CIRP TECHNICAL DISCUSSION
23 MARCH 2021

UPDATE ON AEOLIS MODEL DEVELOPMENT AND EXAMPLE APPLICATIONS

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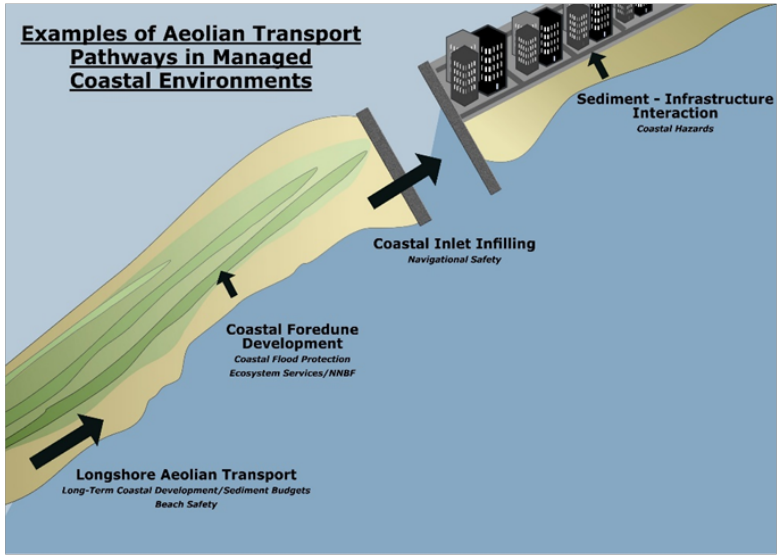
US Army Corps of Engineers®

CHL COASTAL & HYDRAULICS LABORATORY

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

DISCOVER | DEVELOP | DELIVER

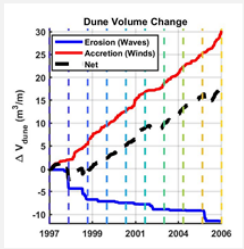


Tools for Simulating Aeolian Sediment Transport Near Inlets

Inlet Engineering Toolbox

Primary Work Unit Goal: Development of process-based numerical modeling tools for simulating aeolian transport and dune evolution in managed coastal environments

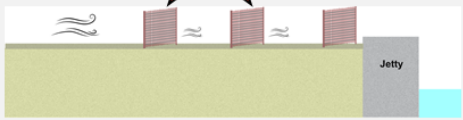
Dune Response Tool



Modeling Aeolian Transport and Coastal Management Alternatives Near Inlets

Aeolis
(open source model)

+ sand fence model
+ vegetation planting



Co-Evolution of Coastal Morphology from Wind and Waves

High — **Tool Level of Maturity** — *Low*

Short (hours to days) — **Time Scale of Interest** — *Long (months to years)*

Outline for Today

- Model Overview

- New Aeolis Capabilities that have been Added this FY

- Example Cases for USACE Applications

- Ongoing Developments and Next Steps

Model Processes

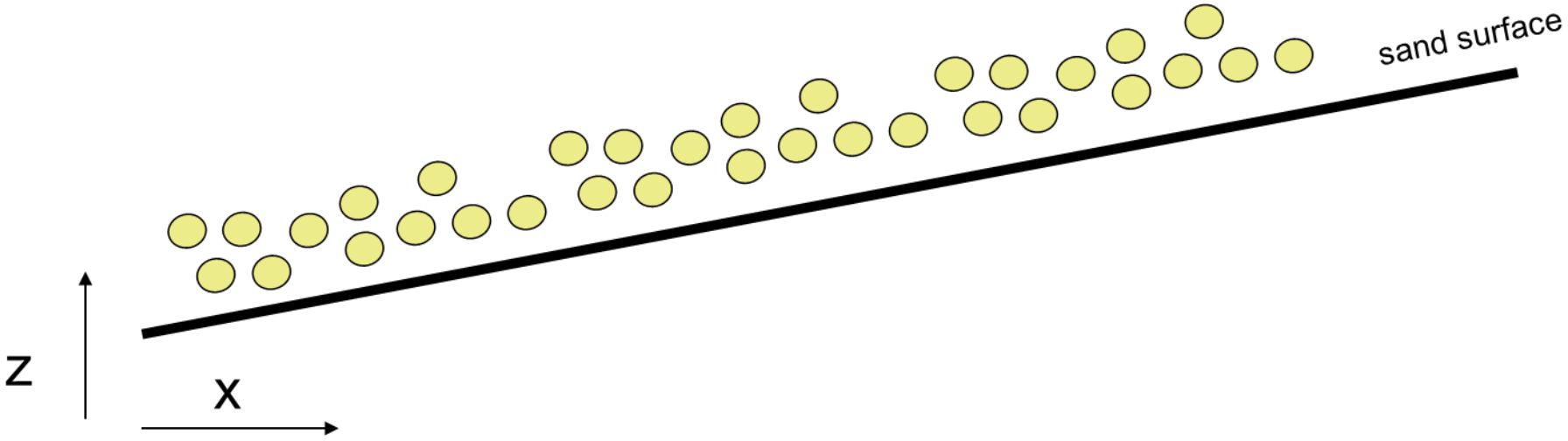
wind (u)

$u < u_{th}$ - no transport

$u \geq u_{th}$ - transport

Factors that Effect Threshold Velocity:

- Grain Size
- Moisture
  - Precipitation
  - Wave Runup
  - Groundwater
  - Humidity
- Bedslope Effects
- Salt Crusting

