CENTRE FOR MARINE APPLIED RESEARCH

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WAVE MODELING VALIDATION STUDY

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IFI – Issued for information
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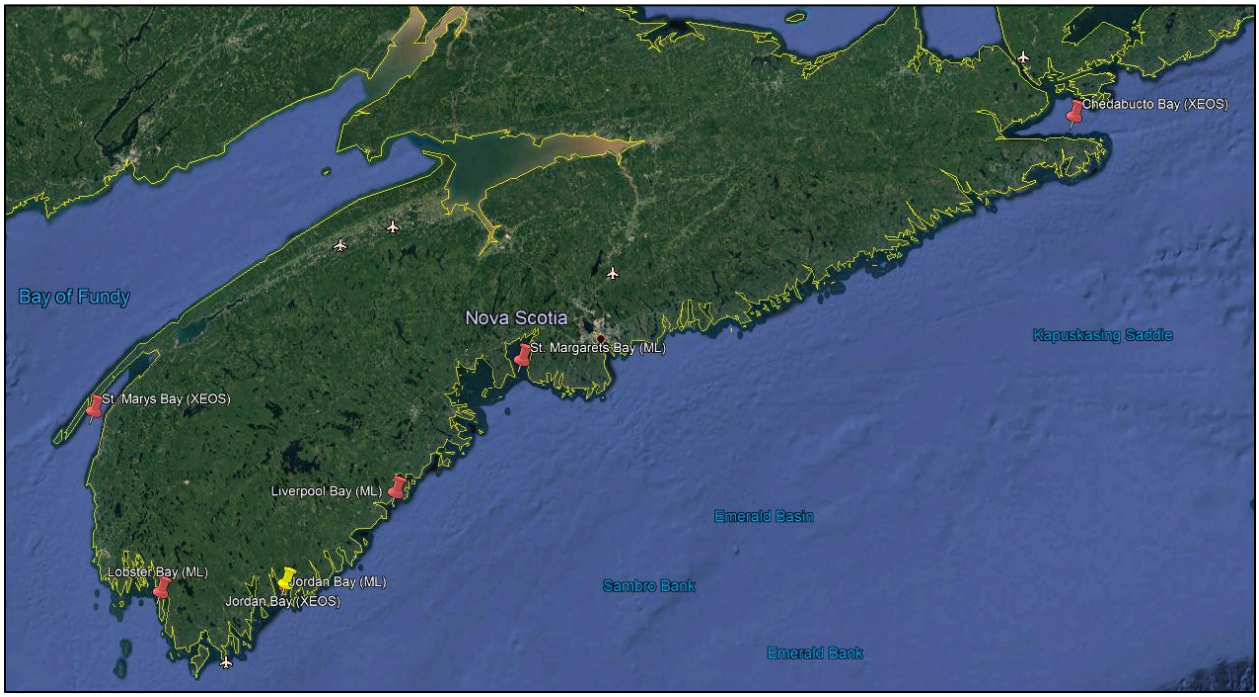
Executive Summary

In support of the Centre for Marine Applied Research (CMAR), the following report summarizes the collection of wave condition measurements using 7 buoys to validate the numerical wave modeling at 6 location in Nova Scotia, Canada. In total, four MarineLabs (ML) buoys and three XEOS buoys have been deployed for wave height measurements between January 2020 and February 2021.

In this report, the measured wave data collected with the buoys is compared with predictions of wave heights from numerical models. This comparison is performed at the 6 locations where the buoys were deployed:

- St. Mary's Bay (XEOS): 44° 18.503'N, 66° 12.238'W.
- Lobster Bay (ML): 43° 39.172'N, 65° 50.050'W.
- Jordan Bay (ML): 43° 41.901'N, 65° 11.720'W, (XEOS): 43° 41.902'N, 65° 11.652'W.
- Liverpool Bay (ML): 44° 2.284'N, 64° 38.332'W.
- St. Margarets Bay (ML): 44° 31.429'N, 63° 59.952'W.
- Chedabucto Bay (XEOS): 45° 23.257'N, 61° 8.084'W.



To determine the wave field evolution at these near shore locations (e.g. within bays and behind coastal islands) and to determine 10- or 50- year return period extreme wave conditions, near shore wave modelling can be used. For all 6 locations listed above, the STWave software was used to model the wave conditions in the water body in which the buoy was located. The STWave model results are determined using wind and wave boundary condition data from the MSC50 HindCast model of an

offshore point close to each bay. The extreme waves at the buoy locations are determined in the model by considering both the propagation of swell and the effects of wind-driven waves.

By comparing the predicted wave conditions from the numerical model with those collected at the buoys, it is possible to validate the modeling methodology and approach. To compare the numerical model and wave measurements, each buoy data was post-processed to predict 10- year return period wave heights for 16 heading-range bins of 22.5 degrees.

In summary, the results of the validation comparison showed that:

- St. Mary's Bay: a good correlation observed between wave modeling and XEOS buoy data. Wave modeling presented larger waves than buoy measurements from SSW (203 deg) which is the dominant wave direction for this region. However, longer wave measurements will provide more consistent agreement between modeling and buoy data.

- Lobster Bay: an unexpected mismatch observed between wave modeling and ML buoy data. Buoy data presented larger waves than wave modeling from SSW (203 deg) to WSW (248 deg). For this site, it is recommended to deploy a XEOS buoy as well to have a better wave modeling validation.

- Jordan Bay: a good correlation observed between wave modeling and XEOS buoy data. A longer wave measurement will provide more consistent agreement between modeling and XEOS buoy data. However, ML buoy data shows lower peak values for the dominant wave directions. These results are likely due to the shorter period of wave measurements in comparison to the XEOS buoy.

- Liverpool Bay: a good correlation observed between wave modeling and ML buoy data. A longer wave measurement will provide more consistent agreement between modeling and ML buoy data.

- St. Margarets Bay: a good correlation observed between wave modeling and ML buoy data. Note that, ML buoy data shows slightly higher peak values than wave modeling in dominant wave directions. However, a longer wave measurement will provide more consistent agreement between wave modeling and ML buoy data.

- Chedabucto Bay: a good correlation observed between wave modeling and XEOS buoy data. Wave modeling presented larger waves than buoy measurements from East (90 deg) and ENE (63 deg) which are the dominant wave direction for this region. However, longer wave measurements will provide more consistent agreement between wave modeling and buoy data.

In general, acceptable agreements have been observed between the wave modeling and wave measurements except for the Lobster Bay.

Based on this comparison, DSA is confident that wave modeling approach which uses the STWave model in conjunction with MSC50 hindcast boundary conditions for determination of 1 in 10 and 1 in 50 year return period wave conditions (see References [2-7]) is sufficiently accurate for engineering purposes.

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1 Introduction

1.1 Overview

Wave buoys were deployed by DSA for CMAR at 6 locations in Nova Scotia: St. Mary's Bay, Lobster Bay, Jordan Bay, Liverpool Bay, St. Margarets Bay, and Chedabucto Bay. The purpose of these deployments was to collect data to validate wave models developed by DSA that predict wave conditions in the bays. The following report presents a comparison study between measured wave conditions in 6 bodies of water and the estimated wave conditions calculated by models developed by DSA using Aquaveo STWave software. The models were validated by comparing predicted 10- year return period wave conditions at the buoy locations that were calculated using the model predictions and calculated through extreme value analysis using the measured wave buoy data.

