Hyperspectral remote sensing of aquatic ecosystems: first experiences with EnMAP and updates on PRISMA

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Consiglio Nazionale delle Ricerche

1st EnMAP user workshop - online
10-11 October 2023

Presentation outline

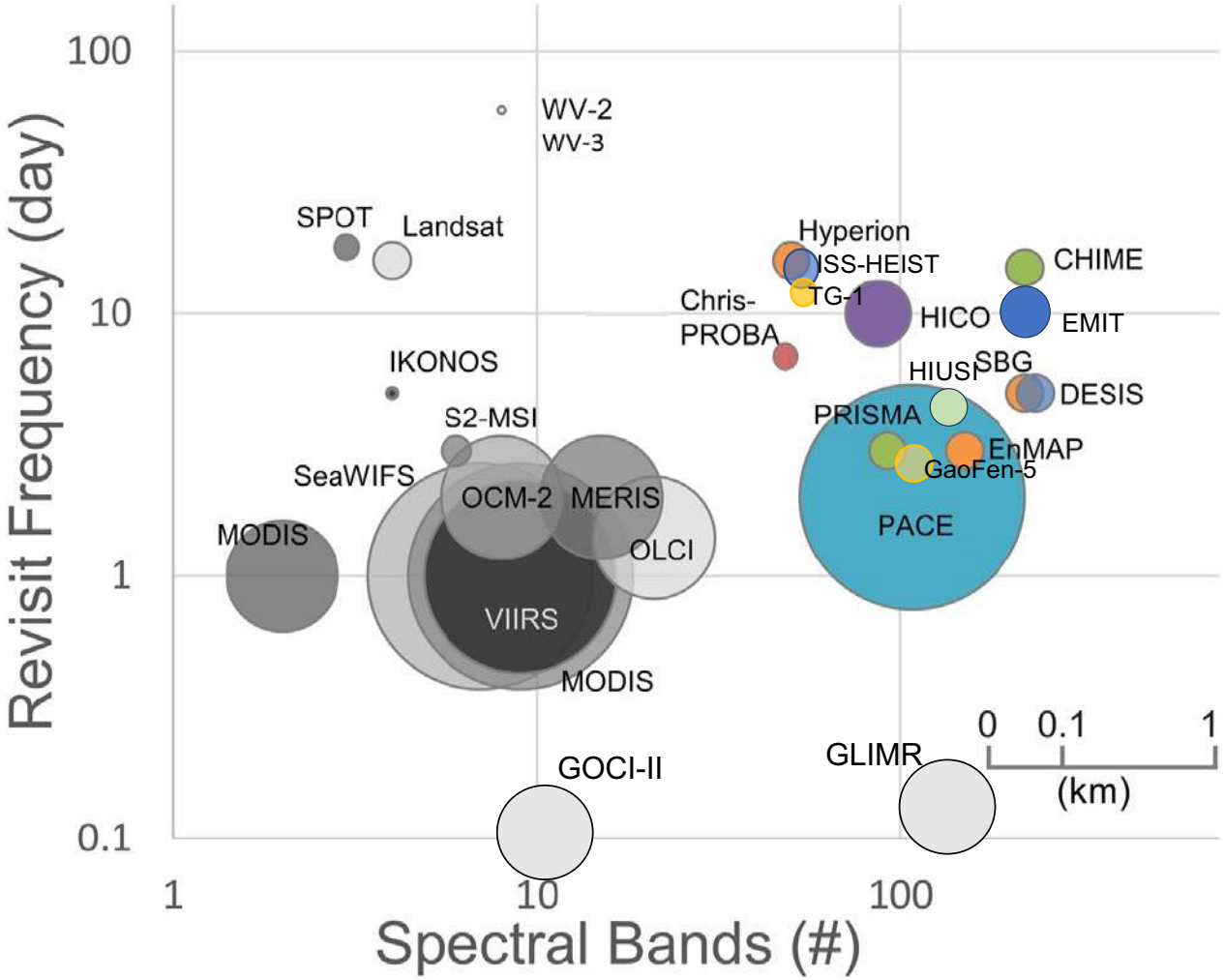
Introduction
Dataset presented in the study
Overview of L2 reflectance of aquatic ecosystems
Few examples of water quality mapping
Conclusions

Hyperspectral remote sensing for water

Primary author (# Coauthors)	Title	Publisher	Year	Subjects covered (relevant to hyperspectral)
Gege and Dekker (2020) (1)	Spectral and radiometric measurement requirements for inland, coastal and reef waters	Rem. Sens.	2020	Sensitivity study of measurement needs for inland and coastal water
Kutser, et al. (2020) (4)	Remote sensing of shallow waters–A 50 years retrospective and future directions	Rem. Sens. Environ.	2020	History, sensors, algorithms, satellite systems, future directions
Dierssen et al. (2020) (4)	Data needs for hyperspectral detection of algal diversity across the globe	Oceanography	2020	Data recommendations, phytoplankton composition, future needs
Banks et al. (2020) (10)	Fiducial reference measurements for satellite ocean color	Rem. Sens.	2020	Framework, standards, and protocols for validation efforts
Jeziorska (2019) (0)	UAS for wetland mapping and hydrological modeling	Rem. Sens.	2019	Hardware, software, regulations, applications, data collection and processing
Wu et al. (2019) (3)	A review of drone-based harmful algae blooms monitoring	Environ. Monit. Assess.	2019	UAVs, sensors, work-flow, algorithms, challenges and opportunities
Giardino et al. (2019) (12)	Imaging spectrometry of inland and coastal waters: State of the art, achievements and perspectives	Surv. Geophys.	2019	Theory, algorithms, uncertainties, applications, future directions, *in situ* observations
IOCCG (2019) (23)	Synergy between ocean color and biogeochemical/ ecosystem models	IOCCG Report 19	2019	Assimilation, forecast, and hindcast modeling relevant to ocean color imagery
CEOS, Dekker et al. (2018) (15)	Feasibility study for an aquatic ecosystem earth observing system	Comm. on Earth obs. Sat. (CEOS)	2018	Spectral, spatial and temporal requirements for coastal and inland aquatic applications
Lodhi et al. (2018) (2)	Hyperspectral imaging of earth observation: Platforms and instruments	J. Indian Inst. Sci	2018	Sensors, platforms, applications (above water, in-water, underwater)
IOCCG, Greb et al. (2018) (23)	Earth observations in support of global water quality monitoring	IOCCG Report 17	2018	Theory, sensors, approaches and limitations to water quality
Manfreda et al. (2018) (22)	On the use of unmanned erial systems for environmental monitoring	Rem. Sens.	2018	Number of articles per year, sensors, software, mission planning, inland waters
Khan et al. (2018). (4)	Modern trends in hyperspectral image analysis: A	IEEE access	2018	HIS analysis approach including deep learning and

