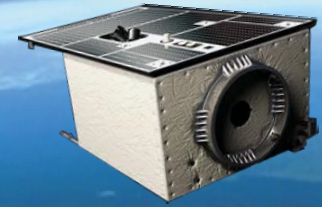


An alternative pre-processing chain for hyperspectral EnMAP data



Daniel Scheffler¹, Maximilian Brell¹, Niklas Bohn¹, Leonardo Alvarado²,
Mariana A. Soppa², Karl Segl¹, Astrid Bracher^{2,3}, Sabine Chabrillat^{1,4}

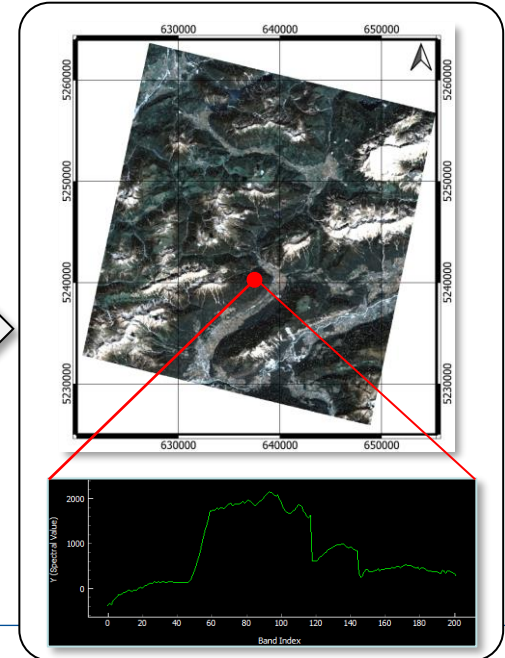
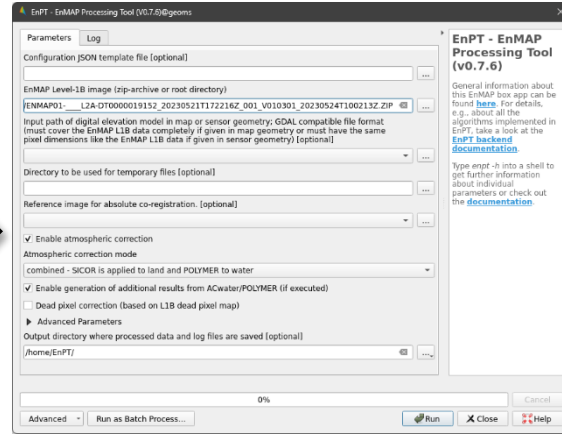
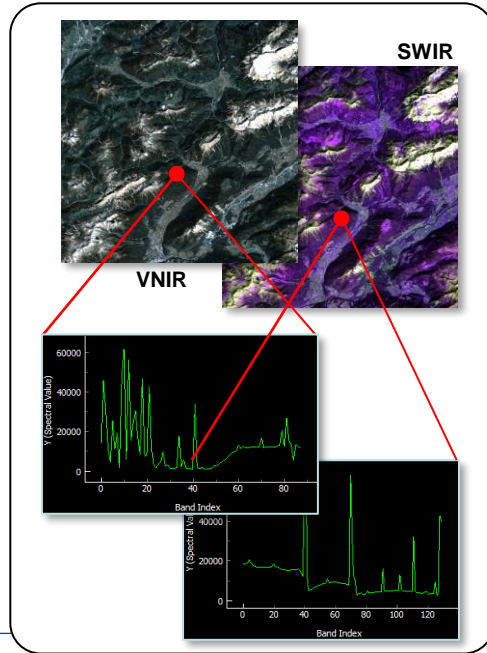
¹GFZ Potsdam, ²AWI Bremerhaven, ³University Bremen, ⁴Leibniz University Hannover

EnMAP Processing Tool - EnPT

A pre-processing software for EnMAP hyperspectral data:

- **Input:** EnMAP Level 1B image (only radiometrically corrected, not ready-to-use)
- **Output:** EnMAP Level 2A image (accurately georeferenced, atmospherically corrected, ready-to-use)

