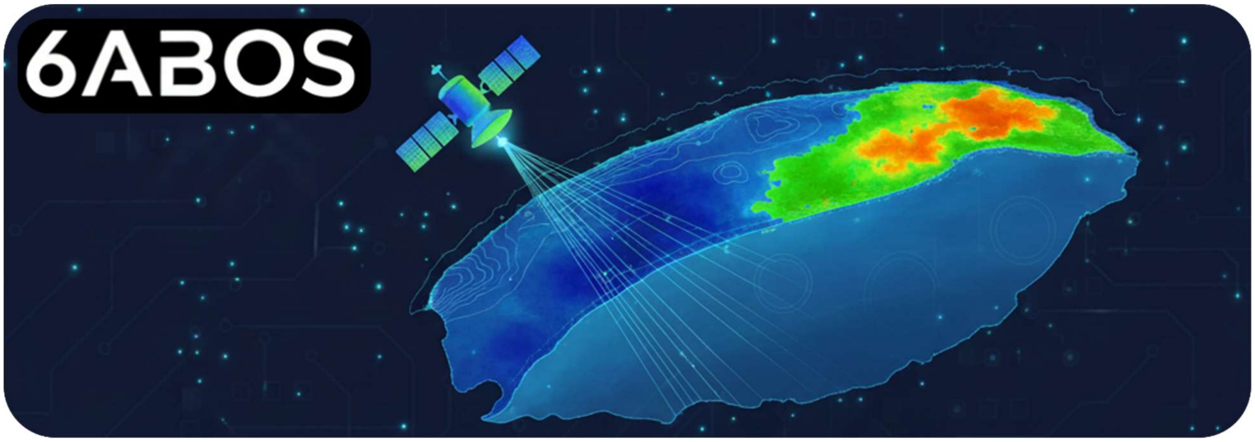
6ABOS User Manual

6S-based Atmospheric Background Offset Subtraction



Introduction

6ABOS is a Python-based framework designed for the atmospheric correction of EnMAP hyperspectral satellite imagery. By utilising the 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) radiative transfer model via the Py6S interface, it allows for a rigorous, physics-based retrieval of surface reflectance.

6ABOS retrieves surface reflectance (ρ_s) by inverting the following radiative transfer equation:

$$\rho_{BOA}(\lambda) = \frac{\left(\frac{L_{TOA}(\lambda)}{T_{g,O_3}(\lambda)} - L_{path}(\lambda)\right)}{\frac{E_s(\lambda)\cdot T_{\uparrow}(\lambda)}{\pi} + S_{atm}(\lambda)\left(\frac{L_{TOA}(\lambda)}{T_{g,O_3}(\lambda)} - L_{path}(\lambda)\right)}$$

Where:

- $L_{TOA}(\lambda)$: TOA radiance.
- $T_{g,O_3}(\lambda)$: Ozone transmittance.
- $L_{path}(\lambda)$: Atmospheric path radiance (Rayleigh + Aerosol scattering).
- $E_s(\lambda)$: Solar irradiance at TOA.
- $T_{\uparrow}(\lambda)$: Upward atmospheric transmittance.
- $S_{atm}(\lambda)$: Spherical albedo of the atmosphere.

6ABOS

1. Getting started

6ABOS is currently distributed as a research repository. To use the framework, you must clone the source code and set up a local Python environment that matches the project dependencies.

1.1 Prerequisites

- Anaconda: Required to manage the environment and the 6s executable.
- Git: To clone the repository.

2. Installation & environment setup

Since 6ABOS is not yet a standalone package, users must replicate the development environment locally using Conda.

2.1 Step 1: Clone the repository

Download the source code to your local machine:

Bash

```bash
git clone https://github.com/PhD-Gabriel-Caballero/6ABOS.git
cd 6ABOS
```

2.2 Step 2: Create the Conda environment

The repository includes an environment.yml file that contains all necessary dependencies, including the 6s executable and Py6S.