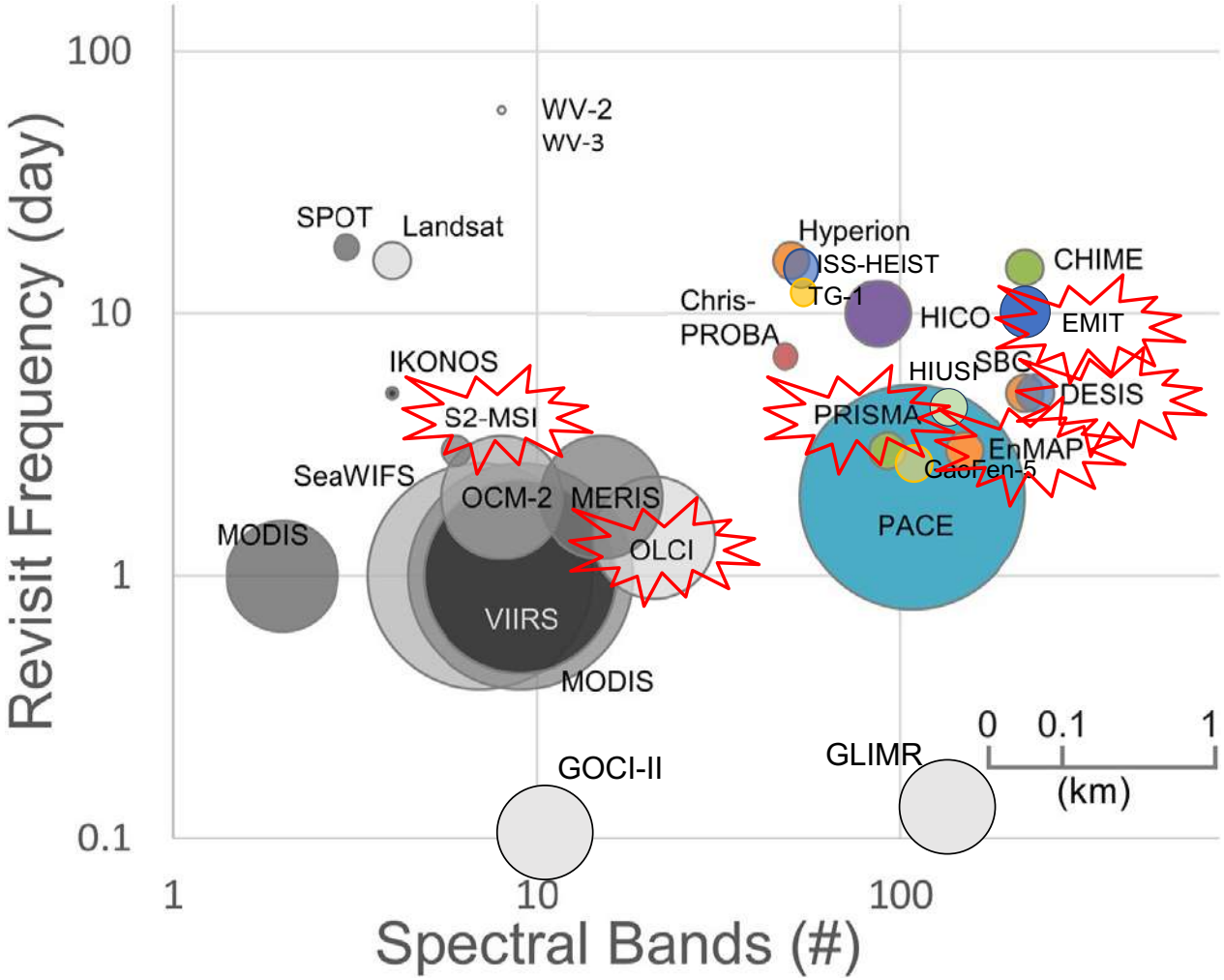
Dierssen et al., 2021

Overview of spaceborne sensors



Dierssen et al., 2021

Overview of spaceborne sensors



Dierssen et al., 2021

Dataset

	ENMAP	DESIS	PRISMA	EMIT	S2	S3	In situ
Curonian lagoon	2023/08/12	-	-	-	-	2023/08/12	-
Venice Lagoon	2022/07/16	-	-	-	-	2022/07/16	-
Venezia AAOT	2023/04/08	-	-	-	-	-	2023/04/08
Gulf of Oristano	2023/05/31	-	-	-	-	-	2023/05/31
Lake Trasimeno	2022/08/12	-	2022/08/12	-	-	-	2022/08/12
Lake Trasimeno	2022/10/05	-	-	-	-	-	2022/10/05
Lake Garda	-	-	2023/08/19	2023/08/07	-	-	-
Lake Garda	2022/12/06	-	-	-	2022/12/07	-	-
Tago river	2022/09/15	2020/09/02	2020/09/03	-	2020/09/01	2020/09/02	-
Danube estuary	2022/09/21	-	-	-	-	-	-

In situ

Fixed positions

- autonomous radiometers (high frequency, but one-point)

Campaigns

- Field data collection (high spatial coverage, often accompanied by bio-geophysical measurements, but low frequency)

HYPERNETS

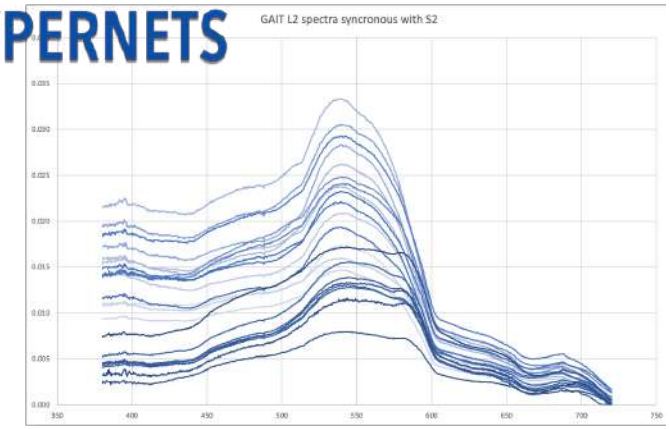
4G Antenna

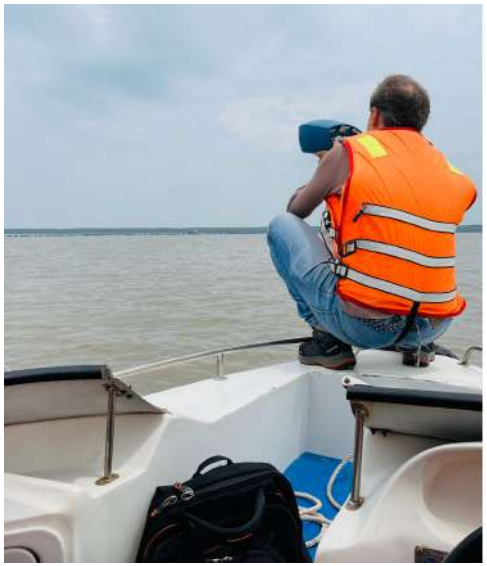
HYPSTAR

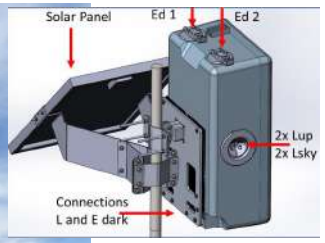
Webcams
Rain/light sensor

Control Unit
(Studiel box)

