Modeling the Influence of Fall Outflow and Community Structure on the Delta Smelt Population

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The ecological significance of the low salinity habitat (LSH, 1-6 psu) in controlling the distribution and abundance of Delta Smelt is increasingly recognized. The response of the Delta Smelt to fall outflows is an area of significant interest in terms of adaptive management. Modeling the complex mechanisms operating in the LSH may contribute to better understanding its underlying ecological processes. The objectives of this study were to model both community structure under 3 outflow scenarios and the effect of outflow on species/trophic levels. The response of the Delta Smelt population was then compared between model predictions and field data. Qualitative and quantitative species interaction models were used to evaluate the response of the community and its stability under 3 fall outflow levels: low (5,000 cfs), intermediate (8,000 cfs) and high (11,400 cfs), where the near-bottom 2 psu salinity position in the estuary (X2), corresponded respectively to X2 of 85, 81 and 74 km. Community composition for each outflow scenario included species/trophic groups relevant to the Delta Smelt subsystem at each X2 level (class I models). Class II models further included outflow and unlike class I models, sustained outflow disturbances (press perturbations) were assumed to transfer indirectly from outflow to other community variables. Both classes I and II models showed the predicted population response of the Delta Smelt were: 1) consistently positive and certain under the high outflow community scenario, 2) generally positive but very ambiguous under the intermediate and low outflow community scenarios. Quantitative simulation models further showed community stability tended to decline from high outflow scenarios to intermediate and low outflow scenarios. Model predictions were consistent with the observed Delta Smelt response and support the hypothesis that the fall outflow action has a positive population level effect on Delta Smelt by shifting the LSH towards X2 = 74 km.

Keywords: delta smelt, flow, management, species interactions, X2, stability, community, model

Poster topic: Modeling

Modeling the Bay-Delta Circulation and Ecosystem

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Coupled physical and biological models are an effective way to address complex resource management questions in dynamic systems such as the San Francisco Bay/Estuary and Sacramento-San Joaquin River Delta (Bay-Delta). An unstructured grid model known as SELFE (Semi-implicit Eulerian-Lagrangian Finite Element) is used to model the 3-dimensional circulation of this system and is coupled to the CoSiNE ecosystem model to study the nutrient and biomass cycle. The CoSiNE ecosystem model consists of 13 tracers (Nitrate, Silicate, Ammonium, Small Phytoplankton, Diatoms, Micro-Zooplankton, Meso-Zooplankton, detrital Nitrogen, detrital Silicate, Phosphate, Dissolved Oxygen, Total CO2 and Total Alkalinity). The air-sea fluxes are provided by a high-resolution (3-km) mesoscale atmospheric model (COAMPS). The river discharge data are used as the lateral boundary condition upstream. The coastal ocean boundary condition is derived from a structured grid California coastal ocean model (ROMS). The coupled circulation-ecosystem model is tested and refined during June-July 2009 against a number of observational data sets. The validated model is then used to make a 10-year hindcast during 2004-2013 with a goal to describe, understand and ultimately predict the influence of climate change scenarios on the nutrient and biomass cycles in the Bay-Delta. Results from the June-July 2009 test run as well as the 10-year hindcast will be presented. Possible ways in which this coupled circulation-ecosystem model can be used to study and manage the Sacramento River Fall Chinook Salmon will be discussed.

Keywords: modeling, circulation, ecosystem, climate, Salmon, prediction, nutrient, biomass, unstructured, grid

Poster topic: Modeling

Sacramento River Chinook: A Statistical Model for Evaluating the Influence of Environmental Variability and Competition on Survival

