

Storm Surge Modeling in the Salish Sea

Zhaoqing Yang^{1,2}, Taiping Wang¹ and Ian Miller³

¹ Marine Sciences Laboratory, PNNL

² Civil and Environmental Engineering, UW

³ Washington Sea Grant, UW

NW Climate Conference

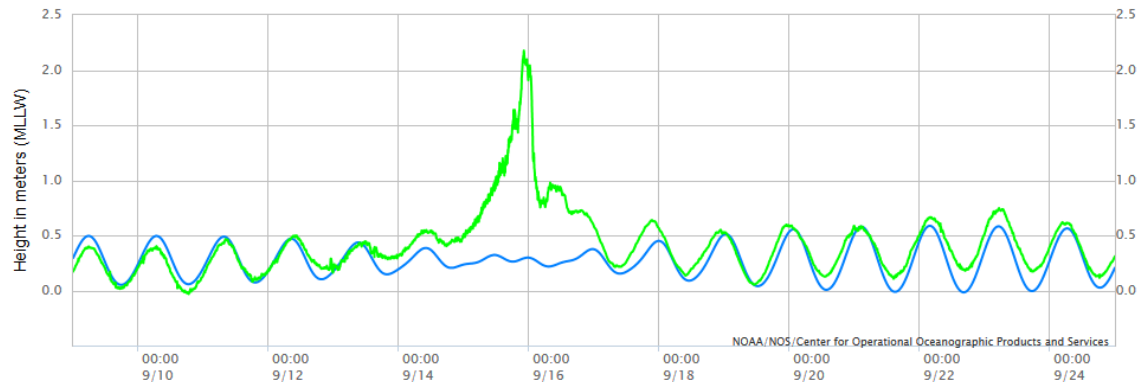
October 10, 2017

Tacoma, WA

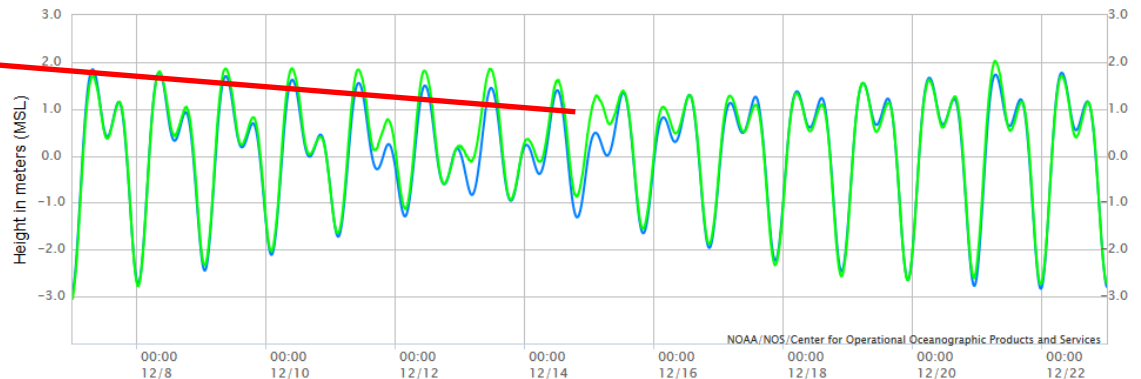
Storm Surge and High Water Level in PNW

- ▶ Windstorms - Mid-latitude extra-tropical cyclones
 - Wind speed ~ Category 3 hurricanes
- ▶ Large tidal range
 - Salish Sea > 4 m
 - GoM < 0.5 m
- ▶ Consider non-tidal residual (NTR)

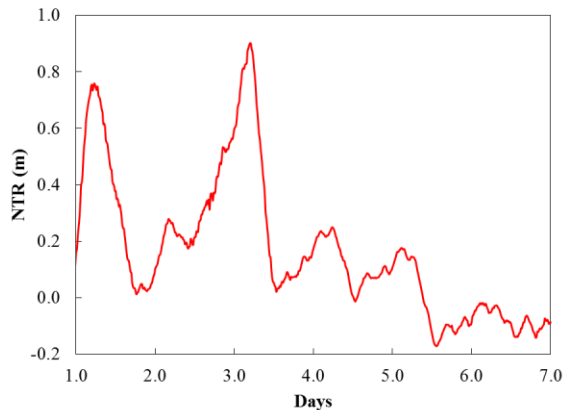
Dauphin Island, AL – Hurricane Ivan (2004)



Seattle, WA - Hanukkah Eve Windstorm of 2006

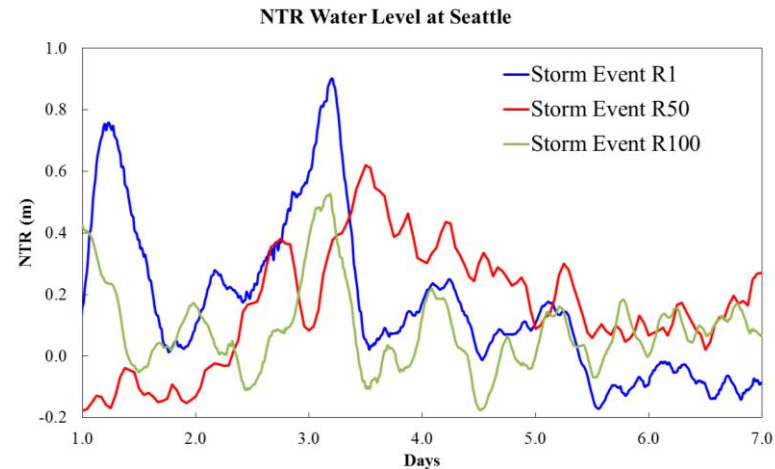


Non-Tidal Residual Water Level



Storm Surge Modeling Approach

- ▶ Storm events for the period of 1960 – 2016
 - Based on the maximum observed non-tidal residual (NTR) at Seattle tidegauge
 - 490 high NTR events were identified