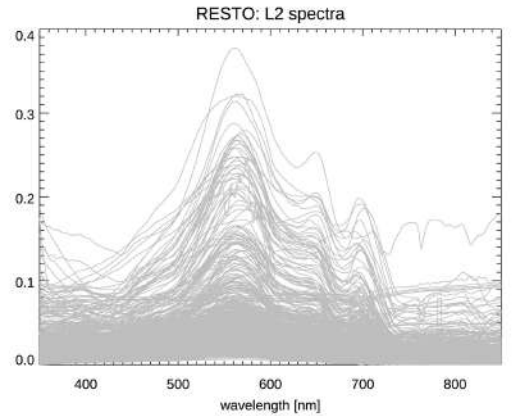
Battery
PV Control Unit
Solar panel



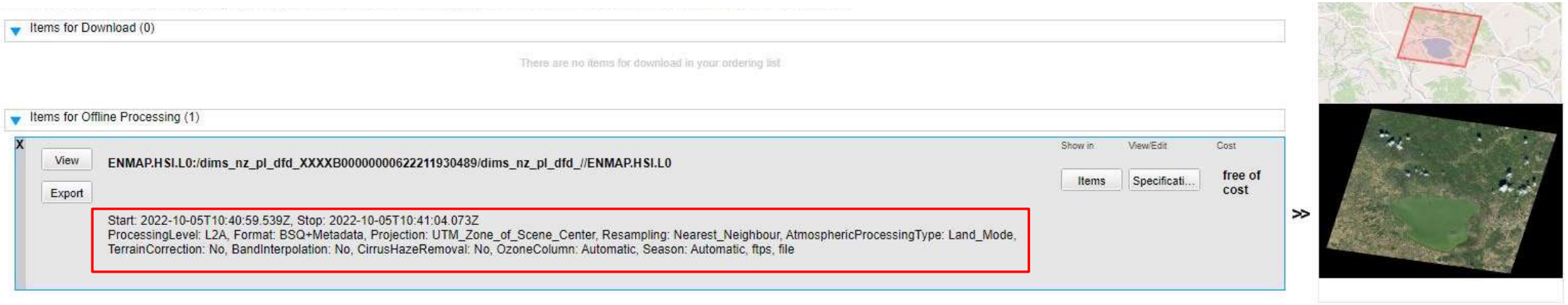


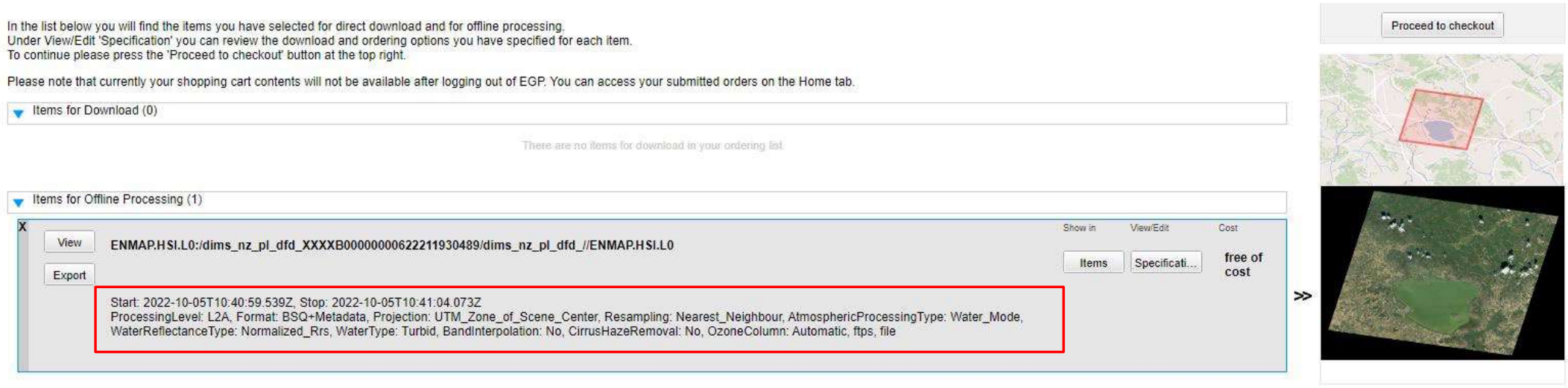


Water Insight



Level 2 standard products



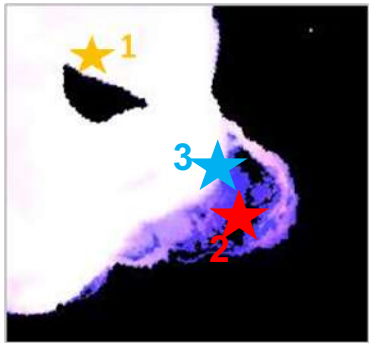


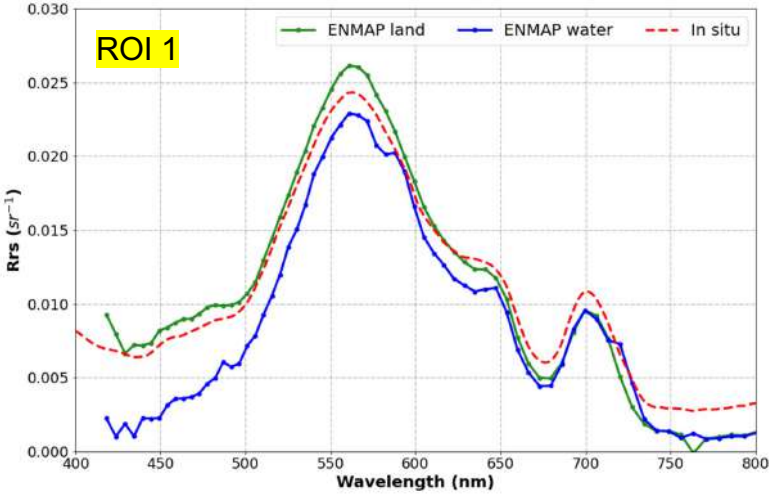
Level 2 standard products: water & land

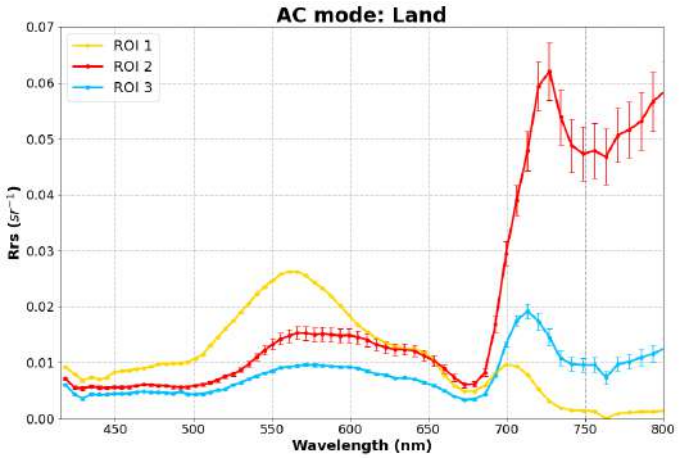
Lake Trasimeno 2022/10/05

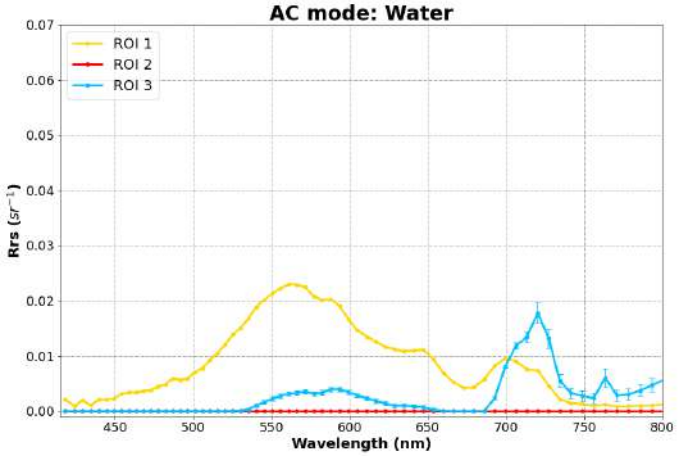
EnMap Land

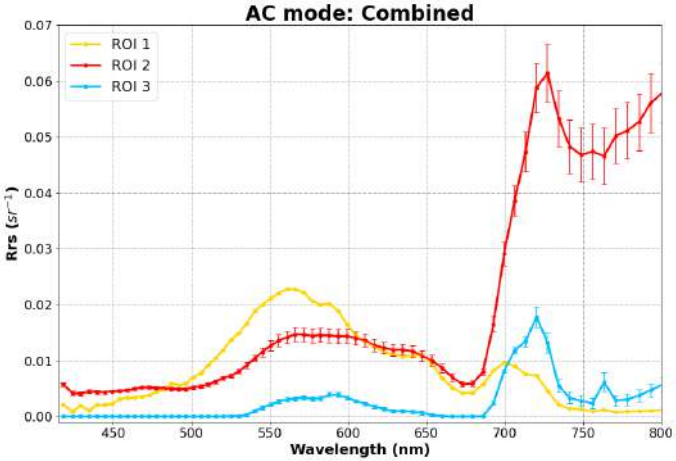
EnMap Water









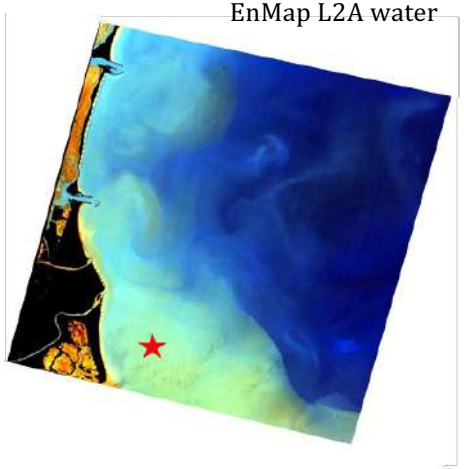


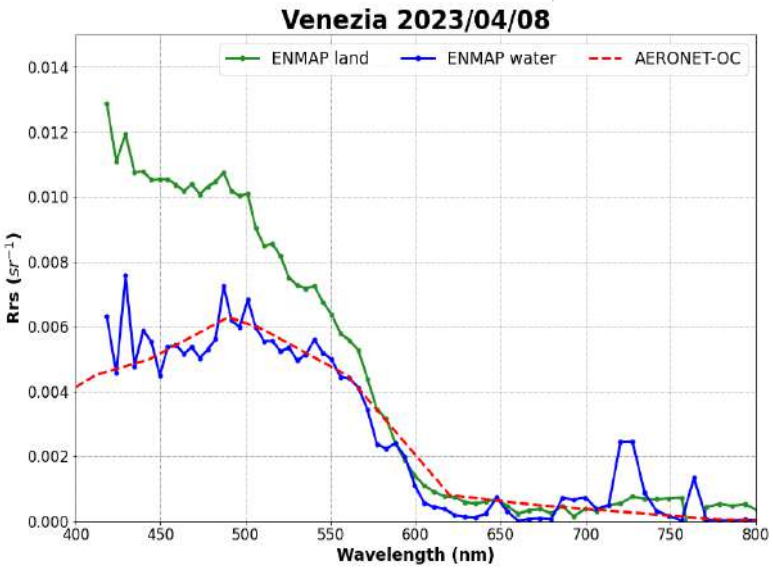
