Measuring Water-Quality of the Lower Severn River Using an Autonomous Surface Kayak

Midshipman 1/C Richmond Paschall, USN, Class of 2019

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Abstract

The U.S. Naval Academy Coastal Kayak autonomous surface vehicle (ASV) was modified and outfitted with specialized commercial off-the-shelf sensors and a custom-built radiometer sled and deployed on an autonomous survey mission to collect continuous *in situ* water quality data from the lower Severn River, MD on 08 November 2018. Results demonstrate the utility of using this versatile, rugged, and low-cost ASV platform for collecting high-resolution water quality data to identify and quantify scales of spatial heterogeneity in shallow, heterogeneous, coastal environments in order to inform future data collection efforts.

Study Area and Methods

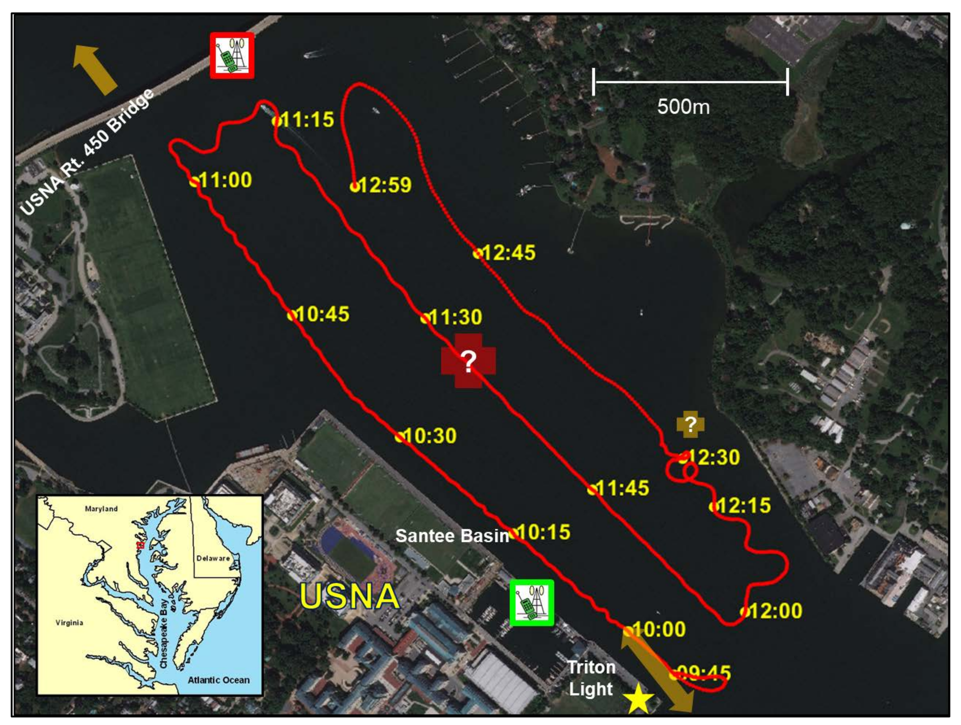

Figure 1. Map of survey area in the lower Severn River showing Coastal Kayak ASV mission track on 08 November 2018. Locations for U.S. Naval Academy (USNA) Severn River Watershed Observatory (SRWO) Node 1 and Node 3 (planned) are also shown along with areas for additional, targeted data collection (spatial and temporal) strategies suggested based on survey results.

The Severn River is a small brackish tributary of the Chesapeake Bay that drains a watershed area of ~ 210 km^2. The typical tidal range is ~ 0.3 m and salinity varies from about 3 – 15 (**Fig. 1**). The USNA Coastal Kayak ASV (*Ackleson et al., 2017*) was modified and outfitted with commercial off-the-shelf sensors and a custom-built radiometer sled (**Fig. 2**) and deployed on a 'ladder' survey mission (**Fig. 3 a & b**) to collect continuous, *in situ* surface water quality data from a roughly 1 km^2 area of the lower Severn River on 08 November 2018 (**Fig. 1**). ArduPilot open-source Mission Planner software (www.ardupilot.org/planner/) was used to plan the survey and the mission was run at the period around slack water. Weather conditions on 08 November 2018 were partly-cloudy, air temperature ~ 12.7 °C, and with winds from the north at 3.5 m/s. Surface water temperature was 14.4 +/- 0.2 °C and salinity was 4.7 +/- 0.1.

