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ANNUAL REPORT 2015

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Falkor off of Australia heading towards Scott Reef in the Timor Sea

Schmidt Ocean Institute founders Eric and Wendy Schmidt.

INTRODUCTION

Four years after the launch of research vessel *Falkor*, Schmidt Ocean Institute continues to support at-sea oceanography around the world, disrupting ocean research with innovative technologies, intelligent observation and data analysis, and open sharing of information. The year of 2015 presented our institute with many unique opportunities to advance our mission, create global impact, and make it one of our most successful years.

SHARING OUR LABORATORIES, COMPUTING AND COMMUNICATIONS FACILITIES ABOARD *FALKOR* IS THE FIRST STEP IN CREATING A NEW KIND OF COLLABORATIVE MARINE SCIENCE COMMUNITY.

— WENDY SCHMIDT, FOUNDER, SCHMIDT OCEAN INSTITUTE

Comprehensive understanding of the ocean's complex biophysical dynamics relies heavily on numeric modeling. While oceanographic data are collected at sea, their assimilation into models usually takes place on shore, where computing resources are readily available. This approach creates delays with data integration and makes it hard to adjust the course of observations at sea in response to insights from the incoming data. To shorten feedback between observations and modeling and provide researchers with better visibility into observed processes, Schmidt Ocean Institute installed a high performance computer (HPC) on *Falkor*, making her the first research vessel with a supercomputing system freely available to the global oceanographic community. In 2015, *Falkor*'s HPC supported three separate cruises, modeling the internal tides in the Tasman Sea, biophysical dynamics in the Timor Sea, and assimilating seafloor imagery into 3D photomosaics at Scott Reef.

In March, *Falkor* supported the first ever deep robotic survey of the previously unexplored Perth Canyon in Western Australia using a combination of multibeam acoustic mapping and interactive visual surveys with a remotely operated vehicle (ROV) deployed from *Falkor*. This was the first time such a project was ever conducted in Australian waters where every ROV dive was planned using fresh acoustic bathymetry from alternating multibeam surveys. According to the Principal Investigator, Dr. Malcolm McCulloch from the University of Western Australia, this methodology revolutionized coastal oceanography in the region, by demonstrating how much more efficient scientists can be if they have access to both of these advanced technologies in one expedition. Many new species were observed in Western Australian waters for the very first time during this cruise.

In late April, *Falkor* supported an unconventional research project focused on advancing autonomous ocean survey technologies. An international team of roboticists field-tested innovative vehicle control and coordination algorithms, enabling real time monitoring and localization of multiple autonomous vehicles, coordinated operation among heterogeneous robotics, and intelligent communications to share sensing capabilities, propagate mission-relevant information, and manage operational risks. The robots also collected hundreds of thousands of underwater images of

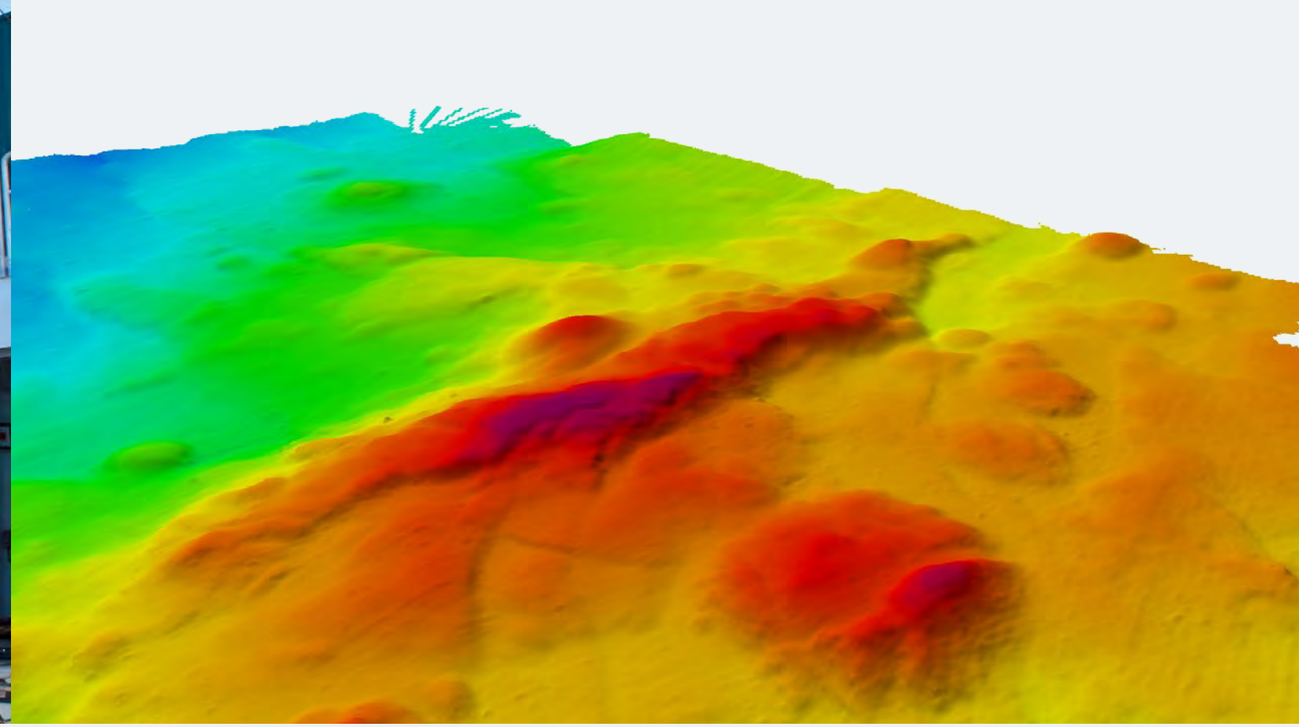
20
EDUCATIONAL TOURS PRESENTED ON *FALKOR*

400
PEOPLE IN ATTENDANCE

6
PRESENTED IN 6 COUNTRIES

60%
INCREASE IN ACADEMIC PUBLICATIONS AND PRESENTATIONS

Falkor crew and science team pose for a photo with the CTD Rosette, on the Mixing up the Tropical Pacific cruise.



Less than three months after announcing Falkor Seamount, the crew found an underwater mountain and named the feature Engineers' Ridge, after the hardworking engineers aboard Falkor.

the remote Scott Reef, which were consolidated into three-dimensional mosaics to enable characterization and shared with the public enabling user-guided virtual exploration of never before seen marine habitats. This process established a foundation for the detailed computational characterization via a citizen science image tagging program.

At the end of 2015, Schmidt Ocean Institute acquired over 367,571 km^2 of detailed, 3D seafloor imagery, covering an area greater than most European countries. For the first time, *Falkor* supported seismic profiling and seafloor mapping in Indonesian waters off the west coast of Sumatra, producing maps with greater resolution than ever seen before in this region. These maps will provide critical information for predicting the likelihood of a tsunami-causing earthquake in the area. This year, *Falkor* also mapped nearly one million square kilometers of the world's single largest underwater volcano and supported the discovery of two underwater features, subsequently named *Falkor* Seamount and Engineers' Ridge.

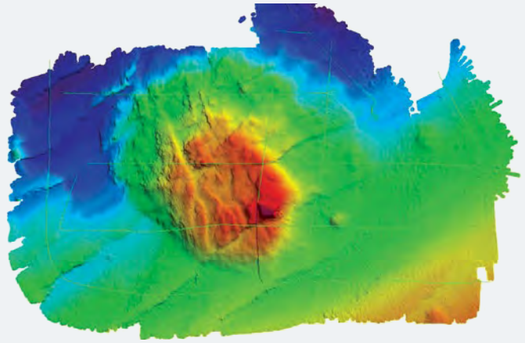
Schmidt Ocean Institute joined the Rolling Deck to Repository (R2R) oceanographic data collection project this year, ensuring that all underway shipboard data is openly and freely shared. During our Coordinated Robotics cruise, in collaboration with the Australian Centre for Field Robotics (ACFR), we used a web-based citizen science image tagging software, *Squidle*, to obtain over 22,000 image tags. The tags were used to train machine learning algorithms to derive pixel-by-pixel classification of features in the acquired seafloor images. Additionally, Schmidt Ocean Institute has streamed over 132 hours of HD videos to YouTube in real time, bringing the beautiful coral reef and underwater canyons to over 11,000 viewers and expanding a collection of openly available oceanographic observational data.

Schmidt Ocean Institute is committed to sharing the outputs of its research with the scientific community, classrooms, and public around the world. Just this past year, 72 academic publications and presentations were produced from previous research completed on *Falkor*. Our team reached more than 3,000 individuals through virtual classroom connections as part of our Ship-to-Shore Program. Four students with no prior seagoing research experience joined *Falkor* through the new Student Opportunities program, which was in addition to the 33 college and graduate students who sailed on *Falkor* with the science party. We were also proud to see Schmidt Ocean Institute featured as one of the 2015 Editor's Choice Top Five Stand-Outs in the Marine Technology Reporter's annual Top 100 innovators in the maritime industry.

In alignment with Schmidt Ocean Institute's Innovate, Explore, Share motto, in 2015 we supported a host of projects in collaboration with leading research groups from Australia, Indonesia, Singapore, Germany, Italy, Korea, and the United States. Since 2013, we have worked with 371 scientists from 87 institutions across 19 countries, including 108 experts from 31 organizations who sailed on *Falkor* in 2015. We continue to broaden our network of partners and collaborating institutions from government agencies to major universities, all working together to accelerate the pace of ocean science. We are excited to share with you our experiences and discoveries from 2015, and this is only the beginning.

A CHARACTERISTIC OF GREAT INNOVATORS IS THEY SEE A SPACE THAT OTHERS DO NOT. THE ROLE OF SCHMIDT OCEAN INSTITUTE IS TO FIND AND WORK WITH THE VERY BEST INNOVATORS TO ACCELERATE THE PACE OF OCEAN SCIENCE.

- ERIC SCHMIDT, FOUNDER, SCHMIDT OCEAN INSTITUTE



Map of Falkor Seamount, which was offically named in 2015 after being discovered by the team on Falkor during a research cruise in 2014.

STRATEGIC FOCUS AREAS

Schmidt Ocean Institute was established to advance the frontiers of ocean research and exploration through innovative technologies, intelligent observation and analysis, and open sharing of information. Our program is structured around the following key focus areas:

Falkor on the Timor Sea during the Coordinated Robotics research cruise.

1

COMMITMENT TO EXCELLENCE IN OCEANOGRAPHIC RESEARCH OPERATIONS

Schmidt Ocean Institute is dedicated to supporting advanced marine science on *Falkor*, including technical and operational improvements, innovative shipboard scientific instruments and systems, supporting remote research via telepresence and satellite data streaming, and high performance computing for at-sea modeling and data analysis.

2

INFRASTRUCTURE, PLATFORM, AND TECHNOLOGY DEVELOPMENT FOR MARINE SCIENCES

To support pioneering research at sea, Schmidt Ocean Institute develops and supports innovative scientific robotic vehicles, platforms, and instruments; deployable scientific platforms and instruments; testing of new research technologies on our vessels and vehicles; and technology focused research and development projects as part of the *Falkor* cruise program.

3

COLLABORATIVE SCIENTIFIC RESEARCH ABOARD *FALKOR*

Schmidt Ocean Institute provides scientists from around the world with access to *Falkor* to foster a deeper understanding of the global ocean, a critically endangered and poorly understood part of our environment. We support environmentally focused and societally relevant ocean research, projects with high intrinsic scientific value and meaningful impact potential, research effectively leveraging innovative technologies, and oceanographic research encouraging student participation.

4

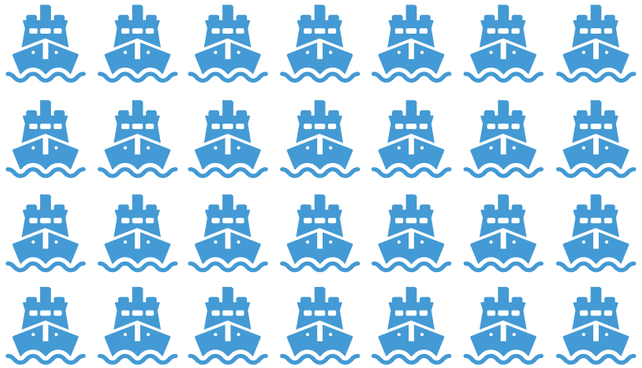
COMMUNICATIONS, EDUCATION, AND OUTREACH PROGRAM

Schmidt Ocean Institute hopes to inspire younger and older generations alike by demonstrating what is possible through technologically advanced oceanographic research. We do this by telling the story of projects supported aboard *Falkor*, supporting continuous online presence and resources for virtual visitors, holding workshops and symposia to discuss progress and future directions, and encouraging partnerships, as well as student, and educator participation.

5

OPEN SHARING OF INFORMATION, DATA, AND RESEARCH OUTCOMES

Schmidt Ocean Institute supports open sharing of information to stimulate the growth of its applications and user community, and amplify further exploration, discovery, and deeper understanding of our environment. These efforts are supported through partnerships with data management experts in the oceanographic community to enable standards-compliant sharing of scientific information and data collected during research cruises.



SINCE 2012

28

MISSIONS INCLUDING

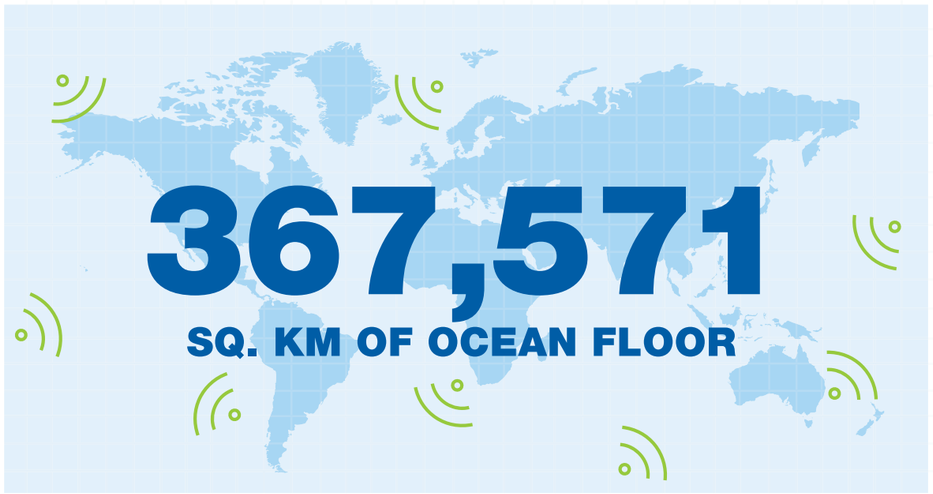
603

SCIENCE DAYS

SINCE 2012 *FALKOR* HAS TRAVELED MORE THAN **120,949 KM**

3x AROUND THE WORLD!

SINCE 2013 *FALKOR'S* MULTIBEAM AND ECHO SOUNDER SYSTEM MAPPED



AN AREA LARGER THAN MOST EUROPEAN COUNTRIES.

IN 2015 WE HAVE MAPPED...

ENTIRE PERTH CANYON OFF W. AUSTRALIA

REMOTE SCOTT REEF IN THE TIMOR SEA

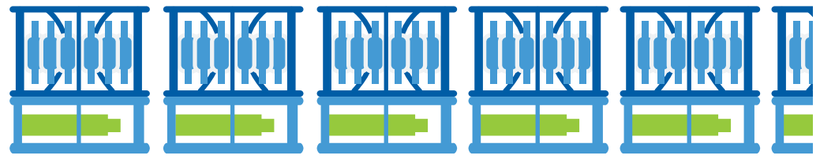
MENTAWAI GAP OFF THE W. COAST OF SUMATRA

WORLD'S LARGEST VOLCANO TAMU MASSIF

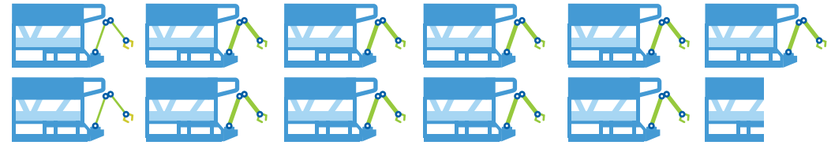
AND NAMED UNDERWATER FEATURES: *FALKOR SEAMOUNT* AND *ENGINEERS' RIDGE*

SINCE 2013 WE HAVE COMPLETED

527
CTD CASTS



116
ROV DIVES



26
AUV DIVES

= 100 = 10 = 5

MAKING A DIFFERENCE, TELLING THE STORY, AND HELPING PEOPLE CARE:

- Since 2012, 371 scientists have sailed on *Falkor*, including 177 students representing 87 institutions and 19 countries.
- In 2015 we have presented to over 3,000 people through community and conference presentations, and 6,352 students through ship-to-shore connections from *Falkor*.
- Since 2014, Schmidt Ocean Institute has hosted over 1,000 people in eight different ports in six countries on *Falkor* ship tours.

