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The State of the Art and Science of Coastal Engineering

Coastal Wave Modeling for Jetty Rehabilitation at Coos Bay, Oregon

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Outline

- Background & Objectives
- Coastal Modeling System & Input Forcing
- Model Calibration
- Synthetic and Storm Wave Simulations
- Summary & Conclusions


Coos Bay Inlet

Background

- Coos Bay is located on the southwestern coast of Oregon, USA. The Coos Bay Inlet is the only outlet connects Port of Coos Bay, the largest deep-draft coastal harbor in Oregon, and Pacific Ocean. The Federal channel, authorized at 210 m wide and 14.3 m deep, is protected at the bay entrance by dual jetties constructed in 1928.
- Both north and south jetties have been deteriorated since their initial construction due to aging, erosion of foundation, lack of adequate maintenance, increased wave environment, and channel deepening and dredging projects in the past.
- The US Army Corps of Engineers (USACE) is presently investigating the rehabilitation and redesign of jetties using numerical and physical modeling of storm waves to ensure navigation safety and guide storm waters through the inlet.

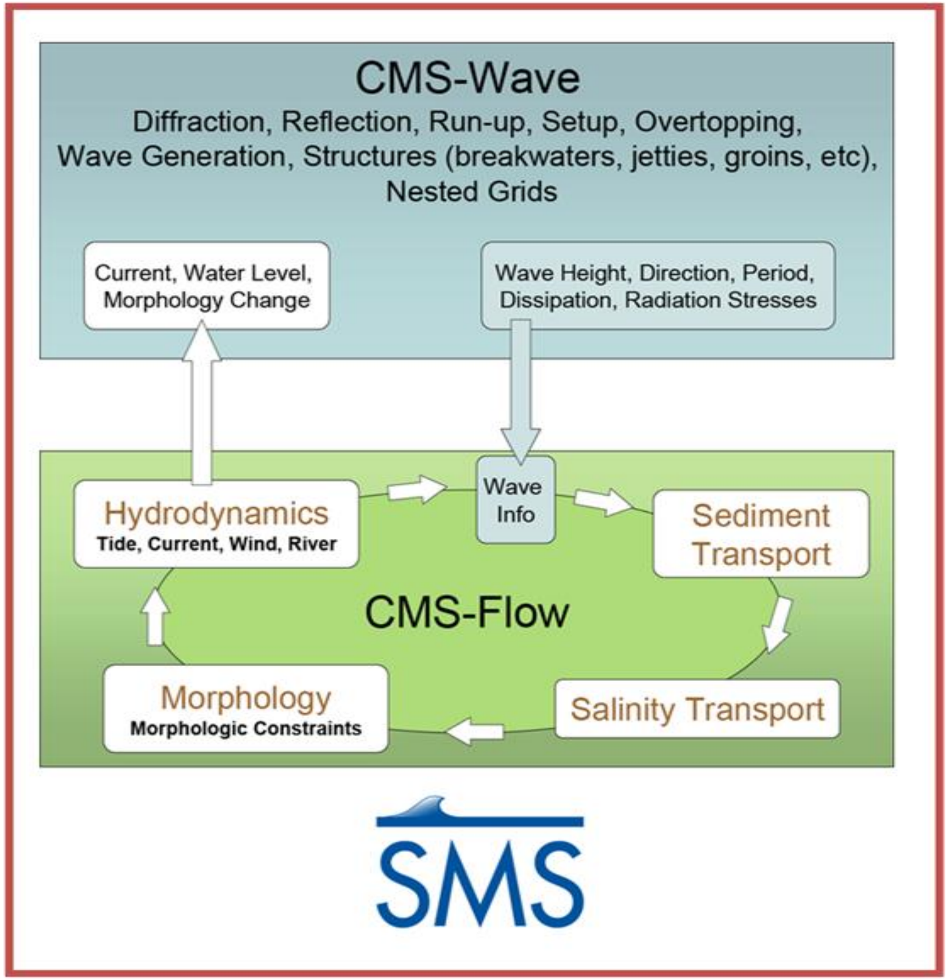
Objectives of Wave Modeling

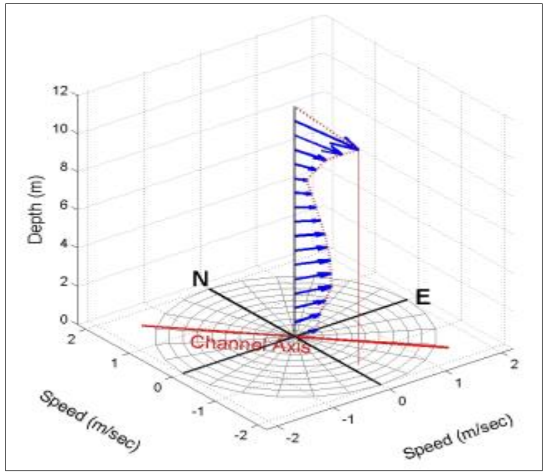
- Analyze and organize regional meteorological and oceanographic data in the study area. Select design wave and water level conditions for the wave modeling.

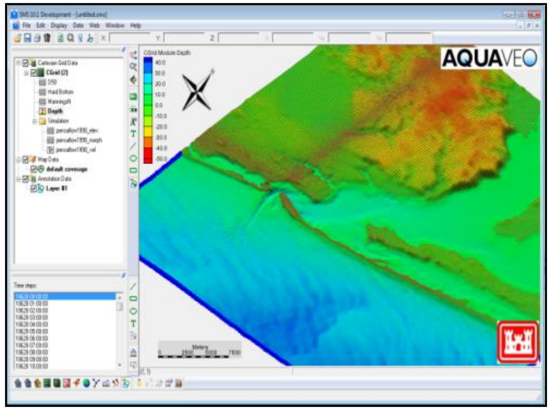
- Apply a Coastal Modeling System (CMS) wave and hydrodynamic models in the present study.

- Conduct wave modeling to simulate synthetic wave and storm conditions for Jetty rehabilitation and redesign use, including providing input information to the physical model.

Coastal Modeling System (CMS)

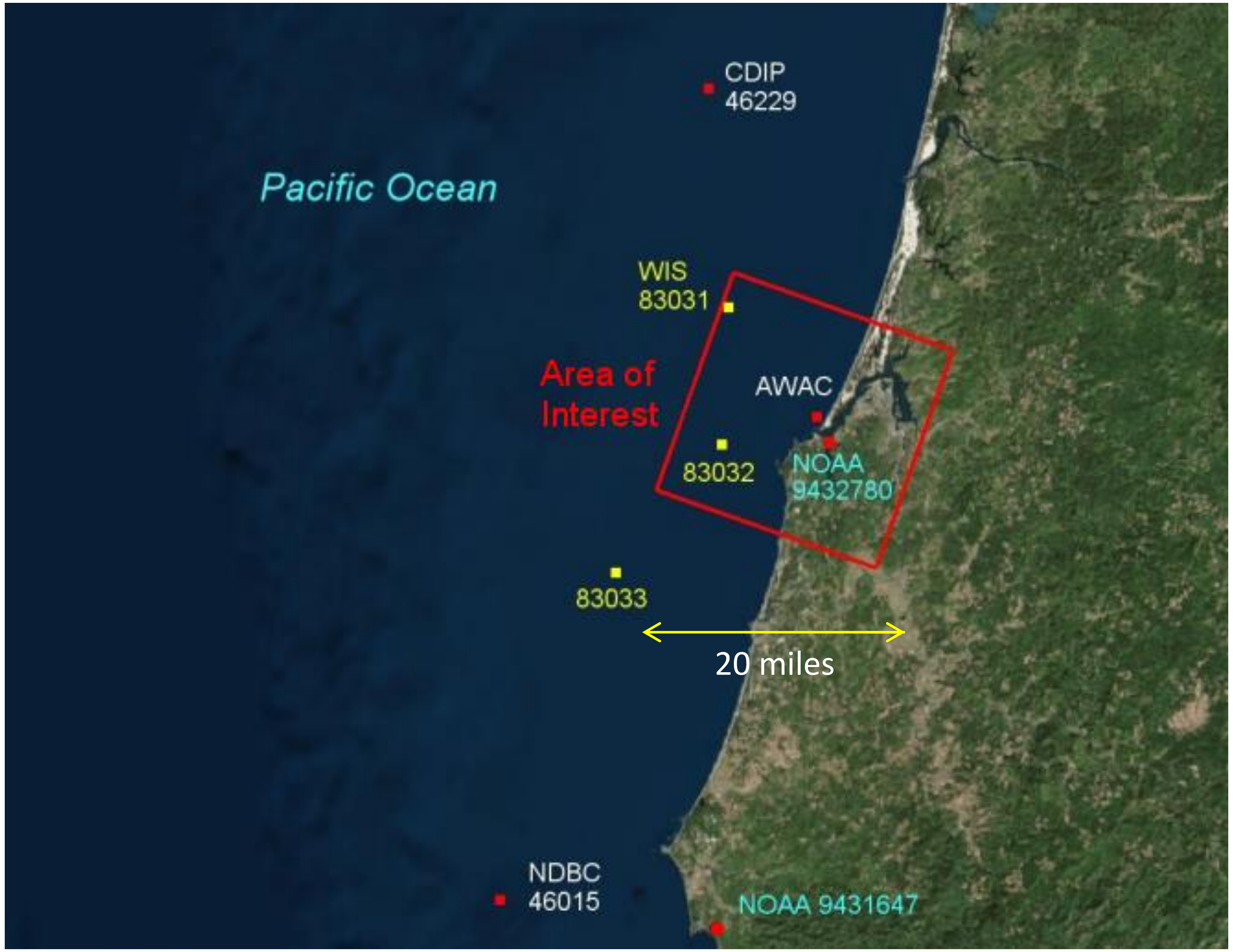






- A suit of time-dependent wave, flow, salinity, & mixed sediment transport models
- Physics-based to simulate complete coastal processes
- Integrated with visual interface thru Surface-water Modeling System (SMS)

