Benthic Event Detectors: a Novel Instrument for Characterizing Sediment Transport Events

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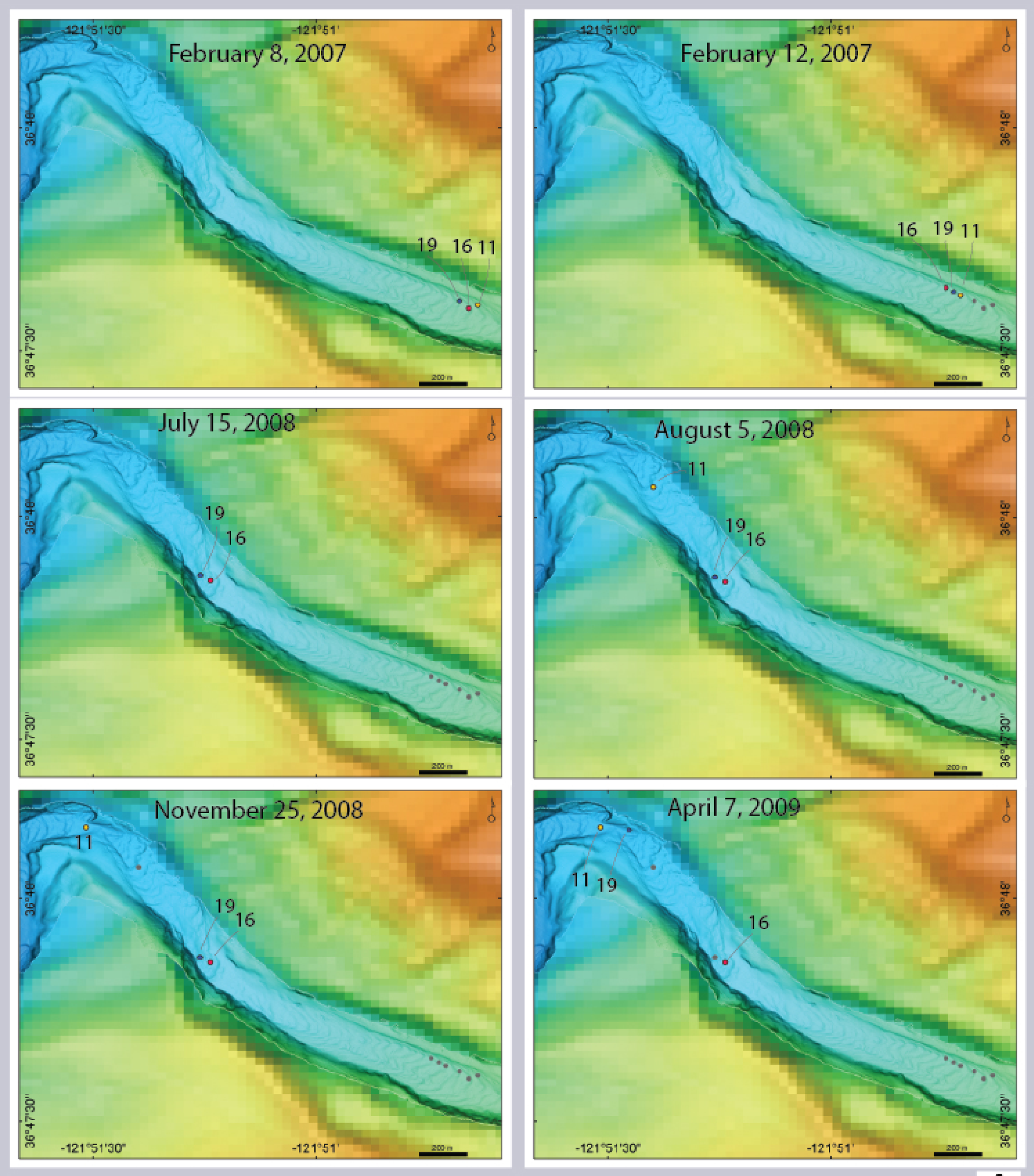
Introduction