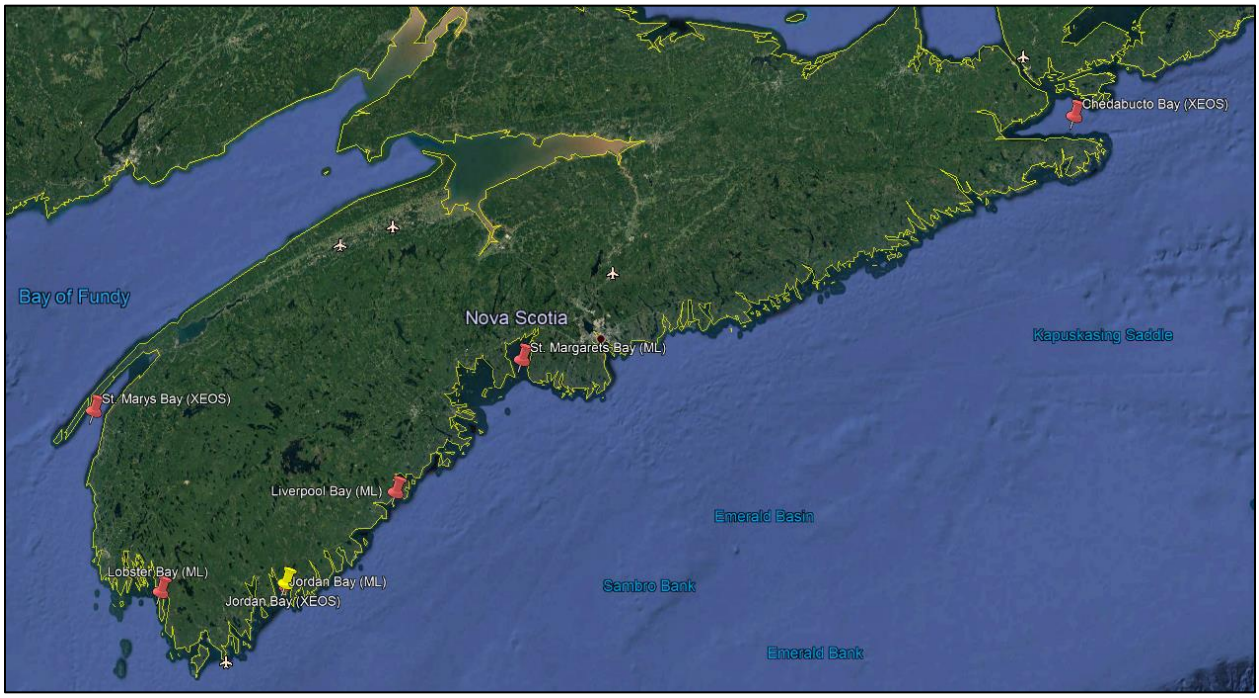

Figure 1 Six (6) site locations at Nova Scotia, Canada. Note that 2 buoys were deployed at Jordan Bay. ML buoy presented with yellow tag and XEOS buoy shown with red tag

1.2 Objective(s)

- Comparison and validation of wave modeling results and processes using buoy data from 6 locations in Nova Scotia, Canada.

2 Abbreviations and acronyms

DSA	Dynamic Systems Analysis Ltd.
SMS	Surface-water Modeling System
CMAR	Centre for Marine Applied Research

CHS	Canadian Hydrographic Services
ML	MarineLabs

3 Reference documents and drawings

[1]	V. Swail, V. Cardone, M. Ferguson, D. Gummer, E. Harris, E. Orelup, and A. Cox, "The msc50 wind and wave reanalysis," in *9th International Workshop On Wave Hindcasting and Forecasting*, 2006.
[2]	Report-DSA-CMAR-19EXM-St. Mary's Bay Wind and Wave Conditions RevB.0.pdf
[3]	Report-DSA-CMAR-19EXM-Lobster Bay and Pubnico Harbour Wind and Wave Conditions RevB.0.pdf
[4]	Report-DSA-CMAR-19EXM-Jordan Bay Wind and Wave Conditions RevB.0.pdf
[5]	Report-DSA-CMAR-19EXM-Liverpool Bay Wind and Wave Conditions RevB.1.pdf
[6]	Report-DSA-CMAR-19EXM-St. Margarets Bay Environmental Conditions RevC.2.pdf
[7]	Report-DSA-CMAR-19EXM-Chedabucto Bay Wind and Wave Conditions RevB.0.pdf

4 Wave Modeling

4.1 Overview

SMS version 12.2.13 was used to setup the bathymetric and computational grid. For the site bathymetries, CHS hydrographic charts are used to generate the bathymetric data for wave modeling.

4.2 Wave Model Description

SMS, created by Aquaveo, is a modelling suite in which various water surface modelling tools, like wave and flow models, can be used. For this analysis SMS in combination with STWave is used. STWave is a nearshore spectral Hydraulics model, developed by U.S. Army Engineer Research and Development Center (ERDC) and Coastal and Hydraulics Laboratory (CHL). It is capable of modelling accurately wave transformation and propagation.

4.3 Boundary conditions – offshore wind and wave conditions

The MSC50 HindCast model [1] data from 6 offshore locations were used to determine the 10- year return periods for wave heights at each site. More information about wave modeling and boundary conditions of each site are available at their detailed wave modeling report [2, 3, 4, 5, 6, 7].

10- year return period conditions of offshore source points are in general achieved by:

- Obtaining hindcast data for parameter in question
- For each parameter, bin data by direction
- Perform extreme value analysis.
    - Extract annual maxima
    - Fit Gumbel or Weibull distribution to this data
    - Use fitted distribution to calculate values corresponding to 10- year return period

5 Buoy Deployment

The period of obtained wave measurements from buoys are listed below:

- St. Mary's Bay: XEOS buoy data from July 16, 2020 to January 27, 2021
- Lobster Bay: ML buoy data from June 22, 2020 to February 1, 2021
- Jordan Bay: XEOS buoy data from January 3, 2020 to February 1, 2021
- Jordan Bay: ML buoy data from June 17, 2020 to November 9, 2020
- Liverpool Bay: ML buoy data from February 4, 2020 to January 23, 2021
- St. Margarets Bay: ML buoy data from May 26, 2020 to December 9, 2020
- Chedabucto Bay: XEOS buoy data from July 7, 2020 to February 1, 2021

10- year return period conditions for wave measurements are in general achieved by:

- Obtaining measured buoy data
- For each parameter, bin data by direction
- Perform extreme value analysis.
    - Extract monthly maxima
    - Fit Gumbel or Weibull distribution to this data
    - Use fitted distribution to calculate values corresponding to 10- year return period

6 Results

In the following sections, scatter plots of significant wave heights vs wave directions from each buoy are presented and 10- yearn return period of measured wave data are compared with 10- year return period of calculated wave modeling results at each site.

6.1 Wave conditions for St. Mary's Bay

The scatter plot of significant wave heights vs wave directions for the XEOS buoy at St. Mary's Bay is presented in Figure 2. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 1. These represent the extreme wave conditions at this coordinate: 44° 18.503'N, 66° 12.238'W.

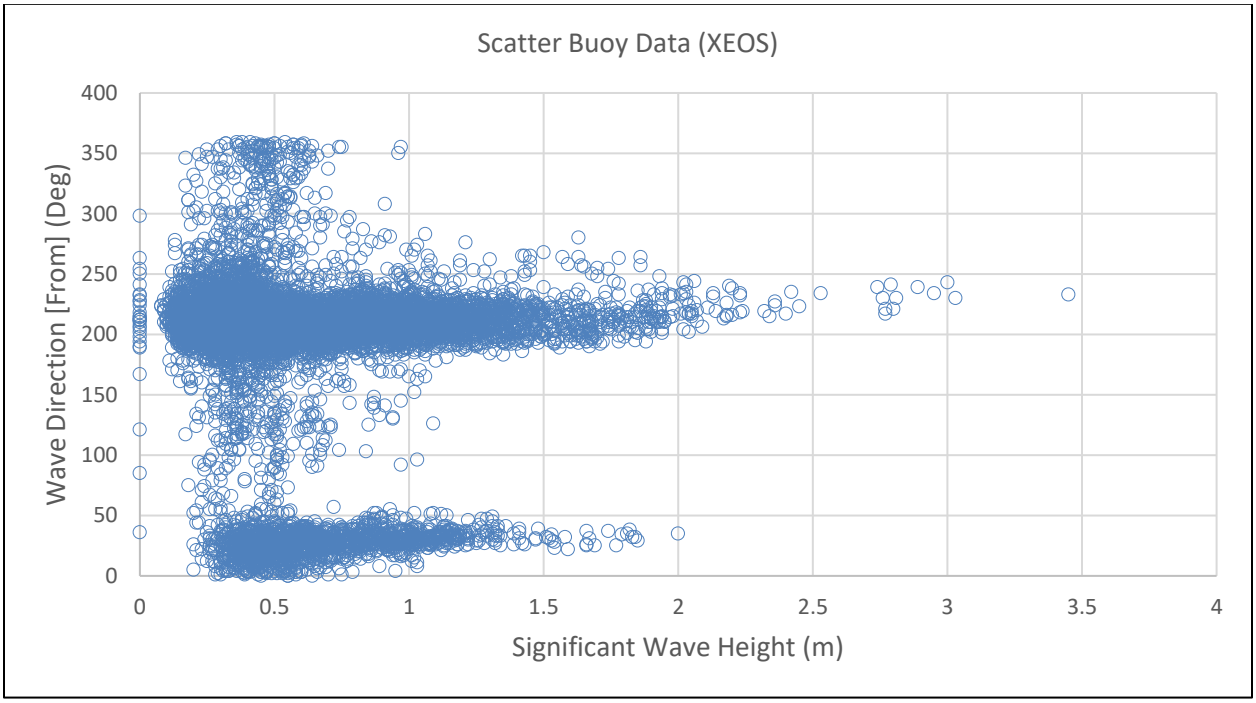

Figure 2 Significant wave heights vs wave direction [from]- XEOS buoy – St. Mary's Bay

