Apr 21st, 9:00 AM - Apr 22nd, 4:45 PM

Mapping Waves and Storm Surge for Coastal Resilience in the Salish Sea

Zhaoqing Yang
Zhaoqing Yang, zhaoqing.yang@pnnl.gov

Pacific Northwest NATIONAL LABORATORY

Modeling Waves and Storm Surge in the Salish Sea

Z. Yang[1,2], G. García Medina[1], T. Wang[1],
W. Wu[3], G. Mauger[2] and I. Miller[2]

[1] Pacific Northwest National Laboratory

[2] University of Washington

[3] Dynamic Solutions-International, LLC

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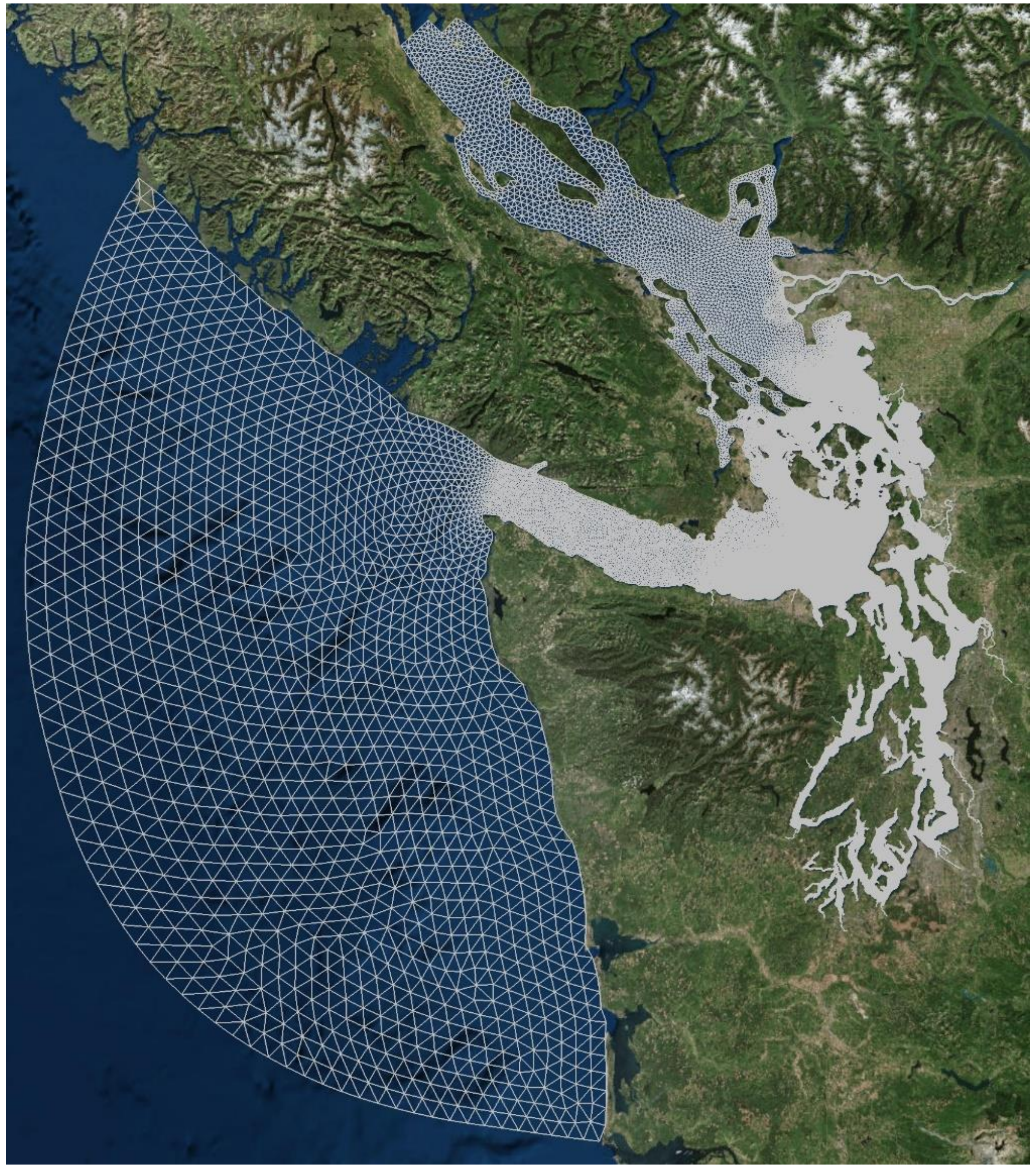
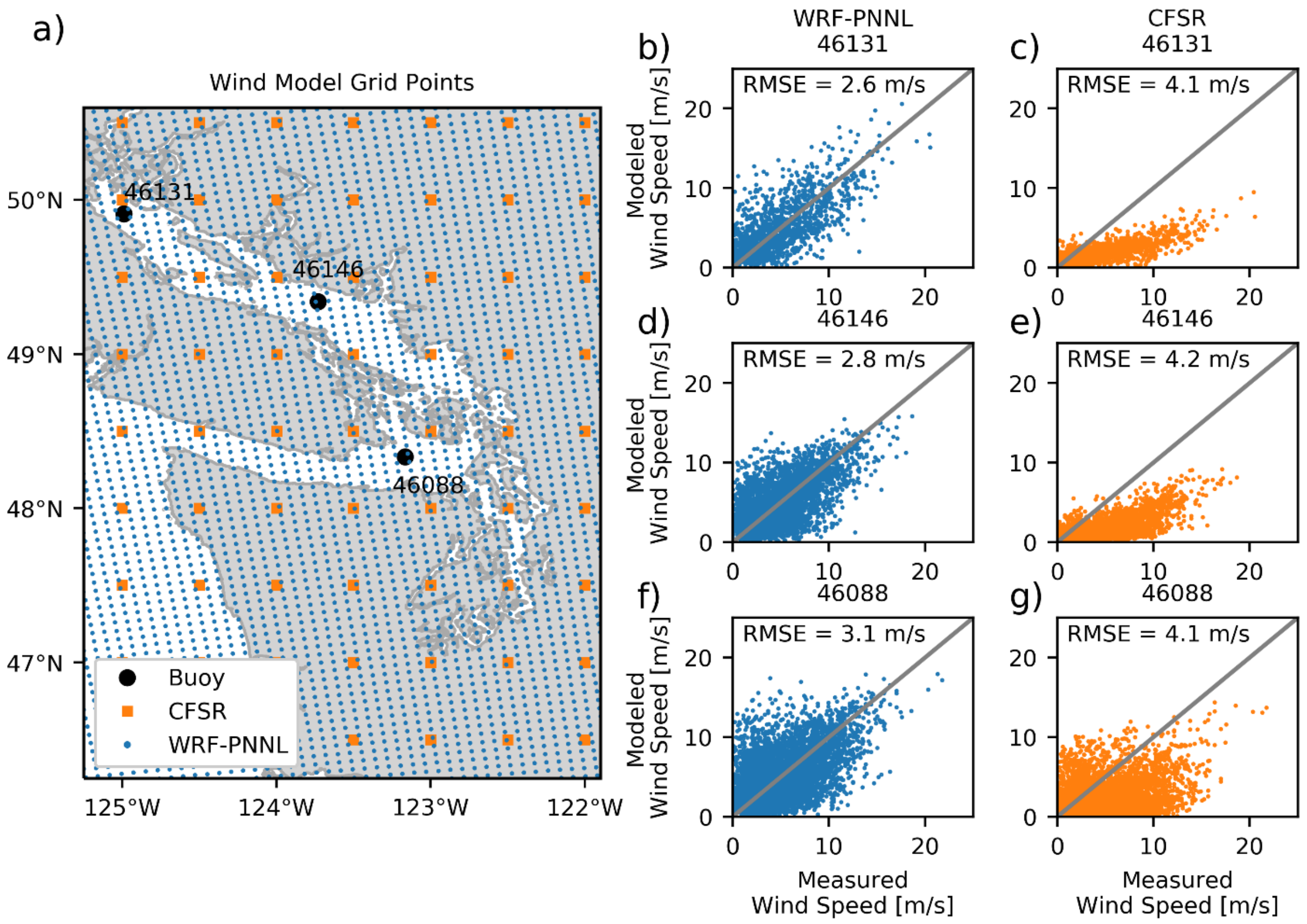
Motivation

- Storm surge and extreme waves pose great risks to coastal communities
- There are very limited data for risk assessment in Salish Sea
- Need for wave and storm surge modeling
  - Unstructured grid modeling approach with a spatial grid resolution of ~ 50 m – 200 m in Puget Sound
  - Simuating WAve Nearshore (SWAN)
  - Finite Volume Community Ocean Model (FVCOM)



