Pacific Northwest
NATIONAL LABORATORY

Modeling Analysis of Extreme Waves along the US Coasts in the Pacific Ocean

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Seattle, WA USA

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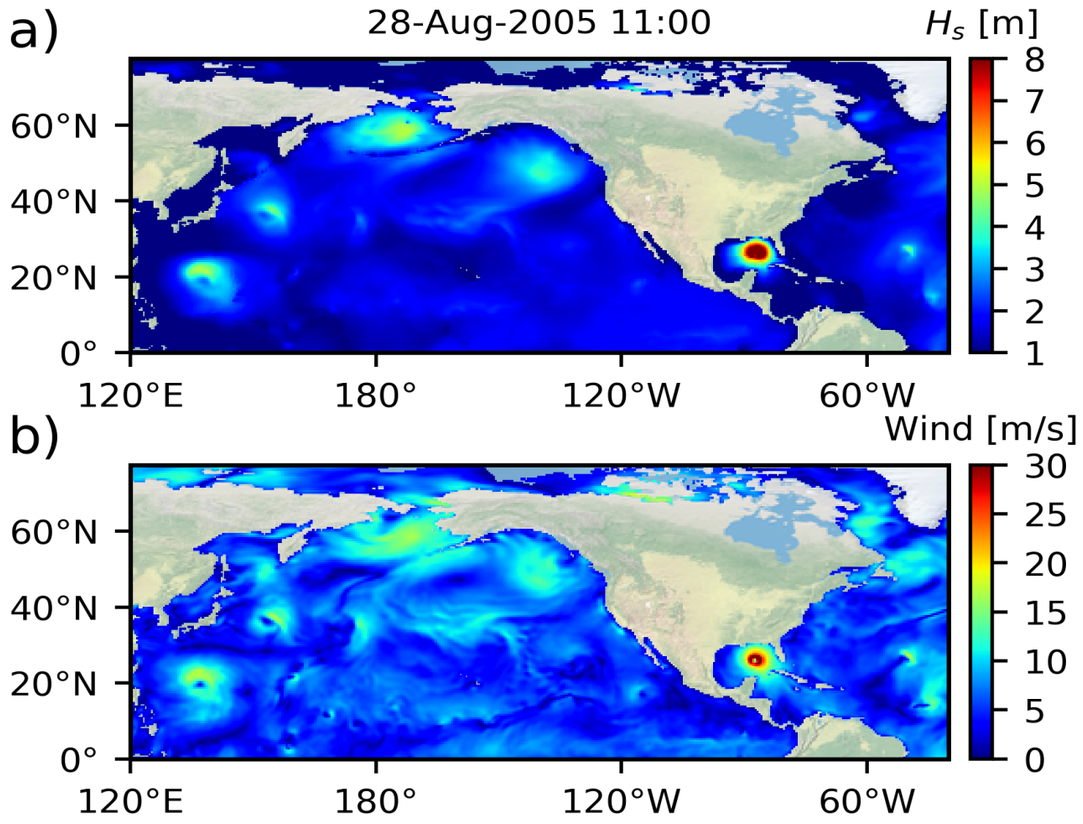
Need of regional high-resolution wave hindcasts

- Previous resource assessment
  - Coarse resolution and short period (EPRI, 2011)
- Follow IEC standards
- US Exclusive Economic Zone (EEZ)
  - Alaska
  - West Coast
  - Hawaii and Pacific Islands
  - East Coast
  - Gulf of Mexico
  - Puerto Rico and U.S. Virgin Islands

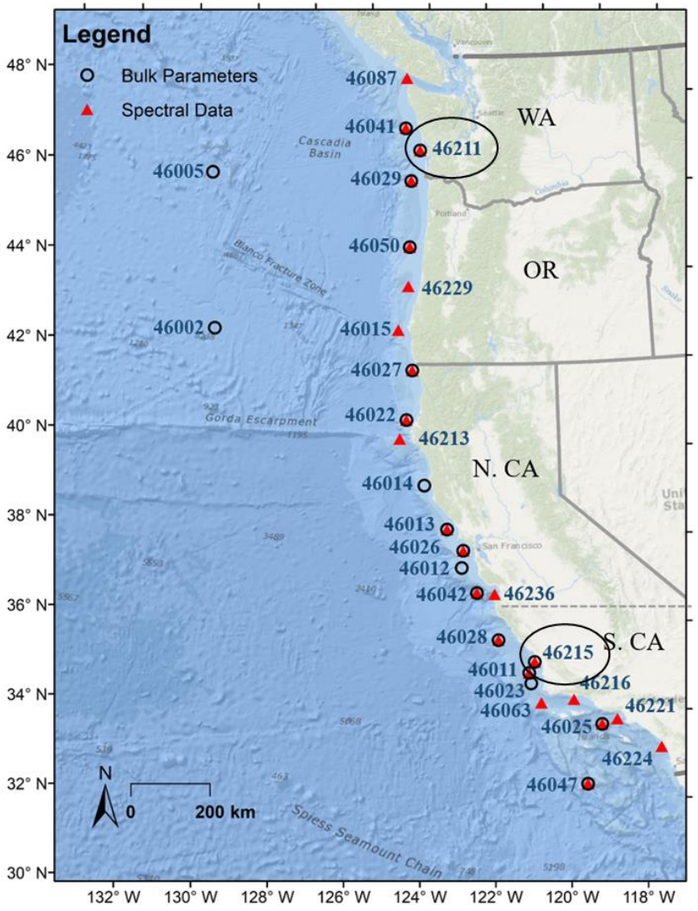
Multi-resolution modeling approach

- Global-regional nested WW3 models
- Unstructured-grid SWAN model
  - High-resolution nearshore (~300 m)
  - long-term hindcast (32-yr, 1979-2010)
- Extensive model validation with spectral data
- CFSR wind and sea ice inputs

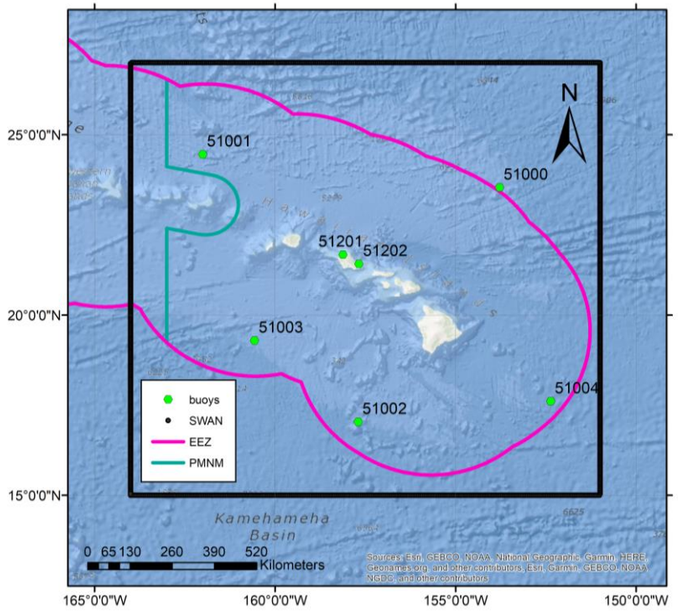


Regional model domains and buoys stations

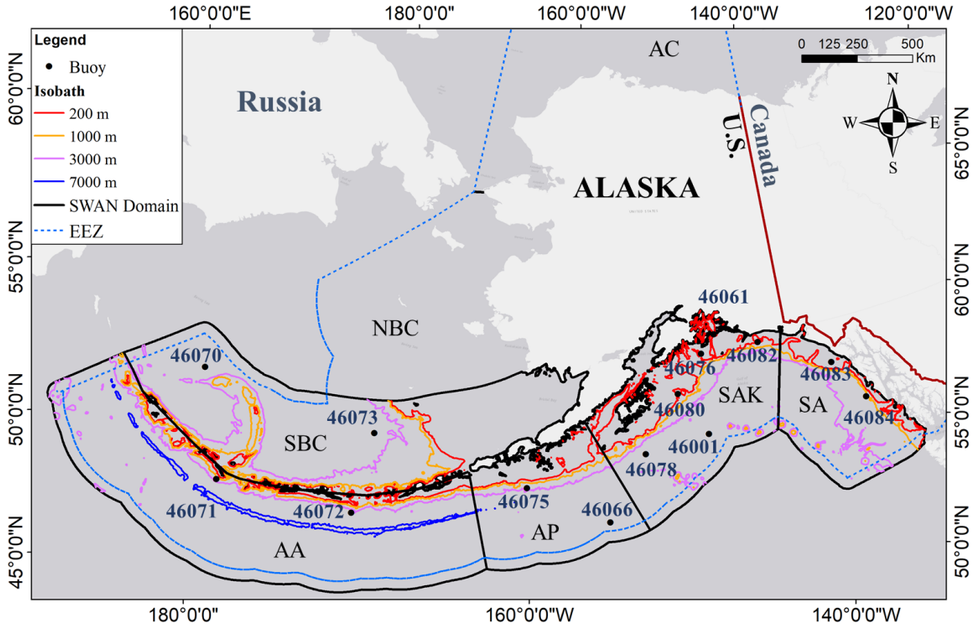
West Coast



Hawaii

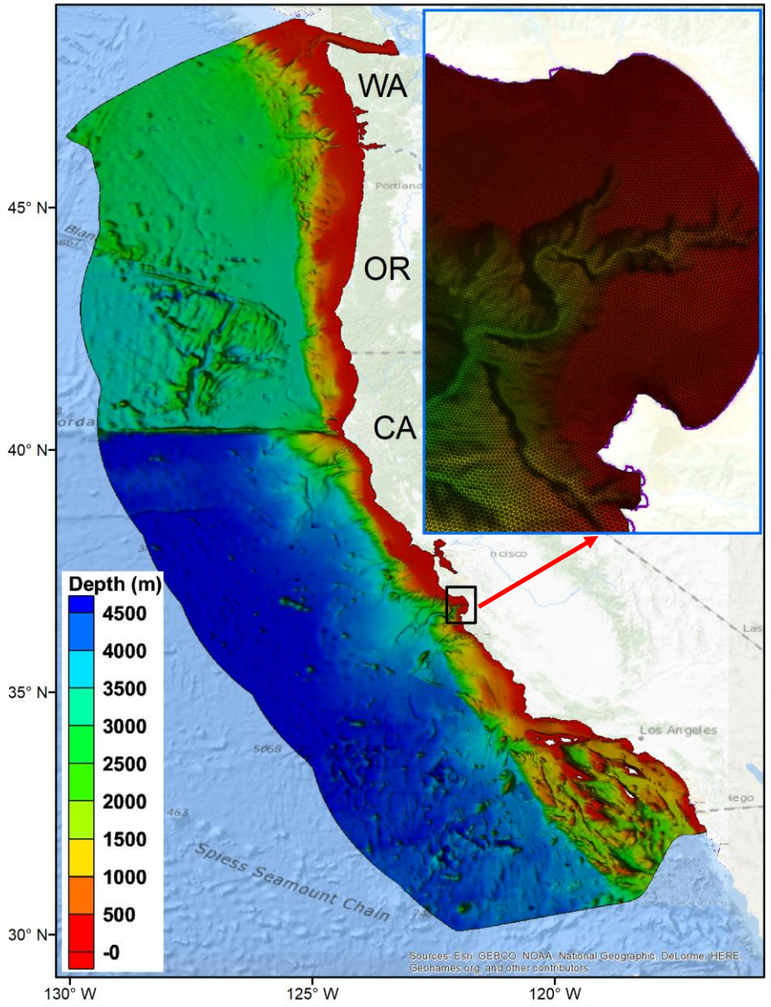


Alaska



High-resolution unstructured-grids

U.S. West Coast



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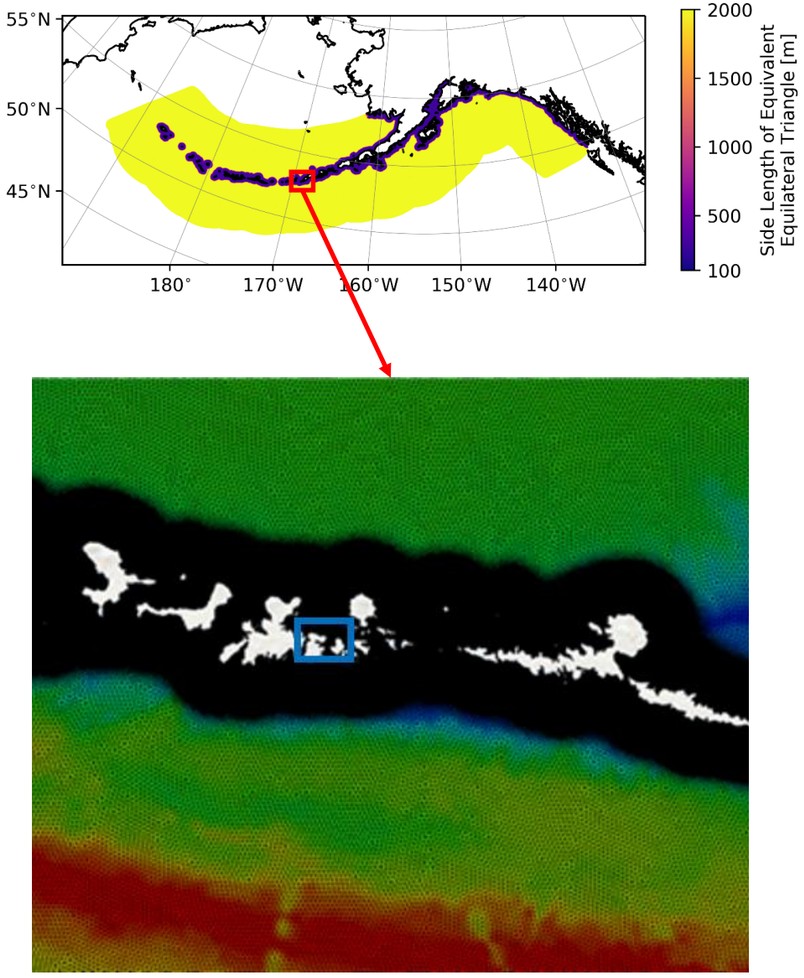