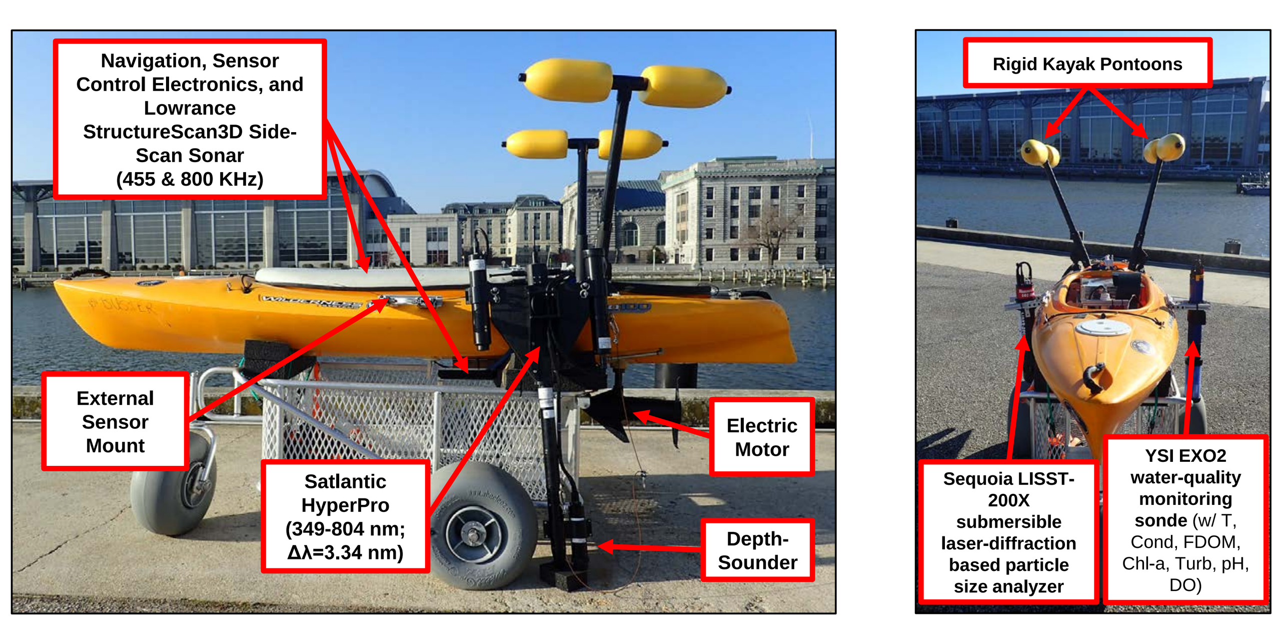

Figure 2. Profile and front views of the Coastal Kayak ASV detailing modifications to include: addition of 80/20 framing and rail mounting brackets to accommodate Sequoia LISST-200X submersible laser-diffraction particle size analyzer and a YSI EXO2 water quality monitoring sonde, tow points for a Satlantic HyperPro radiometer sled, and rigid pontoons for enhanced platform stability.

Figure 3. (**a**) The Coastal Kayak ASV underway in the lower Severn River on 08 November 2019 and (**b**) Midshipman 1/C Paschall observing a successful autonomous mission!

