Three -Dimensional Hydrodynamic Numerical Modeling of Galveston Bay using 3-D Adaptive Hydraulics Code (3D-ADH)

Gaurav Savant
Christopher Wallen
Christopher Hall

Dynamic Solutions LLC

US Army Corps of Engineers
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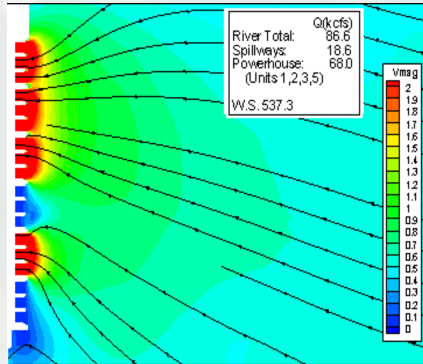
Goals for 3D Modeling of Galveston Bay

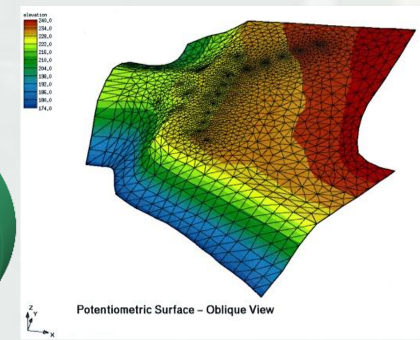
- Develop a hydrodynamic ADH 3D modeling framework of Galveston Bay
- Evaluate framework with comparisons to observed data
- Use framework to evaluate:
  - Oyster habitat suitability
  - Sediment fate modeling

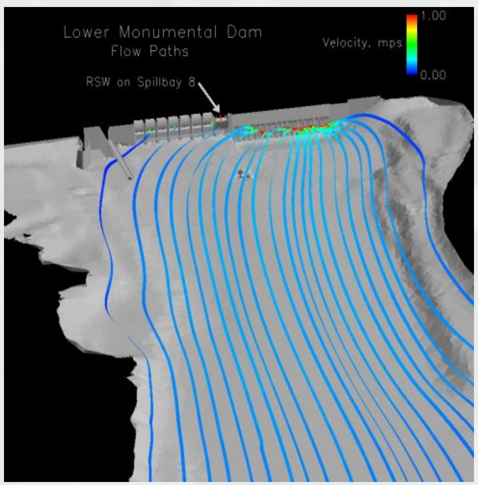
ADH Philosophy

Navier-Stokes
Equations

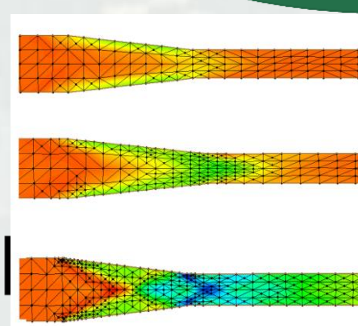


Unsaturated
Groundwater
Equations

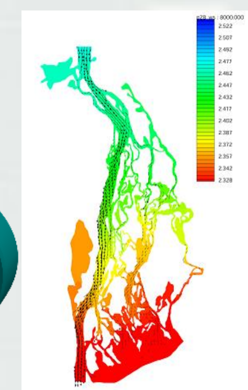




Computational Engine
(FE utilities, preconditioners,
solvers, I/O to xMS GUIs)



