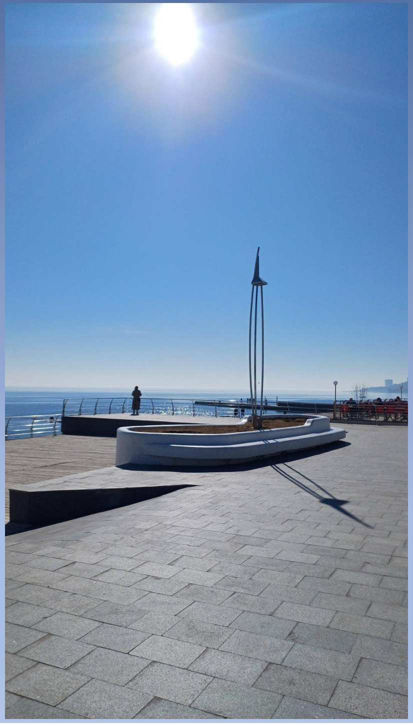
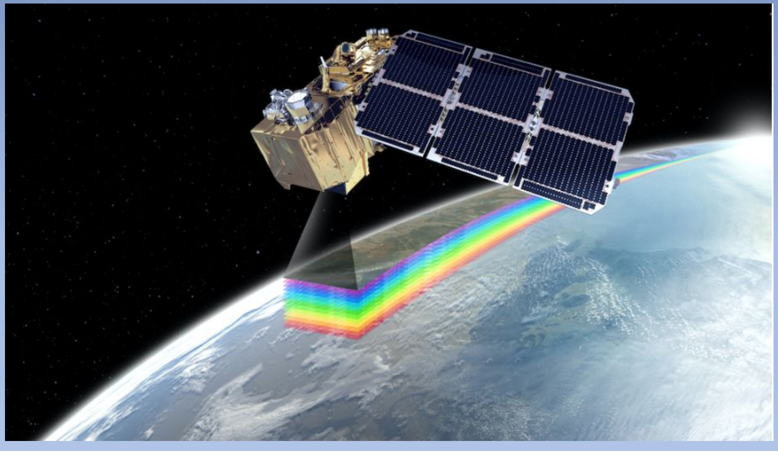
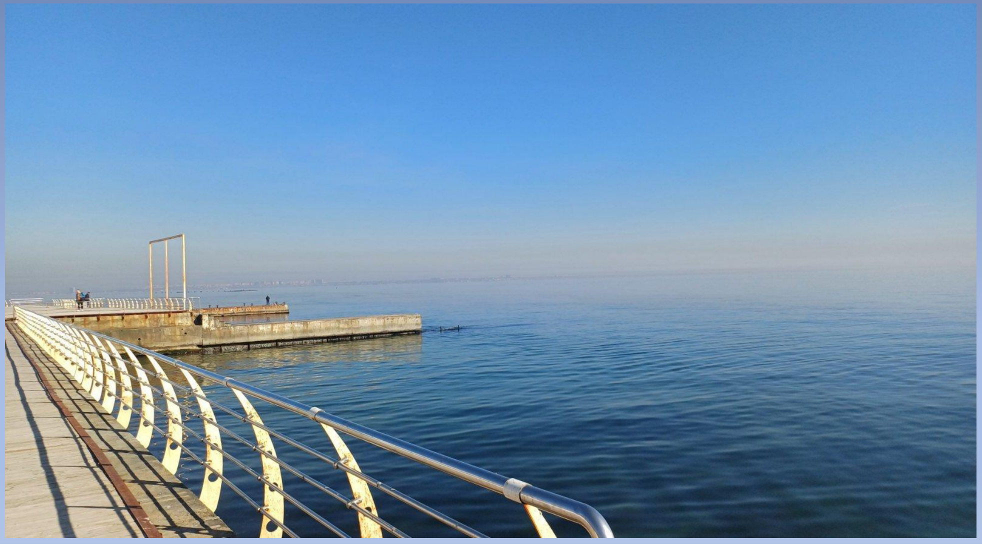
The Satellite Remote Sensing

Environmental Impact of the Kakhovka Dam Destruction Due to War in Ukraine on the Coastal Waters of the Black Sea: Hydrological and Satellite Data Assessment



student-driven citizen science project
March-May 2025





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ІНСТИТУТ МОРСЬКОЇ БІОЛОГІЇ НАН УКРАЇНИ

UkrSCES

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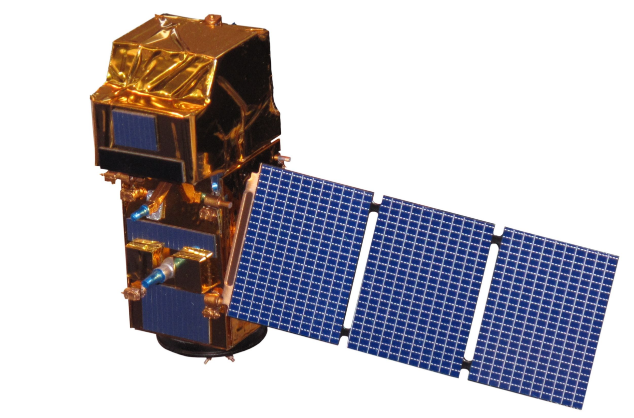
Introduction

Project Objective – to create a database of hydrological, hydrobiological, hydrochemical, and radiometric indicators, along with satellite images of the Black Sea coast, for further verification and calibration of satellite data. The research is conducted within the framework of cooperation among UkrSCES, IBSS, and ONU, as part of the UK-Ukraine Collaboration within the CORNELIA Project under the Twinning Program, aimed at remote monitoring of water bodies and water quality. This is particularly relevant in times of military conflicts or extreme natural conditions.

Satellite Data — Sentinel-2

Sentinel-2 — a series of satellites from the **Copernicus** program by the **European Space Agency (ESA)** providing high-precision Earth monitoring across various spectral bands.

copernicus
Europe's eyes on Earth



Key characteristics:

Resolution:

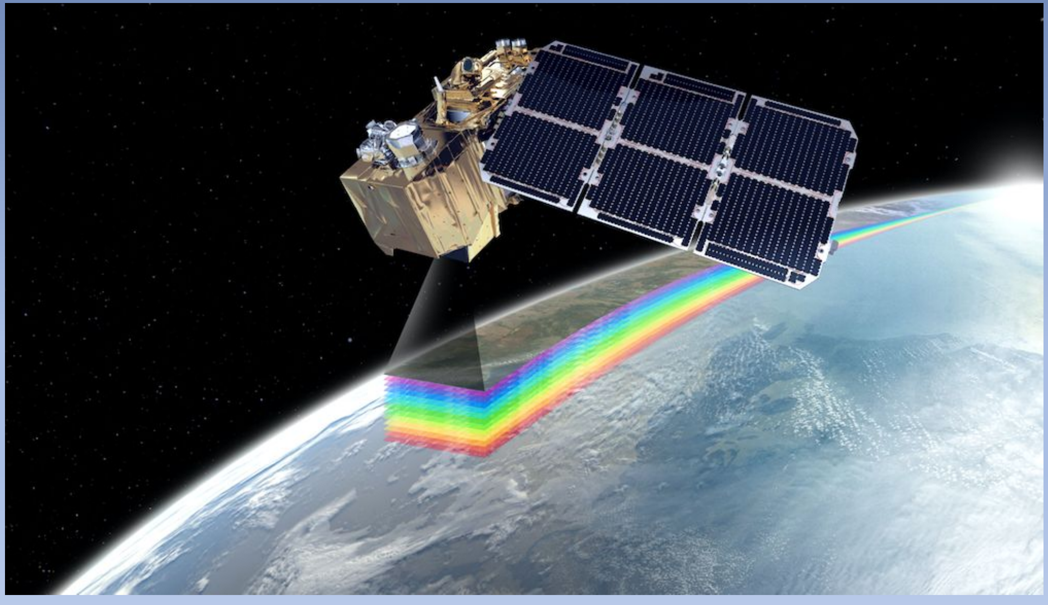
- **Spatial:** 10 to 60 meters (depending on the band)
- **Temporal:** Revisits the same point every 5 days (using Sentinel-2A/2B)

Equipped with **13 spectral bands** for various image types:

- **Visible spectrum:** monitoring vegetation, water resources, soil changes
- **Infrared spectrum:** assessing water content, temperature, etc.

Co-funded by the Erasmus+ Programme of the European Union

Sentinel-2 is equipped with optical sensors to obtain high-quality images, and the data is available through the Copernicus Open Access Hub platform. Sentinel-2's applications include monitoring aquatic ecosystems, in particular assessing pollution levels and chlorophyll content, which is important for studying the state of the Black Sea after man-caused events. Thanks to remote sensing, the satellite allows detecting water blooms, changes in transparency and other ecological changes, analyzing ecosystem dynamics in space and time.

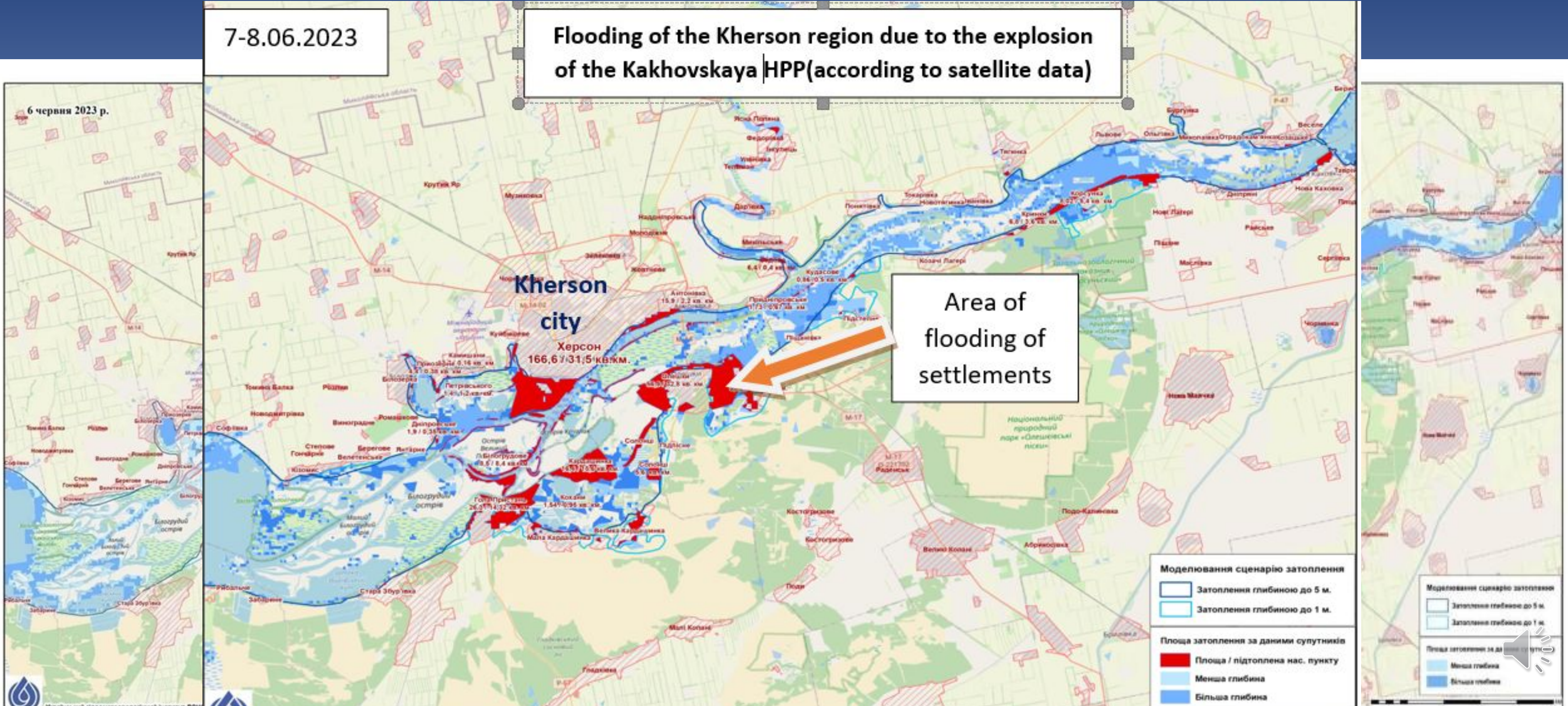


Co-funded by the Erasmus+ Programme of the European Union

Examples of using satellite information to assess the consequences of the dam failure at the Kakhovka HPP

Tychkoveko et all https://doi.org/10.31481/uhmj.32.2023.07

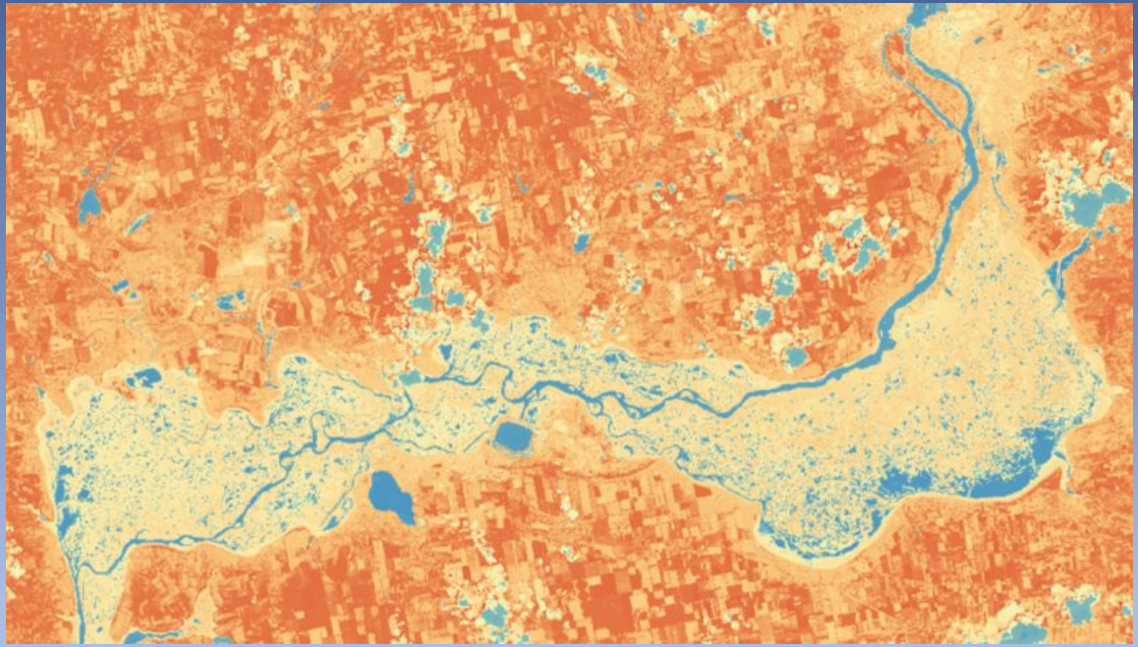
Flooding of the Kherson region due to the explosion at the Kakhovskaya HPP (according to satellite data, UHMI)



Change of water coverage in the reservoir

- Before dam collapse
- Image date: 02 June 2023

- After dam collapse
- Image date: 03 July 2023



- **Reservoir (upstream) become rivers**

Co-funded by the Erasmus+ Programme of the European Union

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Assessment of the impact of blowing up the Kakhovka hydroelectric power station dam on the quality of sea waters of the Odessa Black Sea coast using satellite information

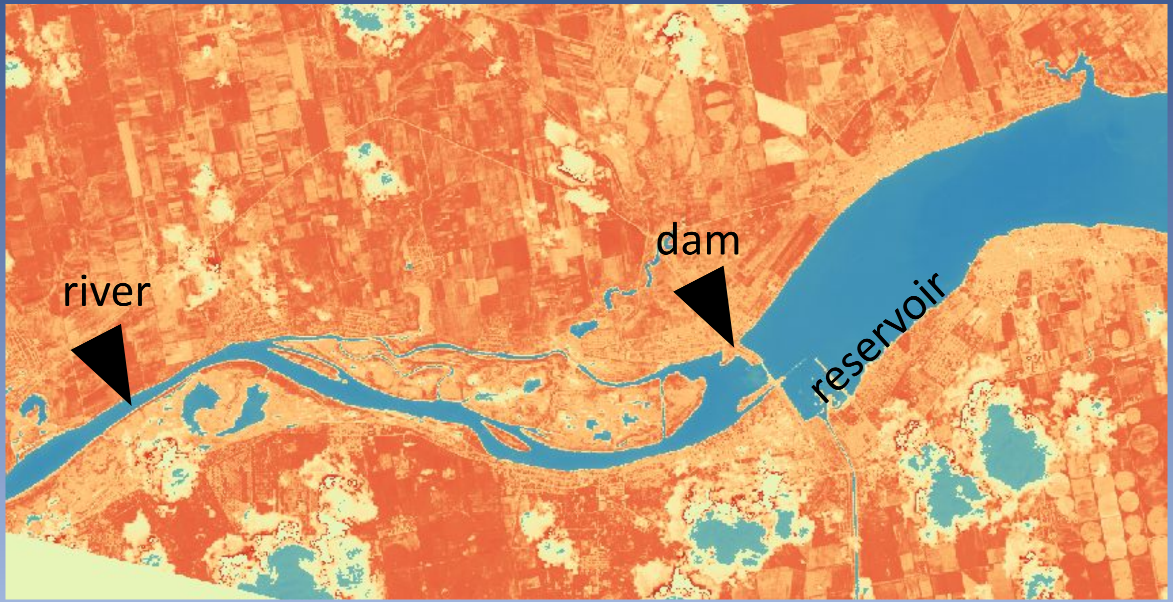
•*Yuriy Tuchkovenko[1], Valeriya Ovcharuk[1], Dalin Jiang[2] Dmitro Kushnir[1], Arkady Torgonskyi[1],Andrew Tyler[2], Valeriy Khokhlov*November 2023

