EuroRun – Final report

❖ Background & Aims of EuroRun

Inland waters contribute to global CO_2 emissions with values comparable to the total CO_2 uptake of the oceans, while running waters emit the largest proportion with about 70%. The processes that influence CO_2 fluxes in running waters are complex and include physical and biological factors that can influence the CO_2 concentration in the water and vary on a diurnal and seasonal scale. However, the magnitude and mechanisms of CO_2 fluxes in running waters are still not adequately quantified or understood, contributing to a high uncertainty in upscaling approaches.

EuroRun aimed towards a better estimation and understanding of CO_2 fluxes in European running waters. The major focus of EuroRun was laid on estimating diurnal and seasonal differences of CO_2 fluxes from European running waters and represented the first coordinated European-wide study to examine fluvial CO_2 fluxes. To get a spatially and temporally resolved dataset, a group of early career scientists from across Europe measured day and nighttime CO_2 fluxes every three months for a one year period. The dataset allows us to:

I. evaluate differences between day and night fluxes in running waters across Europe.

II. understand mechanisms behind observed differences based on physical-chemical parameters of the running waters and catchment characteristics.

❖ The Team

EuroRun was coordinated by Dr. Pascal Bodmer and Dr. Katrin Attermeyer (PIs) and consisted of seven core teams which were each represented by members of the seven limnological societies that provided funding (Germany, Switzerland, Italy, Spain/Portugal, Austria, United Kingdom, France). Those teams were complemented by nine more (to a total of 16) teams that were selected after an open call. EuroRun received 24 applications in response to this call (see Fig. 1 for teams applying and invited). Subsequently, we limited the number of additionally invited teams based on their distribution in Europe to cover a broad geographical gradient (Fig. 1) and our financial possibilities. EuroRun thus coordinated 16 teams from 11 European countries with two to six members each (Fig. 2). This added up to a total of 47 young and early career researchers that were connected via EuroRun. The gender distribution within the project was with 53 % women and 47 % men very balanced (Fig. 3).

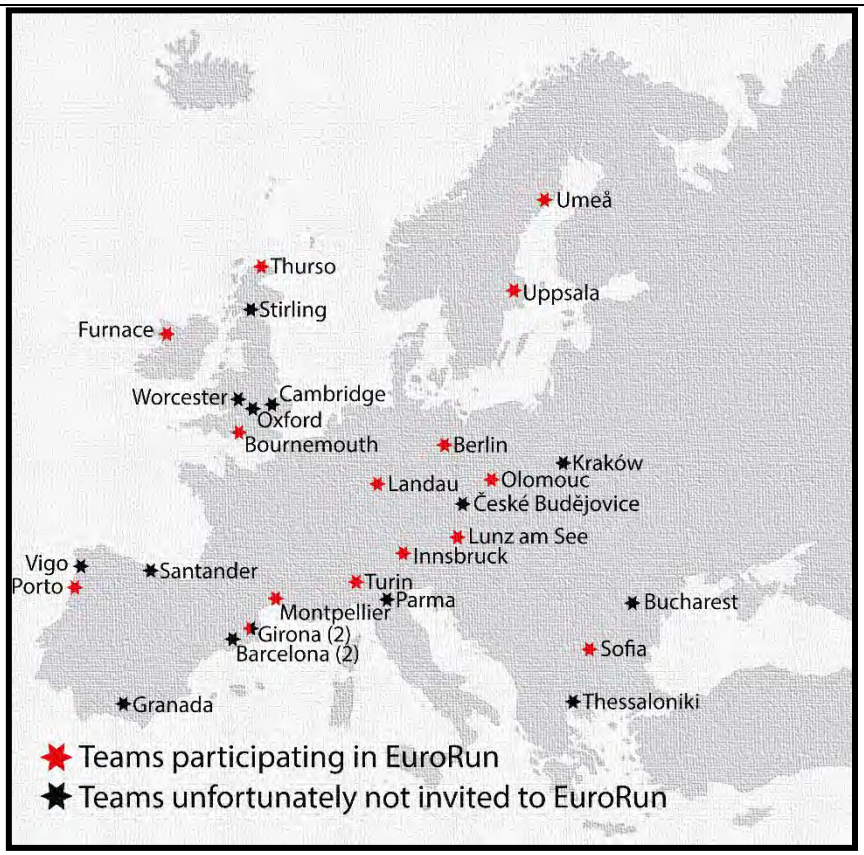

Figure 1. European map showing all teams that applied (black and red stars) and that were finally invited to EuroRun (red stars).

