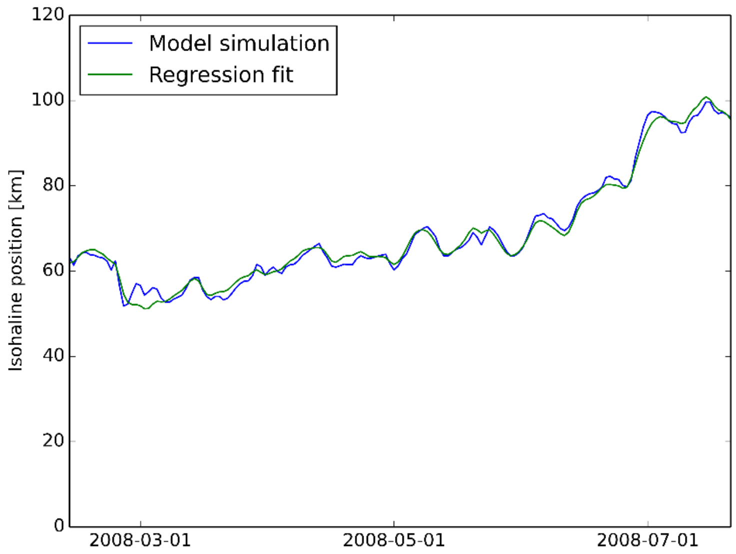
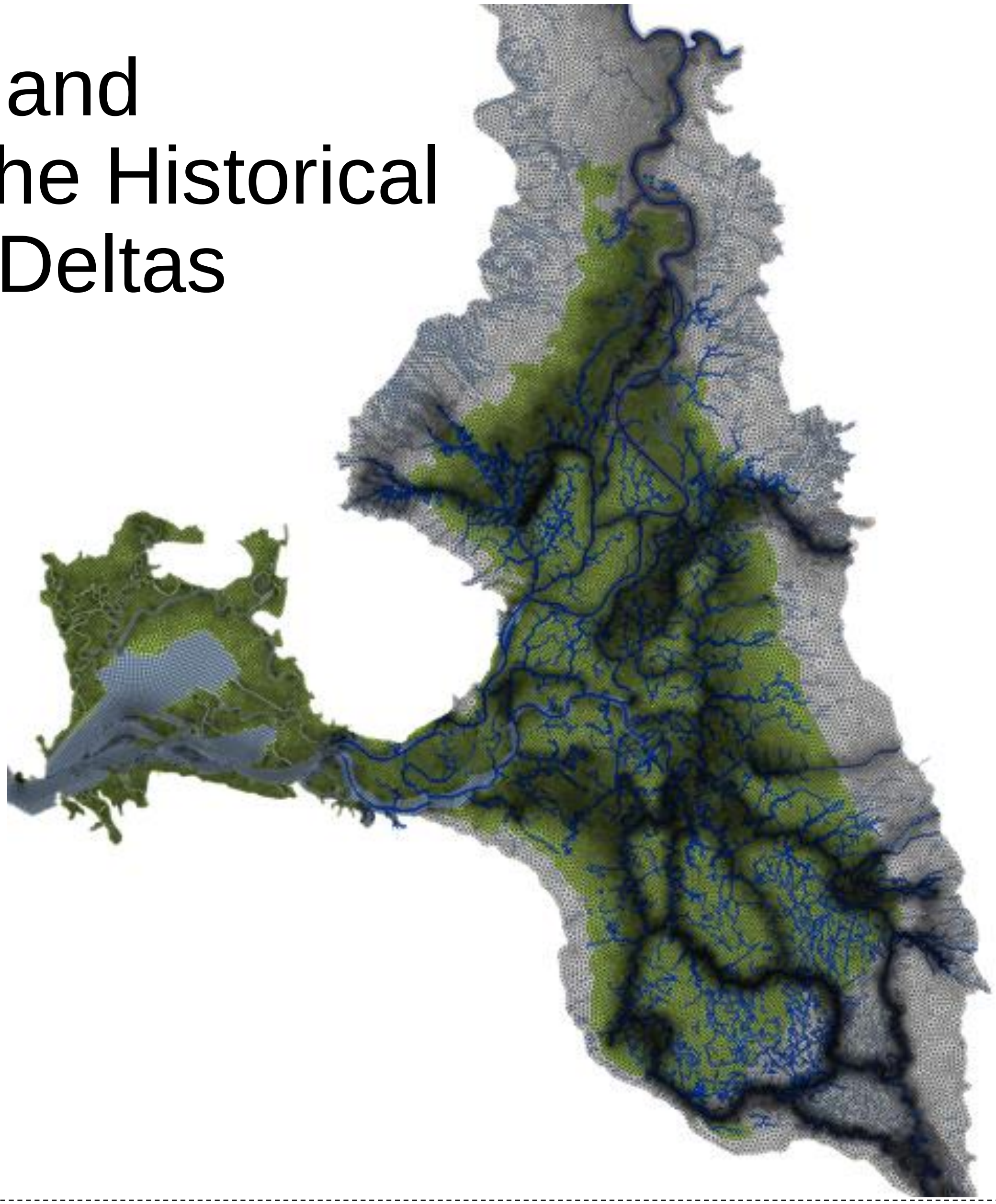
Comparing Salinity and Hydrodynamics in the Historical and Contemporary Deltas





Stephen Andrews, Ph.D.

Ed Gross, Ph.D.

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Stacie Grinbergs, P.E.

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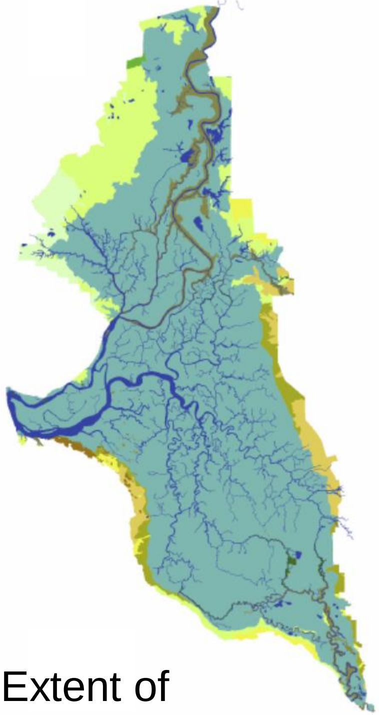
Outline

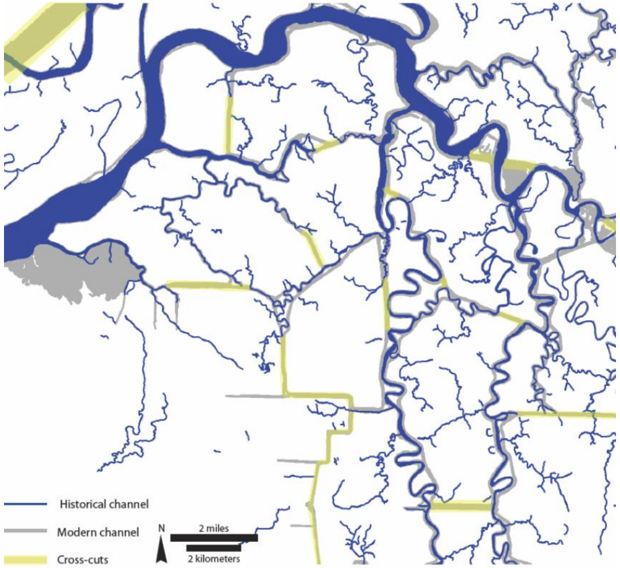
- Project Goals
- Model information
- Historical Delta model
  - Development
  - Calibration
- Contemporary Delta model
  - Calibration
- Comparison simulation info
- Results
  - Salinity
  - Tidal prism
  - Tidal velocities
  - Tracer dispersion
- Conclusions

Project Goals

- Characterize hydrodynamic and salinity regime of Delta prior to geomorphic and hydrologic modifications that began in the 1850s
  - Levee construction, loss of tidal marsh
  - Channel straightening, deepening
  - Upstream dams
  - Flooded islands
  - Bathymetric changes (hydraulic mining sed.)
  - Others…
- Comparison to Current Delta
  - X2 relationship to Net Delta Outflow
  - Tidal prism
  - Flood vs. ebb dominance
  - Advective and dispersive flux



Extent of historical tidal marsh



Changes in channel geometry

From Whipple et al. (2012)

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Project Team

- **Metropolitan Water District of Southern California**
  [Funding agency]
  - Paul Hutton, Project Manager

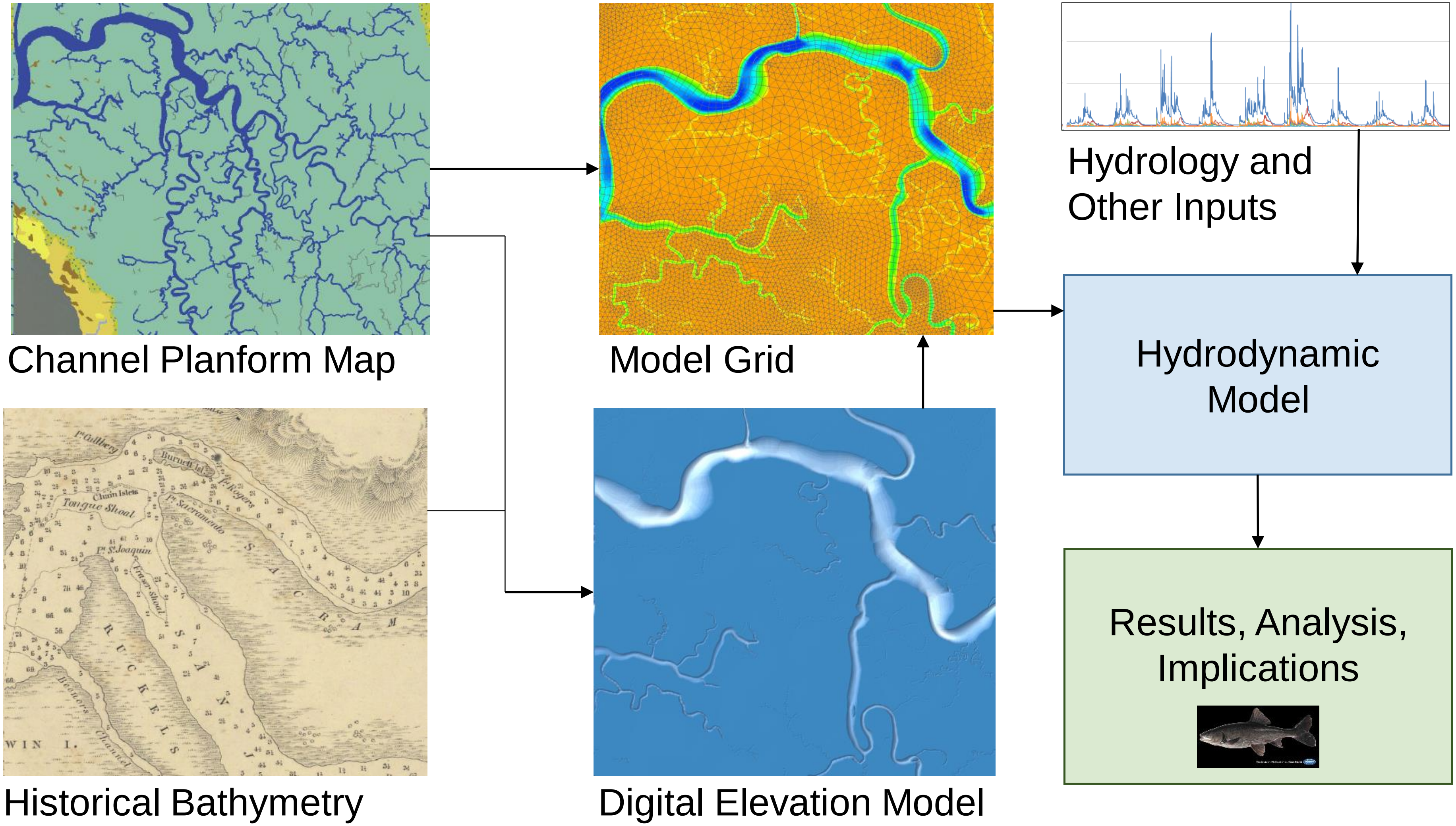
- **San Francisco Estuary Institute**
  [Historical Delta Configuration, Bathymetry]
  - Sam Safran
  - Robin Grossinger
  - Julie Beagle

