

LéXPLORE

LéXPLORE Platform

Scientific report

mid-2024 and 2025



Compiled by Laurence Glass-Haller and the project leaders

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Current running projects

1. Pasche Natacha, Glass-Haller Laurence, Odermatt Daniel, Bonny Adrien, Pochelon Alexis, Mader Suzanne, Camus Alexandre. **Lémanscope**. SNSF Agora.
2. Pasche Natacha, Weil Charlie, Solleder Hugo, Macron Yannick, Keller Jérémy, Cunillera Guillaume. **FAIRifying LéXPLORE: enhancing open research data pipelines for Advanced LaKe Science (FLAKE)**. The ORD Program of the ETH Domain.
3. Foroughan Mehrshad, Slater Ellen, Bouffard Damien, Rinnan Riikka, Kohn Tamar. **Volatile Organic Compound (VOC) Dynamics in Lake Geneva (VOLAKE)**. European Marie Curie Postdoctoral project.
4. Romanello Luca, Holdcroft Kevin, Wolfart Gaston, Orr Lachlan, Tuareg Albert, Paoli Lucas, Kovac Mirko. **MEDUSA: multi-robot aerial system for underwater sampling**. Fondation F.-A. Forel (SCNAT).
5. Cusnir Ruslan, Jaccard Samuel. **Measuring the bioavailability of radionuclides in Lake Léman using diffusive gradients in thin films (IRACTINIDES)**. Lab internal funding.
6. Chappellaz Jérôme, Nouvel Armance, Tellier Alexandre, Sbicego Mauro, Lunven Bénédicte, Cruz Hugo, Lavanchy Sébastien. **An open source, low- tech and performant CTD for lakes and oceans (MAKE-CTD)**. Lab internal funding & additional contribution from the MAKE initiative from EPFL.
7. Ludwig Christian, Breider Florian, Rossi Michel, Pick Horst, Wang Yang. **A Physical-Chemical Approach Towards the Assessment of the Degradability of Plastics (Lém-PLAST)**. Swiss governmental funding of the ETH domain (EPFL project GR-LUD 0234), EPFLglobalLeaders (co-funded by European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 945363) and the China Scholarship Council.
8. Khatun Santona, Chappellaz Jérôme, Perga Marie-Elodie, Lavanchy Sébastien, Cruz Hugo, **Nitrous Oxide (N2O) emission from Lake Geneva (LacNox)**. Lab internal funding.
9. Ibelings Bastiaan, Dugenne Mathilde, Thomas Mridul, Fillion Roxane, Gios Matteo, UNIGE Master students, Carratalà Anna, Muscas Irene, Janssen Elisabeth. **Algal blooms in Lake Geneva facing global changes: from a better understanding of the ecology of harmful and potentially toxic species to preserving good water quality and lake ecosystem- services through the development of decision tools (ALGA)**. INTERREG
10. Perga Marie-Elodie, Devkota Nischal, Sanoza Wyndel. **Quantifying the Zooplankton link in lakes: Lake GENEva as a sandbox (GEN-Z)**. SNSF.
11. Gindro Katia, Köhler Thilo, Queiroz Emerson Ferreira, Wolfender Jean-Luc, Schnée Sylvain, Marcellin-Gros Rémy, Bory Alexandre, Luscher Alexandre, Lecoultré Nicole, Albert Arthur. **Fungi and bacteriophages from lake sediments (MycoMediX)**. SNSF.
12. Chappellaz Jérôme, Lavanchy Sébastien. **Tests and improvements of the SubOcean probe (SubOcean++)**. Lab internal funding.

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13. Tellier Alexandre, Lavanchy Sébastien, Chappellaz Jérôme. **Design and construction of a probe for continuous monitoring of dissolved CO₂ in seawater from a sailboat or a small ship (SENSE-pCO₂).** Lab internal funding.
14. Rossi Pierre, Oppliger Emmy. **Quantification of Quagga mussels within the EPFL water cooling system (QuagPlore).** EPFL-VPO.
15. Morales Lisa, Gios Matteo, Ibelings Bastiaan. **Asterionella chytrids (Asterionella).** SNSF.
16. Bürgmann Helmut, Bouffard Damien, Rathinavelu Sasikaladevi. **Antimicrobial Resistance Tracking and Fate modeling in the Urban flows – Lake interface (ARTFUL).** SNSF.
17. Pasche Natacha, Bouhali Armelle, Courtois Marc-Antoine, Noël du Payrat Louise, Cunillera Guillaume: **Dynamics of the settling particulate matter in Lake Geneva (Lake Snow).** ENAC call for equipment and Lab internal funding.
18. Neronov Andrii, Kneib Jean-Paul, Shutska Lesya, Bernard Florian, Lesrel Jean, Haefeli Guido. **LAC TElescope (LACTEL).** SNSF.
19. Jézéquel Didier, Paris Jean-Daniel, Lozano Mathis, Ruffine Livio, Fandino-Torres Olivia, Grilli Roberto, Chappellaz Jérôme, Mettra François, Perga Marie-Elodie, Berg Jasmine, Khatun Santona: **High-frequency monitoring of CO₂ and CH₄ fluxes at LéXPLORE station by combining different methods (CarboLéX).** PEPR Carbonium.
20. Breider Florian, Hanahan Jonathan, Vernez Karine, Coudret Sylvain, Loizeau Jean-Luc: **Deposition and Accumulation of Microplastics in Lake Sediments (Microsed).** Limnology Center then Lab internal funding.
21. Weyermann Céline, Estoppey Nicolas, Pfeiffer Fabienne, Glanzmann Vick, Reymond Naomi, Huisman Sofie. **Aqua-Gabs/MONET in Lake Lemman (Aqua-Gabs).** Network Research Centre for Environmental Chemistry and Ecotoxicology.
22. Pasche Natacha, Cunillera Guillaume, Dubois Nathalie, Janssen David: **Temporal and spatial variations of the settling particles fluxes in Lake Geneva (SEDTRAP).** Lab internal funding
23. Odermatt Daniel, Werther Mortimer, Wydler Jonas, Rahaghi Abolfazl Irani, Damm Alexander, Tofield-Pasche Natacha, Alikas Krista, Soomets Tuuli, Spyarakos Evangelos: **Monitoring Lake Primary Production using the PACE satellite (Lake3P).** SNSF.
24. Brunetti Maura, Babanin Alexander, Kasparian Jérôme: **Wind2Waves.** Lab internal funding.

Completed projects

25. Bouffard Damien, Gil Coto Miguel, Lavanchy Sébastien, Fernandez Castro Bieito, Doda Tomy : **Autonomous turbulence profiling (LéWalk).** Lab internal funding.
26. Vennemann Torsten, Mottet Lucia, Lutz Samuel, Miesen Floreana. **Rhône River Intrusion and Interflow Dispersion of Nutrients and Organic Matter in Lac Léman (RIDDLE).** Lab internal funding
27. Mori-Bazzano Laureen, Ibelings Bastiaan Willem: **Characterization of Biofilm formation on**

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different types of plastic substrate (Plastisphere). Lab internal funding.

28. Khatun Santona, Berg Jasmin, Perga Marie-Elodie: **Measurement of methane oxidation rate to understand the greenhouse gas emission from Lake Geneva (MethOx).** Lab internal funding

29. Escoffier Nicolas, Keller Jérémy, Khatun Santona, Herr Isabel, Perga Marie-Elodie: **Calcite precipitation dynamics in Lake Geneva (CALCIGEN).** Lab internal funding.

Cancelled projects

30. Perga Marie-Elodie, Dittrich Maria: **Carbonates living factories using cyanobacteria from Lake Geneva (Carbonates).** Lab internal funding.

Ongoing projects without report

31. Mariethoz Gregoire, Koch Erwan, Berne Alexis. **Installation of a drip-based rain gauge on LéXPLORE (RainGauge).** Lab internal funding.

Completed projects without report

32. Adam Nicolas, Selz Jonathan, Lecine Sofian, Hirt Timothée, Deloose Christophe, Bernier-Latmani Rizlan, Maerkl Sebastian. **An automated instrument for water sampling and DNA extraction (GenoRobotics).** Limnology Center then the EPFL Make Project.

33. La Valle Florybeth, Strong Aaron, Jacobs Julian. **Quantification of Lake Geneva biological metabolism and validation of novel pCO₂ sensor system (SIPCO₂).** Lab internal funding.

34. Ibelings Bastiaan, Thomas Mridul, Fillion Roxane, Mesman Jorrit, Devanthery Matthieu, de Loes Sebastien, MUSE-Master students, Müller Beat. **POETICS - PlanktOn vErTICAL Structure**

35. Bakker Eric, Forrest Tara, Zdrachek Elena, Damala Polyxeni, Cherubini Thomas. **Submersible Probe with In-line Calibration and Symmetrical Reference Element for Long-term Continuous Measurement of Environmentally Relevant Ions (Multiple ion)**

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Lémanscope

Natacha Pasche, Laurence Glass-Haller, Daniel Odermatt, Adrien Bonny, Alexis Pochelon, Suzanne Mader-Feigenwinter, Alexandre Camus

Satellite remote sensing of inland water quality relies on in situ data for validation, yet lake-wide observations are often sparse. In Lake Geneva, the Lémanscope citizen science project (2024–2026) addresses this gap by engaging citizens to collect water colour and transparency measurements using Secchi disks and a mobile app, EyeOnWater, in collaboration with EAWAG, the Association pour la Sauvegarde du Léman and UNIL.

Launched in April 2024, the project has enrolled ~700 participants and distributed over 250 Secchi disks, supported by workshops, public events, and activities at the LéXPLORE platform. Since the beginning of the project, more than 3500 measurements have been collected, providing unprecedented seasonal and spatial coverage of Lake Geneva. After a simple, referential quality control that included the removal of records located outside lake boundaries, records with timestamps outside of daylight hours, or Secchi depths exceeding local bathymetry, 2408 measurements were validated and compared with concurrent Sentinel-3 satellite observations.

This study shows that these data significantly improve satellite validation: comparisons with Sentinel-3 reveal best agreement for Secchi depths of 3–10 m, with reduced performance in very clear waters. The dataset also highlights consistent limnological gradients across basins, pelagic versus littoral regions zones, and between lake shores.

Overall, Lémanscope demonstrates that quality-controlled citizen science, when combined with high-frequency observations from the LéXPLORE platform (<https://www.datalakes-eawag.ch>), can strongly enhance satellite validation, reveal ecological patterns beyond traditional monitoring, and strengthen connections between science and society.

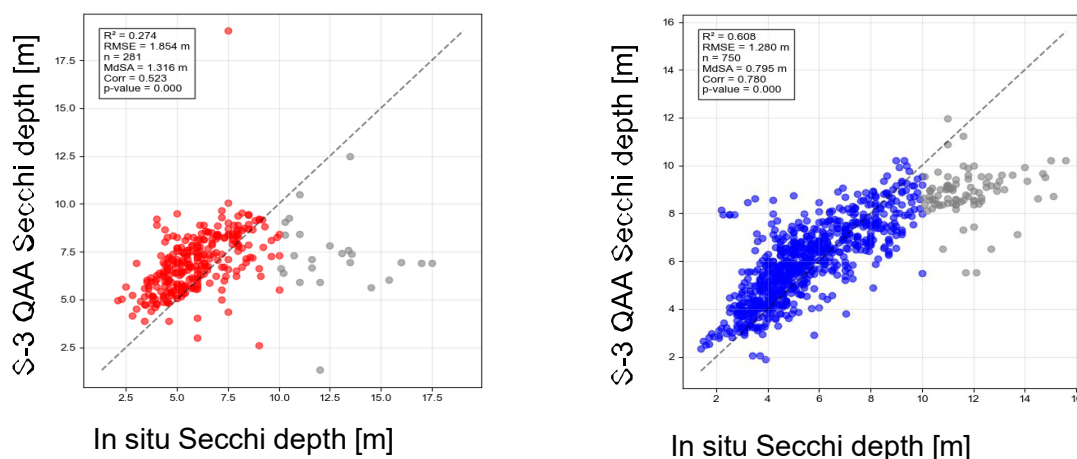


Figure: Matchup validation for measurements in the Grand Lac (blue) and the Petit Lac (red), showing decreasing algorithm performance in smaller basins. In situ Secchi depths larger than 10 m (grey) are excluded from analyses due to known Polymer/QAA product limitations.

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FAIRifying LéXPLORE: enhancing open research data pipelines for Advanced LaKe Science (FLAKE)

Natacha Pasche, Guillaume Cunillera, Jérémy Keller, Hugo Solleder, Charlie Weil, Yannick Marcon, James Runnals, Damien Bouffard

The FLAKE project has strengthened the LéXPLORE data pipeline and established a robust, collaborative framework for quality control of open lake data. Over 2025, the team transitioned almost all instruments from an on-site computer to a cloud-based SFTP infrastructure at Eawag, added automated monitoring and alerts, and clarified responsibilities from field collection to publication in Datalakes.

On the quality side, a new QA/QC tool was co-designed with the LéXPLORE community and fully embedded in Datalakes, to ensure long-term maintenance and reliability. Each dataset now has an assigned data curator and data advisor, supported by a formal data cleaning policy and documentation, enabling interactive flagging, correction, and validation directly in Datalakes.

Community engagement was a central achievement, with two co-design workshops and dedicated data clean-up days that tested the tool and built a motivated network of “data cleaners” around LéXPLORE. Regular monthly meetings continue beyond the funding period to sustain cleaning efforts.



Figure: FLAKE participants enjoying a kayak excursion on Lake Thun during the data clean-up days in Spiez.

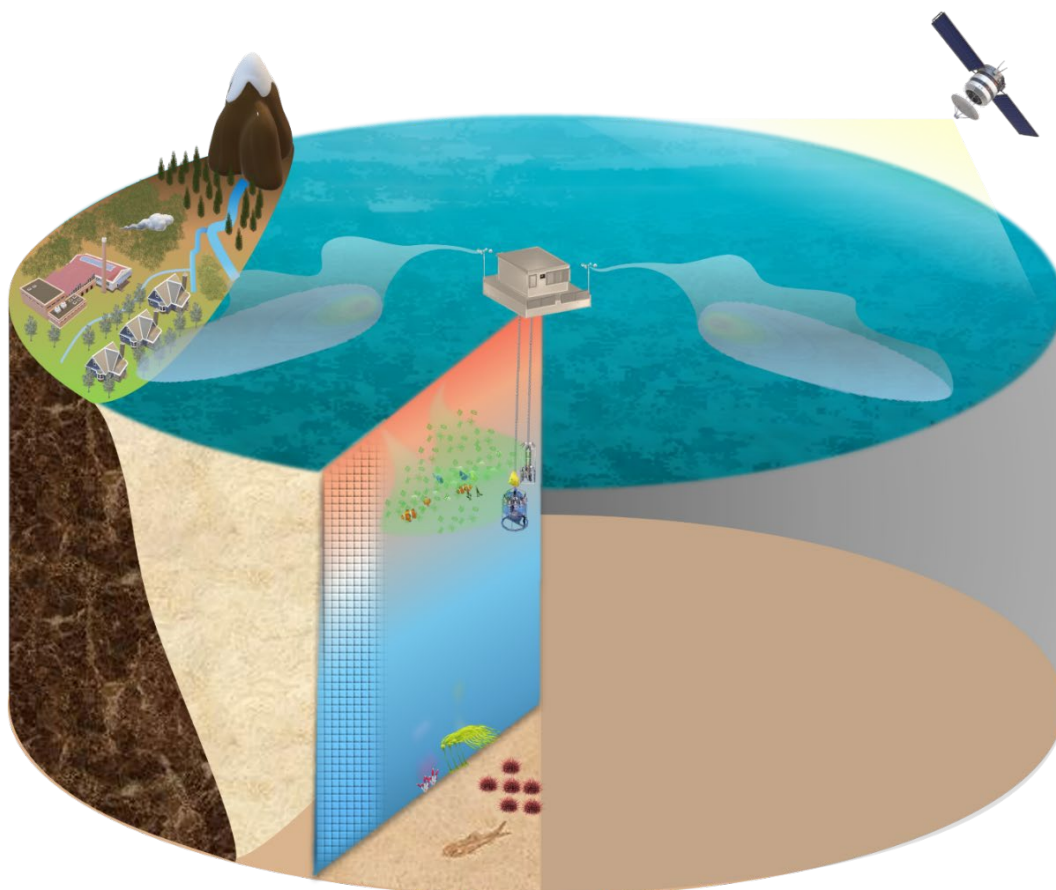
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Volatile Organic Compound (VOC) Dynamics in Lake Geneva

Mehrshad Foroughan, Damien Bouffard, Riikka Rinnan

This project will investigate volatile organic compounds (VOCs) in Lake Geneva. The dynamics of these short-lived trace gases remain poorly understood in freshwater ecosystems despite their crucial role in atmospheric chemistry, air pollution, and ecological interactions. The project aims to:

1) quantify lake-atmosphere VOC exchange using eddy covariance setups; 2) characterize their vertical distribution in the water column, linking it to physical and biogeochemical processes; and 3) develop models connecting lake volatiles to ecological health indicators for monitoring. This work exceeds current research by providing comprehensive temporal coverage of diverse VOCs, examining high-resolution time-depth dynamics, and integrating physical processes with ecological indicators. The results will enhance understanding of freshwater biogeochemical processes and air-water interactions and establish innovative aquatic monitoring practices using VOC variability as a key ecosystem health indicator.



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Multi-Environment Dual-Robot for Underwater Sample Acquisition (MEDUSA)

Gaston Wolfart, Kevin Holdcroft, Luca Romanello, Lachlan Orr, Albert Taureg, Mirko Kovac

The MEDUSA drone, developed by the Laboratory of Sustainability Robotics (LSR) at EPFL and Empa, enables the monitoring and sampling of water in dangerous or difficult to reach areas. The latest version of MEDUSA was field tested in Greenland as part of the Forel expedition last August. This successful field test enabled us to validate the technology and obtain valuable learnings regarding the conditions, operational challenges and potential improvements for the MEDUSA. This expedition and the results will be the subject of a forthcoming publication.

The goal of the MEDUSA drone on board the LéXPLORE is twofold: it serves as a real-life testing ground for the development of this novel sampling/monitoring technology and it extends the capabilities of the platform to enable sampling in a semi-automated manner at an extended range.

The MEDUSA aboard the LéXPLORE will be able to sample 1 Liter and perform Conductivity Temperature and Depth (CTD) measurements up to 30 meters deep. Additionally, drone-based sampling will enable faster and more accurate locational sampling, compared to using a boat and sampling by hand.

The new sampling system, based on purpose-designed Niskin bottles, are aimed to be tested in December 2025 and the full integration with the drone system will be carried out during 2026.

