Exploitation of new hyperspectral sensors in the remote sensing of aquatic ecosystems

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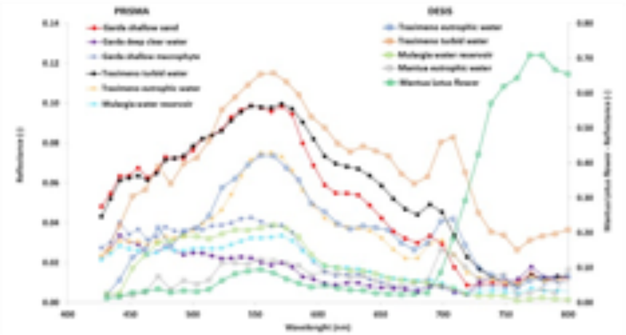
Presentation outline

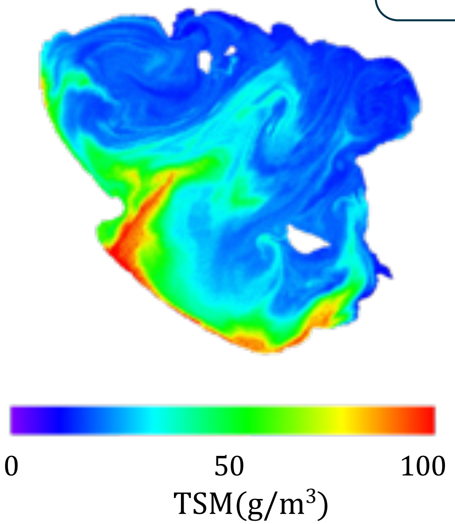
AIM: Evaluation of the consistency of Remote sensing reflectance (Rrs) derived from PRISMA hyperspectral sensor in inland and coastal waters in order to generate water quality maps.

Imagery

Mapping

Spectra





1. Materials & methods
2. Evaluation of hyperspectral data
3. Generation of water quality products
4. Summary and conclusions

Materials & methods

REFERENCE DATA

sentinel-2 sentinel-3

- Autonomous fixed radiometers (CIMEL, WISPStation, PANTHYR)
- Ad-hoc field campaign

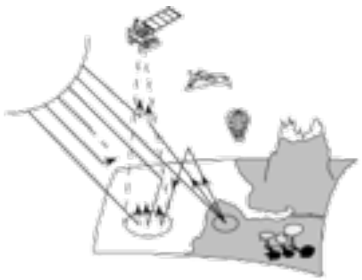


HYPERNETS
EOMORES
NASA

Bresciani et al., 2020
Vansteenwegen et al., 2019

L1 DATA ANALYSIS

In situ → 6SV → TOA L



INPUT: day, month, illumination geometry, view geometry, altitude, AOT

Vermote et al., 2006

L2 DATA ANALYSIS (ATMOSPHERIC CORRECTION)

- ASI automatic processor
- ATCOR
- ACOLITE
- 6SV

INPUT: day, month, illumination geometry, view geometry, altitude, AOT

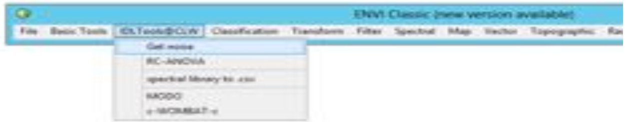
Nazeer et al., 2014
Vanhellemont, 2019
Vermote et al., 2006

L2 DATA ANALYSIS (SUNGLINT CORRECTION)

De-glint processor
(*Sen2coral* plugin)

Hedley et al., 2005
Kay et al., 2008

L2 DATA ANALYSIS (NOISE CALCULATION)

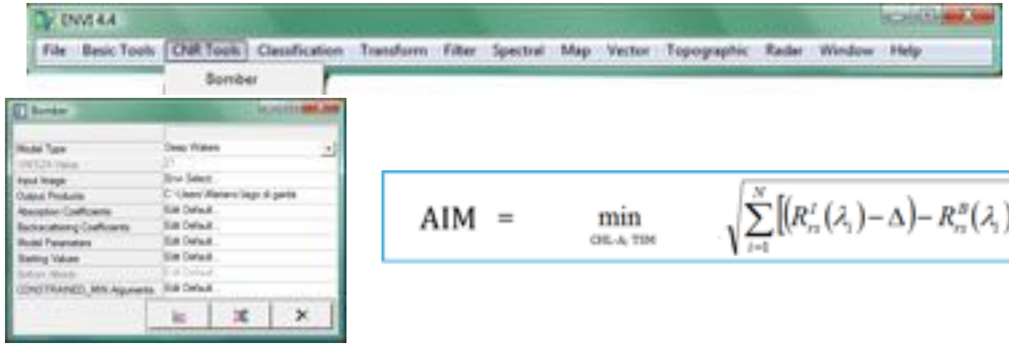


Brando & Dekker, 2003

Materials & methods

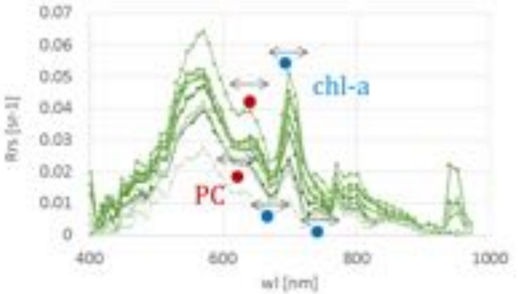
GENERATION OF WATER QUALITY MAPS

BOMBER (Bio-Optical Model Based tool for Estimating water quality and bottom properties from Remote sensing images) is a software package for simultaneous retrieval of the optical properties of water column and bottom from remotely sensed imagery (Giardino et al., 2012) based on Lee et al., (1998, 1999)

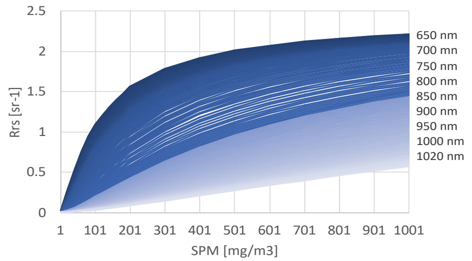


$$AIM = \min_{CHL\text{-}A,\ TSM} \sqrt{\sum_{i=1}^{N}\left[\left(R^{i}_{rs}(\lambda_i)-\Delta\right)-R^{B}_{rs}(\lambda_i)\right]^2}$$

Reflectance ratio taking advantage of continuos-narrow bands, so based on e.g. wavelength-depend peaks/dips (phyto) (Bresciani et al., 2013)



Hyperspectral-wavelength-switching algorithm (spm)



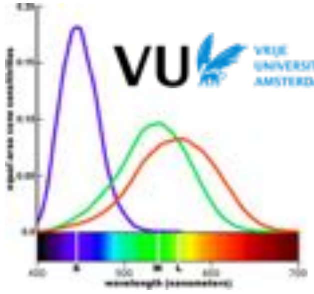
Fwd modelling spectra

GENERATION OF AQUATIC VEG. MAPS

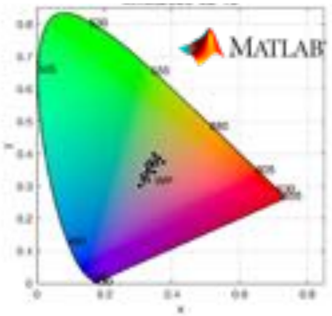
<u>Macrophytes characterization</u>

Classification and thresholding of selected hyperspectral features in VNIR to SWIR ranges, sensitive to association groups of macrophytes (IDL scripts, free). Semi-empirical modelling of macrophyte functional traits (LAI, Chl content) calibrated with in-situ data

GENERATION OF WATER COLOR MAPS



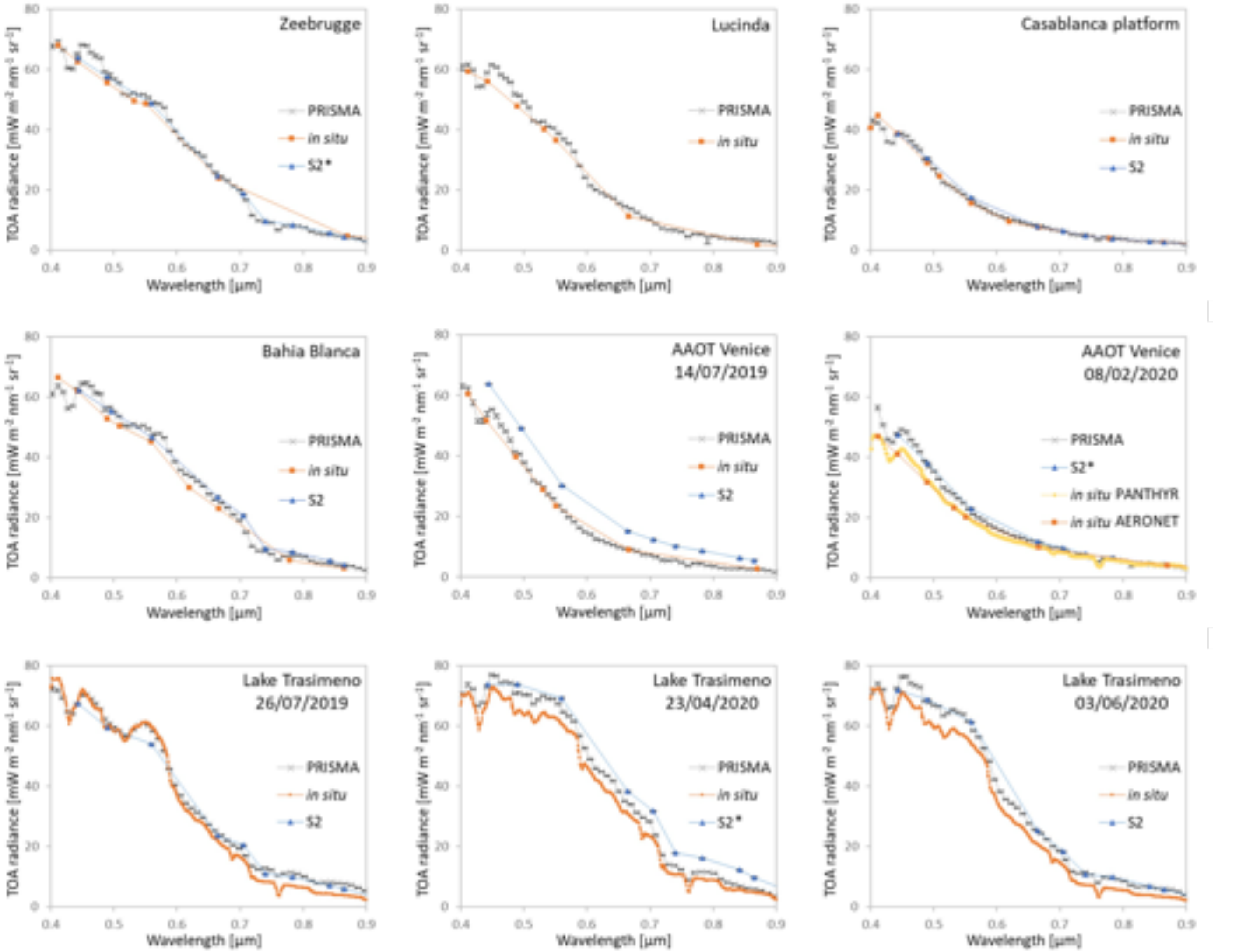
Convolution with eye response filters (no coeff. needed), kindly checked by Hans van der Woerd



