meantime, we prefer that any usage of the database is done in collaboration with us the developers. That way, we can provide assistance in its usage and receive feedback on the database.

The database is provided under CC BY-SA licence [1] and the set of functions under GPL [2], allowing users, to use, modify and (re)distribute the content.

3 Installation and requirements

3.1 Database

The database (rather the data collection) is structured in a number of folders (see Section 4.1). For practicality reasons, each of these folders is packed into a separate `tar.gz`-archive. The user can download individual archive files. They are installed by simply unpacking them in a location of the user's choice.

As a start, we suggest to download the scattering data in (`SSD`). Since the data is stored in netCDF4 files, they can be access with any netCDF4 reader. However, we advise to also download and use the interfaces (available in MATLAB and Python, collected in `DataInterfaces`) that allow to browse, select, and export data.

[1] https://creativecommons.org/licenses/by-sa/4.0/
[2] http://www.gnu.org/licenses/gpl-3.0.en.html

3.2 Interfaces

Installation and testing of the interfaces have so far only been done in Unix-like systems. Other systems are not actively supported.

As for the data collection, the interfaces are packed into one `tar.gz`-archive and are installed by downloading and unpacking the archive file. The unpacked archive will contain three interface folders, one for the MATLAB and one for the Python interface each, and one containing software patches and sample data for RTTOV-SCATT.

MATLAB interface The interface should work with any relatively recent MATLAB version. Only installation required is adding the database folder to MATLAB's search path. Storing data into files suitable as input to the ARTS forward model requires that the Atmlab[3] package is installed and added to MATLAB's search path.

Python interface The interface generally works in both Python 2 and Python 3 environments, but Python 3 ($\geq$ 3.5) is suggested for full functionality. The interface (hard-)requires the following Python packages to be installed:

- `netCDF4`
- `numpy`
- `os`

Certain features have additional requirements,[4] namely (given in the form "requirement: (module) feature"):

- `typhon`, specifically the `arts` submodule: (`assp, demo_ssp4arts`)
  Conversion to ARTS format and writing of ARTS SSP to XML file.
- `scipy`, specifically the `interpolate` submodule: (`assp, sph`)
  Grid interpolations.
- `SHTns` (Fortran) library:[5] (`assp, sph`)
  Conversion of azimuthally random orientation **Z** from Spherical Harmonics coefficients to discrete angle grid values.

Install instructions for typhon can be found on the ARTS tools webpage.[3]

The `netCDF4` is available with and installable through conda[6], as well as available from PyPI[7], or github[8] and installable with pip[9].

All other required Python packages listed above are part of standard Python distributions.

Version 2.8 of the `SHTns` Fortran library is required and needs to be installed to the user's python. For that, download the respective tar-archive (currently:

[3] http://www.radiativetransfer.org/tools/

[4] Unless noted otherwise, this refers to required Python packages.

[5] https://bitbucket.org/nschaeff/shtns

[6] See https://anaconda.org/anaconda/netcdf4 for the package, https://conda.io/docs/ for conda itself.

[7] https://pypi.python.org/pypi/netCDF4/1.3.0

[8] http://unidata.github.io/netcdf4-python/

[9] https://pip.pypa.io/en/stable/

shtns-2.8-r562.tar.gz)[5] and unpack in a location of the user's choice. To configure and install it in the user's python environment:[10]

```
> ./configure --prefix=$(dirname $(which python))/..
  --enable-python --enable-openmp
> make
> python setup.py install --user
```

`SHTns` itself requires the `FFTW` library, which can be installed by

```
> sudo apt-get install libfftw3-dev
```

RTTOV interface For a fully working RTTOV interface, a RTTOV installation (v11.3 or v12.1) as well as the Python interface and typhon are required. The respective patch file needs to be copied into the RTTOV installation's `src/mw_scatt_coef/` subfolder and applied there by[11]

```
> patch -p1 < mw_scatt_coef_*.patch
```

After that, RTTOV needs to be rebuild in the usual way.

4 Content

The specifications of the database are summarized in Table 1 and 2 (continued) for totally random orientation. The numbers next to the habit names refer sections available in the technical report. More detailed information on each habit can be found in the automatically generated documents named `report.pdf` in the folder of the respective habits. These documents can be found in Appendix A as well.

4.1 Database structure

The data is structured using a folder hierarchy, divided at the top level into SSP, interfaces and input data. The structure at the top level of the database is

```
ArtsScatDbase
├── DataInterfaces
├── Input
├── SSD
├── StandardHabits
├── TechnicalReport.pdf
└── README.pdf
```

where `SSD` is an abbrevation for Single Scattering Data. `SSD` acontains the single scattering data, which is described below in Section 4.2. `Input` contains the DDA input data required to reproduce the scattering data, being DDA settings and shape files as described in section (more information in the technical

[10] Alternatively, the prefix might be manually set to the path to the users python installation. This can be derived from executing `which python` and removing the lowest level subfolder name (usually 'bin' from it)

[11] Replace '*' by respective (dot-stripped) version number.

report). `DataInterfaces` contains the Python and MATLAB interfaces, summarized in section 5. `StandardHabits` contains a selection of user-ready habits in the ARTS-xml format. More information on the data is available in a readme file placed in this folder.

4.2 Single scattering data

The files containing the scattering data can be accessed and read directly, being in the netCDF4 format. The format is self explanatory to a reasonable degree. However, the easiest way to browse and access the data is using the provided interfaces, available in either MATLAB or Python (see section 5). The files also contain meta data such as mass, maximum dimension, refractive index, etc., and information necessary to reproduce the given scattering data (i.e. pointer to the input folder and DDA settings).

The single scattering data format is intended to be as general and complete as possible (should be useful for both passive and active applications), and is for all intents and purposes identical to the ARTS single scattering format. In short, the SSP includes the full scattering matrix (sometimes referred to as the phase matrix), the extinction matrix and the absorption vector (as defined in *Mishchenko et al.* (2002)). As such, the data contain some redundancy. Since orientation averaged particles result in both zero elements and symmetries in the scattering variables, some data reduction is possible.

As a complement to the regular netCDF4 data, a set of standard habits scattering data have been included in the `StandardHabits`. They are intended to be user-friendly and come in the ARTS xml format. Furthermore, the aggregate habits have been mixed with suitable particle data in in order to ensure that the size coverage reaches low enough sizes. More information are available in the separate readme file in the `StandardHabits` folder.

4.3 Folder structure

A snapshot of the folder structure can be seen below:

```
SSD
├── TotallyRandom
│   └── Ice
│       ├── Aggregates
│       │   └── Pristine
│       │       └── HongAggregate_Id8
│       │           ├── TotallyRandom
│       │           │   ├── Dmax02528um_Dveq01301um_Mass1.05758e-06kg.nc
│       │           │   └── Dmax02889um_Dveq01487um_Mass1.57881e-06kg
│       │           ├── ...
│       │           ├── report.pdf
│       │           ├── DataSummary.txt
│       │           └── shape_img.png
│       └── SingleCrystals
│           └── ...
├── AzimuthallyRandom
└── ...
```

Table 1: Database specifications for totally random orientation. Continued in Table 2. Habits marked with * are calculated using Mie theory. The last column displays the software or source used to created the shape data of the given habit, with abbreviations being RSP (Recreated Shape Data), RC (RimeCraft), SFTK (SnowFlake Tool-Kit) and ESP (External Shape Data).

Source:	Chalmers University of Technology, University of Hamburg.
Products provided:	Scattering matrix **Z**, absorption vector **a**and extinction matrix **K**.
Orientation:	Totally random.
Frequencies [GHz]:	1, 1.4, 3, 5, 7, 9, 10, 10.65, 13.4, 15, 18.6, 24, 31.3, 31.5, 35.6, 50.1, 57.6, 88.8, 94.1, 115.3, 122.2, 164.1, 166.9, 175.3, 191.3, 228, 247.2, 314.2, 336.1, 439.3, 456.7, 657.3, 670.7, 862.4, 886.4
Temperatures (ice) [K]:	190, 230, 270
Temperatures (liquid) [K]:	230, 250, 270, 290, 310
Refractive index of ice:	*Mätzler* (2006, Eq.(5.30) for all temperatures)
Refractive index of water:	*Ellison* (2007)
Computational method:	DDA, software: ADDA (*Yurkin and Hoekstra*, 2011). Mie theory*, software: Matlab Mie code (*Mätzler*, 2002).

Habits	Id	$D_{\max}$ [μm]	D_{veq} [μm]	No. of sizes	α	β	Software used
Ice:							
Single crystals:							
Pristine:							
Plate type 1 (3.3.2)	9	13 – 10,000	10 – 2,596	45	0.76	2.48	RSP
Column type 1(3.3.2)	7	14 – 10,000	10 – 1,815	45	0.037	2.05	RSP
Thin Plate (3.3.2)	16	25 – 5,059	10 – 2,000	35	30	3.00	RSP
Thick Plate (3.3.2)	15	16 – 3,246	10 – 2,000	35	110	3.00	RSP
Block Column (3.3.2)	12	13 – 2,632	10 – 2,000	35	210	3.00	RSP
Short Column (3.3.2)	13	17 – 3,303	10 – 2,000	34	110	3.00	RSP
Long Column (3.3.2)	14	24 – 4,835	10 – 2,000	35	34	3.00	RSP
Sector Snowflake (3.3.2)	3	20 – 12,000	20 – 1,415	34	0.00081	1.44	RSP
Ice Sphere* (3.2.4)	24	1 – 50,000	1 – 50,000	200	480	3.00	Mie
ICON Cloud Ice (3.2.4)	27	13 – 10,000	10 – 2,929	45	1.6	2.56	RC
GEM Cloud Ice (3.2.4)	31	10 – 3,088	10 – 3,000	45	440	3.00	RC
6-Bullet Rosette (3.3.2)	6	16 – 10,000	10 – 2,371	45	0.48	2.42	RSP
5-Bullet Rosette (3.2.2)	2	17 – 10,000	10 – 2,231	45	0.4	2.43	SFTK
Perpendicular 4-Bullet Rosette (3.2.2)	10	18 – 10,000	10 – 2,071	45	0.32	2.43	SFTK
Flat 4-Bullet Rosette (3.2.2)	11	18 – 10,000	10 – 2,071	45	0.32	2.43	SFTK
Perpendicular 3-Bullet Rosette (3.2.2)	4	19 – 10,000	10 – 2,137	45	0.44	2.47	SFTK
Flat 3-Bullet Rosette (3.2.2)	5	20 – 10,000	10 – 1,882	45	0.2	2.43	SFTK

Table 2: Database specifications for totally random orientation continued. Habits marked with * are calculated using Mie theory.

Habits	Id	$D_{\max}$ [μm]	D_{veq} [μm]	No. of sizes	α	β	Software used
Aggregates:							
Pristine:							
Evans Snow Aggregate (3.3.1)	1	32 – 11,755	50 – 2,506	35	0.20	2.39	ESP
Tyynelä Dendrite Aggregate (3.3.1)	26	595 – 20,826	228 – 3,328	35	0.10	2.25	ESP
8-Column Aggregate (3.3.2)	8	19 – 9,714	10 – 5,000	39	65	3.00	RSP
Small Column Aggregate (3.2.1)	17	105 – 3,855	37 – 738	35	0.14	2.45	SFTK
Large Column Aggregate (3.2.1)	18	368 – 19,981	128 – 3,021	35	0.25	2.43	SFTK
Small Block Aggregate (3.2.1)	21	100 – 7,328	72 – 1,665	35	0.21	2.33	SFTK
Large Block Aggregate (3.2.1)	22	349 – 21,875	253 – 4,607	35	0.35	2.27	SFTK
Small Plate Aggregate (3.2.1)	19	99 – 7,054	53 – 1,376	35	0.077	2.25	SFTK
Large Plate Aggregate (3.2.1)	20	349 – 22,860	197 – 4,563	34	0.21	2.26	SFTK
ICON Hail (3.1.2)	30	120 – 5,349	94 – 5,000	35	380	2.99	RC
ICON Snow (3.1.2)	28	120 – 20,000	94 – 3,219	35	0.031	1.95	RC
GEM Hail (3.1.2)	29	120 – 5,031	94 – 5,000	35	540	3.02	RC
GEM Snow (3.1.2)	32	170 – 10,459	94 – 5,000	35	24	2.86	RC
Rimed:							
Spherical Graupel (3.2.1)	23	622 – 9,744	454 – 5,293	30	13	2.69	SFTK
ICON Graupel (3.1.2)	29	170 – 6,658	94 – 5,000	35	390	3.13	RC
GEM Graupel (3.1.2)	33	120 – 6,597	94 – 5,000	35	170	2.96	RC
Liquid:							
Single crystals:							
Pristine:							
Liquid Sphere* (3.2.4)	25	1 – 50,000	1 – 50,000	200	480	3.00	Mie

The orientation type occurs at both level 1 and 6. The reason for this is that the data size for the azimuthally oriented scattering data is significantly larger compared to totally randomly oriented data. The user may not be interested in the oriented particles, and can therefore choose to only import or download the random data. However, a division on orientation at level 6 is still appropriate since the tilt angle is a continuous variable.

The second level under `SSD` represents the phase, in this case ice, while the second level makes the distinction between aggregates and single crystals. The fourth level distinguishes between rimed and pristine particles, and at the fifth level are the different habits. Finally, at seventh level, under the bottom orientation folder, are the netCDF files. Each netCDF file contains scattering data (scattering matrix $\mathbf{Z}$, extinction matrix $\mathbf{K}$ and absorption vector $\mathbf{a}$), associated meta data (mass, maximum diameter, etc.) and other types of log data mainly related to the DDA calculations, for multiple frequencies and temperatures at the specific habit and size.

At the fifth level (Habit type), there are overview data available in several files. These are:

- `report.pdf`: Automatically generated documentation on the habit and SSP properties.Global:

- `DataSummary.txt`: Summary data available in the .txt-files for easy reading by software. One summary file is available for each orientation and habit combination.

- `shape_img.png`: Image depicting the specific habit.

5 Interfaces

The main tasks of the database interfaces are to provide functionality to:

- Explore the content of the database.
- Extract selected data (habits, orientations, sizes, frequencies, etc.) from the database, and compile it into a more compact data format.
- Interpolate data in temperature, frequency, size, angles.
- Prepare habit mixes and size distribution convolved SSP.
- Conversion to SSP formats as used by forward models.

Interfaces have been implemented both in MATLAB and in Python. Core parts of these two interfaces have been designed such that functionality and usage is identical as far as possible (considering the individual design of each of these programming languages). However, the Python interface is treated as the main one, and some special features are only at hand by this interface.

Details and specifics of both interfaces are presented in the technical report, Sections 7.1 and 7.2. An overview of the functions available is given in the technical report, Appendix C.1.

Both interfaces use the languages' documentation infrastructure. Hence, we skip a detailed description of each individual function. Below, some usage

example are given, though (technical report, Appendix C.2 additionally presents the expected output):

Initialisation A first step necessary is to initialise the interfaces, i.e. build up an internal inventory of the data available, by executing the `ssdb_init` function or, alternatively, the `ssdb_habits` function, both with the SSD folder location as the single function argument:

```
>> topfolder = '/the/users/local/ARTS-SSDB/SSD_TRO/'
>> ssdb_init( topfolder )
```

Exploring the database The database can be explored on different levels using the function `ssdb_display`.

```
>> ssdb_display
```

prints a list over all habits present in the database including their respectively available orientations as well as some auxiliary data (e.g. a and b of mass-size relation).

```
>> habitID = 3
>> orientation = 'totally_random'
>> ssdb_display(habitID,orientation)
```

lists the available particle sizes for the requested habit (through its Id) and orientation.

```
>> habitID = 3
>> orientation = 'totally_random'
>> dveq = 100e-6
>> ssdb_display(habitID,orientation,dveq)
```

list the available frequency and temperature data for a specific particle characteristed by its size (in addition to habit Id and orientation).

Importing data Further data locating and selection commonly works through the habit Id. For example, `ssdb_import_habit` extracts all data for a given habit, identified by the habit Id, and orientation, where the user might optionally specify and limit frequency, temperature, and size ranges:

```
>> data = ssdb_import_habit(habitID,orientation)
```

In this example, by not specifying them, default frequency, temperature, and size ranges are applied, which are set such that no data are removed from the selection. The output variable `data` will be a struct array (MATLAB) or a list of dictionary (Python), with one array/list entry per individual particle (or, particle size) and mainly holding the SSP of the particles in the database format as well as some additional auxiliary parameters (e.g. size description parameters). For example, `data(i).mass` and `data[i]'mass']` would provide the mass of particle `i` in MATLAB and Python, respectively.

The same extraction, followed by a conversion to ARTS SSP format can be achieved by `assp_import_ssdb` (in the Python interface included in the assp module) providing arrays/lists of ARTS single scattering (`S`) and scattering meta data (`M`), e.g.:

```
>> [S,M] = assp_import_ssdb(3,'totally_random')
```

where `S` and `M` then could be written to file using functions provided by the Atmlab or typhon packages.

Interpolation and habit mixtures are provided by the `assp_interp_*` functions (available for frequency, temperature, size, and angle grids) and `assp_create_mix` respectively.

The demo files `demo_ssp4arts.m` and `demo_ssp4arts.py` demonstrate extraction of the data and the creation of ARTS scattering .xml-files, which can be used as ARTS input.

6 Known issues

The database is still in the beta phase, hence there are some unresolved issues that the user should be aware of:

- Currently, no known issues. Please contact if you come upon any.

References

Ellison, W. J. (2007), Permittivity of pure water, at standard atmospheric pressure, over the frequency range 0–25 THz and the temperature range 0–100°c, *Journal of Physical and Chemical Reference Data*, *36*(1), 1–18, doi: 10.1063/1.2360986.

Mätzler, C. (2002), Matlab functions for mie scattering and absorption, version 2, *Tech. rep.*

Mätzler, C. (2006), *Thermal Microwave Radiation: Application for Remote Sensing*, *IET Electromagn. Waves Ser.*, vol. 52, chap. Microwave dielectric properties of ice, pp. 455–462, Inst. Eng. Technol., Stevenage, U. K.

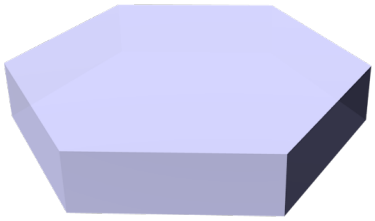
Mishchenko, M. I., L. Travis, and A. Lacis (2002), *Scattering, absorption, and emission of light by small particles*, Cambridge University Press, Cambridge, UK.

Yurkin, M. A., and A. G. Hoekstra (2011), The discrete-dipole-approximation code adda: capabilities and known limitations, *J. Quant. Spectrosc. Radiat. Transfer*, *112*(13), 2234–2247.

A Habit reports

SSP Data Summary

Plate Type 1



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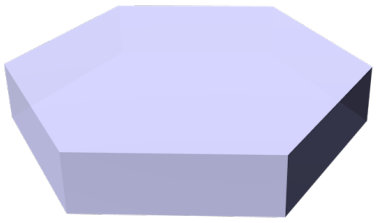
Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal plate, using Hong parametrization (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	Note that values of alpha and beta are calculated for the upper end of d_max.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

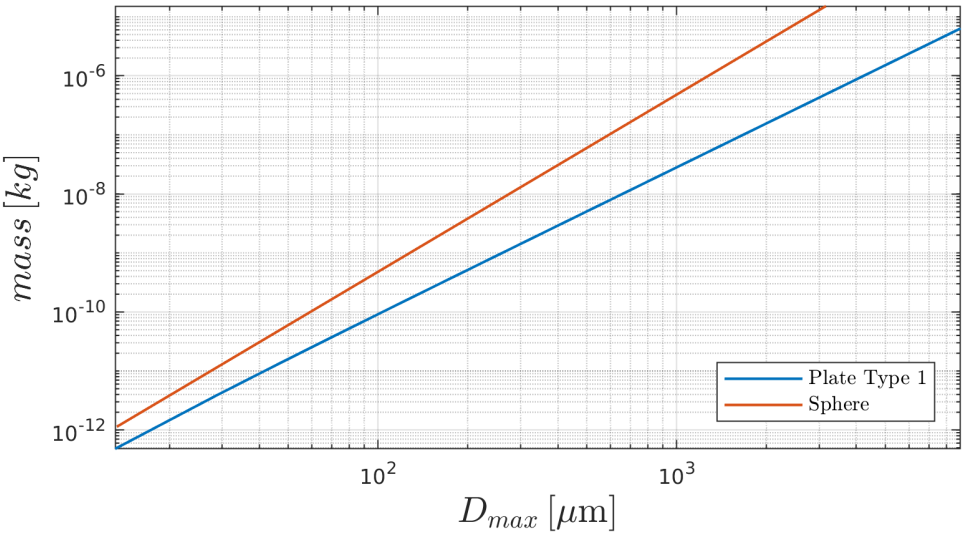
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	13	8933	44
D_e [um]	10	2365	

Table 1.3. Shape parameters

α	0.7570
β	2.4770

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

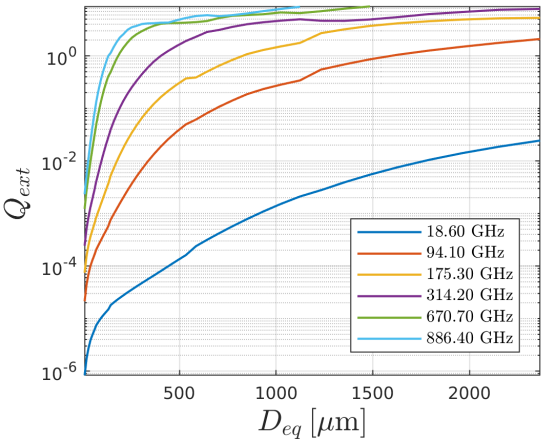
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

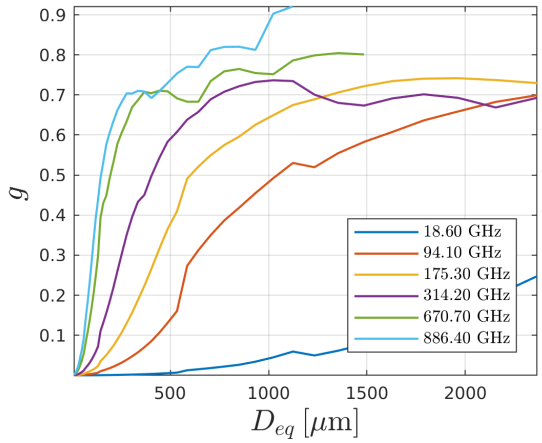
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



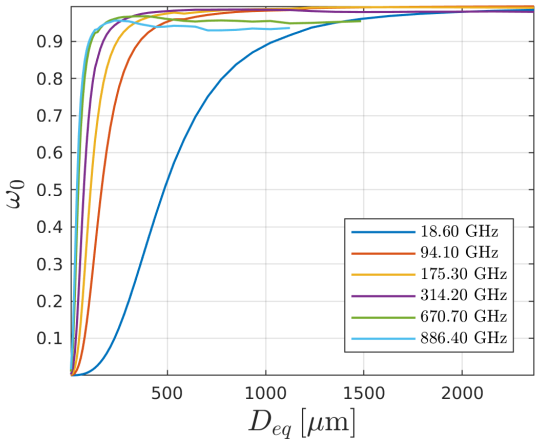
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