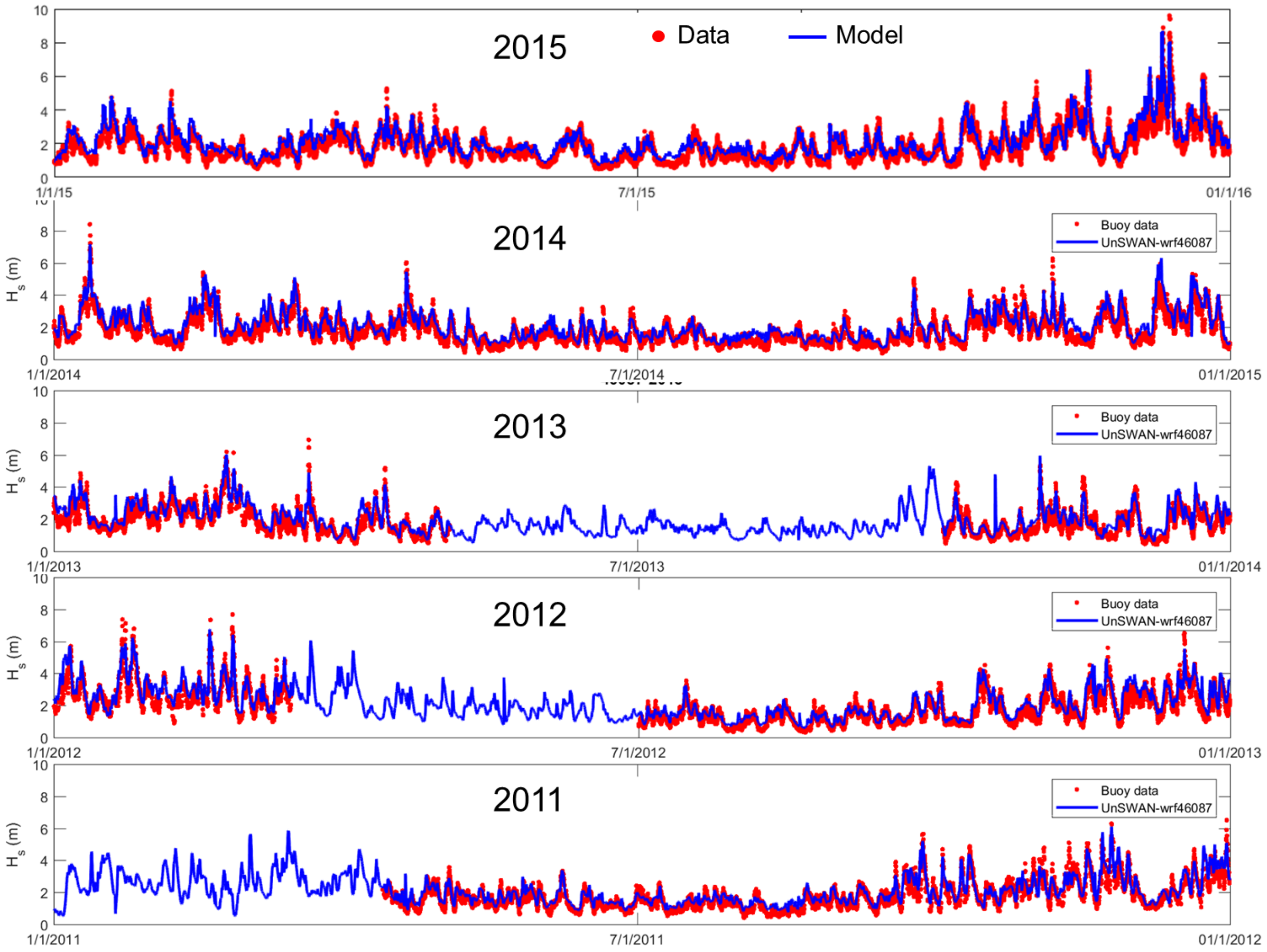
Wave Modeling – Wind Forcing

- Nested-grid approach: global-regional WW3 model to drive the Salish Sea SWAN model
- Global-regional WW3: NOAA NCEP Climate Forecast Systems Reanalysis (CFSR) wind
  - Hourly, 0.5 degree (global)
  - 1979 - present
- Salish Sea SWAN: PNNL Weather and Forecasting Research (WRF) wind
  - Hourly, 6-km (west coast)
  - 1975 - 2015

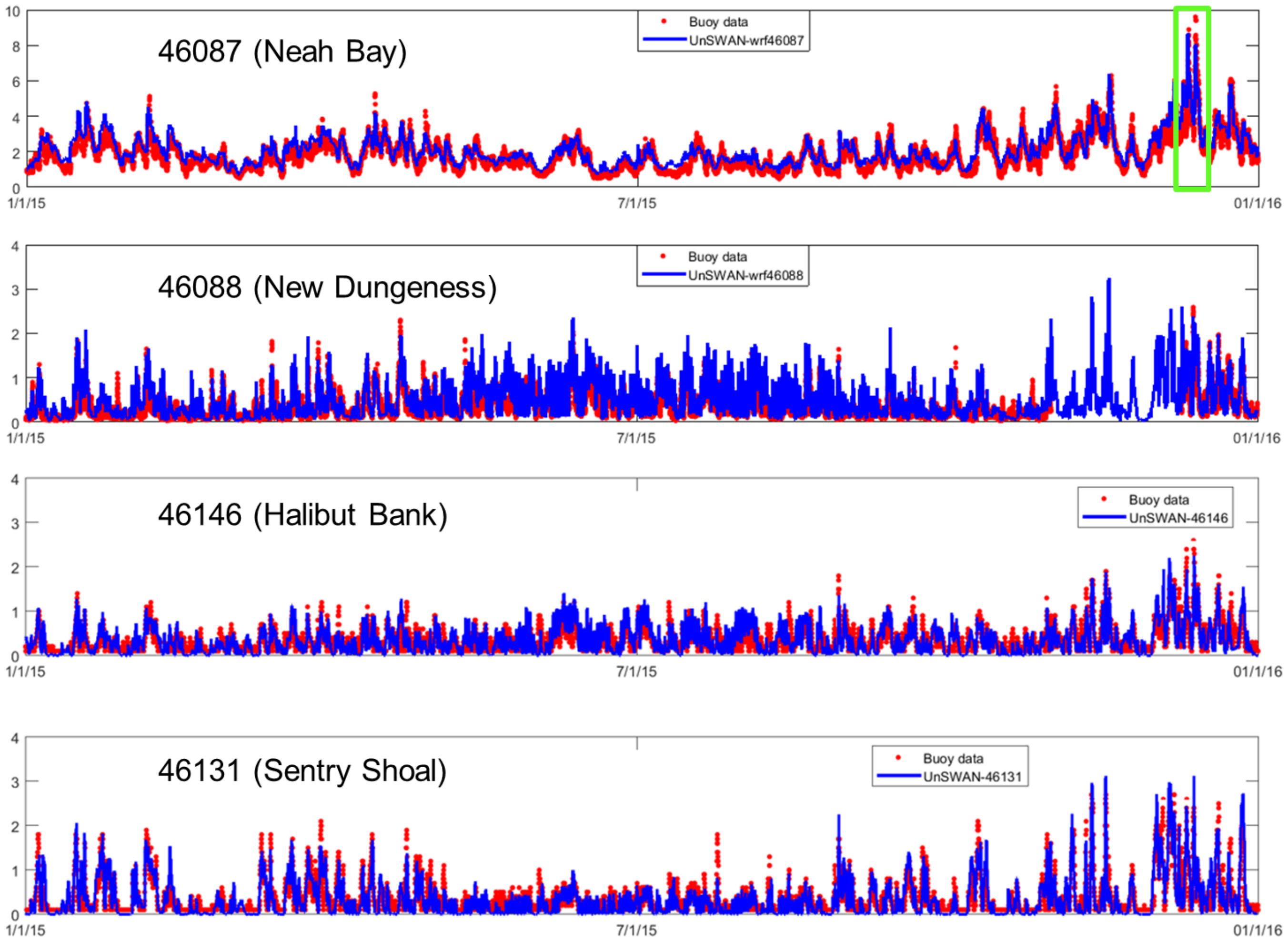


Model Validation – Comparisons of H_s

Significant Wave Height at NDBC Buoy 46087 (Neah Bay)