Water colour categories using the Forel-Ule scale

Evaluation of hyperspectral data

PRISMA L1 data

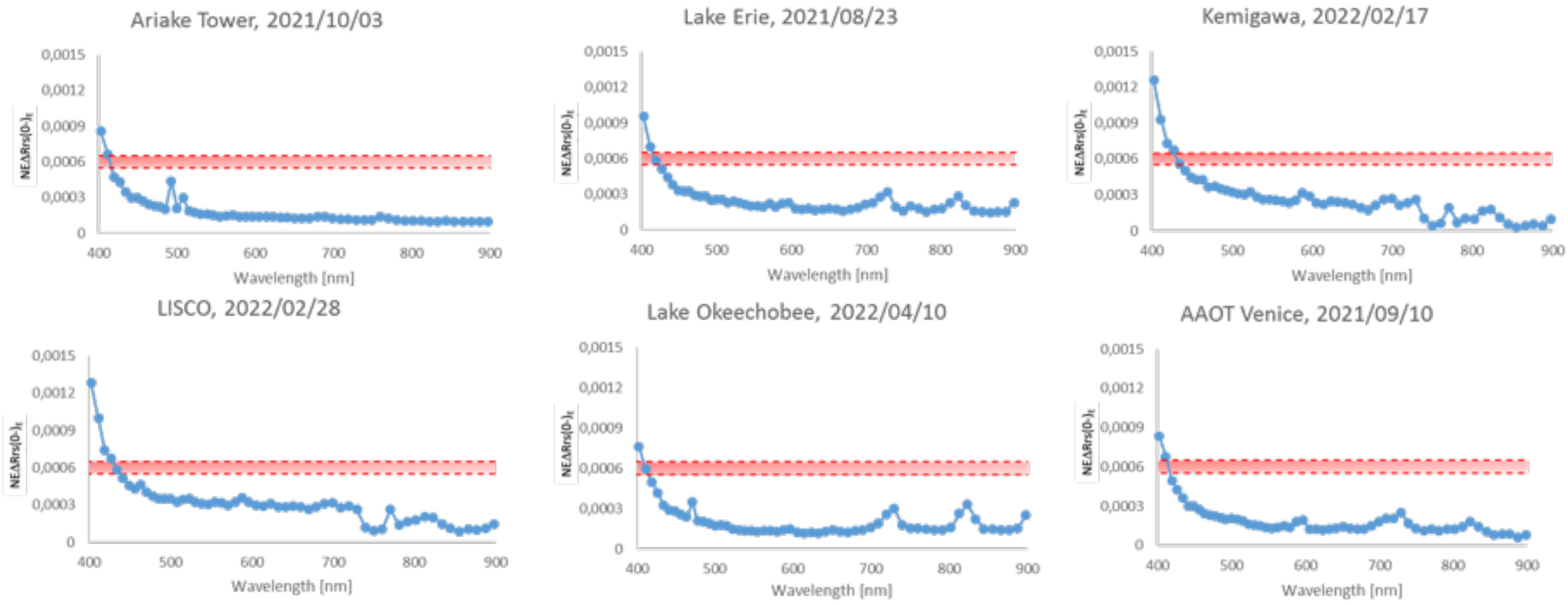


PRISMA vs *In-situ* data
SA = 0.8 - 3.39
RMSE = 0.98

Giardino et al., 2020

Evaluation of hyperspectral data

Examples noise-equivalent reflectance difference calculation (in accordance with Brando & Dekker, 2003)

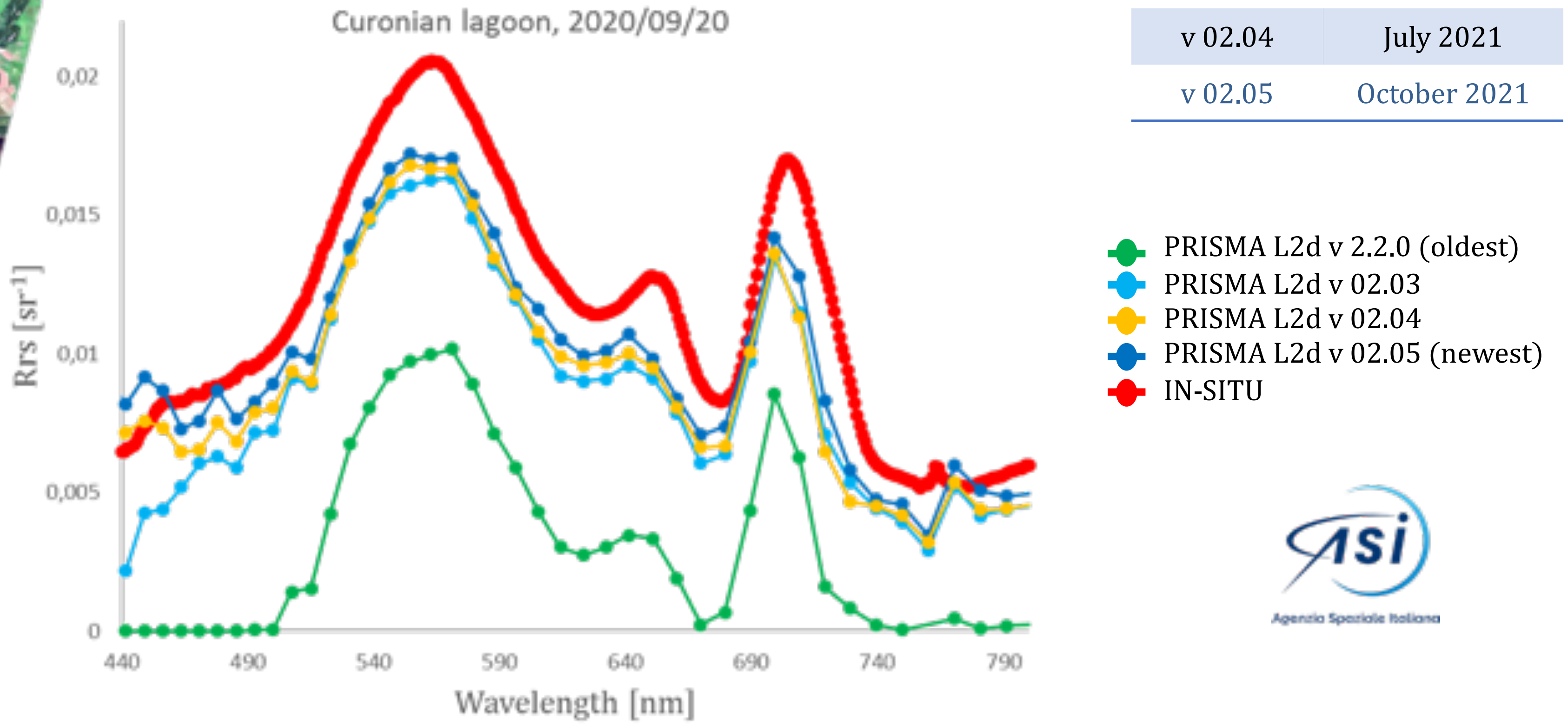


Removal of the noisiest bands (402-411-419-427 nm), for values in the range 0.00055 and 0.00065 [sr^{-1}] and above

Evaluation of hyperspectral data

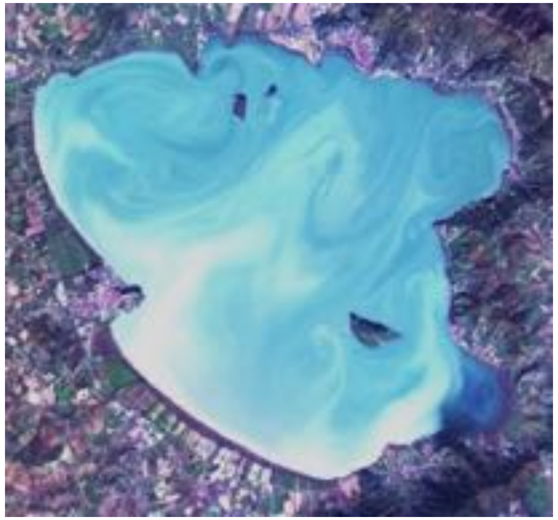
PRISMA L2d processor versions provided by ASI automatic processor