Table 1 Significant wave heights at 10- year return period and direction [from]- St. Mary's Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements
			Hs (m)	Hs (m)
10yr wave	*0*	N	1.11	0.93
	23	NNE	1.32	1.5
	45	NE	1.44	1.84
	68	ENE	1.11	1.36
	90	E	1.17	0.53
	113	ESE	0.7	0.86
	135	SE	0.9	1.05
	158	SSE	1.47	1.03
	180	S	1.7	1.12
	203	SSW	3.4	2.18
	225	SW	2.73	2.58

	248	WSW	1.6	1.65
	270	W	0.87	1.2
	293	WNW	0.63	1.25
	315	NW	0.75	0.86
	338	NNW	0.9	0.89

Polar plots for significant wave heights are presented in Figure 3.

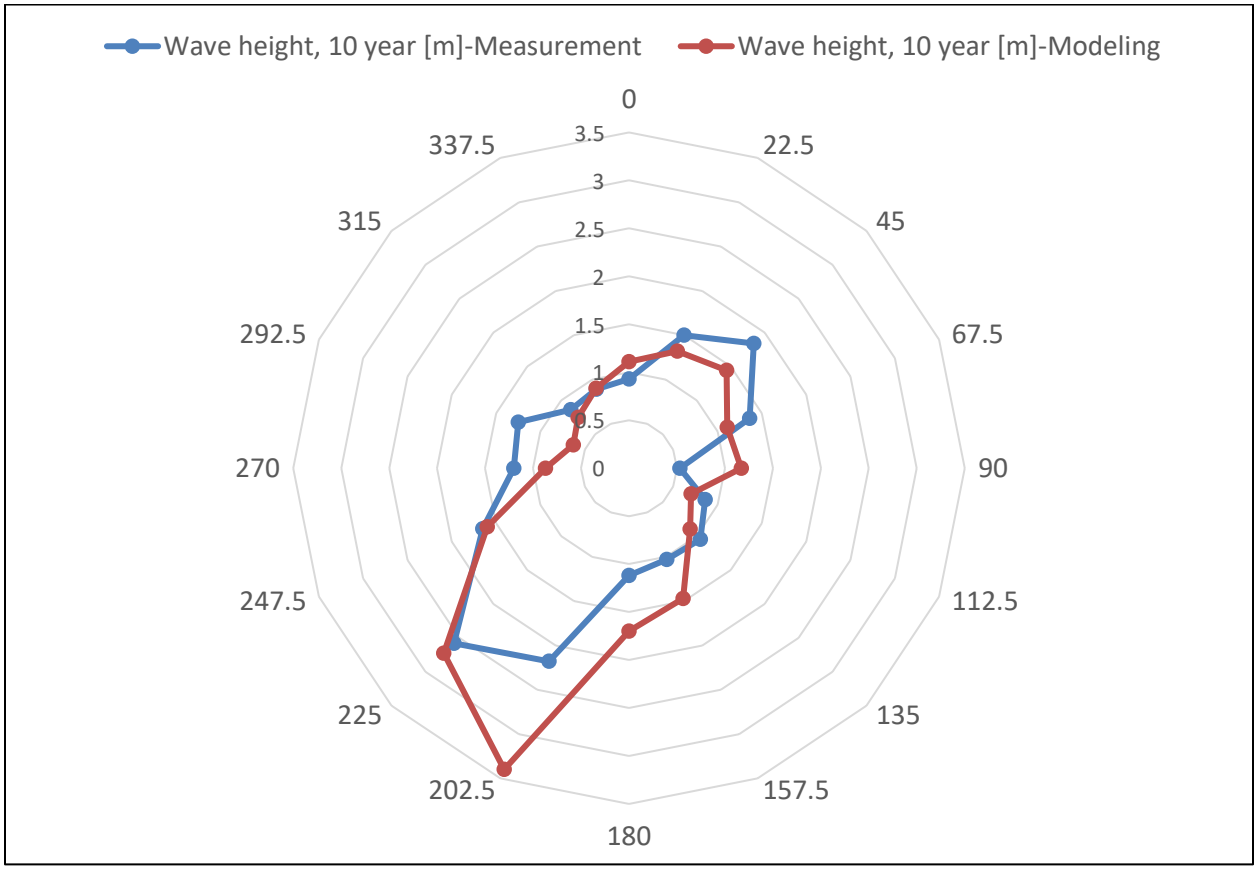

Figure 3 Significant wave heights at 10- year return period and direction [from]- St. Mary's Bay

6.2 Wave conditions for Lobster Bay

The scatter plot of significant wave heights vs wave directions for the ML buoy at Lobster Bay is presented in Figure 4. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 2. These represent the extreme wave conditions at this coordinate: 43° 39.172'N, 65° 50.050'W.

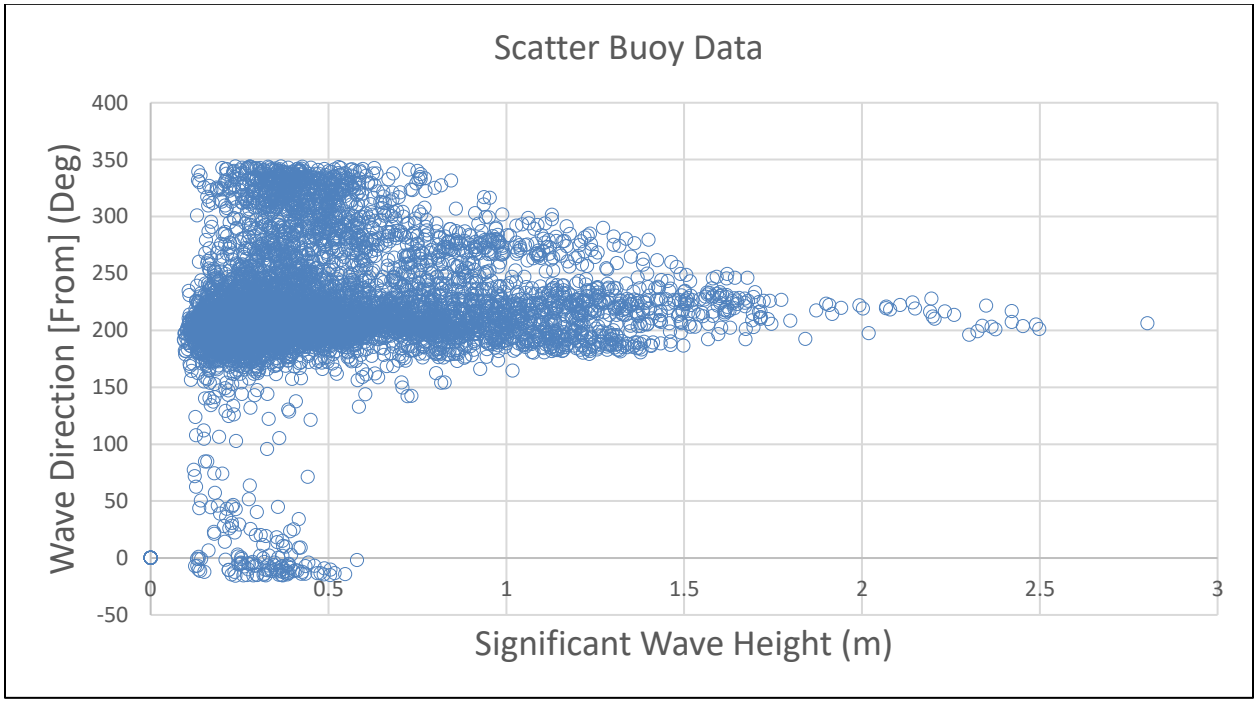

Figure 4 Significant wave heights vs wave direction [from]- ML buoy – Lobster Bay