Available Near-Field Data Stations



- CDIP Buoy – Umpqua, OR
  46229: wave data since 2008

- NDBC Buoy – Port Orford, OR
  46015: wind wave data since 2007

- NOAA Stations – wind & water level data
  9432780 (CHAO3) since 1996
  9431647 (PORO3) since 1996

- WIS Pacific hindcast – 3 nearby stations
  hourly wind wave database (1980-2015)

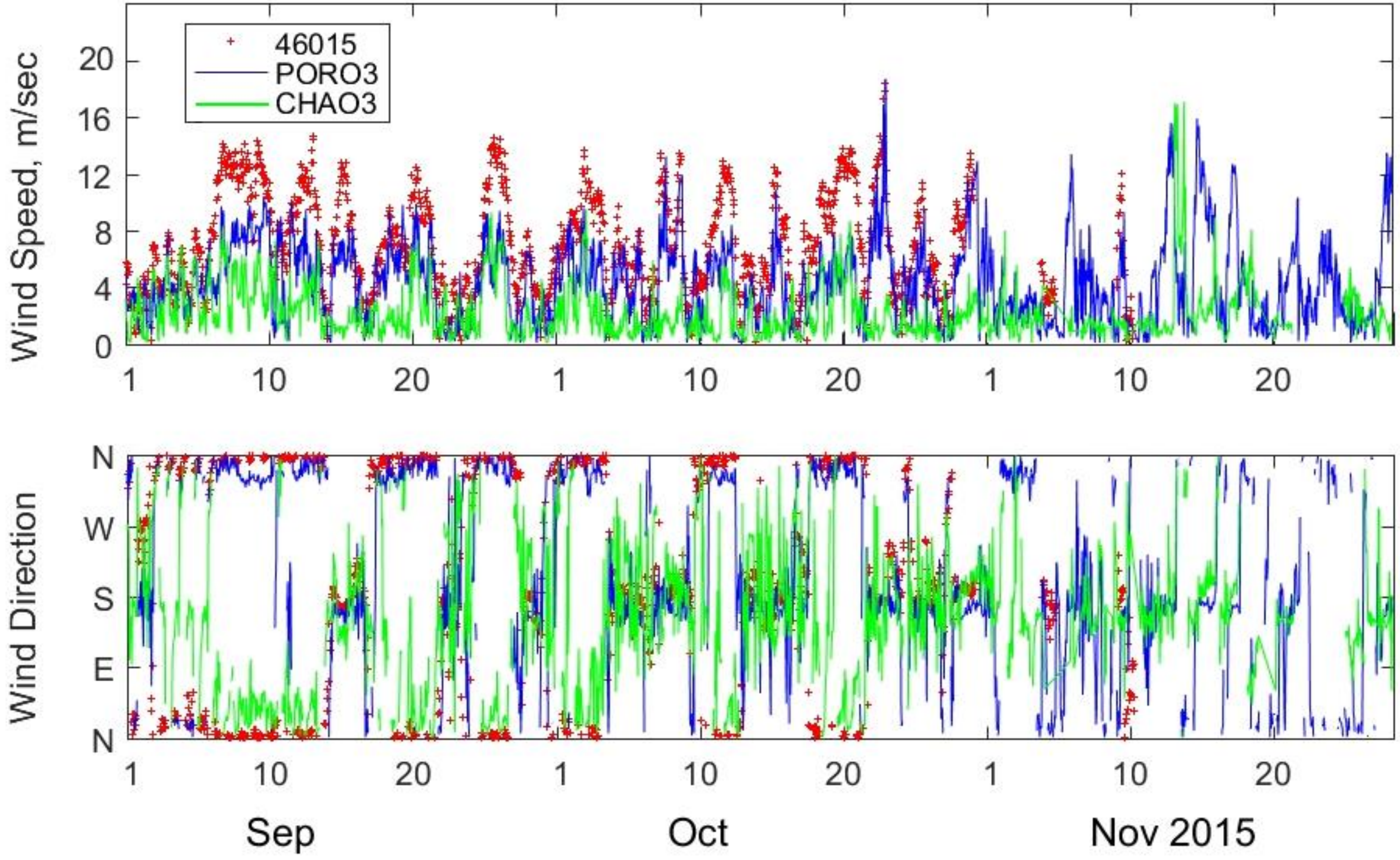
- A nearshore AWAC sensor @ 15-m depth
  wave, current, and water level data
  18 Sep – 20 Nov, 2015

Coos Bay, Oregon – More Buoy Stations

Two far-field NDBC Buoys wind wave data:

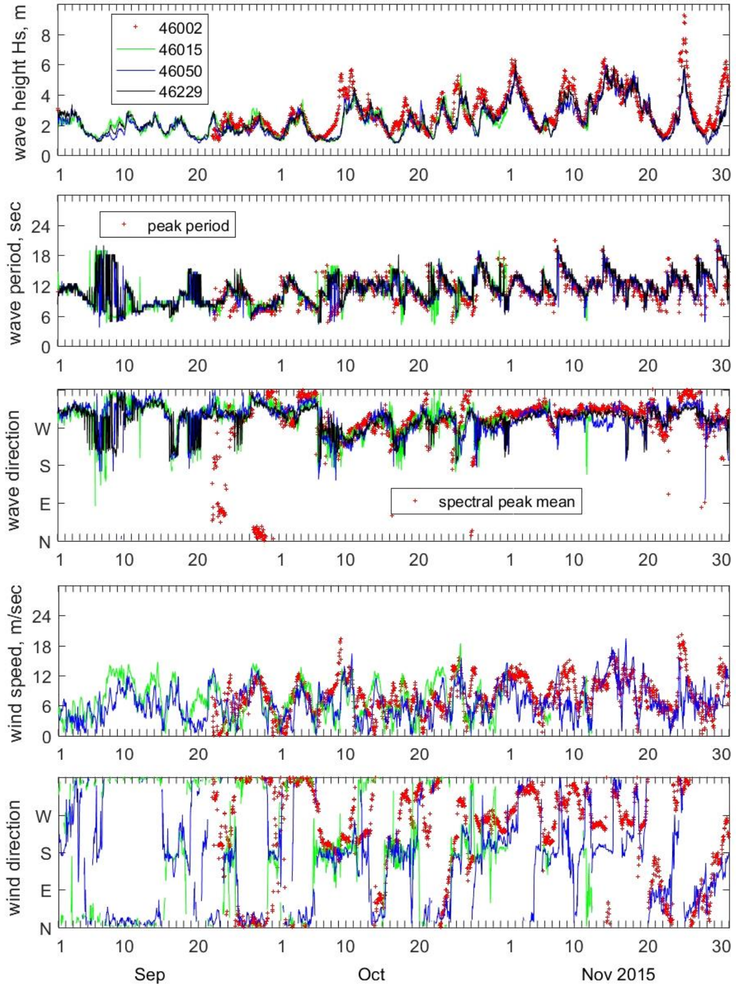
46002 (Coos Bay, OR) since 1996
46050 (Newport, OR) since 1996

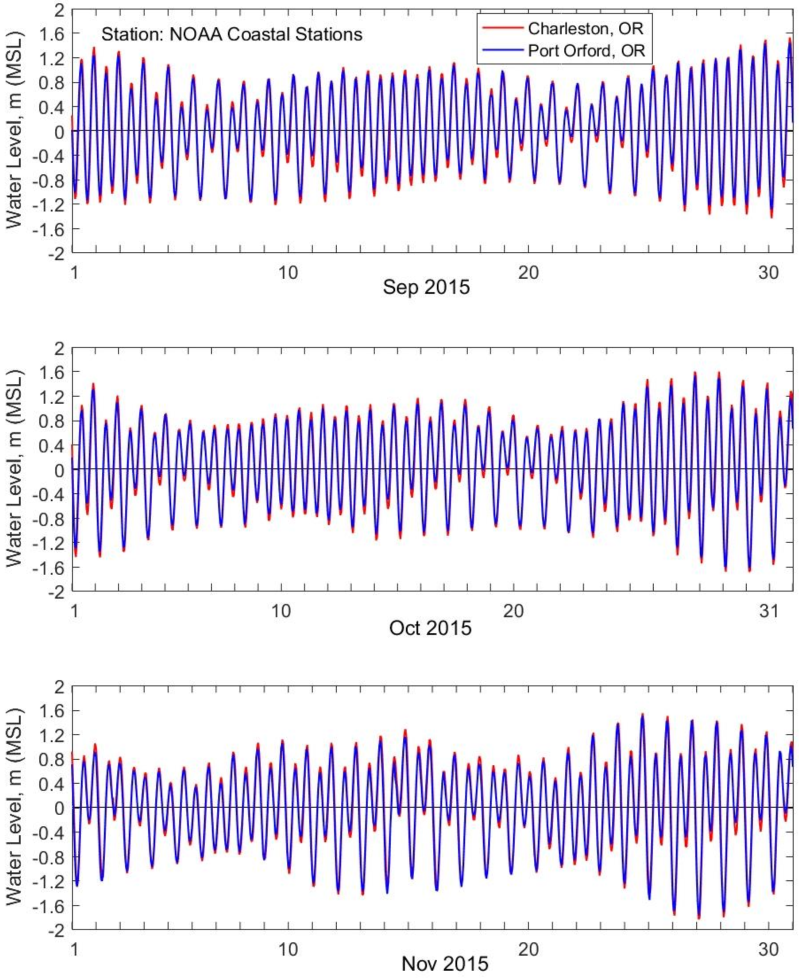
Comparison of Buoy and Coastal Winds



Winds at open water Buoy 46015 are much stronger than at land-based Stations CHAO3 & PORO3

