Consortium Members

D5: UC5 – Consistency of ECVs in the Danube River-Lake-Lagoon - Report

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1. Introduction

The Science Use case 5 - Consistency of ECVs in the Danube river-lake-lagoon, validates the consistency of all variables in the Danube river-lake-lagoon system, particularly focusing on the highly dynamic Danube delta and connected Razelm-Sinoe Lagoon System. The Razelm-Sinoe Lagoon System water body covers about 1000 km^2 and consists of a series of former lagoons transformed into lakes (e. g. Razelm, Golovita, Zmeica) and present-day lagoons with engineered inlets (Sinoe Lagoon), as well as other lakes, ponds and wetlands. Hydromorphological alteration performed around the 1970's increased the connection with the Danube River. As a result, the original oligohaline environment rich in migratory fish (major spawning area for the NW Black Sea) was entirely transformed into a mainly freshwater body (with only Sinoe Lagoon remaining brackish). The change in salinity, water and sediment sources has deeply altered the ecosystems resulting in a fundamental change in the aquatic flora and fauna. The lagoon system has been granted the status of Biosphere Reserve (as part of the wider Danube Delta Biosphere Reserve) and has been improving in recent decades due to reduced nutrient loads.

The study area represents a clear example of dynamic and complex environmental change that serves as a challenging test for remote sensing studies. Water bodies from the lagoon system partly or entirely freeze during winter and undergo changes in suspended sediment load. In addition, the large evaporation rate in summer-autumn may also result in significant lake extension changes. The case study will therefore compare information from Lakes_cci on the temporal dynamics of LSWT, LIC, LWE (possibly LWL) and turbidity and chlorophyll-a from LWLR for all observable water bodies in the region and provide expert analysis of the consistency of these products.

This case study shows how the lakes_cci variables can be utilised to separate climate and human impacts on river-lake-sea systems. It provides feedback on the consistency and accuracy of the time-series within the context of the dynamics observed in the system. The use case will also allow for the determination of the suitability of data formats for users less familiar with EO / geospatial data analysis providing feedback on the utility of data exploration, analysis tools and refining requirements for data sets with a regional focus through data aggregation. Lakes_cci data also fills essential data gaps between field campaigns to corroborate trends in the in-situ data. For example, LSWT dynamics in surrounding lakes will provide a baseline to compare LSWT in the lagoon with both before and after closure of the lagoon to the sea and will be related to ice-on and ice-off observations. This case study will also serve as an example to allow global upscaling follow-on studies for similar lake-lagoon systems.

2. Work done by GeoEcoMar

2.1. Gathering in-situ data

GeoEcoMar has been studying the water and sediment dynamics in the Razelm-Sinoe lagoon system since early 2000 so a set of in-situ data is available for the following parameters: temperature, turbidity, and chlorophyll-a. This database is available for the Lakes_cci project for multiple proposes such as providing data for a comparison with satellite products. In situ data consist of a series of measurements of surface water temperature, chlorophyll-a and turbidity, from 2009 to 2018 (over 200 data points), collected over the lagoon, as well as higher frequency data collected at a fixed station seasonally (i. e. in November, March, May, July). In-situ data is also available from other larger lakes inside the delta, like Fortuna, Matita, Merhei, Rosu, etc. These lakes were added to the CCI data set in V2.0. A total number of 15 lakes from the Danube Delta and SE Romania are now found in V 2.0 of the data set (Fig. 1).

