The EnMAP Ground Segment Processor for Aquatic Applications

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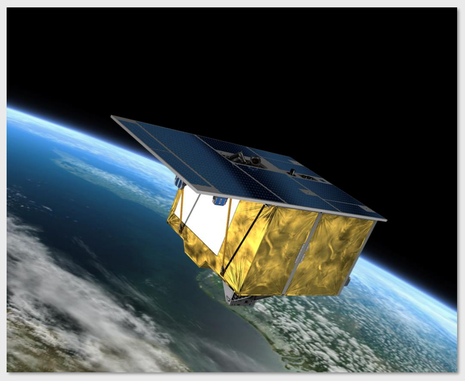
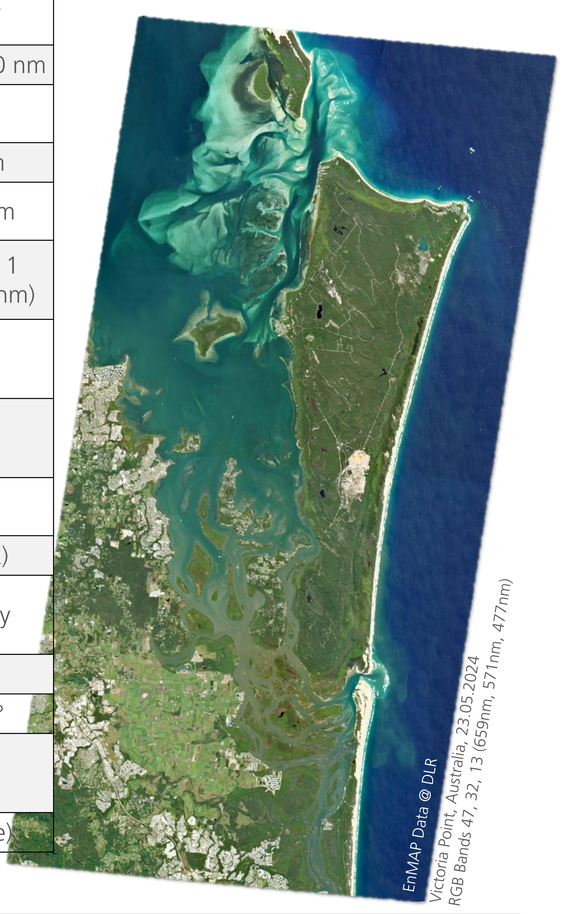
EnMAP (Environmental Mapping and Analysis Program; www.enmap.org), the Environmental Mapping and Analysis Program, is a German satellite mission that was successfully launched in April 2022. EnMAP is an optical (VNIR/SWIR) remote sensing mission with high spatial (30 m GSD) and spectral (FWHM ~6-12 nm) resolution. While initially designed for terrestrial applications, EnMAP holds significant potential for aquatic studies due to its hyperspectral capabilities. What stands out is its separate processing chains for land and water pixels within the L2A processing, offering two types of water reflectance data: subsurface irradiance reflectance and normalized water leaving reflectance.

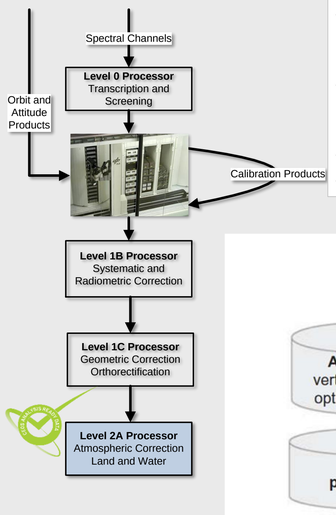


Instrument characteristics and requirements	VNIR	SWIR
Spectral range	420 – 1000 nm	900 -2450 nm
Number of spectral channels	91	133
Spectral sampling interval	6.5 nm	10 nm
Spectral bandwidth (FWHM)	8.1 nm	12.5 nm
Signal to Noise ratio (SNR)	≥ 500 : 1 (@500 nm)	≥ 150 : 1 (@2200 nm)
Radiometric accuracy (absolute)	<5%	
Radiometric stability (between calibrations)	<2.5%	
Spectral accuracy (absolute)	0.5 nm	0.5 nm
Swath width	**30 km** (2.63° across track)	
Swath length - Max. length / day	1000 km - 5000 km / day	
Orbit characteristics		
Orbit / Inclination	sun-synchronous / 97.96°	
Target revisit time	27 days (VZA ≤ 5°) 4 days (VZA ≤ 30°)	
Equator crossing time	11:00 ± 18 min (local time)	

