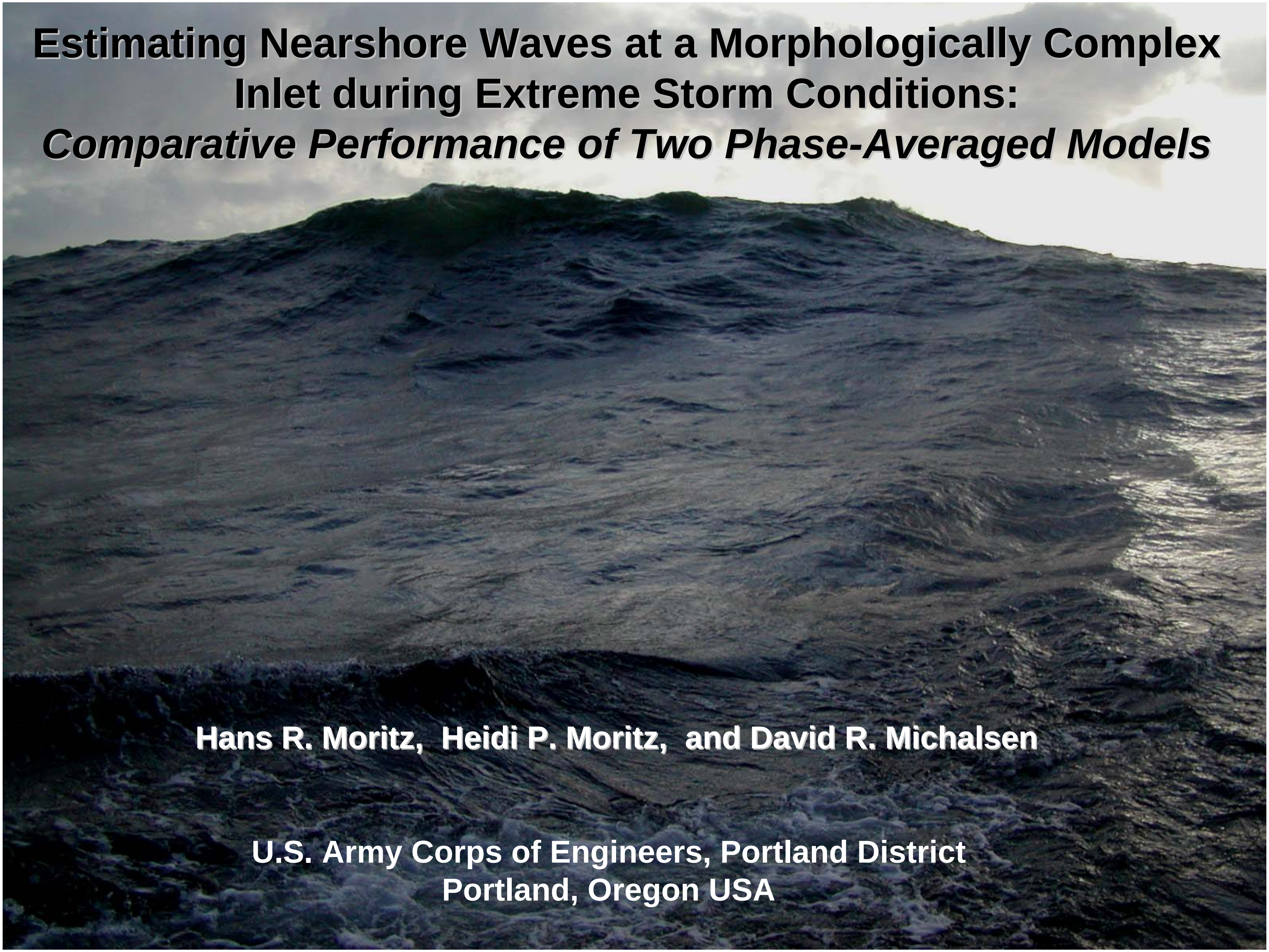
Estimating Nearshore Waves at a Morphologically Complex Inlet during Extreme Storm Conditions:
Comparative Performance of Two Phase-Averaged Models



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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.

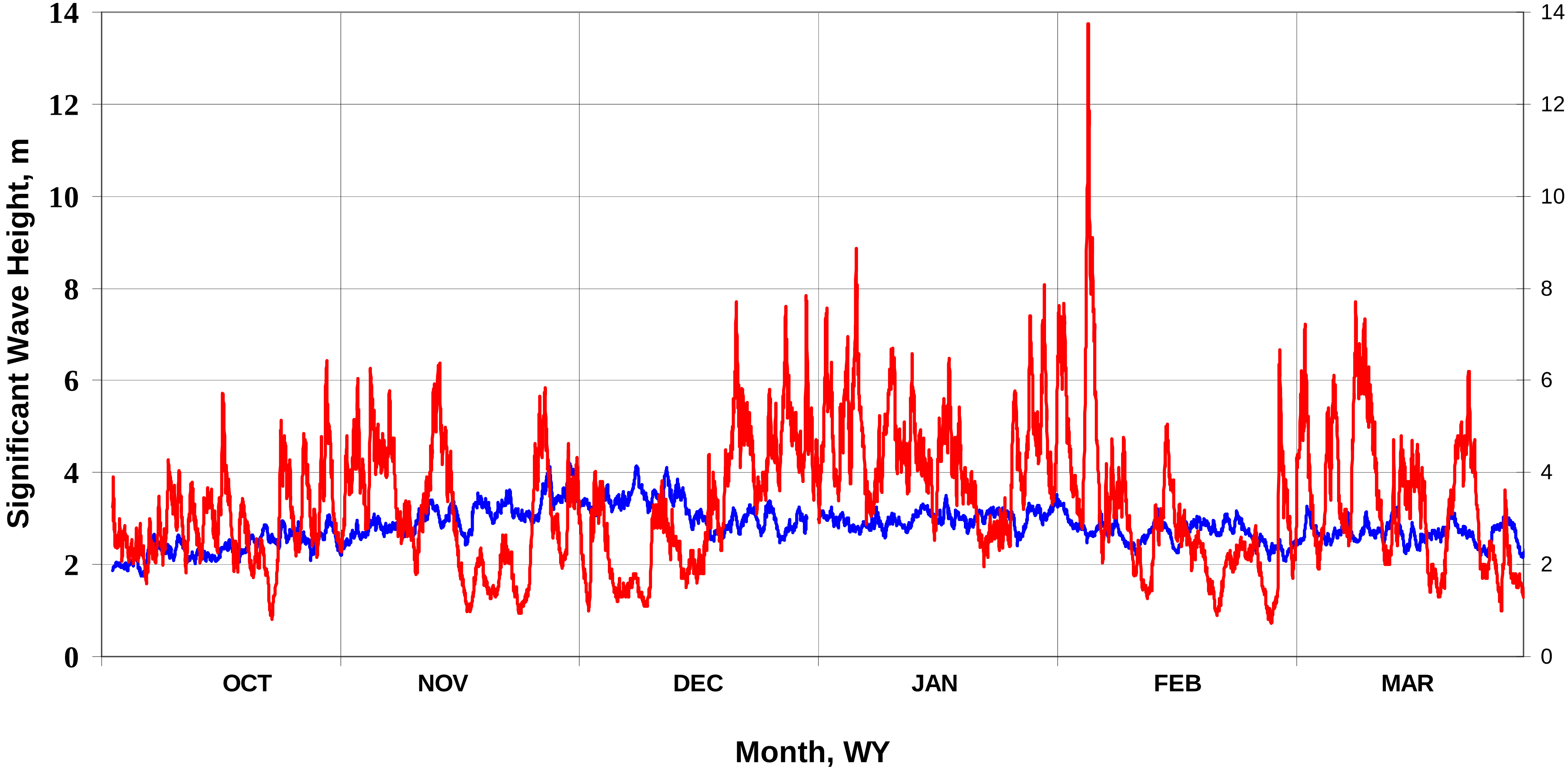
1) **Effect of Large Offshore Submarine Canyon**

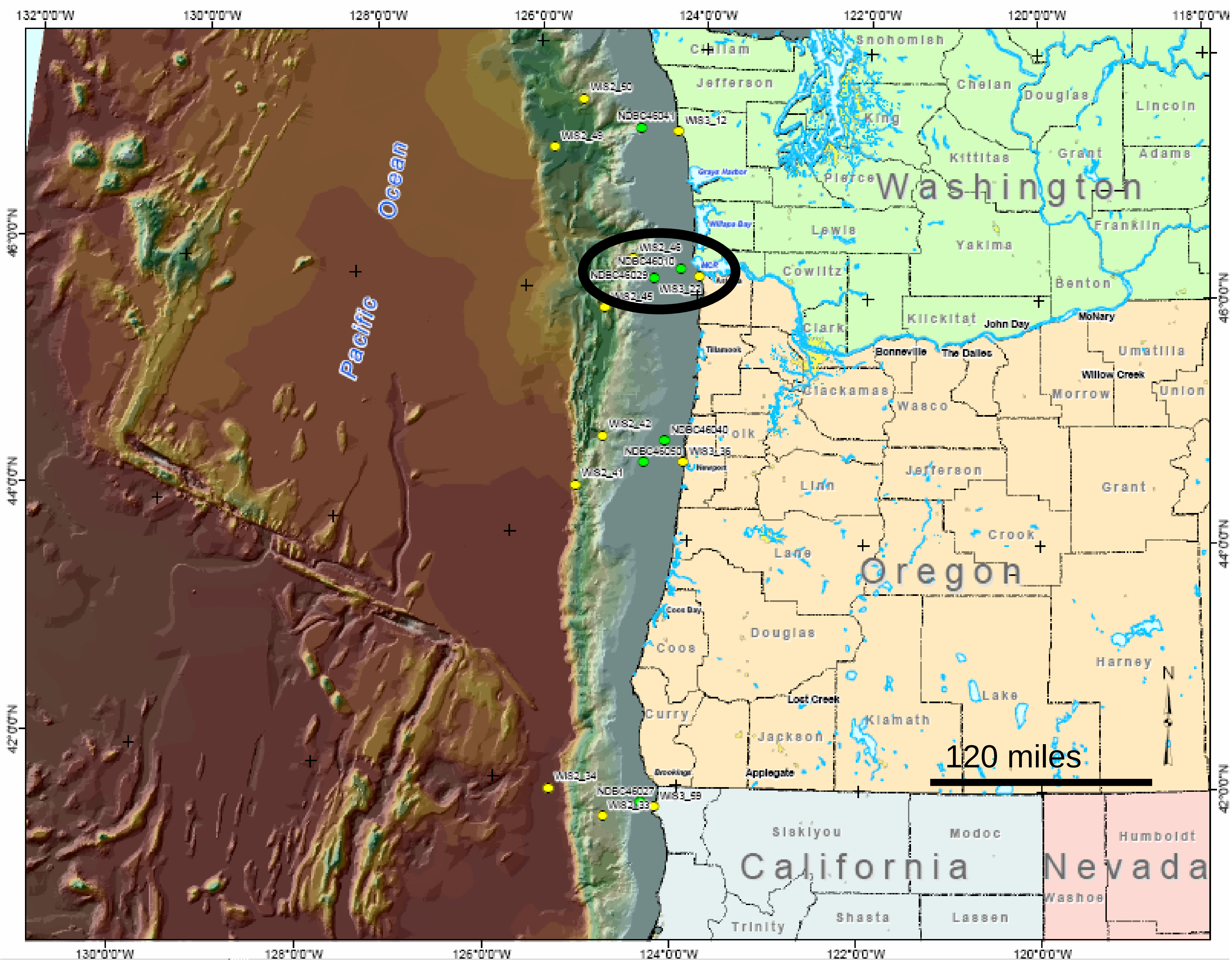
2) **Effect of Nearshore morphology with long jetties**


20 ft

Navigation
Channel

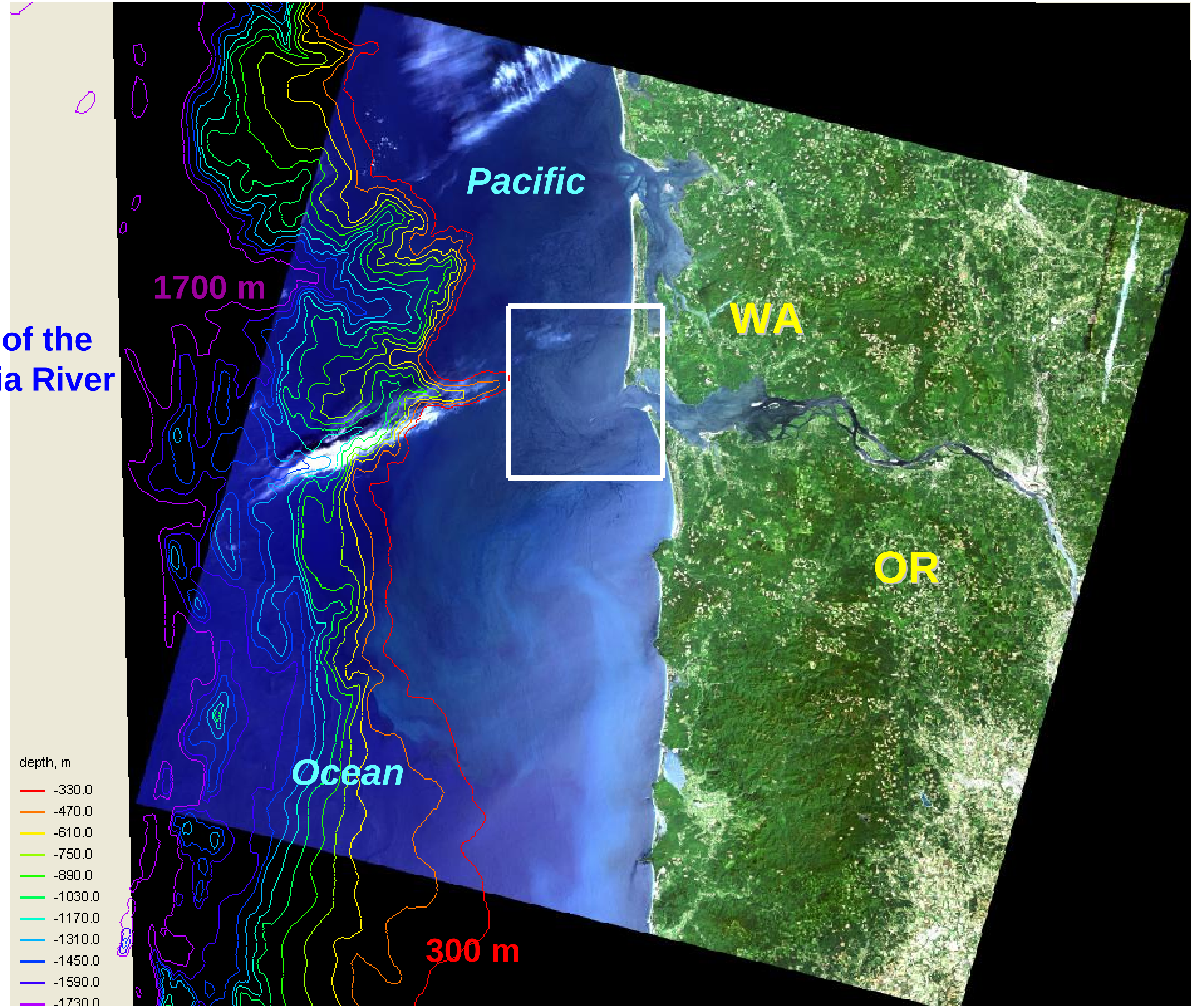
Average Hourly Wave Height Offshore North Oregon Coast for 1985-2005 (NOAA-NDBC)
Compared to Hourly Wave Height for WY 2006 and WY 2005

