Cohesive Sediment Transport Models in an Idealized Estuary

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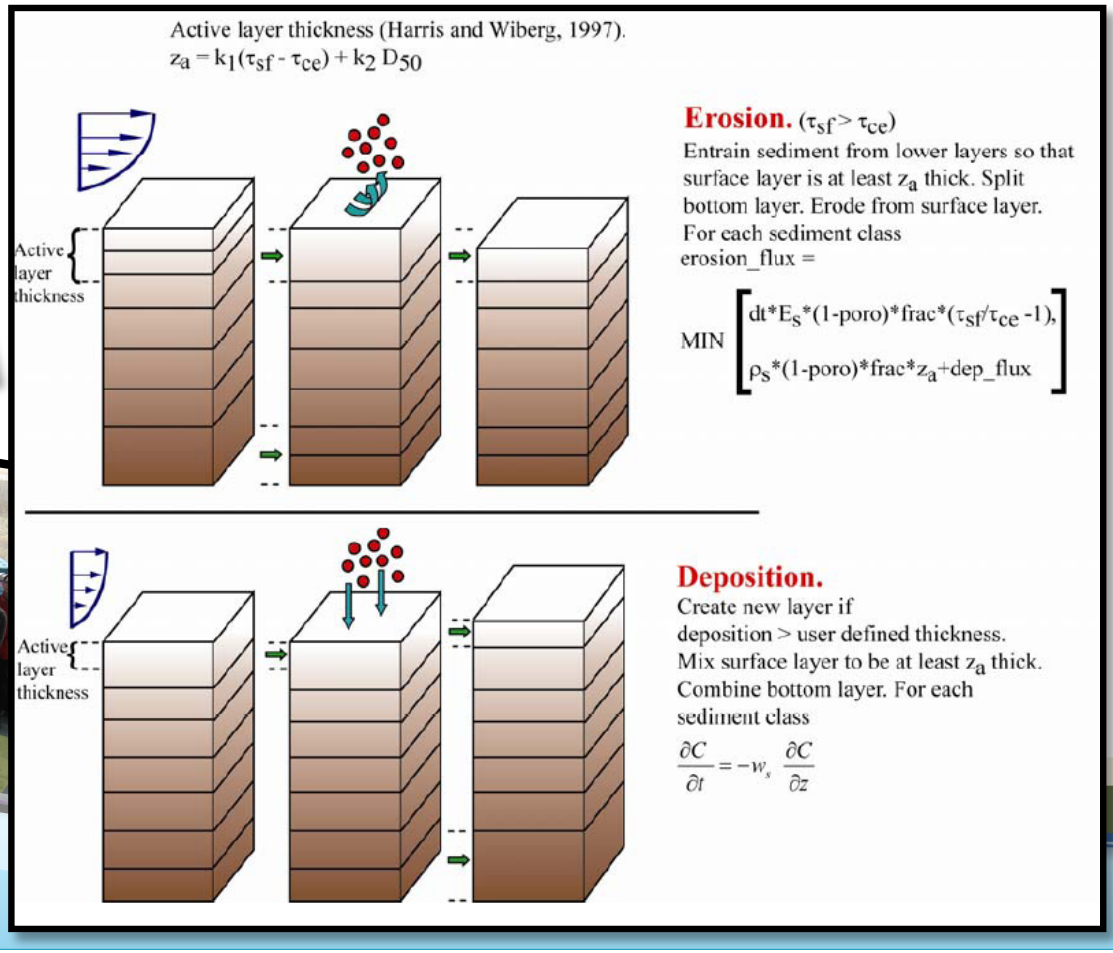
**presenting the webinar today*

Community Sediment Transport Modeling System

COAWST user group meeting, February 2019

- Described in Warner et al. (2008).
- Implemented in ROMS.
- Versions have also been ported to SCHISM, FVCOM, and other models.
- **Noncohesive sediment model.**
- **Treats particulate tracers as inert.**



CSTMS Now Includes Flocculation and Bed Consolidation

Geosci. Model Dev., 11, 1849–1871, 2018
https://doi.org/10.5194/gmd-11-1849-2018

Geoscientific Model Development
Open Access

Cohesive and mixed sediment in the Regional Ocean Modeling System (ROMS v3.6) implemented in the Coupled Ocean–Atmosphere–Wave–Sediment Transport Modeling System (COAWST r1234)

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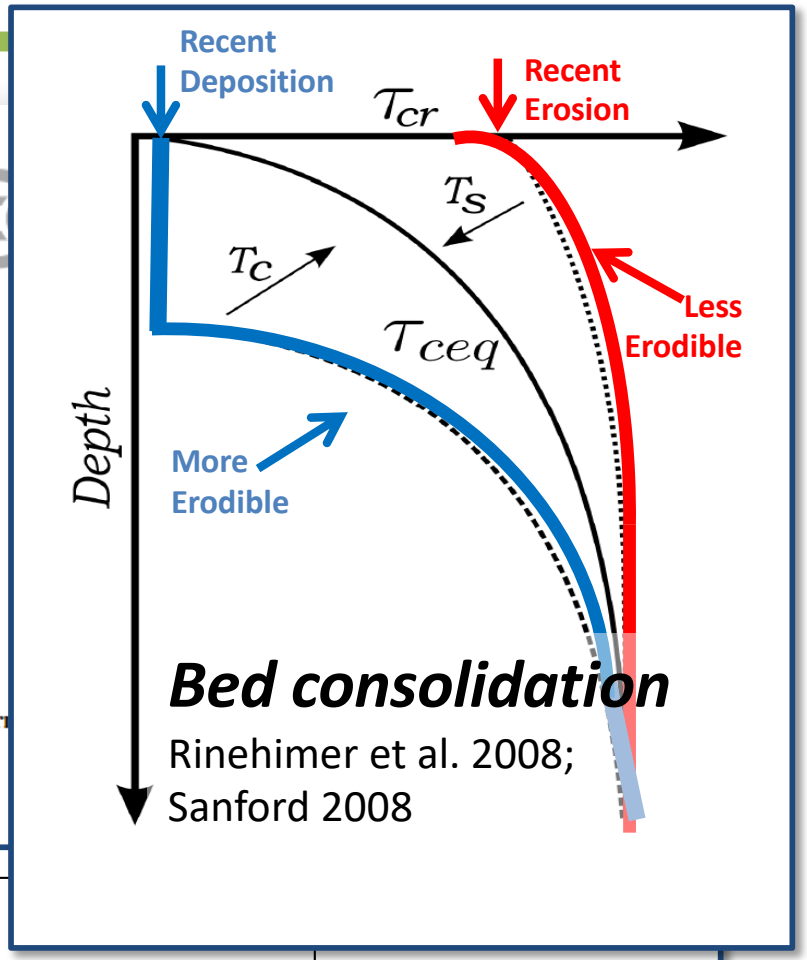
UiT The Arctic University of Norway, 9037 T



Bed consolidation

Rinehimer et al. 2008;
Sanford 2008

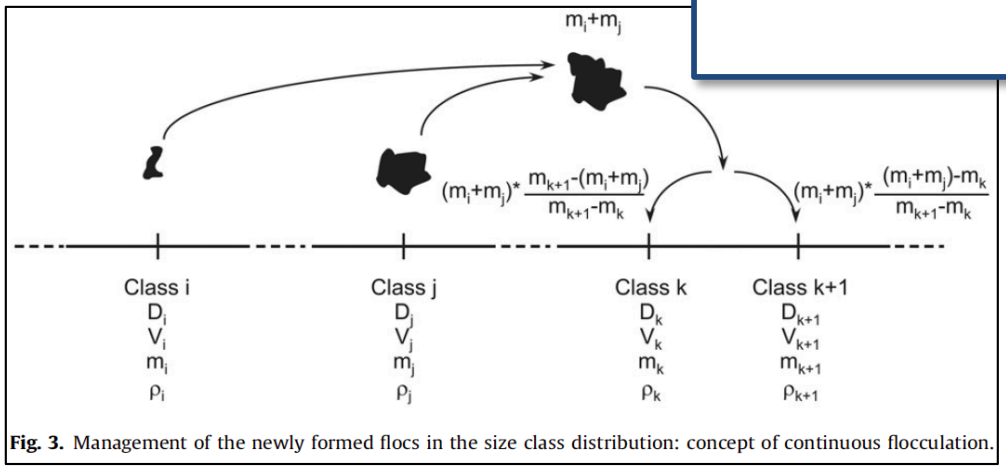


Fig. 3. Management of the newly formed flocs in the size class distribution: concept of continuous flocculation.