- **Hydrology Team**
  - Tariq Kadir (DWR)
  - Guobiao Huang (DWR)
  - Andy Draper (MWH)
  - J. Phyllis Fox
  - Dan Howes (CSU, San Luis Obispo)

- **Resource Management Associates**
  [Hydrodynamics]
  - Steve Andrews
  - Ed Gross
  - John DeGeorge
  - Stacie Grinbergs

- **University of California, Davis Center for Watershed Studies**
  [DEM creation, Hydrodynamics]
  - Andy Bell
  - Bill Fleenor
  - Alison Whipple
  - Steve Micko
  - Fabian Bombardelli
  - Mui Lay
  - Amber Manfree

Historical Delta Modeling Overview

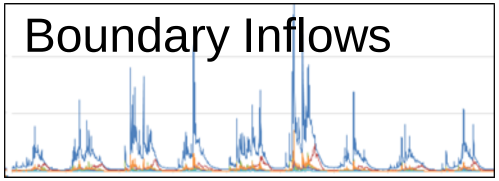


3D Hydrodynamic Modeling Framework

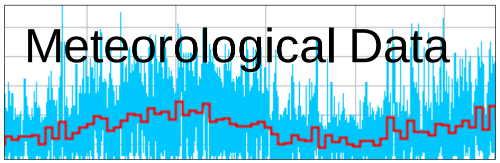
New Application of the UnTRIM Engine by RMA with UCD

Inputs

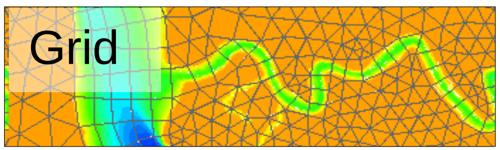
Boundary Inflows



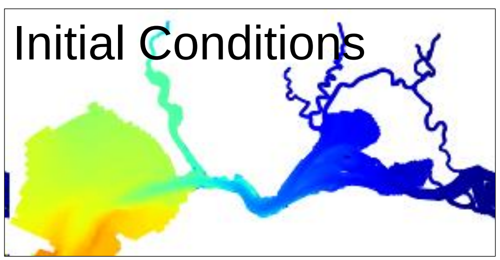
Meteorological Data



Grid



Initial Conditions



Gate Operations
Flow Diversions
Model Parameters

Compute

Interface Code

- Read Inputs
- Write Outputs

Computational Submodels

- Turbulence
- Bed Friction
- Wind
- Hydraulic Structures

Set Forcing

Get Results

UnTRIM Engine
(Vincenzo Casulli, Univ. of Trento, Italy)

Outputs

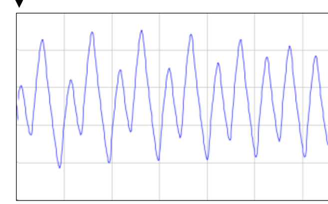
Text Files

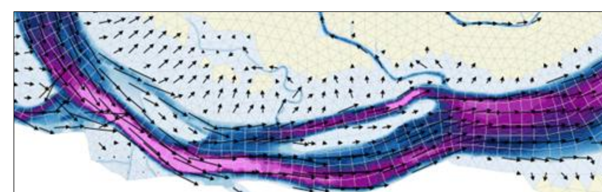
netCDF Files

Flows, velocities, water surface elevations, salinity

Python Post-Processing, Visualization Routines

Time Series
Maps
Animations





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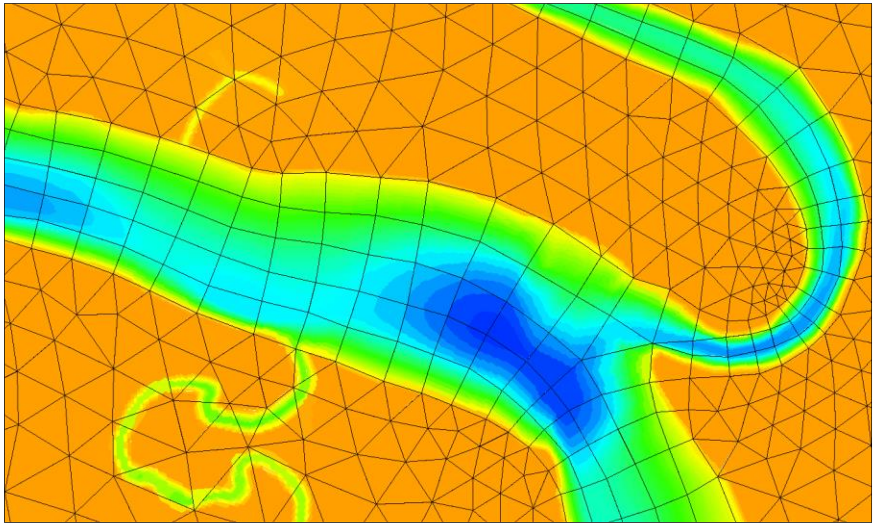
Hydrodynamic Model Information

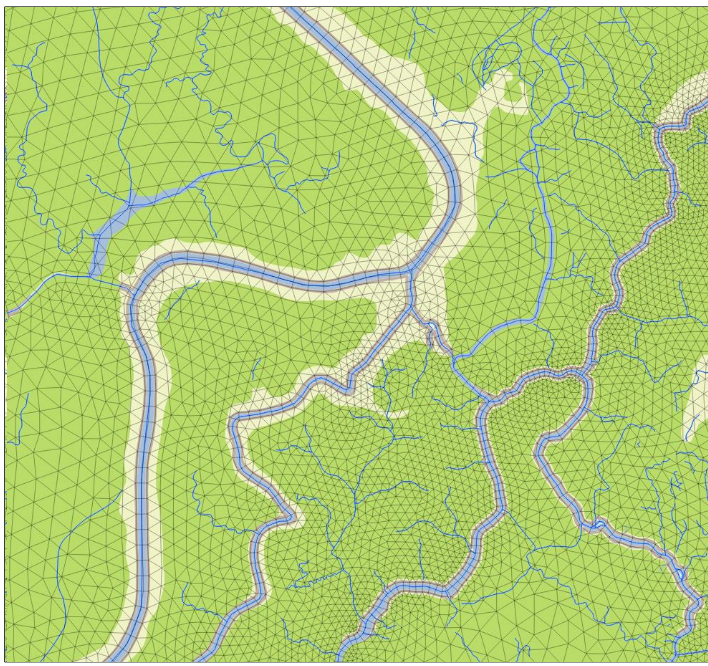
- UnTRIM Computational Engine
  - 3D hydrodynamic and scalar transport model
  - Utilizes unstructured orthogonal grid
  - Computationally efficient and stable
  - Developed and maintained by V. Casulli (Univ. of Trento, Italy)
  - Casulli and Cheng (1992), Casulli and Walters (2000), Casulli and Stelling (2010)
- z0 bed friction parameterization
- Generalized length scale vertical turbulence closure scheme (Warner, 2005)
  - Implemented by Bundesanstalt für Wasserbau (BAW)
- Constant wind stress, evaporation, and precipitation by region
- Target moderate grid resolution with subgrid
  - Produces improved estimates of cell volume and channel conveyance

