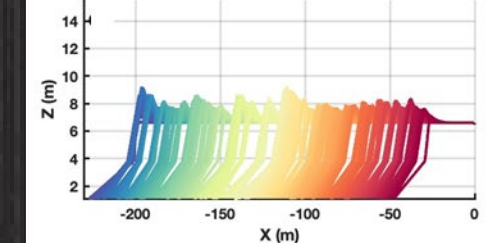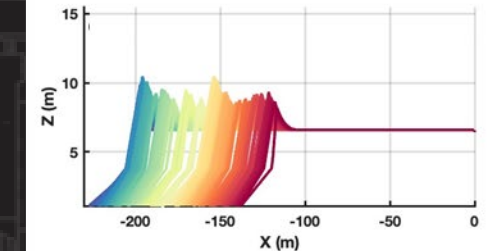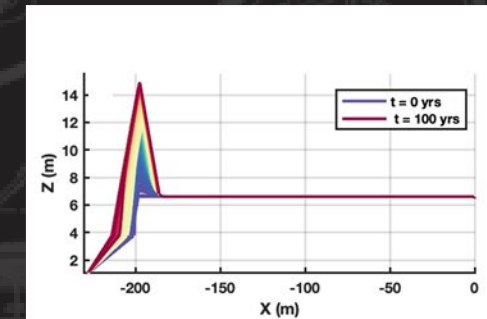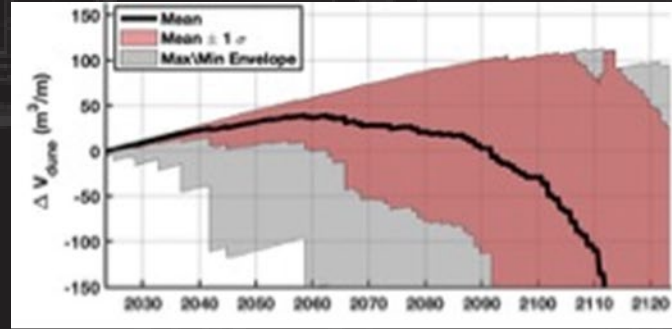# DUNE RESPONSE TOOL:
CAPABILITIES FOR SIMULATING COASTAL DUNE EVOLUTION DETERMINISTICALLY AND PROBABILISTICALLY

Dr. Nick Cohn
Research Oceanographer
US Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory

with major contributions from
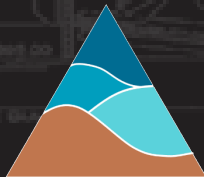Dr. Dylan Anderson (ERDC- CHL)
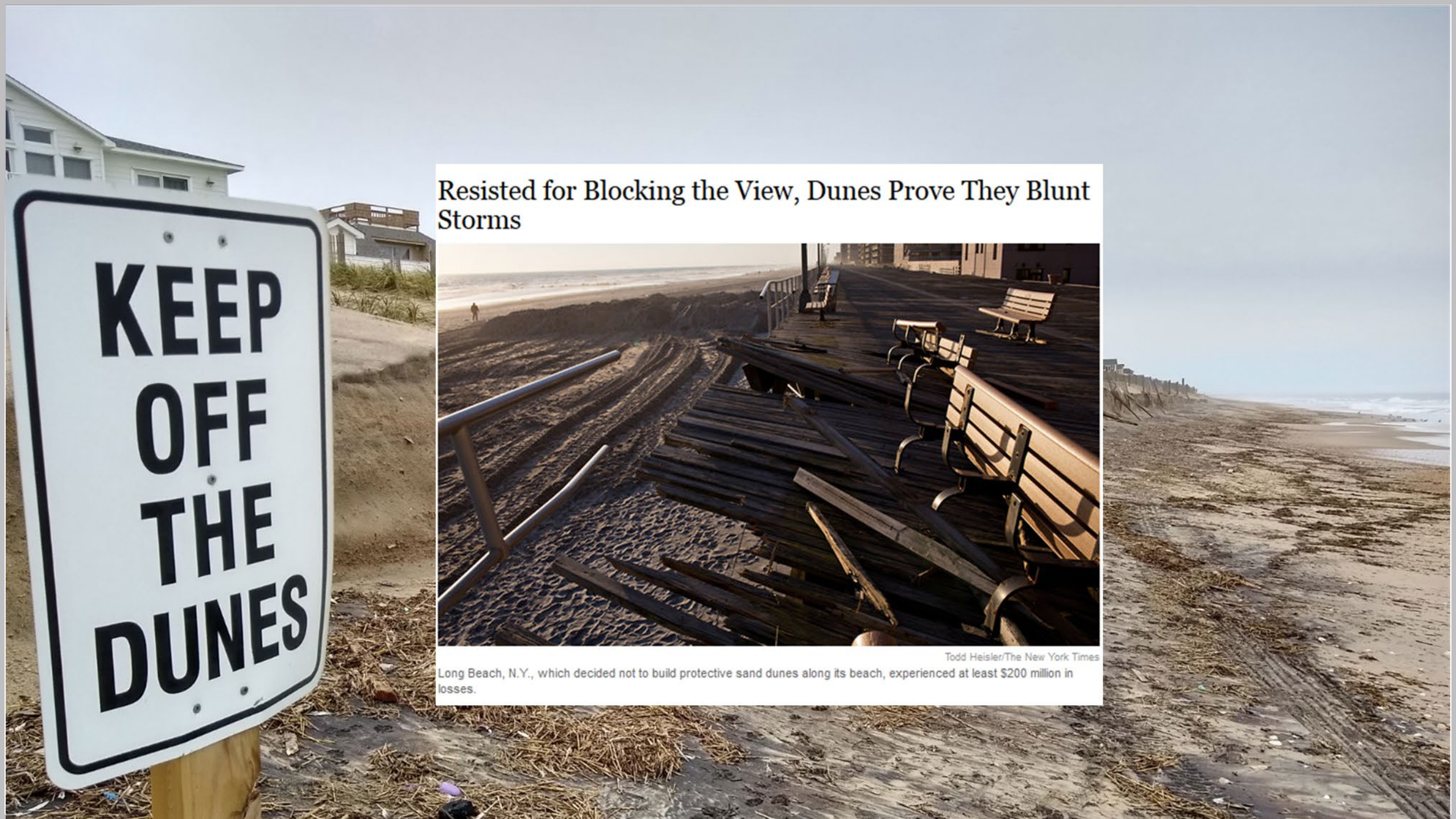
17 September 2024
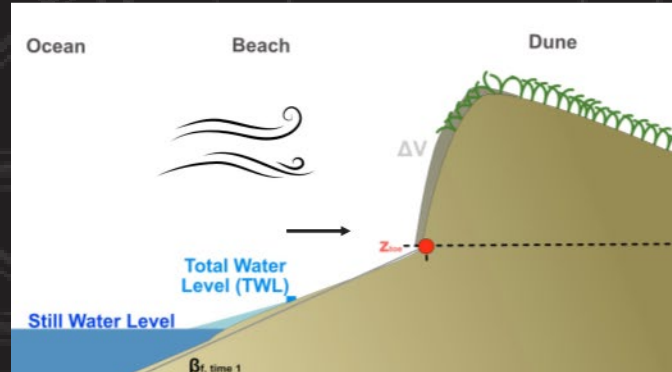
U.S. ARMY | US Army Corps of Engineers | ERDC | CIRP

KEEP OFF THE DUNES

Resisted for Blocking the View, Dunes Prove They Blunt Storms

Todd Heisler/The New York Times

Long Beach, N.Y., which decided not to build protective sand dunes along its beach, experienced at least $200 million in losses.
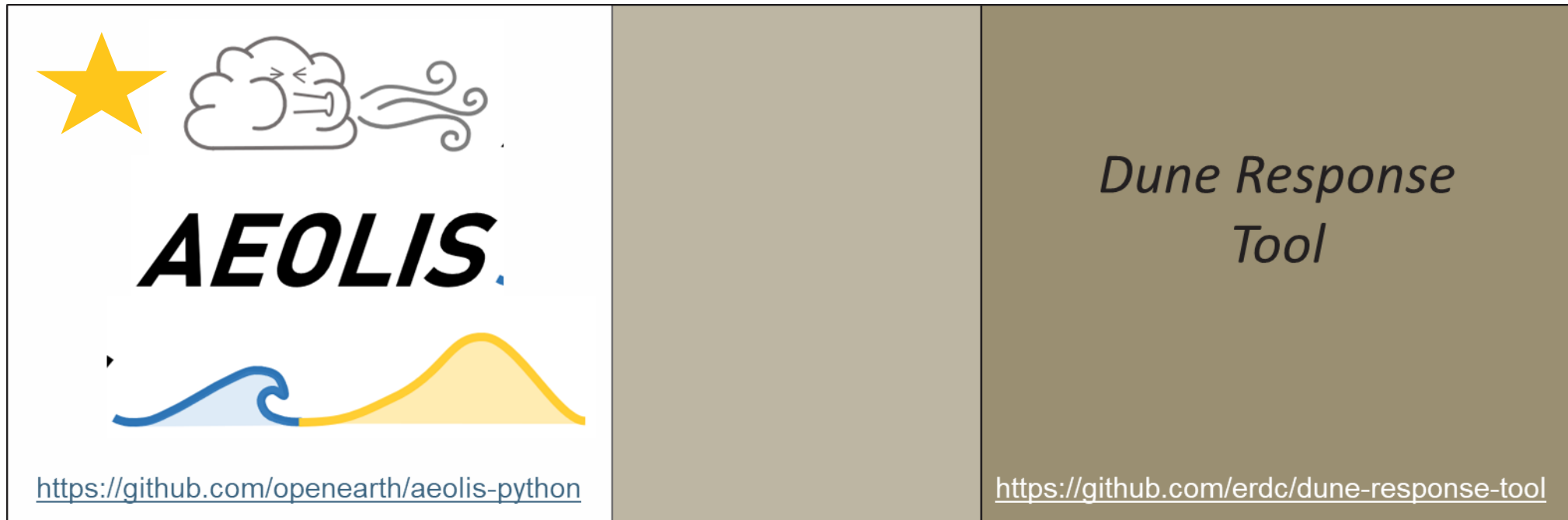
LEVEL OF FIDELITY FOR MODELS

Micro Scale
High Detail/Fidelity

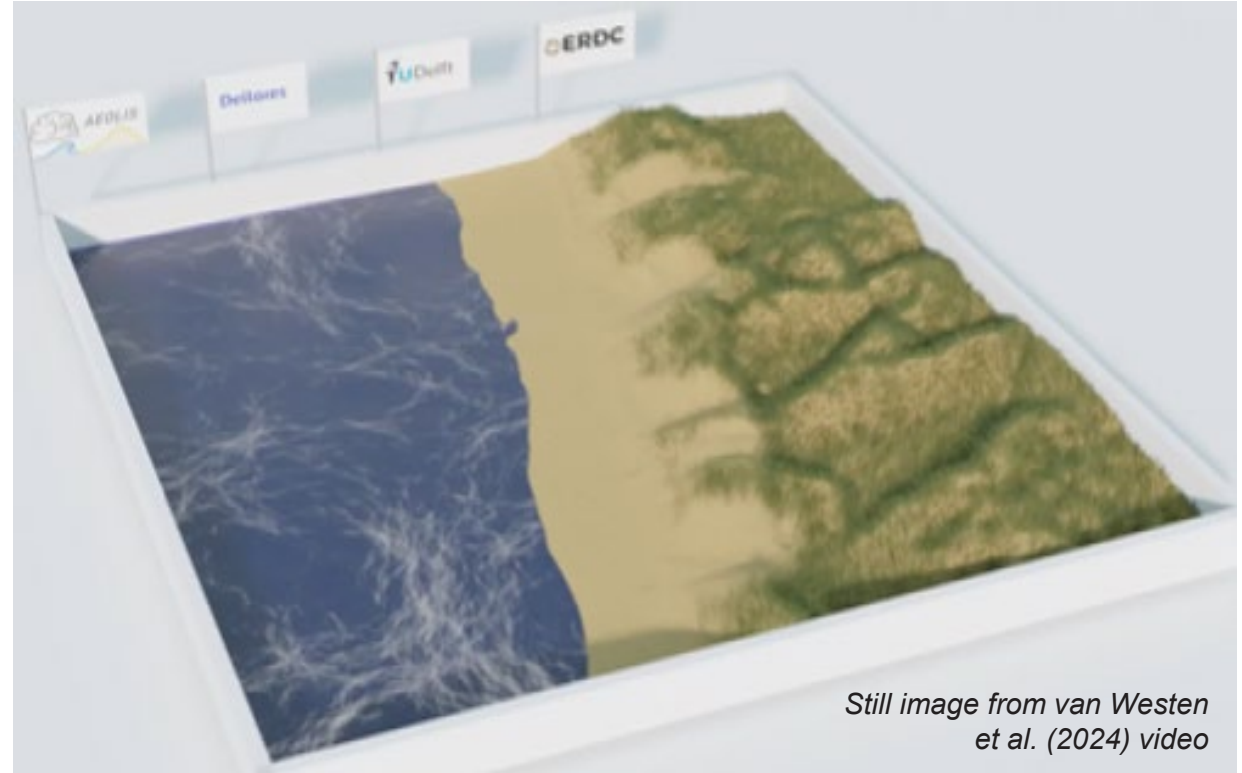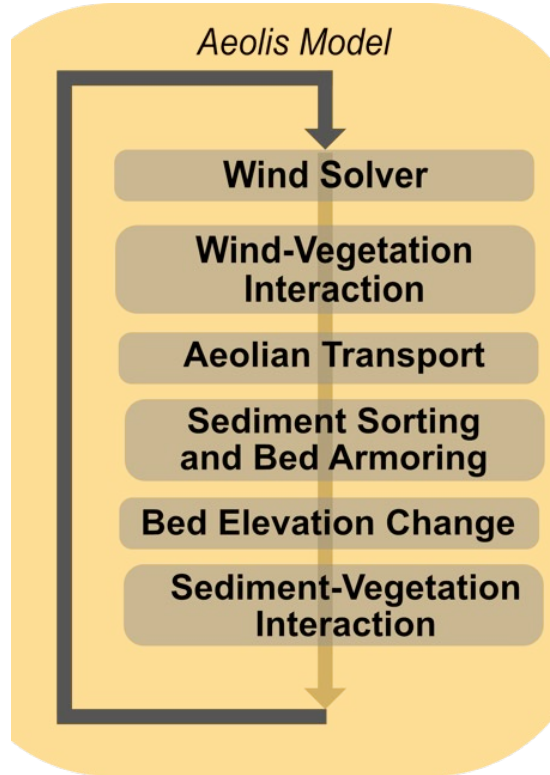*Meso*
Scale

Macro Scale
Lower Detail/Fidelity

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

Dune Response Tool

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

Design and Optimization

Long-Term Planning,
Rapid Assessment

Aeolis: Supply Limited Aeolian Sediment Transport Model

Aeolis Model

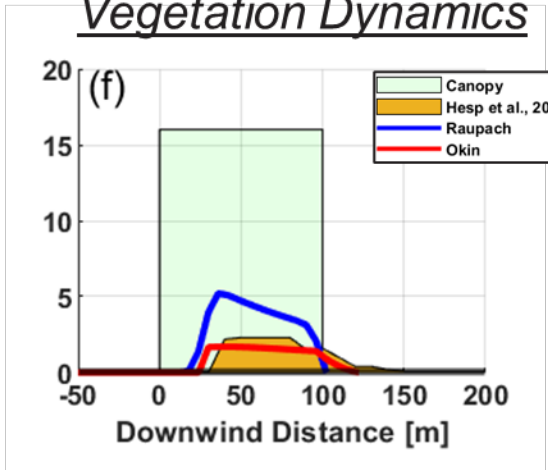- Wind Solver
- Wind-Vegetation Interaction
- Aeolian Transport
- Sediment Sorting and Bed Armoring
- Bed Elevation Change
- Sediment-Vegetation Interaction

Still image from van Westen et al. (2024) video

AEOLIS, CONT.