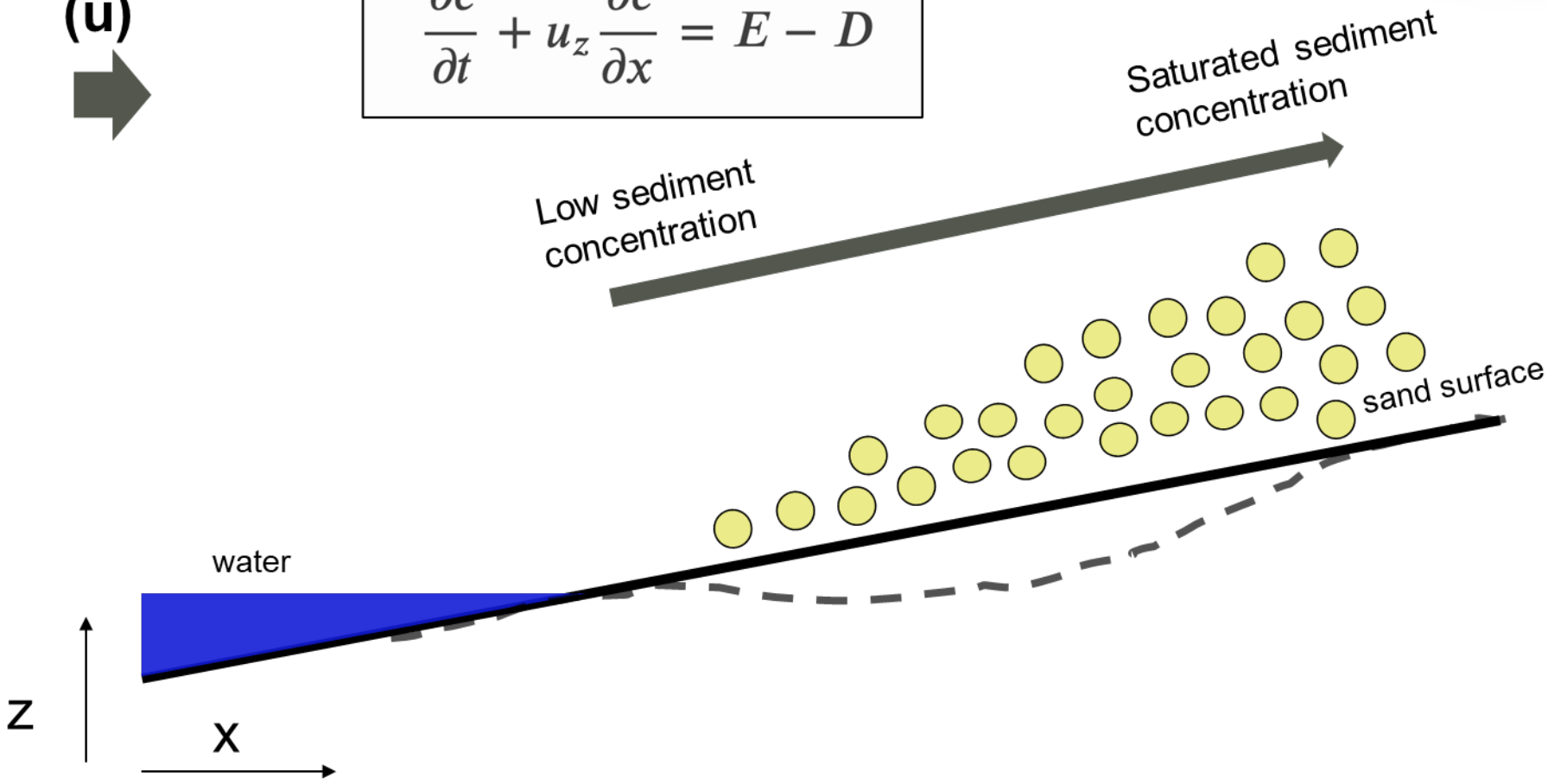


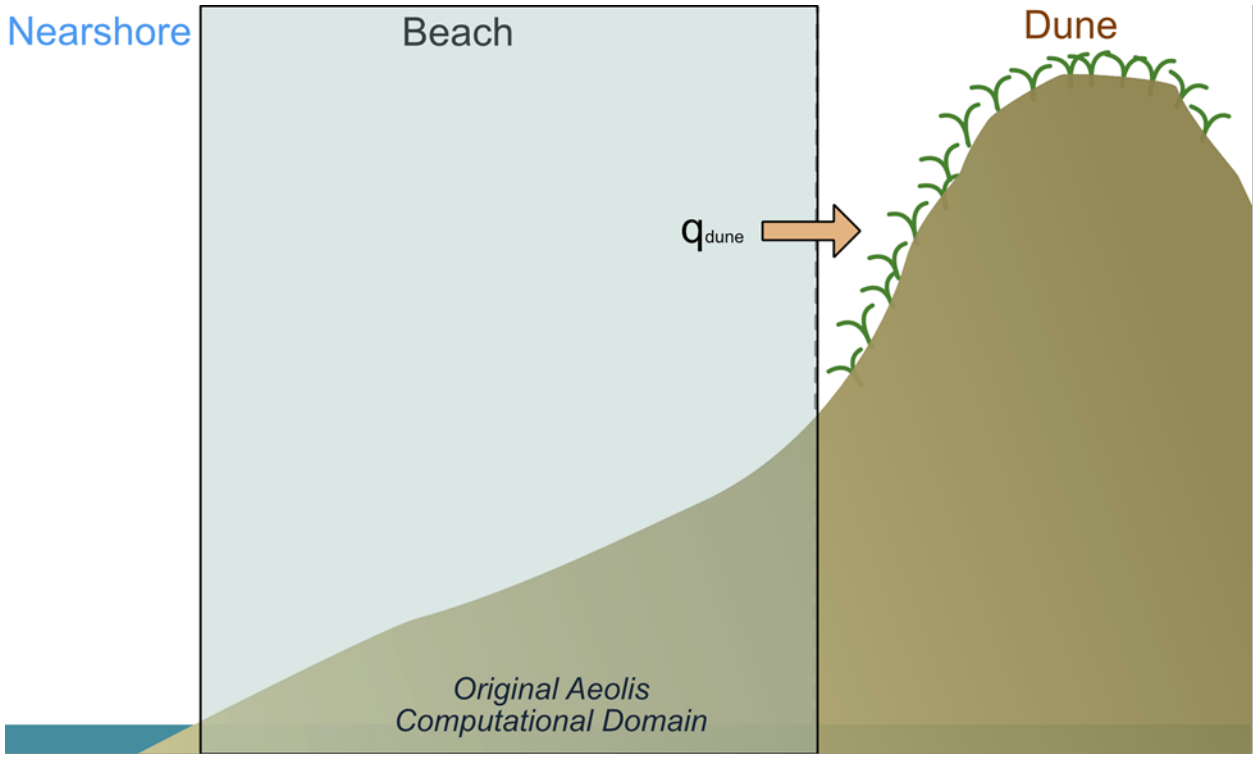
Model Processes

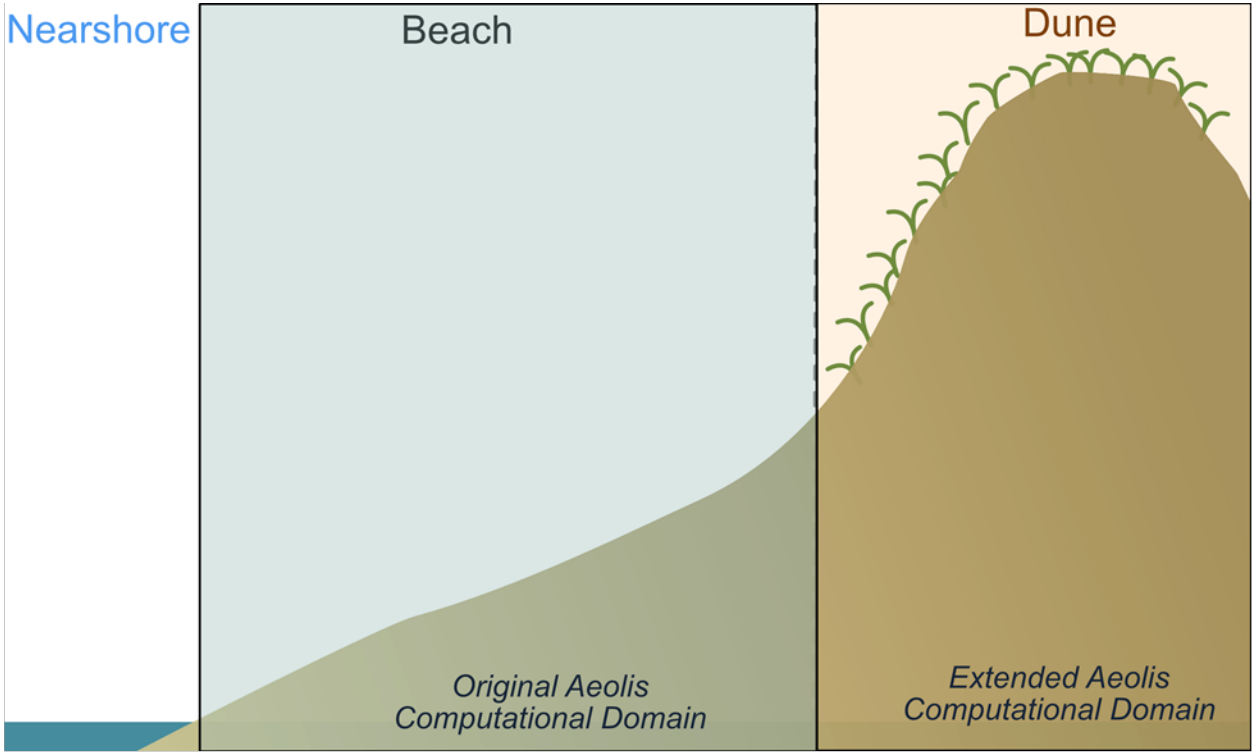
wind
(u)

