

Annual report 2013

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1. Objectives

The aims of the *Physics of Aquatic Systems Laboratory* (APHYS) are to understand the physical processes in natural waters and the responses of aquatic systems to external forcing. The main focus is on anthropogenic influences, such as nutrient input, hydropower production and climate change. We study the effects on natural waters and their sensitivity to those drivers and outline consequences for water resources management.

2. Research activities

2.1. Oxygen depletion in Lake Geneva (SNF funded)

Lake Geneva is still recovering from excessive phosphate loading over the last 60 years. The main goal of this project is to quantify and parameterize the rate of oxygen depletion in Lake Geneva. Using a MP4/8 lander, oxygen microprofiles are measured at high resolution (sub-mm scale) through the water-sediment interface in order to determine the flux of oxygen from the lake water into the sediment. Using ADCP current meter records at four locations we will calibrate two numerical models to determine the flow in the bottom boundary layers of the entire Lake Geneva over time. With these two sets of information, the oxygen depletion of the deep waters of Lake Geneva will be estimated and compared to the CIPEL long-term oxygen profiles since the 1960s.

2.2. Particles distribution in Lake Biel (ESB funded)

The City of Biel uses Lake Biel as a drinking water source. In the winter 2009/2010 extremely high particle concentrations forced the temporary shut-down of the Ipsach/Bienne water treatment plant for the first time in 30 years of operation. The aim of this project is therefore to investigate the causes behind such events and to understand whether this is a returning phenomenon in order to provide guidance for the planned major refurbishing of the lake-water intake system and the water treatment in the City of Biel. The focus of the project is on the fate of the particles entering Lake Biel via Aare at Hagneck and via Suze at Biel.

2.3. Lemman-Baikal Project (Limnology Center funded)

This project aims at developing new remote sensing techniques using hyperspectral camera on ULM and other low-flying platforms to characterise the water quality of both Lakes Geneva and Baikal. Our group specifically focuses on linking optical properties collected from hyperspectral camera to the water constituents, namely to concentrations of chlorophyll-a, particles and coloured dissolved organic matter. This project will provide (i) optimized water quality algorithms for remote sensing in lakes and (ii) better understanding of the horizontal patterns of biophysical parameters. This sub-project is part of an interdisciplinary project coordinated by the Limnology Center.

2.4. High resolution freshwater monitoring (Freshmon, EU funded)

During overflights of satellites such as SPOT, Rapideye or Landsat ground truthing information has been collected to calibrate satellite image information. As a preparation for the upcoming Sentinel-3 mission, we focussed - besides the usual estimation of the concentrations of particles, chlorophyll-a and coloured dissolved organic matter - on photo-spectrometer measurements at the water surface. The long-term goal is to connect satellite images continuously by applying hydrodynamic modelling between the scenes. More information on: <http://www.freshmon.eu/>

2.5. Particles in hydropower reservoirs (Ccem funded)

We seek to retrieve particle mass concentration of suspended particles in the Alpine hydropower reservoirs of the Grimsel area, Switzerland, by remotely sensed data (such as air planes and satellites). To validate remotely sensed data, spectroradiometric *in-situ* measurements are carried out above and below the reservoir water, and water samples are analysed for particle mass concentration, particle size distribution and inherent optical properties.

2.6. Climate change and heat use in Lake Constance (KlimBo; InterregIV funded)

Mild winters, hot summers, extreme heavy rain events, and strong variations of the water level affect all in some ways the hydrodynamic conditions of Lake Constance. The InterregIV project KlimBo (Klimawandel Bodensee) - coordinated by the Institute for Lake Research, Germany - aims to quantify climate-induced changes of those processes. We focus on two subprojects: (i) evaluation of the heat balance of Lake Constance and how it is affected by climate change and heat pollution. The objective is to explore the capabilities and the limits of heat use. (ii) Quantification of climatic and hydrologic developments in the catchment area of Lake Constance in order to calculate the effects on deep water renewal and particle transport into the lake.

