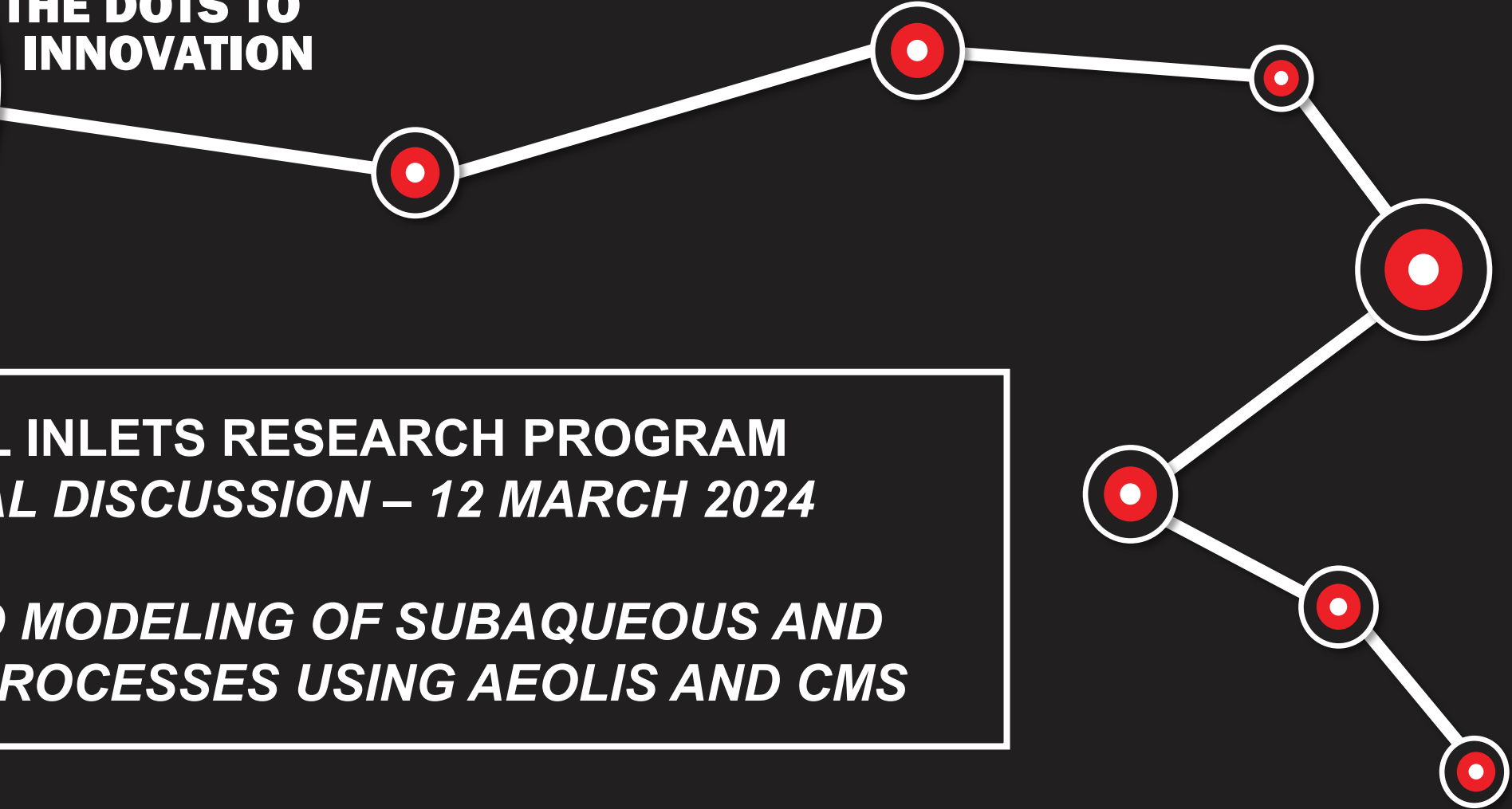


**CONNECTING  
THE DOTS TO  
INNOVATION**



**COASTAL INLETS RESEARCH PROGRAM  
TECHNICAL DISCUSSION – 12 MARCH 2024**

***COUPLED 2D MODELING OF SUBAQUEOUS AND  
SUBAERIAL PROCESSES USING AEOLIS AND CMS***

Dr. Nicholas Cohn, Research Oceanographer  
US Army Engineer Research and Development Center  
Nicholas.T.Cohn@erdc.dren.mil



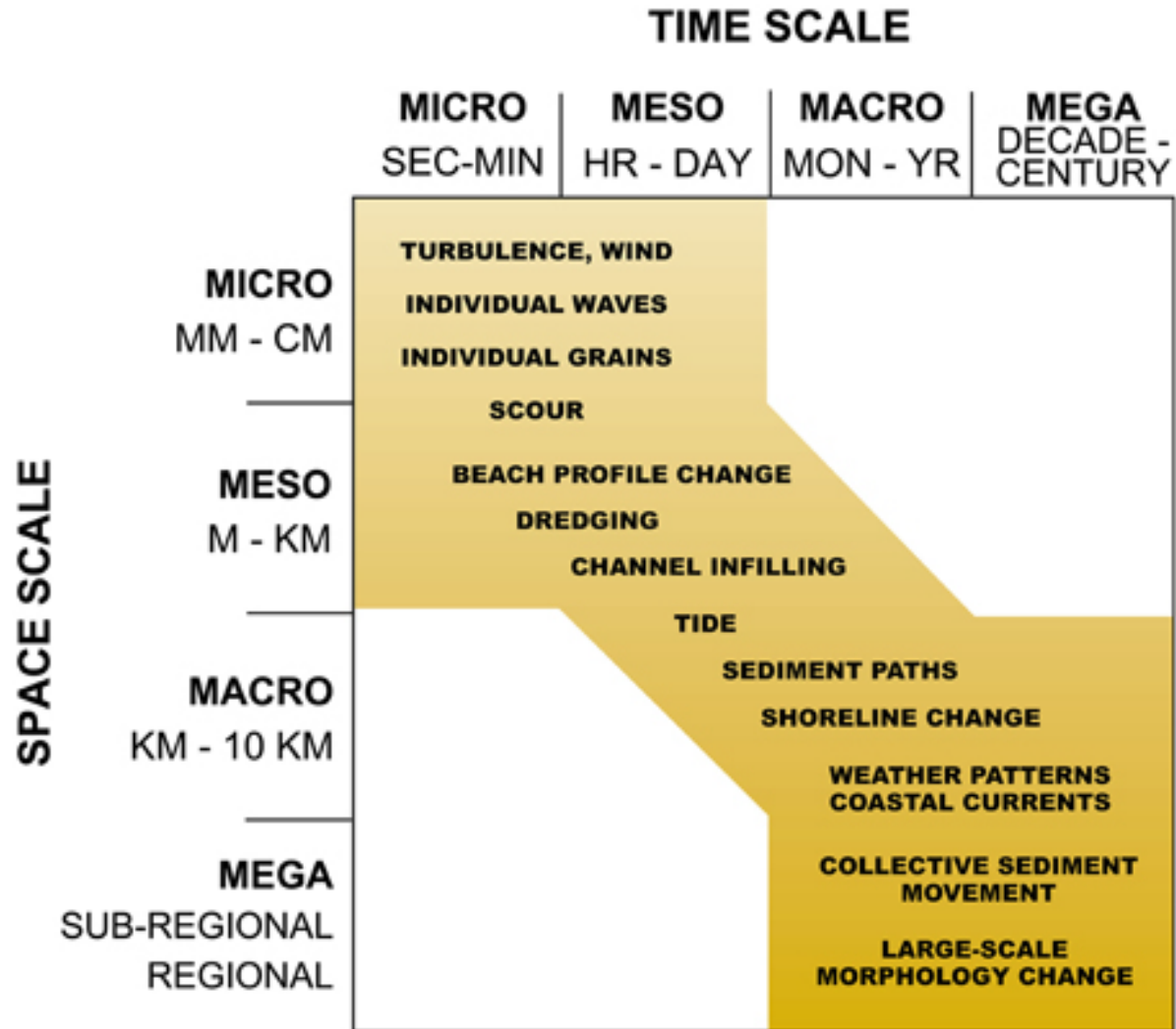
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# OUTLINE

1. Background on Relevant Marine-Aeolian Processes
2. Current Community Capabilities for Modeling Co-Evolution of Nearshore-Beach-Dune Systems
3. ERDC R&D: CMS-Aeolis Coupling
4. Demonstration/Hypothetical Coupled Model Cases
5. Example CONUS Cases
6. Outlook/Next Steps

# 1. BACKGROUND



# 1. BACKGROUND

## Event-Scale

## Annual to Decadal Scale

Aeolian  
Sediment Transport



Wave-Driven  
Sediment Transport



# 1. BACKGROUND

## Event-Scale

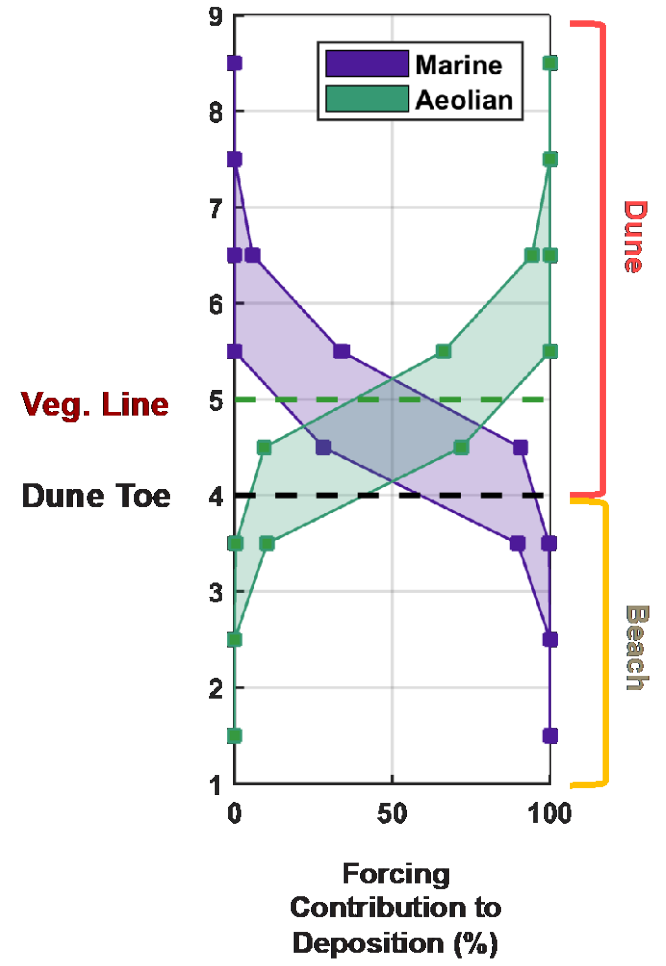
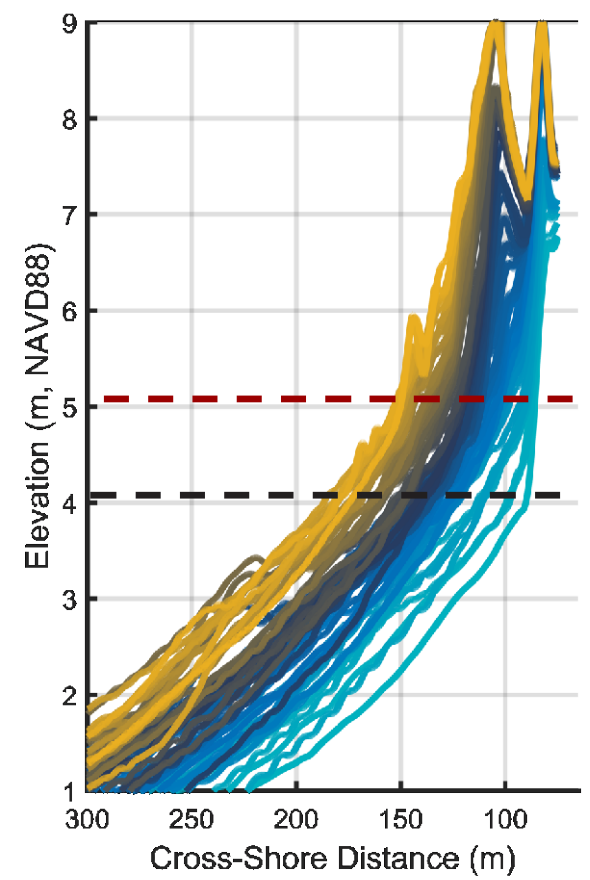
Aeolian  
Sediment Transport



Wave-Driven  
Sediment Transport



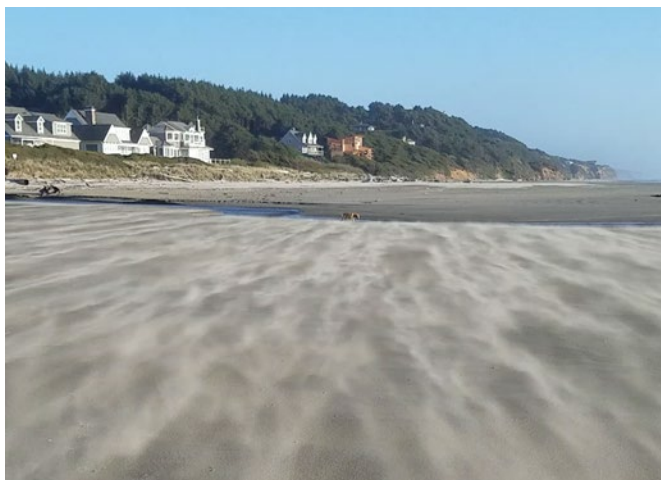
## Annual to Decadal Scale



# 1. BACKGROUND

## Event-Scale

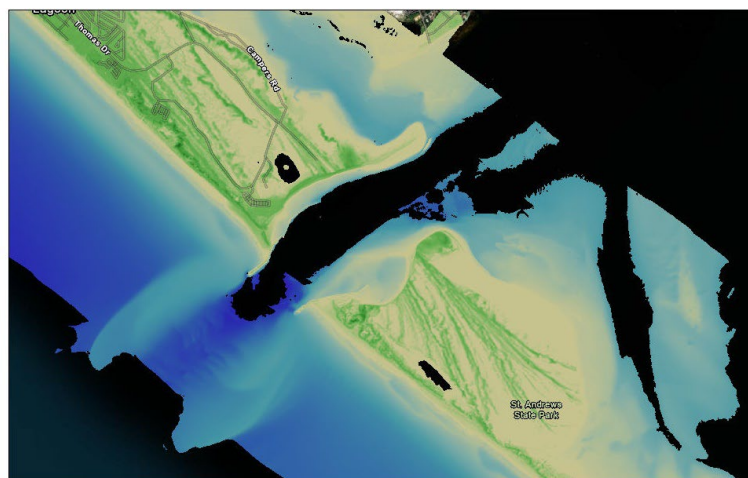
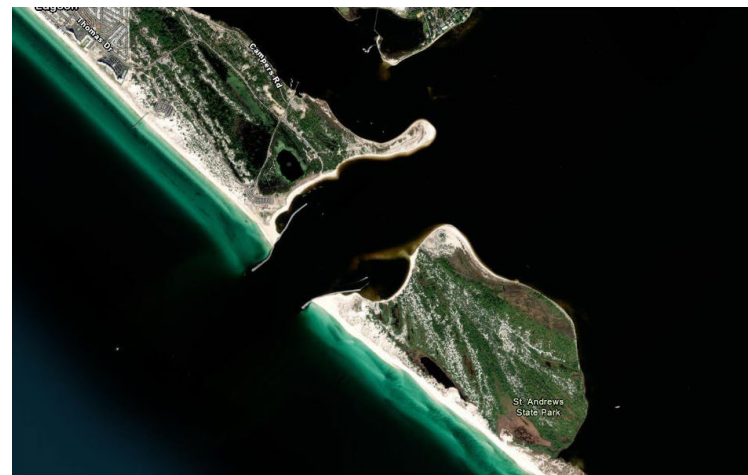
Aeolian  
Sediment Transport



