

# Achievements, Developments and Perspectives of the SARLAKES Project

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## Aim

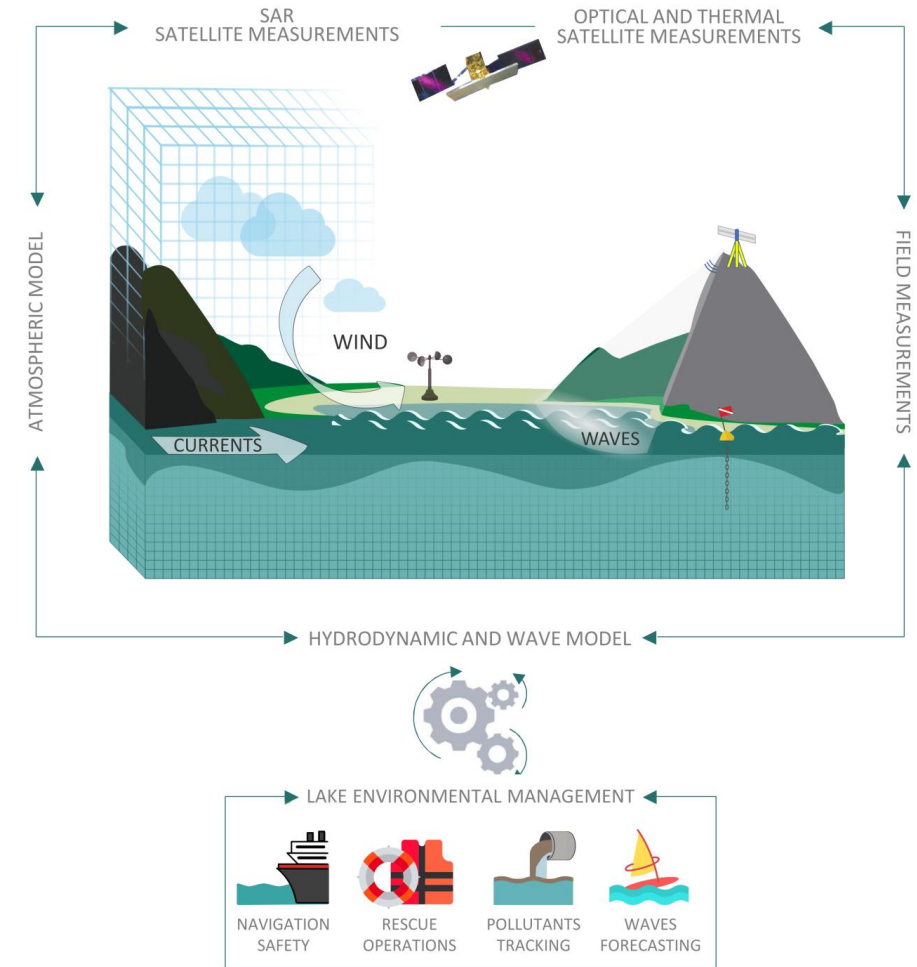
SARLAKES investigate the use of remote and in-situ measurements for the accurate estimation of the water dynamics over large lakes.

## Information sources

- SAR data + complementary satellite data from optical sensors + in-situ measurements
- Experiment of proximal radar measurement with a coherent ground-based radar
- Numerical models developments

## Where

- Development, testing, calibration and validation of SARLAKES modules is carried out primarily on the Garda lake.
- The SARLAKES methodology shall be exported to lake of Geneva where fieldwork activities are active at multiple stations, and a floating platform (<https://lexplore.info/>) continuously records weather variables, flow velocity and temperature along the water column. Moreover, a real-time operational model of lake Geneva is of easy access.



# Satellite Data

High spatial resolution microwave images from Synthetic Aperture Radar for wind, waves and currents:

- COSMO-SkyMed
- RADARSAT
- Sentinel-1

Sentinel-2 MSI and Sentinel-3 OLCI data for water clarity

Landsat thermal imagery for Lake Surface Water Temperature (LSWT) at higher spatial resolution

Ongoing activities for the integration of data acquired by the Capella Space constellation, and TerraSAR-X.

# In situ Measurements

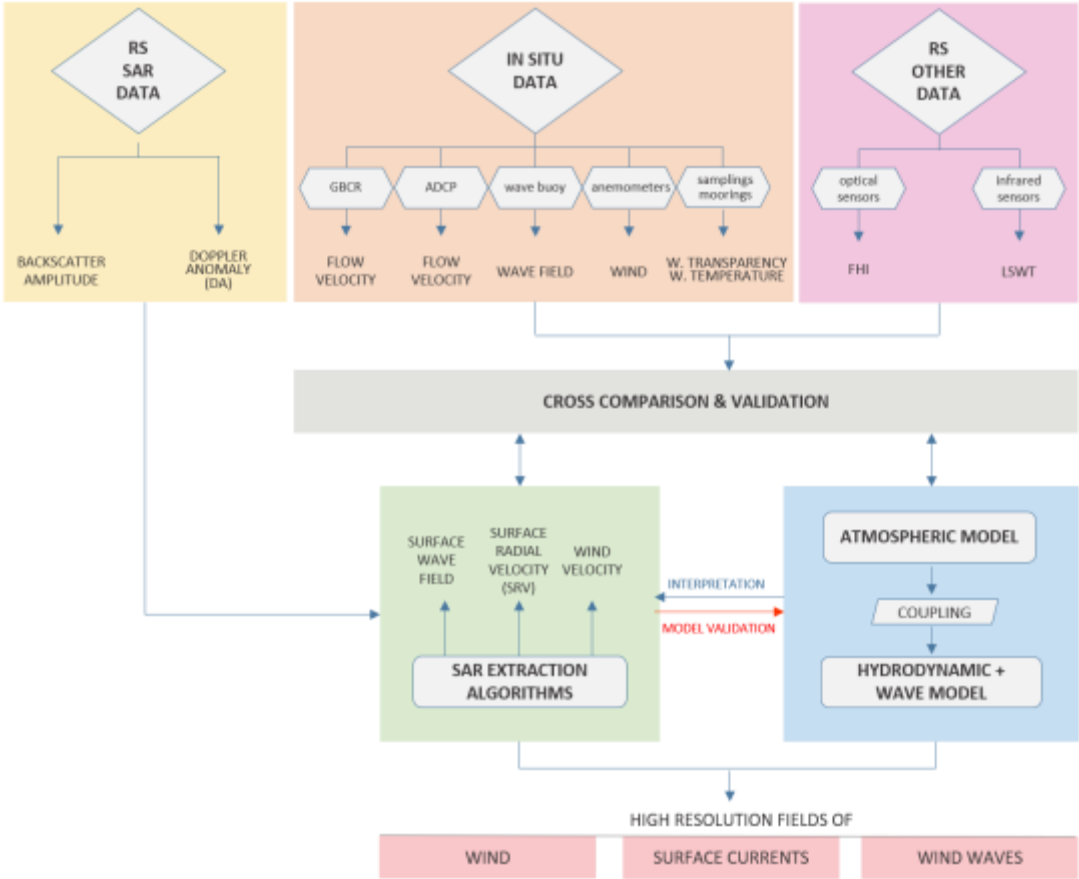
Dedicated campaigns in Lake Garda concurrent with the satellites' overpass

- Meteorological and water temperature data along the water column, measured at two operative moored stations
- Surface drifters at several locations for a few days
- Anemometers
- Local measurements of the water temperature, clarity and TSM
- Ground radar imaging campaign

# Numerical Modeling

- Available a 3D hydrodynamic numerical model for simulating flow field and turbulence, as well as heat and mass transport.
- Such 3D hydrodynamic numerical model (Delft3D) is already interfaced with the WRF atmospheric model. Refinement for RS optical and thermal products and dedicated field campaigns. Refinement also to account for recently available high-resolution bathymetric maps (ISMAR and ACCURATE).
- Development of a SWAN based wave numerical model able to integrate ground measurements.
- Similar modeling chain already available for the secondary case study (Lake Geneva: Delft3D+MeteoSwiss COSMO).