Bash

```bash
conda env create -f environment.yml
conda activate 6abos_env
```

2.3 Step 3: Verify requirements

If you prefer to manage your environment manually, ensure all libraries listed in the requirements.txt file are installed:

Bash

```bash
pip install -r requirements.txt
```

3. Operational workflow

The primary interface for 6ABOS is the Jupyter notebook environment, which allows for step-by-step processing of the atmospheric correction workflow.

3.1 Launching the workspace

1. Activate your conda environment: `conda activate 6abos_env`
2. Start the Jupyter server: `jupyter notebook`
3. Open the file: `notebooks/EnMAP/6ABOS_EnMAP_AC_v1.2_Dic_2025.ipynb`

3.2 Configuration: The config dictionary

The execution of 6ABOS is driven by a configuration dictionary found in the first cells of the Jupyter notebook. Below is a breakdown of how to fill each parameter to match your project requirements.

3.2.1 Global flags

Key	Type	Description
`"verbose"`	bool	Set to True to print detailed status messages during execution.
`"data exporting"`	bool	Enables the export of intermediate data structures.
`"data plotting"`	bool	If True, the notebook will generate spectral plots (TOA vs. BOA) for visual validation.
`"data storing"`	bool	Set to True to save the final output file to the disk.

3.2.2 Sensor & spectral settings

Key	Type	Description
"VNIR"	bool	⚠ **(Work in Progress).** By default, this is set to False to process the combined VNIR + SWIR data cubes. Setting this to True restricts processing to the VNIR detector only; this feature is currently being optimised for standalone VNIR analysis.
"GEE"	bool	When activated, the system will dynamically fetch atmospheric constituents from GEE catalogues instead of utilising the AOD, WV, and O_3 values available in the METADATA.xml of EnMAP L1C files.
"max_wavelength"	int	Upper spectral limit in nm (default for EnMAP is 2480).
"min_wavelength"	int	Lower spectral limit in nm (default for EnMAP is 379).
"wavelength_step"	float	Spectral resolution step (usually 2.5 nm for 6S simulations).
"tgas_threshold"	float	Threshold for total gaseous transmissivity. Bands with values below this (e.g., 0.75) are considered heavily contaminated by absorption and are typically masked.

💡 **Note on GEE Integration:** If `"GEE"` is set to `True`, you must have a valid Google Earth Engine account and the `earthengine-api` authenticated on your machine. The system will automatically query global atmospheric products to provide the necessary inputs for the 6S model.

3.2.3 Directory paths

Note: Use the `r'path'` (raw string) prefix in Python to avoid issues with backslashes on Windows.

- **`input_dir`**: The local path to your EnMAP L1C folder (containing the .xml metadata and GeoTiff spectral data).
- **`output_dir`**: The destination path where your processed L2 (BOA) data will be saved.

3.2.4 Output type

- **`output_rrs:`** Determines the output product type; set to False for Surface Reflectance [0-1] or True for Remote Sensing Reflectance [sr^{-1}].

