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A High-resolution Tidal Hydrodynamic Model for Sequim Bay, WA to Support Marine Renewable Energy Research

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Introduction

Marine renewable energy (e.g., tidal current and wave energy) is a developing set of resources with the potential to provide power to the utility grid or to remote coastal and ocean-based applications. Due to high tidal energy potential, the Salish Sea has been identified among the top candidate sites in the U.S. for tidal energy development. To support a variety of marine energy related research and development activities, Pacific Northwest National Laboratory's Marine and Coastal Research Laboratory (MCRL) has been preparing Sequim Bay as a testbed for researchers to utilize its unique tidal and geographic setting for pilot-scale tidal energy, ocean technology, and environmental monitoring research. This poster summarizes our work in developing a high-resolution tidal hydrodynamic model for Sequim Bay, which provides essential hydrodynamic information to marine energy researchers.

Methods

Study Site: Sequim Bay, WA is a small tidal inlet-bay located on the Olympic Peninsula and connects to the Strait of Juan de Fuca through a narrow entrance (Fig. 1). PNNL's MCRL, the U.S. DOE's coastal research facility, is located at the entrance of Sequim Bay.

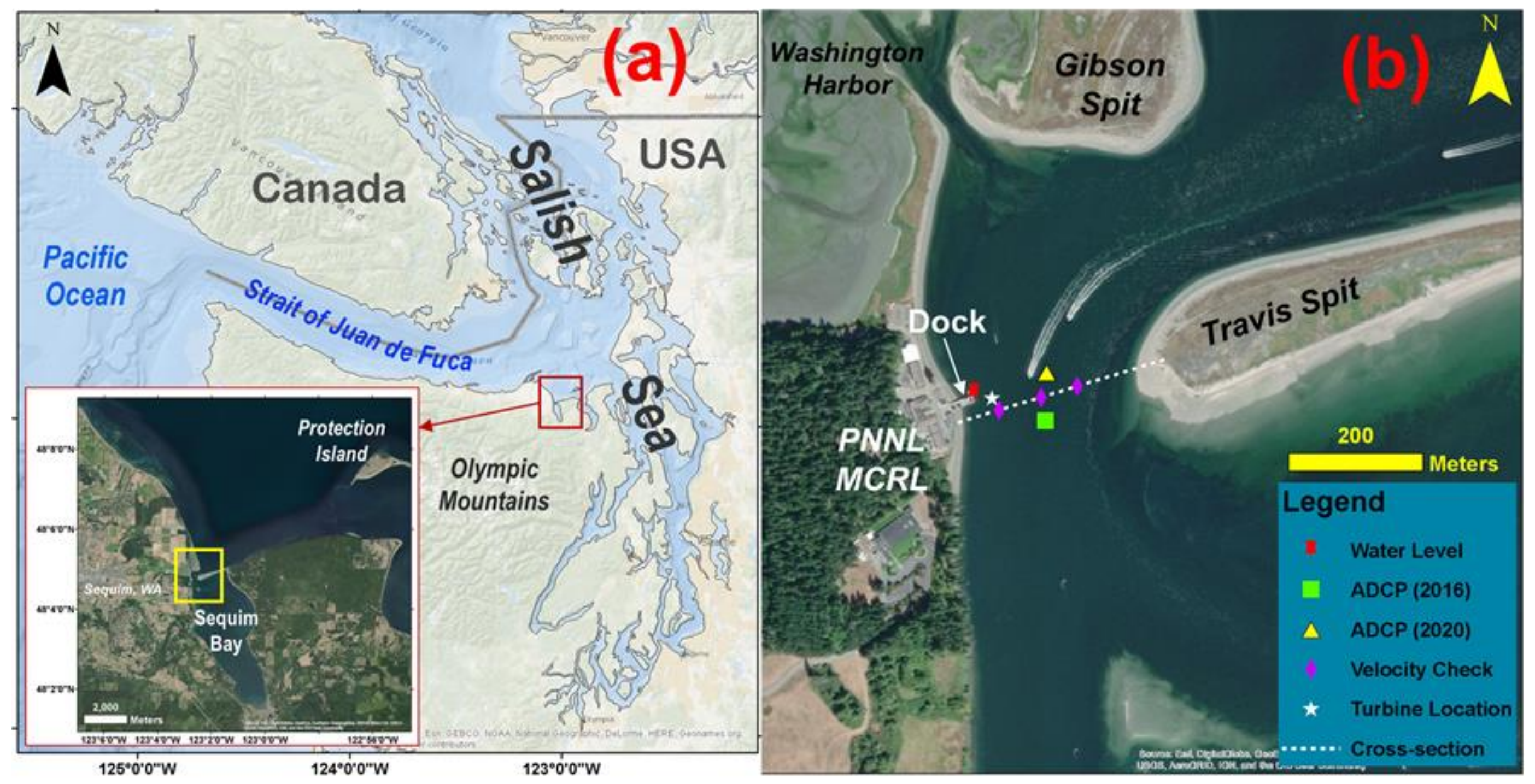

Fig.1. Sequim Bay, WA in the Strait of Juan de Fuca of the Salish Sea (a) and water level and velocity stations in the entrance of Sequim Bay (b).