# Overall scheme

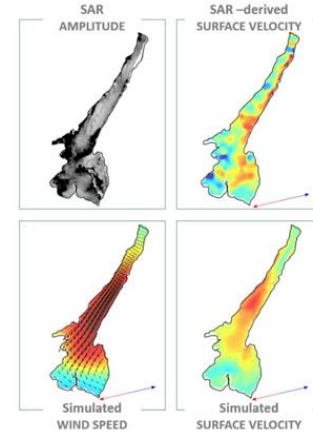
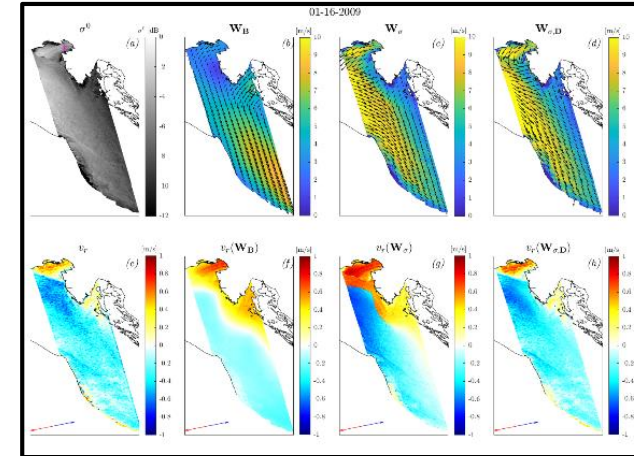


**Figure 2:** SARLAKES methodology flowchart. The color of each box is codified in accordance with that of the working groups reported in Figure 3 and of the WPs in the GANTT diagram

# SAR Activities and Results

Activities are built on the past experience with Envisat (2000-2010):

- *Zamparelli, V.; De Santi, F.; Cucco, A.; Zecchetto, S.; De Carolis, G.; Fornaro, G. Surface Currents Derived from SAR Doppler Processing: An Analysis over the Naples Coastal Region in South Italy. J. Mar. Sci. Eng. 2020, 8, 203.*
- *Zamparelli, V.; De Santi, F.; De Carolis, G.; Fornaro, G. SAR Based Sea Surface Complex Wind Fields Estimation: An Analysis over the Northern Adriatic Sea. Remote Sens. 2023, 15, 2074*
- *Amadori, M.; Zamparelli, V.; De Carolis, G.; Fornaro, G.; Toffolon, M.; Bresciani, M.; Giardino, C.; De Santi, F. Monitoring Lakes Surface Water Velocity with SAR: A Feasibility Study on Lake Garda, Italy, Remote Sens. 2021, 13, 2293.*



Preliminary activities regarded the investigation of the existing data archives and analysis of the different illumination geometry (ascending and descending).

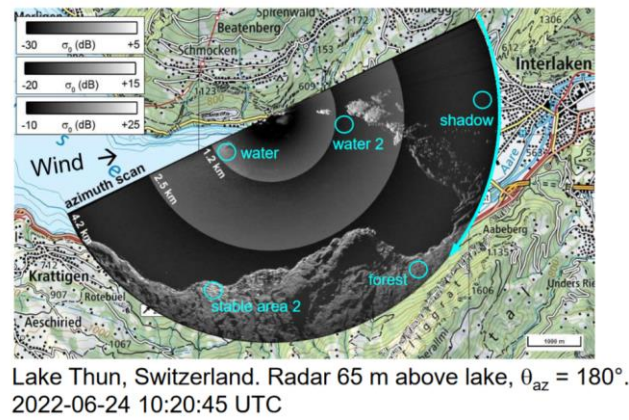
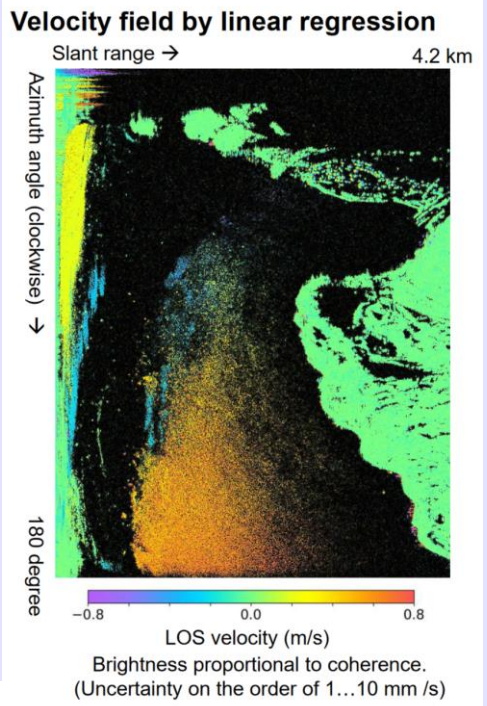
Selected ascending acquisitions in the period 8/2019-2/2024 were processed → *presentation De Carolis at 10:10.*

Ongoing processing on the recent acquisitions.

Focus on 2024 →

Satellite	Sensor Mode	Collection	Product Status	Sensing Date	Sensing Start	Sensing Stop	Orbit Direction	Polarization	Beam	Status
SAR2	STR_HIMAGE	LO_SAR2	ARCHIVED	17/02/2024	4:46:05	4:47:30	A	HH	H4-03	
SAR2	STR_HIMAGE	LO_SAR2		04/03/2024	4:46:05	4:47:30	A	HH	H4-03	
SAR2	STR_HIMAGE	LO_SAR2		20/03/2024	4:46:05	4:47:30	A	HH	H4-03	
SAR2	STR_HIMAGE	LO_SAR2	ARCHIVED	05/04/2024	4:46:05	4:47:30	A	HH	H4-03	
SAR2	STR_HIMAGE	LO_SAR2	ARCHIVED	21/04/2024	4:46:05	4:47:30	A	HH	H4-03	PROCESSED
SAR2	STR_HIMAGE	LO_SAR2		07/05/2024	4:46:05	4:47:30	A	HH	H4-03	
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SAR2	STR_HIMAGE	LO_SAR2	ARCHIVED	10/07/2024	4:46:05	4:47:30	A	HH	H4-03	
SAR2	STR_HIMAGE	LO_SAR2		26/07/2024	4:46:05	4:47:30	A	HH	H4-03	
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SAR2	STR_HIMAGE	LO_SAR2		30/10/2024	4:46:05	4:47:30	A	HH	H4-03	
				15/11/2024						
				01/12/2024						
				17/12/2024						