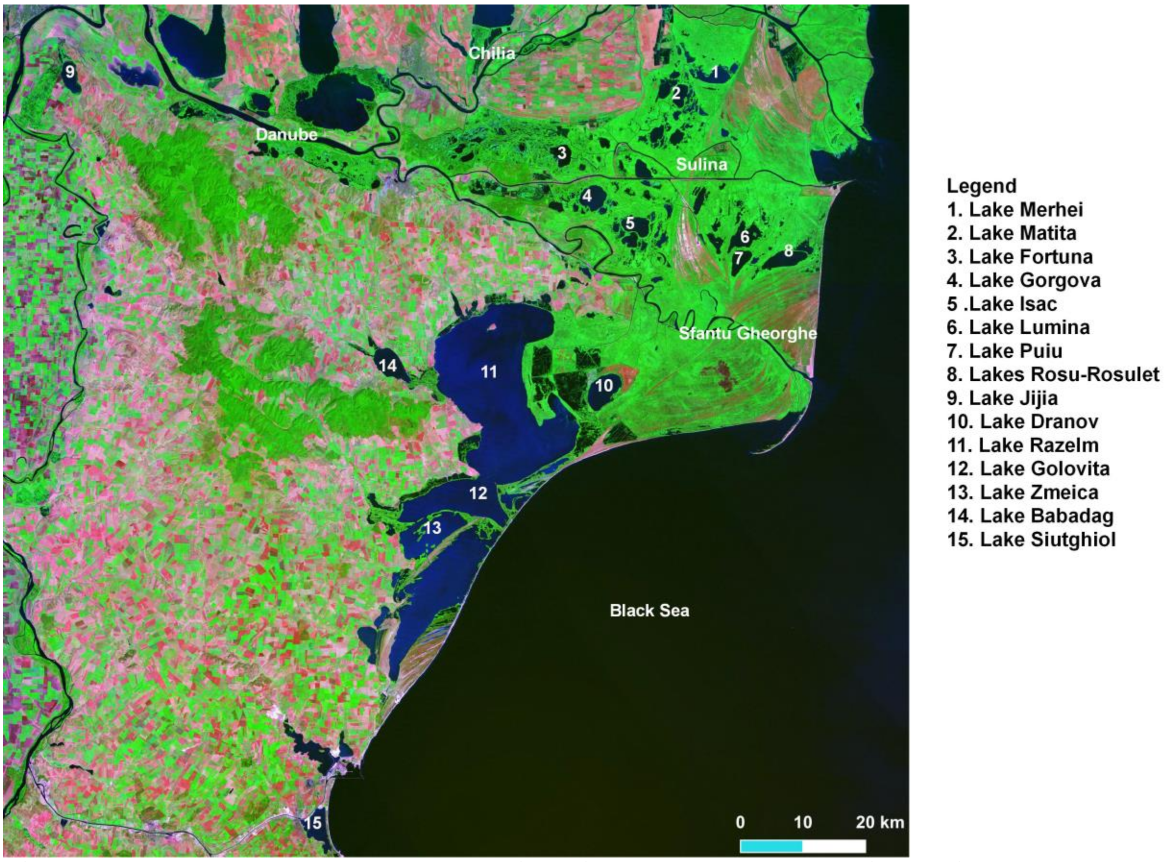

Fig. 1. The Danube Delta and SE Romania, with all 15 lakes found in version V.2.0 of the CCI Lakes dataset. Lakes Razelm, Golovita and Zmeica (marked 11, 12, 13) were included in the initial data set and V1.1

2.2. Evaluation of data consistency V1.1 dataset

When V1.1 of the data was available, an evaluation on time coverage of the lake variables was performed, as a first step. More frequent data is available beginning with 2009 but major challenge for the Danube Delta area, as cloud coverage, can reduce satellite products usage of 50% per year for LSWT, or even to 25% per year for LWSR, in certain years. Overall, in this area, spring to autumn seasons have the most comprehensive time coverage of data sets. In this version, only LSWT and LWSR (chlorophyll-a and turbidity) were available for the selected lakes – Razelm, Golovita and Zmeica.
Lakes_cci satellite products of chlorophyll-a and turbidity were also analysed and compared to in-situ data and trend analysis was performed on monthly averaged data. All ECV variables, available from the V1.1 dataset were assessed in terms of time coverage of the satellite products and consistency, and time series analysis was performed, assessing the time evolution of extremes as well as relationships between parameters.
Good correlations were found between in-situ and CCI Lakes derived ECV for LSWT and turbidity (Fig. 2).

