Particle characteristics of low and high optical-density particles (LODP and HODP) from Focused Shadowgraph Imaging (FoSI) in the NE Atlantic, Jan-Mar 2023 (DESAFÍO)

Website: https://www.bco-dmo.org/dataset/1003429
Data Type: Cruise Results
Version: 1
Version Date: 2026-08-04

Project
» Linking optical characteristics of small particles (50 - 500 micrometer) with their sinking velocities in the mesopelagic environment (Mesopelagic particles)

Contributors	Affiliation	Role
Bochdansky, Alexander Boris	Old Dominion University (ODU)	Principal Investigator
Hernández-León, Santiago	Universidad de Las Palmas de Gran Canaria	Co-Principal Investigator
Couret, Maria	Universidad de Las Palmas de Gran Canaria	Scientist
Huang, Huanqing	Old Dominion University (ODU)	Student
York, Amber D.	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
This dataset comprises particle morphological measurements (for particles 200-1000 micrometer) collected during the DESAFÍO expedition (31 January–2 March 2023) in the northeastern subtropical Atlantic Ocean, spanning 22 CTD casts across the Azores, the Canary Islands, and the intervening open ocean. Particles imaged in situ were classified into two optical density–based pools, a low-optical-density particle (LODP) pool representing gel-like and other translucent particles, and a high-optical-density particle (HODP) pool representing more opaque particles, with morphological attributes including equivalent spherical diameter (ESD), optical density, aspect ratio and circularity recorded for each. Measurements were compiled across three geographic regions (CI, OO and AZ) and three depth strata (epipelagic, mesopelagic, and bathypelagic), allowing characterization of particle shape and composition across spatial and depth gradients in the study region (see listed Results Publications).

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Coverage

Location: Northeastern subtropical Atlantic Ocean
Spatial Extent: **N**:41.09233 **E**:-13.2007 **S**:28.7 **W**:-25.147

Temporal Extent: 2023-01-31 - 2023-03-02

Dataset Description

Note on spatial and temporal resolution: The overall date and location range (lat,lon bounding box) were added to the dataset metadata. More detailed spatial and temporal resolution per profile is included in the related dataset:

Vertical profiles of Low and high-optical-density particles (LODP and HODP) and CTD hydrographic data from Focused Shadowgraph Imaging (FoSI) in the NE Atlantic, Jan–Mar 2023 (DESAFÍO)
https://www.bco-dmo.org/dataset/1003447

Acronyms:

DESAFÍO = DisEntangling Seasonality of Active Flux in the Ocean (expedition name)
FoSI = Focused Shadowgraph Imaging
LODP = Low Optical-Density Particles
HODP = High Optical-Density Particles
OD = Optical Density
ESD = equivalent spherical diameter
AZ = Azores
CI = Canary Islands
OO = Open Ocean
RGF = Relative Gel Fraction
ART ANOVA = Aligned Rank Transform (ART) Analysis of Variance (ANOVA)
ANCOVA = Analysis of Covariance

Methods & Sampling

Particle data were collected during the DESAFÍO expedition (DisEntangling Seasonality of Active Flux in the Ocean; PID2020-118118RB-100) in the Northeastern subtropical Atlantic Ocean, from 31 January to 2 March 2023. Sampling spanned a transect between the Azores (AZ; 41°5'32.39"N, 24°58'41.00"W) and the Canary Islands (CI; 28°41'00.00"N, 13°12'2.40"W). Twenty-two CTD/rosette casts were grouped into three geographic regions — CI (casts 1–6), the open-ocean station OO (casts 7–14, west of CI and south of the Azores), and AZ (casts 15–22) — and particle and hydrographic data within each cast were further partitioned into three depth strata: epipelagic (≤200 m), mesopelagic (200–1,000 m), and bathypelagic (>1,000 m). Four casts (5, 6, 18, and 20) have incomplete particle-image profiles due to unexpected camera shutdowns, likely caused by low battery voltage.

Data Processing Description

Particle images were processed following the pipeline of Huang and Bochdansky (2025), with analysis restricted to particles ≥23.5 µm (linear dimension) to exclude single-pixel noise. Two particle pools were defined by thresholds calibrated with optical density (OD): low-OD particles (LODP; threshold 11, OD = 0.1466), which include the numerically dominant gel particles, and high-OD particles (HODP; threshold 29, OD = 0.2246), representing more opaque particles comparable to those detected by other optical instruments. Morphological metrics (equivalent spherical diameter (ESD), optical density, aspect ratio and circularity) were extracted using MATLAB function regionprops(), with OD calibrated from brightness via an ensemble model. Both particle pools were resolved to 1-m depth bins for downstream analysis, including Theil–Sen regression with Mann–Kendall trend testing, Aligned Rank Transform (ART) ANOVA to assess regional and depth effects on abundance and total particle volume, Kolmogorov–Smirnov and Wilcoxon rank-sum tests for distributional/median comparisons, Wilcoxon signed-rank tests for paired day–night comparisons, calculation of the Relative Gel Fraction (RGF) from LODP and HODP abundances, and particle number spectrum analysis with ANCOVA to test slope homogeneity across regions and depths.

