Study and Modelling of the Water Quality at Lake Guerlédan

Authors: *COTTOUR Ewen, GONNET Arthur, MALULEKE Lani and TRAISNEL Simon*
Supervisor: *Professor Amandine Nicolle*
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ENSTA IP PARIS

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I. Introduction

II. CTD Analysis: Methodology

III. CTD Analysis: Results and Discussion

IV. TELEMAC-3D Model: Methodology

V. TELEMAC-3D Model: Results and Discussion

VI. Conclusion and Perspectives

I. Introduction

- Since 2016, Ensta students have conducted annual water quality surveys at Lake Guerledan.
- Collecting CTD measurements on key water quality parameters.
- Conducting water quality simulations with the TELEMAC-3D Model.
- New advancements were introduced in this year's research:
    - New oxygen sensor added on the CTD probe
    - Expanded the spatial coverage of our measurements
    - For the TELEMAC model the air-water interaction was added

II. CTD Analysis: Methodology

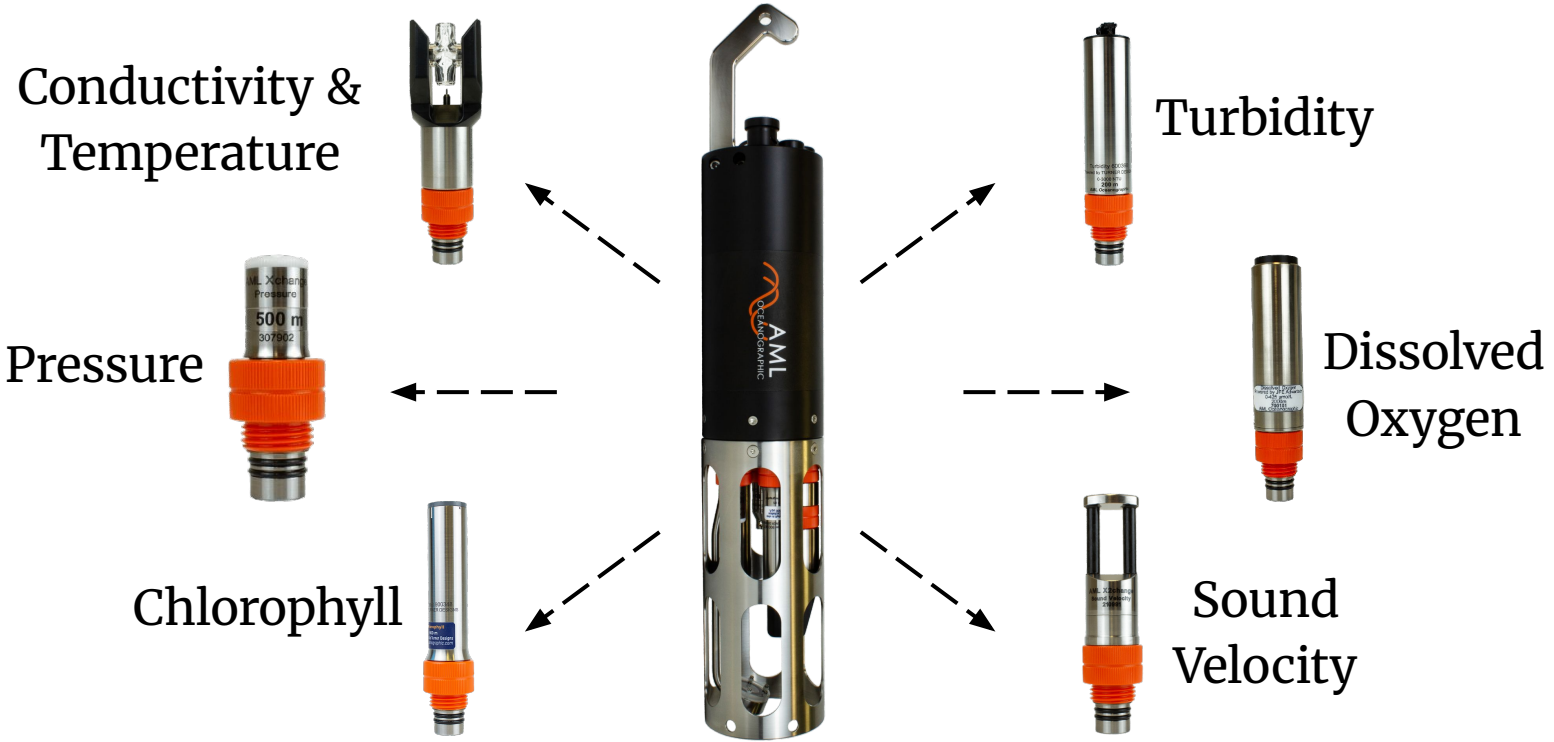


Figure 1 : *AML-6 CTD and the 6 sensors on it.*

II. CTD Analysis: Methodology

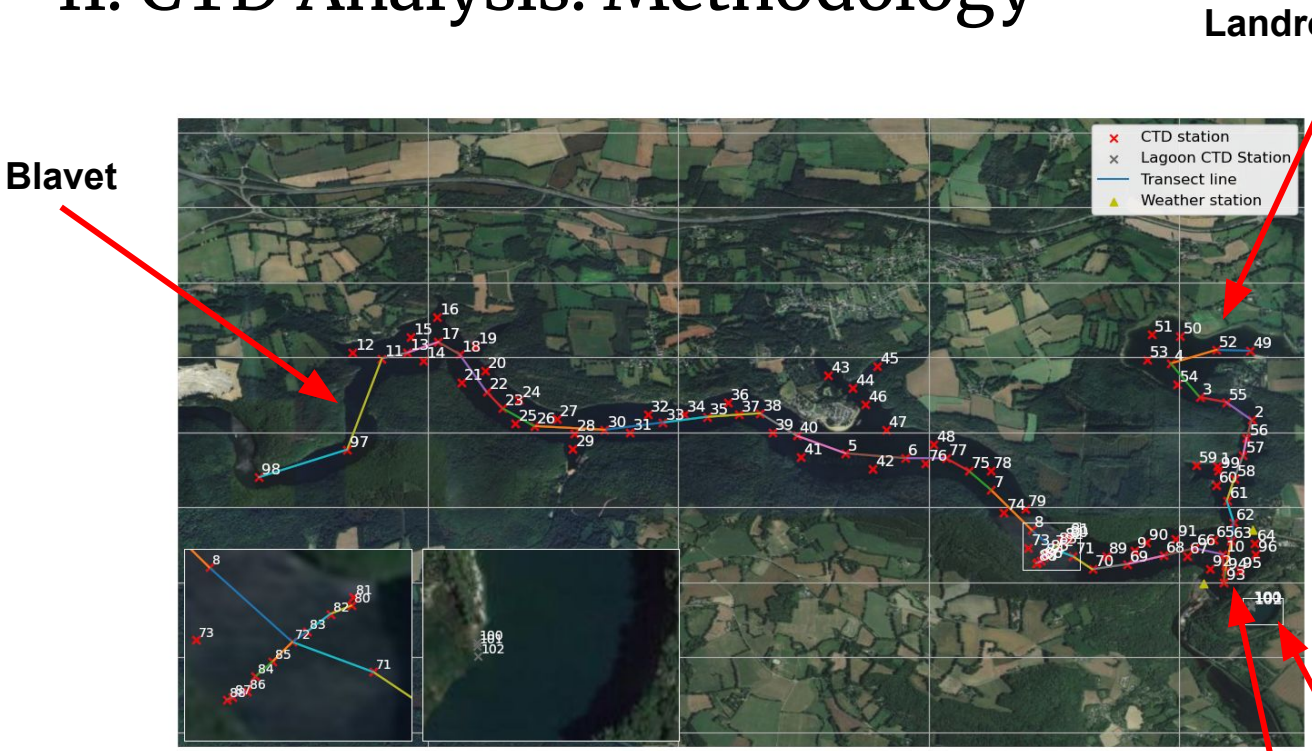
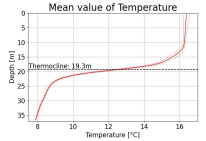
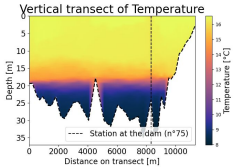