Table 2 Significant wave heights at 10- year return period and direction [from]- Lobster Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements
			Hs (m)	Hs (m)
10yr wave	*0*	N	0.69	0.53
	23	NNE	0.41	0.4
	45	NE	0.39	0.4
	68	ENE	0.47	0.3
	90	E	0.4	0.4
	113	ESE	0.29	0.32
	135	SE	0.38	0.32
	158	SSE	0.81	0.65
	180	S	1.53	1.2
	203	SSW	1.45	1.72
	225	SW	1.21	2.2

	248	WSW	1.46	2.08
	270	W	1.29	1.5
	293	WNW	0.57	1.36
	315	NW	0.65	1
	338	NNW	0.74	0.93

Polar plots for significant wave heights are presented in Figure 5.

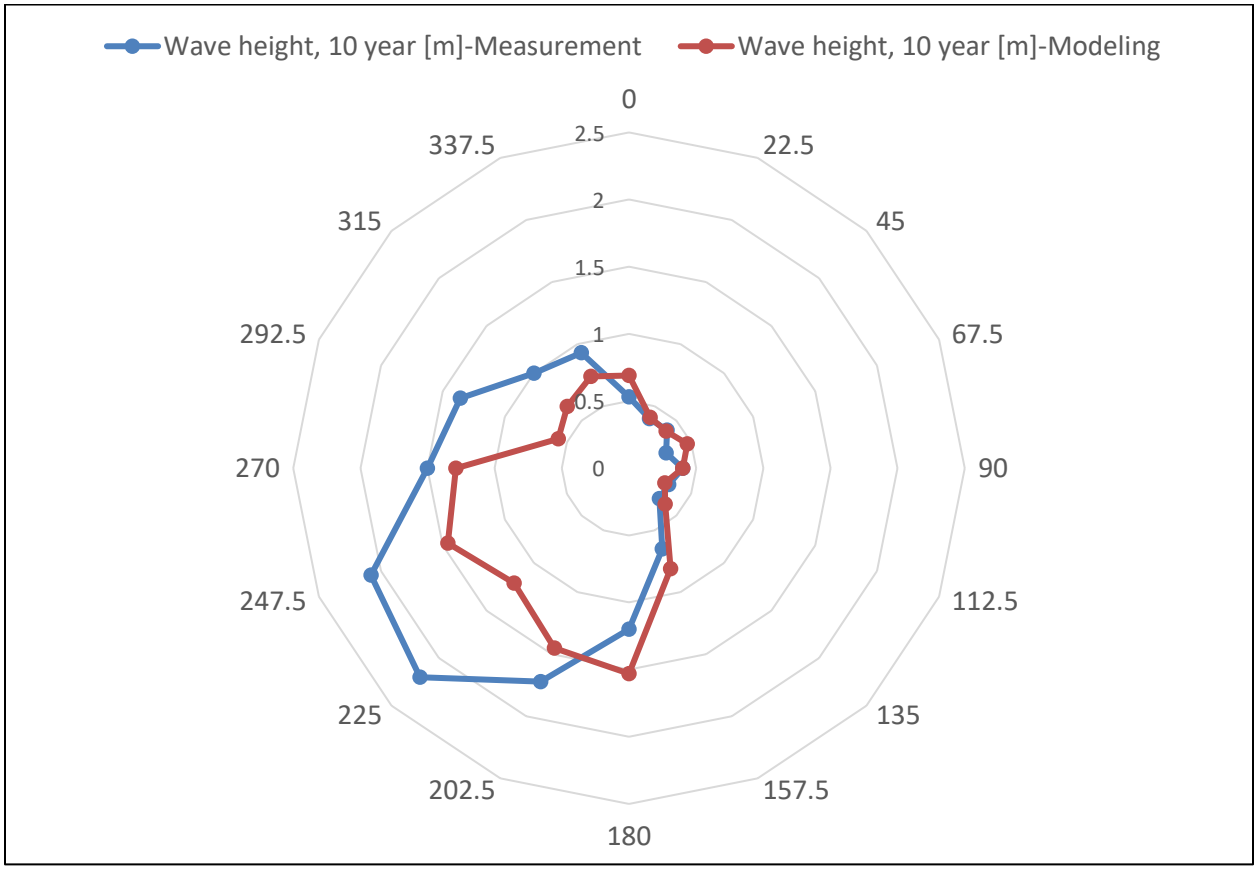

Figure 5 Significant wave heights at 10- year return period and direction [from]- Lobster Bay

6.3 Wave conditions for Jordan Bay

The scatter plot of significant wave heights vs wave directions for the XEOS buoy and ML buoy at Jordan Bay are presented in Figure 5 and Figure 6. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 3. These represent the extreme wave conditions at this coordinate: 43° 41.902'N, 65° 11.652'W.

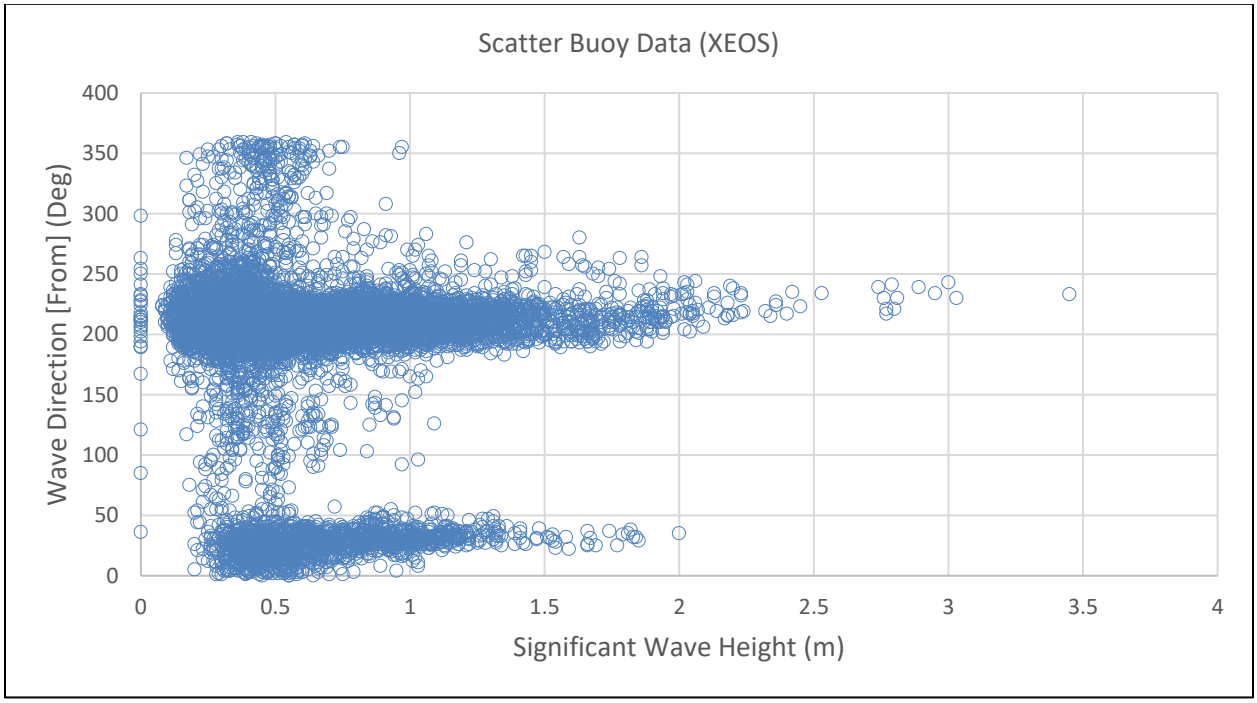

Figure 6 Significant wave heights vs wave direction [from]- XEOS buoy – Jordan Bay