Advection Equation

$$\frac{\partial c}{\partial t} + u_z \frac{\partial c}{\partial x} = E - D$$

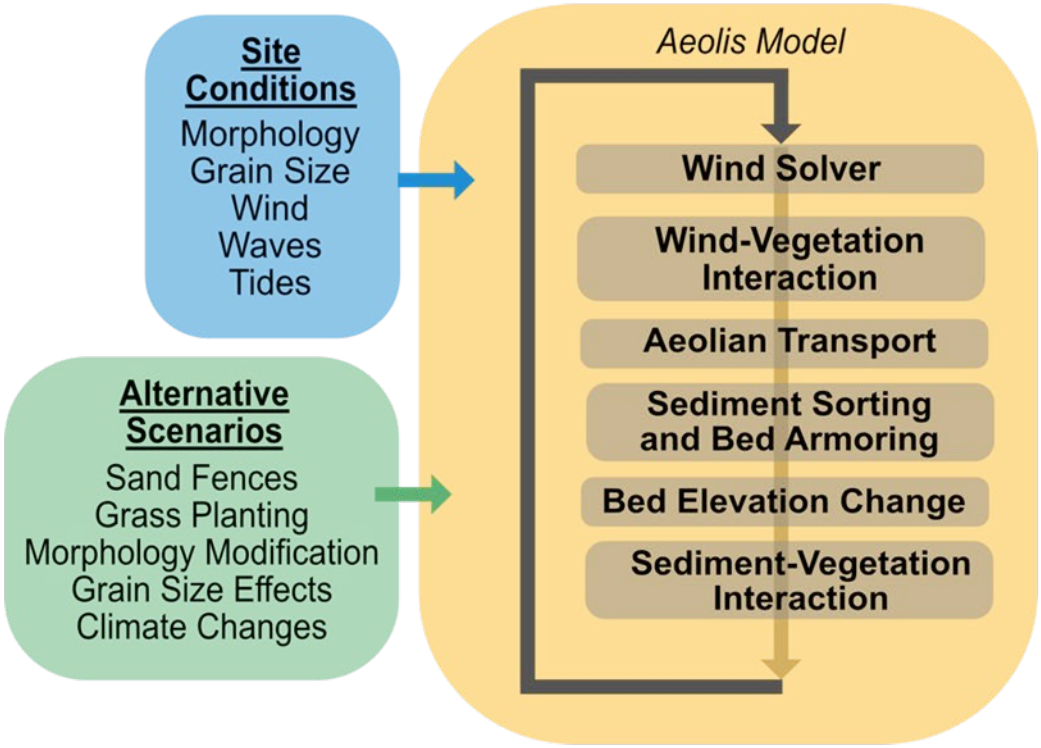



Nearshore
Beach
Dune
q_{dune}
Original Aeolis
Computational Domain

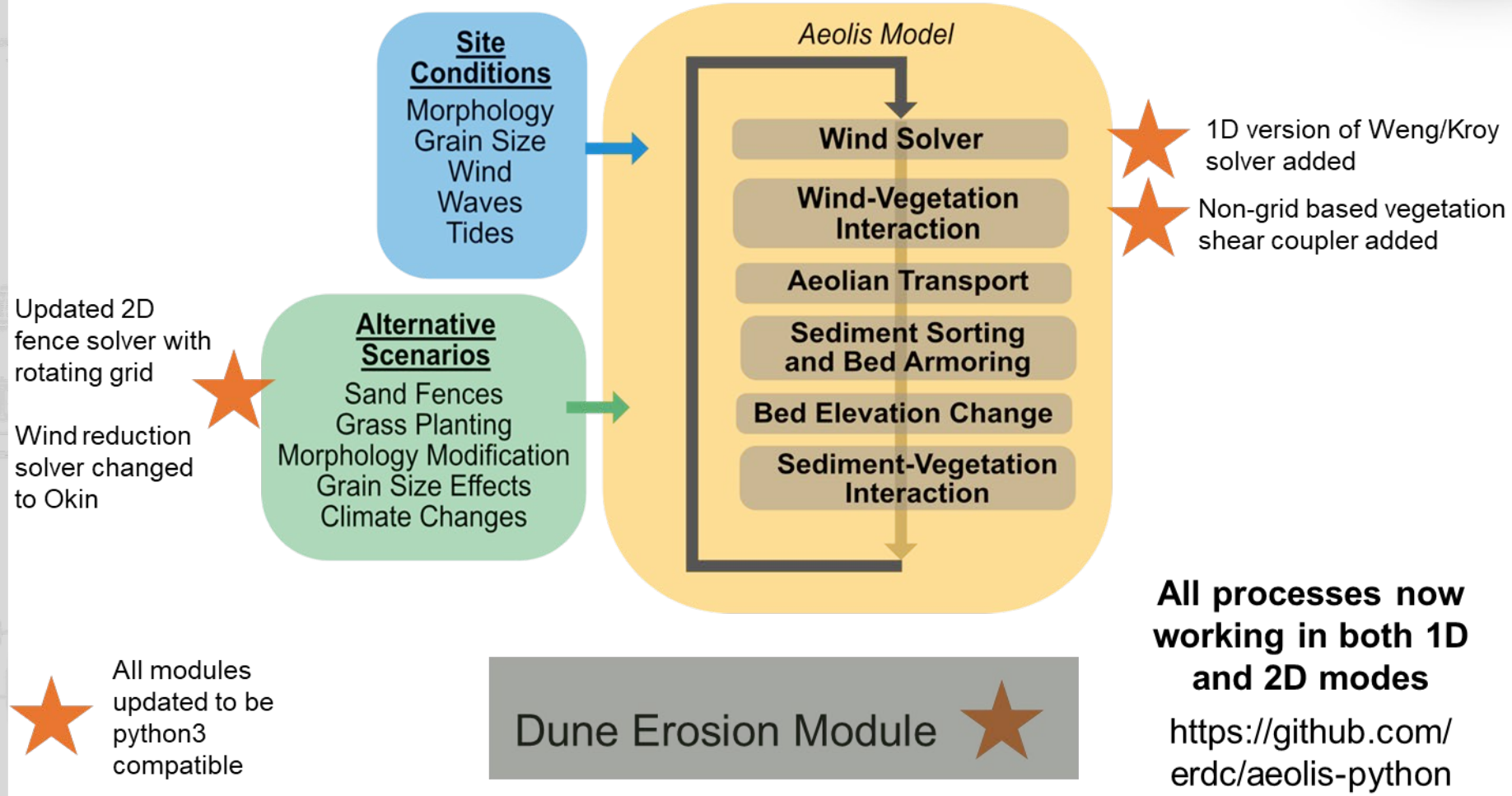


Most important factors to extend domain: wind dynamics, vegetation

Model Processes



New ERDC Model Additions

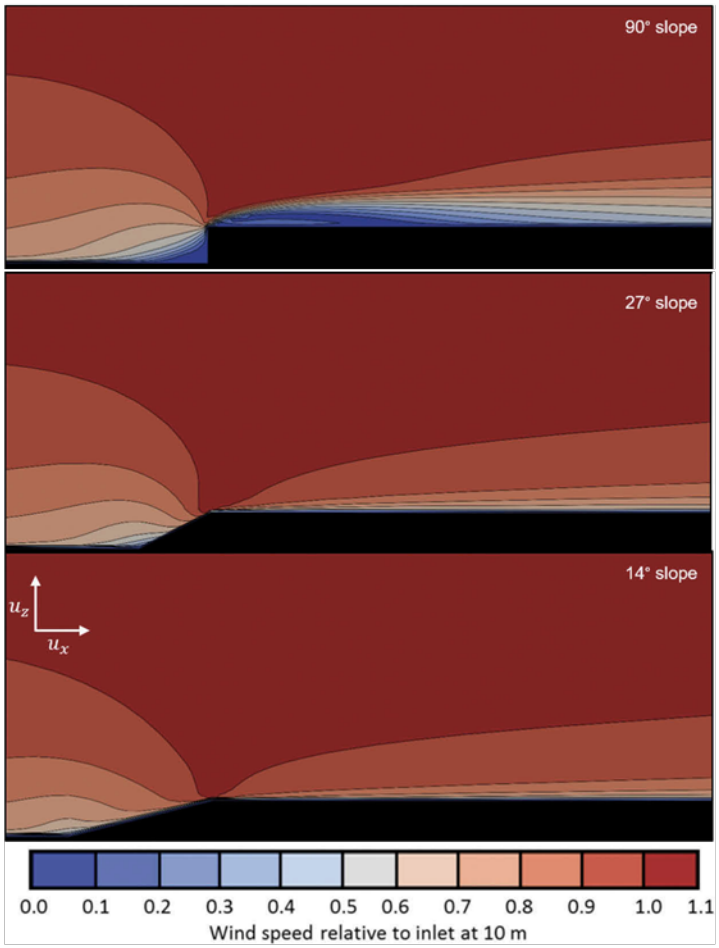


UNCLASSIFIED

New Capabilities Added

- **Wind Flow Dynamics**

Wind speed over different sloped topographies using a CFD Model



from Hesp and Smyth, 2019

But CFD is too computationally demanding for most aeolian transport applications….

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Minimal Model for Sand Dunes

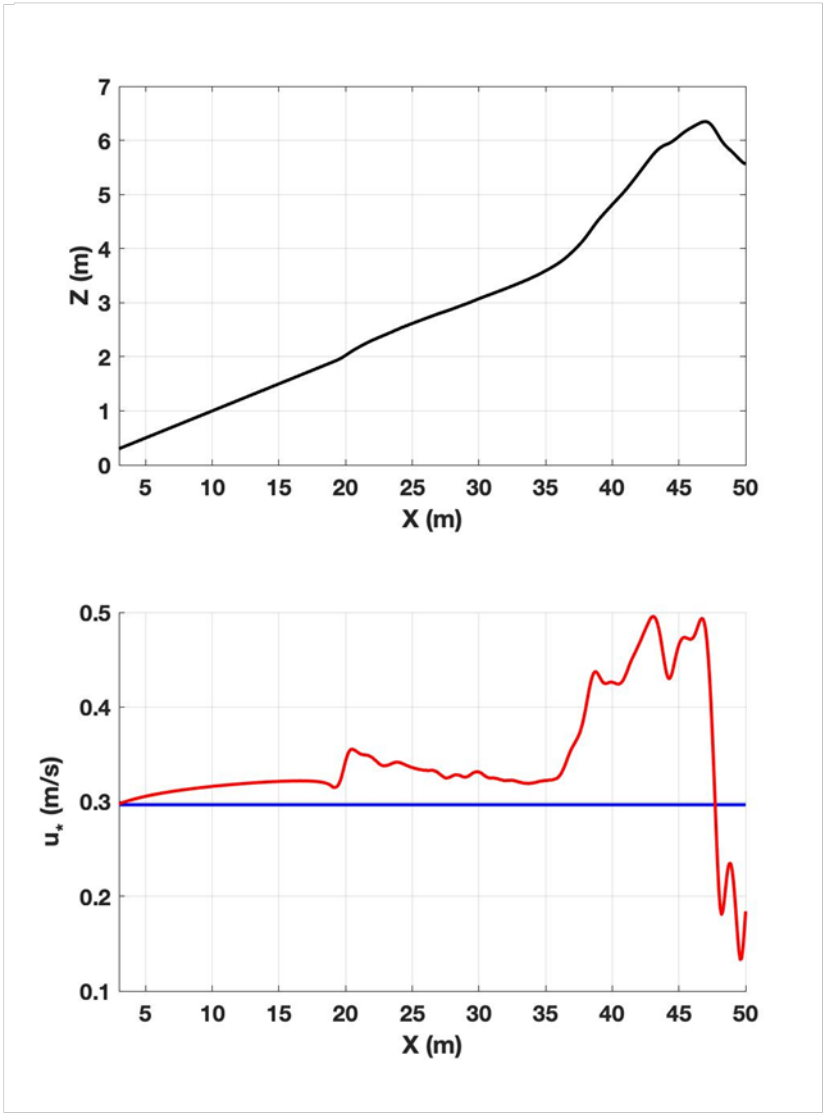
Klaus Kroy,* Gerd Sauermann, and Hans J. Herrmann
PMMH, École Superieure de Physique et Chimie Industrielles, 10, rue Vauquelin, 75231 Paris, Cedex 05, France
(Received 29 January 2001; published 16 January 2002)