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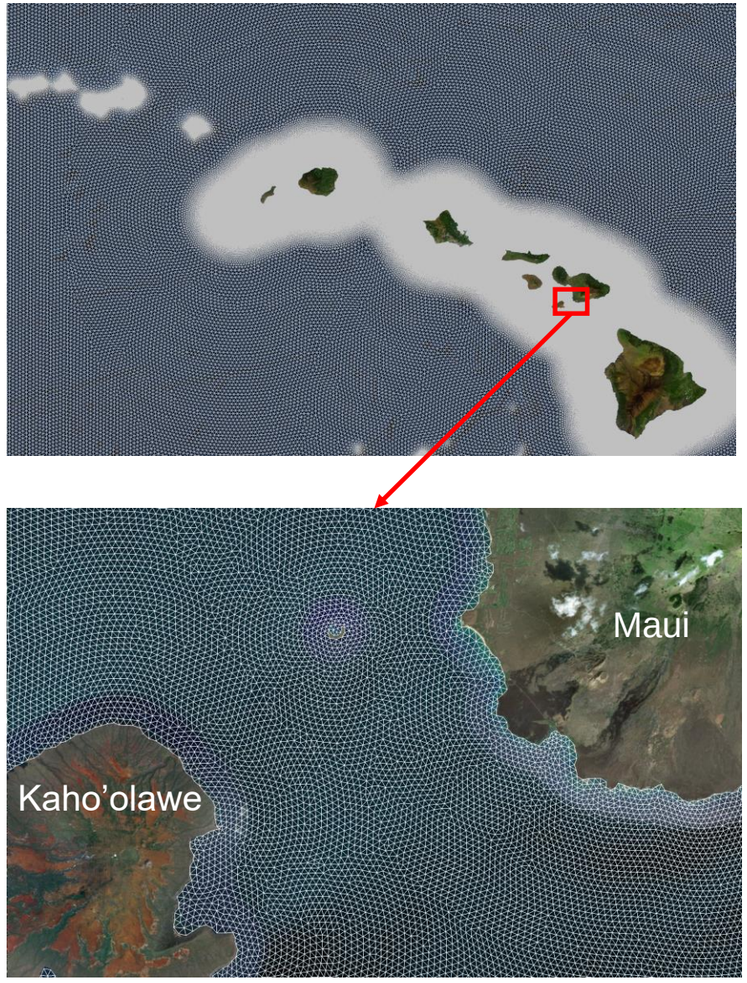
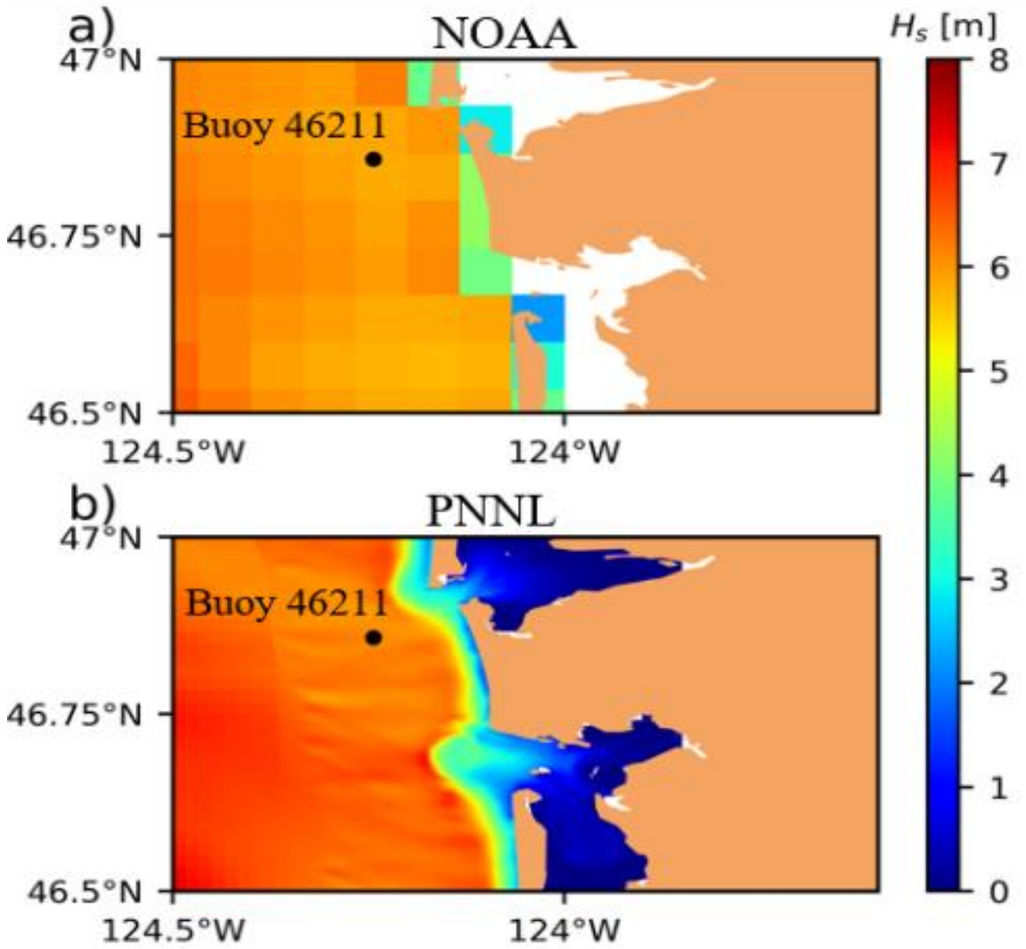


Coastlines and nearshore bathymetry

West Coast



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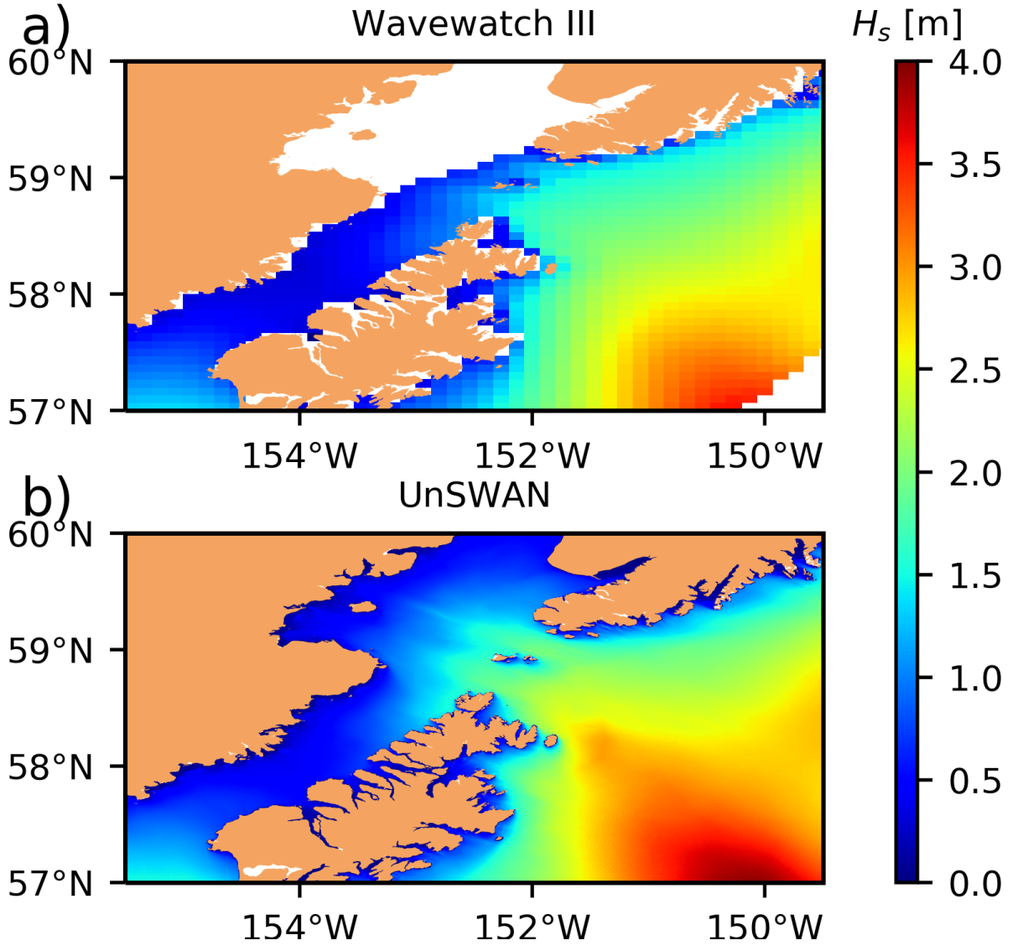
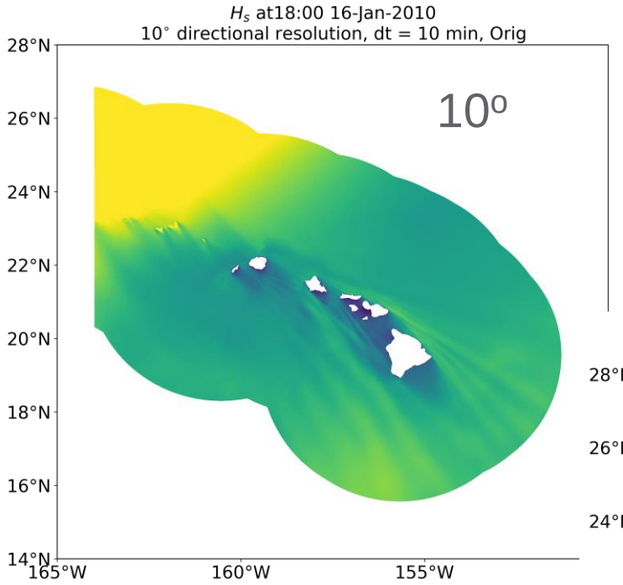
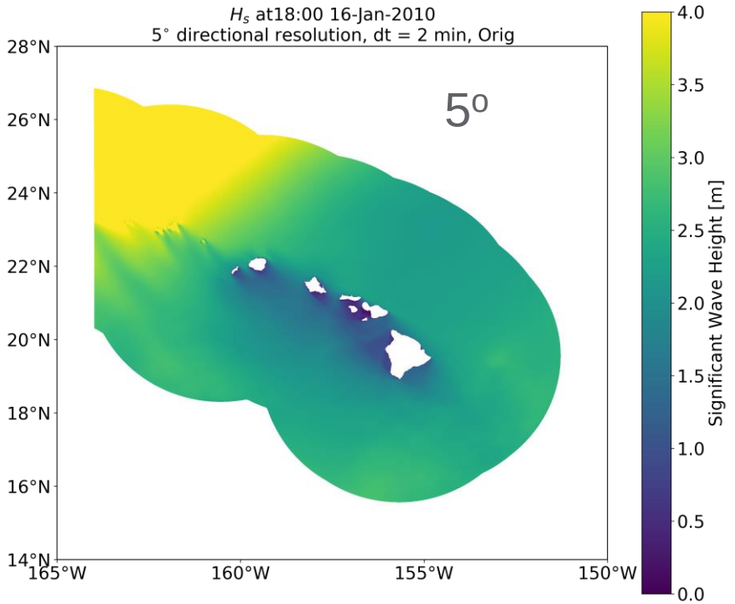