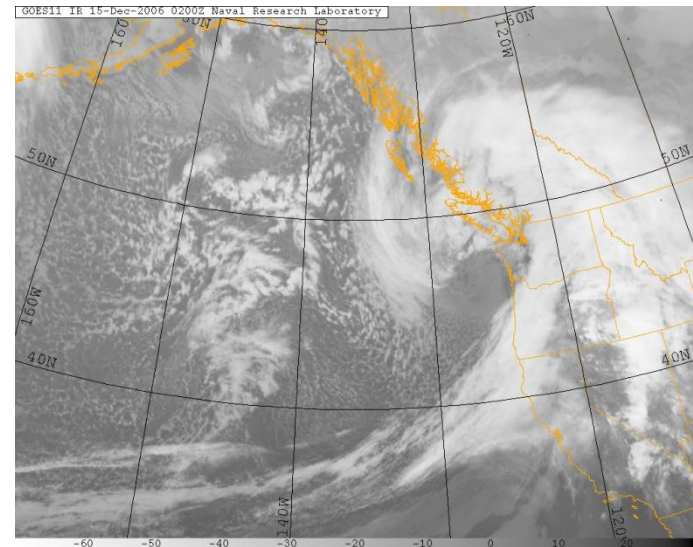
- ▶ Storm surge simulations
 - PNNL's Salish Sea Model
 - Model validation with observed tidal and non-tidal water levels
- ▶ Model forcing
 - Observed water levels at Neah Bay and Campbell River
 - Surface wind and air pressure - **Climate Forecast System Reanalysis (CFSR); NARR, observed wind**



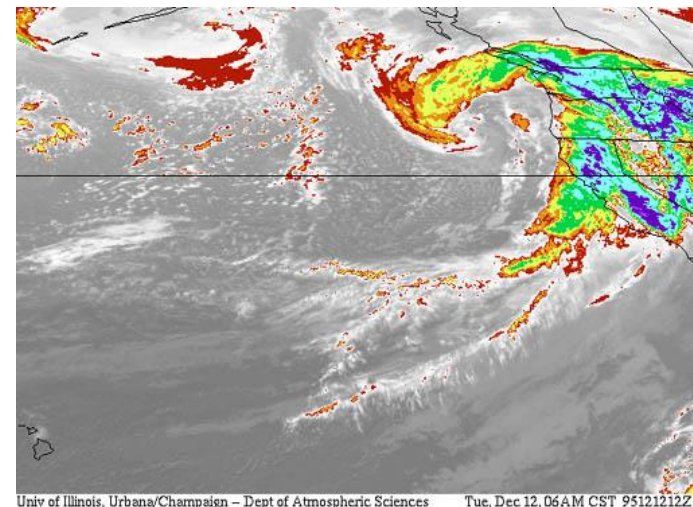
Top 10 NTR Storm Surge Events (Seattle)

Rank (NTR)	Time
1	12/15/2006 13:00
2	12/13/2015 5:00
3	1/18/2010 19:00
4	12/16/2002 14:00
5	1/1/1997 16:00
6	11/16/2006 4:00
7	1/27/1983 12:00
8	12/12/1995 22:00
9	11/25/1998 11:00
10	12/11/2014 20:00

Hanukkah Eve Windstorm (2006)