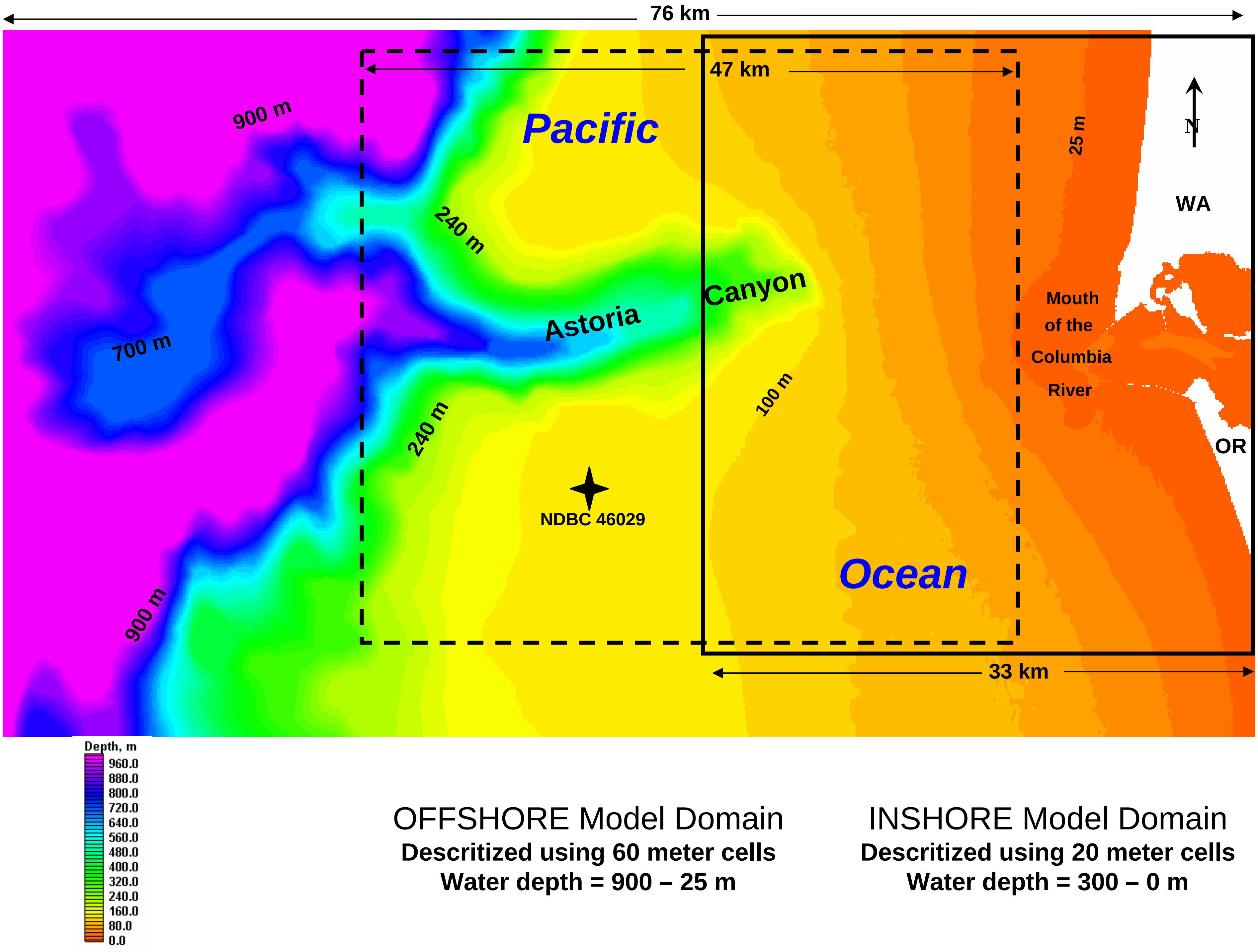




Pacific
Ocean
Washington
Oregon
California
Nevada
120 miles
N
Clallam
Jefferson
Snohomish
King
Chelan
Douglas
Lincoln
Kittitas
Grant
Adams
Pierce
Lewis
Yakima
Franklin
Cowlitz
Benton
Klickitat
Clark
Wasco
Clackamas
Umatilla
Morrow
Union
Linn
Jefferson
Grant
Crook
Lane
Douglas
Coos
Curry
Jackson
Klamath
Lake
Harney
Siskiyou
Modoc
Humboldt
Washoe
Trinity
Shasta
Lassen
John Day
McNary
Bonneville
The Dalles
Willow Creek
Lost Creek
Applegate
WIS2_50
NDBC46041
WIS3_12
WIS2_48
WIS2_46
NDBC46010
NDBC46029
WIS3_22
WIS2_45
WIS2_42
NDBC46040
NDBC46050
WIS3_36
WIS2_41
WIS2_34
NDBC46027
WIS3_59
WIS2_33
132°0'0"W
130°0'0"W
128°0'0"W
126°0'0"W
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
46°0'0"N
44°0'0"N
42°0'0"N

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

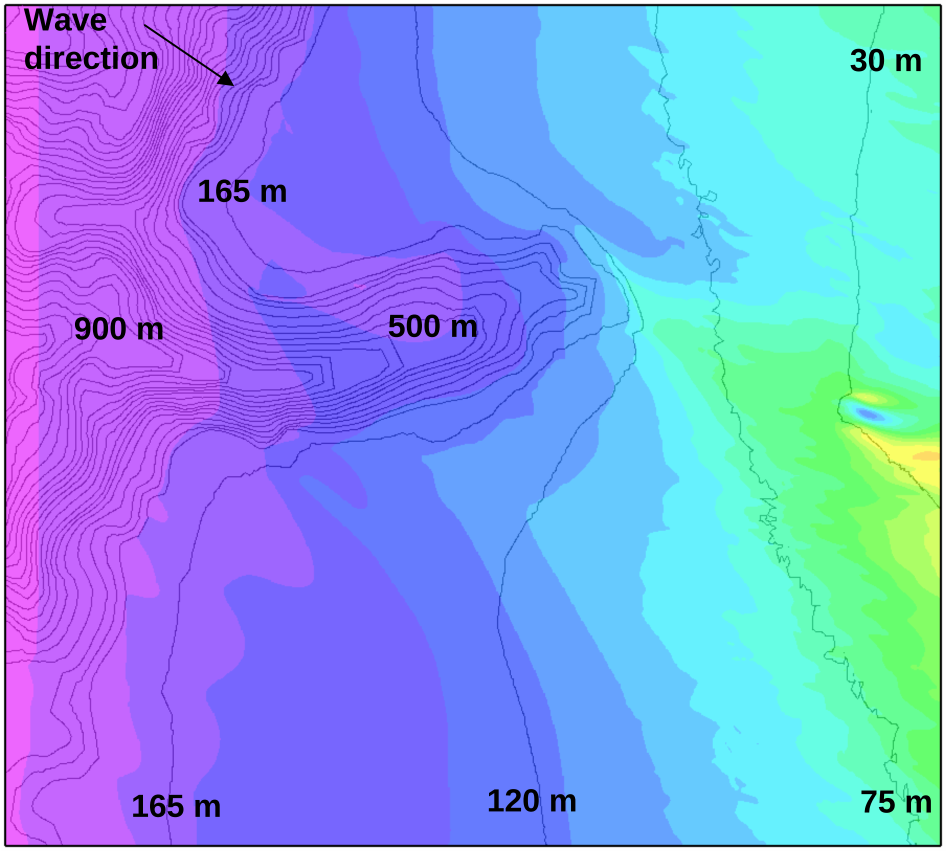
MODELING APPROACH

- 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.

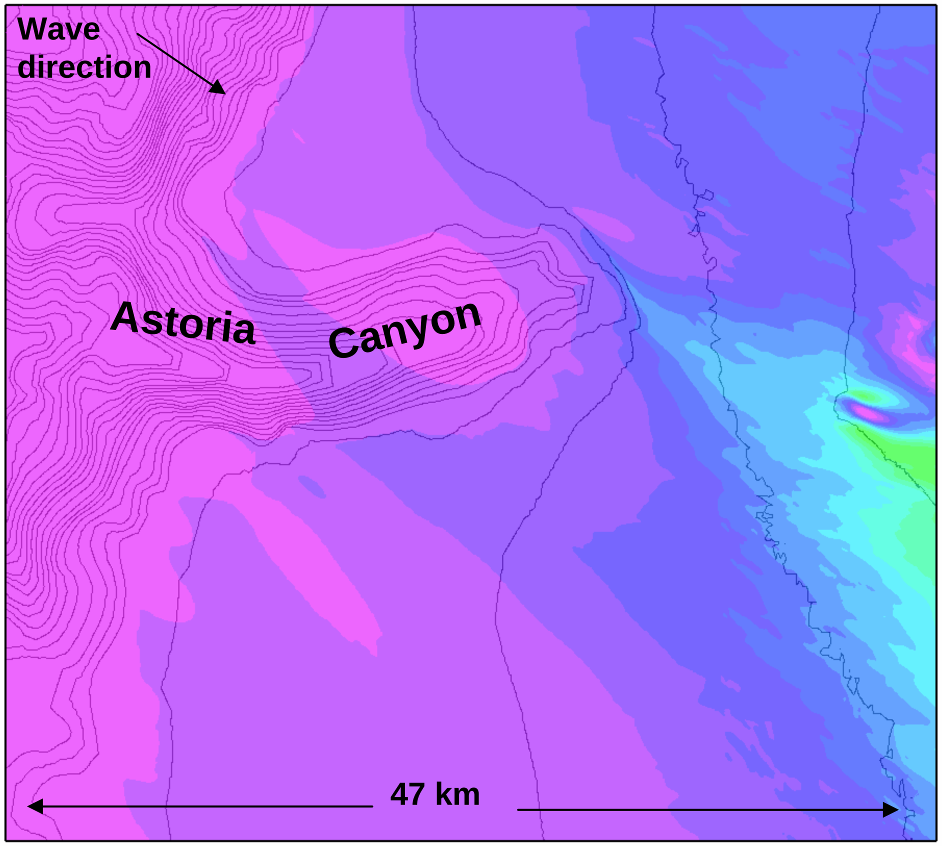
Date of Wave Event	WSE†	Observed Wave Statistics				
		*Offshore-NDBC 46029**				
		Wind-Spd.	Wind-Dir.	Hmo	Tp	Dp
24 NOV 1998	0.8m	15m/s	228°	8.9m	14.3s	262°
3 MAR 1999	0.5m	20m/s	182°	12.8m	16.7s	222°
17 NOV 2003	0.5m	14m/s	279°	9.3m	16.7s	312°
4 FEB 2006	1.85m	20m/s	205°	13.8m	16.7s	230°

