

The CO₂ exchange of a small mountain lake as affected by the local thermo-topographically driven flow regime

Scholz K., Battin, T., Ejarque, E., Hammerle A., Kainz, M., Schelker, J., Wohlfahrt G.

katharina.scholz@student.uibk.ac.at

vEGU21

27.04.2021

Background

- Lakes play an important and active role in the global carbon (C) cycle
- Lakes receive large amounts of C from the surrounding catchment which can be transported downstream, stored in sediments, or outgassed into the atmosphere
- Globally, lake CO₂ emissions are estimated to 0.3 – 0.64 Pg C m⁻² yr⁻¹ *)
- However, large uncertainties remain and long-term, direct measurements of lake-atmosphere CO₂ exchange are sparse; especially data from the Alpine region is lacking
- To quantify water-atmosphere gas exchange, several methods with differing temporal and spatial resolution exist, including chambers, concentration gradient based methods (e.g., boundary layer modeling (BLM)), and the Eddy Covariance (EC) approach.

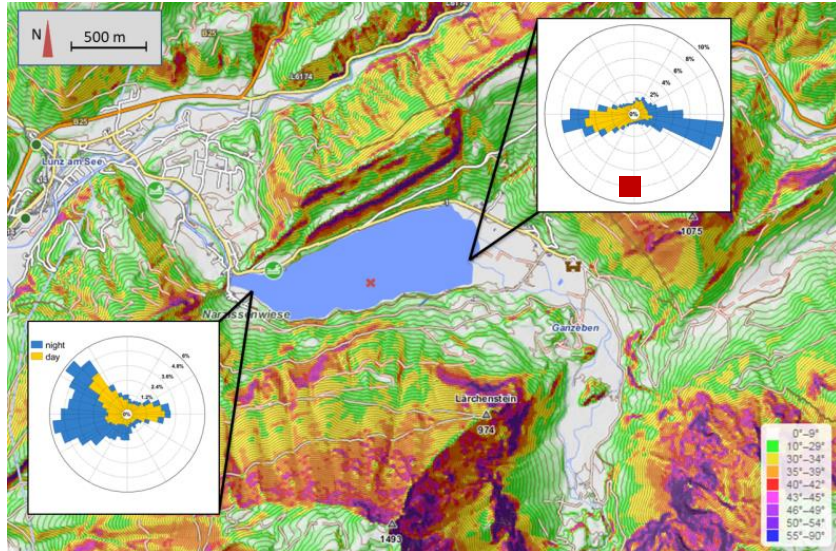
Background

To quantify water-atmosphere gas exchange, several methods with differing temporal and spatial resolution exist:

Method	Concentration Gradient	Floating Chambers	Eddy Covariance
Spatial extent	Point measurement	Chamber surface (~100-1000 cm ²)	'Footprint' (several 100 m ²)
Temporal resolution	If automated: ~ 1hr interval (continuous); often one point measurement / once per season	If automated: < 1hr interval (continuous); often manual measurement campaigns	Generally automated, continuous measurements
pro	Already large availability of pCO ₂ data; gas exchange can be modeled (-> global estimates)	Relatively easy application; cost- efficient	Non-invasive; high temporal resolution and spatial integration
con	Uncertainties in estimation of the gas transfer velocity	Labor intensive; application of the chamber potentially influences gas exchange at the water surface	Expensive instruments

Methods & field site

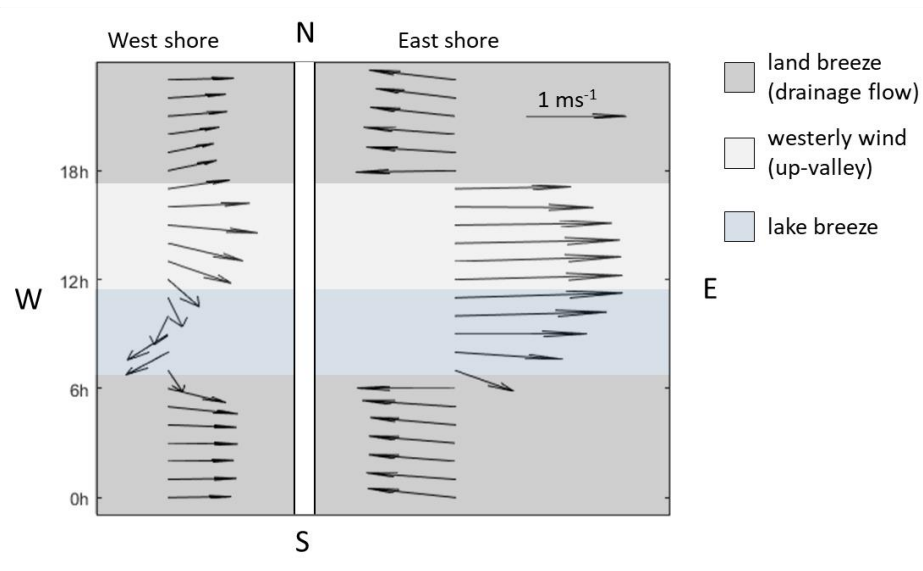
Here, we used both the **BLM** and the **EC** method to quantify the CO₂ exchange of **Lake Lunz**, a small (0.68 km²), oligotrophic, clear-water mountain lake in Lower Austria.



