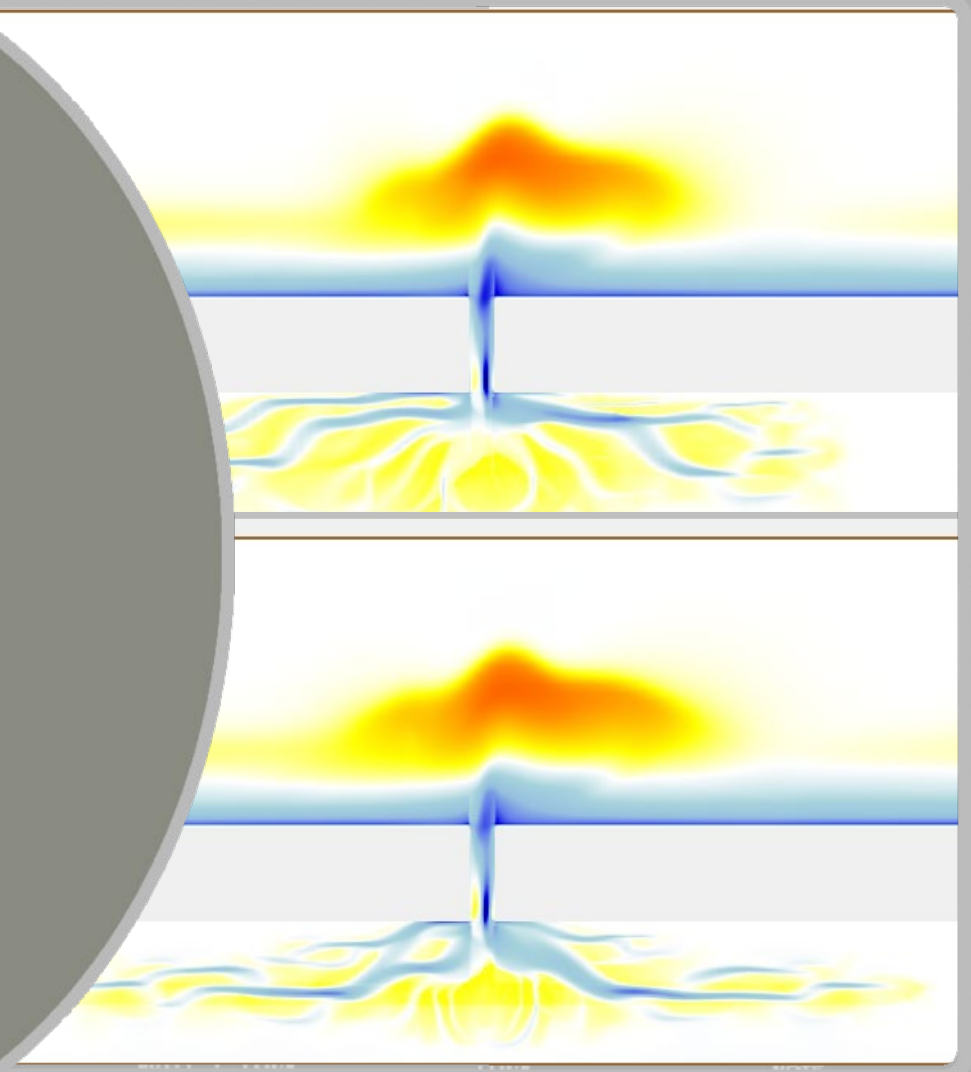
Potential Impacts of Land Use Changes on Sediment Dynamics at Tidal Inlets

INLET GEOMORPHOLOGY WU

Richard Styles, Douglas Krafft, Mitchell Brown



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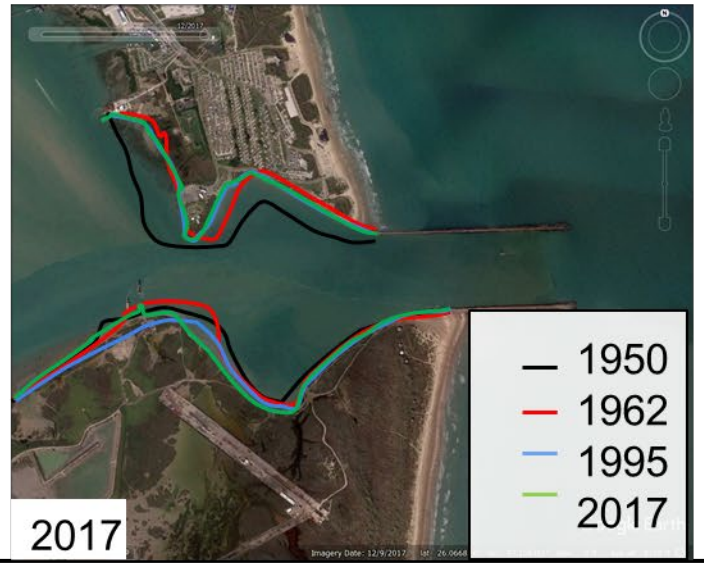
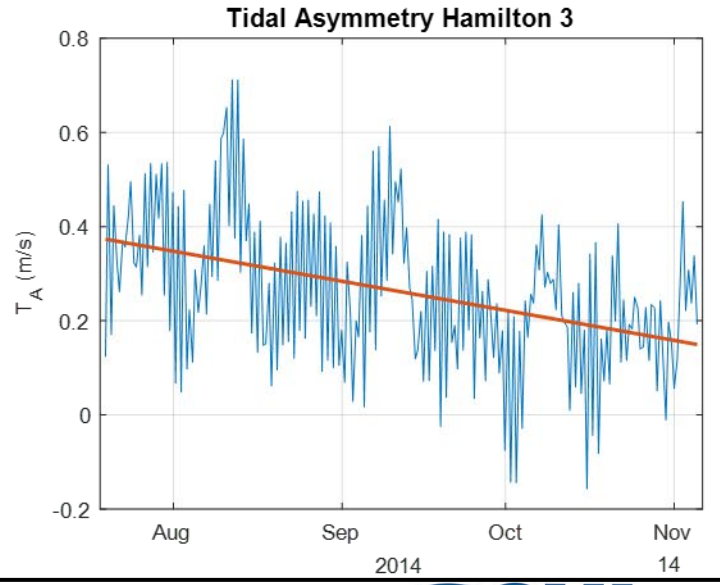
Sediment Transport at Tidal Inlets

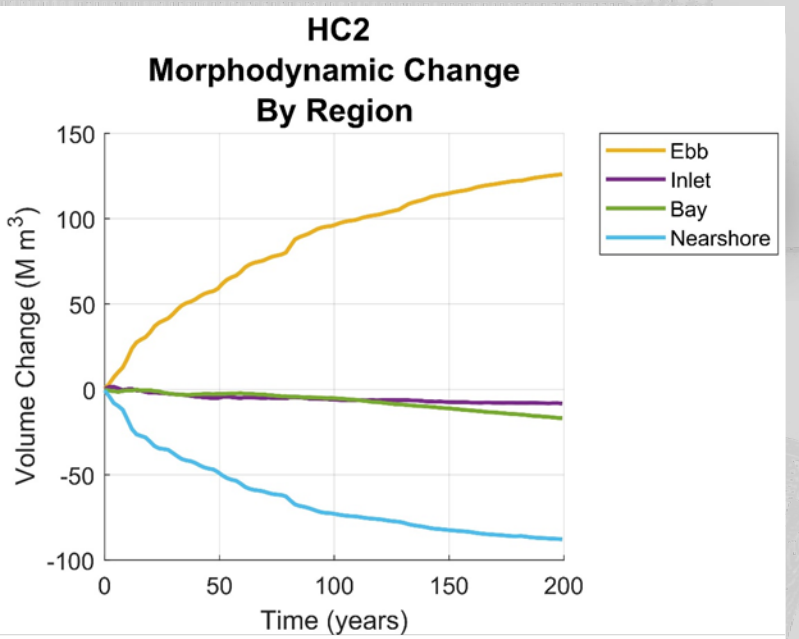
- Existing theory suggests a primary factor controlling hydrodynamics and, by extension, sediment transport is basin morphology (bathymetry)
- One factor not previously explored is sediment availability, which can alter bay morphology leading to potential feedbacks that could modify hydrodynamics of the system.
- Continuing evolution of land use practices (armoring, island construction, reclamation) and sea level change will alter coastal inlets/bays from present day configurations and associated sediment transport characteristics.
- Need to develop approaches to assess inlet/bay system likelihood of undergoing fundamental shifts in sediment transport patterns due to these influences (anthropogenic, sea level rise)

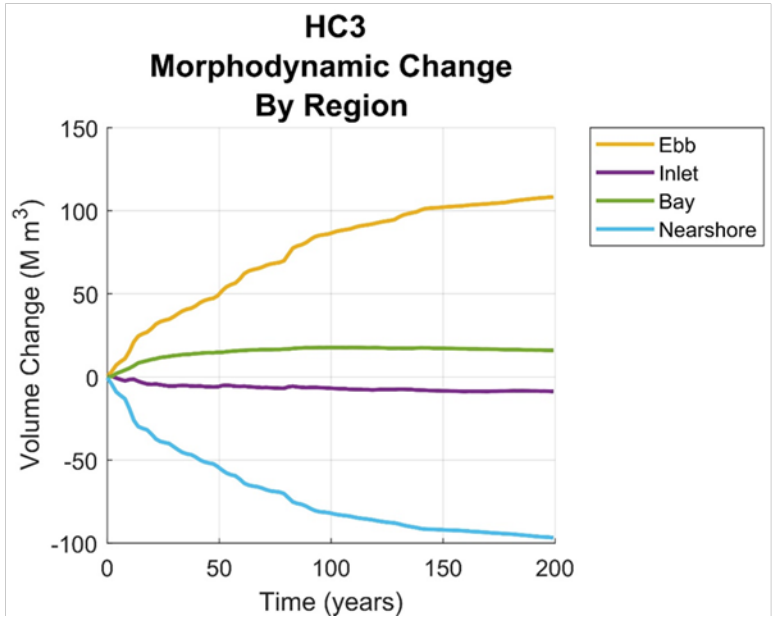




Project Goals

- Develop methodology to determine the likelihood of a inlet system to shift from import/export due to engineering practices (channel modification, wetland restoration, sea level rise)
- Use this information to inform planners & stakeholders of possible impacts to navigation (increase likelihood of channel shoaling, erosion)

