Nearshore Processes

CIRP Tech Discussion
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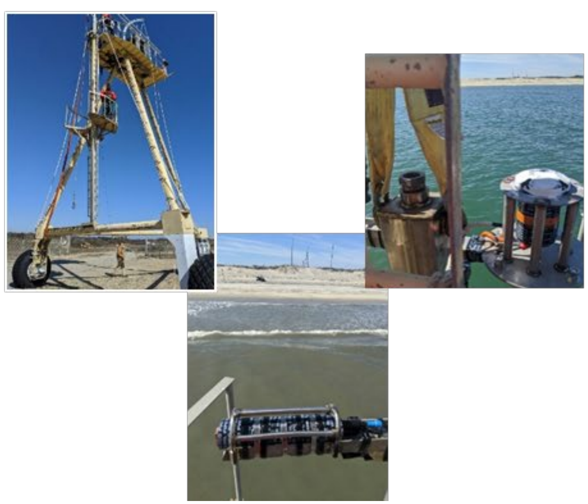
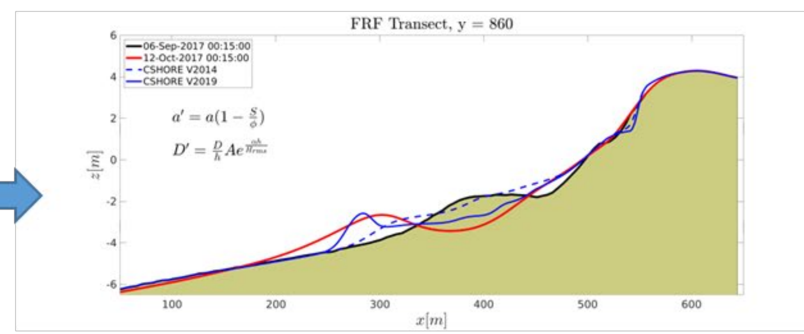
Measured Data to Advance Predictive Technology

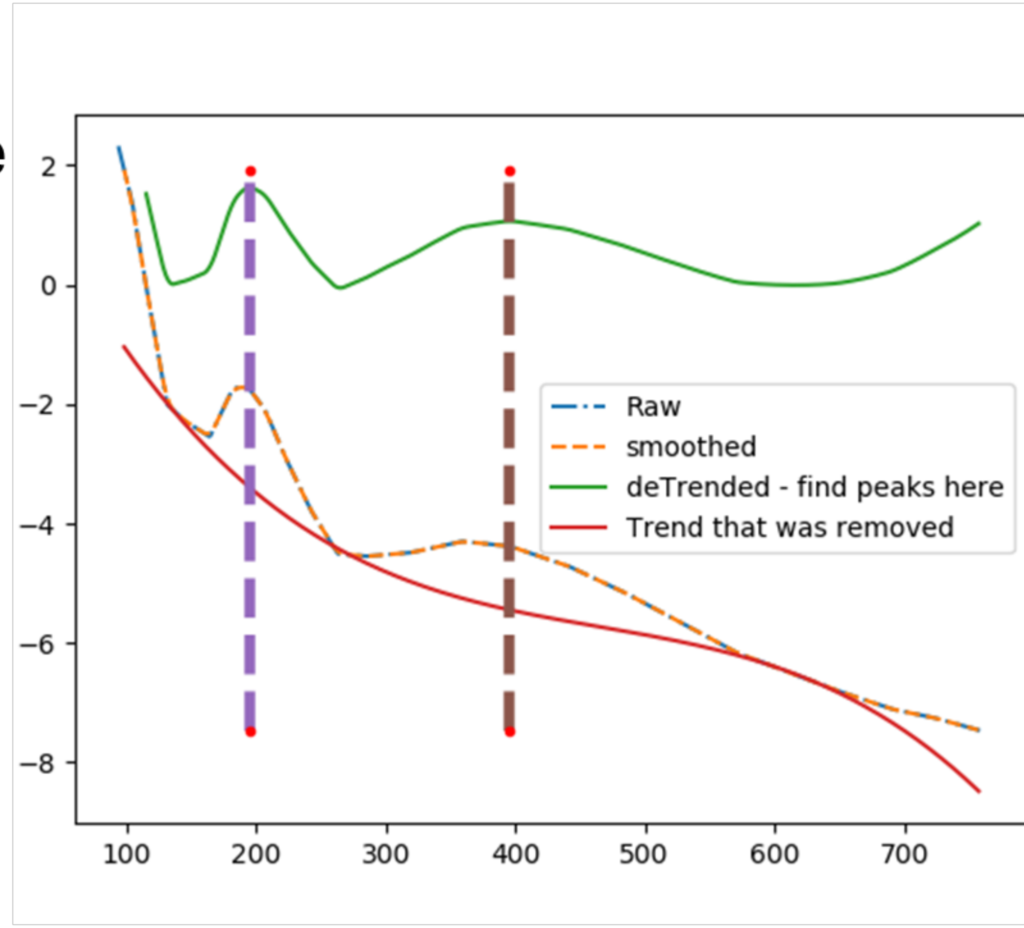
- To develop reliable predictive numerical modeling technology with skill and generality.
- A coherent view of the relevant physics must first emerge from observations. First principles model is not realistic.
- A practical numerical model is dependent on high-quality data for comparison and justification of empirical devices.
- FRF data provides new model/data comparisons for waves, currents, morpho change
- Still dependent on laboratory for detailed sediment data





