The Collaboratory for Coastal Adaptation over Space and Time (C-CoAST): Enabling Co-produced, Coupled Human-Natural Dynamics Research in Support of Coastal Community Resilience Planning

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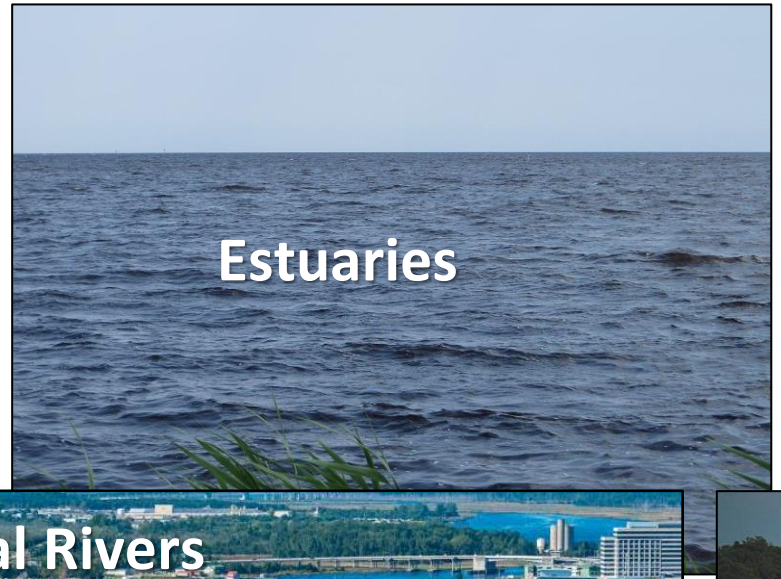
C-CoAST