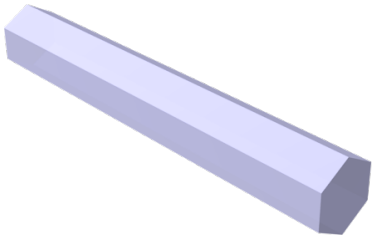
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Column Type 1



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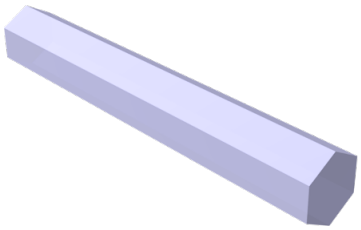
Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column, using Hong parametrization (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	Note that values of alpha and beta are calculated for the upper end of d_max.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

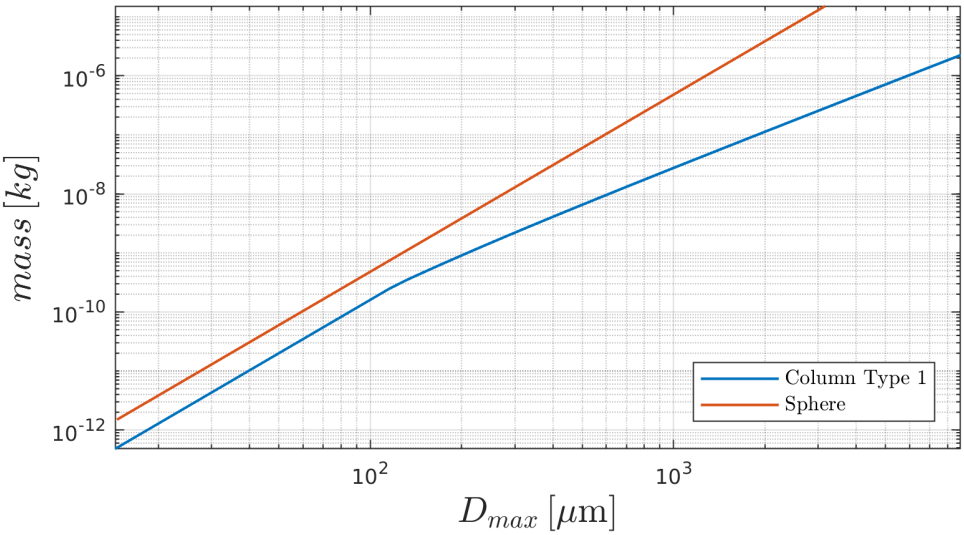
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	14	8835	44
D_e [um]	10	1671	

Table 1.3. Shape parameters

α	0.0380
β	2.0511

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

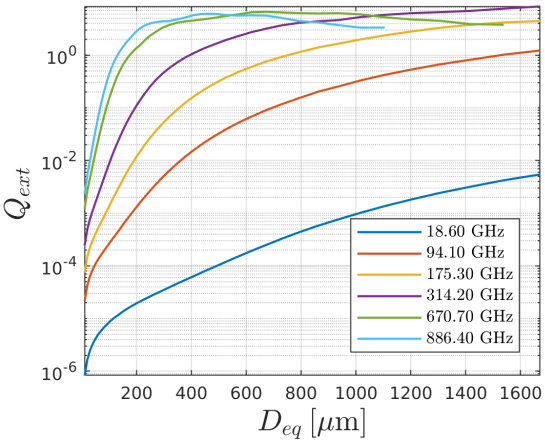
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

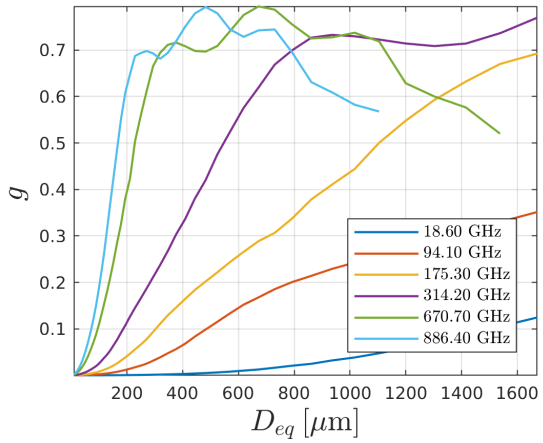
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



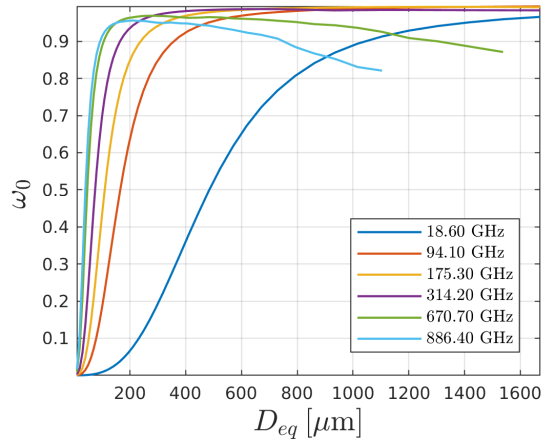
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

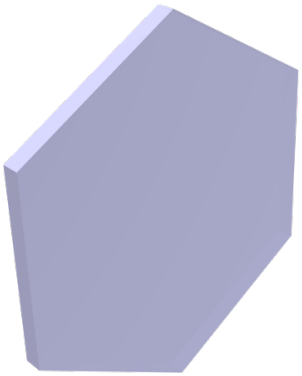
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Thin Plate



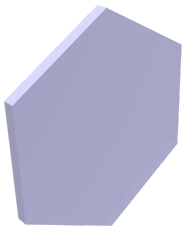
Publication date 20-Nov-2017 22:14:12

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal thin plate, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that aspect ratio is constant.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

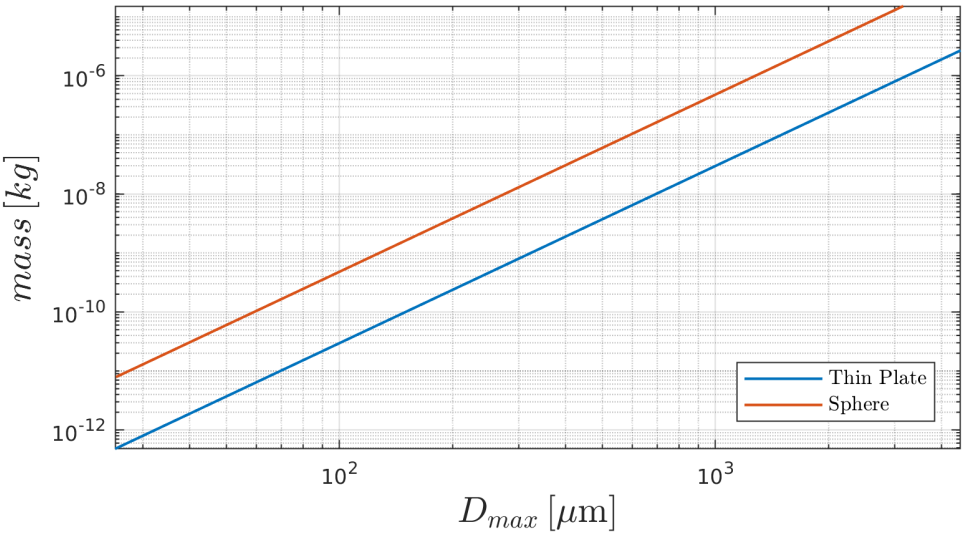
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	25	4490	34
D_e [um]	10	1775	

Table 1.3. Shape parameters

α	29.6594
β	3

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

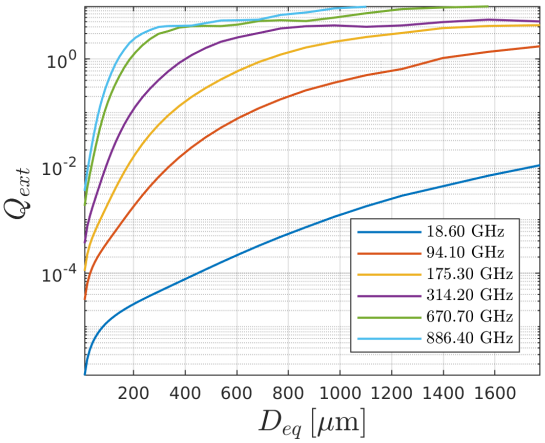
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

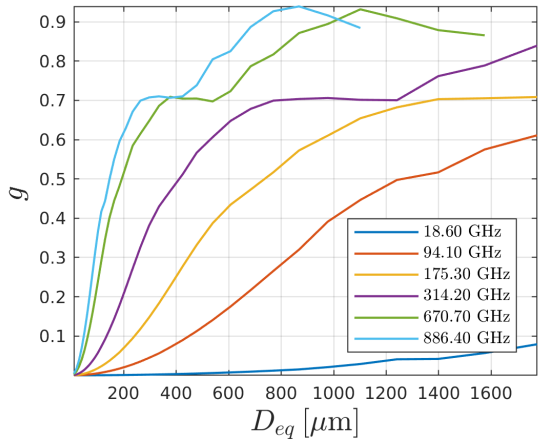
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



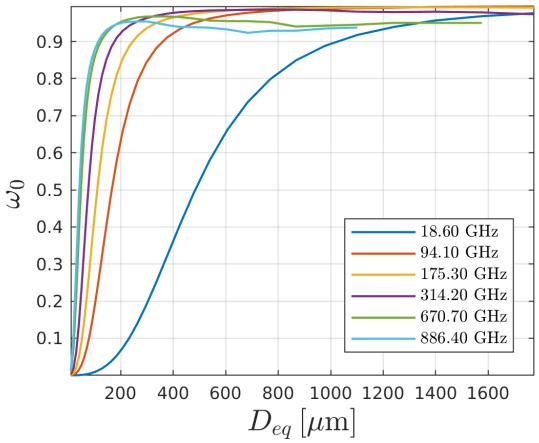
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

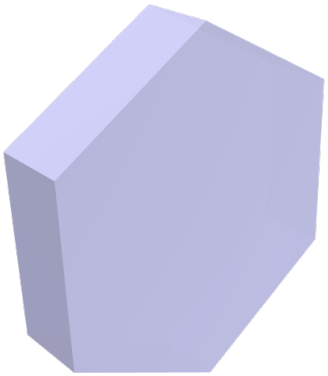
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Thick Plate



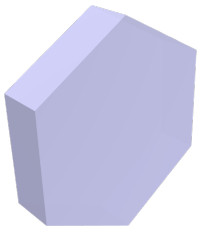
Publication date 20-Nov-2017 22:13:28

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal thick plate, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that aspect ratio is constant.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

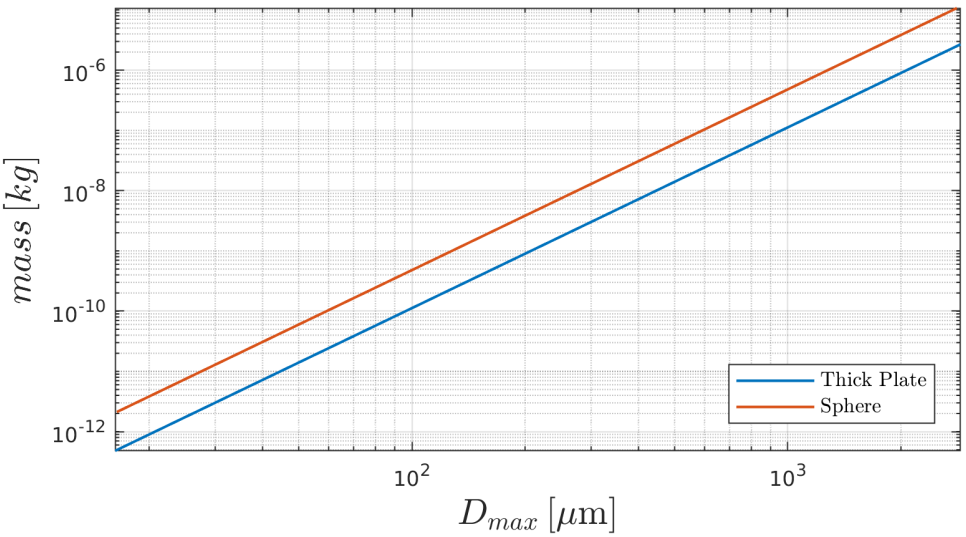
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	16	2881	34
D_e [um]	10	1775	

Table 1.3. Shape parameters

α	112.2791
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

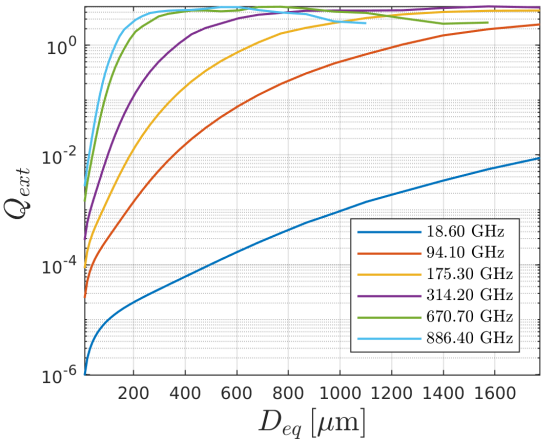
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

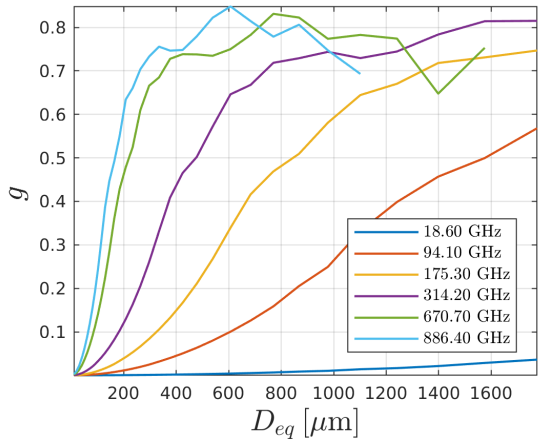
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



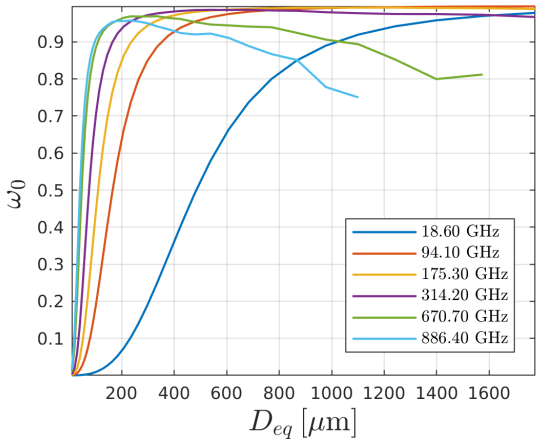
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

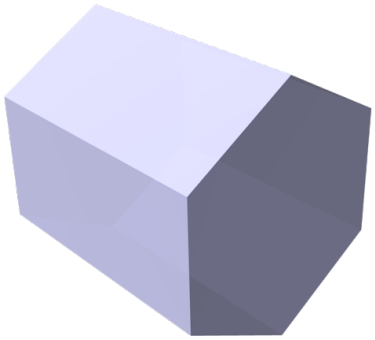
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Block Column



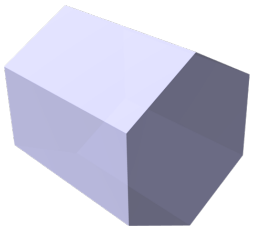
Publication date 20-Nov-2017 22:10:59

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal block column, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that aspect ratio is constant.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

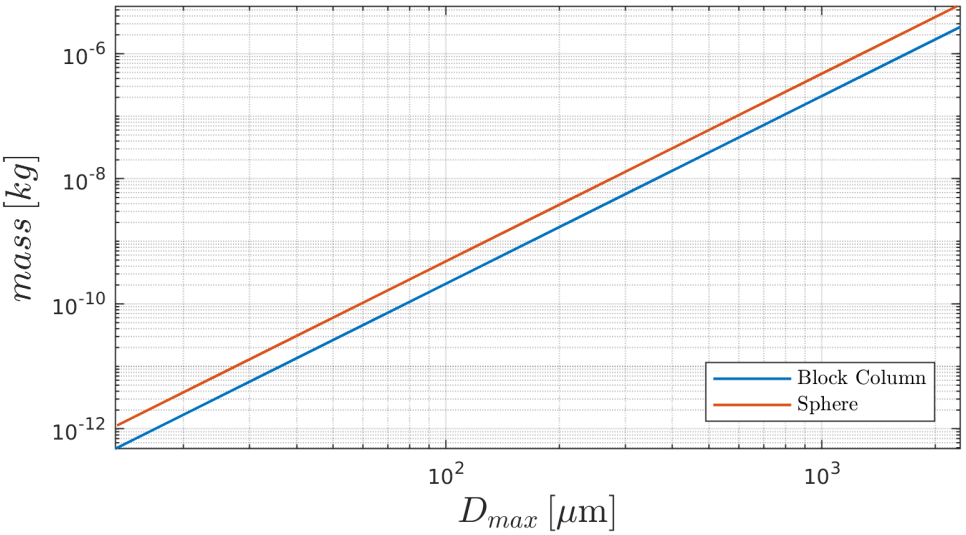
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	13	2336	34
D_e [um]	10	1775	

Table 1.3. Shape parameters

α	210.5107
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

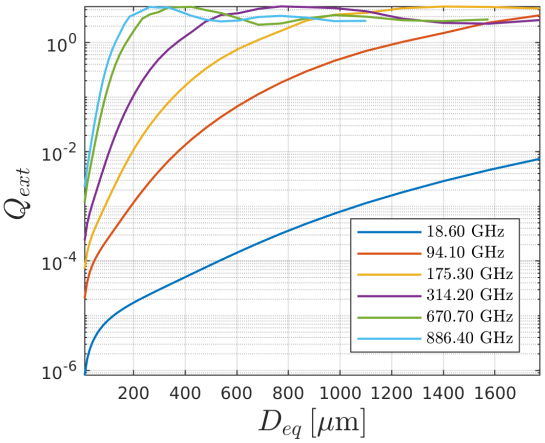
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

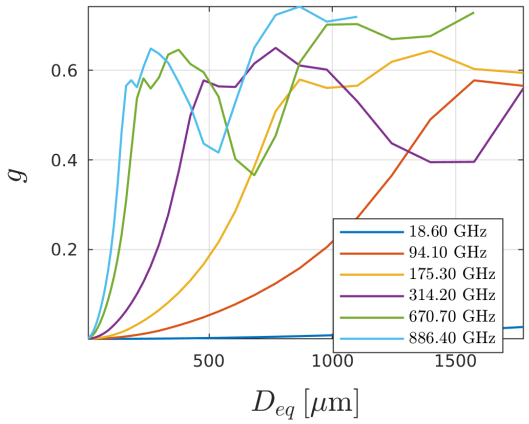
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



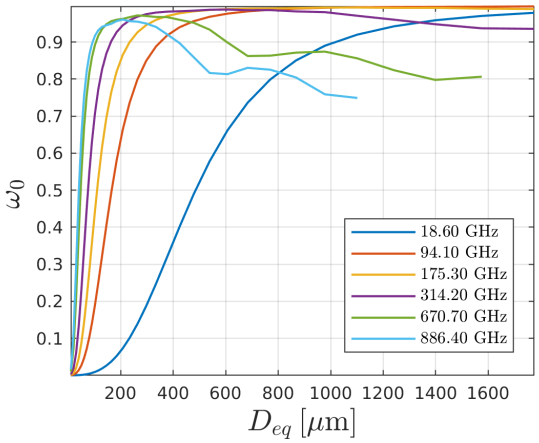
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

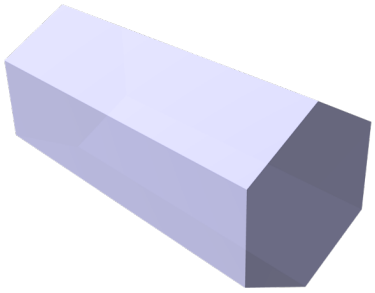
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Short Column



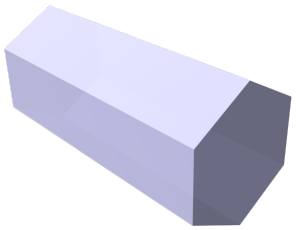
Publication date 20-Nov-2017 22:11:47

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal short column, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that aspect ratio is constant.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

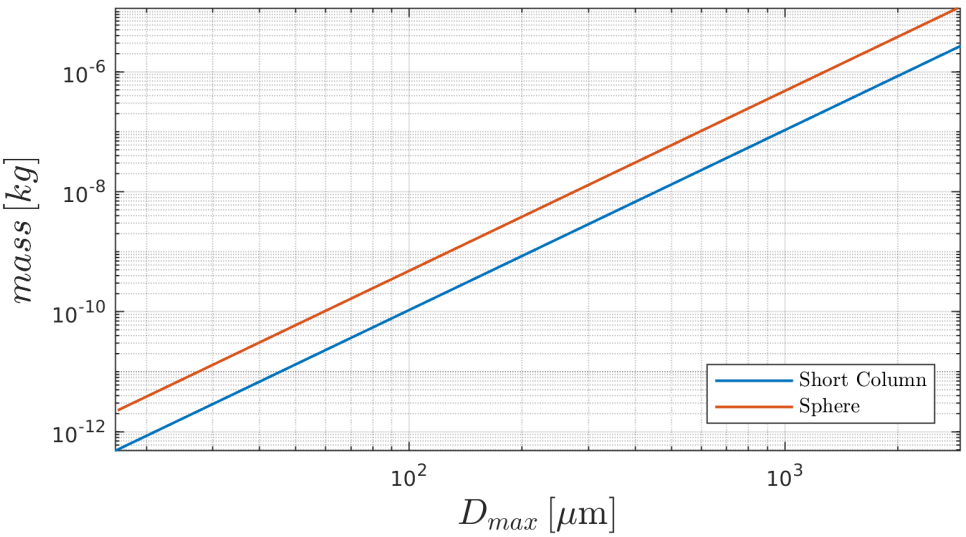
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	17	2932	34
D_e [um]	10	1775	

Table 1.3. Shape parameters

α	106.5109
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

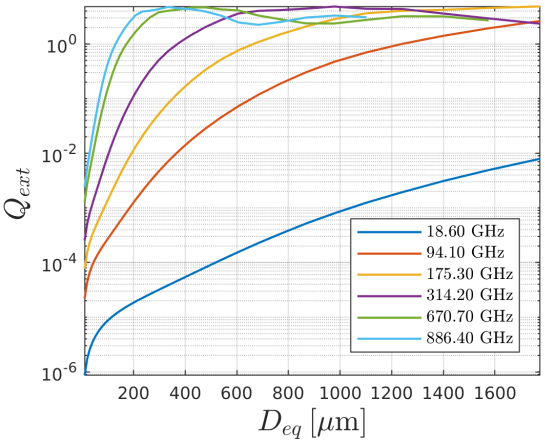
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

