Development of the 3D Natural Delta Model

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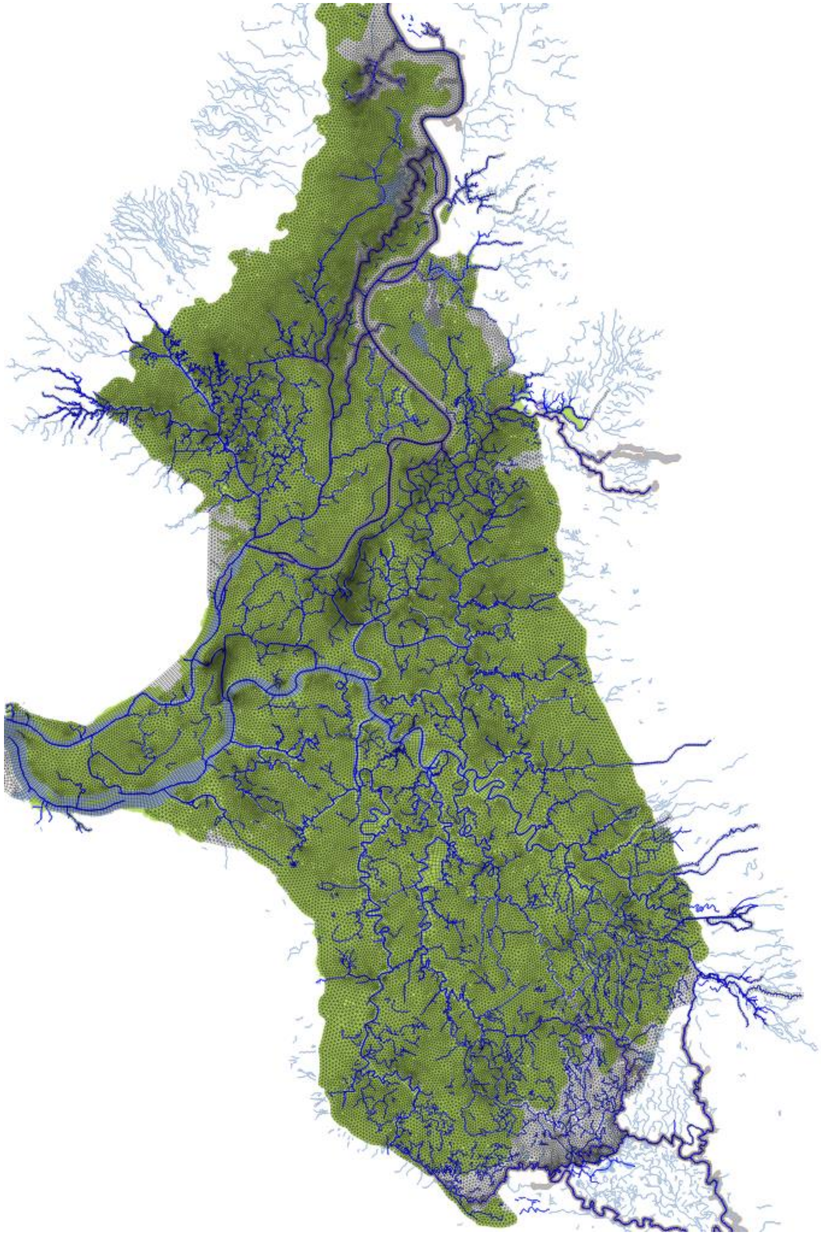


Modeling Strategy

- Objective: characterize salinity regime of Delta prior to geomorphic and hydrologic modifications of the gold rush era
- 1) Model salinity of the Delta in its current state
  - Create grid for current Delta
  - Collect boundary conditions, calibrate model
  - Demonstrate model can predict current conditions
- 2) Model salinity of the historic Delta
  - Create grid for historic Delta using UC Davis DEM based on SFEI historic channel locations and depths
  - Calibrate model based on SFEI historic observations
- 3) Simulate salinity regimes and compare
  - Data visualizations: vertical transects
  - Metrics: X2
  - Reconstructed natural hydrology

Model Computational Engine Information

- **UnTRIM** – developed/maintained by V. Casulli (Univ. of Trento, Italy)
- 3D hydrodynamic and scalar transport model

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{\partial p}{\partial x}+\nu^h\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\frac{\partial}{\partial z}\left(\nu^v\frac{\partial u}{\partial z}\right)$$

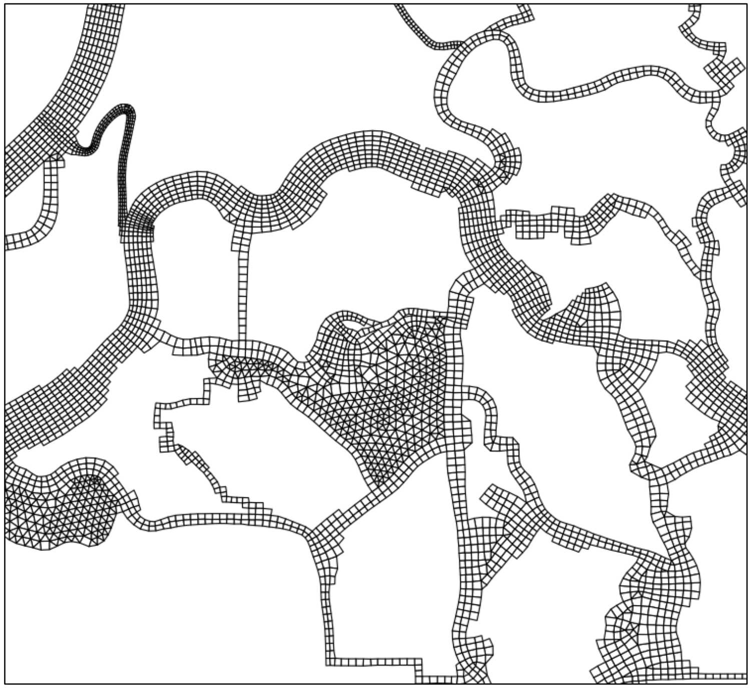
$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{\partial p}{\partial y}+\nu^h\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\frac{\partial}{\partial z}\left(\nu^v\frac{\partial v}{\partial z}\right)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{\partial p}{\partial z}+\nu^h\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}\right)+\frac{\partial}{\partial z}\left(\nu^v\frac{\partial w}{\partial z}\right)-\frac{\rho}{\rho_0}g.$$

$$\frac{\partial C}{\partial t}+\frac{\partial (uC)}{\partial x}+\frac{\partial (vC)}{\partial y}+\frac{\partial[(w-w^s)C]}{\partial z}=\frac{\partial}{\partial x}\left(K^h\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(K^h\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial z}\left(K^v\frac{\partial C}{\partial z}\right).$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0.$$