Funded by NSF Coastlines and People (CoPe) Program

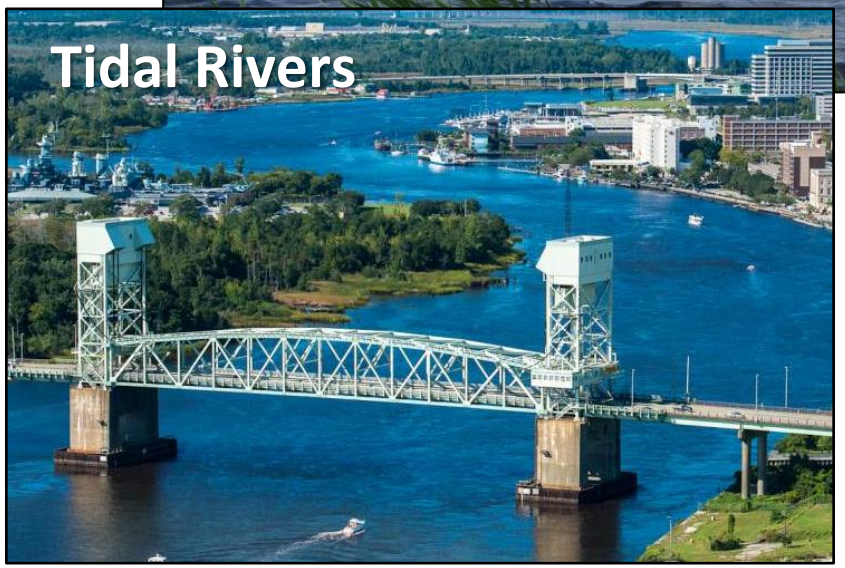
NSF

Low-lying Coastal Environments of North Carolina

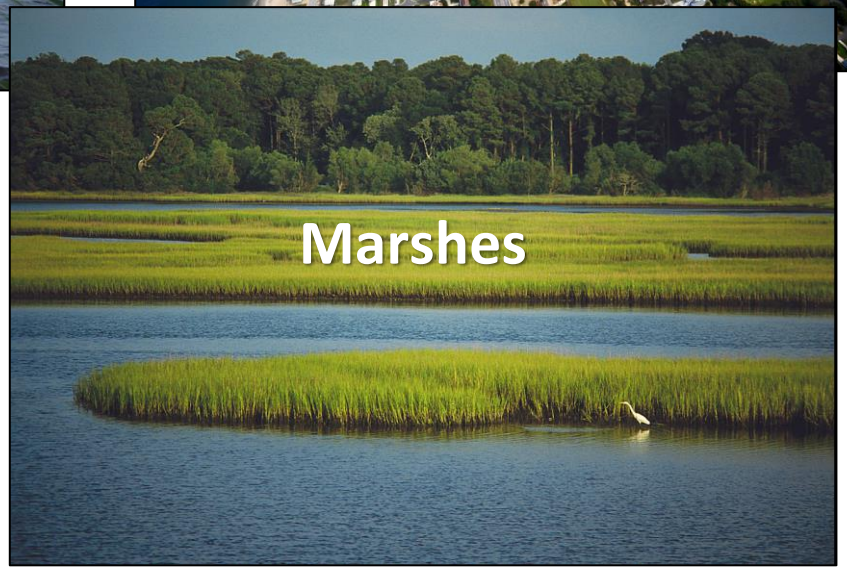


Credit: Wickimedia Commons

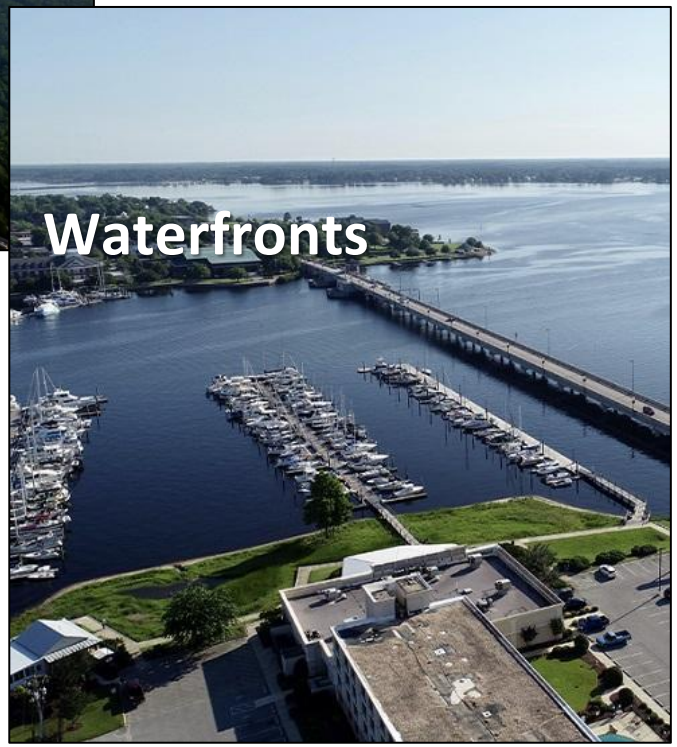
Credit: Brett Clark/UNC CAS



Credit: Wilmingtonandbeaches.com

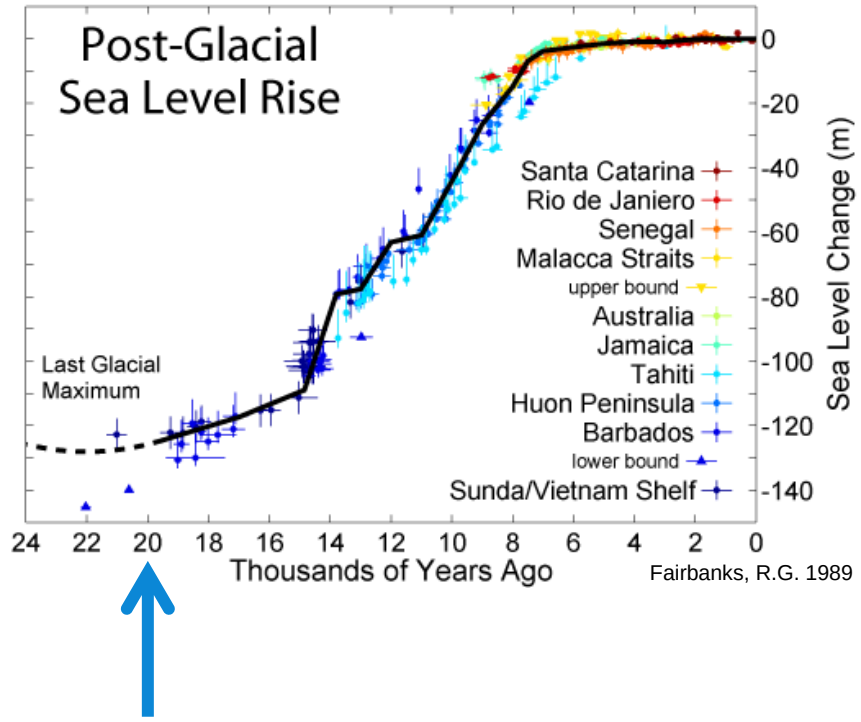


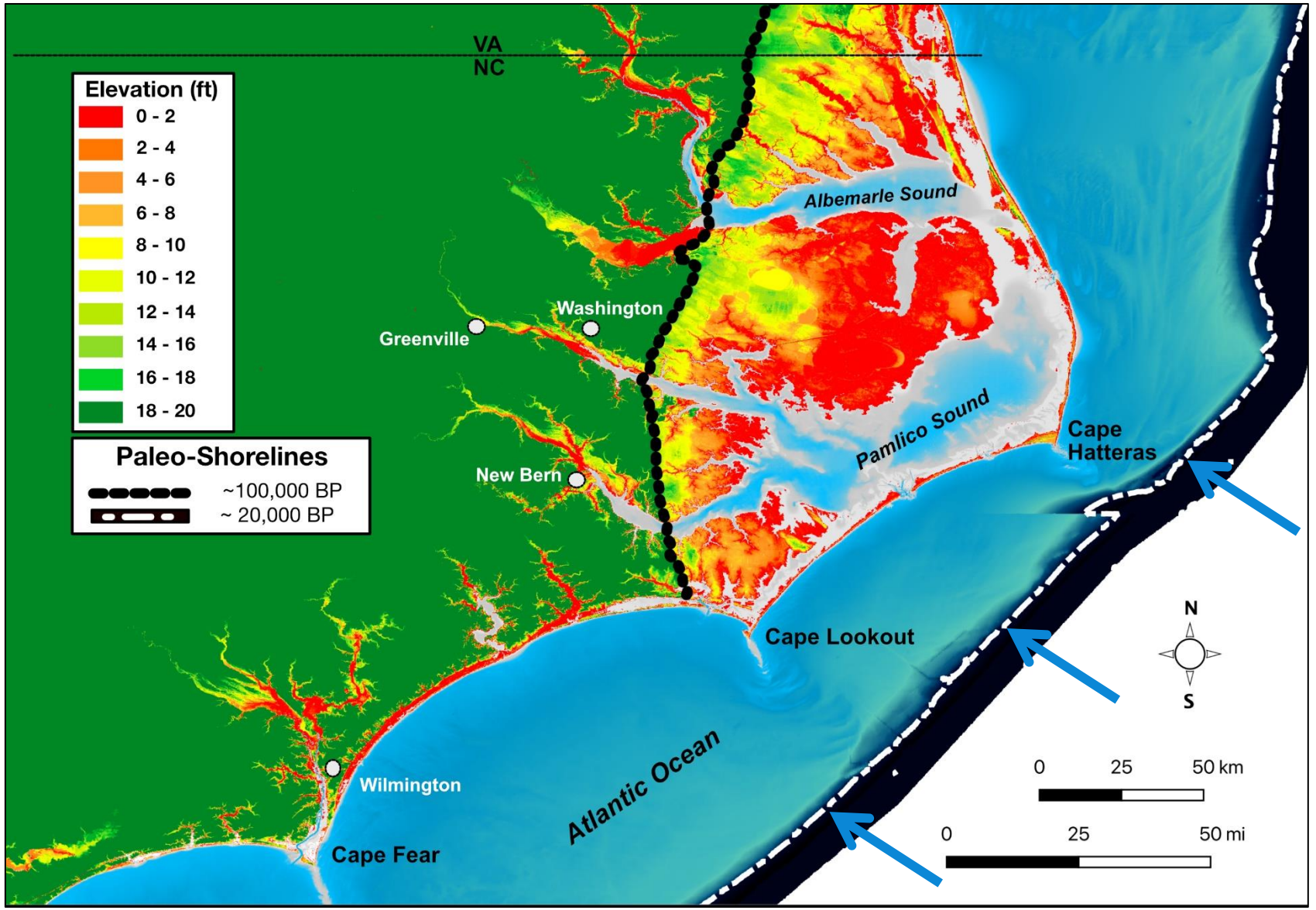
Credit: DEQ



Credit: Emerald Isle Realty

The Dynamic Boundary between Land and Sea





Credit: Reide Corbett, ECU

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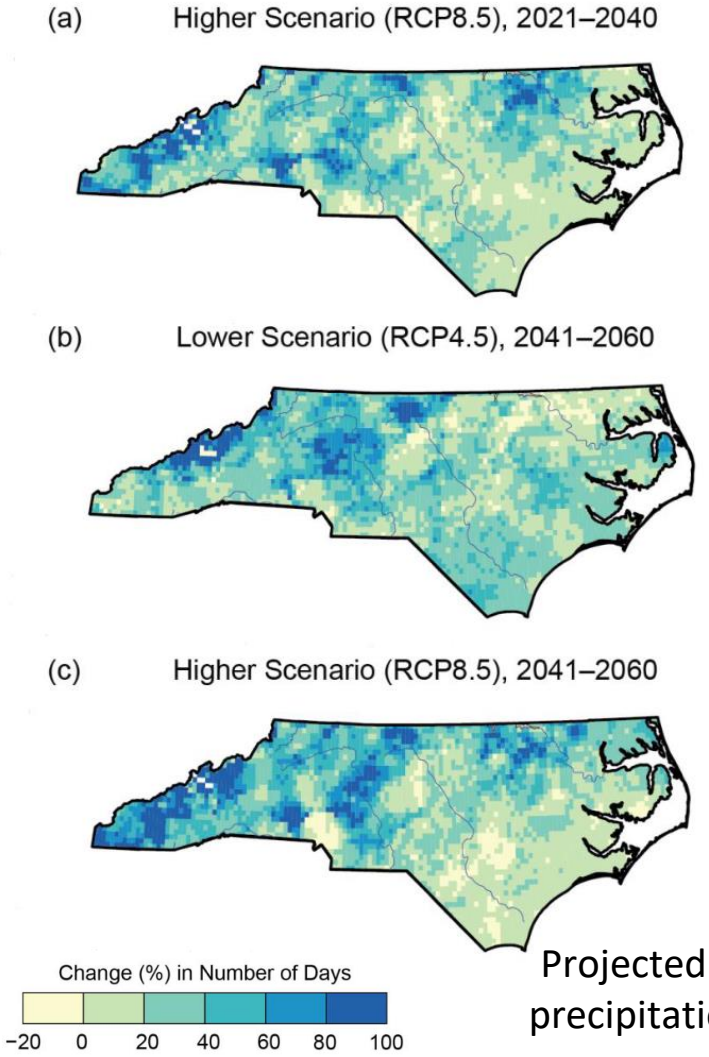
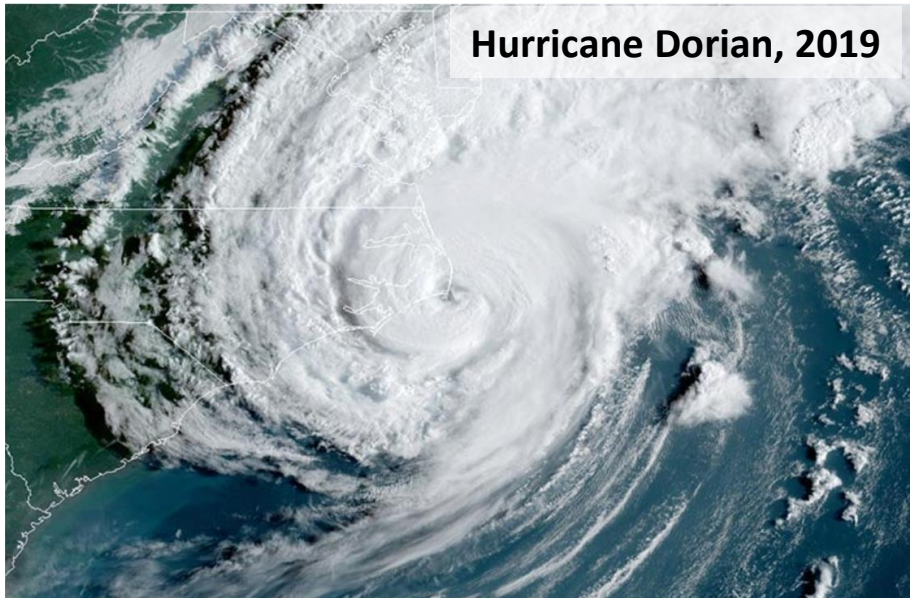
Factors Influencing North Carolina's Coastal Future



Projected changes in annual number of extreme precipitation events days with precipitation ≥3 in.

Kunkel et al., 2020 - NC Climate Science Report

