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The ARTS Single Scattering Database

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Outline

1. Overview
2. Specifications
3. Example results
4. Database structure
5. Summary

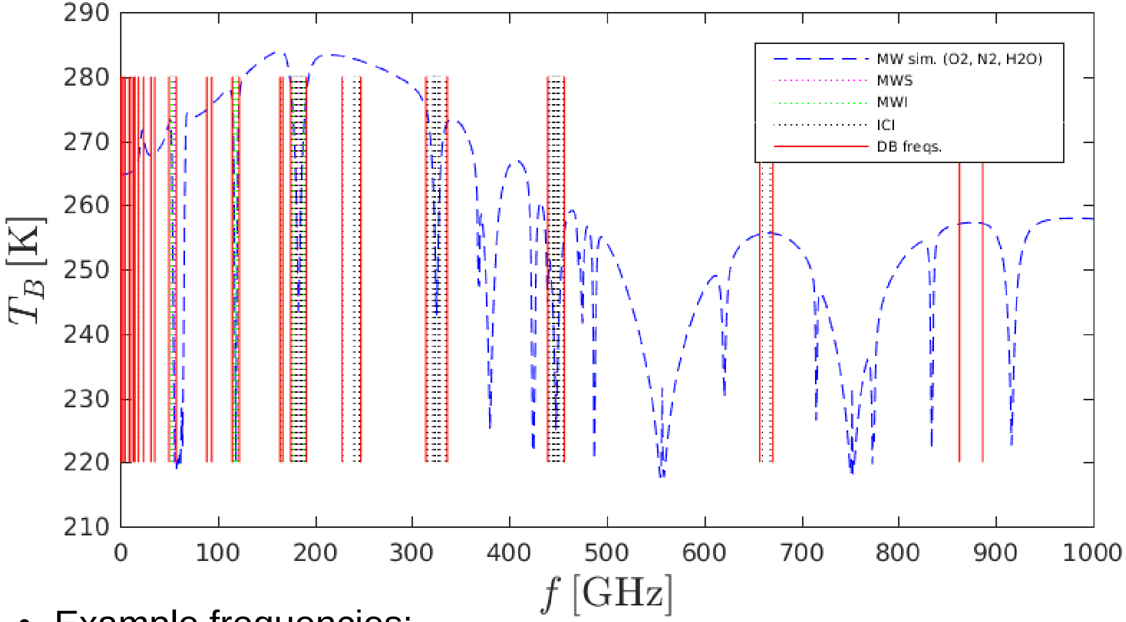
Overview

- Background
  - Passive and active applications
  - ARTS
  - EUMETSAT:
    - ICI, MWI, MWS
- Scope
  - Pristine, aggregate, melting and rimed particles
  - Frequencies: $[1, 1000]\ GHz$
  - Orientations:
    - Totally random
    - Azimuthally random
- Method
  - External and “in-house” generated shape data
  - Amsterdam DDA

Specifications

Frequencies and temperatures

- 32 Frequencies:
- ICI (ISMAR), MWI, MWS.
  - (IceCube, CloudSat, EarthCare)
- 3 Temperatures:
  - 190, 230, 270 K
- Refractive index of ice:
  - Mätzler 2006



- Example frequencies:
  - 1, 31, 94, 118, 165, 175, 230, 330, 444, 664, 874 GHz....