•DOI: 10.13140/RG.2.2.13663.02726

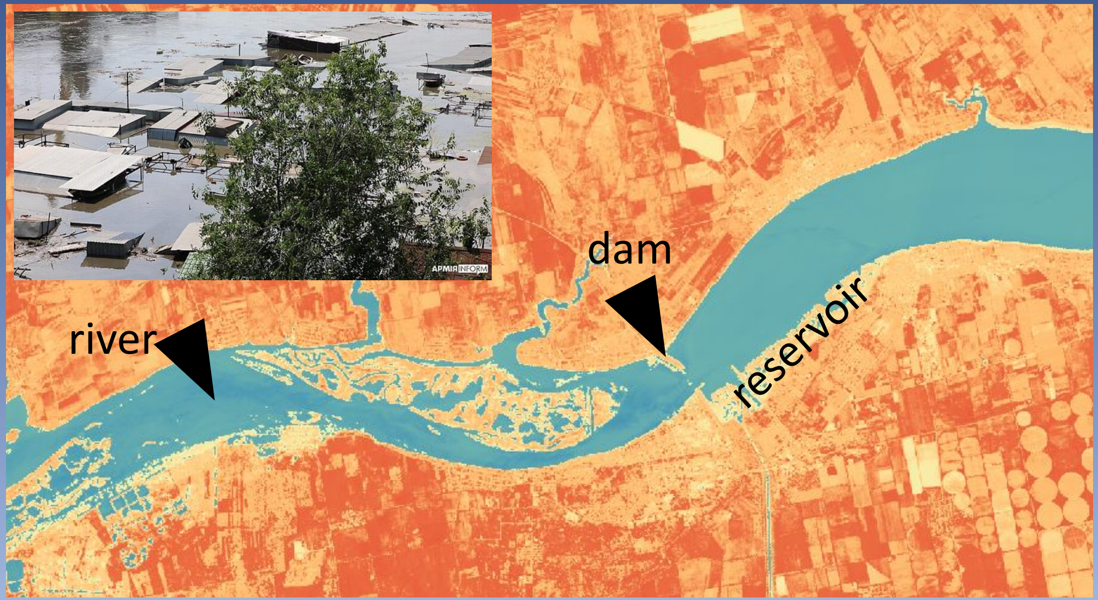
•Conference: Fifth Space for Hydrology Workshop, HYDROSPACE 2023, 27 November - 1 December 2023. FIL Lisbon, Portugal

Change of water coverage in downstream

Before the explosion: 02 June 2023



After the explosion: 09 June 2023



- **River in downstream becomes wider after explosion**
- **Reservoir (upstream) becomes smaller after an explosion**
- **May pose threats to the bathetic animals, wetland, biodiversity etc.**

Assessment of the impact of blowing up the Kakhovka hydroelectric power station dam on the quality of sea waters of the Odessa Black Sea coast using satellite information

•*Yuriy Tuchkovenko[1], Valeriya Ovcharuk[1], Dalin Jiang[2] Dmitro Kushnir[1], Arkady Torgonskyi[1],Andrew Tyler[2], Valeriy Khokhlov*November 2023

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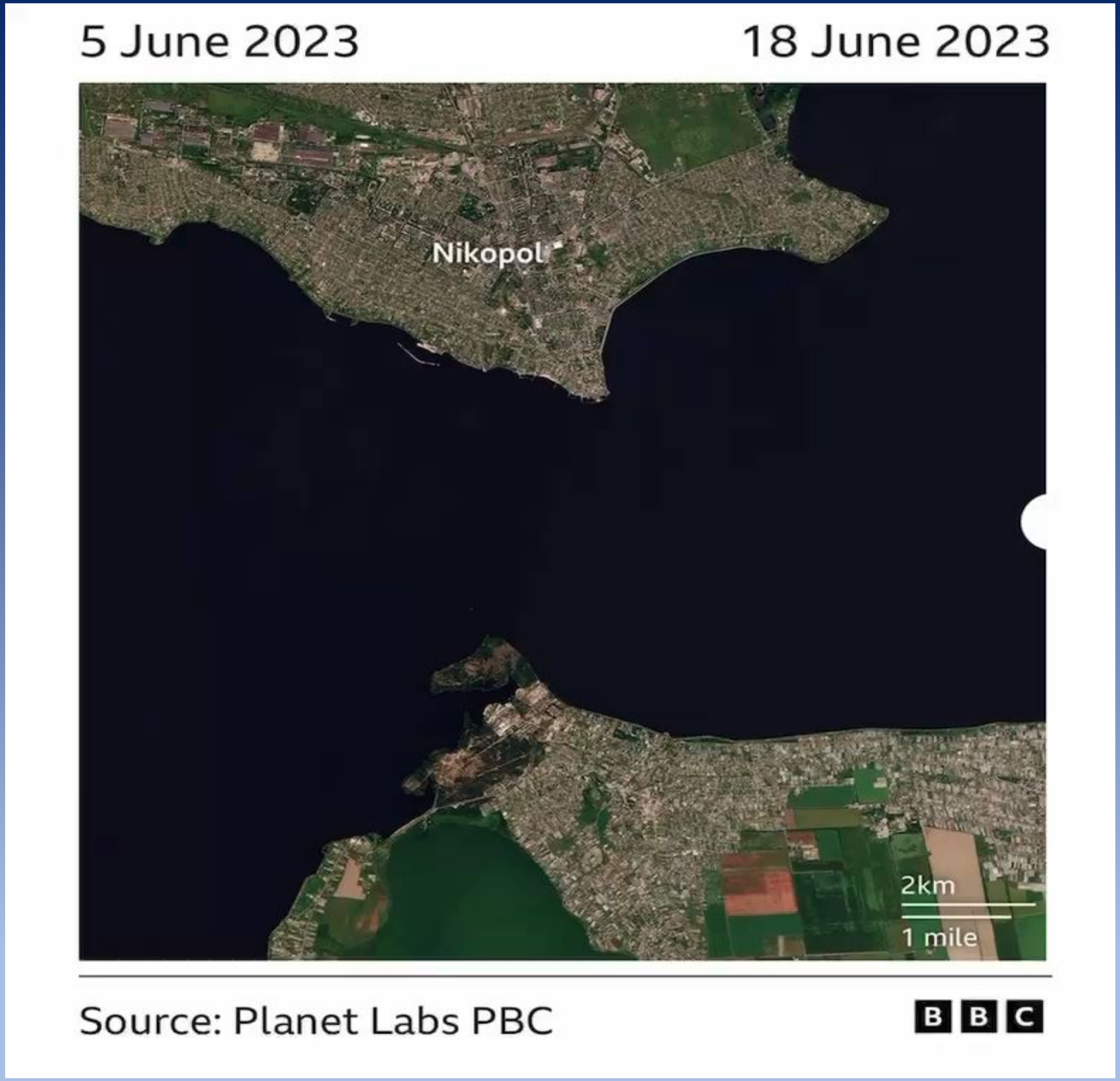
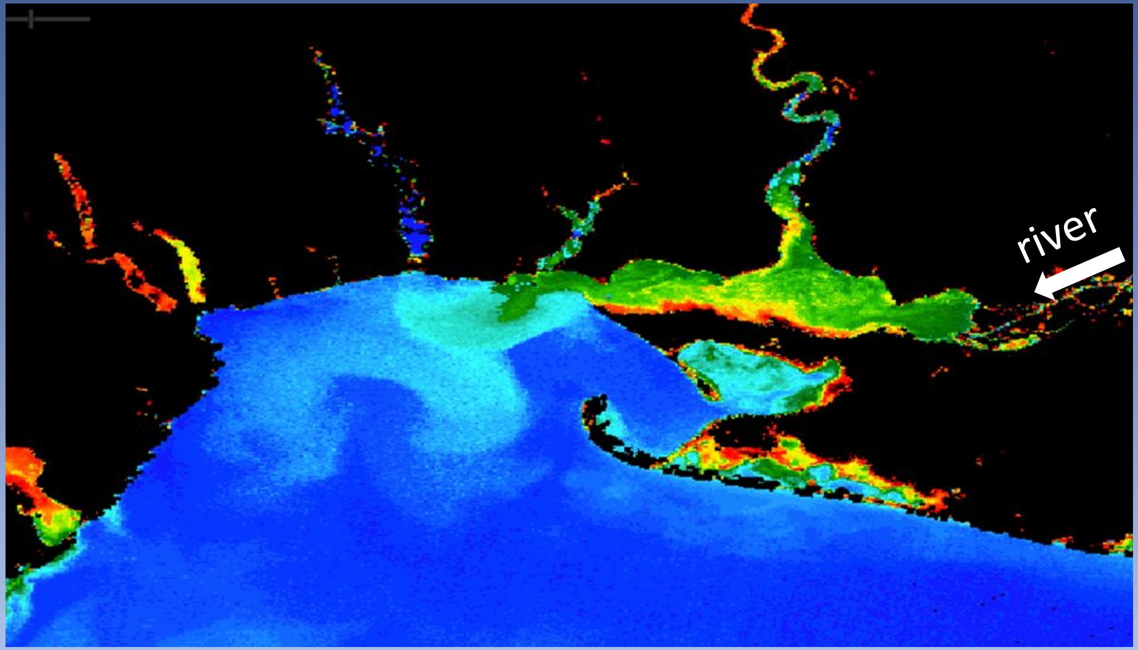


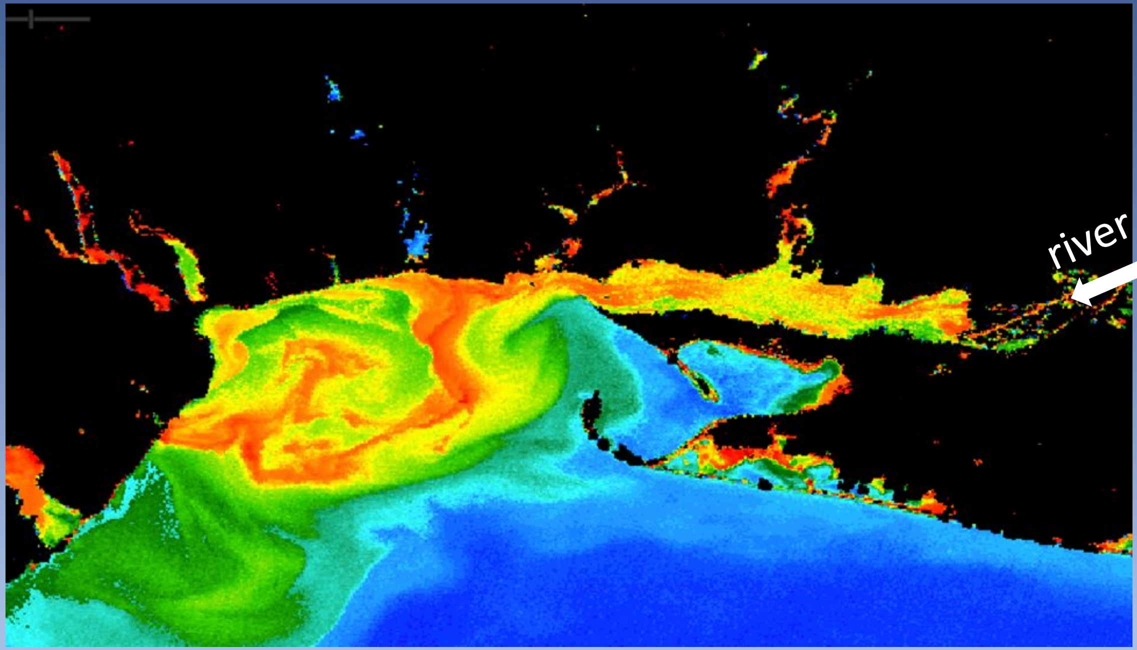
Visualization of the shallowing of the Kakhovka Reservoir by the BBC based on satellite images of the Planet Labs company

Change of total suspended solids (TSS) downstream

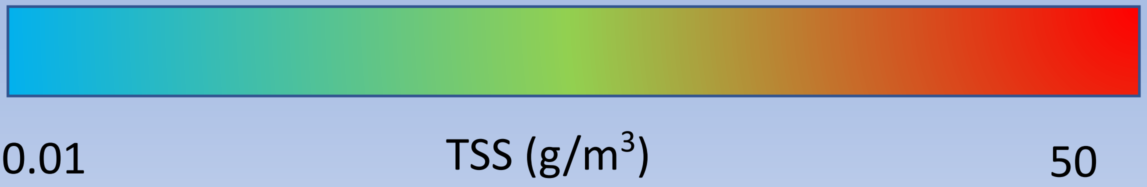
Before the explosion: 05 June 2023



After the explosion: 16 June 2023



- High TSS events were observed downstream and in the bay
- May pose threats to fishes, phytoplankton etc. in the the bay



09.06.2023 polluted waters from the estuarine region of the Dnieper (Dnieper-Bug estuary) have reached Odesa

The situation in the northwestern part of the Black Sea on 8-10 June 2023

The GROMADA satellite remote sensing team

Supervised by Prof. V. Ovcharuk, Head of the Department of Land Hydrology, ONU

Participants: **Yurii Pisariev**, **Andrii Stetsiuk**, and **Alina Tashku** — 4th-year undergraduate students, **Mykyta Rozvod PhD-student**

With fieldwork performed in cooperation with PhD **Maksym Martyniuk**, a researcher at IBSS NAS of Ukraine and **Titiapkyn Andrii**, Head of Marine Ecosystem and Anthropogenic Stress Analysis department at UkrSCES

Research Objective

Main goal: To assess changes in hydrological indicators of the coastal waters of the Black Sea.

Research methods:

- Use of the portable hyperspectral radiometer WISP-3;
- Measurement of algal pigment concentrations using TriLux.

Satellite image analysis:

- Processing data from Sentinel-2A/2B satellites.

Satellite data calibration:

- Comparison with field measurements to improve remote monitoring accuracy.

Methodology

Observations were conducted on the dates of Sentinel-2A/2B satellite overpasses under cloud-free conditions to calibrate satellite data based on laboratory and instrumental (express method) measurements of chlorophyll-a and suspended matter concentrations. The known satellite overpass dates range from March to May 2025.

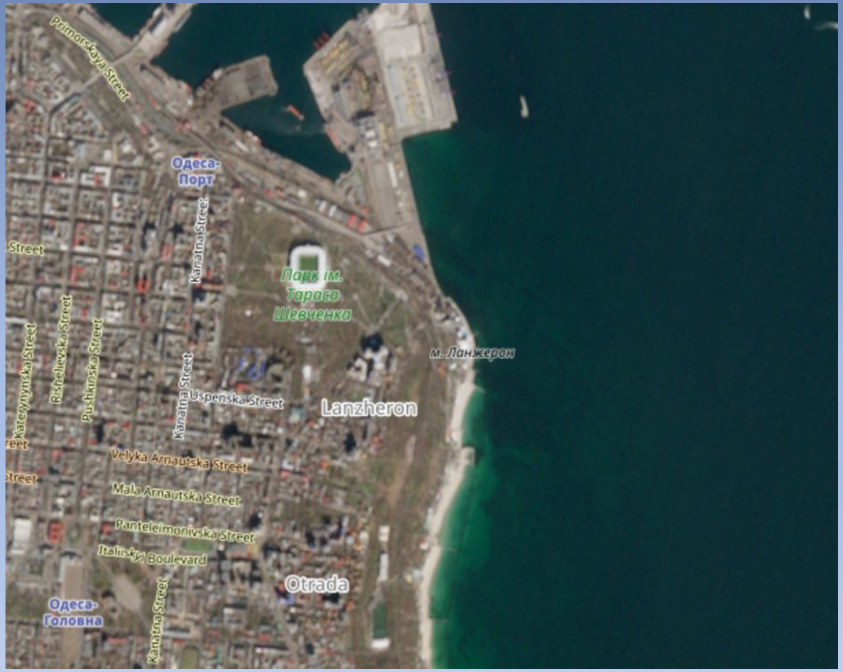
Measurements were carried out in the area of Langeron Beach (coordinates: 46.475048, 30.766554) and, if possible, near the Chornomorskyi Yacht Club (coordinates: 46.460321, 30.764490).

During the observations, water samples were collected to determine salinity (50 ml), suspended matter concentration (2 L), and chlorophyll-a concentration (2 L).

Simultaneously with water sampling, we conducted measurements of water temperature and transparency (using a Secchi disk).

Chlorophyll-a concentration (Chl $mg \cdot m^{-3}$) and phycocyanin (CPC mg· m^{-3}) were measured in the field using two express methods: a portable hyperspectral radiometer, WISP-3, and the Chelsea Technologies Tri-Lux sensor.

Additionally, using WISP-3, values for total suspended inorganic matter (TSM $g \cdot m^{-3}$) and the spectral light attenuation coefficient (Kd m^{-1}) were obtained.



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WISP-3

WISP-3 (Water Insight Spectrometer) — a portable hyperspectral radiometer used to measure spectral characteristics of water.

Key characteristics:

- **Measurement type:** Determining concentrations of chlorophyll-a, total suspended matter (TSM), colored dissolved organic matter (CDOM)
- **Operating principle:** Measures reflected light from the water surface across a wide spectrum, allowing estimation of pigment concentrations and other water properties.

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Advantages of WISP-3:

- **Portability:** Enables on-site measurements in the field
- **Sensitivity:** Detects even minor changes in concentrations of organic and inorganic components
- **GPS integration:** Ensures accurate geolocation of measurements

TriLux — a portable fluorometer from **Chelsea Technologies**, designed to measure concentrations of **chlorophyll**, **phycocyanin**, and **phycoerythrin** in marine waters.

