26th Annual International Workshop on Physical Processes in Natural Waters

Girona, 1-5 July 2024

PROCEEDINGS

Program Overview

PPNW24	Monday, July 1 Faculty of Arts	Tuesday, July 2 Education & Psychology Faculty	Wednesday, July 3 Education & Psychology Faculty	Thursday, July 4 Faculty of Arts	Friday, July 5 Faculty of Arts
8:30-9:00		*Registration*	L. Ing		F.S. Sharifi
9:00-9:30		*Welcome*	B. Boehrer	W. Wang	I. Mammarella
9:30-10:00		M.V. Tenci	P.G.Grochocki	R. Valipour	B. Zamani
10:00-10:30		R. Katsman	E. Asirok	Y. Tong	A. Folkard
10:30-11:00		Coffee break			
11:00-11:30		M. de Vicenzi	M. Toffolon	D.F. McGinnis	P.G.Grochocki
11:30-12:00		M. Mancini	I. Dominovic	H. Shi	J. Vidal-Hurtado
12:00-12:30		*Iris Möller*	*Javier Sánchez-España*	*Rafael Marcè*	M. Fregona
12:30-13:00					***Closure***
13:00-14:00		Lunch			
14:00-14:30		Y. Amitai	Free time	M. Shikhani	Subworkshop Satellites**
14:30-15:00		J. Ala-Köni		A. Lorke	
15:00-15:30		W. Meredith		M. Wells	
15:30-16:00		R. Schwefel		Poster session*	
16:00-16:30		Coffee break		Coffee Break	Coffee
16:30-17:00		J. Jansen		S. Jamali	
17:00-17:30		C. Minaudo		M. Schmid	
17:30-18:00	*Welcome Aperitif*			L. Bryant	
18:00-18:30					
18:30-19:00			*Historical tour*		
19:00-20:00					
20:00-21:00			*Gala Diner* La Rosaleda		
21:00-22:00					

Keynote talk	*Poster session Thursday, July 4		**Subworkshop Satellite Friday, July 5	
	15:30-15:35	A .Rios	14:00-14:20	S. Simis
	15:35-15:40	P. Santoro	14:20-14:40	L. Carrea
	15:40-15:45	J. Mesman	14:40-15:00	P. Pastor
	15:45-15:50	J. Shan	15:00-15:20	M. Amadori
	15:50:15:55	M. Wells		

Detailed Program

MONDAY 1 JULY 2024 (at Faculty of arts)

17:30 – 18:30	Welcome Aperitif

TUESDAY 2 JULY 2024 (at Faculty of Education and Psychology)

9:30 – 10:00	M.V. Tenci	Thermal patterns in a proglacial pond create Windows of Opportunity for periphyton growth (Cevedale glacier, Italy)
10:00 – 10:30	R. Katsman	Methane Gas Dynamics in Sediments of Lake Kinneret, Israel, and their Controls: Insights from a Multiannual Acoustic Investigation and Correlation Analysis
10:30 – 11:00	Coffee break	
11:00 – 11:30	M.de Vicenzi	Mixing regime of Zmajevo oko (Rogoznica, Croatia), a heliothermal lake threatened by rapid deoxygenation
11:30 – 12:00	M. Mancini	Microfibers re-suspension from silty and sandy soil in turbulent environments
12:00 – 13:00	Iris Möller	Keynote: Biophysical interactions in coastal ecosystems: how size (and scale) matters
13:00 – 14:00	Lunch	
14:00 – 14:30	Y. Amitai	Subtropical lake under projected climate change: 3D model assessment and insights
14:30 – 15:00	J. Ala-Köni	Greenhouse gas fluxes and their drivers in large northern boreal lake Pallasjärvi
15:00 – 15:30	W. Meredith	A combined use of General Lake Model and Electrical Resistivity Tomography to identify changes in aquifer-lagoon relationships
15:30 – 16:00	R. Schwefel	Oxycline oscillations in Lake Stechlin – Observations and biogeochemical impact
16:00 – 16:30	Coffee break	
16:30 – 17:00	J. Jansen	Physical and biological drivers of long-term oxygen depletion in northern lakes
17:00 – 17:30	C. Minaudo	Who should you trust? Automated versus expert data processing of in situ CO_2 and CH_4 chamber measurements in complex and heterogeneous aquatic ecosystems

WEDNESDAY 3 JULY 2024 (at Faculty of Education and Psychology)

8:30 – 9:00	L. Ing	Quantifying Methane Ebullition Flux: Investigating Drivers of Ebullition throughout the Year
9:00 – 9:30	B. Boehrer	Gas accumulation in Lake Bosumtwi deep waters and its potential to contribute to fish kills
9:30 – 10:00	P.G. Grochocki	An Efficient and Affordable Marble Equilibrator for Continuous, Low-Energy Consumption Measurements of CO_2 in water
10:00 – 10:30	E. Asirok	Dissolved Oxygen Dynamics in Arctic and Boreal Lakes in Late Winter
10:30 – 11:00	Coffee break	
11:00 – 11:30	M. Toffolon	Can automatic calibration be used to improve the physics behind complex numerical models?
11:30 – 12:00	I. Dominović	Mixing regime of Zmajevo oko (Rogoznica, Croatia), a heliothermal lake threatened by rapid deoxygenation
12:00 – 13:00	Javier Sánchez-España	Keynote: Biogeochemical processes sustaining meromixis in extremely acidic pit lakes
13:00 – 14:00	Lunch	
14:00 – 18:30	Free Time	
18:30 – 20:00	Historical Tour	
20:30 – 22:30	Gala Dinner	

THURSDAY 4 JULY 2024 (at Faculty of arts)

9:00 – 9:30	W.Wang	The impact of extreme heat on lake warming in China
9:30 – 10:00	R.Valipour	Ecological Responses of Large Lakes to Climate Change: outcomes from observations and the application of a coupled watershed-lake model
10:00 – 10:30	Y.Tong	Global lakes are warming slower than surface air temperature due to accelerated evaporation
10:30 – 11:00	Coffee break	
11:00 – 11:30	D.F. McGinnis	What the sediment knows: The paleolimnological history of methane ebullition in a small eutrophic lake
11:30 – 12:00	H.Shi	Influence of global warming on ice cover and its impacts on future ship navigation in Lake Superior

12:00 – 13:00	Rafael Marcè	Keynote: Everything Everywhere All at Once: navigating global lake modeling with the ISIMIP Lake Sector
13:00 – 14:00	Lunch	
14:00 – 14:30	M.Shikhani	Coupled Multi-Lake Model Ensemble with a Multi-Domain Multi-GCM-RCM Ensemble for investigating Climate Change Impacts on Lake Sevan
14:30 – 15:00	A.Lorke	The effect of bottom slope on the generation of basin-scale internal waves in stratified reservoirs
15:00 – 15:30	M.Wells	Novel year-round observations of thermal stratification in the large Lake Ontario
15:30 – 15:35	A.Rios	Hydrodynamics and thermal structure as determinants of water quality in a humid subtropical reservoir undergoing rapid changes in weather
15:35 – 15:40	P. Santoro	Hydrodynamics and water quality in a subtropical hydropower reservoir: a combined modelling and measurement approach
15:40 – 15:45	J.Mesman	Managing Events and Extremes in Water Supplies
15:45 – 15:50	J.Shan	Numerical modelling of the wave interaction with revetment breakwater built on reclaimed coral reef islands in the South China Sea—Experimental verification
15:50 – 15:55	M.Wells	The role of over-winter oxygen dynamics in setting the spring and early summer dissolved oxygen levels in the large ice-covered Lake Simcoe
16:00 – 16:30	Coffee break	
17:00 – 17:30	S. Jamali	Inhibition of spring turnover in a brackish lake subject to ice cover
17:30 – 18:00	M.Schmid	Predicting the mixing depth of deep lakes without a lake model
18:00 – 18:30	L.Bryant	To mix or not to mix? Stratification-preserving vs. destratification aeration of a drinking-water supply reservoir

FRIDAY 5 JULY 2024 (at Faculty of arts)

8:30 – 9:00	F.S.Sharifi	Circulation in brackish ice-covered lakes: effects of salinity and river runoff
9:00 – 9:30	I.Mammarella	Variability and drivers of gas transfer velocity in a regulated river
9:30 – 10:00	B.Zamani	Effects of lake restoration approaches on the ecosystem of a suburban lake in Berlin area
10:00 – 10:30	A.Folkard	Modelling the environmental impacts of floating photovoltaics on their host waterbodies
10:30 – 11:00	Coffee break	
11:00 – 11:30	P.G.Grochocki	Assessment of the Influence of a Floating Photovoltaic System on the Passaúna Reservoir in Brazil
11:30 – 12:00	J.Vidal-Hurtado	Numerical modelling as a management tool of aquatic systems: The case of Berre Lagoon.
12:00 – 12:30	M.Fregona	Assessing LAKE 2.0 model performance in simulating thermal and gas dynamics during shoulder seasons in Lake Kuivajärvi
12:30 – 13:00	Closure	
13:00 – 14:00	Lunch	

Subworkshop Satellites

14:00 – 14:30	S.Simis	Global lake biogeochemistry observations in the Lakes_cci climate data record
14:30 – 15:00	L.Carrea	Global lake surface water temperature and ice cover for climate-related applications from the European Space Agency Climate Change Initiative
15:00 – 15:30	P.Pastor	Monitoring cianobacterial bloom and surface water temperature in protected areas by satellite images
15:30 – 16:00	M.Amadori	Sentinel Lakes of sub-Sahelian Africa: An assessment based on multivariate remote sensing data and numerical modelling
16:30 – 17:00	Coffee	

Invited lecturers

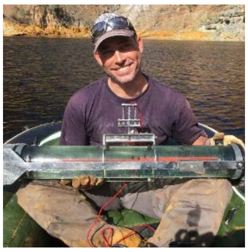
Iris Möller

Prof Möller is a coastal geomorphologist who researches how physical and biological processes interact at the coast, particularly in the intertidal zone (the area between tidal high and low water). She uses these insights to work with others within and beyond the discipline of Geography to develop integrative solutions for a coastal environment in which people are protected from flooding and erosion whilst also taking advantage of the many benefits healthy ecosystems and dynamic coastal landforms, particularly coastal wetlands, have for humans. The monitoring and understanding of long-term coastal morphodynamics (the link between coastal landforms and the processes shaping them) forms a key component of her work, as does how we use these insights to adapt to a changed environmental future through climate change, sea-level rise, and altered storm frequency/severity.

The coast is home to a vast array of different land forms that can rapidly change in response to external drivers, such as sea level rise, altered sediment fluxes, altered atmospheric composition, and human land use. Given the complexity of the coastal system, field observations are crucial in allowing theories to be verified and tested. Similarly, the ability to control conditions in the laboratory context or in numerical models is important in allowing theory to be developed.

In recent years, Prof Möller has worked closely with specialists in deploying remote sensing methods via remotely controlled airborne vehicles (UAVs) and satellite (e.g. the Copernicus suite of Sentinels). Such methods allow the capture of frequent images of a rapidly changing environment without the logistical difficulties of working in treacherous terrain.

Using all of these methods, Prof. Möller and her team and collaborators have led and contributed to a range of projects funded by national and international governmental funding agencies, including the European Union FP7 and Horizon 2020 Programmes, as well as the private sector and non-government organisations



Javier Sánchez-España

Javier obtained a BSc in Geology from the Basque Country University in 1990. In 1995, he joined the Department of Mineralogy and Petrology of that University, and in 2000 he obtained a PhD degree with a thesis devoted to the geochemistry of hydrothermal fluids and water/rock interaction during the formation of volcanogenic, massive sulfide deposits in primitive (Carboniferous) sea floors.

In 2003, he joined the Spanish Geological Survey (IGME-CSIC), where he has been working for twenty years as a scientific researcher. His research topics during this period were mostly related to acid mine drainage pollution in surface waters (rivers, lakes, streams, reservoirs, ponds), where he studied the interaction between metals and acidophilic microbes in extremely acidic and metal-rich mine pit lakes. In 2023 Javier joined the Center for Astrobiology (CAB, CSIC-INTA), where he works as planetary geologist in the Department of Planetology and Habitability. He is also a part-time, Associate Professor at Saint Louis University, where he teaches Earth Science and Oceanography.

Javier has been the principal investigator of more than 20 research projects, as well as the supervisor of 6 PhD thesis and 8 MSc thesis. He has authored or coauthored more than 60 research papers in international scientific journals, and presented talks in more than 70 international conferences worldwide, many of them being invited lectures. His current research deals with geochemical and microbial controls on metal mobility and mineral formation. He is mostly interested in the bacterial mediation of redox reactions, the biogeochemical cycling of iron, sulfur and carbon, as well as in metal/microbe/mineral interactions and biomineralization processes in extreme environments. His current goal is to find biomarkers to be applied in astrobiological research and space exploration.

Rafael Marcè

The general objective of my scientific career is to understand how water scarcity impacts continental aquatic ecosystems and their provision of services to society, in order to adapt to a drier climate. Within this general framework, I study how drying ecosystems change their way of processing and storing carbon, and what consequences this has for the redistribution of anthropogenic carbon in different compartments of the Earth System. This information is crucial to anticipate how mitigation and adaptation actions to climate change will function. I also develop global models of the impacts of climate change on lakes and reservoirs with the ISIMIP network, and work on the detection and attribution of the impacts of global changes on aquatic ecosystems with the collaborative GLEON network. Finally, I design tools for predicting water quality in reservoirs, with a special emphasis on the impacts of droughts and other extreme phenomena.

Practical information

Faculty of Arts
Plaça Josep Ferrater I Mora, 1, 17004

Faculty of of Education and Psychology
Plaça de Sant Domènec, 9, 17004

3 **Gala Diner – Restaurant La Rosaleda Jardí Degustació** – Paseig de la Devesa, 1, 17001

Registration

Registration will be possible on Tuesday morning from 8:30 to 9:00 before the morning session.

Information for speakers

Each presentation has a 15-minute time slot and 15-minute discussion.

Information for posters

Poster will be presented on the walls, so size is free. There will be one poster session in the conference where the Authors will present their posters with 5 min long flash presentation. Discussion will be held after the end of the poster session and during the Coffee break.