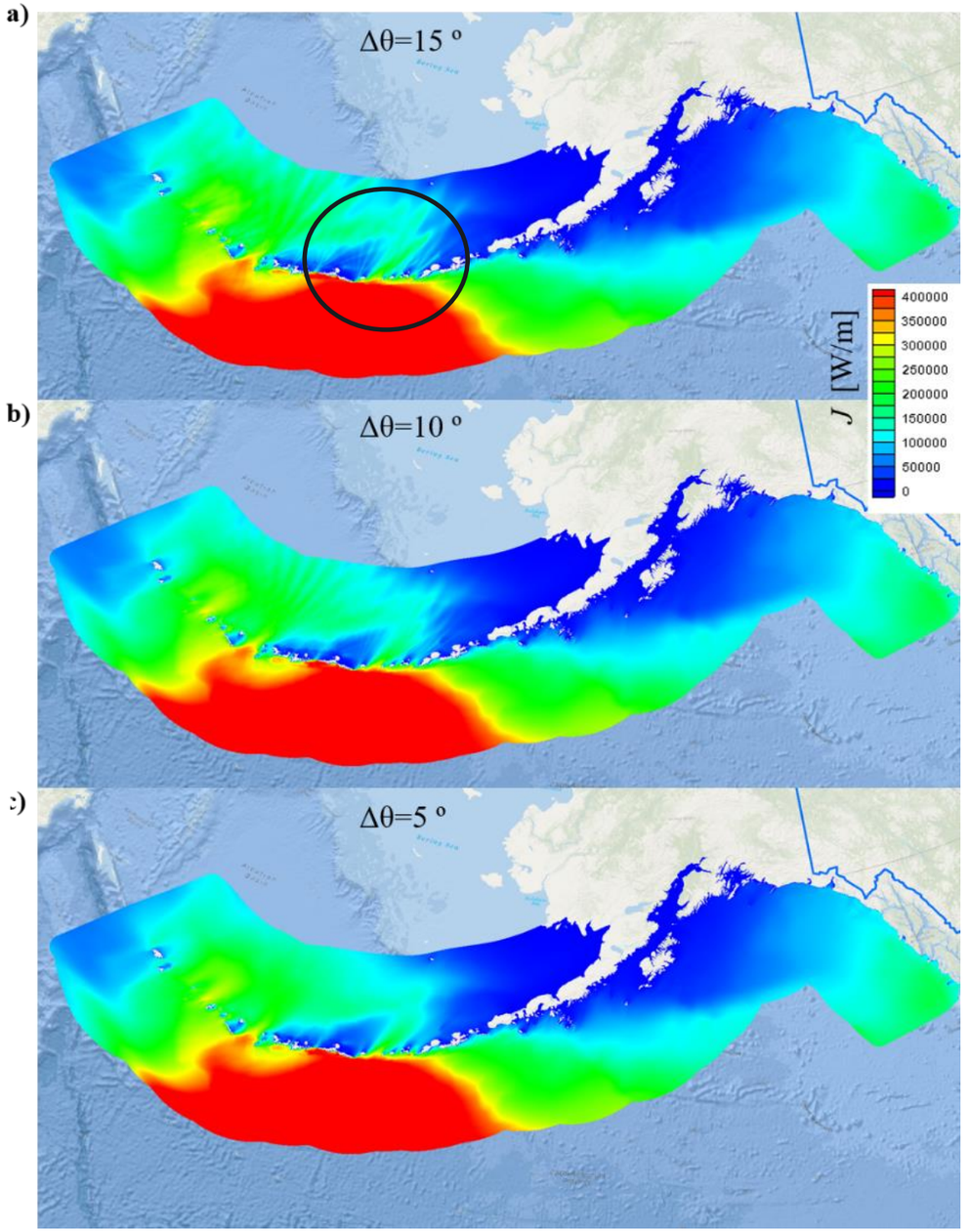
Garden Sprinkler Effect around Islands

- Increasing directional resolution to minimize Garden Sprinkler Effect (GSE)

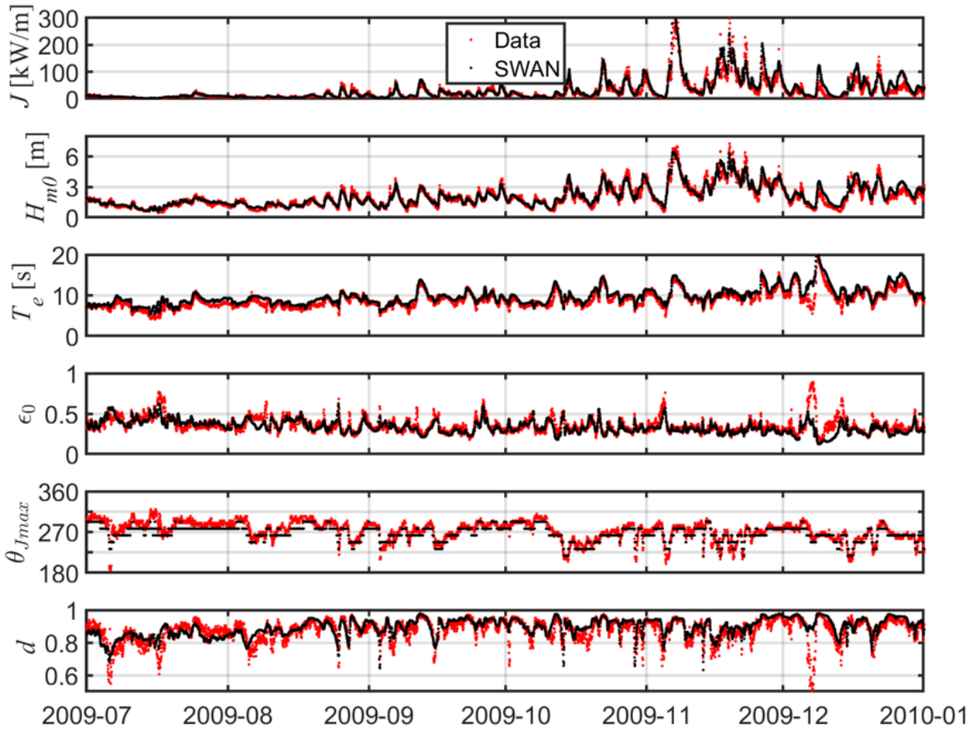


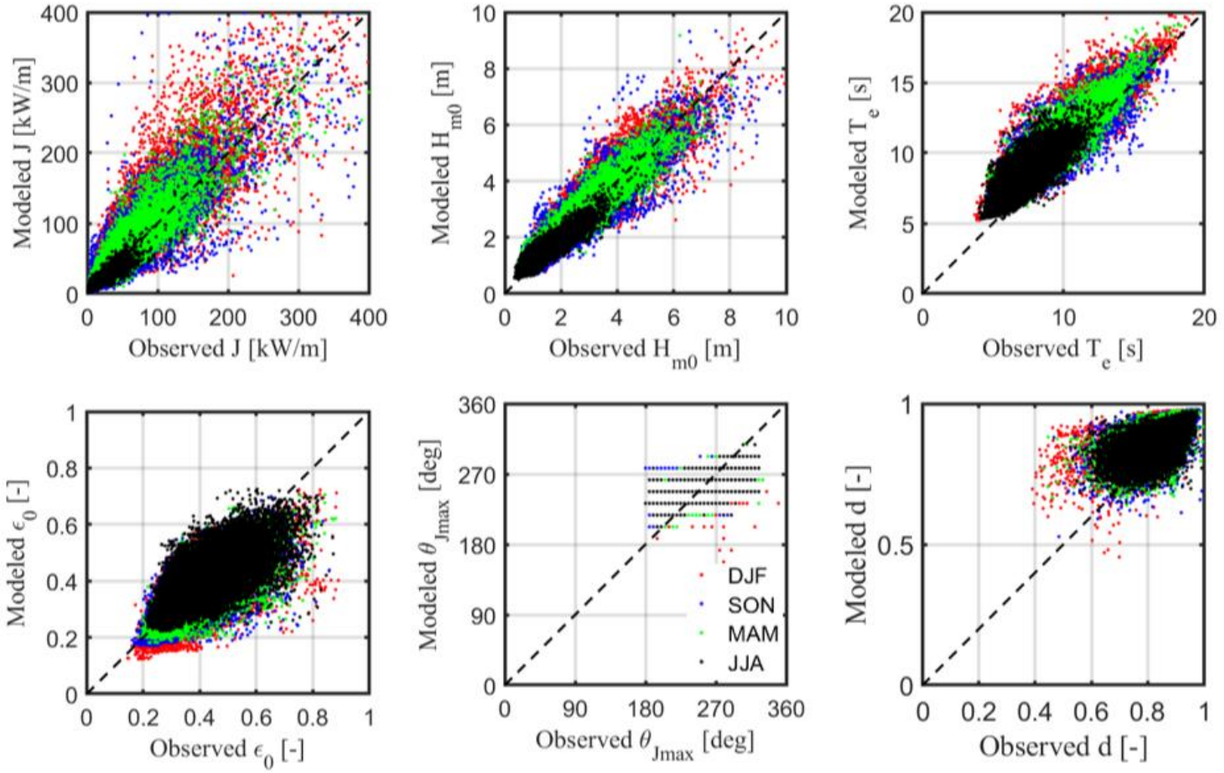


Aleutian Islands, AK



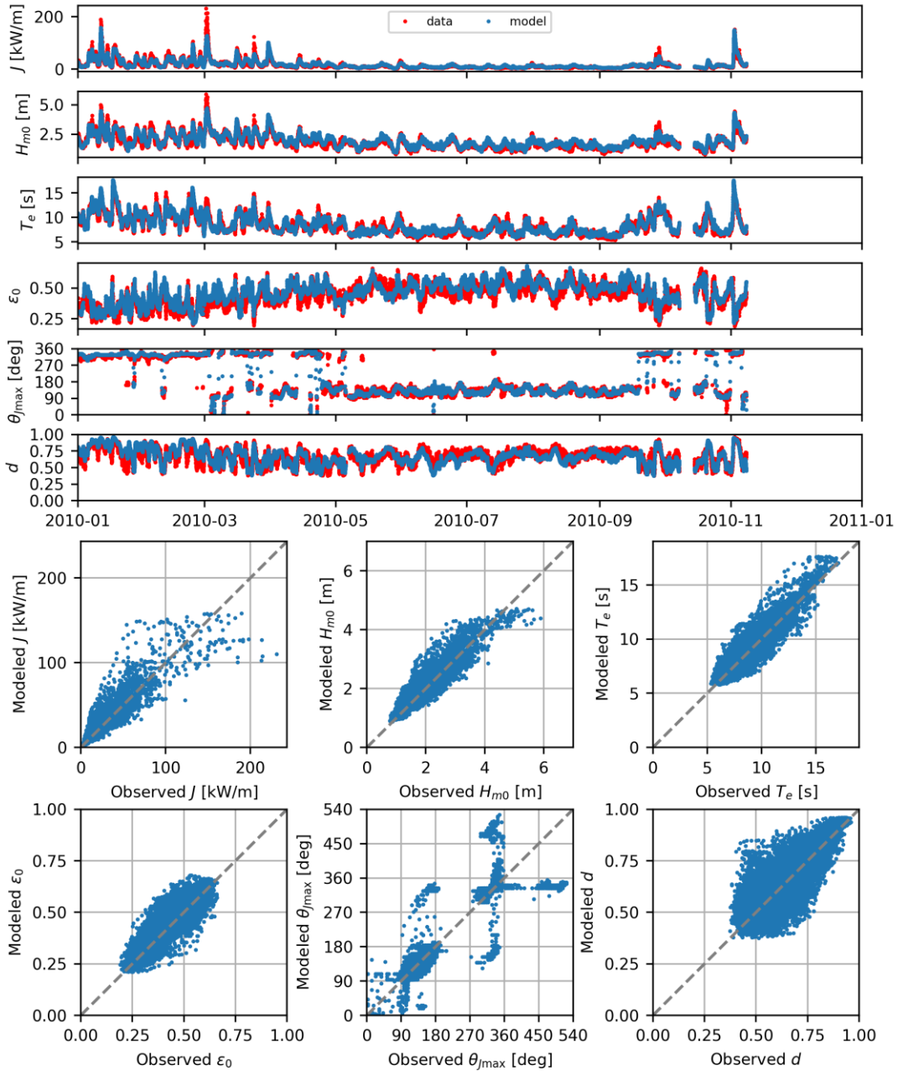
Model validation – 6 IEC resource parameters at buoy 46211 (40m) in the West Coast