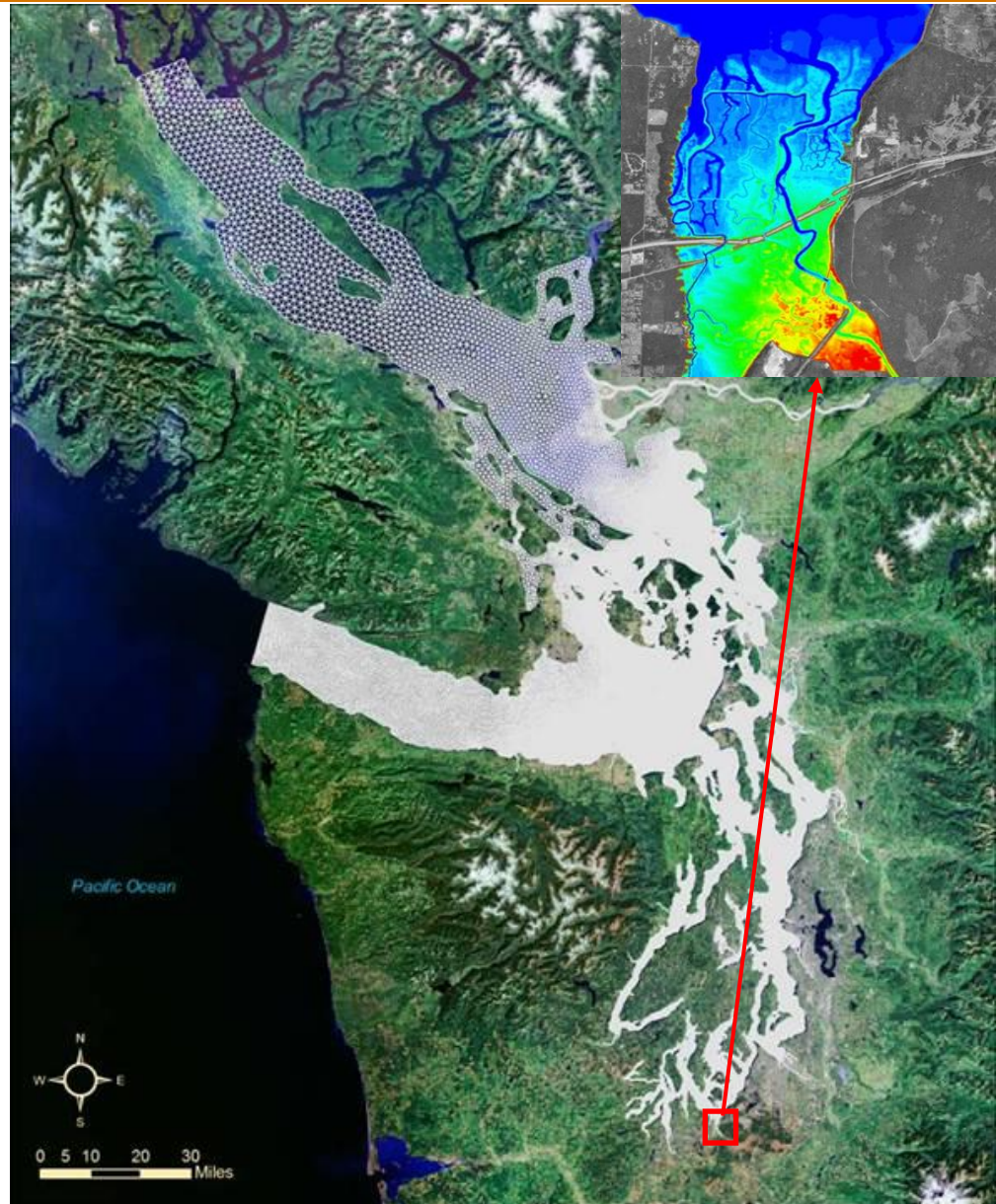


December 1995 Windstorm

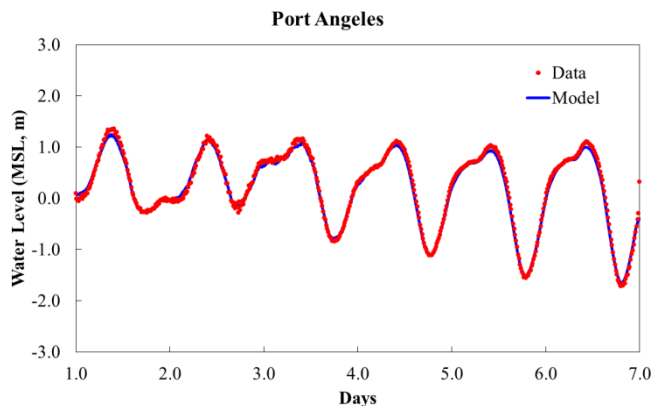
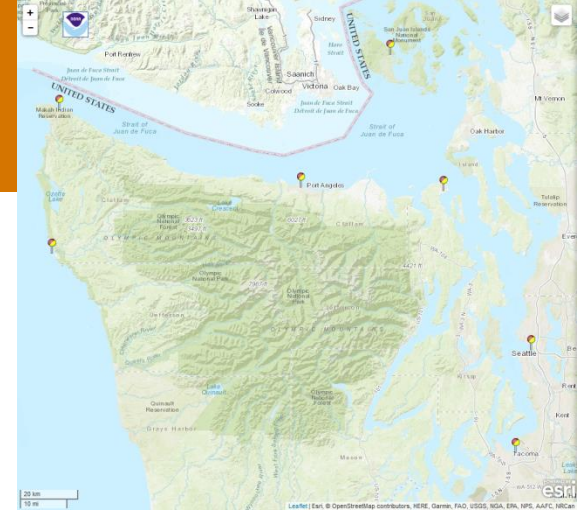


PNNL's Salish Sea Model - FVCOM

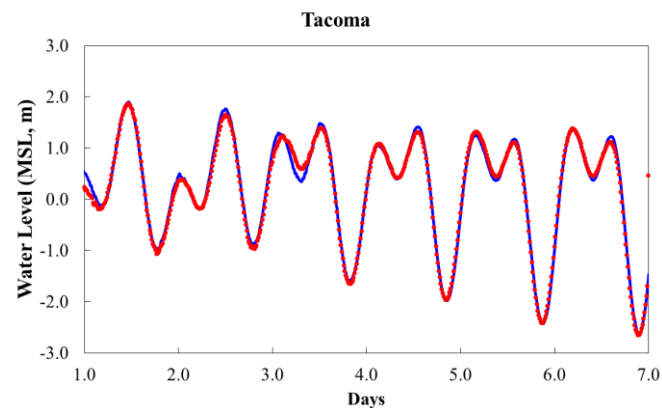
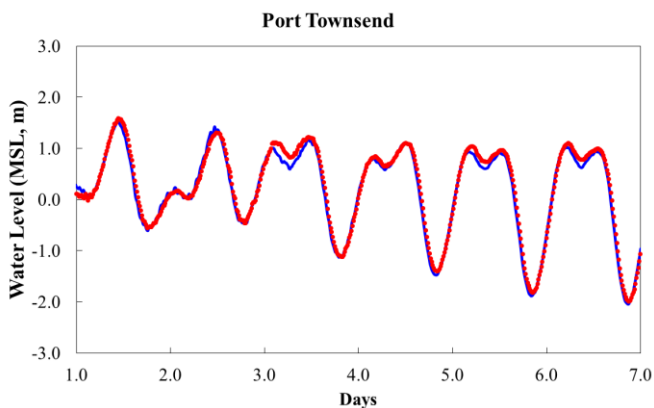
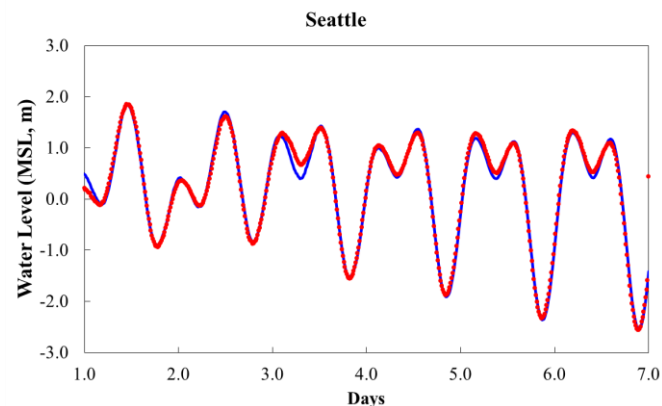
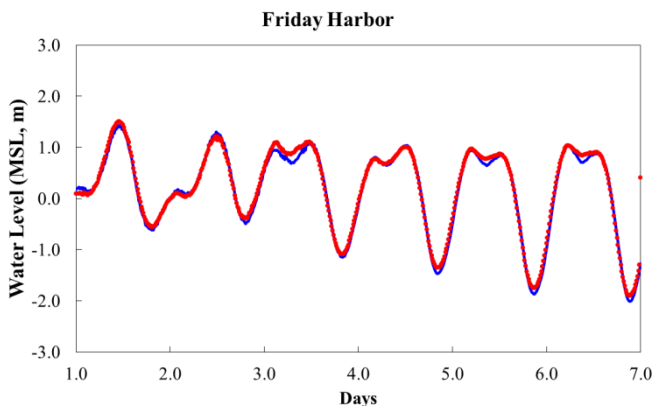
- ▶ Unstructured-grid, finite-volume community ocean model (FVCOM)
- ▶ Extensively used to simulate tides, coastal circulations, storm surge, waves, and tidal energy in Salish Sea
- ▶ Model runs on PNNL's high performance computing system



