Evaluation of the EnMAP water leaving reflectance products from three atmospheric correction methods by validation with hyperspectral and multispectral *in situ* measurements from inland and coastal waters around the world

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Atmospheric Correction (AC) over Water

Determine the water leaving reflectance ($[\rho W]_N$ *or* $[\rho W]$) from top of atmosphere (TOA) radiances (**[LTOA]**).

Intercomparison of AC methods as update to Soppa et al., Optics Express, https://doi.org/10.1364/OE.523813, 2024

MIP EnMAP L2A, 01.05.02 (4 updates since Soppa et al. 2024)

Acolite (update to Soppa et al. 2024)

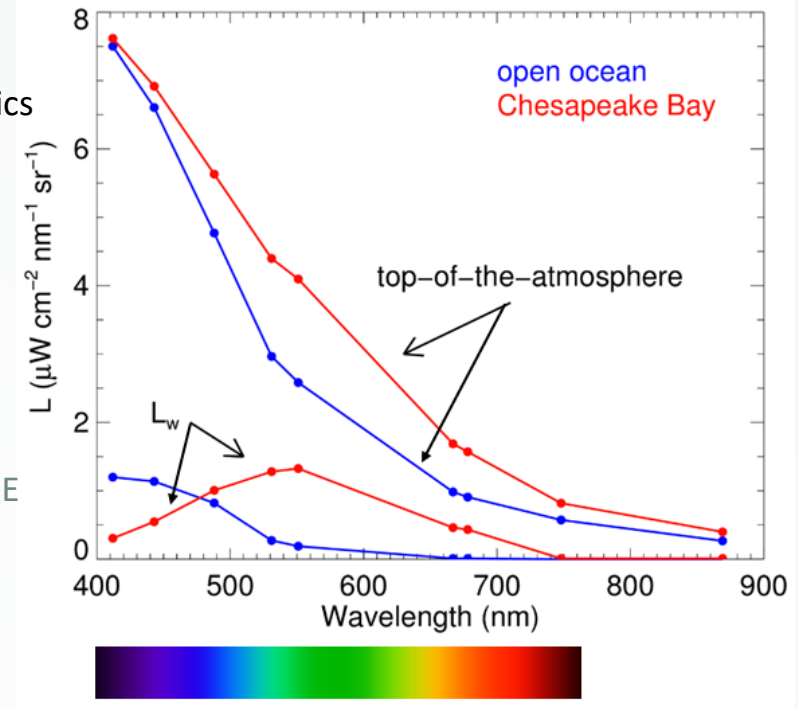
Polymer processor MSI inland water, ACWater implementation v4.16.1 (=Soppa2024) *

PACO-WASI: new sunglint & skyglint corr. (talk by P. Gege CHIME session) **

* update to v5 planned for fall 2025

**Processing for 2024 matchups pending

Robust atmospheric correction is important!



https://coastwatch.gitbook.io/satellite-course/lectures/ocean-color

Lw is only a small part of L_{TOA} (max. 10%)!

In-situ validation sites for EnMAP-AC

Sites	Location	In situ measurement
Acqua Alta AAOT	45.31°N, 12.51°E	Hyperspectral and AERONET-OC
Bahia Blanca	39.14°S, 61.72°W	AERONET-OC
Banana River	28.37°N, 80.63°W	AERONET-OC
Chesapeake Bay	39.12°N, 76.35°W	AERONET-OC
Galata Platform	43.04◦N, 28.19◦E	AERONET-OC
Gironde Estuary	45.54◦N, -1.04°W	Hyperspectral
Irbe Lighthouse	57.75°N, 21.72°E	AERONET-OC
Kemigawa	35.61°N, 140.02°E	AERONET-OC
Lake Constance	47.63°N, 09.37°E	Hyperspectral
Lake Garda	45.57°N, 10.57°E	Hyperspectral
Lampedusa	35.49°N, 12.47°E	Hyperspectral
Lucinda	18.52°S, 146.39°E	Hyperspectral and AERONET-OC
Oostende	51.25°N, 02.92°E	Hyperspectral
MVCO	41.32°N, 70.57°W	AERONET-OC
Rio de la Plata	34.81°S, 57.89°W	Hyperspectral
San Marco	02.94°S, 40.21°E	AERONET-OC
Section7 Platform	44.55◦N, 29.45◦E	AERONET-OC
Socheongcho	37.42°N, 124.74°E	AERONET-OC
South Greenbay	44.60°N, 87.95°W	AERONET-OC
Thornton Bank	51.53°N, 2.95°E	Hyperspectral
Lake Trasimeno	43.12°N, 12.13°E	Hyperspectral
Zeebrugge	51.36°N, 3.12°E	Hyperspectral