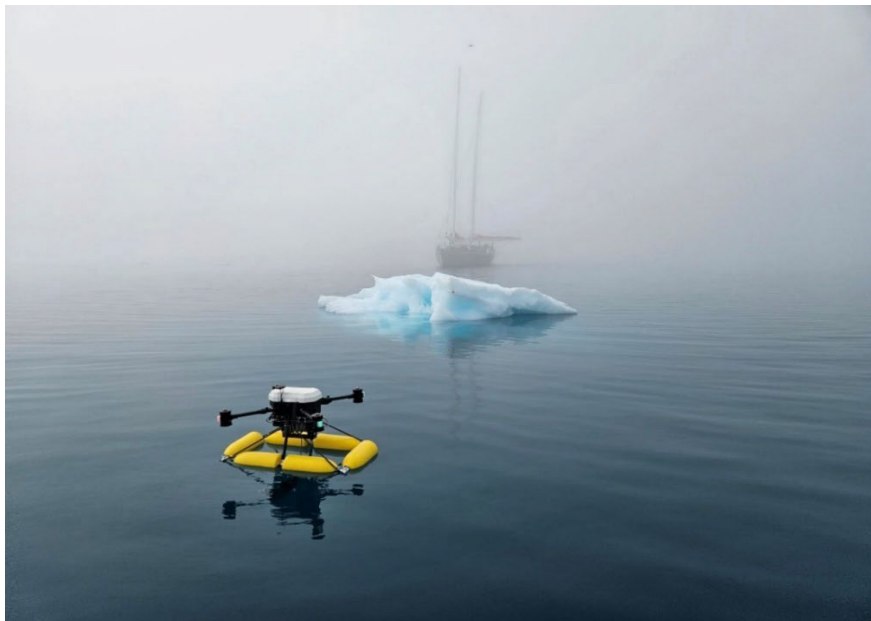


Figure: MEDUSA drone during the Greenland expedition summer 2025, with the Forel sailboat in the background.

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Measuring natural radionuclides in Lake Léman (irActinide)

Ruslan Cusnir

Lake Léman provides important water resources to the Swiss and French society. Radioactive isotopes of uranium (U) and thorium (Th) series, and their descendants, are ubiquitous in the environment and can provide valuable information on diverse hydrogeological processes in lakes. Traces of anthropogenic radionuclides such as plutonium (Pu) and americium (Am) are also found in Lake Léman as a result of the global atmospheric fallout from nuclear weapons testing.

The aim of this project is to determine geochemical background concentrations of natural uranium isotopes (U-238, U-234, U-235) and anthropogenic uranium isotopes (U-233 and U-236), as well as radium isotopes (Ra-226), at different depths in Lake Léman. In addition, we are testing **Diffusive Gradients in Thin films (DGT)**, a passive sampling technique that enables measurement of labile radionuclide fraction averaged over time.

Natural radionuclides are leached from Alpine rocks and supplied to Lake Léman by Rhône River. This results in uranium concentrations approximately three times higher than in comparable freshwater lakes. In a pilot study carried out in summer 2025, we determined the concentrations of ^{238}U and ^{226}Ra in water sampled at the surface, at 10 m, and at 105 m depth. The measured ^{238}U concentration was approximately 30 mBq L^{-1} in all samples and conserved across all depths. This concentration also agreed with earlier measurements and values reported in the literature. The concentration of natural ^{226}Ra was approximately 2 mBq L^{-1} and similarly uniform throughout the depth profile.

The measurement of anthropogenic Pu and Am using DGT technique was attempted for the first in Lake Léman. The concentrations determined in DGT samplers were close to laboratory background in levels. This indicates that the DGT setup applied in this experiment, particularly the binding phase, was likely inadequate for accurate determination of these radionuclides in the freshwater environment of Lake Léman.



Figure: DGT samplers consist of a plastic housing containing a plate with a diffusive gel that allows only labile species to reach the underlying binding resin.

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MAKE-CTD - An open source, low- tech and performant CTD for lakes and oceans

Armance Nouvel, Sébastien Lavanchy, Jérôme Chappellaz, Hugo Cruz, Bénédicte Lunven, Alexandre Tellier

Sailowtech (<https://sailowtech.ch/>) is an association and an EPFL MAKE project that aims to raise awareness about environmental issues, particularly those related to aquatic environments. It promotes frugal and citizen field science, open-source science, and a “tech under constraint” or low-tech approach. To achieve this, Sailowtech organizes scientific sailing expeditions on lakes, seas, and oceans, allowing students to discover field science and to test the protocols and devices they build during semester or Master projects.

One of the current initiatives is the construction of a CTD (Conductivity–Temperature–Depth) probe, which measures the electrical conductivity, temperature, depth, and dissolved oxygen (DO) of water. This instrument is fundamental to oceanographic research, providing essential metadata. The Sailowtech CTD is designed to be low-tech, open-source, sustainable, and practical. This project has been developed in partnership with the SENSE laboratory.

From February to June 2023, EPFL Master student Alexandre Tellier designed and built the first version of the CTD and conducted initial tests on the LéXPLORE platform.

Armance Nouvel was responsible for characterizing the sensors before validating and moving on to the prototyping of Version 2 of the instrument. A few comparison tests were carried out in spring 2025 between the Sailowtech CTD (equipped with different type of Atlas Scientific sensors), and a commercial RBR CTD measuring the same parameters.

Augustin Lecuit (EPFL, Sailowtech) has just taken over the project. He is currently finalizing Version 2 of the instrument, and new tests are planned on LéXPLORE in spring 2026.



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A Physical-Chemical Approach Towards the Assessment of the Degradability of Plastics (Lém-PLAST)

Christian Ludwig, Michel Rossi, Horst Pick, Florian Breider, Yang Wang

This project focuses on understanding the physical, chemical and biological degradation of plastics, through **controlled laboratory experiments (ozone treatment, and solar simulator)** and **real-world environmental interactions**. The environmental exposure studies will utilize samples from Lakes (e.g., **LéXPLORE platform**). This crucial step allows us to capture the full complexity of natural weathering, which inherently combines and probes the interacting effects of physical, chemical, and biological degradation simultaneously.

We monitor polymer changes using advanced analytical techniques. While Fourier-transform Infrared Spectroscopy (FTIR) provides data on average bulk changes, the critical tool is the Knudsen Flow Reactor (KFR). The KFR is a highly sensitive gas-titration approach that uniquely provides quantitative data on the appearance and/or disappearance of key functional groups specifically on the weathered plastic surface, offering essential insights into early-stage chemical degradation kinetics.

The achievement of 2025

This year's research concentrated on understanding the natural environment on PET degradation, the widely used fossil-based polymer. We conducted controlled experiments using both **PET powder and PET film** with varying surface areas exposed to simulated and natural environmental conditions. The resulting characterization data is critical for illuminating the functional group changes on plastic surface. As shown in the Figure 1, six types of probe gases were used for precise functional group characterization. However, a significant analytical challenge exists: due to the low porosity and limited measurable surface area of the PET films, standard methods like BET surface area measurement are difficult to apply. Despite this limitation, our working hypothesis remains critical: we propose that the observed differences in surface area (resulting from material processing or weathering) will lead to a quantifiable change in the number of functional groups formed or lost on the plastic surface. This crucial change can be precisely quantified using the high sensitivity of the KFR, thereby allowing us to correlate material properties with early-stage chemical degradation kinetics. One potential publication is planning to be published in 2026 or early of 2027.

Plan for the next year (2026)

In comparison to fossil-based polymers like PET, biodegradable plastics have seen rapid development in recent years. Key examples include PLA, PBAT, PBSA, and PCL, which are theoretically designed to degrade ideally in specific environments such as compost, soil, or the ocean. However, it is a significant challenge that not all biodegradable plastics degrade effectively in the natural environment. Many of

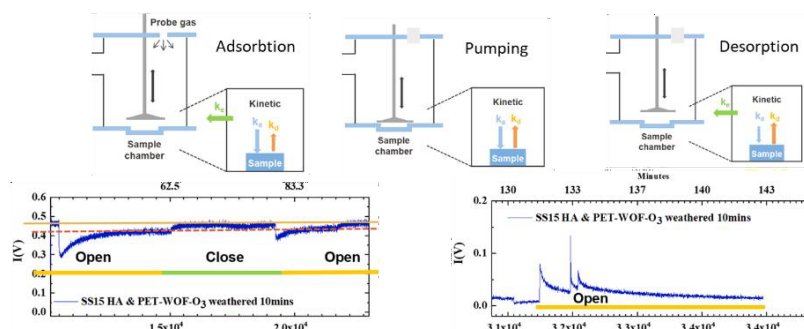
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these alternatives exhibit a similar outcome to PET, persisting and ultimately fragmenting into microplastics, failing to resolve the core issue of environmental pollution. Since both the **conventional polymer PET** and the **biodegradable polyesters (PBAT, PLA, PCL, etc.)** share the fundamental ester bond in their chemical structure, the project's next phase will leverage this commonality.

We will analyze the chemical structure changes of all these polyesters when exposed to natural environmental conditions, **LéXPLORE platform**. This investigation will provide definitive proof regarding how the functional groups of these polyesters change during early-stage weathering. We hope this comparative data will illuminate why certain biodegradable plastics fail to degrade effectively in the actual natural environment, performing instead like conventional polymers and contributing to microplastic pollution. This comparative and quantitative approach is essential for identifying the structural differences that dictate a polymer's environmental fate.

A Physical-Chemical Approach Towards the Assessment of the Degradability of Plastics

KFR Mechanism



Christian Ludwig
(GR-LUD)



Michel Rossi
(GR-LUD)

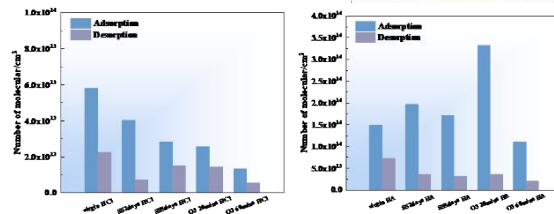


Horst Pick
(GR-LUD)



Yang Wang
(GR-LUD)

PET powder



- PET **powder and films** untreated and treated with acidic probe gas (TFA, HCl) and basic probe gas (HA, TMA), H₂O and O₃.
- Challenge: BET surface area of PET films due to low porosity and limited measurable surface area.

Figure: The mechanism of Kundsens Flow Reactor and partial results for PET plastic.

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Nitrous Oxide Emissions in Lake Geneva (LacNOX)

Santona Khatun, Sébastien Lavanchy, Hugo Cruz, Marie Elodie Perga, Jérôme Chappellaz

The landmark study by Mengis et al. (1996) provided early dissolved nitrous oxide (N_2O) measurements across temperate lakes, revealing that freshwater systems can be substantial atmospheric N_2O sources. Yet nearly 30 years later, little is known about N_2O production and emissions in deep monomictic lakes such as Lake Geneva. N_2O is produced via aerobic nitrification, nitrifier-denitrification under moderate oxygen stress, and heterotrophic denitrification in low-oxygen, nitrate-rich hypolimnion layers. Stratification structures these pathways, and recent changes in nutrient inputs (Calvin et al. 2023; Li et al. 2024) and increasingly stable thermal stratification (Müller et al. 2022) motivate a reassessment of N_2O dynamics.

We hypothesized that dissolved N_2O concentrations and emissions have increased since 1995 and that these increases reflect shifts in environmental conditions enhancing microbial N_2O production across the stratification layers. Seasonal measurements were conducted in spring and early summer 2025 using a high-resolution SubOcean probe, a fast-response in situ membrane inlet-laser spectrometer, and discrete laboratory analyses. Environmental drivers, including temperature, dissolved oxygen, turbidity, conductivity, and nitrate, were recorded with an EXO profiler to provide high-frequency profiles aligned with N_2O data. Laboratory headspace equilibration was used for calibration, and temperature-dependent gas transfer models estimated surface fluxes. All 2025 data were compared directly with November 1995 measurements.

Shortly after spring turnover in April 2025, surface N_2O concentrations reached ~ 35 nM, decreasing to ~ 15 nM during early summer stratification (June 2025). Across all depths, 2025 concentrations were 2–5 times higher than those observed in 1995. Depth-resolved patterns indicated epilimnetic nitrification, metalimnetic nitrifier-denitrification driven by oxygen stress and turbidity, and hypolimnetic heterotrophic denitrification as major contributors to N_2O accumulation. Surface flux estimates revealed enhanced emissions during spring mixing as accumulated deep-water N_2O was transported upward.

These results reveal a substantial intensification of nitrogen cycling in Lake Geneva over the past three decades. Increases in nutrient loading, stronger stratification, and expanding low-oxygen zones likely amplified N_2O production across all microbial pathways. Seasonal transitions, particularly during turnover, contributed disproportionately to annual emissions, suggesting that omitting these periods may underestimate total fluxes by up to a factor of two. When considered globally, large deep lakes like Lake Geneva represent a previously underappreciated source of inland water N_2O , underscoring the need for year-round monitoring and improved incorporation of large lakes into greenhouse gas inventories.

A manuscript detailing these findings is currently in preparation and will be submitted to an international peer-reviewed journal.

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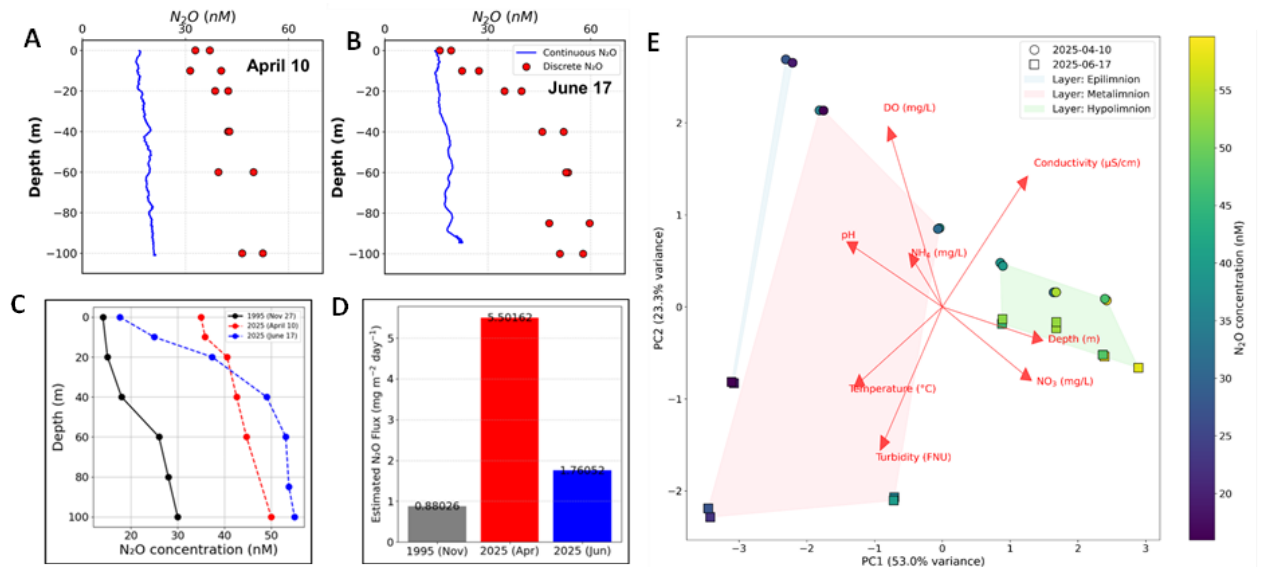
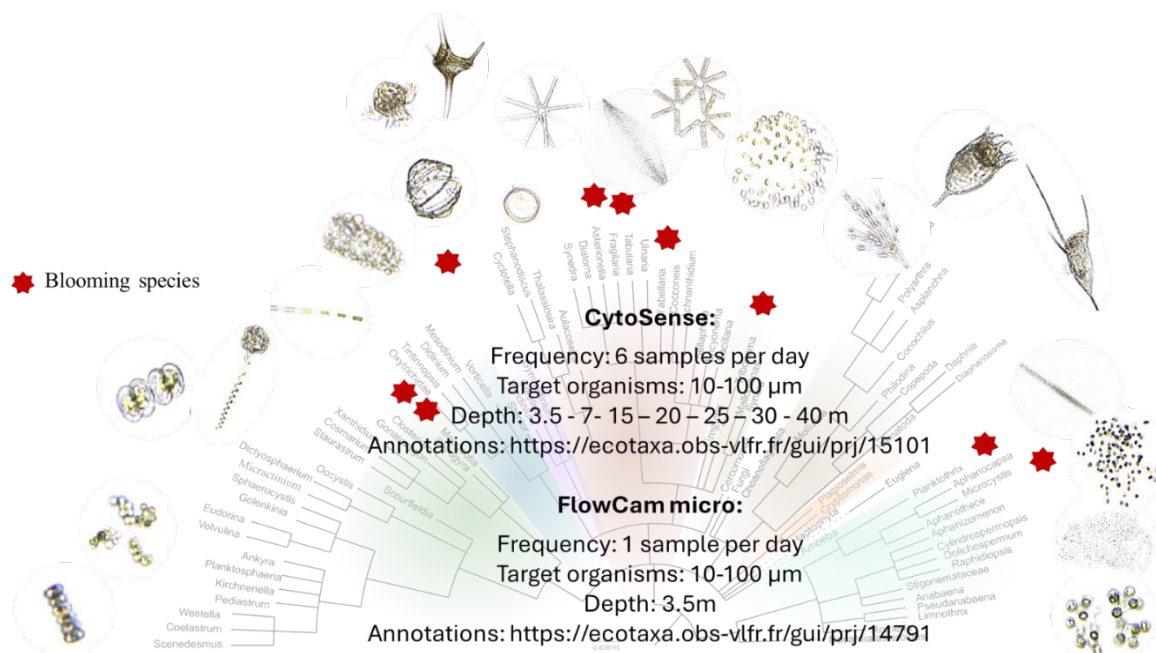


Figure: Dissolved N_2O in Lake Geneva: (A) April 10, 2025, post-turnover; (B) June 17, 2025, early summer stratification. Blue lines: continuous SubOcean probe measurements; red circles: discrete lab samples. (C) Comparison with 1995 (black circles). (D) Surface N_2O fluxes estimated from concentrations and gas transfer. (E) PCA of environmental drivers (NO_3^- , NH_4^+ , DO, pH, temperature, turbidity, conductivity, depth) across epilimnion, metalimnion, and hypolimnion; points colored by N_2O concentration.

Mathilde Dugenne, Irene Muscas, Matteo Gios, Mridul K. Thomas, Bastiaan W. Ibelings

Next, we plan on applying a size-structured population model to estimate population in situ growth rates and link increased rates to environmental drivers like temperature, light, or nutrient concentration. Together with loss rates estimated from parasitic infection or zooplankton grazing, this analysis will provide a complete assessment of the biotic and abiotic factors affecting phytoplankton blooms in Lake Geneva.