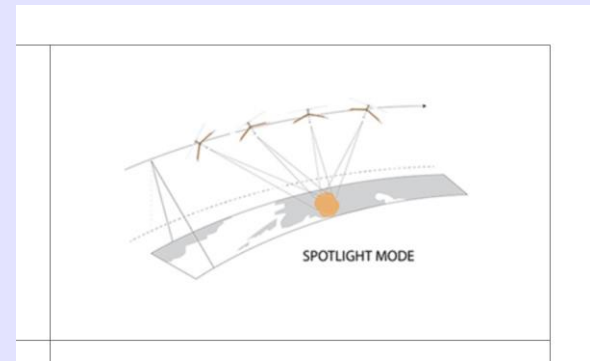
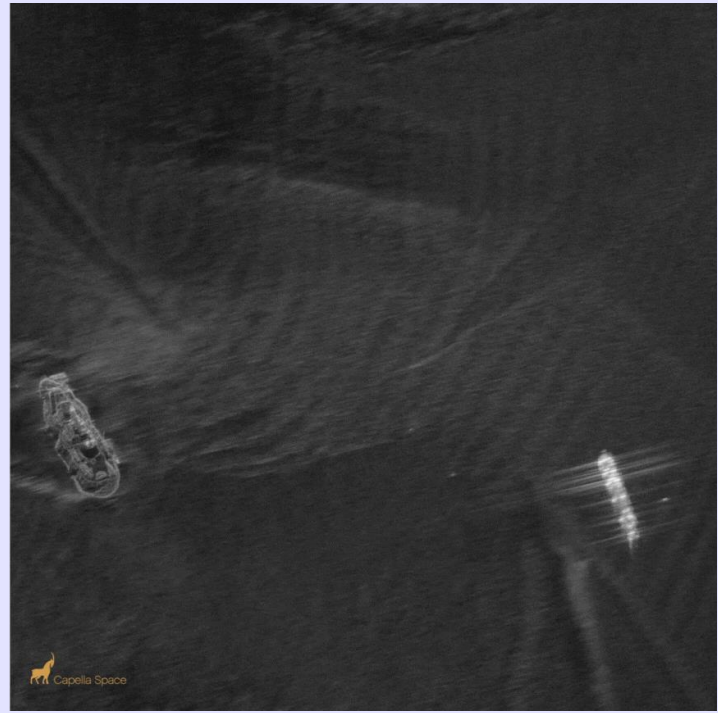
# Further activities on Radar Imaging



## Ground Based Radar Imaging (GBRI)

[https://gamma-rs.ch/uploads/media/poster\\_fringe2023-leinss.pdf](https://gamma-rs.ch/uploads/media/poster_fringe2023-leinss.pdf)

## Video SAR



<https://www.capellaspace.com/earth-observation>



# Activities on Optical Remote Sensing

## Landsat-8/9

Maps of the surface temperature (LSWT) of Lake Garda in **2023 (14 images)**

<b>Sensor</b>	TIRS/TIRS +
<b>Bands</b>	2 bands
<b>Spatial resolution</b>	30 m*
<b>Revisit time</b>	8 days



## Sentinel-3

Solid particulate matter (SPM) and chlorophyll-a (Chl-a) concentration maps of Lake Garda in **2023 (50 images)**

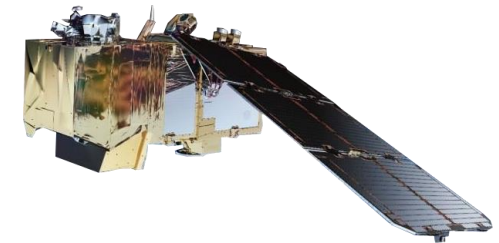
<b>Sensor</b>	OLCI
<b>Bands</b>	21 bands
<b>Spatial resolution</b>	300 m
<b>Revisit time</b>	1 day



## Sentinel-2

Solid particulate matter (SPM) concentration maps during exceptional turbidity events in Lake Garda for the period **2018-2023 (10 images)**

<b>Sensor</b>	MSI
<b>Bands</b>	13 bands
<b>Spatial resolution</b>	10 m
<b>Revisit time</b>	5 days



# LSWT maps



10.01.23

16.04.23

6  15 ° C



19.06.23

14.08.23

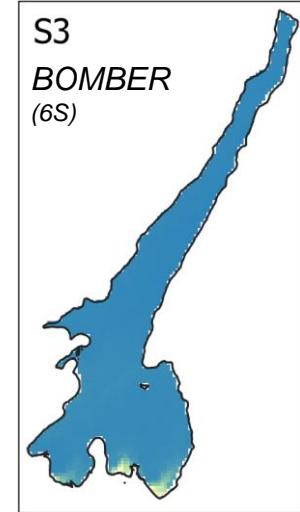
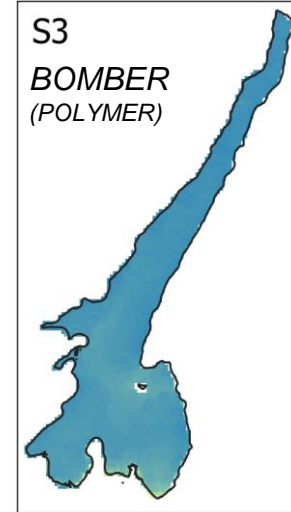
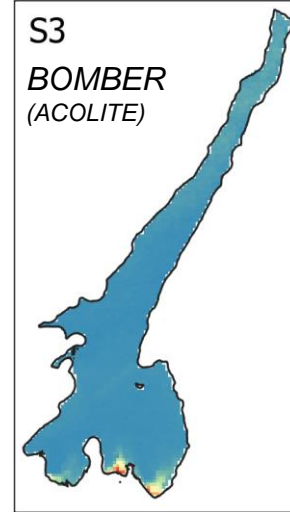
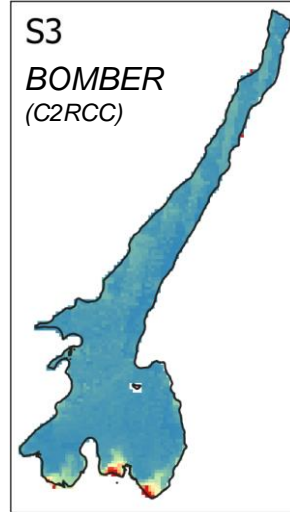
09.10.23

15  30 ° C

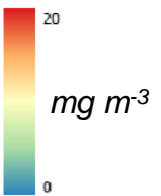
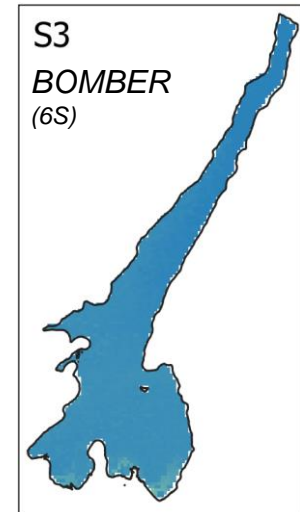
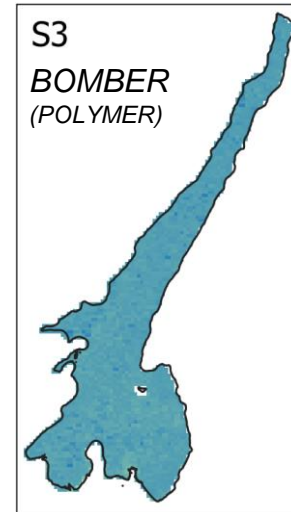
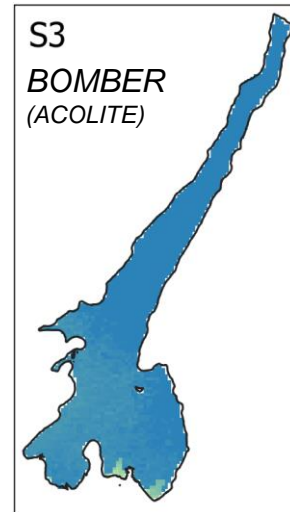
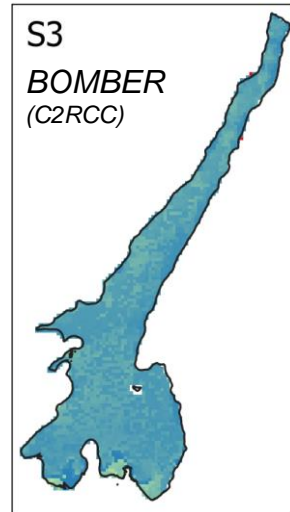
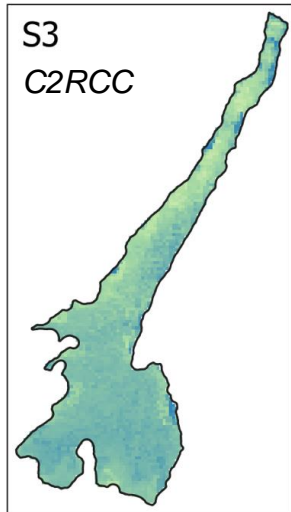
# Water quality maps