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Chinook salmon (*Oncorhynchus tshawytscha*) populations spawning in the Sacramento River, CA and its tributaries have demonstrated high variability, and in some cases significant declines in spawning abundance during the past 40 years. The purpose of this research is to provide a quantitative framework for assessing the influence of both environmental and anthropogenic factors on the survival of Chinook populations in the Central Valley during both freshwater and marine portions of the lifecycle. We employ a stage-structured population dynamics model to evaluate the influence these factors on productivity and capacity limitations during specific life stages, and those resulting from an interaction among co-migrating CV Chinook natural populations and hatchery reared stocks. The stage transitions are modeled using Beverton-Holt functions, in which the productivity and capacity parameters are modeled as a function of the hypothesized factors and abundances of co-migrating populations. The population dynamics model generates predicted abundance for returning spawners and out-migrating juveniles in each year as a function of the hypothesized factors and their associated coefficients which describe their influence. The coefficients are subsequently estimated by using a statistical fitting algorithm that minimizes the error between model predictions and observed adult abundances, and juvenile abundances where available. Alternative models (hypotheses incorporating different combinations of factors) are compared using the Akaike Information criterion (AICc) and a cross-validation approach to balance model complexity with ability to explain historical data. In this analysis we focus primarily on Sacramento River Fall and Spring-run Chinook populations given the potential for interaction throughout the lower Sacramento River, delta and estuary during rearing and outmigration.

Keywords: Chinook, Population dynamics, Survival, Simulation testing, Statistical model

Poster topic: Modeling

SF Estuary Salinity Field and Fish Abundance and Distribution Visualization

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The relationship between the salinity gradient and the abundance and distribution of several species of SF Bay Delta fishes and other aquatic life is important for managing freshwater flows through the estuary but the causes of the relationship are poorly understood. We are developing a visualization of the long-term changes in the salinity field and the abundance and distribution of several SF Bay Delta Estuary fishes to improve our understanding. The visualization tool is produced using ArcMap (a GIS program) which imports 30 years of salinity field predictions developed using a coarse-grid version of the UnTRIM San Francisco Bay-Delta Model, which incorporates complex bathymetry at a sub-grid scale and runs more than 1200 times faster than real-time. Fish monitoring data from California Department of Fish and Wildlife are mapped on a seasonally averaged salinity gradient to produce a 30-year time series that illustrates the long-term changes in abundance and distribution of fishes relevant to the salinity field. The poster summarizes our initial results reviewing Longfin smelt monitoring data changes over the last 30 years mapped on the seasonally averaged salinity gradient. This work is intended to improve our understanding of how the salinity field and abundance and distribution of several estuarine fishes has changed over long time periods and provides a spatial framework to further explore the relationship between salinity gradient and fish abundance.

Keywords: salinity, fish, abundance, distribution, modeling

Poster topic: Modeling

Comparison of Mixing at a Junction Computed With Two- and Three-Dimensional Models to the Simple Flow-Weighting Scheme Used in One-Dimensional Models

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Models that approximate complex channel networks like the Sacrament-San Joaquin Delta with one-dimensional interconnected channels (such as DSM2; Delta Simulation Model II) can be run much faster than their two- and three-dimensional counterparts (such as UnTRIM, Delft3D, SUNTANS). However, calculation of transport in one-dimensional channel networks requires numerous assumptions about dispersion and mixing within the flow, particularly at junctions. The simplest approximation for the mixing at a junction is to assume that scalar mass is partitioned based on flow weighting, whereby the percentage of mass entering a particular channel is given identically by the fraction of flow volume entering that channel. Although this approximation ignores complex three-dimensional flow features at a junction that may significantly affect mixing, we demonstrate that in many circumstances it is reasonable. The three-dimensional SUNTANS model is employed to simulate flow at a junction in the Delta, and we compare direct calculations of flow and mixing at the junction with the SUNTANS model to the simple flow-weighting scheme. The results indicate that the three-dimensional model differs from the simple flow-weighting scheme only in the presence of large and persistent recirculation regions, justifying the use of the flow-weighting scheme for most junctions of interest.

Keywords: Mixing, Junctions, 1D modeling, 3D modeling, Secondary circulation, SUNTANS, DSM2

Poster topic: Modeling

Habitat Restoration and Water Diversion Effects of the Proposed Bay Delta Conservation Plan on the Hydrodynamics of a Key River Junction within the Sacramento-San Joaquin Delta, California