Figure 2 : *Map of Lake Guerlédan. 102 CTD measurements made across the lake in February and 104 in October.*

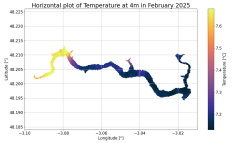
Vertical mean profiles



Vertical transect



Horizontal interpolation



II. CTD Analysis: Methodology

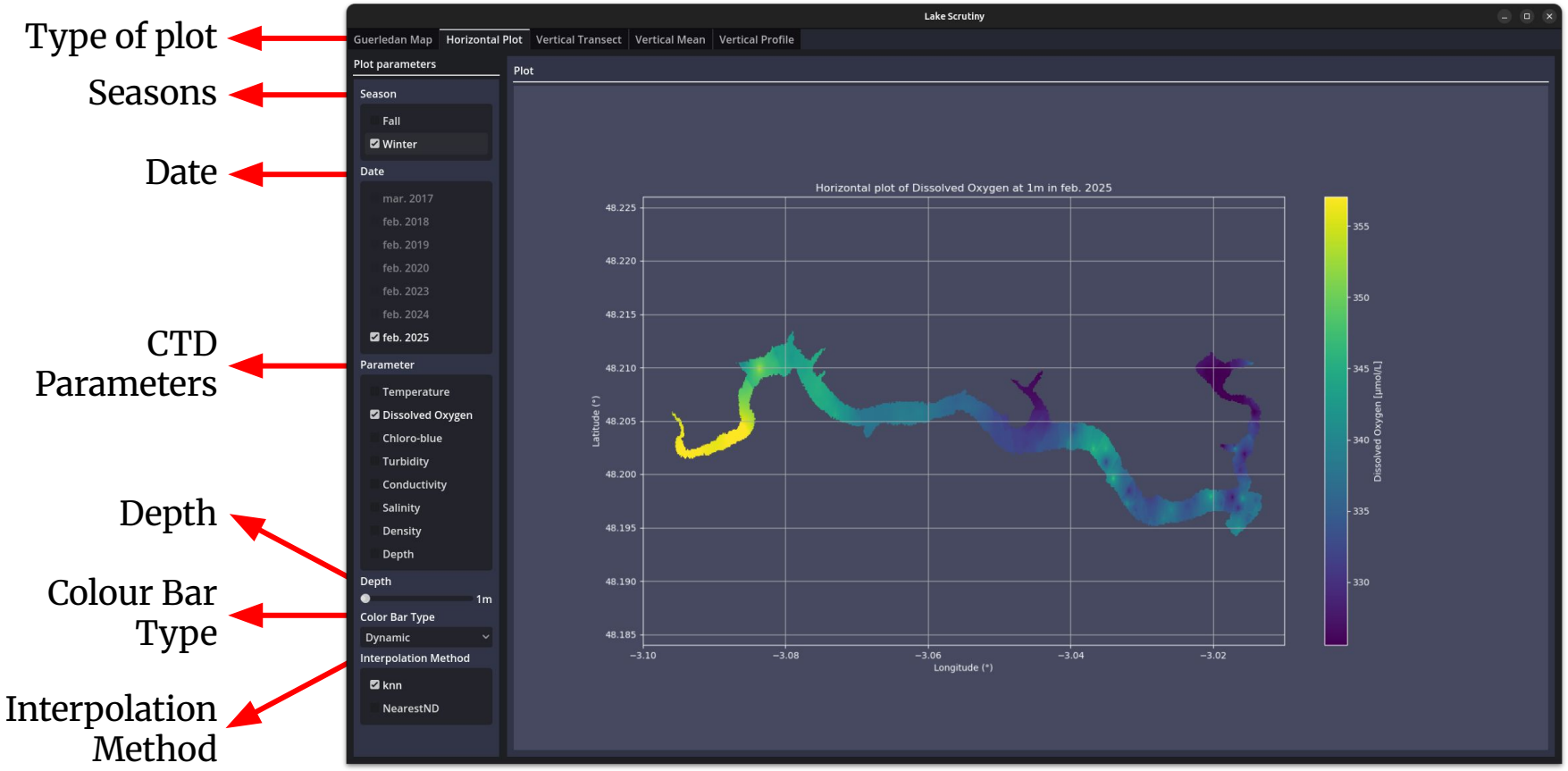


Figure 3 : *Guerlédan Water Quality App*

A. Temperature and DO in October

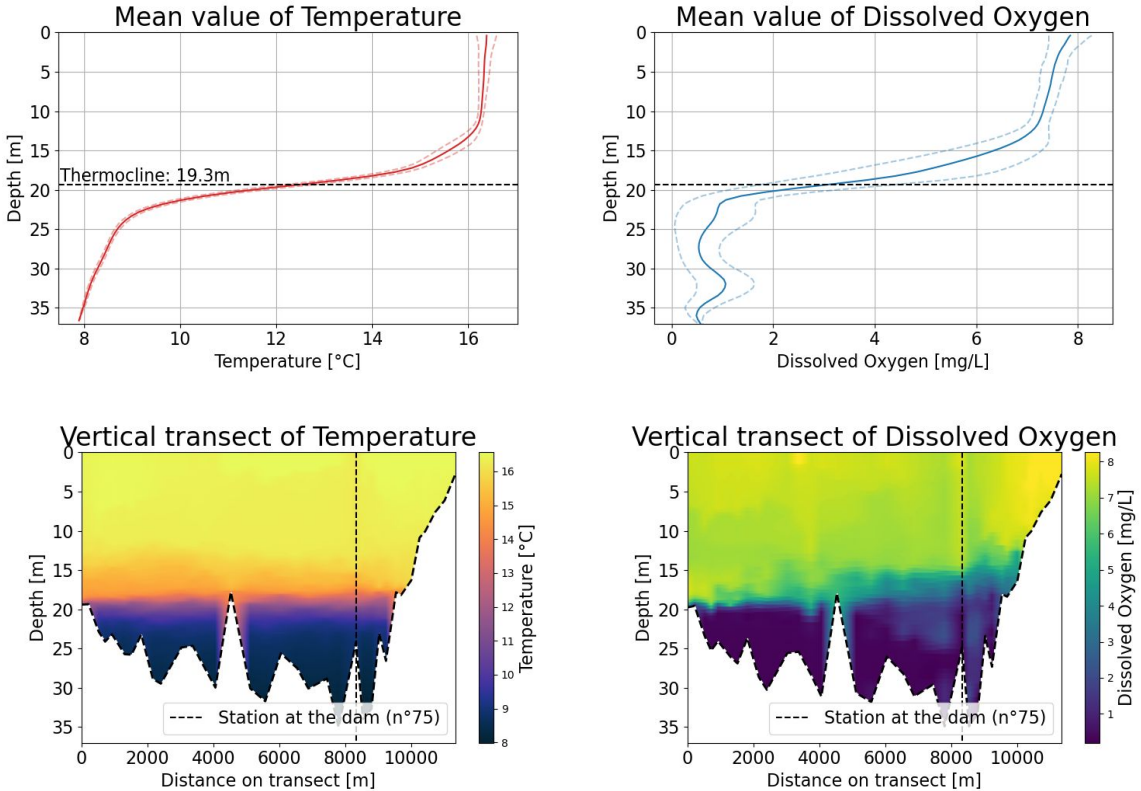
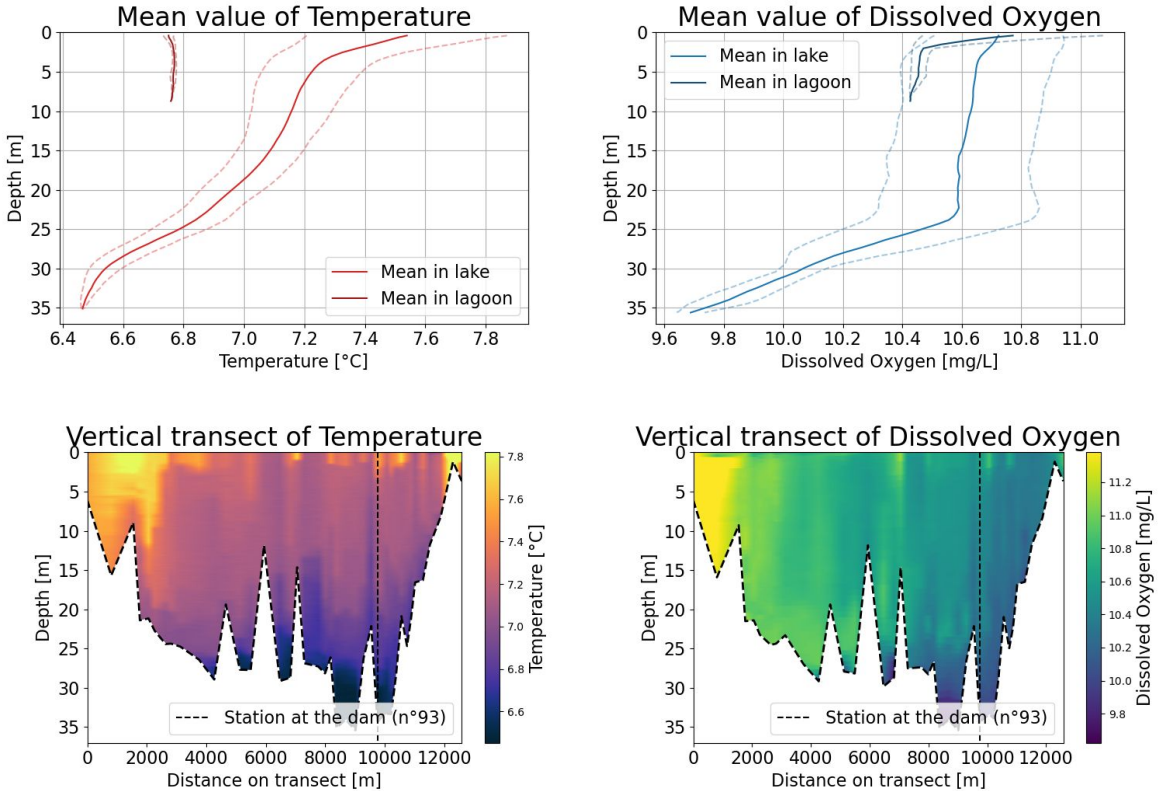


