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Examination of methane ebullition in a Swiss hydropower reservoir

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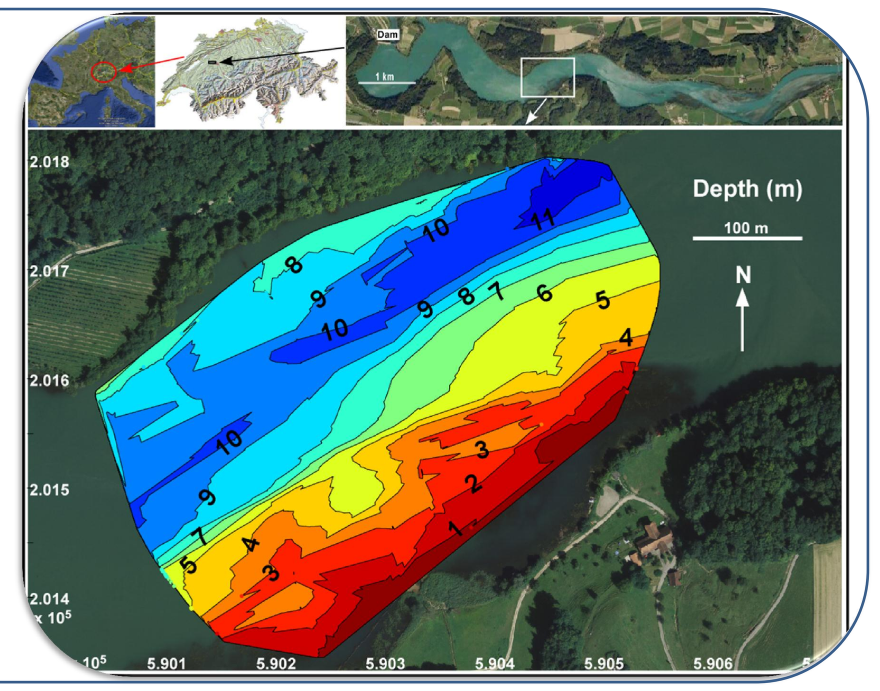
Motivation

- Methane emissions from inland waters, including man-made reservoirs, are often neglected in global budgets[1,2]
- As hydropower reservoirs often act as sediment and carbon traps, they can be methane hot spots thereby potentially reducing the 'greenness' of this energy source[2]
- Ebullition is the most efficient pathway in shallow waters, but is consistently understudied[1]
- The spatiotemporal variability of ebullition also hinders systematic monitoring of atmospheric emissions[1]

Field Site

- Lake Wohlen near Bern, Switzerland is a run-of-river reservoir that has some of the highest ebullition emissions recorded in a temperate system, which are sensitive to temperature changes[3]



Methods

- Seven detailed surveys were conducted in summer 2008 in the most active ebullition region (see map)
- A 120 kHz echosounder (Simrad EK60) was used to locate and quantify ebullition flux *(see Poster 10539 at BG86 for details)*
- Drifting chamber surveys were conducted simultaneously and an eddy covariance system continuously recorded flux[4]

References

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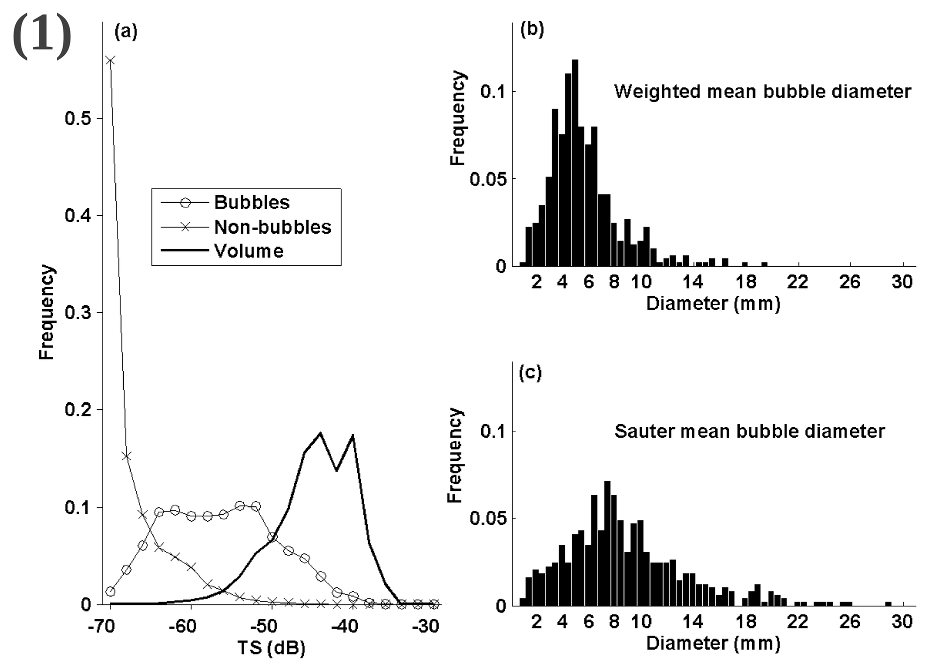
[2]Barros., N., J.J. cole, L.J. Tranvik, Y.T. Prairie, D. Bastviken, V.L.M. Huszar, P. del Giorgio, and F. Roland. 2011. Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. *Nature Geoscience* 4: 593-596. doi:10.1038/NGEO1211

