# IEEE WHISPERS 2023

# The ENMAP L2A Water Processor: Operational Performance and Application of ENMAP Dedicated Water Reflectance Products

Maximilian Langheinrich, Raquel de los Reyes

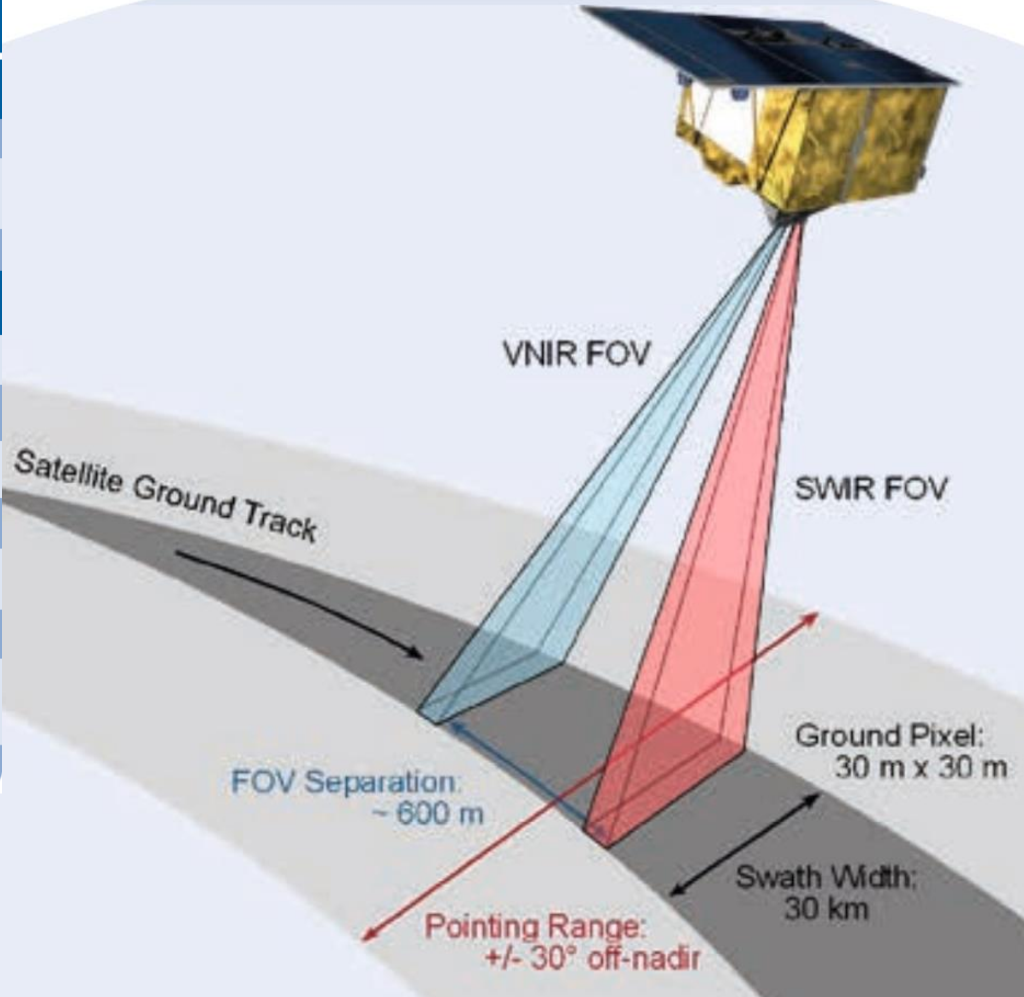
31.10.2023

# The EnMAP Mission

## Orbit characteristics

| Orbit characteristics | | |
|---|---|---|
| Orbit / Inclination | sun-synchronous / 97.96° | |
| Target revisit time | 27 days (Viewing Zenith Angle ≤ 5°) / 4 days (Viewing Zenith Angle ≤ 30°) | |
| Equator crossing time | 11:00 h ± 18 min (local time) | |
| **Instrument characteristics** | *VNIR (visible / near infrared)* | *SWIR (shortwave infrared)* |
| Spectral range | 420 - 1000 nm | 900 - 2450 nm |
| Spectral sampling interval | 6.5 nm | 10 nm |
| Spectral bandwidth (FWHM) | 8.1 ± 1.0 nm | 12.5 ± 1.5 nm |
| Signal-to-noise ratio (SNR) | › 400:1 @495 nm | › 170:1 @2200 nm |
| Spectral calibration accuracy | 0.5 nm | 1 nm |
| Ground sampling distance | 30 m (at nadir; sea level) | |
| Swath width | 30 km (field-of-view = 2.63° across track) | |
| Acquisition length | 1000 km/orbit - 5000 km/day | |