Model Configuration: The model is based on the Finite Volume Community Ocean Model (FVCOM, Chen et al., 2003). Key model configuration:

- Grid resolution: <10 m in the inlet to >500 m at open boundary
- Open boundary forcing is derived from the Salish Sea hydrodynamic model (Yang et al., 2021)
- Meteorological forcing: real-time observations at MCRL dock
- The model is configured in the 3-D mode with 10 sigma layers

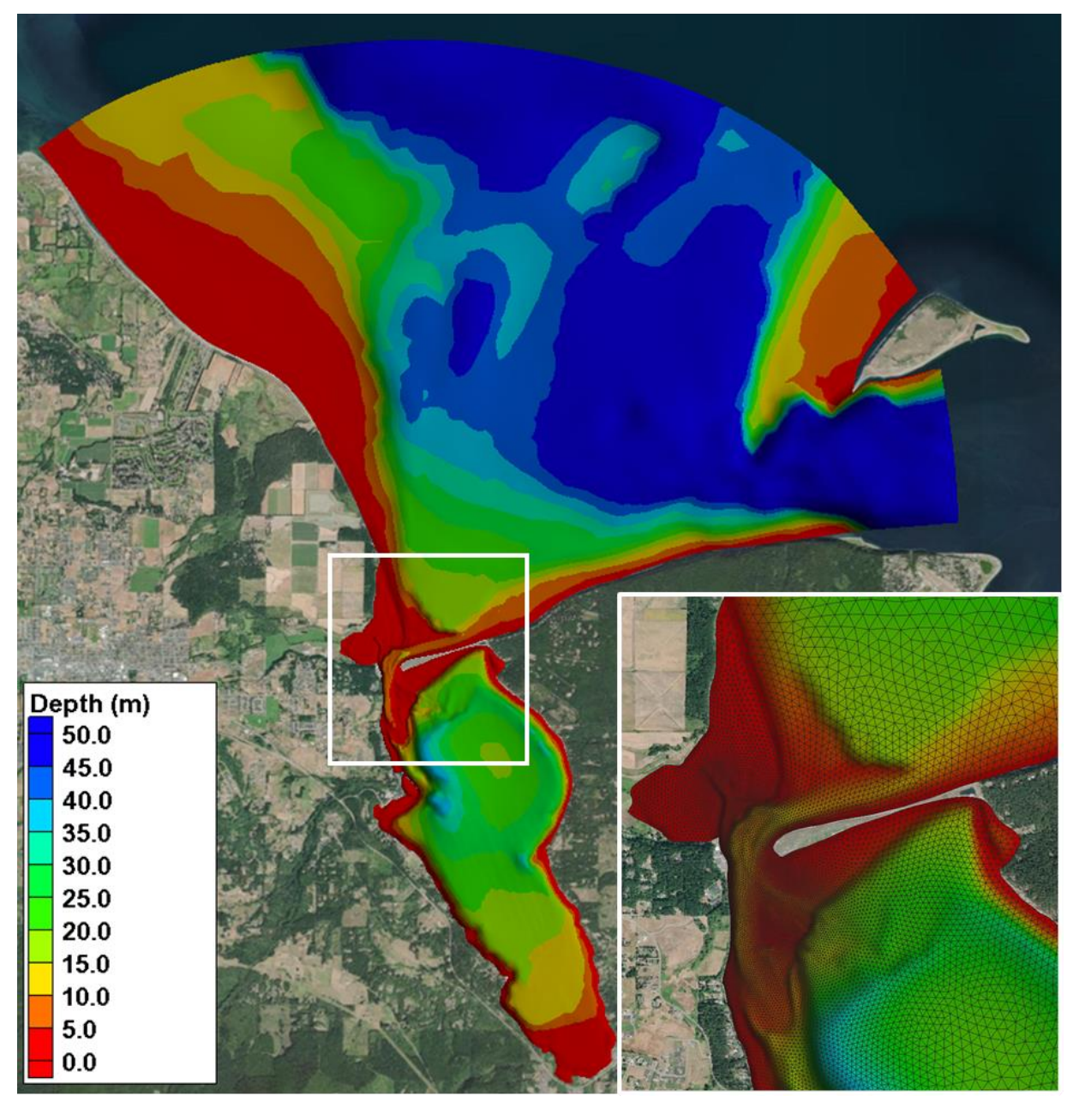

Fig.2. Sequim Bay hydrodynamic model grid and bathymetry.

Results

Model Calibration and Validation: The model results for water level and velocity were compared with field data during two sampling periods in Years 2016 and 2020, respectively. The example comparisons of time series, tidal harmonic constituents, 2-D velocity profiles are presented below. Overall, model predictions match the data very well (Table 1).