[3]DelSontro, T., D. F. Mcginnis, S. Sobek, I. Ostrovsky, and B. Wehrli. 2010. Extreme methane emissions from a Swiss hydropower reservoir: Contribution from bubbling sediments. *Environ. Sci. Technol.* 44: 2419-2425. doi:10.1021/es9031369

[4]Eugster, W., T. Delsontro, and S. Sobek. 2011. Eddy covariance flux measurements confirm extreme CH4 emissions from a Swiss hydropower reservoir and resolve their short-term variability. *Biogeosciences*, 8: 2815-2831. doi:10.5194/bg-8-2815-2011

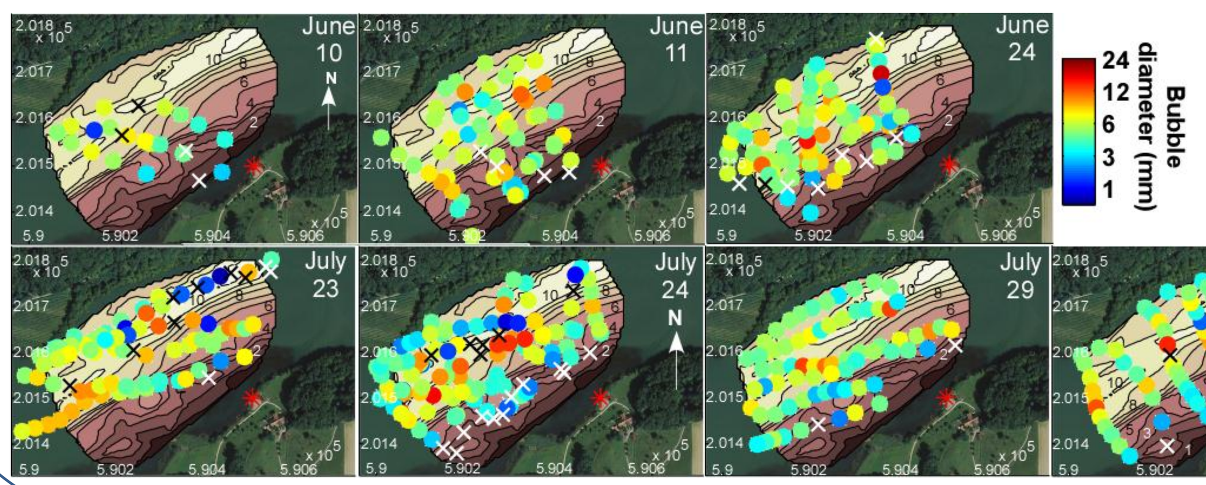
Bubble Size

(1)



- Since the echosounder was calibrated for bubble size, the hydroacoustic data provides valuable insight into bubble size distribution
- The bubble distribution does not significantly overlap with the non-bubble distribution (Fig. 1a)
- Majority of bubble volume is found in the largest bubbles which are few (Fig. 1a)
- If weighted mean diameter is calculated for each analyzed segment, most bubbles are between 4 and 6 mm (similar to other studies) with an average of 5.9 mm (Fig. 1b)
- The Sauter mean diameter (SMD = $\sum d^3 / \sum d^2$) takes into acount the importance of the volume-to-surface area ratio and provides a 10.1 mm average bubble (Fig. 1c)

(2)