Source: enmap.org



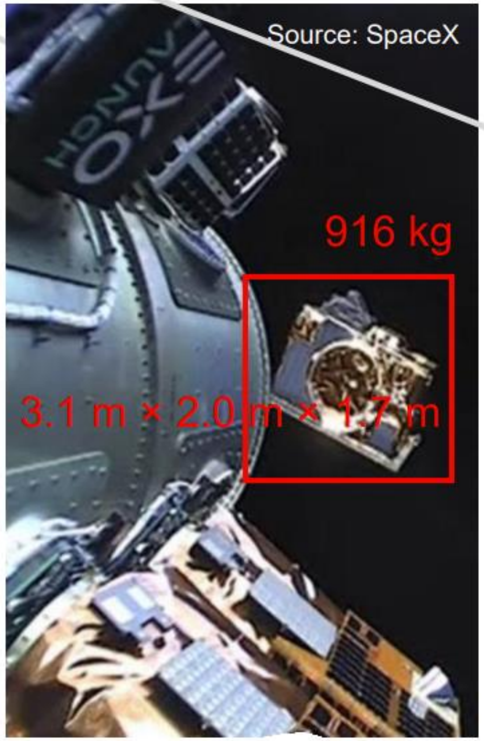
# The EnMAP Mission - Timeline

LEOP 01.04.2022 – 15.04.2022

Commissioning 15.04.2022 – 01.11.2022

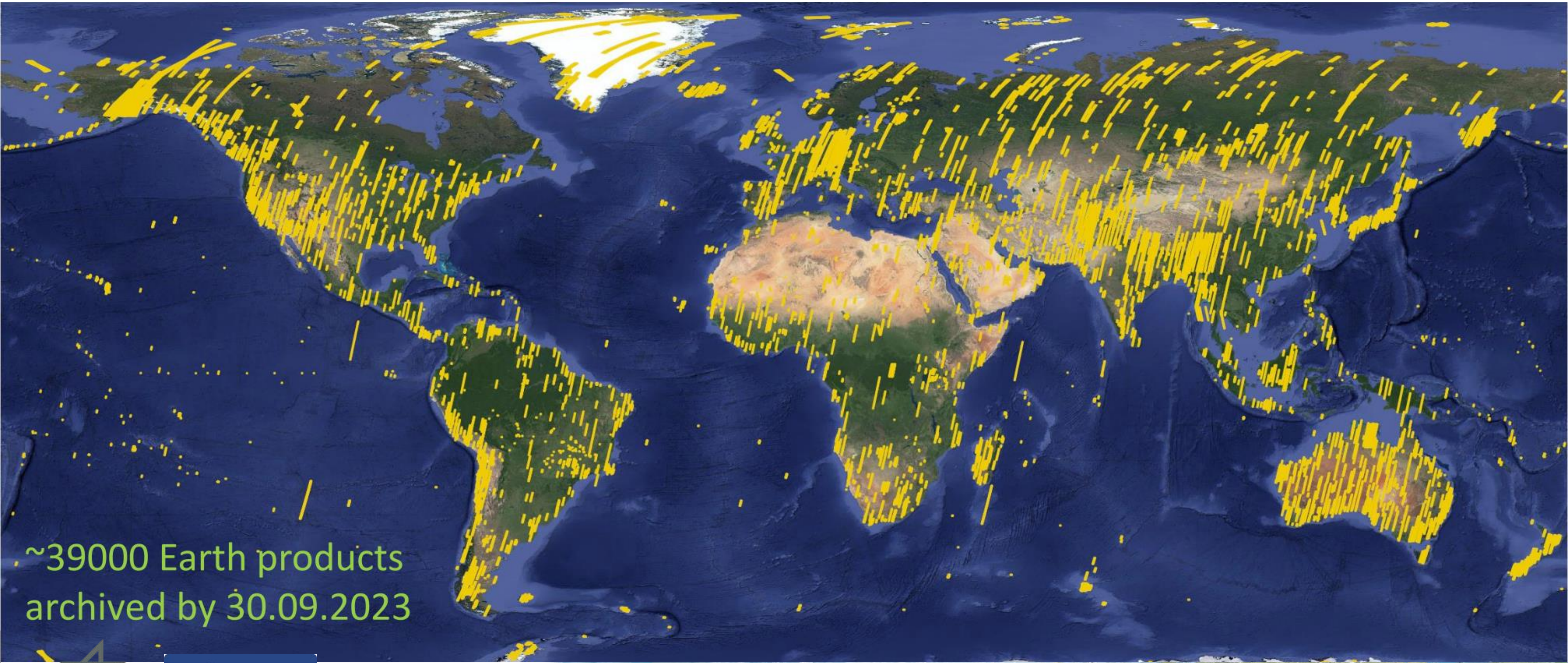
Launch 01.04.2022

First light, 27.04.2022


- 01.04.2022 EnMAP Launch
- Start LEOP Phase until 14.04.2022
- 15.04.2022 Start of commissioning Phase
- 27.04.2022 First light

# The EnMAP Mission - Acquisitions



# Structure of the L2A Processor

## EnMAP L2A Processor

### L1B_int

Simplified Atmospheric Correction for BOA reflectance interpolation (based on PACO)[1,2]

### L2A Land

Full atmospheric correction based on PACO[2]

### L2A Water

Full atmospheric correction over water pixels based on MIP[3]

[1]Langheinrich, Maximilian, et al. "BOA Reflectance Based Dead and Defective Pixel Interpolation in the ENMAP Ground Segment Processing Chain." IGARSS 2023-2023 IEEE IGARSS. IEEE, 2023

[2]De Los Reyes, Raquel, et al. "PACO: Python-based atmospheric correction." *Sensors* 20.5 (2020): 1428.

[3]Heege, Thomas, et al. "Operational multi-sensor monitoring of turbidity for the entire Mekong Delta." *International Journal of Remote Sensing* 35.8 (2014): 2910-2926.