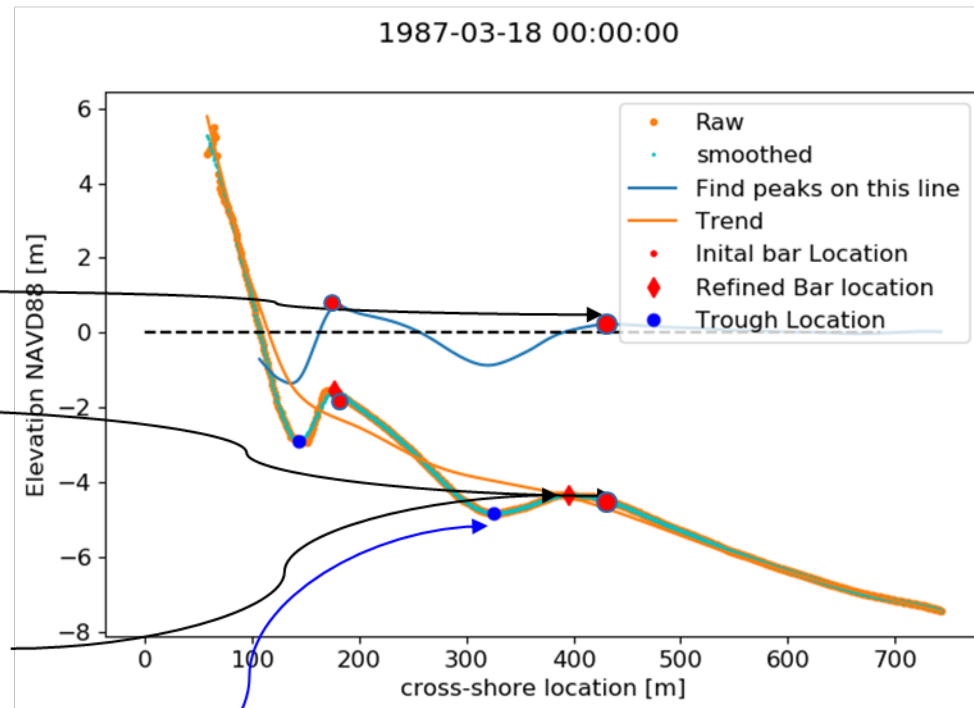
Sandbar evaluation tool

- Status:
  - Developed 1D profile tool
    - Applied it in 2D
      - Worked OK
  - Explored 2D method from GIS world
    - Geomorphons
    - Comes with GRASS
      - GIS world comes with its own complications
        - rigid API's



1D - How's it work?

- Smooth measured data (dots) to produce smoothed profile
- Remove cross-shore trend
  - Mean profile from 1987-2019 (this case)
- Produce detrended signal and find peaks (small dots)
- Place locations (dots) on measured profile
- Find dx/dz = zero onshore of intial bar location to create refined bar location (diamonds)
- For each bar location find deepest location shoreward of point to identify trough locations (circles)

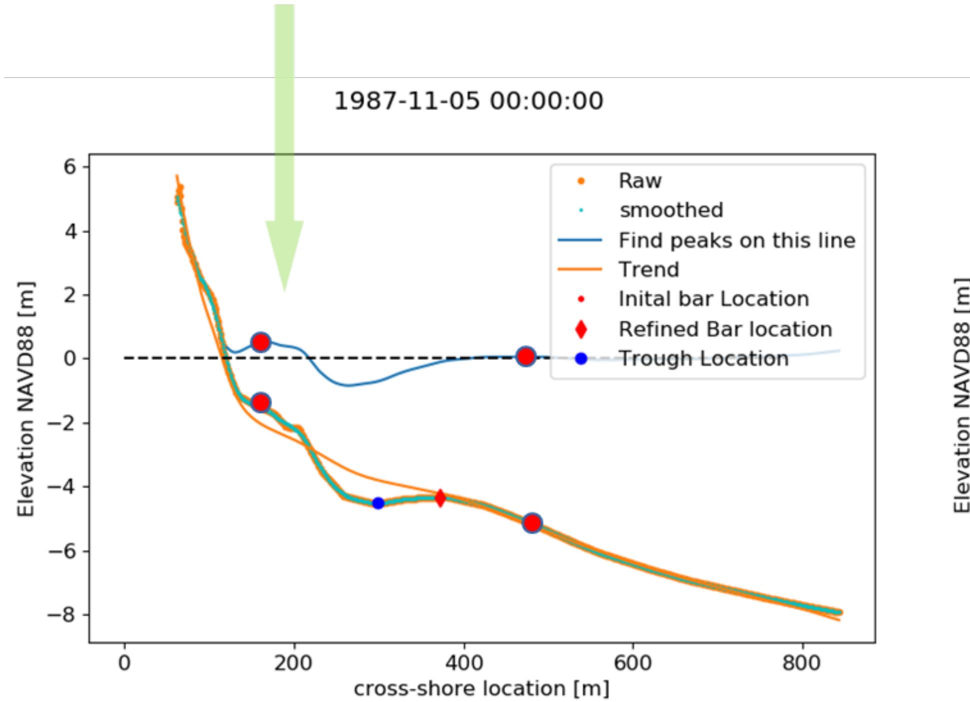


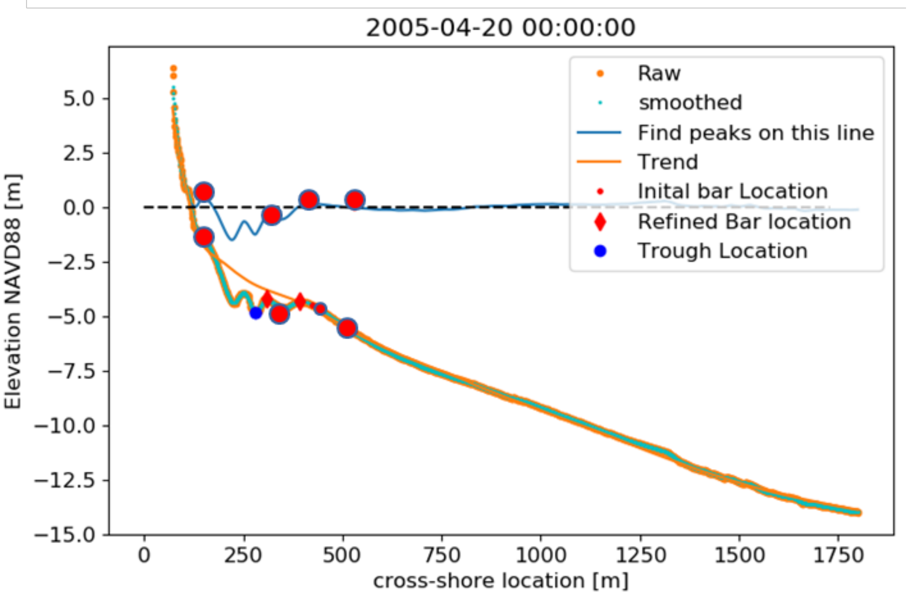
Sometimes it works really well!