Buoy Wind Wave & Coastal WL Data

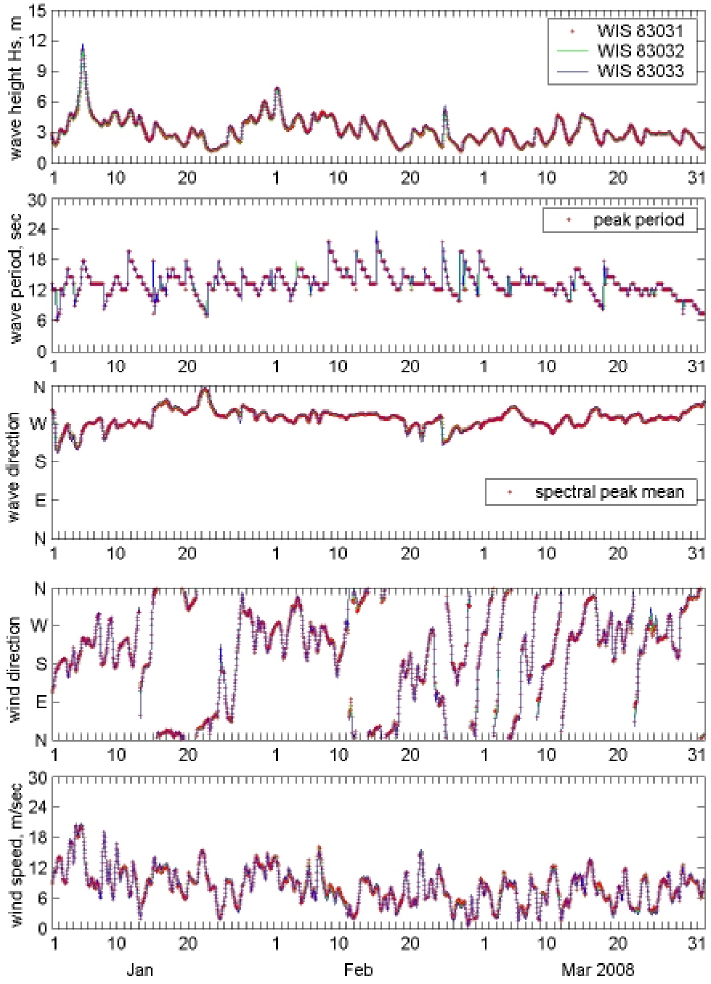


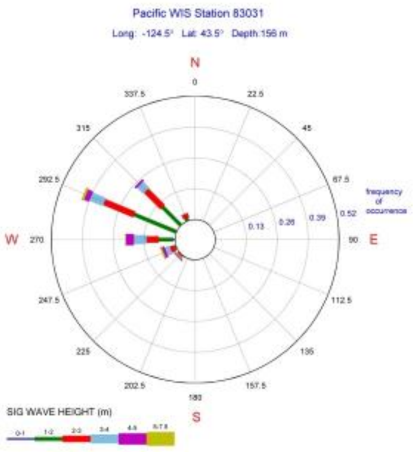


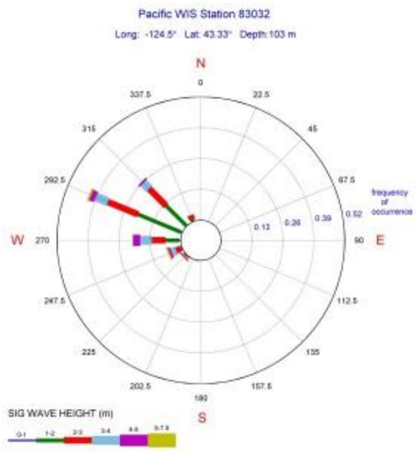
- Waves at the far-side Buoy 46002 are much greater than near coast Buoys 46015, 46050, and 46229

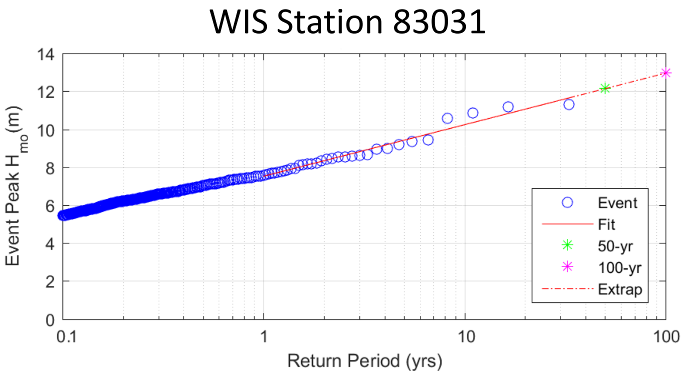
- Difference of water levels at CHAO3 & PORO3 are small

