Ambient Noise Analysis and Modeling in Shallow water of Arabian Sea

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ABSTRACT
This work presents a shallow water ambient noise analysis and modeling effort in the Arabian Sea. Real ambient noise recording at very shallow depths has been analyzed for two environmentally unique periods when the sound velocity profile and the wind conditions present distinct characteristics. Ambient noise data were collected for January and March in the shallow water of Arabian Sea between the wind speed 0.0 m/s to 4.11 m/s. The relative spectral energy distribution of sea noise is presented for a number of wind speeds. Linear relationship between the sea noise spectrum levels and the wind speed were found for the entire frequency range, but the slope were frequency dependent. The results of empirical fitting based on the analysis were used for noise level prediction and the model predictions were compared with the measured noise level. Such study post extensive validation has the potential to develop predictive models for ambient noise estimation based on recorded data.

General Terms
Signal processing, ambient noise analysis

Keywords
Shallow water, ambient noise, sea, noise analysis, Arabian sea.

1. INTRODUCTION
The study of wind dependence of the ambient noise has been carried out in different regions of the world, over the last four to five decades. Since the classical work of Knudsen (1948), many researchers have investigated the wind dependence of noise in the deep ocean and quantified the correlation between ambient noise level and wind speed. The acoustic environment varies with time and it is location dependent in shallow water (Yang & Yoo, 1997) and the noise field has distinct vertical directivity. Piggott (1964) in his pioneering work took shallow water ambient noise measurements on the Scotian shelf at 20– 28 fathom water depths and analyzed the spectral energy distribution for a number of wind speeds and found that the noise was wind dependent in the high frequency range. Also seasonal variation in noise level, which is independent of frequency, was observed. Recent study by Walkinshaw (2005) on ambient noise spectra in South Norwegian Sea showed the correlation between wind speed and ambient noise at low frequency range. It was reported that the average noise level during summer was 5 dB lower than winter and these level differences were attributed to seasonal changes in sound propagation. Similar studies by Hazen & Desharnais (1997) on the shallow water ambient noise revealed the seasonal dependency of the noise levels and reported that on an average noise level in summer was lower than in other seasons. It has been shown that the shallow water acoustic transmission is influenced by the season and the attenuation is proportional to frequency with a season dependent coefficient. The ambient noise was also shown to be site specific in shallow water where speed of the sound and the bottom properties vary substantially with the location. Gayer & Wille (1984) in their work made measurements in North Sea and Baltic Sea and reported that the influence of propagation loss on the wind dependent shallow water noise appears to be marginal even at extremely different area. It was observed that the contradicting behavior of the summer and winter noise levels was due to wind stress at sea surface. Similar work by Ingenito (1989) on site dependence of wind-dominated ambient noise in shallow water reported lower noise level of around 2 dB in the silt bottom at wind speed of 7 m/s when compared to sand bottom at wind speed 3–5 m/s and variability of 10 dB in the average noise spectrum level was observed in the essential fraction of the entire range of the spectrum. The large spread of wind generated noise levels measured for the same wind speed and wave height in the absence of other noise sources is essentially attributed to the site dependence and the primary site dependent factor that influence the noise level being acoustic propagation which in turn are dependent on the season, ocean depth and the bottom composition . Piggott (1964), has reported a logarithm relation for the ambient noise and the wind speed based on his study at two depths in very shallow water (36 m and 51 m), where the non wind dependent factors were reported to be not significant and the contribution of the wind dominated source was observe to be dominant at nearly all wind speeds and all frequencies. The relation has been extensively validated by numerous researchers and adapted for varying sites. The relation is presented below for reference:

$$NL = B + 20 * n * \text{Log}(U) \qquad \text{----} \quad (1)$$

Where NL and U stand for noise level and wind speed, respectively. The constants 'B' and 'n' were determined by fitting the experimental data to the model at different frequencies. The slope (1/20) of the regression line gives 'n' and the ordinate intercept of the line gives 'B' for each empirical fit. The frequency range of interest for the current study was from 500 Hz to 5000 Hz where the best correlation between the wind speed and the noise level has been observed.

Table 1. Sample values of '*B*' and '*n*' for different frequencies

Frequency (Hz)	Monsoon			Summer			Winter		
	B	*n*	*r*	*B*	*r*	*n*	*B*	*n*	*r*
500	78.37	0.93	0.98	69.13	0.74	0.82	71.38	0.57	0.54
2000	71.67	0.70	0.97	62.38	0.63	0.85	65.45	0.13	0.25
3000	68.30	0.63	0.96	61.04	0.49	0.76	61.07	0.28	0.34
4000	66.92	0.39	0.90	57.67	0.56	0.78	62.75	0.05	0.22
5000	65.34	0.21	0.71	56.49	0.59	0.78	63.04	0.13	0.06

B is the vertical intercept in dB, re: 1 μPa^2/Hz at 1 m/s wind speed, *n* is the 1/20th of the slope of the regression line, *r* is the correlation coefficient between noise level and wind speed.