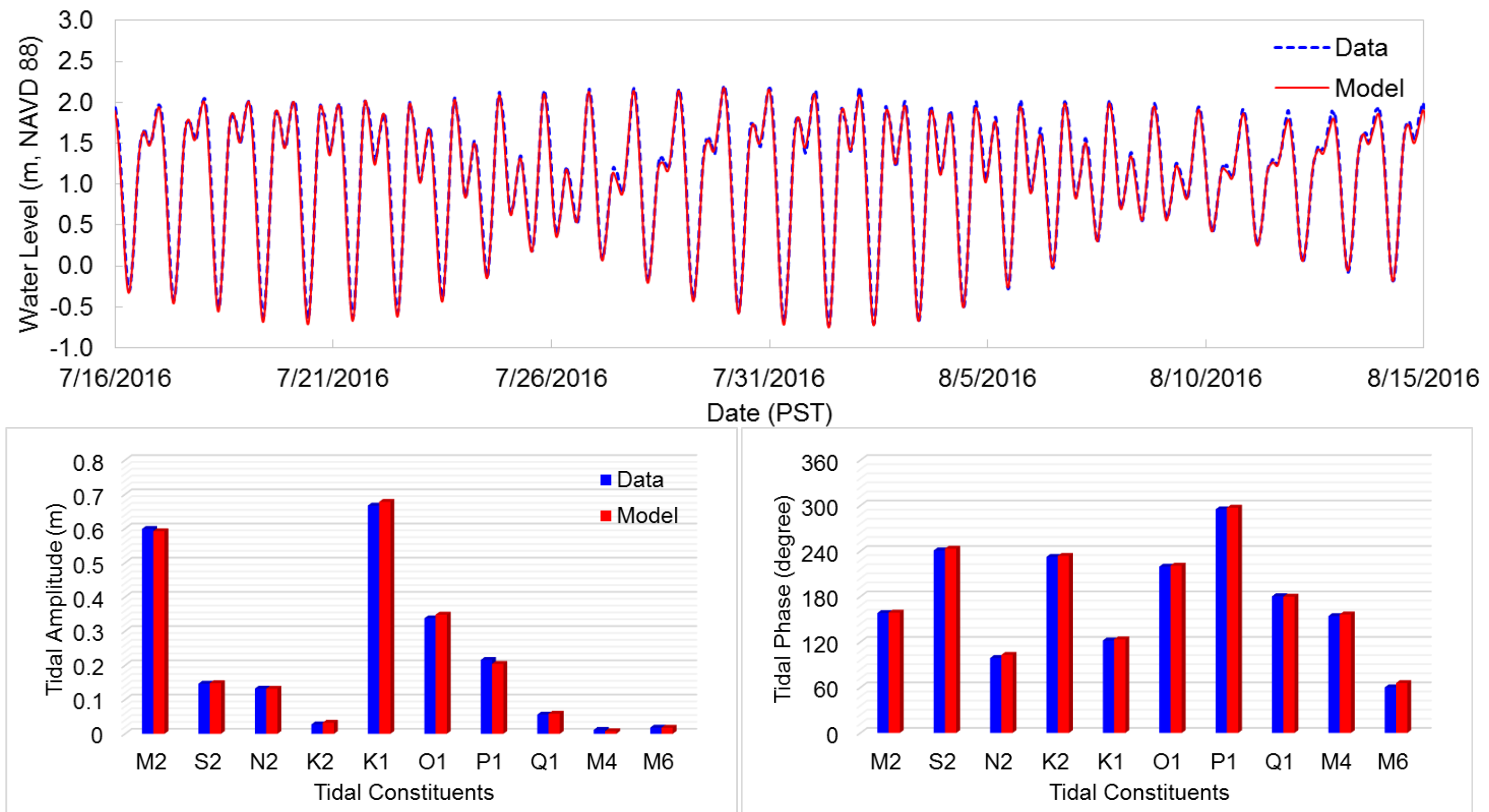

Fig. 3. Model-data comparisons for water level in 2016 (Top – time series; Bottom – harmonic constituents).

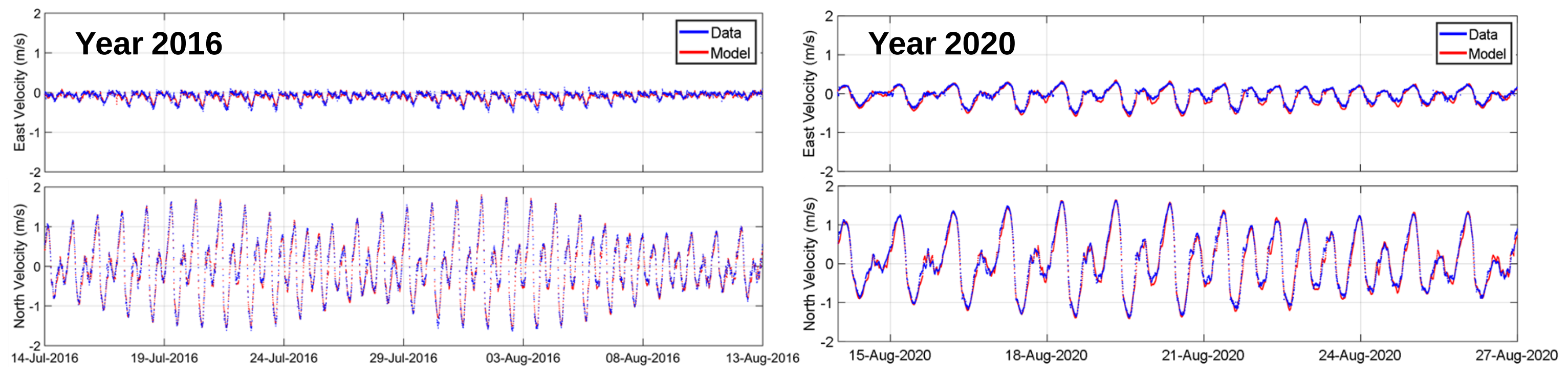

Fig. 4. Model-data comparisons for depth-averaged velocity time series.

