Progress Report
Surface Drifter Program

AOML's component of the Global Drifter Program

Period of Activity: 01 October 2022 – 30 September 2023

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Budget Summary
FY 2023: $828,271
($859,935 in FY20)

Surface Drifter Program

PI: Dr. Rick Lumpkin
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Table of Contents

1. Project Summary

The Surface Drifter Program is the Atlantic Oceanographic and Meteorological Laboratory's (AOML) contribution to NOAA's Global Drifter Program (GDP), a branch of NOAA's Integrated Ocean Observing System, Global Ocean Observing System (IOOS/GOOS) and a scientific project of the Data Buoy Cooperation Panel (DBCP).

AOML's GDP responsibilities are to: (1) maintain a global 5ºx5º array of drifters by managing and coordinating drifter deployments worldwide; (2) assign identification numbers and monitor the quality of the data that are placed on the Global Telecommunications System (GTS) for real-time distribution to meteorological services for improved weather forecasting and ocean state estimation; (3) maintain metadata files describing each drifter deployed, (4) quality control and interpolate the data to provide a data processing system for the scientific use of these data; (5) archive the data at NOAA's National Center for Environmental Information (NCEI) and elsewhere; (6) develop and distribute data-based products; (7) maintain AOML's GDP web pages; and (8) maintain liaisons with individual research programs that deploy drifters.

The drifters provide sea surface temperature (SST) and near surface currents. A subset of the drifters also measures air pressure, winds, subsurface temperatures, salinities, and waves. These observations are needed to calibrate SST and sea surface salinity observations from satellites, initialize global numerical weather and seasonal to interannual predictions to improve prediction skill, and provide nowcasts of the structure of global surface currents. The surface drifter array provides the largest area coverage of all components of the global ocean observing system for surface temperature and currents, with observations provided by the drifters at hourly resolution. Secondary objectives of this project are to use the resulting data to increase our understanding of the dynamics of high frequency to multi-year variability and to perform model validation studies. Thus, this project addresses both operational and scientific goals of NOAA's program for building a sustained ocean observing system for climate. The data are made available in near-real time on the GTS for weather forecasting efforts and archival at NOAA's NCEI, and in delayed mode (approximately 2—3 months, after quality control and interpolation).

2. Scientific and Observing System Accomplishments

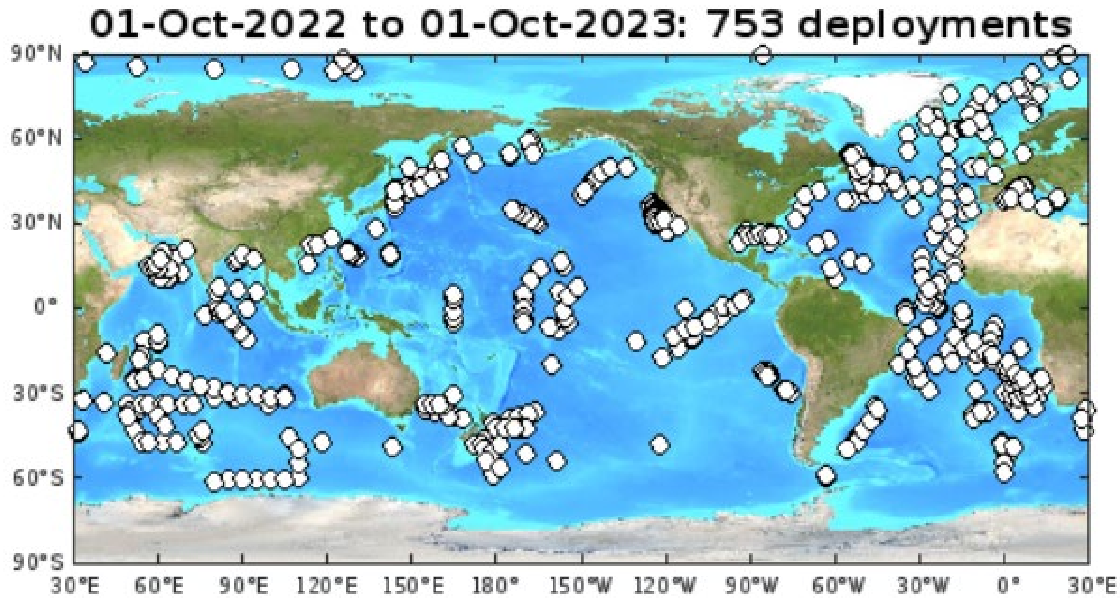
1. Progress on the milestones and performance measures that you selected from the list below and included in your FY 2021 Work Plan.