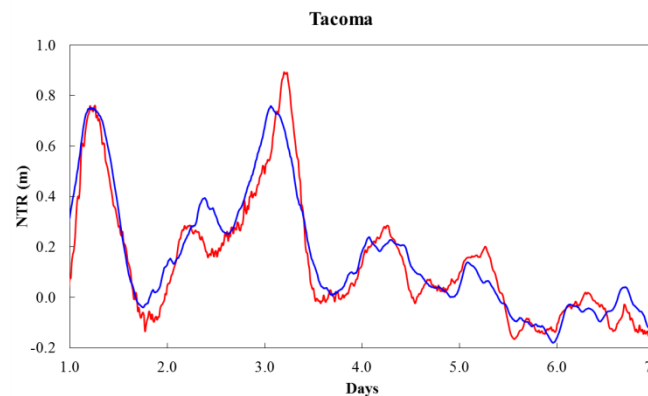
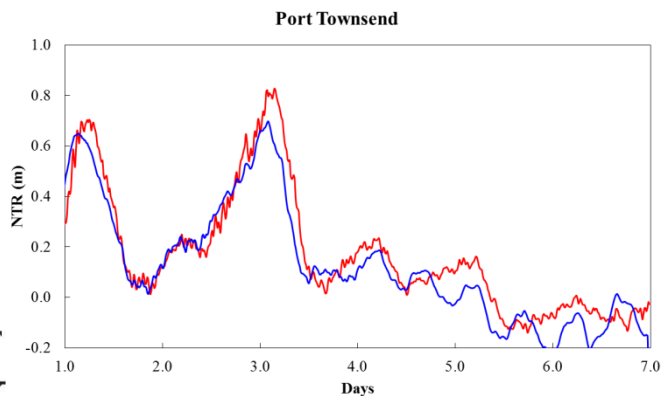
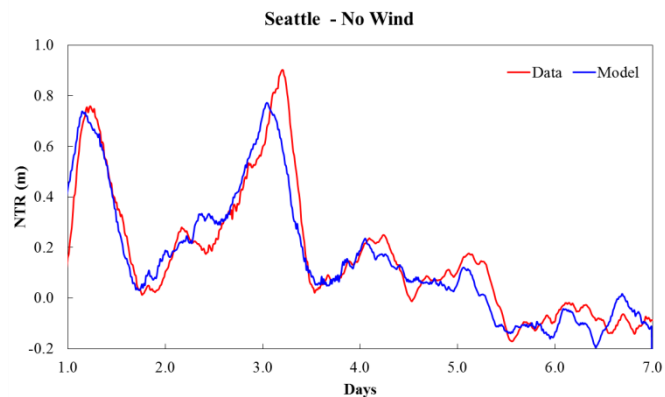
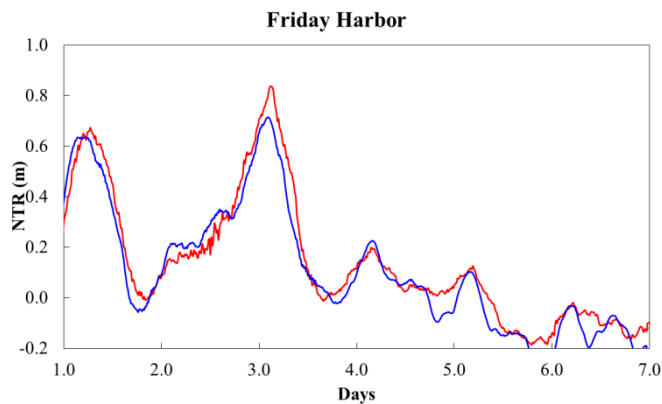
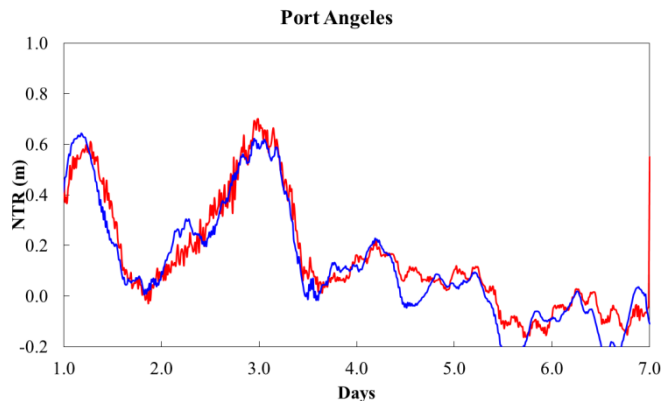
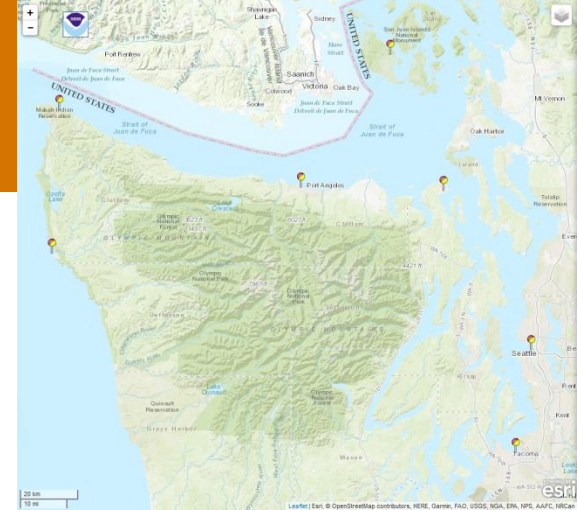
Comparison of Simulated and Observed WL for Event R1



