Sensitivity of a 1-D Coupled Sediment Entrainment and Bioturbation Model to Environmental Forcing

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Outline

1) Introduction

2) Littoral sedimentation and bioturbation model: LSOM-FGS-BIOX (Keen and Furukawa)

3) Test Cases: Examine the non-equilibrium response of the sediments to various external forcings:

   i) Tidally Driven Currents: periodic currents

   ii) Wave Current-Interaction: wave and tidal sea surface changes

   iii) Wind Driven Waves: Time dependent wave height

   iv) Storm Surge: An extremely large and rapid rise in sea level

4) Conclusion

Introduction

Sediment transport impacts bays, estuaries, rivers:

1) Sediment redistribution: Erosion and Deposition
2) Pollutants: transport by sediments
3) Water clarity: Impact on biology, water chemistry
4) Heterogeneous sedimentary environments (mud and sand)

External Forces: A wide range of spatial and temporal scales

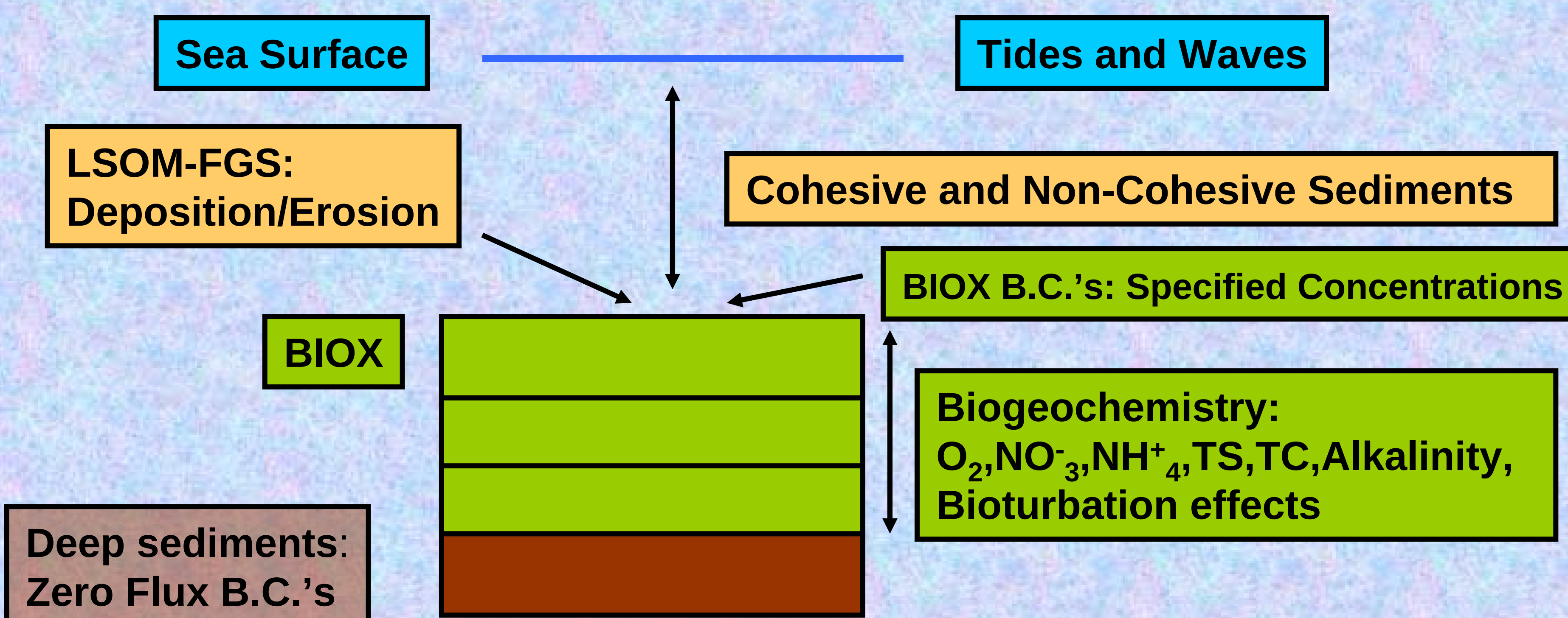
1) Wave (Bottom boundary layer, wave-driven circulation)
2) Wind (mean current, waves)
3) Tides (tidal asymmetry, residual tidal motion)