Scientific committee

- Chairman — Bertram Boehrer, Helmholtz Centre for Environmental Research (UFZ), Germany
- Josef Ackerman, University of Guelph, Canada
- Hrund Andradóttir, University of Iceland, Reykjavik, Iceland
- Lars Bengtsson, Lund University, Sweden
- Damien Bouffard, EAWAG, Kastanienbaum, Switzerland
- Lee Bryant, University of Bath, U.K.
- Xavier Castamitjana, University of Girona, Spain
- Giuseppe Ciraolo, University of Palermo, Italy
- Nikolai Filatov, Karelian Research Centre of RAS, Petrosavodsk, Russia
- Andrew Folkard, Lancaster University, United Kingdom
- Georgiy Kirillin, Institute of Freshwater Ecology IGB, Berlin, Germany
- Charles Lemckert, University of Canberra, Australia
- Madis-Jaak Lilover, Marine Systems Institute, Tallinn, Estonia
- Andreas Lorke, University of Koblenz-Landau, Germany
- Daniel McGinnis, University de Genève, Switzerland
- Marco Pilotti, University of Brescia, Italy
- Francisco Rueda, University of Granada, Spain
- Geoffrey Schladow, University of California, Davis, U.S.
- Teresa Serra, University of Girona, Spain
- Adolf Stips, European Commission, Italy
- Arkady Terzhevik, Karelian Research Centre of RAS, Russia
- Marco Toffolon, University of Trento, Italy
- Lars Umlauf, Leibniz-Institute for Baltic Sea Research IOW, Warnemuende, Germany
- Giulia Valerio, University of Brescia, Italy
- Timo Vesala, University of Helsinki, Finland
- Danielle J. Wain, 7 Lakes Alliance, Belgrade Lakes, U.S.
- Alfred Wüest, EPFL, Lausanne, Switzerland
- Ram Yerubandi, Canada Centre for Inland Waters, Burlington, Canada

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Proceedings

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Abstracts

Tuesday 2nd July 2024

M.V. Tenci*, W. Bertoldi, M. Tolotti, M. Toffolon

Thermal patterns in a proglacial pond create Windows of Opportunity for periphyton growth (Cevedale glacier, Italy)

In high mountain areas, deglaciation is the most evident effect of anthropogenic climatic changes. Glacier retreat is inducing worldwide an increase of both number and size of proglacial lakes and ponds, i.e., lentic water bodies located in the proglacial area and directly linked to the glacier activity: the depressions carved in the land surface allow meltwater impoundment and accumulation of glacier sediment. Over the past decades, glacier-fed lakes have become an increasingly represented ecosystem in the Alpine landscape. However, their ecological characteristics are only partially known. Glacial runoff determines cascade effects in glacier-fed standing waters. It influences both water temperature, by delivering cold meltwater to the system, and water transparency, because of the high amount of inorganic suspended solids (so called "glacial flour") that determine high water turbidity. Therefore, proglacial lakes are highly selective habitats, where planktonic communities are quantitatively scarce and taxonomically simplified. On the other hand, given the low input of allochthonous organic matter from bare proglacial forefields, benthic primary producers (periphyton) are the major autochthonous carbon source sustaining food webs in glacially fed water bodies. Studies on glacial streams show that periphyton growth is concentrated in "Windows of Opportunity" (WOs), mainly occurring in periods of reduced glacial runoff, i.e., autumn. In the euphotic zone along the littoral area of proglacial lakes, local conditions can allow algal growth (e.g., cyanobacteria), and the abrasive impact of glacial flour is low due to scarce water turbulence. Furthermore, in lentic proglacial ecosystems, periphyton ecological niches appear to be influenced also by water thermal stratification dynamics. Previous studies observed different mixing patterns in proglacial and clear mountain lakes (i.e., without glacial influence); high-altitude ponds (surface area < 2 ha) are expected to show even different patterns of response to physical environmental setting. To better understand the link between thermal dynamics and ecology of proglacial lentic systems, we investigated temperature dynamics in the water column of a proglacial pond located in the Eastern Italian Alps (South Tyrol, Italy) and compared them with density and taxonomic composition of benthic diatom communities, which are key components of littoral periphyton in lakes and are useful bioindicators of environmental changes. Diatoms are eukaryotic photosynthetic microalgae, characterised by a cell wall composed of silica (frustule), whose morphological characteristics are used for taxonomical identification. Specific aims of the study were: (i) to characterise the temperature dynamics in a shallow proglacial pond; (ii) to investigate how thermal dynamics can influence the presence of WOs for periphyton growth. The proglacial pond is located at 2850 m a.s.l. in the Martell valley (Stelvio National Park, CE Italian Alps). It is moraine-dammed and originated from the retreat of the Cevedale glacier about 10 years ago. Its surface area is about 4270.5 m^2 with a maximum depth of around 3 m. In the ice-free seasons 2022 and 2023, we installed water level sensors and performed water discharge measurements at the pond outlet with the salt dilution method, to build a flow rating curve and estimate outlet and inlet discharge time series. In summer 2023, we installed two buoys, one in the upstream part of the pond and one in the downstream part. Each buoy was equipped with 5 temperature sensors, located at 0, 0.2, 0.4, 0.8, 1.6 m depth, recording water temperature at 5-minute intervals. We applied the CE-QUAL-W2 model, a 2-D hydrodynamic laterally averaged model, to reconstruct the temperature time series in the water column for both ice-free seasons 2022 and 2023. We calibrated the parameters of the model based on field buoy data. Meteorological data and discharge time series were used as boundary conditions for the model. We developed a simplified numerical model to estimate the inflow water temperature (i.e., glacial runoff running on debris-covered ice) as a function of air temperature and solar radiation. Preliminary results show good agreement between the observed and modelled temperature data (RMSE < 1.5°C). During the Alpine glacial summer, we observed periods of pronounced daily thermal stratification. In these periods, shallow layers showed daily fluctuations, while deeper layers were colder. Total mixing and cooling of the water column followed intense precipitation events, with lower air temperature and solar radiation. In 2022 and 2023, we analysed the benthic diatom communities collected from a known area of colonised substrata (stones covered by a layer of consolidated sediment). In the laboratory, we eliminated the organic matter in the samples by chemical oxidation, to allow the morphological observation of diatom frustules. We equalised the sample volumes at 6 ml and added an aliquot (1 ml) of solution containing a known concentration of divinylbenzene microspheres, which served as reference to compare diatom densities in the different samples. Permanent diatom mounts were prepared, and diatom frustules and microspheres were counted under the optical microscopy. Diatom communities in the Cevedale proglacial pond reached higher density values (1-43 and 2.8-404.9 × 10^3 N valves/cm^2, respectively) than in glacier-fed streams investigated in the same geographical area (Vulcano 2020, unpublished data). Moreover, we observed a density peak in August 2022 (404.9 × 10^3 N valves/cm^2), and not in autumn as expected. In all samples, the community was numerically dominated by the pioneer species Achnanthidium minutissimum s.l. The observed diatom density patterns suggest that periphyton growth in the proglacial pond can be sustained also in periods of high glacial runoff. Accordingly, the model results suggest the presence of additional temperature-driven WOs for periphyton growth during the Alpine summer, with respect to the ones described in glacier-fed streams. The presence and temporal extension of the WOs in the proglacial pond depend on meteorological conditions, as thermal gradients form during dry and warm periods. In a climate change perspective, this implies that colonisation processes in the periphyton of newly formed proglacial ponds may be accelerated by prolonged periods of drought, high air temperatures and increased glacial runoff. Consequently, the natural ecological evolution of proglacial ponds may be accelerated by global warming.

R.Katsman*, E. Uzhansky, A. Lunkov, B. Katsnelson ___________________________________

Methane Gas Dynamics in Sediments of Lake Kinneret, Israel, and their Controls: Insights from a Multiannual Acoustic Investigation and Correlation Analysis

CH4 gas content is accommodated in discrete bubbles in shallow aquatic sediments. The bubble dynamics there are controlled by a diversity of physical, mechanical and biogeochemical processes that vary spatially and temporally over the lake. In this study, a multiannual (2015–2021) acoustic database on gas content in sediments of Lake Kinneret, Israel, is compiled. Gas content is evaluated by acoustic applications based on the sound speed inferred from the reflection coefficient. A multivariate linear regression is fitted and a closed form expression of gas content dependence on the following predictors, which change spatially and temporally over the lake, is obtained: 1) water depth; 2) short-leaving CH4 production rate peaks fuelled by punctuated phytoplankton bloom crashes; and 3) CH4 bubble dissolution rates. Our multidisciplinary analysis indicates that short-leaving CH4 production peaks act as major controls on sediment gas content in in the medium–deep parts of the lake (water depth > 12 m), where the hydrodynamic regime and slopped bottom transport the autochthonous organic matter toward the profundal lake zone. In contrast, the water depth predictor has the least significance, being even insignificant in the deepest lake area (> 30 m water depth), which may be explained by lack of ebullition there. A larger coefficient of determination, $R^2 = 0.653$, evaluated for the sound speed correlation, which points to a smaller sparsity of the experimental results, compared to the $R^2 = 0.540$ evaluated for the corresponding gas content, could be explained by the used power-law relation between the gas content and estimated sound speed in sediment. Our novel process-based correlation analysis enables quantification and prediction of gas content dynamics in sediments of the Lake Kinneret under changing spatial and temporal conditions. Our modelling could be extended to other marine and lacustrine ecosystems with different predictors and temporal variability. Predicting CH4 gas content dynamics is important for accurate evaluation and even reduction of a long-persisting uncertainty related to CH4 flux from aquatic sediments and for assessment of sediment load-bearing capabilities affected by gas presence. [This project is supported by the U.S.–Israel Binational Science Foundation, grant No. 2018150].

M. de Vicenzi ____

Mixing regime of Zmajevo oko (Rogoznica, Croatia), a heliothermal lake threatened by rapid deoxygenation

Floating and emergent species of vegetation are the most advantaged aquatic plants in eutrophic lakes where water turbidity precludes the growth of most submerged plant species. Rooted floating-leaved and emergent species are particularly favoured in shallow lakes, where the low depths allow them to cover a big portion of the water surface (e.g. Nohara et al., 1990). This considerable amount of biomass affects many aspects of the lake ecosystem: water circulation is slowed down by the increased drag; water-atmosphere heat and gas exchanges are hampered by the plants leaves at the interface; oxygen production by photosynthetic organisms in the water column is reduced due to the shadowing effect; a big amount of dead biomass accumulates on the bottom at the end of the vegetative season resulting in high respiration rates. All the above mentioned phenomena can lead to anoxia risk. Moreover, the high sedimentation rate enhances the lakebed aggradation, resulting in improved conditions for the growth of new vegetation, which sets a positive feedback effect.

This is precisely the case with the Mantua Lakes system (Northern Italy), where the allochthonous macrophyte Nelumbo nucifera (lotus flower) forms dense stands in the Superiore lake, covering an area of approximately 1 km^2 over a lake surface of 4 km^2. From the ecological point of view, the lakes system has been well studied (e.g. Pinardi, 2008; Pinardi et al., 2011; Pinardi et al., 2021), while hydrodynamic studies are currently limited to a first modelling insight by Fenocchi (Fenocchi and Sibilla, 2016).

In this contribution we present the preliminary results of an investigation on the effect of N. nucifera stands on the flow field in Mantua Superiore Lake. By combining field monitoring and numerical modelling, we explore the small-scale hydrodynamics potentially triggered by vegetation-induced temperature gradients between covered and uncovered areas.

Mantua Lakes are a shallow (mean depth 3.3 m) fluvial lake system which was created in the 12th century by the damming of the Mincio River. The river drains a watershed that is intensively exploited by agriculture. This resulted in a high nutrient input load that since the 1970s has caused the lakes' eutrophication, eventually worsened by summer low discharges due to water diversion for irrigation purposes. Summer trophic conditions are typically characterized by Secchi depth < 1 m, Chl-a > 100 µg/L, total P > 140 µg/L, D.O. peaks > 300 % (ARPA Lombardia, 2020). N. nucifera was intentionally introduced in the lake in 1921 as a food source and nowadays it has become dominant, replacing the native macrophytes thanks to some physiological traits that makes it particularly invasive (Tóth et al., 2019). Its spread is especially intense in the shallow areas (≍1 m) that guarantee optimal plant growth (Alfasane et al., 2009). Lotus flower expansion is controlled with great efforts by the Mincio Park management authority, which trims it in a leave-shaped patch with many cuttings per year using an adapted boat. This result in a sharp transition between vegetation and open water, which we hypothesize can be able to start thermal siphons.

To study the effect of such a dense aquatic meadow on hydro-thermo-dynamics, starting from November 2023 we deployed 2 chains of temperature and light loggers 30 m apart, one inside and one outside the vegetation. Every chain is equipped with 5 Hobo (MX2202) sensors, 50 cm spaced in depth, acquiring continuous measurements at a sampling rate of 5 minutes. Further profiles of temperature, light, and dissolved oxygen were collected all around the lotus patch in different periods of the year. Velocity at the edge of the vegetation patch was also acquired occasionally with an ADCP. A new bathymetric map was retrieved in 2022 with a Deeper CHIRP+ sonar (Deepersonar). The comparison of the new bathymetry with the previous one dating back to 2006 (Telò et al, 2007) allowed to study the effect of vegetation on the morphological evolution of the lake bottom. A three-dimensional model (Delft3D) of the lake was then set up based on the new bathymetry and calibrated on temperature data. We then focused on a sub-portion of the domain to simulate thermal siphons in idealized conditions and test the influence of bottom slope, vegetation density, and atmospheric forcing.

The comparison between bathymetric data shows a clear trend of bed aggradation inside and near the vegetated area, with a maximum deposition of 1 m (mean 0.4 m) in 16 years. Temperature time series recorded during winter 2023 by the two data-logger chains show cooling near the bottom inside the vegetation during the day, while heating occurs at the same depth in open water. The model results suggest that this effect is generated by night-time differential cooling between the shallowest part of the lake at the centre of the vegetation patch and the deeper region outside. In winter lotus flower loses its leaves, thus its shadowing effect is absent and the bathymetry influence prevails. Simulations of summer conditions suggest instead the onset of a current flowing under the vegetation towards open water for differential heating. Based on these promising results, further fieldwork will take place during summer, when lotus flower is at its vegetative peak and thus it is expected to have the maximum effect on water circulation. This study will help understanding the complex interactions between vegetated and unvegetated areas, where water and chemicals exchanges can have important consequences for the lake ecosystem.

M. Mancini*, J. Colomer, L. Solari, T. Serra ____

Microfibers re-suspension from silty and sandy soil in turbulent environments

Microplastic (MP) pollution in aquatic environments has emerged as a critical environmental issue with far-reaching implications. In freshwater MPs are known to accumulate in sediment beds where they can bury. Once buried they can resuspend due to high energetic events, re-entering the water column again. Therefore, riverbed sediments should be considered as a source rather than a sink for MPs. Synthetic microfibers (MFs) are becoming the focus of attention from the scientific community because of their abundance in natural environment. Moreover, due to their highly elongated shape, their behaviour significantly differs from other organic or inorganic particles that can be found in the aquatic environment, consequently theoretical and empirical models already developed for the sediment re-suspension or for the pollutant transport and successfully applied to 3d-shaped MPs do not fit for MFs. With the aim to fill this knowledge gap, in this work the turbulence induced by an oscillating grid device was used to investigate the resuspension of microfiber (MF) buried into the sediment bed. Four different types of plastic fibres commonly used for several industrial applications (PET, PP, PA and LDPE) and two types of soils (cohesive and non-cohesive) were investigated. Particles were in depth characterized via 3D reconstruction to estimate important parameters like Corey shape factor and settling velocity. Experimental runs explored a wide range of shear stresses, and they varied over time. The concentration of resuspended MFs were correlated with the main geometrical and physical particles properties. Particularly, we examined the effects of the shear rate, the length and diameter of fibres, the polymer type, and the sediment characteristics showing that resuspended sinking MF concentration resulted inversely proportional to their settling velocity. In contrast, the concentration of floating MFs increased as their buoyancy velocity increased. The shear rate increased the resuspension of both floating and sinking MFs. Besides, the characteristics of the soil also played a key role, with more MFs resuspended under silty than in sandy soil conditions. Starting from statistically based observations we defined a model able to predict the concentration of both sinking and floating MFs resuspended along the water column. The physical meaning of the obtained non-dimensional model was discussed, and outcomes were compared with experimental findings from other works. Results of our work could serve as a guide for the advancement in the development of new MPs transport models that aim to include the contribution of those MFs re-suspended from the bottom sediment layer.

