



TOOLS FOR SIMULATING AEOLIAN TRANSPORT NEAR INLETS

PIs: Nick Cohn, Janelle Skaden

Additional Team Members: Brad Johnson, Scott Spurgeon

District PDT Members

Rod Moritz (NWP), Gabriel Todaro/Kelly Legault (SAJ)

COASTAL INLETS RESEARCH PROGRAM

FY22 IN PROGRESS REVIEW

Tiffany Burroughs

HQ Navigation Business Line Manager

Eddie Wiggins

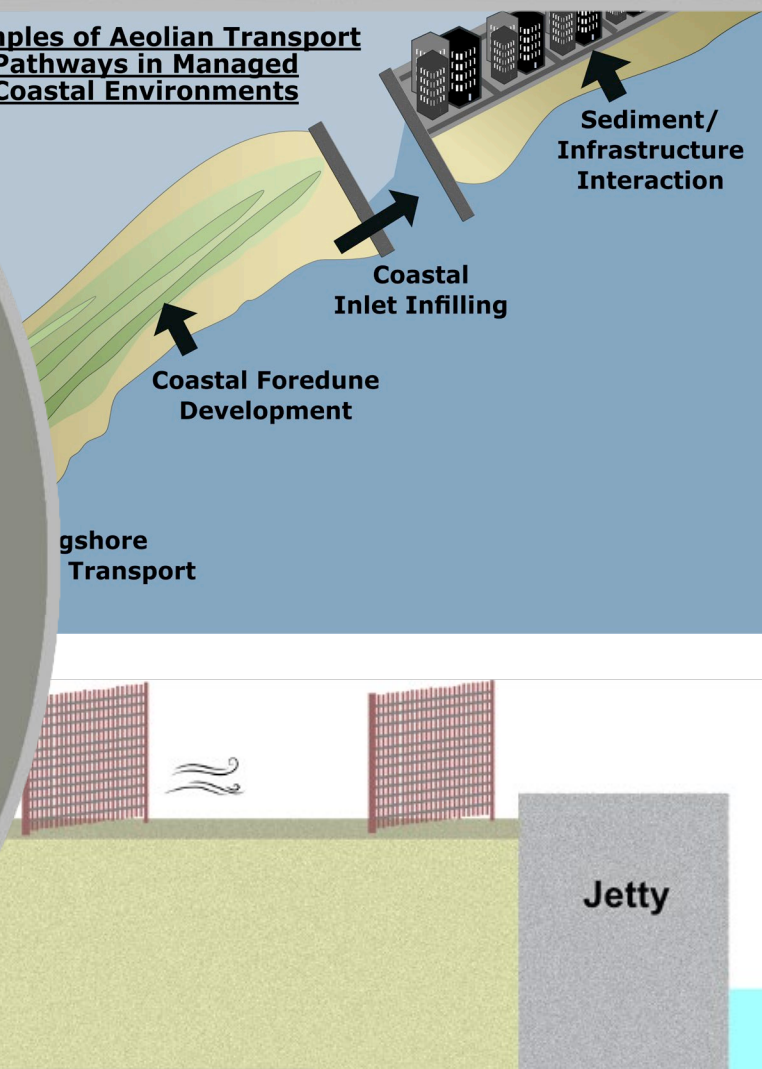
Technical Director, Navigation

Brian McFall

Acting Associate Technical Director, Navigation



Examples of Aeolian Transport Pathways in Managed Coastal Environments



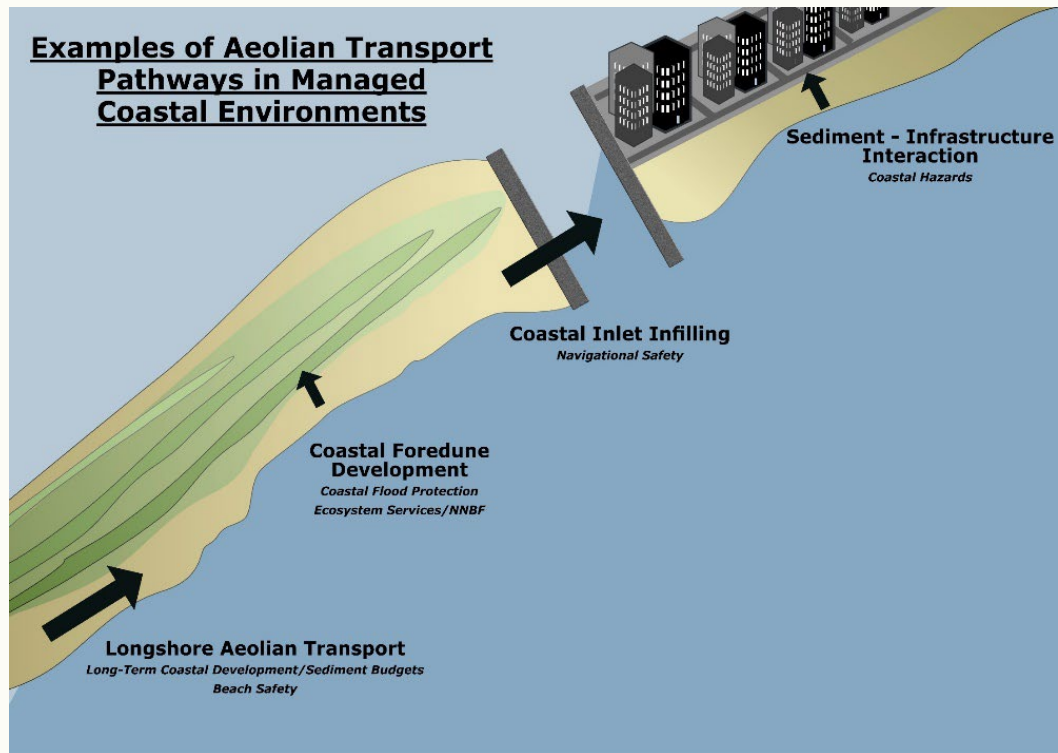
US Army Corps of Engineers®



ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Problem Statement

- Wind can transport sand and modify landscapes in managed coastal systems, resulting in sediment deposition that may adversely (inlet infilling) or positively (dune growth) impact project performance
- Suitable tools do not currently exist for USACE to simulate wind-blown sediment transport and related hazards



Relevant Statements of Need:

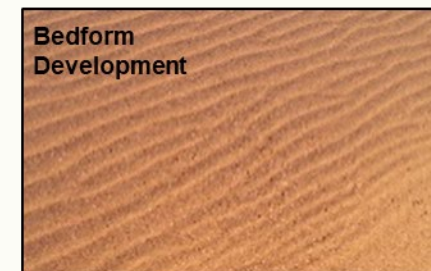
2014-N-10 Update of Engineering Guidance for the Development and Maintenance of Coastal Dune Systems

2017-N-72 Improved Simulation of Dune Morphological Response at Short & Long Time-scales

2020-F-1539 Improved Capabilities for Quantifying Coastal Dune Evolution and Resilience

Capability and Strategic Impact Statement

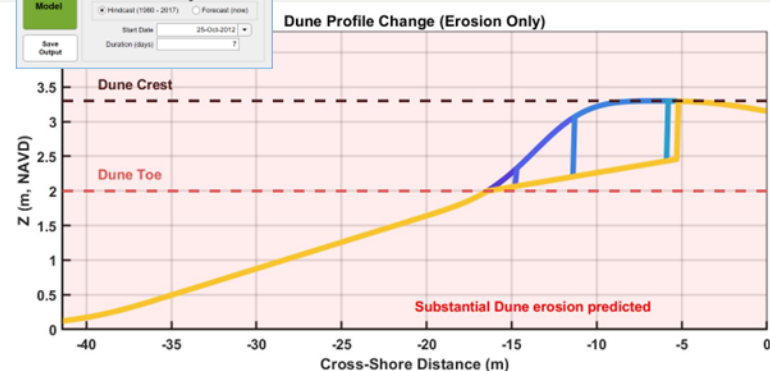
This work unit aims to develop and extend state-of-the-art tools for simulating wind-driven sediment transport processes in proximity to navigational channels and in other USACE-managed coastal settings.