2.7. Double diffusion in Lake Kivu (SNF funded)

The goal of this project is to observationally characterize the interfaces and the mixed layers at small-scale resolution of mm to cm of the double diffusive layering of the water column of Lake Kivu. The observations are interpreted by *Direct Numerical Simulations* which relate the lake *in-situ* data to the underlying physical processes. The goal is to estimate the fluxes of salt, gases and heat through the double diffusive layering.

2.8. Optimization of the EPFL lakewater intake for heating/cooling of buildings

EPFL is using Lake Geneva water for heating/cooling its buildings. The 30 years old infrastructure has already reached its maximal capacity and our goal is to provide recommendations on the best strategy for the optimization of the to-be-replaced infrastructure.

3. Major acquired equipment

3.1. Research boat

The new acquired boat (see image) has an aluminium hull of 7 m length and 2 m width with a carrying capacity of 400 kg and it is equipped with a 70 HP motor and specifically with an A-frame and winch for lake work with heavy loads.



3.2. MiniProfiler MP4/8 automated micro-profiling system for oxygen

The new acquired MP4/8 micro-profiler (see image) can collect up to eight channels from micro-sensors simultaneously and profile from the water into the sediment in steps of 50 micro-meters.

3.3. RBR Duo (records 30 million simultaneous temperature and oxygen measurements)

3.4. Minilogger II (*in-situ* temperature sensors for natural waters)

3.5. ADCP 300 kHz (*in-situ* Acoustic Doppler Current Profiler for natural waters)

3.6. Two Wet-Labs backscattering meters (measures backscattering at 3 wavelengths)

4. Human resources

Dr. Bouffard Damien: Scientist and supervisors of PhD students at EPFL, since November 2012

Schwefel Robert: PhD Student since January 2013, project “Oxygen depletion in Lake Geneva”

Råman Vinnå Carl Love Mikael: PhD student since July 2013, project “Particles in Lake Biel”

Nouchi Vincent Maurice: Scientific assistant since May 2013, project “ULM on Lemman-Baikal”

Dr. Pasche Natacha: Deputy director and scientist for the Limnology Center, EPFL, since September 2013

Gonin Tania: secretary of APHYS and LIMNC since November 2013

Ferrante Ritzi Jessica: secretary of APHYS and LIMNC until October 2013

Eder Elisabeth: PhD student at Eawag, project “Particles in hydropower reservoirs”

Dr. Fink Gabriel: Postdoc at Eawag, project “Lake Constance climate change (Klimbo)”

Dr. Pitarch Jaime: Postdoc at Eawag, project “Freshmon”

Sommer Tobias: PhD student until October 2013 at Eawag, project “Double diffusion in Lake Kivu”

Schurter Michael: highly experienced technician at Eawag

Scharmin Eliane: secretary of APHYS group at Eawag

5. Networking

5.1. Oxygen depletion in Lake Geneva

- Lars Umlauf, Institut für Ostseeforschung, Warnemünde, Germany,
- Dr. Lee Bryant, Helmholtz Institute Geomar, Kiel, Germany,
- Beat Müller from Eawag.

5.2. Particles distribution in Lake Biel

- Roland Kaeser, Water works (ESB) City of Biel
- Natalie Dubois, Eawag.

5.3. Lemman-Baikal Project

- Limnology Center, EPFL
- Russian partners from Moscow State University, Metropol, Ulan Ude University
- EPFL partners, TOPO, LASIG, WIRE, EFLUM, ECOL laboratories

5.4. Freshmon

- Marnix Laanen, Water Insight, Wageningen, Netherlands
- Peter Heege, Eomap Münnich Germany
- Daniel Odermatt and Carsten Brockmann, Brockmann-Consult, Geesthacht, Germany
- Sampsa Koponen, Syke, Finish Institute of Environment, Helsinki Finland.

5.5. Particles in hydropower reservoirs

- Energy Center EPFL (Mohamed Farhat; Anton Schleiss, Massimiliano Capezzali)
- Steffen Schweizer, KWO Grimsel, BKW Bern

- Daniel Odermatt Brockmann-Consult, Geesthacht, Germany.