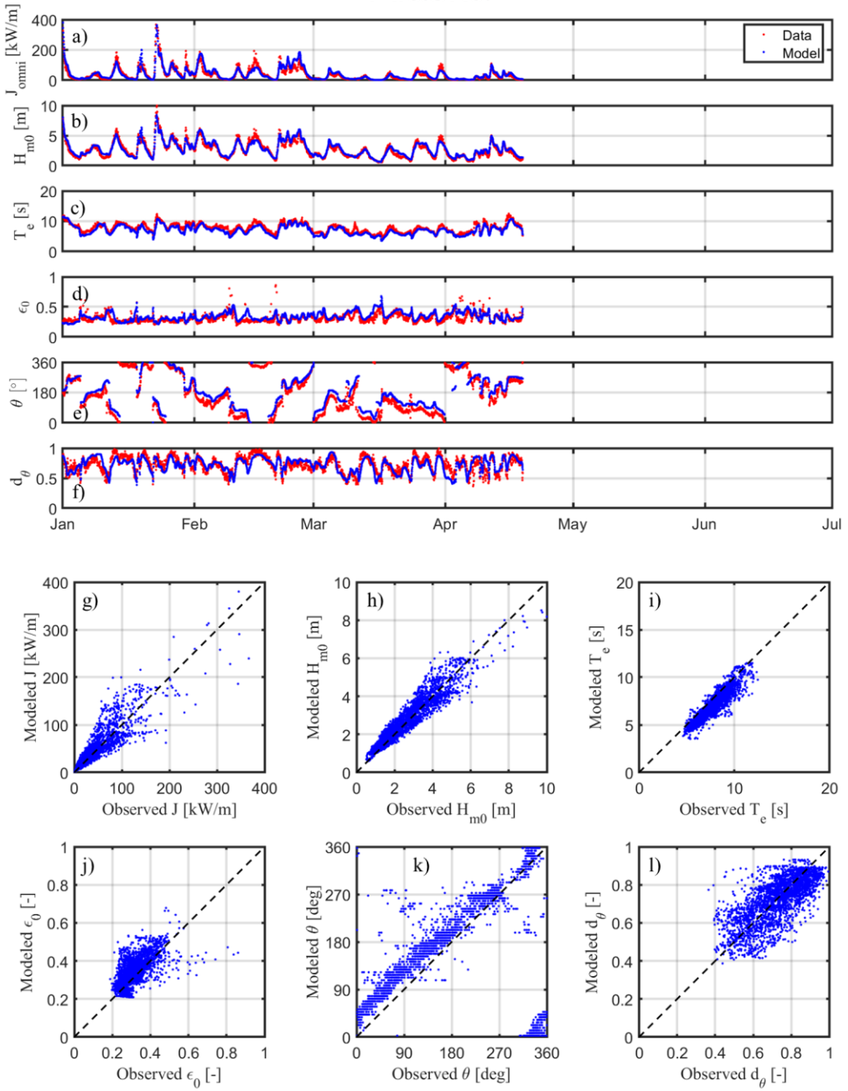


Model Validation in Hawaii and Alaska Regions

Hawaii

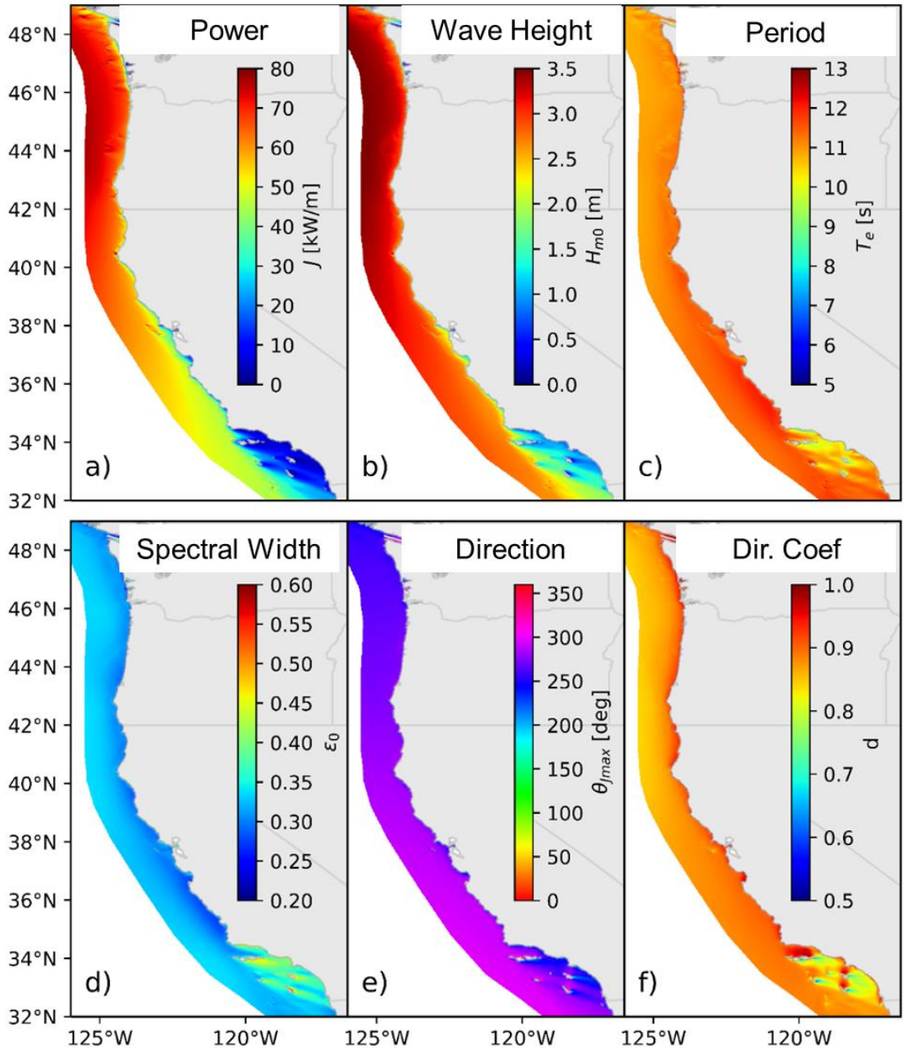


Alaska

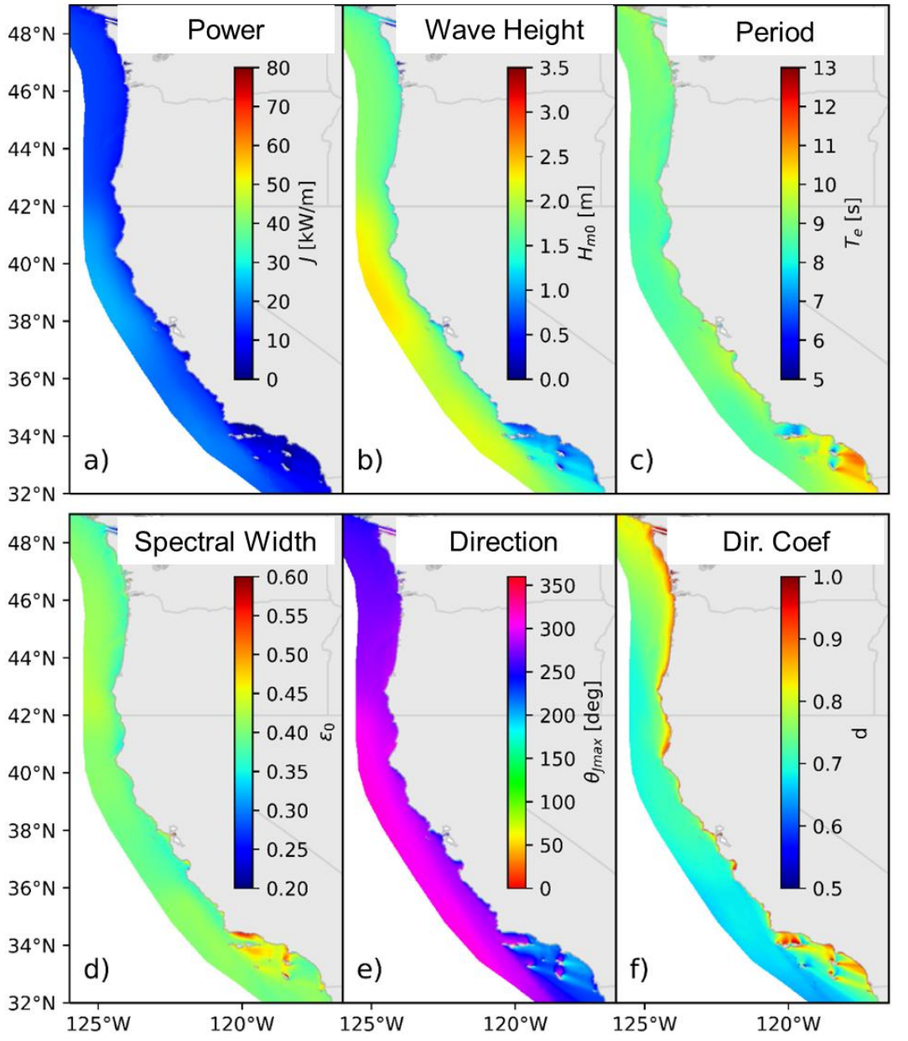


6 IEC resource parameters – West Coast

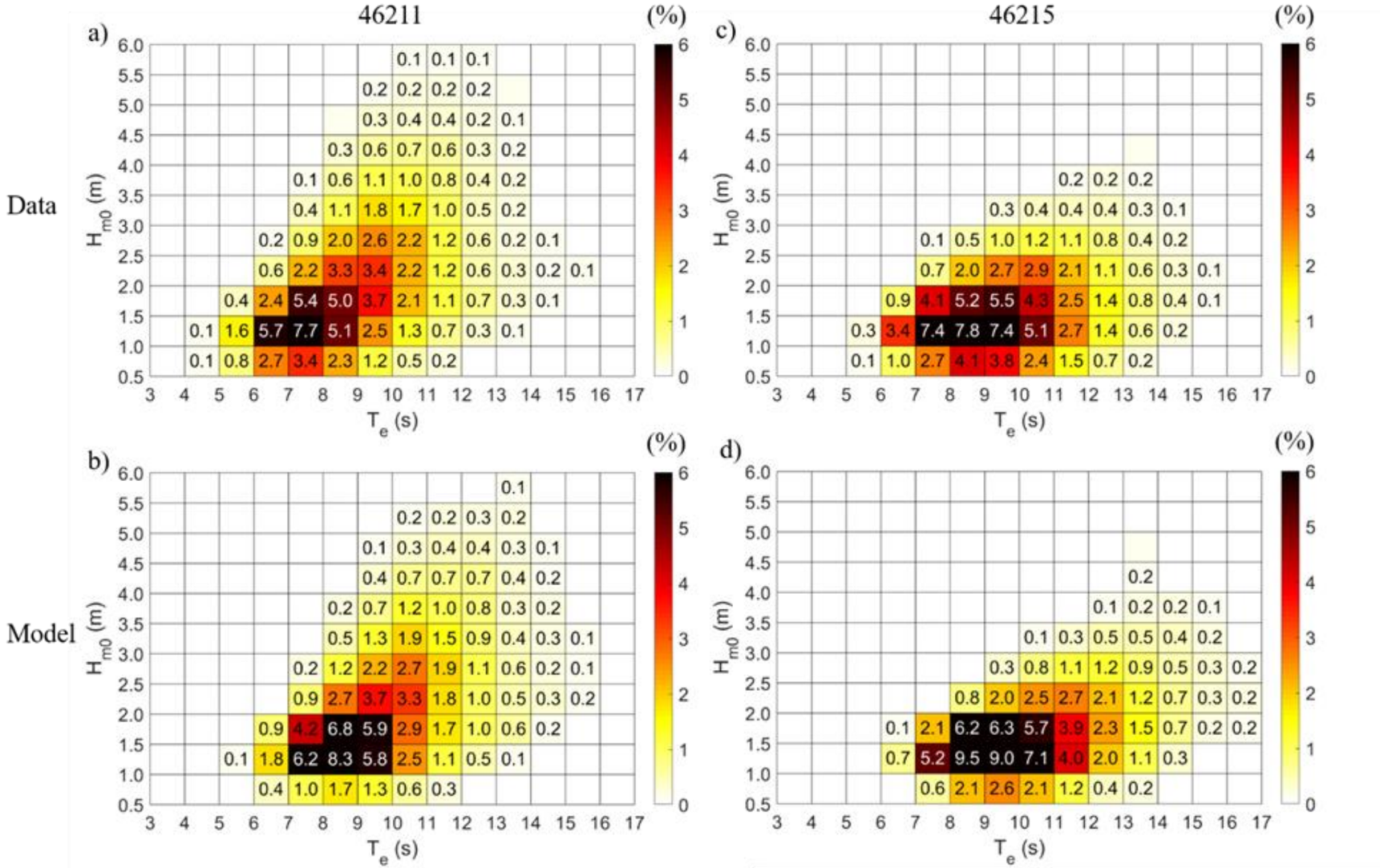
Winter



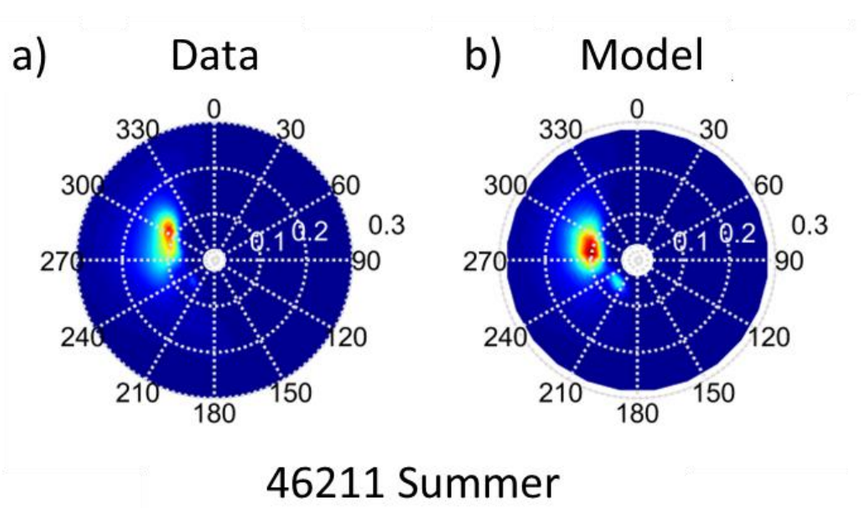
Summer

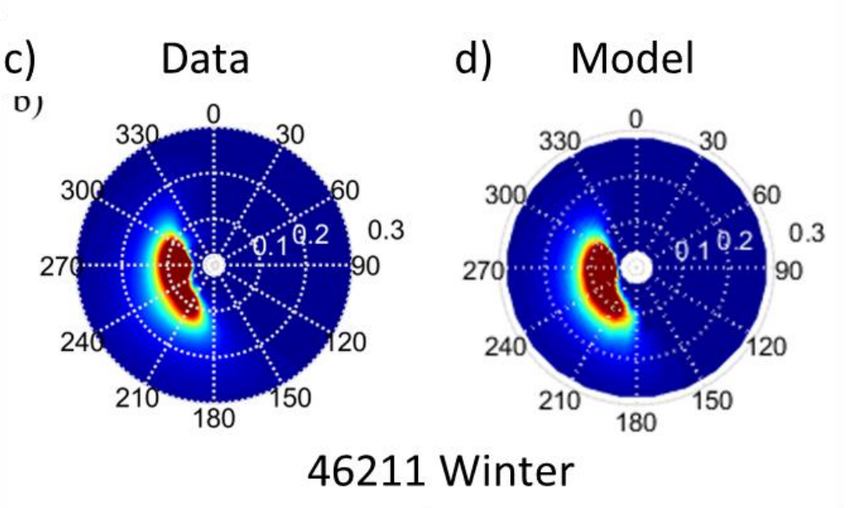