$$\hat{\tau}(x) = \alpha\left[\int_{-\infty}^{\infty} d\xi \, \frac{h'(x-\xi)}{\pi\xi} + \beta h'(x)\right].$$

- This solution coded up in python for 1D cases; provides a faster answer and fewer computational instabilities over previous FFT solver of Weng et al. (1991)
- Solution approximates flow over low sloping dunes. Not a perfect solution for complex cases

New Capabilities Added

- New 1D Shear Solver



Uniform Winds

Wind Solver Added

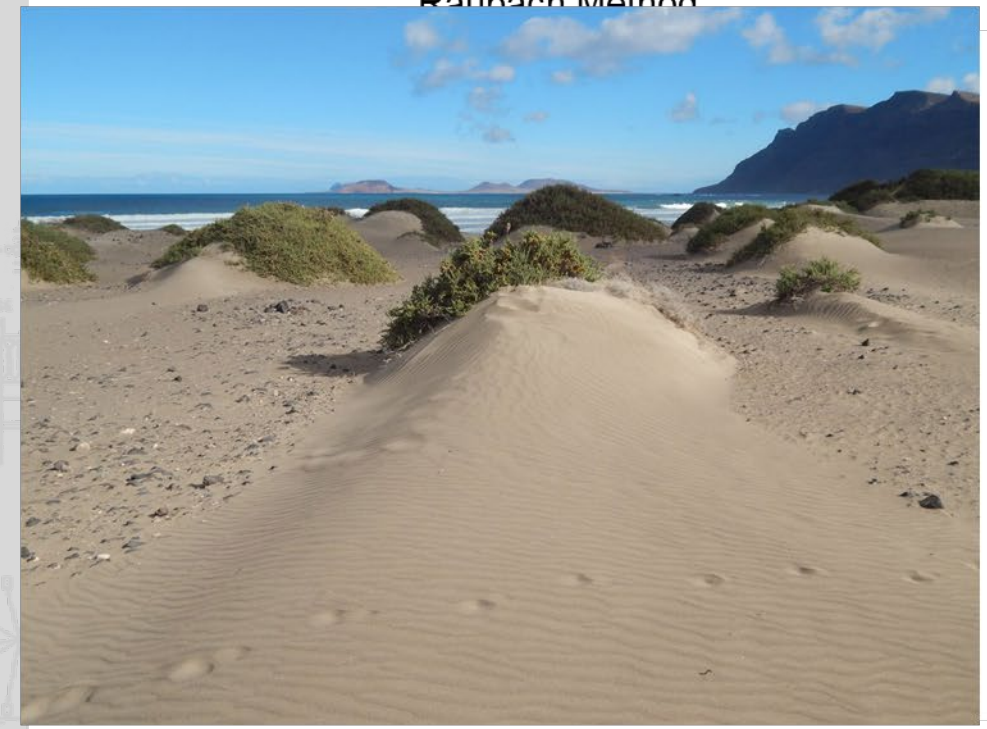
New Capabilities Added

- New Vegetation Shear Coupler Added

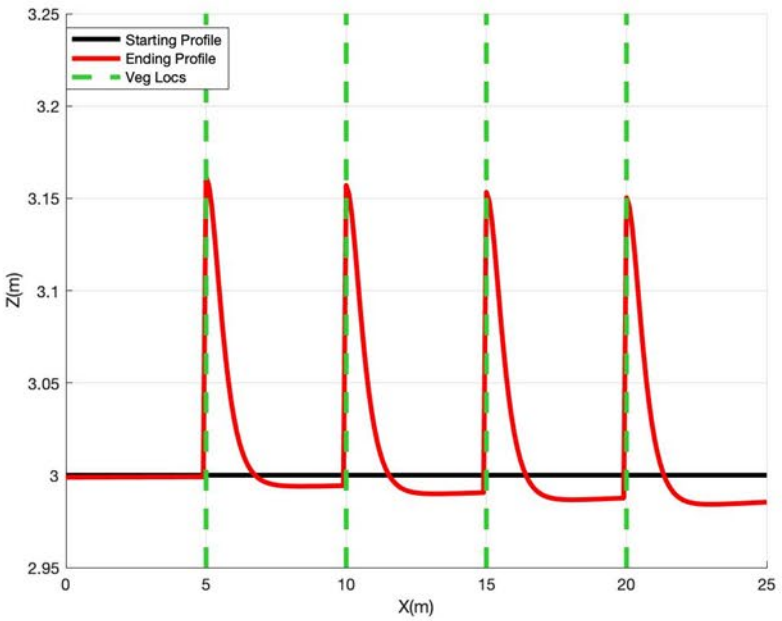
New Capabilities Added

- **New Vegetation Shear Coupler Added**

Raupach Method



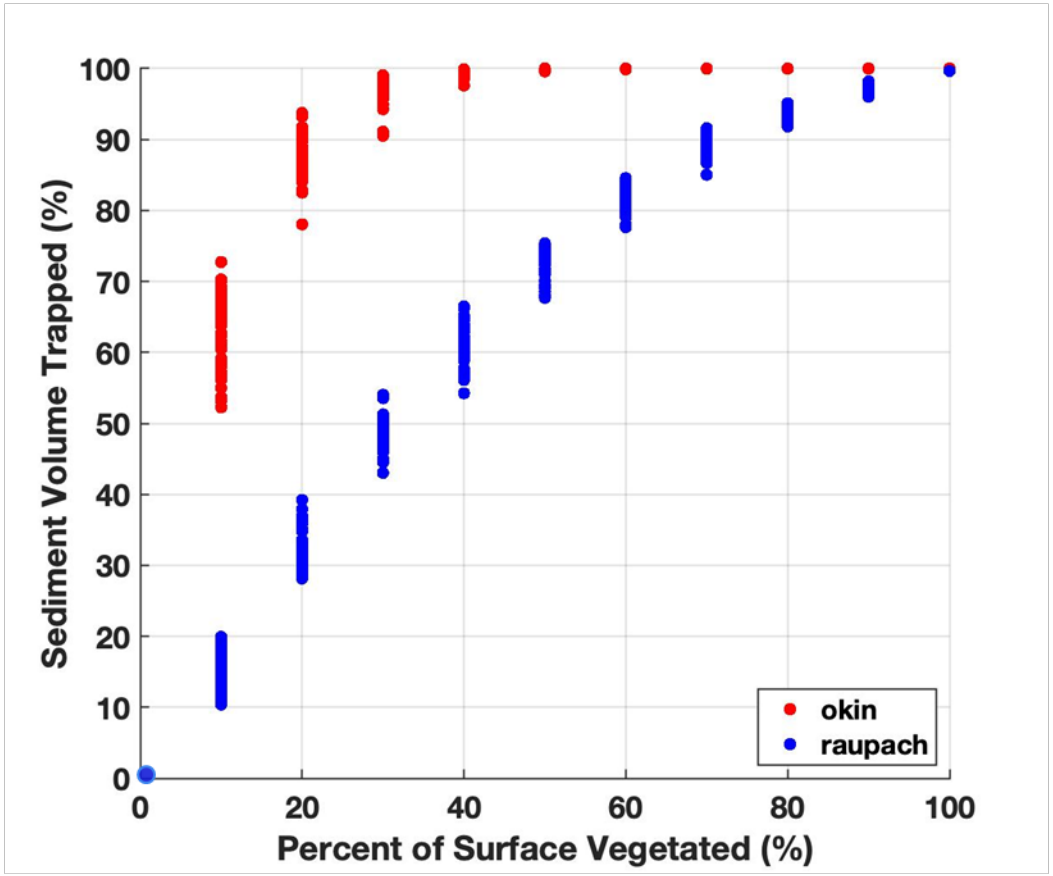
New Okin Method now Implemented in Aeolis