   GOMO Required Performance Measures:

   - Coordinate deployment of ~800 drifters worldwide to significantly improve weather forecasting and ocean state estimation, and to provide a data processing system for the scientific use of these data that support subseasonal-to-interannual predictions as well as ocean and weather research. **Status: done. 753 drifters deployed in FY.**
   - On a quarterly basis, the GDP's drifter Data Assembly Center (DAC) will produce a dataset of quality-controlled, evenly-interpolated drifter data of research quality for the oceanographic and meteorological community. This data set will be archived at AOML and at NOAA/NCEI. **Status: done. Database updated through 30 September 2023. Data available at AOML's GDP ERDDAP Server.**
   - Drifter deployment value maps will be generated to communicate deployment needs with partners and potential partners, in order to leverage ship time and realize cost savings for NOAA's Global Ocean Observing System. These are available at http://www.aoml.noaa.gov/phod/gdp/value_maps.php. **Status: done.**
   - Metadata files will be maintained that document information for each drifter deployed in the global array. Information includes manufacturer, deployment time, deployment location, death location and time, and the time of drogue loss. These files will be made available on the Global Drifter Program web site. **Status: done.**
   - The DAC will continue to produce products derived from the drifter observations including time-mean and seasonal maps of currents, animations of currents, and population reports. **Status: done.**

2. Notable observing achievements during FY 2023

During FY23, the global drifter array was maintained at an average size of 1098 drifters with a standard deviation of 56 drifters. On average, 70% of all relevant 5°x5° bins were sampled by at least one drifter. A total of 753 deployments were coordinated with national and international partners during FY23.



In FY23, AOML launched its Global Drifter Program ERDDAP server for delayed mode, quality controlled data and derived products (https://erddap.aoml.noaa.gov/gdp/erddap). This server currently provides access to hourly and 6h quality-controlled drifter data, drifter climatologies of mean, monthly mean, and eddy variance, looper and nonlooper trajectories, and mirrors the OSMC real-time data for the most recent 90 days.

On 27 July 2023, the GOMO Committee met with Global Drifter Program PIs Rick Lumpkin (AOML) and Luca Centurioni (SIO) to discuss the evolving sampling needs of the program given advances in sensors and satellite missions. It was agreed that the sampling strategy which has existed since OceanObs'99 must be reevaluated, and does not serve identified scientific needs such as resolution of submesoscale features (SWOT), atmospheric rivers, and eddy-driven stirring. Subsequent to this meeting, the PIs initiated this conversation with members of the drifter data user community. The July meeting was also a venue for discussing establishing connections with the private sector, particularly Sofar Ocean, where the challenge of working with restricted data was highlighted in the context of a recent data-sharing agreement between Sofar and NOAA/NWS.

3. Scientific advances and significance of your work

PI Lumpkin served as co- editor of the Oceans chapter of the BAMS "State of the Climate in 2022" report with Greg Johnson (PMEL), and was lead author of the section on Surface Currents (R. Lumpkin, F. Bringas, and G. Goni). This report documented changes in surface currents during the year, anomalies with respect to 2021 and to climatology, and represents an OAR transition to NOAA/Climate Prediction Center.

The Drifter DAC contributed to the monthly "Climate Diagnostics Bulletin" published by NOAA/NCEP's Climate Prediction Center.

PI Lumpkin served as chair of the DBCP Global Drifter Program and as the focal point for the United States delegation to the DBCP. Lumpkin also joined the Ocean Observations panel for Physics and Climate (OOPC) in FY23.

AOML generates a monthly climatology of ocean surface currents derived from the drifter data at http://www.aoml.noaa.gov/phod/gdp/mean_velocity.php. This product is now updated to version number 3.10, released 21 August 2023, including drifter data through February 2023, and is available through our ERDDAP server.

AOML's DAC continues to update its interactive array tool at https://www.aoml.noaa.gov/phod/gdp/interactive/drifter_array.html. This tool provides the ability to zoom and scroll on the array, hover the cursor over drifters to get their identification numbers, and click to see data and metadata including deployment information, manufacturer, and drifter type in an ID card that can be viewed as a high-resolution image with an additional click.