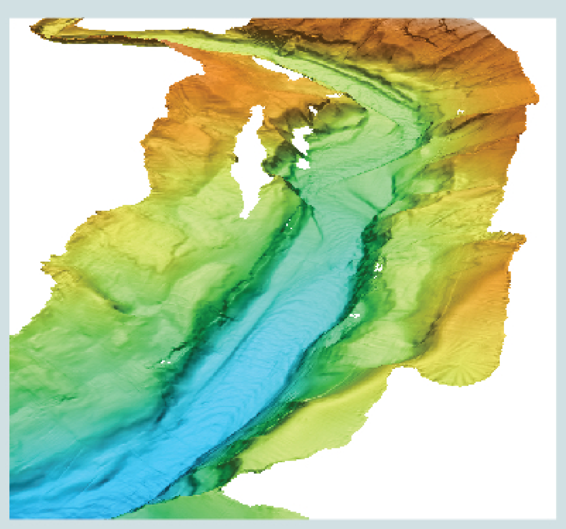
The Benthic Event Detector (BED) project is focused on developing instrumentation to help understand the processes by which sediment moves on the floor of submarine canyons. Submarine canyons, such as Monterey Canyon, are conduits through which sediment, eroded from the continents, moves from shallow waters into the deep-sea. These canyons carry a substantial proportion of all the sediment transported onto the ocean floor. However, the processes that occur within submarine canyons are poorly understood in part because of the lack of appropriate instrumentation.