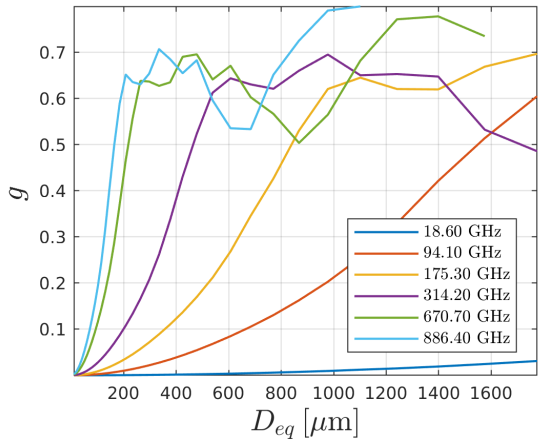
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



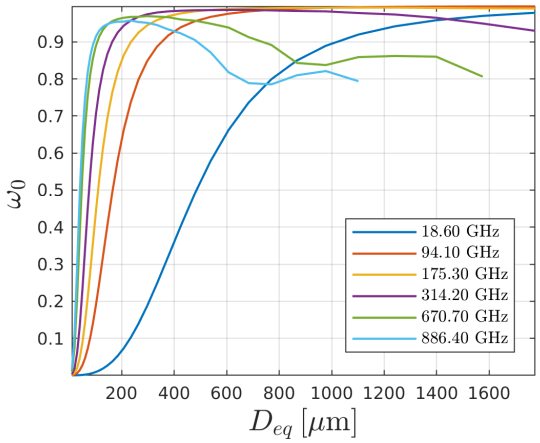
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

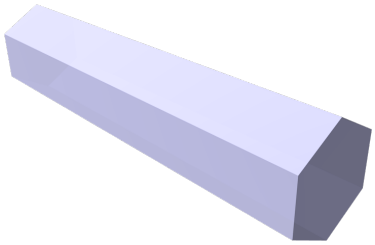
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Long Column



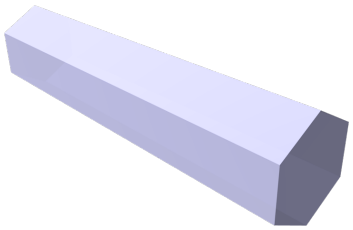
Publication date 20-Nov-2017 22:12:30

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal long column, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that aspect ratio is constant.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

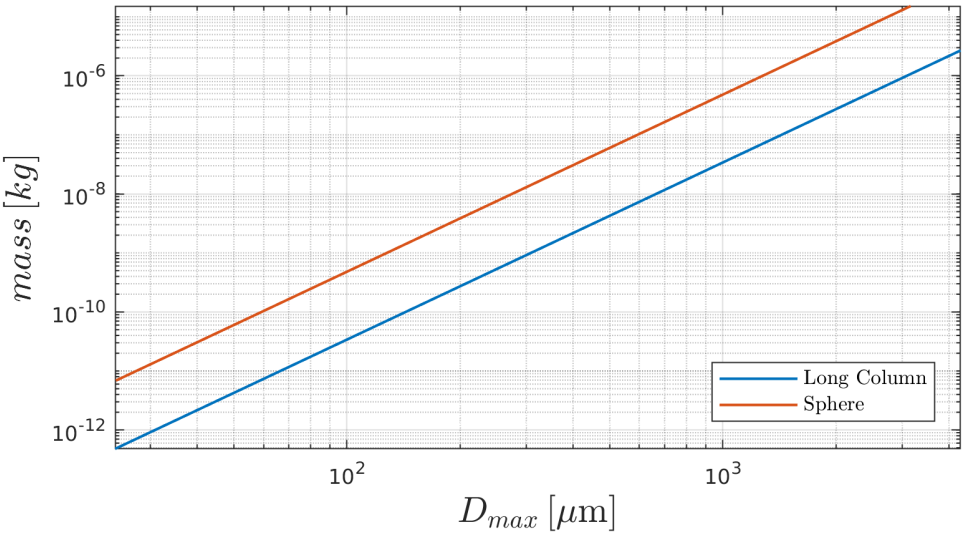
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	24	4291	34
D_e [um]	10	1775	

Table 1.3. Shape parameters

α	33.9786
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

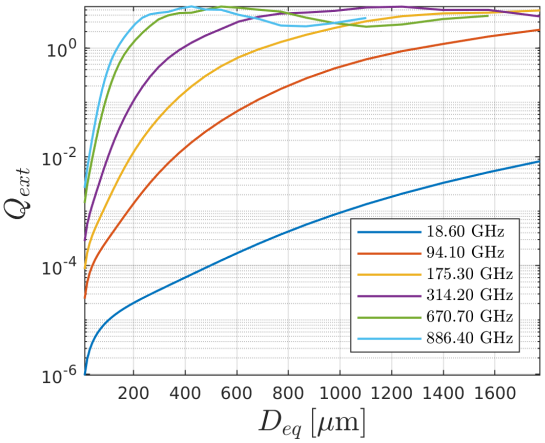
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

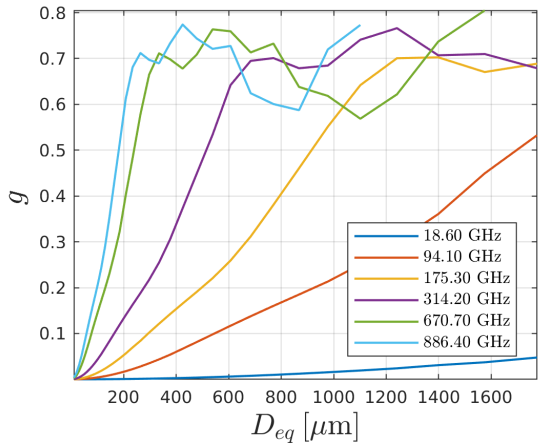
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



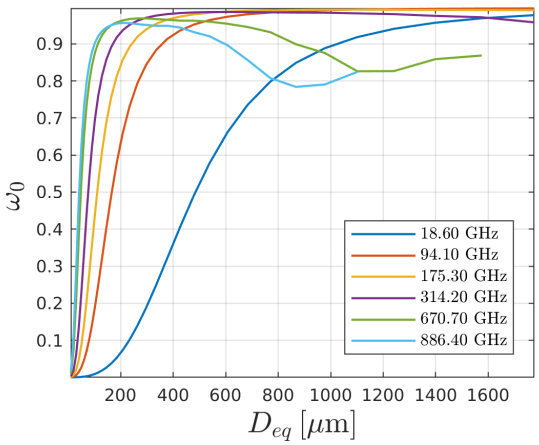
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

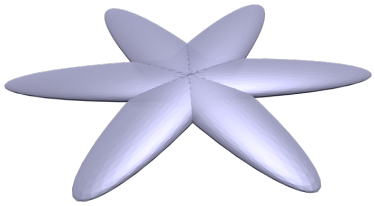
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Sector Snowflake



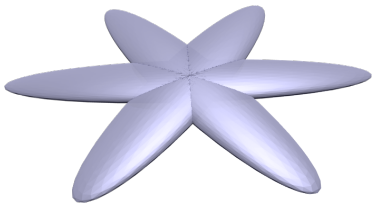
Publication date 20-Nov-2017 22:03:53

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Sector snowflake, using Liu parametrization (Liu 2008).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Liu 2008.
Comment	Note that the alpha and beta values are calculated for the upper end of d_max, since the shape transitions to spheroidal in the lower end of d_max.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

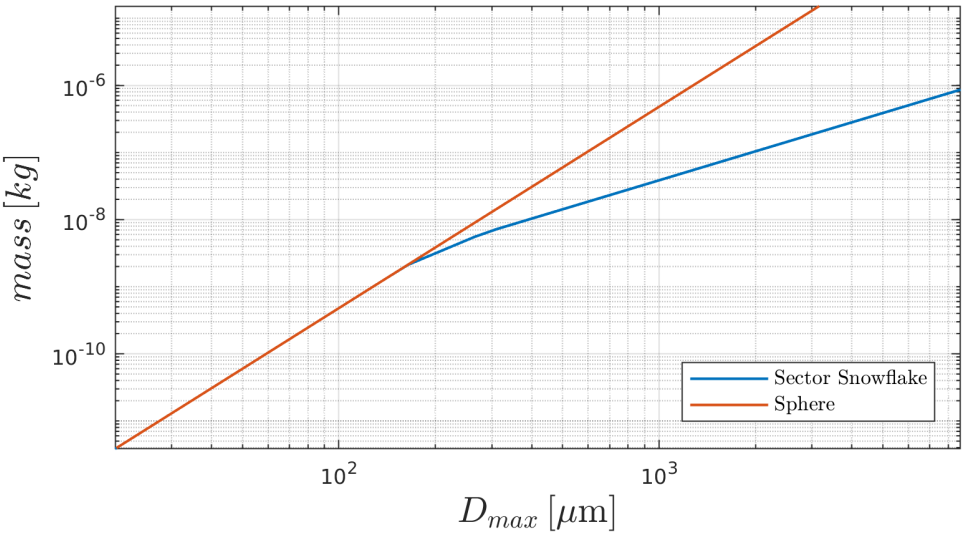
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	20	8735	33
D_e [um]	20	1216	

Table 1.3. Shape parameters

α	8.2226e-04
β	1.4446

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

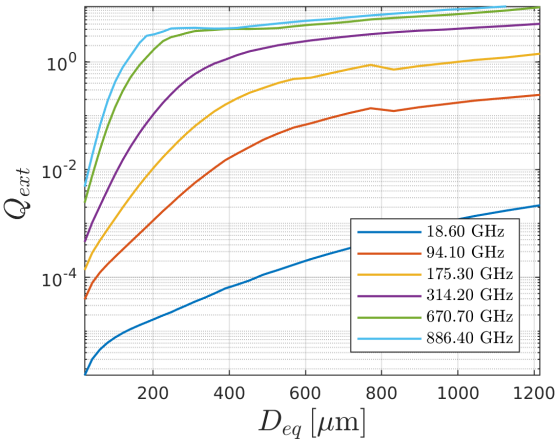
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

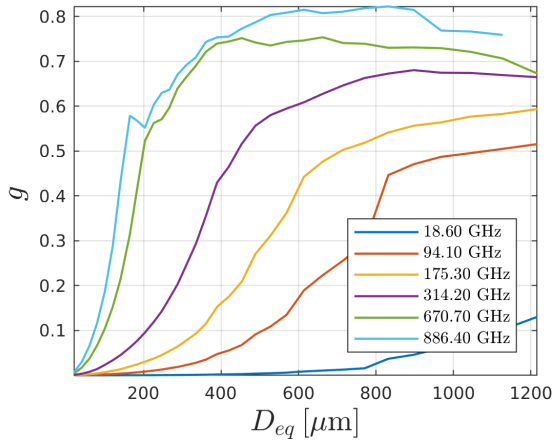
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



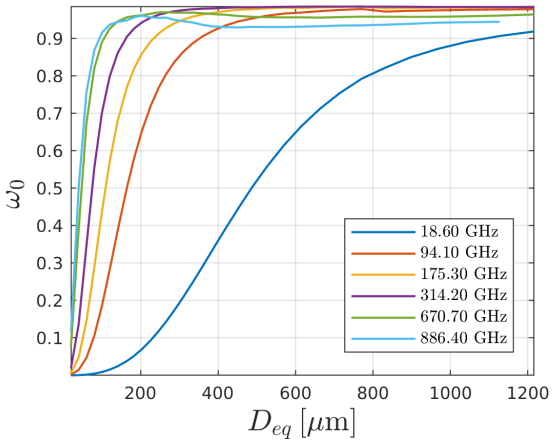
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

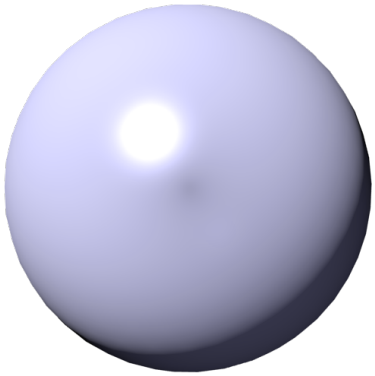
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Ice Sphere



Robin Ekelund

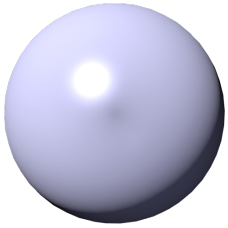
Publication date 25-Oct-2017 21:36:10

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Ice sphere
Source	location: Chalmers
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

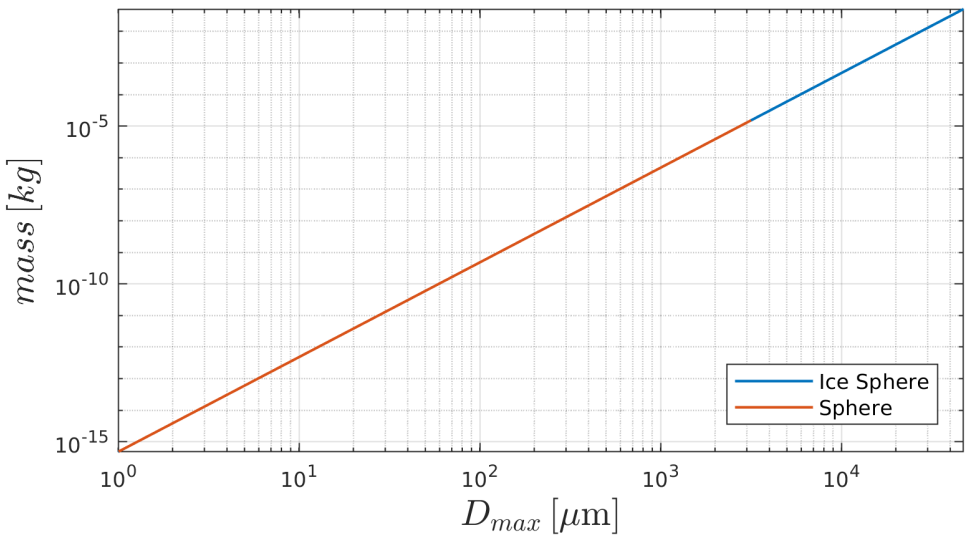
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	1	47354	199
D_e [um]	1	47354	

Table 1.3. Shape parameters

α	479.9830
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

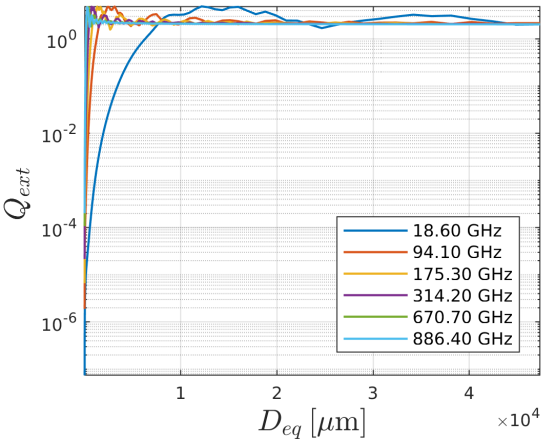
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (405.54)
Refractive index	Matzler 2006

Table 2.2. SSP grid

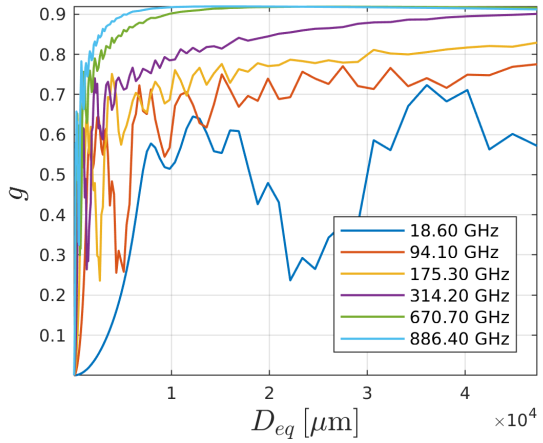
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



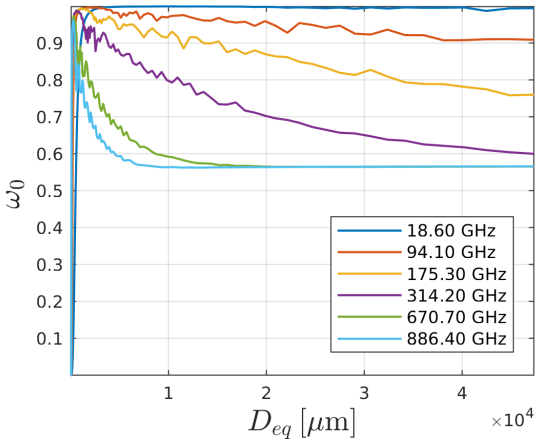
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

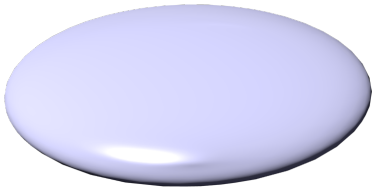
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

ICON Cloud Ice



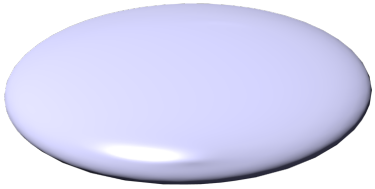
Publication date 20-Nov-2017 22:20:21

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	ICON cloud ice
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

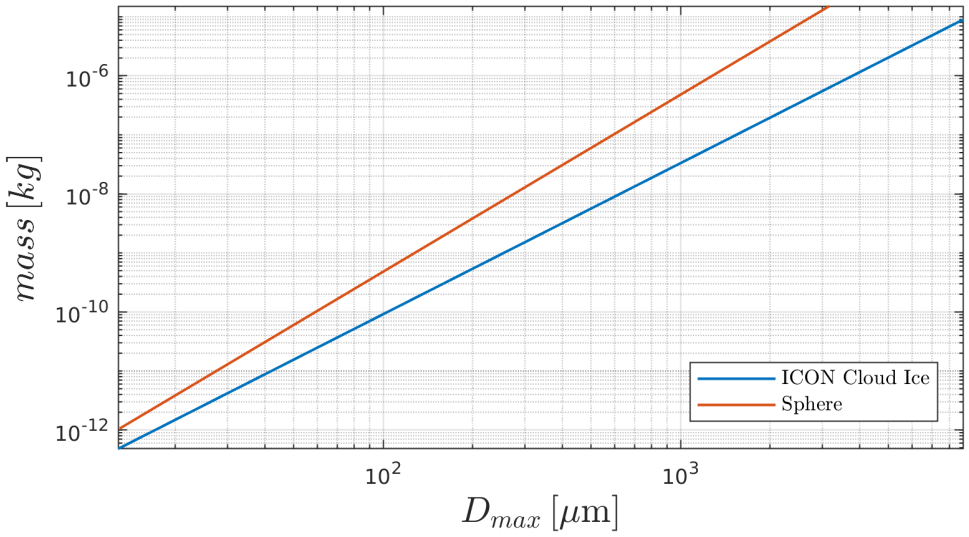
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	13	8931	44
D_e [um]	10	2660	

Table 1.3. Shape parameters

α	1.5900
β	2.5600

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

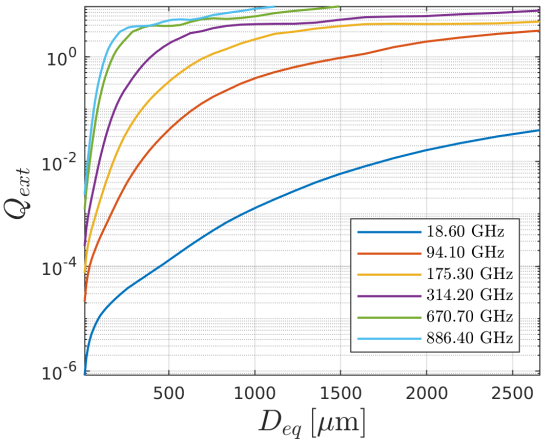
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

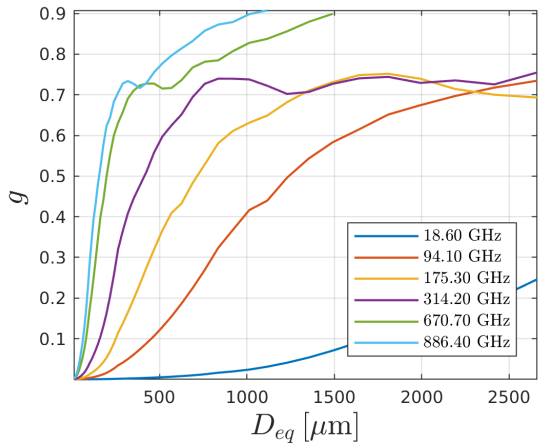
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



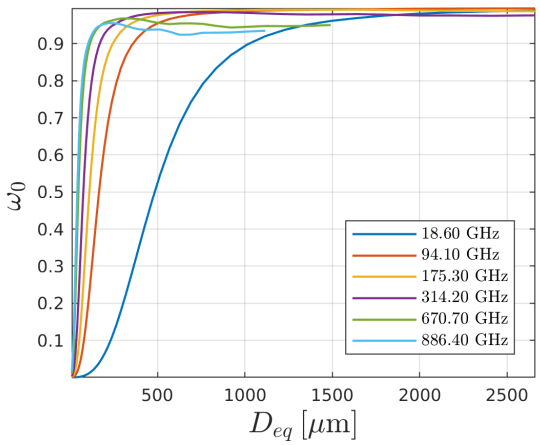
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

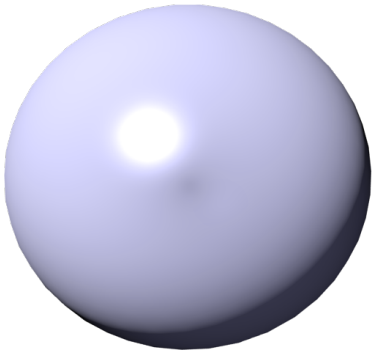
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

GEM Cloud Ice



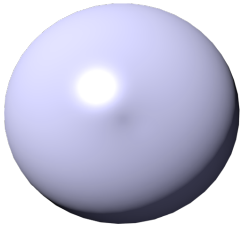
Publication date 20-Nov-2017 22:51:53

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	GEM cloud ice
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

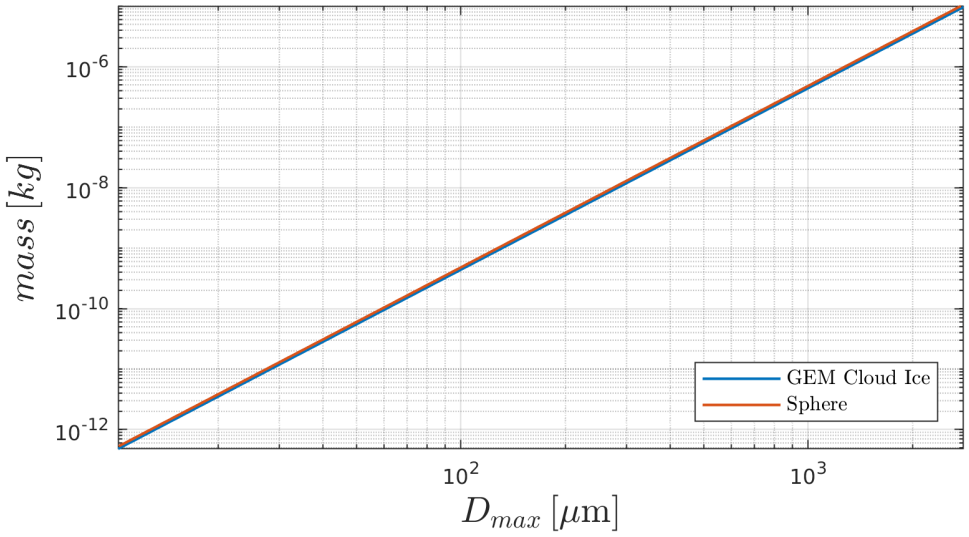
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	10	2802	44
D_e [um]	10	2722	

