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Modeling water exchange and transport timescales in a multi-inlet bay system of Puget Sound, Washington

Taiping Wang
Pacific Northwest National Lab, taiping.wang@pnnl.gov

Zhaoqing Yang
Pacific Northwest National Laboratory

Jill M. Brandenberger
Pacific Northwest National Laboratory

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Taiping Wang, Zhaoqing Yang, and Jill Brandenberger
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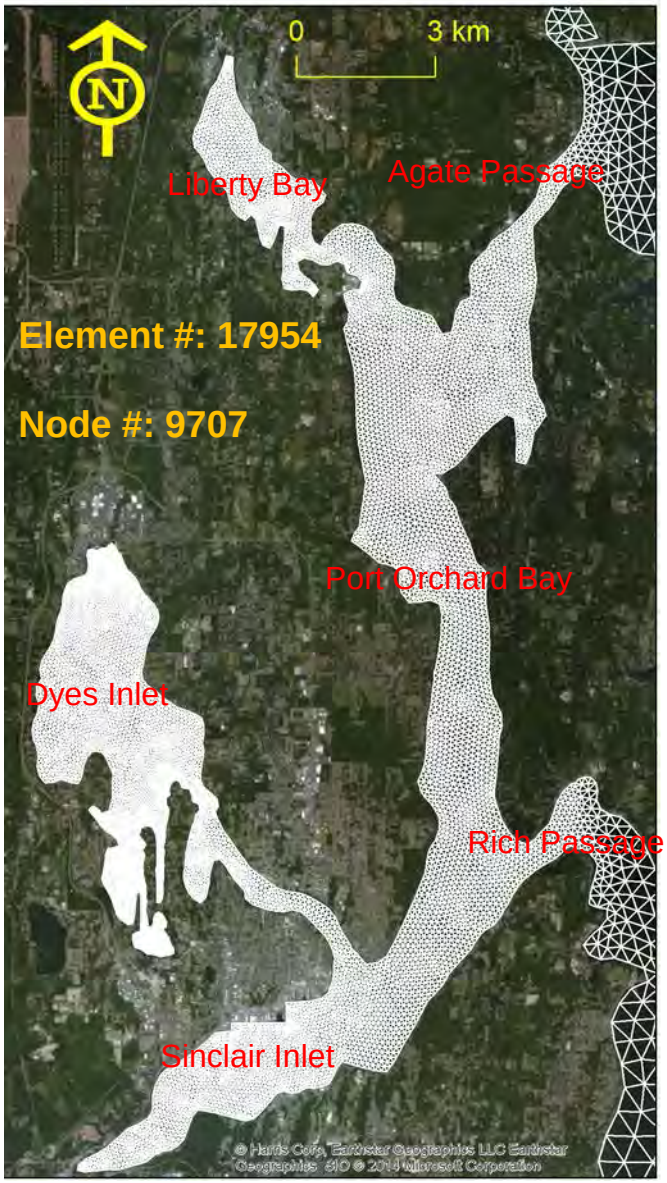
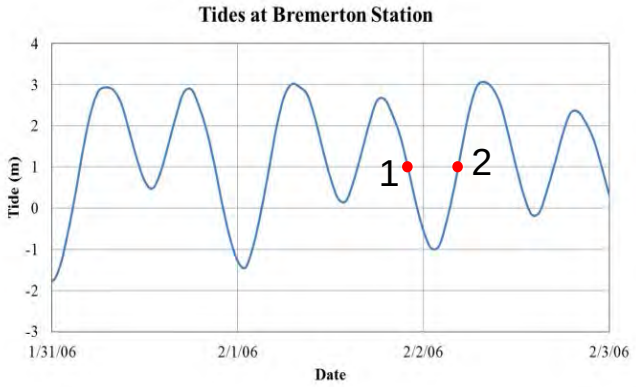
Background & Motivation

- PNNL's Puget Sound circulation model
  - Based on open source, unstructured grid, finite-volume coastal ocean model (FVCOM, Chen et al. 2003)
  - Flexible grid configuration especially suitable for complex geometry
  - Mass conservative and robust wetting & drying schemes
  - Extensive applications to Puget Sound and its subbasins for restoration, circulation, tidal energy, water quality, etc. (Yang and Khangaonkar, 2010; Khangaonkar et al. 2013; Yang et al., 2009, 2010, 2012, 2014)
- Study site - the West Sound
  - Unique multi-inlet bay system – potentially with restricted flushing
  - Water quality issues (low DO, bacteria etc.)
  - Potential tidal energy site
  - EPA and ECY's previous ENVVEST modeling study using HSPF and CH-3D for Sinclair and Dyes Inlets
- Objective
  - Develop an integrated watershed-estuary modeling framework utilizing PNNL's PS model
  - Quantify the transport timescales of the system