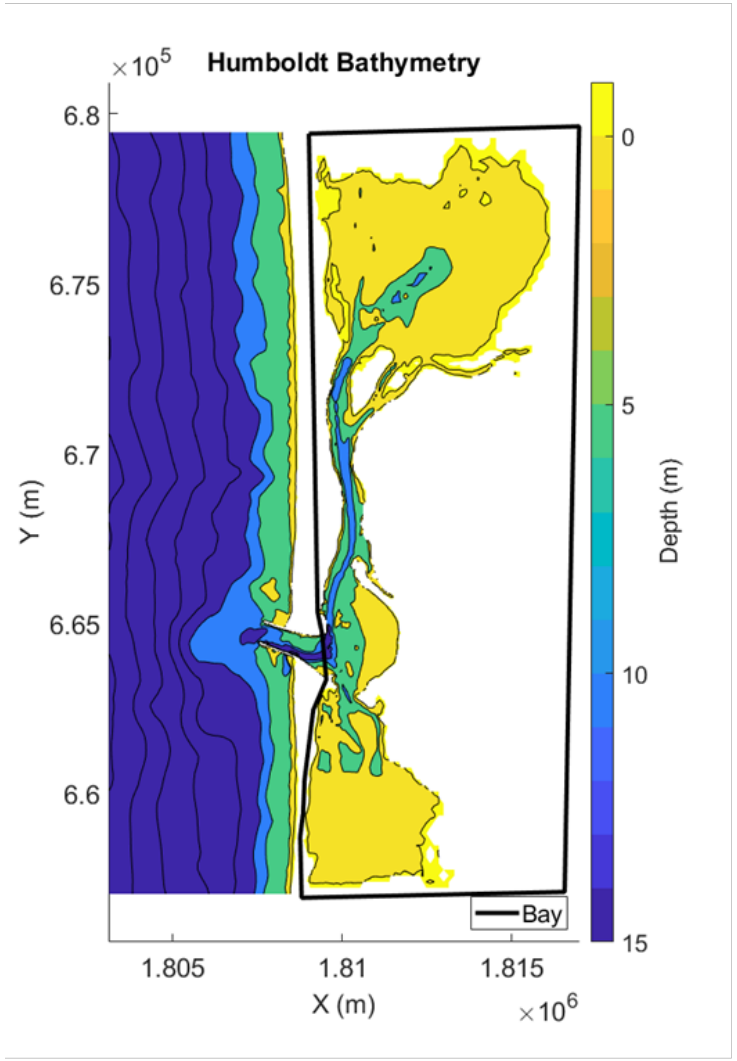


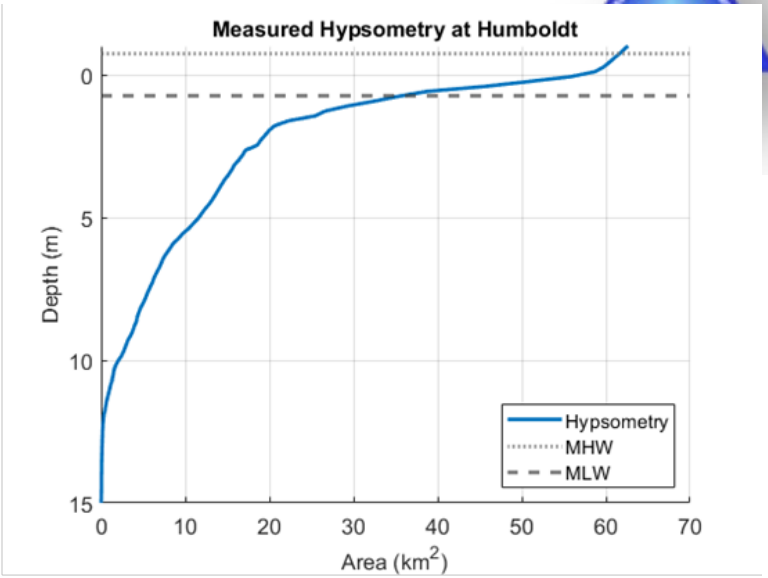


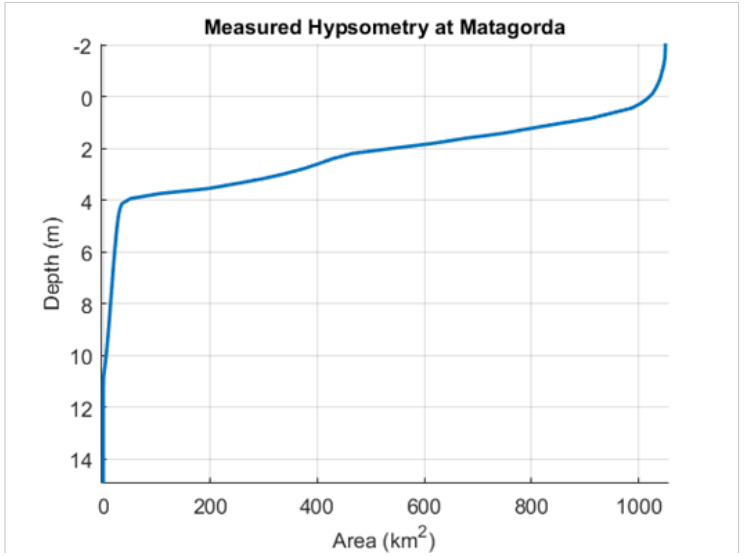
Hypsometry

Why hypsometry as a geomorphology metric?

- Easy to calculate
- Common metric (gauge geographically disparate systems, i.e., similitude)
- Provides information on basin morphological characteristics (inter-tidal coverage, sub-tidal coverage)

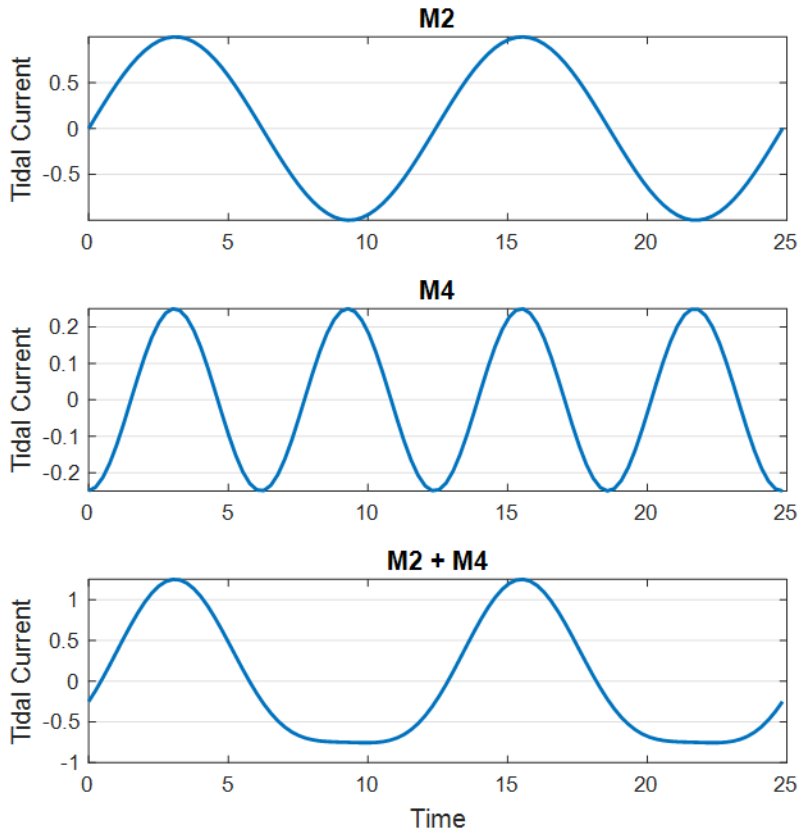




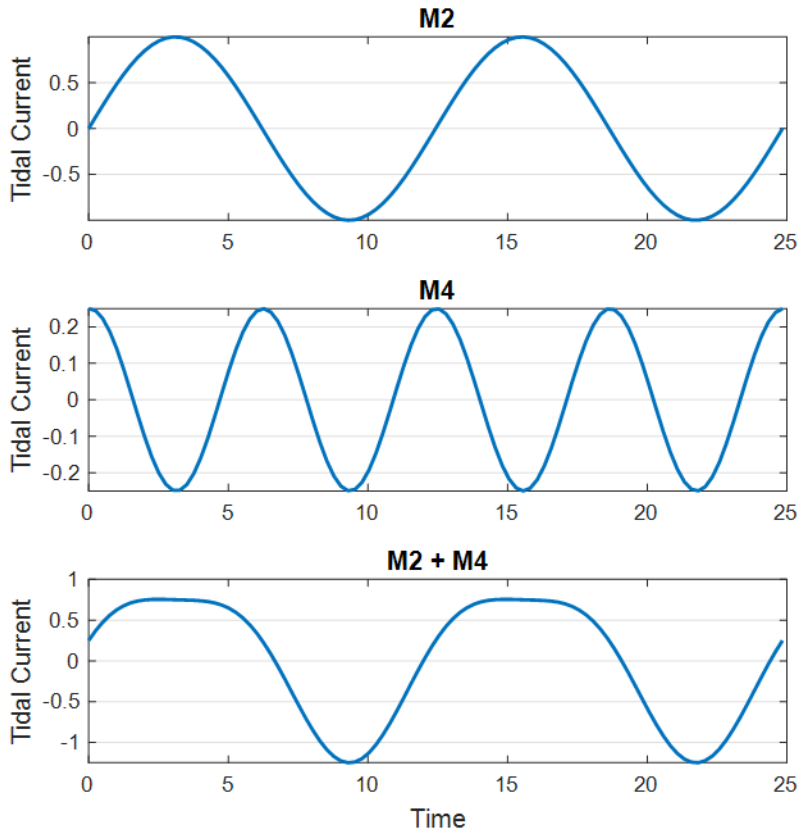


Tidal Asymmetry – a basic example

Flood-dominated



Ebb-dominated



Flood-dominant:

- Higher maximum currents during flood
- Shorter duration (flood)
- Higher shear stress during flood [~velocity^2]

Ebb-dominant:

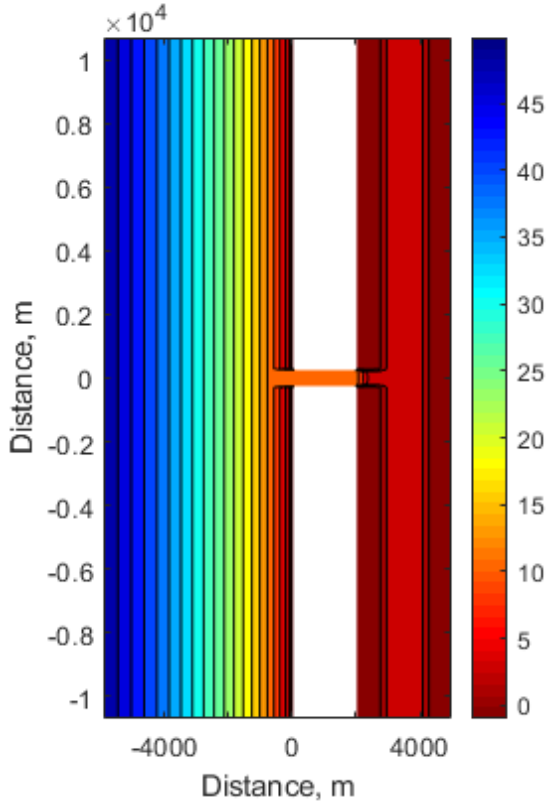
- Stronger maximum currents during ebb
- Shorter duration (ebb)
- Higher shear stress during ebb

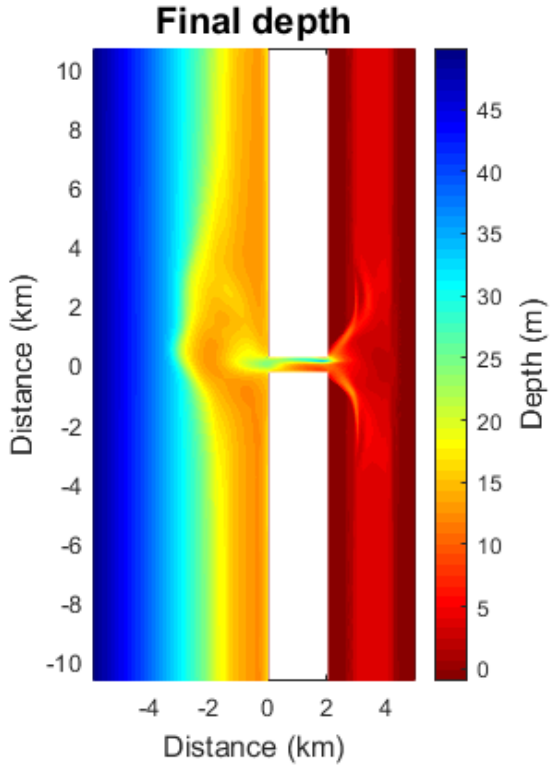
Methodology

- ✓ Setup a series of idealized simulations using CMS
- ✓ Apply morphological acceleration factor to run model for 200 ‘effective’ years
- ✓ Grids forced with tides based on harmonic constituents for Humboldt, CA
- ✓ Wave forcing using WIS spectra at Humboldt
- ✓ 5 hypsometric curves (represent both import/export)

Assumptions – “Lagoonal type inlet”

- No river inputs
- Bar-built system
- Non-cohesive sediments
- Idealized basin geometry

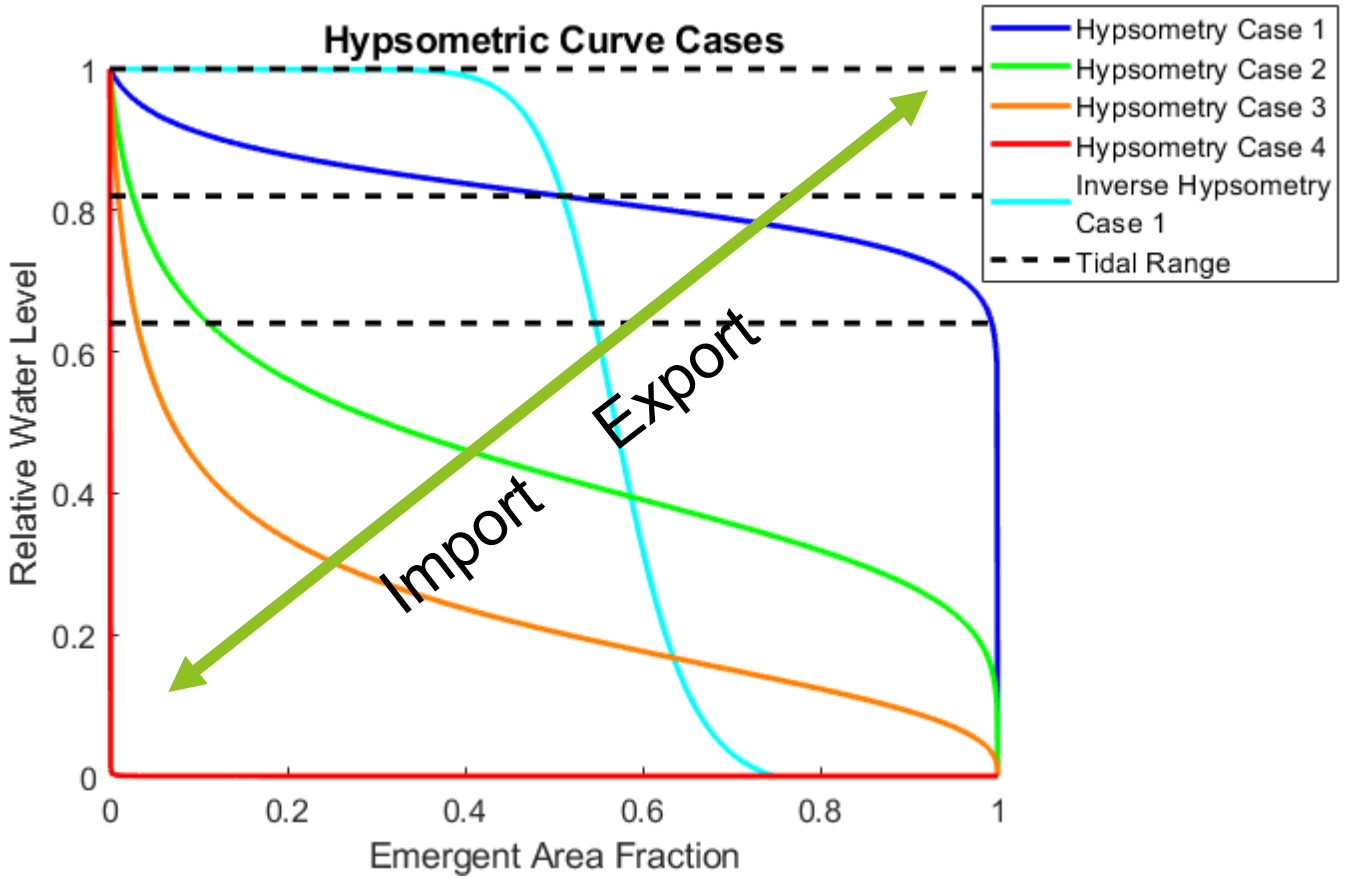




Basin Morphology

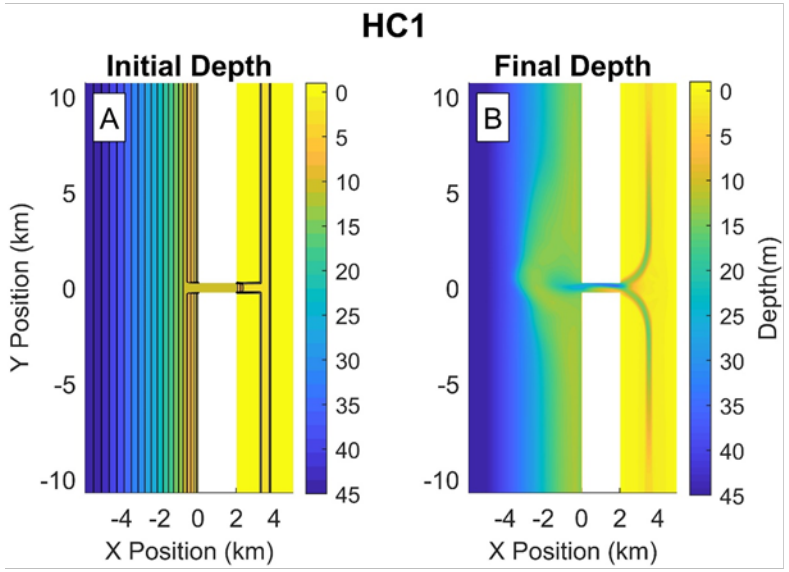
Hypsometry – vertical distribution of land surface (bathymetry)

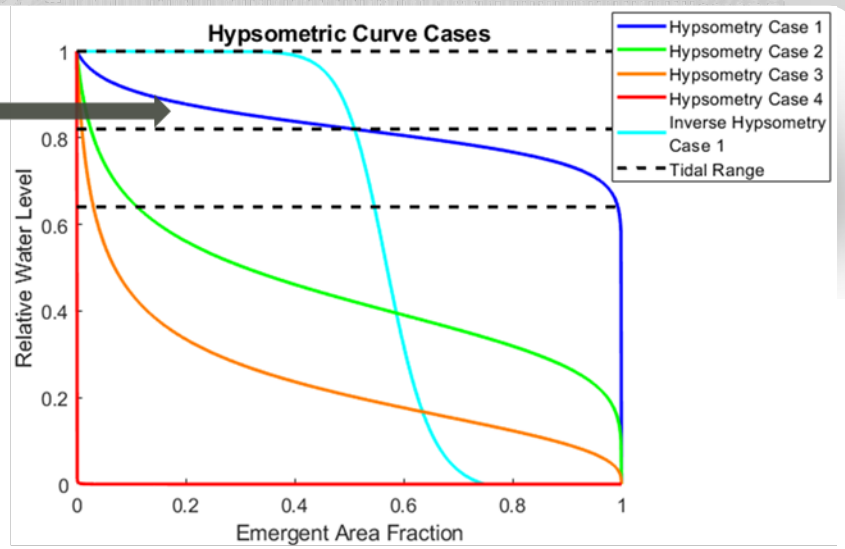
1. Minimal tidal flats with large inter-tidal storage “bathtub”
2. Extensive inter-tidal flats minimal inter-tidal storage (creek networks)
3. Transition between the two cases