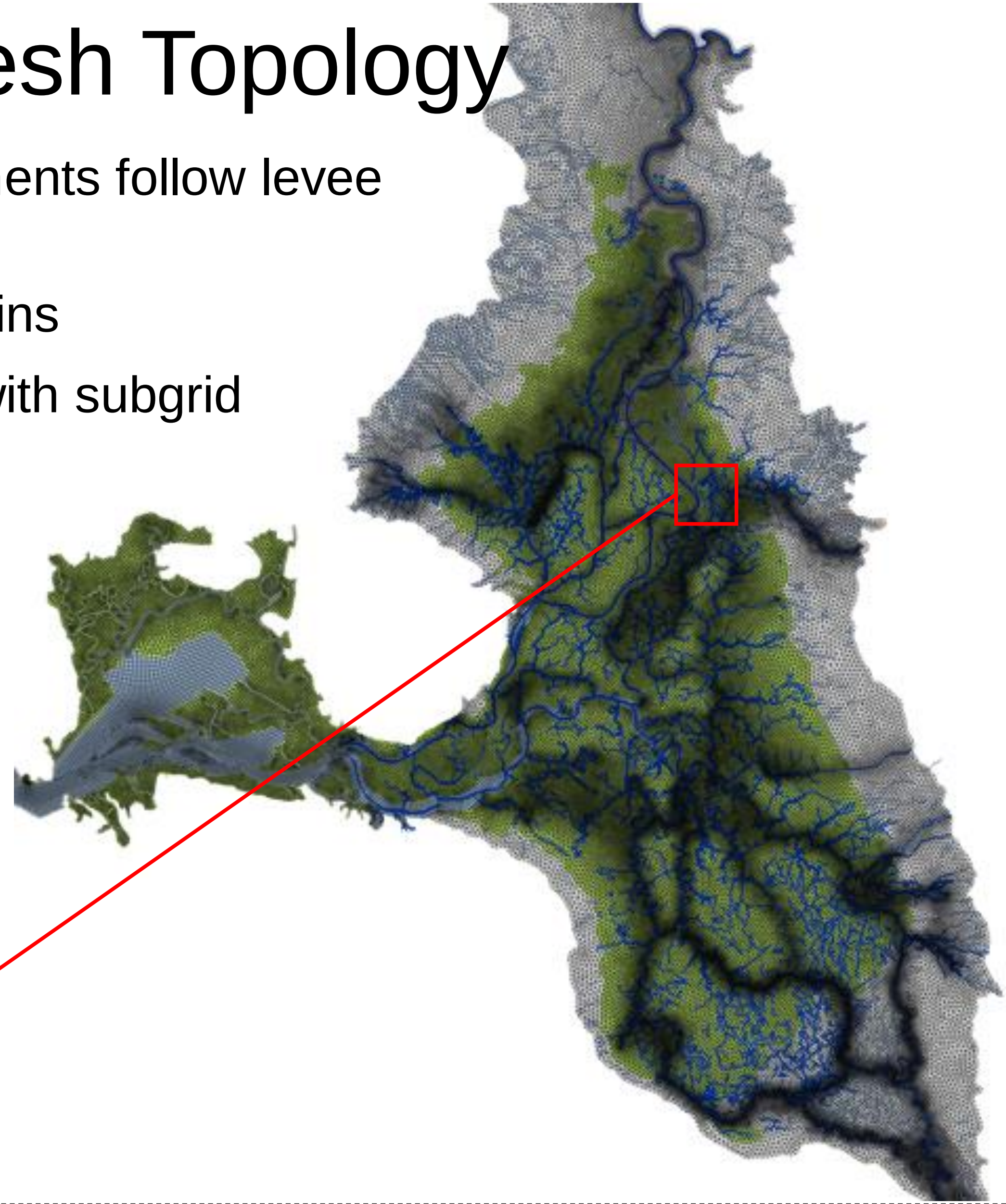


Model geometry with contoured subgrid bathymetry

Historical Delta Mesh Topology

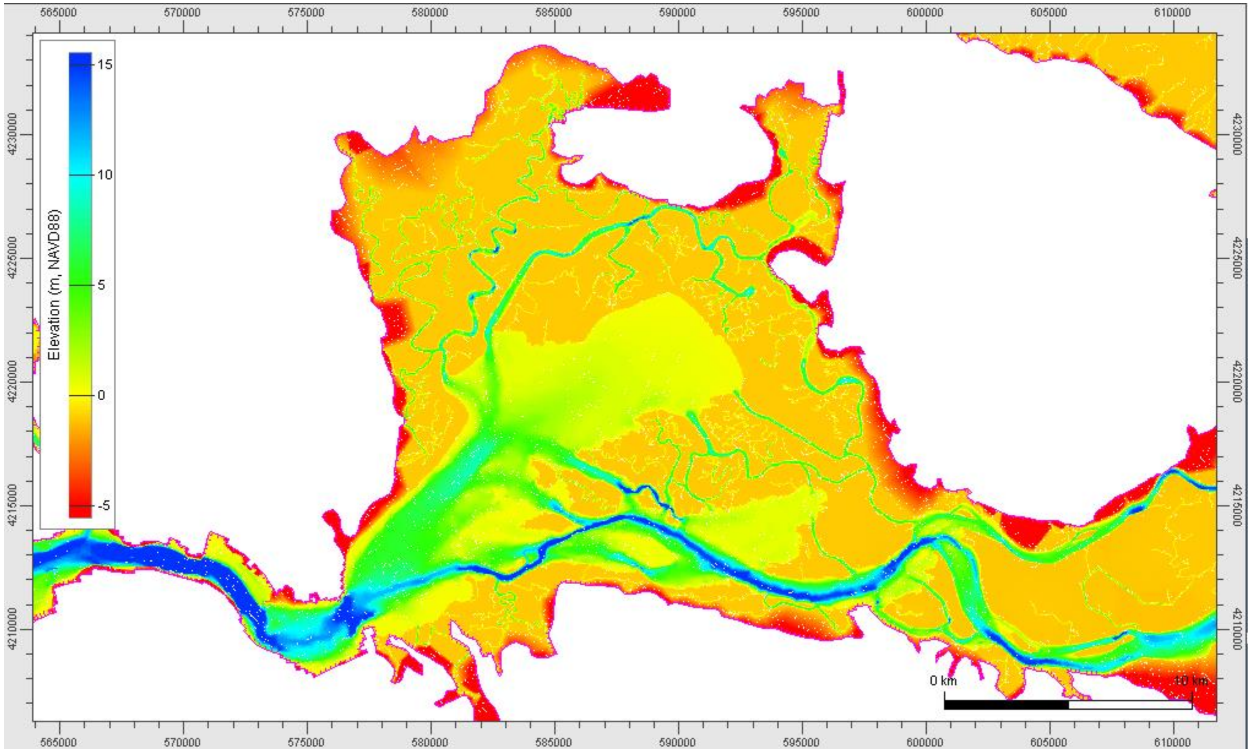
- Flow-aligned quadrilateral elements follow levee crests in main channels
- Triangular elements fill tidal plains
- Low-order channels captured with subgrid
- Janet grid generation software
  (Lippert & Sellerhoff, 2006)