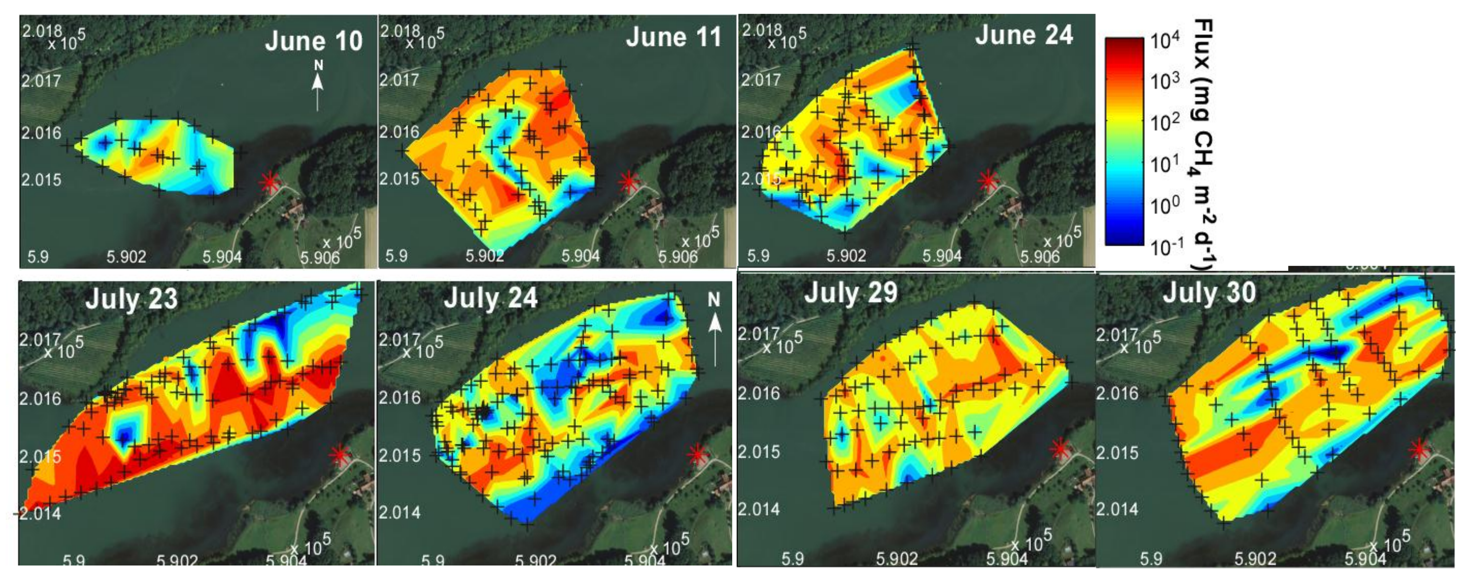


- The weighted mean diameter for bubbles in each segment shows that the largest bubbles occur near the center slope of the old river channel (Fig. 2)
- Near the banks bubbles tend to be smaller
- Majority of no flux zones (labeled with an 'x') lie also in the shallow zone to the south