28.03.23

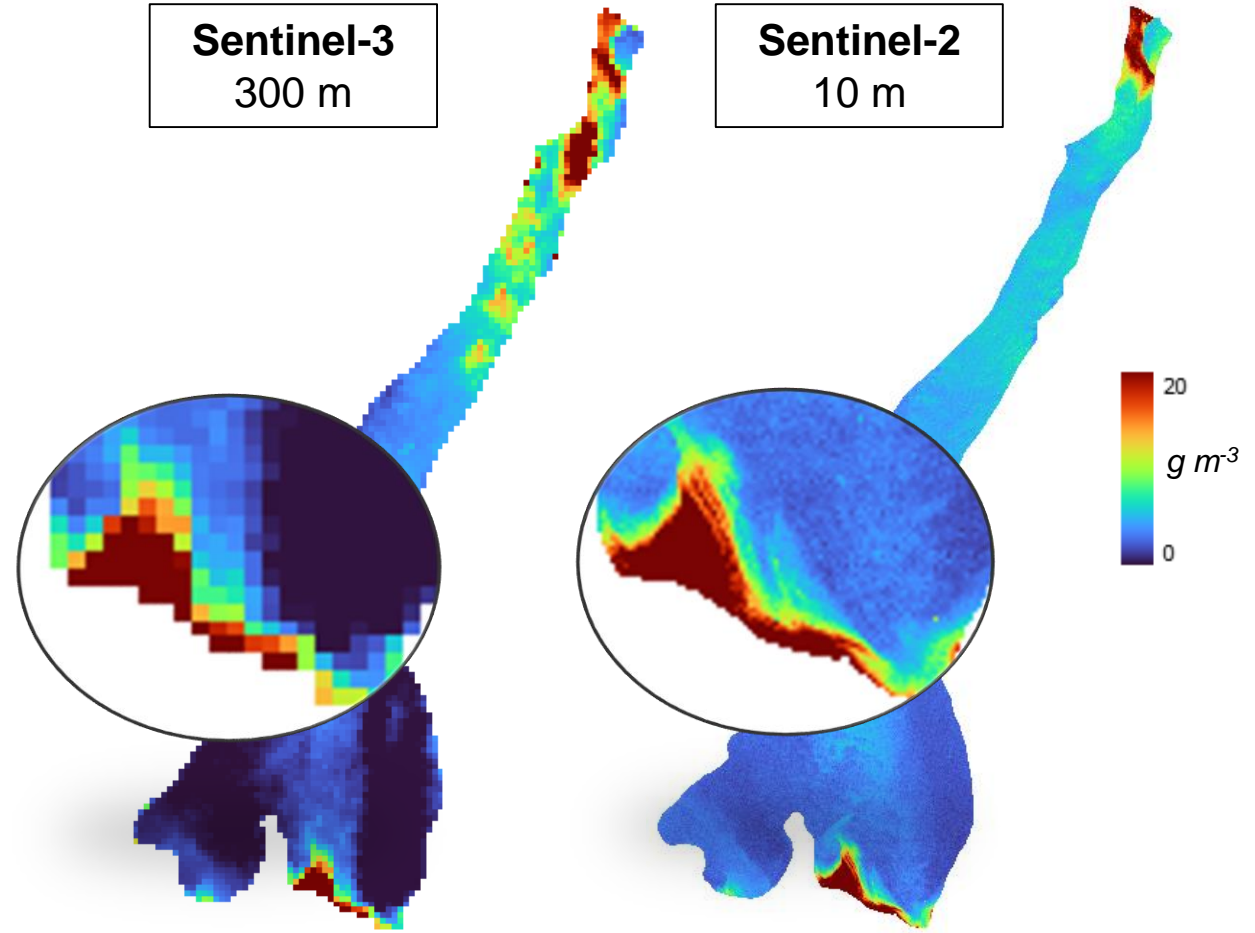
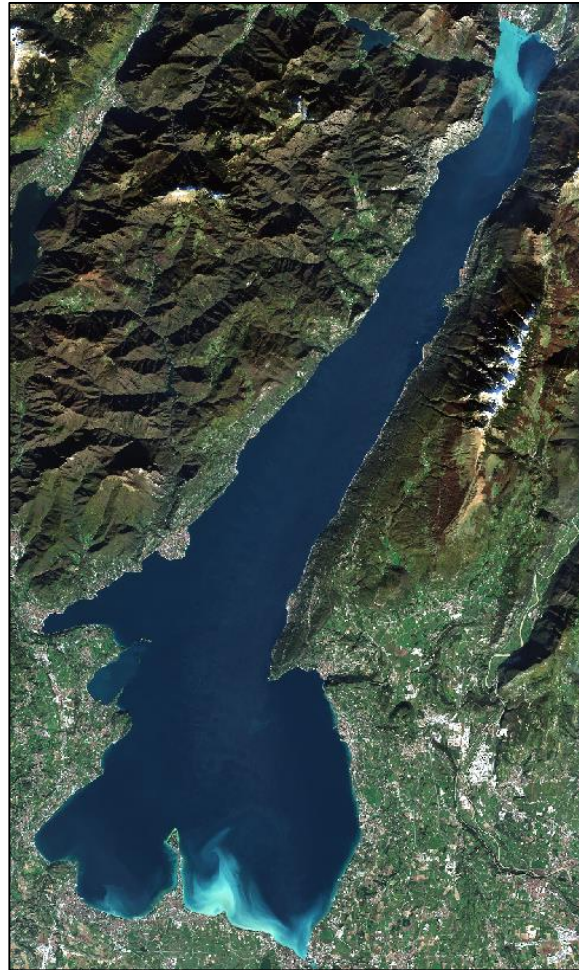
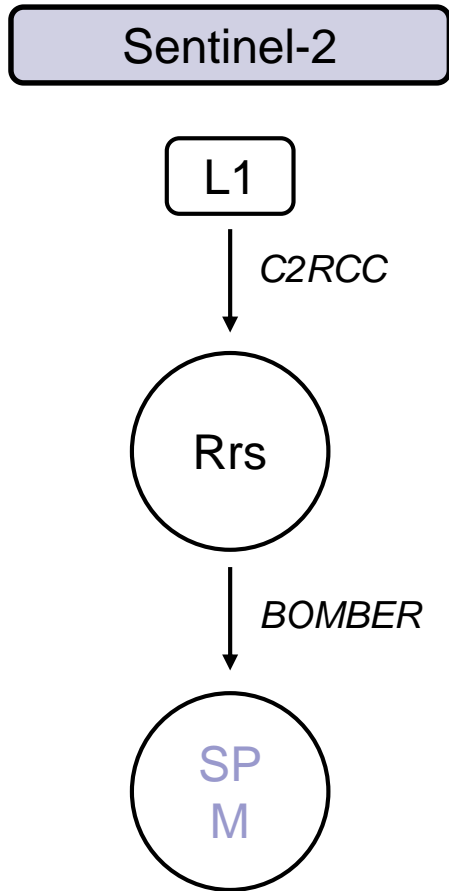
SPM



CHL-a



# Turbidity events



# Numerical Modeling

Weather Research and Forecasting Model (WRF):