* = 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



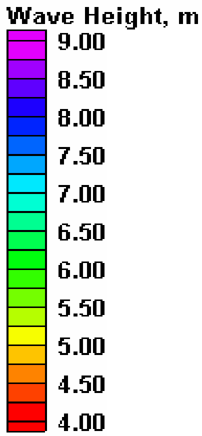
***WABED**, 17 NOV03*

Hmo=9.3 m, Tp = 16.7 sec, Dp=312º



***STWAVE**, 17 NOV03*

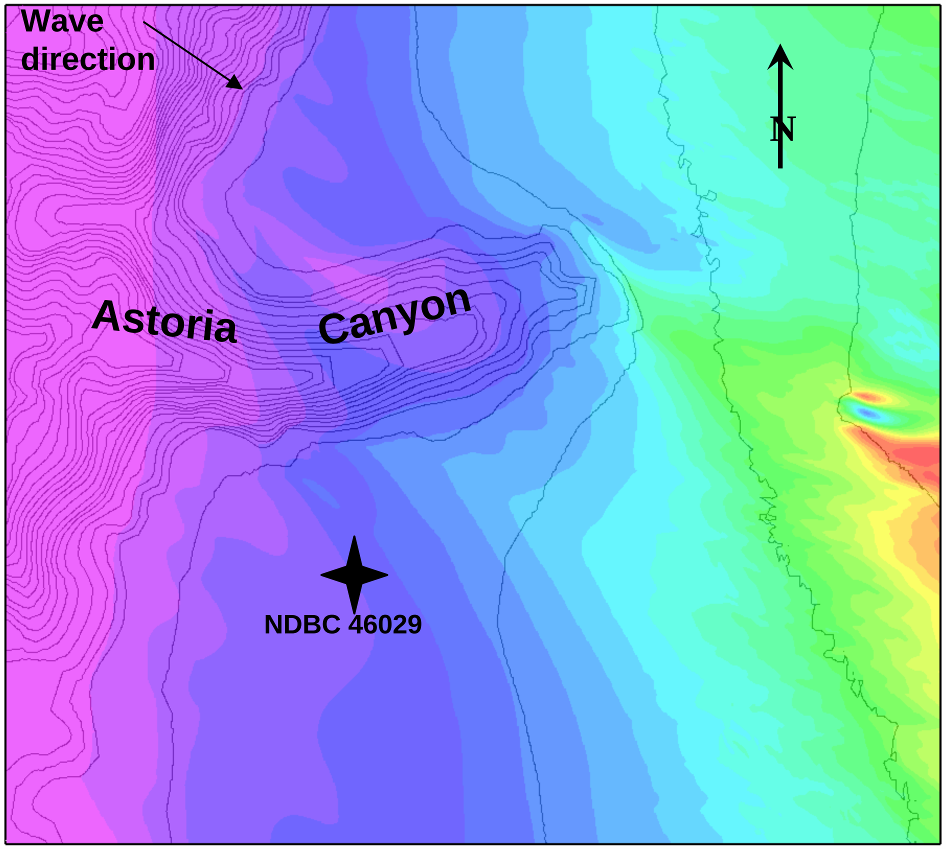
Hmo=9.3 m, Tp = 16.7 sec, Dp=312º



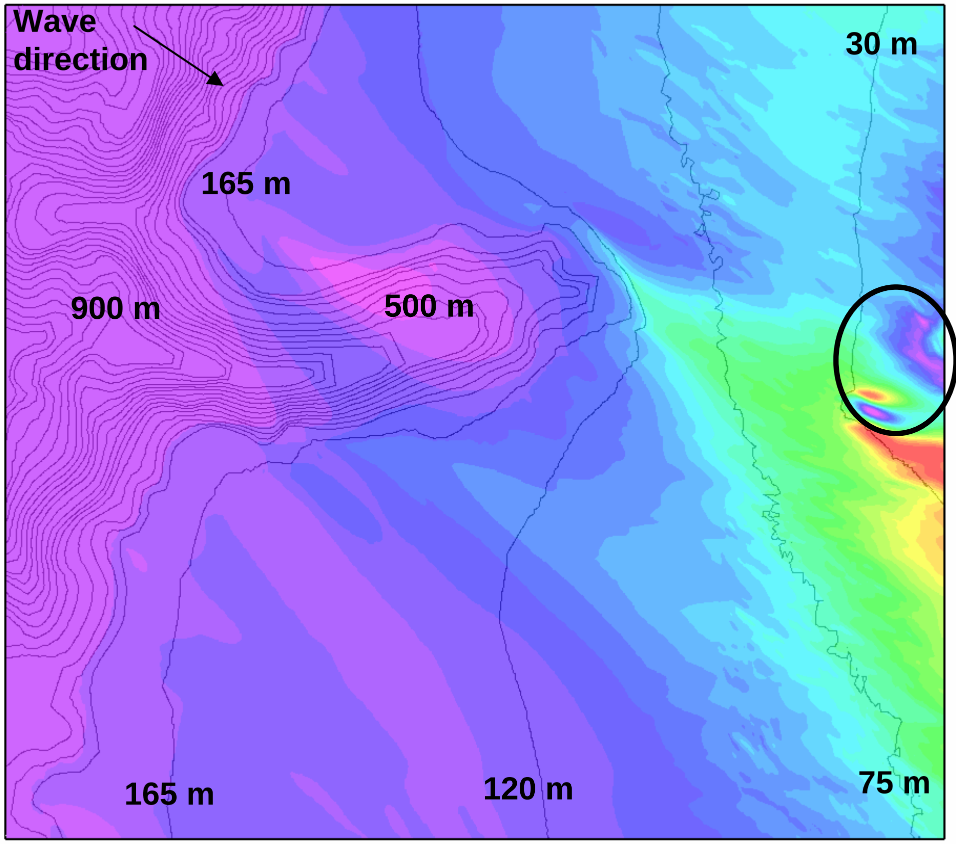
NO WIND

Hmo in <u>Absolute</u> Color Contour scale

Depth shown as linear contours



WABED, *17 NOV03*
Hmo=9.3 m, Tp = 16.7 sec, Dp=312º



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

Wave Height, m

8.58
8.28
7.98
7.68
7.38
7.08
6.78
6.48
6.18
5.88
5.58
5.28
4.98

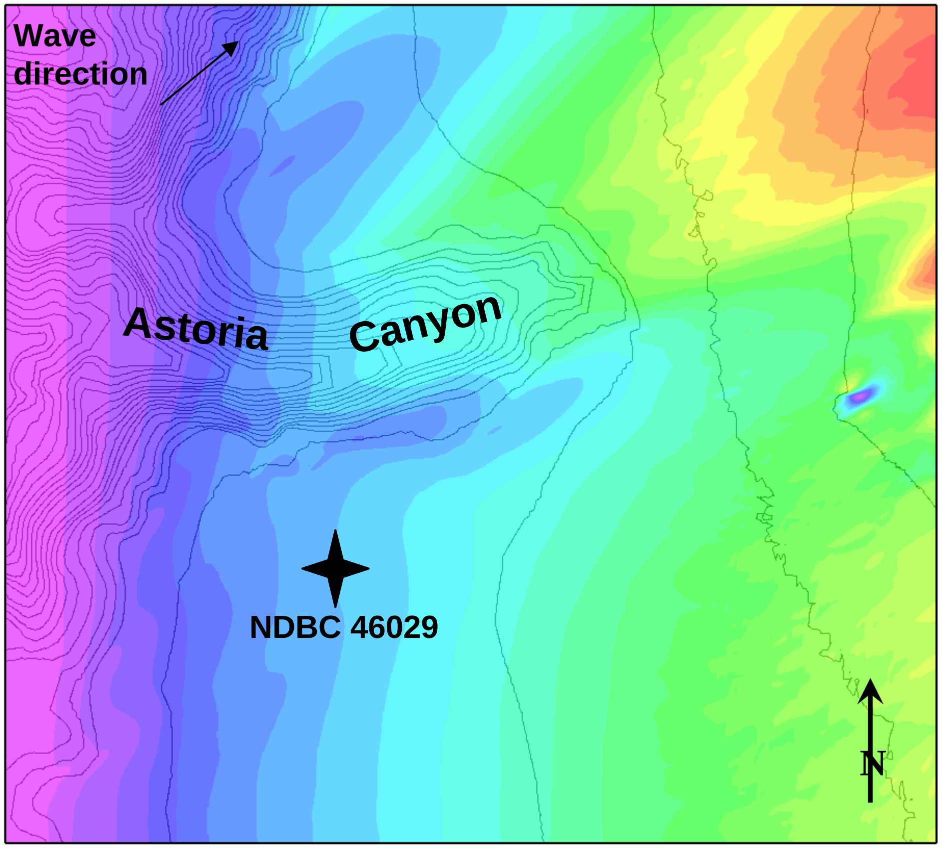
NO WIND

Hmo in Relative Color Contour scale

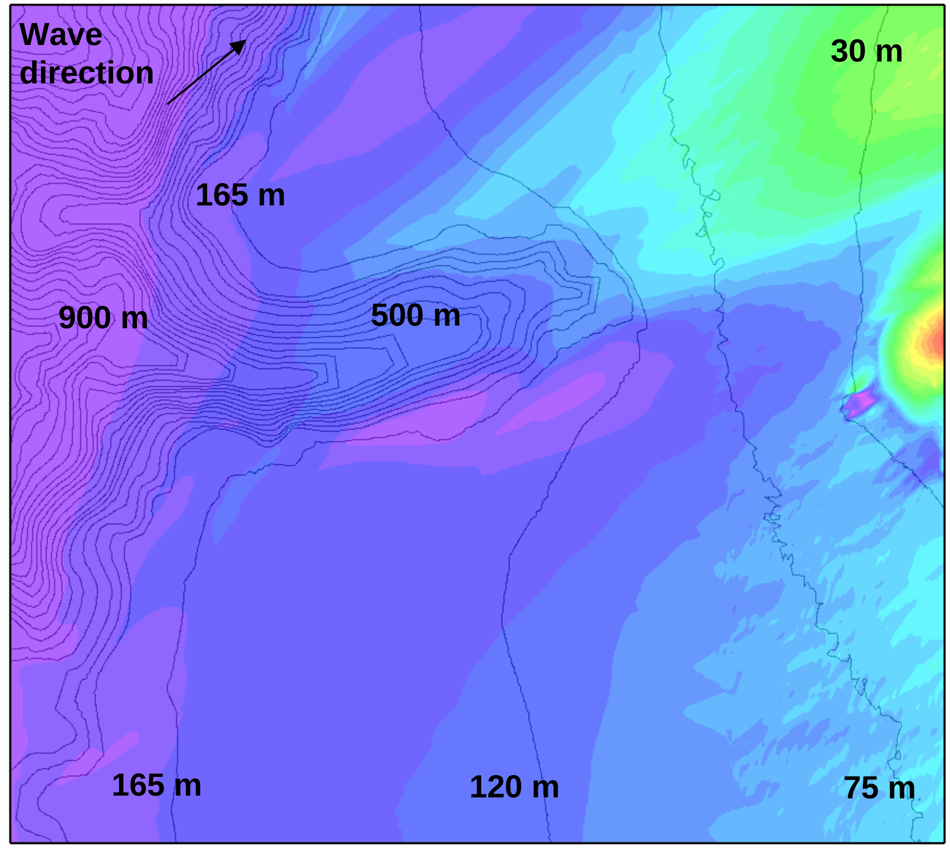
Depth shown as linear contours

Wave Height, m

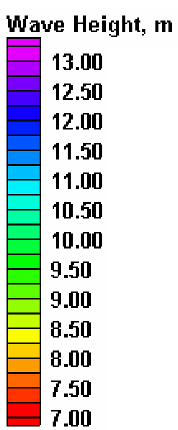
8.95
8.71
8.47
8.23
7.99
7.75
7.51
7.27
7.03
6.79
6.55
6.31
6.07



WABED, *4 FEB 06*
Hmo=13.8 m, Tp = 16.7 sec, Dp=230º



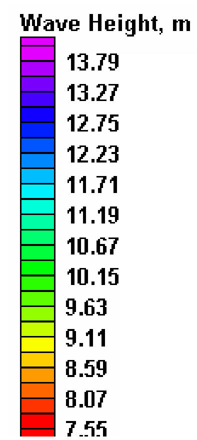
STWAVE, *4 FEB 06*
Hmo=13.8 m, Tp = 16.7 sec, Dp=230º



NO WIND

Hmo in <u>Relative</u> 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)

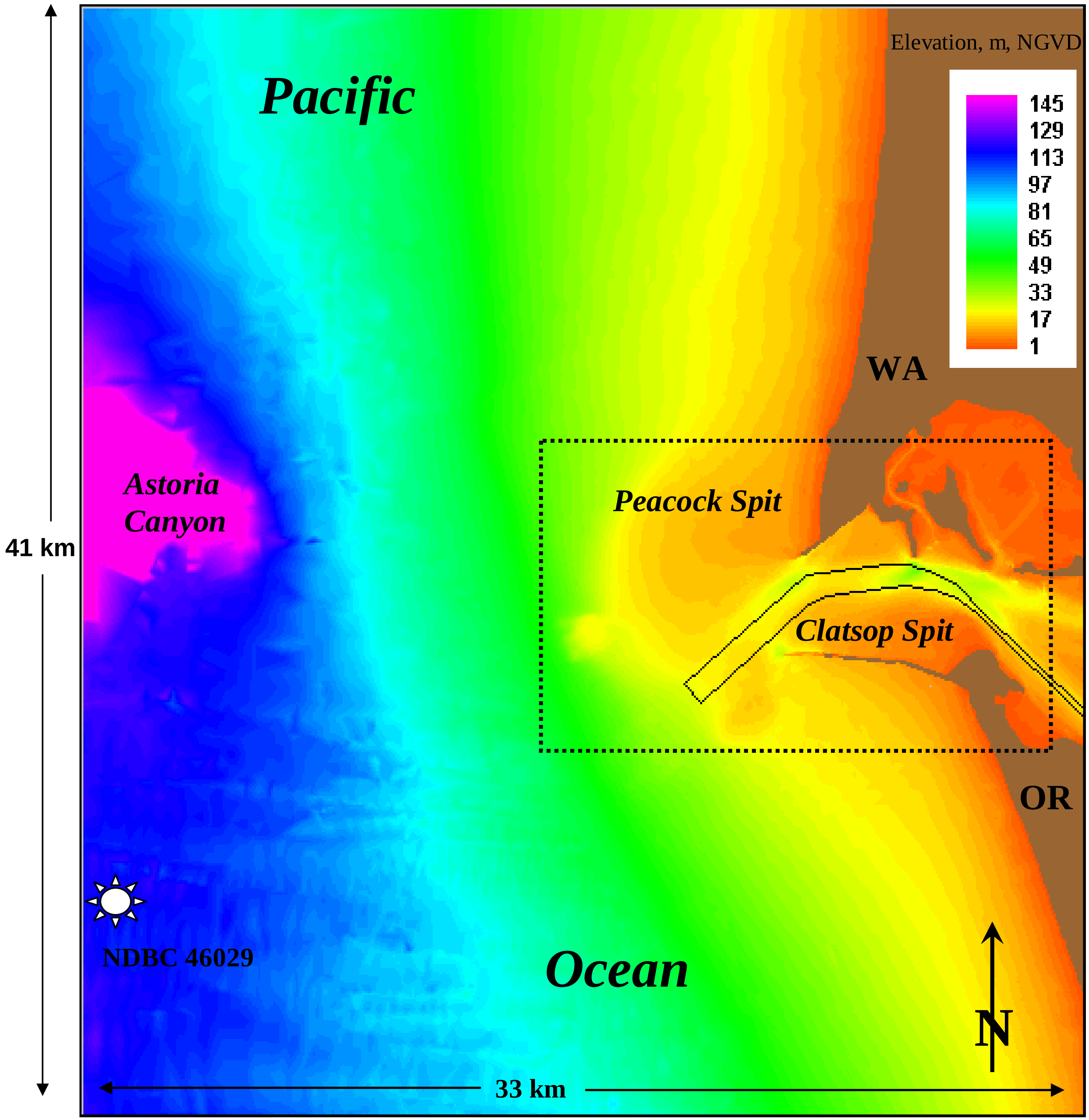
This Finding highlights the need to extend “coastal” wave model boundaries outward to include all bathymetry features that have the potential to affect the wave field of intererst