Level 1B

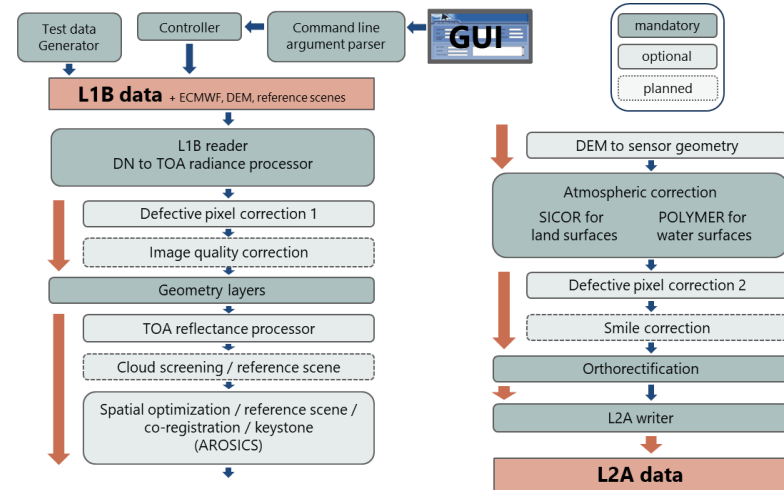


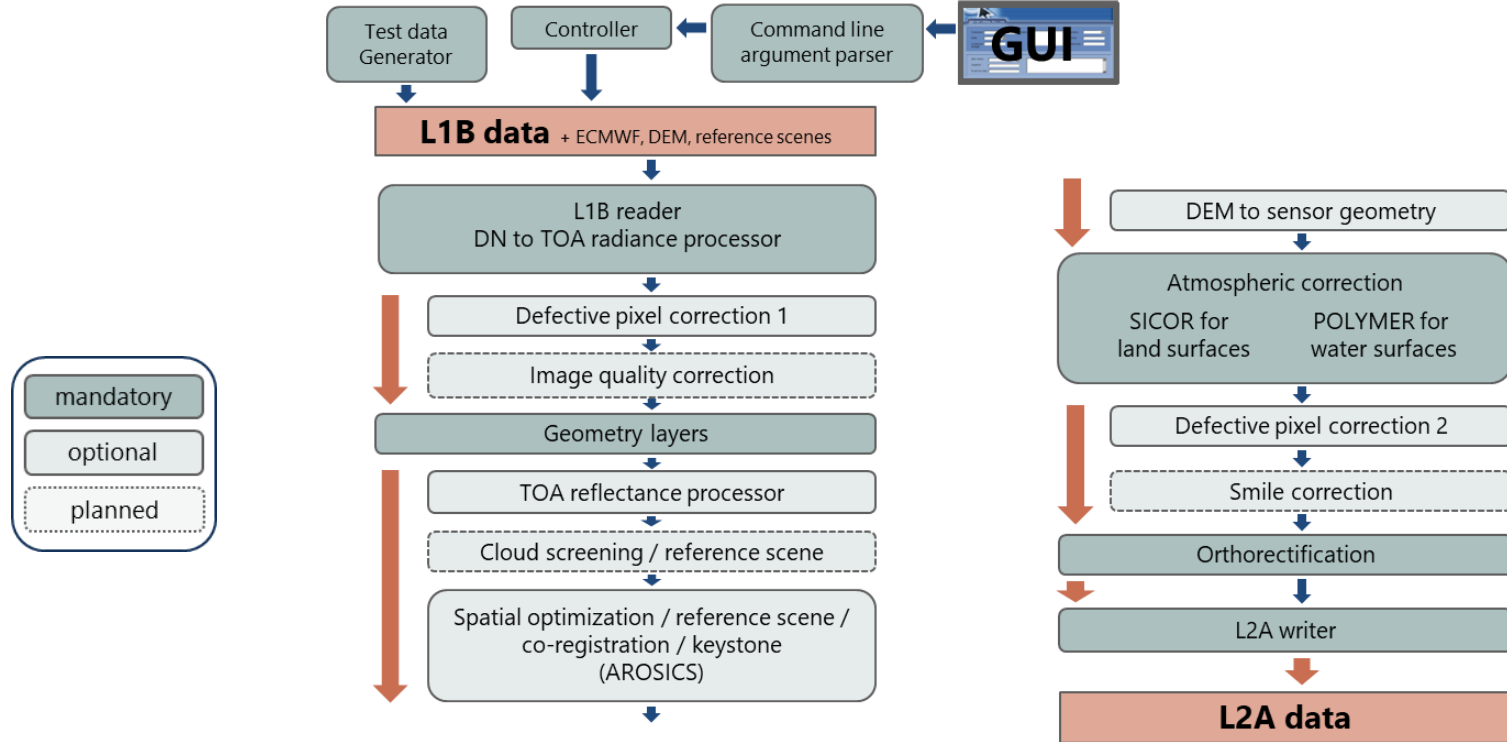
Level 2A



A pre-processing chain to process EnMAP Level-1B data to Level-2A

- GFZ open-source alternative to the processing chain of the EnMAP Ground Segment
- Available as a **standalone Python package** or accessible via a graphical user interface as a **plugin of the EnMAP-Box**
- Relies on open-source algorithms such as **AROSICS, SICOR and Polymer (HYGEOS)**