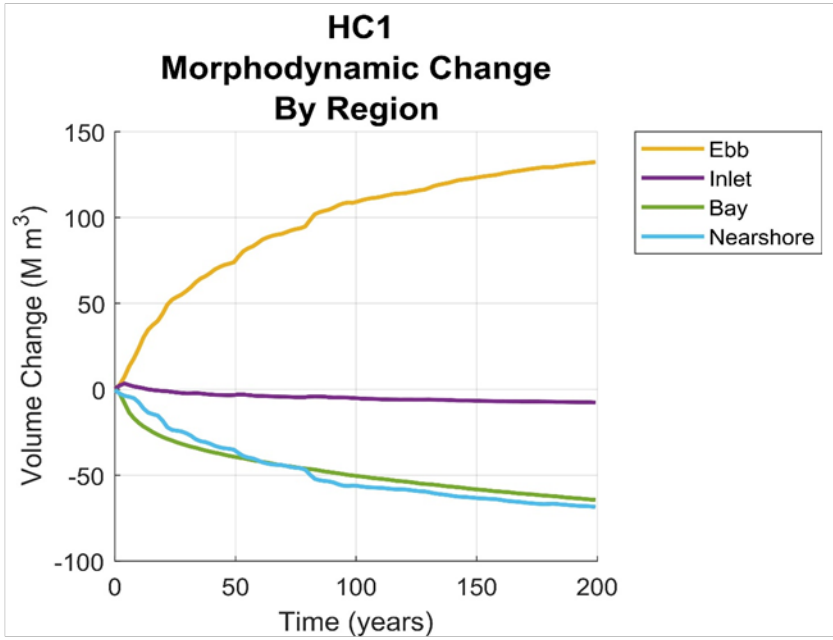


Case HC1

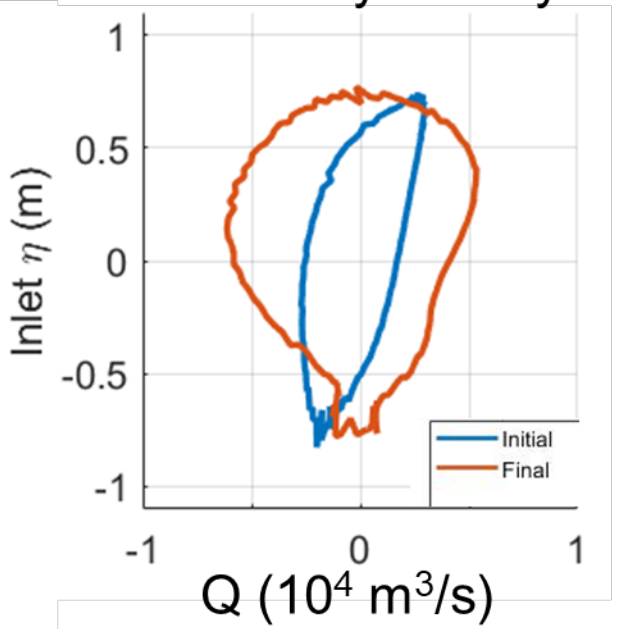
Ebb dominated – export sediment

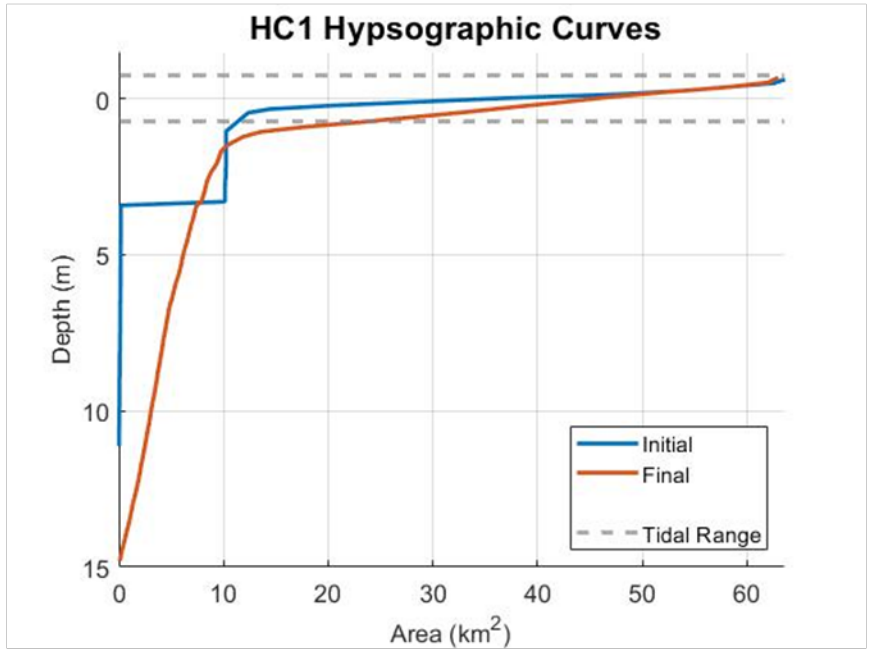




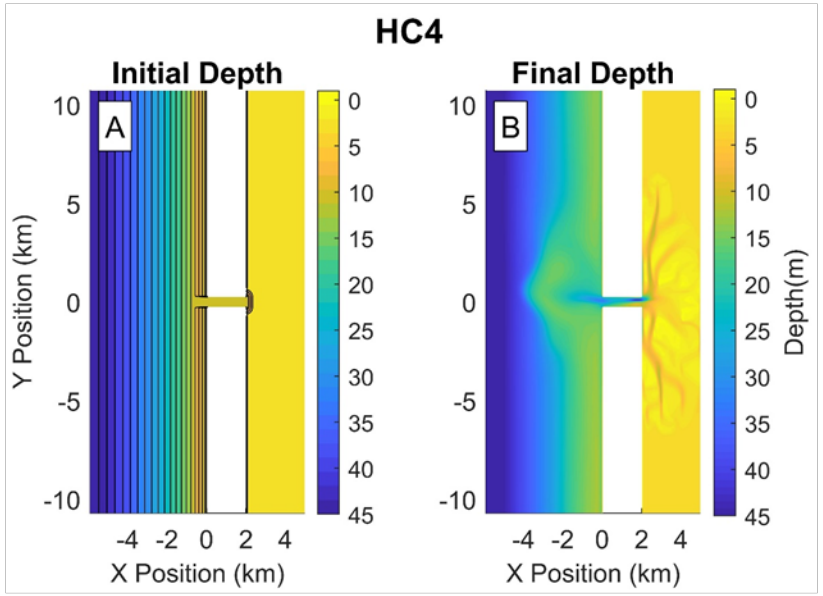


Tidal asymmetry

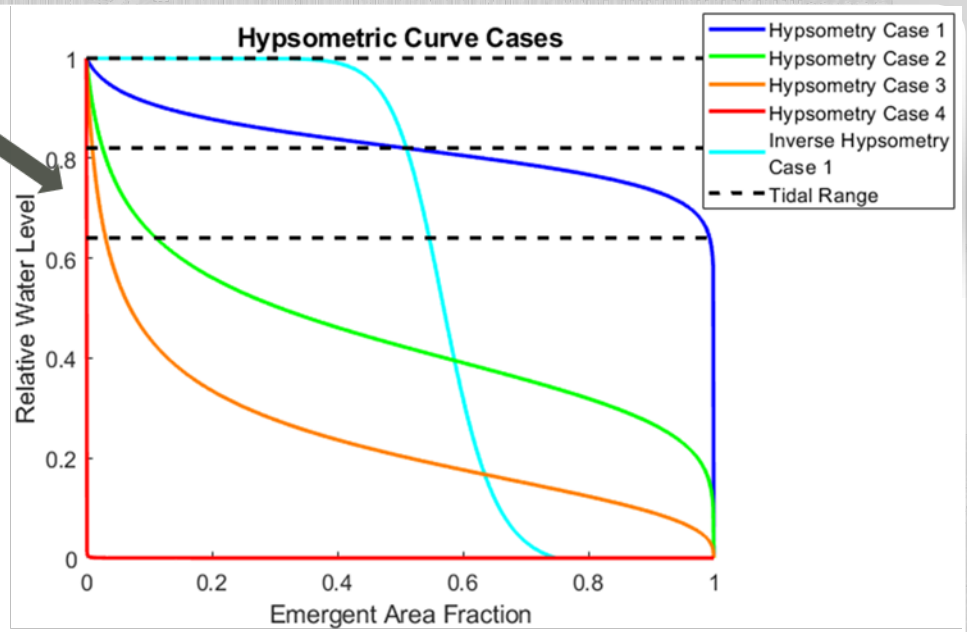


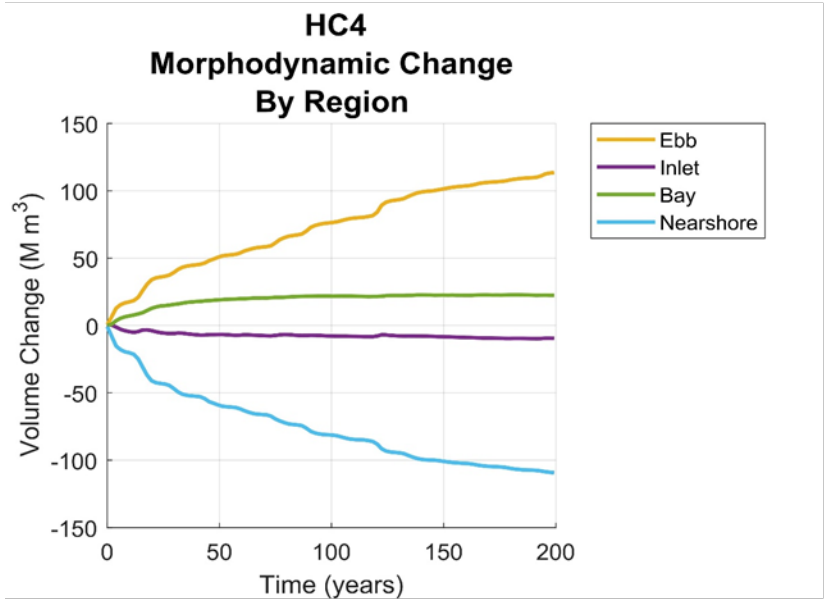


Case HC4

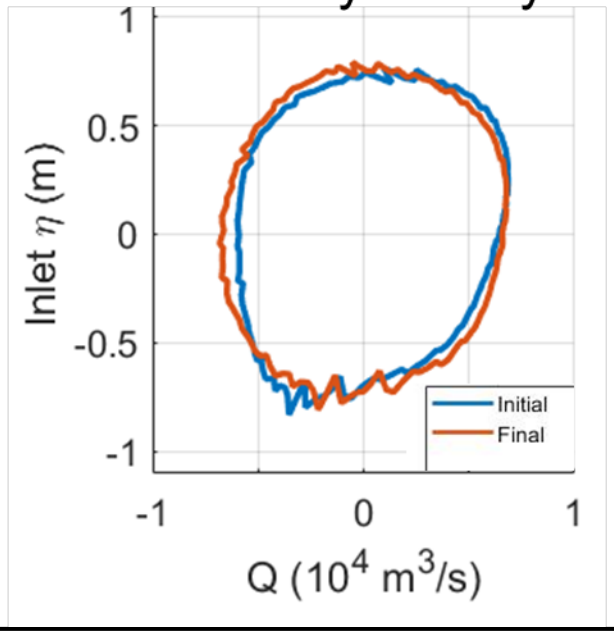


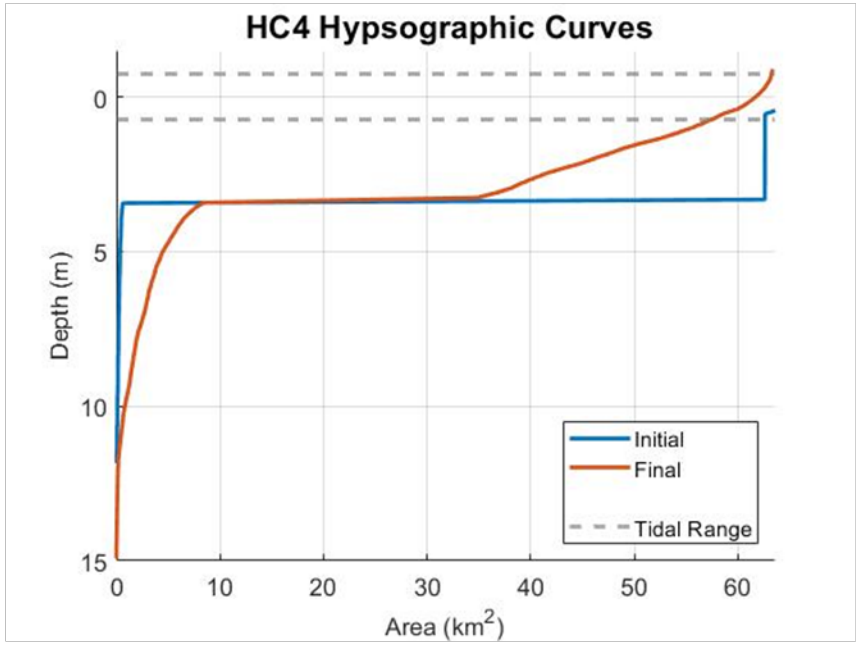
Flood dominated – import sediment



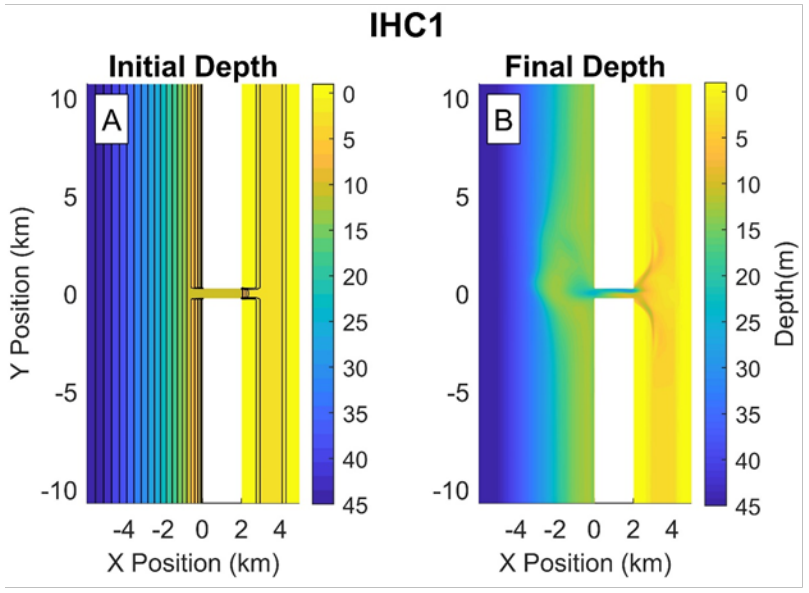


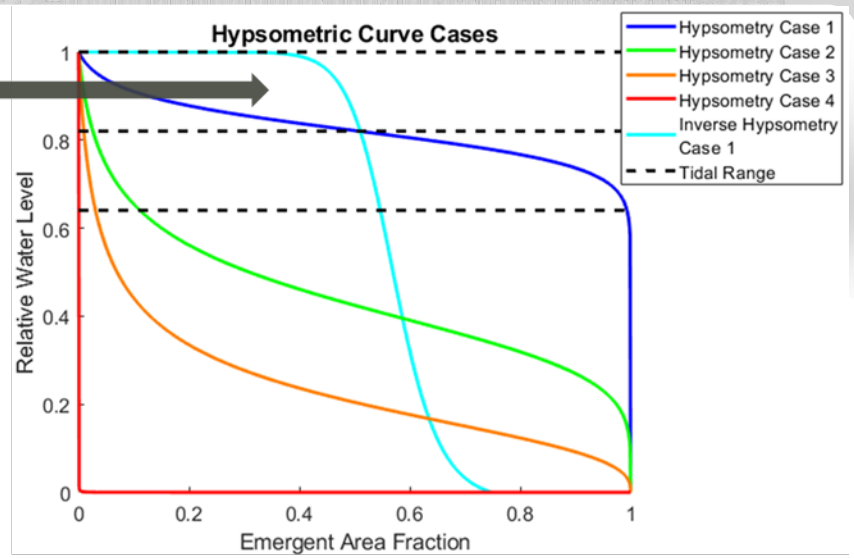