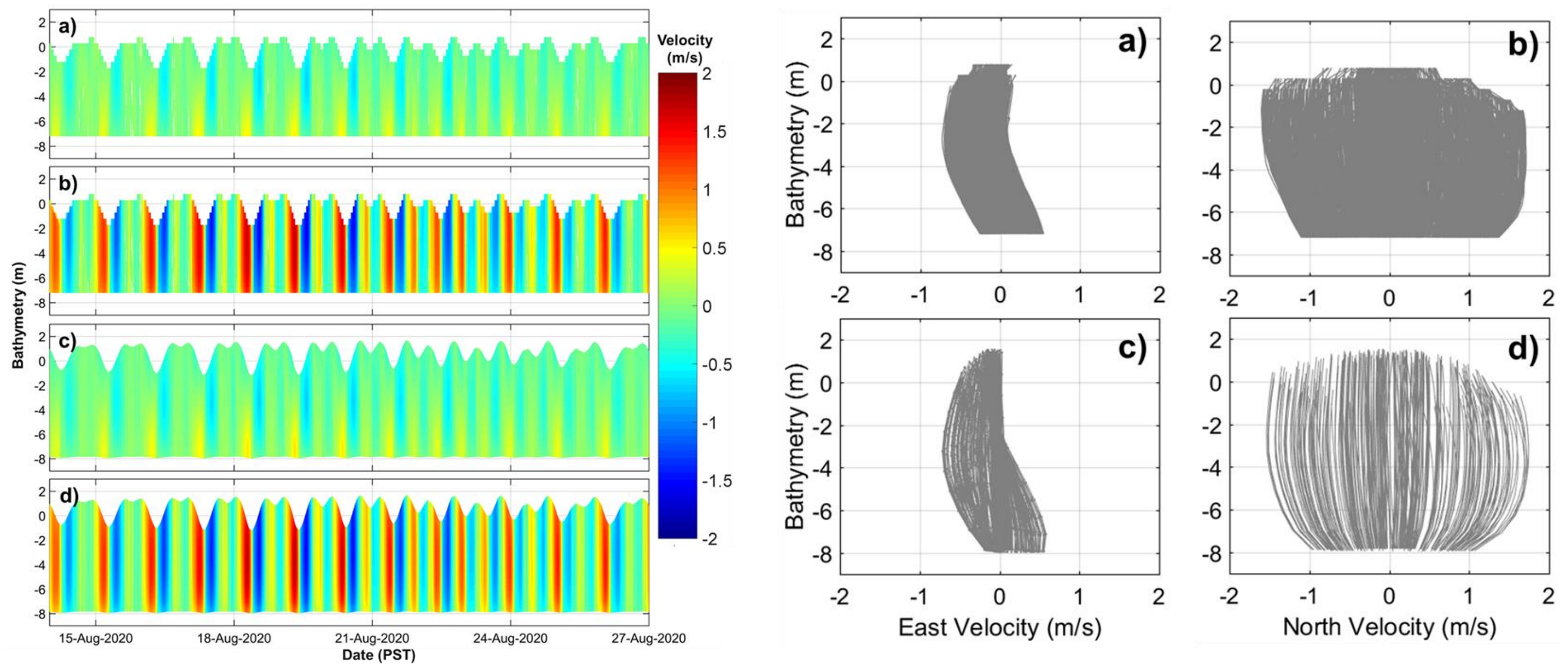

Fig. 5. Velocity profile comparisons between model and data for u and v components (a, b – measured u and v velocity; c, d – modeled u and v velocity).

Table 1. Error statistics for water level and velocity.

Year	Error Statistics	East Velocity	North Velocity	Water Level
2016	RMSE (m/s)	0.064	0.121	0.110
	R	0.831	0.987	0.990
2020	RMSE (m/s)	0.062	0.113	0.074
	R	0.967	0.988	0.996

Model predicted tidal current and power density distributions: The validated model can be used to characterize the spatial and temporal distributions of tidal currents and power density in Sequim Bay to help identify suitable locations for testing environmental monitoring and tidal energy converter devices.

