28th Annual International Workshop on
Physical Processes in Natural Waters

Šibenik, Croatia, 31 August – 4 September 2026

Book of Abstracts

Organization

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Ruđer Bošković Institute
Department for Marine and Environmental Research
Bijenička cesta 54
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Program Overview

28th International Conference on
Physical Processes in Natural Waters (PPNW2026)
Conference Schedule

	MONDAY 31 AUGUST	TUESDAY 1 SEPTEMBER	WEDNESDAY 2 SEPTEMBER	THURSDAY 3 SEPTEMBER	FRIDAY 4 SEPTEMBER
08:30 - 09:00		08:30 - 09:00 Registration			
09:00 - 09:15		09:00 - 09:15 Opening			
09:15 - 10:30		09:15 - 10:30 Session 1	09:15 - 10:50 Session 5	10:00 - 16:00 Boat Field Trip* to National Park Krka & Lunch *(lunch is served around 14 h)*	09:15 - 10 50 Session 9
10:30 - 11:00		10:30 - 11:00 Coffee break	10:50 - 11:20 Coffee break		10:50 - 11:20 Coffee break
11:00 - 13:00		11:00 - 13:00 Session 2	11:20 - 12:00 Session 6		11.20 - 12.00 Session 10
13:00 - 14:30		13:00 - 14:30 Lunch	18.00 - 14:30 Lunch		13:10 - 14.40 Lunch
14:30 - 16:10		14:30 - 16:40 Session 3	14:30 - 14:10 Session 7		15:00 - 17:30 In memory of
16:10 - 16:40		16:10 - 16.40 Coffee breok	16:10 - 16:40 Coffee break		
16:40 - 17:35		16:40 - 17:55 Session 4	16.40 - 17:55 Session 8	16:00 - 19:00 Free	
17:55 - 19:00		17:55 - 19:00 Free	17:55 - 20:00 Free		
19:00 - 20:00	Registration & Welcome Drink *Venue: The Medieval Monactery Mediterranean Garden of Sx Lovre (Šbenik)*			19:00 - 21:00 Poster Session & Light Dinner *Venue: Azimut (Sibenik)*	17:30 - 19:30 City Tour *Location: Šibenik*
20:00 - 21:00			20 00 - 22:00 Gala DInner *Venue: Restaurant No.4 (Š benik)*		
21:00 - 22:00					

* Boat field trip included in the registration fee.
Schedule is subject to change.

Oral presenters are required to upload their presentations to the conference computer before the start of their session.
Poster presenters are required to hand their posters over on Tuesday (all day) or Wednesday (before noon). Student Holpers will be around to help with uploads and collect posters.

Locations

Welcome Drink (Medieval Monastery Mediterranean Garden of St. Lawrence)
https://maps.app.goo.gl/gUNDuoxqJbpg4XHB6

Main Venue (Civitas Sacra)
https://maps.app.goo.gl/Pwc27Yqke4HLcVvh9

Lunch (Hotel Jadran)
https://maps.app.goo.gl/2kAzeGevbC4bSg96A

Gala Dinner (Restaurant No. 4)
https://maps.app.goo.gl/aEnaSfWQattg1nMu9

Field trip gathering spot (the “Mulo Krke” dock)
https://maps.app.goo.gl/5gWKvSdLBTLXkUHm7

Poster Session (Azimut bar)
https://maps.app.goo.gl/TMi3NSpqBAVVC3mL9

Detailed program

Monday, 31 August 2026

19:00 - 21:00	**Welcome Drink**

Tuesday, 1 September 2026

08:30 - 09:00	**Registration**
09:00 - 09:15	**Opening**
09:15 - 10:30	**Session 1** Chair: Lee Bryant Co-chair: Sierra Legare
09:15 - 09:40	Jonas Stankevicius **A Three-Dimensional Hydrodynamic Model of Great Slave Lake: Development, Validation, and Application to Contaminant Transport and Climate Scenarios**
09:40 - 10:05	Sierra Legare **Modelling Contaminant Remobilisation due to Sediment Resuspension**
10:05 - 10:30	Tomy Doda **A simple mass-budget approach to support adaptive management of recreation in alpine lakes**
10:30 - 11:00	**Coffee Break**
11:00 – 13:00	**Session 2** Chair: Lee Bryant Co-chair: Sierra Legare
11:00 - 11:25	Lee Bryant **Mixing and metals: engineered destratification and environmental controls on lake manganese dynamics**
11:25 - 11:50	Robert Schwefel **Citizen science data reveal long-term trends in lake transparency**
11:50 - 12:15	Michael Mannichl **Impacts of Floating Photovoltaics on Oxygen Dynamics: Implications for Nighttime Regression Estimates of Respiration and Reaeration**
12:15 - 13:00	Jadranka Šepić (keynote speaker) **Meteotsunamis: A Global Scale Oceanic hazard**

13:00 - 14:30	**Lunch**	
14:30 – 16:10	**Session 3** Chair: Marco Toffolon Co-chair: Hiroki Matsumoto	
14:30 - 14:55	Péter Torma **Sediment-Water Heat Exchange in a Shallow Lake from Direct Flux Measurements**	
14:55 - 15:20	Marco Toffolon **Monitoring and modelling turbidity currents induced by the Adige-Garda tunnel in Lake Garda (Italy)**	
15:20 - 15:45	Damien Bouffard **Tracking turbidity Currents in lake Brienz: insights from ADCPs, multibeam surveys, and ocean bottom seismometers**	
15:45 - 16:10	Cristobal Molina **Acoustic tools for resolving new challenges in coastal areas**	
16:10 - 16:40	**Coffee Break**	
16:40 – 17:55	**Session 4** Chair: Marco Toffolon Co-chair: Hiroki Matsumoto	
16:40 - 17:05	Keisuke Nakayama **Evaluation of Bottom Boundary Layer Formation in a Deep Lake Using Thorpe Length Scale and a Wind-Driven Two-Layer Theoretical Model**	
17:05 - 17:30	Hiroki Matsumoto **Applicability of theoretical solution in the enclosed basin**	
17:30 - 17:55	Marek Stastna **Modelling Phosphorous loading in Hamilton Harbour: What role for Dynamics?**	

Wednesday, 2 September 2026

09:15 – 10:50	**Session 5** Chair: Alexei Kouraev Co-chair: Francesca Hinegk
09:15 - 09:40	Gabriella Lükő **Impact of internal boundary layer related spatial wind variability in a large and shallow lake**
09:40 - 10:05	Hannah Clercx **Wind-induced circulations in enclosed former estuaries with stratification and strongly varying bathymetry**
10:05 - 10:50	Henk Dijkstra (keynote speaker) **Future projections of salt Intrusion in estuaries worldwide**

10:50 - 11:20	**Coffee Break**	
11:20 – 13:00	**Session 6** Chair: Alexei Kouraev Co-chair: Francesca Hinegk	
11:20 - 11:45	Alexei Kouraev **Ice cover and water dynamics of large deep ice-covered lakes from satellite and in situ observations**	
11:45 - 12:10	Francesca Hinegk **Conventional to pumped-storage hydropower reservoirs: what happens to thermal structure and ice cover?**	
12:10 - 12:35	Corentin Prados **Instabilities and turbulence in supraglacial channels: Competition between shear-dominated and buoyancy-dominated dynamics**	
12:35 - 13:00	Andres Posada-Bedoya **Littoral circulation driven by sediment heating in ice-covered lakes**	
13:00 - 14:30	**Lunch**	
14:30 – 16:10	**Session 7** Chair: Bertram Boehrer Co-chair: Marta Fregona	
14:30 - 14:55	Bertram Boehrer **Dissolved gases and gas pressures in lake water**	
14:55 - 15:20	Marcus Klaus **Bubble size distributions in mountain streams**	
15:20 - 15:45	Mohammad Atif Khan **Evaluating the microbubble hypothesis: Microbubble concentrations in relation to Air-water CH4 and CO2 exchange between inland waters and the atmosphere**	
15:45 - 16:10	Ivan Mammarella **Temporal dynamics and drivers of carbon dioxide emissions from a small boreal lake**	
16:10 - 16:40	**Coffee Break**	
16:40 – 17:55	**Session 8** Chair: Bertram Boehrer Co-chair: Marta Fregona	
16:40 - 17:05	Marta Fregona **Future climate warming prolongs spring mixing and increases annual greenhouse gas emissions in a boreal lake**	
17:05 - 17:30	Marius Mangold **Precise Gas Profiling in the Supersaturated Waters of Lake Kivu**	
17:30 - 17:55	Bertram Reventlow **Extreme Gas Accumulation in Meromictic Lake Kilevann, Norway**	
20:00 - 22:00	**Gala Dinner**	

Thursday, 3 September 2026

10:00 - 16:00	**Field Trip**
19:00 – 21:00	**Poster Session**
Poster ID. 1	Elena Zakharova **Monitoring freshwater lake ice cover - synergy of satellite radar altimetry, in situ observations and numerical modelling**
Poster ID. 2	Ana Erdevicki **Gaussian Process Modeling of Deepwater Cooling in a Very Deep Lake**
Poster ID. 3	Wouter Kranenburg **Measurements of Stratification and Circulation in an Enclosed Former Estuary**
Poster ID. 4	Iva Dominović Novković **Complex interactions in a coastal karstic environment: The case of marine lake Zmajevo oko (Rogoznica, Croatia)**
Poster ID. 5	Marija Marguš **Stable water isotope signatures ($\delta^{18}O$ and $\delta^{2}H$) in a stratified marine lake: evidence of evaporation, stratification and restricted exchange**
Poster ID. 6	Marco Toffolon **Navigating the AI Wave: Generative Artificial Intelligence in Physical Limnology**
Poster ID. 7	Ilaria Dal Dosso **Linking upstream rainfall to turbidity events in a hydropower-regulated sub-alpine lake using satellite observations**
Poster ID. 8	Sara Treccani **Optimizing sediment management in alpine reservoirs through process-based modelling of bottom outlet flushing**

Friday, 4 September 2026

09:15 – 10:50	**Session 9** Chair: Georgiy Kirillin Co-chair: Jean Modeste Mushimiyimana
09:15 - 10:00	Alexander Izhitskiy (keynote speaker) **Extreme environment of the Aral Sea after desiccation**
10:00 - 10:25	Anja Batina **Physical Drivers of Water Quality and Salinity Dynamics in a Coastal Shallow Lake: A GIS-MCDA Approach for Monitoring Optimization**
10:25 - 10:50	Luísa Ciríaco Silva de Oliveira **Stratification and Mixing Dynamics Under Extreme Drawdown and Refilling in a Semi-Arid Reservoir**
10:50 - 11:20	**Coffee Break**

11:20 - 13:00	**Session 10** Chair: Georgiy Kirillin Co-chair: Jean Modeste Mushimiyimana
11:20 - 11:45	Sherif Alaa Ibrahim **What Constitutes a Deep Lake? A Dynamics-Based Definition and the Concept of Anisomixis**
11:45 - 12:10	Georgiy Kirillin **Large-scale dynamics and fine-scale mixing in Lake Issyk-Kul and their relation to biological productivity**
12:10 - 12:35	Jean Modeste Mushimiyimana **Evolution of Thermal Stratification in Lake Kivu and Its Drivers**
12:35 - 13:00	Joshua Marks **3D Modeling of Lake Shikotsu: Thermobaricity controlled Deep Water Circulation**
13:00 - 13:10	**Closing**
13:10 - 14:40	**Lunch**
15:00 - 17:00	Session in memoriam of Dr Dan McGinnis
17:30 - 19:30	Guided city tour

Session 1

Tuesday, September 1st | 09:15 - 09:40

A Three-Dimensional Hydrodynamic Model of Great Slave Lake: Development, Validation, and Application to Contaminant Transport and Climate Scenarios

Jonas Stankevicius[1], Alain Pietroniro[1], Qi Zhou[1]

[1]*Department of Civil Engineering, University of Calgary, Calgary, Alberta, Canada*

The subarctic Mackenzie River Basin in Northern Canada is experiencing climate warming at up to four times the global average, with profound implications for regional hydrology, water quality, and ecosystems. Great Slave Lake, the second-largest lake entirely within Canadian borders and the deepest in North America, serves as a vital ecological and societal resource for the Northwest Territories. Yet its physical and biogeochemical processes remain poorly understood due to its remote location and the challenges of year-round observation.