WHERE WE WENT IN 2015

MAGNETIC ANOMALIES OF THE WORLD'S LARGEST VOLCANO

HYDROTHERMAL HUNT

Guam

Majuro, Marshall Islands

Honolulu, HI

MIXING UP THE TROPICAL PACIFIC

Singapore, Singapore

Padang, Indonesia

UNLOCKING TSUNAMI SECRETS

Darwin, Australia

COORDINATED ROBOTICS AND TIMOR SEA REEF CONNECTIONS

Broome, Australia

PERTH CANYON: FIRST DEEP EXPLORATION

Freemantle, Perth

Hobart, Australia

TRACKING THE TASMAN SEA'S HIDDEN TIDE

TRACKING THE TASMAN SEA'S HIDDEN TIDE

JAN. 17 - FEB. 13, 2015

AMY WATERHOUSE
Chief Scientist

TASMAN SEA, AUSTRALIA
Location

DOI: 10.7284/900735

COLLABORATING INSTITUTIONS

- Scripps Institution of Oceanography
- University of Washington Applied Physics Lab
- University of Minnesota Duluth
- University of Alaska Fairbanks
- University of Tasmania
- Commonwealth Scientific and Industrial Research Organisation
- Environmental Protection Agency of Victoria
- National Science Foundation

In a joint ship operation between *Falkor* and Scripps Institution of Oceanography's *Roger Revelle,* collaborators from U.S. and Australian institutions ran the first comprehensive study of the largest and most focused internal tide on the planet. The tidal beam (T-Beam), which moves across the Tasman Sea, was the center of a study co-lead by Drs. Amy Waterhouse, at the Scripps Institution of Oceanography, and Samuel Kelly, from the University of Minnesota Duluth. The overall research goal was to quantify the velocity of water movement and density at all depths to discern the movement and speed of the internal tide.

> **THE EVOLUTION OF THE INTERNAL TIDE IN THE TASMAN SEA IS A PROCESS THAT WE NEED TO UNDERSTAND IN ORDER TO BROADEN OUR ABILITY TO PREDICT THE FUTURE OCEAN AND CLIMATE, AND WITH THESE SMALL STEPS, SUCH AS THE T-TIDE EXPERIMENT, WE ARE MAKING THAT PROGRESS.**
>
> **— AMY WATERHOUSE**

The Tasman Sea internal tide is the only one known in the world that moves almost completely in one direction. It forms at a ridge south of New Zealand then moves west toward Tasmania, where it reflects and breaks on the continental shelf. Prior to this project, researchers had little data on the internal tide because the area is remote, and weather conditions there can be treacherous. During this coordinated cruise the research teams aboard the two ships amassed water column current data to improve general understanding of the phenomenon, as well as researchers' ability to incorporate internal tide effects accurately in climate models. "The

Peter Strutton and the Falkor crew launch the small CTD that will collect ocean nutrient information.

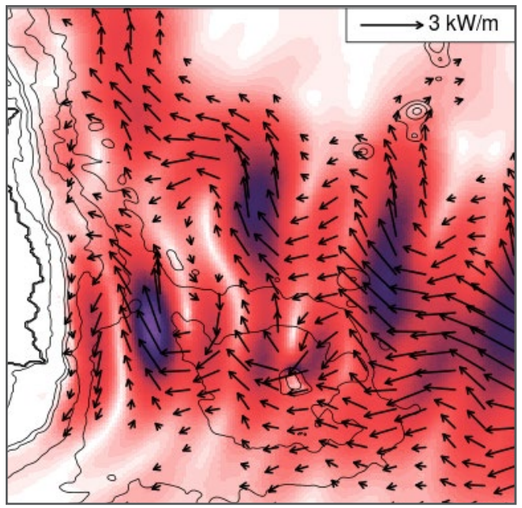
evolution of the internal tide in the Tasman Sea is a process that we need to understand in order to broaden our ability to predict the future ocean and climate, and with these small steps, such as the T-TIDE experiment, we are making that progress" said Amy Waterhouse.

The science teams aboard the *Revelle* and *Falkor* were able to find the beam of the internal tidal energy and even locate the crests of the internal waves on the continental slope and shelf. The team conducted a set of nine 25-30 hour CTD profiling stations along two parallel lines spanning the internal tide beam. Combining this information with current sensors called Acoustic Doppler Current Profilers (ADCPs) and minute temperature sensors called chi-pods, allowed the research team an unprecedented opportunity to study the entire evolution of the tidal beam.

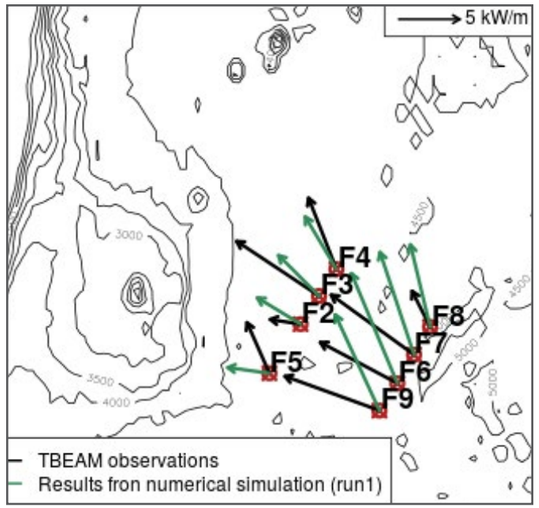
This project was the first to utilize the cloud-based high-performance computer aboard *Falkor* to analyze the enormous amount of data as it was received, allowing the scientists to optimize their sampling plan while underway. On board *Falkor*, scientists utilized the computer to run numerical simulations using the *MITgcm*, a general circulation model created by MIT, to establish updated projections of the tidal beam's pathway. The high-performance computing system offered processing power at a level that researchers would normally only have access to on land. By processing the information during the cruise, the team evolved their predictions of the direction of the waveform based on the new collected data and obtained insights into the true beam pathway.

In addition, the team studied the effects that the tidal beam has on the distribution of chemical nutrients and phytoplankton, specifically looking at the amount of nutrients that were brought to the ocean surface by the internal tide. This information will help scientists better understand what impact the tide has on the plankton population.

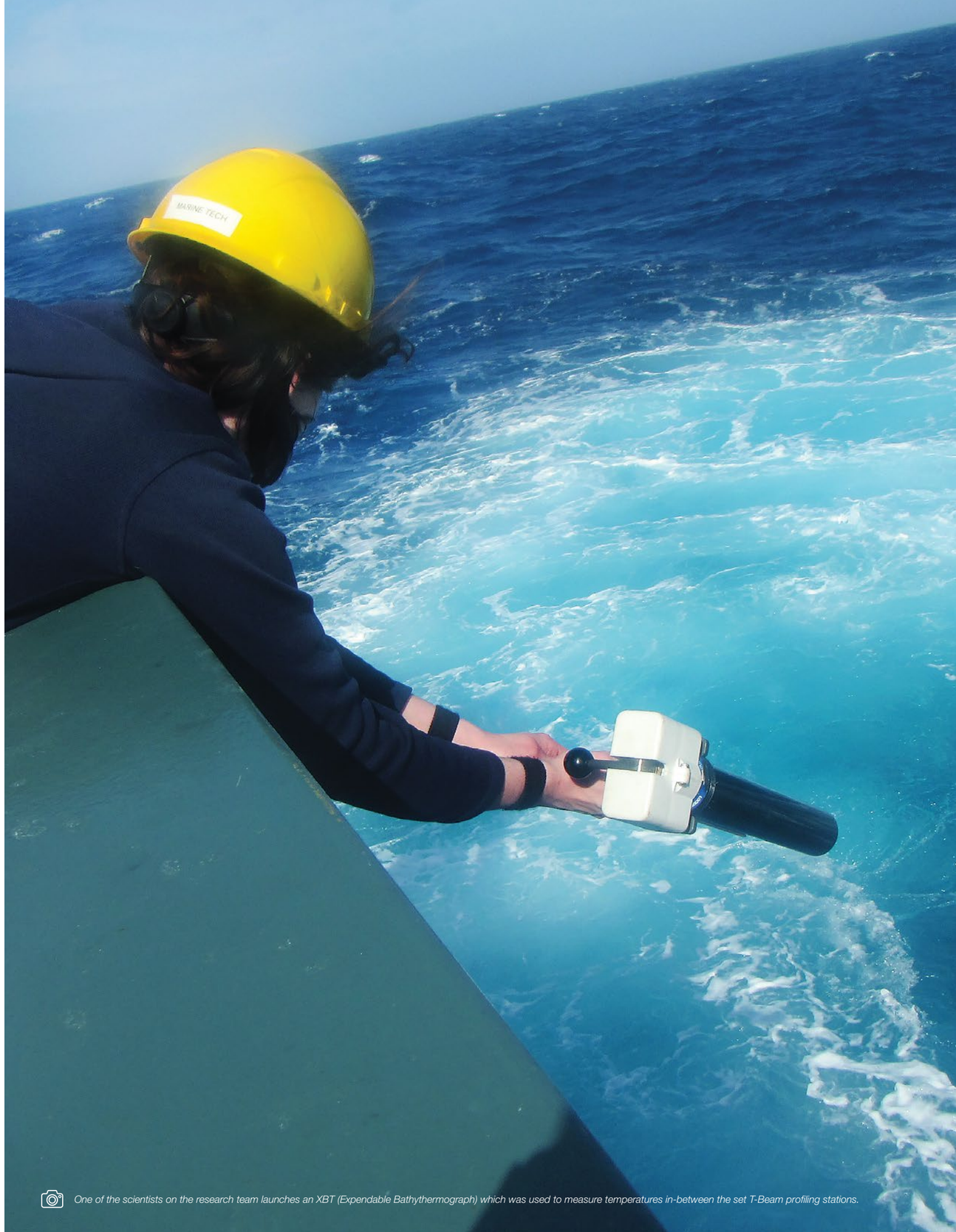
Ultimately, both teams combined their datasets to help further refine the area models that will help researchers better understand the Tasman region and further inform development of local environmental management practices. This information will also help improve modeling of complex internal tidal dynamics and will contribute to better understanding the shifts in the global climate.



A processed model output where internal wave associated energy fluxes are given by arrows and color shading is for magnitude.



A comparison of the observed values with one from numerical simulations.



One of the scientists on the research team launches an XBT (Expendable Bathythermograph) which was used to measure temperatures in-between the set T-Beam profiling stations.

PERTH CANYON: FIRST DEEP EXPLORATION

MAR. 1 - MAR. 12, 2015

MALCOLM McCULLOCH
Chief Scientist

PERTH CANYON, WESTERN AUSTRALIA
Location

DOI: 10.7284/900736

COLLABORATING INSTITUTIONS

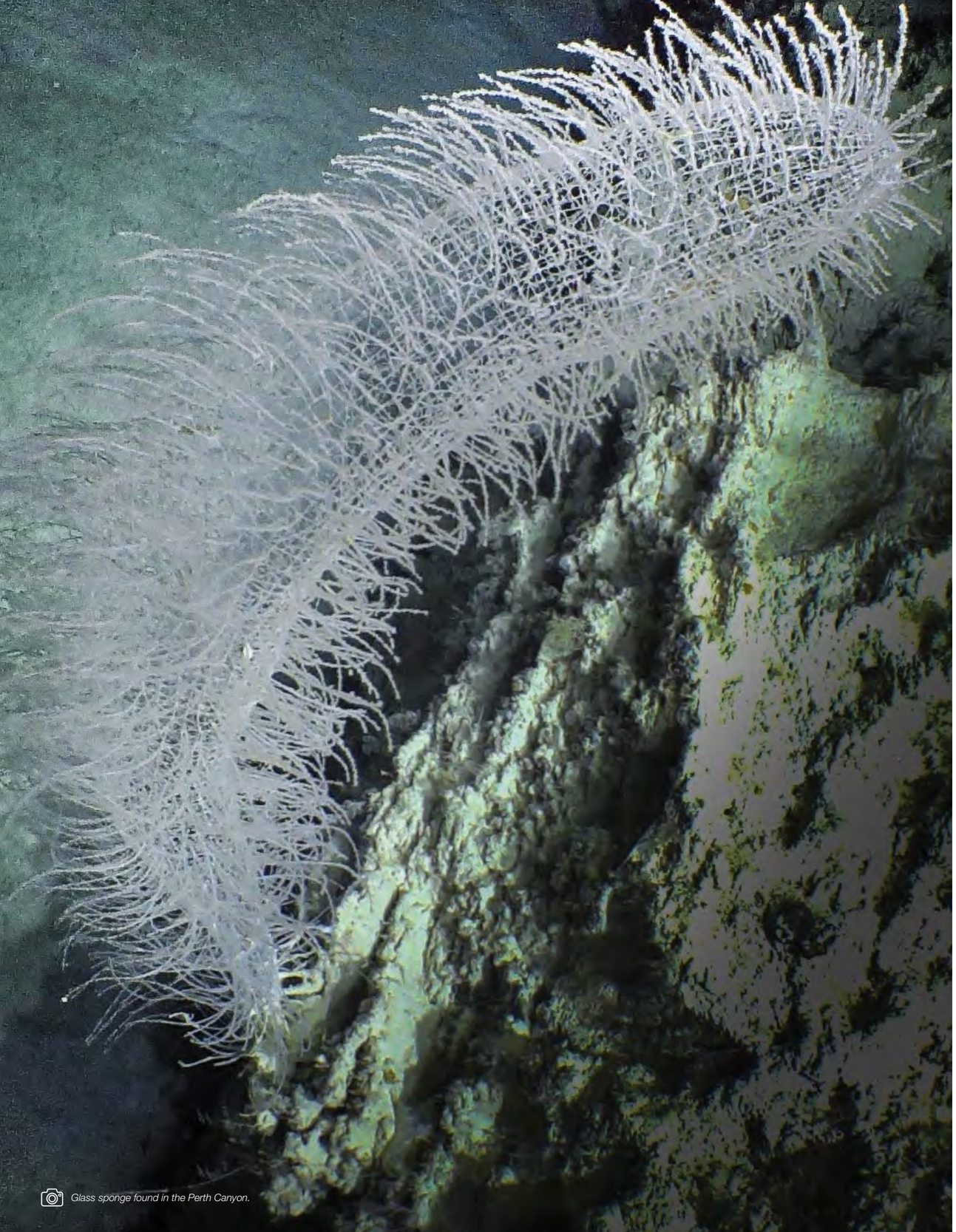
- University of Western Australia
- Western Australian Museum
- Commonwealth Scientific and Industrial Research Organisation
- Institute of Marine Sciences Italy

Similar in size to the Grand Canyon, Perth Canyon is one of Australia's subsea treasures, and as such is a proposed national reserve. Yet, despite being just 50 km or so from Western Australia's capital of Perth, the canyon's deeper reaches remained largely unknown. That is until Professor Malcolm McCulloch, from the University of Western Australia (UWA) along with his collaborative research team conducted the first exploratory expedition of the canyon aboard *Falkor*. Together, the researchers were among the first to survey life in the canyon and to conduct baseline studies of deep corals to aid in determining the likely future impacts of a warming sea and ocean acidification.

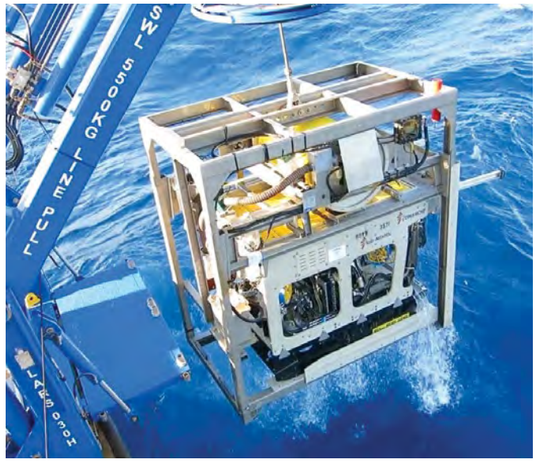
> **THE DEMONSTRATION OF COORDINATED MULTIBEAM AND ROV OPERATIONS WAS UNPRECEDENTED FOR AUSTRALIA AND WILL CREATE REVOLUTIONARY CHANGES IN AUSTRALIAN COASTAL OCEANOGRAPHY.**
>
> **— MALCOLM McCULLOCH**

Australia has no dedicated science remotely operated vehicle capable of exceeding a few hundred meters, so Schmidt Ocean Institute refitted a commercially available ROV, and equipped it with sampling tools and high definition cameras, allowing the science team to complete the first detailed ROV exploration of the canyon. Using the ROV aboard *Falkor*, the scientists were able to survey the flora and fauna that live in this region, their abundance, and determine the best sites for

Cliffs several hundred meters deep were found for the first time during exploration of Perth Canyon with Schmidt Ocean Institute's contracted ROV.