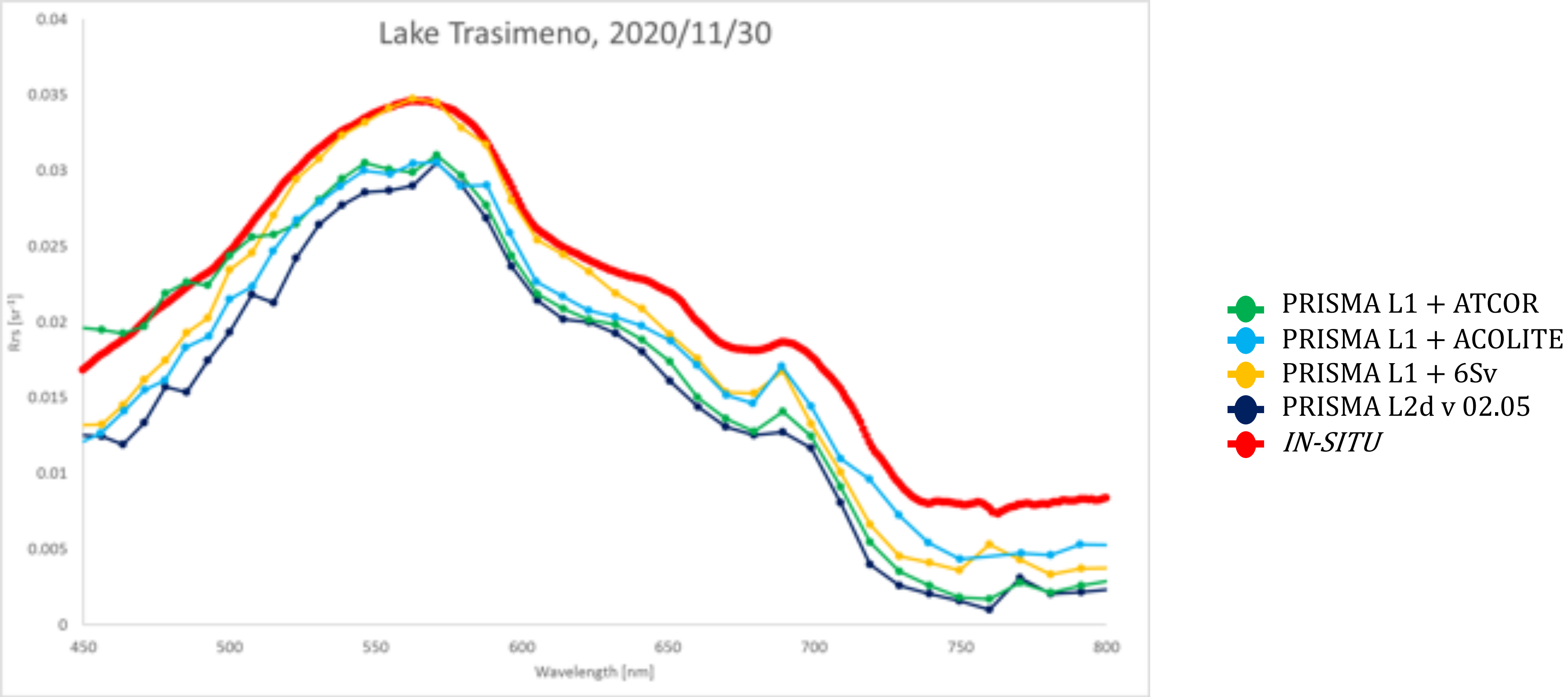
Processor version id	Available since
v 2.2.0	April 2020
v 02.03	January 2021
v 02.04	July 2021
v 02.05	October 2021



Evaluation of hyperspectral data

Atmospheric correction



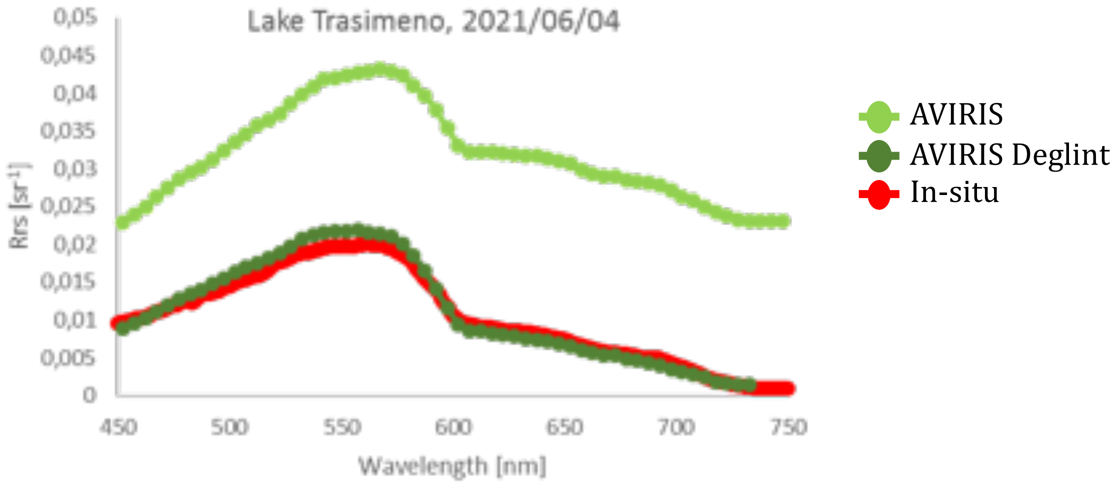


	In-situ VS PRISMA L2d v02.05	In-situ VS PRISMA L1 + ATCOR	In-situ VS PRISMA L1 + ACOLITE	In-situ VS PRISMA L1 + 6Sv
R^2	0.99	0.92	0.98	0.99
RMSE	0.0057	0.0043	0.0045	0.0037

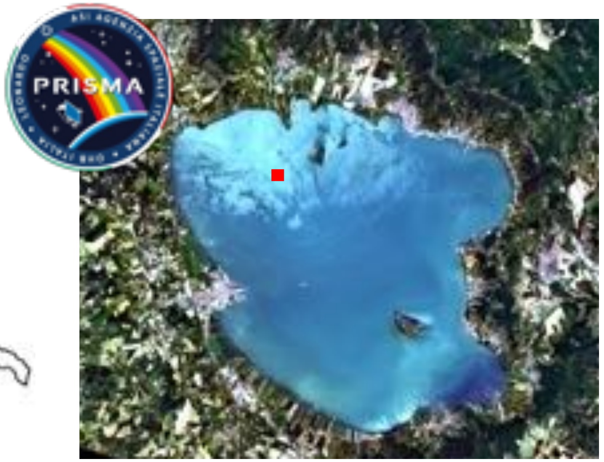
De-glint processor
(*Sen2coral* plugin) SNAP