Specifications
Habits

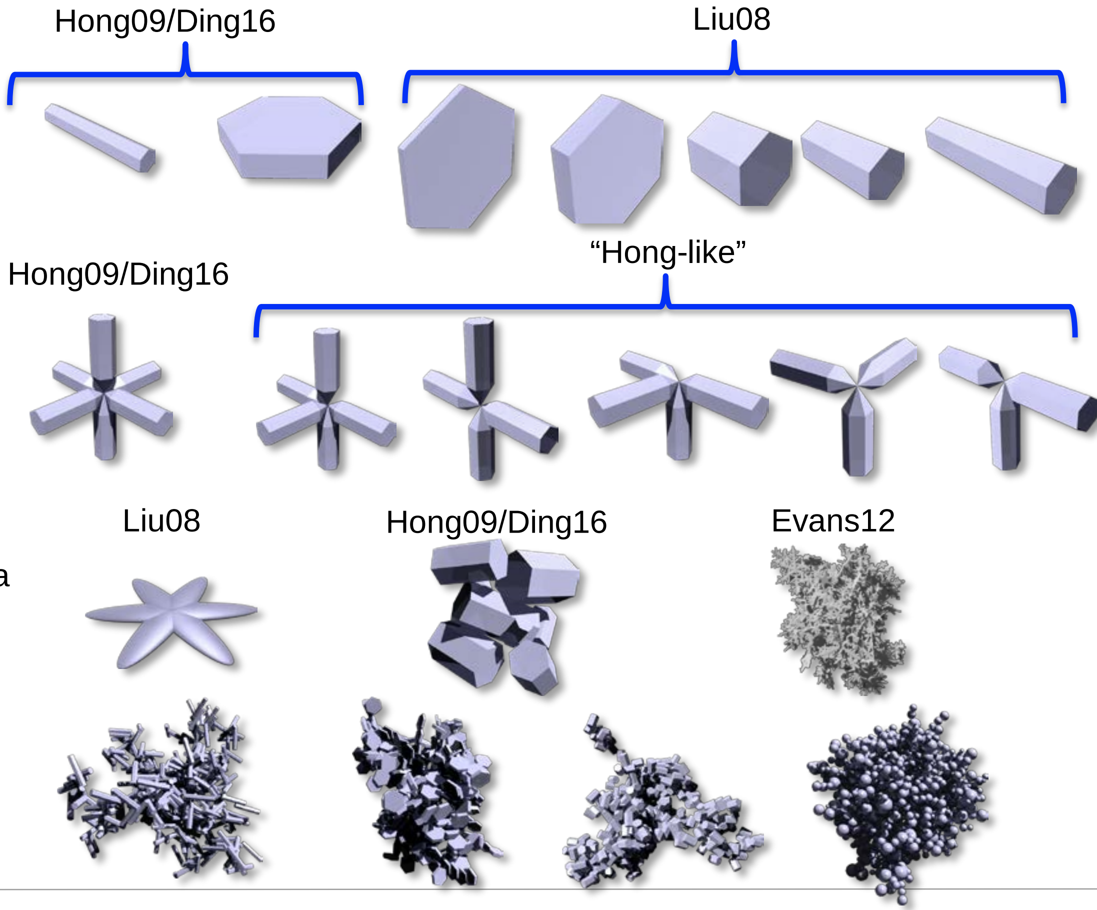
- 32 habits
- Size range:
  - $D_{max} \leq$ 2 cm
  - $D_{veq} \leq$ 5 mm
  - At least 35 sizes per habit.
- $m = \alpha D_{\max}^{\beta}$
- Totally random orientation