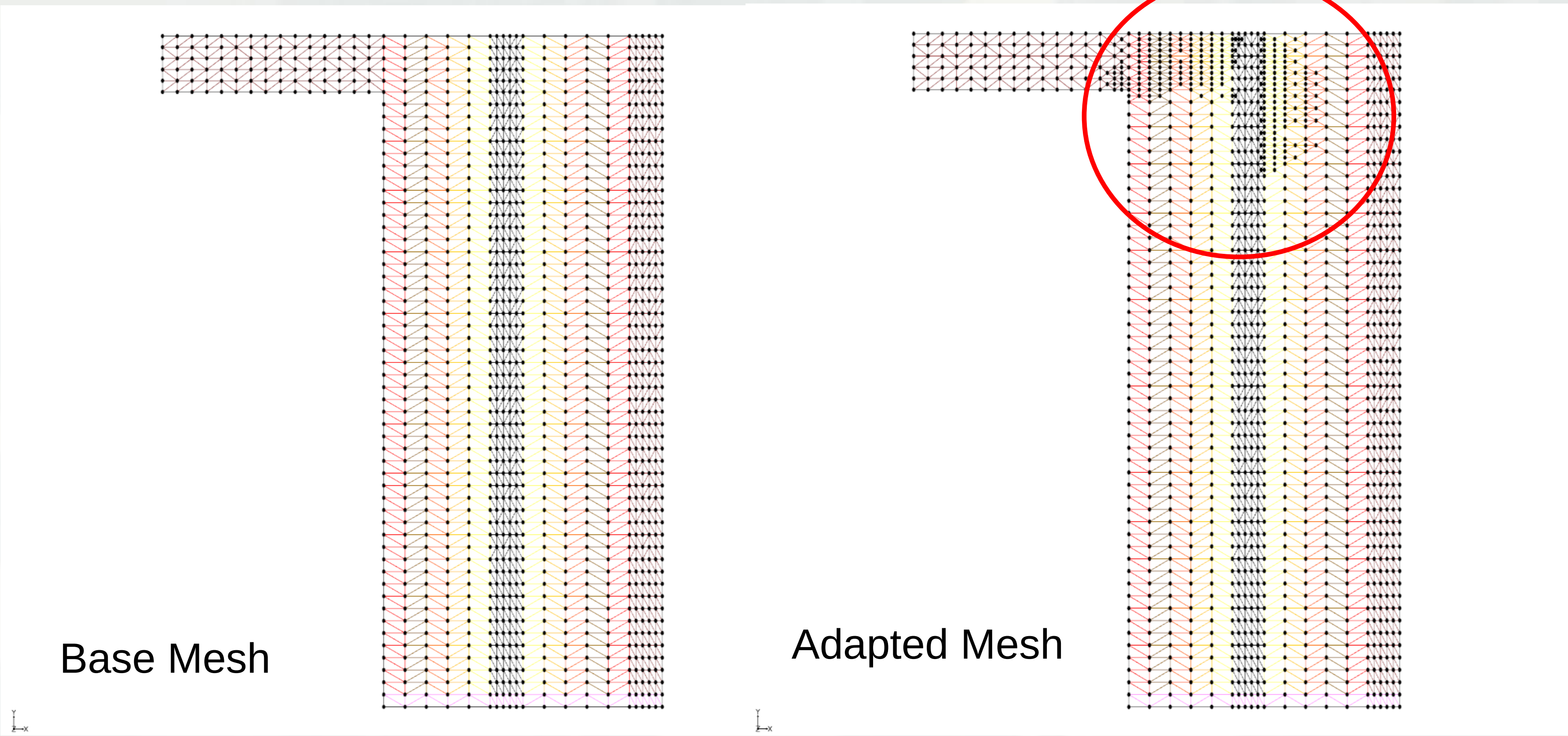
Shallow Water
Equations



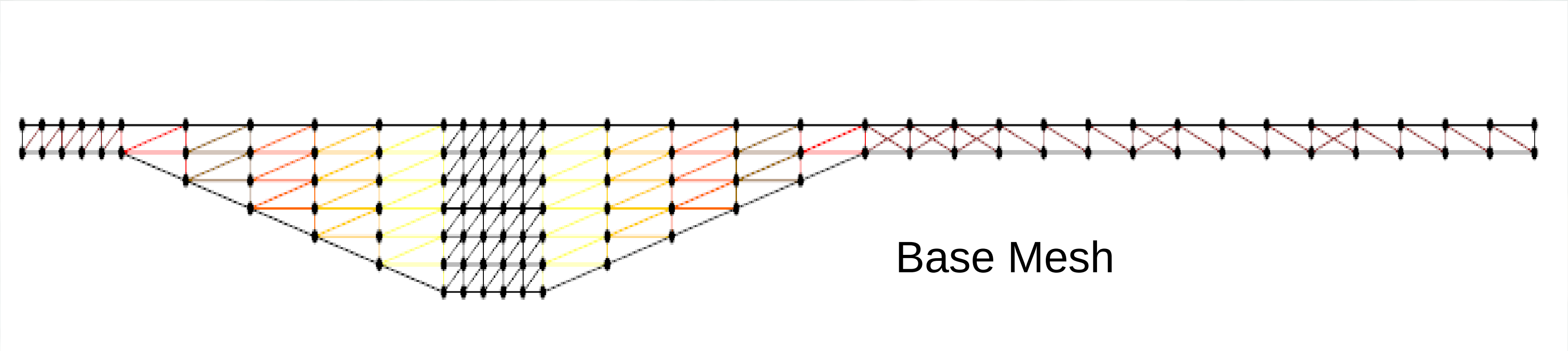
3D SW ADH

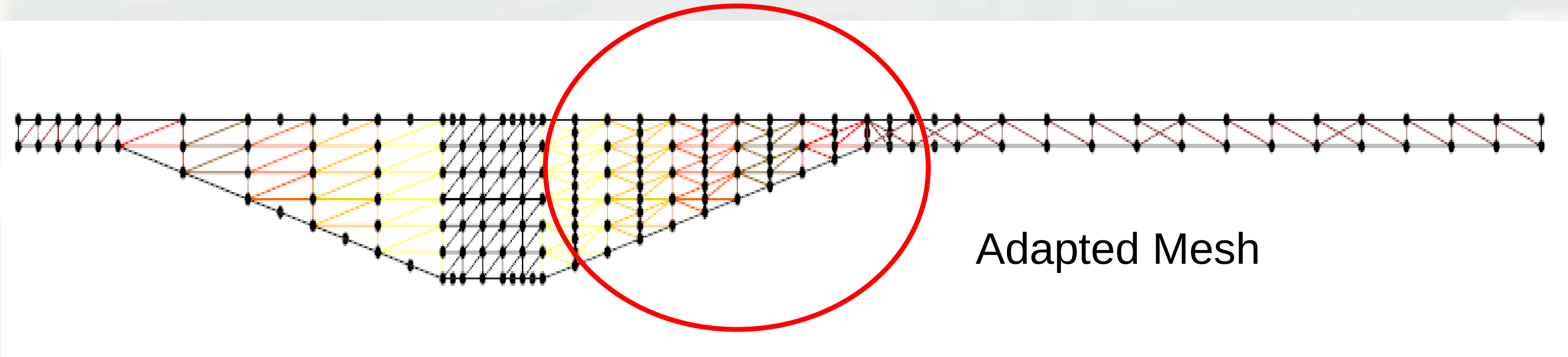
- Technological Leapfrogging of USACE capability for hydrodynamic and environmental modeling:
  - ADH is the only implicit mass conservative “Spatially and Temporally Adaptive Code” in production,
  - Utilizes vertical meshing that is neither Sigma or Z-grid based and hence, is not encumbered by the drawbacks of either,
  - Adaption in the horizontal and vertical allows for accurate representation of hydrodynamics as well as transport,
  - Conservation of fluid and constituent mass,
  - Ease of use: Generation of 3D from existing 2D meshes, execution on HPC, PC, multiple processor PC and others,
  - SEDLIB provides a library of sediment transport processes that are accessible by any hydrodynamic model not just ADH.
  - Wave Forcing

