Optical Swath Detection for Deep Ocean Science: A Laser Swath Mapping System to Locate Hydrothermal Plumes Using AUVs

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In the past decade, free-swimming autonomous underwater vehicles (AUVs) have been making the transition from research and development projects to reliable operational assets that support a wide range of interdisciplinary science. The scientific products generated by AUVs were once limited by technical challenges associated with basic operational considerations (e.g., vehicle navigation, battery duration, etc.), but now AUVs have matured to a point where major limitations are primarily those associated with the sophistication and utility of the onboard sensors.

Still, significant advances have been made in the adaptation and miniaturization of widely used oceanographic sensors for AUV platforms. Most operational AUVs now carry low-power versions of fundamental instruments such as conductivity/ temperature/ depth (CTD) sensors, bathymetric sonars, current meters, magnetometers, etc.

Importantly, AUVs have influenced a paradigm shift in the approach to certain types of marine science. AUVs allow for high spatial resolution surveys that were not previously feasible with towed instruments, particularly in the deep ocean, where the dynamics of passively towing instrumentation behind several kilometers of cable precludes any sort of precise sensor positioning.

The search for hydrothermal plumes at deep-sea vent fields is one type of survey mission presently undergoing a revolution as a result of the new capabilities offered by AUVs. These vehicles' successes have been demonstrated repeatedly over the past few years by WHOI's Autonomous Benthic Explorer (ABE) (Figure 1) in surveys of the Mid-Atlantic Ridge, East Pacific Rise, Juan de Fuca Ridge and the SW Pacific Lau Basin.

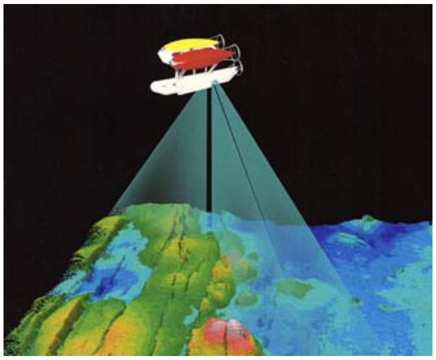

Figure 1. Graphic illustration of AUV ABE conducting an ocean-bottom survey.

Hydrothermal plume detection by optical backscatter (OBS) is a highly effective component of a suite of plume detection techniques currently used on AUV platforms. Hydrothermal fluids are rich in particulates, which are readily detected by OBS sensors that measure the optical clarity, or "cloudiness" of a volume of water right next to the vehicle. The restricted range of the OBS sensor requires that the vehicle swim directly through a plume to detect it – a major shortcoming in the open ocean.

With funding from DOEI, we have designed and completed preliminarily testing of a new OBS instrument capable of detecting a plume several tens of meters to either side of the vehicle, effectively allowing the vehicle to "see" a plume in the distance. The design uses a green laser to illuminate a beam of water projecting to each side of the vehicle. An optical detector system at the aft end of the vehicle measures the intensity of scattered light along the beams.

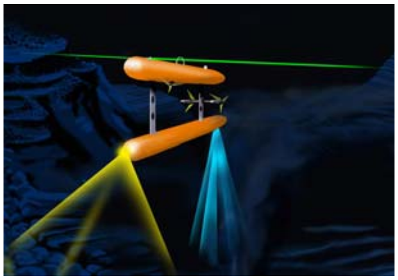

Figure 2. AUV Puma (in development for exploration under arctic ice) shown with the green swath laser on top.

While this technology will prove universally useful to hydrothermal vent research, it is essential for plume mapping in challenging environments, such as under Arctic ice, where using an AUV is the only feasible survey method. Most importantly, it will allow systematic, robust searches for plume stems from an AUV platform. This stand-alone AUV capability will be essential to the success of a NASA-funded Arctic initiative that involves several researchers at WHOI (Sohn, Bradley, Singh, Yoerger, Shank, Humphris) in cooperation with the University of Maryland (Figure 2).

In the summer of 2003, Johanna Mathieu, a WHOI summer student fellow, conducted a preliminary investigation into the properties of an eye-safe green laser in ocean water. Encouraged by her findings, a further study into the quality of optical backscatter in vent plumes was conducted in November 2004 at the Trans-Atlantic Geotraverse (TAG) hydrothermal mound using the remotely operated vehicle (ROV) *Jason II* (Figure 3).

A third phase of the project will involve designing a photodetector based upon data gathered from the TAG voyage, and utilizing the laser/detector system to survey for plumes at various vent fields in 2006-2008. We recently submitted a proposal to the National Science Foundation to build a field-ready version of our laser /detector system.

The laser swath detector will greatly facilitate AUV-based Arctic vent field research and will significantly impact the efficiency with which an AUV can discover and map hydrothermal vents in the deep ocean.

Additionally, this technology will feed directly into an adaptive vent field search algorithm under development by Mike Jakuba, an MIT/WHOI Joint-Program student advised by Dana Yoerger, who successfully developed and tested his software during surveys of the South Pacific Lau Basin in 2004.

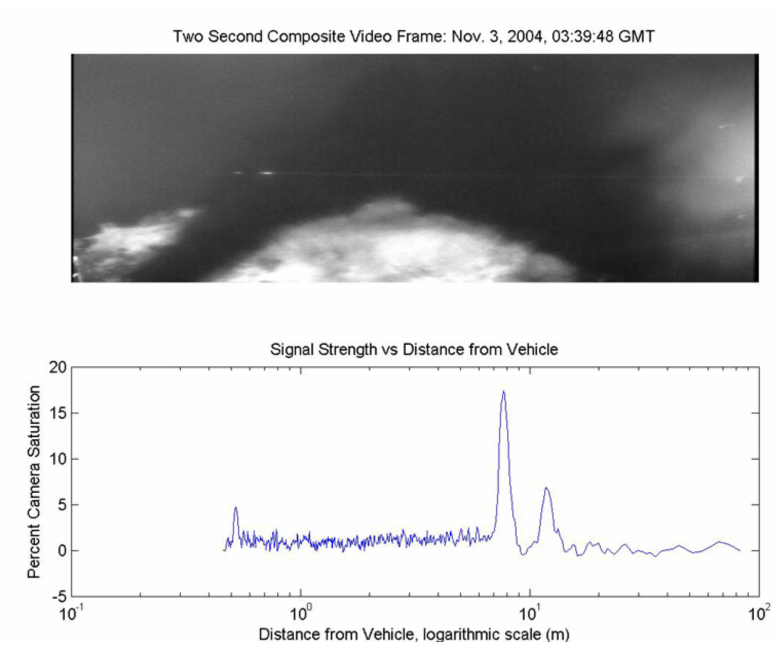

Figure 3: Laser detector data for a near-field hydrothermal plume as imaged by the prototype laser/camera system installed on *Jason II*. The target is approximately 50 meters range, and the black plume is clearly visible in the composite video frame (left). The maximum range of such a sensor is limited by the clarity of the water, the light power available, and the detector's sensitivity.

The graph shows the plume as a spike, indicating a density of dissolved particles in the water. Hydrothermal vent plumes are rich in chemicals, minerals, and bacteria released from the depths of the seafloor. Their presence generally indicates recent volcanic activity.