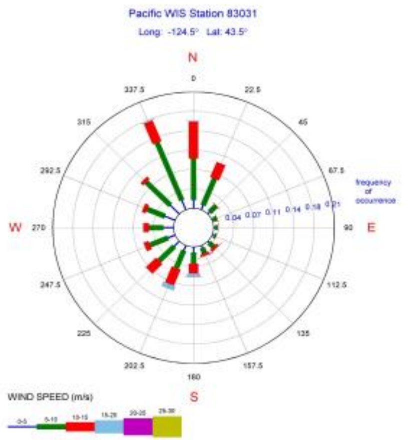
Example of WIS Wind Wave Information

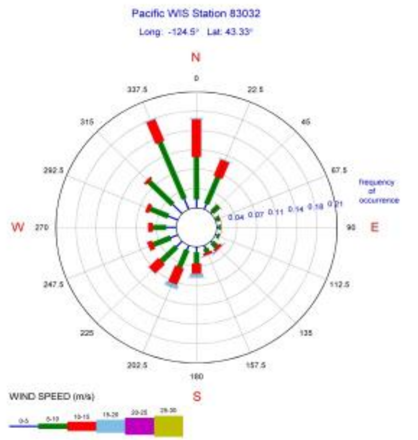


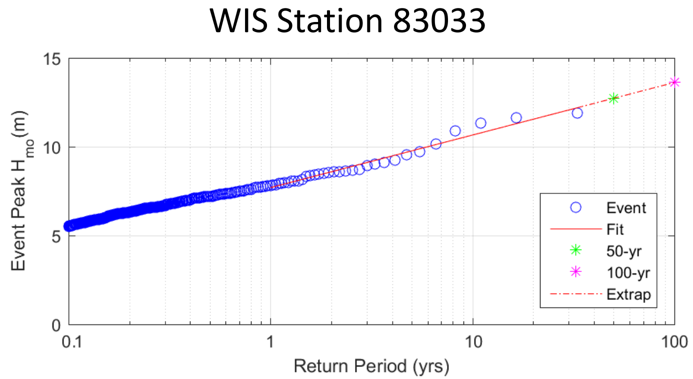










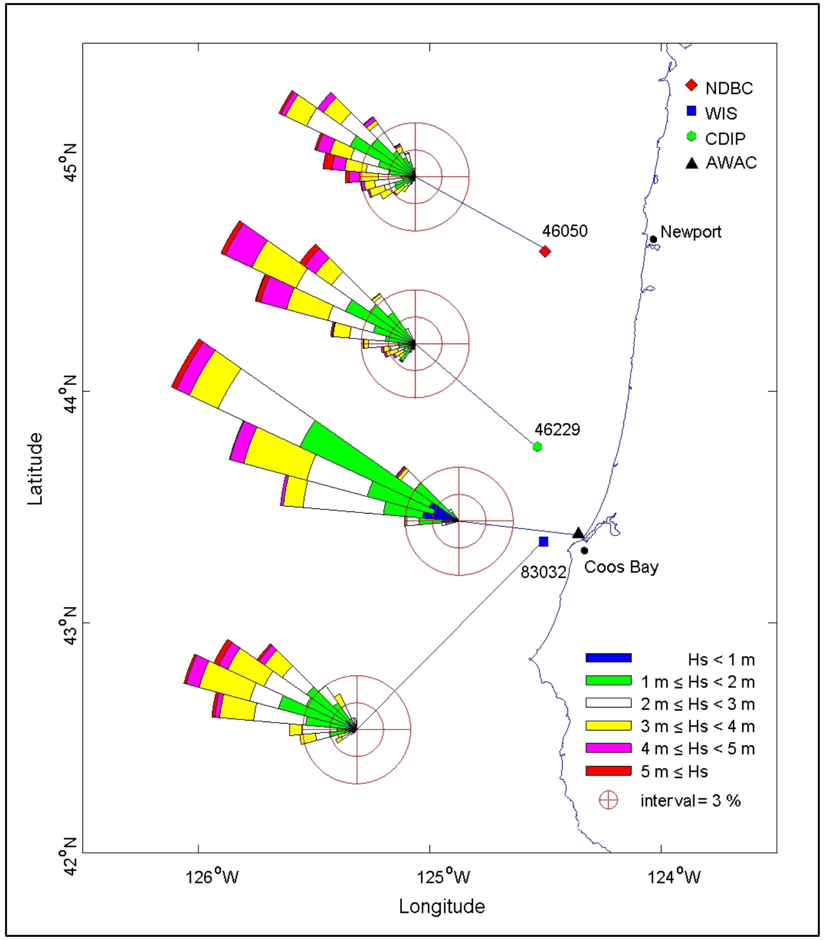


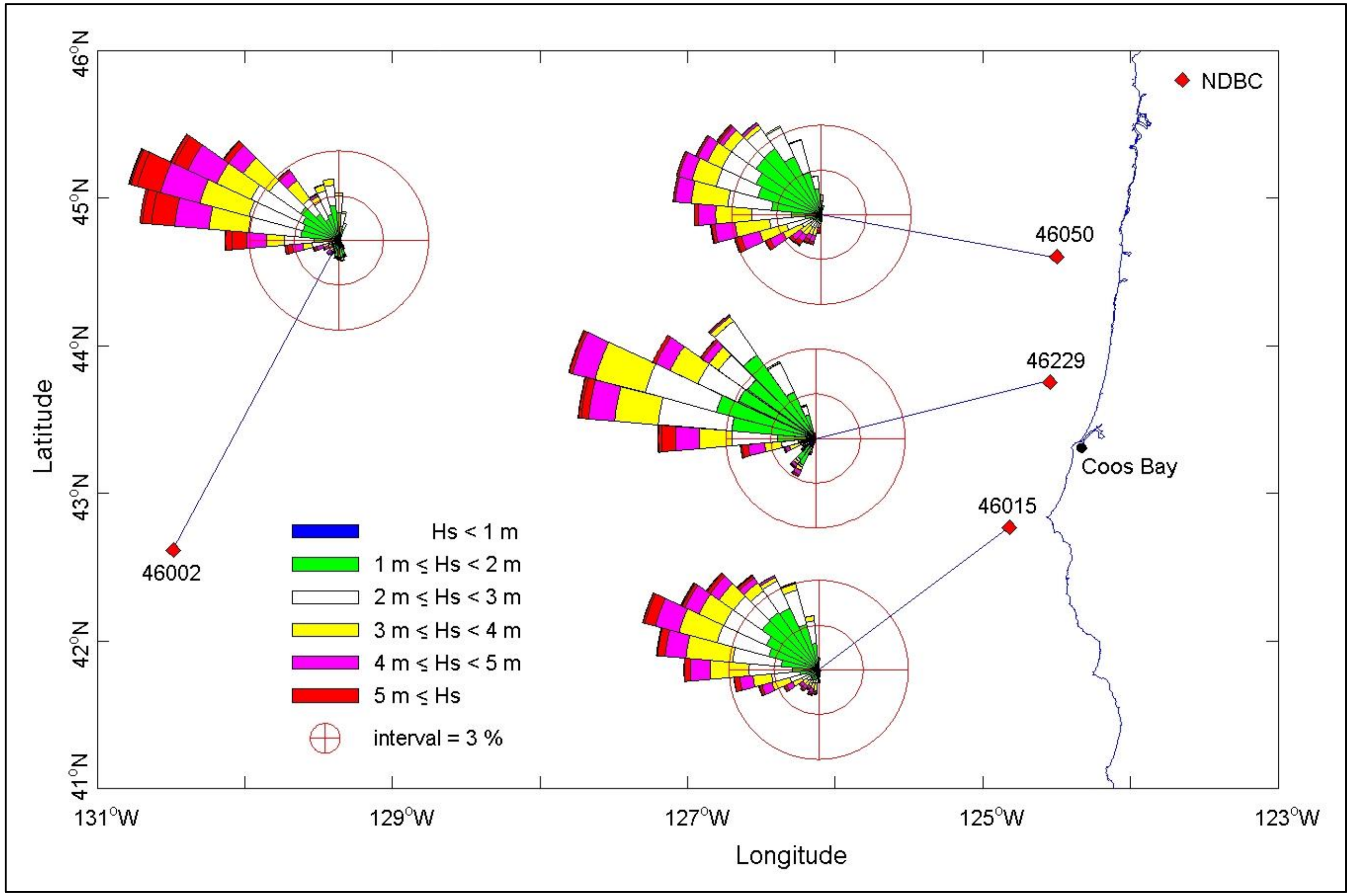
Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	1981/11/14 10:00	11.90	14.75	220.0	6	2001/11/22 13:00	9.70	15.66	261.0
2	2008/01/05 08:00	11.63	18.18	254.0	7	2000/12/22 10:00	9.56	17.24	255.0
3	1995/12/13 01:00	11.32	15.98	244.0	8	1982/12/16 14:00	9.24	16.18	252.0
4	1999/10/28 14:00	10.88	18.01	262.0	9	1998/11/24 11:00	9.09	15.87	264.0
5	2007/12/03 19:00	10.13	14.49	212.0	10	2002/12/16 03:00	9.00	14.69	237.0

An event is defined as any period when $H_{mo} > 5$ m θ_{mean} is direction that waves are arriving from

Example of Wave Roses

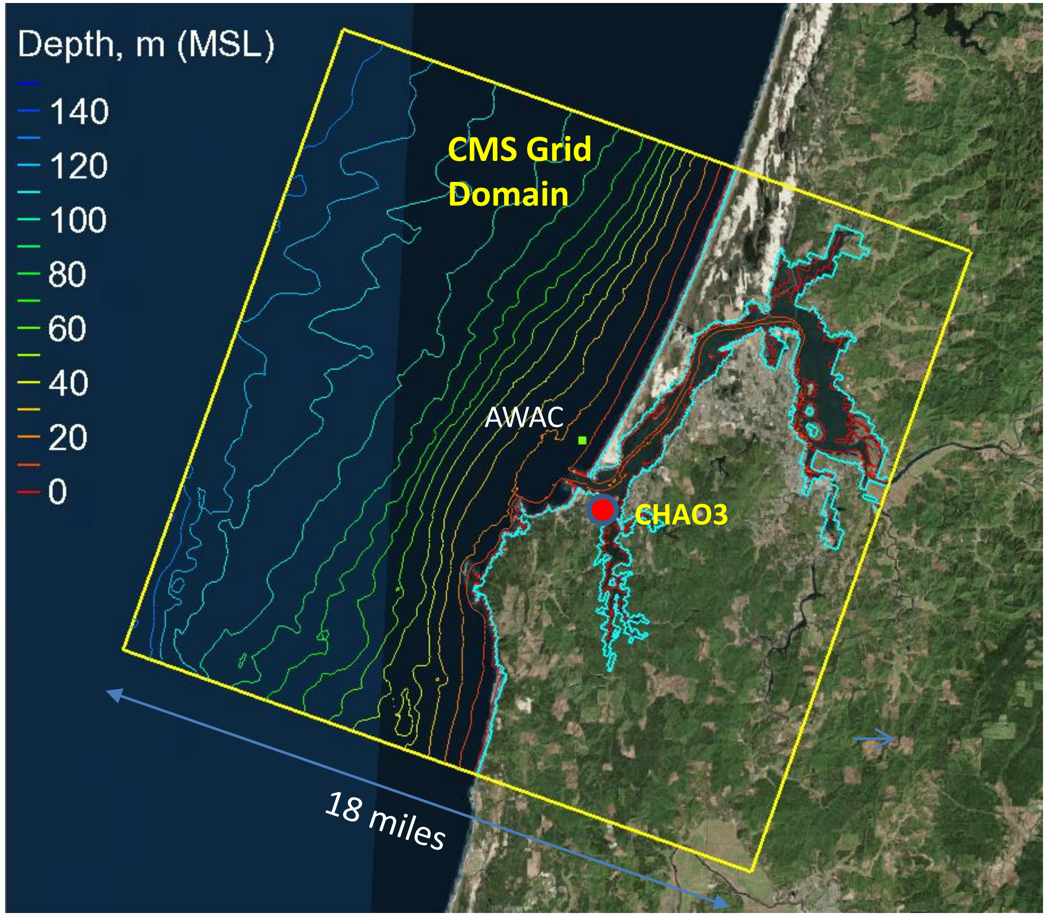




Data for 18 September to 20 November 2015

Data for 2016

CMS-Wave Calibration BC & Settings



CMS grid varying cell spacing: 18 m to 300 m

AWAC Data:

- WL – 21 Sep - 21 Oct 2015
- Current/Wave – 18 Sep – 20 Nov 2015

CMS calibration time period:

18 Sep - 22 Nov 2015

CMS forcing

- WL – CHAO3 (9432780)
- Wind – 46015, 18 Sep – 10 Nov 2015
- 46002, 10 – 22 Nov 2015
- Wave – 46229, 18 Sep – 22 Nov 2015