In situ hyperspectral measurements were provided by the PIs of each site.

For 2022-2024 now 85 matchups to EnMAP L2A in total.

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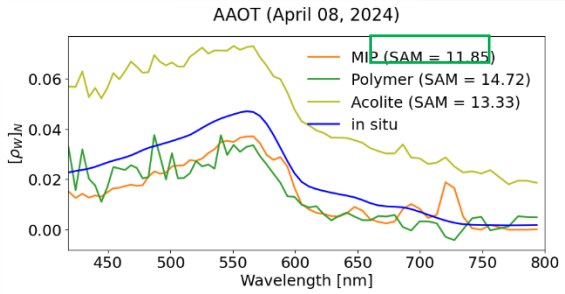
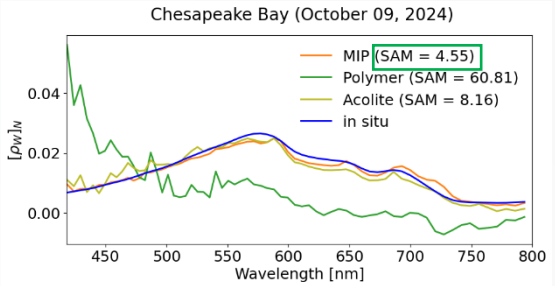
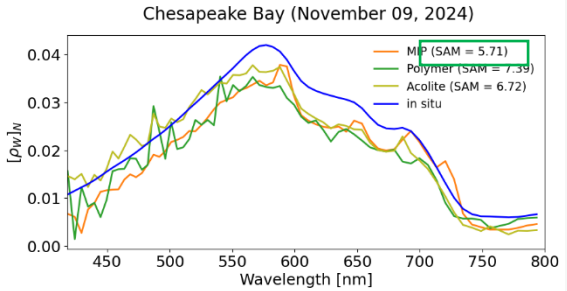
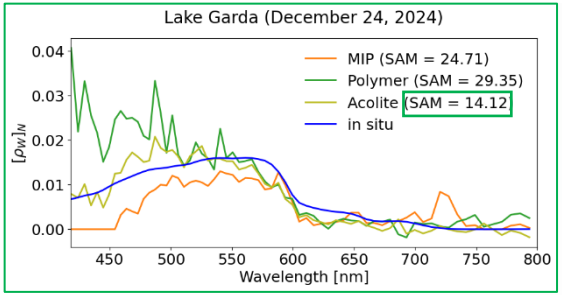
Example matchups *in-situ* [ρ*W*] vs. EnMAP-AC MIP [ρ*W*]$_N$ & Polymer [ρ*W*] & Acolite [ρ*W*]

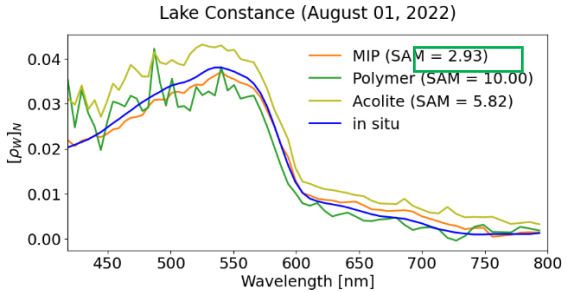
The lower the SAM value, stronger the spectral similarity between *in situ* and EnMAP-AC.

