Planar optode image data from laboratory experiments studying O2 dynamics with sediment and animals collected from an intertidal and shallow subtidal sandflat at Old Ponquogue Bridge Marine Park, NY in 2019 and 2020

Website: https://www.bco-dmo.org/dataset/890950
Data Type: Other Field Results
Version: 1
Version Date: 2023-03-02

Project
» Iron cycling in bioturbated sediments - Fluxes, diagenetic redistribution, and isotopic signatures (Fe flux)

Contributors	Affiliation	Role
Wehrmann, Laura	Stony Brook University - SoMAS (SUNY-SB SoMAS)	Principal Investigator
Aller, Robert C.	Stony Brook University - SoMAS (SUNY-SB SoMAS)	Co-Principal Investigator
Volkenborn, Nils	Stony Brook University - MSRC (SUNY-SB MSRC)	Co-Principal Investigator
York, Amber D.	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
O_2 dynamics recorded by planar optode imaging. These data have been submitted for publication in: Dwyer I., Volkenborn N., Swenson, D., Aller, R.C., Wehrmann L. Seasonality of burrow irrigation behavior of the maldanid polychaete, Clymenella torquata and implications for redox-sensitive processes in permeable sediments. In preparation to be submitted to the Journal of Experimental Marine Biology and Ecology.

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Coverage

Spatial Extent: **Lat**:40.842 **Lon**:-72.498
Temporal Extent: 2019-06-06 - 2020-08-10

Methods & Sampling

Location: Laboratory study at Stony Brook University with sediments and organisms from Shinnecock Bay, Long Island, New York. Sediment and animals for all experiments were collected from an intertidal and shallow subtidal sandflat at Old Ponquogue Bridge Marine Park (40.842° N, 72.498° W).

Sampling and Setup for Summer 2019 Antfarms:
Sediment was collected on 6/5/2019 with 14.5 cm diameter cores that were pushed down to a shell layer at approximately 30 cm depth. The bottoms of the cores were sealed with caps and transported submerged in water to the lab. The upper centimeter was separated from the remainder of each core. Top and bottom sediment was combined from multiple cores, sieved, and homogenized. Antfarms were filled to ~3 cm below

its top with bottom sediment, dropping sediment through water to avoid air bubbles. It was then topped with ~1 cm of top sediment and allowed to settle overnight with recirculating overlying water in a temperature-controlled room at approximately field temperature (~19°C). In parallel with sediment sampling, maldanids polychaetas were collected by splitting sediment with a fork and carefully selecting intact tubes with animals by hand. Animals were transported to the lab and placed in a bucket with aerated overlying water overnight in the same temperature-controlled chamber as the antfarms. The next day, 7 living individuals were selected from among the animals and were placed on the sediment surface in the antfarms and allowed to burrow. Vacated tubes were removed with forceps. During oxygen imaging, temperature was periodically adjusted to create a temperature ramp, ending at approximately winter temperatures. The timing of these changes is noted in the table below. During the final image series, overlying water was injected manually close to the optode in regions unaffected by worms and oxygen concentration declines were used to determine oxygen consumption rates.

Sampling and Setup of intact Cores in Winter and Summer 2020:
Intact cores were collected on 3/9/2020 and 7/24/2020 with 14.5 cm diameter clear polycarbonate tubes that were pushed down to a shell layer at approximately 30 cm depth. Tubes were prepared with oxygen sensitive foils that were glued to the inside of the tubes with double-sticky foil. The bottom of the cores were sealed with caps and transported submerged in a water bath to the lab and hooked up to a recirculating overlying water system in a temperature-controlled room set to approximately field temperature (6°C and 21 °C in winter and summer, respectively). During oxygen imaging, cores were rotated occasionally to look for activity in different parts of the cores. These rotations are readily apparent in the images. On 8/5/2020 from ~Image 1634 in the 200804 data set to ~ Image 5320, a hypoxic/anoxic event was induced by reducing the oxygen supply to the recirculating water and allowing respiration within the cores to draw down the oxygen concentration.