Table 1.3. Shape parameters

α	440.0000
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

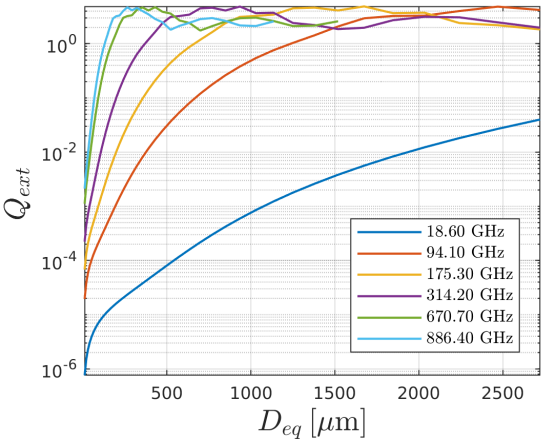
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

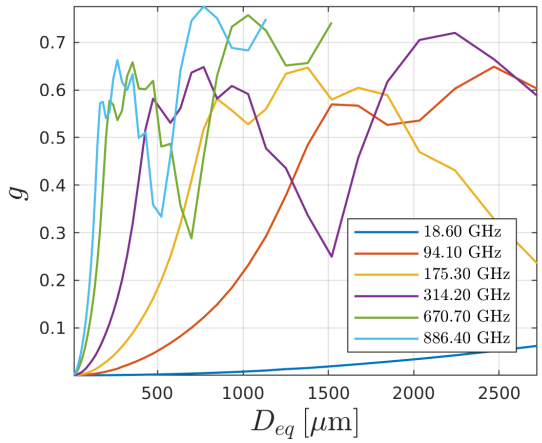
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



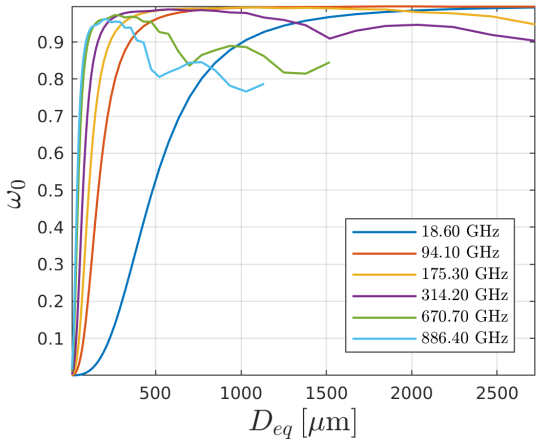
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

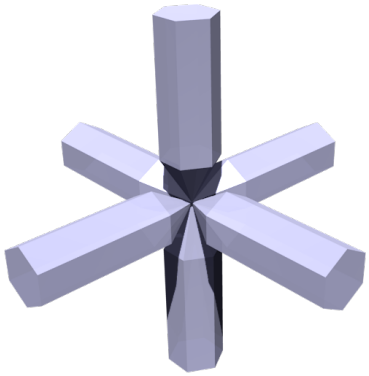
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

6-Bullet Rosette



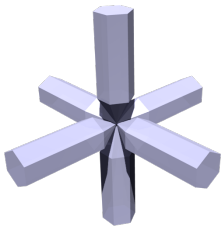
Publication date 20-Nov-2017 22:06:00

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal 6-bullet rosette, using Hong parametrization (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

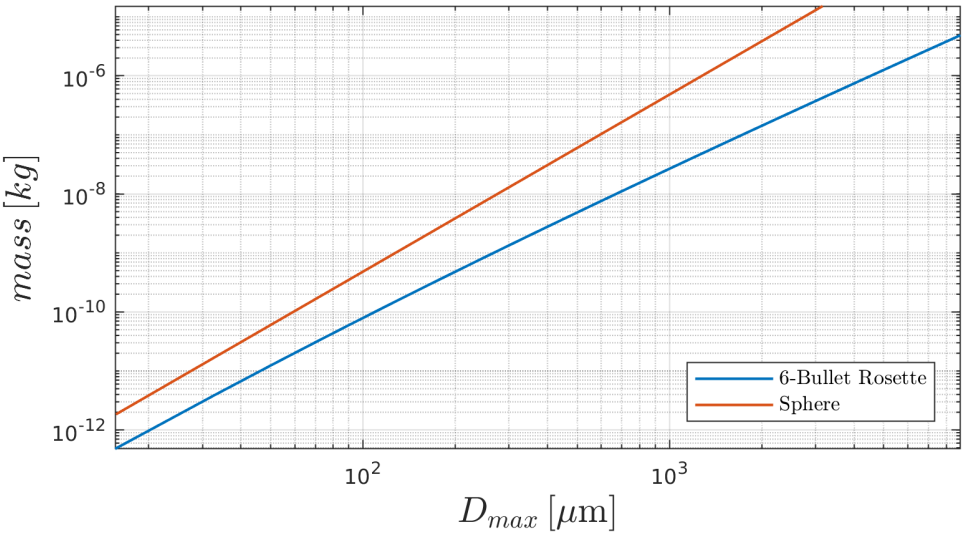
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	16	8905	44
D_e [um]	10	2166	

Table 1.3. Shape parameters

α	0.4927
β	2.4278

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

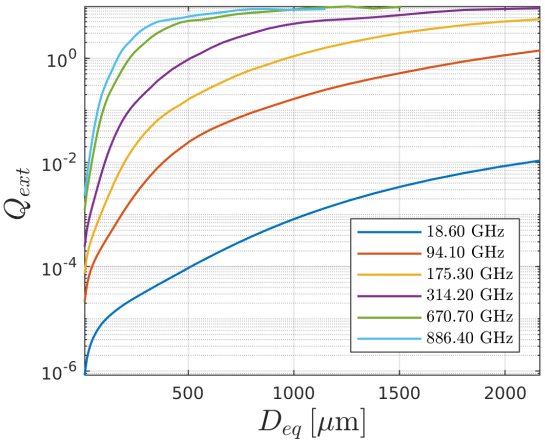
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

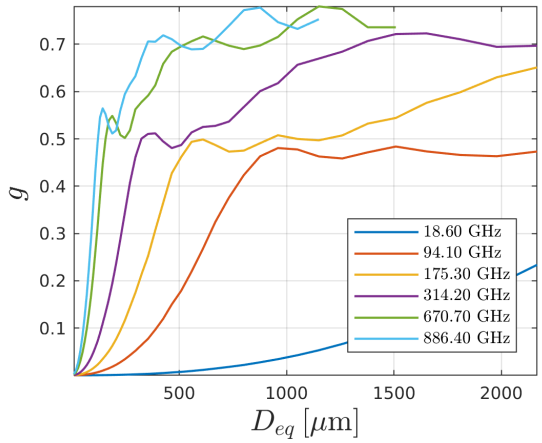
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



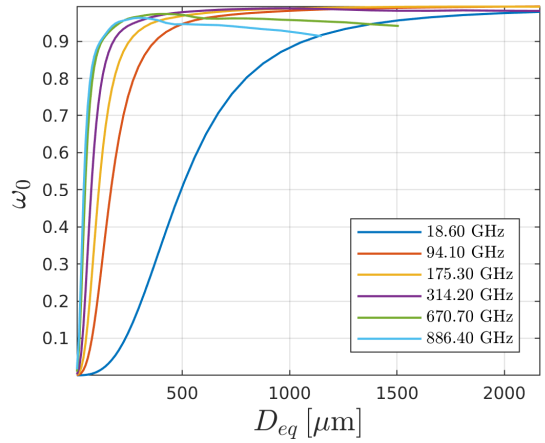
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

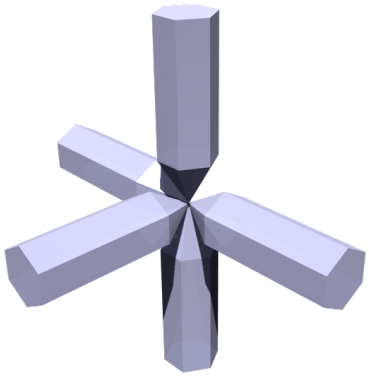
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

5-bullet Rosette



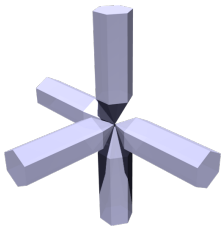
Publication date 20-Nov-2017 22:03:19

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal 5-bullet rosette. The bullets have the same dimensions as in the Hong bullet rosette (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

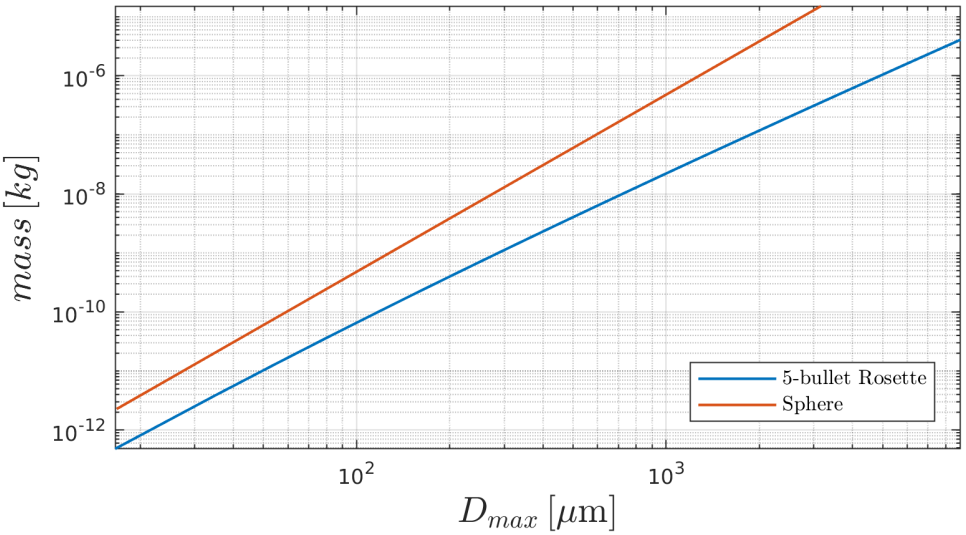
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	17	8924	44
D_e [um]	10	2042	

Table 1.3. Shape parameters

α	0.4047
β	2.4254

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

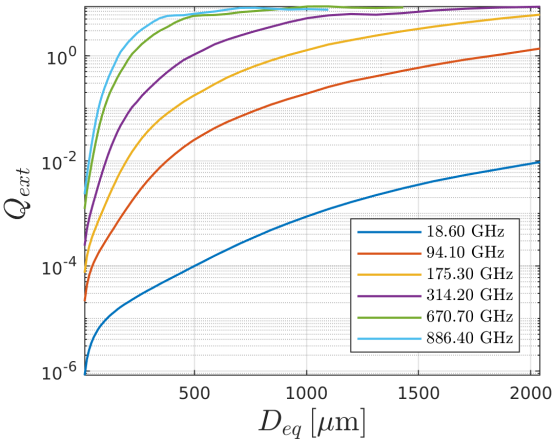
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

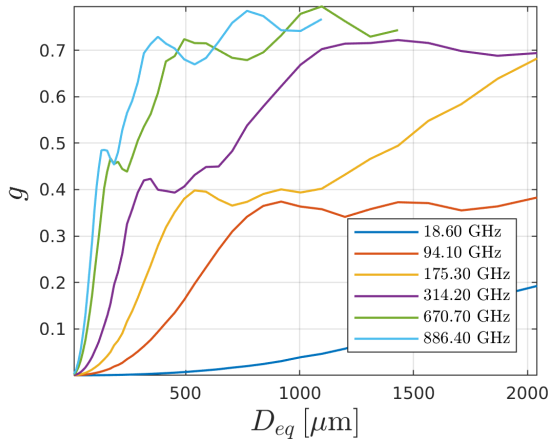
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



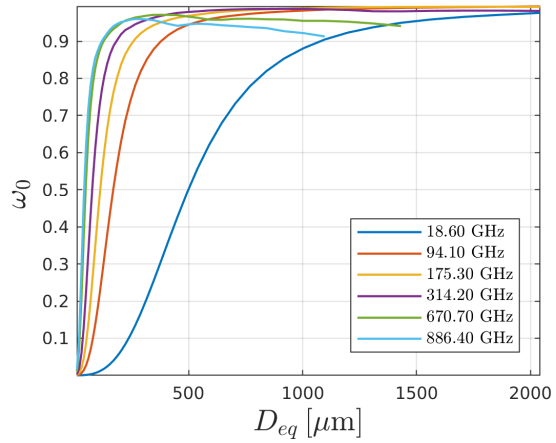
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

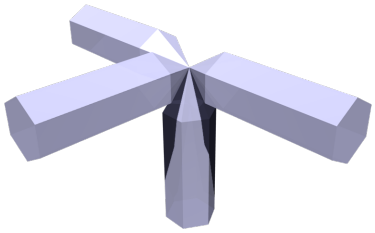
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Perpendicular 4-Bullet Rosette



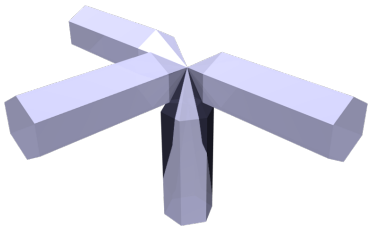
Publication date 20-Nov-2017 22:09:26

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Perpendicular hexagonal 4-bullet rosette. The bullets have the same dimensions as in the Hong bullet rosette (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

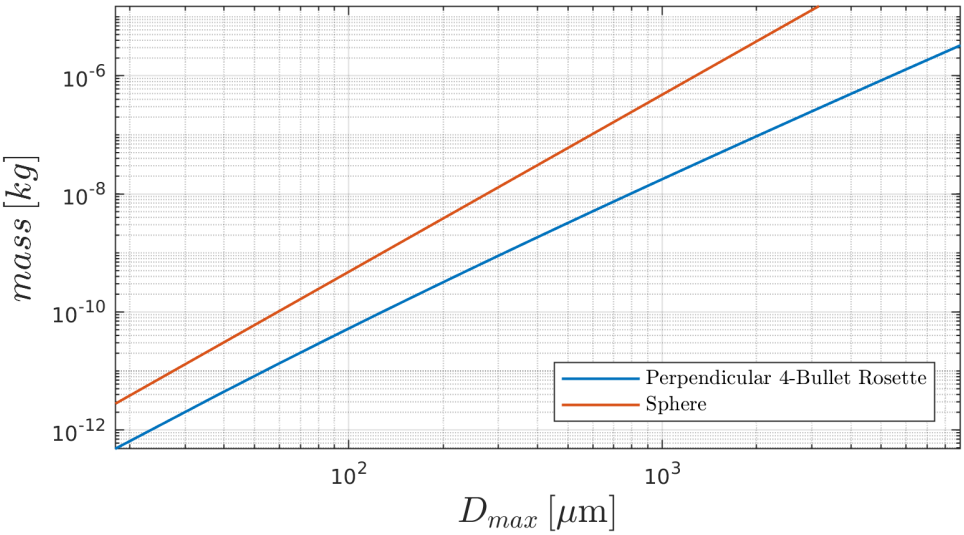
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	18	8949	44
D_e [um]	10	1899	

Table 1.3. Shape parameters

α	0.3248
β	2.4259

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

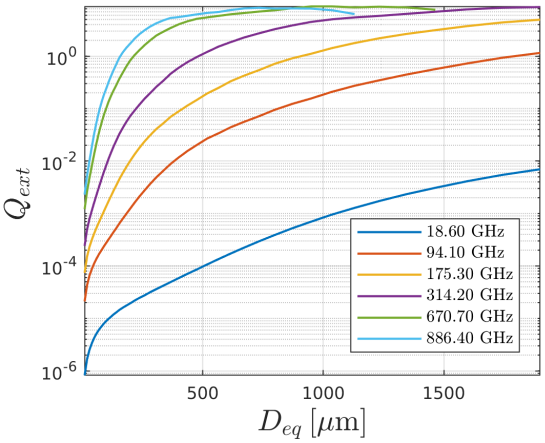
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

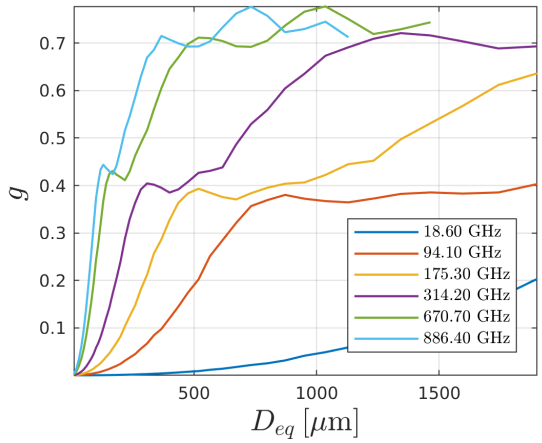
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



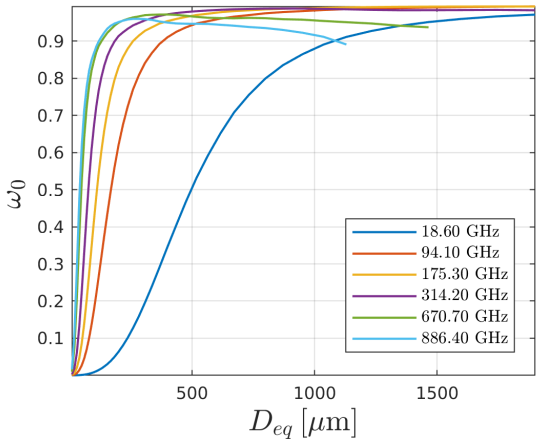
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

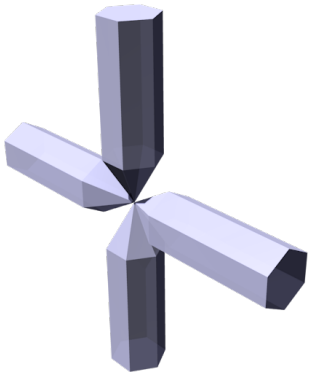
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Flat 4-Bullet Rosette



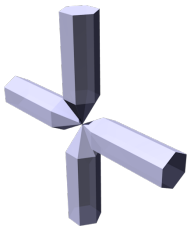
Publication date 20-Nov-2017 22:10:18

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Flat hexagonal 4-bullet rosette. The bullets have the same dimensions as in the Hong bullet rosette (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

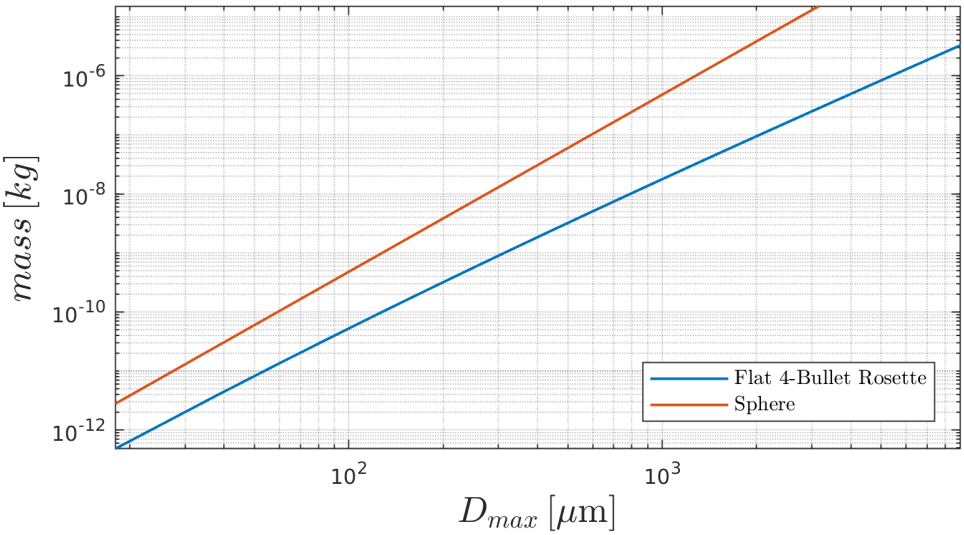
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	18	8949	44
D_e [um]	10	1899	

Table 1.3. Shape parameters

α	0.3248
β	2.4259

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

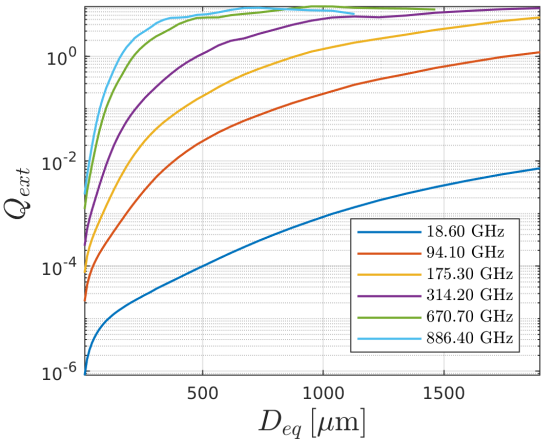
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

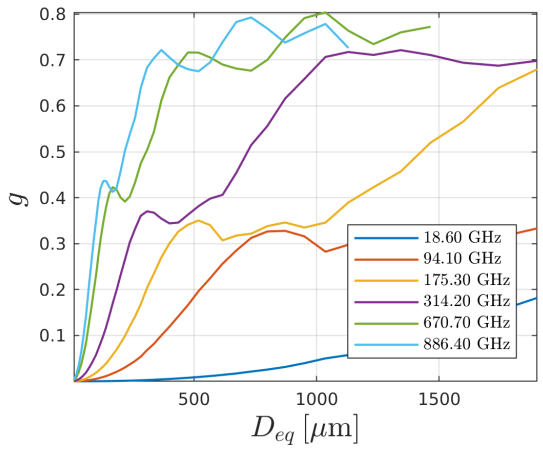
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



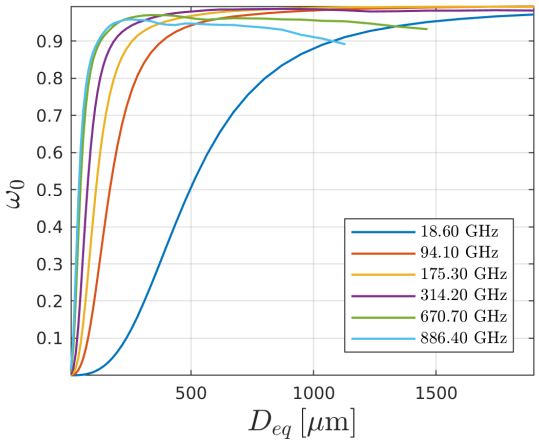
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