Biogeochemical forces:

1) Bioturbation within sediments (local ecosystem)
2) Consolidation (physical-chemical changes with in sediment)
3) External biogeochemical forcing in the water column and water-sediment interface (i.e. benthic boundary layer)
4) Flocculation

LSOM-FGS-BIOX Coupled Model

1) LSOM: Calculates suspended non-cohesive sediment concentrations
2) FGS: Calculates suspended fine grain cohesive sediment concentrations:
3) LSOM-FGS determine the amount of sediment deposition or erosion
4) BIOX: Determines the vertical profiles of various chemical species relevant to bioturbated bottom sediments: Equilibrium and Non-Equilibrium



LSOM-BIOX TEST CASES

The different test cases examine a range of spatial and temporal scales with regard to the external forcing (wind, wave, tides).

Different types of forcing generate distinct regimes of deposition and erosion that result in biogeochemical changes in the bottom sediments.

The sensitivity of the system is examined through the non-equilibrium biogeochemical response of the bottom sediments to deposition and erosion events.

It should be noted that the simulations are sand dominated and that the bottom sediments are represented by a slab of 60 mm for all of the simulations. The BIOX grid resolution is .2 mm and the time step is 1.0 seconds.

CASE 1: Tidally driven currents

Tidal Current Magnitude = 2.0 m/s
Tidal Period = 12 hours

Wave Height = 1.0 m
Wave Period = 8 seconds

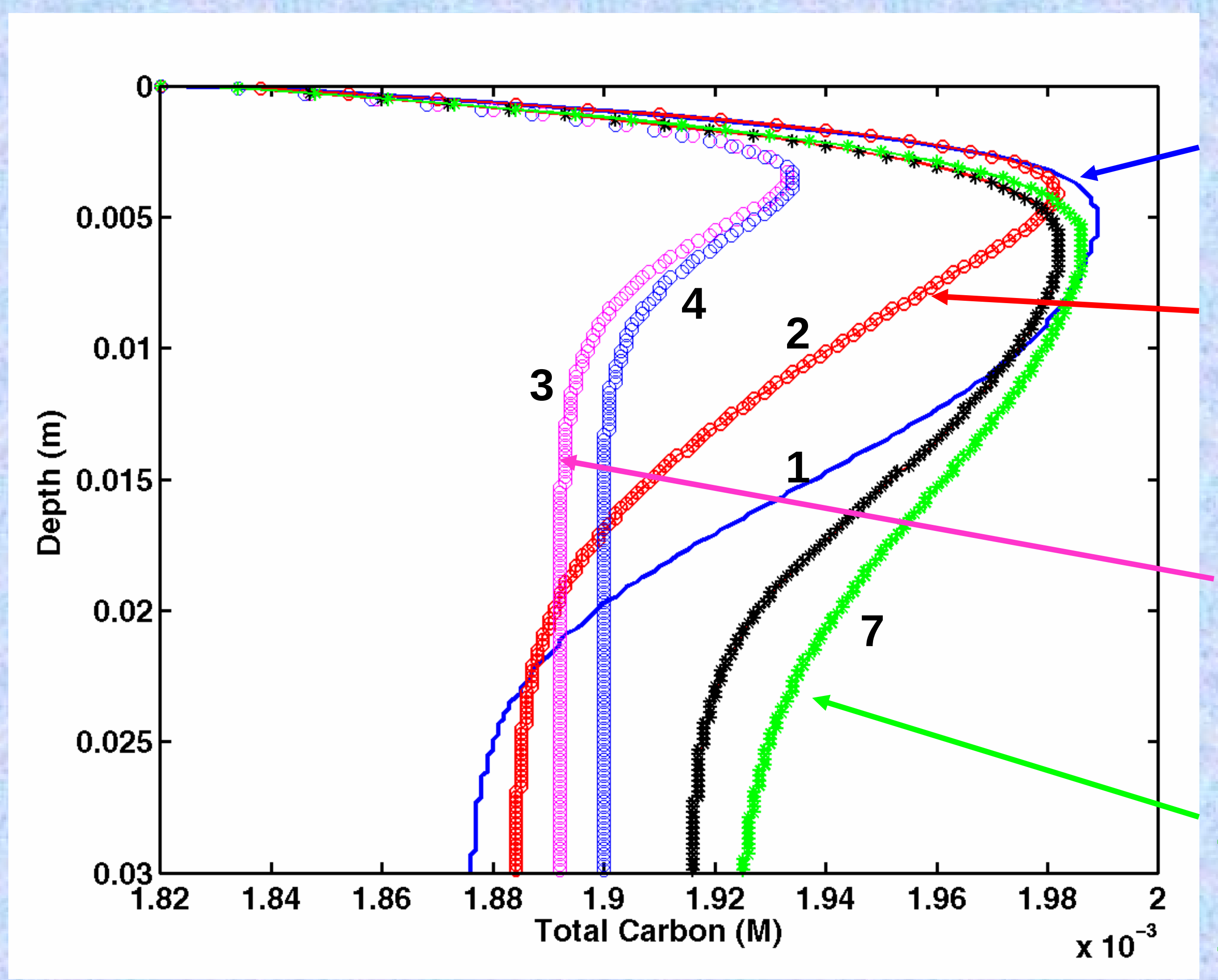
Water Depth = 5.0 m

Time Step = 1.0 hour
Run Duration = 24 hours

90% Sand, 10% Mud

CASE 1: Tidally Driven Currents

Total Carbonate Carbon Profiles: 7 hour period
(Curves 1-4 represent sequential 1 hour time steps)



1) 5.9 mm deposition, tidal current = 0.01 m/s (decreasing), tau=.78 Pa

2) 5.9 mm erosion, tidal current = 1.0 m/s (increasing), tau=2.39 Pa

3) 15.0 mm erosion, tidal current = 1.73 m/s (increasing), tau =5.58 Pa

7) 5.9 mm deposition, tidal current = 0.01 m/s (decreasing), tau = .78 Pa

CASE 2: Wave-Current Interaction

Tidal sea surface height amplitude = .7 m
Tidal Current = 0.8 m/s
Tidal Period = 12 hours

