V Convención Científica Internacional UCLV 2025

Remote Sensing for Water Quality Monitoring

Exploring Trends and Variability of Water Quality Over Lake Titicaca

DIGIWATER

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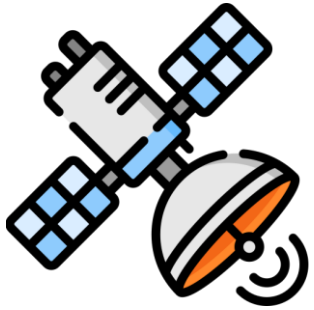
Remote Sensing of Water Quality

Water Quality

Remote Sensing

Remote Sensing of Water Quality



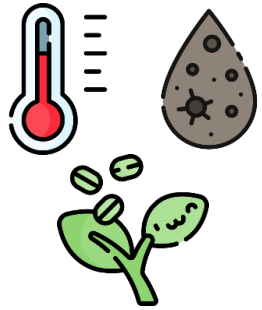
Remote Sensing Data
(e.g., top of the atmosphere reflectance)

- Atmospheric correction
- Radiometric correction
- Etc.

Corrected RS Data
(e.g., surface reflectance)

Estimation Algorithms

- Empirical
- Semi-empirical
- AI



Water Quality Data

Water Quality Data

In-Situ Data

- 14 monitoring campaigns
- LSWT & Turbidity

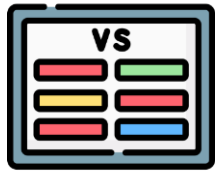
Remote Sensing Data

- 2 Global Products
- LSWT, Turbidity, & Chlorophyll-a (Trophic State Index)

Remote Sensing Products

Database Name / Agency	Coverage Period and Temporal Resolution	WQ Product Spatial Resolution (m)	Satellite and Sensor
Copernicus Global Land Service (CGLS)	May 2002-present; 10-daily	100, 300, and 1000	Sentinel-2: MSI Sentinel-3: OLCI, SLSTR-A Envisat: MERIS, AATSR
European Space Agency (ESA) Lakes Climate Change Initiative (CCI)	Sept 1992-2020; Daily	1000	Envisat: MERIS, AATSR Aqua: MODIS Sentinel 3: OLCI, SLSTR Metop: AVHRR Terra: MODIS

Objectives and Analysis



Evaluate and Compare

Comparison of In-Situ and RS

- In-situ: From 14 monitoring campaigns
  RS: From the closest spatiotemporal location. Maintaining ±3 days match-up
- R^2, Bias, RMSE, & E_{com}

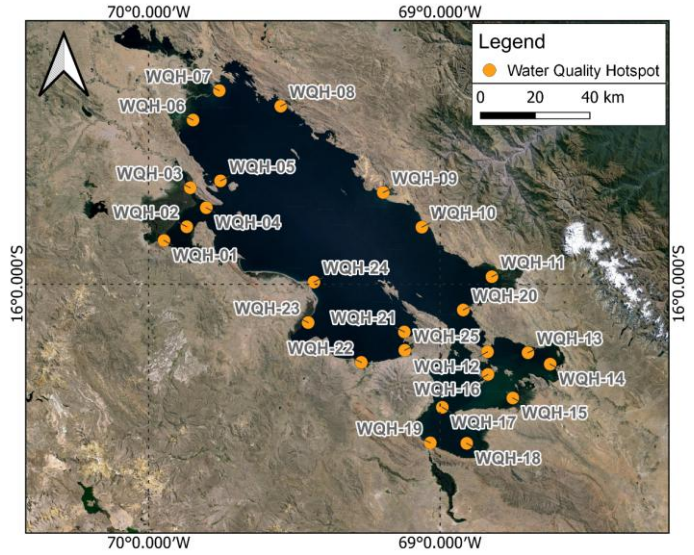
Illustrate and Evaluate

Spatial Analysis

- Only rasters with ≥80% of lake coverage
- Long–term monthly means

Temporal Analysis

- At 25 water quality hotspots

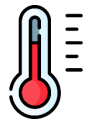


Global RS WQ Products Accuracy

Better correlation of LSWT products with in-situ

- LSWT retrieval is based on physics, which stabilizes performance across space and time (Carrea & Merchant, 2020)

- Factors affecting accuracy
- Measurement methodology
  - In-situ: 20% depth
  - RS: Lake Surface
- Synchronization of Data
  - CGLS: ±4 days
  - ESA-CCI: ±1 day
- Quality of Data



LSWT

PRODUCT	R^2	Bias	RMSE	E_{com}
CGLS	0.359	0.563	1.708	2.052
ESA-CCI	0.268	0.235	1.552	1.792