Tidal asymmetry





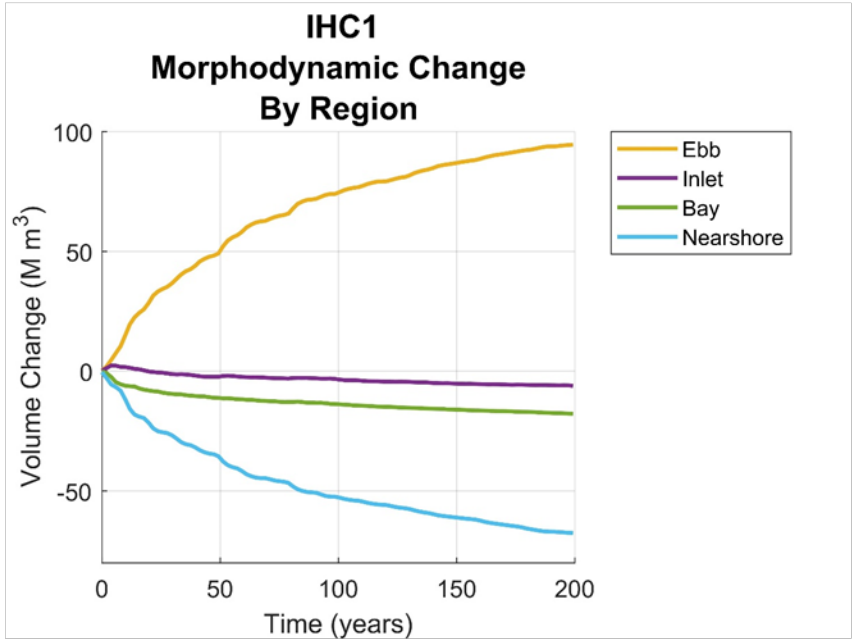
IHC Case 1

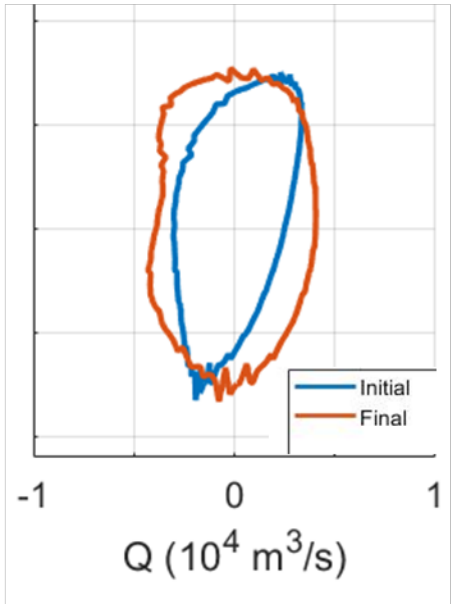


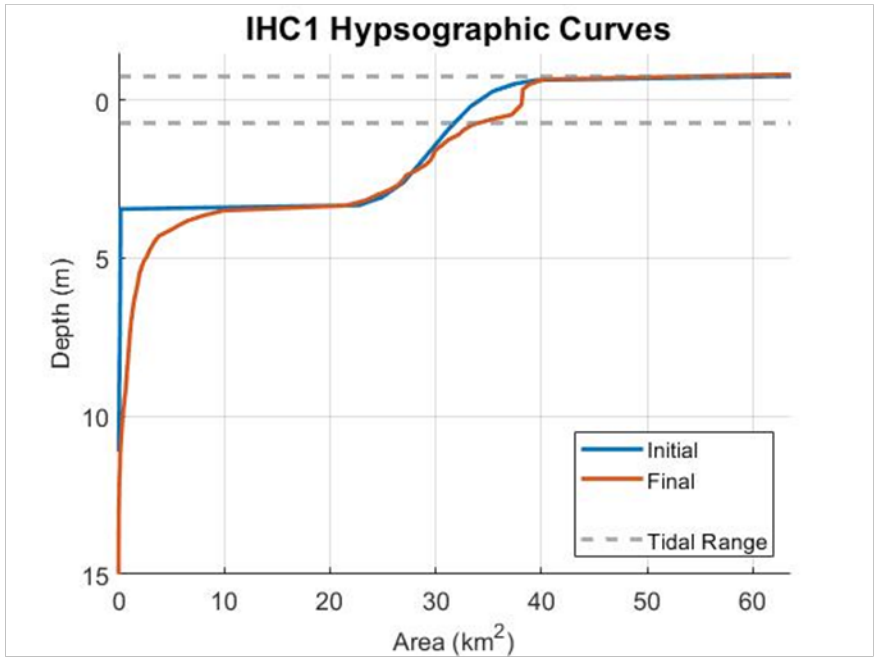


Ebb dominated – export sediment

Tidal asymmetry

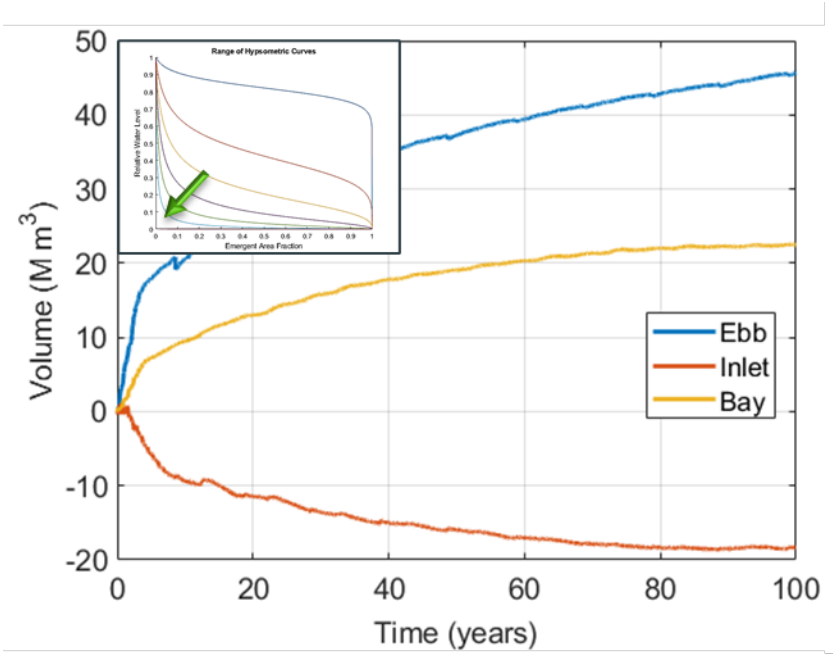


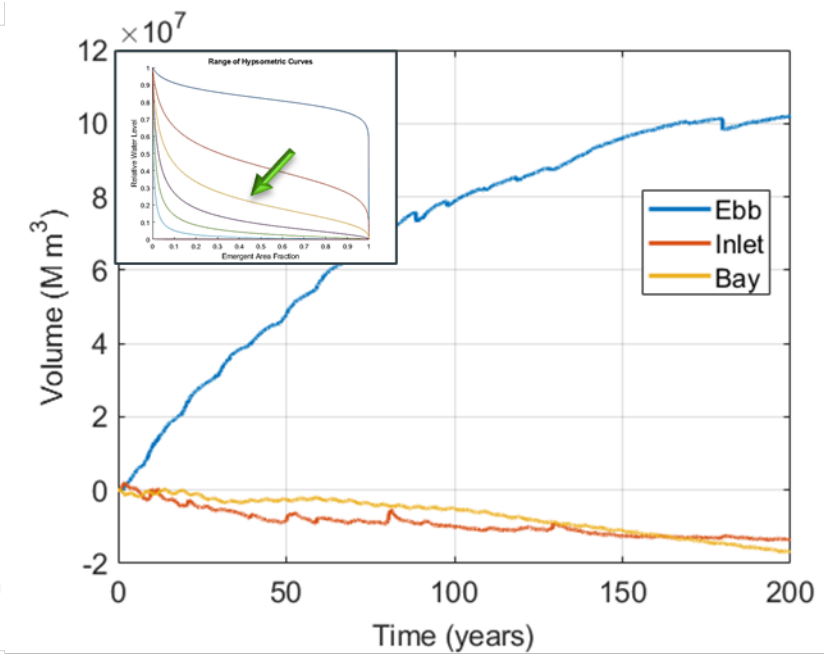


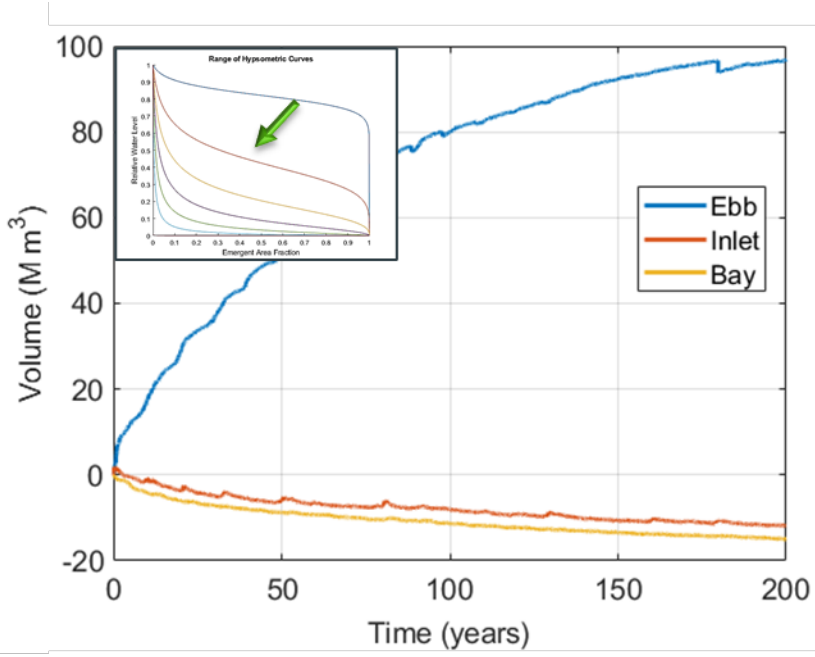


Hypsometry and import vs export

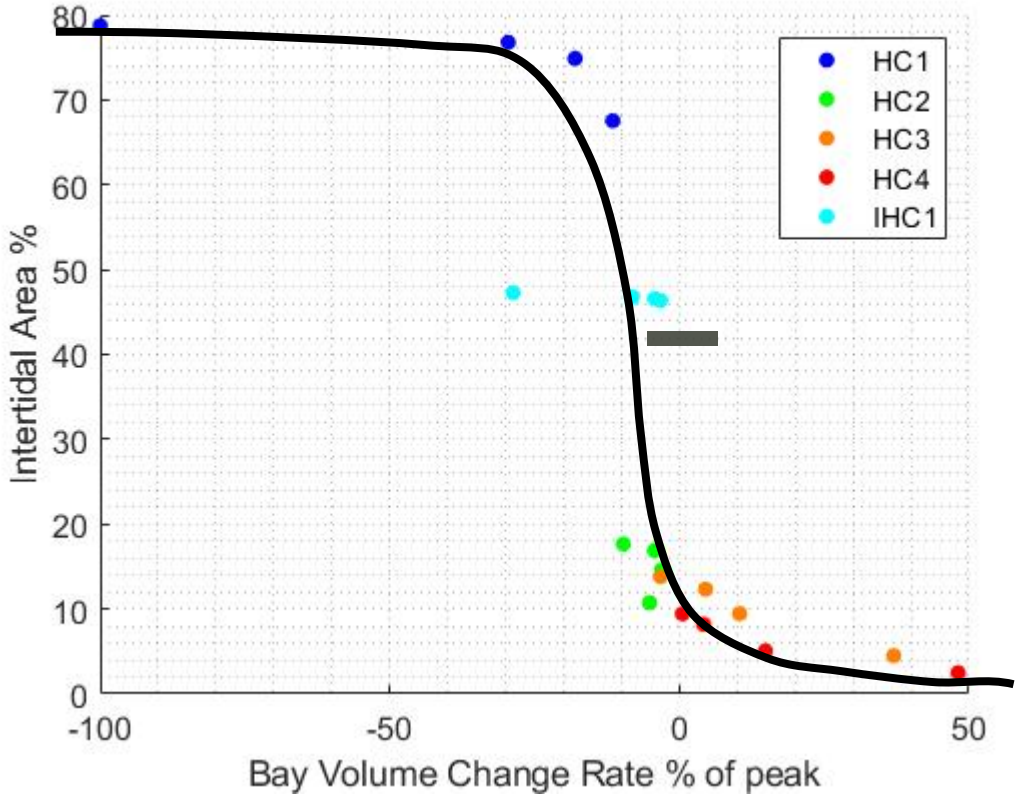
- In all cases ebb shoal gains sediment
- In all cases inlet throat loses sediment
- The bay with extensive tidal flats exports sediment (Case HC1, Case IHC1)