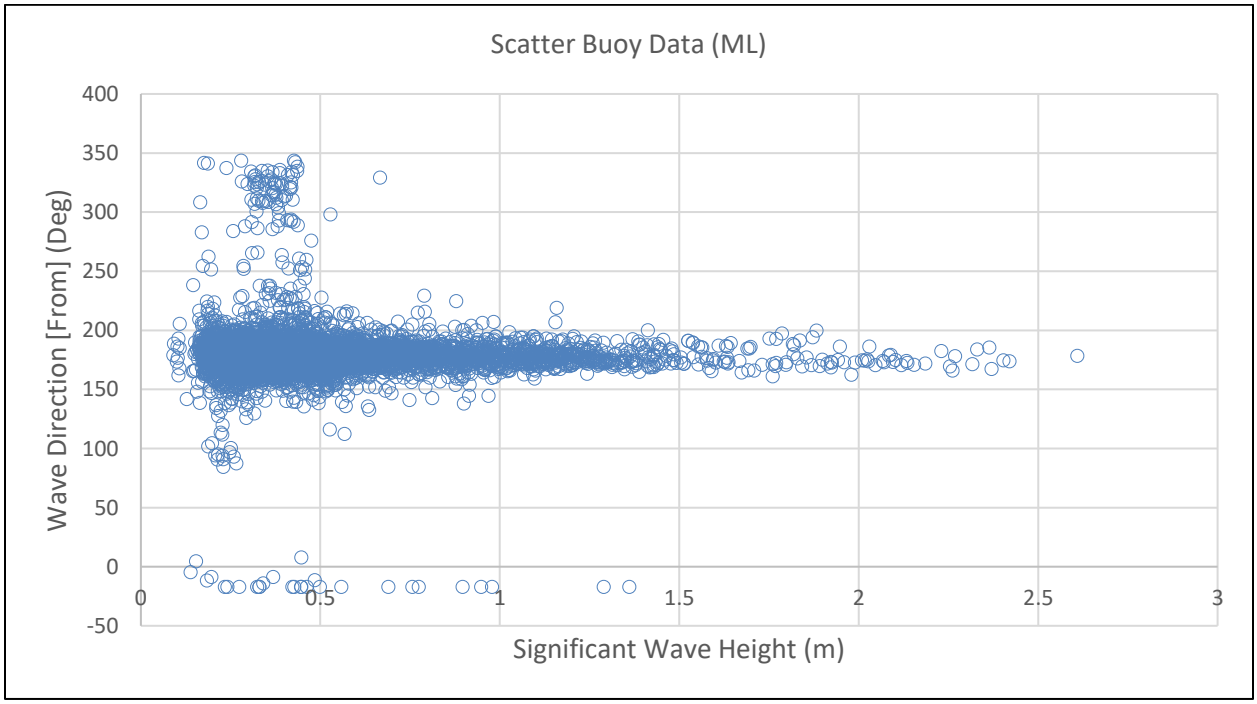

Figure 7 Significant wave heights vs wave direction [from]- ML buoy – Jordan Bay

Table 3 Significant wave heights at 10- year return period and direction [from]- Jordan Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements XEOS	Buoy Measurements ML
			Hs (m)	Hs (m)	Hs (m)
10yr wave	*0*	N	0.73	0.8	0.44
	23	NNE	0.39	0.6	0.45
	45	NE	0.44	0.45	0
	68	ENE	0.51	0.5	0
	90	E	0.48	0.47	0.27
	113	ESE	0.51	0.51	0.57
	135	SE	0.6	0.86	0.55
	158	SSE	1.74	1.71	0.76
	180	S	3.98	3.65	2.55
	203	SSW	2.6	3.3	2.37
	225	SW	0.78	0.9	1.16
	248	WSW	0.66	0.95	0.79
	270	W	0.57	0.7	0.57
	293	WNW	0.48	0.65	0.48
	315	NW	0.74	0.91	0.53
	338	NNW	0.74	1	0.67

Polar plots for significant wave heights are presented in Figure 8.

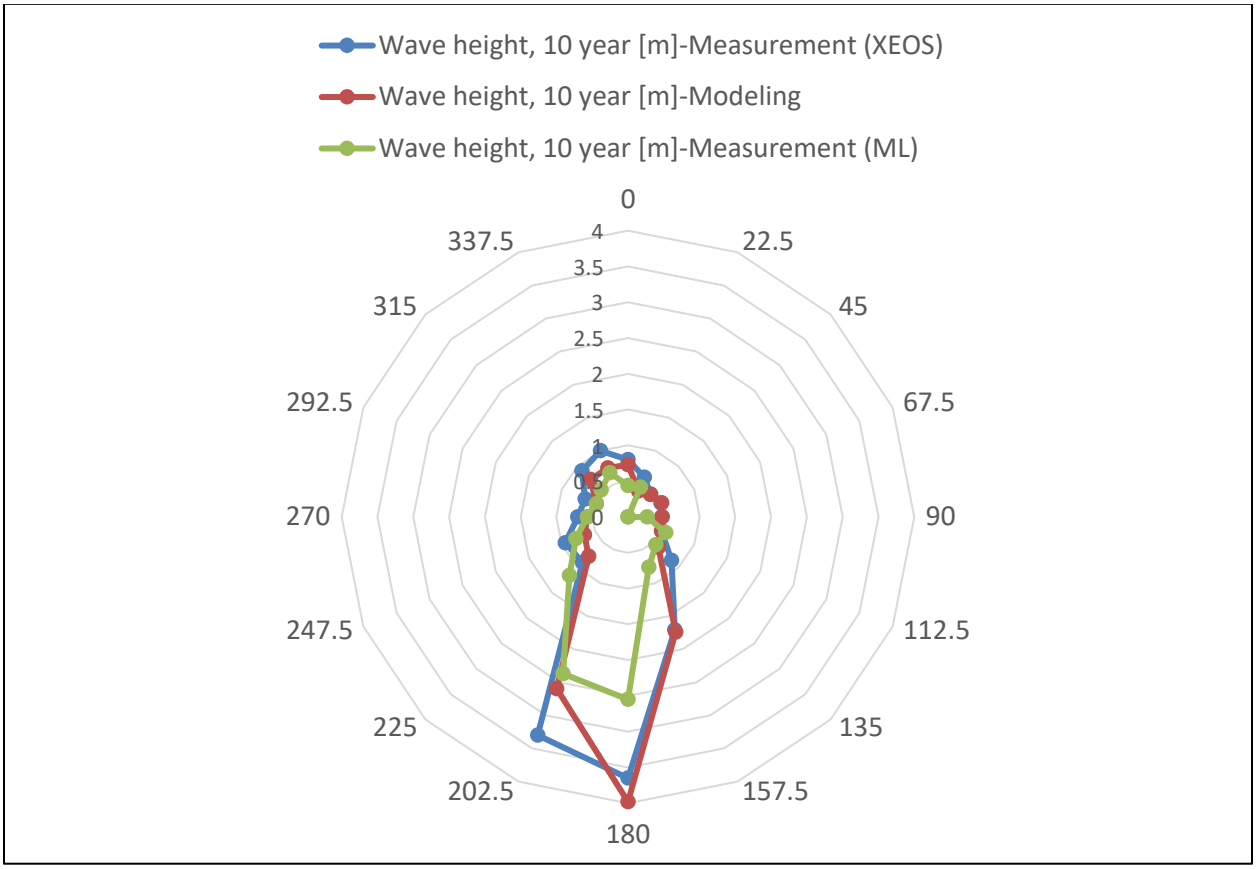

Figure 8 Significant wave heights at 10- year return period and direction [from]- Jordan Bay

6.4 Wave conditions for Liverpool Bay

The scatter plot of significant wave heights vs wave directions for the ML buoy at Liverpool Bay is presented in Figure 9. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 4. These represent the extreme wave conditions at this coordinate: 44° 2.284'N, 64° 38.332'W.

