The Virtual Bay

Modeling Nutrients & Transport In San Francisco Bay

Rusty Holleman, Phil Bresnahan, David Senn
San Francisco Estuary Institute
Why Model?

Role of Models in Decision-making

Models as tools that synthesize our collective knowledge of…

- biogeochemical processes,
- physical processes,
- and the observed state of the system.
Coupled Hydrodynamic and Water Quality Modeling

Hydrodynamics

Conservative Tracers
Transport/Mixing/Dilution

Nitrification
Denitrification
Sediment Flux

Phytoplankton:
Community
Growth

Dissolved Oxygen

Management Scenarios
Environmental Scenarios

Roughly where we are today
Hydrodynamics

WY2013
36 POTWs
5 refineries
73 rivers & creeks
Est. flows, NO3, NH4, PO4
Wind, tides, evaporation

SUNTANS Domain
31 z-layers, (0.5m+)
25k 2D cells
200k 3D cells
70x real-time on 1 core
4km to 200m resolution
Test of Hydrodynamics: Velocity

Model-observation comparisons are good in many parts of the Bay

Velocity Along Principal Axis of Tides
Test of Hydrodynamics: Salinity

Dry-weather salinity, stratification generally good

North Bay salt intrusion under-represented
Water Quality Model: *Delft Water Quality*

- Hydrodynamics, loads as input
- Highly configurable for wide range of studies

**Simple**
transport
de/nitrification
reaeration

**Complex**
Phytoplankton, sediment, …

Necessitates a step-wise approach
Balance completeness vs complexity

In collaboration with USGS-CASCADE II and Deltares
Year 1 Applications
Transport Modeling

Conservative tracers for various discharges.

Depth-averaged: includes dilution by increased depth

Many applications: e.g. CEC sampling strategies
Model-observation Comparison: Dissolved Inorganic Nitrogen

Limited set of nitrogen processes, estimates of NO$_3$ and NH$_4$ loads

→ Modeled concentrations often quite close to observations

![Graph showing model vs. observed DIN concentrations](image-url)
Nutrients: Spatial View

- Provides spatially explicit predictions
- Includes variability in loss terms

Increasing denitrification
Model-observation Comparison: Dissolved Inorganic Nitrogen

Despite the limited set of processes, modeled nutrient concentrations are often quite close to observations. Suggests that dilution and denitrification are significant if not dominant in setting ambient levels.

**Missing processes:** Drawdown by phytoplankton
Adding Phytoplankton

High-res…
- 5-10 days to simulate 1 year
- 100+ GB per run

Low-res…
- 5–20 minutes to simulate 1 year
- Practical for sensitivity analysis, exploration
Low Res
Water Quality

Snapshot of model
April, 2013

Not a 1:1 comparison… but reasonable features and numbers

April 2016
RTC El Niño Cruises
Broader Applications

Coast ↔ Bay linkages for nutrient and contaminant transport

Assessing monitoring program designs

Dilution estimates to inform CEC sampling

Supporting first-cut analysis of transport in Emeryville Crescent
Emeryville Crescent

Part of PCB PMU Study

How far do water parcels move in a single tide?

What fraction of the water is flushed out on each tide?

⇒ Use modeled velocity field in Emeryville Crescent to place bounds on transport.
Emeryville Crescent

How much of the water in the Crescent at high tide leaves and does not return on the following high tide?
Next Steps - FY17

- Continued development, calibration, and testing
- Integration of new hydrodynamics including improved South Bay
- Expand beyond South Bay
- Support range of studies for nutrients, monitoring, and beyond

In collaboration with CASCaDE II, Deltares, TU Delft, RMA