Wave-Driven  
Sediment Transport



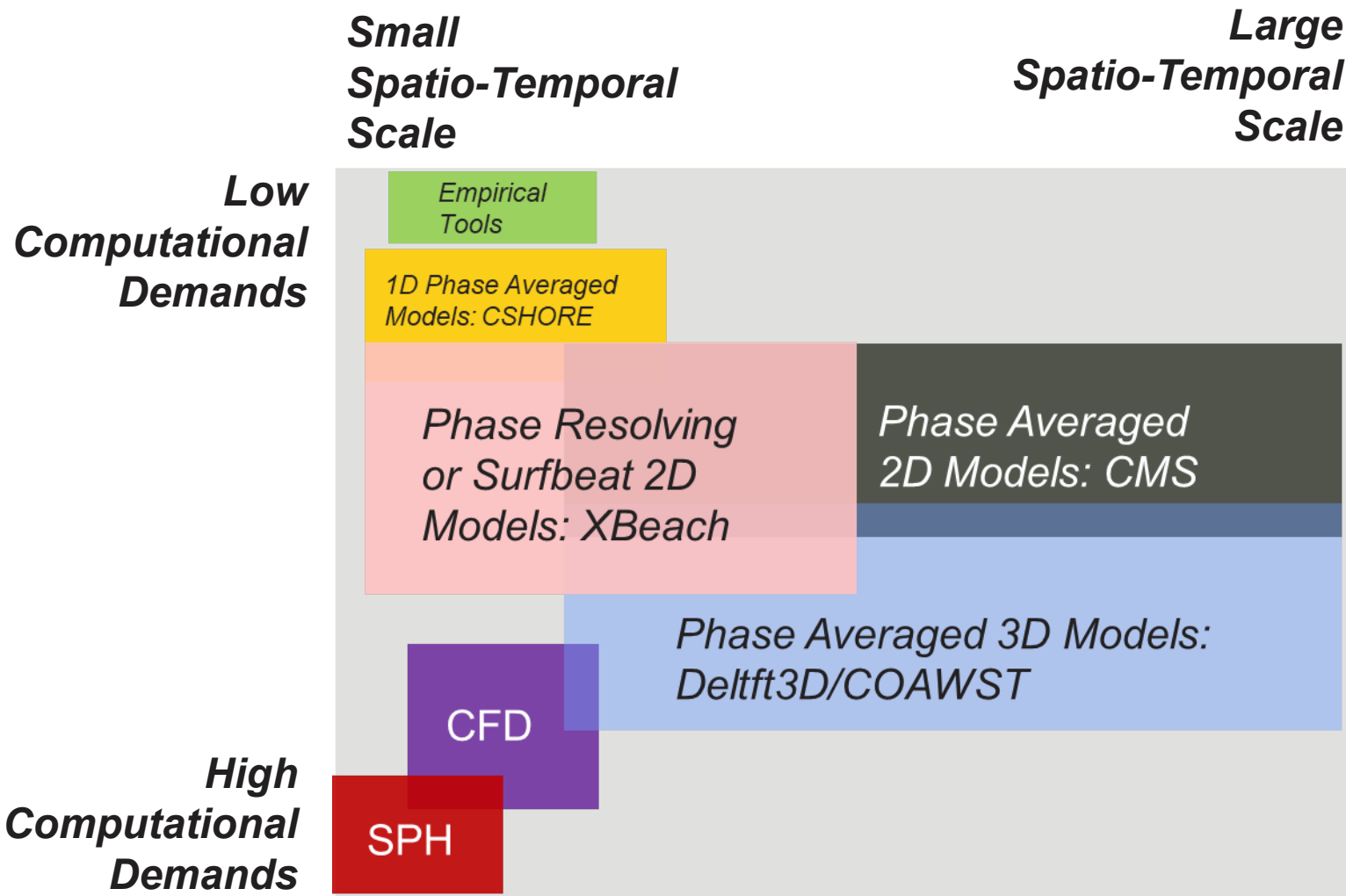
## Annual to Century+ Scale



St Andrews Inlet, Panama City, FL

## 2. CURRENT MODELING CAPABILITIES

Marine



Note: Not a comprehensive list of all available models



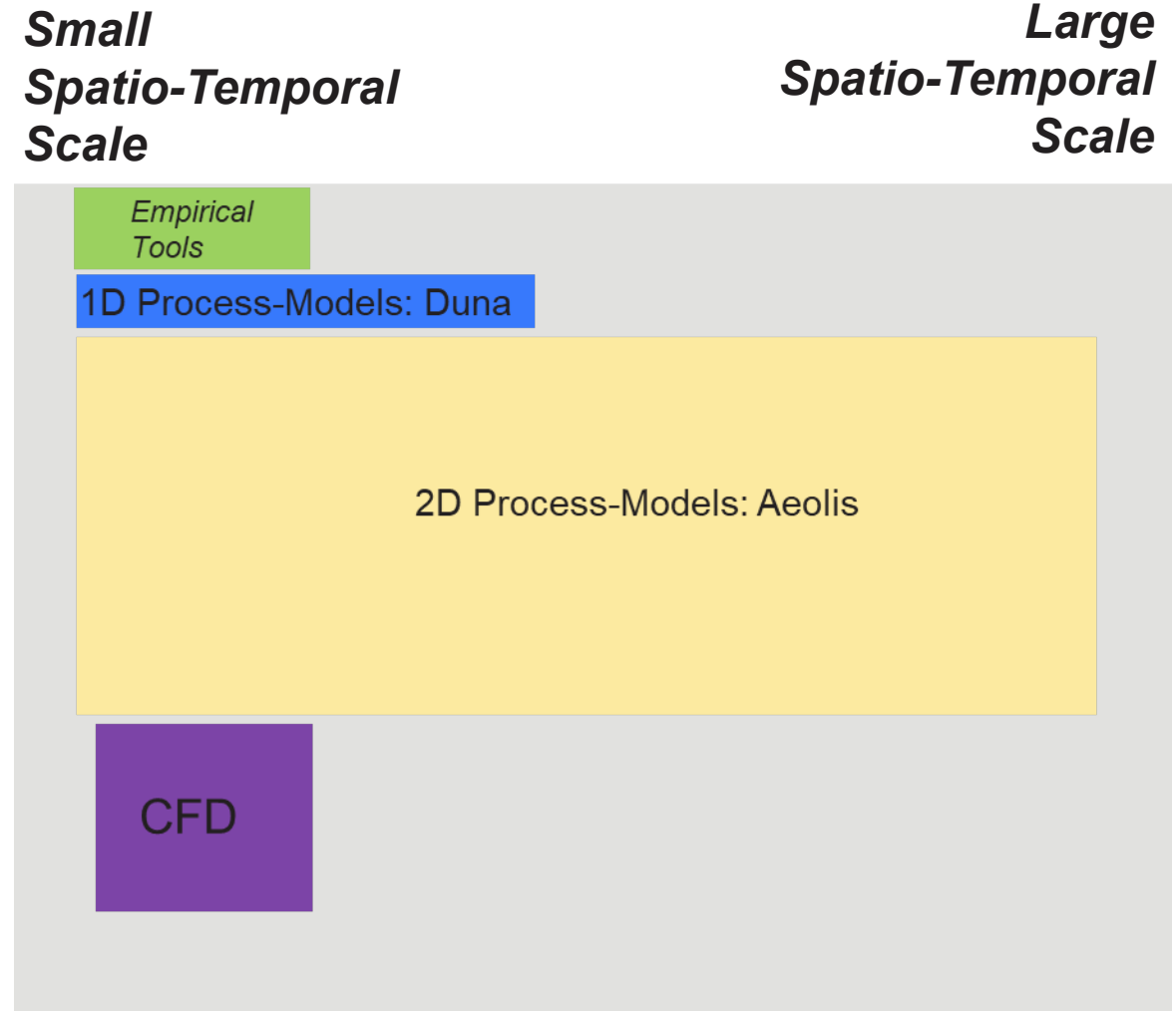
# 2. CURRENT MODELING CAPABILITIES

Aeolian



**Low Computational Demands**

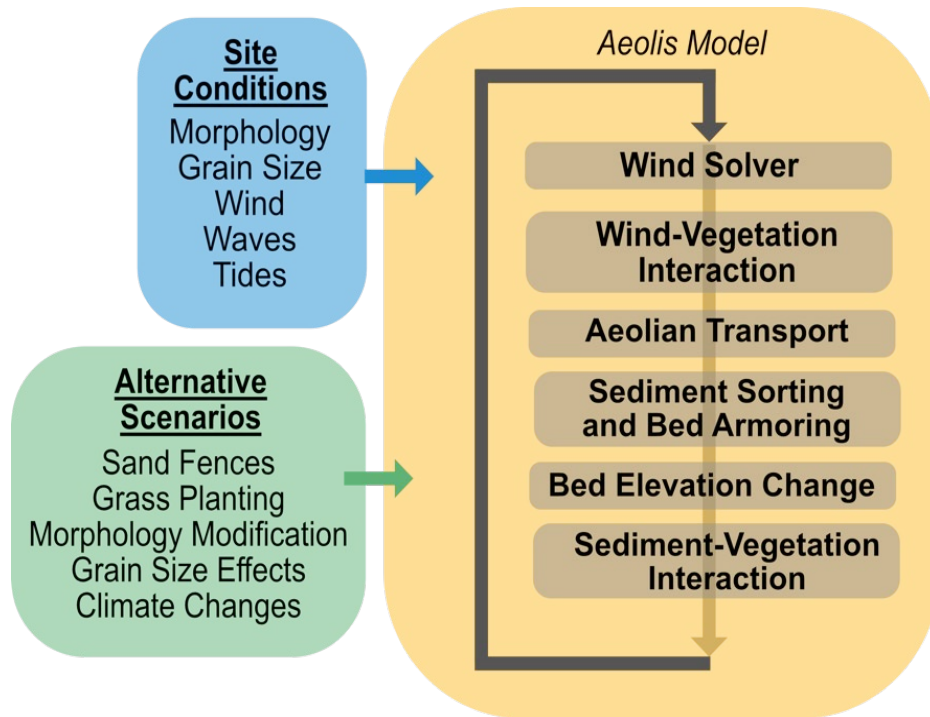
**High Computational Demands**



*Note: Not a comprehensive list of all available models*



## 2. CURRENT MODELING CAPABILITIES

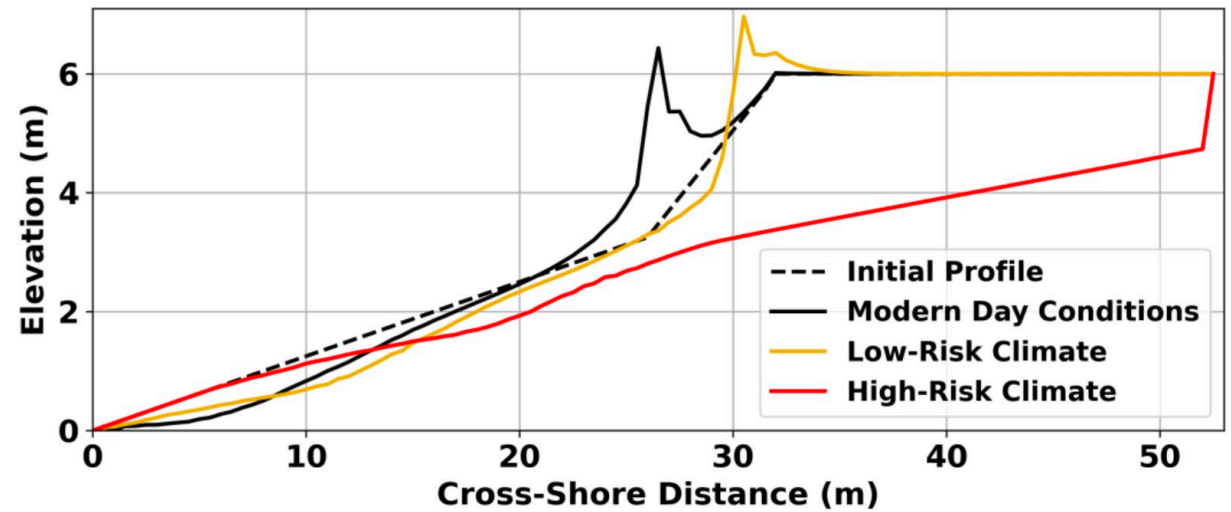
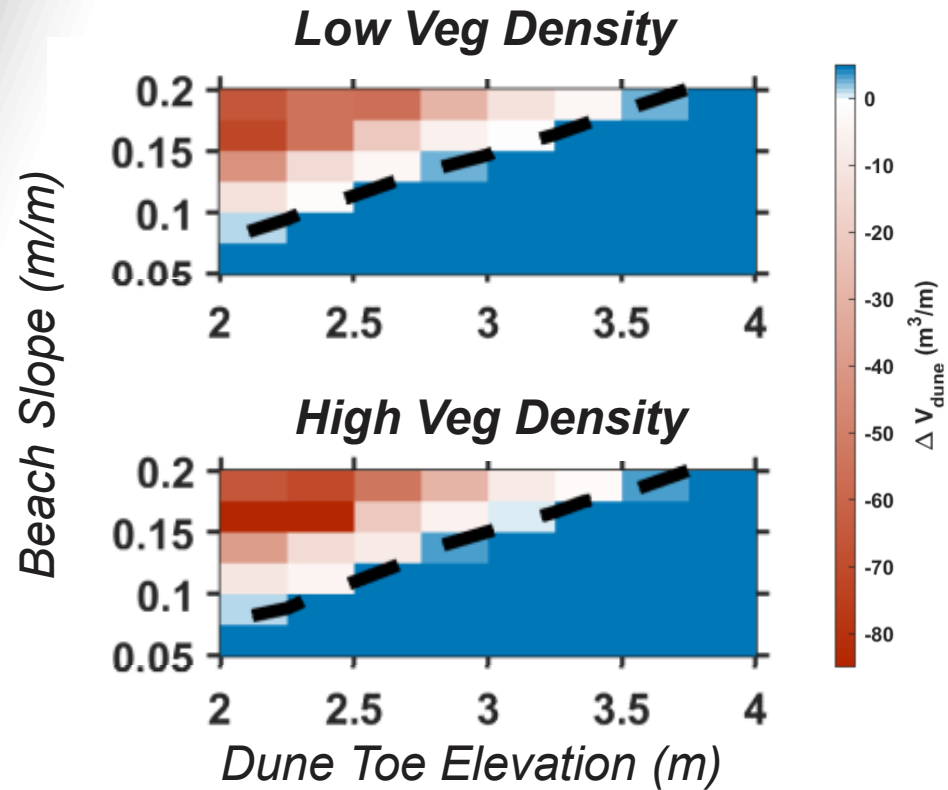