TURB

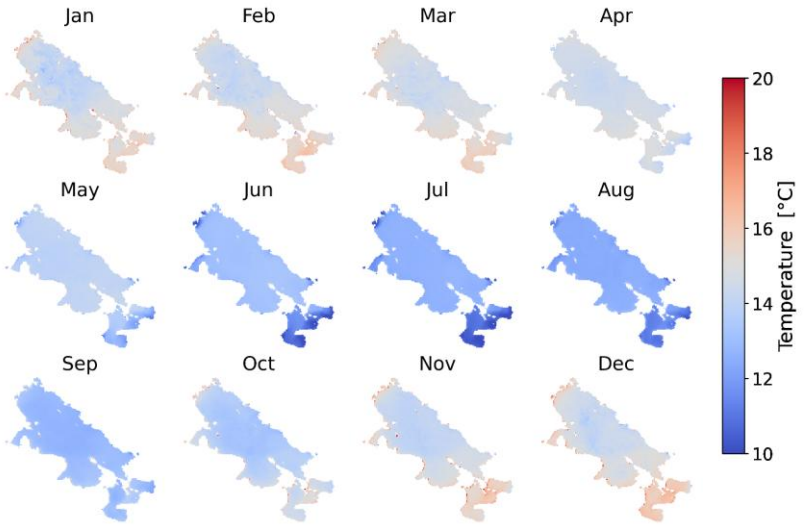
PRODUCT	R^2	Bias	RMSE	E_{com}
CGLS	0.111	-0.053	1.295	1.383
ESA-CCI	0.186	-0.215	0.965	1.096

Spatial Analysis

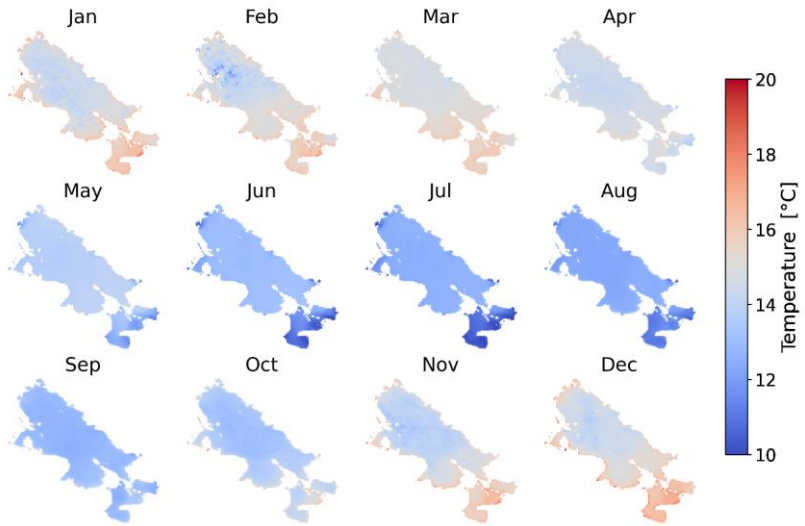
LSWT

TURB

CHLA



CGLS



ESA-CCI

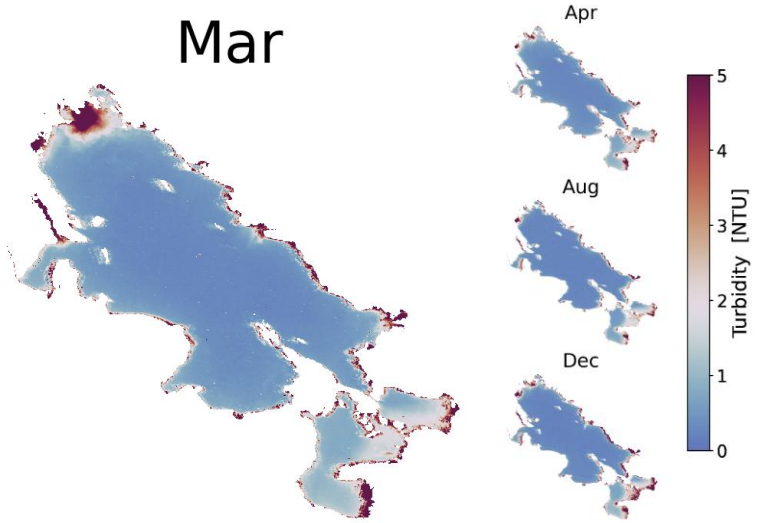
- Almost well-mixed temperature consistent with seasonal climate
- Both products consistent with each other
- Same algorithm and imagery source