Iris Möller ____

Keynote: Biophysical interactions in coastal ecosystems: how size (and scale) matters

Coastal ecosystems, such as dunes and salt marshes, exist (and survive) on account of the interaction between biological, physical, and chemical processes. This interaction is particularly visible in the way in which water flows through, against, and over, the bio-physical structures with which such ecosystems are associated and which they shape. The size and scale of these interactions, however, matters when we want to understand the degree to which coastal ecosystems (a) rely on such interactions and (b) provide benefit to humans and the adjacent natural environment through such interactions (e.g. in terms of carbon sequestration and providing coastal protection and resilience in the face of a changed climate future).

This talk will illustrate these different scales of interactions from the mm to km scale and over instantaneous to decadal time scales. It will further ask questions around how we use existing knowledge and particularly uncertain knowledge for coastal management decision making.

Y.Amitai*, Y. Levi, E. Bucchignani ____

Subtropical lake under projected climate change: 3D model assessment and insights

Located in a highly sensitive climate area, according to the IPCC reports, Lake Kinneret is exposed to extreme changes in the next few decades. It is a warm monomictic lake, located between subtropical and arid climatic belts, which means warmer and dryer conditions are expected to evolve. Lake Kinneret is thermally stratified throughout most of the year and mixes thoroughly each winter for a few months. Changes in the stratification properties resulting from climate warming were already observed and are predicted to become more robust. Unmixed years are expected to appear more often where the lack of mixing between the epilimnion and the hypolimnion may create an environment that is oxygen depleted in which very few organisms can live, hence, might strongly affect the lake's present ecological system, its sustainability, and its water quality. Using high-resolution atmospheric projections obtained from COSMO-CLM simulation to force a 3D hydrodynamical model, we reveal an unexpected cooling trend of the Lake, around the year 2065. This cooling trend is anticipated to mitigate the strengthening of lake stratification. Model results reveal a notable shift in the Bowen ratio, which is the ratio between sensible and latent heat flux, that may account for the abrupt cooling. The shift is attributed to the faster warming rate of the air above the lake compared to the warming of the lake water, resulting in the dominance of the latent heat component over the sensible heat component. Consequently, enhanced evaporation leads to a significant restraint on the expected warming of the Lake. This hypothesis may be tested in lakes with similar atmospheric conditions around the world to classify lakes' reaction to global warming.

J. Ala-Könni ____

Greenhouse gas fluxes and their drivers in large northern boreal lake Pallasjärvi

Boreal and high-latitude lakes are a known source of greenhouse gases (GHG’s) into the atmosphere especially in the boreal zone, where lakes are numerous and form a major part of the landscape. Due to global warming the magnitude of GHG release from lakes is posed to increase with increasing surface water column temperature and shortening ice-on period [1]. Although this is a well recognized fact, there remains numerous uncertainties in our knowledge on lake GHG fluxes. This is due to several reasons: remote locations of high-latitude lakes often make research logistically difficult, the environmental conditions can be rough for research infrastructure and the most commonly used flux chamber method is heavily biased towards daytime and open water flux values.

Here, we present results based on a three year long dataset of carbon dioxide and methane fluxes collected via the eddy covariance (EC) method over a large subarctic Lake Pallasjärvi in Finnish Lapland. The site is located in a unique position where on one hand the southern lobe of the EC footprint represents fluxes from a small, shallow and vegetated bay which receives runoff from the surrounding forest and peatland, and on the other hand, the northern lobe representing the large and deep main basin of the lake, our data thus showcasing essentially two different lakes divided by an esker. EC measurements are supplemented by meteorological parameters, radiation, water side measurements of pCO2, pCH4 and temperature stratification as well as flux chamber measurements. This dataset provides a look into the often overlooked aspects and drivers of lake gas fluxes: diurnal, seasonal and annual variation of fluxes, fluxes during the shoulder seasons (spring and autumn) and during the corresponding overturns of the water column and in general methane flux observations over a large subarctic lake, on which measurements from past are few and far between. CO2 fluxes from Lake Pallasjärvi have been reported previously by Aurela et al. (2015) [2], but only for one year.

The results obtained show that the lake exhibits a large spatial as well as temporal variation in GHG fluxes. The two basins sampled show a strikingly different.

Overall, the biggest driver for methane flux seems to be the surface water temperature, water depth and the presence of vegetation, which has been identified as an important driver for methane fluxes in past literature [3]. For carbon dioxide it was observed to be the incoming solar radiation and presence of vegetation. No clear driver for the changes in methane concentration in the surface layer was observed, necessitating additional analysis into the GHG dynamics in Lake Pallasjärvi.

W. Meredith

A combined use of General Lake Model and Electrical Resistivity Tomography to identify changes in aquifer-lagoon relationships

Coastal lagoons have usually been described as the confluence of inland and marine water, and classified according to their connection to the sea. These ecosystems are key elements of blue landscape connectivity and deliver multiple ecosystem services to people, including carbon storage, water provision, flood control, pollution attenuation and recreation. As their salinity regimes fluctuate significantly according to the amount of freshwater inputs from surface and/or groundwater sources, underlying sediment permeability and the climate, these ecosystems may be particularly vulnerable to climate change. Previous studies in a restored Mediterranean coastal ecosystem (La Pletera salt marsh area, NE Spain) used the General Lake Model (GLM) to assess how the lagoons´ hydrological behaviours contribute not only to their salinity fluctuations but their total water budgets. Due to limitations in acquiring empirical inflow data, a polynomial fit was used to calculate inflow and outflow data according to observed lagoon water levels. Following this, we conducted a study using Electrical Resistivity Tomography (ERT) profiles, combined with continuous electrical conductivity, temperature, and water levels of the main lagoons to determine the hydrogeological behaviour of the aquifer-lagoon system and their seasonal salinity evolution. The combination of this data with the GLM has allowed us to describe and quantify the aquifer-lagoon processes, as well as validate the application of the model in one of the main lagoons, thereby extending knowledge of the limitations of the GLM to the global community.

R.Schwefel*, S. Jordan, M. Hupfer

Oxycline oscillations in Lake Stechlin – Observations and biogeochemical impact

Lake Stechlin has experienced a phase of severe eutrophication with total phosphorus levels increasing from ~10 µg/L in the early 2000s to more than 60 µg/L in 2020. One consequence of this change in trophic state is an increase of the continuously anoxic zone in the deep hypolimnion during summer. Above this continuously anoxic zone, internal waves lead to oxycline oscillations resulting in a large fraction of the lake experiencing periodically anoxic conditions especially during autumn. Between August and December 2023, we installed moorings equipped with oxygen optodes to investigate oxygen concentrations close to the sediment at three different positions of the lake (at 45, 50, and 55 m depth). The layer at 50 m depth became continuously anoxic at the end of November. Starting in September, oxycline oscillations caused oxygen concentrations to fluctuate by up to 6 mg/L on time scales of ~6 hours leading to periodically recurring hypoxic conditions. These fluctuations can impact the oxygen uptake at the sediment and the release of mobile phosphorus and reduced substances. In addition, periodic low-oxygen conditions could affect the microbial communities in the sediments and in turn the chemical bonding forms of the phosphorus in the sediment by increasing the formation of Polyphosphates. Here we describe first results of our field study and discuss possible effects of oxycline oscillations on the biogeochemistry of lake sediments.

J.Jansen*, G. Simpson, G.A. Weyhenmeyer, L.H. Härkönen, A.M. Paterson, P. del Giorgio, Y. Prairie

Physical and biological drivers of long-term oxygen depletion in northern lakes

Oxygen depletion constitutes a major threat to freshwater lake ecosystems and the services they provide. The vast majority of the world's lakes is located at latitudes > 45 °N and experiences rapid climate warming, longer stratification periods and elevated organic carbon loads, potentially exposing a growing number of northern lakes to severe risk of seasonal hypoxia. However, the long-term trajectory of oxygen decline remains highly uncertain because a systematic study is lacking. I will present novel results from a statistical analysis of deep-water dissolved oxygen and thermal and trophic state variables in 14.300 lakes, collected between 1960 and 2022 as part of institutional and governmental aquatic monitoring programs. Results show that a majority of northern lakes is experiencing rapid deoxygenation. I discuss the use of supervised machine learning tools and hierarchical models to analyse 'big' ecological datasets, in this case to examine the physical and biological causes of long-term oxygen loss in northern lakes. In addition, we will explore how climate warming drives distinct changes in ice phenology and thermal stratification in different lake types.

C.Minaudo*, J. Montes Perez, B. Misteli, A. Picazo, C. Rochera, D.Morant, R. Carballeira, B. Obrador, A. Camacho Santamans, M. Cabrera Brufau, K. Attermeyer, A. Camacho, D. von Schiller ____

Who should you trust? Automated versus expert data processing of in situ CO2 and CH4 chamber measurements in complex and heterogeneous aquatic ecosystems

Inland water ecosystems are a net source of greenhouse gases (GHGs) to the atmosphere. Exchanges of GHG at the interface between water bodies and the atmosphere result from complex biogeochemical and physical processes, including photosynthesis and aerobic and anaerobic organic matter mineralization by ecosystem respiration, turbulence and stratification. GHGs' pathways through diffusion or ebullition produce at the interface with the atmosphere highly variable fluxes, both spatially and temporally. Measuring reliable fluxes in inland waters is therefore both crucial in the context of climate change and highly challenging.

GHG fluxes can be measured directly in situ with chambers placed at the sediment or water interface with the atmosphere, and connected to portable gas analysers providing high-frequency timeseries of GHGs partial pressure inside the chamber. Fluxes are usually assumed constant over the time of incubation, but varying GHG sources and changing environmental conditions (e.g. changing gas exchange coefficients or solar radiations), and/or ebullition from the sediment produce non-linear patterns and breakpoints in the timeseries, not mentioning the possibility for poor manipulation of the chamber in the field, disturbance of the sampling site by the operator, or sensors malfunctioning. For all the previous reasons, experts usually visualize and select part of the measurements for each incubation before proceeding with fluxes computation.

In the ongoing Horizon Europe project RESTORE4Cs, we are performing CO2 and CH4 chamber measurements in 36 different sites located in 6 major coastal wetlands across Europe, including intertidal saltmarshes and seagrass beds, freshwater and brackish ponds and marshes, and coastal lagoons. Now halfway through in the sampling campaigns, we already gathered a database of 1570 chamber incubations, collected by multiple operators and with 3 different gas analysers. Prior to the interpretation of fluxes estimates related to the environmental context of each of these sites, here we focus on the data processing part and ask to and ask to what extent we need expert evaluation of the time series to produce reliable flux estimates. To answer this question, we have developed an automated data processing script able to compute fluxes estimates for all incubations. Timeseries are fitted with both a linear and non-linear model. The script identifies probable bubbling in CH4 measurements and estimates the diffusive versus ebullitive components. For a selection of randomly chosen timeseries, we have compared the results from this fully automated processing to the ones computed by several members of our team, all experts in GHG chamber measurements with various levels of experience.

Overall, non-linear fitting performed better than linear models for 90% incubations, although the difference between the two models was less than 10% for 70% of the incubations. Largest discrepancies between linear and non-linear models were observed whenever CH4 bubbling seemed to occur or for CO_2 in vegetated areas with transparent chambers where carbon uptake presented non-linear patterns. Likewise, we found in general a good agreement between expert estimates and the automated approach, except when timeseries clearly showed a non-linear behaviour. To avoid subjectivity and ensure robustness and repeatability of flux estimates, we will present guidelines on how CO_2 and CH_4 incubation time series should be processed, regardless of whether they are processed automatically or manually.

Wednesday 3rd July 2024

L. Ing ____

Quantifying Methane Ebullition Flux: Investigating Drivers of Ebullition throughout the Year

Ebullition of CH_4 from aquatic systems is an important component of global green-house gas emissions. In Base Mine Lake, a pit lake located in the Canadian oil sands region, the ebullition also results in the upward transport of benthic material. During ebullition, bubbles form in the lake sediments due to biological processes, then ascend to the water surface. Preliminary measurements from gas sampling indicate these bubbles are predominantly composed of methane.

Methane ebullition was studied through employing bubble traps equipped with pressure sensors and gas sampling ports at various locations throughout the year, allowing continuous records to be obtained. Ebullition events were triggered by total hydrostatic pressure decreasing below a critical threshold. Spatial variation in flux quantities were evident, and comparisons between open-water and under-ice records were made. Findings were compared with those obtained using the eddy covariance system on-site.

The quantification of methane flux aids in assessing the lake’s suitability as an aquatic habitat and its impact on climate change.

B. Boehrer ____

Gas accumulation in Lake Bosumtwi deep waters and its potential to contribute to fish kills

Lake Bosumtwi formed in a meteorite impact crater in tropical Ghana, West Africa. The lake is deep and overturns seem to be incomplete. In general the deep water is anoxic. Fish kills have been reported and associated with the mixing events in the slightly colder rainy season. Recently, fish kills seemed to happen less frequently. As unpleasant smells from the water during deep mixing had been reported, the question arose to what extent toxic gases that had accumulated in the deep water could be responsible for the fish kills, e.g. hydrogen sulphide or large amounts of carbon dioxide were considered the most probable candidates. The analysis of the water properties however indicated that most probably, bound nitrogen was responsible. We show measurements of dissolved gases and gas pressure.

P.G. Grochocki*, M. Mannich

An Efficient and Affordable Marble Equilibrator for Continuous, Low-Energy Consumption Measurements of CO2 in water

The EQMarble (Marble Equilibrator) was designed to measure trace gases such as CO2 and CH4 in water bodies. These measurements are crucial for understanding emissions of greenhouse gases, as well as processes like photosynthesis, respiration, and acidification in saline environments. Our focus on developing a marble equilibrator goes beyond the norm, addressing both cost and energy efficiency.

To tackle the challenges of measuring pCO2 (dissolved carbon dioxide) in natural waters, where pCO2 levels can vary widely, especially in highly turbid and productive waters, we've designed a downward film equilibrator with small glass spheres which produces fine water films on its surface. Gas is moved counter-currently to concentrate it at the top, a system engineered on a large scale for precise and efficient flow. The marble equilibrator employs hundreds of small glass spheres to fill a vertical cylindrical chamber, maximizing the surface area over which water can flow, enhancing gas exchanges. Water introduced above the marbles flows through the matrix of spherical surfaces and interacts with the air moving upward in the opposite direction.

The porosity of the marble matrix, created by the voids between the marbles, depends mainly on their diameter but changes as suspended solids and debris become trapped, altering the characteristics and flow rate. The film has been deliberately designed without complex interstices, allowing sediments and debris to pass freely over the spheres and be drained by gravity to the equilibrator outlet, making it suitable for high turbidity waters.

For the construction of the equilibrator, the K30 sensor for CO2 was utilized, operating within the range of 0 to 10,000ppmv, with an accuracy of 30ppmv or +/- 3% of the measurement. Water temperature is monitored using a DS18D20 probe, which operates within the range of -10^{o}C to 85^{o}C with an accuracy of 0.5^{o}C and resolution less than 0.1^{o}C. Trials have demonstrated an equilibration period of 4-5 minutes under specific conditions : a water flow rate of 4L/min, powered by a precision gas pump delivering 0.5L/min. The headspace is maintained at 0.5L, while the available surface area for gas exchange measures 0.335m^2.

