ISEO: Improving the lake Status from Eutrophy towards Oligotrophy

fondazione cariplo

Partner presentation
CNR-IREA

Mariano Bresciani
Consiglio Nazionale delle Ricerche

National Research Council of Italy

istituto per il rilevamento elettromagnetico dell'ambiente

Brescia 26-04-2017

Presentation outline

Activities

Field campaigns

Algorithms parametrization

EO processing

Validation

Products

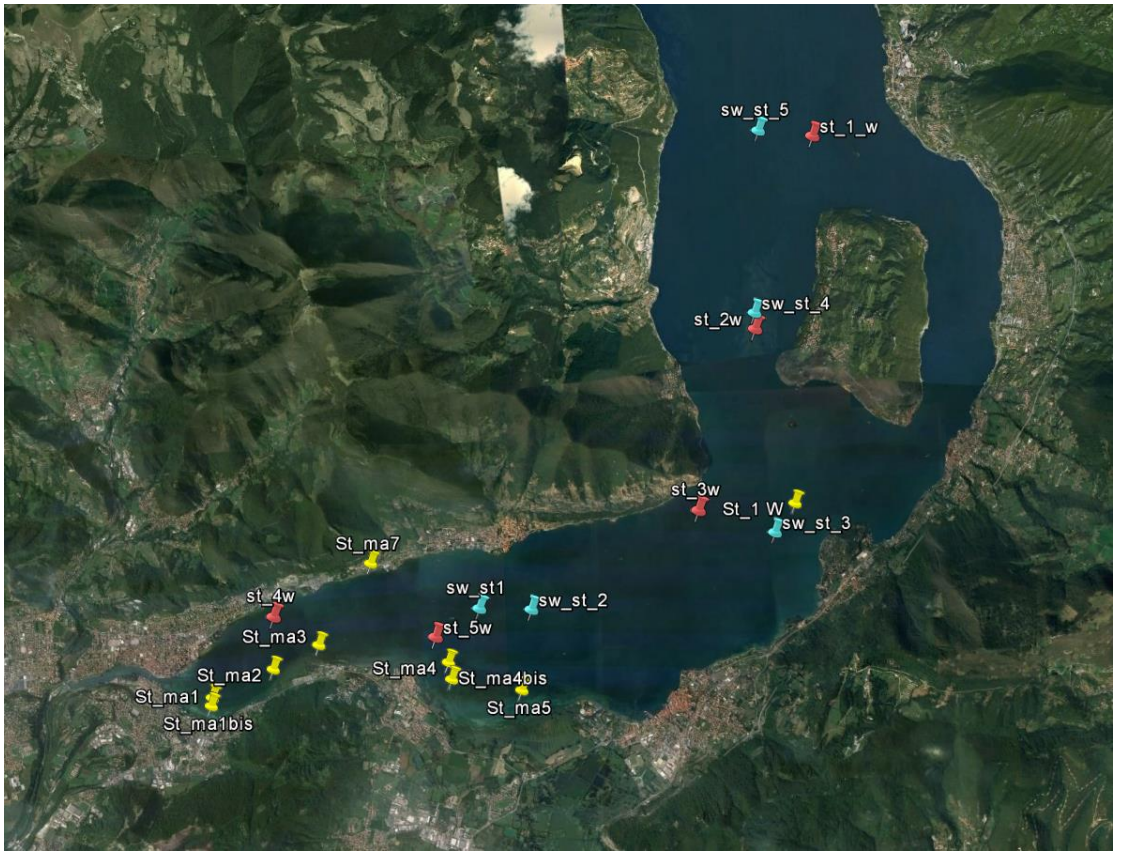
Dissemination

Future activities

Field campaigns

The aims of that field campaign is collected in situ data to:

- calibrate satellite data,
- parametrize algorithms, that will be used to obtain a water quality and macrophytes coverage from satellite products,
- validate a processing (radiometric and atmospheric correction) of satellite data.



Yellow: 7 July; light blue and green: 8 July; Red: 26 September

We have used the following instruments:

WISP-3

ASD FieldSpec Full Range Pro

Spectral Evolution SM 3500

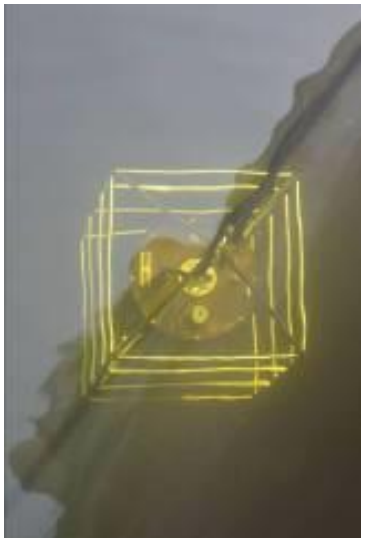
Licor LI-192SA

HOBILabs HydroScat-6

Cyclops-7 Turner Design

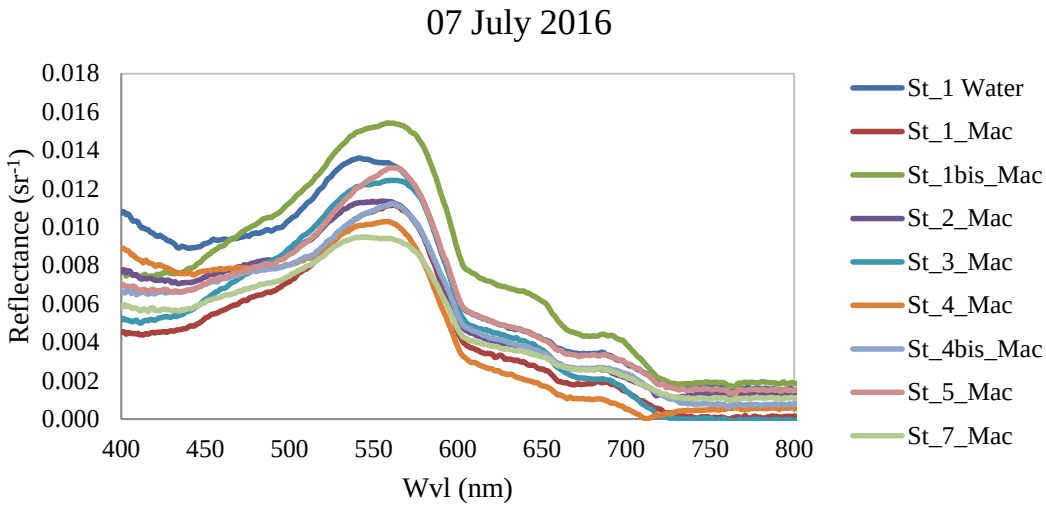
Spectroradiometers

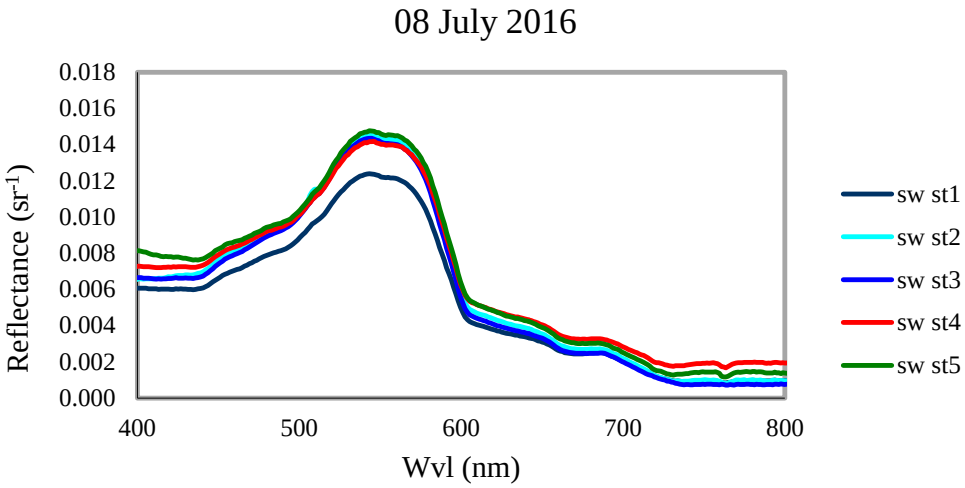
H6

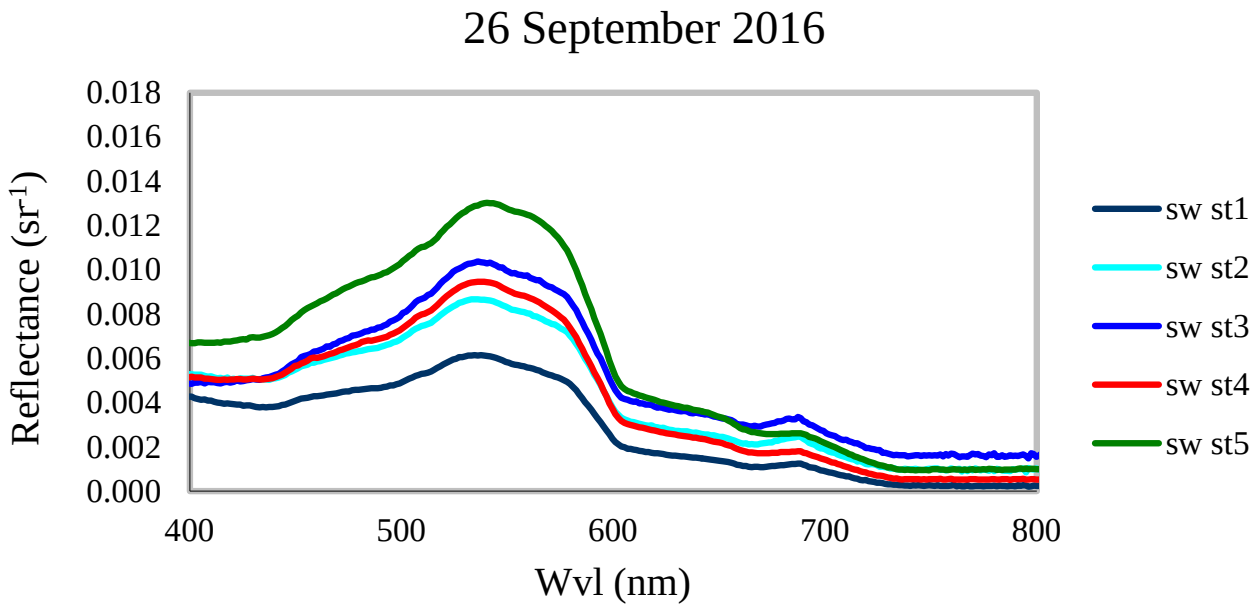


Fluorimeters

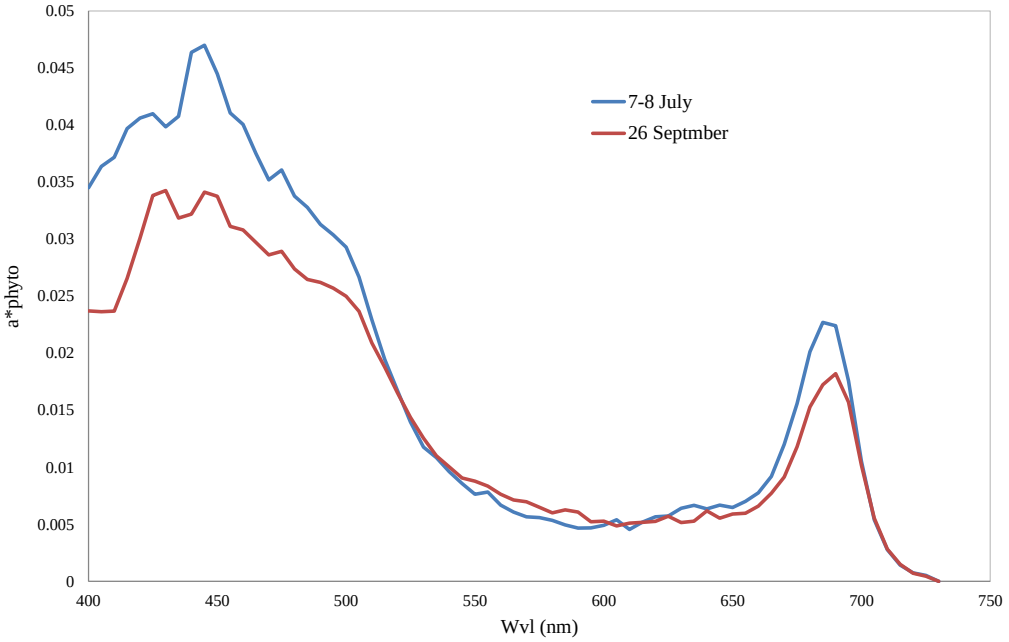
Apparent Optical Measuraments (reflectances)