FLOCMOD

Figure from Verney et al. 2011.

Processes Impacting Floc Size Over a Tidal Cycle in an Idealized Estuary Model

Presented at CERF 2019

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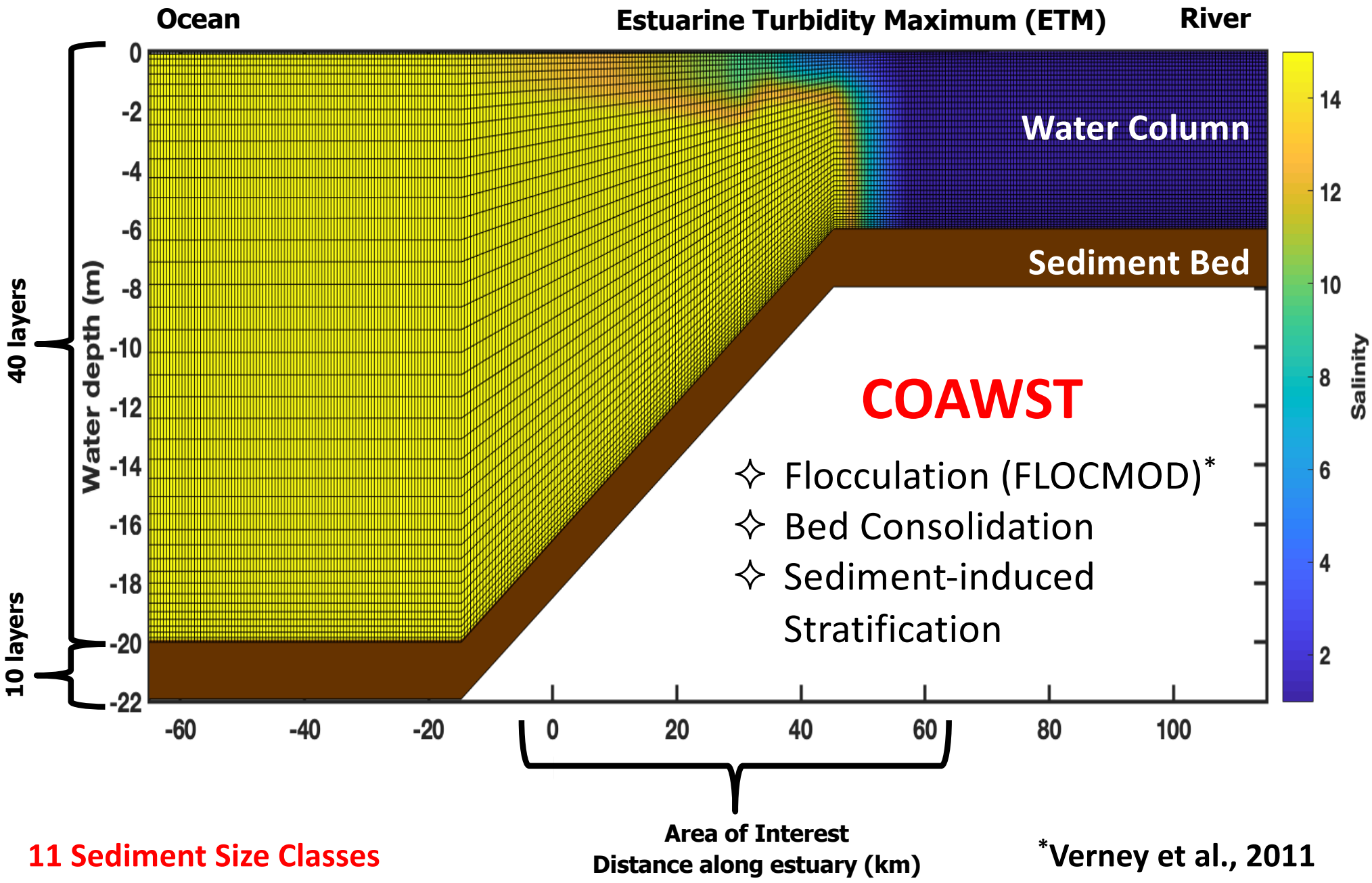

