In Situ Measurements of an Energetic Wave Event in the Arctic Marginal Ice Zone

14th Wave Workshop - 11/09/2015

CO “Tripp” Collins III
ASEE Postdoctoral Fellow, NRL - SSC

W Erick Rogers¹, Aleksey Marchenko², Alexander V Babanin³

¹Oceanographer, NRL – SSC
²Professor, the University Center in Svalbard
³Professor, Swinburn University of Technology
Wave-Ice Interaction: Wave effects on ice

- Stress / Strain
- Creep
- Fatigue
- Failure
- Fracture
- Force Collisions
- Transport
- Compress

$E(f,\theta)$

Free ocean surface $z = -H$
Wave-Ice Interaction: Ice effects on waves

- Scattered
- Reflected
- Transmitted
- Attenuated
- Change in dispersion
- Change in groupiness?

\[ E(f, \theta) \]
Swell and sea in the emerging Arctic Ocean

Thomson & Rogers (2014)

Geophysical Research Letters
Volume 41, Issue 9, pages 3136-3140, 5 MAY 2014 DOI: 10.1002/2014GL059983
Feedback Loop

Less ice cover

Larger waves
Evaluating $S_{\text{ICE}}$

Rogers and Zeiger (2014) New Wave-Ice Interaction Physics in WAVEWATCH III®
Svalbard
UNIS Cruise Synopsis

Hopen Island
Available Fetch

SSM/I F17, 2010-May-02, Morning Passes

Svalbard

5.0 - 23.4 meters/second
R/V Lance
Wave Data Preview

- $\eta$
- $4 \times \text{std}(\eta) \text{ [moving]}$
Analysis

Significant Wave Height

\[ H_s = 4 \left[ \int S(f) df \right]^{1/2} \]

Low Frequency Wave Height

\[ H_{low} = 4 \left[ \int_0^{0.12} S(f) df \right]^{1/2} \]
Hourly Photos
Fracturing
## Arctic Wave Measurement Survey

<table>
<thead>
<tr>
<th>PUBLICATION</th>
<th>STUDY YEAR</th>
<th>LOCATION</th>
<th>METHOD</th>
<th>WAVE HEIGHT ((H_{\text{M}_0}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Fakidov, 1934]</td>
<td>1933-1934</td>
<td>Arctic Ocean</td>
<td>Visual</td>
<td>&lt;&lt; 1 m</td>
</tr>
<tr>
<td>[Crary et al., 1952]</td>
<td>1951</td>
<td>Arctic Ocean</td>
<td>Gravity Meter(^1)</td>
<td>(5 \times 10^{-4}) m</td>
</tr>
<tr>
<td>[Hunkins, 1962]</td>
<td>1957-1958</td>
<td>Beaufort Sea</td>
<td>Gravity Meter</td>
<td>&lt;&lt; 1 m</td>
</tr>
<tr>
<td>[Wadhams, 1975]</td>
<td>1972</td>
<td>Canadian North Atlantic(^2)</td>
<td>Airborne Laser</td>
<td>(~2) m</td>
</tr>
<tr>
<td>[Squire and Moore, 1980]</td>
<td>1979</td>
<td>Bering Sea</td>
<td>floe-borne accelerometers</td>
<td>(~1.5) m</td>
</tr>
<tr>
<td>[Wadhams et al., 1986; Wadhams et al., 1988]</td>
<td>1978, 1979, &amp; 1983</td>
<td>Bering Sea and Greenland Sea</td>
<td>Buoys</td>
<td>(~1) m</td>
</tr>
<tr>
<td>[Liu et al., 1991]</td>
<td>1989</td>
<td>Labrador Sea</td>
<td>Buoy</td>
<td>(~2.6) m</td>
</tr>
<tr>
<td>[McKenna and Crocker, 1992]</td>
<td>1989</td>
<td>Labrador Sea</td>
<td>floe-borne accelerometers</td>
<td>(~0.5) m</td>
</tr>
<tr>
<td>[Rottier, 1992]</td>
<td>1989</td>
<td>Barents Sea and Fram Straight</td>
<td>Buoy</td>
<td>(~0.75) m</td>
</tr>
<tr>
<td>[S. Frankenstein et al., 2001](^3)</td>
<td>1990</td>
<td>Barents Sea</td>
<td>floe-borne accelerometers</td>
<td>&lt; 1 m</td>
</tr>
<tr>
<td>[Marko, 2003]</td>
<td>1998</td>
<td>Sea of Okhotsk(^4)</td>
<td>ADCP</td>
<td>(~1.5) m</td>
</tr>
<tr>
<td>[Asplin et al., 2012]</td>
<td>2009</td>
<td>Beaufort Sea</td>
<td>3-D ship-borne recorder</td>
<td>(~0.75) m</td>
</tr>
<tr>
<td><strong>This Study</strong></td>
<td><strong>2010</strong></td>
<td><strong>Barents Sea</strong></td>
<td><strong>Ship GPS</strong></td>
<td><strong>4-5 m</strong></td>
</tr>
</tbody>
</table>

\(^1\)There are other studies which analyze the observations of gravity meters, seismometers, or tiltmeters deep in the ice field (see the references in Wadhams, 1975), all of which record small \((O(1 \times 10^{-4} \text{ m}))\) vibrations of the ice.

\(^2\)Not within the Arctic region

\(^3\)An event very similar to the one reported in our manuscript was described, but measurements were not made during it

\(^4\)Not within the Arctic region
Ice as low pass filter

Spectral density

- SWAN
- R/V Lance 02 23:24
- R/V Lance 03 00:30
- R/V Lance 03 02:30
- R/V Lance 03 03:30

S(f) [m²/s]

Frequency [Hz]
Summary

• (1) Largest waves measured in Arctic Ice
• (2) Waves present bi-nary behavior
• (3) Ice acts as a low pass filter

As climate warms waves become more important in the Arctic

Future Work
• Continue to develop $S_{\text{ICE}}$
• Field work underway for testing and validation

Evidence of small-scale $O(km, H)$ change in wave-ice interaction
• Can we run coupled models at this scale? What does this imply for operational wave prediction in icy conditions?
Thanks!

Further Reading:
Scientific American (online): Giant Waves Quickly Destroy Arctic Ocean Ice and Ecosystems
Collins, Rogers, Marchenko, & Babanin (2015) In Situ Measurement of an Energetic Wave Event in the Arctic Marginal Ice Zone
Thomson & Rogers (2014) Wind Sea and Swell in the Emerging Arctic Ocean
Squire (2007) Of Ocean Waves and Sea Ice Revisited