Modelling polarized microwave radiation in a 3D spherical cloudy atmosphere

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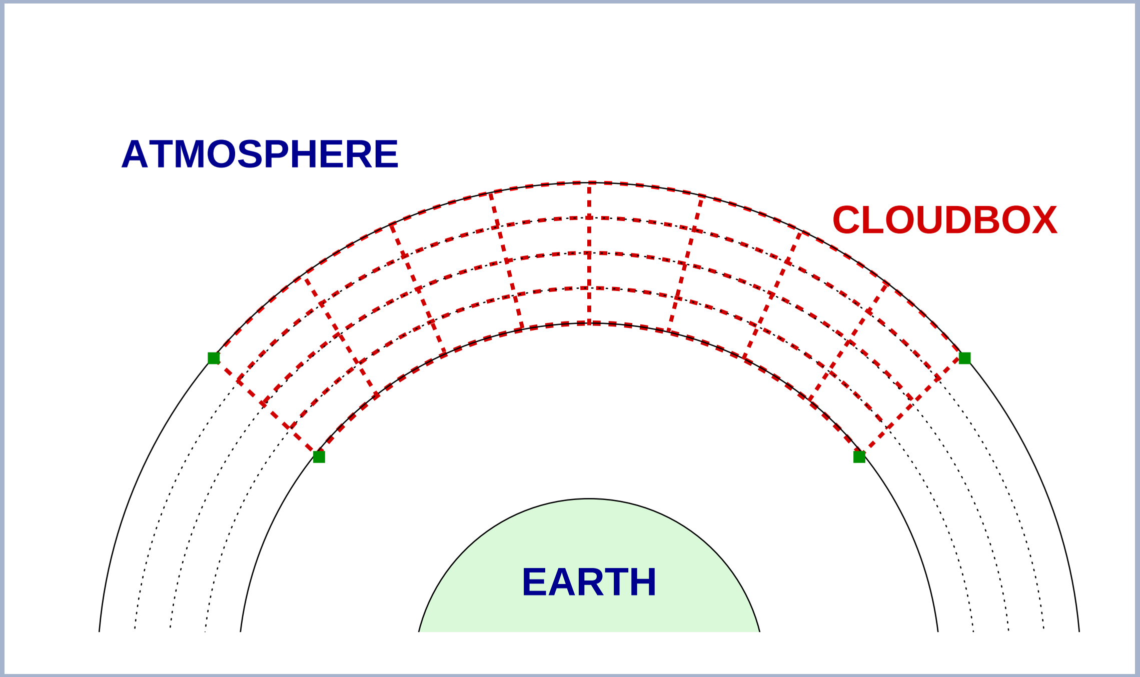
Model atmosphere

- **3D:**
  - Spherical coordinate system (pressure, latitude, longitude)
  - Realistic simulations (strongly inhomogeneous cloud coverage)
- **1D:**
  - Spherically symmetric atmosphere (only pressure coordinate).
  - Estimation of upper limit of scattering effects.
  - Much faster computation than 3D.
- **2D:**
  - Atmosphere extends inside plane (polar coordinate system).
  - Application: Satellite measurements (Observation inside orbit plane).
  - Scattering calculations impractical.

