

SMRT: A new, modular snow microwave radiative transfer model



EMI

Outline

- Overview
- Implementation and structure
- Microstructure
- Model intercomparison via wrappers
- Github / website / help / documentation
- Summary

SMRT: Context



- \rightarrow the different **electromagnetic theories**
- \rightarrow the different **micro-structure representation** used by these models
- \rightarrow the different **solution** of the radiative transfer equation

SMRT: Overview

MICROSTRUCTURAL ORIGIN OF ELECTROMAGNETIC SIGNATURES IN MICROWAVE REMOTE SENSING OF SNOW

Main physics:

- Active / passive
- Multilayer
- Layer microstructure: ACF
- EM Theory: κ_s,κ_a, phase function, ε
- RT Solver
- Interface: Fresnel
- Substrate / atmosphere / permittivity



SMRT: Overview



Switching modules....

- Microstructure
- EM model
- Interfaces
- Substrate
- Atmosphere
- RT Solver

Picard et al. (2018), GMD

SMRT: Overview

...makes model intercomparison easy!



SMRT: Implementation

Why python?

open, object oriented (to realize "easy to use")

Example of a model run:

Imported modules hide computational complexity

	<pre>from smrt import make_snowpack, make_model, sensor</pre>						
Inputs	<pre># prepare inputs thickness = [100] corr_length = [5e-5] temperature = [270] density = [320]</pre>						
Create snowpack	<pre># create the snowpack snowpack = make_snowpack(thickness=thickness,</pre>						
	<pre>microstructure_model="exponential", density=density, temperature=temperature, corr_length=corr_length)</pre>						
Choose sensor config	<pre># create the sensor radiometer = sensor.amsre('37V')</pre>						
Create model	<pre># create the model m = make_model("iba", "dort")</pre>						
Run	<pre># run the model result = m.run(radiometer, snowpack)</pre>						
Outputs	<pre># outputs print(result.TbV(), result.TbH())</pre>						

SMRT: Structure



Implementation

Structure of SMRT after sea-ice:



SMRT: Structure

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Easy to add modules

+ Tests!

SMRT: Microstructure

Layer microstructure:

represented by a two-point correlation function

Implemented models: (and reasons for them)

- Exponential model (MEMLS)
- Sticky hard spheres (DMRT-ML, DMRT-QMS)
- Independent sphere (classic)
- Teubner–Strey (empirical evidence)
- (Level-cut) Gaussian random fields (full-field methods)

Why different choices?

To be flexible with non-obvious correlation functions:





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Micro-CT is not the only way!



SMRT: Legacy

To facilitate model inter-comparison:

Shallow wrappers for MEMLS, HUT, DMRT-QMS (no code)

```
general import for smrt
from smrt import make snowpack, make model, sensor
# import for memls
from smrt.utils import memls_legacy
# prepare snowpack
pc = 0.2e-3
snowpack = make snowpack(thickness=[10], microstructure model="exponential",
                         density=[300], temperature=[265], corr length=pc)
# create the sensor
theta = range(10, 80, 5)
radiometer = sensor.passive(37e9, theta)
# create the EM Model
m = make model("iba", "dort")
# run the model
sresult = m.run(radiometer, snowpack)
# run MEMLS matlab code
mresult = memls_legacy.run(radiometer, snowpack)
# outputs
plt.plot(theta, sresult.TbV(), 'r-', label='SMRT V')
plt.plot(theta, sresult.TbH(), 'r--', label='SMRT H')
```

Waterloo

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SMRT: intercomparison



Picard et al. (2018), GMD

https://github.com/smrt-model/smrt

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git pull

https://www.smrt-model.science

SMRT Home Getting Started Documentation Contribute

SMRT: Snow Microwave Radiative Transfer model

SMRT is an active / passive microwave radiative transfer model for multilayer snow written in Python. It was developed with European Space Agency support in order to investigate the representation of the snow microstructure, the main driver of scattering.

SMRT is modular, so allows easy intercomparisons between different modelling approaches in a plug-and-play way. SMRT proposes different electromagnetic theories to compute scattering (DMRT, IBA, Rayleigh independent, ...). In the case of IBA, different microstructure representations can be used (Sticky Hard Spheres, Exponential, Gaussian random field, ...). The current version proposes only one radiative transfer solver (DORT) but this can be extended. Last but not least, wrappers are included to run MEMLS, HUT and DMRT-QMS models (in their original matlab code) from within SMRT. Whilst there is plenty to get started with, there are more theoretical advances that can be made. SMRT is intended to be a community model - all are welcome to use it, and to contribute to its development!

SMRT uses the lastest python version (e.g. 3.6) but also works with earlier versions (2.7, 3.4 and higher). The code is open source and is hosted on github.

Getting started with SMRT

Using SMRT is easy

You must write a (short) driver code, SMRT is a library that your driver code call to perform a calculation. This is simple, there are four main steps in a typical driver code:

1. construct a snowpack (either from field data or snowpack model).

```
snowpack = make_snowpack(thickness=10., # 10 m deep snowpack
microstructure_model="sticky_hard_spheres",
    density=320.0, # 320 kg/m3
    temperature=260, # 260 K
    radius=100e-6) # 100 microns
```

http://community.smrt-model.science

SMRT community forum

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Online documentation



model, it would be necessary to describe the soil and the atmosphere as layers (exactly as the snowpack is made of snow layers) and to implement <u>emmodel</u> adequately to the soil and atmosphere. The <u>emmodel</u> package includes all the scattering theories available in SMRT (iba, dmrt, independent spheres (Rayleigh), ...). In

The <u>emmodel</u> package includes all the scattering theories available in SMRT (iba, dmrt, independent spheres (Rayleigh), ...). In some case there is an inter-dependence between the choices of micro-structure and of electromagnetic theory. For instance, <u>dmrt_shortrange</u> only works with <u>sticky_hard_spheres</u> microstructure (this is inherent to theory) and <u>rayleigh</u> would work with any microstructure model based on spheres (ie. that defines a *radius* parameter).

The **rtsolver** package includes the numerical codes that solves the radiative transfer equation.

Online documentation



SMRT

Why a new model ?
We don't need a new model (yet) but we need:
a repository of microwave community knowledge
= merge all RT models / theories in one code base, one framework
with extended capabilities to explore the micro-structure
with multi mode capabilities (passive, radar, altimeter)
with easier access for beginners and non-specialists
using modern and more efficient languages and programming techniques

SMRT: flexibility, python, git, forum, documentation

We hope SMRT will be taken up by the community as a **joint** endeavour

https://www.smrt-model.science https://github.com/smrt-model/smrt http://community.smrt-model.science smrt.readthedocs.io