# Global 26s noise peak produced by primary microseisms generated in the Bight of Bonny, West Africa


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## Abstract

For more than 50 years seismologists have observed unusually intense global microseisms at a period of about 26s originating from near the Gulf of Guinea. Using observations from several temporary broadband seismometer arrays in Africa, including one adjacent to the Gulf of Guinea in Cameroon, we present evidence that these microseisms are generated by ocean waves of the same period in the Bight of Bonny (within the Gulf of Guinea) and thus should be classified as primary microseisms. In particular, we use spectrograms of individual seismic stations near the coast to substantiate our primary microseism interpretation and demonstrate that temporal peaks in 26s microseism generation correspond to arrivals of ocean waves of the same period from storms in the South Atlantic and exceed excitation at other frequencies. A new high-resolution frequency-slowness back-projection technique is used to demonstrate that the source location is near the Nigerian and Cameroon coast adjacent to the island of Bioko. Additionally, we observe heightened microseism generation at this location for several other periods: 28s, 21s, 19s, 16s & 14s. We attempt to establish a relationship between the significant wave heights of ocean waves in the Bight of Bonny and the power of microseisms from the same location but this effort is hampered by the lack of an ocean buoy in this region. These observations cast new light on primary microseisms which are thought to be generated by the pressure field of ocean waves near the shore. We hypothesize that the unusual coastal geometry and bathymetry in the Bight of Bonny focuses long period ocean waves arriving from storms in the South Atlantic and thereby enhances primary microseism generation.