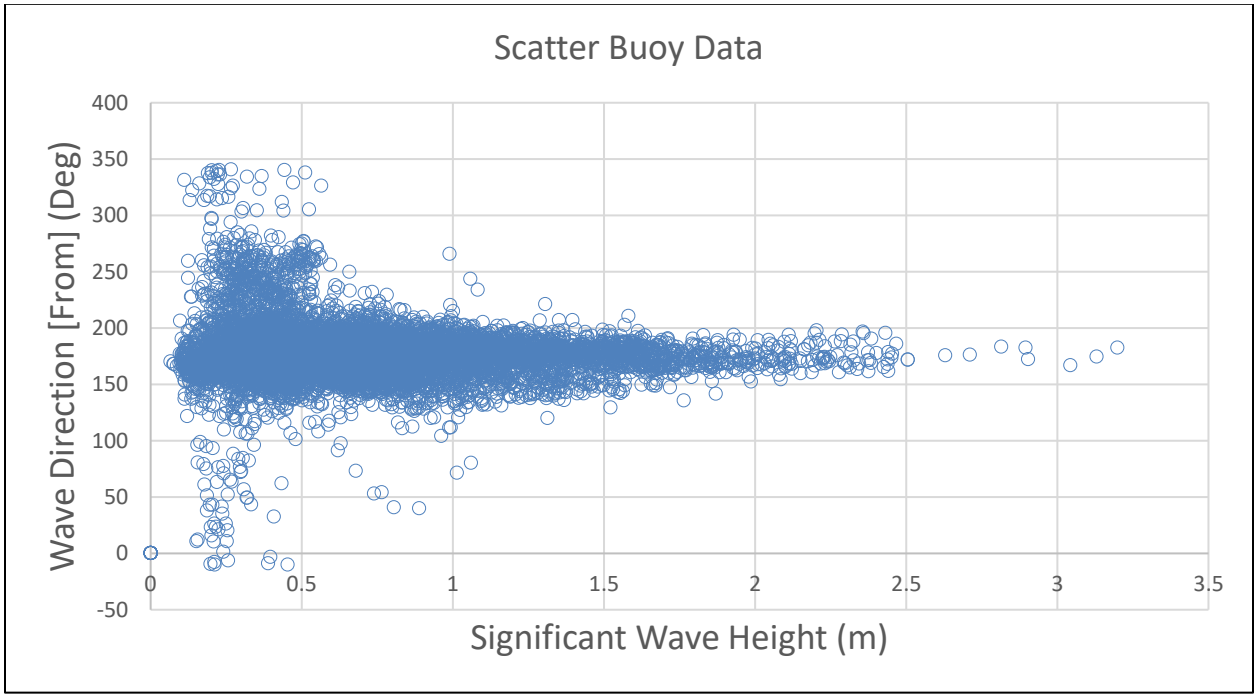

Figure 9 Significant wave heights vs wave direction [from]- ML buoy – Liverpool Bay

Table 4 Significant wave heights at 10- year return period and direction [from]- Liverpool Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements
			Hs (m)	Hs (m)
10yr wave	*0*	N	0.51	0..39
	23	NNE	0.41	0.25
	45	NE	0.4	0.49
	68	ENE	0.28	0.48
	90	E	0.25	0.48
	113	ESE	0.35	0.59
	135	SE	1.29	1.21
	158	SSE	1.82	2
	180	S	3.17	2.9
	203	SSW	3.9	3.38
	225	SW	0.61	1.18

	248	WSW	0.7	1.14
	270	W	0.76	0.84
	293	WNW	0.34	0.63
	315	NW	0.39	0.32
	338	NNW	0.43	0.5

Polar plots for significant wave heights are presented in Figure 10.

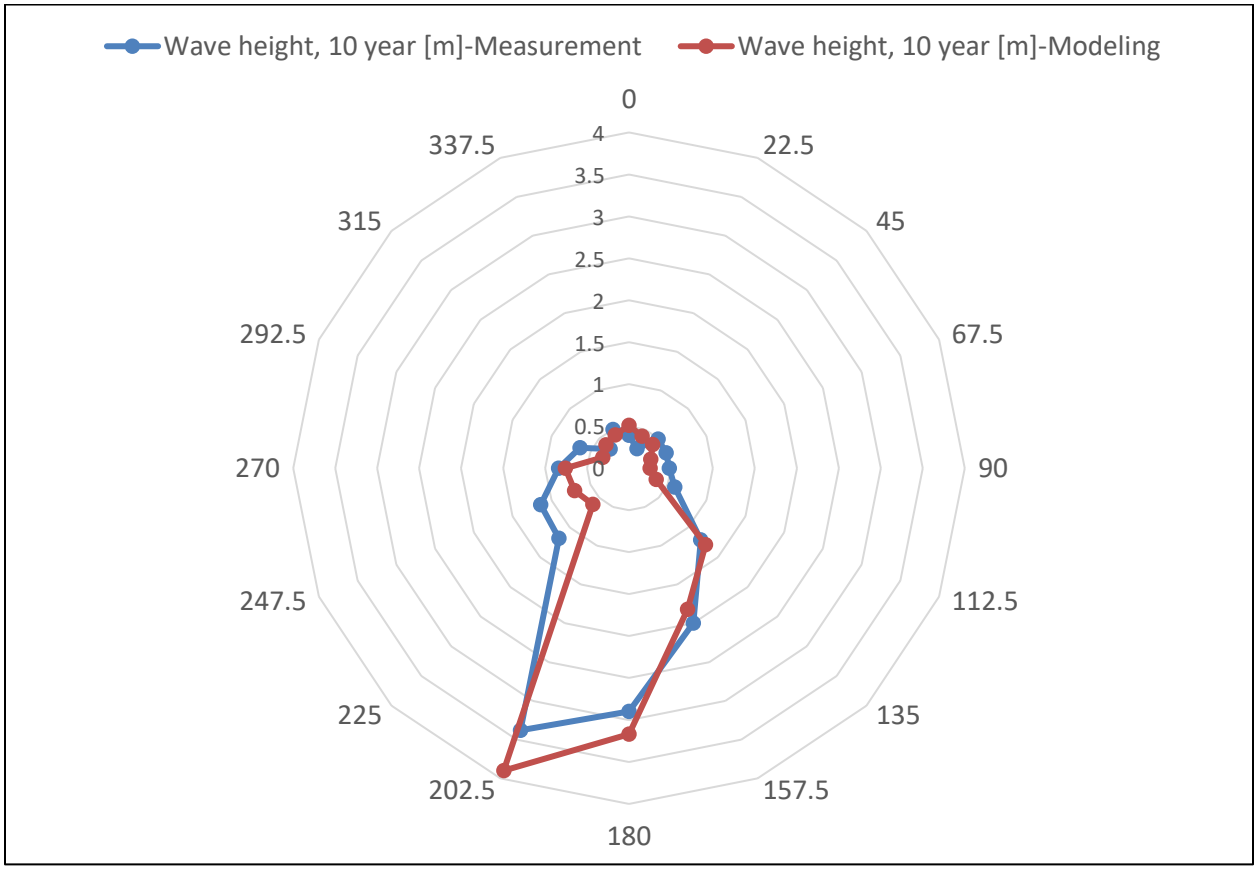

Figure 10 Significant wave heights at 10- year return period and direction [from]- Liverpool Bay

6.5 Wave conditions for St. Margarets Bay

The scatter plot of significant wave heights vs wave directions for the ML buoy at St. Margarets Bay is presented in Figure 11. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 5. These represent the extreme wave conditions at this coordinate: 44° 31.429'N, 63° 59.952'W.

