

Fluctuations in High Frequency Acoustic Propagation

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LONG-TERM GOAL

The long-term goals of this work are to understand the influence of environmental variability on fluctuations in the propagation of high frequency acoustic energy with applications to the improvement of acoustic data communications in shallow water.

OBJECTIVE

The objective of this research is to investigate experimentally how the temporal and spatial variability of environmental parameters in shallow water is coupled into fluctuations in the observed propagation of high frequency acoustic energy, the impact these fluctuations have on acoustic data telemetry, and how frequency and spatial diversity might be used mitigate these effects.

APPROACH

The extreme temporal and spatial variability of shallow water environments can yield time-evolving, complex acoustic propagation effects at high frequencies (> 1 kHz). Thus, the observed signal is influenced by a number of environmental effects simultaneously (e.g. time-varying water column sound speed structure, surface waves, and spatial variability in bottom properties). The medium inhomogeneities and variability are embedded in the fluctuations observed in a received signal. Through the collection of shallow water, fixed source – fixed receiver, acoustic propagation data along with coincident environmental measurements, the relationship between fluctuations in the received acoustic field and spatial and temporal fluctuations in the critical water column parameters affecting acoustic propagation can be studied.

WORK COMPLETED

An early FY98 experiment was conducted in ~ 100 m water over a propagation path of ~ 6 km. Transmissions centered at 2.5, 6.0, and 17.5 kHz were made on a regular basis over several days. The experiment took advantage of a recently-completed 64-element receive array covering the 0.5-20 kHz band which enabled investigating the spatial structure of fluctuations in acoustic propagation at these frequencies.

RESULTS

Figure 1 shows the area where the experiment was conducted (SW of Point Loma off San Diego, CA). Both the sources and 12 m aperture receiving array were moored near the seafloor in ~ 100 m deep

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water. The source – receiving array separation was ~6 km. Environmental measurements were provided by a 16-element thermistor string near the receiving array, an array of 16 conductivity-temperature recorders near the source mooring, frequent CTD's in the area, and a wave wire array to measure surface wave characteristics. Figure 2 shows an example of the thermistor string and CTD data collected during the experiment.

Because of the proximity of the source near the bottom and the downward refracting character of the sound speed structure, significant energy tends to be trapped in the lower (and slower) part of the water column. An eigenray analysis of the source – receiving array propagation predicts several early arrivals (ray paths which either are surface-interacting or turn over mid-water column) followed by the dominant energy which is trapped near the bottom. Figure 3 shows experimental measurements of the channel impulse response from the source to a single element of the receiving array obtained from chirp transmissions (10 kHz bandwidth) centered at 18 kHz. The upper panels contain a single snapshot of the arrival structure at two different times separated by 6 hours. The general arrival structure predicted by the eigenray analysis is seen in these results with the dominant energy arriving 20-25 ms after the earliest arrivals. The lower panels show the time-evolution of the channel impulse response sampled once per second over a 60 second period. Fluctuations of the arrival structure can be seen over periods of several seconds.

IMPACT/APPLICATIONS

The emphasis of this work is on understanding the influence of environmental variability on high frequency acoustic propagation. A specific application area of interest is the impact that these environmentally-driven fluctuations have on acoustic data communications and how best to mitigate their effects.

TRANSITIONS

The measurements made in this project will provide experimental data which can be used for developing both models of the fluctuation characteristics of shallow water acoustic propagation in the 1-20 kHz band as well as adaptive channel equalization algorithms.

RELATED PROJECTS

Related work is being carried out in the project "Environmental Impact on Phase Coherent Underwater Acoustic Communications" (T.C. Yang, A. Al-Kurd, and M. Orr, NRL).

PUBLICATIONS

W.S. Hodgkiss, W.A. Kuperman, J.J. Murray, G.L. D'Spain, and L.P. Berger, "High frequency matched field processing," pp. 229-234. Appears in: N.G. Pace, E. Pouliquen, O. Bergem, and A.P. Lyons (Eds.). High Frequency Acoustics in Shallow Water. SACLANTCEN Conference Proceedings CP-45 (1997).