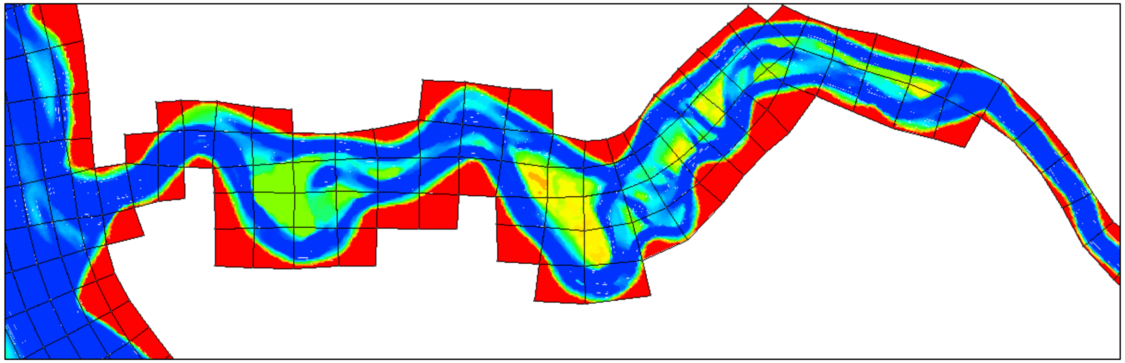
- Uses unstructured orthogonal grid →



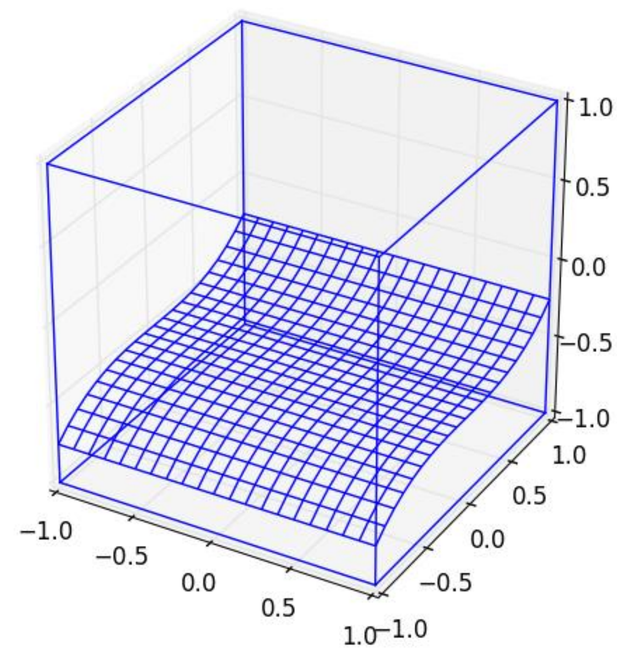
- Computationally efficient and stable
  - Multi-threaded, Fortran engine
- Accounts for relevant physical properties
- Tested/verified in peer reviewed journals
  - Casulli and Cheng (1992)
  - Casulli and Stelling (2010)
- Applied previously to successfully model estuarine circulation

Subgrid

- Accounts for changes in bathymetry as scales smaller than grid resolution

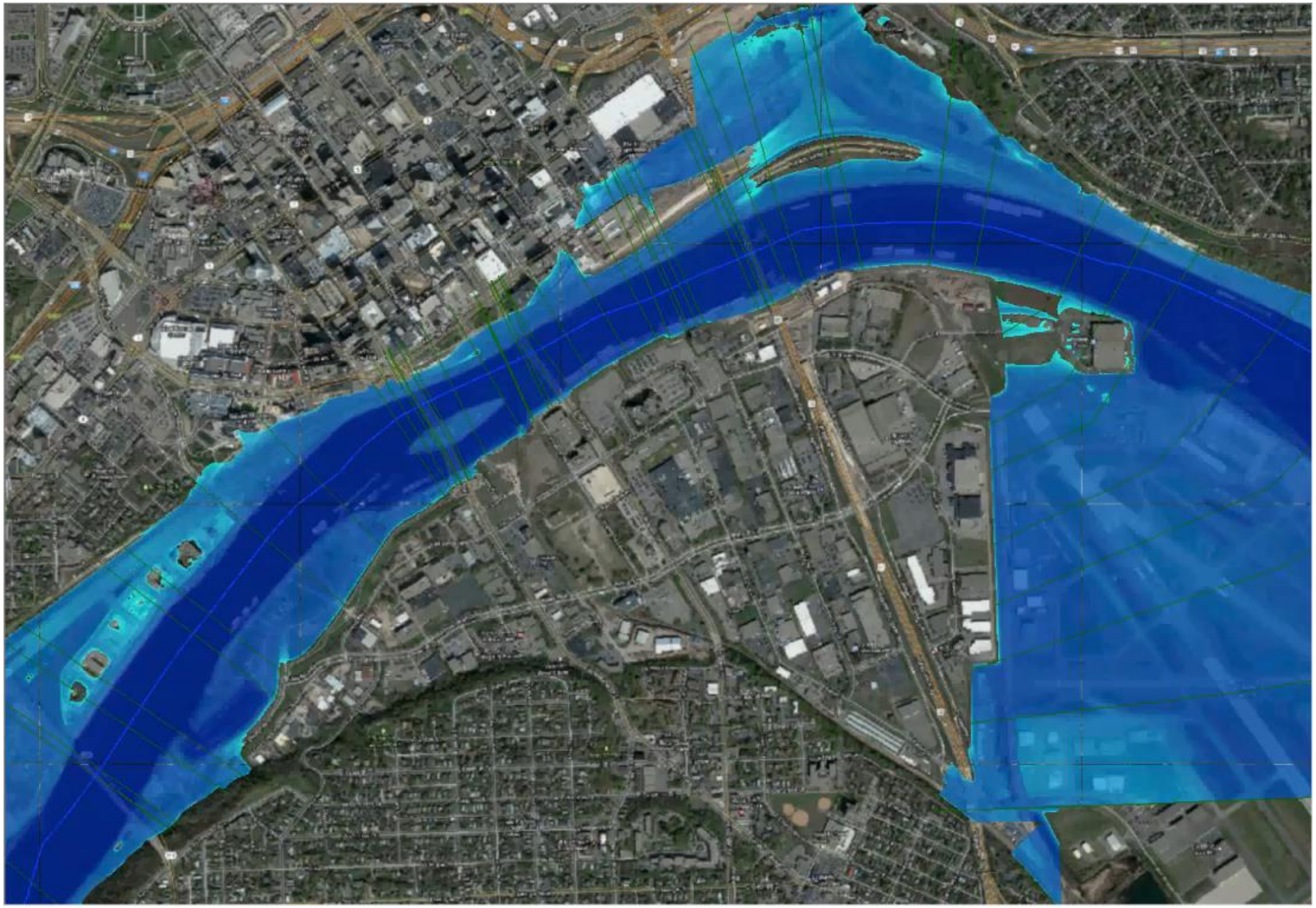


- Computationally efficient
- Produces improved estimates of cell volume and channel conveyance
- Model variables only available at grid scale
- Care must be taken when creating grid to prevent aliasing



