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AMBIENT NOISE IN CANADIAN ARCTIC WATERS

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AMBIENT NOISE IN CANADIAN ARCTIC WATERS

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INTRODUCTION

Underwater ambient noise measurements carried out in the waters of the Canadian Arctic over the past 30 years [1-9] have indicated that the major ambient noise mechanisms are related to the interaction of the atmosphere - i.e. wind and temperature - with the ice cover. The main sources of ice generated noise are pressure and shear ridging in the moving pack-ice, ice floe collisions, ice cracking and blowing snow. This paper describes the present state-of-knowledge of the dominant mechanisms found in the Canadian Arctic. However, since the ambient noise conditions depend strongly on the characteristics of the ice cover, which change significantly from one area to another and with time of year, it is convenient first to identify the various ice regimes of the Canadian Arctic and their related dominant noise sources. Other sources of noise, including wind-induced surface waves, acoustic vocalizations of marine mammals, current-induced turbulent flow noise, thermal noise and man-made noises related to shipping and resource exploration, will not be discussed.

ICE REGIMES OF THE CANADIAN ARCTIC

Canadian Arctic waters can be conveniently divided into the 4 regions shown in figure 1. Region 1 consists of the shallow waters of the southeastern channels and inlets that are completely ice-free from August to October. During this ice-free period wind induced surface waves, biological activity and shipping are the main noise sources. As ice starts to form in the late fall the noise is dominated by the continual breaking up of the new ice under the action of the wind. This ice eventually grows to a thickness of about 2 m by the spring and forms into a single motionless ice sheet. During the period of shore-fast ice the average background noise level is very low with the major noise source being wind-blown snow impacting on the ice surface.

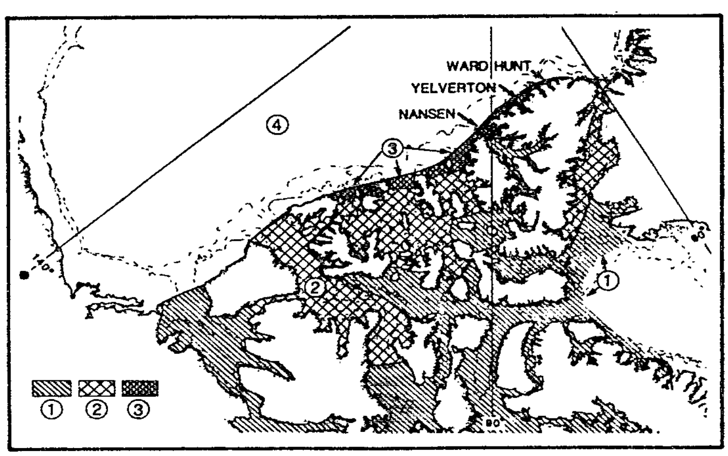

Figure 1. Ice regimes of the Canadian Arctic.

Region 2 includes the northern and western channels adjacent to the Arctic Basin. This region is different from region 1 in that it is never ice-free. During the summer the ice consists of old floes of multi-year polar pack-ice surrounded by leads of low salinity melt water. The major noise sources during this period are collisions between the older ice floes as they are pushed about by wind and current. As the leads begin to freeze in the late fall the dominant sources are the breaking up and crushing of the new ice as the old floes are moved about by wind and current. In the winter when the leads freeze and bind the older floes together, the entire ice sheet becomes shore-fast and the noise levels are very low, as in Region 1. However, during the late winter/early spring, an additional noise source, thermal ice-cracking, is present. This type of ice cracking occurs when the temperature drops, and the surface of the brittle, low-salinity, bare refrozen leads and melt pools contracts and fractures.

In both regions 1 and 2 the lowest noise levels occur during the shore-fast ice period, while the maximum levels occur in the late summer and fall.

