Remotely-generated submesoscale coherent vortices (SCV) within Argo profiles

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Data Type: Other Field Results
Version: 1
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Project
» CAREER: Multiple Scales of Nitrogen Cycle in Oxygen Minimum Zones (Multiple Scales of Nitrogen Cycle in the Ocean)
» Collaborative Research: Understanding the distribution and biogeochemical role of anaerobic microenvironments in the ocean (Ocean Particles and Microenvironments)

Contributors	Affiliation	Role
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Abstract
Remotely-generated submesoscale coherent vortices (SCV) within Argo profiles. The data reveal the date, locations, and identification information of Argo profiles that pierced spicy-core (anomalously warm and salty) and minty-core (anomalously cold and fresh) SCVs. We also include statistics gathered for each SCV, such as core water mass characteristics and height/length scales. These data are described in McCoy et al. (2020); doi: 10.1016/j.pocean.2020.102452

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Coverage

Spatial Extent: **N**:73.1679993 **E**:179.925995 **S**:-63.2553139 **W**:-179.908997
Temporal Extent: 2000-03-27 - 2020-02-11

Dataset Description

Final results for submesoscale coherent vortices (SCVs) detected in McCoy et al. (2020).

Acquisition Description

Based on theory and observations, we identify remotely-generated submesoscale coherent vortices (SCV) within Argo profiles using three primary criteria. First, a SCV must contain a vertically confined, Gaussian-shaped water mass anomaly. Second, the water mass anomaly must be weakly stratified, corresponding to doming/bowling of isopycnals above and below the water mass, respectively. Finally, horizontal velocities estimated from hydrographic properties must suggest a local maxima within the range of the SCV. We establish specific detection criteria corresponding to these conditions, based on: (1) spiciness, a measure of density-compensated thermohaline variability, (2) buoyancy frequency, a measure of the vertical stratification, and (3) dynamic height anomaly, a measure of the horizontal pressure gradient force.

We downloaded Argo float profiles from August 1997 to January 2020 from the U.S. Argo global data center (GDAC). Quality controlled temperature and salinity profiles were then linearly interpolated to a 10 dbar pressure grid from 0 to 2000 dbar, before deriving spiciness, absolute salinity, conservative temperature, and potential density profiles. To identify water mass anomalies associated with remotely-generated SCVs, we compared each profile with the nearest monthly climatological profile from the Roemmich-Gilson Argo Climatology (global gridded Argo climatology obtained from http://sio-argo.ucsd.edu/RG_Climatology.html). In order to better preserve water mass properties, we derived and interpolated climatological profiles of temperature, salinity, pressure, spiciness and buoyancy frequency to each cast potential density, before subtracting them to obtain anomaly profiles along isopycnals.

To quantify the water mass variability at each profile location, we gathered spiciness and buoyancy frequency anomalies from all profiles conducted within 220 km of the cast coordinates that were also conducted within +- 45 days of the cast date, regardless of year. We then calculated the interquartile range (IQR), or the difference between the 75th and 25th percentile, to quantify the statistical spread of anomalies at each density level. After organizing all values into percentiles, we defined upper and lower outlier thresholds at each density level as the 75% value (Q3) plus 1.5 times the IQR, and the 25% value (Q1) minus 1.5 times the IQR, respectively. The upper and lower IQR thresholds in spiciness anomaly were applied to identify isopycnal surfaces with anomalously high or low spiciness, which we labeled as spicy (anomalously warm and salty) or minty (anomalously cold and fresh) water mass intrusions, respectively. Likewise, lower IQR thresholds in buoyancy frequency anomaly were used to identify anomalously weak stratification within the core of each intrusion. Any cast which featured at least two consecutive isopycnal surfaces below the mid-pycnocline which exceeded either of the spiciness thresholds discussed above was kept for further analysis.

