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Detection of Diffuse Sea Floor Venting Using Structured Light Imaging

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Detection of diffuse sea floor venting using structured light imaging

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Structured Light Overview

Identifying and localizing active diffuse low temperature sea floor venting at hydrothermal sites is difficult and inefficient. Typically, such sites are identified by a temperature induced optical shimmering visible during direct visual inspections by a remotely operated vehicle (ROV) working within meters of the sea floor. Such an approach prevents efficient surveys over broad areas and complicates establishing spatial relations between areas of float activity.

Our recent work with a structured light laser system indicates that venting can be detected in survey images in an automated and systematic fashion. During the summers of 2010 and 2011 the E/V Nautilus and ROV Hercules surveyed several active vent sites which provide examples of vent detection.

Fig. 1 Active vent with optical shimmering (center).

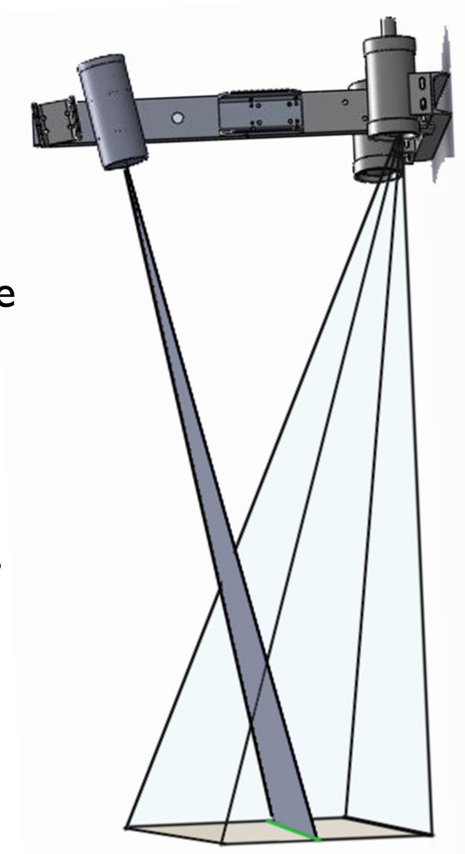

Fig. 2 Structured light sensor. The laser sheet is imaged on the seafloor

A structured light laser system, consists of a camera and verged sheet laser projected at the sea floor with a known relative geometry. Images of the line can be collected at altitudes between 2 and 5 meters with a high frame rate, greater than 10Hz. The position of the laser line in images can be extracted with standard computer vision techniques and is typically used to to determine the 3D height of the bottom along the laser line. A bathymetric survey map can then be created from the individual profiles extracted in a batch process.

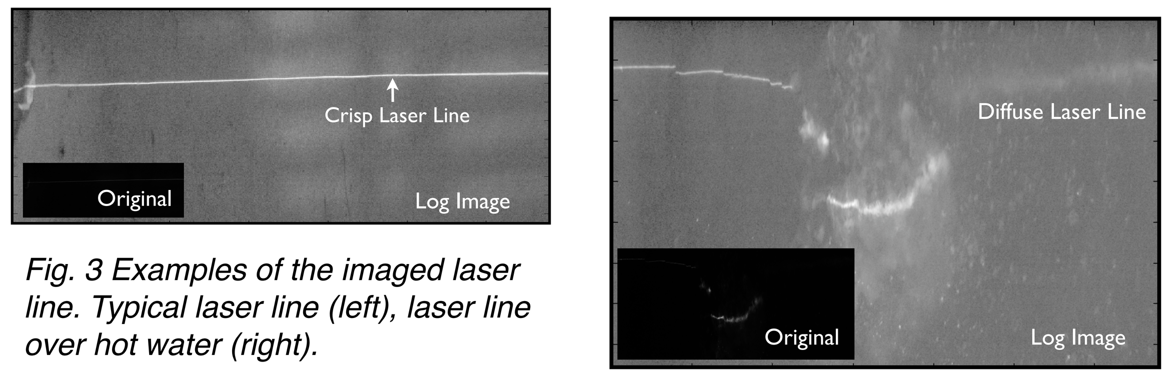

Fig. 3 Examples of the imaged laser line. Typical laser line (left), laser line over hot water (right).