Determination of Porosity and Permeability:
In July of 2017, four 3.8 cm inner diameter cores were filled with sediment from the study site using the same method as the Summer 2019 Antfarm experiment. These cores were allowed to settle overnight and then measured for permeability by constant head tests (Klute and Dirksen 1986), i.e., measuring the flow rate of water through the cores under at least 3 different pressure heads. Cores were subsampled with a cut-off 10 mL syringes and porosity was estimated via weight loss on dehydration of water-saturated sediment. The results of these measurements are reported as estimates for the hydraulic conductivity and porosity of sediments used in these experiments.

Sampling and analytical procedures:

O2 images were taken over a period of multiple days with slightly varying spatial and temporal resolutions. Specifics on each data set are provided in the supplemental table "Dataset Metadata Log." In all cases, O2 optodes were calibrated using the lifetime values measured in the anoxic sediment and in the air-saturated overlying water.

Instruments:

The luminescence lifetime imaging system is modified after Holst and Grunwald (2001) and comprises a cooled CCD camera (pco.1600MOD, PCO AG, Kelheim, Germany), a pulse delay generator (T560, Highland Technology, San Francisco CA), an array of blue-light emitting diodes (LEDs; lambda max = 455 nm, LXHL-LR5C, Philips Lumileds, San Jose, CA) attached to a heat sink, and a custom-made power supply. The oxygen optodes were prepared as described in Precht et al. (2004). The CCD camera accumulates multiple exposures with a programmable modulation time. Using two intensity images, the luminescence lifetime image is calculated (Holst and Grunwald 2001). The peak current through the LEDs (typically 200–300 mA) and the integration time during which both intensity windows are accumulated (typically 250–1000 ms) were adjusted to optimize data quality. The control of the camera, image acquisition through the IEEE 1394 (firewire) interface and of the delay pulse generator through the RS232 serial interface were done by Borland Delphi and C++ computer software developed by Lubos Polercky (Utrecht University, The Netherlands) and Uli Henne (German Aerospace Center, Göttingen, Germany).

Issue Report:
For routine checks and troubleshooting lights were switched on for short periods, or persons were blocking the camera view during the multi-day imaging series. With lights on, the optical O2 measurements is impaired. These images should be excluded from any future analyses and are easily recognizable due to abrupt jumps in the data series. Also, during the Summer 2019 Antfarms experiment, the O2 imaging system was used to simultaneously image O2 distributions in an unrelated column study. These columns are easy recognizable in the right half of the O2 images. In our experience, keeping data spatially uniform and temporally complete - rather cropping images and chopping time-series - makes data analyses much easier. The time-series data therefore include time periods with non-sense data but are always the full 1600 x 1200 pixel O2 image.

Data Processing Description

Data processing

The optode system that was used stores O2 images as B16 files (16-colour Bitmap PCO files) which were converted into more widely used Matlab files. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R. The resultant CSV files contain oxygen concentrations in % air saturation in a spatial data matrix (% air saturation for each pixel row – column coordinate) for the 1600 x 1200 pixel image and can be visualized or further analyzed with open-source software such as Image J (File>Import>Text Image).

Each .mat file contains a data structure (outo2int16) with each row and column coordinate corresponding to a specific pixel in the O2 image. The distance between adjacent pixels in x and y orientation varied between experiments and can be calculated as the square root of the pixel area given in the supplemental file "Dataset Metadata Log." To facilitate orientation in the data set, O2 images of the full dataset are provided as png files. PNG images have a resolution of 1600 x 1200 pixels so that a specific image pixel corresponds to the respective column and row in the csv data files.

See "Data Files" for access to processed optode image .png images, the Matlab files, R-Script, and example CSV files described above. These files were bundled into 7 .zip file bundles. The full file inventory information is in the supplemental file "file_inventory.csv."

BCO-DMO Data Manager Notes:
* Metadata table extracted from Methodology text and added as "Dataset Metadata Log." Non-standard characters (ASCII extended) replaced with interoperable equivalent characters (e.g. Temperature "12→4" changed to "12 to 4."
* Folder hierarchy provided to BCO-DMO was preserved when bundling the data files in the individual zip files (E.g. Summer_2019_Antfarm_part2.zip). Zips made with ZIP64 support since > 4GB.
* Supplemental "file_inventory.csv" contains information for all files including which .zip file it is contained in.

