SRI 2017 - Maritime Security Center

Arctic Acoustics

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Research Question

What is the acoustic frequency and sound pressure level of sound waves emitted from cracking ice cover within the Arctic?

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Why is this research important for the DHS?

- Identification of arctic ice floes
- Navigation of ships through the Arctic Region
- Safety of Life at Sea (SOLAS) Mission

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What is an Acoustic Signature?

A: The unique pattern of pitch, loudness, and timbre associated with an acoustic event.

Our Mission: To replicate the interactions between arctic ice floes, and record their acoustic signatures.
Team Approach

Experimental Setup, Data Collection, and Type of Tests

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Experimental Setup

- microphone
- sound absorbers
- experimental tub
- hydrophone stands and hydrophone
- computer
- hydrophone recorder

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Tests

1. Thermal cracking
2. Ice fracturing
3. Ice shearing

Performed ~ 125 Trials

- Thermal - 56
- Fracture - 19
- Shearing - 15
- Ambient - 6
- Control Measurements - 29
Thermal Cracking

Procedure
• Place block into warm water (about 35°C) and submerge
• Wait for block to crack from water and air temperature contrast

Observations
• Pressure differences between interior and exterior of ice

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Ice Fracturing

Procedure:
- Freeze wedge in water
- Slowly use clamp on metal wedge until ice separates

Observations
- Minor cracks before fracture

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Ice Fracture

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Ice Shearing

Procedure:
• Freeze two wooden wedges in two blocks of ice
• Slide and bump blocks of ice against one another to create a shearing force

Observations
• Ice rubbing sound levels were very low

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Ice Shearing

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Data Collection/Analysis

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Periods

• For thermal cracking, ice fracturing, and ice shearing
  • Acoustic events lasted 20 ms ± 10 ms

• For ice rubbing:
  • Acoustic events lasted 30 seconds ± 2 seconds

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Hydrophone and Microphone Correlation

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Results

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Fingerprinting of Sound Pressure Level

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Fingerprinting of Common Frequencies

Common frequencies are visually identified by common node areas followed by common peak areas across the majority of datasets.

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Thermal Crack with Partitions

Slide 21

Frequency 0-5000 Hz

Relative Loudness

425-825Hz
1550-2100Hz
2500-3050Hz
3900-4750Hz

Microphone
Microphone
Hydrophone
Hydrophone

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Ice Fracture with Partitions

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![Frequency vs. Relative Loudness](image-url)
Ice Shearing with Partitions

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Common Average Frequencies for Different Cracks

Slide 24

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Anticipating Ice Fracturing

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Real World Original Icequake, 0-5000 Hz

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Moving Forward

Future Expansion of this Project

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Recommendations

- Utilize a bigger tank
- Test different block sizes and shapes
- Compare results to more recorded sounds from the Arctic
- Machine Learning

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- MSC Faculty
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- Chef Eric
Auxiliary Slides

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Photographs

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- http://www.newfoundlandlabrador.com/Content/images/Iceberg_shape_chart_accord.png
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- https://www.allaboutbirds.org/guide/PHOTO/LARGE/bald_eagle_adult2.jpg
- https://www.talend.com/blog/2017/04/14/applying-machine-learning-to-iot-sensors/

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Literature Review

- Current conditions of the Arctic
- Properties of ice
  - How ice fractures and different sounds are generated
- Detecting sound in the Arctic
- Search and Rescue in the Arctic