Technological Leap Ahead



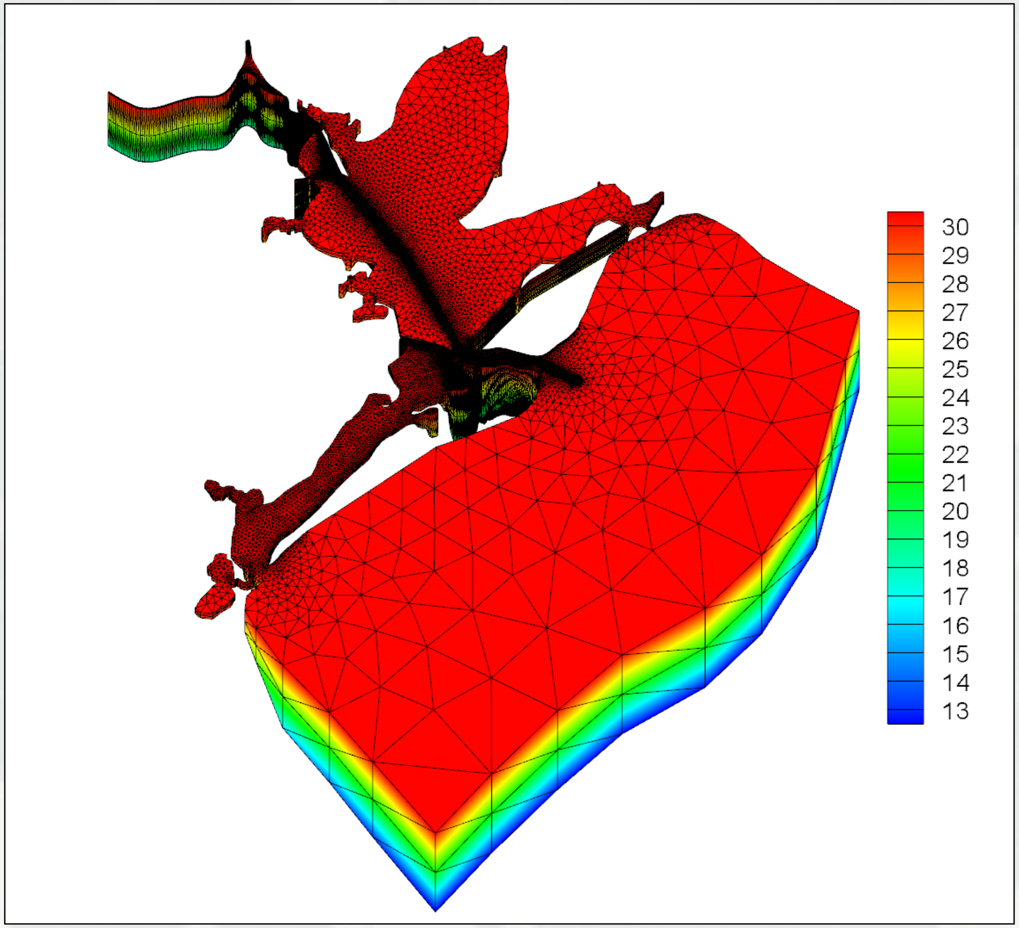
Vertical Adaption



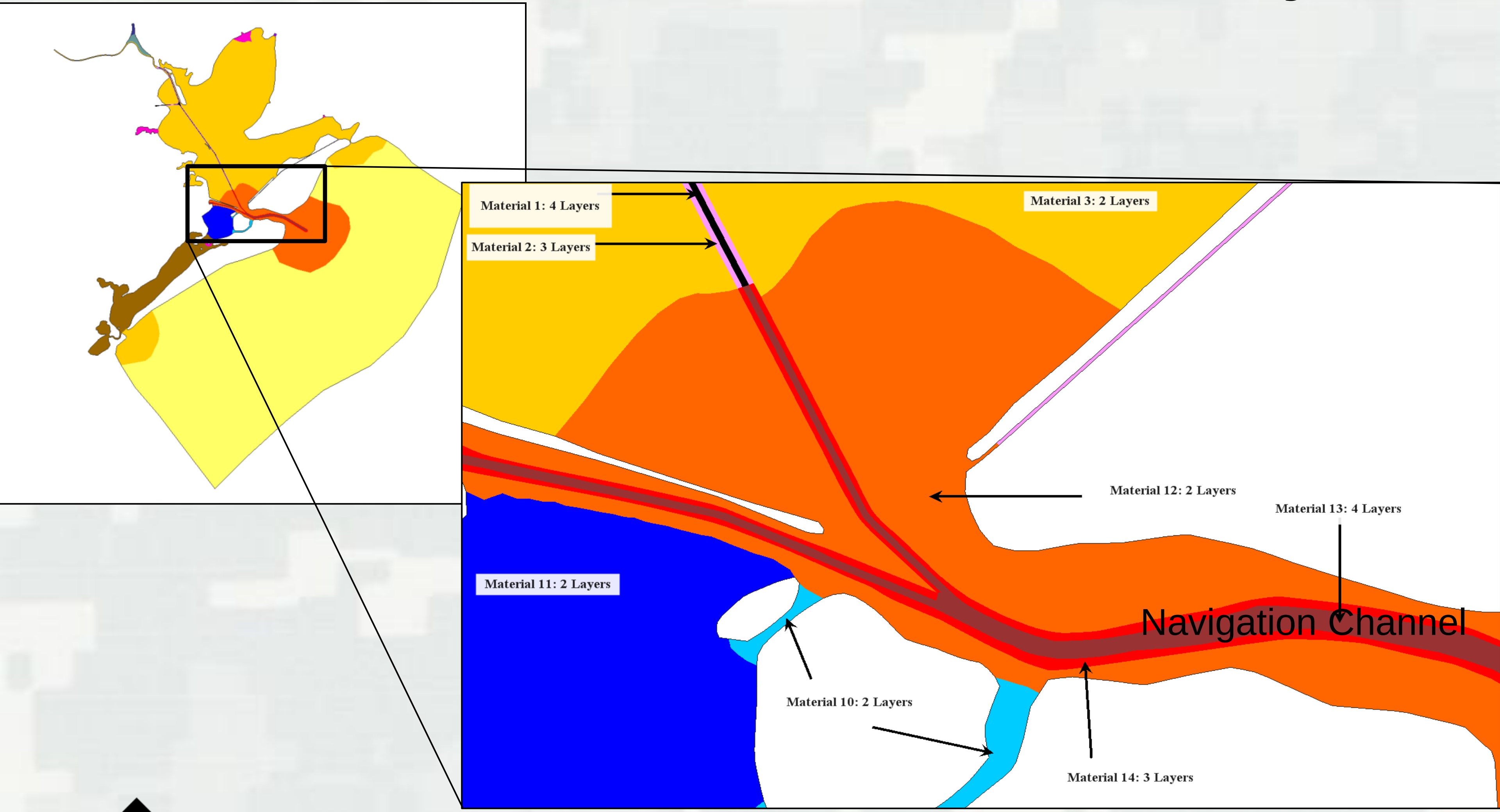


3D SW ADH: Galveston Bay

- Important data rich estuary
- 64,333 initial nodes
- 269,507 initial elements
- Adaption "on" for navigation channel
- Maximum number of adapted nodes 69,743



3D SW ADH: Galveston Bay



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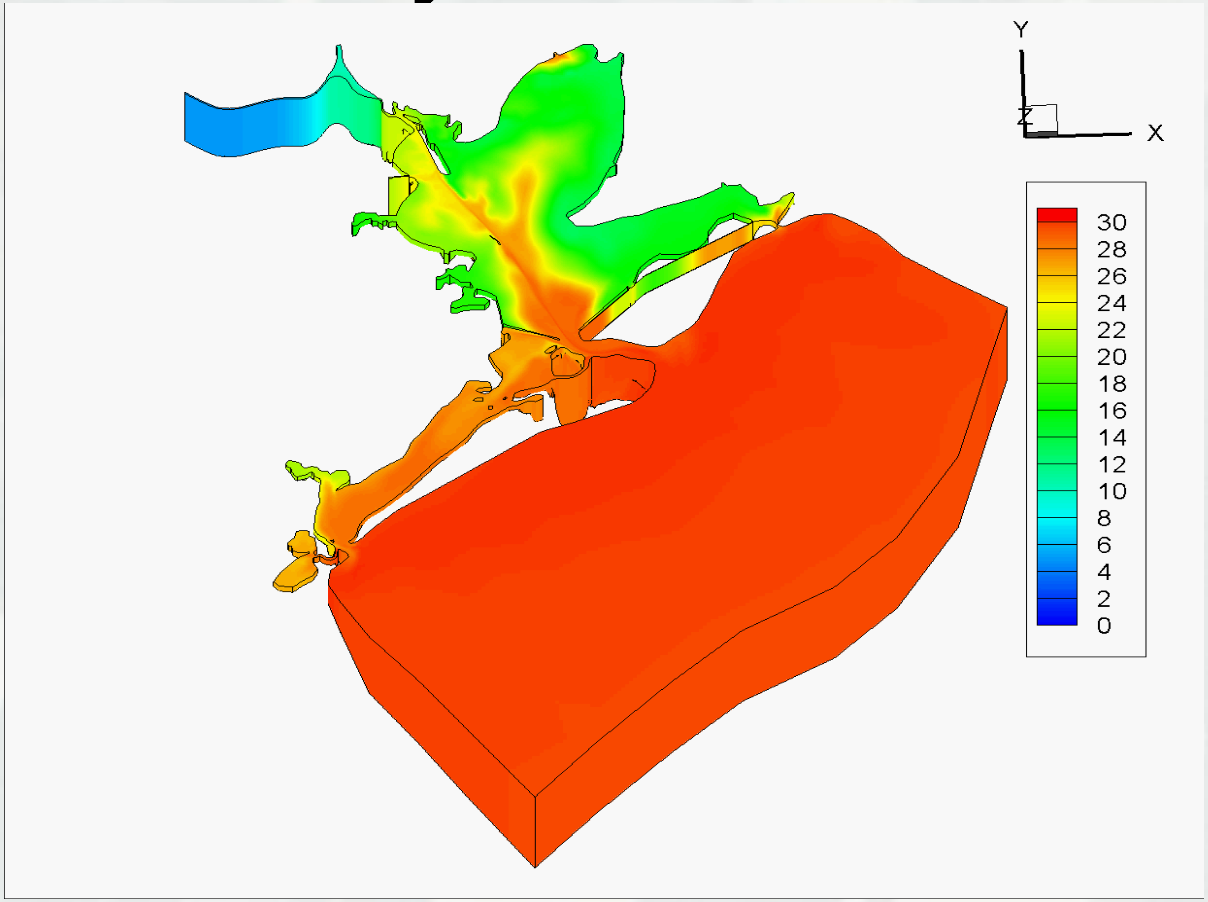
Galveston Bay 3D ADH Animation