## African Arrays

A

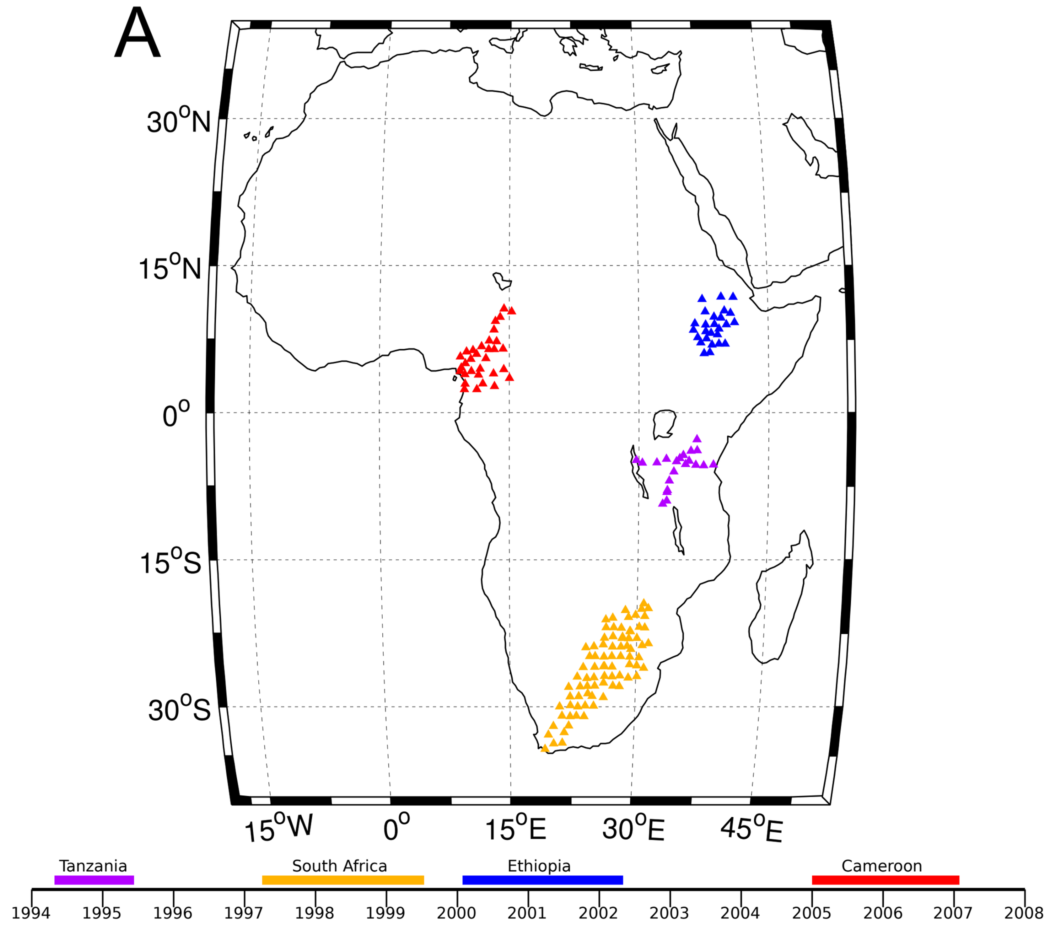



Figure A. Location and deployment times of broadband seismometers in this study. The Tanzania Array (purple) had 21 stations, the South Africa Array (Yellow) had 82 stations, the Ethiopia Array (blue) had 28 stations, and the Cameroon Array (red) had 32 stations.

## Spectral Structure of Correlated Noise From the Bight of Bonny

B

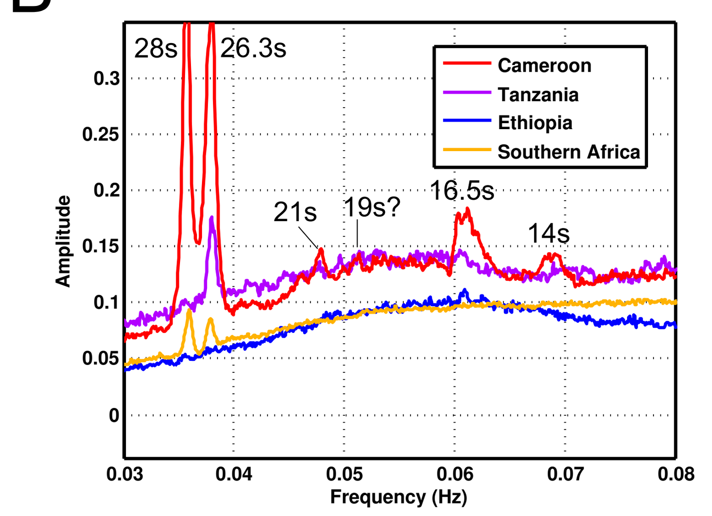



Figure B. Data from each array was processed using noise correlation techniques (Bensen et al., 2007). In the above figure, the cross correlations for each array were stacked for the entire deployment time, converted to the frequency domain, and the amplitude spectra for all these stacks were averaged to get an array spectra. Six peaks are readily seen in the amplitude spectrum of the Cameroon Array while the other arrays have mixed observations indicating that detection of some peaks is limited by distance to the source or wavefield complexity.

C

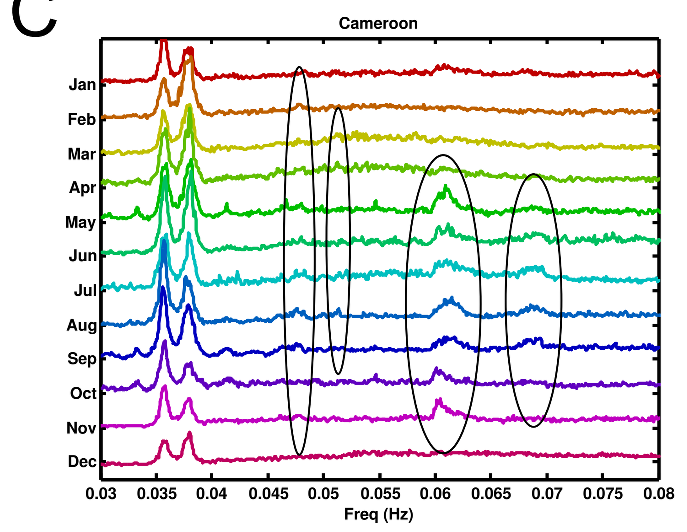



Figure C. Monthly noise correlation amplitude spectra stacks for the Cameroon Array show the seasonality of the Bonny microseism peaks. All 6 peaks are more substantial in the southern winter season indicating that the microseisms are derived from swells.