Not always!

- Next month from previous slide
- Misses potential sandbar
  - What is a sandbar?

- How many sandbars do I have? Troughs?





Extracting Propagations in Data

Classic EOFs can only identify temporal variability of a stationary spatial pattern.

Applying a Hilbert Transform to obtain complex EOFs:

$$\tilde{Z}_b(x,t) = \tilde{z}_{bar}(x,t) + iH(\tilde{z}_b(x,t))$$

Provides spatio-temporally varying EOFs defined by both magnitudes and phases (propagating behavior):

$$\tilde{z}_n(x,t) = S_n(x)R_n(t)cos[\theta_n(x) - \omega_n(t)]$$

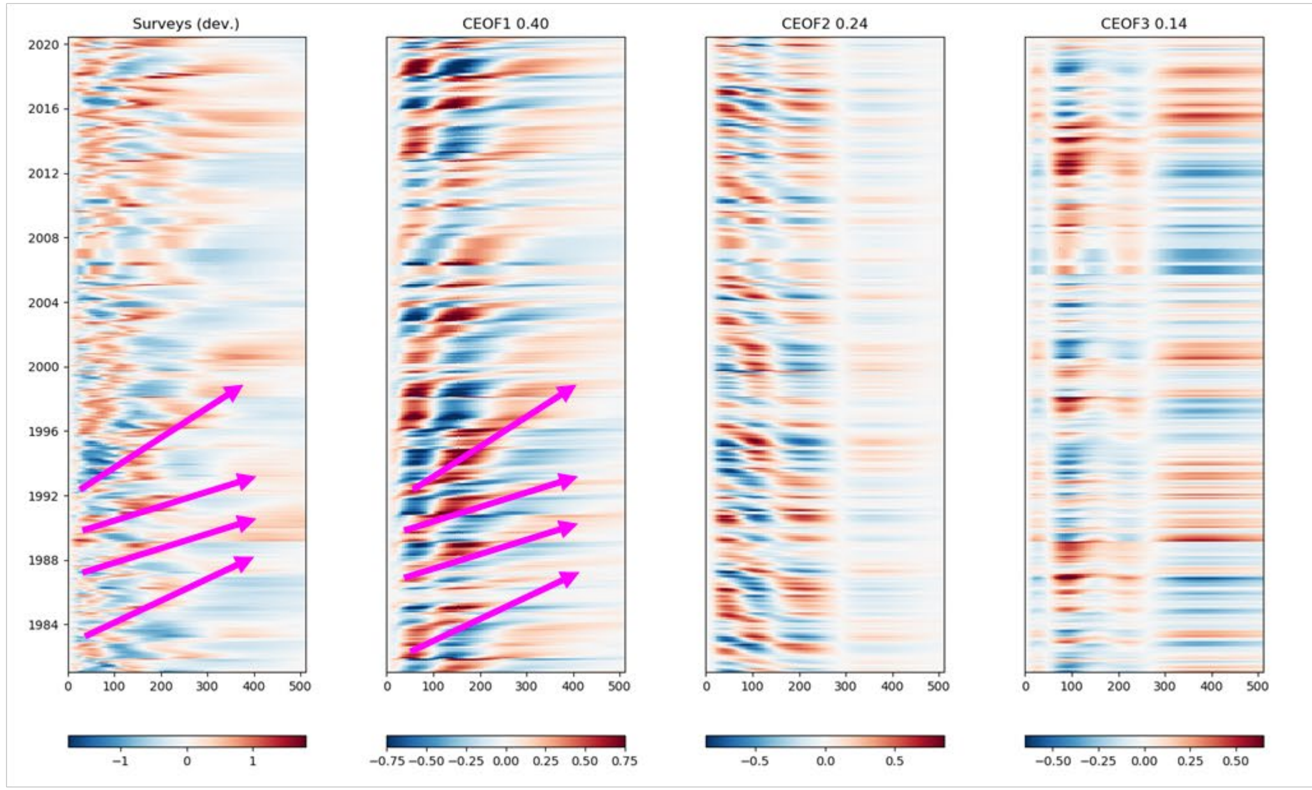
86% of variance is captured in the first 3 complex EOFs.

CEOF #1: Offshore Migrations

CEOF #2: Onshore MIgrations

CEOF #3: Large shifts of profile volumes

CEOF #4: Long-term trend of sediment accumulation (not periodic)