11 Sediment Size Classes

*Verney et al., 2011

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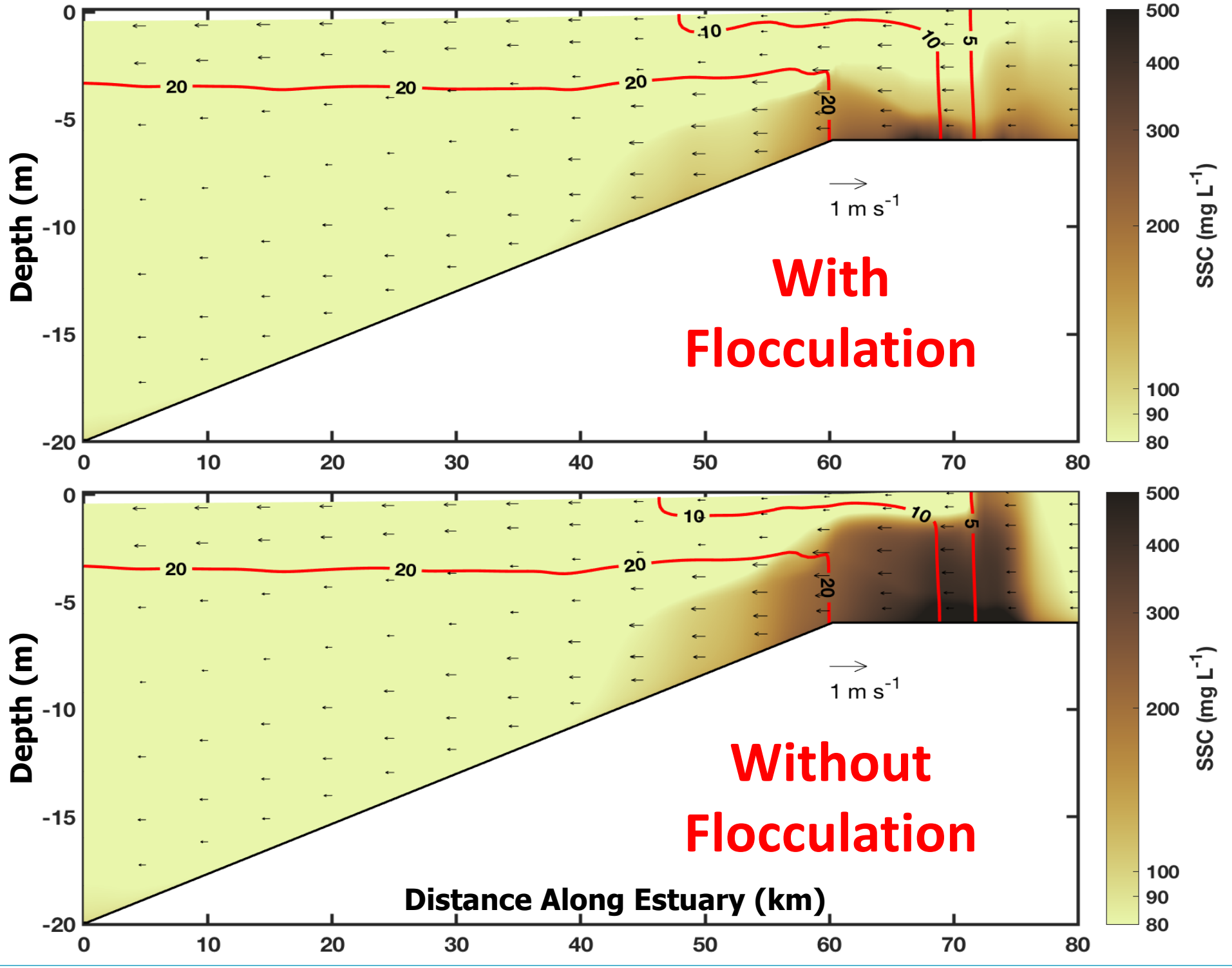
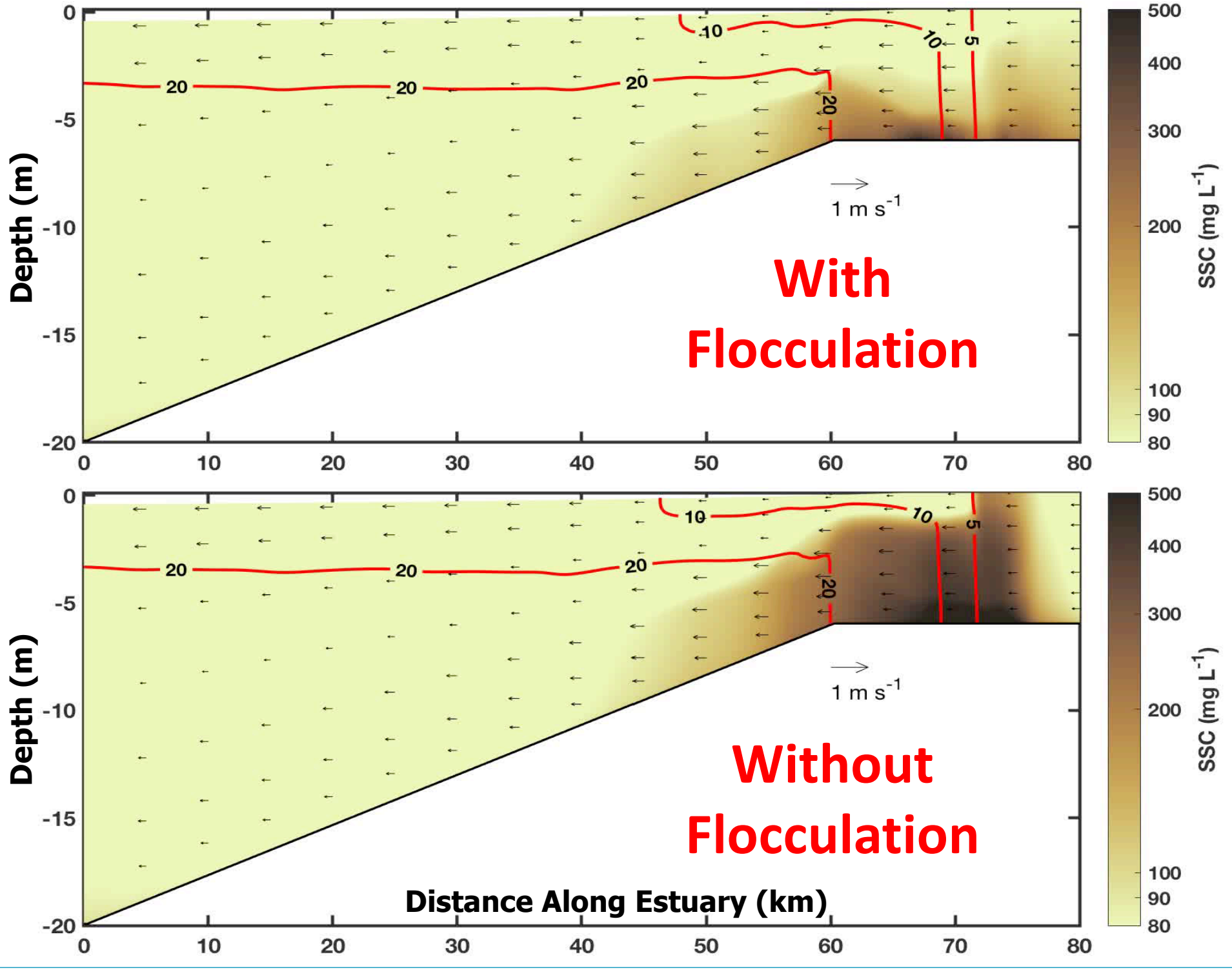
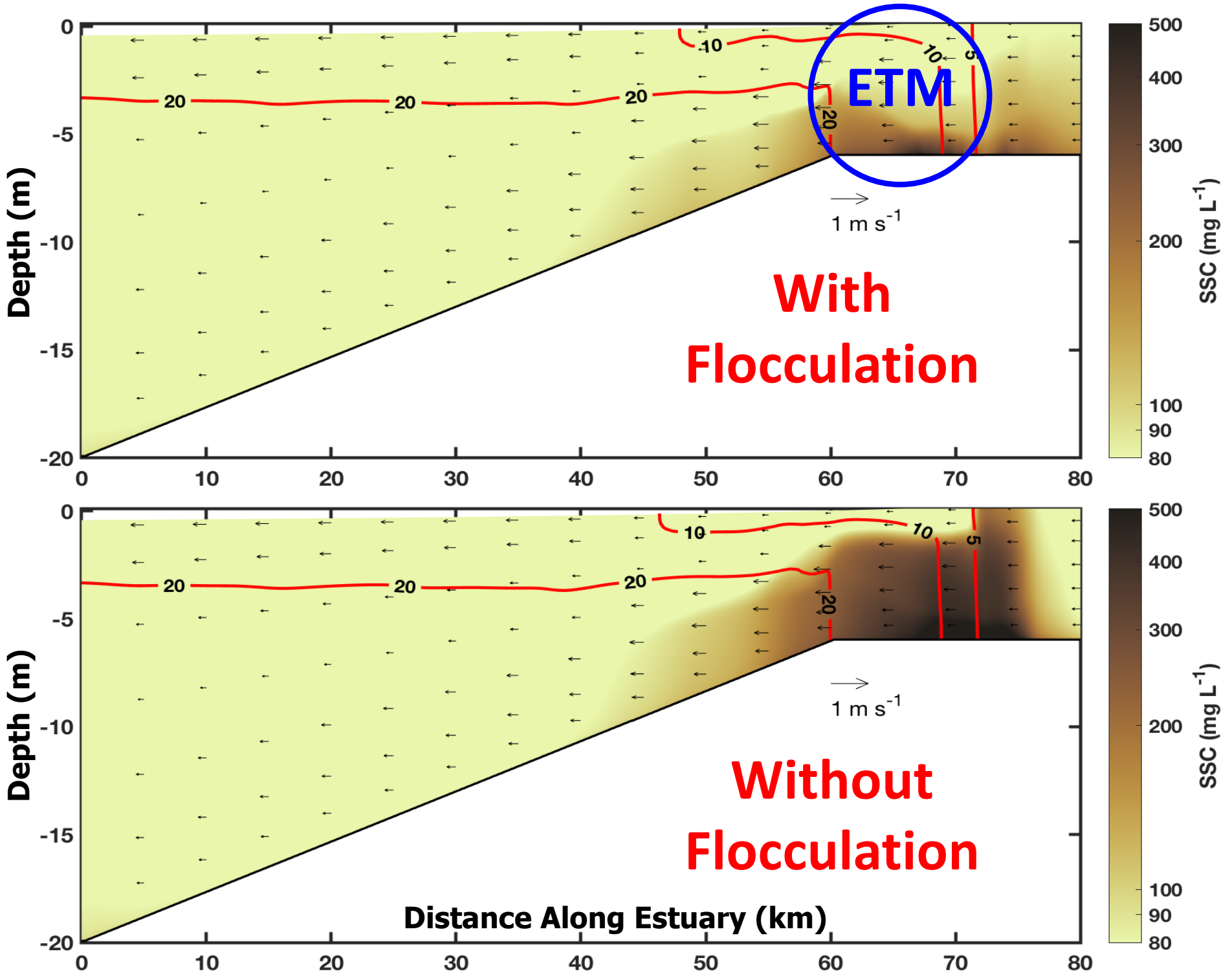
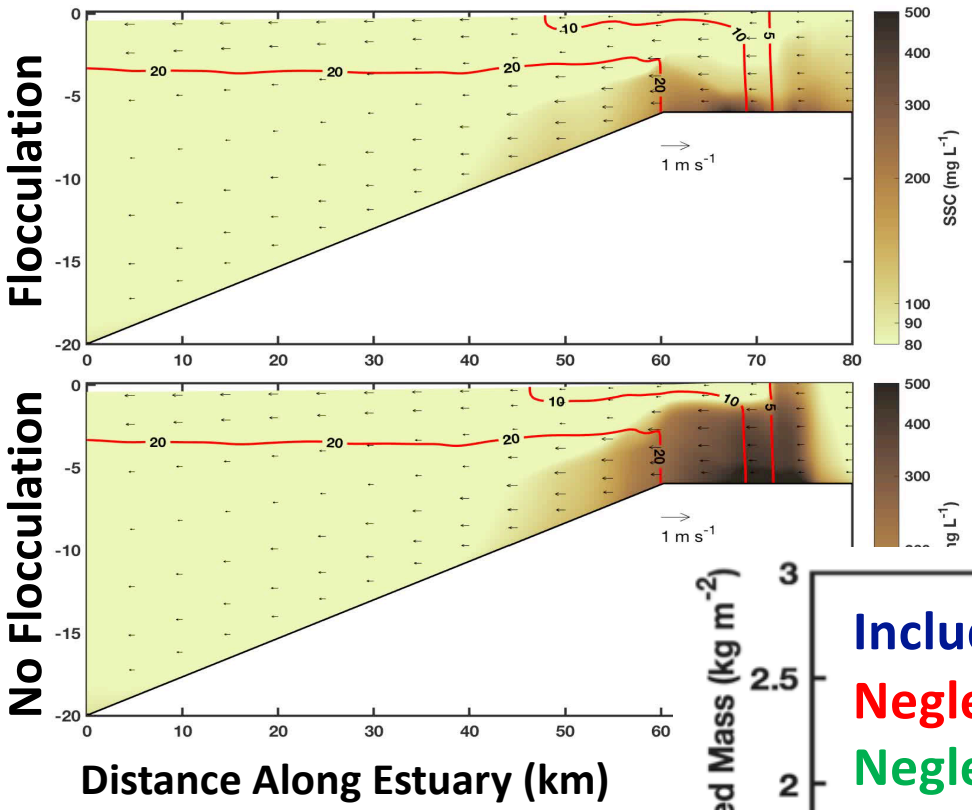
Tarpley et al. 2019. Tidal variation in cohesive sediment distribution and sensitivity to flocculation, bed consolidation in an idealized, partially mixed estuary. *JMSE*