To address this gap, we developed the first three-dimensional hydrodynamic model of Great Slave Lake using the Nucleus for European Modelling of the Ocean (NEMO) framework, adapted for freshwater lake applications. This required construction of the first complete bathymetric map of the lake, in collaboration with the Department of Fisheries and Oceans. The model was configured for multi-year simulation with representations of seasonal ice cover, surface fluxes, vertical mixing, and river inflows. Owing to the lake's remoteness, viable observational data for validation are scarce. We compiled available in-situ and remotely sensed records, including temperature profiles, evaporation, satellite-derived surface temperatures and ice phenology. Validation demonstrates that NEMO robustly captures the lake's thermal structure, stratification dynamics, and ice seasonality.

Building on this validated framework, we apply passive tracer simulations to investigate contaminant transport pathways. River-borne material entering from the Slave River disperses through complex interactions between inflow dynamics, wind-driven circulation, and seasonal stratification. Understanding these processes is critical for assessing the fate of contaminants in a system undergoing rapid environmental change. We further employ the model to run future climate scenarios, assessing projected impacts of warming on the lake's thermal regime, ice seasonality, and circulation. This work establishes a foundational modelling tool for Great Slave Lake that supports ongoing investigations into climate change impacts, water quality, and ecosystem resilience across the Mackenzie River Basin.

Modelling Contaminant Remobilisation due to Sediment Resuspension

Sierra Legare[1], Jason Olsthoorn[1]

[1]*Queen's University*

Contaminants of emerging concern are being increasingly deposited into lakebeds. Simultaneously, legacy contaminants in many lakes and rivers continue to infiltrate the water column. Despite these processes often being driven by sorption (e.g.contaminants sticking to the surface of sediment particles), numerical models often ignore this important process. We present a mathematical model for contaminant transport that accounts for exchange with an underlying sediment layer and reversible sorption. The system is described by two key dimensionless parameters; the ratio of the contaminant and sediment diffusivities, and the ratio of the sorption to sediment suspension timescales. We will primarily discuss a problem in which contaminant concentrations in the surface water become elevated due to the erosion of a contaminated sediment layer. Results from one-dimensional simulations indicate that the relative importance of sorption and the exchange of contaminant mass across the sediment-water interface varies with the ratio of timescales. The contaminant concentrations in the sediment layer control the steady-state concentrations in the surface water, and that the system is sensitive to how the exchange between the water column and sediment layer is treated. Results from numerical simulations of three-dimensional channel flow over bedforms will be discussed and show agreement with our one-dimensional results. We will conclude with a demonstration of the applicability of our model to a broader range of problems and a discussion of how we expect our results to extend to larger-scale systems.

Session 1

Tuesday, September 1st 10:05 - 10:30

A simple mass-budget approach to support adaptive management of recreation in alpine lakes

Tomy Doda[1, 2], Damien Bouffard[1, 2], Alice Nikolli[3], Philippe Bourdeau[4], Marie-Elodie Perga[1]

[1]Faculty of Geoscience and Environment, Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland, [2]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Surface Waters-Research and Management, Kastanienbaum, Switzerland, [3]EDYTEM, University Savoie Mont Blanc, Chambéry, France, [4]PACTE, University of Grenoble Alpes, Grenoble, France

Remote alpine lakes are becoming increasingly attractive to recreational users amid a warming climate and the growing popularity of outdoor recreation. Recreational uses, including hiking, swimming, and camping, are often seen as threats to these ecosystems perceived as pristine. Ordinances restricting recreational activities have multiplied across the Alps, but these are mostly precautionary measures that are not grounded in robust scientific evidence. Although numerous potential impacts of recreational activities have been identified, there is no quantitative assessment of the risks. We present here a mass budget approach designed to provide first-order estimates of the effects of swimming on the water quality of high-altitude lakes and to quantify lake-specific vulnerability to individual contaminants. The model is applied to a set of alpine lakes in the French and Swiss Alps with varying volume $V = 10^3\text{-}10^5$ m^3 and water residence time from days to infinity. Substances considered include UV filters from sunscreen, nutrients and suspended sediment, with varying decay rate $k = 10^{-3}\text{-}10^3$ day^{-1}. The steady-state concentration of each substance is calculated using constant inputs and outputs from recreation, outflow and decay processes, with a conservative approach to maximize the impact of recreation. The vulnerability of a lake to a specific compound is given by a critical visitation rate (i.e., number of recreational users per day) above which concentrations exceed ecotoxicological thresholds. Count-based estimates of current visitation rates are several orders below critical conditions for most of the tested compounds mixed across the surface layer. Yet, threshold concentrations may be reached if compounds accumulate locally, highlighting the need to quantify partitioning processes. The most vulnerable lakes are not necessarily the lakes where recreation is regulated. By offering a process-based approach, this simple mass budget is a first step towards adaptive lake management reconciling recreation with the protection of alpine lake ecosystems.

Mixing and metals: engineered destratification and environmental controls on lake manganese dynamics

Lee Bryant[1], Mahan Amani Geshnigani[1], Summer McMillan[1], Emily Slavin[2], Rob Luckwell[2], Neil Macdonald[3], Thomas Kjeldsen[1]

[1]University of Bath (UK), [2]Bristol Water (UK), [3]University of Liverpool (UK)

Elevated manganese (Mn) concentrations in drinking-water supplies cause water-quality degradation, aesthetic complaints, and increased treatment costs worldwide. In response, water utilities commonly employ engineered oxygenation or aeration (EOA) systems in source-water lakes (i.e., managed reservoirs) to mitigate Mn and other redox-sensitive contaminants. However, EOA performance remains highly variable, reflecting limited understanding of how Mn biogeochemical cycling responds to site-specific physical mixing and catchment controls.

We synthesise research relevant to optimising EOA-based Mn management, focusing on Mn redox cycling and sediment-water exchange, catchment controls on Mn sources and transport, and contrasting outcomes among EOA approaches. Building on this synthesis, we present results from an interdisciplinary field investigation of how EOA bubble-plume destratification influences Mn distributions within a UK drinking-water supply (Blagdon Lake), together with an evaluation of geological and hydrological controls on Mn supply to the reservoir system. Using data from aerated summer periods (2017-2019), historical water-quality records, geological maps, and catchment-focused sampling, we assessed spatial and temporal patterns in Mn and related parameters (e.g., dissolved oxygen, temperature, turbidity). Aeration promoted a persistently mixed and oxygenated water column, resulting in decreased water-column Mn concentrations and increased Mn accumulation in benthic sediments, consistent with oxidation and subsequent precipitation from the water column. Variations in Mn concentrations and sediment composition reflect both operational aeration effects and differences in upstream lithology, highlighting the interaction between reservoir management and geological setting. Sediment-core XRF analyses further indicate that Mn accumulation provides a record of aeration history, catchment-derived inputs, and corresponding water-quality conditions.

Overall, this work demonstrates that effective Mn mitigation requires a holistic, systems-based approach integrating EOA design and operation with lake physics, reservoir management, and catchment monitoring to optimise water quality under evolving environmental pressures.

Session 2

Tuesday, September 1st | 11:25 – 11:50

Citizen science data reveal long-term trends in lake transparency

Robert Schwefel[1], Mia Kolinko[1, 2], Edith Meck-Rieth[3], Michael Hupfer[1]

[1]IGB Berlin, [2]University of Lund, [3]Seen-Transparent, WOM e.V

Since 1991, the citizen-sciene project “Seen Transparent” has been measuring Secchi depth in a large number of lakes of the “Holsteinische Schweiz” region in Northern Germany. Secchi depth is measured in weekly resolution during most of the year and the dataset is complemented by annual measurements of basic chemical and biological parameters during spring convection. In total, 59 monitoring stations at 43 lakes are included in the monitoring program. 32 of them cover the entire period from 1991 to 2025. Seven of the lakes could be compared with sporadic Secchi depth measurements from the beginning of the 20th century.

The long, high-resolution time series allows to evaluate changes in lake transparency in response to land use alterations and global warming. While Secchi depths showed no consistent trend between 1991 and 2025 if annually averaged and depended mainly on trophic state and lake morphometry, Secchi depths during summer were lower in the recent past compared to the beginning of the 20th century in six of seven lakes with data coverage during both periods, hinting to changes in the nutrient content due to agriculture in the catchment area. Secchi depth was not significantly correlated with air temperatures. However, Secchi depth in Summer decreased with increasing spring temperatures, potentially due to earlier nutrient inputs after an earlier start of fertilization. While mean Secchi disk depth showed no consistent trend between 1991 and 2025, phenological changes could be observed. In most of the lakes, minima in Secchi depth due to spring blooms as well as the subsequent clearwater phase occurred earlier in years with high summer temperatures. This study demonstrates how a citizen science project improves the understanding of long-term ecological changes. It also shows that significant phenological shifts can occur despite lacking trends in annually averaged mean values.

Impacts of Floating Photovoltaics on Oxygen Dynamics: Implications for Nighttime Regression Estimates of Respiration and Reaeration

Pedro Gabriel[1], Andreas Lorke[2], Michael Mannich[1]

[1]*Federal University of Paraná,* [2]*Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau*

Floating photovoltaic (FPV) systems are increasingly deployed on inland waters, yet their effects on dissolved oxygen (DO) dynamics remain poorly constrained. Here, we quantify how an FPV array alters DO variability, ecosystem respiration, and air-water gas exchange in the Passaúna Reservoir, Brazil, using continuous high-frequency measurements collected beneath the array and at an adjacent free-water site. Ecosystem metabolism and gas transfer velocities were estimated using the nighttime regression method applied to nocturnal DO time series. A clear diel signal persisted at both sites, indicating that the fundamental photosynthesis-respiration cycle remains intact despite strong surface shading. However, DO variability beneath the FPV was consistently higher, particularly during nighttime when photosynthesis is absent, resulting in steeper nocturnal DO declines and frequent short-term increases in DO. These nighttime increases indicate intrusions of oxygen-rich water from adjacent layers, violating the assumption of negligible mixing required by the nighttime regression method and reducing the number of usable nights. When assumptions were satisfied, respiration estimates were generally higher beneath the FPV, while daytime differences remained small, indicating that FPV effects extend beyond light attenuation alone. Reaeration rates were weakly related to wind forcing at both sites, but were more variable beneath the FPV, with intermittent peaks suggesting localized turbulence. These dynamics reflect physical processes introduced by the floating structure, including platform motion, edge effects, and flow perturbations that modify near-surface mixing. We hypothesize that, under specific wind conditions, resonance-driven motion of the FPV panels may generate sufficiently intense oscillations to induce mixing and promote episodic DO intrusions, although this mechanism remains to be directly verified. Overall, FPVs do not disrupt the diel metabolic cycle, but increase short-term variability and intermittency in oxygen dynamics, with implications for metabolism estimates and gas exchange in systems with expanding FPV coverage.

Meteotsunamis: A Global Scale Oceanic hazard

Jadranka Šepić[1]

[1]*Faculty of Science, University of Split, R. Boškovića 33, 21000 Split*

Meteorological tsunamis (meteotsunamis) are extreme sea level events that can cause coastal destruction and loss of life. Although their spatial extent is smaller, and they are never as destructive as the strongest seismically induced tsunamis, meteotsunamis appear identical to seismic tsunamis to an observer. When they are the strongest, meteotsunamis can reach heights of 6 m or more and generate currents of 15 knots or more. They are generated by atmospheric disturbances of various spatial and temporal scales, characterised by sudden air-pressure changes (up to ~5 hPa per 10 min) and/or short-lived strong wind events. These atmospheric disturbances can be associated with atmospheric gravity waves, pressure jumps, frontal passages, squalls and hurricanes. Under specific conditions, when they propagate over the open sea at a speed equal to or close to the speed of long ocean waves, atmospheric disturbances can resonantly enhance long ocean waves through processes such as Proudman or Greenspan resonance. Once these long ocean waves reach the coast, they can grow further to destructive tsunami heights through additional amplification processes such as shoaling, reflection and harbour resonance.