Vegetation Dynamics

Sand Fencing
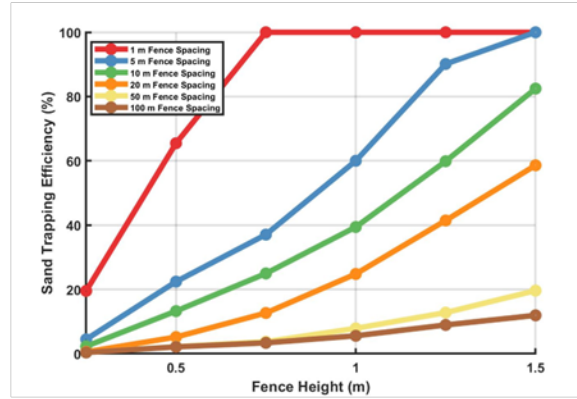
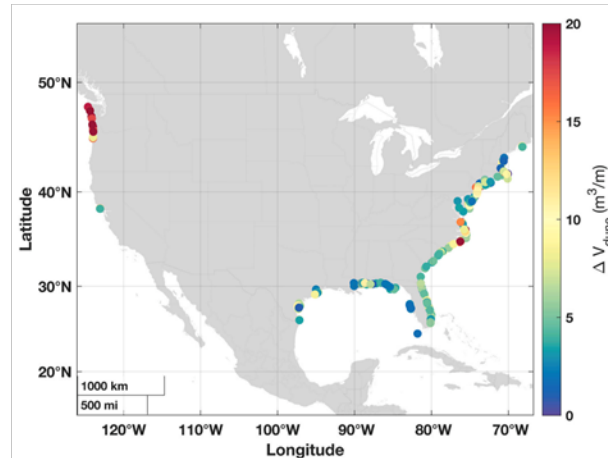## Applications

Model Coupling to Leverage Exising USACE Tools

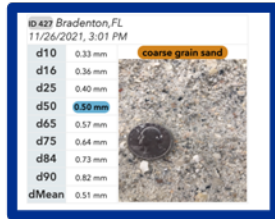CSHORE   Open▽FOAM

GENVEG

CMS

DUNE RESPONSE TOOL

Micro Scale
High Detail/Fidelity

Meso
Scale

Macro Scale
Lower Detail/Fidelity

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

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

Dune Response
Tool
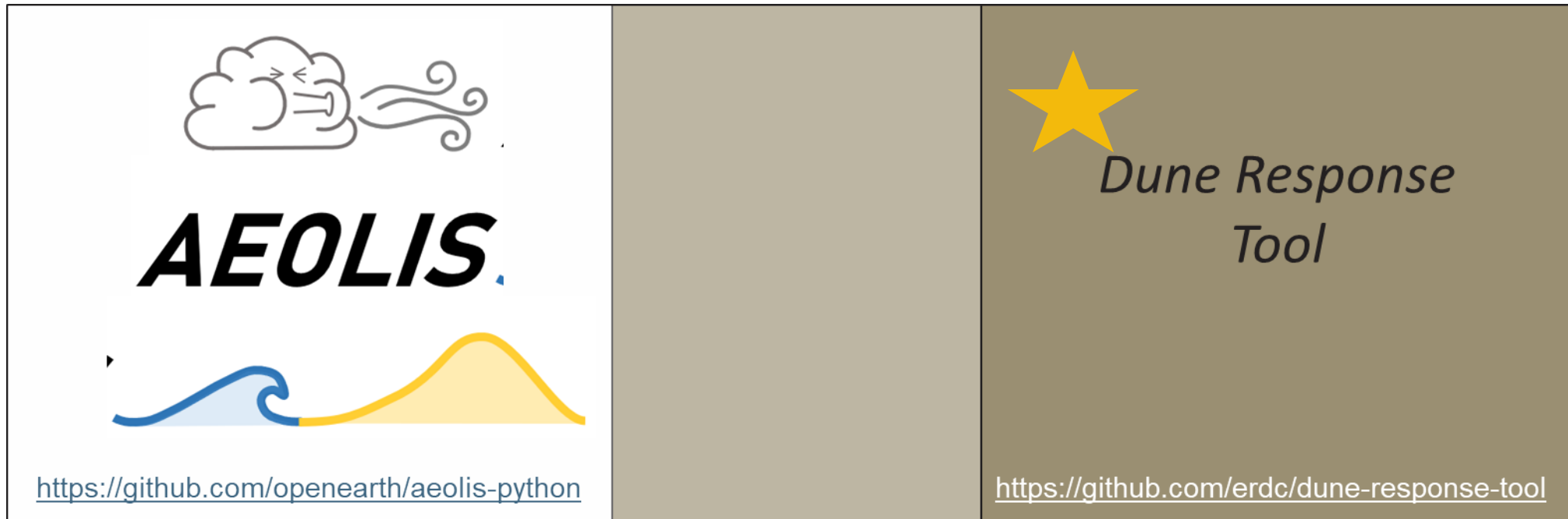
Design and Optimization