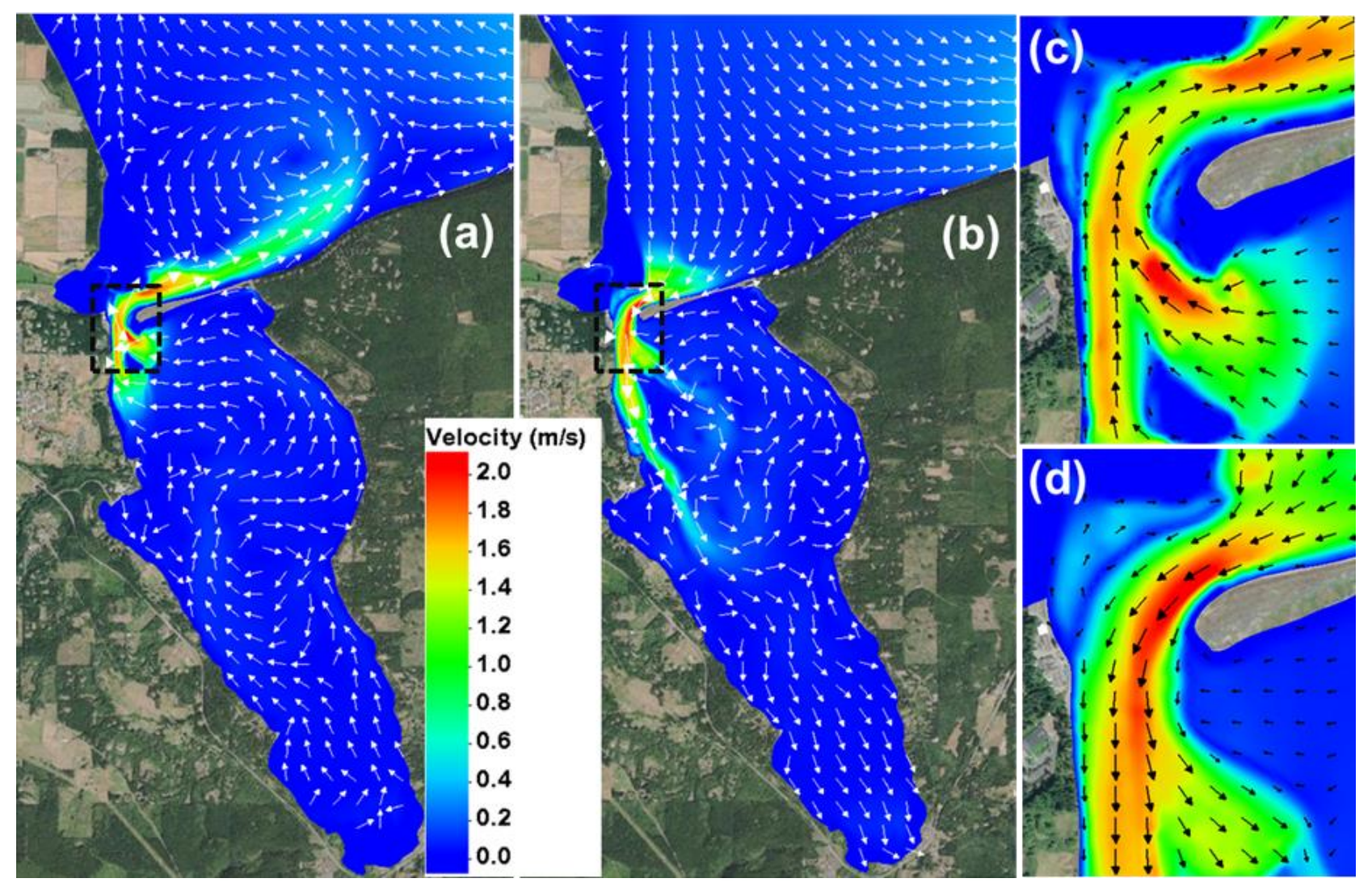

Fig. 6. Depth-averaged ebb (a,c) and flood (b,d) currents in Sequim Bay, showing strong tidal currents near Sequim Bay entrance.

