An Overview of the CASCaDE II Project

Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov

Integrated physical-ecological models spanning the San Francisco Bay-Delta (SFBD) are needed to assess likely consequences of the many resource management options available to decision-makers. CASCaDE II is developing an interdisciplinary suite of state-of-the-art models as a prototype for eventual support of model-informed decision-making. We will provide a broad overview of the project, including discussion of the project's goals, the overall approach involving a framework of linked models, the scenarios being evaluated, and the general status of the project. This talk will serve as an introduction to the CASCaDE II special session.

Keywords: climate change, interdisciplinary, modeling, ecosystem
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Sea Level Rise and Climate Change Scenarios for the Bay-Delta

Daniel Cayan, Scripps Institution of Oceanography, UC San Diego, dcayan@ucsd.edu
Julie Kalansky, Scripps Institution of Oceanography, UC San Diego, jkalansky@ucsd.edu
Sam Iacobellis, Scripps Institution of Oceanography, UC San Diego, siacobellis@ucsd.edu
Noah Knowles, US Geological Survey, nknowles@usgs.gov
Michael Dettinger, US Geological Survey, mddettin@usgs.gov

Understanding possible sea level rise in the Bay-Delta is a crucial issue to plan for future impacts and to form appropriate adaptation options. Projections of major components of SLR have considerable uncertainty and the science is rapidly evolving. Using recent modeling results from the published literature (not our work), a new set of sea level rise (SLR) estimates for San Francisco has been developed, in association with the ongoing California 4th Climate Change Assessment. A probabilistic approach was taken, using recent published results on the primary components that contribute to global and regional sea level rise, along with a model that produces continuous projections of sea level at selected locations along the California coast. Hourly SLR at individual California coastal tide gage sites are produced, allowing analyses of extreme events. Envelopes of possible SLR is based on greenhouse gas emission scenarios RCP 4.5, and 8.5, and a subset of global climate models (GCMs) run under those scenarios. This GCM subset was determined by the California Department of Water Resources Climate Change Technical Advisory Group in support of DWR's need for a tractably sized subset of GCMs which performs reasonably well in simulating global, the Southwest region, and California climatological and climate variability patterns. For present day-mid 21st Century, projections of SLR are broadly consistent with previous estimates, but for long time horizons and high greenhouse gas emissions scenarios, the upper end of the modeled distribution of SLR is considerably higher than many previous estimates. Concerning extreme coastal events, the downscaling from GCM is consistently applied, so that we can investigate how storm systems that drive sea level fluctuations might reinforce with weather patterns that produce heavy precipitation in the upstream Sierra Nevada.

Keywords: sea level rise flooding climate change
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Hydrological and Management Responses to Scenarios of Climate Change in the Bay-Delta Watershed

Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov
Collin Cronkite-Ratcliff, U.S. Geological Survey, ccronkite-ratcliff@usgs.gov

Downscaled meteorology from climate scenarios were used to drive a model of unimpaired hydrology (VIC) which in turn drove models of operational responses (CalSim II, CRESPI). Twenty daily climate change scenarios from WY1980-2099 were evaluated, with the goal of producing inflow boundary conditions for a watershed sediment model and a downstream estuarine hydrodynamic model. The resulting managed-flow time series were analyzed for century-scale trends. All of the twenty scenarios portrayed warming trends, and most had increasing annual flows. Nearly all exhibited increasing frequency of extreme flows and earlier flow timing. Trends in annual mean flow, flow timing, and frequency of extreme flows were found to be highly correlated across GCM runs. Managed-flow timing trends were driven more by precipitation trends than by trends in air temperature. Scenarios for evaluation by the D3D-FM hydrodynamic model and other CASCaDE II models were selected based on these and other trends.

