Simulation of Tides Through a Narrow Inlet at Guilford, CT

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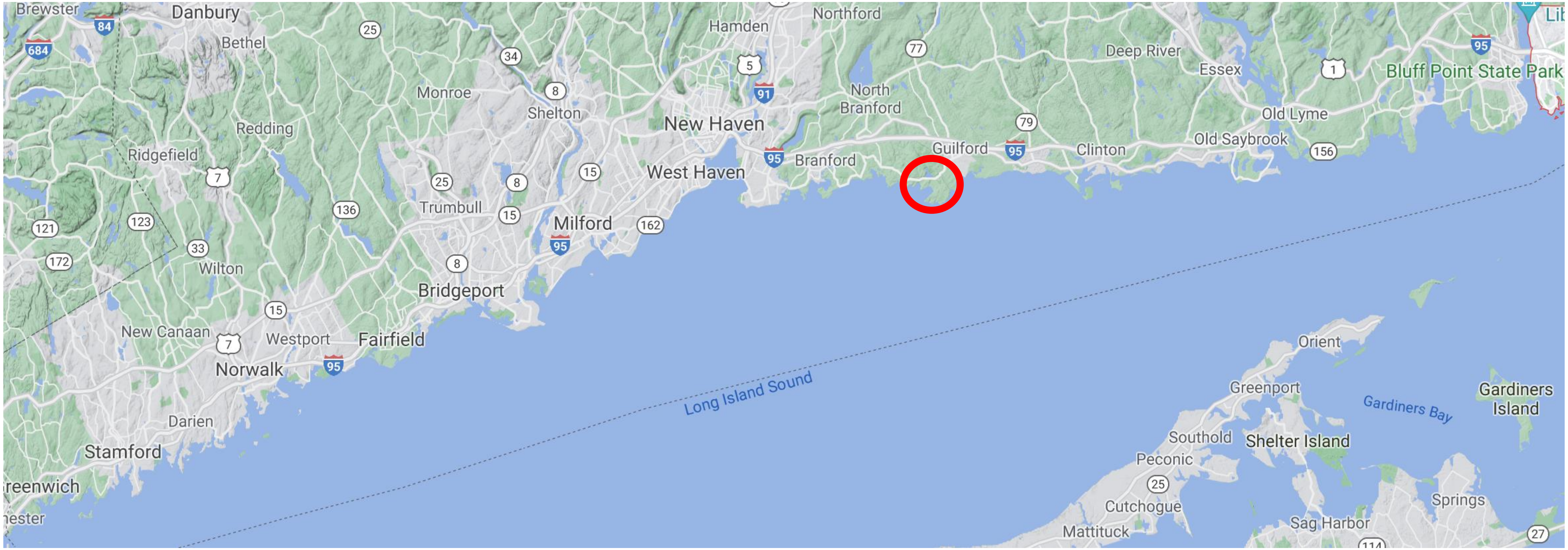
Study area: a salt marsh system in Guilford, CT



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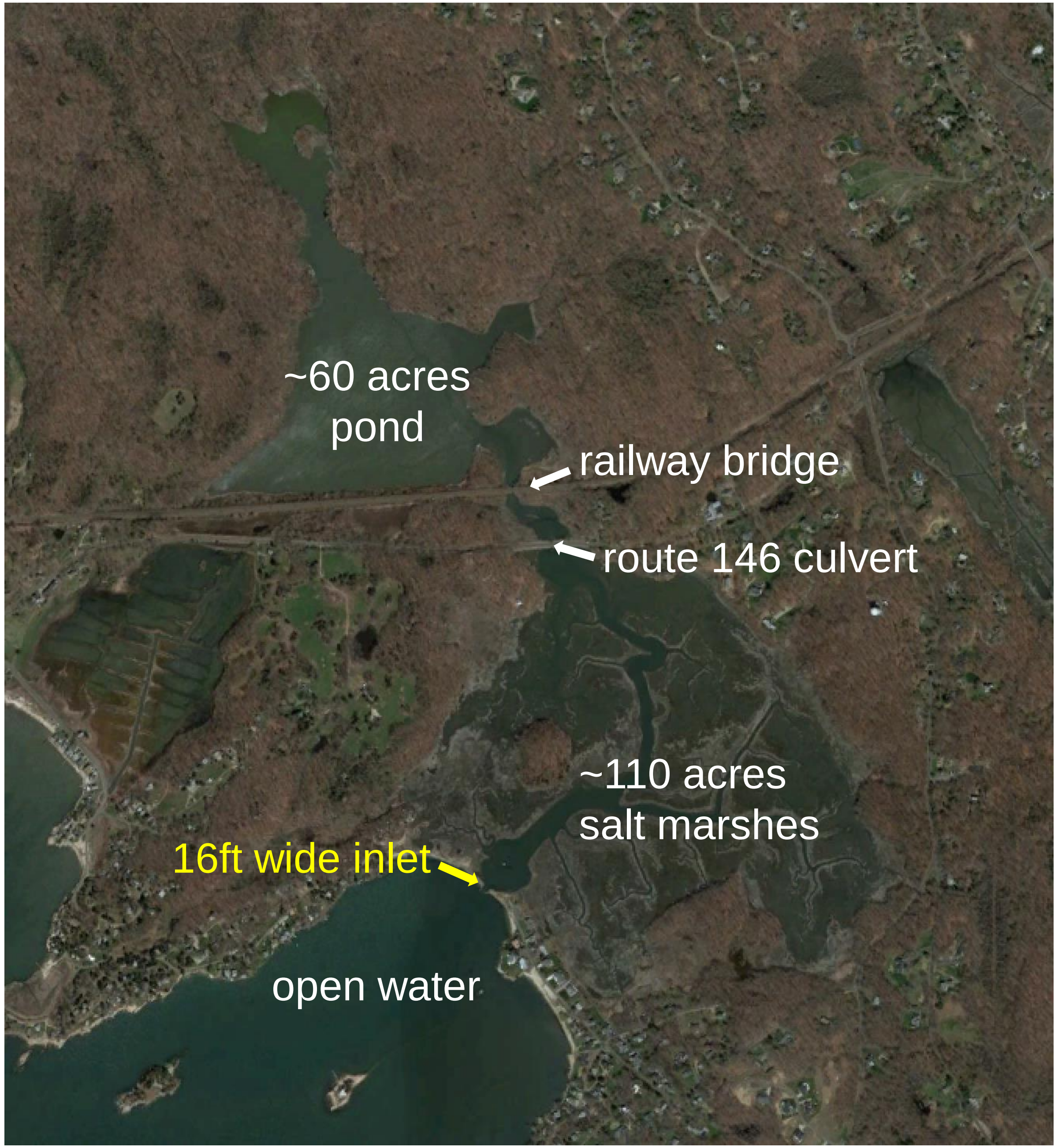