5.6. Klimbo

- Thomas Wolf and Bernd Wahl, Institute for Lake Research - State Institute for Environment, Measurements, Nature Conservation, Baden-Württemberg LUBW, Langenargen, Germany
- Ulrich Lang, Kobus and Partner, Stuttgart, Germany.

6. Conclusion and future directions

Within the next four years, we envisage to initiate the following new projects:

6.1. Sinergia project on underwater robots for high-resolution spatial mapping

This interdisciplinary project is a collaboration with Prof. Bas Ibelings from UNIGE and Prof. Alcherio Martinoli from DISAL laboratory at EPFL. The goal is to use underwater automatic vehicles to investigate the spatial heterogeneity of physico-biological processes in lakes. The proposal will be submitted by 15 January 2014.

6.2. Research platform on Lake Geneva

The aim of this research platform is to acquire continuous records of physical properties, biogeochemical processes, as well as phytoplankton and zooplankton. This platform should also promote international collaboration with other research groups interested in this facility. The equipment will be part of a Requite proposal to FNS in May 2014. First contacts with Canton Vaud and Geneva look promising concerning the required permission for anchorage.

6.3. Sentinel-3 validation team

The satellite Sentinel 3 will be launched in 2014 with high-resolution hyperspectral sensors. The APHYS team will take part as a validation team that will provide ground truthing for the validation of the satellite information. The platform (see above) will be equipped with special sensors for this purpose.

6.4. Lake Prespa

Lake Prespa is an ancient lake shared between Macedonia, Greece and Albania. Its great biodiversity is endangered by eutrophication. The aim of this project is to determine the sources of phosphate pollutions by a two years monitoring, and to test different scenarios for pollution reduction using a lake model and a catchment model. A proposal was sent to UNDP in October 2013.

6.5. Lake Ladoga

The main goal of this research is to study the development of under-ice convection in Lake Ladoga and its implications for algae development under ice. First contacts were taken with the Petrozavodsk University to start the project after a meeting in Switzerland early 2014.

7. Conferences

- Josef Daniel Ackerman, Damien Bouffard, Conference ASLO, Presentation: Impact of Physical processes on oxygen depletion in central Lake Erie, New Orleans, USA, 17.02.2013
- Damien Bouffard, Turbulence Days Workshop, Presentation: Physical processes and hypoxia in central Lake Erie, Warnemünde, Germany, 11-15.08.2013
- Damien Bouffard, Alfred Wüest, Bas Ibelings and Tuia Devis, S3VT ESA workshop. Presentation: Ground truthing in Alpine lakes, Frascati, Italy, 26-29.11. 2013
- Lee Bryant, Andreas Brand, Alfred Wüest et al., Conference ASLO, Presentation: Rocking seiches and sediment dancers: effects on sediment oxygen uptake and porewater chemistry, New Orleans, USA, 17.02.2013
- Elisabeth Eder, Conference SIL XXXII Congress, Poster: Retrieval algorithm for particle mass concentration in Alpine reservoirs Switzerland, Budapest, Hungary, 04.08.2013
- Gabriel Fink, Martin Schmid, Wahl Bernd, Thomas Wolf and Alfred Wüest, Conference Symposium The Water Cycle in a Changing Climate, Poster: Determination of processes causing the climate change signal in the surface water temperature of Lake Constance, Zürich, Switzerland, 01.06.2013
- Jaime Pitarch, Alfred Wüest et al., Conference EGU Meeting. Poster: A physically-based model for total suspended matter retrieval via hyperspectral reflectance inversion in turbid waters, Vienna, Austria, 11.04.2013
- KellyAnn Ross, Benoît Smets, Marc De Batist, Flavio Anselmetti, Martin Schmid and Alfred Wüest, Conference 21st Meeting of Swiss Sedimentologists, Presentation: Limnic eruption at Lake Kivu: hazard assessment from the analysis of bathymetric and sediment data in its main basin, Fribourg, Switzerland, 23.2.2013
- KellyAnn Ross, Martin Schmid, Augustin Gafasi, Elisée Gashugi and Alfred Wüest, Workshop Le Lac Kivu: Tirer les leçons de son passé pour gérer son avenir, Presentation: Hot and cold waters - Properties of groundwater inflows, Bukavu, DR Congo, 22.01.2013
- Kelly Ann Ross, Martin Schmid, Augustin Gafasi, Elisée Gashugi and Alfred Wüest, Workshop Lake Kivu: Learning from the past for managing its future, Presentation: Hot and cold waters - Properties of groundwater inflows, Kigali, Rwanda 17.01.2013
- Martin Schmid, Gabriel Fink and Alfred Wüest, Conference SIL XXXII Congress. Presentation: What drives the warming of Central European lakes? Budapest, Hungary, 04.08.2013
- Martin Schmid, Stefan Hunziker and Alfred Wüest, Conference 14th Swiss Global Change Day. Poster: Lake surface (equilibrium) temperatures in a changing climate, Bern, Switzerland 16.04.2013
- Chrysanthi Tsimitri, Martin Schmid and Alfred Wüest, Conference 16th International Workshop on Physical Processes in Natural Waters, Presentation: Inertial waves in Lake Baikal, Queensland, Australia, 08-11.07.2013
- Chrysanthi Tsimitri, Martin Schmid and Alfred Wüest, Conference European Geosciences Union General Assembly 2013, Poster: The characteristics of Lake Baikal's Internal Wave Spectrum, Vienna, Austria, 07 to 12.04.2013
- Alfred Wüest, Beat Müller and Lee Bryant, Conference ASLO, Presentation: Deep-water oxygen depletion in lakes and reservoirs, New Orleans, USA, 17.02.2013

