# Upper-pelagic particle numbers from imagery on the R/V Atlantic Explorer in the Sargasso Sea and from SCUBA in the Gulf of Trieste in July 2021

**Website**: https://www.bco-dmo.org/dataset/884596
**Data Type**: Other Field Results
**Version**: 1
**Version Date**: 2022-12-28

**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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| Heyl, Taylor | Woods Hole Oceanographic Institution (WHOI BCO-DMO) | BCO-DMO Data Manager |



**Abstract**
This dataset represents Log10-particle numbers per volume versus log10-particle size bins at various threshold levels of the image analysis program taken between 4 and 7-meter depth in the Sargasso Sea and the Gulf of Trieste on July 18, 2021.

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## Coverage

**Spatial Extent**: **N**:45.532 **E**:-13.595 **S**:31.667 **W**:-64.167
**Temporal Extent**: 2021-07-08 - 2021-07-18

### Methods & Sampling

This dataset represents Log10-particle numbers per volume versus Log10-particle size bins at various threshold levels of the image analysis program taken between 4 and 7-meter depth in the Sargasso Sea and the Gulf of Trieste on July 18, 2021.

**In-situ imaging**
The basic configuration of our system is the same as in previous shadowgraph cameras (Arnold and Nuttall-Smith, 1974; Cowen and Guigand, 2008; Ohman et al., 2019), except for the direct inline configuration without mirrors and smaller spatial scales of our system [image field: 15.36 millimeter (mm) x 11.52 mm, 1280 x 960 pixels, image volume: 5.3 milliliters (ml)]. The light source was a red LED (625 nanometers, Cree XLamp) collimated by a 150 mm focal-length plano-convex lens. The light then passes in sequence, through a 25.4 mm sapphire window, 30 mm of seawater, and another 25.4 mm thick sapphire window, a 100 mm plano-convex

lens, before being collected by a 1/3" monochrome CMOS chip with a global shutter (Imaging Source, LLC) and equipped with a 25 mm board camera lens (f/2.5, V-4325, Marshall Electronics). In this telecentric setup, blur at the far edges of the image path is symmetric, and the center of mass is retained so that the edge of the particle is rendered relatively accurately even if it is slightly out of focus (Watanabe and Nayar, 1997; Lange, 2022). Images were recorded by a mini-PC on a 1 TB micro-SD card. For the conductivity, temperature, and depth (CTD) rosette casts in the Sargasso Sea, the optical setup and the electronics were enclosed in a stainless-steel housing rated to 6000 meters. For the shallow deployments in the Gulf of Trieste, optics and electronics were enclosed in a lighter polyvinyl chloride (PVC) housing and still equipped with 25.4 mm sapphire windows to retain the same optical configuration as the deep-sea version. The lower practical particle size cut-off in this analysis was 43 mm, which is equivalent to approximately 4 pixels of linear dimension.

For images from the Sargasso Sea, the camera was mounted on the lower ring of the CTD rosette deployed during the Oceanic Flux Program (Conte et al., 2001). Images (n = 45,512) of the surface layer (0-100 m) were taken at 1-second intervals during 11 casts (both down- and upcasts) from April 14 to April 21, at 31.0 - 32.5 N Latitude and 63.0 - 64.3 W Longitude.

Images in the Gulf of Trieste (n = 2,125; 45° 31.56' N, 13° 35.41 E) were recorded by a SCUBA diver on July 18, 2021, below the first thermocline at depths between 4 and 7 meters for 36 minutes with a frame rate of 1 image per second. A stage micrometer (1 mm total, 0.01 mm increments) and stepped neutral density filters on a microscope slide (11 discrete density steps from OD = 0.04 to 1.0, design wavelengths 400 to 700 nanometers, Edmund Optics) were recorded in pure water for calibration.