Common Morphologic States

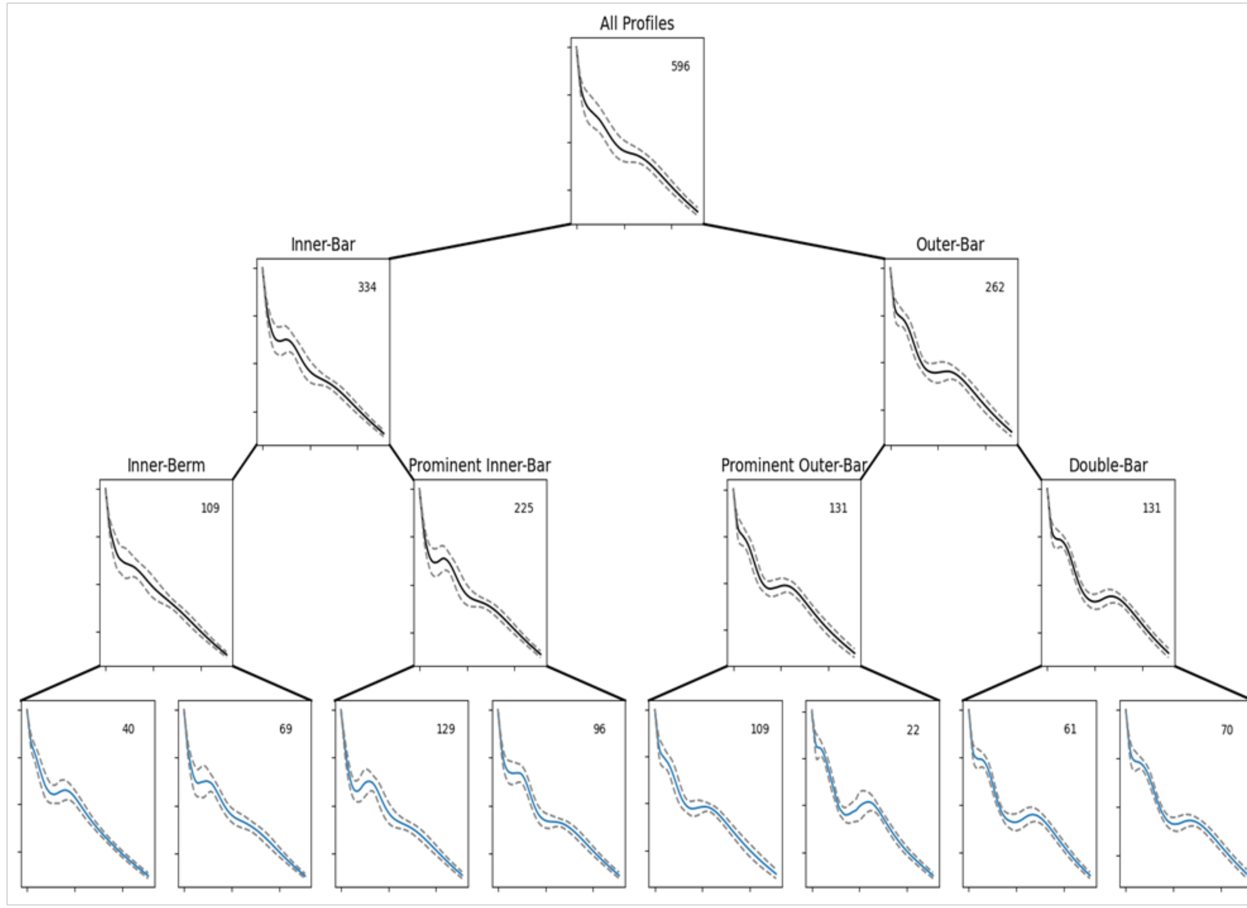
Hierarchical clustering in EOF space

Rather than the common deterministic approach of modeling a single historical sandbar migration (dozens of papers written on a single 3 week period in October 1997), the goal is to identify common transitions and assess if the forcing is statistically different from the climatological norm.

Clustering metrics suggest 8 morphology states is optimal: smallest cluster = 22, largest = 129

Captures a wide distribution in sandbar states while still providing many observations within each cluster to assess environmental forcing

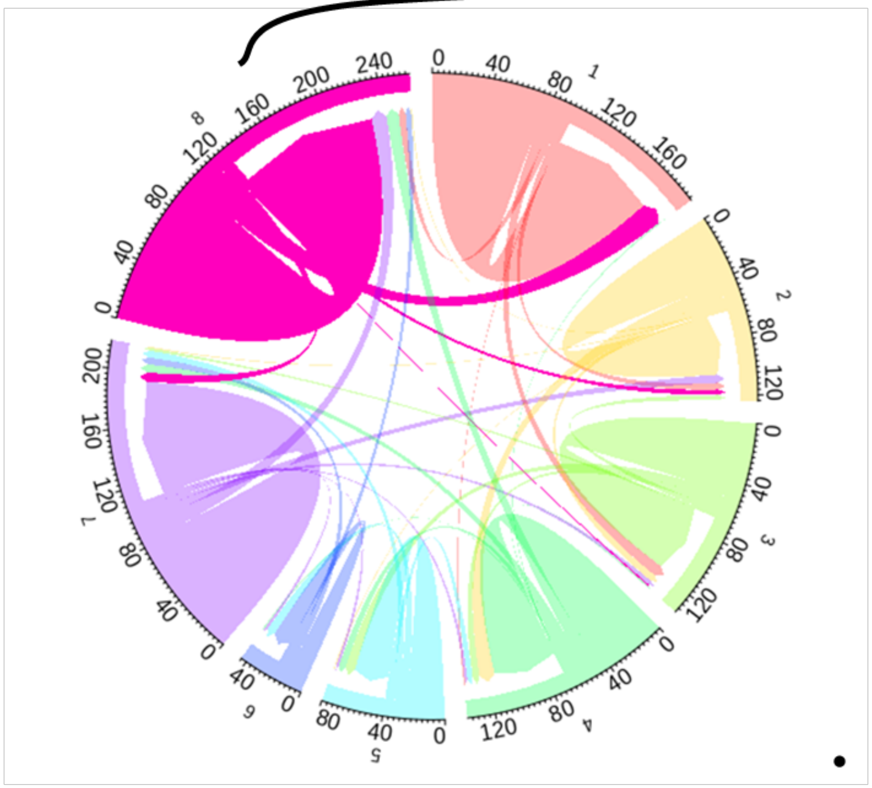
Ordering the clusters with respect to the phase of EOF#1 should logically order with respect to the offshore migration cycle.