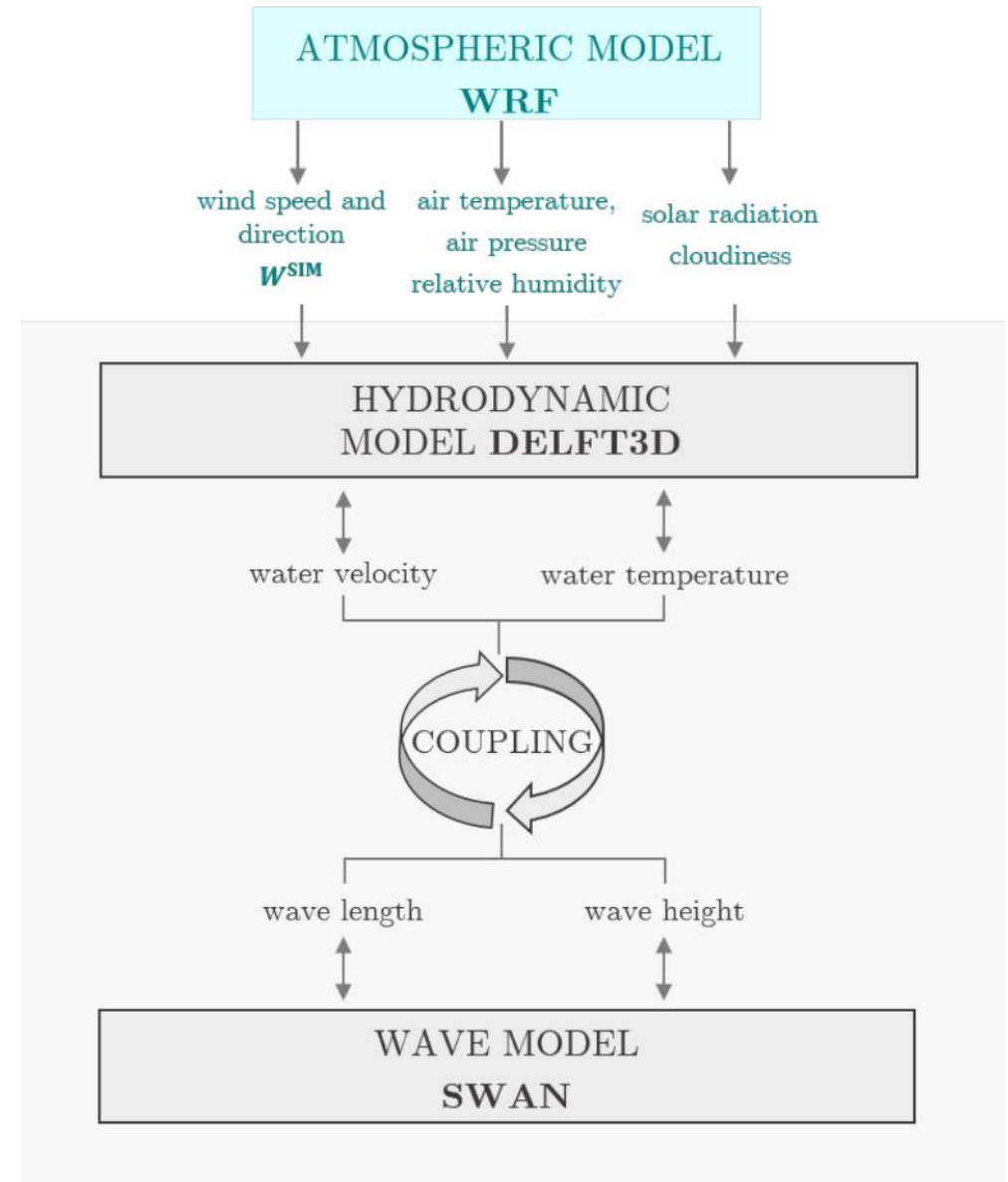
- Simulation + data assimilation
- Spatial resolution: 1 km
- Time resolution: 1 hour
- Available from 2018 to 2024

Delft3D model

- Control run 2022
- 2 spatial resolutions tested: 300 m; 100 m
- Yearly runs from 2018 to 2024
- Daily restart for dates of interest (optical and SAR imagery)

SWAN model: started

- Model setup and calibration with data to be acquired



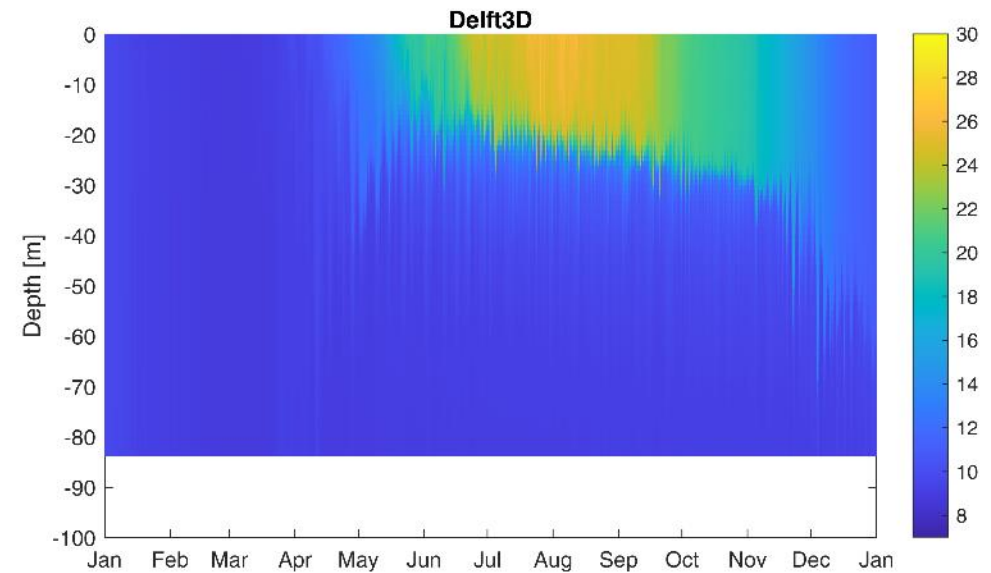
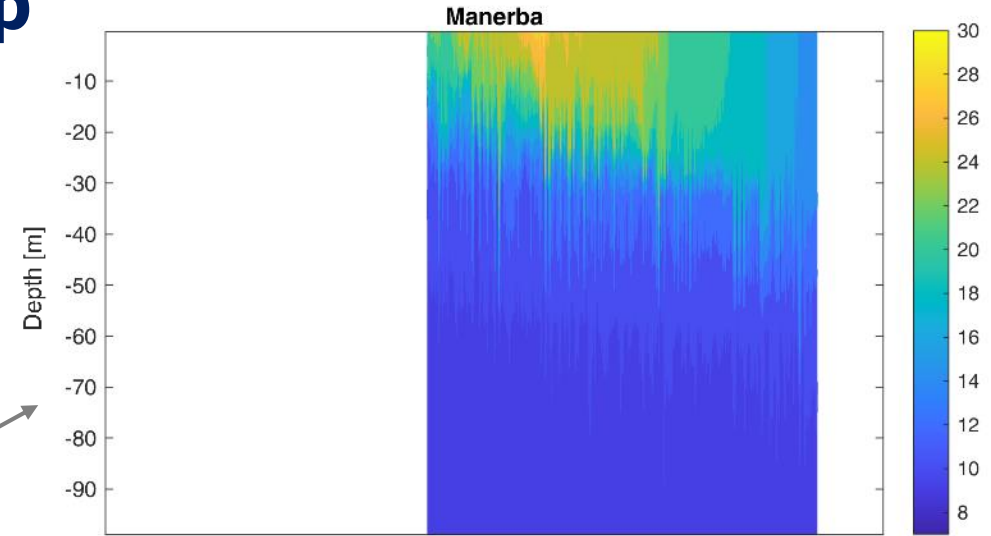
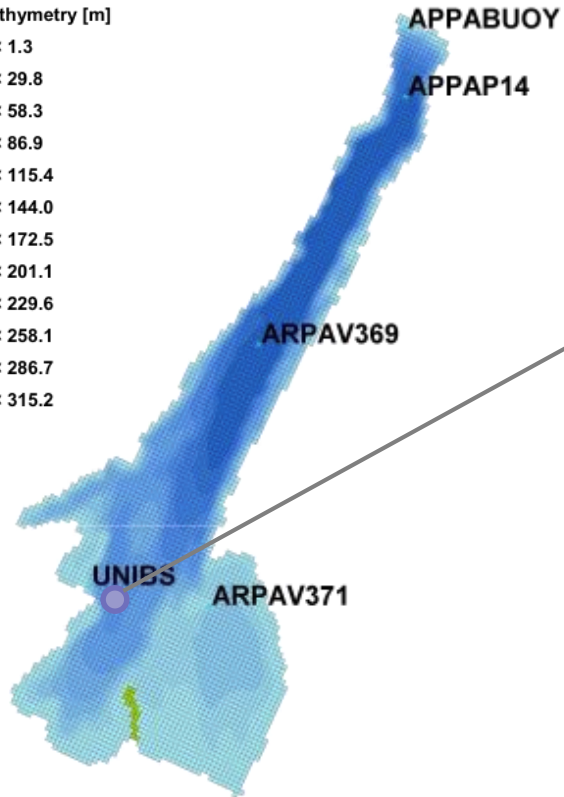
# Modeling chain setup