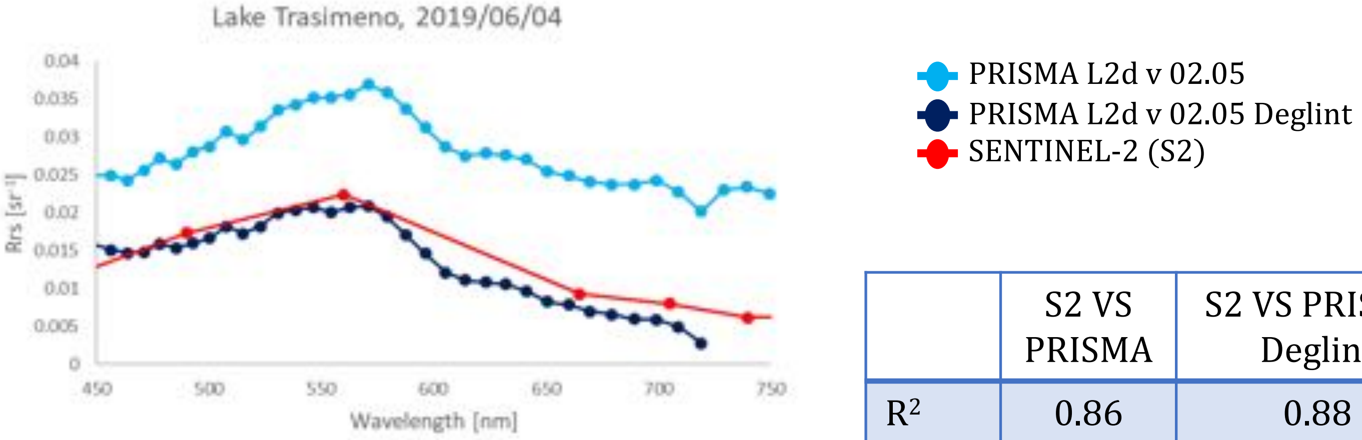
Evaluation of hyperspectral data

Sun-glint correction



	IN-SITU VS AVIRIS	IN-SITU VS AVIRIS Deglint
R^2	0.8	0.99
RMSE	0.022	0.001

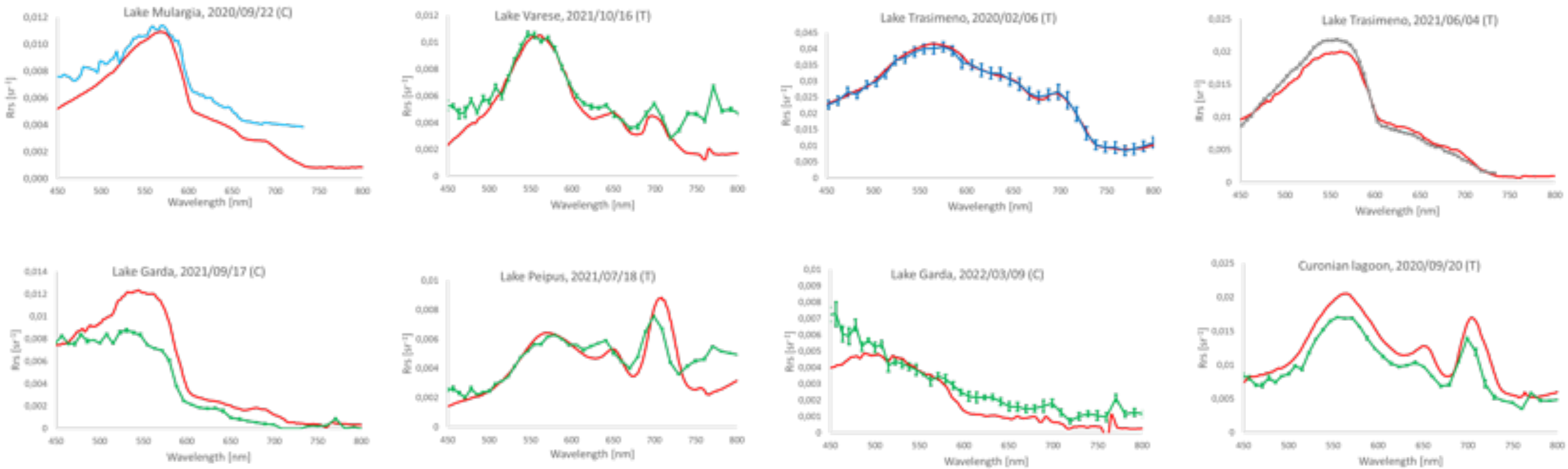


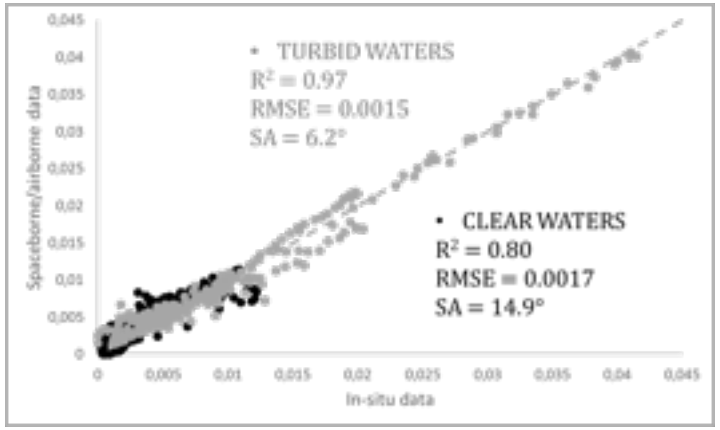


	S2 VS PRISMA	S2 VS PRISMA Deglint
R^2	0.86	0.88
RMSE	0.0179	0.0046

Evaluation of hyperspectral data

Comparison between hyperspectral spaceborne and airborne data with *in-situ* data
Turbid water (T) *vs* Clear water (C)





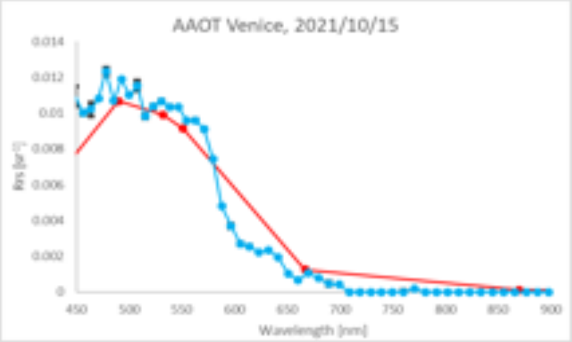
- In- situ
- PRISMA L2d v02.05
- DESIS L2A
- AVIRIS Deglint
- HYSPEX Deglint

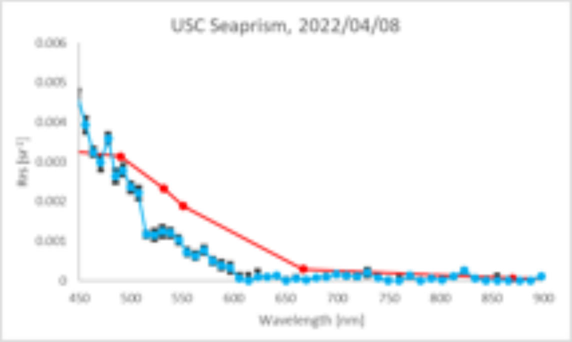
Evaluation of hyperspectral data: ongoing activities

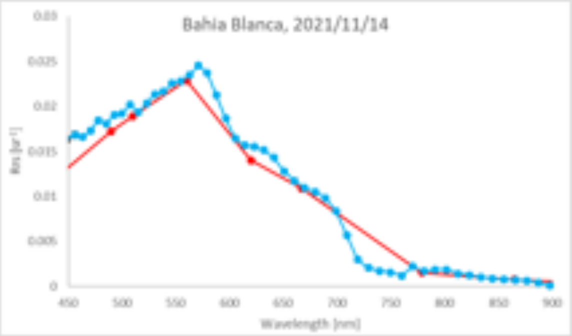
109 PRISMA images (L2d v 02.05) acquired with Cloud Coverage ≤ 2 % were selected over the ~300 images available (synchronous with AERONET-OC measure). Period: July 2019 – July 2022

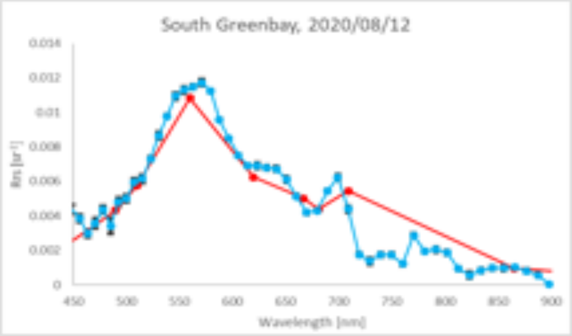
In-situ data: Version 3 Level 1.5 Normalized Water-leaving Radiance