Long-Term Planning,
Rapid Assessment

ATTRIBUTES AND APPLICATIONS

Wind-Driven Growth

Wave-Driven Erosion

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

Desirable Model Attributes

- Ability to simulate dune growth from winds and dune erosion from waves

- Accurate

- Fast

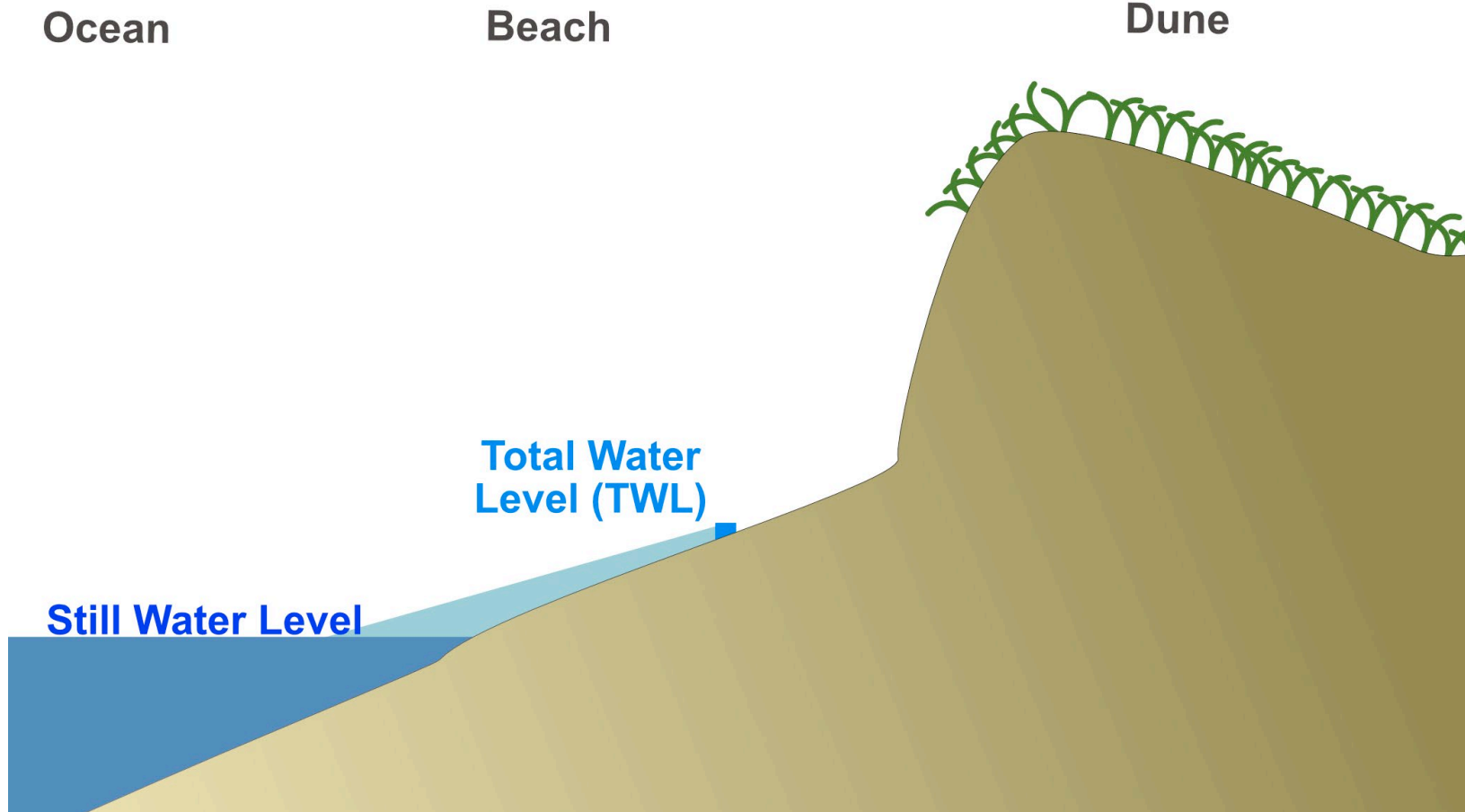- Low Number of Site-Specific Parameters

- Easy to Run

Applications

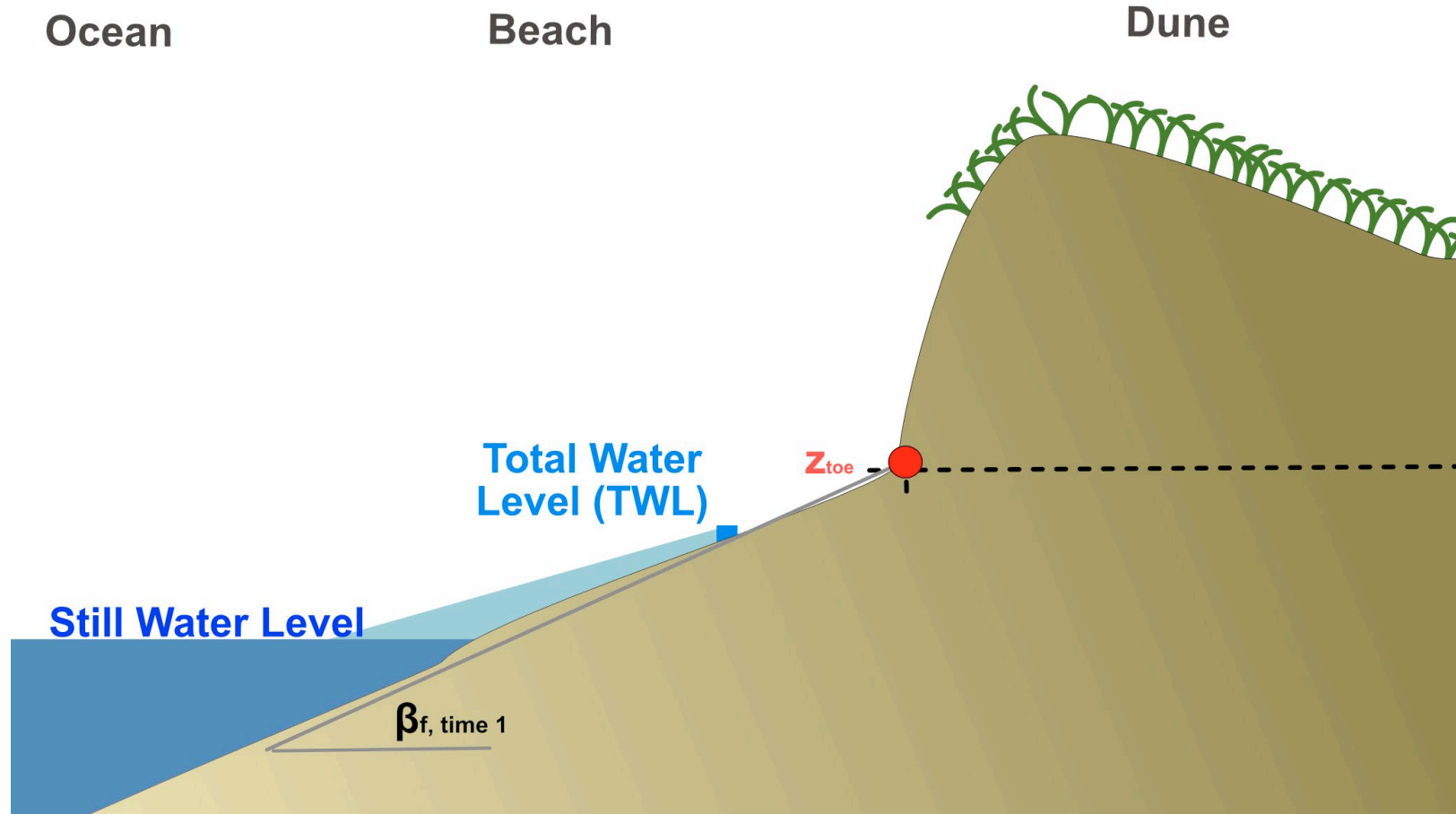- Hindcasting

- Forecasting

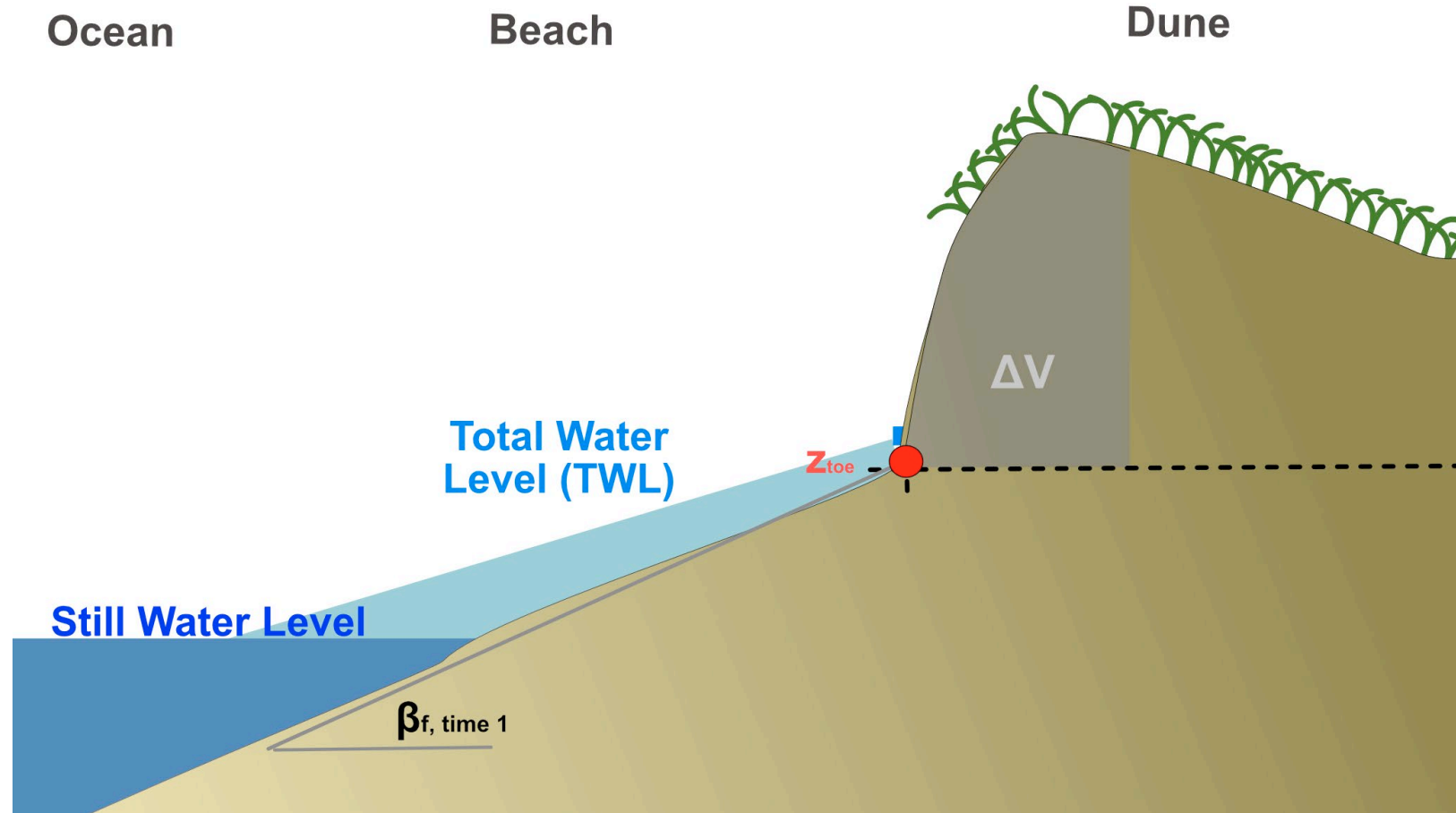- Probabilistic Simulations

DUNE SYSTEM

Ocean

Beach

Dune

Total Water Level (TWL)
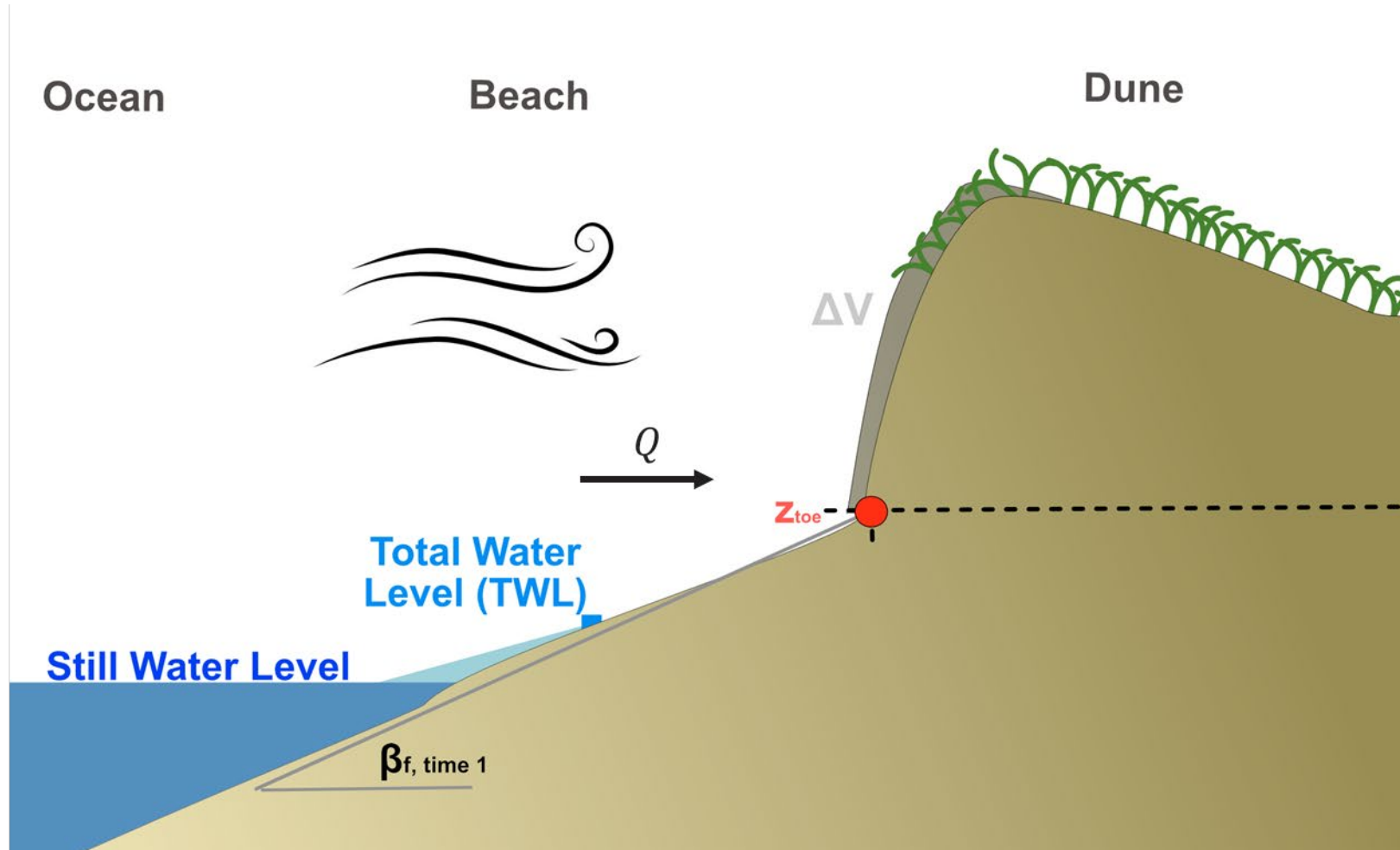
Still Water Level

DUNE SYSTEM, DUNE TOE

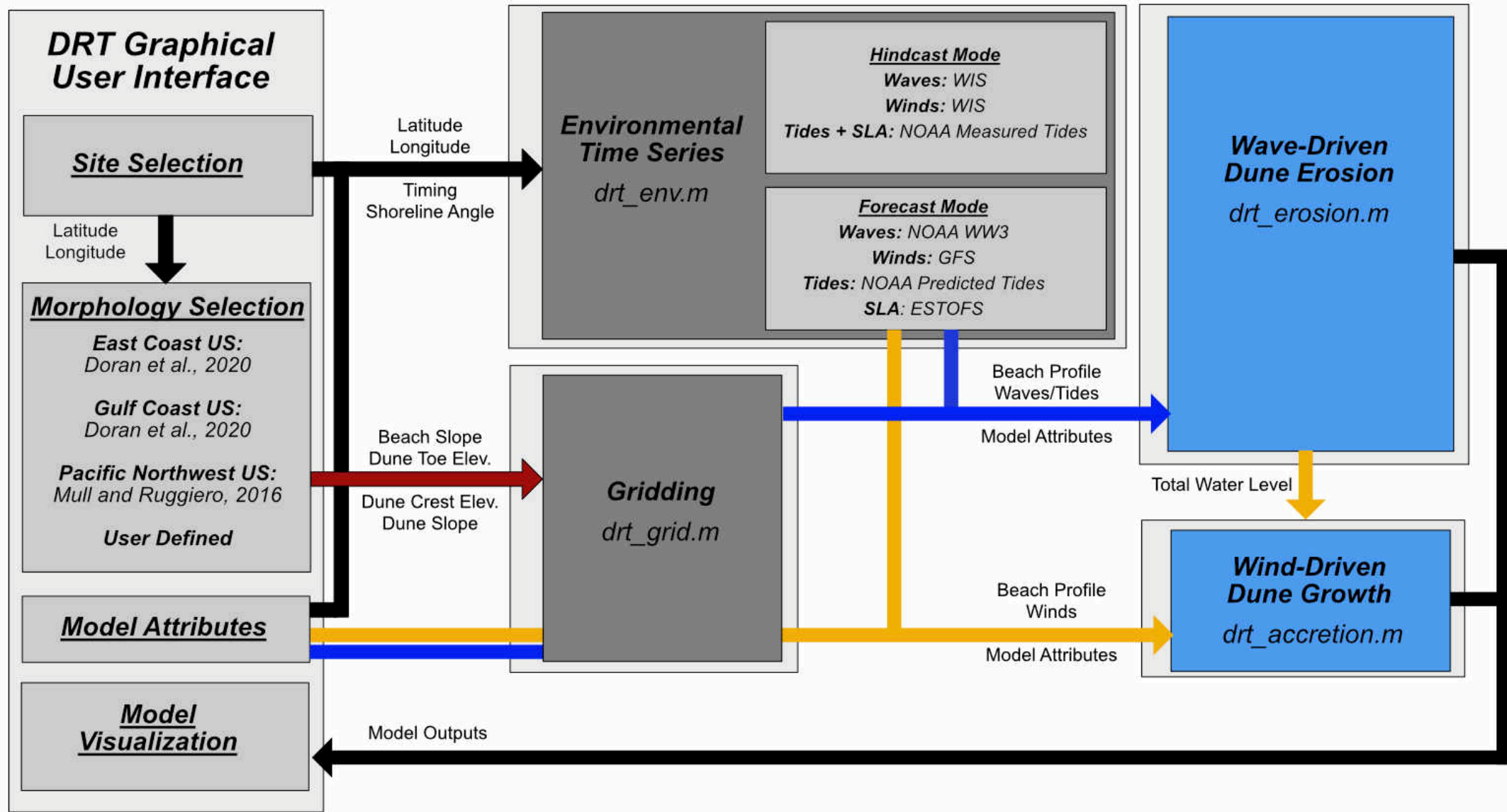# REDUCTION IN VOLUME DUE TO WAVE ACTION
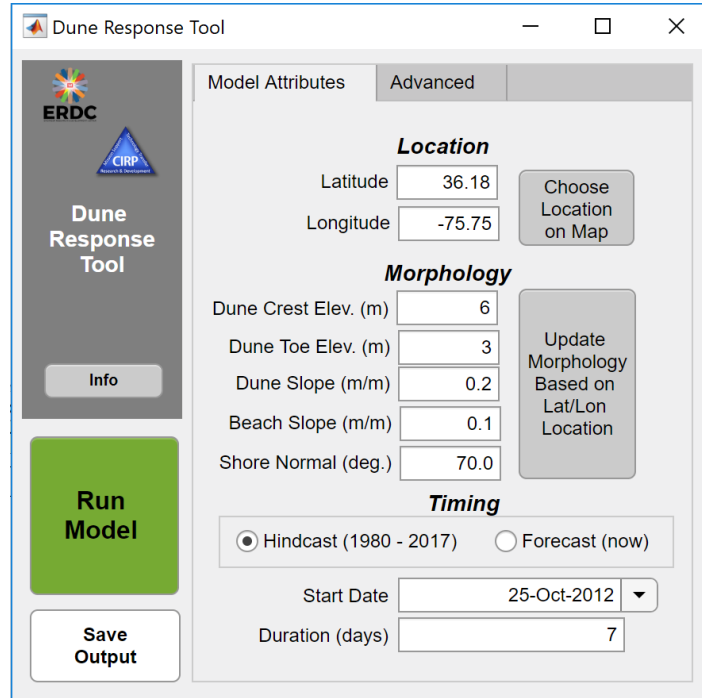
INCREASE IN VOLUME DUE TO WIND ACTION