Moderately clear marine waters

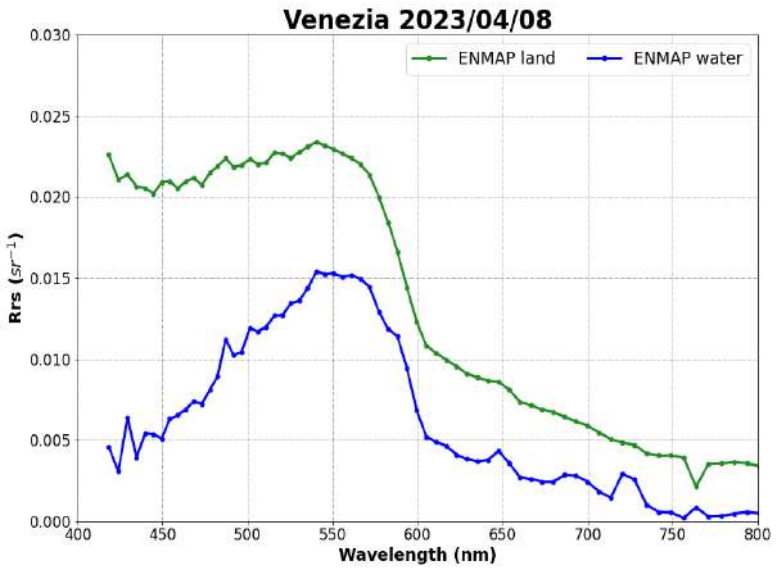
Comparison of EnMAP & in-situ

EnMap L2A water

EnMap L2A water



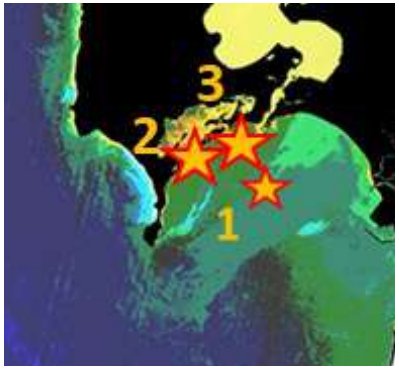




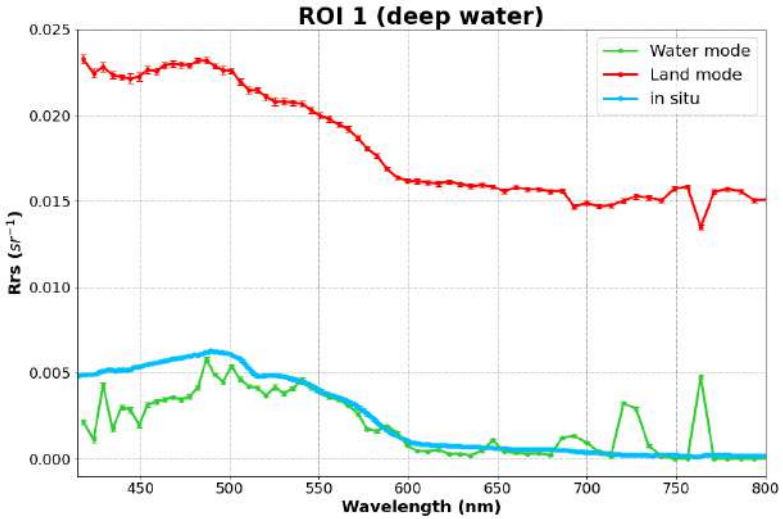
Deep and shallow clear marine waters

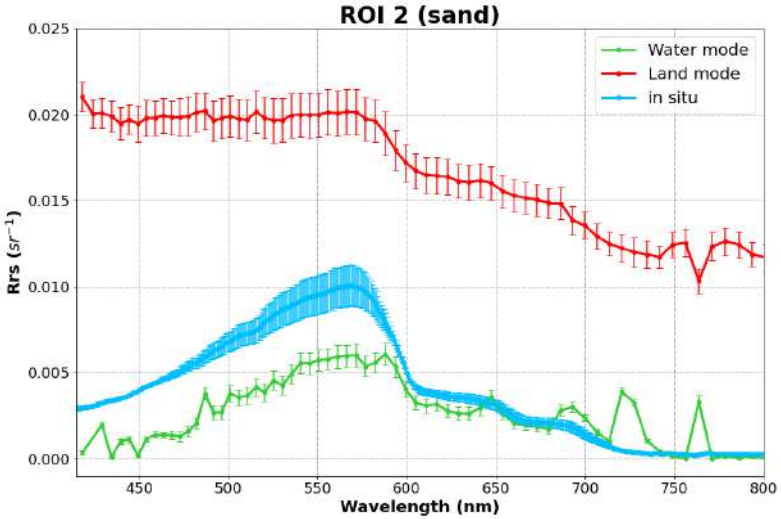
Comparison of EnMAP & in-situ

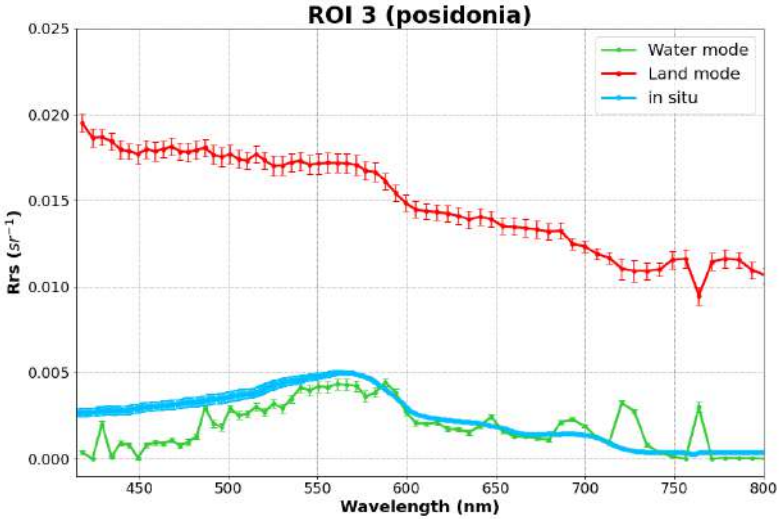
Oristano 2023/07/14 land



Oristano 2023/07/14 water



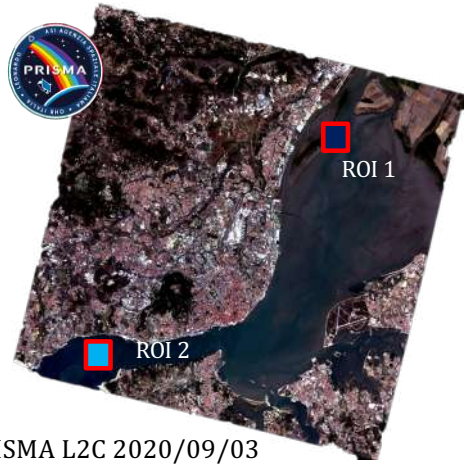




Rivers

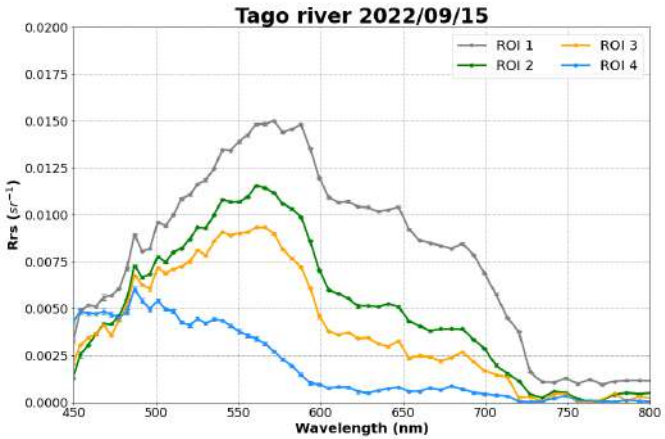
Comparison of EnMAP, DESIS, PRISMA (and S2-MSI & S3-OLCI)