Results and Discussion

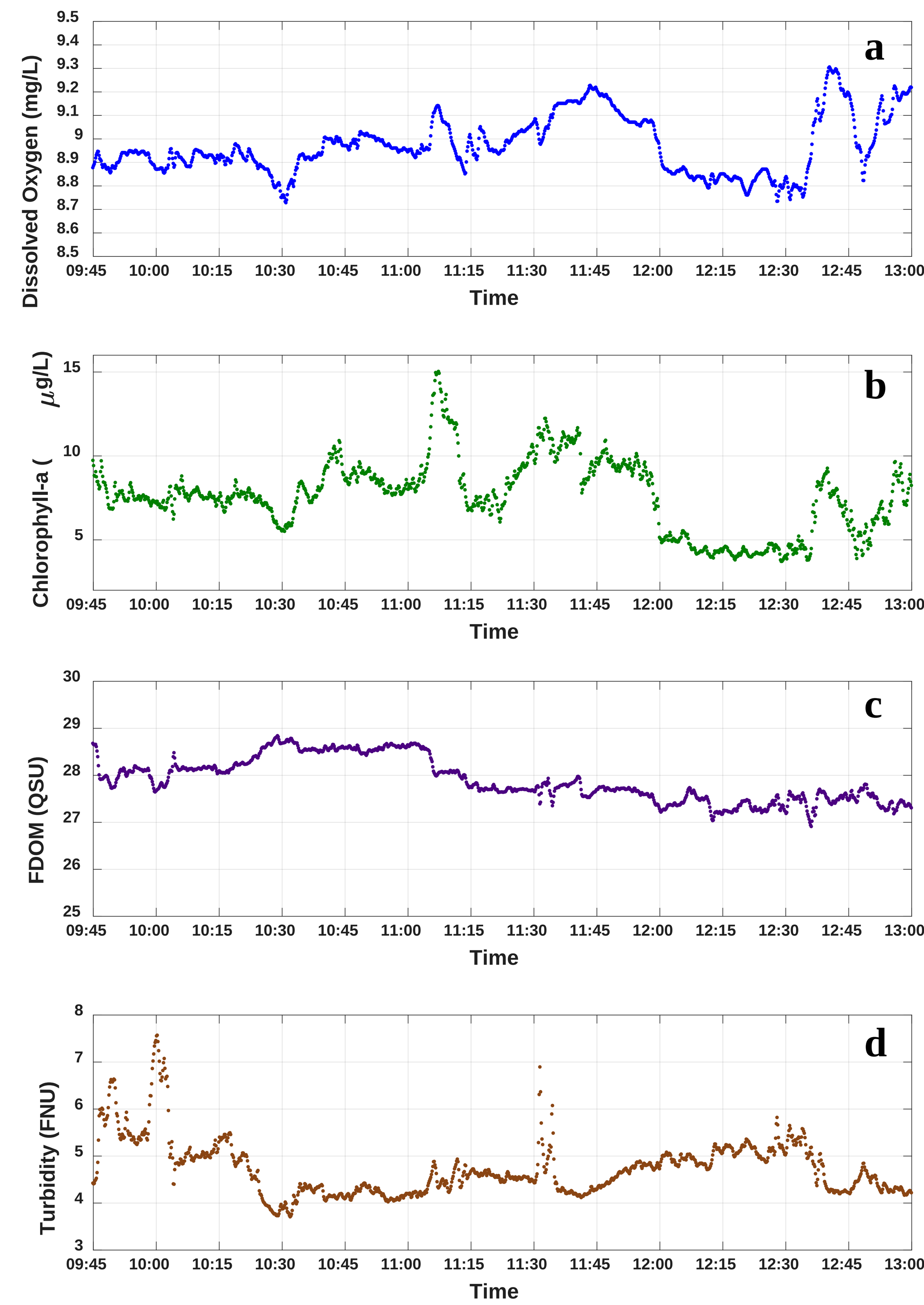

Figure 4. Surface water quality data collected from the lower Severn River on 08 November 2018 during the Coastal Kayak ASV survey mission included (**a**) Dissolved oxygen (DO) concentration (mg/L); (**b**) Chlorophyll-a (Chl-a) concentration (μg/L); (**c**) Fluorescent Dissolved Organic Matter (FDOM; QSU); (**d**) turbidity (FNU); (**e**) mean particle diameter (μm); and (**f**) particle concentration (ppm) plotted vs. time. Also shown (**g**) is the variable particle spectra expressed as size specific (1-500 μm) volume concentration. Dissolved oxygen, Chl-a, FDOM, and turbidity were measured using the YSI EXO2 water quality monitoring sonde and mean particle diameter, particle concentration, and particle size spectra were measured using the Sequoia LISST-200X submersible laser-diffraction particle size analyzer. All data was processed using a 20 sec. moving average. Data from the Satlantic HyperPro radiometer sled is not shown.