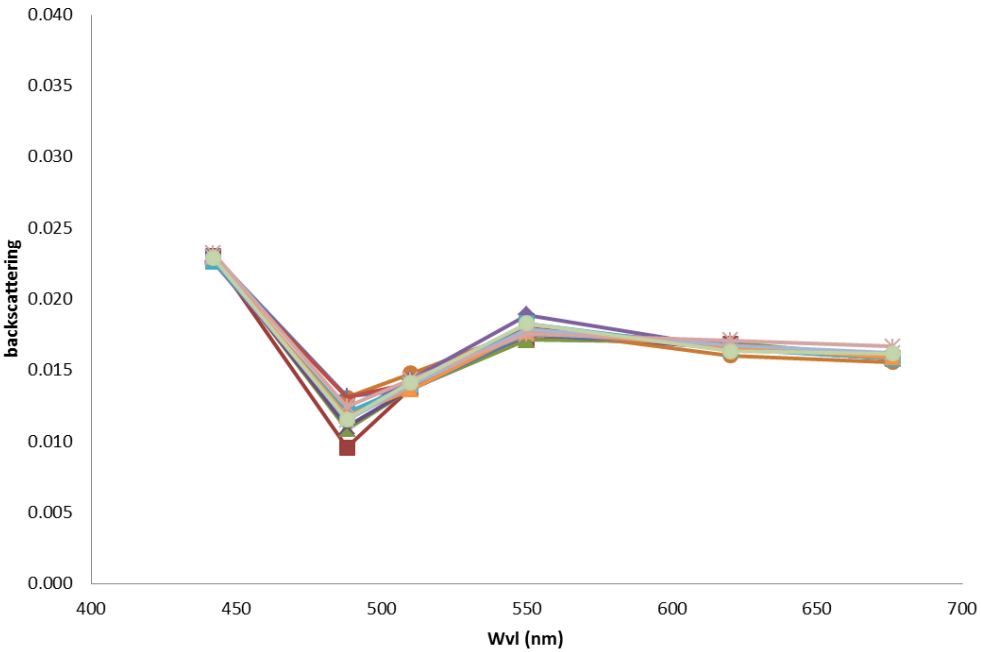


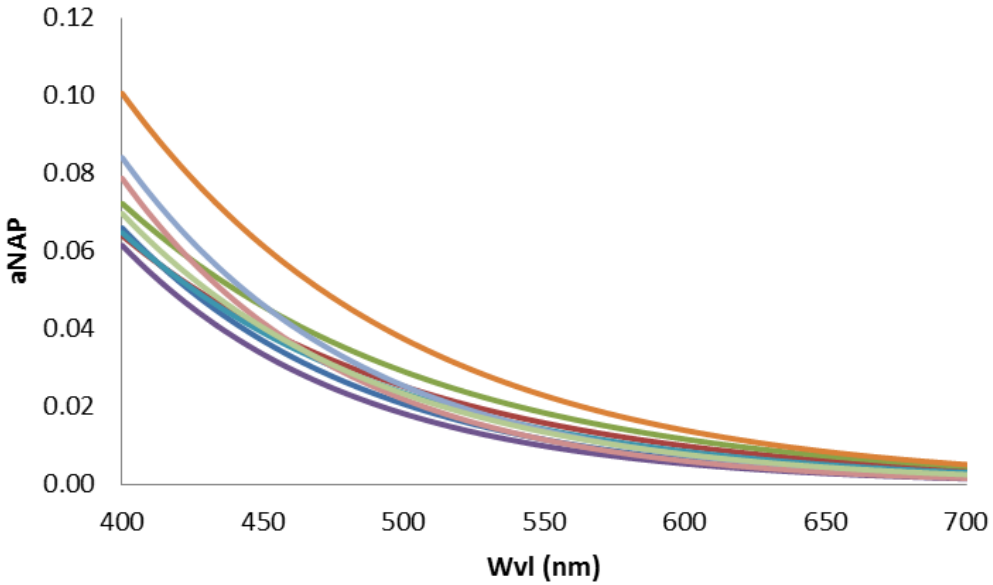


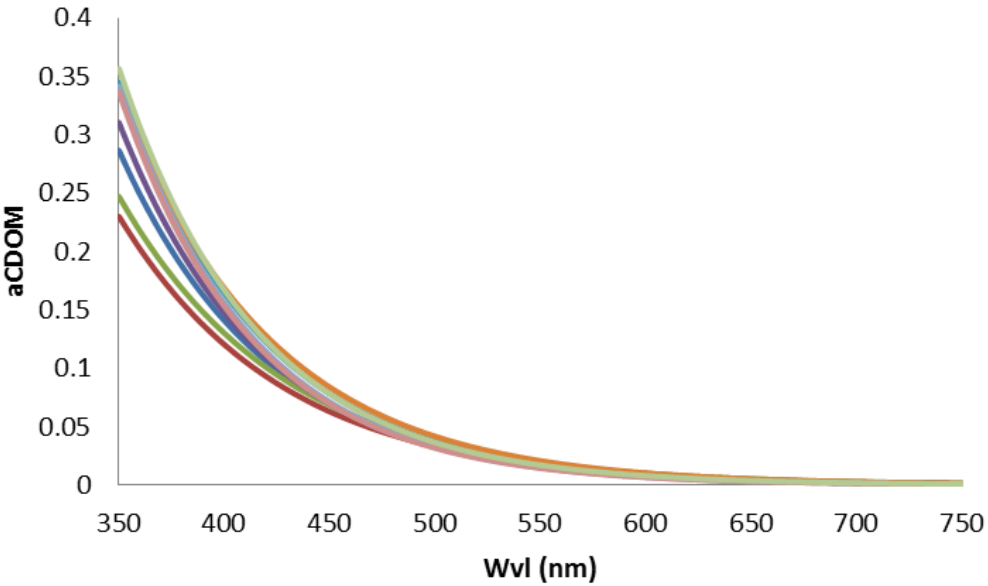


Inherent Optical Measuraments (absorption and back-scattering)

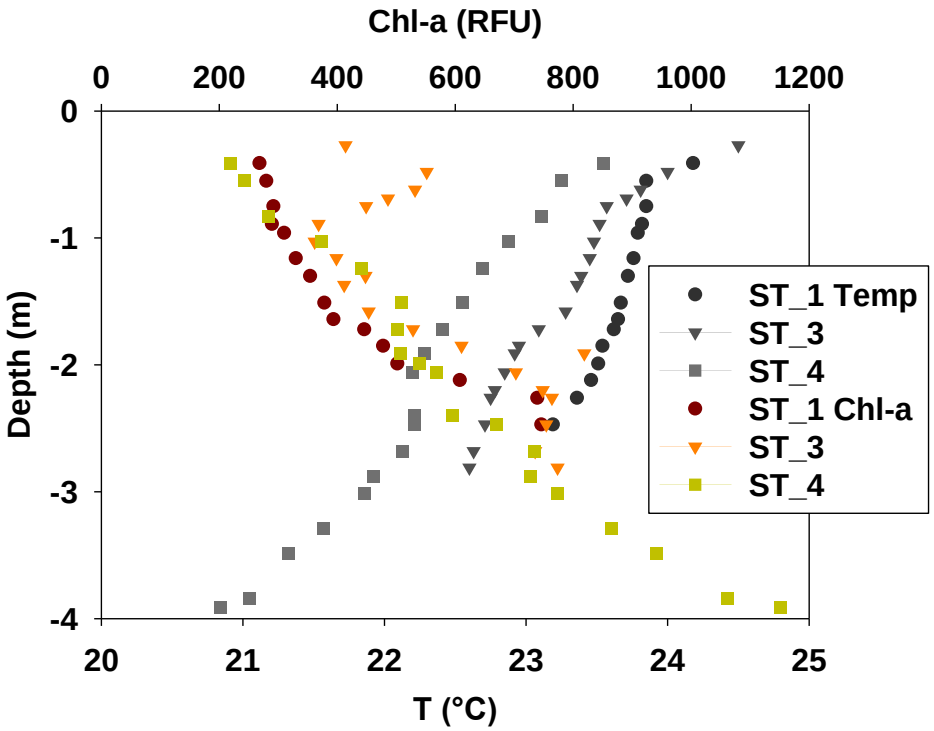


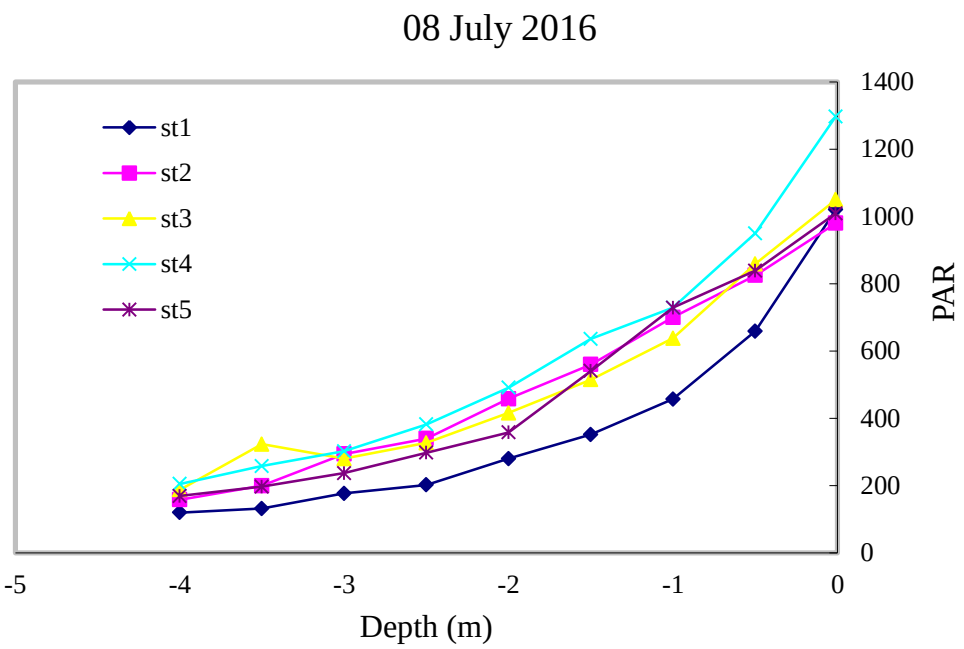






Water quality physical and chemical parameters





		TSM	SPOM	SPIM	SPOM	SPIM	CHL-A	aCDOM (440)	sCDOM	aNAP (440)	sNAP	Secchi Disk
		mg/L	mg/L	mg/L	% TSM	% TSM	µg/L	m-1		m-1		m
08/07/2016	mean	3.31	1.9	1.4	57%	43%	2.65	0.084	0.015	0.048	0.011	2.4
	st.dev	0.28	0.5	0.6	16%	16%	0.45	0.008	0.001	0.009	0.001	0.4
	min	2.86	1.2	0.6	35%	19%	2.04	0.071	0.013	0.038	0.009	1.9
	max	3.75	2.5	2.3	81%	65%	3.60	0.096	0.016	0.068	0.013	3.0
26/09/2016	mean	1.76	1.5	0.3	86%	14%	2.87	0.032	0.019	0.041	0.008	4.4
	st.dev	0.23	0.1	0.3	13%	13%	0.28	0.016	0.004	0.006	0.001	0.6
	min	1.44	1.4	0.0	74%	0%	2.46	0.011	0.015	0.031	0.007	3.5
	max	2.00	1.6	0.5	100%	26%	3.12	0.046	0.025	0.045	0.008	5.0

Macrophytes

Macrophytes

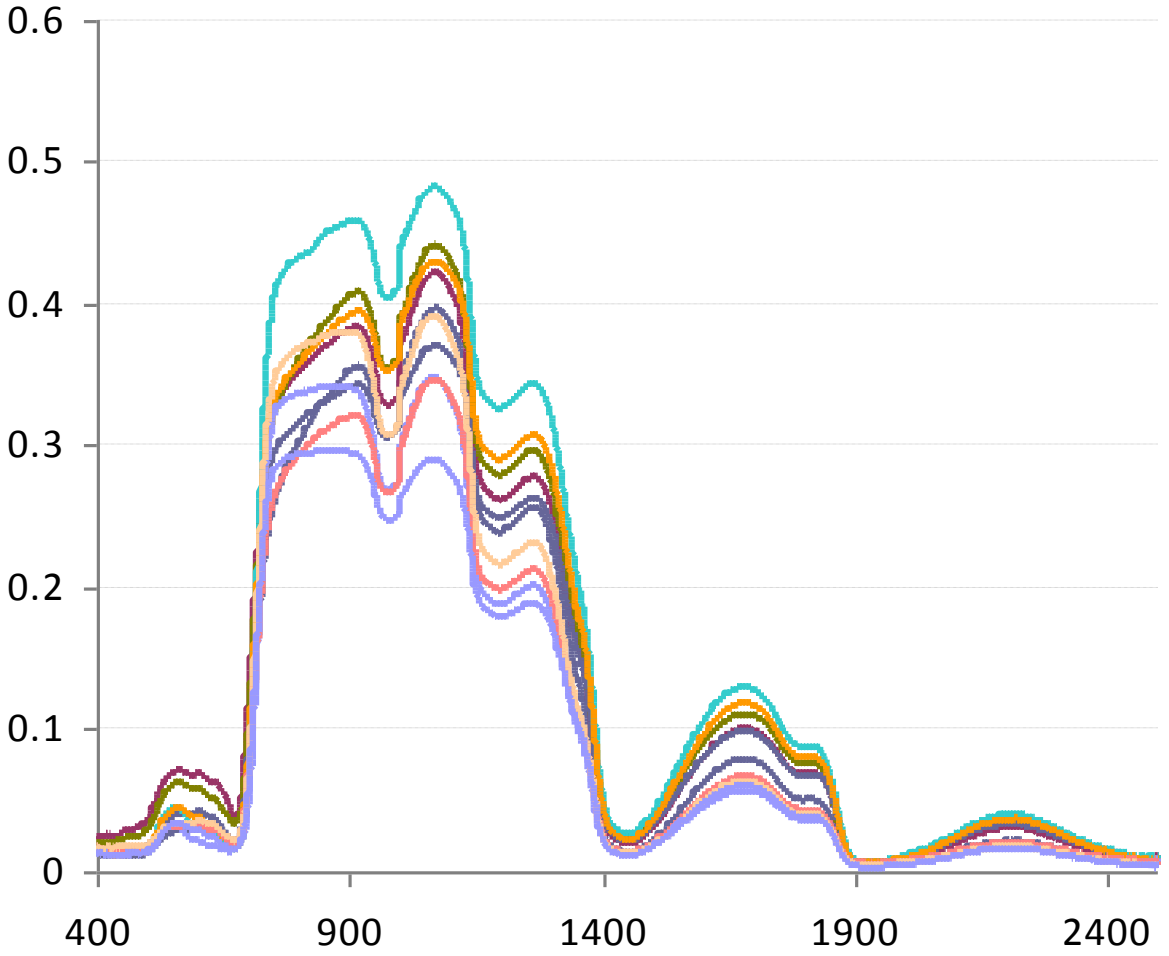
Visual inspection

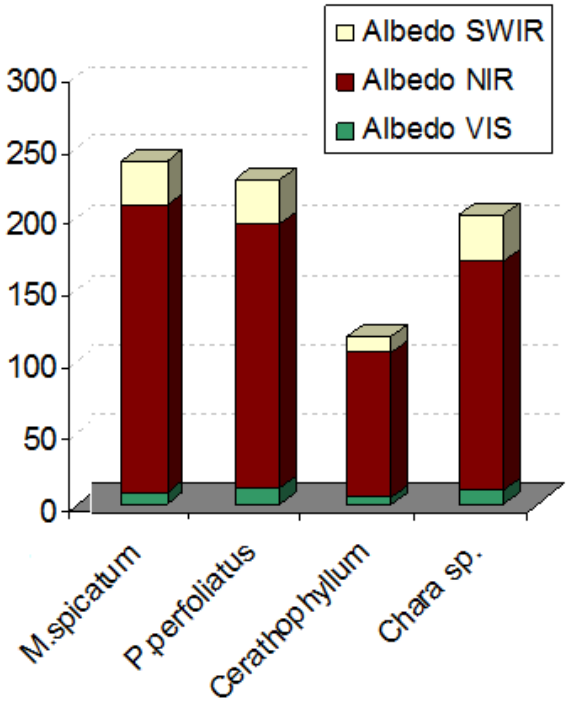
Evaluation of bathymetry

Spectral signature

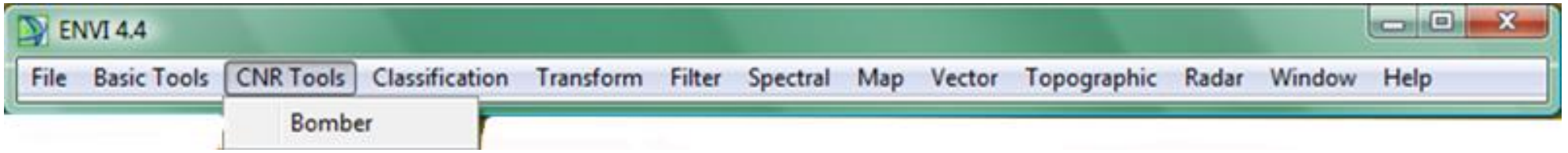
Macrophytes

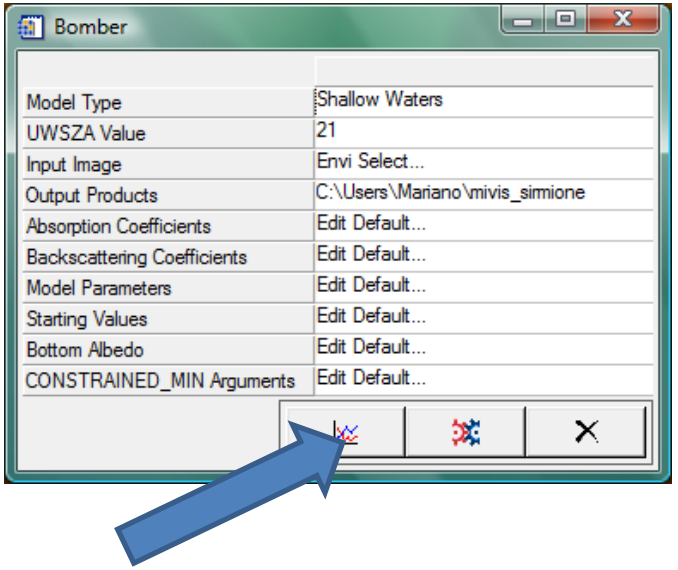
Data-base of macrophytes spectral signatures





BOMBER: Bio-Optical Model for the evaluation of Bottom Effect on water Reflectance