Map from openslopemap.org.

- The lake (47° 51' N, 15° 03' E) is situated in a steep and narrow valley at about 600 m elevation
- Measurements were taken over a period of one year (2017)
- Wind speed and direction were measured at two locations on opposing shores – wind roses are showing the frequency of day (yellow) and night-time (blue) wind directions
- Eddy covariance measurements were conducted on the east shore of the lake (red square)
- pCO₂ (water and air) and water temperature profiles were measured close to the deepest point of the lake (red cross)

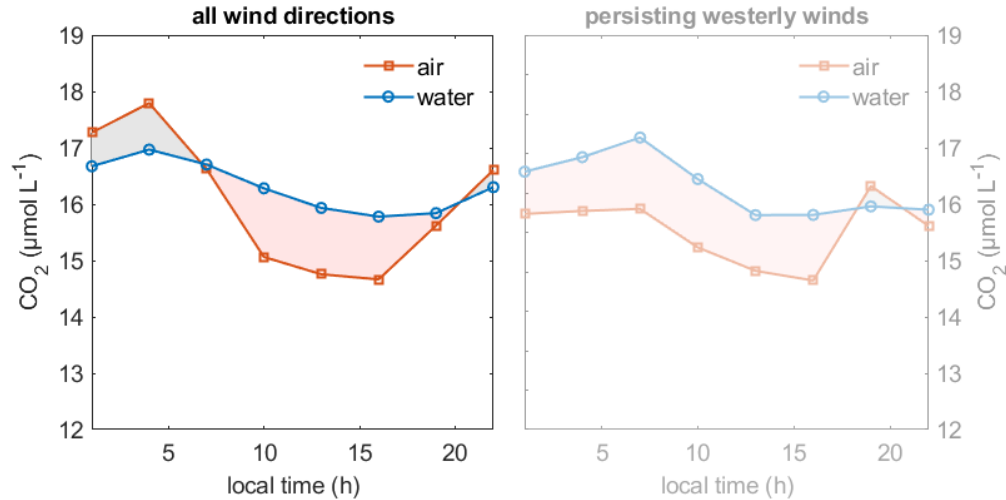
Results: wind regime



During night: typically the wind was blowing from the land at both sites (land breeze; air draining from the surrounding slopes).

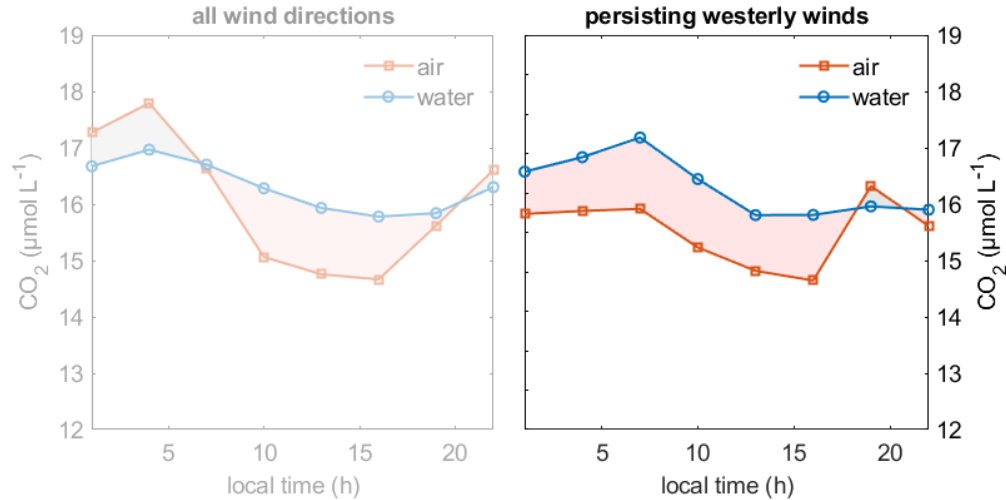
During day: typically the wind turned in the early morning and a lake breeze was observed. During the day, strong westerly winds persisted.