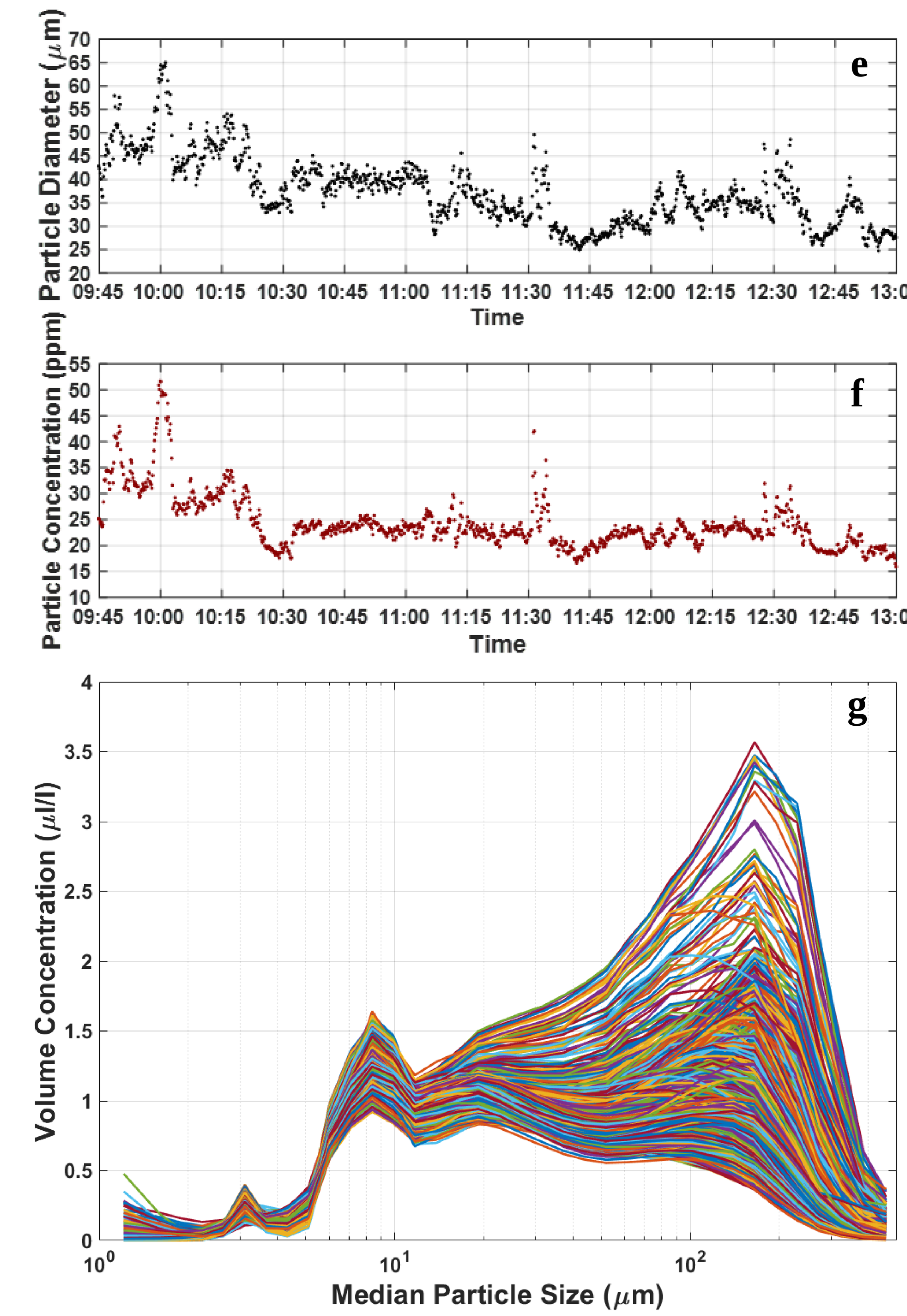

Figure 4 (**a-g**) shows surface water quality data collected during the Coastal Kayak ASV survey mission. There was some variability in DO concentrations coincident with noticeable Chl-a concentration differences, especially between 1100-1115, 1130-1200, and 1200-1230 along the mission track (**Fig. 4a & b**). There was very little difference in measured FDOM concentrations (**Fig. 4c**). Turbidity values showed some variability (**Fig. 4d**) coincident with notable peaks in mean particle diameter and concentration (**Fig. 4e & f**) at 1000 and 1130. The greatest particle size variability occurred at particle size between 8-10 μm and 100-200 μm (**Fig. 4g**).