4. Instrumental records of Essential Ocean Variables , Essential Climate Variables, and related ocean attributes that are relevant for 1) Routine delivery of a range of societally relevant services (e.g. products, forecasts, etc.) and 2) advancing climate, ocean, and related research

Drifters provide observations of sea surface temperature (SST), sea surface velocity (SSV), and sea level pressure (SLP). A smaller number provide sea surface salinity (SSS), directional wave spectrum measurements, winds, and subsurface temperature profiles.

5. Issues related to funding that affect progress (e.g., reductions, delays)

In response to the unexpected increase in DISA Iridium charges, the GDP deactivated a number of drifters and ceased manufacture of DISA-modem drifters while the situation was addressed by GOMO. After extended negotiations, GOMO made the decision to switch to commercial modems and drifter production responded accordingly. This introduced long delays in refreshing national and international drifter storage sites and subsequently deployments, resulting in a loss of coverage as gaps opened in the array that could not be addressed with existing DISA drifters in inventory. These gaps are now targeted for deployments using commercial modem drifters now resupplying storage sites, and coverage should improve in the coming months.

Budget cuts in FY21—FY22 meant that AOML was unable to purchase new drifters, reducing the manufacture diversity of the array. These budget cuts were also absorbed by eliminating most travel in FY21 and 22 (with the exception of travel for loading commercial vessels from Norfolk, VA by Jim Farrington), which did not affect the program due to pandemic restrictions on inperson meetings. While budget cuts continued in FY23, reduction in personnel costs associated with a retirement allowed us to purchase <100 drifters to be deployed in FY24.

6. Website for your program

https://www.aoml.noaa.gov/phod/gdp/index.php

3. Outreach and Education

- The Global Drifter Program has an outreach web page at http://www.aoml.noaa.gov/phod/gdp/outreach.php. This page highlights partnerships with programs like Adopt-A-Drifter, the Seakeepers, and the Ocean Race that have a significant outreach component. The GDP is also actively working with GOMO to refresh the Adopt-A-Drifter program and web page, which will be maintained and updated by AOML starting in FY24.
- PI Rick Lumpkin performed the following outreach activities in FY23:
  - Served as focal point of the US delegation to the Data Buoy Cooperation Panel.
  - Contributed information about the Florida Current for a Washington Post story about migrants crossing the Florida Straits.
  - Conducted an email interview with Tom Bayles (Florida NPR affiliate reporter at WGCU in Fort Myers) on the evolution of Sargassum in the Gulf of Mexico.
  - Worked with Rebecca Lindsey (contractor to NOAA/CPO) to create a climate.gov story about the establishment of the Great Sargassum Belt.
  - Interviewed by ABC-25 WPBF (West Palm Beach) for a news story on Sargassum.
  - Recorded an episode of "The Sargassum Podcast" about the establishment of the Great Sargassum Belt.
  - Conducted live interview with Brigitte Quinn of WCBS 880 Radio in New York City.
  - Interviewed by Suman Naishadham of The Associated Press.
  - Conducted live interview with Doug Saltman of WMBS Pittsburgh.
  - Interviewed by Brian Bushard of Forbes via email.
  - Interviewed by Corina Cappabianca of Spectrum News/News10 ABC.
  - Interviewed by Canadian Broadcasting Corporation's national evening radio program "As It Happens".
  - Interviewed by Saul Elbein of The Hill.

4. Publications and Reports

4.1. Publications by Principal Investigators

All publications satisfy NOAA's Public Access to Research Results (PARR) requirements, including submitting a digital copy of final pre-publication manuscripts to the NOAA

Institutional Repository once accepted for publication and the final pre-publication copy is available.

Published FY23 by PI Lumpkin:

Beron-Vera, J., M. J. Olascoaga, N. Putman, J. Trinanes, G. Goni, and R. Lumpkin, 2023: Dynamical geography and transition paths of Sargassum in the tropical Atlantic. *AIP Advances*, **12**, 105107, https://doi.org/10.1063/5.0117623.

Boyer, T. et al., 2023: Effects of the Pandemic on the Ocean Observing System. *Bull. Amer. Meteor. Soc*., **104**(2), E389-E410, https://doi.org/10.1175/BAMS-D-21-0210.1.

Holbach, H. M., et al., 2023: Recent advancements in aircraft and in situ observations of tropical cyclones. Tropical Cyclone Research and Review, 12(2):81-99, https://doi.org/10.1016/j.tcrr.2023.06.001.