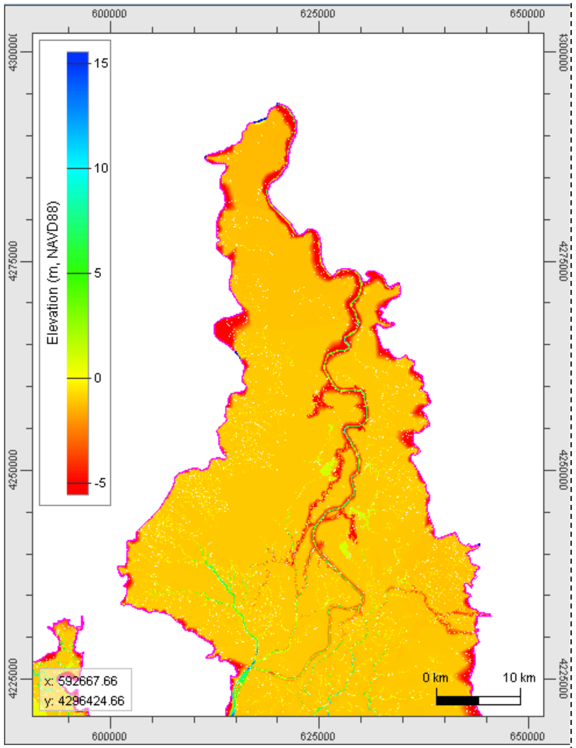


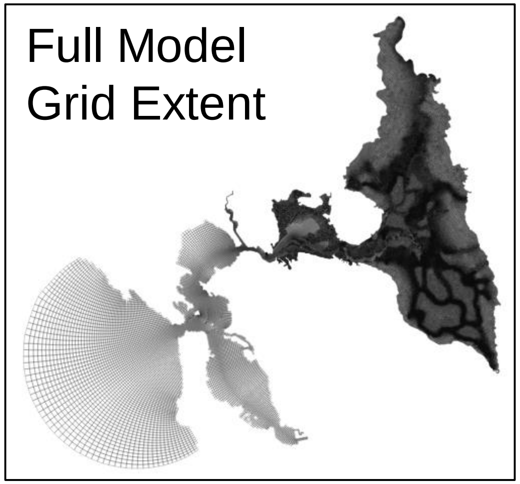


Recent Grid Additions

- Historical Suisun bathymetry
- Expansion of flood basins

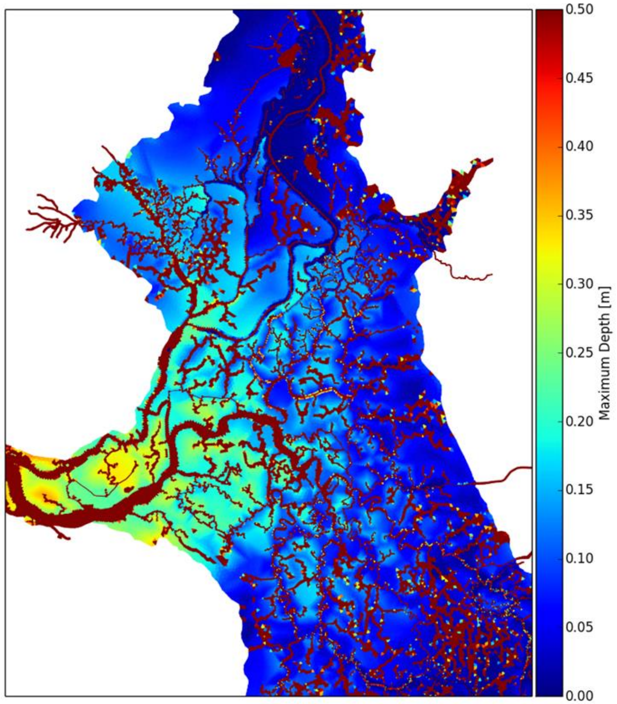


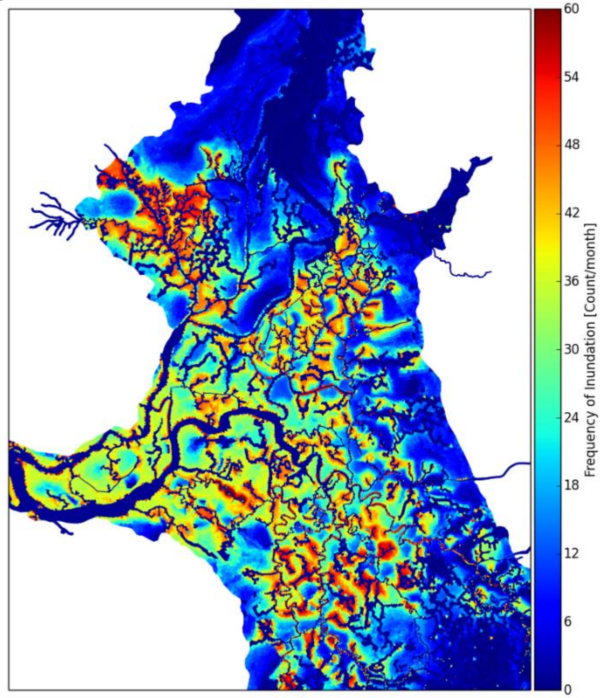


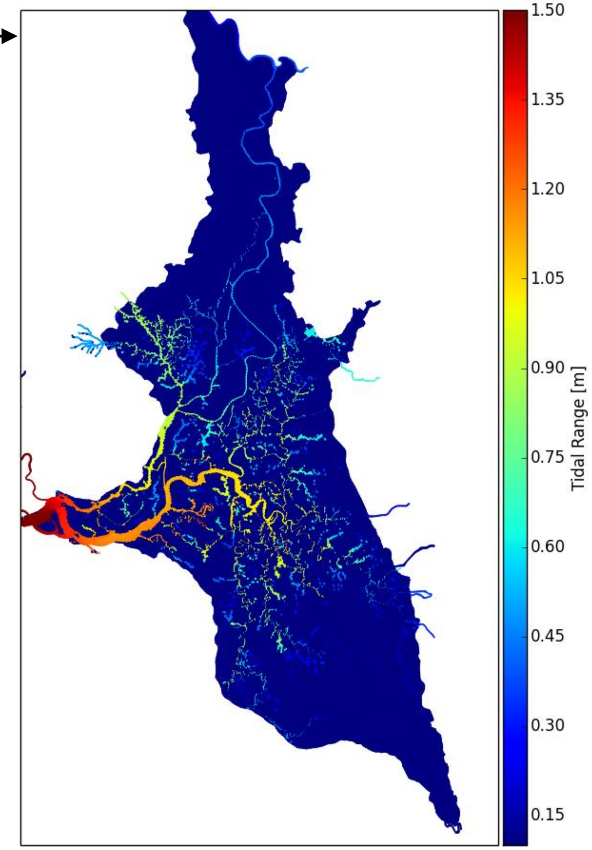


Historical Delta Model Calibration

- Bay-Delta Science Conference presentation, October 2014
- Tidal range in channels
- Depth and frequency of marsh plain inundation



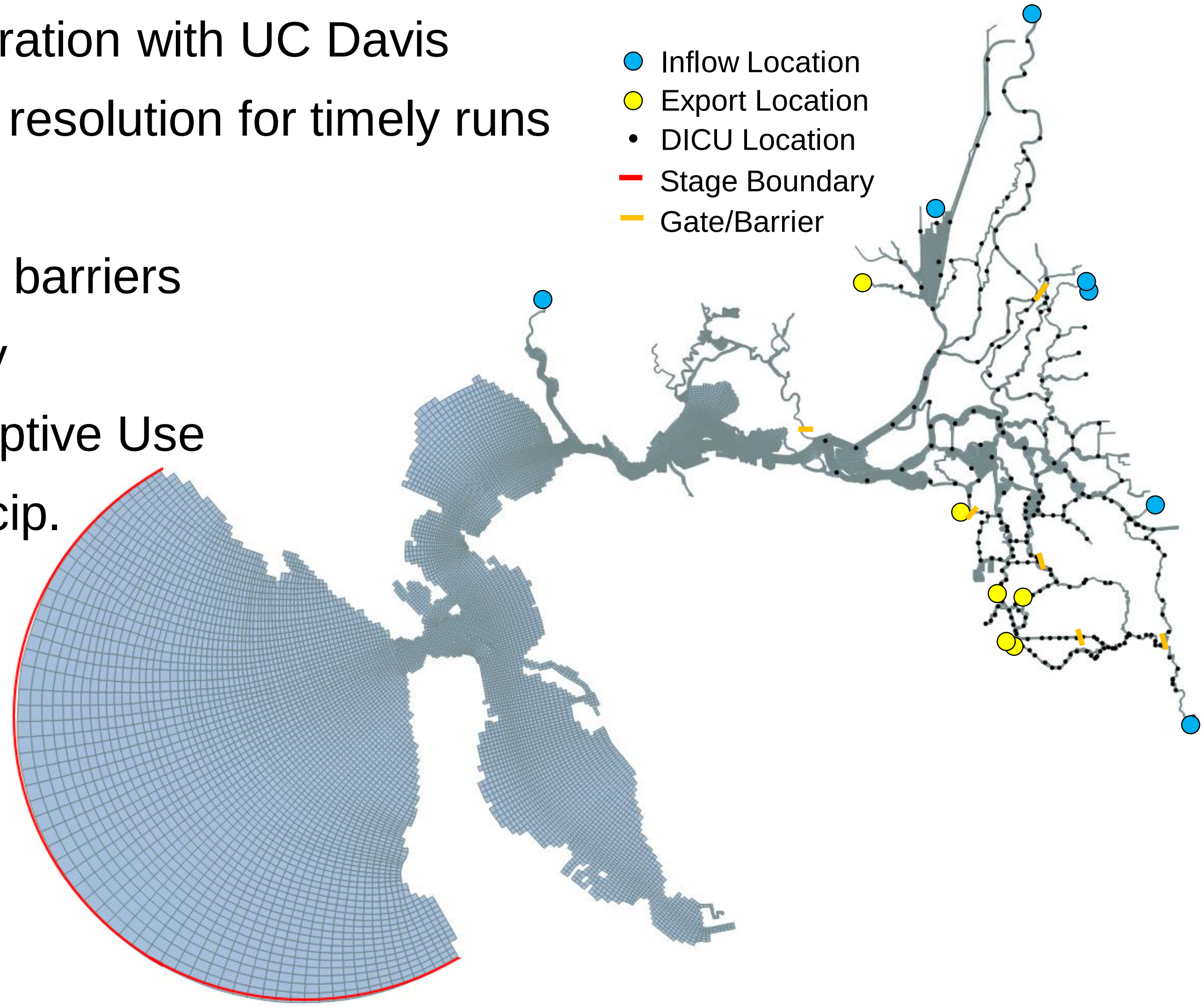




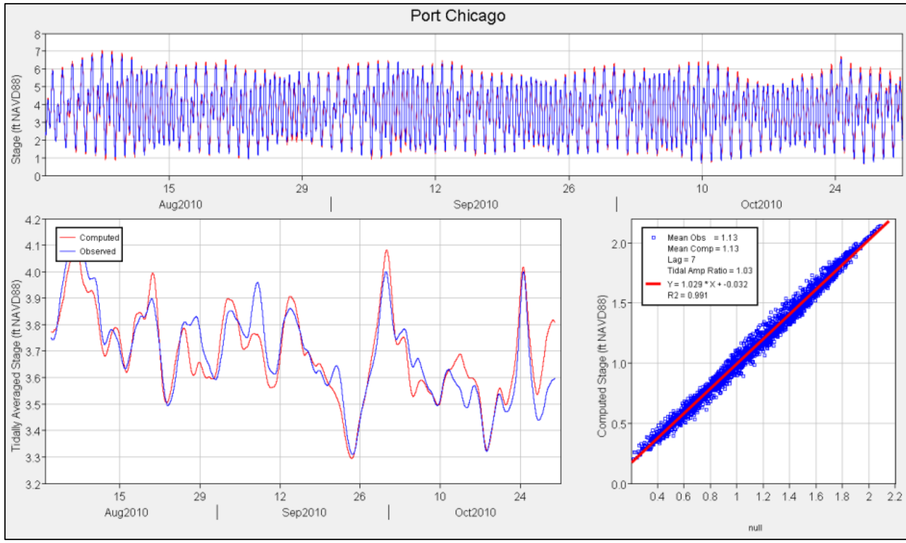
*Historical observations pre-1850 sparse, sometimes questionable

