Continuous CO2 data from a Lake Michigan transect between Milwaukee, Wisconsin and Muskegon, Michigan collected during 2017, 2018, 2019, and 2021

Website: https://www.bco-dmo.org/dataset/737667
Data Type: Cruise Results
Version: 3
Version Date: 2023-12-20

Project
» Collaborative Research: Regulation of plankton and nutrient dynamics by hydrodynamics and profundal filter feeders (Filter Feeders Physics and Phosphorus)

Contributors	Affiliation	Role
Bootsma, Harvey	University of Wisconsin (UW-Milwaukee)	Principal Investigator
Liao, Qian	University of Wisconsin (UW-Milwaukee)	Co-Principal Investigator
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
This dataset provides CO2 data collected during 2017, 2018, 2019, and 2021 from a Lake Michigan transect between Milwaukee, Wisconsin and Muskegon, Michigan. Water chemistry and conductivity-temperature-depth (CTD) profiles were measured at several stations in Lake Michigan, ranging in depth from 10 to 55 m, in a region northeast of Milwaukee Harbor. Measurements included soluble reactive phosphorus, total dissolved phosphorus, particulate phosphorus, chlorophyll a, the concentrations and stable isotope ratios of particulate carbon and particulate nitrogen, dissolved carbon dioxide, dissolved total inorganic carbon, and dissolved organic carbon. In addition, continuous lake surface and atmospheric CO2 data were collected in 2019 and 2021 on a Lake Michigan transect between Milwaukee, WI and Muskegon MI. The water chemistry and CTD data are provided in separate datasets. Measurements were made with a CO2 monitoring system mounted on a high-speed ferry that crosses the lake 4 to 6 times daily between May and October. The monitoring system consists of a "wet" box which includes a peristaltic pump that draws water from the ship's sea chest and an equilibrator in which dissolved gases are equilibrated with a recirculating air flow. The air is pumped through a desiccant to remove moisture, after which it flows to a "dry" box where it passes through an infrared gas analyzer. A similar system, without the peristaltic pump or equilibrator, is mounted near the bow of the ship to record atmospheric CO2 concentration. These chemical measurements have several applications, including: 1) Constructing an annual carbon and nutrient budget for the water column, which is used along with direct measurements of quagga mussel nutrient recycling to assess the role of invasive quagga mussels in the lake's carbon and nutrient cycles; 2) When combined with separate measurements of the vertical structure of water density and currents, to quantify vertical fluxes of dissolved nutrients and inorganic carbon, to determine how carbon and nutrient recycling by profundal quagga mussels may affect plankton production in the euphotic zone; 3) The calibration and validation of physical / biogeochemical models used to better understand how invasive quagga mussel have altered energy flow and nutrient dynamics in the Great Lakes, and guide management decisions with regard to nutrients and fish stocking.

Table of Contents

- Coverage
- Dataset Description
  - Methods & Sampling
  - BCO-DMO Curation Notes
- Data Files
- Related Publications
- Parameters
- Instruments
- Deployments
- Project Information
- Funding

Coverage

Spatial Extent: **N**:43.39868 **E**:-86.2939 **S**:42.81355 **W**:-87.92825
Temporal Extent: 2017-04-28 - 2021-10-28

Dataset Description

Continuous CO2 data from from a Lake Michigan collected during 2017-2019 and in 2021. No samples were collected in 2020, due to COVID-19 restrictions. The sampling system is mounted in the engine room of the Lake Express high-speed ferry, where it draws water from a sea chest that has a residence time of several seconds.

Methods & Sampling

Continuous CO_2: The components of the continuous CO2 monitoring system include a peristaltic pump that forces water through an air-water equilibrator (Membrana mini-module membrane contactor). Reverse-flow air from the equilibrator is pumped through desiccant, after which it flows through an infrared gas analyzer (Li-Cor Li-820) which measures the partial pressure of CO2 normalized to 1 atmosphere. The system also includes a temperature sensor and a WETLabs flow-through fluorometer. The system is controlled by a Campbell CR1000 Controller / Datalogger. Input from a GPS on the ship's upper deck allows all data to be geo-referenced. The system is mounted in the engine room of the Lake Express high-speed ferry, where it draws water from a sea chest that has a residence time of several seconds. Additional details are provided in Zagorski and Bootsma (2006).