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## 2. CURRENT MODELING CAPABILITIES



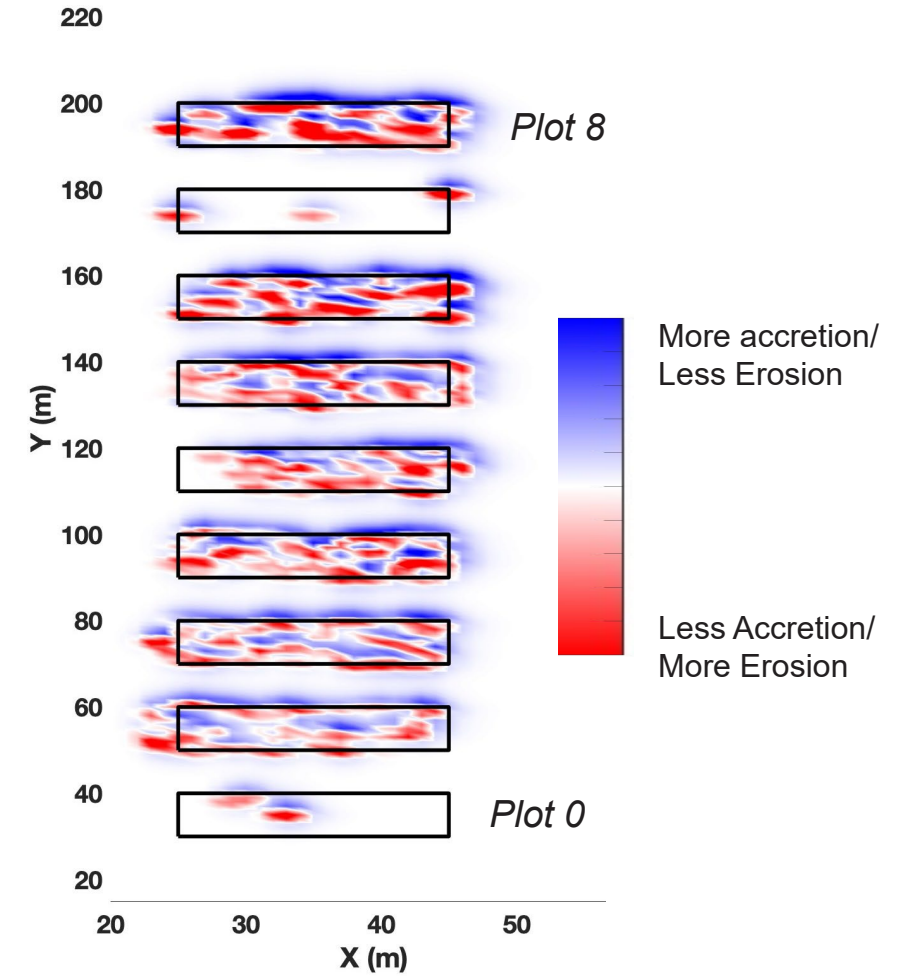
Seminway et al., in revision

## 2. CURRENT MODELING CAPABILITIES



# GENVEG

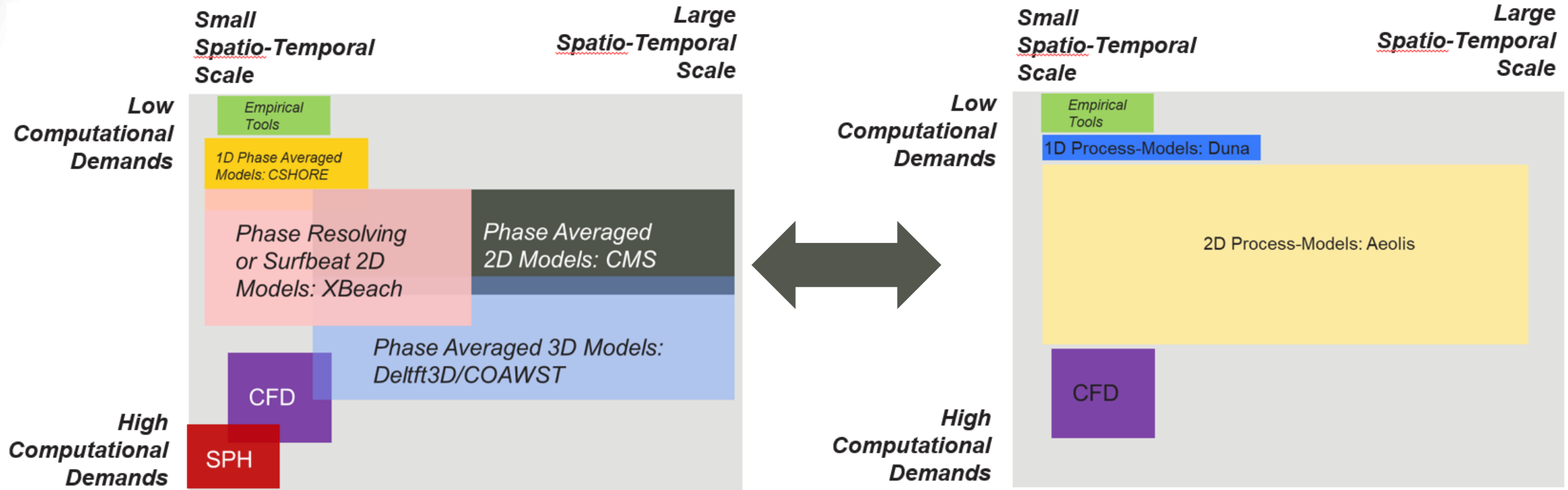
Collaborative with Candice Piercy (EL), Todd Swannack (EL), Oregon State



# 2. CURRENT MODELING CAPABILITIES

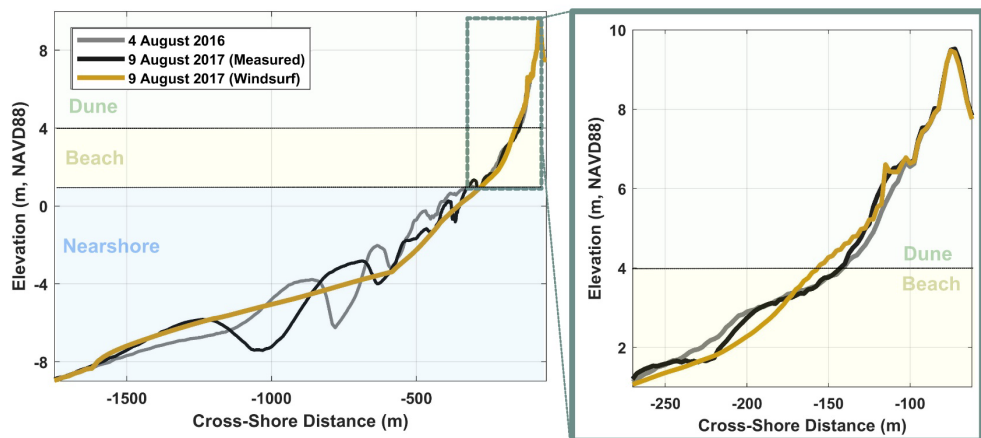
## Marine

## Aeolian

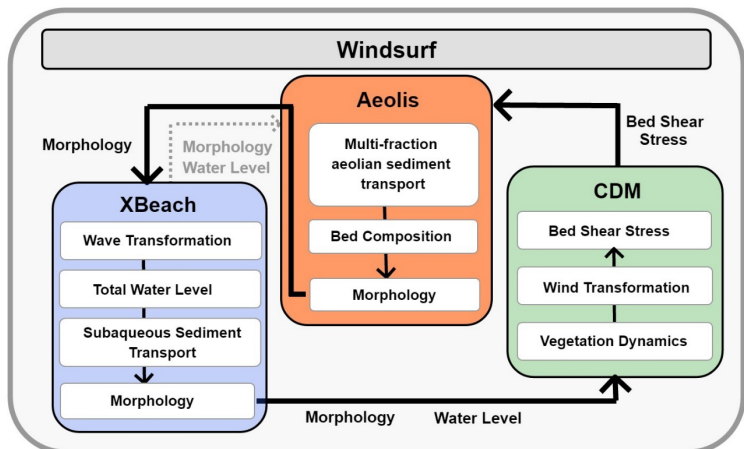
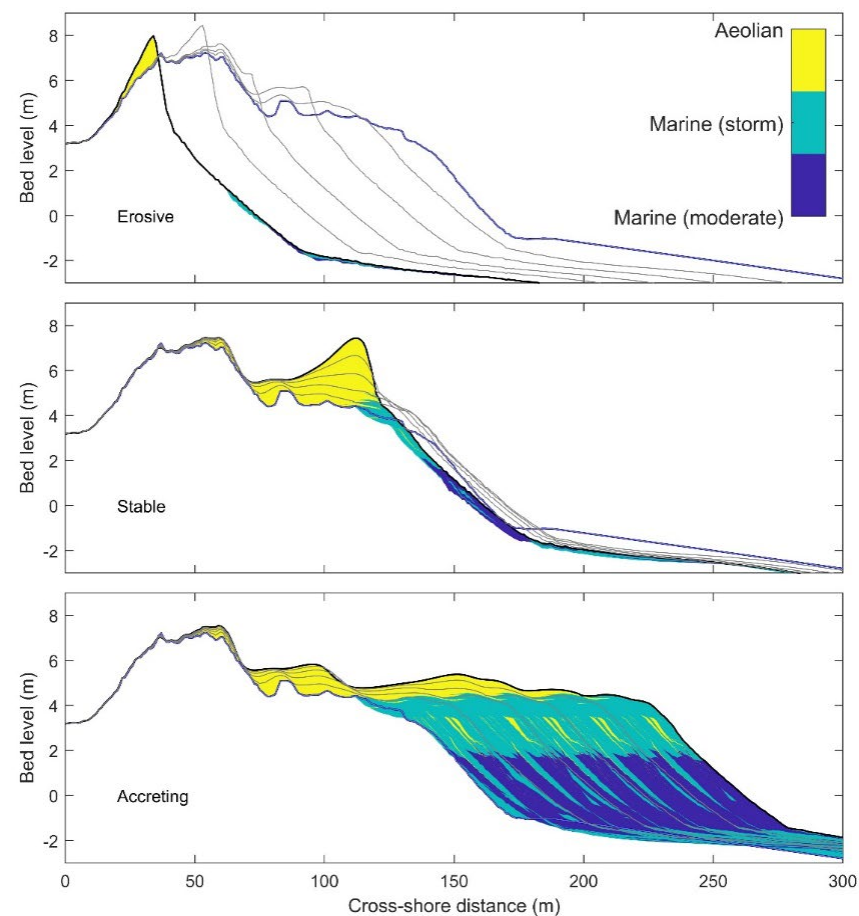


## 2. CURRENT MODELING CAPABILITIES

### Windsurf (XBeach-CDM-Aeolis)



### XBeach-Duna

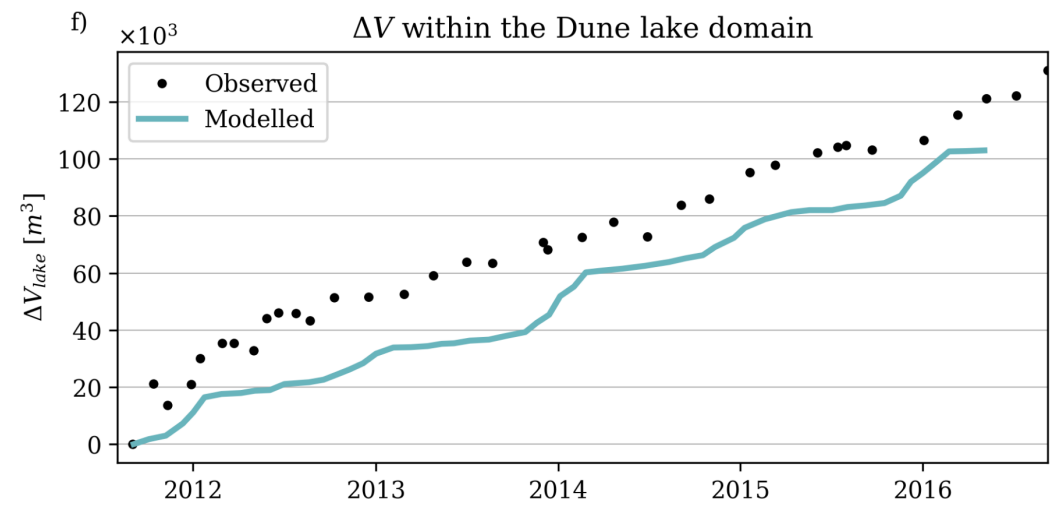
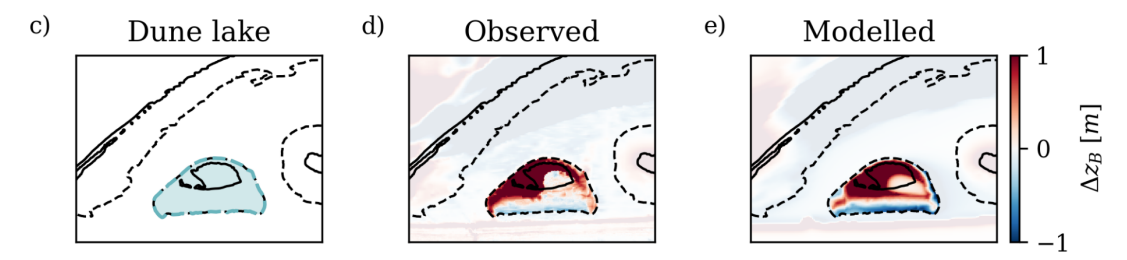
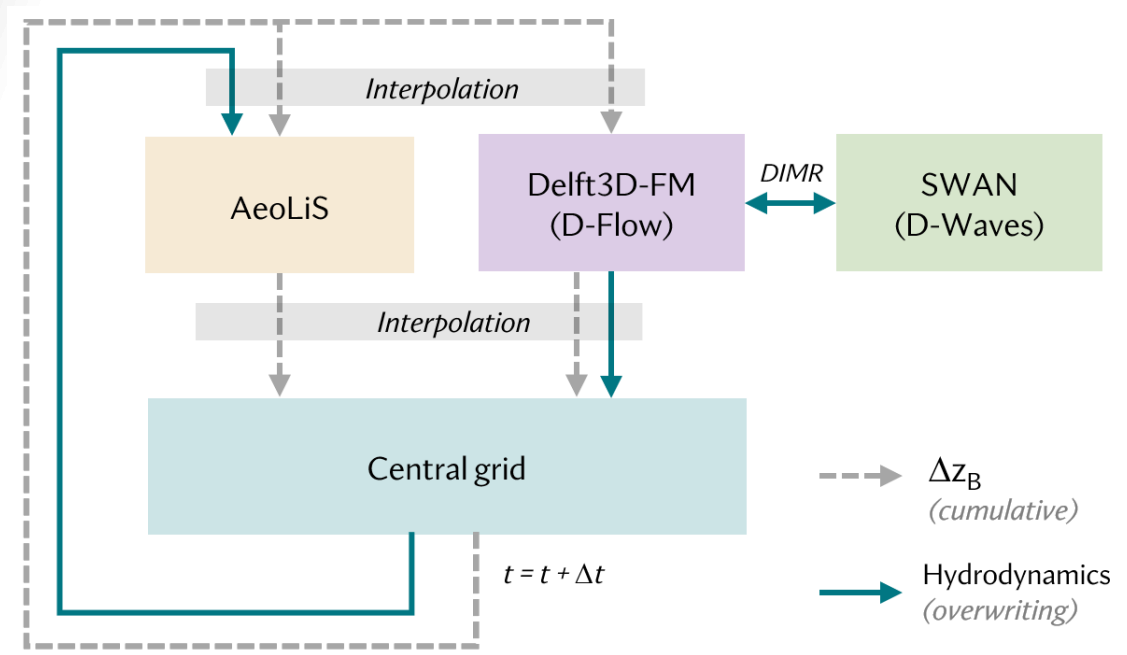