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3D SW ADH: Galveston Bay

- Model Forcings
  - ▶ Tide, salinity, winds
  - ▶ River inflows (San Jacinto and Trinity)
  - ▶ Cedar Point power plant inflow and outflow
  - ▶ Accounting for Mississippi River long shore current
- Model spin up duration 4500 hrs (~ 0.5 Yr)
- Model simulation duration 1.0 yr
- # Processors: 2
- Run time: 2 days (no optimization attempted)

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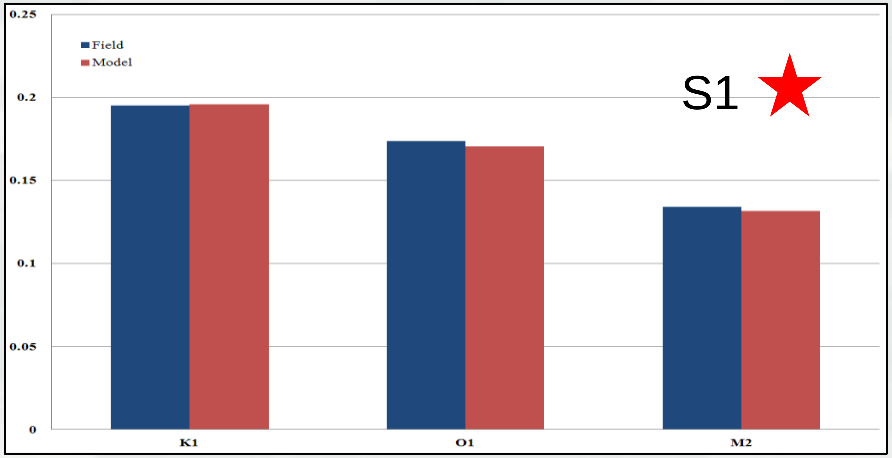
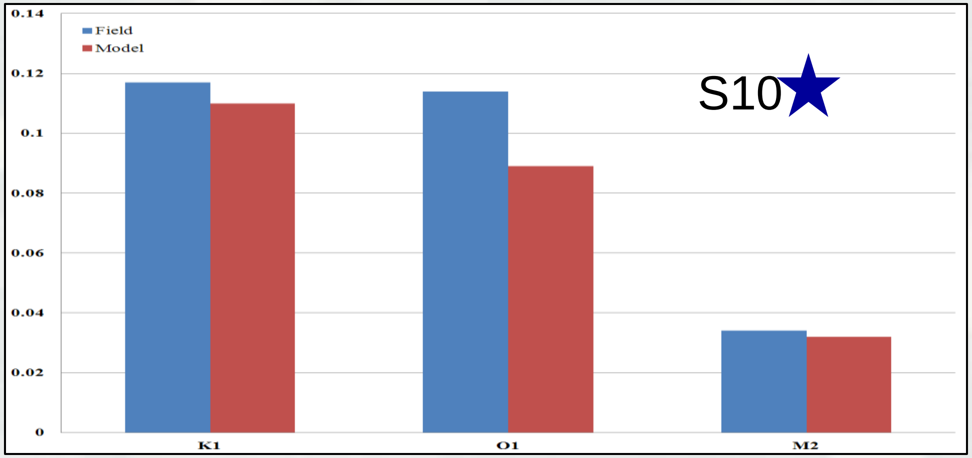
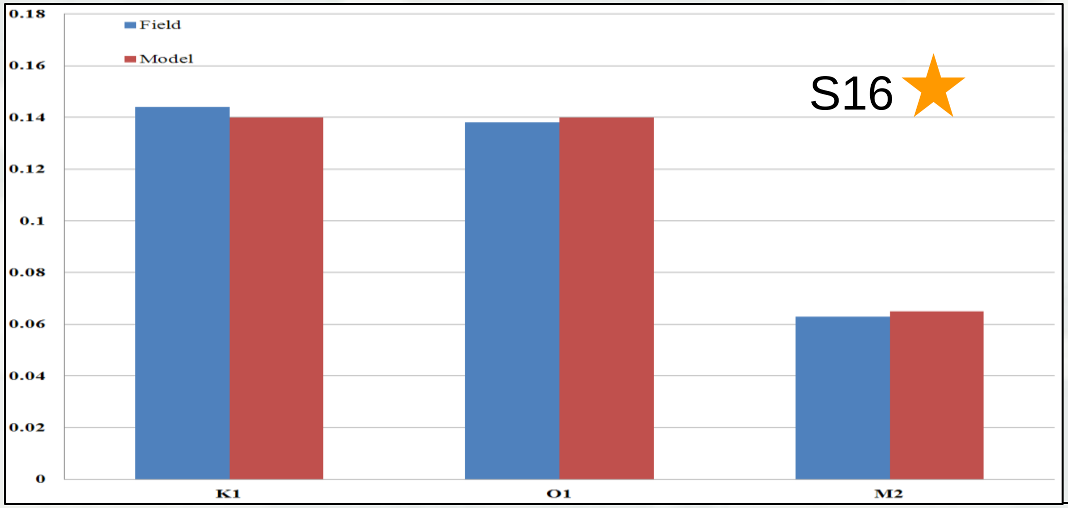
Model Evaluation Parameters