In terms of Examining Wave Propagation ONLY: NO Wind

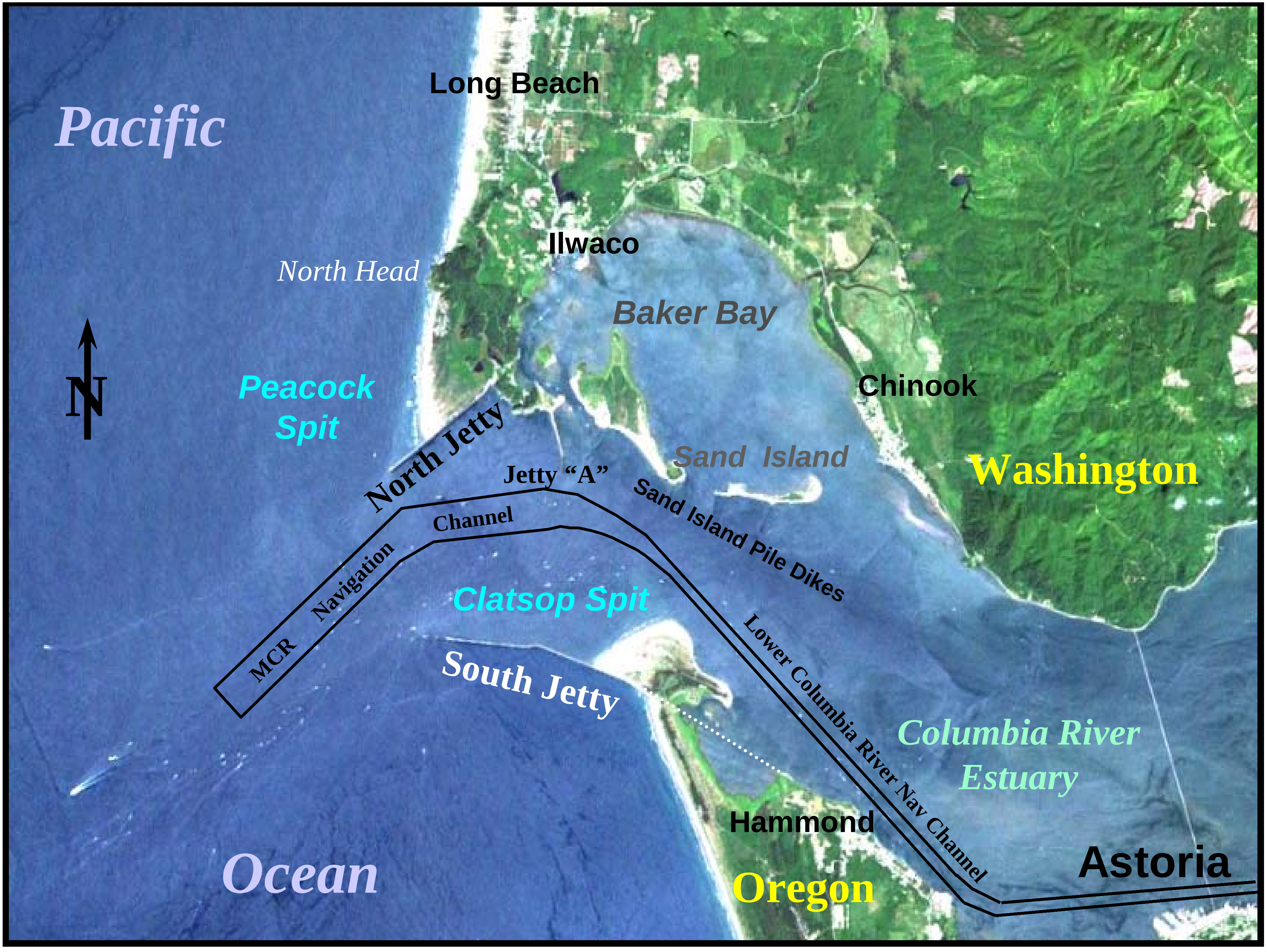
WABED Appears to Dissipate Wave Action <u>More Rapidly</u> than STWAVE

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

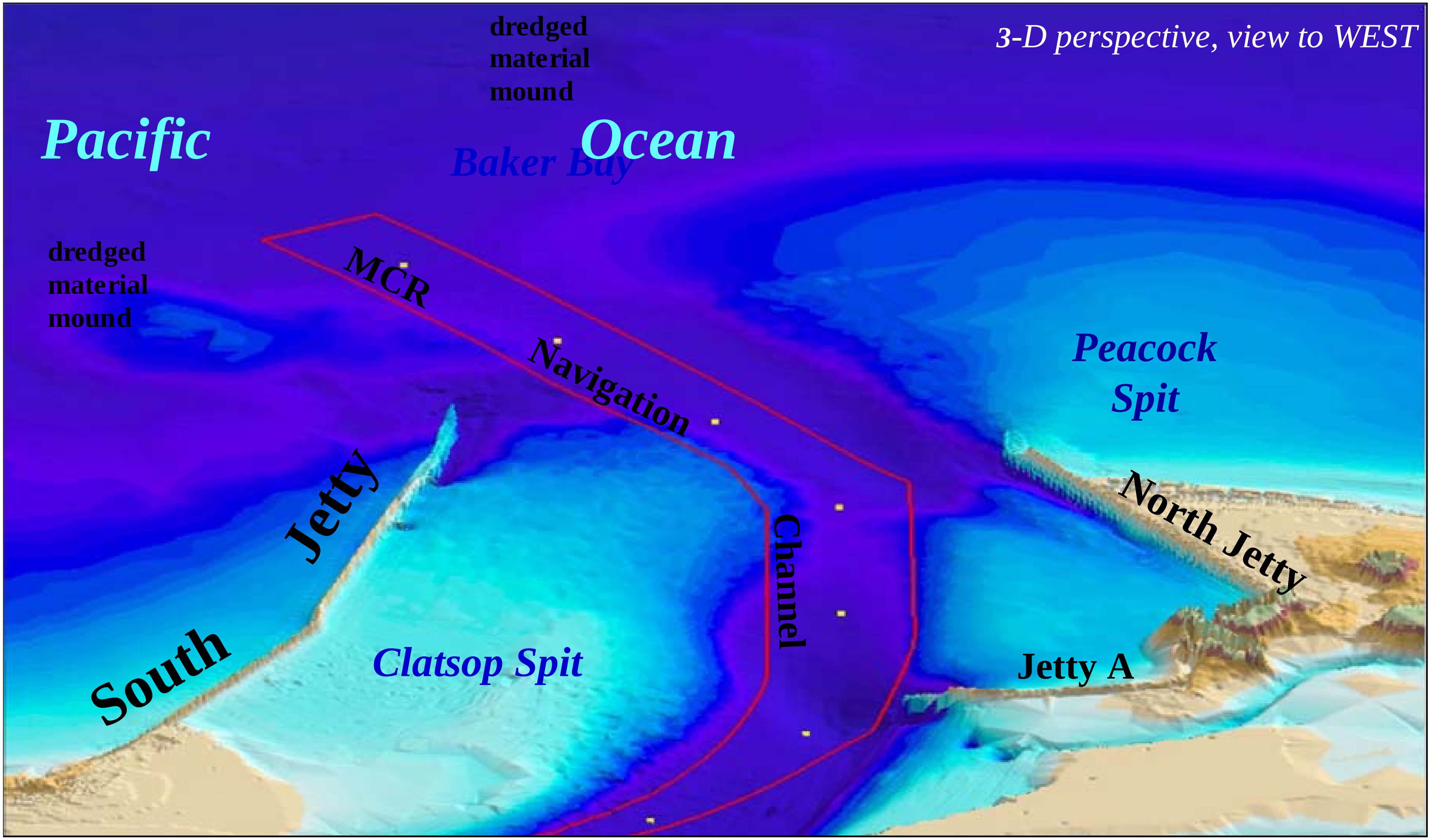
In absence of WIND, STWAVE Produces HIGHER Hmo than WABED; <u>1-2 m higher</u>



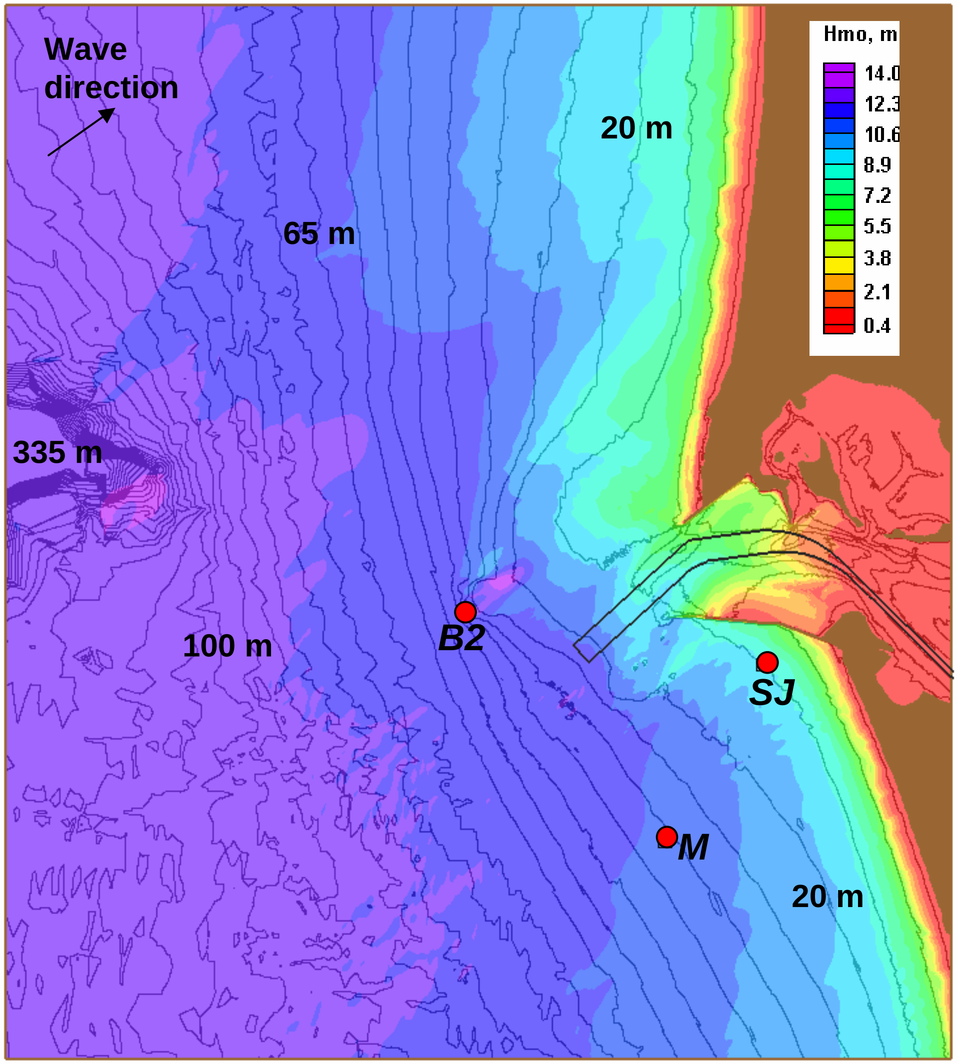
Pacific
Elevation, m, NGVD
145
129
113
97
81
65
49
33
17
1
WA
Astoria Canyon
41 km
Peacock Spit
Clatsop Spit
OR
NDBC 46029
Ocean
N
33 km



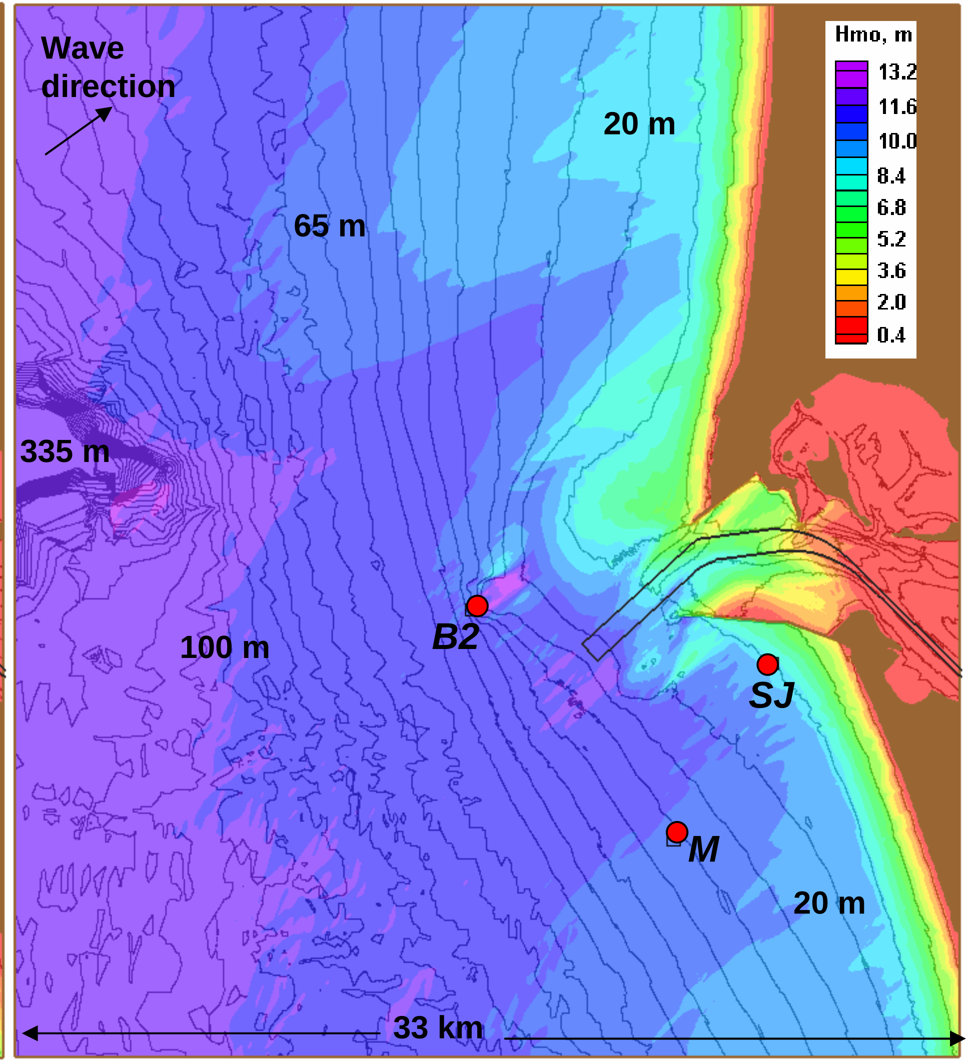
Pacific
Ocean
Long Beach
Ilwaco
North Head
Baker Bay
Peacock
Spit
N
North Jetty
Jetty "A"
Sand Island
Chinook
Washington
Sand Island Pile Dikes
Channel
Navigation
MCR
Clatsop Spit
South Jetty
Lower Columbia River Nav Channel
Columbia River
Estuary
Hammond
Oregon
Astoria