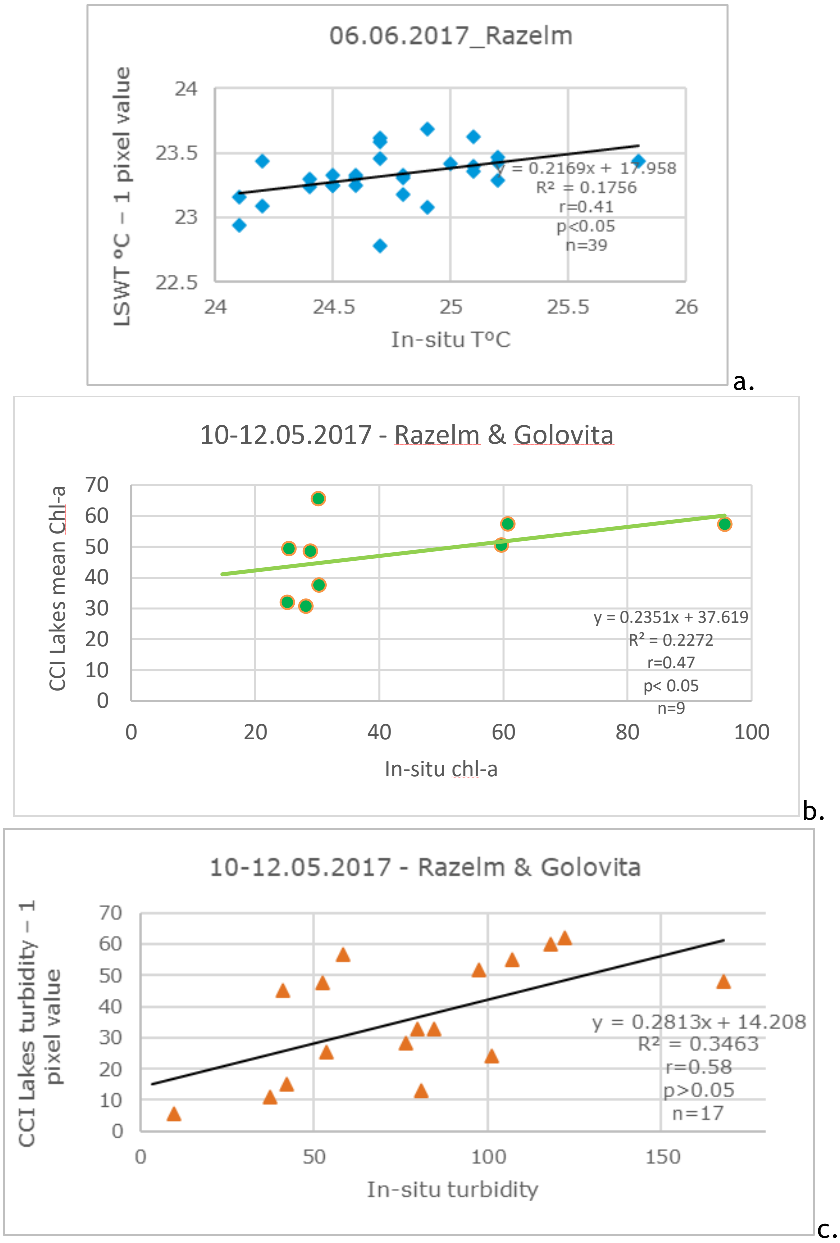

Fig. 2 Correlations between in-situ and CCI Lakes ECV, data from V1.1. a. LSWT (one pixel value) correlated with in-situ measured water temperature, from 39 stations, for one day. b.CCI Lakes chlorophyll-a (one pixel value) correlated with in-situ chlorophyll-a (analyzed by GeoEcoMar) in 9 stations (10-12.05.2017). c. CCI Lakes turbidity (one pixel value) correlated with in-situ measured turbidity in 17 stations (10-12.05.2017).

LSWT, averaged for 3 pixels, in several areas, was compared to air temperature, recorded at Jurilovca station, in the vicinity of the lagoon. The variation over 1995 to 2019 is very similar for the analysed sites and the air temperature, and the difference is consistent - 4.2°C to 3.8°C (Fig. 3).

