A TWO-COMPONENT ARCTIC AMBIENT NOISE MODEL

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ABSTRACT

Short term Arctic ambient noise spectra over the frequency band 2 - 200 Hz are presented along with a two component noise model capable of reproducing these spectra. The model is based on the measured source spectrum and the spatial, temporal and source level distributions of both active pressure ridging and ice cracking. Modelled ambient noise levels are determined by summing the input energy of the distributions of ice cracking and pressure ridging events and removing the propagation loss. Both modelled and measured spectra show that ice cracking may dominate the spring-time ambient noise to frequencies as low 40 Hz with active pressure ridging dominating below this. Modelled results also show that over 80% of the total noise energy above 40 Hz produced by ice cracking is generated within 30 km of the receiving hydrophone while over 50% is generated within 6 km.

1. INTRODUCTION

The long term averaged ambient noise spectrum of the Arctic Ocean over the frequency band of 1 - 1000 Hz exhibits two broad peaks centered near 15 Hz and 300 Hz [1]. Two important factors for many sonar applications are the short term variability of the ambient noise spectrum and the spatial distribution of sources which comprise the ambient noise. This paper examines the short term fluctuations (2 min) of Arctic pack ice ambient noise spectra over the frequency band 2 - 200 Hz and relates these fluctuations to environmental conditions. A two component noise model incorporating both ice cracking and active pressure ridging is presented which is capable of reproducing the measured ambient noise spectra. This model shows the relative importance of each source term over the frequency band examined. Also shown is the maximum range required to model 80% (within 1 dB) and 50% (within 3dB) of the ambient noise created by ice cracking, thus indicating whether ambient noise generated by ice cracking is produced at close or far range.

2. AMBIENT NOISE MEASUREMENTS

The data analyzed in this paper were collected on the pack ice off the northern coast of Ellesmere Island over several days during April 1988. Details on the experimental setup and environmental conditions are available in other papers by the authors [2, 3].

A set of 69 two-minute samples of ambient noise were recorded approximately every 1.5 hours over 100 hours. At the end of this data collection period, a pressure ridge built itself approximately 2 km from the experimental site. Continuous ambient noise measurements were recorded for several hours during the time of this ridge building event.

The 69 two-minute samples of ambient noise recordings were separated into four distinct classes by examining their power spectra. Class one indicated a peak with a level of approximately 86 dB//μPa at 8 Hz and a fall-off to 48 dB//μPa at 200 Hz. Class two contained the same peak near 8 Hz but the fall-off at higher frequency had two stages with a rapid decrease in level out to 35 Hz and a slower decrease beyond 35 Hz to a level of 57 dB//μPa at 200 Hz. Class three contained a weaker and broader peak at 4 Hz with a fall-off at higher frequency to 58 dB//μPa at 200 Hz. Class four showed a continual but slow decrease in noise level with increasing frequency from a level of 85 dB//μPa at 2 Hz to 66 dB//μPa at 200 Hz. The minimum number of data sets used in any class was 14.

The four classes of ambient noise spectra are compared to environmental conditions and the number of detected ice cracking events occurring per minute. The noise level above 35 Hz was found to be highly correlated with both a falling temperature and the rate of detected ice cracking events. This is consistent with previous observations of thermal ice cracking. The strong peak at 8 Hz was found to be highly correlated with wind speed and barometric pressure.

3. MODEL

The goal of the two component ambient noise model described below is to accurately model the ambient noise spectra observed in the Arctic pack ice over the frequency band 2 - 200 Hz. For these frequencies, the ambient noise is assumed to be produced mainly by ice cracking and active pressure ridging. Thus, by summing the acoustic field generated by the distribution of these events, the ambient noise can be reproduced and the relative contributions of each noise source at the receiver can be determined.