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Data Files

File
Summer_2019_Antfarm_part1.zip (Octet Stream, 26.50 GB) MD5:35a6a7b0eba71f5f3dfcd821ff4a8f73 Optode image data (processed .png and Matlab .mat files) Summer_2019_Antfarm_part1.zip contains data folders (folder name is yymmdd): Summer 2019 Antfarm/190606 Summer 2019 Antfarm/190610 Summer 2019 Antfarm/190613 Summer 2019 Antfarm/190618 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.

File
Summer_2019_Antfarm_part2.zip (Octet Stream, 11.92 GB) MD5:4b2b6ca5c88aa34501981aca0a4bc07c Optode image data (processed .png and Matlab .mat files) Summer_2019_Antfarm_part2.zip contains data folders (folder name is yymmdd): Summer 2019 Antfarm/190620 Summer 2019 Antfarm/190622 Summer 2019 Antfarm/190624 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.
Summer_2020_Cores_part1.zip (Octet Stream, 26.68 GB) MD5:14aca0d539839c33be40362955f84811 Optode image data (processed .png and Matlab .mat files) Summer_2020_Cores_part1.zip contains data folders (folder name is yymmdd): Summer 2020 Cores/200725 Summer 2020 Cores/200727 Summer 2020 Cores/200728 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.
Summer_2020_Cores_part2.zip (Octet Stream, 15.97 GB) MD5:424bc93c70529d52601623044ed0bc1b Optode image data (processed .png and Matlab .mat files) Summer_2020_Cores_part2.zip contains data folders (folder name is yymmdd): Summer 2020 Cores/200731 Summer 2020 Cores/200803 Summer 2020 Cores/200804 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.
Summer_2020_Cores_part3.zip (Octet Stream, 28.79 GB) MD5:411b5e76d043c2edfaea0545717200be Optode image data (processed .png and Matlab .mat files) Summer_2020_Cores_part3.zip contains data folders (folder name is yymmdd): Summer 2020 Cores/200807 Summer 2020 Cores/200809 Summer 2020 Cores/200810 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.

File
Winter_2020_Cores_part1.zip (Octet Stream, 23.91 GB) MD5:2a30606793f226e5404ee8abd61c66f6 Optode image data (processed .png and Matlab .mat files) Winter_2020_Cores_part1.zip contains data folders (folder name is yymmdd): Winter 2020 Cores/200309 Winter 2020 Cores/200312 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.
Winter_2020_Cores_part2.zip (Octet Stream, 15.97 GB) MD5:e3a1dc92b0ea15e21afe781c6cf2a99f Optode image data (processed .png and Matlab .mat files) Winter_2020_Cores_part2.zip contains data folders (folder name is yymmdd): Winter 2020 Cores/200316 Winter 2020 Cores/200320 The .png files are processed O2 images from the optode system. The matlab (.mat) files contain data converted from O2 images (B16 files, 16-colour Bitmap PCO files) from the optode system. Matlab files can be converted to CSV text image files using code provided in R_O2_Converter.R (see example output in "190606_csv_examples.zip"). See the "Processing Description" section for more information.

