Observations of turbulence during a zooplankton migration in a small lake

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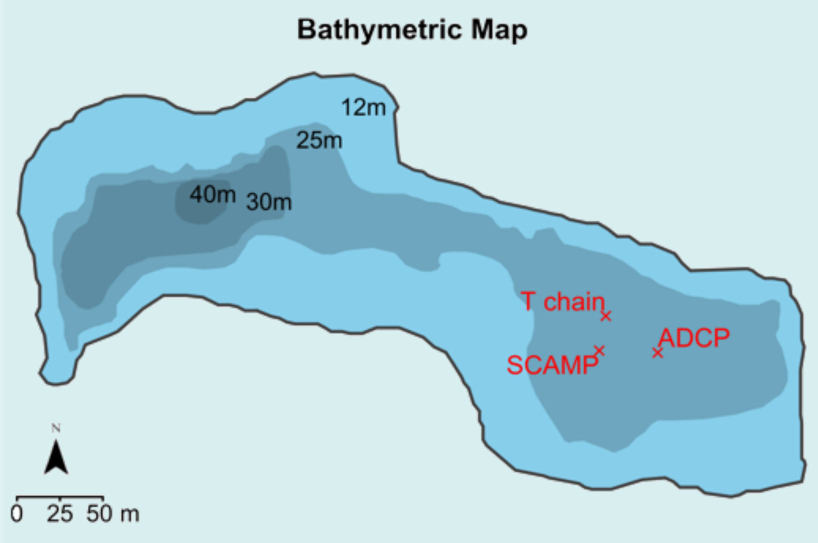
Introduction

As recently summarized by Katija (2012), vertically migrating zooplankton can mix the water column via biogenic turbulence (creating velocity fluctuations in the water by swimming) or transport by drift (dragging fluid with them as they swim). Direct field measurements of biogenic turbulence are rare; Kunze et al. (2006) directly measured the turbulence in a coastal inlet during vertical migrations of krills and observed turbulent dissipation rates 2-3 orders of magnitude greater than background levels. In recent laboratory experiments, Noss and Lorke (2012, 2014), investigated the turbulence generated by swimming ***Daphnia***, a common taxa of lake zooplankton, in a stratified flow tank and found turbulence dissipation rates up to 10^{-6} W/kg and turbulent scales an order of magnitude larger than the length of the ***Daphnia***. However they found that the actual mixing was negligible. This limited evidence from lake species indicates that biogenic turbulence in lakes may be an important and undersampled phenomenon.

Objectives

(1) Measure the turbulence in the thermocline induced by zooplankton in a lake environment
(2) Quantify the efficiency of mixing generated by small zooplankton
(3) Assess the importance of this mechanism by comparison with turbulence generated by internal waves.

Measurements: Vobster Quay, August 2015



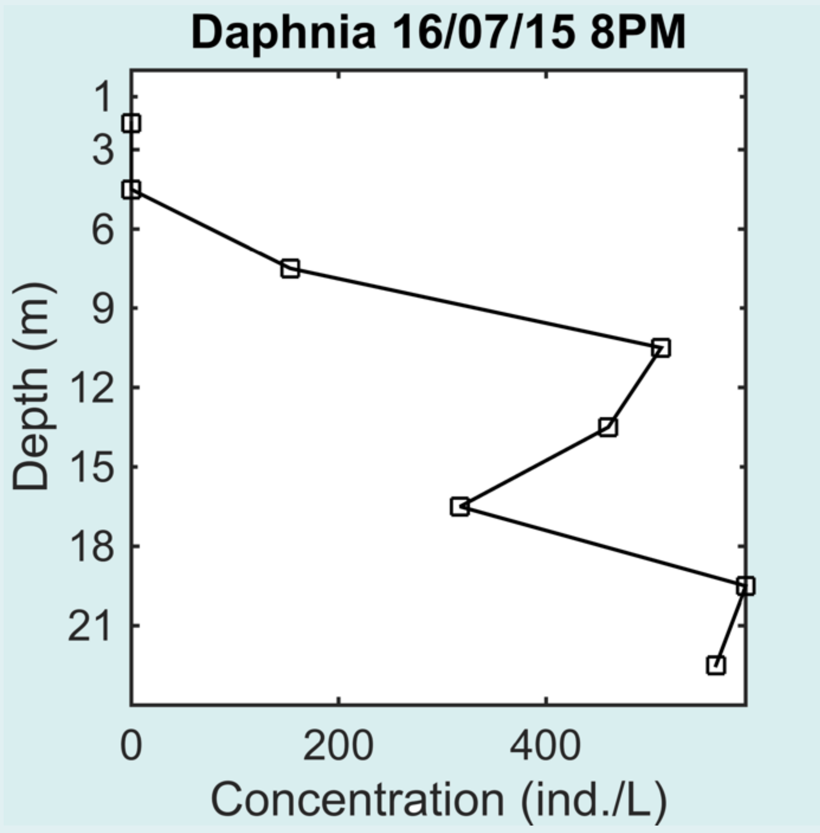
Longitude	51.2458 °N
Latitude	2.4221 °W
Surface area	59,506 m^2