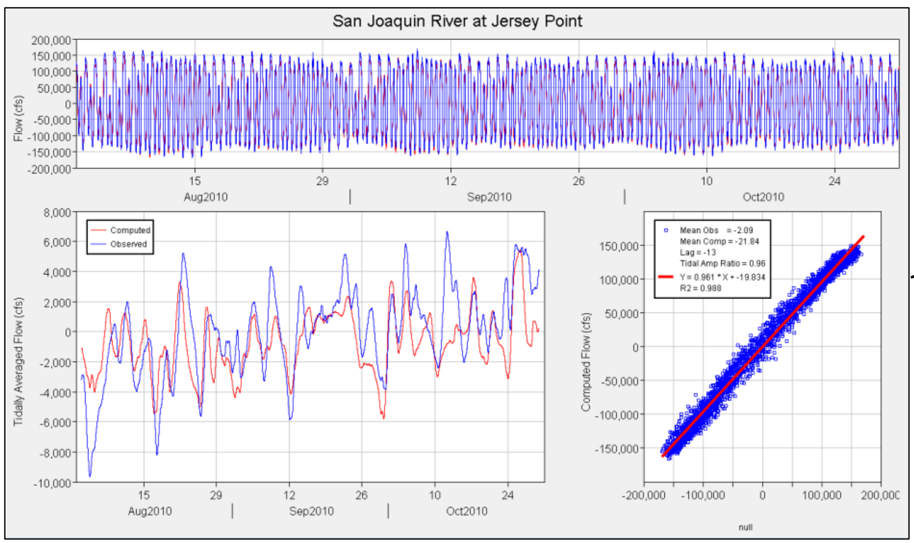
Contemporary Delta Model

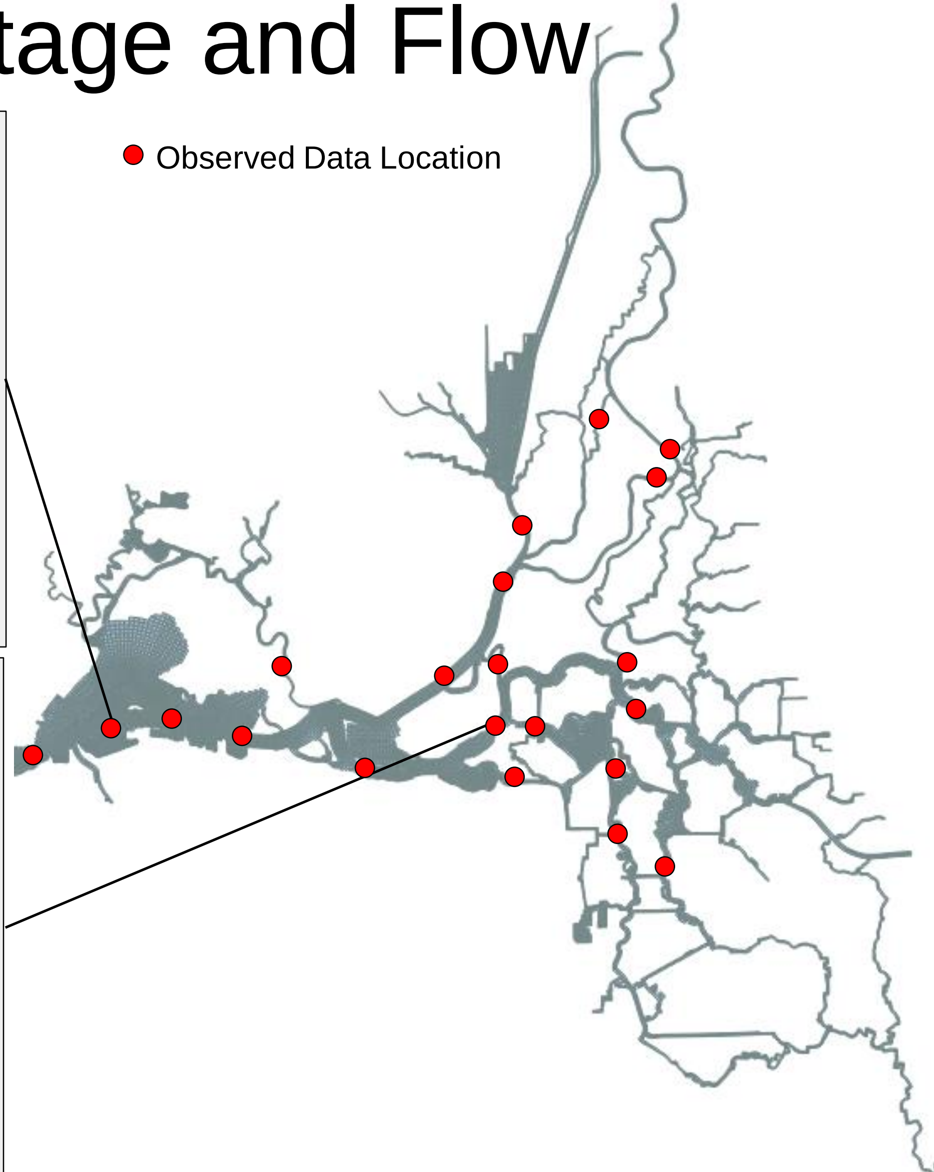
- Developed in collaboration with UC Davis
- Target moderate grid resolution for timely runs
- River inflows
- Major exports, gates, barriers
- Ocean tidal boundary
- Delta Island Consumptive Use
- Evaporation and precip. in bays
- Surface wind stress
- Bed friction
- Generic length scale turbulence closure scheme used in vertical (Warner et al. 2005)