In the presence of sea floor venting, temperature anomalies refract the laser sheet, causing the laser line to appear blurred instead of crisp and clear within the image. By identifying and quantifying this blurring it is possible to identify areas of venting. Our current method uses weighted moments of the laser intensity relative to the peak amplitude detected in each image column. Larger moment values correspond to a spreading of the laser line indicative of heat related refraction.

Vent Detection Algorithm

Determine point of maximum laser intensity (*v*) for each column in the image matrix, shown in red

↓

Compute the second moment about *v*. (Window shown in yellow)

↓

Plot a survey map with each laser line color coded representing the second moment.

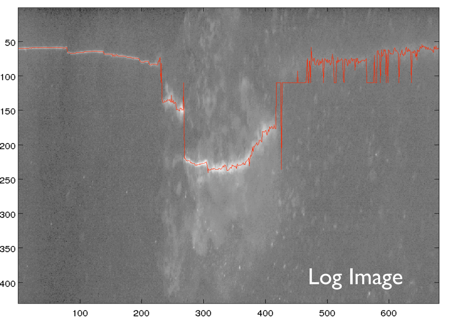

Fig. 4a The point of maximum intensity for each column in the image is shown in red.

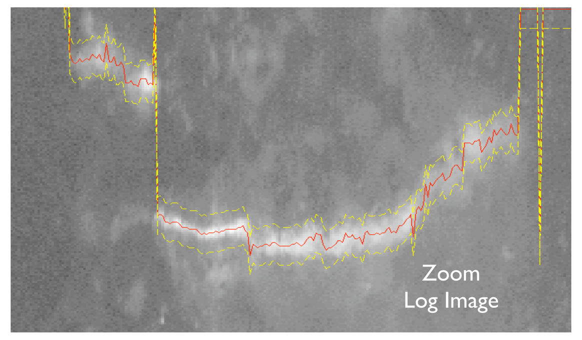

Fig. 4b The intensity values within a 15 pixel window (yellow) about the maximum are used to compute the second moment.

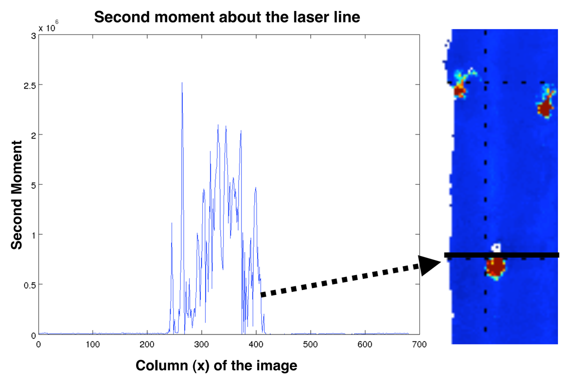

Fig. 4c The second moment values plotted for the image (left) and the corresponding laser line, color coded by the magnitude of the second moment, this image corresponds to detection of an active vent.

Kolumbo Vent Field, 2010

During the 2010 E/V Nautilus expedition active vents were surveyed within the the Kolumbo crater, located about 7km from the coast of Santorini, Greece. At a depth of 500 meters there are numerous chimney vents with temperatures up to 220°C surrounded by larger areas of lower temperature diffuse venting (30°-60°C). The background water temperature in the crater is 16°C. A laser survey was completed over large sections of the vent field, which created dramatic diffraction (Fig 3b). Bathymetry and the second moment of the laser line were then computed and plotted for comparison.