Wave Height = 0.8 m
Wave Period = 10 seconds

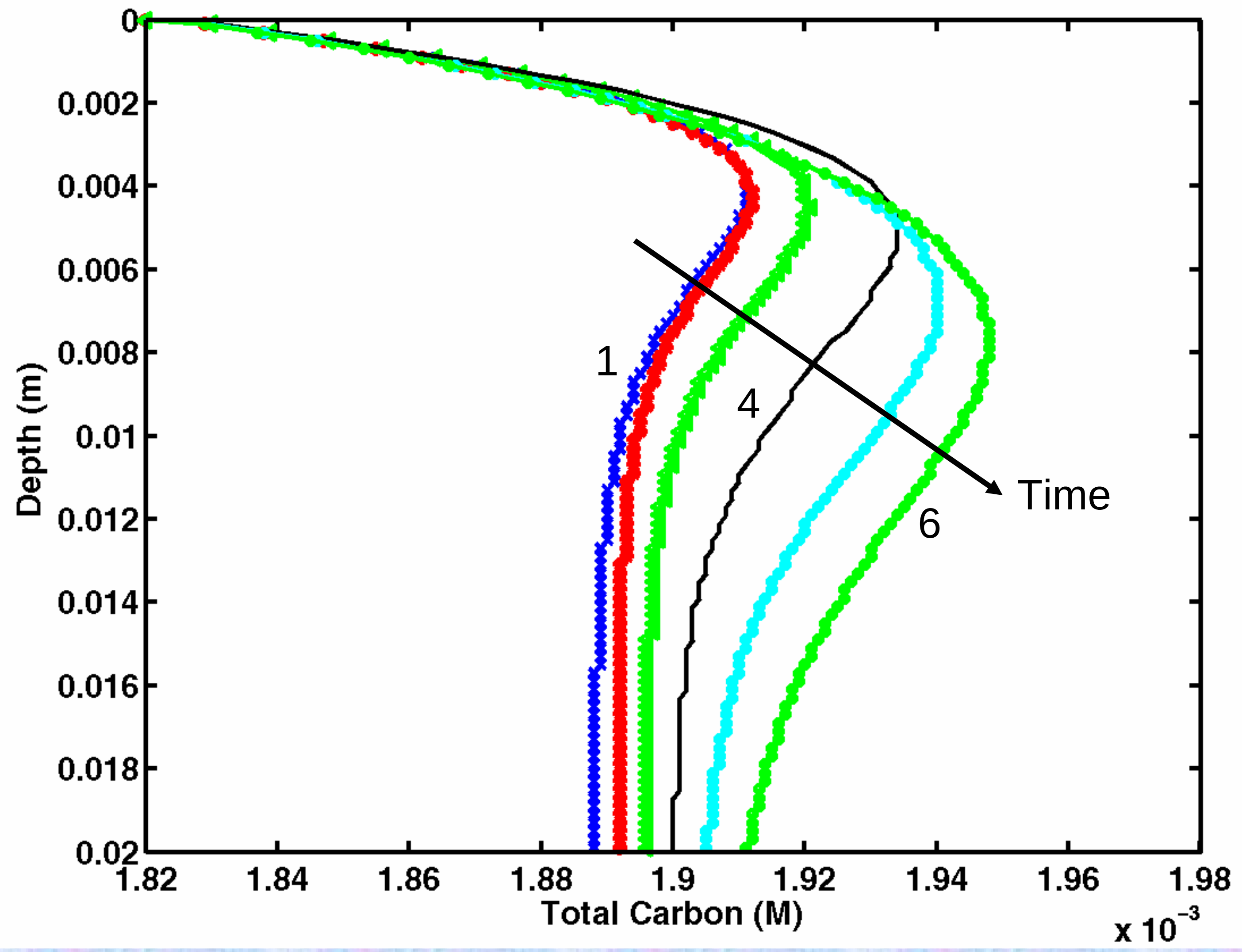
Initial Water Depth = 1.5 m

Time Step = 0.5 hours
Run Duration = 12 hours

70% Sand (fine grain), 30% Mud

CASE 2: Wave-Current Interaction

Total Carbonate Carbon Profiles: 2.5 hour period
(Curves 1-6 represent sequential 0.5 hour time steps)



1) **6.5 mm erosion,**
tidal current = 0.65 m/s (increasing),
Water Depth = 0.894 m
tau = 11.3 Pa

4) **2.8 mm deposition,**
tidal current = 0.72 m/s (increasing),
Water Depth = 0.824 m
tau = 14.6 Pa

6) **7.2 mm deposition,**
tidal current = 0.53 m/s (decreasing),
Water Depth = 1.0 m
tau = 7.7 Pa

CASE 3: Wind Driven Waves

Steady current = 2.0 m/s

Wave Height Min/MAX= 1.0/2.0 m
Wave Period = 6.0 seconds
Period of variation in wave height = 6.0 hours

