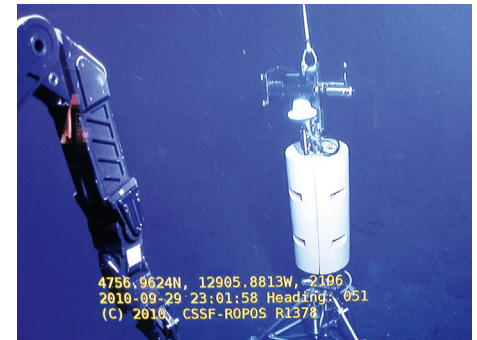


Dr Karen Bemis is a research associate in the Department of Earth and Planetary Sciences at Rutgers University, New Jersey. Dr Bemis has spent her career studying marine geophysics and volcanology, focusing on applying visualisation techniques to study hydrothermal processes. From 2010 to 2015, Dr Bemis deployed COVIS, a sonar system, to characterise hydrothermal activity on the Juan de Fuca Ridge and she is now working towards redeploying COVIS at an active underwater volcano.



A remote operated vehicle (ROV) inspects the sonar platform COVIS on the seafloor.

The ocean covers 71% of our planet's surface and contains 97% of the Earth's water. The world ocean is integral to a variety of processes that support life across the planet, including the carbon cycle and weather and climate systems. Despite its importance, it is estimated that only 5% of the ocean has been explored. To date, over 230,000 species that reside within ocean waters have been identified, but it is highly likely that there are many, many more waiting to be discovered. The ocean also hosts a wide variety of habitats – from estuaries and seagrass beds in coastal waters to the seafloor of the abyss.

The deep ocean is one of the least understood areas of the Earth as its extreme conditions render it highly inaccessible. However, as technology advances, methods of remotely visualising and characterising the seafloor are developing and gradually increasing our understanding of this mysterious environment. Hydrothermal vents are often found at deep mid-ocean ridges, where tectonic plates are separating and forming new oceanic crust. These vents discharge fluids and heat to the surrounding water, creating a unique ecosystem that thrives under the conditions they produce. There are two forms of discharge from these vents: plumes originating from black smokers, and those from diffuse flows which are less visible. It is these plumes that are the primary focus of Dr Karen Bemis' research.

HYDROTHERMAL ACTIVITY

In oceanic hydrothermal environments, seawater enters the Earth's crust where it is heated, rises, and is released back into the ocean at the seafloor. The gases contained in the released fluids, such as methane or hydrogen sulphide, support large bacterial populations in this zone which attract small crustaceans that go on to support a wide and diverse food web. Hydrothermal vents also transfer heat from the mantle to the ocean, making them an important source of heat in abyssal zones. In fact, this process accounts for a third of the total heat transfer from the Earth's

crust into the ocean. Understanding heat transfer from oceanic ridges will further our understanding of the impacts of hydrothermal fluids on circulation in the ocean: a system which has a great effect on marine species and their environments.

Traditionally, measuring heat and chemical outputs from hydrothermal vents has been difficult. Hydrothermal systems can have a wide footprint on the seabed, and their discharges can rise for hundreds of metres, so flow rates, volumes and temperatures cannot be measured at just a single point. An approach was needed that could accurately capture heat and chemical fluxes from the mantle into the ocean over a wide span of both space and time.

One measurement method that can capture such flows over a large area is acoustic imaging, which uses sonar to emit sound waves and then 'listen' for echoes. These echoes can then be used to determine the locations of density differences in the water. Acoustic imaging combines the measurement of sound waves in an environment with scientific visualisation techniques. Using acoustic imaging to study hydrothermal vent systems was first considered in 1984, when a routine sonar scan incidentally detected a hydrothermal plume. In this context, acoustic imaging can identify areas where the water is churning or is warmer than the surrounding