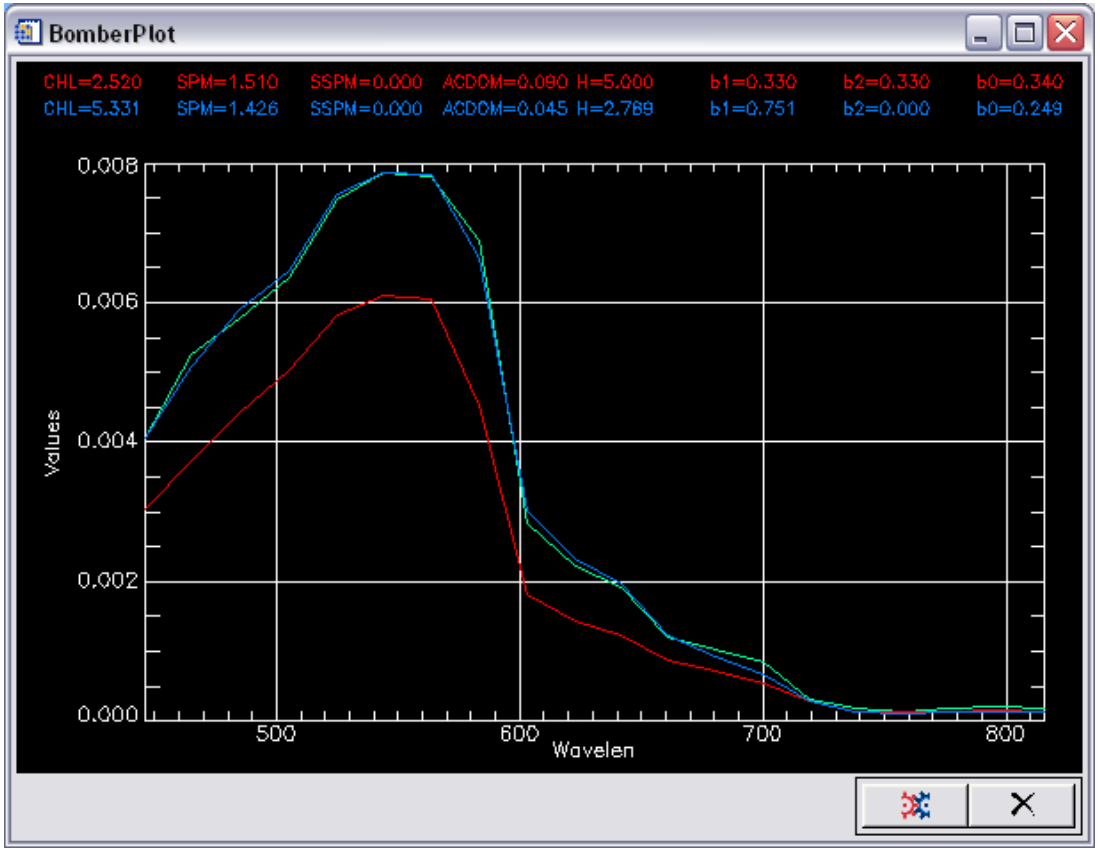




Starting Reflectance

Image Reflectance

Model Reflectance



The bio-optical model

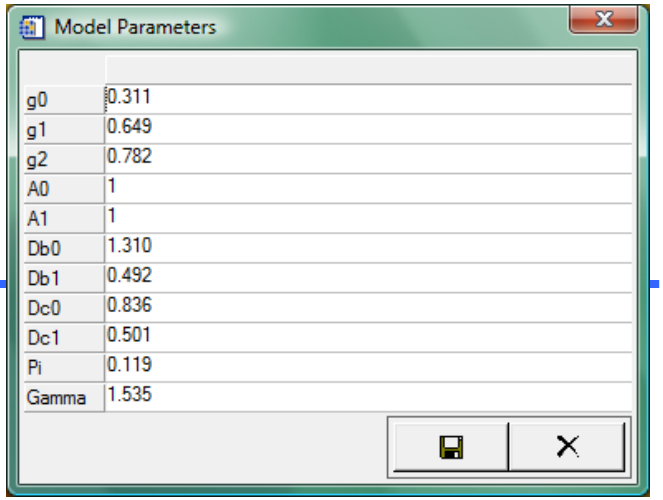
DEEP WATERS

$$R(0-) = R(0-)^{dp} = \left(g_0 + g_1 \cdot u^{g_2}\right) \cdot u$$

$$u = \frac{b_b}{a + b_b}$$

$$a = a_w + a_{CHL} + a_{SPM} + a_{CDOM}$$

$$b_b = b_{bw} + b_{bCHL} + b_{bSPM}$$



SHALLOW WATERS

$$R(0-) = R(0-)^{dp}\left(1 - A_0 e^{\left(-\left(\frac{1}{\cos(\vartheta_w)} + \sqrt{D_0^C\left(1 + D_1^C u\right)}\right)\kappa H\right)}\right) + A_1 \rho e^{\left(-\left(\frac{1}{\cos(\vartheta_w)} + \sqrt{D_0^B\left(1 + D_1^B u\right)}\right)\kappa H\right)}$$

$$\rho = b_0 \rho_{sand} + b_1 \rho_{SV} + b_2 \rho_{HV}$$

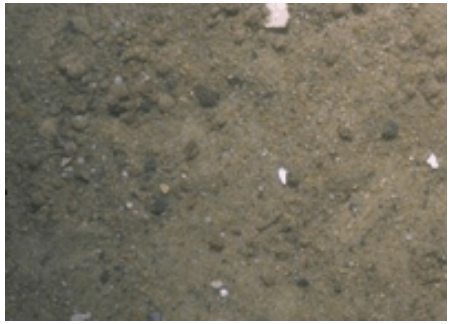
The bio-optical model

Parameter	Symbol	ISEO	Garda	Turbid lakes	Boreal lakes	Eutrophic lakes (with cyanobacteria)
Specific absorption of phytoplankton (chl-a specific)	$a^*_{ph}(\lambda)$	Fixed spectrum	Fixed spectrum	Fixed spectrum	Fixed spectrum	Fixed spectrum
Spectral slope coefficient of CDOM absorption	S_{CDOM} nm^{-1}	0.020	0.021	0.0150	0.0150	0.016
Specific absorption of NAP at 400 nm	$a^*_{NAP}(400) m^2 g^{-1}$	0.075	0.082	0.067	0.13	0.04
Spectral slope coefficient of NAP absorption	S_{NAP} nm^{-1}	0.011	0.012	0.010	0.012	0.0104
Specific scattering coefficient of TSM at 555 nm	$b^*_{TSM}(555) m^2 g^{-1}$	0.62	0.64	0.42	0.81	0.7
Scalar parameters for relating bb_{SPIM} to SPIM	Gb, Ob	0.053 0.073	0.053 0.073	0.053 0.073	0.053 0.073	0.053 0.073
Scattering exponent of TSM[1]	n_b	0.77	0.76	0.79	0.71	0.77
Backscattering ratio	bb/b	0.010	0.011	0.04	0.013	0.18

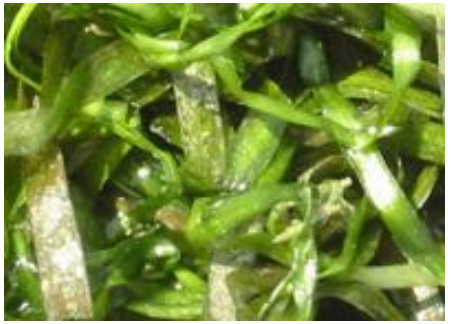
BOMBER : shallow water

$$R(0-) = R(0-)^{dp}\left(1 - A_0 e^{\left(-\left(\frac{1}{\cos(\vartheta_w)} + \sqrt{D_0^C\left(1+D_1^C u\right)}\right)\kappa H\right)}\right) + A_1 \rho e^{\left(-\left(\frac{1}{\cos(\vartheta_w)} + \sqrt{D_0^B\left(1+D_1^B u\right)}\right)\kappa H\right)}$$

$$\rho = b_0\rho_{sand} + b_1\rho_{SV} + b_2\rho_{HV}$$

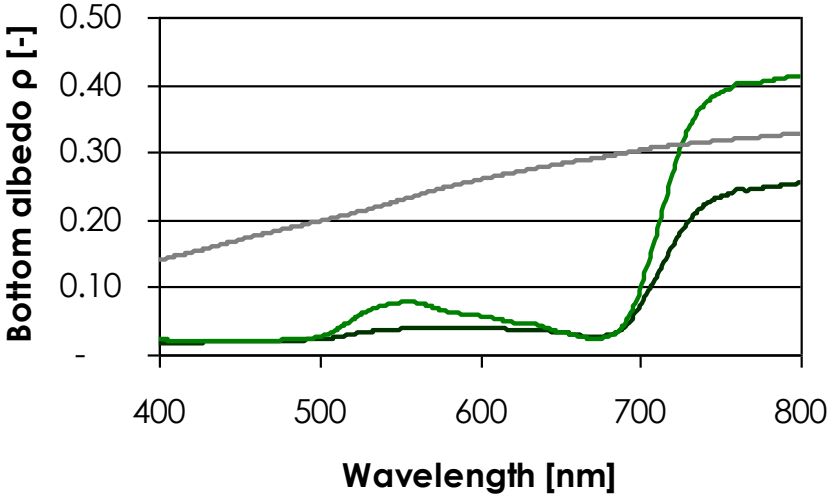


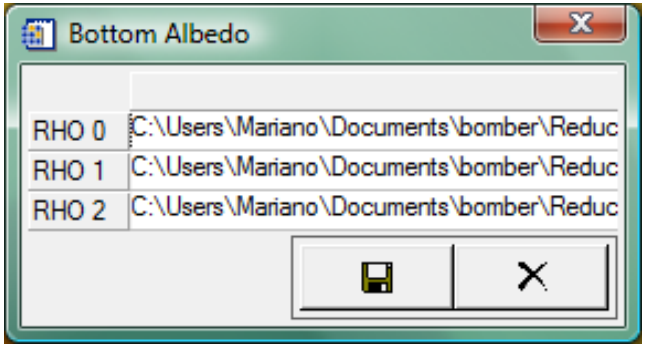
Sand



High albedo Vegetation

Low albedo Vegetation





ACOLITE

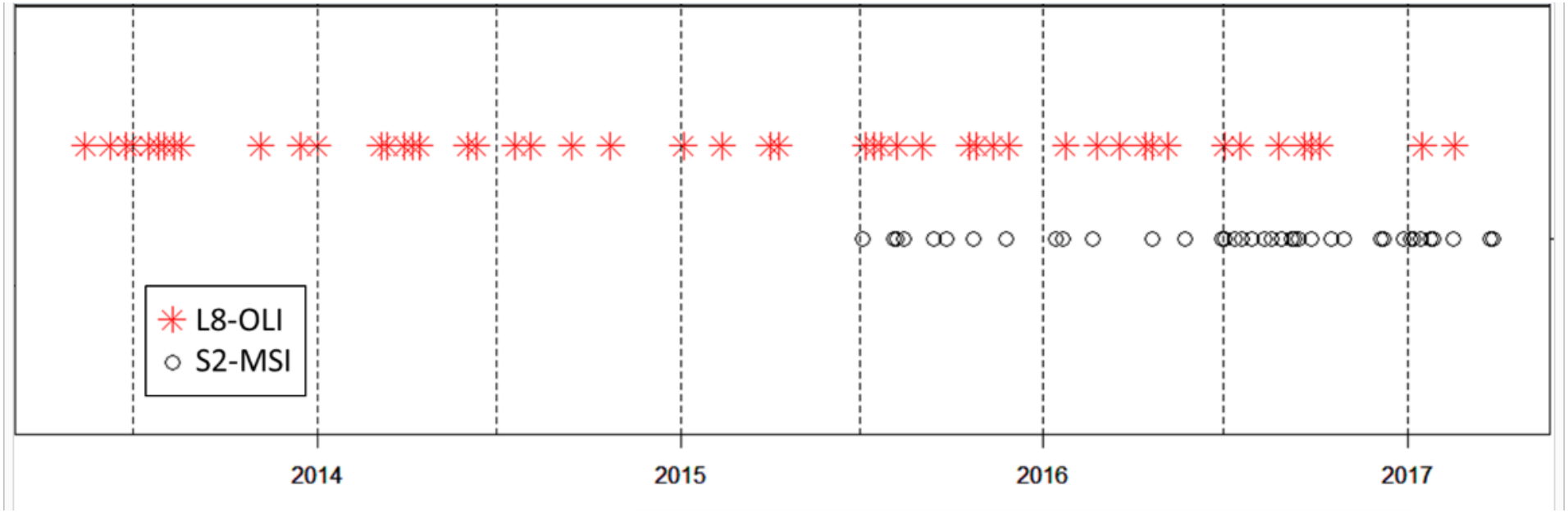
EO data

- **Landsat-8** (water quality, surface temperature) 2013-2017
- **Sentinel-2** (water quality, SAV) 2015-2017
- **Sentinel-3** (water quality) 2017-2018
- **MERIS** (water quality time series) 2003-2011

- **High Spatial Resolution imagery** (SAV) one/two spot

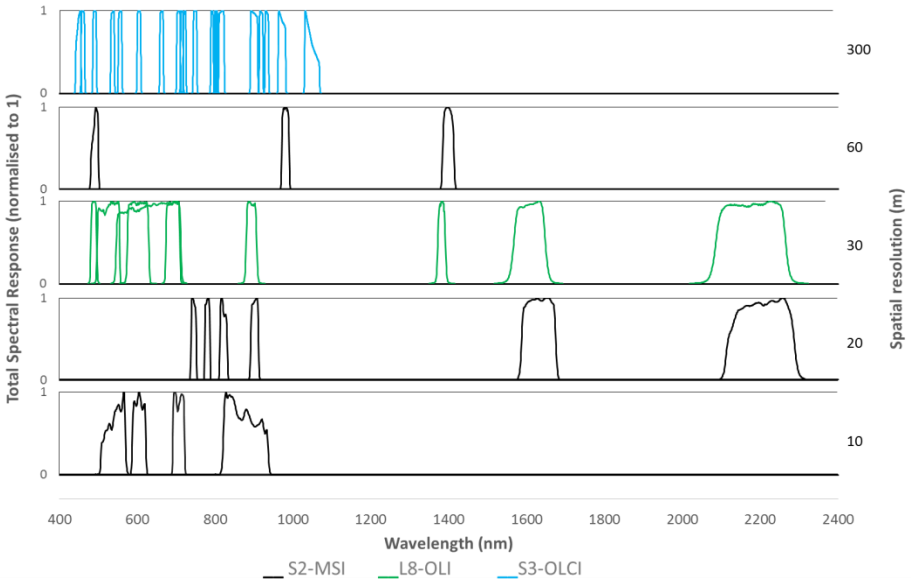
EO data

Download and processing images



48 Landsat-8 images

42 Sentinel-2 images

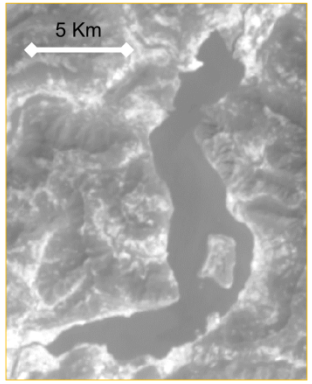


Landsat processing

Digital Numbers DN

Landsat-8

TIRS (TIR-1)



OLI

Radiometric calibration

Atmospheric correction:

$$L_{BOA} = \frac{L_{TOA} - \tau(1-\varepsilon)L_d - L_u}{\tau\,\varepsilon}$$

ε=water emissivity
τ=atmospheric transmittance
L_d, L_u=downwelling-upwelling radiance
τ, L_d, L_u calculated by Atmospheric Correction Parameter Calculator[1] using meteorological surface conditions.