Figure 4 : *Vertical mean profile and transect of temperature and dissolved oxygen in October 2024*

- Stratification
- Oxygen depletion in the lower layer
  ↳Hypoxic (<3mg/L) (CCME, 1999)
- Maximum of oxygen at Landroanec

B. Temperature and DO in February



- No stratification
- Oxygen levels are higher than in October

Figure 5 : *Vertical mean profile and transect of temperature and dissolved oxygen in February 2025*

C. Chlorophyll and Turbidity in October

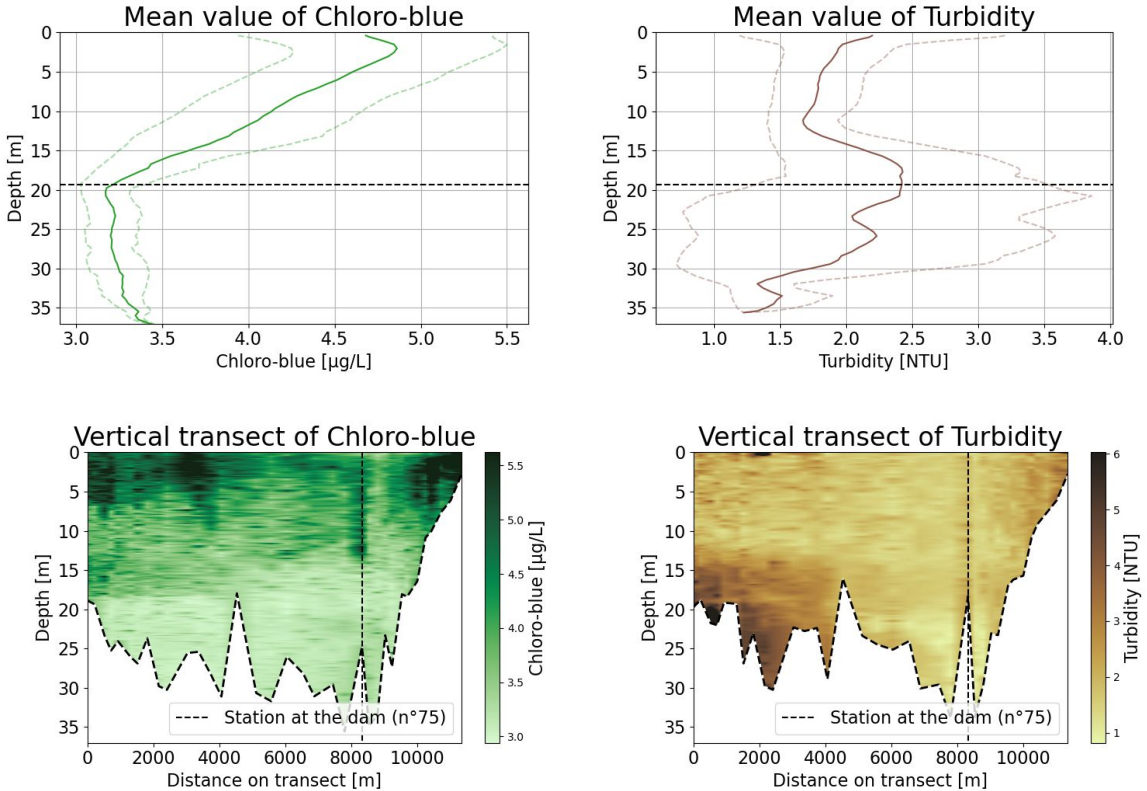


Figure 6 : *Vertical mean profile and transect of chlorophyll and turbidity in October 2024*

- Chlorophyll stratification
  ↳ DO (hypoxic layer)
  ↳ Light (aphotic layer)
- Mesotrophic lake
  ↳CHL 2,5-8 µg/L
  (Istvanovics, 2015)
- Maximum chlorophyll at Landroanec
- Low turbidity (2 NTU)