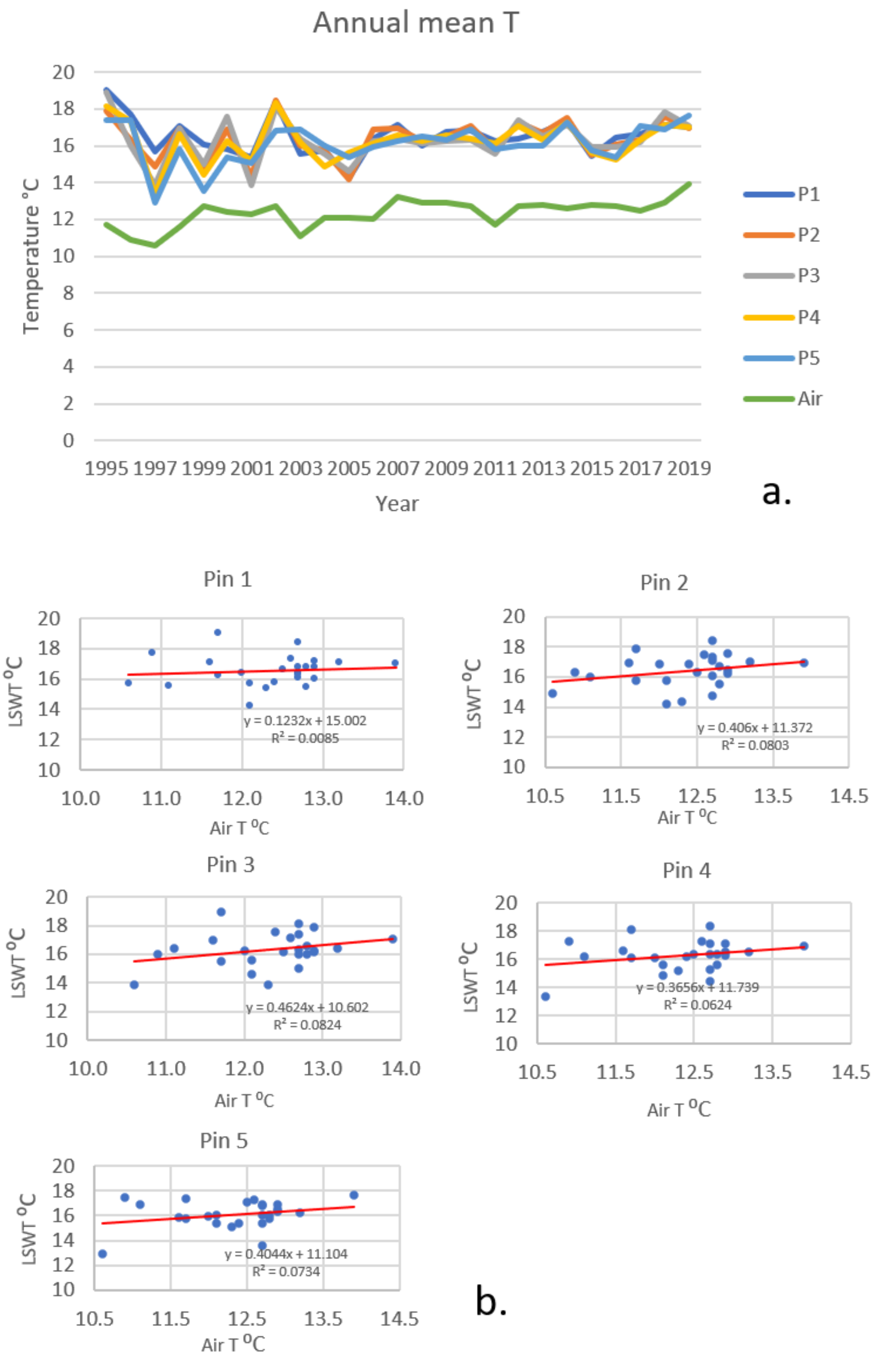

Figure 3. Comparison of lake surface and air annual temperature, starting with 1995. a. Comparison between air temperature, recorded in the W of the lagoon (Jurilovca station) and LSWT from five points (1 to 5 from N to S, see Fig. 6 for map). b. Correlation between air temperature recorded at the same station and LSWT extracted in the five points (3x3 pixels average).

2.3. Trend analysis and correlations

After data was extracted from the V1.1 data set, correlations were made between different variables: LSWT and chlorophyll-a, turbidity and wind speed and precipitation (Fig. 4). The relationships of these parameters are not strong in all cases, which requires looking at a more refined time scale.