- Transition point from export to import between (Cases HC2, HC3 and HC4)







Intertidal Area and Sediment Flux



Note: data points represent different times (25, 50, 100, 200 years)

Increase in inter-tidal area associated with net export of sediment

Decrease in inter-tidal area associated with net import of sediment

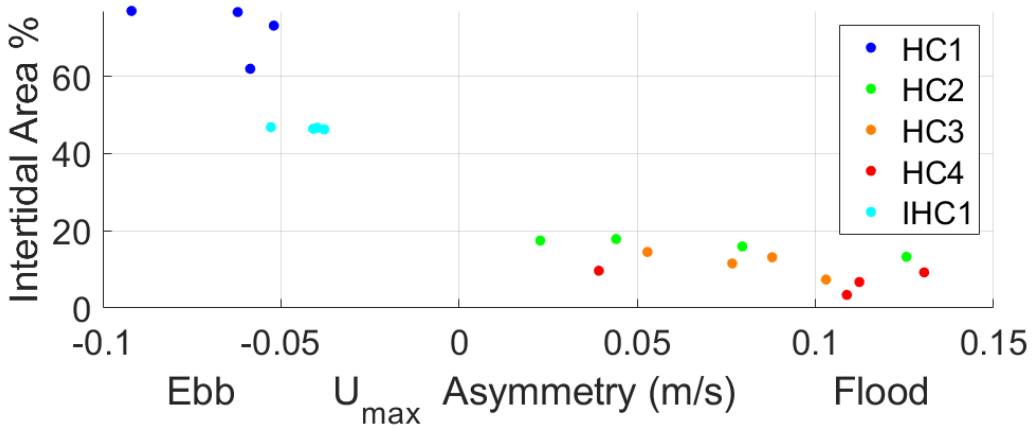
The rate of import/export increases at inter-tidal area extremes (0-10 or 70-80%)

What about real systems?

Can we populate a database using real inlets?