### Data Processing Description

**Image processing**
Raw images were corrected for unevenness in illumination using the flat field method (Wilkinson, 1994). In the laboratory, blank images taken with ultrapure water were subtracted from the experimental images. For analysis of in situ images, and to account for any changes in the overall light field, or changes in the performance of the LED or the camera chip, image pairs of consecutive images were subtracted from each other (Bochdansky et al., 2013). Particles are thus determined by difference, removing any impurities on lens or optical port surfaces, and as such represent conservative estimates of particle numbers. The volume of each image pair used in the analysis is therefore 10.6 milliliters (mL) or 2 x 5.3 mL. Grayscale images were then binarized using global thresholds (5 to 70). Particles were detected by Canny edge detection (Ohman et al., 2019; Giering et al., 2020), and analyzed for size and other characteristics using the Matlab Imaging Toolbox. Particle number spectra were calculated using logarithmic bin sizes (Jackson et al., 1997; Ghasemi et al., 2018). Particle size is calculated as the equivalent spherical diameter of a sphere of the same area as the shadowgram (in pixels) of the original particle (Bochdansky et al., 2017).

**BCO-DMO Processing description:**
- Adjusted field/parameter names to comply with BCO-DMO naming conventions
- Added a conventional header with dataset name, PI names, version date
- Added columns for "Latitude" and "Longitude" in decimal degrees and rounded to 3 decimal places (or to the thousandth place)

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## Data Files

| File |
| --- |
| **particle_number.csv** (Comma Separated Values (.csv), 24.23 KB) MD5:dce912dadd1fe647542959cf3603bc6b<br>Primary data file for dataset ID 884596 |

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## Related Publications

Arnold, G. P., & Nuttall-Smith, P. B. N. (1974). Shadow cinematography of fish larvae. Marine Biology, 28(1), 51–53. https://doi.org/10.1007/bf00389116
*Methods*

Bochdansky, A. B., Clouse, M. A., & Hansell, D. A. (2017). Mesoscale and high-frequency variability of macroscopic particles (> 100 µm) in the Ross Sea and its relevance for late-season particulate carbon export. Journal of Marine Systems, 166, 120–131. doi:10.1016/j.jmarsys.2016.08.010
*Methods*

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*

Bochdansky, A. B., Jericho, M. H., & Herndl, G. J. (2013). Development and deployment of a point-source digital inline holographic microscope for the study of plankton and particles to a depth of 6000 m. Limnology and Oceanography: Methods, 11(1), 28–40. doi:10.4319/lom.2013.11.28
*Methods*

Conte, M. H., Ralph, N., & Ross, E. H. (2001). Seasonal and interannual variability in deep ocean particle fluxes at the Oceanic Flux Program (OFP)/Bermuda Atlantic Time Series (BATS) site in the western Sargasso Sea near Bermuda. Deep Sea Research Part II: Topical Studies in Oceanography, 48(8-9), 1471–1505. doi:10.1016/s0967-0645(00)00150-8 https://doi.org/10.1016/S0967-0645(00)00150-8
*Methods*

Cowen, R. K., & Guigand, C. M. (2008). In situ ichthyoplankton imaging system (ISIIS): system design and preliminary results. Limnology and Oceanography: Methods, 6(2), 126–132. Portico. https://doi.org/10.4319/lom.2008.6.126
*Methods*

Ghasemi, M., Alexandridis, P., & Tsianou, M. (2018). Conversion of particle size distribution data from mass to number-based and its application to biomass processing. Biosystems Engineering, 176, 73–87. https://doi.org/10.1016/j.biosystemseng.2018.10.007
*Methods*

Giering, S. L. C., Hosking, B., Briggs, N., & Iversen, M. H. (2020). The Interpretation of Particle Size, Shape, and Carbon Flux of Marine Particle Images Is Strongly Affected by the Choice of Particle Detection Algorithm. Frontiers in Marine Science, 7. https://doi.org/10.3389/fmars.2020.00564
*Methods*

Jackson, G. A., Maffione, R., Costello, D. K., Alldredge, A. L., Logan, B. E., & Dam, H. G. (1997). Particle size spectra between 1 µm and 1 cm at Monterey Bay determined using multiple instruments. Deep Sea Research Part I: Oceanographic Research Papers, 44(11), 1739–1767. doi:10.1016/s0967-0637(97)00029-0
*Methods*