A

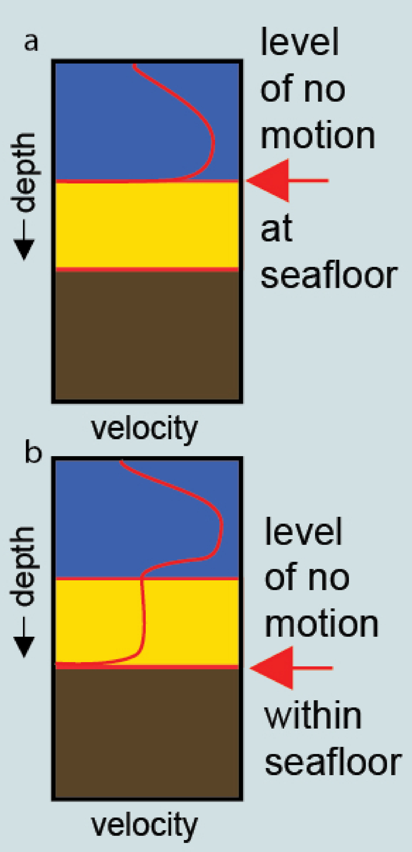
Past studies show episodic events

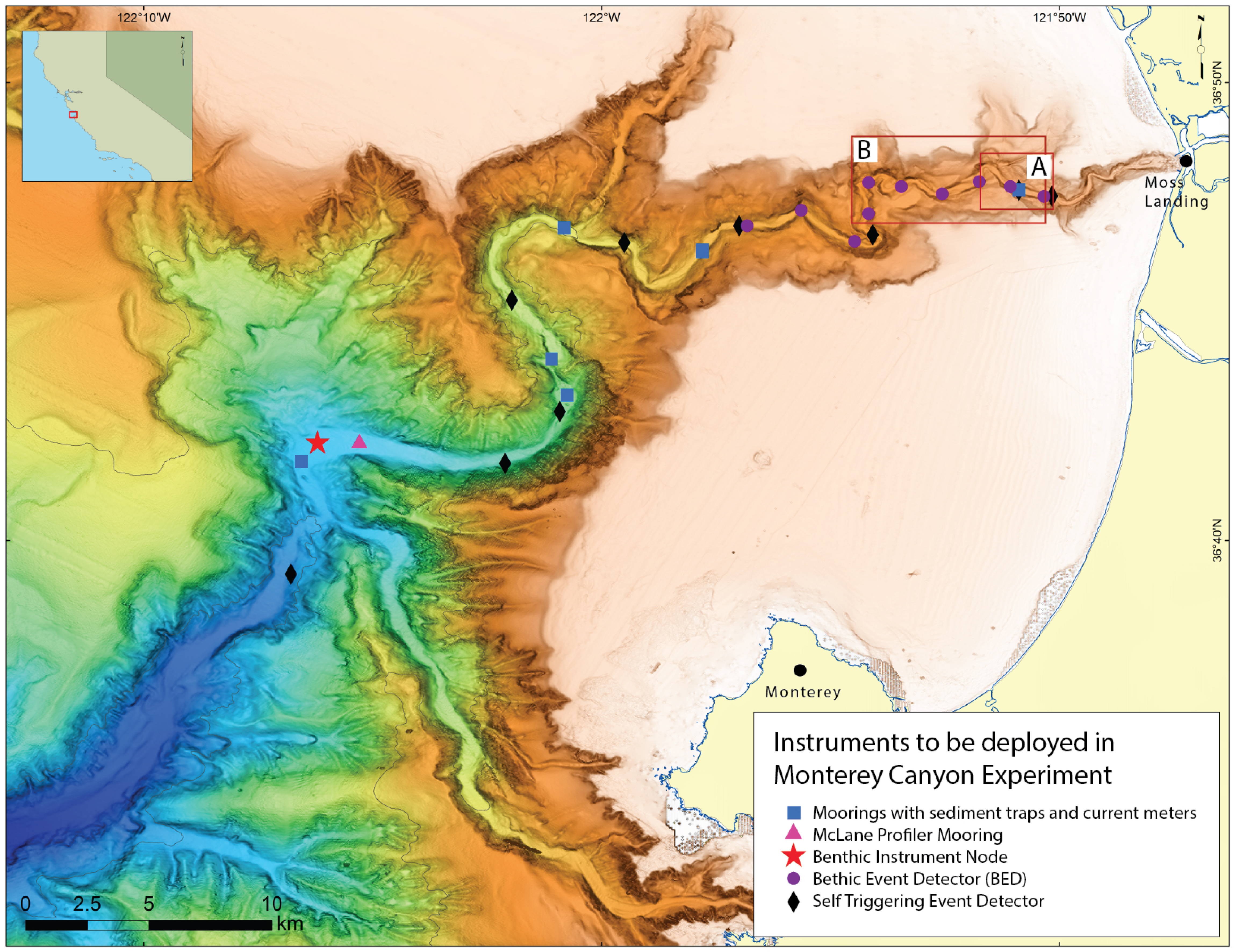
Over the last 14 years efforts by MBARI and other groups working in Monterey Canyon have shown that sediment transport in the canyon is primarily associated with relatively brief events. A previous study captured the episodic movement of boulder-sized monuments (see below), which resulted in approximately 1 km of down-canyon displacement over a two year time span (see maps above (Paull et. al 2010) and main map inset A). This experiment only illustrated the net consequence of the movement and provided no information about the timing, rate, nature, and frequency of that movement.



Capturing the nature of sediment movement

The existing paradigm is that high-energy underwater avalanches of sediment, called turbidity currents, transport boulders over the bottom either in suspension, or as bedload (see diagram (a) to the right). However, previous measurements of large objects deployed on the floor of Monterey Canyon suggest that they may be carried downslope 'within the seafloor' as sections of the seafloor slump downslope. The key question is whether large objects are transported as bedload over the seafloor, or whether they ride down-canyon on or entombed in a carpet of fluidized seafloor sediments (see diagram (b) to the right). These two models imply two different motions: in the former the object will rotate and bounce along the seafloor, whereas in the latter the object will slide down-canyon as if it were riding in a bobsled (see above). To differentiate between these mechanisms a BED will record the motions of an object as it moves down canyon during a flow event. An individual BED will provide detailed data on when an event occurred, how far and fast it moved and the nature of its motion. An array of BEDs deployed simultaneously within the canyon will be used to understand how much of the canyon is affected during an individual flow event.



