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Final Report

SWIFT drifter observations during USRS (UnderSea Remote Sensing)

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SUMMARY

Freely drifting SWIFTs (Surface Wave Instrument Floats with Tracking) were used to measure currents, waves, turbulence, temperatures, salinities, winds, and bathymetry during the USRS (UnderSea Remote Sensing) field campaigns at the James River (VA) and Mobile Bay (AL). These measurements have been assimilated in hydrodynamic models, with application to bathymetry inversion and tracking frontal features. The measurements have also been used to understand the underlying dynamics of frontal features in tidal estuaries.

LONG-TERM GOALS

The long-term goal of this project has been to improve understanding of estuarine dyamics, especially as regards acoustic propagation and remote sensing of bathymetry. These goals are directly related to safe navigation through the littoral and coastal zones, included denied areas with limited in situ measurments available.

OBJECTIVES

The specific objectives have been to

- Add bathymetry measurements to existing SWIFT drifters,
- Use drifters to characterize estaurine flows, especially in shallow regions not accessible to research vessels,
- Understand frontal dynamics and the downwelling of bubbles at fronts, and
- Assimilate drifter data into hydrodynamic models and improve bathymetry estimation.

APPROACH

SWIFT drifters measure currents, waves, turbulence, temperatures, salinities, winds, and bathymetry in a Lagranian reference frame. SWIFTs have been developed under prior ONR support and have a modular payload structure that can accommodate new/different sensors to suit a given project. Here, the version 4 (v4) SWIFTs included Nortek Signature acoustic profilers, with interleaved modes for alitmetery (i.e., bathymetry), mean currents profiles, near-surface turbulence, and echograms (to image bubbles and stratification). The v4 SWIFTs also included a GPS-aided motion sensor to estimate waves and surface drift, along with conductivity and temperature, surface winds, and surface images. The SWIFTs have onboard processing and Iridium telemetry of 12-minute ensemble products, which are publically available in near-realtime for situational awareness and model assimilation.

WORK COMPLETED

Four SWIFT drifters were repeated deployed on daily missions during the USRS field campaigns at the James River (VA) and Mobile Bay (AL). These missions were coordinated with other USRS efforts, including shipboard surveys, moorings, and remote sensing (shore-based radars, uncrewed aerial systems). Raw data were collected at several Hz from all channels, then processed as ensembles every 30 seconds and every 12 minutes. CTD (Conductivity-Temperature-Depth) profiles were also collected at select drifter locations. Data have been shared across the USRS program for collaborative efforts in data-assimilative modeling and synthesis of dynamics.

RESULTS

James River (VA)

The James River field campaing occurred in April 2019. Figure 1 shows the timeseries of surface winds and waves measured by SWIFTs during the one-week experiment, which had stronger winds (and intense wave breaking at the tidal intrusion front) at the beginning of the experiment. Figure 2 shows a map of surface salinity measured by the SWIFTs. The tidal intrusion front formed to the west of the bridge-tunnel, where the SWIFTs (yellow points) accumulated in the convergence. This pattern repeated daily, though the frontal conditions changed with the wind and wave forcing.