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Quantifying the zooplankton link in lakes (GEN-Z)

Marie-Elodie Perga, Nischal Devkota, Wyndel Sanoza, Tomy Doda, Gregoire Mariethoz, Jake Vander-Zanden

GEN_Z's objective is to reach a mechanistic understanding of lake zooplankton's temporal and spatial dynamics and implications for lake biogeochemistry by revamping a quantitative and numerical approach to zooplankton. GEN_Z first aims to revisit how we quantify zooplankton in the field, overcoming the current shortfalls of zooplankton observations and optimizing the information we derive from observation data. The project builds upon high throughput observation techniques recently developed or under development, such as remote sensing, echo-sounding, and automated analyses of digital images (see figure below). These new observation techniques will expand zooplankton observations' spatial and temporal coverage and resolution. Acquired data will be used to hindcast zooplankton's spatial and temporal variability at scales rarely, if not never, reported for lakes. By improving the quantitative view on zooplankton, we expect to initiate a step towards a better zooplankton parametrization for future inclusion within lake ecosystem models.

2024-2025 were dedicated to field work, with LéXPLORE as main headquarters. Field work included six 24-hour shifts in summer and fall 2024 for zooplankton sampling following night-time vertical migration, and a large 48h day- and night-drone flights for Green-LIDAR mapping, with groundtruthing from ADCP transects and spatial distributed zooplankton samplings.

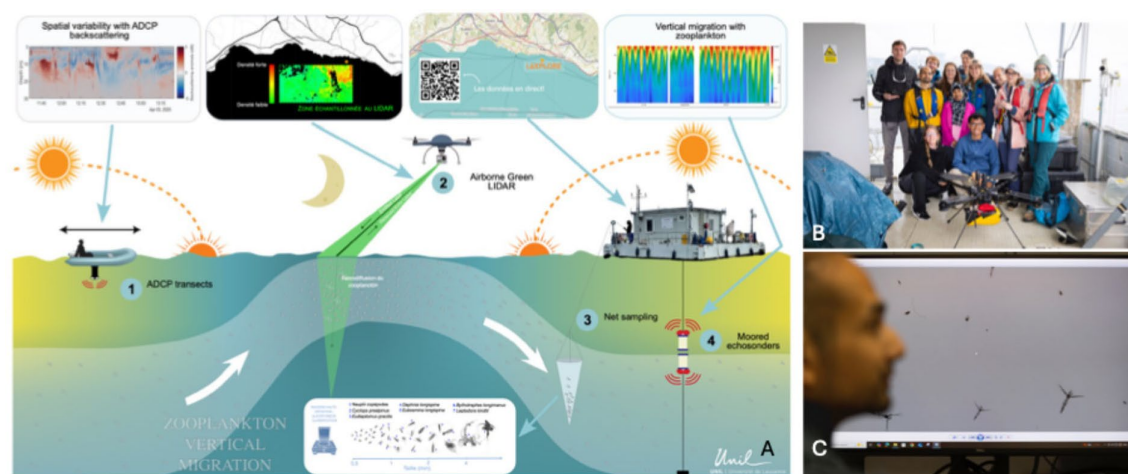


Figure GEN-Z: (A) The overall strategy of the GEN-Z program, (B) the GEN-Z on LéXPLORE for the Green-LIDAR campaign, May 2025, (C) Automated Image analysis for zooplankton identification in the lab. Photos: NicolasLieber.

After intensive fieldwork this year, we are in the process of analyzing the data. GEN-Z results were presented in the Swiss Geoscience meetings 2024 and 2025, the Symposium for the European Freshwater Science (2025), as well as to a broader audience at the Mystères de l'UNIL 2025.

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Fungi and bacteriophages from Lemman Lake sediments for development of innovative therapeutics (MycoMediX)

Katia Gindro, Thilo Köhler, Nicole Lecoultré, Yishan Li, Jean-Luc Loizeau, Alexandre Luscher, Rémy Marcellin-Gros, Anne-Stéphanie Rueff, Sylvain Schnee, Emerson Ferreira Queiroz, Jean-Luc Wolfender

The LéXPLORE platform was used to sample lake sediments as a source of new biological resources with medical potential. Sediments, exposed to unique physico-chemical conditions and strong anthropic impact, represent an untapped reservoir of fungal and viral diversity. During the first campaign, **seven sediment cores were collected from three zones with different sedimentation rates**. Fungi have been isolated from three of these cores, using a protocol based on 20-year age slices made possible by known sedimentation rates. **Fungal isolates were obtained from every time slice, including the oldest layers (>100 years), and more than 131 distinct fungal species have been identified so far**, revealing a remarkable hidden biodiversity.

The fungal strains have been incorporated into the Agroscope fungal collection. Their secondary metabolites were extracted, profiled, and evaluated for antimicrobial and anti-virulence activities as part of the MycoMediX project (**SNSF Bridge 211759, JLW, SS and TK**). Thirty-two extracts demonstrated promising activity against the priority pathogens *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Escherichia coli*. Scale-up of fungal cultures is currently underway to enable the purification of active compounds from these extracts. The investigation of the mode of action of these bioactive molecules will be conducted in the next phase of the project, a necessary step toward their potential development into therapeutic agents.

The fungi will also serve as source of enzymes that will be used for the biotransformation of natural products for the generation of natural product derivatives (project **Biotransform, FNS 205320_215078, EFQ and KG**). The generated data (sequences, isolates, screening results) will be released as open data after publication, in line with LéXPLORE's policy. This project thus links lacustrine microbial biodiversity with therapeutic innovation through an integrative approach combining mycology, microbiology, virology and metabolomics.

In parallel, an attempt to isolate bacteriophages from sediment samples was performed. However, neither in the upper nor in the deeper sediment layers, bacteriophages could be isolated on a *P. aeruginosa* strain.



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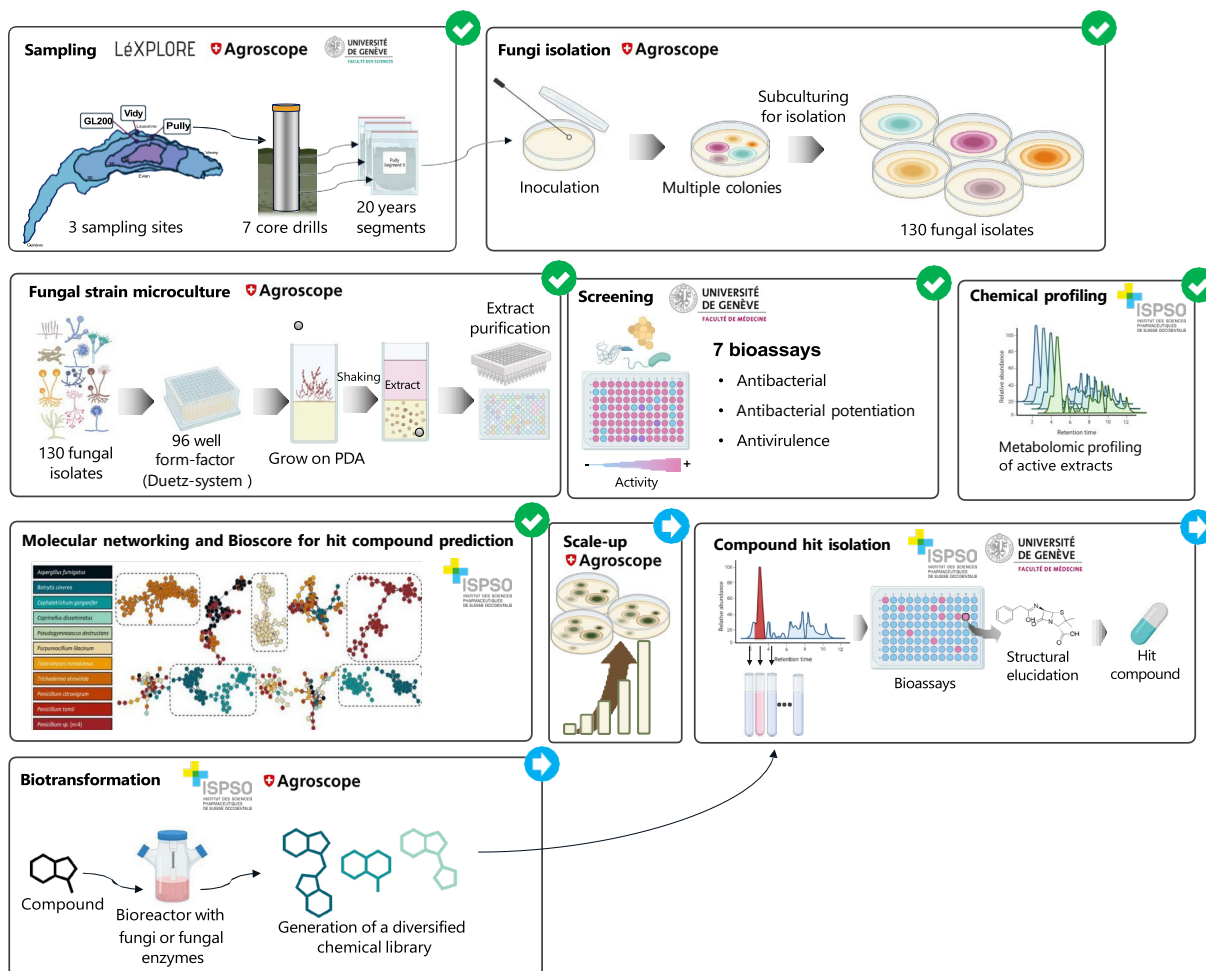


Figure: Experimental workflow of MycoMediX and Biotransform projects.

LéXPLORE

Tests and improvements of the SubOcean probe (SubOcean++)

Sébastien Lavanchy, Jérôme Chappellaz, Hugo Cruz

The **SubOcean probe** is an in-situ sensor equipped with a laser spectrometer, capable of continuously monitoring the concentration of specific trace gases dissolved in water. The **SubOcean++** project aimed to test, characterize, and improve two SubOcean probes manufactured by A2PS in France: one dedicated to CH₄ and its stable carbon isotopes, and the other dedicated to CH₄ and N₂O. The project also sought to improve their design and specifications in order to increase performance and autonomy.

During the period from **01.07.2024 to 31.12.2025**, the following actions were carried out:

1. Testing and evaluation of SubOcean after factory repair/revision

After any major factory revision, onsite retesting of the SubOcean probe is essential. The LéXPLORE platform made it possible to validate the SubOcean N₂O probe in December 2024, and the SubOcean CH₄ probe in April 2025.

2. Characterization of the SubOcean probe behavior

The SubOcean probe is a complex instrument that still requires detailed characterization, particularly regarding deployment speed and the optimization of its internal operating settings.

To address this, the SENSE laboratory conducted three measurement campaigns in **February, April, and September 2025**.

The goal was to use the LéXPLORE station to isolate and evaluate individual parameters or deployment configurations, thereby improving our understanding of how to deploy the SubOcean probe most effectively for accurate water-column characterization.

3. SubOcean probe winch system

The AGO winch was installed on LéXPLORE from November 2024 to September 2025. During this period, it was used successfully for all SubOcean++ tests, as well as for the LakeNOX project.

The winch was also installed on the LEM platform for two spatial sampling campaigns carried out on Lake Geneva.

Planned actions for next year

Additional tests to further characterize the SubOcean probe.

Testing of new custom-made membranes for dissolved-gas separation, developed in collaboration between LAS and SENSE (EPFL).

Integration and testing of the SubOcean probe on autonomous vehicles (ROV, autonomous boats, etc.).



LéXPLORE

Design and construction of a probe for continuous monitoring of dissolved CO₂ in seawater from a sailboat or a small ship (SENSE-pCO₂)

Yanis Mouzaoui, Hugo Cruz, Sébastien Lavanchy, Jérôme Chappellaz, Bénédicte Lunven, Alexandre Tellier

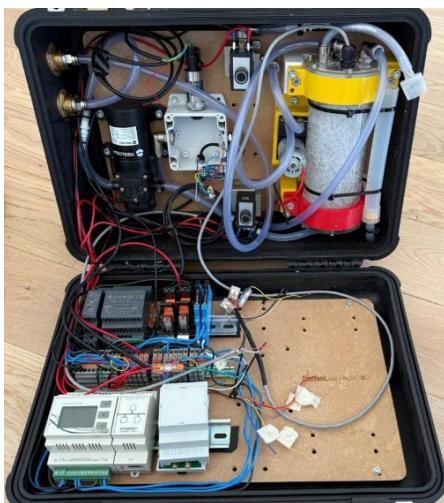
Continuous monitoring of dissolved CO₂ in seawater is critical to evaluate how much anthropogenic CO₂ will be absorbed by the global oceans in the future (about 25% today), as the natural phenomenon contributes to partly mitigate increased greenhouse gas radiative forcing. However, the oceans are strongly under sampled. There is a need to acquire more autonomous and inexpensive observations notably from ships of opportunity such as sailboats.

The objective of this project was to design and construct a compact probe that could easily be installed on a sailboat platform, continuously collect surface seawater, and measure dissolved CO₂ (pCO₂) in a well-calibrated and reliable manner. The LéXPLORE platform served as a unique test site during development.

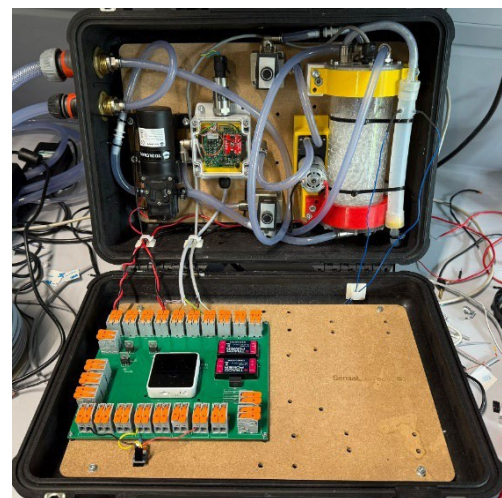
From February to June 2024, EPFL Master student Alexandre Tellier designed and built the first version of the probe, ensuring that the entire system would fit inside a small Pelicase and rely on low-cost, readily available components. Initial tests were conducted on the LéXPLORE platform during this period.

Before further on-site testing, the system required additional robustness developments. From February to July 2025, Yanis Mouzaoui (EPFL Master student) focused on improving the hardware. Unfortunately, there was not enough time to perform new field tests on LéXPLORE.

A new Master thesis will start in spring 2026 to characterize the system, with multiple tests planned on the LéXPLORE platform.



SENSE-pCO₂: Version 2024



SENSE-pCO₂: Version 2025

LéXPLORE

Quantification of Quagga mussels within the EPFL water cooling system (QuagPlore)

Pierre Rossi, Emmy Oppliger; Piet Spaak; Christof Holliger; Florian Breider; Mathurin Dupanier

The quagga mussel (*Dreissena rostriformis bugensis*) is a freshwater invasive species first identified in Switzerland in 2015. This animal is gradually invading lakes across the country, causing serious changes to their ecosystems. These changes are expected to become more pronounced in the coming years. Growth is expected to increase steadily in the coming years, challenging the use of lake water for industrial applications. A negative impact is the clogging of water intake structures such as pipes and grids, which reduces pumping capacity.

The aim of this project is to measure the extent and rate of spread of this animal in the EPFL water pipes used for cooling the school facilities. Monitoring the animals from LéXPLORE at the water pumping depth (-75m) is part of this process. The presence and quantification of the animal is detected by quantitative PCR, a standardized method applied systematically to all samples processed to date. These samples were taken along the pipes of the cold-water distribution network, from the inlet (CCT building) to distribution node 5 (PDD5).

The results obtained over the last 24 months showed that mussel growth is massive at the entrance to the network, indicating that mussel growth gradually increases inside the pipes at a rate significantly higher than that observed in nature. Some sampling points show clear signs of seasonal variation in summer, induced by increases in flow during hot periods. The shape of the pipes also allows for the accumulation of organic matter and increased growth. There has been noticeable growth in the distal part of the network, but it is no greater than that recorded for samples taken from the lake. Furthermore, measurements taken from a tap in the GR-CEL laboratory showed that all lake water supply pipes are contaminated.

At this stage of the measurements, long-term evolution of the situation can be envisaged with a certain degree of certainty. The growth of the animal at the start of the network is almost logarithmic. Given the speed at which the animal is developing, a disruption in the distribution system (for the first EPFL buildings at the head of the network) can be expected relatively quickly. Rapid growth inevitably leads to a reduction in the effective diameter of the pipes, limiting the water supply for applications and cooling buildings during the summer. Ultimately, the growth of the animal and the accumulation of shells will cause a blockage of the pipes.

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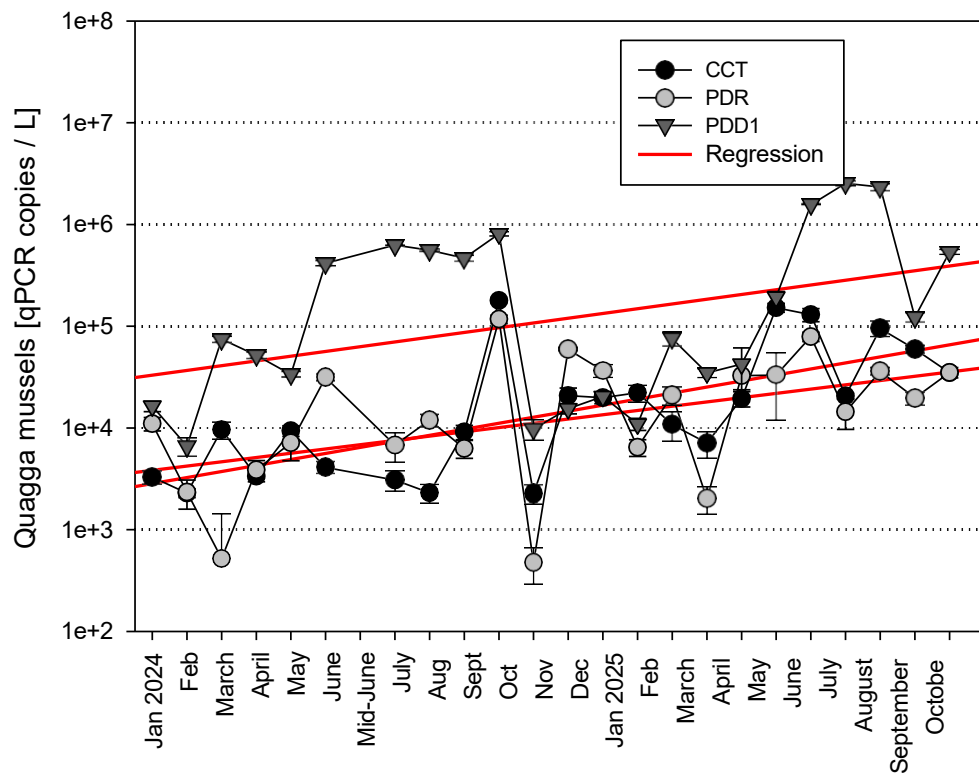


Figure: Quantification of COI mitochondrial genes in quagga mussels in water samples taken at the inlet of the EPFL cold water distribution network (CCT), and at two downstream sampling points (PDR and PDD1), using qPCR. The red line shows the linear regression of the animals' growth over time.