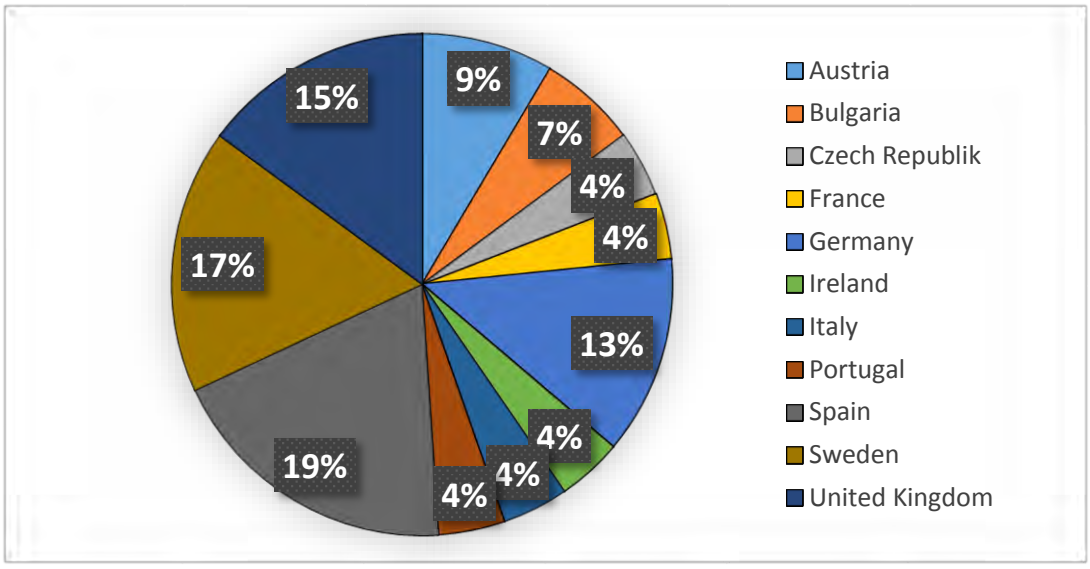

Figure 2. Pie chart showing proportion of EuroRunners in each of the 11 countries.

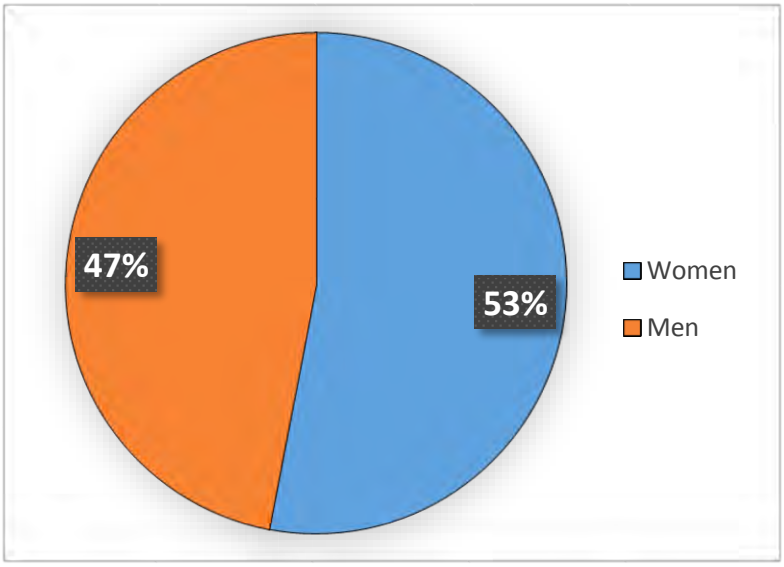

Figure 3. Pie chart showing proportion of women and men participating in the EuroRun project.