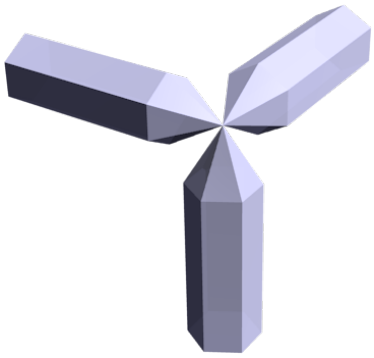
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Perpendicular 3-Bullet Rosette



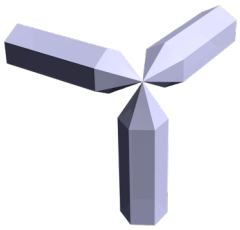
Publication date 20-Nov-2017 22:04:35

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Perpendicular hexagonal 3-bullet rosette. The bullets have the same dimensions as in the Hong bullet rosette (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

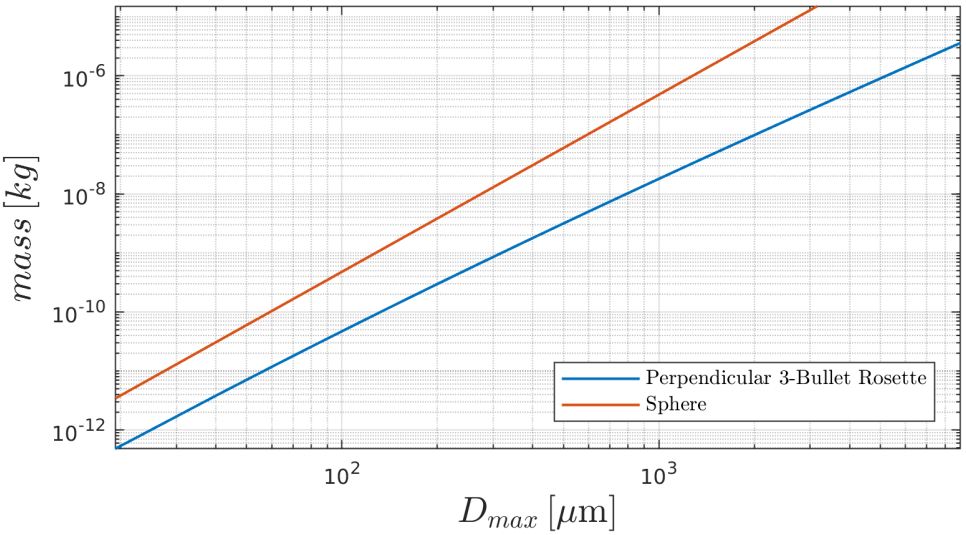
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	19	8949	44
D_e [um]	10	1958	

Table 1.3. Shape parameters

α	0.4373
β	2.4675

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

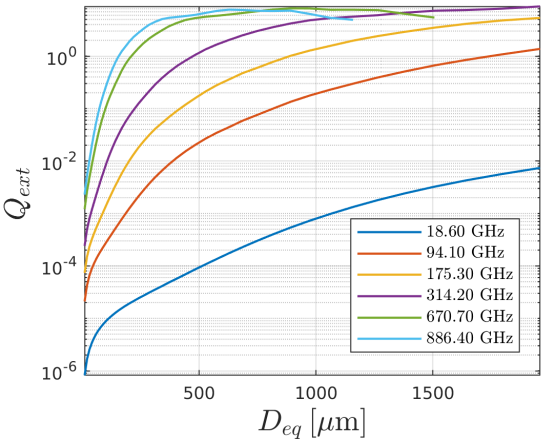
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

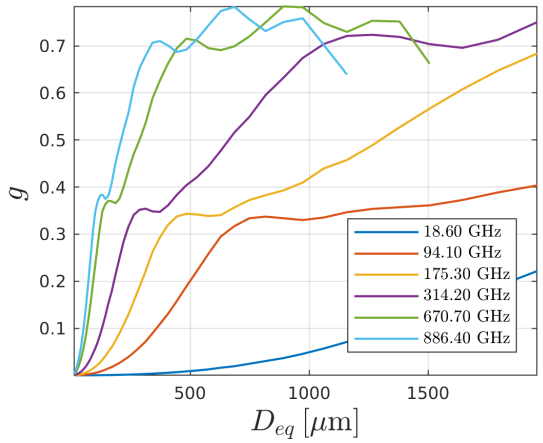
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



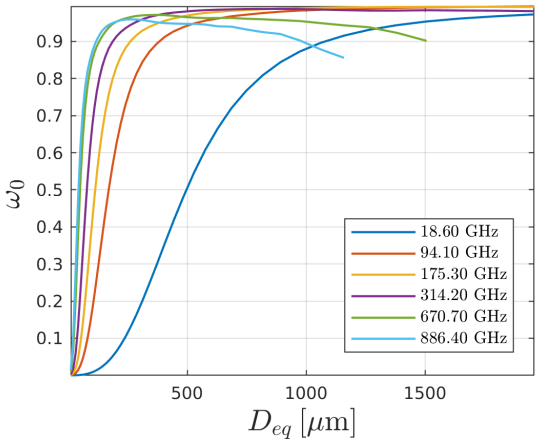
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

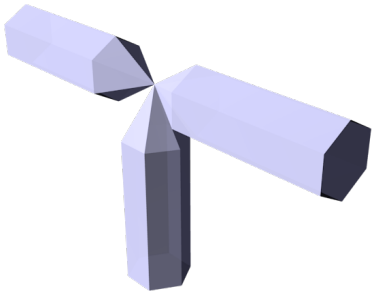
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Flat 3-Bullet Rosette



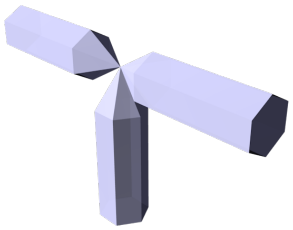
Publication date 20-Nov-2017 22:05:17

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Flat hexagonal 3-bullet rosette. The bullets have the same dimensions as in the Hong bullet rosette (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	-

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

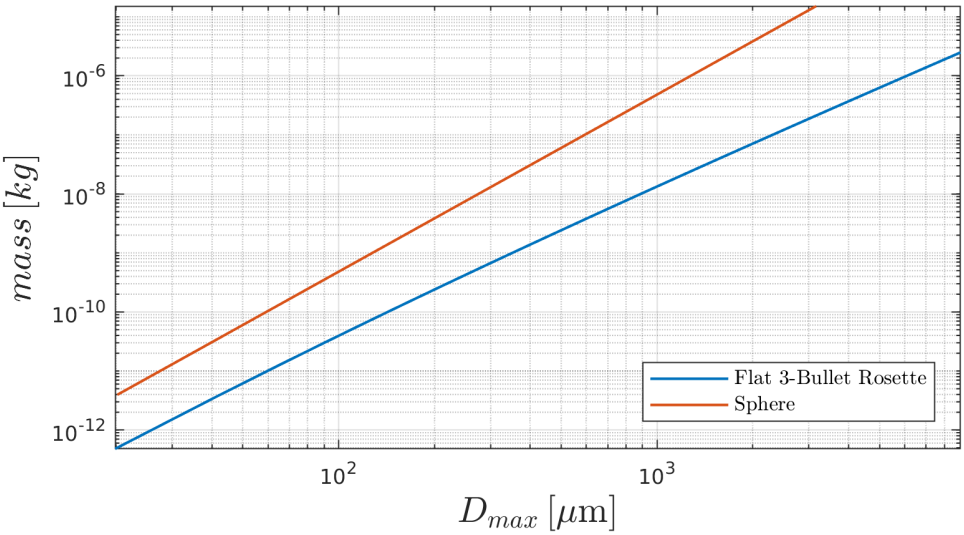
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	20	8980	44
D_e [um]	10	1730	

Table 1.3. Shape parameters

α	0.2433
β	2.4257

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

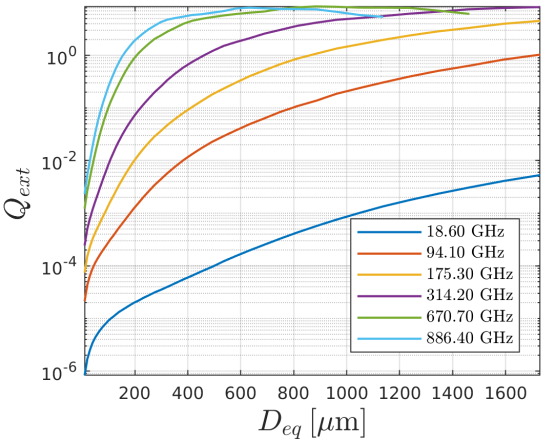
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

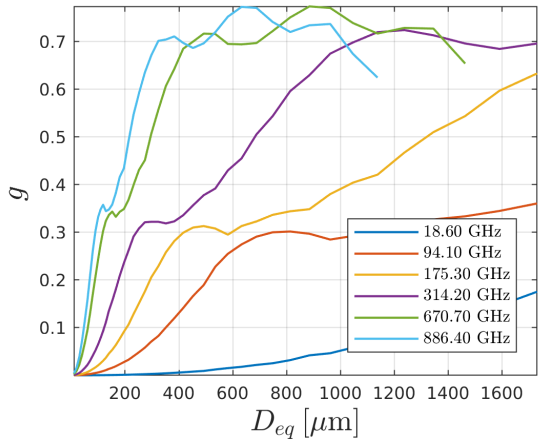
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



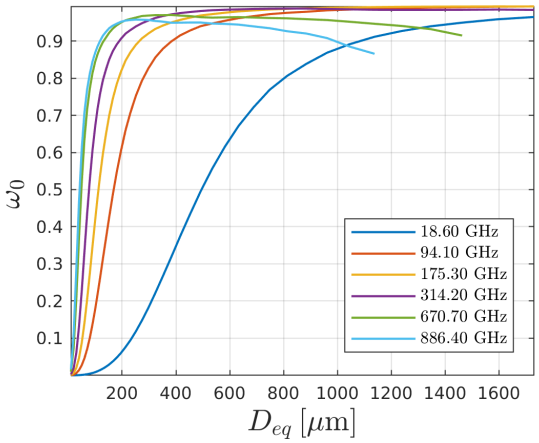
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

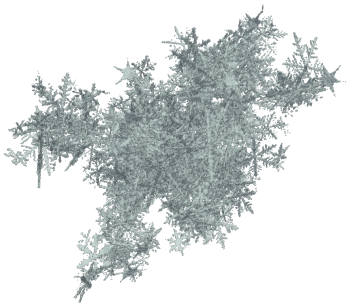
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Evans Snow Aggregate



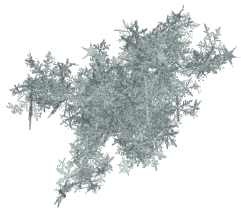
Publication date 07-Dec-2017 18:15:05

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Snowflake aggregate, shape files from Evans 2012
Source	Evans 2012.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

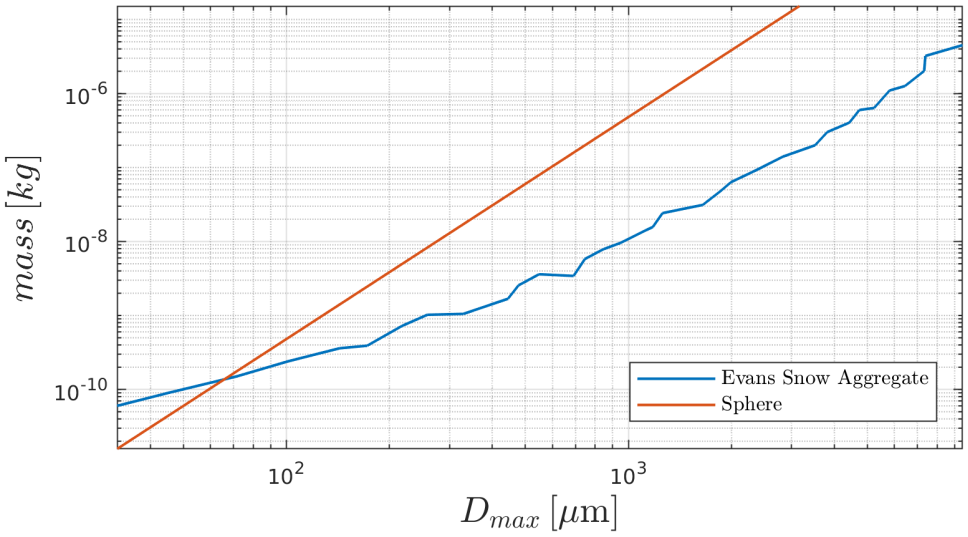
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	32	9483	34
D_e [um]	50	2109	

Table 1.3. Shape parameters

α	0.1963
β	2.3861

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

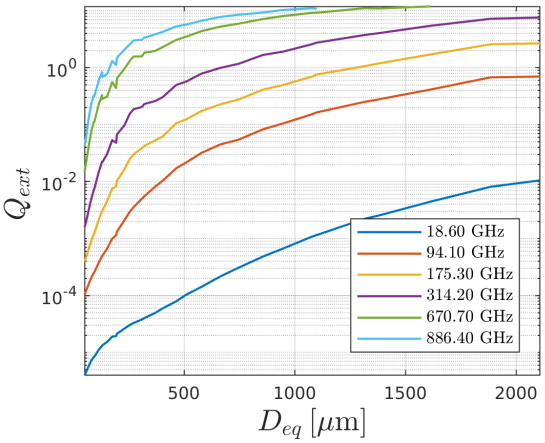
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

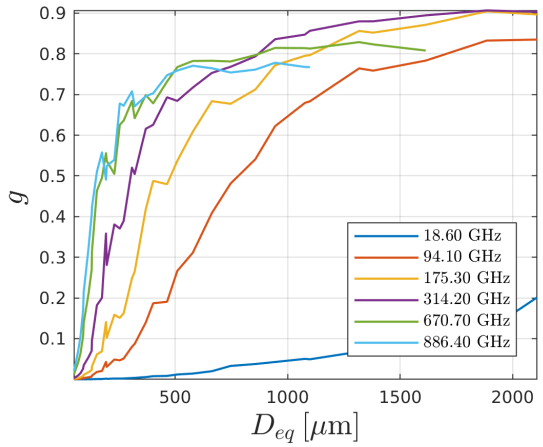
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



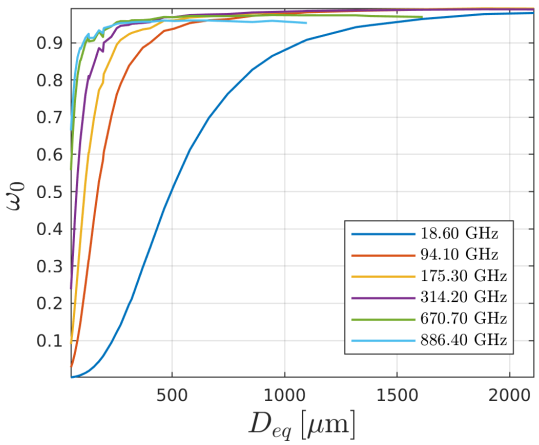
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

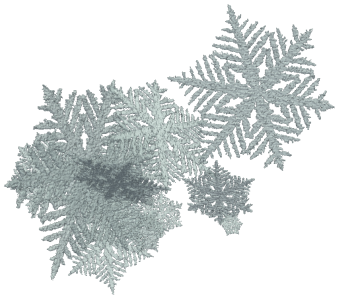
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Tyynela Dendrite Aggregate



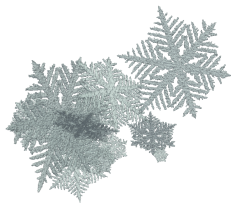
Publication date 07-Dec-2017 18:15:48

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Aggregate of fernlike dendrites.
Source	Tyynela and Chandrasekar 2014.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

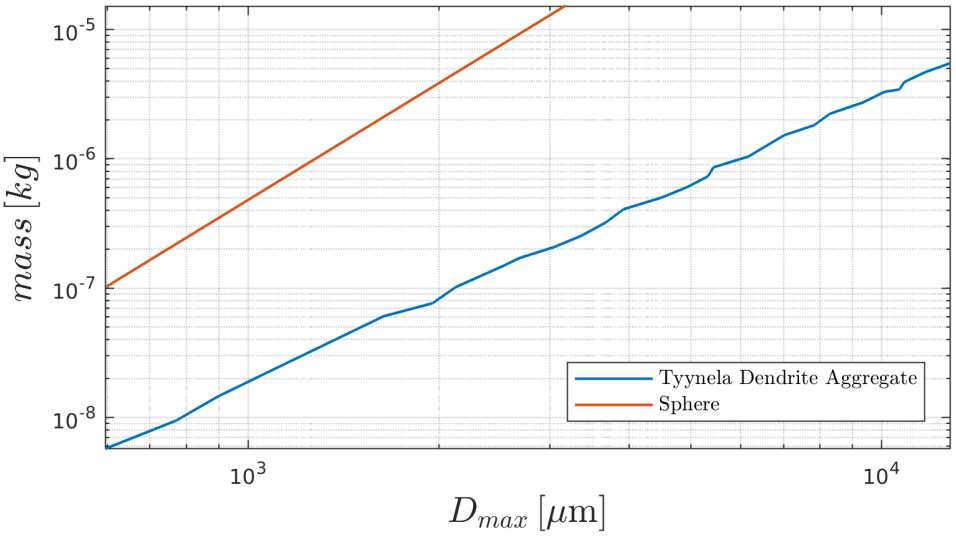
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	595	12845	27
D_e [um]	228	2254	

Table 1.3. Shape parameters

α	0.0970
β	2.2428

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

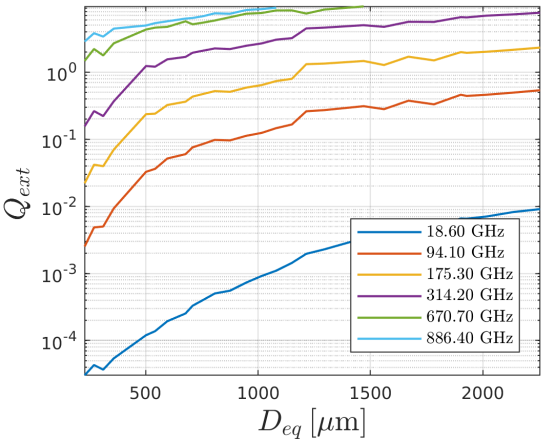
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

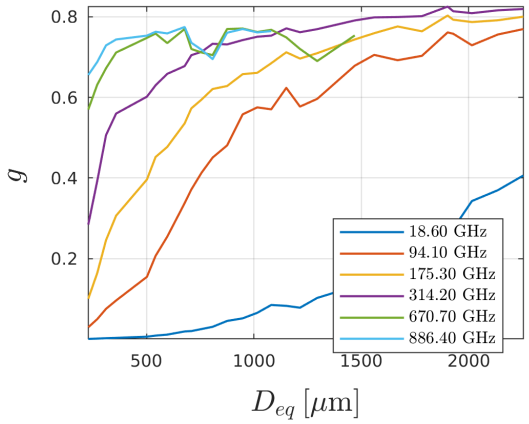
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



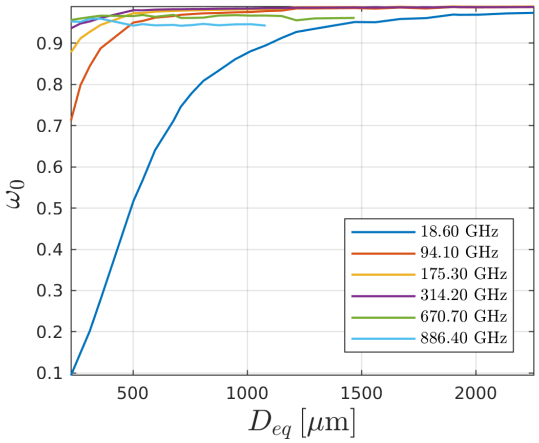
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

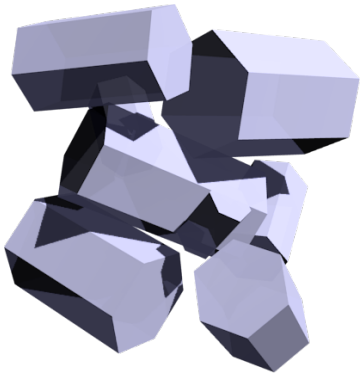
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

8-Column Aggregate



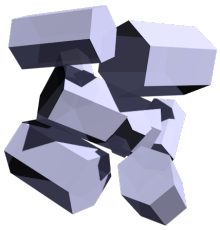
Publication date 20-Nov-2017 22:07:24

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column aggregate, using Hong parametrization (Hong 2007).
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016), parameterization: Hong 2007.
Comment	Note that shape and proportions are constant with size, resulting in beta=3.