With
Flocculation
Without
Flocculation
Depth (m)
Distance Along Estuary (km)
SSC (mg L-1)
1 m s-1
20
10
5
0
-5
-10
-15
-20
0
10
20
30
40
50
60
70
80
500
400
300
200
100
90
80

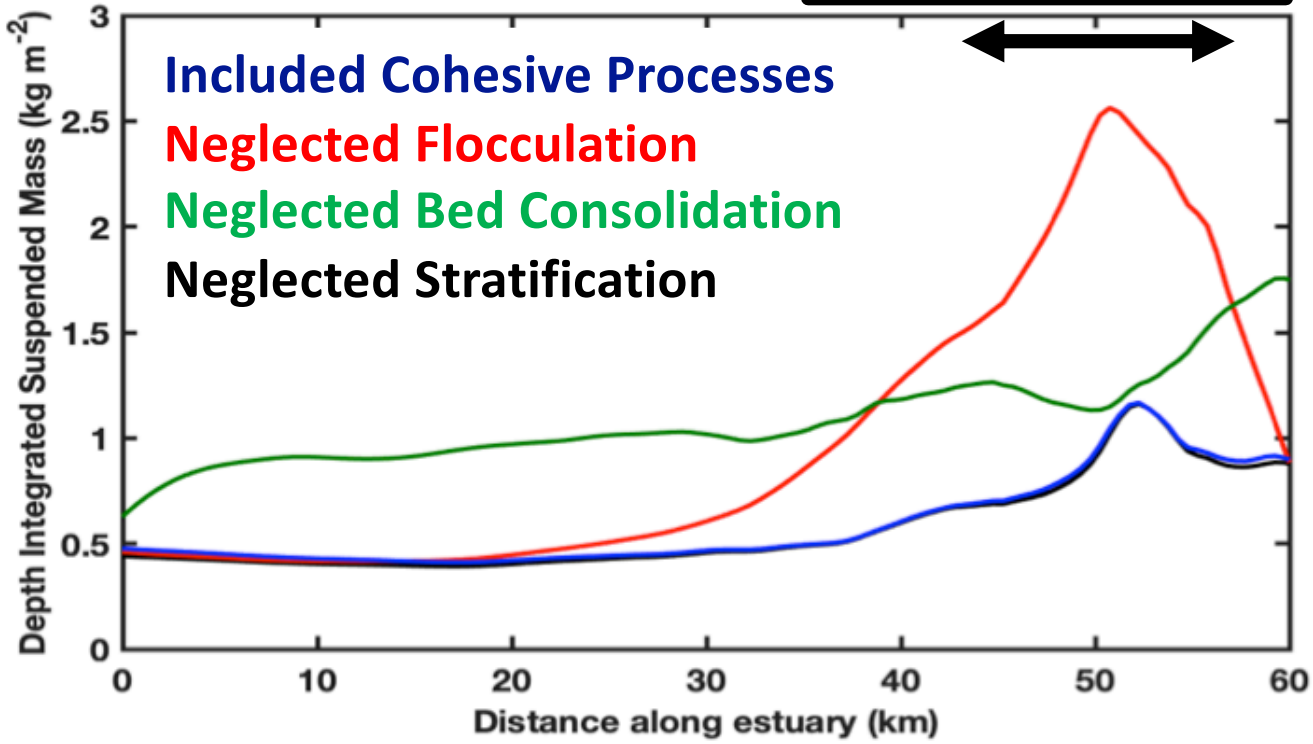

Depth (m)
0
-5
-10
-15
-20
0
10
20
30
40
50
60
70
80
20
20
20
10
10
5
1 m s-1
With
Flocculation
SSC (mg L-1)
500
400
300
200
100
90
80
Depth (m)
Without
Flocculation
Distance Along Estuary (km)


ETM
With Flocculation
Without Flocculation
Depth (m)
Distance Along Estuary (km)
SSC (mg L-1)
1 m s-1
0
-5
-10
-15
-20
0
10
20
30
40
50
60
70
80
500
400
300
200
100
90
80
20
10
5

Including Cohesive Processes in an Idealized Estuary



Estuarine Turbidity Maximum



Tarpley, Harris, Friedrichs and Sherwood, 2019.

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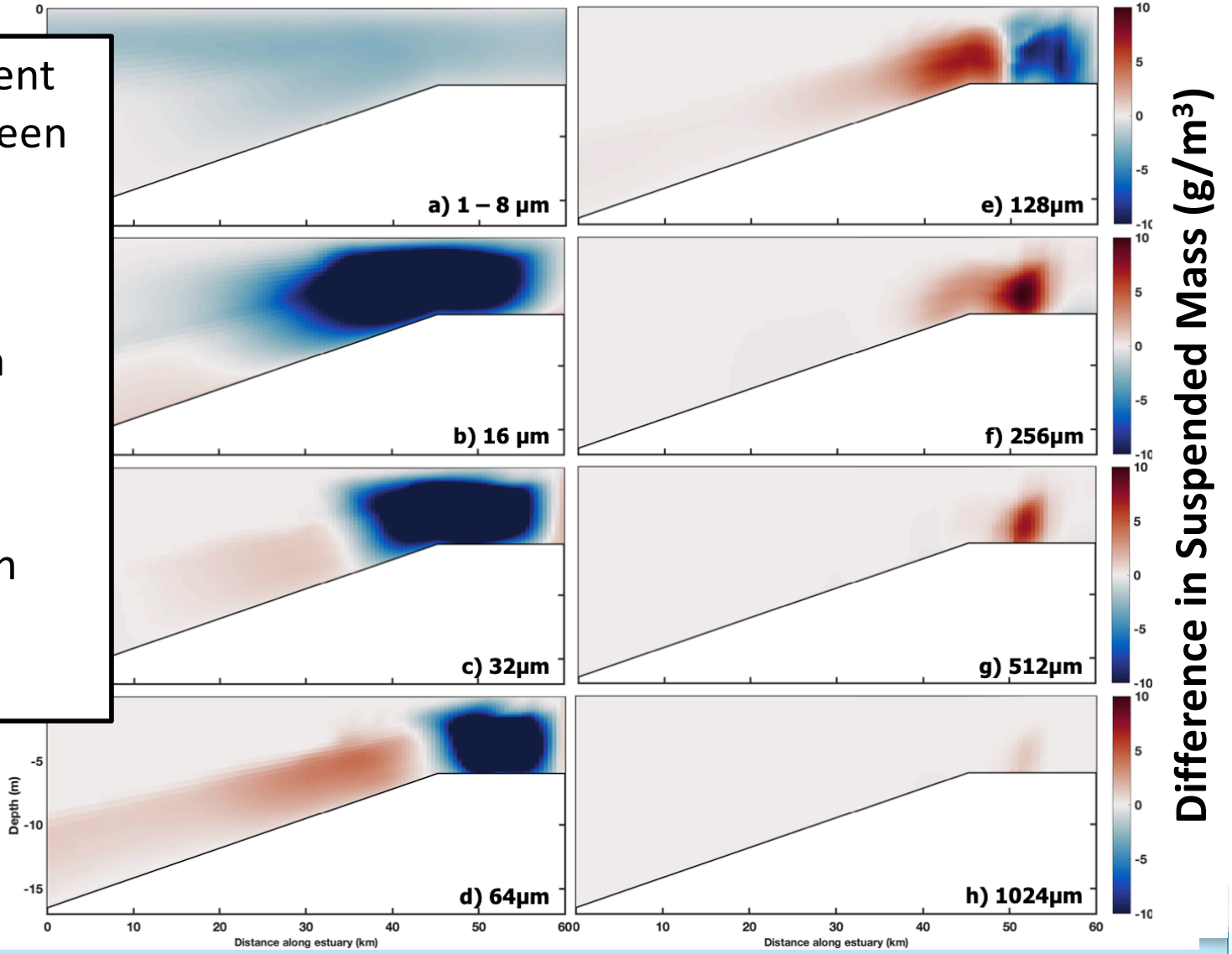
Flocculation shifted distribution toward coarser sediment in ETM