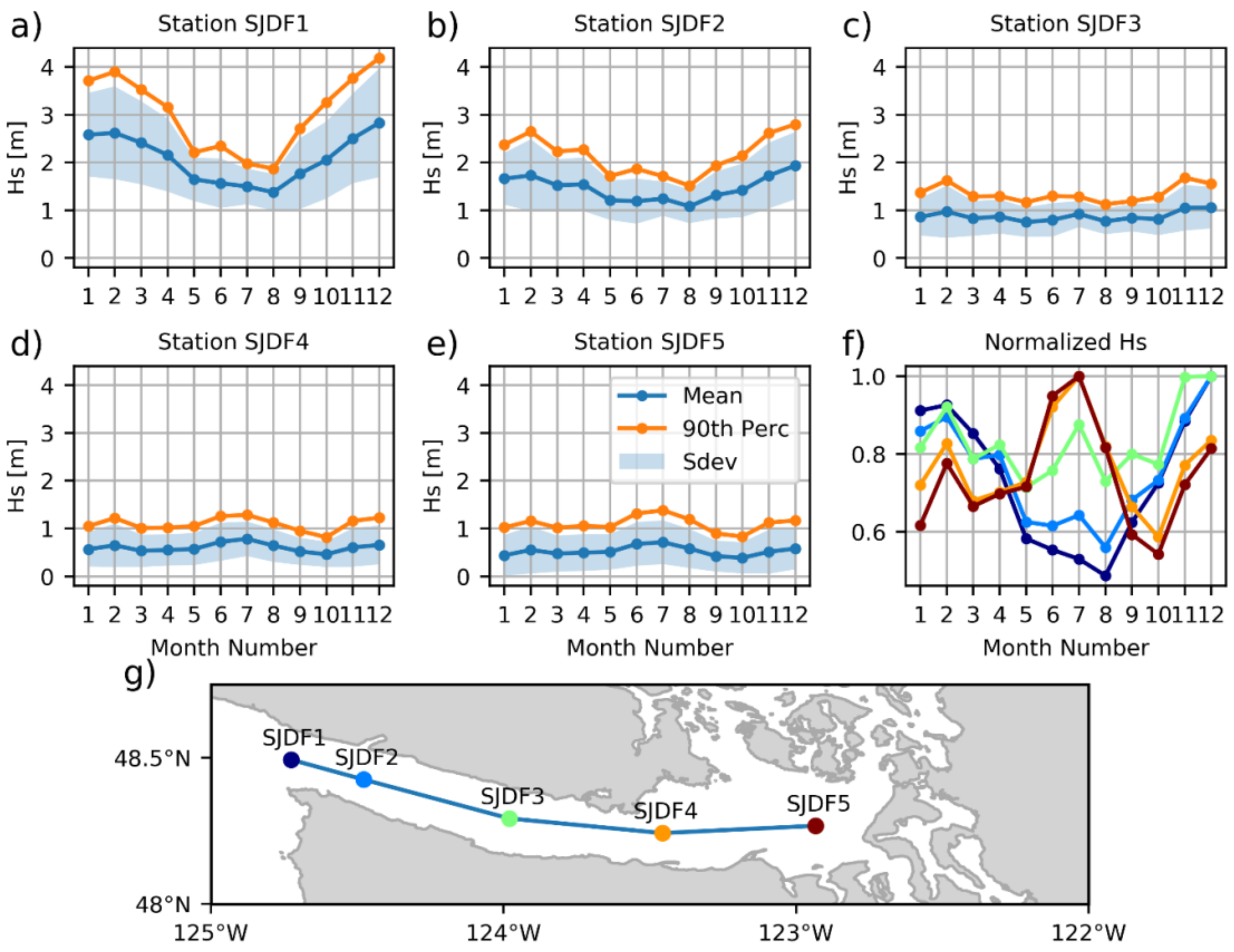


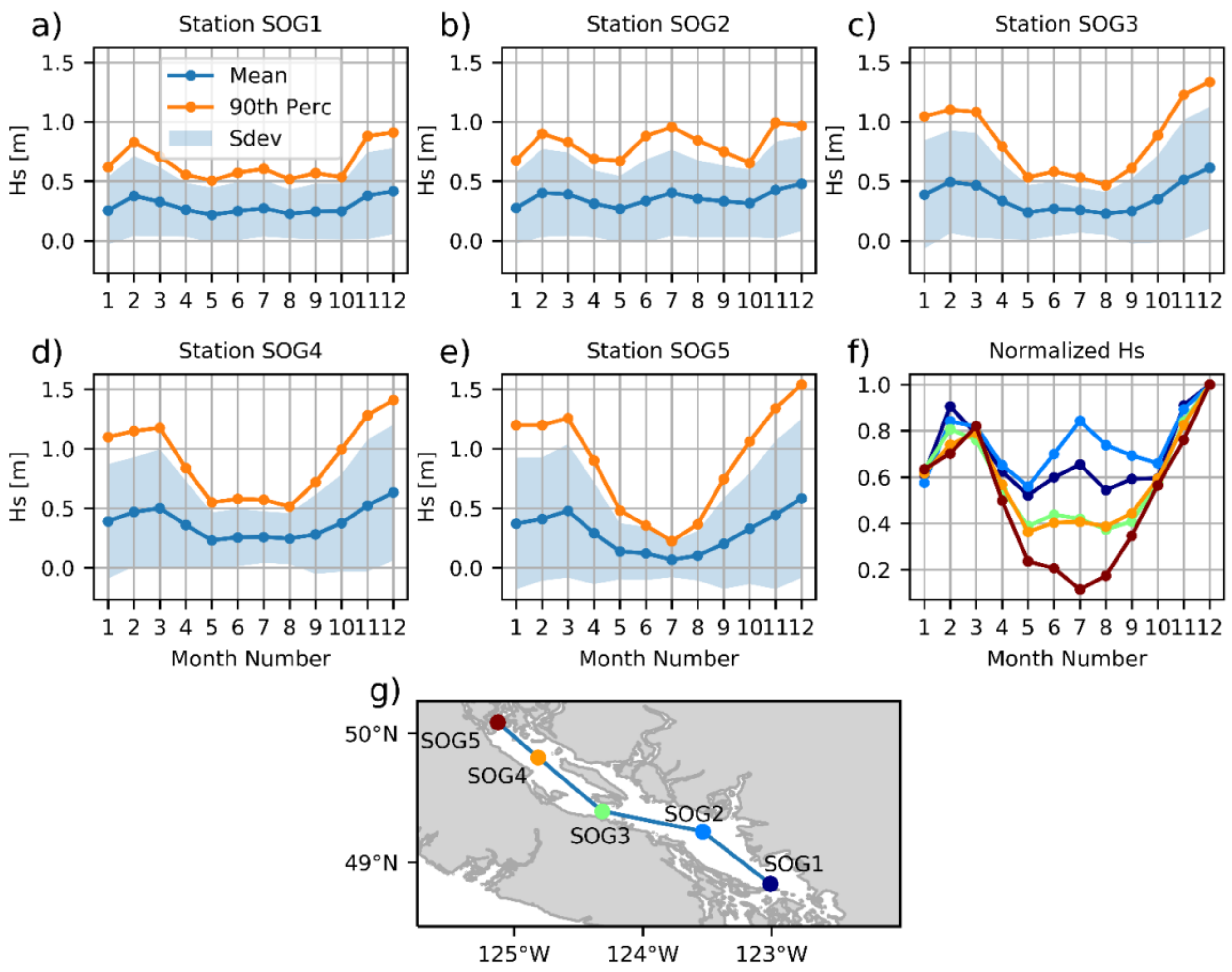
Significant Wave Height at four stations for 2015



Wave Climate in Strait of Juan de Fuca (SJDF) & Strait of Georgia (SoG)