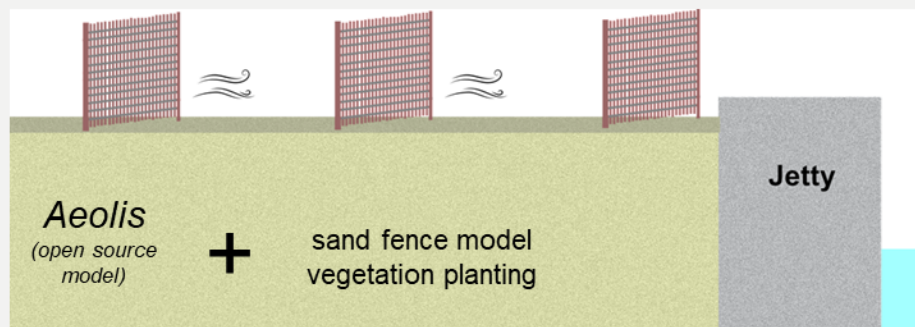
Work Unit Tool Development



Dune Response Tool (DRT)
 Rapid prototyping tool for storm-driven dune erosion and volumetric dune accretion



Aeolis Process-based aeolian transport model with USACE management alternatives being added



Aeolis+C2Shore: Fully coupled subaqueous-subaerial model for simulating the co-cvolution of coastal morphology from wind and waves



Short (hours to days)

Time Scale of Interest

Long (months to years)

Low (Limited Number of Processes Resolved)

Model Fidelity

High

High

Tool Level of Maturity (at Start of Work Unit)

Low

Faster (Seconds to Minutes)

Computational Speed

Slower (Minutes to Days)

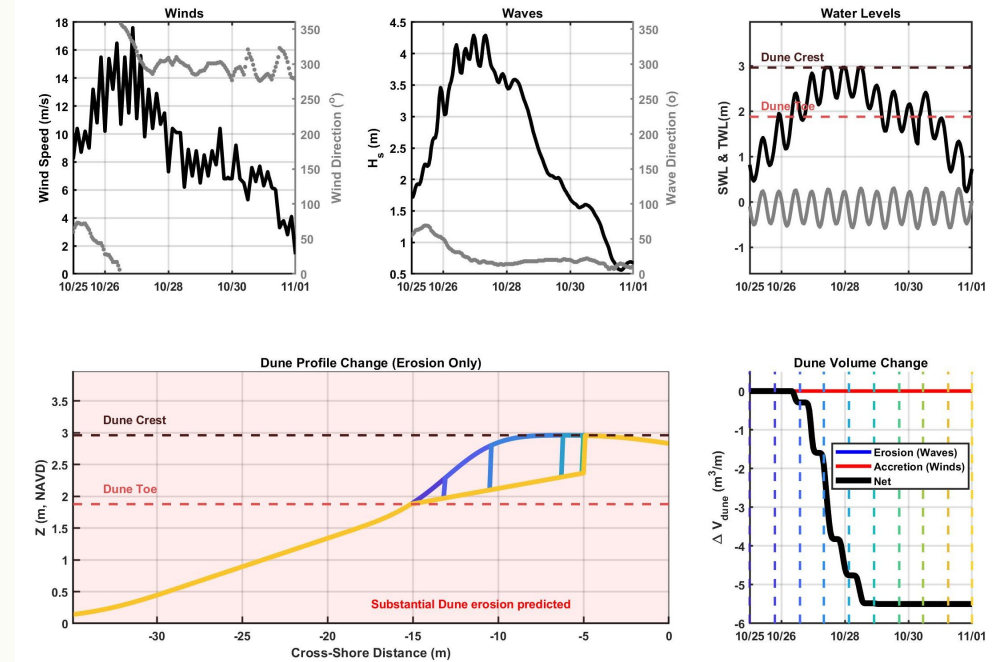
Dune Response Tool

Why Develop DRT

- Reduced Physics Model
- Very fast (seconds to minutes)
- Suitable for planning efforts
- Webtool Capable

Graphical User Interface

Example Model Outputs

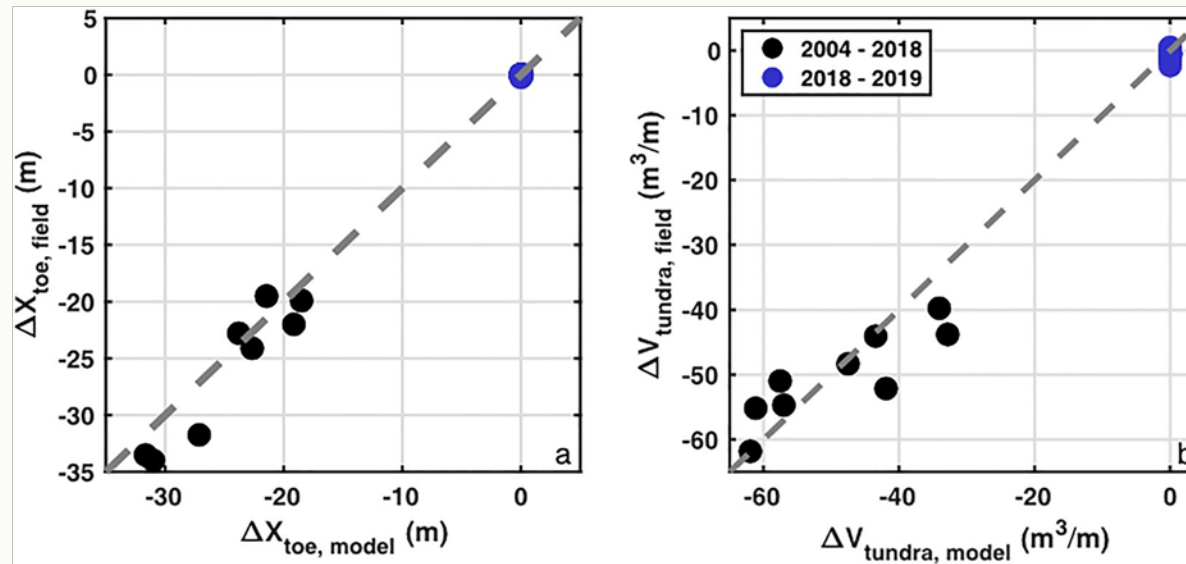


Dune Response Tool

Why Develop DRT

- Reduced Physics Model
- Very fast (seconds to minutes)
- Suitable for planning efforts
- Webtool Capable

Validation of Erosion Module at Interannual Time Scale: Point Hope, AK, USA



JGR Earth Surface

RESEARCH ARTICLE

10.1029/2022JF006813

Special Section:
Prediction in coastal
geomorphology

Assessing Drivers of Coastal Tundra Retreat at Point Hope, Alaska

Nicholas Cohn^{1,2}, Lauren V. Bosche³, Taber Midgley⁴, Christopher Small⁴,
Thomas A. Douglas⁵, and Jeffrey King⁵