* note: further testing needed for suitable values for Okin for typical dune grasses

New Capabilities Added

- New Vegetation Shear Coupler Added



Example of predicted sediment trapping for different vegetation densities on a flat bed between Okin and Raupach

New Capabilities Added

- **New Vegetation Shear Coupler Added**

Example of predicted sediment trapping for different vegetation densities on a flat bed between Okin and Raupach

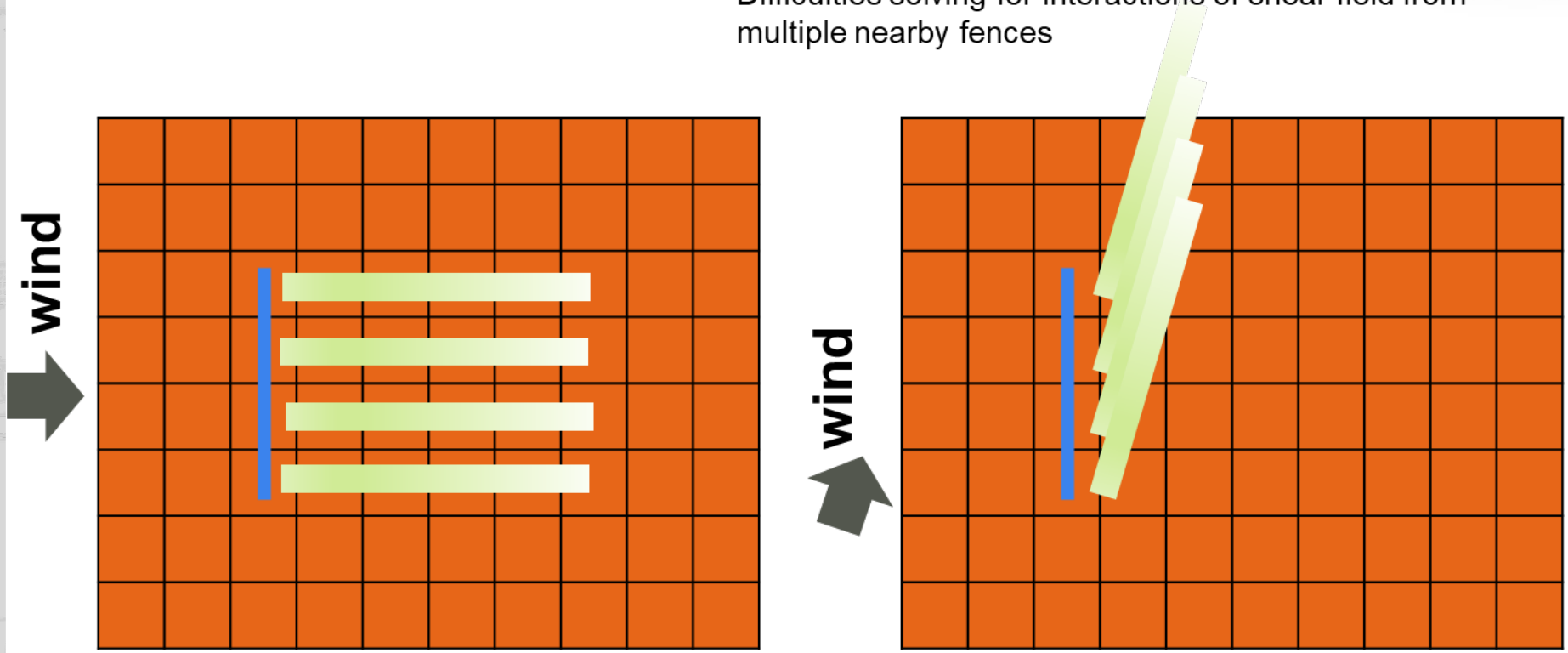
New Capabilities Added

Sand Fence Trapping

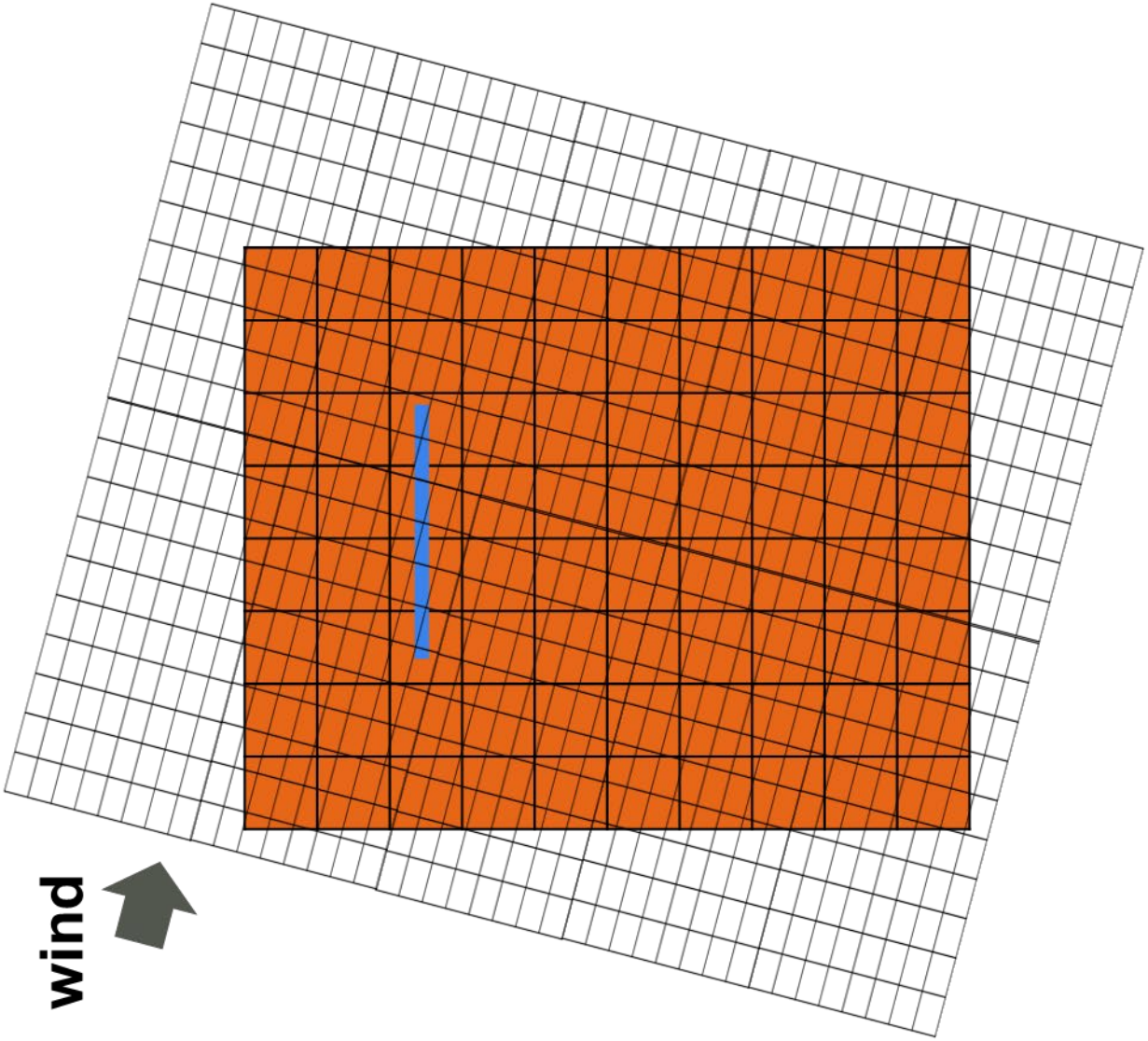
New Capabilities Added

2D Fence Grid Rotation

- Artifacts were showing up when solved geometrically for oblique winds
- Difficulties solving for interactions of shear field from multiple nearby fences