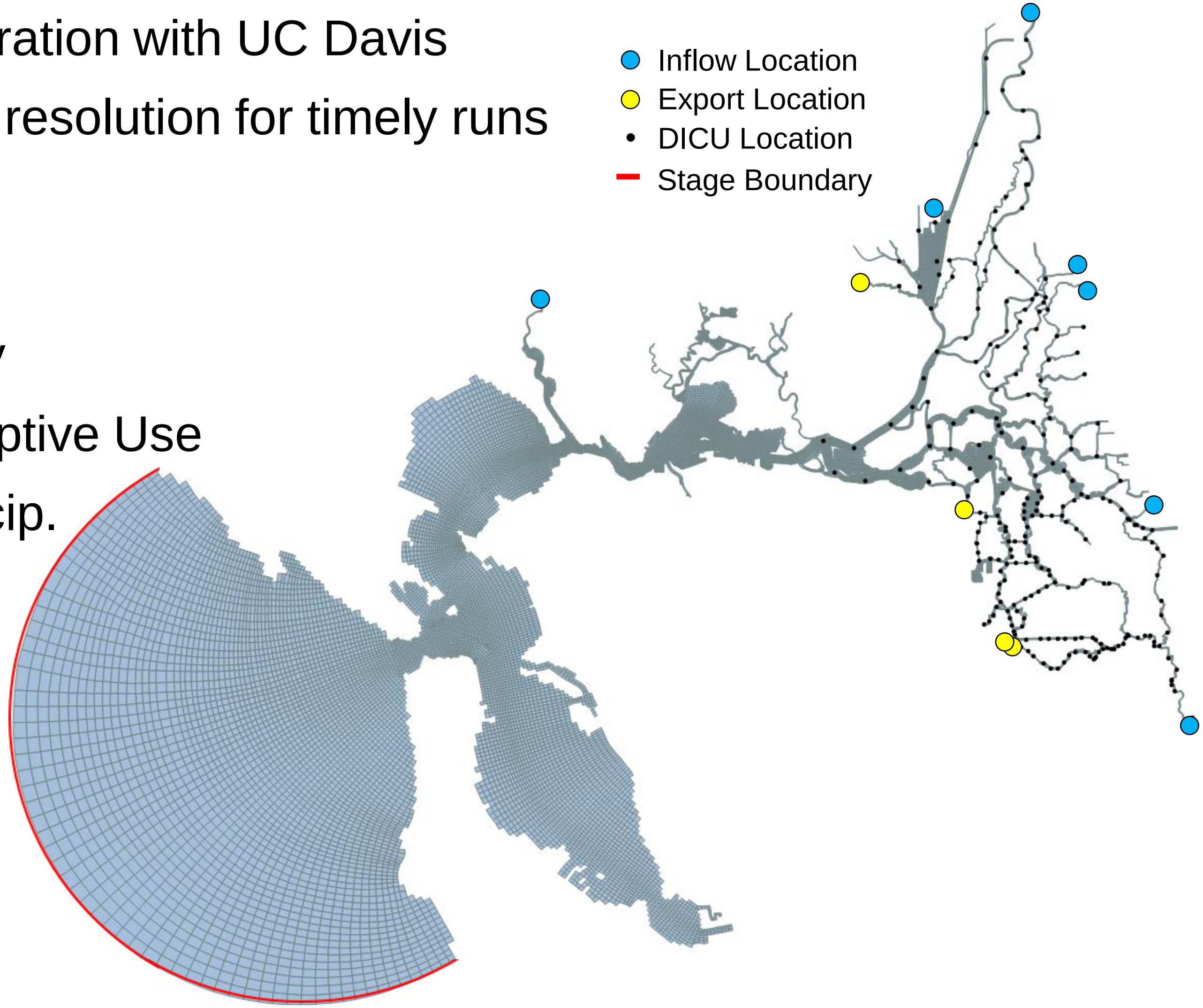
Subgrid Example in HEC-RAS2D

(RAS2D engine developed by RMA under contract to USACE, Hydrologic Engineering Center)