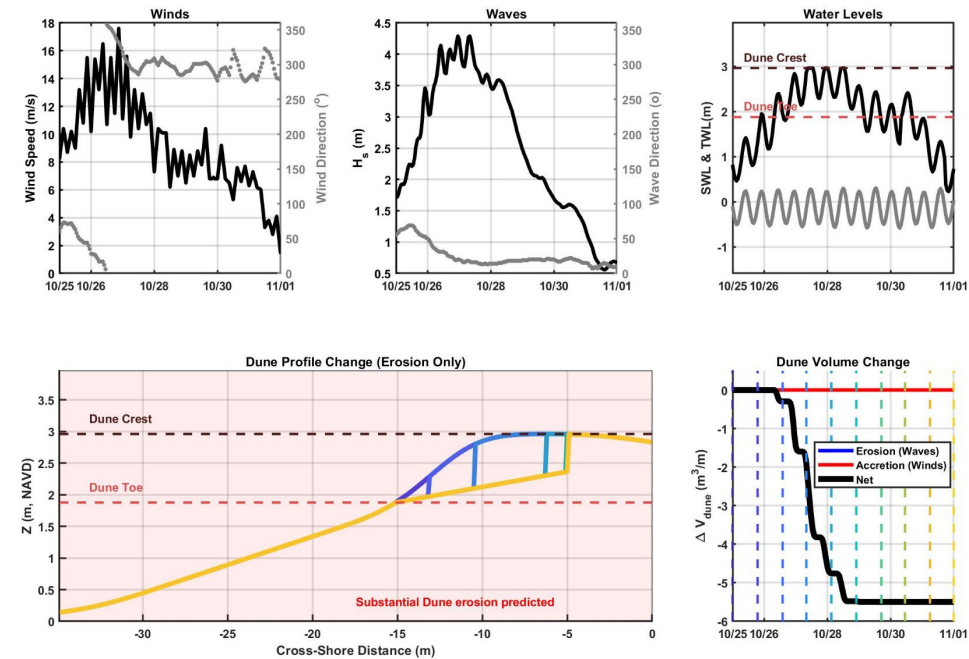# DUNE RESPONSE TOOL STEPS

USER INTERFACE AND MODEL OUTPUTS
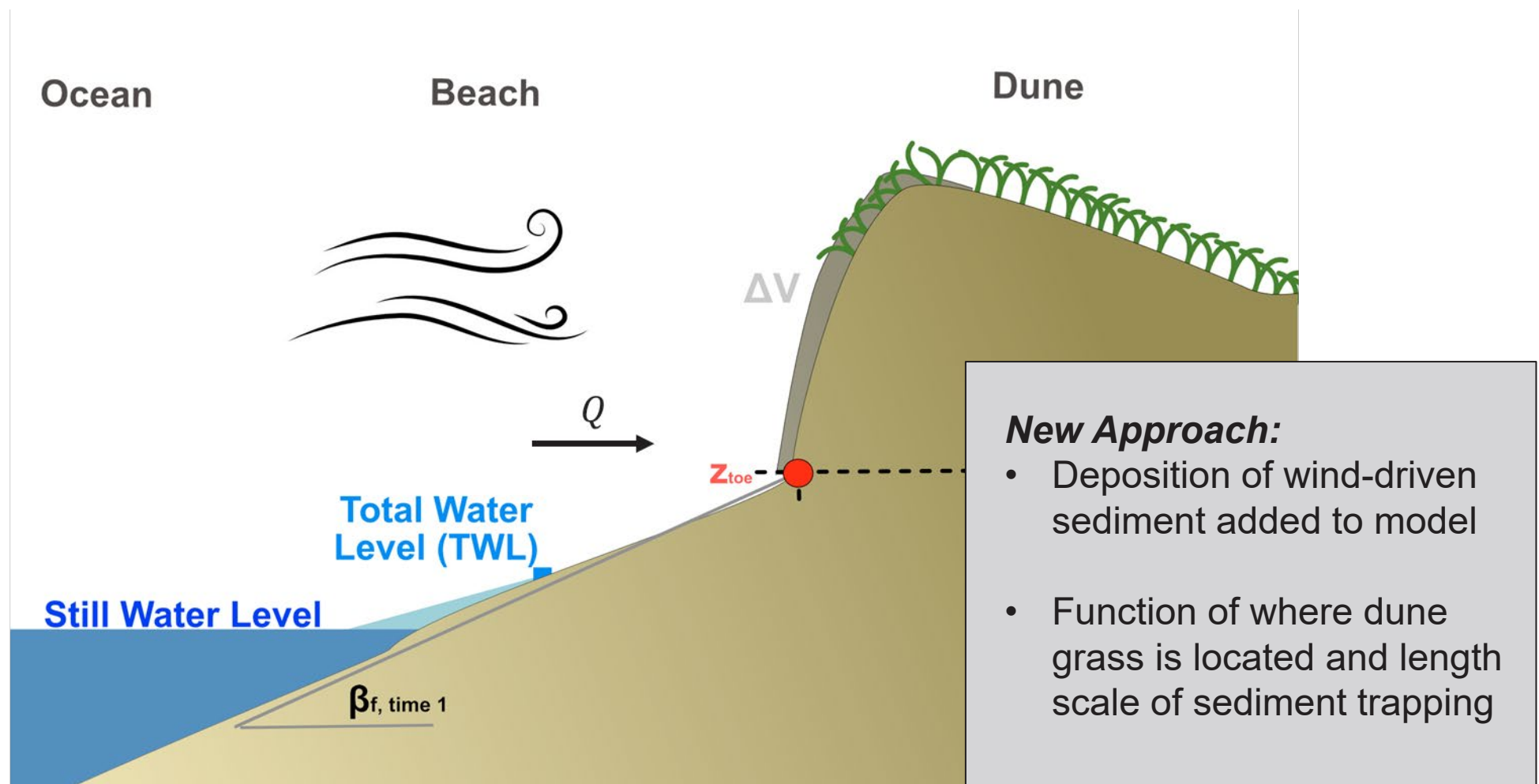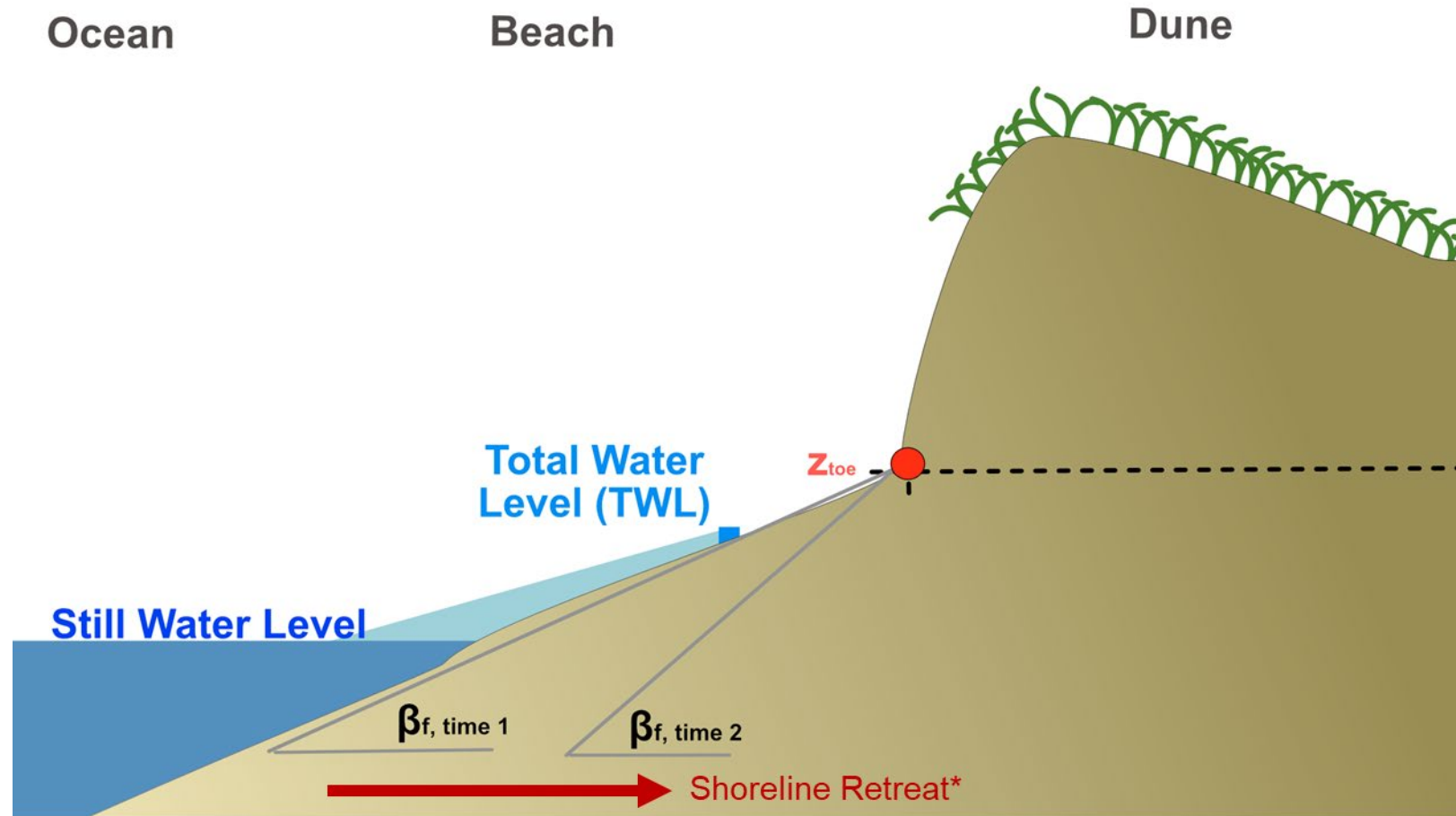
Graphical User Interface

Example Model Outputs

Limitations with past approach:
-Wave and wind-driven processes were assumed to be independent
-Model primarily tracked net volume changes; wind-driven topographic changes not resolved
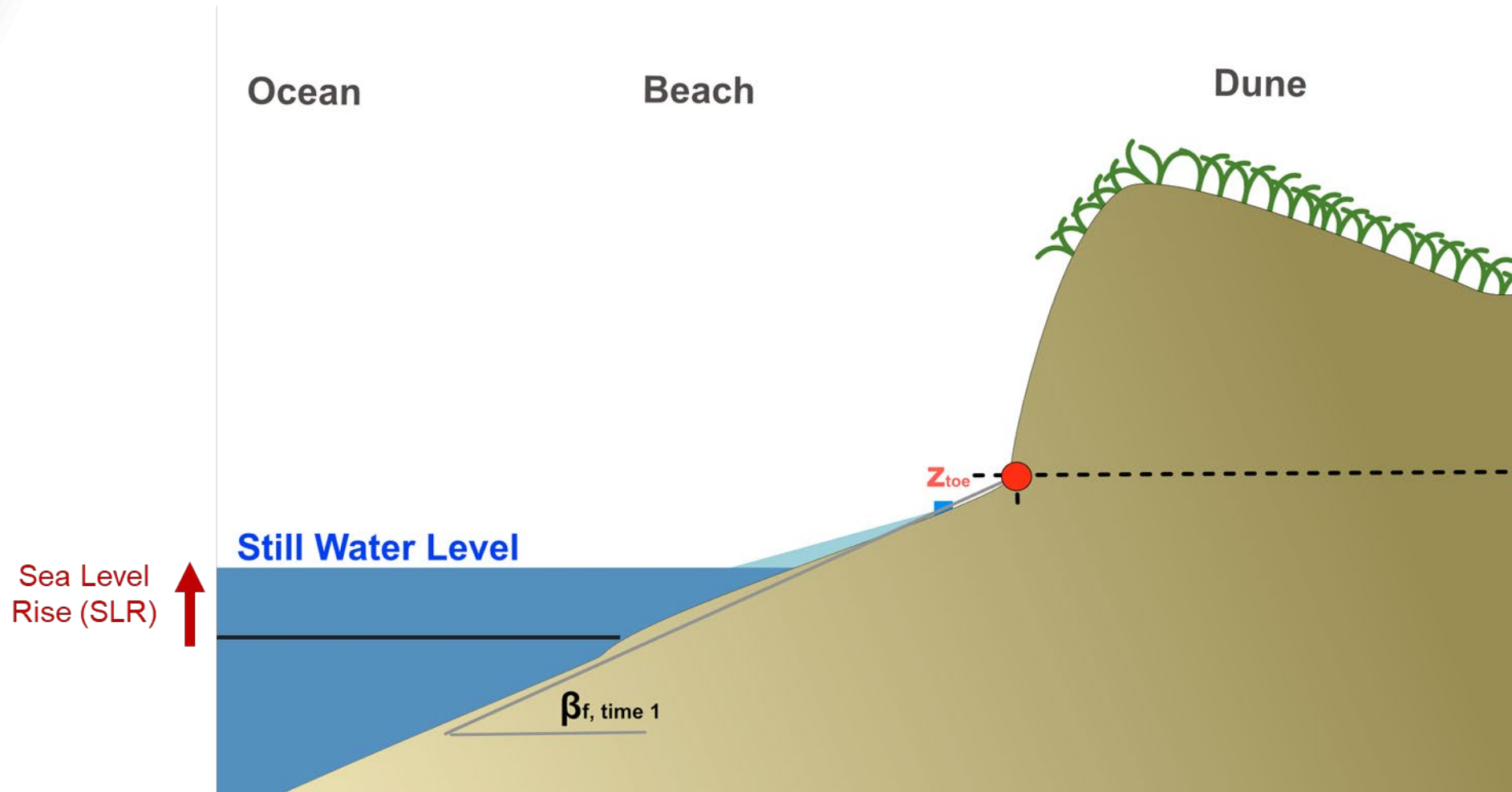
NEW METHODS: WIND-DRIVEN SEDIMENT