- Difference in sediment concentration between two model runs.
- For each size class:
  - Red -> Flocculation **increased** concentration
  - Blue -> Flocculation **decreased** concentration



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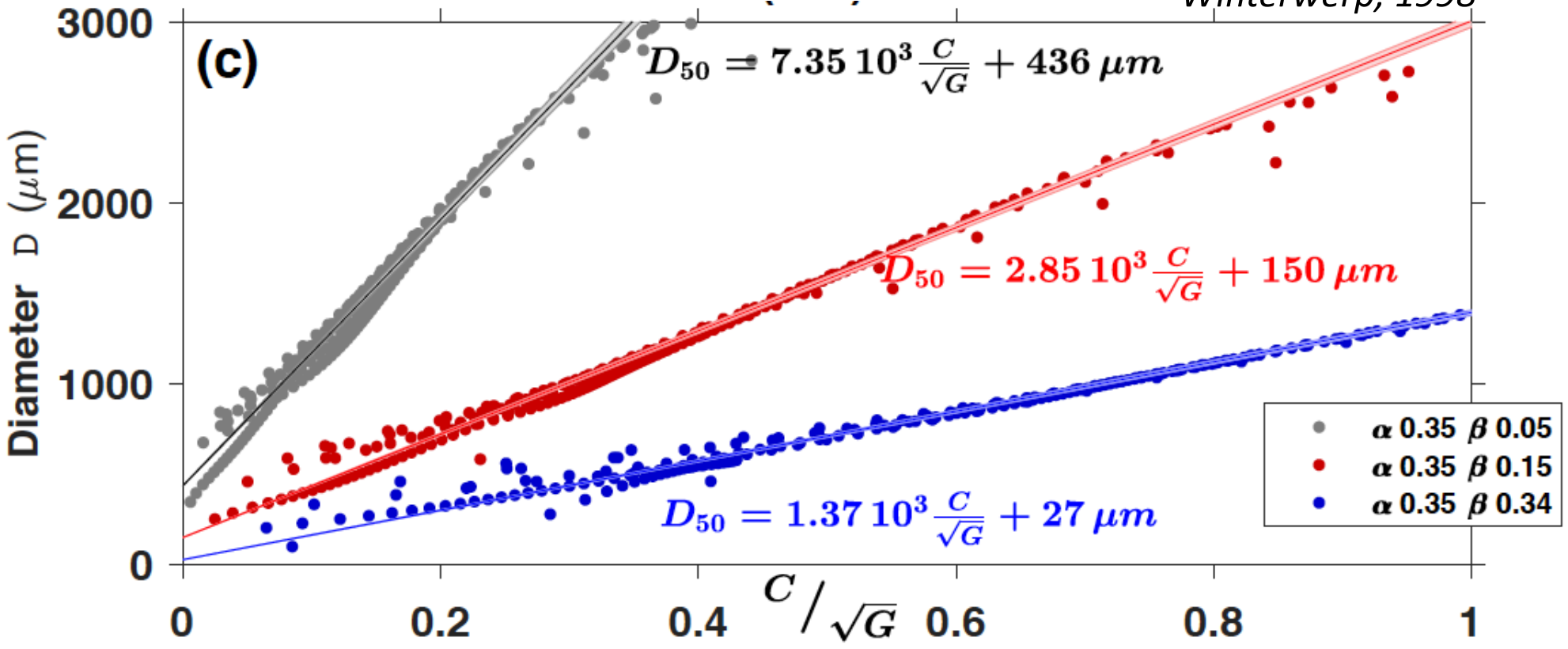
Tarpley, Harris, Friedrichs and Sherwood, 2019.

Question: Do floc sizes reach equilibrium in the idealized estuary?

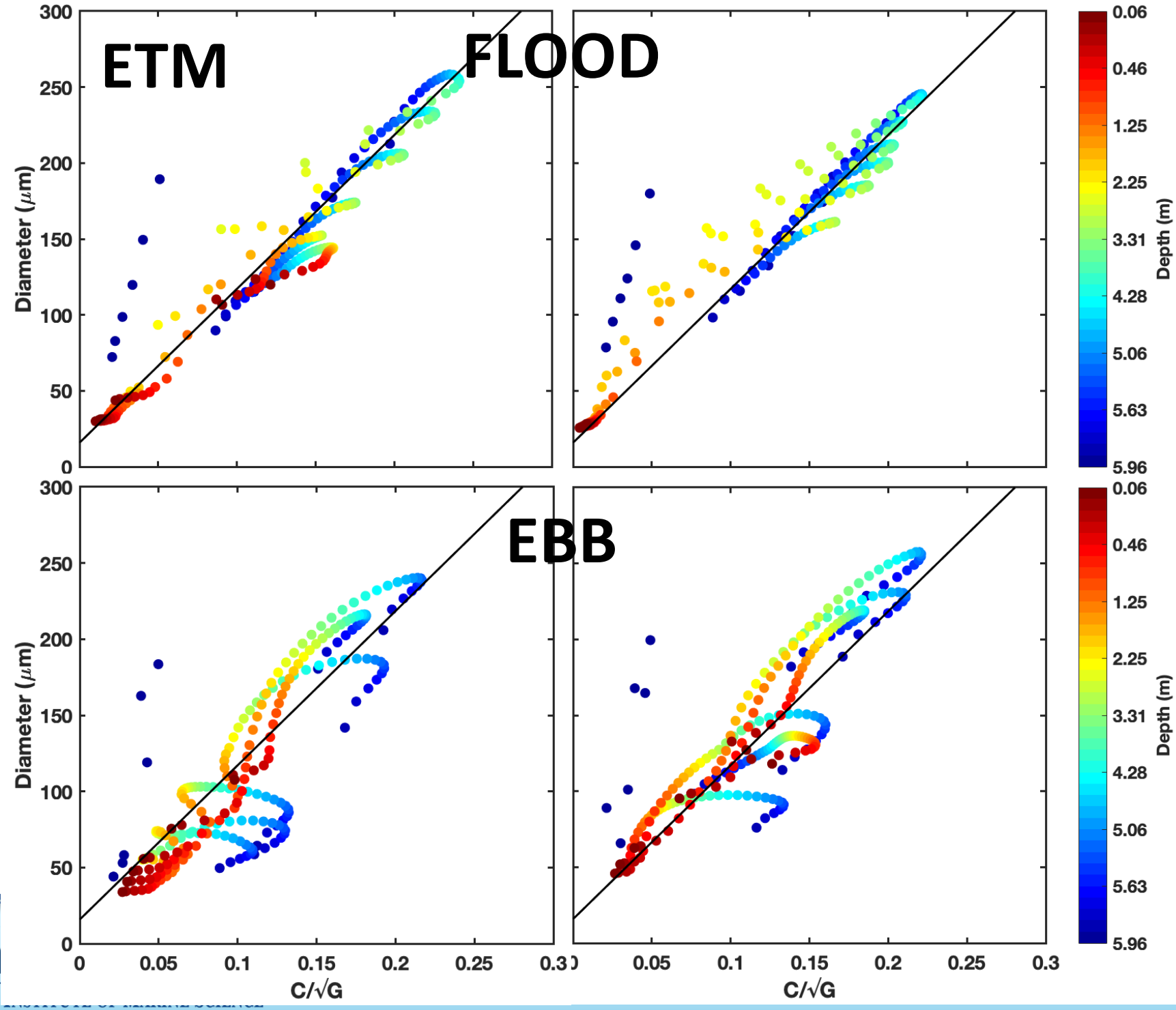
Answer: Sometimes.