Meteotsunamis occur throughout the world's oceans, but are most common at specific locations known as meteotsunami hot spots. These locations include the Adriatic Sea, where the first record of meteorological tsunamis dates from 1614. Other locations around the world where meteotsunamis commonly occur include the Balearic Islands, Malta and Sicily (all in the Mediterranean), the western and northern coasts of the Black Sea, the Great Lakes, the east coast of the USA, Brazil and Argentina, the Yellow Sea coasts of China and South Korea, and the western coast of Japan.

In this lecture, key aspects of meteotsunami research are presented, starting with their definition and the explanation of the generation mechanism, followed by an overview of research history and the strongest events, and concluding with perspectives on meteotsunami forecasting and warning systems and future research. Special attention is given to Adriatic Sea meteotsunamis and to how research on these events has influenced global meteotsunami studies.

Session 3

Tuesday, September 1st 14:30 – 14:55

Sediment-Water Heat Exchange in a Shallow Lake from Direct Flux Measurements

Péter Torma[1], Sebestyén D. Török[1], Gabriella Lükő[1]

[1]*Budapest University of Technology and Economics, Dept. of Hydraulic and Water Resources Engineering*

In very shallow lakes, in addition to atmospheric processes, sediment-water heat exchange can play a significant role in controlling thermal structure and mixing. In systems such as Lake Balaton (mean depth: 3.2 m, area: 596 km^2), diurnal stratification is typically weak and transient; however, persistent near-bed temperature gradients indicate that bottom boundary processes can modify stability. We investigate heat exchange at the sediment-water interface using a high-resolution observational dataset that includes water and sediment temperature profiles, extended with direct sediment heat flux observations (using heat flux plates), full surface energy balance components (radiative and turbulent fluxes), and intermittent velocity profile measurements over the lakebed. First, we test whether heat transfer within the sediment can be described by molecular diffusion by applying and calibrating the heat conduction equation against observations. Deviations from this behavior are used to infer the role of additional processes, including turbulence and porewater advection. Second, one-dimensional model analyses are performed for both the water column and the upper sediment layer to quantify the temporal variability of sediment heat flux and its role in heat budget and stratification dynamics across diurnal to seasonal time scales. Results show that while nighttime surface cooling efficiently mixes the upper water column, stable stratification can persist in the near-bed region for multiple days during summer conditions. This localized stability is closely linked to sediment heat flux and may play a critical role in sustaining bottom boundary layer isolation. Our results demonstrate that sediment-water heat exchange can significantly influence the persistence and vertical structure of the weak stratification in shallow environments, and that has to be included in one-dimensional models and climate impact assessments.

Session 3

Tuesday, September 1st | 14:55 – 15:20

Monitoring and modelling turbidity currents induced by the Adige-Garda tunnel in Lake Garda (Italy)

Sara Treccani[1], Marina Amadori[2], Andrea Bampi[1], Giulio Dolcetti[1], Ali Farrokhi[1], Matteo La Mendola[1], Alessandro Moroni[1], Eleonora Perugini[1], Paolo Scarfiello[1], Marco Toffolon[1], Sebastiano Piccolroaz[1]

[1]University of Trento, [2]CNR-IREA

The Adige-Garda diversion tunnel is a 10 km long, 8 m diameter hydraulic structure connecting the Adige River to Lake Garda (Italy). Completed in 1959 to mitigate flood risk in the downstream Adige basin, including the city of Verona, it is operated during major flood events and opened annually for maintenance. During maintenance operations, river water is typically ~2°C colder than the lake, suspended sediment concentrations at the outlet can reach several thousand mg/L, and approximately 350,000 m³ of water are discharged over a few hours. Under such conditions, the cold, sediment-laden inflow generates a turbidity current that propagates into deeper layers of the lake. Despite ecological and hydrodynamic impacts, the processes governing plume generation, evolution, and deposition remain poorly constrained.

This study builds on a monitoring program initiated in 2023 during annual maintenance openings, with logistical support from the Servizio Bacini Montani of the Autonomous Province of Trento, and funded as a project since 2026. The objectives are to (i) characterise the turbidity plume through field observations, (ii) develop a numerical model reproducing its spatio-temporal dynamics, and (iii) design a monitoring strategy for tunnel operations. The 2026 field campaign marked a step forward, with measurements at both the tunnel inlet and outlet, and in the lake. Discharge upstream from the sluice gates was quantified using ADCP transects, while sediment cores supported grain size analysis and turbidity sensor calibration. At the outlet, turbidimeters, samplers, and a video-based surface velocimetry system were deployed. In the lake, ADCP, microstructure profiler, and multiparameter sonde measurements were conducted at a fixed station and along a transect repeated the following day. Currents and plume dynamics at the lake surface were monitored using UAV imaging. The dataset supports a coupled Delft3D (FLOW-MOR) and WRF modelling framework to reconstruct turbidity current dynamics and inform future tunnel operations.

Session 3

Tuesday, September 1st | 15:20 - 15:45

Tracking turbidity Currents in lake Brienz: insights from ADCPs, multibeam surveys, and ocean bottom seismometers

Gaetan Sauter[1], Mathurin B Wamba[1], Damien Bouffard[2, 3], Katrina Kremer[1, 4]

[1]University of Bern, [2]Eawag, [3]University of Lausanne, [4]ETH Zürich

Understanding how sediments are transferred from catchment to the deep parts of lakes remains a major challenge. In Lake Brienz, Switzerland, we deployed two acoustic Doppler current profilers (ADCPs) and high-frequency temperature sensor arrays over one year, yielding approximately 10 hours of high-quality turbidity current data, reflecting the difficulty of capturing infrequent, short-term hydrodynamic processes. While these measurements provide remarkable insight into local flow dynamics, they also reveal a strong limitation: it is difficult to fully reconstruct the connection between catchment processes and turbidity current generation, particularly the filling-and-flushing mechanisms that control sediment routing. To address this, we combined repeated multibeam bathymetric surveys with ocean bottom seismometers recordings. Together, these approaches allow us to complement the local direct ADCP measurements and help detect and characterise the impact of turbidity current activity. Here, we present the advantages and limitations of each method, and describe the turbidity current dynamics observed in Lake Brienz. Our results highlight how integrating multiple, complementary techniques is essential to capture the full chain of sediment transfer from source to sink in lacustrine environments.

Session 3

Tuesday, September 1st | 15:45 - 16:10

Acoustic tools for resolving new challenges in coastal areas

Cristobal Molina[1]

Nortek[1]

Coastal environments are increasingly exposed to complex natural processes and human interventions, creating a growing need for reliable, high-resolution measurements of sediment transport and wave dynamics. Acoustic instrumentation offers new possibilities for addressing these challenges by combining current, wave, and backscatter measurements within a single observational framework.

This work highlights recent developments in acoustic tools for two key coastal applications: suspended sediment monitoring and infragravity-wave measurements. Conventional sediment-monitoring approaches rely heavily on water sampling and optical sensors, which can be labour-intensive, provide limited spatial coverage, and require frequent recalibration. Acoustic Doppler Current Profilers (ADCPs) can instead provide vertical profiles of suspended sediment concentration together with flow velocity, enabling direct estimates of sediment transport.

Particular attention is given to vertical-beam and multi-frequency echosounder techniques. Multi-frequency measurements at 1000 and 500 kHz can help account for variations in particle size, improving the robustness of backscatter-based concentration estimates and reducing the dependence on extensive water sampling.

The second application addresses infragravity waves, which are increasingly relevant for coastal and offshore operations. Recent developments combine pressure and acoustic surface-tracking measurements with time-, frequency-, and time-frequency-domain analysis to provide continuous observations of these long-period waves. Comparative field tests show good agreement between the different measurement approaches.

Together, these developments demonstrate how advanced acoustic techniques can extend coastal monitoring capabilities and provide more complete information for understanding and managing dynamic coastal environments.

Evaluation of Bottom Boundary Layer Formation in a Deep Lake Using Thorpe Length Scale and a Wind-Driven Two-Layer Theoretical Model

Tomoya Morikawa[1], Keisuke Nakayama[1], Hiroki Matsumoto[2], Chunmeng Jiao[3], Kazuhide Hayakawa[3]

[1]Kobe University, [2]Port and Airport Research Institute, [3]Lake Biwa Environmental Research Institute

Climate change has significantly altered the thermal stratification and mixing regimes of freshwater ecosystems, intensifying the risk of deep-water hypoxia. In deep lakes, the development of a specific Bottom Boundary Layer (BBL) has been reported to accelerate the formation of hypoxic water masses. Such phenomena are observed in Lake Biwa, a representative deep lake in Japan, posing a potential threat to the habitats of bottom-dwelling organisms. Despite its ecological importance, research on the BBL remains limited, and clarifying its formation dynamics is an urgent priority. This study aims to elucidate the formation and decay processes of the BBL based on field observations conducted at the maximum depth of Lake Biwa in 2019, utilizing vertical profiles of water temperature, dissolved oxygen (DO), and turbidity. The BBL thickness was estimated by identifying the points of abrupt change in DO and turbidity gradients. Subsequently, the Thorpe displacement and Thorpe length scale were calculated from the water surface to the lake bottom to determine the viscous dissipation rate. It should be noted that the Thorpe length scale, while widely utilized in oceanographic research, has been applied in only a few cases within limnological studies. Our analysis suggests that the BBL thickness is likely influenced by the input of turbulent kinetic energy. Furthermore, by applying a theoretical solution for a cylindrical two-layer model under wind stress, we successfully evaluated the shear stress exerted on the lake bottom. This model primarily provides the steady-state density interface slope and velocity field, while also accounting for fluctuations induced by internal Kelvin and Poincaré waves.

Applicability of theoretical solution in the enclosed basin

Hiroki Matsumoto[1], Keisuke Nakayama[2]

[1]Port and Airport Research Institute, [2]Department of Civil Engineering, Faculty of Engineering, Kobe University

Understanding material transport is essential for clarifying water quality formation processes and for the effective management of aquatic environments. Because material transport is strongly controlled by flow fields, an accurate understanding of flow dynamics is required. One widely used approach for investigating flow fields is the application of theoretical solutions derived from linear theory. These solutions typically assume spatially uniform wind forcing, include the Coriolis effect, and are formulated for a rectangular basin with a two-layer stratified system. Within this well-defined theoretical framework, the applicability of the solutions is confined to specific physical regimes and therefore requires careful evaluation.

In this study, we examine the applicability of linear theoretical solutions for wind-driven flows in a rotating, two-layer stratified system through comparison with numerical simulations. Particular attention is paid to the Wedderburn number and the duration of wind forcing. The numerical simulations show the generation of internal Kelvin waves along the basin boundary under wind forcing. The characteristic period of the internal Kelvin waves is estimated from the basin perimeter divided by the internal wave phase speed, providing a physically based timescale for comparison with the wind duration.

The results indicate that the theoretical solution reproduces the numerically simulated flow field with high accuracy when the Wedderburn number is large and when the wind duration is comparable to the period of the internal Kelvin waves. These findings clarify the physical conditions under which linear theoretical solutions can be reliably applied and provide useful guidance for the evaluation of flow fields and associated material transport.

Session 4

Tuesday, September 1st 17:30 – 17:55

Modelling Phosphorous loading in Hamilton Harbour: What role for Dynamics?

Marek Stastna[1]

[1]*University of Waterloo*

Hamilton harbour is a natural embayment of Lake Ontario. It is approximately triangular in shape, and has an areal extent of 2200 hectares. It is bordered by a long sand spit, a shallow wetland area, and on one side, heavy industry. The only direct connection to Lake Ontario is via the 118 m wide, 1.4 km long Burlington shipping canal. Hamilton harbour continues to be used for shipping, and experiences algal blooms in many summers, while adjacent regions are important recreational areas for a growing urban population. I will report on modelling of the phosphorous budget in the bay. Starting with statistical analyses I will outline how the dynamics of the stratified season is profoundly different from the well mixed seasons, and how this is reflected in simple box models of the system. I will report on attempts to characterize uncertainty, and time permitting, I will outline efforts to more fully account for the harbour dynamics.