In order to detect the presence of anomalously weak stratification associated with spicy or minty water mass intrusions, we required an estimate of the vertical thickness of each intrusion. Since observations of SCVs suggest that their vertical structure is well represented by a Gaussian monopole, to estimate the vertical thickness or extent we fit a one-term Gaussian model to spiciness anomaly profiles (calculated along isopycnals) in pressure space. After successfully fitting Gaussian curves to spicy and minty intrusions, we sought anomalously weak stratification within the vertical extent of each water mass, indicative of bowling/doming of isopycnals around the intrusion. Since the weak stratification characteristic of SCVs should be most evident within waters just above and below the core of the feature, we defined an additional core vertical thickness or extent. Using the above estimate, we set two strict criteria to check for weak stratification. First, the buoyancy frequency anomaly profile must be less than the lower buoyancy frequency IQR threshold at a depth within the core limits, to represent the abnormally low stratification associated with SCVs. Second, the vertical mean of buoyancy frequency anomaly within this range must also be less than zero to avoid false detections due to occasionally noisy signals. Profiles that did not fit the above stratification criteria were rejected.

The dynamic height differences between two nearby casts can be used as an estimate for the geostrophic velocity streamfunction, assuming flow at depth is relatively weak compared to surface velocities. To test for a local extremum in the horizontal velocity, we calculated the dynamic height profile vs. pressure for both the detected SCV profile and the local Argo climatological profile. We started this calculation from the greatest cast pressure. We translated our velocity maximum criterion into finding a peak in the geostrophic streamfunction within the vertical extent estimate provided by the Gaussian model. Initial results indicated that slight misplacements of the pycnocline in pressure space between the SCV and the climatological profile can lead to large dynamic height anomalies along isobars, which dominated any SCV dynamic signature within the profile. This finding is not surprising given that, away from oceanic margins, the vertical structure of the ocean is almost entirely described by the barotropic and first baroclinic modes. Thus, heaving caused by internal wave motions is an additional source of error in the dynamic height anomaly calculation.

To isolate and remove the impact of first baroclinic mode structures, we decomposed the climatological profile into vertical modes. Briefly, we solved for the linear dynamical modes brought about by the standard eigenvalue problem of internal wave theory. We extracted the first baroclinic horizontal velocity mode produced by the routine and estimated the corresponding modal amplitude (alpha) by restricting the modal structure to be zero at the deepest level of the dynamic height profile before applying a non-linear least-squares optimization to solve for the best fit to the dynamic height anomaly profile. We then removed the fitted first baroclinic mode from the dynamic height anomaly profile and used the adjusted dynamic height anomaly to test for the presence of a local peak in dynamic height anomaly within the vertical extent of each intrusion, rejecting any profiles which did not exhibit this feature, while defining those that passed all the above criteria as spicy or minty-core SCVs.

Previous studies suggest that the SCV radius is comparable to their internal Rossby deformation radius. We used estimates of SCV scale height, core-isopycnal background buoyancy frequency, and the local Coriolis parameter for each detected SCV to infer the first baroclinic deformation radius and thus an idealized horizontal scale.

The submitted data reveal the date, locations, and identification information of Argo profiles that pierced spicy-core and minty-core SCVs. We also include statistics gathered for each SCV, such as core water mass characteristics and height/length scales.

Regarding data accuracy with Argo (https://argo.ucsd.edu/data/data-faq/#accurate):
The temperatures in the Argo profiles are accurate to ± 0.002°C and pressures are accurate to ± 2.4dbar. ;For salinity, there are two answers. The data delivered in real-time are sometimes affected by sensor drift. For many floats this drift is small, and the uncorrected salinities are accurate to ± .01 psu. At a later stage, salinities are corrected by expert examination, comparing older floats with newly deployed instruments and with ship-based data. Corrections are made both for identified sensor drift and for a thermal lag error, which can result when the float ascends through a region of strong temperature gradients.

Following this delayed-mode correction, salinity errors are usually reduced further and in most cases the data become good enough to detect subtle ocean change. The estimated accuracy of the delayed mode quality controlled salinity can be found in the PSAL_ADJUSTED_ERROR fields in the D profile files.

