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A Deep Cabled Observatory: Biology and Physics in the Abyss

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The ALOHA Cabled Observatory (ACO) is the deepest operating observatory on the planet, providing power and communications to scientific instruments on the seafloor. In the future, ACO will add water column measurements, from the seafloor to the surface, using moorings and undersea vehicles. Recent results from video monitoring of deep-sea life and from temperature sensors illustrate the benefit of and need for long-term, sustained, continuous sampling in this abyssal context. The observatory is located at Station ALOHA (A Long-Term Oligotrophic Habitat Assessment), 100 kilometers north of Oahu, at 4728-meter water depth (Figure 1, top).

Station ALOHA is the site of the Hawaii Ocean Timeseries (HOT) program. Quasi-monthly HOT ship visits to ALOHA have contributed the longest full-ocean-depth physical, chemical, and biological data sets in this oligotrophic "desert" ocean setting, one that is representative of roughly 70% of the world ocean (see http://aloha.manoa.hawaii.edu). ACO, using a repurposed submarine telecommunication cable, provides a continuous presence, enabling routine and adaptive robotic sampling of the ocean, complementing the ship-based effort and other projects attracted to ALOHA. The ACO "node" and instrumentation were installed in June 2011 from the R/V *Kilo Moana* using the remotely operated vehicle *Jason*. The project Web page (http://aloha.manoa.hawaii.edu/ACO) gives details on the observatory and real-time data.

Observing Deep-Sea Life

During 6 weeks of video monitoring using an Axis surveillance camera, deep-sea life activity was observed regularly, with an organism moving past the video camera roughly every 40 minutes (~450/month). Fifteen species were identified, including ctenophores, aristeid shrimp, benthic shrimp (unidentified), polychaetes, an elasipodid sea cucumber, and several fish (*Bassozetus* sp., melamphaeid, ophidiid, *Bathysaurus mollis,* and *Coryphaenoides yaquinae*); shrimp and other invertebrates make up 93% of observations.

The most visually striking observation was a deep-sea lizard fish attacking an aristeid shrimp (Figure 1, bottom). ACO scientists knew from diet studies and the behavior of related shallow-living species that the lizard fish is an ambush predator, but it is infrequently observed in Hawaii or elsewhere, unlike more abundant rattails. This is the first observation of this behavior, allowing an evaluation of swimming kinematics.

The detection of such an infrequent event (~1 second in 600 hours) is possible only with a cabled observatory providing continuous and substantial power for lights and camera and real-time communications for the voluminous video data (ACO provides 1200 watts and 100 megabits per second). These results have ramifications for designing future biological sampling of the abyssal ocean, suggesting that continuous or semicontinuous observation can augment more traditional periodic observation systems, for example, with the use of baited cameras (J. Drazen and A. Fleury, personal communication, 2014)