Impact of internal boundary layer related spatial wind variablity in a large and shallow lake

Gabriella Lükő[1], Péter Torma[1]

[1]*Budapest University of Technology and Economics*

Wind fields over large lakes often exhibit strong spatial variability due to the extended surface area and atmospheric processes, including the development of an internal boundary layer (IBL) due to surface roughness transition form land to lake. Despite its importance, the IBL is often neglected in lake modeling for simplicity. This study investigates how spatially varying wind fields, particularly those accounting for IBL development, influence lake hydrodynamics, temperature field and surface heat exchanges. Using Lake Balaton as a case study, we combined extensive hydrometeorological observations with a validated three-dimensional lake model to assess different wind-forcing approaches: (1) spatially interpolated winds including IBL effects, (2) interpolated winds without IBL, and (3) a simplified, uniform vector-averaged wind field. Model results were evaluated against in situ and satellite observations. While simulated water level fluctuations were similar across all scenarios, major differences emerged in circulation patterns. The IBL-based wind field more accurately reproduced both the magnitude and direction of observed flows in the open-water area. These hydrodynamic differences led to distinct thermal responses: depth-averaged and surface temperatures were mainly controlled by spatially variable turbulent heat fluxes, while stratification was influenced by wind-driven mixing. Simplified wind representations that neglect IBL effects produced temperature differences along the fetch up to 100% higher than those obtained with the IBL-based approach. Although horizontal transport played a role, the dominant driver was the spatial variability in turbulent heat fluxes. Overall, incorporating IBL development significantly improves the simulation of both currents and temperature dynamics and thus its incorporation should be considered in the case of large lakes for studies of transport and vertical mixing.

Session 5

Wednesday, 2nd September 09:40 – 10:05

Wind-induced circulations in enclosed former estuaries with stratification and strongly varying bathymetry

Hannah Clercx[1], Wouter Kranenburg[1, 2], Ad Reniers[1]

[1]*Delft University of Technology,* [2]*Deltares*

Enclosed former estuaries (EFEs) are anthropogenic systems, created to increase the coastal safety of an area by keeping the sea at bay through building dams and sluice gates, essentially creating a saline lake. Due to their uneven bathymetry, consisting of what used to be tidal flats and tidal channels, in combination with forcing predominantly by wind, the circulations in these systems are different from natural lakes. In summer, a strong thermal stratification inhibits vertical mixing by wind forcing and the lower layers of the EFE become anoxic. Subsequently, when horizontal and vertical circulations are induced by wind, water mass transport can cause ecological issues when anoxic water is suddenly relocated. Hence, further insight is needed into the wind-driven circulations and water mass transport in EFEs. For this purpose, we conducted field measurements in Lake Veere (2024) and Lake Grevelingen (2025), both located in the south of the Netherlands, for a period of three months during the summer. We collected temperature and flow velocity data at high temporal and spatial resolution, then combined these with wind data to determine the relationship between wind forcing, geometry, flow circulation and stratification. We found that wind forcing can induce a depth-averaged upwind flow in the deep channels of these EFEs and a down-wind flow on the former flats, resulting in a horizontal circulation. This likely also affects the temperature distribution. Tilting of the thermocline through wind forcing was detected as well, which can cause vertical circulations and mixing. Through comparing data from two EFEs, we will explore the coupling between wind, the behavior of the thermocline and the horizontal and vertical circulations in the lake and how the combination of these phenomena influences the water mass transport and temperature distribution.

Session 5

Wednesday, 2nd September 10:05 – 10:50

Future projections of salt Intrusion in estuaries worldwide

Henk Dijkstra[1]

[1]Utrecht University, Utrecht, NL

Increased salt intrusion in surface waters is threatening freshwater availability in coastal regions worldwide. However, future projections of salt intrusion were long limited to local regions or changes to single forcing agents. Recently, compounding contributions from changes in river discharge and relative sea level to changing future salt intrusion under a high-emission scenario (SSP3-7.0) for 18 estuaries around the world were determined (Lee et al., Nature Communications, 16, 3444, 2025). In this presentation, I will focus on the theoretical work behind the results in this paper.

Session 6

Wednesday, 2nd September 11:20 – 11:45

Ice cover and water dynamics of large deep ice-covered lakes from satellite and in situ observations

Alexei Kouraev[1], Elena Zakharova[2, 3], Andrey Kostianoy[4, 5], Nicholas Hall[1], Anna Ginzburg[4], Andrey Suknev[6]

[1]Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), Toulouse, Franc, [2]EOLA, Toulouse, France, [3]Institute of Water Problems, Russian Academy of Sciences, Moscow, Russia, [4]P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia, [5]S.Yu. Witte Moscow University, Moscow, Russia, [6]Great Baikal Trail (GBT) Buryatiya, Ulan-Ude, Russia

Large Eurasian lakes are an integrator of climate processes at the regional scale and a good indicator of climate changes. We focus on lakes Baikal (Russia) and Hovsgol (Mongolia), that are ice-covered for almost half of the year. Variability of ice and snow regime is important for their physical, chemical and biological properties, and for human activity.

First we address eddies that manifest themselves on ice cover as giant ice rings. These rings are dark circular features on the ice with a diameter of 5-7 and a width of about 1 km. Rings appear in an unpredictable manner, in different places and in different years, and the factors leading for their formation were unclear. Our field data shows that the giant ice rings are surface manifestation of lens-like inthrathermocline eddies under ice, that exist before and during formation and development of ice ring.

Next we address drivers and patterns of eddy generation during ice-free season before and after vertical overturning in the Middle Baikal. Satellite remote sensing, historical observations and our in situ data show that the main source of eddy generation in this region is the outflow from Barguzin Bay which interacts with the coastline. We suggest that in the autumn, when the surrounding water cools to a temperature below about 4°C, these cold eddies sink and transform into lens-like eddies that persist under ice and can later create giant ice rings on the Baikal ice cover.

Better understanding of eddy dynamics and continued monitoring help to improve safety for people travelling or working on the ice. There is a need for timely communication of results for non-scientific audience - fishermen, tourists, journalists and local administration.

This research was supported by the CNES TOSCA Lakeddies II, TRISHNA and SWIRL projects, and P.P. Shirshov Institute of Oceanology Project N FMWE-2024-0016

Session 6

Wednesday, 2nd September | 11:45 – 12:10

Conventional to pumped-storage hydropower reservoirs: what happens to thermal structure and ice cover?

Francesca Hinegk[1], Marco Toffolon[1]

[1]*University of Trento*

Pumped-storage (PS) hydropower (HP) systems provide not only electricity generation but also energy storage and grid balancing services, vital to an energy sector increasingly based on renewable sources. However, PS operations intensify water exchanges between reservoirs, enhancing the transfer of heat, momentum, and mass. These processes can significantly influence key physical properties such as thermal stratification and, in cold regions, ice cover dynamics. Understanding these impacts is essential for sustainable reservoir management.

We investigate the response of two Norwegian conventional HP reservoirs to the introduction of PS operations using a 2DV (laterally averaged) hydro-thermodynamic model (CE-QUAL-W2). The model was calibrated with in-situ thermistor chain data, and its ice module was modified to better reproduce ice onset, breakup timing, and growth dynamics. A total of 38 PS scenarios with varying operational configurations were simulated and compared to a reference simulation forced with conventional HP operations.

The effects of pumping were assessed in terms of changes in thermal stratification (Schmidt stability), water temperature, and ice cover duration and thickness, evaluating both the magnitude of system alteration and recovery times. Results indicate that reservoir response to the set-up of PS operations (e.g., pumped volume, timing, duration) strongly depends on site-specific characteristics and conditions, highlighting the complexity of these systems.

A comparison with a 3D model (Delft3D) showed that the 2DV approach adequately captures mid- and far-field dynamics, while near-field processes require more detailed, computationally intensive models. This is particularly delicate for phenomena such as localized ice melting close to the power plant outlet, observed in the study site, as the lateral averaging in the 2DV model hinders its ability to accurately reproduce the vertical heat transport in the near field.

Our findings emphasize the importance of site-specific assessments when implementing PS systems, and of selecting modeling approaches suited to the dynamics of interest.

Session 6	
Wednesday, 2nd September	12:10 – 12:35

Instabilities and turbulence in supraglacial channels: Competition between shear-dominated and buoyancy-dominated dynamics

Corentin Prados[1, 2], Louis-Alexandre Couston[1], Olivier Gagliardini[2]

[1]Laboratoire de Physique de l'ENS Lyon, [2]Institut des Géosciences de l'Environnement, Grenoble

Global warming accelerates the melting of mountain glaciers, leading to the formation of potentially hazardous proglacial lakes. To mitigate the risk of glacial lake outburst floods, a viable strategy involves excavating artificial supraglacial channels to initiate controlled drainage. The success of these interventions relies on the ability to accurately predict the morphological evolution of the channel, which is fundamentally driven by turbulent hydrodynamics and heat transfer toward the ice walls.

This contribution presents a comprehensive study of the turbulent dynamics within supraglacial drainage channels. We employ a high-fidelity numerical approach to solve the Boussinesq equations with a non-linear quadratic equation of state, capturing the density anomaly of freshwater at temperatures below 4°C. The flow dynamics are governed by a complex interplay of physical processes: a mechanical forcing induced by the channel slope (shear flow), a surface thermal forcing driven by atmospheric heat exchange, and a volumetric thermal forcing due to solar radiation.

We evaluate the relative importance of these forcing mechanisms on the resulting flow regimes and wall heat fluxes, which dictate the melting rate and deepening of the channel. We interpret the results of our high-resolution simulations in light of field observations, which we will aim to combine to refine reduced-complexity models of channel growth. Ultimately, this framework will allow for the systematic and robust calibration of artificial channel geometries, ensuring safe and controlled drainage operations.

Littoral circulation driven by sediment heating in ice-covered lakes

Andres Posada-Bedoya[1], Hugo Ulloa[2], Jason Olsthoorn[1], Elise Devoie[1], Leon Boegman[1]

[1]Queen's University, [2]University of Pennsylvania

In early winter, snow and ice cover can isolate the water column from the atmosphere, causing lake circulation to be governed by the release of heat stored in the sediments. This heat flux provides energy for the redistribution of mass and heat. With under-ice water temperatures typically below 4 °C, freshwater will reverse stratify such that colder, lighter water overlies warmer, denser water according to the nonlinear equation of state. As a result, sediment heat release generates a cross-shore buoyancy gradient that drives downslope near-bed flow, which is balanced by a water column return flow from the lake interior. Together, these processes establish a basin-scale overturning circulation. Given the difficulties of conducting under-ice field measurements and the lack of sediment-heating parameterizations in commonly used lake models, this process remains poorly understood.

We performed idealized two-dimensional direct numerical simulations to examine how sediment heating regulates under-ice circulation in the littoral zone. We systematically varied the sediment temperature, bottom slope, and initial stratification to characterize the resulting flow and temperature fields. The simulations were consistent with and extended the laminar boundary layer theory proposed by Malm (1998) for ice-covered lakes. In some cases, the downslope flow generated shear-driven instabilities that locally enhanced diapycnal mixing, with potential implications for oxygen transport during the typically hypoxic early winter period. Linear stability analysis was applied to quantify the nature of the simulated unstable modes.

Our findings provide a mechanistic understanding of under-ice processes during early winter and support their incorporation into lake models, particularly in the context of changing ice regimes.

References

Malm J (1998) Bottom buoyancy layer in an ice-covered lake. Water Resour Res 34:2981-2993.

Session 7

Wednesday, 2nd September 14:30 - 14:55

Dissolved gases and gas pressures in lake water

Bertram Boehrer[1]

[1]Helmholtz Centre for Environmental Research – UFZ

Gases play an important role for the ecology of lakes. Oxygen for example is the central chemical substance controlling where higher organisms can dwell. It is the preferred chemical oxidant. Anoxia indicates the transition into a chemical reducing milieu, which allows the formation and accumulation of undesirable substances.