Huang, H., & Bochdansky, A. B. (2025). Optimizing an image analysis protocol for ocean particles in focused

shadowgraph imaging systems. Frontiers in Marine Science, 12, 1539828.

BCO-DMO Curation Notes

- Loaded particle_characteristics_combined_with_regions.csv from submission storage into table 1003429_v1_fosi-particle-characteristics, using comma delimiter, first row as header, empty string and "nd" set as missing values, casting all columns to strings on load
- Set data types for columns: ESD (number), OD (number), aspect_ratio (number), circularity (number), depth_zone (string), particlePool (string), regions (string)
- Updated column metadata with descriptions, standard name IDs, and supplied units
- Dumped final table to output as 1003429_v1_fosi-particle-characteristics.csv, with unique lat/lon extraction enabled

Problem Description

N/A

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Data Files

File	
1003429_v1_fosi-particle-characteristics.csv	(Comma Separated Values (.csv), 1.54 MB) MD5:c27974ccd5693c98d019bd2ffb33fdcc
Primary data file for dataset ID 1003429, version 1	

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Related Publications

Bochdansky, A. B., Huang, H., & Conte, M. H. (2022). The aquatic particle number quandary. Frontiers in Marine Science, 9. https://doi.org/10.3389/fmars.2022.994515
Results

Huang, H., & Bochdansky, A. B. (2025). Optimizing an image analysis protocol for ocean particles in focused shadowgraph imaging systems. Frontiers in Marine Science, 12. https://doi.org/10.3389/fmars.2025.1539828
Results

Huang, H., A., Couret, M., Hernández-León, S., Bochdansky, A. B. (n.d.) Visualizing the Barely Detectable: Particle Characteristics of the Elusive Aquatic Gel Phase in the Northeastern Subtropical Atlantic. Science Advances. Accepted.
Results

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Related Datasets

IsRelatedTo

Huang, H., Bochdansky, A. B., Couret, M., Hernández-León, S. (2026) **Vertical profiles of low and high-optical-density particles (LODP and HODP) and CTD hydrographic data from Focused Shadowgraph Imaging (FoSI) in the NE Atlantic, Jan-Mar 2023 (DESAFÍO).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-08-04 doi:10.26008/1912/bco-dmo.1003447.1 [view at BCO-DMO]
Relationship Description: Related FoSI particle datasets from the DESAFÍO expedition in the northeastern

subtropical Atlantic Ocean from January 31 to March 2, 2023.

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Parameters

Parameter	Description	Units
particlePool	LODP (low optical-density particles, recognized at threshold > 11) or HODP (high optical-density particles, recognized at threshold > 29)	unitless
depth_zone	epi: epipelagic zone (0-200m);meso: mesopelagic zone (200-1000m); bathy: bathypelagic zone (>1000m)	unitless
regions	The Canary Islands region (CI; casts 1–6), the oligotrophic ocean region (OO; casts 7–14), and the Azores region (AZ; casts 15–22)	unitless
ESD	Equivalent spherical diameter	micrometers
aspect_ratio	The ratio of MajorAxisLength and MinorAxisLength	unitless
OD	Optical density calibrated from intensity (ranging from 0.04-1)	unitless
circularity	A measure of how circular a particle is, calculated from 4*pi*Area/Perimeter^2	unitless