Cohn et al., 2019

Roelvink and Costas, 2019

## 2. CURRENT MODELING CAPABILITIES

### Delft3D-SWAN-Aeolis

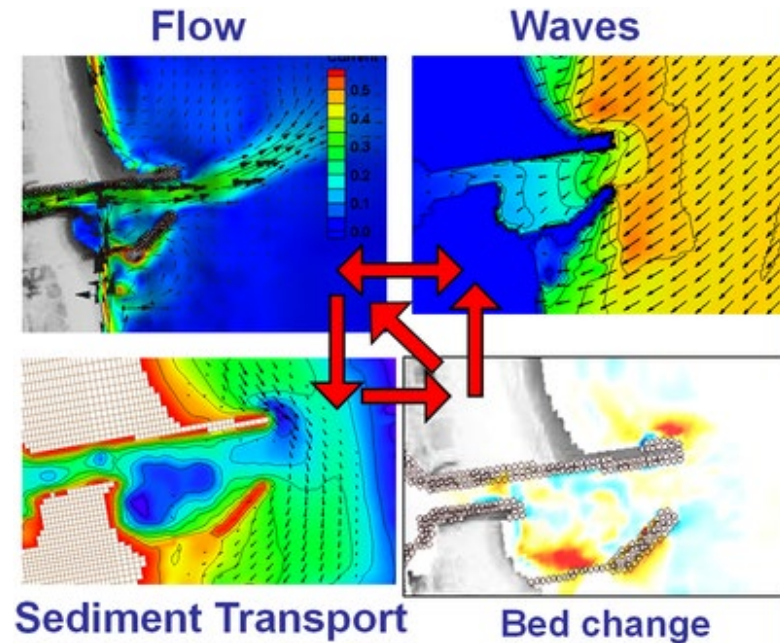


van Westen et al., 2024



### 3. CMS-AEOLIS DEVELOPMENT

#### *Traditional CMS Workflow – Aeolian Transport Not Considered*



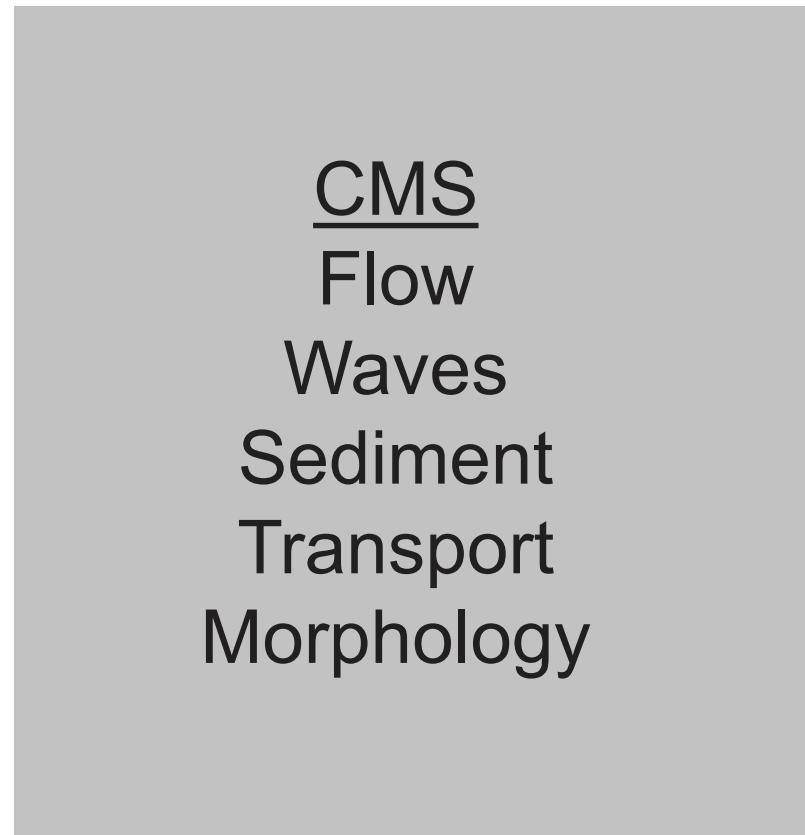
#### Approach:

- **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



### 3. CMS-AEOLIS DEVELOPMENT

- All open-source models
- Extended capability for standard USACE models
- Fast computations



Topography  
Water Depth  
Winds



aeolian.f  
aeolian.py



Updated Topography



**New CMS dependencies:** python, AeoLiS

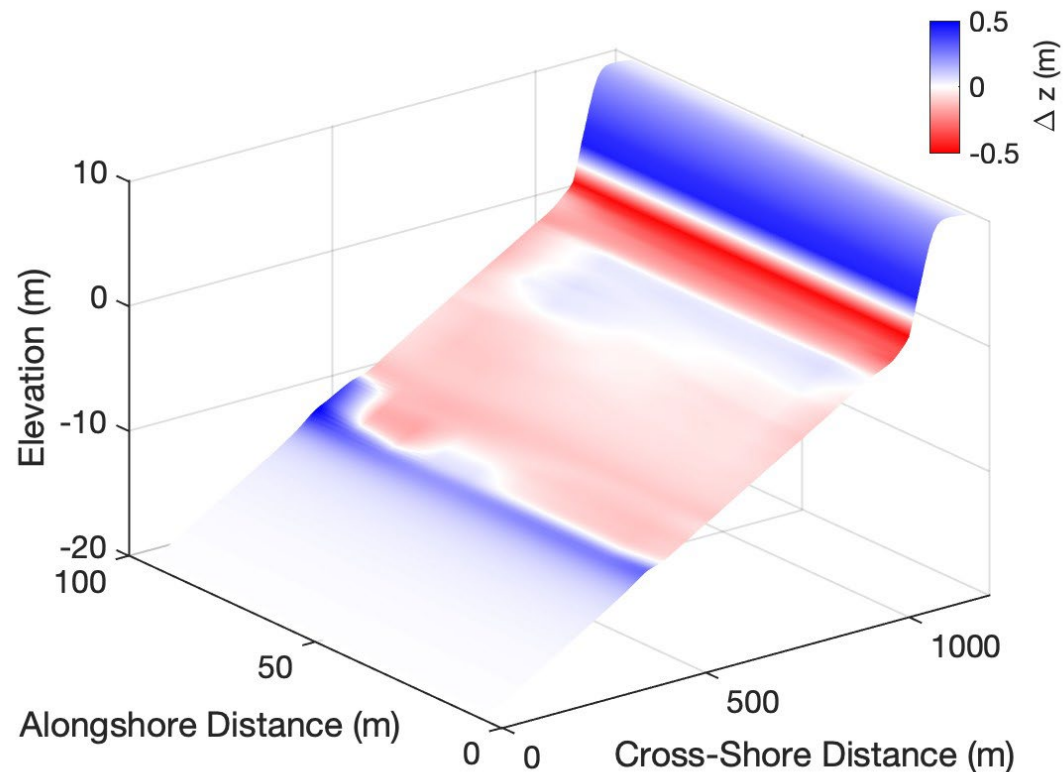
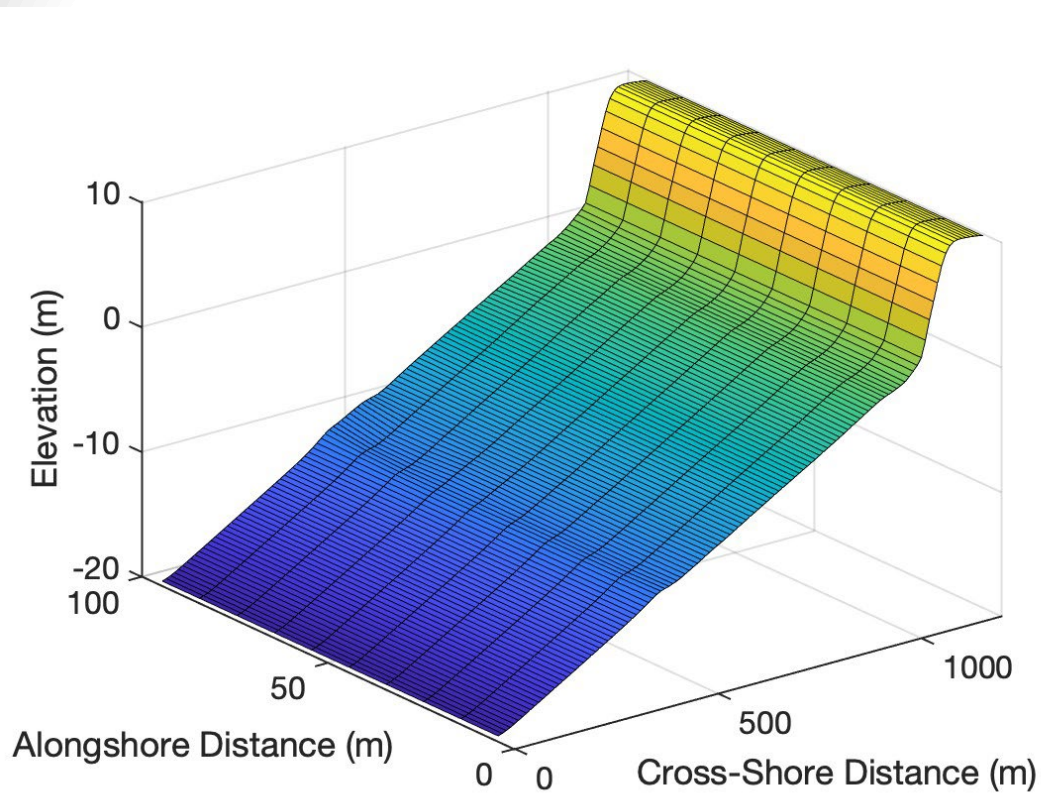




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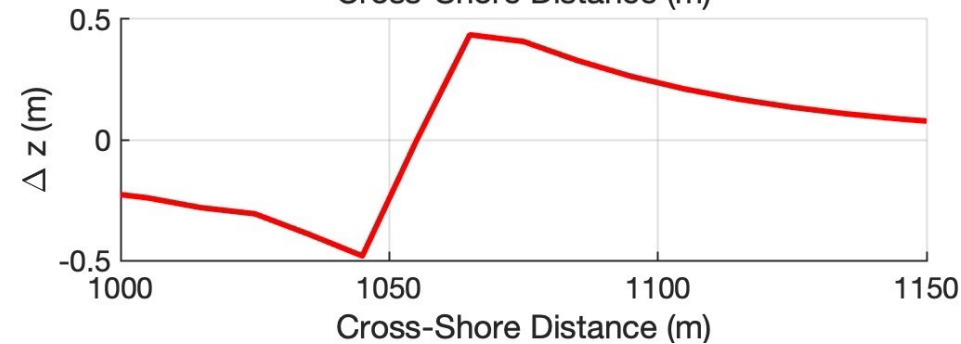
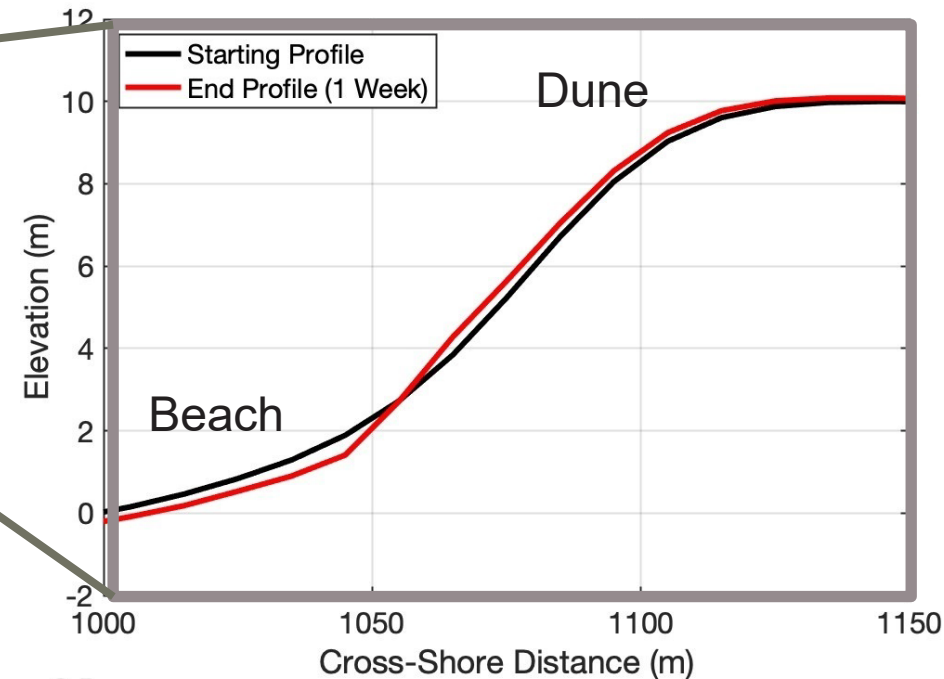
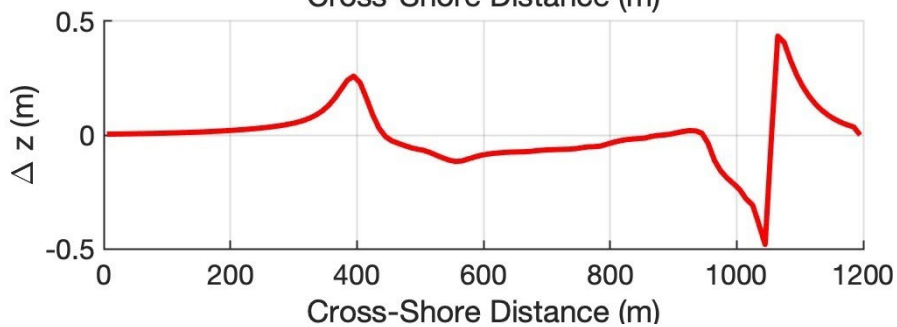
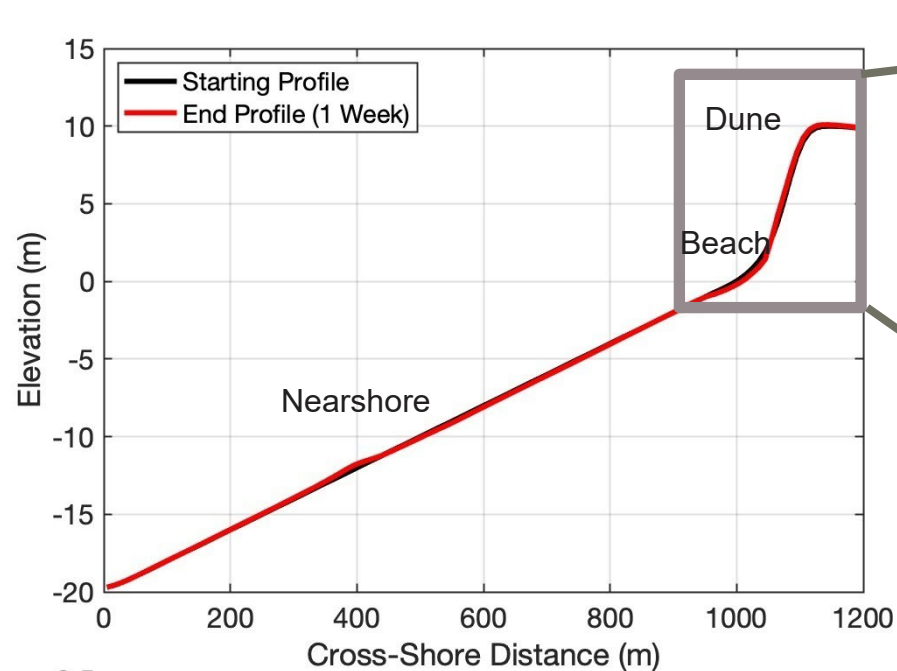