In this presentation, we list the currently valid approaches for solubilities of the most common gases in the aquatic environment. We also include noble gases because of their relevance as inert tracers. We discuss temperature dependence and what the consequences are for gas saturation and how it can be used for tracing (noble gas thermometry). Dissolved gases imply a gas pressure and if sufficiently high this gas pressure will lead to bubble formation. The composition of such gas bubbles is discussed and how it is affected along the path to the surface, where ebullition releases this gas into the atmosphere. Finally, we discuss cases where gas pressure and gas loads are so high that catastrophic degassing events can be feared.

Session 7

Wednesday, 2nd September 14:55 - 15:20

Bubble size distributions in mountain streams

Marcus Klaus[1], Nicola Durighetto[2], Atif Mohammad Khan[1], Eliot Chatton[3], Mats Öquist[1], Paolo Peruzzo[4], Gianluca Botter[4]

[1]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Umeå, Sweden, [2]Water, Energy and Environmental Engineering Research Unit, University of Oulu, Finland, [3]OSUR - Plateforme Condate Eau, Géosciences Rennes, CNRS - Univ Rennes, France, [4]Department of Civil, Environmental and Architectural Engineering, University of Padua, Italy

Streams are hotspots of air-water mass exchange driven by intense bubble entrainment. However, understanding and predicting this process is limited by a severe lack of bubble size distribution data. Here, we measured bubble size distributions at 223 locations across 38 step-pool systems in temperate, boreal, and subarctic mountain streams in France, Italy and Sweden, using novel acoustic bubble spectrometry techniques. Bubble size distributions followed bilinear power-law scaling with spectral slopes shifting from about -3/2 to ≤-10/3, indicating distinct, size-dependent formation and removal mechanisms. Modelling suggests that bubble entrainment occurred primarily through jet impacts at steps, followed by turbulent fragmentation, coalescence, and buoyant rise, while dissolution was negligible. Although these processes broadly resembled those previously observed in ocean breaking waves, stream flow governed distinct bubble evolution mechanisms. Specifically, we found intense formation and downstream transport of previously overlooked microbubbles, with total microbubble concentrations ranging from 10^5 to 10^8 m^{-3}, increasing with turbulent kinetic energy dissipation rates ranging from 10^{-6} to 10^2 m^2 s^{-3}. Bubble size distributions showed clear relationships with readily measurable hydraulic stream characteristics such as discharge, step height and distance from step. We summarize our findings in a novel diagnostic framework that can be used to infer bubble evolution processes from bubble size distributions. In addition, we establish new empirical scaling laws that can be readily used to estimate and upscale bubble size distributions from stream characteristics. Collectively, our work provides a theoretical and empirical foundation for improved understanding and upscaling of air-water mass exchange processes in streams.

Session 7

Wednesday, 2nd September 15:20 - 15:45

Evaluating the microbubble hypothesis: Microbubble concentrations in relation to Air-water CH4 and CO2 exchange between inland waters and the atmosphere

Mohammad Atif Khan[1], Philipp S. Keller[2], Georgiy Kirillin[3], Mats Öquist[1], Hans-Peter Grossart[2], Stella A. Berger[2], Jens C. Nejstgaard[2], Martin Lienenlüke[2], Marcus Klaus[1]

[1]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Skogsmarksgränd 17, 90183 Umeå, Sweden, [2]Department of Plankton and Microbial Ecology, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), 16775 Stechlin, Germany, [3]Department of Ecohydrology and Biogeochemistry, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), 12587 Berlin, Germany

Inland waters are significant sources of carbon dioxide (CO_2) and methane (CH_4) to the atmosphere. Gas exchange is accelerated by air bubbles entrained through turbulent flow or biogeochemical processes. However, gas exchange mechanisms and the upscaling of gas fluxes remain poorly constrained, particularly due to limited knowledge of bubbles smaller than 100 µm (microbubbles). These microbubbles are hypothesized to preferentially enhance the exchange of sparingly soluble gases like CH_4 over CO_2, potentially explaining the elevated normalized gas transfer velocity (k_{600}) ratios of CH_4 over CO_2 observed in many inland waters. This hypothesis has yet to be empirically tested. Here, we present field studies in a lake and in streams to evaluate the microbubble hypothesis by coupling direct measurements of microbubble abundance with air-water gas exchange rates, using novel Acoustic Bubble Spectrometry, and CO_2 and CH_4 concentration and flux chamber measurements. The first study was conducted in a temperate lake (Stechlin, Germany) where microbubble concentrations ranged from 10^{-9} to 10^{-6} with no clear correlation to k_{600} ratios for CH_4 over CO_2. Modelled microbubble induced CH_4 fluxes contributed insignificantly to total CH_4 fluxes. The second study examined 22 step-pool systems in boreal and subarctic streams (Krycklan Catchment and Abisko region, northern Sweden). Microbubble concentrations ranged from 10^{-7} to 10^{-4} and correlated positively with k_{600} ratios in downstream pool-sections with no visible macro-sized bubbles. Modeled microbubble-induced CH_4 flux contributed significantly to total CH_4 fluxes with high CH_4 concentration and turbulence. Together, these results indicate that, under the conditions measured, microbubbles had minimal influence on gas exchange in the sampled lake but locally significant effects in some of the studied streams. Our findings underscore the variable potential of microbubble-mediated gas exchange depending on system-specific hydraulic and biogeochemical conditions, highlighting previously overlooked complexities involved in upscaling gas exchange mechanisms across diverse inland waters.

Session 7	
Wednesday, 2nd September	15:45 - 16:10

Temporal dynamics and drivers of carbon dioxide emissions from a small boreal lake

Ivan Mammarella[1]

[1]*University of Helsinki*

Advancing our understanding on physical and biogeochemical processes controlling turbulent exchange of energy, carbon dioxide (CO_2), methane (CH_4) and other trace gases across lacustrine systems is crucial in order to improve climate and weather forecast models. Lakes are capable of processing large amounts of organic carbon of terrestrial origin, and their importance in landscape carbon cycle and climate change issues is well recognized. Nevertheless, the amount of CO_2 and CH_4 released into the atmosphere is still uncertain.

Here, we investigate the temporal dynamics of and driving factors of CO_2 exchange using 13 years of eddy covariance flux measurements over the Lake Kuivajärvi, a small boreal lake in southern Finland.

The lake ecosystem acted mostly as a net CO_2 source (0.42±1.56 mumol m^{-2} s^{-1}) throughout the ice-free periods and had a relatively high interannual variability when compared to the surrounding forest. Carbon dioxide emissions are largely affected by the weather forcing through the effects of wind shear and nocturnal water cooling, which deepens the mixed layer and enhances gas exchange at the air-water interface.

Future climate warming prolongs spring mixing and increases annual greenhouse gas emissions in a boreal lake

Marta Fregona[1], Joachim Jansen[1], Xuefei Li[1], Ivan Mammarella[1]

[1]*Institute of Atmospheric and Earth System Research/Physics, Faculty of Science, University of Helsinki, Helsinki, Finland*

Seasonally ice-covered lakes are significant sources of methane (CH_4) and carbon dioxide (CO_2), with substantial emissions during spring and autumn turnover. During these events, gases accumulated in the hypolimnion are released to the atmosphere, with turnover accounting for 26-59% of CH_4 and 15-30% of CO_2 in some lakes. Climate change is altering ice cover duration and mixing regimes, affecting greenhouse gas (GHG) dynamics: reduced ice cover prolongs the ice-free period, increasing opportunities for GHG production and release, while changes in turnover timing and duration affect emissions by modifying the redistribution of heat, oxygen, and dissolved gases, thereby influencing CH_4 oxidation, CO_2 production, and hypolimnetic gas accumulation. Although the effects of climate change on lake ice cover and mixing are increasingly studied, the combined impacts on greenhouse gas production and release under future warming scenarios are not well quantified.

We simulated projected changes in ice cover, turnover periods, and GHG dynamics in Lake Kuivajärvi, a small boreal lake in Finland, under future warming scenarios using outputs from five general circulation models and the LAKE model. LAKE reproduces temperature, horizontal velocities, oxygen, CO_2, and CH_4 using a horizontally averaged transport equation, including sediment interactions and a snow-ice module. Our results show substantial inter-model differences in ice cover length, and turnover timing and duration. Trends in ice cover duration and spring turnover are generally consistent—ice cover is decreasing (-14 ± 6 days per decade) and spring turnover is starting earlier and lasting longer (~3.6 days per decade)—whereas changes in autumn turnover are highly uncertain, with low model agreement and high variability.

Session 8

Wednesday, 2nd September | 17:05 - 17:30

Precise Gas Profiling in the Supersaturated Waters of Lake Kivu

Marius Mangold[1], Gilbert Dukuzumuremyi[2], Ange Mugisha[2], Solange Munezero[2], Wolf von Tuempling[1], Bertram Boehrer[1]

[1]UFZ - Helmholtz Centre for Environmental Research, [2]SPLK - Shema Power Lake Kivu

Dissolved methane in the stratified deep waters of Lake Kivu in East Africa represents an important energy resource for Rwanda and the Democratic Republic of the Congo. In order to monitor changes resulting from industrial use, it is necessary to measure the dissolved gases reliably and accurately. However, when highly supersaturated water samples are taken from the depths of the lake, gas bubbles exsolve due to the drop in pressure, complicating quantitative analysis. To account for these contributions, measurements were conducted using sample bags to fully collect the resulting bubbles.

We present a significant methodological improvement for precisely measuring exsolved gas volumes in sampling bags. By submerging the sampling bag in a water-filled bell jar, we determine the gas volume via the weight of displaced water to minimize manual handling errors and improve volumetric precision. The sampling process was streamlined using a specially designed controller which simultaneously collects the required CTD data and actuates the pump. For the numerical calculation, the computer program KIVUBAG was developed, which performs the complex evaluation accurately and robustly.

Using this new methodology during a field campaign in February 2026, vertical concentration profiles were obtained. The results confirm previous concentration profiles for methane (CH_4) and carbon dioxide (CO_2) from 2017/18, showing excellent agreement within uncertainty, while introducing the first reported profiles for nitrogen (N_2) and total sulphide ($H_2S + HS^- + S^{2-}$).

The developed programme is specialised for use on Lake Kivu and enables technical personnel to perform precise measurements. While optimised for Lake Kivu's unique conditions, this methodology is adaptable to any gas-rich system, as demonstrated by its successful application in Lake Kilevann.

Session 8

Wednesday, September 2nd | 17:30 - 17:55

Extreme Gas Accumulation in Meromictic Lake Kilevann, Norway

Bertram Reventlow[1, 2], Bertram Boehrer[2], Florian Meienburg[1], Werner Aeschbach[1]

[1]Institute of Environmental Physics, Heidelberg, Germany, [2]Helmholtz Centre for Environmental Research - UFZ, Magdeburg, Germany

Lake Kilevann, a former fjord in Norway, contains a deep, isolated water body of ancient marine origin. Here we report exceptionally high, fully saturated concentrations of dissolved gases in the deep waters and investigate the physical and biogeochemical processes driving this enrichment.

Results reveal a highly stable, anoxic monimolimnion characterized by pronounced salinity and temperature gradients. Hydrochemical and isotopic signatures confirm the marine origin of the deep water, which is progressively modified by diffusive exchange with the overlying freshwater layer. Fractionation patterns in major ions indicate that turbulent diffusion is strongly suppressed, with transport governed by molecular diffusion, except for a localized double-diffusive convection cell near the sediment.

Dissolved gas concentrations are highly elevated in the monimolimnion, with carbon dioxide and methane concentrations among the highest ever measured in lakes. Stable carbon isotope signatures point to methane production primarily via hydrogenotrophic methanogenesis throughout the monimolimnion, while decreasing gas concentrations and radiocarbon data suggest anoxic methane oxidation near the chemocline. Strong depletion of dissolved argon is consistent with spontaneous ebullition regulating the total dissolved gas pressures.