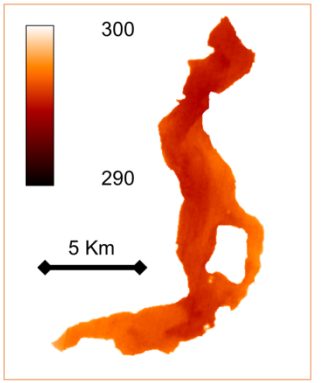
+

Lake Mask using a lake shapefile

Surface Temperature estimation[3]:

$$T = \frac{k_2}{\ln\left(\frac{k_1}{L_{BOA}+1}\right)}$$

$k_2 = 1321.08$
$k_1 = 774.89$



Atmospheric correction and TSM estimation through ACOLITE[2]:

- Pixel-based aerosol load and type estimation using SWIR bands
- Lake mask based on Rayleigh corrected reflectances at 1609 nm with a threshold of 2.15%

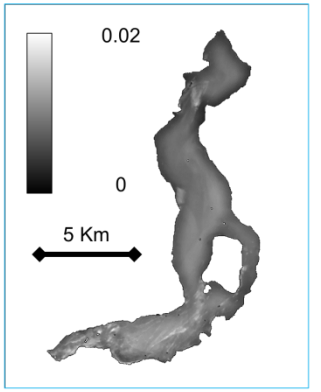
Additional manual masking of glint and shadows

Water Reflectance ρ_W [-]

Surface Albedo calculation[4]:

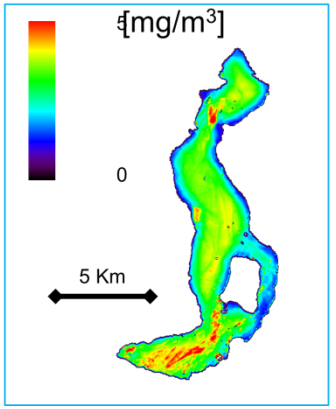
$$\alpha = 0.356\rho_{WB2} + 0.130\rho_{WB4} + 0.373\rho_{WB5} + 0.085\rho_{WB6} + 0.072\rho_{WB7} - 0.0018$$

Albedo α [-]



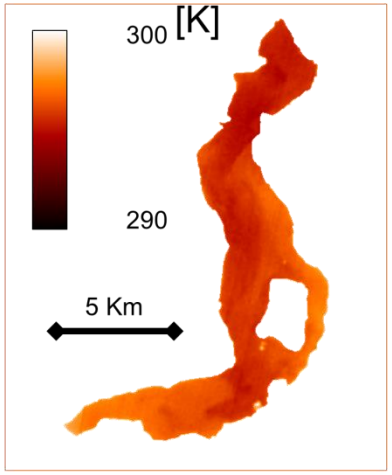
Shallow waters mask

Total Suspended Matter TSM

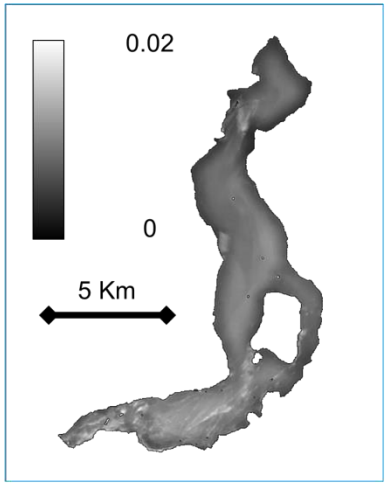


Landsat processing

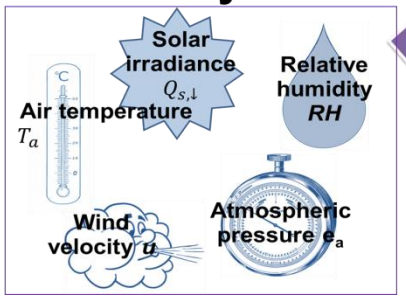
Surface Temperature LST



Albedo α [-]



Ancillary data



Heat budget calculation

$$R_n = Q_{cn} + Q_{an} - Q_w$$

Q_{cn}= Shortwave solar net radiation $= (1-\alpha)\cdot Q_{s,\downarrow}$

Q_{an}[5]= Longwave atmospheric net radiation = $\sigma\ 0.986\ \varepsilon_a\ T_a^4$

Q_w = Longwave emitted radiation by the lake surface = $\sigma\ T^4 \varepsilon_0$

$$Q_x = R_n - Q_e - H$$

H = Sensible heat[5] = $\gamma f(T - T_a)$

Q_e = Latent heat[5] = $f(e_{w_{sat}} - e_a)$

e_{wsat} = Saturated Vapour Pressure

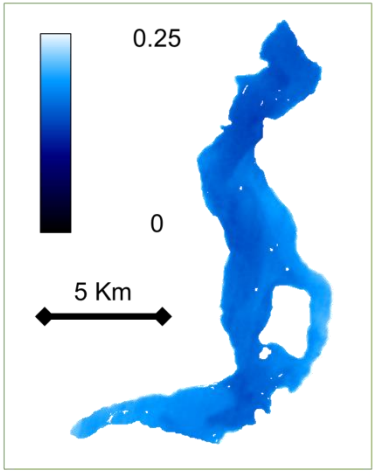
$f = 4.8 + 1.98 \cdot u + 0.28 \cdot (T - T_a)$

$\gamma = \frac{c_p \cdot p}{0.622 \cdot L_v}$

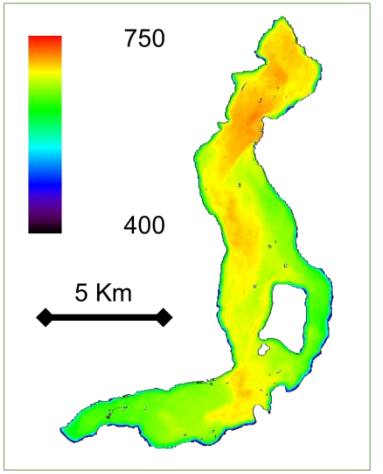
c_p = specific heat of air

L_v = vaporization latent heat

Evaporation Ev [mm/h]

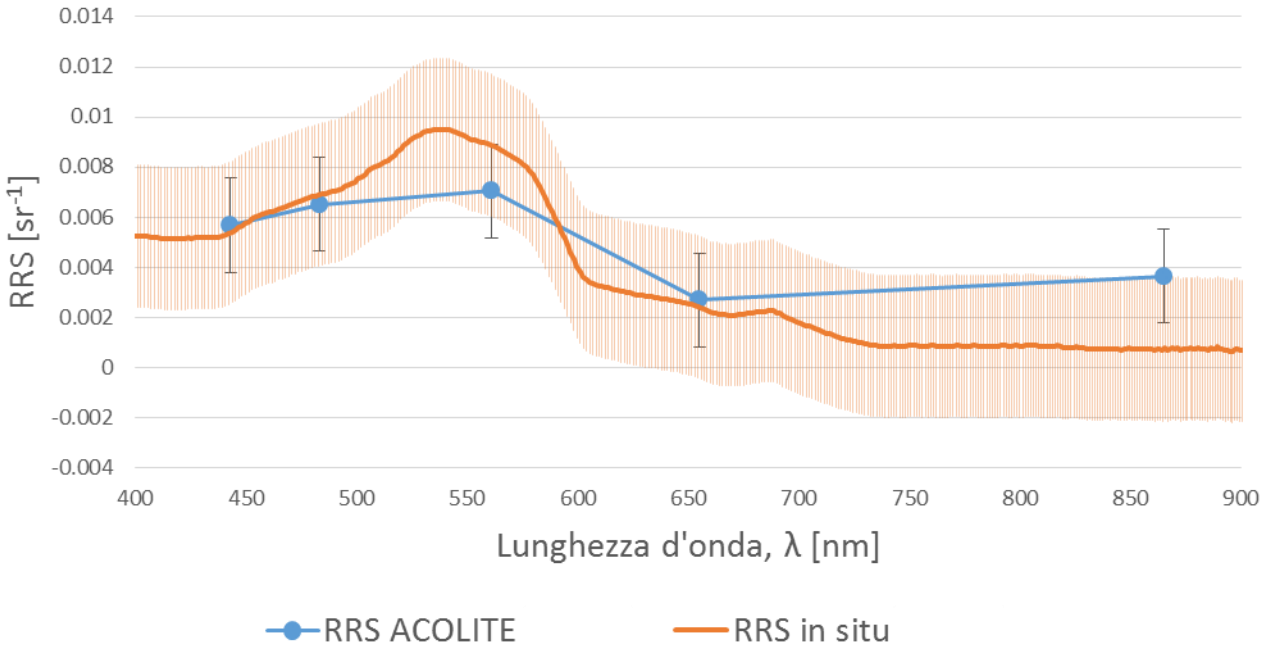


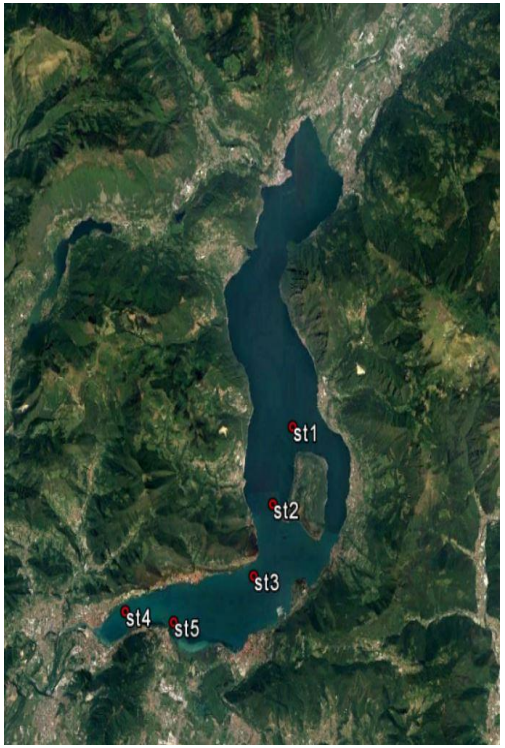
Heat storage Q_x [W/m^2]



Sentinel-2 processing

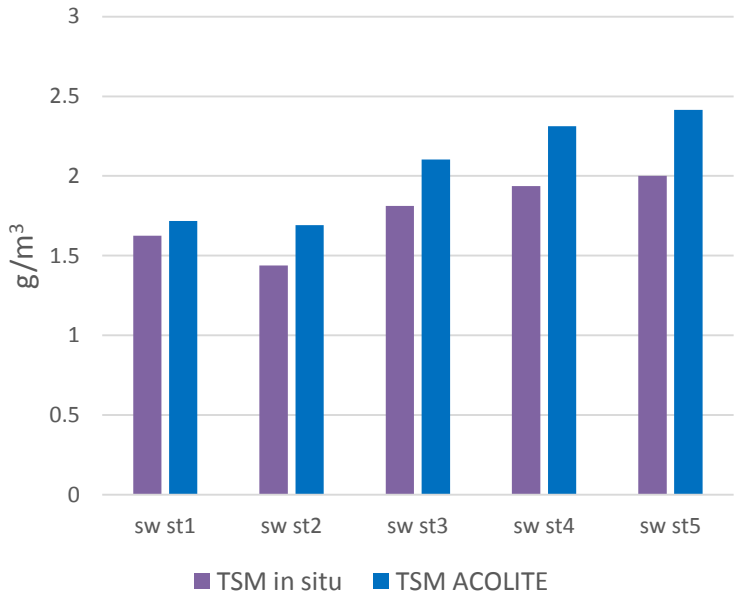
Validation: atmospheric correction

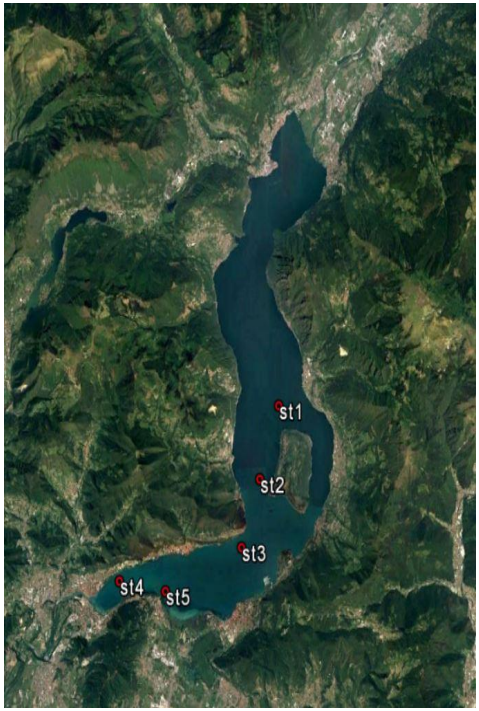


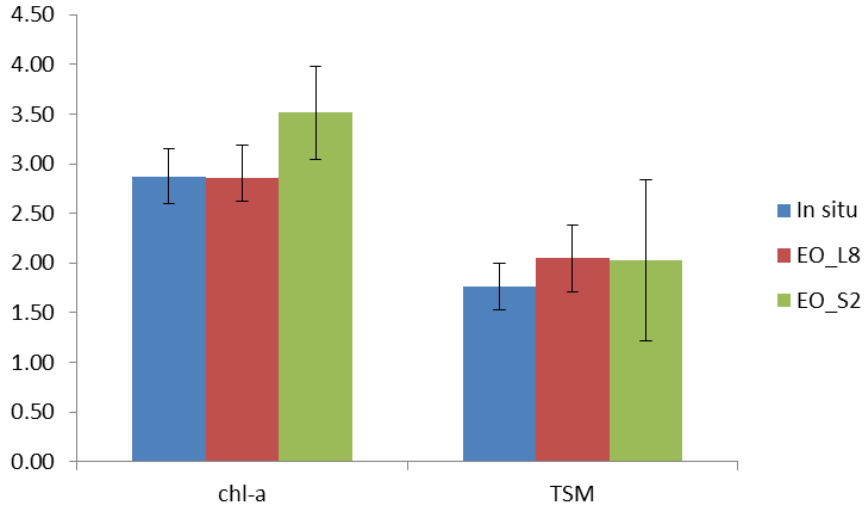


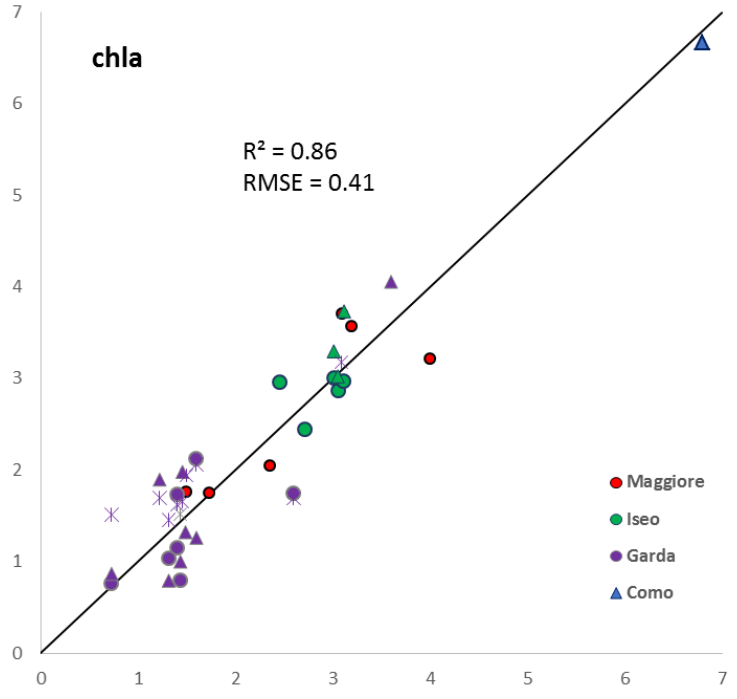
	Atmospheric correction validation
RMSE	0.001 [sr^{-1}]
R^2	0.864

