Preliminary modelling of shallow water waves off the Mackenzie Delta

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IPY: Impact of Arctic storms and climate change on coastal processes
Canadian Panel on Energy Research and Development
Outline/ motivation

1. Introduction to storm climate, tracks etc.
2. Coupled models
   - role of currents and ice
   - Arctic storm example
3. Observed data
   - winds, waves, currents, SST
   - physical processes
4. Wave model comparisons
   - Case studies
5. Conclusions
5. Concluding Remarks

- Model skills vary for different storms and buoys.
- Triad interactions do not have beneficial effect on wave simulations.
- Simulations are sensitive to bottom friction, but bottom friction parameterizations do not give good results in the study area.
  → formulations need to be tuned for the fine sediment and shallow depth of the Mackenzie Delta.
- Of the two SWAN formulations for wave dissipation simulations, Westhuysen option is better than Komen option.
- In most cases MIKE21 simulations are found to be close to the results of Westhuysen option in SWAN.
1. Introduction to storm climate, tracks etc.

Mackenzie Delta Coast
Change in sea ice extent

Figure 6
Comparison of September ice extent for 1980, 2005, and 2007, showing the 2007 ice extent (white region), the 2005 extent (white region), and the 1980 extent (red, pink, and white regions).

Perovich et al, 2008
NCEP reanalysis data storm tracks
2. Coupled models
- role of currents and ice
- Arctic storm example
Atmosphere–Ocean–Ice Coupling

**MC2 Model**
- surface T, U10, SLP, SW radiation, clouds, precip., spec. humidity

**Ice model**
- ice conc.+ thick.

**POM**
- T, S, current

**SST**

**PHC (Polar Science Center)**
- hydrogr. climatology, T,S

**moment., moisture, Heat, SW radiation**
**Experiment Design of models**

**Coupled Model**

**MC2:**
- 25Km resolution
- 30 vertical layers
- 900s time step

**CIOM (Ice-Ocean):**
- ≈ 27.5Km
- 23 vertical layers
- 900s time step
- 7 ice categories
Ice current at 72h for the coupled model, after 1800 UTC 22 Sep., 1999.

Arctic storm case

Model simulation results

Ice speed

Ice current at 1800 UTC 25 Sep.
Time series following storm centre
(after reaching the Beaufort Sea)

![SLP](chart)

![U10](chart)
Time series of air temperature (2 m), (Ta), winds ($m \cdot s^{-1}$), SST ($^\circ C$), and SLP (hPa).
3. Observations: 2007 Field Experiment

NRCAN Composite of Landsat-7

Field data
MODIS SST
Current velocity observations

a) Current velocity observations for different depths:
   - b) $h = 0.5$ m
   - c) $h = 2.5$ m

- Alongshore velocity (m/s) for different depths:
  - d) $h = 0.5$ m
  - e) $h = 2.5$ m
4. Wave model comparisons

Test **SWAN** and **MIKE21 SW** in the Mackenzie Delta.

Test sensitivity of shallow water processes:
- bottom frictions
- nonlinear triads

\[ S_{\text{tot}} = S_{in} + S_{wc} + S_{nl4} + S_{nl3} + S_{bf} + S_{br} \]

where,  
\( S_{in} \) : wind input  
\( S_{wc} \) : whitecapping  
\( S_{nl4} \) : 4-wave interactions  
\( S_{nl3} \) : triads  
\( S_{bf} \) : bottom friction  
\( S_{br} \) : depth-induced breaking.
Computational Domains

Observation stations

<table>
<thead>
<tr>
<th>Buoy</th>
<th>Depth</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEL116</td>
<td>2.24</td>
<td>1985</td>
</tr>
<tr>
<td>MEDS291</td>
<td>7.00</td>
<td>1991</td>
</tr>
</tbody>
</table>

Grid | Latitude, $\lambda$ | Longitude, $\phi$ | $\Delta\lambda$ | $\Delta\phi$ | $n\lambda$ | $n\phi$ | $\Delta t$ (min) |
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>-142.5° ~ -126°</td>
<td>68.9°~71.75°</td>
<td>0.15°</td>
<td>0.05°</td>
<td>111</td>
<td>58</td>
<td>5</td>
</tr>
<tr>
<td>Fine</td>
<td>-138° ~ -133.05°</td>
<td>68.9°-69.85°</td>
<td>0.03°</td>
<td>0.01°</td>
<td>331</td>
<td>191</td>
<td>5</td>
</tr>
</tbody>
</table>
Unstructured Grids in MIKE21 Simulations

Model Setup

MSCB wind

ETOP02 Bathy

Fine resolution bathymetry

Ice Map

Water level

Unstructured grid for MIKE21 SW

MODEL SIMULATIONS

OUTPUTS
MSCB Winds at Tuktoyaktuk during 1985 & 1991 Storms
Ice Cover

16-18 Aug. 1985 storm

03-06 Aug. 1985 storm

Permanent ice

Ice cover on 16 Aug 1985

Ice cover on 17-18 Aug 1985

Ice cover during 03-05 Aug 1991

Ice cover on 6 Aug 1991

Open water

Land
SWAN Sensitivity to Bottom Friction

Hs during 1985 Storm at WELL116 (2.24 m water depth)
SWAN Sensitivity to Bottom Friction

Tp during 1985 Storm at WELL116 (2.24 m water depth)
SWAN Sensitivity to Bottom Friction

1-d spectra during 1985 Storm at WELL116
SWAN Sensitivity to Triad Interactions

Tp during 1985 Storm at WEL116 (2.24 m water depth)

Tp is same with and without TRIAD

Bottom friction off

Bottom friction off
SWAN Sensitivity to Triad Interactions

1-d spectra during 1985 Storm at WEL116
1985 Storm
WEL116
Water depth
2.24 m

cfw: friction co-efficient
default value: 0.0075

fw: friction factor
default value: 0.0212
MIKE21 Sensitivity to Triad Interactions

1985 Storm

WEL116
Water depth
2.24 m

FRICITION OFF
Comparisons of SWAN & MIKE21 Simulations

1985 Storm: Wave Heights & Peak periods

SWAN outperforms MIKE21 in simulating Hs.

MIKE21 similar to SWAN for Tp.

WEL116
Water depth 2.24 m

Without bottom friction & triad interaction
Comparisons of SWAN & MIKE21 Simulations

1985 Storm: 1-d Spectra

MIKE21 overpredicts spectral peaks, whereas SWAN underpredicts spectral peak
Comparisons of SWAN & MIK21 Simulations

1991 Storm: Wave Heights & Peak Periods

- Without bottom friction & triad interaction

MEDS291
Water depth 7m

Graphs showing comparisons of wave heights and peak periods for different models (Komen, Westh, Mike) with observed data.
Comparisons of SWAN & MIK21 Simulations

1991 Storm: 1-d Spectra

MEDS291
Water depth 7m
5. Concluding Remarks

- Model skills vary for different storms and buoys
- Triad interactions do not have beneficial effect on wave simulations.
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