- Alfred Wüest, Conference Cercl'Eau, Presentation: Zuviel und zuwenig – Ausgleich von Wärmeenergie mit Seen“, La Neuveville, Switzerland, 13.06.2013
- Alfred Wüest, Seminar VSA Fortbildungskurs 2013, Presentation: "Seeströmungen, Einschichtung und Verdünnung Bedeutung bei Abwasser- und Wärmeeinleitung", Emmetten, Switzerland, 23.05.2013
- Alfred Wüest, Workshop Tage der Technik (Akademie Empa), Presentation: Sind die neuen Stromquellen umweltverträglich integrierbar? EMPA, Dübendorf, Switzerland, 03.10.2013
- Alfred Wüest et al., Swiss Geoscience Meeting, Presentation: Using lakes as sources and sinks of heat – a new challenge in natural waters management, UNIL, Lausanne, Switzerland, 16.11.2013
- Alfred Wüest, ENAC Inauguration talk, Presentation: Life in waters for life – relating science to management and conservation, EPFL, Lausanne, Switzerland, 25.11.2013.

8. Publications

8.1. Published peer-reviewed papers in 2013

- Bouffard, D., J.D. Ackerman, and L. Boegman (2013). Factors affecting the evolution and dynamics of hypoxia in a large stratified lake: hourly to seasonal patterns. *Water Resour. Res.*, **49**: 2380–2394.
- Bouffard, D., and L. Boegman (2013). A diapycnal diffusivity model for stratified environmental flows. *Dyn. Atm. Ocean.*, **61-62**: 14-34.
- Bouffard, D., and U. Lemmin (2013a). Kelvin waves in Lake Geneva. *Journal of Great Lakes Research*, **39**: 637–645, doi:10.1016/j.jglr.2013.09.005.
- Bouffard, D., and U. Lemmin (2013b). A newly developed moored sensor platform for turbulence measurements in stratified lakes. *J. Atm. Oceanic Tech.*, **30**(8):1789-1802, doi: 10.1175/JTECH-D-12-00159.1
- Finger, D., A. Wüest, and P. Bossard (2013). Effects of oligotrophication on primary production in peri-alpine lakes. *Water Resources Research*, **49**(8): 4700–4710, doi:10.1002/wrcr.20355.
- Jordanoska, B., T. Stafilov and A. Wüest, (2013). Assessment of ecological importance and anthropogenic change of subaquatic springs in ancient Lake Ohrid. *Water Research and Management*, **3**(2): 9-17.
- Kunz, M.J., D.B. Senn, B. Wehrli, E. M. Mwelwa, and A. Wüest (2013). Optimizing turbine withdrawal from a tropical reservoir for improved water quality in downstream wetlands. *Water Resources Research*, **49**: 5570–5584, doi:10.1002/wrcr.20358.
- Razmi, A.M., D.A. Barry, R. Bakhtyar, N. Le Dantec, A. Dastgheib, U. Lemmin, and A. Wüest (2013). Current variability in a wide and open lacustrine embayment in Lake Geneva (Switzerland). *J Great Lakes Research*, **39**: 455 – 465, doi: 10.1016/j.jglr.2013.06.011.