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Field studies have shown that the survival probability of outmigrating juvenile salmonids in the Sacramento-San Joaquin Delta is markedly lower for fish entering the interior Delta through Georgiana Slough than for fish remaining in the main stem Sacramento River. The likelihood of fish entering Georgiana Slough is a function of flow entering the junction, which reflects the interaction of river flow entering the Delta and tides. Under the proposed Bay Delta Conservation Plan (BDCP), a portion of Sacramento River flow would be diverted by three intakes between Clarksburg and Courtland, which has raised management concern because of the potential for a greater proportion of flow, and therefore fish, to enter Georgiana Slough should less river flow lead to stronger tidal influence and an increased frequency of upstream (reverse) flows. The BDCP proposes criteria for flows bypassing the intakes to limit such negative effects, and also proposes extensive tidal habitat restoration, which would result in wide-ranging changes in Delta hydrodynamics. Outputs from the California Department of Water Resources' Delta Simulation Model II suggested that the incidence of reverse flows and the proportion of flow entering Georgiana Slough within the main salmonid migration period (December-June) were similar or slightly lower under various BDCP scenarios, relative to base scenarios with the existing configuration of the Delta and existing water operations. Proposed tidal habitat restoration greatly affected hydrodynamics at the river junction, reflecting assumptions about habitat restoration extent in the Cache Slough complex that would draw tidal energy away from the main stem Sacramento River at Georgiana Slough; this was confirmed by sensitivity analyses of scenarios with proposed BDCP operations but without tidal habitat restoration. It is concluded that proposed BDCP water operations and habitat restoration would not result in an increase in flow and fish entering Georgiana Slough from the Sacramento River.

Keywords: Bay Delta Conservation Plan, Georgiana Slough, Sacramento River, flow, restoration

Poster topic: Modeling

Enhancing the Vision for Managing California's Environmental Information: A Vision Document

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This poster describes the features, impact, and future outreach plans for a "vision document" that has emerged from the Environmental Data Summit, which was convened in June 2014. The product of a collective effort, the vision document reflects the ideas of technologists, data specialists, and scientists who gathered together with a common interest to characterize the opportunities for contemporary data management, to envision how we might identify the obstacles before us, and to chart a path toward an open community of information sharing.
The challenges facing California's Delta are not new, but they are underscored by the urgencies of the moment. Pressing matters such as climate change, an aging water infrastructure, and a deep drought force all Californians to recognize the fragile balance between our natural resources and their competing uses across the state but nowhere so poignantly as in the Delta. There, natural resource decisions must accommodate both the rate of environmental change and the fast pace of intervention efforts.
To be effective under these circumstances, agencies, organizations, and public interests must make use of today's innovations with an equally fast rate of adoption. And they must share the information and data produced through these innovations across conventional jurisdictions and agency boundaries. In short, the need for transparency and sharing of data demands an open community of science with interoperability standards, state-of-the-art data exchange and access tools. Decision makers, analysts, and public interests recognize the need for such a sharing initiative. With the world's most advanced technology resources located here in California, how do we apply our intellectual resources to this problem, to ensure that sharing information becomes the norm for natural resource management rather than the exception? And how do we best complement and build upon on our past technology investments?

Keywords: Big Data, Data Intergration, Knowledge discovery, Data Mining

Poster topic: Modeling

Projecting Boundary Conditions for a Hydrodynamic Model of the Bay-Delta under Scenarios of Climate Change

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The CASCaDE project, funded by the U.S. Geological Survey and the Delta Science Program, was developed to bring together scientists from multiple disciplines to conduct coordinated assessments of the potential effects of climate and infrastructure changes on the Bay-Delta aquatic ecosystem. At the core of this effort are simulations of the response of the estuary to scenarios of change using the Delft 3D Flexible Mesh (D3DFM) hydrodynamic model, which integrates a variety of hydrodynamic, water quality, and biological responses into a single model.

D3DFM is driven at its horizontal boundaries by flow rate, water temperature, salinity and sediment flux, and at the water surface by air temperature, precipitation, wind speed, surface pressure, humidity and cloudiness. Translating GCM outputs into these quantities at the appropriate spatial and temporal scales in a manner that is consistent with real-world behavior has entailed the development of new models and techniques.

In this poster, methods for deriving climate-change time series for several of the D3DFM boundary forcings will be summarized briefly. These time series are all ultimately derived from GCM outputs, with corrections based on relevant historical observations applied to obtain realistic behavior.

