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Underwater sound channel in the northeastern East China Sea

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A B S T R A C T

In May 2015 a shallow-water acoustic variability experiment (SAVEX15) was conducted in the northeastern East China Sea. Surprisingly, an underwater sound channel that is typical for deep water was discovered in this shallow water waveguide (~100 m deep) with the channel axis at around 40 m. For a broad-band source (0.5–2.0 kHz) deployed close to the channel axis, channel impulse responses observed by a vertical array exhibited a complex arrival structure with a large delay spread (e.g., 160 milliseconds). Most arrivals are found to be surface and bottom reflected, while a pair of high-intensity refracted arrivals are embedded in the early reflected arrivals. Broadband simulations based on a normal mode propagation model show good agreement with data.

1. Introduction

The East China Sea (ECS) and surrounding area is an extremely complex region from the perspective of oceanography, hydrography, and bathymetry. In turn, the internal wave activity within this region also is extremely complex (Cho et al., 2016a; Lee et al., 2006). Within the ECS, there are several mechanisms for generating internal waves including: tidal and wind forcing; forcing by the Kuroshio, Tsushima, and Yellow Sea Circular currents; upwelling induced by the intrusion of the Kuroshio across the continental shelf (mostly in the southern region near Taiwan); and freshwater discharged from the Yangtze River, as illustrated in Fig. 1a. Bathymetry is also an important factor in internal wave generation, propagation, and dissipation. The variability in the sound speed field due to internal wave perturbations along with strong currents in the ECS impacts significantly the variability of the acoustic field over various time scales (Smith, 2010).

As a collaborative research effort between the US and ROK (Republic of Korea), a shallow-water acoustic variability experiment (SAVEX15) was conducted in the northeastern ECS in May 2015. The goal of SAVEX15 was to obtain acoustic and environmental data appropriate for studying the coupling of oceanography, acoustics, and underwater communications in the region. A surprising aspect of the oceanography was the revelation of an underwater sound channel (USC) persistent in this shallow water waveguide (~100 m deep) with the channel axis at around 40 m. In this letter, we present preliminary results investigating the impact of the USC on acoustic propagation in the ECS, using both data and a propagation model in the low-to-mid frequency band (0.5–2.0 kHz).

The paper is organized as follows. Section 2 describes the SAVEX15 experiment along with sound speed profiles. In Section 3, channel impulse responses (CIRs) captured by a vertical array at 3.5 km range during a source-tow run is presented for a modest broadband source (0.5–2.0 kHz) deployed to about 50 m depth, indicating a large delay spread of approximately 160 ms. The arrival structure of the CIR is analyzed in Section 4 using a normal mode propagation model and its dispersion characteristics, followed by a summary in Section 5.

2. SAVEX15

The SAVEX15 experiment was conducted 14-28 May 2015 in the northeastern ECS, ~100 km southwest of Jeju Island, using the research vessel (R/V) Onnuri. The experimental site denoted by a solid ellipse in Fig. 1a was a nearly at sandy bottom with water depth of approximately 100 m. Both fixed and towed source transmissions were carried out to two moored receiving arrays over ranges of 1–10 km. The acoustic transmissions were in various frequency bands covering 0.5–32 kHz and included both channel probing waveforms as well as communication transmissions. Environmental data collected included water column