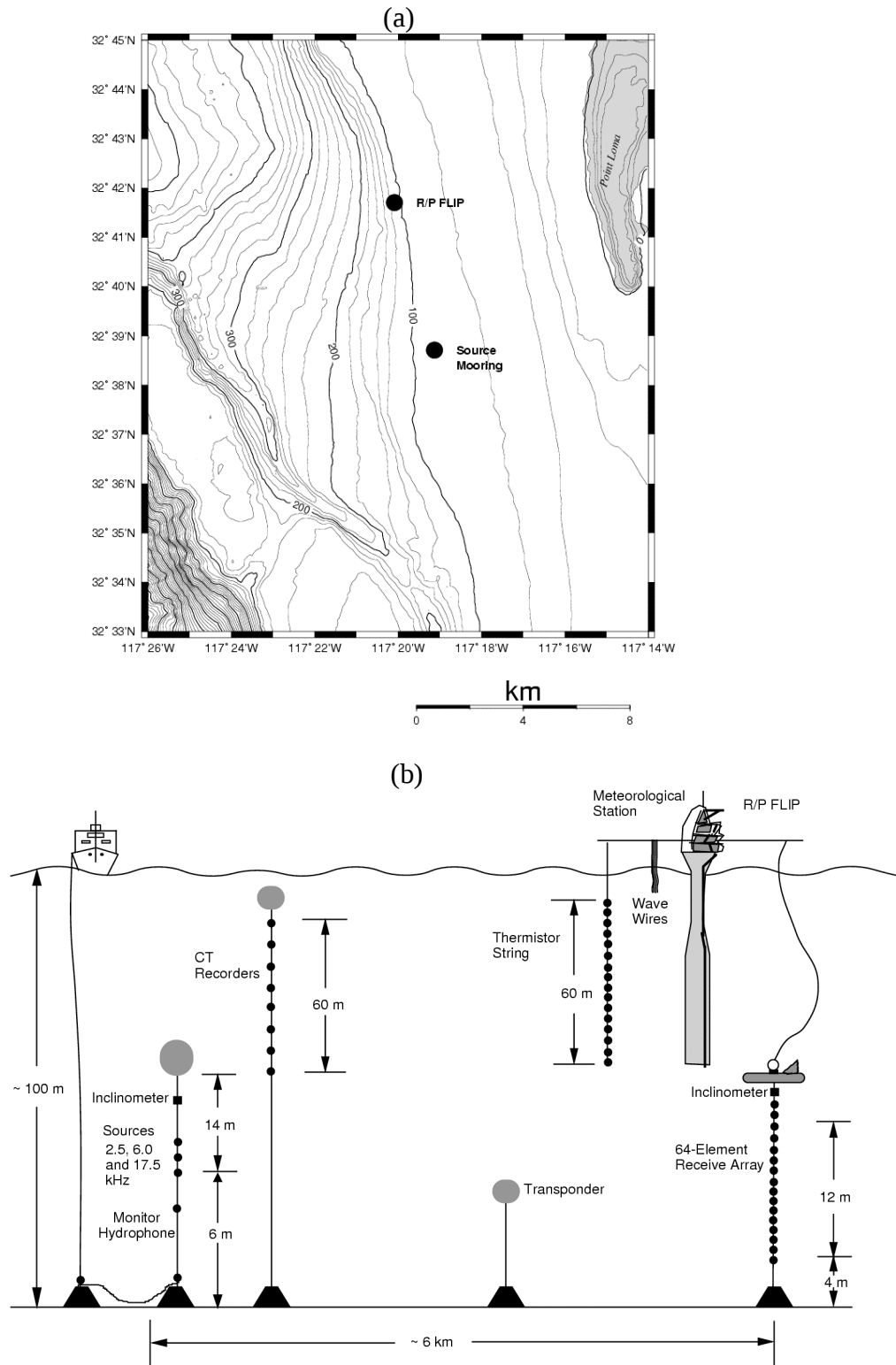


Fig.1: Experimental overview showing (a) the source mooring and receiving array locations along with bottom bathymetry in the area and (b) the geometry of the acoustic and environmental measurement hardware.

