Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 8
Bay-Delta SCHISM Model Developments and Applications

Authors: **Eli Ateljevich, Kijin Nam, Lianwu Liu, Subir Saha, Rueen-fang Wang**
Delta Modeling Section
Bay-Delta Office
California Department of Water Resources

Joseph Zhang
Virginia Institute of Marine Sciences

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8 Bay-Delta SCHISM Model Developments and Applications

8.1 Introduction

The Bay-Delta SCHISM project is an application of the 3D SCHISM (Semi-Implicit Cross-Scale Hydroscience Integrated System Model) that offers the capability to study cross-scale, multidimensional flow and transport in the Bay-Delta. SCHISM is an open source, 3D computational model derivative from an earlier model, SELFE. We have incorporated into SCHISM practical details needed to model the Bay-Delta, such as agricultural sources and sinks, gates and seasonal gates, and barriers. Work on the model has been collaborative with the Virginia Institute of Marine Science (VIMS) and other users.

The model has been deployed for studies over the full domain for two years by California Department of Water Resources (DWR), and we have begun offering institutional support through workshops. The model has also been used as the estuary hydrodynamic component of multidisciplinary collaborations with National Aeronautics and Space Administration (NASA), National Marine Fisheries/National Oceanic and Atmospheric Administration (NOAA), and San Francisco State University, including the SESAME project, a full life cycle model for fish, and NASA-HICO, a remote sensing and nutrient modeling analysis of human impacts.

Development in the past year has emphasized a public release, drought applications, and algorithm improvements. Progress has been made towards diverse capabilities, such as robust flood modeling and temperature calibration. This report surveys some of the work, much of which is in progress.

Last year we reported the model suite under the name SELFE. Around the time of our workshop, the VIMS branch of development of SELFE was renamed. Developments on this version of the model are publically available under the Apache open source license.

8.2 Public Release

The Bay-Delta application of SCHISM, including input files, tutorials, and numerous support tools are now publically distributed at:
http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/bay_delta_schism/.

Links to the executable and VIMS source bundle are also found on this website.

Under the auspices of the California Water and Environmental Modeling Forum (CWEMF), DWR and VIMS conducted managerial and hands-on workshops on SCHISM in December 2014 and January 2015. The purpose of the December workshop was to inform potential stakeholders of the capabilities of the model and to describe possible modes of involvement. The January hands-on workshop spanned nine days over three weeks. It emphasized a review of tidal and mixing processes in the estuary and how they are related to our modeling assumptions, meshing decisions, and algorithmic switches in different parts of the estuary. The DWR computer training capacity of 15 users was fully subscribed, with about half of the participants coming from DWR and half from other agencies.

The biggest barrier to entry operating SCHISM is access to high performance computing (HPC). The mesh resolution of SCHISM is intended to resolve the primary velocity field in major channels. This is really just medium resolution in terms of the physics, but given the extent and complexity of the domain, the problem is computationally burdensome on traditional hardware. Algorithmic improvements described in the next section offer hope that SCHISM will perform meaningful simulations on very high-quality personal computers, at least on shorter time scales.

In the meantime, we and others apply the model over the full Bay-Delta using high performance computing clusters that allow reasonable run times and scaling to larger problems such as the detailed near-scale study of drought barriers. It has not proven difficult for DWR modelers to get used to these types of systems for basic model operation, and such systems are routinely used by oceanographers and coastal modelers. Regardless, only institutional users (DWR, NASA, NOAA, Lawrence Berkeley National Laboratory [LBNL], and some universities) and large consulting firms have regular access to such technologies in-house. Because we have an interest not only in dissemination of the model, but also in establishing redundant platforms for our own use, DWR has tested a small number of commercial cluster services that are available on a commercial basis, including Penguin-on-Demand (POD) and Amazon Web Services (AWS). Of the two, POD offers scientific cluster capabilities that are most compatible with SCHISM and scales up to 128 processing cores with similar performance to our in-house computer. We intend to conduct similar benchmarks on San Diego Supercomputing Center's new Comet supercomputer, which offers time commercially on a discretionary basis. For DWR, these facilities provide redundant capabilities to ensure we can do runs during periods of congested resources For others, they represent a platform to run SCHISM on multi-year studies. We would like to facilitate the sharing of compiled code and data on these systems.