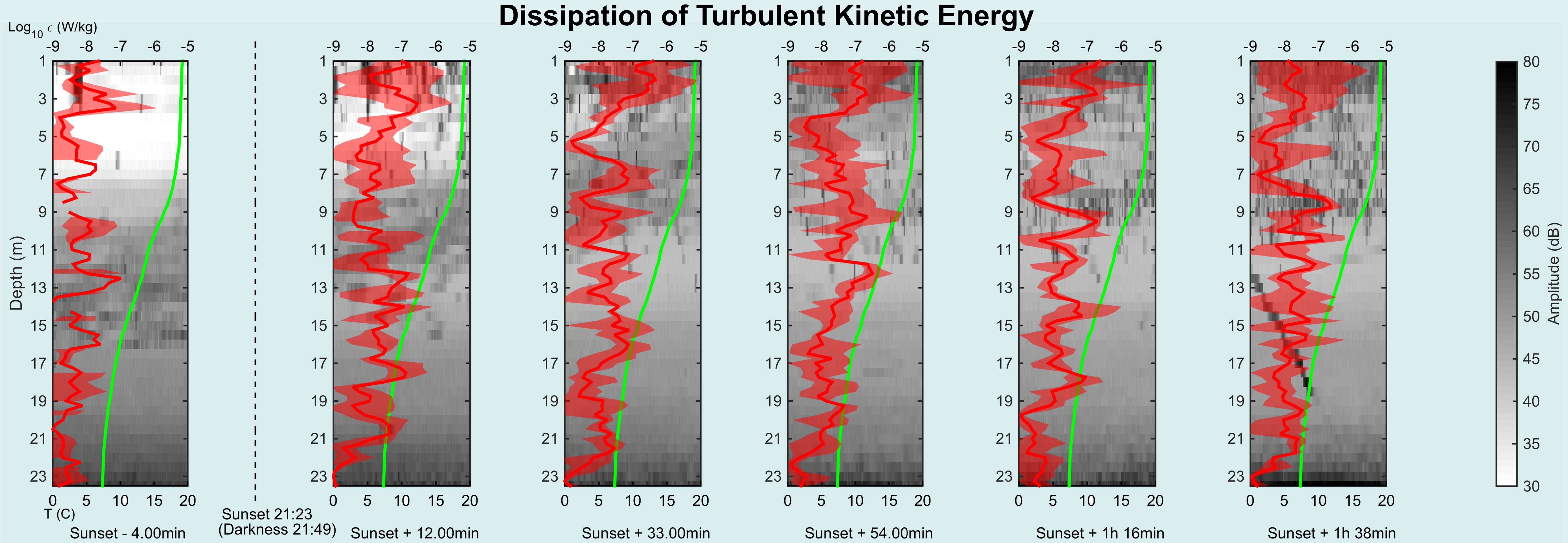
SCAMP (Self-Contained Autonomous MicroProfiler)
- Profiling instrument for measuring temperature microstructure
- 16 profiles, approximately every 5 minutes
- Time series beginning few minutes before sunset and ending 1.6 hrs after