LéXPLORE

Asterionella-parasitic chytrid interactions under changing temperatures.

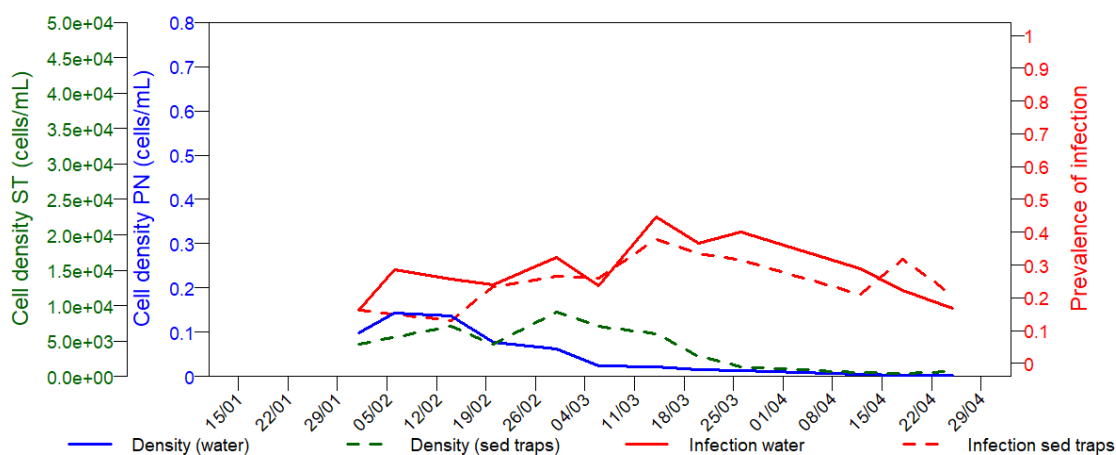
Lisa Morales, Mridul Thomas, Bastiaan Ibelings

Asterionella formosa is a dominant diatom species in many temperate lakes worldwide. Being difficultly edible by zooplankton due to its large size, its blooms can be terminated by a chytrid parasite. Because chytrid infectivity is sensitive to temperature, lake warming might reshape the host-parasite dynamics and subsequently alter carbon fluxes to the sediment. This project aims to assess the host-parasite dynamics and carbon fluxes to the sediment under warmer winter conditions.

Since 2024, host-parasite dynamics and carbon fluxes to the sediment have been monitored from LéXPLORE weekly from January to May. Phytoplankton net samples allow us to determine the prevalence of infection and phytoplankton community composition, integrated water samples quantify *Asterionella* abundance in the water column and are used for nutrient analysis, and sediment traps (80m depth) allow us to measure the carbon and *Asterionella* cells fluxes to the sediment.

Contrary to our expectations, *Asterionella* and chytrid dynamics did not follow the anticipated pattern where warmer winters allowed earlier chytrid infection and reduced *Asterionella* density.

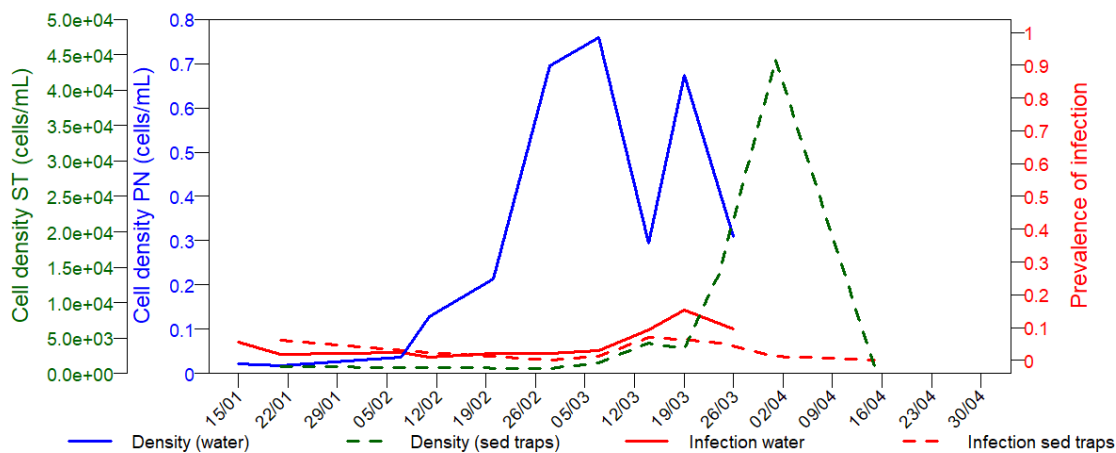
Asterionella density and chytrid infection over time (2024)



In 2024, *Asterionella* reached a relatively low maximum density in early February accompanied by high prevalence of infection (44%). Sediment traps maximum *Asterionella* density happened about 25 days later, indicating sinking rates of approximately 3m/day. The Infection prevalence in the traps closely matched that of the water column.

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Asterionella density and chytrid infection over time (2025)



In 2025, *Asterionella* density was about 5 times higher than 2024, and the bloom peaked one month later, in early March. Despite higher host densities, prevalence of infection remained low (17%). Sinking rates to the sediment traps were similar to 2024, but prevalence of infection was roughly half that of the water column.

Temperature records for both years showed minimum temperatures above 7°C and comparable ranges and timing in temperature increase, providing no evidence that difference in thermal regimes could explain the differences in host-parasite dynamics.

No environmental driver examined so far, including temperature, nutrients, stratification, explains the contrast in prevalence of infection and *Asterionella* density. Possible explanations could be earlier-season host-parasite processes, grazing pressure on chytrids, light, phytoplankton competition. With only two years of data, no robust conclusions can be drawn yet.

We expected carbon fluxes during the sampling season to correlate with *Asterionella* densities in the traps, but total organic carbon showed no strong relationship with cell fluxes in either year. Substantial other particulate material was found in the traps and appears to drive carbon exports more than *Asterionella*.

We will continue to monitor this host-parasite relationship in the lake, look more closely at environmental and biological drivers that could explain these dynamics. Additionally, we will build a carbon budget for *Asterionella* cells and estimate the fraction of cells exported relative to the water column to understand *Asterionella*'s actual contribution to carbon export. Finally, results laboratory experiments looking at the effect of infection on *Asterionella* cells' carbon content and sinking rates will be combined with the monitoring data to parameterize a mechanistic model. This model will allow us to test temperature-driven scenarios of bloom development, parasitic infection and carbon exports.

LéXPLORE

Antimicrobial Resistance Tracking and Fate modeling in the Urban flows – Lake interface (ARTFUL)

Helmut Bürgmann, Sasikaladevi Rathinavelu, Matthew F. Blair, Karin Beck, Madeline Deck.

The goal of project ARTFUL is to improve understanding the dynamics of wastewater-derived antimicrobial resistance (AMR) in Lake Geneva and to improve environmental AMR monitoring methods, as a prerequisite to determine the associated risk of spreading AMR in aquatic environments, and lakes in particular. The objectives of ARTFUL are therefore to i) monitor the AMR dynamics in VidyBay, Lake Geneva that receives WW from Lausanne wastewater treatment plant ii) determine the spatial and temporal distribution of AMR in the lake iii) to evaluate quantitative and targeted metagenomics as an environmental AMR monitoring tool iv) to establish hydrodynamic lake model-supported sampling approaches and to use modeling to assess AMR contamination transport and exposure risks.

Work carried out last year

In 2024/2025 work was primarily focused on sample processing and analysis of the data from the previous year's sampling campaigns which used LéXPLORE as a base of operation and swimming laboratory (Rathinavelu et al., in prep.). In this context we also worked on method development, as a basis for future activities:

- Development of a consolidated set of Taqman-based qPCR-Assays and synthetic quantification standards for environmental surveillance of antimicrobial resistance genes (ARG).: Rathinavelu et al. 2025.
- Development and method comparison of AMR-targeted metagenomics (Blair et al. in prep.).
- Development of improved quantitative tools (retrieval standards) for environmental metagenomics (M. Deck, work in progress).

Results of these activities were presented at the LéXPLORE workshop. While work on publications continues, the postdoctoral team members Blair and Rathinavelu have now left the project, while PhD candidate Madeline Deck has begun her work.

In the reporting period, we have also conducted two additional sampling campaigns at LéXPLORE and in the Vidy Bay area that provided samples used in the methods development activities. As before we used hydrodynamic model predictions to sample water at various points along the predicted location of the wastewater plume. The LéXPLORE was used as a reference sampling site and as base of operations, and we are grateful for the technical and logistical support from the LéXPLORE team.

Planned work

In January/February 2026, we plan a “lagrangian” sampling campaign, repeatedly sampling the same water mass during transport in the lake. This is enabled by using modelling and physical tracers (GPS tracked buoys) and by measuring chemical wastewater tracers (Gadolinium or organic micropollutants). During the further course of the project the following activities involving LéXPLORE are currently foreseen:

LéXPLORE

- Additional sampling campaigns using the Platform as data hub, floating laboratory and operational base.
- An experiment deployed at LéXPLORE for in-situ incubation of wastewater in the Léman to study temporal changes in wastewater microbiomes and resistomes.
- Microbiome / resistome sequencing experiment on LéXPLORE using Oxford Nanopore sequencing technology, demonstrating the feasibility of on-site, real time, sequencing-based monitoring. Perhaps using automated sampling technology on the platform.

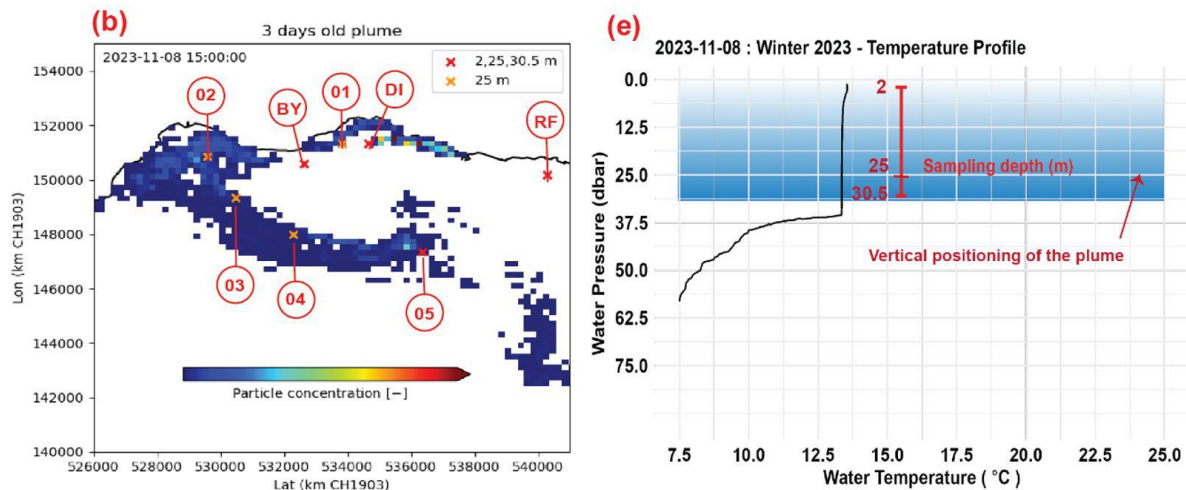


Figure: Left: Position of the wastewater plume in Vidy bay, modelled by a hydrodynamic model and visualized using particle tracking modelling. Sampling points derived from the model prediction are indicated. Reference site "RF" is the LéXPLORE platform. Right: Predicted vertical position of the wastewater plume derived from LéXPLORE thermal monitoring data.

References:

Rathinavelu, S., Beck, K., Wälchli, D. L., & Buerghmann, H. 2025. Optimization and Validation of a Consolidated Set of Taqman Qpcr Assays for the Surveillance of Clinically Relevant Antibiotic Resistance Genes in Environmental Matrices. *MethodsX* 15, 103600. <https://doi.org/10.1016/j.mex.2025.103600>

LéXPLORE

Lake snow - dynamics of the suspended particulate matter in Lake Geneva

Natacha Pasche, Armelle Bouhali, Inès Laury, Guillaume Cunillera

The Lake Snow project investigates suspended particulate matter (SPM) and flocculation in Lake Geneva using the LéXPLORE platform. It combines digital in-line holography (LISST-Holo2) with field observations to track particle size, concentration, and settling behaviour influenced by Rhône River inputs. Between September 2023 and August 2025, 41 field campaigns revealed strong seasonal SPM patterns: turbidity peaks occurred only during stratified periods (May–October), driven by Rhône interflows at 10–35 m depth. For the first time, macrofloc formation was observed within the lake's interior, with particle modes shifting from 56–78 μm in the epilimnion to 152–500 μm near the turbidity peak and in the hypolimnion. Winter conditions showed uniform fine particles, and particle counts correlated strongly with turbidity ($R^2 = 0.83$).

Technical developments included an automated hologram-processing pipeline that cut reconstruction time by 52% and saved 1.5 TB of storage, while deep learning models improved particle segmentation and detection. Laboratory settling experiments showed a strong size–velocity relationship ($R^2 = 0.95$), improving sediment transport parameterization.

These findings demonstrate that flocculation occurs far from the Rhône mouth, advancing understanding of sediment and contaminant pathways in Lake Geneva. Future priorities include SPM calibration with water samples, detailed analysis of particle shape, and broader integration of deep learning for automated particles classification.

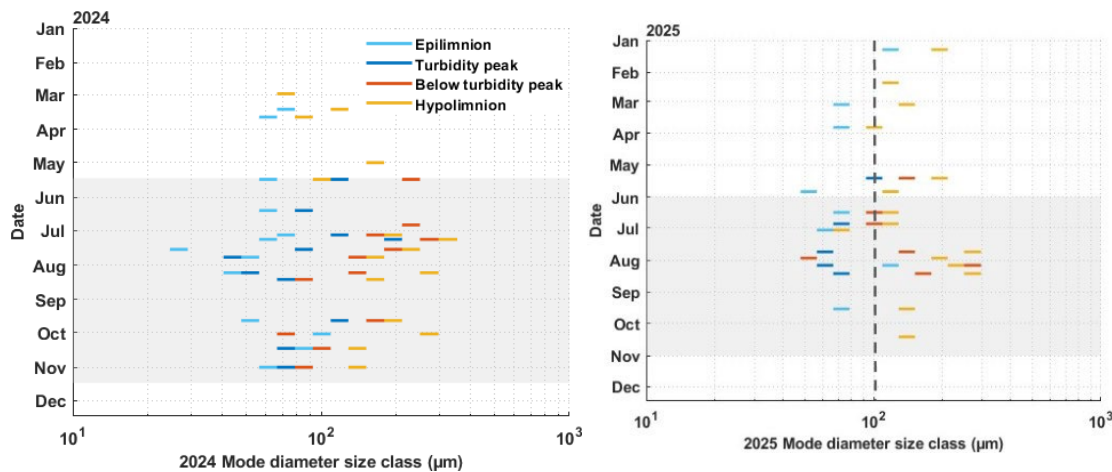


Figure: Size class corresponding to the mode of the mean size distribution of particles of 2024 (left) and 2025 (right). Shaded area represents the stratification period of the lake. The vertical dashed line represents the separation between microflocs size ranges (left part), and macroflocs (left)

LéXPLORE

Prototype elementary cell of Water Cherenkov Detector Array (WCDA) for study of cosmic ray electrons and gamma-ray observations

Andrii Neronov, Jean-Paul Kneib, Florian Bernard, Ettore Zaffaroni

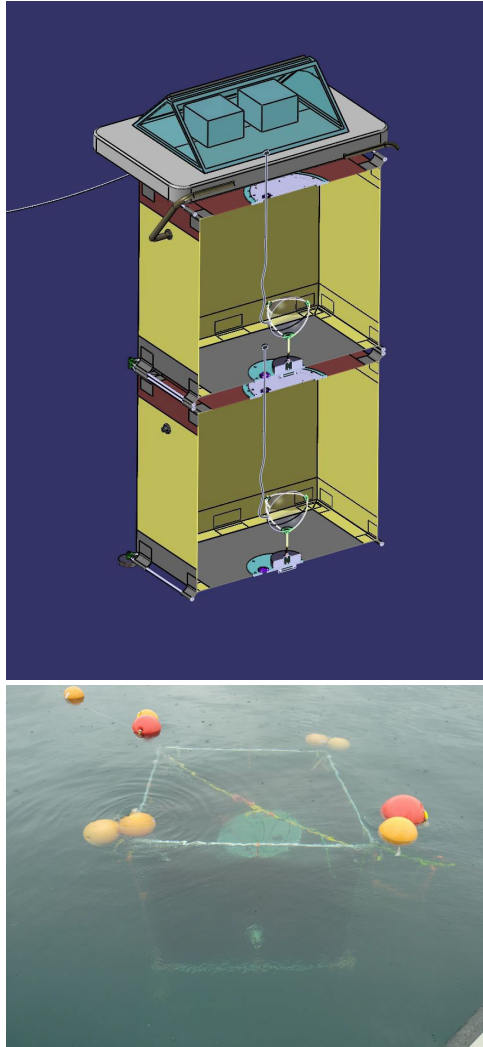


Figure: Top panel: CAD drawing showing cross-section of the EC with the optical module of ANTARES contained in a light-tight tarpaulin. Bottom panel shows the deployed setup.

The project is aimed at testing an improvement for a technique of WCDA for detection of cosmic rays and gamma-rays, high-energy particles emitted by distant sources in the Milky Way and other galaxies. These particles penetrate the Earth atmosphere and induce “showers” of secondary particles that reach the lake and produce short pulses of blue Cherenkov light that can be detected by WCDA. There are two currently operating WCDAs: HAWC in Mexico and LHAASO in China. These detectors have revolutionised the field of very-high-energy gamma-ray astronomy, providing detections of sources in our Galaxy capable of accelerating particles to PeV energies (about 100 times larger than those attainable at the Large Hadron Collider at CERN). However, both detectors have a limited capability for measuring the identity of the primary cosmic ray particles initiating the showers (protons, atomic nuclei or electrons or gamma-rays). Our project aims to improve this capability by adding a deep second layer to WCDA. Such two-layer detector will be able to measure separately the electron-positron content (with the top layer detector) and muon content (with the bottom layer) of the cosmic ray induced showers¹. Proton or nuclei showers yield more muons than electron or gamma-ray-induced showers. Large (hundreds of square meters) WCDA will be assembled from smaller “Elementary Cells” (EC). Our project is a Franco-Swiss collaboration involving EPFL, University of Geneva, Astroparticle and Cosmology laboratory in Paris and Centre for Particle Physics in Marseille. The optical modules are heritage of ANTARES², a neutrino detector now dismantled. Over the last year we managed to

deploy the full EC at the site of LéXPLORE with two storeys equipped with the optical modules and we have started to take data. We have detected energetic muons by observing the upper and lower water tanks of the EC detecting Cherenkov light with slight delay (about 10 ns) expected for muons moving downwards with the speed close to the speed-of-light. We are also testing the robustness of the mechanical design with respect to the environmental conditions of a lake. At the next stage, we plan to finalize the EC design by adding the electronics box (ready, waiting to be installed) that will allow automatic data taking and transmission to the shore.