8.3 Applications

8.3.1 Drought Modeling and Emergency Barriers.

The most specific role that SCHISM has played in drought management has been to identify changes in velocities and circulation patterns near the False River Emergency Drought Barrier. Simulations were carried out in 2014 and 2015 to identify locations in Fisherman's Cut, Old River, and Dutch Slough that might be vulnerable to scour if the barriers were installed. In addition, simulations were performed to show how velocity patterns in Franks Tract might be affected by the closure, how this would change the residence time of different areas of the tract and change the likelihood of toxic algal bloom. Example output is shown in Figure 8-1 for a moment after peak flood tide.

SCHISM was extensively recalibrated for drought in 2014; this is the version that is publically available. SCHISM can now model seasonal salinity changes with the barriers in place, including sensitivity to differing models of agricultural consumptive use. The emphasis with SCHISM has been on showing regional changes in circulation, and demonstrating how the False River Emergency Drought Barrier works.

8.3.2 Temperature Calibration

In collaboration with VIMS and using boundary conditions and assumptions supplied by Resource Management Associates (RMA) as part of the calibration of temperature for DSM2, we are most of the way through a temperature calibration for SCHISM. Our partners at VIMS are currently able to model temperature successfully in much of the Bay-Delta, and we are currently working on methods for handling the ocean boundary robustly and accurately. So far, our SESAME partners have supplied boundary conditions from a 3D model of the near coast (CENCOOS ROMS model), and this method holds some promise (e.g., real-time modeling with short-term predictions and hindcasts from the past decade) when this off-shore data modeling data is available. Results in the Delta do not appear to be sensitive to assumptions on the ocean boundary.

