A COMPARISON OF MEASURED OCEAN ACOUSTIC AMBIENT NOISE WITH ESTIMATES FROM RADARSAT REMOTE SENSING

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1. INTRODUCTION

Ambient noise has been a topic of study in underwater acoustics for over sixty years. In the absence of rain and biological noise sources, wind-generated noise is the dominant source of underwater ambient noise in the 1 kHz to 25 kHz band. The extent to which this noise can be estimated using remotely-sensed data is an area of interest, in particular for the purposes of Rapid Environmental Assessment. Here, synthetic aperture radar (SAR)-derived wind fields measured in littoral areas off the coast of Nova Scotia using Radarsat-1 and Radarsat-2 satellite imagery are compared with data measured using shipboard instruments and by the Gulf of Maine Ocean Observation System (GoMOOS) buoy 'N' in the Northeast Channel. Using an algorithm to predict underwater ambient noise generated due to wind, the modeled ambient noise based on satellite measurements is then compared with in situ measurements recorded on hydrophones.

2. BACKGROUND

2.1 Wind speed dependence of ambient noise

There is an immense amount of literature available concerning ambient noise in the ocean, literally thousands of publications. Urick [1] summarizes much of the early work in this area, including the findings that wind-related processes dominate ambient noise over much of the spectrum below frequencies of 25 kHz. These processes include wind turbulence, surface motion, wave interactions, and spray and cavitation. Shipping can be the dominant noise source for frequencies of tens to hundreds of Hz, but in shallow water without high shipping levels, ambient noise can depend on wind speed at these frequencies as well (e.g., Piggott [2] measured on the Scotian Shelf). Here, a model formulated by Merklinger and Stockhausen (MS) [3], slightly modified [4] is used to calculate expected ambient noise levels given the wind speeds.

2.2 Field trials

Underwater ambient noise levels were collected as part of two field trials off the coast of Nova Scotia. The first trial, designated Q316, took place in September and October of 2008, in the Northeast Channel and Brown's Bank area. The second, designated Q325, took place in Emerald Basin and Emerald Bank area in October and November of 2009. Wind speed data was collected through both trials on ship-borne instruments and deployed sensors. During Q316, hourly averaged wind speeds were obtained from GoMOOS buoy 'N', while during Q325, a meteorology station with anemometer was deployed from October 27, 2009, to November 9, 2009. Their locations are given in Table 1, together with the locations of the ambient noise sensors.

During Q316, three sets of ambient noise data were collected during periods that coincided with the acquisition of satellite SAR imagery, on the 16th, 17th, and 18th of September. The data were acquired using two sub-surface high-fidelity audio recording packages (SHARPs) and one Ocean Bottom Seismometer (OBS). The OBS hydrophone was deployed approximately 1 m above the ocean bottom, in water depth of 107 m. Both SHARP units included two hydrophones, at depths of approximately 55 m and 75 m. SHARP1 was deployed in water depth of 107 m and SHARP2 in water depth of 111 m. All hydrophones were omni-directional with flat frequency responses above 5 Hz.

Table 1. Buoy and sensor locations.

	Latitude	Longitude
GoMOOS buoy	42º 19.014' N	065º 54.010' W
Met station (Q325)	43° 48.348' N	062° 51.534' W
OBS (Q316)	42° 17.488' N	065° 33.123' W
SHARP1 (Q316)	42° 17.637' N	065° 32.987' W
SHARP2 (Q316)	42° 25.412' N	065° 22.287' W
SHARP1 (Q325)	43° 41.555' N	062° 39.391' W
SHARP2 (Q325)	43° 50.823' N	062° 51.161' W

For Q325, ambient noise data were acquired coincidentally with SAR imagery on only one occasion (the 5th of November), although two other sets of ambient noise data were collected as well, one 12 hours after a SAR image in very similar conditions (October 31st), the other set on November 3rd, when the Radarsat overpass was several degrees south of the trial area. Data were acquired on two SHARP units, in water depths of 148 m and 257 m, with hydrophones at approximately 55 m and 75 m depth.

2.3 Radarsat wind speed measurements

Wind speed information can be derived from Synthetic Aperture Radar (SAR) backscatter measurements, using empirical models [5,6]. Both Radarsat-1 and Radarsat-2 use a 5.3 GHz (C-band) SAR sensor in Scan SAR mode to obtain large area wind speeds with 100 m horizontal resolution. Figure 1 shows an example of the wind speed derived from a Radarsat-1 SAR image.