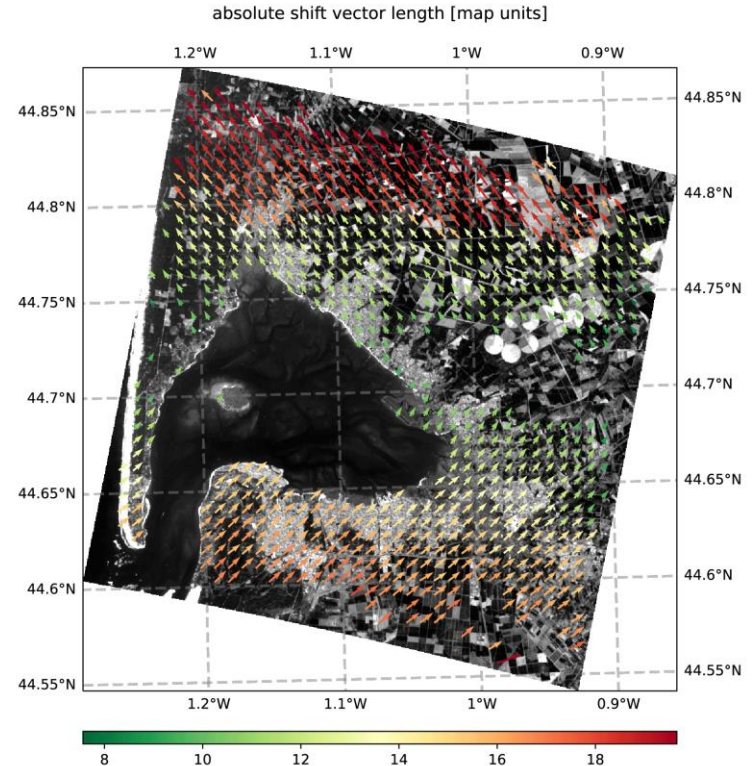


Automatic detection and correction of spatial mis-registrations

- Based on AROSICS (Scheffler et al. 2017)
- Automatic tie-point creation with regard to a user provided reference image
- Open-source Python package available at: <https://git.gfz-potsdam.de/danschef/arosics>

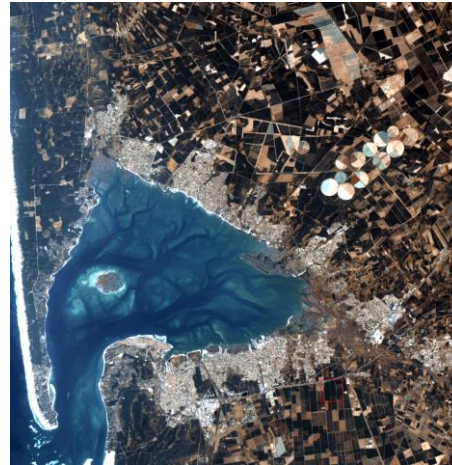


AROSICS
repository

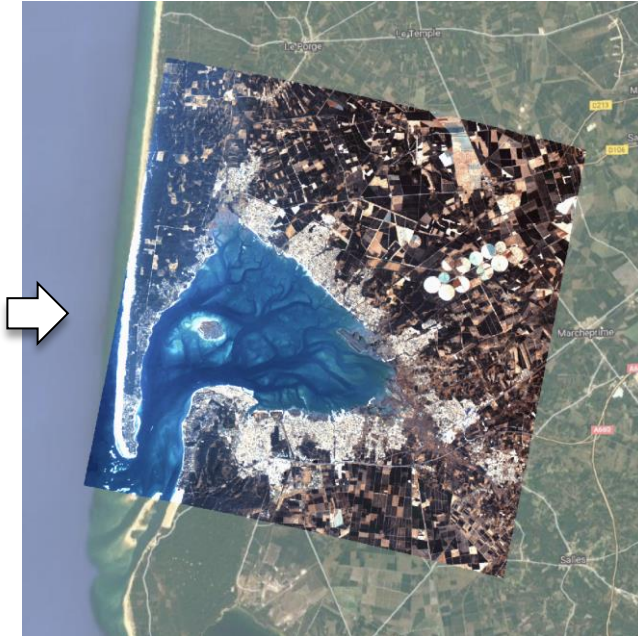


Transformation from sensor to map geometry

- Based on rational polynomial coefficients (RPC)
- Requires a digital elevation model
- Result refined by the tie points created by AROSICS