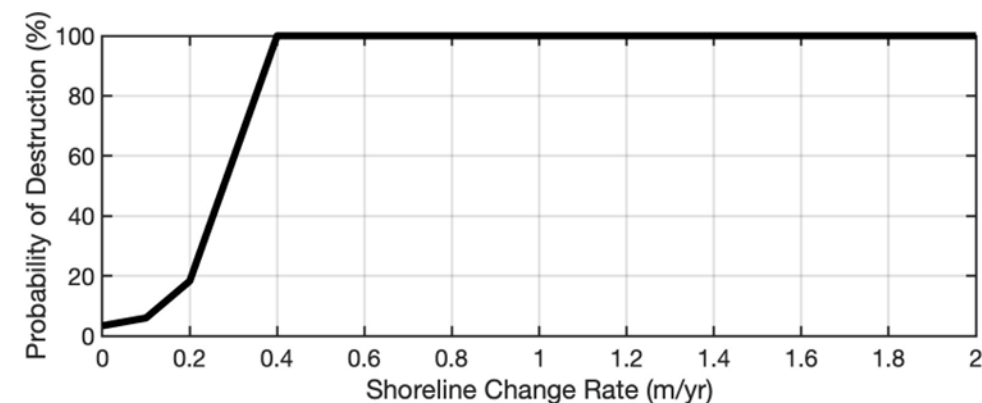
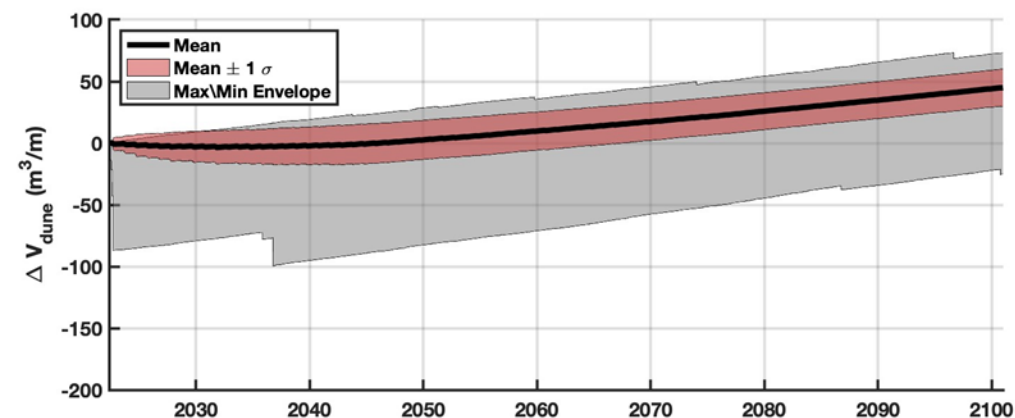
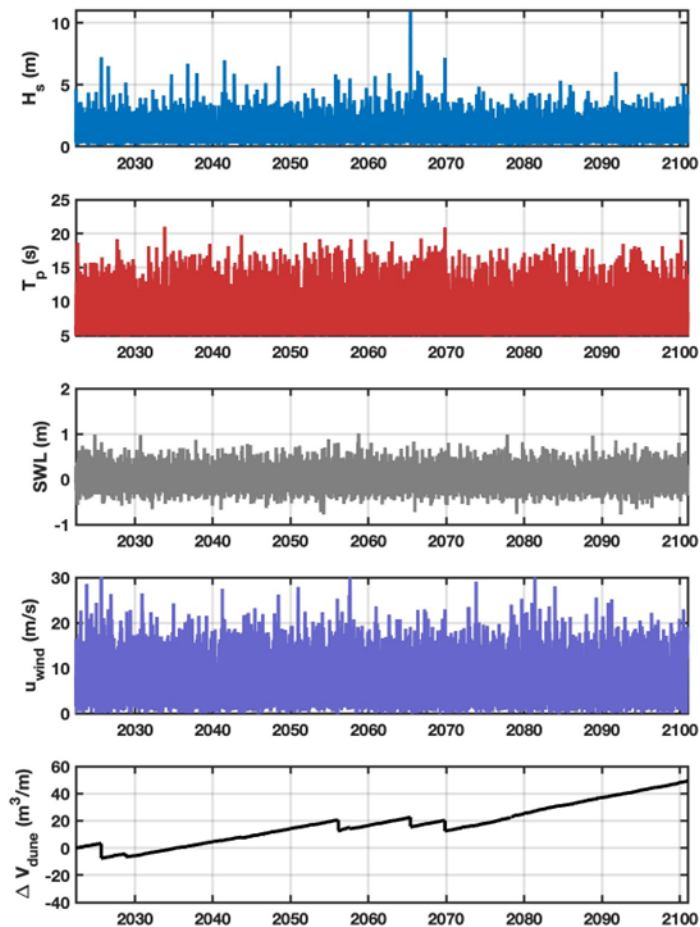


Dune Response Tool

Why Develop DRT

- Reduced Physics Model
- Very fast (seconds to minutes)
- Suitable for planning efforts
- Webtool Capable

Probabilistic Modeling of Dune Growth/Erosion



Dune Response Tool

Why Develop DRT

- Reduced Physics Model
- Very fast (seconds to minutes)
- Suitable for planning efforts
- Webtool Capable

FY22 PMP Tasks:

- **Github – Open Source Code**

<https://github.com/erdc/dune-response-tool>



- **ERDC Tech Note Published**



- **Journal Paper**

Journal of Geophysical Research: Earth Surface
using DRT Erosion engine



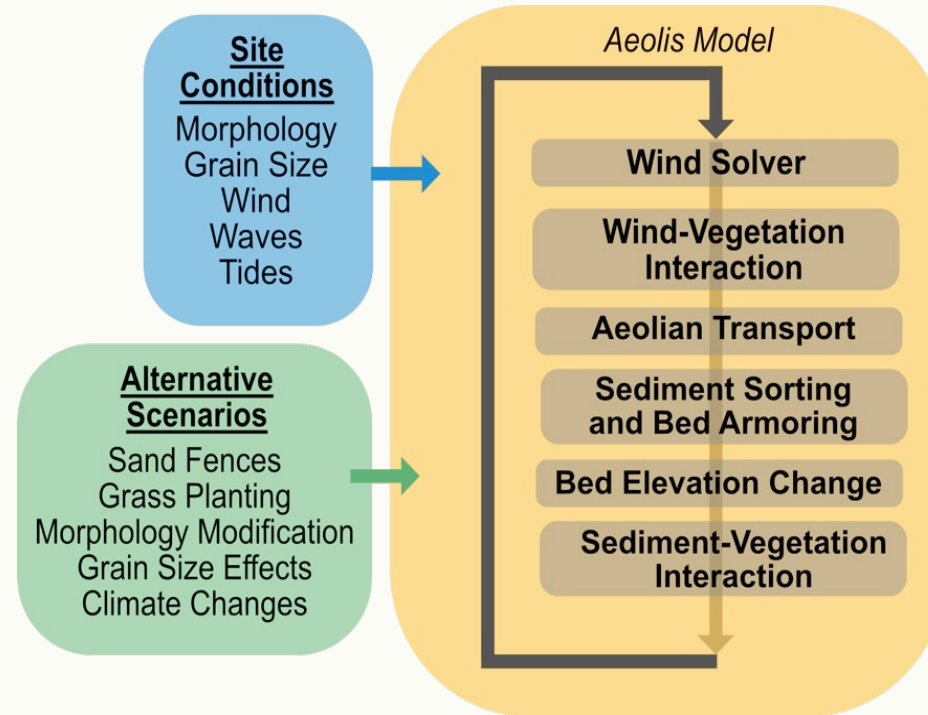
Future Steps:

- JP with both erosional and accretional capabilities
- Collaboration with Oregon State University for dune applications
- Adaptation of erosion engine for Arctic environments (EWN, Congressional Add, ESTCP funds)



Why Develop Aeolis

- 1D and 2D Applications
- Modular code for adding in new USACE-relevant capabilities
- Suitable for planning and design efforts
- Growing user base for aeolian and NNBF applications



FY22 Tasks

- Code Development
- Training Courses
- Applications



Why Develop Aeolis

- 1D and 2D Applications
- Modular code for adding in new USACE-relevant capabilities
- Suitable for planning and design efforts
- Growing user base for aeolian and NNBF applications

Code Development:

- Improved moisture and groundwater capabilities
- Separation bubble dynamics
- Dune erosion module
- Improved aerodynamic roughness parameterization
- Vegetation shear couplers
- Bug fixes
- Improved documentation