Use information to inform inlet/channel shoaling patterns

Intertidal Area and Tidal Asymmetry

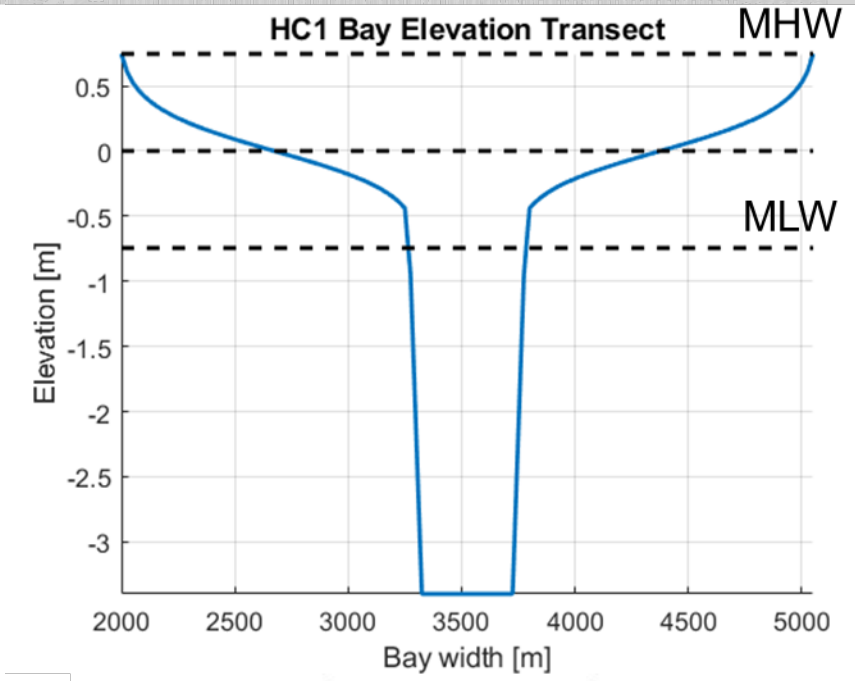


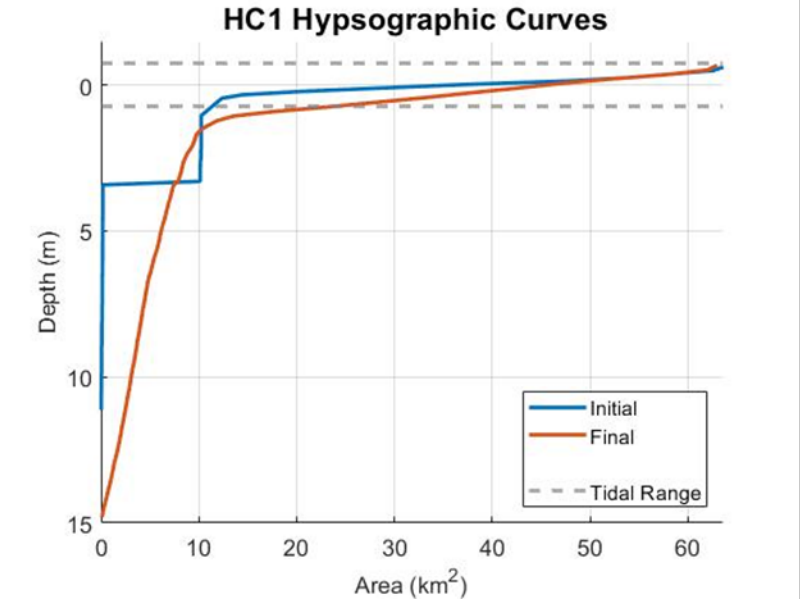
- Increase in inter-tidal area associated with ebb dominance
- Decrease in inter-tidal area associated with flood dominance

Implications for Wetland Restoration

Case HC1

- All material placed in the inter-tidal zone
- Ebb-dominated, export sediment
- Majority of sediment loss occurs lower in the tidal frame, including sub-aqueous regions
- Newly place material likely to reinforce existing platform by maintaining elevation, especially higher in the tidal frame
- However, long-term trend is erosional

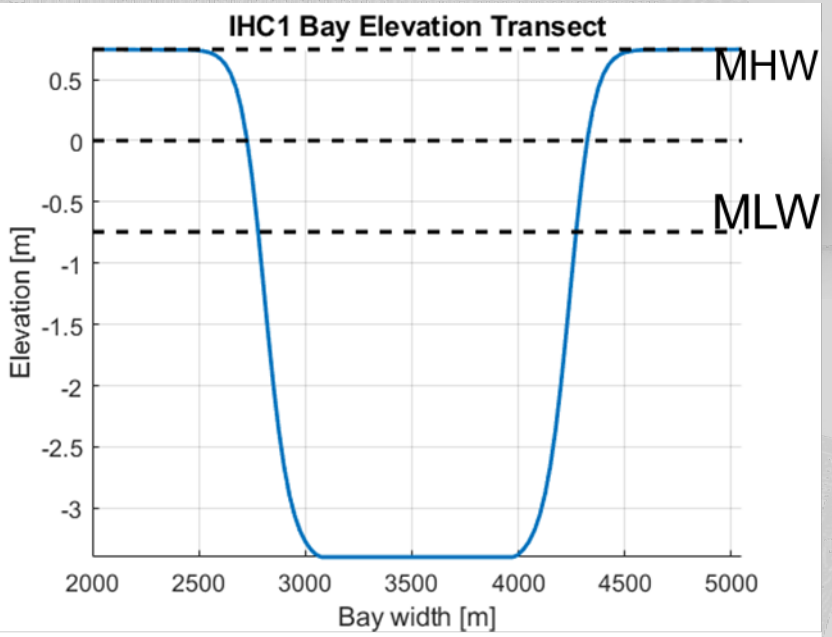


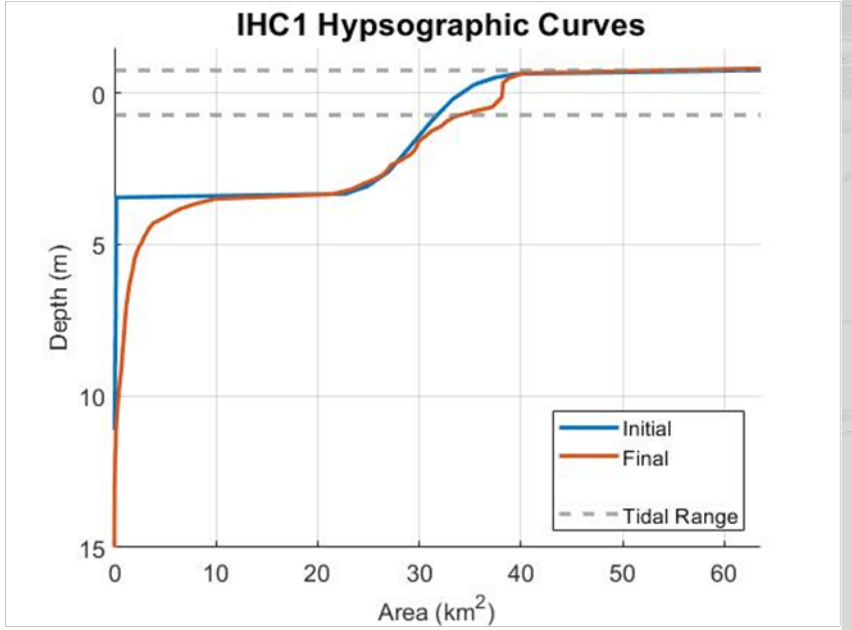


Implications for Land Reclamation

Case IHC1

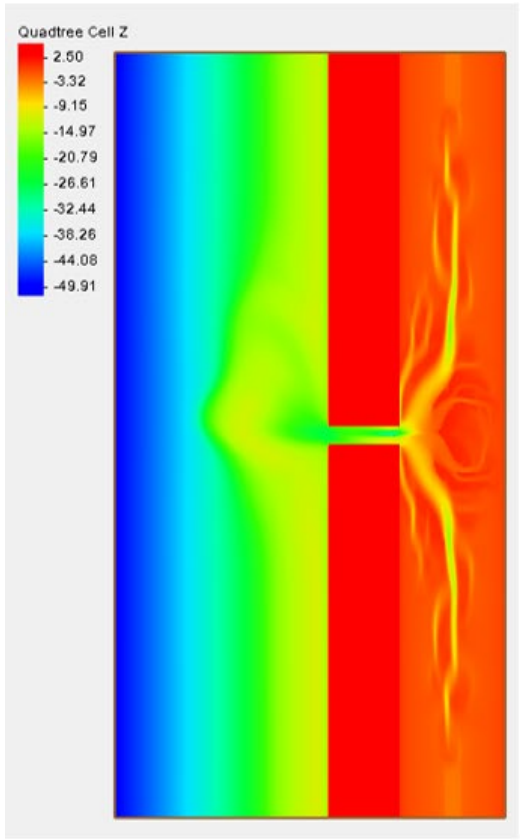
- Most material placed in the subaerial regions
- Ebb-dominated, export sediment
- Majority of sediment loss occurs in the inter-tidal region in such a way as to preserve the inter-tidal area (~3.4% change)
- Would tend to steepen side slopes and possibly affect channel stability
- Subtidal regions are undisturbed suggesting sediment bypasses to the ocean



