Advancing approaches for multi-year high-frequency monitoring of temporal and spatial variability in carbon cycle fluxes and drivers in freshwater lakes

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Photo Credit: Ted Bier
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Why study lakes?

- Inland waterbodies comprise significant component of many landscapes
- They disproportionally influence regional carbon cycles, and possibly global carbon cycle

Adrian et al 2009

Drake 2017
The Problem

- Carbon cycling in lakes involves interaction of multiple physical and biological drivers.
- Measurements of carbon efflux and drivers is often limited to 1-2/year and labor intensive.

Williamson et al. 2009
Further, traditional approaches to estimating $pCO_2$ by carbonate chemistry is fraught with uncertainty!

Therefore,

Can we combine recent advances in *high-frequency eddy covariance over lakes*, *boat-mounted* or *buoy-mounted* gas analyzers, and *direct chamber fluxes* to better investigate role of biology and physics on lake C efflux?
Study site and tools

Loken et al., in prep
Eddy Covariance

\[ \text{Flux} = \rho w' c' \]
Buoy Flux

\[ Flux = k_{600} \cdot Kh \cdot (pCO_{2\text{water}} - pCO_{2\text{air}}) \]
Fast Limnological Automated MEasurements (FLAME)

\[ Flux = k_{600} \cdot Kh \cdot (pCO_{2\text{water}} - pCO_{2\text{air}}) \]

http://flame.wisc.edu

Crawford et al., 2015

Los Gatos, Inc.

Chambers

$$Flux = \rho \frac{Vol}{Area} \left( \frac{dCO_2}{dt} \right)$$
So what do they say?
Six years of a shoreline flux tower!

Blue = Ice covered
White = Open water

![Graph showing daily NEE (gC m^-2 day^-1) from 2012 to 2018. The graph tracks the flux tower's carbon source and sink with color-coded lines for CFL tower, FLAME, Picnic Point tower, and Buoy. Carbon source and sink periods are highlighted with blue bars.](image-url)
Source or sink? Depends who you ask
Lots of noise, but some encouraging signs when looking at details

Angela Baldocchi

**B51I-1941**: A Spatial-Temporal Comparison of Lake Mendota CO₂ Fluxes and Collection Methods, **FRI, 08:00 - 12:20, Poster Hall D-F**
Still, can we learn something about lake carbon efflux?

Cumulative NEE

- Ice covered
- Source
- Mixis
- Stratified season
- Sink

Days Since Ice Out

gC m²

-200 -100 0 100 200 300

-200 -100 0 100 200 300

2012 2013 2014 2015 2016 2017
Spatial variations are persistent

Issues with eddy covariance over lakes

- Fluxes look like they are upside down to others and theory
- Are periods of over ice carbon uptake real?
- Large fall uptake when $pCO_2$ is very large, but lake is convective, so could happen
- High noise floor
- Flux footprint screening
- Shoreline/building flow concerns

Lakes are much harder to make good flux measurements than other surfaces.

Averaging helps. Diurnal cycles have some interesting patterns.
Can we explain interannual variability?
Multi-timescale modes of variability require more sophisticated approaches.

Advancing lake carbon cycle research: The impact of temporal and spatial sampling

Temporal Sampling

Spatial Sampling

Loken et al., in prep
Advancing lake carbon cycle research: Moving towards a global synthesis

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  – Dept. of Energy Ameriflux Network Management Program (ChEAS Core Site)
  – University of Wisconsin WARF UW2020 Discovery Initiative

• Websites:
  – https://flame.wisc.edu/
  – https://lter.limnology.wisc.edu/
  – http://flux.aos.wisc.edu/

• Publications:
  – Malgorzata Golub et al., 2017, J Geophys Res.-G (pCO₂ uncertainty),
  – David Reed et al., in review L&O (CFL Eddy flux Tower)
  – John Crawford et al., 2015 Env. Sci. and Tech. (FLAME Tech)
  – Luke Loken et al., in prep (FLAME Mendota)
  – Angela Baldocchi et al., in prep (FLAME-Tower)
  – Malgorzata Golub et al., near submission, Nature Geo. (Tower synthesis)

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