# 4. DEMONSTRATION CASES





# 4. DEMONSTRATION CASES

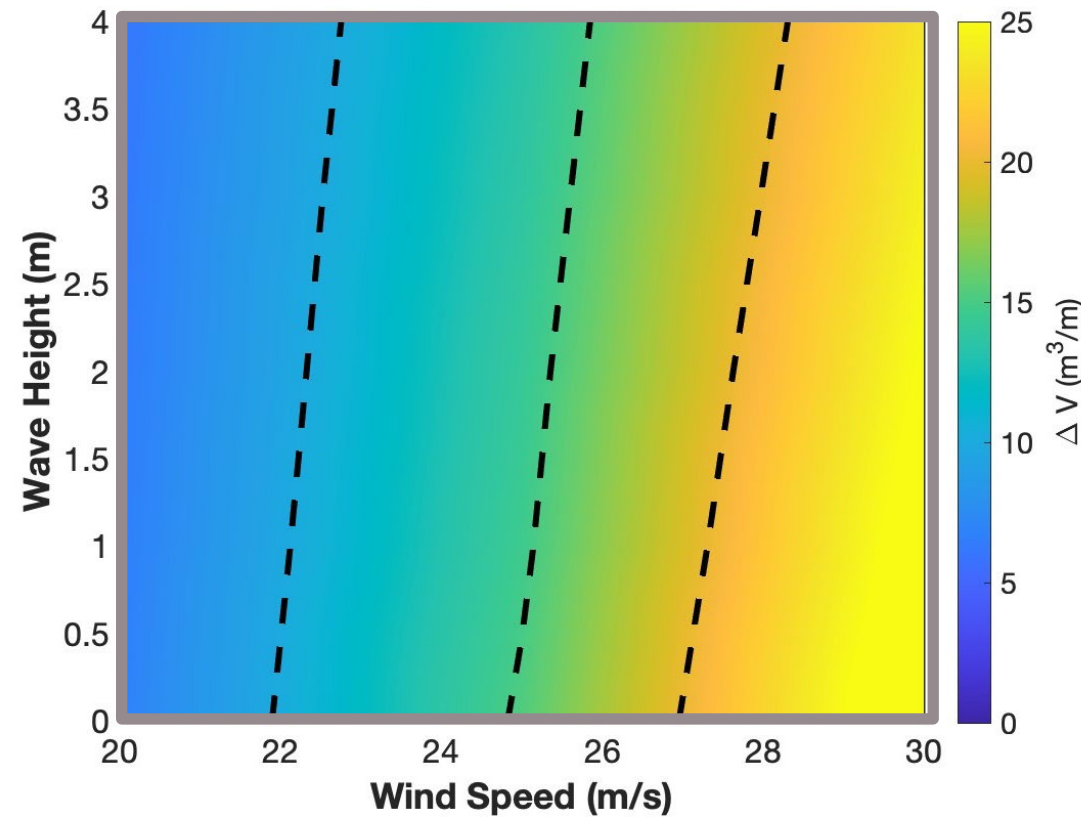
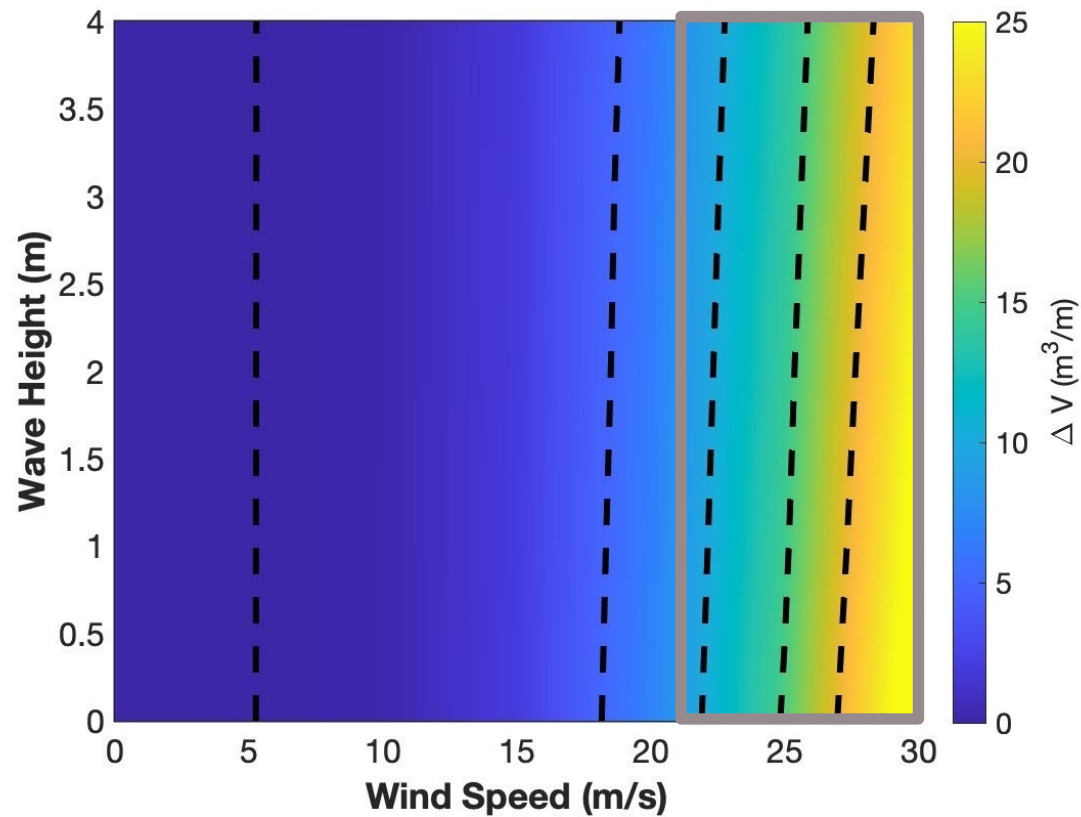




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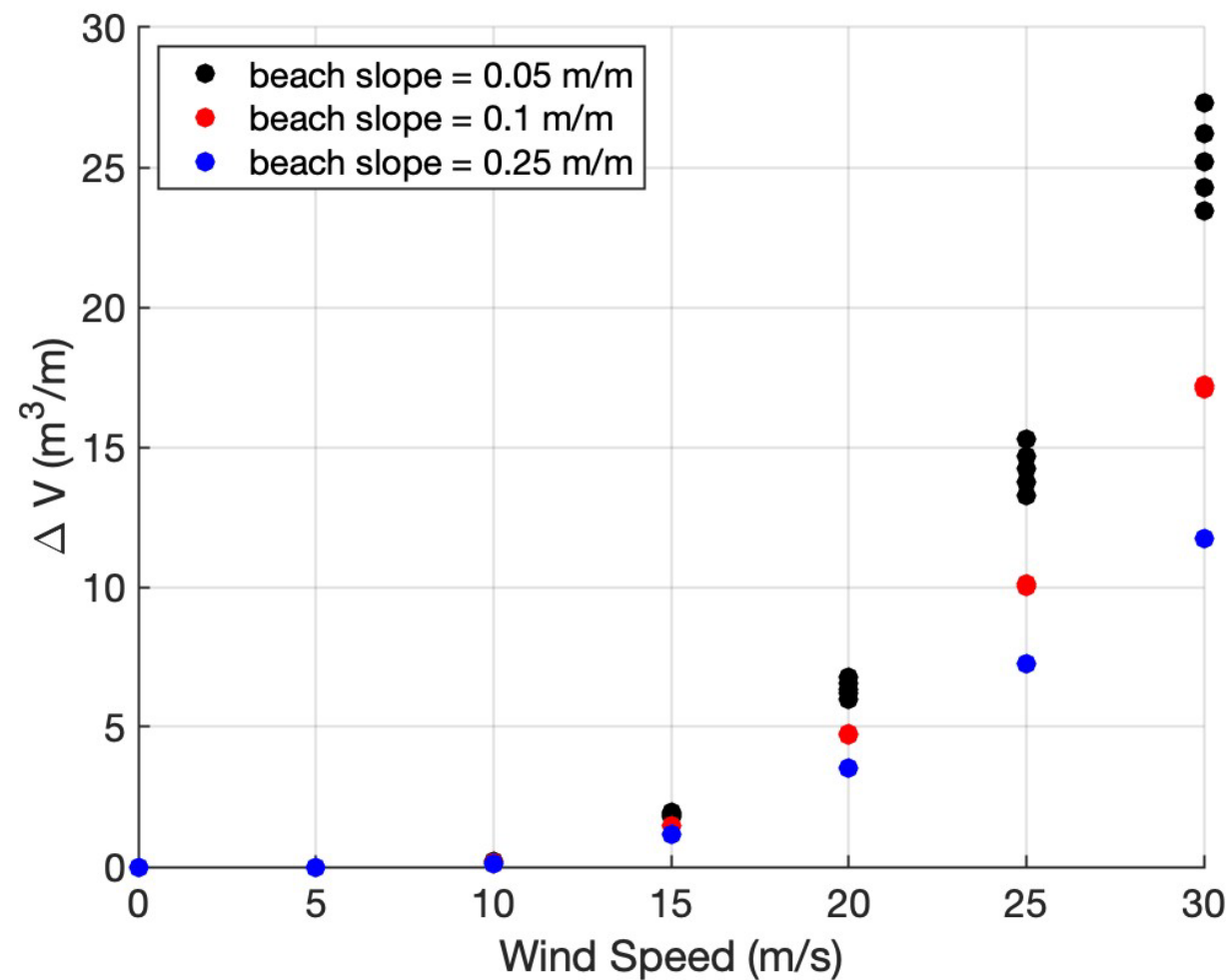


# 4. DEMONSTRATION CASES



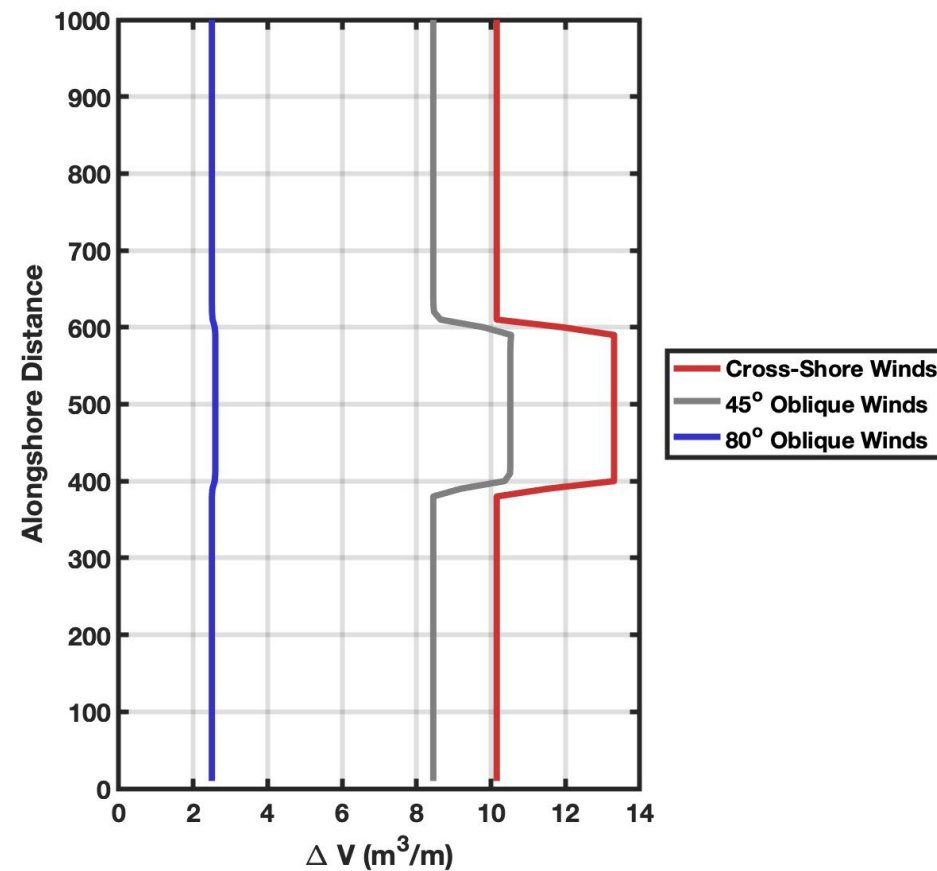
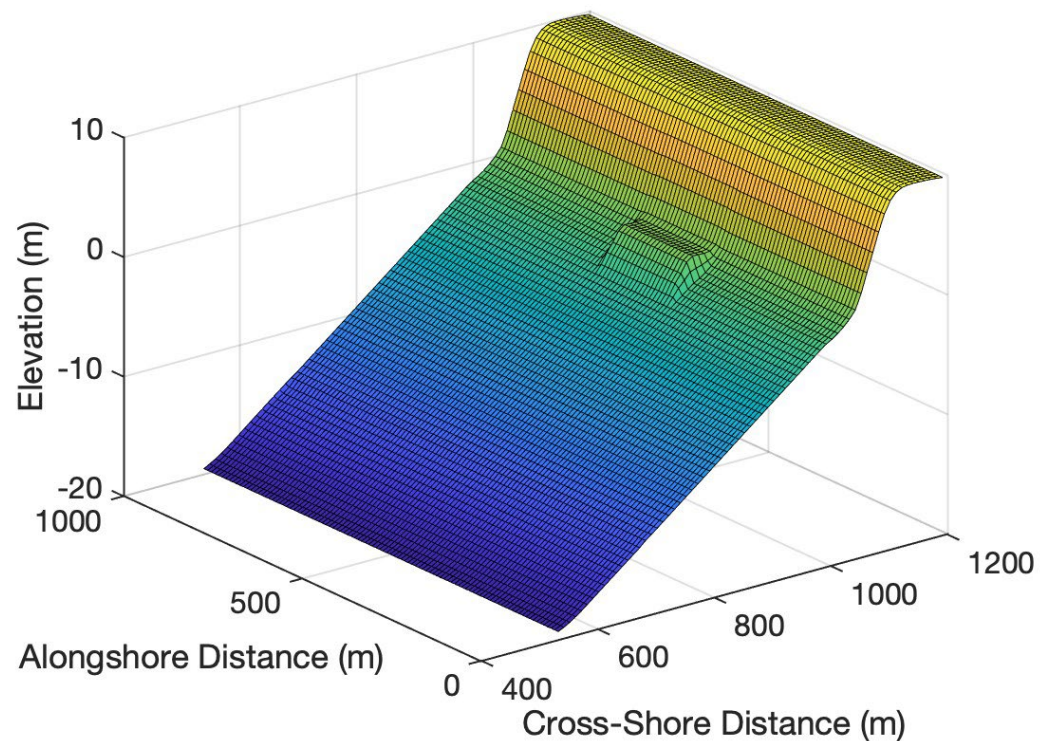