## Delft3D model

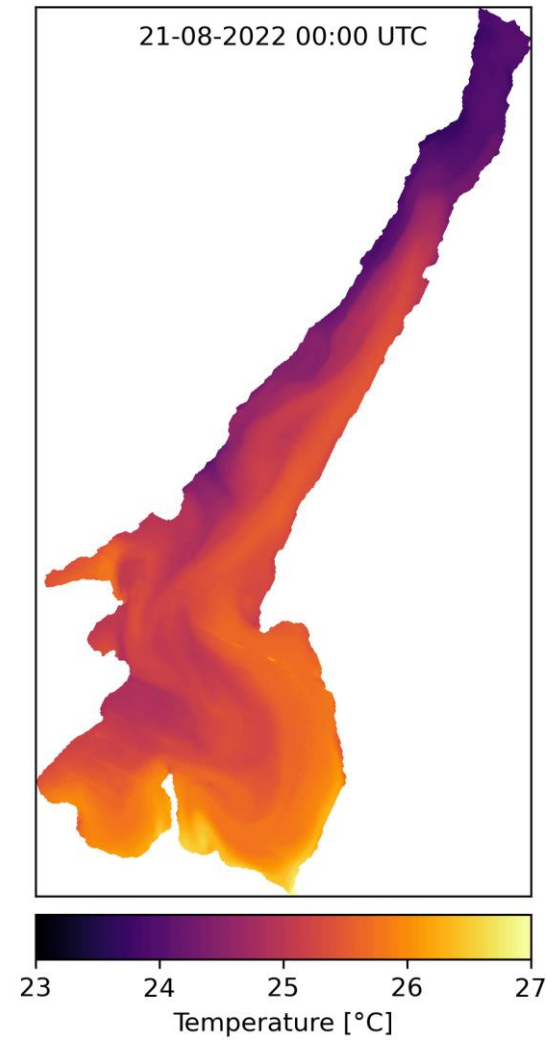
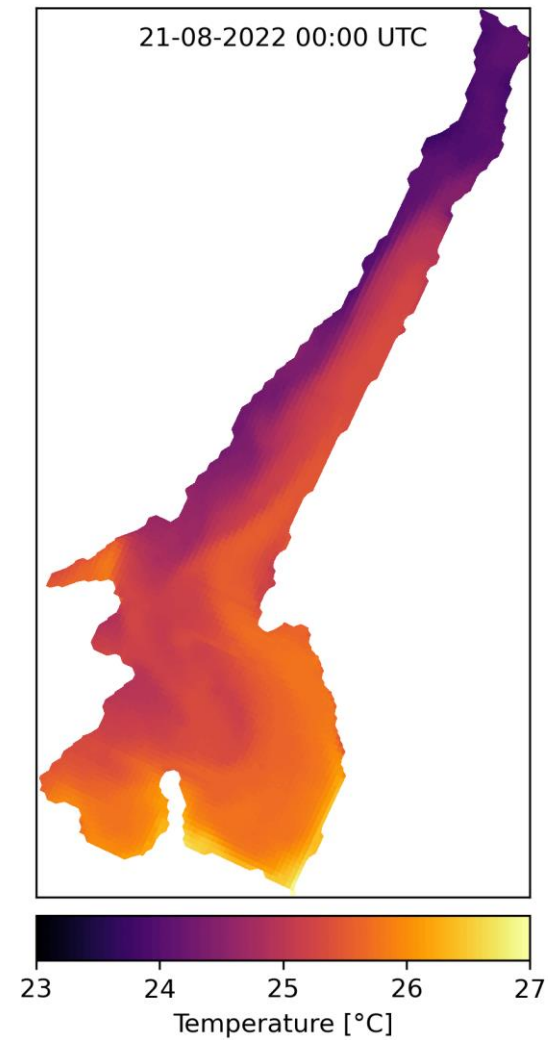
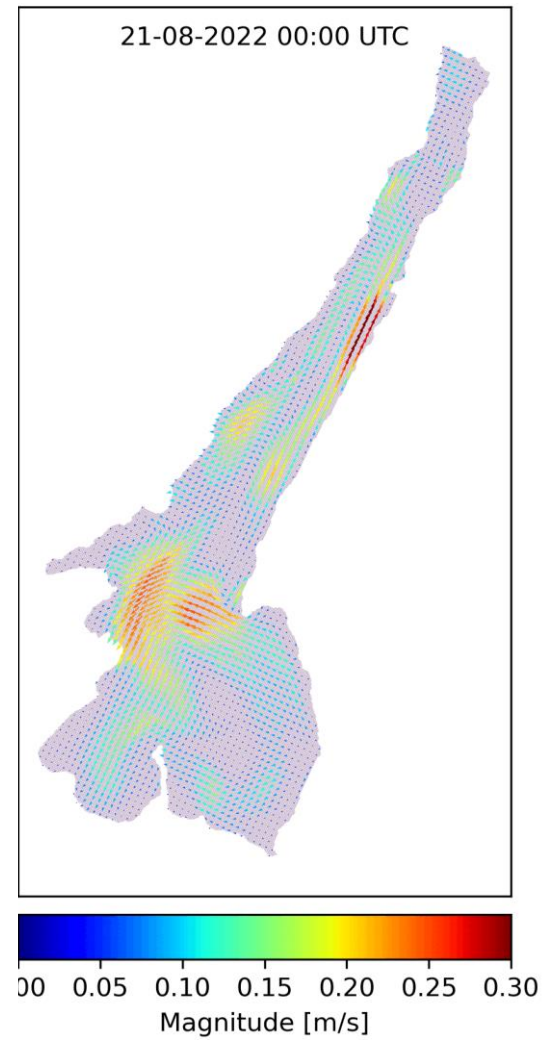
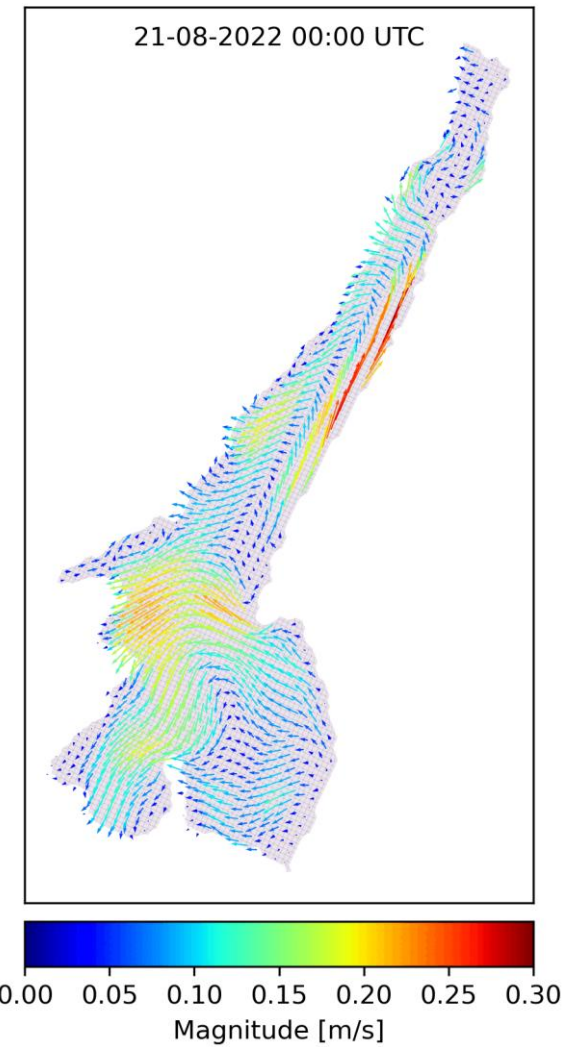
- control year 2022