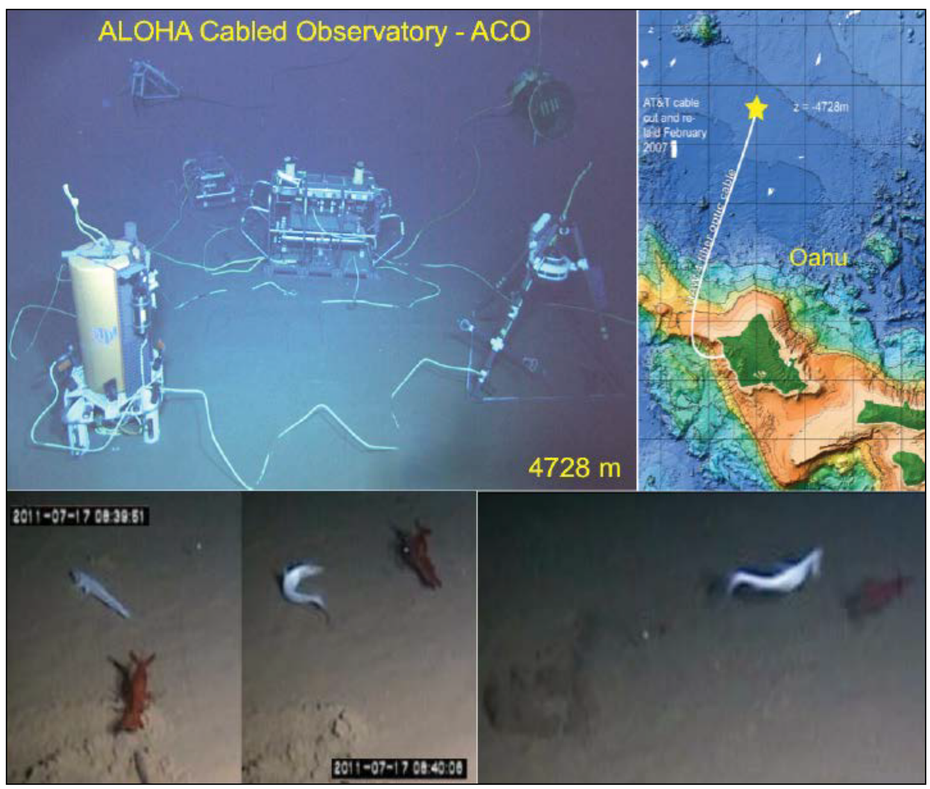

Fig. 1. (top right) The ALOHA Cabled Observatory (ACO) is at Station ALOHA (A Long-Term Oligotrophic Habitat Assessment; 22°45′N, 158°W, 4728-meter water depth), north of Oahu, Hawaii. (top left) Shown are the main "node" with acoustic Doppler current profilers and conductivity-temperature sensor, camera, and lights (right); secondary node with conductivity-temperature-depth-oxygen sensor and fluorometer sensors (left); junction box with hydrophone and pressure (just left of node); and (pasted in the background) the cable termination (left) and thermistor array/acoustic modem (right). (bottom) The video frames show a lizard fish attacking an aristeid shrimp, a rare event lasting about 1 second.

By B. M. Howe

Temperature Measurements

Data from a temperature-conductivity sensor also exemplify several aspects of observatory science. Because a suspected connecting cable fault prevents access to the primary pumped conductivity-temperature-depth (CTD) sensor, observatory scientists have used the secondary temperature sensor (Seabird SBE 37) on the observatory node, located approximately 1 meter above the power supply. Not unexpectedly, it is affected by thermal plumes; fortunately, the intermittent plume signals can be removed with median filtering, leaving a clean temperature series.

Daily mean filtered temperatures show ~20 millikelvin cold events, dynamic oscillations, and slow recovery (months to years). A working hypothesis to explain these observations is that cold water from the Maui deep basin to the east flows westward over the Oahu Seamounts sill into the Kauai deep basin with Station ALOHA and ACO. Oscillations are set up that are likely a sloshing mode and/or bathymetrically trapped edge waves with timescales of days; other data indicate bottom intensification with a scale height of about 100 meters. Furthermore, in each of the four events that have occurred since installation in June 2011, the salinity has varied by about 0.001 practical salinity unit, indicating that somewhat different water masses are involved. A more complete analysis is ongoing.

Such events are likely occurring in many other abyssal locations, causing intense mixing in addition to that caused by internal tides and other phenomena. The magnitudes and timescales of the variations have strong implications for climate studies in regard to observing the deep ocean and suggest that these types of observations have the potential to elucidate deep-water dynamics.

The various temperature measurements at this location (ACO, HOT, moored thermistors) show good agreement (0.3 millikelvin root-mean-square). This is a remarkable result given the three independent systems, truly a tribute to the decades of effort that have gone into the sensor development and calibration methodology. While highly aliased sampling of these events has occurred over the years from the shipboard CTD profiles (10 per year), these events are now well resolved with the cabled observatory infrastructure (~3 per second; R. Lukas and F. Santiago-Mandujano, personal communication, 2014).

Other Science Measurements and Future Work

Additional science results are derived from the bottom-mounted hydrophone and acoustic Doppler current profiler. For example, passive acoustic data are used to study marine mammals, soundscapes, anthropogenic sound (e.g., shipping), wind and rain, surface gravity wave directional spectra, and lithospheric wave propagation. Current measurements reveal significant deep flows (~5–10 centimeters per second), dominated by baroclinic tidal components (E. Firing, personal communication, 2012).

ACO is an example of a modest-scale and cost-effective cabled observatory that reuses a retired submarine telecommunication system. The first annual maintenance cruise was just completed in November 2014, with the installation of a video camera with lights and a basic sensor package. Possible future work could address understanding the ALOHA oligotrophic carbon cycle and ecosystem from surface to bottom, particularly with regard to temporal dynamics, as well as the biophysical interactions, including those due to mixing. The community is encouraged to propose experiments to use and augment this infrastructure to contribute to and benefit from the science conducted at the unique Station ALOHA.

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