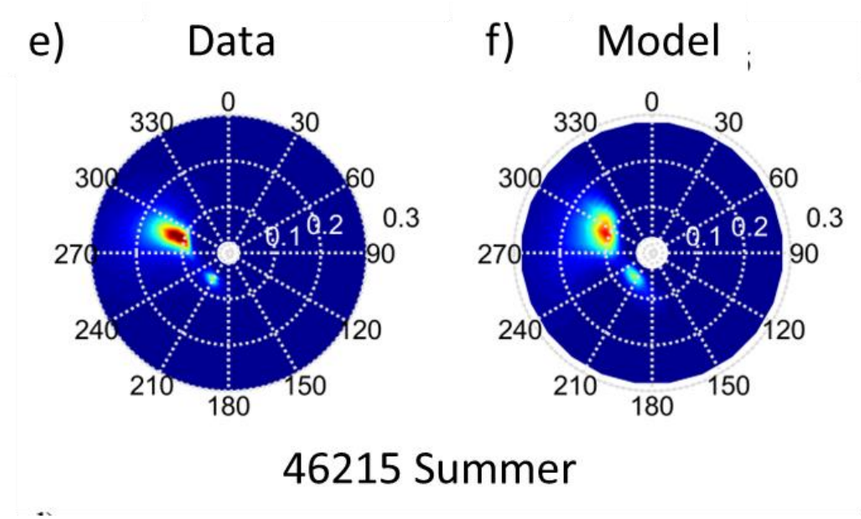
Bivariate histogram of H_s and T_e

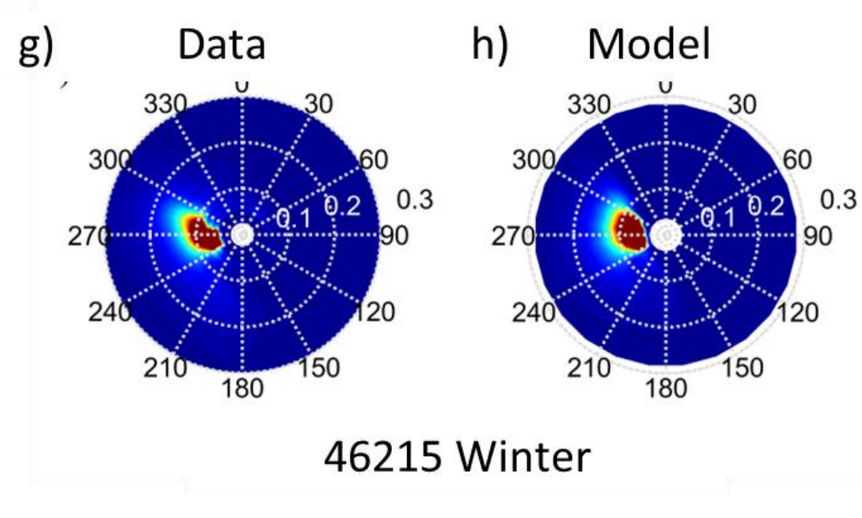


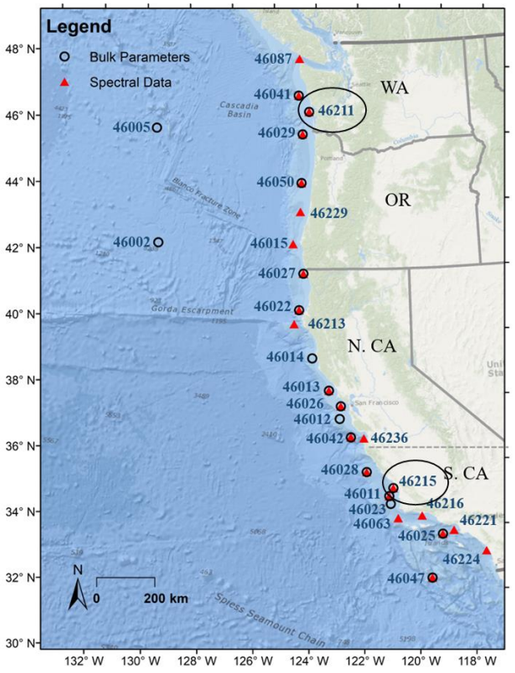
Comparisons of frequency and directional spectra





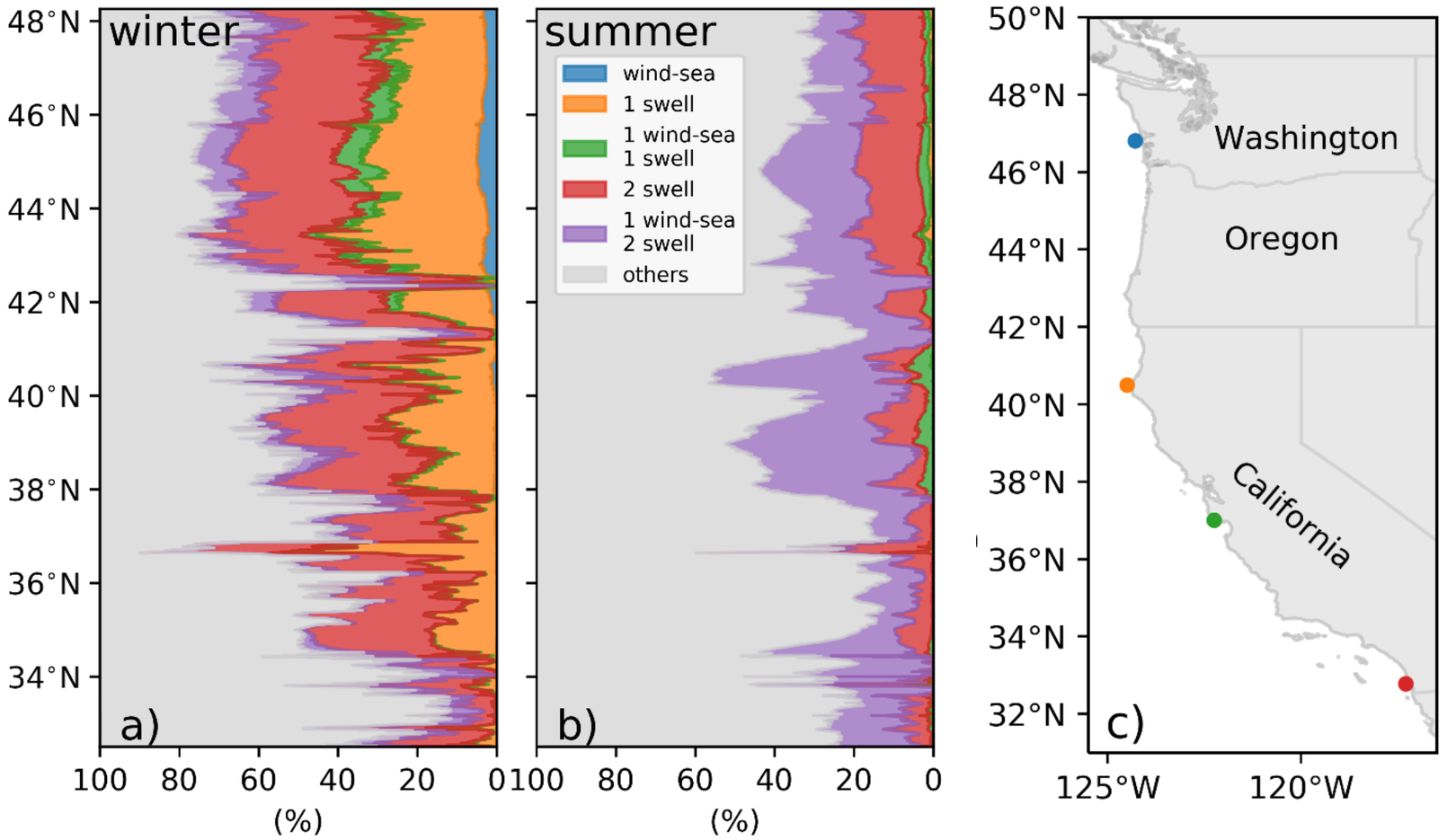




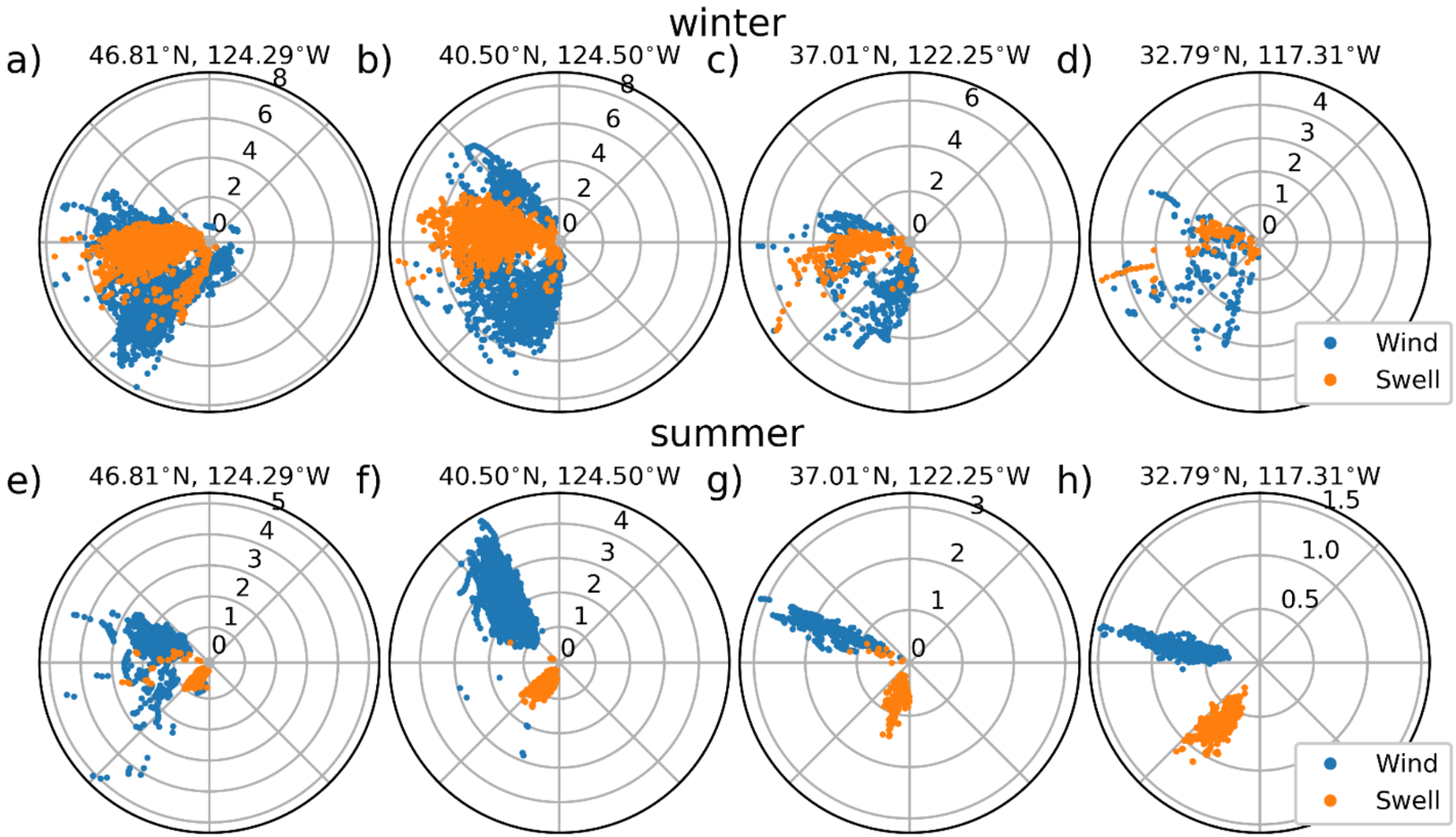


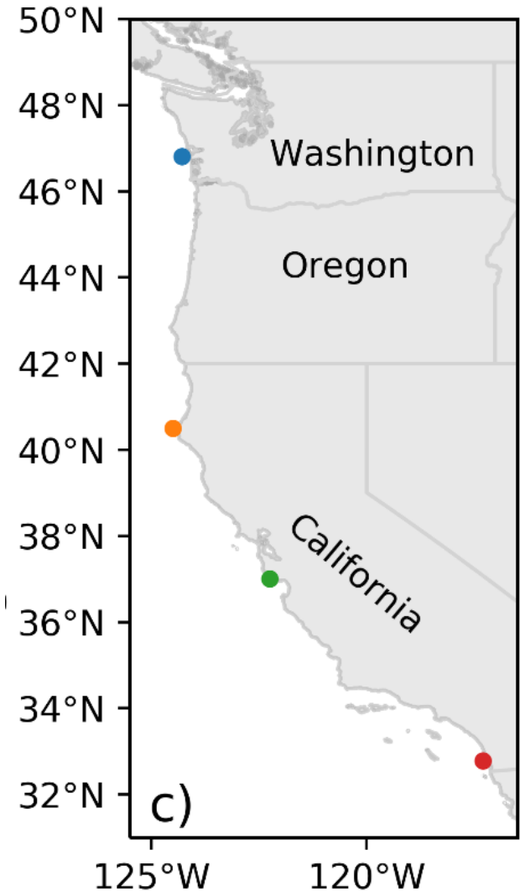
Partitioned Sea States along the West Coast