- Sea level rise of <u>one foot by 2050</u> (Sweet et al., 2022)
- Expected increases in the occurrence of heavy rainfall events, and total annual precipitation.
- Expected increases in the occurrence of strong hurricanes.
  - Heavy rainfall
  - Flooding surge + wave action
- Continued development and encouragement of development (e.g., Interstate 42) in low-lying coastal areas.

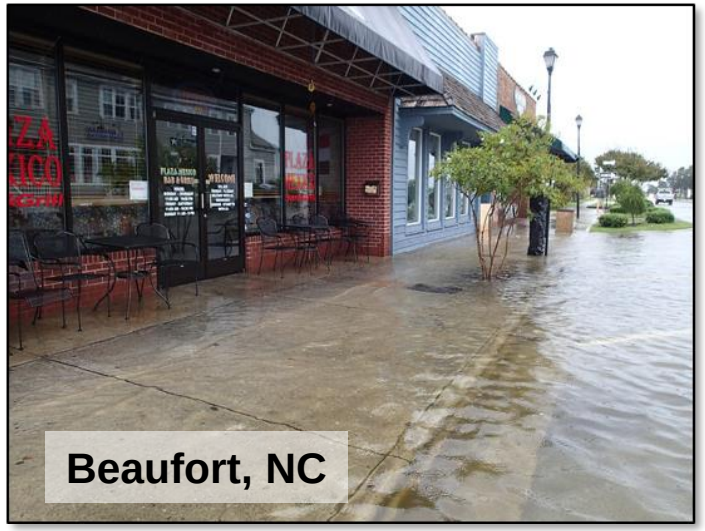


Credit: NOAA/RAMMB

C-CoAST

Acute and Chronic Coastal Hazards

High Tide Flooding



Credit: Miyuki Hino

Credit: DOT

Beach Erosion and Storm Surge Flooding

Credit: Insurancejournal.com

Credit: DOT

Compound Flooding

Credit: AP Photo/Steve Helber

Water Quality Impacts

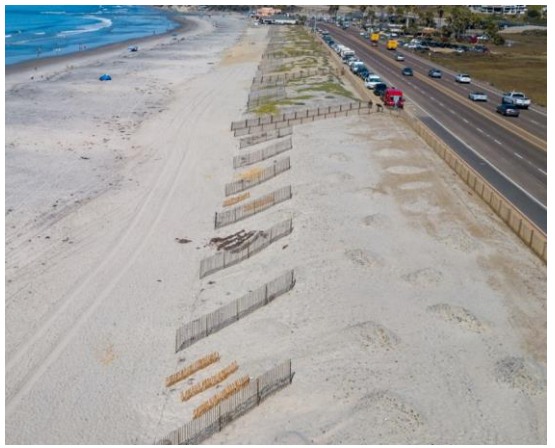
Credit: Hans Paerl

Credit: US NWS

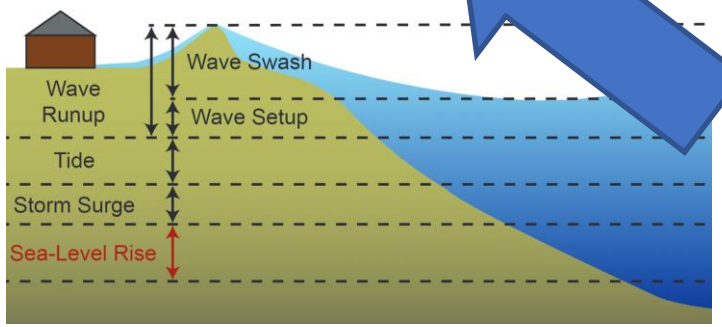
Acute and chronic hazards

Adaptive or unintentionally maladaptive?