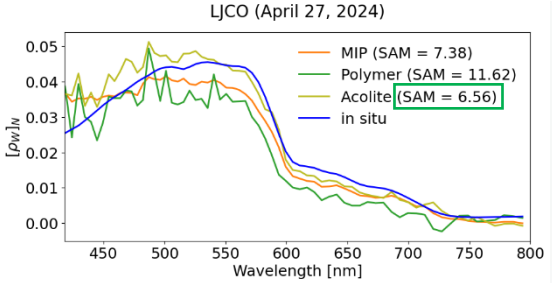


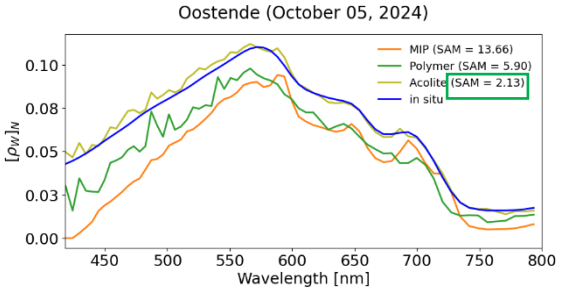


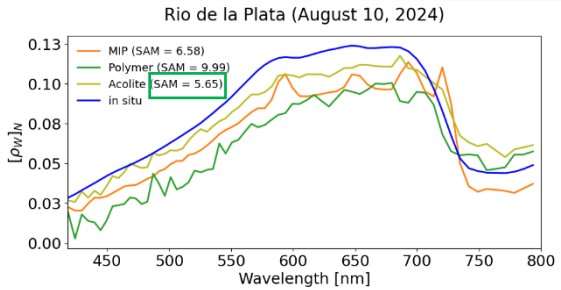


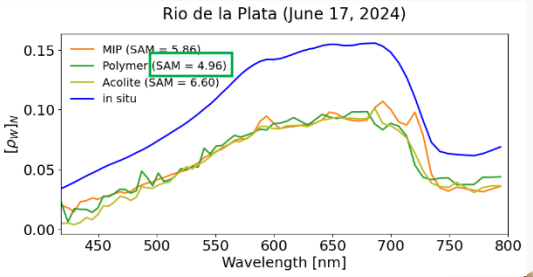




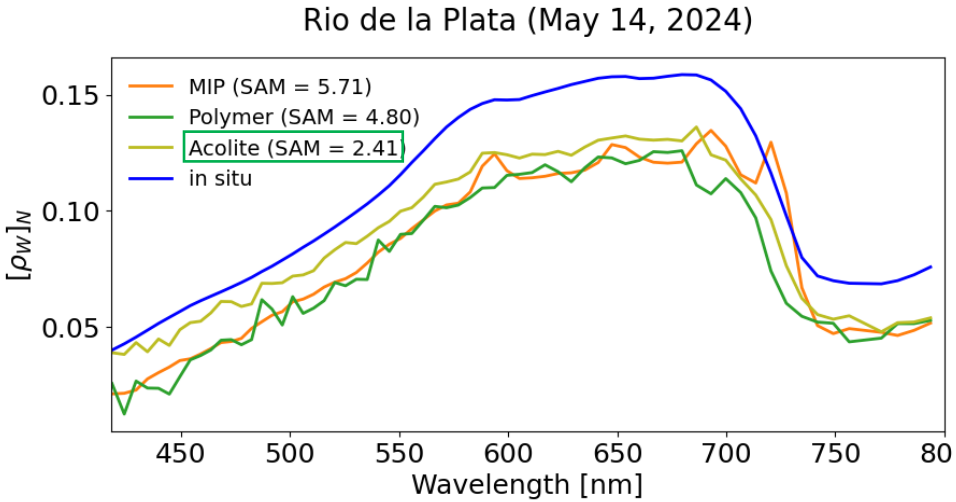




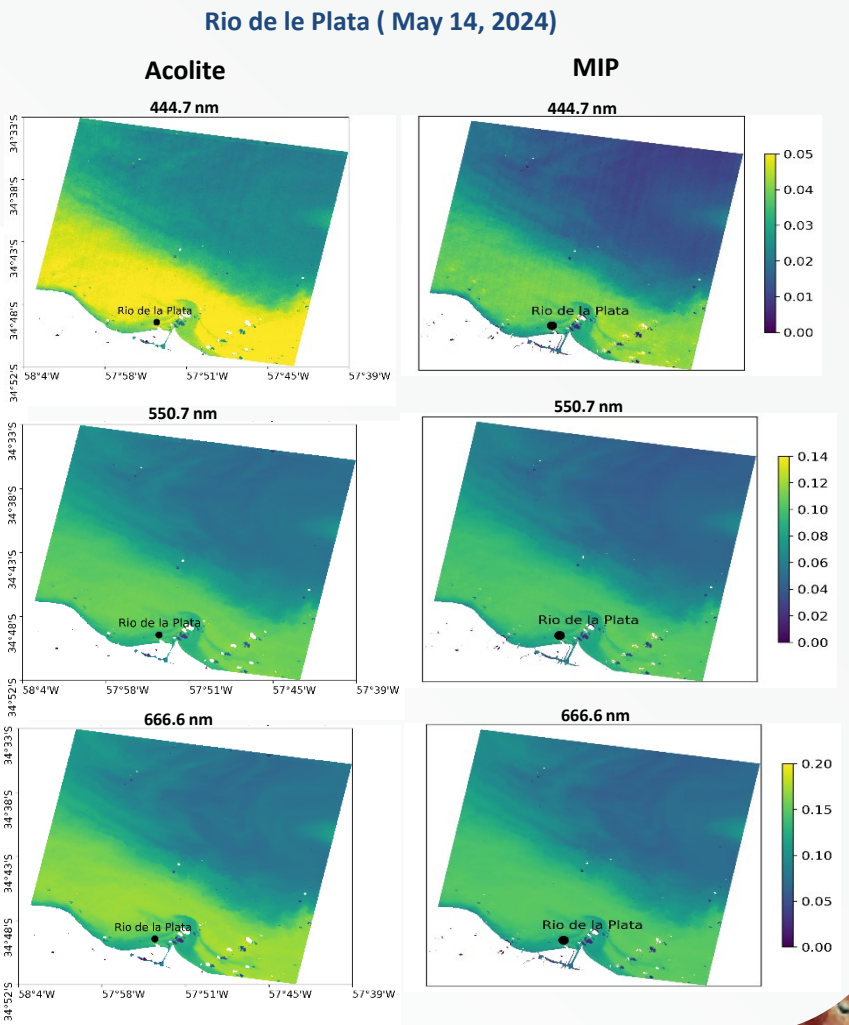




Example comparison hyperspectral in-situ [ρ*W*] vs. EnMAP-AC MIP $[\rho W]_N$ & Acolite [ρ*W*]



The median EnMAP spectra of the 3 x 3 pixel box around the validation site: MIP in orange and Acolite in light green



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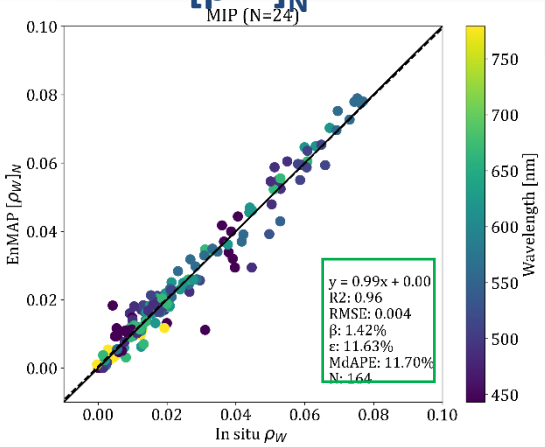
Matchups *in-situ* [ρ*W*] vs. EnMAP-AC