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

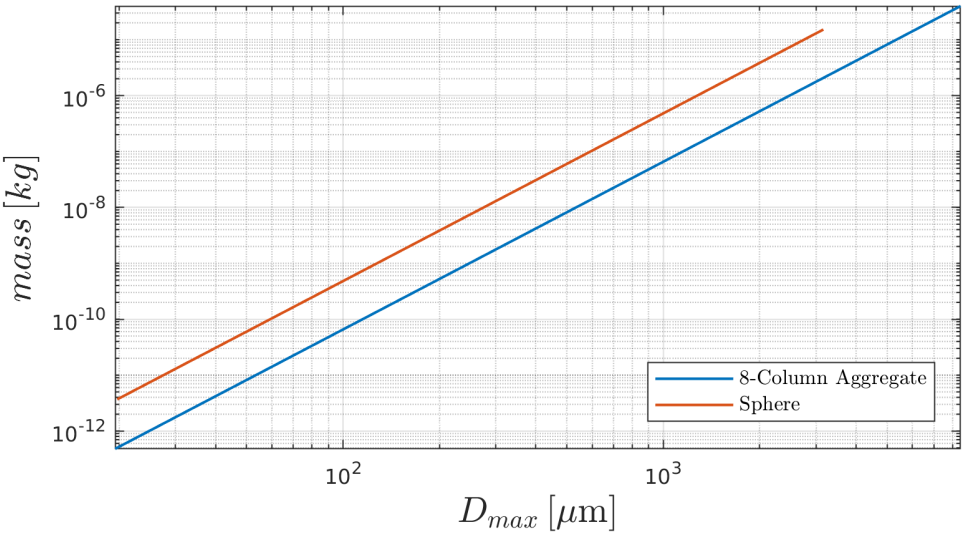
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	19	8478	38
D_e [um]	10	4363	

Table 1.3. Shape parameters

α	65.4480
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

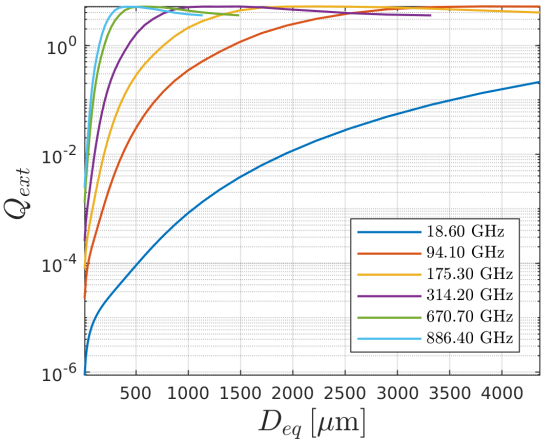
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

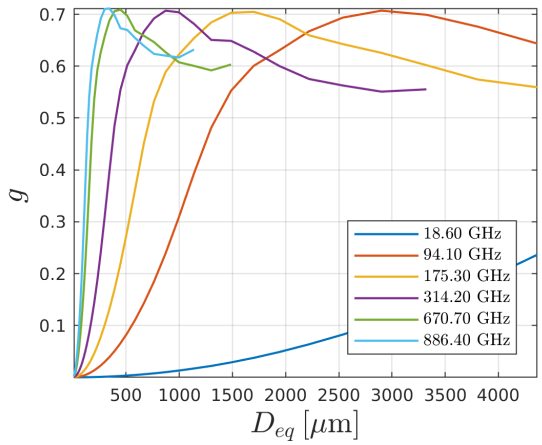
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



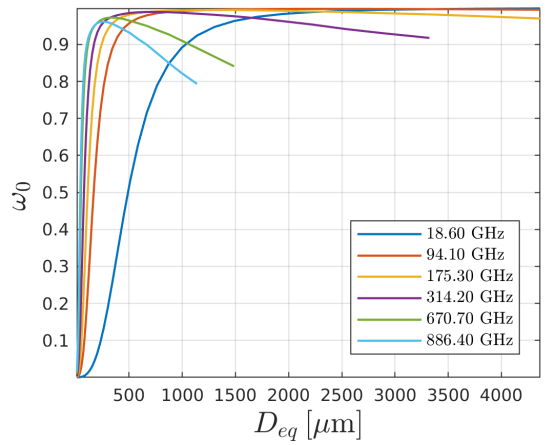
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

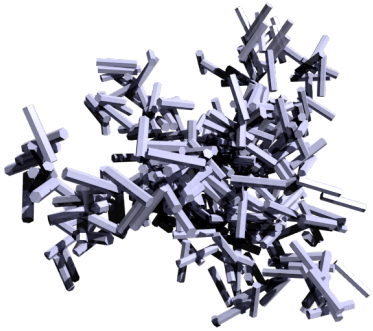
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Small Column Aggregate



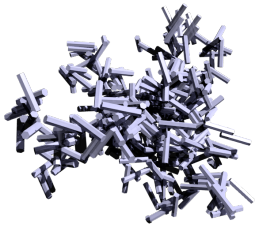
Publication date 20-Nov-2017 22:14:54

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column aggregates, mean aspect ratio = 5. Prototype crystal d_max=100 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

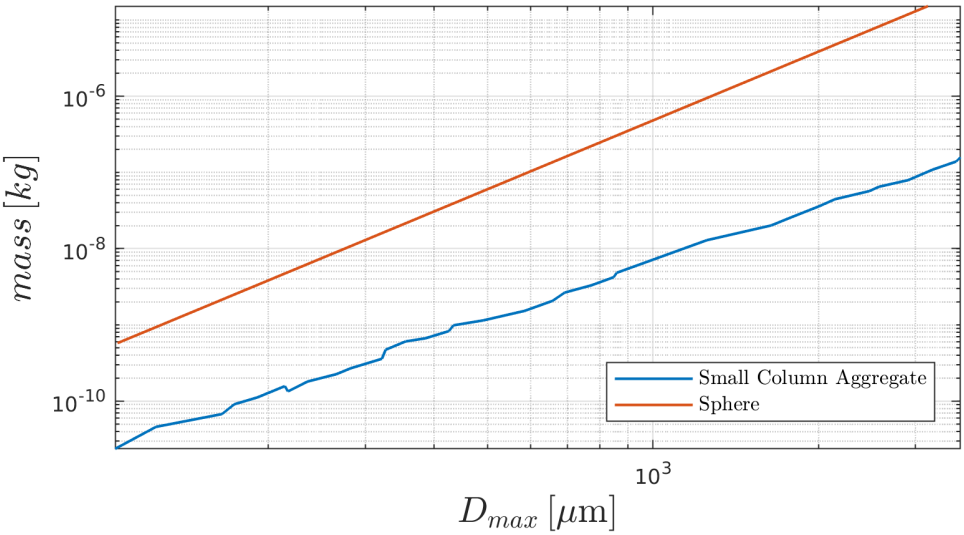
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	105	3624	34
D_e [um]	37	690	

Table 1.3. Shape parameters

α	0.1376
β	2.4438

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

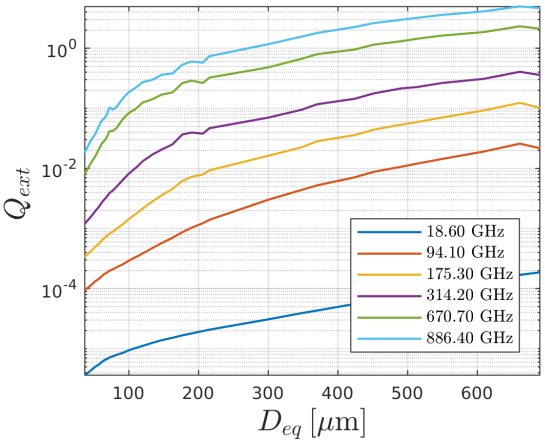
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

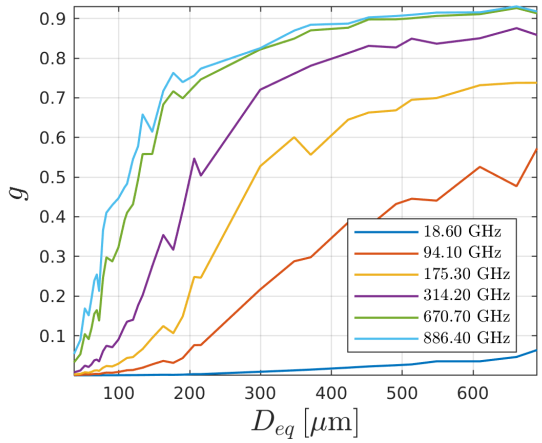
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



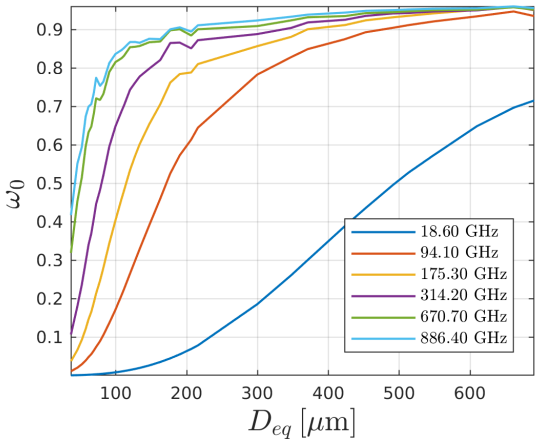
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

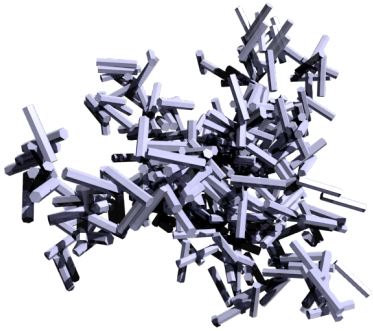
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Large Column Aggregate



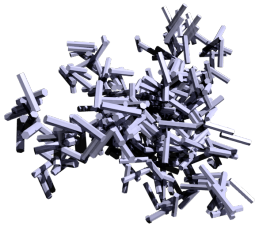
Publication date 20-Nov-2017 22:15:35

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column aggregates, mean aspect ratio = 5. Prototype crystal d_max=350 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

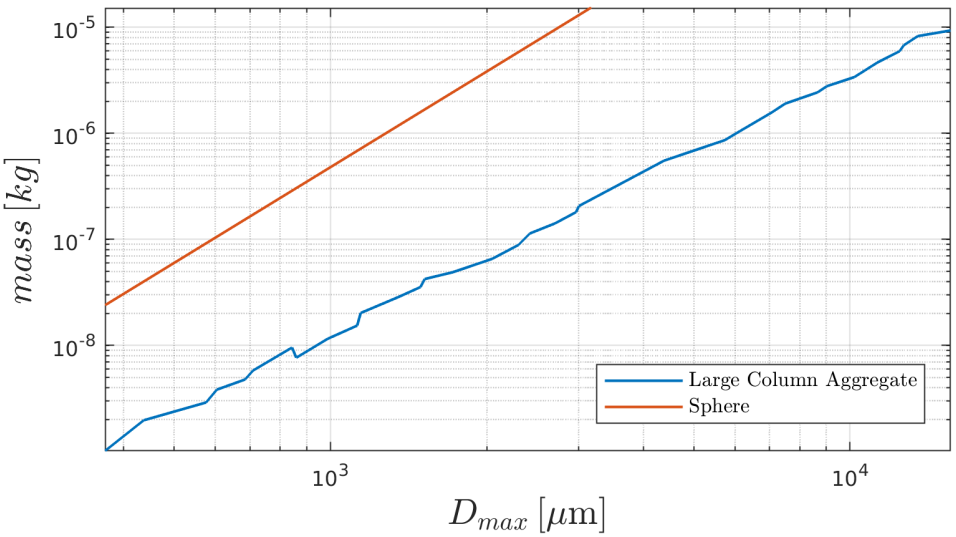
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	368	15602	34
D_e [um]	128	2689	

Table 1.3. Shape parameters

α	0.2758
β	2.4440

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

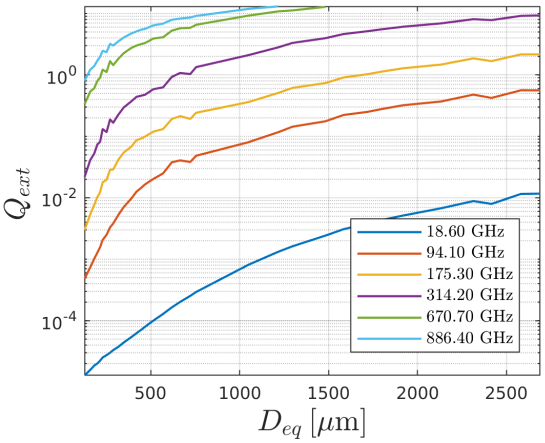
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

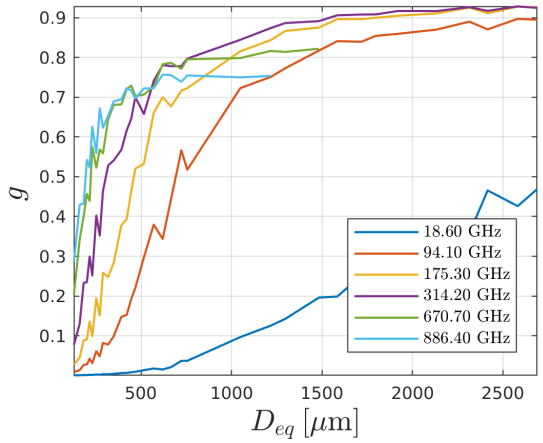
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



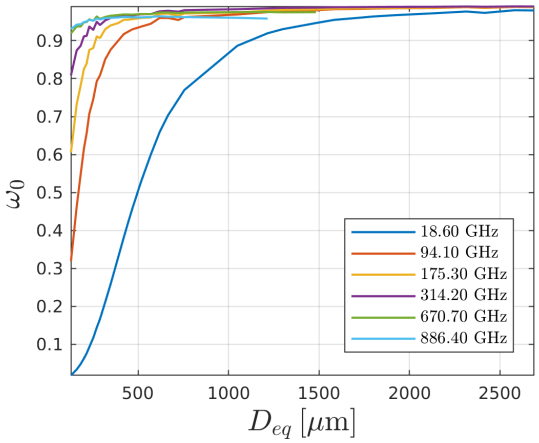
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Small Block Aggregate

Publication date 20-Nov-2017 22:17:44

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column aggregates, mean aspect ratio = 1.25. Prototype crystal d_max=100 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.

Rendering of a selected shape using Blender (https://www.blender.org/).

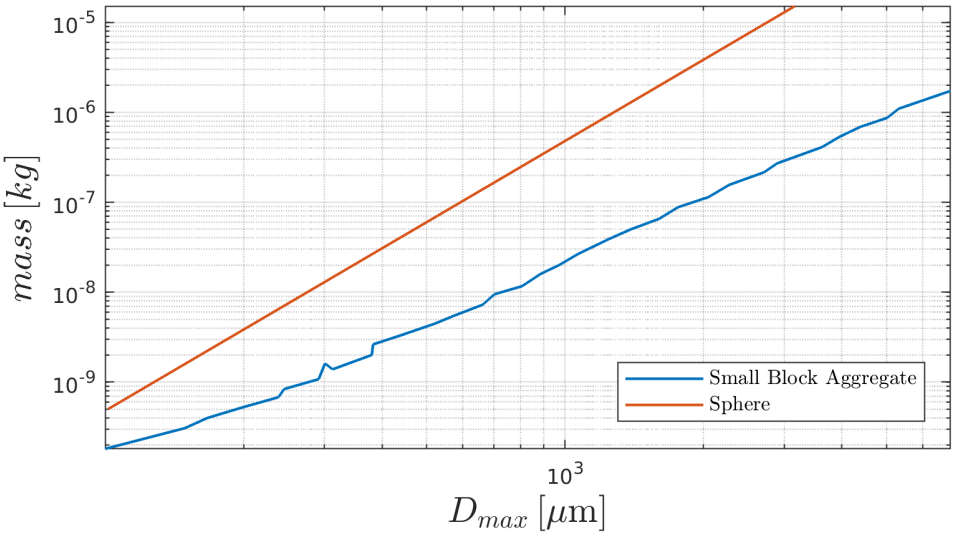
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	100	6891	34
D_e [um]	72	1533	

Table 1.3. Shape parameters

α	0.2137
β	2.3327

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

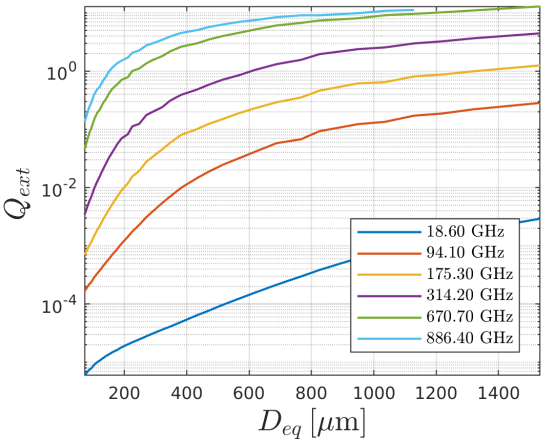
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

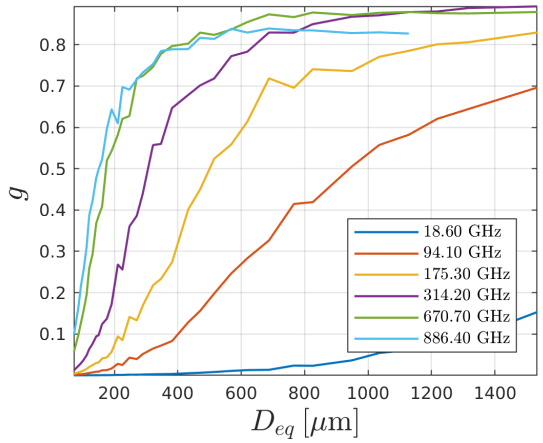
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



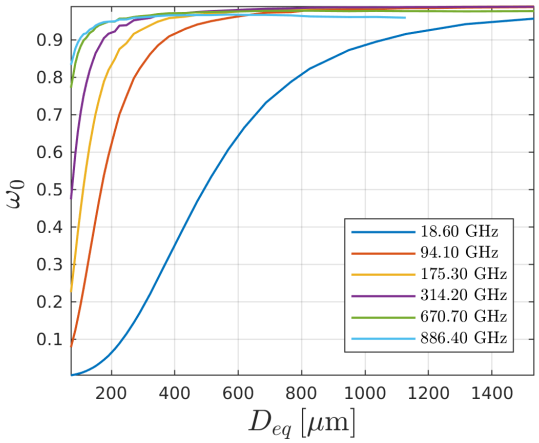
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Large Block Aggregate

Publication date 20-Nov-2017 22:18:26

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal column aggregates, mean aspect ratio = 1.25. Prototype crystal d_max=350 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.

Rendering of a selected shape using Blender (https://www.blender.org/).

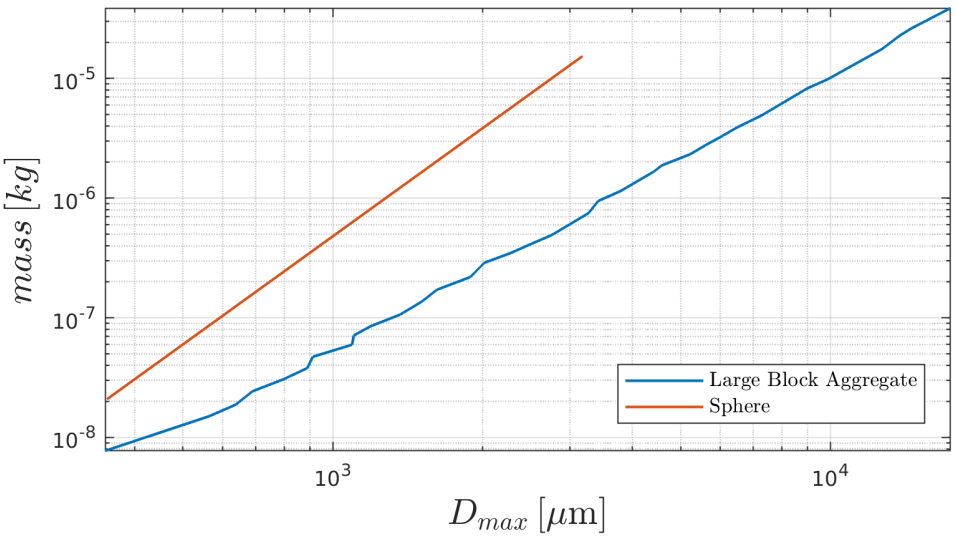
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	349	17437	34
D_e [um]	253	4321	

Table 1.3. Shape parameters

α	0.3499
β	2.2657

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

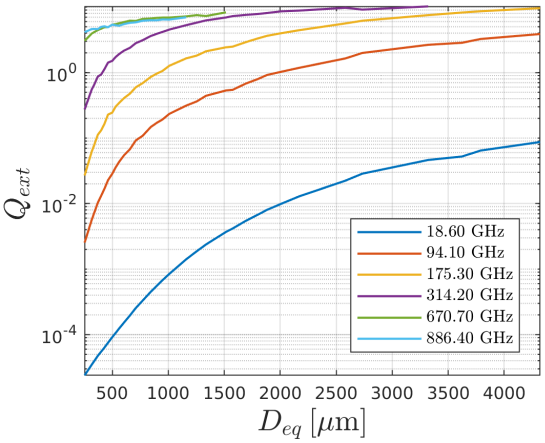
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

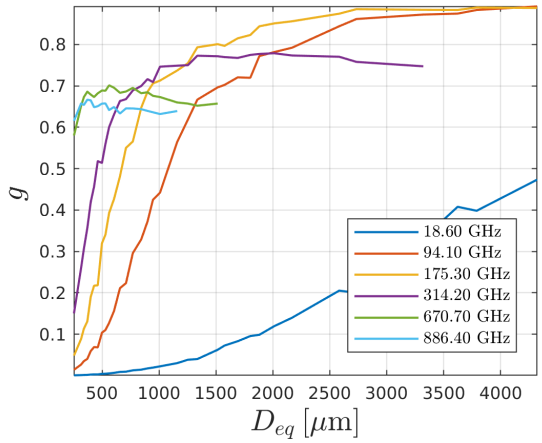
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



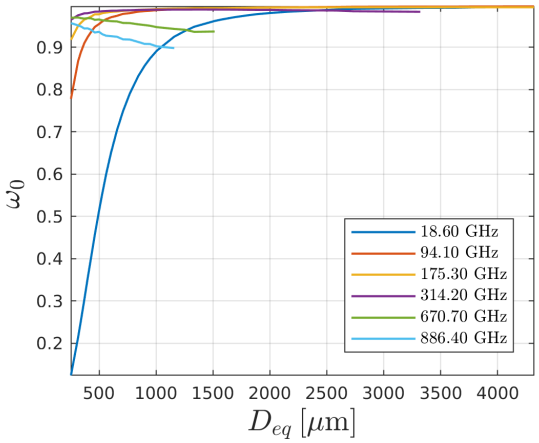
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

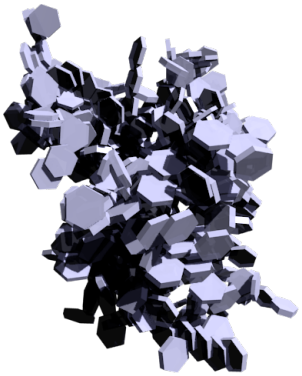
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Small Plate Aggregate



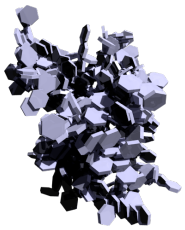
Publication date 20-Nov-2017 22:16:18

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal plate aggregates, mean aspect ratio = 6. Prototype crystal d_max=100 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

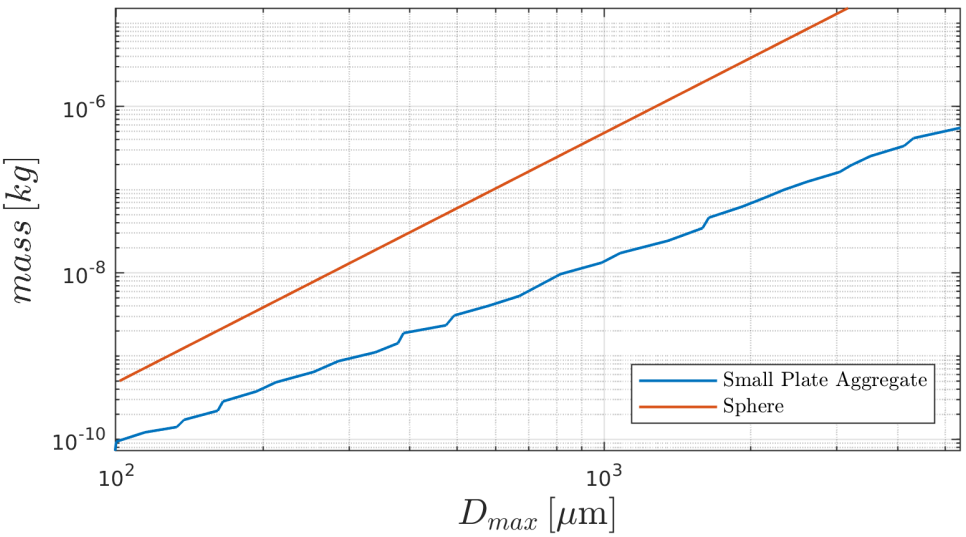
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	99	5378	34
D_e [um]	53	1048	

Table 1.3. Shape parameters

α	0.0772
β	2.2470

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

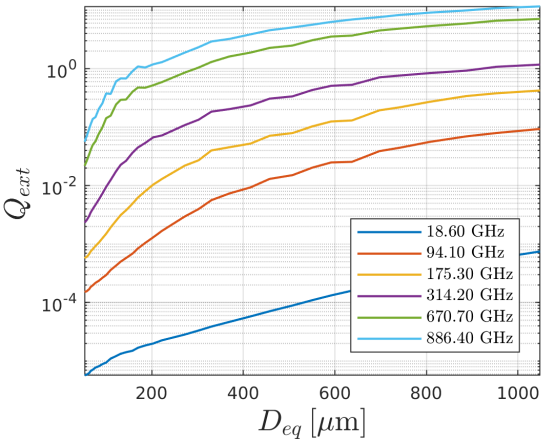
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