D. Chlorophyll and Turbidity in February

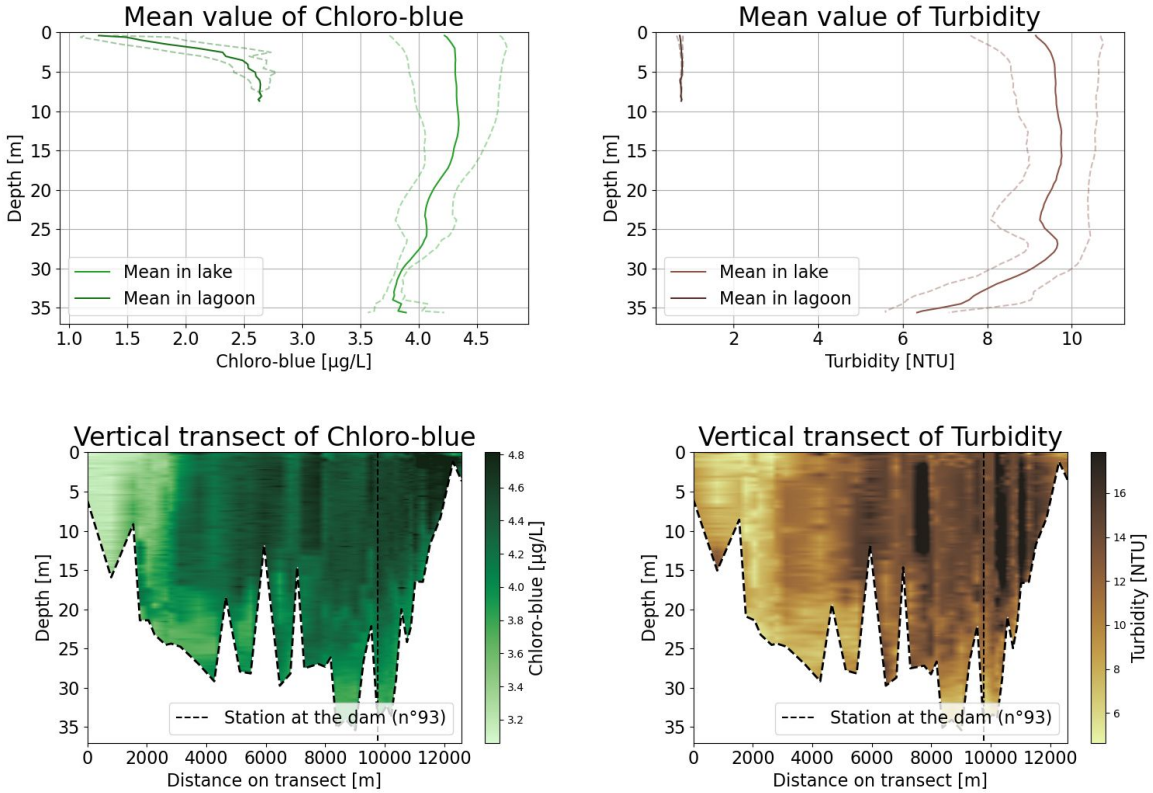


Figure 7 : *Vertical mean profile and transect of chlorophyll and turbidity in February 2025*

- Winter mixing, homogeneity
- Mesotrophic lake
  ↳CHL 2,5-8 µg/L
  (Istvanovics, 2015)
- High turbidity (9 NTU)
- Impact of the Blavet

IV. TELEMAC-3D Temperature Model: Methodology

- **TELEMAC-3D**: Hydrodynamic model that solves Navier Stokes equations

- **Goal** : Model the temperature of the lake with a complete model

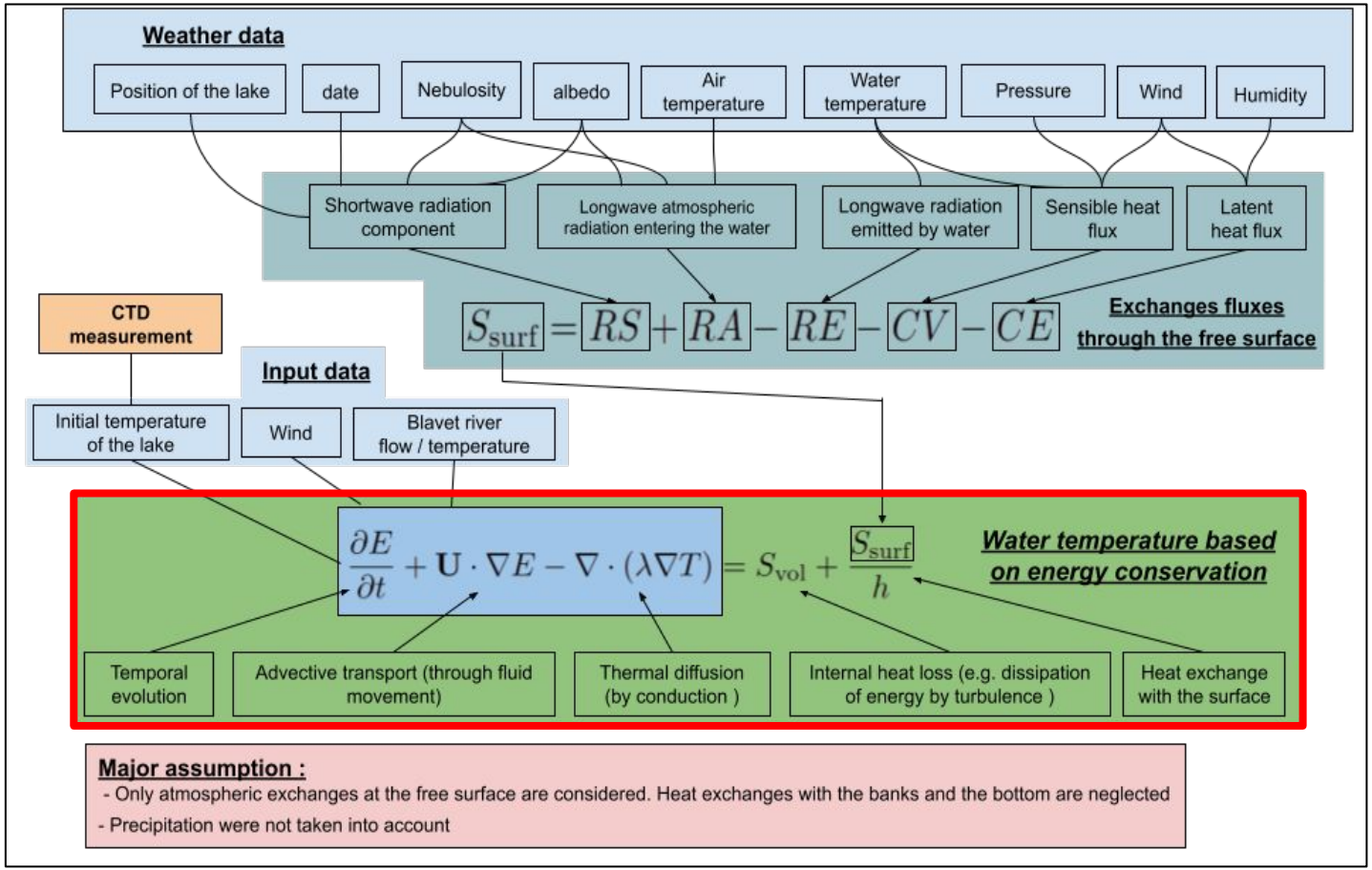


Figure 8 : *Inputs and equations of the Temperature model*

V. TELEMAC-3D Model: Results

- Temperature tracers

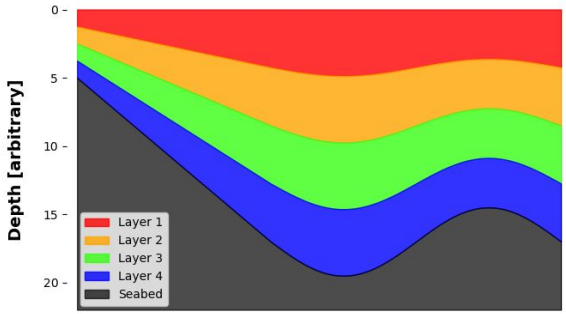


Figure 9 *: Sigma layers.*

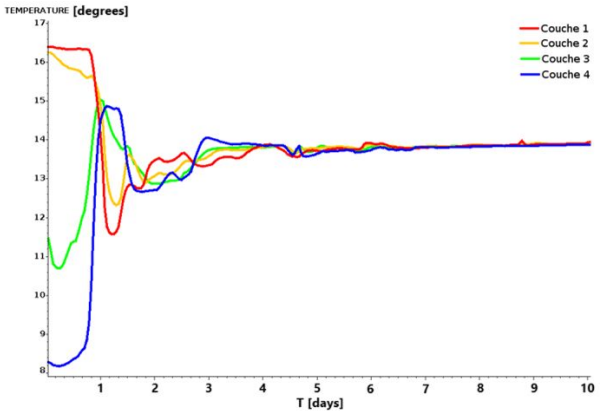


Figure 10 *: Temperature evolution over 10 days - node A - complete model - T Blavet = 16.36 °C*

