High Frequency Radar (HFR) observed surface currents at Palmer Deep Canyon in the coastal ocean west of the Antarctic Peninsula in 2020

Website: https://www.bco-dmo.org/dataset/917884
Data Type: Other Field Results
Version: 1
Version Date: 2024-01-08

Project
» Collaborative Research: Physical Mechanisms Driving Food Web Focusing in Antarctic Biological Hotspots (Project SWARM)

Contributors	Affiliation	Role
Kohut, Joshua	Rutgers University	Principal Investigator
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Abstract
HFRs use doppler-shifted radio waves backscattered off the ocean surface to observe surface velocity. Signals are transmitted and received by an HFR antenna, and Bragg peaks in the measured Doppler spectra are used to calculate radial components of the surface velocity (Barrick et al., 1977). Measured radial components of the surface ocean velocity are directed towards the HFR antenna with a range resolution of 500 m horizontally and 5 degrees in azimuth. Radial components from the three HFR stations are added together to construct magnitude and direction of surface current velocities using an optimal interpolation algorithm (Kohut et al., 2006) providing hourly maps of surface currents at 1km spatial resolution (Veatch et al., 2022,, preprint: not peer reviewed). The three-site network included two remote locations on the Wauwermans and Joubin islands operated at a center frequency of 25 MHz and a third site at Palmer Station operated at 13 MHz (Veatch et al., 2024 Figure 1). The two remote sites located beyond existing power grids used Remote Power Modules (RPMs) constructed on site. These RPMs used small-scale micro wind turbines and a photovoltaic array with a 96-hour battery backup to generate the power required by the HFR (Statscewich and Weingartner, 2011; Kohut, 2014). Redundancies were built in to the RPMs, including wind charging/resistive loads, solar energy, and independent battery banks. Redundancies ensured that the system could autonomously adjust power source if one component failed. RPMs consisted of a single water-tight enclosure that housed all power generating equipment and communication gear. HFR and RPMs were assembled at remote sites using shipboard support and zodiacs that lightered materials to shore. Line of sight radio modems (Freewave) were used to communicate between the two remote sites and a central site collocated with the Palmer Station HFR site. Communication equipment enabled remote site diagnostics and maintenance as well as real-time data communication. The three HFR sites collected hourly radial maps of ocean surface current component vectors over our study area, covering about 1,500 km2 more than 80% of the time (Veatch et al., 2024 Figure 2A). The hourly, two-dimensional surface current maps derived from the radial component vector maps provided by each of the three HFR sites were used to derive our two LCS metrics (Veatch et al., 2024 Figure 2B). Before the Lagrangian coherent structure calculations were done, gaps within the 80% coverage area of the HFR maps were filled using a rigorous HFR-specific method (Fredj et al., 2016). Finally, the "edges" outside of the 80% coverage area were added back into the data structure. This was done to increase the residence time of particle release experiments within the data, however results from outside the 80% coverage were not included in final analysis.

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Coverage

Location: Palmer Deep Canyon in the coastal ocean west of the Antarctic Peninsula (~ 64.3 W, 64.9 S)
Spatial Extent: **N**:-64.7 **E**:-63.8 **S**:-65 **W**:-64.6
Temporal Extent: 2020-01 - 2020-03

Methods & Sampling

Methods for this High Frequency Radar data can be found in Veatch et al. (2024) currently in revision.

High Frequency Radars use doppler-shifted radio waves backscattered off t 181 he ocean surface to observe surface velocity. Signals are transmitted and received by an HFR antenna, and Bragg peaks in the measured Doppler spectra are used to calculate radial components of the surface velocity (Barrick, Evans, and Weber 1977). Measured radial components of the surface ocean velocity are directed towards the HFR antenna with a range resolution of 500 m horizontally and 5 degrees in azimuth. Radial components from the three HFR stations are added together to construct magnitude and direction of surface current velocities using an optimal interpolation algorithm (Kohut, Roarty, and Glenn 2006) providing hourly maps of surface currents at 1km spatial resolution.

The three HFR sites collected hourly radial maps of ocean surface current component vectors over our study area, covering about 1,500 km2 more than 80% of the time. Gaps within the 80% coverage area of the HFR maps were filled using a rigorous HFR-specific method (Fredj et al. 2016).