❖ Methods & Workshop

To collect the data for EuroRun, each team sampled one to three streams, resulting in a total of 34 sampling sites. These sampling sites were sampled within a fixed period of two weeks in four seasons from October 2016 to July 2017. Briefly, CO_2 fluxes were measured at the air-water interface with a drifting chamber equipped with a CO_2 sensor regularly logging CO_2 concentrations in the chamber headspace, while the chambers were allowed to freely drift on the water surface with the water current (*1*, *2*) (pictured in Fig. 4). By the increase or decrease of CO_2 in the headspace of the floating chamber, we calculated the directly measured fluxes. These measurements were done at mid-day (Fig. 4A&B) and midnight (Fig. 4C) in order to compare day and night fluxes of CO_2. Additionally, background data of the stream and the catchment were measured and gathered, respectively.

Figure 4. Drifting flux chamber on (A) the Steinbach (Austria) during the summer campaign 2017 (Photo: Thomas Fuß); (B) the Bystřice (Czech Republic) during the spring campaign 2017 (Photo: Adam Bednařík); (C) the Oskava (Czech Republic) at night during the spring campaign 2017 (Photo: Adam Bednařík).

1. D. Bastviken *et al.*, Technical Note: Cost-efficient approaches to measure carbon dioxide (CO2) fluxes and concentrations in terrestrial and aquatic environments using mini loggers. *Biogeosciences*. **12**, 3849–3859 (2015).
2. A. Lorke *et al.*, Technical note: Drifting versus anchored flux chambers for measuring greenhouse gas emissions from running waters. *Biogeosciences*. **12**, 7013–7024 (2015).

While the CO_2 sensors were prepared before the workshop by the two PIs, the chambers and tests of the CO_2 sensors for the flux measurements were completed during a workshop at Lake Erken, Sweden (Fig. 5A). In addition, the handling of the chamber and data analysis were taught at this workshop (Fig. 5B). It took place from 13.-15.09.2016 and brought together 17 early career researchers who were the representatives of their respective team and hence the major contact persons for the PIs of EuroRun. It was a very stimulating atmosphere and many ideas were discussed and developed during this time. Additionally, there was time for socializing and networking (Fig. 5C).

Figure 5. EuroRun workshop at Lake Erken in Sweden. (A) Group picture with completed flux chambers; (B) Teaching and demonstration of measurement procedures; (C) Common dinner with time for socializing.

❖ Preliminary Results & Next Steps

In order to tackle our overall objective and evaluate differences between day and night CO_2 fluxes as well as understand their mechanisms as formulated in the initial proposal (see summary in section "Background & Aims of EuroRun"), the EuroRun team performed four sampling campaigns (03.-14.10.2016 for autumn; 09.-20.01.2017 for winter; 03.-14.04.2017 for spring, 10.-21.07.2017 for summer).

During the field campaigns and beyond that, we gathered a large data set with a wide range of parameters (Table 1). The EuroRun team collected 1200 CO_2 flux data which are currently screened for quality and analyzed for publication. Preliminary results show, that the majority of the investigated running waters show higher CO_2 fluxes during the night compared to the daytime. Moreover, some running waters turn from a CO_2 sink during daytime to a CO_2 source during the night. Hence, the time of day for the CO_2 flux measurements is crucial and especially important when the aim is to upscale the data. The next steps include the data processing and exploitation of the mechanisms based on the complementary data (Table 1). Finally, we will develop a storyline based on the main objective and aims and write the manuscript. For this purpose, the PIs met at the end of January 2018 and finished the quality screening and started developing a storyline for the publication. We aim to have a first draft of the manuscript ready by summer 2018.