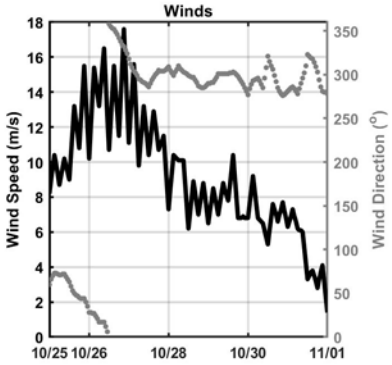
New Capabilities Added

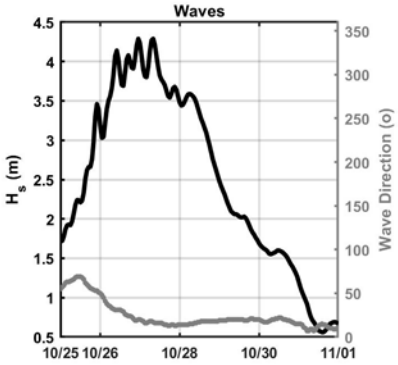


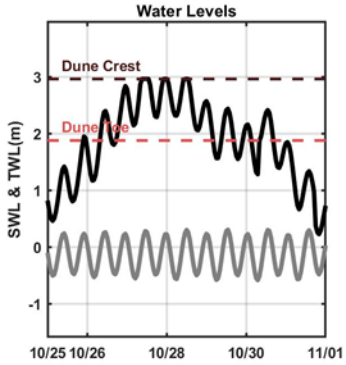
- A temporary computational grid is now set up that is oriented with the wind field
- Solution is interpolated back to the original model grid
- Straightforward to simultaneously account for multiple fences

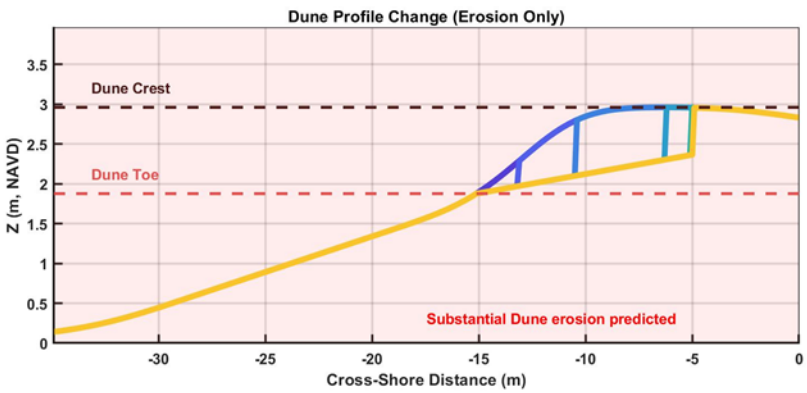
New Capabilities Added

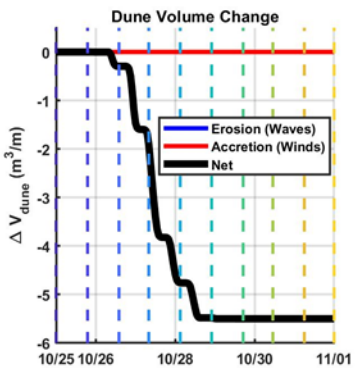
Ft. Lauderdale, FL









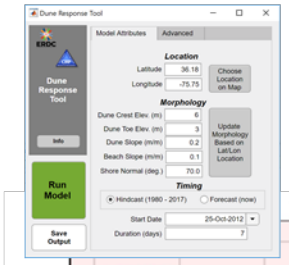


Observed:
Major dune erosion, overwashing

Predicted:
Major dune erosion

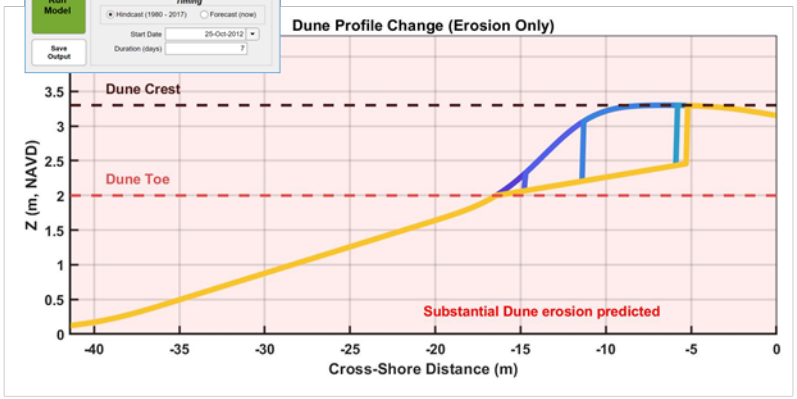
New Capabilities Added

- **Dune Erosion Solver**



Dune Response Tool (*DRT*)

Rapid prototyping tool for storm-driven dune erosion and volumetric dune accretion