Validation: water quality parameters

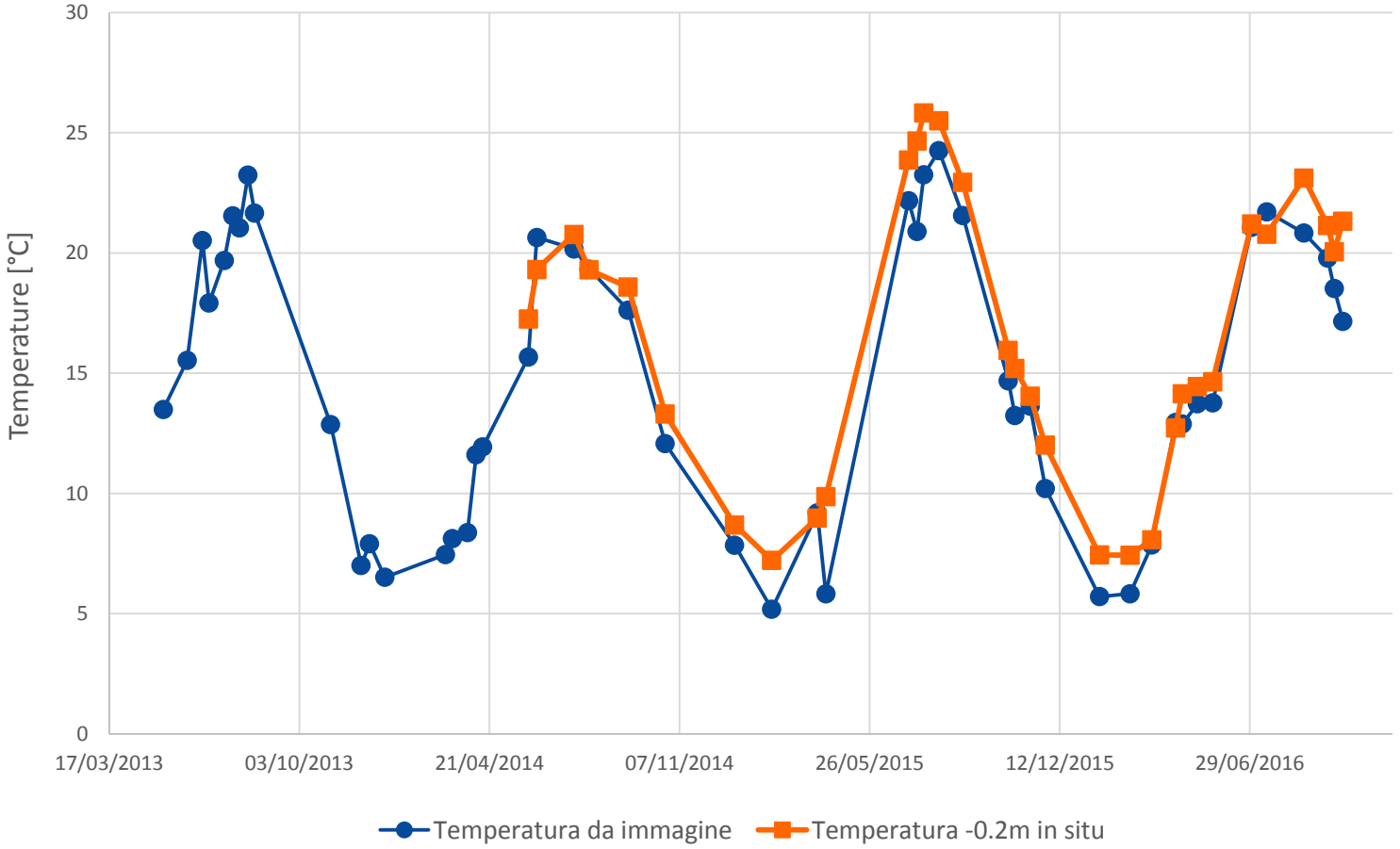








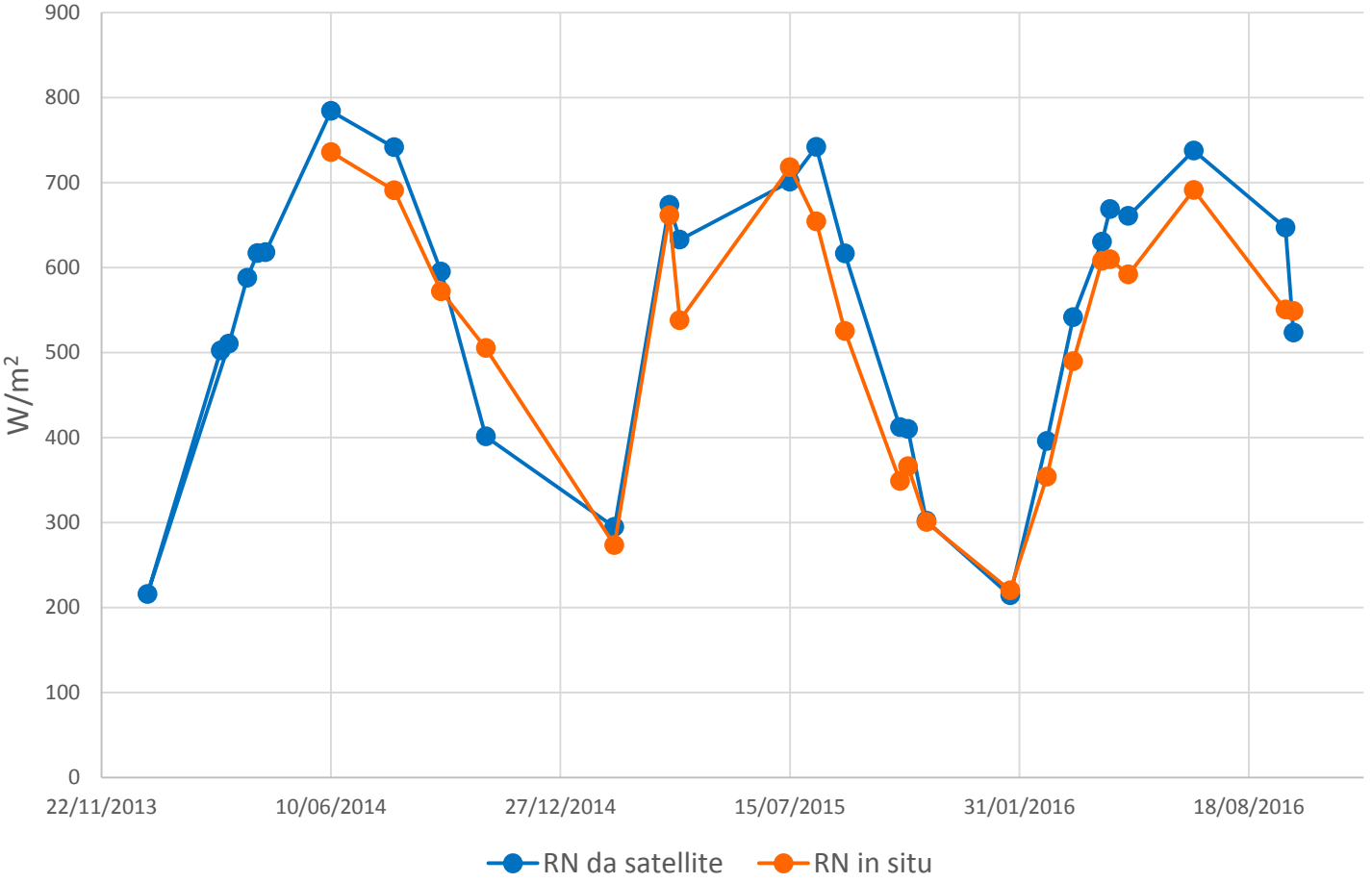
Validation: Surface temperature



$R^2 = 0.954$

$RMSE = 1.771$ [°C]

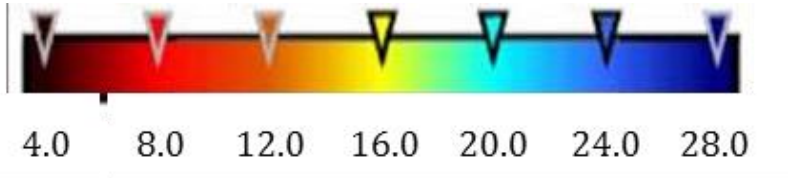
Validation: Net radiation

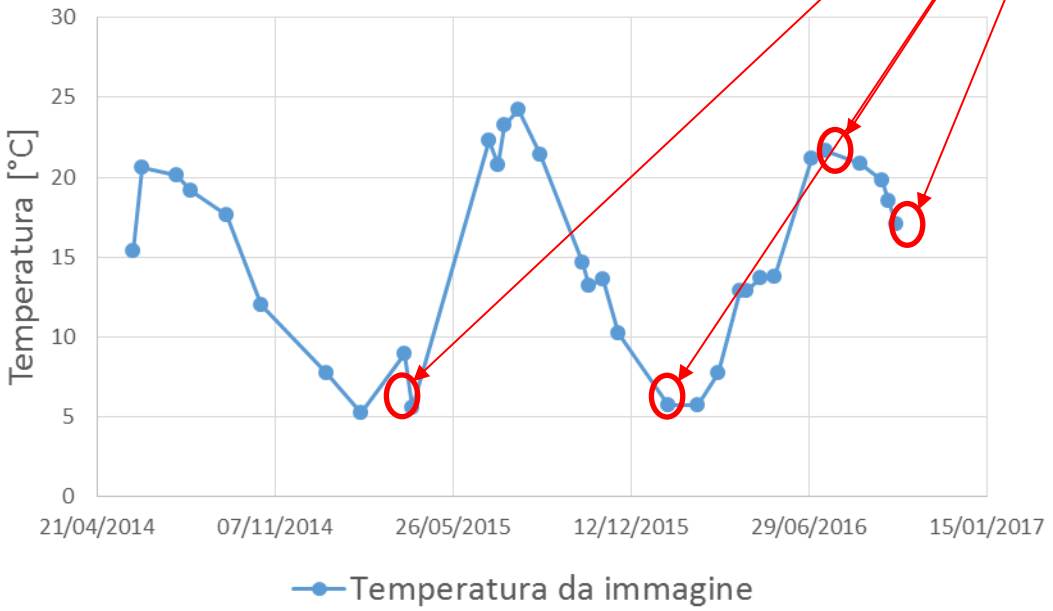


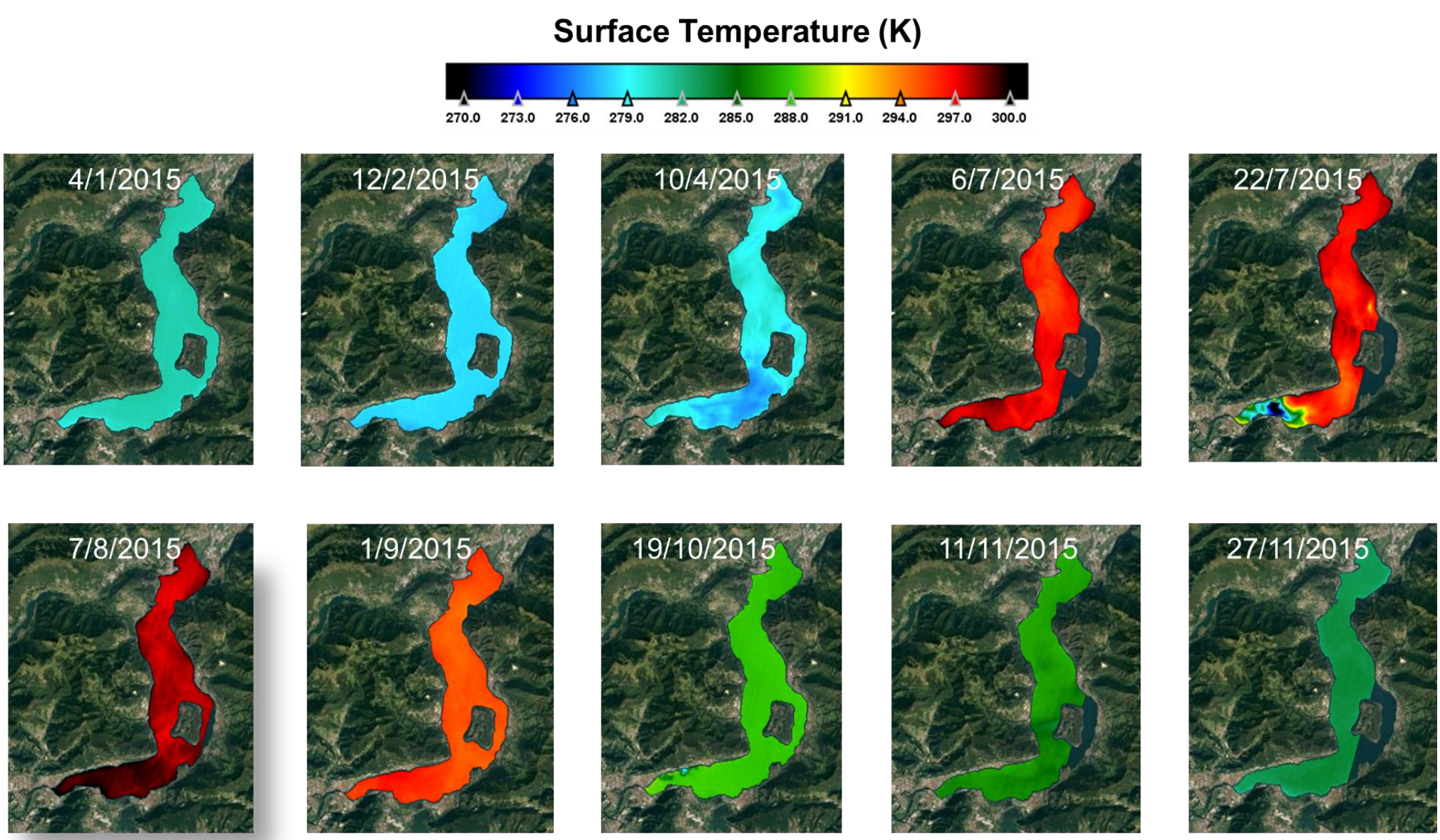
$R^2 = 0.927$

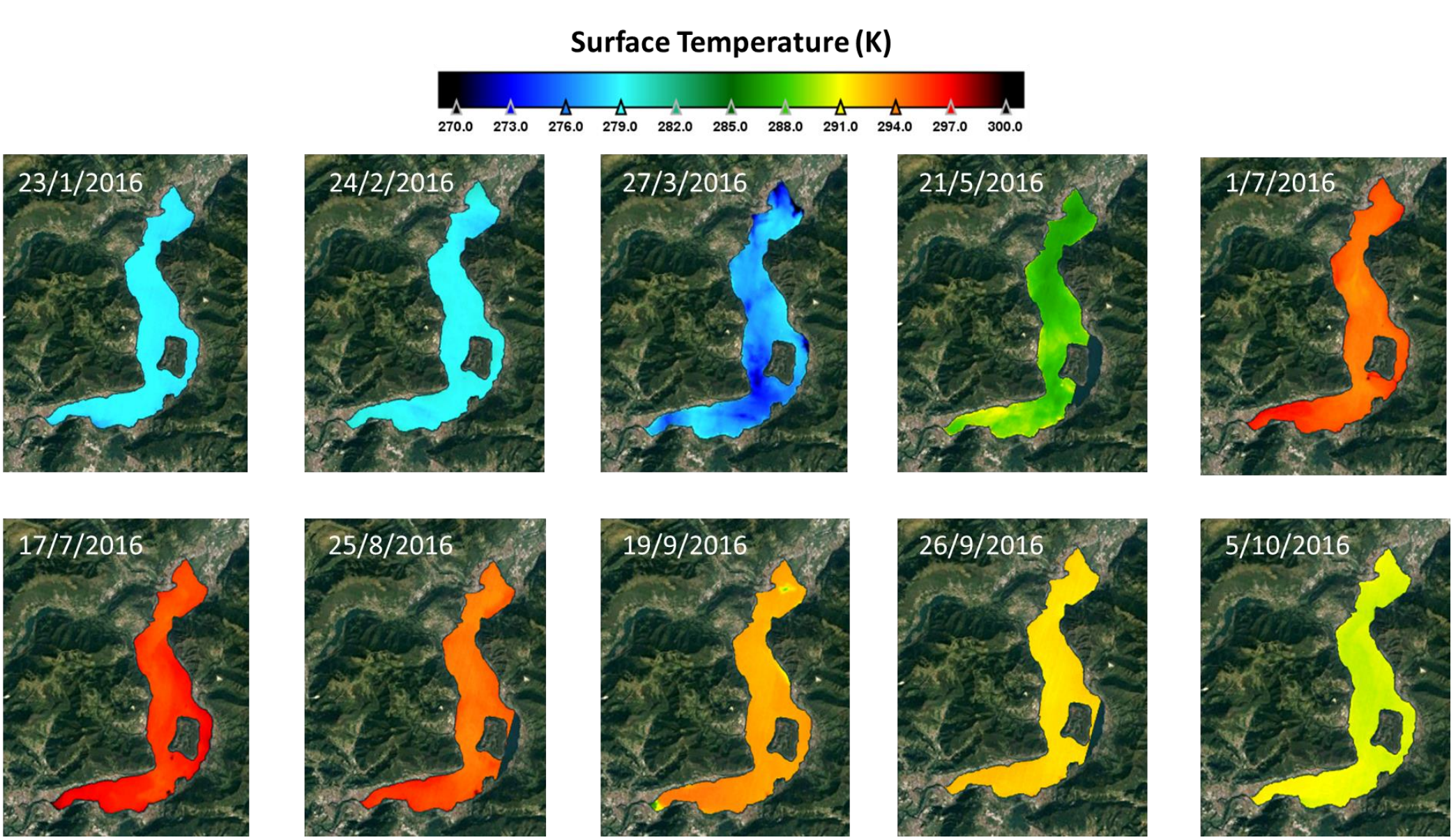
$RMSE = 57.13$ [W/m²]