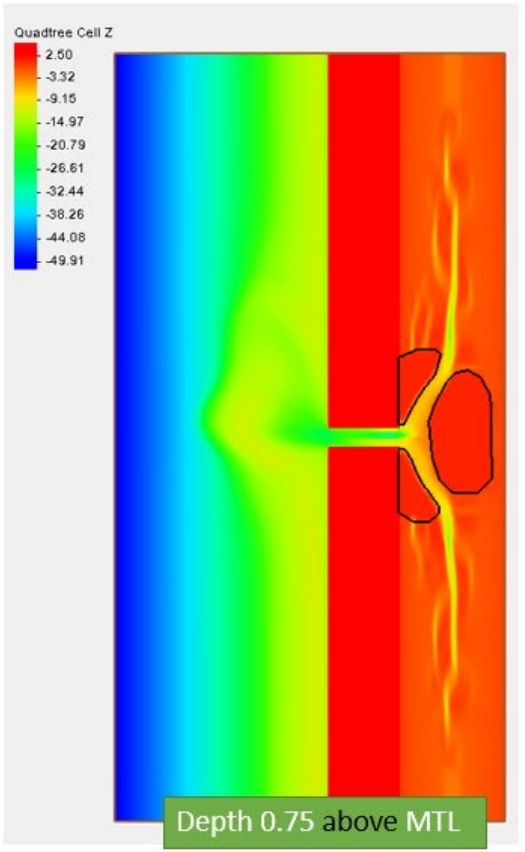


Next Steps

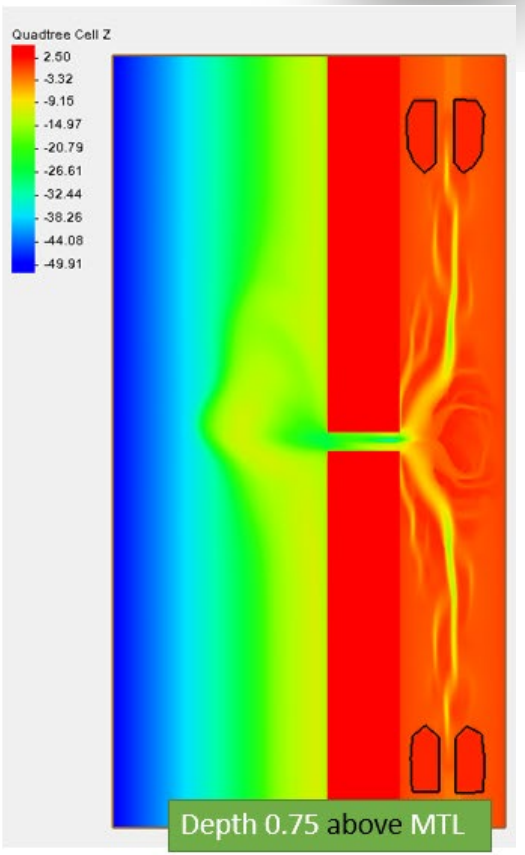
- Explore ebb/flood dominance vs bay geometry/sediment transport
- Relate to theory on bay dynamics
- Identify small class of real tidal inlets and investigate their properties



HR2

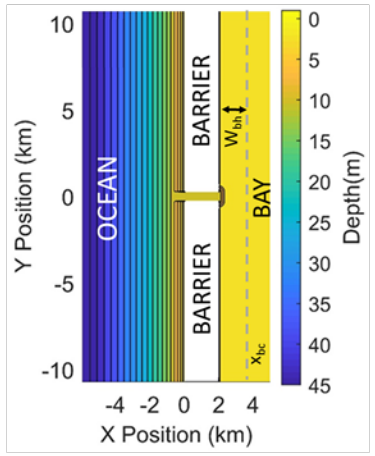


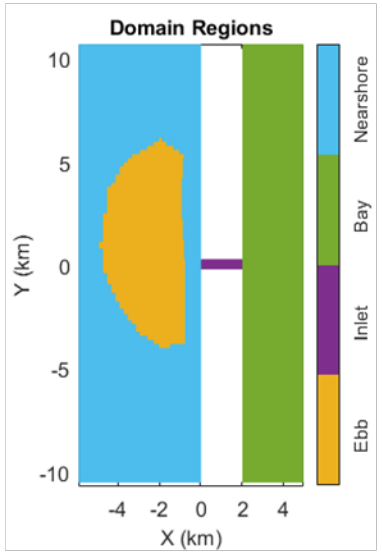
Area: 7,870,948 m^2
Volume: 14,701,500 m^3

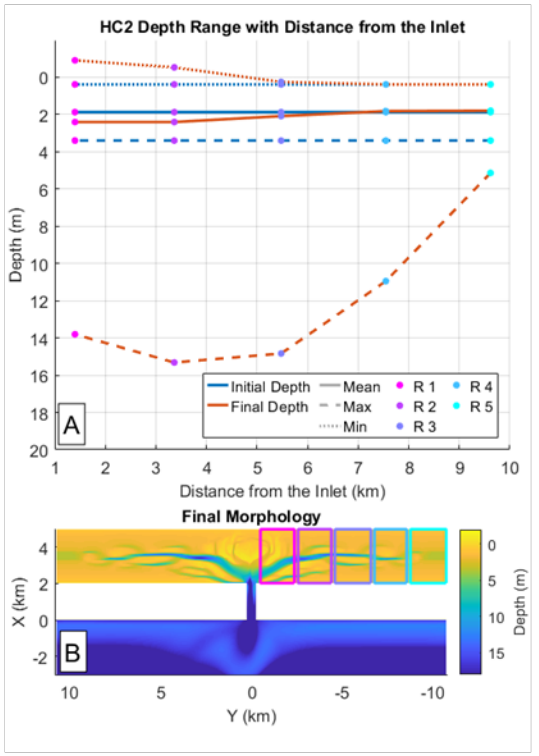


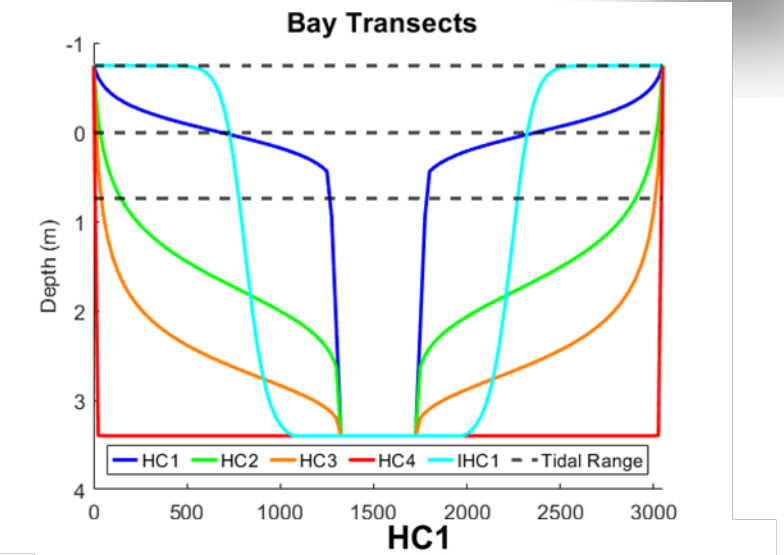
Area: 5,558,302 m^2
Volume: 14,766,700 m^3

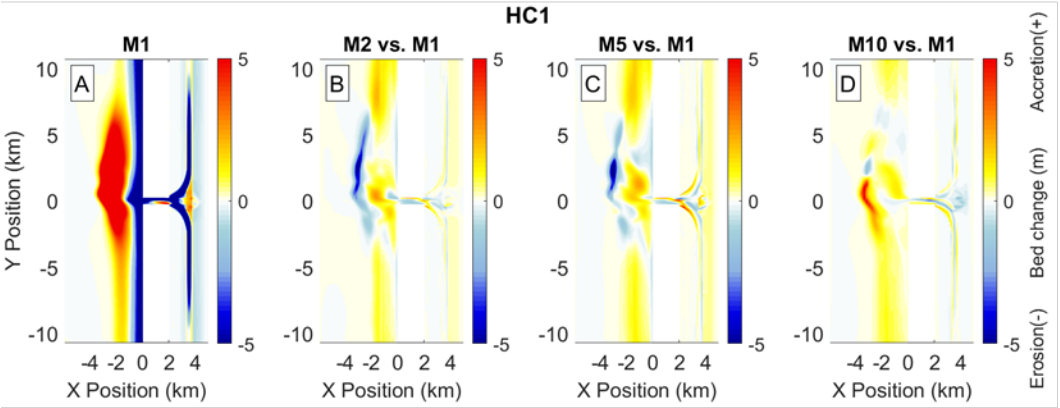
Thanks!

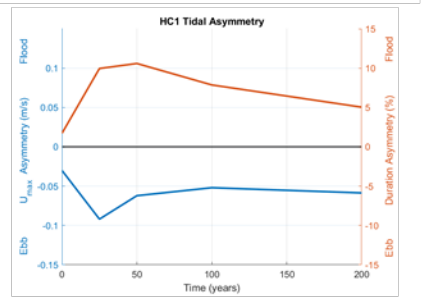

OCEAN
BARRIER
BARRIER
BAY
W_{bh}
x_{bc}
Y Position (km)
X Position (km)
Depth(m)

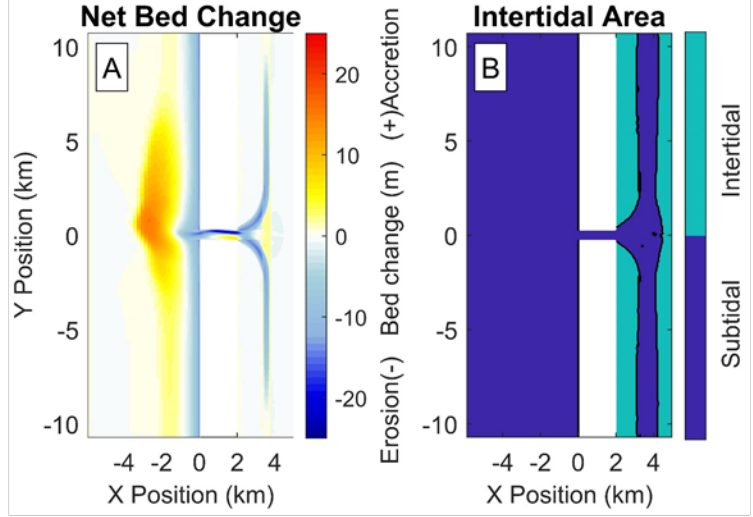

Domain Regions
Nearshore
Bay
Inlet
Ebb
Y (km)
X (km)


HC2 Depth Range with Distance from the Inlet
Depth (m)
Distance from the Inlet (km)
Initial Depth
Final Depth
Mean
Max
Min
R 1
R 2
R 3
R 4
R 5
A
Final Morphology
X (km)
Y (km)
Depth (m)
B


Bay Transects
Depth (m)
HC1
HC2
HC3
HC4
IHC1
Tidal Range
HC1


HC1
M1
M2 vs. M1
M5 vs. M1
M10 vs. M1
A
B
C
D
Y Position (km)
X Position (km)
Accretion(+)
Bed change (m)
Erosion(-)


HC1 Tidal Asymmetry
Flood
Ebb
Time (years)


Net Bed Change
Intertidal Area
A
B
Y Position (km)
X Position (km)
Erosion(-) Bed change (m) (+)Accretion
Intertidal
Subtidal