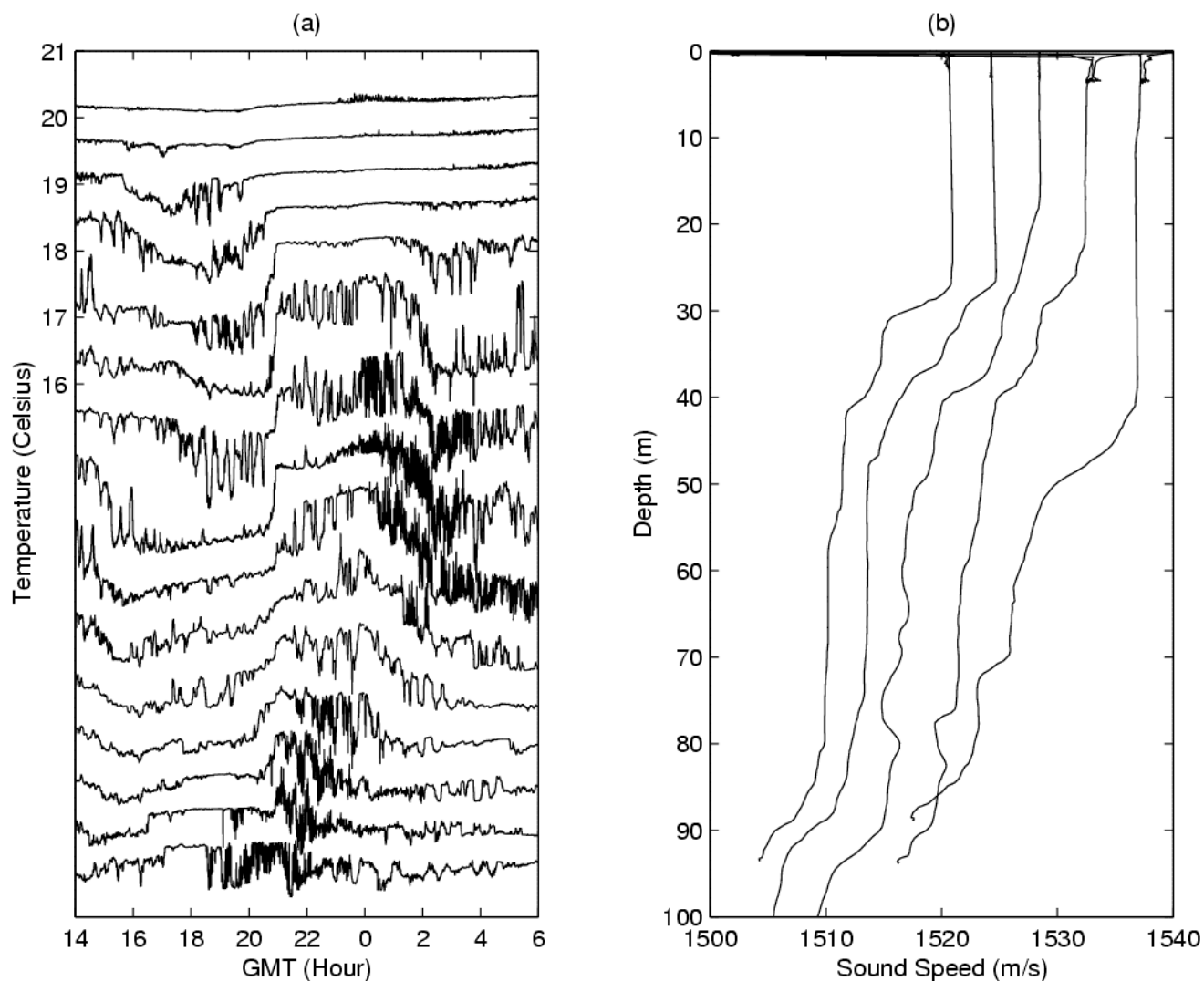


Fig. 2: Water column temperature and sound speed structure. (a) Thermistor string data beginning at 1400 GMT on JD301. (b) Sound speed structure determined from several CTD casts on JD301. (Thermistor data are offset by 0.5 degree per thermistor, with 0 offset reference at the top. The uppermost is at 10 m depth and the lowermost thermistor is at 70 m depth. CTD data are offset by 4 m/s per cast, with 0 offset reference at the left.)