Columns & plates

Bullet rosettes

Misc external data

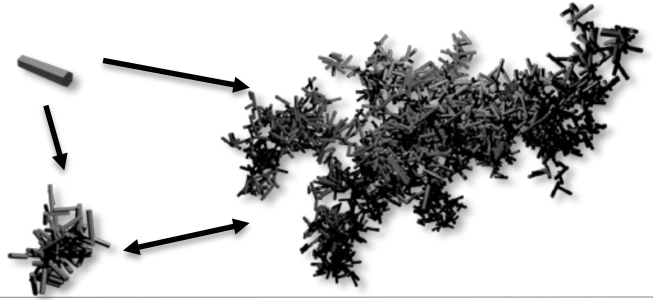
Chalmers aggregates

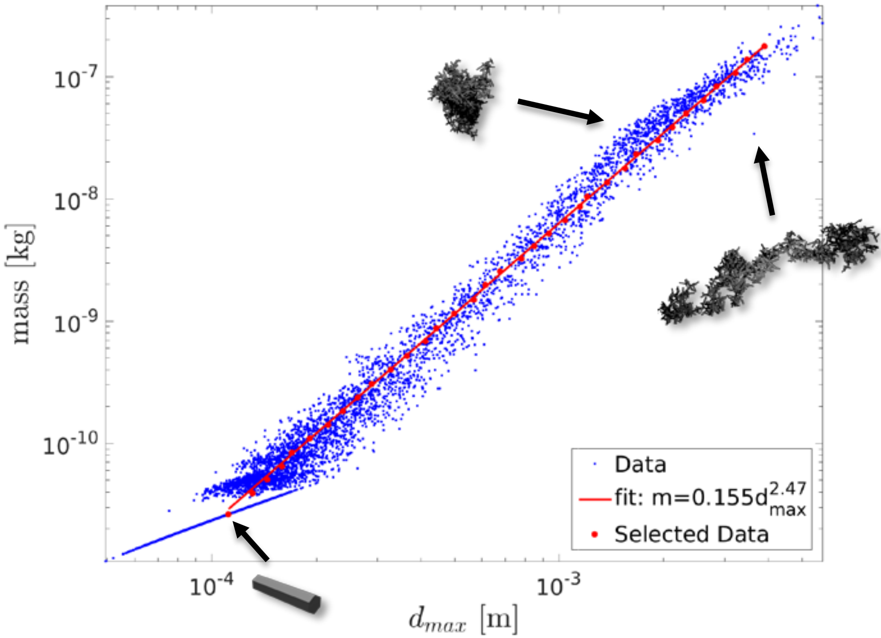


Specifications

Aggregate generation

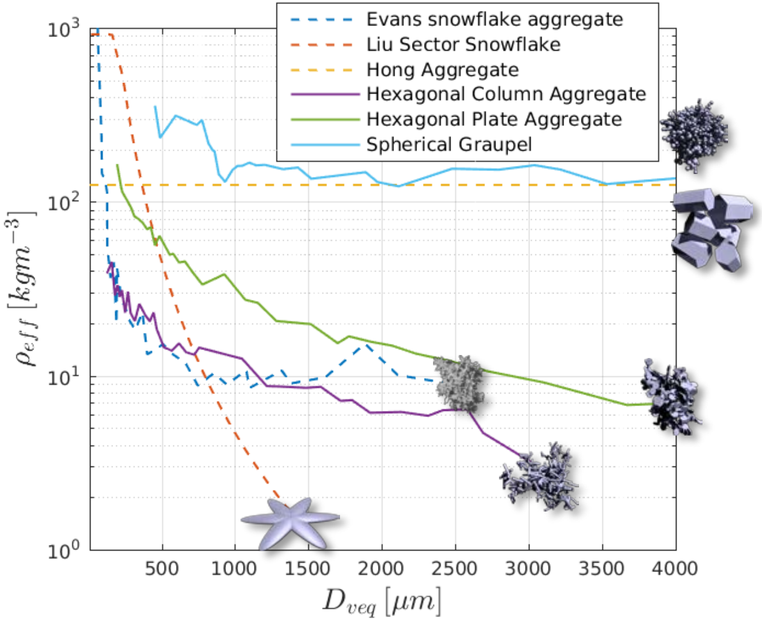
- Iterative “Stochastic collision model”
  - Up to 5,000 particles simultaneously
  - Shape of building blocks customizable.
    - Only hexagonal columns/plates considered currently.
- Particles selected along $m = \alpha D_{\text{max}}^{\beta}$