TriLux

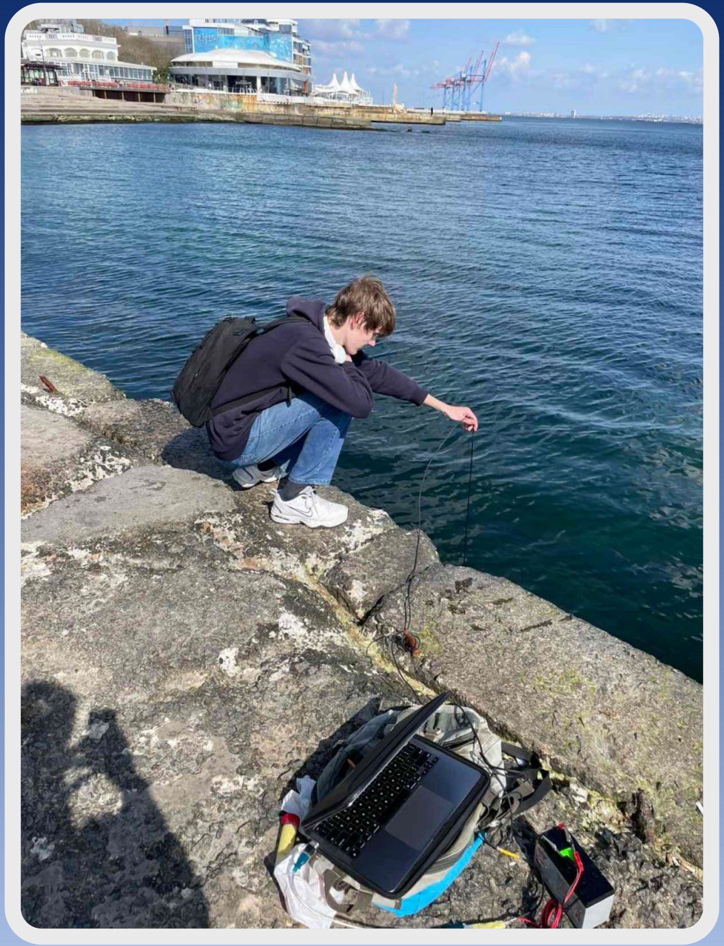
Measurement type:

- **Chlorophyll-a**: the main pigment responsible for photosynthesis in algae
- **Phycocyanin**: a pigment found in cyanobacteria (blue-green algae)
- **Phycoerythrin**: a pigment typical of red algae

Operating principle: Uses fluorescence to measure pigment concentrations. At specific light wavelengths, the fluorometer detects and measures emitted radiation intensity, estimating pigment levels in the water.

Advantages of TriLux:

- High measurement accuracy even at low concentrations
- Compact and user-friendly for field use
- Fast measurement capability, allowing multiple readings in a short time



Calibration and Analysis

Main steps:

- Satellite data calibration: Comparing WISP-3 and TriLux measurements with Sentinel-2 imagery.
- Accuracy assessment: Evaluating correlation between field and satellite data to improve hydrological indicator estimates.
- Profile construction: Determining concentrations of chlorophyll, phycocyanin, and other parameters based on satellite and field data.

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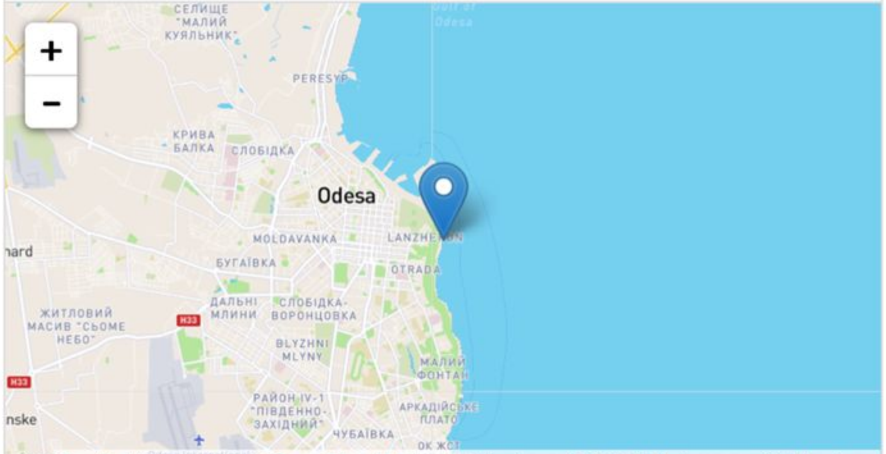
WISP-3 measurement results

Measurement | Metadata

The following water quality parameters have been estimated for this measurement:

Chl	2.7 µg/l
TSM	2.0 mg/l
Kd	0.0 1/m
CPC	0.0 µg/l



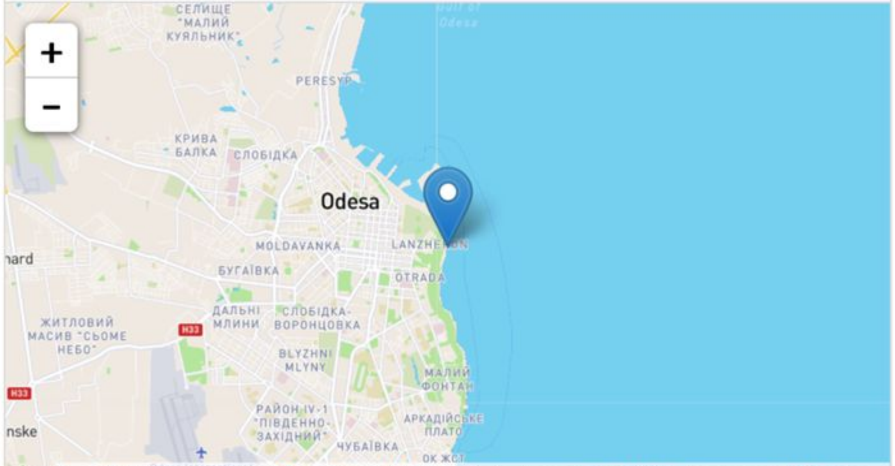
Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox

Compare | Edit | Download Data

Measurement | Metadata

The following water quality parameters have been estimated for this measurement:

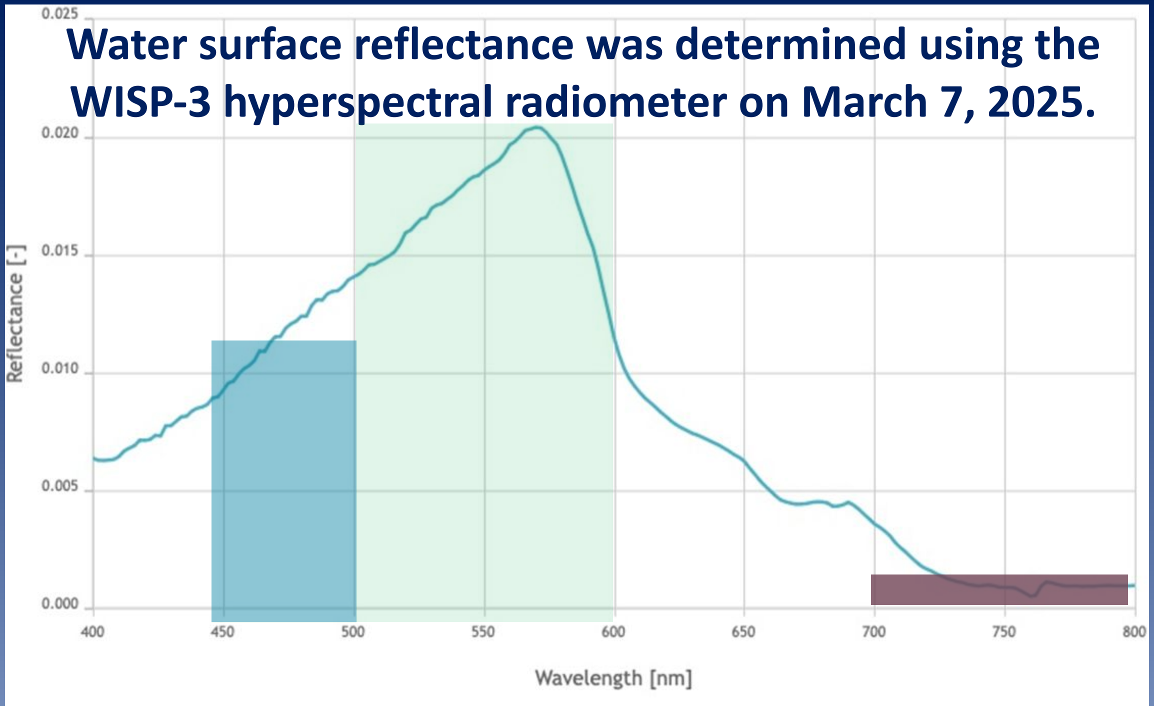
Chl	1.8 µg/l
TSM	1.9 mg/l
Kd	0.0 1/m
CPC	0.0 µg/l



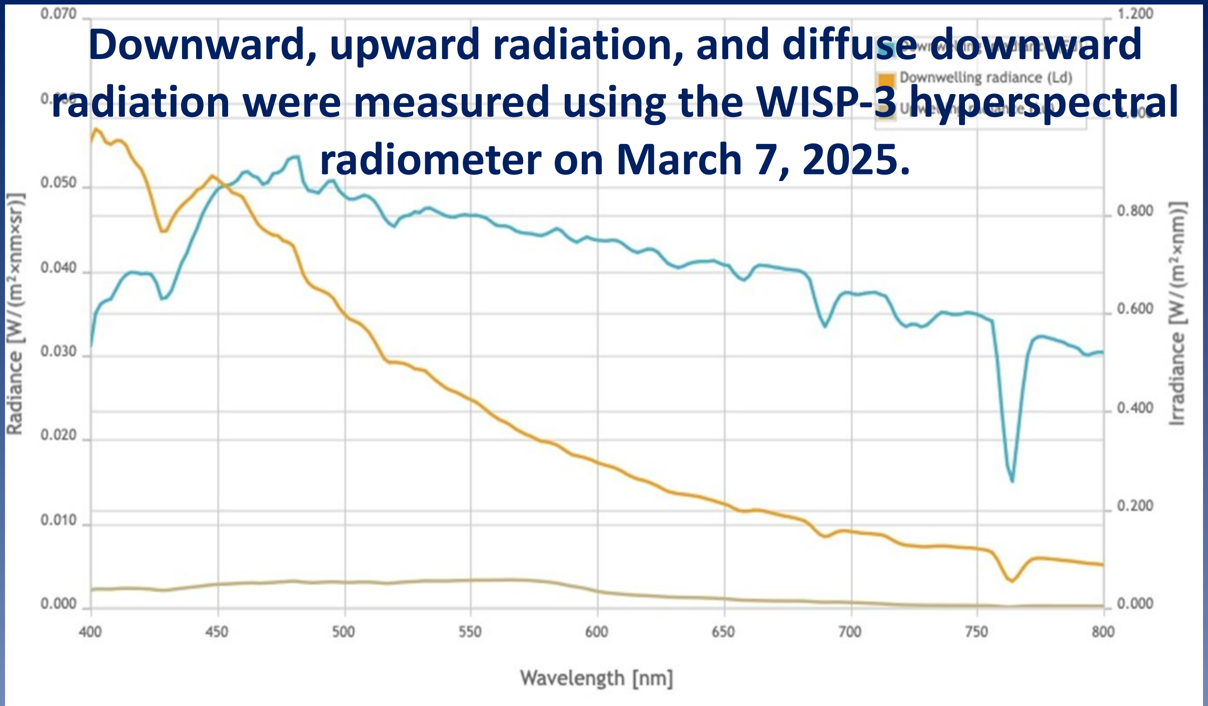
Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox

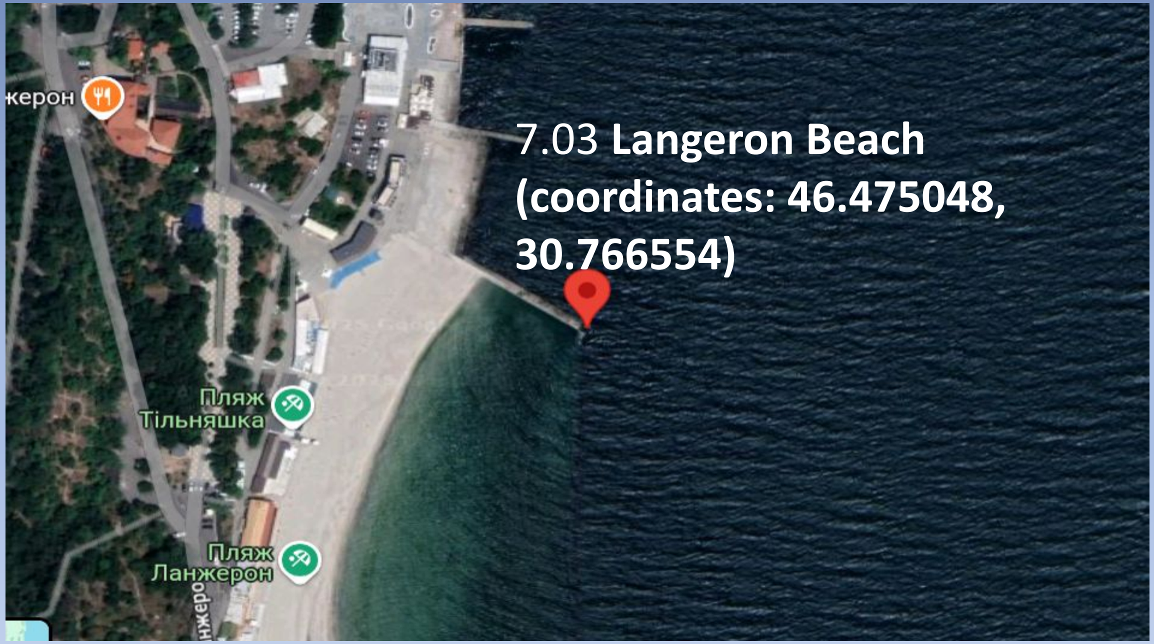
Compare | Edit | Download Data

Water surface reflectance was determined using the WISP-3 hyperspectral radiometer on March 7, 2025.



Downward, upward radiation, and diffuse downward radiation were measured using the WISP-3 hyperspectral radiometer on March 7, 2025.





In WISP-3, when performing a measurement, the water surface reflectance coefficients are automatically calculated (Fig. 1) as the ratio between the downward radiation and the upward radiation (Fig. 2). In general, the water surface reflectance coefficients vary from 0 (the turbidness water) to 1 (the most transparent water) as can be seen from the graph. The highest values in the left part of the graph (400-500 nm) indicate bluish-blue colour of the water, and the lowest values in the right part (700-750 nm) indicate brownish-red colour, which is characteristic of water with a high concentration of suspended solids. Increased values in the range of 500-600 nm indicate green colour of the water.

7.03 **Langeron Beach (coordinates: 46.475048, 30.766554)**

TriLux measurement results

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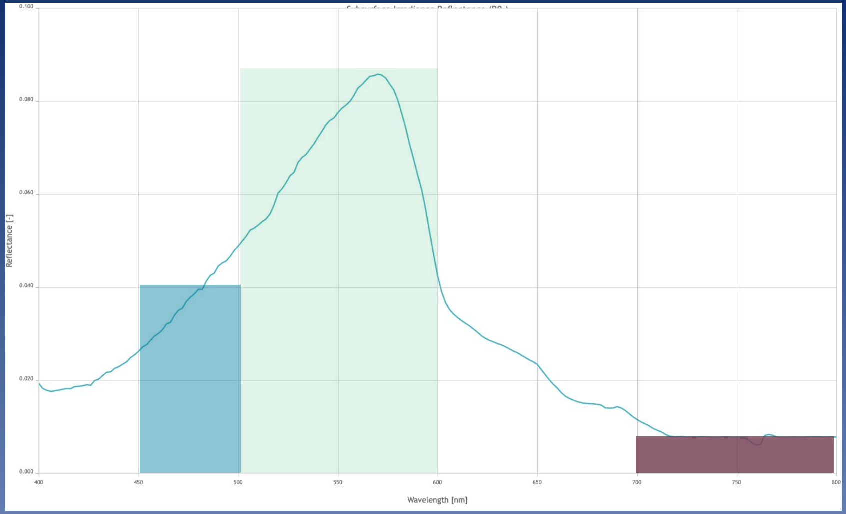
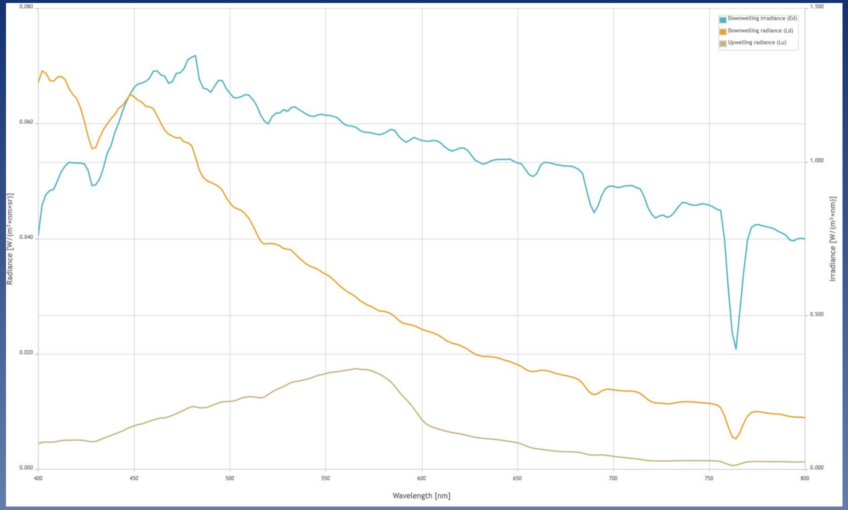
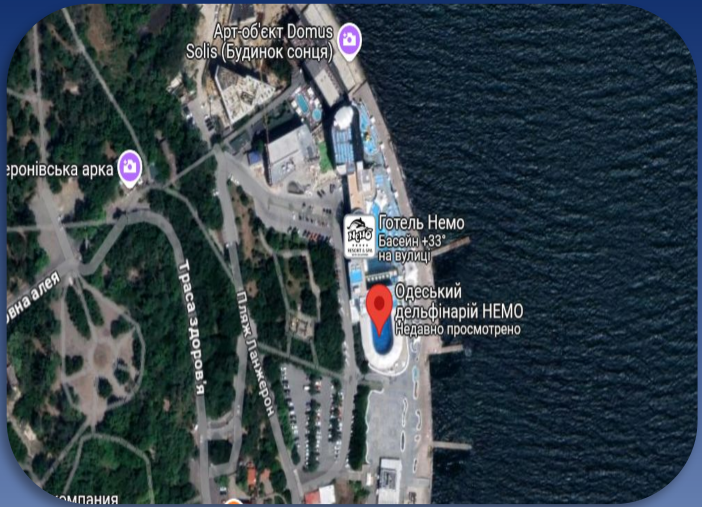
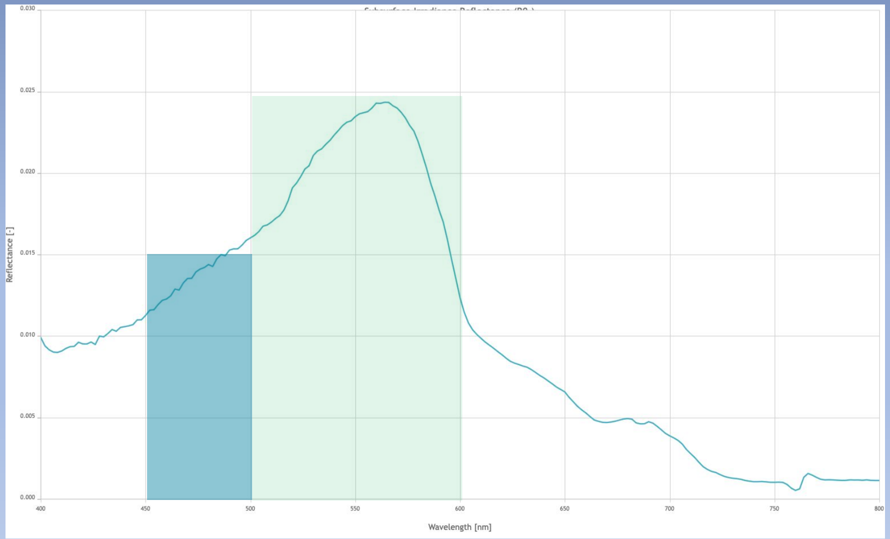
8.04.2025 **Oceanarium (coordinates: 46.4775751; 30.7661947)**