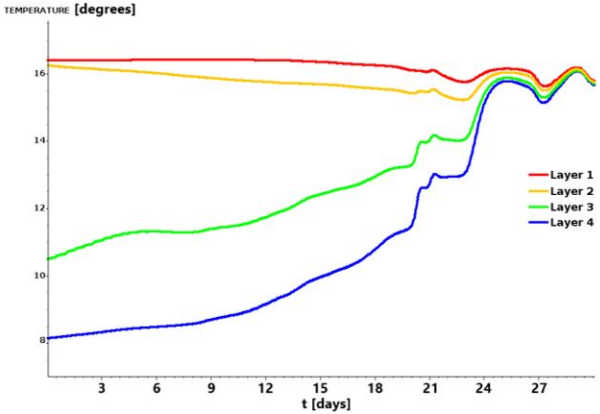


Figure 11 *: Temperature evolution over 30 days - node A - model without wind stress - T Blavet = 16.36 °C*

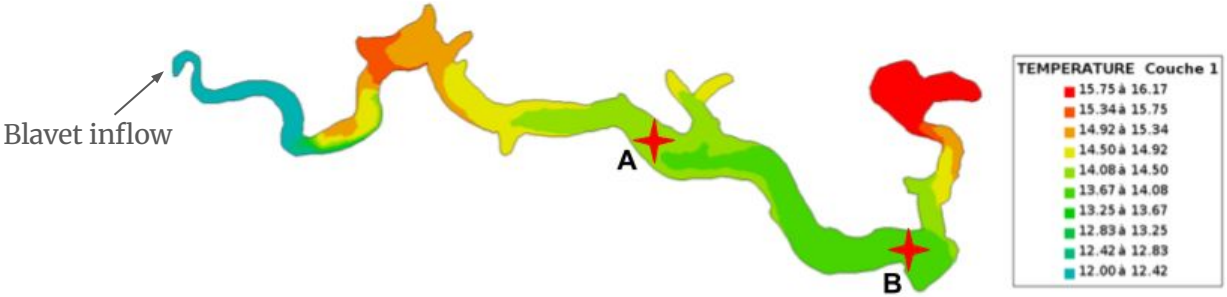


Figure 12 *: Temperature of the upper layer after a 10 days completed simulation - complete model - T Blavet = 12 degrees*

- Limits of our model

VI. Conclusion and Perspectives

- Analysis of temperature, dissolved oxygen, chlorophyll, and turbidity highlighted seasonal and spatial variations across the lake

- TELEMAC model simulated lake temperature dynamics with limitations, resulting in non-realistic results

- Continue measurements
  - pH, nutrients (NO_3, NO_2 and P) which are indicators of eutrophication (Legendre, 1989)
  - see the evolution of DO and other parameters over years

- TELEMAC
  - Get the temperature of the Blavet inflow
  - Calibrate air-atmosphere equations
  - Increase computing power

Table of Figures

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URL:https://www.researchgate.net/profile/Vera-Istvanovics-2/publication/280300164E utrophicationofLakesandRese of − Lakes − and − Reservoirs.pdf

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Thank You !!!

Appendix - Filtering

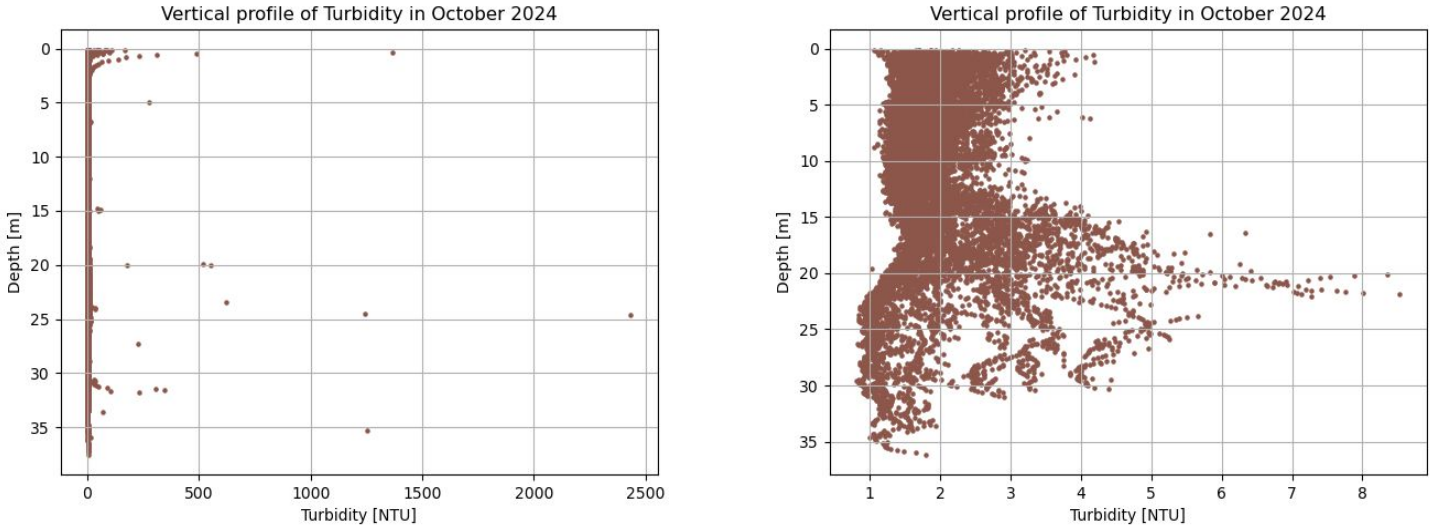


Figure : *Turbidity scatter plot of every station in October 2024 without filtering (Left) and with filtering (right).*

Appendix - Sensor accuracy

Sensor	Temperature	Dissolved Oxygen	Chlorophyll
Range	-5-45 °C	0–425 $\mu mol/L$	0–500 $\mu g/L$
Accuracy	±0.005 °C	±2 % or ±2.0 $\mu mol/L$	±2 %

Sensor	Turbidity	Conductivity	Sound Velocity	Pressure
Range	0–3000 NTU	0-90 mS/cm	1375-1625 m/s	0-100 dBar
Accuracy	±2 % or ±0.2 NTU	±0.01 mS/cm	±0.025 m/s	±0.05 % dBar

Table : *Range and accuracy on each measured parameters*

Appendix - Width transect in February 2025

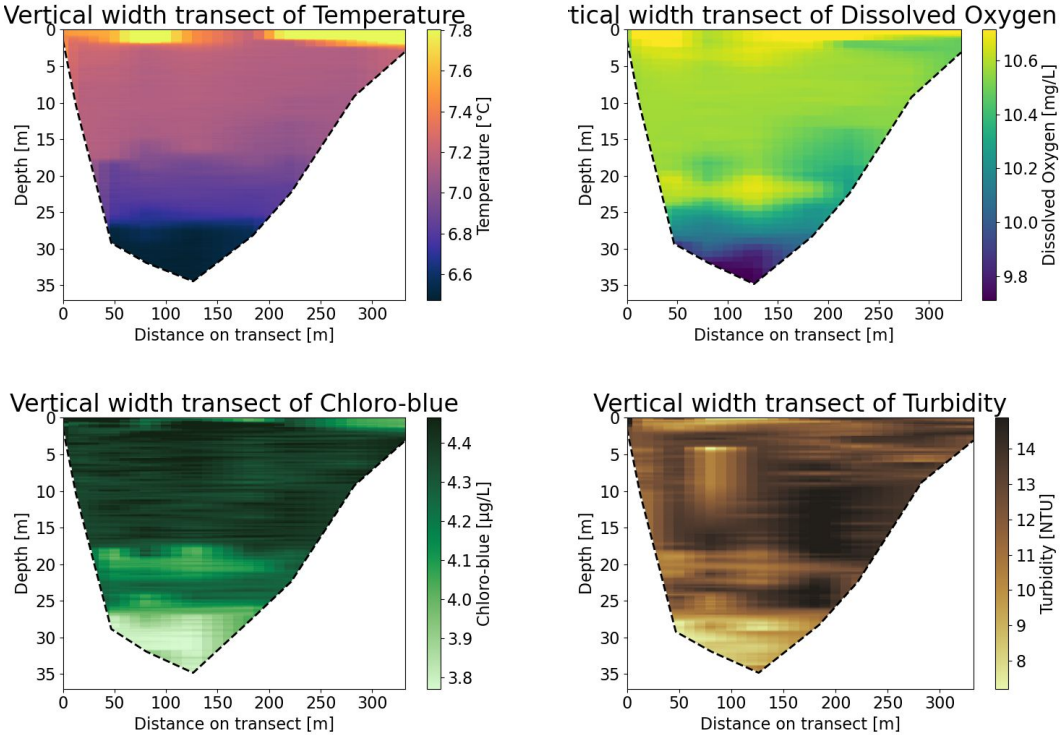


Figure : *Transects of temperature, dissolved oxygen, turbidity and chlorophyll along the width of the lake in February 2025*