Table 1. Measured parameters for 34 European streams during the EuroRun project.

Category	Specific parameters	Frequency of measurements	Provides for example information for:
CO_2 related measurements	• Partial pressure of CO_2 in the surface water • CO_2 flux from/to the atmosphere	Every season at day and night time for each stream	Comparison of day and night CO_2 fluxes, testing North-South gradients of annual CO_2 fluxes
Stream background information	• Stream order • Amount of inflowing tributaries • Distance to upstream lake • Total length of the stream • Catchment area until endpoint of investigated stream reach • Climate zone • GPS coordinates • Altitude • Predominant vegetation which is lining the defined stream stretch	Once for each stream	Characterization of investigated streams
Catchment information	• Percentage of different land use within the catchment until endpoint of investigated stream reach (forest, agriculture, urban) • Predominant geology of the catchment	Once for each stream	Testing the influence of catchment characteristics on measured CO_2 related parameters
Weather data	• Average precipitation (2 weeks) • Average air temperature (2 weeks) • Precipitation (within 24 hours of sampling) • Sunrise and sunset • Average solar radiation (for sampling day) • Sun hours	Once every season for each stream	Characterization of the seasons in which CO_2 related parameters were measured
Physical/chemical parameters	• Water temperature • pH • Conductivity • Oxygen concentration	Every season at day and night time for each stream	Testing the influence of physico-chemical parameters on measured CO_2 related parameters
Hydromorphological parameters	• Wetted stream width • Average cross-sectional area • Average depth • Surface water flow velocity • Total discharge	Once every season for each stream	Testing the influence of hydromorphological parameters on measured CO_2 related parameters
Additional stream specific information	• Canopy cover • Predominant benthonic compartment	Once every season for each stream	Background information for eventual special patterns in measured CO_2 related parameters

❖ List of published & planned publications

Non peer-reviewed

1) Attermeyer, K., Bodmer, P. (2017) EuroRun – Assessing CO_2 fluxes from European running waters. Freshwater Biological Association News, 73: 10-12.
2) Fenoglio, S., Doretto, A., Baltieri, M. (2017) Il respiro del fiume. L'Ora del Pellice, 3: 66-67.
3) Doretto, A., Fenoglio, S., Baltieri, M. (2017) Il respiro del fiume. Fly Line - Ecosistemi fluviali, 32: 65-71.

Peer-reviewed

4) Katrin Attermeyer, Joachim Audet, Laura Barral-Fraga, Tea Basic, Adam Bednařík, Georgina Busst, Joan Pere Casas-Ruiz, Núria Catalán, Sophie Cauvy-Fraunie, Miriam Colls, Elvira de Eyto, Anne Deininger, Alberto Doretto, Brian C. Doyle, Vesela V. Evtimova, Stefano Fenoglio, David Fletcher, Jérémy A. Fonvielle, Anna Freixa, Thomas Fuß, Peter Gilbert, Catie Guttman-Roberts, Sonia Herrero Ortega, Lyubomir A. Kenderov, Marcus Klaus, José L. J. Ledesma, Liu Liu, Clara Mendoza-Lera, Juliana Monteiro, Jordi-René Mor, Magdalena Nagler, Georg H. Niedrist, Christian Noss, Anna C. Nydahl, Nina Pansch, Ada Pastor, Josephine Pegg, Francesca Pilotto, Ana Paula Portela, Clara Romero González-Quijano, Ferran Romero, Martin Rulík, Wiebke Schulz, Danny Sheath, Nikolay Simov, Xisca Timoner, and Pascal Bodmer. Working title: Time of day matters – Diurnal changes of CO_2 fluxes across European streams. In preparation