One of the more complex sets of time series to derive--river flows at the model's upstream boundaries--will be addressed in more detail. The sequence of models and techniques used in this derivation include downscaling and bias correction (using the LOCA method, development of which was sponsored by the California Energy Commission and other agencies) of GCM daily meteorological outputs over California, propagation of these signals through hydrological (VIC) and management (CALSIM II) models, and application of a new method to disaggregate monthly CALSIM flows to the daily time scale. Preliminary results will be presented.

Keywords: climate change, warming, modeling, watershed, snowpack, streamflows, floods, droughts, reservoirs

Poster topic: Modeling

The Calibration of a 3D Hydrodynamic Model for the Assessment of Water Quality Indicators in the San Francisco Bay-Delta System

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The USGS-led CASCaDE II project aims to understand the potential effects of changes in climate and physical configuration on water quality, ecosystem processes, and key species in the San Francisco Bay and Delta through the application of a series of linked models of climate, hydrology, hydrodynamics, sediment, geomorphology, phytoplankton, bivalves, contaminants, marsh accretion, and fish. CASCaDE II extends the work of CASCaDE I in part through the depiction of the Bay-Delta in one continuous domain, allowing for more interaction of hydrodynamics and water quality between the Bay and Delta.

The 3D hydrodynamic model Delft3D-Flexible Mesh (DFM), developed by Deltares, is applied as a foundation for exploring linkages between ecologically relevant processes in the Bay-Delta System, and has been calibrated for water flow, salinity and temperature. The model domain encompasses the coastal ocean, estuary, and lower watershed, and is driven by tidal forcing along the Pacific Ocean boundary in the west, and freshwater inflows from rivers in the North Bay and Delta. The model also includes freshwater withdrawal at major local, state, and federal sites, and the effects of temporary barriers and gates. DFM's combined curvilinear and unstructured grid provides both improved alignment along main flow directions and more natural depictions of irregular shorelines and allows for the flooding of below-sea-level leveed islands. The model is suitable for running on distributed-memory clusters, as well as multi-core local workstations.

The model has shown good agreement with measurements of the aforementioned parameters, and model performance, shown through numerous statistical metrics, is shown to be good for many locations throughout the Bay-Delta. Early results indicate that DFM is a useful tool to improve understanding of the effects of changes in regional climate and infrastructure on Bay-Delta hydrodynamics. Ultimately, through linkages with other models, DFM will shed light on likely resulting ecosystem change.

Keywords: Hydrodynamics, Three-dimensional modeling, Unstructured meshes, salinity, temperature, tidal processes, rivers

Poster topic: Modeling

Airborne Surface Water Elevation Observation for Hydrodynamic Modeling in the Sacramento-San Joaquin Delta

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Hydrodynamic processes in complex environments such as deltas are highly spatially heterogeneous and this spatial variability cannot be fully represented by traditional hydrological monitoring which relies on frequent water level measurements at discrete locations. Remote sensing on the other hand, whether air-or spaceborne, allows for spatially distributed measurements but the frequency of data acquisition is typically too low for the data to be immediately useful in hydrological applications. Because of this, remote sensing data are often used in conjunction with hydrological or hydrodynamic models.

The new AirSWOT instrument provides spatially distributed measurements of water surface elevation from an airborne platform and the Sacramento-San Joaquin Delta is one of its test areas. In order to assess the value of such measurements to hydrodynamic modeling in the Delta, a synthetic data assimilation experiment was designed. A hydrodynamic model of the Delta was set up and run using in situ observations as input to produce a "true" run. Sets of synthetic AirSWOT measurements, covering different locations and at different times, were then generated based this "true" run and expected measurement errors. An ensemble of perturbed runs was generated by perturbing the boundary conditions (upstream inflows, downstream tidal levels and export pumping) and the synthetic data sets were assimilated using the ensemble Kalman Filter. The impact of the assimilation on the hydrodynamic model performance was studied for the different sets of synthetic data to identify the most sensitive measurement times and locations in order to help improve the design of future measurement campaigns.