Code Development



Sprint Sessions:
Sweden,
Netherlands,
USA, Belgium

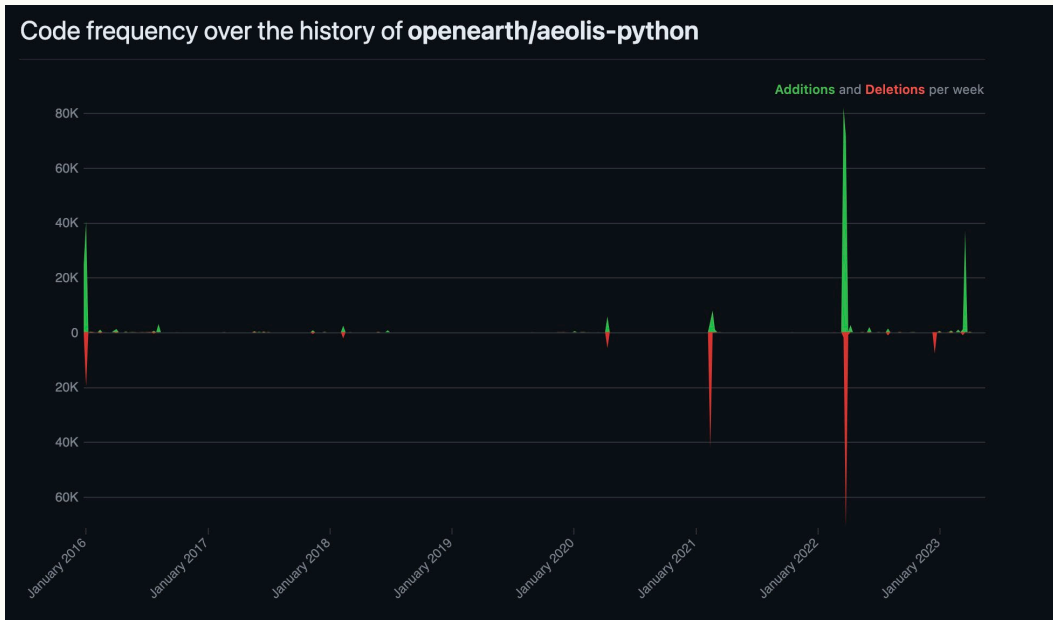




Code Development

<https://github.com/openearth/aeolis-python>

<https://github.com/erdc/aeolis-python>





Training Courses

Self guided python-based course for running Aeolis

<https://github.com/erdc/aeolis-python/tutorials>

CHAPTER 0

Model Introduction, Installation & Set Up, Overview of Model Inputs & Outputs

CHAPTER 1

First Model Run, Introduction to Vegetation, Constant Wind & Tide

CHAPTER 2

Introduce Constant Waves & Runup

CHAPTER 3

Introduce Variable Wind Magnitude & Direction (WIS), Introduction to Selecting Dates to update boundary conditions from WIS & NOAA

CHAPTER 4

Inclusion of Variable Waves & Tides, Introduce Dune Erosion module in model

CHAPTER 5

Introduction to Multifraction Sediment Transport, Utilizes SandSnap Data, Comparison of Multifraction and Single D50 Transport rates

CHAPTER 6

Introduce Changing Locations, Utilizes datasets from the DRT & Sandsnap to update morphology, boundary conditions, and grain size



Training Courses

In person course
development

FY23 Deliverable

jupyter Aeolis - 1. Introduction and sediment sorting (autosaved) Logout

File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 3 (pykernel)

1. Introduction and sediment sorting

This notebook step-by-step introduces the main functionalities of Aeolis. Aeolis is a process-based model for simulating aeolian sediment transport in situations where supply-limiting factors are important, like in coastal environments. Supply-limitations currently supported are soil moisture contents, sediment sorting and armouring and roughness elements.

Along with this notebook a series of Aeolis model schematizations of the Sand Motor is provided. These model schematizations can be used to answer a series of questions at the end of this notebook. Note that these model schematizations are highly optimized for speed and only have an educational purpose.

Execute cells by selecting the cell and press **Shift-Enter**.

Additional information

- The full user documentation of Aeolis can be found at: <http://aeolis.readthedocs.io/>.
- The latest Aeolis source code can be found at: <https://github.com/openearth/aeolis-python>.
- The full scientific description of Aeolis can be found in:

Hoonhout, B. M. and S. de Vries (2016), A process-based model for aeolian sediment transport and spatiotemporal varying sediment availability, J. Geophys. Res. Earth Surf., 121, 1555–1575, <http://dx.doi.org/10.1002/2015.JF003692>.

Helper functions

A few helper functions that you can use to analyze the model output can be found in the file `plot_tools.py` that is shipped with this notebook. You need to execute the next cell with **Shift-Enter** to enable these helper functions. Adapt the functions if appropriate.

The following functions are available:

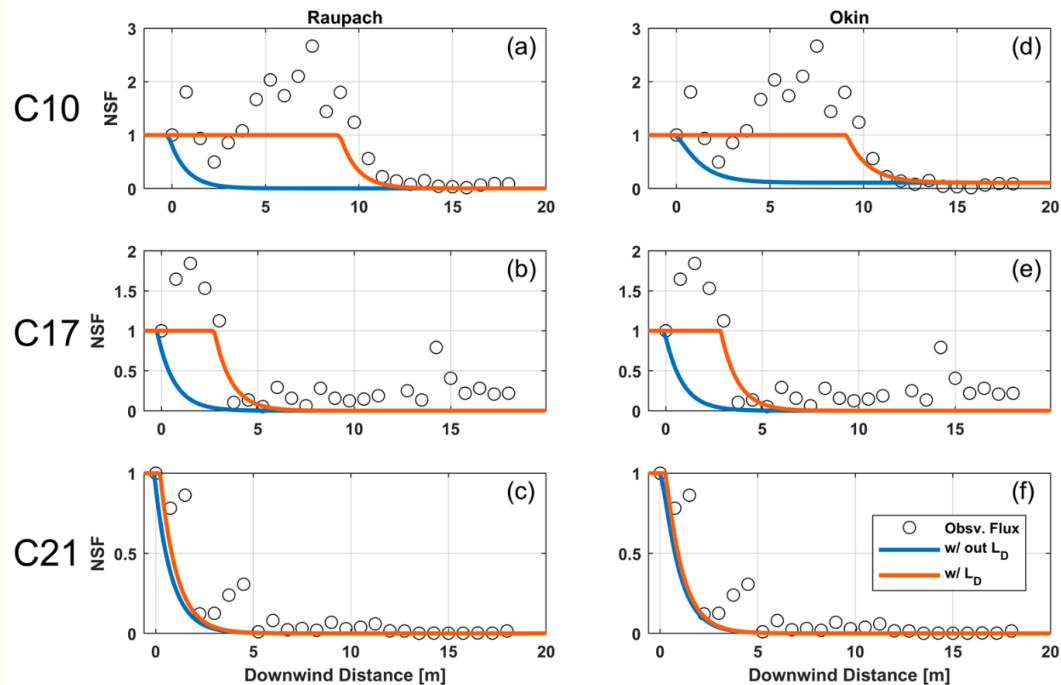
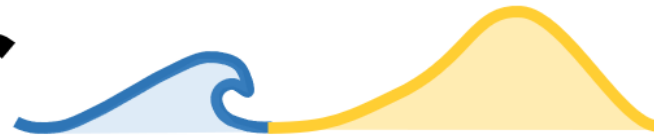
- `plot_bathymetry`
- `plot_erosion`
- `plot_erosion_multi`
- `plot_coverage`
- `create_animation`

```
In [1]: # this line causes plots to appear inline rather than in a separate window
import matplotlib inline

from plot_tools_sandmotor import *
```