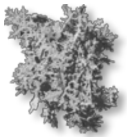


Example results

Effective density



- Evans Snow Aggregate



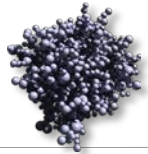
- Sector Snowflake

- Hong Aggregate

- Long Column Aggregate

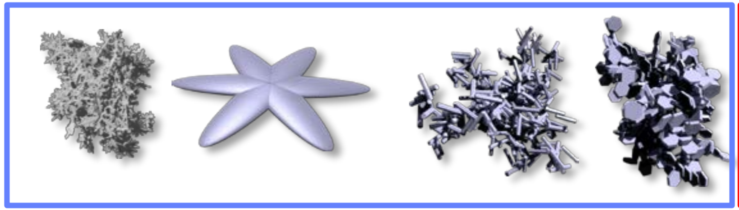
- Thin Plate Aggregate

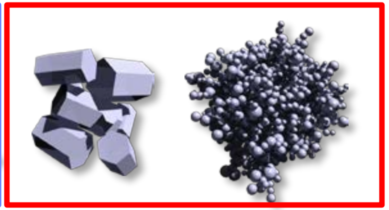
- Spherical Graupel

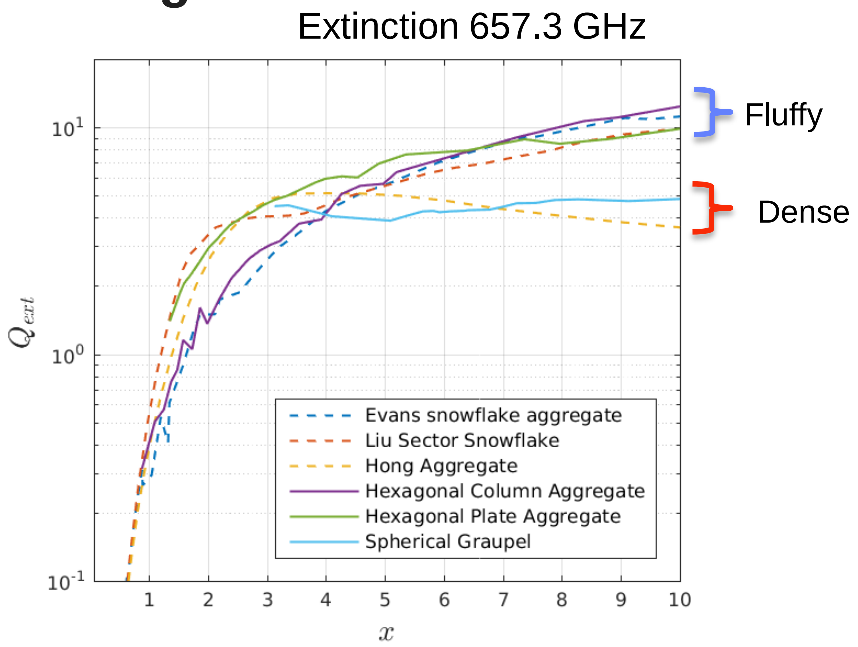


Example results

Scattering

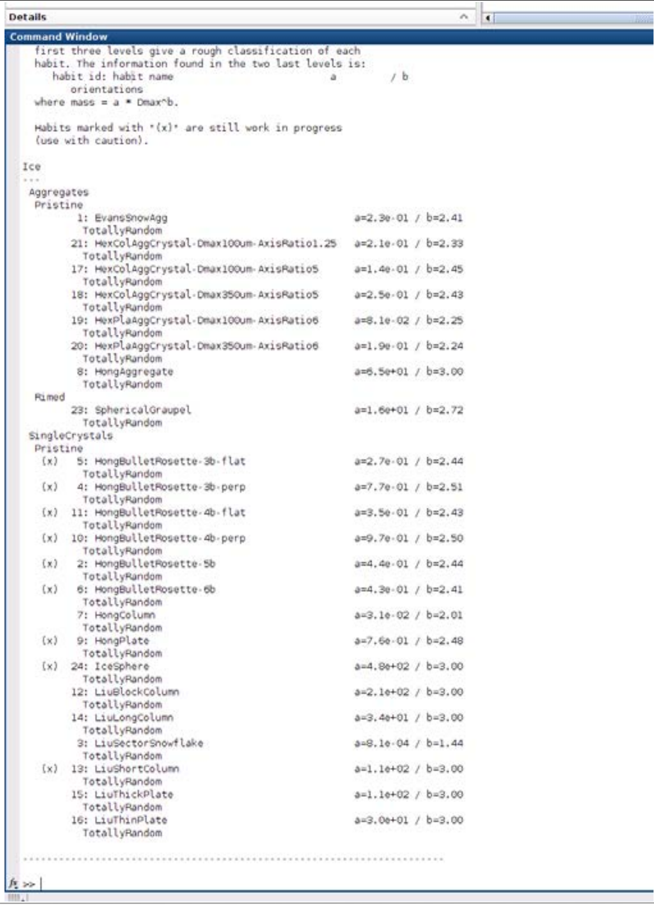






Database structure

- Content
  - Scattering properties
  - Shape data
  - DDA settings
- Format
  - NetCDF4
  - One file for each size, frequency and temperature
- Interfaces
  - MATLAB, Python
- Availability
  - ARTS home page: http://www.radiativetransfer.org
  - Snowport (soon): snowport.meteo.uni-koeln.de/



Database structure

$$\frac{d\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})}{ds} = -\mathbf{K}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}}) + \mathbf{a}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})B(\nu,\hat{\mathbf{r}}) + \int_{4\pi}\mathbf{Z}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}},\hat{\mathbf{n}}')\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}}')d\hat{\mathbf{n}}'$$

Core content

- Stored scattering data :
  - Scattering matrix (4x4)
  - Extinction matrix (4x4)