- Schwalb, A.N., D. Bouffard, T. Ozersky, R.E.H. Smith and L. Boegman (2013). Impacts of hydrodynamics and benthic communities on phytoplankton distributions in a large, dreissenid-colonized lake (Lake Simcoe, Ontario, Canada). *Inland Waters*, **3**(2): 269-284.

Sommer, T., J.R. Carpenter, M. Schmid, R. G.Lueck, M. Schurter, and A. Wüest (2013). Interface structure and flux laws in a natural double-diffusive layering. *J. Geophys. Res. Oceans*, **118**(11): 6092-6106, doi:10.1002/2013JC009166.

Sommer, T., J.R. Carpenter, M. Schmid, R.G. Lueck, and A. Wüest (2013). Revisiting microstructure sensor responses with implications for double-diffusive fluxes. *Journal of Atmospheric and Oceanic Technology*, **30**(8): 1907–1923, doi: 10.1175/JTECH-D-12-00272.1.

8.2. Submitted manuscripts to peer-reviewed Journals in 2013

Fink, G., M. Schmid, B. Wahl, T. Wolf and A. Wüest. Heat flux modifications related to climate-induced warming of large European lakes. *Water Resources Research*, revised.

Müller, B., R. Gächter, and A. Wüest. Vollenweider 1969 revisited after 30 years of lake restoration experiences. *Environ. Sci. Technol.* submitted

Muvundja, F.A., A. Wüest, M. Isumbisho, M. Kaningini, N. Pasche, P. Rinta and M, Schmid. Modelling Lake Kivu water level variations over the last seven decades. *submitted to Limnologica*.

Pitarch, J., D. Odermatt, M. Kawka, and A. Wüest. Retrieval of water optical properties by genetic algorithms in the presence of vertical gradients of total suspended matter. *Remote Sensing of the Environment*, submitted.

Schmid, M., S. Hunziker, and A. Wüest. Lake surface temperatures in a changing climate: a global sensitivity analysis. *Journal Climatic Change*, submitted

Sommer, T., J.R. Carpenter, and A. Wüest. Representativeness of direct numerical simulations for double diffusion in natural systems. *Geophys. Res. Letters*, GRL submitted

8.3. Reports and experts services

Bouffard D. et A. Wüest (2013). Analyse des fluctuations de température dans la station de pompage de l'EPFL. Report APHYS-13-1 for EPFL

Müller B., and A. Wüest (2013). Entwicklung der Sauerstoffzehrung im Hallwilersee, Report for AfU Canton. Aargau.

9. Teaching

PEAK-Basiskurs B20/13, Möglichkeiten und Grenzen von Kleinwasserkraftwerken, Eawag 26-27 Sept. 2013, www.eawag.ch/lehre/peak/kurse/peak_b20_13.pdf

VSA Weiterbildungskurs, Gewässerschutzplanung (Seeströmungen, Einschichtung und Verdünnung Bedeutung bei Abwasser- und Wärmeeinleitung), April 2013, www.vsa.ch/schulungen-und-tagungen/

Environmental Fluid Mechanics – lakes and reservoirs. University Joseph Fourier, LEGI, Grenoble, France, fall semester 2013.