Arctic Sea Ice Maximum at Record Low for Third Straight Year.
Preprints, IUTAM Symp. on Scaling Laws in Ice Mechanics (Univ. of Alaska, Fairbanks, June)
Acoustic Transients of the Marginal Sea Ice Zone: A Provisional Catalog (No. NRL-MR-6408)
Fracture - Antarctic Sea Ice Processes & Climate (ASPeCt)
Acoustic remote sensing of Arctic Sea Ice from long term soundsource measurements
underwater noise transients from sea ice deformation: Characteristics, annual time series, and forcing in Beaufort Sea. The Journal of the Acoustical Society of America
Assessing the U.S. Navy's Arctic Roadmap.
Ice Sound Detection and Localization
Navigating pressured ice: Risks and hazards for winter resource-based shipping in the Canadian Arctic. Ocean & Coastal Management
National Instruments. (2014, November 05). Resolution Bandwidth (RBW)
Mechanical Properties of Ice and Snow. Journal of Materials Science
Search and Rescue in the Arctic
Sound of Ice Break-Up and Floe Interaction. The Journal of the Acoustical Society of America
Automatic extraction of spring-time Arctic ambient noise transients

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Control Measurements

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Ambient: 5,000Hz

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Salinity Control Measurement

Procedure

• Use water-proof speaker to play white noise underwater

• Measure radiant sound when water is fresh, 16ppt, and 32ppt

• Compare power spectrums: if impedance effects from changing salinity will influence power spectrums
Tank Control Measurement

Procedure:

- Nearly identical to previous procedures
- Measure radiant sound when tank is full and ½ full
Possible Sources of Error

- Tank Size
- Frequency Resolution
  - Bandwidth (RBW)
  - Data smoothing
- Delimiting impulse start and end points by visual inspection
## Ice Block Tests

<table>
<thead>
<tr>
<th>Trail #</th>
<th>Date</th>
<th>Type of experiment</th>
<th>Ice generation (yr)</th>
<th>Water Temp, °C</th>
<th>Ice Temp, °C</th>
<th>Room Temp, °C</th>
<th>Salinity, ppt</th>
<th>Block Size</th>
<th>Time</th>
<th>Duration, sec</th>
<th>Time of cracks, sec</th>
<th>Additional Notes</th>
<th>Success</th>
<th>Processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7/10/2017</td>
<td>Thermal</td>
<td>1</td>
<td>22</td>
<td>-14</td>
<td>26</td>
<td>0</td>
<td>35.6cm x 20.3cm x 12.4cm</td>
<td>10:33am</td>
<td>156</td>
<td></td>
<td>no noticeable cracks</td>
<td>Fail</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>7/10/2017</td>
<td>Thermal</td>
<td>1</td>
<td>21</td>
<td>-14</td>
<td>26</td>
<td>0</td>
<td>35.6cm x 20.3cm x 12.4cm</td>
<td>10:38am</td>
<td>158</td>
<td></td>
<td>no noticeable cracks</td>
<td>Fail</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>7/10/2017</td>
<td>Thermal</td>
<td>1</td>
<td>20</td>
<td>-14</td>
<td>26</td>
<td>0</td>
<td>42.5cm x 30.2cm x 17.8cm</td>
<td>11:04am</td>
<td>125</td>
<td>5, 11, 12, 27, 73</td>
<td>large block, distinguish</td>
<td>Success</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>7/10/2017</td>
<td>Ambient</td>
<td>1</td>
<td>N/A</td>
<td>26</td>
<td>N/A</td>
<td>0</td>
<td>35.6cm x 20.3cm x 12.4cm</td>
<td>11:11am</td>
<td>7</td>
<td></td>
<td>James M. talked</td>
<td>Fail</td>
<td>---</td>
</tr>
<tr>
<td>5</td>
<td>7/10/2017</td>
<td>Ambient</td>
<td>1</td>
<td>18</td>
<td>N/A</td>
<td>26</td>
<td>N/A</td>
<td>35.6cm x 20.3cm x 12.4cm</td>
<td>11:12am</td>
<td>20</td>
<td></td>
<td>Ambient noise</td>
<td>Success</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Microphone vs. Hydrophone Secondary Example

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Volumetric Differences in Block Sizes

![Graph showing volumetric differences in block sizes]

- **Standard Size Block**
- **Larger Block**

Relative Loudness vs. Frequency (0-5000 Hz)

- 350-750 Hz
- 1550-2100 Hz
- 2050-3050 Hz
- 3900-4750 Hz

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