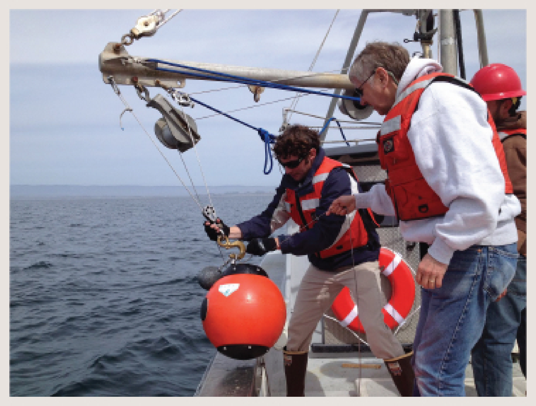


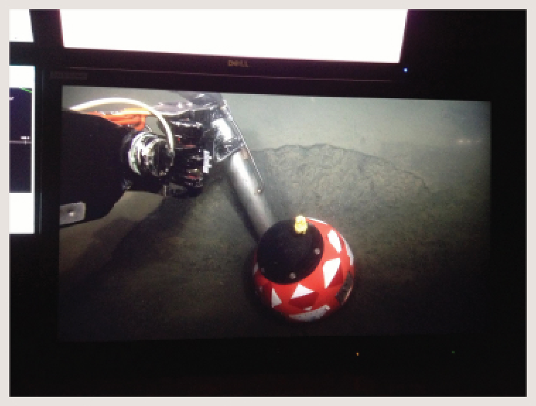
BEDs, part of a Monterey Canyon wide experiment

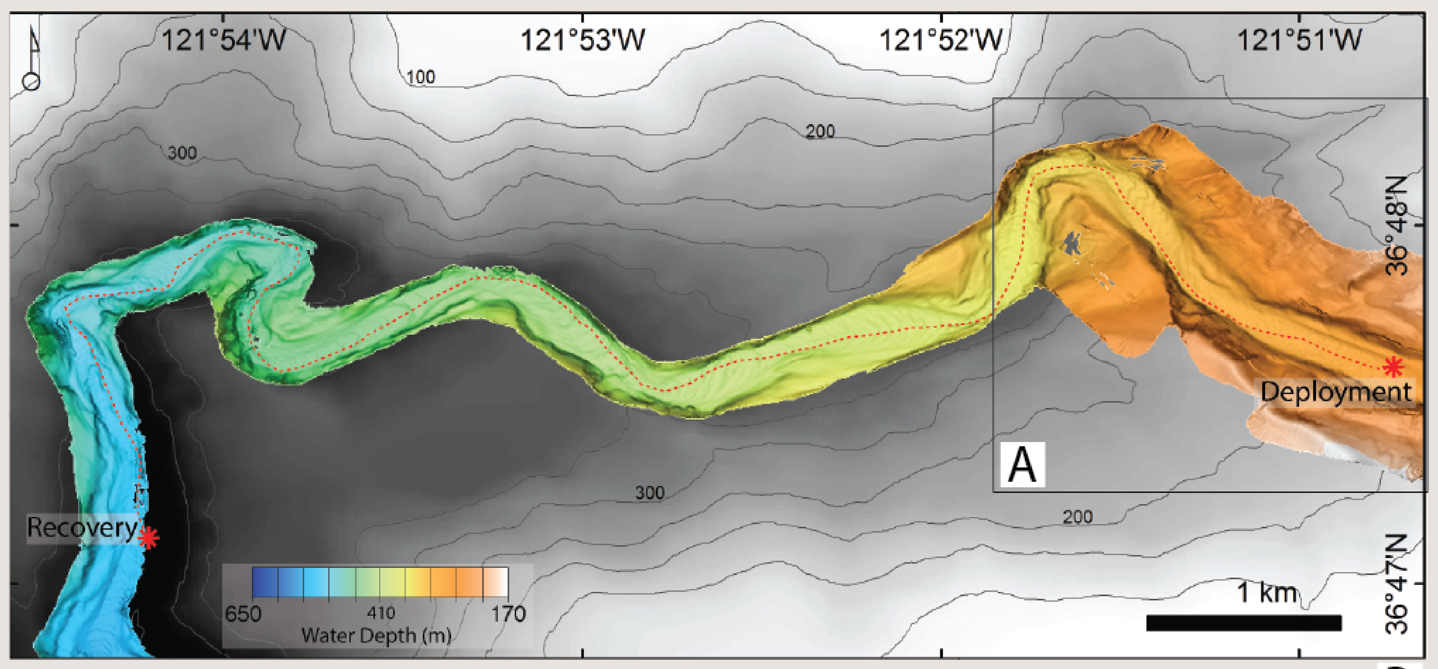
Monterey Canyon is an excellent place to study submarine canyons because it's known to be an active sediment conduit and its proximity to MBARI provides easy access. During 2015-2017 there will be a coordinated experiment funded by MBARI, the British Natural Environment Research Council, and U.S. Geological Survey with the goal of directly documenting the passage of a sediment density flow down through the axis of Monterey Canyon. The strategy is to deploy multiple instrumental assets in the canyon simultaneously. In this experiment direct measurements will be made of the physical properties of the water and the sediment bed during episodic events to document the effects of their passage through the canyon system. The BED instruments are one of the novel sensors that will be utilized in this experiment. The ability of the BEDs to record the start and end times of each event will allow the data to be correlated with other instruments in the canyon and will help provide a complete picture of the processes occurring throughout the length of the canyon during individual events.