Lange, B. (2022). Fixed focal length or telecentric lens? PhotonicsViews, 19(4), 41–43. Portico. https://doi.org/10.1002/phvs.202200034
*Methods*

Ohman, M. D., Davis, R. E., Sherman, J. T., Grindley, K. R., Whitmore, B. M., Nickels, C. F., & Ellen, J. S. (2018). Zooglider: An autonomous vehicle for optical and acoustic sensing of zooplankton. Limnology and Oceanography: Methods, 17(1), 69–86. Portico. https://doi.org/10.1002/lom3.10301
*Methods*

Watanabe, M., & Nayar, S. K. (1997). Telecentric optics for focus analysis. IEEE Transactions on Pattern Analysis and Machine Intelligence, 19(12), 1360–1365. https://doi.org/10.1109/34.643894
*Methods*

Wilkinson, M. H. F. (1994). Shading correction and calibration in bacterial fluorescence measurement by image processing system. Computer Methods and Programs in Biomedicine, 44(2), 61–67. https://doi.org/10.1016/0169-2607(94)90086-8
*Methods*

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## Parameters

| Parameter | Description | Units |
|---|---|---|
| Location | Regional location of sample collection | unitless |
| Latitude | Latitute North of sample collection | decimal degrees |
| Longitude | Longitude East (West is negative) of sample collection | decimal degrees |
| Threshold | Detection threshold of the image analysis program | unitless |
| Center_point | Center points of size bins | millimeters (mm) |
| Particle_number | Particle numbers per size bin per volume | inverse centimeter to the fourth power (cm-4) |

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## Instruments

| | |
|---|---|
| **Dataset-specific Instrument Name** | Marshall Electronics |
| **Generic Instrument Name** | Camera |
| **Dataset-specific Description** | Camera lens: (f/2.5, V-4325, Marshall Electronics). A custom Focused shadowgraph imaging (FoSI) camera was built at Old Dominion University. See Methods for a description of the optical configuration. |
| **Generic Instrument Description** | All types of photographic equipment including stills, video, film and digital systems. |

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|---|---|
| **Dataset-specific Instrument Name** | |
| **Generic Instrument Name** | CTD Sea-Bird |
| **Generic Instrument Description** | Conductivity, Temperature, Depth (CTD) sensor package from SeaBird Electronics, no specific unit identified. This instrument designation is used when specific make and model are not known. See also other SeaBird instruments listed under CTD. More information from Sea-Bird Electronics. |

| | |
|---|---|
| **Dataset-specific Instrument Name** | Cree XLamp |
| **Generic Instrument Name** | LED light |
| **Dataset-specific Description** | a red LED (625 nanometers, Cree XLamp) |
| **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** | SCUBA |
| **Generic Instrument Name** | Self-Contained Underwater Breathing Apparatus |
| **Generic Instrument Description** | The self-contained underwater breathing apparatus or scuba diving system is the result of technological developments and innovations that began almost 300 years ago. Scuba diving is the most extensively used system for breathing underwater by recreational divers throughout the world and in various forms is also widely used to perform underwater work for military, scientific, and commercial purposes.<br>Reference: http://oceanexplorer.noaa.gov/technology/diving/diving.html |

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## Deployments

**AE2106**

| | |
|---|---|
| **Website** | https://www.bco-dmo.org/deployment/885125 |
| **Platform** | R/V Atlantic Explorer |
| **Start Date** | 2021-04-14 |
| **End Date** | 2021-04-21 |
| **Description** | Vessel name: RV Atlantic Explorer Cruise ID: OFP April 2021, AE 2106 Cruise name (nickname) or alternated identifiers: OFP April 2021 cruise Chief Scientist: Maureen Conte, Bermuda Institute of Ocean Sciences Focused Shadowgraph Imaging system attached to the CTD rosette |

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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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