5) Andrea G. Bravo, Dolly N. Kothawala, Katrin Attermeyer, Emmanuel Tessier, Pascal Bodmer, José L. J. Ledesma, Joachim Audet, Joan Pere Casas-Ruiz, Núria Catalán, Sophie Cauvy-Fraunie, Miriam Colls, Anne Deininger, Vesela V. Evtimova, Jérémy A. Fonvielle, Thomas Fuß, Peter Gilbert, Catie Guttman-Roberts, Sonia Herrero Ortega, Liu Liu, Clara Mendoza-Lera, Juliana Monteiro, Jordi-René Mor, Magdalena Nagler, Georg H. Niedrist, Anna C. Nydahl, Ada Pastor, Josephine Pegg, Francesca Pilotto, Ana Paula Portela, Clara Romero González-Quijano, Ferran Romero, Martin Rulík, and David Amoroux. Mercury concentrations in fluvial systems predicted by organic matter signature: A latitudinal study across Europe. Under review in Water Research

6) Pascal Bodmer, Lea Steinle, Katrin Attermeyer, Adam Bednařík, Lukas Thuile Bistarelli, Christoph Bors, Núria Catalán, Sophie Cauvy-Fraunié, Miriam Colls, Elvira de Eyto, Brian C. Doyle, Vesela Evtimova, Stefano Fenoglio, Anna Freixa, Thomas Fuß, Paul Gaffney, Peter Gilbert, Catie Guttman-Roberts, Sonia Herrero Ortega, Marcus Klaus, Dominique Lamonica, Jordi-René Mor, Magdalena Nagler, Georg H. Niedrist, Anna C. Nydahl, Josephine Pegg, Elena Piano, Francesca Pilotto, Ferran Romero, Clara Romero González-Quijano, Martin Rulík, Nikolay Simov, and Andreas Lorke. Working title: Magnitude and drivers of sediment methane production in streams across Europe. In preparation

7) Magdalena Nagler, Katrin Attermeyer, Joachim Audet, Adam Bednařík, Lukas Thuile Bistarelli, Christoph Bors, Núria Catalán, Sophie Cauvy-Fraunié, Miriam Colls, Elvira de Eyto, Brian C. Doyle, Vesela Evtimova, Stefano Fenoglio, Anna Freixa, Thomas Fuß, Paul Gaffney, Peter Gilbert, Catie Guttman-Roberts, Sonia Herrero Ortega, Marcus Klaus, Dominique Lamonica, Jordi-René Mor, Georg H. Niedrist, Josephine Pegg, Elena Piano, Francesca Pilotto, Ferran Romero, Clara Romero González-Quijano, Martin Rulík, Nikolay Simov, Lea Steinle, and Pascal Bodmer. Working title: Biogeography of methanogens and methanotrophs across European streams. In preparation

❖ Outreach & Conference Participations

EuroRun was presented at three conferences, one Mini-Symposium and one student day of SIL-Austria. At the Symposium for European Freshwater Sciences (SEFS) in Olomouc, Czech Republic, the PIs of EuroRun organized a special session (SS06) on "Spatial and temporal heterogeneity of greenhouse gas fluxes in inland waters", a topic related to the EuroRun project. It received 18 abstract submissions (3 posters and 15 talks). Furthermore, there is a homepage with information about the project and updates on what is happening (https://freshproject-eurorun.jimdo.com/). Additionally, a project was created on ResearchGate (https://www.researchgate.net/project/Assessing-CO2-Fluxes-from-European-Running-Waters-EuroRun) which has 61 followers and 513 reads (on the 29.01.2018).

List of conferences/symposia

25th October 2017	Student day SIL-Austria in Innsbruck, Austria, Talk by Georg H. Niedrist
4th July 2017	Symposium for European Freshwater Sciences 10 in Olomouc, Czech Republic, Talk by Katrin Attermeyer
7th June 2017	Mini-Symposium for Early Career Researchers in Uppsala, Poster presentation by Katrin Attermeyer
23rd March 2017	Flow Country Conference IV in Thurso, Scotland, Talk by Peter Gilbert
26th – 30th September 2016	Joint conference of the Austrian and German limnological societies in Vienna, Austria, Poster presentation by Katrin Attermeyer