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Supplemental Files

File
CSV examples filename: 190606_csv_examples.zip (Octet Stream, 9.46 MB) MD5:21d70f15ce8ab14d268b326c01060874 Example CSV file output from script "R_O2_Converter.R" which converts from MATLAB .mat files containing oxygen concentration images into .csv files containing the same information. e.g. Summer 2019 Antfarm/190606_csv_examples/190606_0000_O2.csv
Dataset Metadata Log filename: dataset_metadata.csv (Octet Stream, 1.56 KB) MD5:84716086b59bbea53355612f57e7843e O2 images were taken over a period of multiple days with slightly varying spatial and temporal resolutions. Specifics on each data set are provided in this table. In all cases, O2 optodes were calibrated using the lifetime values measured in the anoxic sediment and in the air-saturated overlying water. Parameter (Column information): Dataset name/date Aquarium dimensions in cm (L x W x D, or diameter, height) Spatial resolution (pixel area in mm2) Temporal resolution, Hours covered (Images min-1) Days after worms added to aquarium Temp. (ºC), worm density (ind. m-2) Sediment hydraulic conductivity (cm min-1) Sediment porosity,OCR (uM min-1) missing data identifier "na"
File Inventory filename: file_inventory.csv (Octet Stream, 24.69 MB) MD5:3dec38add888db452bd3791833e72230 Each zip file bundle contains filesize name, date, and relative filepath within the zipfile bundle. Includes the name of the zipfile bundle each file can be found in.
R-language script (Matlab to CSV format) filename: R_O2_Converter.R (Octet Stream, 1.28 KB) MD5:3d84775f5e09df53139e9d5be3d7f8ea See the example files that were made using this script in: "190606_csv_examples.zip" General Description: This script converts MATLAB .mat files containing oxygen concentration images into .csv files containing the same information. These .csv files are readable as data tables by R and spreadsheet softwares and readable by ImageJ as text images. Each value in the generated .csv represents the oxygen concentration in % air saturation at the pixel corresponding to the same coordinates within the grid. Dependencies & Prerequisites: The script should install the R libraries “R.matlab” and “stringr”, which are required for it to run properly, the first time it runs. They can be installed manually before running this script to ensure proper operation, although this step should not be necessary. This script was written and tested with R version 3.4.1 and RStudio version 1.0.153. It should work with any version of R and RStudio at or above these versions (and likely with older versions as well). Detailed Description: This script uses the “R.matlab” library to open .mat files containing oxygen image information with R. It then extracts the data values from the .mat file (where they are stored as integer values equal to % air saturation multiplied by 100). The extracted data are divided by 100 so that each value in the resulting table is equal to the % air saturation at the corresponding pixel. These resulting values are then written to a .csv file with the same file name (but a different extension) as the original file. This process is performed automatically in numerical order for each file within a user-specified range of file names. The result files are saved to the same directory as the original .mat files. The purpose of this conversion is to allow software other than MATLAB to access, view, and manipulate the raw data contained within oxygen image .mat files.

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Related Publications

Dwyer I., Volkenborn N., Swenson, D., Aller, R.C., Wehrmann L. Seasonality of burrow irrigation behavior of the maldanid polychaete, Clymenella torquata and implications for redox-sensitive processes in permeable sediments. In preparation to be submitted to the Journal of Experimental Marine Biology and Ecology.
Results

Holst, G., & Grunwald, B. (2001). Luminescence lifetime imaging with transparent oxygen optodes. Sensors and Actuators B: Chemical, 74(1–3), 78–90. https://doi.org/10.1016/s0925-4005(00)00715-2
https://doi.org/10.1016/S0925-4005(00)00715-2
Methods

Klute, A., & Dirksen, C. (2018). Hydraulic Conductivity and Diffusivity: Laboratory Methods. Methods of Soil Analysis, 687–734. https://doi.org/10.2136/sssabookser5.1.2ed.c28

Results

Matsui, G. Y., Volkenborn, N., Polerecky, L., Henne, U., Wethey, D. S., Lovell, C. R., & Woodin, S. A. (2011). Mechanical imitation of bidirectional bioadvection in aquatic sediments. Limnology and Oceanography: Methods, 9(3), 84–96. Portico. https://doi.org/10.4319/lom.2011.9.84
Methods

Precht, E., Franke, U., Polerecky, L., & Huettel, M. (2004). Oxygen dynamics in permeable sediments with wave-driven pore water exchange. Limnology and Oceanography, 49(3), 693–705. Portico. https://doi.org/10.4319/lo.2004.49.3.0693
Methods

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	cooled CCD camera (pco.1600MOD, PCO AG, Kelheim, Germany)
Generic Instrument Name	Camera
Dataset-specific Description	Luminescence lifetime imaging with transparent oxygen optodes includes "cooled CCD camera (pco.1600MOD, PCO AG, Kelheim, Germany)." See Methodology for a full description of "Luminescence lifetime imaging with transparent oxygen optodes."
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	array of blue-light emitting diodes (LEDs)
Generic Instrument Name	LED light
Dataset-specific Description	Luminescence lifetime imaging with transparent oxygen optodes includes "an array of blue-light emitting diodes (LEDs; lambda max = 455 nm, LXHL-LR5C, Philips Lumileds, San Jose, CA) attached to a heat sink." See Methodology for a full description of "Luminescence lifetime imaging with transparent oxygen optodes."
Generic Instrument Description	A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.

