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)

Website: https://www.bco-dmo.org/dataset/1003447
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 provides depth-resolved particle and hydrographic profiles 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 abundance and total particle volume, derived from a Focused Shadowgraph Imaging System (FoSI) mounted on a CTD/rosette, were resolved to 1-m depth bins and paired with co-located CTD profiles of temperature, salinity, dissolved oxygen, fluorescence, and turbidity (1 dbar bins) spanning the surface to 4,000 m. Particles were classified into low and high optical-density particles (LODP and HODP) to derive the Relative Gel Fraction (RGF) at each depth. Profiles span 22 casts across three geographic regions (Canary Islands, an open-ocean station, and the Azores) and were analyzed using Theil–Sen/Mann-Kendall trend tests and Aligned Rank Transform ANOVA to assess regional and depth-related variability in particle characteristics relative to the hydrographic context (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.

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 and hydrographic profile 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, along 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 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 profiles were further partitioned into three depth strata: epipelagic (≤200 m), mesopelagic (200–1,000 m), and bathypelagic (>1,000 m). Because the particle imaging system was mounted directly on the CTD rosette, particle and hydrographic data were collected simultaneously on the same vertical casts, allowing direct depth-matching between the two profile types. Four casts (5, 6, 18, and 20) have incomplete particle profiles due to unexpected camera shutdowns, likely from low battery voltage.

Data Processing Description

CTD-derived temperature, salinity, dissolved oxygen, fluorescence, and turbidity profiles were binned to 1 dbar. Particle images were processed following the pipeline of Huang and Bochdansky, restricting analysis to particles ≥23.5 µm to exclude single-pixel noise, and classifying particles by optical density into low-OD (LODP; threshold 11, OD = 0.1466) and high-OD (HODP; threshold 29, OD = 0.2246) pools. Particle abundance and total particle volume (TPV) were resolved to 1-m depth bins to match the vertical resolution of the CTD data, and the Relative Gel Fraction (RGF) was calculated at each depth bin from the ratio of LODP to HODP abundance. Depth-resolved trends in particle metrics were evaluated using the Theil–Sen estimator with Mann–Kendall significance testing.

Huang H and Bochdansky AB (2025) Optimizing an image analysis protocol for ocean particles in focused shadowgraph imaging systems. Front. Mar. Sci. 12:1539828. doi: 10.3389/fmars.2025.1539828

BCO-DMO Curation Notes

- Loaded sum_allcasts_twopools.csv from source submission files, naming resulting table 1003447_v1_fosi-particle-profiles
- Configured CSV parsing with comma delimiter, header row 1, and treated empty string, "NaT", and "NA" as

missing values
- Retained blank-header columns and empty rows were removed as part of load
- Updated column metadata with BCO-DMO standard name IDs, descriptions, and supplied units for Conductivity, Date, Density, Depth, Fluorescence, Latitude, Longitude, Oxygen, PAR, Part_No, ParticlePool, PotentialTemperature, SalinityPractical, TotalParticleArea, TotalParticleVolume, and Turbidity columns
- Flagged Depth, Latitude, and Longitude columns as primary parameters
- Converted Date column from string format %m/%d/%Y to date type with output format %Y-%m-%d, preserving column metadata
- Set column data types: Conductivity, Density, Fluorescence, Latitude, Longitude, Oxygen, PAR, PotentialTemperature, SalinityPractical, and Turbidity set to number type; Depth set to integer type; Date set to date type with format %Y-%m-%d; Part_No, TotalParticleArea, and TotalParticleVolume set to numeric float, ParticlePool to string.
- Dumped final table to CSV output as 1003447_v1_fosi-particle-profiles.csv, including generation of a unique latitude/longitude file and saving of the pipeline specification

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Data Files

File
1003447_v1_fosi-particle-profiles.csv (Comma Separated Values (.csv), 23.05 MB) MD5:731fcc864124dacbc5d33c3f2b5c54b6
Primary data file for dataset ID 1003447, 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) **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) **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).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-08-04 doi:10.26008/1912/bco-dmo.1003458.1 [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
Depth	Depth at which particles were imaged	meters (m)
Part_No	Particle abundance. Particle number per liter of water sample derived from FoSI image data.	particles per liter (#/L)
TotalParticleArea	Particle area per image frame derived from FoSI image data	pix/frame
TotalParticleVolume	Total particle volume concentration in part per million (ppm) derived from FoSI image data	parts per million (ppm)
Date	Date when particles were imaged (ISO format).	unitless
Conductivity	Shows how well the water carries electricity measured by CTD	Siemens per meter (S/m)
Density	Shows how dense the water was, measured by CTD	kilograms per cubic meter (kg/m^3)
Fluorescence	An indicator of Chlorophyll concentration measured by CTD	milligrams per cubic meter (mg/m^3)
Oxygen	Oxygen concentration in water measured by CTD	milliliters per liter (mL/L)
PotentialTemperature	The temperature a water parcel would have if moved adiabatically to the surface, eliminating pressure effects measured by CTD	degrees Celsius
SalinityPractical	Determined by measuring electrical conductivity, in-situ temperature, and pressure (depth) measured by CTD	practical salinity units (PSU)
Turbidity	An indicator of water clarity measured by CTD	nephelometric turbidity units (NTU)
PAR	Photosynthetically Active Radiation measured by CTD	micromoles of photons per square meter per second (umol photons/m^2/sec)

Latitude	The latitude of the sampling cast. North-south position from the equator	decimal degrees
Longitude	The longitude of the sampling cast. East-west position from the prime meridian	decimal degrees
ParticlePool	Indicate which particle pool the data belong to. LODP represent low-optical density particles, HODP represent high-optical density particles.	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 SBE43 dissolved-oxygen
Generic Instrument Name	Sea-Bird SBE 43 Dissolved Oxygen Sensor
Generic Instrument Description	The Sea-Bird SBE 43 dissolved oxygen sensor is a redesign of the Clark polarographic membrane type of dissolved oxygen sensors. More information from the manufacturer: https://www.seabird.com/products/sbe-43-dissolved-oxygen-sensor

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

Dataset-specific Instrument Name	Wet Labs ECO-NTU-RTD fluorometer/turbidimeter
Generic Instrument Name	Sea-Bird WETLabs ECO FLNTU(RT)D combined fluorometer and turbidity sensor
Generic Instrument Description	This optical sensor is available in combinations of backscattering, turbidity, and fluorescence measurements. It records in real-time and does not store data. ECOs feature optional active anti-fouling and internal batteries for long-term deployments. This instrument has a user-selectable sample rate up to 8 Hz The fluorometer can typically measure pigment concentrations in the range 0-75 ug/l, with a sensitivity of 0.037 ug/l, at wavelengths of 470 or 695 nm. The turbidity sensor can measure within the range 0-200 NTU, with a sensitivity of 0.098 NTU, at a wavelength of 700 nm. The instrument is stable over a temperature range of 0-30 degC and is rated to a depth of 6000 m.

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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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