Cloudbox - scattering domain

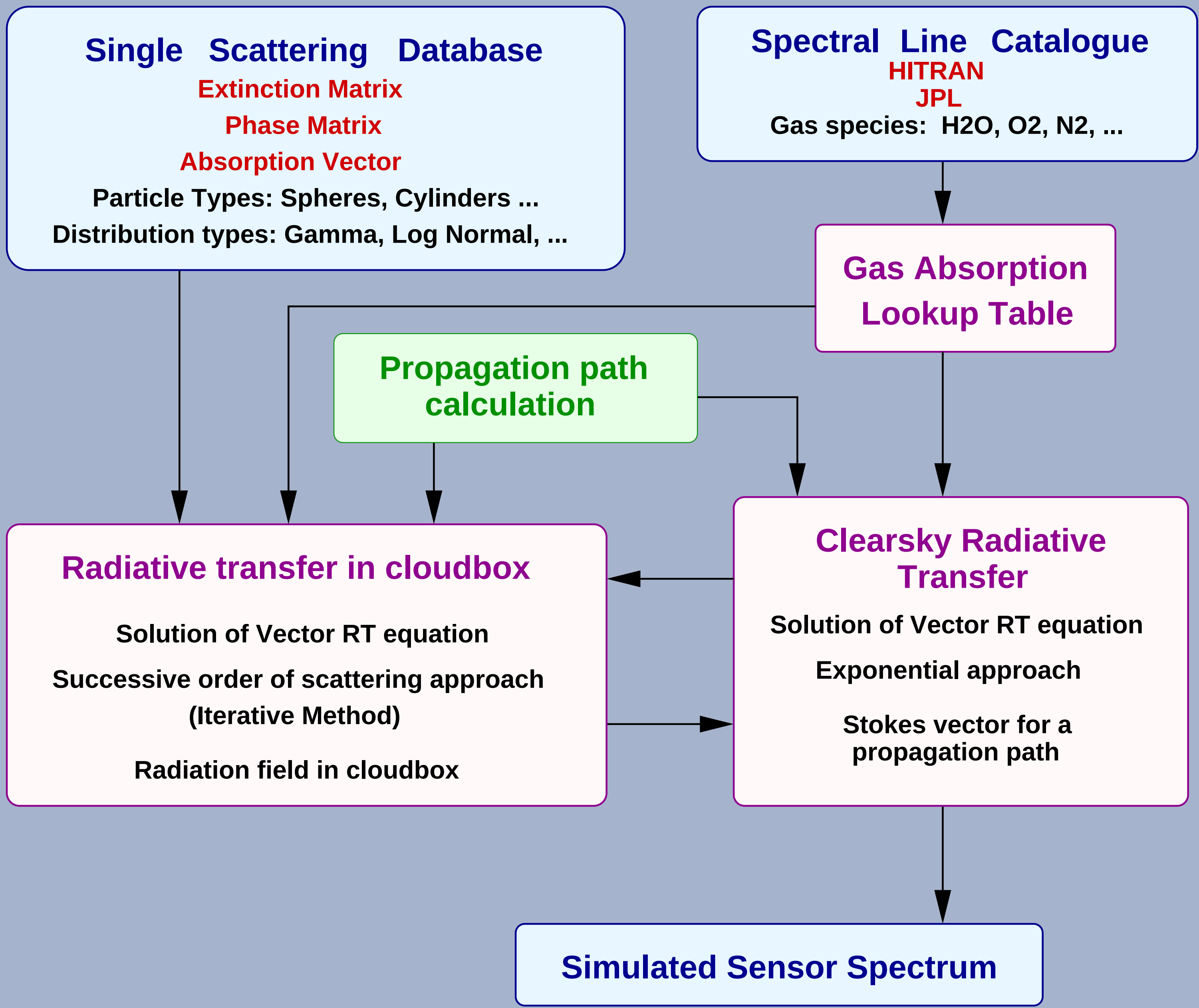


Scattered radiation field is calculated inside the cloudbox using **successive order of scattering approach**.

<ins>Definition of cloudbox:</ins>

- corner points ⇔ atmospheric grid points
- 3D atmosphere:
  $[p_1, p_2, \alpha_1, \alpha_2, \beta_1, \beta_2]$