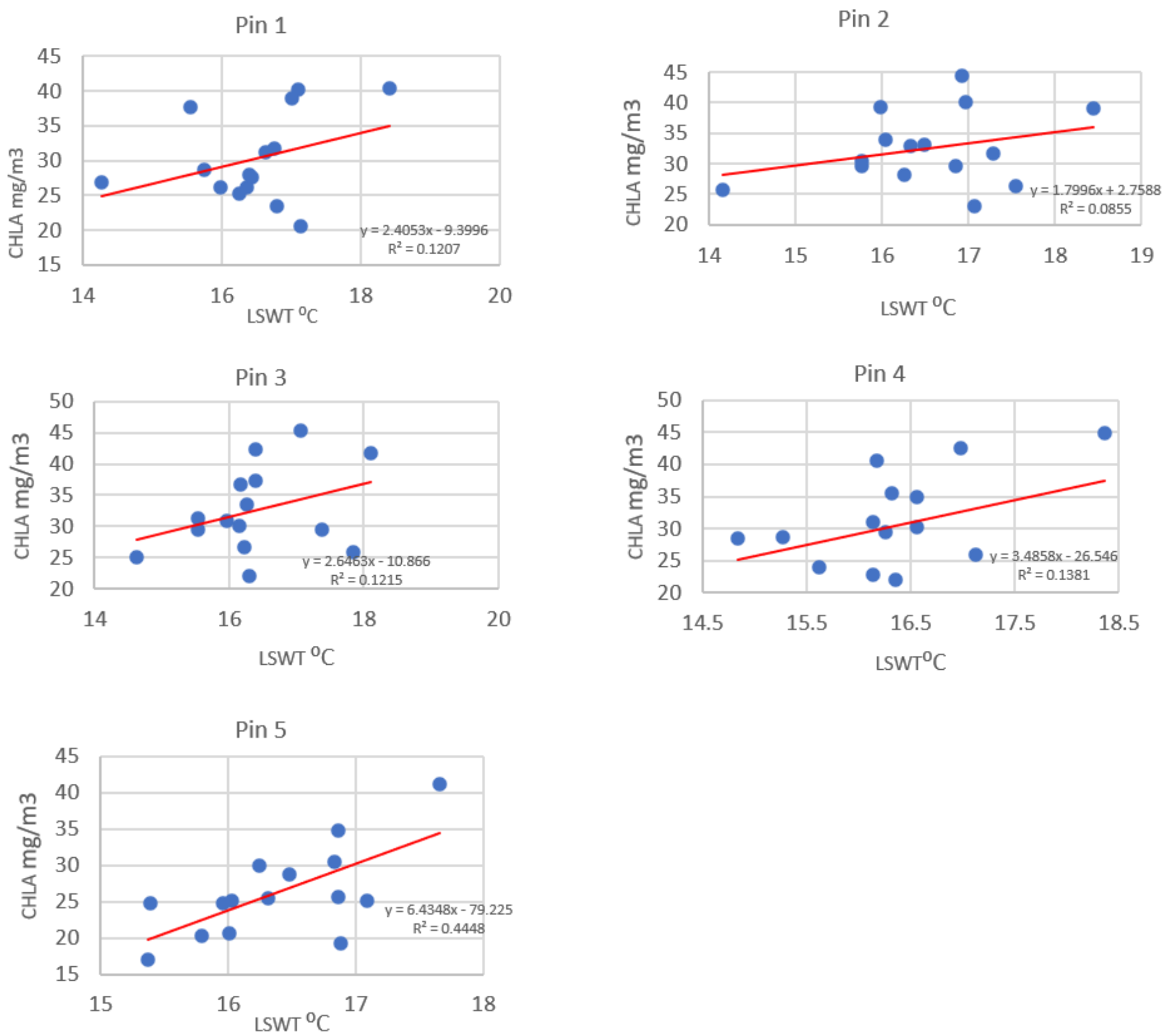

Figure 4. Correlations between CCI Lakes LSWT and Chlorophyll-a (3x3 pixel averages), in five points - locations in Fig 6.

Another correlation was done between turbidity and wind speed. The results are presented in Fig. 5. The results show poor correlation, except for Pin 5 – the shallowest area. This shows that turbidity is only partially controlled by wind in these three lakes. Another comparison was done with precipitation, but the results showed negative and weak correlation.