Landsat-Surface temperature [°C]

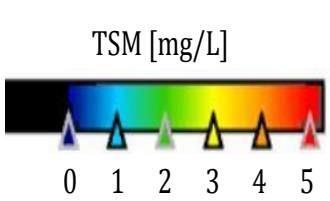




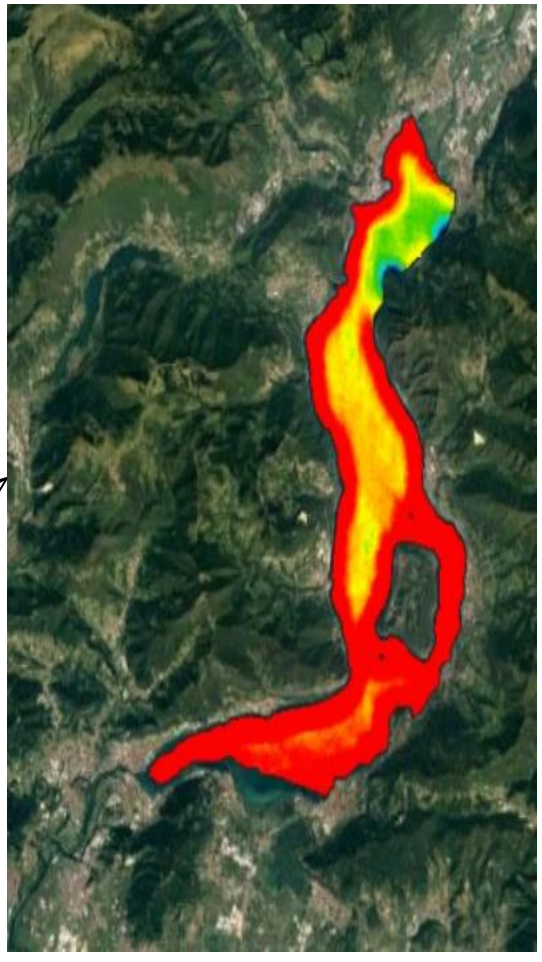

Surface Temperature (K)
270.0
273.0
276.0
279.0
282.0
285.0
288.0
291.0
294.0
297.0
300.0
4/1/2015
12/2/2015
10/4/2015
6/7/2015
22/7/2015
7/8/2015
1/9/2015
19/10/2015
11/11/2015
27/11/2015

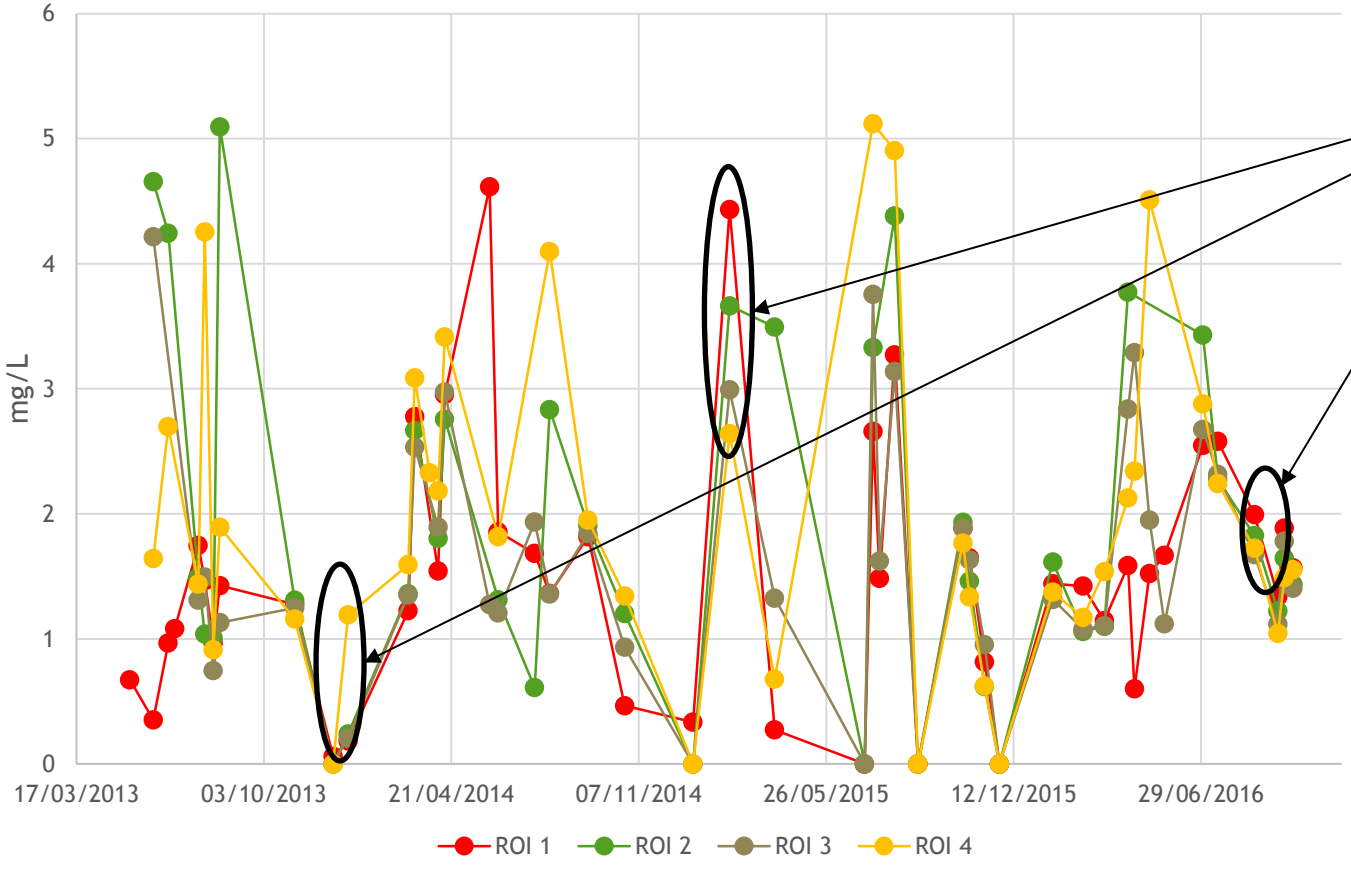

Surface Temperature (K)
270.0
273.0
276.0
279.0
282.0
285.0
288.0
291.0
294.0
297.0
300.0
23/1/2016
24/2/2016
27/3/2016
21/5/2016
1/7/2016
17/7/2016
25/8/2016
19/9/2016
26/9/2016
5/10/2016