Methodology

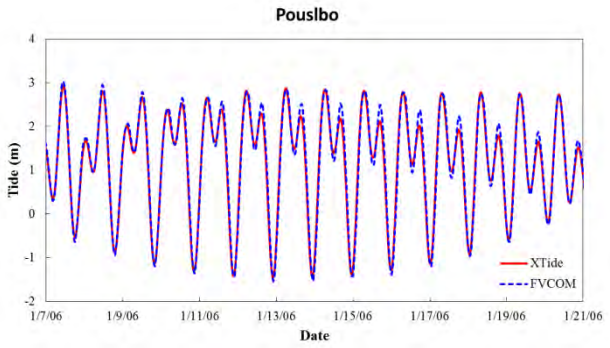


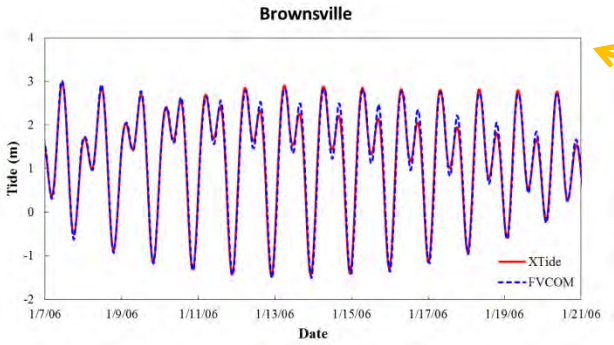
- Model configuration follows Yang and Khangaonkar (2010)
  - Open boundaries: XTide predictions, monthly ECY salinity data
  - River input: HSPF model prediction for watershed surrounding the study area, and daily flows from 19 major rivers of Puget Sound.
  - Wind forcing: hourly, interpolated from NARR 3-hr data.
- Residence time (RT) calculation
  - Tracer method – remnant function (Takeoka, 1984)
  - Lagrangian particle tracking method

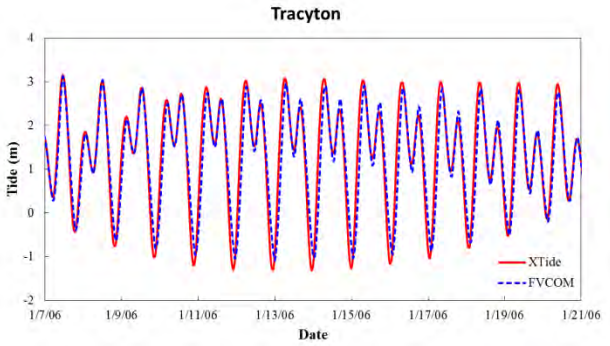


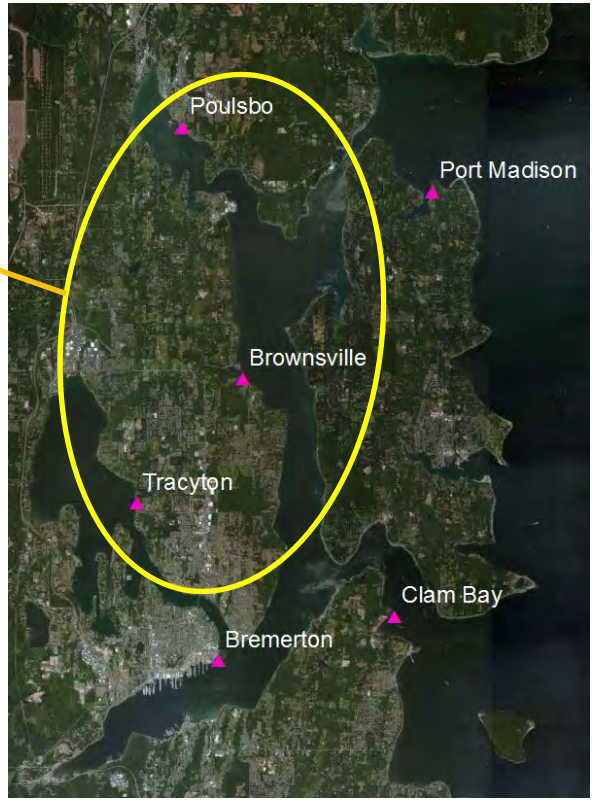
Tracer/particles released at both ebbing and flooding tide