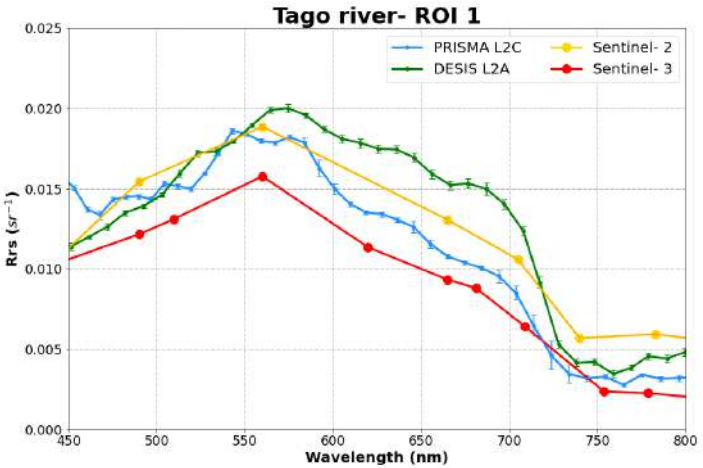
EnMap L2A combined

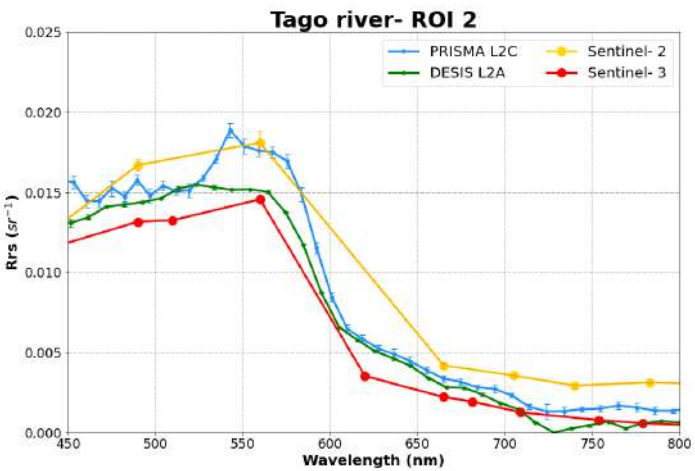


PRISMA L2C 2020/09/03

DESIS L2A 2020/09/02



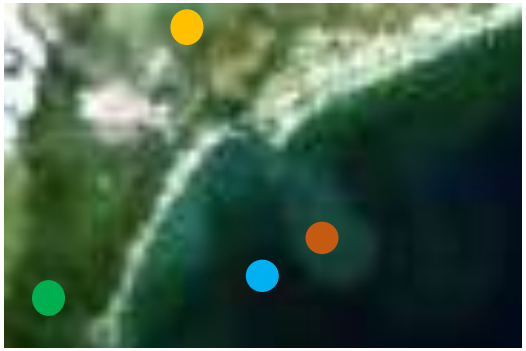




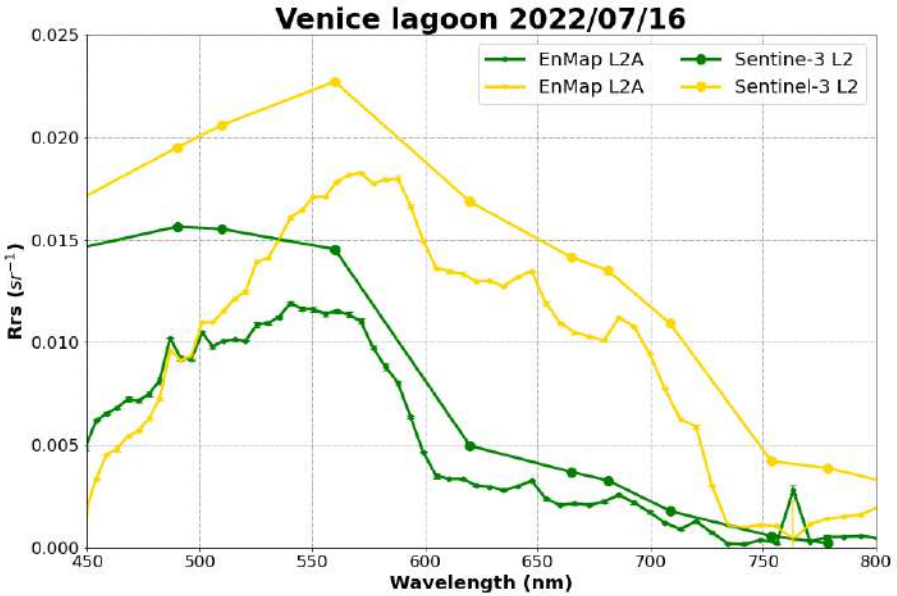
Transitional waters

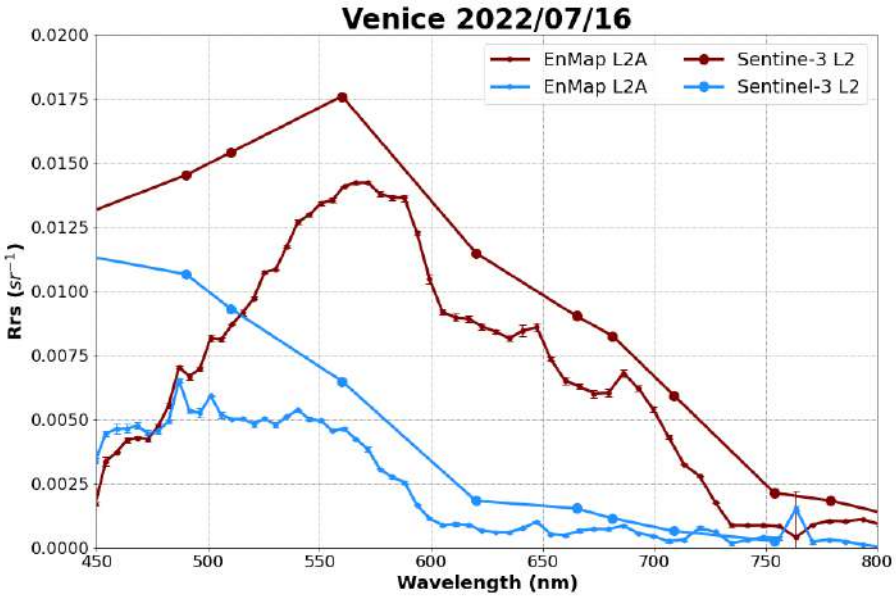
EnMap L2A combined

Comparison of EnMap & S3-OLCI



Sentinel-3 L2 product

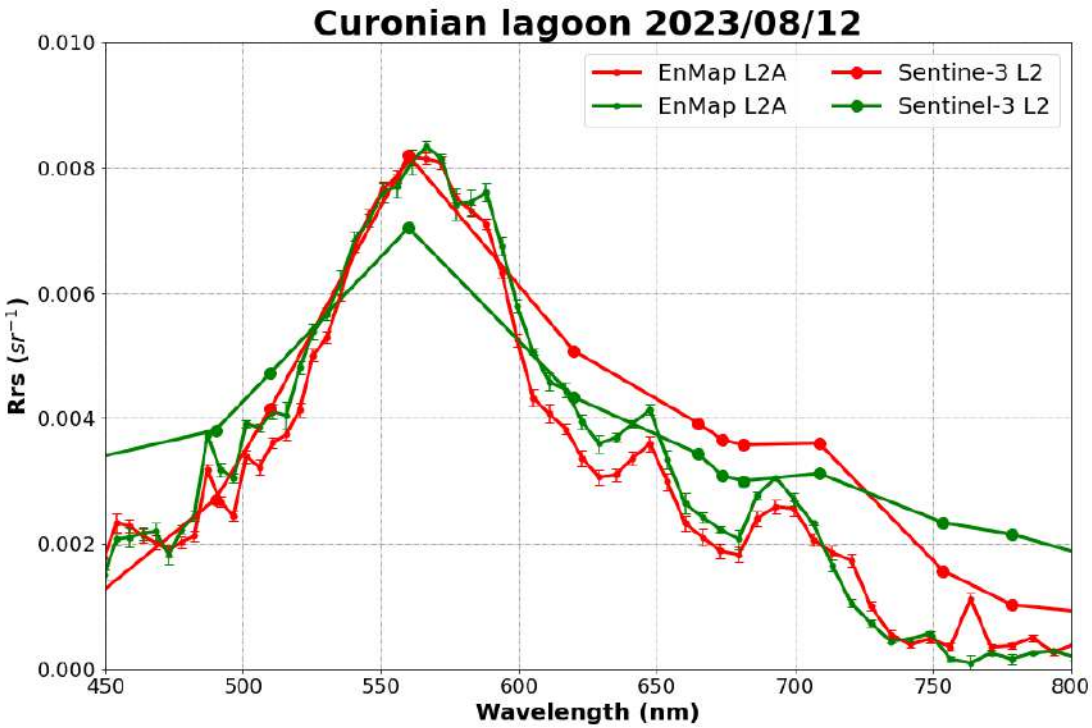


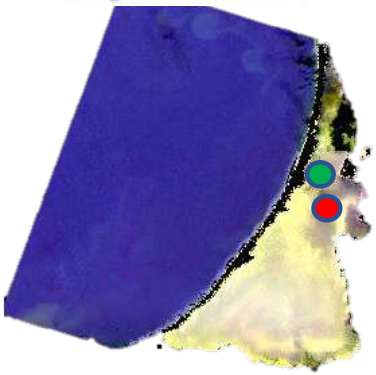


Lagoons

EnMap L2A combined

Comparison of EnMap & S3-OLCI

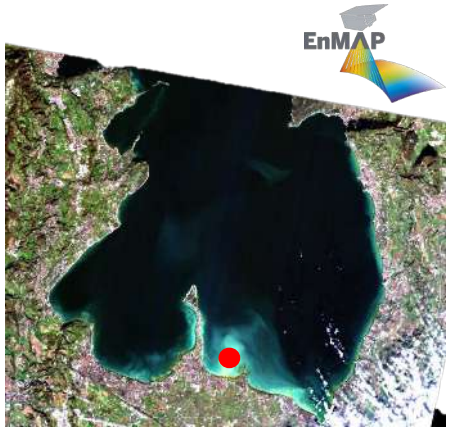




Sentinel-3 L2 product

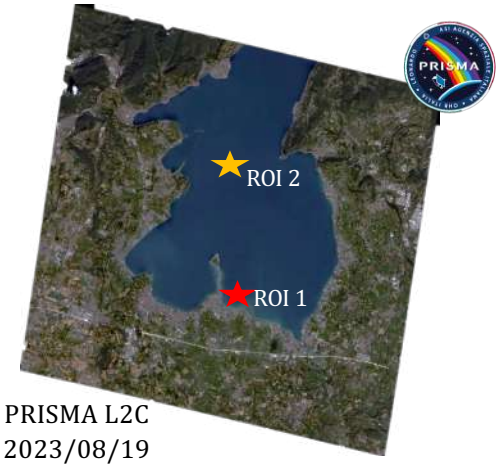
Clear lakes

Comparison of EnMap & S2-MSI & PRISMA & EMIT

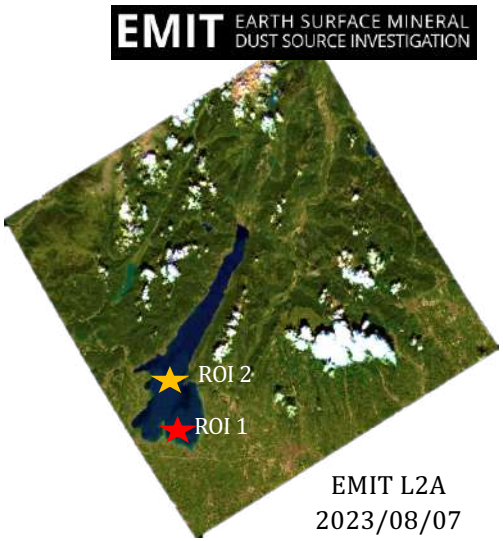


EnMap L2A combined
2022/12/06

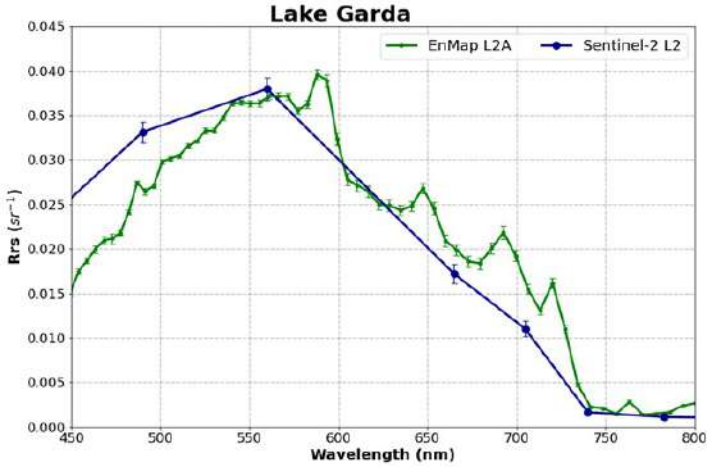