¹ A. Neronov, D. Semikoz, <https://arxiv.org/abs/2102.08456>

² ANTARES neutrino telescope <https://antares.in2p3.fr/>

LéXPLORE

High-frequency monitoring of CO₂ and CH₄ fluxes at LéXPLORE station by combining different methods (CarboLéX)

Didier Jézéquel Didier, Jean-Daniel Paris, Jérôme Chappellaz, Santona Khatun, Viet Tran-Khac, Philippe Quetin

This project has both scientific and methodological objectives:

- 1) To provide new insights into the carbon cycle in Lake Geneva (including the water column and at the air-water interface)
- 2) To characterize the representativeness of eddy covariance (EC) measurements of CO₂ and CH₄ exchanges at the air-water interface.

To achieve this, the project combines long-term monitoring and targeted campaigns. Long-term monitoring includes deployment of an eddy covariance system on the LéXPLORE platform to measure CO₂, CH₄, and water vapor fluxes, alongside continuous measurements of dissolved pCO₂ and pCH₄ using Contros probes and prototype instruments. CO₂ fluxes are also measured using an automated floating chamber. Complementary one-off campaigns include spot measurements with a manual floating chamber (using TDLAS and Licor sensors), as well as dissolved CH₄ and isotopic ($\delta^{13}\text{C-CH}_4$) analyses using the SubOcean spectrometer, both at the platform and through surface water mapping by boat. These data are compared with discrete water samples collected by UNIL.

Continuous monitoring of surface pCO₂ and pCH₄ began on May 29, 2024. Results from late May to late August show that CO₂ concentrations remained below atmospheric equilibrium, indicating net CO₂ uptake by the lake during the productive (photosynthetic) summer period. In contrast, CH₄ concentrations were consistently above atmospheric equilibrium, indicating emissions to the atmosphere. CH₄ peaks coincided with night-time temperature drops, possibly linked to minor mixing events or changes in biological activity, while night-time CO₂ increases reflected dominant respiration processes. During summer, average fluxes are relatively low ($-8.3 \text{ mmol m}^{-2} \text{ d}^{-1}$ for CO₂ and $0.09 \text{ mmol m}^{-2} \text{ d}^{-1}$ for CH₄), but the pronounced temporal variability highlights the importance of continuous high-frequency monitoring to accurately quantify greenhouse gas exchanges.

In 2025, however, the Licor instrument did not function properly. It was dismantled, sent back to the manufacturer for cleaning and recalibration, and reinstalled by the technical team. Despite these efforts, it is still not operational. Further corrections are required from the manufacturer, who has so far been slow to respond.

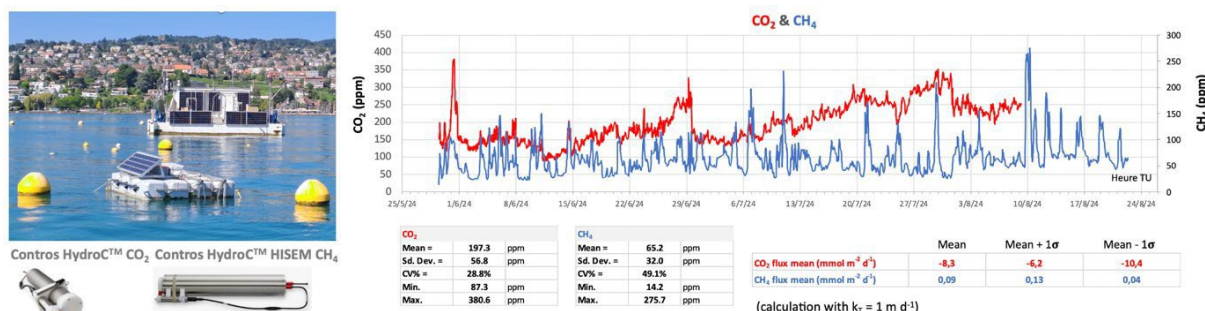


Figure: Temporal evolution of CO₂ and CH₄ from 29/05/24 to 22/08/24, and values of the derived fluxes.

LeXPLORE

Microsed project - Deposition and Accumulation of Microplastics in Lake Sediment

Florian Breider, Sylvain Coudret, Karine Vernez,

The impacts of plastic pollution on aquatic ecosystems remain a major environmental challenge. The Microsed project addresses this issue by using the LeXPLORE platform on Lake Geneva, a large freshwater lake influenced by inflows from the Rhône River, to investigate the distribution, composition, and sedimentation of microplastics under natural conditions. The project aims to quantify microplastics throughout the water column—including the photic zone and thermocline—as well as in lake sediments across a range of depths, thereby improving understanding of microplastic behavior in freshwater ecosystems.

Microplastic sampling on the LeXPLORE platform follows a dual strategy. Water samples are collected every 12 hours at depths of 2 and 30 meters using pumping systems that filter water through 500 μm and 150 μm meshes. In parallel, sedimentation is monitored through monthly collections using cylindrical sediment traps deployed at four depths. In 2025, the microplastic sampling device was optimized (Figure 1) to improve sampling efficiency, facilitate sample collection, and enable remote control of the system, enhancing operational reliability and long-term deployment capabilities. Extracted microplastics are subsequently quantified and characterized using infrared quantum cascade laser (LDIR) spectroscopy to determine polymer types and abundances.

To ensure consistency in data interpretation, a standardized analysis protocol was established in 2025 to process the data generated to date. This protocol is based on YABE, a software application designed to extract and analyze information from raw LDIR chemical imaging data. The analysis relies on the Hit Quality Index (HQI), which assesses the degree of correspondence between measured infrared spectra and reference spectra contained in a spectral library. Beyond harmonizing data processing, this protocol also enables estimation of microplastic mass, improving comparability across samples and monitoring periods.

The microplastic sampling system deployed on LeXPLORE also serves as a demonstrator and experimental platform to test and validate the sampling protocol intended for future deployment in the Red Sea. This transferability is essential for monitoring microplastics in sensitive marine environments such as coral reefs and ensures that methodologies developed in freshwater systems are robust and adaptable.

Future work will focus on completing the analysis of all collected samples, further refining the standardized protocol, and delivering comprehensive datasets describing microplastic concentrations,

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sizes, shapes, polymer compositions, and estimated masses. These results will advance understanding of microplastic dynamics in freshwater lakes and support the development of effective monitoring strategies for marine and coral reef ecosystems.



Figure: Optimized microplastics sampling system used on LéXPLORE

LéXPLORE

Aqua-Gaps/MONET in Lake Lemman

Ines Tascon, Audrey Maillard, Amandine Gardoni, Sofie Huisman, Fabienne Pfeiffer, Vick Glanzmann, Naomi Reymond, Nicolas Estoppey, Céline Weyermann

Global water quality and aquatic food webs are increasingly threatened by the release of synthetic chemicals into the environment. The 'Aquatic Global Passive Sampling (Aqua-Gaps/MONET)' network aims at understanding geographical distribution and temporal trends of persistent organic pollutants (POPs) as well as compounds of emerging concern. Aqua-Gaps/MONET has taken advantage of the key benefits of passive samplers to establish a global monitoring program in the waters of the world¹. The 'Ecole des Sciences Criminelles (ESC)' of the University of Lausanne (UNIL) oversees the deployment of samplers in Lake Geneva since 2016 (Buchillon station)^{2,3}. The results of the first years of sampling (2016 to 2021) have been published recently^{4,5}.

Since 2021, passive samplers are deployed at LéXPLORE instead of Buchillon station. Passive samplers are deployed – for 1 year – at a depth of 3-4 m below surface level using an 'open cage' (see Figure 1). Three types of samplers are deployed. Silicone sheets sample hydrophobic compounds (e.g. PCBs), Speedisks sample polar compounds (e.g. pharmaceuticals) and microporous polyethylene sample per- and polyfluoroalkyl substances (PFASs). Quantification of contaminants in exposed samplers is centrally done by RECETOX (Czech Republic) to ensure a good comparability among all sampling sites around the globe. Produced data are 'concentrations of dissolved contaminants in water', expressed in pg/L or ng/L depending on the contaminants.

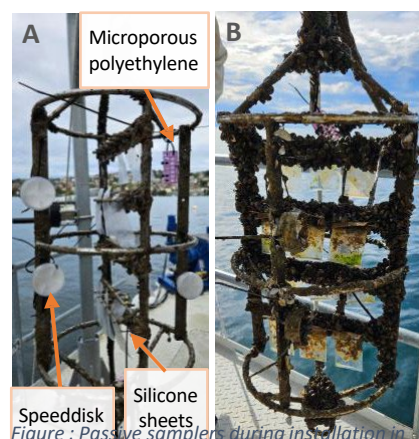


Figure 1: Passive samplers during installation in Lake Geneva in October 2024 (A) and retrieval in October 2025 (B)

From 2021 to 2024 similar contamination trend was observed for each type of target compounds. For example, among the deployed samplers around the world, this site always showed the highest concentrations of γ -hexachlorocyclohexane (around 100 pg/L), an insecticide banned for over 20 years. Other compounds showed high but varying concentrations as the synthetic musk, galaxolide (3-100 ng/L). From these samplers, precious data on levels of contaminants in Lake Geneva is provided. The most problematic compounds can be highlighted and integrated in future passive sampling-based monitoring campaigns in Lake Geneva tributaries.

In the next years, further passive samplers' deployments at LéXPLORE are planned to extend the knowledge of the contamination problems in the region and to follow their evolution.

¹ Lohmann, R., & Muir, D. (2010). Global Aquatic Passive Sampling (AQUA-GAPS): Using Passive Samplers to Monitor POPs in the Waters of the World. *Environmental Science & Technology*, 44(3), 860–864. doi:10.1021/es902379g

² Lohmann, R., & al. (2017). Aquatic Global Passive Sampling (AQUA-GAPS) Revisited: First Steps toward a Network of Networks for Monitoring Organic Contaminants in the Aquatic Environment. *Environmental Science and Technology*, 51(3), 1060–1067. doi:10.1021/acs.est.6b05159

³ Sobotka, J., & al. (2022). Performance comparison of silicone and low-density polyethylene as passive samplers in a global monitoring network for aquatic organic contaminants. *Environmental Pollution*, 302, 119050. doi:10.1016/j.envpol.2022.119050

⁴ Lohmann, R., & al. (2023). Passive-Sampler-Derived PCB and OCP Concentrations in the Waters of the World—First Results from the AQUA-GAPS/MONET Network. *Environmental Science & Technology*, 57(25), 9342–9352. doi:10.1021/acs.est.3c01866

⁵ Lohmann, R., & al. (2024). AQUA-GAPS/MONET-Derived Concentrations and Trends of PAHs and Polycyclic Musks across Global Waters. *Environ Sci Technol*. doi:10.1021/acs.est.4c03099

LéXPLORE

Temporal and spatial variations of the settling particles fluxes in Lake Geneva (SEDTRAP)

Natacha Pasche, Emma Faval, Nathalie Dubois, David Janssen, Guillaume Cunillera, Jérémy Keller

The SEDTRAP project monitored settling particle fluxes at LéXPLORE in 2024 and 2025, using sediment traps deployed at 10, 30, 50, and 100 m depths. In 2025, we completed detailed analyses of the 2020–2024 dataset and prepared the manuscript *Rivers beneath the surface: how riverine inputs shape sedimentation in a large peri-alpine lake* (Faval et al.), which was submitted to *Aquatic Sciences*. The full dataset has also been made publicly available on Zenodo (<https://zenodo.org/records/17607859>).

Our analysis highlights the dominant role of extreme hydrometeorological events in driving particle transport and sedimentation. The 2021 flood produced the highest fluxes across all depths, facilitated by an efficient Rhône interflow. In contrast, the 100-year floods in 2024 resulted in weaker sedimentation due to a deeper interflow. Additional strong flux pulses were associated with intense storms in summer 2022 and in late 2023, both of which triggered shoreline resuspension.

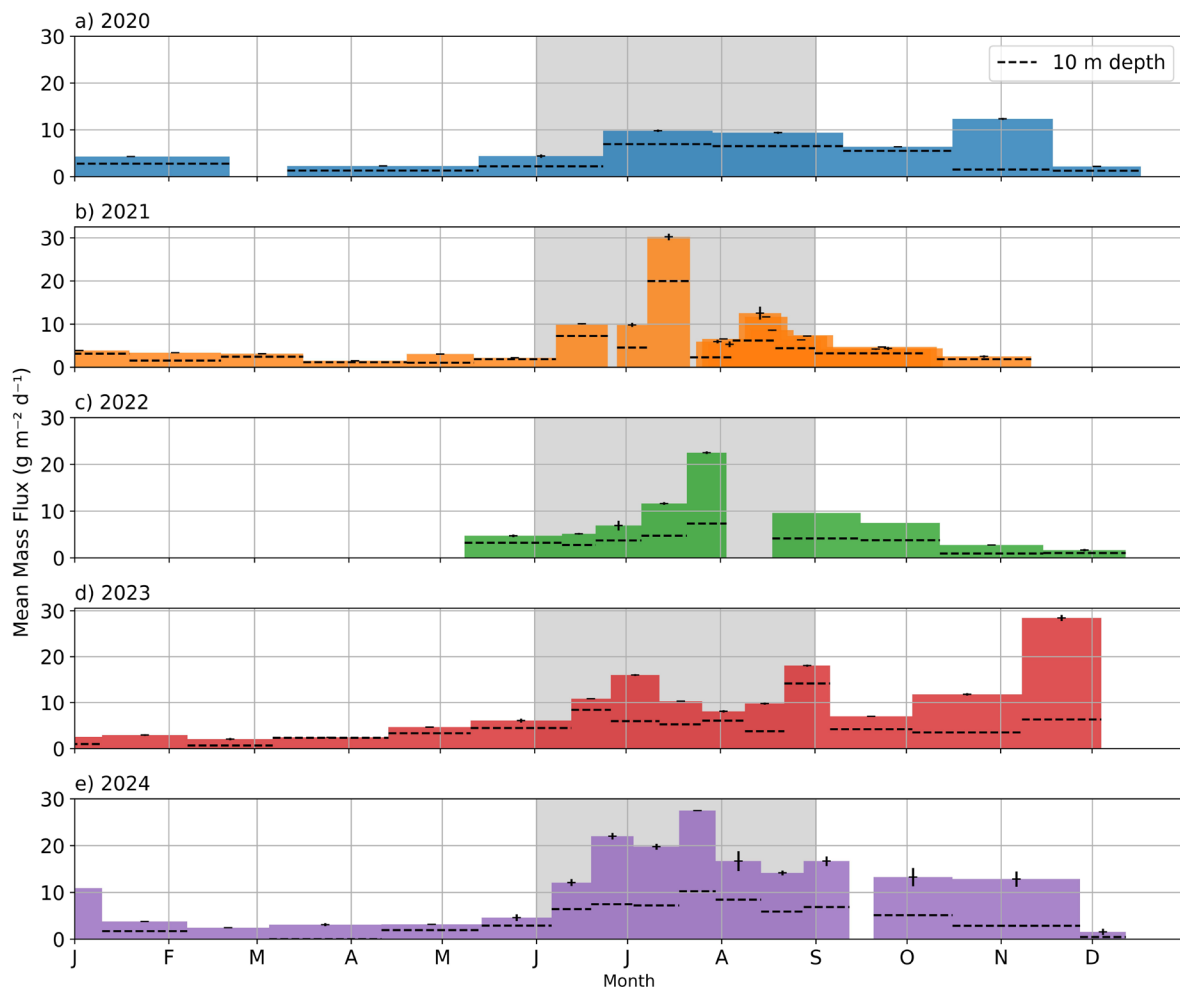


Figure: Total mass fluxes ($\text{g m}^{-2} \text{d}^{-1}$) from 2020 to 2024. Averaged values are presented for 30, 50 and 100 m depths (colored bars) in 2020 (a), 2021 (b), 2022 (c), 2023 (d) and 2024 (e). The black dashed line represents the total mass flux at 10 m depth. The peak in discharge from 1st June to 31st August is highlighted in grey.

LéXPLORE

Project: Lake Primary Production using PACE (Lake3P)

Daniel Odermatt, Mortimer Werther, Jonas Wydler

Optical Earth observation satellites provide a very efficient means to model aquatic primary production based on direct input estimates of photosynthetic pigment absorption, downwelling irradiance, and light attenuation. The Lake3P project aims to investigate bio-optical model performance in and their adjustment for stratified water bodies, and how the latest generation of hyperspectral satellite sensors can improve the estimation of primary production.

After transitioning from ^{14}C to ^{13}C primary production incubation sampling in Spring/Summer 2024, several campaigns were conducted on LéXPLORE between July 2024 - September 2025. During the 2024 incubation campaigns, we sampled also vertical profiles of bulk spectral absorption, attenuation and scattering (the inherent optical properties), and concentrations of optical agents to parameterize bio-optical primary production models. In between campaigns, we rely on bio-optical measurements acquired by the Thetis profiler, which however in early 2025 experienced a complicated hardware issue that could not be resolved until September 2025. The Thetis profiler is planned to be back in operation early 2026. Furthermore, we developed a flow-through system in 2024 - 2025 that can operate nearly the same instrument setup as Thetis. It can be used in two modes: 1) on a slowly cruising boat rather than on a profiler, allowing for complementary transect measurements at a single depth, 2) stationary, if water is pumped from multiple depths. To maintain continuous measurements of inherent optical properties on LéXPLORE, the flow-through system can be further developed either as a backup system for Thetis, or if the profiler is discontinued, as a replacement.

PhD student Jonas Wydler completed a manuscript in which we systematically evaluated the influence of three key elements of bio-optical primary production models: (1) vertical chlorophyll resolution, (2) planar-to-scalar irradiance conversion, and the photosynthesis-irradiance (P-I) relationship on primary production estimates in optically complex waters. Using a unified framework, 16 model configurations were tested against a diverse *in-situ* dataset spanning oligotrophic to eutrophic conditions in Lake Geneva, Estonian lakes, and the Baltic Sea. The results demonstrated that the choice of P-I function is the most critical factor, driving a range in both magnitude error and vertical shape correlation. Specifically, functions that accounted for photoinhibition were essential for accurately capturing the shape of production profiles in the upper water column. In contrast, using depth-resolved chlorophyll profiles offered only modest and inconsistent improvements, while the choice of irradiance conversion factor had a negligible impact. These findings highlight that model accuracy is currently constrained more by parameterization and validation data uncertainties than by the complexity of the model structure itself. Consequently, in our future research we will prioritize the refinement of P-I relationships and the development of standardized validation datasets that include concurrent measurements of inherent optical properties, such as those carried out at LéXPLORE in 2024-2025.