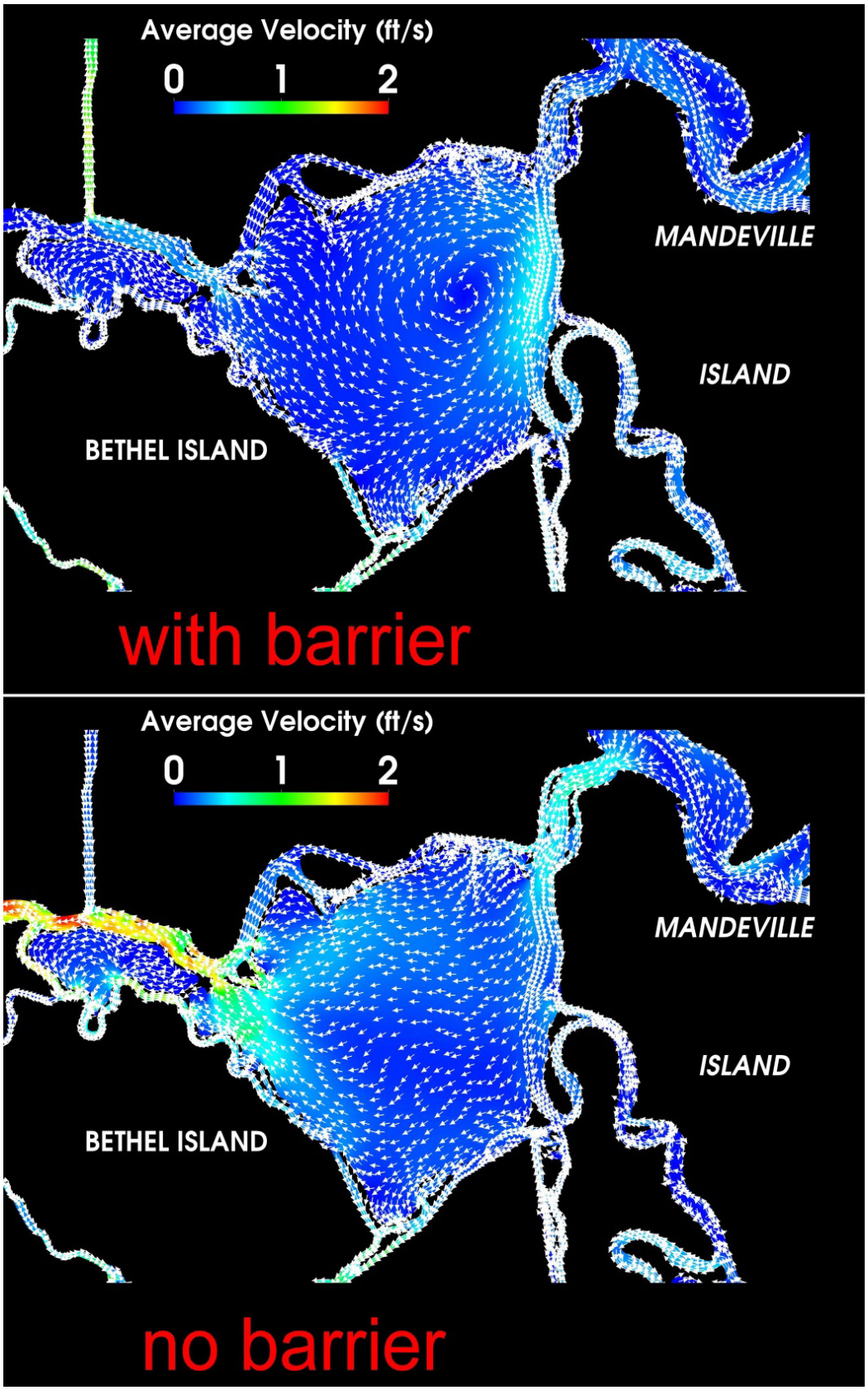

Figure 8-1 From a Study of Circulation Patterns in Franks Tract With and Without Barriers

8.3.3 Flood Robustification

SCHISM was calibrated during 2009-2010, which was a fairly low water period. Because of interest by the DWR Division of Flood Management, in February we began investigating the use of SCHISM for significant storm events and island flooding, using 1997 as a model. Floods require much more thorough delineation of floodplains along the major rivers emptying into the San Joaquin, Old, and Middle rivers (Figure 8-2) than we originally used for general tidal modeling.

This work is still in calibration and will be reported in more detail in coming months. Further work may be necessary to stably model extreme (100-year return period) floods coincident with storm surge.

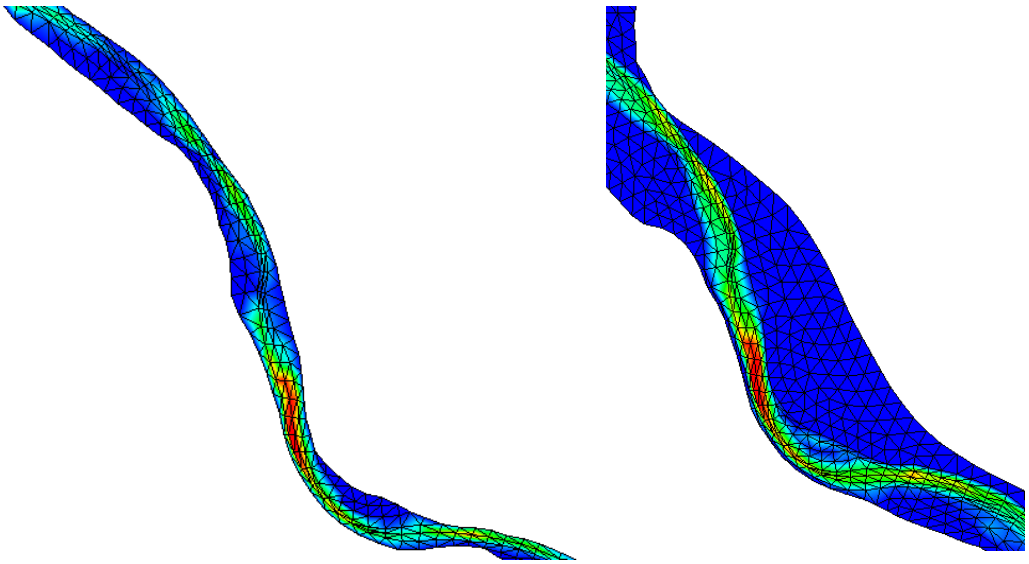

Figure 8-2 A Stretch of the San Joaquin River with the Original (left) and Fully Delineated (right) Floodplain

8.3.4 Liberty Island and Yolo Bypass

For our 1997 flooding project, Yolo Bypass was modeled as a boundary condition, but explicit modeling of the bypass is in development as well. For Yolo Bypass, a key challenge has been gracefully transitioning from the fairly small scale processes of summer flows around Liberty Island and incipient flooding to full floods. We are discussing how insights gained from this project can be used to improve the DAYFLOW index of net Delta outflow.

8.4 Algorithmic Improvements

This year, three improvements to SCHISM will be released that can increase the model's performance and accuracy.

Quadrilateral elements. SELFE and SCHISM were originally restricted to triangular meshes. Quadrilaterals are thought to be a more efficient meshing shape and will allow channelized regions to be covered with the same number of nodes, but roughly half of the elements. The count, after this conversion, is anticipated to be 180,000 elements instead of 250,000, with no loss of fidelity in the bathymetry. Although quadrilaterals have been supported by SCHISM for some time, the transition to quadrilaterals is not anticipated until the end of the year because we have to carefully test and adjust

for its effects on calibration and retool our visualization pre-, and post-processing tools to handle a hybrid triangle-quadrilateral mesh.