This design not only ensures precise equilibration with aqueous CO2 concentrations but also demonstrates functionality across a wide range of gas concentrations, showcasing a response time comparable to other equilibrator designs. The average t90 result achieved was 60 seconds, indicating a 30% reduction in equilibration time compared to the findings of Frankignoulle et al. (2001), and a 50% decrease compared to the results of Yoon et al. (2016). Furthermore, when compared to the study conducted by Miller et al. (2019), our results demonstrate a 20% shorter time required to achieve total equilibrium in measurements. When compared to membrane-type sensors, the time savings are even more significant, as they typically require around 900 seconds (Yoon, 2016). The relatively low average equilibration time is attributed to the measured pCO2 concentration closely matching the CO2 concentration within the equilibrator. In extreme scenarios, where the CO2 concentration in the equilibrator chamber deviated significantly from equilibrium conditions, the time extended to 190 seconds. Importantly, the strategic utilization of free-flowing, falling water as the medium for gas exchange renders our equilibrator remarkably resistant to clogging with total construction cost of $500, less expensive than the premium equipment available on the market.

For validation, most literature works compare the developed equilibrators with measurements of pH like Cotovicz (2016) or other gas analysers, not a measurement of the direct pCO2. In the former case, errors arise due to estimates of dissolved CO2 concentration in water, particularly in environments with high organic matter content. In comparisons between sensors, only the gas in equilibrium between the sensors is measured, rather than the dissolved gas itself. Conducting dissolved CO2 measurements by alkalinity method ensures a direct comparison between the equipment's measurement and the determination of concentration through direct measurement of dissolved gas in water. The most significant differences recorded were below 6% in the range of 300-2000ppmv, attributed to both sensor precision and inherent chemical method errors for measurement from ~300ppmv in laboratory, ~900 ppmv in a reservoir and ~2000 ppmv in a drainage pond. The power consumption measured is around 15W, resulting in exceptional battery life, with the option to be powered by a power bank or small electric vehicle batteries and rechargeable via solar panels, it also been very portable with only 1.5kg.

The results indicate that this equipment is not only a low-cost, energy-efficient solution but also yields good results for environmental and scientific applications, contributing to the advancement of environmental monitoring and meeting the demands of long-term continuous measurements.

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E.Asirok*, G. Kirillin

Dissolved Oxygen Dynamics in Arctic and Boreal Lakes in Late Winter

Arctic and Boreal lakes in the Northern Hemisphere experience annual ice cover lasting 4 to 7 months. Freshwater lakes in cold regions are sensitive to subtle environmental changes and influenced by various physical and biogeochemical factors. Our study focuses on comparative analysis of under-ice metabolism shaped by the thermal and oxygen dynamics of Arctic Lake Kilpisjärvi and Boreal Lake Pääjärvi during the late winter. We aim to understand the effect of different trophic levels and light regimes on lake metabolism within cold regions by using high frequency data on temperature, dissolved oxygen, and solar radiation for Lake Kilpisjärvi in 2019 and 2020, and Lake Pääjärvi in 2022. Besides the long-term data, we compared the phytoplankton biomass and chemical parameters obtained from water samples collected from different depths. We studied the changes in the vertical distribution of lake metabolism by diel cycles by considering the strength and influence of internal motions on temperature and oxygen data. Our results demonstrate that following prolonged darkness, a significant increase in dissolved oxygen occurs in the upper water column of Lake Kilpisjärvi. The depth of the mixed layer increases with depth, ranging from 1.1 m/day to 2.3 m/day for 2019 and 2020 in Kilpisjärvi. In contrast, Lake Pääjärvi has a slower and steady rate of deepening at 0.55 m/day, resulting in a comparatively shallow mixed layer.

M.Toffolon*, M. Amadori, A. I. Rahaghi, D. Bouffard ______________________________________

Can automatic calibration be used to improve the physics behind complex numerical models?

Models are simplified descriptions of reality and are intrinsically limited by the assumptions that have been introduced in their formulation. Being models a potentially general tool to simulate different types of environments, however, modellers are not always aware of the consequences that flaws in the original assumptions may have in applications to other environments. Here we discuss how the use of an optimization toolbox (DYNO-PODS) enabled us to disclose the effect of simplifications embedded in the formulation of a widely used hydro-thermodynamic model

(Delft3D-FLOW). DYNO-PODS facilitates the calibration of a relatively high number of selected parameters and handles different objective functions. Originally developed for coastal, estuarine and fluvial environments, Delft3D-FLOW is also routinely used within the limnological community. In its code, this model adopts a simplified form of the Beer law that does not include the absorption of a fraction β of shortwave radiation at the water surface, probably because this process was not relevant in the original applications and then remained in the code as a technological lock-in. Most lake-specific models instead include β as it is important for the correct distribution of heat along the water column of lakes and directly affects the thermal stratification, especially at the very surface layers.

Using Lake Murten (Switzerland) as a case study, we automatically calibrated a Delft3D model based on measured temperature profiles. The optimal parameters search showed that the absence of β can be compensated by higher values of the light extinction coefficient κ. The optimization indeed pushes κ towards values corresponding to unrealistic low transparency because the model needs to reproduce a significant absorption of heat at the surface, which is not prescribed by the simplified Beer law. The by-product of this flaw in the model, however, is that it tends to simulate a surface layer that is typically colder than the layers beneath, an issue that was known by some Delft3D users but never noticed as critical, also because it can be masked by an increase of the vertical diffusion processes. While it is well-known that β is significantly larger than zero, the simple modification of the (open-source) code was never done, at least to our knowledge. When we implemented it, we were able to calibrate values of β in the range 0.3-0.4, as usually adopted in lake-dedicated models. Moreover, by introducing β, the optimal κ converged towards values corresponding to the measured Secchi disk depth.

The use of an automatic calibrator, which exploits surrogate models, allowed us to extend the search of the optimal parameters in a broader parameter space by exploring also unrealistic values uncharted to manual calibration. This allowed us to identify a flaw in the heat fluxes parameterization of Delft3D and to improve the physics behind such a widely used model. We believe that the extensive use of automatic calibration may offer similar outcomes in other applications, even in the case of computationally heavy simulations.

I.Dominović*, M. Marguš, G. Kirillin, I. Ciglenečki-Jušić, I. Vilibić

Mixing regime of Zmajevo oko (Rogoznica, Croatia), a heliothermal lake threatened by rapid deoxygenation

Zmajevo oko lake (ZO, Rogoznica Croatia; 43°32' N, 15° 58' E) is a shallow saline lake (max. depth 13.45m) situated at the Adriatic Sea coast. The lake is connected to the sea through the surrounding porous karst. This relationship manifests itself both in tides (~ 25 cm tidal range) that are damped inside the lake and high bottom salinity (~ 37 ppt). At the same time, the atmospheric influence is evident in substantially lower surface salinity (as low as 14 ppt) due to surface runoff and precipitation. Most of the year the lake is strongly stratified, with a well-defined upper oxic layer and a deeper anoxic layer (i.e. similar to meromictic lakes). Yet, in some early autumns, the lake can exhibit an abrupt overturn, becoming holomictic and anoxic with high aerobes mortality.

Worryingly, these events are happening more frequently in the last decade, which does not leave enough time for the lake’s ecosystem to recover. The latest studies on the lake's physical processes have focused on investigating the long-term causes of the sudden stratification breakdown. It has been shown that the average water column salinity is negatively correlated with annual precipitation, leading to substantial weakening of the halocline by the end of the summer in drier years. This seems to be a precondition to the autumnal mixing triggered by wind-driven cooling events, as it leads to a hydrostatically more labile water column quantified by a low Schmidt’s stability index. On the background of the bottom-layer quasi-decadal salinity oscillations, the surface layer warming does not propagate to deeper parts but concentrates in the upper layer that has been exhibiting constant shallowing in the last decades. Moreover, thermal stratification gets especially pronounced in summer months when subsurface temperature maximum forms, with temperatures reaching up to 34°C that classify ZO as a heliothermal lake. These observations imply reduced oxygen solubility, and when combined with the continual decrease of the oxic water volume since 1996 (progressive deoxygenation), show that ZO is a highly stressed environment, making its survival questionable in the future climate that could enhance its ecosystem degradation.

Javier Sánchez-España ____

Keynote: **Biogeochemical processes sustaining meromixis in extremely acidic pit lakes**

Mine pit lakes are singular water bodies formed in abandoned open pits of coal and metal mines by their flooding with groundwater, runoff and rainfall after the cessation of maintenance and dewatering operations. In the presence of oxygen and water, the oxidative dissolution of pyrite and other sulfides in the wall rocks usually produces a strong acidification of the pit lake waters, as well as the dissolution of many metal (oid)s which are leached from the sulfides and accompanying gangue minerals. As a result, many pit lakes are very acidic (pH 1.5-3.5) and contain elevated concentrations of many toxic metals (e.g. Fe, Al, Mn, Cu, Zn, Co, Ni, Cd, Cr, As, Pb). In addition, many of these mine pits have a high relative depth (i.e. depth-to-surface area ratio) which limits convection through the water column and favours the development of meromixis (permanent stratification). From an environmental perspective, these water bodies pose a serious threat to the surrounding water resources (creeks, streams, aquifers) which are hydrologically connected with them. Besides, the monimolimnia of these meromictic pit lakes (i.e. the anoxic bottom layers permanently isolated from the atmosphere) may accumulate important amounts of reduced substances (e.g. Fe2+, NH4+) and dissolved gases (e.g. CO2, N2, H2S, CH4) which can also represent additional safety issues in the surrounding areas. These environmental and safety aspects have stimulated multi- and trans-disciplinary scientific research in these acidic lakes in the last decades, with most studies having a strong applied aspect, e.g. bioremediation. From a merely scientific perspective, however, acidic pit lakes have considerably attracted the attention of many limnologists, biogeochemists and microbiologists who see in these extreme environments natural laboratories of great value for the study of geomicrobial interactions and the search for novel species of poly-extremophiles (i.e. acidophiles, thermophiles, halophiles, etc.) of potential use in biotechnology. One of the most interesting aspects of pit lake research refers to the interaction between acidophilic microorganisms, metal ions in solution and mineral phases, and the contribution of these interactions to the development and stabilization of density stratification in these lakes. Some important biogeochemical processes which have been studied in recent years in some of the most acidic and metal-concentrated pit lakes of SW Spain include: (1) the bacterial oxidation of Fe(II) and subsequent formation of Fe(III) mineral particles of different crystallinity in the oxygenic mixolimnion, (2) the formation of deep chlorophyll peaks and metalimnetic oxygen maxima at certain depths (4-8 m) due to the establishment of acidophilic microalgae adapted to extremely low light conditions, (3) the activity of sulfate- and sulfur-reducing microorganisms below the redoxcline producing hydrogen sulfide (H2S) which then reacts with dissolved metals to form insoluble metal sulfides (e.g. CuS, ZnS, PbS, FeS, As2S3) that subsequeently settle through the water column, (4) the bacterial mediation in the formation of certain minerals (e.g., proto-clays) in the water column, (5) the reductive dissolution of Fe(III)-rich minerals in bottom sediments w hich favour the development of steep vertical gradients of many solutes (e.g., Fe(II), SO42-, TOC, P, etc.), or (6) the inflow of metal-rich groundwater from flooded mine tunnels connected to the pits. All these processes have a significant contribution to the increase of density of the bottommost layers though the input of either dissolved substances or pelagic particles. Further, the vertical transport of key elements like oxygen, carbon, basic nutrients (P, N) and many metals through the water column largely relies on different metal/microbe/mineral interactions occurring at different scales. For example, the metabolic activity of Fe(II)-oxidizing bacteria (e.g. Acidithiobaciullus, Leptospirillum, Ferrovum) allows the conversion of Fe2+ ions to Fe3+ mineral colloids (e.e. schwertmannite, jarosite) which can transport many adsorbed metals (e.g. Al3+, Cu2+, Zn2+) and nutrients (P) to deeper oligotrophic levels. Likewise, the photosynthetic production of oxygen by acidophilic eukaryotes (e.g. Chlamydomonas acidophila, Coccomyxa onubensis, zignematales) allows oxidative metabolisms in deep levels that would be suboxic or even anoxic without this microbial activity. In addition, the decomposition of settling algal biomass from the phytoplanktonic communities often represents a highly valuable source of fresh organic carbon for many heterotrophic microbes like iron- and sulfate-reducing bacteria which play a key role in the cycling of these two elements. The activity of sulfate-reducing bacteria during long periods (years to decades) can lead to the partial or total removal of toxic metals like Cu, Zn or As from the water column, which precipitate as biogenic metal sulphides and transport these metals to the bottom sediments. Once in the sediments, these metals can be incorporated again to the aqueous phase by the anaerobic metabolism of iron and sulfate-reducing bacteria, thus producing increased concentrations of metals near the sediment/water interface in the pit lake bottom. This microbial activity is also responsible for the release of carbon dioxide and methane, which not only contribute to the carbon cycling but also may increase notably the total dissolved gas pressure, producing gas-charged deep waters that can even pose a serious risk of a gas outburst. Finally, electron microscopy studies conducted at the cell scale (e.g. using different tools like SEM, TEM, STEM, cryo-TEM, XAS or 3D-tomography) has shown that many bacterial cells have the ability to accelerate nucleation and mineral precipitation by intra- and extra-cellular biomineralization processes. A clear example is the formation of aluminosilicates (so called “proto-clays”) around the cell wall of bacterial rods, in the cytoplasm, and in spherical structures outside the cell which allow mineral precipitation at geochemical conditions a priori considered to be unfavourable for mineral formation (e.g. based on thermodynamic calculations). These observation show the ability of microbes to chemically modify the aqueous medium where they inhabit and their important role in mineral formation through different metabolic pathways and detoxifying mechanisms. The finding of these biomineralization processes, along with the discovery of novel bacterial and archaeal species in the deep, anoxic waters of these acidic lakes through different “omics”, make them highly attractive from an astrobiological perspective, since they can be potentially used as proxies of microbial life in planetary systems (i.e. biomarkers) that could be of great help in future space exploration missions.

W. Wang

The impact of extreme heat on lake warming in China

Global lake ecosystems are subjected to an increased occurrence of heat extremes, yet their impact on lake warming remains poorly understood. In this study, we employed a hybrid physically-based/statistical model to assess the contribution of heat extremes to variations in surface water temperature of 2260 lakes in China from 1985 to 2022. Our study indicates that heat extremes are increasing at a rate of about 2.08 days/decade and an intensity of about 0.03 °C/ day·decade in China. The warming rate of lake surface water temperature decreases from 0.16 °C/decade to 0.13 °C/decade after removing heat extremes. Heat extremes exert a considerable influence on long-term lake surface temperature changes, contributing 36.5% of the warming trends within the studied lakes. Given the important influence of heat extremes on the mean warming of lake surface waters, it is imperative that they are adequately accounted for in climate impact studies.

R.Valipour

Ecological Responses of Large Lakes to Climate Change: outcomes from observations and the application of a coupled watershed-lake model

We present the historical surface temperature changes in the Laurentian Great Lakes and their impacts on the lakes' ecosystem. Our study also includes multi-year results and future climate projections for a case study in the Lake of the Woods with a complex topography and geometry, shared between the United States and Canada. The model was initialized, calibrated and validated using mooring deployments, lake-wide water quality observations, Satellite Images, and different functional groups of total chlorophyll-a collected between 2016 and 2018. After presenting initial validation during the winter regimes, we examine model runs with future climate projections for 2079-2100 using a lake-wide watershed model riverine outputs, and outflows at Kenora and Norman dams. The modelled ecological responses suggest noticeable shifts in favourable time for the predominant of different algae functional groups due to shifts in optimum waters temperatures, and significant changes in ice duration and thickness by the end of the century.