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The new PACE satellite launched by NASA in February 2024 provided the first imagery of Lake Geneva a few weeks after launch, however the necessary atmospheric correction methods to convert top-of-atmosphere radiance into water-leaving reflectance necessary for bio-optical retrieval of primary production rates only became available months after launch. Tests with available Thetis hyperspectral reflectance measurements show good agreement (Fig. 1a). These PACE hyperspectral reflectance products are subsequently used to produce prototype primary production products based on chlorophyll, but not yet hyperspectral inherent optical property inputs (Fig. 1b).

Future efforts will thus leverage the insights gained into bio-optical primary production modelling on Lake Geneva and the NASA PACE mission to develop improved approaches applicable to Lake Geneva. These approaches will be primarily calibrated using measurements from LéXPLORE and will enable a near-daily estimation of primary production.

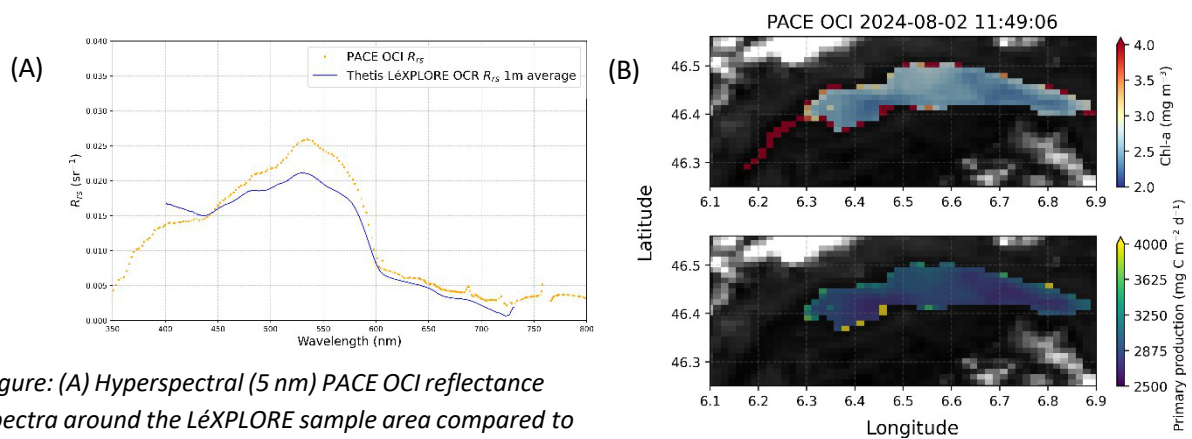


Figure: (A) Hyperspectral (5 nm) PACE OCI reflectance spectra around the LéXPLORE sample area compared to Thetis Profiler OCR reflectance.

(B) Top: Chlorophyll-a concentration (Chl-a) obtained through the Smith-OC6 model, Bottom: Daily phytoplankton primary production obtained through the VGPM model using the Smith-OC6 Chl-a values for parameterisation.

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WIND2WAVES

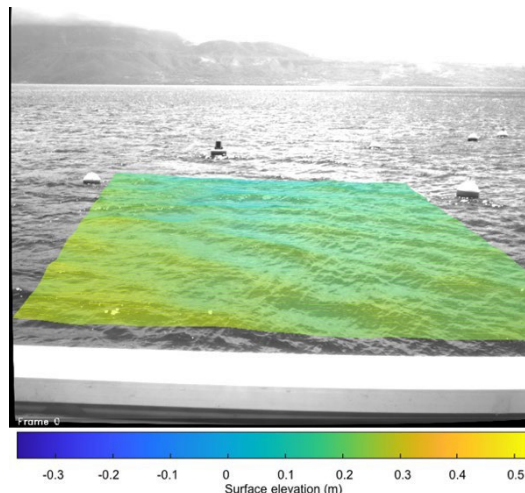
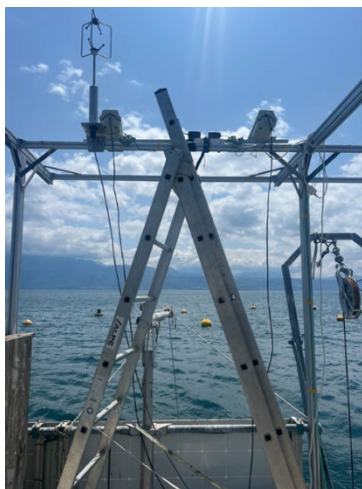
Andrea Belli Contarini, Bryan Kunz, Maura Brunetti, Jérôme Kasparian, Damien Bouffard, Alexander Babanin

The interaction between wind and waves is a central process in fluid dynamics, governing energy and momentum exchanges at the air–water interface. Understanding these mechanisms in lakes is particularly relevant, as they provide an intermediate scale and complexity between controlled wave flumes and oceanic environments.

In April, we resubmitted the project to the Swiss National Science Foundation. Although the project was not funded, we made some progress with the help of two Master students.

Using financial support from the Physics Department and the Institute for Environmental Sciences, we bought additional instruments: a second anemometer and an accelerometer. From February to May, Andrea Belli Contarini worked in Geneva on his Master's project. He designed, validated, and deployed the multi-sensor system based on synchronized stereo imaging and two ultrasonic anemometers. He also developed a complete data-analysis pipeline in Python, from the reconstruction of the surface elevation (using WASS, the Waves Acquisition Stereo System developed by Bergamasco *et al.* in Venice, Italy) to the estimation of directional wave spectra. He tested the entire setup on a small water tank, on the Small Lake and finally on the LéXPLORE platform in June. He defended his Master's thesis in October at the University of Rome 'La Sapienza' with the highest grade.

Since September, Bryan Kunz has taken over. He is currently optimising and improving the whole experimental setup. In the meantime, with the help of Michel Moret at the Physics Section and the technicians on the platform, we are planning the optimal configuration for the horizontal extensions and the metallic structure to be attached to the masts on the platform to install the instruments. These extensions will be soon commissioned to the Mechanical Workshop of the Physics Section at the University of Geneva.



Left: The experimental setup on the platform for the preliminary measurements performed in June 2025.

Right: Surface elevation reconstructed by the WASS model from the stereo images.

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Autonomous turbulence profiling (LéWALK)

Tomy Doda, Damien Bouffard, Sebastiano Piccolroaz, Miguel Gil Coto, Sébastien Lavanchy, Guillaume Cunillera, Christian Dinkel and Bieito Fernandez Castro

Abstract

The LéWalk preliminary project successfully achieved its mission of developing and validating autonomous turbulence profiling systems for lakes, establishing the technical and scientific foundation that secured a four-year SNSF project (2026-2030) on surface layer dynamics. Through extensive field testing and sensor comparisons, we demonstrated operational capabilities that address current research gaps in lake turbulence measurements, particularly during extreme forcing events.



Figure 1: Photo of the autonomous turbulence profiler used on the LéXPLORE platform

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Main results

Autonomous microstructure profiler development

We successfully adapted an innovative autonomous profiler that harvests energy from surface waves to conduct measurements during windy conditions—precisely when traditional boat-based or LéXPLORE-based sampling is impossible. With 4 FP07 fast-response thermistors mounted on a Rockland Micropod, sampling at 512 Hz while ascending at ~ 20 cm/s, this configuration achieved millimeter-scale spatial resolution with mK temperature sensitivity, enabling dissipation rate estimates from 10^{-10} to 10^{-6} W/kg. Multiple deployment configurations were tested to optimize sensor placement and minimize flow disturbance.

Argo-Inspired buoyancy-controlled profiler development

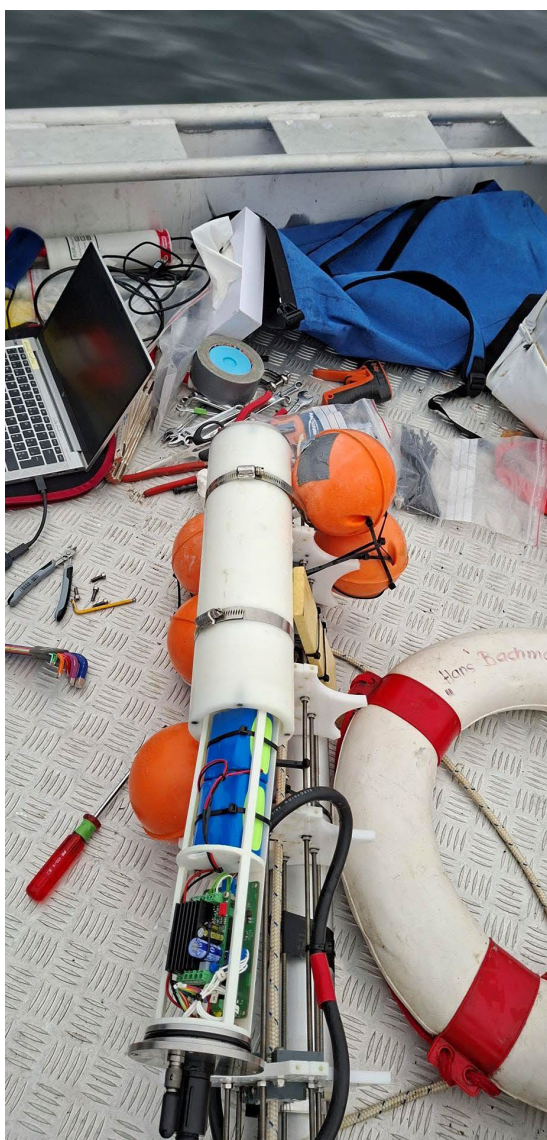


Figure 2: Photo of the developed Argo-like CTD profiler

This project was also an opportunity to initiate parallel development of a battery-powered profiler with piston-controlled buoyancy that provides complementary capabilities similar to classical oceanographic Argo floats. The system tested on LéXPLORE is now operational on Lake Lucerne since July, with data available on Datalakes (<https://www.datalakes-eawag.ch/datadetail/1421>).

The system allows programmable depth cycling (0-50 m), payload integration with CTD and microstructure sensors, and battery endurance (>50 profiles per charge). Future telemetry for real-time data transmission is now being developed. Given the reduced cost, the system is planned for deployment to remote alpine lakes in the future.

LéWALK results enabling SNSF proposal

Using LéXPLORE data, it became evident that the dynamics of the surface layer were not well documented. The problem became clear when we compared the thermally-defined surface layer (epilimnion) extent with the actively turbulent surface mixed layer (ASL) depth identified from dissipation profiles. These observations directly motivated the central research question of the SNSF project: distinguishing physical processes governing the ASL (actively mixing) from those controlling the SL (thermal structure), which are routinely conflated in lake literature despite representing fundamentally different dynamics with distinct implications for biogeochemistry.

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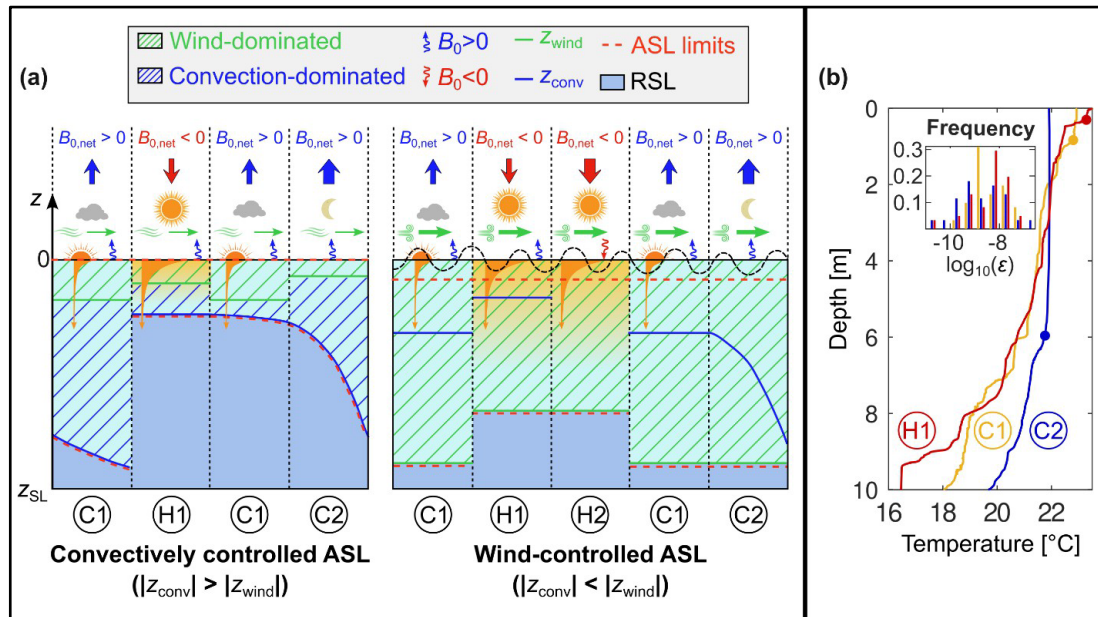


Figure 3: Evolution of the ASL based on forcing conditions. (a) Forcing cases representative of a typical diurnal cycle, in the case of a convectively (left) and wind (right) controlled ASL. (b) Microstructure temperature profiles collected at LéXPLORE on 27-28.08.2019 over the 10 m-thick SL, with the distribution of temperature-based dissipation values shown as an inset. The dots on the profiles depict the base of the ASL from visual inspection

The validated measurement capabilities directly enabled our successful SNSF proposal, which focuses on four research questions:

1. **SL Structure and Forcing Response:** How does vertical SL structure respond to rapid forcing changes? How can we parameterize SL limits? What is the role of diurnal re-stratification, surface convection, and shortwave radiation penetration? Our ability to profile continuously through forcing transitions provides the observational foundation.
2. **TKE Pathways:** How do turbulent kinetic energy sources and sinks vary over diurnal and seasonal cycles? How does wind energy transfer efficiency depend on waves and stratification? What are the relative contributions of wind vs. convection?
3. **Parameterization Testing:** What is the applicability of existing SML depth and turbulent diffusivity parameterizations? What are the effects of surface waves, Langmuir circulation, and lateral processes?
4. **Measurement Methodology:** How can we quantify turbulence at high frequency over seasonal scales? How do different measurement methods compare? How can we quantify error in turbulence estimates? The sensor testing program addressed these questions during the preliminary phase and established protocols for the full study.

This project will be conducted on the LéXPLORE platform and is only possible thanks to the LéXPLORE platform.

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Conferences

Doda T., Rama J., Sepúlveda Steiner O., Ulloa H. N., Janssen D., Bouffard D. 2025. *Spatial variability of turbulent mixing across the constriction of a two-basin lake.*, EGU

Collected data

Data produced by the ARGO-type profiler <https://www.datalakes-eawag.ch/datadetail/1421>

Data from the LéWALK were used for method development and do not reach the quality for publication.

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The impact of the Rhône River intrusion on nutrient and organic matter distribution at the LÉXPLORE platform, Lake Geneva: allochthonous and autochthonous contributions

Lucia Mottet, Torsten Vennemann

Abstract

The Rhône River is the main tributary of Lake Geneva and plays a central role in shaping its physical and biogeochemical dynamics. During periods of thermal stratification, the cold, dense, and sediment-rich waters of the Rhône enter the lake and form a subsurface interflow that propagates laterally at intermediate depths. This intrusion can extend over tens of kilometers and represents an efficient pathway for the transport of dissolved and particulate matter from the watershed into the pelagic zone. Understanding the extent and biogeochemical impact of this interflow is therefore essential for assessing nutrient and carbon cycling in Lake Geneva.

This study investigates how the Rhône interflow influences the vertical distribution of nutrients and organic matter at the LÉXPLORE research platform. Particular attention is given to distinguishing between allochthonous inputs derived from the Rhône River and autochthonous material produced within the lake itself. The study focuses on seasonal contrasts between summer stratification and autumnal mixing, two key periods controlling the fate of riverine inputs in large peri-Alpine lakes.

To achieve these objectives, vertical profiles of physical parameters (temperature, electrical conductivity, and pH), major ions, carbon fractions (dissolved inorganic carbon, total organic carbon, and suspended organic matter), and stable isotopes were measured during two field campaigns conducted in August and October 2024. Water samples were collected from depth of 0 to 70 m, with a higher vertical resolution at the interflow depth at the LÉXPLORE platform, while representative samples of the Rhône River were collected at Porte du Scex, before it enters the lake. A two-endmember mixing model based on $\delta^{18}\text{O}$ was applied to estimate the fraction of Rhône water at each depth in the lake water column. In addition, carbon stable isotope compositions ($\delta^{13}\text{C}$) of dissolved inorganic carbon (DIC) and suspended organic matter (SOM) were analyzed, and the isotopic difference between these two pools ($\Delta\delta^{13}\text{C} = \delta^{13}\text{C-SOM} - \delta^{13}\text{C-DIC}$) was used as an indicator to distinguish between autochthonous production and allochthonous organic matter inputs.

The results demonstrate that the Rhône interflow exerts a strong and measurable influence on the physical, chemical, and isotopic structure of the water column at the LÉXPLORE site. In summer, the interflow is clearly confined to the metalimnion, where distinct anomalies in temperature, conductivity, water isotopes, and conservative ion concentrations reveal the presence of Rhône-derived water. In autumn, as thermal stratification weakens and vertical mixing develops, the Rhône signal becomes deeper and more diffuse, indicating increased dilution and redistribution of riverine inputs within the water column. The combined use of physical tracers, conservative and reactive ions, carbon concentrations, and stable isotopes ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$, $\delta^2\text{H}$) proved effective for identifying the intrusion and constraining its seasonal variability.

Overall, the results highlight the mixed origin of the lake's carbon pool, shaped by both Rhône-derived allochthonous material and autochthonous biological production within the lake. Variations in $\Delta\delta^{13}\text{C}$ provide valuable insights into the relative importance of these sources and their vertical and seasonal

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distribution. These findings emphasize the importance of monitoring Rhône-derived intrusions beyond the river mouth, as they influence the pelagic zone not only through the direct delivery of dissolved and particulate matter, but also indirectly by interacting with in-lake biogeochemical processes. By combining multi-parameter vertical profiling with isotope-based mixing models, this work provides a comprehensive view of the seasonal dynamics of a major fluvial input to Lake Geneva and contributes to a better understanding of river–lake interactions in large stratified lake systems.

