Measurements of near-bottom sediment resuspension and transport by internal tides in Monterey Submarine Canyon: Initial results from the Coordinated Canyon Experiment

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Abstract

A six-month deployment of subsurface moorings in 300 and 800 m water depths as part of the Coordinated Canyon Experiment reveals new insights into the transport of sediment in the bottom-boundary layer of Monterey Canyon, offshore central CA, USA. Downward-facing acoustic Doppler current profilers mounted 10 m above the seabed record high-resolution profiles of currents and suspended sediments down to 1.5 m above seabed. Net near-bottom flux was in opposing directions at the two sites; net flux was down canyon at the 300-m site, whereas net flux was up-canyon at the 800-m site. Much of the flux is due to strong internal tides, which have been shown to intensify toward the seabed. One particularly strong internal tide event on 30 November 2015 was characterized by currents in excess of 1 m/s at the seabed that were oriented up-canyon at the 300-m site. Seafloor shear stress induced by the currents was above critical for medium silt during 40 percent of the record at the 800-m site, and during 44 percent of the record at the 300-m site, while shear stress was above critical for fine sand during 6 percent and 12 percent of the records at the 800-m and 300-m sites, respectively. These results explain why fine-grained sediment does not appear to accumulate in the thalweg of the canyon, and suggest convergence in the section of the canyon between 300 and 800 m water depth. The fact that currents are often strong enough to move fine sand and medium silt suggest that internal tides may contribute to the reorganization of sand waves that are consistently observed along the canyon thalweg.

Monterey Coordinated Canyon Experiment

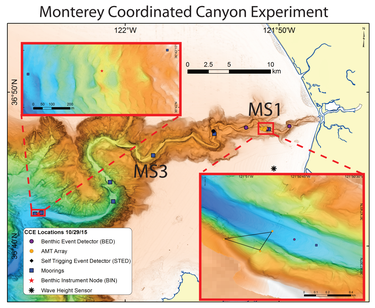
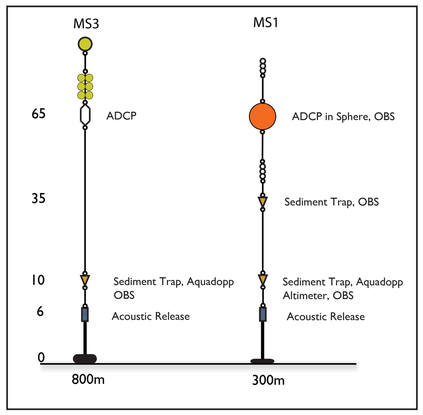


Figure courtesy of Eve Lundsten, MBARI

Mooring Design

- A 300 kHz RD Instruments ADCP was mounted 65mab at each site, collecting profiles of currents at 30s intervals.
- MS1 and MS3 had Aquadopp profilers at 10mab to acheive better resolution of currents near the seabed, along with sediment traps and optical back-scatter for suspended sediment measurements.
- MS1 also had a 450kHz altimeter/backscatter to obtain range to bottom measurements

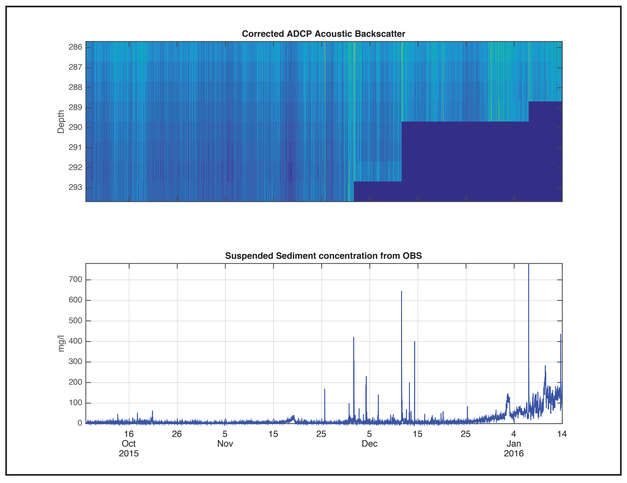


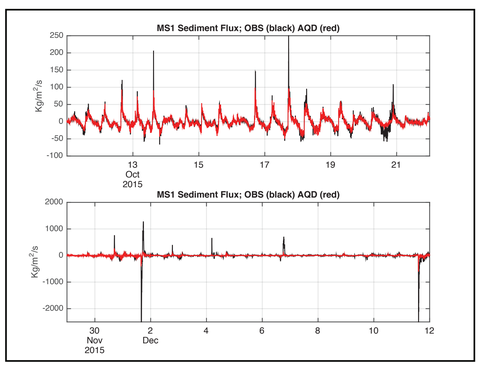
Methods

- First, the Optical Backscatter (OBS) measurements were calibrated in the laboratory using sediment from a seafloor sample in the axis of the canyon at MS2. This then gives a time series of suspended sediment concentration 10mab in mg/l.
- Backscatter from the acoustic profiling instruments need to be corrected for attenuation of sound in water such that data from each bin can be comparable to one another. A simple formula used by Thevenot (1993) and Gartner (2004) allows for the correction of attenuation by water but does not account for attenuation by suspended sediment itself.
- Finally, a regression between backscatter and OBS measurements (in mg/l) gives a calibration of backscatter into a concentration in mg/l. While there are difficulties with this approach, it allows for an examination of relative magnitudes of suspended sediment flux between sites in the very near-bottom layers that has previously not been possible, and to understand processes most responsible for observed fluxes.