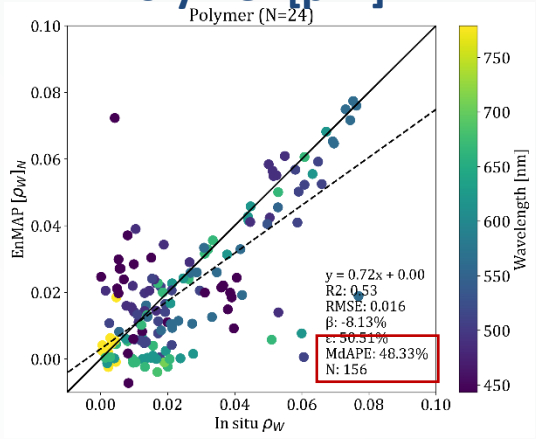
MIP $[\rho W]_N$

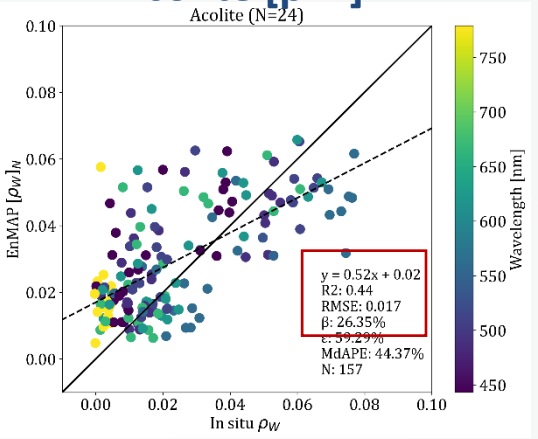
Polymer [ρ*W*]

Acolite [ρ*W*]

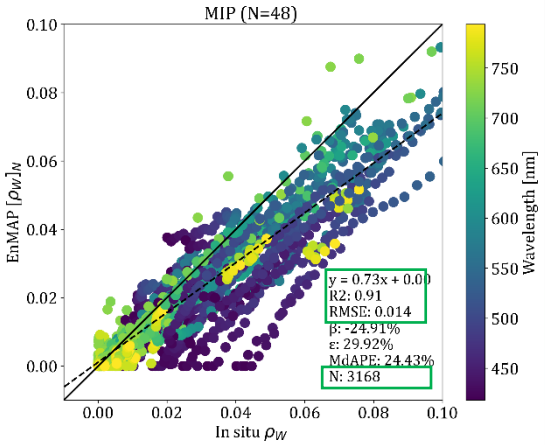
vs. *in situ* multi-spectral (N=24)

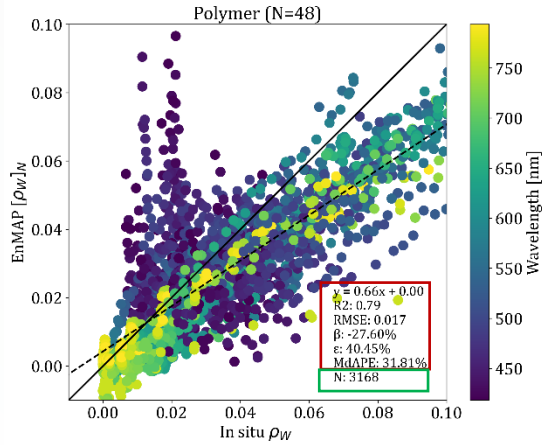


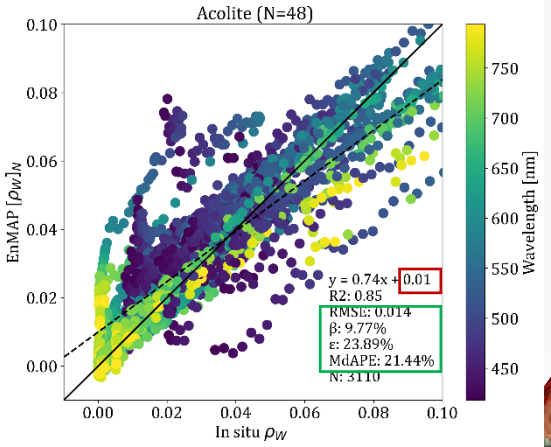




vs. *in situ* hyper-spectral (N=43)







