Size fractionated Particulate Carbon Flux 100-500m measured by autonomous Carbon Flux Explorers deployed during the CCE-LTER process study (P1706) between June 2 and July 1, 2017 in the California Current Regime.

Website: https://www.bco-dmo.org/dataset/823408
Data Type: Other Field Results
Version: 1
Version Date: 2020-09-16

Project
» California Current Ecosystem Long Term Ecological Research site (CCE LTER)
» Carbon Sedimentation In the Ocean Watercolumn (C-SNOW): Calibration (C-SNOW)
» Carbon Flux Explorer Development (C-SNOW Development)

Programs
» Ocean Carbon and Biogeochemistry (OCB)
» Long Term Ecological Research network (LTER)

Contributors	Affiliation	Role
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Abstract
Size fractionated Particulate Carbon Flux 100-500m measured by autonomous Carbon Flux Explorers deployed during the CCE-LTER process study (P1706) between June 2 and July 1, 2017 in the California Current Regime.

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Coverage

Spatial Extent: **N**:35.2 **E**:-120.8 **S**:33.5 **W**:-123.5
Temporal Extent: 2017-06-02 - 2017-07-01

Dataset Description

Size fractionated Particulate Carbon Flux 100-500m measured by autonomous Carbon Flux Explorers deployed from R/V Roger Revelle (RR1701), CCE-LTER process study (P1706), between June 2 and July 1, 2017 in the California Current Regime.

These data are submitted with this manuscript: Bourne *et al.,* 2020

Methods & Sampling

To understand the vertical variations of carbon fluxes in biologically productive waters, four autonomous Carbon Flux Explorers (CFEs) and ship-lowered CTD-interfaced particle-sensitive transmissometer and scattering sensors were deployed in a filament of offshore flowing recently upwelled water during the June 2017 California Current Ecosystem – Long Term Ecological Research process study. The Lagrangian CFEs operating at depths from 100-500 m yielded carbon flux and its partitioning with size from 30 µm –1 cm at three intense study locations within the filament and at a location outside the filament.

The Carbon Flux Explorer (CFE) dives below the surface make particle flux observations at target depths as it drifts with currents. The Optical Sedimentation Recorder (OSR) wakes once the CFE has reached the target depth. On first wake-up of a given CFE dive, the sample stage is flushed with water and images of the particle-free stage are obtained. Particles settle through a 1-cm opening hexagonal celled light baffle into a high-aspect ratio funnel assembly before landing on a 2.54 cm diameter glass sample stage. At 25-minute intervals, particles are imaged at 13 µm pixel resolution in three lighting modes: dark field, transmitted and transmitted-cross polarized.

Sampling procedures described in Bourne *et al.,* 2019 and Bishop *et al.,* 2016.

Different particle classes (anchovy pellets, copepod pellets and >1000 µm aggregates) dominated the 100-150 m fluxes during successive stages of the filament evolution as it progressed offshore. Fluxes were very high at all locations in the filament; below 150 m, flux was invariant or increased with depth at the two locations closer to the coast. Martin curve 'b' factors for total particulate carbon flux were +0.1, +0.87, -0.27, and -0.39 at the three successively occupied locations within the plume, and in transitional waters, respectively. Particle transfer efficiencies between 100 to 500 m were far greater within both filament and California Current waters than calculated using a classic Martin 'b' factor of -0.86. Interestingly, the flux profiles for all particles <400 µm were a much closer fit to Martin; however, most (typically >90%) of particle flux was carried by >1000 µm sized aggregates. Mechanisms to explain a factor of three flux increase between 150 and 500 m at the mid plume location are investigated.

Data Processing Description

The software package ImageJ 1.52 (IJ, National Institutes of Health) was used for particle size analysis. In this method, we manually inspected the 4 to 5 sequential attenuance images taken during a two hour long image cycle to determine the point of onset of particle overlap. The image at this point was subtracted from the image of the clean sample stage taken immediately preceeding the image set.