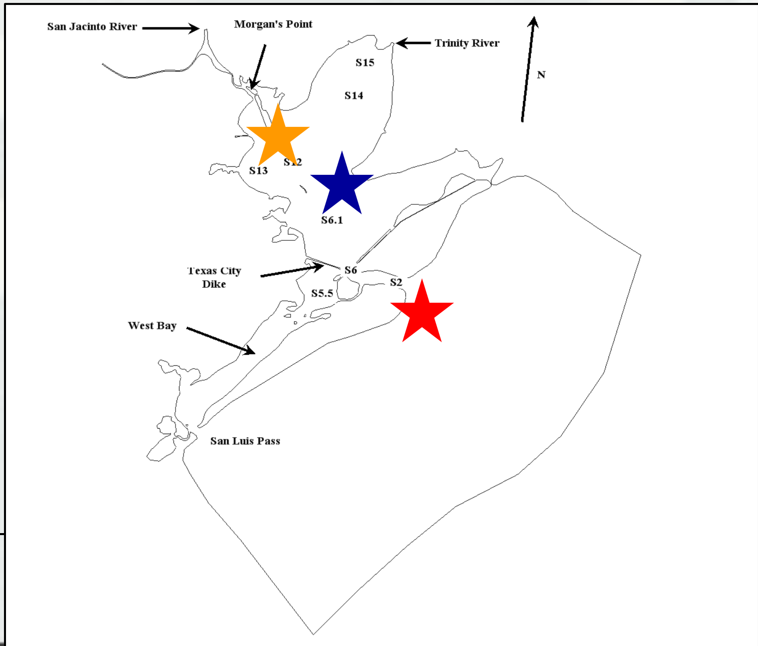
- Observation stations in both the navigation channel and shallow tidal areas
- Harmonic Analysis
- Salinity Comparison
- Velocity Comparison
  - Surface and Bottom Observations