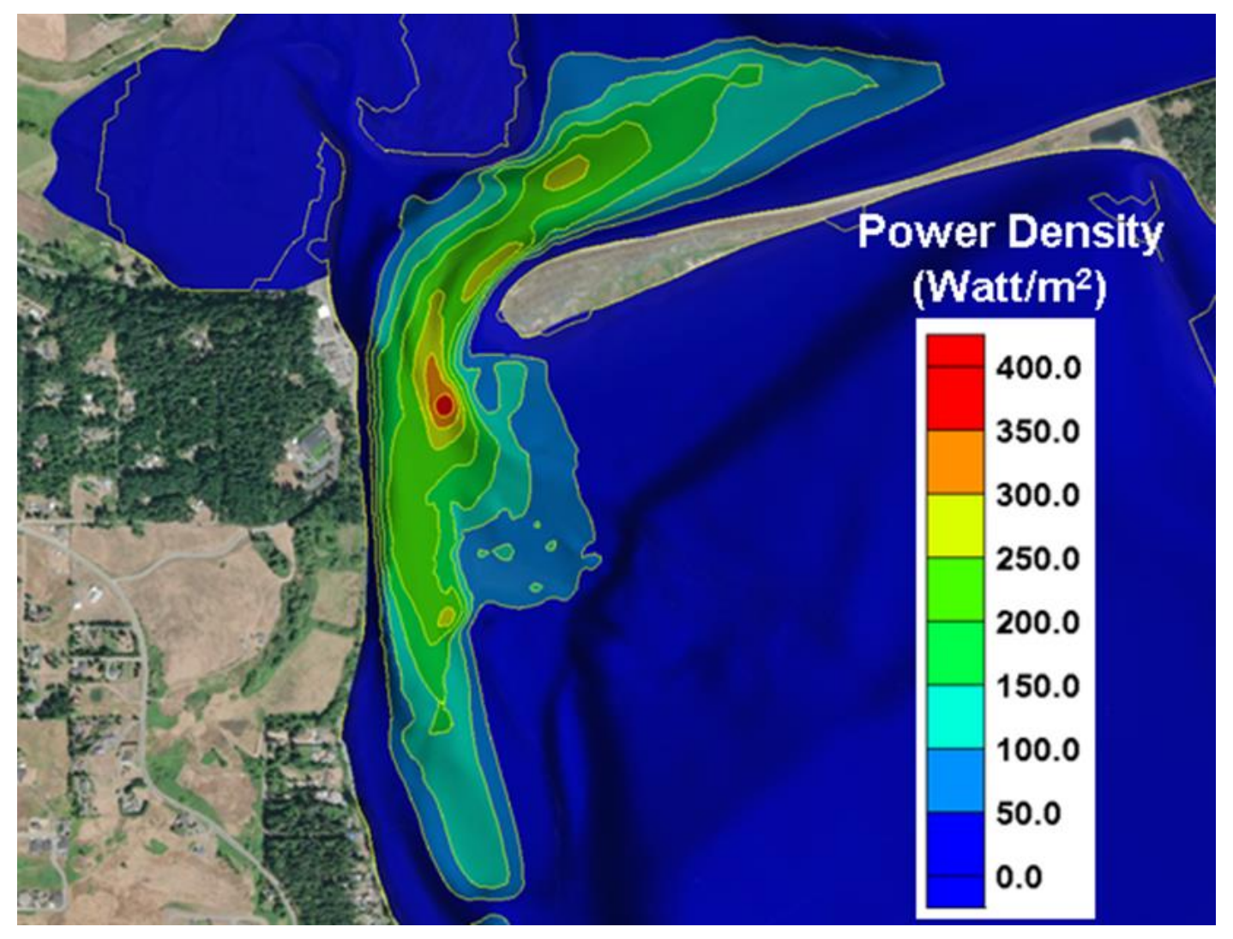

Fig. 7. Simulated time and depth-averaged power density distribution near Sequim Bay entrance.