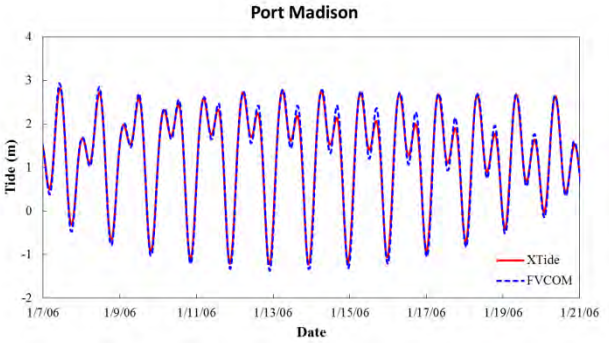
Tidal Simulation

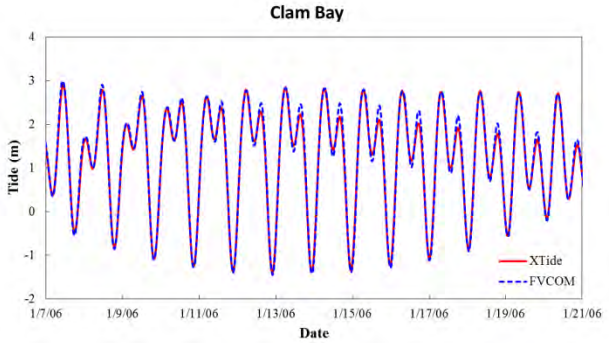


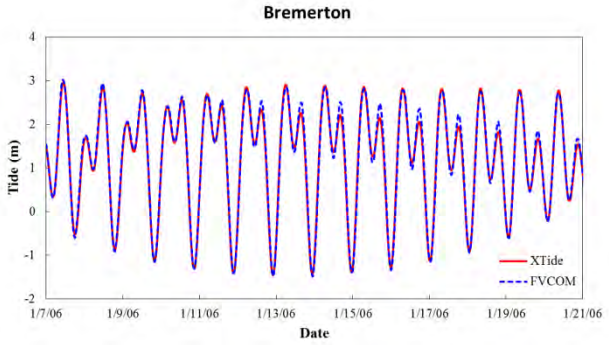








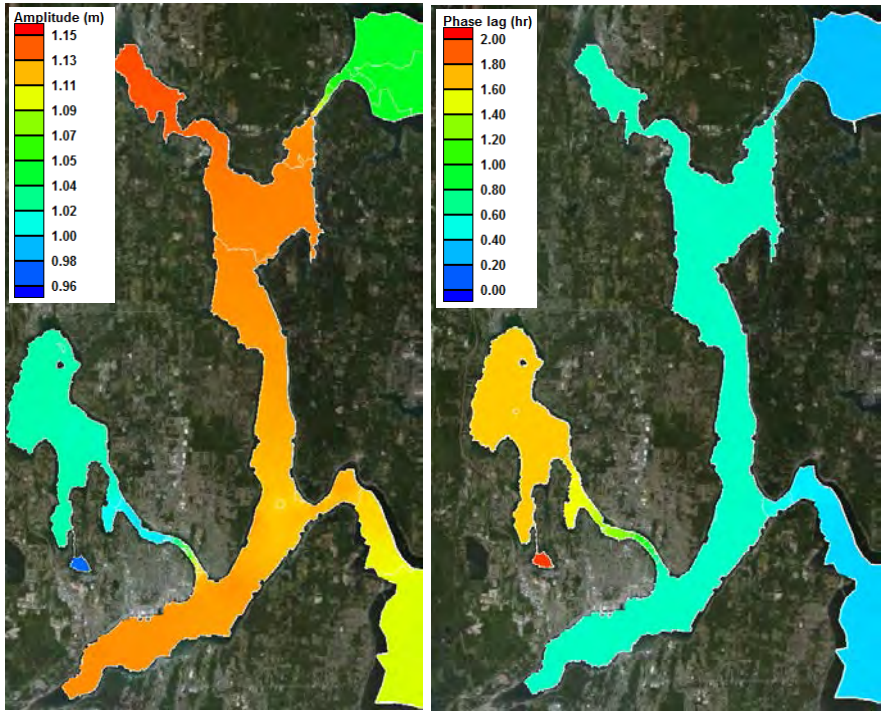