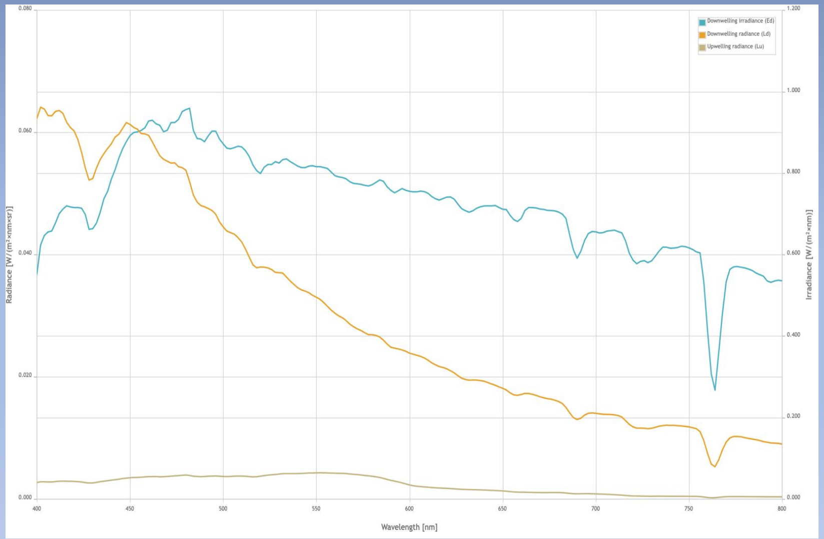


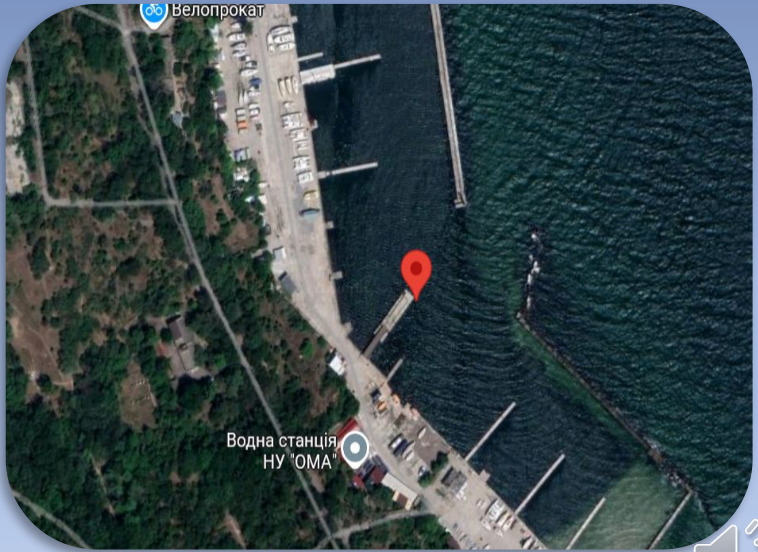




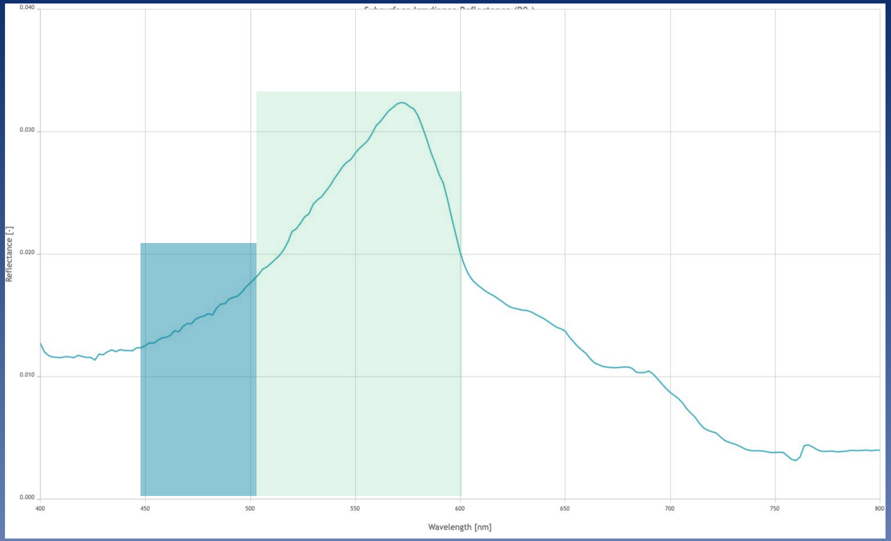
8.04.2025 **Chornomorskyi Yacht Club (coordinates: 46.460321, 30.764490).**

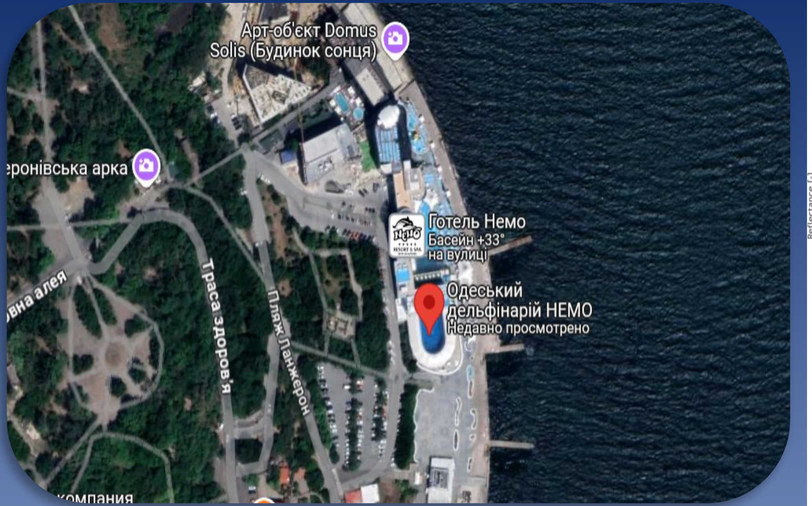


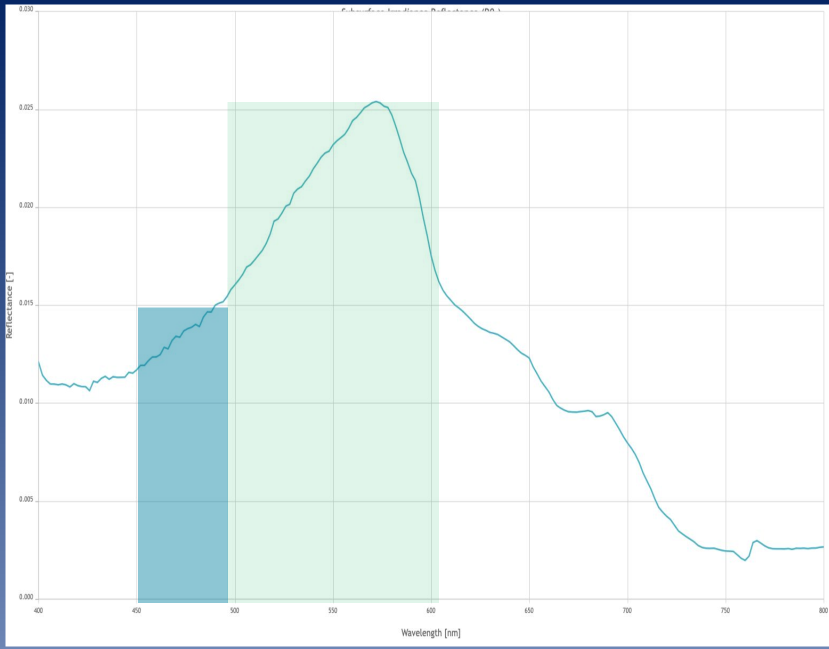




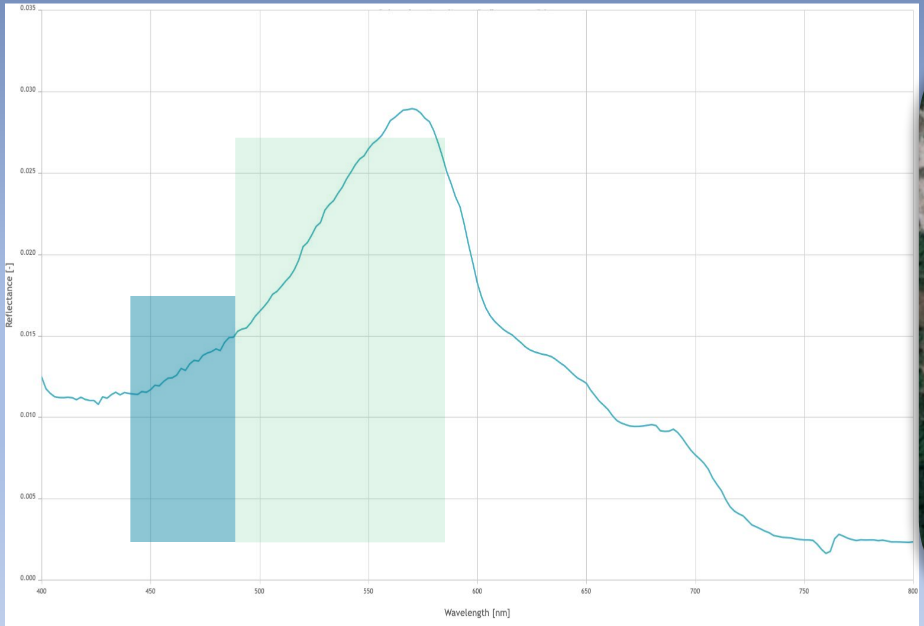
21.04.2025 **Oceanarium (coordinates: 46.4775751; 30.7661947)**

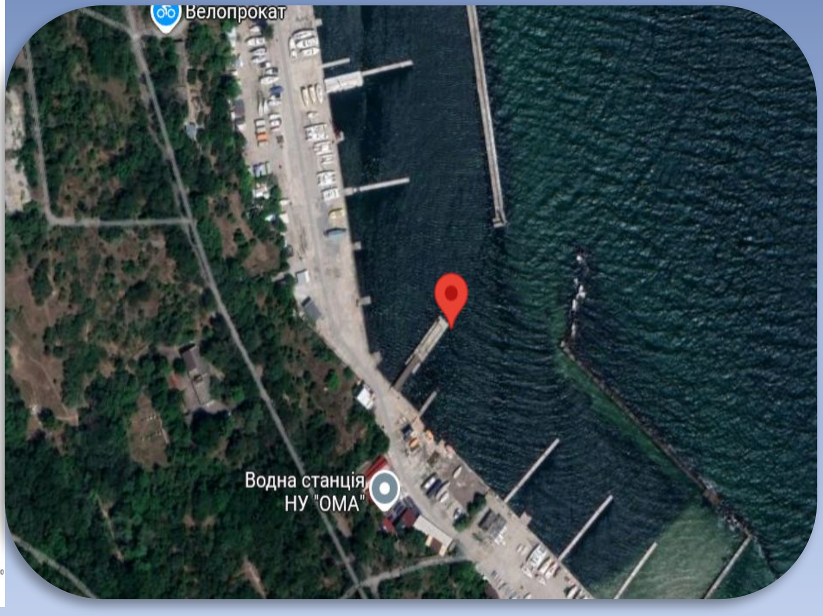




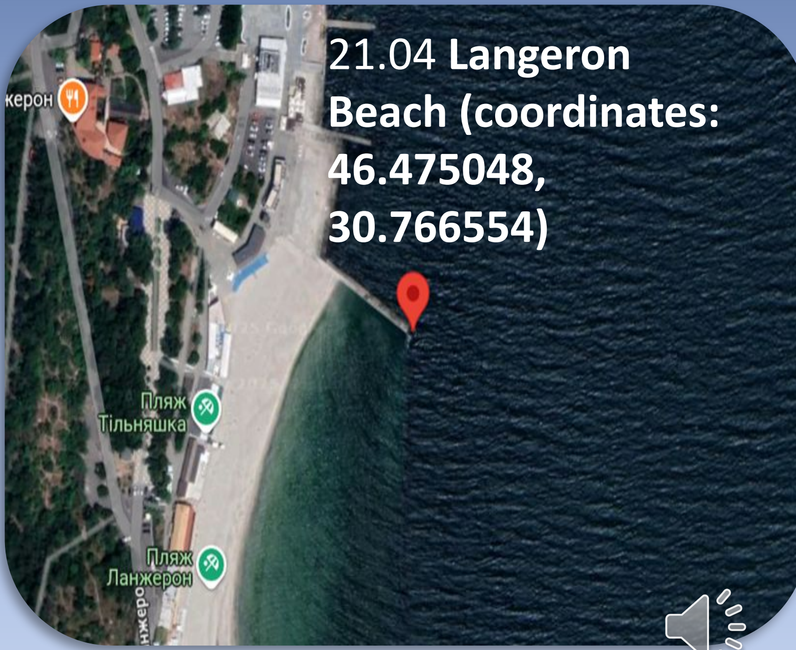


21.04.2025-**Chornomorskyi Yacht Club (coordinates: 46.460321, 30.764490).**

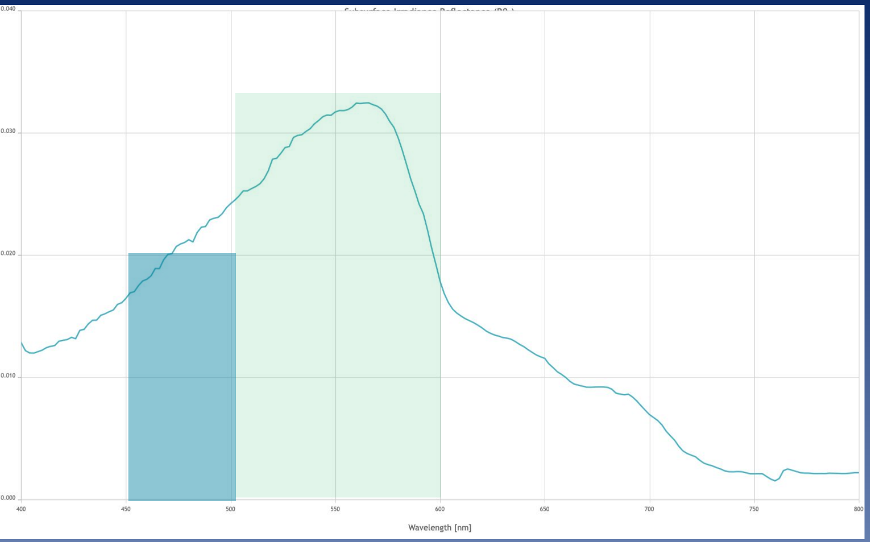


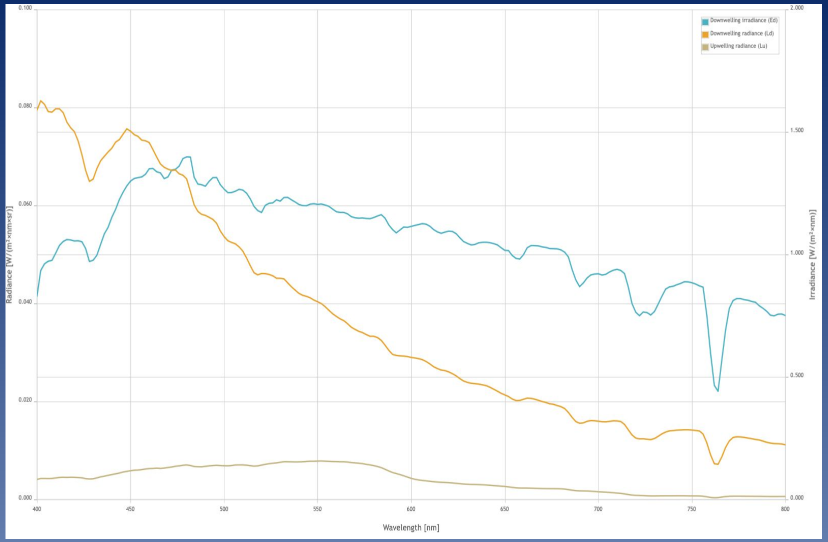


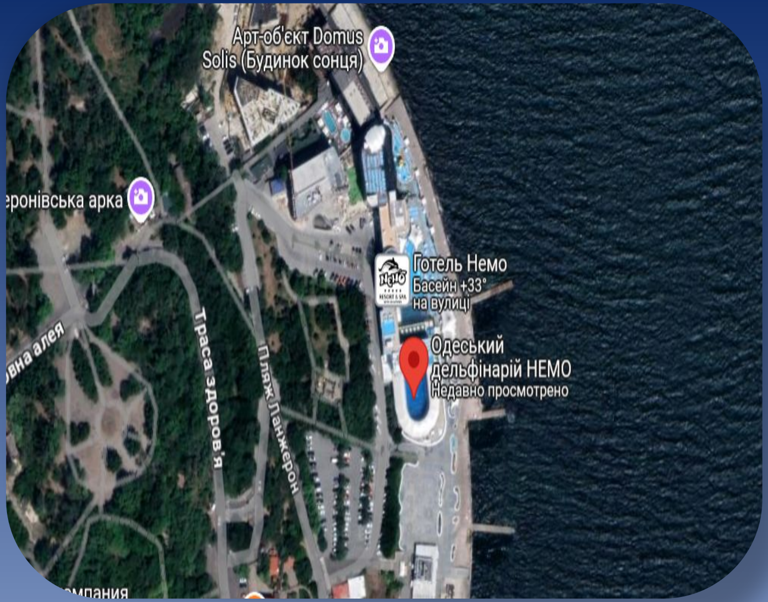
21.04 **Langeron Beach (coordinates: 46.475048, 30.766554)**