D

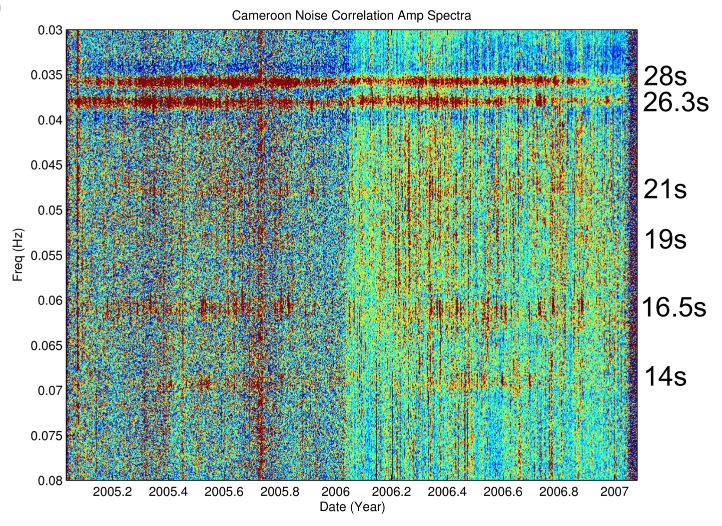



Figure D. Daily noise correlation amplitude spectra for the Cameroon array over the entire deployment. The spectral peaks as well as spectral troughs are apparent. Seasonal patterns are consistent with the monthly stacks.

## High-Resolution Frequency-Slowness Backprojection

E

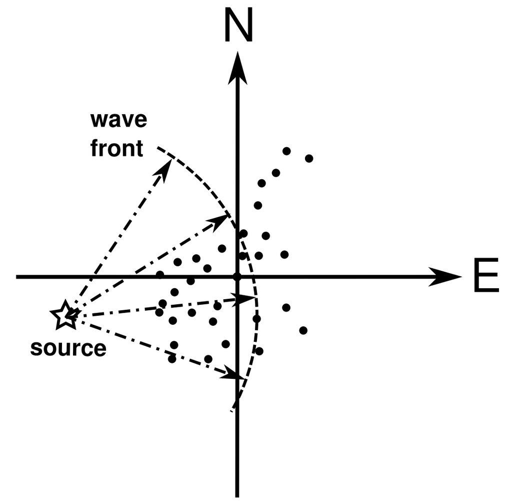



Figure E. Sketch illustrating an expanding wavefront passing through the Cameroon Array. The differences in radial distance between every pair of stations and a each potential source position provide the phase adjustments necessary to calculate the power spectra as a function of source frequency, slowness and position. The plane-wave frequency-slowness approach is the far-field approximation to this method.