Johnson, G. and R. Lumpkin, 2023: Overview [in Chapter 3 of "State of the Climate in 2022"]. *Bull. Amer. Meteor. Soc.,* **104** (9), S173–S176, https://doi.org/10.1175/BAMS-D-23-0076.2.

Lee, S.-K., R. Lumpkin, F. Gomez, S. Yeager, H. Lopez, F. Takglis, S. Dong, W. Aguiar, D. Kim, and M. Baringer, 2023: Human-induced changes in the global meridional overturning circulation are emerging from the Southern Ocean. *Communications Earth & Environment*, **4**, https://doi.org/10.1038/s43247-023-00727-3.

Lumpkin, R., F. Bringas, G. Goni, and B. Qiu, 2023: Surface Currents [in Chapter 3 of "State of the Climate in 2022"]. *Bull. Amer. Meteor. Soc.,* **104** (9), S173–S176, https://doi.org/10.1175/BAMS-D-23-0076.2.

Putman, N., R. Taylor Beyea, Lowell Andrew R. Iporac, Joaquin Triñanes, Emilie G. Ackerman, Maria J. Olascoaga, Christian M. Appendini, Jaime Arriaga, Ligia Collado-Vides, Rick Lumpkin, Chuanmin Hu, and Gustavo Goni, 2023: Improving satellite monitoring of coastal inundations of pelagic Sargassum algae with wind and citizen science data. *Aquatic Botany*, 188:103672, https://doi.org/10.1016/j.aquabot.2023.103672.

Tuchen, F. P., R. C. Perez, G. R. Foltz, P. Brandt, and R. Lumpkin, 2023: Multidecadal Intensification of Atlantic Tropical Instability Waves. *Geophys. Res. Lett*., 49(22):e2022GL101073, https://doi.org/10.1029/2022GL101073.

4.2. Other Relevant Publications

Aijaz, Saima, Gary B. Brassington, Prasanth Divakaran, Charly Régnier, Marie Drévillon, Jan Maksymczuk, K. Andrew Peterson, 2023:Verification and intercomparison of global ocean Eulerian near-surface currents. *Ocean Modelling*,186, https://doi.org/10.1016/j.ocemod.2023.102241.

Brolly, M. T., 2023: Inferring ocean transport statistics with probabilistic neural networks. *Journal of Advances in Modeling Earth Systems*, 15, e2023MS003718. https://doi.org/10.1029/2023MS003718.

Clément, L., E. Frajka-Williams, N. von Oppeln-Bronikowski, I. Goszczko, and B. de Young, 2023: Cessation of Labrador Sea Convection Triggered by Distinct Fresh and Warm

(Sub)Mesoscale Flows. *J. Phys. Oceanogr*., 53, 1959–1977, https://doi.org/10.1175/JPO-D-22-0178.1.

Contreras, M., L. Renault, and P. Marchesiello, 2023: Understanding Energy Pathways in the Gulf Stream. *J. Phys. Oceanogr*., 53, 719–736, https://doi.org/10.1175/JPO-D-22-0146.1.

Debreu, L., N.K.-R. Kevlahan, P. Marchesiello, 2022: Improved Gulf Stream separation through Brinkman penalization. *Ocean Modelling*, 179, https://doi.org/10.1016/j.ocemod.2022.102121.

Duyck, E., & De Jong, M. F., 2023: Cross-shelf exchanges between the east Greenland shelf and interior seas. *Journal of Geophysical Research: Oceans*, 128, e2023JC019905. https://doi.org/10.1029/2023JC019905.

Esposito, G., Donnet, S., Berta, M., Shcherbina, A. Y., Freilich, M., Centurioni, L., et al., 2023: Inertial oscillations and frontal processes in an Alboran Sea jet: Effects on divergence and vertical transport. *Journal of Geophysical Research: Oceans*, 128, e2022JC019004. https://doi.org/10.1029/2022JC019004.

Hormann, V., Centurioni, L. R., & Paluszkiewicz, T., 2023: Persistence of cold wedges in the Somali current system. *Geophysical Research Letters*, 50, e2022GL101876. https://doi.org/10.1029/2022GL101876.

Hu, Z., and Coauthors, 2023: Observations of a Filamentous Intrusion and Vigorous Submesoscale Turbulence within a Cyclonic Mesoscale Eddy. *J. Phys. Oceanogr*., 53, 1615–1627, https://doi.org/10.1175/JPO-D-22-0189.1.