A threshold of 0.04 attenuance unts and above was used to define the presence of particles to facilitate particle identification. At this threshold setting, large aggregates were fully detected; however, touching particles – particularly 200-400 µm sized fecal pellets were not separable. Each IJ-identified "particle" with multiple units was counted and these counts assigned to its sequence number. Inspection of the imagery also identified touching aggregates which were similarly treated.

During secondary data processing (using written Fortran codes), the area of each multi-unit "particle" was divided by the number of subunits, and its particle number was changed from 1 to the determined count. Living organisms rarely appeared in images; when when they did appear, we were able to identify Pteropods, Amphipods, Copepods, Siphonophores, Acantharia, Radiolaria, and Foraminifera. These, identified living particles were removed from the secondary processed data. Total particle attenuance (average particle attenuance times particle area) and particle number were binned into 65 logarithmically spaced size catagories from (30 µm to 20000 µm).

Data from each image cycle were weighted by the total number of images in that cycle; data from the multiple imaging/cleaning cycles during a dive were binned and weighted by the duration of each imaging cycle. The particle attenuance and number size-binned data were scaled to convert results to flux units (mATN–cm2 cm–2 d–1; and number m–2 d–1). The partitioning of particle flux was further broken into 30-100,100-200,200-400,400-1000, and >1000 µm categories. The 200-400 µm bin primarily was populated by the numerous ovoid pellets. The >1000 µm bin was dominated by aggregates.

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Data Files

File
carbon_flux_data_concat.csv (Comma Separated Values (.csv), 1.19 MB) MD5:f995a0d3468ed1695cc40a59f74c106e
Primary data file for dataset ID 823408

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Related Publications

Bishop, J. K. B., Fong, M. B., & Wood, T. J. (2016). Robotic observations of high wintertime carbon export in California coastal waters. Biogeosciences, 13(10), 3109–3129. doi:10.5194/bg-13-3109-2016 https://doi.org/https://doi.org/10.5194/bg-13-3109-2016
Methods

Bourne, H. L., Bishop, J. K. B., Connors, E. J., & Wood, T. J. (2020). Carbon Export and Fate Beneath a Dynamic Upwelled Filament off the California Coast. doi:10.5194/bg-2020-342
Results

Bourne, H. L., Bishop, J. K. B., Wood, T. J., Loew, T. J., & Liu, Y. (2019). Carbon Flux Explorer optical assessment of C, N and P fluxes. Biogeosciences, 16(6), 1249–1264. doi:10.5194/bg-16-1249-2019
Methods

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Related Datasets

IsDerivedFrom

Bishop, J. K. (2020) **Original transmitted-light imagery and processed attenuance images of sinking particles observed by autonomous Carbon Flux Explorers deployed 100-500m in the California Current Regime, during the CCE-LTER process study (P1706) between June 2 and July 1, 2.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2020-09-17 doi:10.26008/1912/bco-dmo.825076.1 [view at BCO-DMO]
Relationship Description: This dataset is based on the imagery in https://www.bco-dmo.org/dataset/825076

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Parameters

Parameter	Description	Units
Cruise	Cruise Roger Revelle (RR 1710)	unitless
CCE_LTER_ID	Process study designation PYYMM	unitless
CCE_CYCLE	sequential intensive studies	unitless
CFE	Carbon Flux Explorer (CFE) serial number (1 through 4)	unitless
CFE_type	CFE_TYPE: 1 = SOLO1-OSR, 2 = SOLO2-OSR with Cal Sampler	unitless
Location	Location - Designation used in Bishop et al. 2020 (submitted)	unitless
UTC_deploy_date	UTC deployment data in ISO format (yyyy-mm-dd)	unitless
ddays_dep	decimal days at time of deployment (2017 UTC days since Jan 1 2017 0000	decimal days
lat_dep	decimal latitude at time of deployment	decimal degrees
lon_dep	decimal longitude at time of deployment	decimal degrees
ddays_rec	decimal days at time of recovery (2017 UTC days since Jan 1 2017 0000)	decimal days
lat_rec	decimal latitude at time of recovery	decimal degrees
lon_rec	decimal longitude at time of recovery	decimal degrees
cycle	California Current Ecosystem (CCE) Cycle number (1 through 4)	unitless
dive	Carbon Flux Explorer (CFE) dive number	unitless