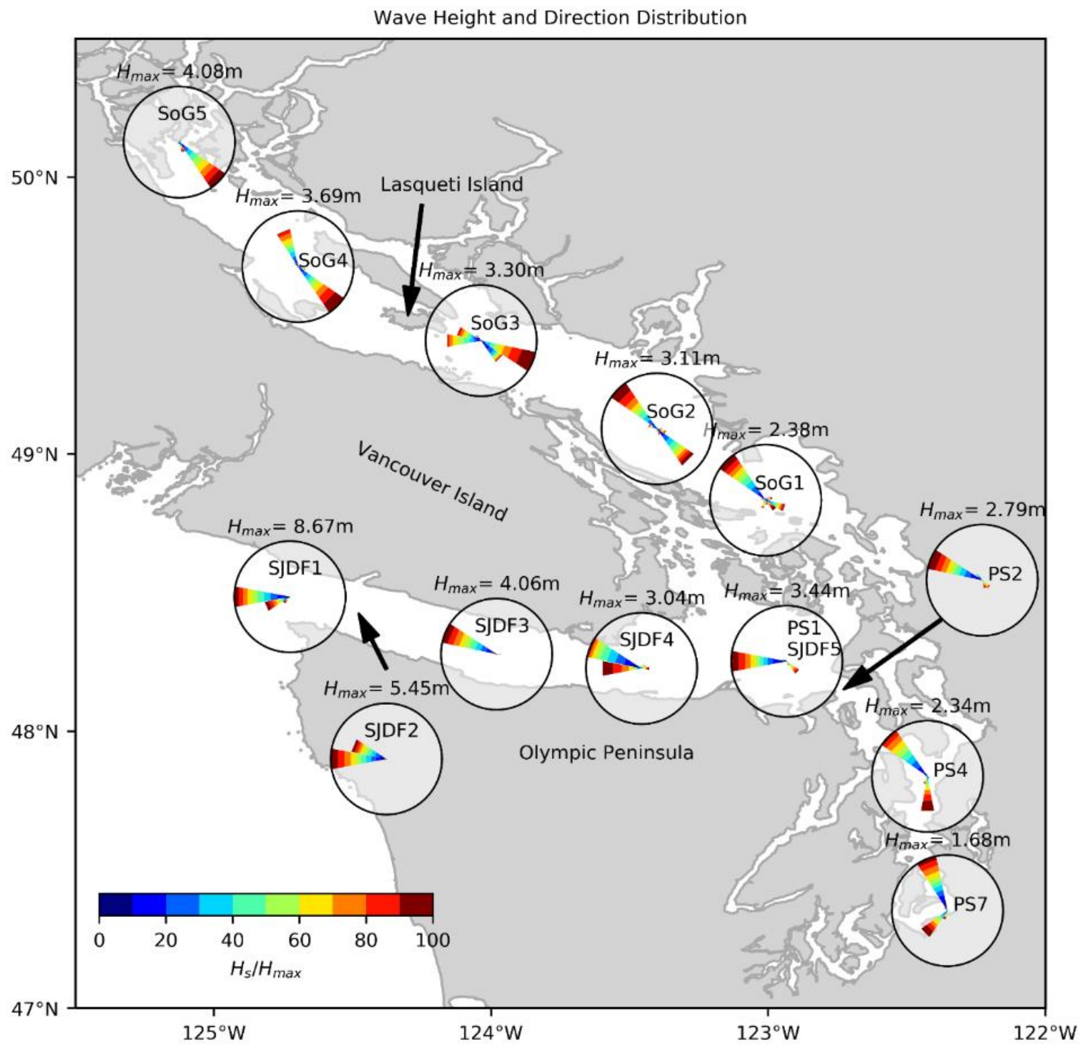
- Swell dominant in SJDF and wind-sea dominant in SoG

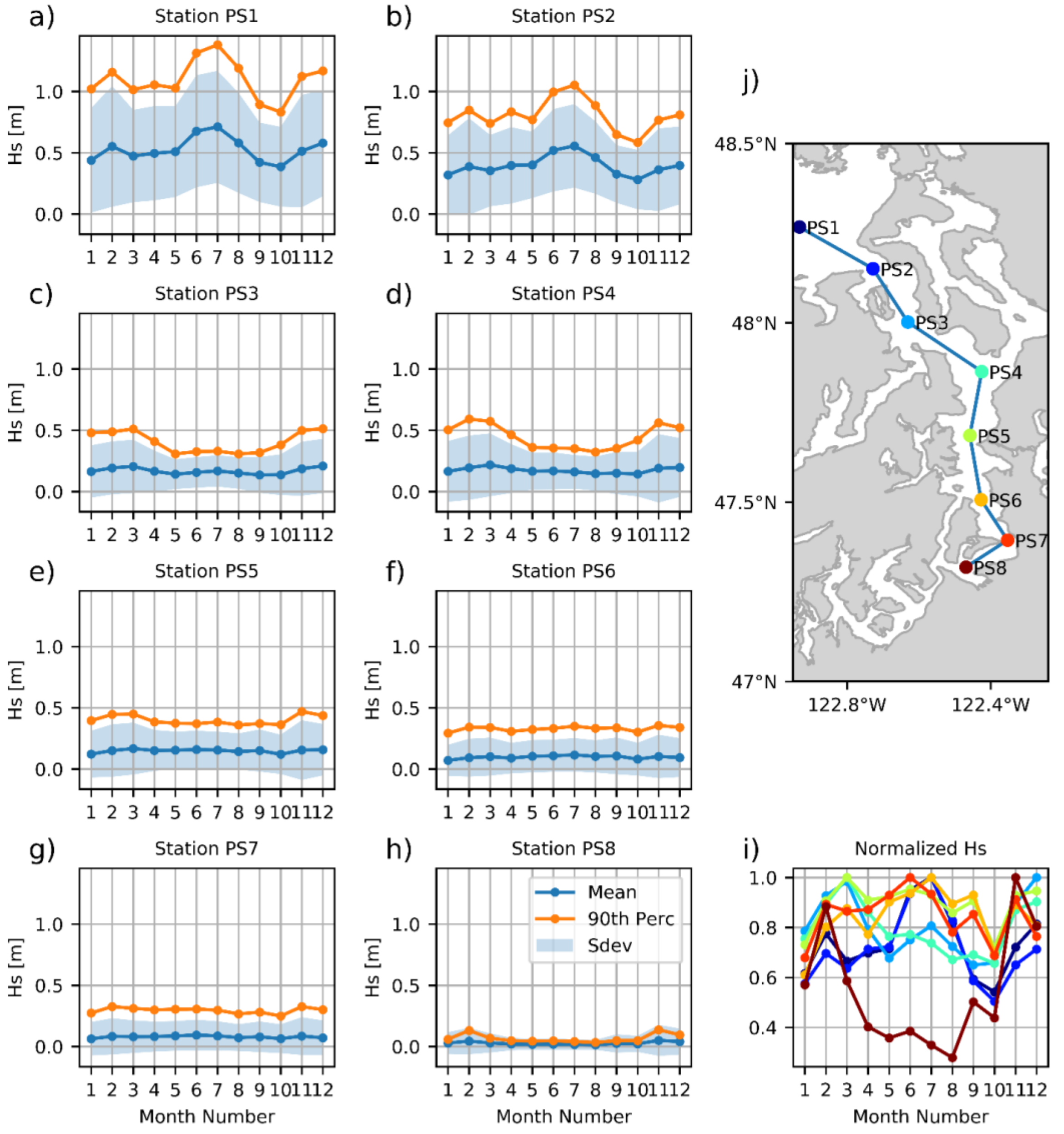




Wave Climate in Puget Sound

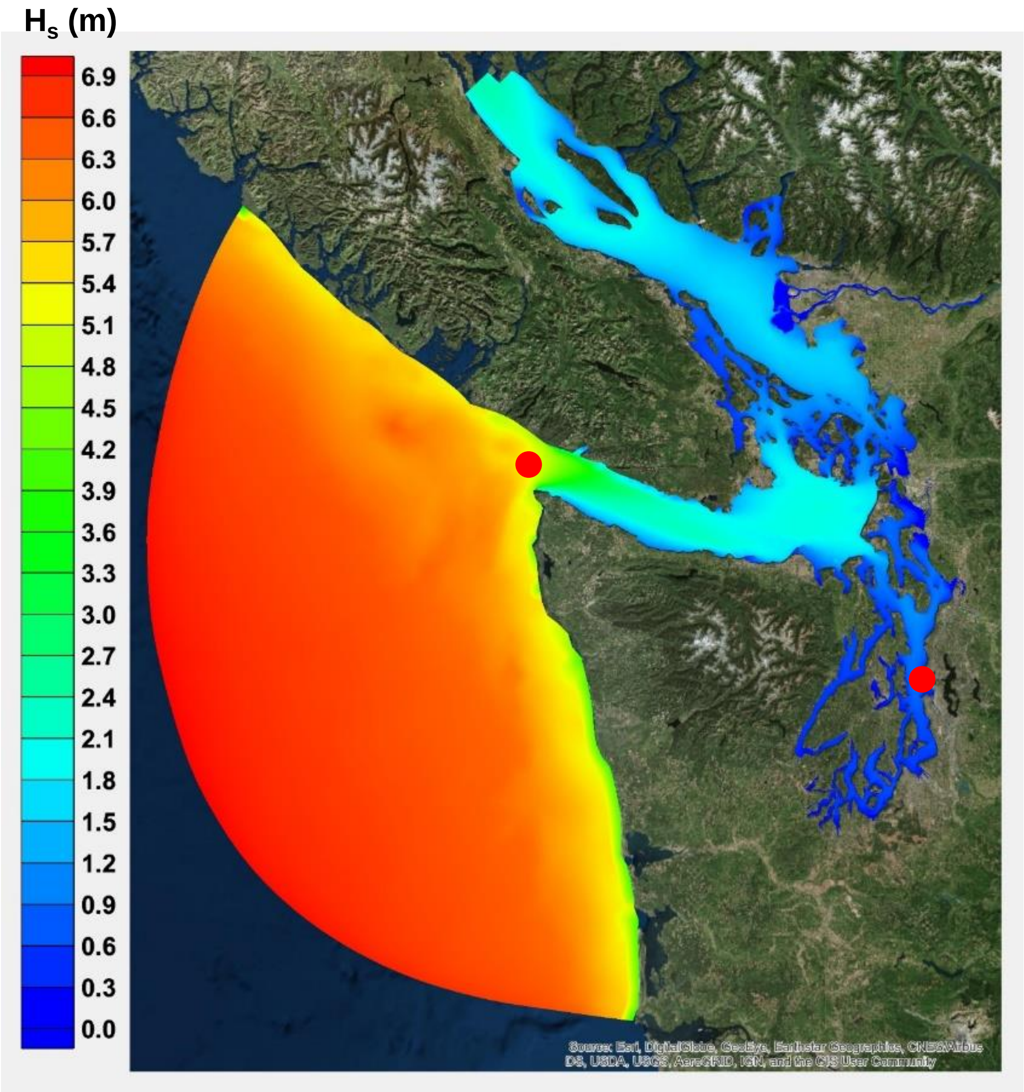
- Wind-sea dominant in Puget Sound
- Waves corelate well with wind roses