Results - Data

- A major turbidity current occurred on 15 January, which broke mooring MS1 loose and therefore truncated the deployment
- There were also several slump events prior to the turbidity current, which brought large amounts of sand to the mooring site
- The OBS sensor began to biofoul after 25 December, therefore only data up until this point were used to run calibrations of the acoustic backscatter.

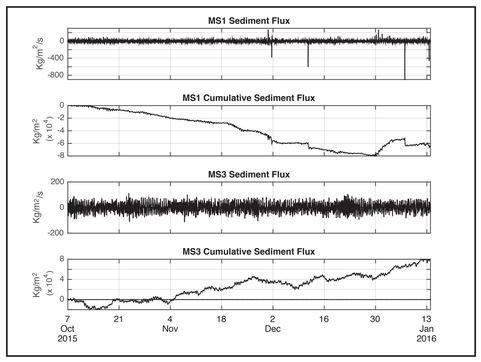




Results - Calibrations

- Calibration of OBS gave good results overall, though there was a discrepancy between concentrations from calibrated OBS and backscatter, primarily during the larger events.
- This is most likely due to the fact that the two instruments respond to variability in grainsize differently.
- Nevertheless, the calibration of backscatter allows for estimates of near-bottom transport after biofouling of the OBS.

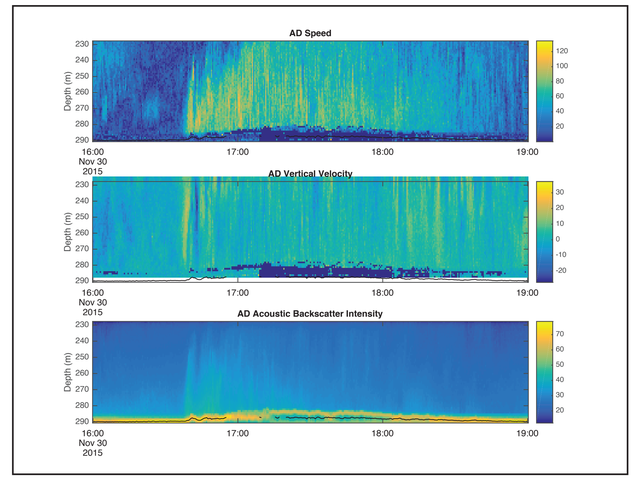
Results - Fluxes

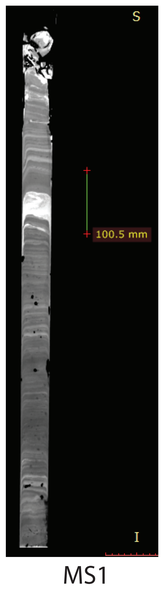


- Near-bottom suspended sediment flux was predominantly up-canyon at MS3 and down-canyon at MS1, with some periods of reversal.
- Up-canyon flux does occur at MS1, primarily during strong internal tide events
- Because of the discrepancy between methods, flux estimated by calibrated acoustic backscatter was lower than that by optical backscatter, but net flux appeared to be about equal between sites.

November 30 Event

- One particularly strong internal tide event was characterized by near bottom currents in excess of 1 m/s up-canyon and suspended sediment concentrations over 400mg/l at 10 mab.
- Vigorous horizontal velocities were noted throughout the water column, as well as vertical velocities in excess of 30 cm/s.
- In concert with higher seafloor stress and vertical velocities, elevated backscatter was noted throughout the water column in the ADCP data.





MS1

- Data from the sediment traps also show evidence of multiple internal tide events in addition to the November 30 event. Significant banding on the cm to mm scale show repeated depositional events. Time markers (not shown) indicate that the layer of sand in the middle of the trap was deposited before December 1. A large slump event occurred on December 1, but a peak in turbidity at 35mab was not noted until after the tide had shifted, suggesting that any deposit that may have occurred in conjunction with this event was fine grained.
- Other evidence of erosion of the toe of a sandwave on November 30 come from other markers in the canyon placed by MBARI as a part of the overall experiment. A significant shift in pitch and roll was noted in one of the markers on this date, just prior to the December 1 event, in which the frame of the marker completely tipped over down canyon.
- While this event was somewhat anomalous, it demonstrates that internal tides are vigorous enough to redistribute the sand wave field in the canyon.

Conclusions

- Internal tides are vigorous enough to prevent fine grained sediment from accumulating in the axis of the canyon.
- Internal tides can also move fine-grained sand, which is the major mode of sediment grainsize on the canyon floor. While net flux is down canyon, flux at higher shear stresses is equally distributed.
- Convergence in this stretch of the canyon may lead to higher deposition rates, and may explain some of the morphology, such as narrowing of canyon walls and sinuosity.