histptr	Size bin number	unitless
ECD_um	Particle Equivalent Circular Diameter; lower size limit of particles in a bin	micrometers (um)
ATNflux	Attenuance flux in specific bin	cm2 cm-2 d-1
cumATNflux	Flux summed across all bins from large to small	cm2 cm-2 d-1
maxATNflux	Total sum of flux	cm2 cm-2 d-1
ATNflux1	Attenuance flux in specific bin with correction	cm2 cm-2 d-1
cumATNflux1	Flux summed across all bins from large to small with correction	cm2 cm-2 d-1
maxATNflux1	Total sum of flux with correction	cm2 cm-2 d-1
NOflux	Number flux in bin	#m-2 d-1
cumNOflux	Number flux summed from large to smallest particle	#m-2 d-1
maxNOflux	Total sum of number flux	#m-2 d-1
NOflux1	NOflux1 - number flux in bin but with corrections	#m-2 d-1
cumNOflux1	Number flux summed from large to smallest particle with corrections	#m-2 d-1
maxNOflux1	Total sum of number flux with corrections	#m-2 d-1
pressavg	Averaged pressure during dive (from float CTD)	dbars
tempavg	Averaged in-situ temperature during dive (missing data set to 0)	degrees celcius
salavg	Averaged salinity during dive (missing data set to 0).	PSU
cmsec_avg	Averaged float sinking or rise rate during flux measurement	cm s-1
ddaystart	Decimal days at time when CFE reached its target depth (since 0000 Jan 2017 in UTC time)	decimal days
ddaysend	Decimal days at time when CFE terminated operations	decimal days
latavg	Averaged decimal latitude for dive	decimal degrees
lonavg	Averaged decimal longitude for dive	decimal degrees

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Instruments

Dataset-specific Instrument Name	Carbon Flux Explorer
Generic Instrument Name	Carbon Flux Explorer
Dataset-specific Description	The CFE and the operation of its particle flux sensing Optical Sedimentation Recorder (OSR) have been discussed in detail in Bishop et al. (2016). CFE has a design mission capability of 8 months of hourly operations (16 months @ 2 hours ...) and has been demonstrated by deployments of 40 days; CFE design depth is 1500m and it has been proven to 1000 m. The system has demonstrated operations in high sea states. Briefly, once deployed, the CFE dives below the surface make particle flux observations at target depths as it drifts with currents. The OSR wakes once the CFE has reached the target depth. On first wake-up of a given CFE dive, the sample stage is flushed with water and images of the particle-free stage are obtained. Particles settle through a 1-cm opening hexagonal celled light baffle into a high-aspect ratio funnel assembly before landing on a 2.54 cm diameter glass sample stage. At 25-minute intervals, particles are imaged at 13 µm pixel resolution in three lighting modes: dark field, transmitted and transmitted-cross polarized.
Generic Instrument Description	The Carbon Flux Explorer (CFE) is designed to perform sustained high-frequency observations of POC and PIC sedimentation within the upper kilometer (or twilight zone) of the ocean for seasons to years and to operate in an observational context not dependent on ships. The CFE melds the concept of current-following, sample-collecting neutrally buoyant sediment traps with photographic imaging of the particles as they are deposited in a sediment trap. The CFE and the operation of its particle flux sensing Optical Sedimentation Recorder (OSR) have been discussed in detail in Bishop et al. (2016). CFE has a design mission capability of 8 months of hourly operations (16 months @ 2 hours) and has been demonstrated by deployments of 40 days; CFE design depth is 1500m and it has been proven to 1000 m. The system has demonstrated operations in high sea states. Diagram: https://datadocs.bco-dmo.org/docs/302/C-SNOW/data_docs/CFE_CFE-Cal.png Bishop, J. K. B., Fong, M. B., and Wood, T. J.: Robotic observations of high wintertime carbon export in California coastal waters, Biogeosciences, 13, 3109–3129, https://doi.org/10.5194/bg-13-3109-2016, 2016. Bourne, H. L., Bishop, J. K. B., Wood, T. J., Loew, T. J., and Liu, Y.: Carbon Flux Explorer optical assessment of C, N and P fluxes, Biogeosciences, 16, 1249–1264, https://doi.org/10.5194/bg-16-1249-2019, 2019