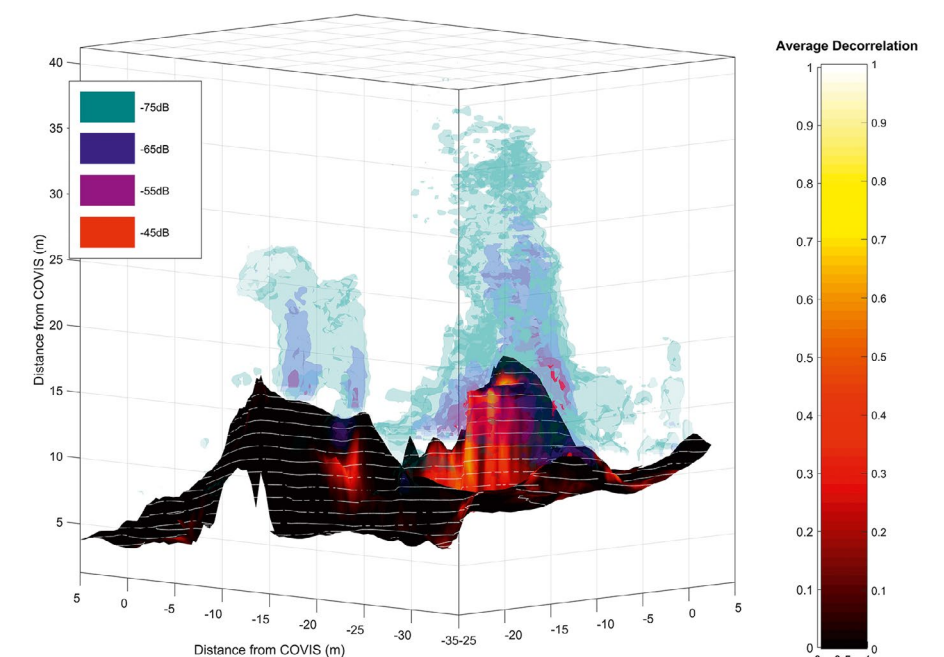


Image created from COVIS data coupled with data describing the seafloor (bathymetry). Diffuse discharge is detected on the seafloor (in red) while plumes (in purple, blue and green) rise above black smokers. The bathymetry data was collected by Dave Clague of MBARI.

COVIS is a high-frequency sonar system that has two modes that can capture different aspects of hydrothermal activity

Measuring hydrothermal flows by acoustic imaging



COVIS on board ship prior to deployment. Photo taken by Peter Rona who headed the project until his death in 2014.

area and so give insight into the behaviour of hydrothermal plumes.

Drawing on this, a team of researchers, including Dr Karen Bemis, developed the Cabled Observatory Vent Imaging Sonar (COVIS), which was specifically designed to monitor hydrothermal flows.

ACOUSTIC IMAGING – COVIS

COVIS is a high-frequency sonar system that has two modes that can capture different aspects of hydrothermal activity. The Imaging-Doppler mode measures the vertical velocity and heat content of rising

Understanding of hydrothermal fluid circulation will further our understanding of the heat transfer from the Earth's crust to the overlying ocean, which has a great effect on marine species and their environments

plumes, and the Diffuse mode scans an area of the seafloor to detect variations in sound speed that indicate areas of more turbulent water, indicating hydrothermal flows.

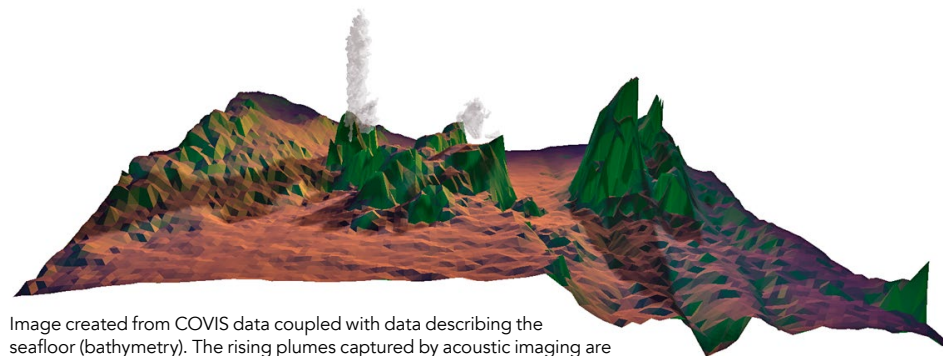


Image created from COVIS data coupled with data describing the seafloor (bathymetry). The rising plumes captured by acoustic imaging are visualised here as a single grey surface. The bathymetry data was collected by Dave Clague of MBARI and the visualisation was created by Li Liu, a PhD student in visualisation.

COVIS was first deployed in 2010 on the Canadian NEPTUNE underwater observatory at the Grotto vent on the Juan de Fuca Ridge, which is located off the western coast of North America. Over the course of five years, COVIS gathered a wealth of backscatter, discharge location, vertical velocity, and heat flux data from the vent. These data are still being analysed, but so far, the Imaging-Doppler scans have been used to reconstruct 3D images of plumes to measure heat flux and depict how their behaviour is affected by certain factors, such as tidal activity or currents. It is expected that the Diffuse scans will be able to produce a map that can indicate spatial thermal variance and identify the intensity of discharge at certain areas.

Q&A

What do you expect you may find if you can observe an eruption with COVIS?

