Time-Varying Cycling Rates of size-fractionated Particulate Organic Carbon during the Decay of a North Atlantic Spring Bloom in May 2021

Website: https://www.bco-dmo.org/dataset/969521
Data Type: model results
Version: 1
Version Date: 2025-08-12

Project
» Collaborative Research: Estimation of particle aggregation and disaggregation rates from the inversion of chemical tracer data (Particle aggregation)

Program
» EXport Processes in the Ocean from Remote Sensing (EXPORTS)

Contributors	Affiliation	Role
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Abstract
Here, measurements of POC concentration in two size fractions, the small size fraction (SSF; 1–5µm) and the large size fraction (LSF; > 5 µm) from the EXPORTS North Atlantic cruise in the Porcupine basin are combined with a non-steady state POC cycling model to estimate rates of POC production, (dis)aggregation, sinking, remineralization, and active export mediated by migrating zooplankton.

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Coverage

Location: Porcupine basin in the North Atlantic from 0-500 m depth
Spatial Extent: **N**:50 **E**:-14 **S**:48 **W**:-16
Temporal Extent: 2021-05-06 - 2021-05-27

Dataset Description

Here we provide only model output. The raw data can be accessed through the NASA SeaBass repository (see related datasets).

Methods & Sampling

Location: The model is fit to size-fractionated POC concentration data, as well as primary production and respiration rate data, to estimate the temporal and vertical variations in POC cycling rates in the upper 500 m of the Porcupine Basin during the decline of a phytoplankton bloom. The data used to estimate model parameters and the cycling rates of POC, were collected during the N. Atlantic EXPORTS cruise in May 2021.

Data: The particle cycling model is fit to Measurements from the N. Atlantic EXPORTS cruise in May of 2021. The following lists these data, which can all be found on the NASA SeaBass repository, cruise dataset (see related publications).

- Size fractionated POC data from Large Volume *in situ* filtration pumps (K. Buesseler)
- Primary production using ^{13}C incubations (A. Marchetti)
- Size fractionated respiration rates (S. Gifford)
- RESPIRE trap respiration rates (A. Santoro)
- Zooplankton concentrations from MOCNESS (A. Maas)

Data Processing Description

Inverse Method: Two inverse methods of sequential estimation theory are applied: an Extended Kalman Filter (EKF) and a linearized Rauch-Tung-Striebel (RTS) smoother. These two methods are applied in order to provide estimates of the time-dependent rate parameters. By construction, these estimates are consistent both with the measurements (section 2) and with the governing equations of the POC cycling model described in Clements et al. 2025 (see related publications). Both methods can be viewed as recursive weighted least-squares methods: equations are fitted in the least-squares sense to data by adjusting the rate parameters when data are available, and the fit is weighted by the respective uncertainties in the data and in the equations.

The code to generate these data are provide in github repository “github.com/djclements1/NA_Export_POC-rate-inversion” and stored on Zenodo (see related publications).

BCO-DMO Processing Description

* added netcdf dimensions and variables to file description

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Data Files

File

EKF_POC_Cycling_Exports.nc (NetCDF, 129.45 KB)

MD5:b37e8b90749fb84488282cd40160192e

This netcdf output model estimates the temporal and vertical variations in POC cycling rates in the upper 500 m of the Porcupine Basin during the decline of a phytoplankton bloom.

The netcdf file includes 5 dimensions:

t = 30; time (days)
x = 1 ; no meaning to this, just for consistent vector notation (unitless)
z = 7 ; depth dimension (meters)
y = 2 ; denotes the upper and lower bound of depth bins (meter)
v = 14 ; number of state variables in the model (unitless)

The netcdf file includes 18 variables:

Name,Description,Units ,Missing data /no data value,Data Type,Dimensions,,
Date,Day of the month for model inversion,,,double,,,
Depth_bins,The depth range estimate encompasses,,,double,"(y,z)",,
Depth_ctr,The center of the depth bins,,,double,"(x,z)",,
Units,Units for each of the subsequent rates,,,string,"(x,v)",,
SSF_entrain,The entrainment rate for the small size fraction POC,mmolC m^-3 d^-1,9.9692E+36,double,"(z,t)",,
LSF_entrain,The entrainment rate for the large size fraction POC,mmolC m^-3 d^-1,9.9692E+36,double,"(z,t)",,
POC_s,Concentration of the 1-5 µm POC ,mmolC m^-3,9.9692E+36,double,"(z,t)",,
POC_l,Concentration of the > 5 µm POC ,mmolC m^-3,9.9692E+36,double,"(z,t)",,
SinkingSpeed_s,Sinking speed of the SSF POC,m d^-1,9.9692E+36,double,"(z,t)",,
SinkingSpeed_l,Sinking speed of the LSF POC,m d^-1,9.9692E+36,double,"(z,t)",,
Production_s,Primary Production rate of the SSF POC,mmolC m^-3 d^-1,9.9692E+36,double,"(z,t)",,
Production_l,Primary Production rate of the LSF POC,mmolC m^-3 d^-1,9.9692E+36,double,"(z,t)",,
Remin_s,Remineralization rate of the LSF POC,d^-1,9.9692E+36,double,"(z,t)",,
Remin_l,Remineralization rate of the LSF POC,d^-1,9.9692E+36,double,"(z,t)",,
Disaggregation,Disaggregation rate of the LSF POC,m^3 mmol^-1 d^-1,9.9692E+36,double,"(z,t)",,
Aggregation,Aggregation rate of the SSF POC,d^-1,9.9692E+36,double,"(z,t)",,
Grazing,Zooplankton prey capture efficiency (grazing efficiency rate),m^3 mmol^-1 d^-1,9.9692E+36,double,"(x,t)",,
Egestion,Zooplankton fecal pellet egestion rate,d^-1,9.9692E+36,double,"(x,t)",,

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Related Publications

Bryson, A. E., & Ho, Y.-C. (2018). Applied Optimal Control. Routledge. https://doi.org/10.1201/9781315137667
Methods

Clements, D. J., Lam, P. J., Marchal, O., Maas, A. E., Steinberg, D. K., & Paul, N. (2025). Time-Varying Cycling Rates of size-fractionated Particulate Organic Carbon during the Decay of a North Atlantic Spring Bloom. https://doi.org/10.22541/essoar.175138840.05852941/v1
Results

djclements1. (2025). *djclements1/NA_Export_POC-rate-inversion: V1.0* (Version V1.0) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.15733708 https://doi.org/10.5281/zenodo.15733708
Software

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Related Datasets

IsDerivedFrom

SeaBASS. (2018). *EXPORTS* [Data set]. NASA Ocean Biology Distributed Active Archive Center. https://doi.org/10.5067/SEABASS/EXPORTS/DATA001 https://doi.org/10.5067/SeaBASS/EXPORTS/DATA001

IsRelatedTo

NASA EXPORTS Project. (2021). EXPORTSNA Cruise Dataset. NASA Goddard Space Flight Center, SeaBASS. Retrieved from https://seabass.gsfc.nasa.gov/cruise/EXPORTSNA

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Parameters

Parameters for this dataset have not yet been identified

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Deployments

DY131

Website	https://www.bco-dmo.org/deployment/893299
Platform	RRS Discovery
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/report/17779/
Start Date	2021-05-01
End Date	2021-06-01
Description	See additional information from the British Oceanographic Data Centre (BODC): https://www.bodc.ac.uk/resources/inventories/cruise_inventory/report/17779/

SG2105

Website	https://www.bco-dmo.org/deployment/966300
Platform	B/O Sarmiento de Gamboa
Report	https://twilightzone.whoi.edu/missions/r-v-sarmiento-de-gamboa-may-2021/
Start Date	2019-05-03
End Date	2019-05-21
Description	Science Questions: How does carbon from the upper ocean move through the twilight zone? How do animals living in the twilight zone affect the global carbon cycle?

JC214

Website	https://www.bco-dmo.org/deployment/880457
Platform	RRS James Cook
Start Date	2021-05-01
End Date	2021-06-01
Description	Objective: The aim of the EXPORTS 2021 North Atlantic deployment is to sample the demise of the annual spring bloom. Hence our requested May 1 start of sampling somewhere near the PAP site (49N 16.5W). The exact location will be dependent upon the oceanographic features observed from remote sensing and autonomous vehicles beforehand. We will attempt to measure all aspects of the biological carbon pump – vertical fluxes, food web processes, physics, geochemistry, etc. Hence, there are officially 54 PIs collaborating on EXPORTS, although many will not sail. (from https://www.bodc.ac.uk/resources/inventories/cruise_inventory/report/17792/)

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Project Information

Collaborative Research: Estimation of particle aggregation and disaggregation rates from the inversion of chemical tracer data (Particle aggregation)