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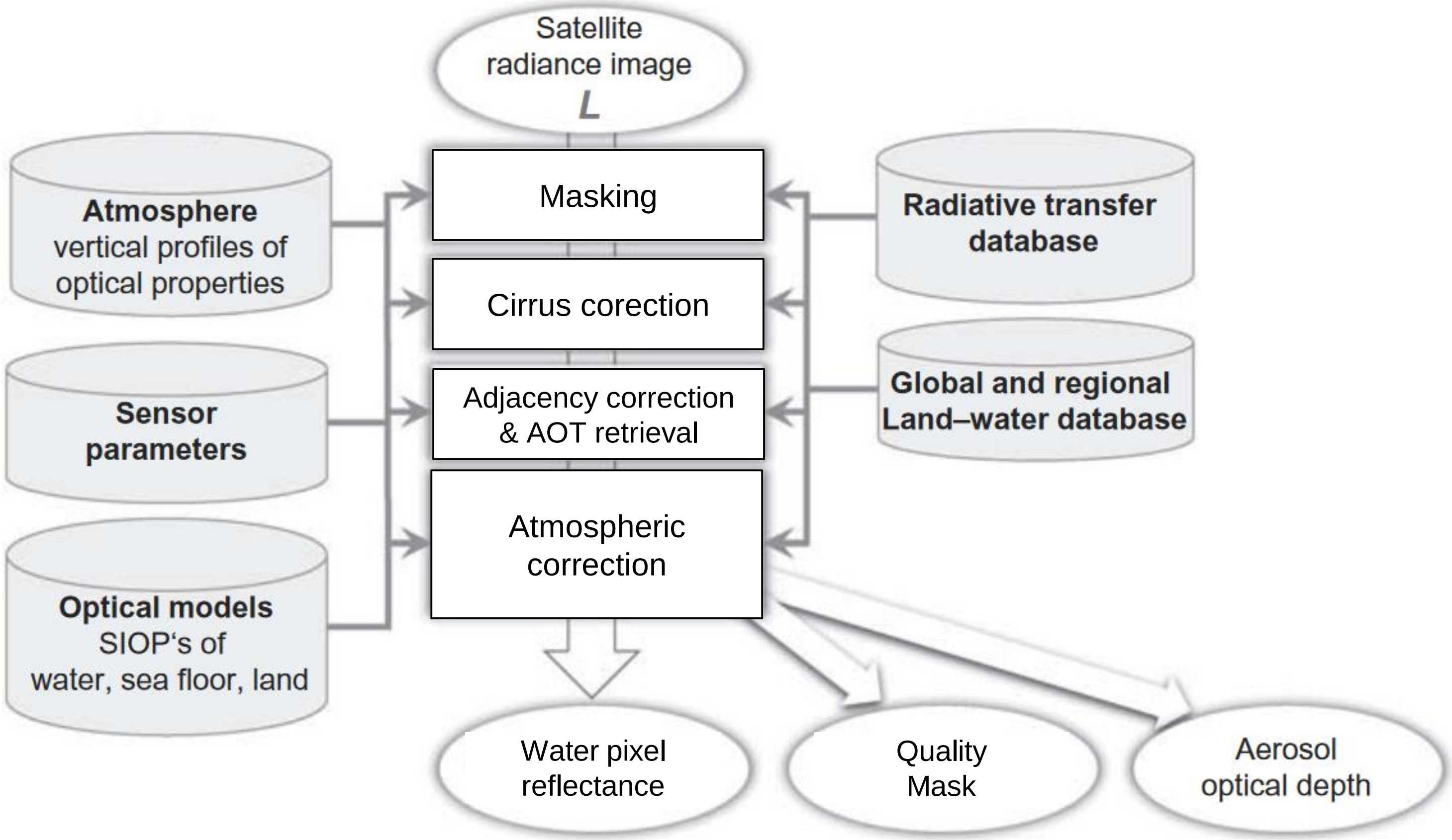
# L2A Water algorithm

L2A Water 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)