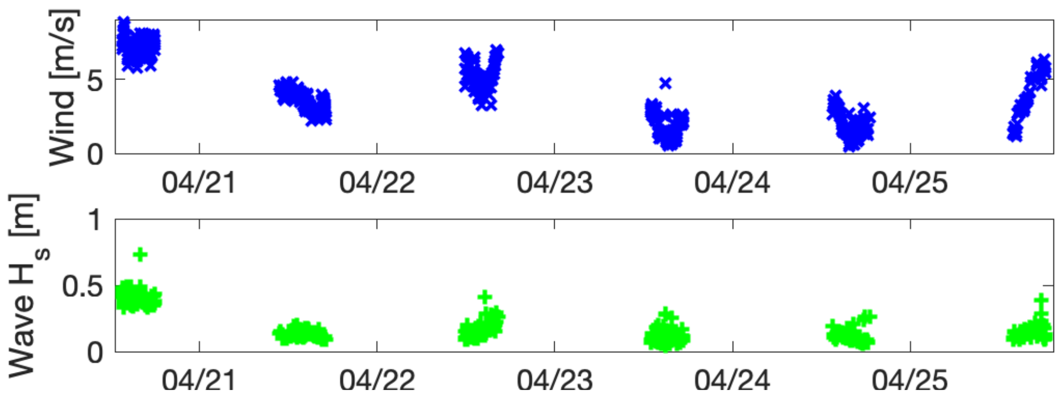

Figure 1: Time series of winds and waves measured by SWIFTs during the James River experiment.

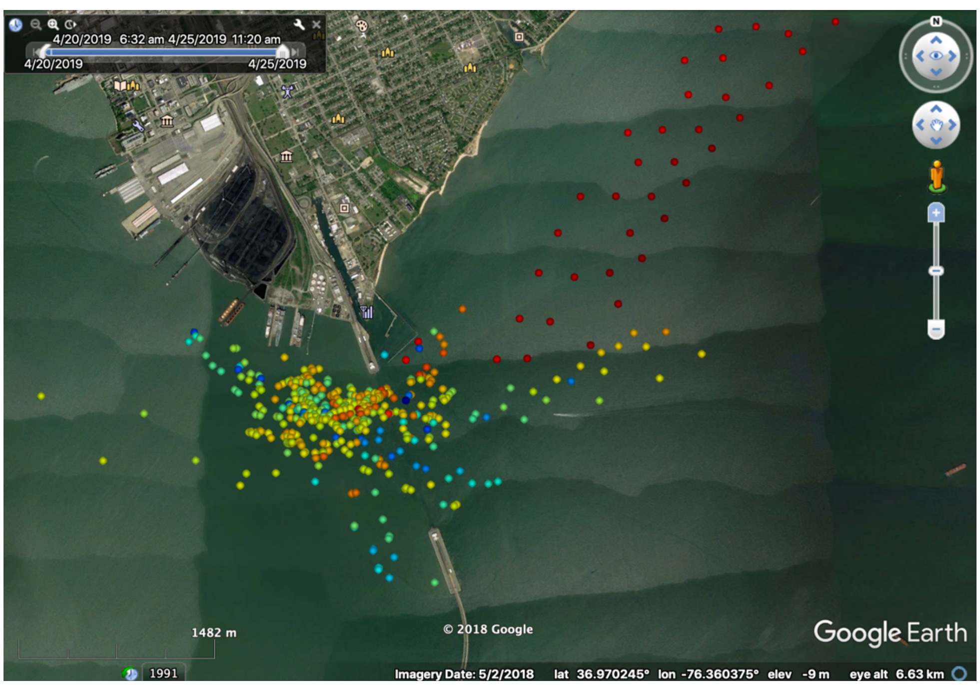

Figure 2: Map of SWIFT ensembles at James River tidal intrusion front. Color is salinity (red = 16 PSU, blue = 6 PSU).

The tidal intrusion front at James River causes strong wave breaking and bubble production. As desribed in Bassett et al (2023), the bubbles provide strong acoustic backscatter. Figure 3 shows an example from a downlooking Nortek Signature1000 on a SWIFT as it becomes entrained in the convergent front. Both the high-resolution (HR) profiles near the surface and the broadband profiles of the full depth profile are shown. The surface conditions become rough at the front, and surface foam is everywhere. Below the surface, the acoustic backscatter is elevated within the front, and vertical velocities (vertical bars) become strongly negative. These downwelling velocities can exceed 10 cm/s and carry bubles to depths far beyond direct injection by breaking waves. The smaller bubbles are persistent and the acoustic backscatter signals are elevated beyond the narrow frontal region. The turbulent dissipation rates are also elevated (not shown), and this is likely a combination of wave breaking turbulence with shear-driven turbulence.