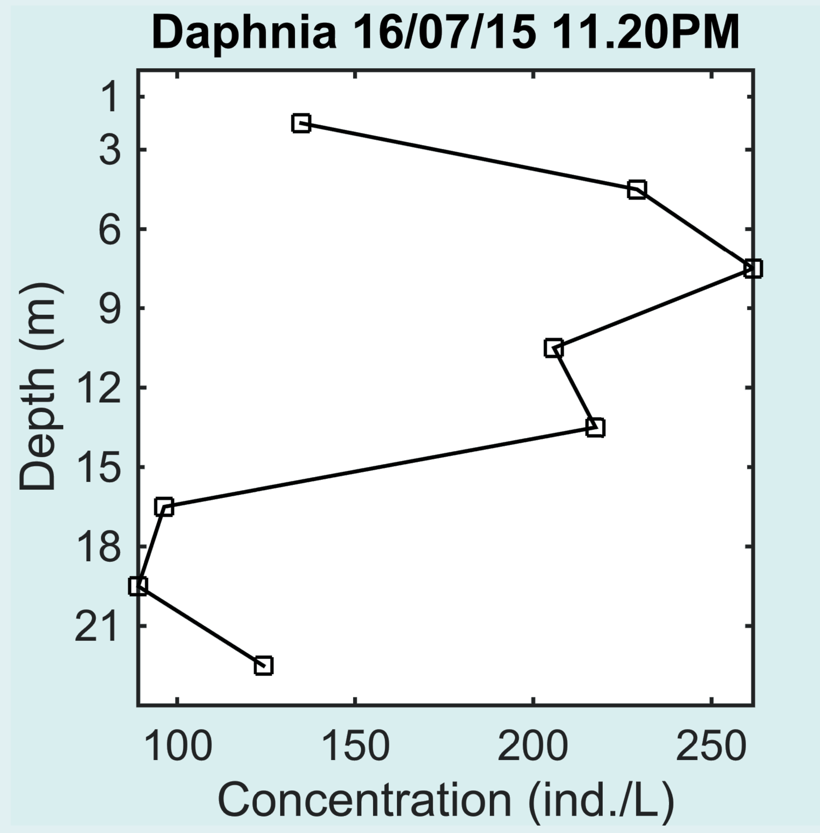
ZOOPLANKTON SAMPLING
- Vertical sampling from 1m up to 24m every 3 m
- Sampling done at approximately 8 PM and 11.20PM, sandwiching SCAMP measurements
- Organisms were trapped with 100-µm mesh in a conical net

ADCP 500 kHz
- The energy of the returned sound wave (Amplitude) was used as a proxy to track the zooplankton concentration and migration