New Approach:
- Deposition of wind-driven sediment added to model

- Function of where dune grass is located and length scale of sediment trapping

NEW METHODS: SHORELINE CHANGE RATE

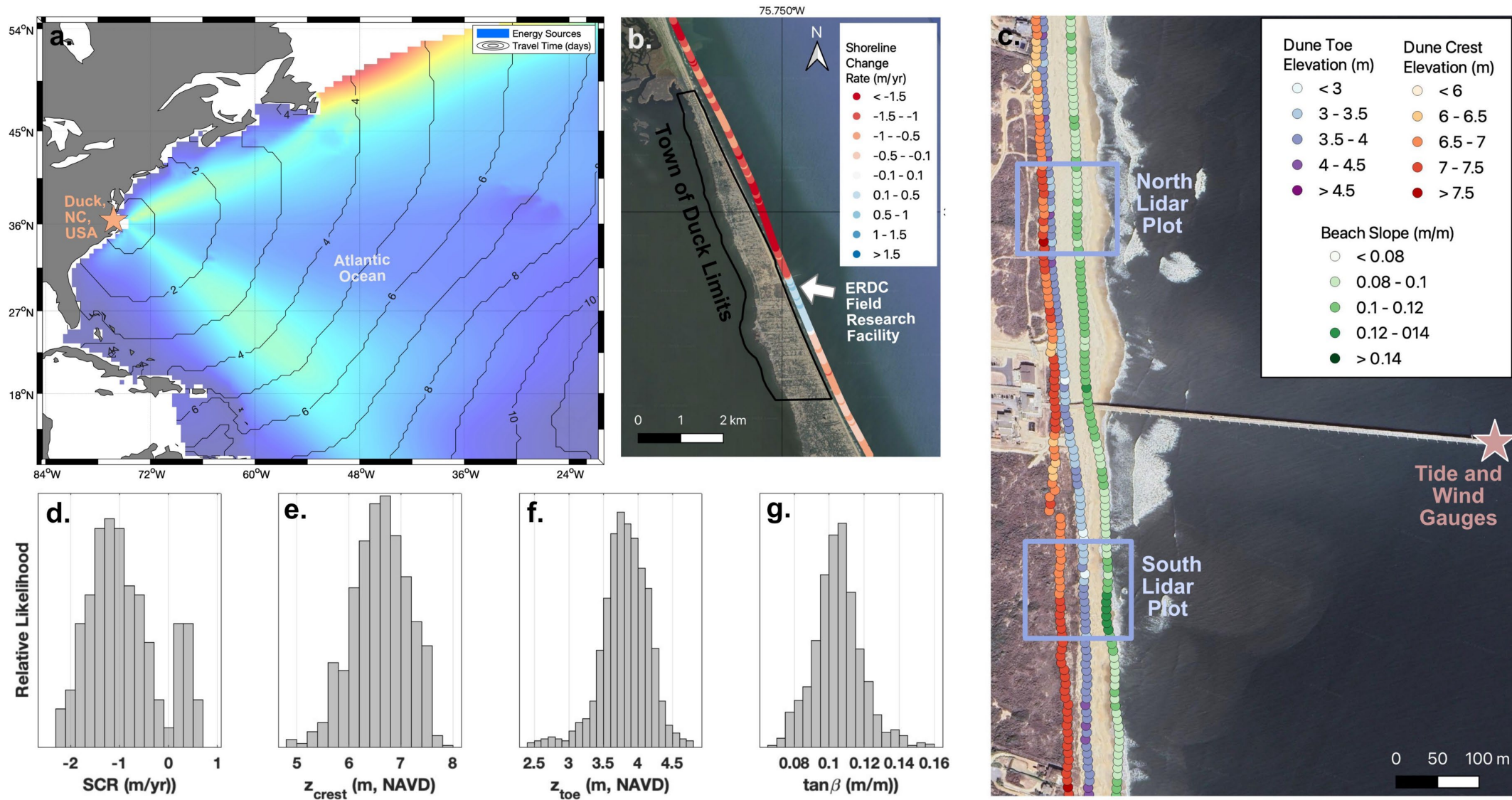* Note, added in the model as a constant shoreline change rate (SCR)
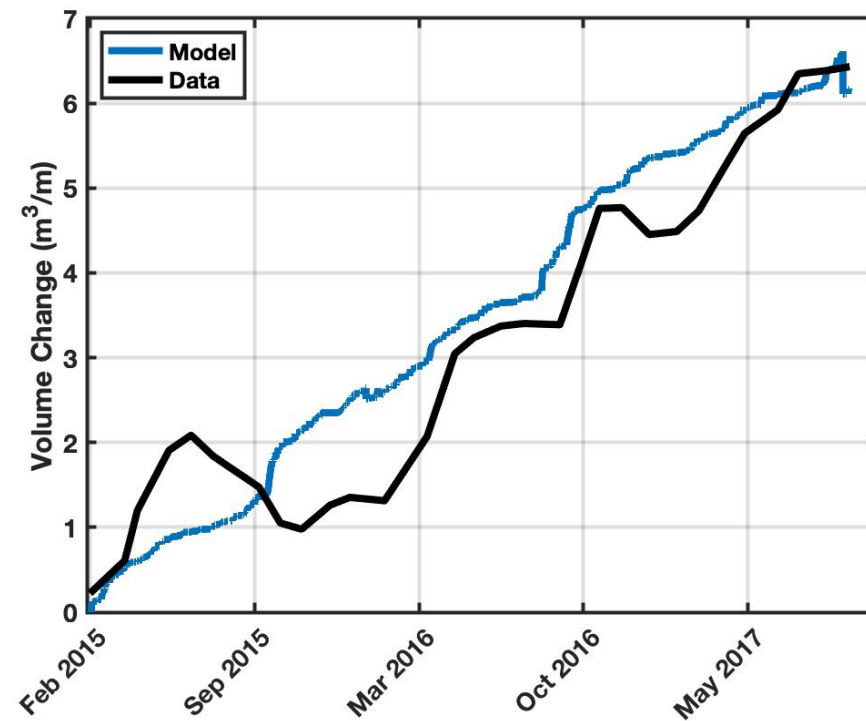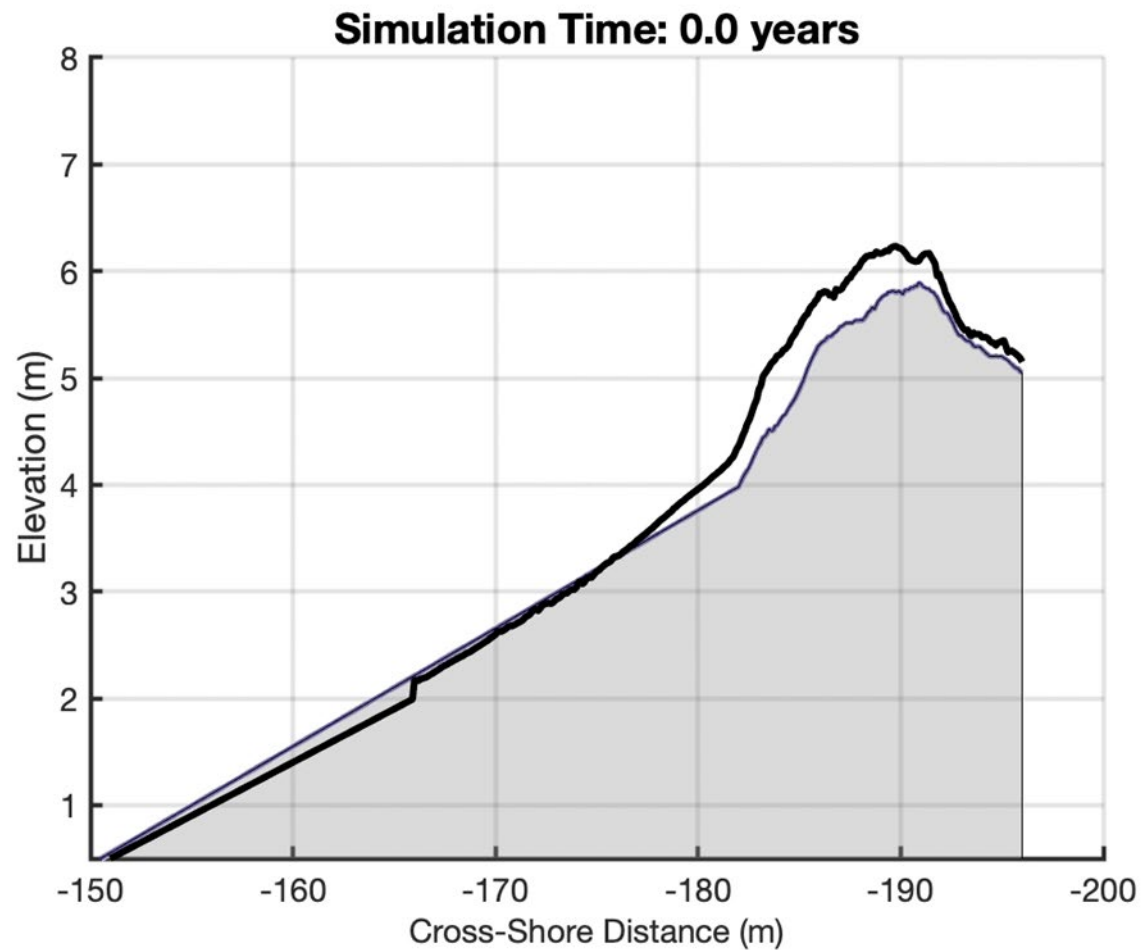
NEW METHODS: SEA LEVEL CHANGE
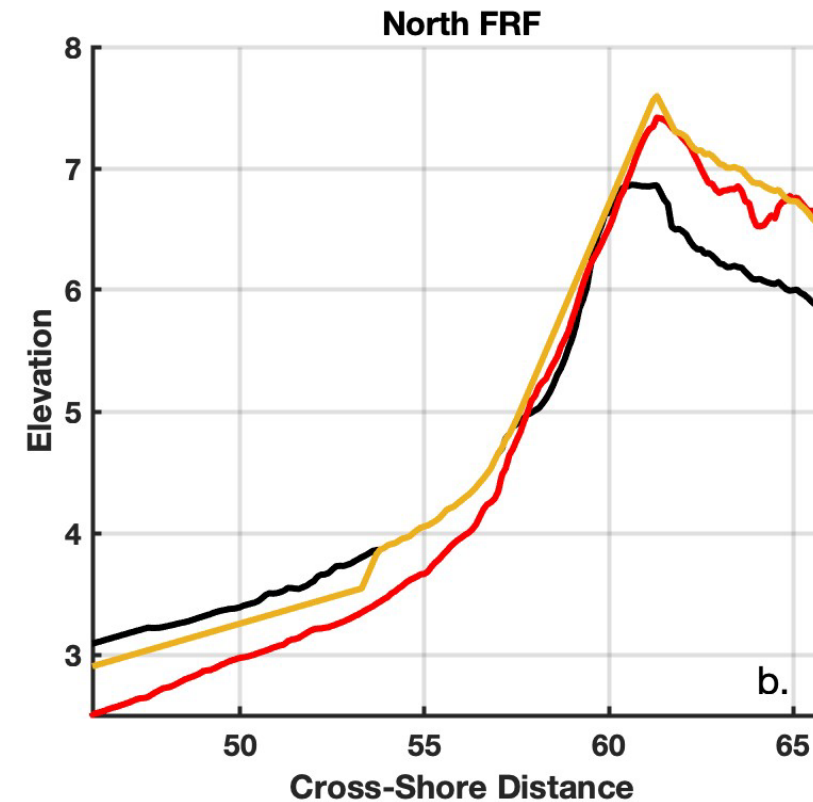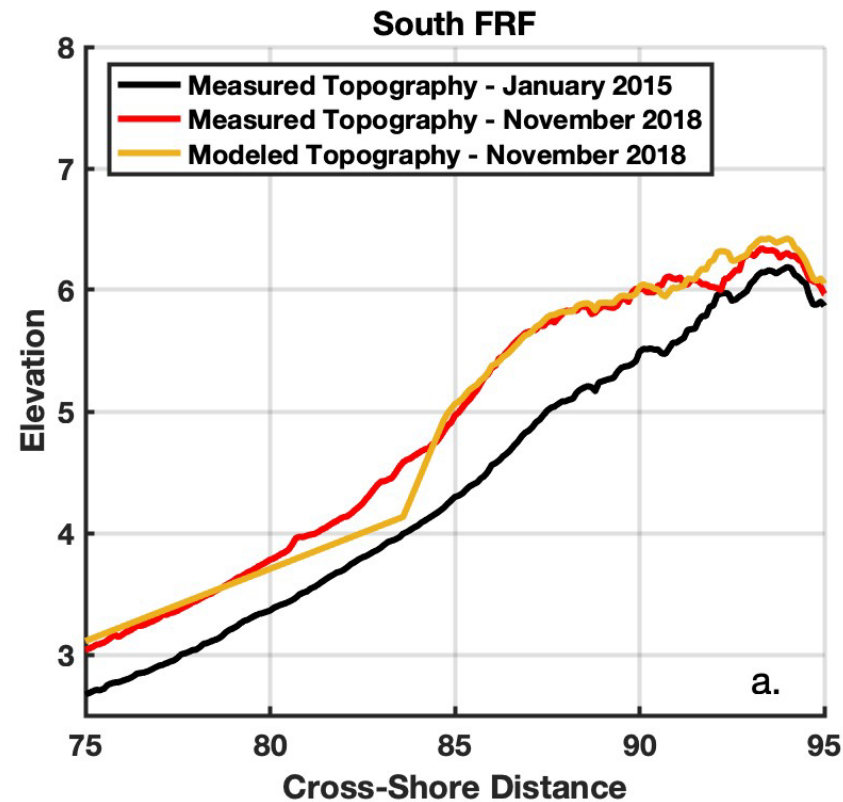
Outer Banks Model Hindcast

Outer Banks Model Hindcast, 2-year run

Outer Banks Model Hindcast, calibration

Automated genetic algorithm used to calibrate model to converge on single parameter that worked at both sites

Parameter	Calibrated Value
Veg Deposition Length Scale (L)	21.2 m
Dune Erodibility Coefficient (C_s)	0.0015
Runup Coefficient (K)	1
Angle of Repose ($\tan\alpha$)	35.2°

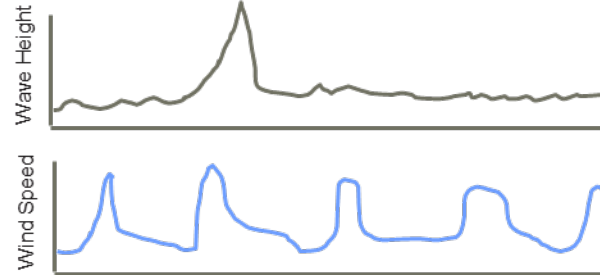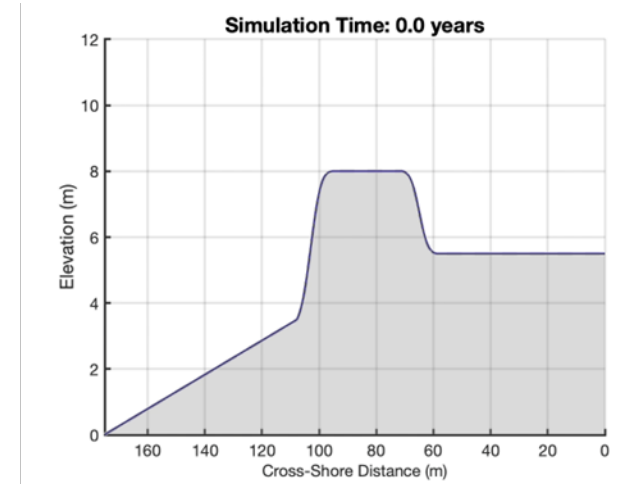# Deterministic hindcasts vs Probabilistic forecasts