Instrument and Orbit characteristics

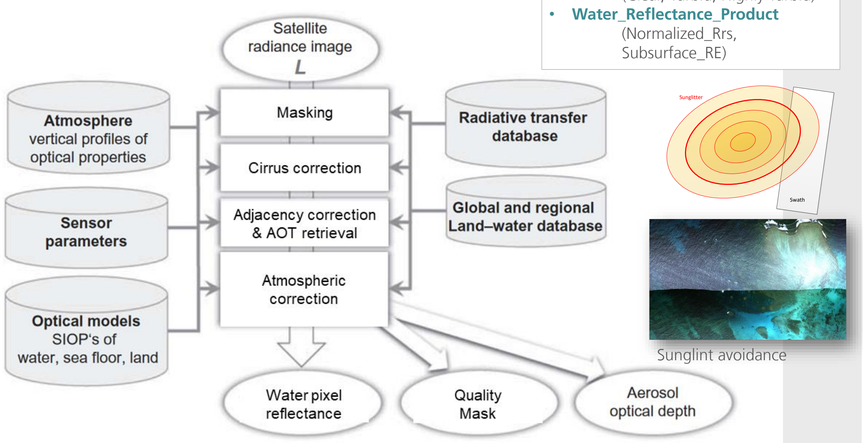


Processing Chain



- **Level 1 B**
  top-of-atmosphere radiance
- **Level 1C**
  geometrically corrected (orthorectified) and re-sampled to a specified map grid
- **Level 2 A**
  Converts Level 1C products to surface reflectances separately for **land and water.**
- Calibration of the instrument during operations
- Quality control of the products.

L2A User Parameters:
- **Correction_Type** (Combined, Land, Water)
- **Terrain_Correction** (Automatic, Yes, No)
- **Band_Interpolation** (Yes, No)
- **Cirrus_Haze_Removal** (No, Cirrus, Cirrus/Haze)
- **Ozone_Column** (Automatic, Custom Value)
- **Season** (Automatic, Summer, Winter)
- **Water_Type** (Clear, Turbid, Highly Turbid)
- **Water_Reflectance_Product** (Normalized_Rrs, Subsurface_RE)

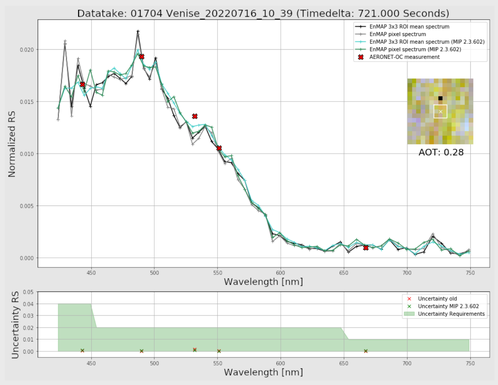


Sunglint avoidance

Modular Inversion Processor (MIP)

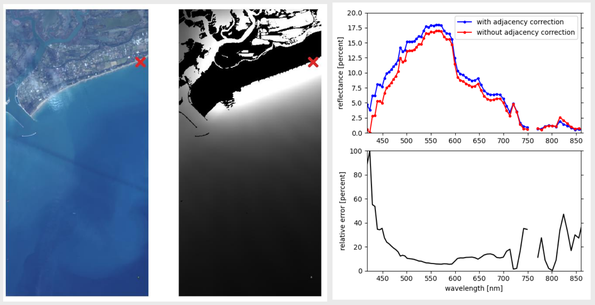
Fully physics-based processor for EnMAP AC correction over water, includes coupled AC-water retrieval

L2A Water Processing Updates



Version 01.04.02 Spectral noise in water spectra below 500 nm in L2A water products.

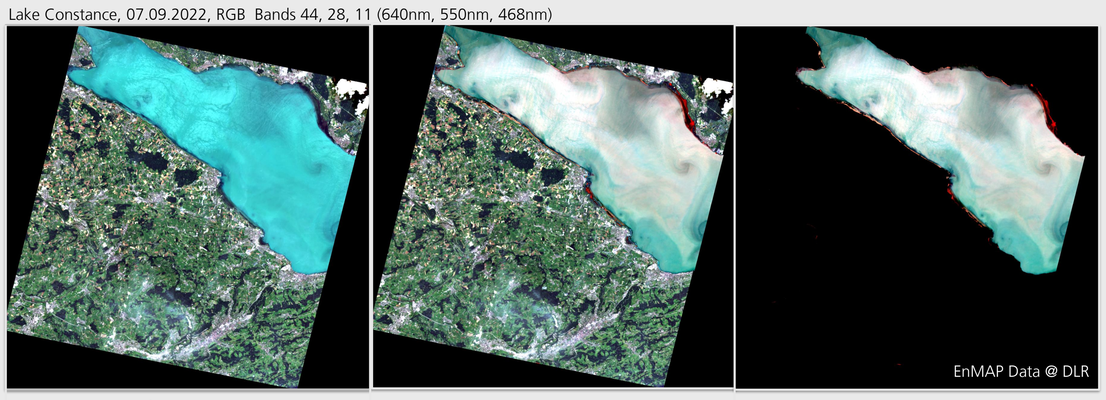
- **Version 01.04.00:** Re-activated adjacency correction over water in L2A water products.
- **Version 01.04.02:** Fixed spectral noise in water spectra below 500 nm in L2A water products.