Motivations:

- Salt marshes connect to coastal waters through narrow inlets.
- Marshes and culverts affect the amount of flooding extent and create challenges in predicting flood water level.

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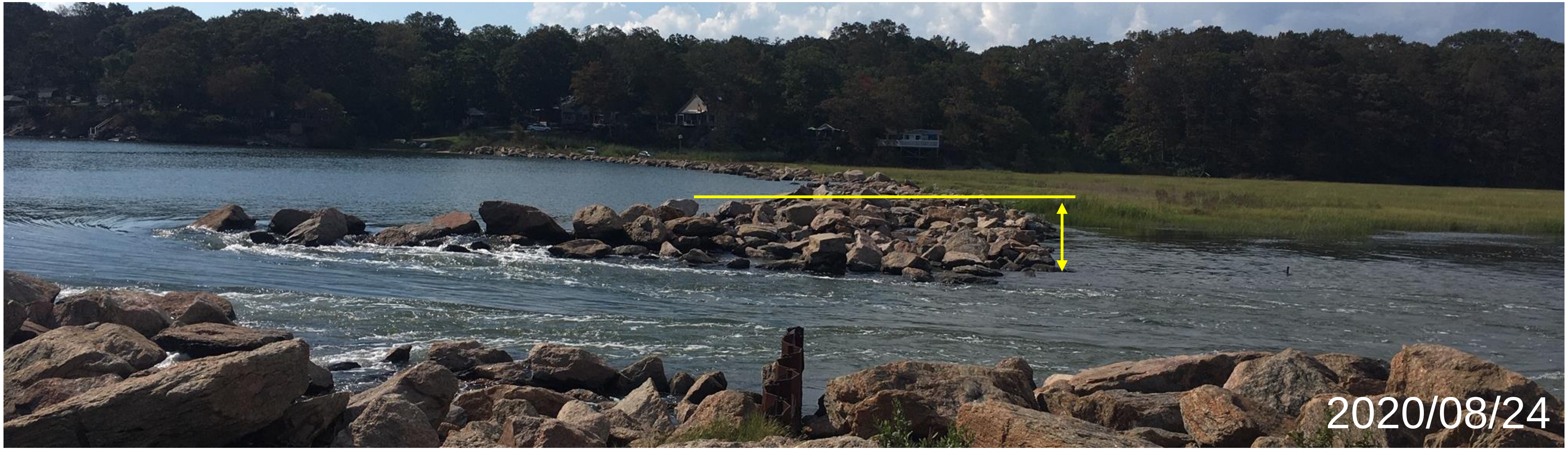
Google Earth