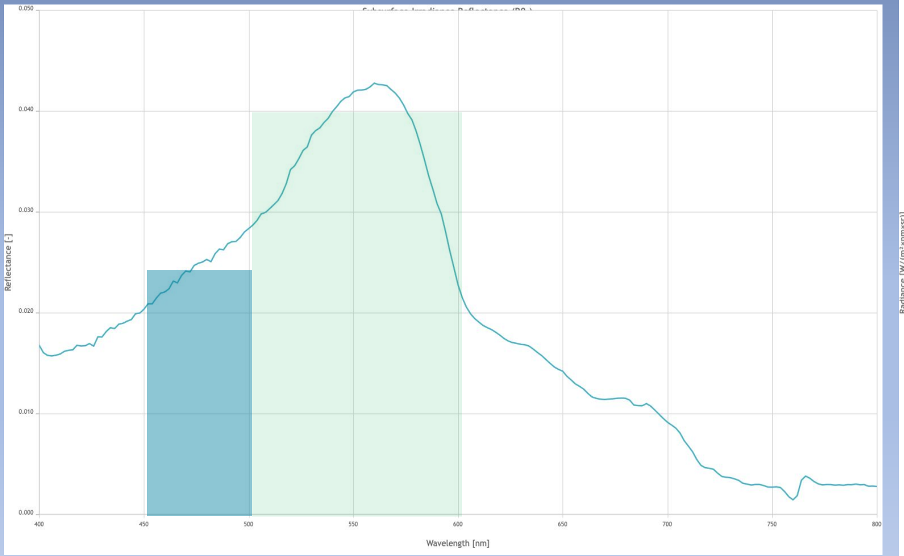
8.05.2025 **Oceanarium (coordinates: 46.4775751; 30.7661947)**

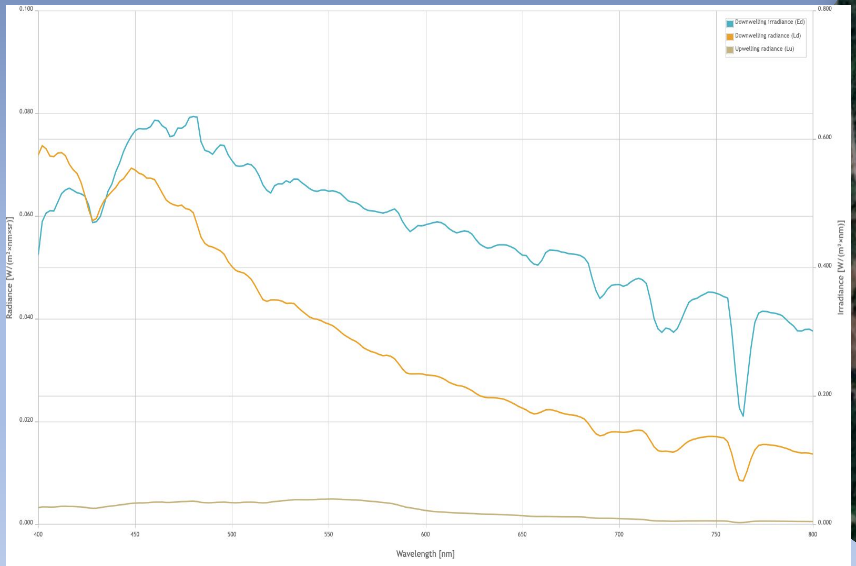


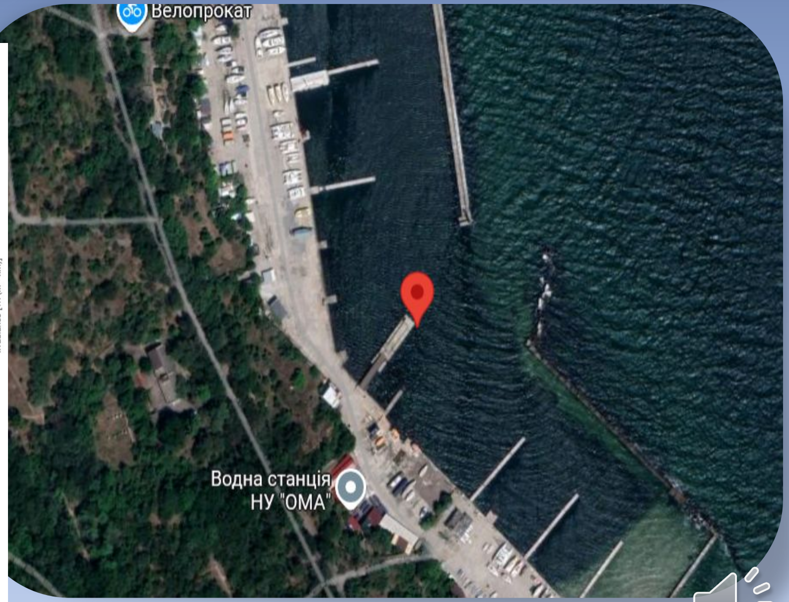




8.05.2025-**Chornomorskyi Yacht Club (coordinates: 46.460321, 30.764490).**

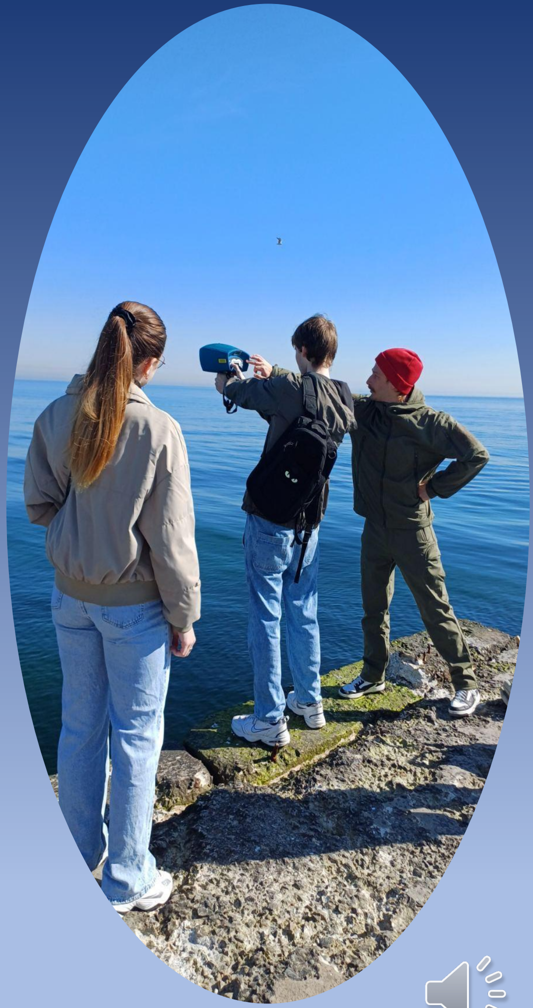




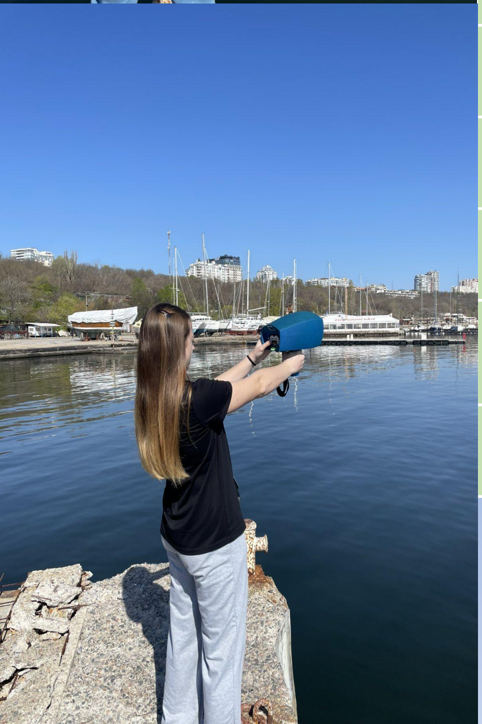


Participants' measurement results

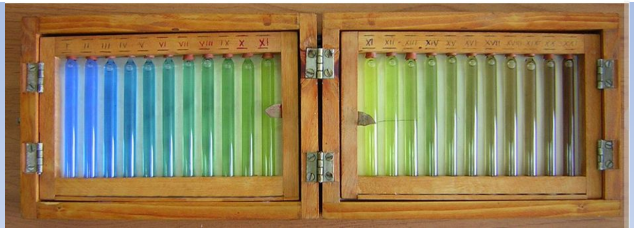
Object	Station	Coordinate	Name of participant	Tw, °C	Concentration Chl.A, mcg/l WISP-3	Concentration Chl.A, mcg/l Tri-Lux	Date, Time	Depth, м
Black Sea	Langeron Beach	46.475048, 30.7665544	Yurii Pisariev	4,6	2,7		7.03.2025 11:00	2,7
Black Sea	Langeron Beach	46.475048, 30.7665544	Andrii Stetsiuk	4,6		4,1	7.03.2025 11:00	2,7
Black Sea	Langeron Beach	46.475048, 30.7665544	Alina Tashku	4.6	1,8		7.03.2025 11:00	2,7



Participants' measurement results

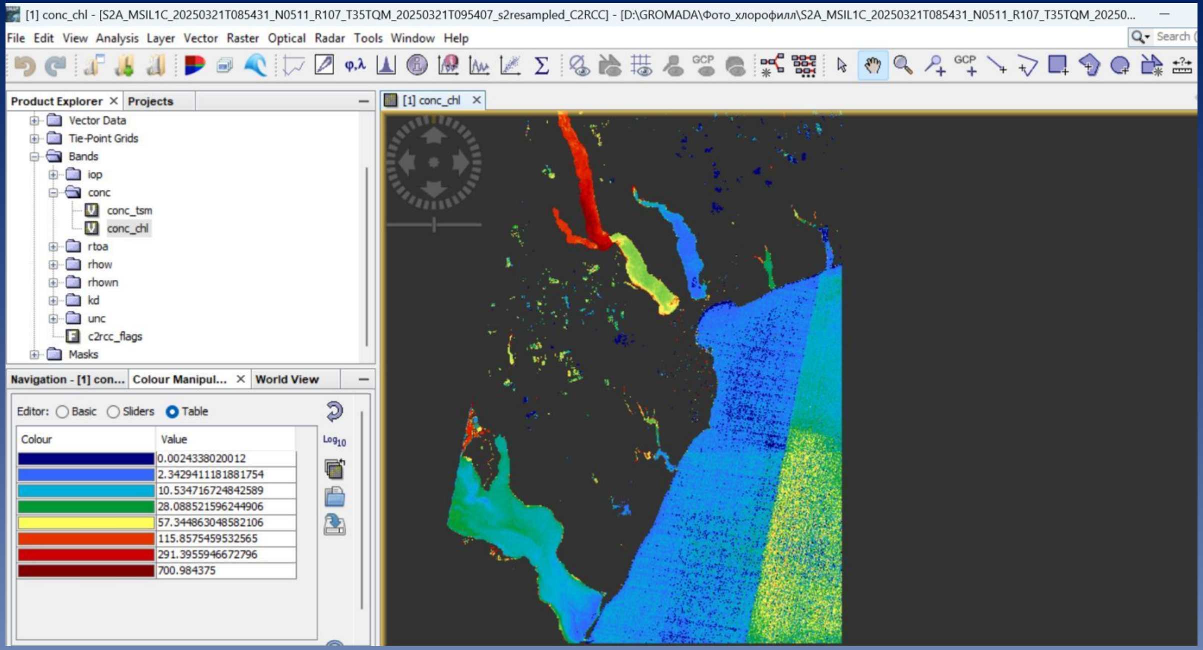


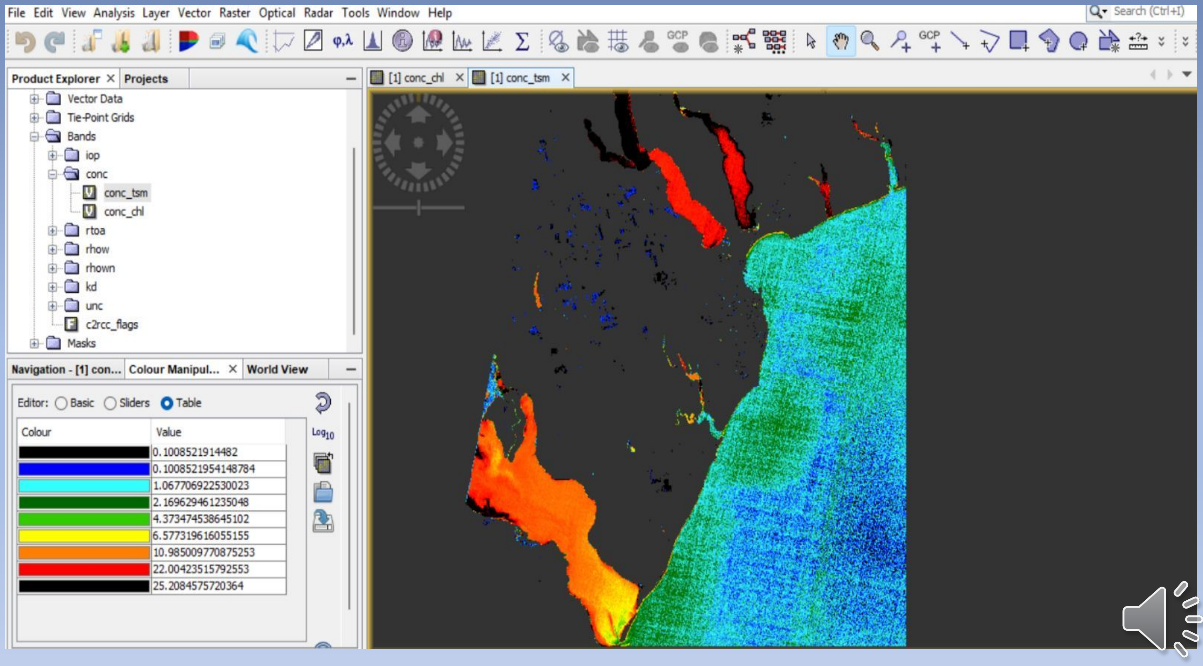
lab. №	Sample	Coordinates	Date	T, °C	Chl-a, µg/l	S, psu (IMB)	WISP-3 Chl, µg/l	WISP-3 TSM, mg/l	WISP-3 Kd, 1/m	WISP-3 CPC, µg/l	Colour
8146	**Yacht Club**	46.4603445; 30.7644295	08.04.2025	7,6	0,88	15,49	0,00	1,70	0,00	0,00	VIII
8147	**Langeron Beach**	46.4750700; 30.7665326	08.04.2025	7,5	0,78	15,87	0,00	1,10	0,00	0,00	X
8148	**Oceanarium**	46.4775751; 30.7661947	08.04.2025	7,5	0,84	15,56	0,00	3,20	0,00	0,00	X
8155	**Yacht Club**	46.4603445; 30.7644295	21.04.2025	14,1	3,10	10,33	3,20	2,70	0,20	0,00	XI
8156	**Langeron Beach**	46.4750700; 30.7665326	21.04.2025	14,5	3,31	10,41	3,60	2,80	0,40	2,20	XI
8157	**Oceanarium**	46.4775751; 30.7661947	21.04.2025	14,1	3,27	10,68	4,10	3,00	0,20	1,70	XI
8170	**Langeron Beach**	46.4750700; 30.7665326	08.05.2025	15,2	0,92	14,98	0,00	2,40	0,00	0,00	IX
8171	**Yacht Club**	46.4603445; 30.7644295	08.05.2025	14,8	2,04	14,78	2,30	2,80	0,10	0,00	XI
8072	**Oceanarium**	46.4775751; 30.7661947	08.05.2025	14,6	0,99	14,85	0,90	2,40	0,10	0,00	IX