Y.Tong

Global lakes are warming slower than surface air temperature due to accelerated evaporation

Widespread increases in lake surface water temperature have been documented in recent decades. Yet our understanding of global lake warming is mainly based on summertime measurements and includes relatively few observations from high latitudes (>60° N) where half of the world's lakes are located. Here we provide temporally and spatially detailed high-resolution lake surface water temperatures for 92,245 lakes (36% are located within the Arctic) based on satellite remote sensing and numerical modelling. The global lake surface water temperature data suggested a mean increase of +0.24 °C decade^{-1} (uncertainty 0.02 °C decade^{-1}) from 1981 to 2020, which is significantly ($P < 0.05$) slower than the change in surface air temperature (mean rate +0.29 °C decade^{-1}) during the same period. We show that climatic forces (long- and short-wave radiation and specific humidity) other than surface air temperature contribute more than half of the lake warming, and energy loss, through accelerated evaporation rate, is mainly responsible for the slower warming rate. Lake warming is likely to continue from 2021 to 2099 unless a low greenhouse gas emission scenario is followed. Our dataset provides important baseline information to further evaluate the physical and biological responses of lakes to past and future warming.

D.F. McGinnis ____

What the sediment knows: The paleolimnological history of methane ebullition in a small eutrophic lake

Bubble CH4 emissions from lakes will likely increase in the future with ongoing eutrophication and global warming. The mechanistic understanding of ebullition is thus required to mitigate future CH4 emissions from inland waters. We reconstructed historic ebullition in Soppensee (Switzerland) based on extended sediment records. Using two independent modelling approaches based on sediment accumulation rates and from porewater noble gas data yielded comparable results. Depleted porewater dissolved noble gas data indicate that ebullition started in 1875 AD, with an average rate of 3.6 mmol m^{-2} d^{-1}. However, from sediment accumulation rates we derived that ebullition started in 1900 AD, increasing continuously from 1 mmol m^{-2} d^{-1} to present day rates of 4 mmol m^{-2} d^{-1}, agreeing well with current ebullition measurements. The ebullition model based on accumulation rates further showed that both organic and inorganic matter sedimentation contributed to CH4 ebullition. We conclude that without currently high rates of calcium carbonate precipitation, ebullition would be orders of magnitude lower or even nonexistent. With reference to the paleolimnology of Soppensee, these results illustrate how land use changes can rapidly exacerbate eutrophication, anoxia and CH4 ebullition. This suggests that for the mitigation of CH4 bubble emissions from aquatic systems, sedimentation of both organic and inorganic material need to be considered, and reductions in CH4 ebullitive emissions are feasible with agricultural management.

H.Shi*, P. Xue, I. Woolway ____

Influence of global warming on ice cover and its impacts on future ship navigation in Lake Superior

The Laurentian Great Lakes and surrounding regions have experienced rapid warming in recent decades, with projections indicating continued warming throughout the 21st century (Zhong et al., 2016; Xue et al., 2022). Consequently, significant reductions in ice cover area and duration are expected by century's end (Xue et al., 2022), potentially leading to increased winter shipping traffic in the Great Lakes - St. Lawrence Seaway system. This study aims to assess the impact of global warming on Lake Superior's ice cover and its subsequent effects on ship navigation throughout the 21st century, utilizing projected ice data over the entire period.

Materials and methods

Projected ice data in Lake Superior over the 21st century under the high-end Representative Concentration Pathway scenario (RCP 8.5) was extracted from a two-way lake-ice-atmosphere coupled model (GLARM-v2) as reported by Xue et al. (2022). This model couples a regional climate model (GISS) to simulate land and atmospheric processes and a 3D hydrodynamic model (FVCOM) to simulate lake, thermal and ice dynamics (Xue et al., 2017). The projected ice data in the longitude-latitude coordinate (EPSG: 4269) is reprojected into a Cartesian coordinate system (EPSG:

3174) in this study with a horizontal resolution of 1 km × 1 km and a time resolution of one day. The ice data (ϕ) represents the ice cover of the lake surface denoting the percentage of frozen area in a single horizontal cell ($\phi = 1$ means the cell is fully ice-covered and $\phi = 0$ means ice-free). We

assume that a single cell of the Lake Superior is passable for ship navigation if $\phi < 0.5$. Five major ports along the lake coastal line (Fig. 1, Table 1), composing ten port pairs, are chosen for ship navigation analysis. The shortest navigation route for a specific port pair is determined when the entire lake is ice-free. In ice seasons, three situations are possible for a single port pair: (Short) the shortest navigation route is still available; (Long) the shortest route is blocked by ice but there are other routes connecting the port pair; (Block) all routes are blocked by ice. The third situation is firstly determined using a connected-component labelling algorithm (He et al., 2017). The situations (1) and (2) are then distinguished using a path-planning algorithm: Theta*, which was designed to find paths in grids with blocked and unblocked cells (Daniel et al., 2010).

Results and discussion

Figure 1 shows an example of different ice cover distributions on Jan 31st of 2000 and 2099, showing a much smaller ice area in 2099 compared with 2000 on the same date. It means that ship navigation routes were blocked by ice on Jan 31st, 2000, but will be accessible on the same date in 2099 due to global warming. Three periods (2000-2019, 2030-2049 and 2080-2099) are chosen for comparison of navigation availability among ports in the Lake Superior. Figure 2 counts the number of days for the abovementioned three different situations (Short, Long and Block) in the selected twenty-year periods for different port pairs. Warm seasons (from April 1st to September 30th) are excluded in this analysis as the Lake is always ice-free in these seasons. As a result, each twenty-year period contains 3645 days in total. Figure 2 shows that for each port pair, the accessible duration of the shortest navigation route (Short) increases while the Block duration decreases. The variation of longer navigation route (Long) duration differs in different port pairs because less ice cover can lead to different consequences: Block to Long, Long to Short or Block to Short. In general, decreasing ice cover arisen from climate change in the 21st century will realize the potential of winter ship navigation in the Lake Superior.

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Rafael Marcè ____

Keynote: Everything Everywhere All at Once: navigating global lake modeling with the ISIMIP Lake Sector

The task of modeling the physics and biogeochemistry of lakes is challenging. While fundamental principles are well-established and often mathematically defined, the sheer diversity of ecosystems and multitude of external factors necessitate a degree of calibration to local conditions in most modelling exercises. Yet, some researchers refuse to acknowledge those limitations, and take the rocky path towards modelling thousands of lakes across extensive spatial scales. In this presentation, I will reflect on the insights gained (or perhaps overlooked) through our leadership of the ISIMIP Lake Sector since 2018. This collaborative community of lake modellers is committed to detecting, attributing, and projecting the impacts of climate change on lakes, employing a standardized protocol within a multi-model framework. We will delve into the strategic decisions made to confront the formidable task of modelling thousands of lakes using dynamic models over centuries, at a daily time-step. Along this journey, we will revisit the choices we've made, the lessons learned, and our vision for the future of global simulations. Through this discussion, we aim to highlight both the successes and failures, advocating for the value of modelling lakes at such large scales.

M.Shikhani*, R. Ladwig, J. Feldbauer, D. Mercado, M. Schultze, B. Boehrer, T. Shatwell, A. Gevorgyan, C. Mi, K. Rinke ____

Coupled Multi-Lake Model Ensemble with a Multi-Domain Multi-GCM-RCM Ensemble for investigating Climate Change Impacts on Lake Sevan

Climate change imposes increases threats on freshwater lakes ecosystems, particularly the impacts on the thermal and stratification dynamics. Where as there are many studies using one lake models and limited number of GCMs to generate an ensemble of lake temperature studies, there is a knowledge gap in creating workflows to generate a large ensemble using both climate models and lake models. We present in this study a workflow utilizing a large multi-domain, multi-scenario, multi-GCM-RCM combinations from the Coordinated Regional Downscaling Experiment (CORDEX)

coupled with a multi-1D lake model ensemble approach from the LakeEnsemblR platform, offering a powerful tool to simulate a wide spectrum of possible outputs while also addressing the variability and uncertainty propagating in modelling chain across different dimensions of the ensemble and quantifying the contributions of the sources of uncertainty. This workflow was employed to simulate the effects of climate change on Lake Sevan (Armenia) and comprehensively address the variability in climate-forcing data and the lake models by generating an ensemble of 500 domain-GCM-RCM-lake model combinations projections. For the last decade of the 21st century, under RCP 8.5, the ensemble projections show an increasing trend in surface and bottom temperature anomalies in Lake Sevan reaching 4.27 K and 1.74 K, respectively, longer stratification periods of 55 days, absence of ice cover, and a shift in the mixing regime that increases the potential of insufficient cooling and alteration in the thermal dynamics in the lake. This workflow offers a more robust and comprehensive approach to generate large ensembles, as well as addressing the uncertainties in this projections.

R. de Carvalho, T. Bleninger, A. Lorke* ___

The effect of bottom slope on the generation of basin-scale internal waves in stratified reservoirs

Basin-scale internal waves (internal seiches) are important hydrodynamic features of density-stratified water bodies and are often the dominant source of currents and mixing below the surface boundary layer. The generation of internal seiches by wind forcing, their dynamics, and their effect on internal mixing processes, are often assessed for idealized (rectangular) basin geometries. However, recent observations suggest that internal seiche generation can be suppressed in reservoirs, where water depth often increases continuously from the inflow region to the dam. The gentle bottom slopes gives rise to propagating, high-frequency internal waves, which are subject to wave breaking and lead to more rapid dissipation of the energy that is transferred from wind to water. A systematic analysis of the influence of bottom slope on internal seiche generation and energy dissipation in reservoir-shaped water bodies, however, is lacking. Here we analyse the results of numerical simulations with a three-dimensional hydrodynamic model (Delft3D) applied in non-hydrostatic mode. In a total of 43 simulations, we applied a wind pulse of equal duration to hypothetical reservoirs with systematically varying bottom slope, Wedderburn number, and basin length. We specifically followed the generation and decay of kinetic energy in basin-scale internal waves and in residual water motions over 7 days. We found that in larger reservoirs (10 km long), the basin-scale internal waves persisted for several wave cycles for bottom slopes exceeding a critical value of 0.0025. For more gentle slopes, the interaction between the wave and the sloping bottom leads to rapid energy dissipation due to wave breaking and the generation of high-frequency waves that propagate in upslope direction. The critical slope value for the generation of internal seiches increases for decreasing basin length. The distinct responses of reservoir-shaped water bodies to wind forcing are expected to have import implications for the transport of nutrients, chemicals and organisms, which are not accounted for in one-dimensional simulations and bulk assessments with idealized basin geometry.

M.Wells

Novel year-round observations of thermal stratification in the large Lake Ontario

Long records of thermal stratification in the Great Lakes in North America are rare, and there are almost no observations of thermal stratification during "winter" (from late October through to April). In this paper we analyse data from 13 temperature logger chains and 92 benthic loggers that were deployed for two years across the 300 km length of Lake Ontario. We find that the timing and duration of the fall overturn appears to correlate closely with the local average water depth. As Lake Ontario is only partially ice covered, wind driven mixing can continue to stir the water column throughout winter. Hence a classic vertical inverse thermal stratification is largely absent. Spatially the depth-averaged winter water temperatures vary between 0 – 4 C, with the coldest temperatures (near 0.1 ^{o}C) found in the shallow Kingston basin, and warmest temperatures (near 4 ^{o}C) at sites near the 244 m deep Rochester Basin. In spring (April-May) the shallow sites warm faster, resulting in a thermal bar. Based on our observations, Lake Ontario does not have a strongly dimictic mixing pattern (as the is no sustained inverse stratification in winter) but rather the temperature distribution is more representative of a warm monomictic mixing cycle (with continuous deep mixing from fall to spring). We discuss the implications of these 2-year observations of thermal stratification in Lake Ontario for fisheries management.

A.Rios (Poster)

Hydrodynamics and thermal structure as determinants of water quality in a humid subtropical reservoir undergoing rapid changes in weather

Introduction

Paso Severino reservoir is the drinking water source for 2 million people in Uruguay. It has a storage capacity of 65 Hm^3 and a surface area of 15 km^2, with maximum depth of 18 m. The embankment dam discharges through an uncontrolled concrete spillway, and the water intake is at 14 m depth.

The reservoir is located at 34°S in a region with humid subtropical climate. Although the country presents four marked seasons, the low altitude of the territory makes it vulnerable to rapid changes in weather.

The intense economic activity in the basin has led to impacts on the water quality: the reservoir presents hypereutrophic conditions related to TP concentrations (in average, 85% is bioavailable). However, phytoplankton blooms are rare and chlorophyll-a levels correspond to mesotrophic conditions. The influence of physical aspects such as residence times, vertical mixing and light penetration remains unknown.

In this work, we present ongoing studies on hydrothermodynamics and water quality processes in the reservoir combining numerical tools, historical periodic monitoring data and our own measurements. The aim is to understand reservoir's hydro-thermodynamics and its influence in the transport of substances and the growth of primary producers.

Materials and methods

Data collection

Bathymetry, as well as hydrological and water quality data are measured by different national agencies and were collected in this work.

Within the framework of this study, high-frequency temperature measurements are being made at a point near the dam at 0.5 m and 12 m depth since April 2022. We are also carrying out field campaigns to measure Secchi disk depth (SDD); vertical profiles of temperature, turbidity (OBS-3+, Campbell Scientific) and PAR (PAR-LOG ICSW, Sea-Bird Electronics) with a CTD profiler SBE 19plus V2 Sea-Bird Electronics; vertical profiles of pH, DO, fDOM, chlorophyll-a and phycocyanin (fluorescence) with an EXO2, YSI; and grab subsurface samples to analyze TSS, VSS, FSS, particle size distribution (LISST-200x, Sequoia Inc.), TOC (SM5220D), DOC (SM5220D), color (SM2120C), CDOM absorbance between 250 nm and 800 nm, nitrogen and phosphorus. Measurements in field campaigns are taken at the main tributary and at a point near the dam under different hydrological conditions.

Numerical model

We are using Delft3D-FLOW to simulate hydro-thermodynamics in the reservoir. The domain is discretized by an orthogonal grid with a horizontal resolution of 70mx70m while the thickness of the vertical Z-layers is 1 m. Vertical eddy viscosity and diffusivity are calculated with a k-ε turbulence model. The wind drag coefficient is defined as a piecewise linear function of wind velocity at 10 m with higher values at low windspeeds and a minimum around 5 m/s (Wüest and Lorke, 2003).

Air-water heat exchanges are modelled from hourly meteorological data according to Ocean Model formulations (implemented in Delft3D based on Gill, 1982). The terms of the heat balance are net short-wave radiation; effective back radiation (EBR); latent heat flux and sensible heat flux. The latter two terms are split into a contribution by forced and free convection. Heat exchange with the bottom is neglected.

Manual calibration on temperature is being performed over the period 2022/04/01 to 2023/04/01. Calibration parameters include free convection coefficient, Dalton and Stanton numbers and wind drag coefficient. An analysis of the contribution of each heatflux term at different time scales is being made, to evaluate possible modifications in the formulations according to our local weather conditions.

Results and discussion

During the period of 2022/04/01 to 2023/04/01 high frequency surface and bottom temperature measurements showed polymictic behaviour. Stratification periods of about a week were common, while the longest stratification period lasted around 30 days in spring, from 2022/11/10 to 2023/12/13. Water levels varied between 30.5 m and 37 m above sea level while surface temperatures varied between 10 °C in July to 30 °C in December.

Modelling results showed a relatively good agreement with measured water level (RMSE of 0.2 m) and water temperature (RMSE 0.74°C for surface temperature and 0.67°C for bottom temperature).