Instruments

The three-site network included two remote locations on the Wauwermans and Joubin islands operated at a center frequency of 25 MHz and a third site at Palmer Station operated at 13 MHz. The two remote sites located beyond existing power grids used Remote Power Modules (RPMs) constructed on site. These RPMs used small-scale micro wind turbines and a photovoltaic array with a 96-hour battery backup to generate the power required by the HFR (Kohut 2014; Statscewich and Weingartner 2011). Redundancies were built in to the RPMs, including wind charging/resistive loads, solar energy, and independent battery banks. Redundancies ensured that the system could autonomously adjust power source if one component failed. RPMs consisted of a single water-tight enclosure that housed all power generating equipment and communication gear. HFR and RPMs were assembled at remote sites using shipboard support and zodiacs that lightered materials to shore. Line of sight radio modems (Freewave) were used to communicate between the two remote sites and a central site collocated with the Palmer Station HFR site. Communication equipment enabled remote site diagnostics and maintenance as well as real-time data communication.

Data Processing Description

All data were processed using MATLAB 2019b. Scripts used for data analysis can be found at https://github.com/JackieVeatch/SWARM_CODAR .
* Curatorial note: See attached supplemental file SWARM_CODAR-related_to_bcodmo_917884_v1.zip which contains a release corresponding to commit (2e7aba4).

BCO-DMO Processing Description

* netcdf file imported into BCO-DMO. No changes made.
* A copy of code repository supplied by submitter https://github.com/JackieVeatch/SWARM_CODAR (commit 2e7aba4) forked to BCO-DMO for curatorial purposes and a release was made on 2024-01-08 https://github.com/BCODMO/SWARM_CODAR/releases/tag/related_to_bcodmo_917.... No changes to the code were made. Zip file of this release attache as a supplemental file.

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Data Files

File	
High Frequency Radar observed surface currents (netCDF format) filename: CODAR_filled_edges.nc	(NetCDF, 226.21 MB) MD5:3bc746acb8e9d3177a33cecae393430f

High Frequency Radar observed surface currents (U and V components) in netCDF format with coordinates, timestamps, and relevant metadata.

```
ncdump -h CODAR_filled_edges.nc
netcdf CODAR_filled_edges {
dimensions:
        Time = 1453 ;
        Lon = 101 ;
        Lat = 101 ;
        Char = 20 ;
variables:
        double U(Time, Lat, Lon) ;
                U:long_name = "Eastward Surface Current (cm/s)" ;
                U:standard_name = "surface_eastward_sea_water_velocity" ;
                U:units = "cm/s" ;
                U:FillValue = "0" ;
        double V(Time, Lat, Lon) ;
                V:long_name = "Northward Surface Current (cm/s)" ;
                V:standard_name = "surface_northward_sea_water_velocity" ;
                V:units = "cm/s" ;
                V:FillValue = "0" ;
        double time(Time) ;
                time:long_name = "Time" ;
                time:standard_name = "time" ;
                time:units = "days since 0000 01-01-T00:00:00; datenum serial date number" ;
                time:FillValue = "NaN" ;
                time:calendar = "georgian" ;
                time:TimeZone = "GMT" ;
        double lon(Lon) ;
                lon:long_name = "Longitude" ;
                lon:standard_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:FillValue = "NaN" ;
        double lat(Lat) ;
                lat:long_name = "Latitude" ;
                lat:standard_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:FillValue = "NaN" ;
        char time_readable(Char, Time) ;
                time_readable:long_name = "Time" ;
                time_readable:standard_name = "time" ;
                time_readable:units = "date_string" ;
                time_readable:FillValue = "NaN" ;
                time_readable:calendar = "georgian" ;
                time_readable:TimeZone = "GMT" ;
}
```