Keywords: climate change, hydrology, management, modeling
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Conditional Simulation of Streamflow Time Series and Application to Boundary Conditions in the San Francisco Bay-Delta Watershed

Collin Cronkite-Ratcliff, U.S. Geological Survey, ccronkite-ratcliff@usgs.gov
Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov

CASCaDE II requires estimates of daily streamflow below physical impairments throughout the San Francisco Bay-Delta watershed. At many of these locations, the distribution and temporal patterns of the unimpaired daily streamflow time series, estimated by the VIC land surface hydrology model, are distinct from those of the streamflow below the respective impairments. This talk will present CRESPI, a new statistical model for the simulation of daily streamflow time series developed as part of the CASCADE II project. In this application, the CRESPI model is used to simulate daily inflow boundary conditions for 1) a watershed sediment model with boundary conditions located below physical impairments, and 2) the upstream boundary of an estuarine hydrodynamical model of the San Francisco Bay-Delta. For each of the climate scenarios considered in CASCaDE II, the streamflow simulated by CRESPI is conditioned on the daily unimpaired streamflow estimated by VIC. This output can also be constrained to monthly impaired streamflow estimated by the CalSim II water management model. Additionally, information on storage levels in surface reservoirs can be incorporated into the model in order to improve the reproduction of peak flow rates.

Keywords: cascade, hydrology, modeling, statistics, streamflow, timeseries, machine-learning, watershed, reservoir
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Future Trends of Sediment Supply to the San Francisco Bay-Delta Using Downscaled CMIP5 Climate Scenarios and a Calibrated Watershed Model of the Sacramento River Basin, CA

Michelle Stern, USGS, mstern@usgs.gov
Lorraine Flint, USGS, lflint@usgs.gov
Alan Flint, USGS, aflint@usgs.gov
Noah Knowles, USGS, nknowles@usgs.gov
Scott Wright, USGS, sawright@usgs.gov

Turbidity in the San Francisco Bay-Delta, which affects the habitat suitability of key species and the ability of delta marshes to keep up with sea level rise, is highly dependent on sediment supply from contributing watersheds. A watershed model of the Sacramento River Basin in northern California was developed to simulate daily streamflow and suspended sediment transport to the San Francisco Bay-Delta for 2010-2100 using the Hydrological Simulation Program – FORTRAN (HSPF) as part of the Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE II) project. The HSPF model for the Sacramento River Basin is one of a set of interconnected models and provides sediment inputs to a hydrodynamic model of the San Francisco Bay-Delta used for the assessment of hydrologic, water quality, and biologic impacts of climate. The HSPF model was calibrated to available historical streamflow and sediment data from 1958-2008 for 99 sub-basins. The model was applied using 10 Localized Constructed Analogs (LOCA) future climate change scenarios with two representative concentration pathways (RCP 4.5 and 8.5) and the Livneh modeled climate dataset (1979-2013) for baseline comparison. The average results from the 10 climate-change scenarios indicated 37% and 42% increases in sediment loads by mid-century and increases of 52% and 73% by the end of the century for RCP 4.5 and RCP 8.5, respectively. Four scenarios that highlight the range of potential climate change effects on streamflow and sediment indicated that sediment loads decreased 18% for the 'warm and dry' scenario and increased 30%, 107%, and 230% for the 'hot and dry', 'warm and wet', and 'hot and wet' scenarios by the end of century.

Keywords: Sacramento River, Sediment supply, CASCaDE II, CMIP5, Watershed model, HSPF
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Projections of Bay-Delta Hydrodynamics under Future Climate and Hydrology Conditions using a 3D Numerical Model

Rosanne Martyr-Koller, University of California - San Diego, rmartyr@ucsd.edu
Julia Vroom, Deltares Inc., Julia.Vroom@deltares.nl
Mick van der Wegen, UNESCO-IHE, m.vanderwegen@unesco-ihe.org
Lisa Lucas, US Geological Survey, llucas@usgs.gov
Noah Knowles, US Geological Survey, nknowles@usgs.gov
John Helly, University of California San Diego, hellyj@ucsd.edu

San Francisco Bay-Delta water-quality, ecosystem health, and species viability can be affected by planned and unplanned changes in regional infrastructure and future climate conditions. The USGS-led CASCaDE II project comprises a model-based approach for determining how multiple drivers of environmental change, including climate change and infrastructural alterations, could impact the Bay-Delta ecosystem (http://cascade.wr.usgs.gov/).

