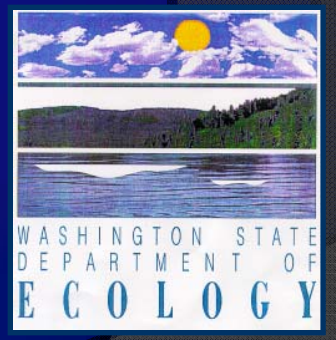
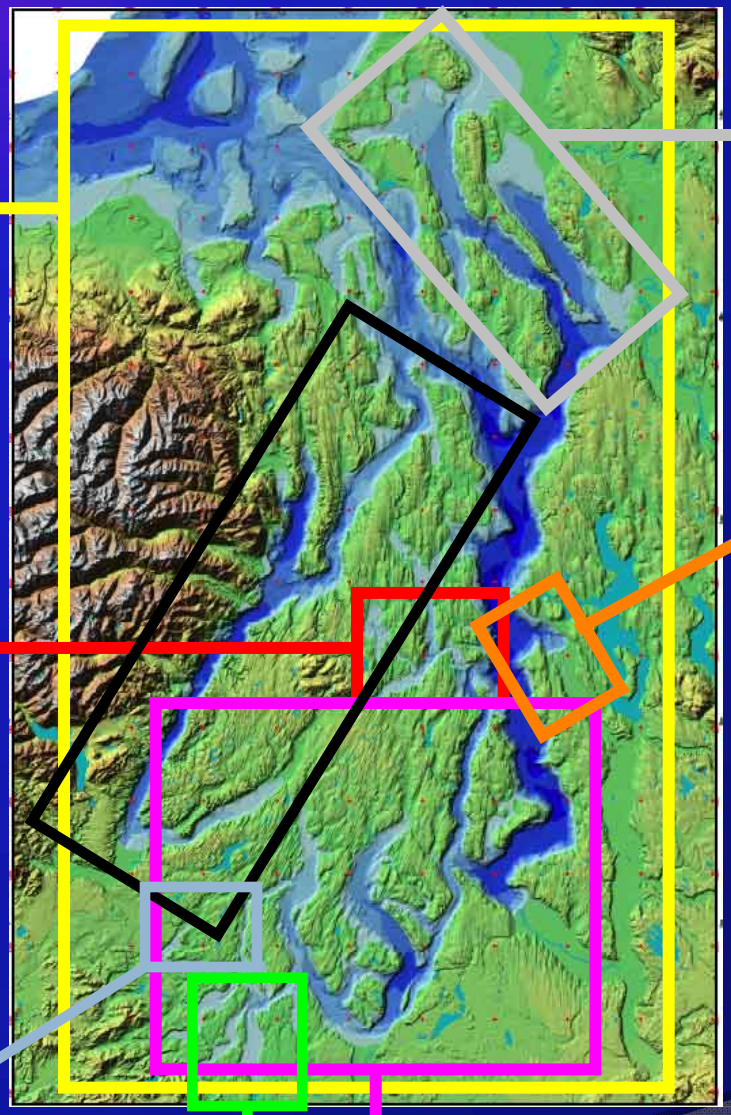
DEVELOPMENT OF THE SOUTH PUGET SOUND HYDRODYNAMIC MODEL AND APPLICATION TO DERIVING RESIDENCE TIMES FOR INLETS

Skip Albertson, Anise Ahmed, Mindy Roberts, and Greg Pelletier (Venkat Kollaru and Environmental Resources Management (ERM) staff for model development)



Modeling efforts in Puget Sound



PRISM (UW, KC-DNR, Ecology); Brightwater (KC-DNR)
(PRISM currently includes hydrodynamics, temp, & salinity. Scope includes adding nutrients, phytoplankton, zooplankton, & DO for POM-ABC model. Brightwater analysis included hydrodynamics, temp, salinity, & tracer.)

Whidbey Basin (PNNL)
(hydrodynamics, temp, salinity)

Dyes/Sinclair Inlet (PSNS & Ecology)
(hydrodynamics, temp, salinity, fecal coliform)

Duwamish Estuary/ Elliott Bay (KC-DNR)
(hydrodynamics, temp, salinity, metals, organics, fecal coliform)

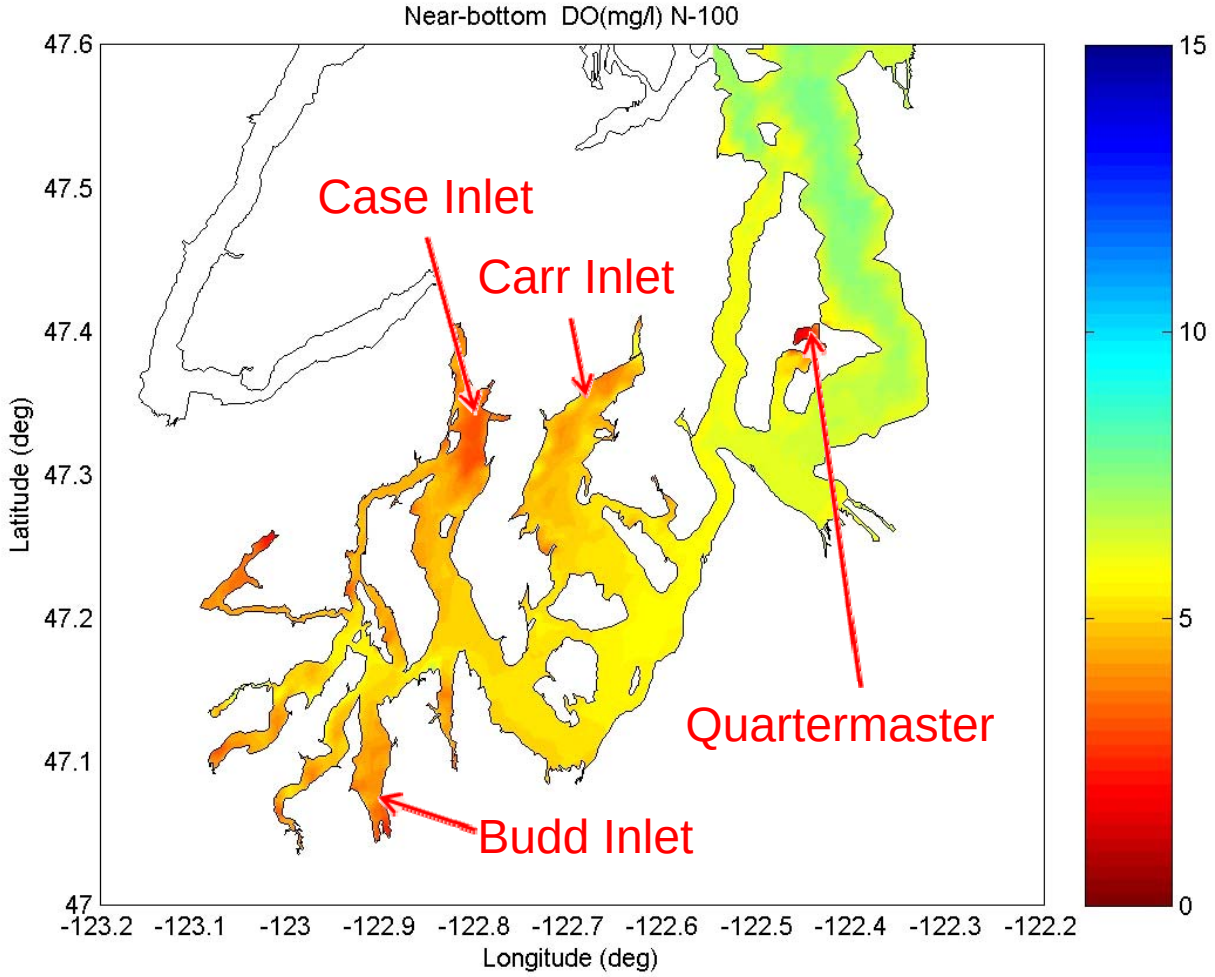
Hood Canal (HCDOP: UW, USGS, Ecology)
(hydrodynamics, temp, salinity, nutrients, phytoplankton, DO)

Oakland Bay (Ecology)
(hydrodynamics, temp, salinity, fecal coliform)

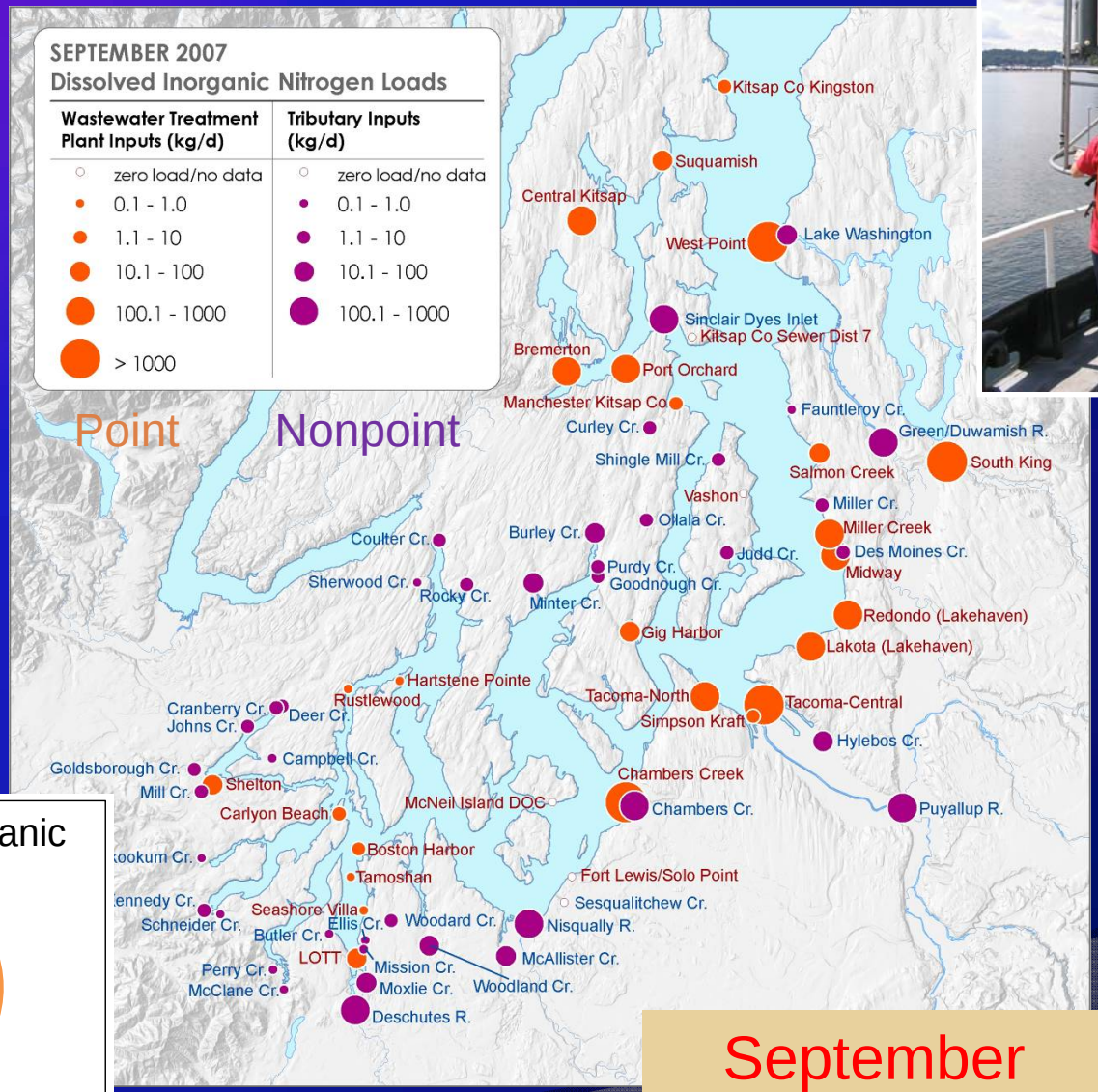
Budd Inlet (Ecology/LOTT)
(hydrodynamics, temp, salinity, nutrients, phytoplankton, DO)