Spatial Analysis

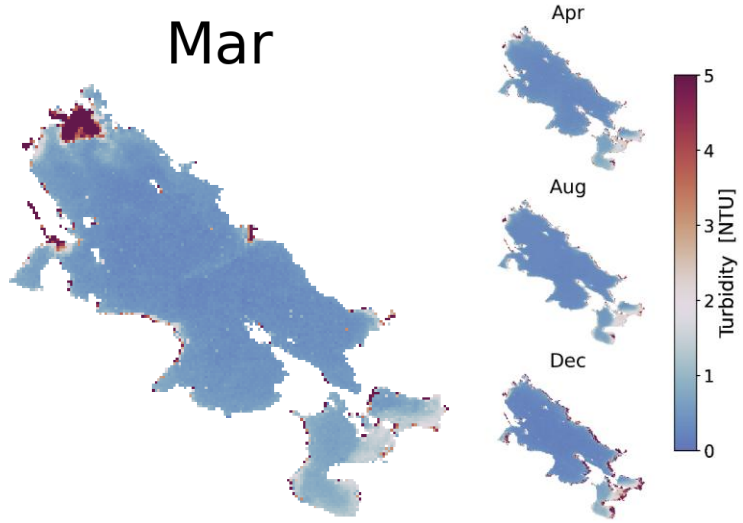
LSWT

TURB

CHLA



CGLS



ESA-CCI

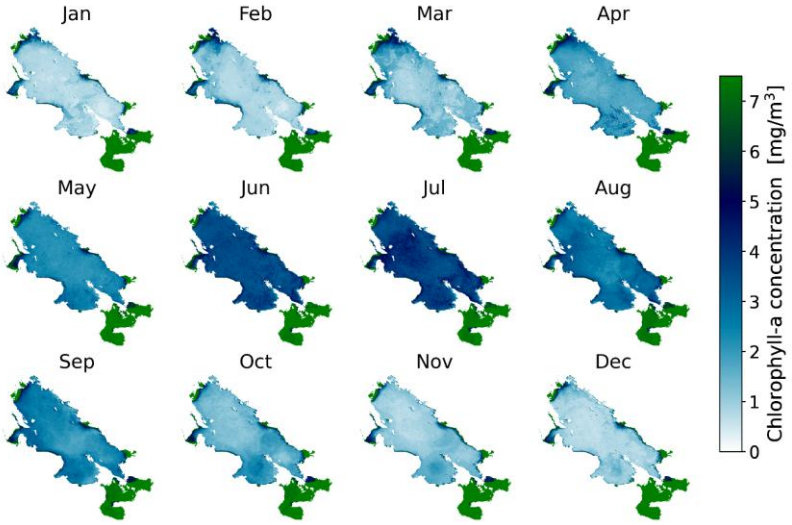
- High turbidity along the shores
- More pronounced high turbidity at the shores (CGLS)
- Same processing chain (Calimnos) but different versions
  - ESA-CCI uses the more updated version which added new optical water types

