Estimating Nearshore Waves at a Morphologically Complex Inlet during Extreme Storm Conditions: Comparative Performance of Two Phase-Averaged Models

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MOTIVATION

Phase-Averaged Steady State Wave Models are Utilized Extensively at the “Field Office Level”, due to ease of use and usual robustness of results.

BUT, which model to use? Are some models better than others, due to improved numerics and approximations? Do careful applications yield reliable results?

Examine **STWAVE** (Smith, Sherlock, Resio 2001) and **WABED** (Mase et al 2005).

Comparatively Apply the models at the Mouth of the Columbia River to assess model skill.

1) Effect of Large Offshore Submarine Canyon

2) Effect of Nearshore morphology with long jetties
Average Hourly Wave Height Offshore North Oregon Coast for 1985-2005 (NOAA-NDBC) Compared to Hourly Wave Height for WY 2006 and WY 2005
Mouth of the Columbia River
OFFSHORE Model Domain
Descritized using 60 meter cells
Water depth = 900 – 25 m

INSHORE Model Domain
Descritized using 20 meter cells
Water depth = 300 – 0 m
MODELING APPROACH

• NO Current Included
• Models Run as “Black Box”; NO Tuning
• NDBC 46029 Directional Spectra used as Boundary Condition, 120 m, 33 Km offshore
• Compare Models on Relative Basis
• Compare Model to Observed Data
Table 1. Summary of observed wave events used to run and compare STWAVE and WABED.

<table>
<thead>
<tr>
<th>Date of Wave Event</th>
<th>WSE†</th>
<th>Offshore-NDBC 46029*</th>
<th>Observed Wave Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wind-Spd.</td>
<td>Wind-Dir.</td>
</tr>
<tr>
<td>24 NOV 1998</td>
<td>0.8m</td>
<td>15m/s</td>
<td>228°</td>
</tr>
<tr>
<td>3 MAR 1999</td>
<td>0.5m</td>
<td>20m/s</td>
<td>182°</td>
</tr>
<tr>
<td>17 NOV 2003</td>
<td>0.5m</td>
<td>14m/s</td>
<td>279°</td>
</tr>
<tr>
<td>4 FEB 2006</td>
<td>1.85m</td>
<td>20m/s</td>
<td>205°</td>
</tr>
</tbody>
</table>

* = NDBC directional spectrum used as an ocean wave boundary condition to drive WABED and STWAVE models
† = Water Surface Elevation, NGVD (tide +surge). All elevations in this paper are reference to NGVD.
0 NGVD = +1.1 m MLLW
EFFECT OF ASTORIA CANYON ON WAVES APPROACHING THE COAST

WABED, 17 NOV 03
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

STWAVE, 17 NOV 03
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

NO WIND

Hmo in Absolute Color Contour scale
Depth shown as linear contours
WABED, 17 NOV03
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

STWAVE, 17 NOV03
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

NO WIND
Hmo in Relative Color Contour scale
Depth shown as linear contours
**WABED, 4 FEB 06**

Hmo=13.8 m, $T_p = 16.7$ sec, $D_p=230^\circ$

**STWAVE, 4 FEB 06**

Hmo=13.8 m, $T_p = 16.7$ sec, $D_p=230^\circ$

**NO WIND**

Hmo in Relative Color Contour scale

Depth shown as linear contours
Effect of Offshore Large Scale Bathymetry Features

Both WABED and STWAVE show that Astoria Canyon Affects LARGE Waves (when Tp is larger than 14 sec)

This Finding highlights the need to extend “coastal” wave model boundaries outward to include all bathymetry features that have the potential to affect the wave field of interest.

In terms of Examining Wave Propagation ONLY: NO Wind

WABED Appears to Dissipate Wave Action More Rapidly than STWAVE

STWAVE Appears to Simulate Refraction and Shoaling Effects more Vigorously than WABED

In absence of WIND, STWAVE Produces HIGHER Hmo than WABED; 1-2 m higher
ASSESSMENT OF WAVE TRANSFORMATION ON INSHORE DOMAIN

Peacock Spit
Clatsop Spit
Astoria Canyon

Pacific
Ocean

Elevation, m, NGVD

41 km
33 km

NDBC 46029

WA
OR

41 km

145
129
113
97
81
65
49
33
17
1

Peacock Spit
Clatsop Spit
STWAVE, 3 MAR 99
Hmo=12.8 m, Tp = 16.7 sec, Dp=222°

WABED, 3 MAR 99
Hmo=12.8 m, Tp = 16.7 sec, Dp=222°

WIND = 20 m/s @182°
WABED, 3 MAR 99
Hmo=12.8 m, Tp = 16.7 sec, Dp=222°

STWAVE, 3 MAR 99
Hmo=12.8 m, Tp = 16.7 sec, Dp=222°

WIND = 20 m/s @182°
**WABED, 17 NOV 03**  
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