South Sound (Ecology SPS-MEM)
(hydrodynamics, temp, salinity, nutrients, phytoplankton, DO)

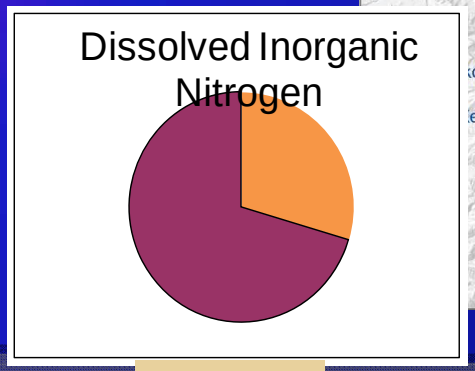
South Puget Sound phase 1



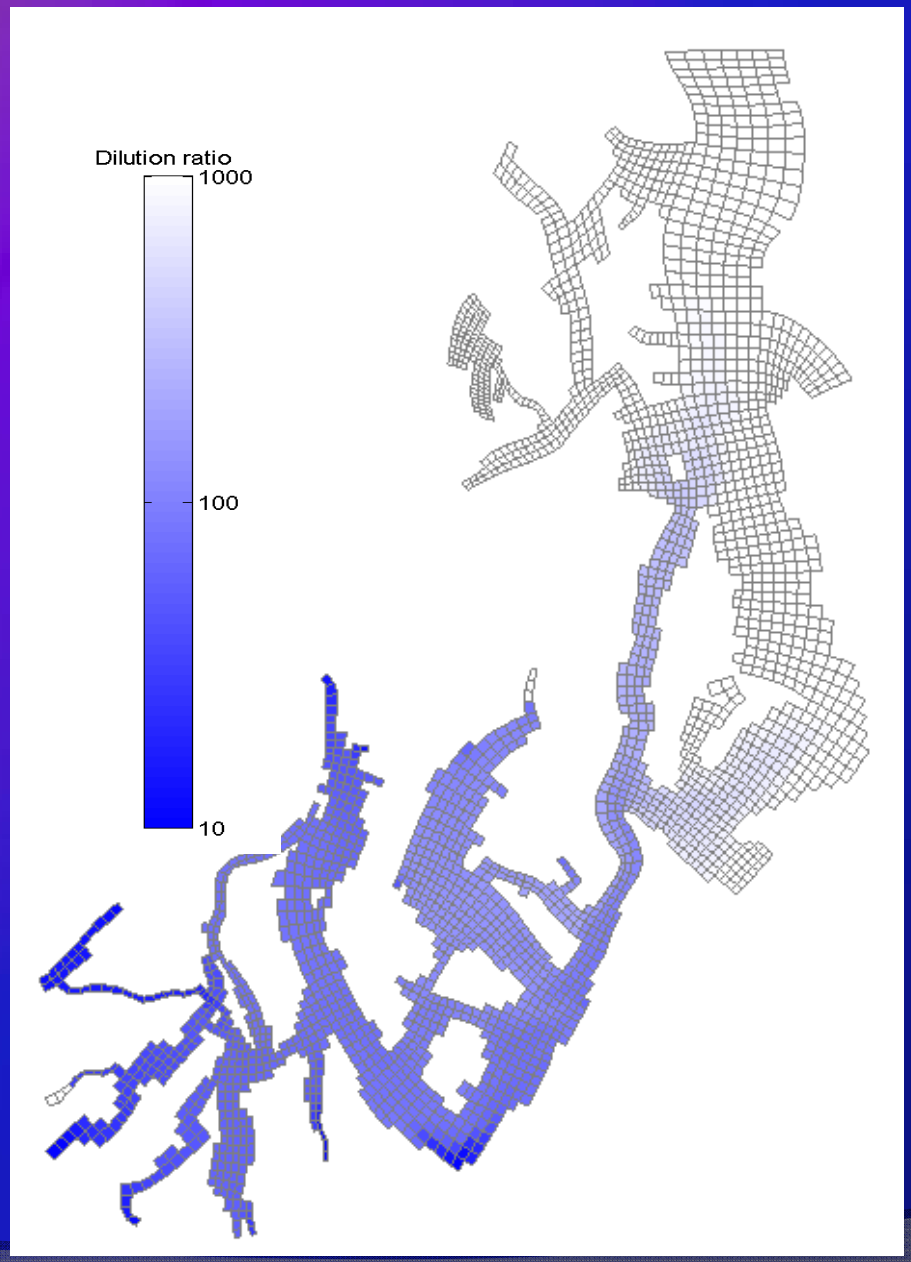
Reactive nitrogen input



September



Annual

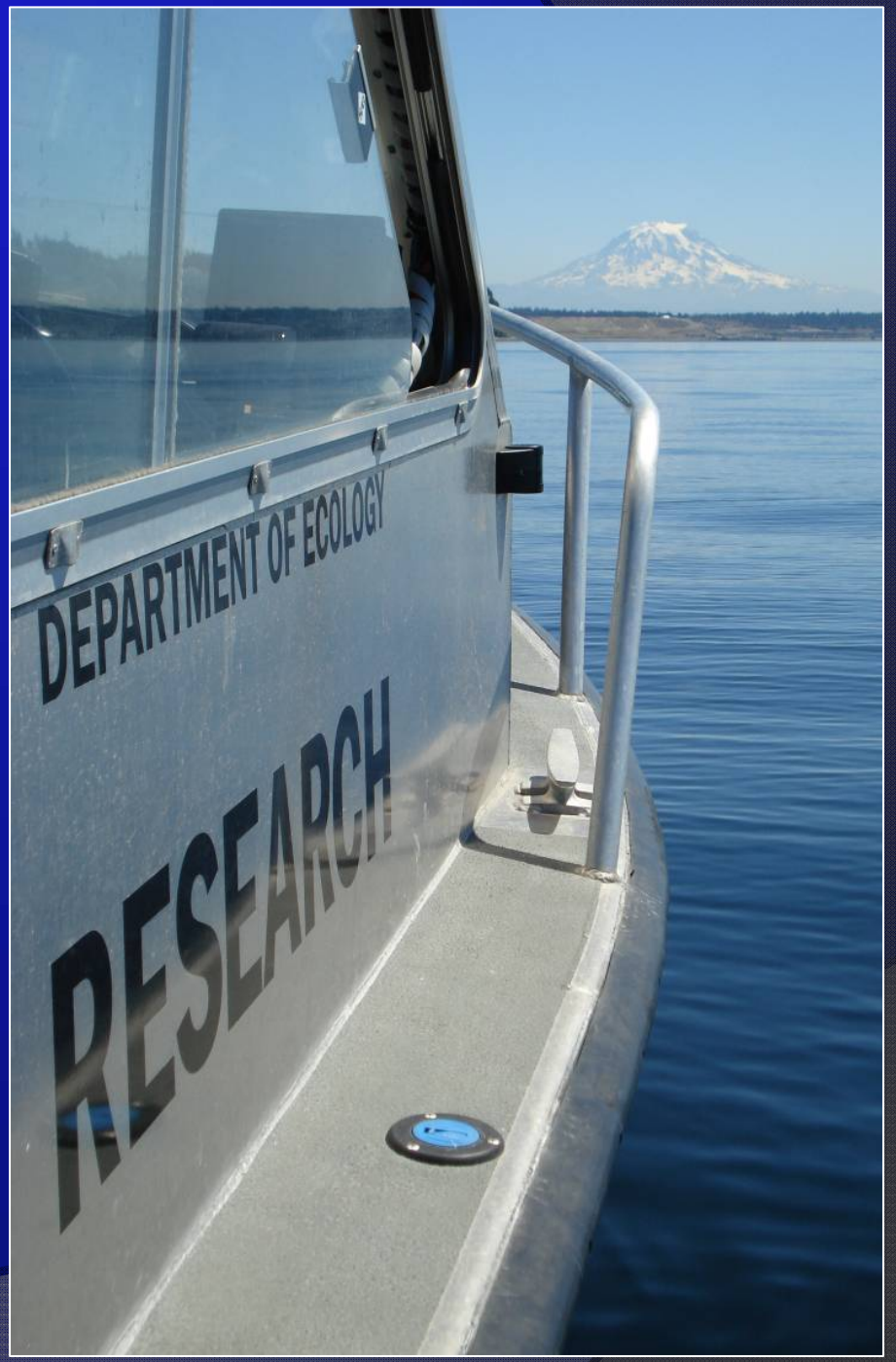


Riverine input south of Tacoma Narrows spreads itself far and wide over many tidal cycles before making an exit out of Colvos Passage.