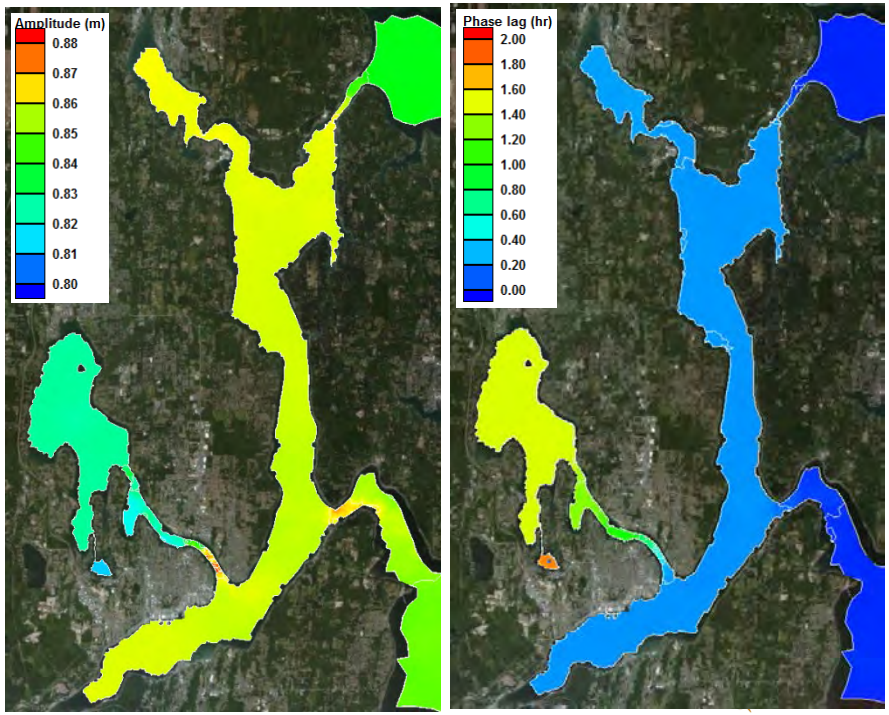
Tidal amplitude and phase

- Changes of tidal amplitude and phase
  - M2: ~20 cm for amplitude, and 1-2 hours for phase lag
  - K1: ~5 cm for amplitude, and 1-2 hours for phase lag