A test run

The first deployments of a BED occurred in the winter and spring of 2013 at 300 m water depth (see photos to the right). The initial tests validated event detection, acoustic communication between a ship and a BED, and also demonstrated that geolocation by acoustic ranging is feasible. During this deployment the BED traveled nearly 9 km down the canyon's axial channel (see below and main map inset B). Event data were downloaded using the modem and showed that the BED was swept down canyon on June 1st in a ~50 minute long sediment transport event.







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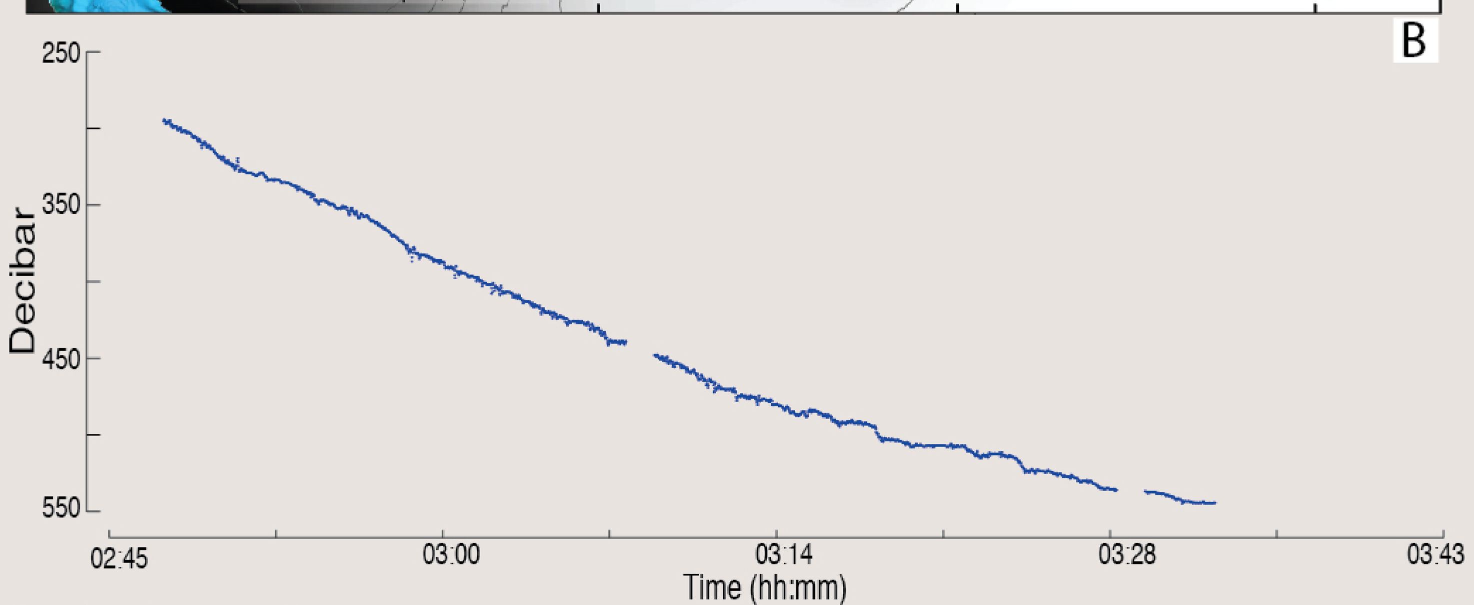