## 4. DEMONSTRATION CASES



## 4. DEMONSTRATION CASES

Modified 2D Example with Beach  
Nourishment or Berm





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## 4. DEMONSTRATION CASES

### What Dynamics Successfully Capturing:

- (1) More Energetic Winds → More Dune Growth ✓
- (2) Lower Sloped/Wider Beaches → More Dune Growth ✓
- (3) Lower Sloped/Wider Beaches → More Influence of Waves on Aeolian Processes ✓
- (4) Realistic Cross-Shore Dune Growth Patterns ✓
- (5) Alongshore Variability in Dune Growth Based on Beach Properties and Wind Angle ✓

## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA



## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA

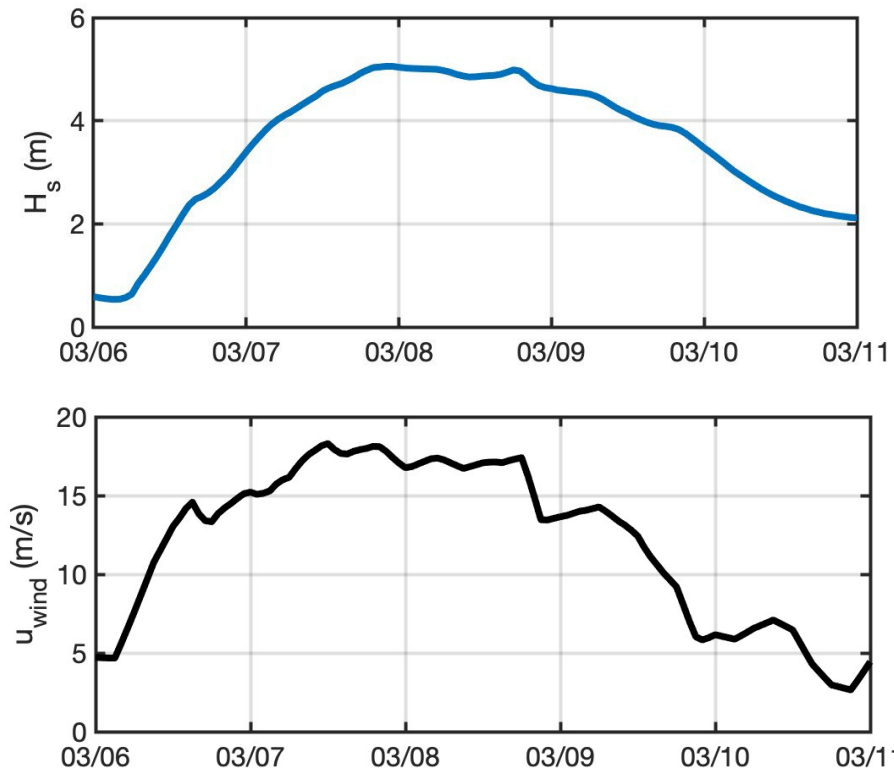




## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA

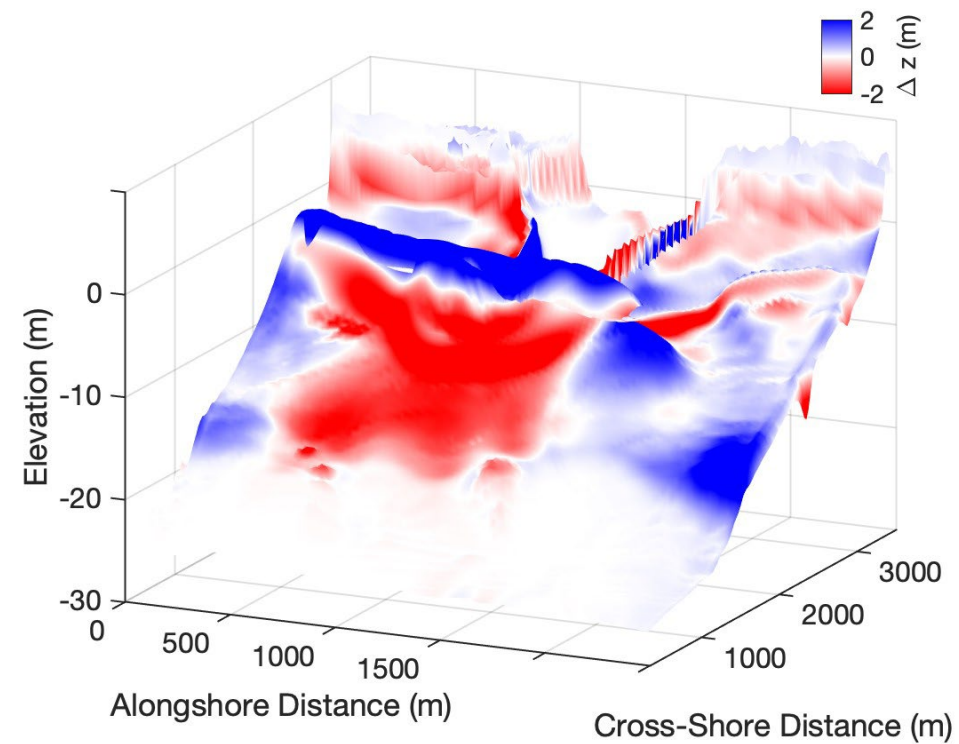
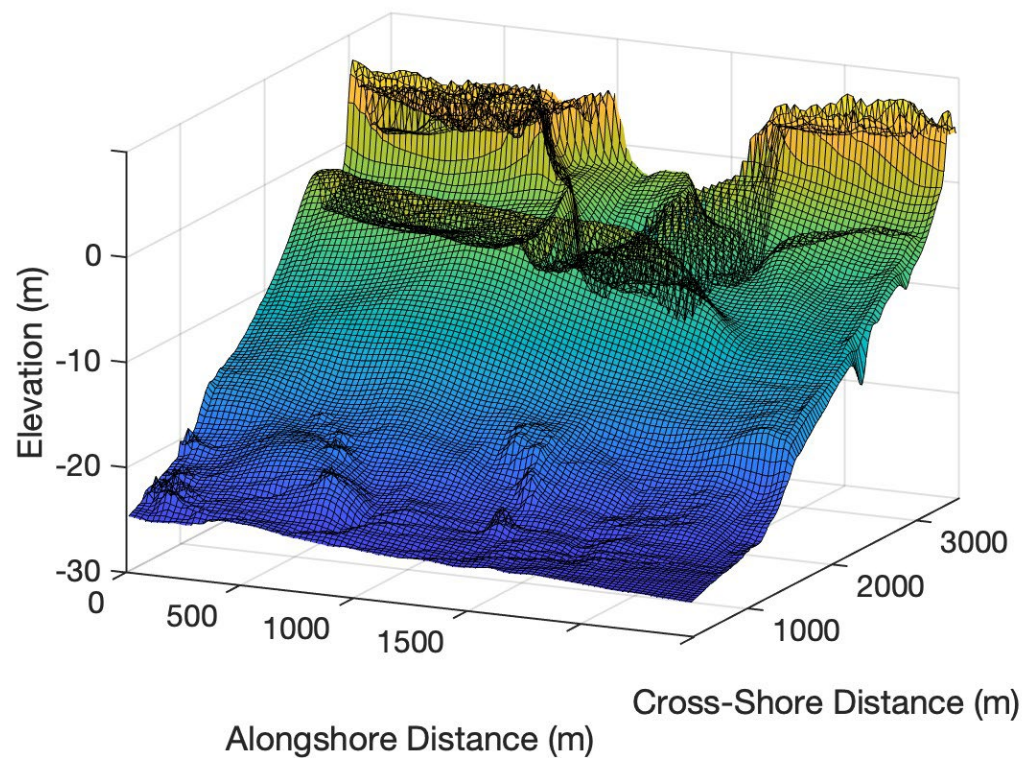
March 2013 Nor'Easter





## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA



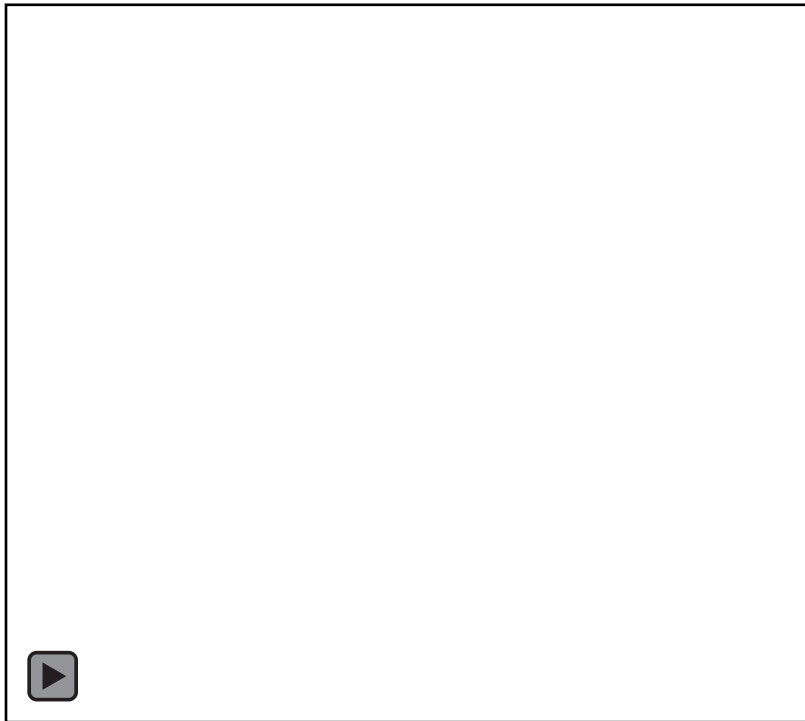


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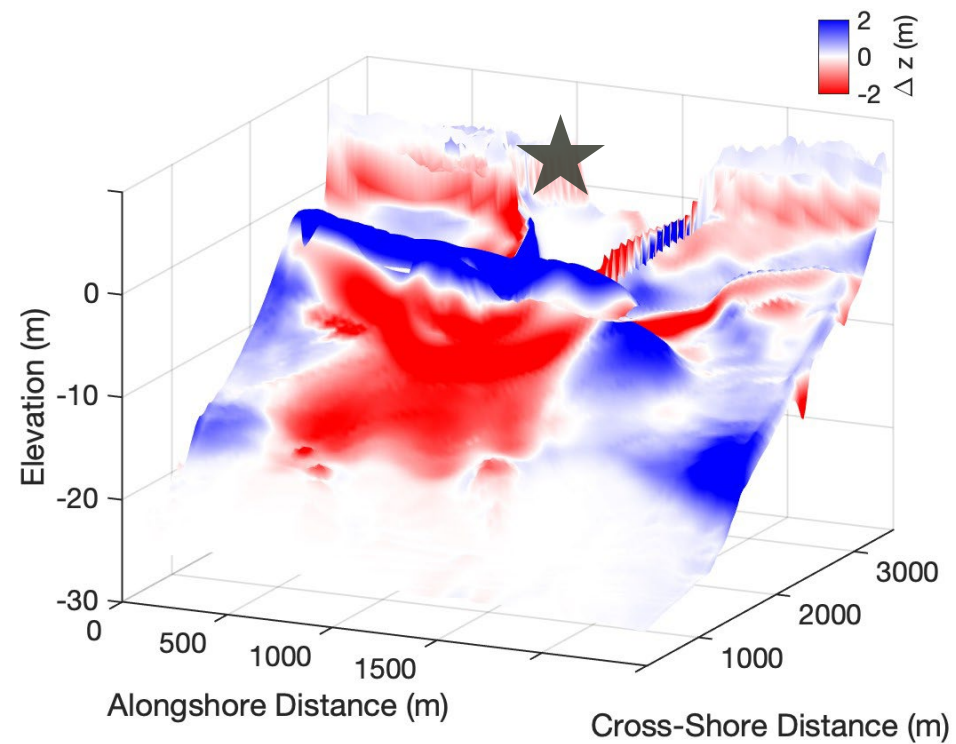
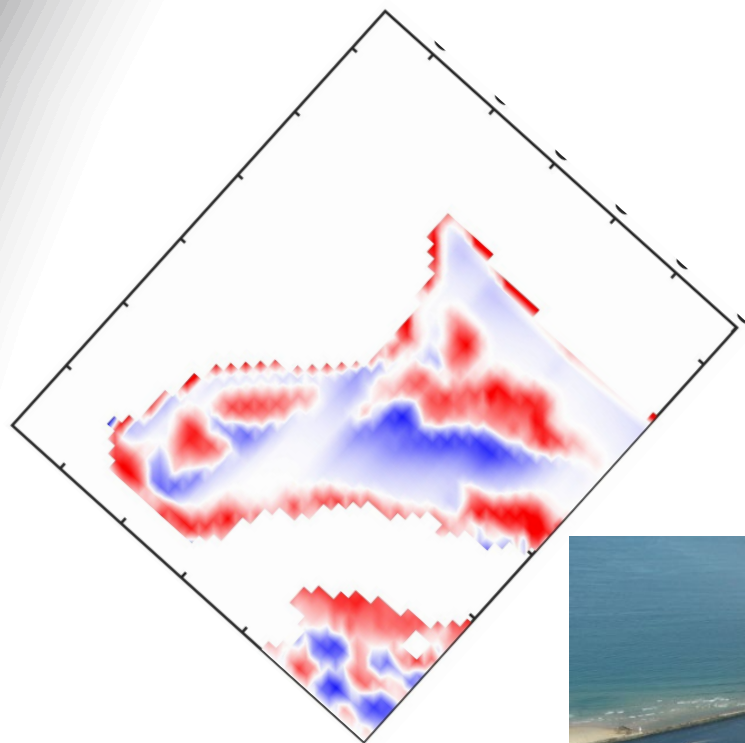
## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA



## 5. REAL WORLD CASES

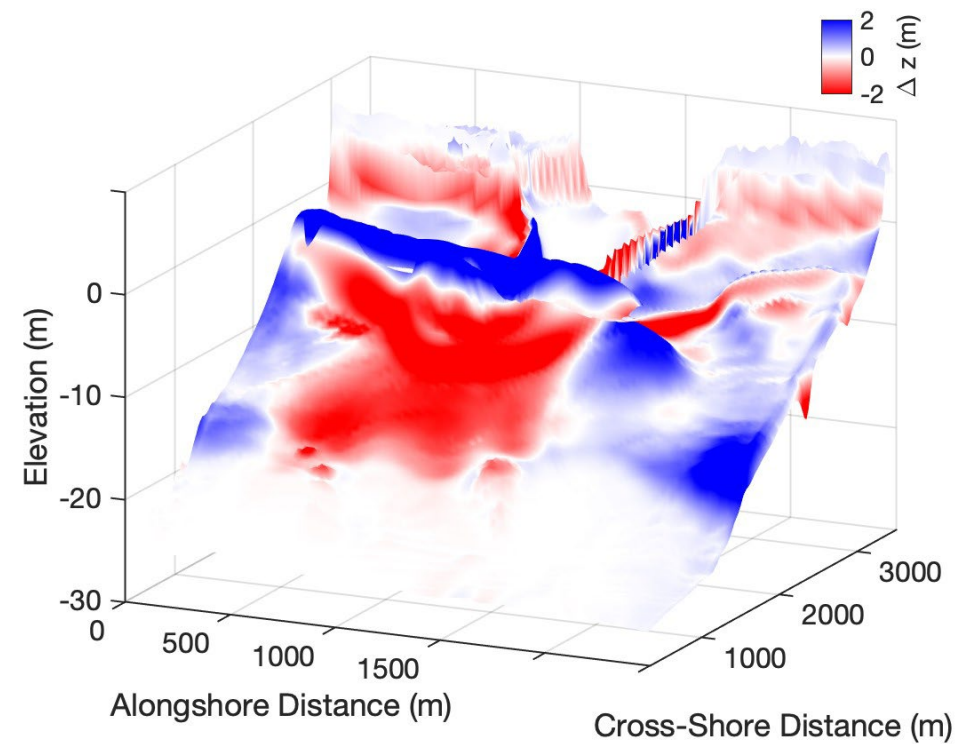
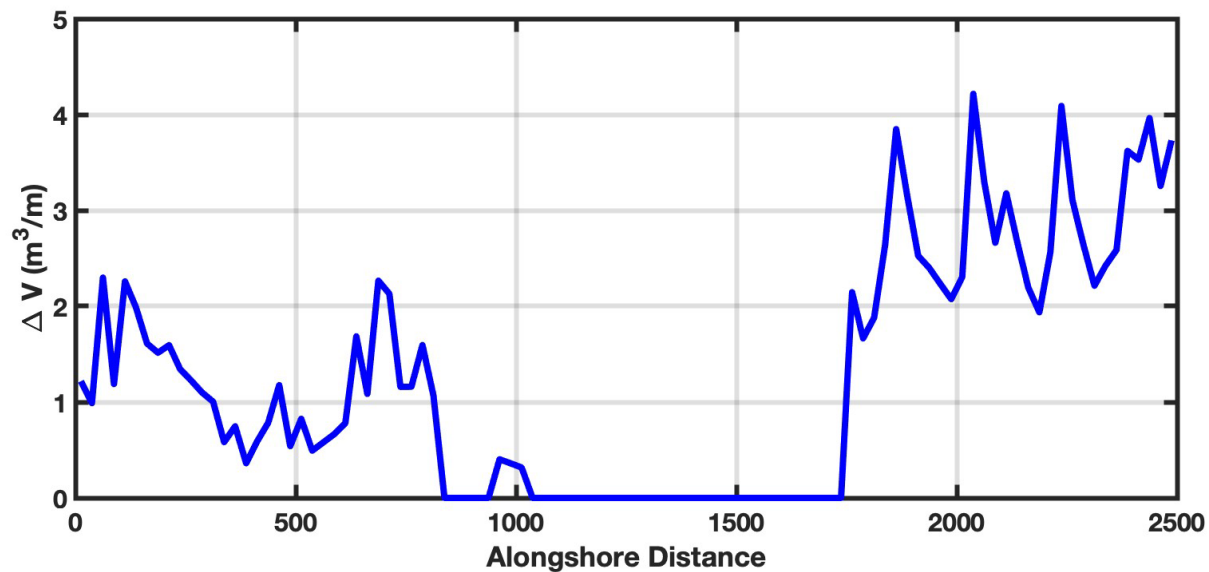
Merrimack Inlet/Newburyport, MA





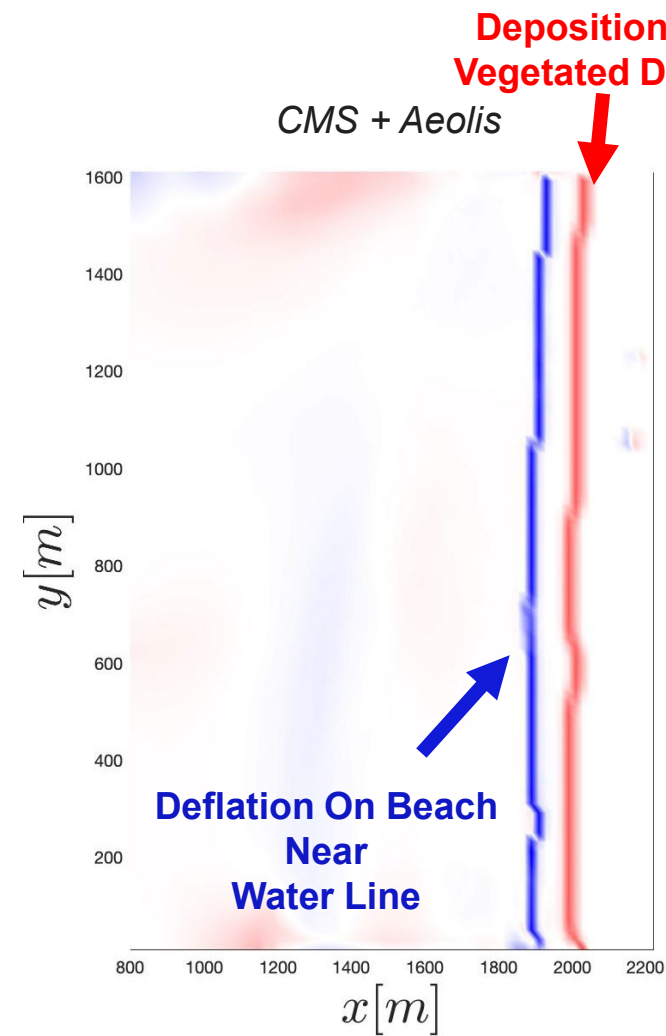
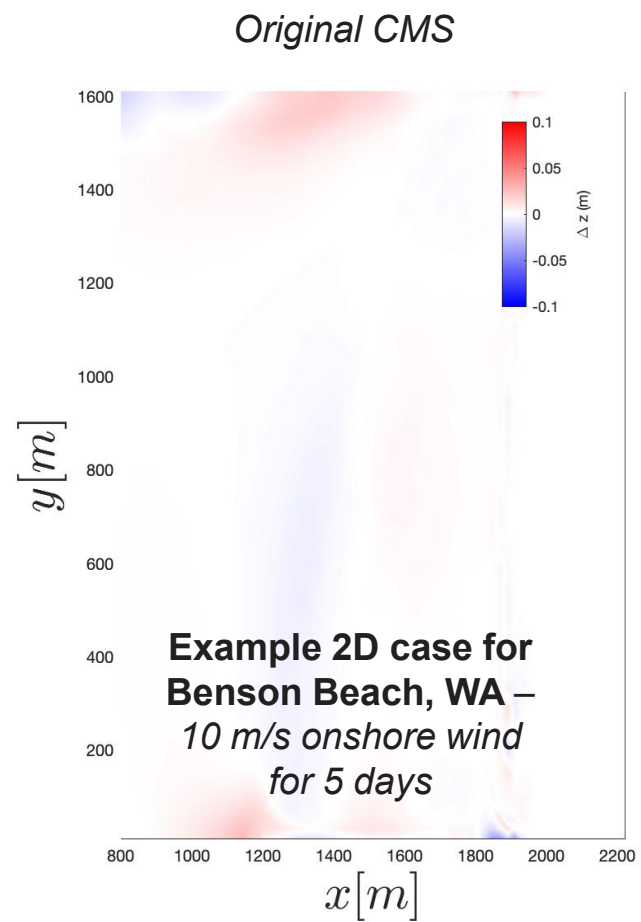
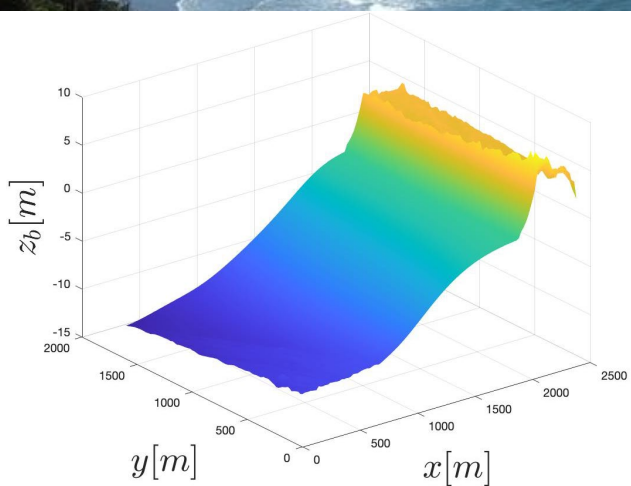
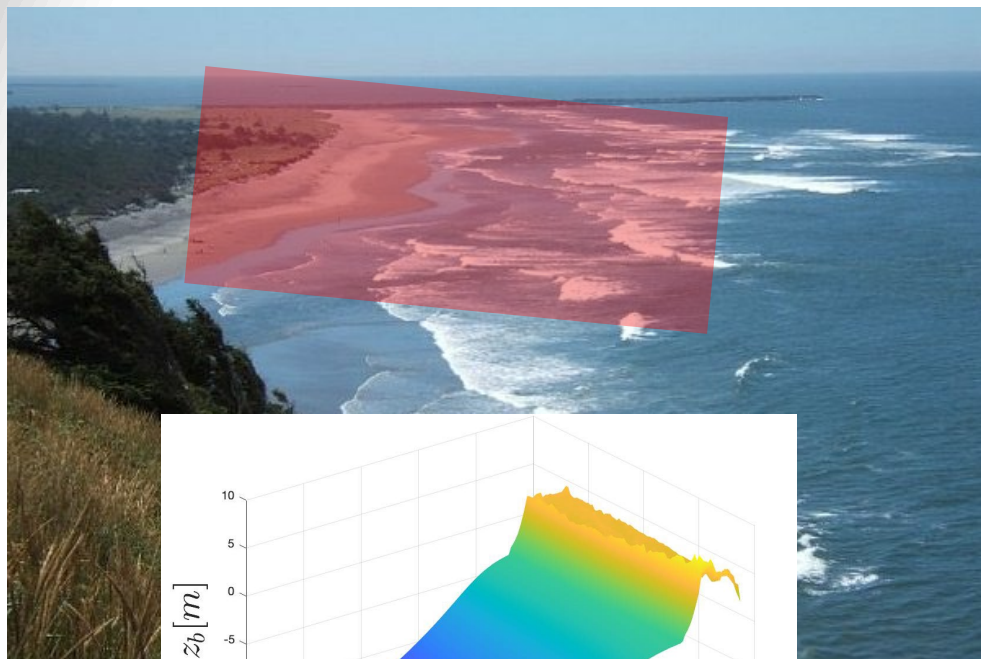
## 5. REAL WORLD CASES