Processing Description

All data processing was performed using MATLAB (https://www.mathworks.com/products/matlab.html).

For obtaining codes used in processing, please go to: https://doi.org/10.5281/zenodo.4037179

BCO-DMO Processing:
- converted Cycle_Date to ISO8601 format.

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Related Publications

McCoy, D. (2020). DcCoy/ArgoSCVs: Finalized matlab scripts for Argo-based SCV detection (Version v1.3) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.4037179
https://doi.org/10.5281/zenodo.4037179
Software

McCoy, D., Bianchi, D., & Stewart, A. L. (2020). Global observations of submesoscale coherent vortices in the ocean. Progress in Oceanography, 189, 102452. doi:10.1016/j.pocean.2020.102452
Results

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Parameters

Parameter	Description	Units
SCV_Type	SCV type: 'S' for spicy-core SCVs, 'M' for minty-core SCVs	unitless
ID	Unique ID for each cast	unitless
Platform	Argo float ID number	unitless
Cycle	Float cycle	unitless
Longitude	Longitude of cycle	degrees
Latitude	Latitude of cycle	degrees
Cycle_Date	Cycle date; format: dd-month-YYYY hh:mm:ss	unitless
Cycle_ISO_DateTime_UTC	Cycle date and time formatted to ISO8601 standard; format: YYYY-mm-ddThh:mm:ss	unitless
Core_Pressure	Pressure at SCV core	decibars (dbar)
Core_Density	Potential density, referenced to surface, at SCV core	kilograms per cubic meter (kg/m^3)
Core_Temperature	Temperature at SCV core	degrees Celsius
Core_Salinity	Salinity at SCV core	practical salinity units
Core_Spiciness	Spiciness at SCV core	kilograms per cubic meter (kg/m^3)
Core_N2	Squared buoyancy frequency at SCV core	1/s^2
Core_Dynamic_Height_Anomaly	Dynamic Height Anomaly at SCV core	m^2/s^2
Vertical_Extent	Vertical extent of SCV as estimated by Gaussian model	meters (m)
Scale_Height	Vertical scale height as estimated by Gaussian model	meters (m)
Deformation_Radius	Horizontal scale length as estimated by Gaussian model	meters (m)
Shallow_Pressure	Shallow limit of SCV	decibars (dbar)
Deep_Pressure	Deep limit of SCV	decibars (dbar)
Shallow_Density	Deep limit of SCV	kilograms per cubic meter (kg/m^3)
Deep_Density	Deep limit of SCV	kilograms per cubic meter (kg/m^3)

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Project Information

CAREER: Multiple Scales of Nitrogen Cycle in Oxygen Minimum Zones (Multiple Scales of Nitrogen Cycle in the Ocean)

Coverage: Global

NSF Award Abstract:
The nitrogen cycle in the ocean is key to ocean productivity, carbon storage, and emissions of nitrous oxide, a potent greenhouse gas, to the atmosphere. The chemical processes that connect nitrogen species in the ocean are sensitive to the amount of oxygen dissolved in seawater. These reactions become more intense within oxygen minimum zones, areas of the ocean with little or no dissolved oxygen. Oxygen minimum zones are affected by currents that range in scale from hundreds to less than few kilometers. These currents create microhabitats where nitrogen cycling and nitrous oxide emissions are higher. This project investigates the interaction between small-scale ocean circulation, oxygen availability, and the nitrogen cycle. It uses a series of increasingly finer-scale numerical simulations of the Pacific Ocean, where two of the largest oxygen minimum zones are found. These simulations provide information about nitrogen transformations and nitrous oxide emissions on timescales from less than one year to several decades, and spatial scales from a few kilometers to the basin scale. This research will increase our ability to simulate and predict ocean responses to natural and human disturbances, with implications for society. The educational component of the project establishes a series of ocean-going chemical oceanography activities for approximately 100 undergraduate students at the University of California at Los Angeles each year. The field trips involve half-day cruises in the Santa Monica Bay, where students sample a variety of biogeochemical properties. Observations collected during the field trips will be used as a resource in classroom activities and student research projects. The field trips and educational materials offer opportunities to explore cutting-edge questions in ocean biogeochemistry, increase student interest in ocean sciences and access to research, and enhance student learning and self-efficacy, ultimately promoting retention in oceanography and STEM.