- Occurrences of 6 sea states along the 50m isobath



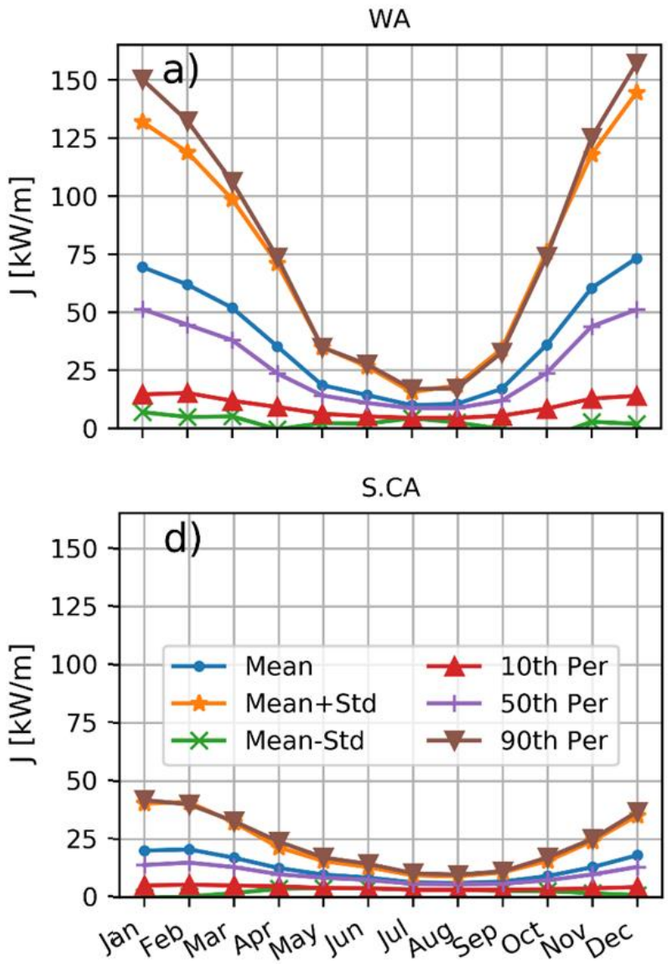
Bi-modal Sea States – Wind-sea and Swell



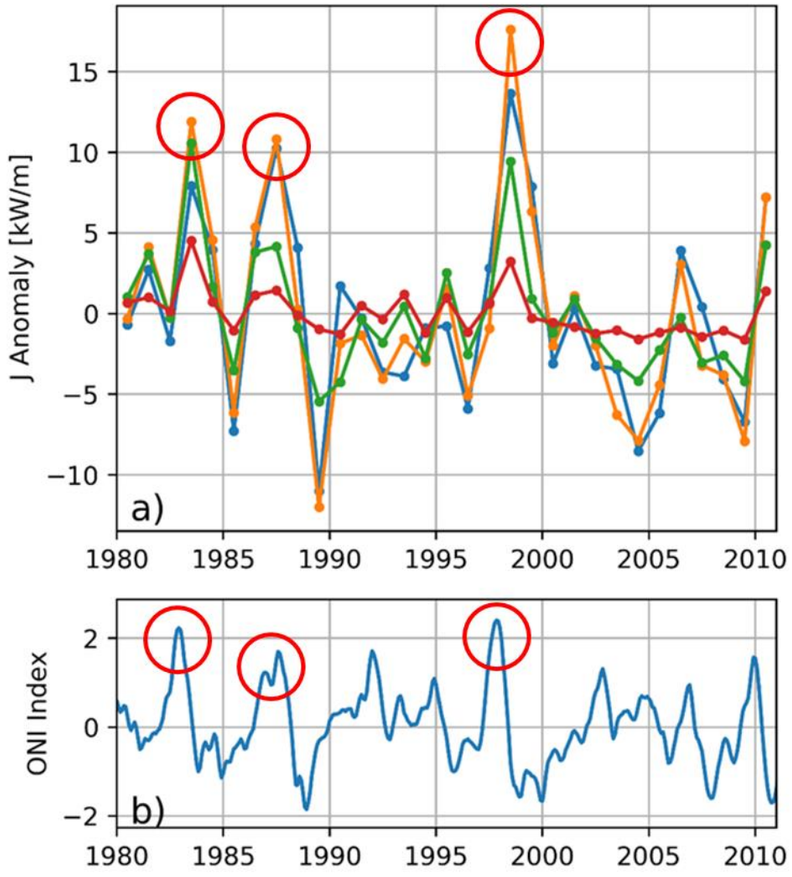


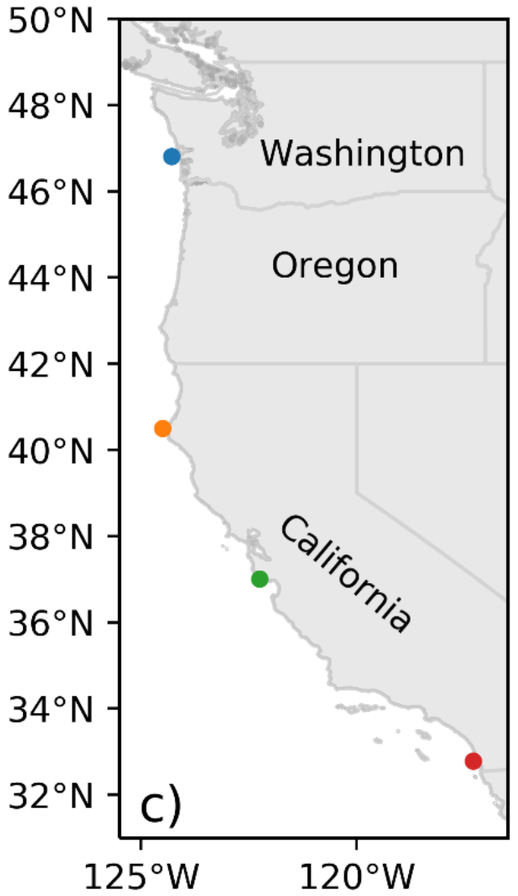
Seasonal and Decadal Variability

Seasonal variations



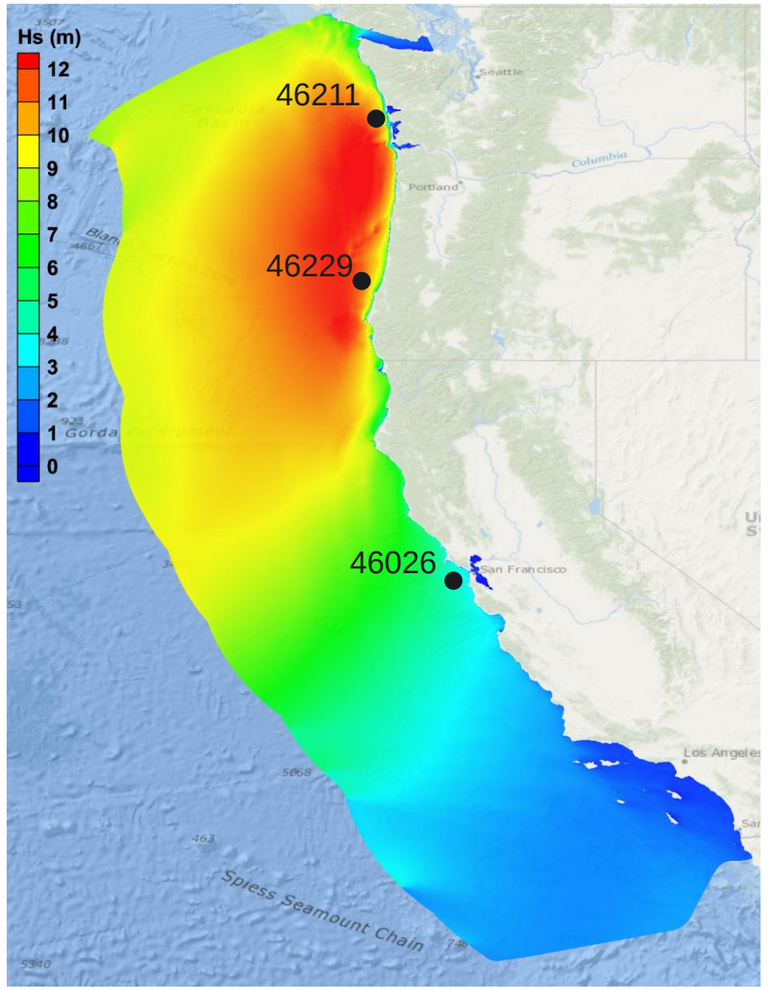
Three major El Niño events
(1982–83, 1987–88, and 1997–98)