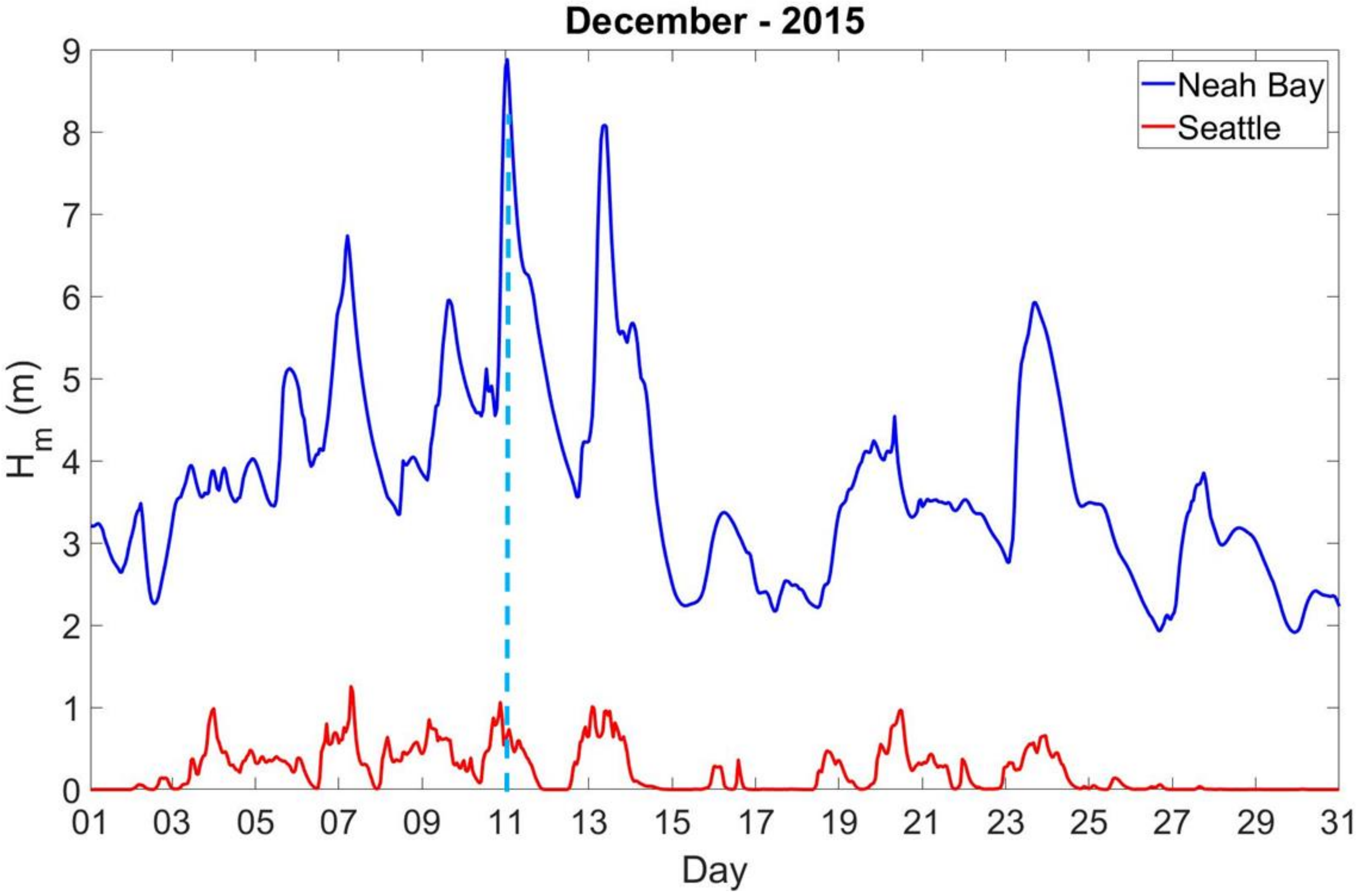


Wave Mapping in the Salish Sea

- Top 1% significant wave height based on 5-year simulations

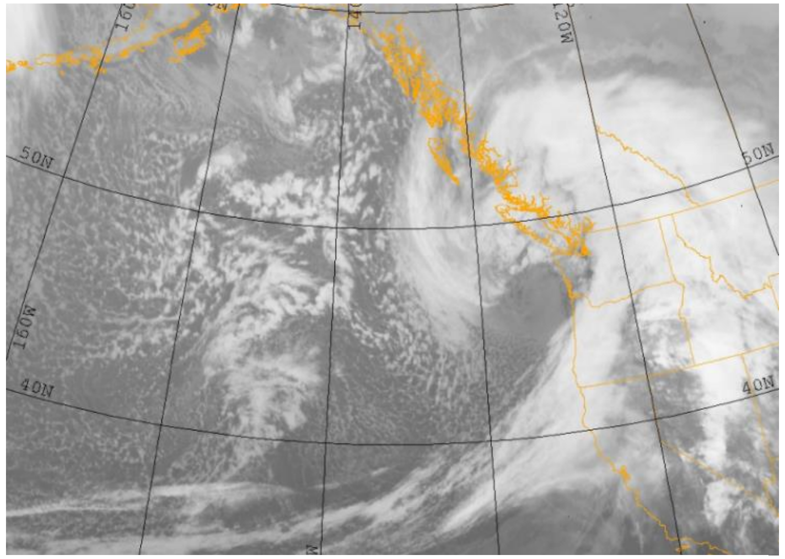


- Significant wave heights at Neah Bay and Seattle during a storm event in December 2015