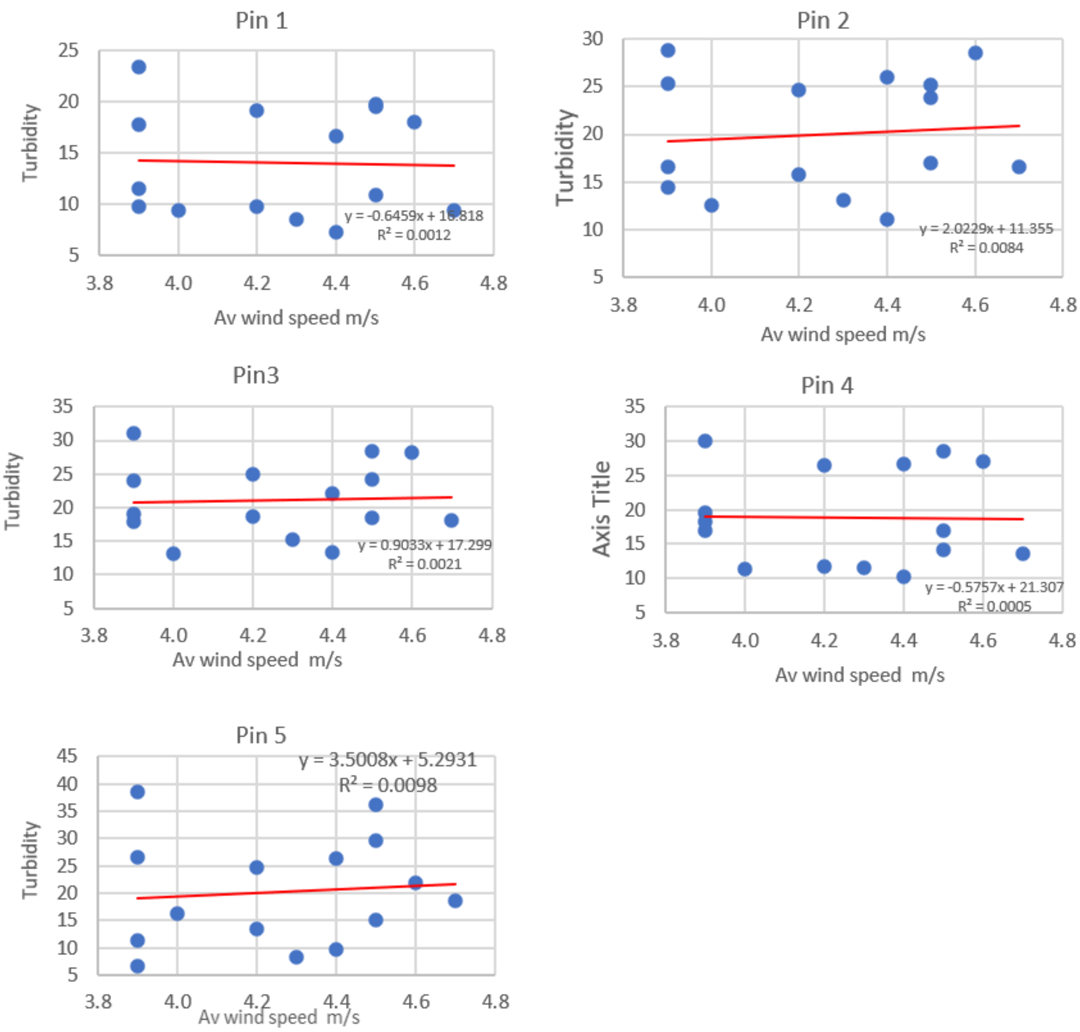

Figure 5. Correlations between CCI Lakes turbidity (3x3 pixel averages) and wind speed, recorded at Jurilovca station, in five points - locations in Fig 6.

Trend analysis was done for the data extracted in the five areas for LSWT, turbidity and chlorophyll-a. Considering the available data for each season, a seasonal average was calculated. Overall, trend analysis of seasonal values revealed mostly positive increases in temperature, turbidity and autumn chlorophyll (Figure 6). The increase in spring average temperature was significant in the north and east of the lagoon system (marked with red in Table 1).