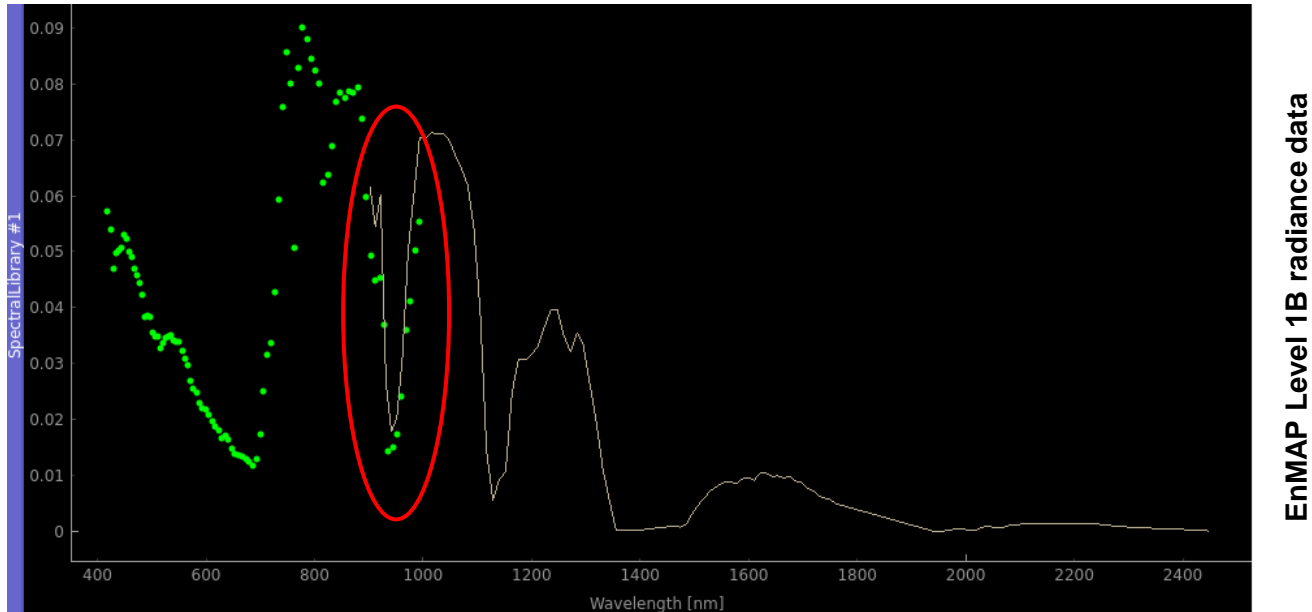


Arcachon, tile 2, Level 1B



Arcachon, tile 2, Level 2A

Spectral overlap between VNIR and SWIR needs to be handled:



Two algorithms implemented:

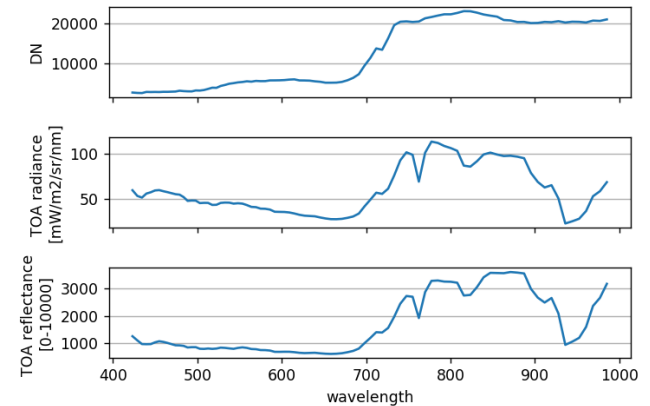
- **SICOR (GFZ)**: mainly for land surfaces
- **ACwater/Polymer (AWI)**: water surfaces



SICOR
repository

Three modes of atmospheric correction:

- **land**: SICOR applied to all surfaces
- **water**: ACwater/Polymer applied to water only
- **combined**: SICOR applied to land and ACwater/Polymer to water surfaces



Sensor **I**ndependent atmospheric **COR**rection of optical Earth Observation data

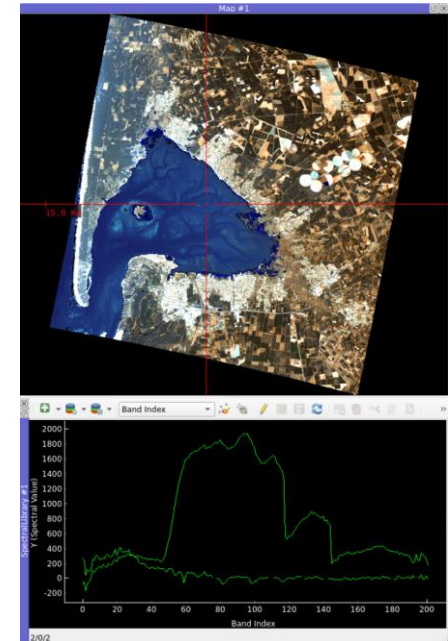
(Bohn, Scheffler, Brell, Preusker, Diedrich, Hollstein 2016)