2. MEASUREMENT AREA AND RECORDING INSTRUMENTATION

The ambient noise in the coastal waters of Arabian Sea was recorded off the Goa coast close to a busy port at less than 20 Nm. The shipping traffic in the port typically consists of large cargo vessels that are anchored away from the port and smaller (length 70 m, width 13.5 m and height from keel to deck 4.25 m) self propelled (twin diesel engine of 280 HP) barges carrying iron ore from the port to the cargo ships at anchorage. These barges account for the bulk (up to 100 per day) of the traffic in the port. The barges have a very simple machinery configuration with two shafts connected to a four blade propeller (A mechanical device that rotates to push against air or water) that typically rotate at 1800 rpm (30 Hz). The barges being a product of low cost design by local shipyards have poor propeller design and thus have reported excessive cavitation resulting in prominent broadband noise in the radiated noise spectrum.

The recording period was such that the influence of shipping traffic would be similar, however, the surface parameters varied significantly in the two months considered for study. In the first month i.e., Jan 2010, has low sea state (< sea state 2) resulting in calm surface agitation due to lower wind speeds (< 4 m/s). The second month i.e., Mar 2010, has higher sea surface temperature resulting in rough sea conditions (> sea state 2) and higher wind speeds (> 4 m/s). The recordings were undertaken in extremely shallow waters at a depth of 30 m, with flat bottom for a major region around the recording sensors.

The data recording has been undertaken eight times in a day on specific days in the two months of Jan 2010 and Mar 2010. The data recordings has been undertaken periodically at an interval of one hour starting from 0930 hrs to 17:30 hrs (GMT + 5:30 h) for duration of 2 min. The environmental parameters have been collected at a close proximity from the recording sensor location, simultaneously for the period of data recordings.

3. RESULTS AND ANALYSIS

The shallow water region where the data has been recorded limits, the propagation of high frequency, thus the analysis has been restricted to the lower frequency band.

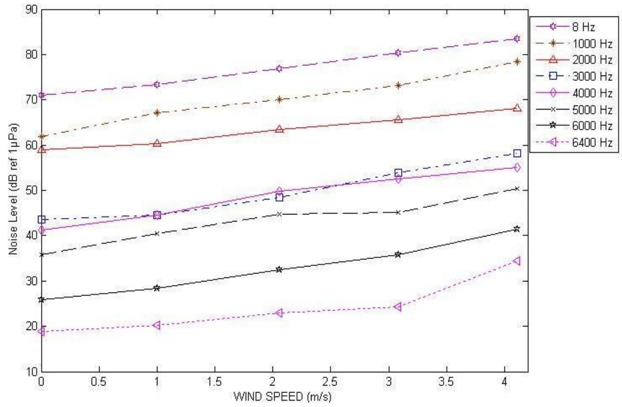

Fig. 1 Noise level at different frequencies for varying wind speeds

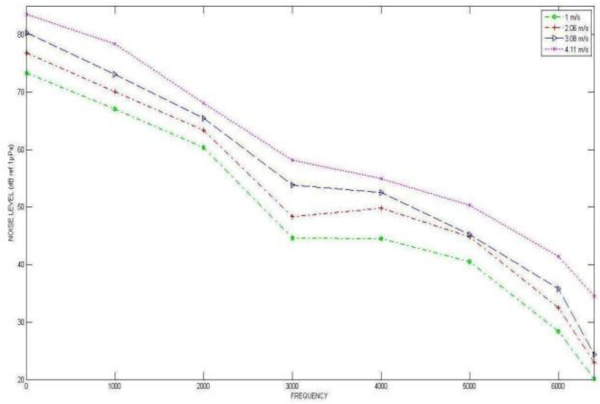

Fig. 2 Noise level at different wind speeds for varying frequencies

It can be seen from the figures (fig1 & 2) that there is a steep increase in the slope and noise level as the wind speed increases. The slope of the spectrum in the band 0 Hz to 6.4 KHz decreases by 5 dB per octave expect in the band 3 KHz to 4 KHz, where it is almost flat. The amplitudes in this band vary from (i) 73 dB–20 dB for the wind speed of 1 m/s (ii) 77 dB –23 dB for 2.06 m/s (iii) 80 dB –24 dB for 3.08 m/s (iv) 84 dB –35 dB for 4.11 m/s.