Glass sponge found in the Perth Canyon.



Schmidt Ocean Institute's contracted ROV retrieved from a dive at Perth Canyon.

> **THE SPECIES OF PERTH CANYON ARE A TESTIMONY TO THE ABILITY OF LIFE TO PERSEVERE UNDER CHALLENGING CONDITIONS.**
>
> **— JIM FALTER**

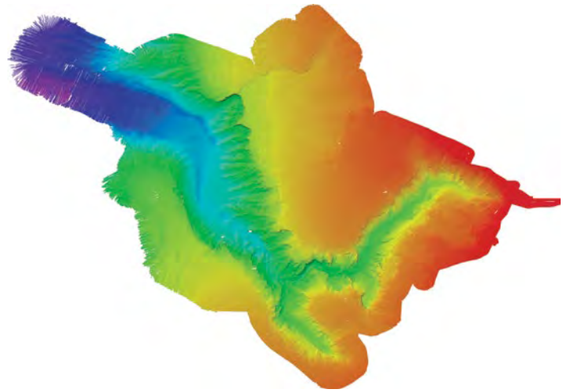
more focused research. “The demonstration of coordinated multibeam and ROV operations was unprecedented for Australia and will create revolutionary changes in Australian coastal oceanography” said Chief Scientist Malcolm McCulloch.

The team discovered new species on almost every ROV dive, finding many organisms that were observed in Western Australian waters for the very first time. For example, the glass sponges (*Euplectella spp.*) collected during the cruise are possibly a new species and the Venus FlyTrap anemone (*Actinoscyphia aurelia*) found on one dive was the first seen along the Western Australian coast. All 11 ROV dives were recorded and shared openly on YouTube, resulting in over 54 hours of footage and over 8,732 views. During the dives, samples were collected to help understand the effects of global warming and ocean acidification on the deep corals living in the canyon.

Hundreds of seawater samples were obtained for temperature and pH analysis, to determine how water chemistry changes with depth in the water column. Professor McCulloch and his team found that the water quality below 1,000 m was acidic enough to dissolve aragonitic coral. Even in those conditions scientists discovered aragonitic coral species that were growing successfully as a result of increasing their internal pH to help build their skeletons. “The species of Perth Canyon are a testimony to the ability of life to persevere under challenging conditions” said Jim Falter.

In addition to the ROV dives, multibeam mapping was completed to create a high-resolution map of the entire Perth Canyon, revealing jaw-dropping features like narrow gorges, wide valleys and cliffs several hundred meters deep. One area even featured a gigantic amphitheater type feature and evidence of an ancient waterfall plunging down 600 m, 12 times higher than the world famous Niagara Falls. The science party mapped over 4,000 km² and recorded the canyon’s maximum depth at 4,276 m.

By completing this expedition and exploring Perth Canyon, the researchers have developed an understanding of what species exist in the canyon and the degree to which coral species there are able to adapt. This has allowed them to extrapolate hypotheses about how calcification-dependent species are likely to be affected under future climate change scenarios.



The first complete high-resolution multi-beam map of Perth Canyon.

The science party and Falkor crew on the Coordinated Robotics cruise.

COORDINATED ROBOTICS

MAR. 24 - APR. 6, 2015

OSCAR PIZARRO
Chief Scientist

TIMOR SEA, AUSTRALIA
Location

DOI: 10.7284/904920

COLLABORATING INSTITUTIONS

- Australian Centre for Field Robotics, University of Sydney
- Woods Hole Oceanographic Institution
- University of Rhode Island
- University of Hawaii
- University of Michigan
- James Cook University

The Coordinated Robotics expedition took place in the remote area of Scott Reef, in the Timor Sea between Australia and Indonesia. Chief Scientist Oscar Pizarro from the Australian Centre for Field Robotics, University of Sydney, in collaboration with an international team of acclaimed robotics researchers and engineers, developed and tested advanced methodologies for autonomous robotic ocean surveys using a wide array of simultaneously deployed coordinating marine robots including autonomous underwater vehicles (AUVs), gliders, Lagrangian floats, and autonomous surface vessels (ASVs). This project demonstrated the latest advancements in oceanographic robotics, bringing engineers closer to being able to deploy large groups of robotic vehicles to autonomously carry out sophisticated oceanographic surveys over long periods of time.

(L-R) Chris Roman, Ariell Friedman, Oscar Pizarro, Stefan Williams, and Will Snyder check the realtime status of AUVs on Falkor's wireless Internet while on the aft deck.

A total of six robotic platforms were deployed from *Falkor*, sometimes operating simultaneously, collecting data and exchanging information in near real time. The AUVs performed tasks such as taking photographs and collecting water measurements at various depths. The float drifted with ocean currents and adjusted its distance to the bottom while collecting seafloor imagery and other parameters such as temperature or salinity, and the glider collected water column data and bathymetry as it moved up and down through the water. The ASV offered an additional way to track and relay messages to the underwater vehicles. The team developed a visualization tool for tracking the multiple vehicles so that anyone could see what was happening in real time. This allowed the floats to "fly" within just tens of meters from the reef surface, whereas, without such additional stream of information, gliders would not normally be able to operate.

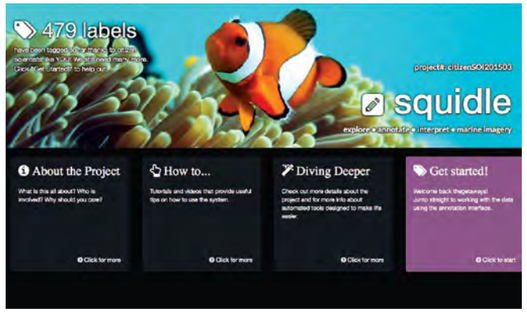
Additionally, the science team was able to use bathymetric maps collected using *Falkor's* multibeam echosounders to determine what areas were not well understood given existing imagery in other parts of the lagoon. Using the bathymetry in conjunction with the imagery, the scientists were able to identify sites that were of most value in improving habitat models and target them for surveys with the AUVs on board. *Falkor's* high-performance computing system as well as computers on land through *Falkor's* satellite link were used to correlate the ship's multibeam sonar data with the AUV benthic imagery, and then propagated the visual features to the seafloor areas that were mapped acoustically.

In two weeks, the science team was able to collect a huge amount of data, including approximately 400,000 images - about a terabyte of raw data. Some of the images were collected from locations previously visited in 2009 and 2011, and will be added to a multi-year image library, providing valuable long-term monitoring. The imagery collected by these AUVs is also utilized in other ways to support reef monitoring research. Many of the photos were taken with a stereoscopic camera in a very precisely navigated grid. Stereo imaging allows scene depth calculation, which can be used to create 3D maps. Some of this imagery and its corresponding maps have been gathered into SeafloorExplore, an iOS app that visualizes 3D models of the seafloor. It provides users with a view from above the reef, and a controlled "flight" through the growth of coral. Besides being a useful research tool that allows the user to observe the reef and associated spatial patterns at multiple scales, this interactive data set is an amazing experience for casual viewers and ocean lovers.

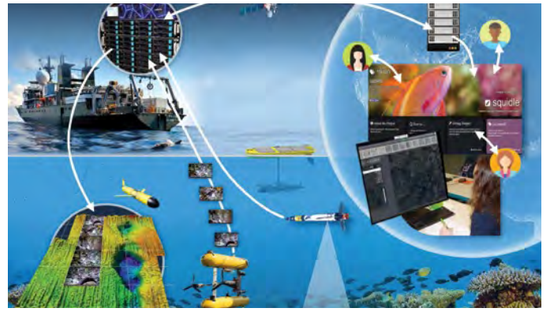
The science team also programmed computers to assist using algorithms so that they were able to translate the massive amount of images into quantitative information. Australian Centre for Field Robotics postdoctoral research engineer Ariell Friedman developed a citizen science website called *Squidle* using the images collected from the AUVs.

The *Squidle* site allowed participants to label over 22,569 images of coral reefs and ocean floor. Using the public to tag these images helped to provide more examples to the computer algorithms, increasing the computer's accuracy. Essentially, the team harnessed the power of the public to improve image tagging accuracy that will eventually be completed by computers. "We hope that this can be a fun and educational tool that allows students to engage in real science", said Ariell Friedman. Once they have a large number of labels, the scientists will conduct rigorous analysis to validate the data for training machine learning algorithms.

> **WE HOPE THAT THIS CAN BE A FUN AND EDUCATIONAL TOOL THAT ALLOWS STUDENTS TO ENGAGE IN REAL SCIENCE.**
>
> **— ARIELL FRIEDMAN**



Screen capture of the Squidle citizen science website.



Coordinated Robotics data transfer diagram.

Chris Roman (center) shows Richard Camilli the inner workings of the Lagrangian Float, while Angelos Mallios (right) looks on.

TIMOR SEA REEF CONNECTIONS

MAR. 24 - APR. 6, 2015

GREG IVEY
Chief Scientist

TIMOR SEA, AUSTRALIA
Location

DOI: 10.7284/901584

COLLABORATING INSTITUTIONS
- University of Western Australia
- Australian Institute of Marine Science
- Stanford University
- Griffiths University

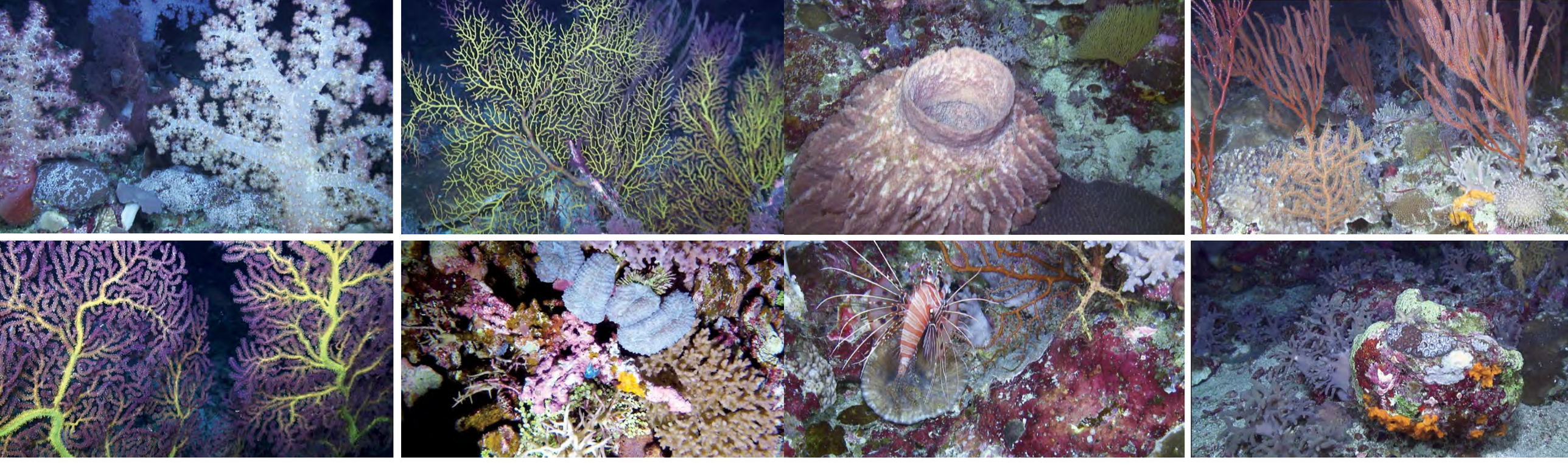
A second expedition to Scott Reef in the Timor Sea took place in the spring led by Professors Greg Ivey and Ryan Lowe from the University of Western Australia (UWA), and co-led by Andrew Heyward from the Australian Institute of Marine Science (AIMS). The goal of this project was to characterize the biophysical dynamics in one of the world's most energetic tidal regions, where tide ranges reach 11 m, and huge volumes of water flush on and off the continental shelf. These tides generate powerful currents and mixing processes that support nutrient delivery to coral reefs in a place that would otherwise be an oceanic desert.

In the deep central channel of Scott Reef, the team recorded currents in excess of 1.5 m/second at more than 200 m depth. The structures around the remote region are known to support extraordinary biological communities, but the linkage between the physical oceanographic processes and the biodiversity of these emergent and submerged reefs has remained unexplained.

To better understand the biological and physical connections between the surrounding ocean, lagoon, and reef systems, the science party installed moorings at 27 separate sites, ranging in depth from 1 to 400 m of water. The moorings held sensors allowing them to be equally spread between the surface and the seafloor, enabling the science team to observe ocean currents and temperatures at various depths. The sensors measured average currents, the intensity of turbulent mixing, temperature, salinity, and a range of biological and chemical parameters. The resulting data reveal very different hydrodynamics in the Northern Scott Reef lagoon compared to the adjacent South lagoon. Of the nearly 50 instruments on these moorings, the team had almost 100% data return, a very rare occurrence.

On *Falkor*, scientists deployed the TurboMAP turbulence probe and Schmidt Ocean Institute's 300 m remotely operated vehicle. All 16 of the ROV dives totaling 77 hours were broadcast live to over 2,600 viewers. Scott Reef appears to be a healthy reef system and the team was pleased to see that the coral habitats are highly significant in their spatial extent. This is especially true for the deep coral assemblages

Falkor crew lower the 300 m SAAB ROV into Scott Reef waters.



Coral and fish species imaged at the remote Scott Reef with Falkor's 300 m SAAB ROV. (images above and below)

that the team observed in the central lagoon. Deep-water coral communities have been documented in other regions around the world. However, it is likely this single mesophotic reef lagoon system accounts for a large portion of this coral habitat type throughout the entire Australian Northwest Marine Bioregion.

Historically, the shallow areas of Scott Reef have periodically been disturbed by coral bleaching events and storms, but the impact of these changes on the deeper lagoon is likely to have been much less. Identifying which coral species occur in the deeper lagoon is important for providing a measure of biodiversity and understand the potential for the deeper area to provide a reservoir of species.

Due to the high rate and variability of the ocean currents in this region, it was not practical to predict the flow patterns ahead of the cruise. Every night, the science party combined weather data with shipboard instrument measurements into a high-resolution model running on *Falkor's* high-performance computer to generate current forecasts for the following day.

16

ROV DIVES

77

HOURS OF FOOTAGE

2.6k

VIEWERS WATCHING THE LIVE BROADCAST

This process allowed the team to adjust the research activities with very high precision. For example, on some occasions, *Falkor* had to be positioned with spacial accuracy of just 200 m (three times the ship length) within minutes, to collect the 1.5 m/second peak current measurements at 200 m depth.

A wide range of tidal conditions displayed on the team's array of temperature sensors and current meters revealed how the combination of breaking internal waves and strong tides collectively drive transport and material exchange into and across the reef. Professor Ivey estimates the cruise collected close to 16.5 terabytes of data. Through continuous 24 hour operations on *Falkor* that integrated both oceanography and benthic habitat mapping, the scientists now have a unique opportunity to assess how the hydrodynamics, nutrient, and heat fluxes shape the spatial ecological patterns documented within Scott Reef and its surrounding shoals. Chief Scientist Greg Ivey agreed "the cruise integrated physical, biological and chemical oceanographic measurements to understanding the ecological functioning of one of the world's most unique deep-water mesophotic coral reef systems."

BEING ABLE TO RUN A HIGH RESOLUTION OCEAN CIRCULATION MODEL ON THE SHIP'S SUPERCOMPUTER TO FORECAST CURRENTS AND TEMPERATURE FLUCTUATIONS PROVED INVALUABLE IN PLANNING OUR DAILY SCHEDULES AND IN INTERPRETING THE DATA.