Short-term decisions

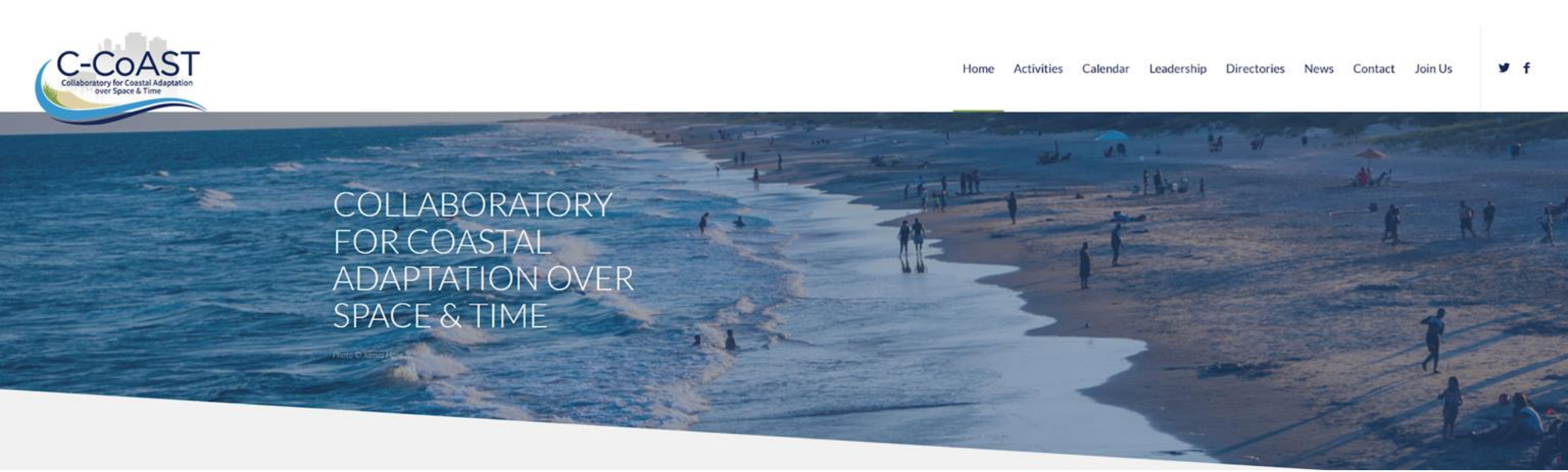


Changes to natural processes



Changes to Landscape and environment

Coupled Human-Natural System



C-CoAST is a network of researchers, stakeholders, and practitioners
(nearly 250 registered participants from 17 U.S. states and 8 countries)

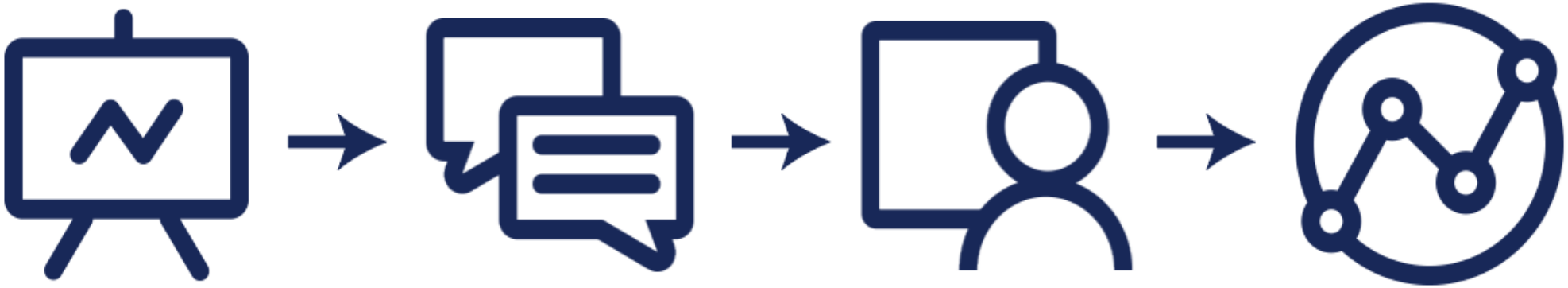
<u>Funded in April 2020 to build capacity to address:</u>

- How do decisions made in the short-term alter future risks and resilience?
- What actions/policies may enable, or inadvertently inhibit, coastal resilience?

Coastlines and People (CoPe)

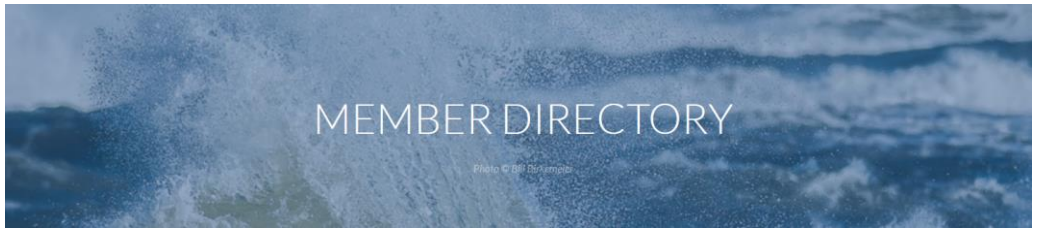
C-CoAST | The University of North Carolina at Chapel Hill | Duke University | UNCW | ECU | NCCentral University | NC State University | The Nature Conservancy North Carolina | N.C. Division of Coastal Management | US Army Corps of Engineers | Sea Grant North Carolina

Capacity building through C-CoAST Activities



Disciplines 101 → **Listening Sessions** → **Gallery Walks** → **Research Agenda Workshop**

… plus



c-coast.org

C-CoAST Listening Sessions

- Guiding question: How do coastal residents and stakeholders understand connections between short-term and long-term coastal decisions?