Spatial Analysis

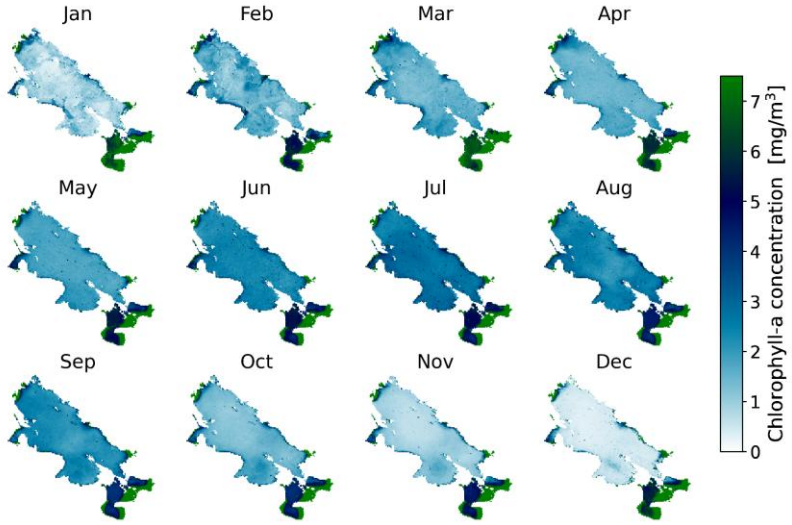
LSWT

TURB

CHLA



CGLS

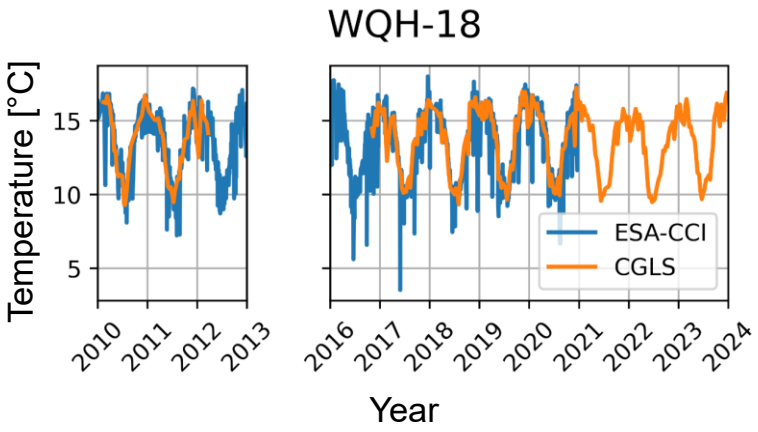


ESA-CCI

- High concentration in Lago Menor
- Seasonal pattern of high concentration coincides with the wet season

Temporal Analysis

LSWT



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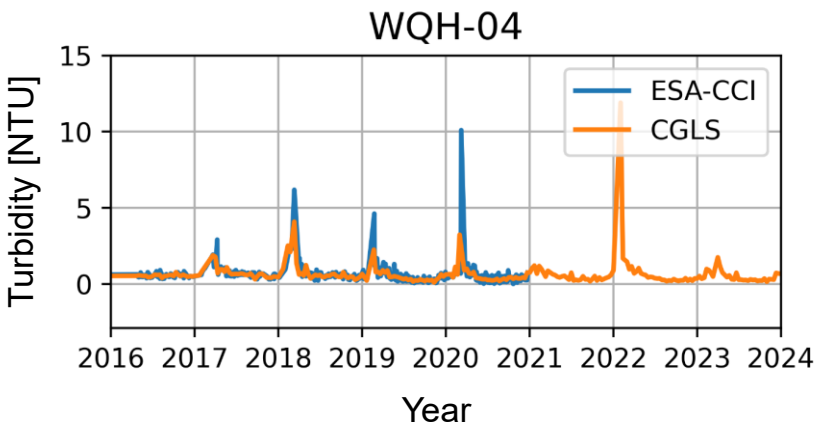
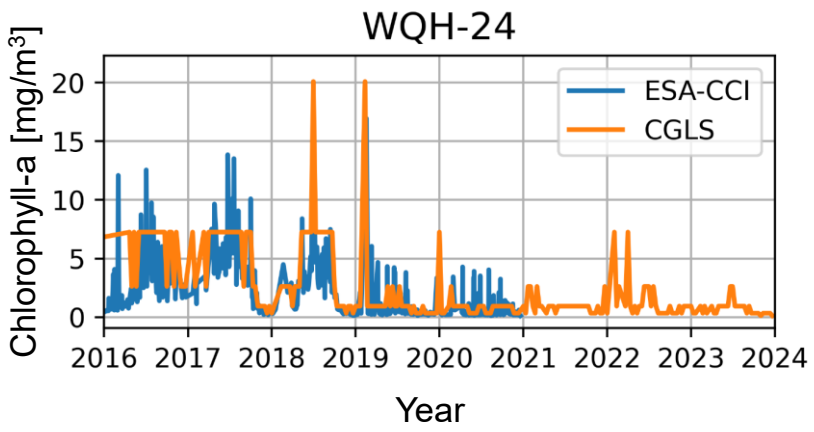


CHLA



Comparison of Global RS WQ Products

- **Copernicus GLS**
  - – 10-daily aggregation
  - \+ Available until the present
  - \+ Spatial resolutions of 100,300, and 1000 m
  - – TSI available in place of chl-a conc.
  - – Processing chain: Calimnos v1.4

- **ESA Lakes CCI**
  - \+ Daily aggregation
  - – Available until the end of 2020
  - – Spatial resolution of 1000 m
  - \+ Chlorophyll-a concentration available
  - \+ Processing chain: Calimnos v2.1

Summary of Findings

- **LSWT estimates are better correlated** with in-situ data than turbidity estimates
- **Remarkable consistency** in the spatiotemporal pattern between the two LSWT products
- **Accurate spatial patterns** of the water quality parameters with actual field conditions
- **Both products are on par with each other**, with some advantages and disadvantages

Conclusion

Correct pixel identification

Accurate optical water type definition

Better algorithms

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Exploring Trends and Variability of Water Quality over Lake Titicaca Using Global Remote Sensing Products

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