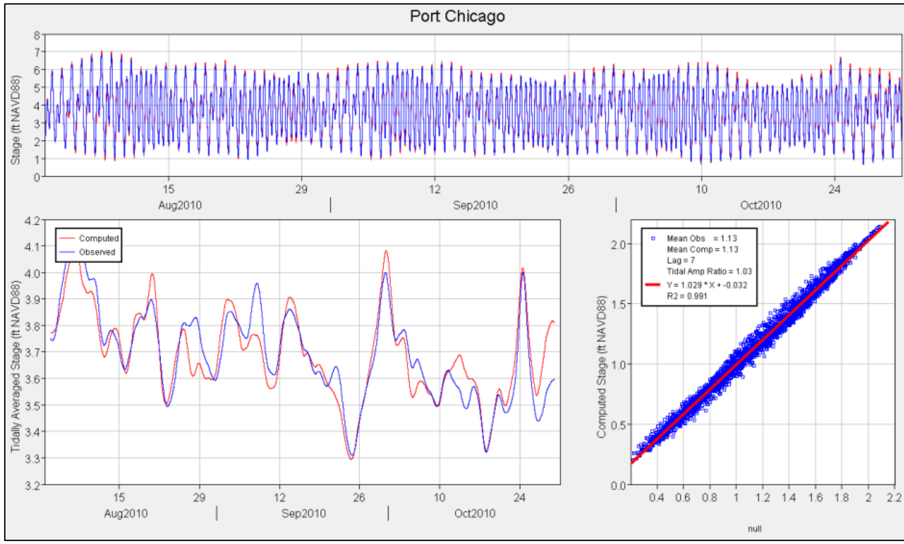


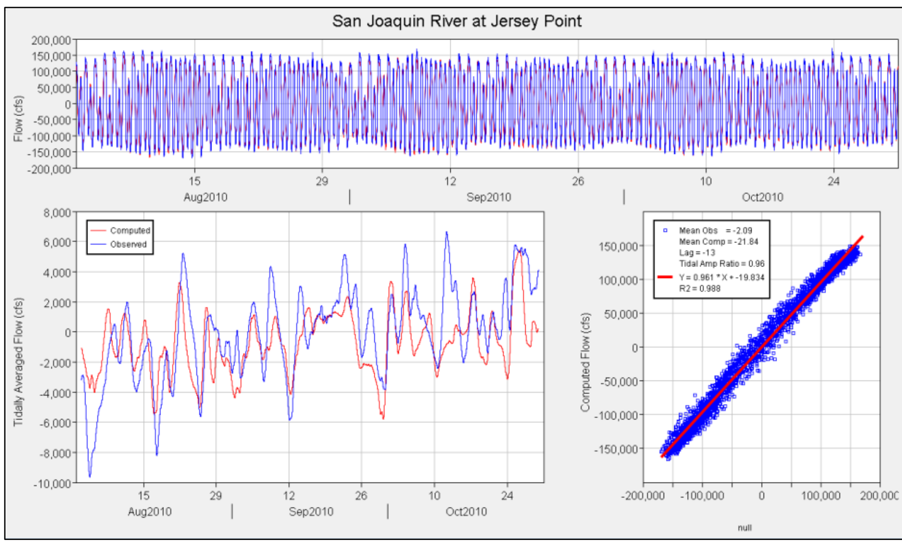
Contemporary Delta Model

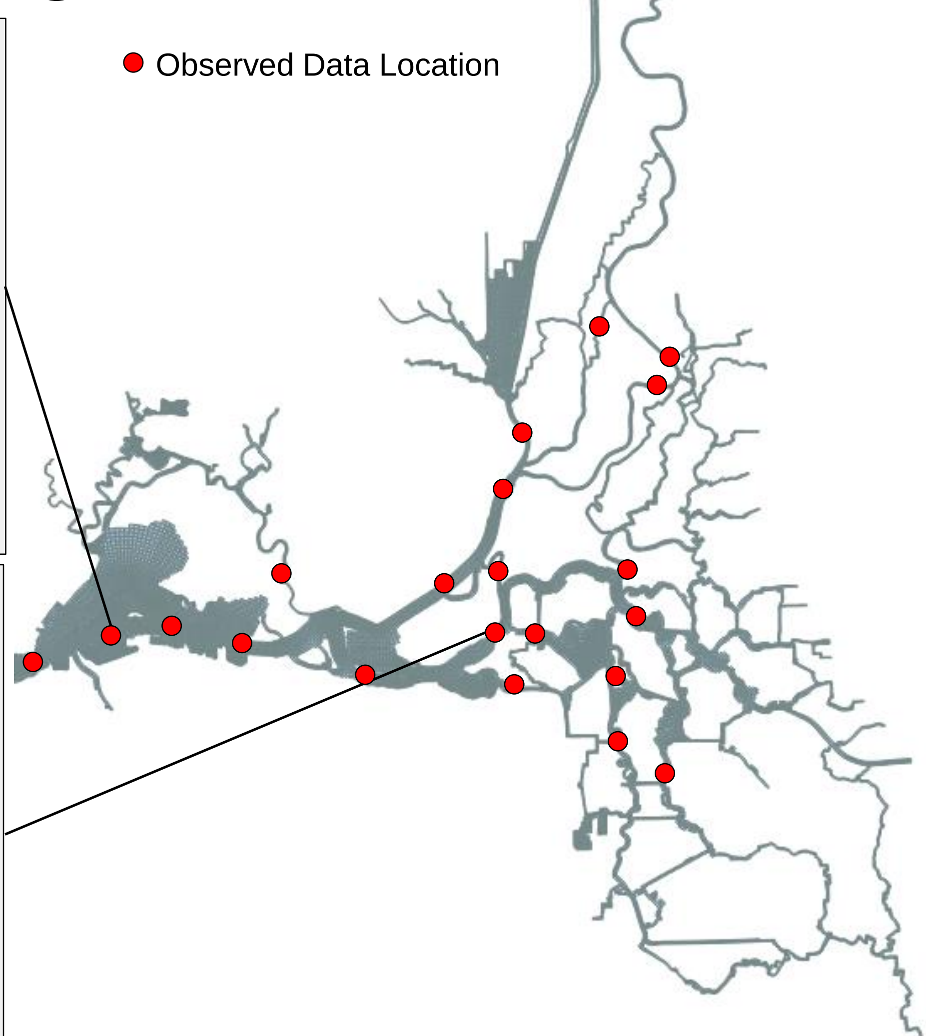
- Developed in collaboration with UC Davis
- Target moderate grid resolution for timely runs
- River inflows
- Major exports
- Ocean tidal boundary
- Delta Island Consumptive Use
- Evaporation and precip. in bays
- Surface wind stress
- Bed friction
- Generic length scale turbulence closure scheme used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