• Data
— Model

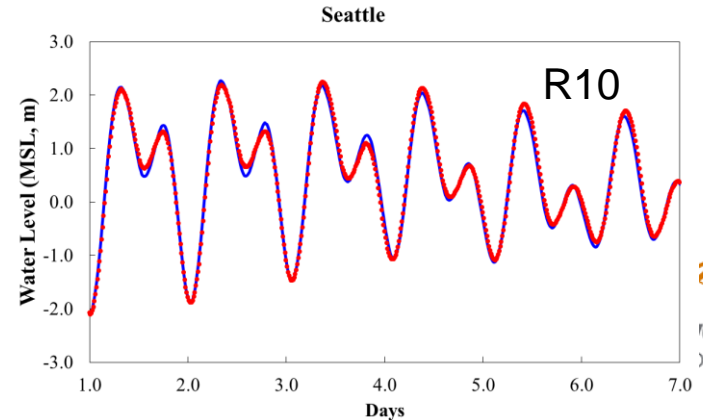
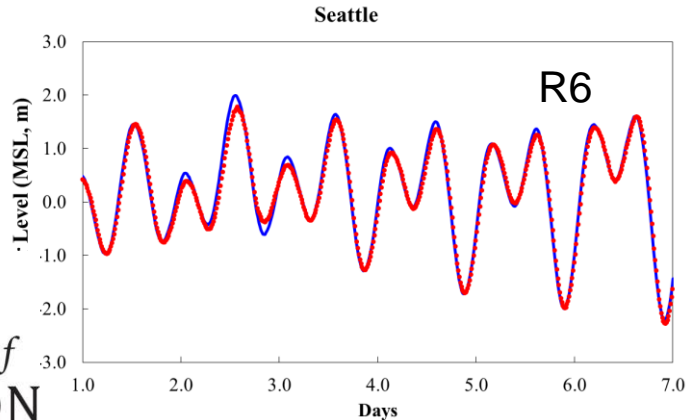
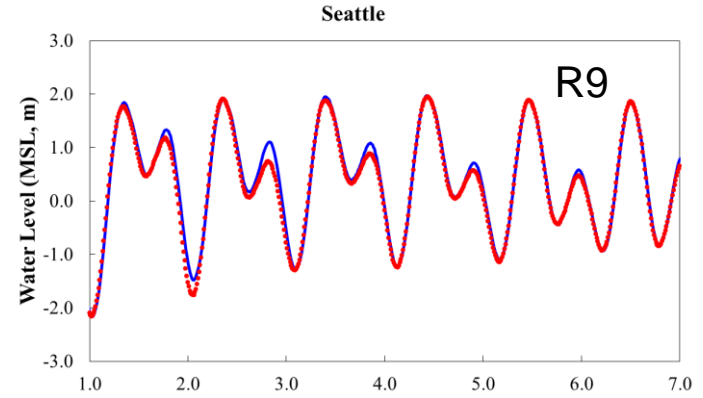
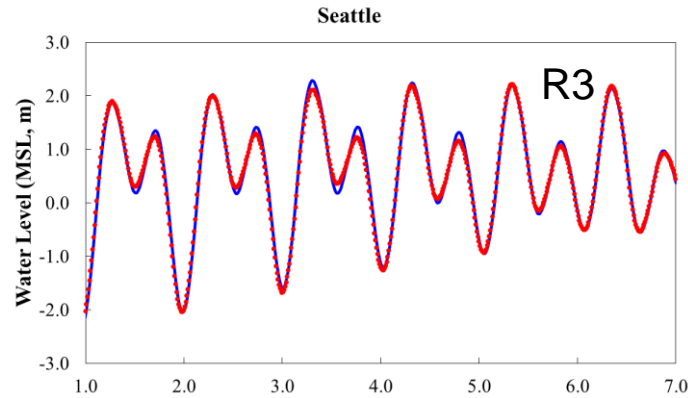
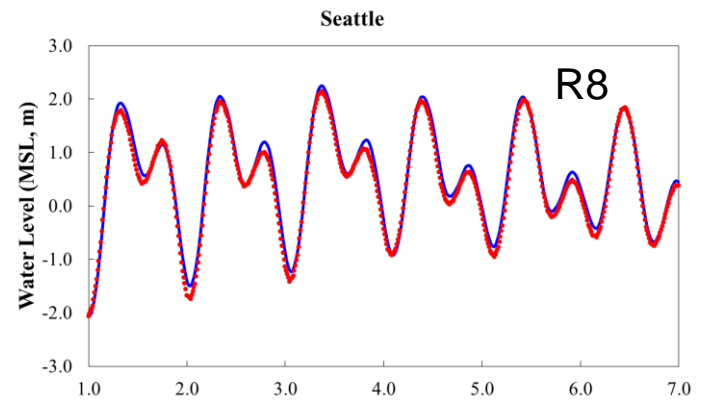
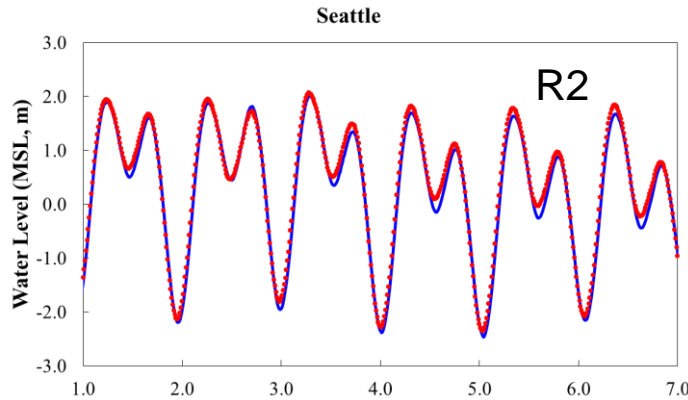