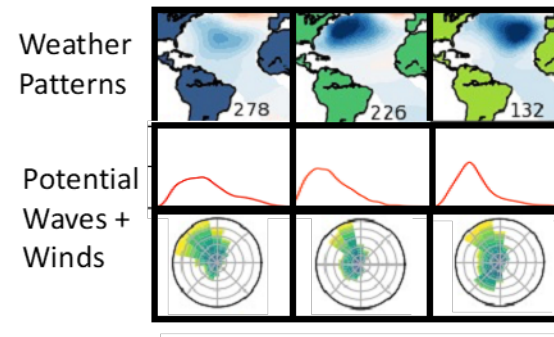https://github.com/erdc/dune-response-tool

Lifespan Projections

Dune Lifespan Projections

Stochastic Climate Generator

- Inter-annual sea surface temperature variability
- Intra-annual solar input
- Intra-seasonal outgoing longwave radiation

Stochastic Weather Generator

Synthetic daily weather predicted by ALR:

f(ENSO, MJO, seasonality, daily markov chain)
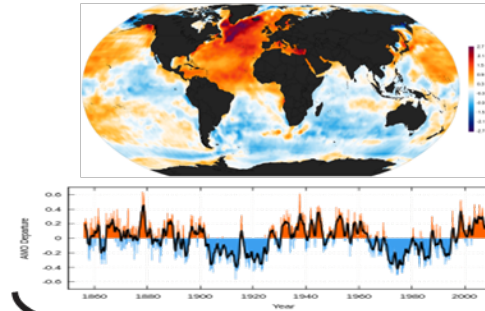*(Anderson et al. 2019, Time-varying Emulator.. JGRO)*
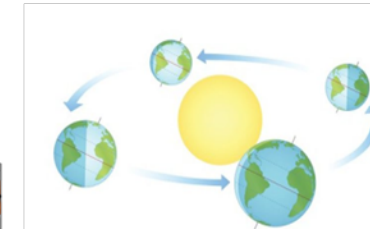
Downscaled Wave & Wind Conditions

Synthetic hourly time series of wave and water levels conditions
(Anderson et al. 2021, Hybrid Statistical Downscaling... Earth's Future)

Sea Ice Coverage

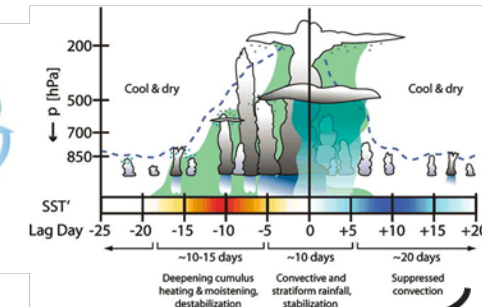Weather Patterns

Wave Heights

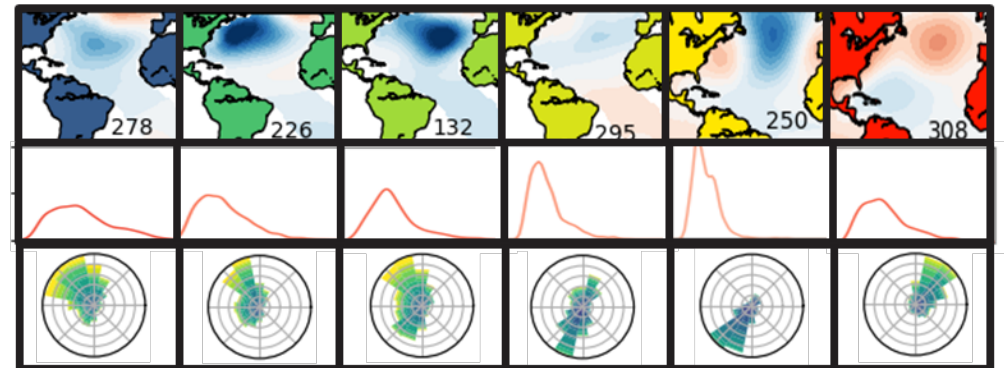Atlantic Multi-Decadal Oscillation
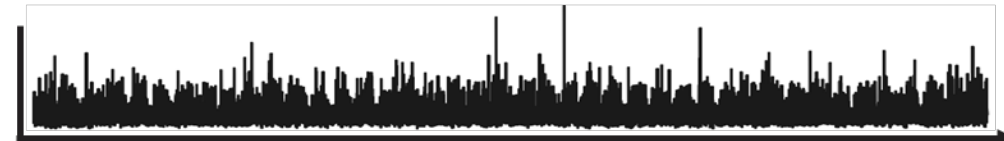
Seasonality

Madden-Julian Oscillation

Weather Patterns

Potential Waves + Winds

Hs (m)

Wind (m/s)

time

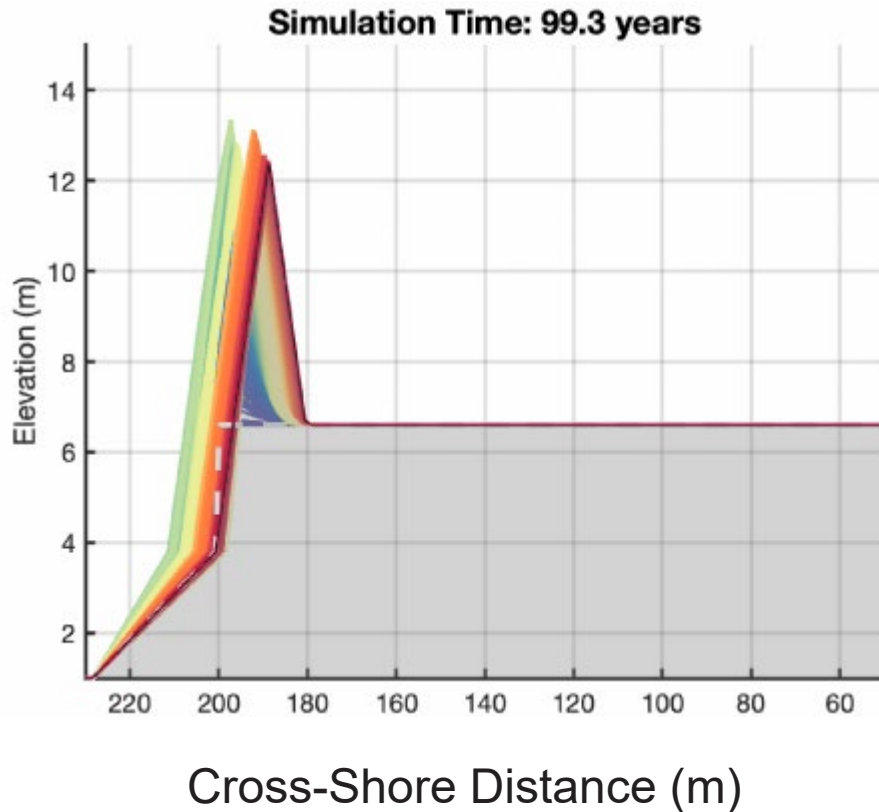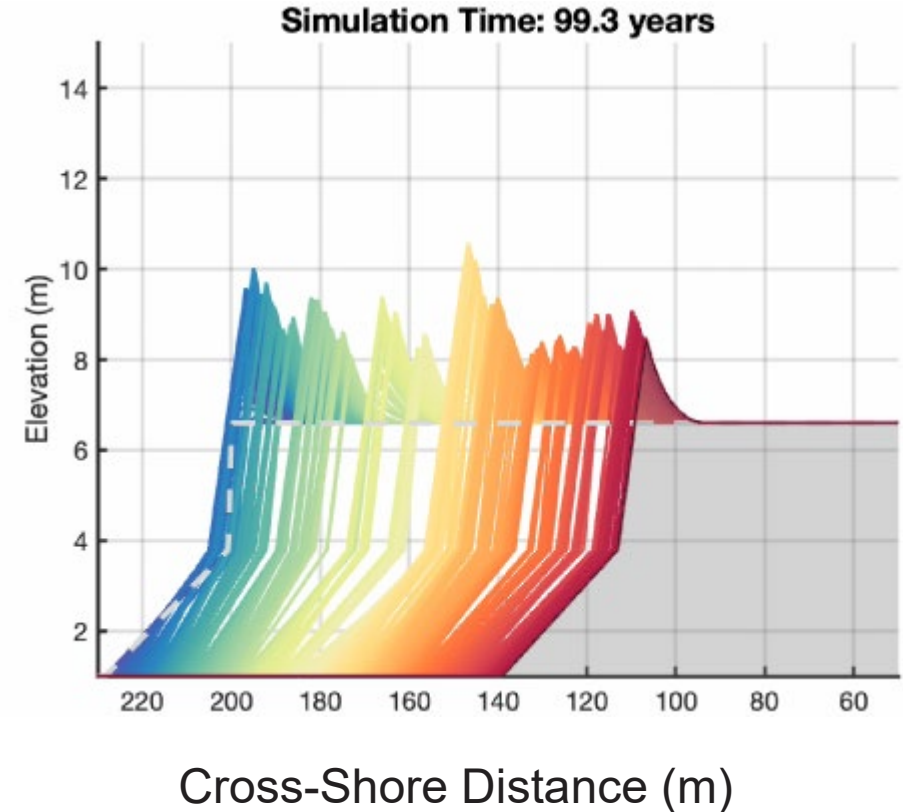# 100-year runs

Stable Shoreline, Intermediate SLR Curve

Mean Shoreline Change Rate,
Intermediate SLR Curve

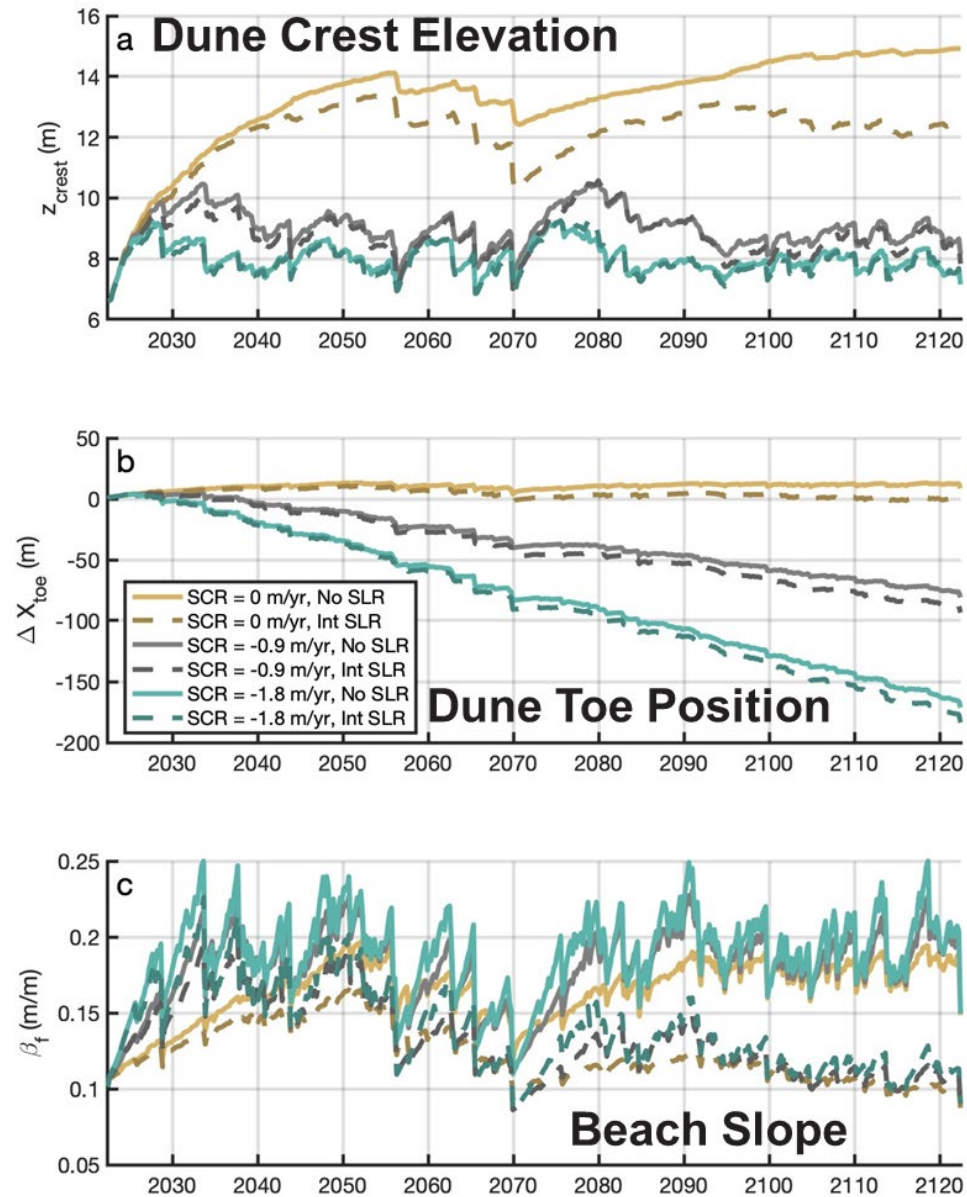

Cross-Shore Distance (m)