The concept of ARTS



Single Scattering Database

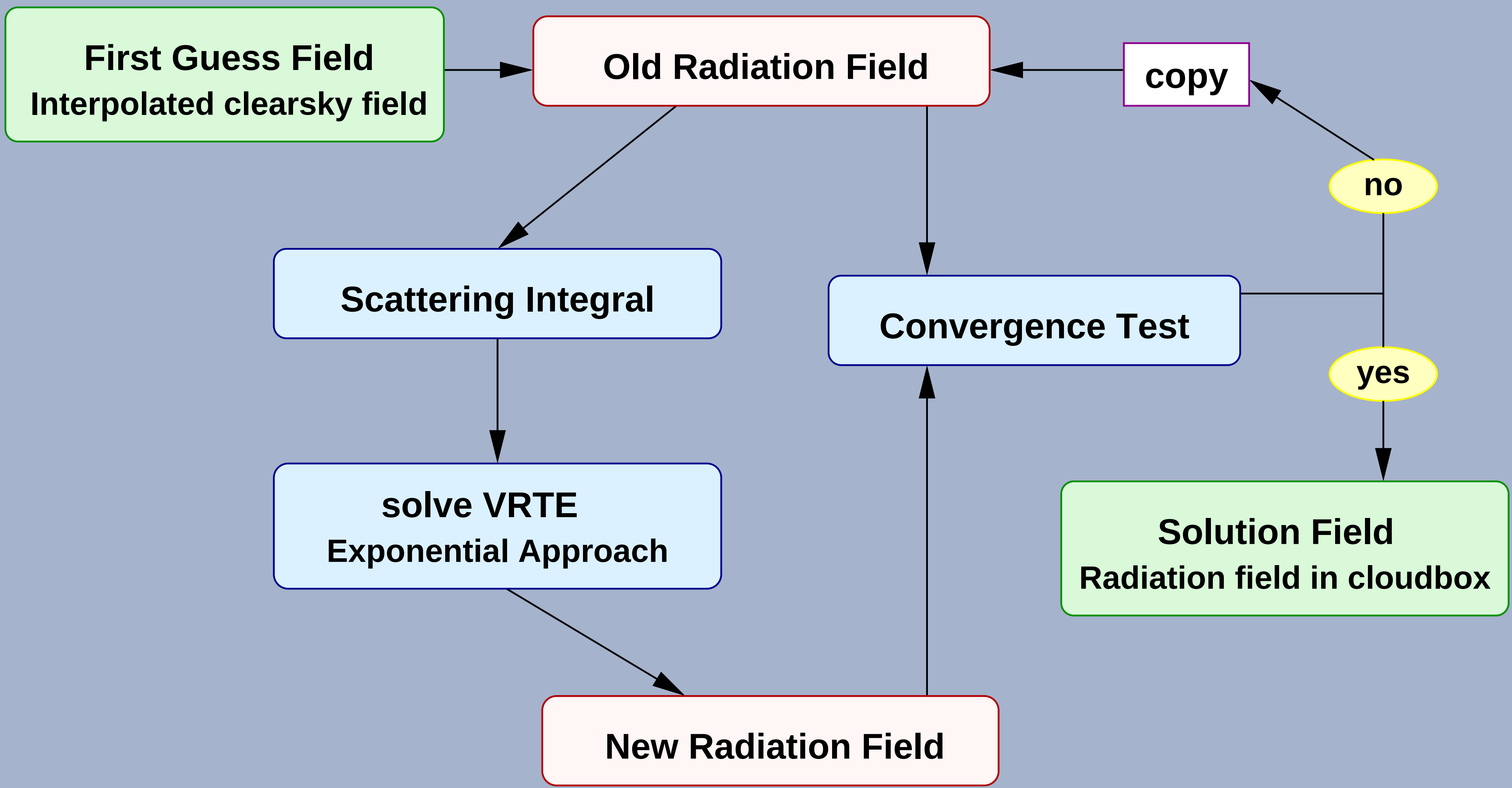
- Hydro-meteor species defined by
  - Phase matrix
  - Extinction matrix
  - Absorption vector
- One species can be ensemble or single particle.
- T-matrix method for computation (Mishchenko code).
- Data format: XML

Vector radiative transfer equation

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

$\mathbf{I} = (I, Q, U, V)$	Stokes Vector
$\mathbf{n}$	propagation direction of the radiation
ν	frequency
$\mathbf{K}$	extinction coefficient matrix
$\mathbf{a}$	absorption coefficient vector
B	Planck function
$\mathbf{Y}$	phase matrix