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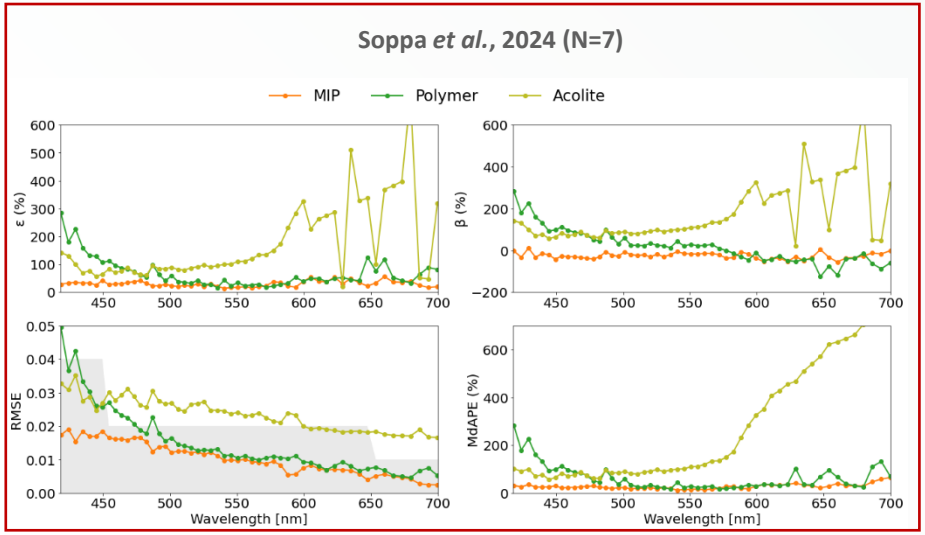
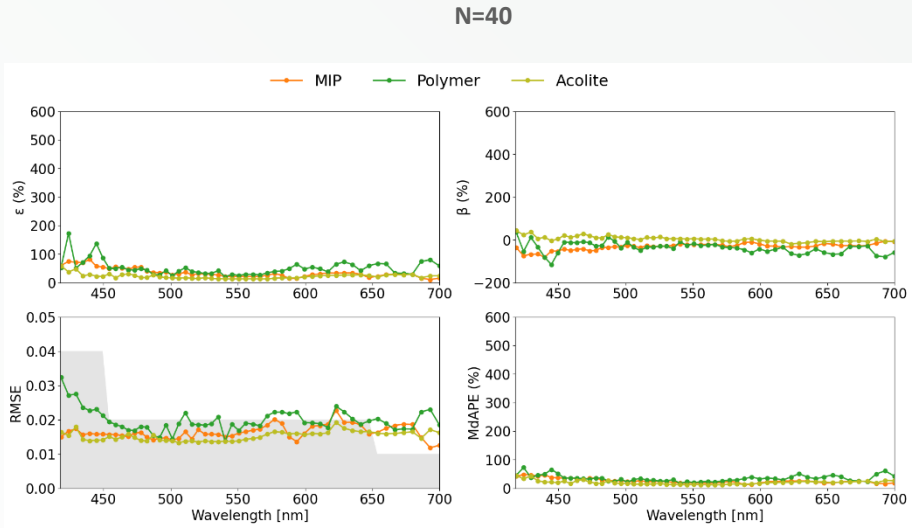
Spectra of ϵ, β, RMSE and MdAPE for MIP and Acolite for coincident hyperspectral match-ups (N) during the operational mission phase

Grey = required uncertainty (RMSE) outside of strong atmospheric absorption regions and for AOT at 550 nm lower than 0.4 as defined by EnMAP Ground Segment