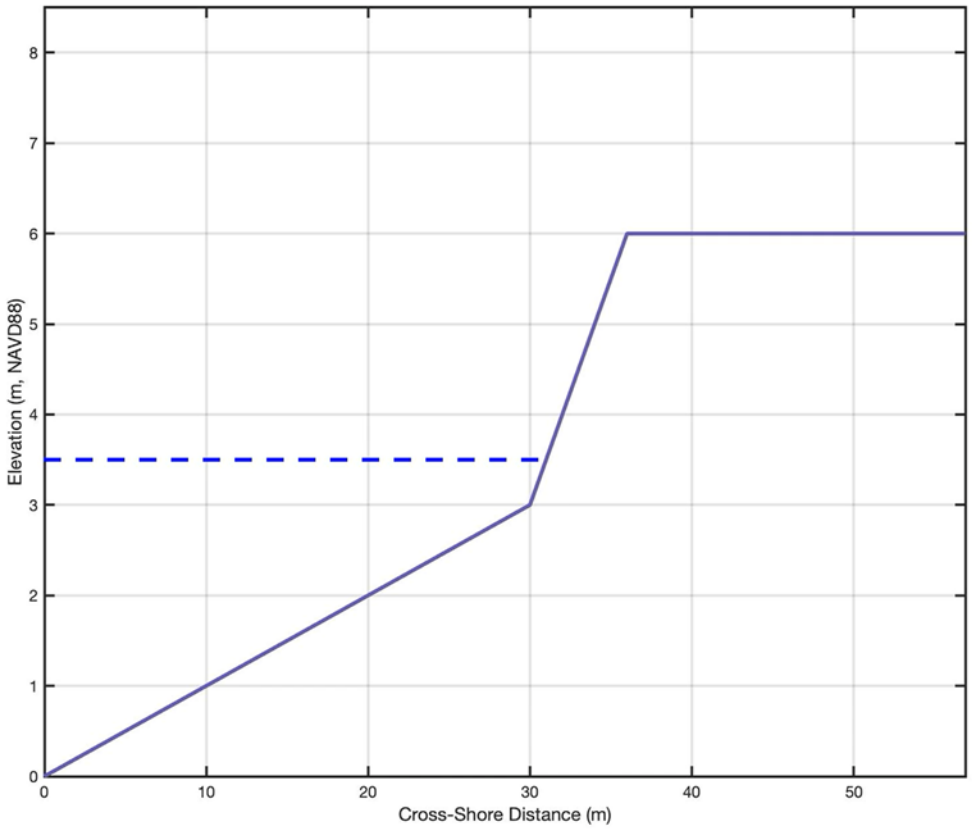


Palmsten and Holman (2012) dune erosion model

Aeolis

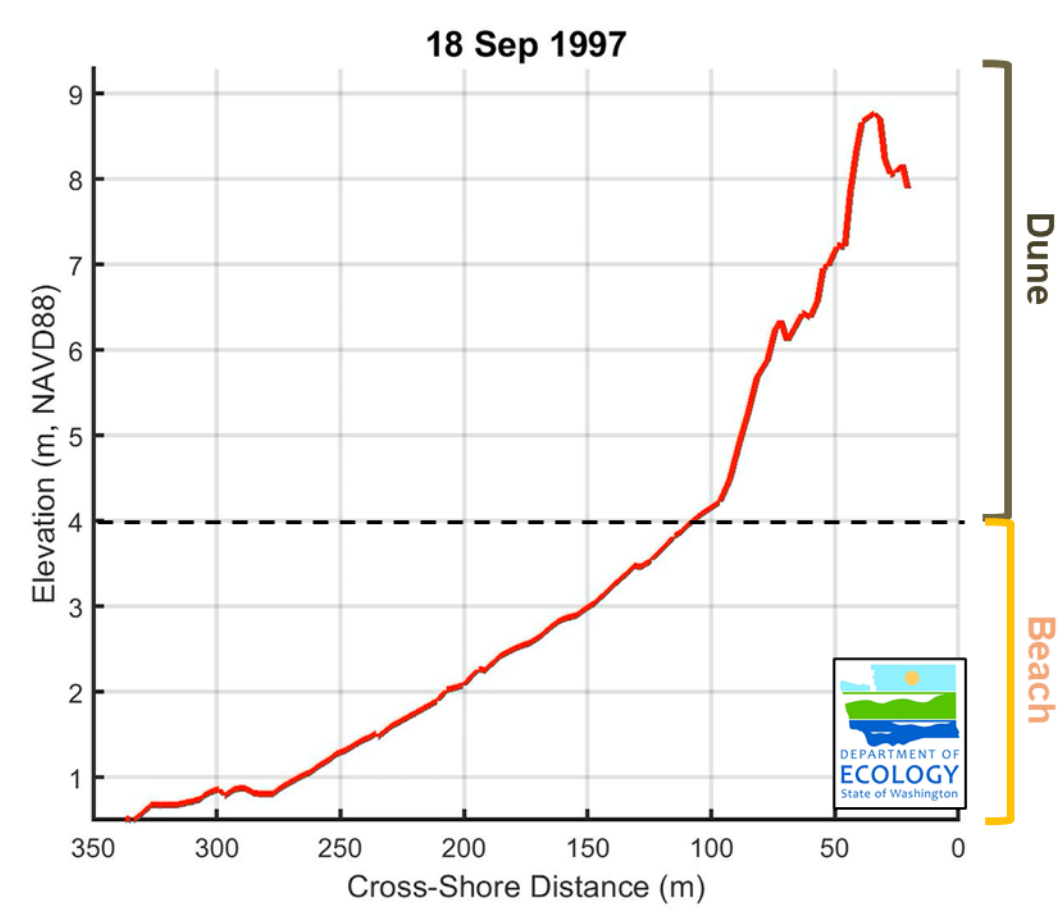
New Capabilities Added

- **Dune Erosion Solver**

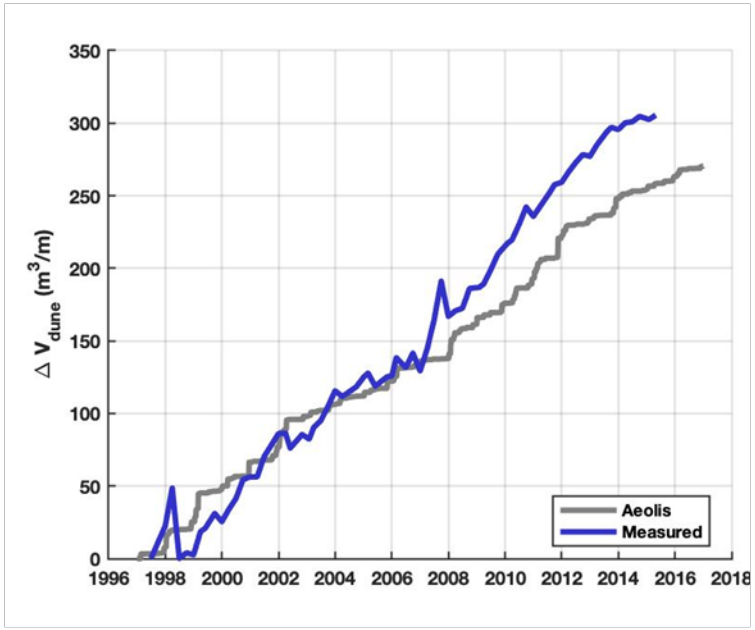


How can USACE use these models?

Example One Dimensional Aeolis Cases

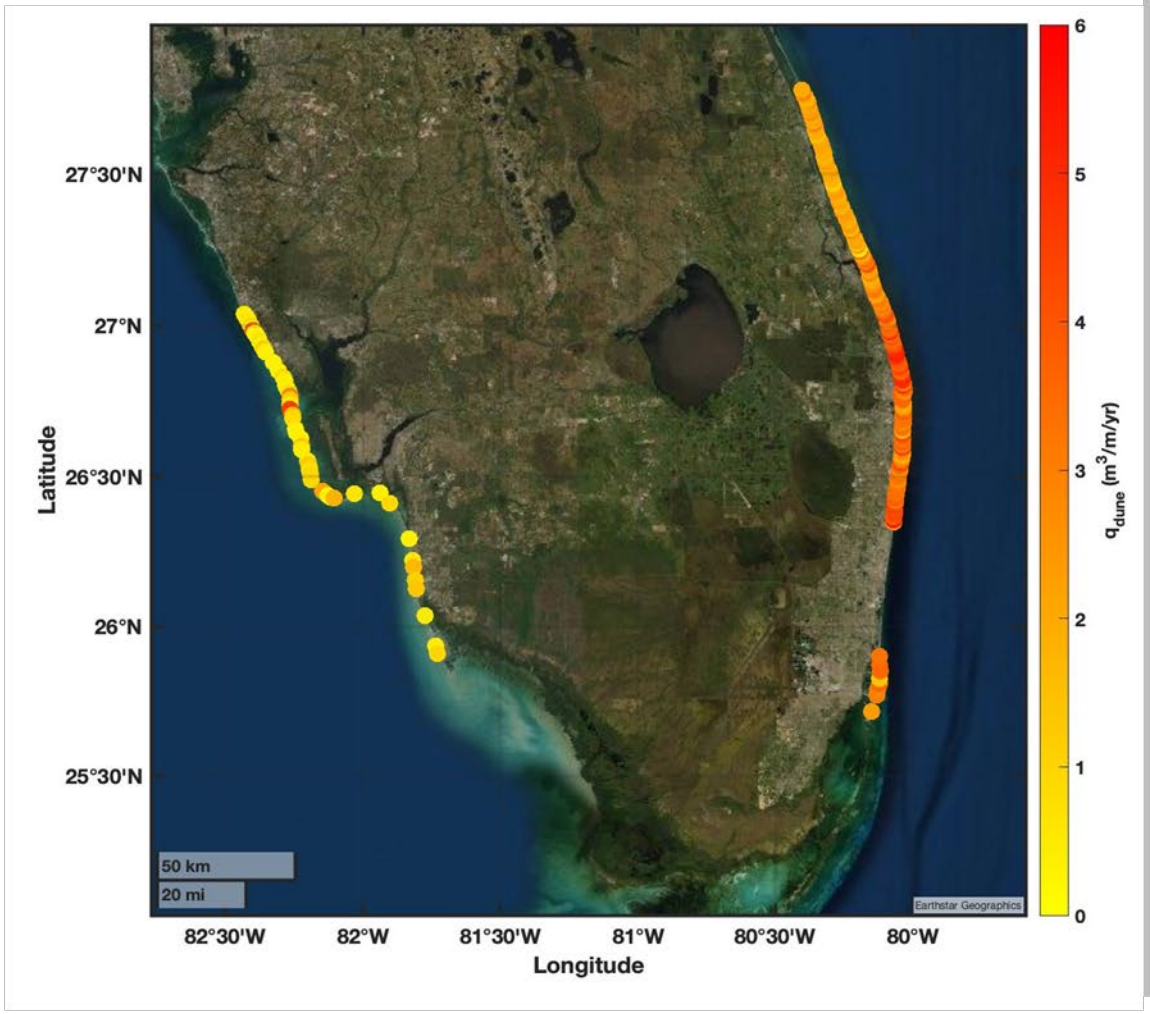


Aeolian Fluxes to Dune: Oysterville, WA



Example One Dimensional Aeolis Cases

Aeolian Fluxes to Dune: Florida



Some potential ways to use the model:

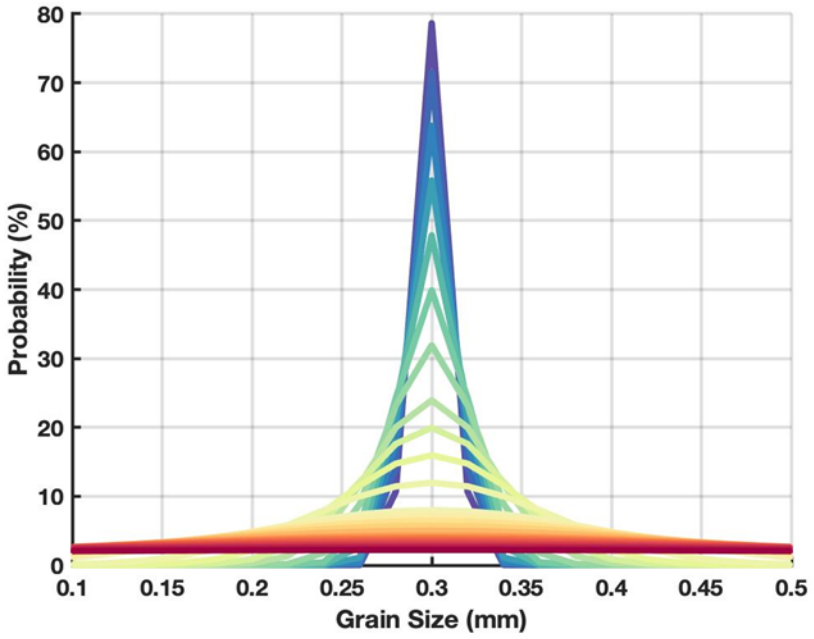
- *Understand spatial variability in dune fluxes*
- *Insights into whether EwN or structural solutions more effective*
- *Inform where placed sediment is more likely to cause nuisance problems*