2006/10 Ebb tides

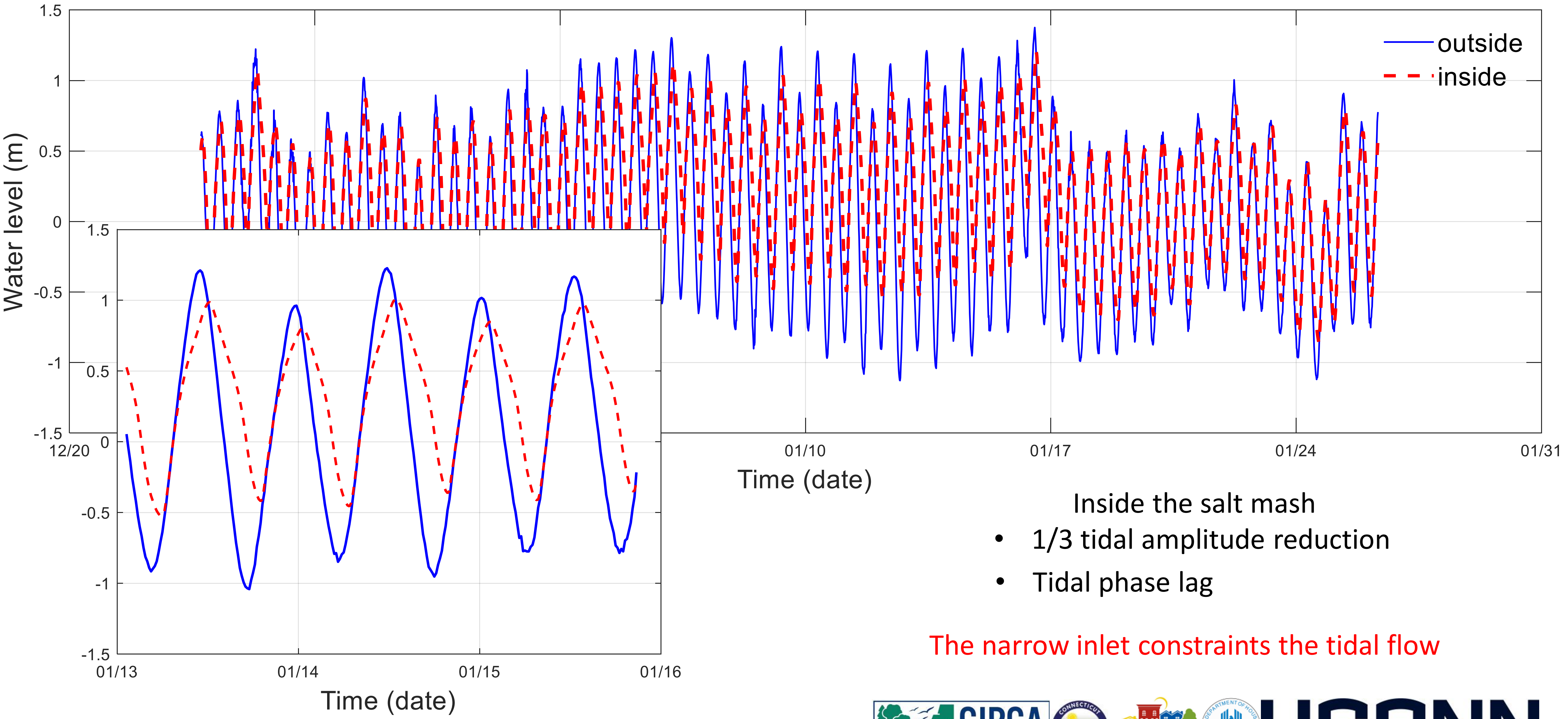
2020/02 Flood tides

Large water level difference during flood tides at the inlet



How does the inlet impact the tides?

Month-long water level observations during winter 2020



Inside the salt mash

- 1/3 tidal amplitude reduction
- Tidal phase lag

The narrow inlet constraints the tidal flow

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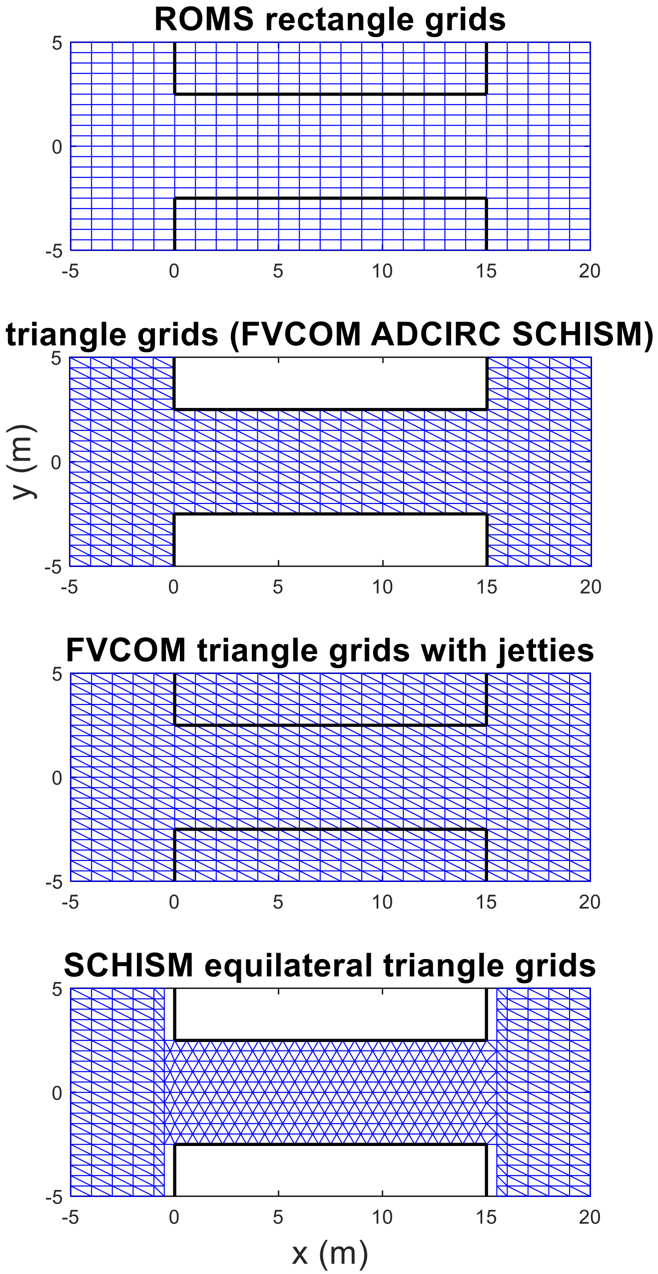
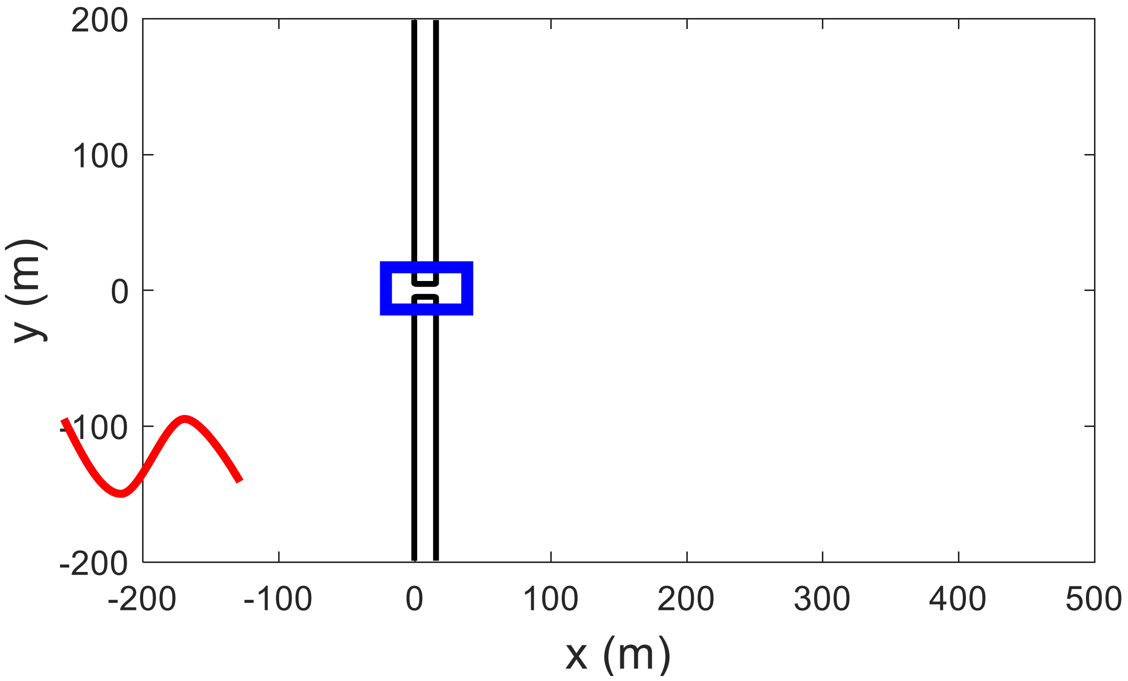
Hydrodynamic models