Model Calibration: Stage and Flow

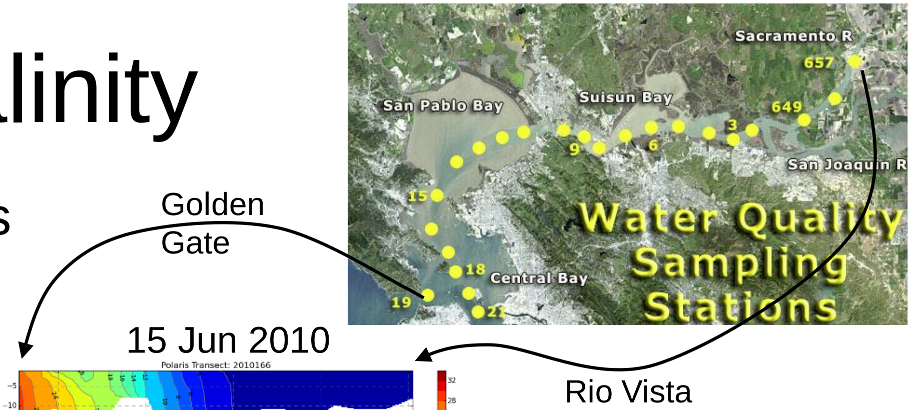


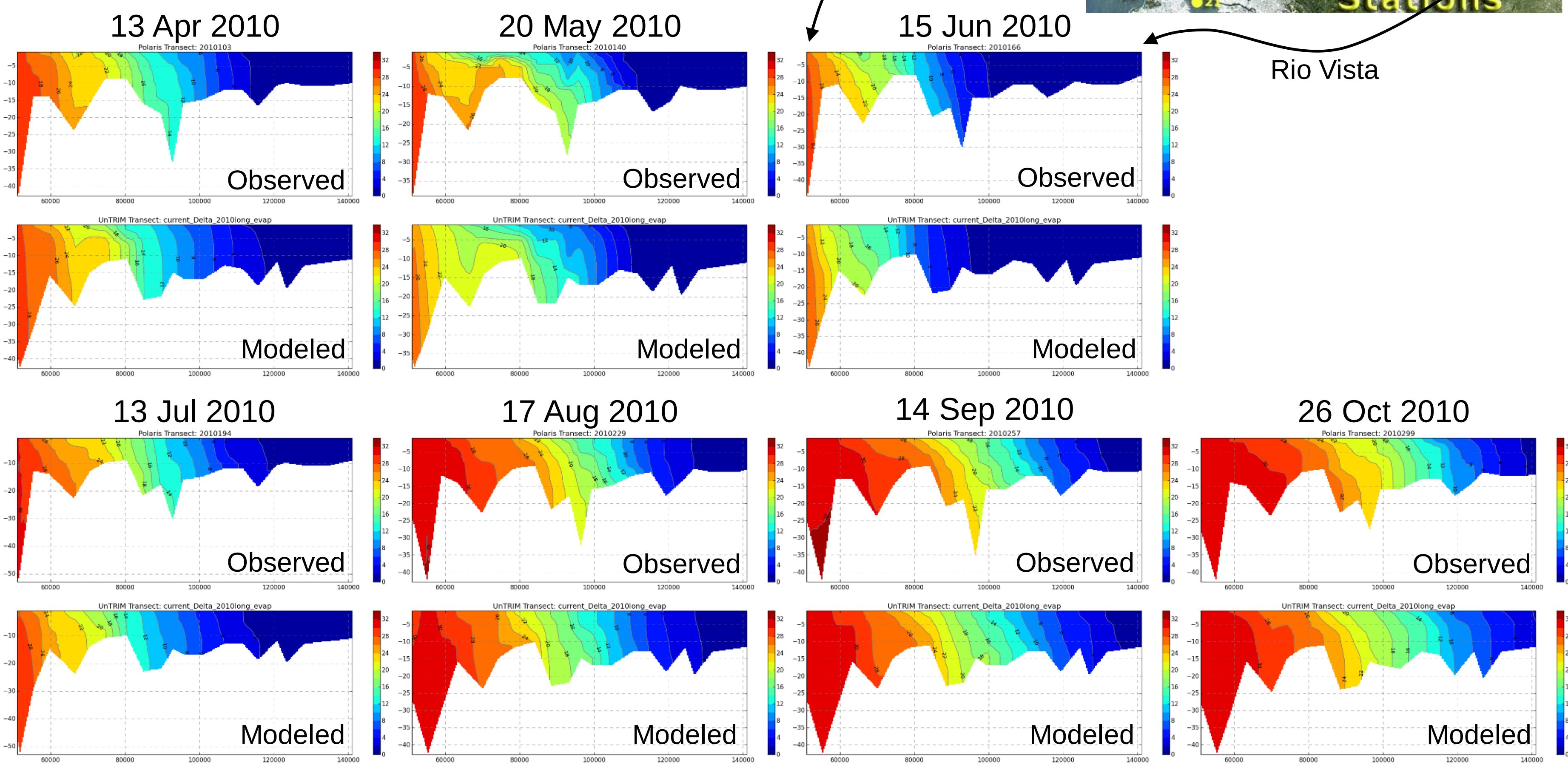




Model Calibration: Salinity

- USGS Polaris water quality transects

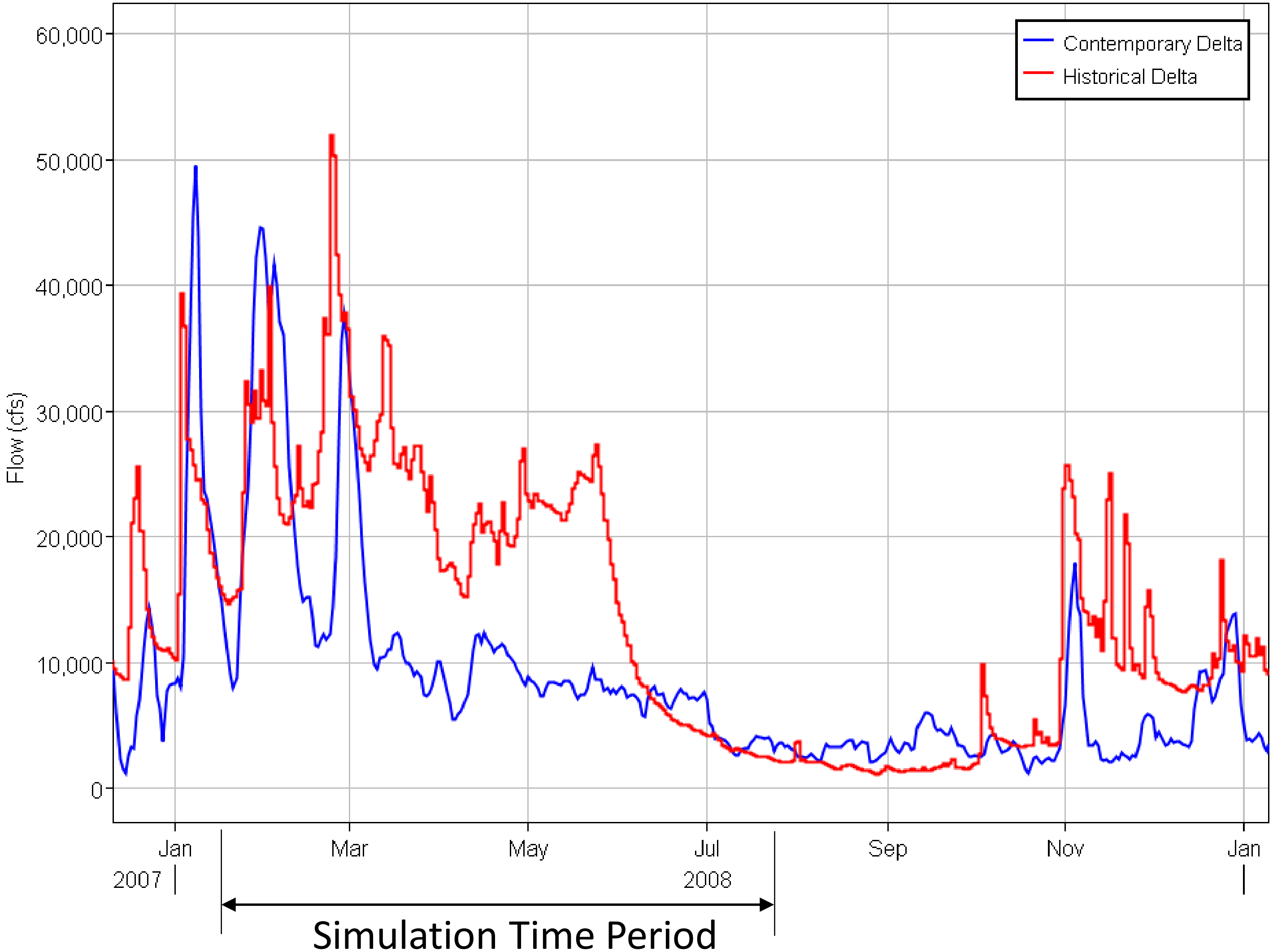




Comparison Runs: Boundary Conditions

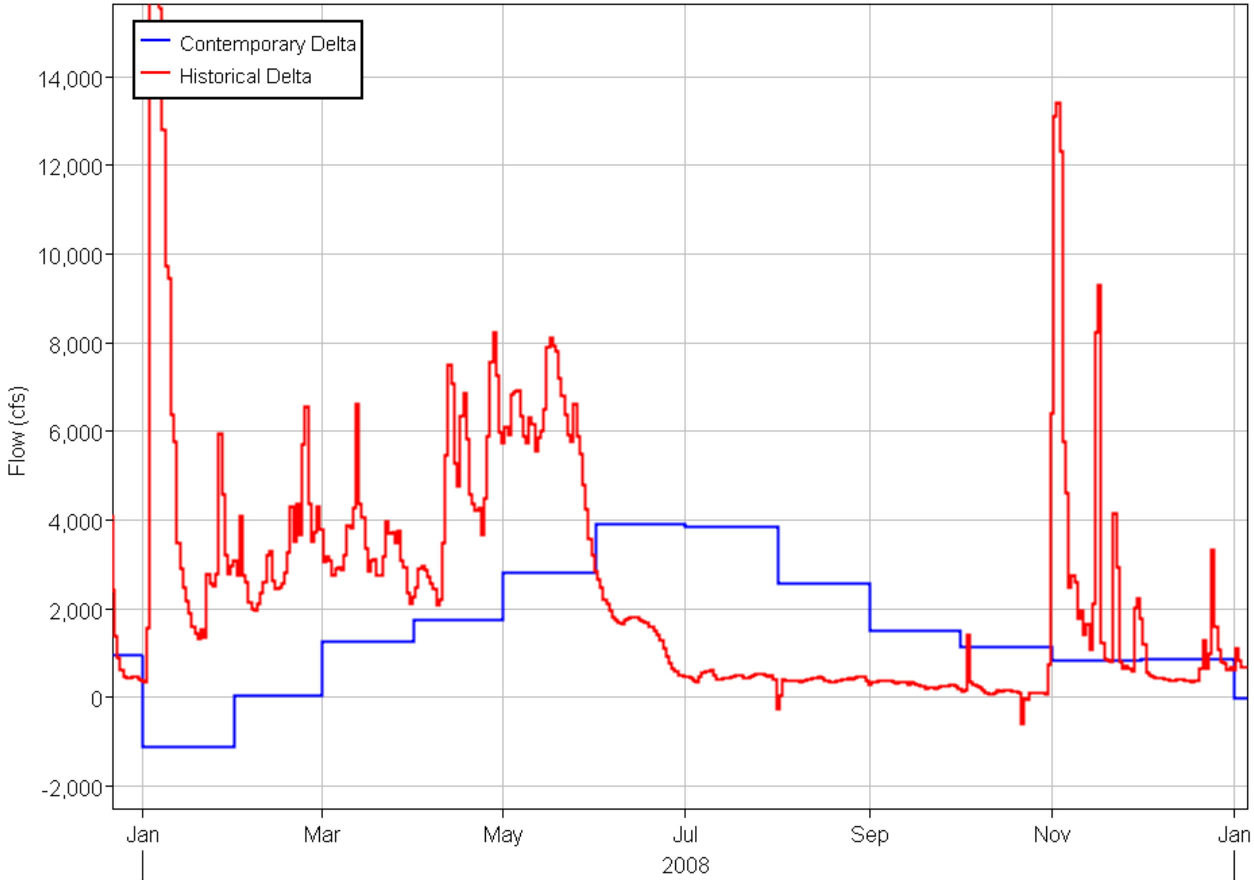
	Contemporary	Historical
Inflows	USGS, DWR Observed	C2VSim
Exports	DWR	None
Delta Use	DWR DICU	C2VSim Inflows - Outflow
Ocean Water Level	NOAA Point Reyes Station	Point Reyes – 1ft to account for sea level rise
Meteorological Inputs	NOAA, CIMIS Observed	Same
Hydraulic Structure Operations	USBR, DWR	None
Initial Salinity Condition	USGS Polaris	Same