Appendix - Horizontal interpolation in February 2025

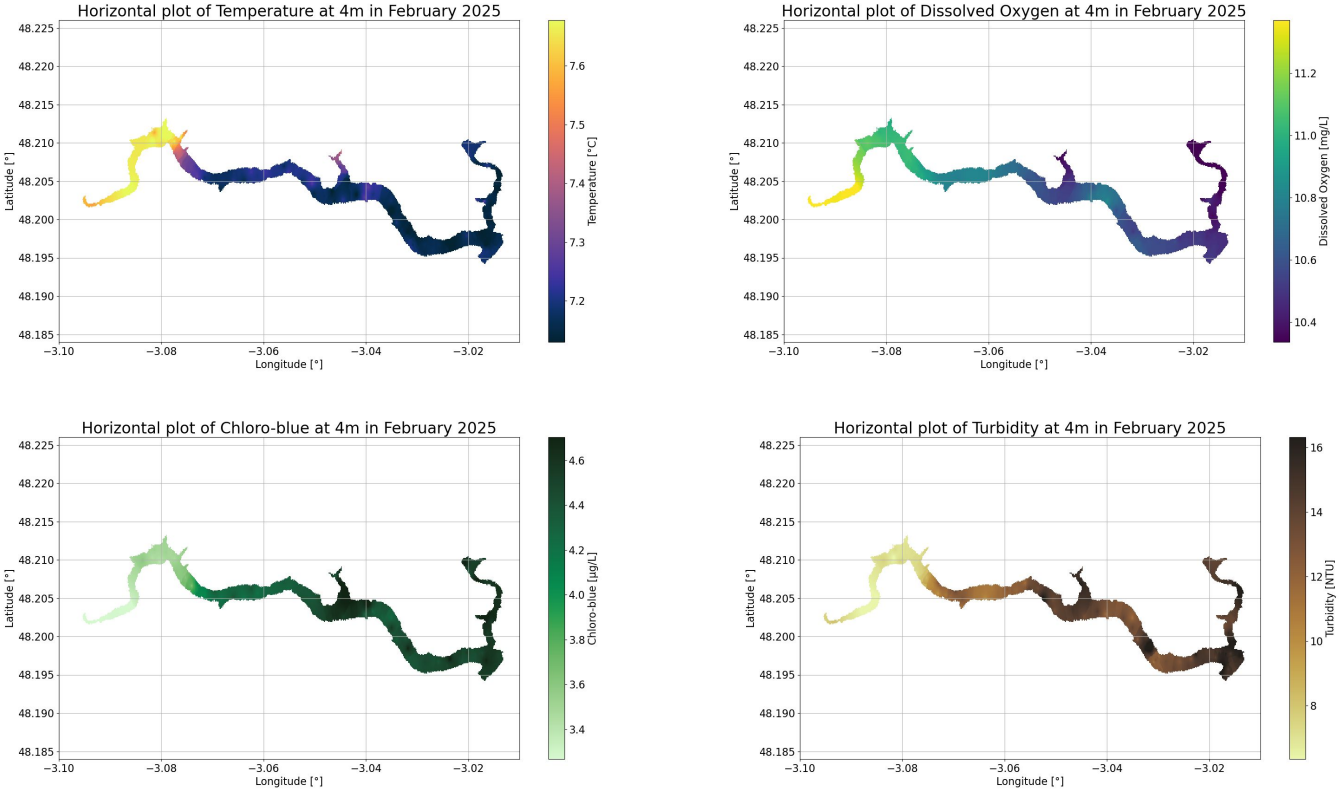


Figure : *Horizontal interpolation of temperature, dissolved oxygen, chlorophyll and turbidity in February 2025 at 4m depth.*

Appendix - Temperature over years

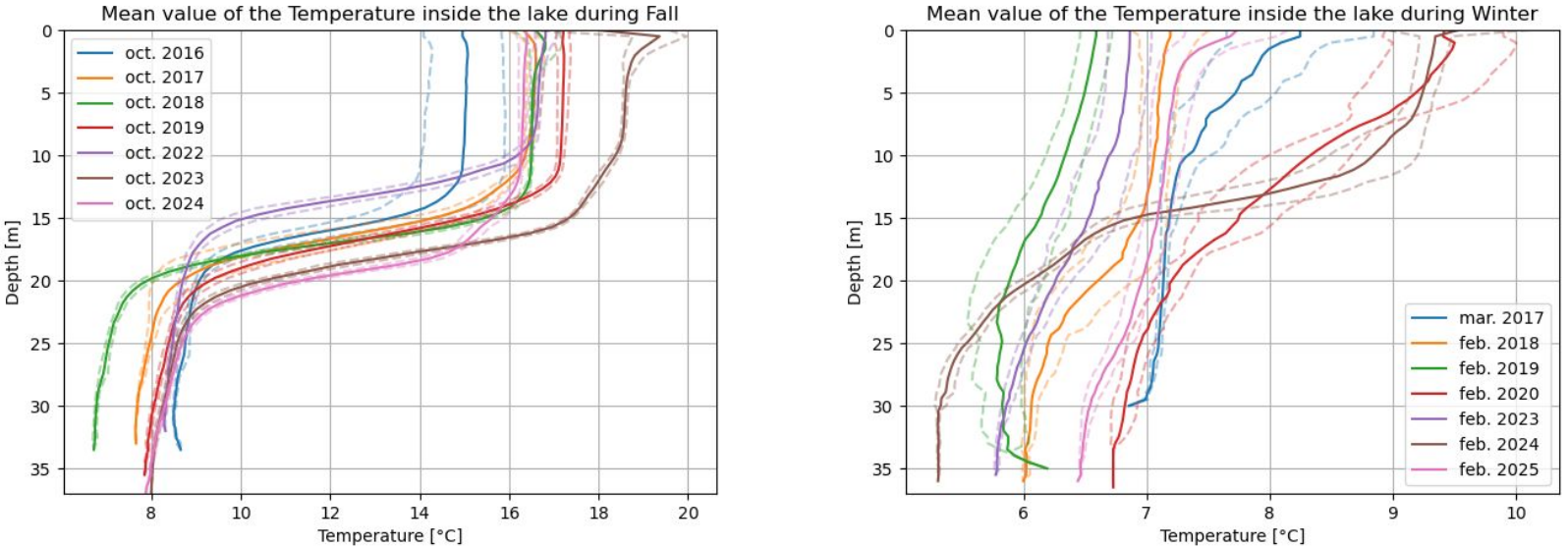


Figure : *Vertical mean profiles of temperature across the entire lake for all recorded autumn (left) and winter (right) seasons throughout the observed years*