Small-scale spatial heterogeity of ebullition

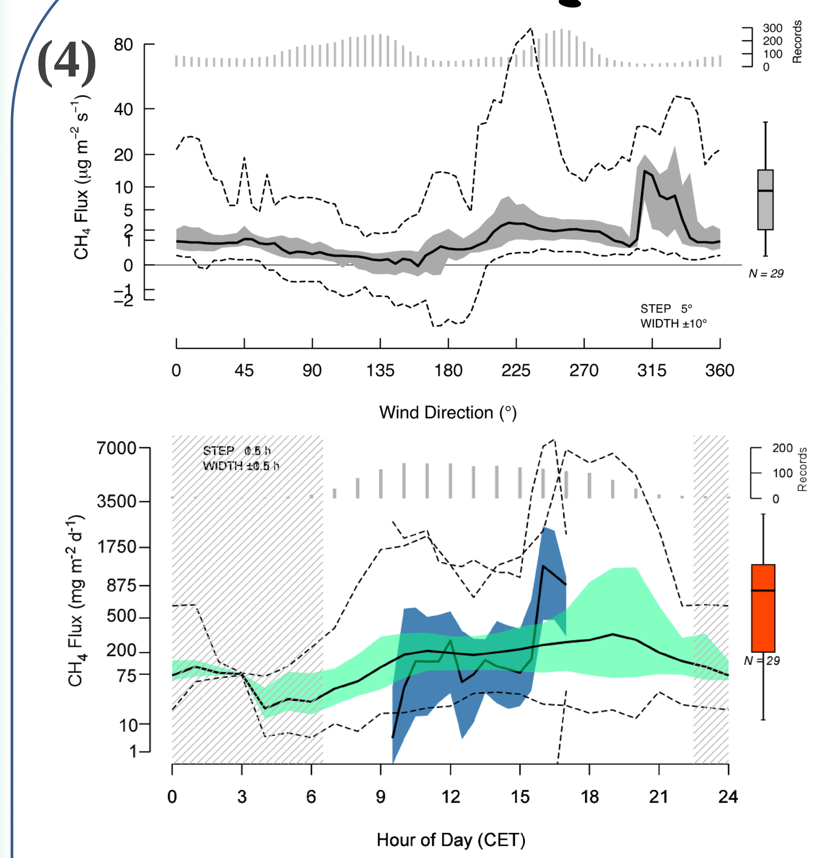
- Between 400 and 1600 m^2 of the active ebullition region was surveyed via hydroacoustics
- With the bubble sizes known, ebullition flux from the sediments can be estimated (Poster 10539)
- Fluxes ranged from 0 to ~10^4 mg CH_4 m^{-2} d^{-1} with the majority between 10^2 and 10^3 mg m^{-2} d^{-1}
- CH_4 bubble flux from the sediment into the water column was contoured to illustrate any spatial trends in flux (Fig. 3)
- The highest fluxes were observed on July 23 and occurred in the center of the survey region
- Low flux zones were found along the southern and northern banks of the survey region

(3)



Method Comparison

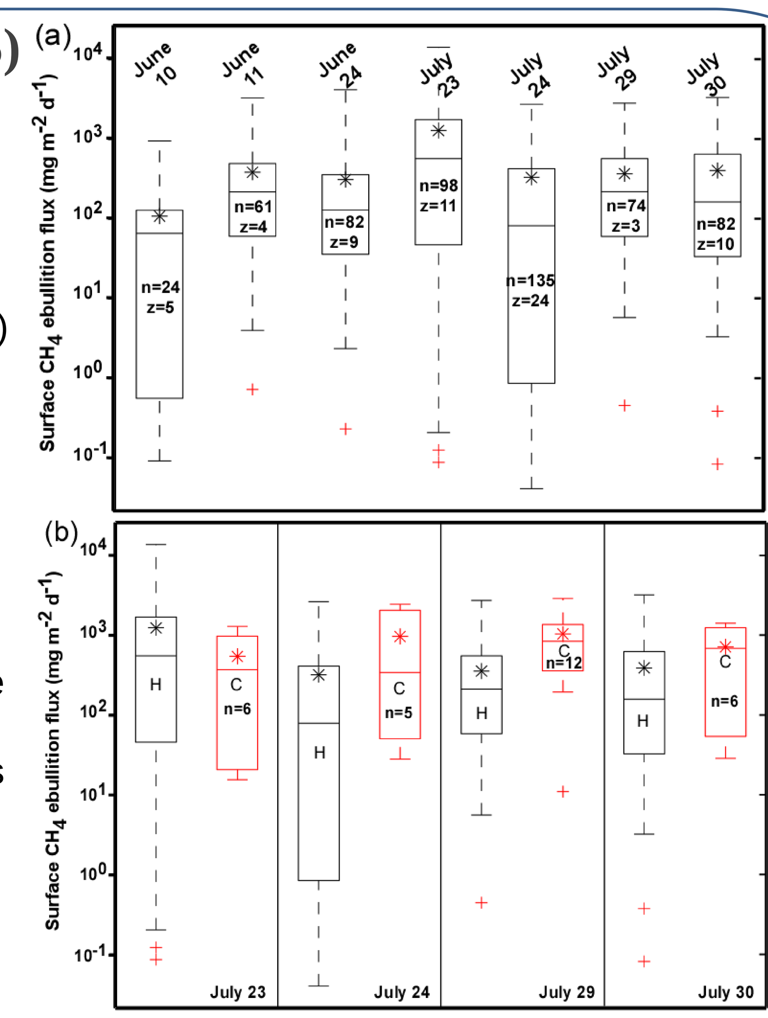
(4)



(4) Top: Eddy covariance (EC) flux measurements (thick line, avg) according to wind diretion. **Bottom:** EC flux range (green) and acoustic flux range (blue) according to hour of day. Boxplots are of chamber data in both panels.