Model	Grid type	2D circulation
ROMS	Arakawa-C	Yes
FVCOM	unstructured, finite volume	Yes
ADCIRC	unstructured, finite element	Yes
SCHISM	unstructured, finite element	Yes

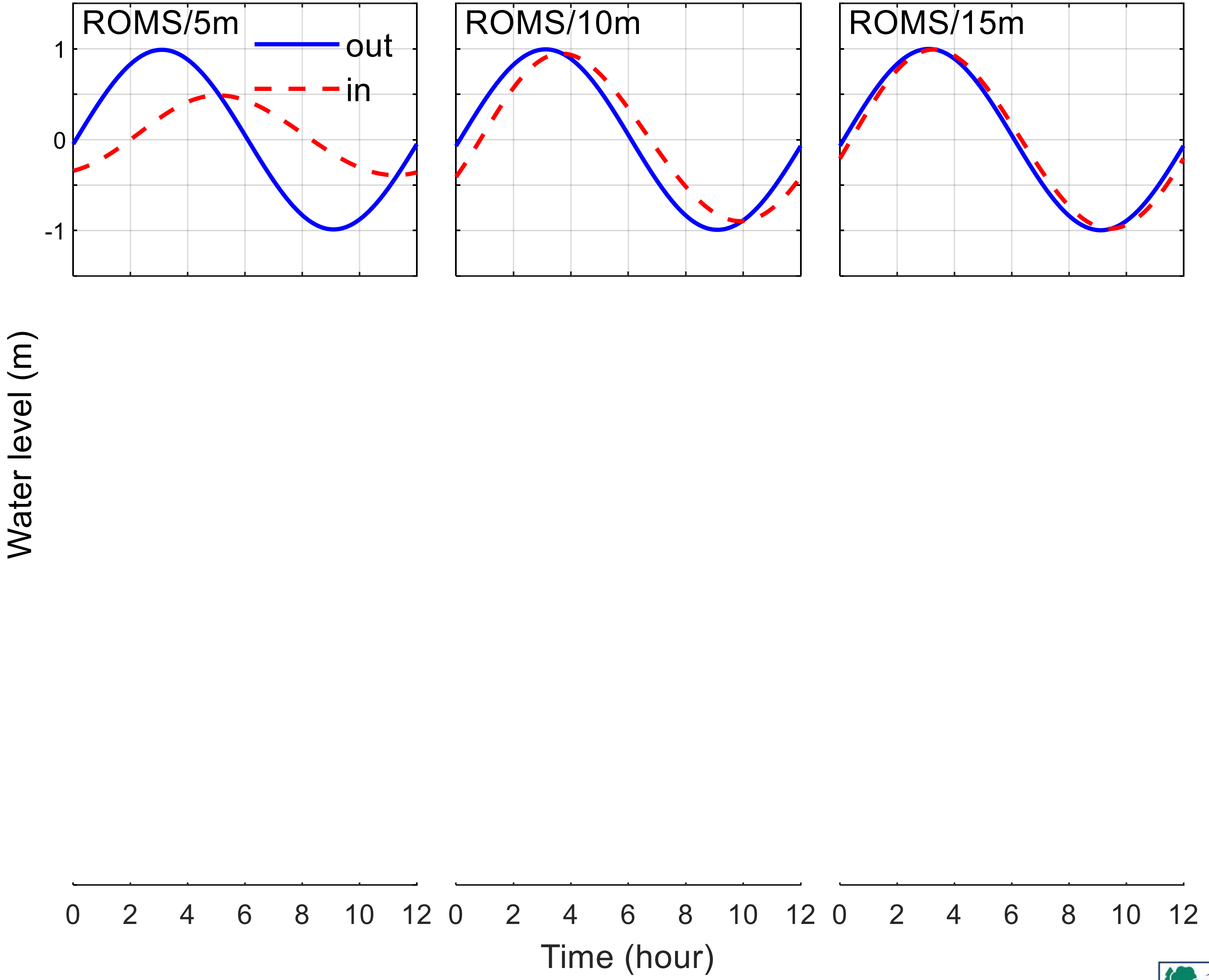
Numerical simulations





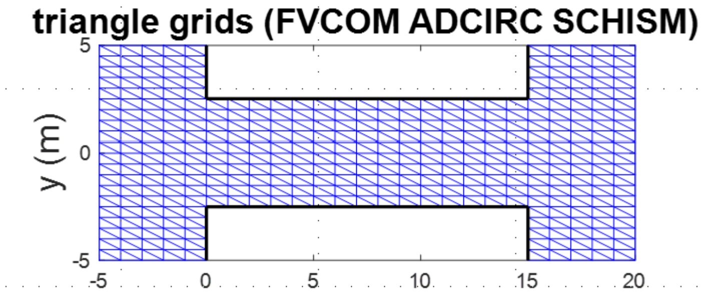
- Domain: a 3-m deep pool with an inlet
- Inlet length 15m (49ft); width 5, 10, or 15m.
- Resolution: 1m x 0.5m at inlet
- Horizontal eddy viscosity coefficient, $2m^2s^{-1}$.
- Quadratic bottom friction, C_d 0.003.
- 1-m amplitude S_2 tide is imposed from left.
- Run 24 hours, only use the last 12-hour results.
- 4 models: ROMS, FVCOM, ADCIRC, SCHISM