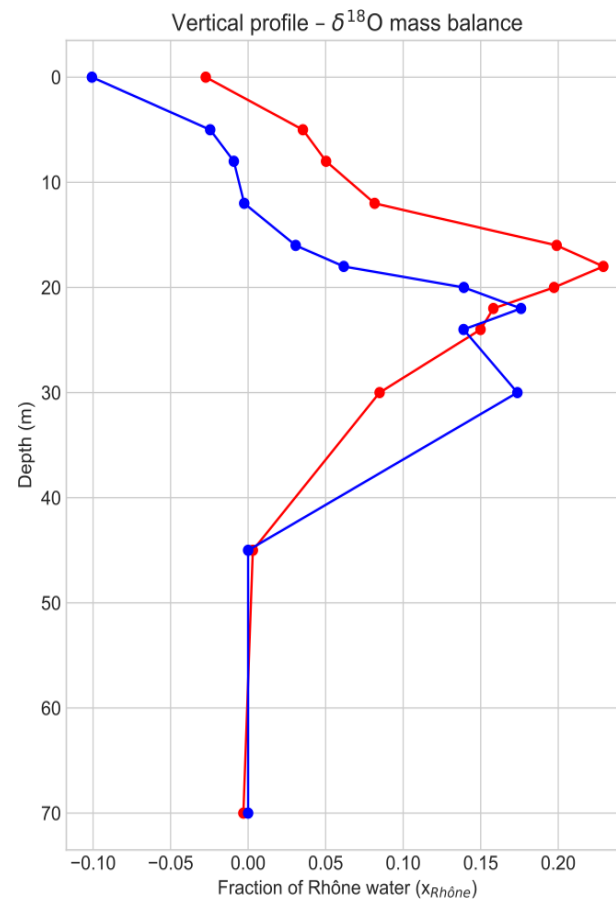


Figure 1: Vertical profiles of the fraction of Rhône River water ($x_{\text{Rhône}}$) in Lake Geneva during the August (red) and October (blue) sampling. The uncertainty corresponds to $\pm 2\%$ on $x_{\text{Rhône}}$ for both profiles.

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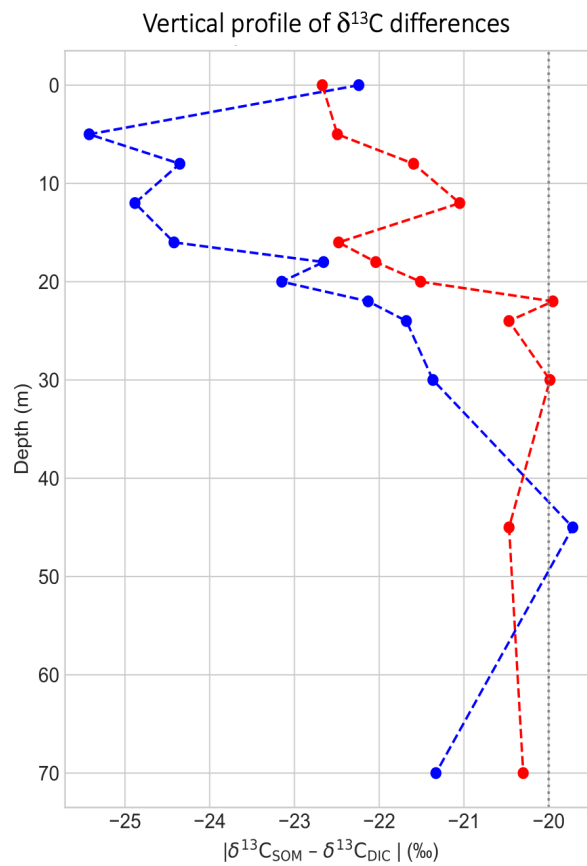


Figure 2: Vertical profiles of $\Delta\delta^{13}\text{C}$ in Lake Geneva during the August (red) and October (blue) sampling. The grey dashed line indicates the expected difference (~ 20 ‰) between SOM and DIC. Error bars are not visible as the uncertainty on $\Delta\delta^{13}\text{C}$ is ± 0.11 ‰ on xRhône for both profiles.

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Main results

This study provides a detailed characterization of the physical, chemical, and isotopic imprint of the Rhône River intrusion on the water column of Lake Geneva at the LéXPLORE platform. By combining high-resolution vertical profiles, conservative and reactive tracers, and stable isotope analyses, the results highlight the seasonal dynamics of the Rhône interflow and its influence on nutrient and carbon distribution in the pelagic zone.

The hydrodynamic structure of the lake differed markedly between the two sampling periods. In August 2024, strong thermal stratification was observed, with a well-defined thermocline and stable epilimnetic conditions. Temperature and conductivity profiles revealed distinct anomalies between approximately 12 and 30 m depth, indicating the presence of a subsurface Rhône interflow. In contrast, October 2024 conditions showed weakened stratification and the onset of vertical mixing, resulting in a broader and deeper zone of physical heterogeneity extending from about 18 to 45 m. Below these depths, physical parameters converged toward homogeneous deep-water values during both campaigns.

Stable water isotopes ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) provided clear evidence of Rhône-derived water within the lake water column. In August, both isotopes exhibited pronounced minima within the metalimnion, consistent with the isotopically depleted signature of Rhône water relative to Lake Geneva. The $\delta^{18}\text{O}$ -based two-endmember mixing model indicated a maximum Rhône water fraction ($x_{\text{Rhône}}$) within the interflow layer, confirming the lateral propagation of the river plume at intermediate depths. In October, the isotopic signal was weaker and more diffuse, reflecting enhanced dilution and redistribution of Rhône water due to seasonal mixing. The uncertainty associated with $x_{\text{Rhône}}$ estimates remained low ($\pm 2\%$), supporting the robustness of the isotopic mass balance approach.

The vertical distribution of conservative ions (Cl^- , Na^+ , F^- , Br^- , Li^+) closely mirrored the isotopic and physical patterns. In August, several conservative tracers displayed local minima or inflection points within the interflow zone, consistent with the lower ionic concentrations of Rhône water compared to lake water. In October, these anomalies were attenuated but still detectable over a wider depth range. Linear relationships between conservative ion concentrations and $x_{\text{Rhône}}$ confirmed that these elements primarily reflected physical mixing processes, with limited influence from internal biogeochemical transformations.

In contrast, biologically active ions exhibited more complex vertical patterns. Nutrient species such as nitrate, ammonium, and sulfate showed depth-dependent variations influenced by both Rhône inputs and in-lake processes, including biological uptake, remineralization, and redox reactions. Calcium, magnesium, and strontium concentrations were affected by carbonate equilibrium and calcite precipitation, particularly in surface and metalimnetic waters during summer. These results indicate that the Rhône interflow not only transports solutes into the lake but also interacts with internal biogeochemical cycles.

Carbon-related parameters further highlighted the mixed origin of organic matter in Lake Geneva. Dissolved inorganic carbon (DIC) concentrations increased with depth, while $\delta^{13}\text{C}$ -DIC values reflected the combined effects of photosynthetic uptake in surface waters and respiration at depth. Suspended organic matter (SOM) concentrations and $\delta^{13}\text{C}$ -SOM values showed distinct vertical gradients, with isotopic signatures indicating a combination of autochthonous production in the photic zone and allochthonous Rhône-derived material within the interflow. The isotopic difference $\Delta\delta^{13}\text{C}$ between DIC

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and SOM varied with depth and season, indicating changes in the relative influence of autochthonous production and allochthonous inputs, while reflecting the complex mixing and transformation of carbon sources within the water column.

Overall, the results demonstrate that the Rhône interflow exerts a strong, seasonally variable control on the physical structure and biogeochemical functioning of the pelagic zone at the LéXPLORE platform.

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Collected data

This study is based on a set of physical, chemical, and isotopic data collected at the LéXPLORE research platform in Lake Geneva and at the Rhône River near its river mouth. The datasets were acquired during two dedicated field campaigns conducted on 28 August 2024 and 22 October 2024, and are complemented by reference data provided by institutional monitoring programs. The following metadata summarize all datasets collected and used in this study.

Physical parameters

Vertical profiles of water temperature ($^{\circ}\text{C}$), electrical conductivity (mS cm^{-1}), and pH (–) were obtained at the LéXPLORE platform using a CTD profiler. Measurements were conducted on the same days as water sampling and cover the upper 70 m of the water column, with higher vertical resolution in the Rhône interflow zone. These data characterize the hydrodynamic structure of the lake and were used to identify stratification, thermocline depth, and physical anomalies associated with the Rhône intrusion.

Stable water isotopes

Water samples were collected at discrete depths at LéXPLORE and analyzed for stable oxygen and hydrogen isotopes ($\delta^{18}\text{O}$ and $\delta^2\text{H}$, expressed in ‰ relative to VSMOW). Samples were filtered in the field ($0.22\text{ }\mu\text{m}$) and analyzed by cavity ring-down spectroscopy (CRDS). These isotopic data were used to trace Rhône-derived water within the lake and to quantify the Rhône water fraction ($x_{\text{Rhône}}$) using a two-endmember mixing model.

Carbon-related parameters

Carbon-related datasets include dissolved inorganic carbon (DIC, mg L^{-1}), total organic carbon (TOC, mg L^{-1}), suspended organic matter (SOM, $\mu\text{g L}^{-1}$), and the carbon isotopic composition of DIC and SOM ($\delta^{13}\text{C}$, ‰ relative to VPDB). Samples were collected at LéXPLORE at twelve discrete depths between the surface and 70 m. DIC concentration and $\delta^{13}\text{C}$ -DIC were measured by isotope ratio mass spectrometry (IRMS), TOC by high-temperature catalytic combustion, and SOM by gravimetric filtration followed by isotopic analysis. These data document the vertical distribution and origin of carbon pools in the lake.

Major ions

Major dissolved anions (F^{-} , Cl^{-} , Br^{-} , NO_3^{-} , NO_2^{-} , PO_4^{3-} , SO_4^{2-}) and cations (Li^{+} , Na^{+} , NH_4^{+} , K^{+} , Mg^{2+} , Ca^{2+} , Sr^{2+}) were measured on filtered water samples ($0.22\text{ }\mu\text{m}$) collected at LéXPLORE during both campaigns. Analyses were performed by ion chromatography. These datasets provide information on conservative mixing processes and biologically active solutes associated with Rhône inputs and in-lake biogeochemical cycling.

Rhône River reference data

Surface water samples from the Rhône River were collected at the Porte du Scex monitoring station prior to each lake sampling campaign. These samples provide reference endmember values for stable isotopes, major ions, and carbon parameters. In addition, continuous Rhône River data for temperature, electrical conductivity, and pH were provided by the Swiss Federal Office for the Environment (FOEN) for the corresponding periods.

Plastisphere in Lake Geneva

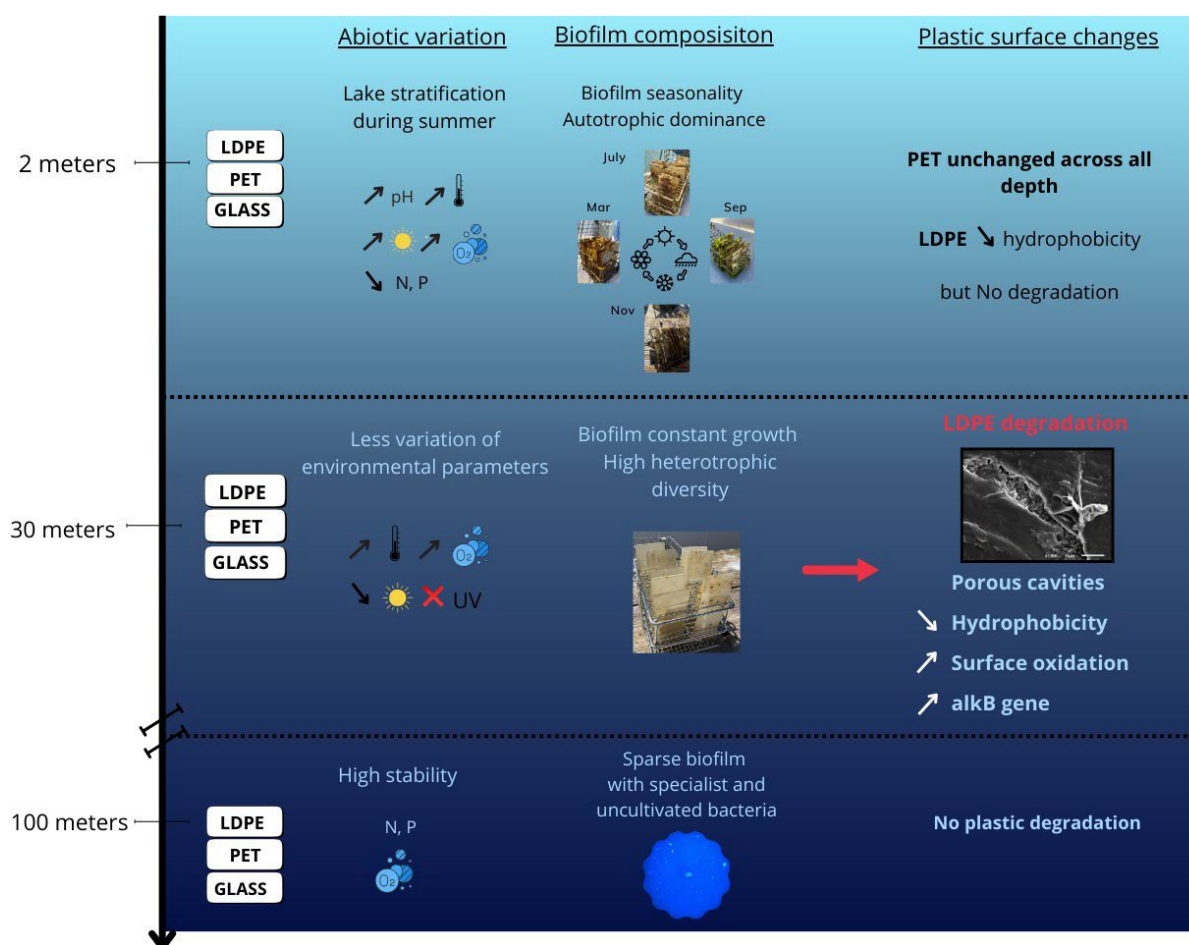
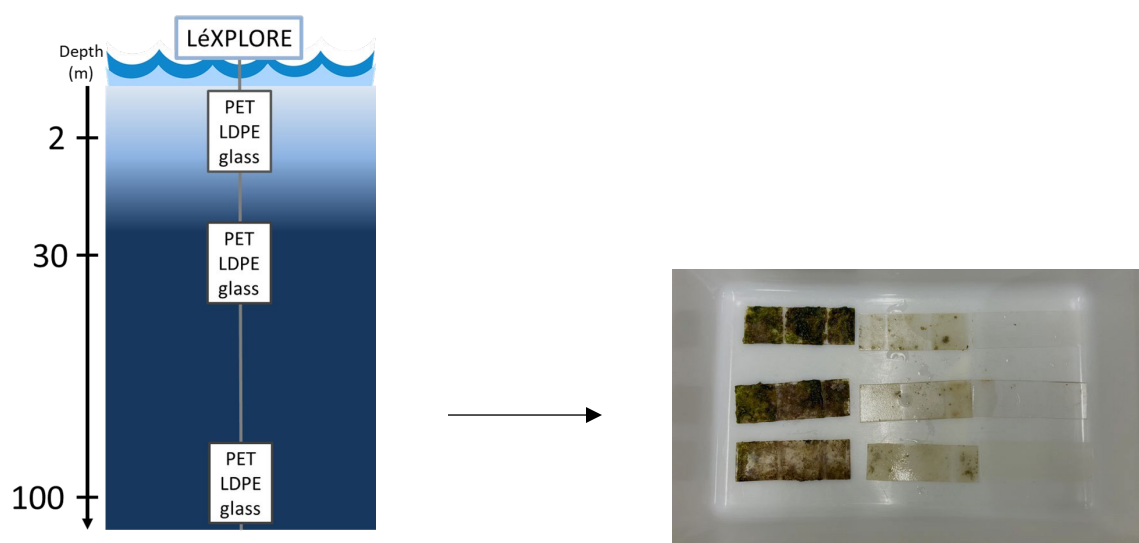
Laureen Mori-Bazzano, Bastiaan Ibelings

Abstract

This project aims to identify the composition of the plastic-associated microbial community in Lake Geneva and to understand the time scale of the colonization under different seasonal and spatially conditions. In addition to the microbiology, we monitor the plastic surface changes over time to determine any possible degradation. Plastic degradation can be caused by abiotic factors like weathering or can be biotic due to microbial degradation. The platform LéXPLORE offers a unique opportunity to study biofilm colonization on plastic in the natural environment. We chose low-density polyethylene (LDPE) and polyethylene terephthalate (PET) because they are mostly used for packaging and frequently found in the environment. Furthermore, LDPE and PET are chemically different thus differ in their interaction with the water and microbial life therein; LDPE is an amorphous hydrocarbon and PET is a semi-crystallin aromatic polyester. LDPE, PET, and glass pieces (2 x 7 cm) have been incubated since January 2023 at different depths in the lake (2 meters, 3 meters, and 100 meters) to represent various environmental conditions. Plastics are sampled periodically and returned to the laboratory for analysis. On the one hand, the biofilm's DNA is collected and extracted for molecular study using Next Generation Sequencing and qPCR. Several primers are used to identify bacteria (16S), algae (18S), and fungi (ITS), hence the diversity of the microbial community. Regarding the qPCR, we are looking at the abundance of genes corresponding to the metabolism of plastics and alkane enzymatic degradation. Once the biofilm has been removed from the plastic in the lab, we look at possible changes in the plastic surface chemistry. The contact angle (θ_c) quantifies the wettability of a surface; if the angle is more than 90° degrees the surface is hydrophobic, when less hydrophilic. The biofilm formation can decrease the hydrophobicity of plastic because of the secretion of EPS which acts as a surfactant. Secondly, we use Fourier Infrared spectroscopy to monitor the plastic's surface chemistry. With plastic degradation, we expect to have the formation or missing of functional groups on the surface of the polymer. Finally, we look at the plastic surface through Scanning Electron Microscopy which gives precise imaging at a very low scale.

These results indicate that the stratification of Lake Geneva creates unique environmental niches that promote biofilm development. This study also reveals the presence of freshwater plastisphere taxa that had not been previously reported. Furthermore, our findings suggest that heterotrophic microorganisms contribute more to plastic degradation at 30m depth.

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Main results

Our results indicate that the abundance and composition of the biofilm are driven by the depth gradient of the lake and seasonality, reflecting the lake stratification process. In the upper layer, spring warming favours rapid biofilm development dominated by photoautotrophic colonisers, such as *Licmophora juergensii* and *Sellaphora puppula*, which contribute significantly to plastisphere dynamics. During summer, high solar radiation and lake stratification may become unfavourable for biofilm growth due to photo-inhibition and nutrient scarcity. In autumn, surface conditions return to being favourable for autotrophic colonisation and biofilm development, especially filamentous Cyanobacteria. At 30 m depth, environmental conditions are more stable, allowing continuous biofilm development. Lower temperature and near-absence of light favour the colonisation by heterotrophic microorganisms; the community is more diverse, and includes bacteria, ciliates and fungi. The ciliate *Acineta flava* manages to colonise all substrate types at all depths, even at 100 m, where the community is sparse. At 100 m, environmental conditions remain nearly constant; low temperature reduces the metabolic activity and constrains biofilm development. Although substrate type had no significant effect on the overall community composition, we observed the presence of specific taxa on plastic versus glass and substrate.