Amplitude of Tidal Components

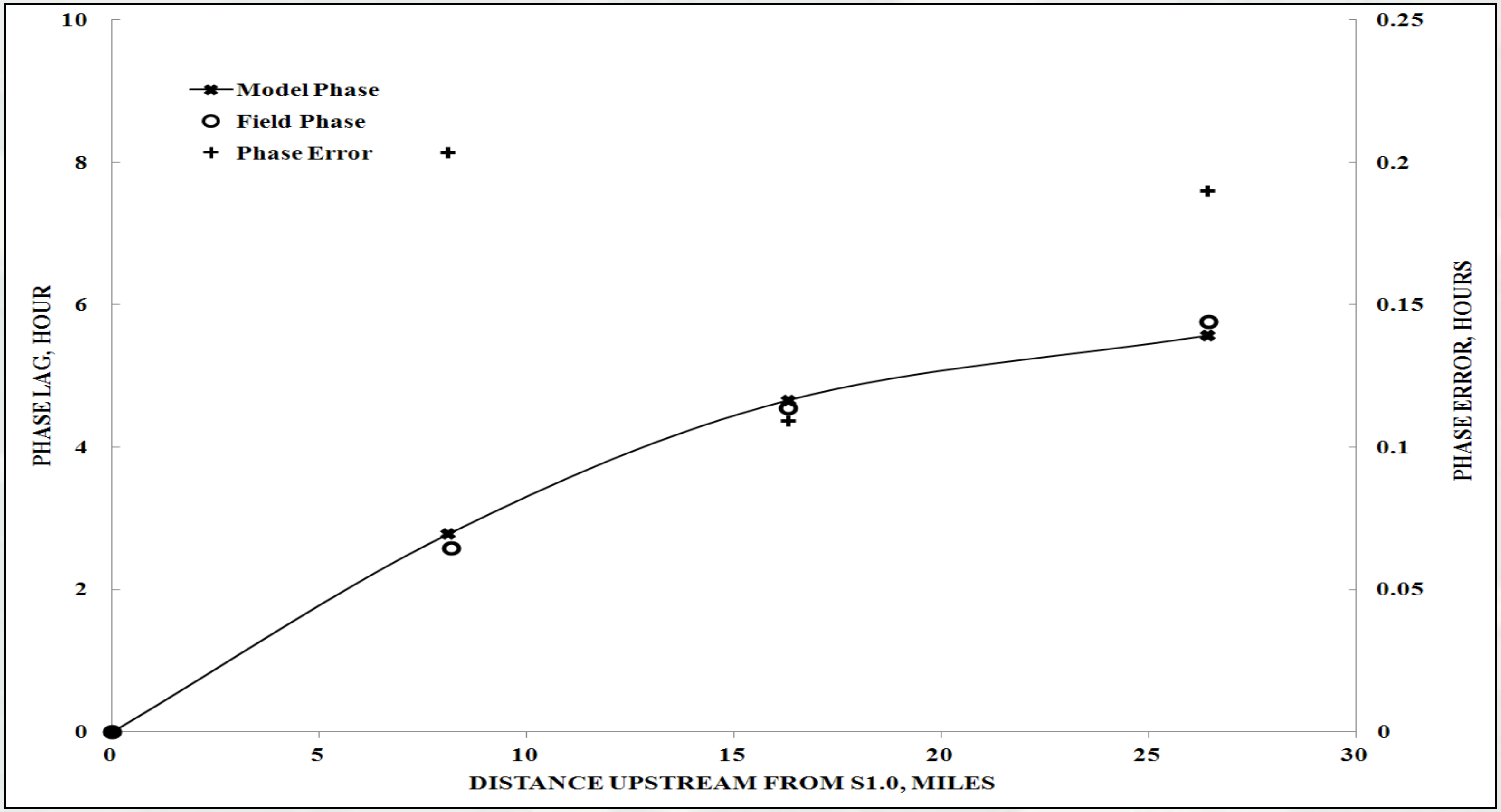








Harmonic Analysis – Lag and Phase Error



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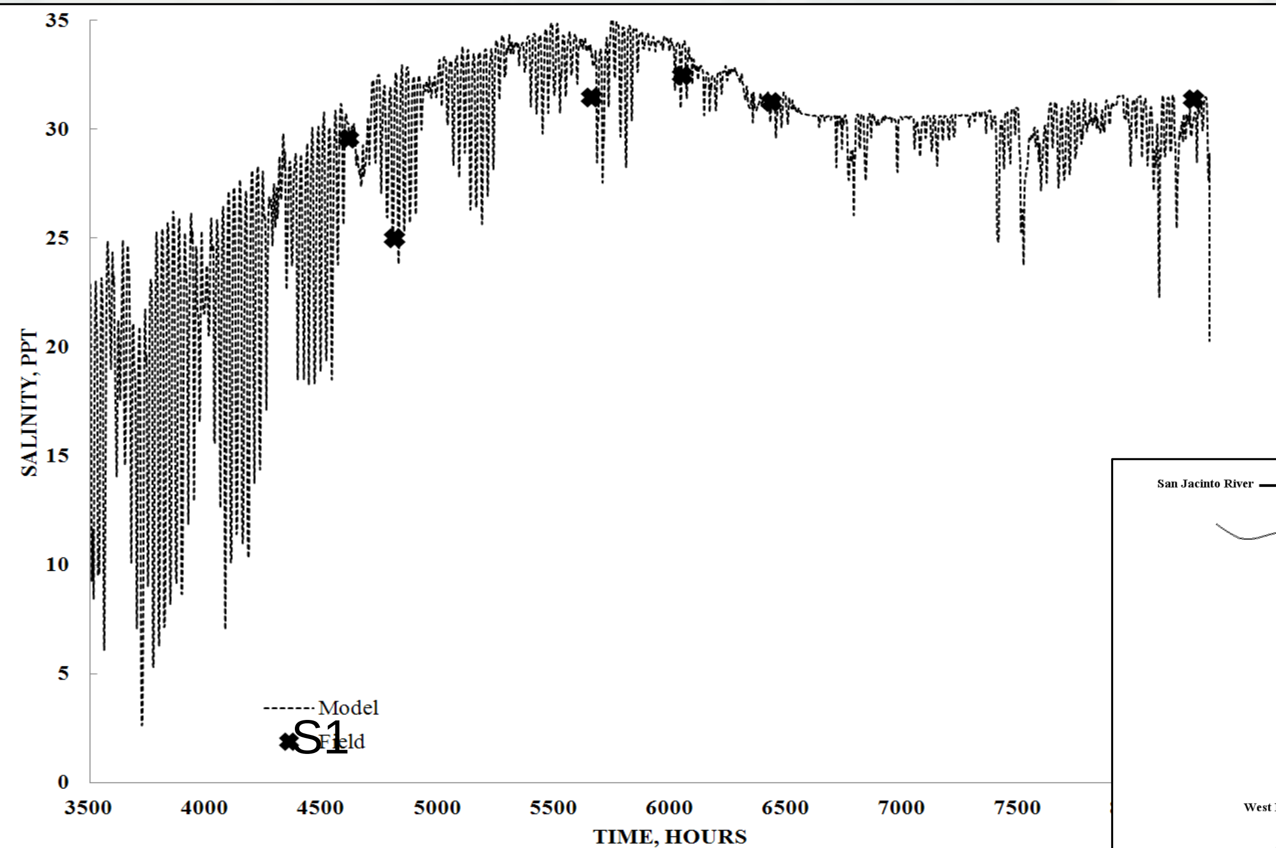
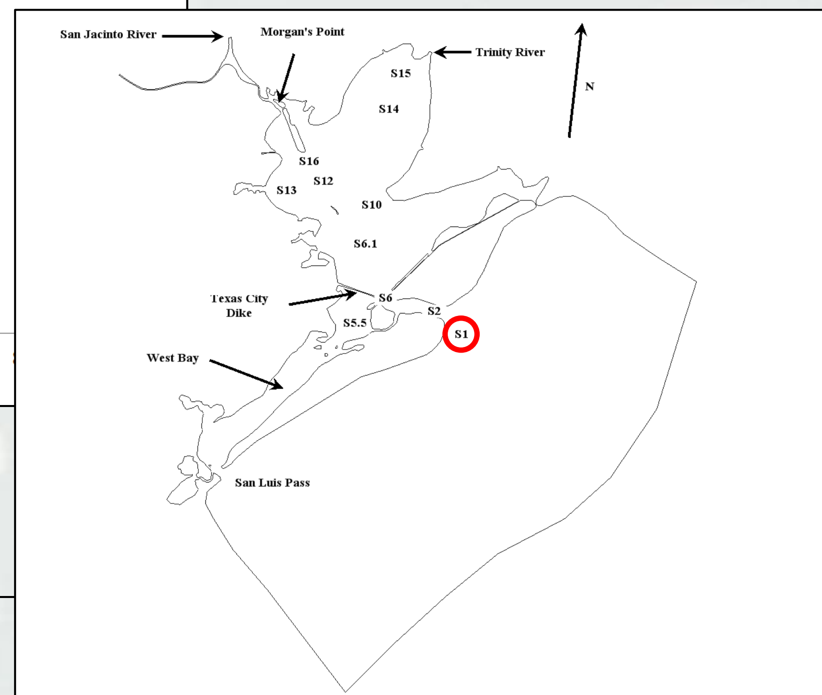
Salinity Comparison





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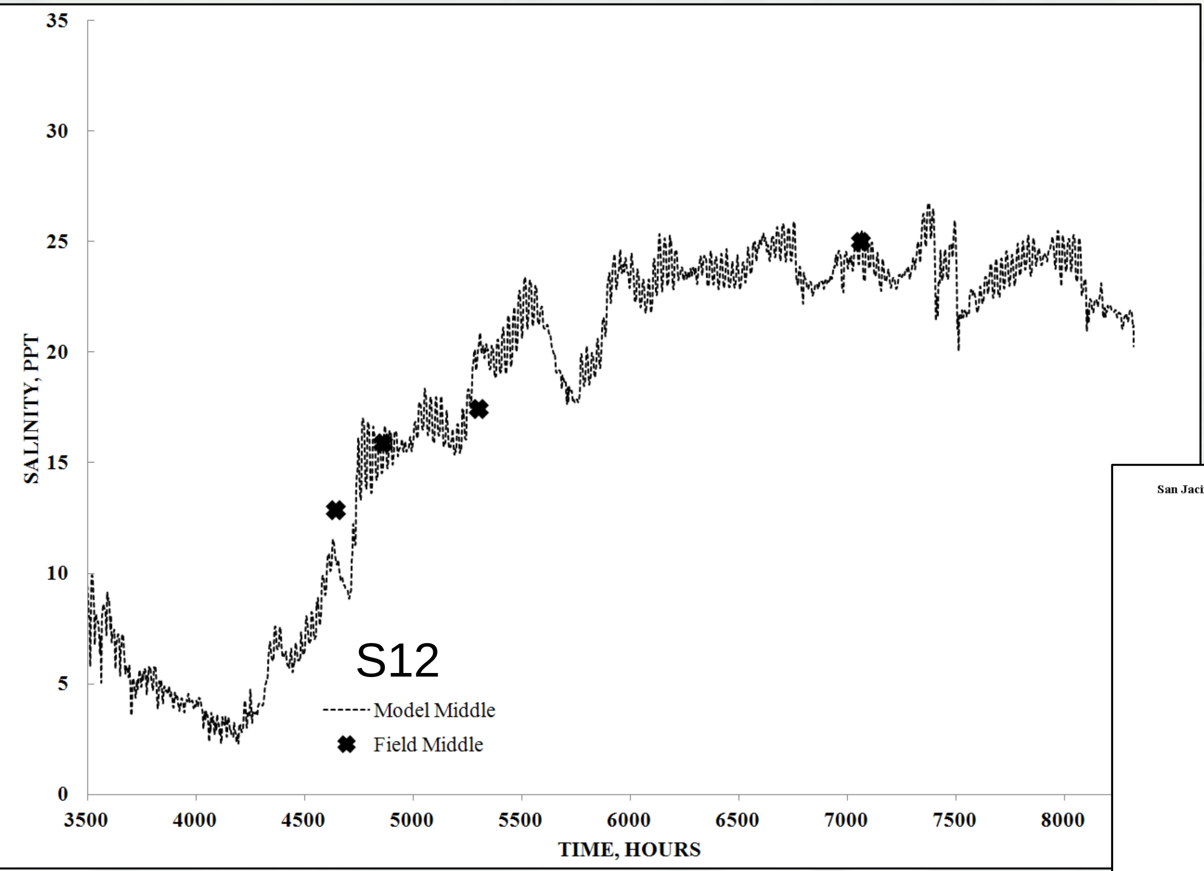
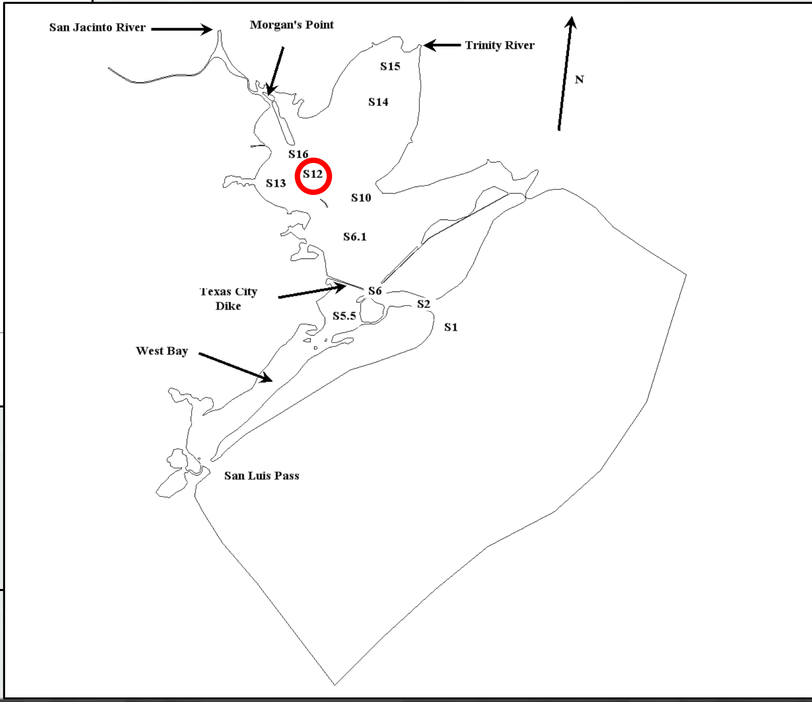
Salinity Comparison