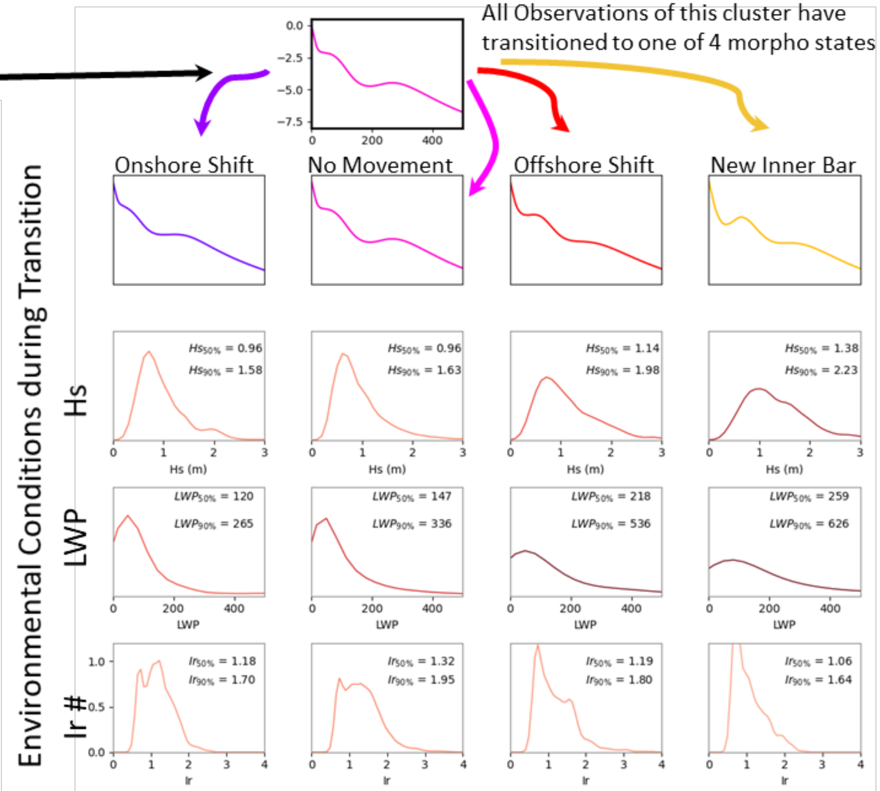


Environmental Forcing

Identifying what leads to onshore vs. offshore migration

Subset and bin environmental conditions between each survey depending on which morphologic state they created.

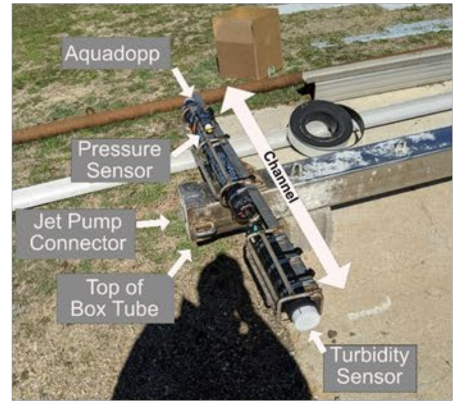


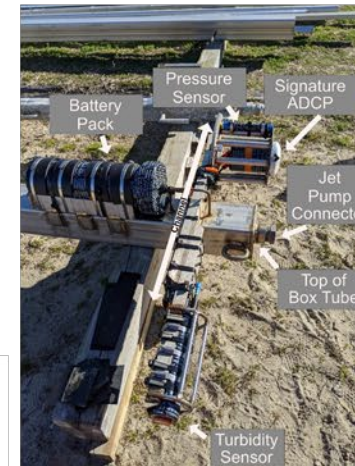


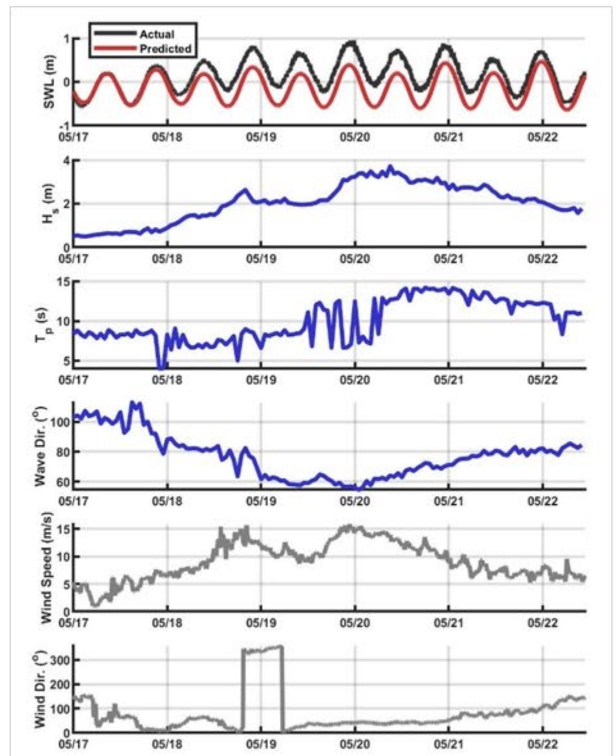
- Different distributions for different transitions!

Modeling Currents - data

- Objective is to develop an improved morphodynamic model
- Models generally have poor skill, but inaccuracy may be due to waves, currents, suspension, transport
- Opportunity to make a fundamental check on our models with new FRF data
- Data includes waves, wl, winds—So use as much of the available data to avoid compounding errors
- Currents-
  - **Sampling Plan:**
    Deployment – early March 20202
    Recovery – early June 2020
  - **Hydrodynamic Measurement Types:**
    Wave Spectra
    16 Hz Waves and Water Levels
    Vertical Current Profiling
    Turbidity Measurements