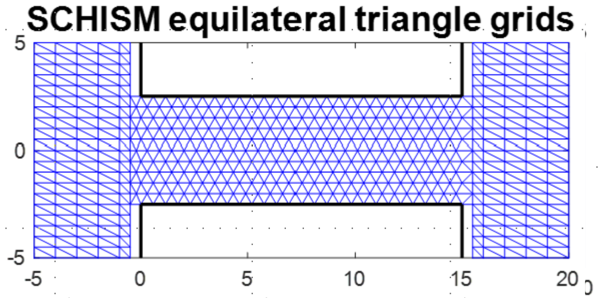
Modeled water levels inside and outside the inlet



Strength of the inlet constraint

- Narrow inlet > wide inlet
- ROMS>FVCOM>ADCIRC-a
- ROMS ≈ FVCOM-jetty > SCHISM-equi
- SCHISM-equi > SCHISM-right





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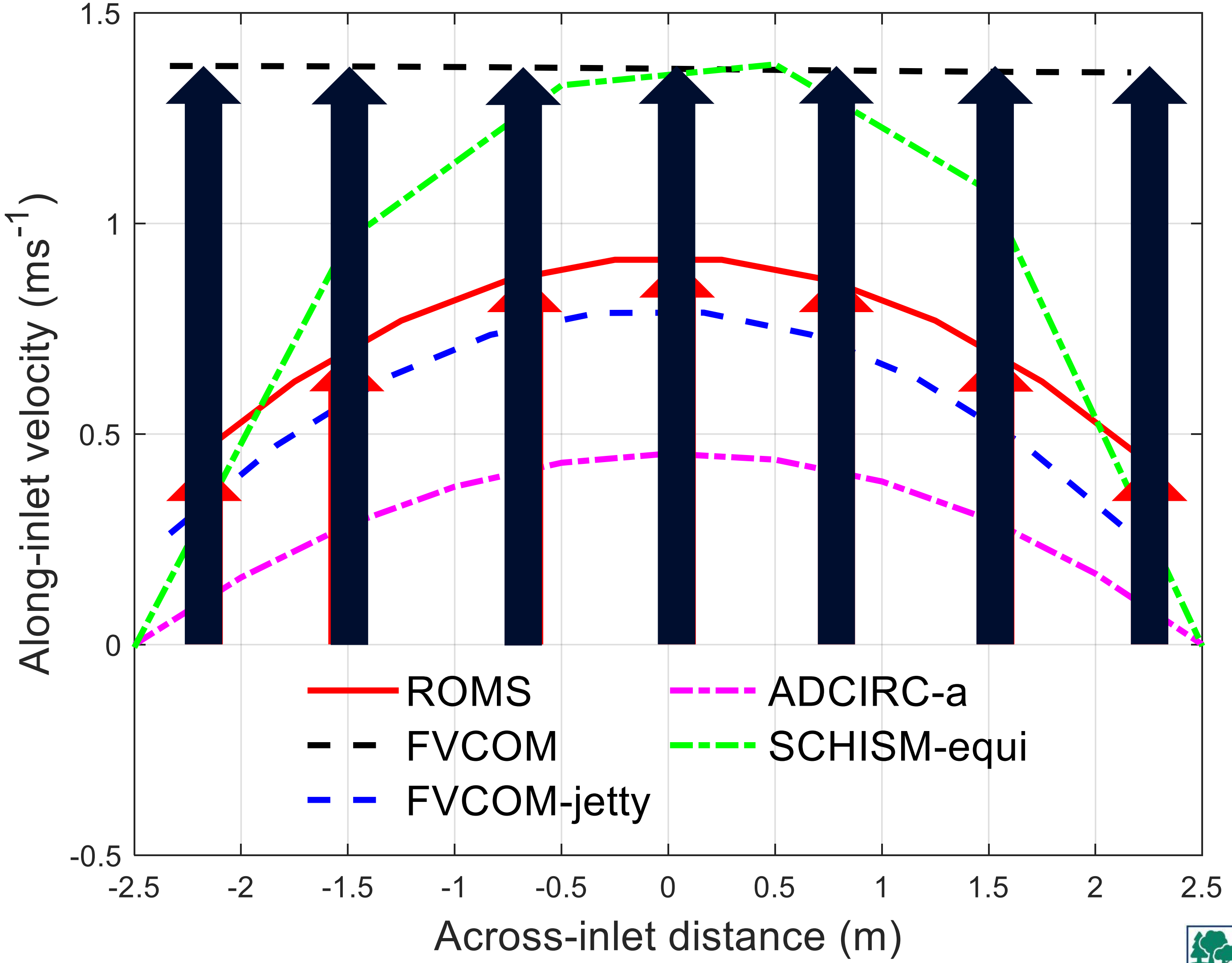
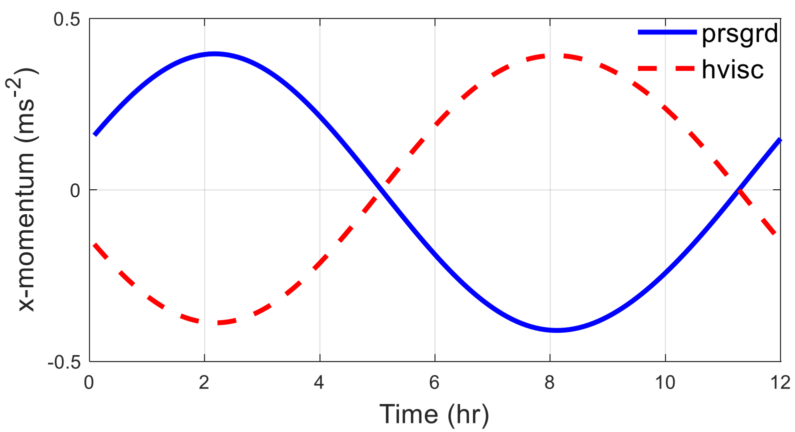
Across-inlet profile of the along-inlet current during flood tides



Lateral shear of the current

- No, the FVCOM case
- Yes, the others

Along-inlet momentum balance with lateral shear: ROMS



Pressure gradient force = Horizontal eddy viscosity

(Pressure drop caused by the along-inlet water level drop)