Cross-Shore Distance (m)
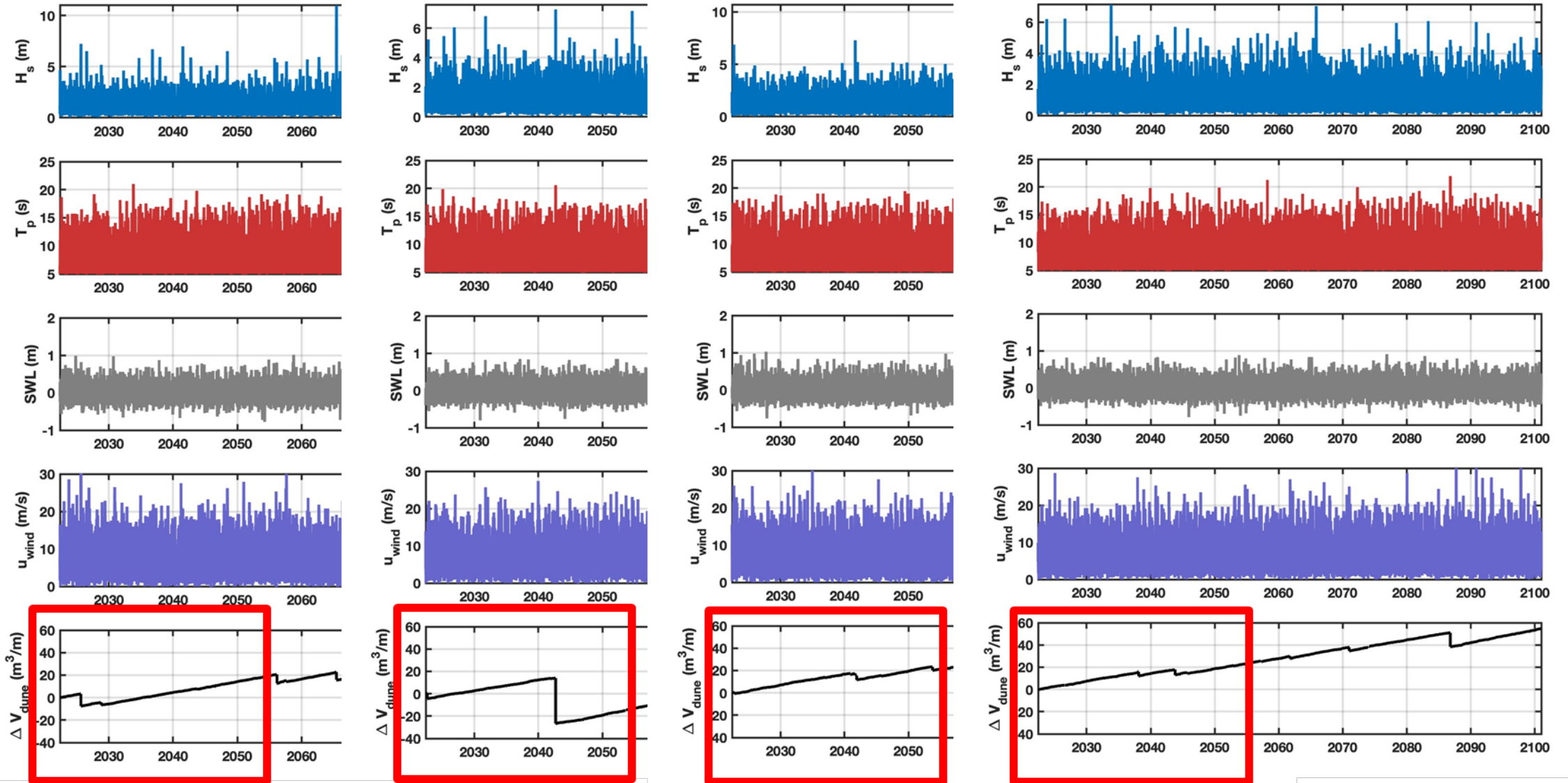
Change in dune characteristics over time

Dune toe position changes out to 100 years for different shoreline change rates (SCR) and sea level rise (SLR) scenarios
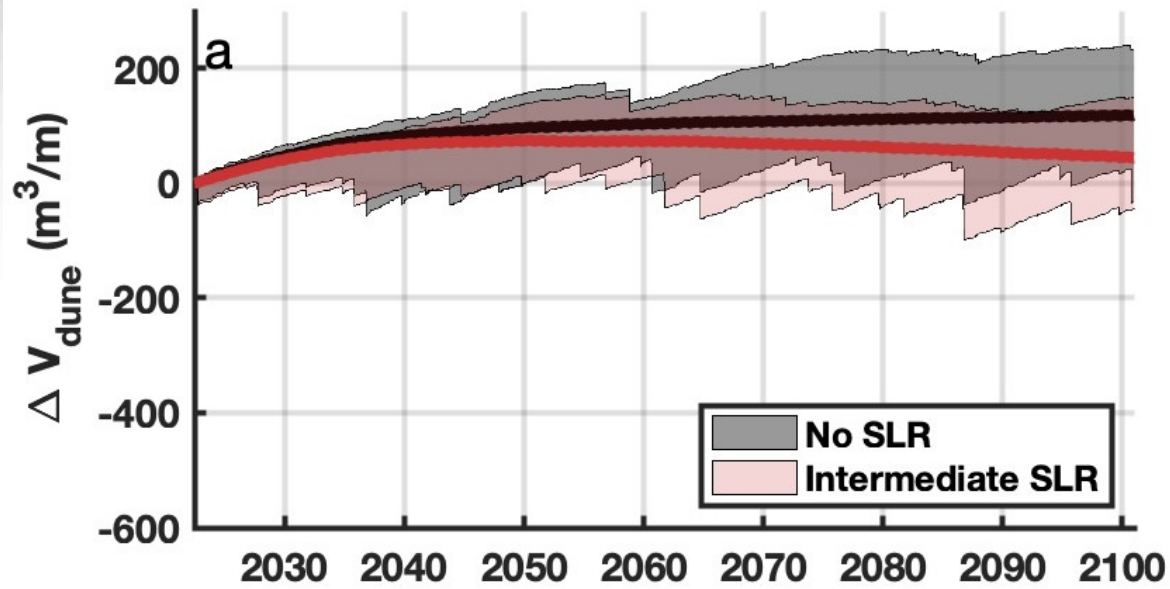
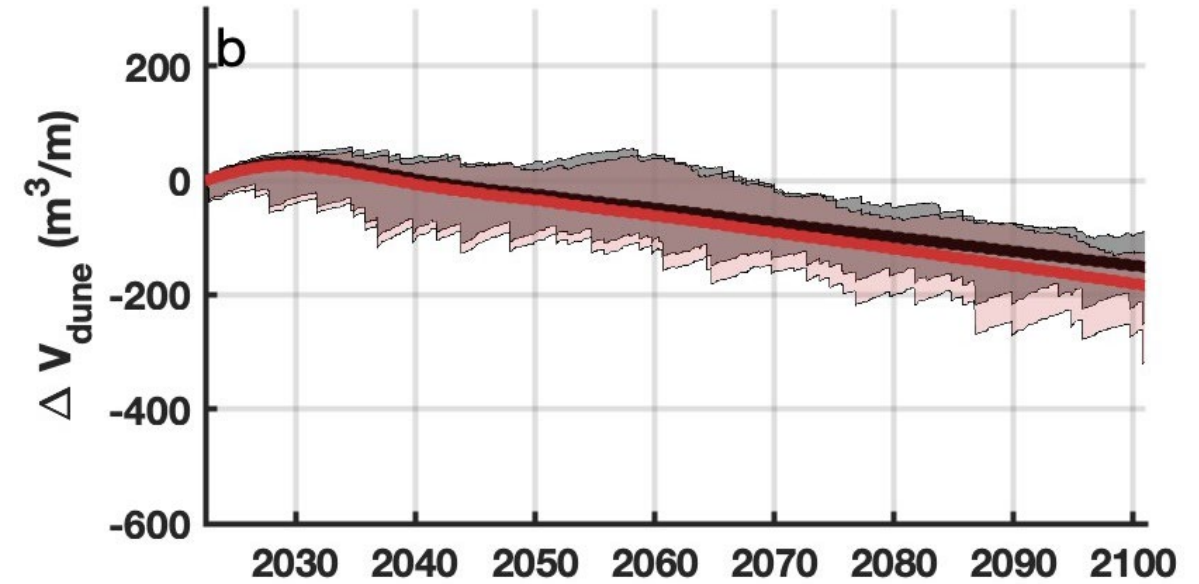# Change in dune response due to forcing changes

Ensemble Results (1000 Simulations)

Stable Shoreline
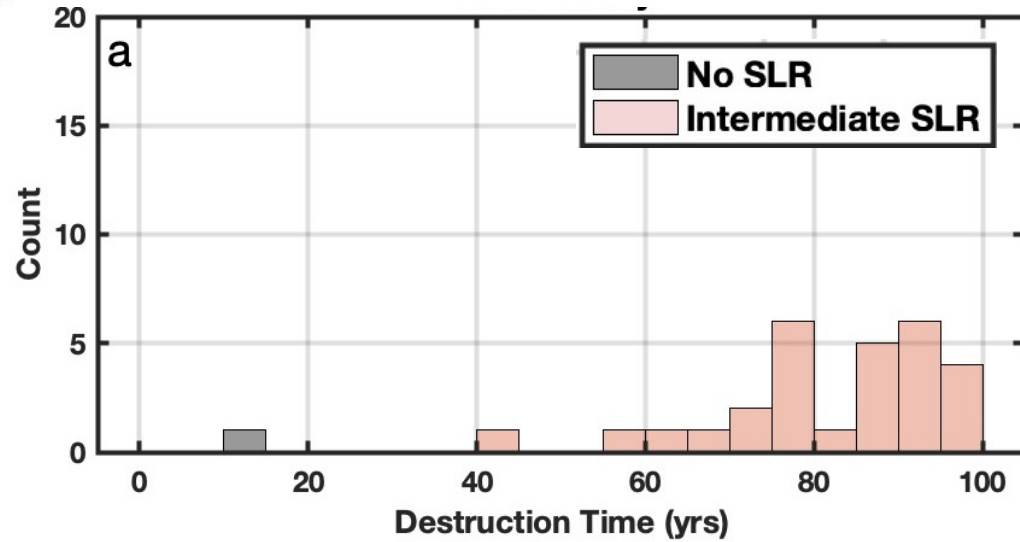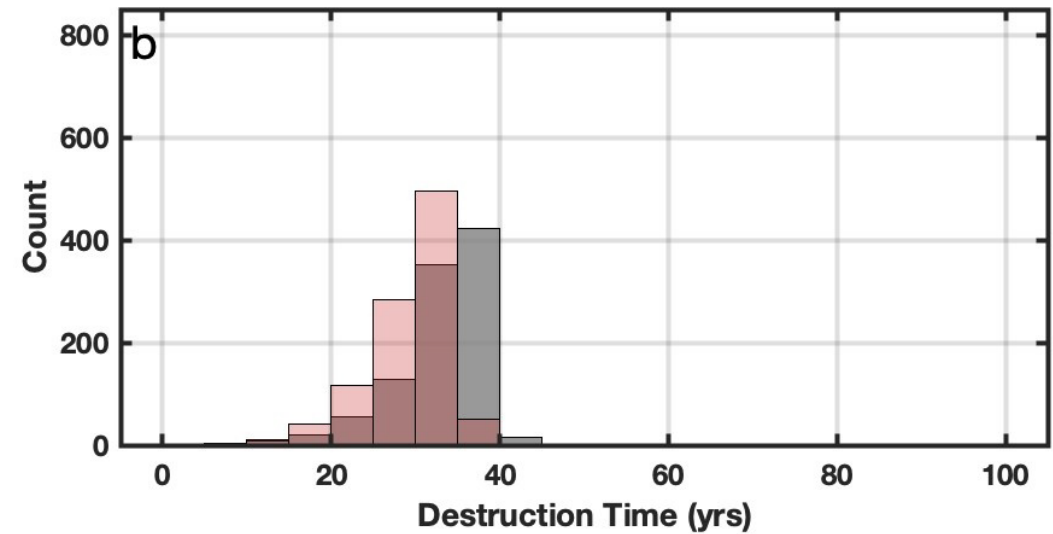
Mean Shoreline Change Rate

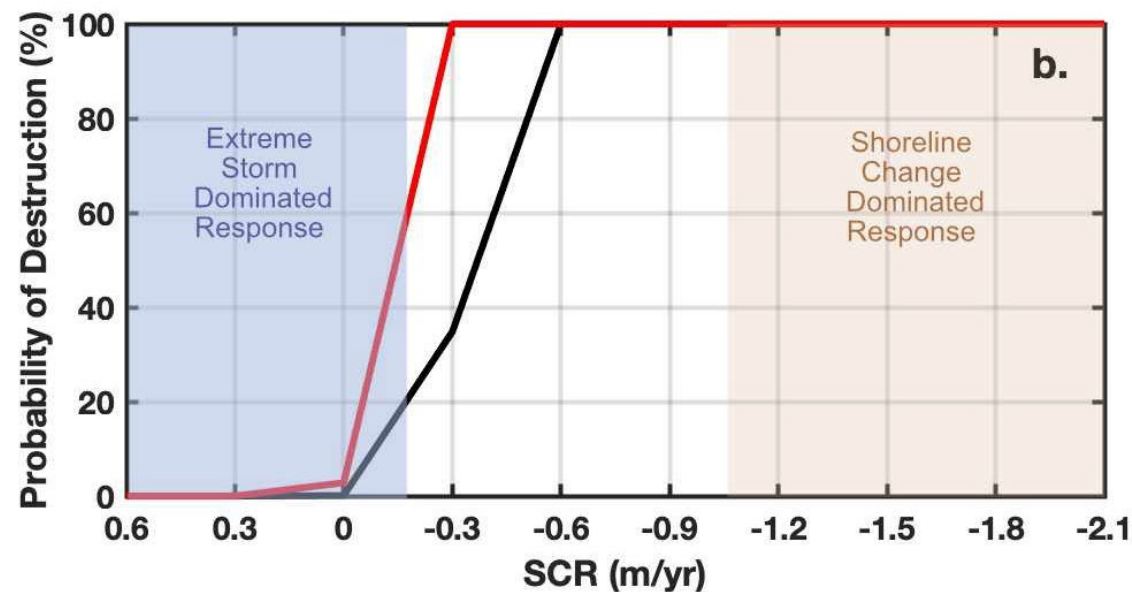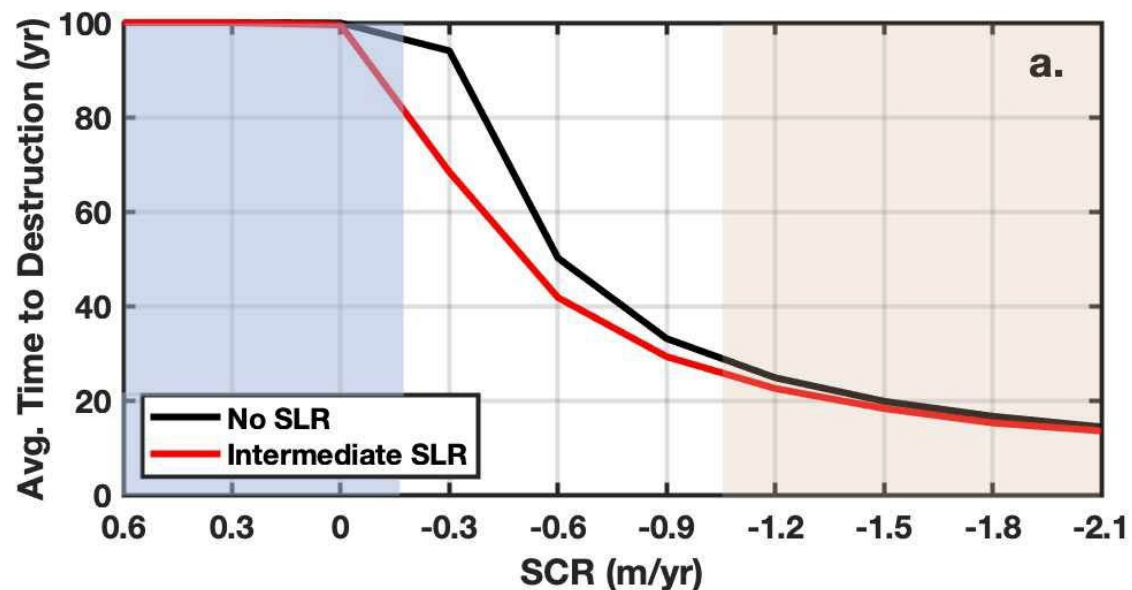# Time and Likelihood of Dune Loss at Site