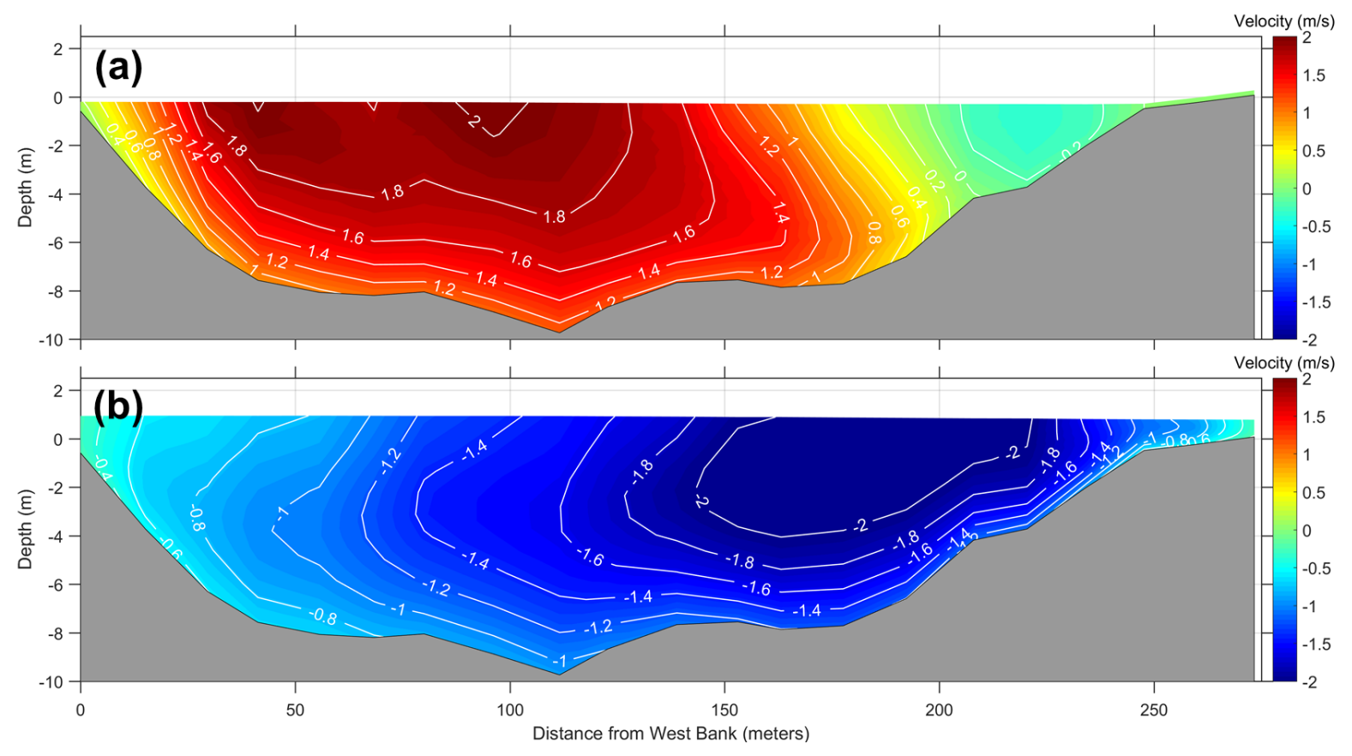

Fig. 8. Simulated cross-sectional ebb (a) and flood (b) currents in Sequim Bay entrance.

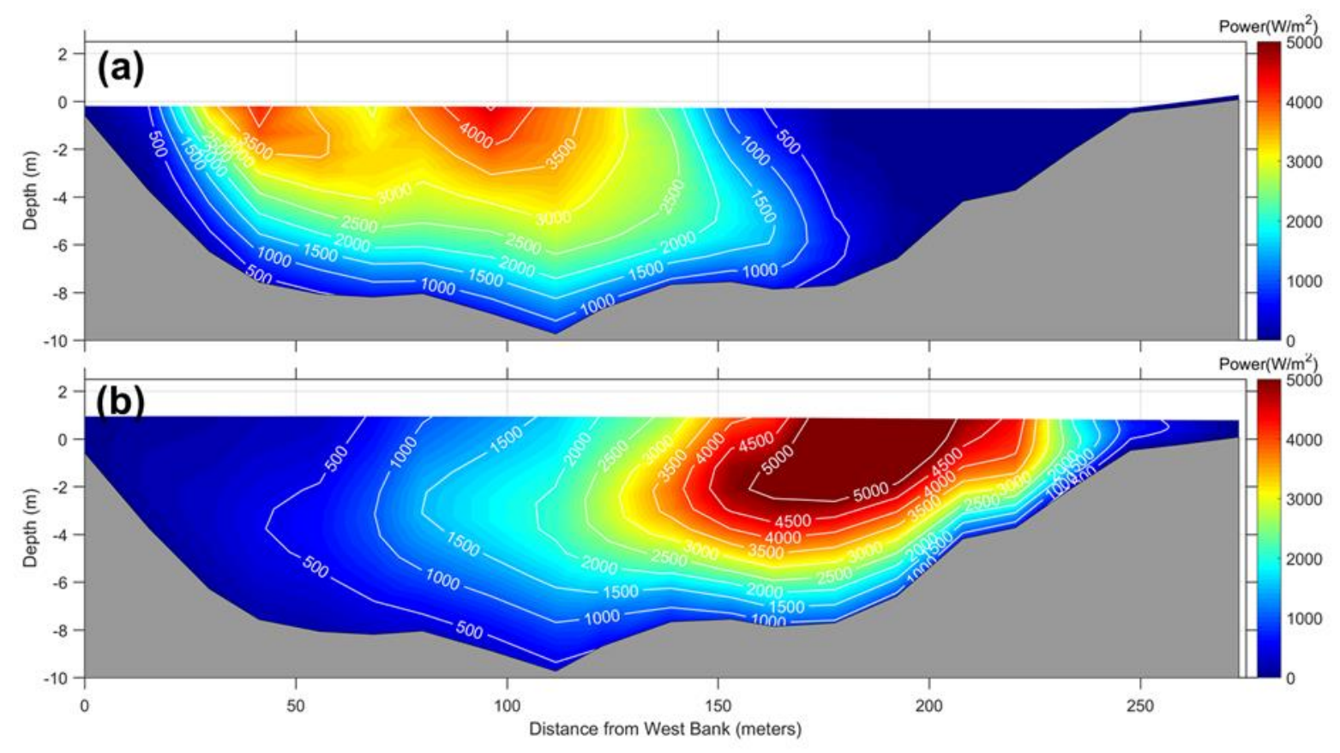

Fig. 9. Simulated cross-sectional power density during ebb (a) and flood (b) in Sequim Bay entrance.