❖ Associated Projects

The framework of the EuroRun project offered a great opportunity for associated projects. The PIs of EuroRun always encouraged other researchers to use the structure of EuroRun and think about their own ideas. In collaboration with Andrea Garcia Bravo, additional samples from 27 out of 34 sampling sites were collected during the first sampling campaign in October 2016. The major aim of this study was to examine the influence of dissolved organic matter composition, catchment characteristics and water chemistry to predict total mercury, methylmercury concentrations, and the percentage of methylmercury out of total mercury in

European running waters. The EuroRun network offered the opportunity to take samples in a large number of running waters across Europe and thereby represents one of the first assessments of mercury concentrations of European running waters. The data are analyzed and the manuscript is under review. Pascal Bodmer received funding from the German Research Foundation (DFG) for a project about "The Magnitude and Drivers of Sediment Methane Production in Streams across Europe" (BO 50505/1-1) and 15 teams from the EuroRun project participated and collected samples for this project. The EuroRun teams were always open for new ideas and reacted positively towards the ideas that came up during the EuroRun project.

❖ Finances

The total budget of EuroRun was 13.000 € of which 8.000 € was provided by the FreshProject call and 5.000 € from the Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin. Part of the money was used for a workshop in Linköping where we learnt to modify the CO_2 sensor and build the chamber (light blue). A total of 19 % was used to buy the material for the chambers for all participating teams (orange and light gray). Another 29 % went into the workshop held at Lake Erken in Sweden where all team representatives were flown in and accommodated (yellow and blue). The sampling expenses added up to 12 % of the budget (green) and 3 % for outreach such as poster printing and conference participation (dark blue). Approximately 10 % will be used to organize meetings for data discussion and paper writing (brown) and the rest (24 %) will be used to pay the open access publication which will happen after the final report is due. Figure 3 shows the expenses split by the different actions of EuroRun.