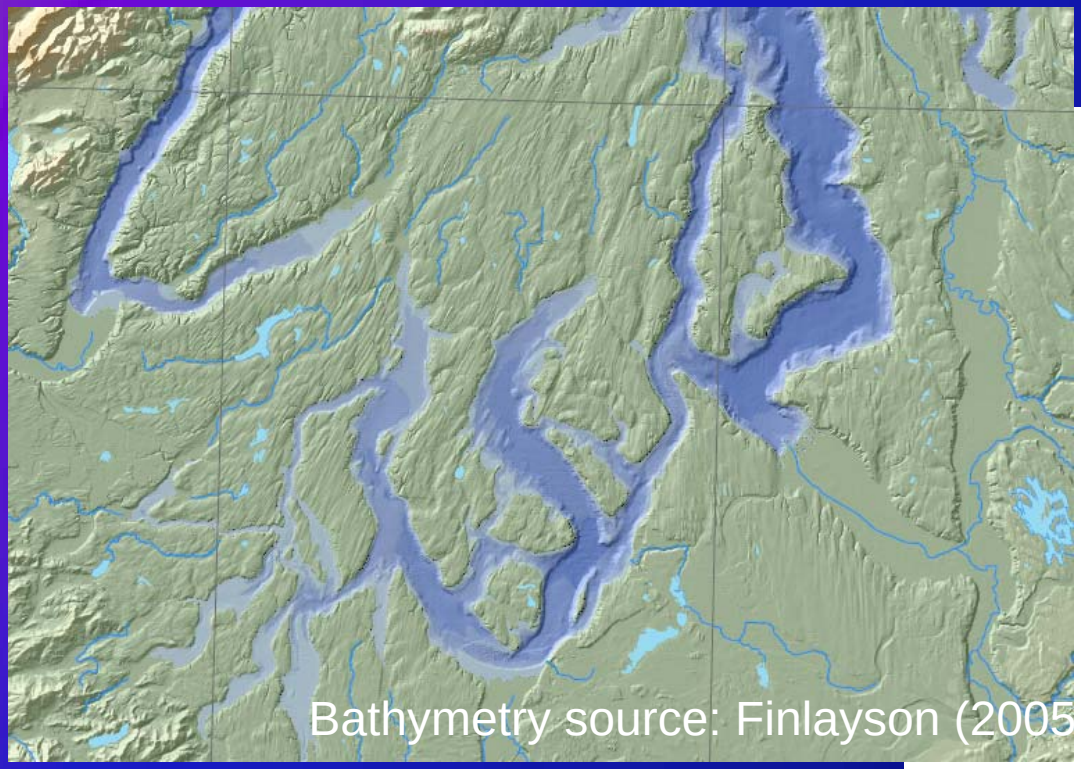
Project components

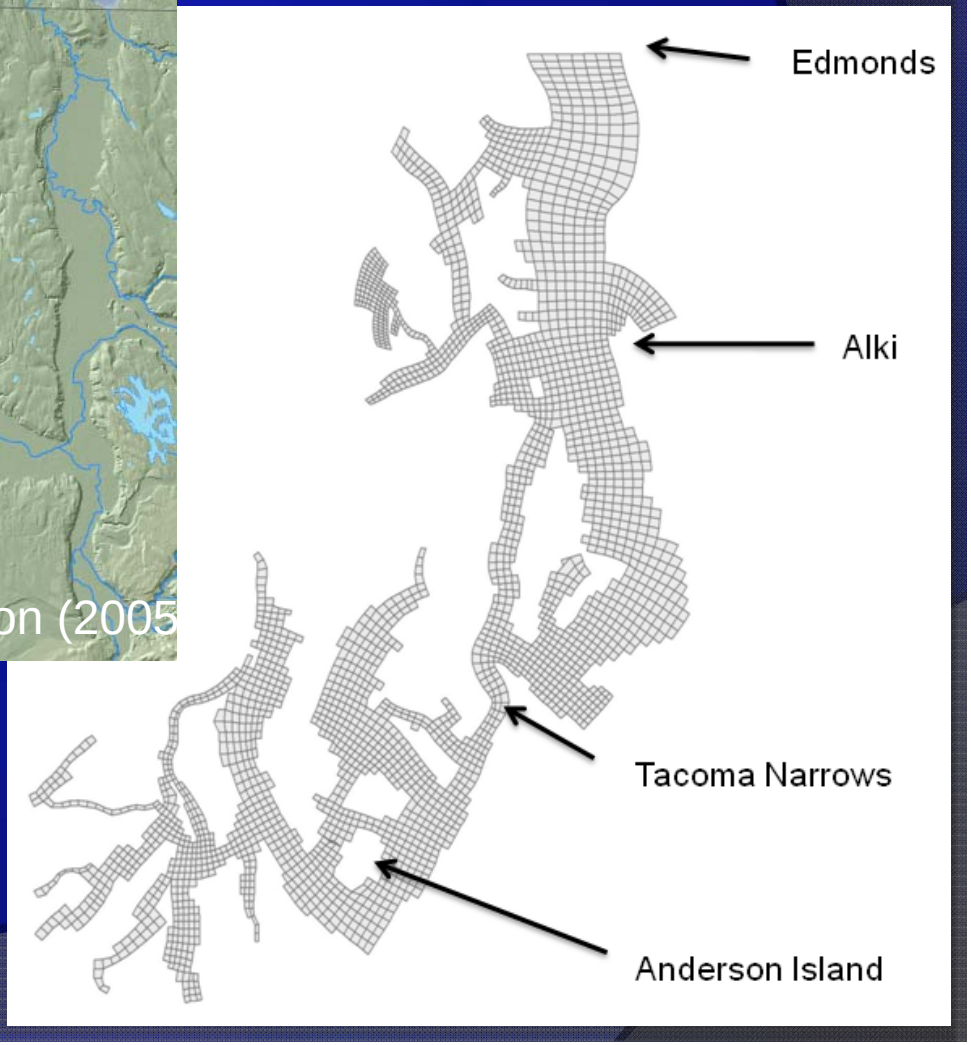
- Data collection (for ICs, BCs, calibration and confirmation
- 3-D Circulation model
- Water quality model

The hydrodynamic model in Generalized Environmental Modeling System for Surfacewaters (GEMSS) is the three-dimensional Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport (GLLVHT) model (Edinger and Buchak, 1980).



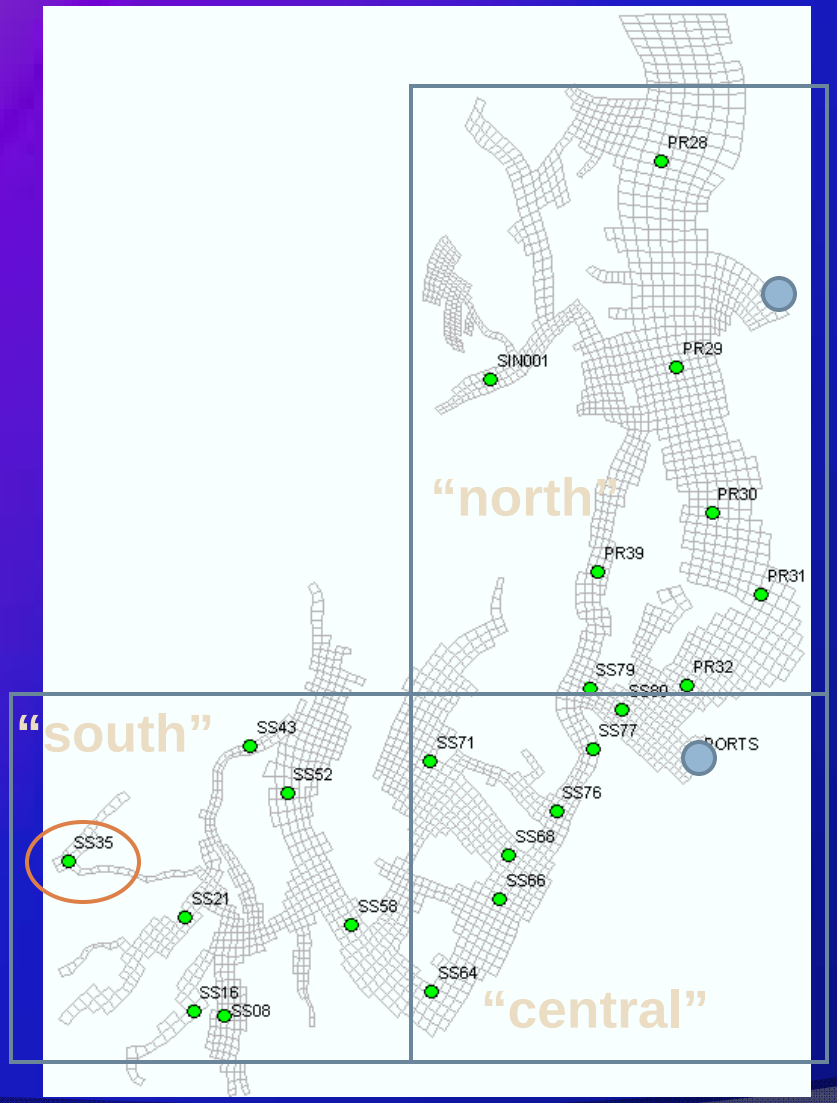
GEMSS application (overview)





- 2,623 grid cells
- 500 m X 500 m (nominal)
- Up to 17 layers

Water surface elevation, T, & S

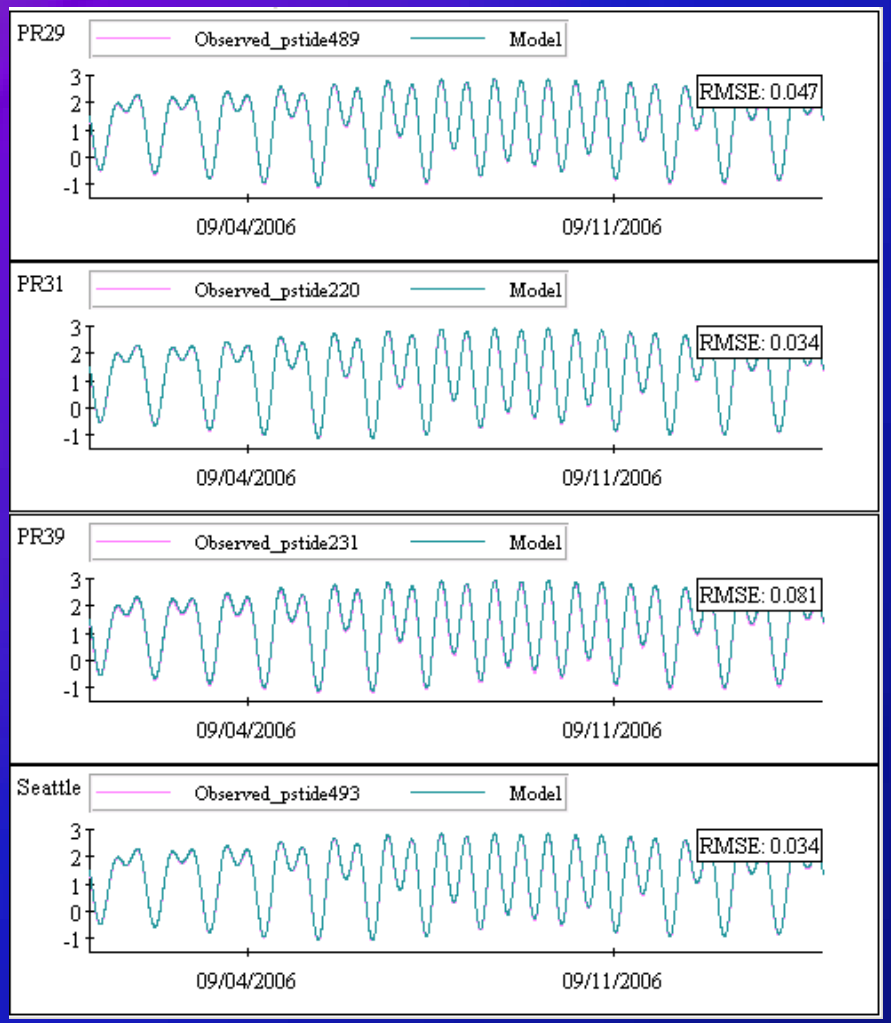


- Root mean square error (RMSE) is the square root of the mean square error:

$$RMSE = \sqrt{(\text{model} - \text{data})^2}$$

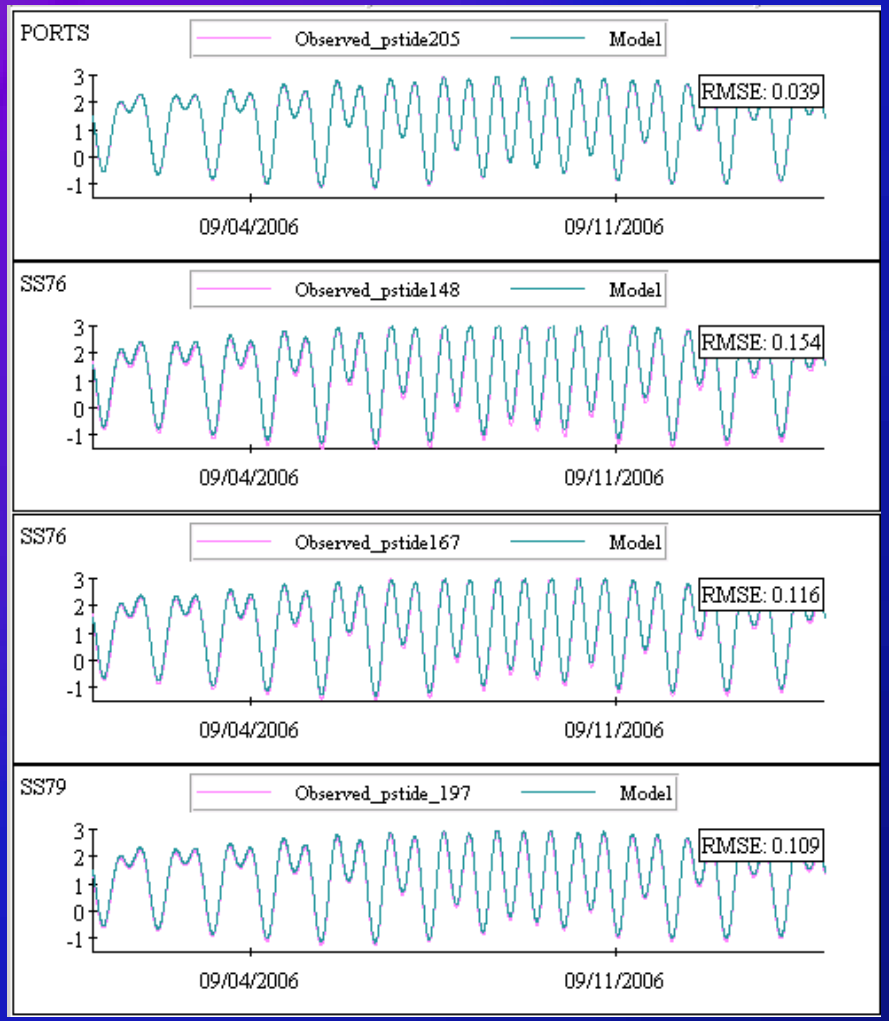
- Goal: minimize RMSEs

North water surface elevations



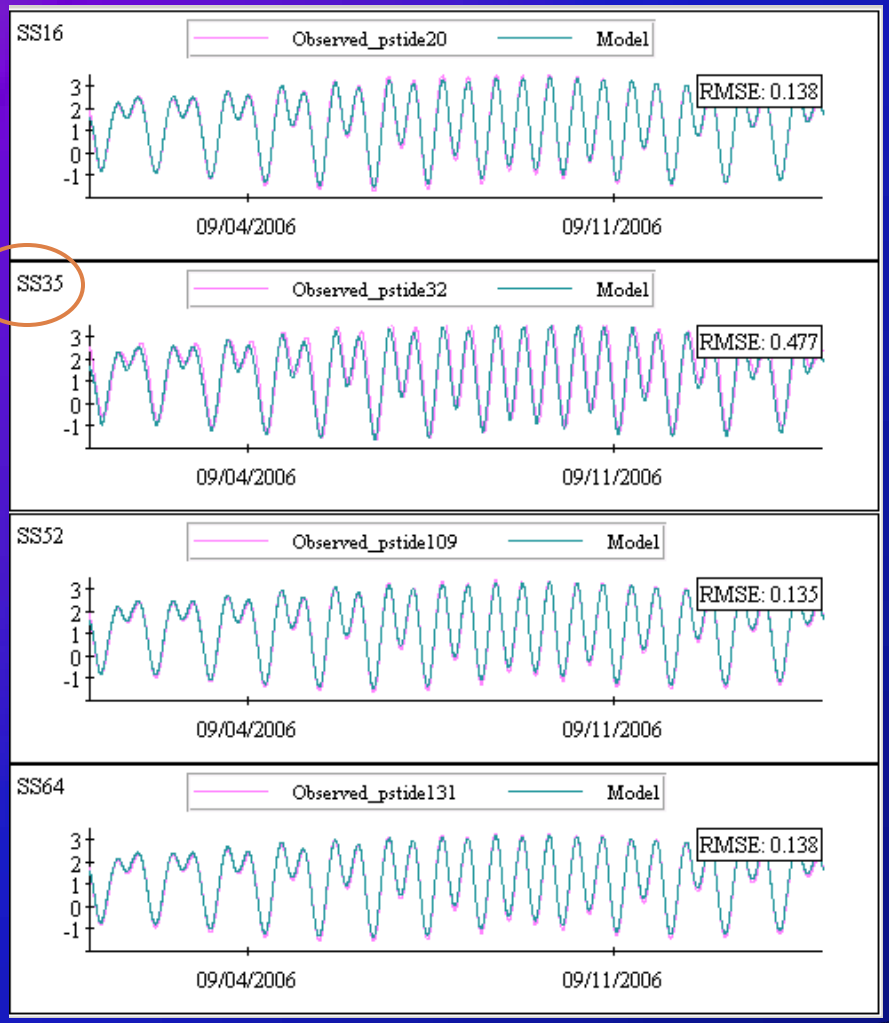
- RMSEs 3 to 8 cm
- Tidal amplitudes: 3 m
- RMSE ~1-2% of range

Central water surface elevations

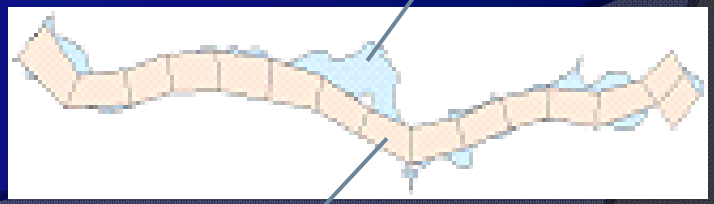


- RMSEs 4 to 15 cm
- Tidal amplitudes: 4 m
- RMSEs ~1-4% of range

South water surface elevations

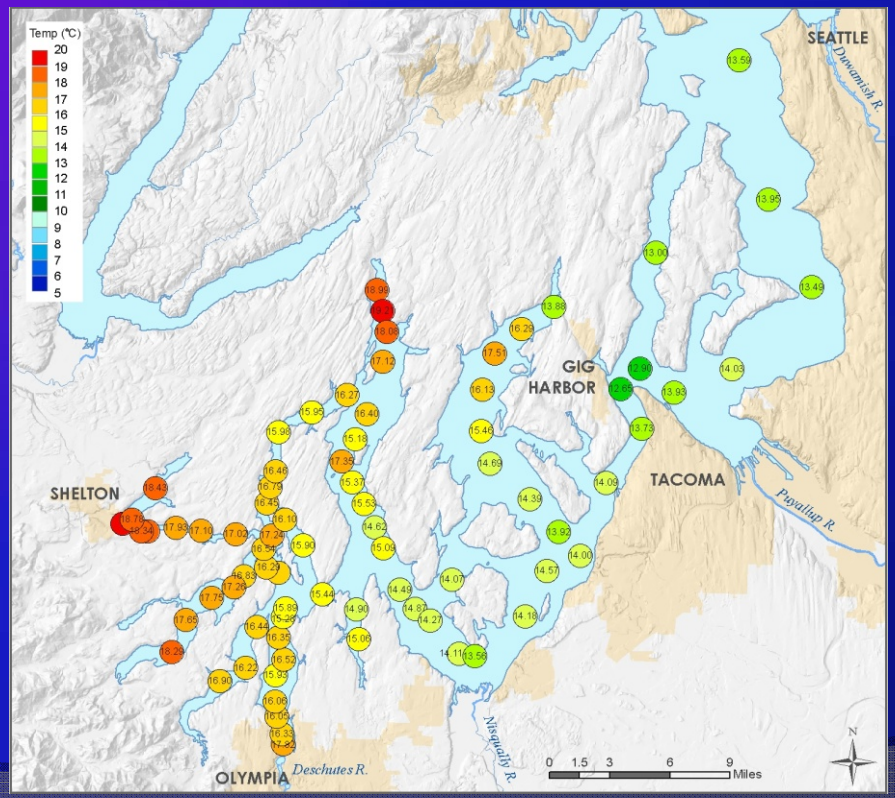


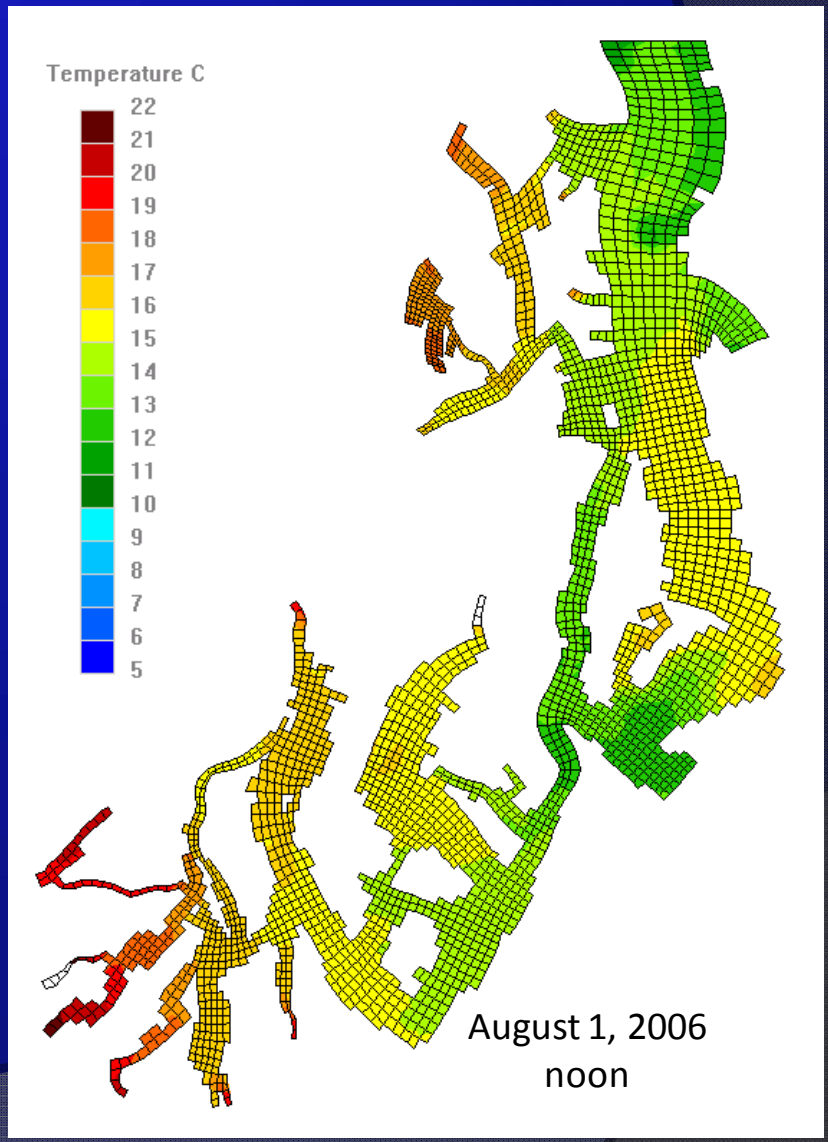
- RMSEs 14 cm (3% of 5m amplitudes)
- Oakland Bay 48 cm!
  - Due to phasing: 40-min advance
  - Amplitudes are good
  - Smooth bend needed for model stability



Surface temperature (summer)