Region 3 consists of a relatively narrow strip of shore-fast ice along the northwest coast of the Archipelago. In this region, particularly along the northwest coast of Ellesmere Island, the ice in the mouths of most of the bays and inlets exposed to the Arctic Basin consists of either 40 to 60 metre-thick ice shelves or 6 to 10 metre-thick ice plugs. As might be expected, the ambient noise conditions in this areas fall somewhere between those of Region 2 and the Arctic Basin. Experimental measurements carried out by DREP at a number of locations along the coast of Ellesmere Island from Nansen Sound to Ward Hunt Island indicate that most of the noise is generated in the pack-ice and along the shear zone between the pack-ice and shore-fast ice. Thermal ice-cracking has only been observed at one location in Region 3 — the ice plug at the mouth of Nansen Sound. This ice plug is composed of large floes of old polar ice similar to the ice found in Region 2, held together by low salinity refrozen leads. These are blown relatively clear of snow thus allowing thermal ice-cracking to occur in the late winter/early spring. Other locations, including the Ward Hunt and Milne Ice Shelves and the ice plug at the mouth of Yelverton Bay, are normally blanketed by about 1 m of snow, effectively preventing thermal ice-cracking from occurring.

Region 4 consists of that part of the Arctic Basin adjacent to the Canadian Archipelago covered by the permanent polar ice pack. The dominant sources of noise in this area are ice cracking, the formation of pressure and shear ridges and ice floe collisions caused by wind and currents. The major difference between this area and Region 2 is that the ice becomes shore-fast in Region 2 while the pack-ice of the Basin is in constant motion all year round. During the summer melt season the noise is generated by old ice floes bumping and grinding together. In the winter, leads are forming and breaking up constantly as the pack-ice moves.

In both regions 3 and 4, the lowest noise levels occur during the summer while the highest levels occur in the winter.

AMBIENT NOISE MECHANISMS

Ice Floe Dynamics

The dominant sources of ambient noise in Arctic waters, from late fall through to spring, are the interactions of ice floes under the influence of winds and currents. Pressure and shear ridging are the major sources, while the jostling and bumping of floes in the summer is a relatively minor noise source [2]. Pressure ridges form when adjacent ice floes move towards each other. As the ice floes advance, the ice between them is thrust either over or under one of the floes causing sufficient stresses to break the floe. This in turn induces compressional, shear and flexural waves and buoyant bobbing motions in the ice floes which radiate acoustic energy into the water below. This type of noise is generally impulsive and non-stationary. However, the ridging activity can also excite relatively narrowband tonals and low frequency standing gravity flexural waves [10] in individual ice floes.

Shear ridging, which is very common along the shear zone between the moving pack-ice and shore-fast ice of Region 3, occurs when adjacent floes grind or slide past each other. The shearing action can excite various resonances within the ice floes, and produce relatively narrowband tonals with frequencies varying from less than 5 Hz up to several hundred Hz.

Ambient noise levels recorded simultaneously at hydrophones suspended from the ice at Yelverton Bay and from a hydrophone located 22 km away at Milne Fiord revealed a few interesting features of the nature of the noise associated with ridge building. The measurements indicated that the same low frequency events, ranging from impulses several seconds long to events lasting from one to ten minutes were received at both sites. This is illustrated in Figure 2, which shows the intensity in the octave band centred at 10 Hz for a series of high level impulses received at both sites over a 22 minute period. Based on measurements of the time

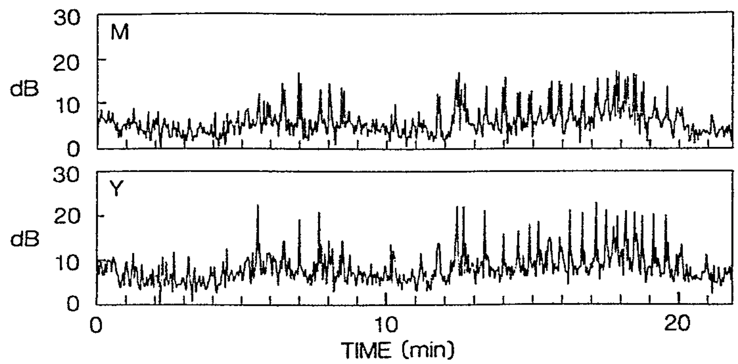

Figure 2. 10 Hz octave band noise levels recorded at Milne Fiord and Yelverton Bay in May 1984.

delay between the energy received at two Yelverton hydrophones and the time delay between the hydrophones at Yelverton Bay and Milne Fiord, the positions of these noise events was estimated to be within a small area approximately 10 km from the shore-fast ice about midway between the Yelverton and Milne hydrophones. The energy in these noise bursts is mostly below 50 Hz, with a spectral peak at about 10 Hz. This is in agreement with a model of a single acoustic noise burst due to ice cracking and breaking, proposed by Dyer [11].