Appendix - Evolution of temperature over years

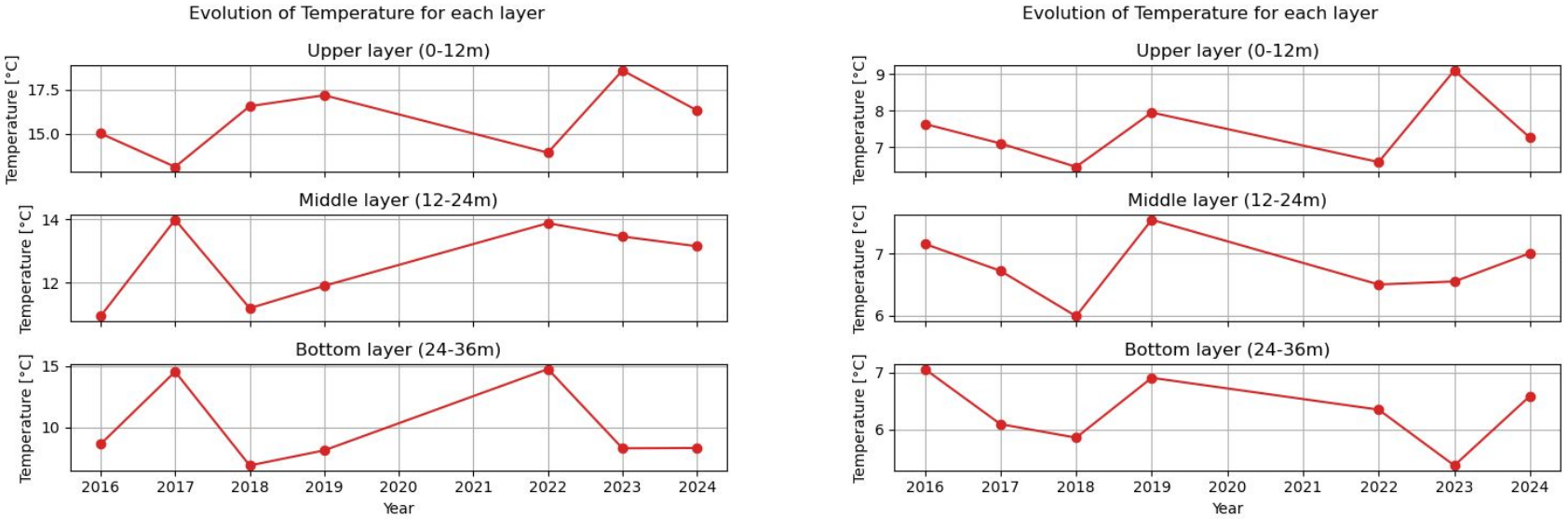
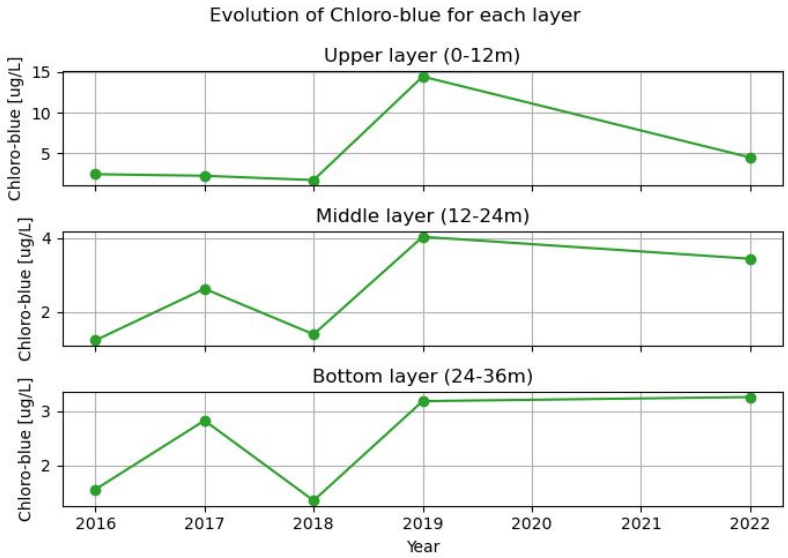


Figure : *Evolution by layer of temperature in October (left), and in February (right)*

Appendix - Evolution of chlorophyll over years



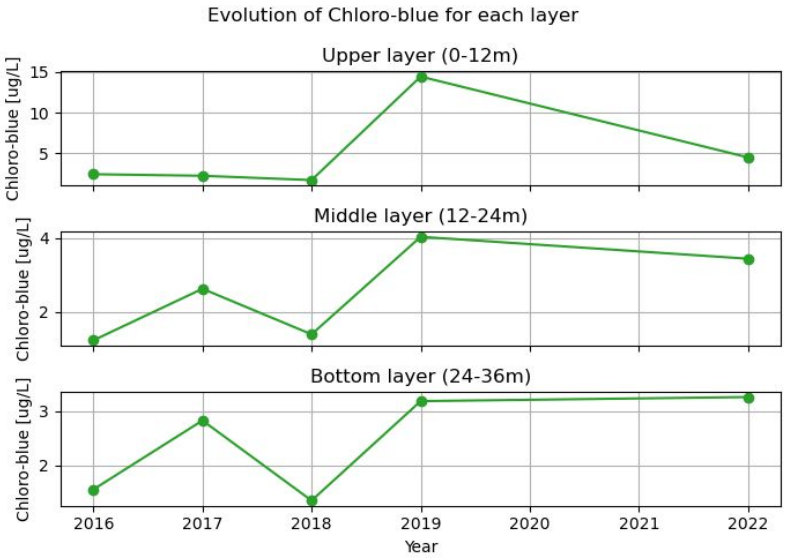


Figure : *Evolution by layer of chlorophyll in October (left), and in February (right)*

Appendix - Evolution of parameters over years

Date	Surface T	Bottom T	ΔT	Thermocline	Chloro-blue	Turbidity
October 2016	15.0°C	8.6°C	6.4°C	16.2m	1.75 $\mu mol/L$	2.61 NTU
October 2017	16.6°C	7.7°C	8.9°C	16.8m	2.12 $\mu mol/L$	2.02 NTU
October 2018	16.5°C	6.8°C	9.7°C	16.8m	1.53 $\mu mol/L$	1.51 NTU
October 2019	17.2°C	8.0°C	9.2°C	16.7m	-	-
October 2022	16.7°C	8.2°C	8.5°C	13.2m	1.80 $\mu mol/L$	2.20 NTU
October 2023	18.6°C	8.0°C	10.6°C	17.7m	7.14 $\mu mol/L$	2.18 NTU
October 2024	16.3°C	7.8°C	8.5°C	19.3m	3.71 $\mu mol/L$	1.93 NTU

Date	Temperature	Chloro-blue	Turbidity
March 2017	7.33°C	2.67 $\mu mol/L$	1.96 NTU
February 2018	6.65°C	4.37 $\mu mol/L$	2.41 NTU
February 2019	6.11°C	1.91 $\mu mol/L$	3.60 NTU
February 2020	7.45°C	-	-
February 2023	6.48°C	1.42 $\mu mol/L$	2.20 NTU
February 2024	7.01°C	4.06 $\mu mol/L$	4.10 NTU
February 2025	6.95°C	4.14 $\mu mol/L$	9.24 NTU

Figure : *Mean value of parameter over years*

Appendix - Eutrophication

Trophic status of a water body can roughly be assessed by using information about the concentration of the limiting nutrient (phosphorus), chlorophyll (an indicator of phytoplankton biomass), and transparency (dependent on both algal biomass and sediment resuspension, expressed as Secchi depth). The most widely accepted limits are those suggested by the Organization for Economic Cooperation and Development (OECD):

Trophic category	*Mean total, P (μg l^{-1})*	*Mean (μg chl-a l^{-1})*	*Max. (μg chl-a l^{-1})*	*Mean Secchi depth (m)*
Oligotrophic	<10	<2.5	<8	>6
Mesotrophic	10–35	2.5–8	8–25	6–3
Eutrophic	>35	>8	>25	<3

Figure : *Istvanovics, V. (2015), Eutrophication of Lakes and Reservoirs, Budapest University of Technology and Economics*