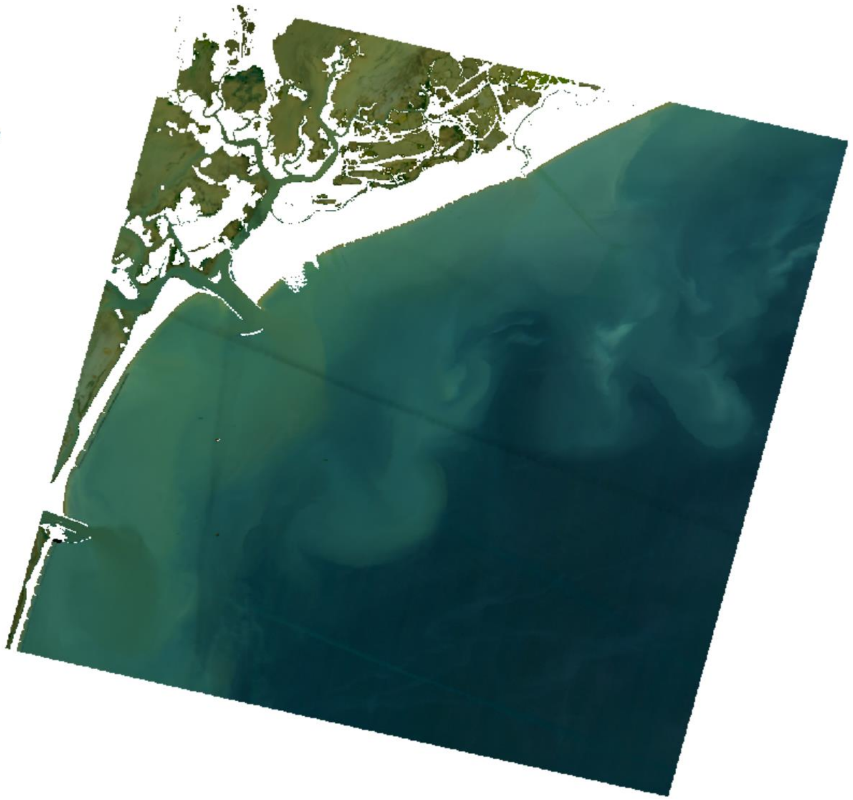


# L2A Products

Quicklook VNIR TOA Radiances
R: 635.112 nm
G: 550.687 nm
B: 463.730 nm

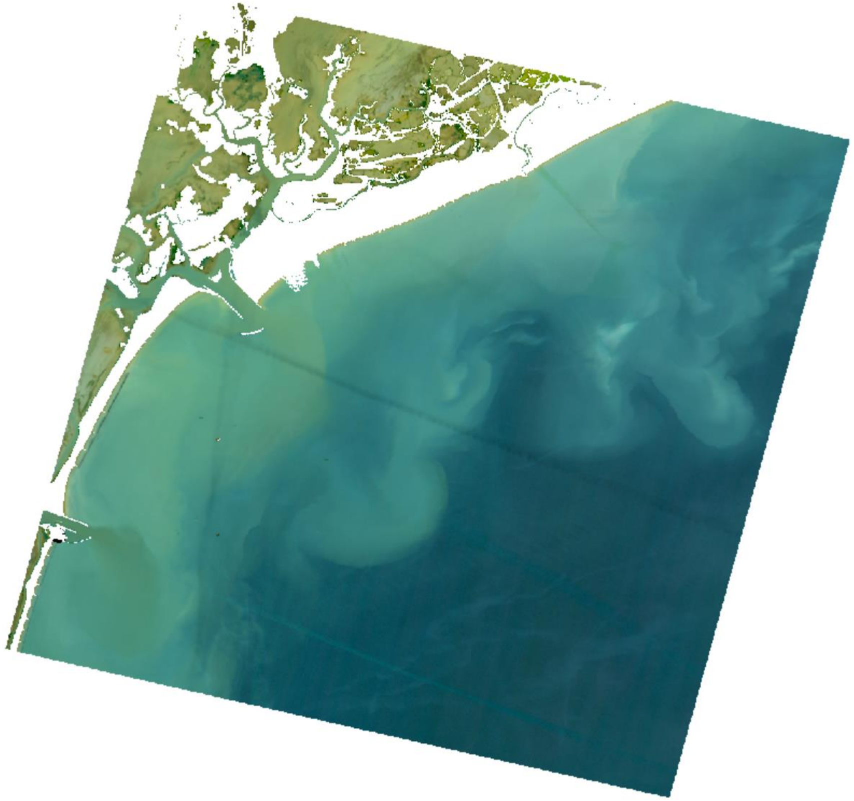
**Normalized water-leaving reflectance**

$$R_N = \pi * Rrs^{\{0+\}}(0,0) = \frac{\pi L_u^{\{0+\}}(0,0)}{E_d^{\{0+\}}(0)}$$



**Subsurface irradiance reflectance**

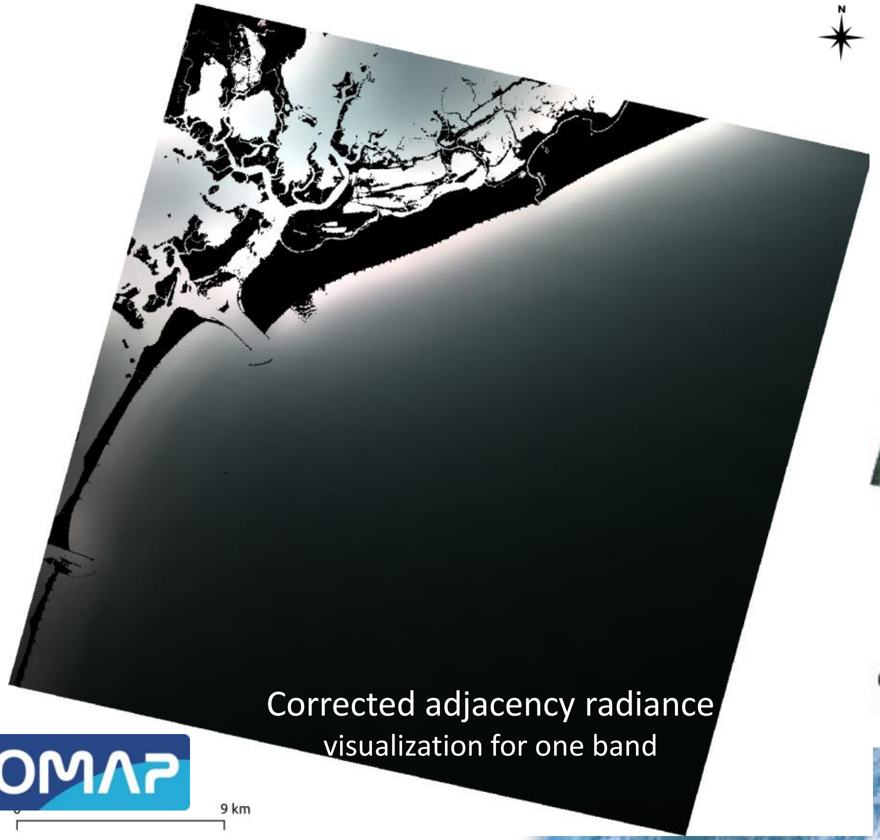
$$R^{0-}(\Theta_s) = \frac{E_u^0(\Theta_s)}{E_d^0(\Theta_s)}$$