CASCaDE II implements Delft3D-FM, an unstructured grid, coupled hydrodynamics and water-quality model that describes the evolution of hydrodynamic and water-quality characteristics as the critical drivers in the Bay-Delta system. The model domain encompasses the coastal ocean, estuary, and lower watershed, and includes regional rivers, freshwater withdrawal at major local, state, and federal sites, and regional barriers and gates. The 3D model has been applied to replicate historical hydrodynamic parameters over multiple seasons and wide-ranging hydrological conditions. Model performance was assessed through model timing and scalability on various parallel (high-performance) computing platforms, and fidelity to historical observations of water levels, flow, salinity, and temperature.

Recent Delft3D-FM applications have been driven by a subset of downscaled climate scenarios based on the UN IPCC 5th Assessment, resulting in year-long projections of Bay-Delta hydrodynamics for the near-future and end of century. This talk will focus on these year-long projections by exploring variations in mean sea levels, tides, and salinity and temperature distributions under near-term and end of century conditions. Frequency of extreme environmental conditions, including peak water levels, salinity intrusion, and water temperature relative to historical observations will be discussed. These hydrodynamics projections will be used to partly drive water-quality and ecological models in the CASCaDE II framework. In addition, the model will be made available for third parties via the San Francisco Bay-Delta Community Model website (www.d3d-baydelta.org) after publication of the main findings. Third parties will be allowed to download and adapt the Bay-Delta model for their own use.

Keywords: Climate change, Hydrodynamics, Modeling, Environmental Indicators, Extremes
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Three-Dimensional Chemical Transport Modeling of Selenium in the San Francisco Bay-Delta

James Bishop, U.S. Geological Survey, jmbishop@usgs.gov
Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov

Selenium has been a contaminant of concern in the San Francisco Bay-Delta system since the 1980's when elevated Se concentrations were observed in estuarine vertebrates. Despite reductions in Se loading from oil refineries in 1998, Se concentrations in estuarine organisms remain elevated. While the sources and loads of Se are well documented, the transport pathways and residence times of Se are uncertain. In this study, we couple a DELWAQ water-quality model with a Deltft3D-FM 3-dimensional hydrodynamic model, developed within the USGS CASCaDE II project, to examine travel times and transport pathways from various Se sources and the residence time of Se in different ecoregions of the Bay-Delta. We also examine the effect of changes in flow from the San Joaquin and Sacramento Rivers on estuarine Se concentrations and residence time. Finally, we compare modeled aqueous Se concentrations at specific locations to measured Se concentrations in clam tissues (*Potamocorbula. amurensis*) at the same location. *P. amurensis* bioaccumulate Se and are prey for a number of estuarine fishes and thus are good indicators of Se concentrations in those fish species. This work will aid in understanding the various sources and hydrodynamic factors controlling selenium distributions and entry into the estuarine food web and how proposed river water diversions may affect Bay-Delta selenium loading and exposures.

Keywords: selenium, CASCaDE II, modeling, contaminant, bioavailability, transport, estuary, hydrodynamic, hydrology
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Physical Models to Ecological Response: Challenges in Understanding the Effects of Climate Change on the San Francisco Estuary

Larry Brown, U.S. Geological Survey, lrbrown@usgs.gov
Judith Drexler, U.S. Geological Survey, jdrexler@usgs.gov
A. Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov
Janet Thompson, U.S. Geological Survey, jthompso@usgs.gov
Francis Parchaso, U.S. Geological Survey, parchaso@usgs.gov
James Bishop, U.S. Geological Survey, jmbishop@usgs.gov
Marissa Wulff, U.S. Geological Survey, mwulff@usgs.gov