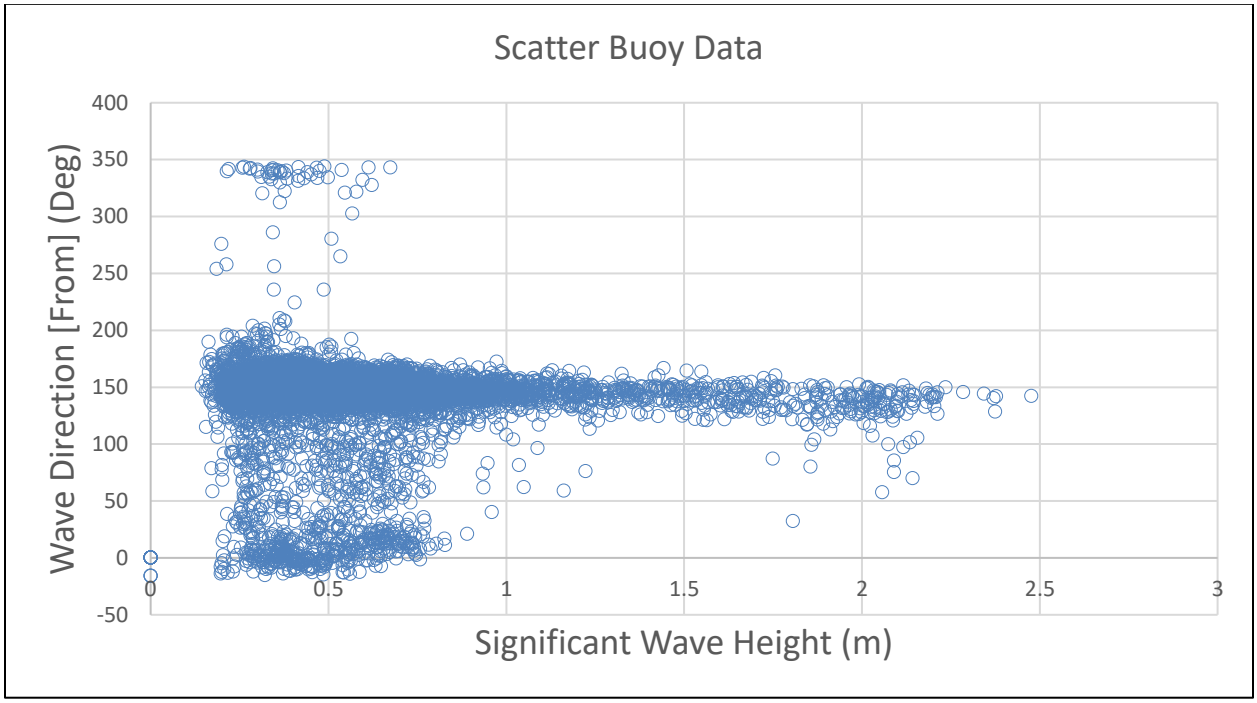

Figure 11 Significant wave heights vs wave direction [from]- ML buoy – St. Margarets Bay

Table 5 Significant wave heights at 10- year return period and direction [from]- St. Margarets Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements
			Hs (m)	Hs (m)
10yr wave	*0*	N	1.44	1.54
	23	NNE	1.1	1.17
	45	NE	1	1.43
	68	ENE	1	1.25
	90	E	0.85	1.45
	113	ESE	1.31	1.3
	135	SE	2.04	2.35
	158	SSE	2.29	2.54
	180	S	1.67	1.53
	203	SSW	0.43	0.55
	225	SW	0.3	0.4

	248	WSW	0.32	0.4
	270	W	0.36	0.33
	293	WNW	0.37	0.4
	315	NW	0.62	0.55
	338	NNW	1.13	0.65

Polar plots for significant wave heights are presented in Figure 12.

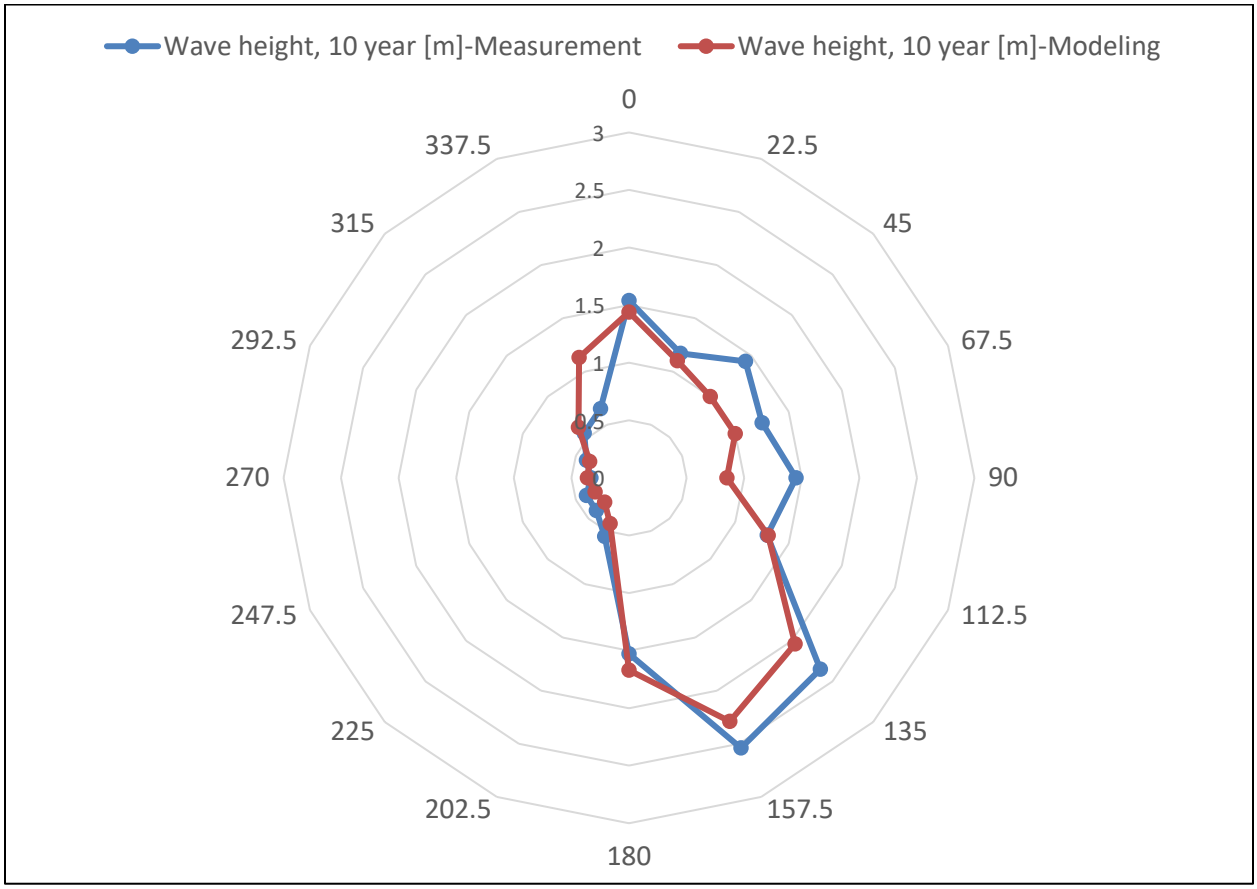

Figure 12 Significant wave heights at 10- year return period and direction [from]- St. Margarets Bay

6.6 Wave conditions for Chedabucto Bay

The scatter plot of significant wave heights vs wave directions for the ML buoy at Chedabucto Bay is presented in Figure 13. The 10- year return period wave results from the STWave model and buoy measurements are summarized in Table 6. These represent the extreme wave conditions at this coordinate: 45° 23.257'N, 61° 8.084'W.