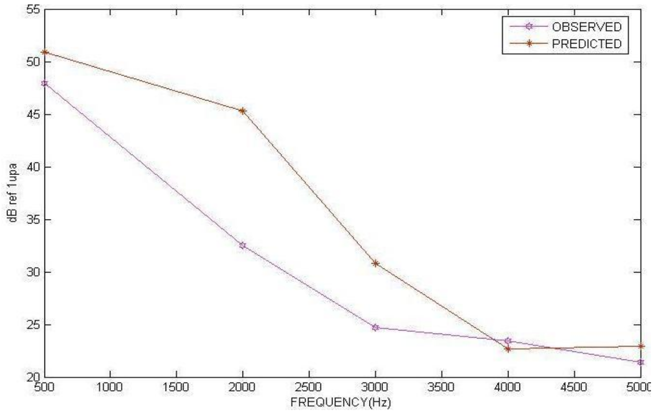

Fig. 3 Comparison of the observed and model predicted noise level

Figure 3 shows a typical comparison plot for frequency range between 500 Hz and 5000 Hz was generated for a representative wind speed of 1.03 m/s. The value of slope (n) and B obtained from the empirical fitting were used for validation with measured noise level. It is seen that the predicted noise level generated by the model is in good agreement with the measured noise levels. The data collected during January & March was used for wind –noise empirical modeling. The results show good correlation between noise spectrum level and wind speed in the frequency range between 500 Hz and 5000 Hz.Scatter plot of wind speed versus temperature were obtained by plotting wind speed along y axis & temperature along x axis. The data used was from 9:30 am to 12:30 pm and 2:30 pm to 4:30 pm. The plots obtained are shown below. Figure 4 & Figure 5 show that there is no statistical relation between temperature & wind speed in Arabian Sea.

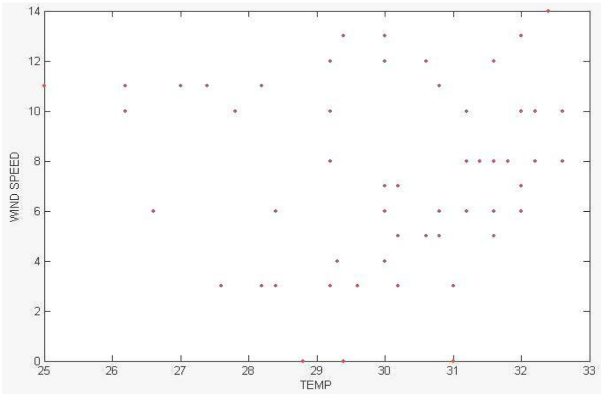

Fig. 4 scatter plots to show relation between temperature & wind speed (morning)

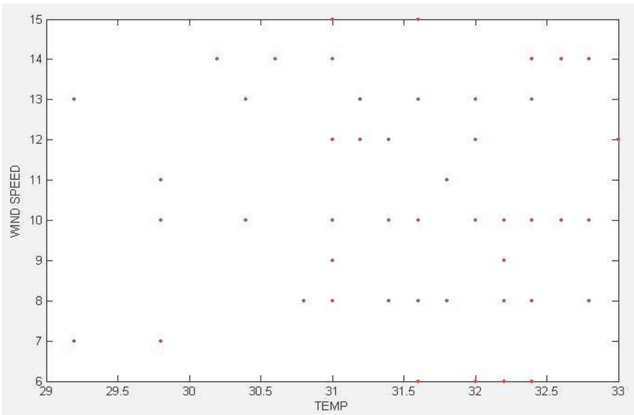

Fig. 5 scatter plots to show relation between temperature & wind speed (afternoon)

4. CONCLUSION

The study of wind dependence of ambient noise in sea has been carried out as it serves as a basis for the estimation of ambient noise using empirical model. Most of the work on wind dependence of ambient noise is reported for deep waters due to its predominance in these zones. It has been shown that the ambient noise is highly variable in shallow water due to the site and season dependent factors. In this work, an experimental study of the wind dependency of shallow water ambient noise level of Arabian Sea is reported. The analysis shows that the noise spectrum level increases with wind speed and the correlation between the noise level and wind speed was good in the frequency range between 0.0 Hz and 6400 Hz. Noise levels recorded were higher in shallow water than those reported for deep waters (1970). This could be attributed to the fact that the shallow water ambient noise is more affected by surface winds. Comparison of the predicted noise level from the empirical fit and the measured noise levels show good agreement. However, behavior of the empirical model would further be improved if site specific long term sound speed profile measurement and ocean bottom parameters are also incorporated (Yang & Yoo, 1997). It also appears that such analyses are useful for the improvement of signal to noise ratio of acoustic instruments.

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