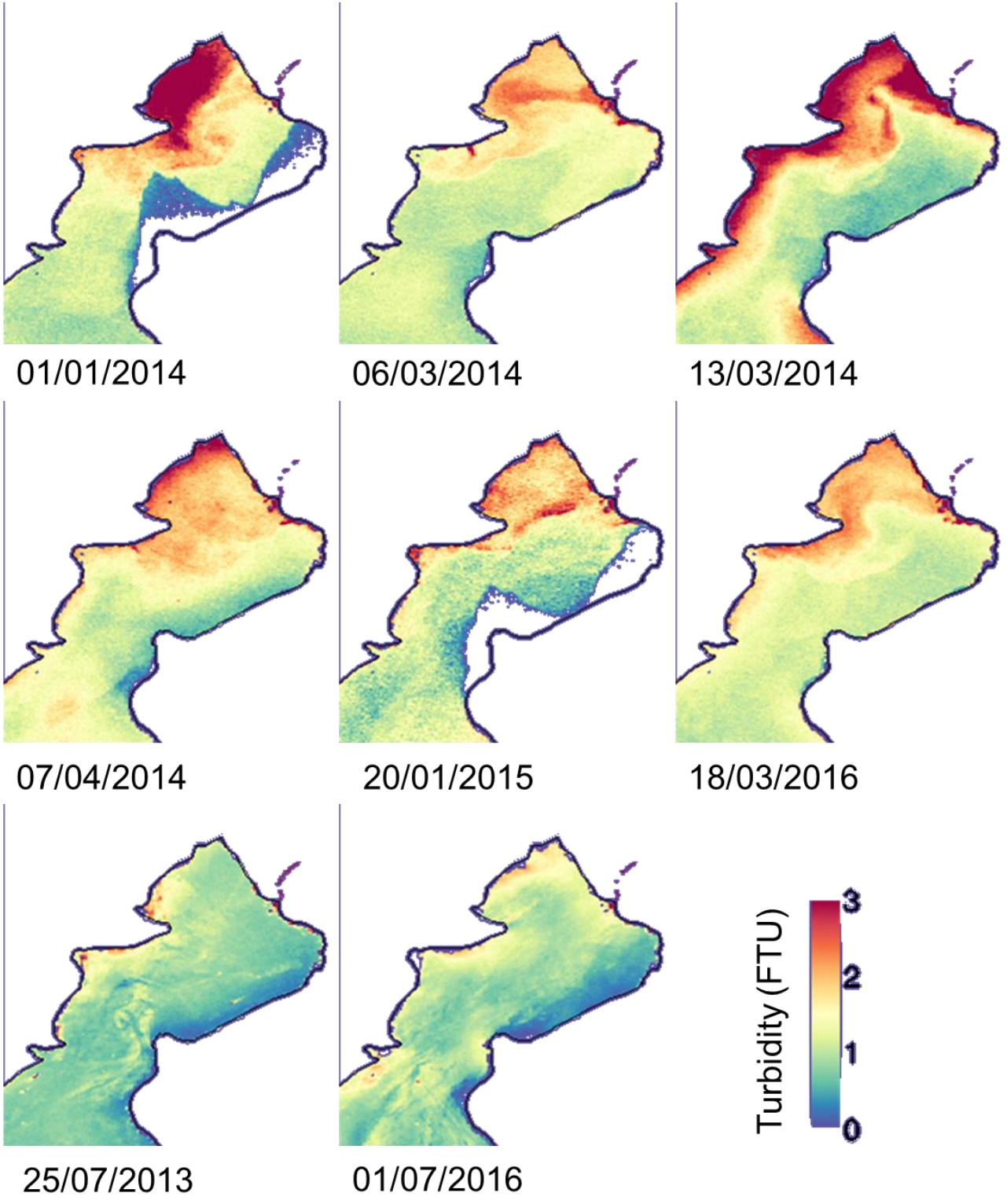
Landsat-TSM



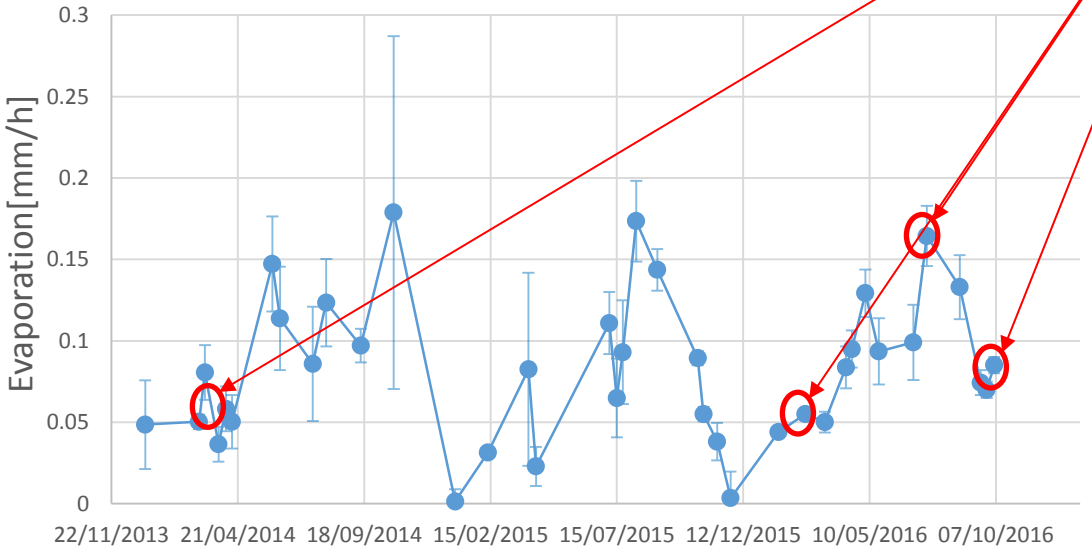
23/08/2014

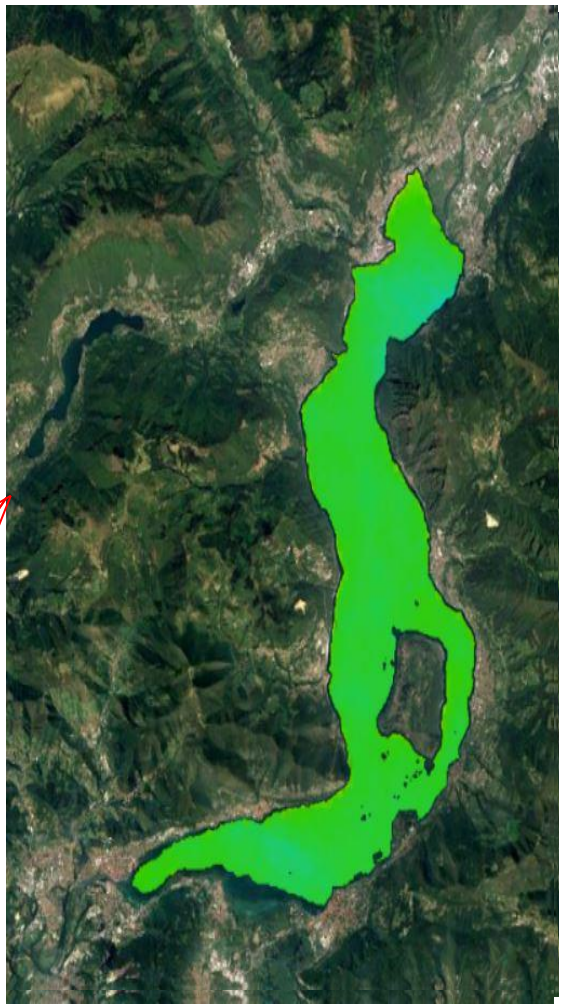




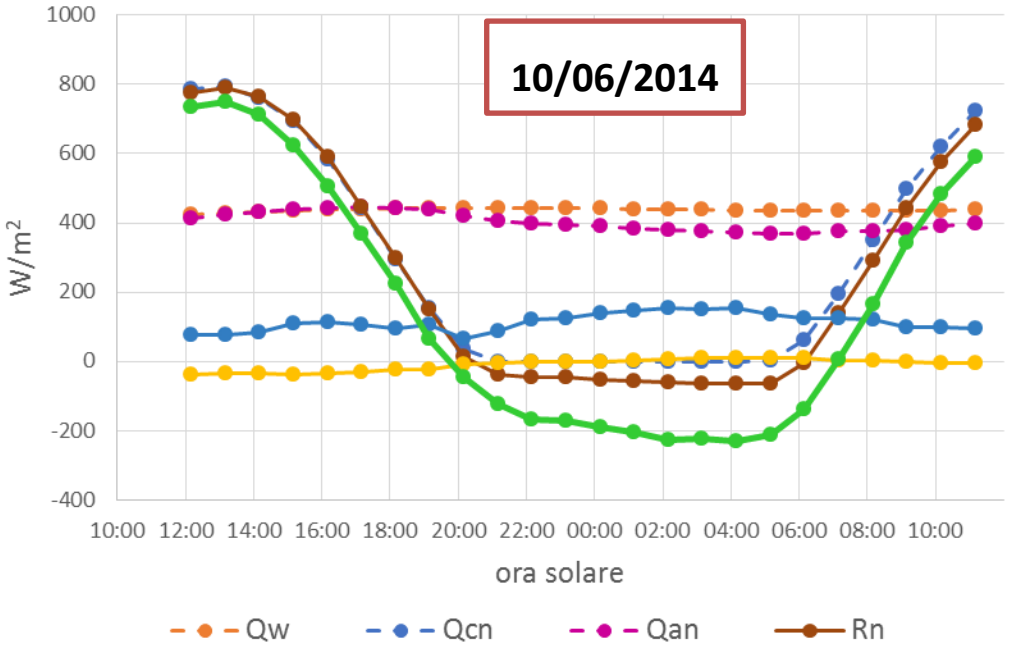

01/01/2014
06/03/2014
13/03/2014
07/04/2014
20/01/2015
18/03/2016
25/07/2013
01/07/2016
Turbidity (FTU)
3
2
1
0

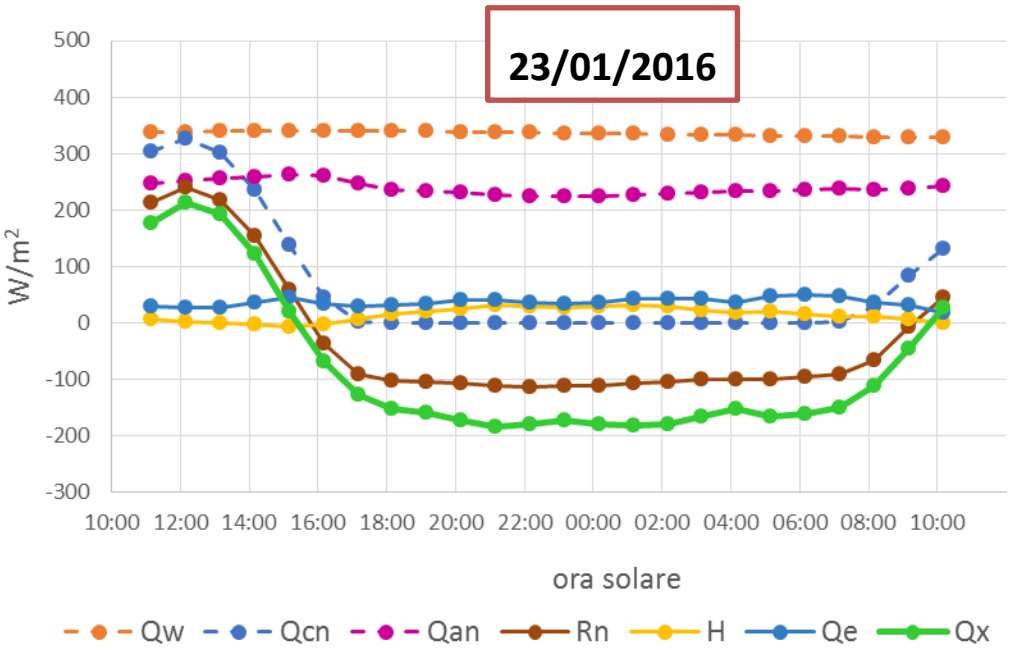
Landsat-Evaporation [mm/h]



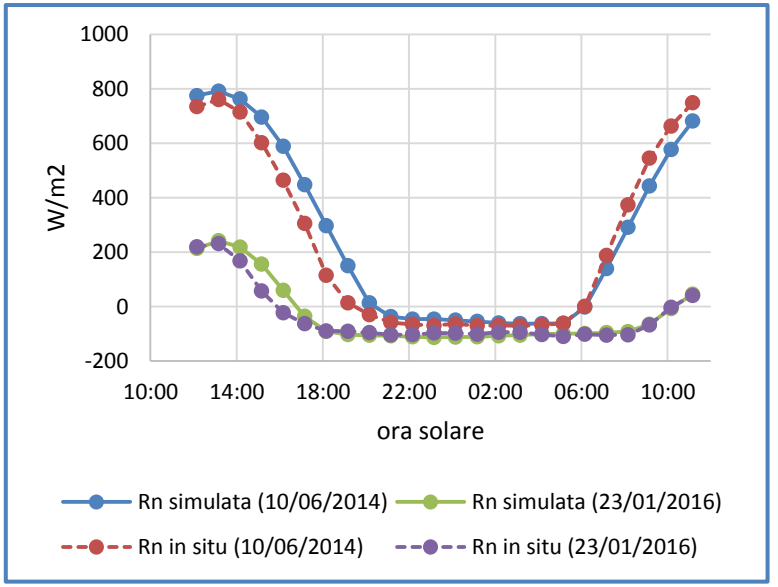


Risultati: bilancio termico giornaliero



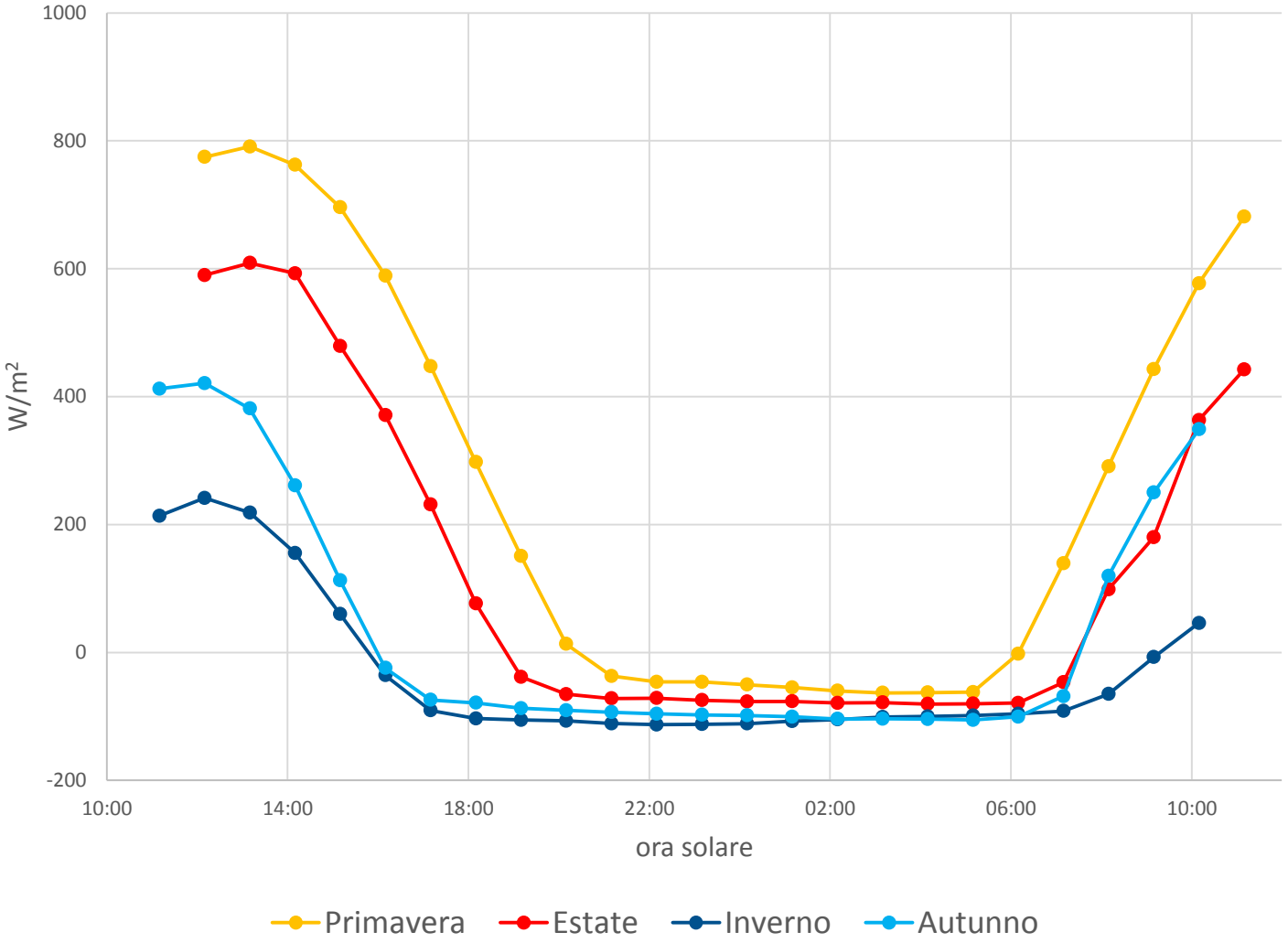


Validazione della radiazione netta giornaliera

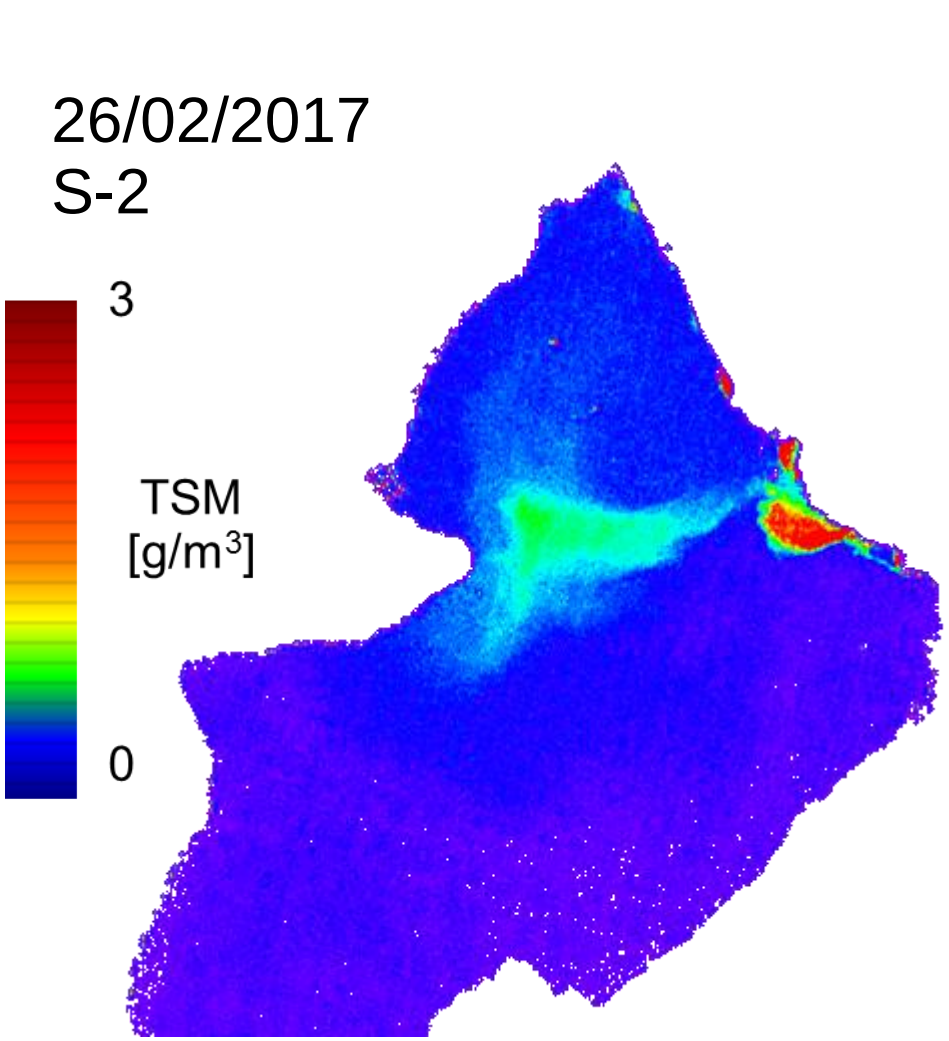


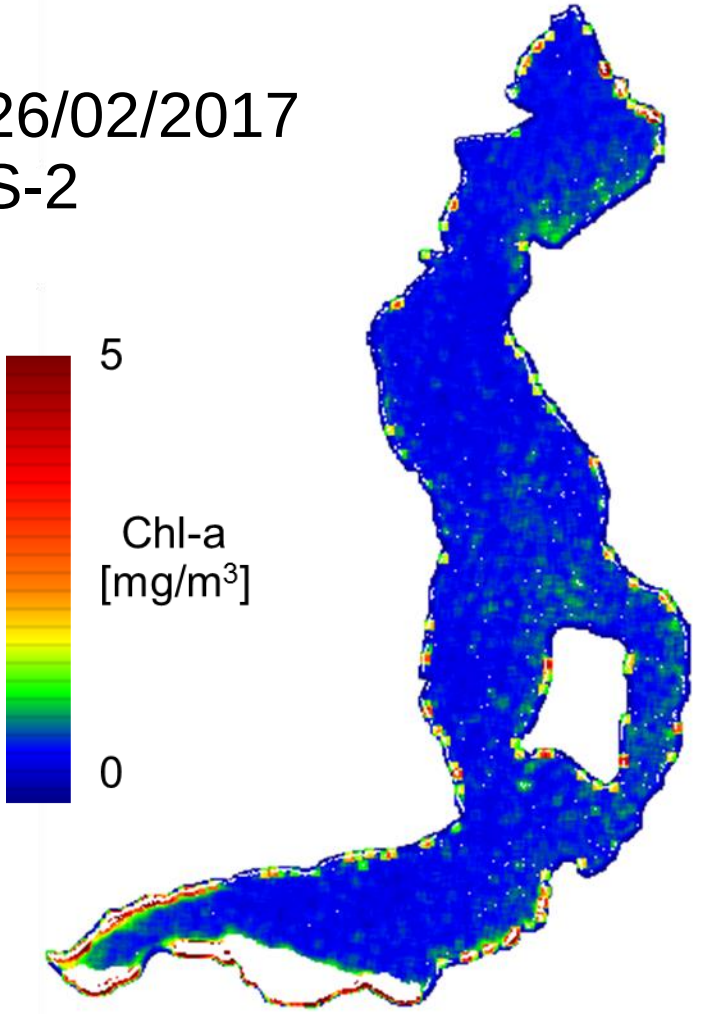
	10/06/2014	23/01/2016
R^2	0.95	0.95
$RMSE$	75.51 [W/m²]	29.96 [W/m²]