Mouth of the Columbia River

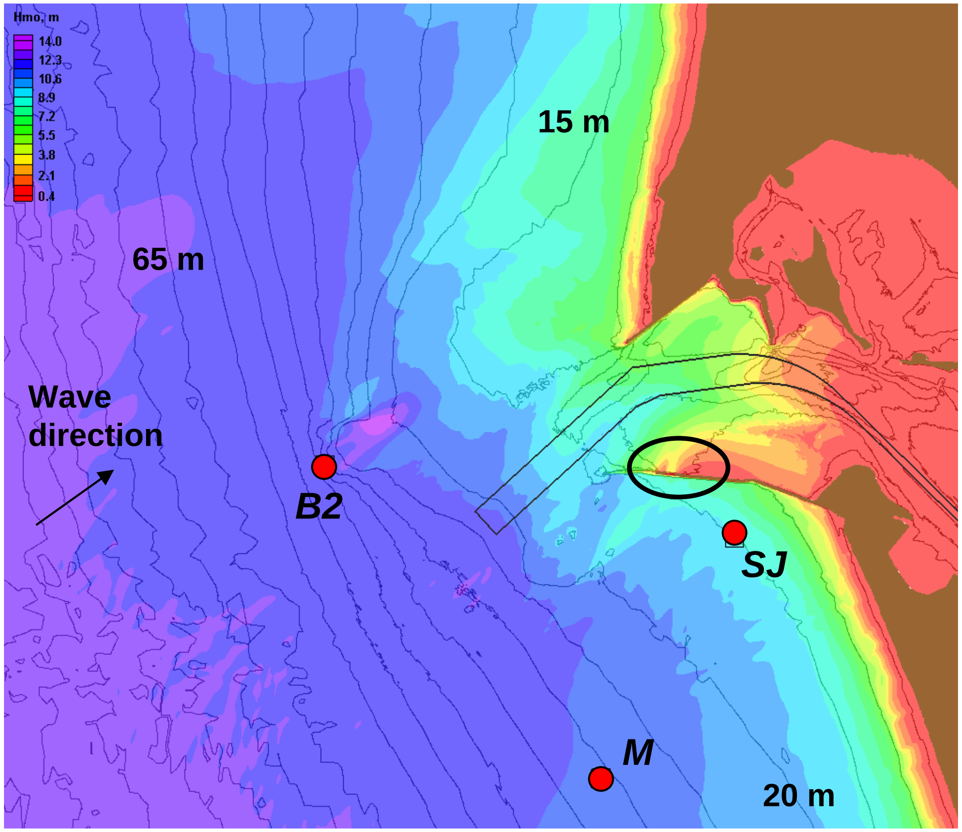


WABED, *3 MAR 99*
Hmo=12.8 m, Tp = 16.7 sec, Dp=222º

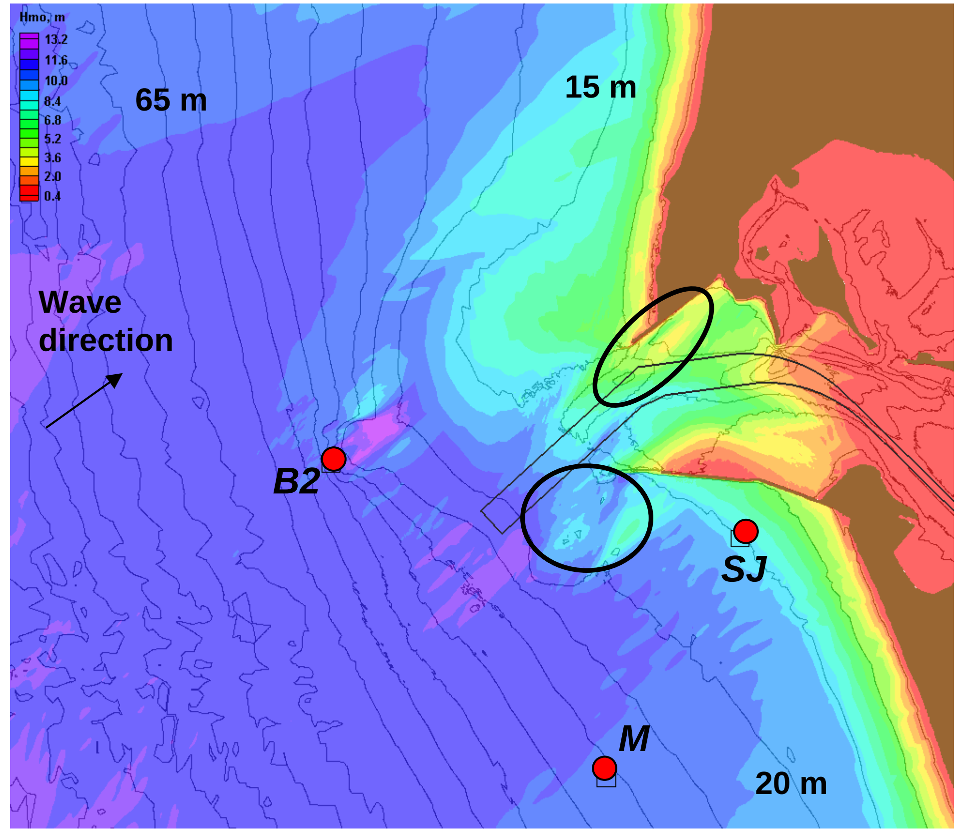


STWAVE, *3 MAR 99*
Hmo=12.8 m, Tp = 16.7 sec, Dp=222º

WIND = 20 m/s @182°

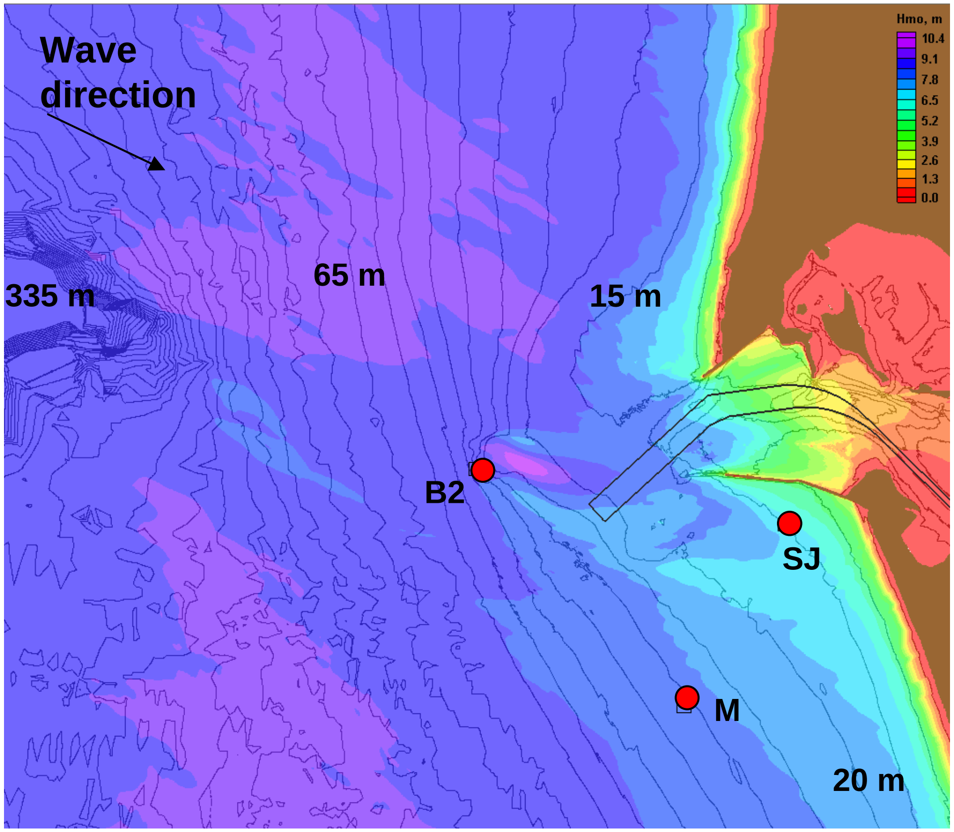


WABED, *3 MAR 99*
Hmo=12.8 m, Tp = 16.7 sec, Dp=222º

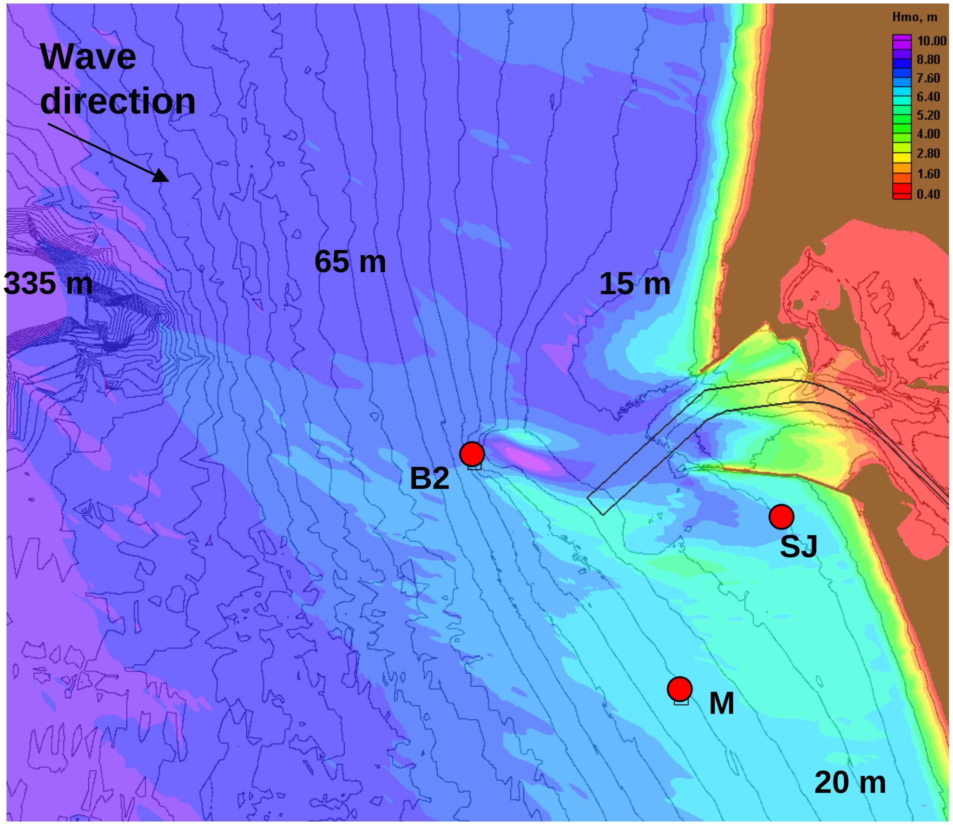


STWAVE, *3 MAR 99*
Hmo=12.8 m, Tp = 16.7 sec, Dp=222º

WIND = 20 m/s @182°

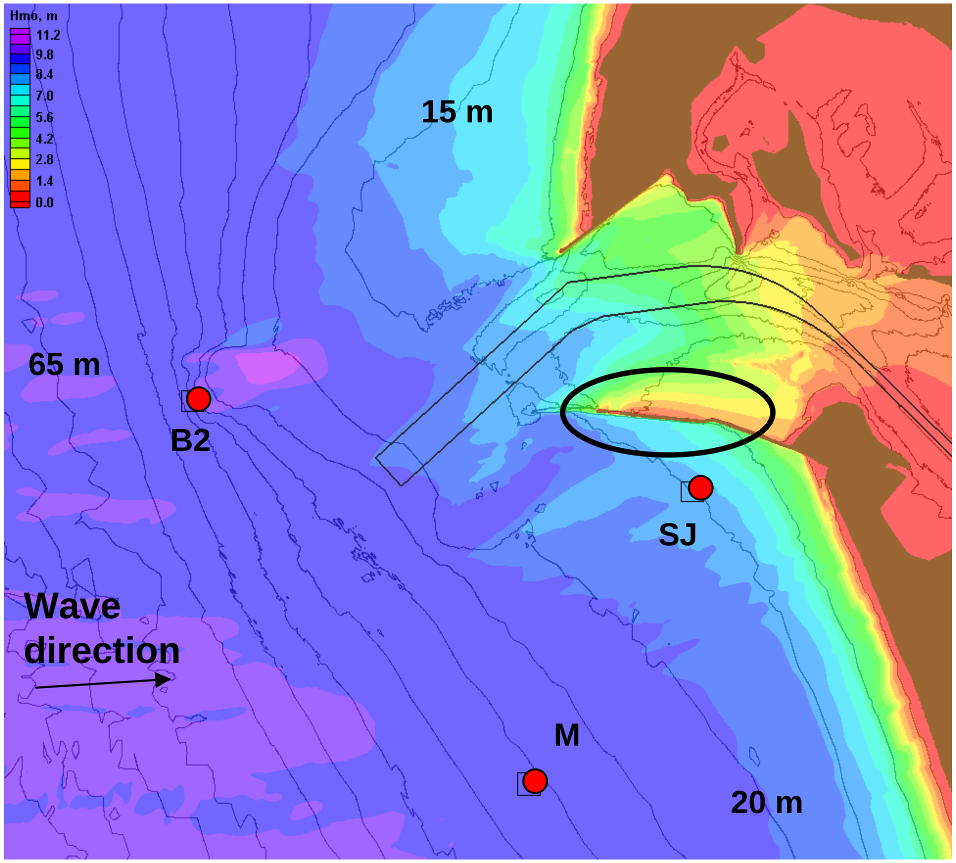


WABED, *17 NOV 03*
Hmo=9.3 m, Tp = 16.7 sec, Dp=312º

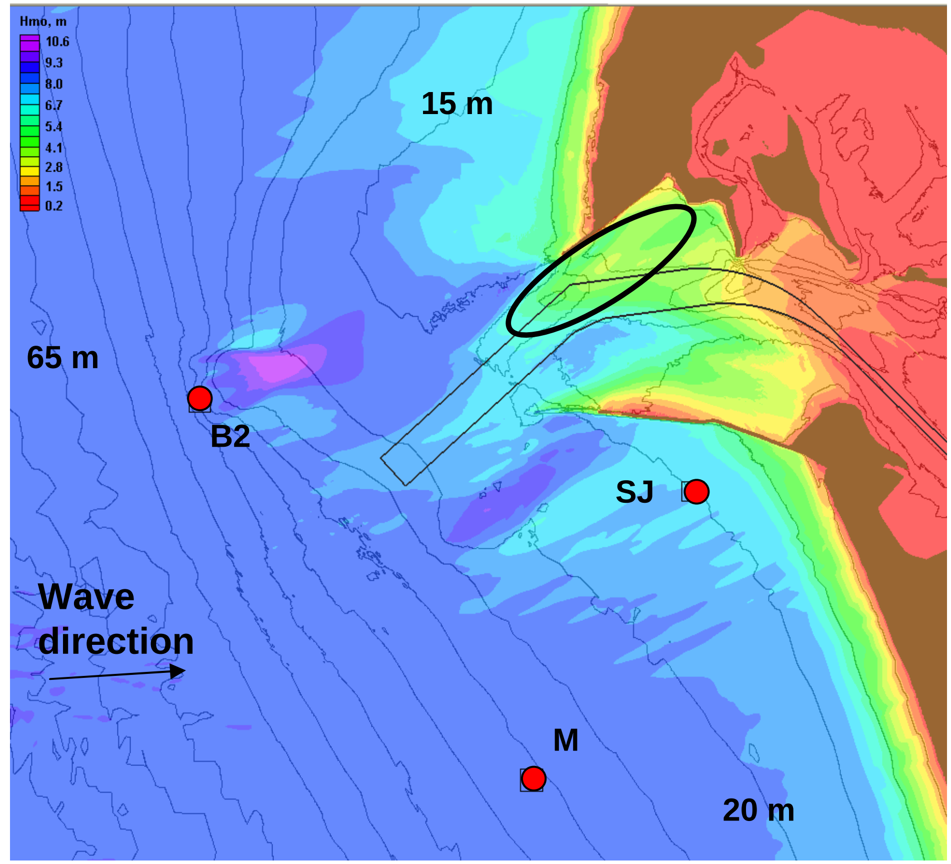


STWAVE, *17 NOV 03*
Hmo=9.3 m, Tp = 16.7 sec, Dp=312º