F

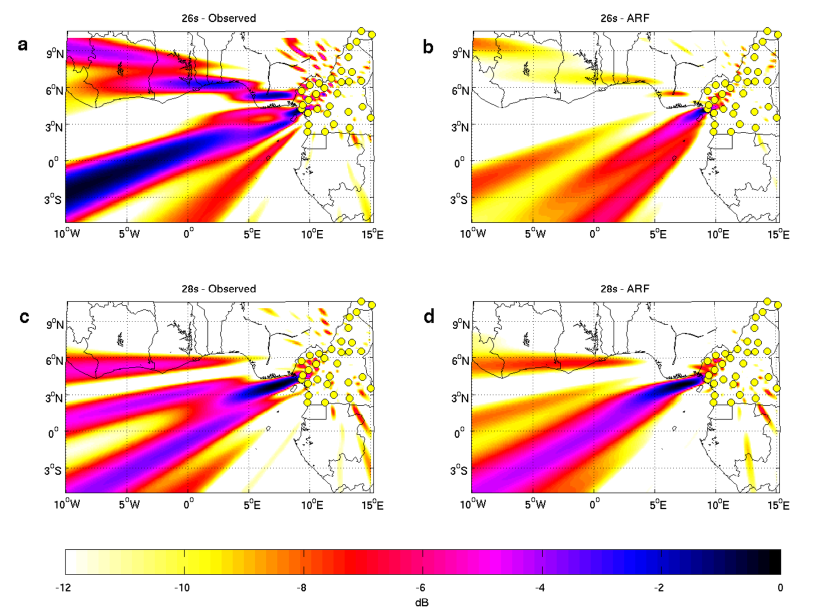


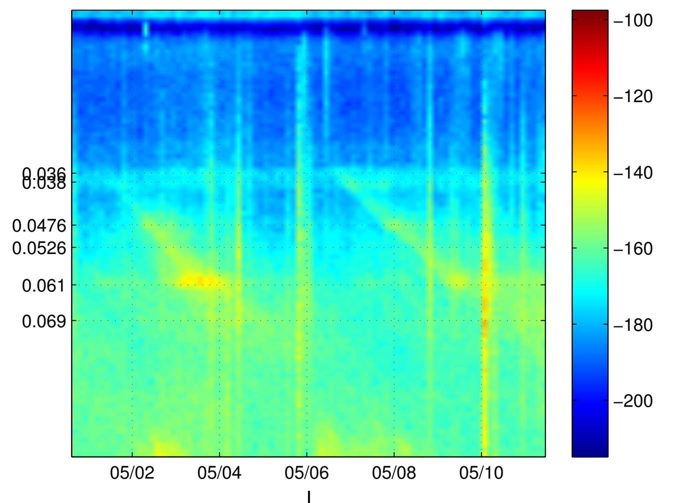

Figure F. Frequency-slowness-position power spectra of the Cameroon array at (a) 26.3s & (c) 28s indicate that the array is able to precisely locate the source location within the Bight of Bonny. (b) & (d) show the array response functions (ARFs) corresponding to a single point source that provide the best fit to the observed spectra. This gives a quantitative means to interpret the source location. In this case the overall spatial aliasing pattern is quite similar spatially although the amplitudes of the spectra vary substantially (possibly due to lateral heterogeniety).

G


Figure G. Map of the Gulf of Guinea region showing the Bonny microseism point source interpretation as a function of frequency. The track is shown in white with positions at specific periods marked. There are separate segments for the 28s and 26.3s peaks as the source location becomes unresolved in the spectral gap between the peaks. The orange line is the 350ft ocean depth countour that roughly corresponds to the edge of the continental shelf. Dashed line indicates a suggested track between 25s & 28s.

## Single Station Spectra

H



Remove Median

I

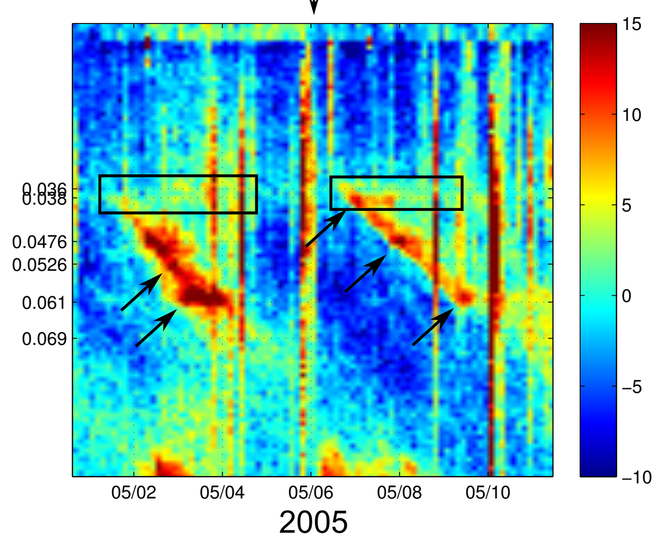
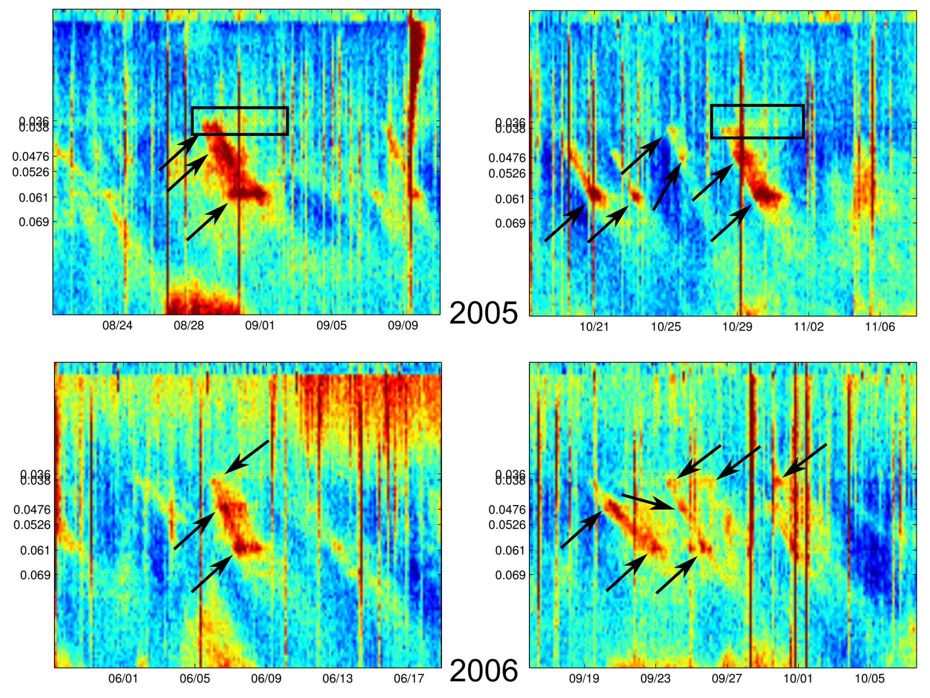