**STWAVE, 17 NOV 03**  
Hmo=9.3 m, Tp = 16.7 sec, Dp=312°

**WIND = 14 m/s @279°**
**WABED, 24 NOV 98**

$H_{mo}=8.9 \text{ m}, \ T_p = 14.3 \text{ sec}, \ D_p=262^\circ$

**STWAVE, 24 NOV 98**

$H_{mo}=8.9 \text{ m}, \ T_p = 14.3 \text{ sec}, \ D_p=262^\circ$

**WIND = 15 m/s @228^\circ**
Table 2. Comparison of observed wave events to STWAVE and WABED estimates.

<table>
<thead>
<tr>
<th>Date of Wave Event</th>
<th>Modeled Wave Statistics</th>
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<tbody>
<tr>
<td></td>
<td><strong>WABED</strong></td>
<td></td>
<td></td>
<td><strong>STWAVE</strong></td>
<td></td>
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<tr>
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<td>Dp</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Observed Wave Statistics</th>
<th>Nearshore</th>
<th>Site</th>
<th>Depth</th>
<th>Hmo</th>
<th>Tp</th>
<th>Dp</th>
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</thead>
<tbody>
<tr>
<td>B2</td>
<td>39m</td>
<td>7.2m</td>
<td>14.2s</td>
<td>266°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>34m</td>
<td>7.0m</td>
<td>14.2s</td>
<td>263°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>34m</td>
<td>11.2m</td>
<td>17.1s</td>
<td>220°</td>
<td></td>
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<tr>
<td>SJ</td>
<td>14m</td>
<td>6.2m</td>
<td>16.7s</td>
<td>252°</td>
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</tr>
</tbody>
</table>

*RED = poor model comparison to observation (Hmo > ± 30% difference)*

*BLUE = fair model comparison to observation (Hmo > ± 10% and < 20% difference)*

*GREEN = good model comparison to observation (Hmo < 10% difference)*
**WABED, 4 FEB 06**

$H_{mo}=13.8 \text{ m, } T_p = 16.7 \text{ sec, } D_p=230^\circ$

---

**STWAVE, 4 FEB 06**

$H_{mo}=13.8 \text{ m, } T_p = 16.7 \text{ sec, } D_p=230^\circ$

---

**WIND = 20 m/s @205^\circ**
Along Shore Transect

Water Depth, m

Alongshore Distance, Km

South view toward offshore (west)

North

Depth
WABED
STWAVE

MCR Nav Channel

South

North
Mouth of the Columbia River

Pacific Ocean

-90 m

-35 m

-20 m

WA

OR

SJ 14 m

Mouth of the Columbia River

Pacific Ocean

-90 m

-35 m

-20 m

WA

OR

SJ 14 m
Comparison Between Observed and Simulated Wave HEIGHT: Sta SJ

- **NDBC 46029, 20 km offshore, 120m**
- **Observed at SJ, 3km offshore, 15 m**
- **Windspeed/10 at 46029**

Days, After 8 OCT 2003
Comparison Between Observed and Simulated Wave HEIGHT: Sta SJ

Days, After 8 OCT 2003

Wave Height, m, Hmo

NDBC 46029, 20 km offshore, 120m
Observed at SJ, 3km offshore, 15 m
STWAVE at SJ
WABED at SJ
Windspeed/10 at 46029
Comparison Between Observed and Simulated Wave ANGLE: Sta SJ

Days, After 8 OCT 2003

Wave Direction, deg

NDBC 46029, 20 km offshore, 120m

Observed at SJ, 3km offshore, 15 m
Comparison Between Observed and Simulated Wave Angle: Sta SJ

Wave Direction, deg

Days, After 8 OCT 2003

- NDBC 46029, 20 km offshore, 120m
- Observed at SJ, 3km offshore, 15 m
- STWAVE at SJ
- WABED at SJ
Both WABED and STWAVE show that: Wave refraction motivated by Astoria Canyon can cause the affected wave field to change direction by 7-10° and have Hmo changed by 1-2 meters. These affects can extend all the way to shore.

If no (or weak) wind forcing is included in the simulations (as was the case for the “offshore” domain), then STWAVE tends to predict higher Hmo than WABED (by 0.5-2 m).

For the “nearshore” domain, WABED appears to estimate a higher Hmo (by 0.5-2m) than does STWAVE when strong wind forcing is included within the simulations.

These “wind” differences appear to diminish as the wave field propagates closer to shore where the wave field being affected by depth limited shoaling and refraction.
WABED employs a more sophisticated algorithm to estimate wave diffraction than does STWAVE, yet the two models produced similar results for the wave field in the lee of the south jetty for storm wave approaching form the SW.

It appears that the diffraction method used within STWAVE is robust enough for engineering estimates at MCR, where the jetties are concerned. More work is needed to evaluate diffraction within both models (comparison to prototype data).

Shoaling and refraction appears to be more vigorously simulated within STWAVE than WABED; likely the result of how the wave action conservation equation is solved within each model. More work is needed to evaluate this.
The two models produced results that in many ways were qualitatively similar. But there were significant absolute differences between the two models at localized locations where refraction/shoaling was severe.

Dissipation appears to be simulated substantially different between the two models; more work is needed to evaluate this.

Wind forcing appears to be treated significantly different between the two models, producing results which may be substantially different in terms of Hmo.