WIND = 14 m/s @279°



WABED, *24 NOV 98*
Hmo=8.9 m, Tp = 14.3 sec, Dp=262º



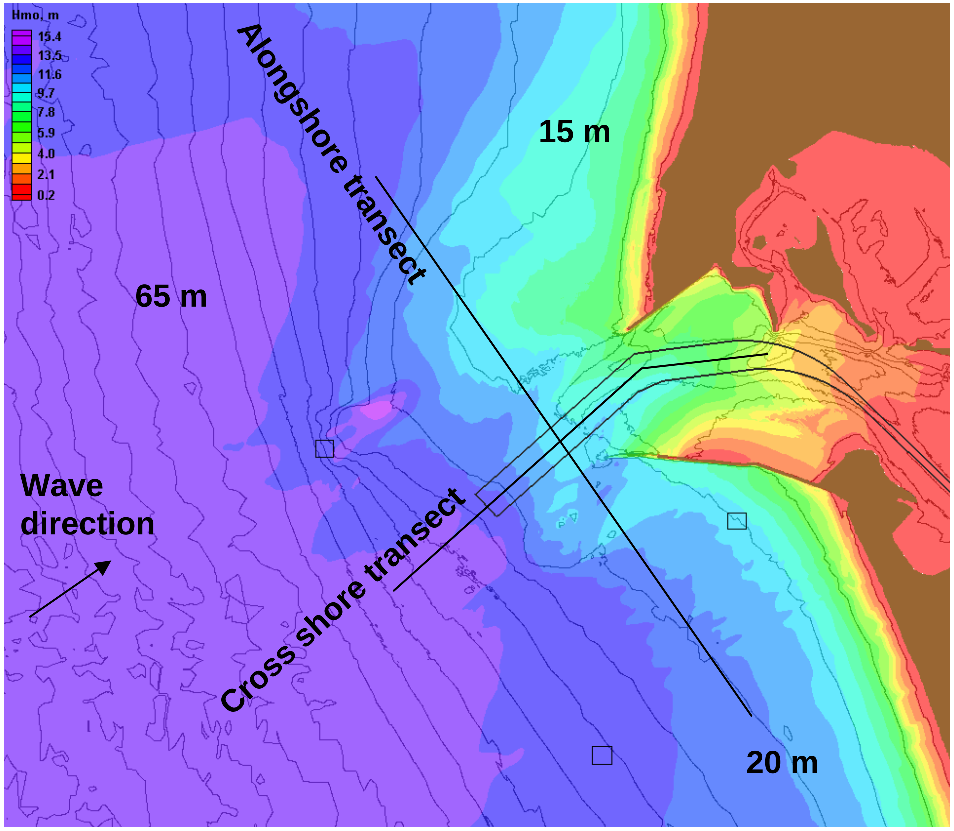
STWAVE, *24 NOV 98*
Hmo=8.9 m, Tp = 14.3 sec, Dp=262º

WIND = 15 m/s @228°

Table 2. Comparison of observed wave events to STWAVE and WABED estimates.

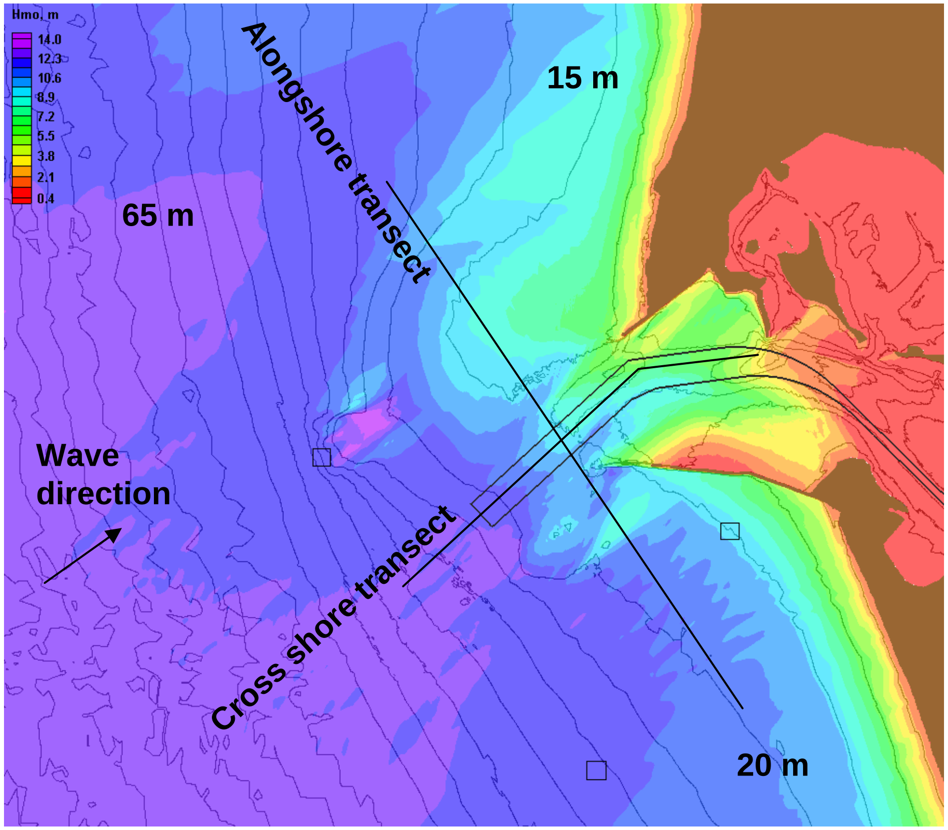
Date of Wave Event	**Modeled Wave Statistics**						**Observed Wave Statistics**				
	WABED			***STWAVE***			**Nearshore**				
	Hmo	Tp	Dp	Hmo	Tp	Dp	Site	Depth	Hmo	Tp	Dp
24 NOV 1998							**B2**	39m	7.2m	14.2s	266°
							M	34m	7.0m	14.2s	263°
3 MAR 1999							**M**	34m	11.2m	17.1s	220°
17 NOV 2003							**SJ**	14m	6.2m	16.7s	252°