- Facilitated discussions to identify decision consequences

- Five sessions held online in Spring 2021
  - ~80 participants from 11 coastal counties
  - Residents, elected officials, town & county government staff, state agency personnel, consultants, non-profits

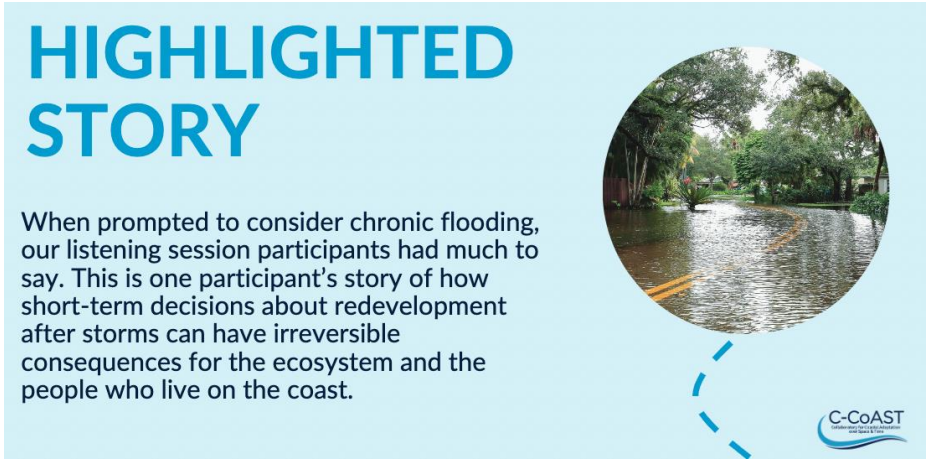
C-CoAST Gallery Walk

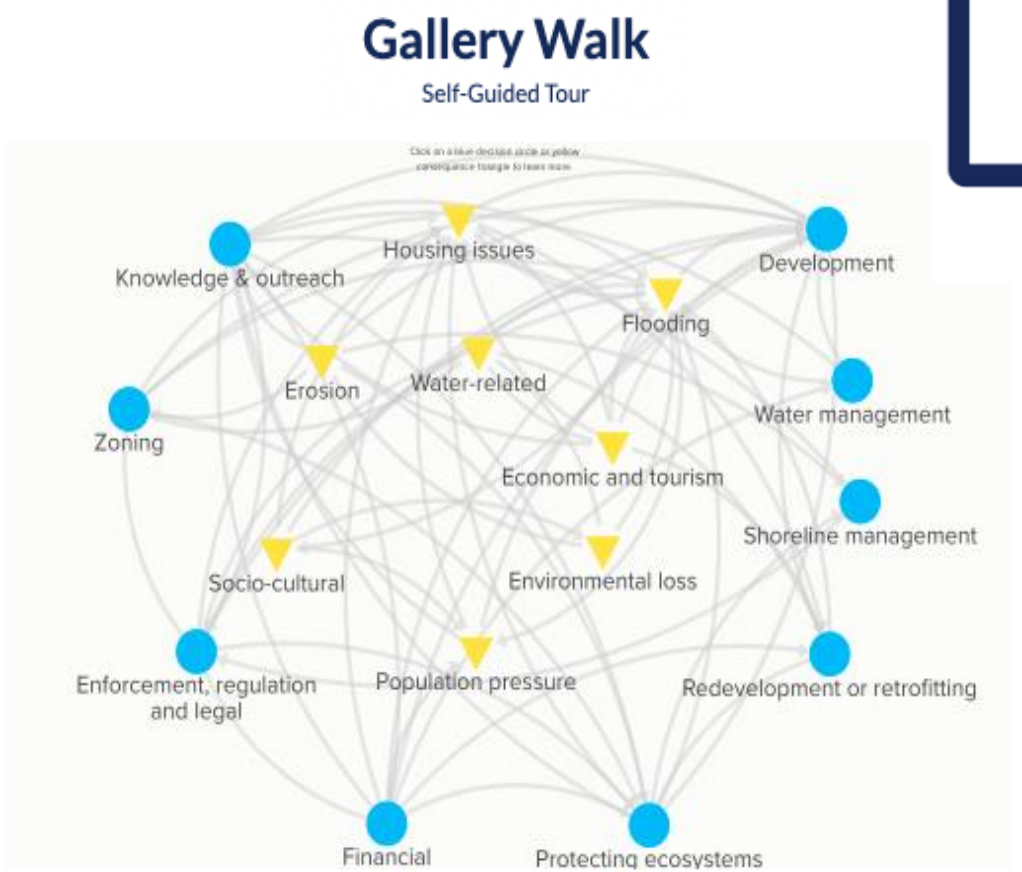
- Guiding goals:
  - Share what was learned from Listening Sessions
  - Get feedback to refine what was heard
  - Expand participation; include more voices

- Launched Fall 2022 on “Activities” tab at: c-coast.org

- Virtual with opportunities to contribute.

C-CoAST Gallery Walk: 3 experiences





https://c-coast.org/activities/gallery-walk/

C-CoAST - Related Projects…

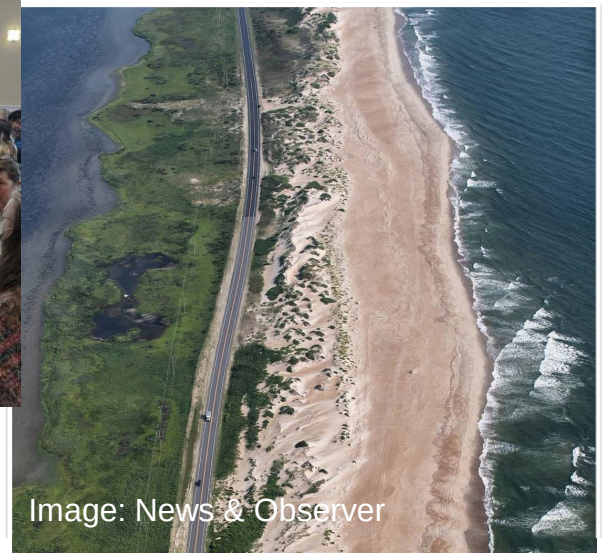
How do decisions made in the short-term alter future risks and resilience?

What actions/policies may enable, or inadvertently inhibit, coastal resilience?