Comparison of Simulated and Observed NTR for Event R1



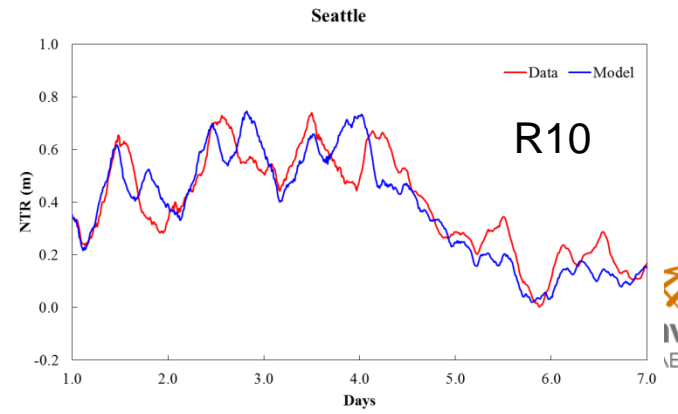
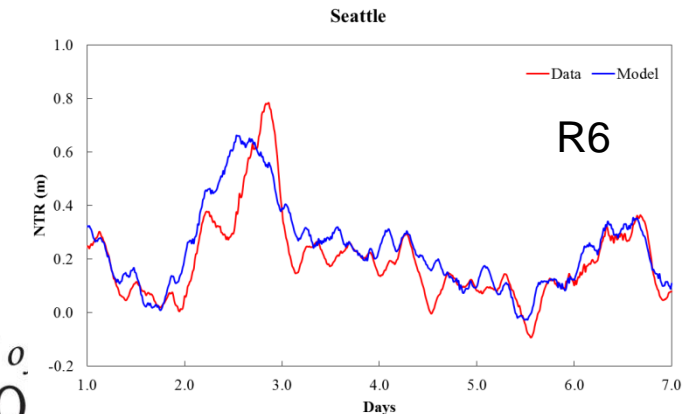
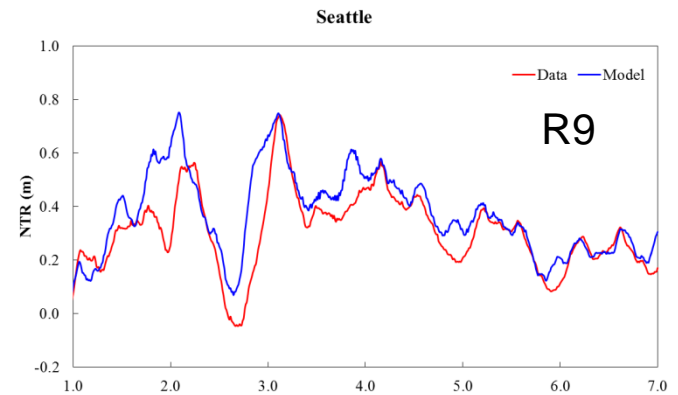
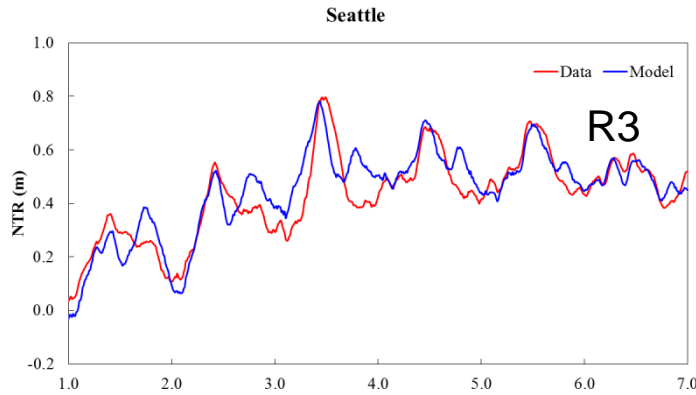
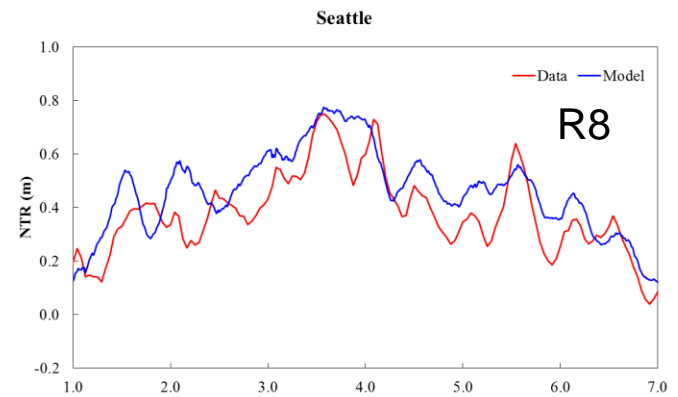
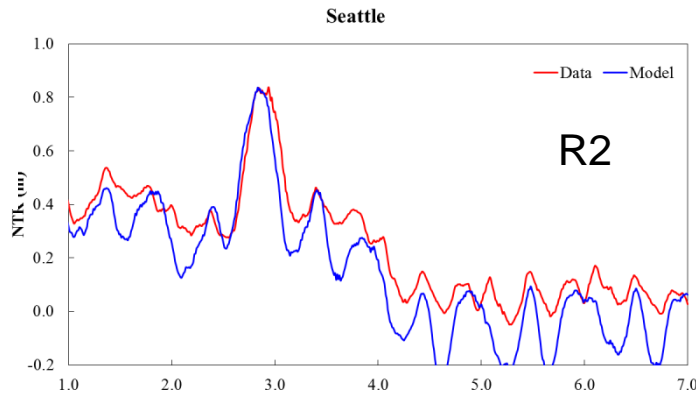
Comparisons of Simulated and Observed WL at Seattle for Event R2 – R10