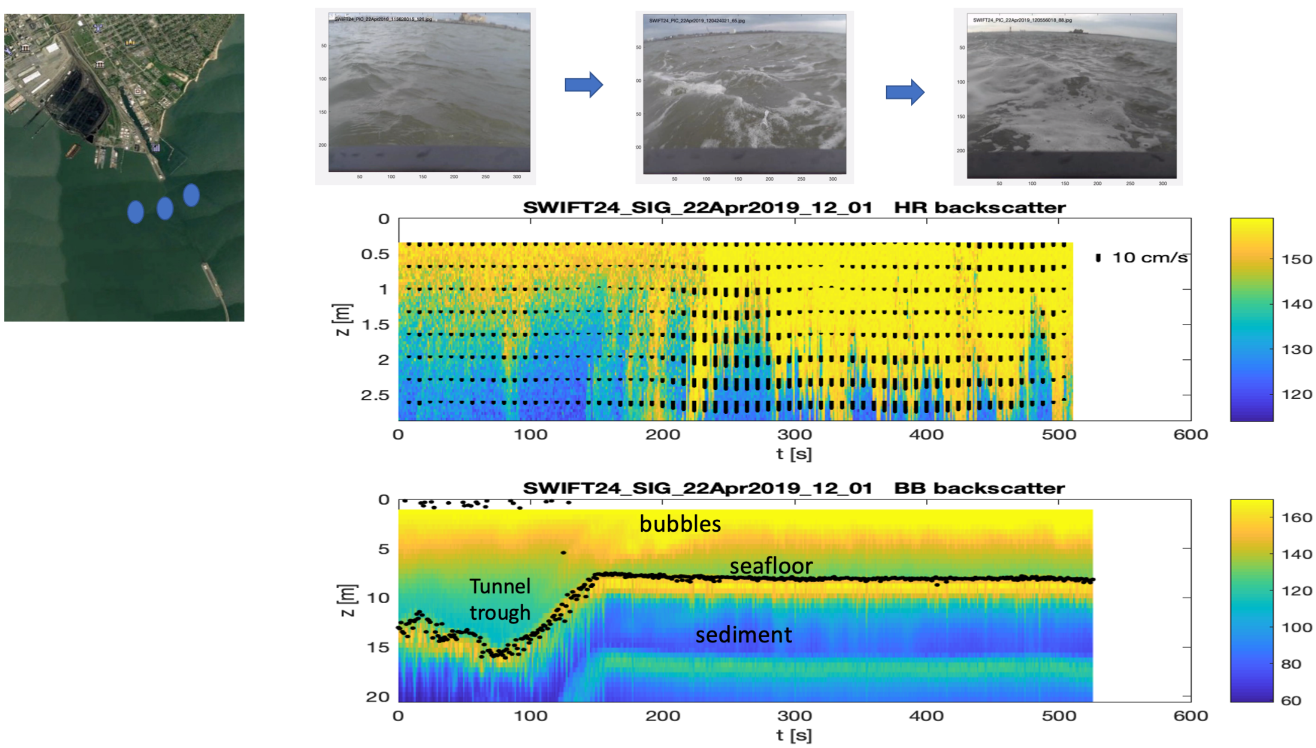

Figure 3: Example frontal sampling by a SWIFT at the James River tidal intrusion front. The three drift positions in the map (left) correspond to the three surface images (top). The acoustic backscatter profiles (lower panels) are 512 seconds of Nortek Signature1000 data (dB backscatter units) associated with the middle position, as the SWIFT becomes entrained in the front.

Mobile Bay (AL)

The Mobile Bay field campaign occurred in June 2021. Figure 4 shows a time series of the wind and wave conditions, and Figure 5 shows a map of SWIFT observations colored by salinity (overlaid on the bathymetry). The dredged channel has a strong control on the tidal currents observed.