Modeling Longshore Currents

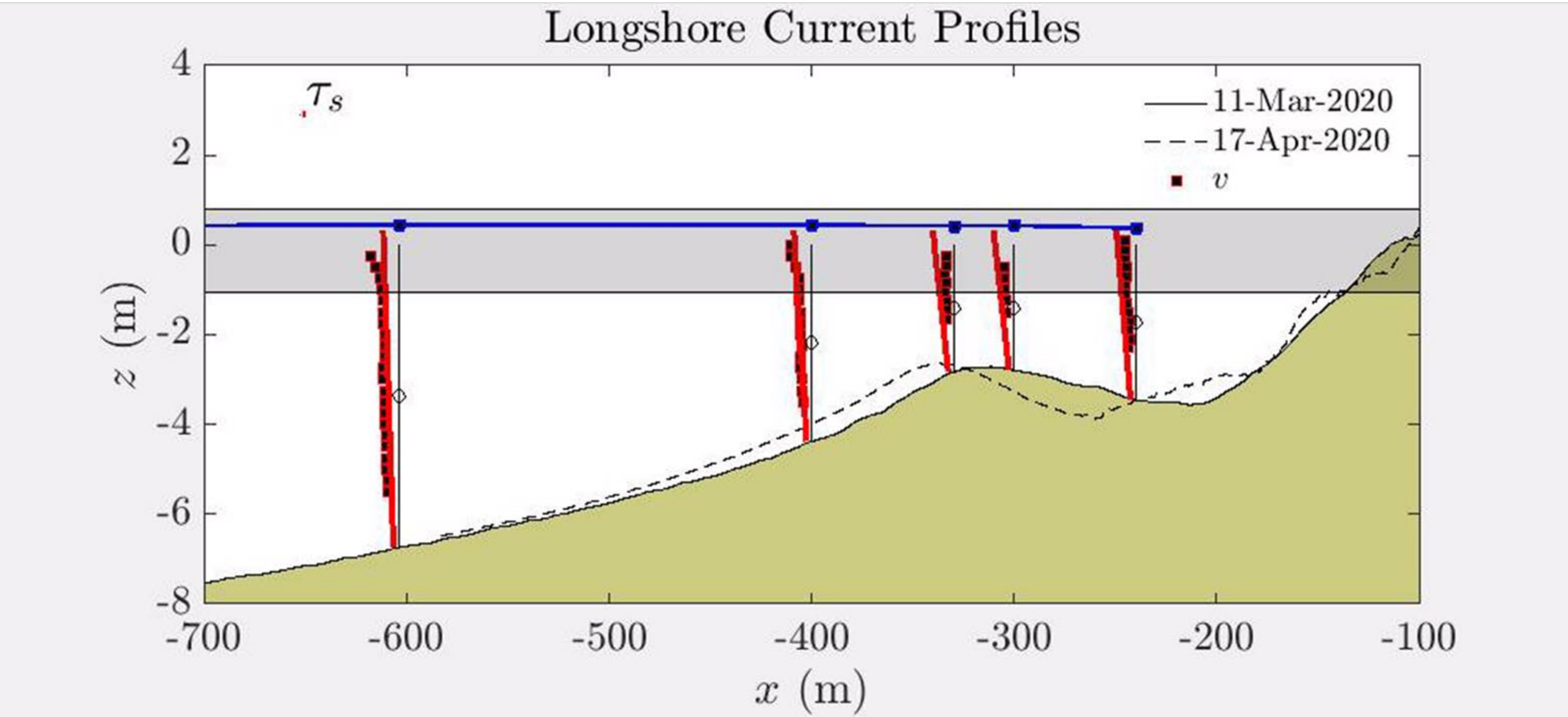
$$v = V + \tilde{v} + v'$$

$$\frac{\partial VU}{\partial x} + \frac{\partial VW}{\partial z} + \frac{\partial \overline{\tilde{v}\tilde{u}}}{\partial x} + \frac{\partial \overline{\tilde{v}\tilde{w}}}{\partial z} = \frac{1}{\rho}\left\{\frac{\partial}{\partial x}\tau_{xy} + \frac{\partial}{\partial z}\tau_{zy}\right\}$$

$$V = V_b + \frac{\tau_b}{\rho \nu_t} z' - \frac{D_B \sin\alpha}{\rho \nu_t c\,(\sinh 2kh + 2kh)}\left(kz'^2 + \frac{\cosh 2kz' - 1}{2k}\right)$$

- Data provides a justification for the simplifications
- Bottom shear stress is comprised of surface shear and wave stress
- Expression is ‘nearly’ quadratic