The research described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Keywords: hydrodynamic modeling, remote sensing, data assimilation

Poster topic: Modeling

Lessons Applicable to the Bay-Delta Nutrients Program from a Nutrient TMDL Developed for a Polluted Urban Watershed

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Lessons learnt from a nutrient total maximum daily load (TMDL) allocation study for a historically eutrophic urban lake are presented in the context of the numeric nutrient endpoint program that is underway for the San Francisco Bay and Delta. Even though the TMDL was developed for a lacustrine system the technical and regulatory challenges provided unique insights that are relevant to the Bay-Delta. Onondaga Lake, a dimictic, water body located in central New York, has a 100-year history of legacy municipal and industrial pollution. The lake drains into Seneca River in which navigable water levels are maintained by the operation of a series of locks. Filter feeding dreissenid mussels have played a major role in affecting the water quality of the Seneca River, and to a lesser extent in Onondaga Lake. The development of the TMDL follows a 1998 Consent Judgment that required an extensive monitoring program, and the development of a series of mathematical models of the lake, its watershed, and the Seneca River to provide an integrated assessment of potential point and non-point nutrient loading mitigation measures. Ongoing improvements to point sources and implementation of gray and green infrastructure programs (e.g., Save the Rain program) have resulted in a remarkable improvement in water quality. Additional mitigation measures were put into context through two bounding scenarios: the lake under pre-colonial conditions; the lake with loadings continued before the ACJ was passed. Model projections showed only modest improvements in lake water quality with inter-annual variability far greater than the improvements simulated between scenarios, and that anoxic conditions likely existed even under pre-colonial conditions. Paleolimniological evidence derived from the lake's sediments independently confirmed the model findings. NYSDEC used these results in developing phosphorus TMDL allocation for the lake, which was approved by U.S. EPA in 2012.

Keywords: TMDL, Eutrophication, Food web, Water Quality Modeling, Point/Non-Point source control

Poster topic: Modeling

Improving Process Based Modeling of CO_2 and CH_4 from Managed Wetland and Rice Systems in the Delta

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Under California's Cap-and-Trade program, companies are looking to invest in land use practices that will reduce greenhouse gases (GHG). Restoring drained cultivated peatlands to flooded conditions in the Sacramento-San Joaquin River Delta may significantly reduce GHG emissions. However, in order for land owners to participate in the Cap-and-Trade program, we need a reliable method for quantifying the GHG emissions associated with flooding cultivated peatlands. Process-based biogeochemical modeling can provide a cheap and rigorous method for calculating GHG reductions associated with land use change. The goal of our research is to contribute to emission protocol development by provideing accurate biogeochemical models calibrated to diverse land uses in the Delta. We took a hierarchical modeling approach to develop and test a soil CO_2 and CH_4 emission model in the Delta. First we adapted the Dual Arrhenius Michaelis-Menten kinetics model (DAMM) to predict soil surface CO_2 and CH_4 emissions using temperature, plant productivity, soil C substrates, and water table depth. The modified DAMM model was integrated with a simple light use efficiency model. This allowed not only accurate simulation of gross primary productivity but also the influence of plant productivity on microbial production of CO_2 and CH_4. The modified DAMM model has 2 C pools differing in lability and inputs including a labile soil C pool (associated with plant photosynthetic C) and a recalcitrant C pool (associated with soil organic matter). Water table depth allowed accurate simulation of inhibited soil respiration and enhanced methanogenesis during inundated conditions. The modified DAMM and plant productivity model was then parameterized in both restored wetland and rice systems using net ecosystem exchange of CO_2 and CH_4 measured with the eddy covariance technique. This ecosystem model will advance understanding of biogeochemisty in managed peatland systems as well as aid the development of a GHG protocol in the Delta.

Keywords: Rice, Managed wetlands, biogeochemical modeling, light use, efficiency, methane, emission

Poster topic: Modeling

Modeling Selenium Biogeochemistry in the Delta and San Francisco Bay

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San Francisco Bay is the subject of a total maximum daily load (TMDL) evaluation for selenium given elevated tissue concentrations in some species. Selenium is present at background levels in the Sacramento River and Pacific Ocean, at elevated levels in the San Joaquin River and certain tributaries, and is also discharged through refinery and other point sources in the Bay. Selenium exists in multiple oxidation states and in different dissolved and particulate forms that are relevant to its biological uptake. Here we present the results of modeling of different selenium species through the Delta (using the Delta Simulation Model, DSM2), and the in the bay using an estuary biogeochemistry model (ECoS). The model is calibrated and validated with speciated selenium transect data across the estuary collected in 1999-2000 and in 2000-2012, as well as data from tributaries, the major rivers, and point sources collected over the last 5 years. The modeling shows the changing contribution of Delta loads to the bay by water year type and season, with varying San Joaquin inflow volumes. The resulting effects in the bay water column selenium species, both dissolved and particulate, are well represented through the modeling framework. The model is used to evaluate the bay-wide impacts of changing specific selenium loads, such as refinery loads and riverine loads, and large scale changes such as the implementation of selected alternatives envisioned as part of the Bay Delta Conservation Plan.