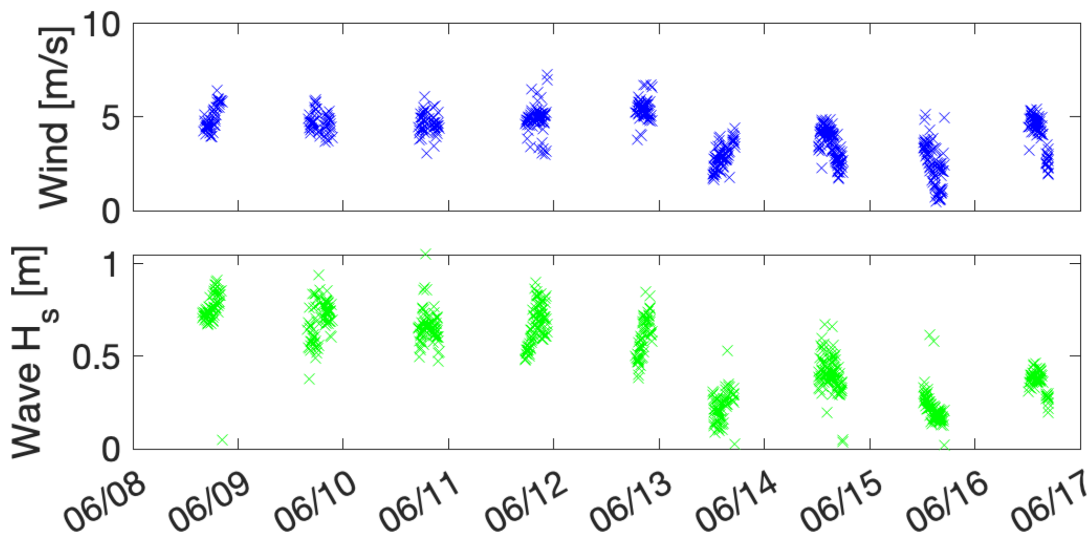

Figure 4: Timeseries of winds and waves measured by SWIFTs at Mobile Bay.