Merrimack Inlet/Newburyport, MA



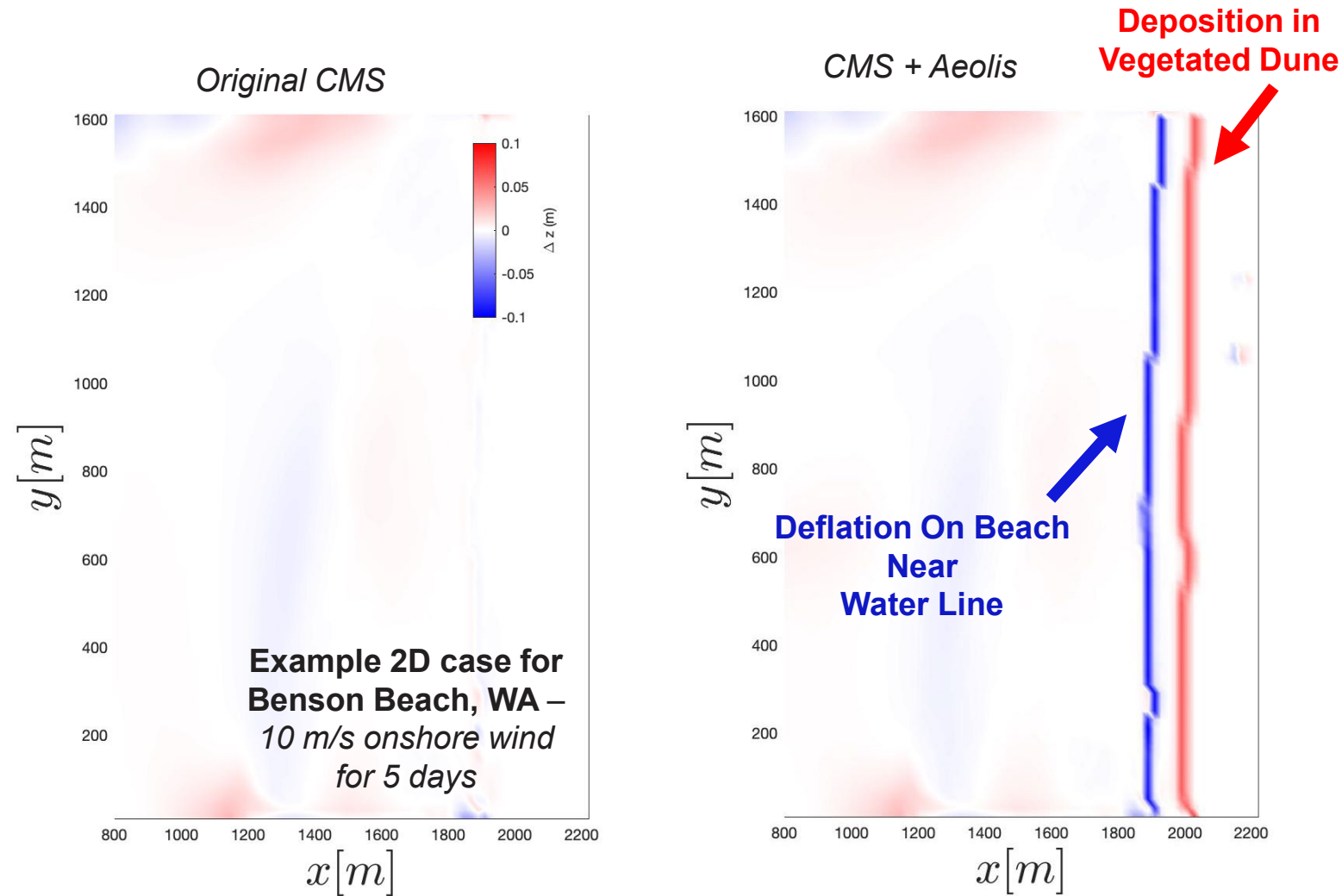
# 5. REAL WORLD CASES

## Benson Beach, WA





# CMS-AEOLIS COUPLING

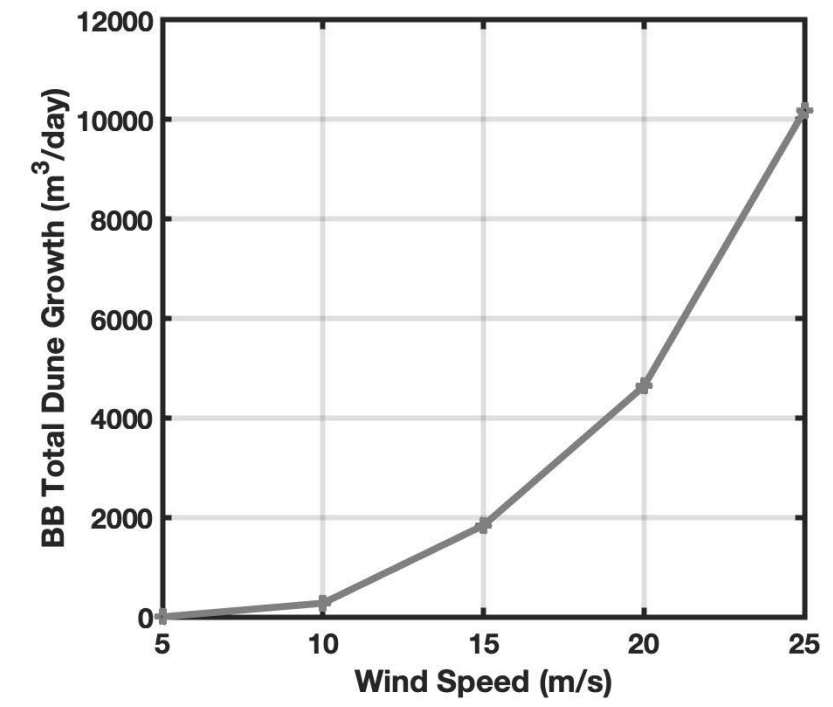
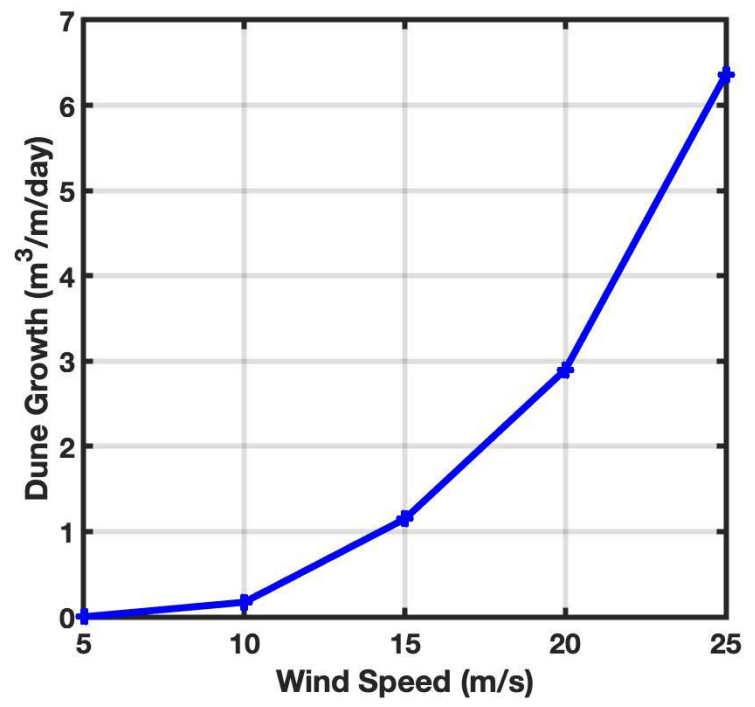




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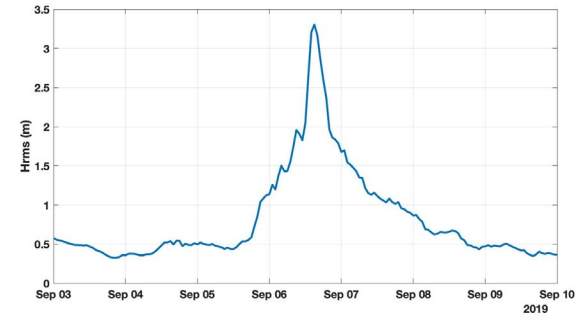
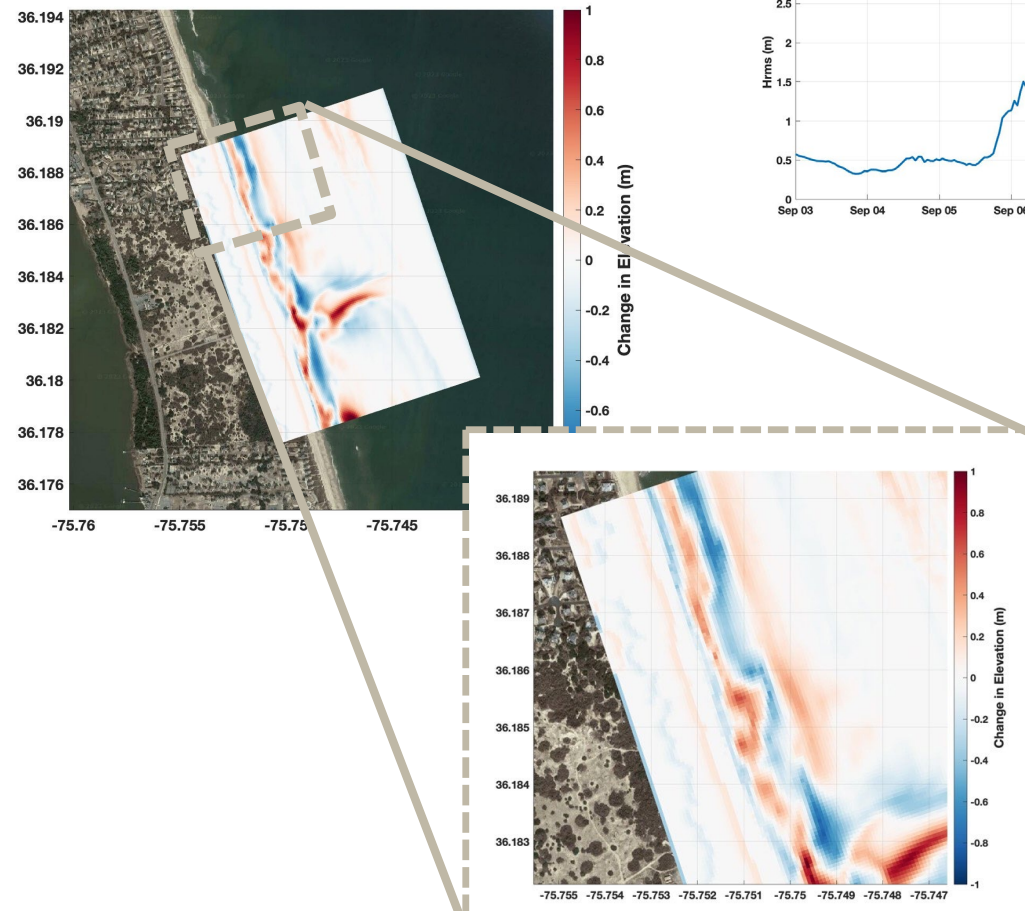


### Average Daily Growth of Dunes for Different Wind Conditions

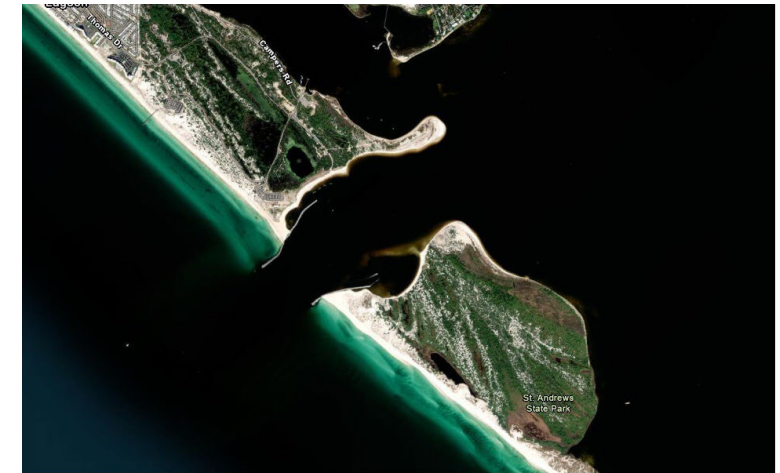




## Example 2D case for USACE Field Research Facility



## Panama City, FL



## Long Branch, NJ

Other Sites of Interest?



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# Aeolis Setup Scripts

```

if 'aeolian.py' not in os.listdir(run_folder):
    shutil.copy(base_folder + 'python_setup_scripts/aeolian.py', run_folder)
    shutil.copy(base_folder + 'python_setup_scripts/aeolis_setup_utils2.py', run_folder)

#####
##### MODEL SET UP #####
#####
# create grid from geoTiff images
if grid_input_type == 1:
    initial_data, final_data = readTiff(geoTiffFolder, filenames, int_dx, int_dy, min_x, max_x, min_y, max_y, xo, yo, int_elev_c
    model_grid, global_grid = make_grid(xo, yo, alfa, L, W, dx, dy, final_data)

    fig = plt.figure()
    ax = fig.add_subplot()
    c = ax.pcolor(global_grid['X'], global_grid['Y'], global_grid['Z'], cmap='terrain', shading='auto')
    plt.colorbar(c, ax=ax)
    plt.xlabel('Cross-Shore (m)')
    plt.ylabel('Alongshore (m)')

    fig = plt.figure()
    ax = fig.add_subplot()
    c = ax.pcolor(model_grid['X'], model_grid['Y'], model_grid['Z'], cmap='terrain', shading='auto')
    plt.colorbar(c, ax=ax)
    plt.xlabel('Cross-Shore (m)')
    plt.ylabel('Alongshore (m)')

# basic model set ups to write input cards
main_inputs = write_main_inputs(name, startTime, endTime, run_folder) # initializes cmcard & std inputs
cmcard_inputs, std_inputs = main_inputs.defaults()

# can modify cmcard_inputs & and std_inputs dictionary inputs to be specific to each location and simulation
# example
cmcard_inputs['AEOLIAN'] = 'ON'

# write main cards
main_inputs.write_std(std_inputs)
main_inputs.write_sim()
main_inputs.write_cmcards(cmcard_inputs)

# pull necessary environmental data based on information provided above
if env_input_type == 1:
    wave_data, wind_data, water_data = boundaryConditionsNDBC(station_waves, station_water, station_wind, windType, startTime, e
elif env_input_type == 2:
    wave_data, wind_data, water_data = boundaryConditionsNDBC(station_waves, station_water, station_wind, windType, startTime, e

    wave_data['wave_hs'] = np.ones(np.size(wave_data['wave_hs']))*hs_constant
    wave_data['wave_hrms'] = np.ones(np.size(wave_data['wave_hs']))*hs_constant/1.4142
    wave_data['wave_tp'] = np.ones(np.size(wave_data['wave_hs']))*tp_constant
    wave_data['wave_dir'] = np.ones(np.size(wave_data['wave_dir']))*wd_constant
    wind_data['wind_speed'] = np.ones(np.size(wind_data['wind_speed']))*ws_constant
    wind_data['wind_dir'] = np.ones(np.size(wind_data['wind_dir']))*wdir_constant
    water_data['water_elevation'] = np.ones(np.size(water_data['water_elevation']))*tide_constant

# write all CMS boundary condition files
enviro_inputs = write_enviro_inputs(name, startTime, endTime, wind_data, wave_data, water_data, model_grid, run_folder)
enviro_inputs.write_wavebc()
enviro_inputs.write_windbc()
enviro_inputs.write_tidebc()
enviro_inputs.write_dep()
enviro_inputs.write_cart()
enviro_inputs.write_bid()

# write aeolis params file & veg grid file
aeolian_duration = cmcard_inputs['AEOLIANINTERVAL']*60*60 # aeolis total duration

params = default_aeolis_parameters()
params = update_aeolis_params_cms(params, model_grid['nx'], model_grid['ny'], model_grid['dx'], model_grid['dy'], aeolian_grain_
params = update_processes_parameters(params, use_shear=use_shear, use_vegetation=use_vegetation, use_tide=use_tide, use_wave=use
params = update_veg_parameters(params, veg_max_height, veg_min_elev, vegshear_type, veg_density, True, run_folder, np.transpose(
params = update_gridFiles_parameters(params, veg_file='veg.grd')

```



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## 6. NEXT STEPS

- **Ongoing Aeolis Development at ERDC (CIRP, Congressional Adds)**
  - ▶ Continued Model Algorithm Development/Improvements
  - ▶ Coupling with GenVeg to Extend Ecological Capabilities (with Candice Piercy and Todd Swannack)
- **2D CMS-Aeolis Coupling (CIRP)**
  - ▶ True Validation/Benchmarking (District partner?)
  - ▶ Extension/Demonstration for Longer Timescales
  - ▶ Multifraction Capability Linkage
  - ▶ Structure Incorporation into Aeolis
  - ▶ Code Refactoring to Run on ACE-IT
  - ▶ GUI Model Setup/Easier Setup Solutions



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QUESTIONS?