No degradation was observed on PET surface at both depths over time, which is consistent with its chemical structure, making it more resistant to environmental pressures. Physiochemical changes were observed on LDPE at 2 m, a decrease in hydrophobicity, and the SEM imaging revealed deterioration of the surface, but without oxidation. Furthermore, only at 30 m, the LDPE displayed signs of degradation, confirmed by the presence of oxidative groups through FTIR and porous cavities observed via SEM. As incident light is minimal at 30 m, biofragmentation is suggested as the main degradation mechanism of LDPE. These findings align with the presence of plastic-degrading bacterial taxa, such as the genus *Sphingomonas* and the family 67–14 belonging to the *Actinobacteria*, or fungal taxa such as the genus *Cladosporium* and *Tetracladium*. The increase of the *alkB* gene abundance can be linked to the enzymatic activity of the bacterial taxa supporting the process bio-fragmentation hypothesis of LDPE. Advancing our understanding of plastic-associated microbial communities in freshwater ecosystems is crucial for assessing their role in plastic degradation and broader environmental impacts.

LéXPLORE

Publications

Laureen Mori-Bazzano , Nhung H.A. Nguyen , Alena Sevcu , Jakub Riha , Tingting Fu , Vera

I. Slaveykova , Bastiaan W. Ibelings (2025). Plastic degradation in Lake Geneva: Influence of depth, seasonal shifts, and bacterial community dynamics. *Science of the Total Environment* 983, 179615.

Laureen Mori-Bazzano, Nhung H.A Nguyen; Alena Sevcu; Jakub Riha; Vera I. Slaveykova; Bastiaan W. Ibelings (under review in *Water Research*). Spatio-temporal succession in a biofilm community on plastic in Lake Geneva.

Conferences

SETAC 2024 poster presentation

EMEC 2024 poster presentation, prize for best poster communication

Collected data

Over 2023:

- Environmental parameters: CTD profile at every sampling session
- Nutrient analysis: TOC/DOC and TN concentration in lake water at 2m, 30m and 100m
- Biomolecular analyses: Amplicon Sequence Variant of 16S (prokaryote), 18S (eukaryote), and ITS (fungi) gene in the biofilm at 2m, 30m and 100m

MethOX: Measurement of Methane Oxidation Rate to Understand Greenhouse Gas Emission from Lake Geneva

Santona Khatun, Jasmine S. Berg, Marie-Elodie Perga

Abstract

Methane (CH₄) emissions from freshwater lakes are a significant component of global greenhouse gas fluxes, yet they remain poorly constrained due to limited data on sources and sinks. Large natural lakes, such as Lake Geneva, can release CH₄ at rates comparable to or exceeding oceanic emissions, contributing to the so-called “freshwater methane paradox.” While CH₄ is primarily produced in anoxic sediments, repeated observations of metalimnetic CH₄ supersaturation in oxic waters of Lake Geneva suggest additional processes are involved. The role of water-sediment microbial communities in regulating CH₄ dynamics and accumulation remains largely unclear.

To address this, we conducted a spatial survey of water and sediment samples along a transect from the Rhône River delta to the LéXPLORE station, including wetlands in the Rhône delta. We measured CH₄ concentrations, $\delta^{13}\text{C}$ isotopic signatures, and the abundance and composition of microbial communities associated with methane cycling. Our results show that CH₄-related microbes are significantly more abundant in sediments than in the water column, consistent with higher CH₄ concentrations and more depleted isotopic values in sediments. These findings indicate that deltaic sediments, rather than wetlands, are the primary source of CH₄ accumulation in the metalimnion.

Microbial community analysis identified **SAR11**, **hgcl clade**, and **Flavobacterium** as dominant taxa potentially responsible for controlling metalimnetic CH₄ accumulation. The lateral transport of deltaic methane into the metalimnion via Rhône River intrusion, combined with partial oxidation, provides a mechanistic explanation for the observed CH₄ peaks at the LéXPLORE station. The efficiency of lateral transport, facilitated by turbulent diffusion, internal waves, and advection, allows CH₄ produced in sublittoral sediments to affect the lake center over distances exceeding 20 km.

These results highlight the importance of combining chemical, isotopic, and microbial analyses to resolve methane dynamics in large lakes. Although biogeochemical hotspots such as deltaic sediments occupy a small fraction of the lake surface, they play a disproportionately large role in shaping methane fluxes due to transport and accumulation processes. Future research will focus on mapping the directional pathways of deltaic CH₄ transport to fully understand the interaction between riverine and in-lake processes in forming metalimnetic CH₄ peaks.

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Overall, this study provides new insights into methane cycling in large lakes, clarifies the contributions of deltaic sediments and microbial communities to metalimnetic CH_4 accumulation, and improves our understanding of freshwater greenhouse gas emissions, which are critical for refining global CH_4 budgets and predicting climate feedback.

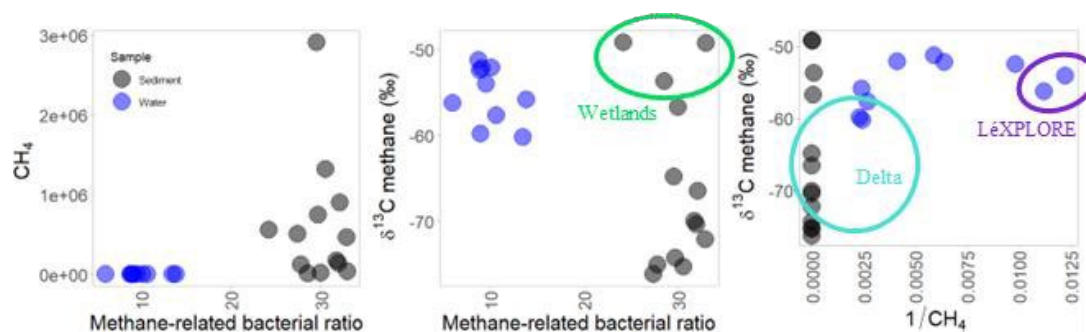


Figure 1: Methane-related microbial communities in waters and sediments of Lake Geneva. Sediment microbes showed higher abundance than in waters, and isotopic signatures indicate that deltaic CH_4 oxidation contributes to metalimnetic methane even at the LéXPLORE station.

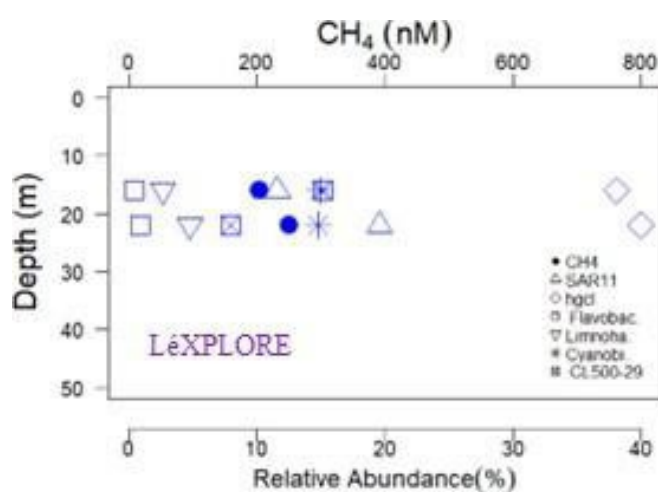


Figure 2: Distribution of sediment microbial communities potentially responsible for metalimnetic methane accumulation at the LéXPLORE station.

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Main results

Higher microbial abundance in sediments: Methane-related microbial communities were significantly more abundant in sediments than in water columns (Fig. 1). This indicates that sediments are the primary reservoir for CH₄-related microbes in Lake Geneva.

Deltaic sediments as main CH₄ source: Isotopic analyses of $\delta^{13}\text{C-CH}_4$ showed more depleted values in sediments compared to waters and wetlands, suggesting that deltaic sediments, rather than wetlands, are the source of metalimnetic CH₄ accumulation (Fig. 1).

Microbial taxa involved: Sediment microbes such as SAR11, hgcI clade, and Flavobacterium were identified as dominant communities potentially controlling CH₄ accumulation in the metalimnion (Fig. 2).

Transport mechanisms: The metalimnetic CH₄ peak at the LéXPLORE station is likely explained by lateral transport of deltaic CH₄ through Rhône River intrusion into the metalimnion, where partial oxidation occurs.

Learning points/challenges:

- Wetlands, initially suspected as CH₄ sources, were ruled out based on isotopic signatures.
- Capturing lateral CH₄ transport remains technically challenging due to turbulent diffusion and internal wave dynamics.

Implications: Understanding microbial mediation and deltaic CH₄ transport provides critical insights into greenhouse gas fluxes from large lakes.

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Publications

Khatun, S. *et al.* (2024) “Long-range transport of littoral methane explains the metalimnetic methane peak in a large lake,” *Limnology and Oceanography*, 69(9), pp. 2095–2108. Available at: <https://doi.org/10.1002/lno.12652>.

Khatun, S., Berg, J.S., Perga, M.-E. (2024). “Spatial distribution of microbial communities and methane dynamics in Lake Geneva,” 22nd Swiss Geoscience Meeting, Basel, Switzerland.

Manuscript in preparation for submission to an international peer-reviewed journal.

Conferences

Swiss Geoscience Meeting, Basel, 2024: Oral presentation on metalimnetic methane dynamics in Lake Geneva.

Collected data

Dataset	Type of data	Date collected	Description
Water CH ₄ concentration	Environmental	2024	Methane concentration measurements at multiple depths from Rhône delta to LéXPLORE station
Sediment microbial abundance	Microbial	2024	16S rRNA sequencing of sediment microbial communities
δ ¹³ C-CH ₄ isotopes	Chemical	2024	Stable isotope analysis of CH ₄ in water and sediment
Environmental parameters	Physical/Chemical	2024	Temperature, turbidity, oxygen, and other parameters

All datasets generated in this study, including CH₄ concentrations, δ¹³C isotopes, and microbial community data, will be deposited in the EPFL Data Repository for open access and long-term preservation. If required, we can discuss integrating these datasets into www.datalakes-eawag.ch for additional visibility and interoperability with other freshwater research datasets.

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Woszczyk, M. and Schubert, C.J. (2023) "Methane and Nitrous Oxide Emissions From an Anthropogenically Transformed Lake (Lake Licheńskie, Poland)," *Journal of Geophysical Research: Biogeosciences*, 128(12), p. e2023JG007594. Available at: <https://doi.org/10.1029/2023JG007594>.

Calcite precipitation dynamics in Lake Geneva (CALCIGEN)

Nicolas Escoffier, Jérémy Keller, Santana Khatun, Marie-Elodie Perga

Abstract

Inland waters play a major role in the global carbon cycle. Acting as biogeochemical reactors, freshwater ecosystems deliver only a fraction of the carbon received from land to the oceans, the remaining being buried in sediments or outgassed as CO_2 and CH_4 towards the atmosphere. Constraining the mechanisms of carbon transformation is key for refining the contribution of inland waters in global carbon models, however, our understanding of some important processes is still incomplete. In lakes, metabolic processes have commonly been assumed as central to carbon cycling. Yet, studies of hardwater systems have underlined the overlooked role of inorganic carbon processes, and particularly the precipitation of calcium carbonate (CP). While the dynamics of CP is linked to that of primary production, the exact implications of this coupling remain unclear.

The precipitation of CaCO_3 in deep lakes is commonly related to the small class size of autotrophic picoplankton and considered as a passive extracellular process. Biologically controlled mechanisms consisting of intracellular inclusions have, however, also been uncovered in distinct taxonomic groups. To date, observations of these mechanisms under natural conditions have remained elusive, confounding our comprehension of their environmental drivers and ecological relevance.

The project aimed at developing a methodology to reconcile the macroscopic dynamics of CP with its underlying microscopic mechanisms. To this end, CALCIGEN combined high frequency (HF) sensor data with discrete sampling to refine these questions in Lake Geneva. At LéXPLORE, HF data of temperature, conductivity and pH were acquired in the uppermost 30 m of the water column to describe the dynamics of CP and metabolic regime at fine scale. In parallel, discrete water column profiling and sampling were performed and coupled with flow cytometry and spectroscopic analytical techniques to further resolve environmental conditions and the role of picoplankton during CP.

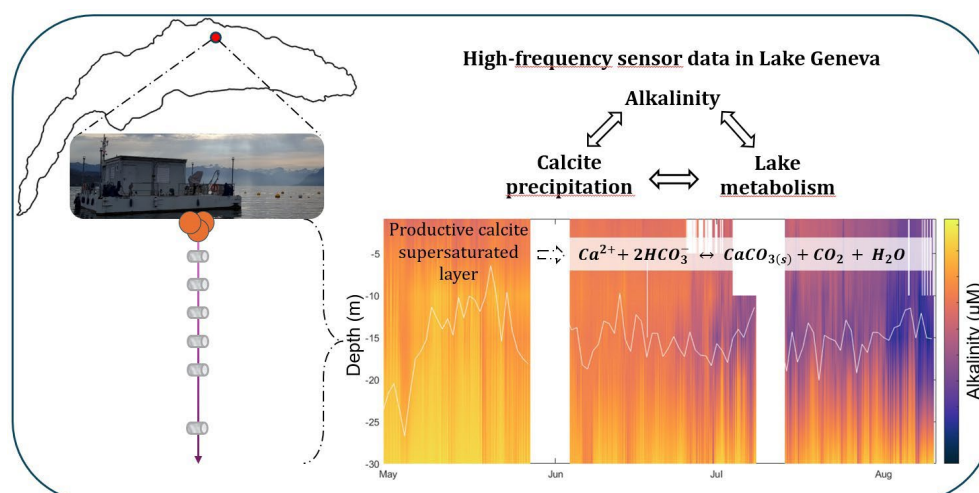


Figure 1. Schematic of the CALCIGEN sampling strategy at LéXPLORE aiming at describing calcite precipitation dynamics at fine scale and resolving its environmental drivers.

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Main results

Within the project, lake hydro-biogeochemical conditions were described through depth-resolved HF sensor data measured at LéXPLORE between July and October 2024 (Fig. 2). During this window, discrete samples were also collected at distinct depths and across several dates. Analyses of all data have not been finalized yet, but preliminary results offer an encouraging perspective on the findings expected within the project.

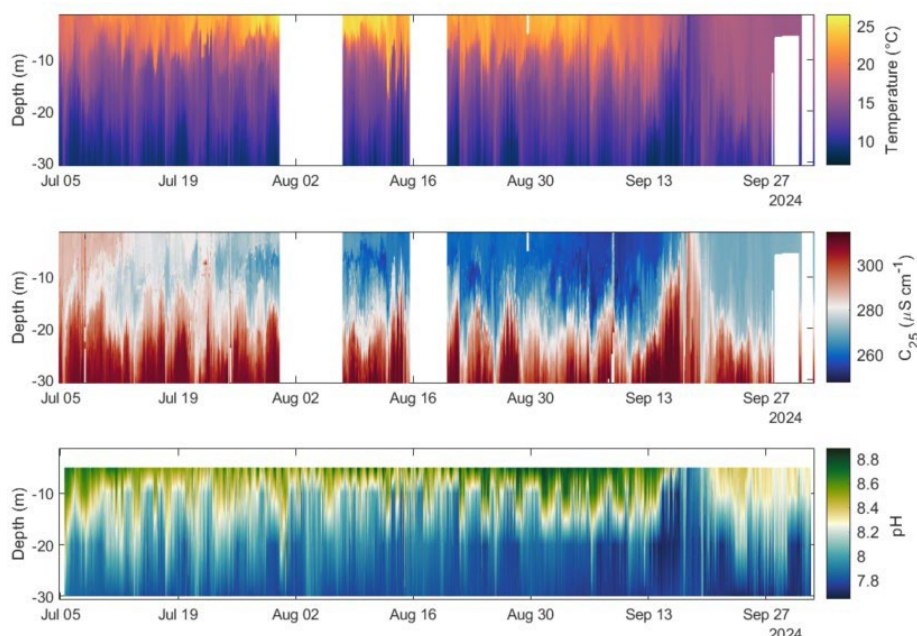


Figure 2. Timeseries of water temperature ($^{\circ}\text{C}$), specific conductivity at 25 C (C_{25} , $\mu\text{S cm}^{-1}$) and pH in 2024.

Beyond their short-term variability, the HF data illustrate the typical conditions associated with the thermal stratification of the lake water column during summer. During this stratified period, primary production occurred in surface layers (i.e., from the surface down to $\sim 15 - 20$ m depth), as reflected by the corresponding high pH values recorded (i.e., > 8.3). This also coincided with lower C_{25} values in lake surface waters, due to the loss of alkalinity (Alk) and Ca^{2+} ions by calcite precipitation, as previously shown in Lake Geneva.

The abundances of picoplankton populations were analyzed from discrete samples using full spectrum flow cytometry (FC) and specific spectral fluorescence signatures to discriminate phycoerythrin (PE)-rich picocyanobacteria and chlorophyll-rich picoeukaryotes. Results underlined that PE-rich picocyanobacteria were the dominant picoplankton population during summer 2024, with maximum abundances (i.e., $\sim 10^5$ cells ml^{-1}) being two orders of magnitude higher than that of the chlorophyll-rich picoeukaryotes. The temporal dynamics of the dominant population also showed its progressive concentration around 10m, which corresponds to the depth of higher stability at the thermocline. Compared to HF data, these observations confirm that higher Alk loss coincided with the period of maximum growth of picocyanobacteria.

The picoplankton populations identified by full-spectrum FC were additionally isolated using cell-sorting flow-cytometry techniques to investigate their role in the nucleation of calcite crystals. Using confocal Raman microscopy, analyses allowed detecting 57 Subsequent analyses were therefore performed by scanning electron microscopy coupled to energy dispersive X-ray analyses (SEM-EDX). While still ongoing, these analyses provide an enhanced resolution on distinct biocalcification patterns

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across dates of sampling, which should then be related to the finely resolved dynamics of CP and metabolic regime.

Publications & Conferences

The results presented in this report correspond to ongoing research. Once all analyses are finalized, the outcome of the project will be valued through the submission of a scientific peer-reviewed publication and communications at international conferences.

Collected data

- High frequency sensor data of water temperature ($^{\circ}\text{C}$), conductivity ($\mu\text{S cm}^{-1}$) and pH measured at several depths.
- Data on the physico-chemical composition of water samples (e.g., concentrations of major ions, alkalinity, nutrients) and abundances of picoplankton populations collected at several dates and depths.
- Micro-spectroscopic data on the chemical composition of mineral or biological particles isolated from water samples collected at several dates and depths.

Data are saved at the Institute of Earth Surface Dynamics at the University of Lausanne.