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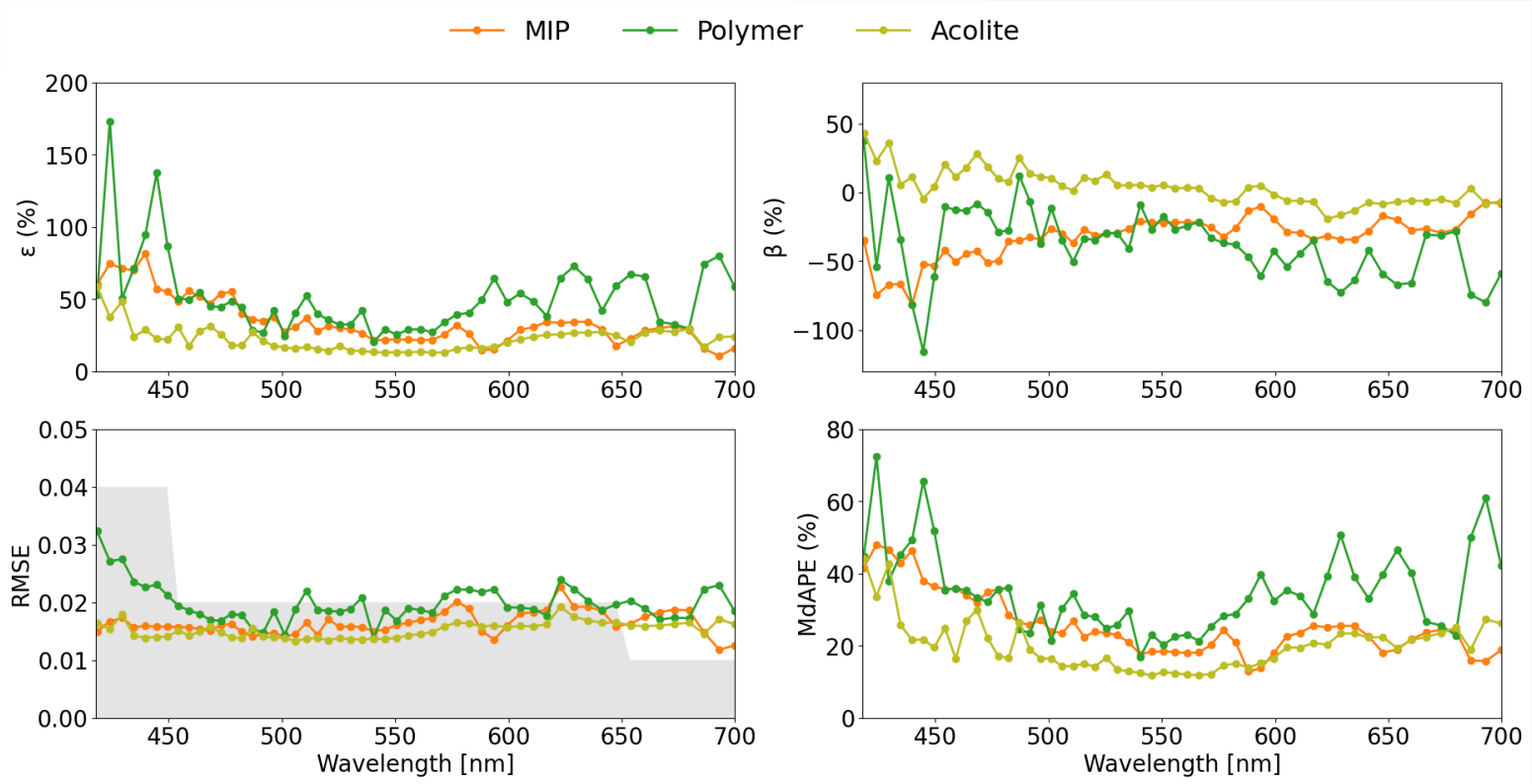
Spectra of ϵ, β, RMSE and MdAPE for MIP and Acolite for coincident hyperspectral match-ups during the operational mission phase (N=40)

Grey = required uncertainty (RMSE) outside of strong atmospheric absorption regions and for AOT at 550 nm lower than 0.4 as defined by EnMAP Ground Segment