Sentinel-2 L2 product
2022/12/07

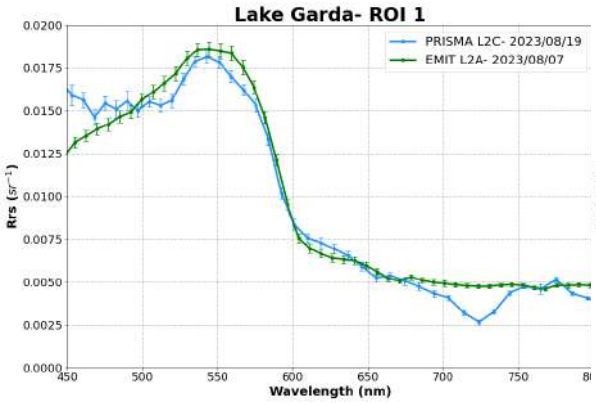


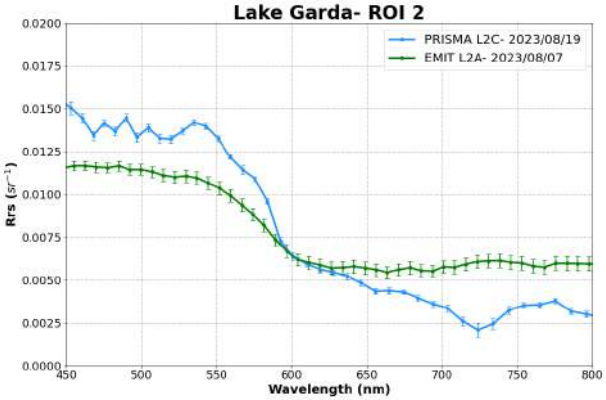
PRISMA L2C
2023/08/19



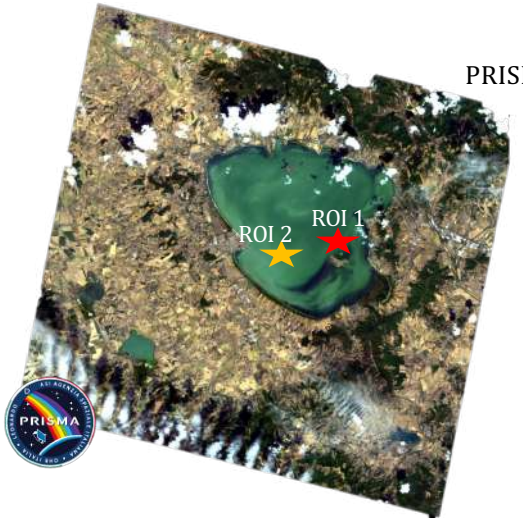
EMIT L2A
2023/08/07





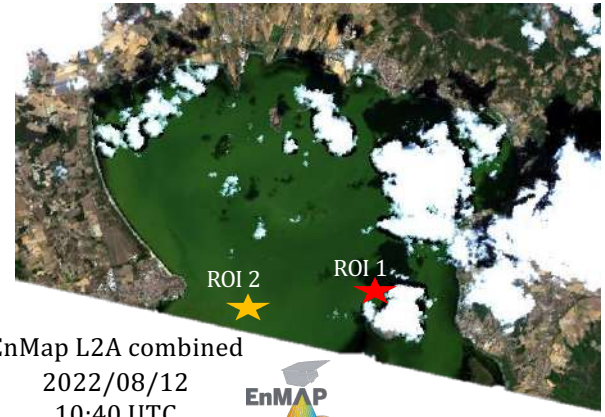


Turbid lakes

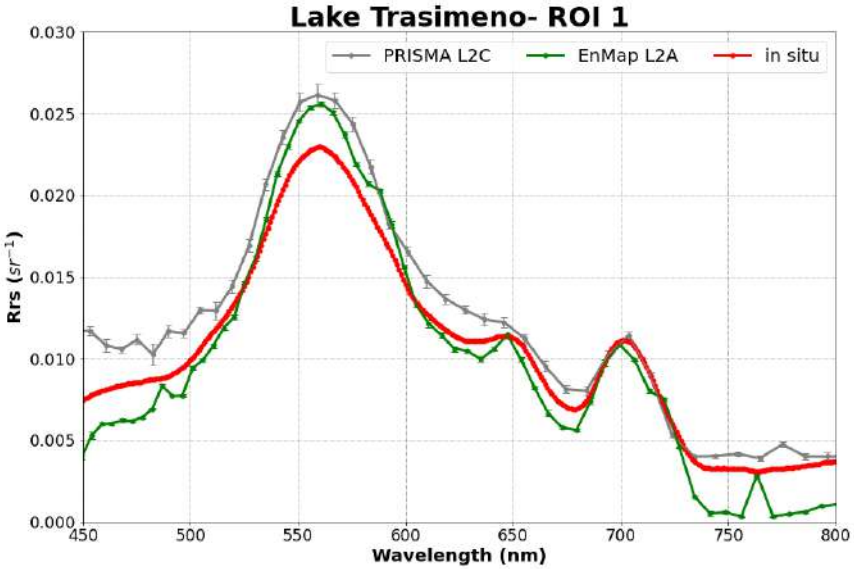


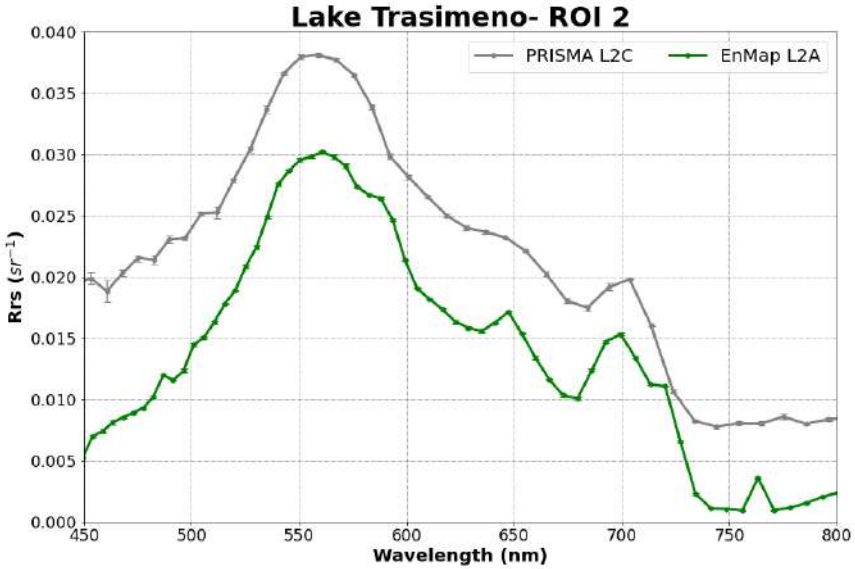
PRISMA L2C 2022/08/12
10:05 UTC

Comparison of PRISMA, EnMAP & in situ



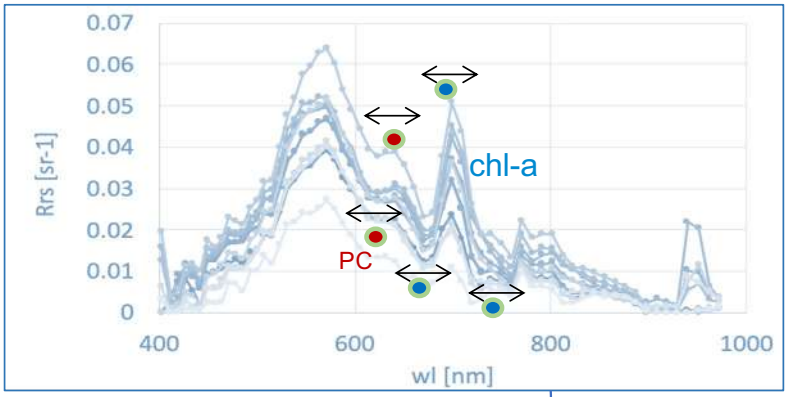
EnMap L2A combined
2022/08/12
10:40 UTC

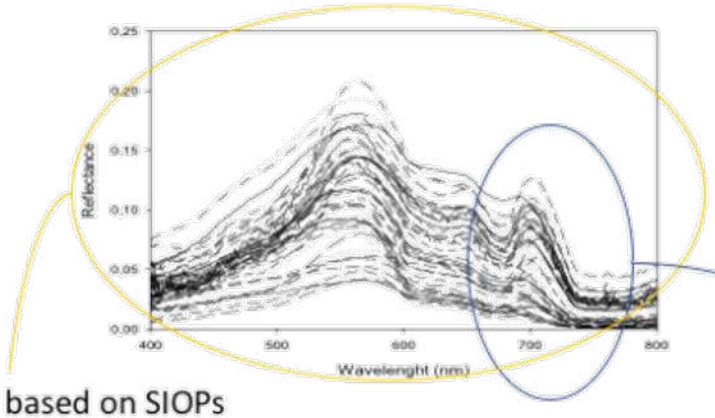




Water quality products

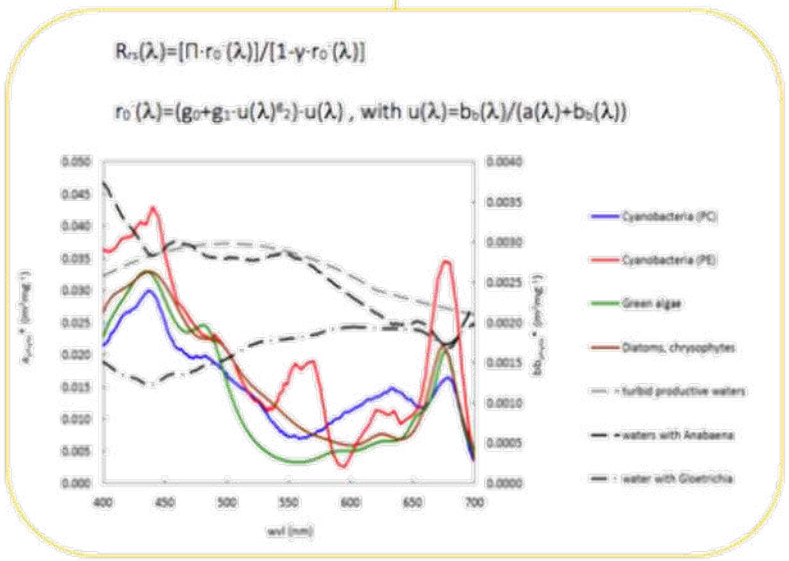
- Bio-optical modelling inversion **BOMBER** (Giardino et al., 2012);
- semi-empirical methods **adaptive band-ratios** based approaches (IDL script a/o R scripts, free),

