Scale Matters: The Need for a Customizable Autonomous Platform for Estuarine Research

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Abstract:

Estuaries are dynamic regions where salt and freshwater mix. Physical, chemical, and biological processes interact in a non-linear fashion on tidal to inter-annual scales resulting in a high degree of spatial and temporal heterogeneity. Due to their proximity to land estuaries are subject to anthropogenic forcing such as land-use change, pollution, and eutrophication. The Chesapeake Bay is a large, ecologically-complex, and dynamic estuarine system that has been and continues to be subject to eutrophication. Within the Bay system there are a plethora of tributaries and creeks where heterogeneity is even more pronounced. Detailed characterization of processes in these systems over significant spatial and temporal scales using discrete or *in situ* sampling is extremely difficult, limited in scope and scale, cost prohibitive, and impractical. In this study, data on water column parameters was collected from the Severn River, a small tributary of Chesapeake Bay, on different scales. Results show that low resolution data fails to adequately capture the spatial heterogeneity in this small tributary system. There is a need to design affordable, multi-use autonomous research platforms that are scalable, tailorable, and customizable for use in estuarine systems, specifically in sub-estuaries of the Bay like the Severn River. Data collection and research in these areas could be improved by the development of autonomous research platforms like the Coastal Kayak proposed in this work.

Study Area and Methods:

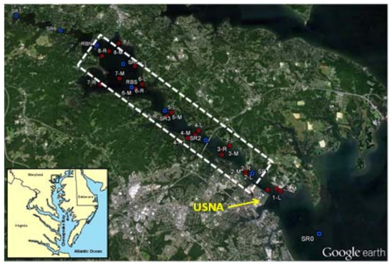
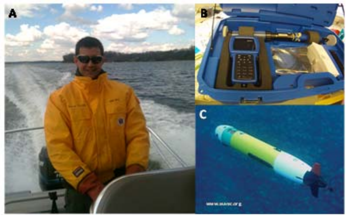


Figure 1. Severn River study area. Red points indicate sites for 26 MAR 2013 sampling event. Blue squares indicate 15 JUN 2011 sampling sites from Severn River Keeper long-term monitoring plan. Dashed white bounding-box indicates REMUS-100 AUV coverage area for 15 JUN 2011 deployment.

Figure 1 shows Severn River study area. Dissolved oxygen (DO) profiles were collected (**Fig. 2A**) at 8 transects, 3 sites (Right, Middle, Left) along the main channel using a YSI EXO-1 (**Fig. 2B**). Each transect was spaced ~1.5 km apart to enable high resolution sampling of the water column. On 15 JUN 2011 a REMUS-100 Autonomous Underwater Vehicle (AUV) (**Fig. 2C**) equipped with a DO Sensor was deployed in the same area. Water column DO profiles were also collected on 15 JUN 2011 by the Severn River Keeper as part of a long-term monitoring plan.

Figure 2. (**A**) MIDN 1/C Scott Stamer conducting research aboard small watercraft with a (**B**) YSI EXO-1 multi-parameter water quality sonde. (**C**) Picture of REMUS-100 AuV similar to vehicle used on 15 June 2011.



Results:

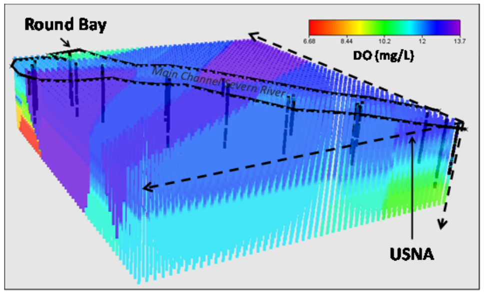


Figure 3. 3-D gridded contour of measured dissolved oxygen (DO) profiles from data collected on 26 MAR 2013 in Severn River from all transects and sites. The 3-D plot was created using Voxler 3.0 and Surfer 11.0 using inverse distance squared interpolation scheme. Areas in blue indicate higher DO concentrations and red indicates lower concentrations. The black satellite outline shows the rough geometry of the shoreline around the main channel. Arrows indicate the approximate location of USNA and Round Bay.