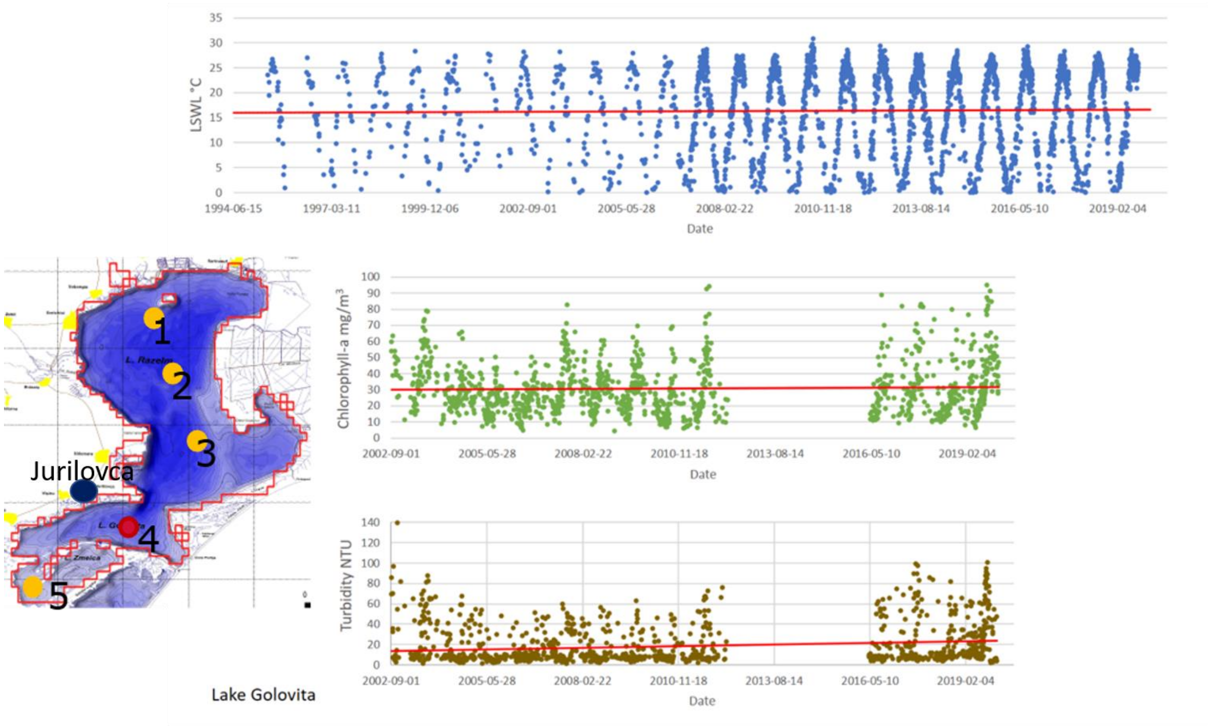

Figure 6: The 5 selected points inside the lagoon (1-3 in Lake Razelm, 4 in Golovita and 5 in Zmeica) and general trends for water temperature, chlorophyll-a and turbidity in Lake Golovita (Point 4 in the map). Data from CDRP V1.1. location of the meteo station in Jurilovca is marked in black.

Table 1. Trend for mean LSWT in the five selected locations. Annual, spring, summer and winter trends are presented as increasing (+) or decreasing (-), the statistically significant trends are marked in red.

Point Id	Annual average	Spring average	Summer average	Winter average
1	-	+	+	-
2	+	+	+	+
3	+	+	+	-
4	+	+	+	-
5	+	+	+	-

2.4. Main challenges

After the initial evaluation of the data set, several challenges arose:

- The cloud cover in the area reduces data availability by of 50% per year for LSWT, or even to 25% per year for LWSR, in certain years. The most affected months are the winter ones, when data is very scarce, which means averages are calculated with 3-

5 values, compared to other seasons, where more than 20-30 values are available. **Solution** – interpret results with care and take this into consideration

- Consistency of the chlorophyll-a data – even if the comparison with the in-situ data is promising, there are some anomalies - spring averages are greater than summer averages, which doesn't happen in reality. **Solution**: Do a trend analysis first and a careful comparison with in-situ data, exclude values which are too high/low
- Available meteorological data – finding meteorological data with a more refined temporal resolution has proven difficult so far. **Solution**: use freely available data, such as ERA5 data https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview

2.5. V2.0 dataset

We have started downloading and extracting data from version V2.0. There are 15 lakes from Romania in this dataset (as presented in Fig. 1).