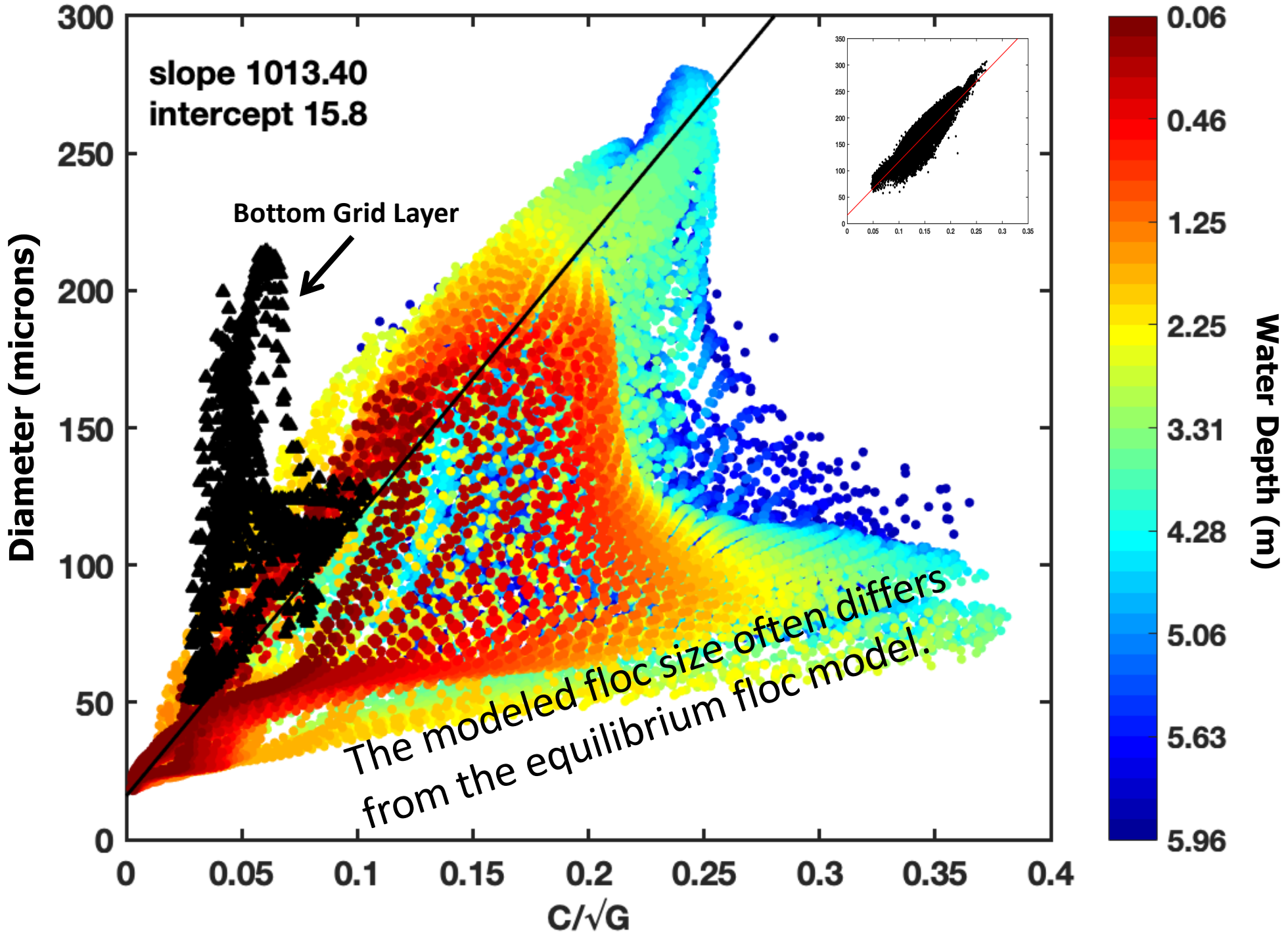
$$D_e = D_p + \frac{k_A c}{k_b \sqrt{G}}$$

Winterwerp, 1998



Sherwood et al., 2018


ETM
FLOOD
EBB
Diameter (μm)
C/√G
Depth (m)
0
50
100
150
200
250
300
0.05
0.1
0.15
0.2
0.25
0.3
0.06
0.46
1.25
2.25
3.31
4.28
5.06
5.63
5.96


slope 1013.40
intercept 15.8
Bottom Grid Layer
The modeled floc size often differs from the equilibrium floc model.
Diameter (microns)
C/√G
Water Depth (m)
0
50
100
150
200
250
300
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.06
0.46
1.25
2.25
3.31
4.28
5.06
5.63
5.96

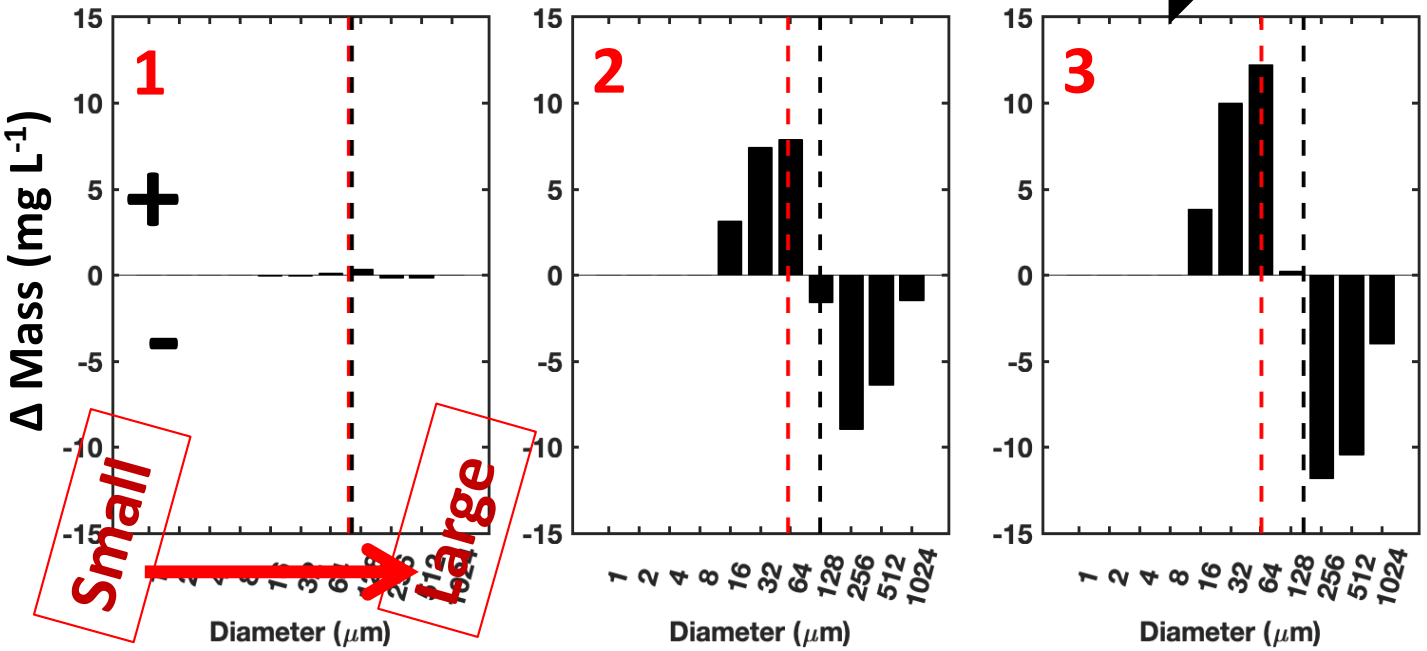
Equilibrium D
Modeled D

ETM Near Bed (~3 cmab)