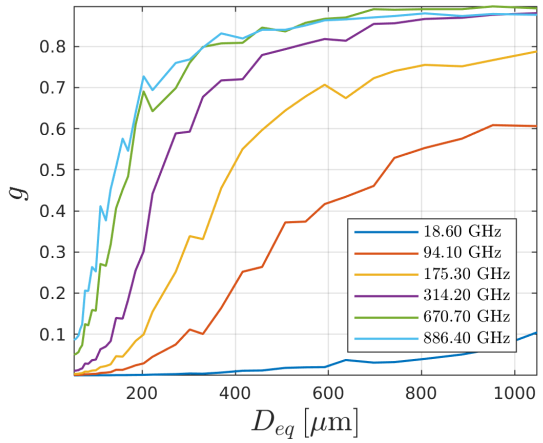
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



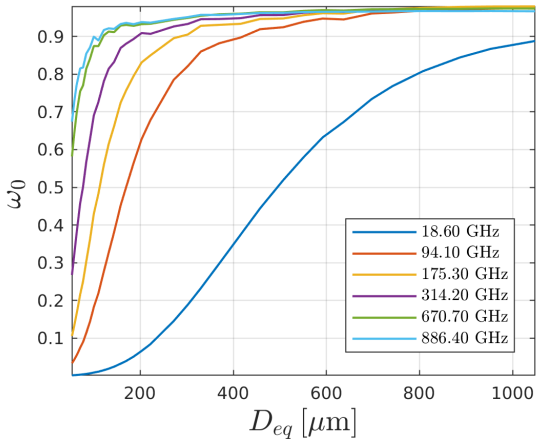
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

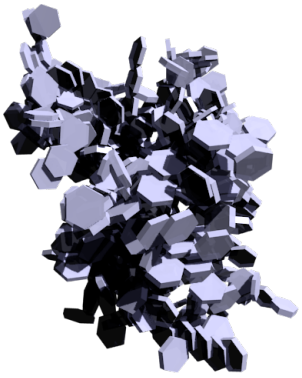
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Large Plate Aggregate



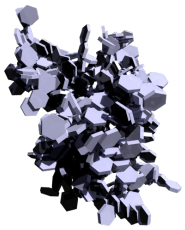
Publication date 20-Nov-2017 22:17:01

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Hexagonal plate aggregates, mean aspect ratio = 6. Prototype crystal d_max=350 um.
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

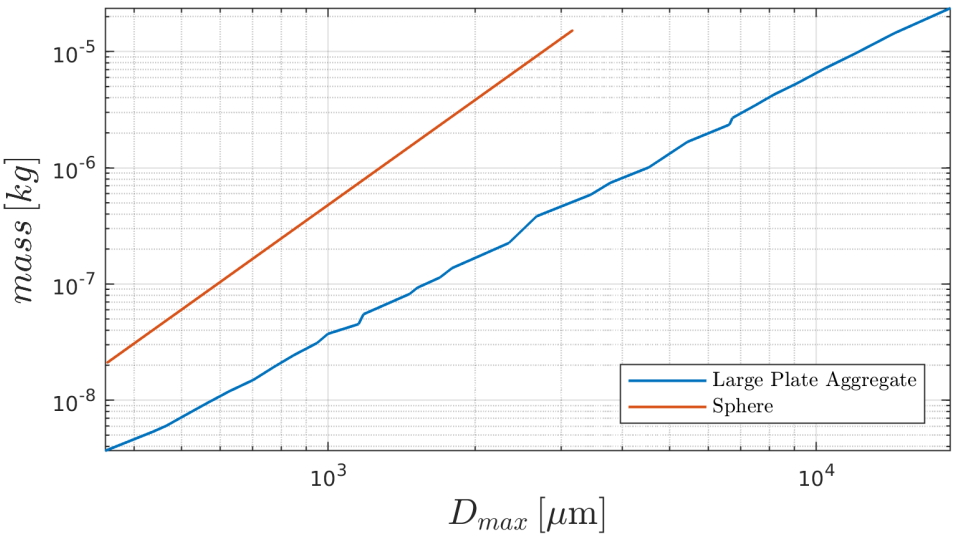
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	349	18824	33
D_e [um]	197	3669	

Table 1.3. Shape parameters

α	0.2085
β	2.2571

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

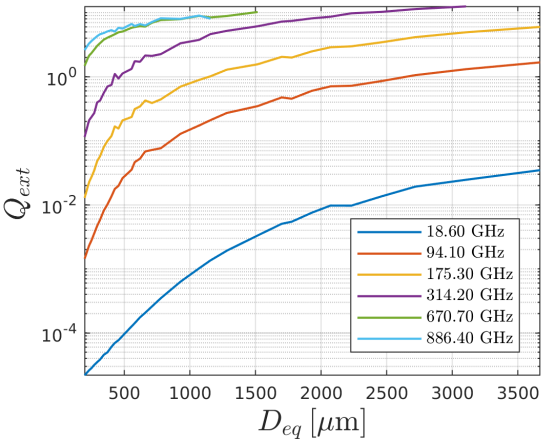
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

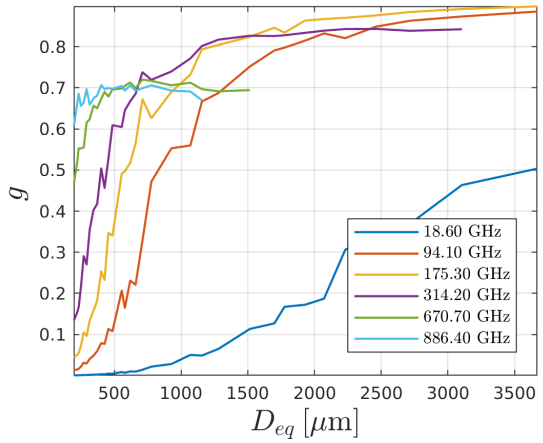
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



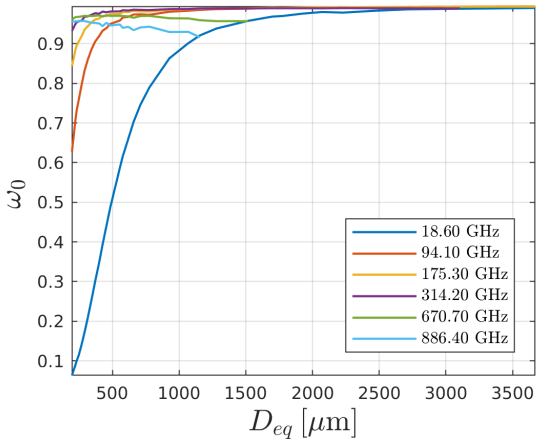
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

ICON Hail

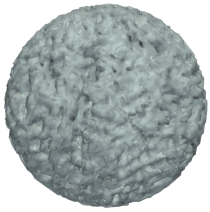
Publication date 07-Dec-2017 18:17:46

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	ICON hail
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

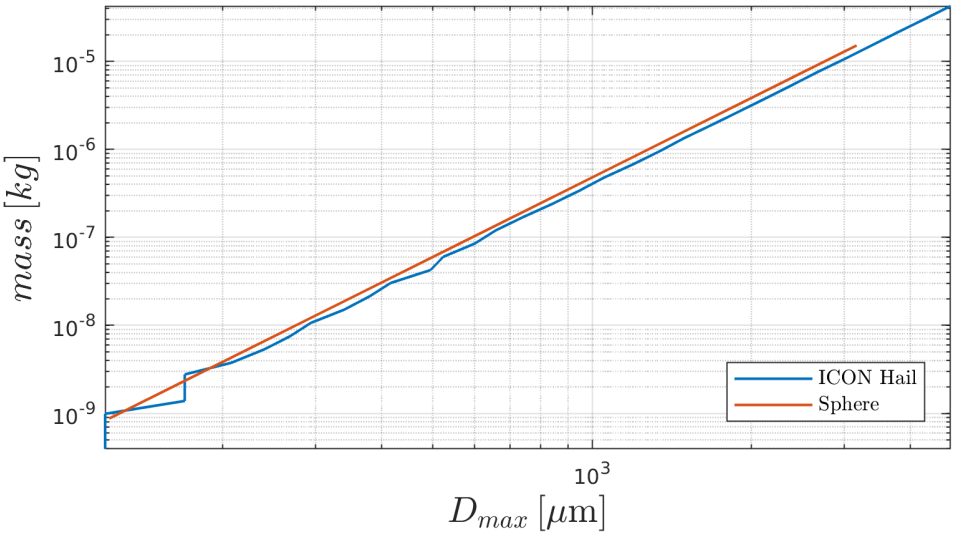
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	120	4759	30
D_e [um]	94	4457	

Table 1.3. Shape parameters

α	383.5055
β	2.9942

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

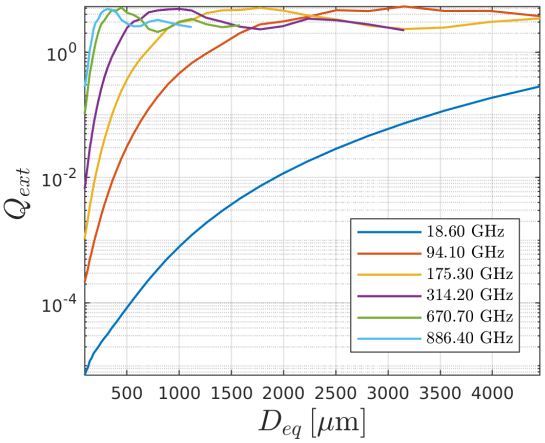
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

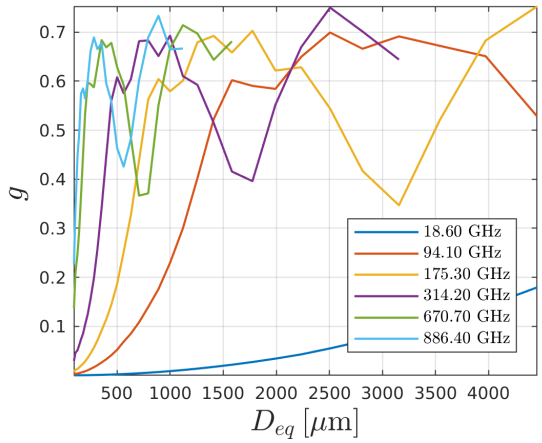
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



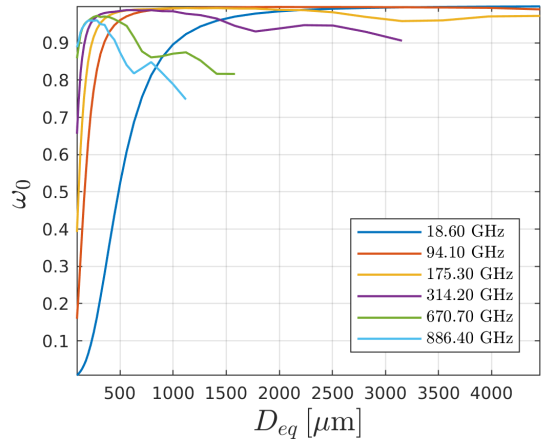
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

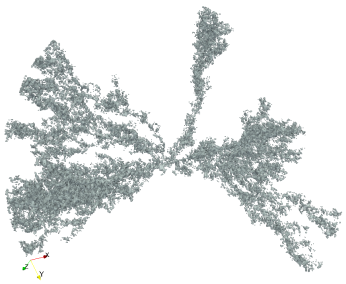
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

ICON Snow



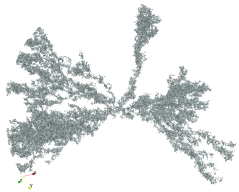
Publication date 07-Dec-2017 18:16:25

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	ICON snow
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

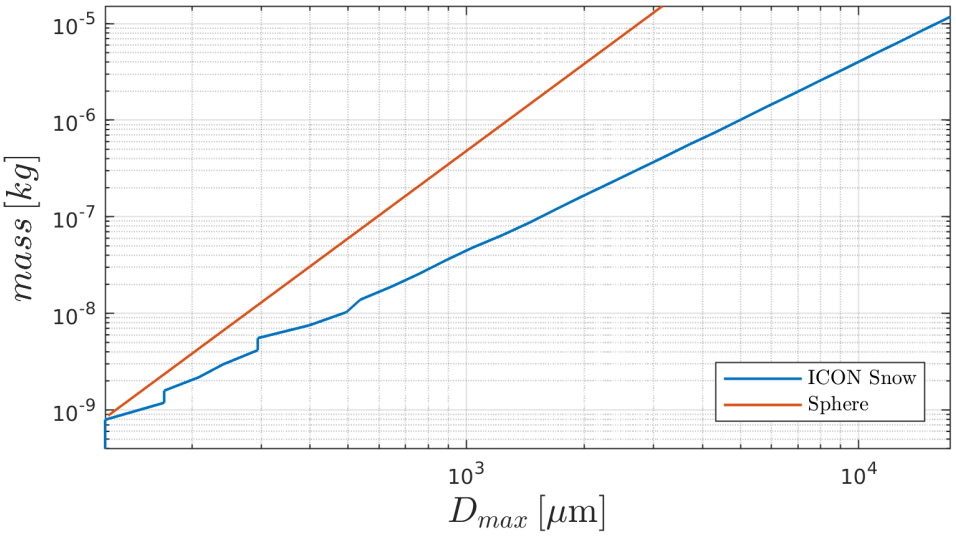
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	120	17153	30
D_e [um]	94	2906	

Table 1.3. Shape parameters

α	0.0311
β	1.9486

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

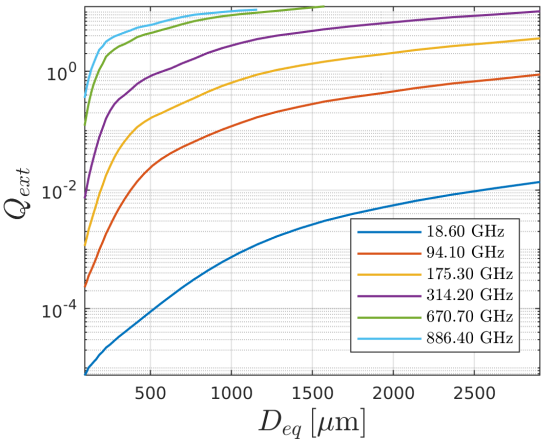
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

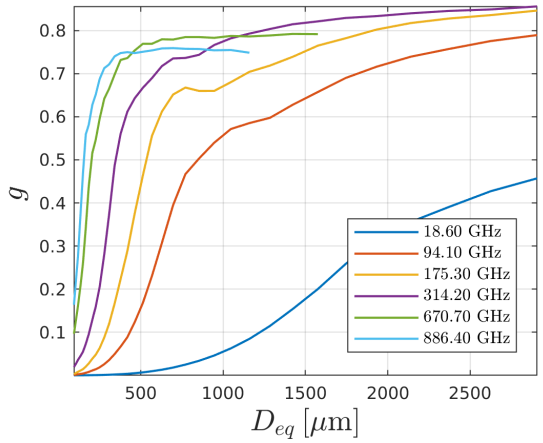
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



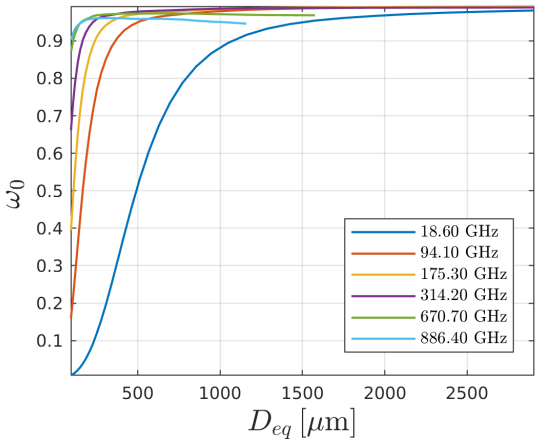
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

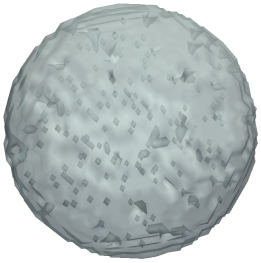
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

GEM Hail



Publication date 07-Dec-2017 18:19:35

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	GEM hail
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.

Rendering of a selected shape using Blender (https://www.blender.org/).

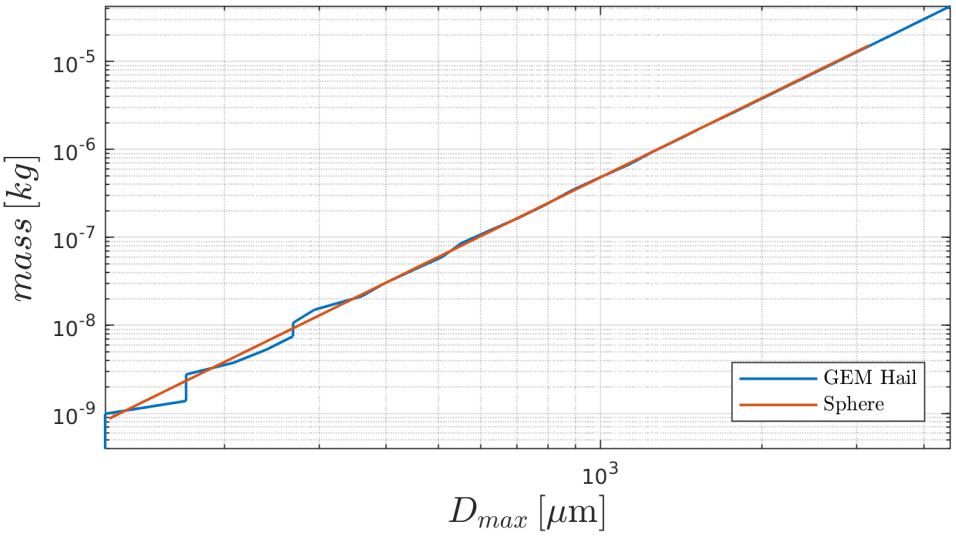
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	120	4482	29
D_e [um]	94	4457	

Table 1.3. Shape parameters

α	535.4203
β	3.0187

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

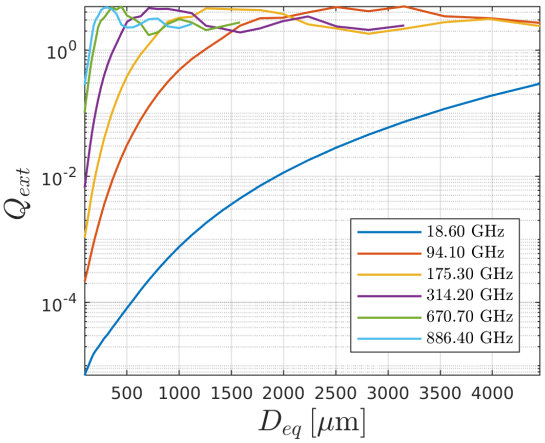
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

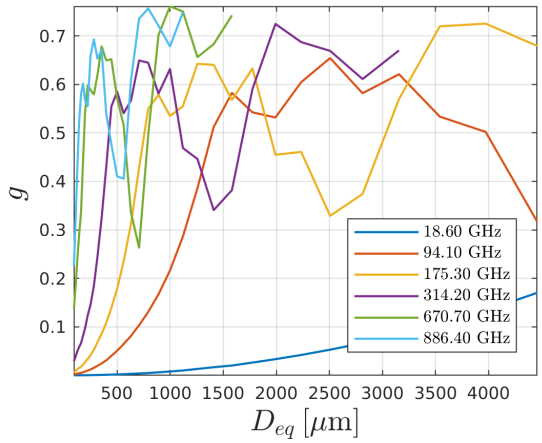
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



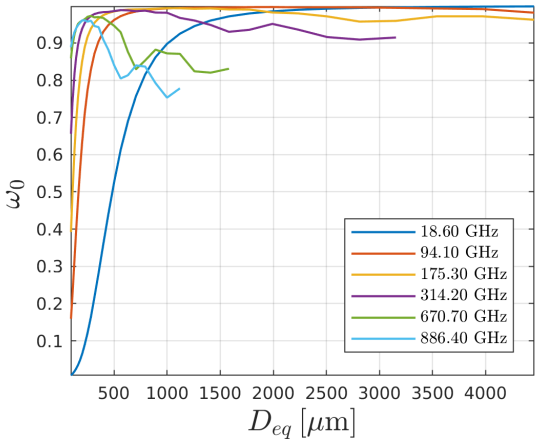
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

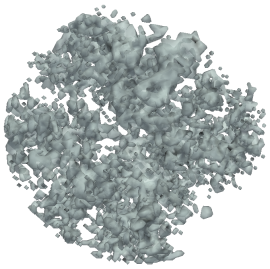
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

GEM Snow



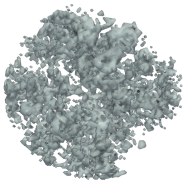
Publication date 07-Dec-2017 18:18:22

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	GEM snow
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

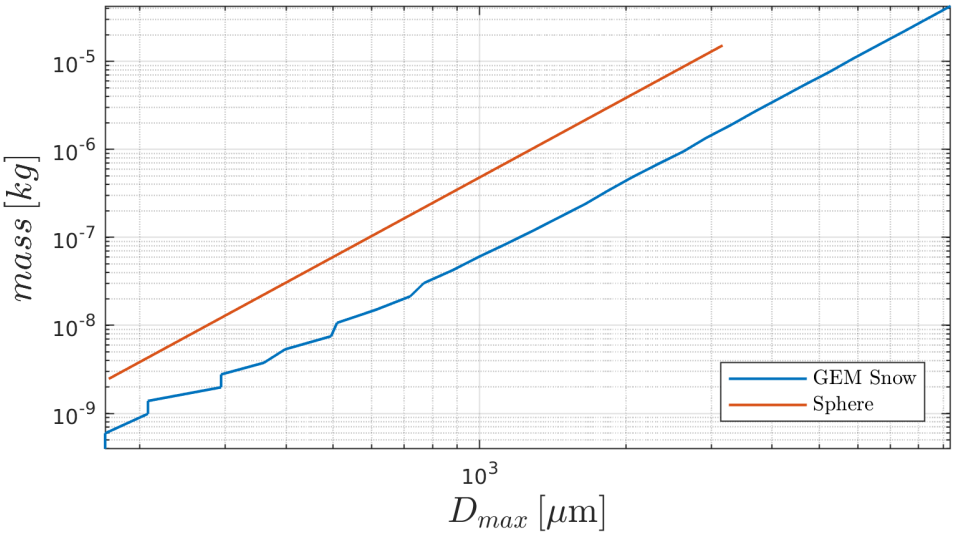
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	170	9309	31
D_e [um]	94	4457	