No evidence for recent large-scale mixing is observed, indicating long-term stability of the stratification. However, the elevated gas pressures imply a potential risk of a limnic eruption if the system is disturbed by external forcing.

Poster Session	
Thursday, September 3rd	19:00 - 21:00

Monitoring freshwater lake ice cover - synergy of satellite radar altimetry, in situ observations and numerical modelling

Elena Zakharova[1, 2], Alexei Kouraev[3], Justin Murfitt[4], Claude Duguay[4], Theo Hrvatin[3], Andrey Suknev[5], Carlos Yanez[6]

[1]EOLA, Toulouse, France, [2]Institute of Water Problems, Russian Academy of Sciences, Moscow, Russia, [3]Université de Toulouse, LEGOS (CNES/CNRS/IRD/UT3), Toulouse, France, [4]H2O Geomatics, Inc. Waterloo, Canada, [5]Great Baikal Trail (GBT) Buryatiya, Ulan-Ude, Russia, [6]Centre National d'Études Spatiales (CNES), Toulouse, France

Many Eurasian lakes are ice-covered for several months each year. Ice cover has significant implications for lake physical, chemical, and biological processes, as well as for human activities. One of the main tools for monitoring ice cover state and water level of lakes is satellite observations, especially those from radar altimetric missions, including recent SAR altimetric missions (Sentinel-3, -6, and SWOT).

However, the presence of ice significantly affects the microwave remote sensing signal that can lead erroneous water level estimates in winter. The aim of this study is to improve understanding and quantify this issue through analysis of seasonally ice-covered lakes using data from radar altimetry missions, ancillary multi-satellite and multi-frequency observations, field campaign measurements, and numerical modelling.

Our study focuses on Lake Hovsgol in Mongolia. This large lake is located in a mountainous area within an arid climate zone, characterised by low snowfall, and affected by strong winds. As a result, our observations include highly heterogeneous icescapes - smooth and rough/eroded clear black ice, various types of hummocked ice, firn-like snow compacted by wind, etc. These field observations are compared with satellite observations in the active and passive microwave ranges, as well as with complementary satellite imagery.

To further explore the influence of ice cover properties on satellite observations, we use the active-passive microwave model SMRT (Snow Microwave Radiative Transfer), that includes a recently developed module dedicated to SAR altimetry. The model shows a good sensitivity to key freshwater ice characteristics such as roughness at the ice-water interface, air bubble fraction, snow-on-ice presence, ice thickness, ice/snow wetness, etc. This numerical analysis examines several large lakes, such as Baikal and Hovsgol in Siberia, as well as lakes in Canada.

This research was supported by the CNES R&T R-S25/OT-0003-104-01 project, Lakeddies II, and SWIRL projects.

Poster Session

Thursday, September 3rd 19:00 - 21:00

Gaussian Process Modeling of Deepwater Cooling in a Very Deep Lake

Sherif Alaa Ibrahim[1], Ana Erdevicki[1], Parvin Ghafarian[2], Peter L. Jackson[2], Bernard E. Laval[1]

[1]Department of Civil Engineering, University of British Columbia, [2]Department of Chemistry, Environmental Science & Environmental Engineering,University of Northern British Columbia

Machine learning applications in limnology are limited and in cold deep lakes, where data are relatively scarce, they may seem inappropriate to apply. Yet there are regression methods capable of dealing with very limited datasets such as Bayesian Gaussian Processes. We aim to understand multi-annual variations of deepwater ventilation in Quesnel Lake (>524 m), and how a changing climate might affect these processes.

We utilize observations spanning a decade (2017-2025) from a temperature mooring deployed in Quesnel Lake (M14, 400 m local depth), with a wind field estimated using the Weather Research and Forecasting (WRF) Model validated against shore-based measurements. Surface heat fluxes are estimated using in-situ meteorological measurements and the WRF-derived wind forcing. We predict deepwater (>200 m) heat content loss during cooling periods using predictors selected through feature selection, including surface heat fluxes as an integrated measure of winter severity (i.e., the combined effects of cold air and windstorms) and initial conditions of the deepwater (i.e., the remnants of previous years' stratification). Gaussian Processes are used for non-parametric, nonlinear regression, given their strength in capturing complex relationships between predictors and response without overfitting, while explicitly accounting for uncertainty in limited datasets.

Preliminary results suggest the magnitude of deepwater heat content loss, linked to ventilation and potential nutrient redistribution, varies appreciably between years. This statistical approach provides a complementary means of understanding interannual variability in deepwater ventilation, and may offer estimates of how such processes could change under anticipated shifts in atmospheric forcing (i.e., less frequent windstorms and/or extreme cold air temperatures). More broadly, this framework highlights the potential of data efficient and uncertainty aware methods in limnology to advance understanding of lakes with limited datasets, when even decade long observations yield only a small number of independent observations for statistical analysis.

Poster Session

Thursday, September 3rd 19:00 - 21:00

Measurements of Stratification and Circulation in an Enclosed Former Estuary

Wouter Kranenburg[1, 2], Hannah Clercx[1], Patrick de Bruijn[1], Ad Reniers[1]

[1]Delft University of Technology, [2]Deltares

Around the world, estuaries have been closed off from the sea to improve safety against flooding. However, various of these Enclosed Former Estuaries (EFEs) experience ecological issues. An example is Lake Veere, The Netherlands. The issues are strongly related to summer stratification and hypoxia. However, recent fish mortality events indicate that on top of the seasonal variation, wind-induced thermocline height variations on shorter time scale affect the ecology. We therefore aim to investigate how the spatial variation of stratification, circulation and thermocline height in Lake Veere depends on the wind, and explore measuring this using backscatter.

For three months, flow velocity profiles were measured with upward looking ADCPs at four locations in the lake, with high-resolution narrowband backscatter measurements at 250, 500 and 1000 kHz at two of them. Simultaneously, moorings with temperature sensors (vertical spacing 0.4 m) were deployed at three locations, with oxygen measurements at two vertical levels at one of them. Intercomparison showed that the backscatter unfortunately only tracked the thermocline during extended warm periods, likely explained by vertical gradients in phytoplankton concentration only developing after days of temperature stratification. A clear tilting of the thermocline was observed for wind perpendicular to the longest axis of the EFE, signalling wind-induced upwelling. Also for axial winds, an increased bulge of colder water was observed at the upwind side, and oxygen levels decreased near the surface. However, in this case also a strong horizontal circulation was established, with upwind flow over the deeper parts of the system, which we explain from the bathymetry of the EFE that still shows the typical estuarine channel - shoal characteristics. This raises the question whether it is upwelling or rather horizontal circulation that is responsible for the transport of anoxic water from the deeper to the shallower parts of the system.

Poster Session	
Thursday, September 3rd	19:00 - 21:00

Complex interactions in a coastal karstic environment: The case of marine lake Zmajevo oko (Rogoznica, Croatia)

Iva Dominović Novković[1], Marija Marguš[1], Tatjana Bakran-Petricioli[2], Donat Petricioli[3], Georgiy Kirillin[4], Peter Robins[5], Irena Ciglenečki[1], Ivica Vilibić[1, 6]

[1]Division for Marine and Environmental Research, Ruđer Bošković Institute, Croatia, [2]Department of Biology, Faculty of Science, University of Zagreb, Croatia, [3]D.I.I.V. Ltd. for Marine, Freshwater and Subterranean Ecology, Croatia, [4]Department of Ecohydrology and Biogeochemistry, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany, [5]School of Ocean Sciences, College of Science & Engineering, Bangor University, UK, [6]Institute for Adriatic Crops and Karst Reclamation, Croatia

Lake Zmajevo oko is a eutrophic marine lake - predominantly meromictic but abrupt mixing events occasionally occur, causing the water column to become anoxic. Analysis of long-term physicochemical data, collected seasonally between 1996 and 2022, has revealed that haline stratification controls vertical mixing of the lake, particularly during dry years. During the period 2021-2023, the undersground connection between the lake and the sea, maintained through the karstic limestone, was investigated. Two submerged connection points were identified, where seawater enters the lake indirectly as a mixture of seawater, lake water, and freshwater, which influences temperature near the lake boundaries and introduces nutrients into the lake. Water exchange is largely controlled by tidal fluxes, whose signal reaches the lake attenuated and with a time lag of approximately three hours. A hydrodynamic model of Zmajevo oko was developed using Delft3D FM, forced with ERA5 reanalysis data. The model qualitatively reproduced a mixing event during 2021 and preserved stratification during 2023, as observed. Furthermore, it overestimated wind-driven mixing and underestimated freshwater inflow, primarily due to coarse ERA5 forcing data. Continued long-term monitoring of physicochemical properties at high spatial resolution is therefore recommended to improve the model performance. Additionally, the inclusion of water quality indicators in the model is essential for assessing ongoing and future climate changes. Finally, future research should investigate the role of double diffusion in the vertical mixing of Zmajevo oko, which has been indicated by the model to occur in its deeper layers.

Poster Session

Thursday, September 3rd | 19:00 - 21:00

Stable water isotope signatures ($\delta^{18}O$ and δ^2H) in a stratified marine lake: evidence of evaporation, stratification and restricted exchange

Marija Marguš[1], Iva Dominović Novković[1], Georgiy Kirillin[2], Irena Ciglenečki[1]

[1]Ruđer Bošković Institute, Division for Marine and Environmental Research, Zagreb, Croatia, [2]Department of Ecohydrology and Biogeochemistry, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

The stable isotopic composition of water ($\delta^{18}O$ and δ^2H) was used to investigate hydrological processes in the stratified and euxinic Lake Zmajevo oko. Variations in water mass structure control mixing within the water column, while restricted exchange with the atmosphere, surrounding sea, and groundwater imparts a distinct isotopic signature. Depth profiles from October 2023 and July 2024 show systematic isotopic enrichment with depth. The $\delta^{18}O$ increases from approximately 1.15-1.20 ‰ in the epilimnion to 1.67-1.71 ‰ at 10-12 m, while the δ^2H increases from 3.8-4.2 ‰ to 6.7-7.6 ‰, with generally higher values observed in October 2023. In both periods, $\delta^{18}O$ varied conservatively with salinity, with a stronger positive correlation observed in October 2023 ($R^2 \approx 0.85$) than in July 2024 ($R^2 \approx 0.34$). This suggests stronger and more stable summer stratification and partial vertical mixing in autumn. The $\delta^{18}O$-δ^2H relationship defines a local evaporation line with slopes ranging from approximately 6.6 in summer to 7.6 in autumn, both lower than the Global Meteoric Water Line, indicating evaporation-driven isotopic fractionation under restricted atmospheric exchange. The d-excess values are consistently negative (mean ≈ −5.75 ‰), further supporting evaporative enrichment of the water column. Seasonal differences are evident in both the isotopic range and the slope of the evaporation line. Summer conditions exhibit a stronger evaporative influence and a narrower isotopic gradient, whereas autumn profiles display a wider isotopic range and a slightly steeper slope, potentially reflecting partial mixing and/or the contribution of less evaporative-modified water masses.Overall, the combined isotopic and density structure indicates that vertical gradients in Lake Zmajevo oko are primarily controlled by persistent stratification and evaporation, with limited influence from external water inputs. These results demonstrate the utility of stable isotopes as tracers of internal hydrological structure and restricted lake-sea exchange.

Poster Session

Thursday, September 3rd | 19:00 - 21:00

Navigating the AI Wave: Generative Artificial Intelligence in Physical Limnology

Marco Toffolon[1], Annunziato Siviglia[1]

[1]*Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy*

The rapid emergence of Generative Artificial Intelligence (GenAI) is reshaping scientific research. In the field of physical limnology, where understanding complex hydrodynamic processes, thermal stratification, and turbulence requires intensive data processing and code development, these tools offer transformative potential.

This poster explores the integration of GenAI within physical limnological studies. We present practical applications including: (1) accelerating literature reviews for complex theoretical frameworks; (2) assisting in the development and debugging of scripts for analyzing high-frequency sensor data or hydrodynamic model outputs; (3) facilitating the conceptualization of physical processes for university-level instruction; and (4) acting as a collaborative research partner to brainstorm innovative hypotheses and explore novel experimental designs.