- **Optimal Estimation (OE)**
- **MODTRAN® Radiative Transfer Code**
- **Available as Git Repository and as Python package on PyPI and conda-forge:**

<https://git.gfz-potsdam.de/EnMAP/sicor>

<https://pypi.org/project/sicor>

<https://anaconda.org/conda-forge/sicor>



- **Features:**

- **Simultaneous retrieval of atmospheric water vapor, surface liquid water, and ice** path lengths by fitting absorption features at 940 and 1140 nm (Green et al. 2006, Fig. 1)
- **SLIC Segmentation + Empirical Line Solution** (Thompson et al. 2019)
- Optional output of several **retrieval uncertainty measures** from OE:
 - * Jacobian of solution state
 - * Convergence message
 - * Number of iterations
 - * Gain matrix
 - * Averaging kernel matrix
 - * Value of cost function
 - * Degrees of freedom
 - * Information content
 - * Retrieval noise
 - * Smoothing error

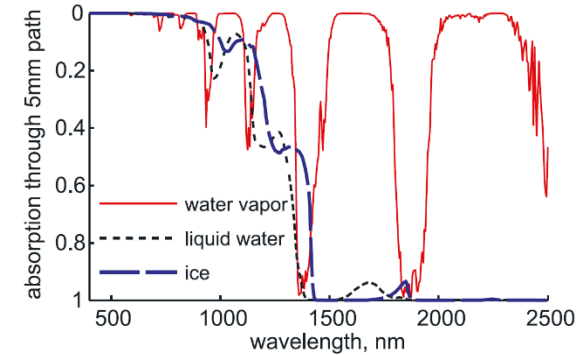
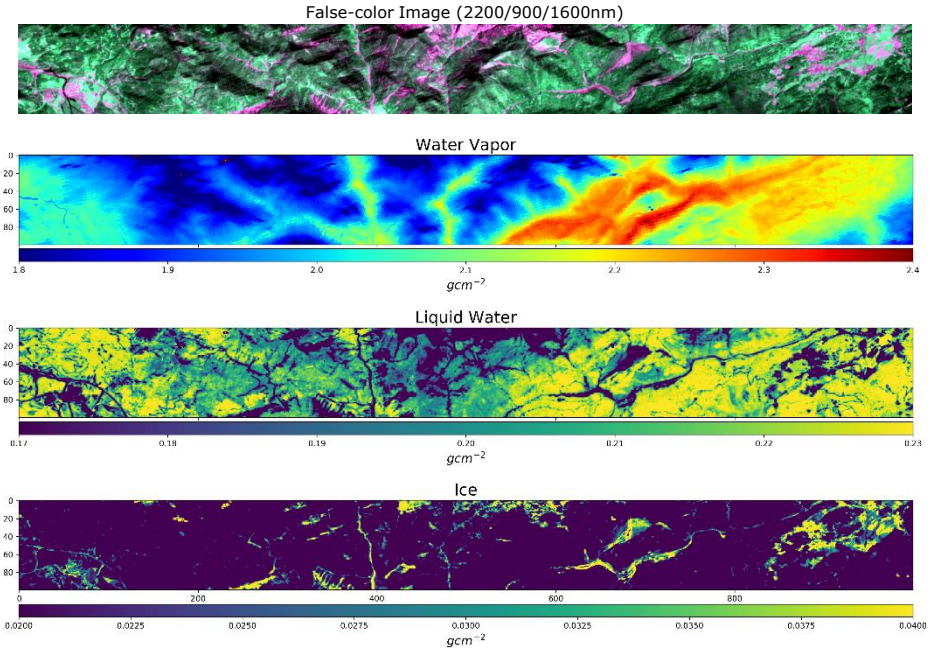
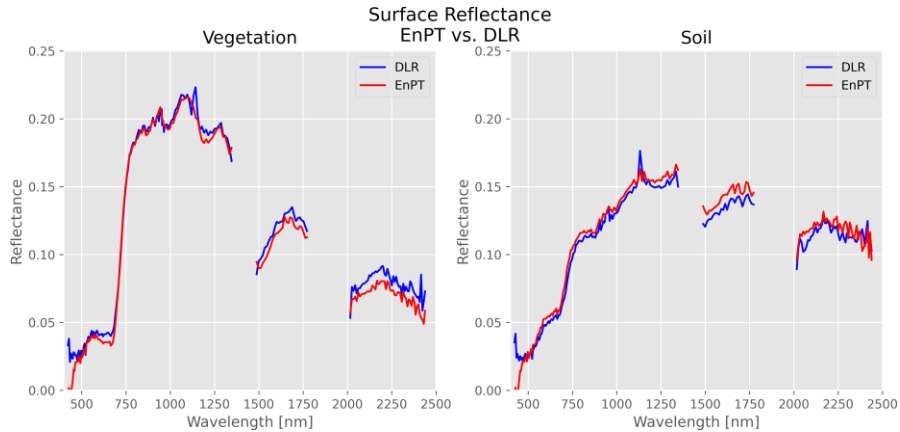


Fig. 1: Absorption spectra of water vapor, liquid water, and ice at 10 nm spectral resolution, calculated for 5 mm path lengths (Green et al. 2006).