Initial results

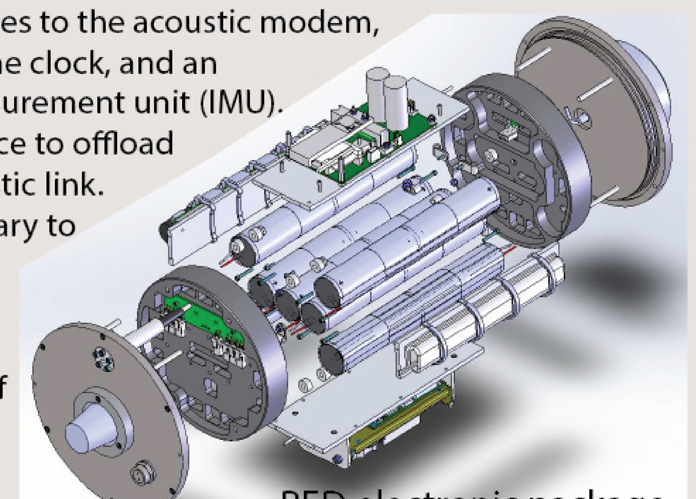
Plot above shows pressure change with time during the event recorded in the initial BED test deployment. Other sensor data show both rolling and sliding motions which will be displayed on a monitor during the poster presentation.

BEDs

BEDs are designed to do little until triggered by an initial acceleration, which inevitably marks the beginning of an event. Once triggered the instrument 'wakes-up' and starts to record any continuing accelerations, changes in orientation, and pressure (depth) at a high frequency until the accelerations stop. From these data the nature of movement of the instrument can be reconstructed.

Electronics and Software

The BED software interfaces to the acoustic modem, pressure sensor, a real-time clock, and an off-the-shelf inertial measurement unit (IMU). It also provides an interface to offload event data over the acoustic link. Accurate timing is necessary to correlate event start/end times with other instruments or BEDs deployed in other areas of the canyon.