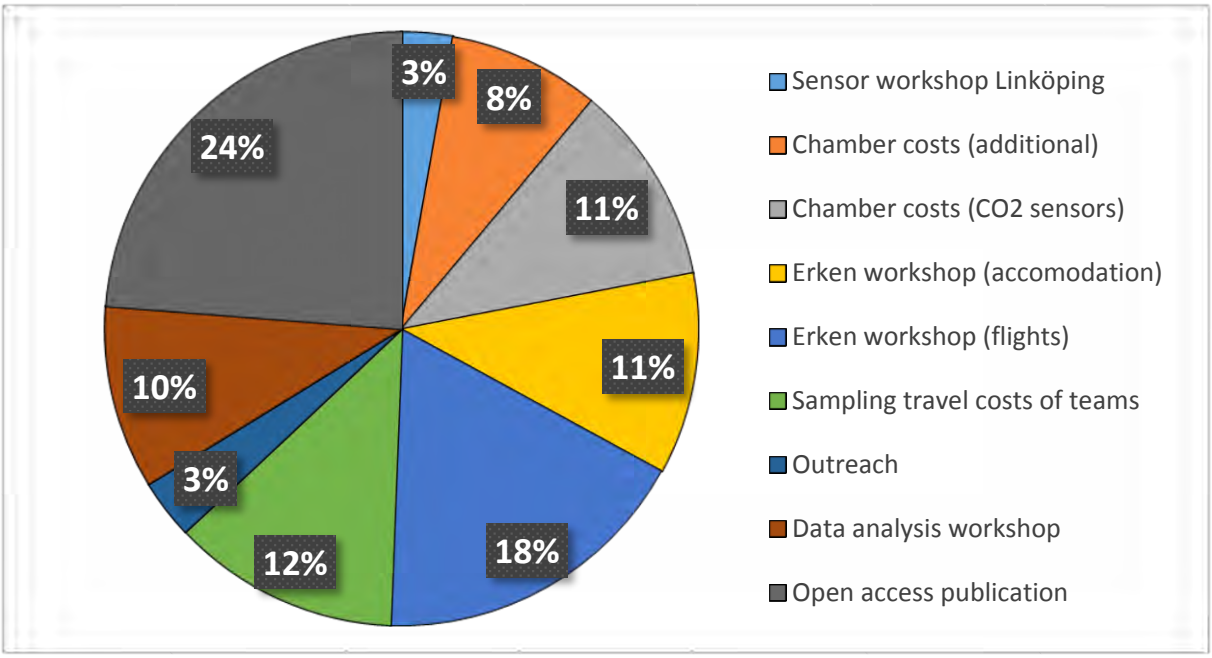

Figure 6. Expenses of EuroRun (total of 13.000 €).

❖ Review of Initial Goals of the Call & Experiences Transferrable to Future Projects

"*It has the primary goals of encouraging young freshwater researchers across **Europe** to create synergistic interactions that lead to new knowledge, promote **networking** among young European Limnologists and offer experience in generating research ideas, acquiring funding, planning and carrying out a collaborative international **scientific project**.*" (1st Collaborative European Freshwater Science Project for Young Researchers, ("FreshProject")" - call for Proposals)

Reviewing the primary goals of the initial call, we were able to fulfil all of them. EuroRun was built, according to the initial call (text above in bold), on the three pillars "Europe", "Science", and "Network" (Fig. 7). With the available budget, we were able to bring together 47 freshwater scientists from 11 European countries (= Europe). All teams sampled in all seasons (except some teams in winter when there was ice coverage) which led to a total number of 1200 CO_2 flux values and additional parameters, enabling to assess differences between day and night CO_2 fluxes from streams and evaluate the mechanisms of the observed differences (= Science). In addition, we created a network of 47 young and early career researchers and organized a workshop where the team representatives met and connected with each other (= Network). In summary, we conducted a collaborative international scientific project leading to results which will be published in a peer-reviewed journals and is thus relevant for the scientific community.

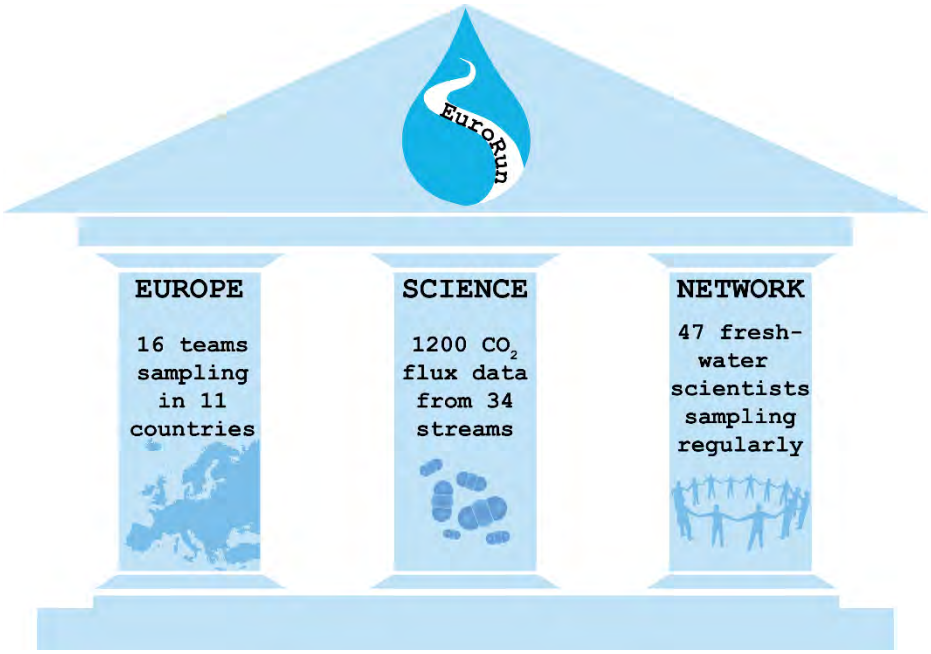

Figure 7. Summary of initial goals of the project call and their implementation in the EuroRun project.