Net Delta Outflow

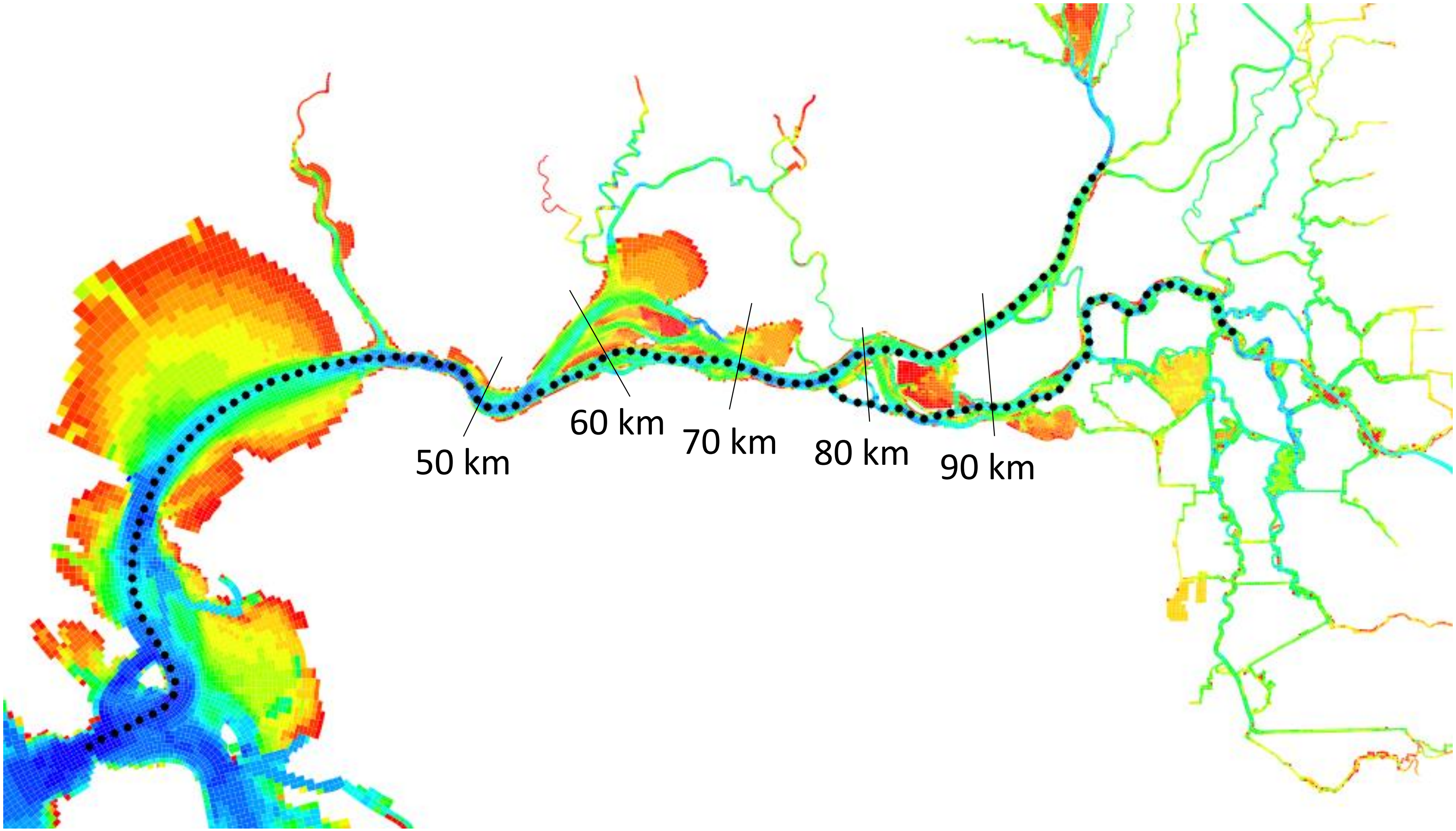


In-Delta Water Use Processes

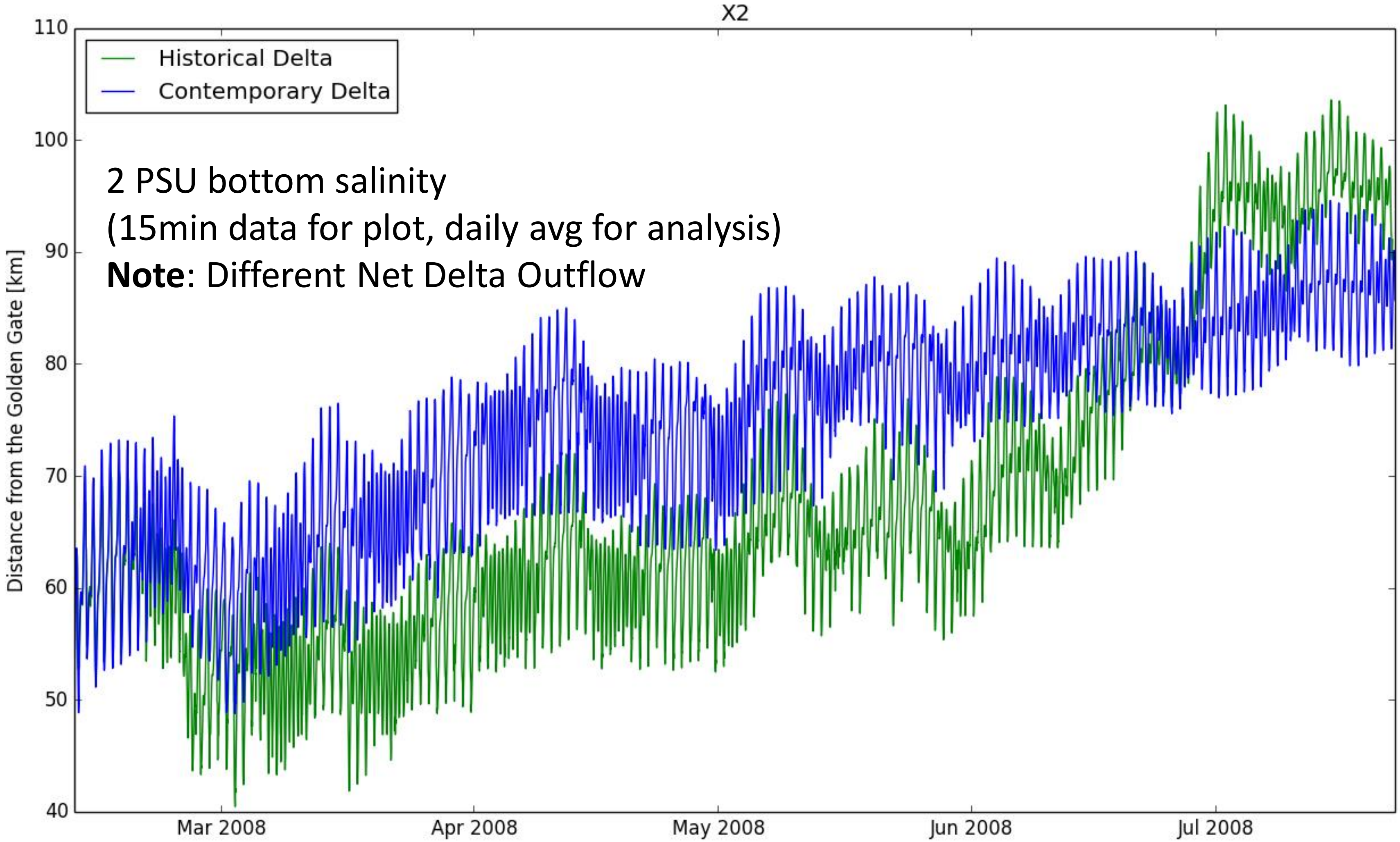
- Contemporary Delta – withdrawals, return flows, seepage, evaporation
- Historical Delta – evapotranspiration from marsh, ponds



X2 Transect Location



X2 Time Series Comparison



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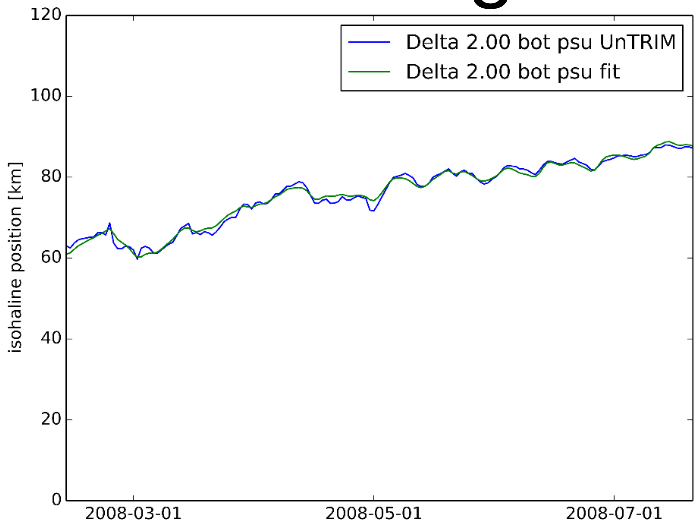
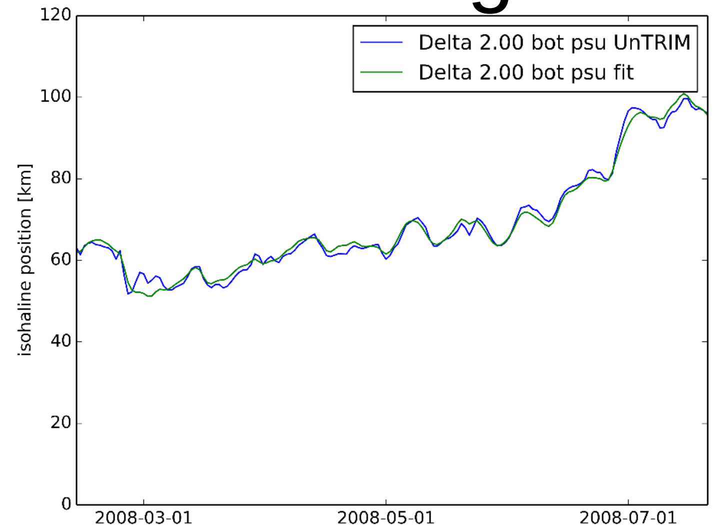
Net Delta Outflow – X2 Regression

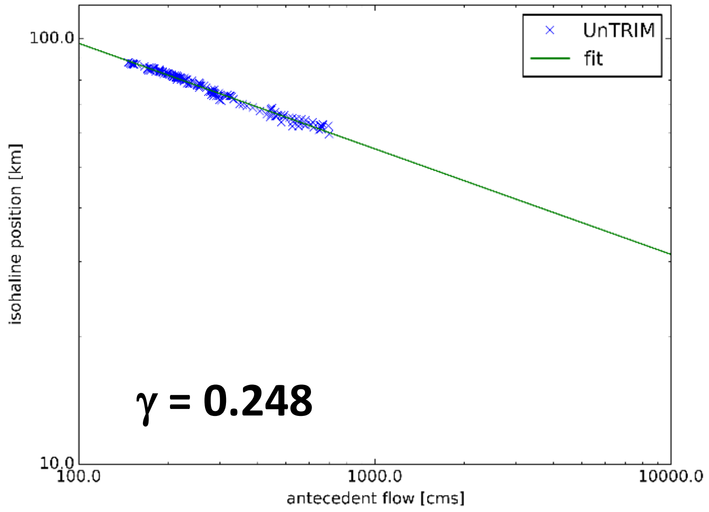
- Monismith, et al. 2002; Gross, et al. 2010
- Salt balance equation: $Q\,S = -K_x\,A\,dS/dx$
  - Q = Net Delta Outflow
  - S = tidally-averaged salinity
  - A = cross-sectional area
  - dS/dx = longitudinal salinity gradient
  - K_x = longitudinal dispersion coefficient
- Hansen and Rattray derivation of K_x , algebra
  - $X2 = \beta\,Q^{1/3}$
- Generalize: $X2 = \beta\,Q^{\gamma}$
- Take in account effect of preceding flow with autoregressive term
- $X2(t) = \alpha\,X2(t-1) + (1+\alpha)\,\beta\,Q^{\gamma}$
- Gamma parameter indicates sensitivity of X2 to NDO