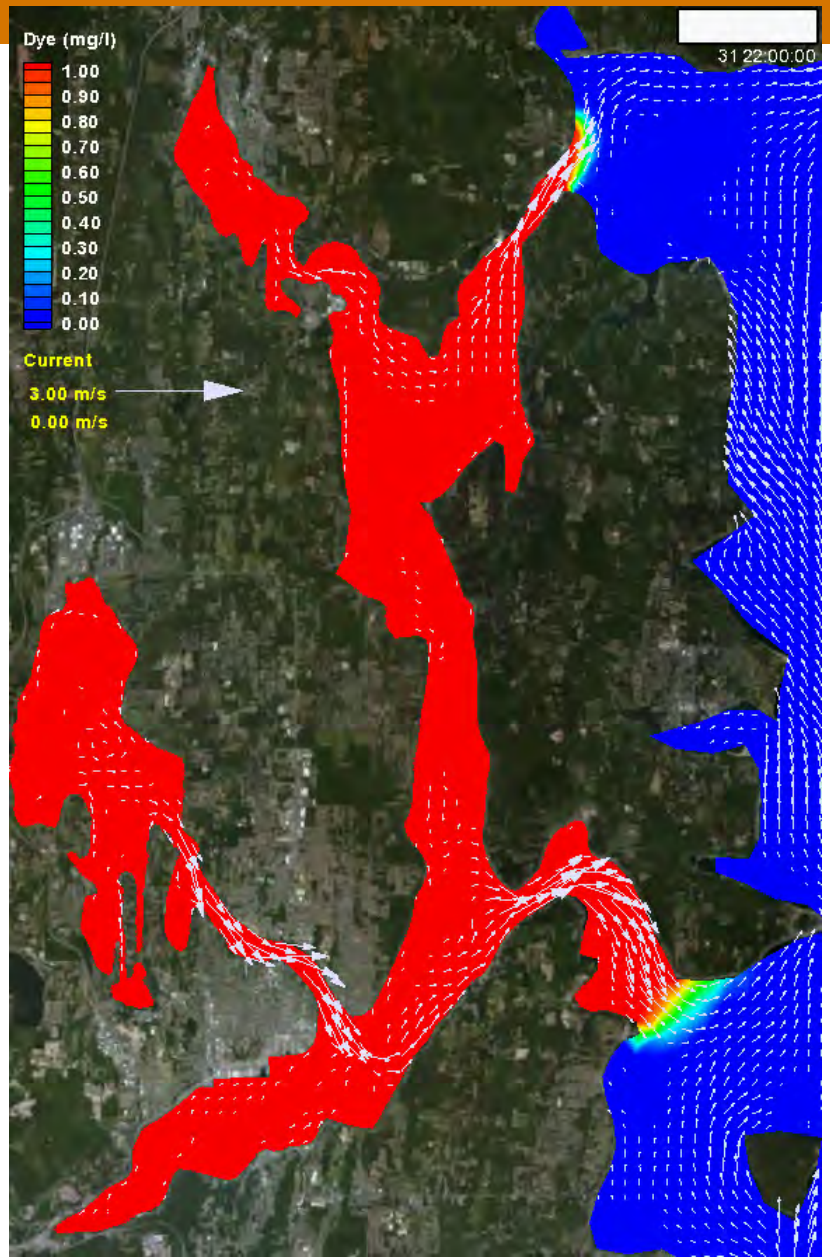
M2 tide



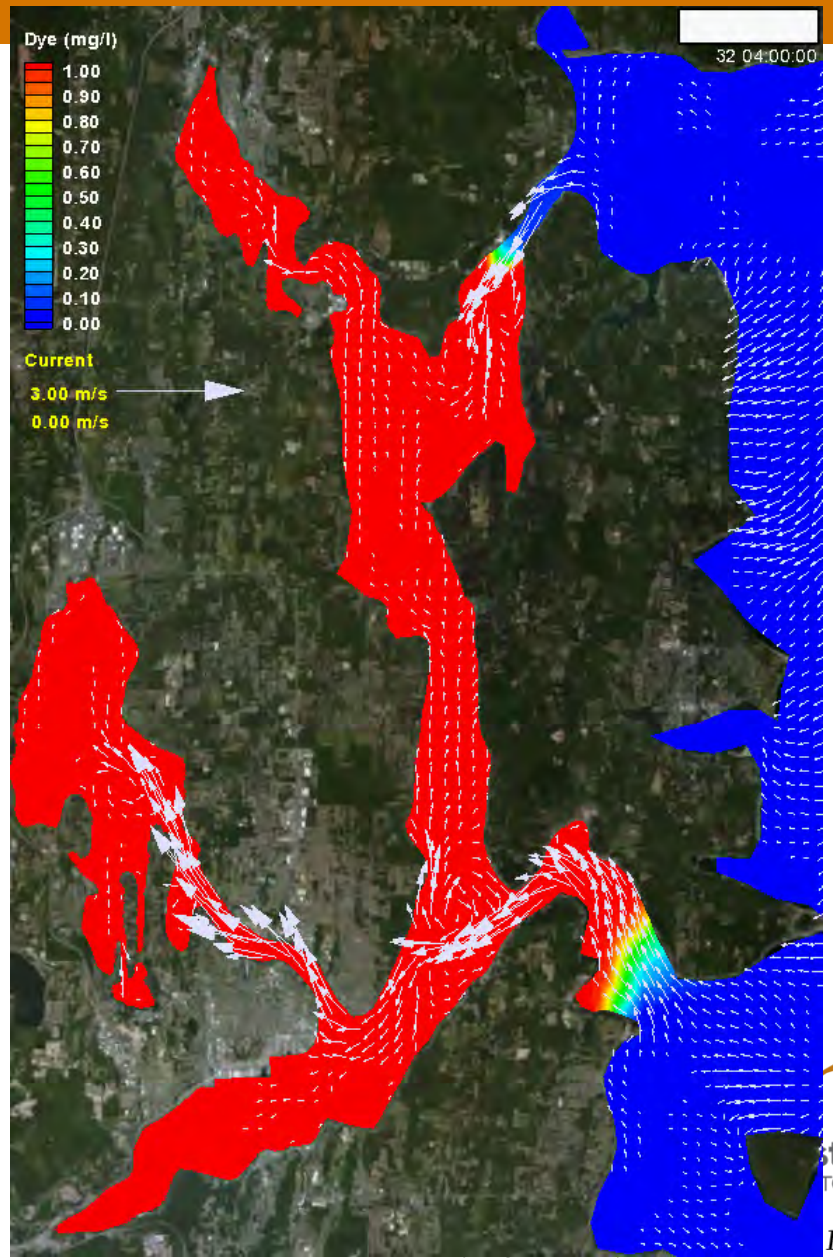
K1 tide



Ebb Release

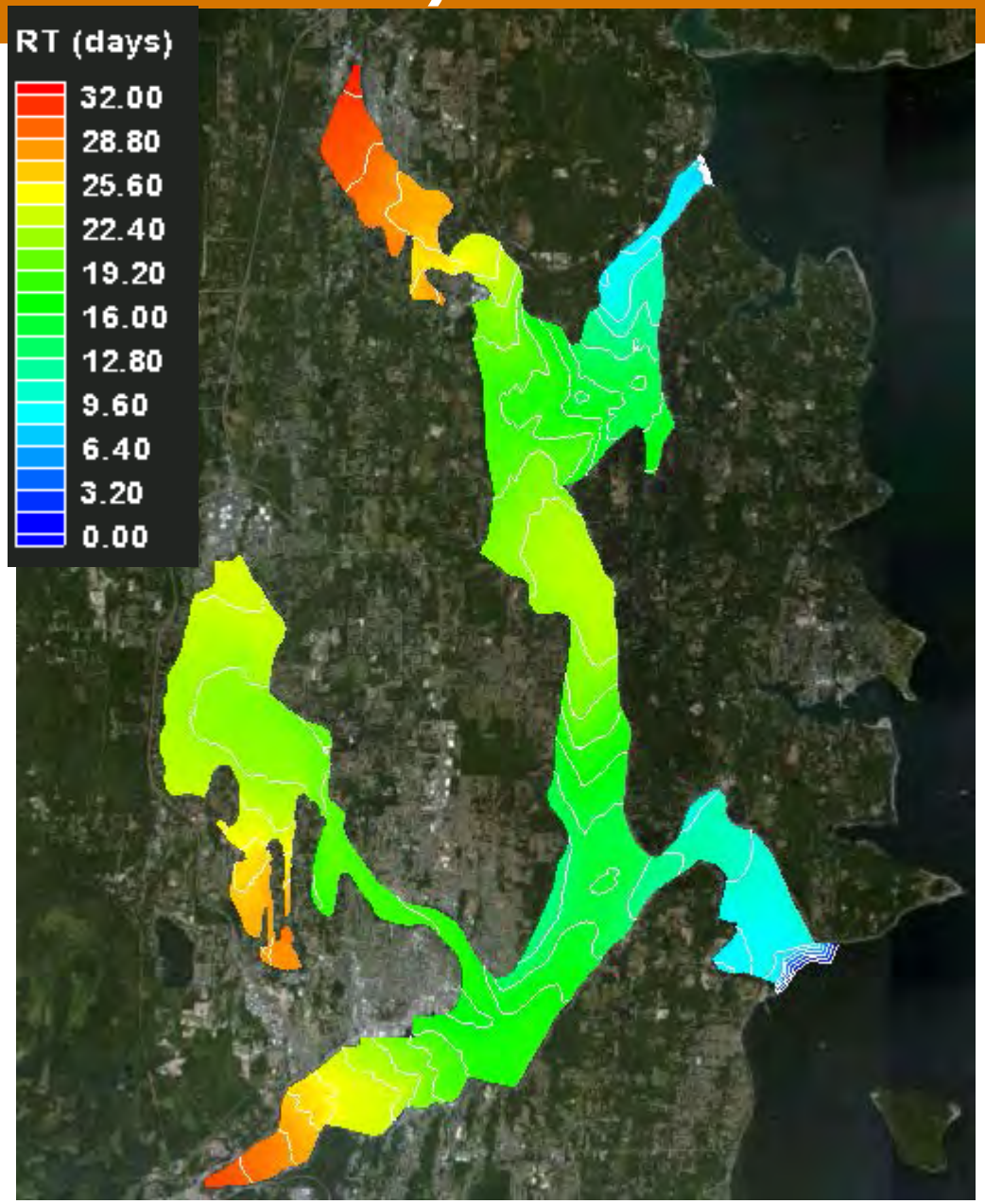


Flood Release



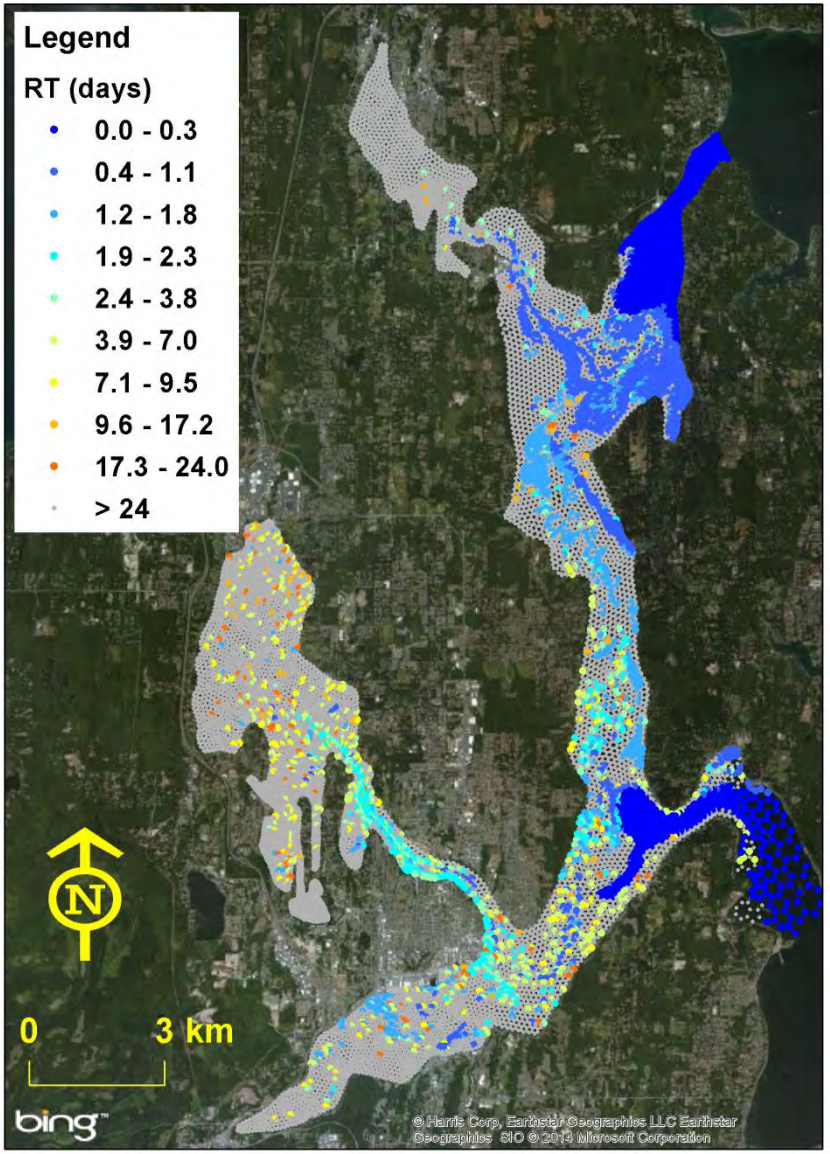
Residence Time (tracer method)

- Depth-averaged RT varies from near 0 to ~32 days.
- System-wide averaged RT is about 18 days, which could be shorter if freshwater discharge from the watershed is included.



Residence Time (particle tracking method)

- Surface RT varies from near 0 to >24 days, and expect to increase with time.
- Will need a number of ensemble runs to reach the final results.



Summary & Future Work

- A 3-D hydrodynamic model was developed for the West Sound.
- Tides vary substantially in the system due to complex geometry.
- Preliminary results suggest the residence time in the system varies from 0 to ~32 days.

- Future work
  - To include watershed model (HSPF) predicted river discharge into the hydrodynamic model and improve model results
  - To connect physical transport with water quality issues in the system

Thank you!

Taiping Wang
Pacific Northwest National Lab
taiping.wang@pnnl.gov