Table 1.3. Shape parameters

α	24.0072
β	2.8571

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

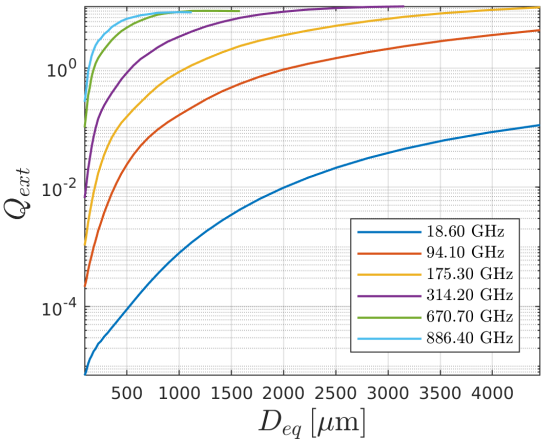
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

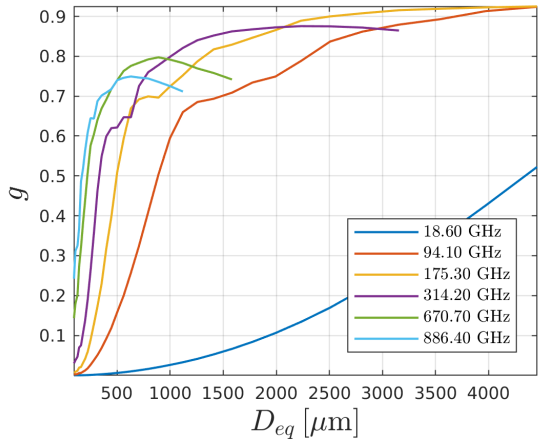
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



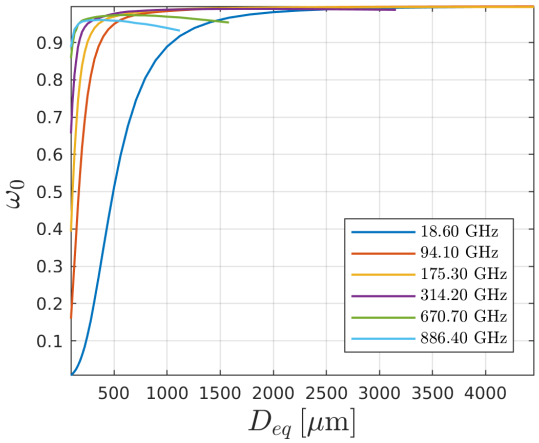
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

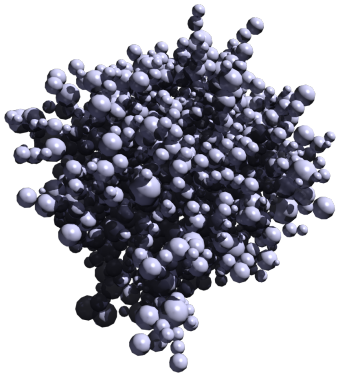
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Spherical Graupel



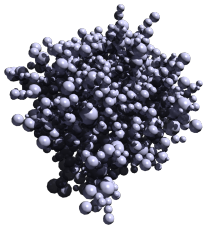
Publication date 20-Nov-2017 22:19:01

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Spherical graupel
Source	location: Chalmers, software: Snowflake-toolkit (Rathsman 2016).
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

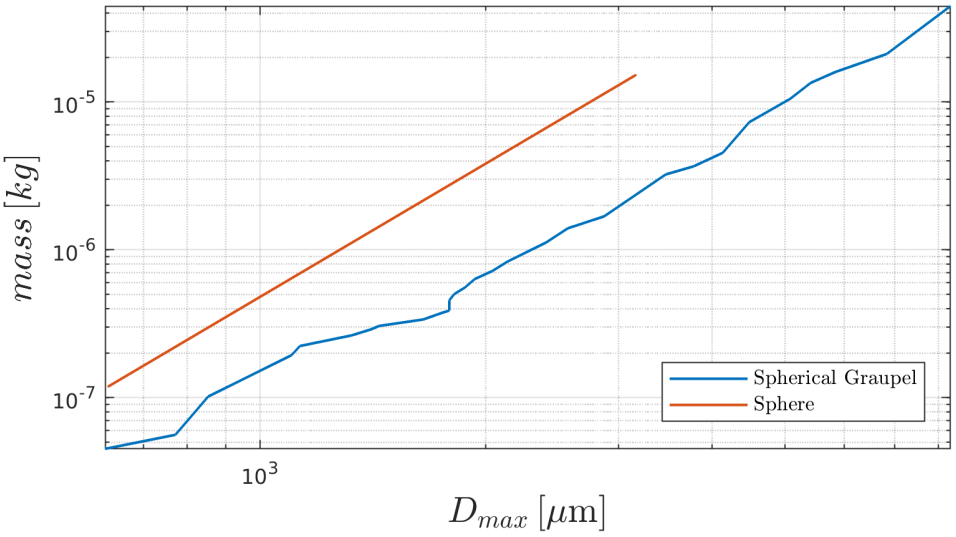
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	622	8308	29
D_e [um]	454	4528	

Table 1.3. Shape parameters

α	13.2741
β	2.6862

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

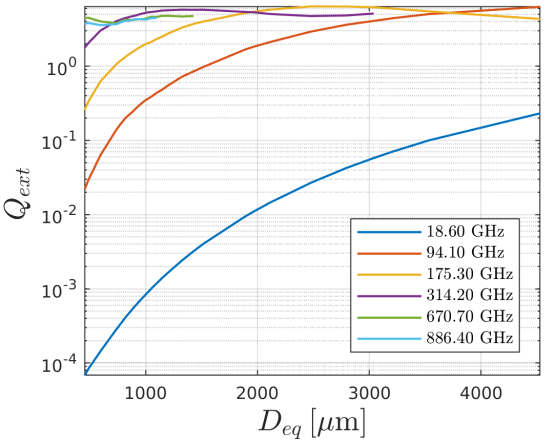
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

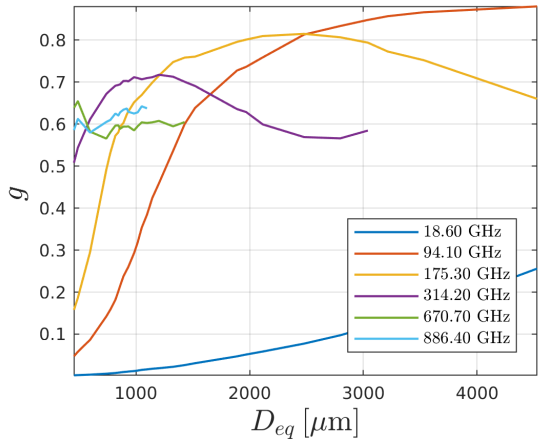
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



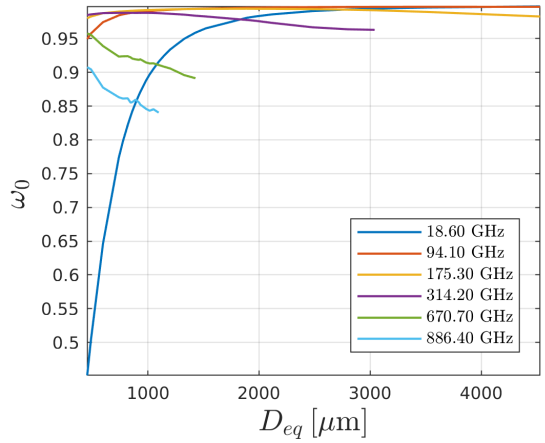
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

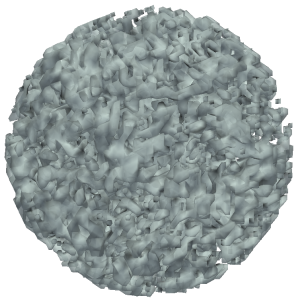
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

ICON Graupel



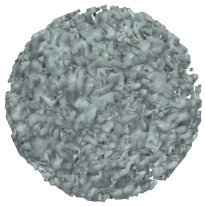
Publication date 07-Dec-2017 18:17:06

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	ICON graupel
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

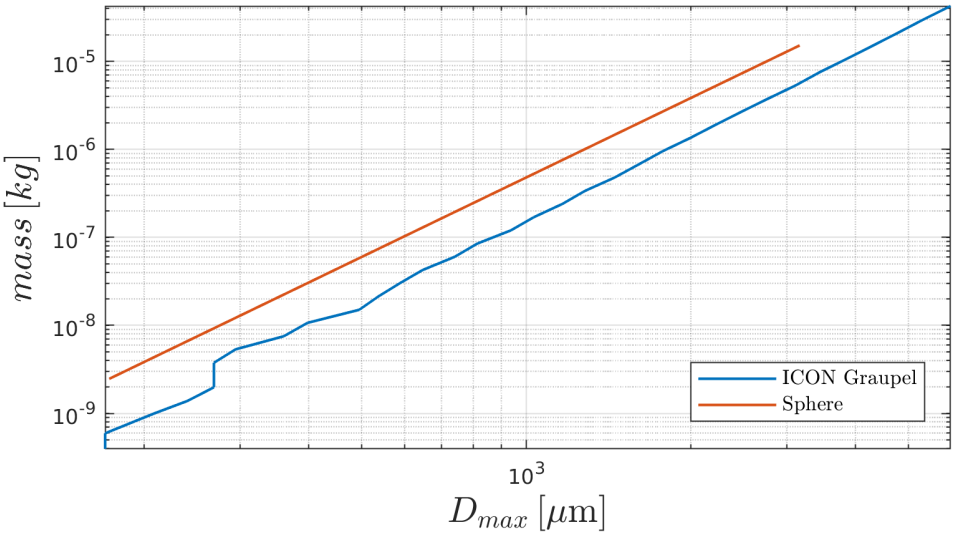
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	170	5969	31
D_e [um]	94	4457	

Table 1.3. Shape parameters

α	394.8402
β	3.1345

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

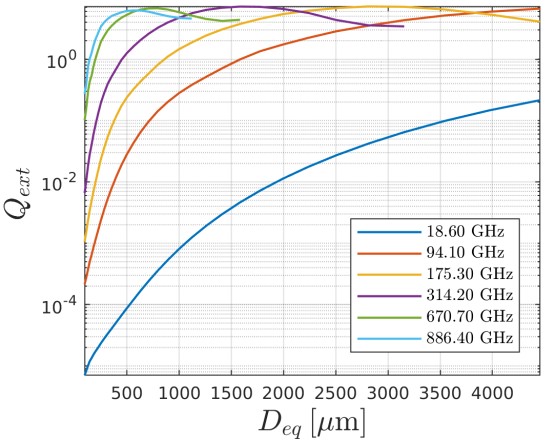
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

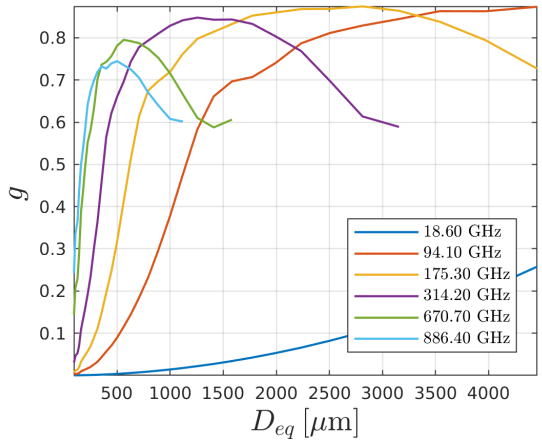
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



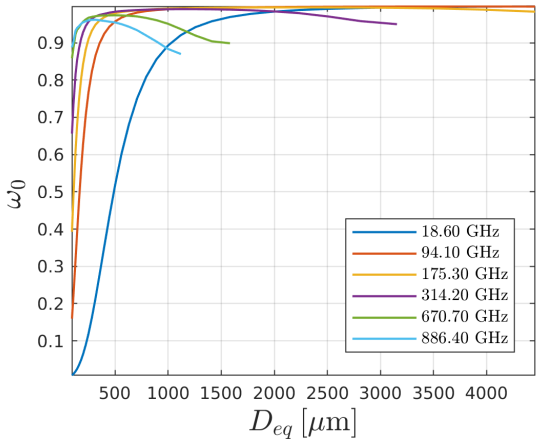
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

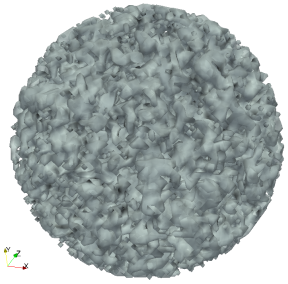
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

GEM Graupel



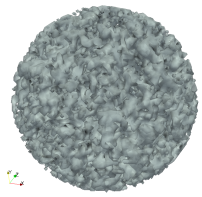
Publication date 07-Dec-2017 18:18:59

Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	GEM graupel
Source	location: Chalmers, software: Rimecraft.
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

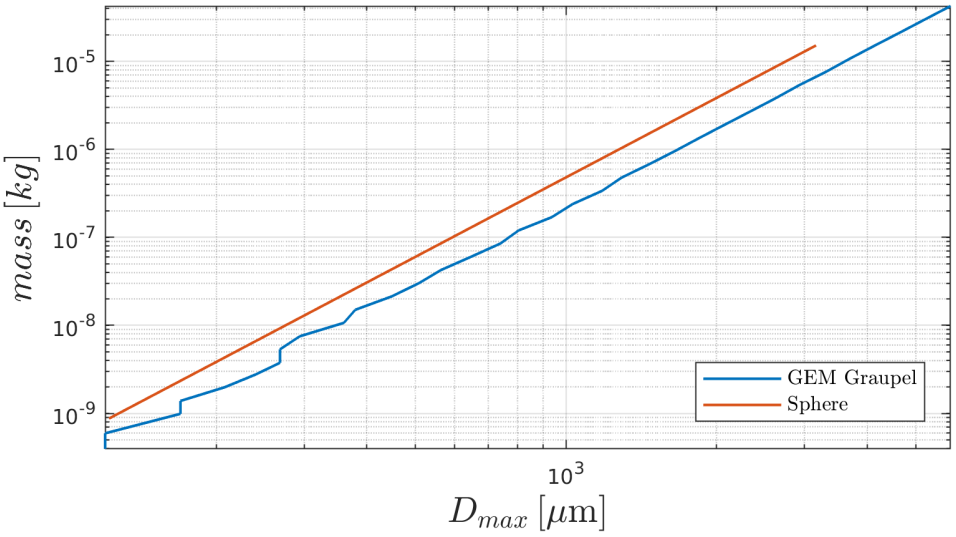
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	120	5871	31
D_e [um]	94	4457	

Table 1.3. Shape parameters

α	172.7527
β	2.9646

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

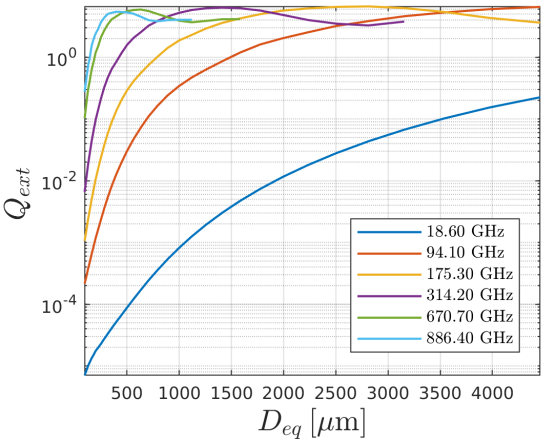
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (916.70)
Refractive index	Matzler 2006

Table 2.2. SSP grid

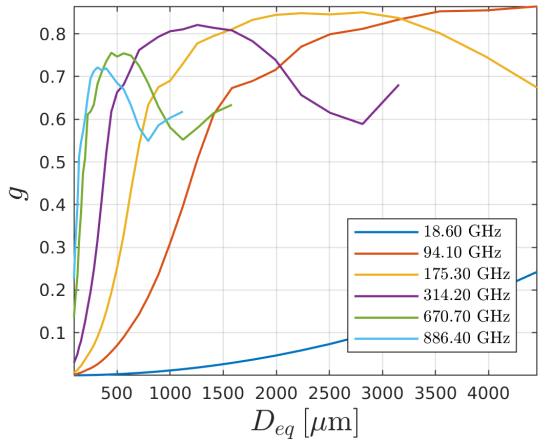
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	190, 230, 270,

Figure 2.1. Extinction



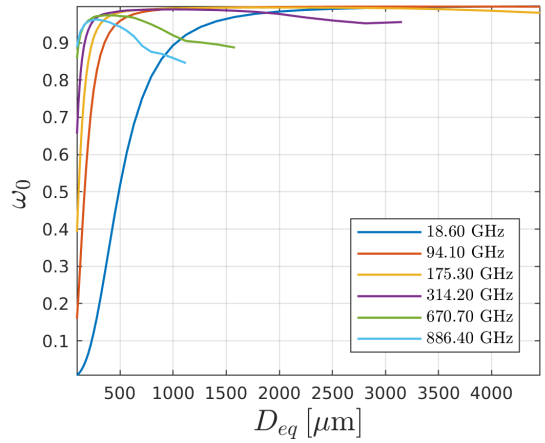
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

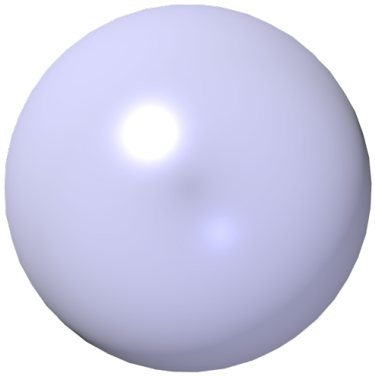
Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 230 K.

SSP Data Summary

Liquid Sphere



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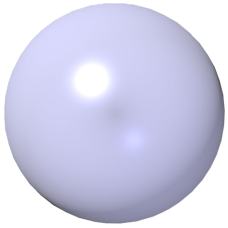
Chapter 1. Habit Specifications

Table 1.1. Habit description

Description	Liquid sphere
Source	location: Chalmers
Comment	

Figure 1.1. Shape rendering.



Rendering of a selected shape using Blender (https://www.blender.org/).

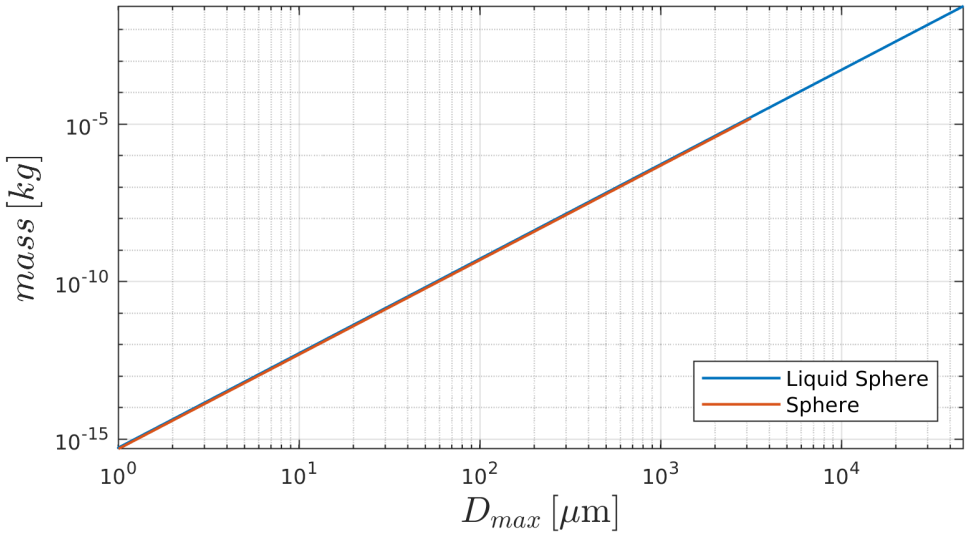
Table 1.2. Size parameters

	min	max	# of sizes
D_max [um]	1	47354	199
D_e [um]	1	47354	

Table 1.3. Shape parameters

α	523.5988
β	3.0000

Figure 1.2. Mass-size relationship



Mass as a function of D_max. Sphere included as a reference. Ice density assumed.

Chapter 2. Single Scattering Properties

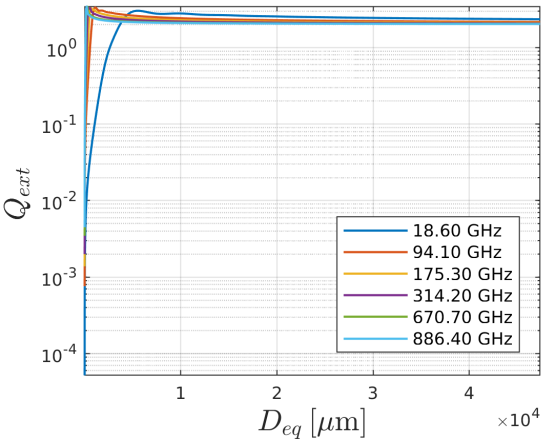
Table 2.1. SSP description

Source	ADDA (Yurkin 2011)
Format	ARTS SSP format v.3
Orientation	totally_random
Density [kg/m³]	ice (520.77)
Refractive index	water_ellison07

Table 2.2. SSP grid

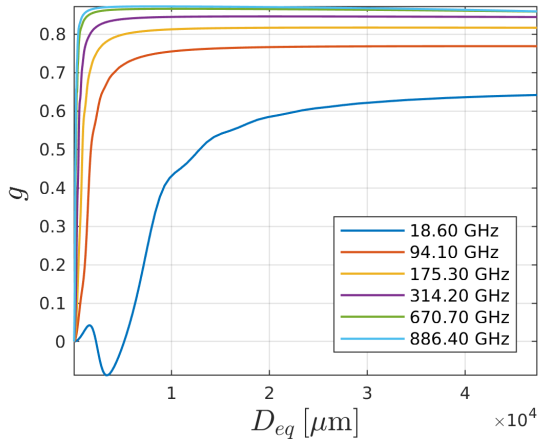
frequency [GHz]	1, 1, 3, 5, 7, 9, 10, 13, 15, 19, 24, 31, 32, 36, 50, 58, 89, 94, 115, 122, 164, 167, 175, 191, 228, 247, 314, 336, 439, 457, 657, 671, 862, 886,
Temperature [K]	230, 250, 270, 290, 310,

Figure 2.1. Extinction



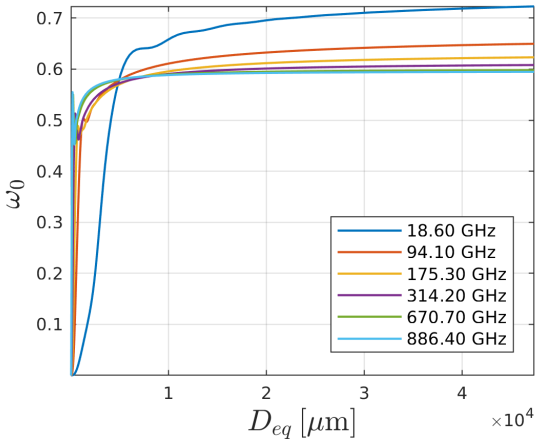
Extinction efficiency as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 270 K.

Figure 2.2. Assymetry parameter



Assymetry parameter as a function of volume equivalent diameter, for a selection of six frequencies. Temperature is 270 K.

Figure 2.3. Single scattering albedo



Single scattering albedo as a function of volume volume equivalent diameter, for a selection of six frequencies. Temperature is 270 K.