Karen Bemis: So little is known about the relationship between the long term hydrothermal circulation and the eruptive process that predictions are difficult – but we can speculate that we would see a dramatic increase in flow during the eruption. We might also see plumes above any active lava flows that come within the sonar's scan range.

What further work will you be doing with the data collected between 2010 and 2015?

Karen Bemis: Two distinct projects are ongoing. One project uses COVIS Imaging-Doppler mode data to explore how three nearby plumes interact looking at variations in heat flux, vertical velocity and bending. Strong plumes draw in the ocean water creating inward currents whose speeds can exceed those of ambient ocean currents during slack tides. Weaker plumes may then be drawn to the stronger plumes. We are also interested in whether any changes in heat flux occur simultaneously at nearby plumes. The other project explores small-scale spatial and temporal variations in temperature using both COVIS Diffuse mode data and thermistors placed on the ocean bottom. This project attempts to understand the dynamics of large area diffuse venting of fluids.

How would using an AUV to measure hydrothermal flow further your work?

Karen Bemis: AUVs can operate

independently to survey one area while the ship/ROV does something else. This increases the spatial coverage possible for a given set of resources. AUVs, as robots, are also more patient than human operators in repeating the same tasks. For hydrothermal systems, an AUV flying about 30m above the seafloor could potentially survey an area using thermal and chemical sensors to detect plumes at its altitude and acoustics to trace those plumes to their seafloor sources.

How does the heat released from hydrothermal activity affect the wider ocean environment?

Guangyu Xu: The heat released from hydrothermal activity can drive or alter abyssal currents, enhance mixing of the deep waters, and influence the biological habitats on the seafloor and within the Earth's crust.

To what extent do you feel this work will further our understanding of the deep ocean?

Guangyu Xu: Hydrothermal circulation is an integral part of the Earth-ocean system and is intimately connected to many aspects of the deep ocean. This work advances our means of observing and quantifying hydrothermal discharge and furthers our knowledge of the interactions of hydrothermal vents with the physical, geological, and biological processes in a deep-sea environment.

FUTURE DIRECTIONS

With the wealth of background knowledge about COVIS' use and functioning from its five-year deployment in the Northern Pacific, Dr Bemis and her team are now funded to redeploy the system in the caldera of the active Axial volcano on the Juan de Fuca Ridge. As this volcano has erupted several times in recent years, they hope to capture vent field data during an eruption in an exciting first-time recording.

They are also looking to use the knowledge and techniques gained from the operation

of COVIS to develop a non-stationary tool that can be attached to submersibles or autonomous underwater vehicles (AUVs) so that they can identify and gather data about plumes as they move along their path. This would allow for even farther-reaching observations and visualisations of plume patterns than the stationary COVIS could achieve, ultimately characterising how geological and organic matter released from vents are delivered into the ocean, and how their dispersal is affected by ocean currents.

Detail

RESEARCH OBJECTIVES

Karen Bemis explores the application of mathematical analysis, fluid mechanics and computer visualisation to better understand physical volcanology, hydrothermal processes and subduction processes. Using acoustic imaging and computer visualisation, she investigates the 3D structure and fluid mechanics of seafloor hydrothermal plumes.

FUNDING

National Science Foundation (NSF)

COLLABORATORS

COVIS team: Guangyu Xu, WHOI; Darrell Jackson, APL-UW; Anatoliy Ivakin, APL-UW; Tim McGinnis, APL-UW; Aaron Marburg, APL-UW; Russ Light (deceased); Peter Rona (deceased)

Other Collaborators: Leonid Germanovich, Georgia Tech; Bob Lowell, Virginia Tech; David Butterfield, NOAA; Raymond Lee, WSU; Deborah Silver, Rutgers; Min Chen, Oxford; Li Lui, Rutgers

Groups that contributed to COVIS's successes: Ocean Networks, Canada and their NEPTUNE cabled observatory ROVs ROPOS and Jason and their excellent teams

BIO

Karen Bemis received her PhD in Geological Sciences at Rutgers in 1995 on the shape of volcanoes. Since joining the Department of Marine and Coastal Science at Rutgers, she has explored data visualisation, monitored the heat output of hydrothermal systems using sound, and continued to study volcano shape.



CONTACT

Dr Karen Bemis. Research Associate
Department of Marine and Coastal
Sciences, Rutgers, The State University of
New Jersey
71 Dudley Rd
New Brunswick, NJ 08901
USA

E: bemis@marine.rutgers.edu

T: +1 848 932 3384

W: <https://marine.rutgers.edu/main/karen-g-bemis>