  - Absorption vector (4x1)
- Other common parameters easily derived
  - Single scattering albedo
  - Back-scattering
- Data reduction:
  - Non-zero and non-unique elements omitted.
  - Angular dependency expressed in terms of scattering angle for totally random orientation.

- Scattering matrix

$$\mathbf{Z}(\theta_{sca},\phi_{sca},\theta_{inc},\phi_{inc}) = \begin{pmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{pmatrix}$$

- Extinction matrix

$$\mathbf{K}(\theta_{inc},\phi_{inc}) = \begin{pmatrix} K_{11} & K_{12} & K_{13} & K_{14} \\ K_{12} & K_{11} & K_{23} & K_{24} \\ K_{13} & -K_{23} & K_{11} & K_{34} \\ K_{14} & -K_{24} & -K_{34} & K_{11} \end{pmatrix}$$

- Absorption vector

$$\mathbf{a}(\theta_{inc},\phi_{inc}) = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix}$$

- /

Conclusion

- Current version (beta) available
  - ARTS home page: http://www.radiativetransfer.org
  - Snowport (soon): snowport.meteo.uni-koeln.de
- So far:
  - Totally random orientation
  - 32 habits (more on the way)
  - 32 frequencies in [1, 900] GHz
- Future:
  - Azimuthally random orientation
  - Melting particles

End

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Backup slides

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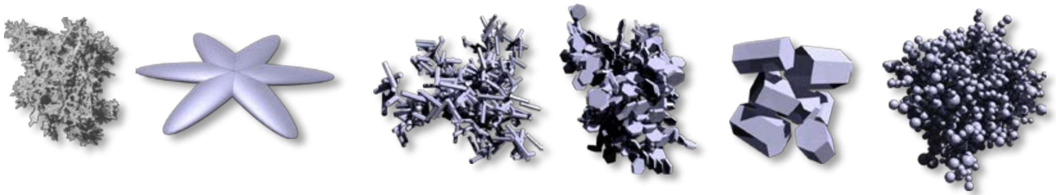