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Depth Averaged Salinity Comparison

Station	Willmott Coefficient, d
S1	0.83
S2	0.75
S5	0.71
S5.5	0.96
S6	0.87
S12	0.96
S13	0.74
S14	0.98

$$d = 1 - \left[\sum_{i=1}^{N} (P_i - O_i)^2 / \sum_{i=1}^{N} (|P_i'| + |O_i'|)^2 \right], \quad 0 \leqslant d \leqslant 1$$

$$P_i' = P_i - \bar{O} \text{ and } O_i' = O_i - \bar{O}$$

Pi is the model predicted value
Oi is the observed value

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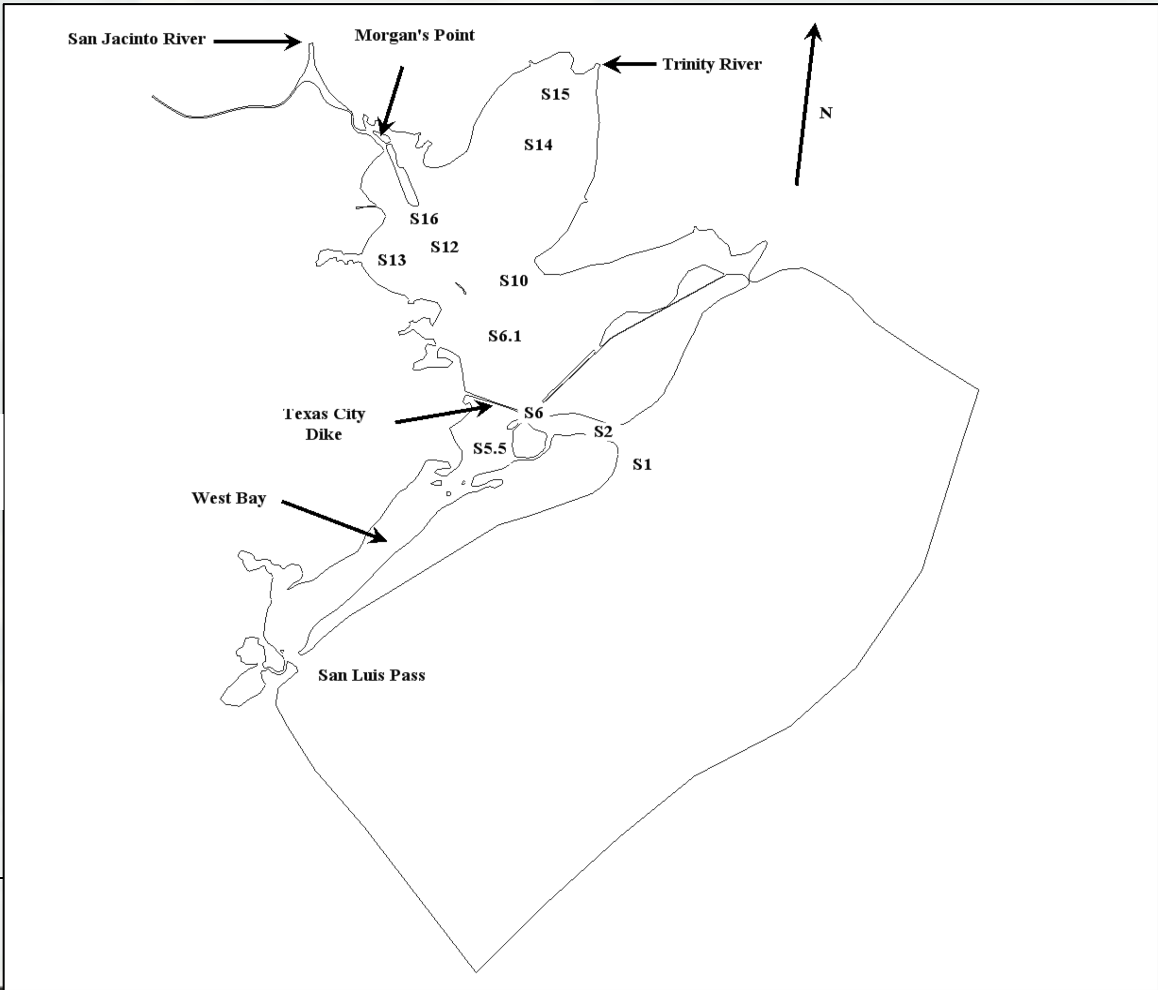
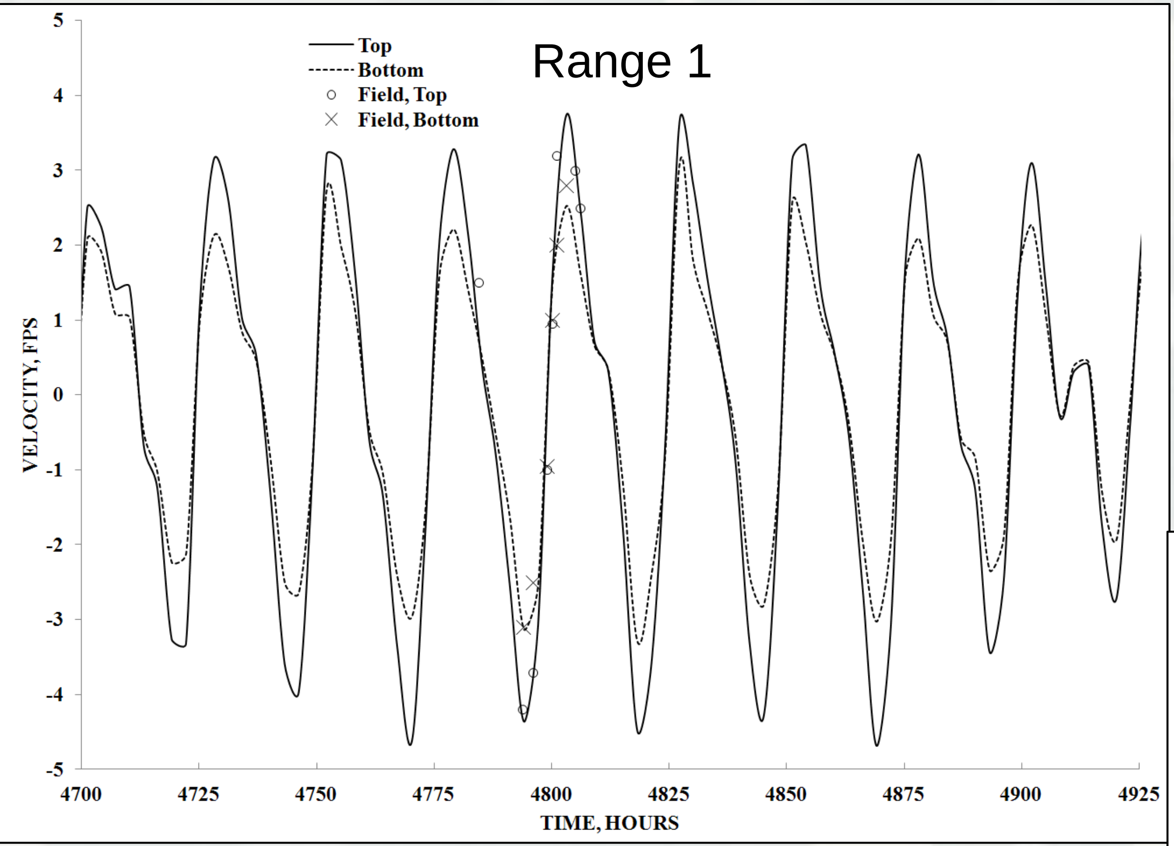
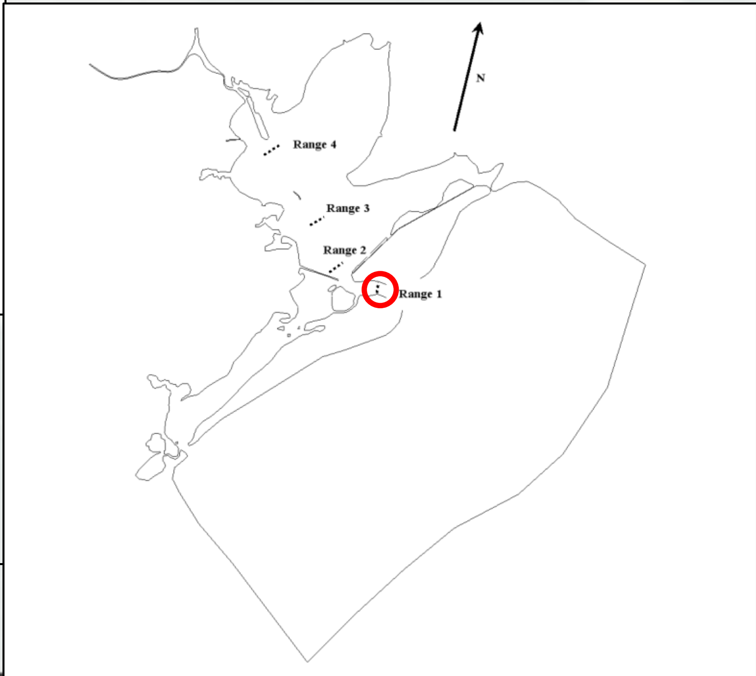