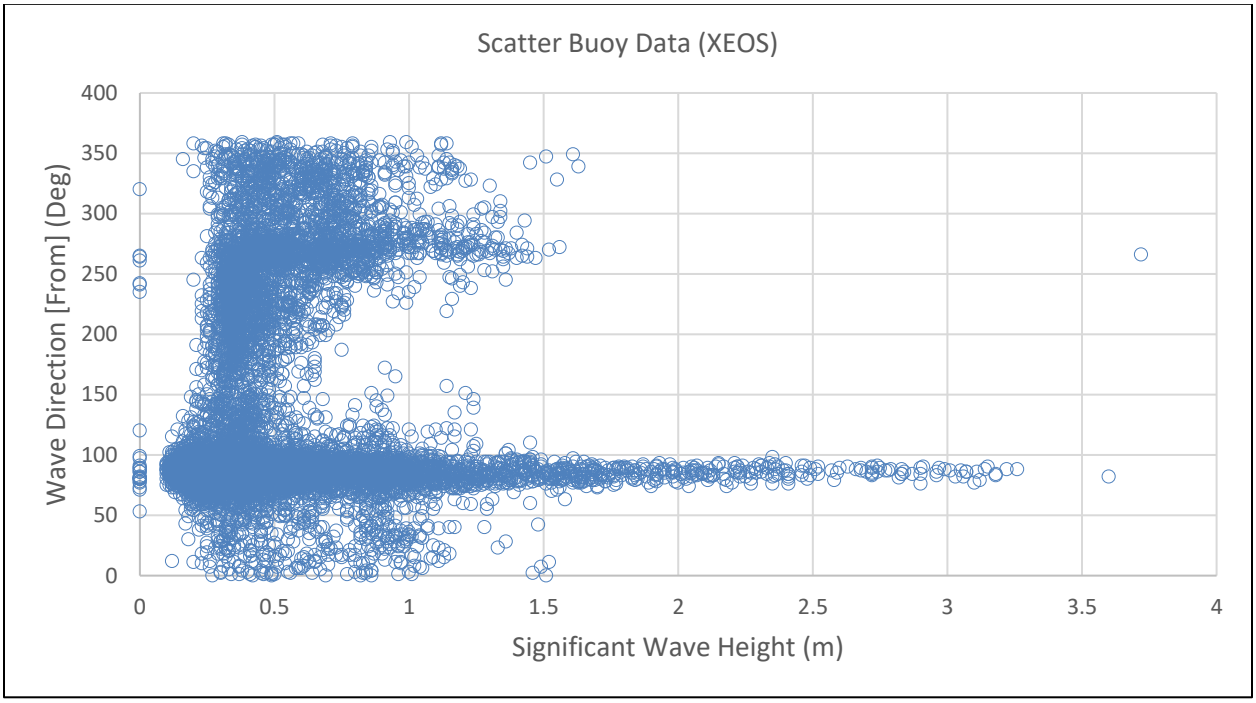

Figure 13 Significant wave heights vs wave direction [from]- XEOS buoy – Chedabucto Bay

Table 6 Significant wave heights at 10- year return period and direction [from]- Chedabucto Bay

Wave conditions	Direction [from] [°]		Wave Modeling	Buoy Measurements
			Hs (m)	Hs (m)
10yr wave	*0*	N	1.8	1.6
	23	NNE	1.22	1.52
	45	NE	1.65	1.33
	68	ENE	3.18	1.33
	90	E	4.46	3.55
	113	ESE	3.2	2.98
	135	SE	1.02	1.49
	158	SSE	1	1.14
	180	S	0.89	0.99
	203	SSW	0.62	0.99
	225	SW	0.81	1.02

	248	WSW	1.66	1.6
	270	W	2.1	2.4
	293	WNW	1.38	1.76
	315	NW	1.63	1.63
	338	NNW	1.72	1.1

Polar plots for significant wave heights are presented in Figure 14.

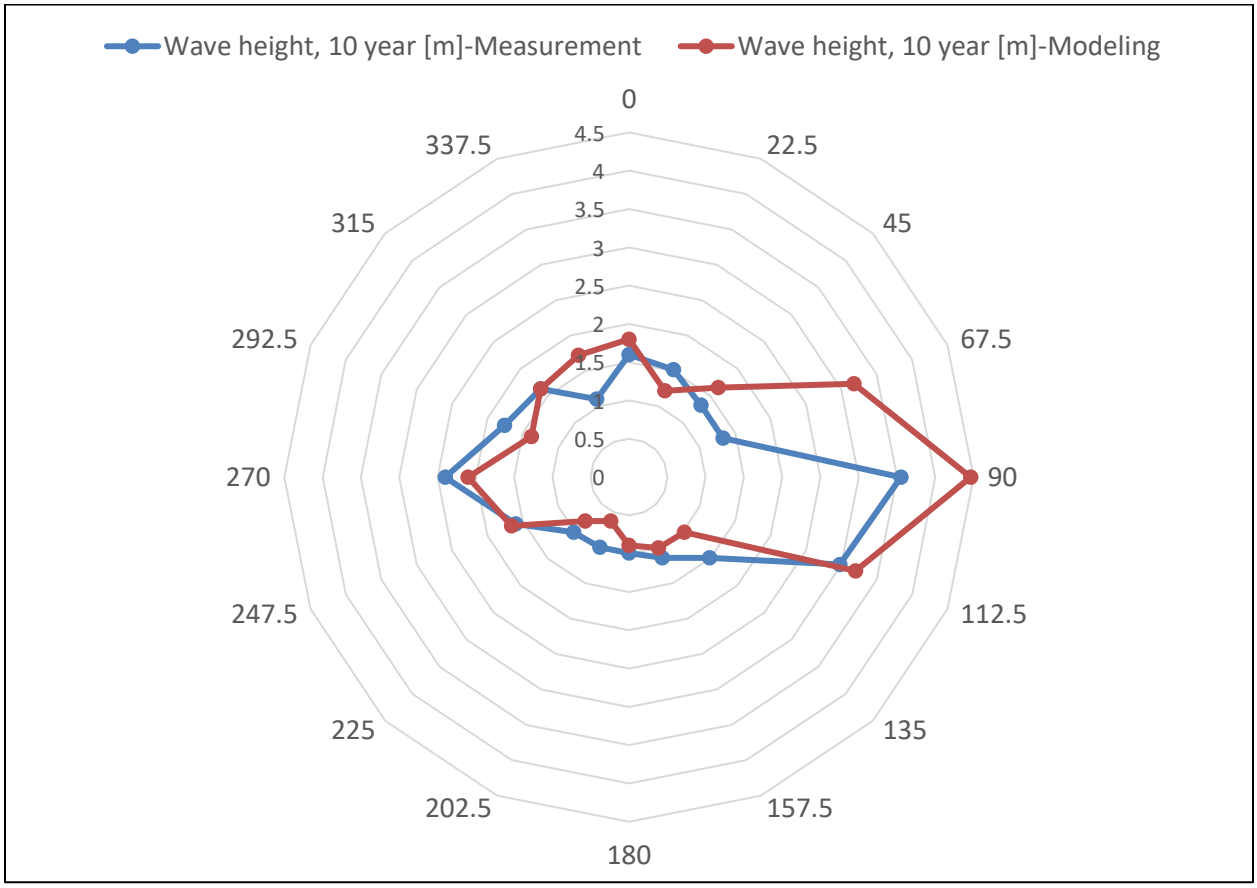

Figure 14 Significant wave heights at 10- year return period and direction [from]- Chedabucto Bay

7 Conclusions

This report presents the results of 7 wave measurements using MarineLabs (ML) and XEOS buoys to validate the numerical wave modeling (STWave modeling) at 6 locations in Nova Scotia, Canada. To validate the numerical model against wave measurements, each buoy data has been post-processed to determine 10- year return period significant wave heights for 16 headings. The following results were found for each location:

- St. Mary's Bay: a good correlation observed between wave modeling and XEOS buoy data. Wave modeling presented larger waves than buoy measurements from SSW (203 deg) which is the dominant wave direction for this region. However, longer wave measurements will provide more consistent agreement between modeling and buoy data.

- Lobster Bay: an unexpected mismatch observed between wave modeling and ML buoy data. Buoy data presented larger waves than wave modeling from SSW (203 deg) to WSW (248 deg). For this site, it is recommended to deploy a XEOS buoy as well to have a better wave modeling validation.

- Jordan Bay: a good correlation observed between wave modeling and XEOS buoy data. A longer wave measurement will provide more consistent agreement between modeling and XEOS buoy data. However, ML buoy data shows lower peak values for the dominant wave directions. These results are likely due to the shorter period of wave measurements in comparison to the XEOS buoy.

- Liverpool Bay: a good correlation observed between wave modeling and ML buoy data. A longer wave measurement will provide more consistent agreement between modeling and ML buoy data.

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- Chedabucto Bay: a good correlation observed between wave modeling and XEOS buoy data. Wave modeling presented larger waves than buoy measurements from East (90 deg) and ENE (63 deg) which are the dominant wave direction for this region. However, longer wave measurements will provide more consistent agreement between wave modeling and buoy data.

In general, acceptable agreements have been observed between the wave modeling and wave measurements except for the Lobster Bay.