Coverage: Ocean Station Papa, North Atlantic, North Pacific

NSF Award Abstract:
The biological carbon pump in the ocean is an important process by which atmospheric carbon dioxide (CO2) is effectively transported from the surface ocean to the deep ocean, and thereby removing CO2 from the atmosphere. This transport occurs in a multi-step process. First, phytoplankton carry out photosynthesis in the surface, sunlit waters of the ocean, taking up atmospheric CO2 and fixing it into particulate organic carbon. A portion of the organic carbon contained in the phytoplankton is packaged into larger clusters (aggregates) that can sink to the deep ocean. The deeper these aggregates sink, the longer the carbon contained in them is removed from the atmosphere. The depth to which aggregates sink varies greatly over time and space and are difficult to predict. In general, larger aggregates sink more quickly, and thus more deeply, than smaller particles. Processes that promote aggregation to larger particles should enhance the biological pump, and processes that promote disaggregation (breakdown of particle clusters) and regeneration (decomposition) of the organic carbon should decrease the strength and efficiency of the biological pump. Particle aggregation and disaggregation rates are thus crucial to understanding the variability of the biological pump, but are very difficult to measure directly. This project will use chemical tracers and a modeling approach to quantify the rates of these important processes. The investigators will apply the approach to a variety of oceanic environments and provide the first large-scale effort to quantify these rates in the upper 500 meters of the ocean. As part of this project, they will interface with the CalTeach program, which is a University of California Science and Math Initiative to place university science, math, and engineering majors in K-12 classrooms. Many of these CalTeach interns go on to become K-12 science teachers in California. Two undergraduate students enrolled in the CalTeach program at the University of California, Santa Cruz (UCSC) will participate as laboratory assistants and develop a hands-on teaching module on the carbon cycle and biological pump for K-12 classrooms.

Scientists from the University of California at Santa Cruz and Woods Hole Oceanographic Institution propose to estimate the rates of particle aggregation and disaggregation in the mesopelagic zone through the inversion of observations of three chemical tracers, namely thorium (Th)-234, lithogenic particles, and particulate organic carbon (POC) distributed between small, suspended particles and large, sinking particles. The isotopes of Th have long been used to estimate rates of particle dynamics processes because of their known source function and particle-reactive behavior. Previous work has shown that lithogenic particles act as an inert, passive tracer of particle dynamics. The investigators will couple thorium and lithogenic particle measurements to measurements of POC to estimate particle aggregation and disaggregation rates from a wide range of oceanographic environments. Estimates of particle cycling rates deduced from the inversion of chemical tracer data provide a crucial quantitative constraint to which rates derived from other approaches can be compared. The main objective of this work is to estimate depth- varying (dis-) aggregation rates at each station of the EXPORTS and GEOTRACES cruises that are most consistent with the tracer data. This work will also produce depth-varying estimates of POC remineralization rates and particle sinking rates.

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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Program Information

EXport Processes in the Ocean from Remote Sensing (EXPORTS)

Website: http://oceanexports.org/

EXport Processes in the Ocean from Remote Sensing (EXPORTS) is a large-scale NASA-led field campaign that

will provide critical information for quantifying the export and fate of upper ocean net primary production (NPP) using satellite observations and state of the art ocean technologies.

Ocean ecosystems play a critical role in the Earth’s carbon cycle and the quantification of their impacts for both present conditions and for predictions into the future remains one of the greatest challenges in oceanography. The goal of the EXport Processes in the Ocean from Remote Sensing (EXPORTS) Science Plan is to develop a predictive understanding of the export and fate of global ocean net primary production (NPP) and its implications for present and future climates. The achievement of this goal requires a quantification of the mechanisms that control the export of carbon from the euphotic zone as well as its fate in the underlying "twilight zone" where some fraction of exported carbon will be sequestered in the ocean’s interior on time scales of months to millennia. In particular, EXPORTS will advance satellite diagnostic and numerical prognostic models by comparing relationships among the ecological, biogeochemical and physical oceanographic processes that control carbon cycling across a range of ecosystem and carbon cycling states. EXPORTS will achieve this through a combination of ship and robotic field sampling, satellite remote sensing and numerical modeling. Through a coordinated, process-oriented approach, EXPORTS will foster new insights on ocean carbon cycling that maximizes its societal relevance through the achievement of U.S. and International research agency goals and will be a key step towards our understanding of the Earth as an integrated system.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829614
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829790

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