Measurement of the Optical Properties of Severn River Surface Waters with an Autonomous Underwater Vehicle

Midshipman 1/C Daniel C. McDonald and Midshipman 1/C Jordan J. Neal, USN, Class of 2020

Advisor(s): Instructor Alexander R. Davies, Dr. Joseph P. Smith, Instructor Brianna Tracy

Abstract

The optical properties of surface waters in dynamic, shallow water estuarine systems exhibit a high degree of heterogeneity due to factors such as organic matter (OM) inputs from land, high rates of primary production, and (re-)suspended sediments. In this study, a Xylem YSI EcoMapper autonomous underwater vehicle (AUV) equipped with sensors to measure temperature, conductivity, fluorescent dissolved organic matter (fDOM), and Chlorophyll-a (Chl-a) fluorescence was used to quantify spatial variability in wintertime fDOM and Chl-a fluorescence along the entire axis of the Severn River, MD, a small sub-estuary of the Chesapeake Bay. Results suggest that variability in wintertime surface water fDOM and Chl-a fluorescence along the axis of the Severn River is related to interactions between material source functions and inputs (OM and nutrients), geomorphology and land-use, and the degree of surface water stratification vs. mixing. These results will inform follow-on studies to better understand factors that contribute to seasonal-to-annual variability in the optical properties of the entire water column of the Severn River and other shallow estuarine systems.

Study Area and Methods

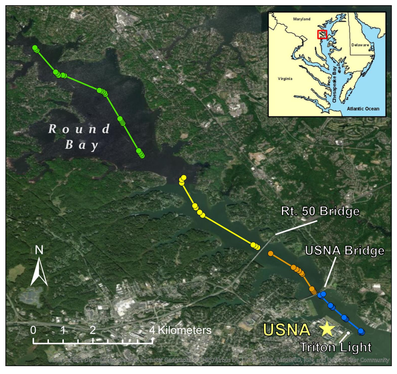


Figure 1. Map of the Severn River, MD near the U.S. Naval Academy (USNA) showing four Xylem YSI EcoMapper AUV missions: Leg 1: 28 FEB 2020 (blue); Leg 2: 26 FEB 2020 (orange); Leg 3: 25 FEB 2020 (yellow); Leg 4: 26 FEB 2020 (green). The AUV was deployed from a small boat to collect high-resolution data from the 1 m depth along mission legs. The AUV uses a Doppler Velocity Logger (DVL) and magnetic compass to navigate underwater and was programmed to surface every 500-1700 m along mission legs for a GPS fix and course correction to the planned mission track.

A Xylem YSI EcoMapper AUV with sensors for measuring temperature, conductivity, turbidity, Chl-a, and fDOM was programmed and deployed to perform four different mission legs to collect optical data from surface waters (1 m) along the axis of the Severn River (**Fig. 1**; **Fig. 2**). Turbidity measurements were calibrated using a YSI 12.7 NTU standard, Chl-a was calibrated using rhodamine dye, and fDOM was calibrated using a quinine sulfate solution. Chlorophyll-a fluorescence is reported as µg/L Chl-a and fDOM is reported in quinine sulfate units (QSU). All measured turbidity values were < 1 NTU and not reported. Data was down-sampled to 1 Hz resolution and averaged using a 3-second running mean (MATLAB) and plotted as a georeferenced contoured track on a satellite image of the Severn River using ESRI ArcGIS Pro. Water column profile data (temperature and conductivity) was collected concurrently along AUV mission tracks using a SonTek CastAway CTD (**Fig. 2**) and used to create contour plots of temperature and salinity.

Figure 2. Midshipman 1/C Dan McDonald, Midshipmen 1/C Jordan Neal, and Instructor of Practical Applications Alex Davies deploy the YSI Xylem EcoMapper AUV and perform SonTek CastAway CTD casts from a small boat in the Severn River.