Results: CO₂ concentrations



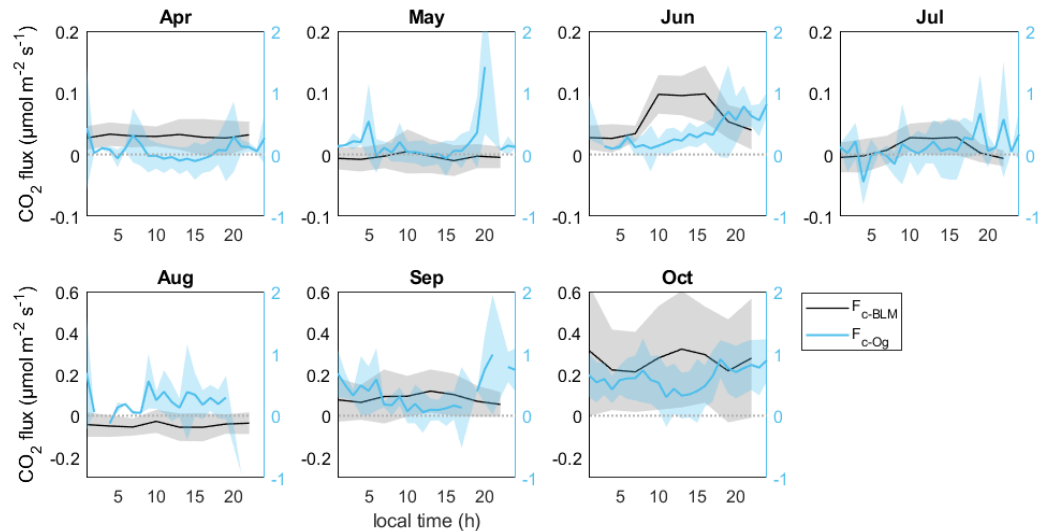
- At the same time, the atmospheric CO₂ showed a strong diel pattern, especially during summer.
- During the night when the wind was blowing from the land, typically the atmospheric CO₂ concentration was very high and mostly higher than the aquatic CO₂ concentration.
- During the day, the atmospheric CO₂ concentration decreased and was typically lower than the aquatic CO₂ concentration. This caused a diel pattern in CO₂ fluxes with higher emissions during the day and low emissions or even uptake during the night.

Results: CO₂ concentrations



- However, there were also days when the strong westerly winds also persisted throughout the night.
- During those occasions, the nocturnal increase in atmospheric CO₂ was not observed and CO₂ emissions were generally higher.

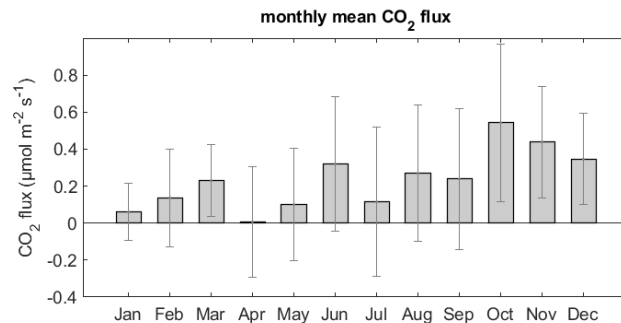
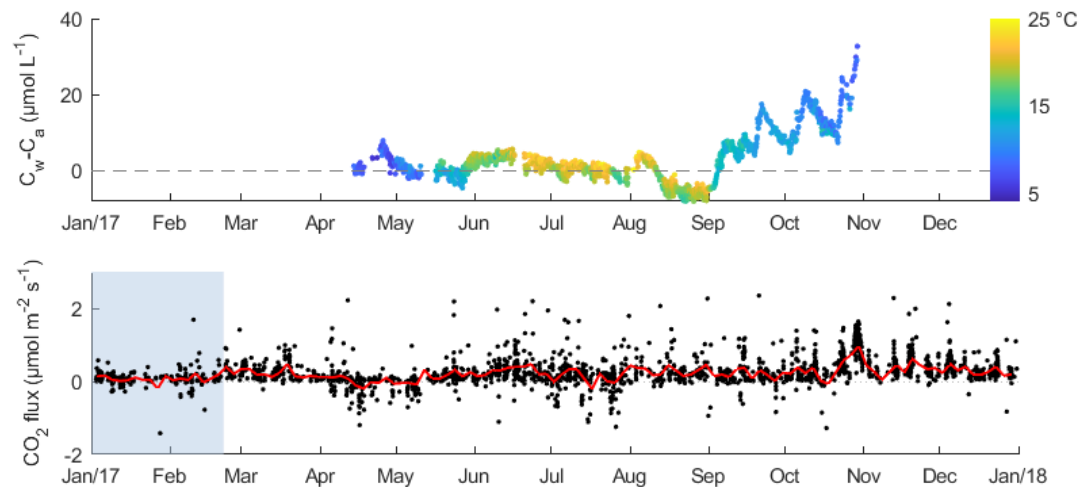
Results: CO₂ emissions



