Evaluating the effects of cohesive processes on sediment distribution in an idealized, partially-mixed estuary using a numerical model

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**Recommended Citation**

Tarpley, Danielle; Harris, Courtney; and Friedrichs, Carl. "Evaluating the effects of cohesive processes on sediment distribution in an idealized, partially-mixed estuary using a numerical model". 2-21-2016. 2016 Ocean Sciences Meeting, New Orleans, LA. https://doi.org/10.21220/V5MJ0G.
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Cohesive Properties

- Surface charge on clay particles leads to:
  - Flocculation and variations in settling velocity.
  - Consolidation on the seabed and reduced erodibility (Fig. 2)
- At elevated suspended concentrations, sediment-induced stratification can limit sediment entrainment.
- Sediment transport models often neglect these processes.

Model Design

- Scaled similar to York River Estuary, VA.
  - 500 m along estuary
  - 120 m3 s-1 river discharge
  - 0 – 26 psu salinity range
  - Idealized, 12 hour tidal period
- Grid Resolution
  - 40 vertical layers
  - 10 bed layers

Results

Using Standard (Std.) run as the reference:

Bed thickness (Fig. 5A):
- Stratification decreases the deposit (89%);
- Consolidation alone increases the deposit (49%);
- Combination decreases the deposit (97%).

Applied bed stress (Fig. 5B):
- Reduced significantly by sediment stratification.

Suspended mass (Fig. 5C):
- Stratification - decrease 72%
- Consolidation - increase 88%
- Combination - decrease 36%

Erodibility:
- ETM is most erodible (Fig. 6)
- Including stratification reduced the calculated erodibility (Fig. 8).

Objective & Questions

Objective:
- Use a numerical model of an idealized, partially-mixed estuary to examine ETM dynamics.

Research Questions:
What are the relative roles of sediment – induced stratification and bed consolidation on:
1. the location and magnitude of the ETM?
2. sequestering different size sediment classes in the ETM?

Sediment Trapping in the ETM:

- Standard run (no stratification or consolidation): preferentially trapped slow settling material (Fig. 7A).
- ETM trapped all sediments equally when stratification or consolidation limited erosion (example, Fig. 7B).
- Stratification provided more of a limit to sediment entrainment than bed consolidation at the ETM (Fig. 9).
- When both consolidation and stratification were included, suspended concentrations were very limited (Fig. 9): bed armoring?

Conclusions

- An idealized estuarine model developed to scale with the York River Estuary, Virginia, produces an Estuarine Turbidity Maximum (ETM).
- In the ETM:
  - Neglecting stratification effects and bed consolidation overestimates suspended sediment concentrations (SSCs), fluxes, and net deposition.
  - Including suspended sediment stratification reduces the bed stresses, SSCs, and net deposition.
  - Bed consolidation limits erosion downstream, but unreasonable erosion upstream remained.
- Stratification governs the vertical suspension of the differing size classes and consolidation confines sediment to the bed. The combination produces a reasonable ETM location and magnitude, and allows all size classes to converge in the ETM.

Future Work

- Include aggregation and breakup of flocculated particles (Fig. 10) – FLOCMOD:
  - population size class model.
- Capture the dynamics of the Secondary Turbidity Maximum (STM)
  - Full 3-dimensional model of the York River estuary (Rinehimer, 2008; Fall et al, 2014; Fig. 11)

References


Acknowledgments

Thanks to Julia Moriarty for assistance with data analysis. Thank you to Adam Miller and the IT team maintaining the HPC (Siclone) and to Eric Walter for the many hours spent assisting in switching to the new HPC. This work was funded by NSF Grant OCE-1459708