Initial Calibration: Stage and Flow

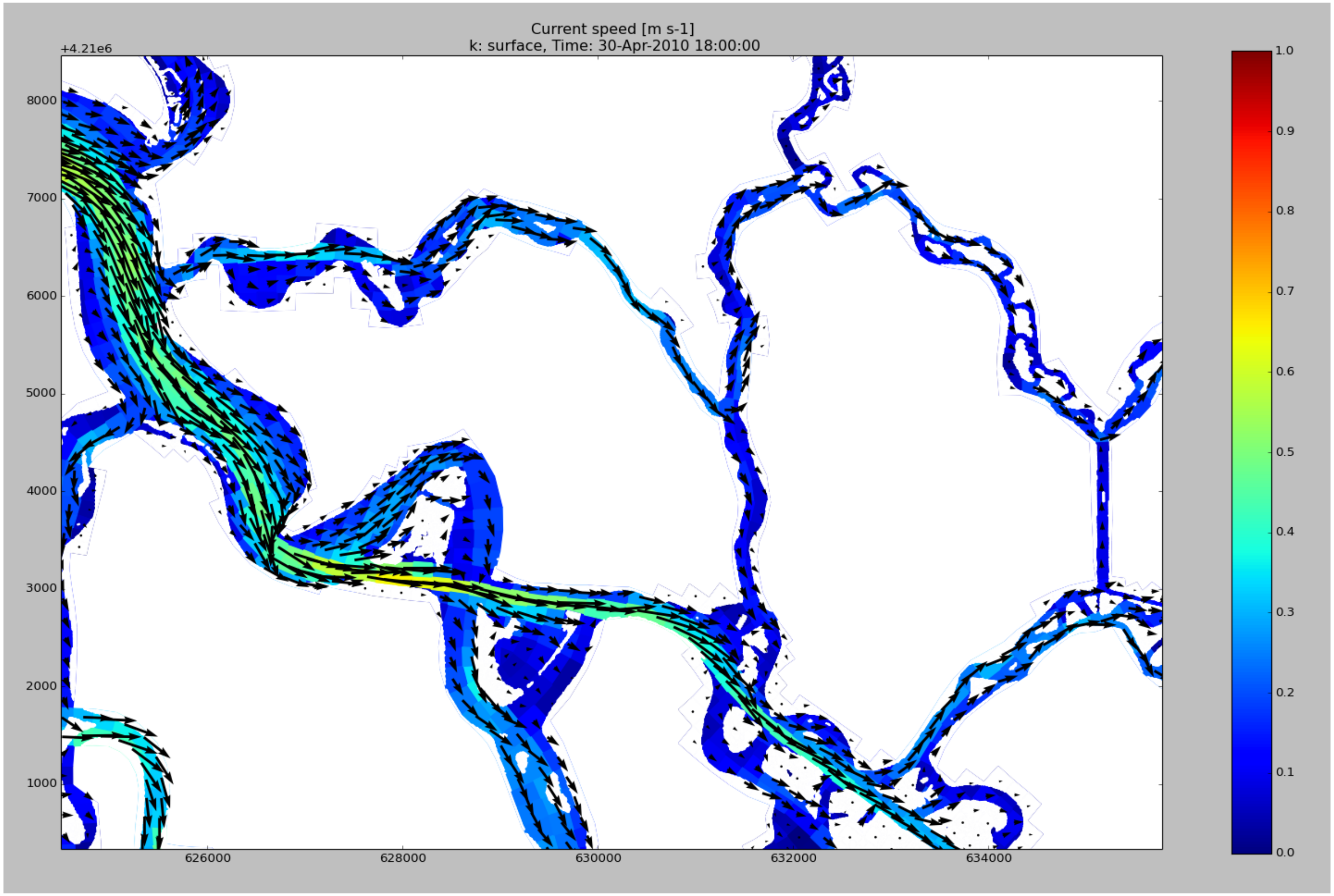






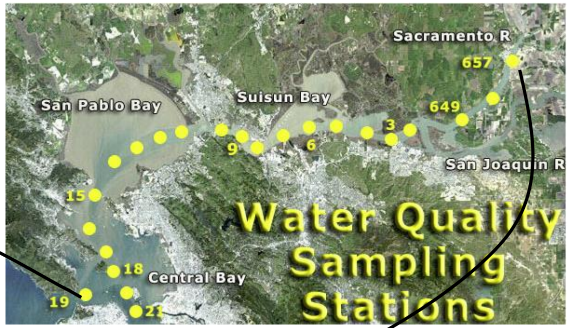
Preliminary Calibration Results

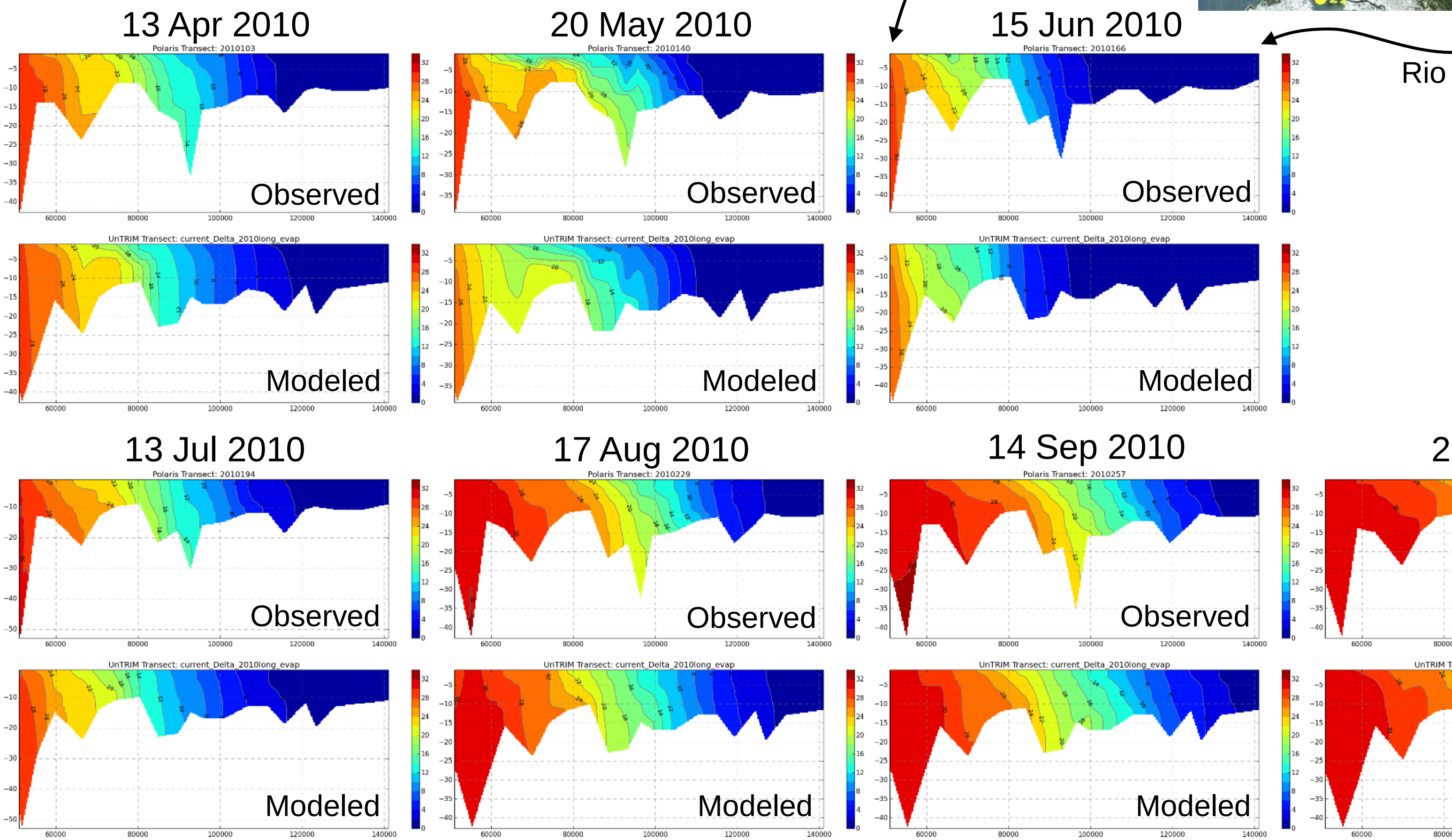
Subgrid Masked Velocities



Initial Calibration: Salinity

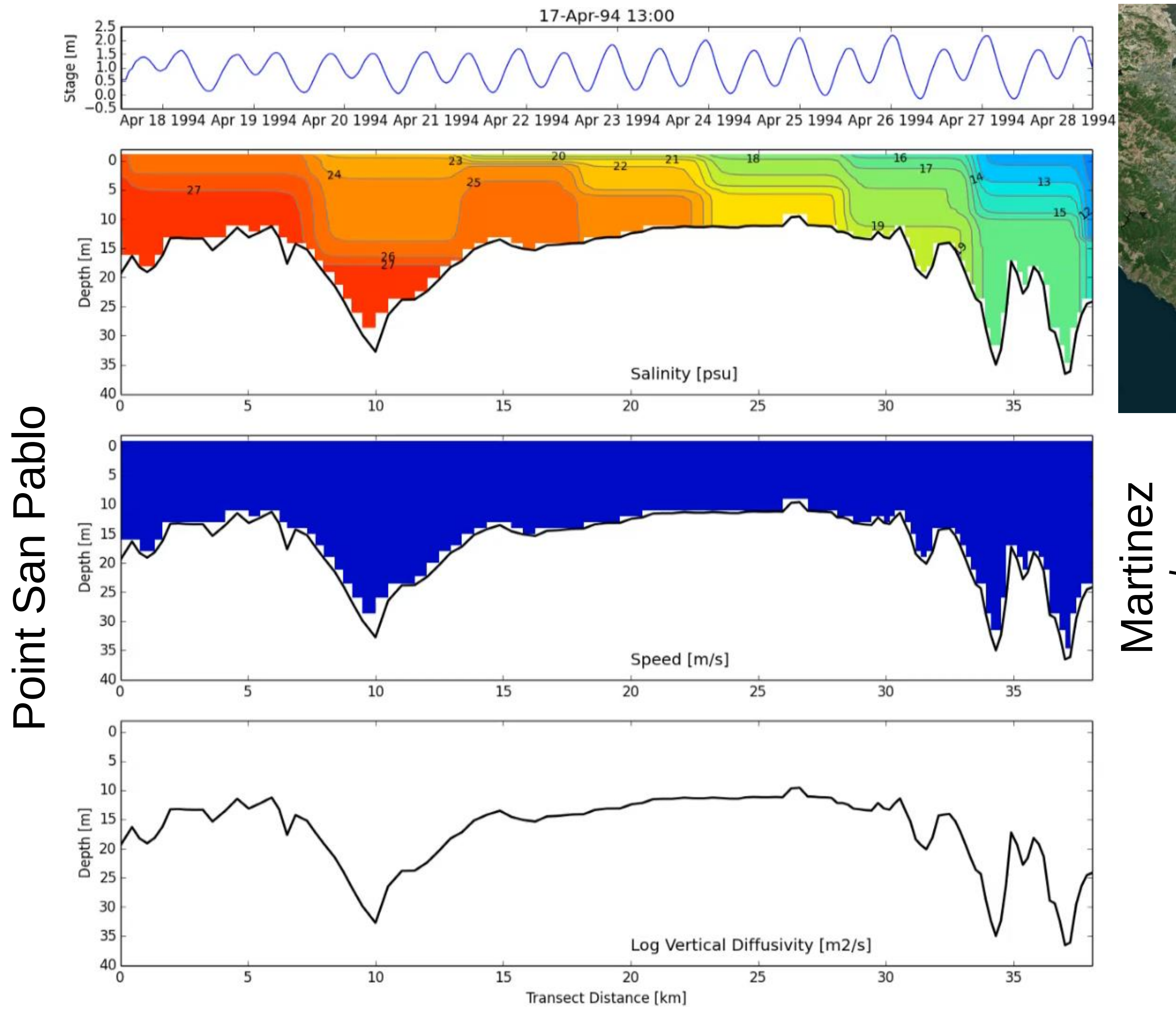
- USGS Polaris water quality transects





Preliminary Calibration Results

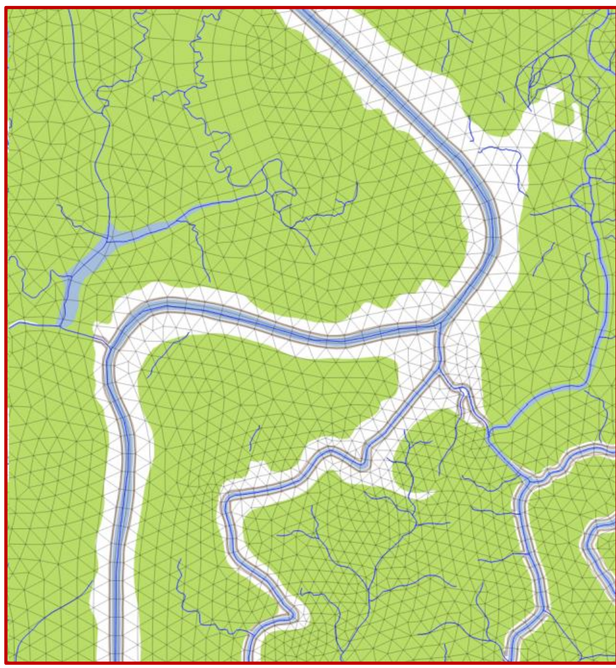