AEOLIS



Model Applications

RESEARCH ARTICLE

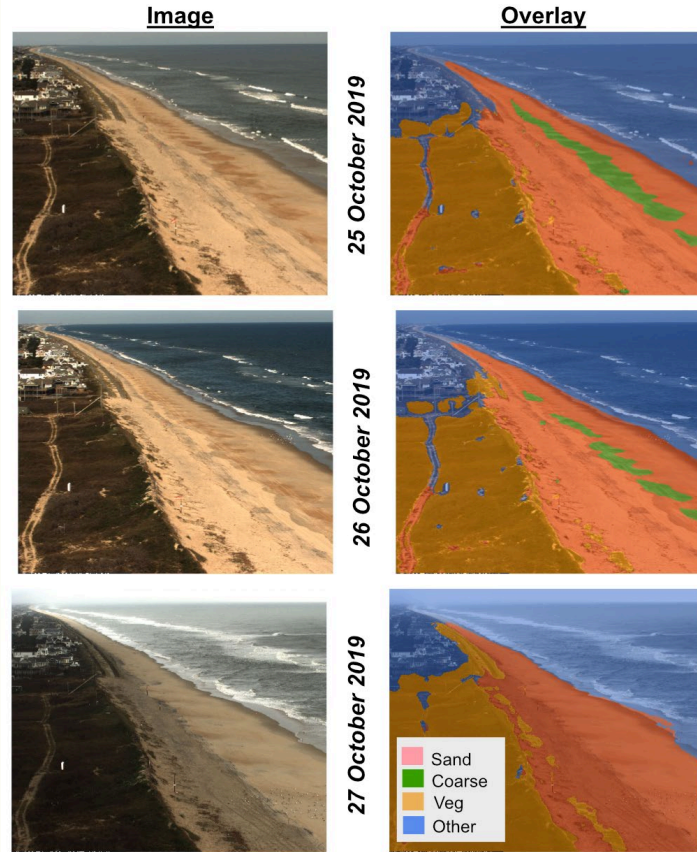
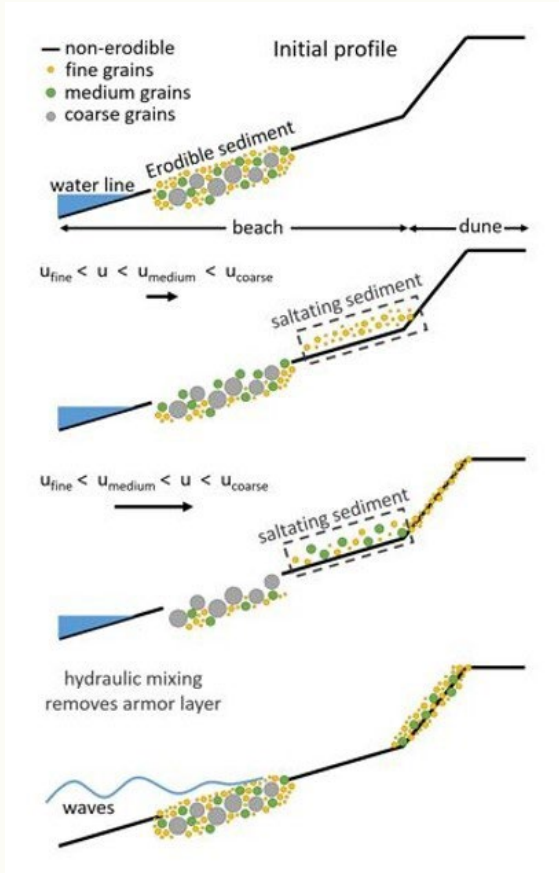
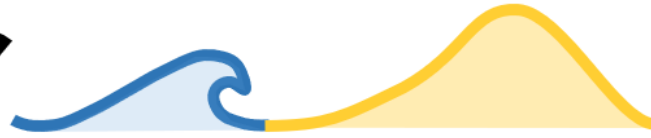
ESPL WILEY

Observations and modeling of shear stress reduction and sediment flux within sparse dune grass canopies on managed coastal dunes

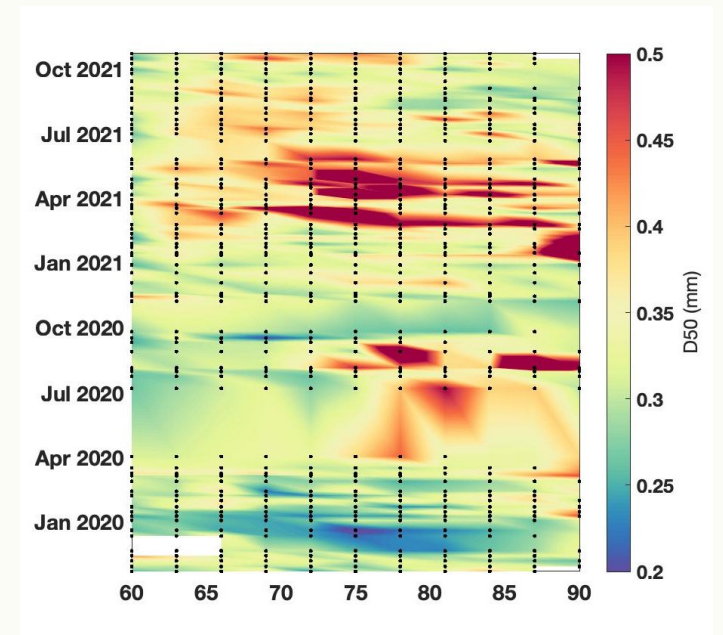
John Dickey^{1,2} | Megan Wengrove¹ | Nicholas Cohn³ | Peter Ruggiero⁴ | Sally D. Hacker⁵

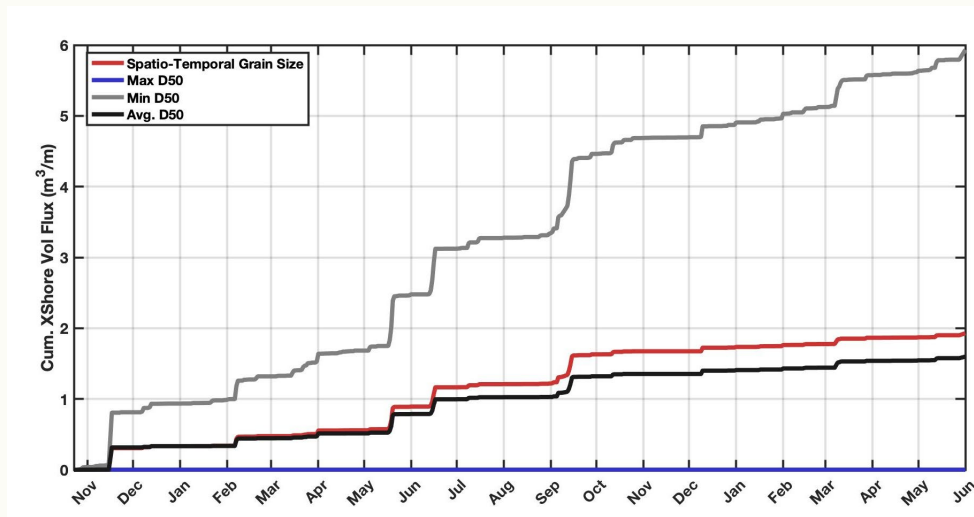


AEOLIS



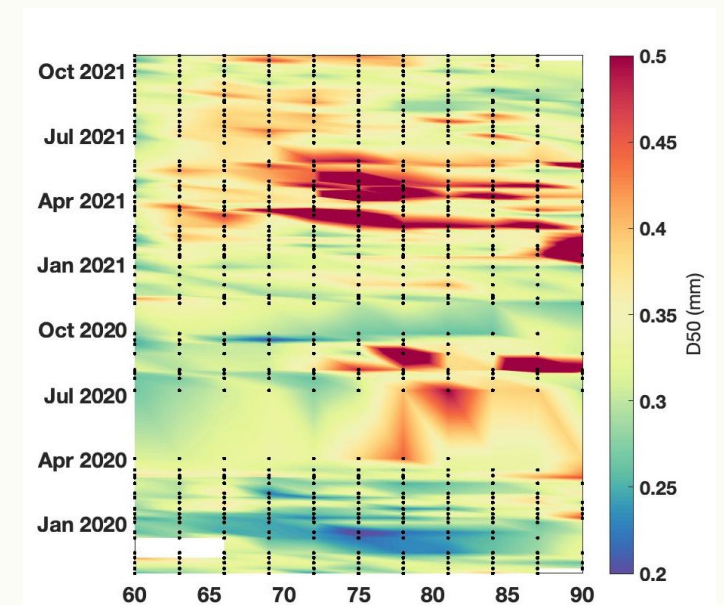
Does spatio-temporal variability in grain size on the beach influence long-term wind-blown transport rates?