Shortwave radiation was the main source of heating. Measurements SDD varied between 0.45 m and 1.30 m, and its product with the attenuation coefficient varied between 1.8 and 2.2 because of color and turbidity dynamics. This still needs to be considered in the model to better represent shortwave attenuation in the water column, as the Ocean Model considers a fixed value of SDD and a value of 1.7 of its product with attenuation coefficient.

Regarding heat losses, latent heatflux dominated in summer, early autumn and spring, while EBR dominated in late autumn and winter. In general, forced convection predominated over free convection. During cooling months, free convection was significant, resulting in a contribution of around 40 % of the total monthly mean in April and May, and with daily peaks reaching values between 60% and 70% of the total.

Atmospheric stability showed changes through seasons and at shorter timescales. Almost 70% of the time the atmosphere was unstable, what made free convection a relevant component as was mentioned. EBR formulation could be improved as it considers equilibrium between water and air temperature, condition rarely encountered. The period that EBR dominates losses, the model presents poorest fit. Sensible heatflux is a minor component, Bowen ratio varied from 0.34 in May to 0.10 in January.

Thermal structure is relevant to hydrodynamics and water quality in the reservoir. For instance, the highly variable periods of stratification and mixing govern phytoplankton's access to light and nutrients. Also, the numerical model showed that rapid changes in weather during storms leads to the formation of density currents in the main channel because of differential changes in water temperature between the main inflow and the reservoir. The latter, combined with hysteresis (clockwise and counterclockwise) observed in water quality data at the inflow during the storm events, is a key factor in the explanation of substances fate in the reservoir. Currently, Delft3D-ECO is being set-up with hydrothermodynamics results as input.

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P.Santoro*, C. Paz, S. Delgado, A. Rios (Poster)

Hydrodynamics and water quality in a subtropical hydropower reservoir: a combined modelling and measurement approach

The major hydropower reservoir of Uruguay, Rincón del Bonete, has exhibited water quality problems, particularly phytoplankton blooms, almost every year over the last few decades. Although the reservoir's water quality has been monitored since the beginning of the 2000s, little is known about how hydro-thermodynamics influence the transport of substances and establish conditions for the growth of primary producers.

This work aims to contribute to better management of hydropower reservoir water quality by developing numerical tools that help understand the system dynamics and allow for prediction of its future behaviour. The objective is to characterize the hydrodynamics, transport time scales, water temperature dynamics, and water quality dynamics of the major reservoir in Uruguay.

The work is based on the analysis of numerical results from a circulation and water quality model implemented for the Rincón del Bonete reservoir using the DELFT-3D model. To implement the numerical model, several field campaigns were conducted to collect hydrodynamic and water quality data at different points in the reservoir. The hydrodynamic model was calibrated and validated based on a combination of continuous measurements generated during the project, estimations from satellite images, and historical periodic monitoring data.

The hydrodynamic model was used to characterize the circulation in the reservoir and evaluate the influence of different forcings (hydrometeorological and dam operation) through numerical experiments. Transport time scales in the reservoir were analysed based on numerical experiments with a passive tracer. Flushing lag and e-flushing time maps were computed based on simulations with realistic forcings. The sensitivity of the water quality model results to several parameters, as well as different scenarios of nutrient boundary conditions, was analysed.

The numerical model results show very good agreement with the measured data, satisfactorily representing the main features of the reservoir dynamics. Field data reveals a complex circulation in the reservoir. In a narrow section in the middle of the reservoir (200m wide and 15 meters depth), the entire water column frequently flows upstream, events well-represented by the numerical model. Numerical experiments turning off different forcings showed that both wind and dam operation play a relevant role. Analysis of transport time scales showed heterogeneous results along the reservoir, emphasizing the advantage of this approach over classical bulk estimations of residence time. Simulations with realistic forcings underscored the significant influence of hydrometeorological conditions on substance transport in the reservoir. Critical zones with higher flushing times were identified, correlating with zones of higher chlorophyll-a values identified based on remote sensing.

Sensitivity analyses performed with the water quality model demonstrated the significant role of light climate and vertical mixing in the adequate simulation of phytoplankton. Sediment dynamics are relevant for adequately representing the light climate but also significantly influence phosphates dynamics in the system. The model showed sensitivity to border conditions of nitrogen and phosphorus regarding chlorophyll-a and bioavailable forms of nitrogen and phosphorus results.

In summary, both field data and the numerical model indicate that the reservoir has complex hydrodynamics, with frequent flow reversals responding to dam operation and wind action. The latter plays a crucial role in circulation and substance transport in the reservoir. The implemented model integrates physical aspects of hydrodynamics, temperature, and sediment dynamics with biochemical processes linked to the nitrogen and phosphorus cycles, as well as biological processes related to the net growth of different groups of phytoplankton. The generated tool can reproduce available data and contributed to identifying and quantifying processes determining phytoplankton dynamics in the reservoir. It allowed exploration of scenarios related to reservoir management, hydrometeorology, and nutrient input.

After demonstrating the significance of vertical mixing and light climate for reservoir water quality, current efforts are focused on enhancing our understanding and modelling capabilities of these processes.

J.Mesman (Poster)

Managing Events and Extremes in Water Supplies

The MEWS project (Managing Events and Extremes in Water Supplies) was recently funded by the

EU Water4All joint project initiative, which had the goal of examining the effects of hydroclimatic extreme events on society. Central to our project is the need to not only examine the effect of these extremes on input or lack of input to a water supply, but also to explicitly consider the effect of hydroclimate extremes on the transport and processing of materials entering and transported through a water supply. This is of particular interest for drinking water suppliers due to the fact that the water inflows are often separated from the drinking water withdrawal by significant distance and time of transport.

The project will use the open-source 3D GETM model, which will be coupled through the FABM framework to water quality (WQ) models (Selmaprotbas and DOMCAST), allowing biogeochemical processes to be simulated in response to changing conditions along the hydrologic flow path. The primary state variables of interest are chlorophyll-a and Dissolved Organic Matter (DOM). Both variables can have important implications for drinking water provisioning and are affected by climate warming and extreme events, creating a concern for water managers. Three demonstration sites were selected for this project: Lake Mälaren (Sweden), Lake Kinneret (Israel), and Ohra Reservoir (Germany), where we will work together will local water managers to co-develop a freely available comprehensive modelling tool that will allow stakeholders to evaluate the effects of floods and droughts on drinking water quality. And, we aim to develop a set of instructions that will allow water managers to adopt this scheme in other locations as well. Catchment modelling will not be explicitly considered in this project, but each demonstration site has a working catchment model, and water managers often have their own models ready, which can serve as inputs for the reservoir model.

The 3D approach contrasts with the 1D approach chosen for many lake WQ model applications. Spatially-resolved WQ models have considerably longer runtimes, especially if calibration is required and long-term climate scenario studies are of interest. An important aspect of the project will be to optimize the 3D grid to provide sufficient resolution of lateral transport between the river mouth and drinking water intake points and have runtimes that allow for long-term simulations. This means that we will have to make trade-offs between model complexity, spatial resolution, and runtime. An advantage in this regard is the use of the FABM framework, which allows the same WQ models to be coupled to either a 1D or a 3D model. We will therefore calibrate the WQ models in a 1D setting, and then apply them when coupled to the 3D model.

A 3D physical lake model coupled to a complex WQ model has a strong potential for water management, but such models are used sparingly due to the considerable time investment to get familiar with the model, licensing costs, and runtime considerations. The MEWS project hopes to make such models more readily available to water managers, so that mitigation or forecasting efforts related to climate warming and extreme events can be supported by model simulations.

J.Shan (Poster) ____

Numerical modelling of the wave interaction with revetment breakwater built on reclaimed coral reef islands in the South China Sea—Experimental verification

The South China Sea (SCS) is an important channel, which plays a significant role in global economic trade and in the maintenance of world energy security. A series of artificial lands have been successfully built on the top of natural coral reefs in the SCS by the way of reclamation in recent years. In order to prevent those artificial lands from wave scouring and impacting, a great number of revetments and breakwaters have been constructed along the margin of these artificial lands. The revetment breakwaters have great significance and practical value to ensure the stability of these reclaimed lands, and to guarantee their normal long-term service performance. In this study, taking the reclamation project in the SCS as the engineering background, a computation model for the interaction between ocean waves, revetment breakwater and its calcareous coral sand foundation is established by taking the CFD solver OlaFlow as the computation platform which was developed based on the open source library OpenFOAM. Then this established computation model is verified by some laboratory testing data of wave profile and wave impact which have been measured in several wave flume physical model tests. The comparison between the testing data and the computational results indicates that the computation model established adopting OlaFlow can reliably simulate the wave generation, propagation, the dissipation of wave energy as well as the complicated interaction between ocean wave, the revetment breakwater and its calcareous coral sand foundation. This verification work will be a solid basis for the subsequent investigation of the interaction between severe ocean waves and the revetment breakwaters in large-scale, as well as the quantitative evaluation of the stability of the revetment breakwater build on reclaimed coral sand foundation in the SCS.

L.Shi*, M. Wells (Poster)

The role of over-winter oxygen dynamics in setting the spring and early summer dissolved oxygen levels in the large ice-covered Lake Simcoe

Lake Simcoe is a large dimictic lake in southern Ontario that suffers from hypoxia. While the dynamics of low dissolved oxygen (DO) have been studied in detail during the last 30 summers, the role of over-winter oxygen dynamics in setting the spring and early summer DO levels in Lake Simcoe has received much less attention. Winter water quality in Lake Simcoe likely play an unrecognized role in influencing late summer DO levels, hampering efforts to understand how we can reach the guideline of 7 mg/L of DO in late summer. Traditionally winter has been largely ignored, in part because it has been difficult to collect reliable winter data due to the safety challenges of working on ice – hence the need for under-ice moorings that can record water quality conditions for the 6 months between October and May. This presentation will discuss our analysis of 6 years of high-frequency records of under-ice water quality in the 40 m deep water column of Kempenfelt Bay, in the context of a warming climate. The new data analysis will determine how previously unrecognized phytoplankton production in late winter influences the early spring DO levels, which in turn sets the stage for how much oxygen depletion occurs by late-summer in Lake Simcoe.

S.Jamali

Inhibition of spring turnover in a brackish lake subject to ice cover

Situated at 57°1′N, 111°37′W in Alberta, Canada, Syncrude Canada Ltd.'s Base Mine Lake (BML) is the first full-scale demonstration of an end pit lake in the oil sands industry. Formed through backfilling of fluid fine tailings into a previously mined-out pit, followed by capping with a water layer, BML has been under thorough monitoring since its commissioning in 2012.

Recent studies have shown that the presence of low levels of salinity, as low as 1 ppt, can have dramatic effects on the circulation of lakes subject to ice-cover. The exclusion of salt from ice as it forms can result in a relatively fresh surface layer immediately after ice melt. The density contrast between the ice-melt and the more saline water beneath it can be sufficient to hinder, or even prevent, spring turnover, thereby inhibiting the replenishment of oxygen to deeper waters.

In this study, we investigate the inhibition of spring turnover in a brackish pit lake, BML, with salinity of 2 ppt. To achieve this, we employ a one-dimensional lake model, specifically the General Lake

Model (GLM), to evaluate changes in evolution of the salinity and temperature during spring. Our model results compare well with extensive field measurements gathered over a period of 10 years. Moreover, preliminary results indicate that spring turnover is sensitive to the timing and magnitude of the wind, rain, and inflow events, including the expression of saline pore water. Following model validation, we anticipate predicting how changes in BML dynamics, particularly an increase in lake depth as the settled fluid fine tailings accumulate, will impact spring turnover.

T.Lorimer, F. Bärenbold, M. Schmid* ____

Predicting the mixing depth of deep lakes without a lake model

Modelling the mixing depth of deep lakes using process-based models is difficult, because mixing depth depends on tiny density differences that arise from the integration of uncertain forcing through imperfectly modelled processes. Moreover, for meromictic deep lakes, the relevant timescales of forcing integration can be several years. We have to try to model deep mixing though, because mixing supplies deep water oxygen, and oxygen is important for life Instead of trying to perfect the process-based integration, we ask whether the integration can be circumvented entirely by a data-driven approach. To do this we construct nested multiscale time-series embeddings of forcing variables, and use these to predict mixing depth directly, without any lake parameters. We find that out-of-sample mixing depth predictions using this approach can outperform our operational forecasts with the one-dimensional hydrodynamic lake model Simstrat. Moreover, we achieve these results using daily-resolution regional climate model forcing, and a very basic random forest. This surprising accuracy from such a simple approach, suggests that it might be possible to find an empirical effective theory for lake mixing depth: one that does not explicitly include fine-timescale physical processes known to influence lake mixing.

L.Bryant*, D. Austin, N. Brockbank ____

To mix or not to mix? Stratification-preserving vs. destratification aeration of a drinking-water supply reservoir

Aeration is used globally as a remediation method for lakes and reservoirs with methods generally falling into two categories, those which preserve natural stratification (hypolimnetic aeration; HA) and those which destratify reservoirs through mixing of the water column (destratification aeration; DA). The United Kingdom largely focuses on destratifying methods to manage harmful algal blooms and decrease trace metal concentrations, whereas the United States and Europe frequently focus on hypolimnetic techniques to increase dissolved oxygen concentrations and decrease benthic nutrient and metal release from the sediment. Whilst established as successful approaches, both methods can also have unintended negative effects on reservoir water quality. Comparison of HA and DA performance across different study sites is difficult due to site-specific influences of bathymetry, water quality, local land use and geology, etc. A more holistic understanding of the different techniques and their relative merits should lead to more efficient treatment, reducing wasted energy and other costs during both reservoir aeration and the drinking water treatment process.

This innovative study evaluates HA and DA and compares the effects of each aeration strategy on stratification and dissolved oxygen and cyanobacteria concentrations in a single reservoir. Focus is placed on transferring knowledge of HA, which is currently more established in the scientific literature, to increase understanding of DA. Novel field-based results obtained during the 2016 spring/summer season characterise the influence of both HA and DA in CW Bill Young Regional Reservoir, located in central Florida (USA), thereby allowing for direct comparison of these methods within the same aquatic system. HA initially maintained oxic conditions in the hypolimnion; however, this aeration approach was found to have limited capacity to relieve hypoxia as thermal stratification and near-sediment anoxia developed. HA was observed to promote increased oxygen flux into the hypolimnion but still had difficulty raising DO > 2.0 mg/L because of sediment-driven oxygen demand in the hypolimnion. DA is shown to be a viable alternative to HA, particularly for preventing thermal stratification and corresponding hypolimnetic anoxia, though neither approach maintained saturated DO conditions at the sediment-water interface (SWI). Hydrodynamic suppression of cyanobacteria blooms is considered as a further advantage of DA over HA. Oxygen dynamics were more variable under the DA regime which may be partly attributed to increased mixing and the influence of external factors like pumped inflow, as suggested by water column stability quantified by the Schmidt stability index. DA also results in higher oxygen fluxes (and corresponding oxygen demand) in the water column and near the sediment; these are attributed to increased mixing and sediment resuspension caused by increased turbulence at the SWI. Results highlight that it is of utmost importance to consider the local climate, including wind speed and temperature, when specifying a DA regime. Results further establish HA and DA approaches as successful aeration strategies depending on management goals; however, it is emphasized that performance is strongly site-specific. Both approaches are likely to become increasingly important as reservoir management tools with the pressing threats of growing anthropogenic activity and climate change.