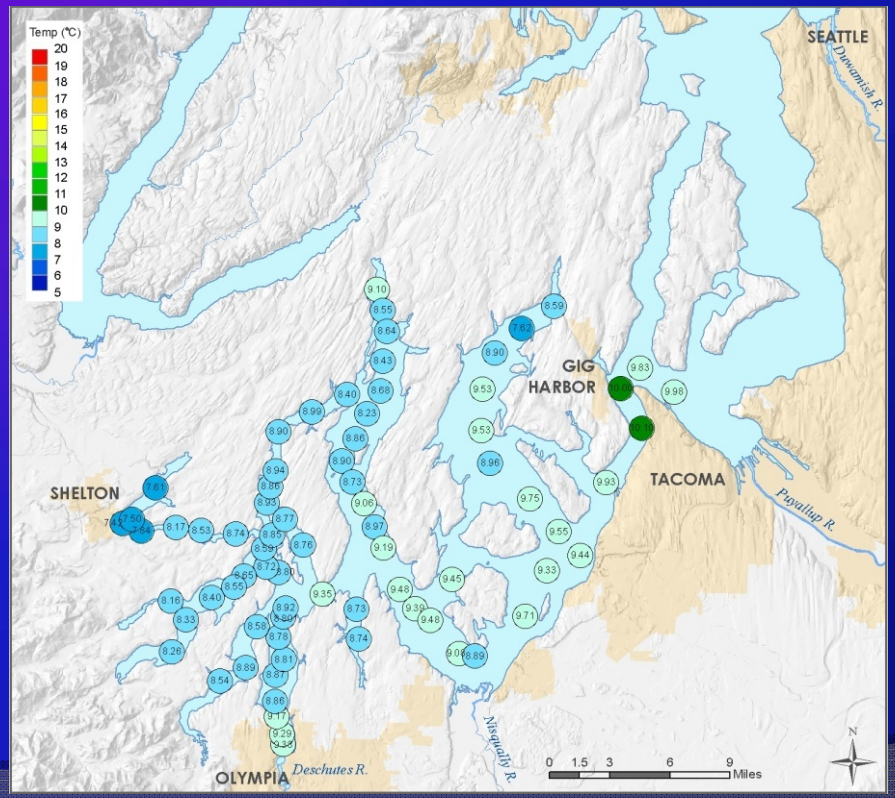
More variable than near-bottom conditions
Affected by air temp, wind, solar radiation, …

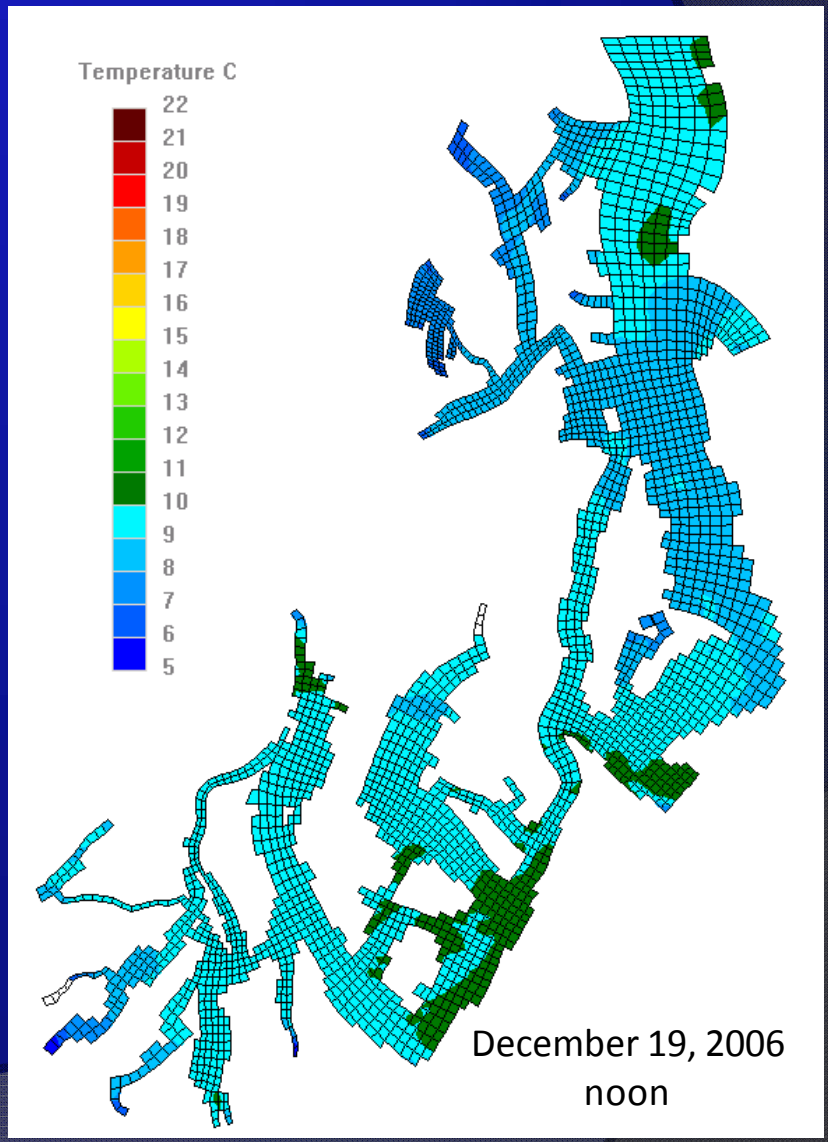




Surface temperature (winter)

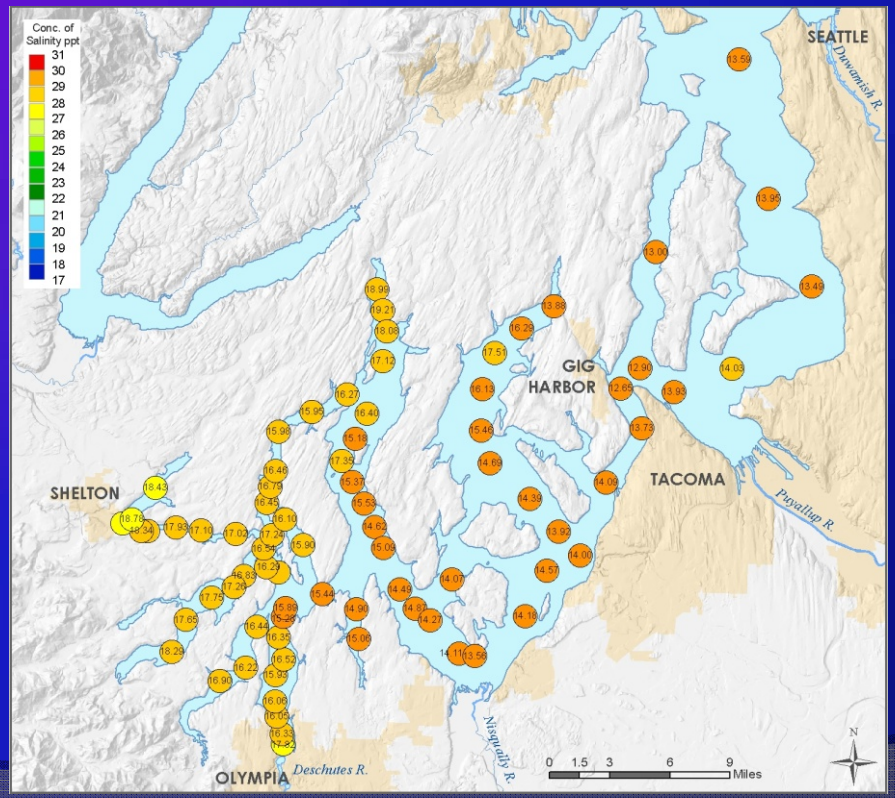
More variable than near-bottom conditions
Affected by air temp, wind, solar radiation, …

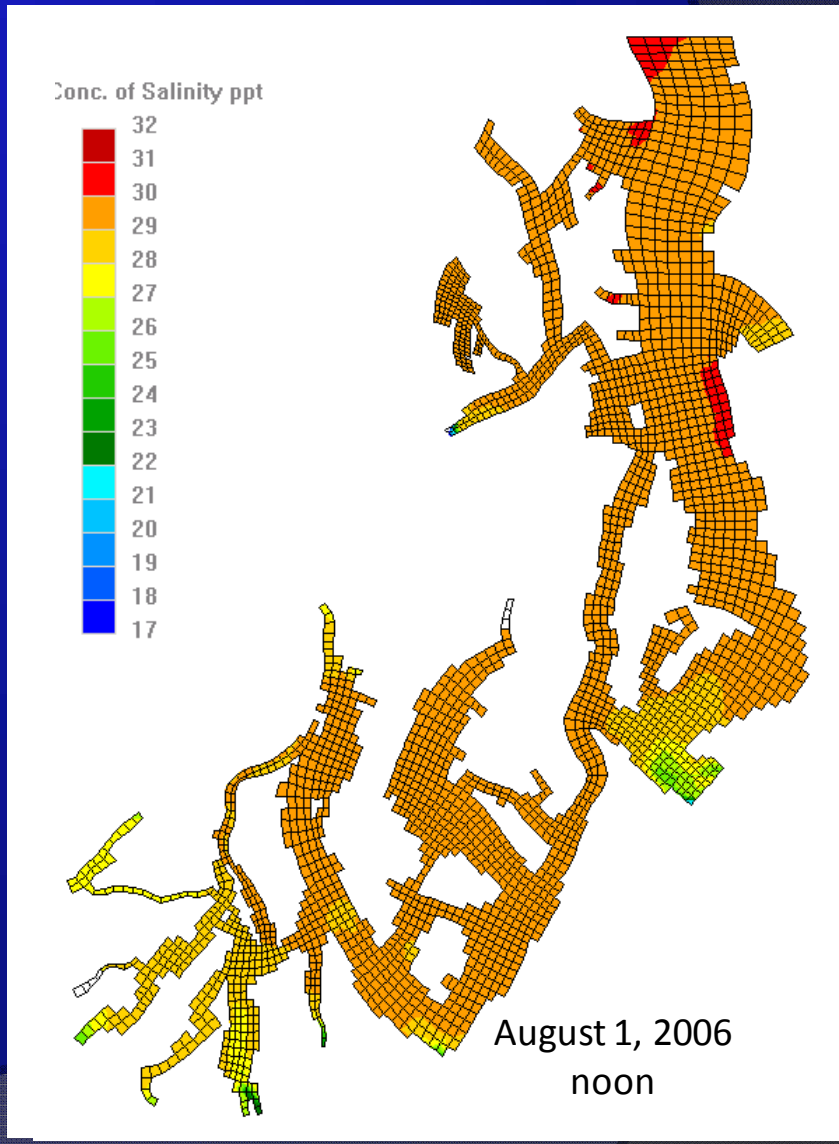




Surface salinity (summer)

More variable than near-bottom conditions
Affected by river inflows, seasonal ocean conditions, …