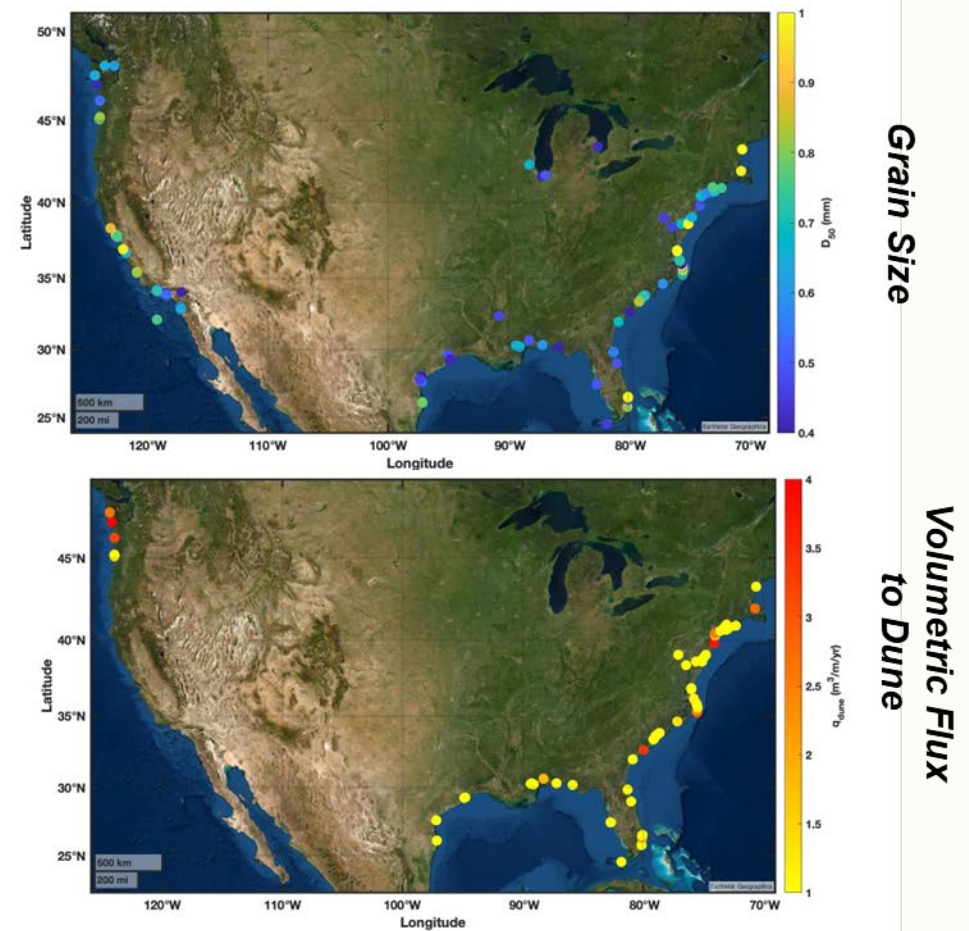
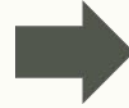


- **Average D50** across all samples results in ~20% less transport than more frequent data availability. Need to pick grain size data carefully
- 2D simulations suggest that persistence of coarse deposits on the beach can have alongshore dune growth rates

Does spatio-temporal variability in grain size on the beach influence long-term wind-blown transport rates?



Product: CIRP TD, Future JP?



Automated codes to estimate wind-blown sediment fluxes around the country using SandSnap grain size and public data sources for winds, waves, tides, and morphology

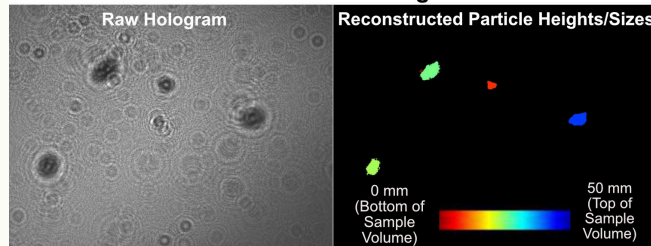
Product: CIRP TD



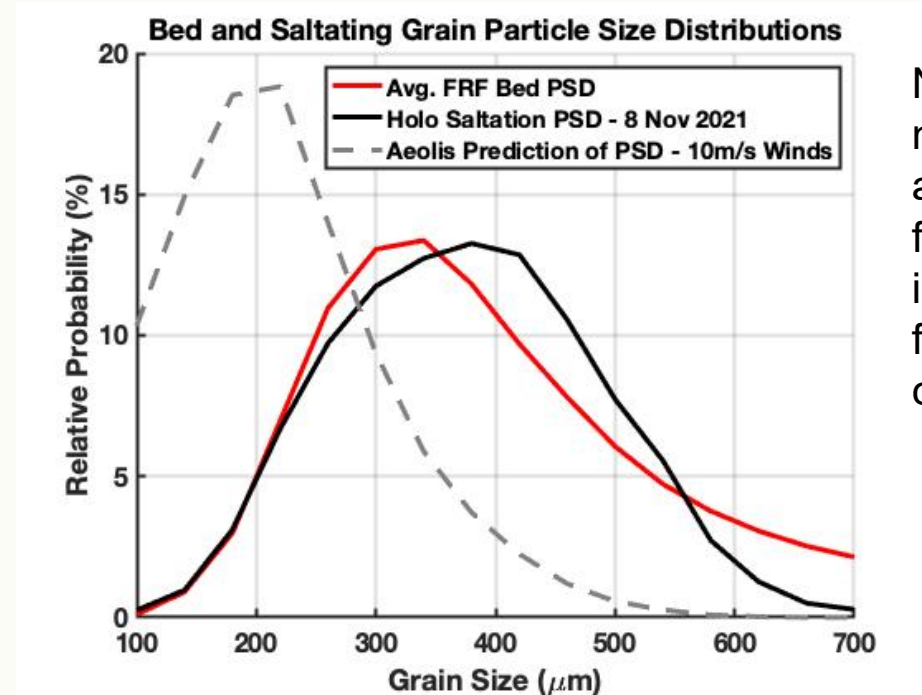
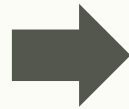
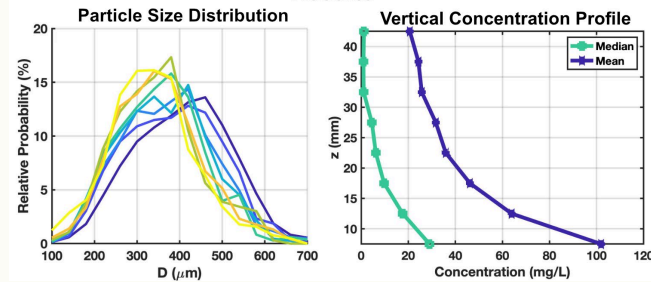
Field Data Collection
Nor'Easter Event (8 Nov 2021)



Data Processing



Results



New field measurements are guiding need for model improvement for future R&D cycles

Product: RD22 Presentation



Why Develop Aeolis

- 1D and 2D Applications
- Modular code for adding in new USACE-relevant capabilities
- Suitable for planning and design efforts
- Growing user base for aeolian and NNBF applications

FY22 PMP Tasks:

- **Model Development, Sprints, and Maintenance** ✓
- **Course Development** ✓
- **Model Applications** ✓
- **Journal Paper**
ESPL using Aeolis ✓

Future Steps:

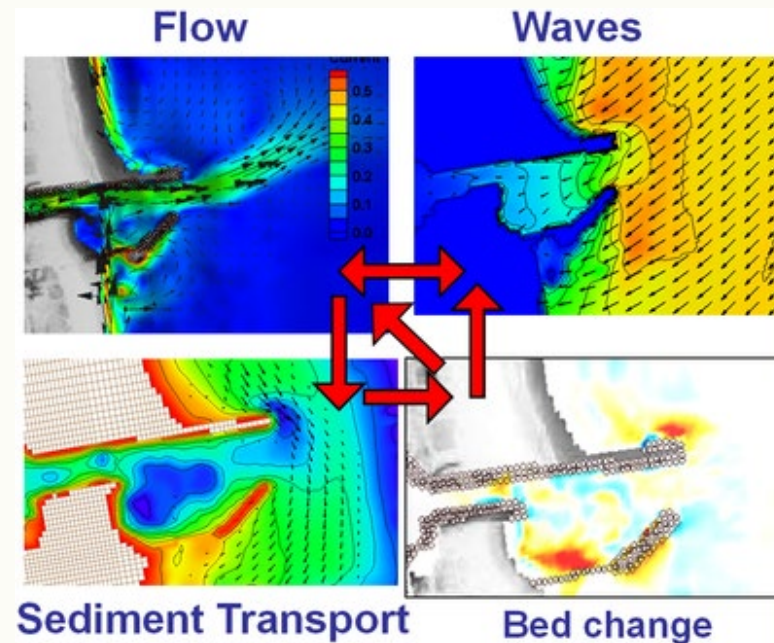
- JP on Aeolis
- Ongoing collaboration with TU Delft, Lund University, Oregon State University, and others
- Model coupling efforts to integrate Aeolis to USACE models
 - GenVeg/Doonies → EWN, OSU Add
 - CSHORE --> USCRP, OSU Add
 - CMS → CIRP

2D CMS-Aeolis Coupling

Why Develop 2D Coupling Capabilities

- Both subaerial and subaqueous processes important for driving the evolution of coastal systems
- Quantifying aeolian transport effects on inlet fluxes requires 2D coupled solutions
- Leverages existing USACE models and GUI tools

Traditional CMS Workflow – Aeolian Transport Not Considered



Goal:

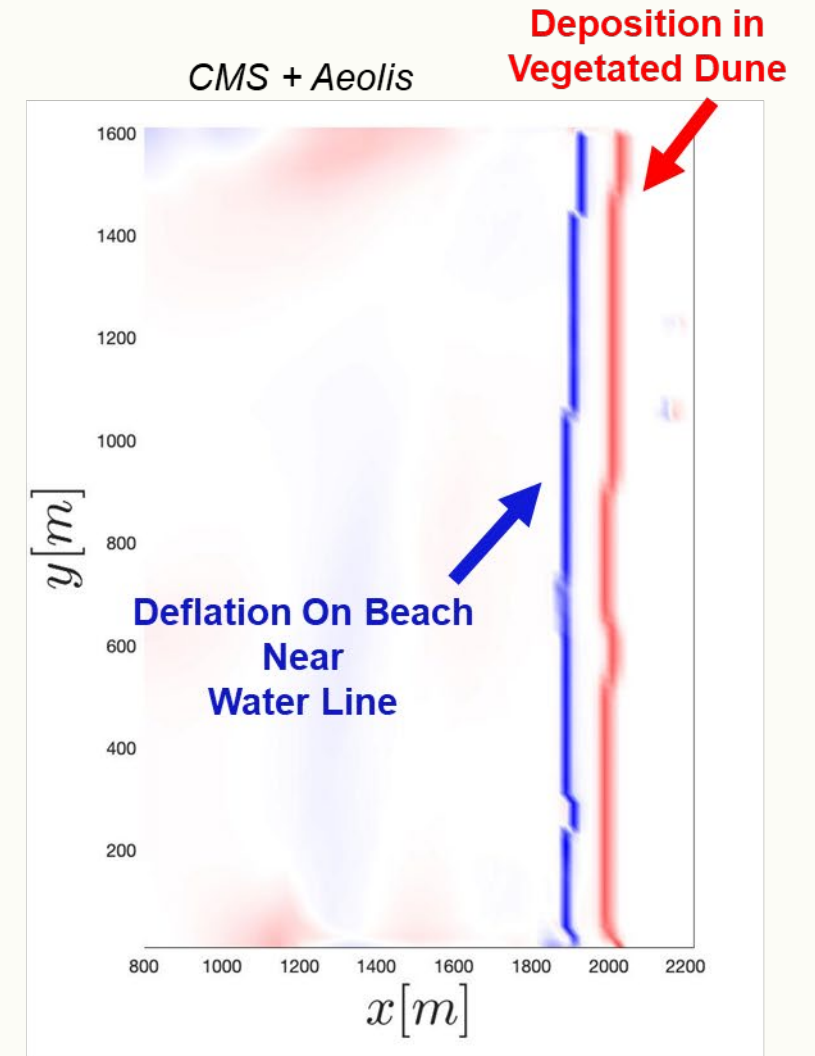
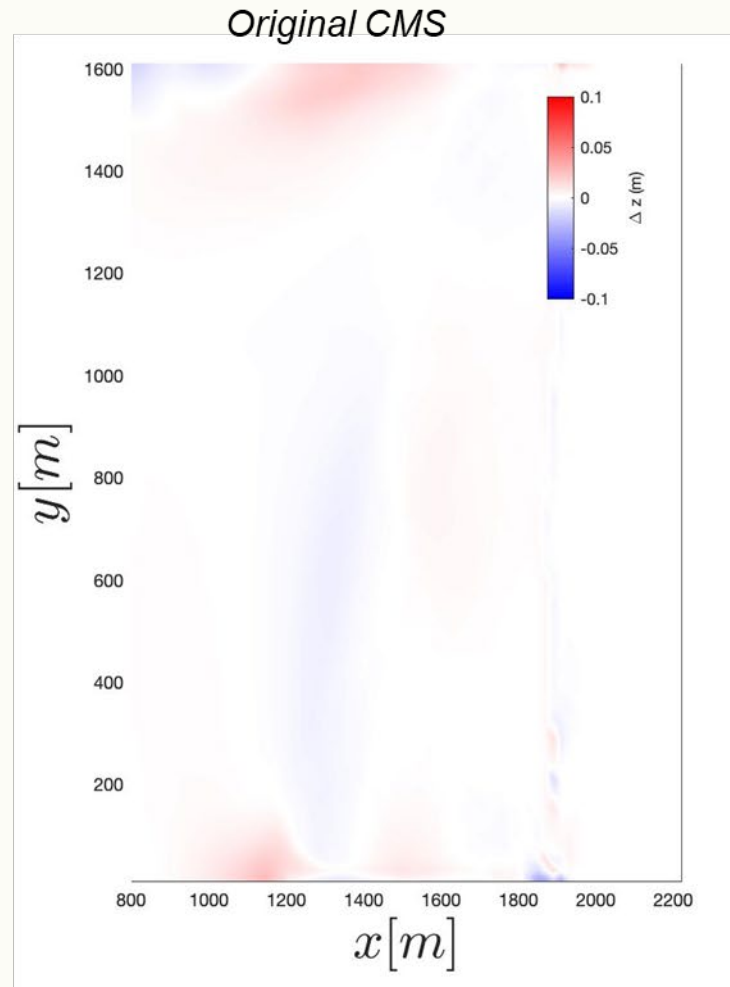
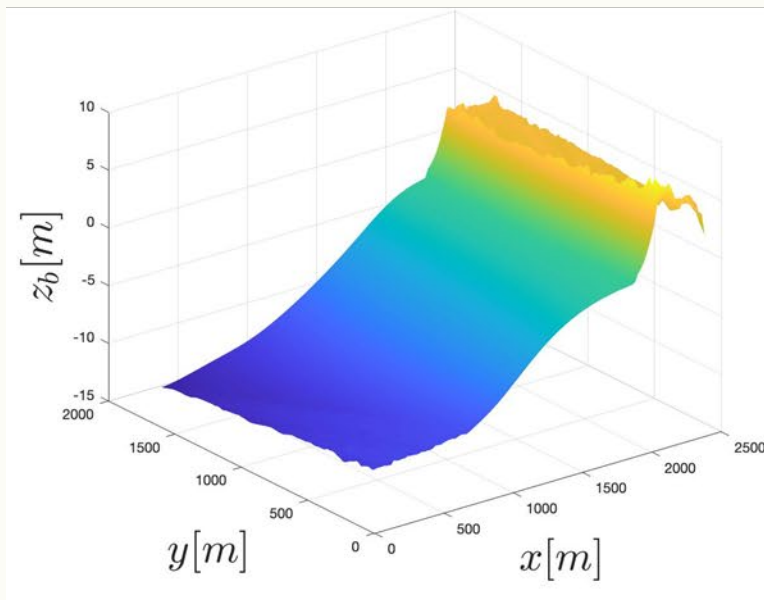
Add in capability to directly couple Aeolis with CMS for 2D applications