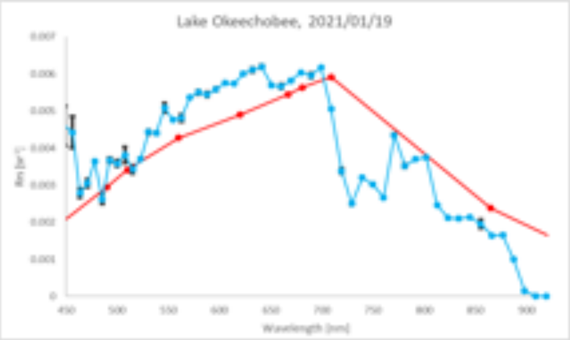
AERONET PRISMA L2d v 02.05

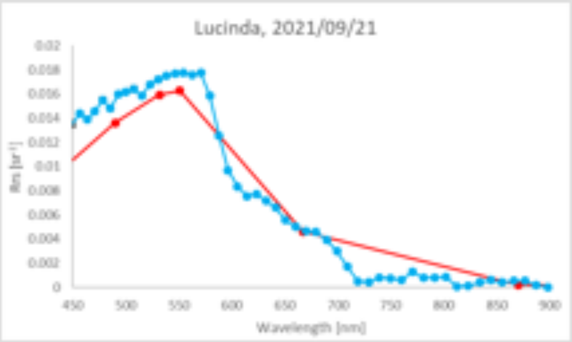


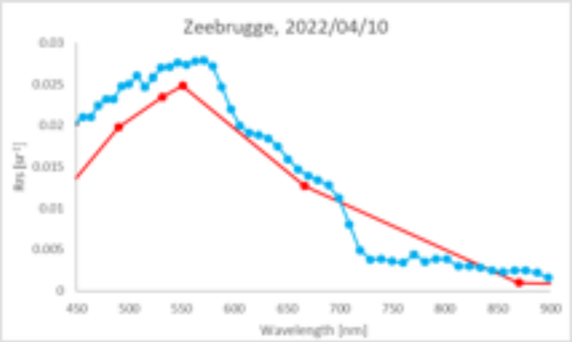






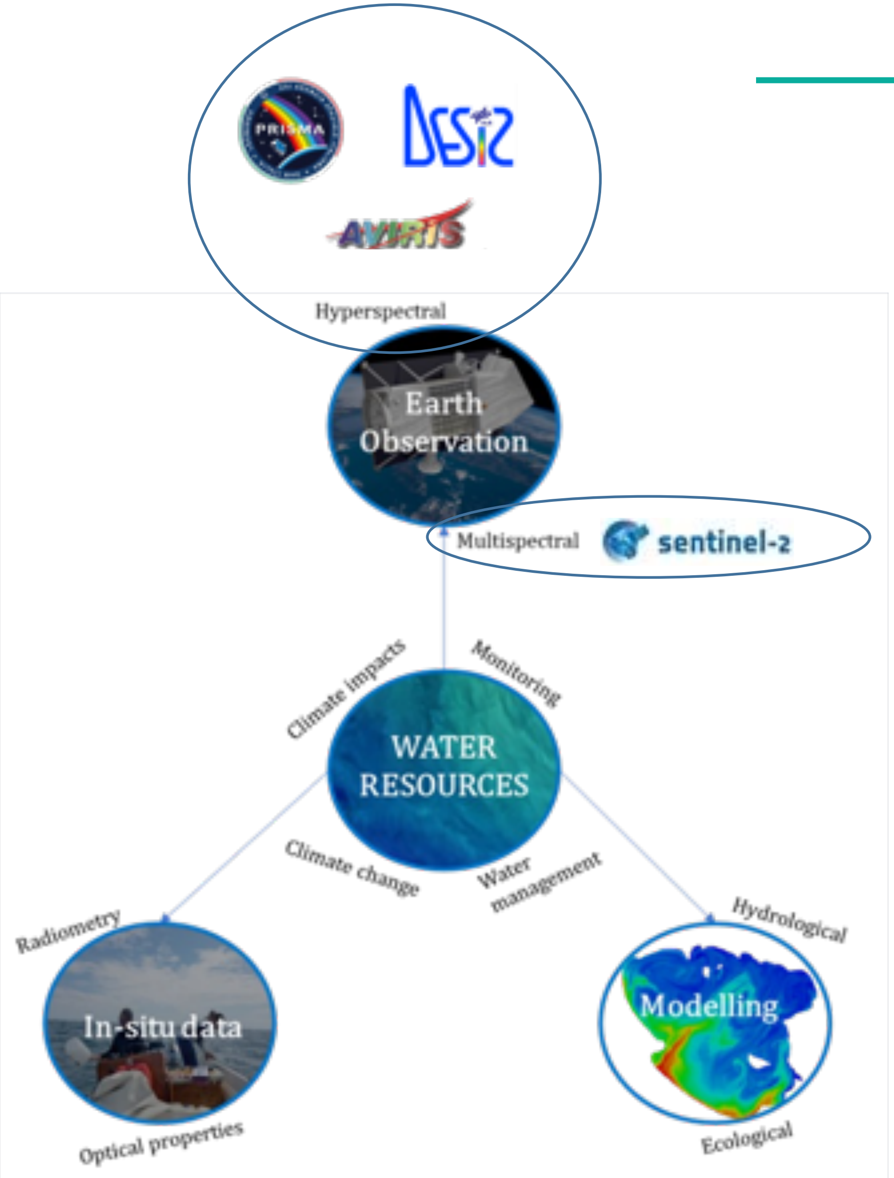






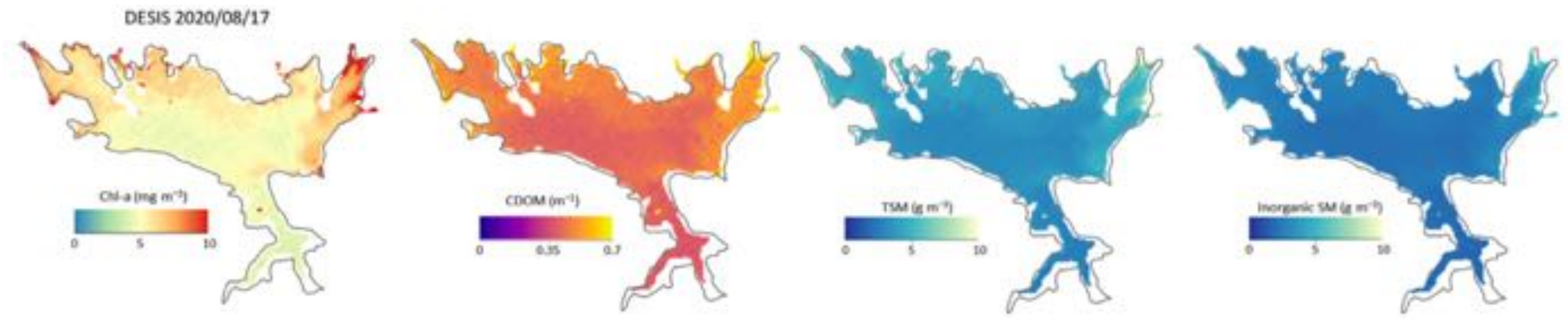
Generation of water quality products

Applications in different study areas



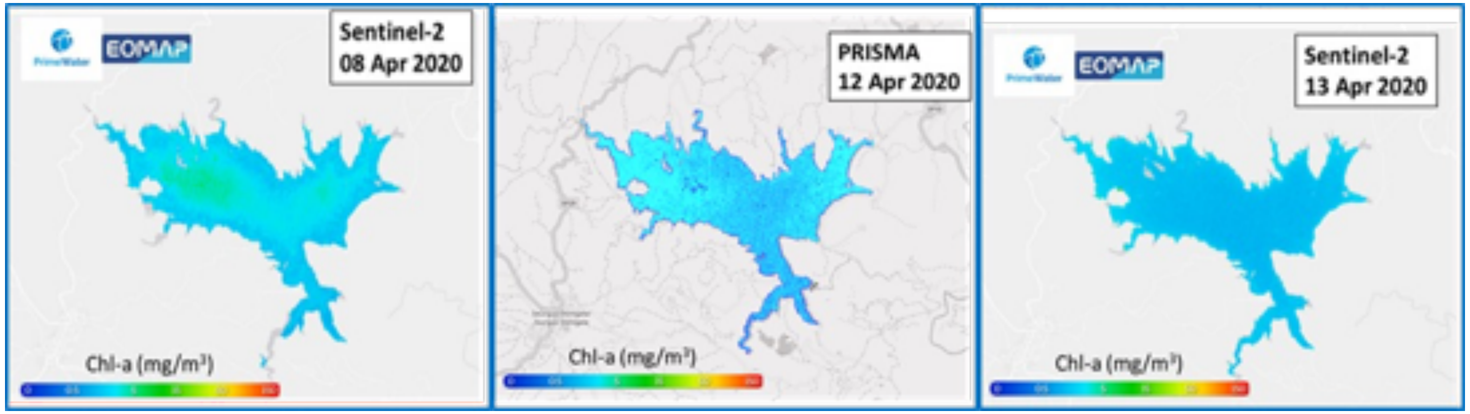
Generation of water quality products

Water quality products



Simultaneous retrieval from BOMBER of Chl-a, CDOM, TSM and Inorganic SM.

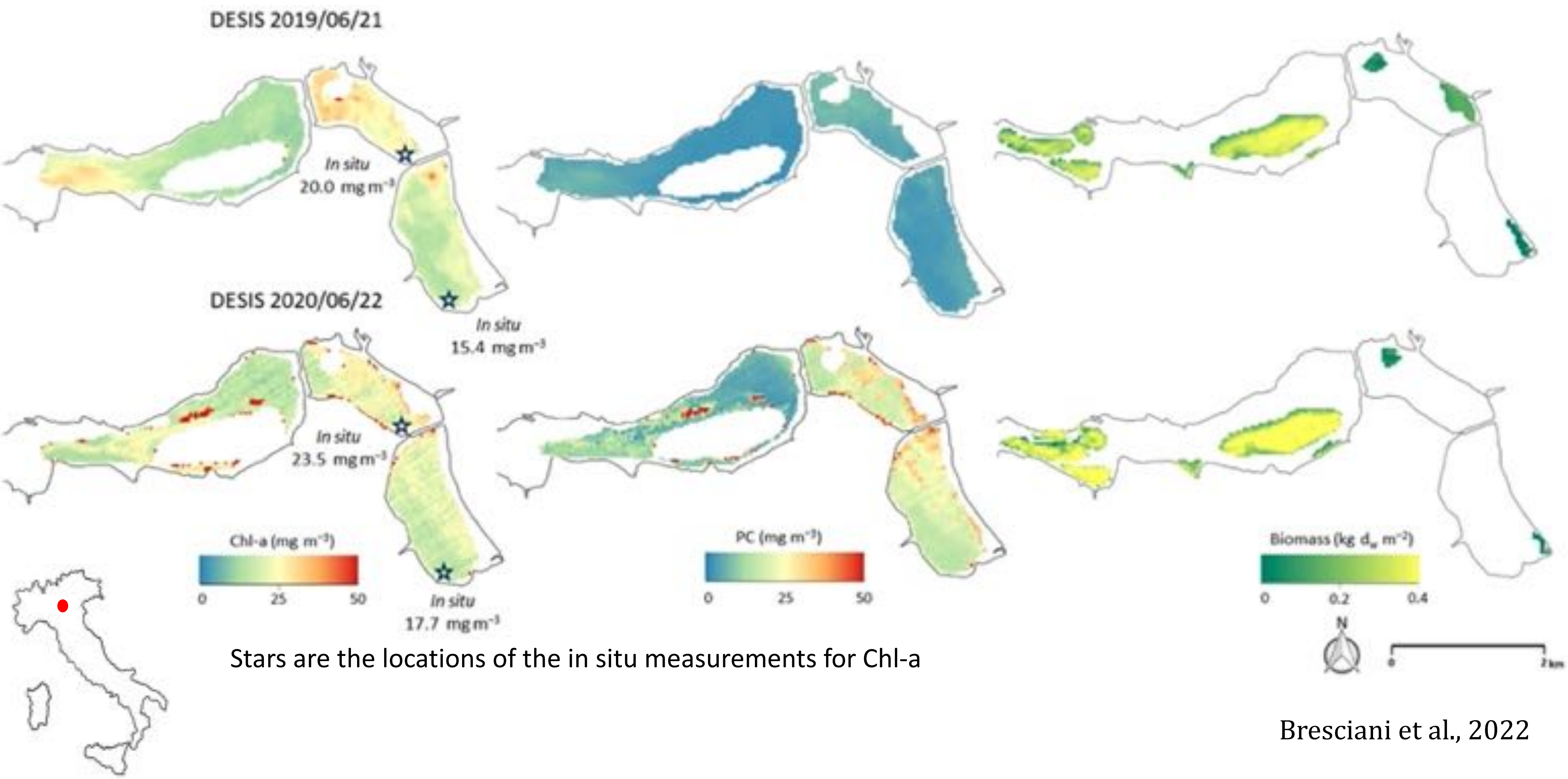
Bresciani et al., 2022



Temporal dynamic (8-13 April 2020) of Chl-a mapping from S2-MSI and PRISMA

Generation of water quality products

Aquatic vegetation



Stars are the locations of the in situ measurements for Chl-a

Maps of concentration of phytoplankton pigments (Chl-a and PC) and of floating-leaved and emergent macrophyte biomass

