Ambient OBN Data Processing and Environmental-dependent Interferometric Analysis

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ABSTRACT

Low-frequency ambient surface-wave analysis of ocean bottom node (OBN) recordings offers a promising pathway for estimating long-wavelength shear-wave velocity (V_S) models that can serve as starting models for elastic full waveform inversion (E-WI). Large-scale OBN arrays deployed for active-source acquisition concurrently and continuously record sub-1 Hz ambient wavefields containing contributions from multiple distinct source environments, including shooting versus non-shooting times and more singular events such as earthquakes and hurricanes. When examined using seismic interferometry, the heterogeneous nature of these ambient wavefields raises an important question: do the characteristics of different environmental source types contribute differently to the quality, coherence, and modal structure of surface waves observed across different sub-1 Hz frequency bands and receiver components of calculated virtual shot gathers (VSGs)?

To address this question, this study examines ambient wavefield information recorded on a 2742 four-component (4-C) nodal array deployed over a 2750 km^2 area of the Gulf of Mexico for over a three-month period. We present a source-environment-dependent multicomponent VSG workflow that extends prior ambient interferometry work (Girard et al., 2024) that reported recovery of coherent surface-wave from 0.01-1.0 Hz using only vertical (Z) and pressure (P) OBN components. The study also identified that sub-0.3 Hz VSG energy is dominated by active air-gun shooting rather than naturally occurring microseism energy. The present work addresses two key aspects not previously covered: (1) the absence of environmental source-type discrimination in the ambient window selection process; and (2) the restriction to Z- and P-component analysis that leaves horizontal wavefield information unexploited.

The ambient data preprocessing workflow applied follows that of Girard and Shragge (2020) with a few key methodological extensions. The goal of applying the workflow was to partition continuous OBN records into 60-minute windows with synchronized start and stop times across all 2742 nodes that are appropriate for the subsequent interferometric analysis. We first applied judicious zero-padding to ensure inter-node time synchronization across the full array. The next preprocessing step involved applying multiple passes of a low-frequency ($\leq$ 0.01 Hz) detrending algorithm to the full time record to remove baseline drift and thereby minimize DC shift errors when forming time windows for interfereometric processing. We then applied a frequency-domain debursting to attenuate strong narrow-band energy (if present), and then time-domain debursting to suppress impulsive burst-like noise.

After completing the full-trace analyses, we next partitioned the full calendar time record into the four data subsets corresponding to the different source environments examined in this study: (1) active-source shooting times; (2) non-active shooting intervals; (3) windows with regional earthquake arrivals; and (4) a four-day period when a large hurricane passed over top of the array. This partitioning took into account additional information of a range of sources, including source-boat acquisition timing data, regional earthquake catalogs (USGS), and weather data (NOAA). Each of these data subsets was subsequently processed independently in a similar manner.

Within each dataset, windows with RMS energy exceeding the 70th percentile were subsequently removed to eliminate anomalously high-amplitude records prior to interferometry that likely exhibited non-stationary environmental source characteristics. Finally, we applied trace-balancing to the selected 30-minute data windows that provided an empirically improved the resulting VSG stacks.

After completion of the data preprocessing and conditioning steps, we applied cross-coherence interferometry to each environmental source data subset across all four OBN components. We computed two-dimensional VSG panels for each source subset and component pair. Initial results from Z-component VSGs filtered between 0.05–0.2 Hz reveal source-dependent differences in wavefield character across the four subsets. Active shooting windows exhibit coherent surface-wave arrivals with clear symmetric moveouts, while non-shooting ambient windows show significantly reduced coherence and weaker signal due to the significantly smaller number of ambient windows. Earthquake windows exhibit strong but irregular broadband energy with moveouts consistent with arrivals from earthquake sources located at epicentral distances greater than 10°. Finally hurricane windows produce highly coherent yet complex crossing wavefields indicative of multi-directional guided P- and surface-wave propagation. These observations confirm that environmental source classification critically affects VSG quality and character, with implications for subsequent dispersion analysis and V_S model building.

These findings demonstrate that source classification is a critical and previously overlooked step in large-scale OBN ambient interferometry workflows. Ongoing work includes dispersion panel generation, multimodal surface-wave dispersion curve identification and selection across source subsets, and comparison of fundamental and higher-mode content as a function of source type.

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