Particle number spectra 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/1003458
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
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Abstract
This dataset presents particle number spectra from the DESAFÍO expedition (PID2020-118118RB-100), collected in the northeastern subtropical Atlantic between the Azores and Canary Islands (31 Jan–2 Mar 2023). Particle images were acquired with a Focused Shadowgraph Imaging (FoSI) System (11.75 µm/pixel) mounted on a CTD/rosette across 22 casts, spanning three regions and three depth strata (epipelagic, mesopelagic, bathypelagic). Particles ≥23.5 µm were classified by optical density into low-OD (gel proxy) and high-OD pools, sorted into size classes, and normalized to compute particle number spectra. Spectral slopes were compared across regions and depths using ANCOVA to assess spatial variability in particle size distributions (see listed Results Publications).

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Coverage

Location: Northeastern subtropical Atlantic Ocean
Spatial Extent: **N**:41.0923 **E**:-13.2007 **S**:28.7 **W**:-25.147
Temporal Extent: 2023-01-31 - 2023-03-02

Dataset Description

See the "Related Datasets" section for other datasets from the same profiles.

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 two depth strata: the mixed layer and the mesopelagic zone. 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, with analysis restricted to particles ≥23.5 µm (linear dimension) to exclude single-pixel noise. Particles were classified by optical density (OD) into two pools — low-OD particles (LODP; threshold 11, OD = 0.1466), used as an approximation for gel particles, and high-OD particles (HODP; threshold 29, OD = 0.2246), representing more opaque particles comparable to those detected by other optical instruments. For particle number spectrum analysis, particles were sorted into discrete size classes and the number size spectrum n was calculated by normalizing the particle count N in each size bin by the bin width (upper minus lower size limit) and the sampled water volume V. Spectra were computed across geographic regions and depth strata to assess spatial variability in particle size distribution, and the homogeneity of spectral slopes among regions/depths was evaluated using ANCOVA, testing the significance of the interaction term between size and the grouping factor.

The particle size bins (in micrometers) used in the analysis are as follows:

edges=[

34.78505426

43.79178876

55.1305957

69.40530789

87.37610582

110

138.4817953

174.3382512

219.4788546

276.3075075

347.8505426

437.9178876

]

BCO-DMO Curation Notes

- Loaded FoSI_spectrum.xlsx (Sheet1) from source file, header row 1, into table named 1003458_v1_fosi-spectrum
- Preserved Excel cell display formatting during load
- Renamed columns to BCO-DMO-conformant parameter names: "log10 (size bin (cm))" to log10_size_bin, "log10 spectrum_LODP_ML" to log10_spectrum_LODP_ML, "log10 spectrum_LODP_meso" to log10_spectrum_LODP_meso, "log10 spectrum_HODP_ML" to log10_spectrum_HODP_ML, "log10 spectrum_HODP_meso" to log10_spectrum_HODP_meso
- Set types of log10_size_bin, log10_spectrum_HODP_ML, log10_spectrum_HODP_meso, log10_spectrum_LODP_ML, and log10_spectrum_LODP_meso columns to number
- Added originally submitted table FoSI_spectrum.xlsx as a supplemental file (is in wide format with columns per spectra for each particle pool, and depth zone).
- Then for the main form of the dataset, transformed to long form table with columns for particlePool, depth_zone,log10_size_bin, log10_spectrum. Unpivot operation.
- - Created new column particlePool (extracted LODP/HODP from original column names) and depth_zone (extracted ML/meso from original column names)
- - Created new value column log10_spectrum holding the unpivoted values
- Set types: depth_zone and particlePool as string, log10_size_bin and log10_spectrum as number
- Reordered columns to: particlePool, depth_zone, log10_size_bin, log10_spectrum
- Column descriptions and units from provided metadata.
- Rounded log10_size_bin to 9 decimal places, preserving trailing zeros, to match the precision of the format shown in Excel in the source file
- Output final table as 1003458_v1_fosi-spectrum.csv

Problem Description

N/A

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Data Files

File	
1003458_v1_fosi-spectrum.csv	(Comma Separated Values (.csv), 3.47 KB) MD5:85fda577f0ff46c9029b44fa820573bc
Primary data file for dataset ID 1003458, version 1. See supplemental files for this same data in an alternate format (wide form table).	

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Supplemental Files

File	
FoSI_spectrum.xlsx	(Microsoft Excel, 9.89 KB) MD5:8ab186ff02671b6f79478952ab66cd5a
Alternate data format for the number spectra of LODP and HODP in the mixed layer and the mesopelagic zone. This is the same data as in the primary table of this dataset but in a different format. This table has separate columns for: log10 (size bin (cm)) log10 spectrum_LODP_ML log10 spectrum_LODP_meso log10 spectrum_HODP_ML log10 spectrum_HODP_meso	

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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) **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).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-08-04 doi:10.26008/1912/bco-dmo.1003429.1 [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.

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	Depth zone (ML=mixed layer, meso=mesopelagic zone)	unitless
log10_size_bin	The log-10 transformed middle points of each size bin used in number spectrum analysis	log10(cm)
log10_spectrum	The log-10 transformed number spectrum	log10(cm^-4)

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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 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	[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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