Salinity Field Characterization

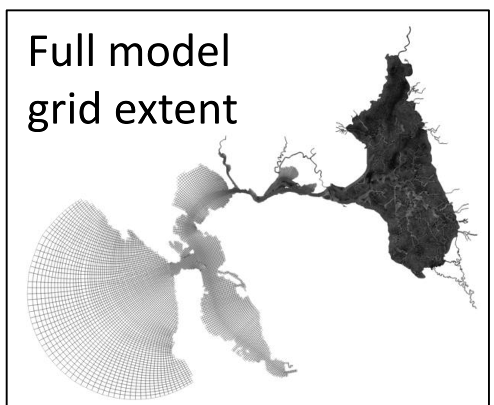


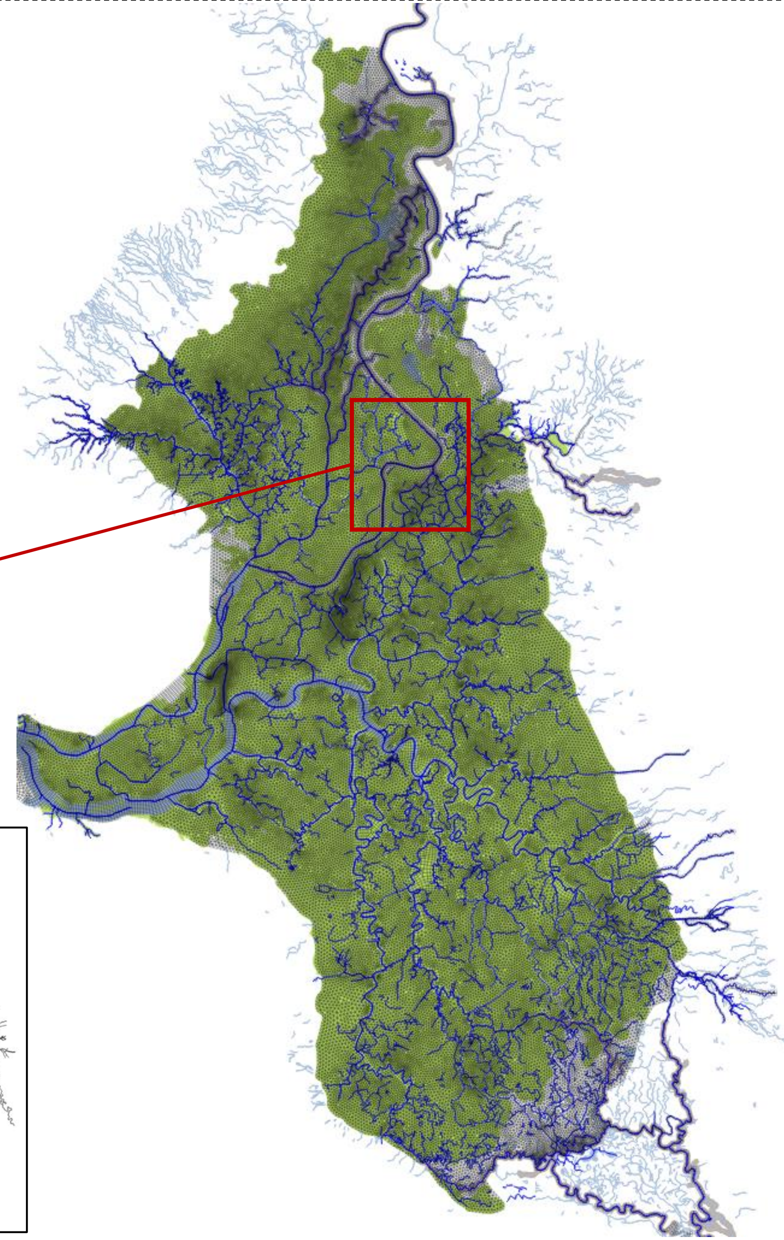
Transect Location

Historic Grid Construction

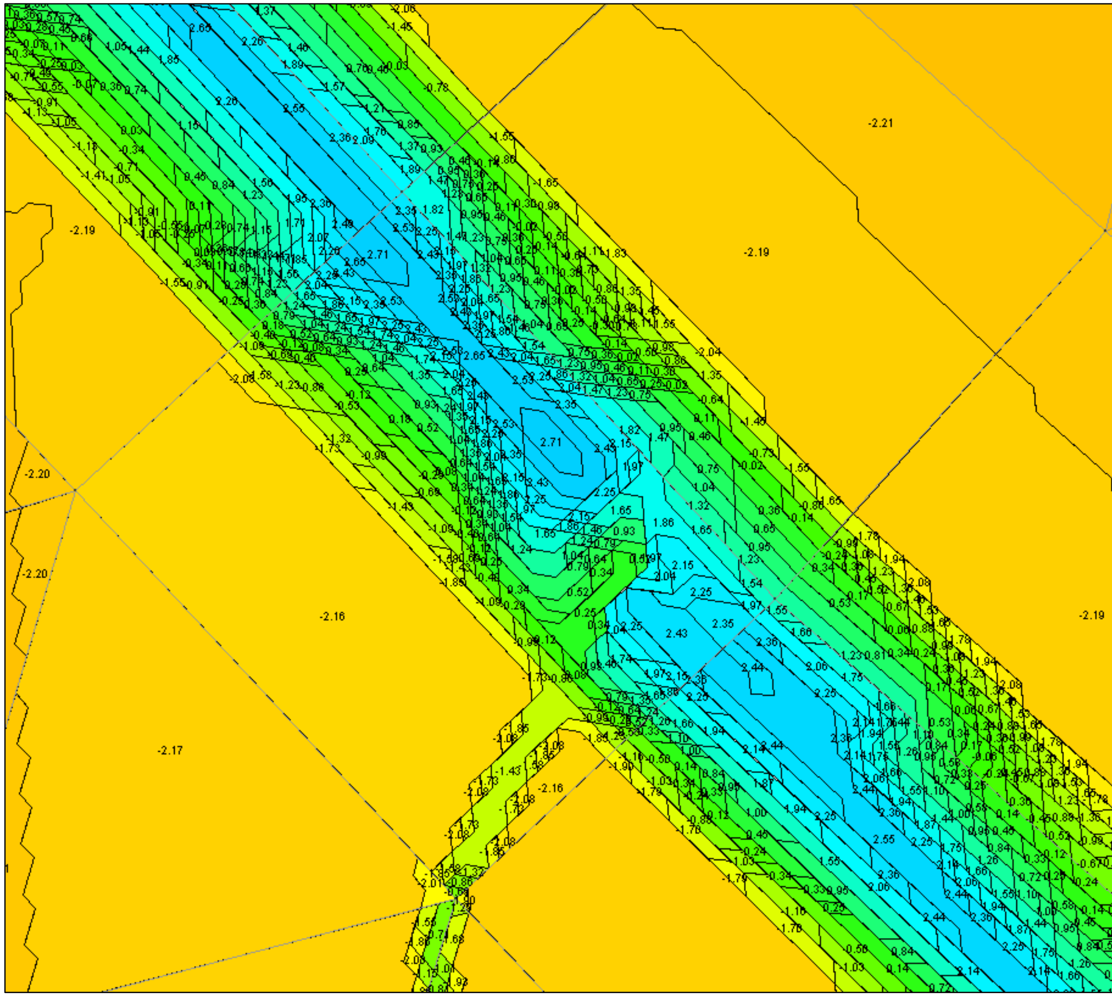
- Flow-aligned quadrilateral elements follow levee crests in main channels
- Triangular elements fill tidal plains
- Low-order channels captured implicitly using subgrid
- ~125,000 elements