— GREG IVEY

UNLOCKING TSUNAMI SECRETS

MAY 27 - JUN. 22, 2015

SATISH SINGH
Chief Scientist

MENTAWAI STRAIT, INDONESIA
Location

DOI: 10.7284/901585

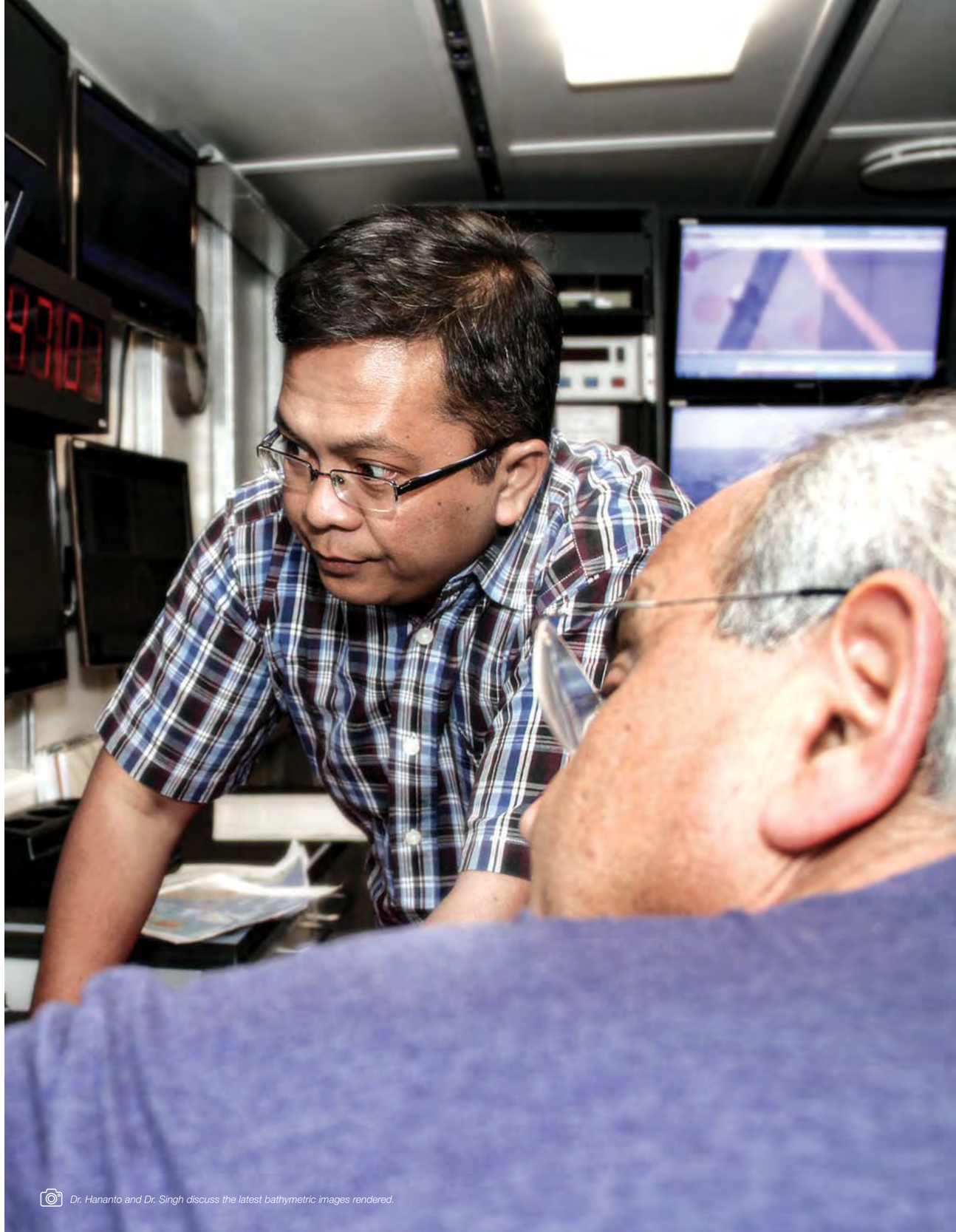
COLLABORATING INSTITUTIONS
- Earth Observatory of Singapore, Nanyang Technological University
- Institut de Physique du Globe de Paris (IPGP)
- Indonesia Institute of Sciences (LIPI)

In May, *Falkor* left port in Singapore to venture into Indonesian waters for the first time to explore one of the most destructive forces on the planet, tsunamis, and namely what causes them in the Sumatra region.

The expedition known as The Mentawai Gap—Tsunami Earthquake Risk Assessment (MEGA-TERA), targeted two areas, (1) Wharton Basin where two great earthquakes occurred in 2012 and (2) the region west of Siberut Island, identified as the Mentawai Gap, which is the only area of the geologically active Sumatra-Andaman zone that has yet to have a large earthquake in the last 200 years.

The international science team led by Professor Satish Singh, from the Institut de Physique du Globe de Paris (IPGP) and Earth Observatory of Singapore (EOS), and Dr. Nugroho Hananto of the Indonesian Institute of Sciences (LIPI), were able to acquire high-resolution seismic reflection and bathymetry data for both Wharton Basin and the Mentawai Gap during the 34 day expedition. The scientists acquired 19,515 km^2 of high-resolution bathymetry mapping, along with 2,780 km of seismic profiling. The team found many active faults at Wharton Basin with different orientations, suggesting that the whole area is deforming on different scales. The Wharton Basin is under enormous stress due to the continental collision between India and Eurasia to the north and the Sumatra-Andaman zone to the east.

In the Mentawai Gap region, seismic images show active faults near the Sunda trench, both on the subducting plate and on the overriding plate. A detailed analysis of this seafloor data will allow the scientists to better understand the nature of a tsunami being produced by an earthquake in this region. The team anticipates that it will take several years to fully analyze the data and provide answers to the causes of tsunamis in this region. At the conclusion of the expedition, Chief Scientist Satish Singh stated that “this has been a very exciting experiment. We have imaged the seafloor with resolution never done before, which should help us to address the link between

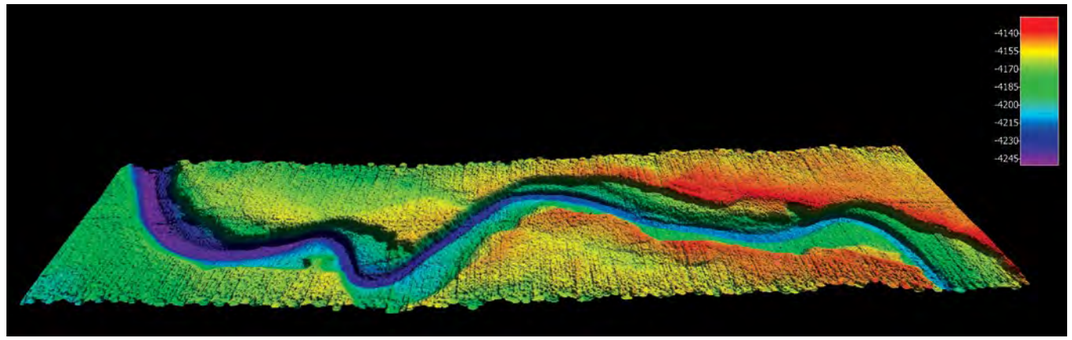


Dr. Hananto and Dr. Singh discuss the latest bathymetric images rendered.

earthquake and tsunamigenisis." The resolution of bathymetric data collected from the seafloor in this region was a great improvement from what had been previously collected and used for science.

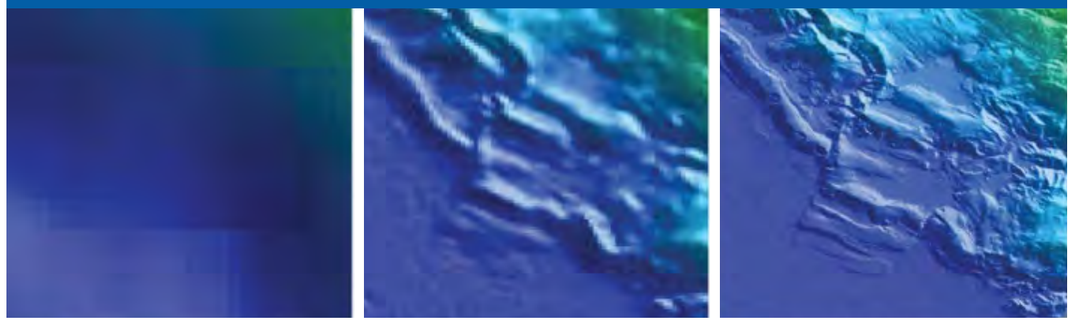
Additionally, the research will impact the citizens of the region. In the Padang area alone, there are over 500,000 people residing less than five meters above sea level and over seven million people living along the central and southern coasts of Sumatra and the Mentawai Islands. The improved maps resulting from the MEGA-TERA expedition will be extremely valuable in predicting the likelihood of a tsunami-causing earthquake in the region and provide some potential scenarios for size and direction of such a tsunami. This information, and the advance planning it will enable, is invaluable to the citizens of the region in preparing for potential tsunami situations.

> **THIS HAS BEEN A VERY EXCITING EXPERIMENT. WE HAVE IMAGED THE SEAFLOOR WITH RESOLUTION NEVER DONE BEFORE, WHICH SHOULD HELP US TO ADDRESS THE LINK BETWEEN EARTHQUAKE AND TSUNAMIGENISIS.**
>
> **— SATISH SINGH**



Bathymetric map of a meandering canyon at the Wharton Basin.

Bathymetry Data



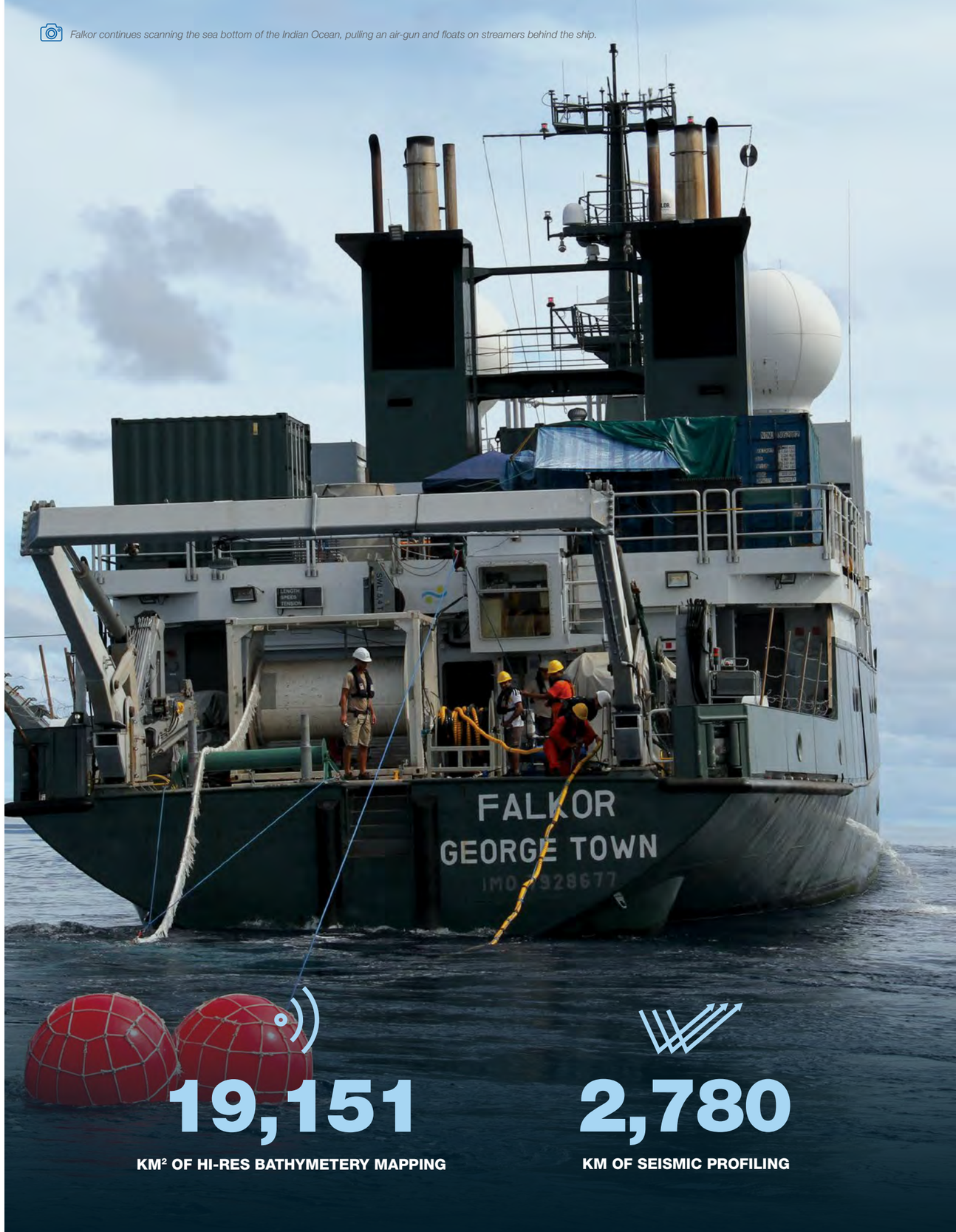
GEBCO

Complication from previous cruises 2005 - 2009 (Marion Dufrensne, Sonne, HMS Scotts)

***Falkor* 2015**

Maps demonstrating the varying visual quality of previous maps.

Falkor continues scanning the sea bottom of the Indian Ocean, pulling an air-gun and floats on streamers behind the ship.



The MEGA-TERA team on the foredeck of Falkor.

SINCE 2014 SCHMIDT OCEAN INSTITUTE HAS HOSTED **1,000+** PEOPLE IN... **8** DIFFERENT PORTS IN... **6** COUNTRIES ON *FALKOR* SHIP TOURS

MIXING UP THE TROPICAL PACIFIC

JUL. 30 - AUG. 17, 2015

KELVIN RICHARDS
Chief Scientist

WESTERN EQUATORIAL PACIFIC
Location

DOI: 10.7284/901885

COLLABORATING INSTITUTIONS
- University of Hawaii Manoa
- National Science Foundation
- Japan Agency for Marine-Earth Science
- National Research Foundation of Korea
- Ministry of Oceans and Fisheries of Korea

Falkor sailed across the central equatorial Pacific in August giving researchers their first view of the water profiles in this region during El Niño conditions. The timing was perfect for this expedition, as Principal Investigator, Dr. Kelvin Richards from the University of Hawaii at Manoa, and his team completed an 11 day time-series at the equator. Dr. Richards has completed similar water profiling in the western equatorial Pacific region. However, this was the first move towards the central Pacific, to observe if mixing trends remained similar to that of data collected from previous western Pacific cruises.

The ocean helps to regulate Earth's temperature with the movement of heat through vertical mixing in the ocean layers. However, El Niño Southern Oscillations (ENSOs) alter regular ocean temperatures with anomalously warm waters off the western coast of South America, causing climatic changes across the tropics and subtropics. The movement of ocean heat is especially important in understanding El Niño events that spawn weather shifts such as flooding in relatively dry regions of the western U.S., droughts in typically wetter regions in the western Pacific, and the lessening of trades and warmer temperatures in Hawaii.

Recent research has suggested that small-scale turbulence in the ocean plays a critical role in large ocean processes like El Niño. The science team is now analyzing the 155 CTD casts that were collected during the cruise, examining the ocean mixing patterns to improve climate models, and provide more accurate forecasting of ENSOs.

From the water profiles collected, the data indicate that there are indeed mixing patterns, perhaps even stronger than in the west, giving an indication that these features are important in

> **WE ARE SEEING THAT THE EQUATORIAL REGION IS A SPECIAL PLACE FOR THE PRODUCTION OF THESE SMALL VERTICAL SCALE VELOCITY STRUCTURES AND MIXING.**
>
> **— KELVIN RICHARDS**

Student Opportunities participant Julianna Diehl collects water from a sample bottle that will provide scientists with new information on the waters of the central equatorial Pacific.

turbulent mixing. The mixing is produced by a combination of factors including wind blowing across the surface of the ocean. The wind not only generates surface waves, but also produces internal waves that propagate downwards and towards the equator. Through an amalgamation of spatial and temporal sampling of the ocean, the science team was able to capture one of these waves as it descended through the thermocline. “We are seeing that the equatorial region is a special place for the production of these small vertical scale velocity structures and mixing" said Chief Scientist Kelvin Richards.

The next step for the science team is to run numerical models with some of the observed winds to cross check with the data collected. The scientists think that the water profile features may have been created with one of the westerly wind events earlier in July. These westerly winds are strongly associated with El Niño conditions. The team will run models and compare the characteristics of the waves in the model with what they are observing in the data to see if they can conclusively ascribe the conditions to this particular wind event.

The ultimate goal is to use these and similar data collected from future cruises to improve how mixing is represented in climate models, leading to better models of the El Niño Southern Oscillation. These small-scale processes have a large impact on broader ocean movement and conditions.