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

Hmo=13.8 m, Tp = 16.7 sec, Dp=230º

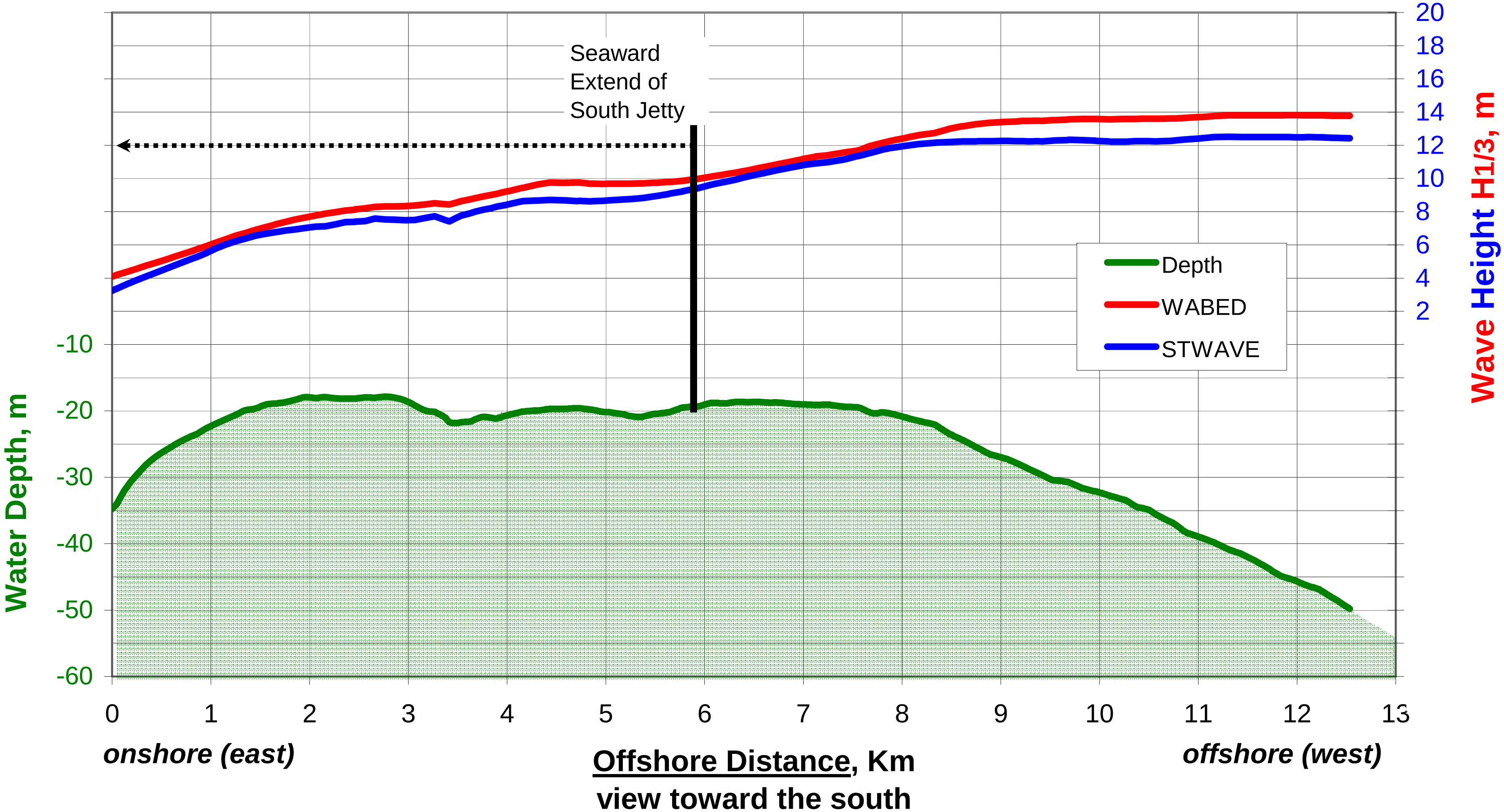


STWAVE, 4 FEB 06

Hmo=13.8 m, Tp = 16.7 sec, Dp=230º

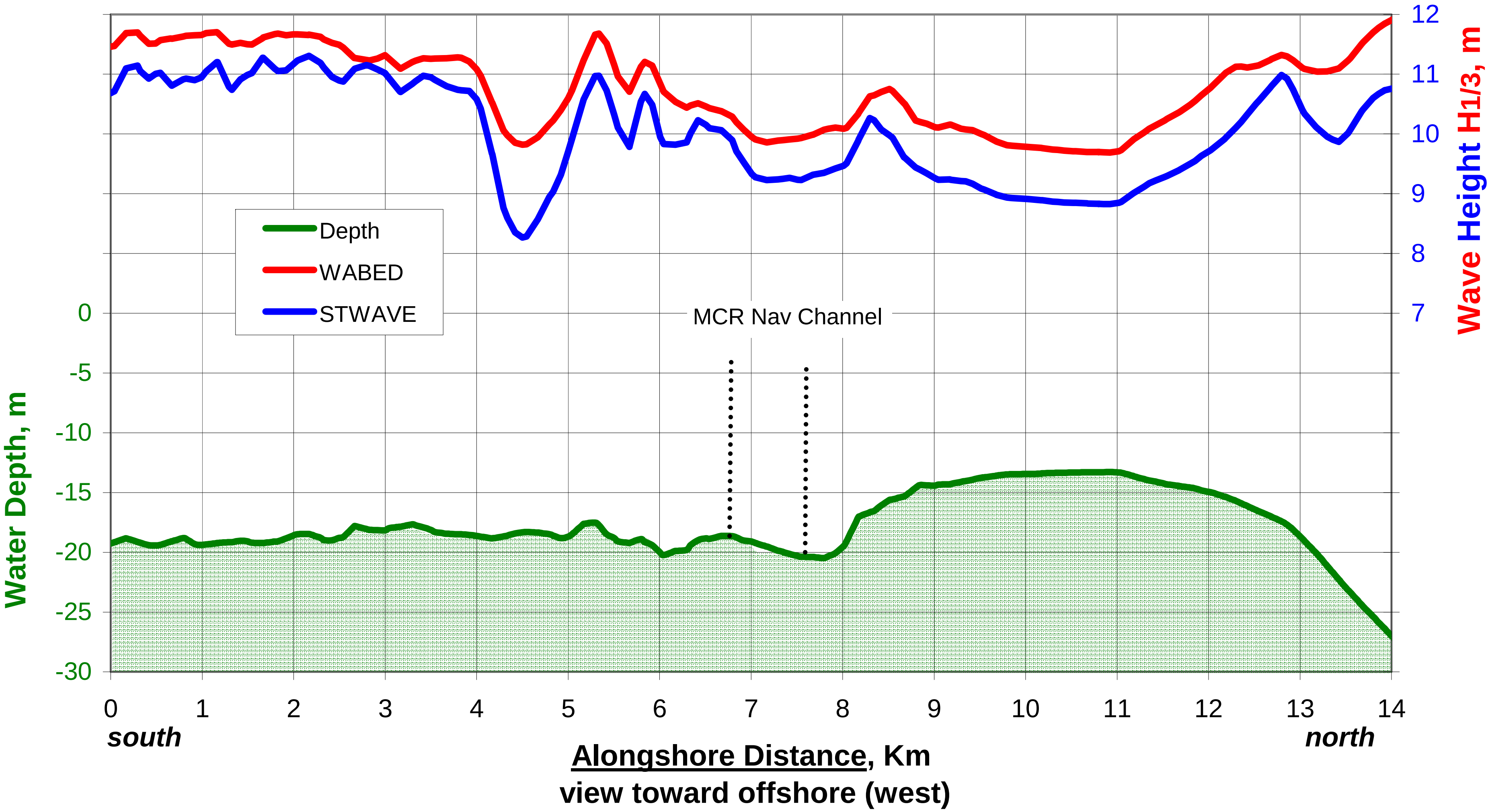
WIND = 20 m/s @205°

Cross Shore Transect

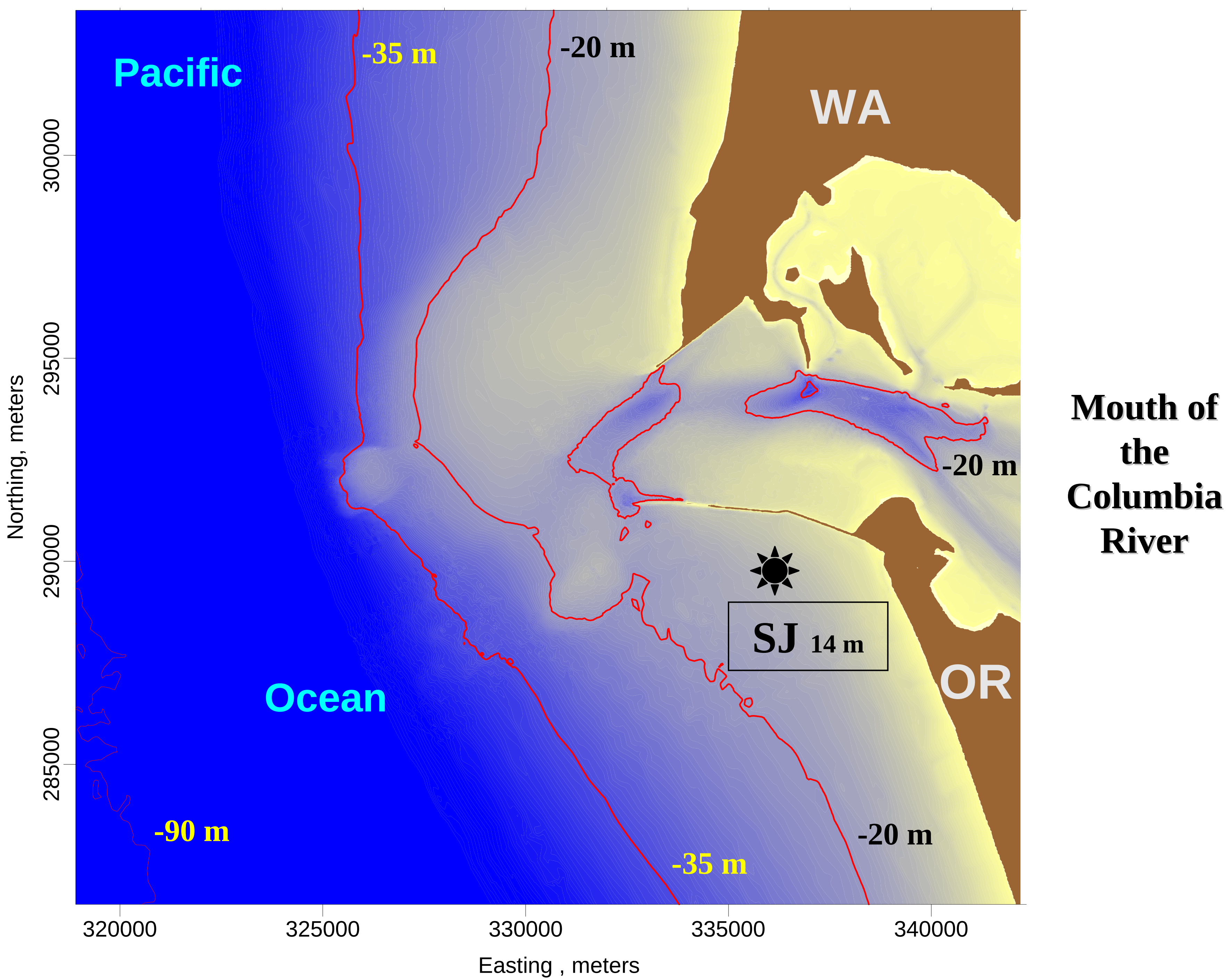


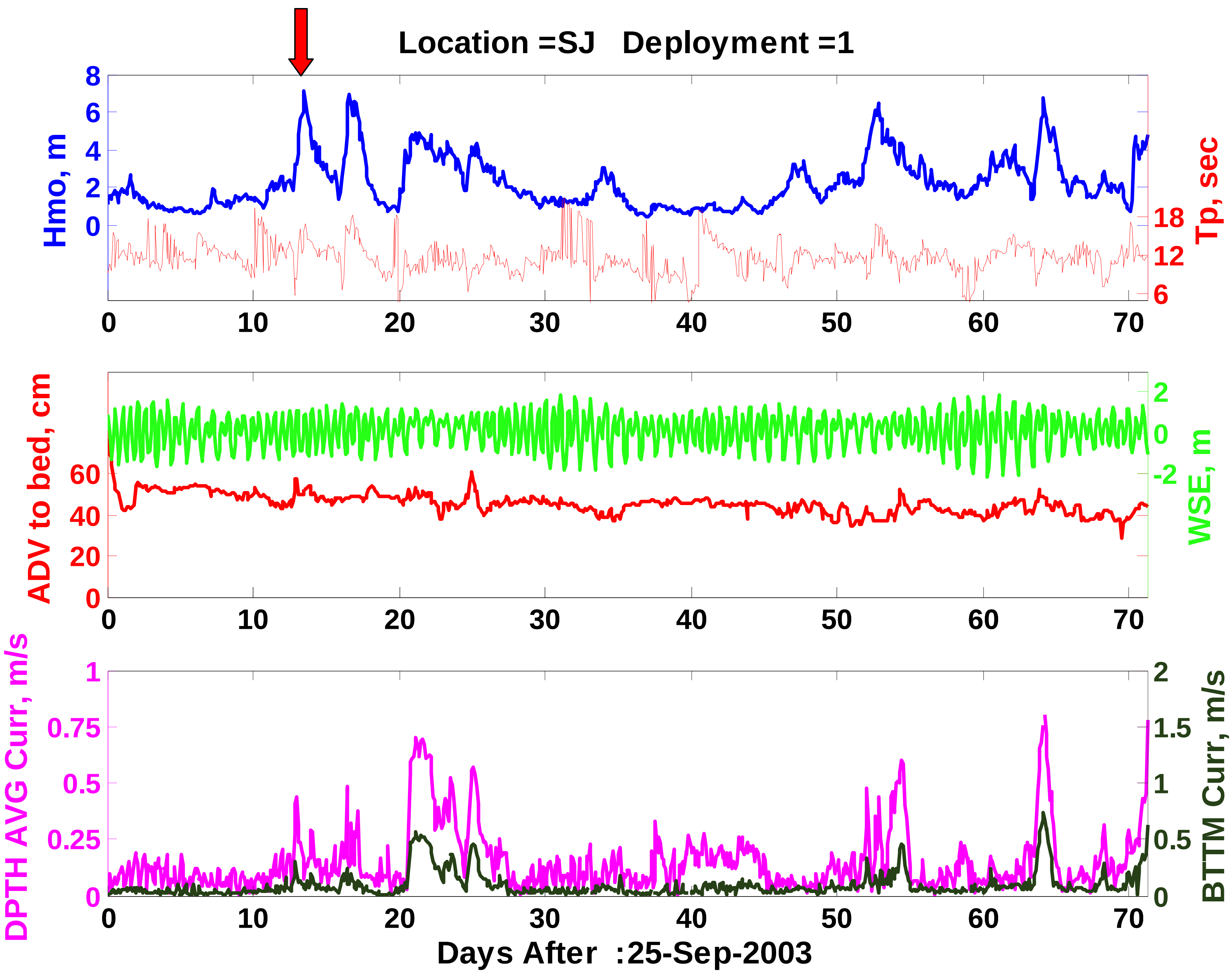
Channel ***Ocean***

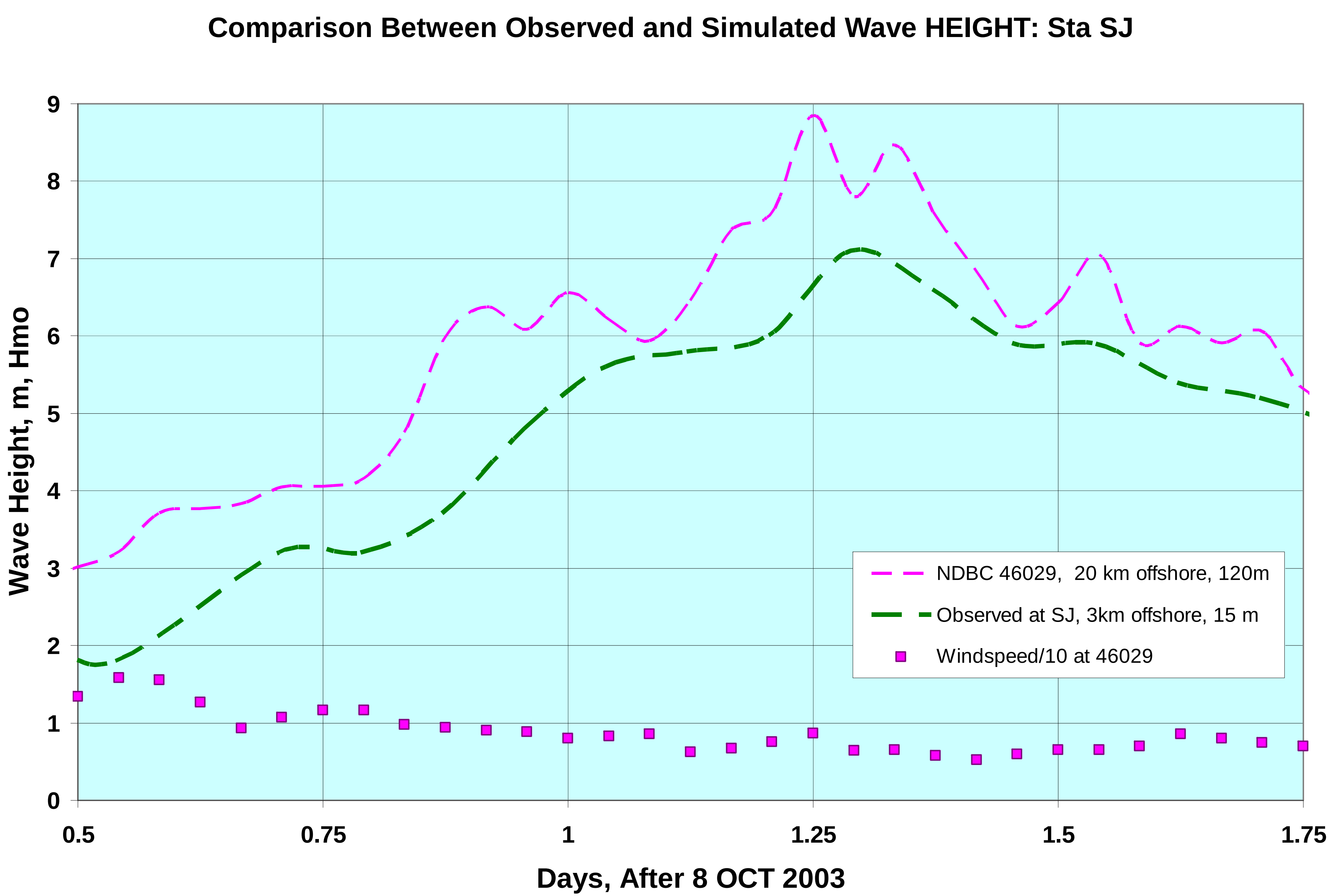
Along Shore Transect

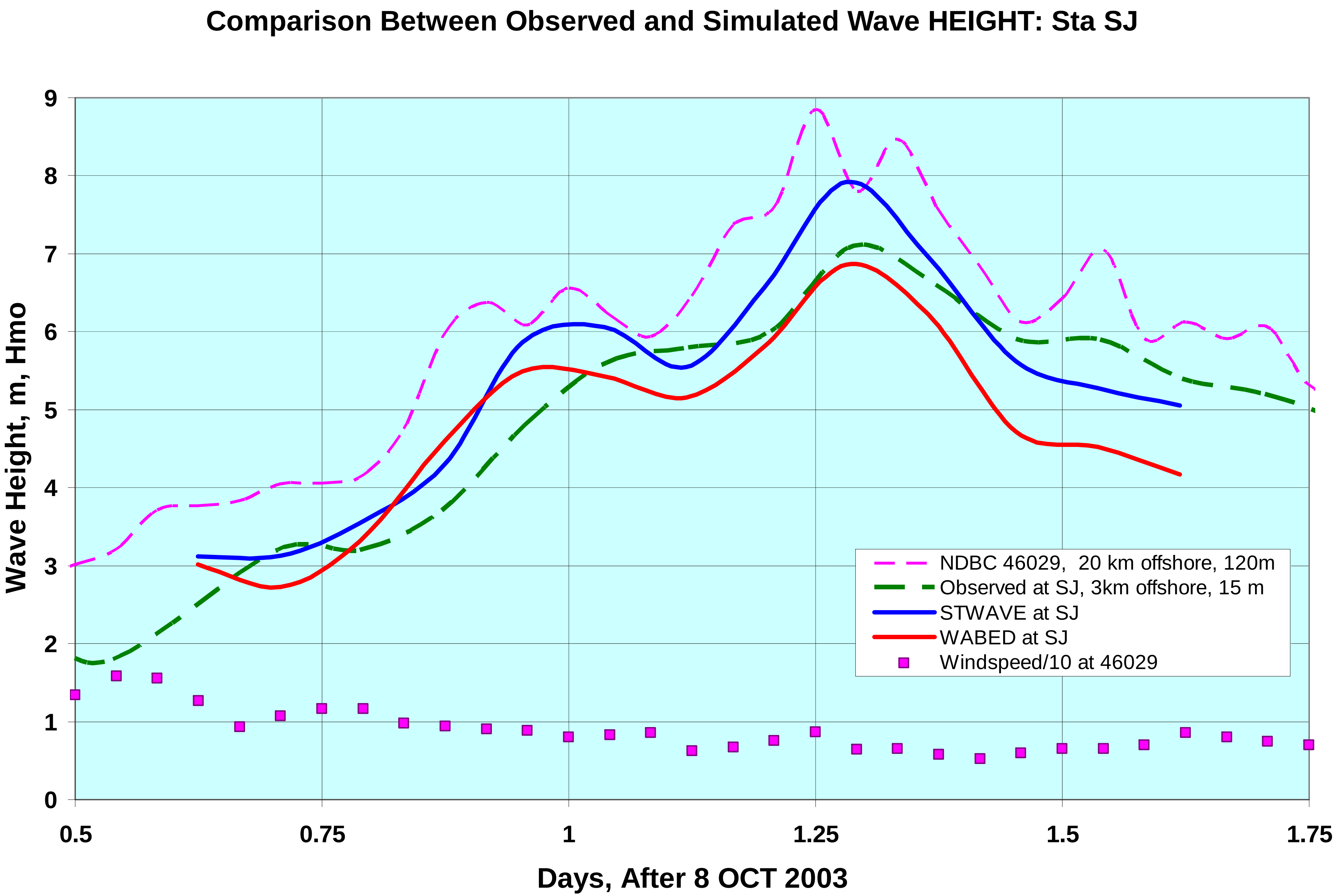


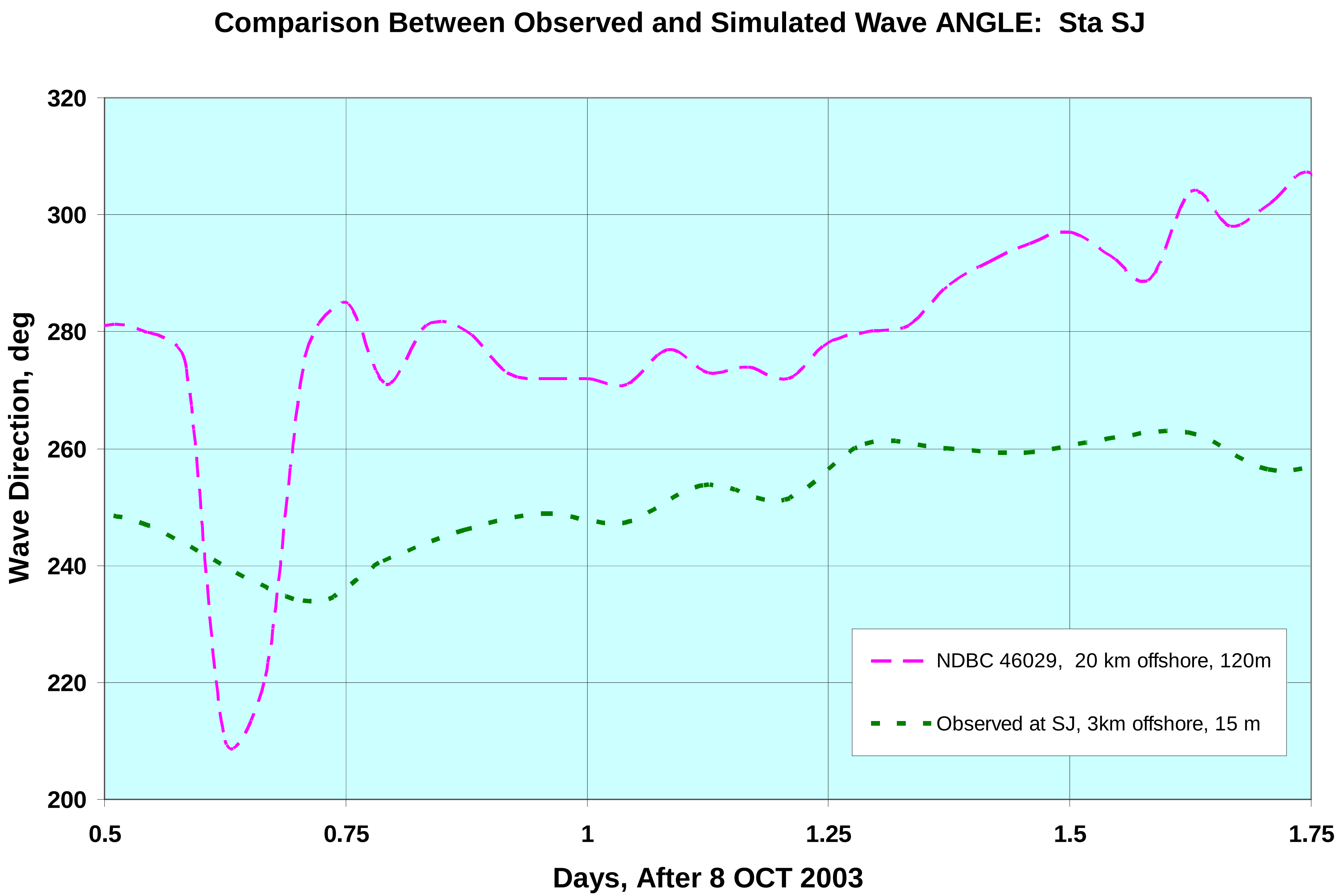
South **North**

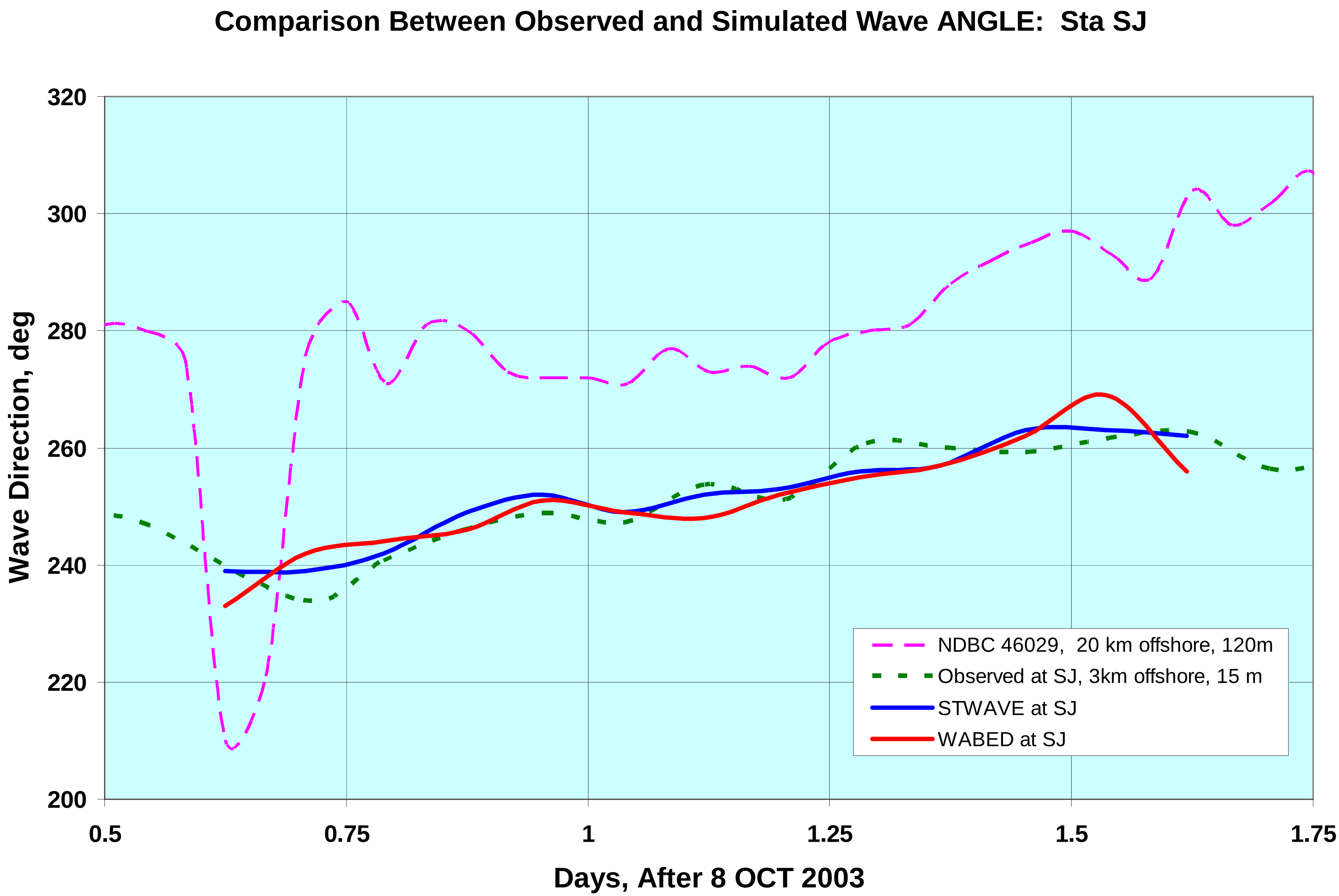

Pacific
Ocean
WA
OR
-35 m
-20 m
-20 m
-90 m
-35 m
-20 m
SJ 14 m
Northing, meters
300000
295000
290000
285000
Easting , meters
320000
325000
330000
335000
340000
Mouth of the Columbia River


Location =SJ   Deployment =1
Hmo, m
8
6
4
2
0
Tp, sec
18
12
6
0
10
20
30
40
50
60
70
ADV to bed, cm
60
40
20
0
WSE, m
2
0
-2
DPTH AVG Curr, m/s
1
0.75
0.5
0.25
0
BTTM Curr, m/s
2
1.5
1
0.5
0
Days After :25-Sep-2003


Comparison Between Observed and Simulated Wave HEIGHT: Sta SJ
Wave Height, m, Hmo
Days, After 8 OCT 2003
NDBC 46029, 20 km offshore, 120m
Observed at SJ, 3km offshore, 15 m
Windspeed/10 at 46029
0
1
2
3
4
5
6
7
8
9
0.5
0.75
1
1.25
1.5
1.75


Comparison Between Observed and Simulated Wave HEIGHT: Sta SJ
Wave Height, m, Hmo
Days, After 8 OCT 2003
0
1
2
3
4
5
6
7
8
9
0.5
0.75
1
1.25
1.5
1.75
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
320
300
280
260
240
220
200
Wave Direction, deg
0.5
0.75
1
1.25
1.5
1.75
Days, After 8 OCT 2003
NDBC 46029, 20 km offshore, 120m
Observed at SJ, 3km offshore, 15 m



Comparison Between Observed and Simulated Wave ANGLE: Sta SJ
320
300
280
260
240
220
200
0.5
0.75
1
1.25
1.5
1.75
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

FINDINGS-1

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.

FINDINGS-2

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.

FINDINGS

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.