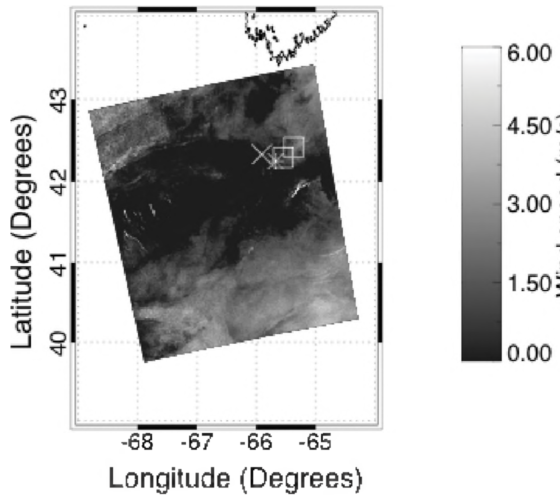

Figure 1. SAR-derived wind speed from Radarsat-1 from September 17, 2008, 2214 UTC. The SHARP recorders are shown as squares, GoMOOS as an X, ship location an asterisk.

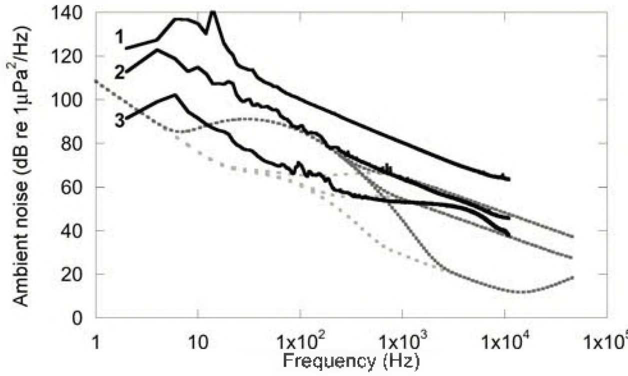

Figure 2. Measured ambient noise from SHARP2, lower hydrophone: (1) Sept. 16, 2008, 6.6 m/s wind speed; (2) Sept 17, 2008, 1.8 m/s wind speed; (3) Sept. 18, 2008, 0.1 m/s wind speed. Dotted lines show MS model results for given SAR-derived wind speeds, together with light and heavy shipping curves (light and heavy dashed lines).

3. RESULTS

3.1 Wind speed comparison

Fourteen data points were available for comparison of directly measured wind speed with that obtained using the SAR imagery: three GoMOOS buoy measurements, seven measurements from ship-borne instrumentation, and four readings from the deployed meteorology buoy. An hourly mean and standard deviation of wind speed were calculated for the ship anemometer and meteorology station, the GoMOOS buoy already providing hourly averaged wind speeds. Wind speeds ranged from 0 m/s to 11.2 m/s. Wind speed estimates from the SAR imagery were obtained by calculating the mean and standard deviation of the wind speed in a 10-km radius around the location of each wind sensor and hydrophone. After correcting for sensor height, wind speeds from the Radarsat and other sensors agreed to within one standard deviation for 8 data points, and two standard deviations for 3 data points. The other three data points were all for wind speeds less than 2 m/s, for which estimates made using the Radarsat imagery were too low. It was anticipated that it might be difficult to estimate very low wind speeds from the Radarsat images [7].

3.2 Ambient noise comparison

Figure 2 shows a comparison of ambient noise measured during Q316 on the lower hydrophone of the SHARP2 unit, during the periods when SAR imagery was collected (Radarsat-1 on September 16th, Radarsat-2 on the 17th and 18th). The data was sampled at 22050 Hz. Power spectral densities were computed by averaging 1200 half-second square-windowed periodograms.

4. DISCUSSION

As seen in Figure 2, there is an obvious dependence of the measured ambient noise on wind speed, demonstrating the potential for ambient noise estimates over a wide area to be derived from Radarsat remotely sensed data. It is evident however that the measured ambient noise is considerably higher than that predicted by the MS model, particularly at the lowest wind speed (0.1 m/s). There is also wind speed dependence at all frequencies, including the frequency regime normally expected to depend on shipping noise. This is consistent with the observations of Piggott [2], however, the noise levels measured here are higher, possibly due to the nature of the propagation in the area. Further analysis of data from both the Q316 and Q325 experiments may help resolve this issue.

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