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SenSE: Community SAR ScattEring model

Thomas Weiß [1,2,3] **and Alexander Löw**[1]

1 Department of Geography, Ludwig-Maximilians-Universität München, 80333 Munich, Germany **2** Geodesy and Geoinformatics, University of Rostock, Justus-von-Liebig-Weg 6, 18059 Rostock, Germany **3** Fraunhofer Institute for Computer Graphics Research IGD, Joachim-Junigus-Straße 11, 18059 Rostock, Germany

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Summary

SenSE is a comprehensive community framework designed for radiative transfer (RT) modeling in the active microwave domain. It summarizes various RT models developed for synthetic aperture radar (SAR) to simulate backscatter responses from open soil and vegetated land surfaces, primarily in agricultural settings. This integration encompasses different models for scattering and emission across various surfaces, providing a cohesive operational structure.

One of the framework's most significant advantages is its modular design, which allows for the easy substitution and analysis of different surface and canopy scattering models within a single system. This flexibility facilitates seamless model exchange, enhancing the framework's adaptability and utility. The SenSE package currently includes several surface models such as Oh92 (Y. Oh et al., 1992), Oh04 (Yisok Oh, 2004), Dubois95 (Dubois et al., 1995), IEM (Fung et al., 1992), and the surface component of the Water Cloud Model (WCM) (Attema & Ulaby, 1978). For canopy modeling, it supports models like SSRT (Roo et al., 2001; Ulaby & Long, 2014) and WCM (Attema & Ulaby, 1978).

Additionally, the framework incorporates the dielectric mixing model by Dobson et al. (1985), available in various versions for converting soil moisture content to a dielectric constant. SenSE also includes essential utility functions, such as those for frequency-wavelength conversion and calculating Fresnel reflectivity coefficients, further enhancing its analytical capabilities.

For more detailed information, users are directed to the ReadtheDocs documentation and the original sources of each model, ensuring comprehensive access to technical details and operational guidelines.

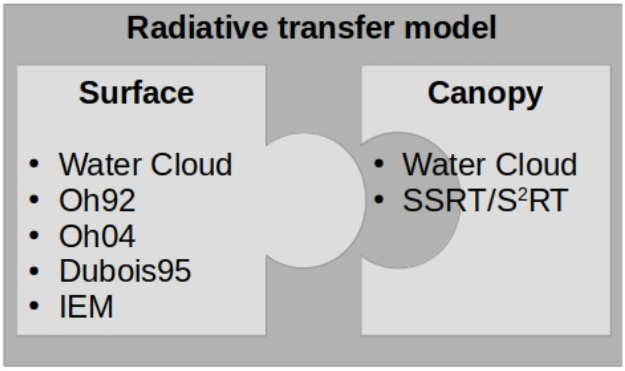

Figure 1: Implemented RT models within SenSE

Statement of need

Over the last several decades, various (empirical to physically based) RT models in the active microwave domain have been developed, tested, and further modified. However, an easy-to-use framework combining the most common microwave RT models (simulating backscatter responses of active microwave sensors) is lacking. Thus, every researcher must produce their own code implementation from the original source. This Python framework aims to serve as a first attempt to combine the most common active microwave-related RT models in a modular way. As a result, surface and volume scattering models can be easily exchanged with one another. Such a modular framework provides an opportunity to easily plug and play with different RT model combinations for various research questions and use cases. SenSE facilitates the application of RT models, especially for comparative analysis. Over time, the framework is expected to grow, incorporating more RT models (e.g., passive microwave domain) and supplementary functions (e.g., more dielectric mixing models).

While SenSE is a theoretical framework, it is designed to be compatible with data from a wide range of active microwave platforms, including both space-borne missions—such as Sentinel-1 (C-band), ALOS-2 PALSAR-2 (L-band), and TerraSAR-X (X-band)—and various air-borne SAR sensors. To utilize data from these platforms within the framework, the primary requirement is the provision of sensor-specific parameters, namely the incidence angle (θ), the radar frequency or wavelength, and the polarization state (e.g., VV, VH, HH). Additionally, since the RT models within SenSE typically operate on calibrated backscatter coefficients, input data must be pre-processed to provide sigma nought backscatter values.

Applications

The Python framework was employed within the EU-sponsored MULTIPLY Project (https://cordis.europa.eu/project/id/687320). Furthermore, the implementation of RT models in SenSE played a crucial role in the analysis conducted for several publications (Weiß et al., 2020, 2021, 2024). Additionally, the functionalities of SenSE are planned to be utilized in Project 2 - Remote Sensing of Vegetation Canopy Properties: States & Spatio-temporal Dynamics of the Land Atmosphere Feedback Initiative (LAFI) (https://www.lafi-dfg.de/p-2). Further collaboration with researchers in the field of vegetation optical depths in forest areas is ongoing. Consequently, the functionality of SenSE will continue to be used, and further extensions of SenSE are anticipated.

Other available software scripts (Ulaby and Long code library)

Ulaby & Long (2014) authored an extensive book on the fundamentals of microwave remote sensing, including a wealth of MATLAB codes for demonstration purposes. However, these MATLAB codes consist of individual snippets from different RT models, which makes it challenging to interchange combinations of RT models. While the interactive version of the MATLAB codes is effective for demonstration, it does not support processing large datasets. SenSE addresses the limitations of the MATLAB approach through practical examples provided in various Jupyter notebooks.

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In memory of Alexander Löw († 2 July 2017) who started this library.

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