Thermal Ice-Cracking

Ambient noise measurements carried out by Milne [1-7] in the 1950's and 1960's led to the identification of thermal ice-cracking as a major source of noise in the Canadian Archipelago. Basically, as the air temperature drops, the ice cover contracts and the resultant stresses produce cracks in the top few tens of centimetres of ice. During springtime the falling temperatures correspond with the daily solar cycle and hence the thermal cracking noise has a distinct daily period with maximum levels at midnight. Conditions are ideal for thermal ice-cracking in the wind-blown refrozen leads and melt pools of Regions 2 and 3. The ice is low in salt content and, hence, is brittle, and the snow cover is thin to nonexistent which allows the ice surface temperature to follow changes in the air temperature. The power spectra of the cracks measured by Milne [4] in Region 2 have a broad maximum at about 200 Hz and fall off at about 5 db/octave below that frequency.

The spectral characteristics of ice-cracking noise observed at Nansen Sound (Region 3) exhibited the same broad peak at about 200 Hz. However, at this location an additional relatively narrow spectral peak appeared at about 5 Hz during times of high ice-cracking activity. This is illustrated in Figure 3, which shows the average relative noise levels as a function of time of day for the month of April, for 1/3rd-octave bands centred at 5, 20, and 200 Hz. This dramatic nightly increase in the 5 Hz band, which has not been observed previously, is not likely due directly to ice cracking.

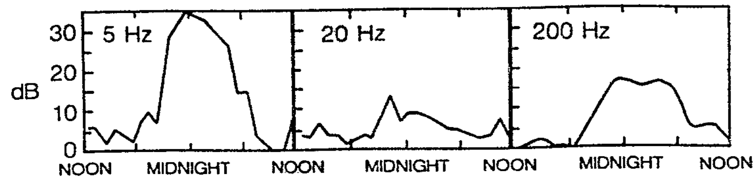

Figure 3. Average 1/3rd-octave band noise levels versus time of day for the month of April.

The most probable explanation is that the ice cracking excites standing waves - either direct ice-coupled or air-coupled flexural waves - in the ice sheet that are enhanced further by standing wave resonances in the 500 m water column. The exact relationship is not known at this time.

Blowing Snow

Blowing snow is an important noise source during the winter and spring, especially under the quiet shore-fast ice conditions of the Archipelago. This type of noise occurs when the wind blowing over the sea ice dislodges grains of snow from the snow surface and sends them saltating downwind. The impacts of these grains on the surface produce noise which is transmitted through the snow and sea-ice into the water below [12]. The large numbers of individual impacts produce Gaussian noise. Milne [12] concluded that the noise intensity increases at a rate approaching the cube of the wind speed in the frequency band 2 to 20 kHz.

SUMMARY

The Canadian Arctic can be divided into four basic geographic regions, each with unique ice and ambient noise conditions: first, the southeasterly channels of the Archipelago where the ice cover is seasonal, second, the northwesterly channels where polar floes exist throughout the year, third, a narrow strip of shore-fast ice along the northwest coast of the Archipelago and fourth, the Basin which is covered by the constantly moving polar pack-ice.

The wind is a major noise producing source. In the Arctic Basin it is a contributing factor to the strongest noise sources in the Arctic - pressure and shear ridging. In the Archipelago it creates noise through the breakup of the thin winter ice in the southeasterly channels and by being the dominant moving force of the ice floes in the northwesterly channels. During the periods of late winter and spring, when the ice in the Archipelago is shore-fast, it produces noise by blowing snow over the surface.

Short term variations in air temperature lead to thermal ice-cracking, which is an important source in the Northwestern channels when the ice is shore-fast.

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