Example results

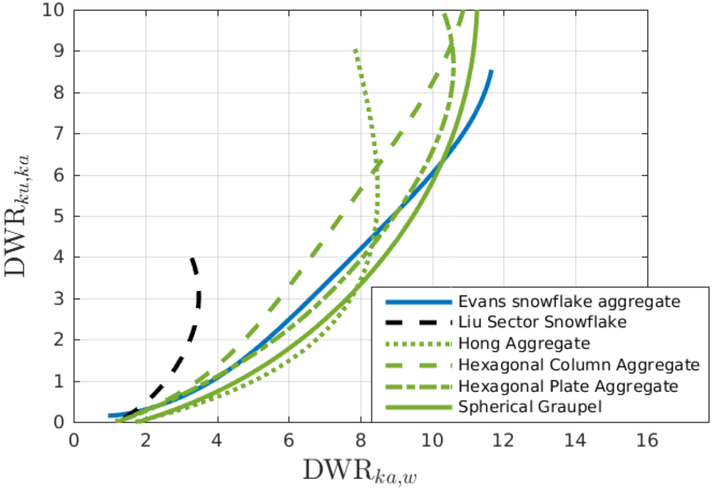
Radar triple frequencies

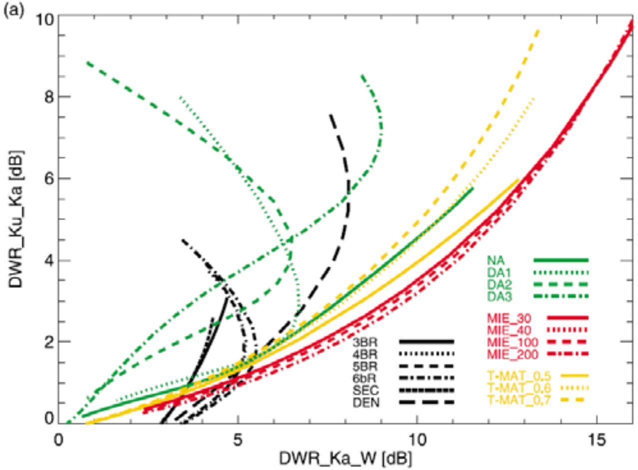
Exponential PSD

- $N = N_0 e^{-\Lambda D_{max}}$
- $\Lambda: [100, 500]\ m^{-1}$

Ku, Ka, W band

- 13.4, 36.5, 89.0 GHz





Kneifel et al. 2011

Overview

Parameters

- Stokes parameters formalism (radiance): $\mathbf{I} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$

- Radiative transfer equation:

$$\frac{\mathrm{d}\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})}{\mathrm{d}s} = -\mathbf{K}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}}) + \mathbf{a}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}})B(\nu,\hat{\mathbf{r}}) + \int_{4\pi}\mathbf{Z}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}},\hat{\mathbf{n}}')\mathbf{I}(\nu,\hat{\mathbf{r}},\hat{\mathbf{n}}')\mathrm{d}\hat{\mathbf{n}}',$$

Extinction matrix (4x4)

Absorption/emission vector (4x1)

Scattering matrix (4x4)

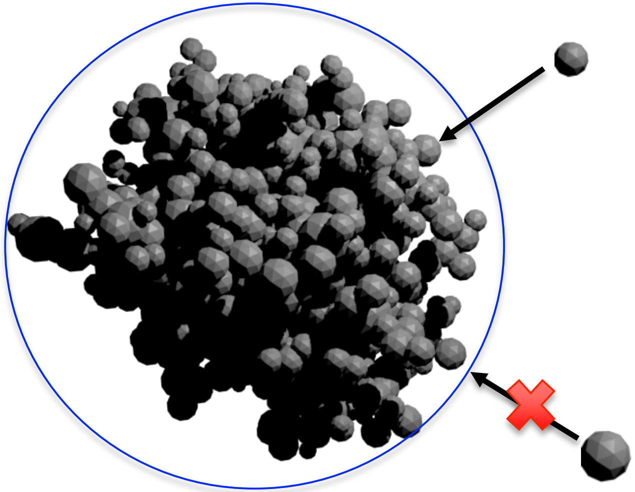
$$\mathbf{K}(\theta_{inc},\phi_{inc}) = \begin{pmatrix} K_{11} & K_{12} & K_{13} & K_{14} \\ K_{12} & K_{11} & K_{23} & K_{24} \\ K_{13} & -K_{23} & K_{11} & K_{34} \\ K_{14} & -K_{24} & -K_{34} & K_{11} \end{pmatrix}$$

$$\mathbf{a}(\theta_{inc},\phi_{inc}) = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix}$$

$$\mathbf{Z}(\theta_{sca},\phi_{sca},\theta_{inc},\phi_{inc}) = \begin{pmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{pmatrix}$$

Shape data
Other

- “Graupel” tool-kit
    - Rime



- Rimecraft
    - Rime
    - Melting