Approach:

- **cms_flow.f90 (modification)** – modify main code to call aeolian steering file and handle topographic updates (Brad Johnson)
- **aeolian.f90 (new)** – steering file to update topography from wind Includes system call to **aeolian.py** which generates all Aeolis input files, runs Aeolis, and returns data to CMS
- **scenario.cmcards (modification)** – new options for coupling interval and subaerial grain size

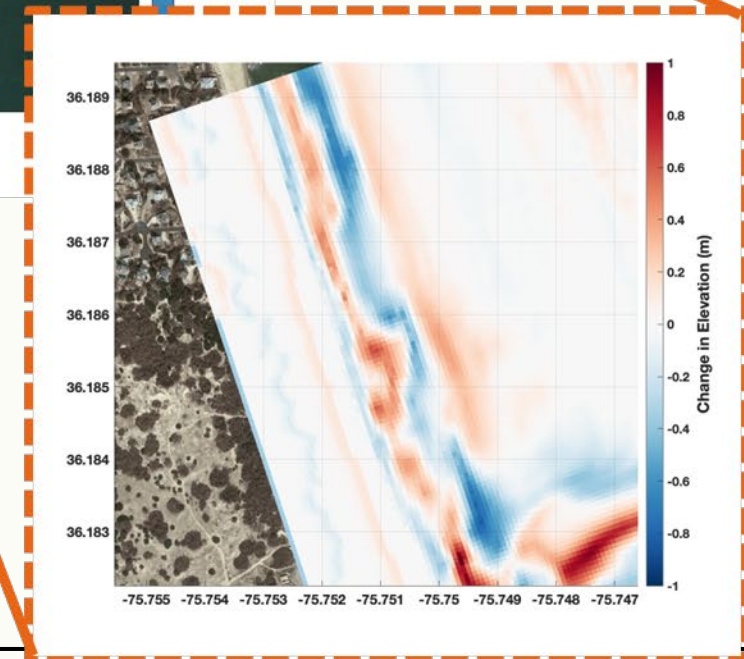
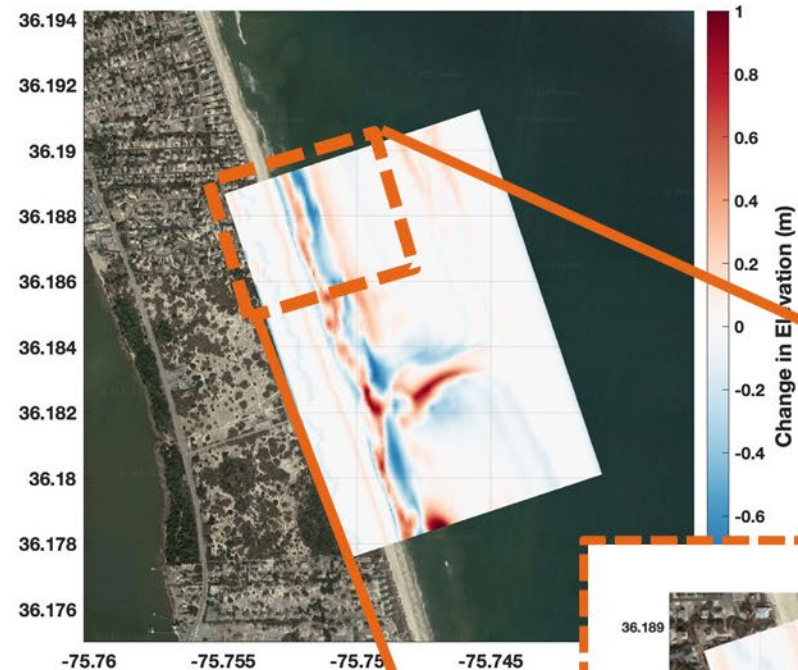
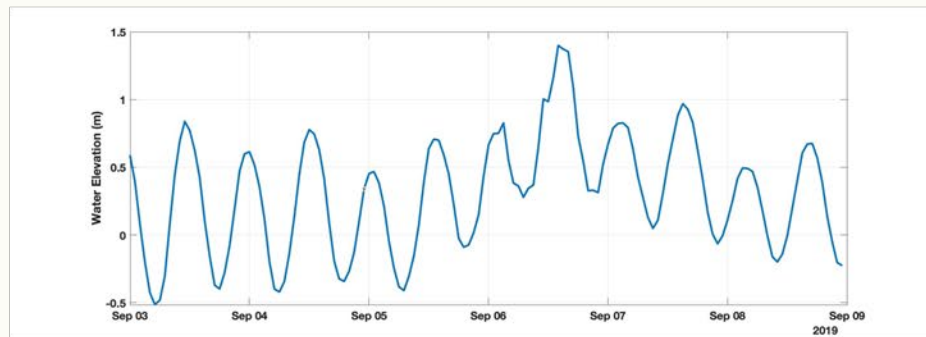
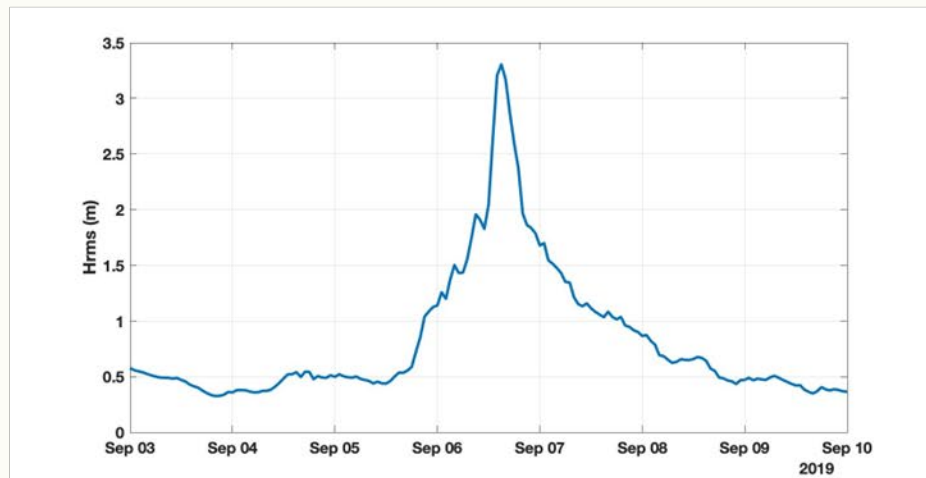
2D CMS-Aeolis Coupling

**Example 2D case for
Benson Beach, WA –
10 m/s onshore wind for
5 days**



2D CMS-Aeolis Coupling

Example 2D case for USACE Field Research Facility



US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Summary

FY22 Major Advances in Capability

- **Aeolis**
 - ▶ Major code updates for 1D and 2D applications
 - ▶ Bug tracking system
 - ▶ Self Guided Short Course Development
 - ▶ In Person Course Development
 - ▶ Journal Paper, Tech Note
- **DRT + CMS/Aeolis**

FY22 Major Products & Collaborations

- **2 TNs published**
- **2 JPs published**
- **1 Conference Presentation**
- **1 CIRP TD and 1 PDT Meeting**
- **Collaboration with Oregon State University, Lund University, TUDelft, KU Leuven, and Deltares on Aeolis Development**

Planned Outyear Products/Advances

- **Aeolis**
 - ▶ In-person model training (Coastal Sediments)
 - ▶ Conference presentations and papers
- **2D CMS-Aeolis Coupling**
 - ▶ Major development push and application of tool to real world conditions
 - Atlantic, Pacific, and Gulf Coasts