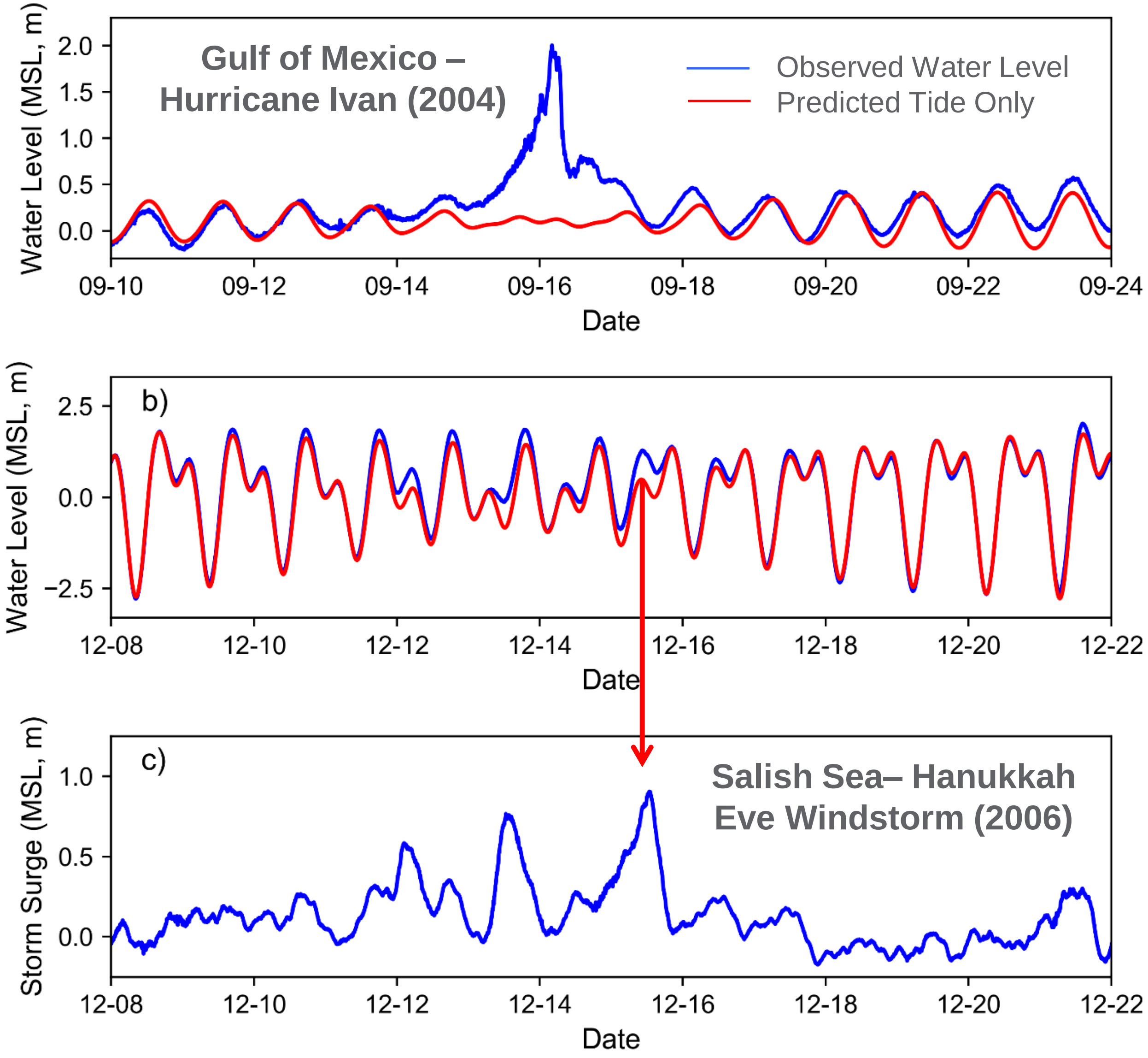


Modeling Storm Surge in the Salish Sea

- Quantify storm surge in Salish Sea using Non-Tidal Residual



Satellite images from NASA



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Historical Storm Surge Events for Simulations

- Modeling approach

Compile subtidal water level data at NOAA tide gauges* (1980 – 2016)

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Select storm events with a max surge height > 0.5 m at any of tide gauges

↓

Select the top 20 events at each of the tide gauges and the common events ranked in the top 50

↓

Finalize 34 storm events for model simulations

↓

Conduct model simulations with observed water level boundary condition and tidal boundary condition for each storm event

↓

Generate storm surge distribution by subtracting the simulated tidal levels from total water levels for each event

↓

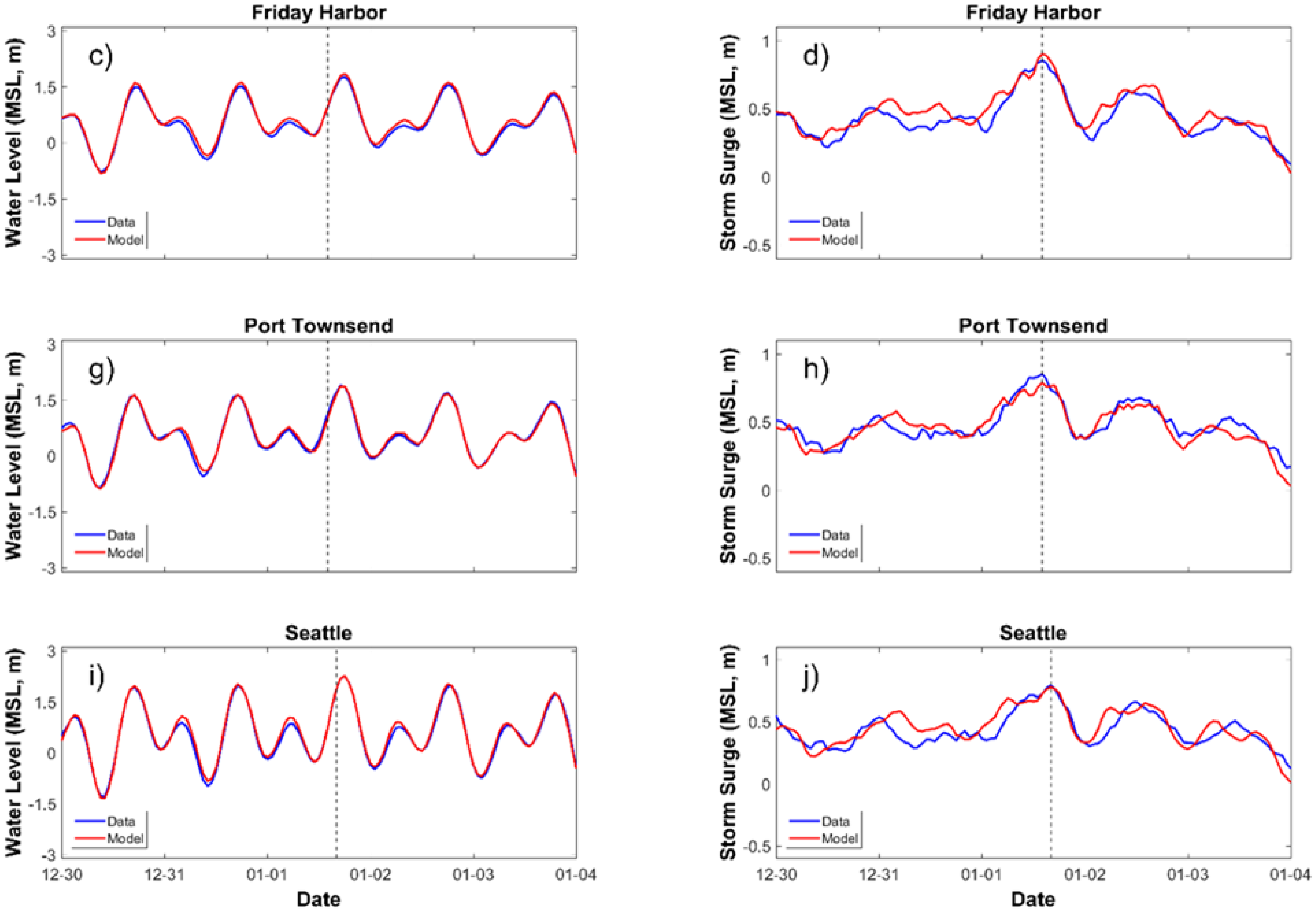
Produce the maximum storm surge map based on the maximum surge height of 34 storm events at each grid point

