Event Response Using Observatory-Based Autonomous Underwater Vehicles

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1. Introduction

Autonomous Underwater Vehicles (AUVs) operated from a subsea observatory can provide crucial capabilities for capturing the dynamics of events, such as the large plumes that accompany tectonic or volcanic events. An AUV docked to an observatory node could be recharged and while docked would have continuous communication with researchers ashore. Such a vehicle could reach an event long before we could mount a response with a ship and perhaps quicker than could an AUV launched from an aircraft. In addition to being close to an event, an AUV docked at a node could be ready to run at a moment's notice, requiring only information relevant to the event to be downloaded.

Autonomous Underwater Vehicles (AUVs) can be built in a variety of shapes and sizes, which translate into a wide range of capabilities in terms of speed, range, maneuverability, and payload. Likewise, we have a variety of choices for the design of docking stations, navigational infrastructure, and communications capability. This presentation will use an event response example to motivate a discussion of how observatory system architecture, AUV performance characteristics, and sensing capabilities will effect our ability to achieve scientific goals during an event response. Specifically, we will examine the following AUV attributes:

- range
- speed
- maneuverability
- payload capability
- battery characteristics

At a system level, we will examine the following:

- navigation infrastructure
- docking station capabilities
- number of vehicles per node
- number of docking stations per node

As an example response, we will consider the mapping of a new hydrothermal plume created by a tectonic or volcanic event. The goal of the event response will be to localize the plume, determine its size, shape, heat flux, and composition, and to observe the evolution of the plume over time. Such a vehicle would likely be equipped with a standard suite of oceanographic measurements (conductivity, temperature, optical backscatter, vertical velocity) as well as other in-situ chemical measurements that are just now emerging.

A typical event response might proceed in several steps. First, we must identify the event. An observatory equipped with a network of seismometers and hydrophones should be able to detect and localize events. One or more AUVs from the nearest node would be dispatched to localize the event, as would AUVs from other nearby nodes. The AUVs from more distant modes might be required to stop at nodes along the way to recharge batteries. As AUVs arrive at the event, they should conduct a survey in a coordinated fashion to maximize spatial and temporal coverage. As AUVs run short of battery power, they would return to the nearest node for recharge and to offload data, then return to gather more data.

2. Vehicle Characteristics

The size of an AUV critically defines many of its characteristics. If a vehicle's performance approaches attainable limits, larger vehicles have longer range and can attain higher speeds. As vehicles get larger, they also become more expensive and less maneuverable. In this section, we will attempt to establish a framework for discussing how the design of the AUV will affect our ability to respond to events.

To motivate the discussion, we will consider a family of AUVs based on MIT's Odyssey IIb vehicle (Bellingham 1995). By gathering a number of experimental data points, we can project the performance of an Odyssey-like vehicle if careful attention was paid to hydrodynamics, propulsion, and power management. From that vehicle, using straightforward scaling relationships, we can project the performance of larger and smaller vehicles. The complete range versus speed curve for a family of such vehicles is shown in figure 1. By considering these relations along with cost estimates, we can determine whether we should employ fewer, more capable vehicles or a larger number of smaller, cheaper vehicles, or perhaps a combination.

3. Node Capabilities

The characteristics of the nodes will strongly effect our abilities to respond to an event. For example, the rate of battery recharge may limit the speed at which a vehicle could return to a node for recharge, then return to continue surveying. The number of vehicles that could recharge at any time might limit our ability to mobilize vehicles from other nodes.

4. Navigation and Communications Infrastructure

While some observatory nodes will be located near potential sites of important events, inevitably we will want to send vehicles to events substantial distances from the nodes. We must consider enhancing our current acoustic navigation capabilities to enable vehicles to determine their positions over ranges of many tens of kilometers. Additionally, our positioning solutions must accommodate multiple vehicles. Reliable, two-way acoustic communication will also play a key role enabling multiple vehicles to survey in a coordinated manner, as well as providing near-realtime feedback to researchers ashore.

5. Locating and Surveying Hydrothermal Plumes with an AUV

Recently, we have gained considerable experience surveying hydrothermal plumes with our ABE AUV (Yoerger 2000), shown in figure 2. These results can guide our planning for an event response mission. In a recent cruise to the Main Endeavour Field (MEF) on the Juan de Fuca Ridge (Stahr, 2000), ABE performed autonomous plume survey covering 226km in 114 hours over 10 dives as part of the FLOWMOW effort. In addition to yielding estimates of the total heat flux from the MEF, we learned valuable lessons concerning how to detect and localize plumes. While flying at a carefully chosen height above the seafloor, ABE could detect and quantify plumes from a variety of sensors (temperature, conductivity, redox potential), perhaps the clearest signal came from vertical velocity. We estimated the vertical velocity both from an on-board acoustic current meter as well as from the vehicle dynamic response with comparable results. Figure 3 summarizes some typical data, showing changes in temperature, salinity, and vertical velocities while ABE passed through the MEF plumes at a height of 75 meters off the seafloor.