Example configuration snippet

Python

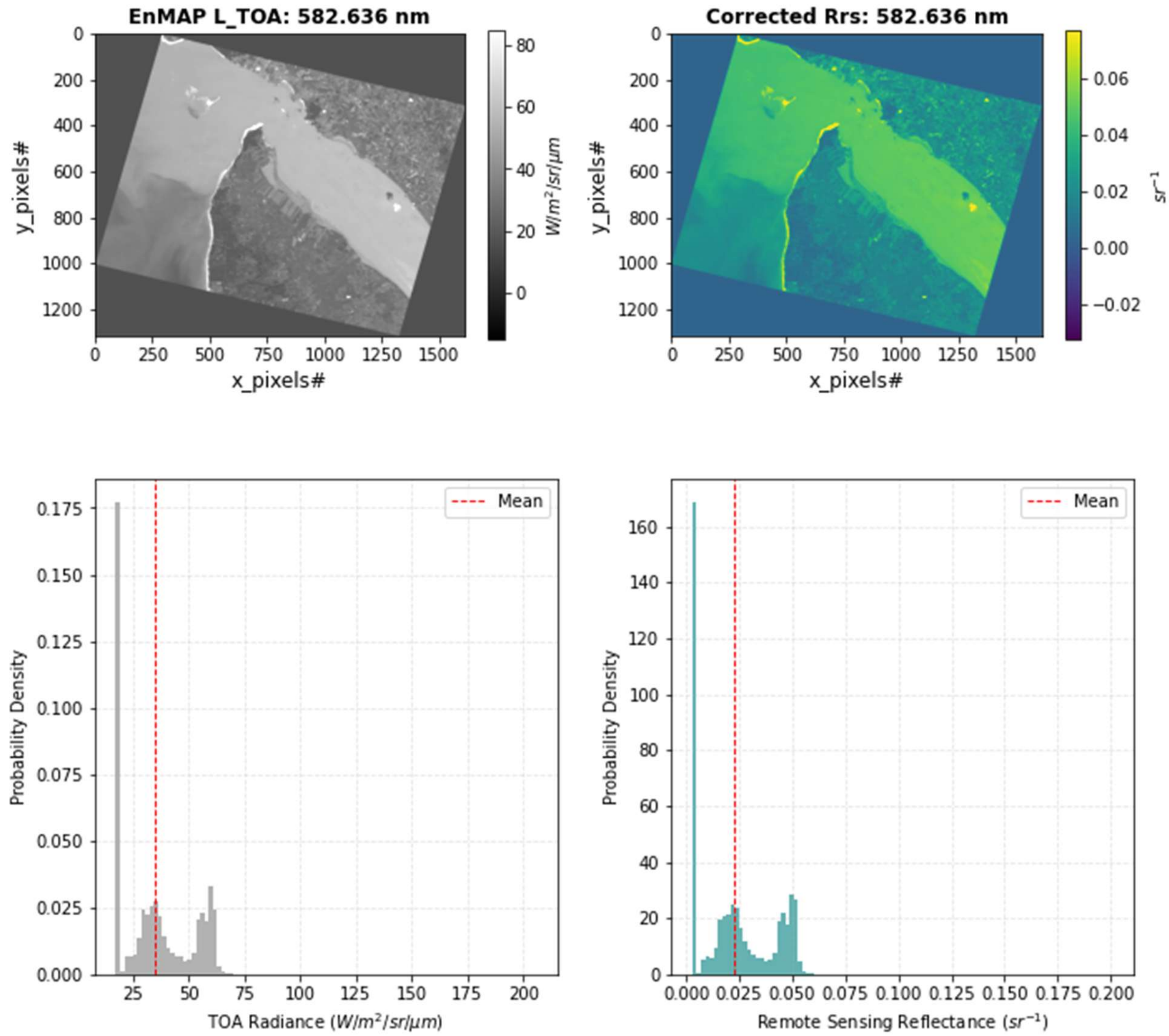
```python
# Configuration dictionary for a standard EnMAP L1C scene
conf = {
    "verbose": True,
    "data exporting": False,
    "data plotting": True,
    "data storing": True,
    "testing": False,
    "VNIR": False,
    "GEE": False,
    "max_wavelength": 2480,
    "min_wavelength": 379,
    "wavelength_step": 2.5,
    "tgas_threshold": 0.75,
    "input_dir": r'C:\Data\EnMAP_Scene_L1C',
    "output_dir": 'C:/6ABOS_Results/',
    "output_rrs": False # Returns rho_boa
}
```

4. Tutorial: Analyzing results & outputs

After running the processing cells in the Jupyter notebook, 6ABOS generates several outputs to help you validate the quality of the atmospheric correction.