Velocity Comparison





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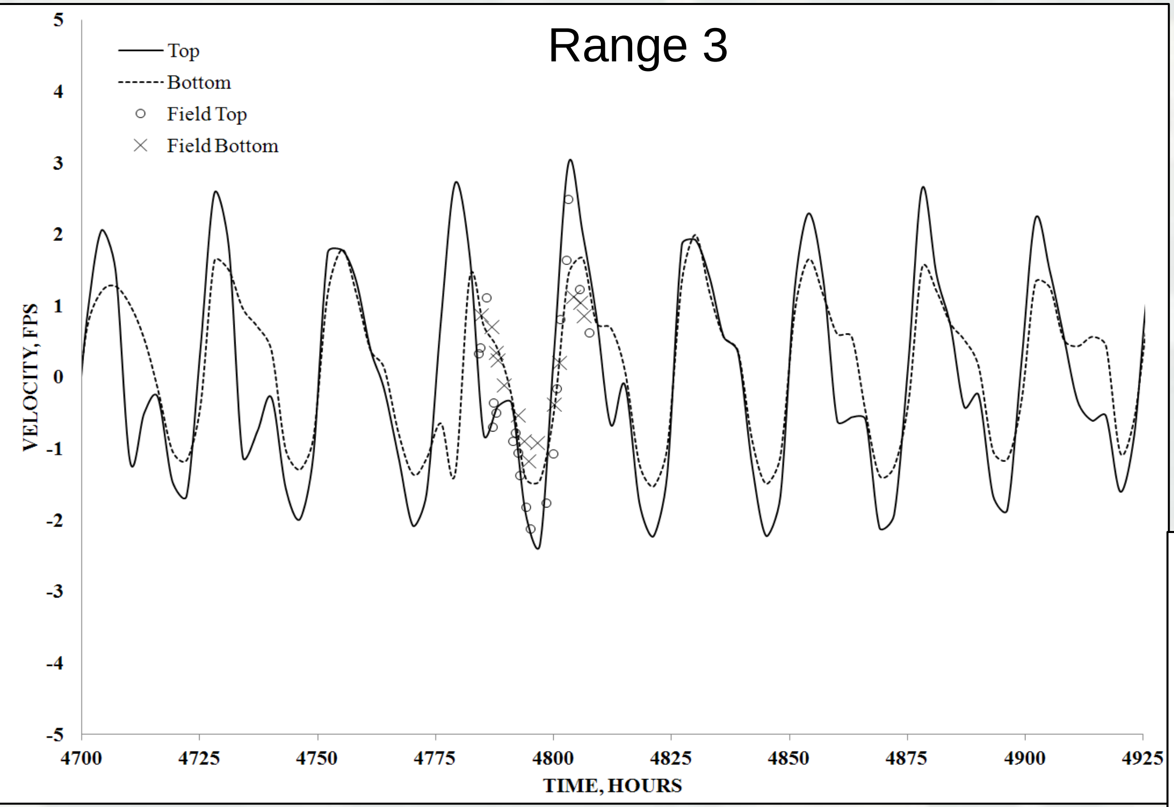
Velocity Comparison



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Summary

- The ADH 3D Model framework provides US Army Corps of Engineers and other State/Federal/local agencies and Stakeholders with a modeling tool that can be applied to oyster habitat evaluation and sediment fate determination (ongoing).

Discussion

Contact Information:
Dynamic Solutions, LLC
Gaurav Savant
GSavant@dsllc.com
(601) 634-3213

Christopher Wallen
cmwallen@dsllc.com
(865) 212-3331

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