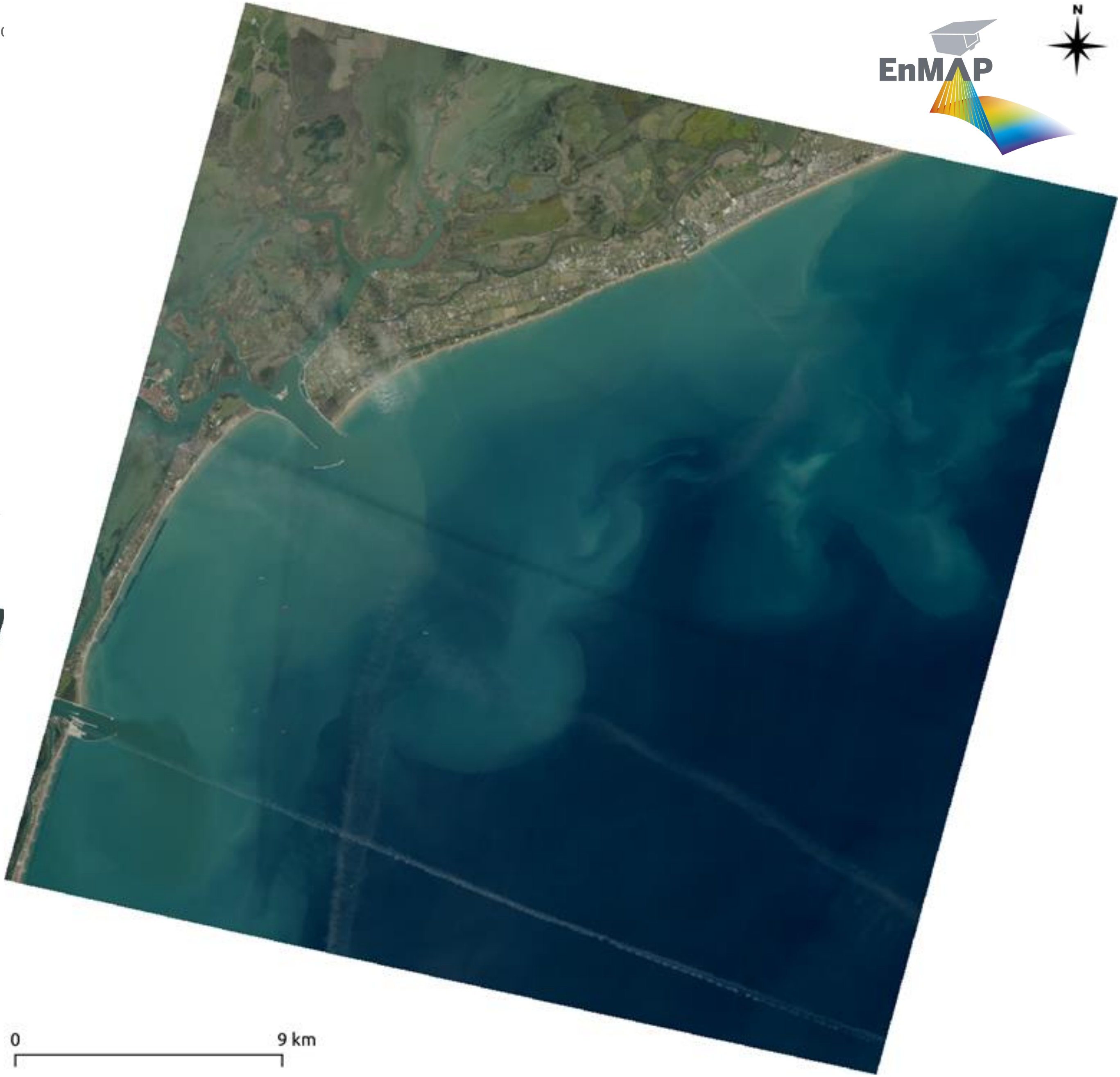
# ENMAP water specific AC products

Enmap's water AC processor includes:

- Fully physics-based modelling of radiative transfer
- Correction of adjacency, cirrus and aerosol effects
- Transformation to subsurface properties including bidirectional water surface




Corrected adjacency radiance visualization for one band



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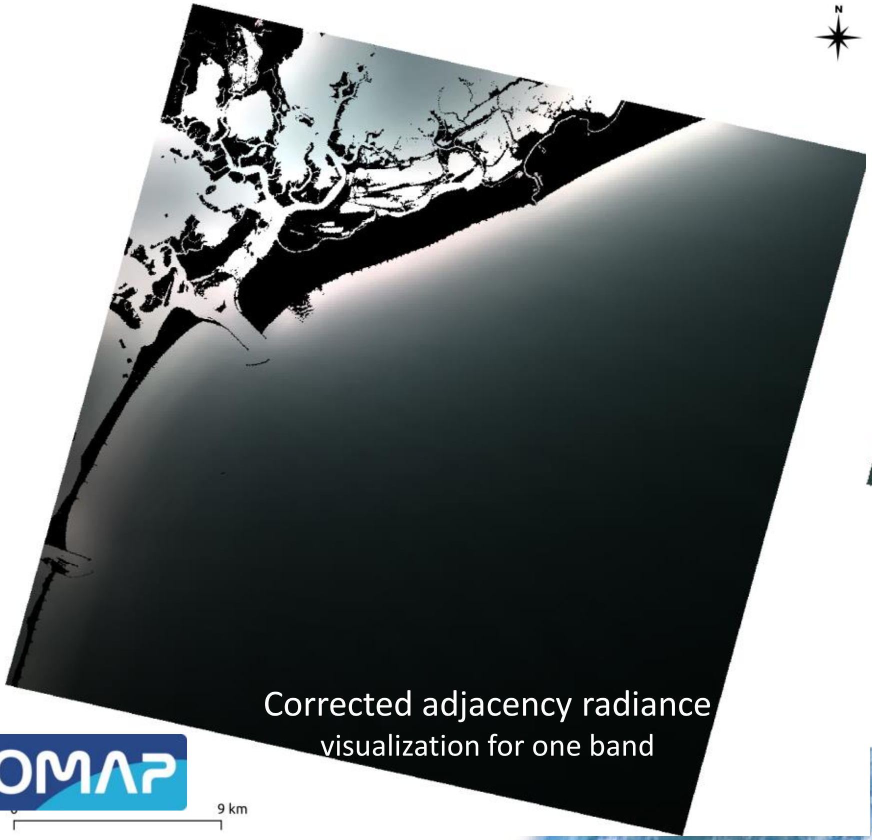