CMS-Flow

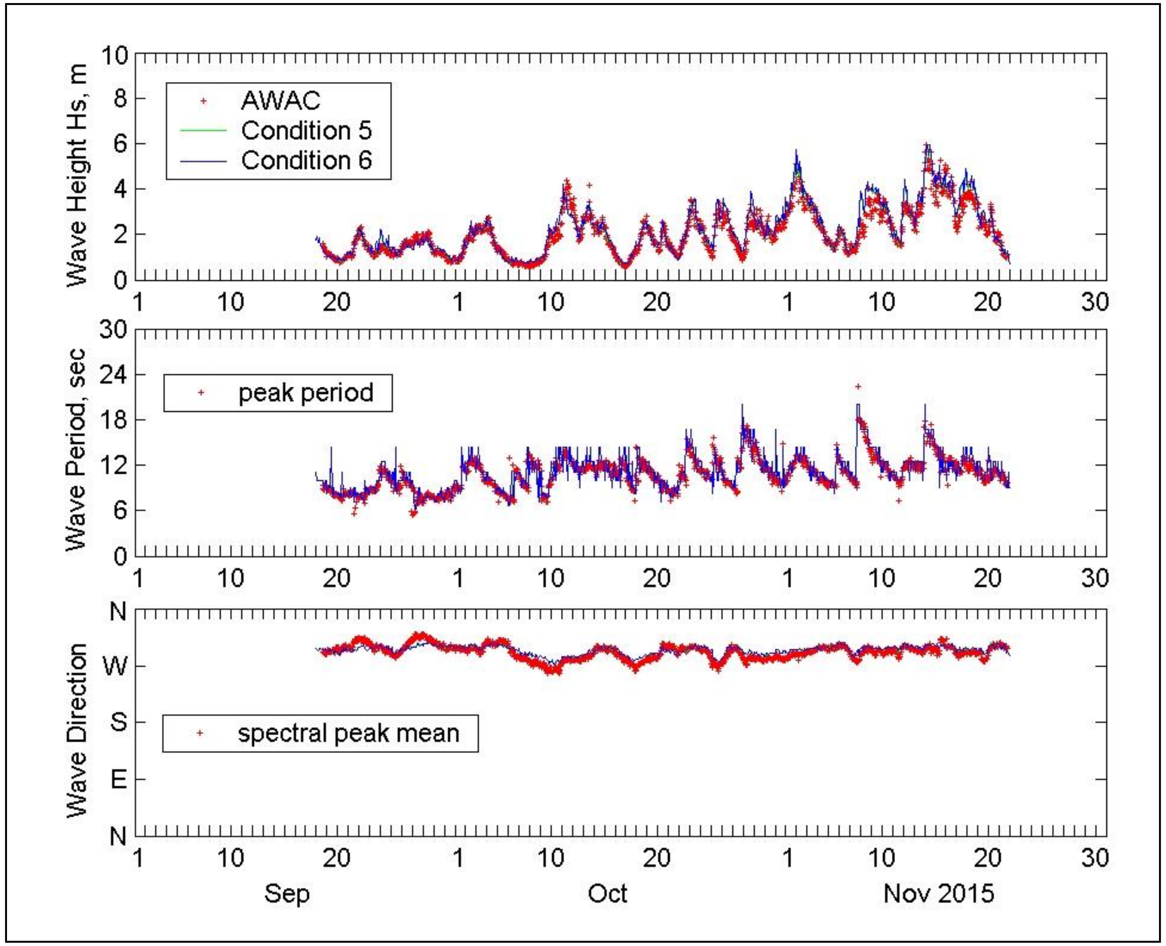
- Bottom friction:
  Manning's n = 0.021, open coast
  n = 0.015, inside bay

CMS-Wave calibration for 18 Sep – 22 Nov, 2015

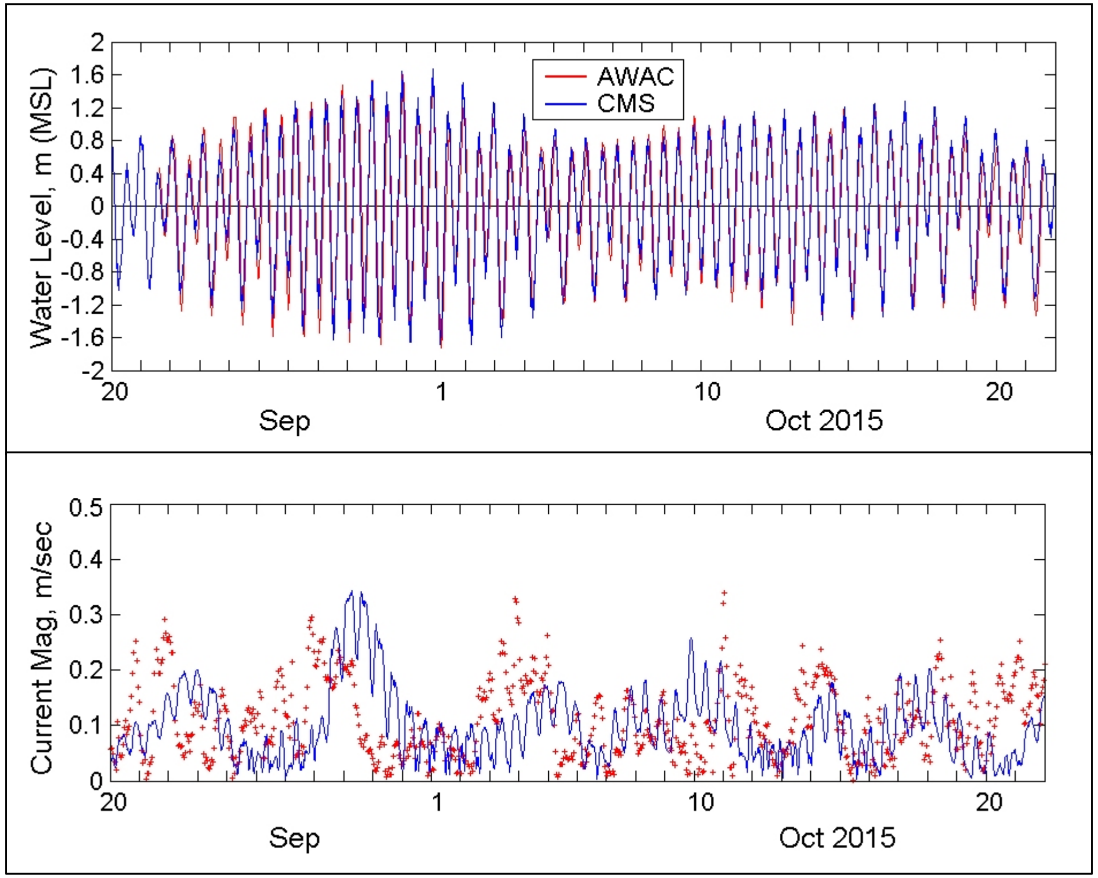
Condition	CMS-Wave	Water Level Input	Wind Forcing	With Circulation*
1	X			
2	X	X		
3	X		X	
4	X	X	X	
5	X	X		X
6	X	X	X	X

* Coupling CMS-Wave and CMS-Flow.

Example of CMS-Wave calibration Results



Condition 6: WL and current magnitude comparison



Statistics of Model Waves vs AWAC Data

Validation Condition	$H_{s,mean}$ (m)	$H_{s,bias}$* (m)	$H_{s,max}$ (m)	$H_{s,max,bias}$* (m)	$H_{s,rmse}$ (m)
1	2.17	0.07	5.82	-0.13	0.24
2	2.17	0.07	5.79	-0.16	0.24
3	2.13	0.03	5.56	-0.39	0.23
4	2.13	0.03	5.57	-0.38	0.23
5	2.19	0.09	5.87	-0.08	0.22
6	2.21	0.11	5.96	0.01	0.23

* Bias = mean(model calc.- data)

mean($H_{s,AWAC}$) = 2.1 m; max($H_{s,AWAC}$) = 5.95 m

Validation Condition	$T_{p,mean}$ (sec)	$T_{p,bias}$* (sec)	$T_{p,rmse}$ (sec)	$\lvert\theta_{m,bias}\rvert$** (deg)	$\theta_{m,rmse}$ (deg)
1	11.2	0.25	1.08	3.4	7.4
2	11.2	0.25	1.08	3.4	7.4
3	11.3	0.32	1.09	4.2	8.4
4	11.3	0.32	1.08	4.2	8.4
5	11.2	0.27	1.07	3.1	7.4
6	11.2	0.27	1.07	3.2	7.4