- Selected 34 storm surge events

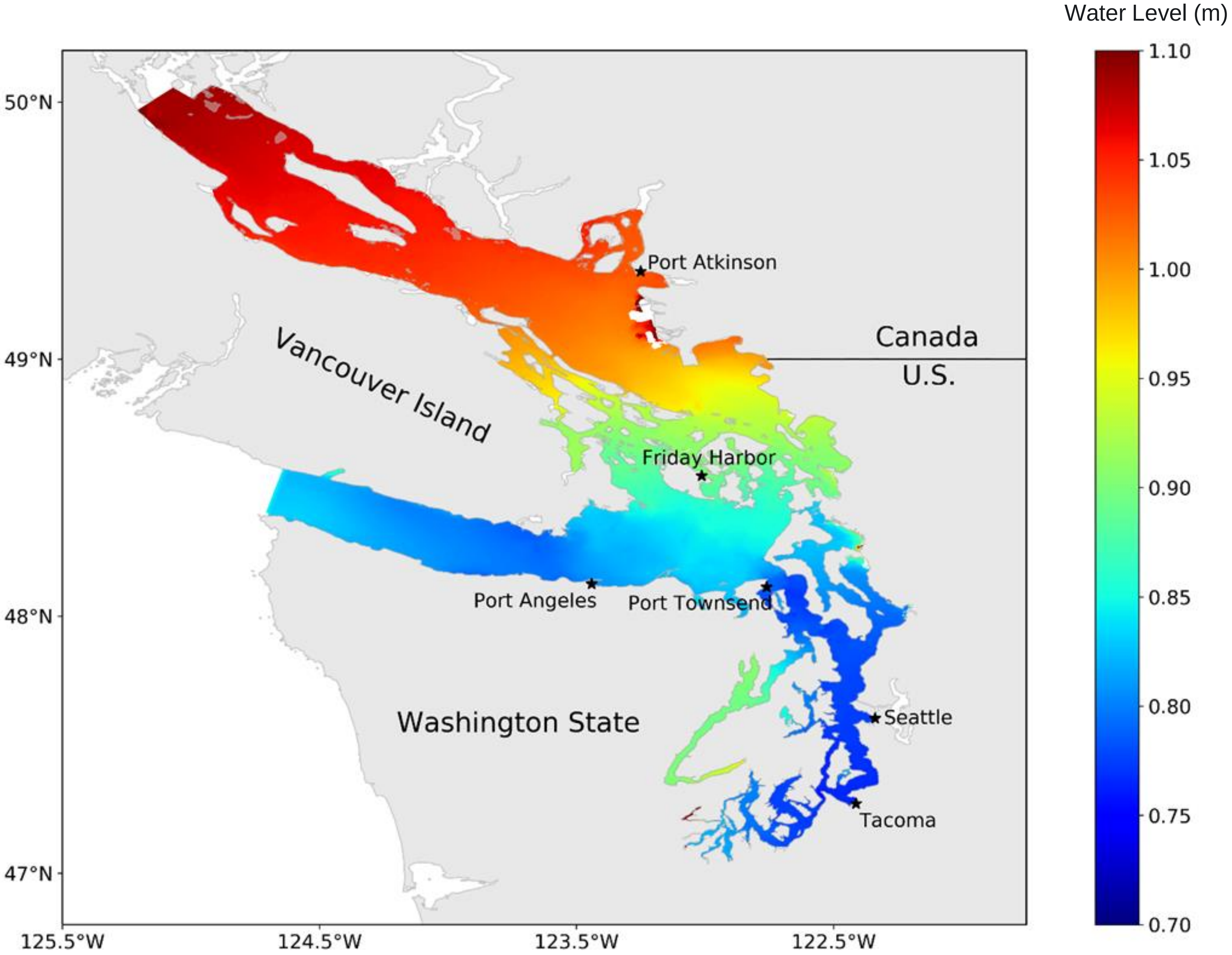
Station Name	Neah Bay (m)	Port Townsend (m)	Seattle (m)	Tacoma (m)
2016 - 10 - 16	0.684	0.663	0.712	0.711
2016 - 03 - 10	0.621	0.738	0.723	0.681
2016 - 03 - 06	0.518	0.749	0.709	0.720
2015 - 12 - 13	0.641	0.804	0.826	0.811
2014 - 12 - 11	0.707	0.698	0.739	0.714
2012 - 12 - 02	0.675	0.646	0.647	0.598
2010 - 01 - 18	0.660	0.751	0.760	0.796
2008 - 01 - 05	0.693	0.667	0.640	0.662
2007 - 12 - 03	0.710	0.711	0.730	0.741
2007 - 11 - 12	0.529	0.532	0.675	0.709
2006 - 12 - 15	0.651	0.797	0.901	0.886
2006 - 11 - 16	0.629	0.676	0.780	0.713
2006 - 02 - 04	0.635	0.691	0.732	0.639
2006 - 02 - 01	0.635	0.691	0.732	0.639
2002 - 12 - 16	0.814	0.804	0.794	0.848
1999 - 03 - 03	0.654	0.709	0.661	0.643
1998 - 11 - 25	0.629	0.705	0.741	0.667
1998 - 02 - 21	0.598	0.710	0.710	0.694
1998 - 02 - 12	0.659	0.637	0.637	0.627
1998 - 02 - 07	0.610	0.685	0.667	0.658
1997 - 10 - 04	0.639	0.620	0.629	0.597
1997 - 01 - 01	0.850	0.852	0.792	N/A
1996 - 02 - 21	0.669	0.530	0.551	N/A
1992 - 01 - 31	0.691	0.662	0.658	N/A
1992 - 01 - 28	0.664	0.650	0.658	N/A
1987 - 12 - 09	0.662	0.626	0.658	N/A
1987 - 12 - 01	0.654	0.685	0.722	N/A
1987 - 11 - 17	0.727	0.730	0.670	N/A
1983 - 11 - 11	0.756	0.655	0.648	N/A
1983 - 02 - 12	0.668	0.582	0.583	N/A
1983 - 01 - 27	0.860	0.858	0.754	N/A
1982 - 12 - 19	0.826	0.749	0.720	N/A
1981 - 11 - 15	0.760	0.667	0.683	N/A
1980 - 01 - 12	0.649	0.723	0.651	N/A

Comparison of Total Water Level and Storm Surge induced 1996 White Christmas Snowstorm