BCO-DMO Curation Notes

Versions 1 and 2:
- modified parameter names to conform with BCO-DMO naming conventions;
- re-formatted date to ISO format;
- replaced missing data with nd ("no data");
- updated to version 2 on 21-May-2019.

Version 3:
- converted date/time field to ISO 8601 format;
- modified parameter names to conform with BCO-DMO naming conventions;
- removed 'nd' and 'NA' as missing data identifiers (missing data are empty/blank in the final CSV file);
- updated to version 3 on 2023-12-20 and saved the final file as "737667_v3_lake_michigan_co2.csv".

[table of contents | back to top]

Data Files

File	
737667_v3_lake_michigan_co2.csv	(Comma Separated Values (.csv), 16.06 MB) MD5:3961d669bec1b9a0e38d5e3c57bc57ee
Primary data file for dataset ID 737667, version 3	

[table of contents | back to top]

Related Publications

Shen, C., Liao, Q., Bootsma, H. A., Troy, C. D., & Cannon, D. (2018). Regulation of plankton and nutrient dynamics by profundal quagga mussels in Lake Michigan: a one-dimensional model. Hydrobiologia, 815(1), 47–63. https://doi.org/10.1007/s10750-018-3547-6

Results

Zagorski, J., & Bootsma, H. (2006). High spatial-resolution monitoring of surface CO2 concentrations in Lake Michigan. OCEANS 2006. https://doi.org/10.1109/oceans.2006.307084 https://doi.org/10.1109/OCEANS.2006.307084
Methods

[table of contents | back to top]

Parameters

Parameter	Description	Units
ISO_DateTime_UTC	UTC date and time formatted to ISO 8601 standard. Local time + 5 hours between March 12, 2:00 a.m. and November 5, 2:00 a.m. Local time + 6 hours between November 5, 2:00 a.m. and March 12, 2:00 a.m.	unitless
Year	Year	unitless
Lat	Latitude. Locations south of equator are negative. Resolution = 0.00001; accuracy = 0.00017.	Decimal degrees
Long	Longitude. Locations west of prime meridian are negative. Resolution = 0.00001; accuracy = 0.00024.	Decimal degrees
Speed	Speed of ferry on which CO2 system is installed; resolution = 0.1; accuracy = 0.5	Knots (multiply X 0.5144 for meters per second)
P_kPa	Pressure in Li-Cor infrared gas analyzer; resolution = 01; accuracy = 0.5	kPa
AtmP	Ambient atmospheric pressure; resolution = 01; accuracy = 0.5	kPa
WaterCO2	Partial pressure of carbon dioxide (pCO2) in the water body as measured with an infrared gas analyzer in a gas stream that has been equilibrated with the water; resolution = 0.1; accuracy = ±3%; detection limit = 0.5.	micro atmospheres (uatm)
AirCO2	Partial pressure of carbon dioxide in air; resolution = 0.1; accuracy = ±3%; detection limit = 1	micro atmospheres (uatm)

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	Li-Cor Li-820
Generic Instrument Name	CO2 Analyzer
Generic Instrument Description	Measures atmospheric carbon dioxide (CO2) concentration.

Dataset-specific Instrument Name	WETLabs flow-through fluorometer
Generic Instrument Name	Fluorometer
Generic Instrument Description	A fluorometer or fluorimeter is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. The instrument is designed to measure the amount of stimulated electromagnetic radiation produced by pulses of electromagnetic radiation emitted into a water sample or in situ.

[table of contents | back to top]

Deployments

Lake_Michigan_ferry_2017-2021

Website	https://www.bco-dmo.org/deployment/737776
Platform	Lake Express
Start Date	2017-04-28
End Date	2021-10-28
Description	A continuous CO2 system was mounted in the engine room of the Lake Express high-speed ferry, where it draws water from a sea chest that has a residence time of several seconds.