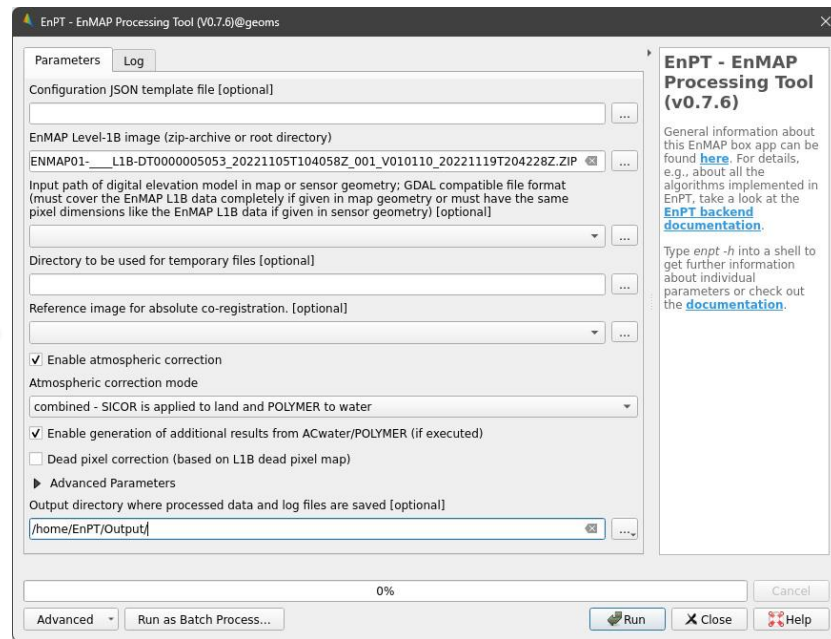
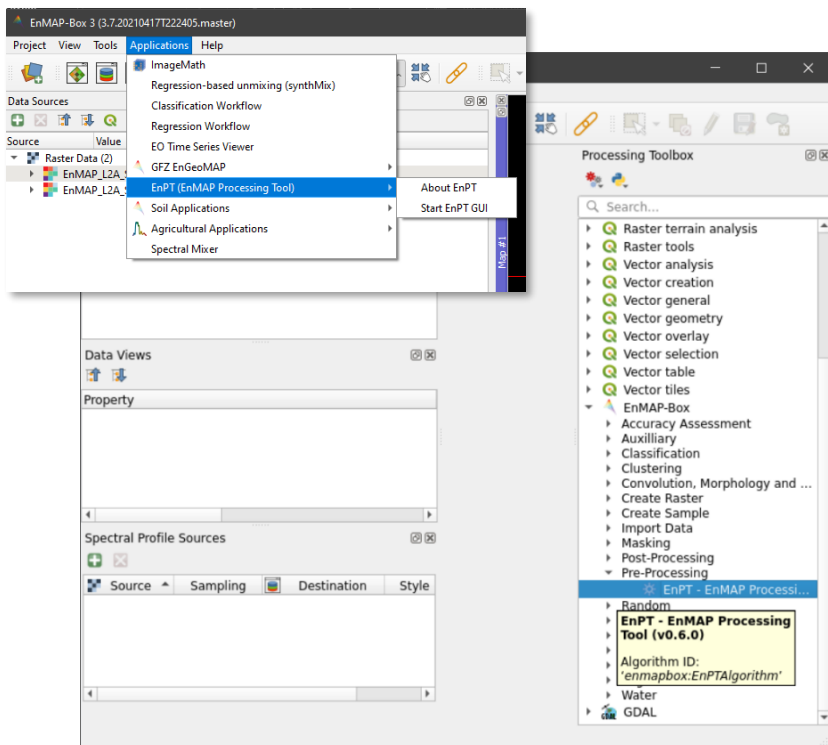
Products: surface reflectance (HDRF), water vapor, liquid water and ice maps





Planned features and improvements:

- Add SICOR retrieval maps to EnPT L2A output
- Revise and speed-up the orthorectification module
- Implement ISOFIT as alternative atmospheric correction approach
 - Improved overall correction performance
 - BOA reflectance uncertainties
- Improve water mask, include own cloud masks?
- Evaluate EnPT on real EnMAP data and publish results