The data coverage for each on is presented in table.2

Table 2. CCI Lakes data in V2.0 available for each lake

id	Short name	Name	lat	long	Lwl	Lwe	Lswt	Lic	Lwlr
17329	GLWD00017329	Merhei	453,236	294,542	FALSE	FALSE	TRUE	TRUE	TRUE
208447	GLWD00208447	Matita	453,014	293,708	FALSE	FALSE	TRUE	TRUE	TRUE
208662	GLWD00208662	Fortuna	452,153	291,264	FALSE	FALSE	TRUE	TRUE	TRUE
13916	GLWD00013916	Gorgova	451,542	291,903	FALSE	FALSE	TRUE	TRUE	TRUE
208962	GLWD00208962	Isac	451,097	292,819	FALSE	FALSE	TRUE	TRUE	TRUE
16814	GLWD00016814	Lumina	450,875	294,903	FALSE	FALSE	TRUE	TRUE	TRUE
209099	GLWD00209099	Puiu	450,569	294,792	FALSE	FALSE	TRUE	TRUE	TRUE
15309	GLWD00015309	Rosu-Rosulet	450,569	295,681	FALSE	FALSE	TRUE	TRUE	TRUE
16662	GLWD00016662	Jijila	453,486	281,208	FALSE	FALSE	FALSE	TRUE	TRUE
9168	GLWD00009168	Dranov	448,708	291,903	FALSE	FALSE	TRUE	TRUE	TRUE
358	GLWD00000358	Razelm	449,069	289,486	TRUE	FALSE	TRUE	TRUE	TRUE
		Golovita			TRUE	FALSE	TRUE	TRUE	TRUE
		Zmeica			TRUE	FALSE	TRUE	TRUE	TRUE
8089	GLWD00008089	Badabag	449,236	287,597	FALSE	FALSE	TRUE	TRUE	TRUE
3E+08	HYLA00014302	Siutghiol	442,542	285,958	FALSE	FALSE	TRUE	TRUE	TRUE

2.6. Work in progress. Data of V2.0 and paper outline

The current work is focusing on extracting and exploring data from V2.0 dataset.

Data from all the lakes will be used for a science paper. Paper outline:

Untangling climate change and effects of anthropic interventions in the lakes and lagoons of the Danube Delta

Aim of UC: This case study exemplifies how the CCI Lake variables can be utilized by limnologists and geologists interested in separating climate and human impacts on river-lake-sea systems. The use case will provide feedback on the consistency and accuracy of the time-series within the context of the dynamics observed in the system. This UC will also be an exercise to determine the suitability of data formats to users less familiar to EO / geospatial data analysis context, thus providing feedback on the utility of existing data exploration and analysis tools and specifying requirements for data sets with a regional lake focus through data aggregation.

Aim of the paper: to use this data merely as a tool to assess effects of climate change and anthropic interventions in the area

Hypothesis: The lakes and lagoons of the Danube Delta have been affected by both climate change and anthropic changes and, as they acted almost at the same time, it is hard to differentiate historically

Need: Identify changes in lakes and understand their cause, differentiate between local anthropic impacts and climate change effects, assess the utility and uses of satellite derived climate data

Scientific gaps: climate change effects in the Danube Delta area (see especially seasonality, temperature changes, average seasonal temperature, time of temperature shift, effects of ice cover loss, effects of anthropic interventions on lake and lagoon environments (lakes well connected to the Danube would suffer less from temperature changes than the others, could we point to high blooms and when, identify hypoxia events)

Objectives:

- Analyze time series data of ECV
- Look at trends and relationships between ECVs and other climate data
- Analyze change and seasonality, etc

Novelty:

Climate change effects in this area, why and how, factors that may accelerate or not these changes, such as the anthropic interventions, climate change may accentuate or make the anthropic effects to persist

Data needs: ECV extracted for lakes, in-situ data from GeoEcoMar, climate data to validate/correlate

Structure:

Abstract

Introduction

Regional framework: natural factors and anthropic changes

Data and methods

Results: Data consistency – validation, accuracy. Time series analysis. Relationships between variables

Discussion: Use of the data. Trends of evolution. Separating climate and human interventions

Conclusions