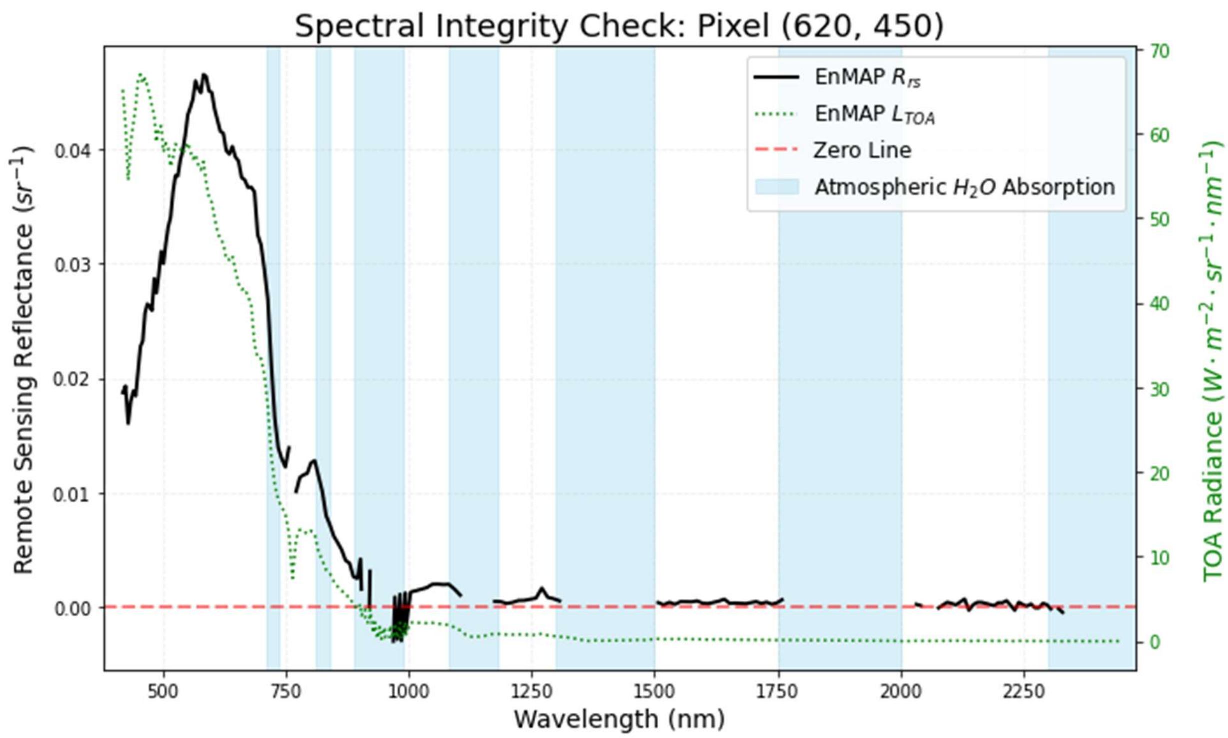
4.1 Per-band real-time monitoring

As 6ABOS processes the hyperspectral cube, it generates a diagnostic figure for each band (e.g., at 582.636 nm). This allows the user to monitor the atmospheric correction performance in real-time.



4.2 Spectral Signature Validation

The most critical output is the spectral comparison plot. 6ABOS automatically generates a figure showing the Top-of-Atmosphere radiance versus the Bottom-of-Atmosphere reflectance.



5. How to cite

If you use 6ABOS in your research, please cite the repository as follows:

Standard citation

Caballero, G. [ORCID]. (2025). 6ABOS: 6S-based Atmospheric Background Offset Subtraction Framework (Version 1.0.0). GitHub. https://github.com/PhD-Gabriel-Caballero/6ABOS

BibTeX (for LaTeX)

```
@software{Caballero_6ABOS_2025,
      author = {Caballero, Gabriel},
      title  =  {{6ABOS:  6S-based  Atmospheric  Background  Offset  Subtraction
      Framework}},
      url = {https://github.com/PhD-Gabriel-Caballero/6ABOS},
      version = {1.0.0}, year = {2025}
}
```