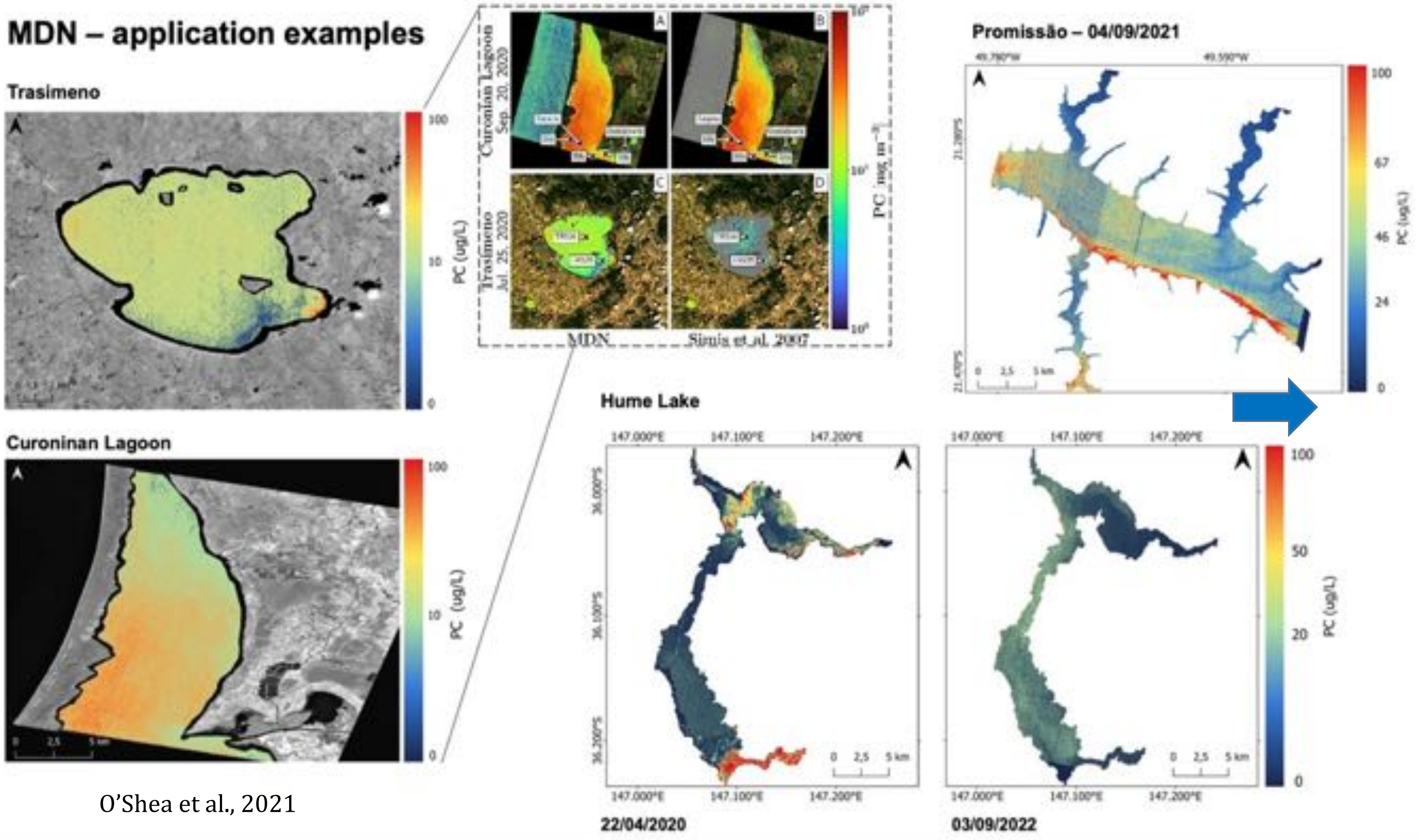
Bresciani et al., 2022

Generation of water quality products

Water quality maps in terms of Phycocyanin

Mixture Density Networks (MDN) for mapping PC from HICO or PRISMA:

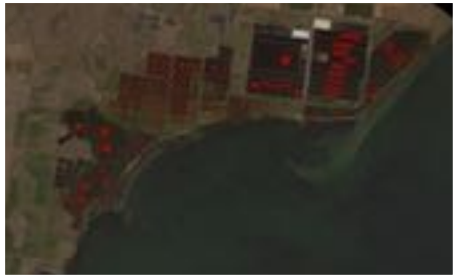
https://github.com/STREAM-RS/STREAM-RS



O'Shea et al., 2021

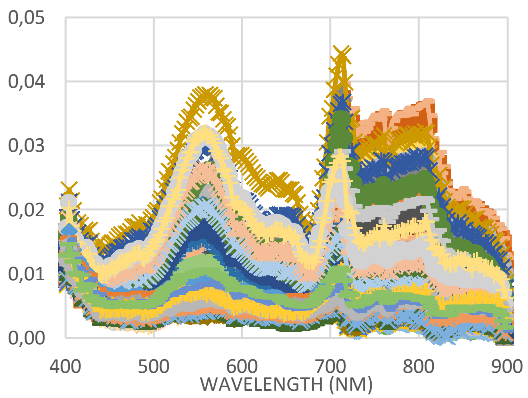
Generation of water quality products

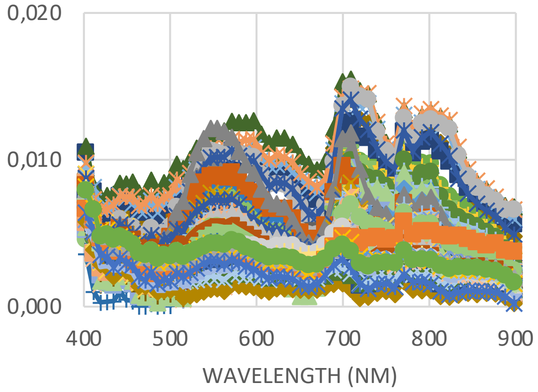
Chromaticity analysis

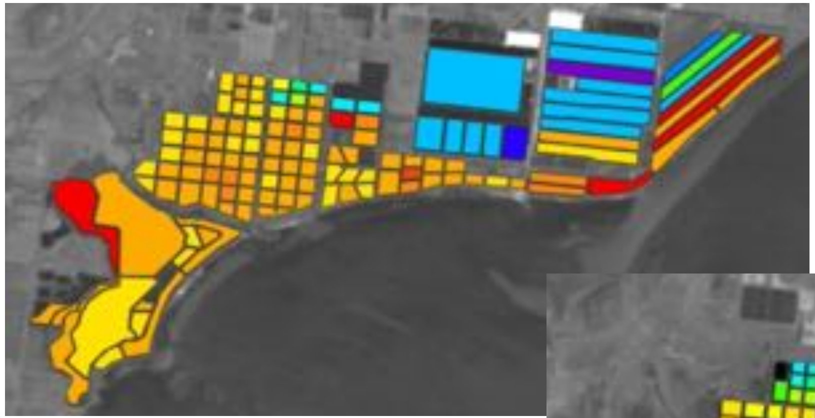


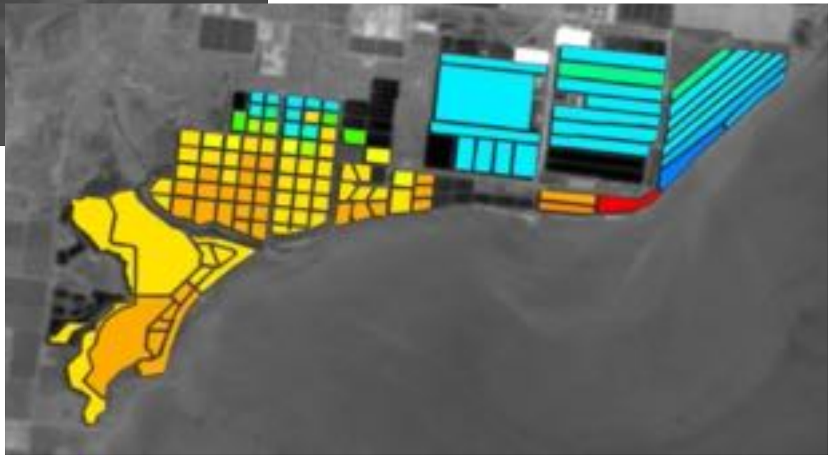
126 ROIs

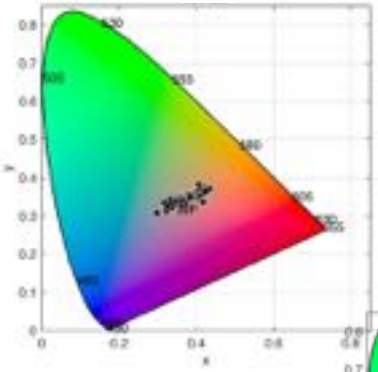
114 ROIs

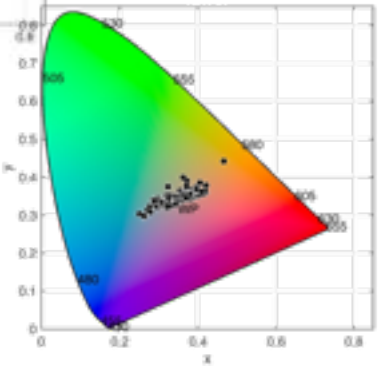






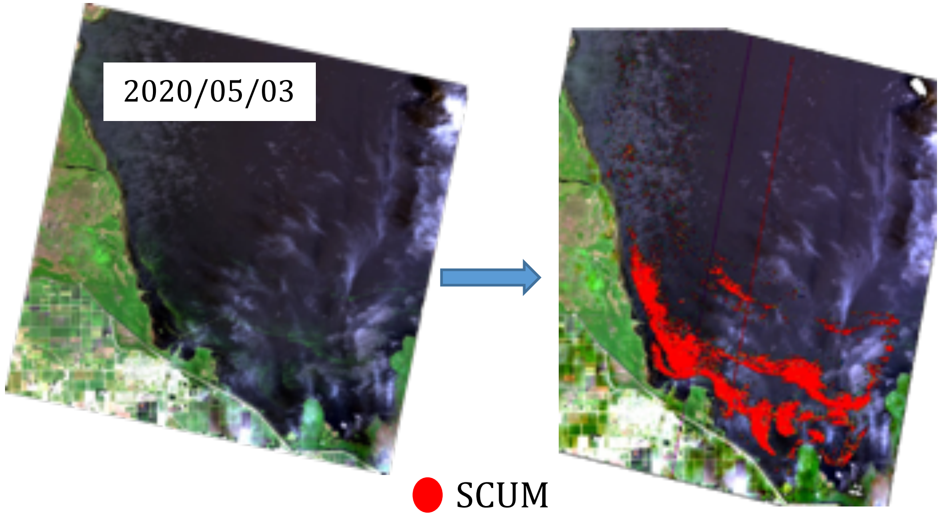


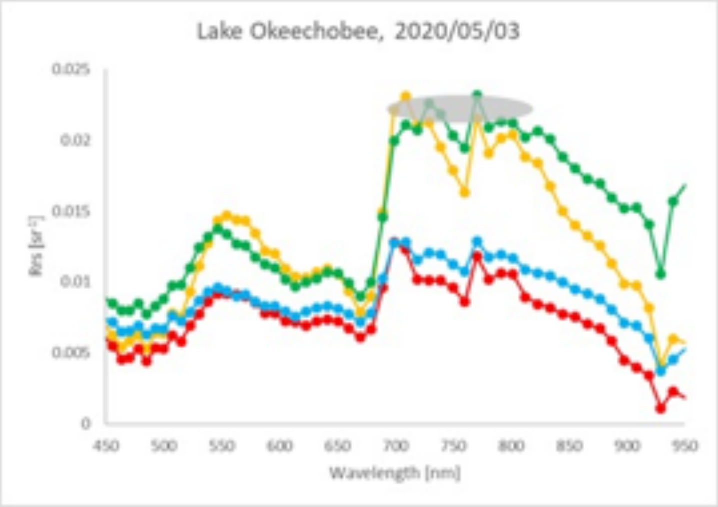


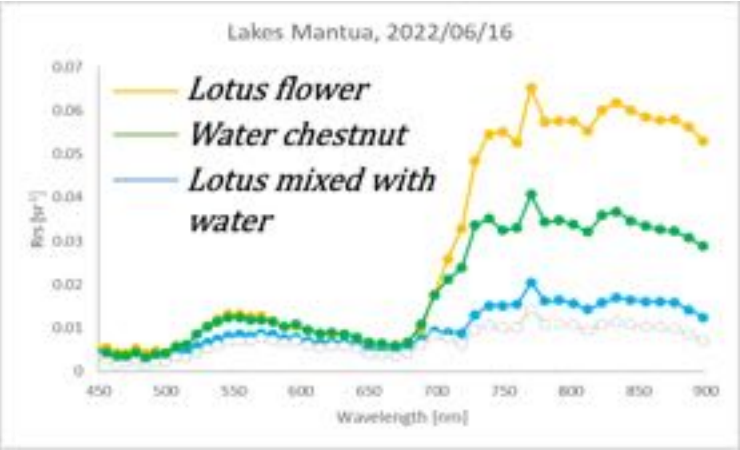


Generation of water quality products

Water quality map: Floating matter

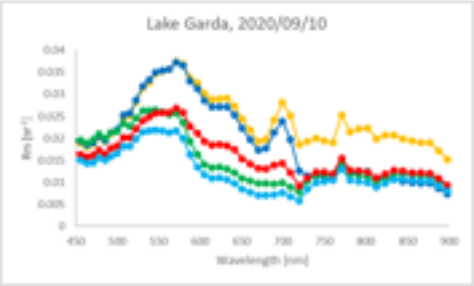


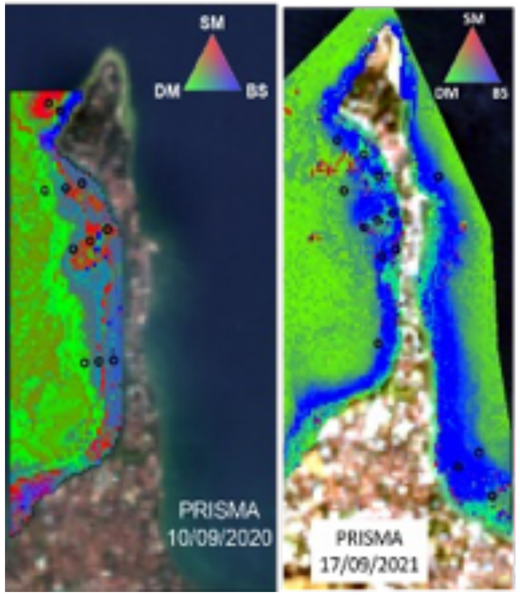




Generation of water quality products

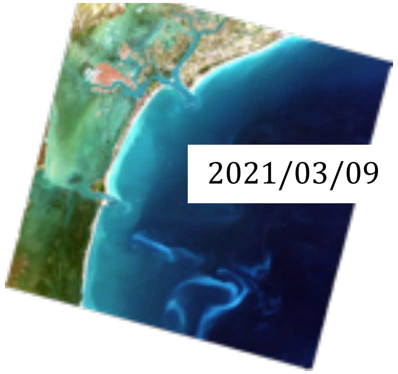
Water quality map: Bottom substrates

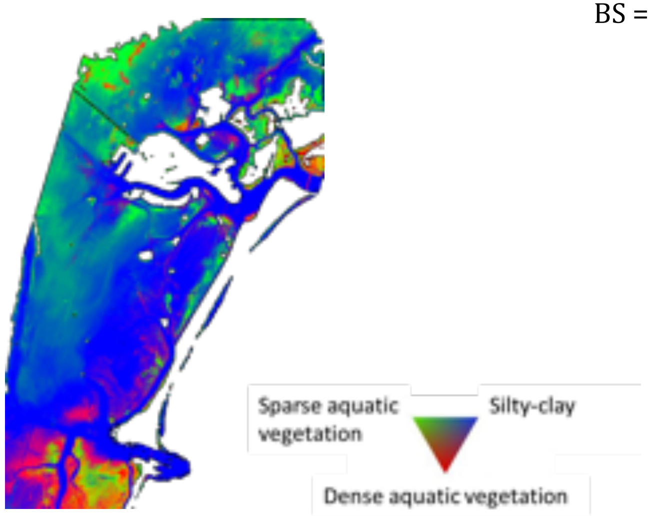




		In situ			
		BS	SM	DM	User's Accuracy
Classified	BS	5	0	0	100%
	SM	2	5	1	62.5%
	DM	0	1	8	88.9%
	Producer's Accuracy	71.4%	83.3%	88.9%	81.8%

BS = Bare Sediment, SM = Sparse Macrophyte, and DM= Dense Macrophyte

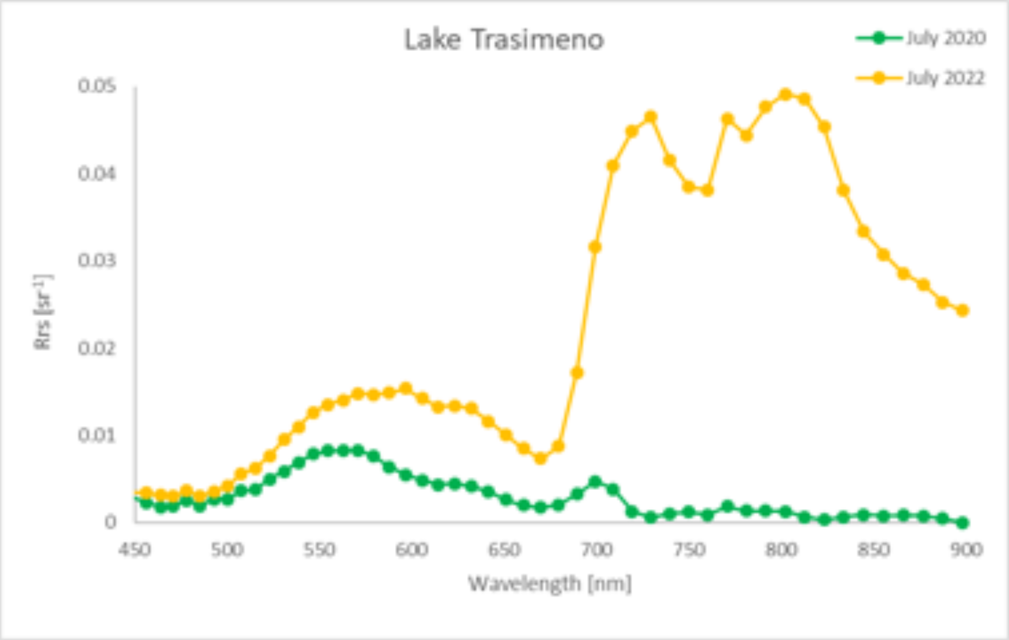


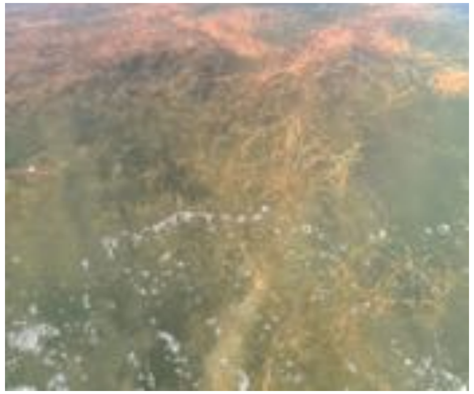


		In situ			
		BS	SM	DM	User's Accuracy
Classified	BS	7	1	0	88.0%
	SM	1	7	1	80.0%
	DM	0	2	6	75.0%
	Producer's Accuracy	87.5%	70.0%	85.7%	80.0%