Keywords: selenium, DSM2, biogeochemistry, speciation

Poster topic: Modeling

How Much Floodplain Habitat is in the Central Valley and How Much Do We Need to Achieve the AFRP Chinook Salmon Doubling Goal?

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We applied best available tools and data to quantify the area of all types of existing Central Valley floodplain habitat and to estimate the amount of additional floodplain rearing habitat that would be needed in each of the Central Valley Flood Protection Plan (CVFPP) Conservation Planning Areas (CPAs) to achieve the Anadromous Fish Restoration Program (AFRP) "doubling goal" for Central Valley Chinook salmon populations. Historical and existing salmonid rearing habitat acreages were determined using an Estimated Annual Habitat (EAH)-based approach (Matella and Jagt 2013) that considers current and historical (i.e., before construction of Central Valley dams and levees) hydrology together with pre-levee and leveed flow-area relationships to calculate the area of rearing habitat historically and presently inundated with timing, duration, and frequency meaningful to juvenile Chinook salmon. Rearing habitat needed to support the doubling goal populations was estimated using the Emigrating Salmonid Habitat Estimation (ESHE) model, a territory size-based model that uses empirically-derived salmonid survival rates, growth rates, and migration rates to determine habitat area needs. Initial results from this investigation provide spatial and quantitative information to guide identification and prioritization of floodplain reconnection or restoration areas that could contribute to satisfying the AFRP Doubling Goal. Additional ongoing work is refining the spatial scale of the initial analysis to support site-specific levee configuration evaluations for floodplain habitat reconnection and restoration throughout the Sacramento and San Joaquin River watersheds.

Keywords: Floodplain, Doubling Goal, Estimated Annual Habitat, Emigrating Salmonid Habitat Estimation

Poster topic: Modeling

Building a Public Community around the D3D-FM San Francisco Bay-Delta Model

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The San Francisco Bay-Delta system is complex in its physical and environmental dynamics. Modeling tools that integrate hydrodynamics and water quality dynamics are essential to unravel the governing processes on various spatial and temporal scales and assess potential developments due to climate change and adapting management strategies. There is a need for open access, publicly available, integrated modeling platforms to facilitate and enhance interdisciplinary and interagency scientific communication, collaboration, and understanding.

Cascade project partners (http://cascade.wr.usgs.gov/) currently develop a 3D hydrodynamic surface water flow model applying the Delft3D FM (flexible mesh) Deltares software. The domain covers an area from Point Reyes up to the tidal limits near Sacramento and Vernalis (http://san-francisco-bay-delta-model.unesco-ihe.org/). A high resolution mesh allows for detailed computations of flow and water quality including turbidity, phytoplankton, nutrients, and contaminants. The Bay Nutrient Strategy also recently adopted this model to inform nutrient management decisions.

We aim to present a web-based infrastructure around this SF Bay Delta model to stimulate and enhance knowledge and understanding of the Bay-Delta system. The SF Bay Delta community model is open access (publicly available, but only 2D in first instance) and the modeling software (Delft3D FM) will be released as open source. The web-based infrastructure will support other open-source implementations of the SF Bay-Delta system, such as SUNTANS, ROMS, UNTRIM, which are also under active development. Ultimately, the platform will enable community involvement in the development and comparison of modeling systems.

It is our hope that the SF Bay-Delta community model will stimulate scientific co-operation and knowledge sharing by providing a sound and continuous basis for future scientific or operational projects. We intend for both users and developers to contribute to further optimization of model performance in multidisciplinary studies related to salinity intrusion, water quality, contaminants, morphodynamics, flooding and interaction with groundwater flow.

Keywords: process-based modeling, community, model, open source, scientific co-operation

Poster topic: Modeling