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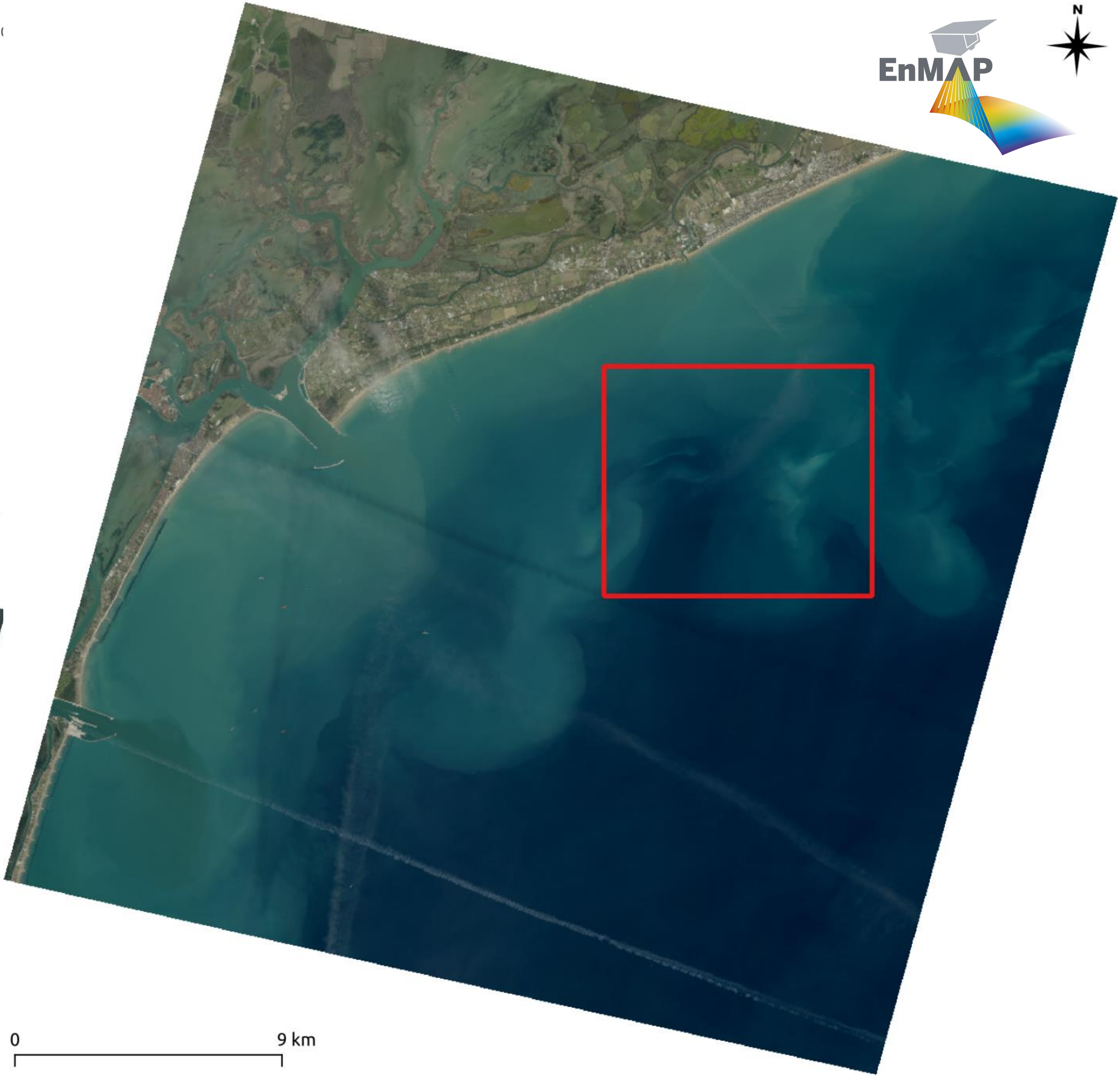
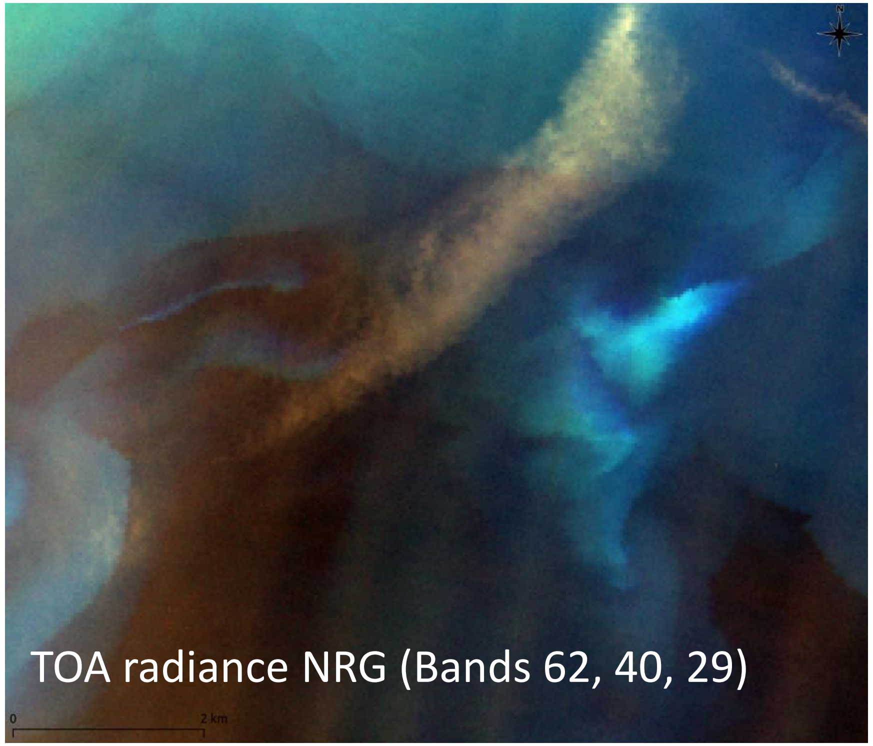