Sea water colour scale

SNAP

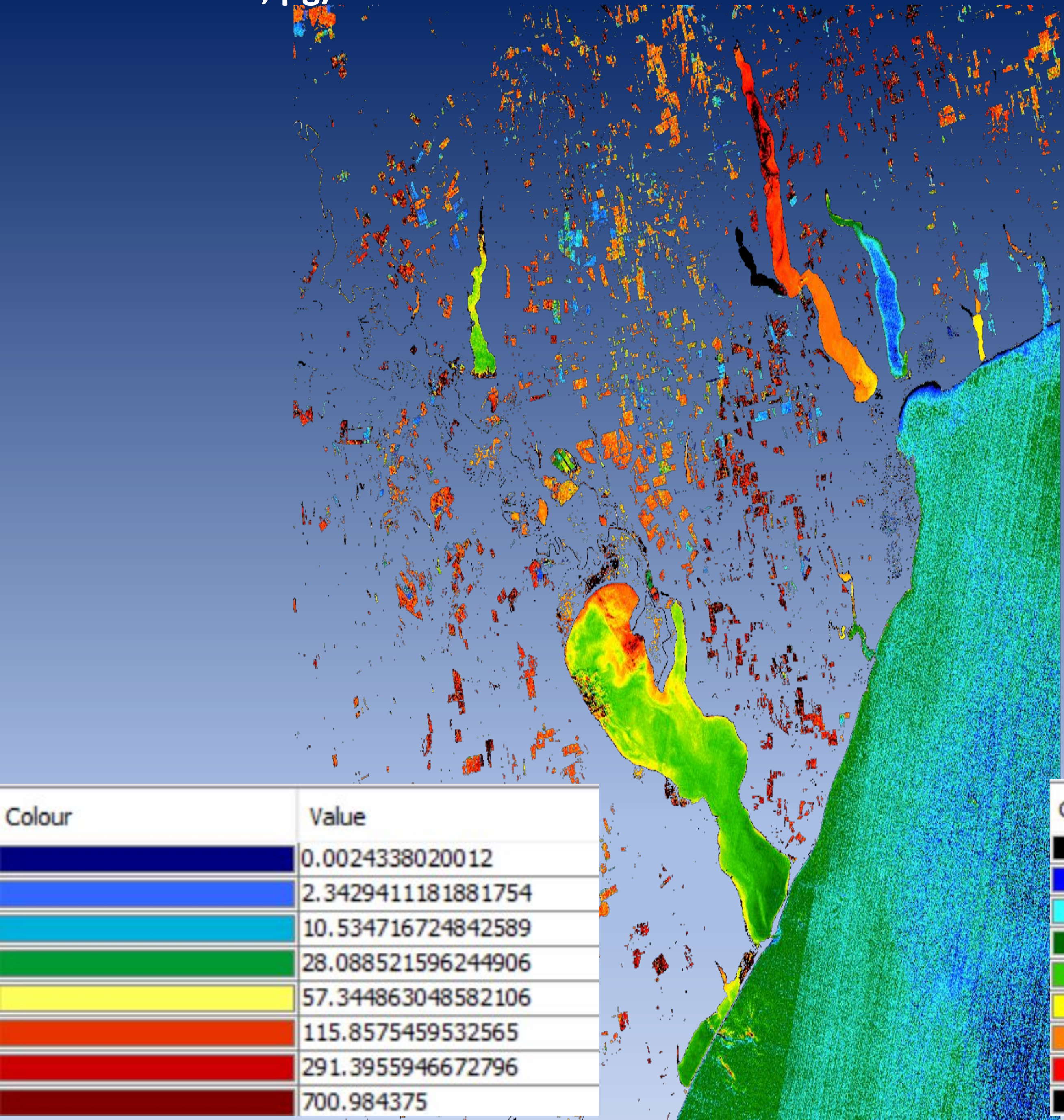




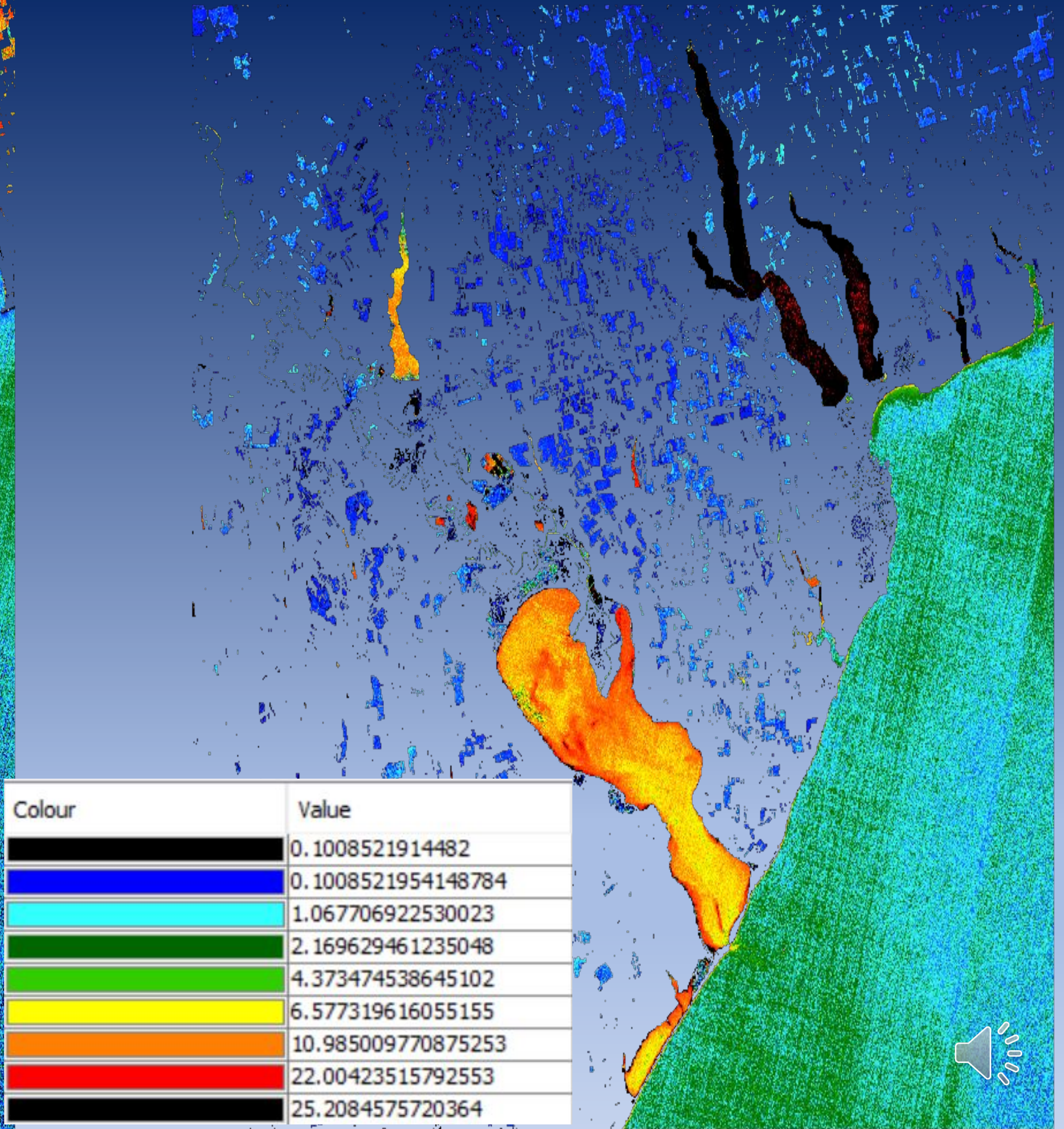
The Sentinel Application Platform (SNAP) is a common architecture for all Sentinel Toolboxes.

The SNAP architecture is ideal for Earth observation (EO) processing and analysis due to the following technological innovations: extensibility, portability, modular rich client platform, generic EO data abstraction, tiled memory management, and a graph processing framework.

7.03.2024 Chl, µg/l

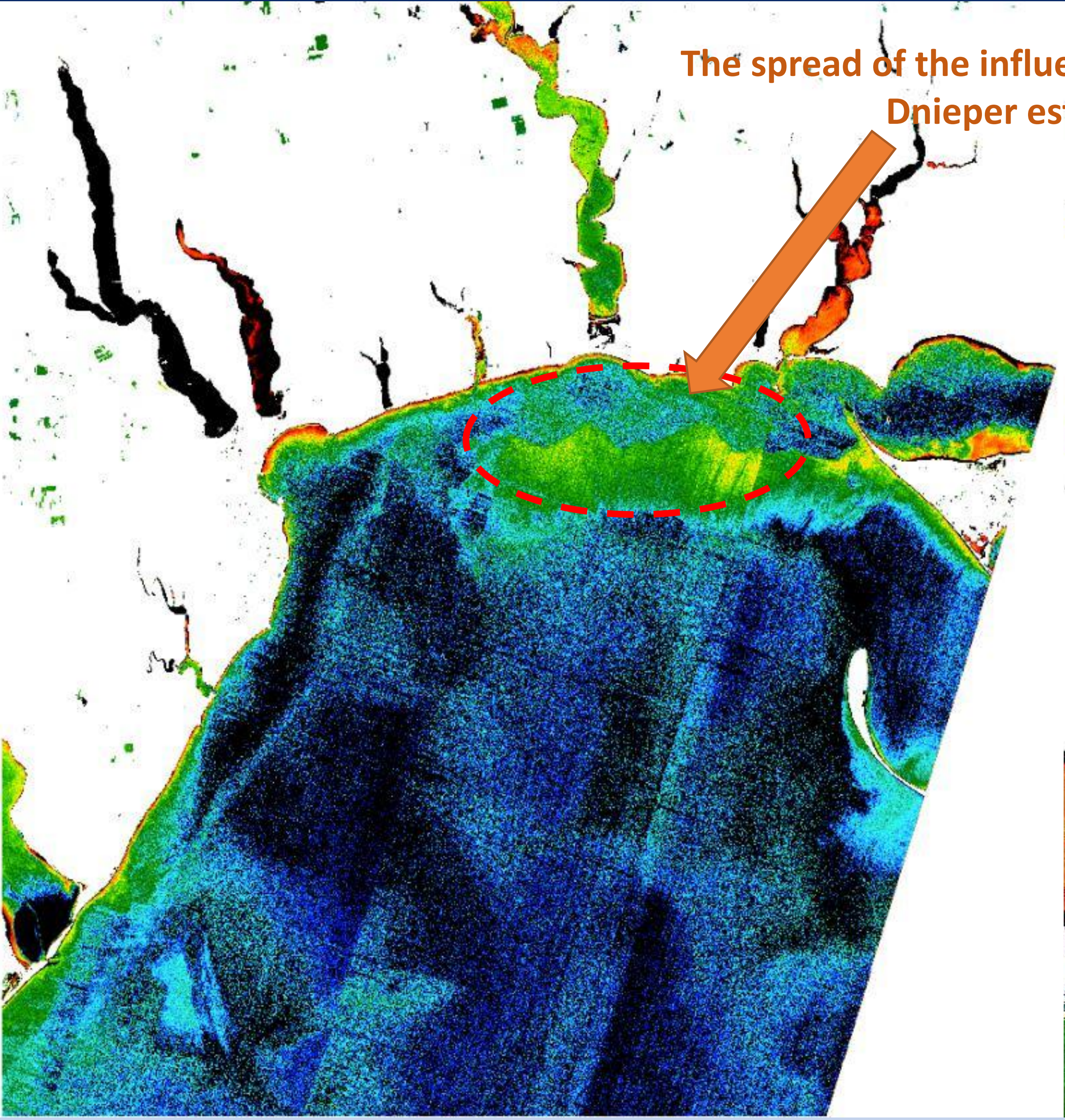


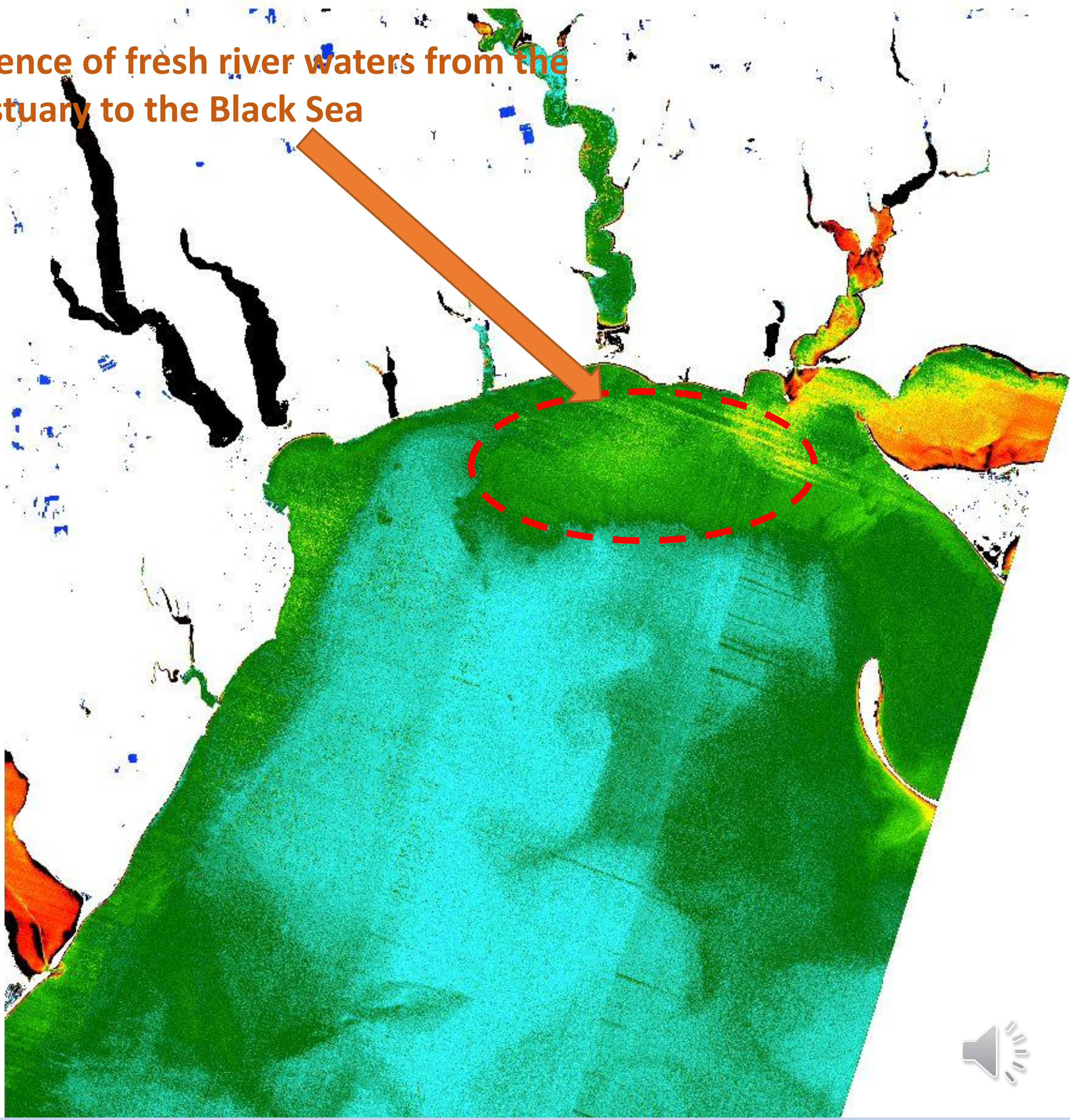
7.03.2024 total suspended matter TSM, mg/l