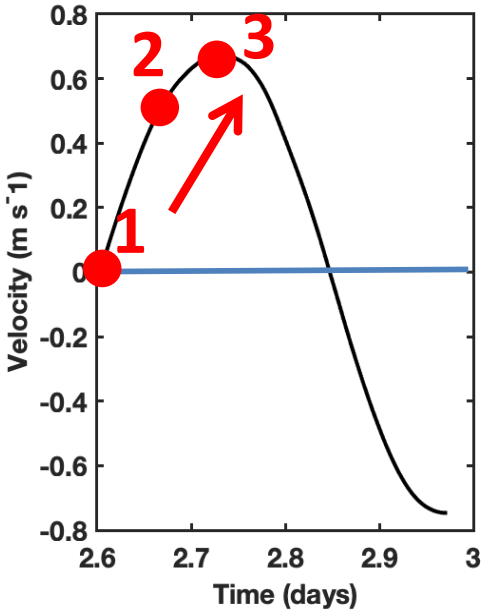
Slack

Increasing Flow

Flood



Depth Averaged
U-Velocity

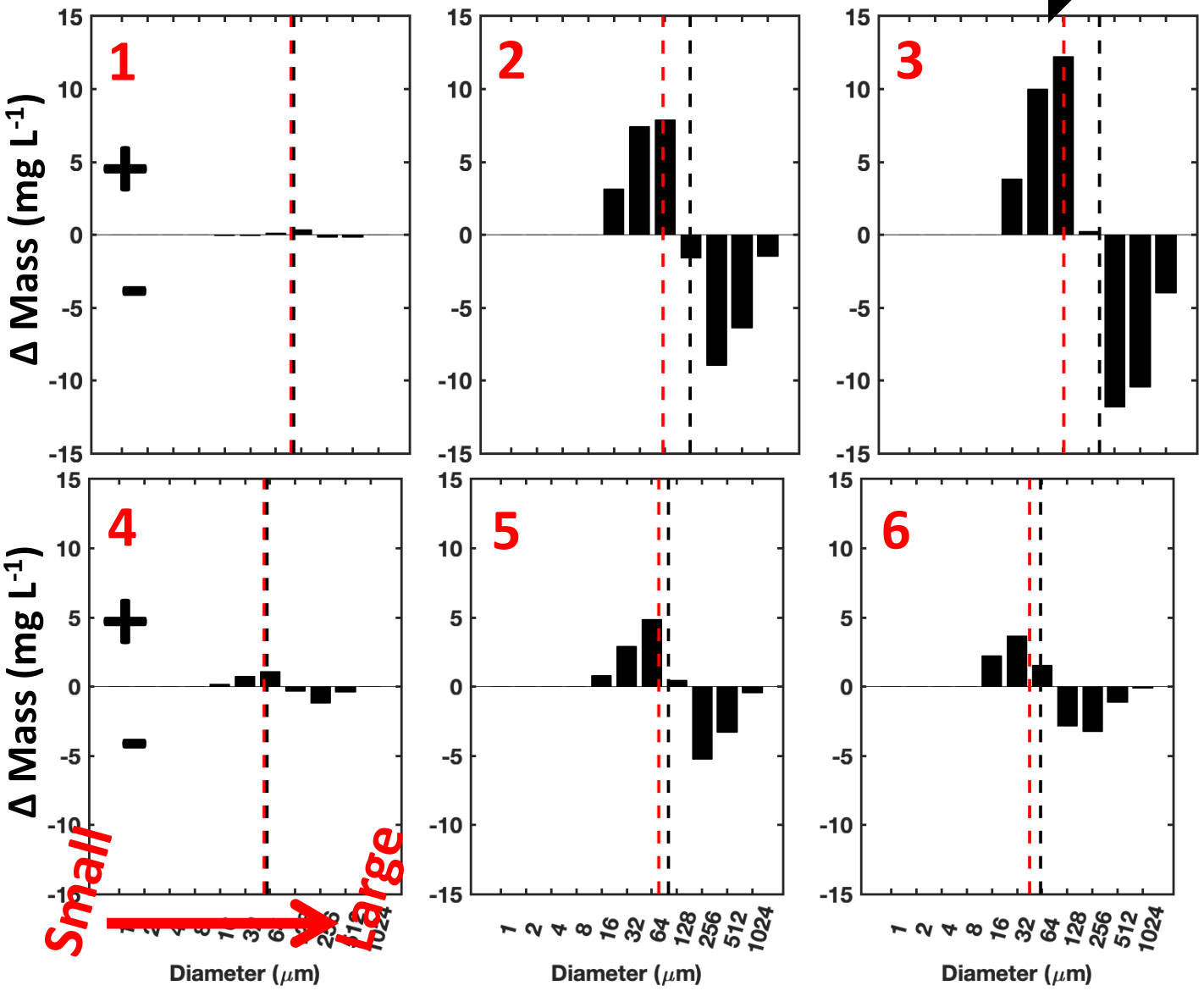


Disaggregation

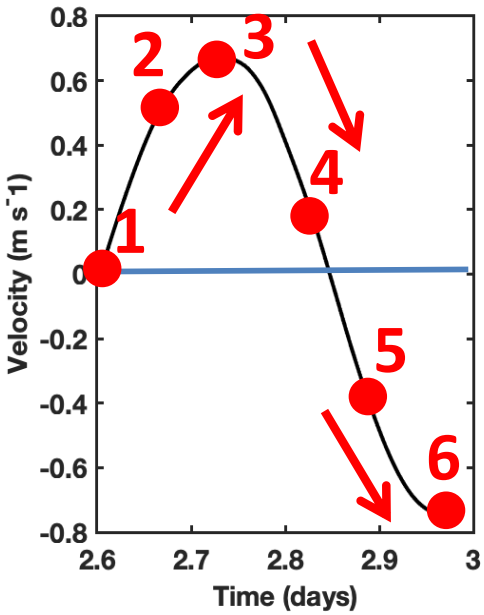
Equilibrium D
Modeled D

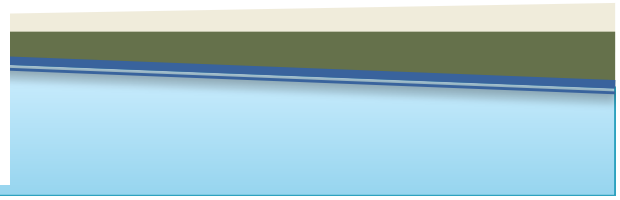
ETM Near Bed (~3 cmab)