- Eddy covariance (EC) fluxes peaked from the direction of the active ebullition region of the lake (315-345°, Fig. 4 top)
- Chamber fluxes were similar to the peak fluxes recorded by EC (boxplot, Fig. 4 top)
- Hydroacoustic and EC fluxes were similar and relatively constant during most of the day, but both methods showed an increase in fluxes after hour 15 (Fig. 4 bottom)
- Hydroacoustic fluxes were lowest on June 10, but there was less coverage that day, and highest on July 23. Very similar fluxes were observed on all other days (Fig. 5a)
- Chamber fluxes were usually higher than hydroacoustic fluxes, but chamber data integrated over the no flux zones and covered less area. Averages for both were between 10$^{2.5}$ and 10^3 mg CH4 m^{-2} d^{-1} (Fig. 5b)

(5)

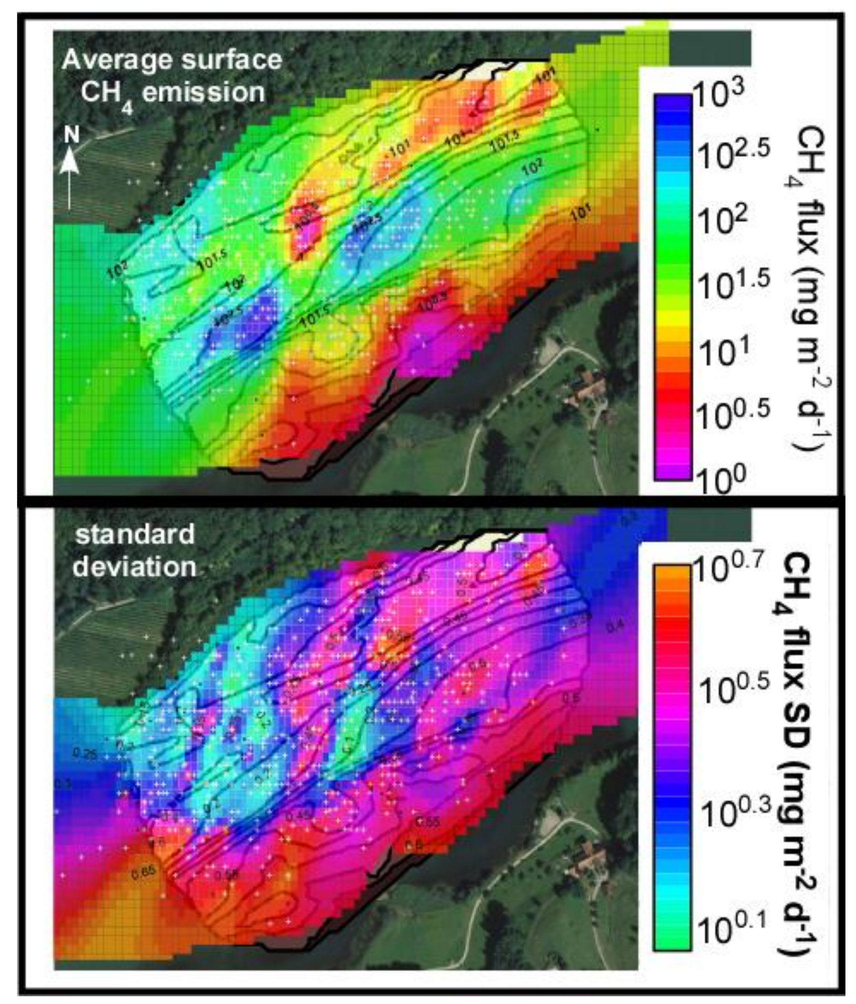


(5) (a): All hydroacoustic fluxes. **(b)** Hydroacoustic fluxes (H) compared with chamber fluxes (C). Star is average in both panels.

Implications

- Average hydroacoustic-derived surface emissions for all surveys indicate a high flux zone (blue-green area, Fig. 6 top) along the center on a sloping lake bed
- Low fluxes are generally found in the deepest part (old river channel) and along the southern shallow shelf, although the variability is high there and fewer measurements were made (Fig. 6 bottom)
- Hydroacoustic methods provide higher spatial resolution of fluxes than chambers and gives a more accurate location of where ebullition occurs compared to EC data
- Spatial variability of ebullition can then be explored in more detail once the ebullition regions have been identified

(6)



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