Version 01.04.00 Adjacency correction over water in L2A water products. Bay of Venice, 16.03.2023. Adjaceny radiance for band 10 at 463 nm.

L2A Data Products

Lake Constance, 07.09.2022, RGB Bands 44, 28, 11 (640nm, 550nm, 468nm)

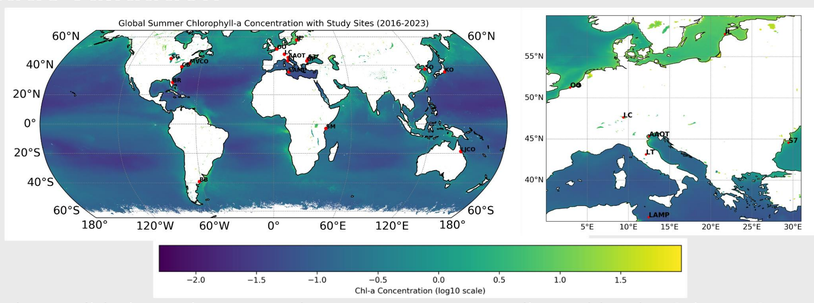


L2A Land	L2A Combined	L2A Water
Land pixels ➡ Remote sensing reflectance Water pixels ➡ Remote sensing reflectance	Land pixels ➡ Remote sensing reflectance Water pixels ➡ Normalised water leaving reflectance OR Subsurface irradiance reflectance	Land pixels ➡ not processed Water pixels ➡ Normalised water leaving reflectance OR Subsurface irradiance reflectance
Remote sensing reflectance	Subsurface irradiance reflectance	Normalised water leaving reflectance
$Rrs = \frac{L_u}{E_d}$	$R^0(\Theta_s) = \frac{E_u^0(\Theta_s)}{E_d^0(\Theta_s)}$	$R_N = \pi * Rrs^{\{0+\}}(0,0) = \frac{\pi L_u^{\{0+\}}(0,0)}{E_d^{\{0+\}}(0)}$

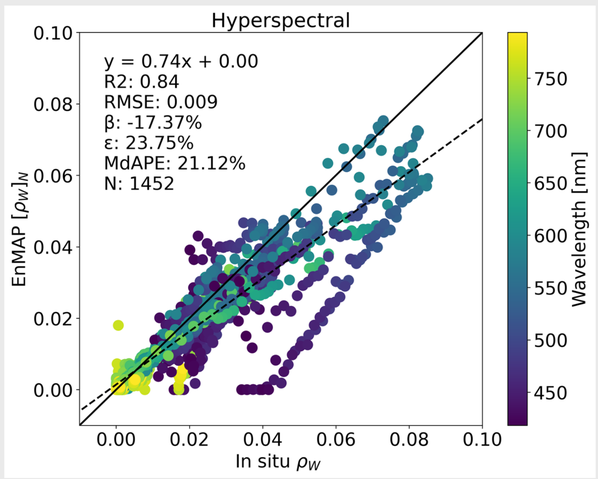
Free and open data policy

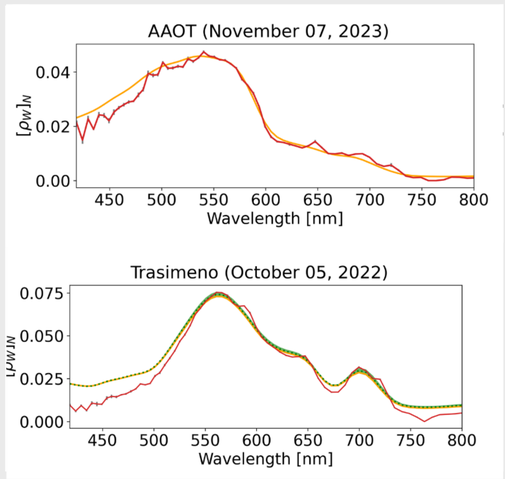
Data Access: https://planning.enmap.org/

L2A Aquatic Validation



Independent validation using ground measurements coordinated by the Science Segment





Soppa, M.A. et al, (2024) Full mission evaluation of EnMAP water leaving reflectance products using three atmospheric correction processors, Opt. Express 32, 28215-28230. https://doi.org/10.1364/OE.523813.

Storch, T. et al, (2023) The EnMAP imaging spectroscopy mission towards operations. Remote Sensing of Environment, 294, 113632. https://doi: 10.1016/j.rse.2023.113632

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