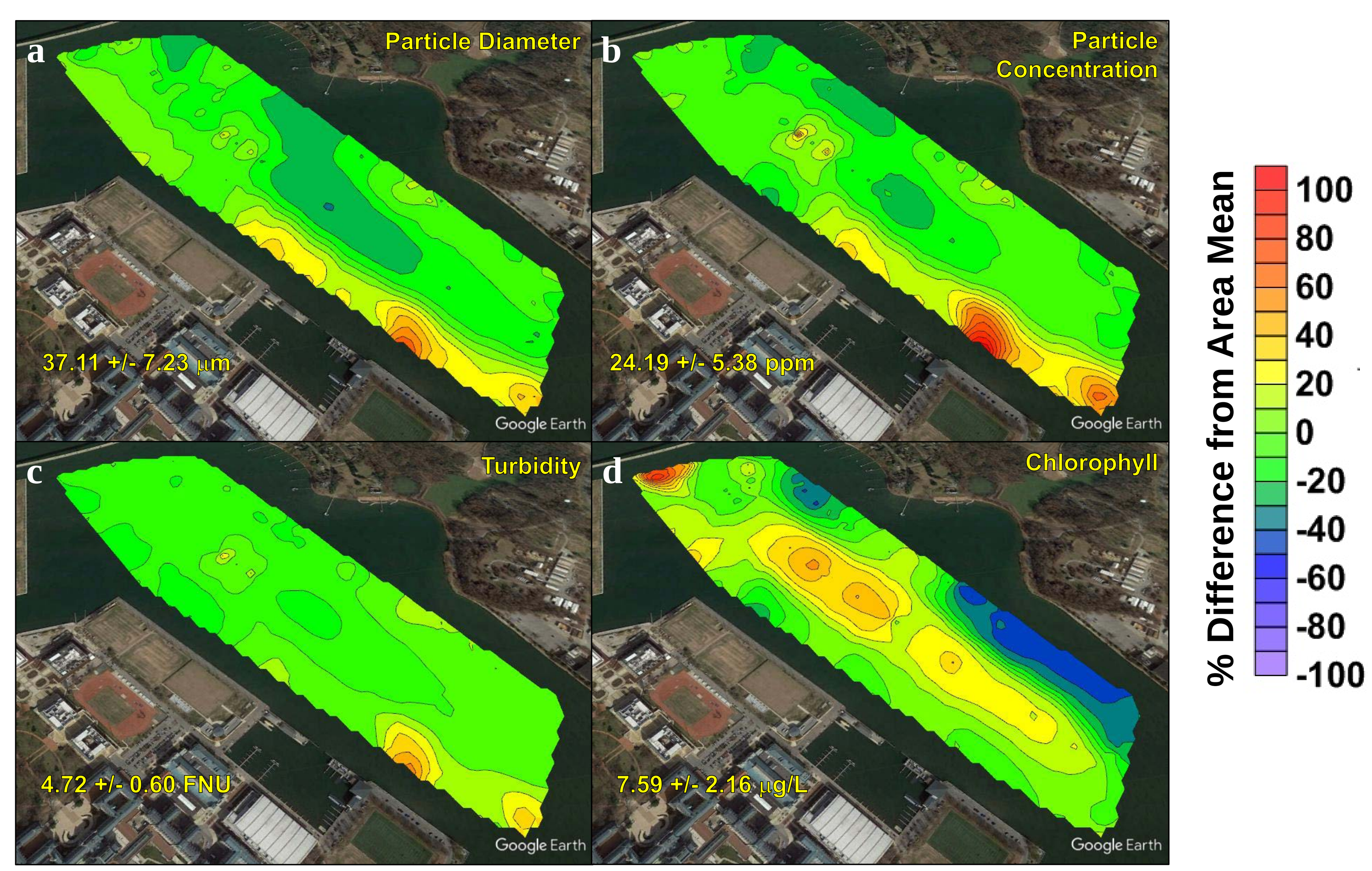

Figure 5. Contour plots of spatial variability in surface water quality parameters in the lower Severn River, November 8, 2018 showing: (**a**) Mean particle diameter (μm); (**b**) Particle concentration (ppm); (**c**) Turbidity (FNU) and (d) Chl-a concentrations (μg/l). Data is expressed as % difference from the area mean (shown in lower left corner of each sub-plot). Contour plots were made using Surfer v.11 using an inverse distance weighting interpolation.

Figure 5 shows contour plots of spatial variability in surface water quality parameters in the lower Severn River, November 8, 2018. There was little variation in measured DO and FDOM concentrations but significant spatial variability in mean particle size (**Fig. 5a**) and particle concentration (**Fig. 5b**). Likewise, turbidity (**Fig. 5c**) and Chl-a concentrations (**Fig. 5d**) exhibited significant spatial variability. Differences in turbidity, particle size, and particle concentration (near Santee Basin and Triton Light) are likely due to movement of particles and re-suspended sediments whereas differences in Chl-a concentrations (USNA Bridge, mid-channel, left (north) bank) were likely due to localized phytoplankton blooms. Based on these results, the planned location of SRWO Node 3 makes sense but additional data collection and monitoring strategies should be considered. Data collection needs to be in the area between Santee Basin and Triton Light, as well as in the mid-channel and left (north) bank of the lower Severn River (**Fig. 1**) in order to account for and capture heterogeneity in water quality.

Conclusions

- ***The USNA Coastal Kayak ASV was successfully used measure surface water quality and to identify and quantify scales of spatial heterogeneity in water quality data in the lower Severn River (~ 1 km^2)***
- ***Results suggest a need for additional, targeted data collection and monitoring strategies (spatial and temporal?) in order to account for/capture heterogeneity in water quality in the lower Severn River***

ASVs like the USNA Coastal Kayak will play a key role in the 'Next Wave' in water quality monitoring in coastal systems like the lower Severn River

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