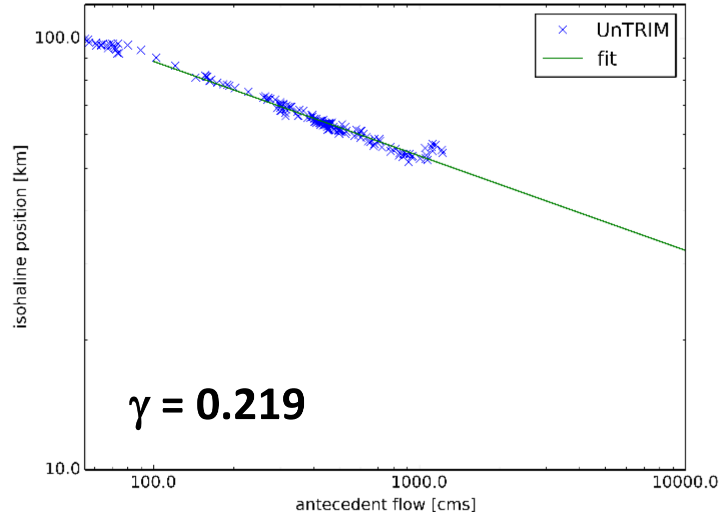
Contemporary Simulation Regression

Historical Simulation Regression

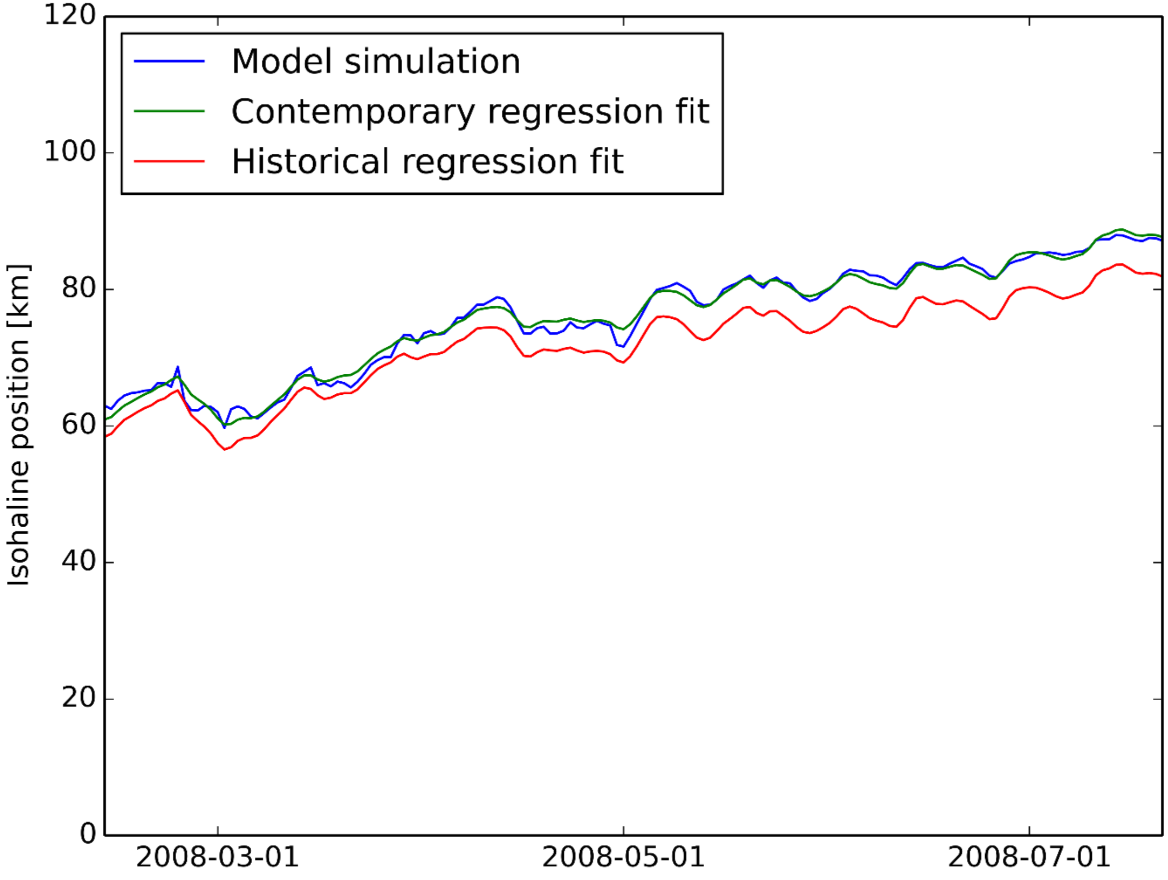








Contemporary Flows with Contemporary and Historical Regression Fits

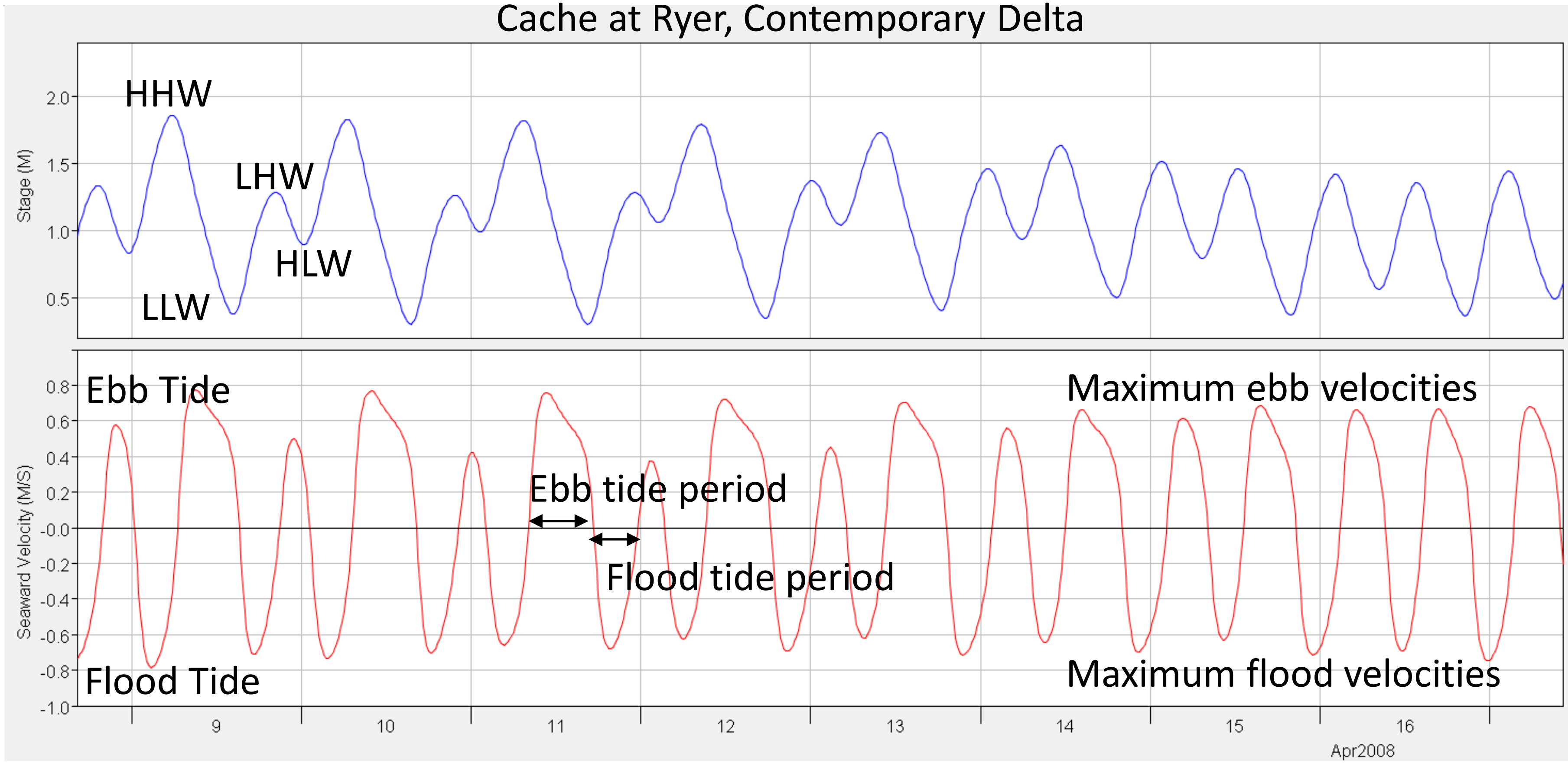


Tidal Prism

- Volume of water that enters/exits the Delta between mean low tide and mean high tide
- Determined by analysis of flow record at Martinez
- Historical Delta -> greater marsh area to flood
- Contemporary Delta -> wider and deeper channels
- Model Results:
  - Historical Delta: 205 x 10^6 m^3 (166,000 acre-feet)
  - Contemporary Delta: 200 x 10^6 m^3 (162,000 acre-feet)
- Slight (2.5%) increase for historical Delta

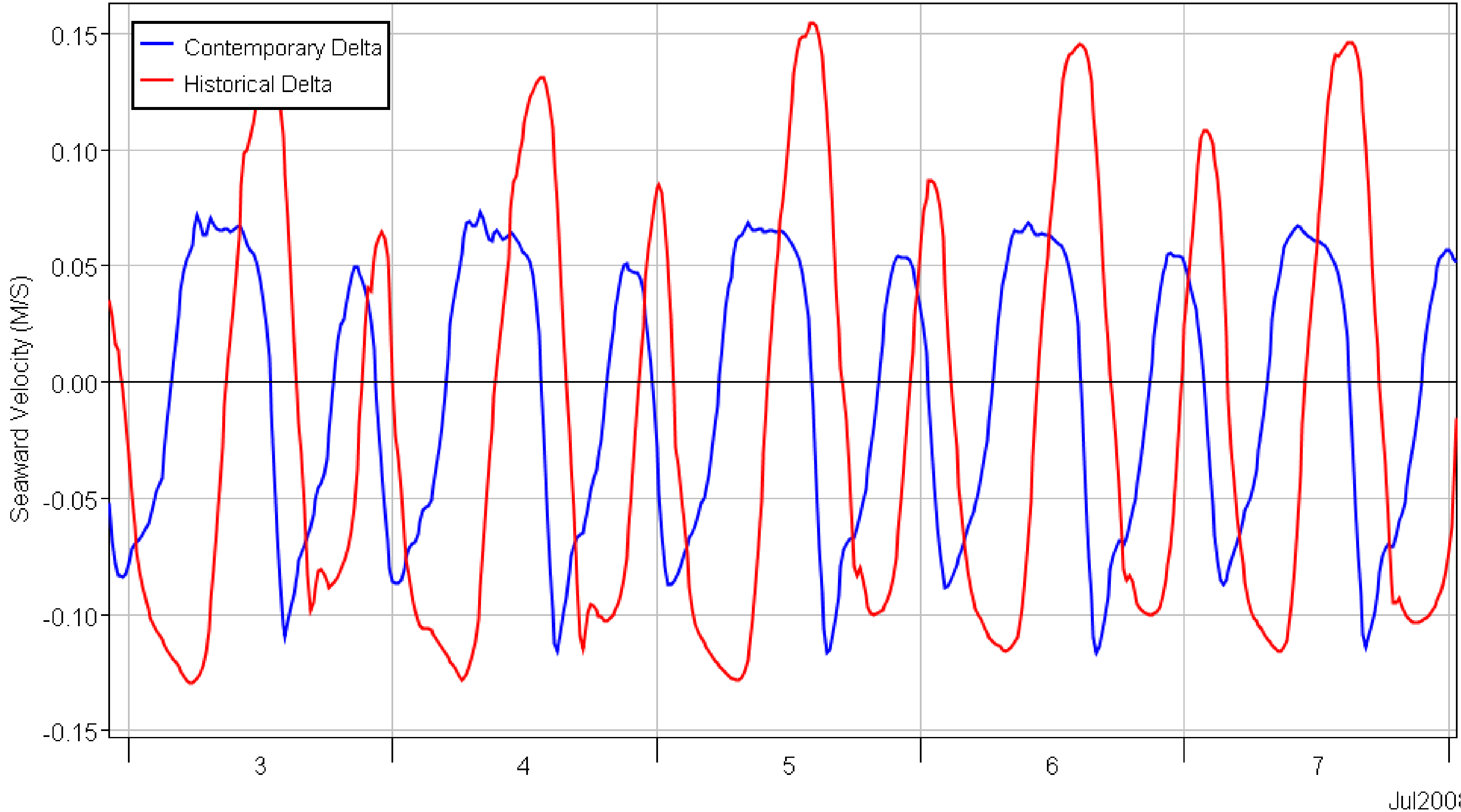
Flood versus Ebb Tide Dominance

- Flood tide dominance: flood tide shorter in duration, higher tidal velocities
- Ebb tide dominance: ebb tide shorter, with higher tidal velocities
- Implications for transport of sediment, material, aquatic organisms



Marsh Causes Shifts To Flood Dominance?

- Hypothesis: marsh draining elongates ebb period, shifts velocities towards flood dominance (however, we saw the opposite)



Conclusions and Future Work

- Reached calibration with adequate representation of the tidal range and inundation characteristics of the historical Delta and Suisun Bay/Marsh
- Performed salinity regression comparison
  - Very similar X2 dependence on Delta outflow for moderate flows
  - Next: analysis of longer time period with low-flow in the historical Delta
- Small differences in tidal prism with historical Delta, even with large increases in marsh area
  - Seen in other RMA studies (BDCP, levee break simulations)
- Counter-intuitive tidal velocity results – currently being analyzed
- Collaborations for future investigations?

Thanks!

- **Metropolitan Water District of Southern California**
  [Funding agency]
  - Paul Hutton, Project Manager

- **San Francisco Estuary Institute**
  [Historical Delta Configuration, Bathymetry]
  - Sam Safran
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- Development, calibration, and the simulations shown here using the Historic Delta Model were funded by the Metropolitan Water District of Southern California, under the direction of Paul Hutton
- DWR and UCD are independent collaborators

- **University of California, Davis Center for Watershed Studies**
  [DEM creation, Hydrodynamics]
  - Andy Bell
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Referenced Works

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