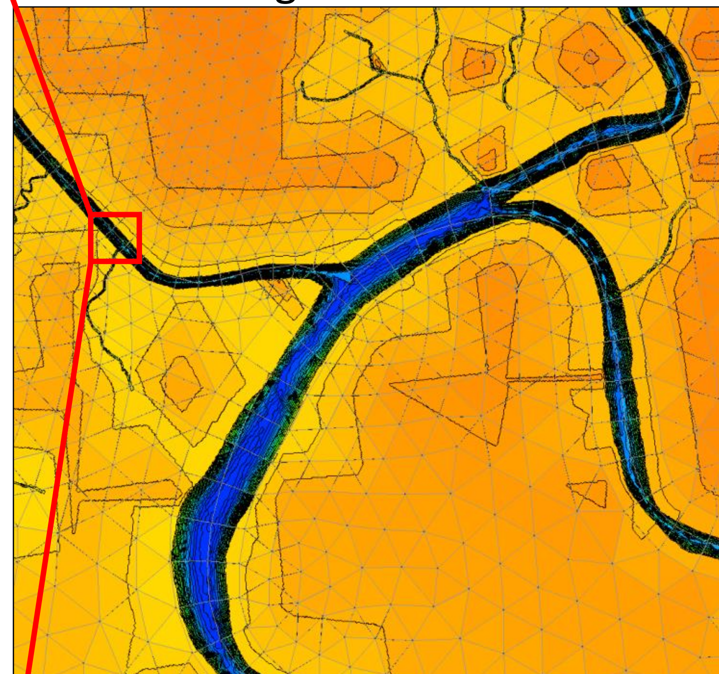




Historic DEM (UCD) → Historic Subgrid



UnTRIM Subgrid

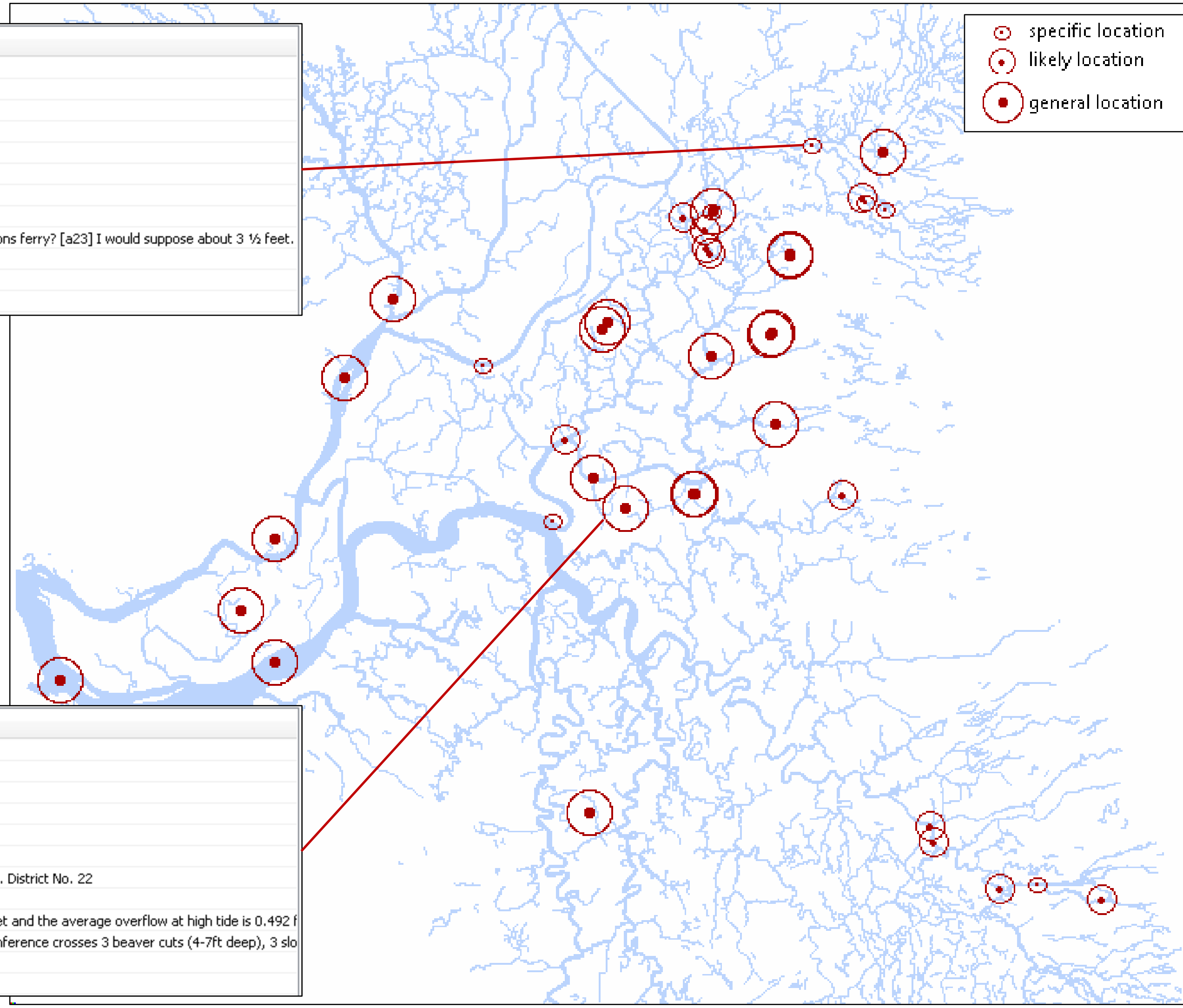


5-10 meter subgrid resolution →| |←

Historical Model Calibration Data (SFEI)