Increasing Flow



Depth Averaged
U-Velocity

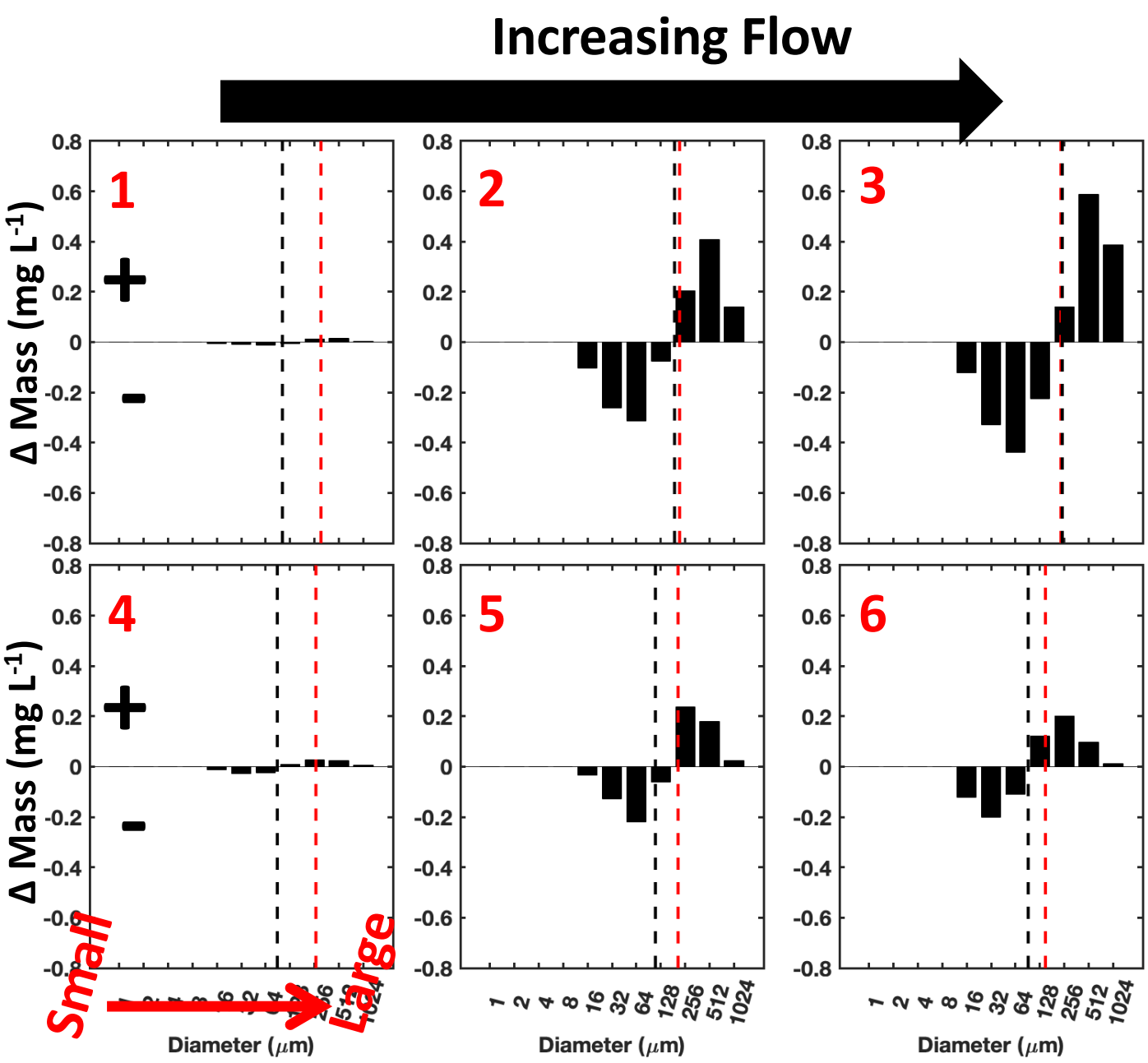




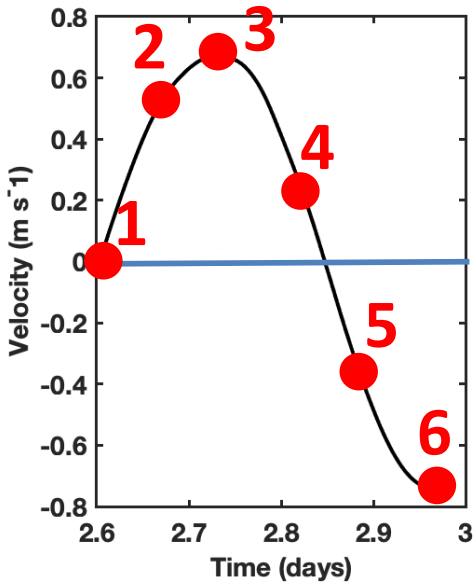
Equilibrium D

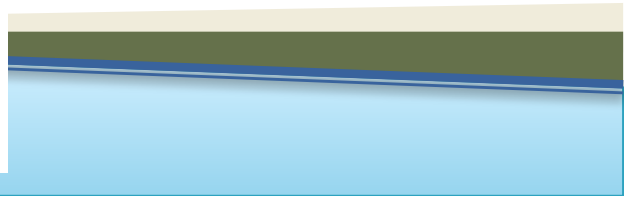
Modeled D

ETM @ ~90 cmab



Depth Averaged U-Velocity

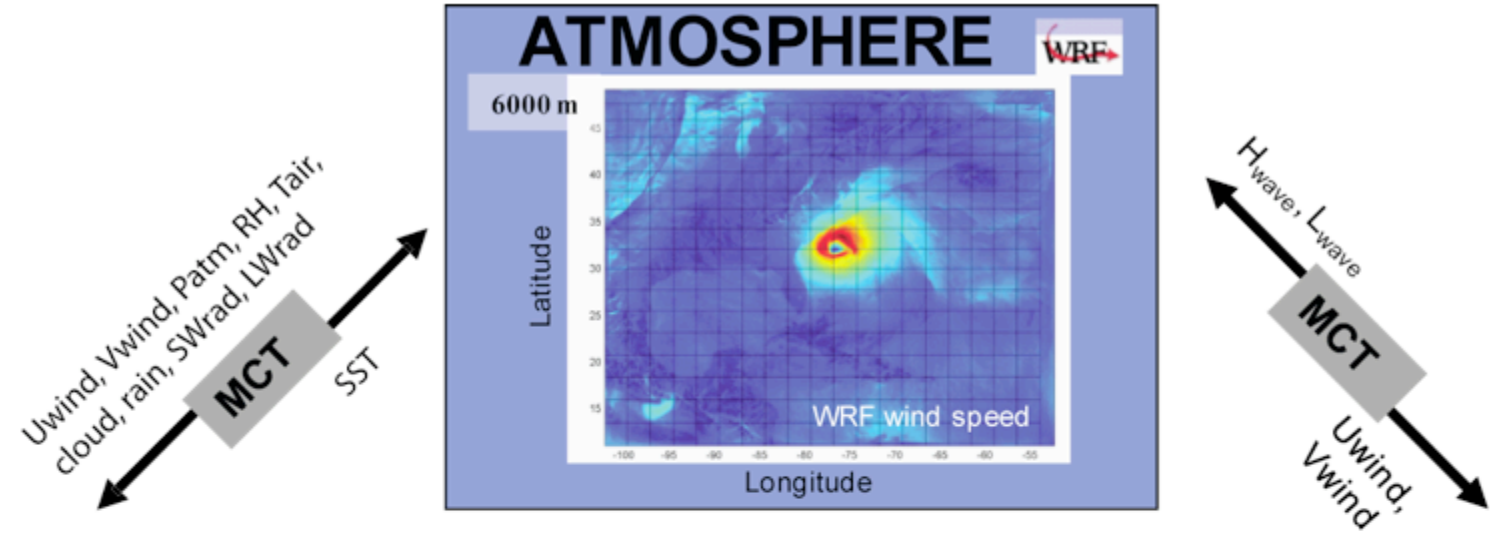


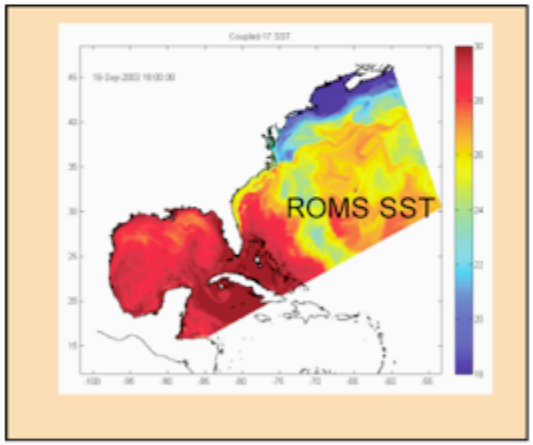


Conclusions from Idealized Estuary:

- The idealized estuary model reproduced key features such as estuarine circulation the ETM, and and relied on inclusion of cohesive processes (bed consolidation and flocculation). *(Tarpley et al. 2019)*
- Flocculation had the largest impact on SSC within the ETM. It reduced the average depth-integrated suspended mass by ~50% there. *(Tarpley et al. 2019)*
- Outside of the ETM, bed consolidation had the largest impact. It decreased the average depth-integrated suspended mass by ~50%. *(Tarpley et al. 2019)*
- Flocculation transferred as much or more sediment mass than horizontal and vertical advection and settling in the ETM.
- The floc model produced floc sizes that were often not equilibrated with the scaling expected by $C/\sqrt{G}$

COAWST: Model Coupling



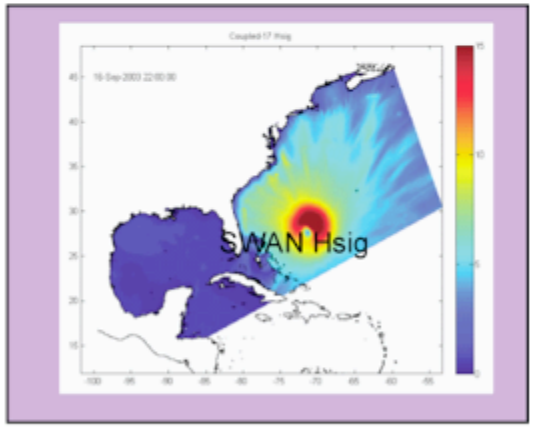


OCEAN ROMS

H_{wave}, L_{wave}, D_{wave}, T_{surf}, T_{bott}, Q_b, W_{dissip}, U_b

MCT

u_s, v_s, η, bath



WAVE SWAN

SEDIMENT

from: https://woodshole.er.usgs.gov/operations/modeling/COAWST/