BED electronic package

syntactic foam sphere BED housing

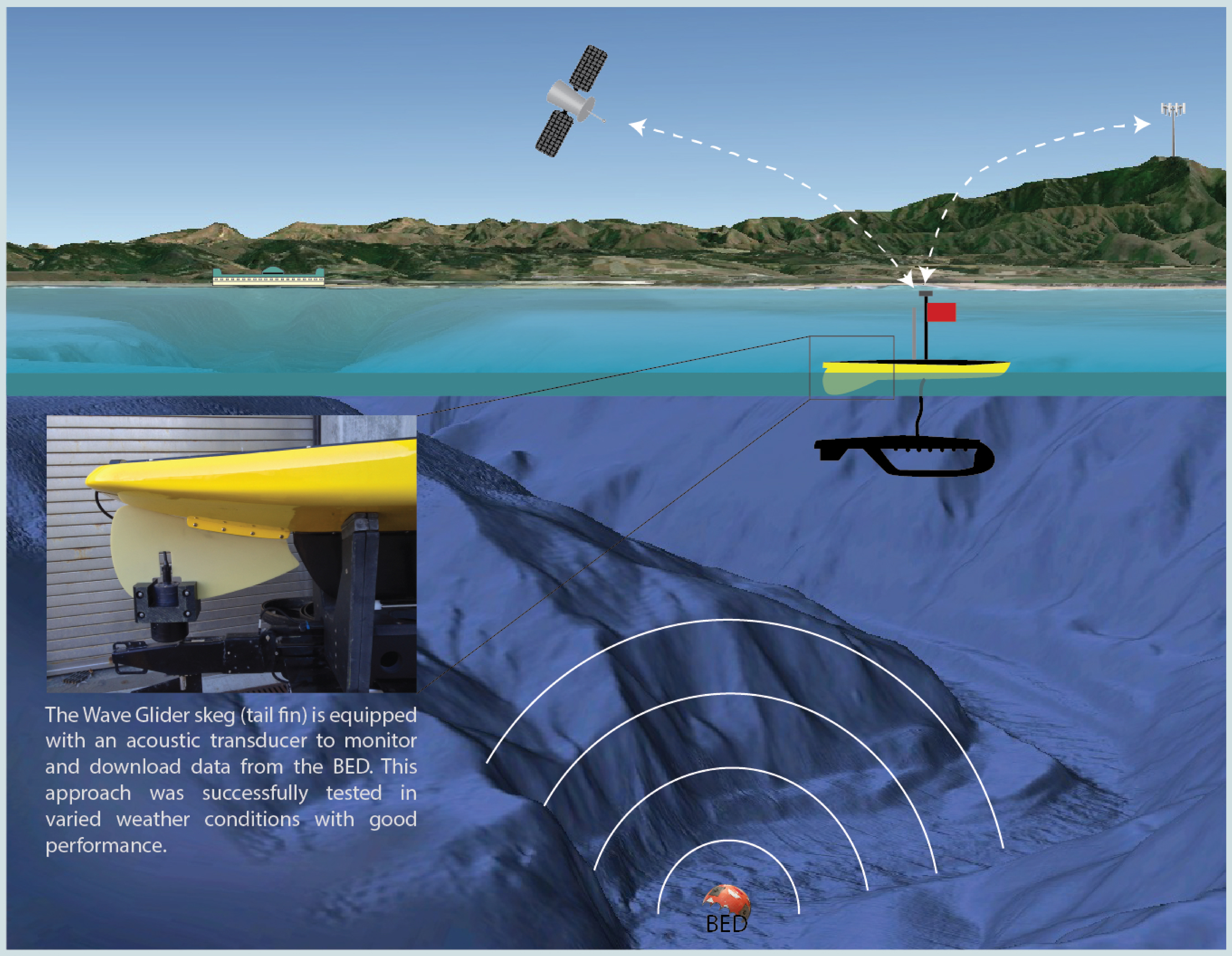
The BED housing is made of carbon fiber with titanium endcaps and is designed to be placed into various host containers such as the syntactic foam sphere (seen above) to allow scientists to alter the shape, density, and size of the overall instrument package.

Present data recovery method

The BED design does not depend on physically recovering the instrument, but instead the data recorded by the BED can be transmitted acoustically to a mobile receiver. Currently, the mobile receivers can be deployed from a boat or carried on an ROV. Using a boat to communicate with an array of BEDs over a long period of deployment can be logistically challenging (see above), time consuming and costly.

Long term data recovery method

In 2014 the BED project is focused on developing methods to use Wave Gliders as mobile hotspots to both locate and download event data. An acoustic transducer will be carried by a Wave Glider that is positioned nearby and will be used to monitor BED movement and recover data from the instrument (see below). This approach will enable BED deployment in remote environments where regular visitation with a boat is impractical.



The Wave Glider skeg (tail fin) is equipped with an acoustic transducer to monitor and download data from the BED. This approach was successfully tested in varied weather conditions with good performance.

References

Paull, C.K., Ussler, W., III, Caress, D.W., Lundsten, E., Barry, J., Covault, J.A., Maier, K.L., Xu, J.P., and Augenstein, S., 2010, Origins of large crescent-shaped bedforms within the axial channel of Monterey Canyon: Geosphere, v. 6, p. 755–774, doi: 10.1130/GES00527.1.