The CASCaDE II project includes 10 modeling components representing 5 physical processes and five ecological processes. In this presentation we share information concerning the ecological processes: marsh sustainability, contaminants in organisms, phytoplankton production, clam grazing, and fish habitat use. Our objective is to understand how climate change could impact these ecological processes, with specific emphasis on the recovery of listed species in the Delta. Evaluations of previous climate-change scenarios have shown that Delta Smelt would experience increasingly stressful conditions throughout their life cycle, in particular, high temperatures (>24°C) during summer and fall. High temperatures are directly stressful to individuals and would decrease the time available for fish maturation before spawning. In CASCaDE II, we expect to learn more about impacts on Delta Smelt by modeling available habitat based on selected environmental parameters. We used CASCaDE II outputs to carry out 450 simulations by using the one-dimensional marsh surface elevation model (WARMER), and learned that the primary drivers affecting Delta marsh sustainability were the rate of sea-level rise and sediment supply. In particular, we learned that sea-level rise rates of 133 and 179 cm by 2100 resulted in only 32% and 11%, respectively, of scenarios having sustainable marshes. Preliminary modeling of within-estuary selenium loads in CASCaDE I highlighted the importance of tidal dispersion in understanding Se distributions. CASCaDE II modeling will incorporate changes in flows from the Sacramento and San Joaquin Rivers to provide insight into how water management could affect selenium delivery to the estuary's food webs. The interacting phytoplankton and grazing models are still being developed because they are highly dependent on outputs from the physical-process models, but should be ready for application in 2017. Projections regarding ecological impacts of climate change will be critical for planning future management and restoration activities in the Delta.

Keywords: climate change, scenarios, modeling, biological processes
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Impact of Sea Level Rise and Foreseen Engineering Measures in Sediment Trapping Efficiency by Means of a 2D Process-Based Model

Fernanda Achete, UNESCO-IHE, fernandaachete@gmail.com
Mick van der Wegen, UNESCO-IHE, m.vanderwegen@unesco-ihe.org
Bruce Jaffe, USGS-Pacific Science Center, bjaffe@usgs.gov
Dano Roelvink, UNESCO-IHE, Deltares, d.roelvink@unesco-ihe.org

Rivers transport fine sediment, carrying nutrients and contaminants, which partly deposit in the channel network. We use a two-dimensional horizontal, averaged in the vertical (2DH), process-based, numerical model (Delft3D FM) to evaluate the impact of sea level rise and engineering-related changes on trapping of fine sediment in the Sacramento-San Joaquin Delta. Trapping efficiency (Ψ) dictates the amount of sediment that will be available in the Delta system, for example for marsh restoration projects.

The base-case (BCS) reflects current conditions and is used as the standard run for comparison with the other scenarios. Here we show 3 additional scenarios: sea level rise (+1.67m), Delta island flooding, and a decrease in sediment input. The flooded island scenario floods former leveed land where levee breaches result in a "lake" and increases the delta tidal prism by 20%. The scenario of a decrease in sediment input is based on an average rate of 0.8% per year, which is observed in the long term in situ observation and is linked with river damming.

On average 70% of the input sediment in the system is trapped in the Delta. The model reproduces these Ψ within 90% of accuracy. The Ψ decreases by 10% in the sea level rise scenario due to increase in the flow velocities in the Delta. In contrast, the flooded island scenario decreases flow velocities and creates more accommodation space increasing Ψ by 20%. The decrease in sediment input does not affect Ψ.

The increase in tidal prism by flooding from breaches in levees has the most impact on sediment trapping efficiency in the Delta. Our approach shows that validated process-based models are a useful tool to address long-term (decades to centuries) changes in sediment dynamics. In addition, they provide a useful starting point for long-term, process-based studies addressing ecosystem dynamics and health.

Keywords: fine sediment, numerical model
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310