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Deployments

RR1710

Website	https://www.bco-dmo.org/deployment/823418
Platform	R/V Roger Revelle
Report	http://cce.lternet.edu/data/cruises/cce-p1706
Start Date	2017-06-01
End Date	2017-07-02

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Project Information

California Current Ecosystem Long Term Ecological Research site (CCE LTER)

Website: http://cce.lternet.edu/

Coverage: California coastal current

From ccelter.edu:
The California Current System is a coastal upwelling biome, as found along the eastern margins of all major ocean basins. These are among the most productive ecosystems in the world ocean. The California Current Ecosystem LTER (32.9 degrees North, 120.3 degrees West) is investigating nonlinear transitions in the California Current coastal pelagic ecosystem, with particular attention to long-term forcing by a secular warming trend, the Pacific Decadal Oscillation, and El Nino in altering the structure and dynamics of the pelagic ecosystem. The California Current sustains active fisheries for a variety of finfish and marine invertebrates, modulates weather patterns and the hydrologic cycle of much of the western United States, and plays a vital role in the economy of myriad coastal communities.

LTER Data:
The California Current Ecosystem (CCE) LTER data are managed by and available directly from the CCE project data site URL shown above. If there are any datasets listed below, they are data sets that were collected at or near the CCE LTER sampling locations, and funded by NSF OCE as ancillary projects related to the CCE LTER core research themes.

NSF Award Abstract (OCE-2224726):
Coastal upwelling regions are found along the eastern boundaries of all ocean basins and are some of the most productive ecosystems in the ocean. This award is supporting the California Current Ecosystem Long Term Ecological Research (CCE LTER) site in a major upwelling biome. It leverages the 73-year California Cooperative Oceanic Fisheries Investigations (CalCOFI) program which provides essential information characterizing climate variability and change in this system. The CCE LTER addresses two over-arching questions: What are the mechanisms leading to ecological transitions in a coastal pelagic ecosystem? And what is the interplay between changing ocean climate, community structure, and ecosystem dynamics? The investigators are working towards diagnosing mechanisms of ecosystem change and developing a quantitative framework for forecasting future conditions and how these might affect the management of key living marine resources, including numerous fishes, invertebrates, marine mammals, and seabirds. They are training graduate and undergraduate students, as well as providing educational opportunities for teachers. Public programs and outreach efforts in collaboration with the Birch Aquarium at Scripps Institution of Oceanography are increasing public awareness and understanding of climate effects on coastal pelagic communities and connecting the public to cutting-edge ocean research.

This project is adding to understanding of the mechanisms underlying abrupt ecological transitions with three interrelated foci: (1) investigation of marine heatwaves and resultant multiple stressors on organisms and communities, (2) elucidation of ecological stoichiometry and the response of multiple trophic levels to altered elemental ratios of source nutrients, and (3) analysis of top-down pressures mediated by a diverse suite of organisms. It is sustaining multi-scale measurements of five core LTER variables and responses to ocean warming, increased stratification, acidification, deoxygenation, and altered nutrient stoichiometry in the Northeast Pacific. The investigators are using long-term, spatially-resolved time series at multiple spatial scales to evaluate community shifts at multiple temporal scales, with new measurements allowing interrogation at finer taxonomic levels. They are conducting in situ multi-factorial experiments (temperature, macronutrients, micronutrients, light, grazing) in combination with genomic and transcriptomic analyses. These will complement time series measurements, inform next-generation biogeochemical models, and test hypotheses related to ecological stoichiometry and marine heatwaves. The team is also using a suite of imaging techniques, molecular and morphological methods, and active and passive acoustic approaches to quantify vertical structure and cooccurrence of organisms across trophic levels and test hypotheses about top-down control of the ecosystem.