This was also the first cruise to implement Schmidt Ocean Institute’s new Student Opportunities Program, providing two marine science undergraduates a chance to participate in meaningful scientific research. The Student Opportunities Program aims to help train the next generation of scientists and ignite a spark for ocean exploration. One of our first participants, Julianna Diehl, returned to *Falkor* at the end of 2015 to work aboard the ship as a Deck Cadet as part of her continued training for a science career at sea.

The science team prepares the Vertical Microstrure Profiler (VMP) on the aft deck of Falkor before deployment.

Falkor crosses the equator to collect shear and small scale mixing data during the Mixing Up The Tropical Pacific cruise.

MAGNETIC ANOMALIES OF THE WORLD'S LARGEST VOLCANO

OCT. 5 - NOV. 10, 2015

WILLIAM SAGER
Chief Scientist

TAMU MASSIF, NW PACIFIC OCEAN
Location

DOI: 10.7284/906518

COLLABORATING INSTITUTIONS

- University of Houston
- Texas State Aquarium
- National Science Foundation
- Chiba University
- National Geographic Society

Schmidt Ocean Institute's longest expedition of the year was tremendously ambitious, spending close to 477 hours on a mapping survey of the world's single largest underwater volcano. The science team, led by Dr. William Sager of the University of Houston, was able to gather nearly 73 million bathymetric soundings and approximately 1.7 million measurements of the volcano's magnetic field. The cruise survey was very successful, accomplishing 98% of the planned mapping track and covering an area of nearly one million square kilometers.

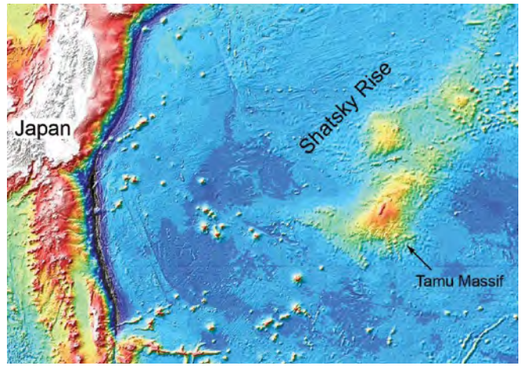
The Magnetic Anomolies cruise was focused on Tamu Massif, located about 1,600 km east of Japan. The process that created this undersea volcanic mountain, with an area equivalent to the U.S. state of New Mexico, remains a mystery. The goal of this research was to better understand how Tamu Massif was formed, by collecting magnetic data with a magnetometer. One of the few oceanic plateau volcanoes formed during a time of geomagnetic reversals, Tamu Massif holds a unique record of undersea geographic formation: magnetic anomalies in the oceanic crust. This makes it easier to understand the underwater volcano's history and the key interactions it has with the mid-ocean ridges.

> **ONE THING THAT STANDS OUT ABOUT THIS SURVEY IS ITS SHEER SIZE. IT WAS AN AMBITIOUS CRUISE TO COVER ALL OF TAMU MASSIF, THE WORLD'S LARGEST KNOWN SINGLE VOLCANO.**
>
> **— WILL SAGER**

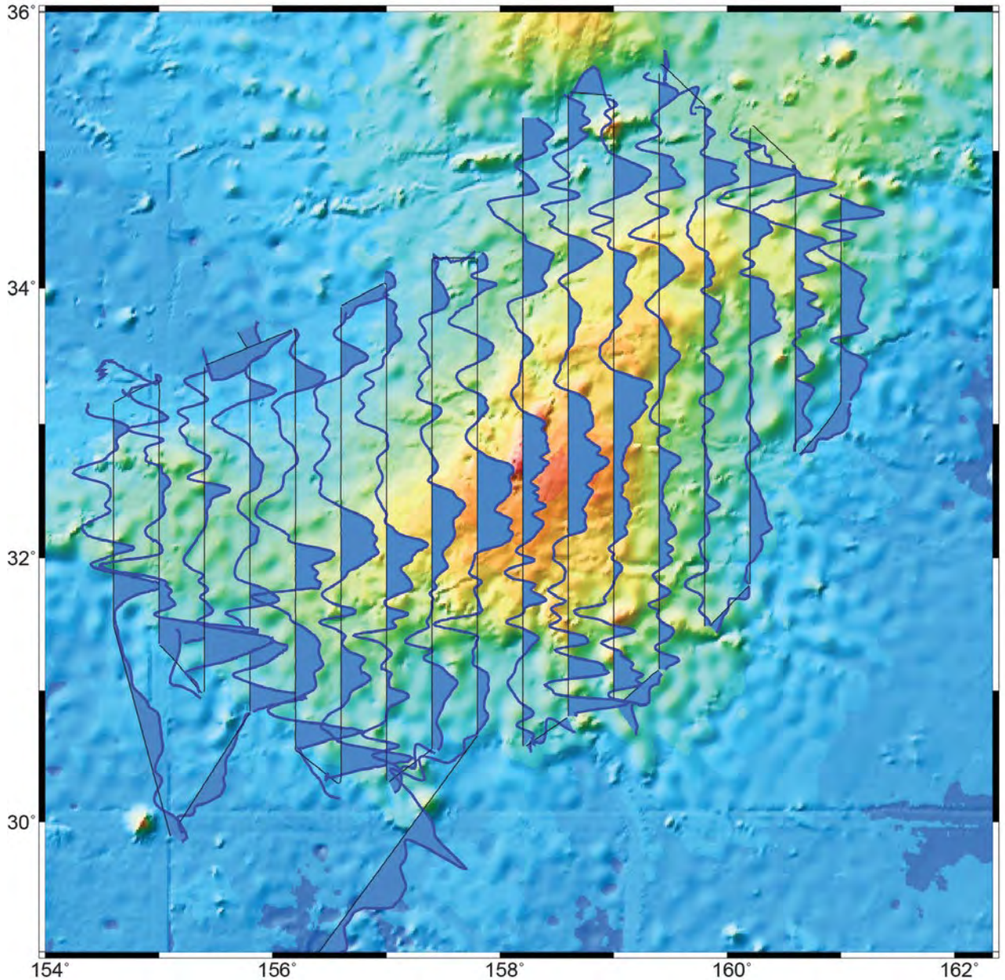
By gathering the magnetic data, scientists are able to "read" the magnetic anomalies preserved within the plateau during its eruption. These stripes indicate laterally-constrained volcanism similar to mid-ocean spreading ridges, but this interpretation is not consistent with previous theories of Tamu Massif as

Student watchstanders remain diligent in their record keeping and discussions of Tamu Massif as the data streams into Falkor's Science Control Room.

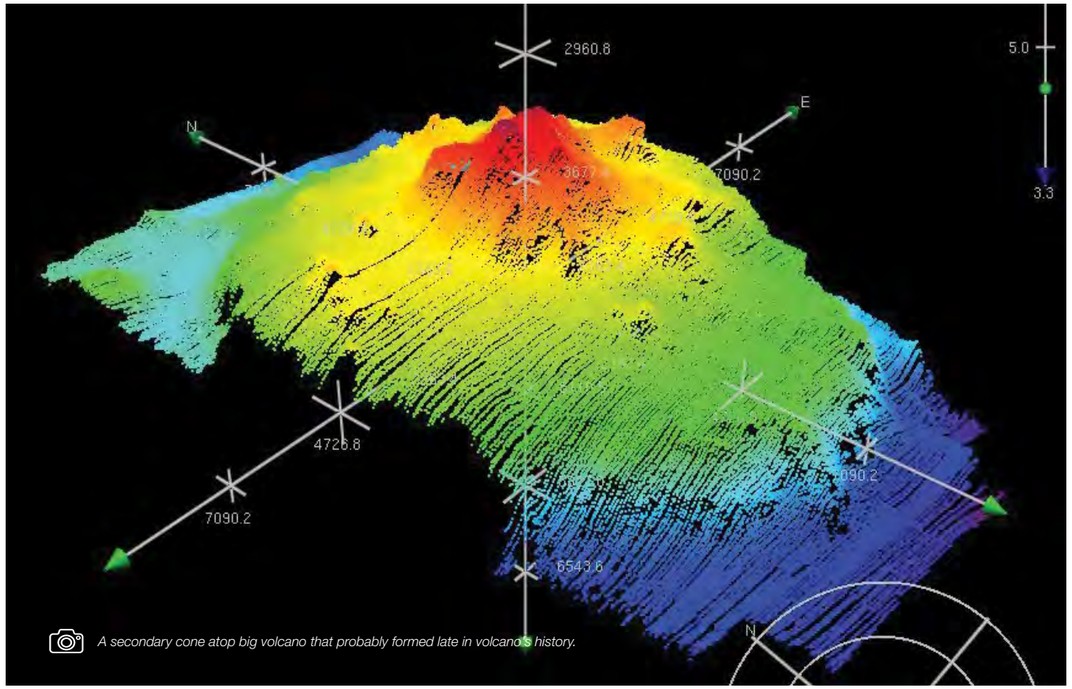
an effusive volcano with far-traveled lava flows. Indeed, from older data it appears that the northeast end of the volcano has stripes, but the southwest part does not. The magnetic anomalies map created during this cruise will take some time to analyze, but a wide positive anomaly oriented SW-NE along the axis of Tamu Massif can clearly be seen. This is flanked by deep low magnetic anomalies on the north and south side. What this indicates is that Tamu Massif has zones of stronger and weaker magnetization. “Previous work on the Tamu Massif magnetic anomaly has been frustrated by the poor quality of older geophysical survey data. With careful attention to magnetic data collection and navigation, the new *Falkor* data will make it possible to make the best-ever magnetic anomaly



Map of Shatsky Rise also known as Tamu Massif.



Wiggle map showing positive anomalies on the right (shaded areas) and negative anomalies on the left.



A secondary cone atop big volcano that probably formed late in volcano's history.

PREVIOUS WORK ON THE TAMU MASSIF MAGNETIC ANOMALY HAS BEEN FRUSTRATED BY THE POOR QUALITY OF OLDER GEOPHYSICAL SURVEY DATA. WITH CAREFUL ATTENTION TO MAGNETIC DATA COLLECTION AND NAVIGATION, THE NEW *FALKOR* DATA WILL MAKE IT POSSIBLE TO MAKE THE BEST-EVER MAGNETIC ANOMALY AND BATHYMETRY MAPS OF THIS GARGANTUAN VOLCANO.

— WILL SAGER

and bathymetry maps of this gargantuan volcano” said Chief Scientist Will Sager.

In addition to mapping magnetic anomalies, dozens of secondary cones atop the big volcano, probably formed late in the volcano’s history, were also imaged. In places like Hawaii, many volcanoes form along rift zones, but here, the cones were scattered all over, implying Tamu Massif does not have well-defined rift zones. There were also many canyons cut into the sedimentary cover by the downslope sediment flows, which will be identified and traced using the new data. The maps also show basal escarpments (cliffs) on the west side of Tamu Massif. The science team now has more questions, wondering if these faults could be formed by different parts of the volcano sinking at different rates, or if they are the results of landslides?

Dr. Sager has referred to Tamu Massif as having a “Jekyll and Hyde” personality because of the differences in styles of eruption (constrained or effusive) implied by the magnetic anomaly data. The massive volcano developed at a triple junction of spreading ridges, which left behind recordings of magnetic anomalies that are the key to figuring out how it erupted. The science team expects that the large amount of new data collected during this expedition will help unlock the answers.

HYDROTHERMAL HUNT AT MARIANA

NOV. 20 - DEC. 17, 2015

JOSEPH RESING
Chief Scientist

MARIANA BACK-ARC, GUAM
Location

DOI: 10.7284/906519

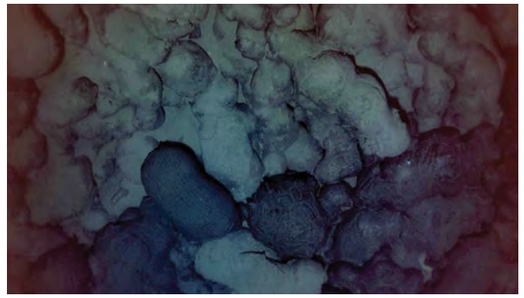
COLLABORATING INSTITUTIONS

- Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
- Cooperative Institute for Marine Resources Studies, Oregon State University
- National Oceanic and Atmospheric Administration Pacific Marine Environmental Lab
- National Oceanic and Atmospheric Administration Office of Ocean Exploration and Research

The last expedition of 2015 brought *Falkor* back to the Marianas Trench Marine National Monument for a 28-day cruise that explored a 600 km stretch of the Pacific Ocean seafloor. The expedition was the first to systematically explore the Mariana Back-arc, a region west of the trench, where plate spreading and submarine volcanism are concentrated.

The research cruise led by Dr. Joseph Resing, from the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington, and Dr. Bill Chadwick from the Cooperative Institute for Marine Resource Studies (CIMRS) at Oregon State University, resulted in the doubling of known hydrothermal vent sites in the Back-arc, from three to seven. Amongst these newly discovered sites included one of the deepest vents ever found. There are nearly 700 known vents around the world, and only three are deeper than the new one detected at a depth of 4,230 m.

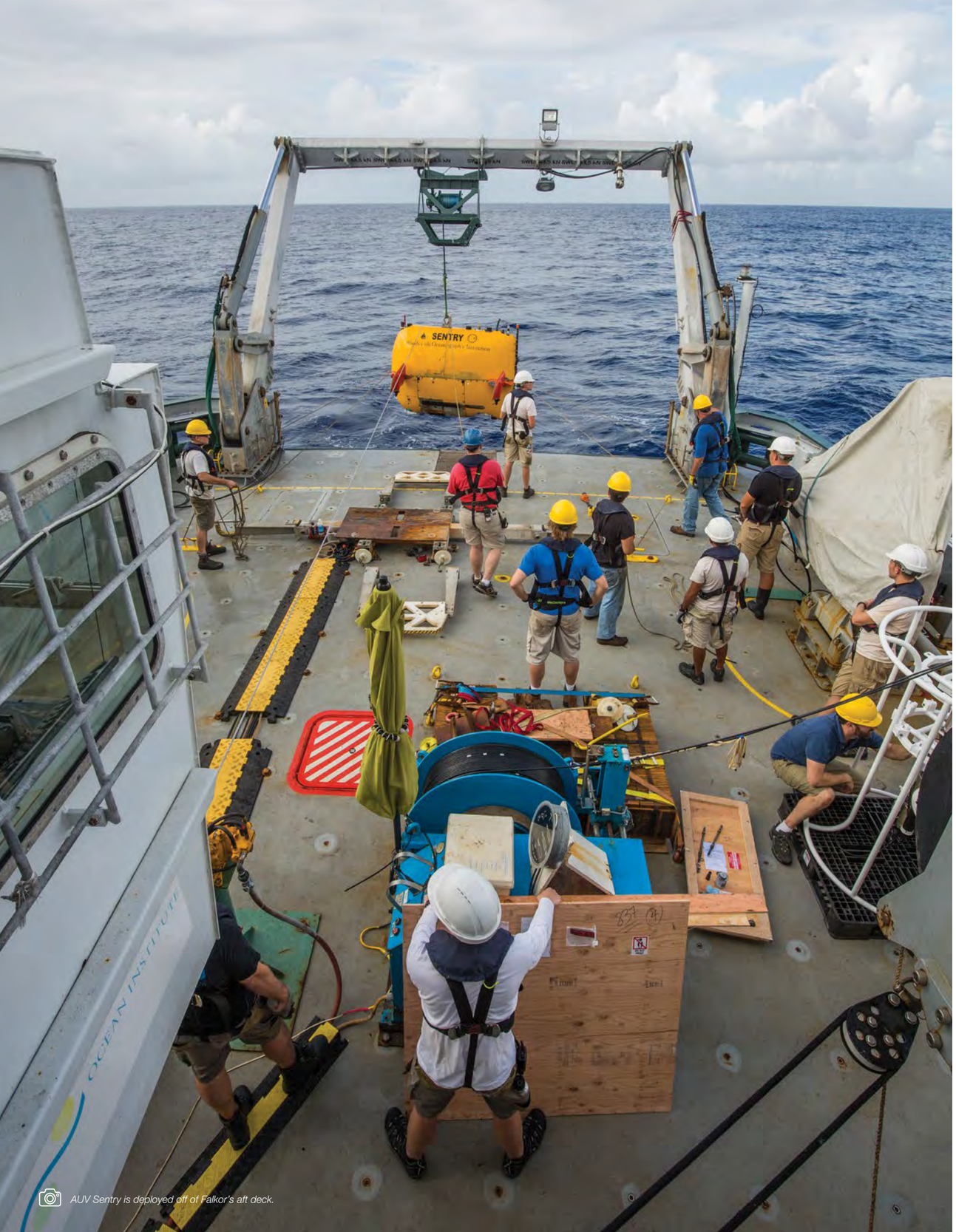
Another momentous discovery was a brand new lava flow, still cooling and likely only a few months old. “When the autonomous underwater vehicle *Sentry* came back on board *Falkor* and we looked at the photo survey, our jaws just dropped,” said Dr. Chadwick. The flow “looks like it could have come out yesterday, and that was totally a surprise. It’s in a fascinating part of the Back-arc with whopping hydrothermal



Photograph taken by AUV Sentry showing the edge of the young lava flow (dark) over the surrounding older seafloor (light), showing contact between old and young lava formations.