- Fluxes estimated based on the BLM method ($F_{c\text{-BLM}}$) showed a diel pattern with higher emissions during the day.
- Fluxes estimated using the EC method ($F_{c\text{-Og}}$) were generally higher and did not capture this diel pattern.
 - EC measures an upwind signal. Because the EC instruments were located on the east shore in our case, lake EC fluxes were only measured during westerly winds.

Results: CO₂ emissions

Overall, the difference of CO₂ concentrations at the air-water interface ($C_w - C_a$) was low and CO₂ fluxes were small. Highest emissions were observed in fall when low temperatures and strong winds induced lake mixing leading to an increase in aquatic CO₂ concentration.



Pre-print related to this study available at:

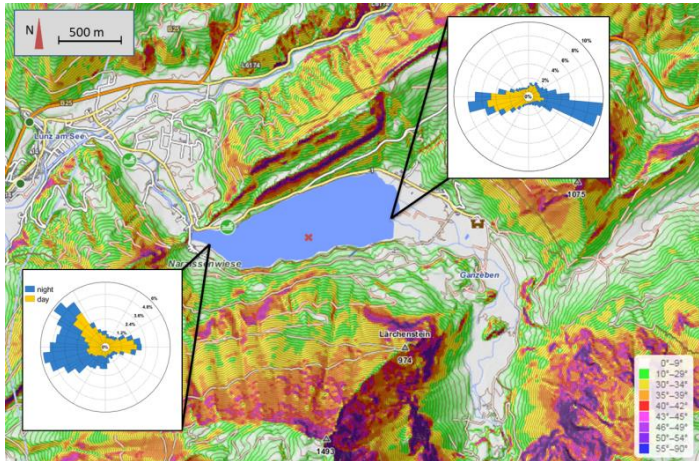
<https://www.essoar.org/doi/10.1002/essoar.10506202.1>

The CO₂ exchange of a small mountain lake as affected by the local thermo-topographically driven flow regime

1. Field site

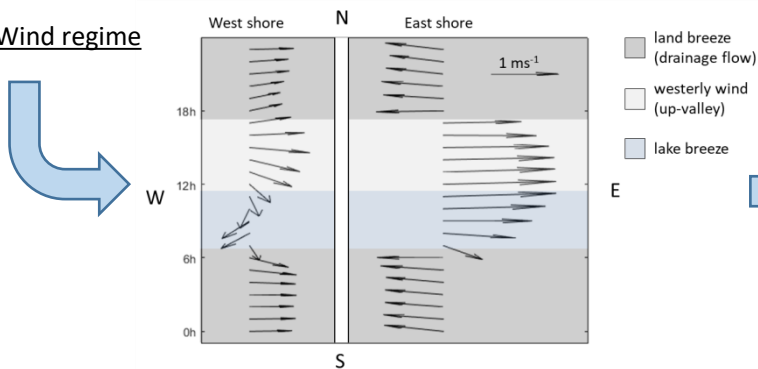
Scholz K., Battin, T., Ejarque, E., Hammerle A., Kainz, M., Schelker, J., Wohlfahrt G.

katharina.scholz@student.uibk.ac.at

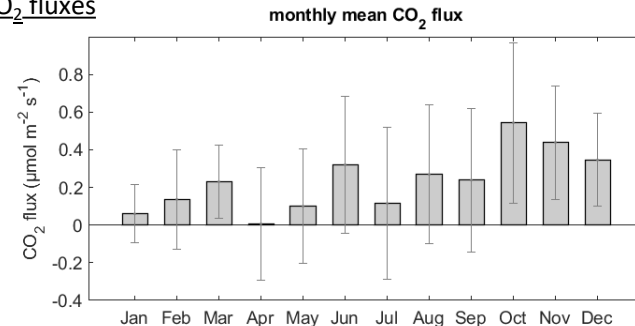


- CO₂ flux – EC method
- pCO₂ – water & air (BLM method)
- Wind speed & direction

2. Wind regime



4. CO₂ fluxes



3. CO₂ concentrations