# ENMAP underwater reflectance

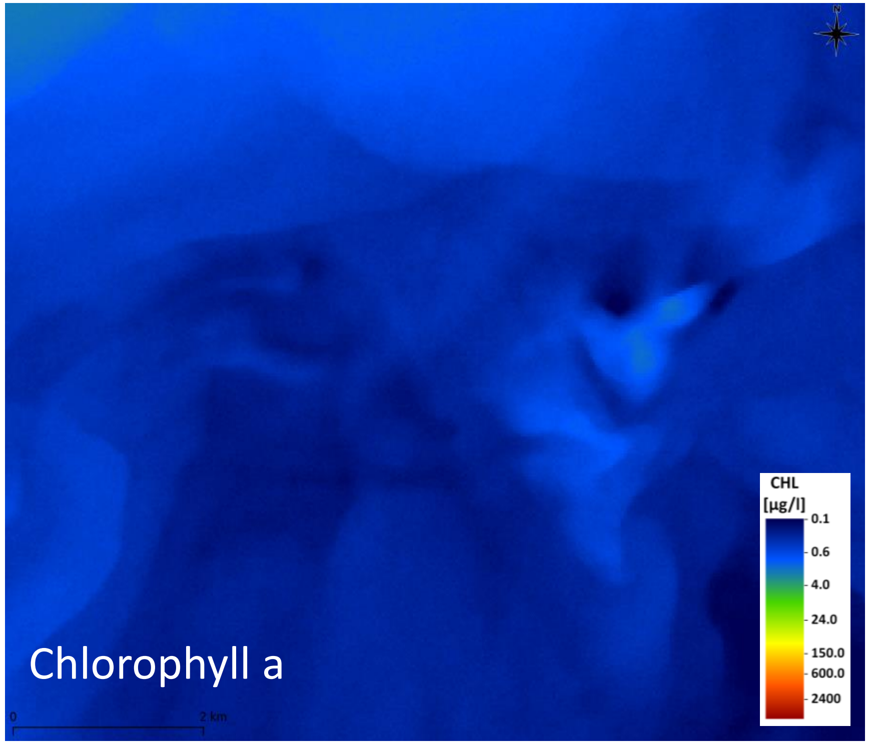
ENMAP AC processor:
Direct transformation of TOA radiance to underwater reflectance,
avoiding errors from simplefied $R^+$ to $R^-$ conversions

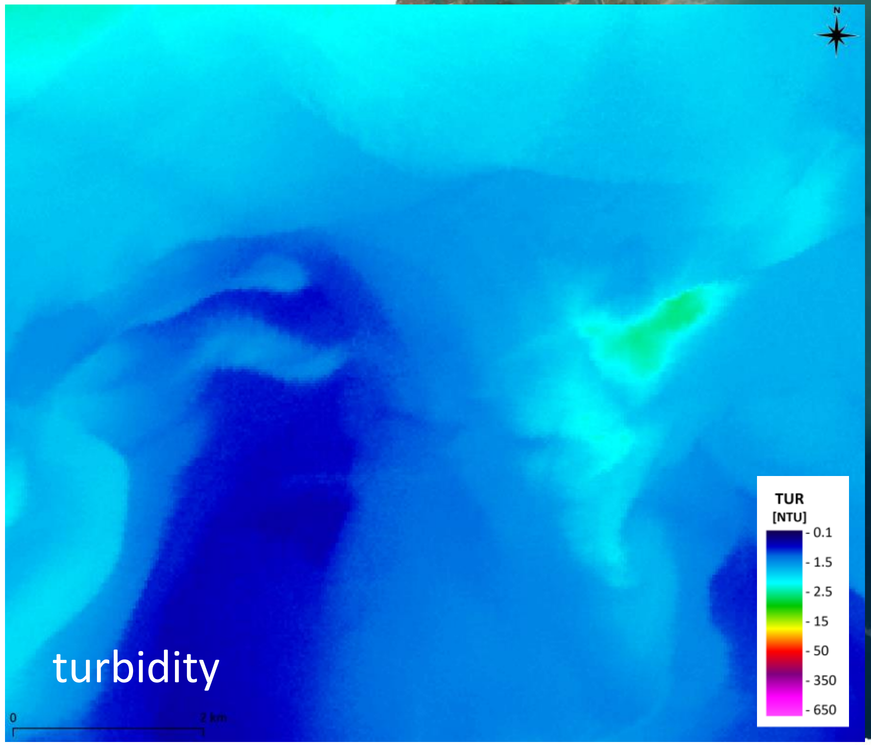




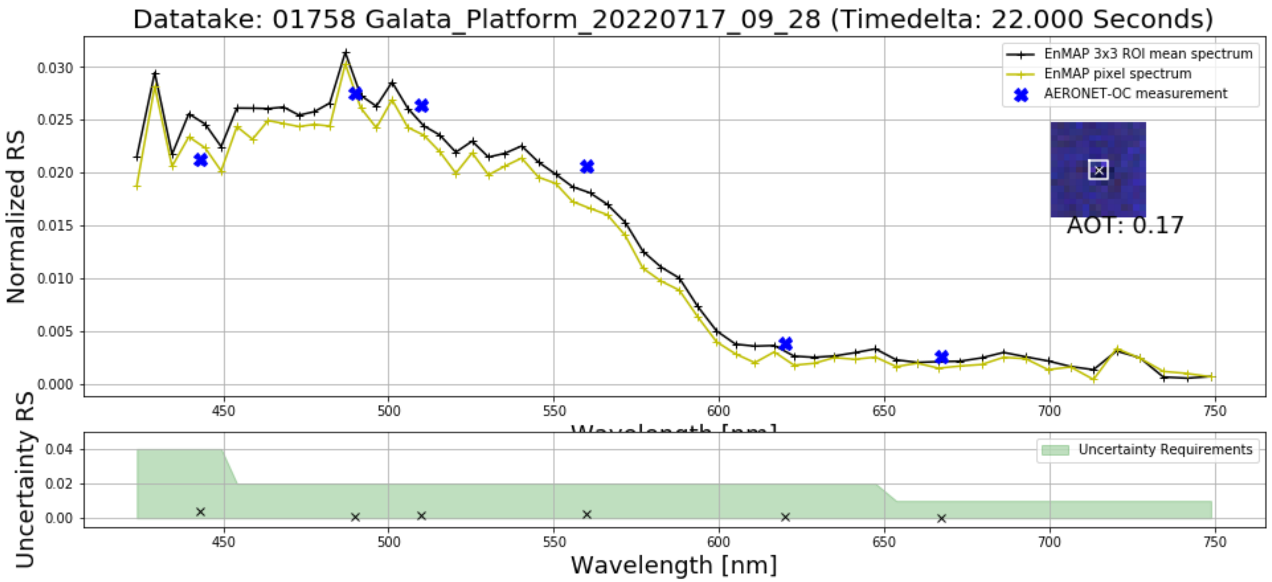
# From subsurface reflectance to water properties