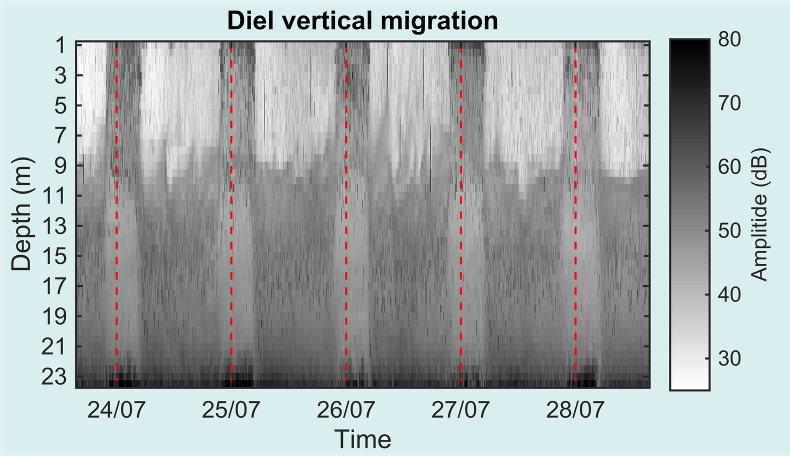
Dissipation of Turbulent Kinetic Energy



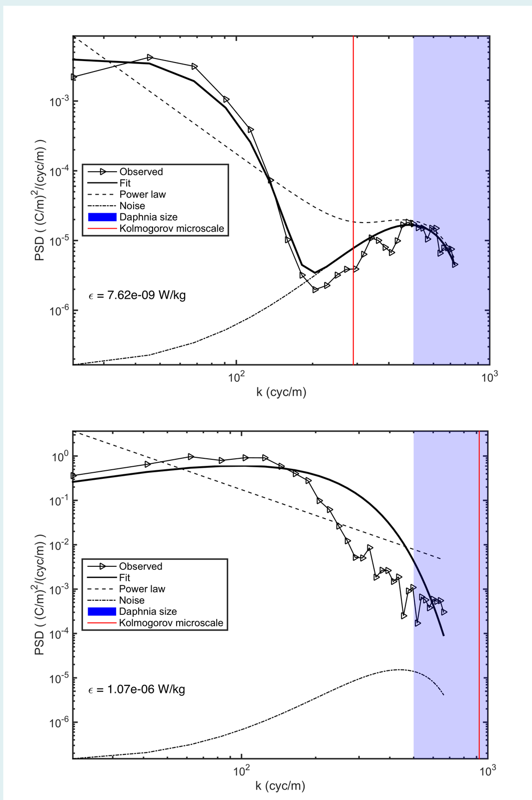




Discussion

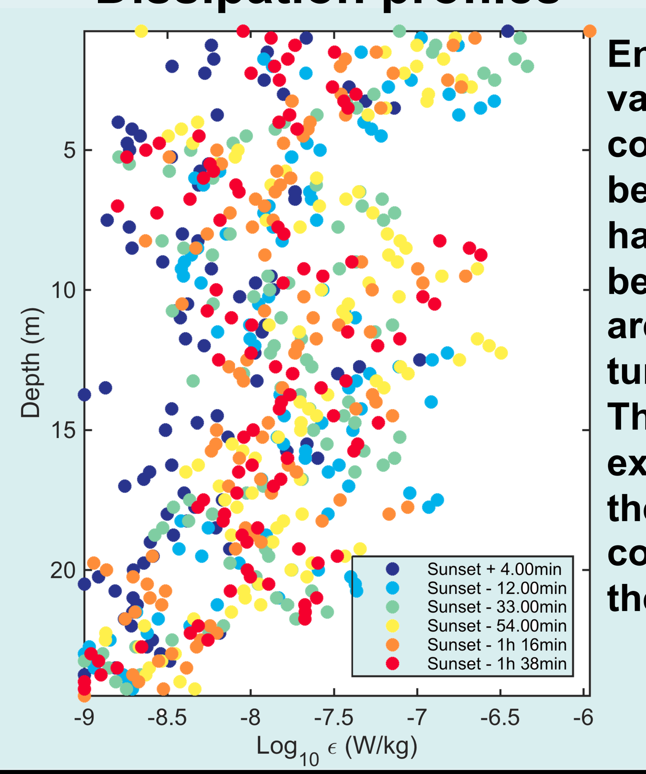


Zooplankton tows at the sampling site show higher counts of ***Daphnia*** at 9m and near the bottom before sunset (8PM). Samples after dusk (11.20PM) showed an increase on the surface layer. However migration happens also horizontally.



The dissipation rates were estimated by fitting the SCAMP data to the theoretical Batchelor spectrum of temperature fluctuations. While the spectra fit well, in few cases we able to resolve the length scale of the single ***Daphnia*** either before the noise level or the Kolmogorov micro-scale is reached

Dissipation profiles



Ensemble-averaged profiles show a great variation of the dissipation rates over the course of the time series. In particular between 6m and 12m where the DVM is happening and with respect to the profiles before sunset. However additional data are required to better characterise the turbulence before the migration starts. There was no wind during the experiments and the high turbulence at the surface is consistent with penetrative convection. Turbulence also increased in the bottom boundary layer

Conclusion

(1) The first direct measurements of turbulence through migrating zooplankton in a lake show an increase of dissipation during the migration
(2) Further profiles before the sunset as well as additional dataset are need to draw a proper conclusion about bioturbulence and the actual impact on the ecosystem
(3) Given the uncertainty in measuring the length scales of turbulence associated with small zooplankton, it is not certain if the observed turbulence is due to the migration or other causes.
(4) Enhanced mixing will be measured by dye injection into thermocline and measuring its diffusion due to zooplankton migration.

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Further information

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