Acknowledgements: *This work was made possible by a generous gift of funding from the Volgenau family. Special thanks to the crew at the USNA Cutter Shed for providing small boat support.*

References*: Casper et al., 2012, Applied Geography 32: 455-464.; Osburn et al., 2016, Front. Mar. Sci. 2:127.*

Results and Discussion

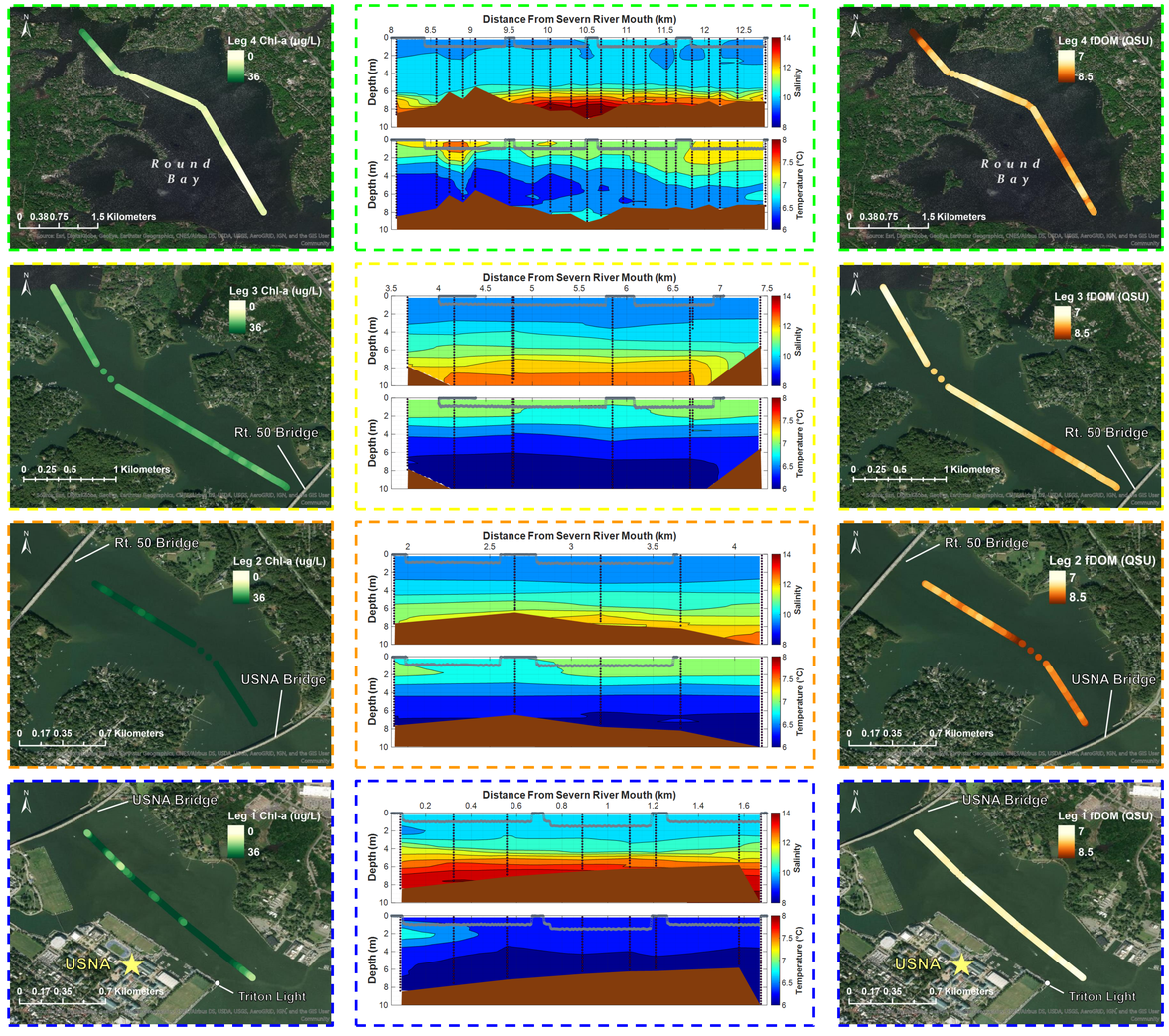


Figure 3. (left column) Contoured Chl-a concentrations along AUV each mission leg (µg/L); (right column) contoured fDOM fluorescence along each AUV mission leg (QSU), and; (middle column) cross-sectional contours of salinity and temperature along each AUV mission leg (shown as grey symbols) from CastAway CTD casts (black dashed line). Results are shown from top-to-bottom, referenced to **Figure 1**, for: Leg 4 (green); Leg 3 (yellow); Leg 2 (orange), and; Leg 1 (blue).

