Orientation and growth of colonies of four diatom species (Stephanopyxis turris, Pseudo-nitzschia sp., Skeletonema sp., and Odontella sinensis) in Couette flow

Website: https://www.bco-dmo.org/dataset/864069
Data Type: experimental
Version: 1
Version Date: 2021-11-04

Project
» Collaborative Research: Orientation of elongate diatoms as a strategy for light harvesting (Phytoplankton Orientation)

Contributors	Affiliation	Role
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Abstract
This dataset includes data on the orientation and growth of colonies of four diatom species (Stephanopyxis turris, Pseudo-nitzschia sp., Skeletonema sp., and Odontella sinensis) in Couette flow. Experiments were conducted at Harbor Branch Oceanographic Institute in Fort Pierce, FL, USA from March 2020 to June 2021. Data are provided from all replicates and summary data (means) are provided as a Supplemental File.

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Coverage

Spatial Extent: **Lat**:27.53428 **Lon**:-80.35547
Temporal Extent: 2020-03-23 - 2021-06-26

Acquisition Description

Uni-algal cultures of the colonial diatoms *Stephanopyxis turris*, *Pseudo-nitzschia* sp., *Skeletonema* sp., and *Odontella sinensis* were grown in 2 separate Couette chambers under controlled shear conditions for up to 24 days. The Couette chambers (40 cm height) consisted of an inner rotating cylinder (12.7 cm radius) and an outer stationary cylinder (14.92 cm radius). A laminar flow chamber rotated at 0.5 rpm and a turbulent flow chamber rotated at 13 rpm. The gap between the cylinders was filled with 8 L of sterile L1 medium (Guillard and Hargraves 1993). Experiments took place in a temperature and light controlled walk-in incubator at 20° C with a 12:12 hour light:dark cycle. Light was provided by cool white fluorescent lamps producing 33 µmol photons m^{-2} s^{-1} at the center of each chamber.

Digital holograms through the entire height of each Couette chamber (40 cm) were acquired at ~1 day intervals during each experiment. Each hologram imaged 19.25 mL of water. The total volume imaged and analyzed on each day and for each chamber was ~1.5 L.

A custom digital holographic microscope (DHM) was constructed to image particles within the Couette chambers. Coherent illumination was provided by a green (532 nm) nanosecond pulsed laser. The incident beam was directed upward through the bottom of the chamber and images were acquired by a CCD camera (4896 x 3264 pixels) positioned above the chamber looking downward through the illuminated volume. An objective lens in front of the camera increased magnification and positioned the hologram image plane at the water surface. Hologram resolution was 1.74 µm/pixel.

Processing Description

Data Processing:
Holograms were numerically reconstructed in Matlab (version 2019a) using the Kirchoff-Fresnel convolution kernel (Katz and Sheng 2010) at 1 mm intervals throughout the height of the chamber. Reconstructed images were combined to produce a single extended depth of field (EDF) image for each hologram. These EDF images were segmented with a fixed threshold and particle measurements were obtained through automated region analysis in Matlab. See Nayak et al. 2018 for further details.

BCO-DMO Processing:
- concatenated data from separate Excel files into one dataset;
- created the "Replicate" and "Species" columns;
- renamed fields to conform with BCO-DMO naming conventions;
- changed Date to YYYY-MM-DD format;
- concatenated each of the Summary data files into one dataset (see Supplemental Files).

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Supplemental Files

File
Summary Data filename: summary_data.csv (Comma Separated Values (.csv), 25.84 KB) MD5:458049382731212353d75c485aa31679 *Summary data from Couette flow experiments of four diatom species (Stephanopyxis turris, Pseudo-nitzschia sp., Skeletonema sp., and Odontella sinensis). Associated with dataset https://www.bco-dmo.org/dataset/864069.* *Column names, descriptions, and units:* *Species = species names* *Replicate = replicate number* *Date = date; format: YYYY-MM-DD* *No_of_colony_0_5_rpm = number of colonies analyzed; from the laminar flow chamber rotating at 0.5 rpm (count)* *Total_Volume_0_5_rpm = volume analzyed; from the laminar flow chamber rotating at 0.5 rpm (milliliters (mL))* *Mean_Orientation_0_5_rpm = mean colony angle from direction of flow; from the laminar flow chamber rotating at 0.5 rpm (degrees)* *Mean_Major_Axis_Length_0_5_rpm = mean colony length; from the laminar flow chamber rotating at 0.5 rpm (micrometers (um))* *Mean_Aspect_Ratio_0_5_rpm = mean ratio of colony length to width; from the laminar flow chamber rotating at 0.5 rpm* *No_of_colony_13_rpm = number of colonies analyzed; from the laminar flow chamber rotating at 13 rpm (count)* *Total_Volume_13_rpm = volume analzyed; from the laminar flow chamber rotating at 13 rpm (milliliters (mL))* *Mean_Orientation_13_rpm = mean colony angle from direction of flow; from the laminar flow chamber rotating at 13 rpm (degrees)* *Mean_Major_Axis_Length_13_rpm = mean colony length; from the laminar flow chamber rotating at 13 rpm (micrometers (um))* *Mean_Aspect_Ratio_13_rpm = mean ratio of colony length to width; from the laminar flow chamber rotating at 13 rpm*