• Data
— Model



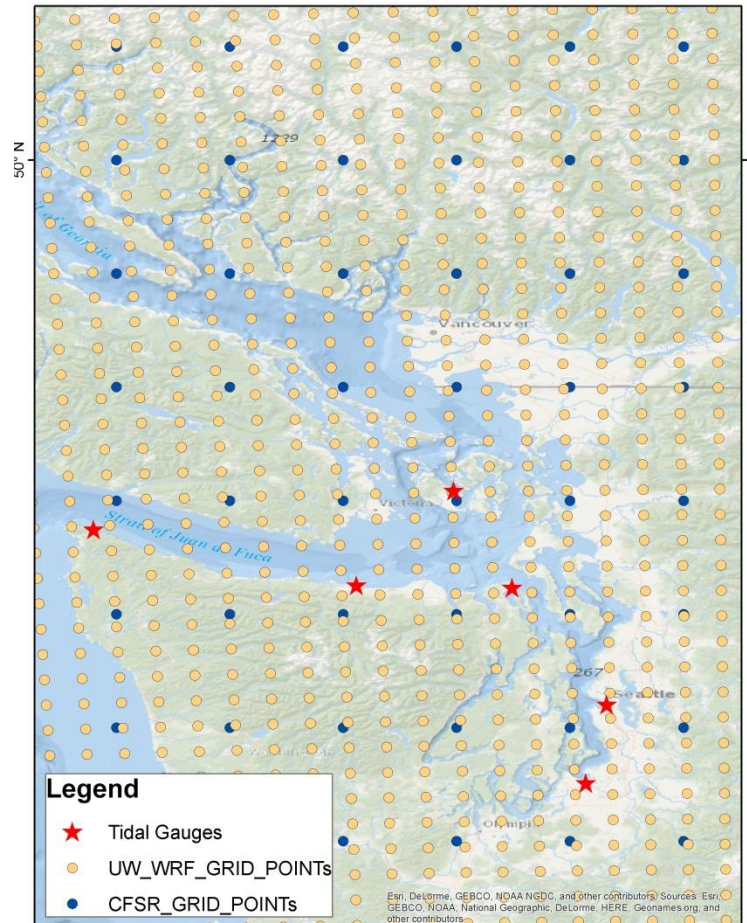
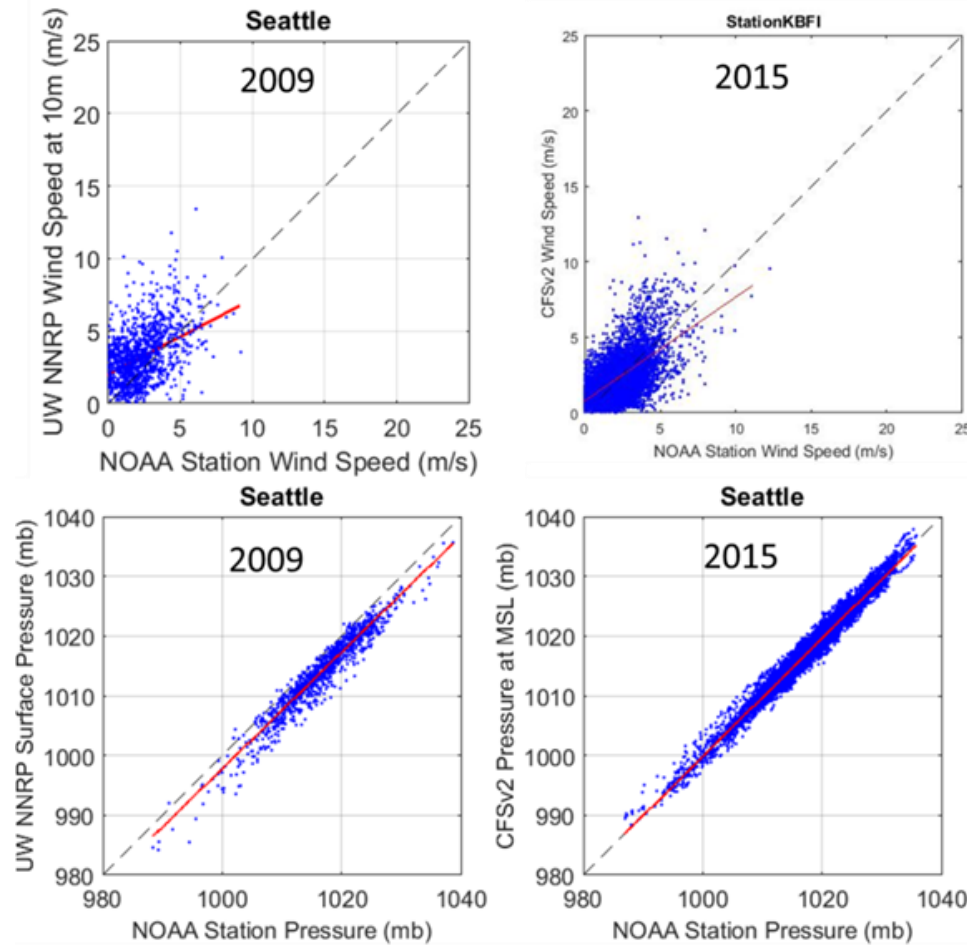
Comparisons of Simulated and Observed NTR at Seattle for Event R2 – R10