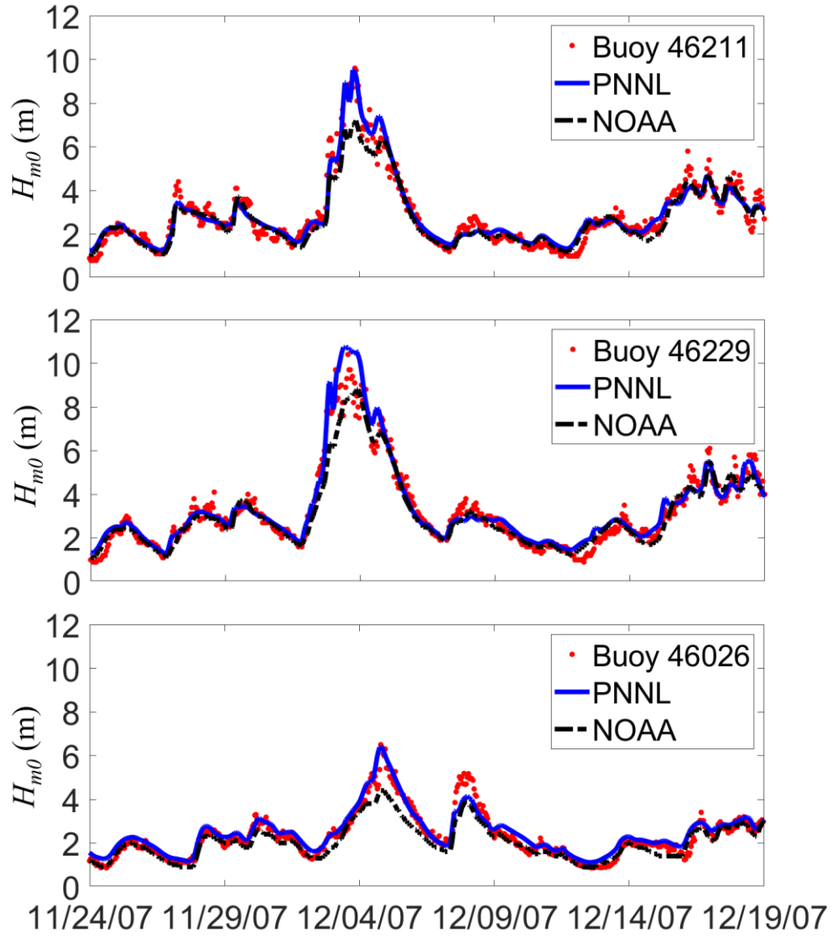




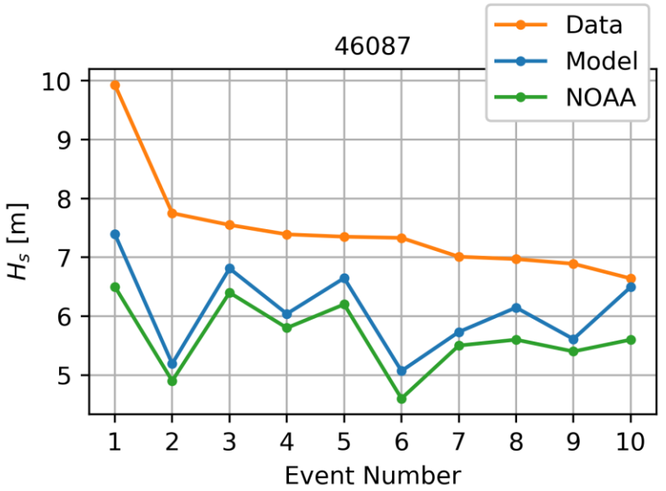
Extreme Wave Prediction

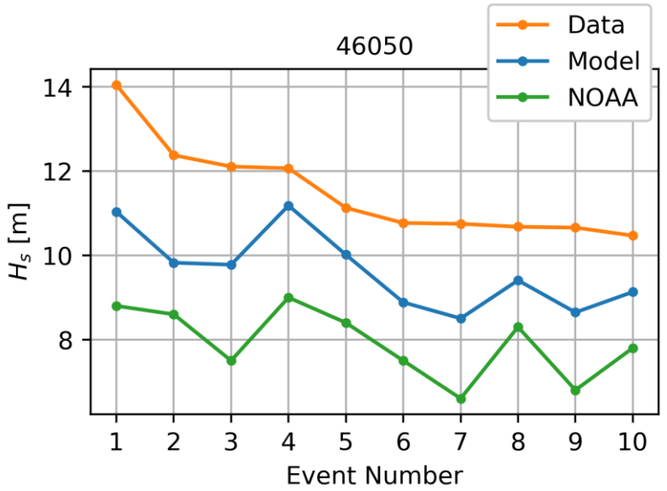
- Comparison of extreme wave prediction with
  - NOAA 4’ WW3 (~6 km)
  - PNNL SWAN (~300 m)
- 2007 Great Coast Gale windstorm