Observed Data
Model Prediction

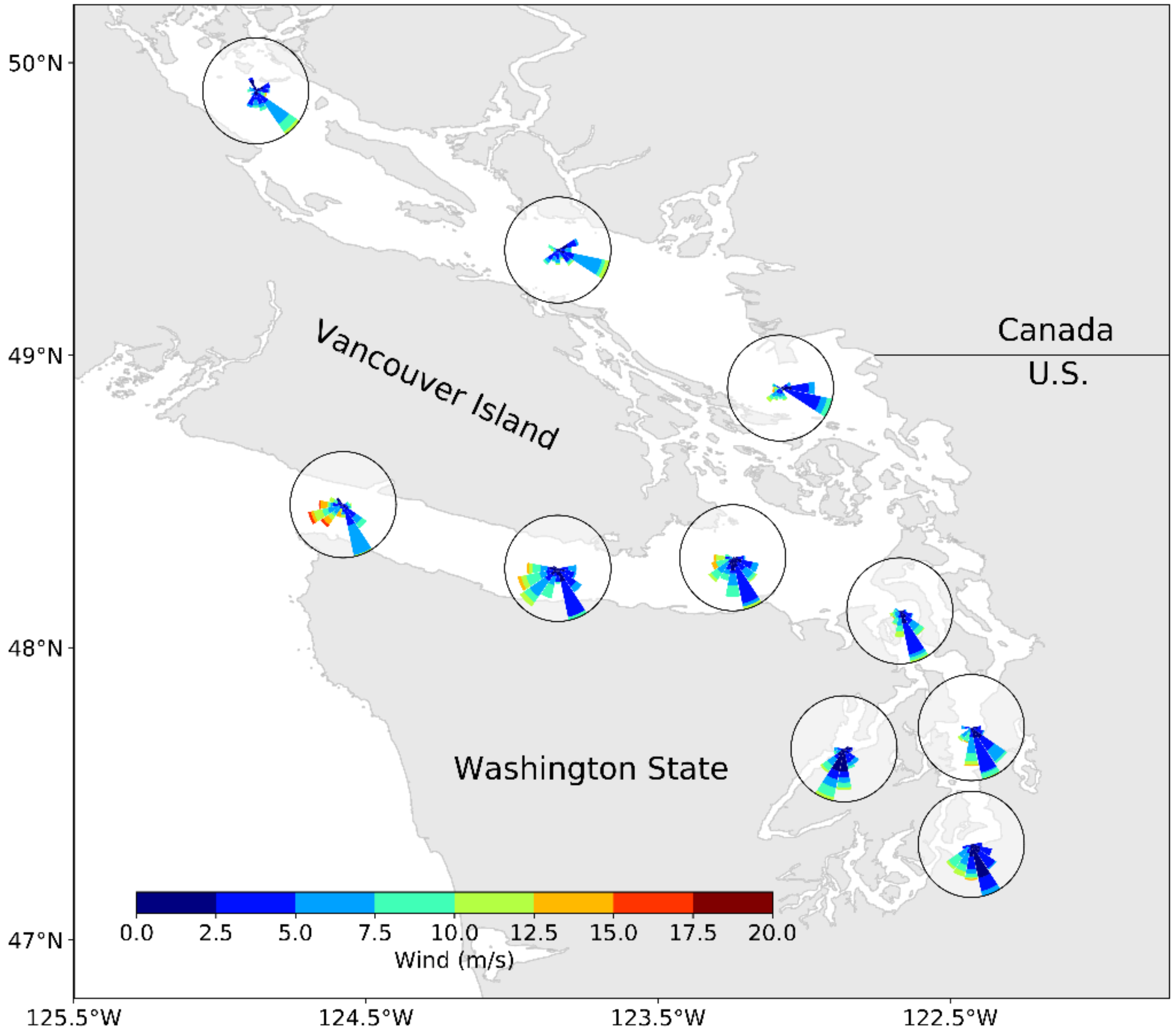


Simulated Total Water Level induced by 1996 White Christmas Snowstorm

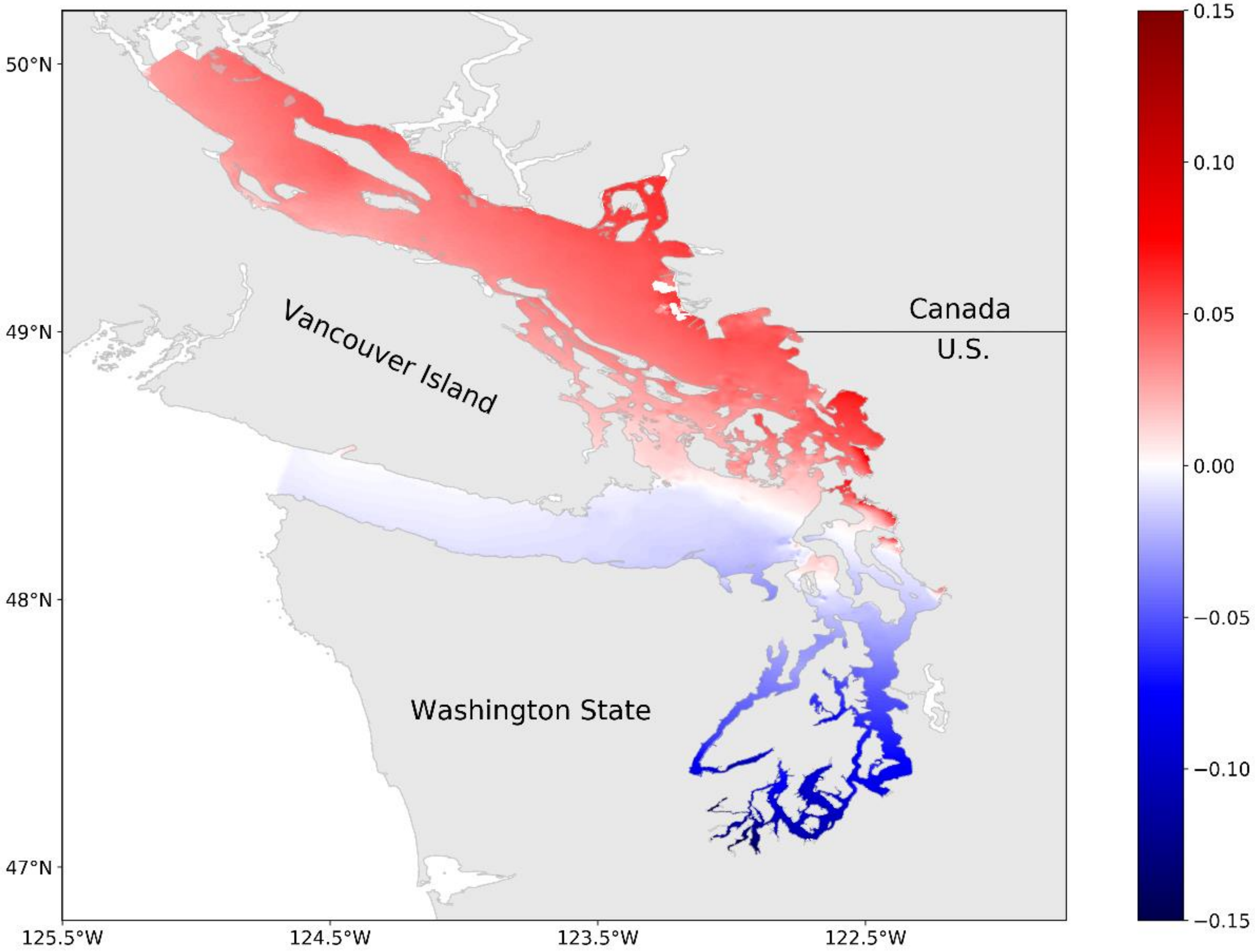


Sensitivity Analysis of Local Wind Effect – 1996 White Christmas Snowstorm

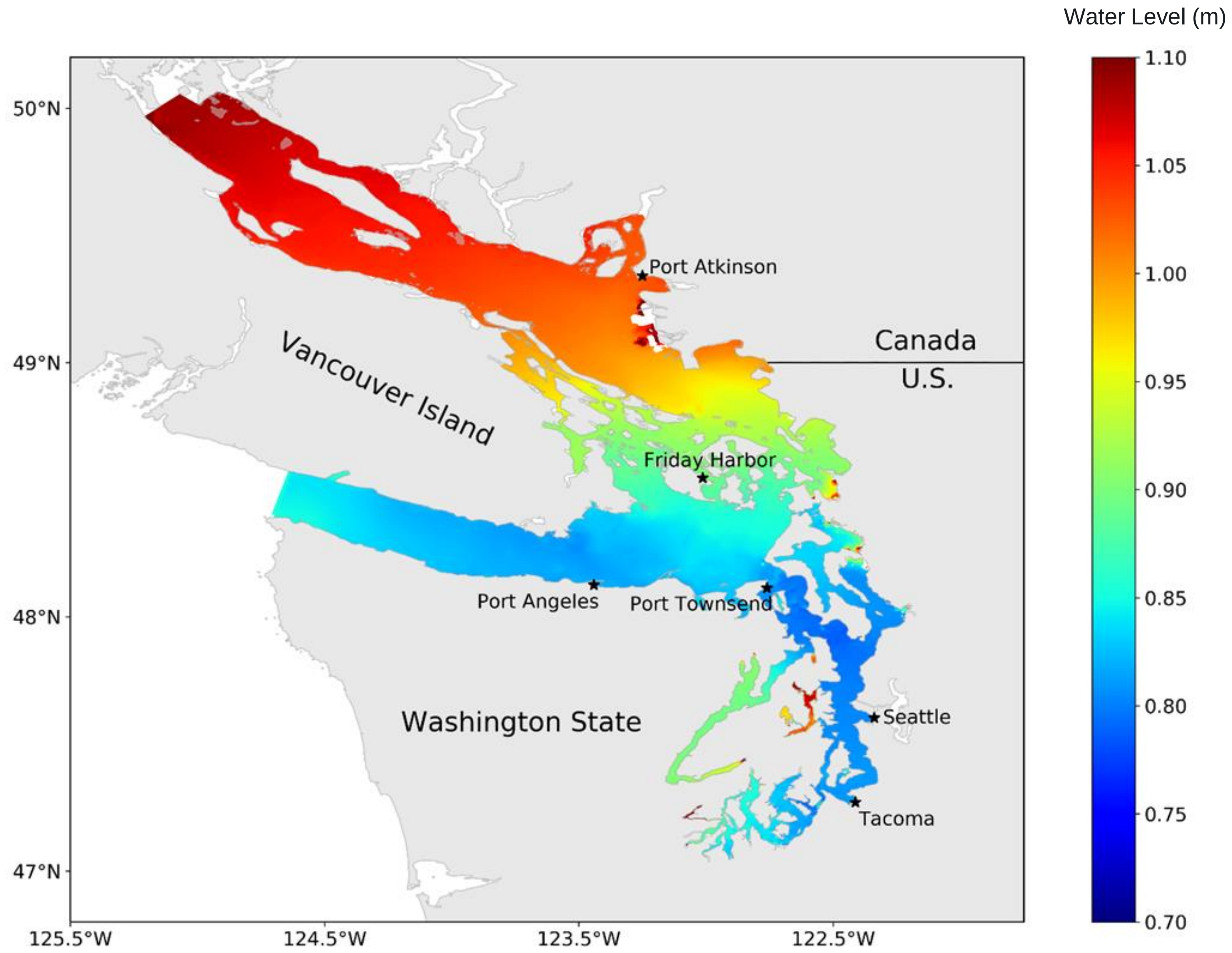
Wind rose distribution during the storm event



Water level difference with and without wind



Maximum Storm Surge Height in the Salish Sea based on 34 Simulated Storm Surge Events



Conclusions

- Waves in the Strait of Juan de Fuca (SJDF) are dominated by long-period swells generated remotely in the Pacific Ocean
- In the Strait of Georgia and Puget Sound, waves are dominated by local wind in the direction oriented to the main channel
- Waves in Puget Sound are small and primarily contributed by wind-sea with peak periods < 5 s and maximum significant wave heights < 2.0 m
- Storm surge in the Salish Sea is primarily controlled by remote surge from the Pacific Ocean and further modulated by local wind forcing
- The largest storm surge occurs in the Strait of Georgia (1.03 m) and smallest surge in the Strait of Juan de Fuca and Main Basin of Puget Sound (0.8 m)
- Contribution of local wind to storm surge height is less than 20%

Thank You!

Contact: Dr. Zhaoqing Yang
Pacific Northwest National Laboratory
zhaoqing.yang@pnnl.gov
(206)528-3057

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Peer-reviewed publications and study report can be downloaded from:

- *Yang et al. (2020) Modeling assessment of storm surge in the Salish Sea, Estuarine, Coastal and Shelf Science, 238; https://doi.org/10.1016/j.ecss.2019.106552*
- *Yang et al. (2019). Modeling analysis of the swell and wind-sea climate in the Salish Sea. ECSS, 224, 289-300; https://doi.org/10.1016/j.ecss.2019.04.043*
- *Miller et al. (2019). Extreme Coastal Water Level in Washington State: Guidelines to Support Sea Level Rise Planning. A collaboration of WSG, UW-CIG, OSU,UW, PNNL and USGS. Prepared for the Washington Coastal Resilience Project. https://cig.uw.edu/news-and-events/publications/extreme-coastal-water-level-in-washington-state-guidelines-to-support-sea-level-rise-planning/*