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# **pyPro4Sail Documentation**

***Release 1.0.0***

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Prospect5 and 4SAIL Radiative Transfer Models for simulating the transmission of radiation in leaves and canopies.



# CHAPTER 1

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## Summary

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This project contains *Python* code for *Prospect* and *4SAIL* Radiative Transfer Models (**RTM**) for simulating the transmission of optical and thermal electromagnetic radiation through leaves and vegetated canopies.



## 2.1 README

Prospect5 and 4SAIL Radiative Transfer Models for simulating the transmission of radiation in leaves and canopies.

### 2.1.1 Synopsis

This project contains *Python* code for *Prospect* and *4SAIL* Radiative Transfer Models (**RTM**) for simulating the transmission of optical and thermal electromagnetic radiation through leaves and vegetated canopies.

The project consists of:

1. lower-level modules with the basic functions needed in *Prospect5* and *4SAIL* RTMs.
2. higher-level scripts for easily running ProSAIL in both forward and inverse mode.

### 2.1.2 Installation

Download the project to your local system, enter the download directory and then type.

```
python setup.py install
```

if you want to install pyTSEB and its low-level modules in your Python distribution.

The following Python library is required for running Prospect and 4SAIL:

- Numpy

In addition, the inversion of both RTMS requires.

- Scipy
- cma [Optional]

## 2.1.3 Code Example

### High-level example

You can automatically run the coupled leaf+canopy Prospect5+4SAIL RTM with *pyPro4Sail.py* module.

```
[N, chloro, caroten, brown, EWT, LMA, LAI, hot_spot, solar_zenith, solar_azimuth,
↪view_zenith, view_azimuth, LIDF]=[1.5,40,8,0.0,0,01,0,009,3,0.01,30,180,10,180,(-
↪0.35,-0.15)]
import pyPro4SAIL
wl,rho=pyPro4SAIL.run(N, chloro, caroten, brown, EWT, LMA, LAI, hot_spot, solar_
↪zenith, solar_azimuth, view_zenith, view_azimuth, LIDF, skyl=0.2,
↪soilType=pyPro4SAIL.DEFAULT_SOIL)
```

Also it is possible to simulate the surface land-leaving thermal radiance with the function `run_TIR`.

### Low-level example

#### Prospect5 RTM

You can run *Prospect* by importing the module `Prospect5.py` and then either calling the function `Prospect5` for simulating the full optical spectrum (400-2500nm), or the function `Prospect5_wl` for simulating the leaf reflectance and transmittance for a given wavelength.

```
# Running Prospect5
import Prospect5
# Simulate leaf full optical spectrum (400-2500nm)
wl, rho_leaf, tau_leaf = Prospect5.Prospect5(Nleaf, Cab, Car, Cbrown, Cw, Cm)
```

You can type `help(Prospect5.Prospect5)` to understand better the inputs needed and the outputs returned

#### 4SAIL RTM

You can run *4SAIL* by importing the module `FourSAIL.py` and then either calling the function `FourSAIL` for simulating the reflectance and transmittance factor of a given canopy given a list of leaf reflectances and transmittances, or you can call the function `FourSAIL_wl` for simulating the leaf reflectance and transmittance factor of a given canopy at for a single wavelength.

```
# Running the coupled Prospect and 4SAIL
import Prospect5, FourSAIL
# Simulate leaf full optical spectrum (400-2500nm)
wl, rho_leaf, tau_leaf = Prospect5.Prospect5(Nleaf, Cab, Car, Cbrown, Cw, Cm)
# Estimate the Leaf Inclination Distribution Function of a canopy
lidf = CalcLIDF_Campbell(alpha)
# Simulate leaf reflectance and transmittance factors of a canopy
tss, too, tsstoo, rdd, tdd, rsd, tsd, rdo, tdo, rso, rsos, rsod, rddt, rsdt, rdot, rsodt, rsost,
↪rsot, gammasdf, gammasdb, gammasowl = FourSAIL.FourSAIL(lai, hotspot, lidf, SZA, VZA,
↪PSI, rho_leaf, tau_leaf, rho_soil)
# Simulate the canopy reflectance factor for a given diffuse/total radiation
↪condition (skyl)
rho_canopy = rdot*skyl+rsot*(1-skyl)
```

You can type `help(FourSAIL.FourSAIL)` to understand better the inputs needed and the outputs returned

## 2.1.4 Basic Contents

## High-level modules

- `.src/pyPro4SAIL.py`

Runs the coupled Prospect5+4SAIL to estimate the canopy directional reflectance factor and 4SAIL to estimate the land-leaving broadband thermal radiance.

## Low-level modules

The low-level modules in this project are aimed at providing customisation and more flexibility in running TSEB. The following modules are included.

- `.src/Prospect5.py`

core functions for running Prospect5 Leaf Radiative Transfer Model.

- `.src/FourSAIL.py`

core functions for running 4SAIL Canopy Radiative Transfer Model.

- `.src/CostFunctionsPROSPECT4SAIL.py`

merit functions used to invert Prospect and/or 4SAIL from a given spectrum

- `.src/cma.py`

Covariance Matrix Adaptation Evolution Strategy optimization method for inverting Prospect5 and/or 4SAIL.

## 2.1.5 API Reference

<http://pyPro4Sail.readthedocs.org/en/latest/index.html>

## 2.1.6 Main Scientific References

- S. Jacquemoud, F. Baret, PROSPECT: A model of leaf optical properties spectra, Remote Sensing of Environment, Volume 34, Issue 2, November 1990, Pages 75-91, ISSN 0034-4257, [http://dx.doi.org/10.1016/0034-4257\(90\)90100-Z](http://dx.doi.org/10.1016/0034-4257(90)90100-Z).
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- W. Verhoef, L. Jia, Q. Xiao and Z. Su, Unified Optical-Thermal Four-Stream Radiative Transfer Theory for Homogeneous Vegetation Canopies, IEEE Transactions on Geoscience and Remote Sensing, vol. 45, no. 6, pp. 1808-1822, June 2007. <http://dx.doi.org/10.1109/TGRS.2007.895844>.

## 2.1.7 Tests

*to be included*

### 2.1.8 Contributors

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### 2.1.9 License

pyPro4Sail: a Python Two Source Energy Balance Model

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## 2.2 pyPro4SAIL package

## 2.3 Prospect5 package

## 2.4 FourSAIL package

## 2.5 Prospect5Jacobian package

## 2.6 FourSAILJacobian package

## 2.7 CostFunctionsPROSPECT4SAIL package

## CHAPTER 3

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### Indices and tables

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