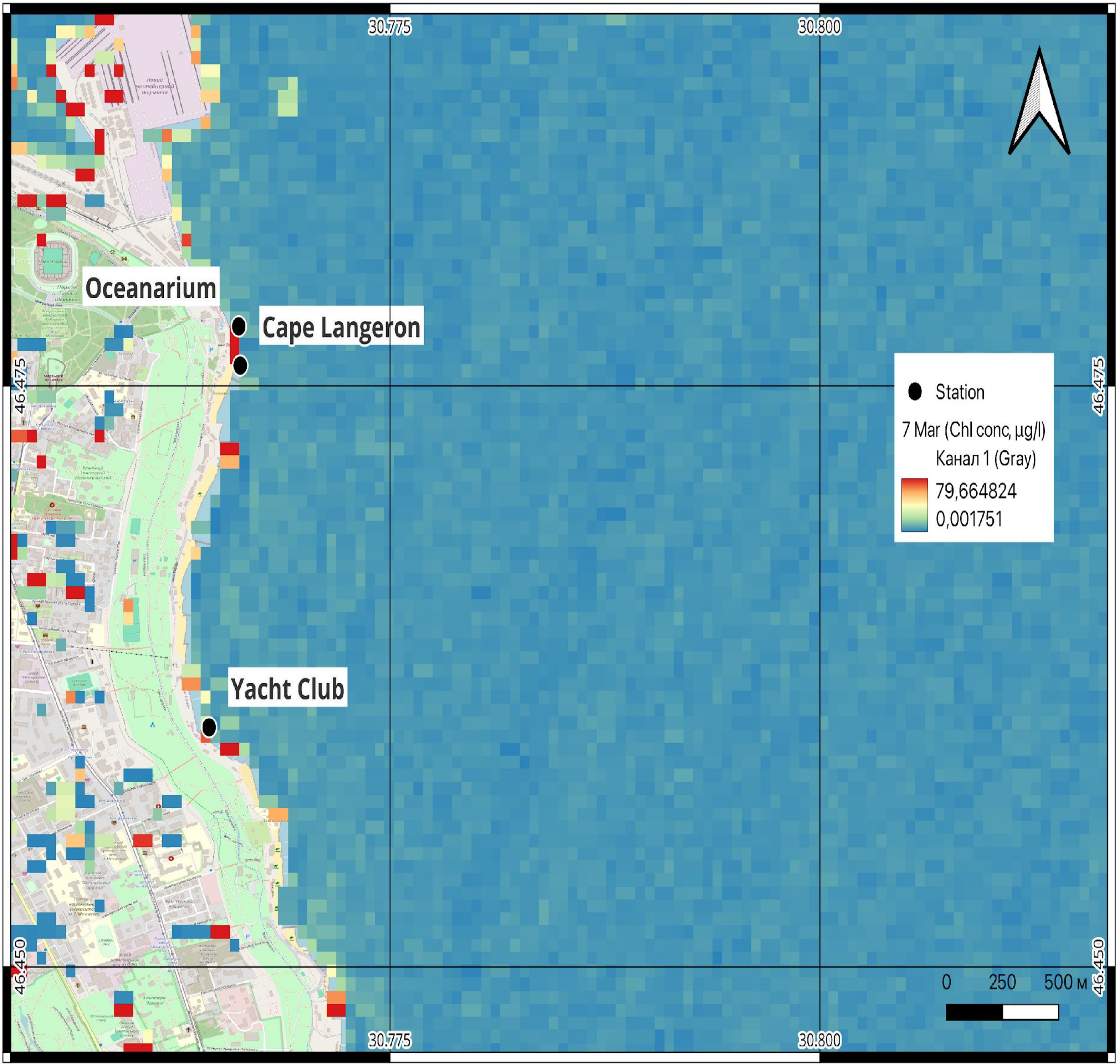
21.04.2024 Chl, µg/l

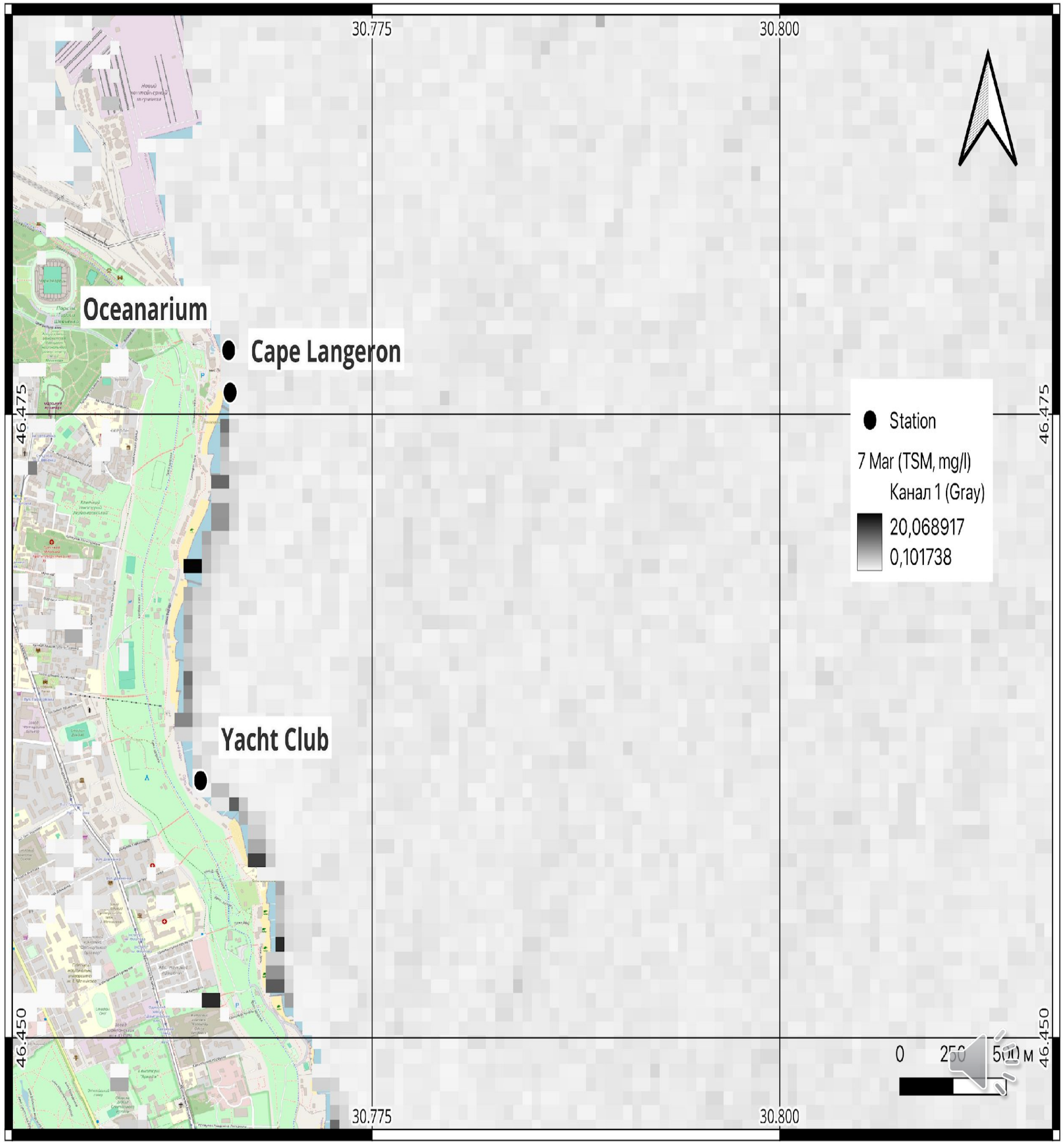
21.04.2024 total suspended matter TSM, mg/l



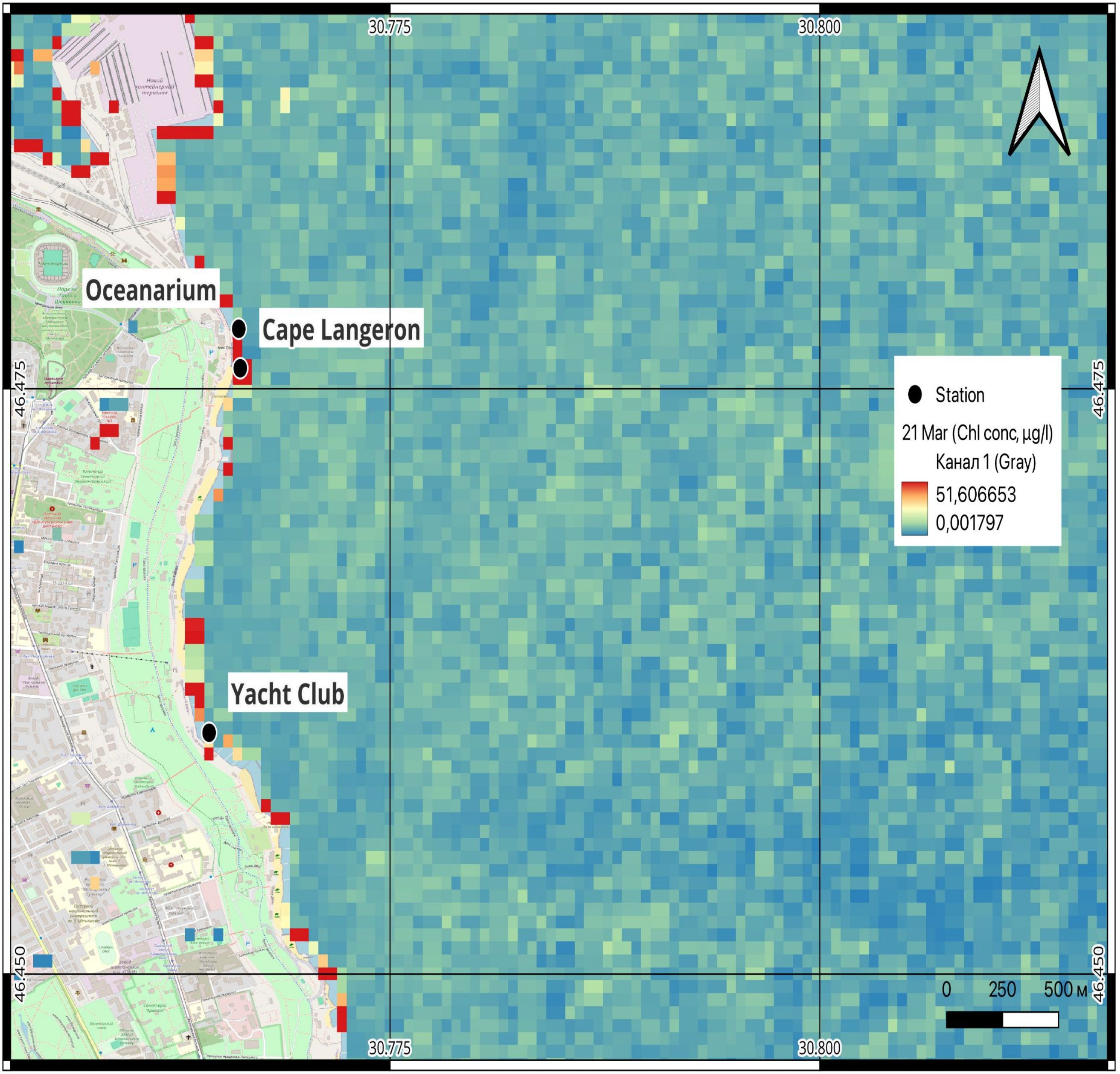


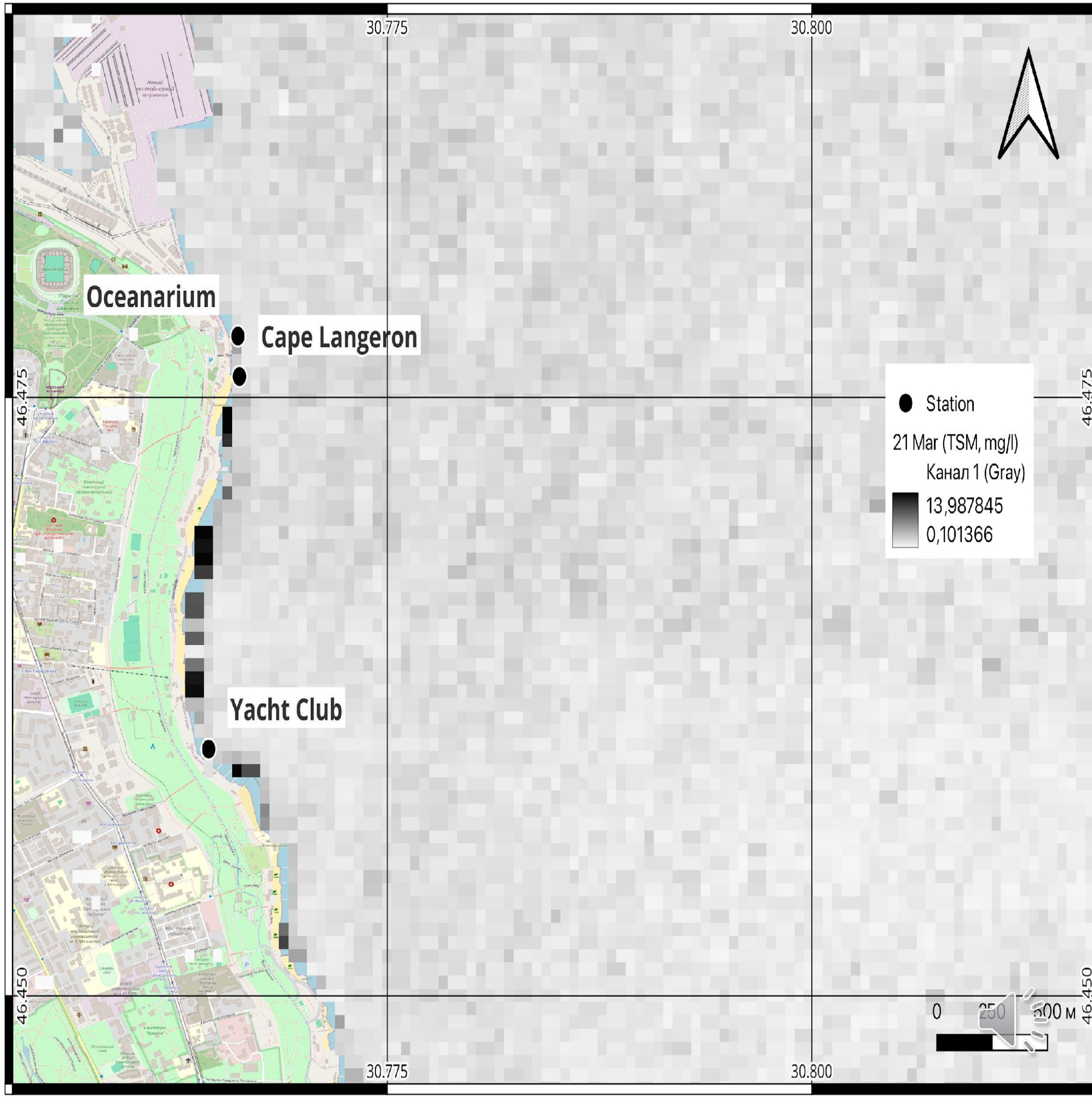
Final visualization of results using GIS



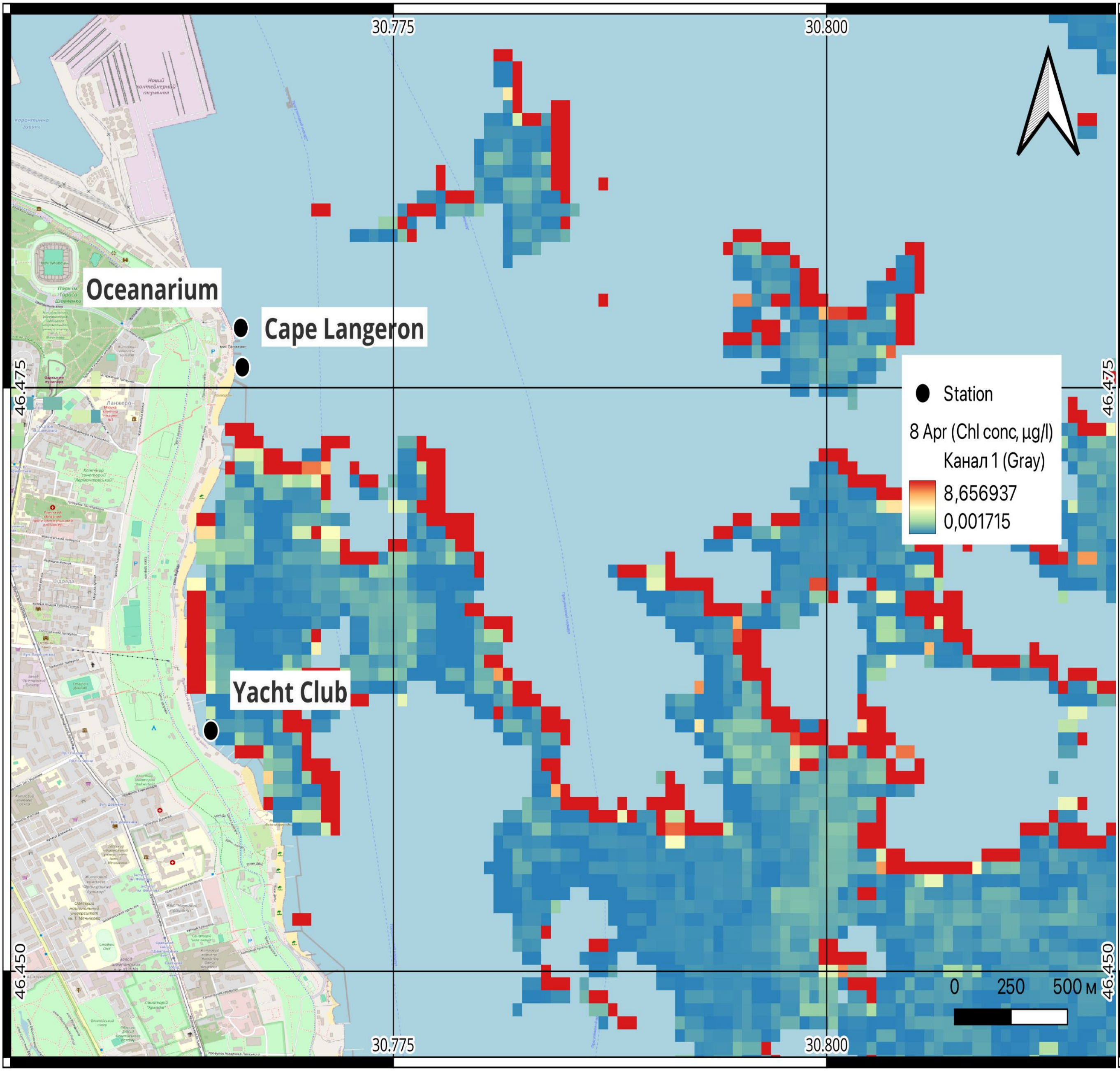


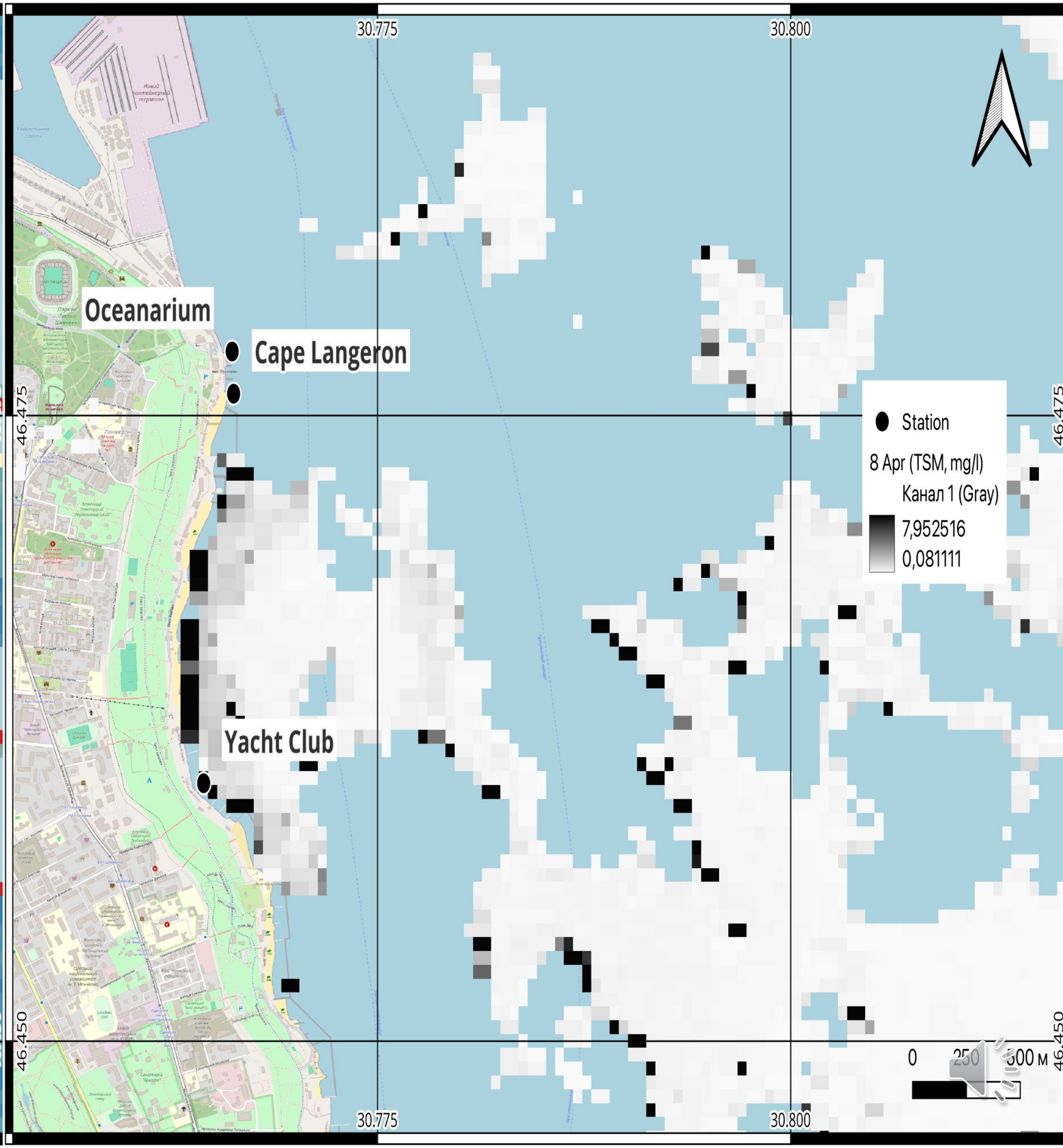
Final visualization of results using GIS