A comprehensive understanding of the chemical, physical and biological response to management strategies like aeration is required. Results highlight the importance of monitoring the water body in real-time to i) observe its unique reactions to aeration and shifts in stratification or destratification and ii) ensure the most effective solution is administered for the problems at hand. In this study, DA was a timely solution to the dispersal of the incipient cyanobacteria bloom and near-sediment anoxia in the hypolimnion. Continuous monitoring revealed the formation of these issues in real-time and informed a switch from HA to DA, thereby allowing for a pro-active rather than reactive approach to reservoir management and subsequent drinking water treatment. The ability to respond in real time to dynamic reservoir conditions is a key finding of this study. Ultimately, results can be applied to optimisation of aeration techniques supporting source water management, sustainable drinking water supplies and, ultimately, improved energy consumption for water treatment processes and enhanced aquatic ecosystem health. Particularly in light of climate change (and related implications on reservoir stratification and oxygen dynamics) and the needed focus on more sustainable approaches to managing our water supplies, it is a critical time for better understanding how management strategies like aeration can be used to mitigate effects thermal stratification and corresponding water quality issues in drinking water reservoirs.

Friday 5th July 2024

F.S. Sharifi*, R. Hinkelmann, T. Hattermann, G. Kirillin

Circulation in brackish ice-covered lakes: effects of salinity and river runoff

The effects of freshwater river runoff on ice-covered brackish lakes have not been fully investigated to date. The circulation patterns of brackish lakes are complex due to the nonlinear effects of temperature and salinity on density stratification and mixing and, as a result, on ice melt. In order to gain a better understanding of the circulation of large endorheic lakes in cold regions, as well as their ecological and physical characteristics, it is essential to quantify these effects. We present simulation results on the circulation caused by river runoff in an idealized ice-covered brackish lake obtained by means of the Regional Ocean Modelling System (ROMS). The salinity of the lake water was set to 14 practical salinity units (PSU), characteristic for large brackish lakes in endorheic regions. In the initial state, the water temperature increased linearly from the freezing point at the surface to the maximum density value at the bottom, the salinity was set uniform within the lake. Mixing of cold freshwater river inflow with warm saline water produces negative buoyancy, which results in downslope density currents (in the order of 10^{-5}-10^{-6} ms^{-1}) near the river inlets with a secondary geostrophically-balanced circulation throughout the lake. Adding cold freshwater of a river to the lake leads to cooling the whole lake's water column, which is balanced by solar radiation penetrating into the water column. We quantify the contribution of this circulation mechanism to lake-wide circulation and deep ventilation and evaluate the outcomes of the model with solar radiation added.

I.Mammarella

Variability and drivers of gas transfer velocity in a regulated river

Freshwater systems (lakes, river and streams, estuaries) have been recognized as a significant yet uncertain component of the global carbon cycle (Raymond et al, 2013). Rivers and streams receive substantial carbon input from terrestrial ecosystems, which is then laterally transported and further processed along the Land Ocean Aquatic Continuum (LOAC). A large fraction of carbon is emitted from the LOAC back to the atmosphere as carbon dioxide (CO2) and methane (CH4), the two most important anthropogenic greenhouse gases (GHG).

The diffusive flux of a slightly soluble gas such as CO2 or CH4 through the air-water interface is driven by the mean partial pressure gradient and is controlled by the turbulence in the water-side surface layer (MacIntyre et al, 1995). For this reason, the flux can be considered to be restricted by the amount of dissolved gases, the efficiency of the turbulent transfer, or both (Roches-Ros et al., 2019). A conventional approach to quantify the efficiency of the water side turbulent transfer is through the so-called gas transfer velocity k, which relates the mass diffusive flux F to the difference between the water-side bulk gas concentration (cw) and the gas concentration at the water surface that is assumed to be in equilibrium with the overlaying atmosphere (ceq). Thus, the turbulent flux can be expressed as F=k(cw-ceq) , where k must be externally supplied, modelled, or derived from dimensional considerations and scaling analysis (Lorke and Peeters, 2006). To evaluate such approaches to k, measurements of gas concentration differences and fluxes are required and frame the scope of the work. In this study, measurements of gas transfer velocity in a regulated river, derived from simultaneous atmospheric eddy covariance CO2 fluxes and water and air concentrations, are presented. The gas transfer velocity parameterizations are constrained by using independent measurements of water side turbulence conducted using acoustic doppler velocimeter that can be used to estimate the turbulent kinetic energy dissipation (ε).

The field campaign was conducted at the River Kitinen in northern Finland and lasted from the 1st of June until the 17th of October 2018. The experiment site (67.37N, 26.62E, 173 m above sea level) was located next to the Finnish Meteorological Institute's research and weather station in Tähtelä, 5 km south of the town of Sodankylä. At the experiment location, the river is 180 m wide and forms a straight section extending approximately 600 m upstream and 1000 m downstream from the site with a gentle bed slope of 0.5 m km-1. The mean annual discharge, measured at the closest power plant downstream, is 103 $m^3 s^{-1}$. The River Kitinen's Strahler stream order at the site is 5. The water flow velocity at the experiment site was almost completely controlled by the hydropower dam regulation located 11 km downstream. Flow regulation in the river followed a certain pattern where the flow would be small or completely halted during most nights. The eddy covariance (EC), meteorological, and water side measurements were conducted on a floating platform in the channel, where the water depth was 4.5 m, as well as on the riverbank. These include EC CO2 fluxes, air temperature, relative humidity, upwelling and downwelling short and long radiations, water temperature profile, CO2 partial pressure in water, water flow and turbulence measurements.

The EC derived k was proportional to independent estimates of dissipation rate of turbulent kinetic energy at the water surface, following the small eddy model (Katul et al, 2017) with a constant of proportionality equal to 0.42 (i.e. $k=0.42\ (Sc)^{-1/2}\ (\nu\varepsilon)^{1/4}$, Sc is the molecular Schmidt number, and ν is the waterside kinematic viscosity). The coefficient 0.42 is close to the empirical value (Zappa et al., 2007) reported for many ecosystems and the expected theoretical value derived from Karman--Howarth equation (Katul et al, 2018). Moreover, the results show a clear temporal variability of near surface turbulence and k, caused by a combined effect of changes in the river flow regulation and atmospheric forcing (wind and buoyancy). The average values of k, ranging between 6 and 25 cm/h, are well in agreement with those reported in other field experiments for similar river systems (Alin et al, 2011). The spatial variability of near surface turbulence forcing and related k is further assessed by contrasting measurements conducted in the channel and the riverbank. The empirically derived hydraulic model for k, typically parameterized as a function of stream slope, depth, water discharge and flow velocity (Raymond et al, 2012), appears not suitable for regulated river systems, highlighting the need to include atmospheric forcing in current models.

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B.Zamani*, F.L. Hellweger ______________________________

Effects of lake restoration approaches on the ecosystem of a suburban lake in Berlin area

Lakes with no surface inflow/outflows are very sensitive to any groundwater level changes in their catchment. This, in combination with increased groundwater extraction and frequent and longer drought periods in Berlin area, has resulted in a declining water level trend in Lake Sacrow. In this study, as a part of the CliWaC consortium project (Climate and Water under Change), we modelled hydrodynamics and ecosystem of Lake Sacrow, a dimictic lake in the Berlin/Potsdam area. Lake Sacrow has been suffering from long oxygen depletion periods in the hypolimnion. This problem has intensified in the past two decades due to warming trends and longer stratification periods and is expected to become even worse under the gradual transition of the lake's thermal regime due to climate warming. To evaluate the possible solutions to maintain and increase the lake water quality (together with quantity), we employed the three-dimensional hydrodynamic and aquatic ecosystem model AEM3D to simulate physical processes, nutrients cycle, and phytoplankton dynamics, with a final goal to develop solutions for the future decades under climate change impact. This model is now employed as a scientific modelling tool which also plays its role as a decision-making tool for stakeholders. The ecosystem model is validated using measured water column profiles of year 2017 for three phytoplankton groups of toxic producers (cyanobacteria), silica-dependent and non-silica-dependent groups. In parallel to the ongoing testing and preparing of the model to simulate future scenarios (through hindcast runs to evaluate multidecadal bias in simulations), we evaluate and compare different solutions of controlling phosphorus release from sediments, which include hypolimnetic aeration and hypolimnetic withdrawal techniques.

A TIBEAN hypolimnetic aeration system was installed and run in 1992-1993. However, it was deactivated after two years due to high operating costs and other reasons (but still exists in the lake). As CliWaC is an interdisciplinary project and stakeholders in the Berlin area are also involved, solutions for lake restoration were of interest to the stakeholders and the local community. Thus, as a part of our lake modelling project, we modelled the effects of reactivating the installed aeration system on the oxygen cycle, sediment phosphorus release and general water quality of Lake Sacrow. The model results were compared to the measured oxygen profiles of the years with running aeration system. Although from different years (same stratification period, however), a reasonable agreement is seen between the model results and the measured data. Results are evaluated in terms of P release from bottom sediments and phytoplankton biomass. The simulation of hypolimnetic withdrawal scenarios is under preparation and will be compared with hypolimnetic aeration as soon as results are obtained.

A.Folkard*, G. Exley, Q. Ji, L. Zhao, S. Midauar, G. Rocha, T. Page, S. Thackeray, A. Armstrong __

Modelling the environmental impacts of floating photovoltaics on their host waterbodies

Floating photovoltaics (FPVs) are a rapidly growing response to the urgent global need for transitioning away from fossil fuel energy sources to more environmentally sustainable and renewable sources. They comprise arrays of photovoltaic solar panels, which are typically deployed on reservoirs or lakes, thus avoiding the use of potentially valuable land space, improving FPV efficiency via water cooling, and reducing evaporative water losses. These clear environmental benefits notwithstanding, their impact on the water quality and ecological health of their host waterbodies is not currently well understood. These impacts may be positive - for example, their shading effect may reduce the rate of biomass production by harmful algal blooms. But they may also be negative - for example, they may reduce oxygenation of the water column. Moreover, these impacts may be dependent on which climate change scenario comes to pass. Here, we present the results to date of an ongoing programme of modelling efforts aimed at providing forecasts of these impacts with greater confidence. The most developed results come from 1D-vertical physical-biogeochemical modelling using MyLake. They show that FPV coverage significantly impacts the thermal stratification of waterbodies, and that this impacts phytoplankton biomass and species composition. Difference in response were found to be dependent on the FPVs' location in relation to the waterbody's hydrography, thus identifying location as well as percentage coverage as a parameter that could be used to manage their impacts. Modelling of the impact of FPVs in the context of different climate change scenarios suggest further it may be possible to use them to mitigate future climate change impacts on water temperature, stratification duration, phytoplankton biomass, and nuisance-species proliferation. Our findings suggest that this will vary seasonally, and depend on future emissions levels and desired management goals. Our current work is extending these findings, via 3D modelling using Delft-3D and EFDC+. This presentation will review our work on this topic to date and discuss potential future directions for this research.

M.K.Prandini, P.G. Grochocki*, L.H. Novak, M. Mannich, T. Bleninger

Assessment of the Influence of a Floating Photovoltaic System on the Passaúna Reservoir in Brazil

Floating photovoltaic systems (FPV) emerge as an innovative technology for renewable energy generation on artificial water bodies, such as public water supply, hydropower or mining reservoirs. These reservoirs, considered crucial aquatic ecosystems, play pivotal roles for both human uses and nature conservation and are subject to various alterations due to human activities. In this context, FPV present themselves as a promising alternative for renewable energy, especially in a scenario of climate change and the need to optimize land use. However, the impacts of FPV on water quality and physical processes at the air-water interface, as well as on the water body as a whole, are still not well understood by the technical-scientific literature. Additionally, FPV can still assume different typologies, show different reservoir coverages, among other characteristics, such as geographic location, which can influence their impact on the aquatic environment.

This study aimed to evaluate the influence of a pilote scale scale FPV (~0.01% reservoir coverage) on water temperature (WT), dissolved oxygen (DO), and photosynthetically active radiation (PAR) parameters.

The FPV study area was located at the Passaúna reservoir (25°30'43.55" S, 49°22'9.50" W), in the state of Paraná, Brazil, launched in 2019, this plant boasts 396 modules and a remarkable maximum capacity of 130 kWp, spanning an area of approximately 1,200 m^2 that represents 0.01% of the reservoir area. Two monitoring points were selected: PV point: monitoring performed below the FPV; and LR point: a free water monitoring point far from the FPV influence. Continuous monitoring was carried out by installing the following data loggers: Vemco Minilog II-T (WT), miniDOT (DO), and miniPAR (PAR). The sensors were attached to ropes tethered to buoys to maintain constant depth throughout the monitoring period. The installation depths of the sensors, both at the influenced and non-influenced points of the FPV, were: 0.25 m – WT and 0.50 m – DO and PAR, relative to the surface.

The continuous data monitoring period ranged from October 2021 to September 2023. WT: Slight differences were observed for WT, with the mean difference between series (LR - PV) being -0.01 ± 0.11 °C. The series means were 18.77 ± 1.75 °C and 18.76 ± 1.74 °C for PV and LR, respectively. The medians were 18.26 °C and 18.22 °C for PV and LR, respectively. Extremes ranged from 15.97 °C (both points) to 24.40 °C and 24.28 °C for PV and LR, respectively. Counterintuitively, the main differences observed in WT were related to higher daily temperature peaks at the PV point, despite shading (blockage of radiation in the water column) generated by the FPV influence. The physical explanation may be associated with less water column mixing due to stability and lower wind stress provided by the FPV. In the WT time series, approximately 3.10% of the time PV and LR were equal, 55.28% LR > PV, and 41.62% PV > LR. During the WT monitoring months (April to September 2023), the monthly temperature averages were similar between PV and LR (differences in monthly means not exceeding 0.02 ± 0.05 °C).

PAR: The greatest differences were observed for PAR, with the mean difference between series (LR - PV) being 82.43 ± 170.08 µmol/sm^2. The series means were 86.66 ± 175.66 µmol/sm^2 and 4.23 ± 19.38 °C for LR and PV, respectively. The medians were 0.30 µmol/sm2 and 0.10 µmol/sm^2 for LR and PV, respectively. Maximum values were 1992.90 µmol/sm^2 and 918.10 µmol/sm^2 for LR and

PV, respectively. In summary, PAR is practically eliminated due to the shading effect of the FPVS. In the PAR time series, approximately 29.35% of the time PV and LR were equal (likely due to the night period), 66.35% LR > PV, and 4.30% PV > LR. From March to September 2023, PAR e at the LR point was consistently higher than at the PV point, with a monthly average difference of 97.31 ± 60.65 µmol/sm^2.

DO: More pronounced differences were observed for DO, with indications of higher DO concentration at the point without FPV influence, despite the mean difference between series (LR - PV) being -0.20 ± 1.06 mg/L. The series means were 7.71 ± 0.86 mg/L and 7.51 ± 1.07 °C for PV and LR, respectively. The medians were 7.91 °C and 7.83 °C for PV and LR, respectively. Extremes ranged from 4.30 mg/L to 10.23 mg/L for PV, and 2.95 mg/L to 12.90 mg/L for LR, respectively. In the DO time series, approximately 0.05% of the time PV and LR were equal, 67.23% LR > PV, and 32.72% PV > LR. From October 2022 to March 2023, DO at the LR point was, on average, 0.27 ± 0.1 mg/L higher than at the PV point. From April to June 2023, DO at the PV point was, on average, 0.99 ± 0.89 mg/L higher than at the LR point. From August to September 2023, DO at the LR point again was, on average, 0.17 ± 0.06 mg/L higher than at the PV point. The area beneath the panels most of the time presents higher DO levels compared to the control region (LR > PV), largely due to algal bloom events in the reservoir, which do not occur under the solar panels due to low PAR. LR < PV events occurred mostly during the night and during bloom periods; the decrease in DO is primarily caused by high oxygen consumption, leading to a decrease in DO during the night.

