Seafloor seismology with Distributed Acoustic Sensing in Monterey Bay

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Emerging distributed fiber-optic sensing technology coupled to existing subsea telecommunications cables enable access to meterscale, multi-kilometer aperture, broadband seismic array observations of ocean and solid earth phenomena. In this talk, we report on two multi-day Distributed Acoustic Sensing (DAS) campaigns conducted in 2018 and 2019 with the Monterey Accelerated Research System (MARS) observatory tether cable. In both experiments, a DAS instrument located on shore was connected to a fiber inside the buried MARS cable and recorded a ~10,000-component, 20-kilometer-long, strain-rate array. We use the 8 TB DAS dataset to address three questions:

1. How can seafloor DAS earthquake records inform offshore seismic hazard assessments? Offshore seismic hazards are poorly characterized despite dense coastal populations. The MARS DAS array captured multiple unaliased earthquake recordings, which document phase conversions and abrupt S-wave delays of 0.25 s at mapped (and unmapped) faults that transect the cable. Minor earthquakes in Northern California produce seismic waves in the range 0.5 - 50 Hz, which interact with submarine faults lying just offshore. Spectral ratios and wavefield synthetics are used to explore how seismic waves from well-characterized earthquakes interact with poorly-characterized subsea faults.

2. How are ocean microseisms and other coastal processes recorded by subsea DAS? Horizontal seabed ambient noise recorded with the MARS DAS array matches the expected dispersion of primary microseisms (f~0.05-0.15 Hz) induced by shoaling ocean surface waves, but at a higher band than onshore observations. Separation of incoming and outgoing waves recorded over the DAS array validates the Longuet-Higgins-Hasselmann theory that bi-directional ocean wind-waves undergo nonlinear wave interaction, producing secondary microseisms (f~0.4-1.5 Hz), even when the outgoing energy is observed to be <1% of the incoming energy. Continuous wavelet transforms of sea state observations from buoys, onshore broadband seismometers, and subsea DAS provide insight into the physics of microseism generation and ocean-solid earth coupling. Additionally, DAS provides observation of post-low-tide tidal bores (f~1-5 Hz), storm-induced sediment transport (f~0.8-10 Hz), infragravity waves (f~0.01-0.05 Hz), and breaking internal waves (f~0.001 Hz) consistent with previous point sensor observations in Monterey Bay.

3. How is the coastal seafloor structure organized from shore to shelf break? The northern continental shelf of Monterey Bay is comprised of allochthonous Cretaceous granite overlain by marine sediments of varying thickness, and is crosscut by abandoned (and subsequently filled) paleochannels. Noise interferometry applied to the full MARS DAS dataset in the 0.25 - 5 Hz range retrieves Scholte waves, which are dispersive and coherent over 2 - 6 kilometers. We apply fundamental mode dispersion (1.5D) imaging to subarray noise correlations in order to understand the sediment thickness distribution across the shelf. Our model is compared with recent seismic reflection profiling conducted by the USGS California Seafloor Mapping Program.

Keywords: fiber-optic, microseism, distributed acoustic sensing