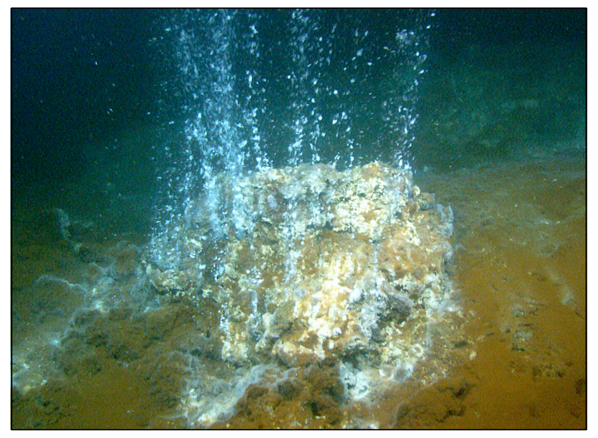

Fig. 5 Active vent within the Kolumbo crater

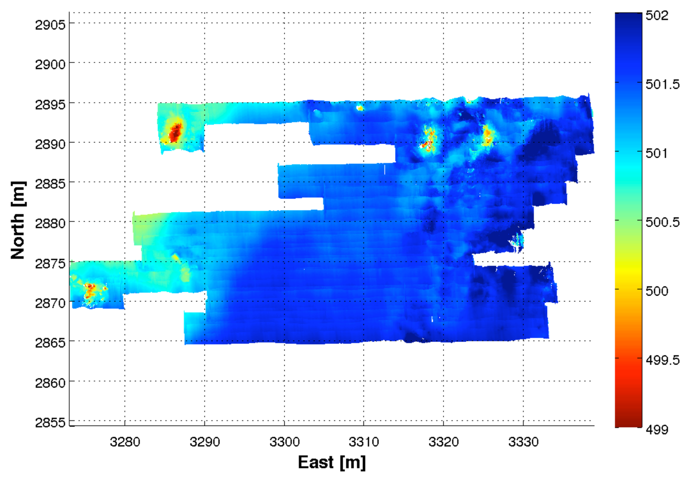

Fig. 6a Laser bathymetry survey map.

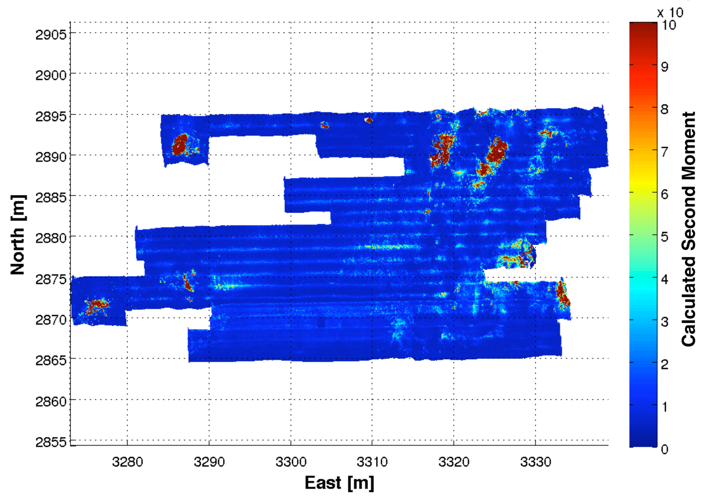

Fig. 6b Laser vent detection survey map. Detected active vents are shown in red.

Further work: This data set provided vents that were easy to detect and isolate. The significant distortion of the laser line however made it harder to reliably estimate the bathymetry over the active vents. Future work will investigate the magnitude of the induced bathymetry errors.

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Kolumbo Vent Field, Poet's Candle 2011

Within the Kolumbo crater, the around the Poet's Candle vent, there is a region of diffuse venting and associated coverage by a white bacteria mat (Fig 7). A 2011 laser survey over the area was able to capture lower temperature venting, measured 25°-45°C above ambient.

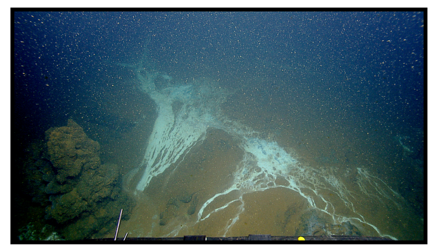

Fig. 7 White bacteria mats near Poet's Candle

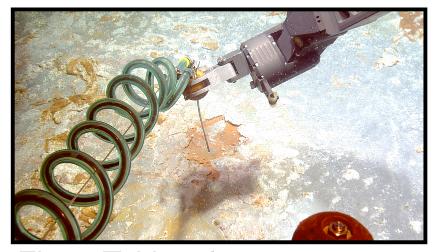

Fig. 8 Taking the temperature of the white bacteria mats. Temperature reading: 58°C, ambient 16°C