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Instruments

Dataset-specific Instrument Name	Focused Shadowgraph Imaging (FoSI) System
Generic Instrument Name	Camera
Dataset-specific Description	Vertical profiles of conductivity, temperature, dissolved oxygen, fluorescence, and turbidity were measured from the surface to 4,000 m using a Sea-Bird SBE911 Plus CTD fitted with a Sea-Bird SBE43 dissolved-oxygen sensor and a Wet Labs ECO-NTU-RTD fluorometer/turbidimeter, all mounted on the rosette sampler; these profiles were binned to 1 dbar. Particle imagery was collected concurrently using a Focused Shadowgraph Imaging (FoSI) System attached to the base of the CTD rosette, providing particle data co-located in space and time with the CTD sensor suite. The configuration of FoSI was described by Bochdansky et al. (2022) and Huang and Bochdansky (2025). The FoSI imaged particles at a resolution of 11.75 µm/pixel.
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Sea-Bird SBE911 Plus CTD
Generic Instrument Name	Sea-Bird SBE 911plus CTD
Dataset-specific Description	Vertical profiles of conductivity, temperature, dissolved oxygen, fluorescence, and turbidity were measured from the surface to 4,000 m using a Sea-Bird SBE911 Plus CTD fitted with a Sea-Bird SBE43 dissolved-oxygen sensor and a Wet Labs ECO-NTU-RTD fluorometer/turbidimeter, all mounted on the rosette sampler; these profiles were binned to 1 dbar. Particle imagery was collected concurrently using a Focused Shadow Imaging System (FoSI) attached to the base of the CTD rosette, providing particle data co-located in space and time with the CTD sensor suite. The configuration of FoSI was described by Bochdansky et al. (2022) and Huang and Bochdansky (2025). The FoSI imaged particles at a resolution of 11.75 µm/pixel.
Generic Instrument Description	[tethered, real-time] The Sea-Bird SBE 911 plus is a type of CTD instrument package for continuous measurement of conductivity, temperature and pressure. The SBE 911 plus includes the SBE 9plus Underwater Unit and the SBE 11plus Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 plus and SBE 11 plus is called a SBE 911 plus. The SBE 9 plus uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 plus and SBE 4). The SBE 9 plus CTD can be configured with up to eight auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). more information from Sea-Bird Electronics

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Deployments

PID2020-118118RB-100

Website	https://www.bco-dmo.org/deployment/1004063
Platform	R/V Sarmiento de Gamboa
Start Date	2023-01-31
End Date	2023-03-02
Description	Cruise name and ID: DisEntangling Seasonality of Active Flux in the Ocean expedition (DESAFÍO; PID2020-118118RB-100)

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Project Information

Linking optical characteristics of small particles (50 - 500 micrometer) with their sinking velocities in the mesopelagic environment (Mesopelagic particles)

Coverage: North Atlantic

NSF Award Abstract

Globally, the ocean removes more carbon dioxide than it releases into the atmosphere storing a portion of the excess carbon in the deep sea. Sinking particles, both living plankton and non-living detritus, are major contributors to this flux of carbon. Modern camera systems and image analysis techniques have made it

possible to count, measure and classify these particles, thus providing oceanographers with a tool to estimate carbon transfers to the deep ocean at high resolution in space and time. Unfortunately, it is not enough to know the sizes of particles to estimate how fast these particles sink because shape and particle density also influence the sinking velocity. This project examines the velocities of individual particles as they sink into the deep ocean using a camera attached to a particle trap. For each of these particles, classification criteria, such as size, shape factors, optical density, and in the case of plankton, taxonomic identification, is determined and compared to their individual sinking velocities. This information serves to calculate overall sinking velocities from surveys of particles in the water column and thereby produce more reliable estimates of carbon fluxes from camera images. This project supports technology development in underwater imaging systems, graduate and undergraduate student education, and science literacy initiatives for middle-school students and their mentors through public outreach programs.

Shipboard and autonomous vehicle surveys of oceanic particle inventories hold great promise for estimating carbon fluxes at high temporal and spatial resolutions. However, while the sinking velocities of larger particles such as foraminifera shells and fecal pellets of salps, krill, and larger copepods are relatively well constrained, the dynamics of the smaller particle size pool (50–500 micrometers) remain more elusive. Despite their size and presumed slow sinking velocities, small particles occur in large numbers in the mesopelagic layer and sediment-trap material. Their abundance in the mesopelagic could be the result of deep mixing, or small particles could be remnants of digested larger particles, particles with a high excess density such as lithogenic dust particles, minipellets egested by protists, protist spores, or the result of fragmentation at depth due to the activity of flux feeders, among other possibilities. This project addresses some unanswered questions about the small particle pool by linking individually-resolved optical features with sinking velocities. Using Stokes' law, excess density is being estimated from size and sinking velocity and then assigned to particles from optical surveys. A horizontally installed camera system records sinking velocities, sizes, and features of particles in a sediment trap attached to the Oceanic Flux Program mooring array. The recorded particles are being characterized using 1) classic image analysis, taking various shape factors into account; 2) opacity of individual particles; and 3) image classification with supervised and unsupervised deep learning using convolutional neural networks. A second identical camera surveys the particle inventory at the same station and time in the water column to integrate flux estimates over the existing and undisturbed particle pool. Niskin bottle samples and microscopic examination of particles augment the interpretation of image data. The results of this project contribute to the overarching goal of achieving higher predictive power for carbon flux models based on optical particle surveys.

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-2128438

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