Stable Shoreline

Mean Shoreline Change Rate

Destruction = volumes falling below FEMA 540 rule

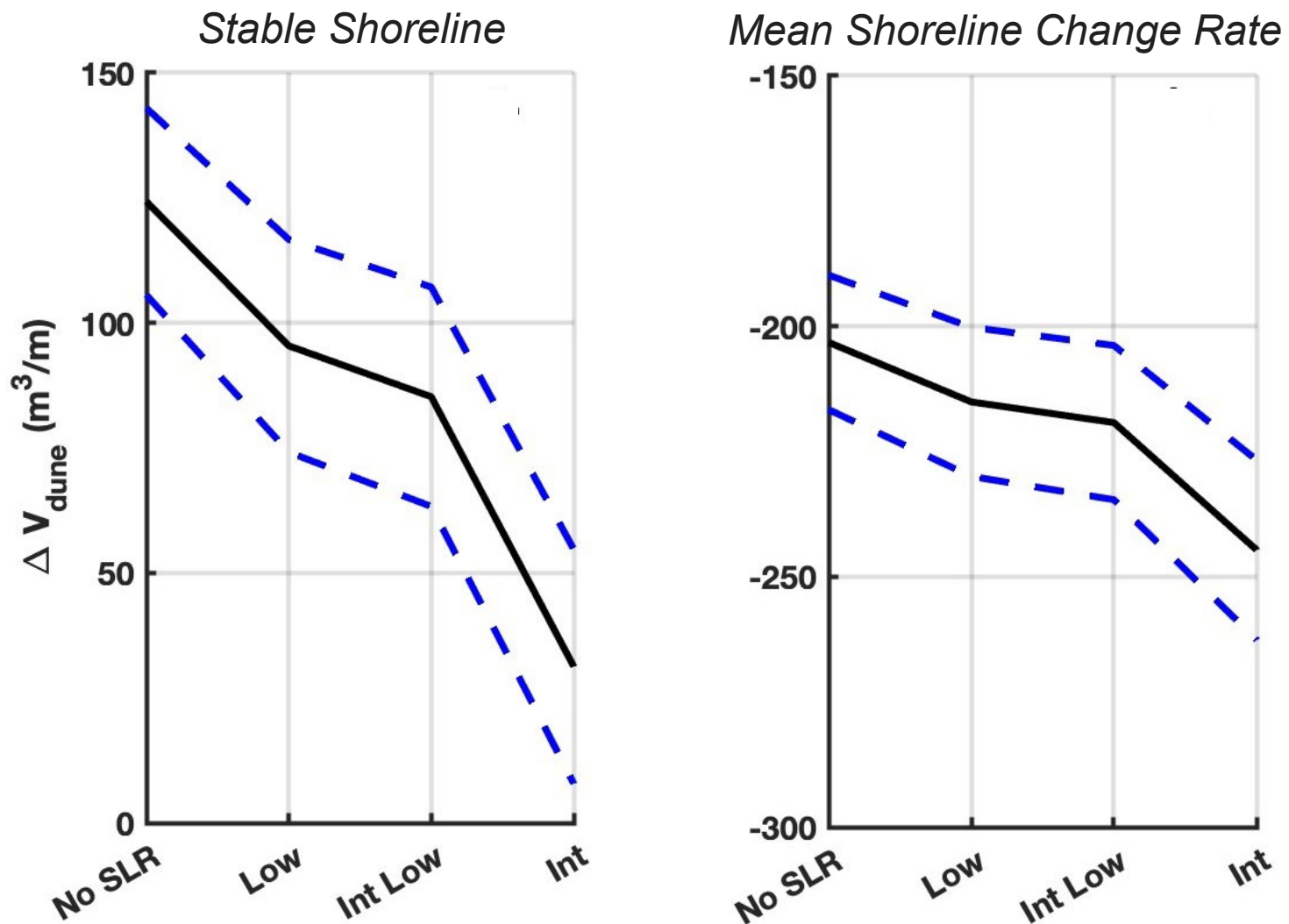# Destruction related to
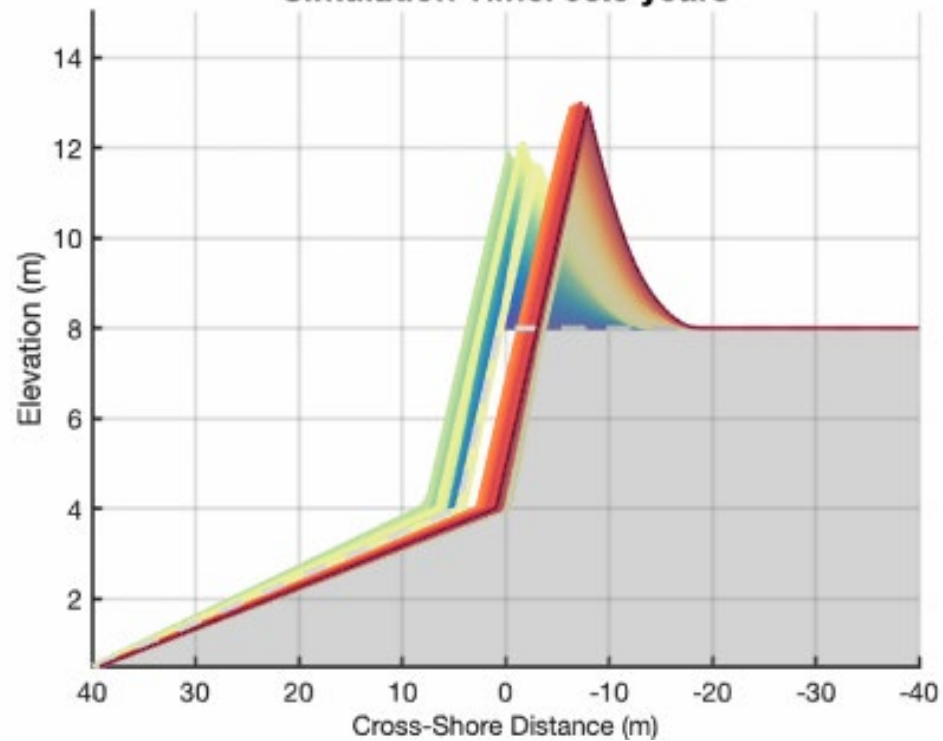# Extreme Storms vs Shoreline Change

Sea Level Rise Effects

Stable Shoreline

Mean Shoreline Change Rate

Possible Future R&D Direction

Incorporation of Internal Biomass into Model
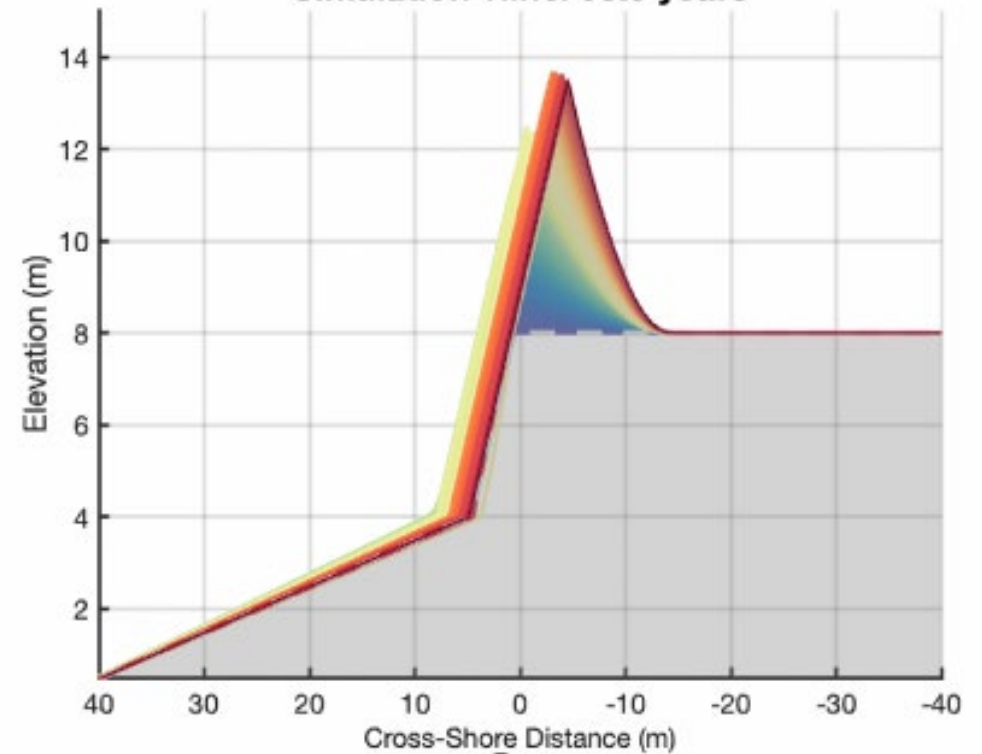

Future 100 Year Simulation
w/ Intermediate SLR

Future 100 Year Simulation
w/ Intermediate SLR + Reduced
Erodibility of Dune
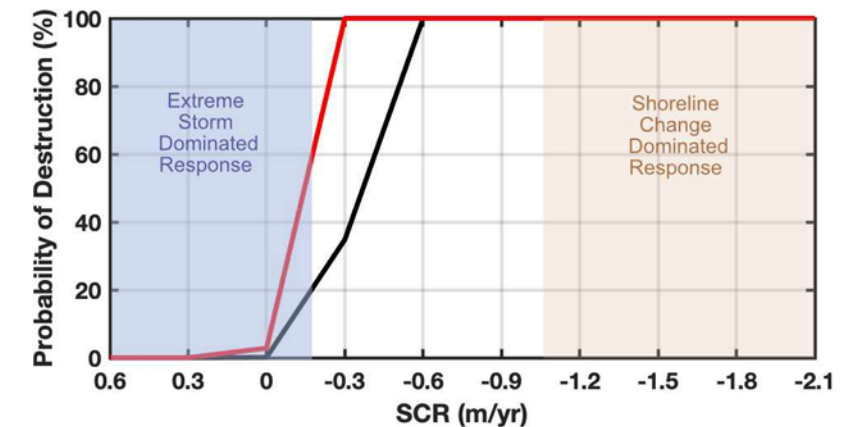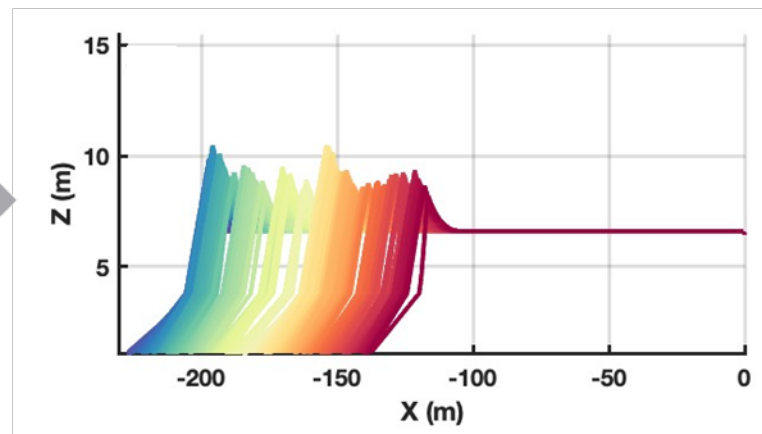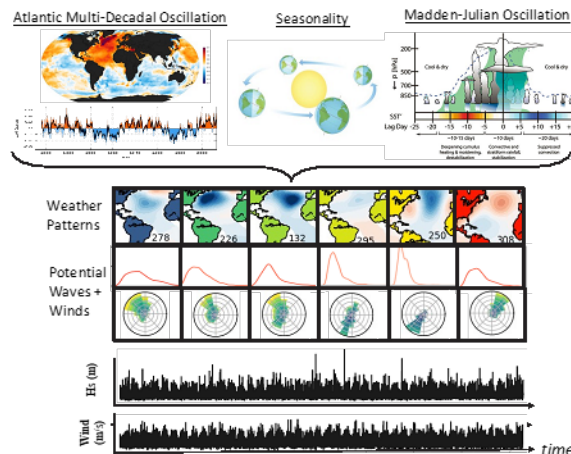
Summary

Main Findings:

- Reduced complexity dune model shows some skill against field data
- Fast model enables long term/repeat simulations
- Tight coupling found between beach and dune behavior
- Broad stochasticity in future dune state depending on details of environmental forcings and sequencing of storms
- SLR major control on both dune growth and erosion

Notes:

- DRT GitHub branch includes full capabilities presented here
- Full morphological capabilities not yet implemented in GUI

Next Steps:

- OCPP SFA/CODS: dev on beach-dune coupling & probabilistic capabilities
- Military reimbursable funding for application/select development
- Academic collaborations (OSU, UF)

Questions?