Kuhn, A. M., Mazloff, M., Dutkiewicz, S., Jahn, O., Clayton, S., Rynearson, T., & Barton, A. D., 2023: A global comparison of marine chlorophyll variability observed in Eulerian and Lagrangian perspectives. *Journal of Geophysical Research: Oceans*, 128, e2023JC019801. https://doi.org/10.1029/2023JC019801.

Liu, G., Chen, Z., Lu, H., Liu, Z., Zhang, Q., He, Q., et al., 2023: Energy transfer between mesoscale eddies and near-inertial waves from surface drifter observations. *Geophysical Research Letters*, 50, e2023GL104729. https://doi.org/10.1029/2023GL104729.

Olivé Abelló, A., J. L. Pelegrí, and F. Machín, 2023: A Simple Method for Estimating Horizontal Diffusivity. *J. Atmos. Oceanic Technol*., 40, 739–752, https://doi.org/10.1175/JTECH-D-22-0097.1.

Quay, P., 2023: Organic matter export rates and the pathways of nutrient supply in the ocean. *Global Biogeochemical Cycles*, 37, e2023GB007855. https://doi.org/10.1029/2023GB007855.

Reynolds, C. A., and Coauthors, 2023: Impacts of Northeastern Pacific Buoy Surface Pressure Observations. *Mon. Wea. Rev*., 151, 211–226, https://doi.org/10.1175/MWR-D-22-0124.1.

Skyllingstad, E. D., R. M. Samelson, H. Simmons, L. S. Laurent, S. Merrifield, T. Klenz, and L. Centuroni, 2023: Boundary Layer Energetics of Rapid Wind and Wave Forced Mixing Events. *J. Phys. Oceanogr*., 53, 1887–1900, https://doi.org/10.1175/JPO-D-22-0150.1.

Thomas, L. N., E. D. Skyllingstad, L. Rainville, V. Hormann, L. Centurioni, J. N. Moum, O. Asselin, and C. M. Lee, 2023: Damping of Inertial Motions through the Radiation of Near-Inertial Waves in a Dipole Vortex in the Iceland Basin. *J. Phys. Oceanogr*., 53, 1821–1833, https://doi.org/10.1175/JPO-D-22-0202.1.

Tillette, C., Tailladnier, V., Bouruet-Aubertot, P., Grima, N., Maes, C., Montanes, M., Sarthou, G., Vorrath, M.E., Arnone, V., Bressac, M., Gonzalez-Santana, D., Gazeau, F., & Guieu, C., 2022: Dissolved Iron Patterns Impacted by Shallow Hydrothermal Sources Along a Transect Through the Tonga-Kermadec Arc. *Global Biogeochemical Cycles*, 36(7). https://doi.org/10.1029/2022GB007363

Wang, G., Wu, L., Mei, W. et al. Ocean currents show global intensification of weak tropical cyclones. *Nature* 611, 496–500 (2022). https://doi.org/10.1038/s41586-022-05326-4

Zheng, Y., Z. Ma, J. Tang, and Z. Zhang, 2023: The Coastal Effect on Ahead-of-Eye-Center Cooling Induced by Tropical Cyclones. *J. Phys. Oceanogr*., 53, 1519–1534, https://doi.org/10.1175/JPO-D-22-0139.1.

Zhao, Z., Wu, W., Xia, Y., & Du, Y., 2023: Interior route and seasonal dynamics of the meridional current in the eastern Indian Ocean tropical gyre. *Journal of Geophysical Research: Oceans*, 128, e2023JC019959. https://doi.org/10.1029/2023JC019959.

5. Data and Publication Sharing

All GDP data are transmitted on the GTS for near-real-time distribution. In delayed mode, the data are quality controlled and interpolated to regular 6-hourly and hourly values available at https://erddap.aoml.noaa.gov/gdp/erddap/index.html.
The GTS and delayed mode QC data are archived at Coriolis and NOAA/NCEI. QC data are also available from the GDP web page and are available and readily discoverable using NOAA's Observing System Monitoring Center (OSMC). For details, see http://www.aoml.noaa.gov/phod/gdp/real-time_data.php for real-time data access, https://www.aoml.noaa.gov/phod/gdp/hourly_data.php for QC hourly data access, and https://www.aoml.noaa.gov/phod/gdp/interpolated/data/all.php for QC 6-h data. The drifter data management plan is described in the OceanObs'09 Community White Paper "Data Management System for Drifting Buoys" by Keeley, Pazos and Bradshaw, available at www.oceanobs09.net/blog/?p=225.

6. Project Highlight Slides

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