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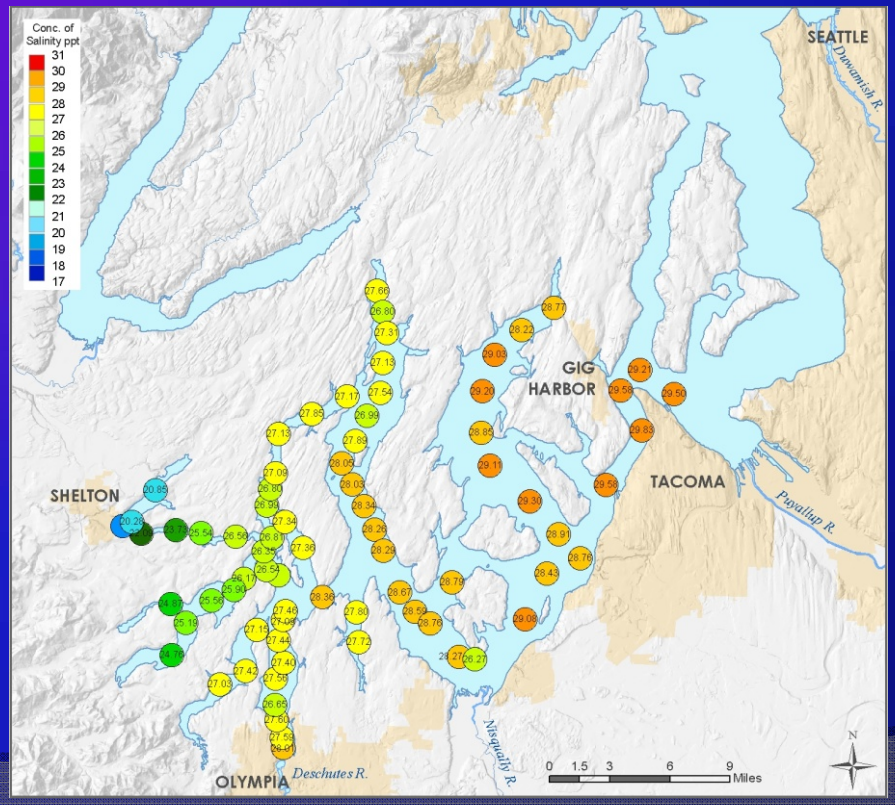
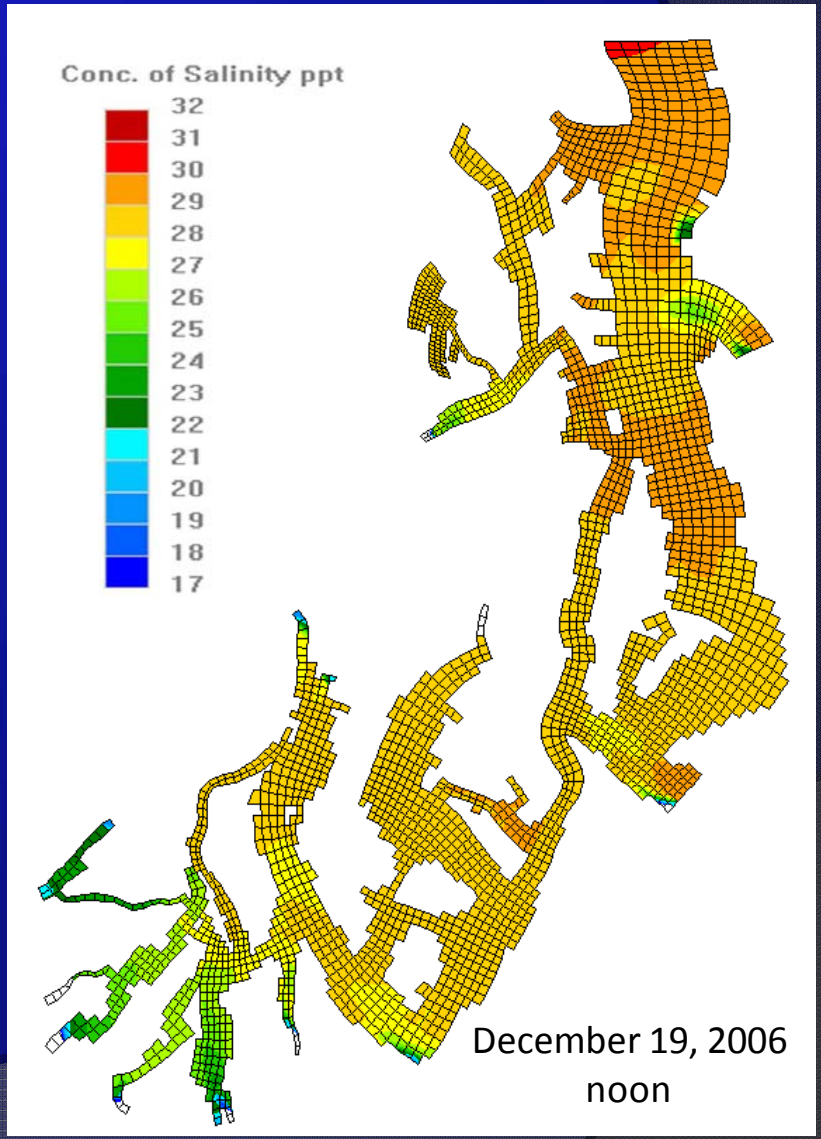
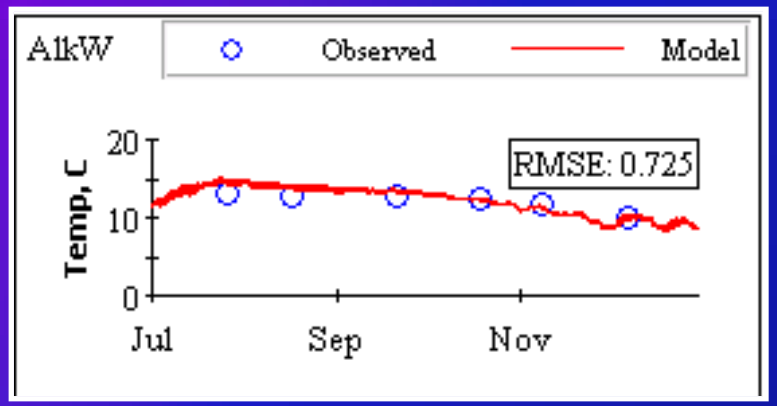
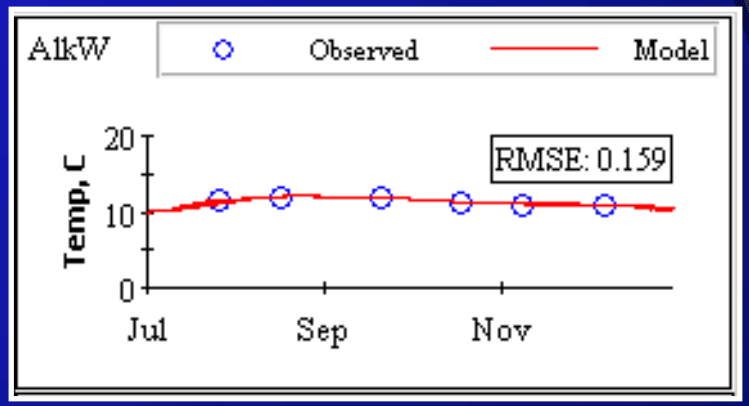
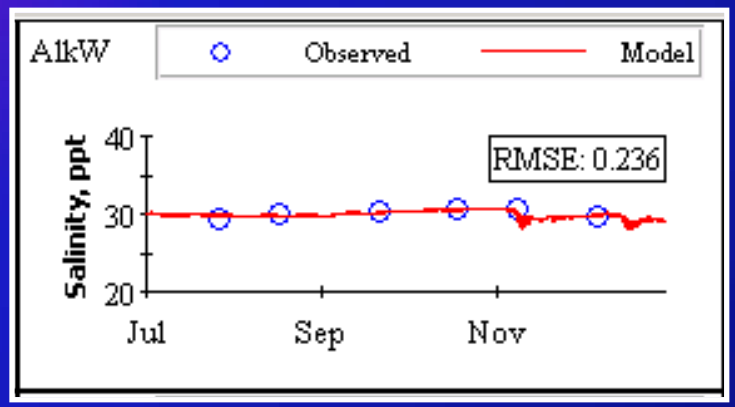