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.

This project is supported by continuing grants with name variations:

- LTER: Nonlinear transitions in the California Current Coastal Pelagic Ecosystem
- Ecological Transitions in the California Current Ecosystem: CCE-LTER Phase II
- LTER: CCE-LTER Phase III: Ecological Transitions in an Eastern Boundary Current Upwelling Ecosystem
- LTER: Ecosystem controls and multiple stressors in a coastal upwelling system - CCE IV

Carbon Sedimentation In the Ocean Watercolumn (C-SNOW): Calibration (C-SNOW)

Website: http://oceanbots.lbl.gov

Coverage: California Current System and surrounding waters 33°N, 125°W to 39°N, 119°W

NSF Award Abstract:

Carbon sedimentation (10 Pg C/year) via the ocean biological carbon pump is important to the regulation of atmospheric CO_2, yet is poorly observed in space and time due to limitations of current methodology (moorings/ships), and thus is poorly understood and consequently is poorly represented in carbon cycle simulations. Current estimates of the strength of the ocean biological carbon pump are highly uncertain. The one year project will deploy and calibrate low-cost robotic ocean-profiling current-following Carbon Flux Explorers (CFEs) which is a necessary step paving the way high frequency broad scale monitoring and prediction of carbon sedimentation in the ocean. Project scientists will work with the San Francisco Exploratorium to enhance public knowledge of the ocean carbon cycle, ocean robotics. UC Berkeley undergraduate students will be exposed to this research activity in the class-room, as laboratory assistants, and in hands-on experience at sea.

The CFEs represent the integration of an ocean profiling float-- similar to those widely deployed in the ocean as part of the ARGO program-- with the UC Berkeley / Lawrence Berkeley National Laboratory - developed Optical Sedimentation Recorder (OSR). The CFEs dive to depth and the OSR uses a camera and three modes of illumination to image particles over time as they accumulate in a sediment trap. Periodically the sample is removed and the imaging resumes. The use of transmitted, transmitted cross-polarized transmitted, and side illumination permits three modes of quantification sample loading as measured sample attenuance, sample cross-polarized photon yield, and sample reflectance. The project specifically aims to relate the three optical metrics of sample load to the amount of particulate organic carbon, particulate inorganic carbon (also known as calcium carbonate), and other biogenic particle phases. Thus, the development will demonstrate the ability of the Carbon Flux Explorer to measure the strength of carbon sedimentation in the ocean. In a one year project. Scientists at University of California, Berkeley and engineers at Lawrence Berkeley National Laboratory and Scripps Institution of Oceanography will build/modify 2 Carbon Flux Explorers to enable the collection of samples for their calibration. These and two other CFEs and a surface tethered OSR will be co-deployed during an oceanographic expedition in California coastal and offshore waters. Collected samples will be analyzed and compared with the optical metrics of sample load, collected at the same time. The project will thus meet its major goal of demonstrating that the CFEs can measure the strength of ocean carbon sedimentation as a function of depth, time, and ocean location, in a way here-to-fore impossible to achieve from ships.

Carbon Flux Explorer Development (C-SNOW Development)

NSF Award Abstract:

The PIs request funding to complete the development of the Carbon Flux Explorer (CFE), a fully autonomous and free robotic system designed to measure and relay in real time via Iridium satellite link the hourly/diurnal variations of particulate organic carbon (POC) and particulate inorganic carbon (PIC) flux at various depths in the upper kilometer of the ocean for seasons to year-long time scales. CFEs are the successful integration of the Sounding Oceanographic Lagrangian Observer (SOLO) float (developed at Scripps) and LBNL/UC Berkeley?s imaging Optical Sediment Trap (OST). The first prototype CFE was successfully tested at sea for 2 days to 800 m in June 2007.