Beyond these technical applications, our primary goal is to stimulate a community-wide discussion. While GenAI enhances productivity, it raises critical questions regarding accuracy, potential biases in physical modeling, and the necessity of rigorous human oversight. We view this contribution as a collaborative space for the Physical Processes in Natural Waters (PPNW) community to share experiences, challenges, and best practices.

We invite colleagues to engage with us on how to ethically adopt these tools, ensuring they complement—rather than replace—the physical intuition and scientific rigor fundamental to our field. Our aim is to foster a dialogue on integrating AI into both research workflows and university curricula, ensuring the next generation of limnologists is well-equipped to navigate this technological transition.

[*Reflecting the subject of our research, this abstract was collaboratively written with the assistance of Generative AI tools and finalized by the authors.*]

Poster Session

Thursday, September 3rd | 19:00 - 21:00

Linking upstream rainfall to turbidity events in a hydropower-regulated sub-alpine lake using satellite observations

Ilaria Dal Dosso[1], Ali Farrokhi[1], Marina Amadori[2], Sebastiano Piccolroaz[1], Marco Toffolon[1]

[1]Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy, [2]Institute for Electromagnetic Sensing of the Environment, National Research Council, Italy

Lake Cavazzo is a small sub-alpine lake located in north-eastern Italy, whose natural hydrological regime has undergone substantial anthropogenic alteration following the commissioning of the Somplago hydropower plant in the late 1950s. The introduction of water inputs derived from intake structures distributed across a large portion of the Tagliamento river basin has modified the physicochemical equilibrium of the lake, introducing hydraulic inputs alien to its natural dynamics.

Among the effects attributed to the operation of the plant, episodes characterised by marked turbidity have raised significant concern in the local communities. Despite their environmental relevance, the spatio-temporal distribution of turbidity events and their dependence on upstream hydrometeorological forcing have not been systematically quantified.

The present study pursues two primary objectives. First, turbidity episodes are identified by processing multi-temporal satellite imagery acquired by the optical sensors onboard Sentinel2 and Landsat8-9 missions and combining spectral bands that maximise the sensitivity to suspended sediment content. Then, the resulting maps are correlated with precipitation time series recorded over the sub-basins of the hydropower intake system, which also include two other reservoirs. Based on the statistical correlation between hydrometeorological forcing and the turbidity response of the lake, we find that turbidity events are systematically associated with significantly higher mean precipitation values in the preceding days compared to non-turbid episodes, suggesting a non-causal link between antecedent rainfall accumulation over the catchment and the consequent release of turbid discharges.

The findings establish a quantitative framework for the water quality assessment of Lake Cavazzo and lay the methodological groundwork for the development of an early warning system for turbidity forecasting, with potential applicability to lacustrine water bodies subject to analogous hydropower-related impacts.

Poster Session

Thursday, September 3rd 19:00 - 21:00

Optimizing sediment management in alpine reservoirs through process-based modelling of bottom outlet flushing

Sebastiano Piccolroaz[1], Sara Treccani[1], Marco Toffolon[1], Luigi Fraccarollo[1], Marina Amadori[2], Franco Garzon[3], Matteo Vicenzi[4]

[1]University of Trento, [2]CNR-IREA, [3]Dolomiti Energia, [4]Magis Power

Reservoir sedimentation is a persistent challenge for dam operations, progressively reducing storage capacity and threatening hydropower production. While controlled strategies such as drawdown operations and flood-induced flushing via bottom outlet opening can mitigate sediment accumulation, their effectiveness is highly site-specific and strongly influenced by reservoir morphology and operational flexibility. Process-based numerical modelling provides a powerful framework to evaluate and optimise such strategies prior to field implementation.

This study investigates the hydro-morphodynamic response of two Alpine reservoirs in Trentino-Alto Adige (Italy) - Busa and Stramentizzo - using the Delft3D modelling suite (FLOW and MOR modules). The two systems differ markedly in geometry and operational constraints, offering complementary test cases. In the Busa reservoir, where water levels are maintained at the maximum regulation level, simulations assess the impact of bottom and surface outlet activation under both steady and unsteady inflow conditions. In the Stramentizzo reservoir, where pre-emptive drawdown is operationally feasible, the model is applied to identify optimal drawdown strategies that balance sediment flushing efficiency through bottom outlet opening with regulatory limits on downstream suspended sediment concentrations; the company managing the reservoir is currently awaiting authorization from the competent authorities to implement this operating mode. In both cases, hydrostatic full-domain and non-hydrostatic sub-domain approaches were tested.

Results highlight distinct sediment dynamics. In the Busa reservoir, bottom outlet activation induces localized erosion near the outlet, effectively maintaining a clear zone for operational safety, but does not significantly enhance overall sediment export. On the other hand, the Stramentizzo reservoir exhibits a clear optimal drawdown level that maximizes sediment release while remaining within downstream environmental thresholds. In both reservoirs, erosion patterns remain spatially constrained.

These findings demonstrate the value of process-based modelling for designing site-specific sediment management strategies and highlight the importance of targeted field data to constrain model uncertainty and support robust decision-making.

Session 9

Friday, September 4th | 09:15 - 10:00

Extreme environment of the Aral Sea after desiccation

Alexander Izhitskiy[1]

[1]*Shirshov Institute of Oceanology, Russian Academy of Sciences*

Once the fourth largest lake in the world, the Aral Sea has undergone severe desiccation since the 1960s and has lost more than 90% of its surface area. Located within one of the largest endorheic basins under arid climatic conditions and subject to intense anthropogenic influence, the Aral Sea's rapid shrinkage has led to large-scale socio-economic consequences for the region, the collapse of regular monitoring, the retreat of the shoreline away from settlements, and the transformation of the lake into a complex system of residual water bodies. Despite a common origin, the residual basins have evolved into sharply contrasting ecosystems due to differences in freshwater inflow, lake-floor morphology, and water regulation practices. In the recent stage of desiccation, the cessation of inter-basin exchange has led to further isolation of the newly formed water bodies. We focus on the consequences of desiccation for the present physical state of the Aral Sea residual system, based on annual intensive short-term field campaigns including CTD measurements, water sampling, and long-term autonomous observations of seasonal temperature and oxygen cycles. These observations were conducted in the Aral Sea for the first time and provide new insights into the physical regime of the major residual basins. Present salinity conditions vary widely between basins, from brackish (10-11 g/kg) to hypersaline (>240 g/kg). In terms of mixing regimes, conditions ranging from dimictic and polymictic to mer omictic can be identified, while strong interannual variability indicates rapid transitions between these states driven by climate forcing and anthropogenic impact on the water balance. The study of physical processes under the rapidly changing conditions of the Aral Sea is highly relevant for understanding the impacts of global change in other endorheic systems.

Session 9

Friday, September 4th | 10:00 - 10:25

Physical Drivers of Water Quality and Salinity Dynamics in a Coastal Shallow Lake: A GIS-MCDA Approach for Monitoring Optimization

Anja Batina[1], Ante Šiljeg[1]

[1]*University of Zadar*

Water quality dynamics in coastal shallow lakes are strongly controlled by physical processes, including hydrodynamic mixing, meteorological forcing, and salinity variability driven by marine influence. This study investigates the interaction between physical and biogeochemical processes in Vrana Lake, a coastal shallow lake in Dalmatia, Croatia, influenced by seasonal water level fluctuations and periodic seawater intrusion from the Adriatic Sea. A spatial multi-criteria framework based on GIS-MCDA and Fuzzy Analytical Hierarchy Process (F-AHP) was applied to evaluate water quality patterns and optimize the monitoring network using data collected from July 2023 to June 2024. The analysis integrates key physical drivers, including air temperature, wind, and precipitation, with water quality parameters (electrical conductivity, turbidity, dissolved oxygen, and water temperature) and environmental pressures such as water resource, nutrient runoff, and pollution sources. Results reveal that water quality variability is primarily governed by the interaction of physical forcing and hydrological connectivity. Elevated air temperatures increase water temperature and influence oxygen dynamics, while wind-driven mixing enhances sediment resuspension and turbidity. Seawater intrusion and evaporation contribute to salinity gradients, particularly in southern regions, affecting conductivity and ecosystem processes. Increased runoff during precipitation events promotes nutrient input and phytoplankton growth, indicating strong coupling between physical and biogeochemical dynamics. The resulting spatial classification highlights distinct zones of water quality linked to hydrodynamic conditions and external pressures. An optimized monitoring network of seven stations captures key physical gradients and improves system representation. This study demonstrates how integrating physical limnological processes with spatial analysis supports more effective monitoring of coastal lakes and provides a transferable framework for understanding coupled physical-biogeochemical dynamics in climate-sensitive aquatic systems.

Session 9

Friday, September 4th | 10:25 - 10:50

Stratification and Mixing Dynamics Under Extreme Drawdown and Refilling in a Semi-Arid Reservoir

Luísa Ciríaco Silva de Oliveira[1, 2], Tobias Bleninger[3], Stephan Fuchs[2], Iran Eduardo Lima Neto[1]

[1]Federal University of Ceará, Department of Hydraulic and Environmental Engineering, Fortaleza, Brazil, [2]Karlsruhe Institute of Technology, Institute of Water and Environment, Karlsruhe, Germany, [3]Federal University of Paraná, Department of Environmental Engineering, Curitiba, Brazil

Reservoirs in semi-arid regions are subject to extreme hydroclimatic variability, including multi-year droughts, intense evaporation, and strong anthropogenic water withdrawals, leading to pronounced water-level fluctuations. Under such conditions, reservoirs can experience transitions from near-full storage to less than 1% of capacity, fundamentally altering the hydrodynamic behavior. Despite their global relevance, the physical response of these highly dynamic systems remains poorly understood. In this study, we applied the three-dimensional Delft3D model to investigate hydrodynamic processes in the Pentecoste Reservoir, a tropical semi-arid system located in northeastern Brazil, with a maximum storage capacity of 360 hm^3, a surface area of 46.64 km^2, an average depth of 6.5 m, and maximum depth of 19.8 m under full conditions. Two multi-year periods were simulated: a prolonged drought phase characterized by severe drawdown, and a subsequent refilling phase. This approach allowed to examine how large water-level variations influence thermal structure, stratification, and mixing dynamics across distinct system states. Preliminary results suggest a shift in hydrodynamic regime between the two periods. During the drought phase, reduced water levels are associated with a predominantly well-mixed system, characterized by weak and transient stratification and high sensitivity to wind forcing. In contrast, the refilling phase is expected to promote the development of more stable and persistent thermal stratification, linked to increased water depth and enhanced vertical stability. These patterns indicate a strong control of water-level fluctuations on stratification dynamics, potentially exceeding the influence of seasonal variability. By focusing on the physical response of a system undergoing extreme volumetric changes, this study contributes to the understanding of non-stationary reservoir dynamics and provides insights into how water bodies may respond to intensifying climate variability.