Generation of water quality products

Submerged aquatic vegetation



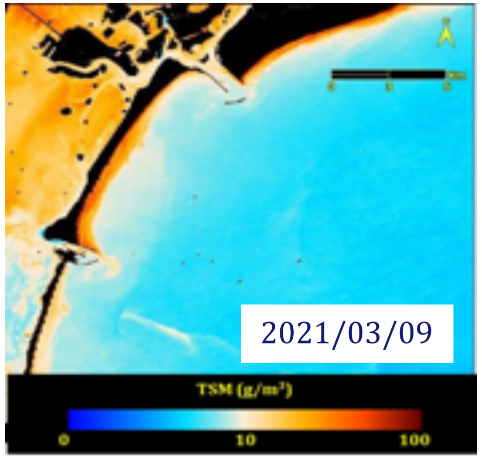


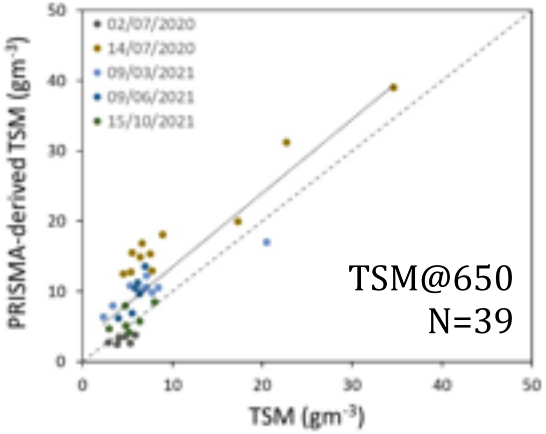
In 2022, hydrometric levels were recorded approximately 145 cm lower than the reference

Generation of water quality products

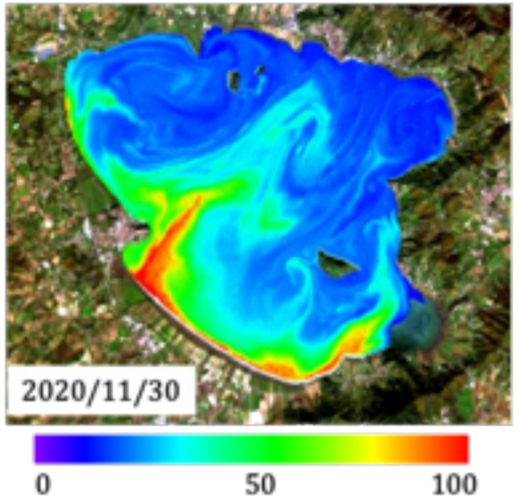
Validations of the water quality products

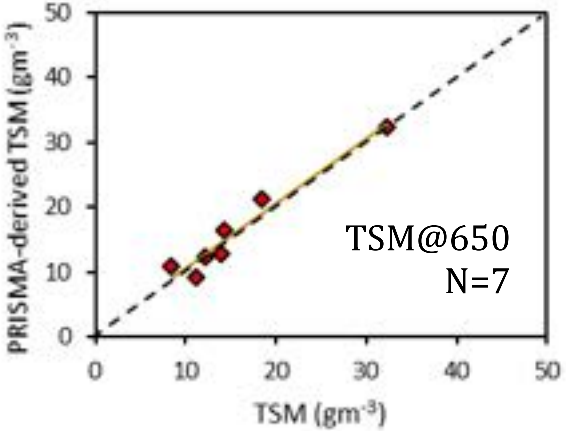
Venice lagoon



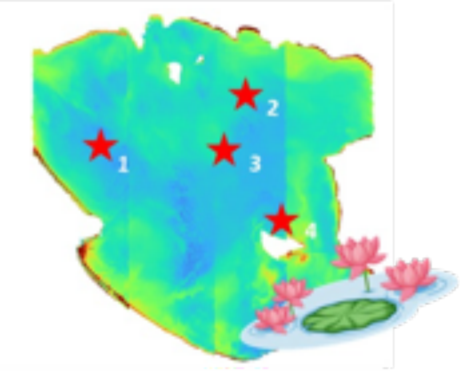


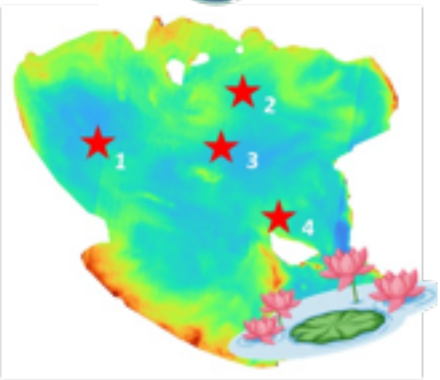
Lake Trasimeno

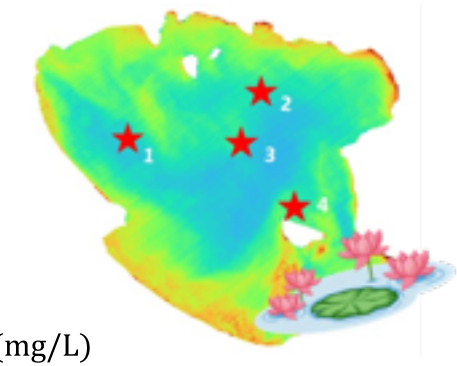




Lake Trasimeno, 2021/06/04





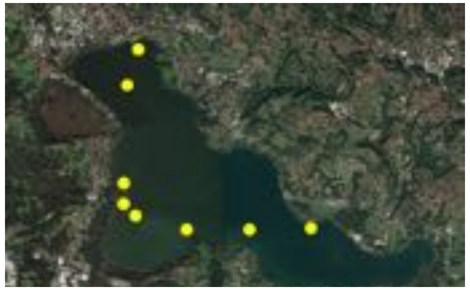


TSM (mg/L)

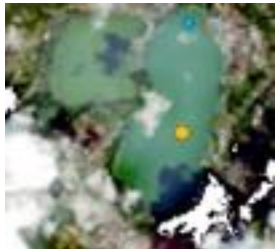
Sensors data VS *in-situ* data TSM (mg/L)			
Statistic	PRISMA	DESIS	AVIRIS DEGLINT
MAE	0.5	0.5	0.5
RMSE	0.7	0.7	0.6

Generation of water quality products

Validation of the water quality products

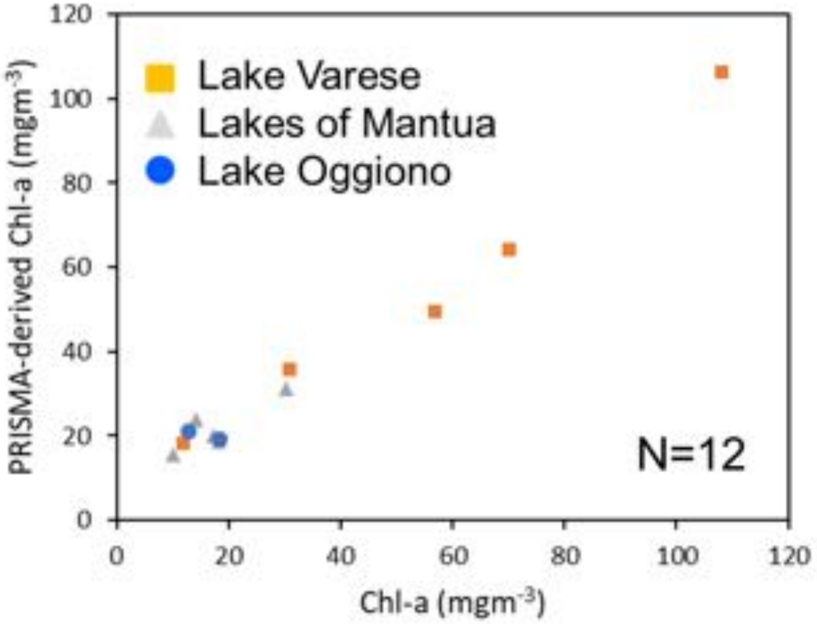


Lake Varese – 2021/10/16

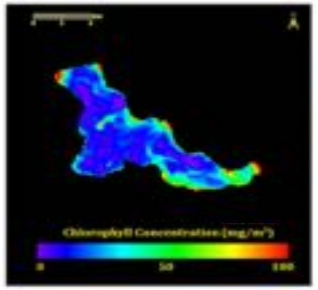


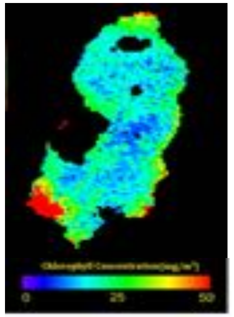
Lake Oggiono – 2021/08/31

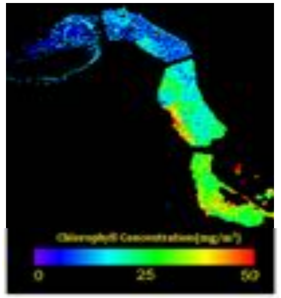
Lake Mantua – 2021/10/27



	R^2	RMSD	MAD	Bias	Intercept	Slope
Chl-a	0.93	5.48	4.61	1.96	-6.20	1.12







Summary & conclusions

- Water quality products were evaluated in inland and coastal waters characterised by different optical properties. The results highlight the hyperspectral contribution in the retrieval of adequate water quality products.

- The results are very promising for the synergic use of spaceborne imaging spectroscopy with the existing operational satellites (e.g. Sentinel-2, Sentinel-3).

- Under specific environmental conditions (i.e. oligotrophic waters, glint), the retrieval of water reflectance seems challenging and ad-hoc processing might be necessary to include the specific requirements of atmospheric correction of water targets (e.g. ACIX-III Aqua).

- Further validation activities are needed to extend performance analysis to other water bodies, characterised by a wider range of water optical properties (e.g. need of expanding hyperspectral validation sites).

PRISCAV

HYPER- prototypes

CHIME: Mission Requirement Consolidation Study

Principal Investigators

Thank you for your attention ☺