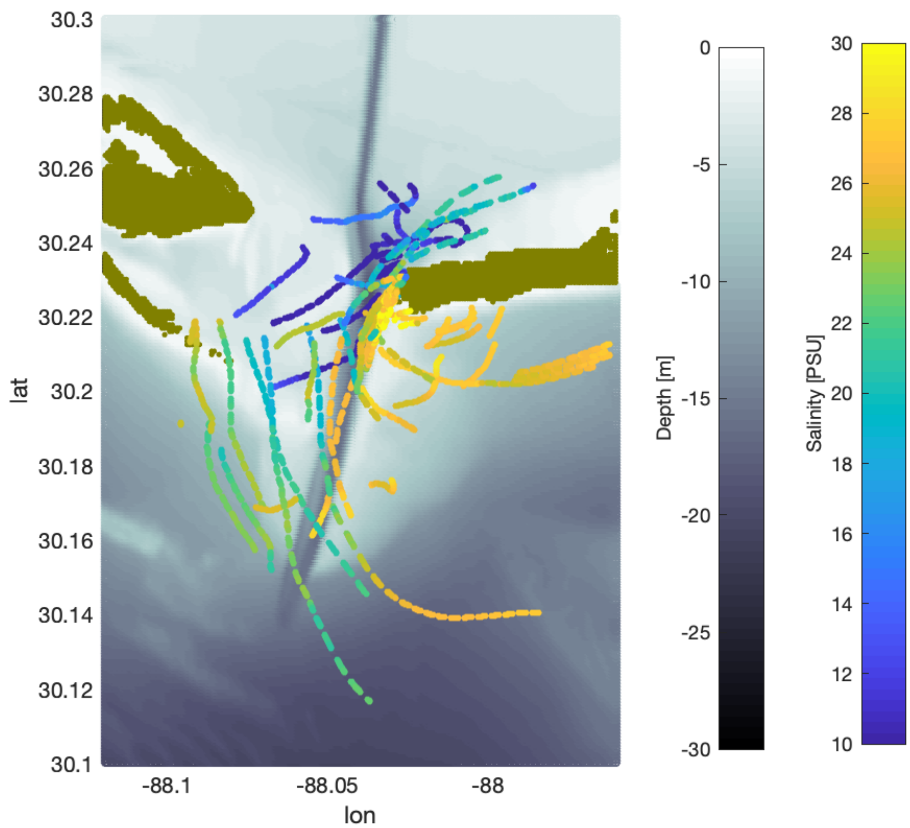

Figure 5: Map of SWIFT drifter measurements at Mobile Bay. Color scale is salinity. Grey scale is bathymetry.

The SWIFT measurements at Mobile Bay include both ebb fronts outside of the bay and tidal intrusion fronts at the mouth of the bay. The tidal circulations are strongly controled by the dredged channel, which contains much faster flows than the surrounding shoals. SWIFTs were able to sample throughout the domain, including the shallow shoals that retain fresh water (Figure 6). Acoustic observations at the fronts often showed multiple layers and fine scale stratification. Figure 7 has an example.

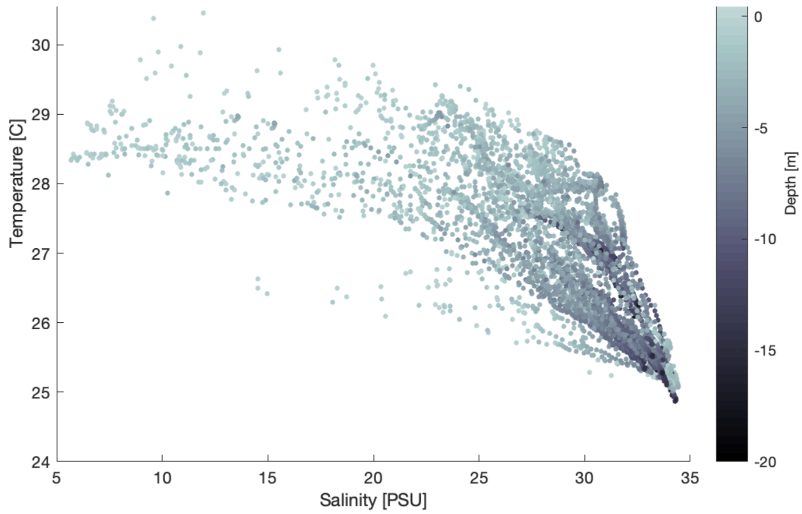

Figure 6: Temperature and salinity diagram from Mobile Bay, including casts on the shoals in 1-2 m.