Successive order of scattering method

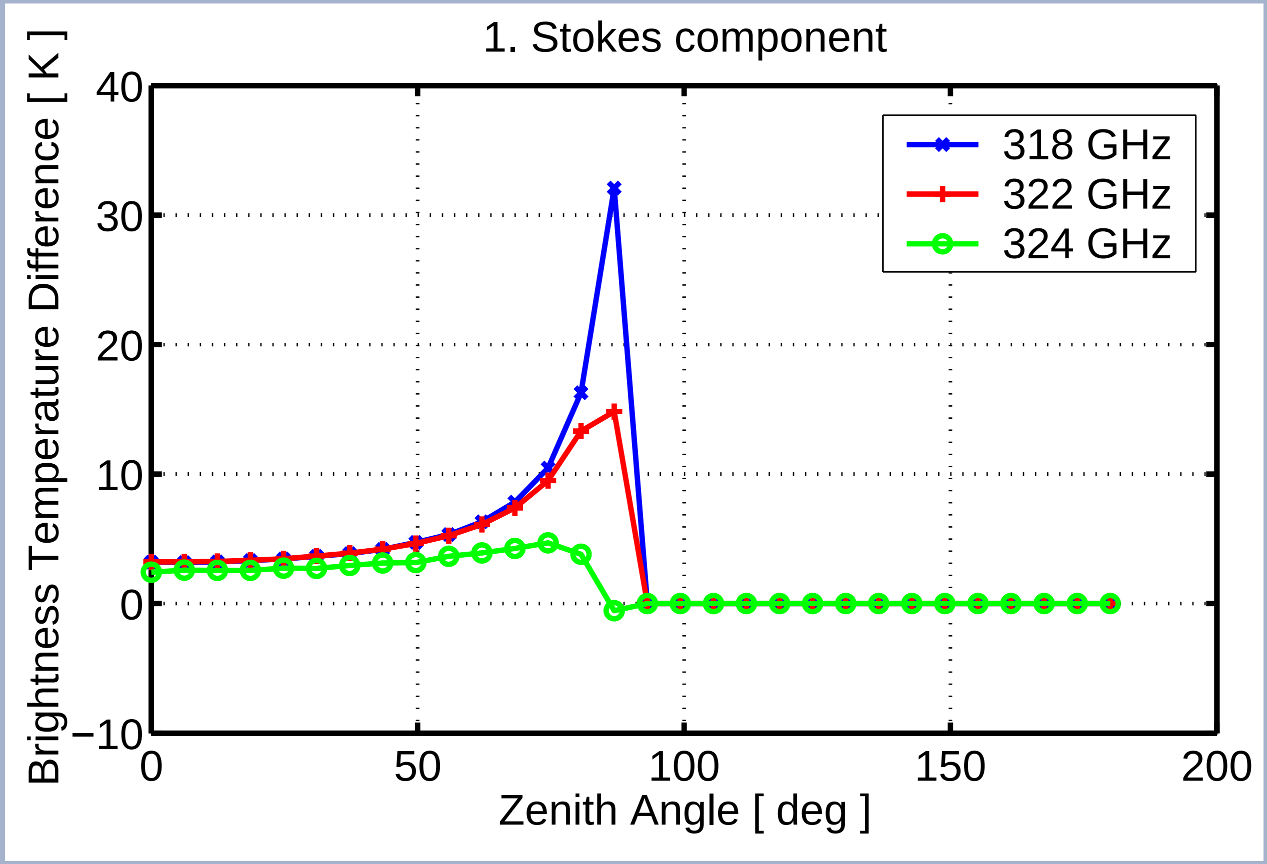


1D test calculations for a homogeneous cloud

Setup:

- 1D atmosphere.
- Cloudbox from 360 hPa to 280 hPa.
- 12 pressure levels.
- Spherical ice particles, radius 200 μm
- Constant particle number density: 1297 m^{-3}
- Absorption from lookup table for the species: H_2O, O_3, O_2, N_2
- Frequencies:
  - 318 GHz: Case for low absorption.
  - 322 GHz: Case for medium absorption.
  - 324 GHz: Case for high absorption.