Bathymetry [m]

- < 1.3
- < 29.8
- < 58.3
- < 86.9
- < 115.4
- < 144.0
- < 172.5
- < 201.1
- < 229.6
- < 258.1
- < 286.7
- < 315.2



# Modeling: water velocity and temperature

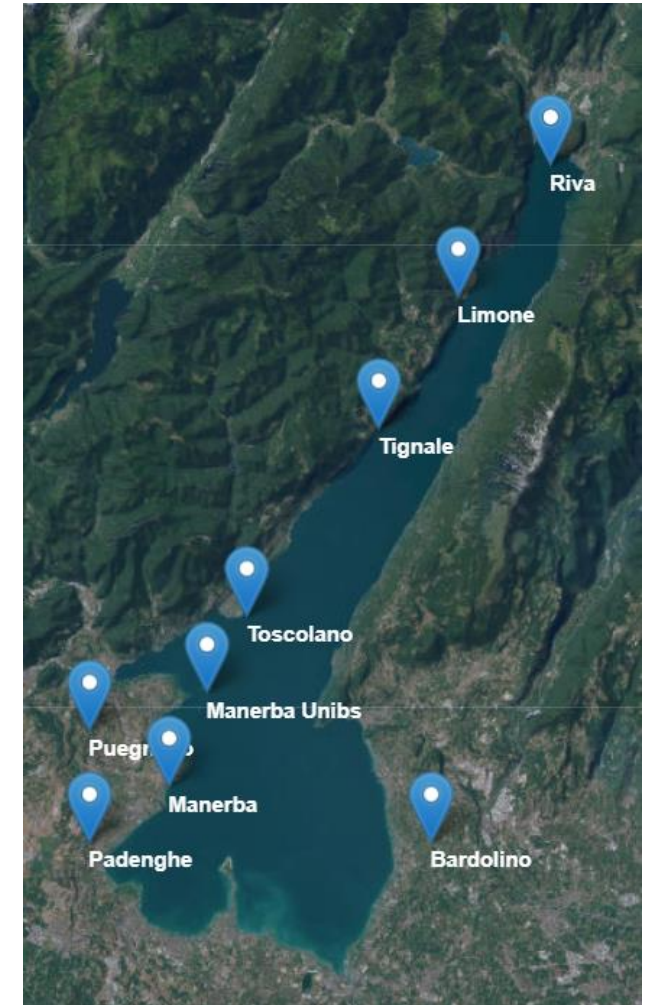
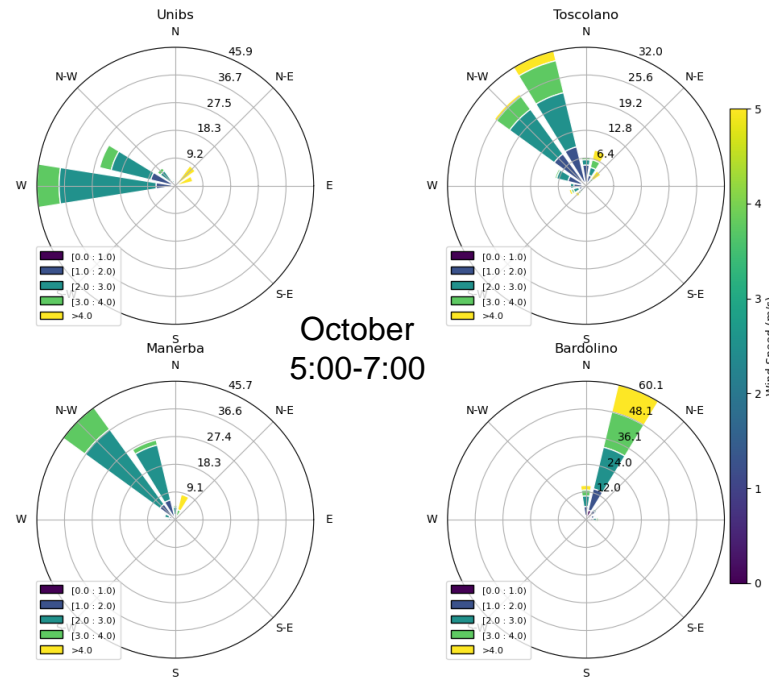
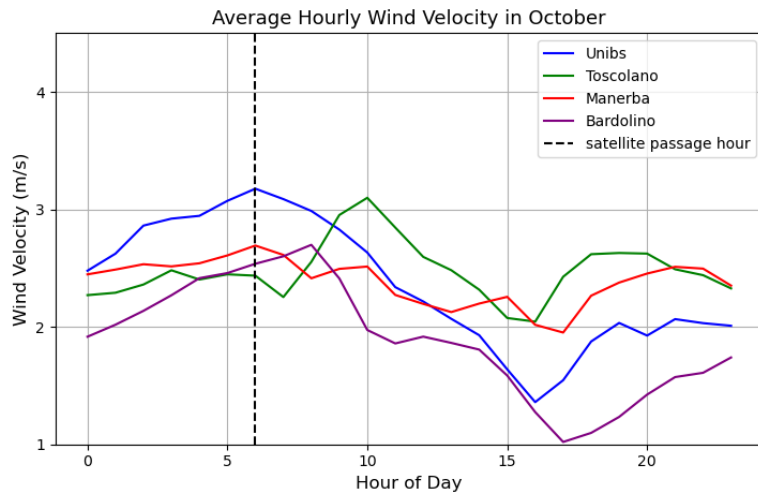


# In situ measurements: weather stations

Data extraction from weather stations around the lake.