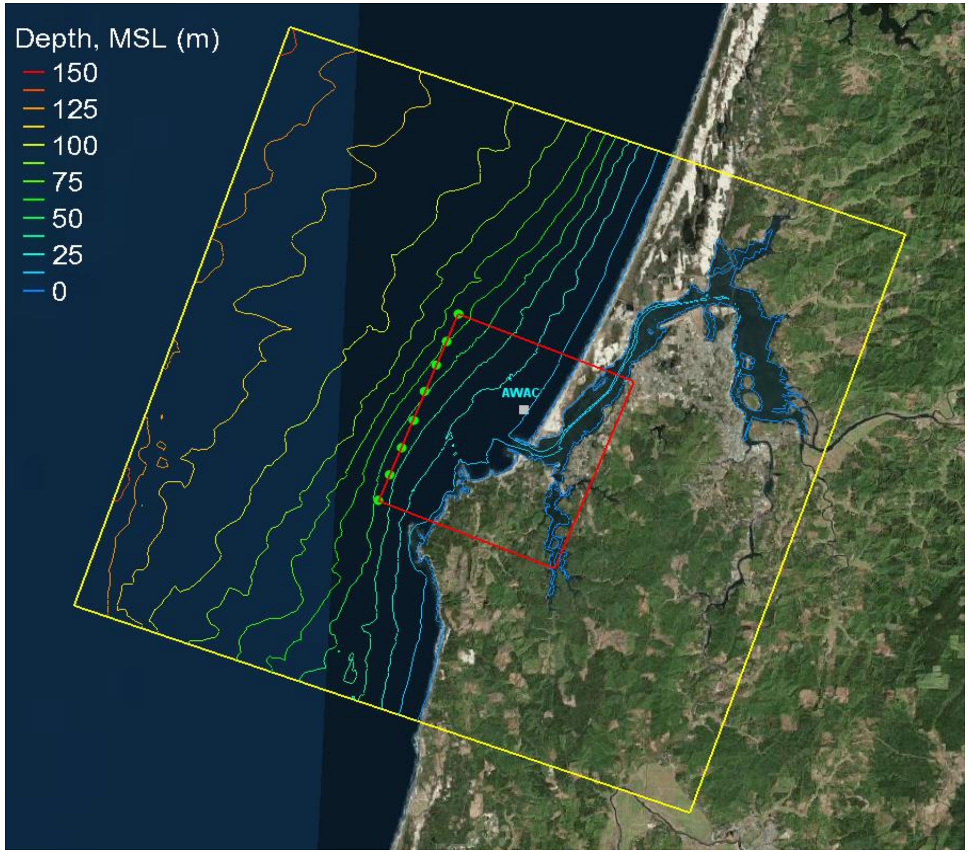
* Bias = mean(model calc.- data)

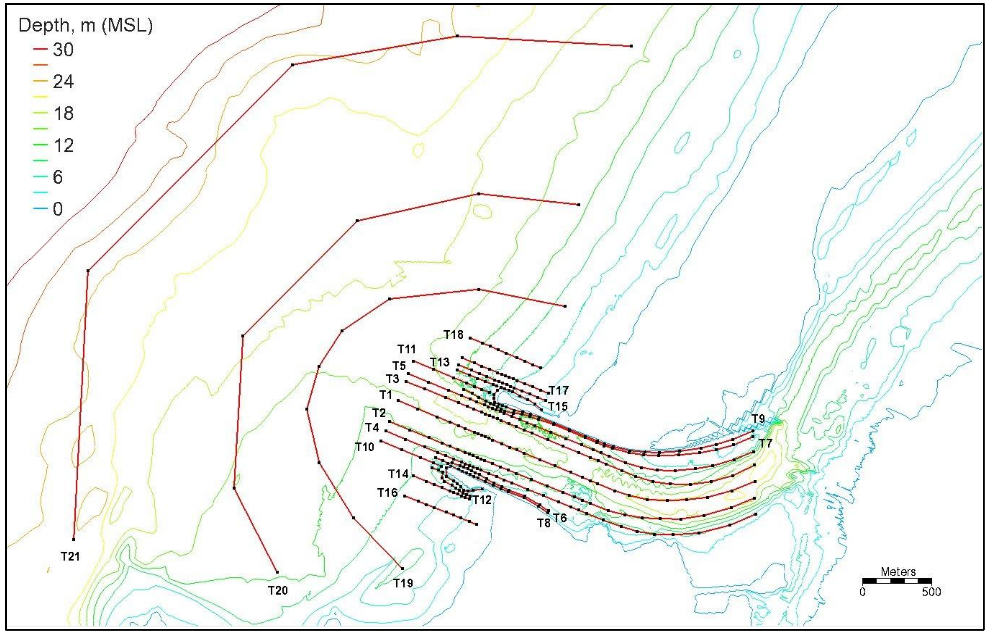
mean ($T_{p,AWAC}$) = 10.9 sec

** $\lvert\theta_{m,bias}\rvert$ is the absolute bias of mean model wave direction;

$\theta_{m,AWAC}$ = 292 deg

Wave Transformation to Nearshore Jetties





Save locations:

358 save stations along 21 transects (T1 – T21)

Parent grid domain (yellow box) & **child grid domain** (red box)

Wave Transformation Incident forcing Conditions

Simulation conditions*

(1) Synthetic wave conditions

(2) Top 20 storms

* based on WIS Station 83032 hindcast data

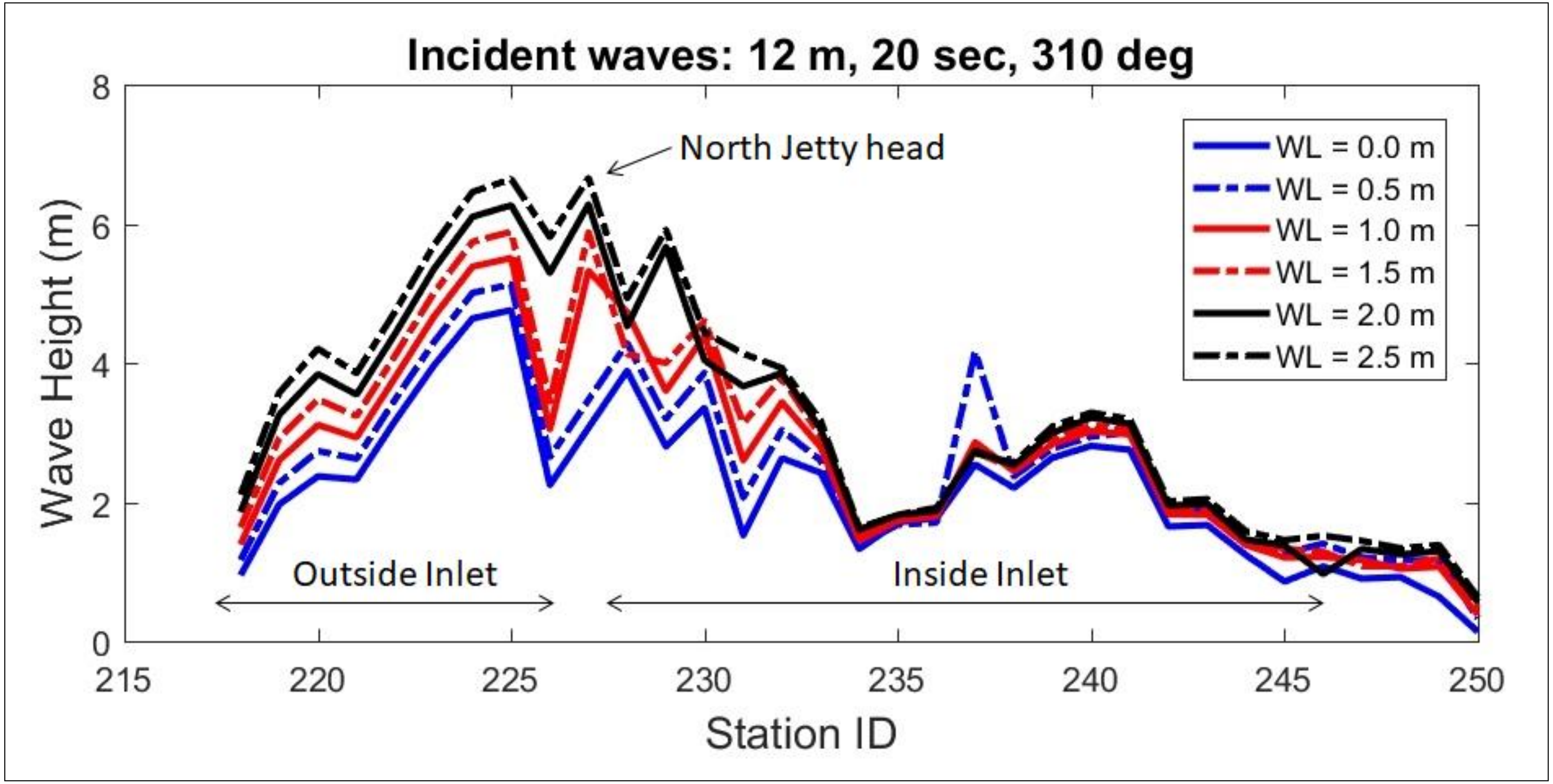
Offshore Wave Forcing Parameters	Increments *
Significant Height (m)	1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
Peak Period (sec)	8, 10, 12, 14, 16, 18, 20, 22
Mean direction (deg)	220, 250, 280, 310, 340
Water Level, MSL (m)	-1.5, -1, -0.5, 0, 0.5, 1, 1.5, 2, 2.5
* A total of 4320 (12 x 8 x 5 x 9) combinations	

Rank	Start Timestamp*	End Timestamp*	Peak Timestamp*	$H_{s,max}$** (m)	T_p** (sec)	θ_m** (deg)	Duration (hrs)
1	2008010414	2008010609	2008010508	10.97	18.34	256	43
2	1981111403	1981111506	1981111414	10.82	15.47	243	27
3	1995121208	1995121516	1995121302	10.55	16.09	248	80
4	1999102802	1999102909	1999102814	10.39	18.1	263	31
5	2001111918	2001112307	2001112213	9.19	15.63	261	85
6	2000122202	2000122304	2000122210	9.04	17.25	255	27
7	2007120216	2007120509	2007120319	8.92	14.59	220	68
8	1982121416	1982121915	1982121615	8.65	16.21	255	120
9	1998112312	1998112706	1998112411	8.63	15.88	264	90
10	1987113020	1987120317	1987120206	8.32	17.33	270	70
11	2015121000	2015121212	2015121100	8.91	16.96	270	60
12	2014011115	2014011220	2014011205	8.67	16.06	285	29
13	2006121308	2006121604	2006121507	8.3	14.46	264	68
14	2001121318	2001121504	2001121407	8.29	13.28	288	34
15	2006020406	2006020513	2006020415	8.25	14.48	260	31
16	2002121411	2002121801	2002121600	8.17	14.51	239	86
17	1983012405	1983012800	1983012622	8.15	19.94	250	91
18	1999030300	1999030403	1999030308	8.13	13.31	236	27
19	2010102415	2010102610	2010102508	8.12	16.05	278	43
20	1984022409	1984022517	1984022501	8.07	15.81	280	32