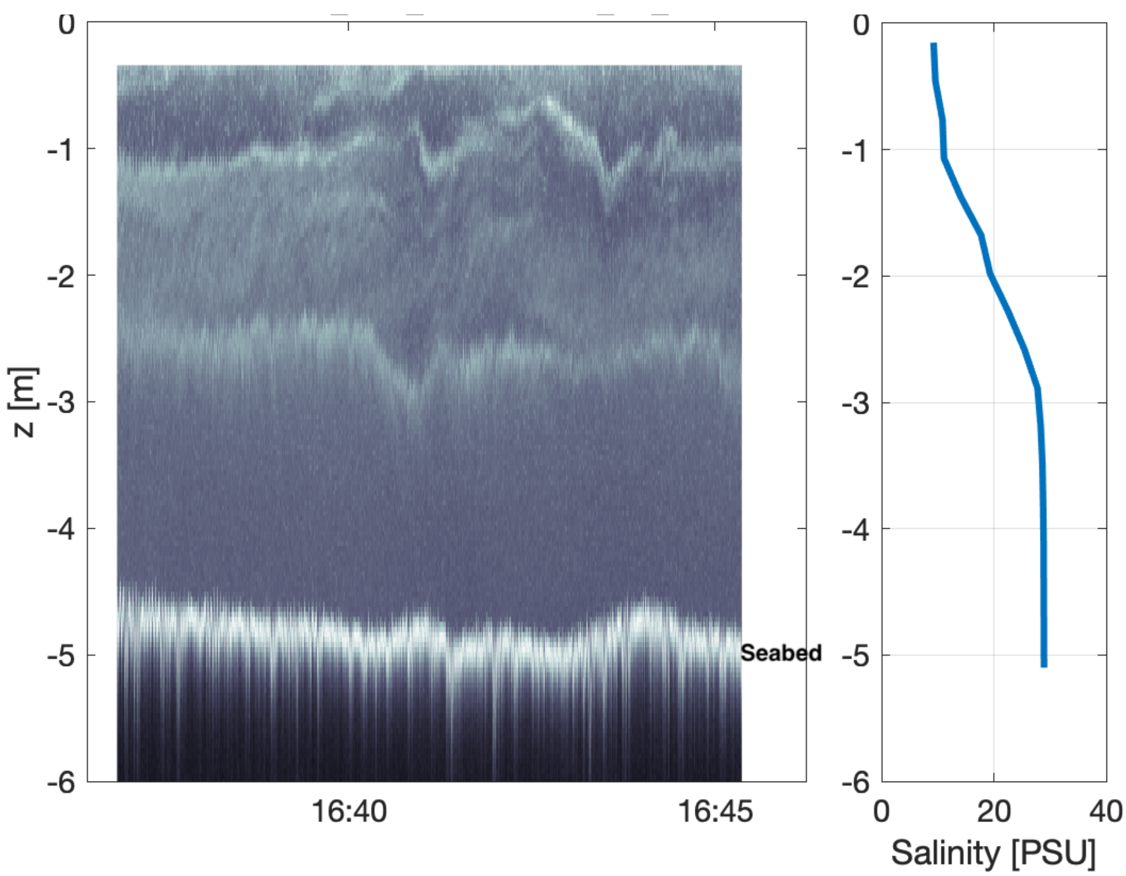

Figure 7: Example echogram from SWIFT showing fine-scale stratification that is obscured by the relatively coarse (0.1 m) resolution of a nearby CTD cast.

IMPACT/APPLICATIONS

These results are being applied to improve understanding and operational capabilities in tidal estuaries, where strong stratification and bathymetry cause large gradients that complicate inference from remote sensing and acoustic methods. These data also provide essential information for assimilation into models, and thereby add hydrodynamic constraints to bathymetry estimates.

PRODUCTS

Data products have been shared across USRS investigators via Google Drive. Data products are ready for permanent shared archive, pending issue of a DOI and curration by collaborators at the Woods Hole Oceanographic Instituion.

PUBLICATIONS

- Bassett et al, Acoustic backscattering at a tidal intrusion front, *Progress in Oceanography,* 2023. [in revision, refereed]
- Harrison, T.W., N. Clemett, B. Polagye, and J. Thomson, Experimental validation of float array tidal current measurements in Agate Pass, WA, *J. Atmos. Ocean. Technol.,* (2023). [published, refereed]
- Guimaraes et al, Relative current effect on short wave growth, *Ocean Dynamics* (2022). [published, refereed]
- Moulton, M., C. Chickadel, J. Thomson, Warm and cool nearshore plumes connecting the surf zone to the inner shelf, *Geophys. Res. Let.* (2021). [published, refereed]
- isher, A., J. Thomson, M. Schwendeman, Rapid deterministic wave prediction using a sparse array of buoys, *Ocean Engineering* (2021). [published, refereed]

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Ocean surface waves, estuaries, stratification, tidal fronts, wave breaking, bubbles, downwelling, surface drifters

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