Oxygen minimum zones host major nitrogen transformations, including denitrification, anammox, and nitrous oxide production, which are essential for biogeochemistry and climate. These reactions are strongly partitioned along oxygen gradients in the suboxic range, making them sensitive to ventilation and chemical heterogeneity driven by variable ocean currents. However, the nature of this sensitivity is poorly understood. The objective of this project is to test the hypothesis that physical circulation at scales from tens of kilometers (mesoscale) to less than one kilometer (submesoscale) is critical in shaping these nitrogen cycle transformations. To test the hypothesis and investigate its implications, we will optimize a new model of the nitrogen cycle against a range of recent observations, and implement it in a realistic three-dimensional hydrodynamic-biogeochemical model. We will adopt a nesting strategy to downscale a Pacific-wide historical simulation to a series of regional domains at resolutions down to few kilometers or less, resolving the oxygen minimum zone boundaries and their fine-scale variability. By analyzing these model solutions, we will: (1) constrain the sensitivity of the microbial nitrogen cycle to oxygen, ventilation, and chemical heterogeneity; (2) in light of this sensitivity, quantify the role of mesoscale and submesoscale processes in shaping nitrogen transformations and transport across oxygen minimum zone boundaries; and (3) investigate the response of the nitrogen cycle to climate variability, in particular fixed-nitrogen losses and nitrous oxide emissions to the atmosphere.

Collaborative Research: Understanding the distribution and biogeochemical role of anaerobic microenvironments in the ocean (Ocean Particles and Microenvironments)

NSF Award Abstract:
Until recently, organic matter decomposition (respiration) was thought to occur primarily in oxygenated seawater; however, evidence has surfaced that respiration can occur under low oxygen conditions (anaerobic) similar to those found within microenvironments of suspended particles. As such, the possibility exists that these anaerobic reactions are more widespread than previously thought and could play a significant role in the cycling of sulfur, nitrogen, and some trace metals. Researchers from the University of California-Los Angeles and the University of Washington plan to study these reactions by developing a particle-redox model to simulate the biogeochemistry of anaerobic microenvironments and

make predictions which can be tested against available ocean data (GEOTRACES program). The study is intended to understand the conditions needed to cycle nitrogen and sulfur in these particle microenvironments, the scavenging of trace metals during sulfide precipitations, and develop a tracer for particle bound denitrification (removal of nitrogen by microbes). This project will be the first funding support for two tenure-track faculty who are dedicated to education and public outreach to help broaden involvement in ocean sciences. One of the investigators will be involved as a youth educator in the "Students on Ice" program which conducts workshops that allows youth to gain experience at sea learning about oceanography, whereas the other would organize a series of workshops to engage students from the Rochester City School District in science.

This project seeks to investigate the evidence that has been coming out in recent years that anaerobic microenvironments within organic particles are widespread throughout the ocean and are a significant contributor to denitrification and sulfur reduction rates in otherwise oxygenated waters. To do so, the researchers plan to develop a new modeling framework to simulate the biogeochemistry of anaerobic microenvironments and make predictions which can be tested against available observations such as those from the GEOTRACES program. Overall the objectives of this research are to (1) understand the water column conditions and particle properties that lead to these anaerobic microenvironments, (2) test whether sulfate reduction rates are consistent with the metal precipitation signatures known for low oxygen water, and (3) predict the geochemical signature of particle bound denitrification and determine its rate from the large-scale distribution of nitrogen tracers. Understanding the anaerobic processes taking place within anaerobic microenvironments of organic particles in the water column is likely to update the biogeochemical cycles of nitrogen, sulfur, and trace metals.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1847687
NSF Division of Ocean Sciences (NSF OCE)	OCE-1635632

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