Dataset-specific Instrument Name	Luminescence lifetime imaging with transparent oxygen optodes
Generic Instrument Name	Optode
Dataset-specific Description	In all cases, O2 optodes were calibrated using the lifetime values measured in the anoxic sediment and in the air-saturated overlying water. See Methodology for a full description of "Luminescence lifetime imaging with transparent oxygen optodes."
Generic Instrument Description	An optode or optrode is an optical sensor device that optically measures a specific substance usually with the aid of a chemical transducer.

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Project Information

Iron cycling in bioturbated sediments - Fluxes, diagenetic redistribution, and isotopic signatures (Fe flux)

Coverage: Long Island

NSF Award Abstract:

Dissolved iron (Fe) is an important nutrient for photosynthetic microalgae in the surface ocean and low concentrations in seawater can limit their growth. Because microalgae are the basis of marine food webs, scientists strive to improve our understanding of Fe availability in the oceans and the importance of different iron sources. Iron enters the ocean via rivers, groundwater, and wind-blown dust; however, release from the seafloor can be an additional source but this contribution is not well known. In this project, scientists from the State University of New York, Stony Brook (SUNY-SB) will investigate how chemical reactions in ocean sediments and bottom-dwelling organisms, such as burrowing clams and worms, affect the transport of Fe from the seafloor into the overlying water. Animals pump water through their burrows to obtain oxygen and in the process, transport dissolved Fe out of the sediment and into the overlying water. We will analyze the Fe concentration in both muddy and sandy sediment and in the water that enters and exits animal burrows, as well as determine the isotope composition of the Fe. Different sources of Fe can have different isotope compositions which may help trace the origin of this element found in different parts of the ocean. An improved understanding of Fe cycling at the ocean seafloor will help us to better predict how changing environmental conditions, for example due to human influence, will affect important processes in the ocean, such as primary production by microalgae.

The project will allow two PhD students and several undergraduate students to take part in laboratory experimental work, sediment sampling during research cruises and train in chemical analysis of sediment and water. Undergraduate student involvement will be facilitated through the Undergraduate Research and Creative Activities (URECA) program at SUNY-SB. Also, in collaboration with the Science and Technology Entry Program (STEP), a summer module "Buried Alive" will be offered to historically underrepresented and economically disadvantaged high school students. It combines field sampling, laboratory experimentation, data analyses, and scientific communication. Students will set-up their own "seafloor ant farms" and record the activities of animals living in the sediment using photographic equipment. Students will be trained in using image analysis software to produce time-lapse movies which they will present on the final day of the program. Public outreach will be fostered through annual hands-on demonstrations of "seafloor slices" at the New York Marine Science Festival "Submerge" and at SUNY-SB earth celebration day "Earthstock" with real-time visualizations of pressure dynamics in the sediment induced by living organisms or by injecting water with syringes. The project supports the advancement and development of two Early Career Scientists with no prior NSF research support.

Dissolved Fe is an important nutrient for photosynthetic microalgae in the surface ocean and can limit their productivity. Iron is supplied to the ocean from multiple sources, including rivers, groundwater, hydrothermal vents, and by release from the seabed. This project will fill key gaps in our knowledge of seabed sources, and emphasizes the interconnected effects of bioturbation by infaunal organisms, bottom water oxygen (O2) concentrations, sedimentary organic matter content, and sediment permeability on iron cycling and isotopic redistribution in continental margin sediments. Specifically, we will gain a mechanistic understanding of the impact of variable O2 concentrations within infaunal burrows (as a function of irrigation activity and sedimentary setting) and in the overlying water (in response to large scale environmental change) on dissolved Fe fluxes and re-precipitation, the isotopic fractionation related to these processes, and the consequences for isotopic signatures of dissolved Fe in the water column and particulate Fe preserved in sediments. This project will significantly advance understanding of sedimentary Fe cycling and the use of Fe isotopes to constrain the magnitude and dynamics of the benthic Fe source to the ocean. Improved understanding of sedimentary Fe cycle will enhance prediction of future responses of biogeochemical processes such as primary production to rapidly changing environmental conditions and to optimally infer past conditions from authigenic Fe minerals preserved in the sedimentary record. This knowledge is particularly valuable with regard to continental shelf environments where anthropogenic effects are altering deposition patterns of organic carbon and expanding oxygen minimum zones.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1757045

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