In general the project worked well and smooth. In the following we summarized the main points eventually relevant for future projects and our personal experiences.

- *Communication between PIs*: EuroRun was mutually led by the two PIs, whereby the communication was very intensive (e-mails, Skype, Whatsapp). The work was split in a balanced way and decisions and strategies were made and set mostly in consultation with each other. When one PI was not able to invest time in EuroRun, the other helped out and took over the communication for a while, enabling a constant communication within EuroRun.
- *Communication between PIs and EuroRun teams*: The main communication was through e-mails. The teams were contacted through group e-mails, usually followed by individual e-mails to clarify questions. A shared dropbox folder was created, where the main documents (papers, calculation sheets) where accessible for all team members and a google drive was available where pictures were uploaded.
- *Level of data quality*: Data quality had from the beginning a very high priority. Hence, we used the workshop to make sure all EuroRun teams have sufficient background knowledge to perform the measurements in a sophisticated way. Furthermore, we wrote a detailed sampling manual containing all relevant steps for the fieldwork, a checklist for the field and several calculation sheets in order to standardize the data processing.
- *Networking*: The workshop was a great success for connecting the team representatives. The workshop and the common experiences in the field (although in different places) brought the people together. The result could be nicely seen in funny and supporting posts in Whatsapp groups and at the partial reunion at the SEFS 10 conference (Fig. 8).

Figure 8. Partial EuroRun reunion at the SEFS 10 conference in Olomouc (Czech Republic).

- *Visibility*: We created a homepage with a news section, which got regularly updated. In parallel, we created a project on ResearchGate which increased the visibility of the project massively. We also reported about the project and our experiences in an article published by the Freshwater Biological Association of the United Kingdom reaching around 2000 freshwater scientists in the United Kingdom. Furthermore, we got in contact with the GLEON initiative (project DC-FLUX; http://gleon.org/research/projects/dc-flux) which aims to assess diurnal CO_2 fluxes in lakes across the globe and with scientists from GLEON and beyond.

It was a great pleasure to lead and coordinate EuroRun with such a large and diverse group of early career researchers despite stressful periods and high demands onto the two of us as PIs. However, in a project of this magnitude, with a very limited budget, we also faced great challenges. First, it is very important that everybody is properly informed and for this purpose, we wrote and received several hundreds of e-mails which can be highly time consuming. Secondly, we had to coordinate four sampling campaigns in four seasons over one year where 47 scientists were sent out in the field each time. Field work itself is challenging and always requires a certain amount of flexibility when something goes wrong, the equipment stops working or the conditions at the sampling sites change. Here, we communicated via e-mail and Whattsapp to be able to respond quickly and solve technical issues and answer urgent questions, even in the middle of the night or at the weekend. Furthermore, the high workload at certain phases of the project can cause problems, especially when it interferes with the other project that we were actually paid for. In our case, we were very happy that our projects and supervisors gave us the freedom to spend the time we needed onto this project. But then the project can only work when also the other participants invest time and get this freedom during their other projects. Especially early career researchers are often integrated and paid by other projects and thus need to participate in a project like EuroRun during their free time. However, during EuroRun, we did not encounter major problems with this issue and were able to finish all sampling campaigns with the full team of EuroRunners. During the coordination of the EuroRun project, we came across guidelines from fellowships that do not allow the participation in such projects because they want the recipients to focus only on the project they are paid for. Although this is understandable, it can cause problems for such projects that are aiming at building networks among researchers that do not get the freedom to connect and engage in other projects.

Nevertheless, despite the stress and workload, we would always do it again and we can only recommend to other early career researchers to participate in those calls and initiate such projects. The EuroRun project demonstrates that working with young and early career scientists is very rewarding and those scientists should be given more opportunities to create and conduct their own research independent of their own projects and supervisors with their own money and providing them with time to do it.