The proposed new work will refine and challenge the CFE design with successively longer deployments in coastal and California Current waters to evaluate and address real world issues such as biofouling and animal invasions. At the same time, engineering refinements will improve power budget and solve multiple minor system issues. On-board image processing/data reduction software will be fully established. Calibration samples (POC and PIC flux) will be obtained concurrently with CFE testing using a buoy tethered twinned OST system operating at similar depths. At the end of this project, three fully developed Carbon Flux Explorers (CFEs) will be deployed (and recovered if possible) in the open ocean for at least 3-6 months in the subarctic N Pacific.

Carbon sedimentation via the bio-carbon pump of the ocean is important to the regulation of atmospheric CO_2. Due to limitations of current observational methodology (moorings/ships), carbon export (or sedimentation) is poorly observed in space and time and therefore is poorly understood and parameterized in carbon cycle simulations. CFE deployments in the world?s ocean have the potential to lead to fundamentally new insights into the biology/biogeochemistry of carbon sedimentation.

Broader Impacts:

The potential benefits to society due to the proposed activities are important. These actives will help improve confidence in future carbon cycle predictions. The results could maybe a key to helping society deal with the potentially economically and environmentally hazardous consequences due to climate change. Through education, the proposed activities and technologies developed will make the ocean more accessible to the public in general. An improved understanding of the ocean by the public will help protect the ocean's environment. The real-time observations offered by the proposed activities will help bring about such an understanding and diminish the perceived remoteness of the ocean. The proposed activities will advance ocean related scientific teaching and education. The technology in development will help enliven the ocean in the classroom, moving from textbook knowledge to real-time interactions. The proposed activities will allow students to become more connected to the global environment. The technology will help educate the public in manner needed if society is to overcome the environmental problems humanity currently faces.

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Program Information

Ocean Carbon and Biogeochemistry (OCB)

Website: http://us-ocb.org/

Coverage: Global

The Ocean Carbon and Biogeochemistry (OCB) program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners. Important OCB-related activities currently include: the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP); U.S. contributions to IMBER, SOLAS, CARBOOCEAN; and numerous U.S. single-investigator and medium-size research projects funded by U.S. federal agencies including NASA, NOAA, and NSF.

The scientific mission of OCB is to study the evolving role of the ocean in the global carbon cycle, in the face of environmental variability and change through studies of marine biogeochemical cycles and associated ecosystems.

The overarching OCB science themes include improved understanding and prediction of: 1) oceanic uptake and release of atmospheric CO_2 and other greenhouse gases and 2) environmental sensitivities of biogeochemical cycles, marine ecosystems, and interactions between the two.

The OCB Research Priorities (updated January 2012) include: ocean acidification; terrestrial/coastal carbon fluxes and exchanges; climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles; mesopelagic ecological and biogeochemical interactions; benthic-pelagic feedbacks on biogeochemical cycles; ocean carbon uptake and storage; and expanding low-oxygen conditions in the coastal and open oceans.