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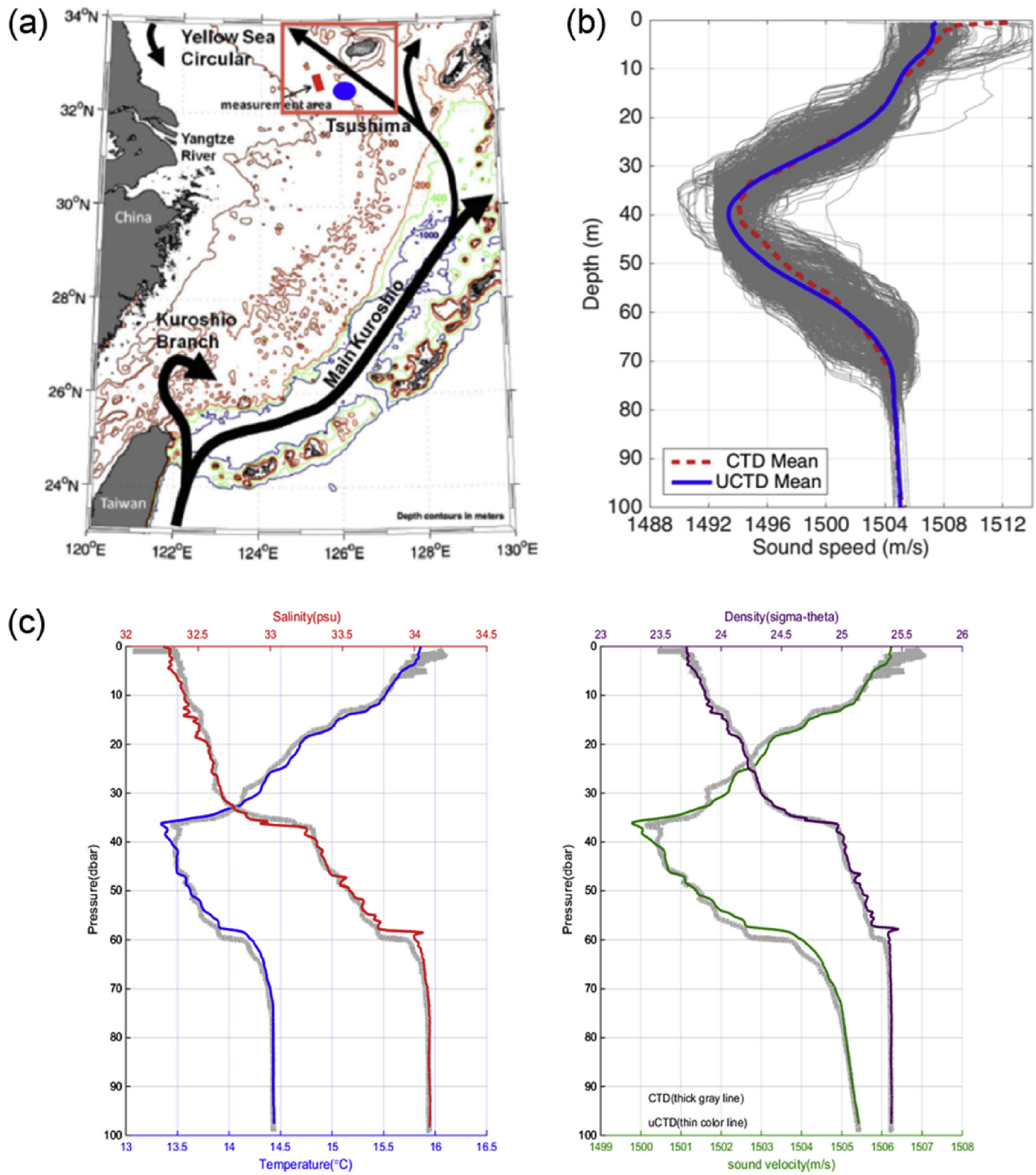

Fig. 1. (a) Bathymetry and major currents in the ECS. Depth contours are in meters. The SAVEX15 was conducted in May 2015, about 100 km southwest of Jeju Island (top). The experimental site marked by a solid ellipse was a nearly at sandy bottom with water depth of approximately 100 m. (b) Sound speed profiles obtained from both CTD (26 profiles) and UCTD (1062 profiles) in grey color. Mean profiles of CTD (dashed) and UCTD (solid) are similar except near the surface. (c) Comparison between UCTD and CTD (gray) for calibration: temperature (blue), salinity (red), density (purple), and sound speed (green). Note that the sound speed profile (green) closely follows the temperature profile (blue).

sound speed structure, sea surface directional wave field, and local wind speed and direction.

Sound speed profiles (SSPs) are displayed in Fig. 1b. They were obtained from both standard CTD (conductivity, temperature, and depth) and underway CTD (UCTD) data. The UCTD is a rapid profiling CTD system that provides high quality profiles during ship's transit (up to 20 kts) (Ullman and Herbert, 2014). A calibration test was conducted against the more accurate CTD as a precaution and showed good agreement between the two (Fig. 1c). Over the duration of the experiment, we collected a total of 1062 UCTD profiles as compared to just 26 CTD profiles (in grey color). The mean profiles of CTD (dashed) and UCTD (solid) are similar except near the surface (Fig. 1b).

Clearly, the SSPs indicate an underwater sound channel (USC) with the channel axis at around 40 m, almost symmetric with respect to the