[table of contents | back to top]

Project Information

Collaborative Research: Regulation of plankton and nutrient dynamics by hydrodynamics and profundal filter feeders (Filter Feeders Physics and Phosphorus)

Coverage: Lake Michigan

Overview:
While benthic filter feeders are known to influence plankton and nutrient dynamics in shallow marine and freshwater systems, their role is generally considered to be minor in large, deep systems. However, recent evidence indicates that profundal quagga mussels (Dreissena rostriformis bugensis) have dramatically altered energy flow and nutrient cycling in the Laurentian Great Lakes and other larges aquatic systems, so that conventional nutrient-plankton paradigms no longer apply. Observed rates of phosphorus grazing by profundal quagga mussels in Lake Michigan exceed the passive settling rates by nearly an order of magnitude, even under stably stratified conditions. We hypothesize that the apparently enhanced particle deliver rate to the lake bottom results from high filtration capacity combined with vertical mixing processes that advect phytoplankton from the euphotic zone to the near-bottom layer. However, the role of hydrodynamics is unclear, because these processes are poorly characterized both within the hypolimnion as a whole and within the near-bottom layer. In addition, the implications for phytoplankton and nutrient dynamics are unclear, as mussels are also important nutrient recyclers. In the proposed interdisciplinary research project, state-of-the-

art instruments and analytical tools will be deployed in Lake Michigan to quantify these critical dynamic processes, including boundary layer turbulence, mussel grazing, excretion and egestion, and benthic fluxes of carbon and phosphorus. Empirical data will be used to calibrate a 3D hydrodynamic-biogeochemical model to test our hypotheses.

Intellectual Merit:
This collaborative biophysical project is structured around two primary questions: 1) What role do profundal dreissenid mussels play in large lake carbon and nutrient cycles? 2) How are mussel grazing and the fate of nutrients recycled by mussels modulated by hydrodynamics at scales ranging from mm (benthic boundary layer) to meters (entire water column)? The project will improve the ability to model nutrient and carbon dynamics in coastal and lacustrine waters where benthic filter-feeders are a significant portion of the biota. By so doing, it will address the overarching question of how plankton and nutrient dynamics in large, deep lakes with abundant profundal filter feeders differ from the conventional paradigm described by previous models. Additionally, the project will quantify and characterize boundary layer turbulence for benthic boundary layers in large, deep lakes, including near-bed turbulence produced by benthic filter feeders.

Broader Impacts:
The project will provide new insight into the impacts of invasive dreissenid mussels, which are now threatening many large lakes and reservoirs across the United States. Dreissenid mussels appear to be responsible for a number of major changes that have occurred in the Great Lakes, including declines of pelagic plankton populations, declines in fish populations, and, ironically, nuisance algal blooms in the nearshore zone. As a result, conventional management models no longer apply, and managers are uncertain about appropriate nutrient loading targets and fish stocking levels. The data and models resulting from this project will help to guide those decisions. Additionally, the project will provide insight to bottom boundary layer physics, with applicability to other large lakes, atidal coastal seas, and the deep ocean. The project will leverage the collaboration and promote interdisciplinary education for undergraduate and graduate students from two universities (UW-Milwaukee and Purdue). The project will support 3 Ph.D. students and provide structured research experiences to undergraduates through a summer research program. The project will also promote education of future aquatic scientists by hosting a Biophysical Coupling Workshop for graduate students who participate in the annual IAGLR conferences, and the workshop lectures will be published for general access through ASLO e-Lectures and on an open-access project website.

Background publications are available at:
http://onlinelibrary.wiley.com/doi/10.1002/2014JC010506/full
http://link.springer.com/article/10.1007/s00348-012-1265-9
http://aslo.net/lomethods/free/2009/0169.pdf
http://www.sciencedirect.com/science/article/pii/S0380133015001458

Note: This is an NSF Collaborative Research Project.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1658390
Great Lakes Observing System (GLOS)	NA16NOS0120025

[table of contents | back to top]