Monitoring Air-Sea Exchange Using Ambient Sound

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Abstract: Wave breaking and precipitation are important processes contributing to the exchange of momentum, heat, water and gas at the air-sea interface. These processes are also principal generators of high frequency (over 500 Hz) underwater ambient sound. Furthermore, the bubbles generated by the breaking waves and raindrop splashes can be stirred downward into the ocean forming an effective sound absorption layer. When present, this layer modifies the ambient sound field, and can thus be detected using passive acoustics. Using the passive sound field as an exploratory tool, more conventional measurements of salinity, temperature, bubbles, wind and surface waves are examined. Anomalies in near surface salinity are explained by acoustically derived rainfall measurements. The influence of rain on the surface wave field is discussed. Enhanced injection of bubbles into the mixed layer by rain in the presence of high wind is indicated by changes to the shape of the underwater sound spectrum.

INTRODUCTION

Physical processes at the air-sea interface, in particular, wave breaking and precipitation, play a central role in the exchange of heat, momentum, water and gas between the ocean and the atmosphere. Accurate measurements of these processes is difficult, especially in remote oceanic regions. Fortunately wave breaking (usually wind generated) and precipitation (both drizzle and heavier rain) are the principal sources of high frequency (over 500 Hz) underwater sound in the ocean. The interpretation of the underwater sound field can thus be used to detect and quantitatively measure these processes.

BACKGROUND

Sources of ambient sound in the ocean have been explored for years (1). Above 500 Hz, the principal physical sources of underwater sound are 1) wave breaking due to wind and changing seas and 2) precipitation, including both drizzle and heavy rain. The sound field is further modified by the presence of ambient sub-surface bubbles (2). In each situation, the sound field is distinctive, allowing acoustic identification of surface conditions (3). In particular, four weather classifications are acoustically identified: wind, drizzle, heavy rain and ambient bubbles present.

Wind generates sound through breaking waves. The mechanism is acoustic radiation from individual bubbles at their well-defined resonant frequencies (4). The sound produced by precipitation is due to individual raindrop splashes and depends on the distribution of raindrop sizes in the rain. Drizzle produces sound underwater from small raindrops (0.8-1.1 mm diameter) by a unique bubble production mechanism associated with the splash physics of that drop size (5). Heavier rain often contains large raindrops (> 2 mm diameter) with different splash physics (6). In both cases, the distribution of bubble sizes produced is different than those associated with breaking waves.

EXPERIMENTAL DATA

The Acoustic Surface Reverberation Experiment (ASREX) took place from 19 Dec 1993 to 16 Mar 1994 at 70°W, 34°N. One component of the experiment was measurements of the ambient sound field in 12 frequency bands from 50 Hz to 25 kHz. Surface moorings in ASREX provide a variety of more conventional data which can be compared to the acoustically derived quantities. Among these measurements are 1-meter depth salinity and temperature, air temperature, 10m depth temperature, significant wave height, 10m wind speed and acoustic backscatter.
Figure 1 shows an example of acoustical measurements of wind and rain. The measurements are compared to 10m wind speed from an anemometer, significant wave height and 1m salinity. Acoustic wind speed measurements agree with anemometer wind measurements during most of the ASREX experiment. The acoustic rainfall measurements explain 1-m deep salinity anomalies. The largest salinities anomalies occur during long-duration light rain with low winds present (shallow mixing). There is limited evidence that rainfall suppresses the surface wave field. Ambient bubble populations are enhanced during heavy rain and high wind conditions.

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