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Supplemental Files

File
SWARM HFR (data in alternate format, Matlab) filename: CODAR_filled_edges.mat (MATLAB Data (.mat), 20.14 MB) MD5:562dec9e85c062695cf9ce2f7d204702 Data in alternate format (matlab .mat). These files contain the same dataset as the primary file for this dataset CODAR_filled_edges.nc (netCDF). Note that the .nc file contains datetime in string format while the .mat files contain only matlab datenum type. Mat file of the velocity vectors every hour between January 9 and March 9 2020 for the area around Palmer Deep Canyon. Name Description Units Missing data identifier U east-west velocity cm/s V north-west velocity cm/s dnum date number of velocity field serial date number a serial date number represents the whole and fractional number of days from January 0,0000 in the proleptic ISO calendar lon longitude decimal degrees lat latitude decimal degrees CODAR_filled_edges = struct with fields: U: [101x101x1453 double] V: [101x101x1453 double] dnum: [737799 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 7.3780e+05 ...] (1x1453 double) lon: [101x1 double] lat: [101x1 double]
SWARM_CODAR (github code release) filename: SWARM_CODAR-related_to_bcodmo_917884_v1.zip (ZIP Archive (ZIP), 4.51 MB) MD5:3b653118b6553a3479e777f19fdc67f3 Code release made from https://github.com/JackieVeatch/SWARM_CODAR forked to BCO-DMO https://github.com/BCODMO/SWARM_CODAR/releases/tag/related_to_bcodmo_917884_v1 for curatorial purposes. The repository was forked from https://github.com/JackieVeatch/SWARM_CODAR on 2024-01-08. No changes to the code were made. Release corresponds to commit https://github.com/JackieVeatch/SWARM_CODAR/commit/2e7aba46617cb748aa5a74ef9f661b0d33922416 Repository README: SWARM_CODAR FILL GAPS in CODAR scripts will interpolate gaps in data surrounded by quality controlled data with minimal smoothing. This is a published technique: Fredj, E., Roarty, H., Kohut, J., Smith, M., and Glenn, S. 2016. Gap Filling of the Coastal Ocean Surface Currents from HFR Data: Application to the Mid-Atlantic Bight HFR Network. Journal of atmospheric and oceanic technology, 33: 1097-1111. fillgaps scripts are two versions of similar code: "add_edges" will put the quality controlled data that is outside of the domain back into the data structure to increase residence time of particles. The domain was defined as every grid point that contains data at least 80% of the time. PLOT CODAR function used to plot HFR data from project SWARM (three HFRs deployed around Palmer Deep Canyon from Jan-March 2020). plotting dependencies are located in "antarcticaPlotting" folder. Many thanks to the Rutgers Uiversity Center for Ocean Observing Leadership for the building of a lot of this code, especially Hugh Roarty and Laura Nazarro.

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Related Publications

Barrick, D. E., Evans, M. W., & Weber, B. L. (1977). Ocean Surface Currents Mapped by Radar. Science, 198(4313), 138–144. https://doi.org/10.1126/science.198.4313.138
Methods

Fredj, E., Roarty, H., Kohut, J., Smith, M., & Glenn, S. (2016). Gap Filling of the Coastal Ocean Surface Currents from HFR Data: Application to the Mid-Atlantic Bight HFR Network. Journal of Atmospheric and Oceanic Technology, 33(6), 1097–1111. https://doi.org/10.1175/jtech-d-15-0056.1 https://doi.org/10.1175/JTECH-D-15-0056.1
Methods

Kohut, J. T., Roarty, H. J., & Glenn, S. M. (2006). Characterizing Observed Environmental Variability With HF Doppler Radar Surface Current Mappers and Acoustic Doppler Current Profilers: Environmental Variability in the Coastal Ocean. IEEE Journal of Oceanic Engineering, 31(4), 876–884. https://doi.org/10.1109/joe.2006.886095 https://doi.org/10.1109/Joe.2006.886095
Methods

Kohut, J., Bernard, K., Fraser, W., Oliver, M. J., Statscewich, H., Winsor, P., & Miles, T. (2014). Studying the Impacts of Local Oceanographic Processes on Adélie Penguin Foraging Ecology. Marine Technology Society Journal, 48(5), 25–34. https://doi.org/10.4031/mtsj.48.5.10 https://doi.org/10.4031/MTSJ.48.5.10
Methods

Statscewich, H., Weingartner, T., Danielsen, S., Grunau, B., Egan, G., & Timm, J. (2011). A High-Latitude Modular Autonomous Power, Control, and Communication System for Application to High-Frequency Surface Current Mapping Radars. Marine Technology Society Journal, 45(3), 59–68. https://doi.org/10.4031/mtsj.45.3.7 https://doi.org/10.4031/MTSJ.45.3.7
Methods

Veatch, J., Fredj, E., & Kohut, J. (2022). High Frequency Radars as Ecological Sensors: Using Lagrangian Coherent Structures to Quantify Prey Concentrating Features. OCEANS 2022, Hampton Roads. https://doi.org/10.1109/oceans47191.2022.9977356 https://doi.org/10.1109/OCEANS47191.2022.9977356
Methods

Veatch, J., Kohut, J., Oliver, M., Statscewich, H., Fredj, E. (2024) Quantifying the role of sub-mesoscale lagrangian transport features in the concentration of plankton in a coastal system ICES JMS, In Revision.
Results

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Related Datasets

IsRelatedTo

Veatch, J., Klinck, J. M., Oliver, M., Kohut, J., Statscewich, H. (2024) **Relative Particle Density (RPD) calculations using High Frequency Radar (HFR) observed surface currents around Palmer Deep Canyon from January to March of 2020.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-01-08 doi:10.26008/1912/bco-dmo.917926.1 [view at BCO-DMO]
Relationship Description: The "High Frequency Radar, Palmer Deep" dataset provided the observed surface currents (velocity field) from which these Relative Particle Density were calculated from.