High-tide Flooding

Compound Flooding

Community Understanding of Climate Change



Participatory Modeling of Landscape Change

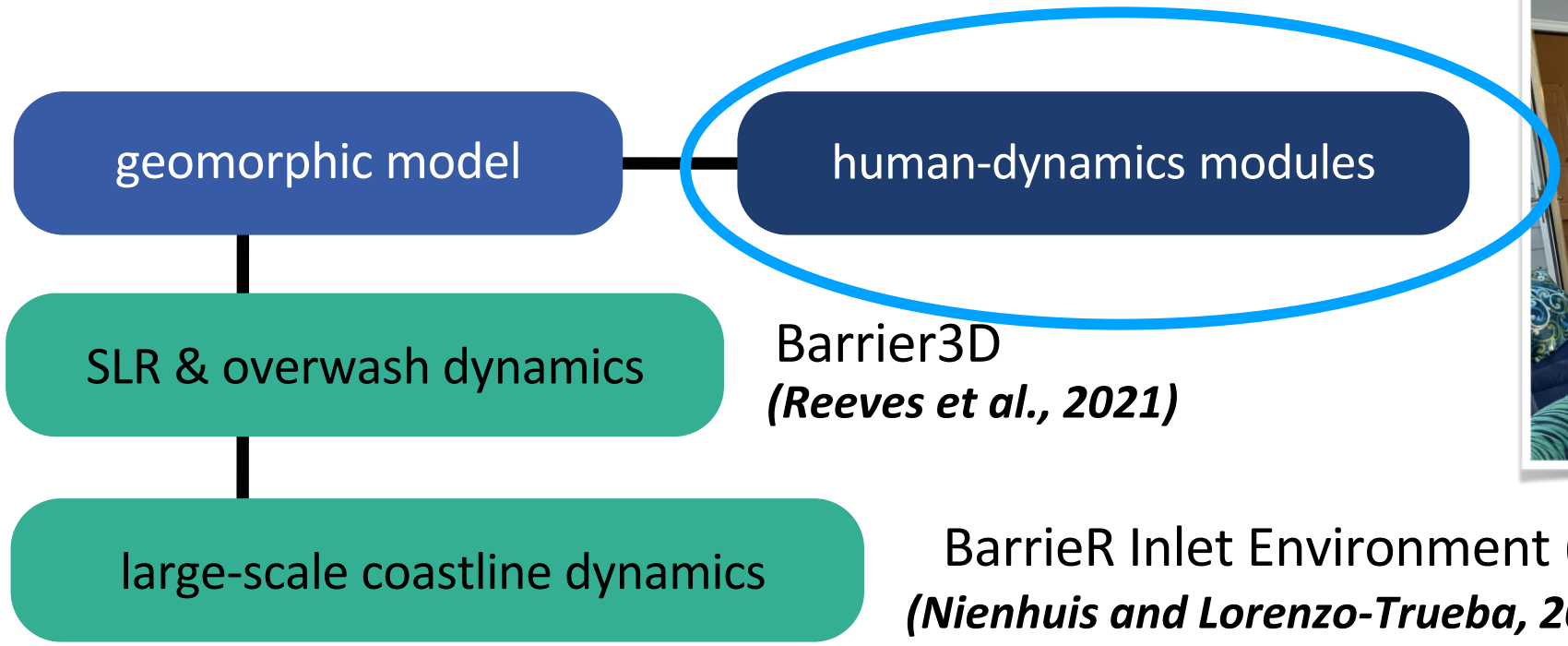
Katherine Anarde

Ian Reeves

How might coastal management affect barrier habitability and lead to drowning?

CoASTal Community lAnDscape Evolution model

A new (coupled) exploratory modeling framework of barrier evolution

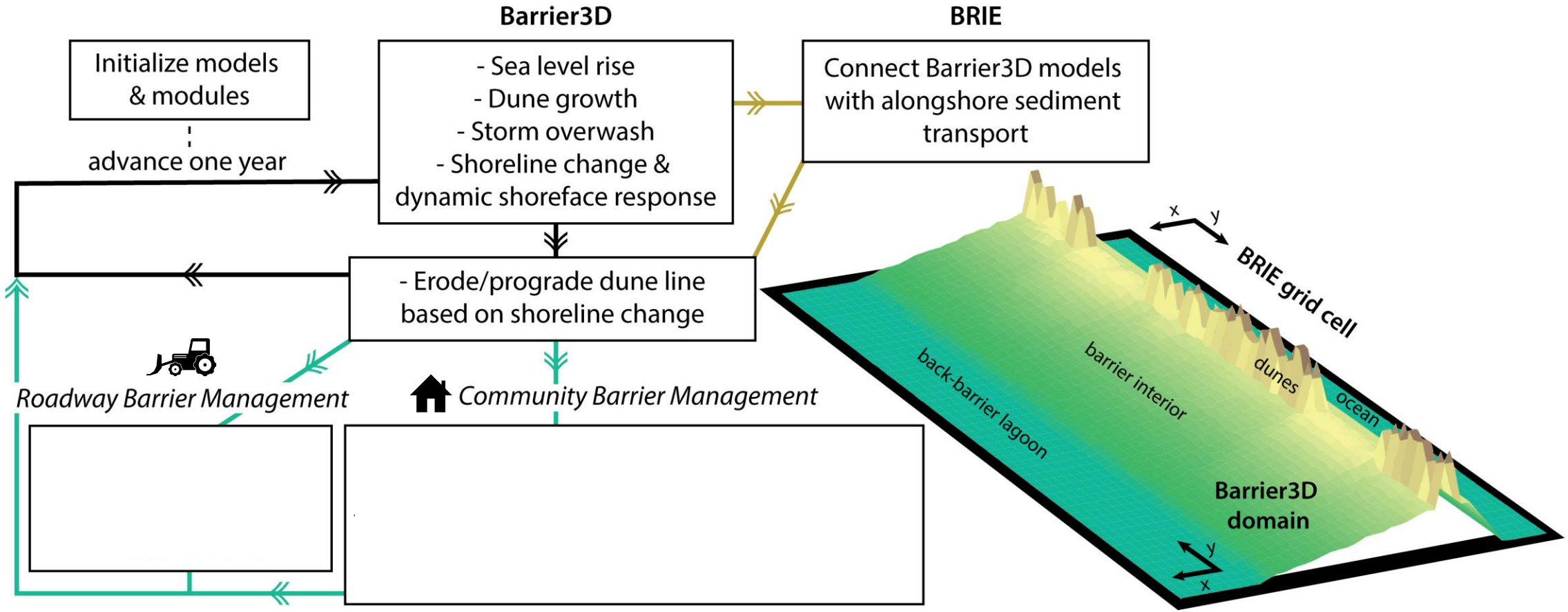


Barrier3D
(Reeves et al., 2021)

BarrieR Inlet Environment (BRIE) model
(Nienhuis and Lorenzo-Trueba, 2019)