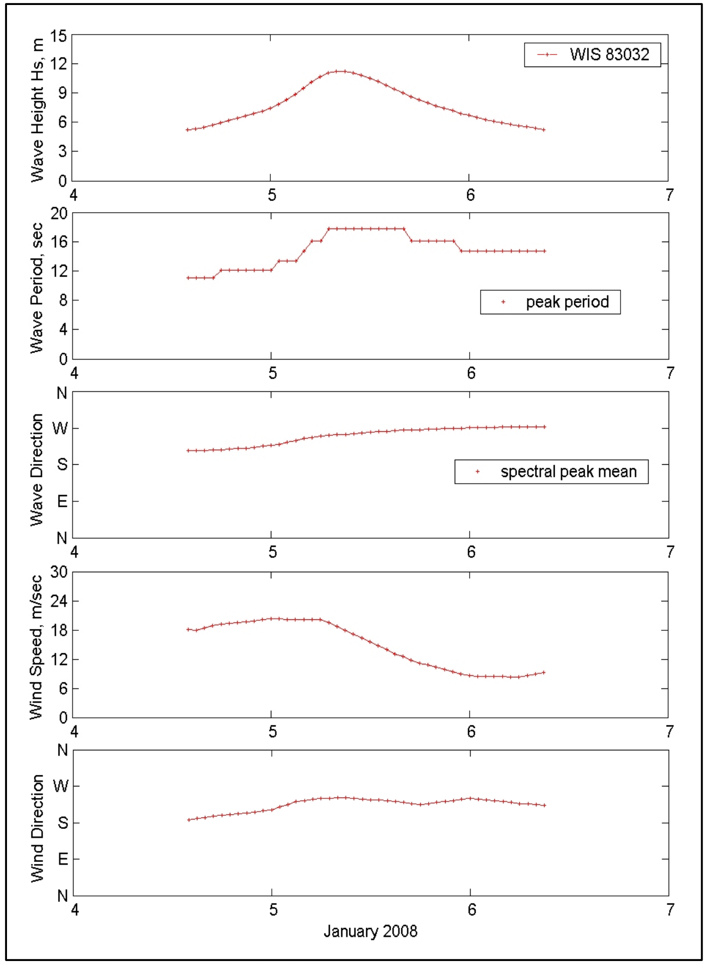
* 10-digit timestamp in "yyyymmddhh": yyyy for year, mm for month, dd for day, and hh for hr (GMT)

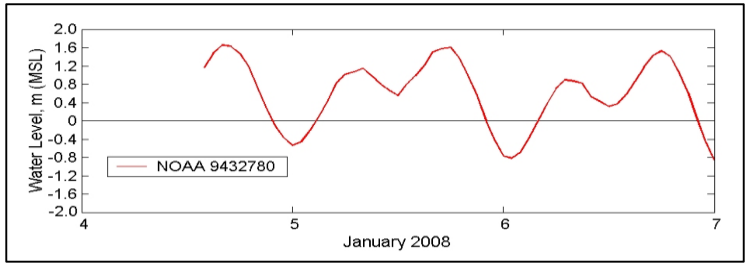
** $H_{s,max}$, T_p, and θ_m corresponding to storm peak wave height condition