(lateral eddy mixing introduced by the bank friction)

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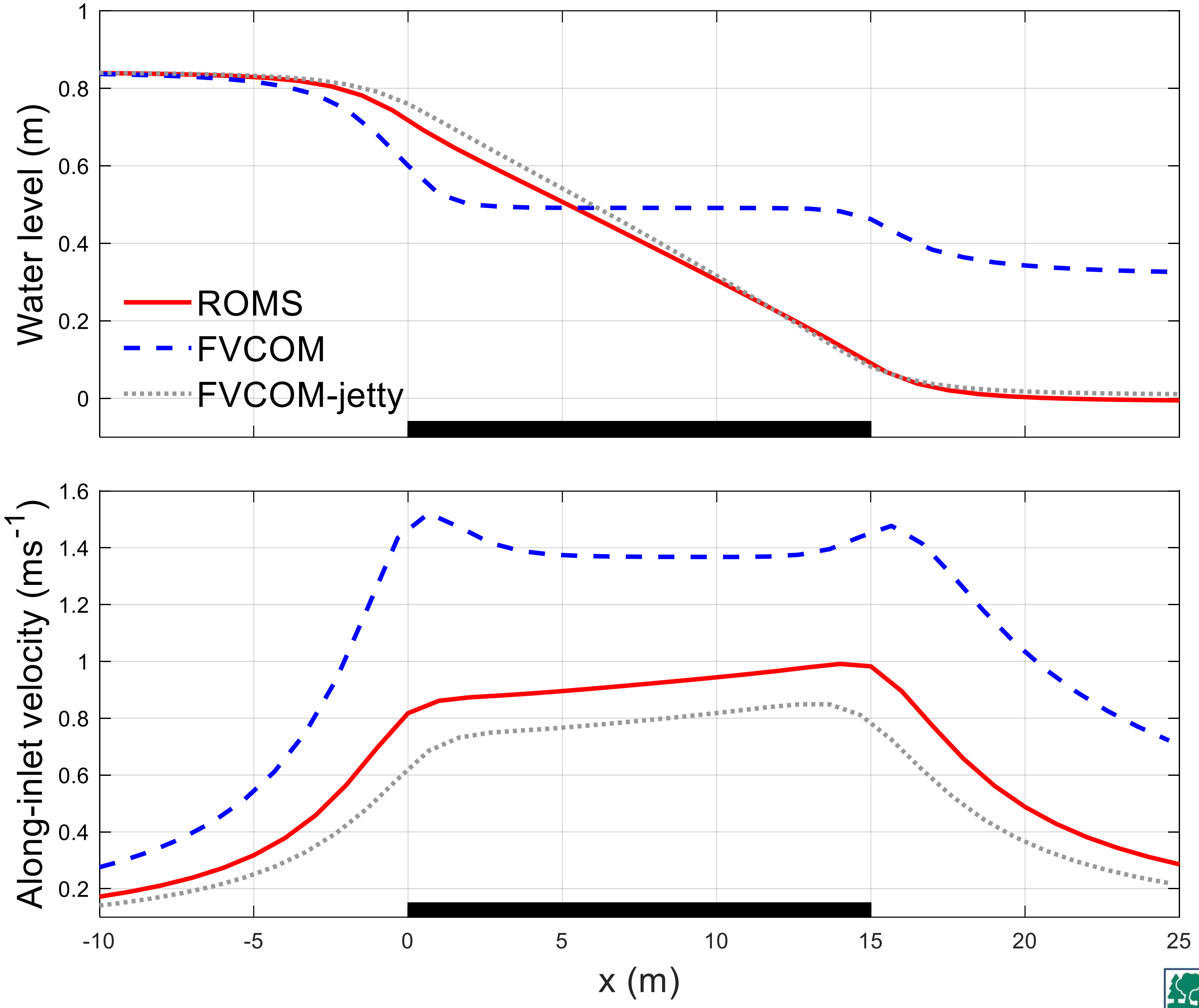
Along-inlet profiles of the water level and current during flood tides



- With lateral shear:

water level drops through the inlet

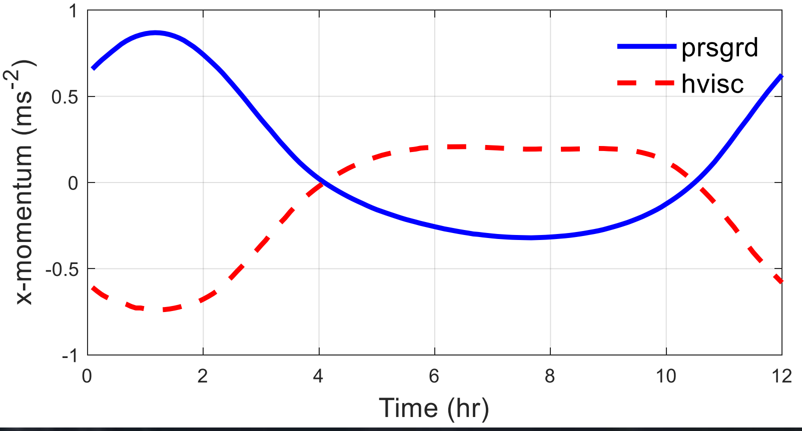
- Without lateral shear:

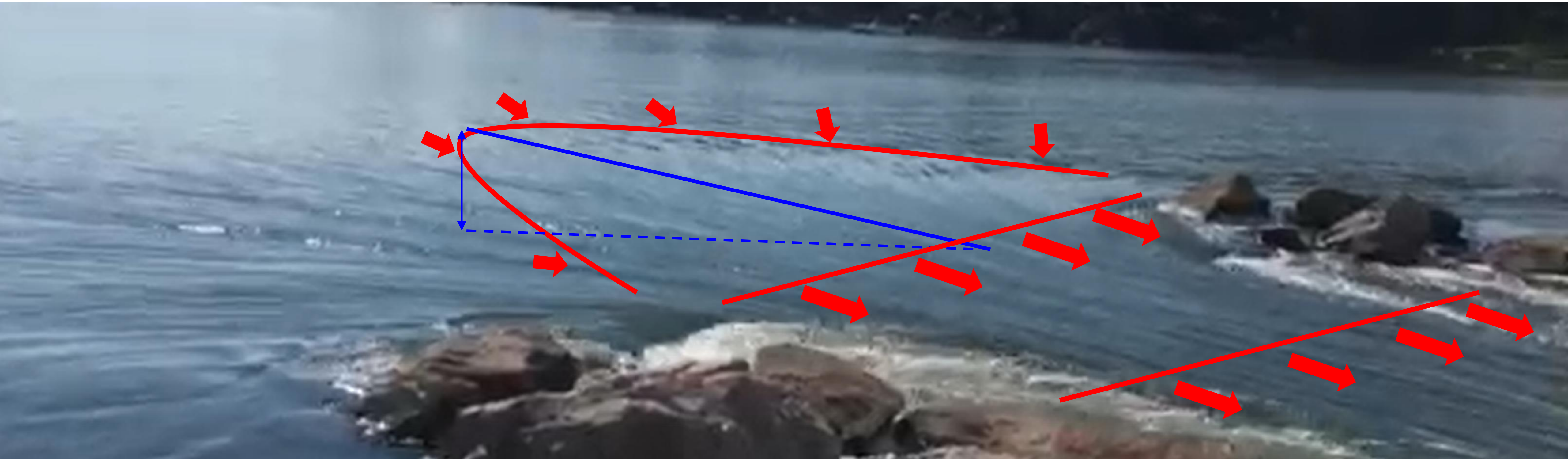
water level drops at the inlet heads

Momentum balance without lateral shear: FVCOM

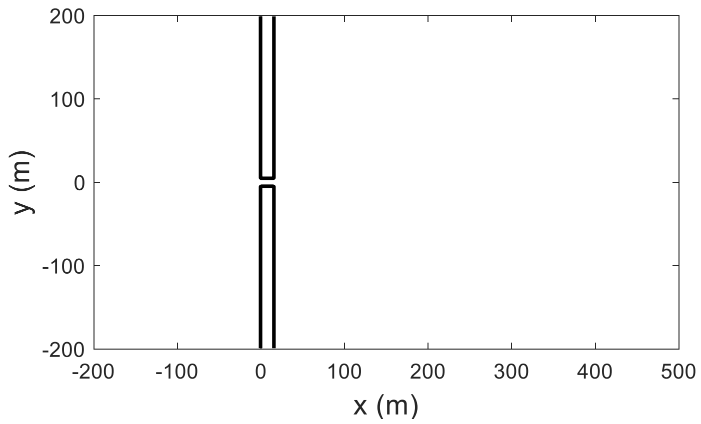
Pressure gradient force = Horizontal eddy viscosity

(Pressure drop caused by the along-inlet water level drop) (Uneven velocity changing)





A two-dimensional time varying problem



$$\frac{\partial \eta}{\partial t} + \frac{\partial UH}{\partial x} + \frac{\partial VH}{\partial y} = 0$$

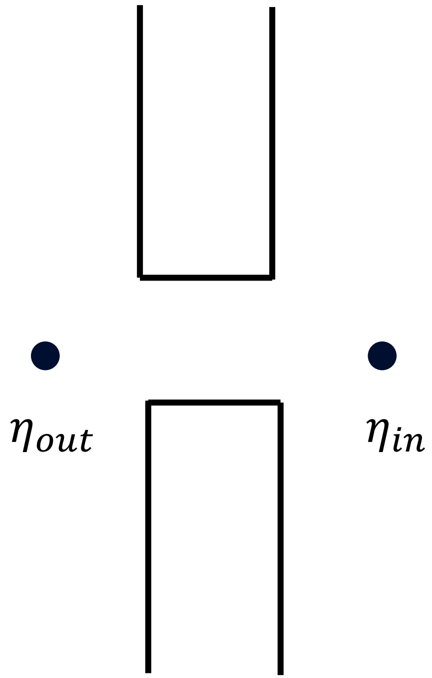
$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV + g\frac{\partial \eta}{\partial x} - \nu\nabla^2 U + \left(\frac{C_f\sqrt{U^2 + V^2}}{H}\right)U = 0$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + fU + g\frac{\partial \eta}{\partial y} - \nu\nabla^2 V + \left(\frac{C_f\sqrt{U^2 + V^2}}{H}\right)V = 0,$$

simplified

- Momentum balance
- Water exchange only through the inlet

A two-point time varying problem



$$\frac{\partial \eta_{in}}{\partial t} = \alpha(D + \eta_{out})(\eta_{out} - \eta_{in})$$