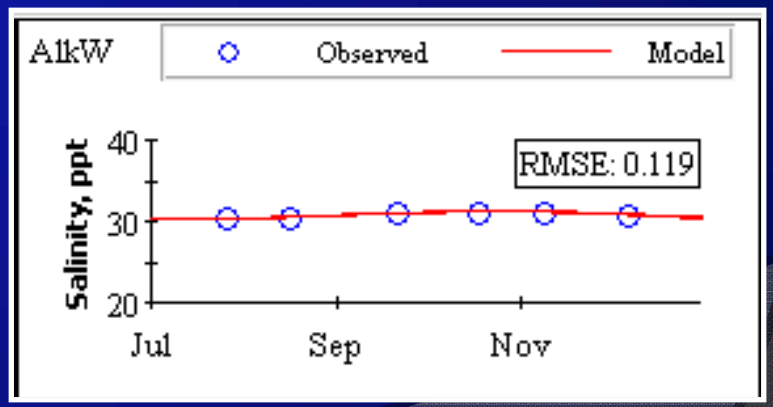


Top and bottom layers at Alki West

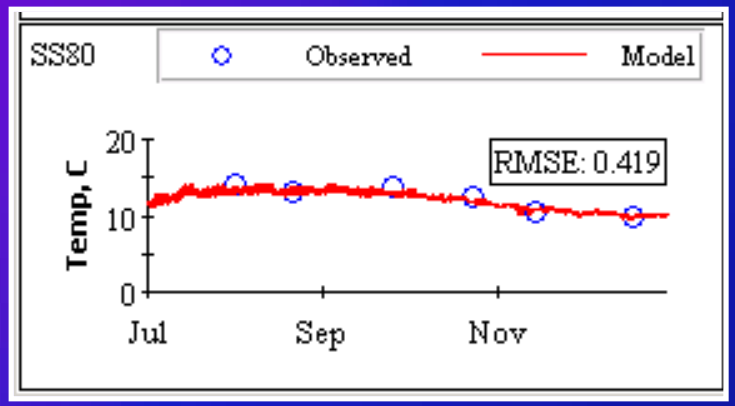


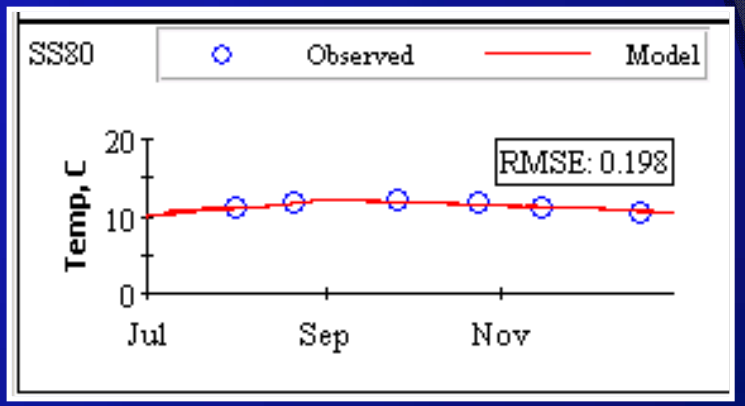


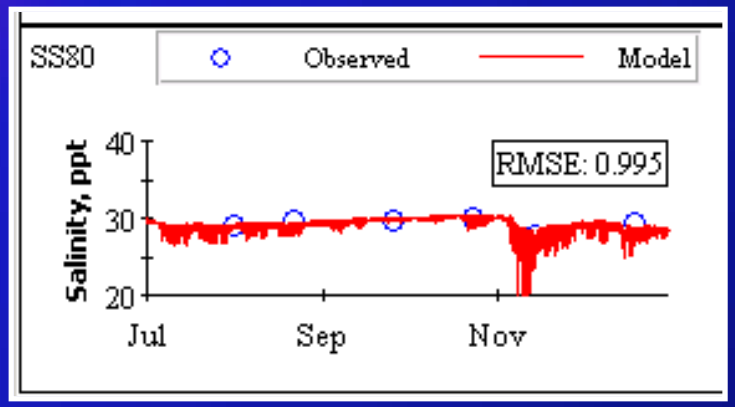


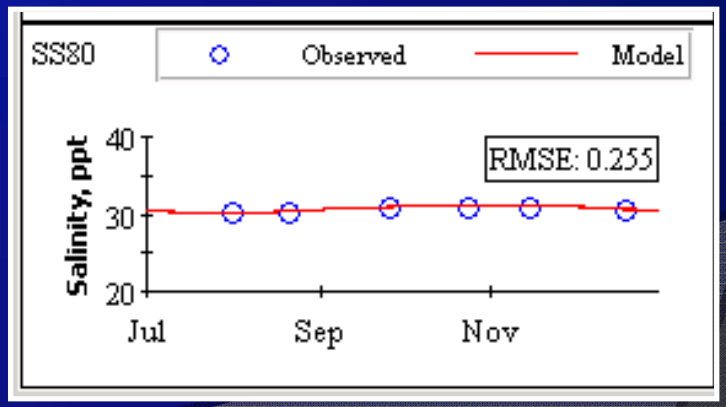


Top and bottom layers at Tacoma Narrows

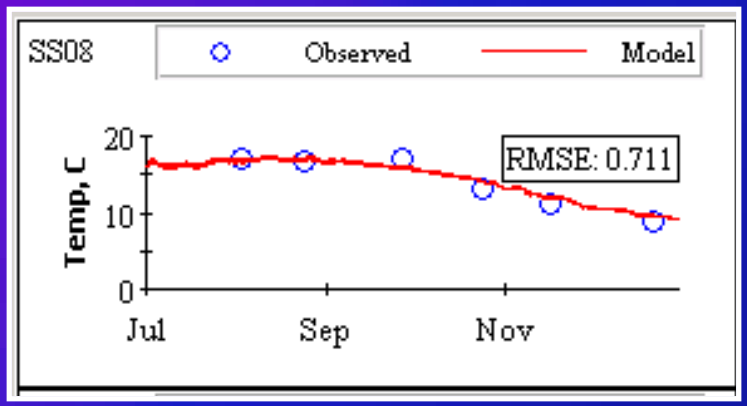


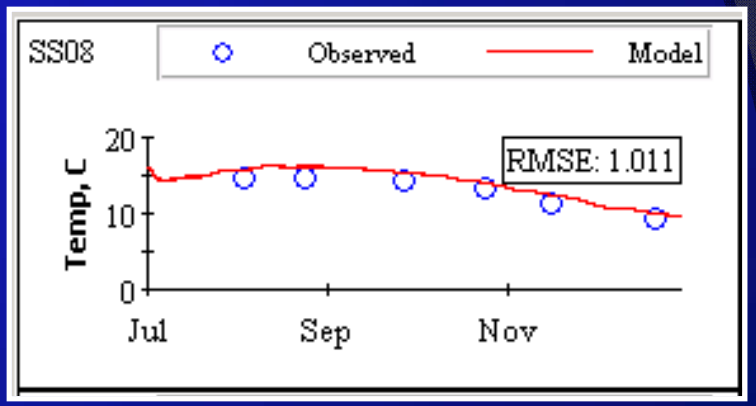


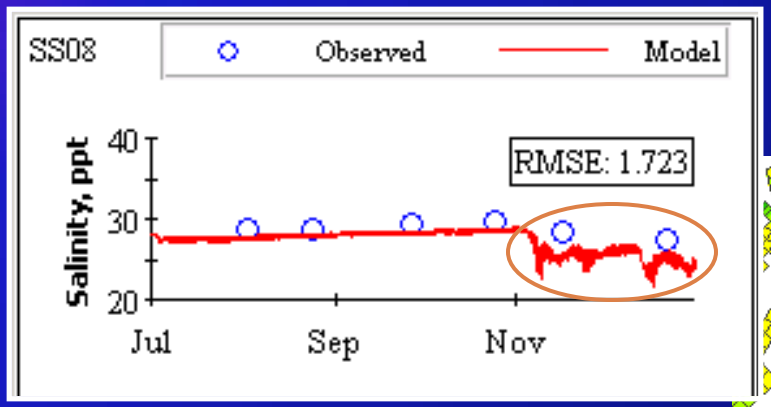


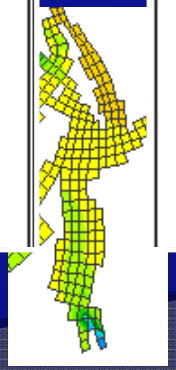


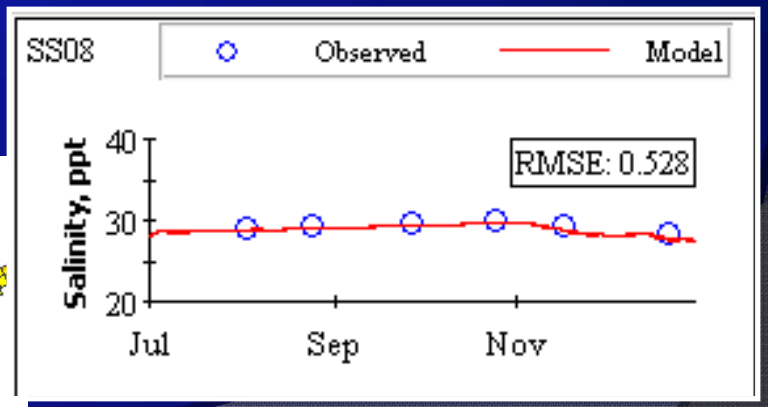
Top and bottom layers in Budd Inlet



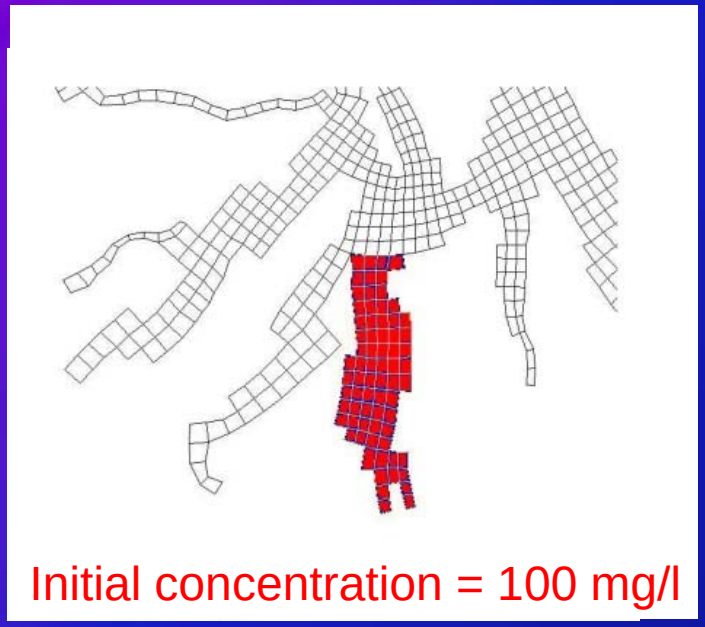




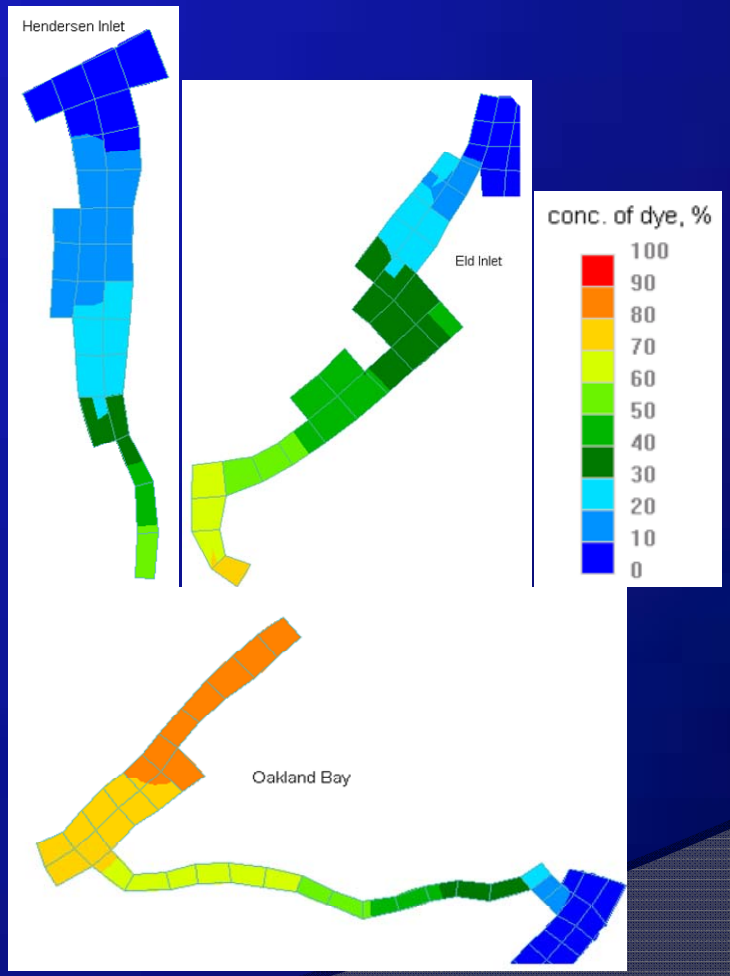


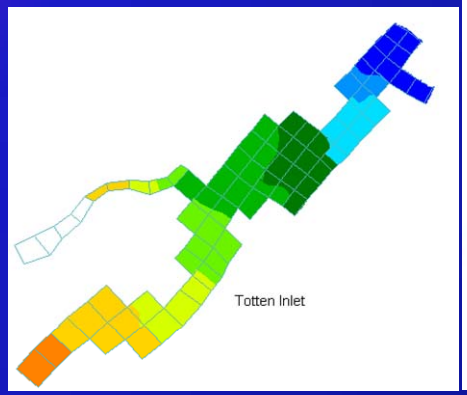


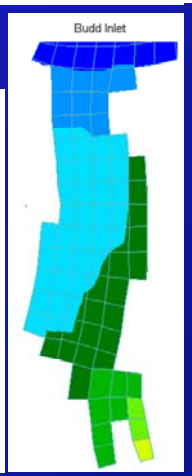
Flushing Time, Residence Time, Age



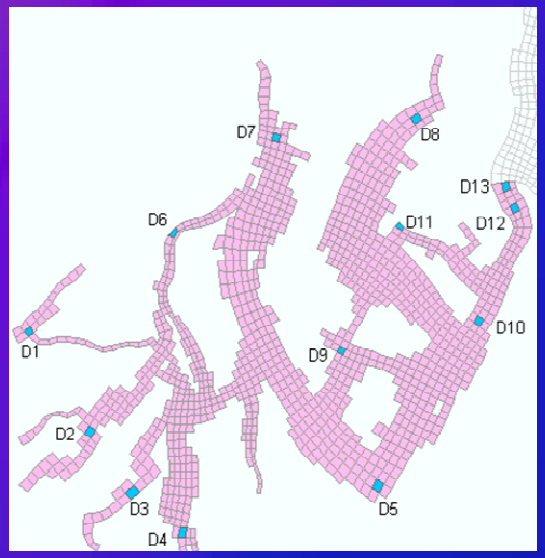