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Related Publications

Guillard, R. R. L., & Hargraves, P. E. (1993). Stichochrysis immobilis is a diatom, not a chrysophyte. Phycologia, 32(3), 234–236. doi:10.2216/i0031-8884-32-3-234.1
Methods

Katz, J., & Sheng, J. (2010). Applications of Holography in Fluid Mechanics and Particle Dynamics. Annual Review of Fluid Mechanics, 42(1), 531–555. doi:10.1146/annurev-fluid-121108-145508
Methods

Nayak, A. R., McFarland, M. N., Sullivan, J. M., & Twardowski, M. S. (2017). Evidence for ubiquitous preferential particle orientation in representative oceanic shear flows. Limnology and Oceanography, 63(1), 122–143. doi:10.1002/lno.10618
Methods

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Parameters

Parameter	Description	Units
Species	name of species	unitless
Replicate	replicate number	unitless
Date	date of analysis; format: YYYY-MM-DD	unitless
Orientation_0_5_rpm	colony angle from direction of flow; from the laminar flow chamber rotating at 0.5 rpm	degrees
Major_Axis_Length_0_5_rpm	colony length; from the laminar flow chamber rotating at 0.5 rpm	micrometers
Aspect_Ratio_0_5_rpm	ratio of colony length to width; from the laminar flow chamber rotating at 0.5 rpm	unitless (ratio)
Orientation_13rpm	colony angle from direction of flow; from the laminar flow chamber rotating at 13 rpm	degrees
Major_Axis_Length_13_rpm	colony length; from the laminar flow chamber rotating at 13 rpm	micrometers
Aspect_Ratio_13_rpm	ratio of colony length to width; from the laminar flow chamber rotating at 13 rpm	unitless (ratio)

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Instruments

Dataset-specific Instrument Name	Couette chamber
Generic Instrument Name	Taylor–Couette system
Generic Instrument Description	An apparatus composed of two vertically oriented, coaxial cylinders separated by a gap that contains seawater. During operation, the outer cylinder rotates at a prescribed speed causing relative motion between the cylinders and thereby shearing the seawater between them.

Dataset-specific Instrument Name	digital holographic microscope (DHM)
Generic Instrument Name	Digital inline holographic microscope
Generic Instrument Description	A Digital Inline Holographic Microscope (DIHM) uses coherent (laser) light and a digital camera to image objects with micrometer scale resolution. A portion of the light scattered by illuminated objects interferes with incident light in a predictable manner. The resulting interference patterns projected onto a two-dimensional plane (i.e. digital camera sensor) are recorded as holograms. These digital holograms are then numerically reconstructed to produce an in-focus image at a given distance from the recording plane. A relatively large illuminated volume (>100 mL) can be reconstructed in this manner to produce a single image with an extended depth of field.

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Project Information

Collaborative Research: Orientation of elongate diatoms as a strategy for light harvesting (Phytoplankton Orientation)

Coverage: Laboratory based experiments conducted at FAU-HBOI and URI

NSF Award Abstract:
Phytoplankton have an intimate connection to the hydrodynamic environment in which they live.

Previous studies have examined the role that turbulence and shear play in nutrient uptake, patch/layer formation, and predator-prey encounters, but the role of phytoplankton orientation to increase light capture (and ultimately primary production) has been largely overlooked. Compelling evidence of persistent horizontal orientation of chain-forming diatoms, obtained from novel in situ holographic imaging, has led to a hypothesis that in regions of strong stratification, shear flows will lead to systematic horizontal orientation of elongate phytoplankton forms that maximizes their cross-sectional area (and light capture) in the ambient downwelling light field. It has also been suggested that variations in phytoplankton size and shape are fundamental traits conferring selective competitive advantages in certain hydrodynamic environments, thus modifying/mediating community composition. The interdisciplinary research of this project crosses three scientific disciplines (biology, optics and fluid dynamics) and will advance our understanding of the function of diverse forms of phytoplankton, their interactions with fluid flows, and the resultant impacts on the optics of the environment. The project will support a number of undergraduate and graduate students, and post-doctoral researchers.

This project combines analysis of previously collected field data with laboratory experiments and modeling. For the field data analysis, phytoplankton orientation is quantified from in situ holographic images of the undisturbed water column along with concurrent high resolution measurements of critical physical (turbulence/shear/stratification) and optical parameters collected from a ship-based holographic bio-physics profiler. In the laboratory, the orientation response of different phytoplankton species and morphologies is evaluated in custom built shear tanks under controlled laminar and turbulent conditions to confirm that elongate forms can orient in certain hydrodynamic environments to maximize light capture. In addition, controlled growth/physiology experiments in various shear tank treatments will explore the effects of orientation on growth, photosynthetic parameters and productivity. Lastly, the project results will be incorporated into a global analysis of observed and modeled physical, bio-optical and ecologically-relevant parameters, to quantify the relevance of this phenomenon to primary production and the carbon cycle.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1657332

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