Despite the small structure of the FPV compared to the reservoir's surface area, it can be observed that the FPV influences the aquatic environment bellow it. DO and PAR showed clear differences among the free water and PFV measurement points. Studies in different locations and FPV configurations are essential to assist in decision-making and regulation, especially regarding the popularization of technology use and environmental impact assessment compared to alternative energy sources.

J.Vidal-Hurtado ____

Numerical modelling as a management tool of aquatic systems: The case of Berre Lagoon.

Berre lagoon is a Mediterranean lagoon deeply impacted by industry and urban activities. The lagoon covers an area of 155.3 km^2 with a maximum depth of 10 meters and it is linked to the Mediterranean Sea through a narrow channel (Caronte). It receives freshwater from three rivers and -since 1966- from a hydroelectric plant fed by the EDF canal of the Durance River. The latter has become the main tributary since the beginning of its functioning. As such, salinity - and stratification - are intimately correlated with the discharged freshwater. The annual allowed water volume quota has evolved from its opening to the current quota established in 2006. Additionally, EDF must respect a weekly volume and suspended solids quotas as well a s a lagoon's salinity

threshold. In that context, EDF has developed different numerical approaches to support the hydroelectric plant management. A simplified model is used to predict salinity evolution as a function of the discharged freshwater to respect the salinity threshold. Likewise, a 3D hydrodynamic model has been used to better understand the processes that determine the water quality of the lagoon, subject to multiple and complex forcings. Under normal conditions, the seawater entering throughout Caronte plunges to the bottom of the lagoon. The freshwater overflows at the surface where it mixes with the salty lagoon water in the first few meters. This generates a strong haline stratification in the lagoon. During the warm months the oxygen demand is such that anoxia occurs regularly in the deeper layers. Under warm and calm conditions, the anoxic layers may rise towards the surface and become shallower. In extreme conditions, as such of 2018, they generate anoxic crises known as 'Malaïgues'. Fortunately, the lagoon is occasionally (about once a month) subject to strong Mistral winds that generates upwelling of the 'marine' deep waters and -if they last long enough- complete vertical mixing. The 3D hydrodynamic model has shown a good representativeness of the behaviour of the lagoon with a good accuracy between results and observations (temperature, salinity, stratification,…). Hence, the 3D model has been shown to be a valuable tool to propose and to evaluate new modes of management as: Seasonality of the discharges (ie: reduced summer discharges) or revision of the salinity thresholds.

M.Fregona ____

Assessing LAKE 2.0 model performance in simulating thermal and gas dynamics during shoulder seasons in Lake Kuivajärvi

Lakes generate a significant amount of carbon dioxide, methane and other greenhouse gas (GHG) emissions. Recent research of CO2 emissions estimated that these ecosystems release an amount of CO_2 equal to about 20% of emissions from fossil fuels and that these releases have global implications (Desai et al., 2015). In addition, the carbon budget of lacustrine ecosystems is changing rapidly in response to the influence of climate change (Golub et al., 2023). Being able to accurately simulate thermal and gas related dynamics thus turns out to be a relevant task because it enables the prediction of future shifts in temperature patterns and gas exchange rates between lakes and the atmosphere. Despite this, however, most studies that have investigated this topic refer to sampling limited to the open-water season or summer with limited consideration of interannual-scale variations (Desai et al., 2015). In particular, in lake GHG's related research, ice cover is poorly investigated. This is critical because the ice cover prevents the release of greenhouse gases by causing them to accumulate under it and then be released when the ice breaks up. This dynamic significantly affects the seasonal variability of GHGs concentrations and fluxes in lakes that freeze seasonally (Kiuru et al., 2018).

Here we investigate the ability of the LAKE 2.0 model (Stepanenko et al., 2016) to accurately simulate the surface energy balance and GHGs exchange between lakes and the atmosphere. Special attention is devoted to the model´s ability to predict lake mixing regimes and concentration of dissolved gases (oxygen, carbon dioxide and methane) during shoulder seasons (spring and fall) and during the winter time. LAKE 2.0 is a one-dimensional model that allows coupled simulation of thermodynamics and biogeochemical characteristics in lakes and reproduces profiles and time series of water temperature, and concentrations of O2, CO2 and CH4. The model is forced using a meteorological data set from Lake Kuivajärvi, a small boreal lake in Finland located next to the

SMEAR II Forest station (Hari and Kulmala, 2005). Results from the LAKE 2.0 model are compared to 30 minutes water temperature and weekly gas concentrations measurements from the lake (Miettinen et al., 2015; Miettinen et al., 2020).

The model effectively reproduces the observed seasonal temperature pattern in the lake. Overall, also seasonal dynamics of gases are well represented. Focusing on shoulder seasons, the model is able to reproduce temperature and gases dynamics fairly well. Nevertheless, there are some shifts in gas accumulation amount and timing. During the spring period, O2 concentration increases and CO2 and CH4 release are slightly delayed. In the beginning of autumn, the cooling process properly induces formation of a growing mixed layer, but the consequent overturn is simulated too early by the model with correspondent shift in gas concentration. In early winter, ice formation induces water column mixing, instantaneously lowering water temperature. This triggers a rise in O_2 concentration and prevents gas accumulation until a definitive ice layer forms. This dynamic is particularly evident in case of warm winters with intermittent ice cover. Overall, errors related to modelled gas concentration and release are highly dependent on the model's ability to accurately simulate temperature dynamics. It is essential to keep this in mind especially because thermal dynamics in lakes are predicted to shift due to climate change. As warmer winters with intermittent ice cover will be an increasing common occurrence, models should be able to accurately reproduce these dynamics as well.

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Subworkshop Satellites

S.Simis ____

Global lake biogeochemistry observations in the Lakes_cci climate data record

The Lakes Essential Climate Variable captures both the physical state of lakes, and their biogeochemical response to physical and chemical drivers. Biogeochemistry state variables include the concentration of chlorophyll-a as a proxy of phytoplankton biomass, and turbidity as proxy for suspended mineral and organic solids. In the past year, the Lakes CCI has also worked towards global retrieval of coloured dissolved organic matter as proxy for the dissolved fraction of lake carbon.

In several small-scale studies we have described multidecadal trends and global clusters of lake biogeochemical responses to the compound impacts of land use and climate change. These include overall trends in lake phytoplankton biomass, observed patterns in turbidity in relation to water level, and the biological response of lake phytoplankton during the 2019 double heatwave and subsequent low-pressure events in Europe.

In future, it is essential that these trends and response types become better understood through the integrated use of observation data with models. A focus on African lakes will apply a 1D model based on air temperature, water temperature and water depth to identify lake stratification changes, to be related with time series and climatology of water temperature, water quality data and associated meteo-climatic variables.

This presentation aims to prompt discussion on the optimal integration of global lake observation time series with models, the readiness of these disciplines to leverage synergies, and where to guide future research.

L.Carrea ____

Global lake surface water temperature and ice cover for climate-related applications from the European Space Agency Climate Change Initiative

Lakes are a very important component of freshwater resources and fundamental for terrestrial life. Specifically, lake variables are recognised by the Global Climate Observing System (GCOS) as an Essential Climate Variable (ECV) because they contribute critically to the characterization of Earth's climate. Therefore, observing and monitoring precisely, accurately, and consistently their spatial and temporal variability from local to global scale has become critical.

The Lakes ECV as defined by GCOS-245 includes the following thematic variables: lake water level and extent, lake surface water temperature, lake ice cover and thickness, and lake water-leaving reflectance. While in situ measurements are very valuable, they have limitations since they are point measurements collected by diverse instruments with very different time coverage and frequency. Satellite Earth observation data provide lake observations consistently both spatially and temporally.

This contribution deals with the thermal aspect of lakes, which impacts lake ecology and hydrology since water temperature and lake ice coverage influence both chemical and biological processes and determines air–water heat and moisture exchanges.

Here, we present the latest version of the lake surface water temperature (LSWT) and lake ice cover (LIC) datasets generated and validated within the European Space Agency (ESA) Climate Change Initiative (CCI) dedicated to lakes. The ESA CCI dataset v2.1 consists of daily observations (depending on cloud cover) over the period 1995-2022 for LSWT and 2000-2022 for LIC. The LSWT and LIC datasets have been derived from multiple instruments onboard various satellites with compatible algorithms in an effort to ensure homogeneity and stability over time.

LSWT and LIC are available on a regular latitude-longitude grid with spacing of about 1 km for 2024 lakes distributed globally, covering a wide range of hydrological and biogeochemical regimes. The

LSWT observations are accompanied by a quality level indicating confidence and an uncertainty estimate, which make the dataset particularly suitable for climate applications. For LIC, uncertainty is provided as overall classification errors for each class (ice, water and clouds) obtained from a random forest algorithm.

An overview of the CCI v2.1 LSWT and LIC datasets, their validation and comparison with insitu temperature data (when available), the geographical distribution of the lakes and the way to access the dataset will be presented together with some major global trends and patterns observed in LSWT/LIC. Finally, plans currently being considered for future versions of the datasets will be presented and discussed.

P.Pastor*, J.A. Domínguez-Gómez, A. Díez-Chiappe, A. Justel, A. Quesada, E. Perona

Monitoring cianobacterial bloom and surface water temperature in protected areas by satellite images

Remote sensing emerges as a valuable instrument for water management, facilitating the examination of key pollution sources like cyanobacterial harmful algal blooms. These organisms are on the rise due to eutrophication and the detrimental impacts of global change, leading to a decline in water quality. Leveraging satellite remote sensing imagery as bio-optical instruments proves effective in monitoring and regulating chlorophyll-a concentrations, serving as indicators of cyanobacterial presence. An analysis on the reservoirs of Monfragüe National Park has been developed within Cianopark project to detect and monitor temperature and cyanobacterial bloom as indicators of global change. For this study, 24 geo-referenced chlorophyll-a concentration measurements were performed in-situ using Moldaenke BBE Algae Analyser fluorimeter. Laboratory spectrophotometric measurements allowed for chlorophyll-a concentration from cyanobacteria to be innovatively used for the predictions. Spectral data from Sentinel 2 and Landsat 8 thermal imagery differed by 2/3 days from field data sampling dates. Water-Leaving reflectance images got from Acolite's atmospheric correction allow us to differentiate between three types of pixels: scum, bloom, and no bloom. In the development of the algorithm to derive the concentration of cyanobacteria's chlorophyll-a and its evolution through time from the reflectance measured by the multispectral instrument sensor of the Sentinel 2 satellite, the pigments absorption bands (B443, B490 and B668) as well as the fluorescence band of chlorophyll-a (B705) were considered. After a calibration phase, the algorithm was validated by splitting the data into training (70%) and test (30%) set. After the removal of outliers and the adjustment for the logarithmic transformation, the robustness of the algorithm was significantly increased, obtaining a determination coefficient of 0.634 and a Root Mean Squared Error of 8.1 μg/L. Alarming chlorophyll-a concentrations from cyanobacteria were observed in some reservoirs at certain times of the year which can cause environmental health issues established by the World Health Organization in an area inhabited by endangered species. A fast monitoring of the temporal and spatial distribution of cyanobacterial bloom at any aquatic system with remote sensing would prove advantageous specially for the management of protected areas. Results about the process, the algorithm and the mechanisms of use will be presented in detail.

M.Amadori*, A.J. Greife, M. Pinardi, L. Carrea, R. Caroni, J. Pitarch Portero, C. Giardino, B. Mariano, R. Maidment, I. Woolway ____

Sentinel Lakes of sub-Sahelian Africa: An assessment based on multivariate remote sensing data and numerical modelling

Africa is considered to be extremely vulnerable to climate change while contributing little. According to the latest IPCC report, five out of nine key risks for Africa are related to freshwater resources deterioration, increasing demand and sensitivity to climate-related extreme events. Compared to lentic ecosystems in other parts of the world, the study of lakes on the African continent is limited and concentrated in the African Great Lakes. However, many lakes populate the regions below the Sahel belt and contribute to the food security of millions of people. Most animal protein consumed in this region is indeed derived from lake fish, whose production has been substantially reduced in the past decades due to climate change. Changes in the distribution of fish species is only one of the many effects of ecological regime shifts recorded in lakes in the region and associated to climate change. Other effects include, but are not limited to, surface warming and related increase of thermal stability, with impacts on nutrient and oxygen availability, and consequently on phytoplantkton dynamics. In many cases, e.g. Lake Tanganyika and Victoria, these effects have been also linked to changes in precipitation patterns.

In this contribution we undertake an assessment of sub-Sahelian lakes using global datasets. The aim is to identify “sentinel” lakes that most clearly show climate-change-sensitive behaviours such as warming water temperatures, modified hydrological processes, ecologically significant stratification changes and critical response to extreme events.

The study sites are characterized by different morphological, trophic and climatic characteristics. In most of these lakes, with the exception of a few thoroughly investigated lakes, obtaining in situ measurements is challenging, due to lack of necessary infrastructure and funding. For this reason, data available from the European Space Agency (ESA) Lakes Climate Change Initiative (CCI) project are exploited to obtain timeseries of lake variables derived from satellite imagery. The analysis of water quality parameters through satellite imagery provides a cost-effective way of monitoring important water quality variables across wide geographic ranges. In particular, we extract from the CCI LAKES dataset v2.1 the following variables for a selection of 140 lakes in sub-Sahelian Africa: chlorophyll-a concentration, turbidity, water temperature, level and extent, and water leaving reflectances. In addition to the variables provided within the CCI data, we estimate vertical diffuse attenuation using different bands of the spectral signature from and we use it as a proxy of water transparency. At the same time, atmospheric variables (air temperature, shortwave and longwave solar radiation, humidity, wind speed, precipitation) are extracted from the global ERA5-Land dataset. For a better characterization of the precipitation, satellite-derived datasets such as TAMSAT and CHIRP rainfall are also included. For each lake, the precipitation is extracted as the amount of rain within the catchment defined in Lake TopoCat, a global lake drainage topology and catchment database.

First, a characterization of the lakes' behaviour in response to climatic drivers is performed through the evaluation of the climatology of all involved lake and atmospheric variables. A Principal Component Analysis reveals the high heterogeneity of the case studies in terms of LSWT and confirms the climatic classes (e.g. from Koppen classification) generally identified for lakes in this area. While LSWT in all sub-Sahelian lakes appear to equally react to shortwave solar radiation, the relative importance of longwave radiation and air temperature reduces towards the Equator, giving way to rainfall and relative humidity.

Warming and changes in stratification are simulated using LSWT observations and ERA5 forcing data constraining the air2water and FLake models. Estimates of mixed layer depth from both models are compared and used to evaluate the temporal evolution of the thermally reactive layer volume and identify lakes showing the most alarming decreasing trends of this quantity. In parallel, biogeochemistry and catchment interactions via water level variations and precipitation are also considered. By analysing the timeseries of water transparency, heat budget and water volume in all lakes at annual scale, lakes undergoing, or being more likely to undergo, ecological regime shifts are searched.

By exploring the potential role of remote sensing to overcome data scarcity in sub-Sahelian African lakes, our study provides the first multivariate assessment of climate change effects on water quality in this region, in support of a more sustainable management of lakes' resources and climate risk mitigation actions.

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