> **THIS REGION PROBABLY EXPERIENCES ERUPTIONS NO MORE THAN ONCE A CENTURY, MAKING THE 125 M THICK LAVA FLOW A VERY SIGNIFICANT FIND.**
>
> **— JOSEPH RESING**

Susanna Michael tends the Go-Flo bottles in Falkor's Wet Lab for detecting trace metals. Because of the sensitivity of the tests, contamination from the metals of the ship were a possibility, so the crew set up a temporary lab surrounded by plastic sheeting, nicknamed "The Bubble."



AUV Sentry is deployed off of Falkor's aft deck.

The science control room on Falkor where the science team monitored sensor data from towed instrument packages during their hunt for new hydrothermal vents in the Mariana Back-arc.

signals." Chief Scientist Dr. Resing explained the rarity of the event, "this region probably experiences eruptions no more than once a century, making the 125 m thick lava flow a very significant find." The vent and lava flow discoveries were made using AUV *Sentry*, "tow-yo" casts with a CTD rosette, and a mobile lab built on *Falkor* to search for trace metals.

The hard work of the chemists, geologists, and oceanographers making up the science team on this cruise, resulted in locating new sites of hydrothermal activity and the production of new higher-resolution maps of the Back-arc seafloor. After constructing a geological and geochemical model of the Back-arc vent settings, the team plans on combining the model with biodiversity data, to better define the relationships between geologic setting, chemical environment, and biological communities.

The Mariana subduction system offers an ideal location for diverse chemosynthetic ecosystems due to the presence of hydrothermal activity in a variety of settings. Chemosynthetic ecosystems vary with different geophysical and geochemical conditions which results in diversity of biological communities on the seafloor. The research from this cruise will help test the idea that arc and Back-arc sites have distinct ecosystems, controlled by each settings' geology and unique fluid chemistry. The scientists on this expedition plan to return to the site on board *Falkor* later in 2016, using the data collected on the active vent sites to further characterize the geologic setting, temperature, chemical composition, and biological communities. During this next expedition, the scientists are planning to use Schmidt Ocean Institute's new, under development 4,500 m ROV to visually explore and sample the new vent sites on the seafloor.

SINCE 2012

371

SCIENTISTS HAVE SAILED ON *FALKOR* WITH

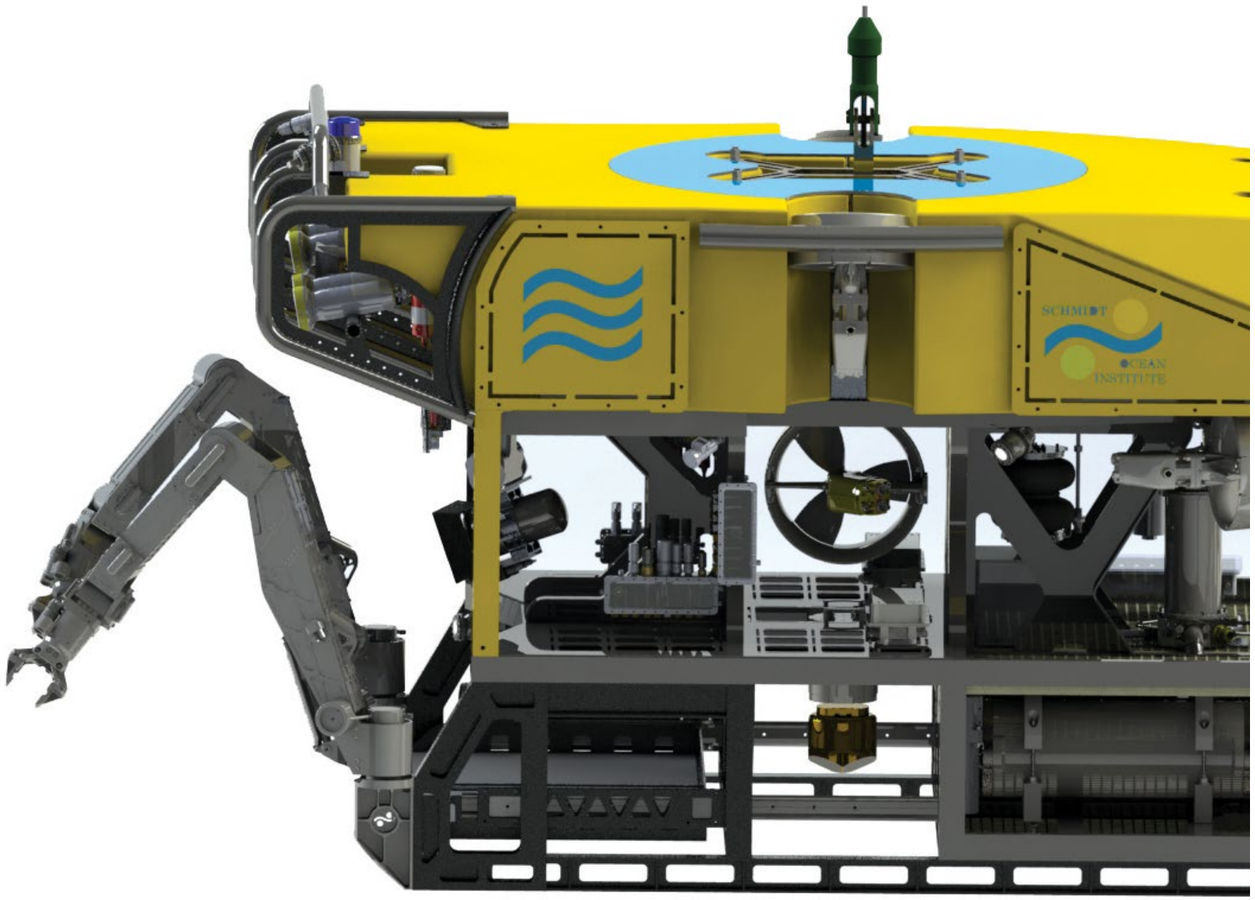
177

STUDENTS REPRESENTING...

87

INSTITUTIONS AND 19 COUNTRIES

Scientists and crew on the Hydrothermal Hunt expedition, with AUV Sentry in the background.



The new 4,500 m ROV built for Falkor.

BUILDING NEW TECHNOLOGY

This past year was extremely busy with the development of a program to support the in-house design, manufacture, and operation of a Remotely Operated Vehicle. In 2015, the engineering team focused on the development of Schmidt Ocean Institute's first 4,500 m underwater robotic vehicle, scheduled for delivery in 2016.

The engineering team successfully completed the vehicle's final design, including reviews, in December, allowing for the components to be manufactured and put into production in early 2016.

In designing a vehicle specifically for *Falkor*, the over-boarding systems were specially designed to work with *Falkor's* layout, capacity and power requirements. The major sub system components was also evaluated and subsequent vendors were selected based on performance and proven experience in similar ROV systems.

The engineering team worked closely with a selected Science Advisory Group (SAG) comprised of leaders in the field of marine exploration, marine robotics, and deep sea ecology. The SAG participated in a series of surveys designed to elicit their input on science mission requirements as well as the systems and equipment the deep ocean scientific user community would need to conduct research. The group's input has been integral to the engineering team, allowing them to develop final specifications for the vehicle's science systems including core sensors, lighting, cameras and navigation systems. The imaging system specifications and final designs will include state-of-the-art science cameras, capable of transmitting both 4K Ultra High Definition (UHD) video and 20 megapixel still images from the same camera.

Additionally, the electrical engineers on the ROV team have worked closely with an external vendor to develop a collaborative, custom-designed, subsea electronics and telemetry system. This system will be housed in two same sized pressure housings supported by a state-of-the-art technologically innovative user interface, which is commencing final manufacture.

Jason Williams, Lead Mechanical Engineer, completes the factory acceptance test of the new ROV manipulator arms.

With most of the primary components and sub systems specified, a final vehicle layout was determined. The resulting information from the weights and balance was used to finalize the designs of the syntactic foam and main vehicle frame. The design is nearing completion with the final manufacturing details being worked out with the frame fabricators to ensure the plans support successful manufacturability. The team is looking forward to integration of all the vehicle subsystems, followed by tank testing and sea trials in Guam later in 2016.

FALKOR UPGRADES AND IMPROVEMENTS

This was an exciting year for *Falkor* filled with groundbreaking science, ship upgrades, and many firsts. In July, the Wendy Schmidt Ocean Health X Prize announced their winning sensor for measuring pH accurately: *Sunburst Sensors*, a team from Minnesota, USA. Following the announcement, one of the winning sensors was installed aboard *Falkor* to begin collecting pH data continuously while at sea. While the first data from the system hasn't been published yet, we are excited to contribute to the collection of Ocean Health data.

The CTD (Conductivity-Temperature-Depth) and water sampling system aboard *Falkor* is one of the most used pieces of equipment on the vessel. It collects water samples from various depths for a variety of water analyses and is used on virtually every expedition. This year, we added a new Launch and Recovery System (LARS) for the CTD and upgraded the instrument to accept serial digital sensors, an advancement in water sample collection on board. Other equipment additions include a new over-the-side sonar transducer pole to allow for the temporary installation of cruise specific sonar and acoustic systems, and a new transducer pole for the small work boat to allow for similar data collection in shallow water.

The new pH sensor and CTD equipment contribute to conducting state-of-the-art science at sea. In 2015, *Falkor* also saw additional "firsts" related to conducting research. For example, in May, seismic equipment was successfully integrated onto *Falkor* for its first seismic cruise, conducted in Indonesia. Contributing to a cruise of firsts for *Falkor*, a marine magnetometer was installed and towed alongside the seismic gear and *Falkor's* sub-bottom sonar was used to continuously profile shallow geologic features beneath the seafloor sediments. *Falkor's* 300 m SAAB ROV was also put to extensive scientific use for the first time in 2015, collecting samples and over 130 hours of high resolution video from shallow reef sites on two separate cruises. The use of this vehicle greatly increased the scope of research that was possible on these cruises.

In addition to the new science equipment, the video matrix system was expanded to include the addition of screens and terminals in the Library as well as doubling the number of inputs and outputs. This upgrade has led to a new and improved presentation center in the ship's Library to enhance ship-to-shore outreach and communications, as well as allowing for more information to be conveyed in one spot. Additionally, multiple cameras were added around *Falkor* to provide for new viewing angles. Other technology upgrades included the installation of a high-performance computing system, making it easier and more efficient to conduct science at sea. The onboard computing capabilities allow scientists to integrate collected data into models on a near-real-time basis.

Falkor's new CTD Launch and Recovery System (LARS).

SHARING THE PASSION

2015 was Schmidt Ocean Institute's busiest year with more ship tours, presentations and remote ship-to-shore connections than ever before. We relish the opportunity to bring teachers, students, and the public along on our exploration of the ocean.

The audience participates in a student Question-and-Answer session at Singapore's Science Center for the Unlocking Tsunami Secrets cruise.

Chief Scientist William Sager hosts a ship-to-shore with a middle school class during the Magnetic Anomalies of the World's Largest Volcano research cruise.

They became part of our journey, and we are able to share the experience of history-making research in classrooms and people's homes. It is this type of outreach that truly inspires the next generation of scientists to continue exploring and conserving our oceans. Several new education initiatives were undertaken in 2015 including the Student Opportunities Program, to further enhance our connection and reach, continuing our goal of sharing cutting-edge science.

OUTREACH

This year Schmidt Ocean Institute gave 37 community and conference presentations to over 3,000 people in nine different countries. We also opened up *Falkor* to the communities in which she sailed in, offering 20 educational tours for over 400 people. During the Unlocking Tsunami Secrets expedition a special effort was made to provide ship tours, classroom visits and presentations in both Singapore and Indonesia. Through

6,400

STUDENTS REACHED

3k

PEOPLE PRESENTED TO THROUGH COMMUNITY AND CONFERENCE PRESENTATIONS

6.3k

STUDENTS THROUGH SHIP-TO-SHORE CONNECTIONS FROM *FALKOR*

a dedicated outreach tour, Schmidt Ocean Institute was able to participate in 11 bi-lingual community events, reaching over 1,730 students, government officials, and community participants. We also remotely reached an additional 6,352 students in 157 classrooms through ship-to-shore connections from *Falkor*. Scientists and crew were able to obtain a new record during the Magnetic Anomolies at the World's Largest Volcano cruise, connecting with over 4,000 students in 90 ship-to-shore connections through a partnership with the Texas State Aquarium. Not only were we able to reach elementary, high school, and college classes this year, but we also shared our science with the public through remote connections with Exploratorium, Texas State Aquarium, Florida State Aquarium, ExplorOcean, Hatfield Marine Science Center and Smithsonian Natural History Museum, amongst other locations. Additionally, analysis of data collected on *Falkor* was disseminated by collaborating science parties producing 72 academic publications and presentations in 2015, including contributions towards three graduate student's dissertations.

Rachel Edwards participates in a ship-to-shore connection lead by Suraida Nanez James during the Magnetic Anomalies of the World's Largest Volcano research cruise.

WEB PRESENCE

Schmidt Ocean Institute's online presence continues to grow as evidenced by the 82,664 new visitors to our website, a 32% increase from last year and the 409,000 page views our site received. This year we have been developing a new website, which will provide a more user-friendly and interactive interface. The new site is scheduled to launch in early 2016 and will have new publication and cruise search features, as well as a media library. During this undertaking we have also made real-time cruise tracking and data available, as well as a language translation app. Our dedicated team of multimedia

Student Opportuntities participant Julianna Diehl is interviewed by the press following the Mixing Up the Tropical Pacific cruise.

journalists offer daily blog updates on our cruises by working with our science parties to share the stories from sea. This year we focused on providing weekly video blog updates and shared 165 science blogs, a 66% increase from last year. Several of our cruises were featured on the AGU Blogosphere, and for the first time we offered a contest so that audiences could participate in predicting where new hydrothermal vents would be found. We continue to actively interact with the community through our social media accounts, increasing followers on Facebook, Twitter, and YouTube. Schmidt Ocean Institute received 347,609 page views on Facebook, 388,800 on Twitter, and 114,519 on Google Plus, indicating a 3,000% increase in traffic this year. Our YouTube page also received attention when *Falkor* shared live HD video streams of ROV dives during research cruises in the Timor Sea and in Perth Canyon.

MEDIA

In 2015, Schmidt Ocean Institute received over 220 news media stories in international and national television, radio, print, and web publications. We were also proud to be featured this year as the Editor's Choice top Five Stand-Outs in the in the *Marine Technology Reporter's* annual Top 100 innovators in the maritime industry. Additionally, the Hawaii-based *All Things Marine* radio show partnered with Schmidt Ocean Institute, broadcasting live from *Falkor* during four different research cruises. *Falkor* was also featured in a chapter of James Nestor's book *Deep*, and in several television series including *Voices of the Sea*, *North 23 Degrees*, *Animal Planet*, and the documentary film *Perspectives on Ocean Exploration*.

Lead Marine Technician Leighton Rolley and Communications Manager Carlie Wiener particpate in a Ship-to-Shore connection with San Francisco's Exploratorium.

SCHMIDT OCEAN INSTITUTE'S ONLNE PRESENCE IN 2015

388,800
TWITTER PAGE VIEWS

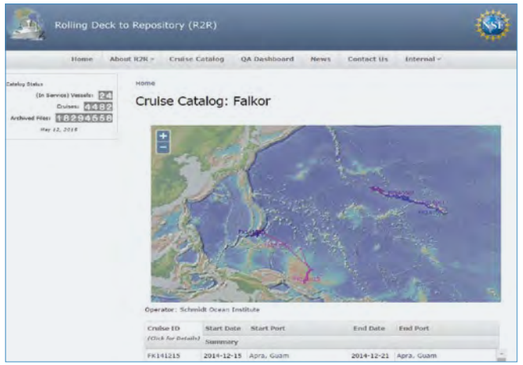
347,609
FACEBOOK PAGE VIEWS

114,519
GOOGLE+ PAGE VIEWS

3,000%
INCREASE IN TRAFFIC

NEW DATA SHARING ACTIVITIES

Sharing data and communicating the outcomes is at the heart of Schmidt Ocean Institute's core focus areas and mission statement. In 2015, we continued to broaden our network of partners and collaborators, especially in the area of data management and stewardship in order to help accelerate the pace of collecting and sharing data.