EnPT – The EnMAP Processing Tool – Code Repository



EnPT repository



The screenshot shows the GitLab interface for the EnPT repository. At the top, it displays the repository name 'EnPT' and project ID '88'. Below this, it shows statistics: 980 Commits, 5 Branches, 85 Tags, and 2 GB Project Storage. The main content area shows a commit message: 'Merge branch 'maintenance/update_tutorial' into 'master'' by Daniel Scheffler, dated Mar 1, 2023, 11:54 PM. Below the commit message, there are buttons for 'Find file', 'Web IDE', 'Clone', and 'Add Kubernetes cluster'. A table lists the repository's directory structure and the last commit for each:

Name	Last commit	Last update
.github	Releases in the GitHub-Mirror-Repository...	Apr 9, 2020, 1:52 PM
docs	Final revisions.	Mar 1, 2023, 11:42 PM
enpt	Bump version.	Mar 1, 2023, 1:48 AM
examples/notebooks	Updated copyright within license notes. ...	Oct 23, 2019, 5:00 PM
tests	Add typeguard to enmapbox requirements.	Mar 1, 2023, 12:32 PM
.coveragerc	Fix issue #81 [Coverage raises warnings ...	Jan 3, 2022, 10:37 PM
.gitattributes	Improved Test_Spatial_Optimizer_DLR. Ad...	Sep 21, 2020, 11:43 AM

https://git.gfz-potsdam.de/EnMAP/GFZ_Tools_EnMAP_BOX/EnPT

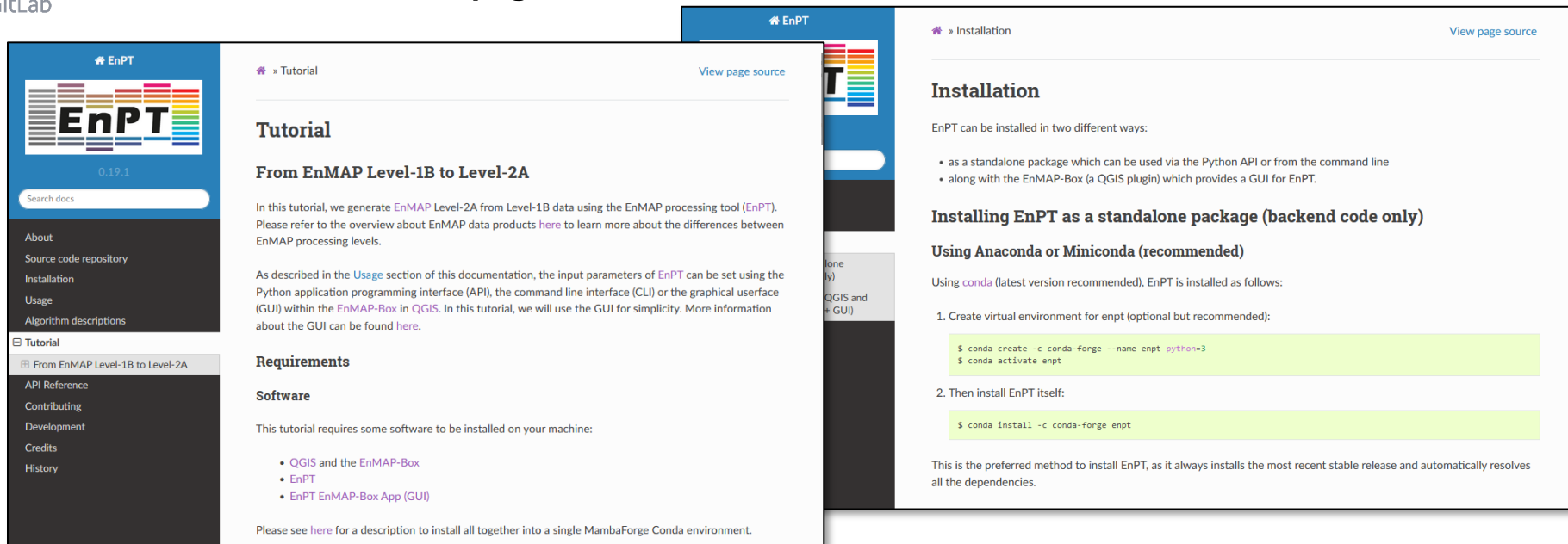
Issue tracker:

The screenshot shows the GitLab issue tracker for the EnPT repository. It displays a list of issues with the following details:

- Open:** 26, **Closed:** 75, **All:** 101
- Search and filter results...** (with a search icon and a dropdown for 'Created date')
- Issue #97:** RuntimeError appears in combination with overzided DEM and gapfill options. Created Feb 9, 2023, 3:11 PM by Maximilian Brett. Status: Bug report. Updated Mar 2, 2023, 6:41 PM.
- Issue #94:** Remaining image stripes in L2A result. Created Jan 19, 2023, 6:02 PM by Daniel Scheffler. Status: Enhancement. Updated Jan 19, 2023, 6:06 PM.
- Issue #93:** Re-enable first guess water vapor retrieval. Created Dec 8, 2022, 7:40 PM by Daniel Scheffler. Updated Dec 8, 2022, 7:43 PM.
- Issue #88:** Adapt output filenames to clearly reflect EnPT as processing chain + EnPT version. Created Aug 19, 2022, 11:46 AM by Daniel Scheffler. Status: Enhancement. Updated Mar 1, 2023, 1:25 AM.
- Issue #86:** ValueError during SNR computation due to unexpected number of bands. Created Aug 11, 2022, 2:51 PM by Daniel Scheffler. Status: To Do. Updated Aug 11, 2022, 2:53 PM.
- Issue #85:** Nodata value of 0 causes L2A image to look holey in QGIS. Created Mar 21, 2022, 6:57 PM by Daniel Scheffler. Status: Enhancement. Updated Mar 21, 2022, 7:08 PM.
- Issue #83:** Mask output files should always be saved with BSQ interleave. Created Feb 15, 2022, 9:46 PM by Daniel Scheffler. Status: Enhancement. Updated Feb 15, 2022, 9:46 PM.
- Issue #82:** Improve documentation of advanced parameters. Created Feb 8, 2022, 11:01 AM by Daniel Scheffler. Status: Enhancement. Updated Feb 8, 2022, 11:03 AM.
- Issue #80:** Use 'new_kurucz' solar model when calling SICOR for simulated EnMAP data. Created Jul 1, 2021, 3:36 PM by Daniel Scheffler. Status: To Do. Updated Feb 17, 2023, 4:15 PM.



GitLab documentation page:



The screenshot displays the GitLab documentation page for EnPT. The page is divided into several sections:

- Tutorial**: A section titled "From EnMAP Level-1B to Level-2A" which describes generating EnMAP Level-2A data from Level-1B data using the EnMAP processing tool (EnPT). It includes a "Requirements" section listing QGIS and the EnMAP-Box, and a "Software" section stating that the tutorial requires some software to be installed on the machine.
- Installation**: A section titled "Installing EnPT as a standalone package (backend code only)" which provides instructions on how to install EnPT using conda. It includes a list of steps and code snippets for creating a virtual environment and installing EnPT.

https://enmap.git-pages.gfz-potsdam.de/GFZ_Tools_EnMAP_BOX/EnPT/doc/

EnPT - EnMAP Processing Tool

Free software (GNU General Public License v3 or later (GPLv3))

Features overview

- Free software license (GPL)
- Open-source code
- Automated and robust open-source image co-registration software
- Free software license (GPL)
- Open-source code
- Automated and robust open-source image co-registration software

History / Changing

Recent changes (please see the [EnPT package log](#).)

Credits

This software was developed within the context of the EnMAP project supported by the EU Space Administration with funds of the German Federal Ministry of Economic Affairs and Energy on the basis of a contract with Space Technology (STW) (50% contribution from ESA, 50% and 50% from STW).

Software is further enhanced and data have been provided by:

This package was created with [Conan.io](#) and the [conda/conda-recipes](#) ecosystem templates.



EnPT @ GitLab



AROSICS @ GitLab



SICOR @ GitLab

Thank you for your attention!

Dr. Daniel Scheffler
daniel.scheffler@gfz-potsdam.de
 Tel.: +49 331 6264 3041

AROSICS

An Automated and Robust Open-Source Image Co-Registration Software for Multi-Sensor Satellite Data

Features overview

- Free software license (GPL)
- Open-source code
- Automated and robust open-source image co-registration software

Global co-registration - fast but only for static 3DvTs

Global co-registration is a pipeline to co-register a multi-sensor satellite image stack based on an image matching approach. It is designed to be used for the registration of multi-sensor satellite data. It is designed to be used for the registration of multi-sensor satellite data. It is designed to be used for the registration of multi-sensor satellite data.

Recent publications

Recent publications related to the software include:

- Scheffler, D., & Schmitt, M. (2018). AROSICS: An Automated and Robust Open-Source Image Co-Registration Software for Multi-Sensor Satellite Data. *Remote Sensing*, 10(12), 1912.
- Scheffler, D., & Schmitt, M. (2019). AROSICS: An Automated and Robust Open-Source Image Co-Registration Software for Multi-Sensor Satellite Data. *Remote Sensing*, 11(1), 1.

SICOR - Sensor Independent Atmospheric Correction

SICOR is a software tool for the atmospheric correction of satellite data. It is designed to be used for the atmospheric correction of satellite data. It is designed to be used for the atmospheric correction of satellite data.