Figure 3 shows a 3-D gridded contour plot of DO profiles based on all data collected during the 26 MAR 2013 sampling event. The measured DO concentrations were generally high because it was the end of winter and the beginning of spring but it still can be clearly seen in the detail that DO is at noticeably lower concentrations in North Round Bay, primarily near the bottom. It is important to note inverse distance squared interpolation method used in creating the plot. The inverse distance gridding method operates on the principle of interpolation, where each input point has an influential effect on neighboring points. The relative location and number of data points has a direct influence on how detailed the gridding scheme will appear.

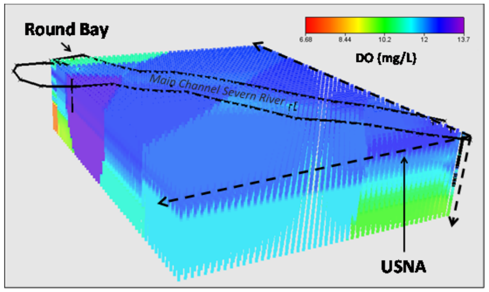


Figure 4. 3-D gridded contour of measured dissolved oxygen (DO) profiles from data collected on 26 MAR 2013 in Severn River from every other transect and all sites.

Figure 4 shows the same plot of DO profiles from 26 MAR 2013 omitting data from transects 2,4,6, and 8. Detail is lost as compared to the full-resolution case (**Fig. 3**), especially in areas such as North Round Bay. **Figure 4** fails to capture the full extent of low DO. This is a major concern because of the creek-tributary-main stem estuary interfaces possessing the most physical complexity. This is a graphic depiction of how scale matters; important information is lost when less data is acquired or represented.

Discussion:

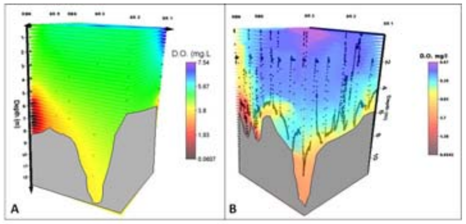


Figure 5. (**A**) 3-D gridded contours of measured dissolved oxygen (DO) profiles in Severn River for 15 JUN 2011 from data collected at long-term monitoring stations used by the Severn River Keeper (Dr. Pierre Henkart, used with permission). (**B**) High-resolution 3-D gridded contours of measured dissolved oxygen (DO) profiles in Severn River for 15 JUN 2011 from data collected by a REMUS-100 AUV deployed from a small boat by Dr. Andrew Muller and CDR J. P. Smith (USNA Oceanography) and CAPT Jack Nicholson (USNA Systems Engineering).

Figure 5A shows a 3-D gridded contour plot of DO profiles from Severn River Keeper data collected 15 JUN 2011. A high-resolution, 3-D gridded contour plot of DO data collected using a REMUS-100 AUV on the same day reveals a higher degree of spatial heterogeneity (**Fig. 5B**). It is clear that high-resolution data is necessary to understand the complexity of dynamic tributaries like the Severn River that are subject to summertime hypoxia/anoxia. The REMUS-100 AUV is expensive and difficult to deploy in a these types of shallow environments. This research proposes an affordable, multi-use autonomous research platform called the Coastal Kayak (**Fig. 6**) that can be used in estuarine systems, specifically in sub-estuaries of the Bay like the Severn River.

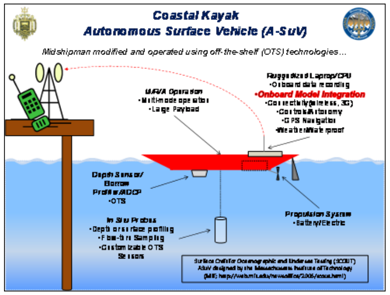


Figure 6. Conceptual diagram of Coastal Kayak Autonomous Surface Vehicle (ASuV).

Conclusions:

- ***Low resolution data fails to adequately capture spatial heterogeneity in small tributary systems like the Severn River.***
- ***There is a need to design affordable, multi-use autonomous research platforms for use in dynamic estuarine systems.***
- ***Data collection and research in estuaries will be improved by the development of autonomous platforms like the Coastal Kayak.***

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