SHARING UNDERWAY ENVIRONMENTAL SENSOR DATA

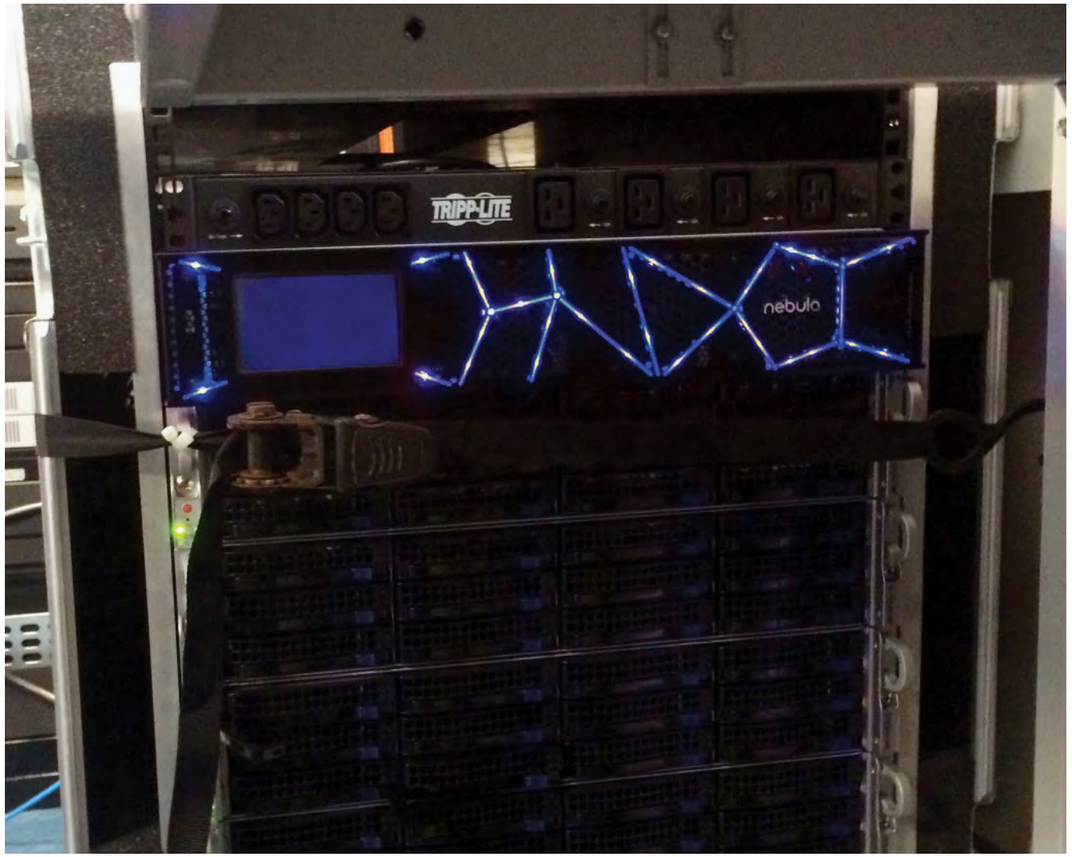
Earlier this year, Schmidt Ocean Institute signed on to share our underway environmental sensor data streams via the Rolling Deck to Repository (R2R) program. R2R is a national program led by Columbia University in partnership with Scripps Institution of Oceanography, Florida State University, and Woods Hole Oceanographic Institution, with support from the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA) and Office of Naval Research (ONR). Following each *Falkor* cruise, the R2R team organizes the underway data, creates an entry in the national cruise catalog, submits the data to an appropriate long-term archive, creates standard products such as quality-controlled shiptrack navigation, and publishes a Digital Object Identifier (DOI) for the cruise that facilitates linking the cruise data with articles in scientific journals. Data from *Falkor* is the only privately-funded, global-ranging vessel to become part of the R2R archive. Schmidt Ocean Institute is the only organization that contributes an entire research vessel's data to the MGDS archives. In September, *Falkor* was highlighted at the Ocean Data Interoperability Platform (ODIP) Workshop in Paris, France, as part of a multi-year/international effort to build a global catalog of research cruises.

SHARING MULTIBEAM BATHYMETRY DATA

Also led by Columbia University, the Integrated Earth Data Applications: Marine Geoscience Data System (IEDA: MGDS), has partnered with Schmidt Ocean Institute to curate and archive data collected onboard *Falkor* by its embedded submersibles and third party science instruments. Additionally IEDA: MGDS also curates processed data products for multibeam bathymetry, merges it into the Global Multi-Resolution Topography synthesis and publishes with Google.

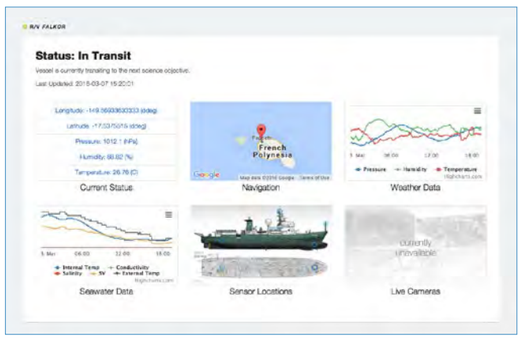
SHARING THE STATUS OF *FALKOR* IN REAL TIME

Another new data sharing mechanism is the *Falkor* Status page on Schmidt Ocean Institute's website. Users can now



The new high-performance supercomputer onboard Falkor.

visit the website and learn whether the ship is currently at sea or in port. If the ship is at sea and collecting data, visitors can find out its position, weather data, seawater data, and learn more about *Falkor's* sensors that are collecting all of this information. These data are pulled onto the web from *Falkor's* Open Vessel Data Management System (OpenVDM), designed to help vessel operators manage the data created from a dizzying array of sensors and systems installed aboard research vessels. With Schmidt Ocean Institute's support, OpenVDM has been able to provide a consistent end-of-cruise data package, while remaining flexible to a vessel's evolving sensor technology. The system was developed to be open source, and recently was released for download on GitHub, an online software repository. Today, technicians from different vessels and institutions can work together to tackle the universal problem of managing shipboard sensors and data outputs by supporting the development of a single system.



LOOKING BACK:

RESEARCH UPDATES FROM 2014 CRUISES

Oscar Pizarro and Lachlan Toohey watch a brilliant sunset from Falkor's Aft Deck over the Timor Sea during the Coordinated Robotics cruise.

STUDENT CRUISE UPDATES, HAWAII, CHIEF SCIENTISTS ADRIENNE COPELAND AND ERICA GOETZE

Pilot whales (Globicephala) were observed and studied off Hawaii Island during the first student cruise focused on deep diving whale behavior.

The purpose of our inaugural student cruises was to increase the understanding of deep diving odontocetes (toothed whales) foraging behavior. The first cruise had Adrienne Copeland, a PhD student, act as Chief Scientist. Adrienne Copeland and Giacomo Giorli both used data from this cruise to complete their PhD dissertations. Giacomo Giorli completed his dissertation, titled *Deep Diving Odontocetes Foraging Strategies and Their Prey Field as Determined by Acoustic Techniques*, and received his PhD this fall.

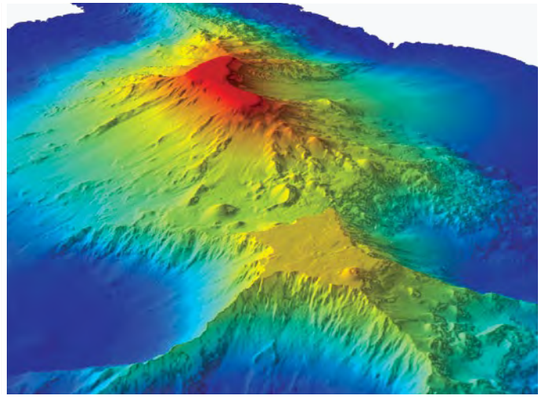
Another student cruise took a group of students to Station ALOHA (A Long-term Oligotrophic Habitat Assessment) to investigate copepod distribution. The team is still analyzing the data collected and expect several publications to result. In particular, University of Hawaii Manoa undergraduate student Stephanie Matthews is using samples collected as her honors undergraduate thesis. She received a research grant from the University to support her work, based on the material collected during this cruise. Stephanie plans to defend her thesis in May 2016 and will present her work at the 2016 Ocean Sciences Meeting. Another graduate student, Michelle Jungbluth, changed her sampling plan for another cruise scheduled in 2014 based on her observations from this expedition. She was able to collect a large amount of data, in part because of her revised collection plan.

University of Hawaii graduate and postdoctoral students were able to collect zooplankton samples for copepod grazing and paternity experiments as part of their own research during the third student cruise.

LOOKING BACK: RESEARCH UPDATES FROM 2014 EXPEDITIONS

REVEALING THE HIDDEN PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT (PMNM) HAWAII, CHIEF SCIENTIST CHRISTOPHER KELLEY

Falkor's Science Control Room during Leg One of Papahānaumokuākea Marine National Monument mapping cruise.



Bathymetric map of Bank 9 in the Papahānaumokuākea Marine National Monument.

Over two separate cruise legs in 2014, *Falkor* mapped over 125,000 square kilometers of the seafloor in PMNM, including the northern end of the Monument where very little mapping data existed previously. The mapping data collected by *Falkor* have been incorporated into a new bathymetry synthesis of the Monument's seafloor, and the multibeam data is available through the Marine Geoscience Data System and NOAA's National Center for Environmental Information.

The high-resolution bathymetry and backscatter data were used in 2015 by the NOAA's Office of Ocean Exploration and Research (OER) to plan and execute 18 *Deep Discover* ROV dives off the *Okeanos Explorer.* The maps produced by *Falkor* were critical to the success of NOAA's projects in the region.

The dives conducted by NOAA resulted in the discovery of six new high-density deep-water coral and sponge communities in the Monument. Additionally, rock samples taken during the NOAA dives will help untangle the complex geologic history of the Monument's northern end. Furthermore, biological specimens also collected during the NOAA dives include suspected new species or records for the Central Pacific, all of which are now housed at the Smithsonian. A dive conducted on the northern end of Bank 9, mapped for the first time by *Falkor*, resulted in the discovery of the largest sponge ever recorded on the planet, which is now the topic of a manuscript currently in review. NOAA plans to return to the PMNM's northern end in 2016, again using maps produced from *Falkor's* previous mapping expedition in the region.

125,000
SQ. KM OF SEAFLOOR MAPPED

6
NEW DEEP-WATER CORAL AND SPONGE COMMUNITIES DISCOVERED

THE IRON EATERS OF LOIHI SEAMOUNT HAWAII, CHIEF SCIENTIST BRIAN GLAZER

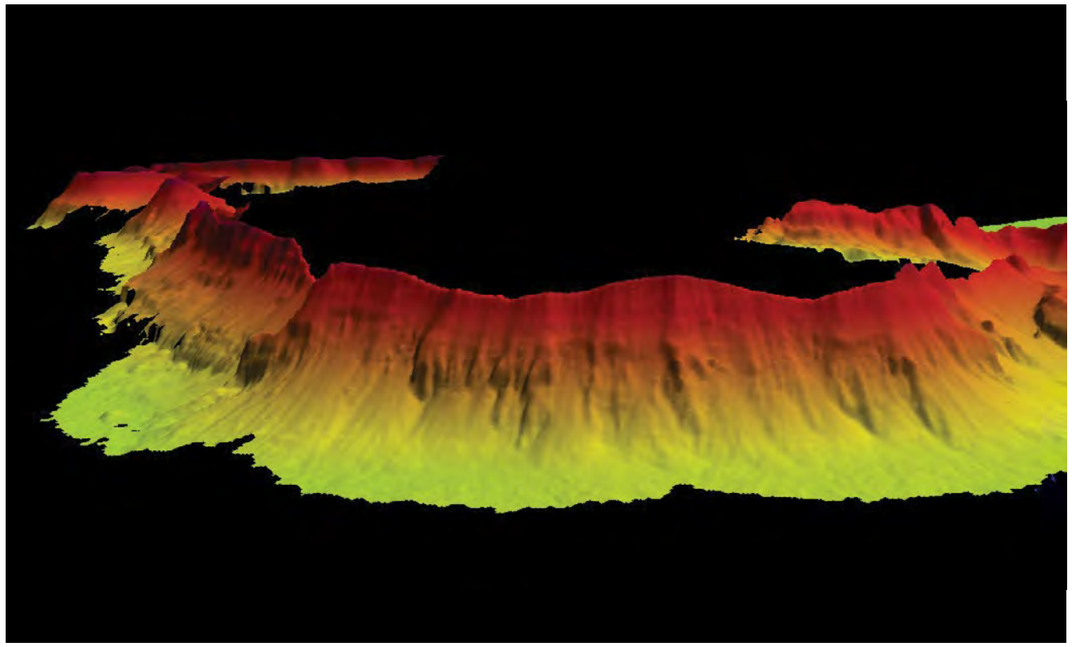
AUV Sentry is loaded onto Falkor after a deployment at Loihi Seamount.

In the summer of 2014, *Falkor* traveled to Loihi Seamount to explore the geology, chemistry and microbial communities found at the underwater volcano off the coast of Hawaii. Dr. Glazer and the science team discovered iron-oxidizing bacterial formations at 5,000 m below sea level, at the base of Loihi during the expedition. To fully understand the microbial activity around the seamount, the team recorded over 49,000 images collected by AUV *Sentry* and 150 km^2 of bathymetric mapping data. All seafloor images have been processed, and the scientists have begun to stitch together the photomoasic images to map the extent of seafloor iron-oxidizing microbes.

Interpretation of the high-resolution multibeam seafloor maps, coordinated with bottom photo identifications have led to several potential targets of interest for a return expedition with an ROV for fluid and microbial sampling efforts to better understand carbon and iron cycling in these deep ocean diffuse hydrothermal systems. Additionally, most geochemical analysis on water column samples collected from the Loihi Seamount have been completed and manuscripts for publication are being prepared. To date, researchers have presented results from this expedition at University departmental seminars and at the Goldschmidt Conference.

LOOKING BACK: RESEARCH UPDATES FROM 2014 EXPEDITIONS

THE MYSTERIES OF ONTONG JAVA WESTERN EQUATORIAL PACIFIC, CHIEF SCIENTIST MIKE COFFIN



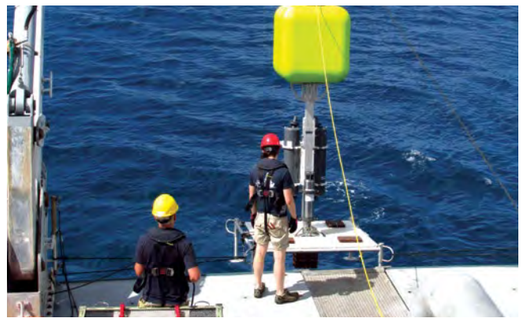
Bathymetric map of the mysterious Ontong Java atoll.

In 2014, an international team of scientists aboard *Falkor* explored aspects of the largest submarine igneous plateau on Earth, Ontong Java. The Ontong Java plateau has immense significance for understanding mantle processes, yet it still remains mysterious because of limited research in the remote area. *Falkor's* highly accurate navigation and state-of-the-art multibeam echosounders were two keys of the expedition's success, mapping a portion of the Plateau's eastern flank for the first time. Researchers created the first maps of Kroenke Canyon, revealing it to be the world's longest (>700 km) and most voluminous (>6,800 km^3) submarine canyon. The existence of a canyon was first suggested in the 1972 PhD thesis of Dr. Loren W. Kroenke. In 2014, 42 years later, the first mapping of the canyon was made possible by Schmidt Ocean Institute. These maps led scientists to presume that Kroenke Canyon originated in the vicinity of Ontong Java and Nukumanu atolls, and initiated when the atolls were volcanic islands. Additionally, the mapping revealed the seafloor morphology of Ontong Java (Solomon Islands) and Nukumanu (Papua New Guinea) atolls for the first time, which is critical for tsunami risk assessment. The bathymetric data will feed models of how wave energy will propagate shoreward across the plateau, improving the region's tsunami preparedness. A high-impact, initial manuscript on the findings as a result of the mapping is currently in preparation.