Local sigma coordinates with shaved cells (LSC^2). In Zhang et al. (2015), we introduced a new vertical mesh in SCHISM that is still terrain-following, but transitions in the number of layers between regions of deep and shallow terrain. Figure 8-3 shows a section of mesh in steep terrain in the Bay-Delta with the vertical direction greatly exaggerated. Note that vertical layers vanish gradually as the mesh advances into shallower areas. The new mesh remedies some numerical difficulties that nag terrain-following coordinates, such as pressure discretization errors and spurious diapycnal mixing (transport across the density gradient). On a practical note, this innovation will eliminate the restriction under traditional S coordinates that all regions of the estuary have the same number of layers. Since the Delta is mostly shallow, this will result in a vast reduction of nuisance resolution caused by the crowding of S layers in upstream reaches.

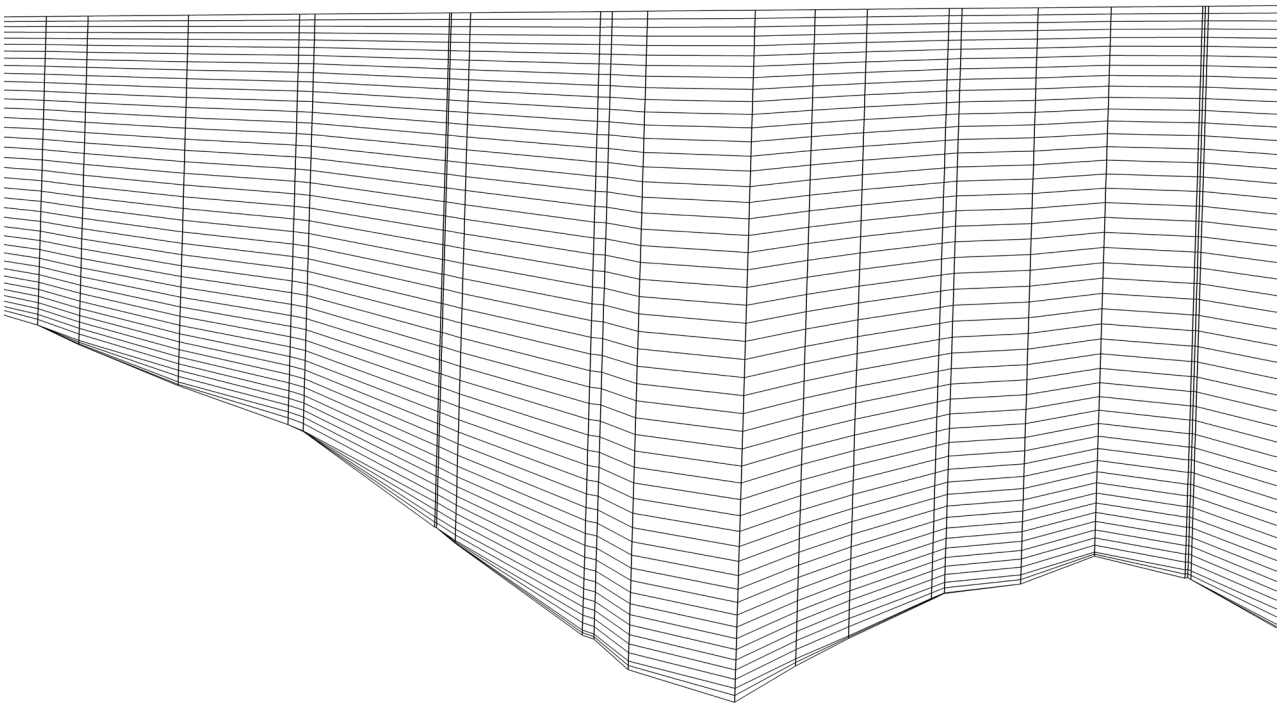

Figure 8-3 New LSC^2 Mesh with Vanishing Layers and Shaved Cells

Note: The apparently variable horizontal lengths of the prism are caused by drawing a straight line across triangles.

Implicit, TVD transport algorithm. Until recently, the high-resolution transport option in SCHISM was adopted from Casulli and Zanolli (2005). When a terrain-following mesh is used, the time-step restrictions of this algorithm can become a costly controlling factor on performance. Recently, Fei Ye of VIMS introduced a new algorithm to SCHISM, based on work by Duraisamy and Baeder (2007), that enjoys accuracy and non-oscillatory behavior at least on par with as the original algorithm, but with more relaxed performance restrictions.

8.5 References

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