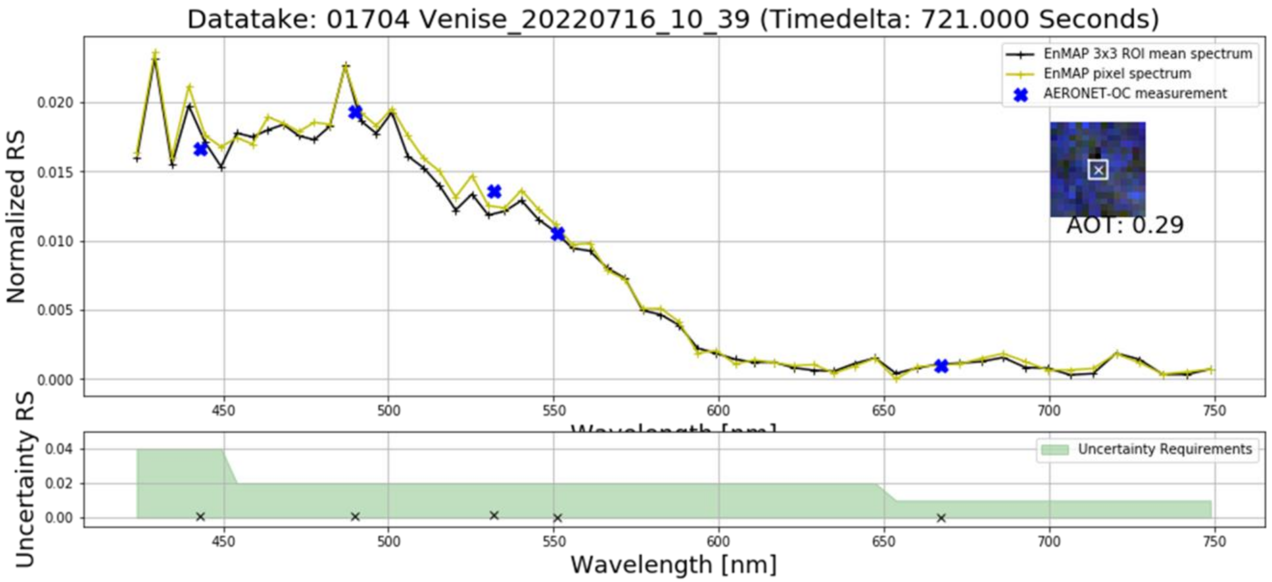
- Higher accuracy to derive water related products straight from underwater reflectance

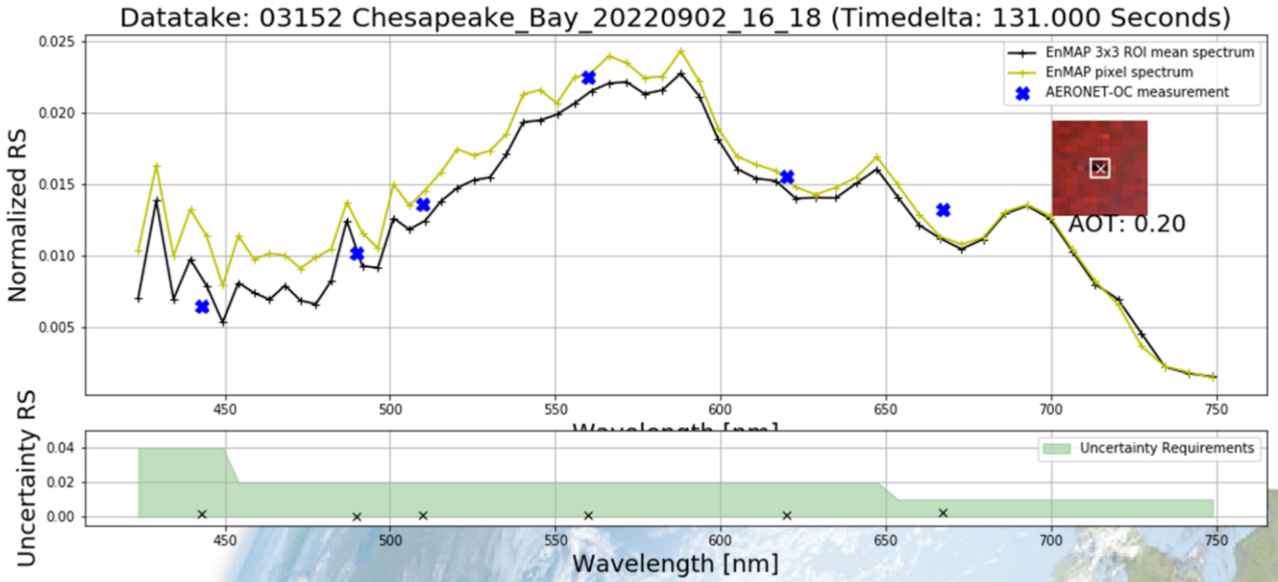



# L2A Water Products - Requirements



# Conclusions & Take-Aways

- EnMAP L2A Processor runs according to the mission requirements.
- EnMAP Hyperspectral mission delivers two unique, dedicated water products.
- Overall L2A product comes in different flavors that can be chosen by the user:
  - Land product from land AC processor
  - Subsurface irradiance reflectance for water from dedicated water AC processor
  - Normalized water-leaving reflectance for water from dedicated water AC processor
  - Combined product delivering results from both algorithms
- **EnMAP L2A Water processor implements an atmosphere <-> water coupled atmospheric correction that directly outputs subsurface reflectances. *Try using it for your water applications!***