Veatch, J., Klinck, J. M., Oliver, M., Statscewich, H., Kohut, J. (2024) **Results from Finite Time Lyapunov Exponent calculations using High Frequency Radar observed surface currents around Palmer Deep Canyon from January to March of 2020.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-01-08 doi:10.26008/1912/bco-dmo.917914.1 [view at BCO-DMO]
Relationship Description: The "High Frequency Radar, Palmer Deep" dataset provided the observed surface currents (velocity field) from which these Finite Time Lyapunov Exponent Results were calculated from.

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	High Frequency Radar (CODAR Ocean Sensors SeaSonde HFR)
Generic Instrument Name	High Frequency Radar
Dataset-specific Description	HFR used was CODAR Ocean Sensors SeaSonde HFR. The two sites on the Joubins and Wauwermans operated at 25 MHz and the PAL site operated at 13 MHz.
Generic Instrument Description	High (5-50 MHz) frequency radar transmits electromagnetic waves and records the backscattered signal. Oceanographic usage includes sea surface radar in which the backscattered signals are analyzed to obtain surface current and wave parameters.

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Project Information

Collaborative Research: Physical Mechanisms Driving Food Web Focusing in Antarctic Biological Hotspots (Project SWARM)

Coverage: West Antarctic Peninsula

NSF Award Abstract:
Undersea canyons play disproportionately important roles as oceanic biological hotspots and are critical for our understanding of many coastal ecosystems. Canyon-associated biological hotspots have persisted for thousands of years Along the Western Antarctic Peninsula, despite significant climate variability. Observations of currents over Palmer Deep canyon, a representative hotspot along the Western Antarctic Peninsula, indicate that surface phytoplankton blooms enter and exit the local hotspot on scales of ~1-2 days. This time of residence is in conflict with the prevailing idea that canyon associated hotspots are primarily maintained by phytoplankton that are locally grown in association with these features by the upwelling of deep waters rich with nutrients that fuel the phytoplankton growth. Instead, the implication is that horizontal ocean circulation is likely more important to maintaining these biological hotspots than local upwelling through its physical concentrating effects. This project seeks to better resolve the factors that create and maintain focused areas of biological activity at canyons along the Western Antarctic Peninsula and create local foraging areas for marine mammals and birds. The project focus is in the analysis of the ocean transport and concentration mechanisms that sustain these biological hotspots, connecting oceanography to phytoplankton and krill, up through the food web to one of the resident predators, penguins. In addition, the research will engage with teachers from school districts serving underrepresented and underserved students by integrating the instructors and their students completely with the science team. Students will conduct their own research with the same data over the same time as researchers on the project. Revealing the fundamental mechanisms that sustain these known hotspots will significantly advance our understanding of the observed connection between submarine canyons and persistent penguin population hotspots over ecological time, and provide a new model for how Antarctic hotspots function.

To understand the physical mechanisms that support persistent hotspots along the Western Antarctic Peninsula (WAP), this project will integrate a modeling and field program that will target the processes responsible for transporting and concentrating phytoplankton and krill biomass to known penguin foraging locations. Within the Palmer Deep canyon, a representative hotspot, the team will deploy a High Frequency Radar (HFR) coastal surface current mapping network, uniquely equipped to identify the eddies and frontal regions that concentrate phytoplankton and krill. The field program, centered on surface features identified by the HFR, will include (i) a coordinated fleet of gliders to survey hydrography, chlorophyll fluorescence, optical backscatter, and active acoustics at the scale of the targeted convergent features; (ii) precise penguin tracking with GPS-linked satellite telemetry and time-depth recorders (TDRs); (iii) and weekly small boat surveys that adaptively target and track convergent features to measure phytoplankton, krill, and hydrography. A high resolution physical model will generalize our field measurements to other known hotspots along the WAP through simulation and determine which physical mechanisms lead to the maintenance of these hotspots. The project will also engage educators, students, and members of the general public in Antarctic research and data analysis with an education program that will advance teaching and learning as well as broadening participation of under-represented groups. This engagement includes professional development workshops, live connections to the public and classrooms, student research symposia, and program evaluation. Together the integrated research and engagement will advance our understanding of the role regional transport pathways and local depth dependent concentrating physical mechanisms play in sustaining these biological hotspots.

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 Office of Polar Programs (formerly NSF PLR) (NSF OPP)	OPP-1745009
NSF Office of Polar Programs (formerly NSF PLR) (NSF OPP)	OPP-1744884
NSF Office of Polar Programs (formerly NSF PLR) (NSF OPP)	OPP-1745011

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