Modeling Longshore Currents

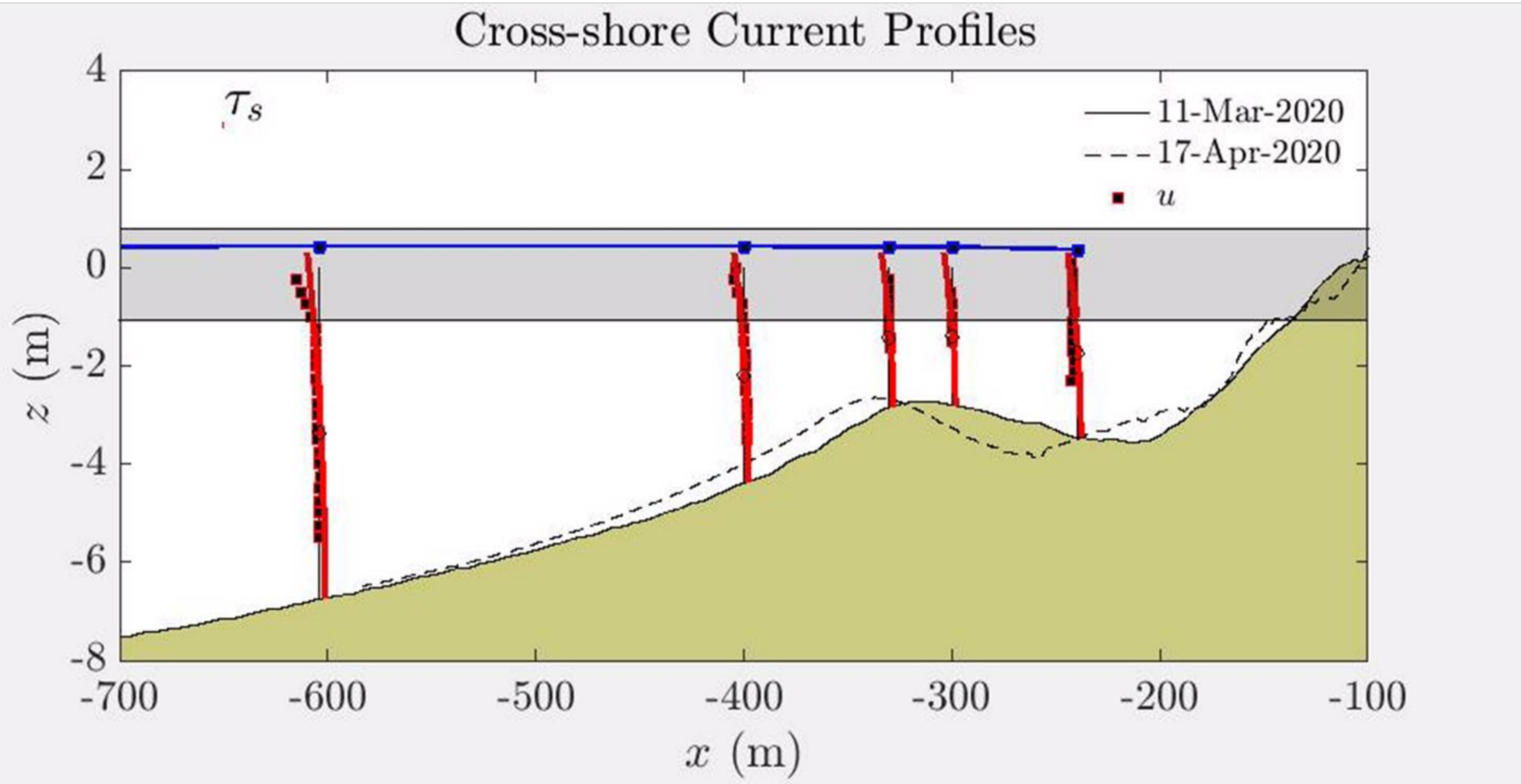


Modeling Cross Shore Currents

- The exact same approach used in LS is not possible in cross-shore (owing to the pressure part of the wave stress)
- If we assume that wave stresses(?) and eddy viscosity(ok) are depth-invariant, then appropriately described by quadratic in the vertical
- 3 conditions, stress on bottom, stress on top, Mass flux:

$$U = \left(\frac{Q_x}{h} - \frac{\tau_{bx} h}{2\rho\nu_t} - \frac{\tau_{sx} - \tau_{bx} h}{6\rho\nu_t} \right) + \left(\frac{\tau_{bx}}{\rho\nu_t} \right) z' + \left(\frac{\tau_{sx} - \tau_{bx}}{2h\rho\nu_t} \right) z'^2$$

Modeling Cross Shore Currents



Modeling Suspended Sediment

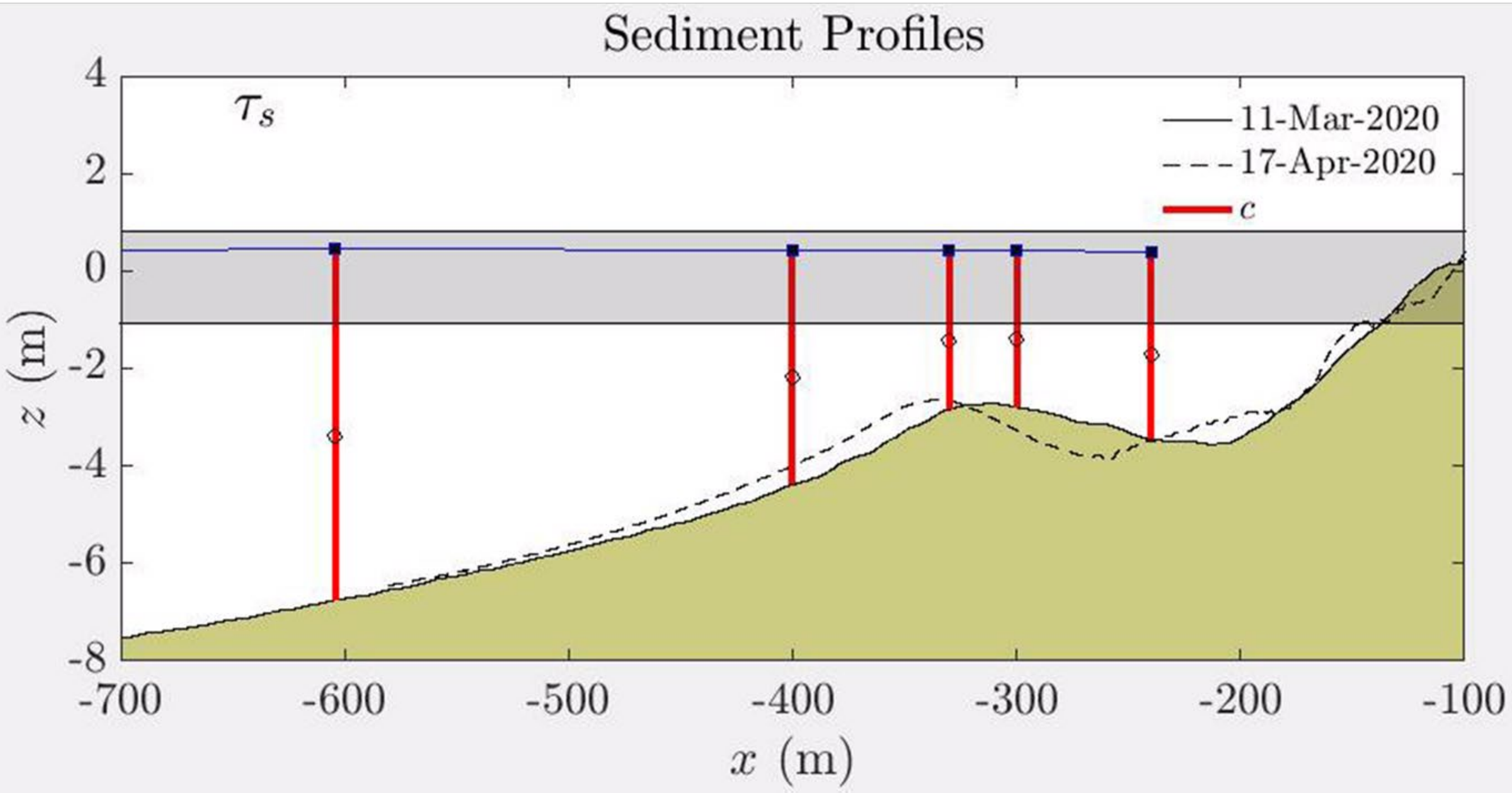
- •Depth-dependent currents provides the opportunity to move towards process-based models
- •Requires depth-dependent sediment profiles.