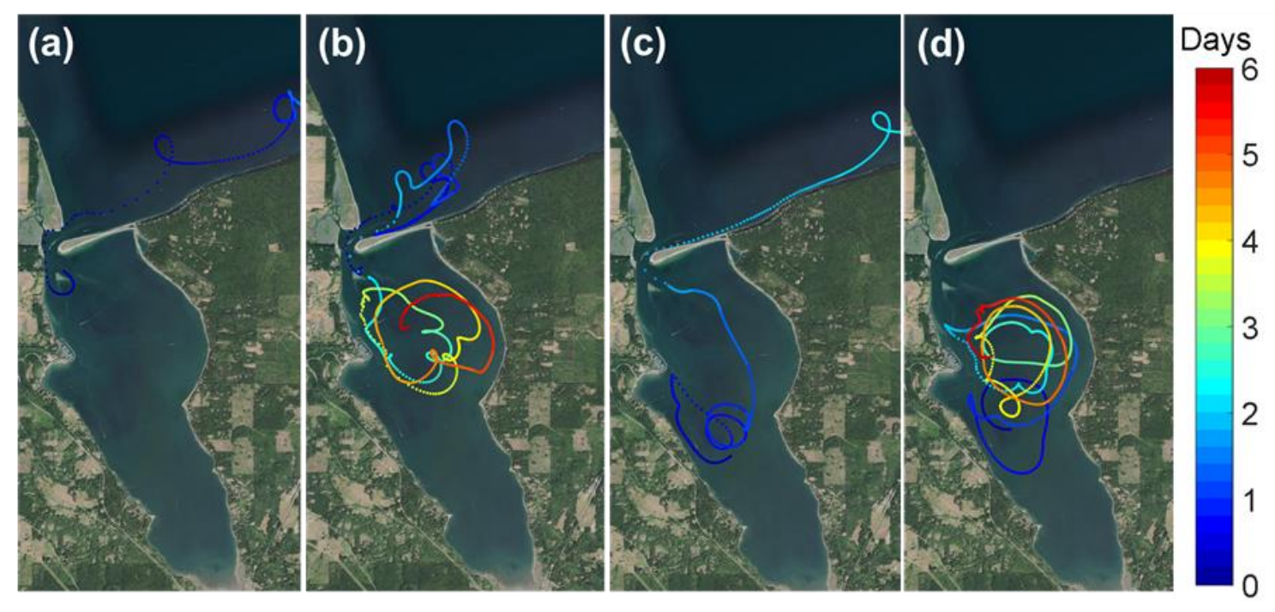

Fig. 10. Lagrangian particle tracking simulation – trajectories for particles released at different initial locations.

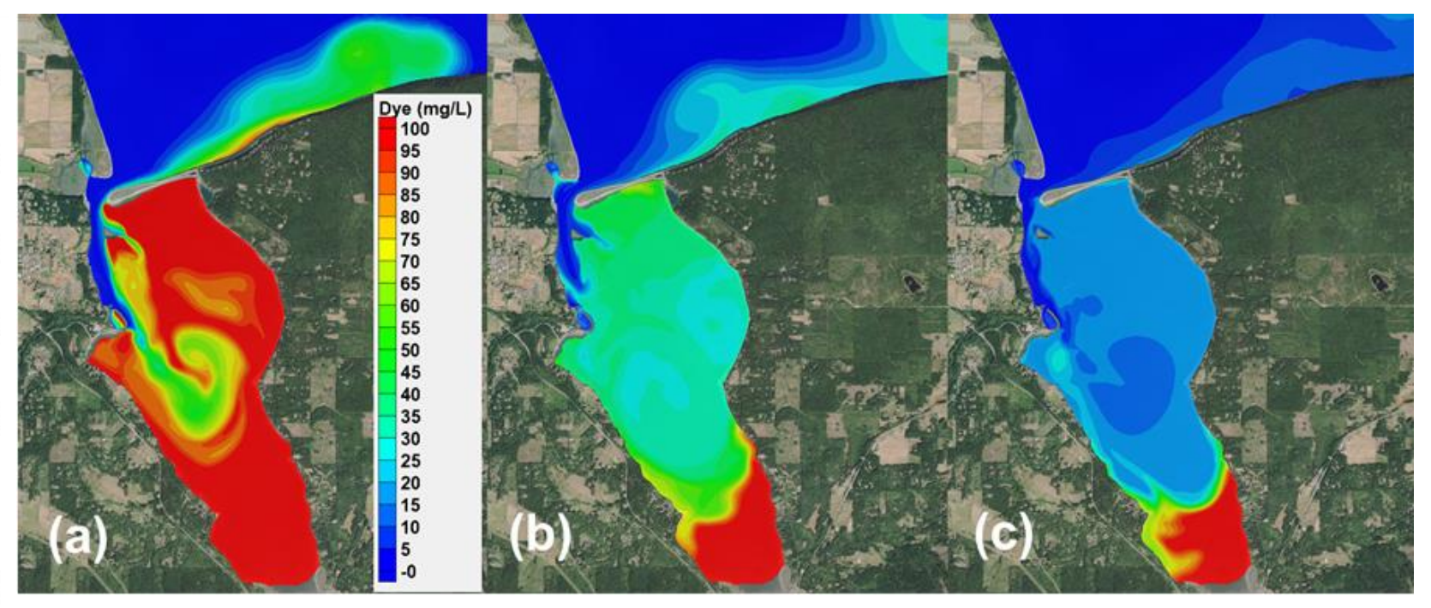

Fig. 11. Tidal flushing simulation – instantaneous dye concentration field on Days 1, 6, and 12, respectively, following initial release.

Literature cited

1. Chen, C. H. Liu, R. C. Beardsley. 2003. An unstructured, finite-volume, three-dimensional, primitive equation ocean model: application to coastal ocean and estuaries. *Journal of Atmospheric and Oceanic Technology,* 20: 159-186.
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https://www.pnnl.gov/projects/ocean-dynamics-modeling