The data has been considered for the selection of CSK acquisitions

Installation of an anemometer on Isola del Garda



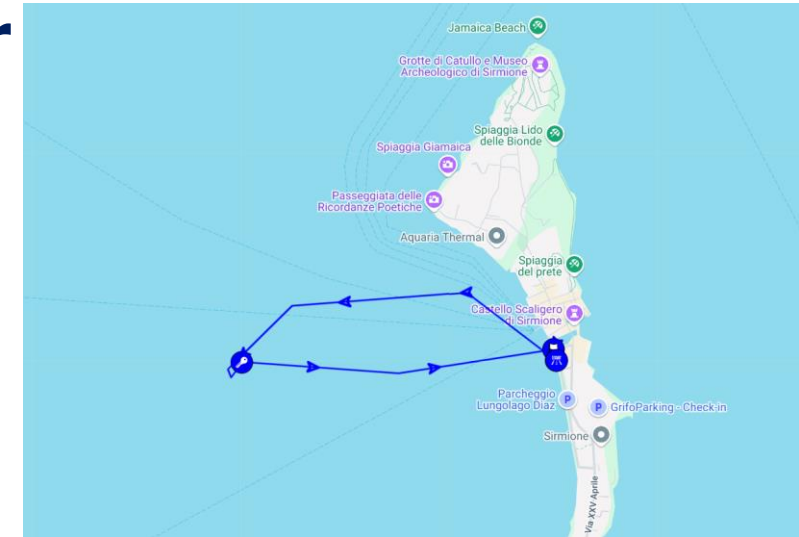


# In situ measurements: drifter



**Buoy + GPS**

Already tested twice in Lake Iseo and Lake Garda, trying different materials, structures and GPSs.



**Drogue**

GPS coordinates accuracy and precision tested successfully.



*Example of real time data output*

Targa	Date	Latitude	Longitude
BOA01	04/07/24 12:41:26	45.49099	10.607482
BOA01	04/07/24 12:51:38	45.49098	10.607445
BOA01	04/07/24 13:01:41	45.49348	10.602745
BOA01	04/07/24 13:11:44	45.49298	10.593528
BOA01	04/07/24 13:21:45	45.49063	10.590155
BOA01	04/07/24 13:32:03	45.49035	10.59029
BOA01	04/07/24 13:42:08	45.4906	10.590608
BOA01	04/07/24 13:52:16	45.4906	10.590808
BOA01	04/07/24 14:02:14	45.49092	10.590862
BOA01	04/07/24 14:12:10	45.49049	10.599135
BOA01	04/07/24 14:22:10	45.49141	10.607492
BOA01	04/07/24 14:32:15	45.49142	10.607333

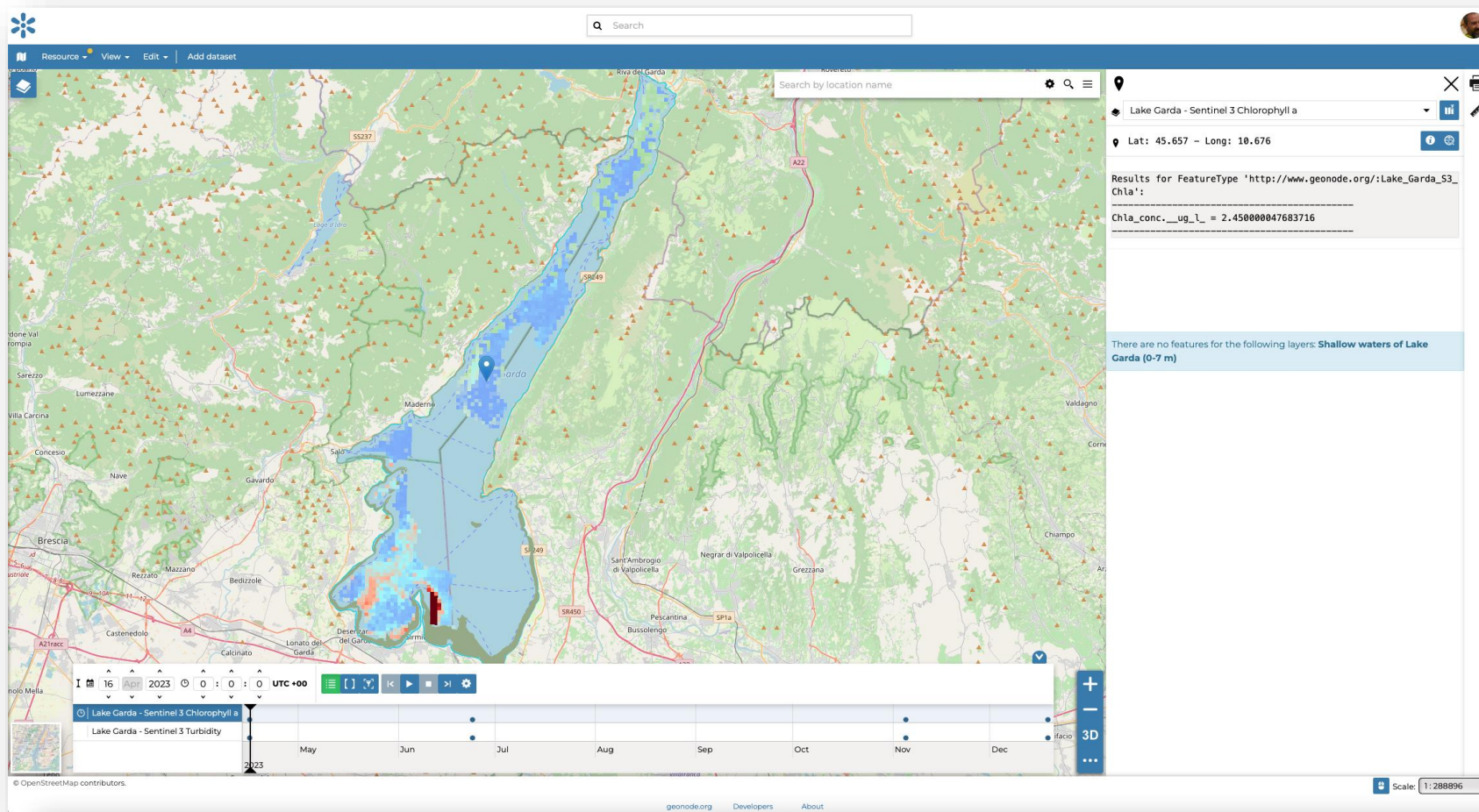
# Project Website

<https://sarlakes.irea.cnr.it/>

## Current Pages:

- **Home:** Project background and general objectives
- **News/Updates:** Regular updates on the project's progress and events
- **Case study:** description of case study (Garda Lake)
- **Team:** Information about the project team
- **Contact:** official project email ([sarlakes@irea.cnr.it](mailto:sarlakes@irea.cnr.it))

# Data Portal



**Lansat\_SWT/  
 S1\_Wave/  
 S1\_Wind/  
 S2\_Chla/  
 S2\_Turbidity/  
 S3\_Chla/  
 S3\_SWT/  
 S3\_Turbidity/**

Ongoing discussion about the use of in situ datasets in support of Radar product validation, like Eawag's Data Portal - Datalakes ([datalakes-eawag.ch](http://datalakes-eawag.ch))

# Conclusions

SARLAKES aims to provide a strong advancement in the field of limnological numerical modeling. Numerical models are fundamental and necessary tools for understanding the behavior of lakes and for their management in a changing environment, both in a short and long term perspective.

Along this lines, the activities carried out in the first year of the project have already demonstrated the advancement associated with the use of high resolution spaceborne SAR data, specifically 3m resolution COSMO/Skymed acquisitions over ascending passes.

Spaceborne SAR imaging complements the well-assessed optical satellite remote sensing technology capable to provide surface water temperature and water quality products. With this regards difficulties are mainly associated with the concurrency of the measurements.

Ongoing activities are focused on the implementation of a specific campaign for the integration of spaceborne and in-situ measurements, including proximal radar remote sensing.

Unconventional acquisition SAR modes are being considered for overcoming the limitations of the current technology mainly associated with the scalar nature of the measurements.

Thank you – Grazie !!!!!