$$c = c_0 e^{-k_s z} \quad ; \quad k_s = \frac{w_0}{\nu_s}$$

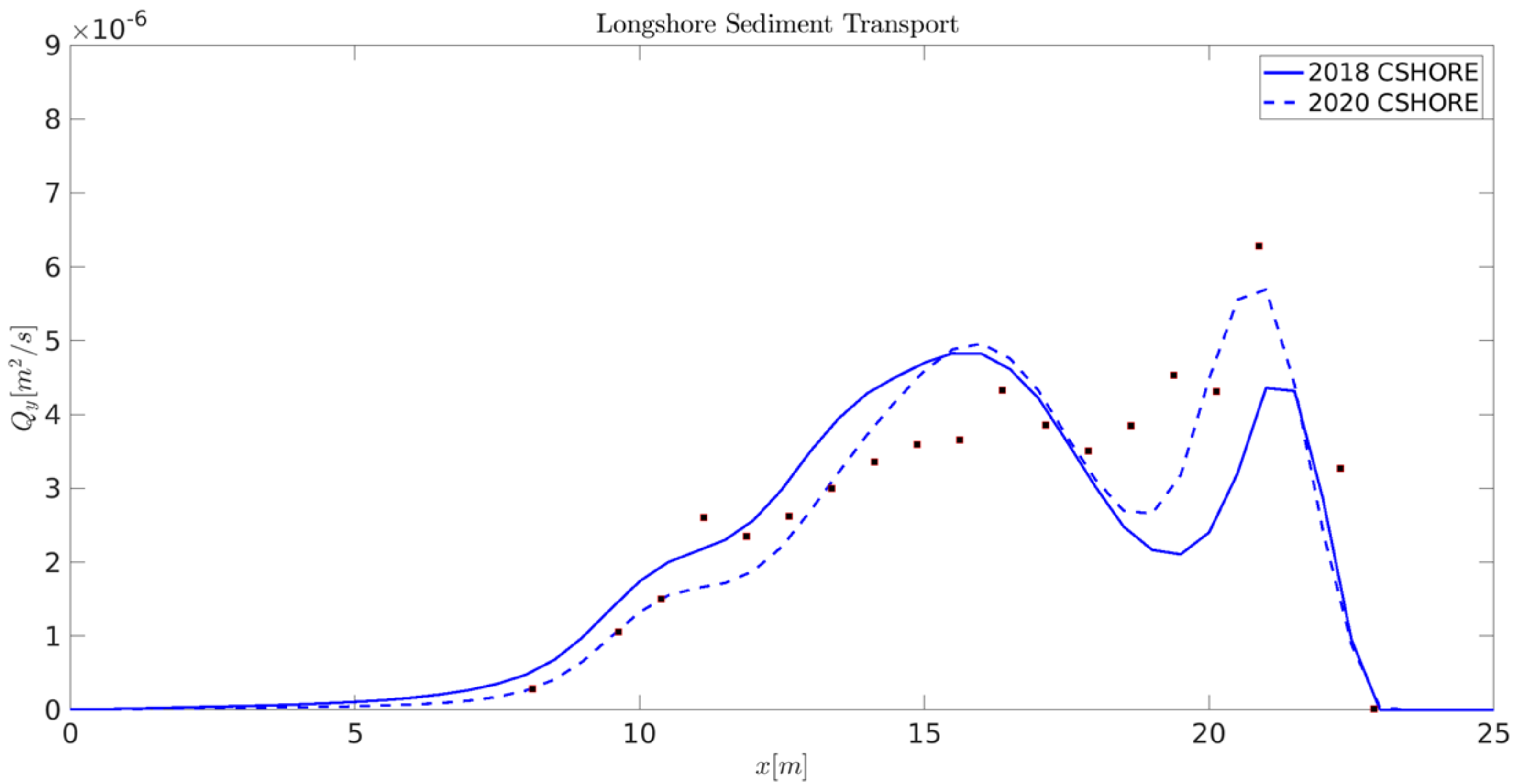
- •Tantamount to fall velocity matched by upward gradient diffusion
- •Near-bed concentrations are related to turbulent dissipation (a modified CSHORE method)
- •Simple analytic expressions permit the corrected transport at no computational expense

$$\int_0^h cU\,dz = \frac{c_0 A_0}{k_s}\left(1 - e^{-k_s h}\right) + \frac{c_0 A_1}{k_s^2}\left(1 - e^{-k_s h}(k_s h + 1)\right) + \frac{c_0 A_2}{k_s^3}\left(e^{-k_s h}\left(-k_s h(k_s h + 2) - 2\right) + 2\right)$$

Modeling Suspended Sediment



Modeling Suspended Sediment



Conclusions

- New data collection campaign is complete
- Analysis has goal of revealing the link where environmental conditions force morphology change(the detailed physical description can follow).
- New automated tool provides sandbar characteristics from survey data
- Simplified expressions for nearshore currents are developed, accounting for wind, waves stresses, depth-integrated mass-flux
- Model and data compassion is encouraging indicate: breaking region is more accurate, wind is important, stress model at bed needs improvement.
- Analytic expressions for sand concentration are introduced, permit analytical expressions for transport. Departure from depth-integrated values may be important in ongoing comparisons to FRF morphology
- Improved inner surf zone transport prediction is shown in lab data.