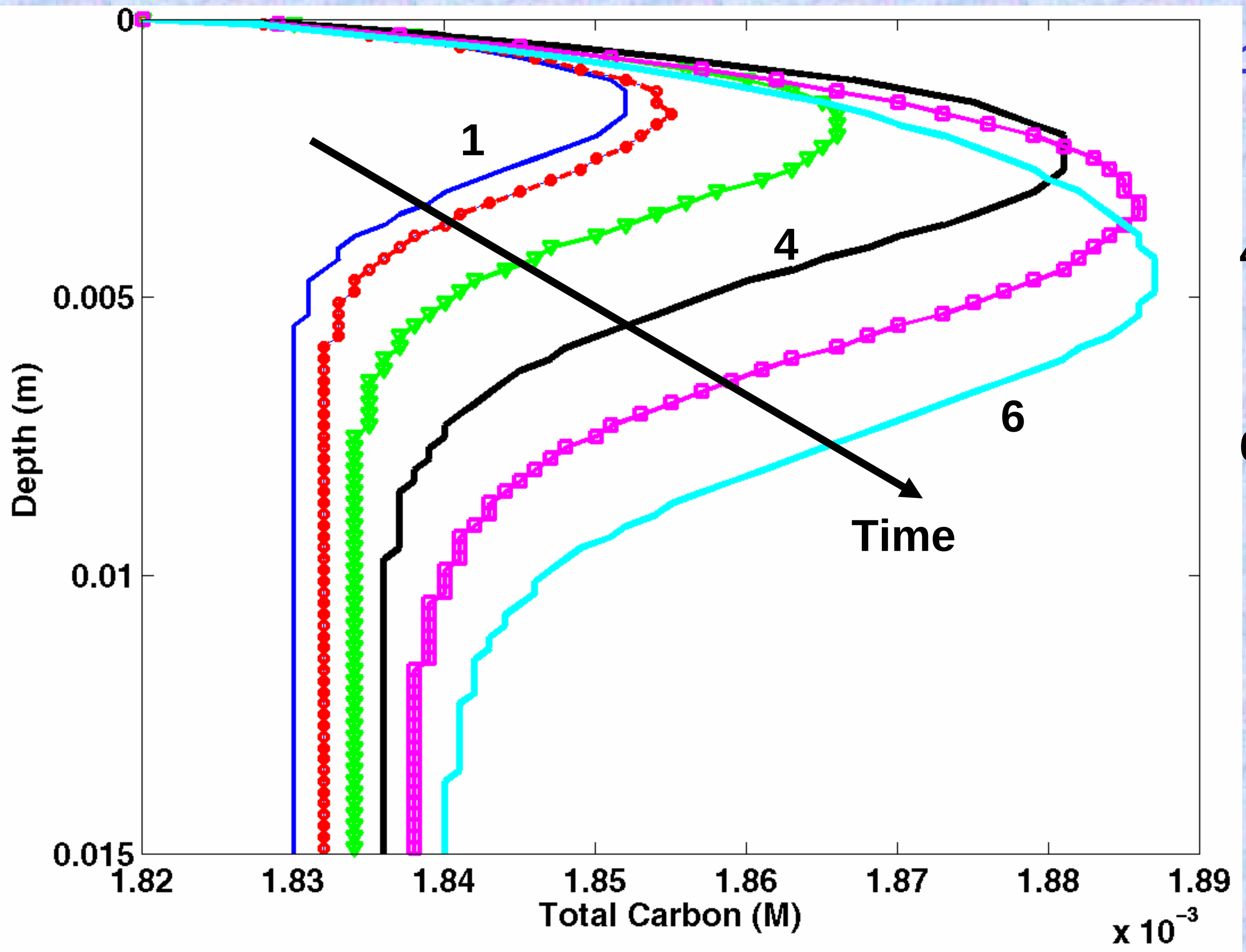
Water Depth = 2.0 m

Time Step = 15 minutes
Run Duration = 3 hours (half period of change in wave height)

80% Sand, 20% Mud

CASE 3: Sea Breeze

Total Carbonate Carbon Profiles: 7 hour period
(Curves 1-6 represent sequential 15 minute time steps)



1) **4.6 mm erosion,** wave height = 1.86 m

4) **1.1 mm deposition,** wave height = 1.96 m

6) **4.6 mm deposition,** wave height = 1.71 m

CASE 4:Storm Surge

Tidal Amplitude = 3.0 m
Tidal Current Amplitude = 4.0 m/s
Tidal Period = 24 hours