Risultati: radiazione netta giornaliera

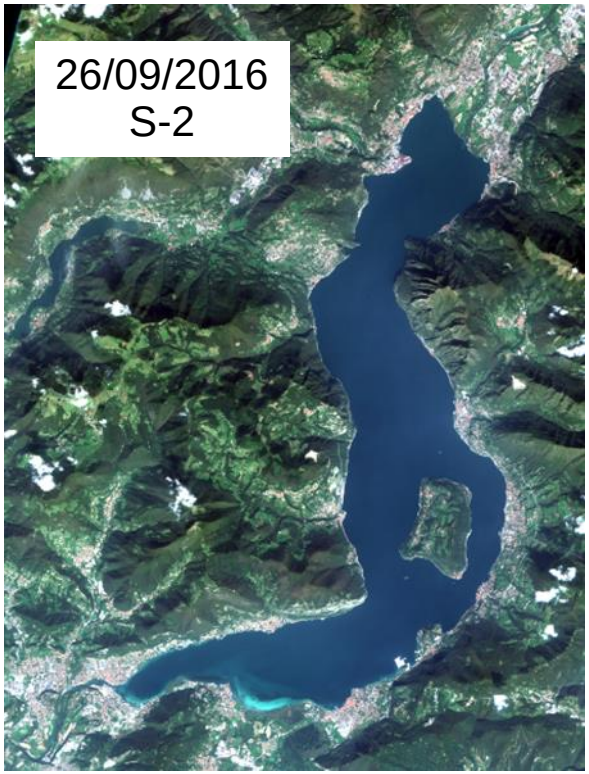


Sentinel-2: water quality





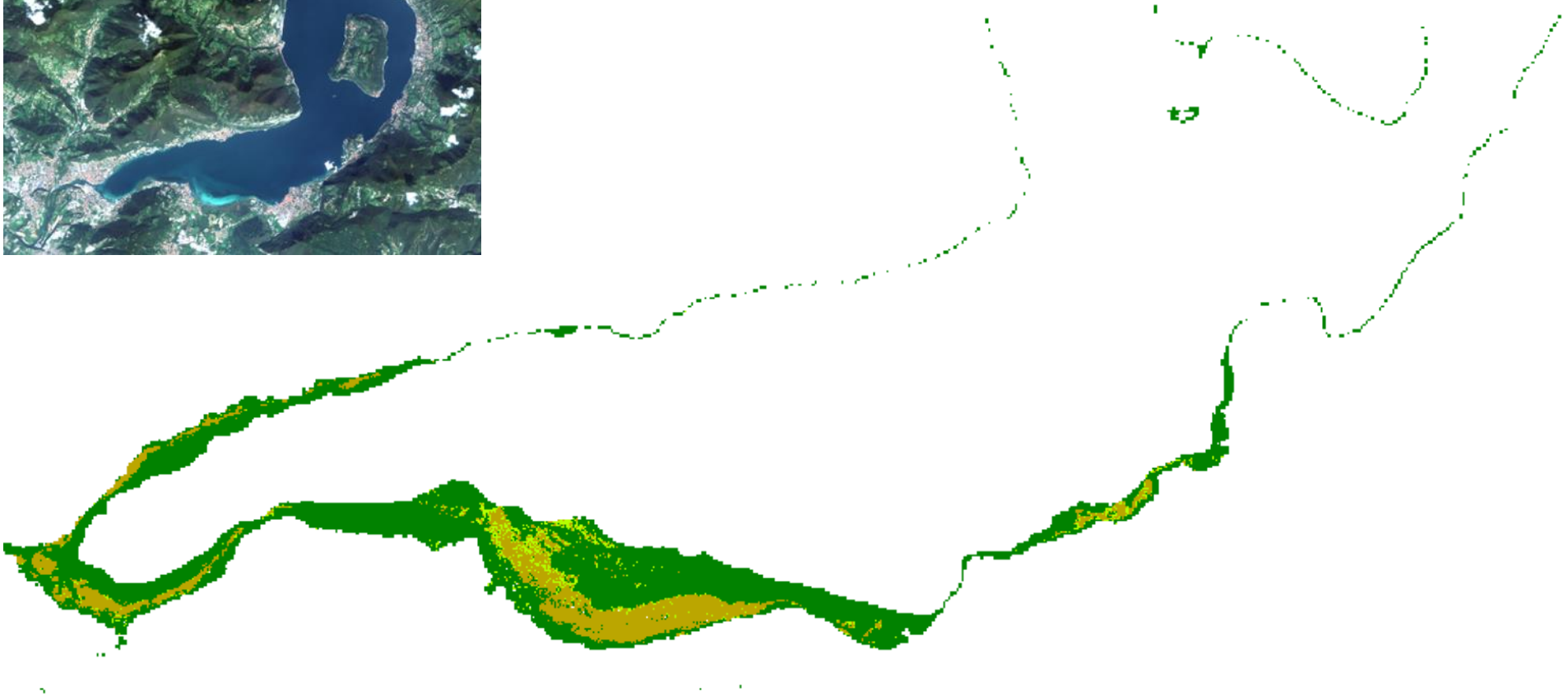
Sentinel-2: Bottom coverage



Macrophyte low albedo

Macrophyte high albedo

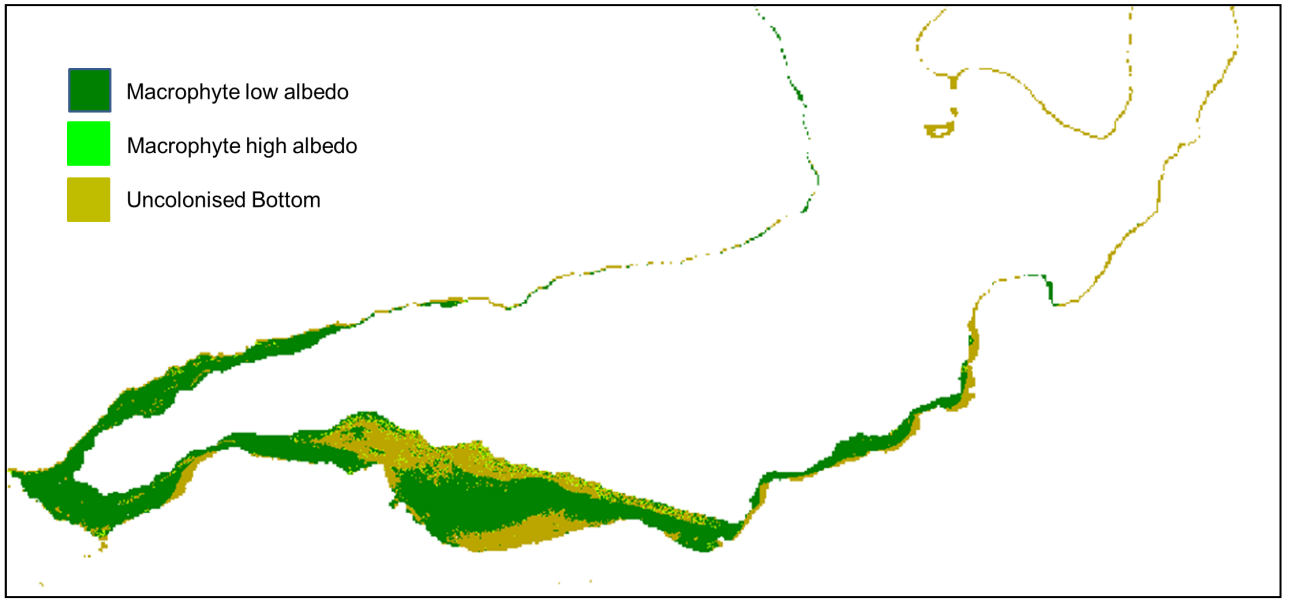
Uncolonised Bottom

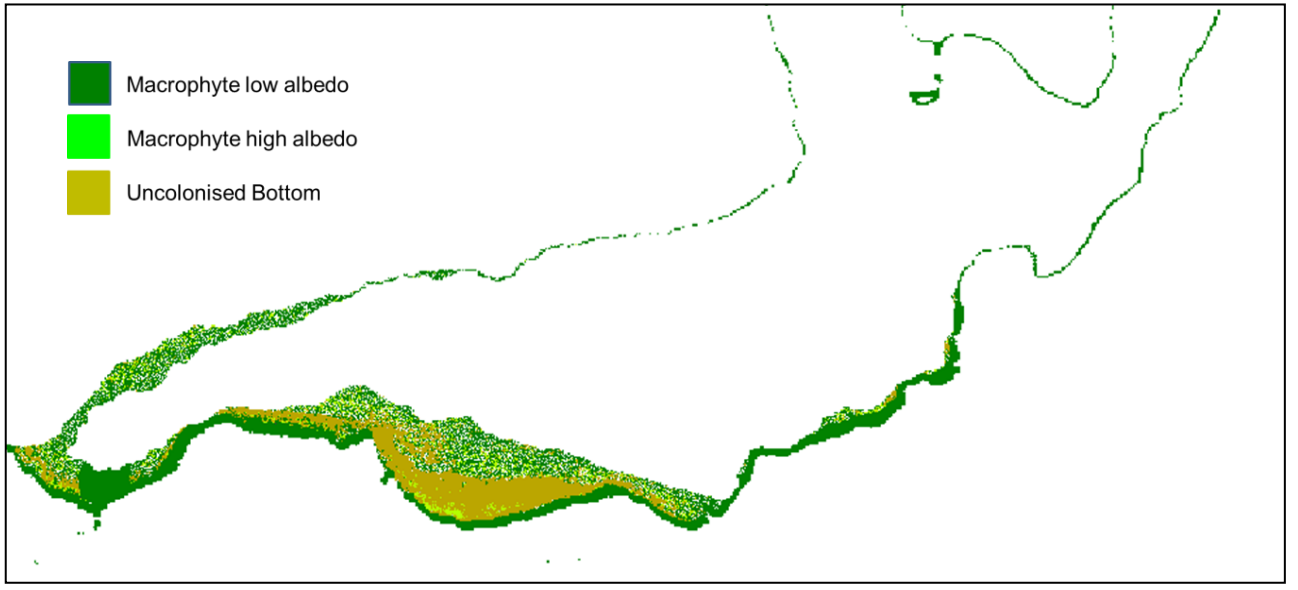


Sentinel-2: Bottom coverage

04/07/2015
S-2

22/10/2015
S-2



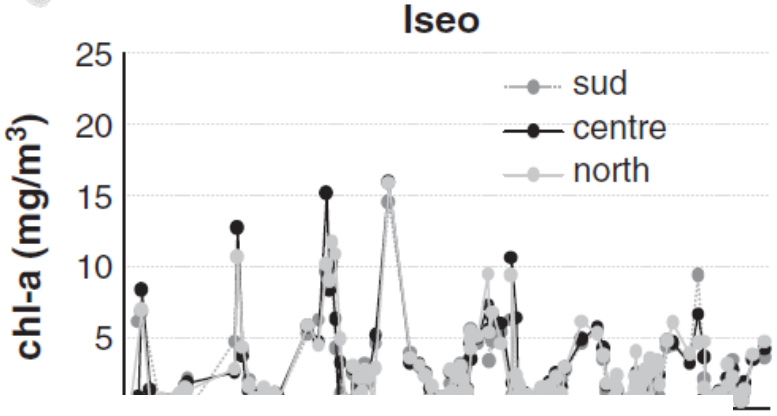


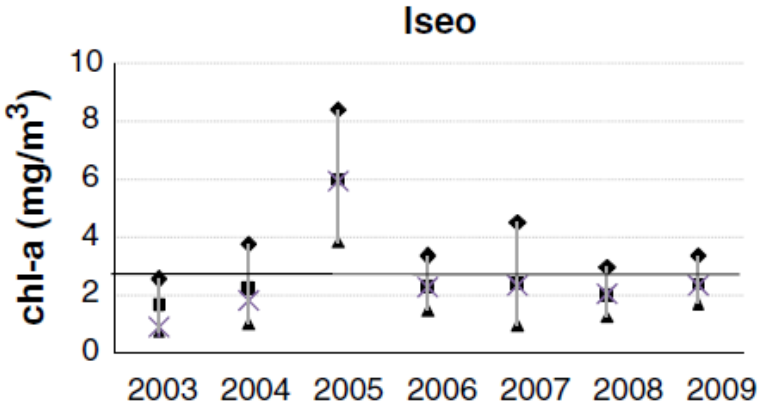
ISEO: Improving the lake Status from Eutrophy towards Oligotrophy

fondazione cariplo

EO data – initial datset

MERIS
Medium Resolution Imaging Spectrometer





Science of the Total Environment 409 (2011) 3083–3091

Contents lists available at ScienceDirect

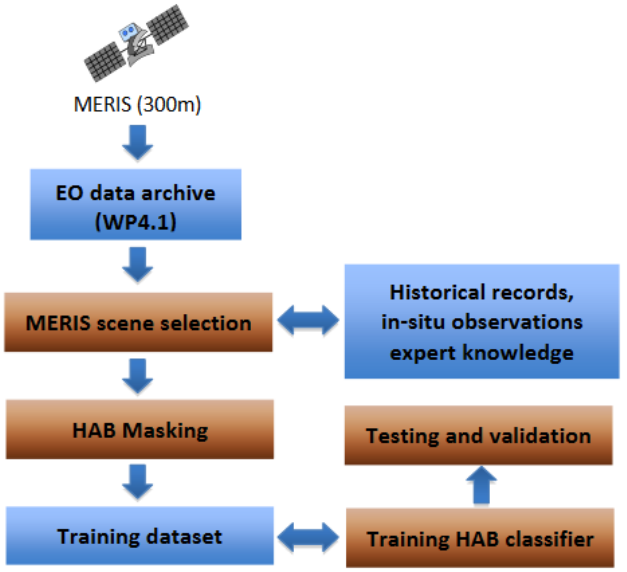
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessing remotely sensed chlorophyll-a for the implementation of the Water Framework Directive in European perialpine lakes

Mariano Bresciani [a], Daniela Stroppiana [a], Daniel Odermatt [b], Giuseppe Morabito [c], Claudia Giardino [a,*]

[a] Optical Sensing Group, Institute for Electromagnetic Sensing of the Environment, National Research Council of Italy, via Bassini 15, I-20133 Milano, Italy
[b] Remote Sensing Laboratories, University of Zurich, Zurich, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland
[c] Institute for the Ecosystems Study, National Research Council of Italy, Lgo Tonolli 50-52, I-28922 Verbania-Pallanza, Italy



Dissemination

Cazzaniga I., Giardino C., Bresciani M., Elli C., Valerio G., Pilotti M. **Assessing heat fluxes and water quality trends in subalpine lakes from EO.** Geophysical Research Abstracts, Vol. 19, EGU2017-19233-1, 2017. EGU General Assembly 2017

Giardino C. et al., 2017. **Qualification of water quality retrieval from OLI-MSI-OLCI for European inland waters**. ASLO 2017 Aquatic Sciences Meeting. Feb 26 – Mar 3, 2017, Honolulu, Hawai.

Cazzaniga I. et al., 2016. **Assessment of atmospheric correction methods of Sentinel-2 in italian lakes**, 1st Sentinel-2 Validation Team Meeting, Roma, Novembre 2016.

Chiara Elli (2017) Tesi di Laurea: **LAGO D'ISEO: remote sensing per il bilancio energetico e lo studio dei parametri biogeofisici.** Politecnico di Milano, Ingegneria per l'Ambiente e il Territorio. Matr. 841730. A.A. 2016/2017. Relatore: Gianinetto M.; Co-relatore: C.Giardino, M. Bresciani, I. Cazzaniga.