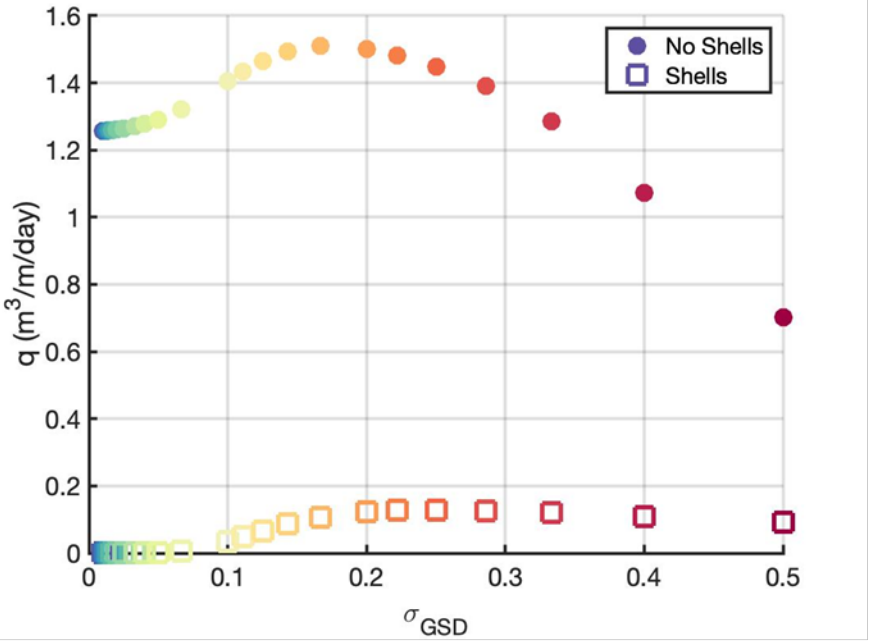
Example One Dimensional Aeolis Cases

Exploration of Grain Size Distribution Effects

Example One Dimensional Aeolis Cases

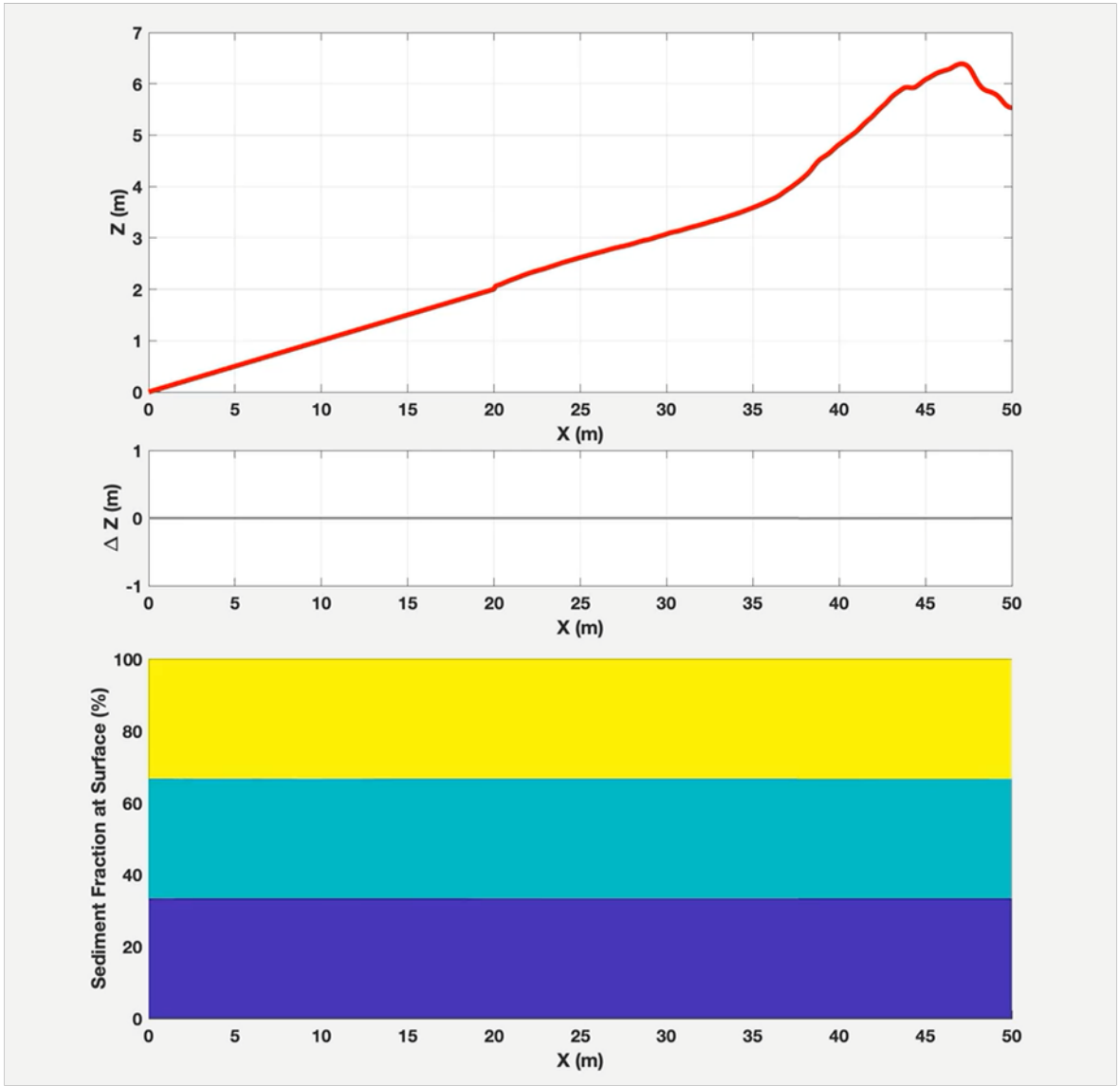
Exploration of Grain Size





Example One Dimensional Aeolis Cases

Exploration of Grain Size



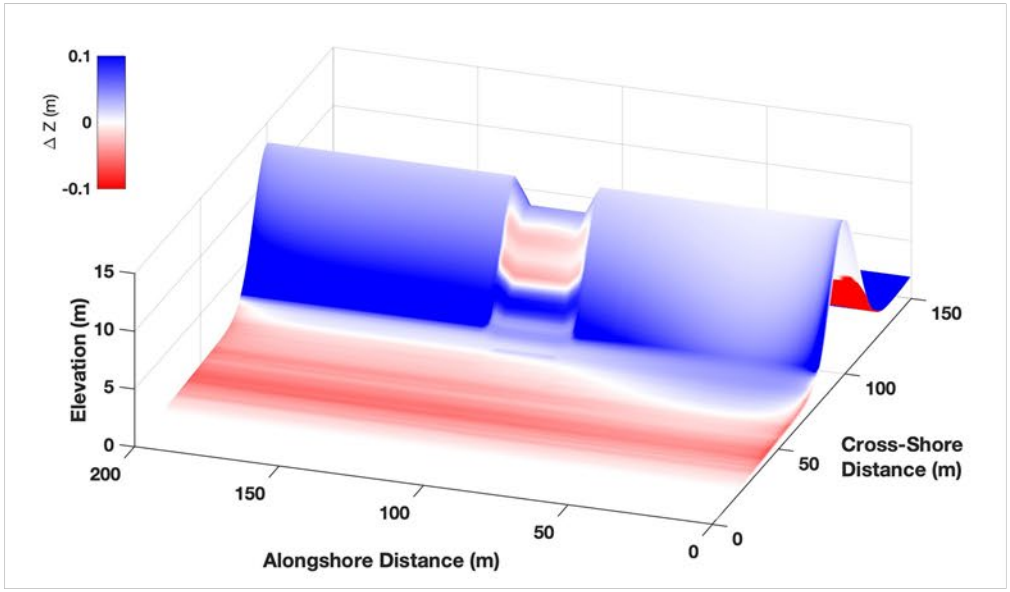
Coarse Sand

Medium Sand

Fine Sand

Example Two Dimensional Cases

Dune Management Strategies: Walkover Optimization



Next Up

- **Other Potential Applications**
  - Quantifying Sediment Fluxes and Pathways
    - Transport Into Harbors and Inlets
  - Coastal Management Alternatives
  - Dune Design
- **Aeolis Code Updates**
  - Fixing remaining 2D → 1D bugs for wind module
    - Separation bubble
  - Bug fixing
  - ***Validation for 1D and 2D***
- **Documentation**
  - Github
    - Example cases on the web
  - Tech Note - 1D cases (about to submit)
  - Sand Fence Paper
- **Additional Developments**
  - Aeolis SMS GUI Integration (w/ Mitch Brown)
  - Aeolis + C2Shore/CMS Coupling via Steering Files (w/ Brad J)

Questions/Comments?

Up to Date ERDC version of code:
https://github.com/erdc/aeolis-python

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