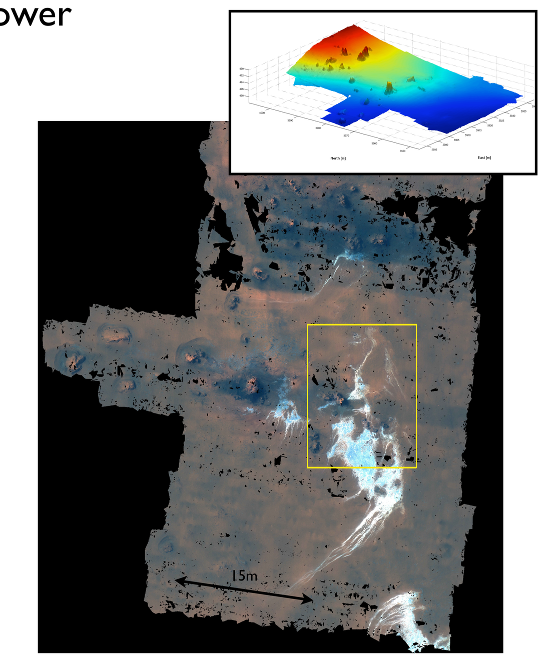

Fig. 9 Mulitbeam bathymetric map (above) and stereo map of the Kolumbo vent field. The area of focus is boxed in yellow.

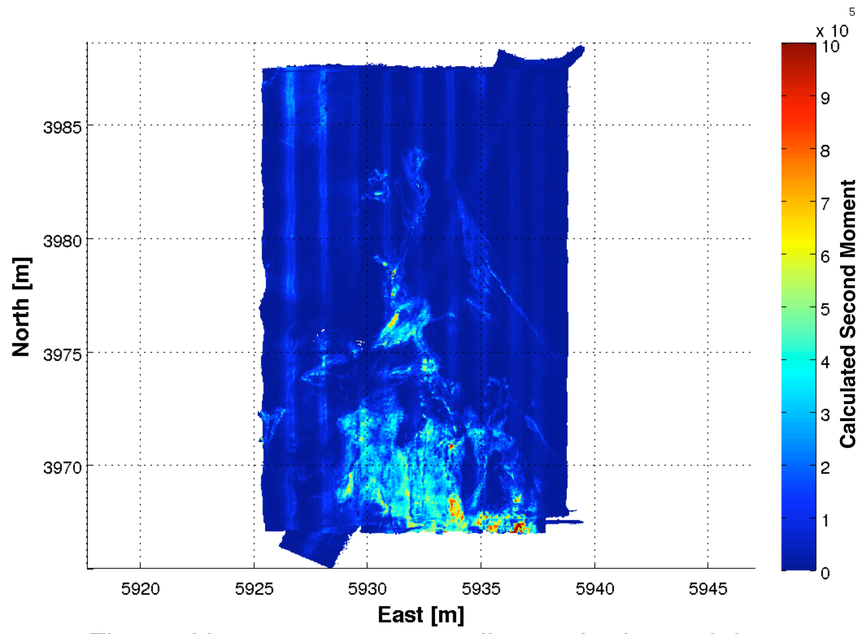

Fig. 10 Hot water corresponding to the bacterial mats is detected by the laser. Additionally, areas along the lower edge of the image have a more pronounced second moment, indicating significant venting.

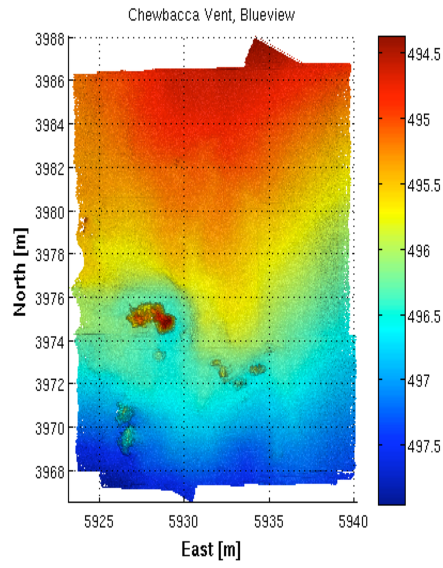

Fig. 11 Multibeam bathymetry

Further work: Over this area the detection of venting coincided with the coverage of the white bacterial mat. Over the mat the laser line was likely subject to blurring from both the temperature refraction and a general "blooming" due to the highly reflective and somewhat opaque bacteria. We are currently investigated ways to differentiate these two effects.

Palinuro Seamount, Tyrrhenian Sea, 2011

Small active vents discharging shimmering water were discovered on the western flank of the large Palinuro seamount in the Tyrrhenian Sea at depths of 600m. Maximum fluid temperatures were 68°C in two rocky areas where tubeworm colonies were growing (Fig. 12).