Figure J. Several more examples of unusually enhanced primary microseism production in the Bight of Bonny as recorded by Cameroon array station CM18. The power spectra are all deviatoric spectra (the median value for each frequency is removed).

J




Figures H & I. Analysis of displacement power spectrogram for Cameroon Array station CM18. The raw spectrum is converted to a deviatoric spectrum by removing the median value for each frequency. Diagnal streaks are dispersed primary microseisms (secondary microseisms not shown) from South Atlantic storms. Vertical lines are from teleseismic earthquakes. Each vertical column is a 3 hour time block. Values are found by taking the median of 10 1024s non-overlapping windows in each 3 hour time block. Arrows point out unusual peaks in primary microseisms corresponding to the observed noise correlation peaks. Black boxes highlight enhanced 26-28s power spectra after storm swell impact the Bight of Bonny.

K

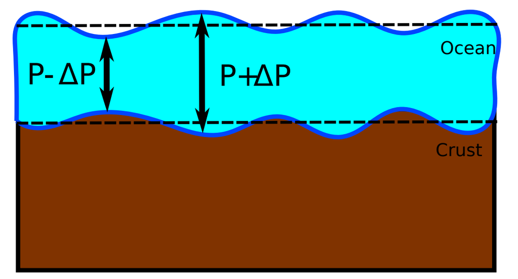



Figure K. Sketch of how primary microseism generation occurs. Swells in shallow water push on the sea floor, giving rise to Rayleigh waves (see Hasselmann, 1963).

## What We Can Conclude

- The Bight of Bonny region is associated with enhanced microseism production at several frequencies (we refer to these as the Bonny microseism peaks)

- The Bonny microseism peaks are persistent with seasonal fluctuations consistent with the southern hemisphere extratropical cyclone season

- The localization of the 26s source indicates that other microseism source regions have substantially less microseism production at this frequency

- The localization of the 26s source to near Mt. Cameroon suggests a (likely passive) link to the local subsurface geology

- The inconsistent detection of the peaks by the arrays indicates azimuthal variations in the radiated wavefield

- The unusual enhancement of 26s microseism levels from the Bight of Bonny contemporaneous with the arrival of 26s swell in the Bight of Bonny indicates that the microseisms are caused by ocean swell of the same period and may be classified as primary microseisms.

- The continued production of 26s microseisms after the arrival of 26s swell suggests that the swell energy is trapped and converted until substantial dissapat ion occurs.

## How Does the 26s "Resonance" Occur?

A couple physical oceanography processes that could explain the observations are the focusing of swell due to bathymetry or the excitement of seiche waves and edge waves. Another possibility is that primary microseism generation is enhanced at narrow frequency bands due to the rather unique underlying geologic structure (a volcanic lineament), although the generation of primary microseisms is poorly understood (Hasselmann, 1963).

Swell Focusing? Seiche or Edge Waves? Mt. Cameroon?