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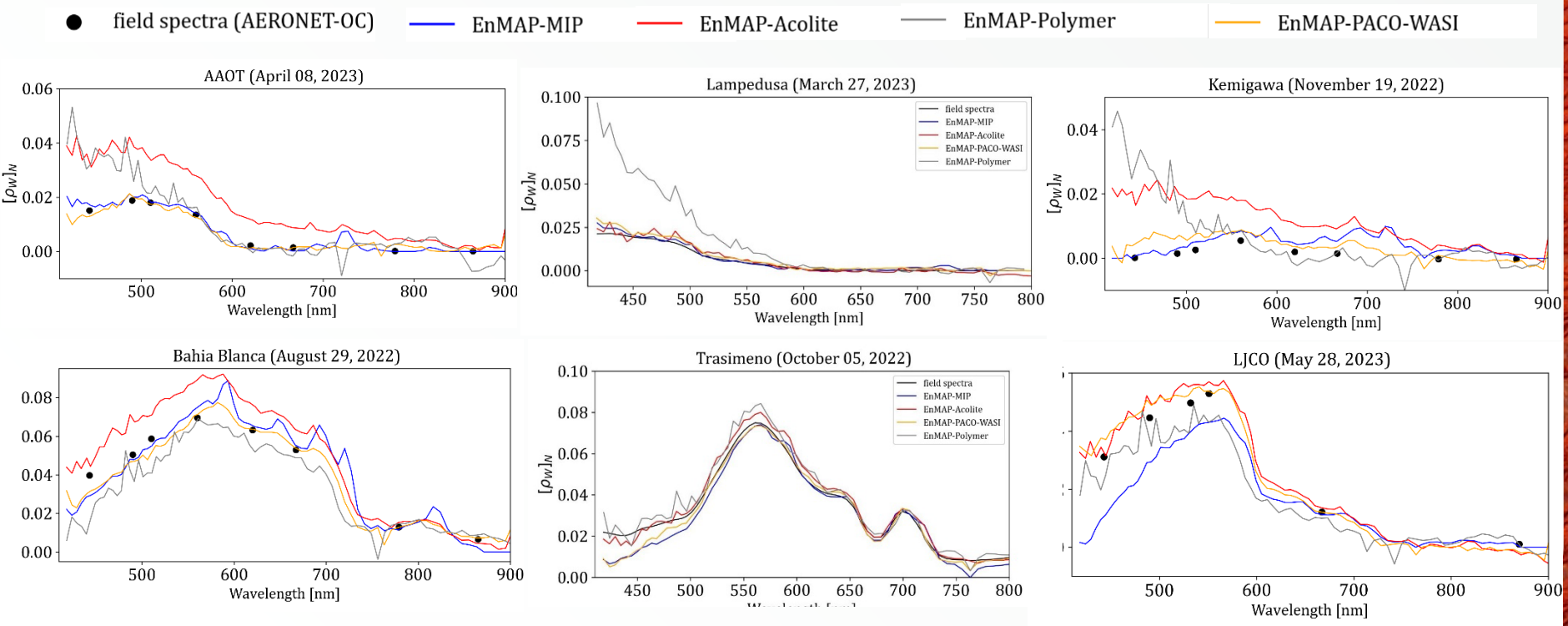
Comparison of EnMAP $[\rho W]_N$ or $[\rho W]$ from MIP, Acolite, PACO-WASI, and Polymer (ACWater) to multispectral *in-situ* match-ups



Summary & Outlook

• In **2024 in-situ matchups for water reflectance validation doubled** as compared to 2022-2023 (Soppa et al. 2024), benefitting from new installations of many automated hyperspectral in-situ stations (WATER-HYPERNET, …).

• **EnMAP L2A (MIP; v01.05.02) performs similar for all hyperspectral bands**, and **even better** when just considering AERONET-OC **bands**, as compared to assessment by Soppa et al. (2024) and within mission requirements.

• **Similar performance** of EnMAP-MIP (better R2, slope, intercept) **to Acolite** (lower bias and errors) and better performance of MIP compared to Acolite regarding comparison to hyperspectral and multispectral in-situ matchups, respectively. **Polymer** is mostly worse but has not been **update**d since the comparison of Soppa et al. 2024 which is **planned for fall 2025**.

•First results from **PACO-WASI** show **promising results** and similar to MIP.

• **Monitoring of level 2 EnMAP water product will continue** in 2026 and hopefully beyond. As for PRISMA ACIX III we plan in the next step an analysis for different water types to further provide insights where AC methods can improve.

•We **welcome more contributions of matchup in situ data** for ENMAP mission AC method evaluations (coauthorship granted).

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