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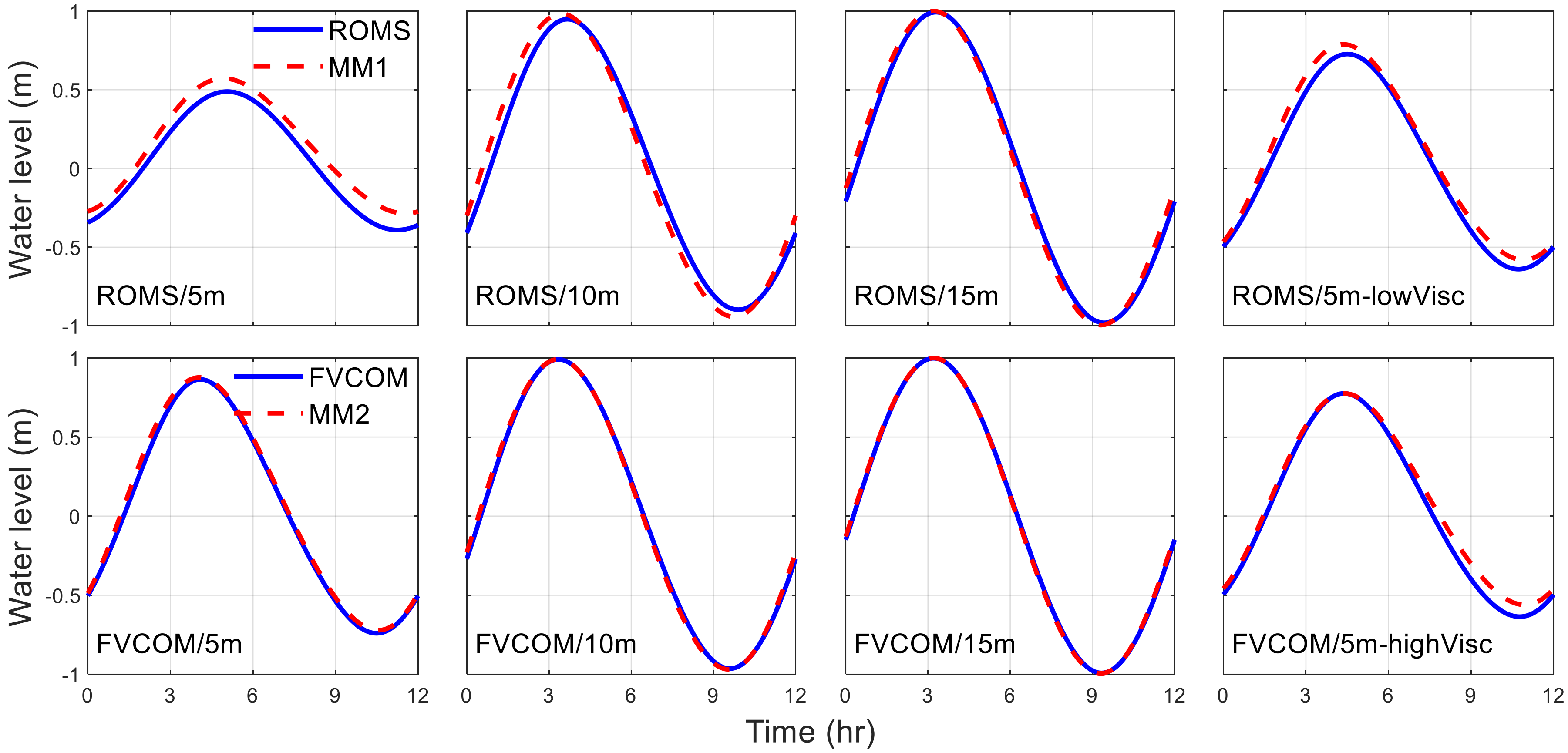
The simple prediction model

$$\frac{\partial \eta_{in}}{\partial t} = \alpha(D + \eta_{out})(\eta_{out} - \eta_{in})$$



$$\alpha = \left(\frac{1}{2\gamma} - \frac{1}{24}\right)\frac{gW^3}{\varepsilon AL}$$

$$\alpha = \frac{g\beta W^2}{(\pi - 2)\varepsilon A}$$

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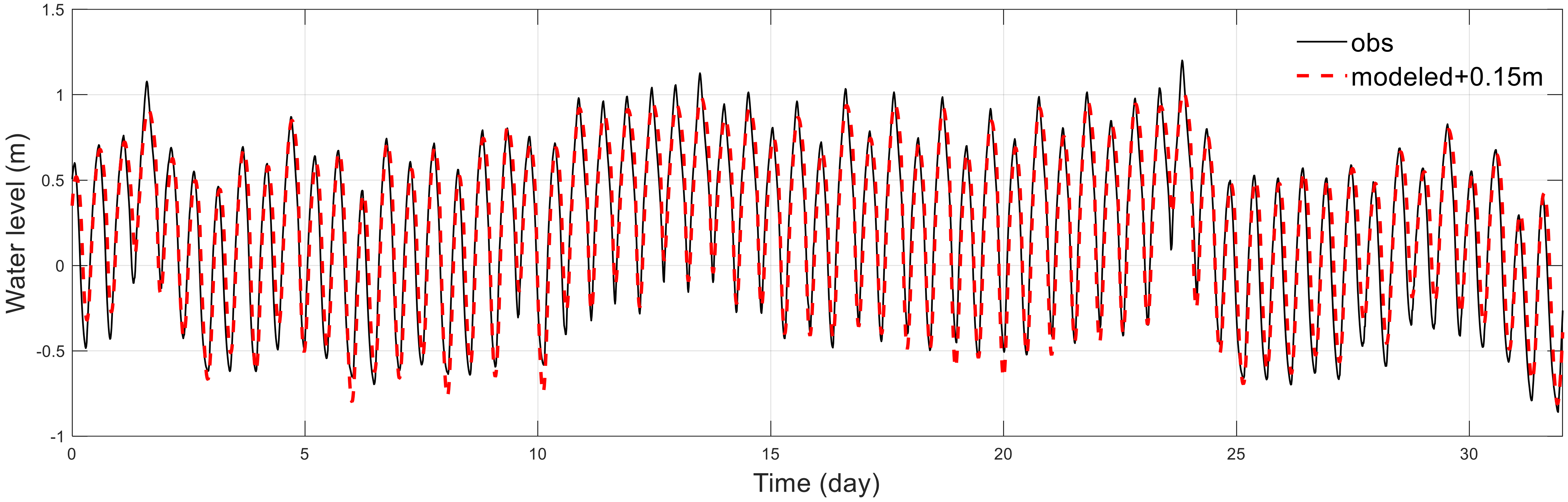
Water levels inside the salt marshes
observed vs. simple model with lateral shear



Conclusions

- Both field observation and model study show that a narrow inlet has strong constraint on water exchange between basins.
- Four hydrodynamic models (ROMS, FVCOM, ADCRIC, & SCHISM) are compared on the inlet constraints problem. The results can direct model selection and grid design in coastal modeling.
- Horizontal eddy viscosity plays important role on balance the sharp water level change through the inlet.
- A couple of simple predicting models are developed based on different the momentum balance scenarios from the numerical simulation, which can provide quick and useful guidance on water exchange rates at the inlet for ecologists and coastal engineers.

Thank you