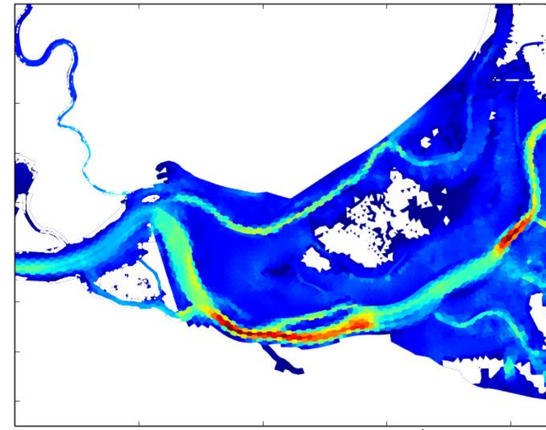
Field	Value
OBJECTID	1
Shape	Point
Class	Tidal range in channel
TidalRange	3.5 ft (spring tide)
ChannelDepth	<null>
TidalInundationDepth	<null>
Source	406 ND 1859, Samuel R. Thornton, 208
Date	1859
Quote	[q23] How high do the spring tides rise in the M river at Bensons ferry? [a23] I would suppose about 3 ½ feet.
Quote_summary	spring tide 3.5 ft in M river
LocationPrecision	Benson's Ferry
Location_precision_code	1

- Tidal range
- Depth of marsh plain inundation
- Channel depth



Field	Value
OBJECTID	35
Shape	Point
Class	Depth of marsh plain inundation
TidalRange	<null>
ChannelDepth	<null>
TidalInundationDepth	6 inches MHHW (banks)
Source	Hall 1861, S&O Reports Correspondence. Beaumont, Duncan. District No. 22
Date	1861
Quote	The average difference between high and low tide is 6.12 feet and the average overflow at high tide is 0.492 f
Quote_summary	tide range 6.12ft, overflow at high tide ~6in on banks, circumference crosses 3 beaver cuts (4-7ft deep), 3 slo
LocationPrecision	Bouldin Island, District No. 22
Location_precision_code	3

Iterative Calibration Strategy



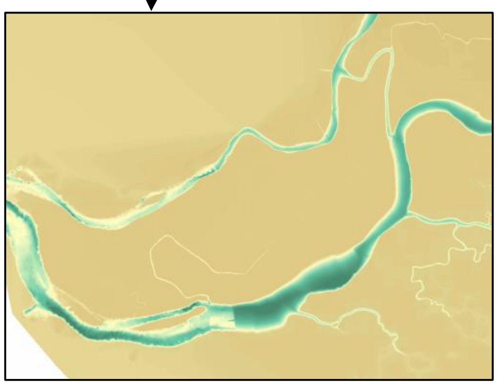
Initial guess at MSL and marsh plain elevations based on current Delta conditions

Run Historic Delta Model
(RMA)

Calculate mean sea levels, tidal marsh inundation depths
(RMA)

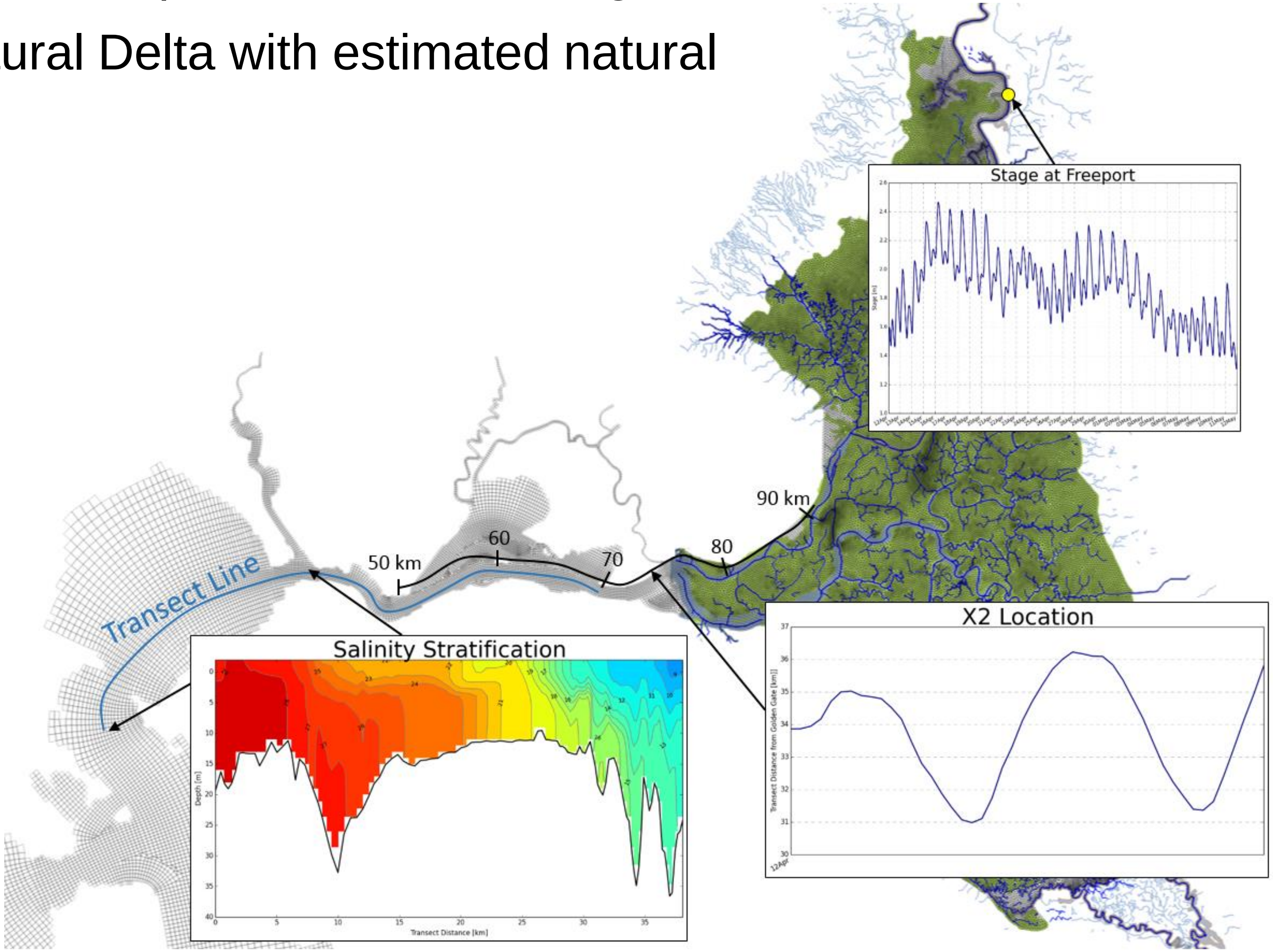
Set channel and marsh plain elevations
(UC Davis)

Generate Historic Delta DEM
(UC Davis)



Ongoing Work

- In Phase I of the iterative process of calibrating the historic Delta model
- Comparison of natural Delta with estimated natural hydrology
  - Stratification
  - X2 location
  - Tidal range



Thank You

- Development and calibration of the historic model grid was funded by the Metropolitan Water District of Southern California, under the direction of Paul Hutton
- UC Davis collaborator: Bill Fleenor, Watershed Sciences
- SFEI collaborator: Robin Grossinger