3.1. Pressure Ridging

Measurements by SEASAT SAR give pan sizes for ice floes of 10 - 100 km. Pans are defined as groups of ice floes which move together. Because of the large spatial separation of active pressure ridges, the component of ambient noise caused by pressure ridging may be dominated by single or few events occurring at some large distance from the array. Thus, examining a single pressure ridging event as a function of range may provide insight into the role of pressure ridging on the ambient noise. This requires only knowledge of the source spectral level and the propagation loss.

The source spectral level of active pressure ridging was reported in a previous paper [2] and shown to be monotonously decreasing. When this spectral level is corrected for propagation loss, the resulting spectrum of a very distant ridging event exhibits a broad infrasonic peak as found in the ambient noise [2].

3.2. Thermal Ice Cracking

In order to develop the thermal ice cracking component of the ambient noise model, the spatial, temporal and source level distributions along with the source spectrum and directivity of thermal ice cracking must be known. The spatial distribution of events over the entire 69 two minute samples was found to be uniform. This gives some justification to the proposed model of determining an average input energy per unit area. Note however that two forms of short term fluctuations of the average input energy can occur. The first is a strength fluctuation in the overall input level applied to all locations as the rate of ice cracking changes. The second is a random statistical fluctuation in the spatial distribution which may cause local areas of weak or intense ice cracking. These random statistical fluctuations have more effect on the ambient noise when occuring at close range and thus are applied only within 1 km of the hydrophone.

For the 2 - 200 Hz frequency band observed, the source directivity of thermal ice cracking was found to be well described by a monopole in the ice while the source spectrum was found to be relatively flat [3]. Thus, the source strength distribution of these events does not depend on frequency for this frequency band. Source levels of detected events were measured in the range of 110 - 180 dB//μPa at 1m and approximated a linearly decreasing function on a log-dB scale of the number of events versus source level [3]. The decrease in occurring events with increasing source level is proportional to $10^{-\alpha SL}$ with $\alpha \approx 0.08$ for source levels below 160 dB//μPa and $\alpha \approx 0.12$ for source levels above.

Using the source level distribution along with the fact that the events are spatially uniform, the mean energy input into the ice per square kilometer as a function of source power can be determined as:

$$E(P) = \delta t \; N(P) \; P$$

where $N(P)$ is the mean number of events occurring at source power P per square kilometer per minute, and δt is the mean time duration in minutes of an event. From our data, δt was found to be approximately 0.1 seconds. The total average energy entering the ice per square kilometer is then obtained by summing over all source powers as:

$$E = \delta t \sum_{P=Pmin}^{Pmax} N(P) \; P.$$

This gives an average energy input into the ice of 116.6 dB/km^2//μPa at 1 m. Using the average energy input per square kilometer calculated above, the average energy received at a hydrophone from a given source location is simply the average input minus the propagation loss associated with that location.

Finally, the thermal ice cracking model outlined above is capable of determining the relative contribution of close versus far range events in producing the ambient noise. Over 80% (within 1 dB) of the total noise energy produced from all thermal ice cracking events was generated within 30 km of the hydrophone while over 50% (within 3 dB) was generated within 6 km range.

4. RESULTS

The two-component noise model reproduced all four classes of measured real spectra within 1.5 dB for all frequencies above 3 Hz. The model showed that the measured ambient noise spectra can be reproduced by a single active pressure ridging event, along with a distribution of thermal ice cracking events. For frequencies below 40 Hz, the ambient noise spectrum may be determined by the range and level of the strongest received active pressure ridge. For frequencies above 40 Hz, the ambient noise spectrum is determined by thermal ice cracking, with overall levels and spectral shape dependent on the intensity of ice cracking and the relative strength of local to average events. For purposes of our model, local events are considered to be within 1 km of the hydrophone.

It was also noted that all of the data files used in classes 1 and 2 for real data occurred during a 66 hour span within the middle of the experiment while all except one of the data files used in classes 3 and 4 occurred before or after this time. This suggests that active pressure ridging was occurring at approximately 40 km range during the entire 100 hours of ambient noise measurements and that for a 66 hour span of time in the middle of the experiment, a much stronger active pressure ridge built itself at a range of approximately 70 km.

REFERENCES

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