Figure 3 shows along-track contours of surface water Chl-a concentrations and fDOM fluorescence along each AUV mission leg along with a cross sectional contour of temperature and salinity. **Figure 4A-D** shows Chl-a concentrations and fDOM fluorescence along the entire axis of the Severn River. During mission runs, temperature and salinity at the 1 m depth was between 6-8 °C and 8-10 PSU, respectively. Measured Chl-a concentrations were highest (yet variable) along the Leg 1 and Leg 2 AUV tracks near the mouth of the Severn River with the highest values (> 40 µg/L) measured in Leg 2 between the USNA Bridge and Rt. 50 Bridge. Chlorophyll-a concentrations decreased landward up-estuary in Legs 3 and 4 past the Rt. 50 Bridge to values < 20 µg/L until increasing slightly at the northwest corner of Round Bay (**Fig. 3**; **Fig. 4A&B**). The reasons for the "patchiness" in the data and the overall trend are unclear but could be related to slightly fresher, more stratified water column in Round Bay as compared the mouth of the Severn and potential nutrient inputs from creeks along the axis of the Severn River (*Casper et al., 2012*). Measured fDOM fluorescence was low (7-8.5 QSU) but variable along the axis of the estuary but highest along the Leg 2 and Leg 4 AUV tracks. Peak fDOM fluorescence values (>8 QSU) were noted in the middle of Leg 2 and at the northwest corner of Round Bay. In general, fDOM fluorescence increased moving up-estuary landward from the more developed and urbanized mouth of the Severn River toward the less developed suburban and forested reaches of Round Bay (**Fig. 3**; **Fig. 4C&D**). Since fDOM is a proxy for DOM, this trend is consistent with a dominant terrigenous organic matter source for DOM (*Osburn et al., 2016*).

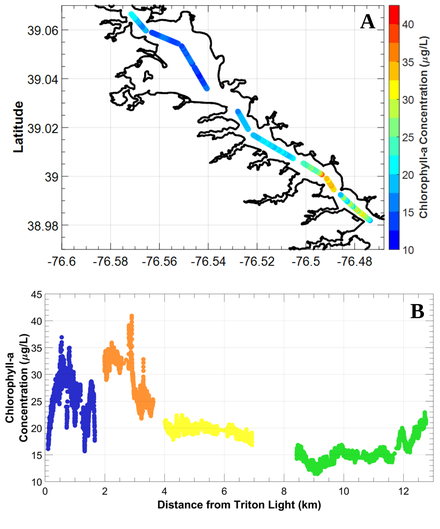
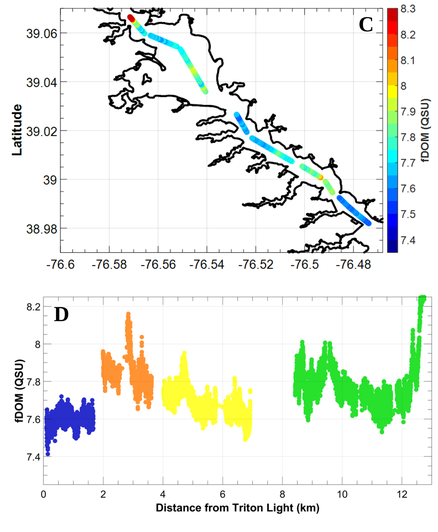


Figure 4. (**A**) Contoured Chl-a concentrations (µg/L) at 1 m depth along the axis of the Severn River; (**B**) Relative Chl-a concentrations (µg/L) at 1 m referenced by distance up-estuary from Triton Light (Leg 1; **Fig. 1**); (**C**) Contoured fDOM fluorescence (QSU) at 1 m depth along the axis of the Severn River, and; (**D**) Relative fDOM fluorescence (QSU) at 1 m referenced by distance up-estuary from Triton Light (Leg 1; **Fig. 1**).



Conclusions

- ***Results from this first ever AUV survey of the wintertime optical properties of surface waters along the entire axis the Severn River reveal low but variable fDOM and Chl-a fluorescence related to interactions between material source functions and inputs (OM and nutrients), geomorphology and land-use, and the degree of surface water stratification vs. mixing.***
- ***Follow-on surveys should be conducted to determine factors that control seasonal-to-annual variability in the optical properties (to include other parameters like turbidity) of the entire water column of the Severn River and other shallow estuarine systems to help the U.S. Navy and Marine Corps better understand these important, dynamic operational environments.***