Wave Height = 2.0 m
Wave Period = 10.0 seconds

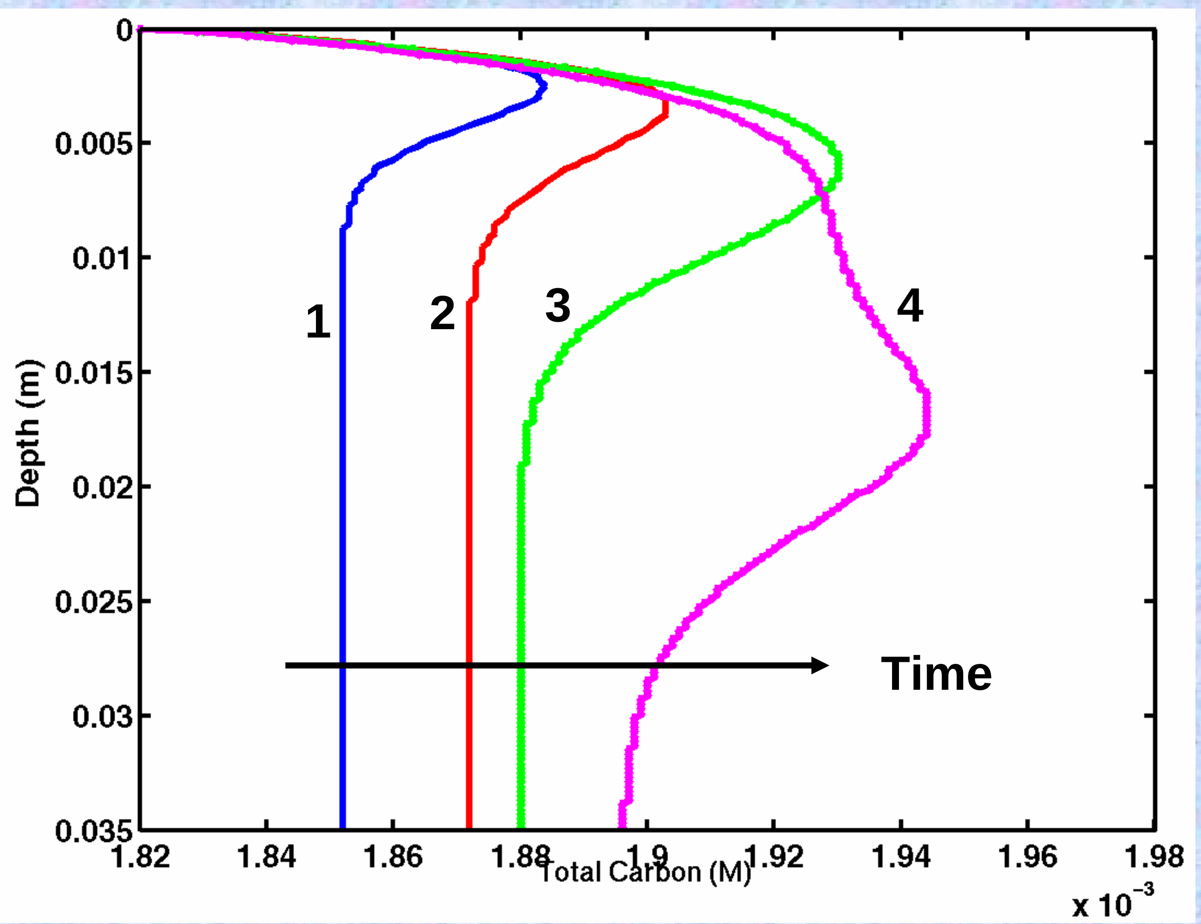
Initial Water Depth = 4.0 m (Max 7.0 m)

Time Step = 30 minutes
Run Duration = 12 hours

90 % Sand, 10% Mud

CASE 4:Storm Surge

Total Carbonate Carbon Profiles:
***Curves 1 and 2 are before or at max height/current)**
***Curves 3 and 4 are after max height/current**



1) 17.7 mm erosion,
Tidal current = 3.17 m/s,
Water Depth = 6.38 m
Time = 3.5 hours

2) 2.5 mm erosion,
Tidal current = 4.0 m/s,
Water Depth = 7.0 m
Time = 6.0 hours

3) 7.2 mm deposition,
Tidal current = 3.86 m/s,
Water Depth = 6.89 m
Time = 7.0 hours

4) 17.7 mm deposition,
Tidal current = 2.83 m/s,
Water Depth = 6.12 m
Time = 9.0 hours

Conclusion

1) Successful demonstration of 1-D coupled littoral sedimentation and benthic boundary layer model, LSOM-FGS-BIOX, in a broad range of nearshore scenarios.

   i) Cohesive and non-cohesive littoral sedimentation used for the determination of entrained sediments.

   ii) Benthic boundary layer model determines reactive chemical transport and bioturbation effects in the bottom sediments for a number of important chemical species.

2) Non-equilibrium time-dependent profiles of the concentration of total carbonate carbon were determined for a reasonable range of sedimentation events (1 – 18 mm) in sand dominated environments (70 - 90%).

3) Coupled model system demonstrated realistic sensitivity to external forcing (further benchmarking is required).