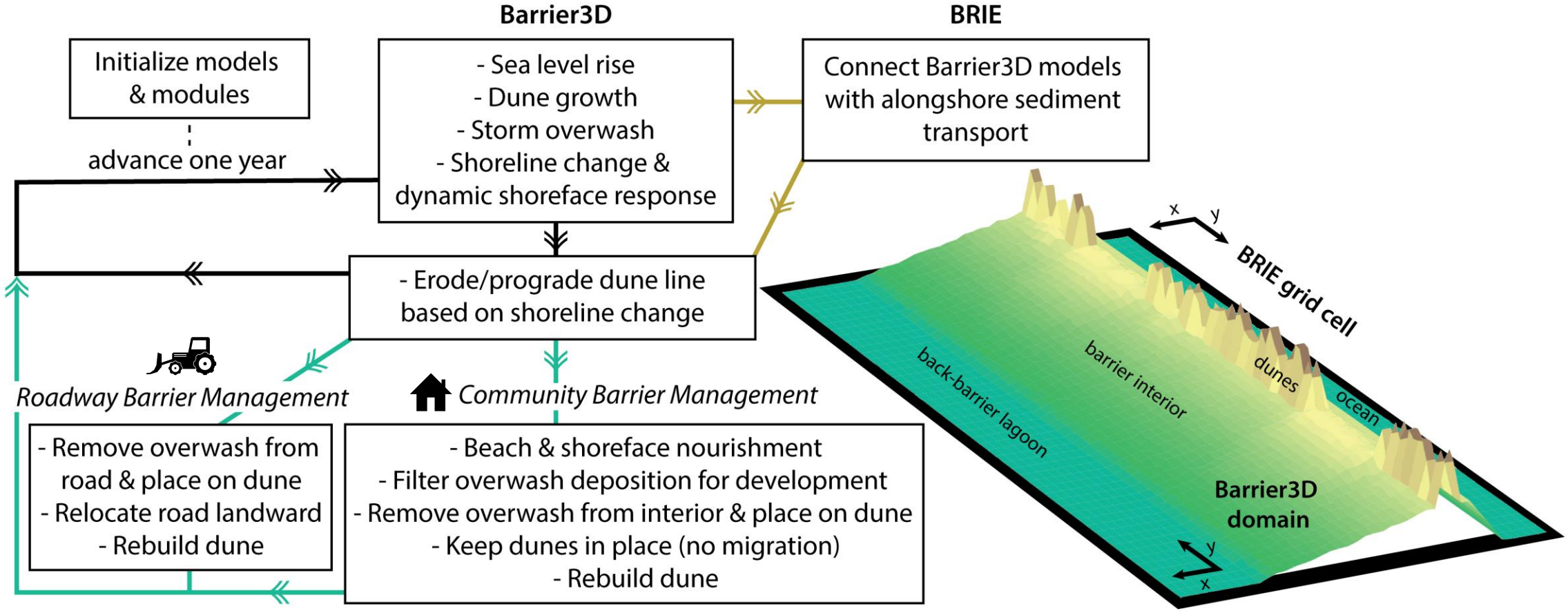
CSDMS
community surface dynamics modeling system

CoASStal Community lAnDscape Evolution model



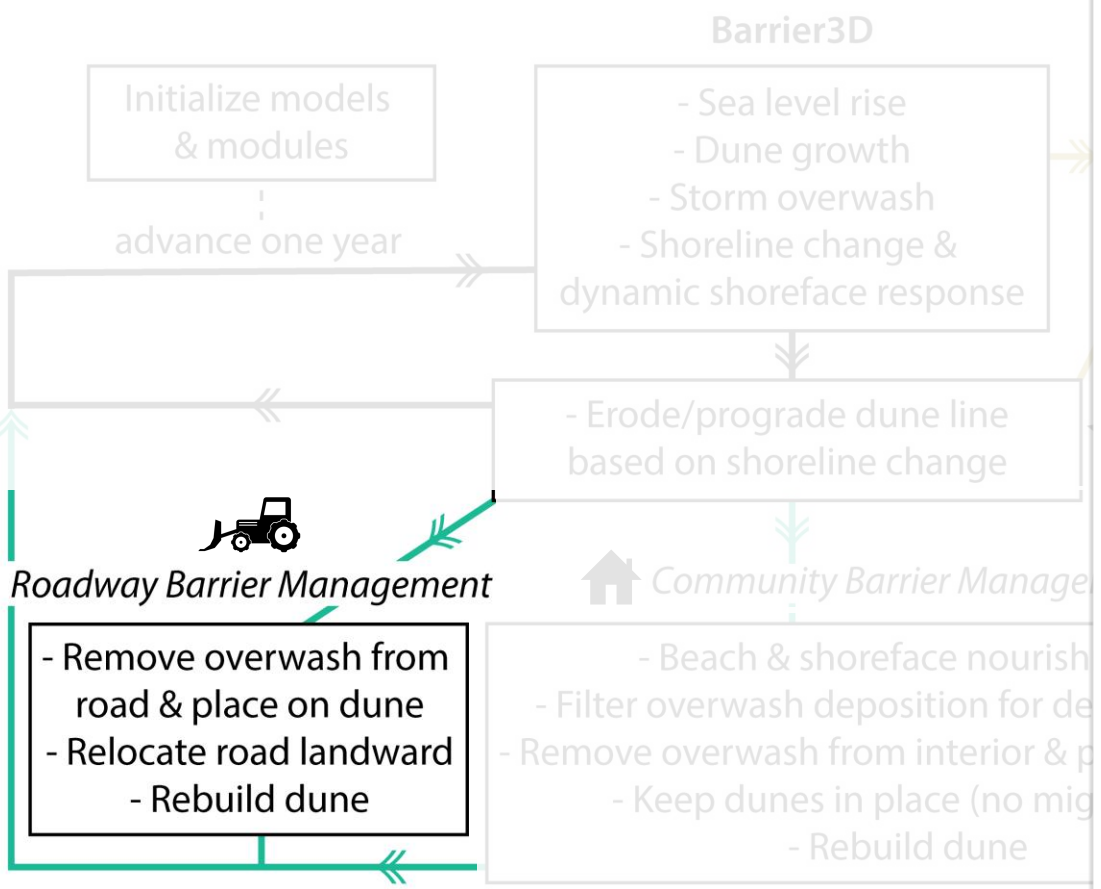
Anarde, Moore, Murray & Reeves Part I & Part II, In review