Initial concentration = 100 mg/l

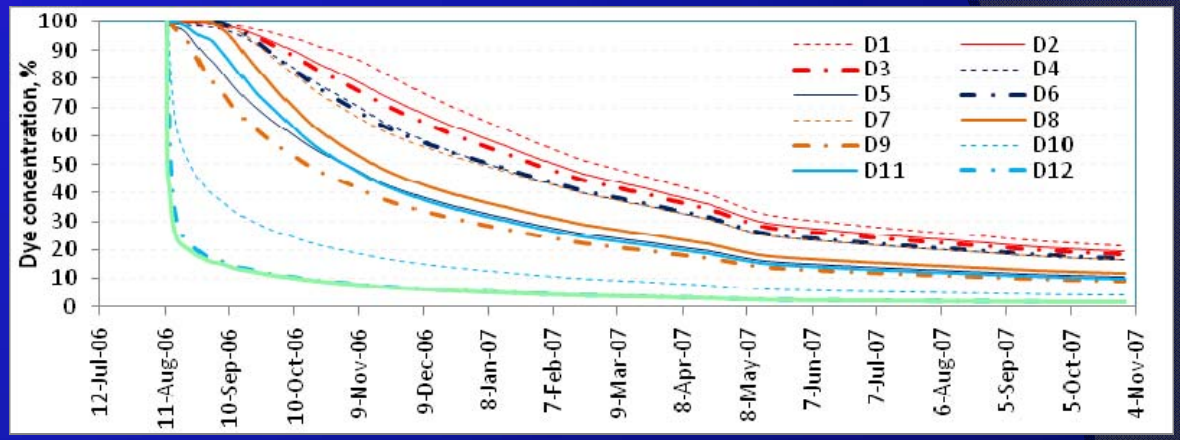


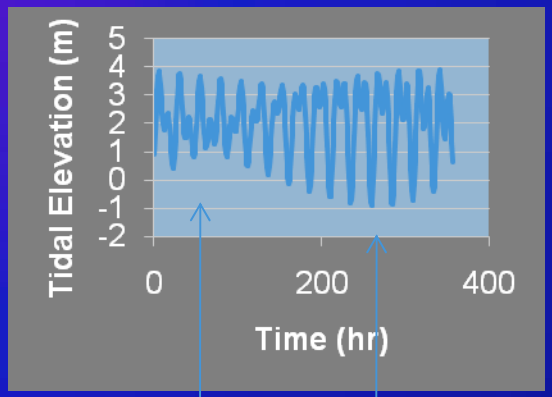




Removal of dye

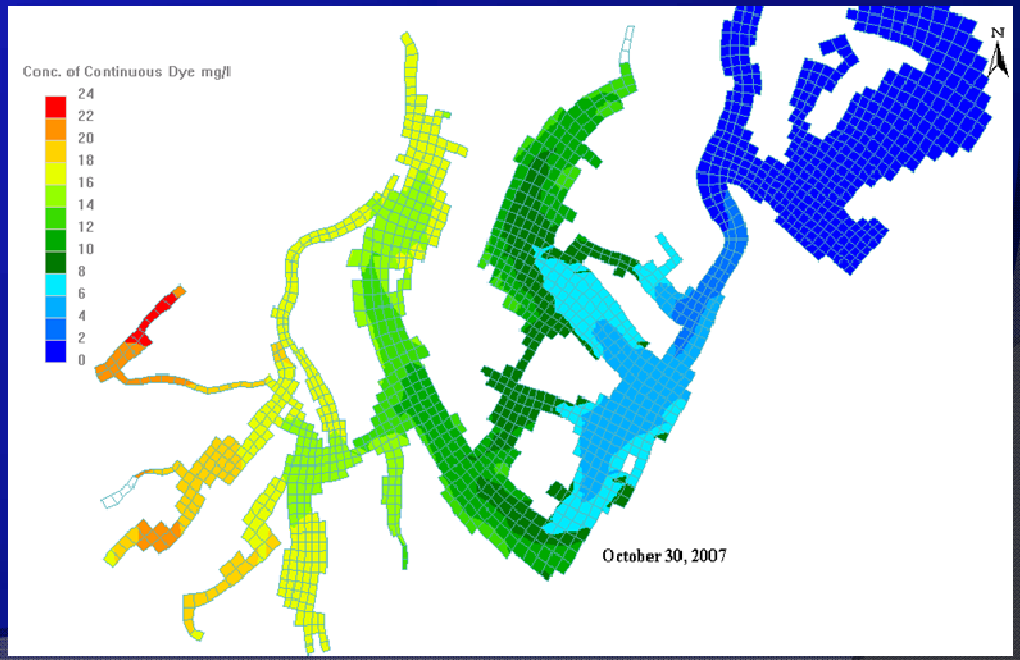






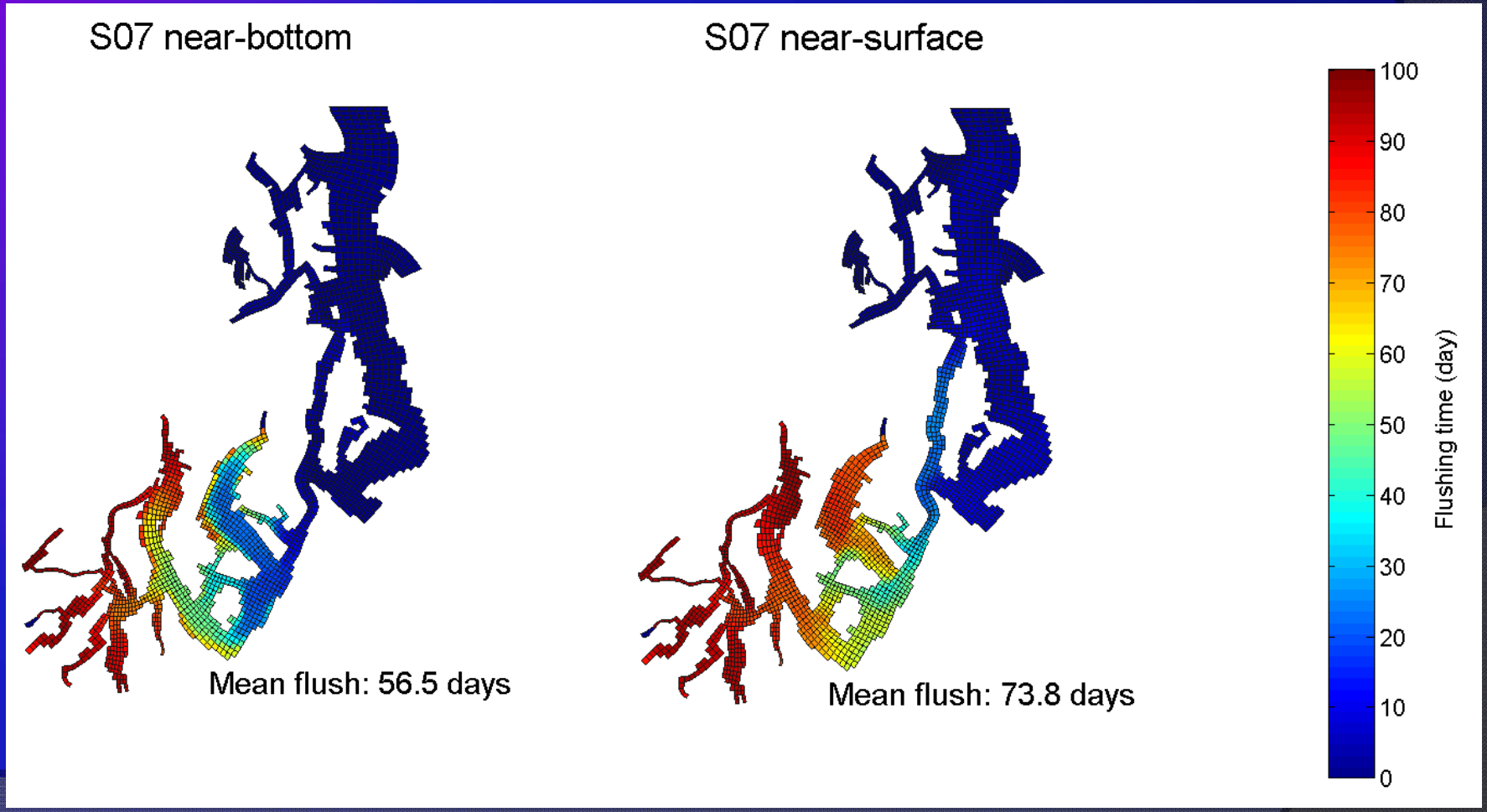
neap tides

spring tides

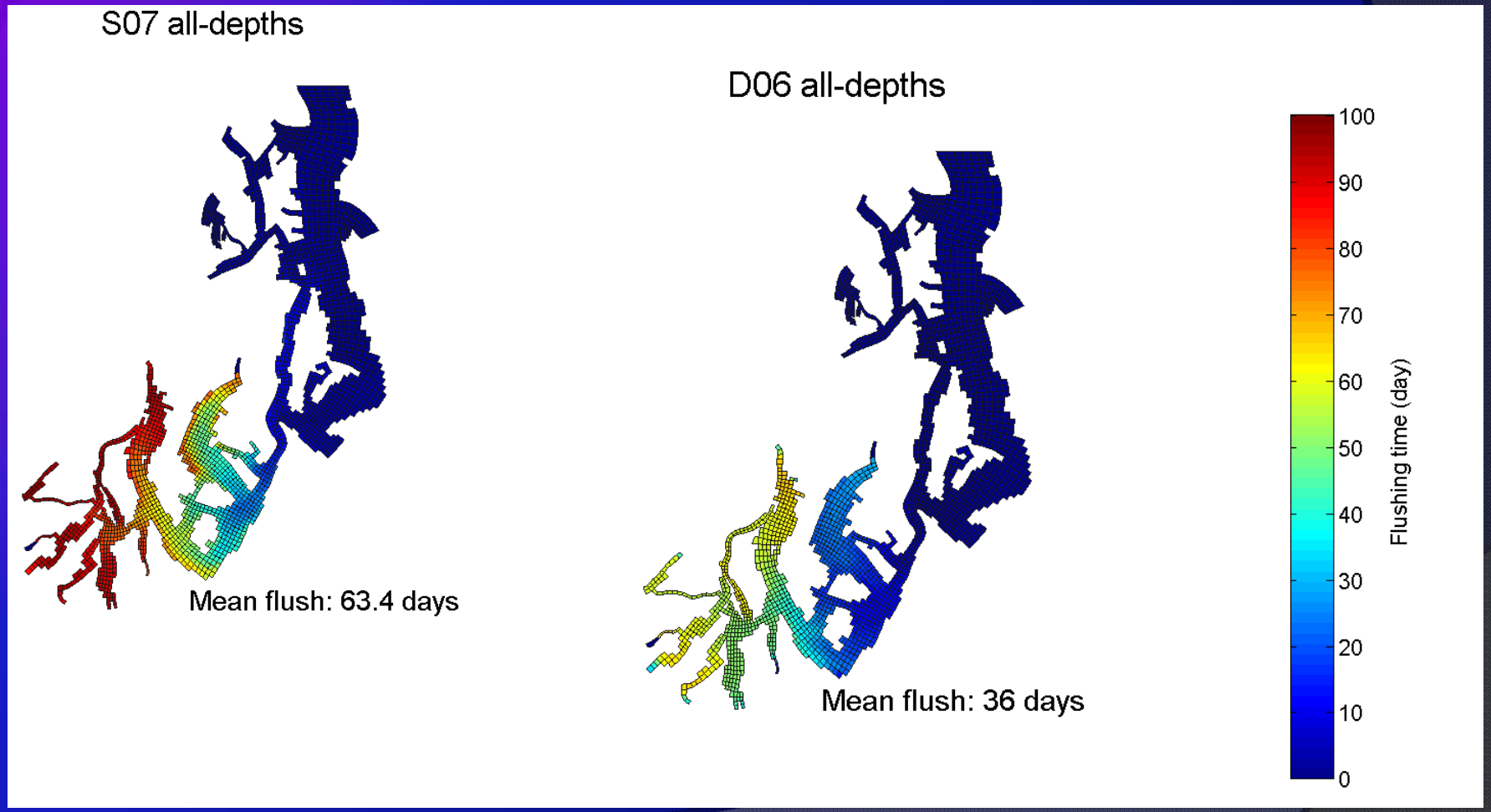


Converting to an age gridcell-by-gridcell
(by assuming an exponential first-order decay)

$$D(I,J,t) = D_O\, e^{-t/\tau(I,J)}$$



Seasonality



Conclusions:

- Flushing time depends on location.

- Flushing time varies seasonally and between years; flushing changes by a factor of two in most places due to seasonal changes in wind, freshwater input, and tidal forcing.

- Longest flushing times in summer and fall, shortest in winter.

- We find an average flushing time of about 67 days versus 56 days in literature.