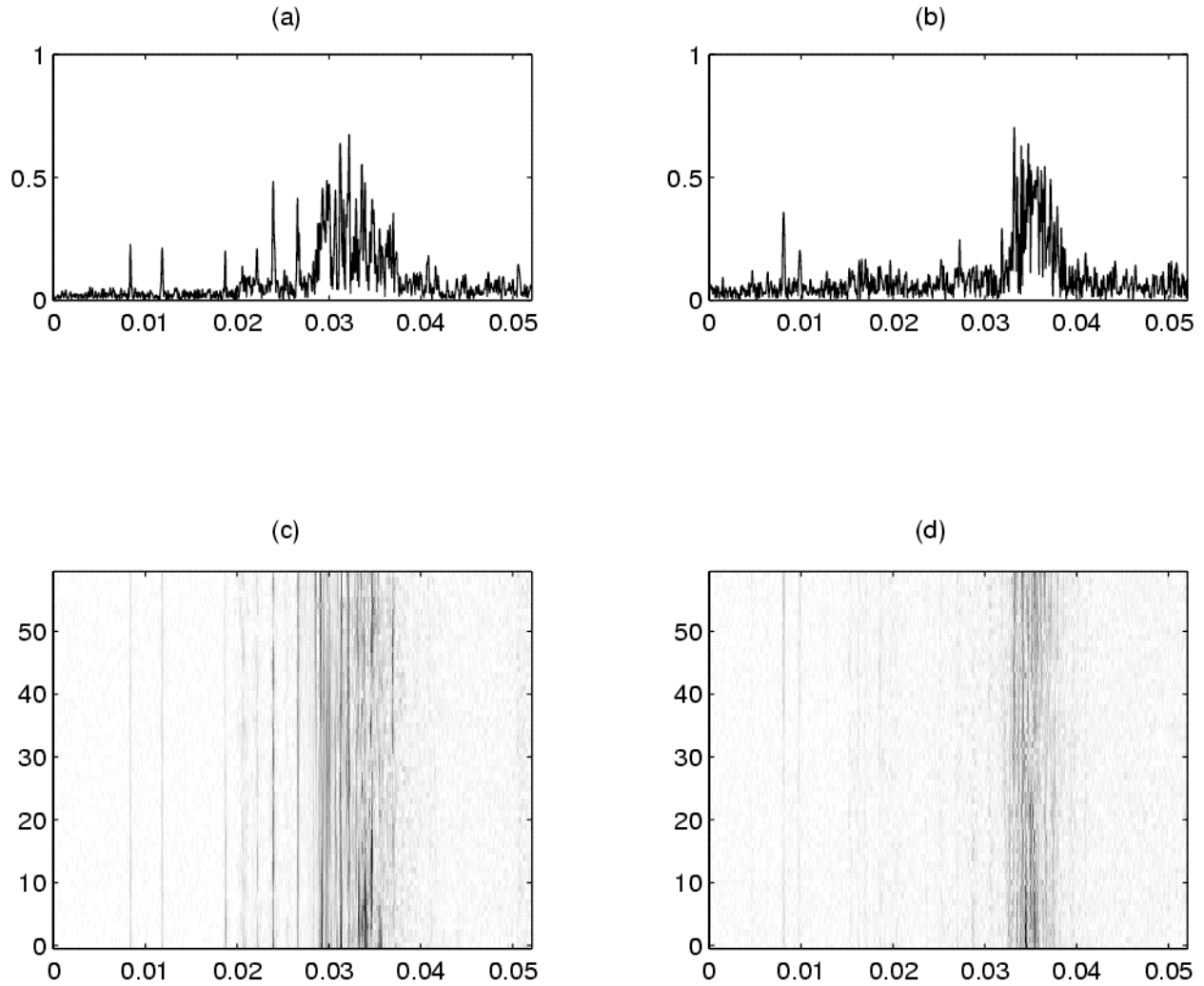


Fig. 3: Channel impulse response for JD301.1600 and JD301.2200. Panels (a) and (b) contain a single snapshot of the impulse response at two different times separated by 6 hours. Panels (c) and (d) show the temporal evolution of the impulse response over a period of 60 seconds. The horizontal axis (delay in seconds) has been offset from the nominal propagation delay time.