• Data
— Model



Consideration of Wind and Air Pressure

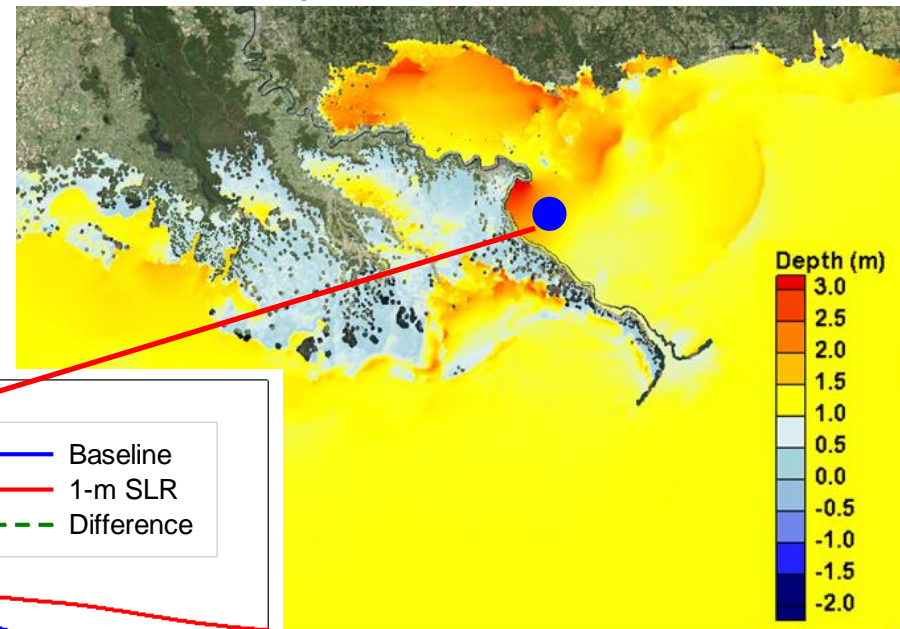
- ▶ High spatial and temporal resolution
- ▶ Long-term record (1960 – present)



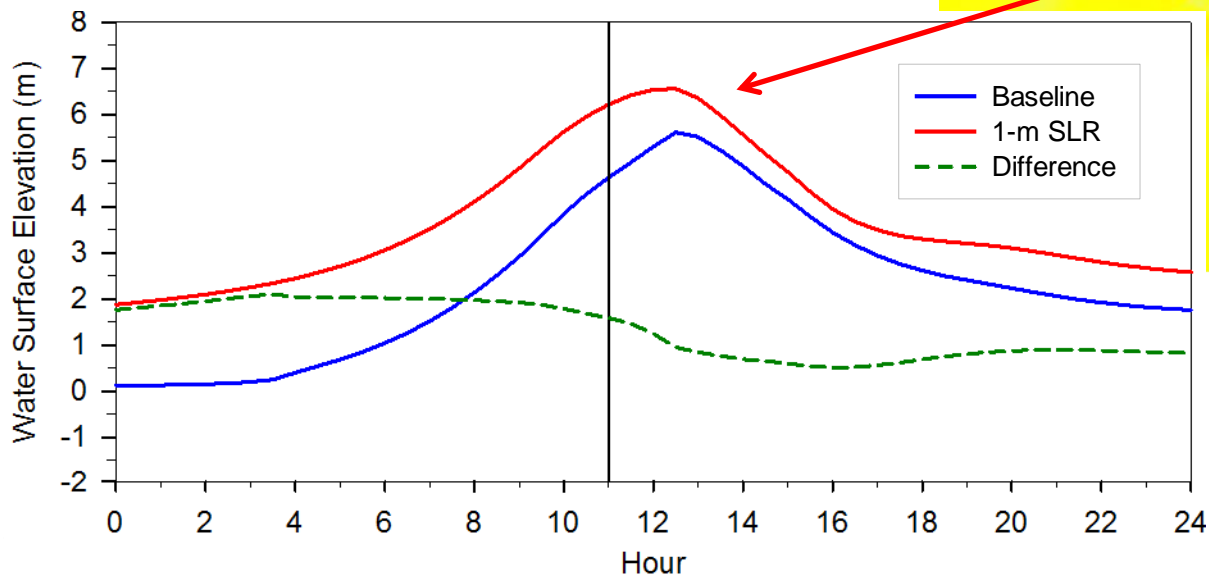
Effect of Sea Level Rise on Storm Surge

- ▶ Nonlinear effect: combined water level \neq surge + SLR
- ▶ SLR will exacerbate coastal inundation and storm surge height.

Simulated change of inundation depth due to SLR during Hurricane Katrina landfall



Simulated storm surge induced by Hurricane Katrina and SLR



From Yang *et al.* (2013)

Conclusions and Next Steps

- ▶ Non-tidal residual water level (NTR) should be used to quantify storm surge in Puget Sound
- ▶ Preliminary results indicate the Salish Sea Model can successfully simulate storm surge in Puget Sound
- ▶ Storm surge in Puget Sound is dominated by surge at the entrance of the Strait of Juan de Fuca
- ▶ Nest steps
 - Improve model performance with wind forcing
 - Complete model simulations (>100 events)
 - Evaluate model skill with a set of error statistics
 - Maximum water level analysis and mapping





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Thank you!

Zhaoqing Yang

Pacific Northwest National Laboratory

zhaoqing.yang@pnnl.gov

206-528-3057