What Constitutes a Deep Lake? A Dynamics-Based Definition and the Concept of Anisomixis

Sherif Alaa Ibrahim[1], Eddy Carmack[2], Kelly Graves[3], Svein Vagle[2], Stephen Russell[4], Bernard E. Laval[1]

[1]Civil Engineering Department, University of British Columbia, [2]Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia, Canada, [3]Knight Piésold, Vancvouer, British Columbia, Canada, [4]Department of Greek & Roman Studies, McMaster University, Ontario, Canada

The genealogy of deepwater ventilation in temperate lakes is closely tied to Lake Baikal. As the deepest freshwater lake on Earth, Baikal is unquestionably "deep”. While its deepest waters are renewed, classical top-down convection alone cannot homogenize its full water column, requiring additional processes for deepwater ventilation. Yet lakes up to two orders of magnitude shallower are often described as "deep" because they are the deepest within a region. This raises two fundamental questions: 1) what constitutes a deep lake, and 2) how should lakes that are not represented by existing lake-mixing classifications be classified? We argue that "deep" should not be defined by an arbitrary depth threshold or relative depth, but by the physical mechanisms that govern renewal of its deepest waters. A lake becomes dynamically deep when seasonal free and forced convection no longer achieve annual basin-wide homogenization and at least one additional process is required to ventilate its deepest waters. Drawing on observations from lakes spanning more than an order of magnitude in depth, from Deeks Lake (100 m, British Columbia) to Lake Baikal (1,642 m, Siberia), we show that these systems share a common dynamical structure despite contrasting morphometry and climates. The upper water column behaves as a classical mono- or dimictic system, while below this seasonally homogenized layer renewal of the deepest waters depends on additional renewal processes arising from interactions among non-linearities in the equation of state, basin morphometry, atmospheric forcing and external buoyancy inputs. The boundary between these regimes varies spatially, temporally, and with atmospheric forcing, even within a single lake. We propose the term ***anisomixis***, derived from the Greek *anisos* (unequal) and *mixis* (mixing), for this intermediate dynamical regime, in which the deepest waters are renewed but annual basin-wide homogenization does not occur. This way, lakes are defined by ventilation dynamics and classified as **meromictic, oligomictic, or anisomictic.**

Large-scale dynamics and fine-scale mixing in Lake Issyk-Kul and their relation to biological productivity

Georgiy Kirillin[1], Peter Zavialov[2], Salmor Alymkulov[3], Sergey Rozhdestvensky[2]

[1]IGB Berlin, [2]Shirshov Institute of Oceanology, Moscow, [3]Kyrgyz State Technical University named after Iskhak Razzakov

Terminal lakes of the arid endorheic zone of Central Asia are among the largest inland water bodies worldwide, yet they remain understudied in modern limnology. Despite their importance for the regional water budget and their high sensitivity to global change and catchment water use, systematic studies of these systems are rare. With their large volumes and salinities ranging from brackish to hypersaline, the physical processes in these lakes share characteristics of both marine and freshwater environments and reveal transport and mixing mechanisms that shed new light on lake physics. We present new observational results from a recently established monitoring program at Issyk-Kul, a deep alpine brackish lake in Kyrgyzstan. Lake Issyk-Kul has a maximum depth of nearly 700 m and a surface area exceeding 6,000 km², making it the tenth largest lake by volume and the deepest alpine lake in the world. While detailed analyses and further process-oriented investigations are ongoing, this overview provides insight into the temporal and spatial scales of physical processes specific to large deep lakes, the role of salinity and freshwater inflows in stratification and mixing, and the physical controls on primary production under ultra-oligotrophic conditions. Among the most notable features are Kelvin-like basin-scale waves with amplitudes exceeding 100 m and spatial extents of tens of kilometers, potentially contributing to deep mixing. Lateral salinity gradients generated by river inflows promote double-diffusive mixing and cabbeling. High water transparency allows the surface mixed layer to deepen to 10-20 m. The underlying thermocline controls the development of a deep chlorophyll maximum. Additional notable features of lake dynamics include deep oxygen transport, localized decreases in salinity within the pycnocline, and increased turbidity in nearshore zones associated with internal wave shoaling. Overall, these results provide valuable insight into the key processes governing large-scale lake hydrodynamics and their role in biological production.

Evolution of Thermal Stratification in Lake Kivu and Its Drivers

Jean Modeste Mushimiyimana[1, 2], Fabian, Bärenbold[1], Tomy, Doda[3], Eric, Ruhanamirindi Mudakikwa[4], Martin, Schmid[1]

[1]Swiss Federal Institute of Aquatic Science and Technology, Kastanienbaum, Switzerland, [2]Swiss Federal Institute of Technology, Zürich, Switzerland, [3]University of Lausanne, Lausanne, Switzerland, [4]Rwanda Environment Management Authority, Kigali, Rwanda

Besides the unusually large amounts of dissolved gases in Lake Kivu, its stratification has particularly become well known for its water temperature that increases with depth. As a meromictic lake, it undergoes seasonal mixing only down to approximately 65 m, whereas the underlying monimolimnion remains permanently stratified. Within this deep layer, double-diffusive transport dominates due to the strong opposing effects of temperature and salinity on density. This unique stratification is maintained by multiple external forcings, including climate variability and regional volcanic activity. In addition to atmospheric heat exchange, the lake receives heat inputs from a complex subsurface geological system that involves two active volcanoes, Nyamuragira and Nyiragongo. Historical observations since the 1970s indicated persistent warming throughout the lake water column; however, the drivers of this observed warming and their relative contributions remain unclear. Although Lake Kivu is permanently stratified, continued warming of the water column may increase the risk of a catastrophic limnic eruption from the deep waters, underscoring the potential hazards associated with temperature-driven changes. In this study, we employed one-dimensional lake model in combination with temperature observations to estimate heat budgets for the principal stratified layers. We further assessed the relative contributions of major external heat sources, quantifying the extent to which observed warming can be attributed to climate forcing and volcanism-related inputs, such as hydrothermal groundwater inflows and geothermal heat flux. Additionally, we evaluated whether double-diffusive processes alone can account for the observed deep-water warming. Our results provide clear evidence that volcanism-related heat inputs constitute a dominant control on the long-term thermal evolution of Lake Kivu’s monimolimnion.

3D Modeling of Lake Shikotsu: Thermobaricity controlled Deep Water Circulation

Joshua Marks[1, 2], Firmijn Zijl[3], Kazuhisa A. Chikita[4], Bertram Boehrer[1, 2]

[1]Department of Lake Research, Helmholtz Centre for Environmental Research - UFZ, Magdeburg, Germany, [2]Faculty of Physics and Astronomy, Heidelberg University, Heidelberg, Germany, [3]Department of Hydrodynamics and Forecasting, Deltares, Delft, Netherlands, [4]Arctic Research Center, Hokkaido University, Sapporo, Japan

Thermobaricity is the temperature dependency of the compressibility of water and leads to a change in temperature of maximum density with depth. This effect is crucial for the deep water circulation in many deep fresh water lakes. However, our knowledge of deep water circulation in those lakes is based on point measurements and estimated exchange volumes. We expect a much more detailed understanding of the circulation from numerical models that are able to tackle thermobaricity.

Lake Shikotsu, located in Hokkaido, Japan, is a good example of deep water circulation controlled by thermobaricity. It is a temperate lake of volcanic origin whose surface water temperature falls below 4°C each year. We measured several profiles as well as continuous surface water temperatures in the period of October 2023 to May 2025. The constant isothermal deep water, which is consistently below 4°C throughout the year, and small salinity gradients indicate a dominant influence of thermobaricity on the deep water circulation. The rather cylindrical shape of the bathymetry and the steep sidewalls suggest a rather one dimensional behavior of the deep water circulation but its influence compared to other three-dimensional circulation patterns cannot be assessed solely by the measurements.

To investigate the deep water circulation in Lake Shikotsu in more detail we modelled the lake with Delft3D, a three dimensional model created for a wide range of applications including lakes. Thermobaricity has recently been implemented in Delft3D, where it affects both the horizontal baroclinic pressure gradient and buoyancy production in the k-ε turbulence model. The model is able to reproduce the measured temperature structure and thereby gives insight into the circulation patterns, helping to disentangle different mixing processes in Lake Shikotsu.

List of Participants

Name		Affiliation	Country	E-mail
Sherif	Alaa Ibrahim	Department of Civil Engineering, University of British Columbia	Canada	sherif.ibrahim@ubc.ca
Anja	Batina	University of Zadar	Croatia	abatina@unizd.hr
Bertram	Boehrer	Helmholtz Centre for Environmental research - UFZ	Germany	bertram.boehrer@ufz.de
Damien	Bouffard	EAWAG	Switzerland	damien.bouffard@eawag.ch
Lee	Bryant	University of Bath	United Kingdom	lb712@bath.ac.uk
Irena	Ciglenečki	Ruđer Bošković Institute	Croatia	irena@irb.hr
Luisa	Ciriaco Silva de Oliveira	Karlsruhe Institute of Technology / Federal University of Ceara	Germany	luisa.ciriaco@kit.edu
Hannah	Clercx	Delft University of Technology	Netherlands	h.m.clercx@tudelft.nl
Ilaria	Dal Dosso	Università degli Studi di Trento	Italia	ilaria.daldosso@unitn.it
Henk	Dijkstra	IMAU, Department of Physics, Utrecht University	Netherlands	h.a.dijkstra@uu.nl
Tomy	Doda	University of Lausanne	Switzerland	tomy.doda@unil.ch
Iva	Dominović Novković	Ruđer Bošković Institute	Croatia	iva.dominovic@irb.hr
Ana	Erdevicki	UBC Canada	Canada	anaerdevicki.5@gmail.com
Marta	Fregona	University of Helsinki	Finland	marta.fregona@helsinki.fi
Francesca	Hinegk	University of Trento	Italy	francesca.hinegk@unitn.it
Alexander	Izhitskiy	Shirshov Institute of Oceanology RAS	Russia	pan.izhitsky@gmail.com
Joachim	Jansen	University of Helsinki	Finland	joachim.jansen@helsinki.fi
Mario	Kassabji	BELMET 97	Croatia	mario.kassabji@belmet97.hr
Mohammad Atif	Khan	Swedish University of Agricultural Sciences, Umeå	Sweden	atif.khan@slu.se
Georgiy	Kirillin	IGB Berlin	Germany	georgiy.kirillin@igb-berlin.de
Marcus	Klaus	Swedish University of Agricultural Sciences	Sweden	marcus.klaus@slu.se
Alexei	Kouraev	CNRS/LEGOS/UT	France	alexei.kouraev@utoulouse.fr
Wouter	Kranenburg	Delft University of Technology & Deltares	Netherlands	w.m.kranenburg@tudelft.nl
Sierra	Legare	Queen's University	Canada	sierra.legare@queensu.ca
Gabriella	Luko	Budapest University of Technology / Uppsala University	Sweden	luko.gabriella@emk.bme.hu
Ivan	Mammarella	University of Helsinki	Finland	ivan.mammarella@helsinki.fi
Marius	Mangold	UFZ - Helmholtz Centre for Environmental Research	Deutschland	mangoldmarius@gmail.com
Michael	Mannich	Federal University of Parana	Brazil	mannich@ufpr.br
Marija	Marguš	Ruđer Bošković Institute	Croatia	mmargus@irb.hr
Joshua	Marks	UFZ - Helmholtz Centre for Environmental Research	Germany	joshua.marks@ufz.de
Hiroki	Matsumoto	Port and Airport Research Institute	Japan	matsumoto-h-p@p.mpat.go.jp
Cristobal	Molina	Nortek AS	Norway	cristobal.molina@nortekgroup.com
Jean Modeste	Mushimiyimana	EAWAG, ETH Zürich	Switezrland	mmushimiyima@ethz.ch

Keisuke	Nakayama	Kobe University	Japan	nakayama@phoenix.kobe-u.ac.jp
Andres	Posada Bedoya	Queen's University	Canada	21afpb@queensu.ca
Petra	Prskalo	Geophysical Department, University of Zagreb	Croatia	prskalo.petra@student.pmf.hr
Corentin	Prados	IGE CNRS	France	corentin.prados@ens-lyon.fr
Bertram	Reventlow	Institut für Umweltphysik	Deutschland	reventlow@iup.uni-heidelberg.de
Robert	Schwefel	IGB Berlin	Germany	robert.schwefel@igb-berlin.de
Jonas	Stankevicius	University of Calgary	Canada	jonas.stankevicius@ucalgary.ca
Marek	Stastna	University of Waterloo	Canada	mmstastn@uwaterloo.ca
Jadranka	Šepić	Faculty of Science, University of Split	Croatia	jsepic@pmfst.hr
Marco	Toffolon	University of Trento	Italy	marco.toffolon@unitn.it
Péter	Torma	University of Technology and Economics, Budapest	Hungary	torma.peter@emk.bme.hu
Sara	Treccani	University of Trento	Italy	sara.treccani@unitn.it
Timo	Vesala	University of Helsinki	Finland	timo.vesala@helsinki.fi
Ivica	Vilibić	Ruđer Bošković Institute	Croatia	ivica.vilibic@irb.hr
Elena	Zakharova	CNRS/EOLA	France	zavocado@gmail.com