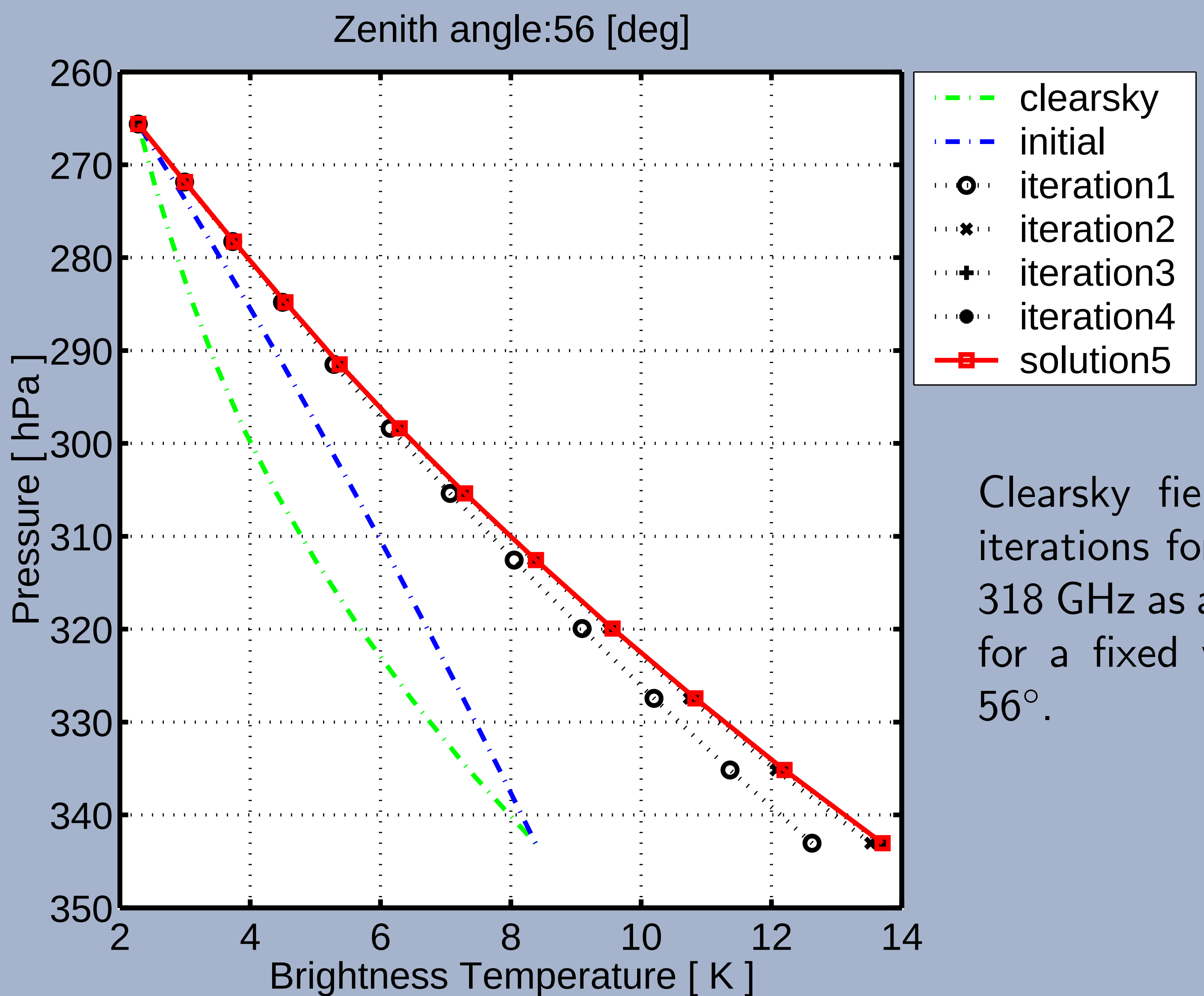
Calculation for three frequencies



Difference between clearsky field and scattered field for three test cases.

Radiation field for all viewing directions at the bottom of the cloud.

Convergence behaviour



Clearsky field, initial field and iterations for the intensity (I) at 318 GHz as a function of altitude for a fixed viewing direction of 56°.

Summary

- Scattering calculations performed for 1D and 3D test cases.
  $\Rightarrow$ Reasonable results.

- Successive order of scattering method implemented for solving VRTE.

- Polarized and unpolarized radiation fields can be simulated.

- T-matrix method selected for calculating single scattering properties.

- Geometrical propagation path calculations implemented for 1D, 2D and 3D; with and without refraction.

Outlook

- Main problem: Using all implemented features at the same time requires long computation time and large working memory.
- Optimizations (e.g. improved first guess field) planned to be implemented.

More information availabe on web-page:

http://www.sat.uni-bremen.de/arts/