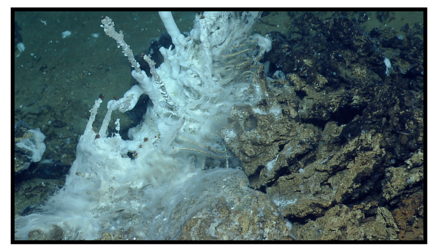

Fig. 12 Active vent site with tubeworms & shimmery water.

Fig. 13 Active vent temperature: 68°C

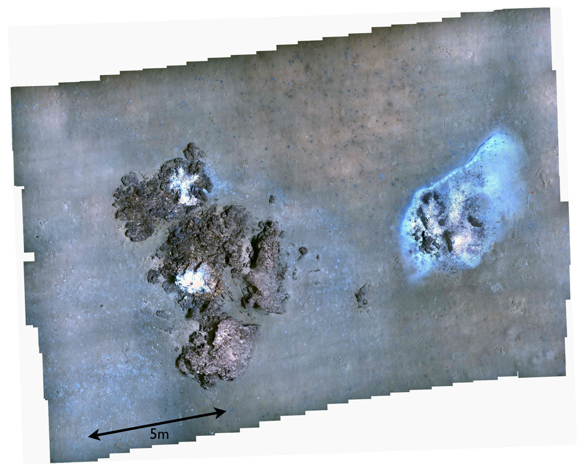

Fig. 14 Stereo map of the survey area

During this survey, a Minature Autonomous Plume Recorder (MAPR) was mounted on Hercules for additional vent data acquisition, including temperature. The recorded temperatures are shown over bathymetry (Fig. 15), however, it is notable that the maximum temperature variant is only 0.15°C, and is only loosely correlated with the exact location and magnitude of the venting. This emphasizes the role of diffusion and bottom currents, and illustrates the difficulty in locating vents while surveying 2-3 meters off the sea floor. In comparison, the laser is capable of locating the active vents due to the diffraction of the laser line.

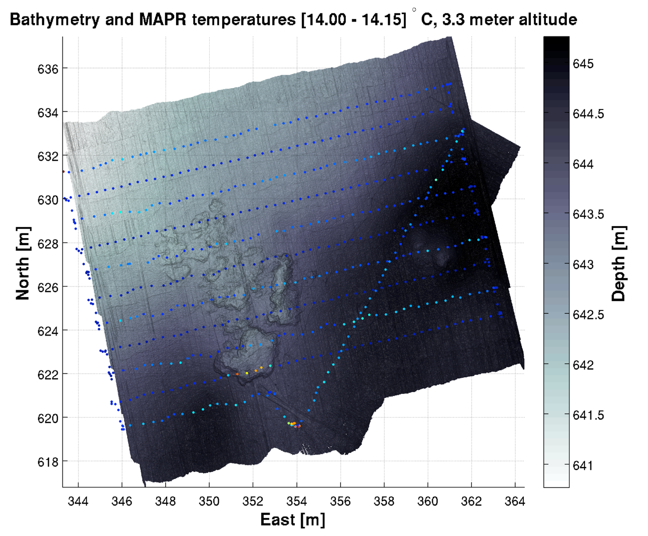

Fig. 15 Temperature color coded track lines over the bathymetry.

Further Work: Additional work will seek to relate the laser image statistic to the vent intensity in a more quantitative way.

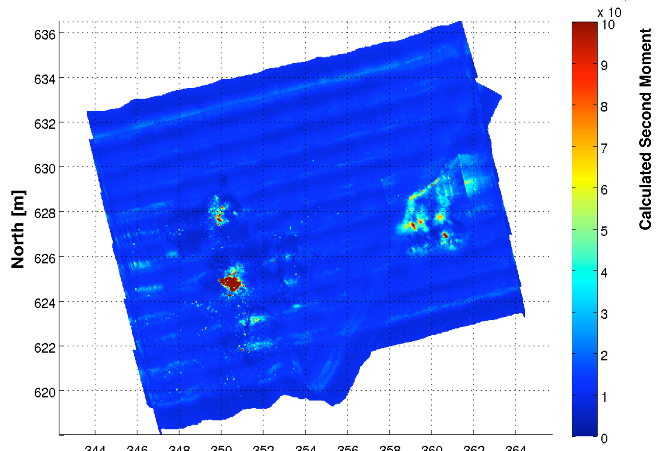

Fig. 16 Map of active venting in the area.