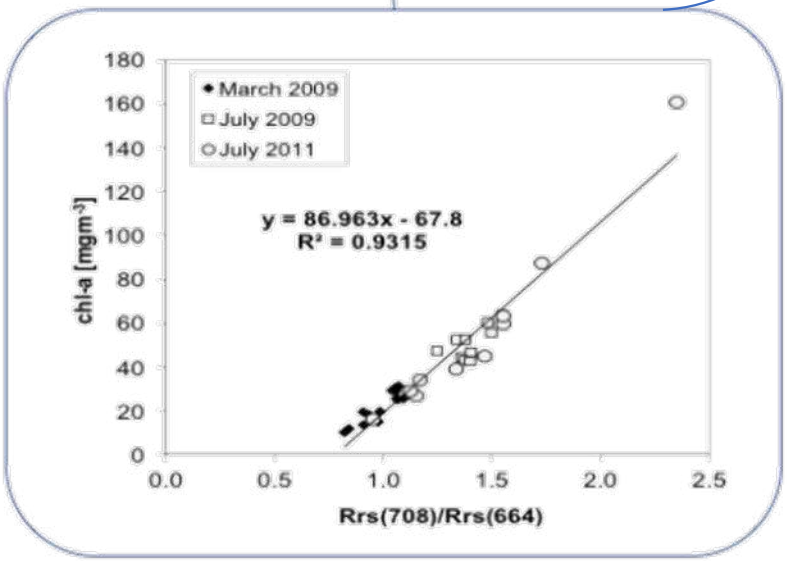




Bio-optical family based on SIOPs

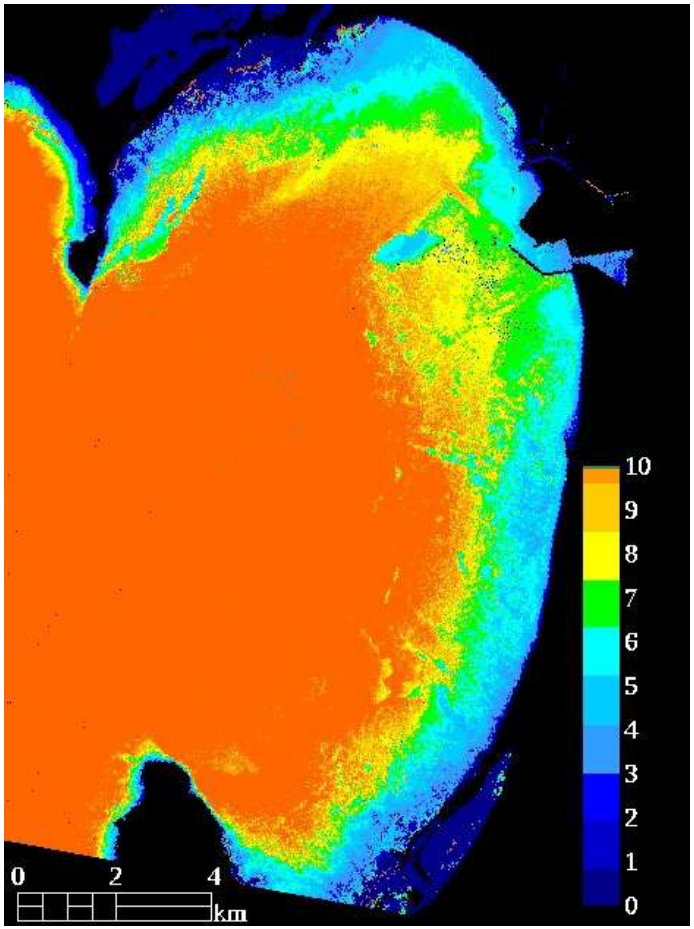
band/ratios family

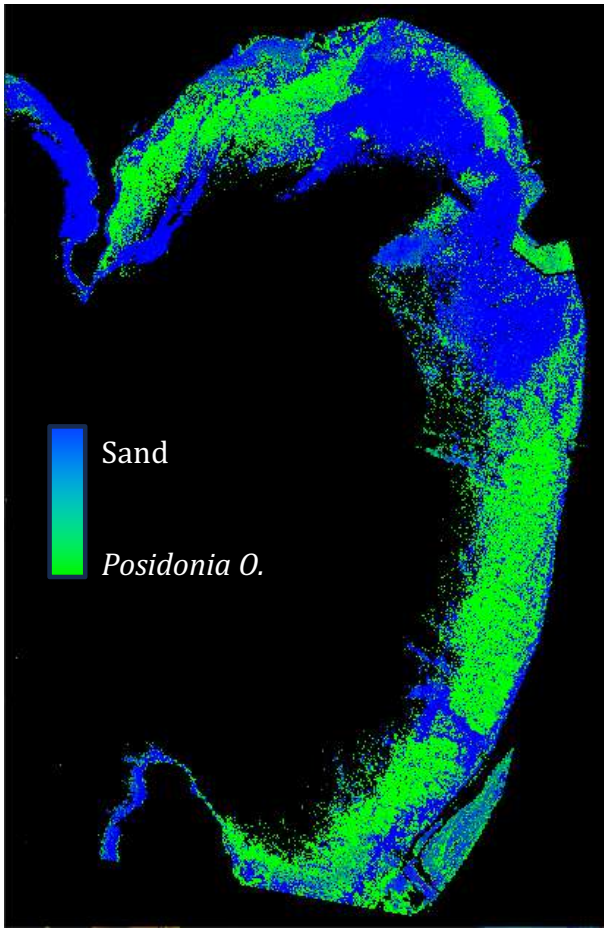




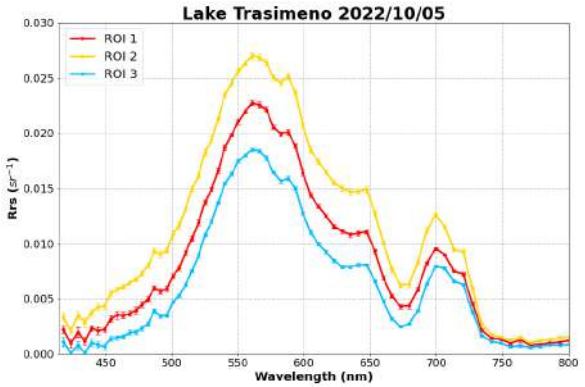
Shallow waters with EnMAP

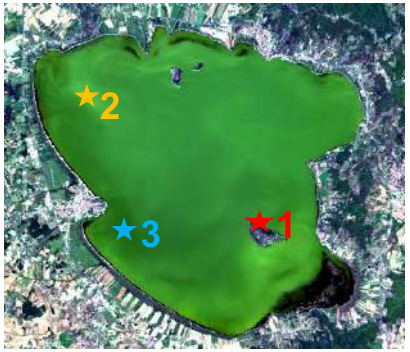
Gulf of Oristano

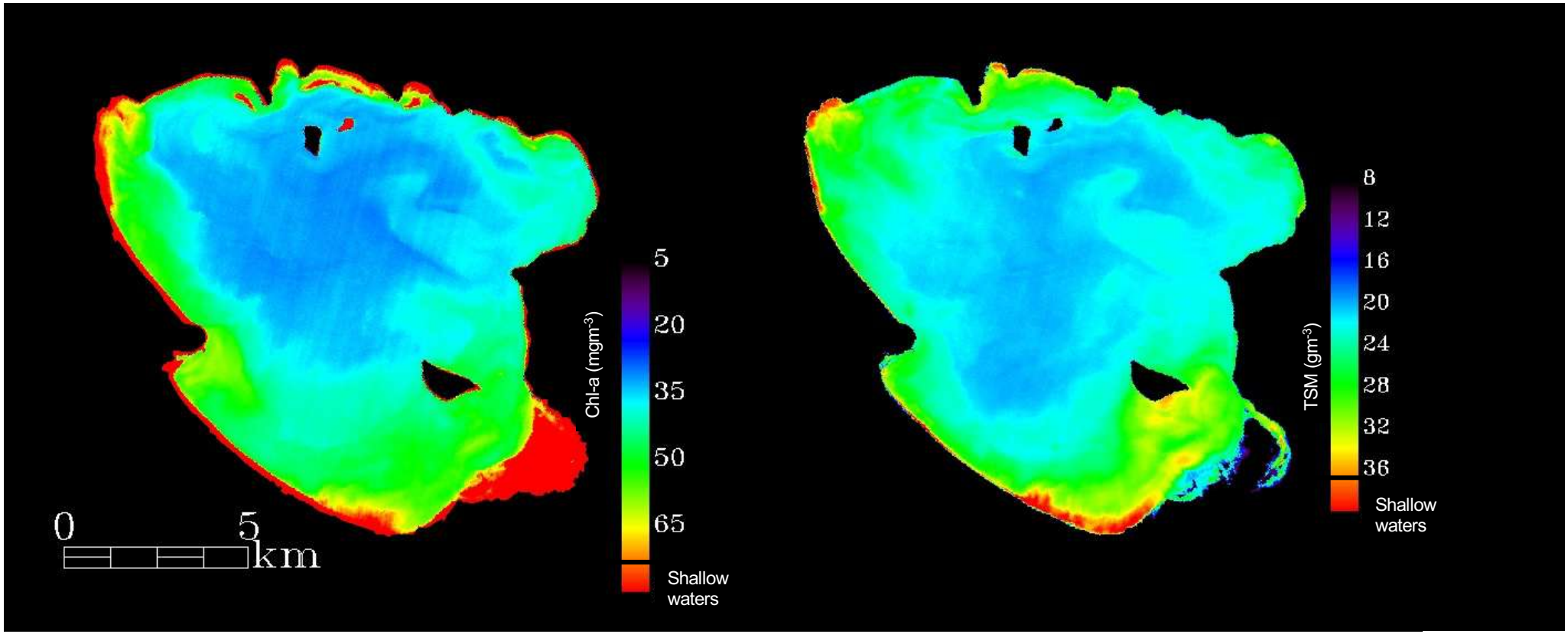




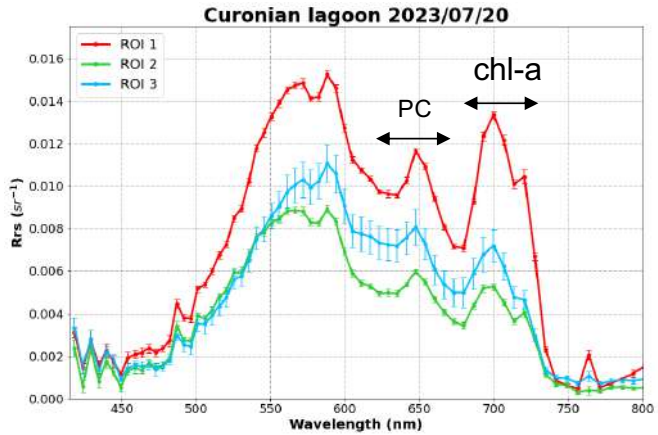
Water quality with EnMAP

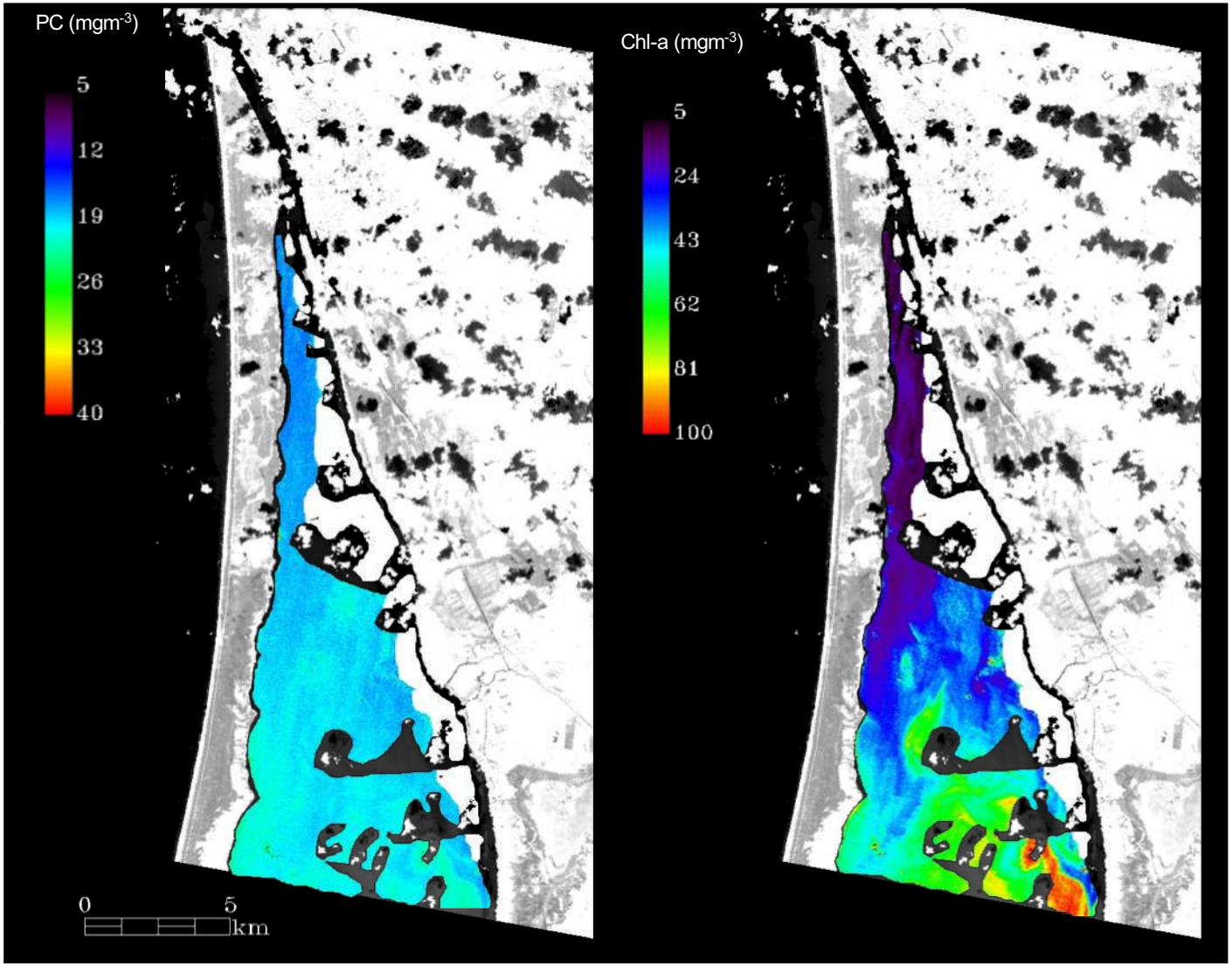






Phytoplankton pigments with EnMAP





Summary and conclusions

- First investigation of EnMap products for water applications is encouraging; particularly L2-water products show significant-reliable values across different water types
- EnMap products seem comparable with those acquired by other sensors so that a synergic use is foreseen

- A statical analysis comparing EnMAP vs. RS data (e.g., in situ, PRISMA, MSI, OLCI) with related metrics (accuracy, error, bias, SAM, etc) is ongoing to quantitively support such preliminary findings; new EnMAP data will be also added
- For some images we will also compare EnMAP-derived water quality products with field data

Summary and conclusions

- As EnMAP is now part of the spaceborne imaging spectroscopy fleet (of e.g., PRISMA, DESIS, HIUSI, EMIT) we would like to perform an analysis of L1 and L2 products over CAL/VAL sites used also by other missions for enabling a sensors performances, also in view of next generation of satellite missions (e.g. CHIME, PRISMA-NG, SBG)

Water - ForCE

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Agenzia Spaziale Italiana

PANDA-WATER

EnMAP, subalpine lakes

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Thanks to EnMAP team!