A Report

Submitted to the Tall Tower and Surface Research Network for the Verification of Climate Relevant Emissions of Human Origin

On

An International Workshop 'Advancing the science of gas exchange between fresh waters and the atmosphere' held in the University of Helsinki during 15-19th September 2014 & visiting Forest Research Station of the University of Helsinki with Professor Timo Vesala with a view to develop collaborative research

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Introduction

Better understanding of the sources and sinks of greenhouse gas emissions are of utmost importance. Fresh waters are important carbon and nitrogen cycling components in the landscape. Streams and rivers transport substantial quantities of organic and inorganic C and N to downstream ecosystems, such as lakes, and to the oceans. They also efflux large quantities of N_2O , CO_2, CH_4, DOC, DIC to the atmosphere. As with rivers, lakes tend to efflux N_2O , CO_2, CH_4 to the atmosphere. Understanding the roles fresh waters play in landscape scale C and N dynamics is critical to understanding the full N and C cycle; however; we are only beginning to quantify key C and N fluxes between fresh waters and their adjacent ecosystems and have much to learn about the controls over carbon flux and how they change across ecosystem gradients and space and time scales. The people across the world working on greenhouse gas measurement and

mitigation in fresh water need to meet and discuss towards the advancement of the methodological development as well as abate the emissions in fresh waters.

Objectives

1. Form an international community of scientists who study gas exchange between the atmosphere and fresh waters
2. Begin to develop standards (or best practices) for the measurement of gas exchange over fresh waters, as well as identify critical variables necessary for, comparisons across systems
3. Draft one or more manuscripts in the following areas:

   a. Synthesis of the state of the science of gas exchange between fresh waters and the atmosphere

   b. Comparison of gas exchange across key ecosystem gradients, such as lake trophic state, lentic to lotic systems, lake size, etc.

Scientific Programmes

I reached Helsinki on 14th September and travelled to the Hyytiala Forest Station on 15th September. The programme started on 15th September at the evening with an introductory speech of Professor Timo Vesala followed by a dinner and collecting keys for the room. The programme continued though the week and ended with the visit of the Forest Research Station of the University of Helsinki followed by a boreal dinner.

Working on Greenhouse Gas Emissions and Mitigations

There were some common and group based discussions on measurement methodologies of greenhouse gases in lakes, rivers and wetlands. The major challenges to address were identified as below:

- how can we select sites, measure well, and spatiotemporally scale lake-atmosphere flux measurement and connect to lake process measurements and models?
- at single sites, across regions, globally
- with protocols for harmonization of measurement and data processing (quality control) across groups

- for both the cases of monitoring "supersites" and large sample of sites for process understanding/experiments
- with a particular focus on emerging use of eddy covariance and floating chambers over lakes

Methods used to measure greenhouse gases

- Eddy covariance
- Diffusive gradient
- Chambers (floating, bubbles)
- Remote sensing/spectral
- Water budget (residual of other terms)
- Atmospheric budget/inversion
- Atmospheric flux gradient

Recommendations

- Annual GHG Emissions and budget
  - Requirement: need to measure and evaluate stocks and fluxes with sufficient frequency to scale over time and over whole system
  - Caveat: Flux tower isn't always the best tool for this.
  - If this is only question, don't need a flux tower
  - If you want to be in ICOS, you need a tower, but if fluxes of a GHG in your system is small, then you should opt for chambers instead of EC
- Understanding processes and drivers of trends and patterns of GHG emissions and budgets
  - Requirement: measure environmental and biological drivers across time
- Predicting future carbon storage, terrestrial/ocean subsidy (active/passive pipe), climate change impacts to aquatic biogeochemistry and hydrology
  - Requirement: Relevant parameters for predictive lake and climate models
- Decision support questions: Water quality, acid deposition (lake acidification + acid rain), policy for water management, water levels/drought and floods, invasive species, food web, fish

- How do thermal and hydrologic budgets of inland water systems vary and are influenced/feedback to atmosphere (e.g., large lakes)
- Grand challenges in ecology
- Exploratory science, curiosity driven questions on fundamental questions in limnology, measurement science, surface-atmosphere exchange, geography
    - Requirement: Having a core set of long-term measurements that provides the basis for interpreting hypotheses about physics, chemistry, biology, geology, ecology of a system

Remarks

- Advection can be of the same magnitude as turbulent flux over small lakes, recirculation flows at forest/lake edge can create persistent + and - flux biases
- Convection can produce significant C flux, k is sensitive to water body type and stability, pCO_2 can vary by 200 ppm with depth near surface (and this gradient changes diurnally)
- Floating chambers and eddy fluxes have similar magnitudes but differing temporal patterns. Relationship for k based on w* does better than one on wind speed on fitting EC tower C flux
- Floating chambers work, maintain turbulence, and are not the same as soil chambers and can't be directly compared to EC

Conclusions

More evaluation of EC over lakes needed, multiple measurements are key, need to lay out protocols for flux measurement - both experimental and theoretical issues exist. A set up of details study site, called supersite, in Europe is needed. Every method has its own benefit in measuring greenhouse gas but more comparisons of study needed for eddy covariance, camber and diffusive methods used throughout the world. A report as a book or review paper will be published based on the workshop. The workshop will be organized every second here at the same venue to continue meeting with scientists, early career researchers and PhD students for addressing the challenges identified in this meeting. I global project will be submitted to establish a supersite in Europe to measure greenhouse gas in fresh waters.