6. Conclusion

While observatory-based AUVs can certainly play a strong role in responding to events, we need to carefully consider how the specific design choices will either enable or constrain the scientific survey results. Vehicle range/speed tradeoffs, node capabilities for vehicle recharge, and navigational and communications infrastructure will strongly effect our capabilities. We need continued dialog between AUV designers, observatory designers, and scientists interested in event response to make the best choices.

References

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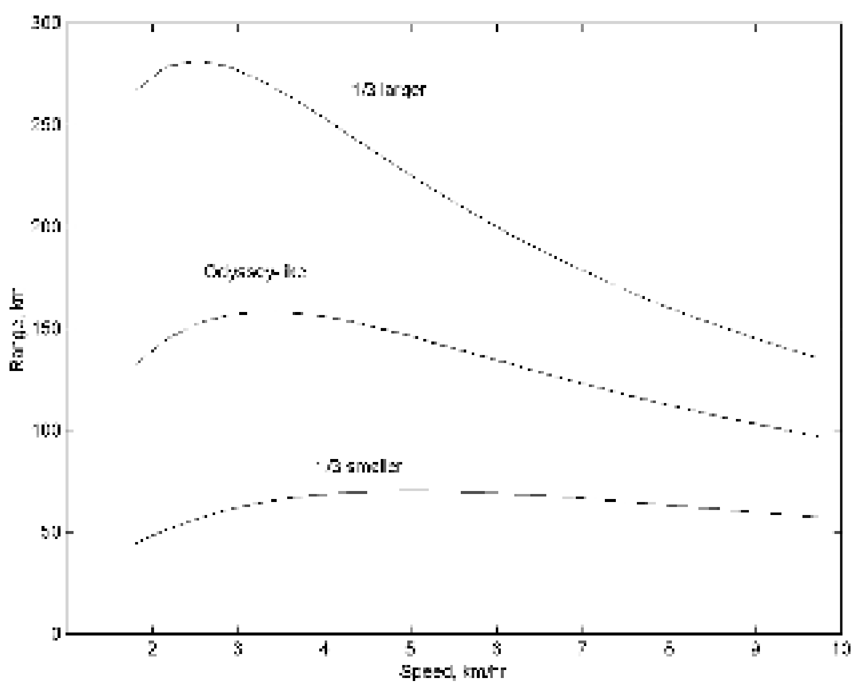

Figure 1. This plot summarizes the range-speed tradeoff for an AUV based on the OdysseyIIB design, and a larger and smaller variant. Larger vehicles can go faster and farther, and if the power consumption of the non-propulsion elements remains small, they will also benefit from transitting at a lower speed.

Figure 2. In the FLOWMOW project, we used the autonomous vehicle ABE to survey the hydrothermal plumes of the Main Endeavour Field on the Juan de Fuca Ridge. We can use data from this effort to consider how an AUV might detect and map plumes associated with a volcanic or tectonic event.

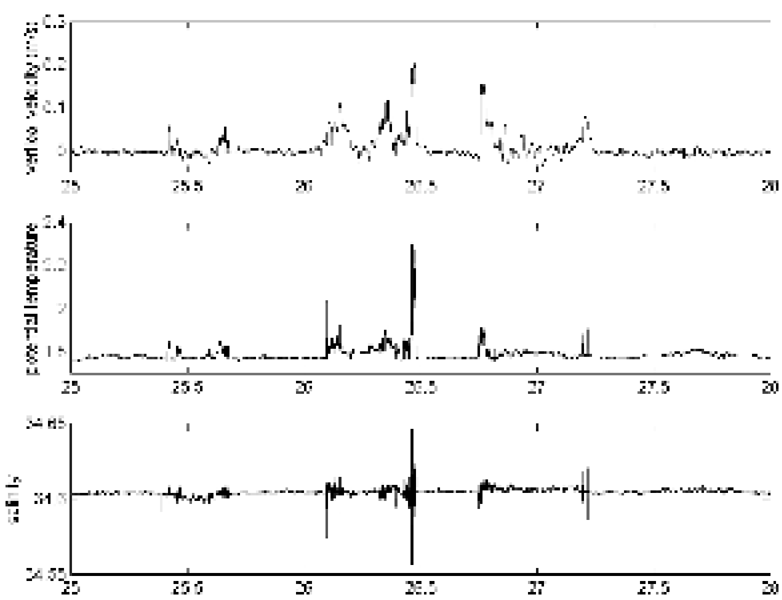

Figure 3. These plots show vertical velocity, temperature, and salinity measured by ABE as it passed through the MEF plumes over 3 hours. While the plumes show up clearly in all sensors, vertical velocity may be the most sensitive measure of plume activity.