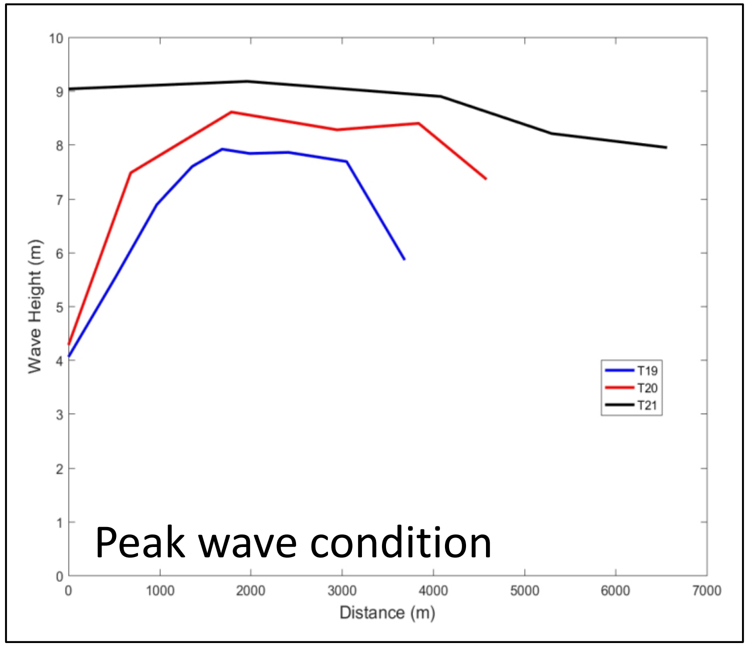
Example of Model Wave Heights Along T9

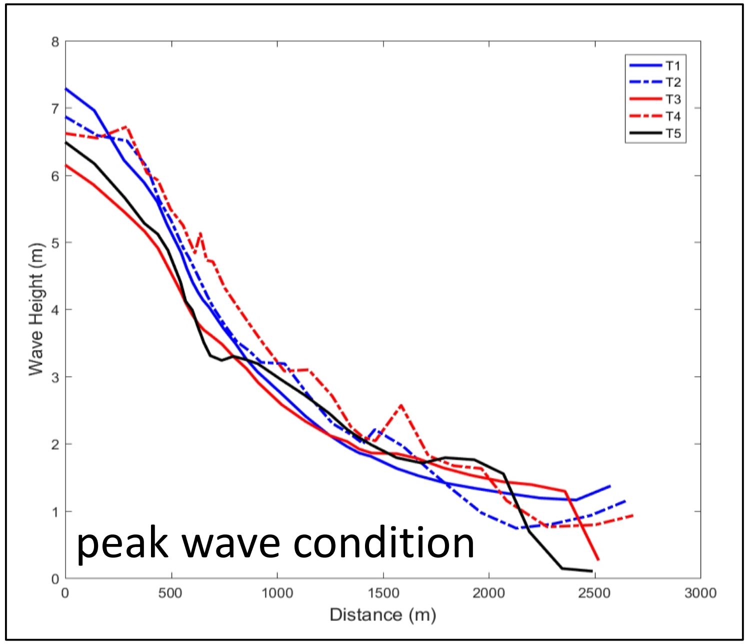


Example of Storm 1 Forcing and Model Waves







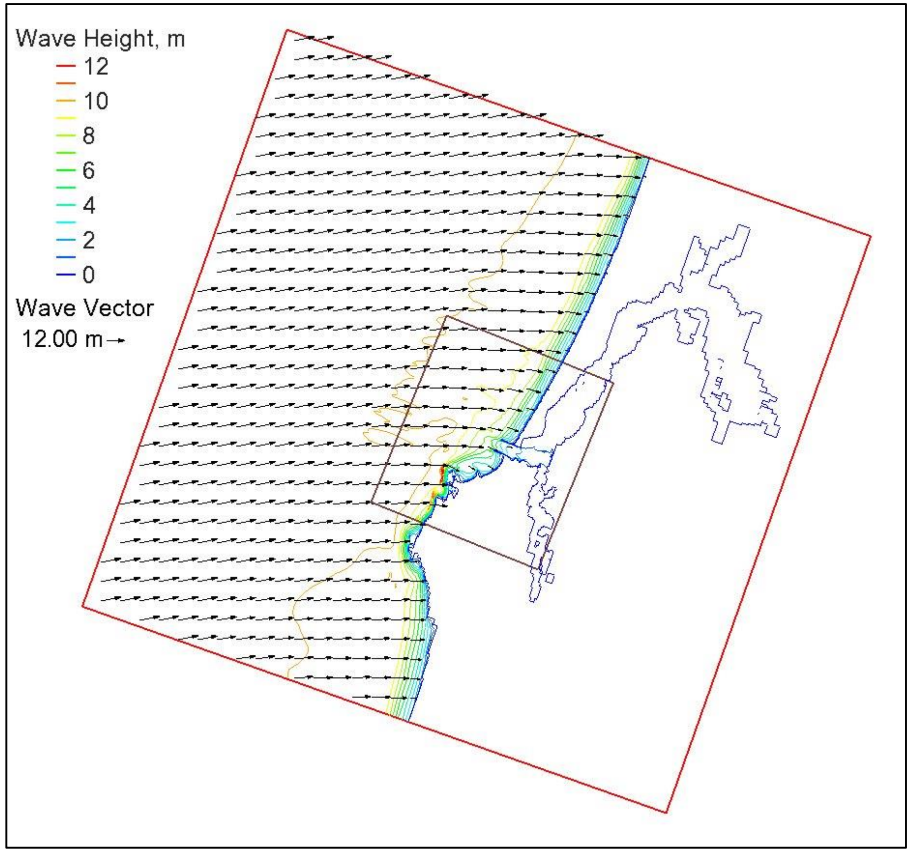


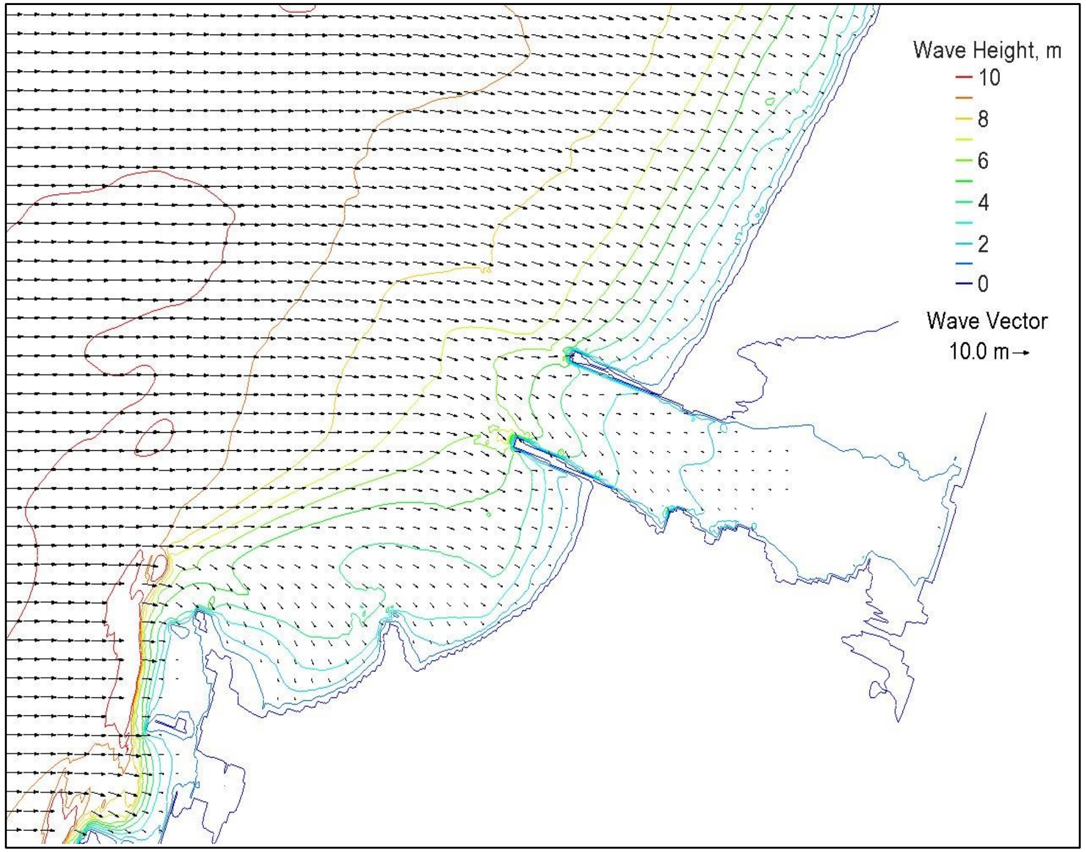
Storm 1: 4 – 6 January 2008

Incident peak waves:

11 m, 18.5 sec from WSW

Storm 1 Peak Wave Height Field

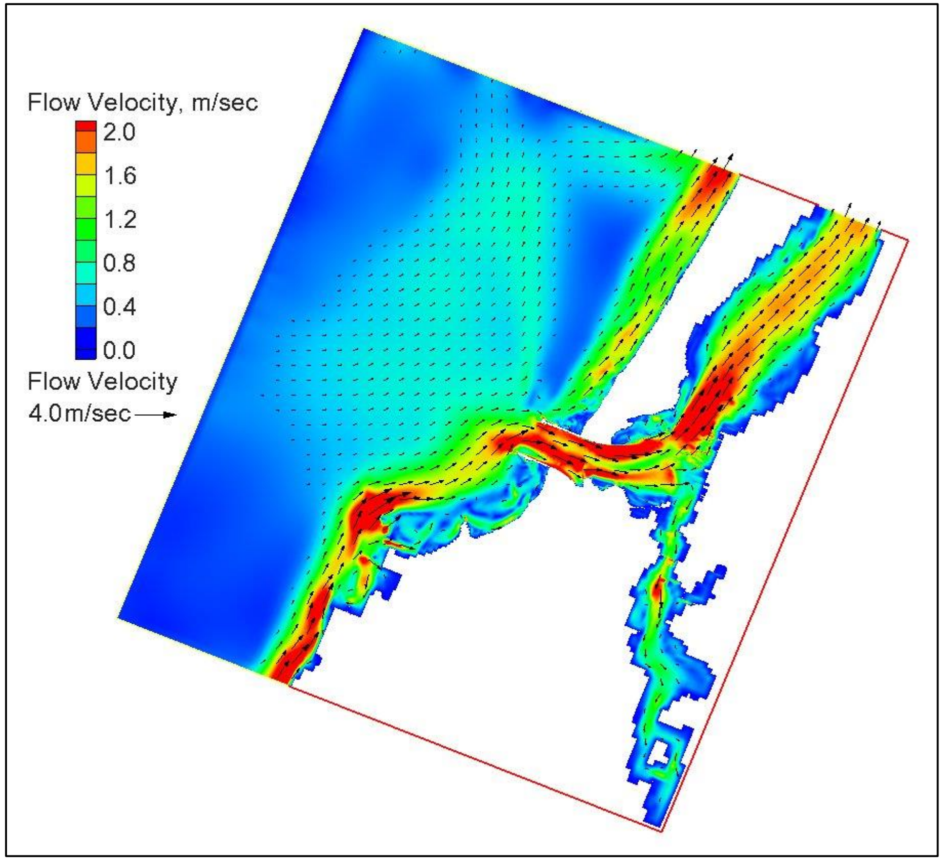




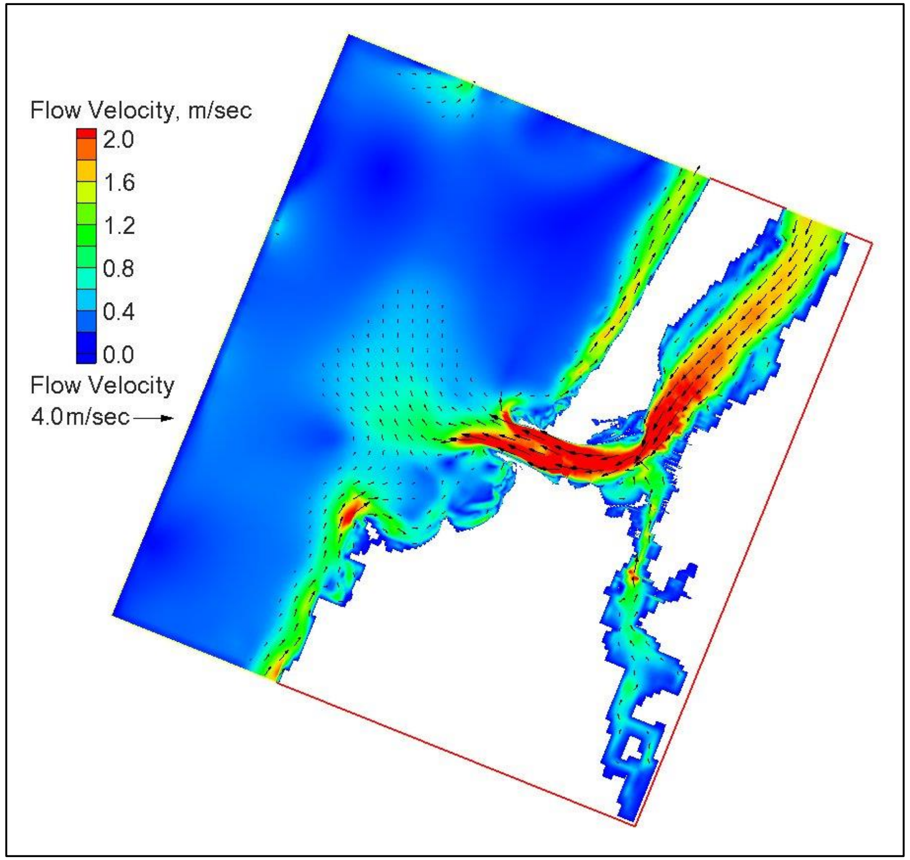
Parent Grid simulation

Child Grid simulation

Storm 1 Max Current Fields near Peak Storm



Max flood current field



Max ebb current field

Summary & Conclusions

- US Army Engineers ERDC is assisting Portland District to investigate the rehabilitation and redesign of jetties using numerical and physical modeling of storm waves to ensure navigation safety and guide storm waters through the Federal Channel at Coos Bay Inlet.

- The ERDC Coastal Modeling System (CMS) models were used to estimate storm waves at and around the inlet. Model calibration was based on the wave, water level, and current data collected at a nearshore AWAC sensor near North Jetty.

- Wave modeling was conducted for a set of synthetic incident wave conditions and top 20 severe storms to provide input information for physical modeling and rehabilitation of inlet jetties.

- The CMS can be run with efficiency using the nesting grid approach (parent and child grids). Model results show variation of storm wave heights along jetties are approximately linearly proportional to water level change (e.g., wave setup, storm surge, sea level rise) above the MSL.

Thank you!


Coastguards headed out Coos Bay Inlet

Questions?

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