Appendix - Flow rate of the Blavet

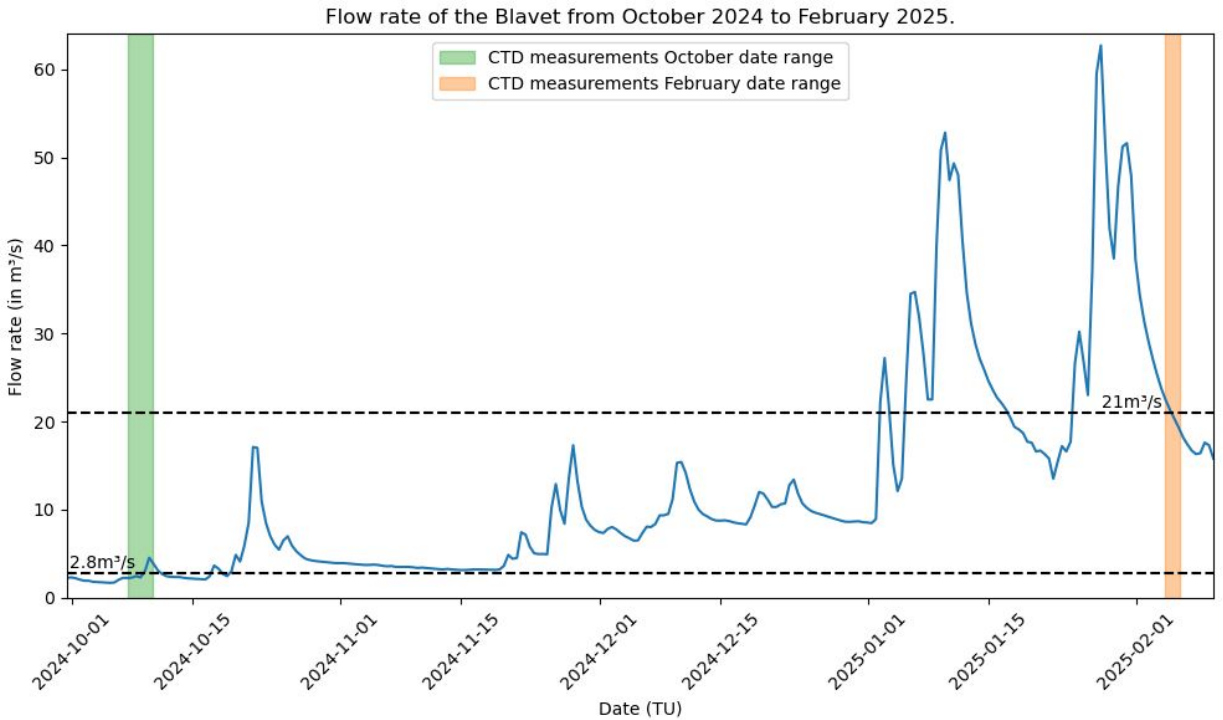


Figure : *Flow rate of the Blavet River from October 2024 to February 2025 (Eaufrance, 2025).*

Appendix - Linearization of the temperature

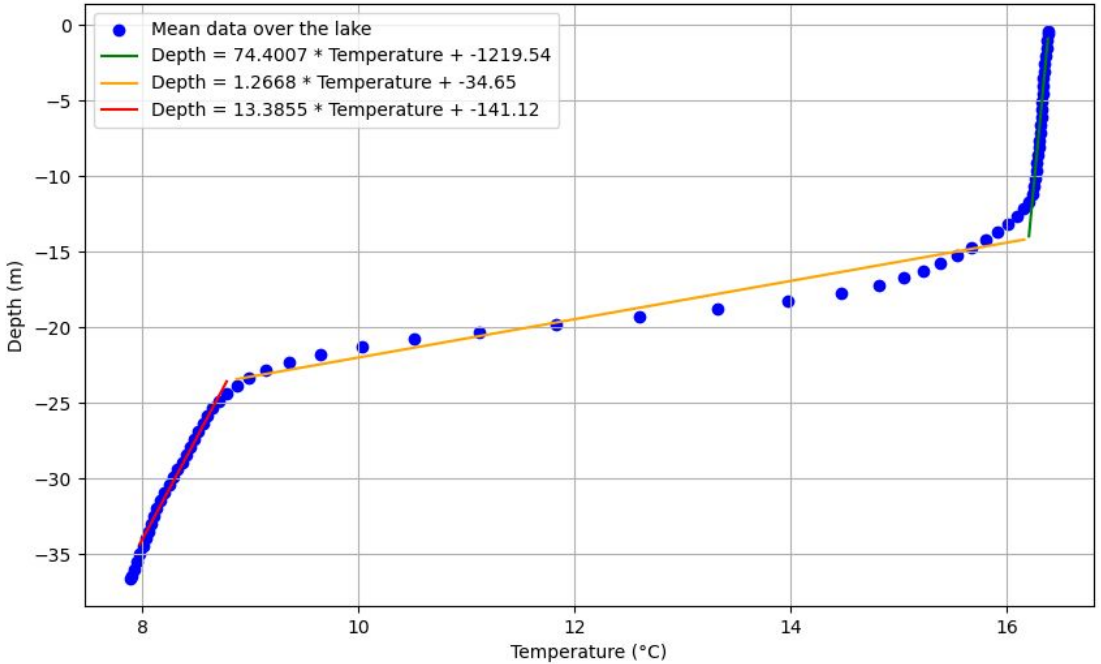


Figure *: Linearization of the mean temperature across the Lake Guerlédan- CTD data - October*

Appendix - TELEMAC water level

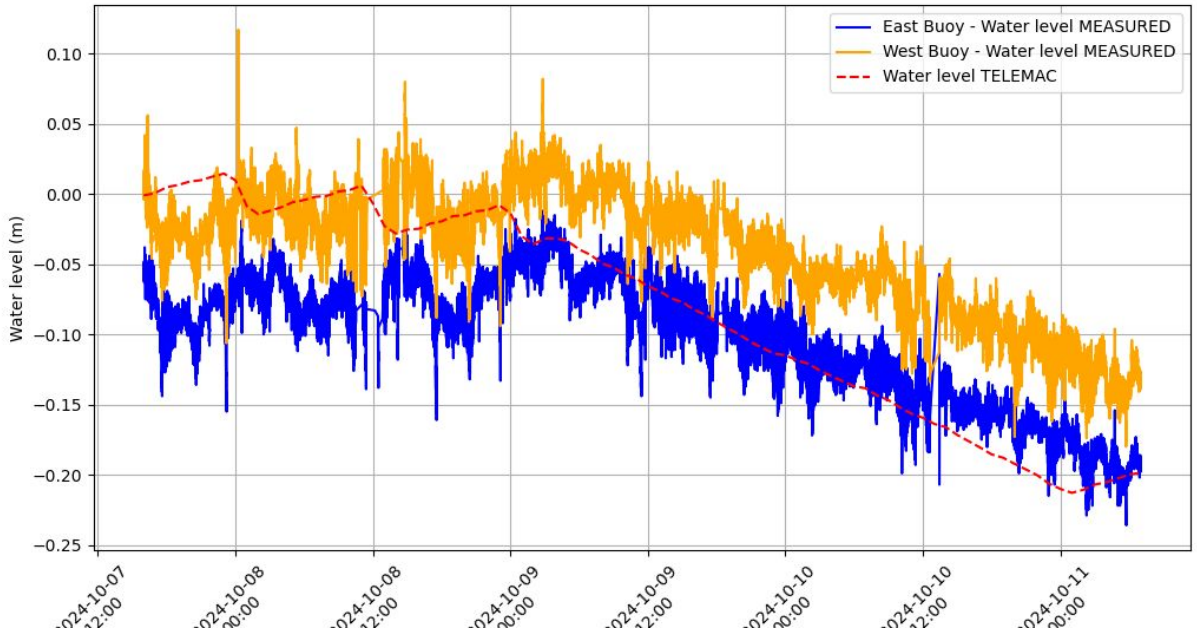


***Figure**: Water level normalized to 0 meters, recorded by two buoys and simulated by the TELEMAC model.*