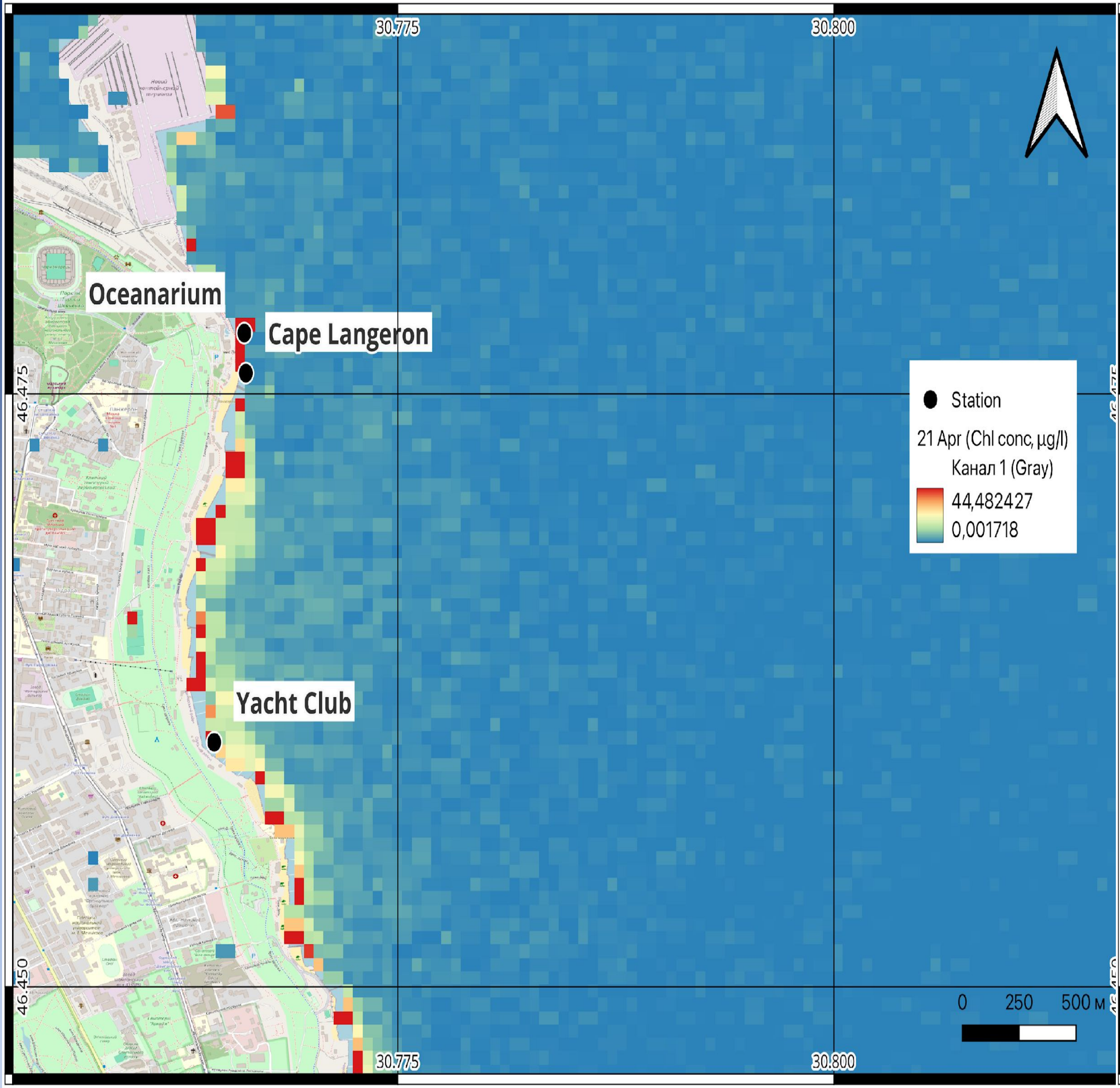


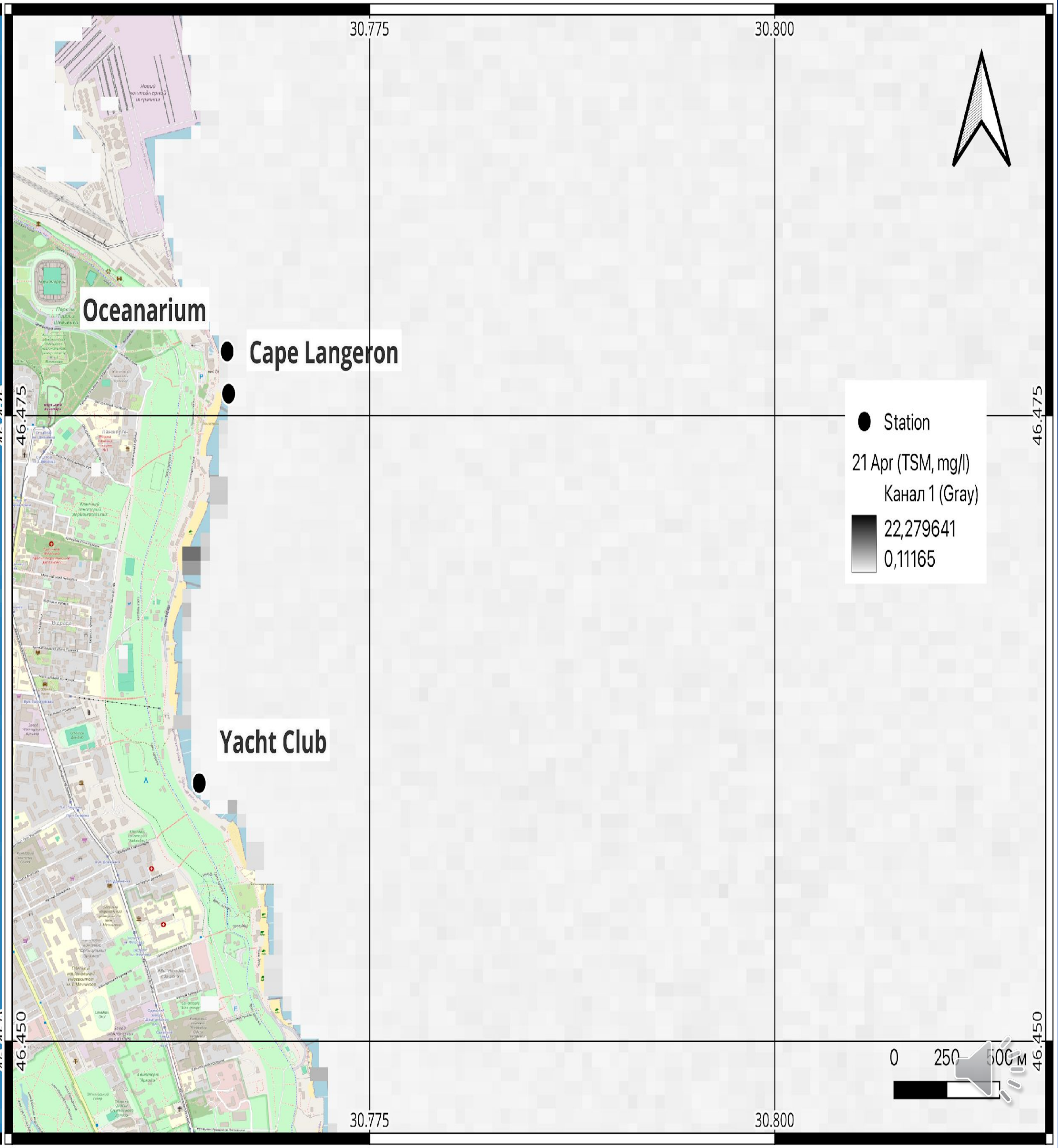
Final visualization of results using GIS



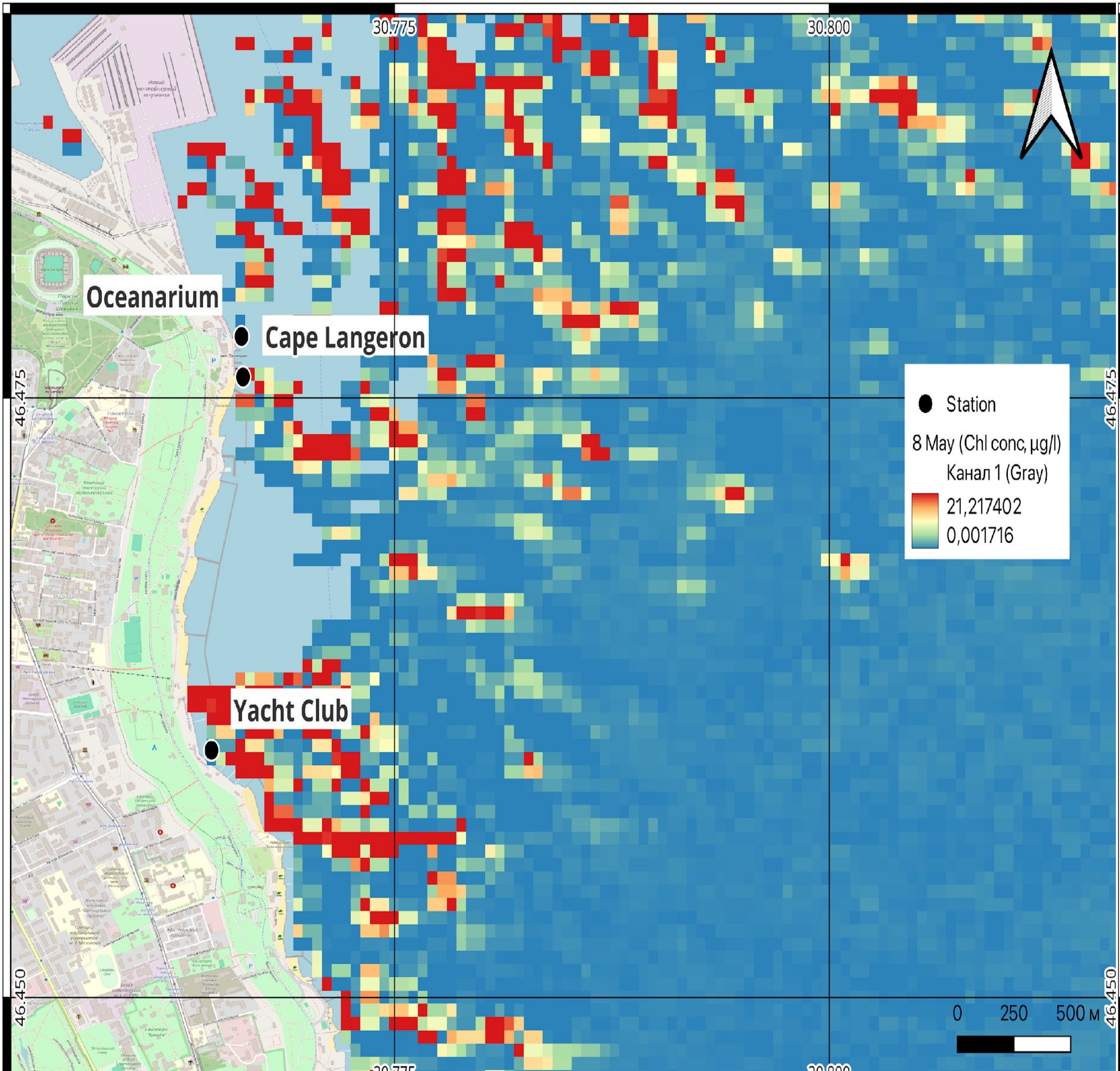


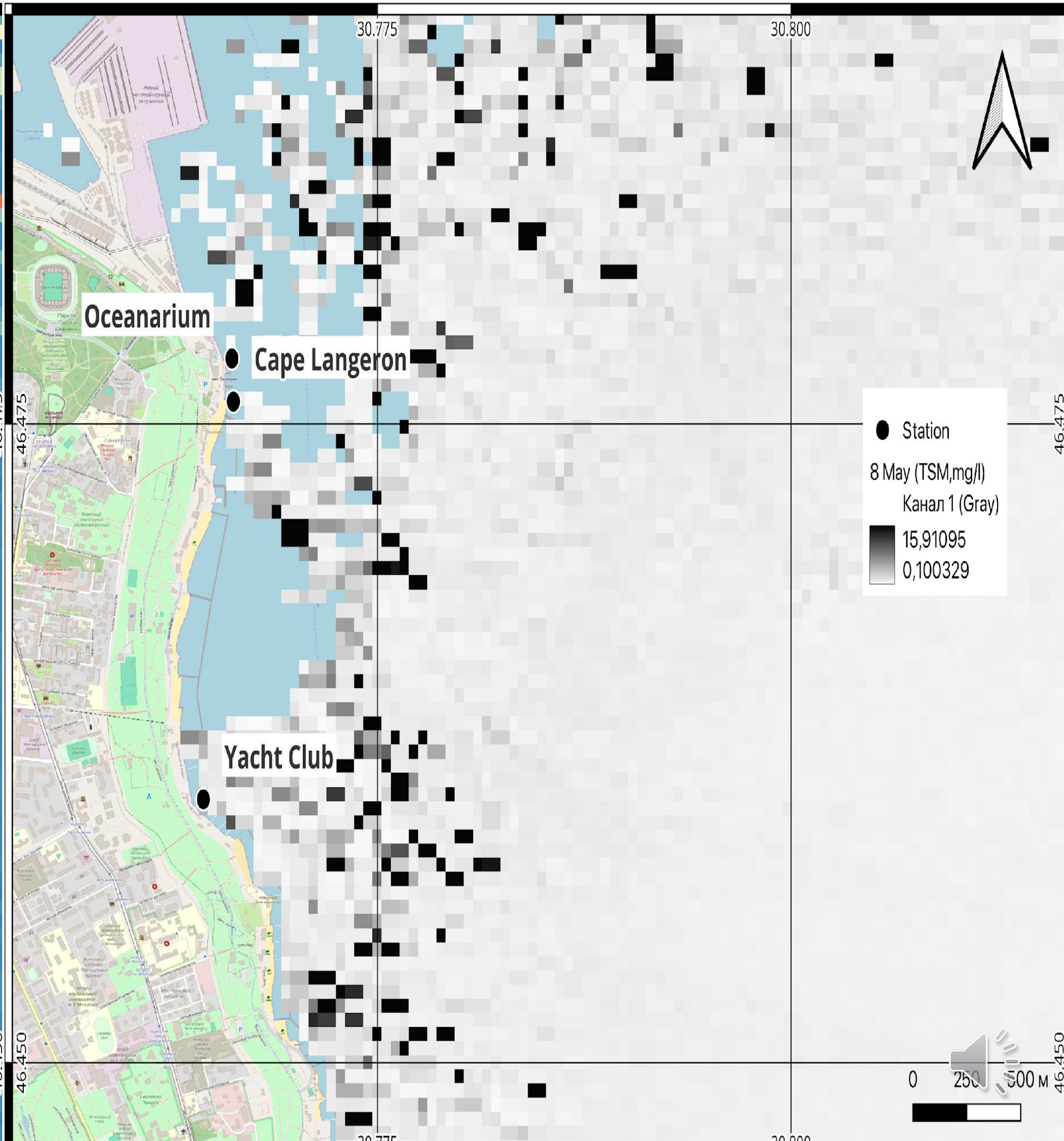
Final visualization of results using GIS





Final visualization of results using GIS





Conclusions

The integration of satellite remote sensing and field measurements proved good in monitoring coastal hydrological and ecological changes. The project demonstrated that using tools like WISP-3 and TriLux, calibrated with Sentinel-2 data, enhances the accuracy of water quality assessments, particularly for chlorophyll-a, total suspended matter, and salinity.

The results clearly show that remote sensing allows:

- detecting environmental changes after the extreme events (e.g., the Kakhovka HPP dam collapse),
- tracking the movement of river waters into the Black Sea,
- visualizing pollution zones and suspended solids concentrations over time.

Fieldwork by students and researchers contributed to building a reliable database for satellite data verification and laid the foundation for long-term coastal zone monitoring. According to the conducted measurements, chlorophyll-a concentrations were generally within normal limits; however, elevated values were recorded at certain coastal stations, likely due to the impact of the shoreline. This highlights the spatial variability of hydroecological parameters and emphasizes the need for continued and extended monitoring to ensure reliable interpretation and a timely environmental response.

THE FINDINGS CONFIRM THE IMPORTANCE OF ONGOING DATA COLLECTION FOR ENVIRONMENTAL ASSESSMENTS AND INFORMED DECISION-MAKING IN WATER QUALITY MANAGEMENT, PARTICULARLY DURING CRISIS CONDITIONS.

Dissemination of research results

- Citizen-science student project under GROMADA Erasmus+: assessing the hydrological and satellite data on Black Sea coastal waters after Kakhovka Dam destruction / V. Ovcharuk, M. Martyniuk, Yu. Pisariev, A. Stetsyuk, A. Tashku, A. Sryberko // Climate Services: Science and Education [Electronic resource] : Proceedings of the Second International Research-to-Practice Conference (Odesa, 16-18 April 2025). – Electronic text data (1 file : 5,7 MB). – Odesa : Odesa I. I. Mechnikov National University, 2025. – P. 103–104.

https://dspace.onu.edu.ua/handle/123456789/41300

- **Ю. Г. Пісарєв, А. В. Стецюк, А. Г. Ташку**, Визначення гідрологічних характеристик прибережних вод Чорного моря з використанням WISP-3 та супутникових даних (в межах проєкту Gromada). Матеріали до 81-ої звітної студентської наукової конференції ОНУ імені І. І. Мечникова. Секція «Гідрометеорологія і екологія». (Одеса, 23–25 квіт. 2025 р.) – Одеса: Одес. нац. ун-т ім. І. І. Мечникова, 2025. С.210-2014 ISBN 978-966-186-350-6

Thank you for your attention!