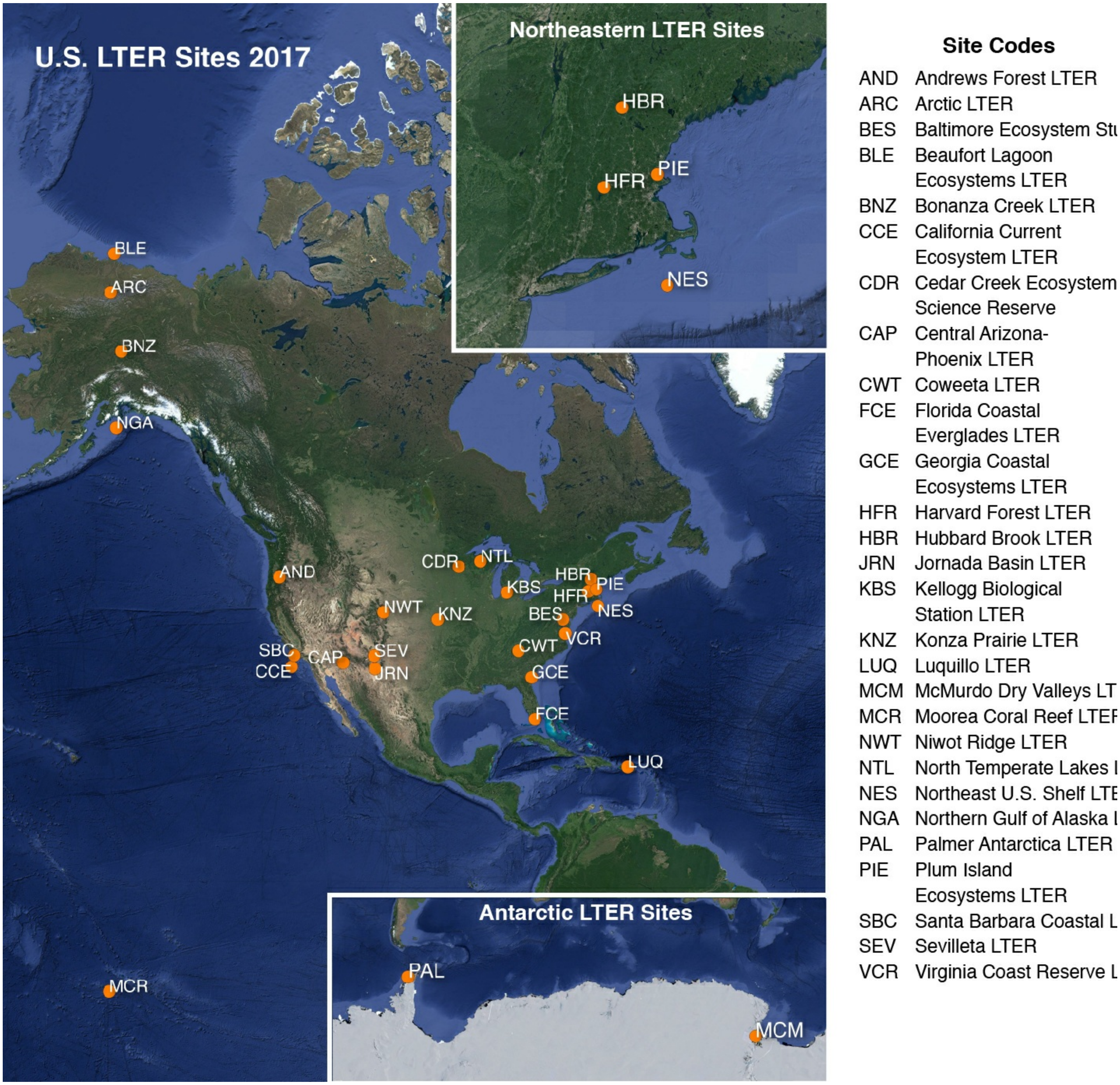
Long Term Ecological Research network (LTER)

Website: http://www.lternet.edu/

Coverage: United States

adapted from http://www.lternet.edu/

The National Science Foundation established the LTER program in 1980 to support research on long-term ecological phenomena in the United States. The Long Term Ecological Research (LTER) Network is a collaborative effort involving more than 1800 scientists and students investigating ecological processes over long temporal and broad spatial scales. The LTER Network promotes synthesis and comparative research across sites and ecosystems and among other related national and international research programs. The LTER research sites represent diverse ecosystems with emphasis on different research themes, and cross-site communication, network publications, and research-planning activities are coordinated through the LTER Network Office.



2017 LTER research site map obtained from https://lternet.edu/site/lter-network/

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1538686

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