EXPLORING THE MARIANA TRENCH GUAM, CHIEF SCIENTISTS JEFF DRAZEN

The ghost fish found during the expedition; the deepest fish ever discovered at 8,143 m.

In November 2014, a team of scientists set out to explore the Mariana Trench through the deployment of Oceanlab and Schmidt Ocean Institute's newly built full-ocean-depth landers. The cruise completed the first ever comprehensive study of the ocean's greatest depths, completing an entire cross-section of the trench through 92 lander station deployments and recoveries. The landers deployed coring respirometers to measure the productivity of the mud, filmed the world's deepest fish at 8,143 m depth, and collected the deepest rocks ever from the Mariana forearc at 8,720 m depth. Following the cruise, many of the scientists participated in a specially-dedicated hadal session at the 14th Deep Sea Biology Symposium, in Aveiro Portugal, chaired by collaborating scientist Alan Jamieson. The team continues to analyze the depth distributions of the organisms found and a clear zonation pattern of the hadal scavenging fauna appears to be similar to other deep trenches. Scientists are currently teasing apart the factors that may govern these patterns, such as physiology and ecology. Additionally, sediment community oxygen consumption (SCOC) was found to be very high in the trench. Given that SCOC correlates strongly with food supply, this suggests there is more detrital food available in the trench than would be predicted from depth and the oligotrophic overlying water column. All of these findings support the project's hypothesis that trenches accumulate detrital food and are biological hotspots.



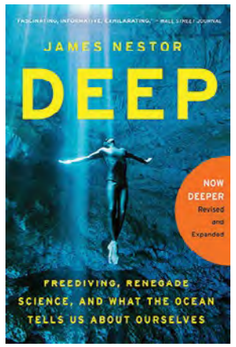
The Falkor crew launches the brand new full ocean depth lander off the aft deck Falkor.

LOOKING BACK: RESEARCH UPDATES FROM 2014 EXPEDITIONS

EXPANDING MARIANA TRENCH PERSPECTIVES GUAM, CHIEF SCIENTIST DOUG BARTLETT

A lander attracts amphipods in the Challenger Deep, Mariana Trench, at 10,920 m depth.

The second cruise to the Mariana Trench in 2014 focused on collecting trench bacteria, video, and samples of bottom-laying organisms. The project utilized the lander-elevator system and resulted in the first-ever sound recordings at such deep depths. High definition video, ambient sound, and animal samples were obtained from two locations within the Challenger Deep section of the Mariana Trench at depths ranging from 9,000 to 10,900 m. The lander system successfully collected highly abundant microbes and amphipods using a pressure-retaining sampling system. The amphipods were used for comparative mitrochondrion sequencing, metagenomics and metatranscriptomics, and morphological studies. Multimedia journalist, Cynthia Matzke used the footage collected in a documentary she is producing called Spiral Pacific. She also used the footage to conduct outreach around San Diego county, including a program for the Ruben H. Fleet Science Center's group of "SciTech Girls." The program is designed to encourage 4th and 5th grade female students in underserved schools to embrace math and science by learning from women active in STEM careers. A three-hour lesson plan was created called "Deep Space and Deep Sea: Exploring the Similarities and Differences." The program was given in five schools and reached over 100 enthusiastic female students. Additionally, James Nestor, author of *Deep*, revised the book to include a chapter on *Falkor's* cruise to the Mariana Trench and is now available in English, Chinese, German, Portuguese and Italian.



Deep. Written by James Nestor

PUBLICATIONS AND PRESENTATIONS RESULTING FROM CRUISE DATA

CONFERENCE POSTERS AND ACADEMIC PRESENTATIONS

Adams, N. (2015). Bathymetry of Kroenke Canyon. *Guest Lecturer*, Institute for Marine and Antarctic Studies Honours Seminar, University of Tasmania, Hobart, Tasmania, AUS.

Ajemian, M.J., Wetz, J.J., and G.W. Stunz. (2015). Fish Community Assessment on Artificial Reefs of the Western Gulf of Mexico: Potential Impacts of “Rigs-to-Reefs” Programs. *2nd Annual Texas Artificial Reef Symposium*, Corpus Christi, TX, USA.

Algar, C., et. al. (2015). A Reactive-transport Model Describing Methanogen Growth and Methane Production in Diffuse Flow Vents at Axial Seamount. *AGU Fall Meeting*, San Francisco, CA, USA.

Barclay, D.R., Buckingham, M.J. Bevans, D. (2015). Ambient Noise in the Challenger Deep, *Acoustics Week in Canada 2015*, Halifax, Canada.

Bartlett, D. (2015). Technologies Associated with Collecting Deep-sea Life. *Microbiology and Biogeochemistry of the Deep Sea and the Deep Biosphere Workshop*, Shanghai, China.

Bartlett, D. (2015). *Microbial Diversity in the Deep Sea. Microbiology and Biogeochemistry of the Deep Sea and the Deep Biosphere Workshop*, Shanghai, China.

Bartlett, D. (2015). Microbial Trophic Dynamics as a Function of Depth. *Microbiology and Biogeochemistry of the Deep Sea and the Deep Biosphere Workshop*, Shanghai, China.

Bartlett, D. (2015). Deep Subsurface Microbiology. *Microbiology and Biogeochemistry of the Deep Sea and the Deep Biosphere Workshop*, Shanghai, China.

Bartlett, D. (2015). Genomics of Piezophiles and Other Deep-sea Microbes. *Microbiology and Biogeochemistry of the Deep Sea and the Deep Biosphere Workshop*, Shanghai, China.

Bartlett, D. (2015). Microbial Life in Hadal Trenches: Technology, Diversity, and Function. *Marine Molecular Ecology Gordon Research Conference,* Hong Kong, China.

Bartlett, D.H., Tam, J, Kwan, T, and Peoples, L. (2015). *Microbial Diversity in the Mariana and Kermadec Trenches. Deep-Sea Biology Symposium 2015*, Aveiro, Portugal.

Bartlett, D. (2015). Microbiology of the Kermadec, Tonga, and Mariana Trenches. *Guest Lecturer*, University of Tokyo, Japan.

Bartlett, D. (2015). Progress and Future of Deep-Sea Microbiological Research and Development. *Guest Lecturer*, University of Tokyo, Japan.

Bartlett, D. (2015). Microbial Life in Ultra-deep Ocean Habitats of the Piezosphere. *Guest Lecturer*, Renssellaer Polytechnic Institute, Troy, New York, USA.

Bartlett, D. (2015). Hyperpiezophile Research. *Ocean Worlds Meeting 2015*, Washington, DC, USA.

Bartlett, D. (2015). Overview on Adaptation Mechanisms of Extremophiles. *Sloan Foundation Deep Carbon Observatory Workshop on Extreme Biophysics*, Washington, DC, USA.

Butterfield, D.A. and M. Lilley. (2015). Hydrothermal Discharge: Chemistry-Volatiles-Heat. NOVAE - *Networked Observations and Visualizations of the Axial Environment*, Seattle, WA, USA.

Cardona, Y., Ruiz,D., Baums, I.B., and A. Bracco. (2015). Potential Connectivity of Coldwater Black Coral Communities in the Northern Gulf of Mexico. *2015 Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Houston, TX, USA.

Cardona, Y., Ruiz,D., Baums, I.B., and A. Bracco. (2015). Potential Connectivity of Coldwater Black Coral Communities in the Northern Gulf of Mexico. *XVI Congresso Latino Americano De Ciencias Del Mar- Colacmar y XVI Seminario Nacional de Ciencias y Tecnologias del mar*, Santa Marta, Colombia.

Coffin, M.F., Adams, N.J., Whittaker, J.M., Lucieer, V.L., Heckman, M., Ketter, T., Neale, J., Reyes, A.J., and A. Travers. (2015). The World’s Largest Submarine Canyon - Kroenke Canyon in the Western Equatorial Pacific. *Poster Presentation at American Geophysical Union Fall Meeting*, San Francisco, CA, USA.

Cordes, E.E. (2015). Understanding the Deep Sea in the Anthropocene: Oil Spills and Ocean Acidification Threaten Deep Water Corals in the the Gulf of Mexico. *Guest Lecturer*, Lamont-Doherty Earth Observatory, Palisades, NY, USA.

Dannenberg, R., Baums, I., Ruiz, D., and C. Fisher. (2015). Deep Sea Coral-associated Bacterial Community Composition Analysis Using 16S rDNA. *2015 Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Houston, TX, USA.

Drazen, J., Nunnally, C., Gerringer, M., Fryer, P., Yancey, P., Jamieson, A., Linley, T., Shank, T., et. al. (2015). Studying the Biology of the Mariana Trench, the Deepest Place on Earth. *Guest Lecturer,* Science Cafe, Honolulu, HI, USA.

Drazen, J., Sackett, D., Moriwake, V., Misa, W., Moore, C., Demarke, C., and C. Kelley. (2015). Evaluating Bottomfish Restricted Fishing Areas Using Stereo Video Cameras: An Update on Recent Results. *2015 NOAA Bottomfish Workshop*, Honolulu, HI, USA.

Drazen, J., Fryer, P., Jamieson, A., Mayor, D., Piertney, S., Yancey, P., Shank, T., Demopoulos, A., and C. Young. (2015). Studying the Biology of the Mariana Trench, the Deepest Place on Earth. *Guest Lecturer*, University of Guam Marine Laboratory, Guam, USA.

Fisher, C. (2015). Mechanisms of Impact from the Deepwater Horizon Oil Spill to Corals and Associated Communities in the Deep Gulf of Mexico. *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Houston, TX, USA.

Fisher, C. (2015). Anthropogenic impact to the Earth’s Final Frontier. *Guest Lecturer*, Rochester Institute of Technology, Rochester, NY, USA.

Fisher, C. (2015). Covered with Oil in the Ivory Tower. G*uest Lecturer*, University of South Florida, Tampa, FL, USA.

Fisher, C. (2015). Update on the Status of Deep Water Corals Impacted by the Deepwater Horizon Oil Spill. 1*4th Deep-Sea Biology Symposium*, Aveiro, Portugal.

Fortunato, C.S. and J.A. Huber. (2015). Understanding the Diversity of Microbes across Gradient-driven Environments, from Estuaries to the Deep-sea. *Guest Lecturer*, Friday Informed Seminar Hour, Bridgewater State University, Bridgewater, MA, USA.

Fortunato, C.S. and J.A. Huber. (2015). Comparing Chemolithoautotrophic Subseafloor Communities Across Gradients Using Meta-omics and RNA-SIP. *AGU Fall Meeting*, San Francisco, CA, USA.

Fryer, P. (2015). Three Good Reasons to Care About the Bottom of the Ocean. *Guest Lecturer*, Hanauma Bay Education Program, Hanuama Bay, HI, USA.

Gerringer, M., Linley, T., Jamieson, A., Drazen, J., Scott-Murray, A., and D. Stein. (2015). A Newly Discovered Hadal Liparid (Pisces: Liparidae) from the Mariana Trench. *Marine Alliance of Science and Technology Scotland Annual Meeting*, Glasgow, Scotland.

Gerringer, M.E., Yancey, P.H., Davydov, D., and J.C. Drazen. (2015). Trends in Metabolic Enzyme Activities and Pressure Related Changes in Maximum Reaction Rate of Lactase Dehydrogenase in Abyssal and Hadal Fishes. *14th Deep-sea Biology Symposium*, Aveiro, Portugal.

Giorli, G. (2015). Deep Diving Odontocetes Foraging Strategies and Their Prey Field as Determined by Acoustic Techniques. *Guest Lecturer*, Universita' di Pisa, Pisa, Italy.

Girard, F., Berlet, S.P., and C. Fisher. (2015). Understanding the impact of the Deepwater Horizon Oil Spill on Coral Communities in the Deep Gulf of Mexico: The Importance of Symbiosis. *Gulf of Mexico Oil Spill & Ecosystem Science Conference*, Houston, TX, USA.

Hananto, N., Singh, S., Tapponnier, P., Sieh, K., Carton, H., Leclerc, F., Carson, S., Wei, S., Nugroho, A., Avianto, P., Gemilang, W., Duperray, R., Permana, H., et. al. (2015). Evidence of Frontal Rupturing in the Mentawai Gap, SW Sumatra, Newly Acquired High-Resolution Reflection and Bathymetry Data. *American Geophysical Union Fall Meeting*, San Francisco, CA, USA.

Hicks, D. et. al. (2015). 3D Undersea Adventure (featuring underwater video relic of coral reef banks in the southern Gulf of Mexico taken from a Remotely Operated Vehicle deployed from *Falkor* of the Schmidt Ocean Institute). *Guest Lecturer*, Oceanarium, Gladys Porter Zoo, Brownsville, TX, USA.

Hicks, D. et. al. (2015). 3D Marine Biology (featuring underwater video relic of coral reef banks in the southern Gulf of Mexico taken from a Remotely Operated Vehicle deployed from *Falkor* of the Schmidt Ocean Institute). *Guest Lecturer*, Lee H. Means Elementary School, Harlingen, TX, USA.

Hicks, D. et. al (2015). Texas Coral Reefs (featuring 3D underwater video relic of coral reef banks in the southern Gulf of Mexico taken from a Remotely Operated Vehicle deployed from *Falkor* of the Schmidt Ocean Institute). *Guest Lecturer*, University of Texas at Brownsville (Upward Bound Program), Brownsville, TX, USA.

Huber, J.A. (2015). Microbes, Fluids and Rocks: Life Beneath the Seafloor. *Guest Lecturer*, University of Tennessee, Knoxville, TN, USA.

Huber, J.A. (2015). Carbon Cycling Beneath the Seafloor. *Gordon Research Conference on Applied and Environmental Microbiology*, Mount Holyoke, MA, USA.

Huber, J.A. (2015). How Geochemical Landscapes Shape Seafloor Microbial Communities at Deep-sea Hydrothermal Vents. *Gordon Research Conference on Chemical Oceanography*, Holdren, NJ, USA.

Huber, J.A., Juniper, K., and J.F. Holdren. (2015). Microbial and Viral Research at Axial Seamount. *NOVAE - Networked Observations and Visualizations of the Axial Environment*, Seattle, WA, USA.

Ivey, Greg. (2015). Ocean-coral Reef Connectivity: Physics Meets Biology. *Ecole Normale Superieure de Lyon*, Lyon, France.

Ivey, Greg. (2015). Ocean - reef Interactions, Scott Reef, Western Australia: Physics Meets Biology. *Scottish Association for Marine Science (SAMS)*, Oban, Scotland.

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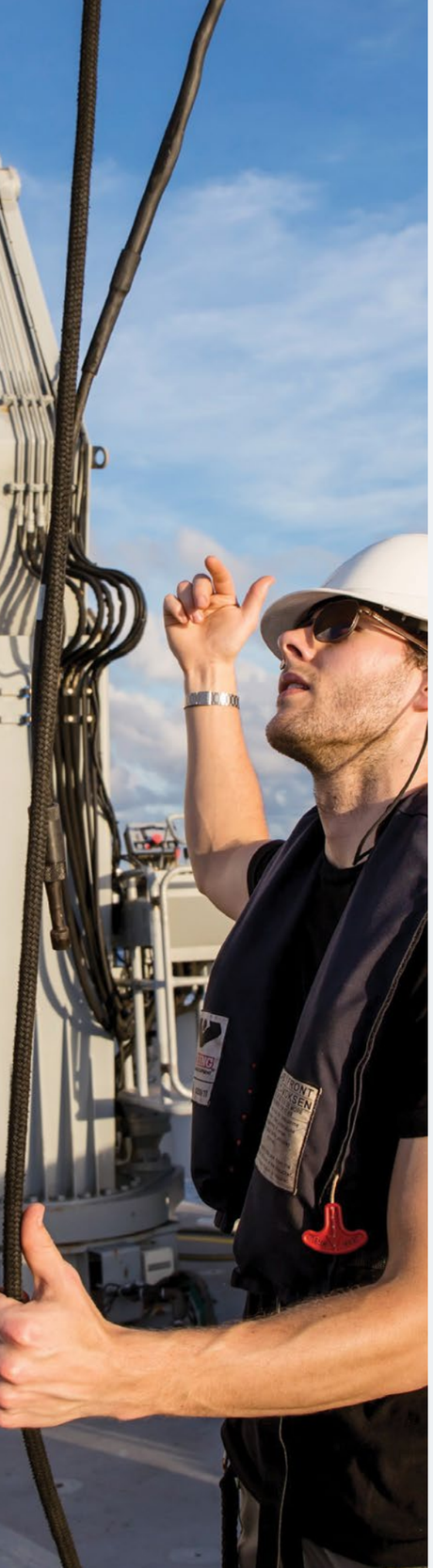

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