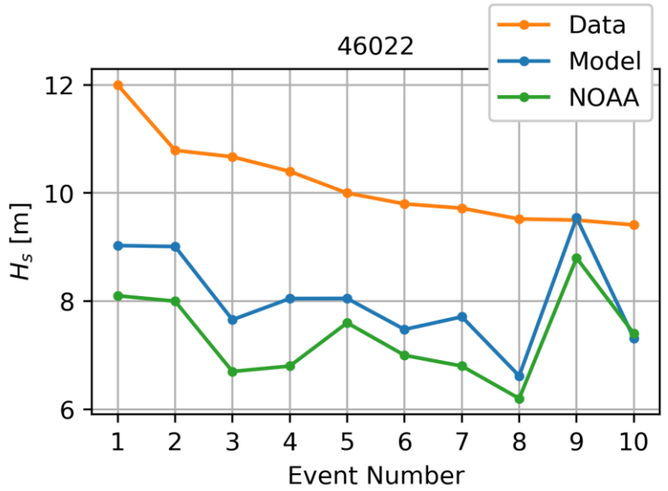


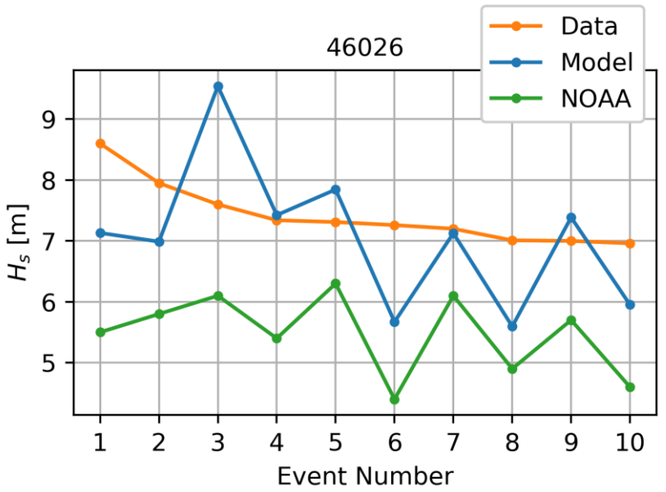


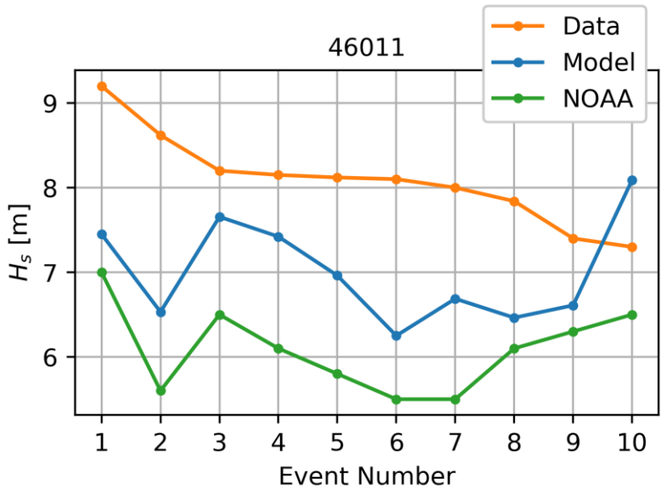
West Coast: 10 Largest Events

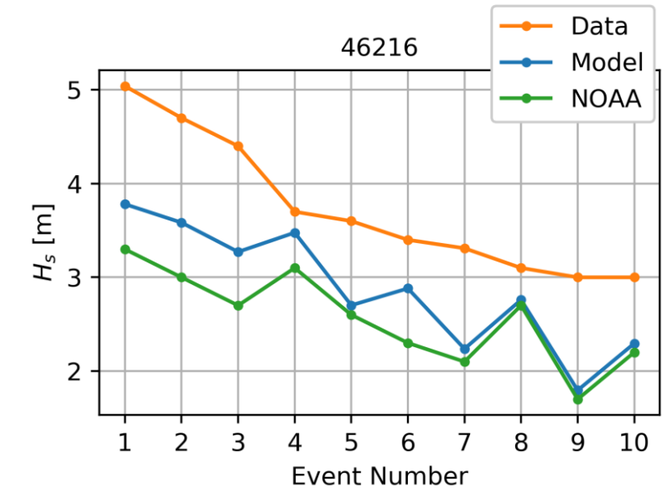




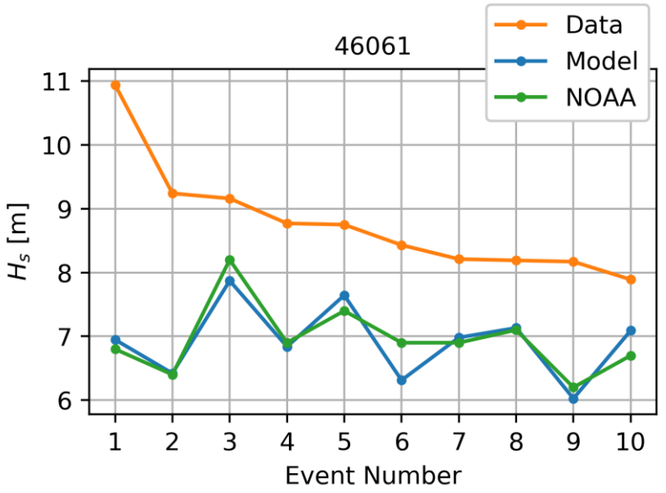


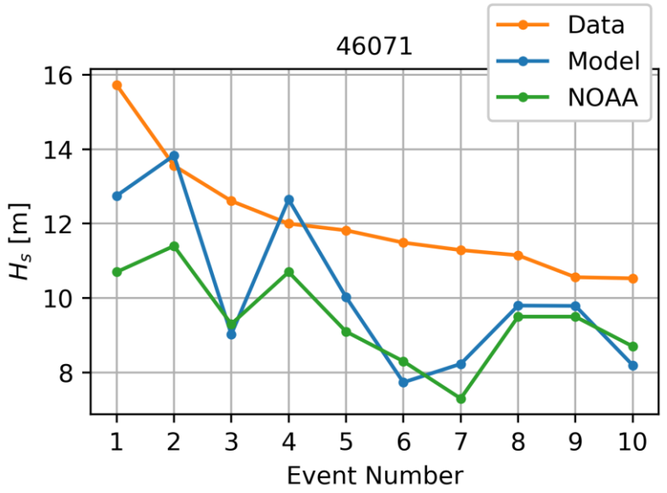


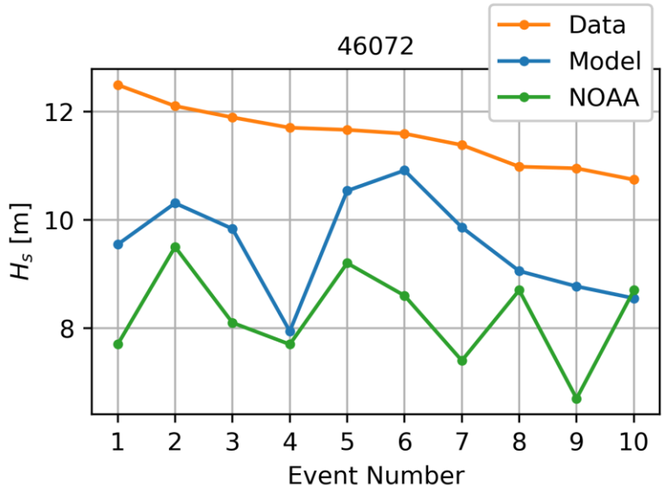


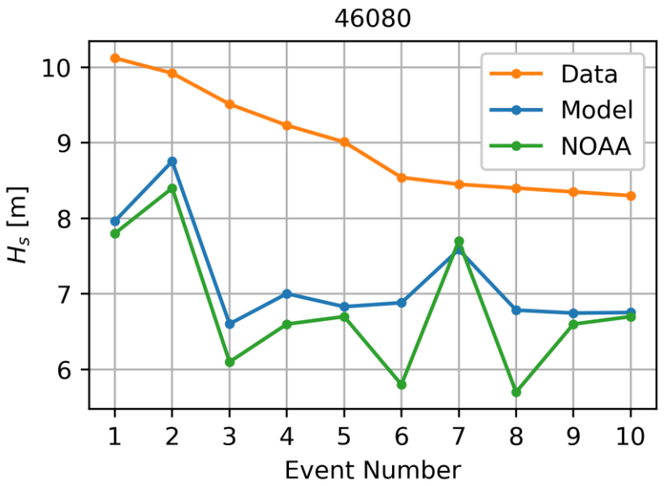


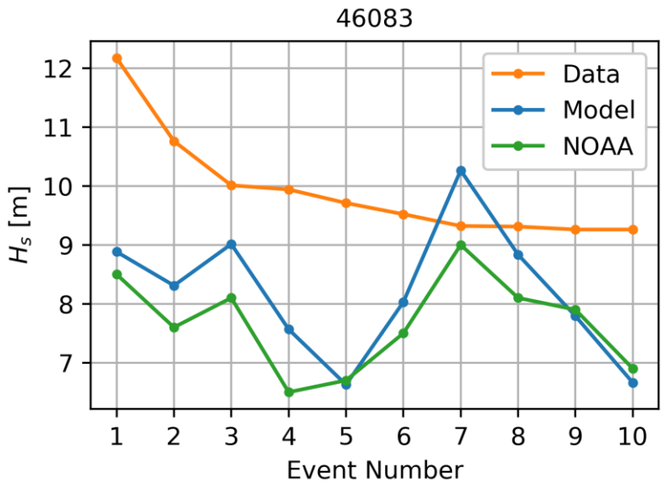
Alaska Coast: 10 Largest Events

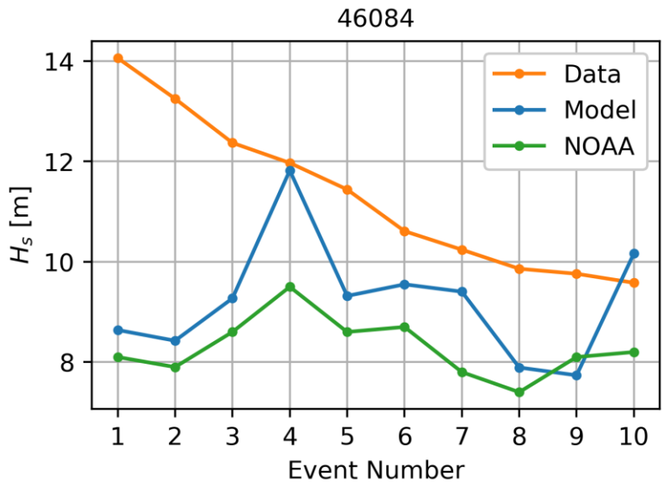




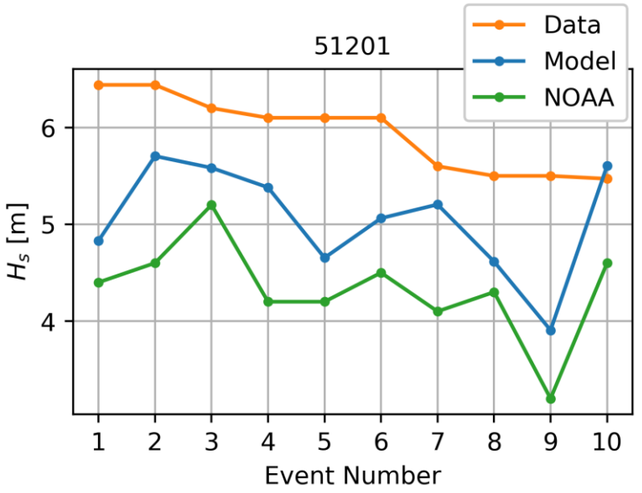


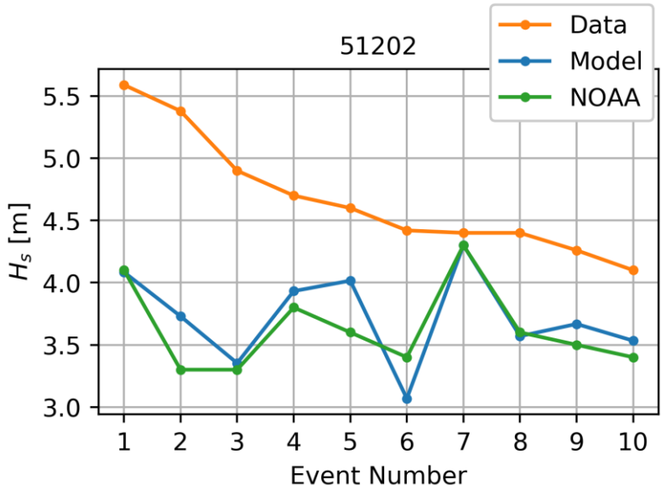


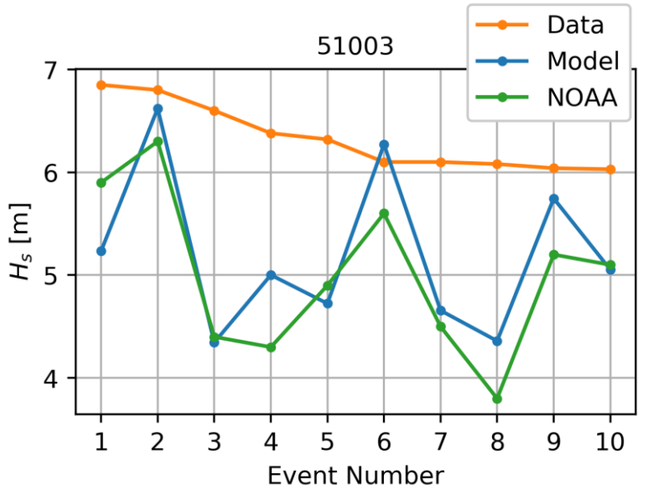


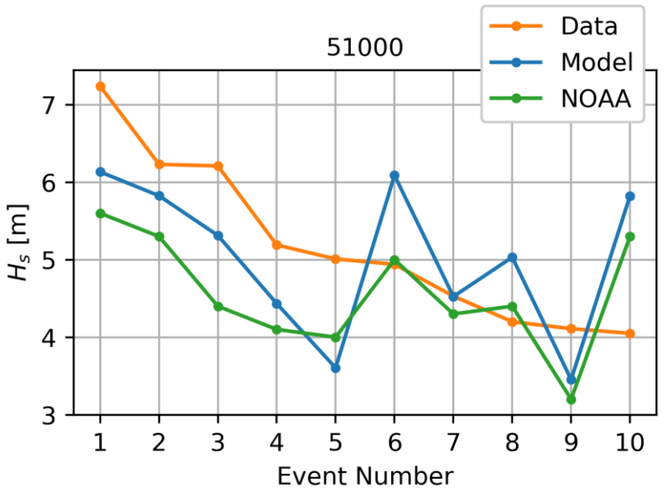


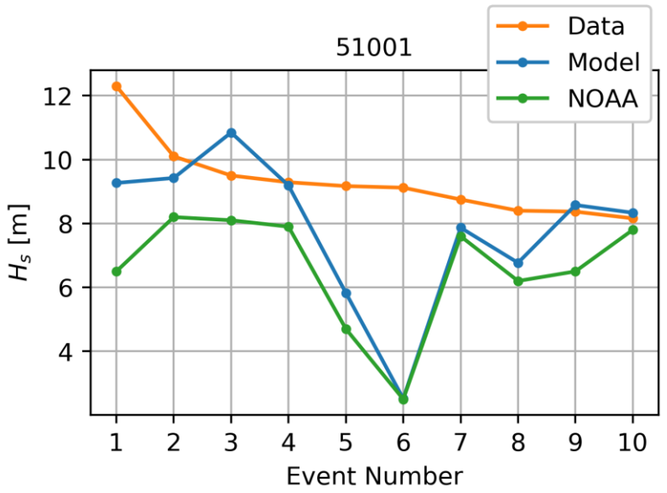
Hawaii Coast: 10 Largest Events

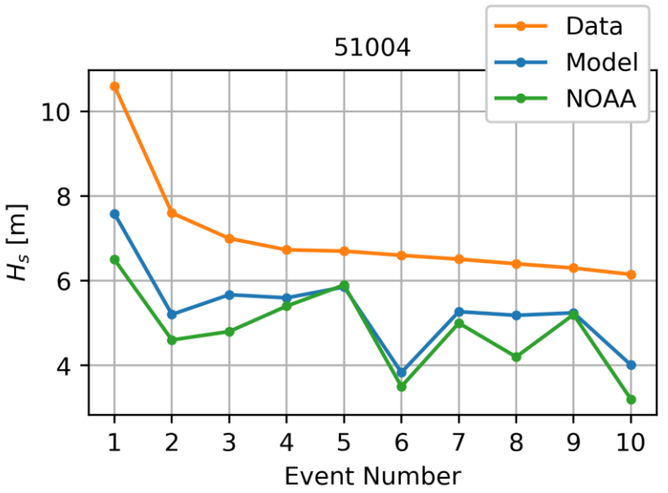






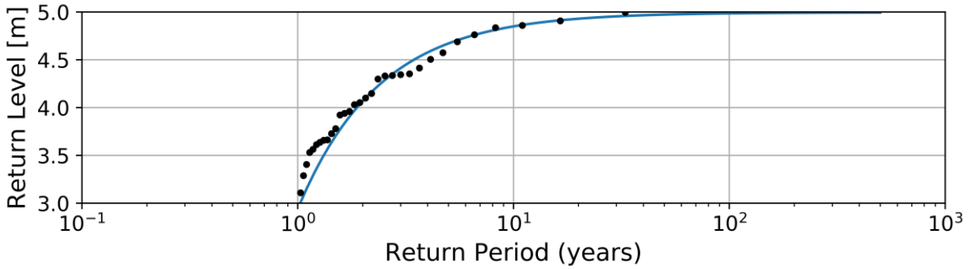




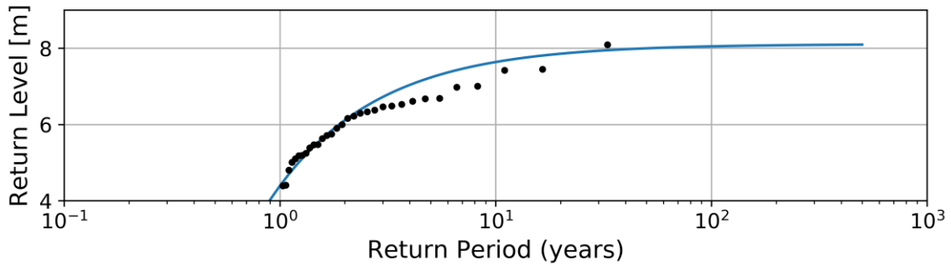


Estimation of return values of wave height

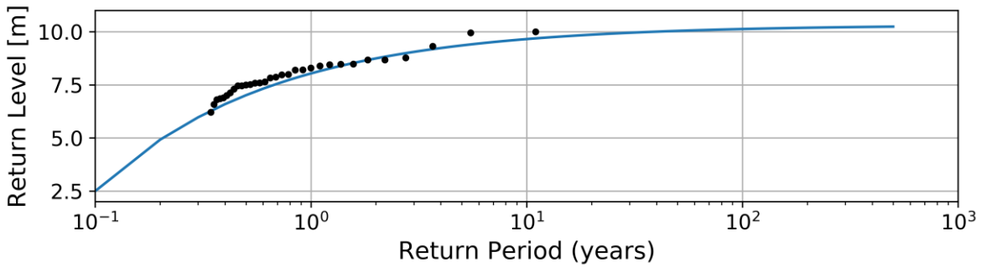
Hawaii

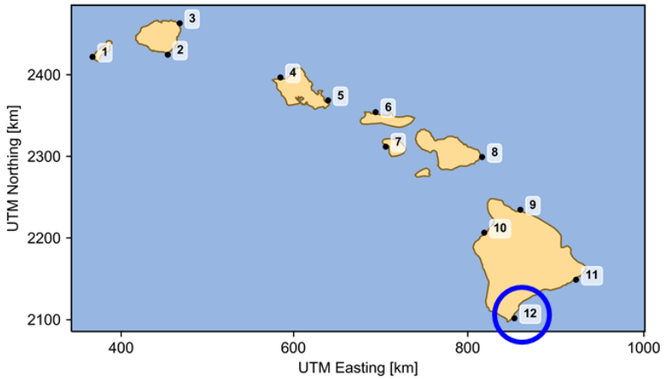


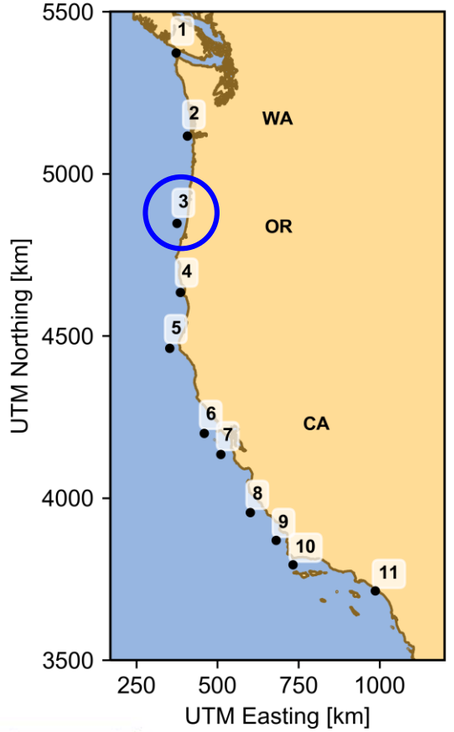
West Coast

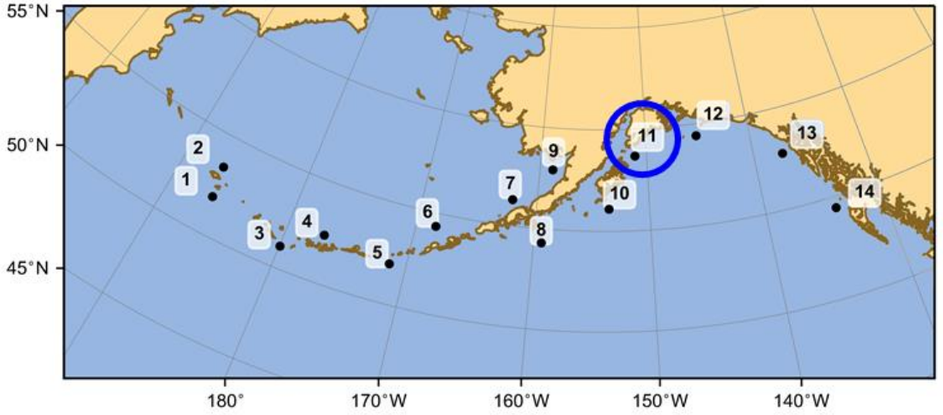


Alaska









Conclusions

- A nested WW3 and unstructured-grid SWAN modeling approach
  - Detailed wave climate in the nearshore
  - Improvement in large wave predictions
  - Long-term hindcasts to reduce uncertainty and estimate return values

Acknowledgements

This study was funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Water Power Technology Office, under contract DE-AC05-76RL01830 to Pacific Northwest National Laboratory.

Model Configuration

Selected Config Details	PNNL	NOAA CFSR Phase 2
Resolution	300 m – 5 km	5 – 7.5 km (4 arc-minute)
Focus Area	Nearshore	Deep water and shelf
Hindcast Period	1979 – 2010	1979 – 2009
Source Terms	ST4 (WW3) Janssen (SWAN)	ST4
Wind	CFSR (0.5 arc-degree)	
Directional resolution	5 – 10°	10°
Frequency range	0.035 – 0.505 Hz	0.035 – 0.964 Hz

Model	Nodes	Elements
Alaska	3,894,283	7,719,870
Hawaii	700,414	1,393,661
West Coast	699,904	1,389,904