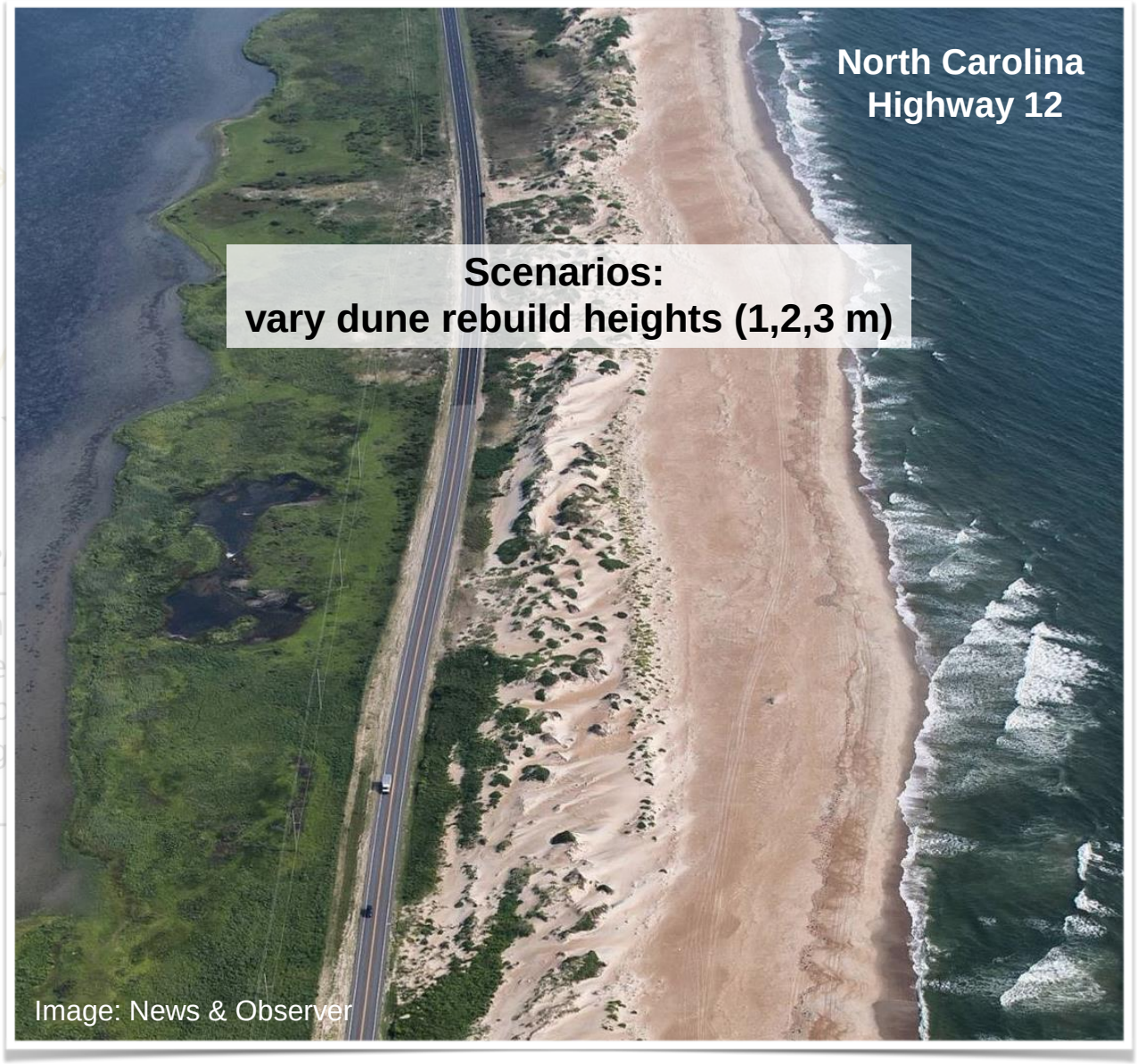
CoASTal Community lAnDscape Evolution model



Anarde, Moore, Murray & Reeves Part I & Part II, In review

Roadway Barrier Management





Roadway management ceases when:

1) roadway cannot be relocated into interior
2) bay encroaches on road (20% touch water)

Community Barrier Management

Barrier3D

Initialize models & modules

advance one year

- Sea level rise
- Dune growth
- Storm overwash
- Shoreline change & dynamic shoreface response

- Erode/prograde dune line based on shoreline change

Roadway Barrier Management

- Remove overwash from road & place on dune
- Relocate road landward
- Rebuild dune

Community Barrier Management

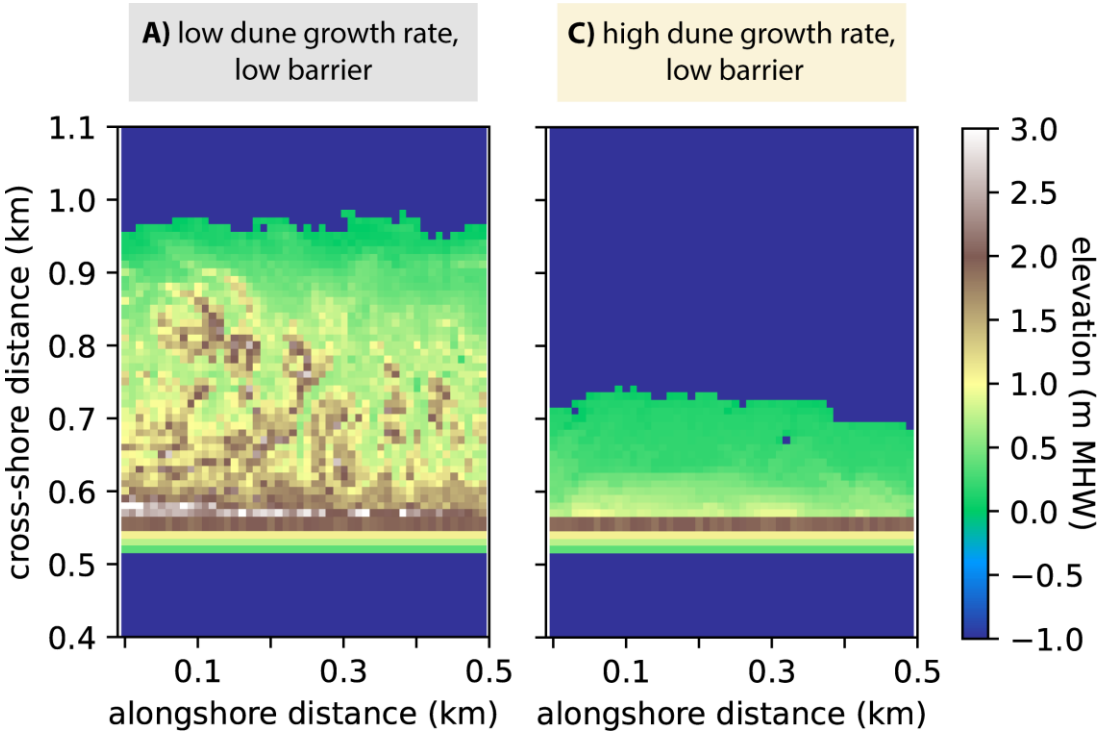
- Beach & shoreface nourishment
- Filter overwash deposition for development
- Remove overwash from interior & place on dune
- Keep dunes in place (no migration)
- Rebuild dune

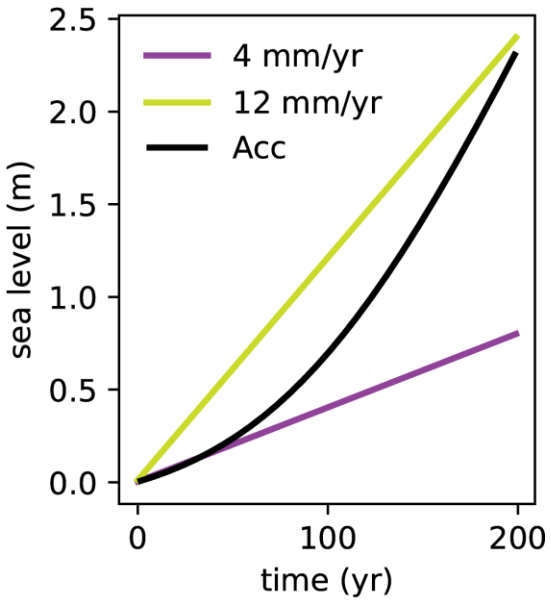
Rogers et al., 2015

Management ceases when barrier becomes too narrow for a house + roadway

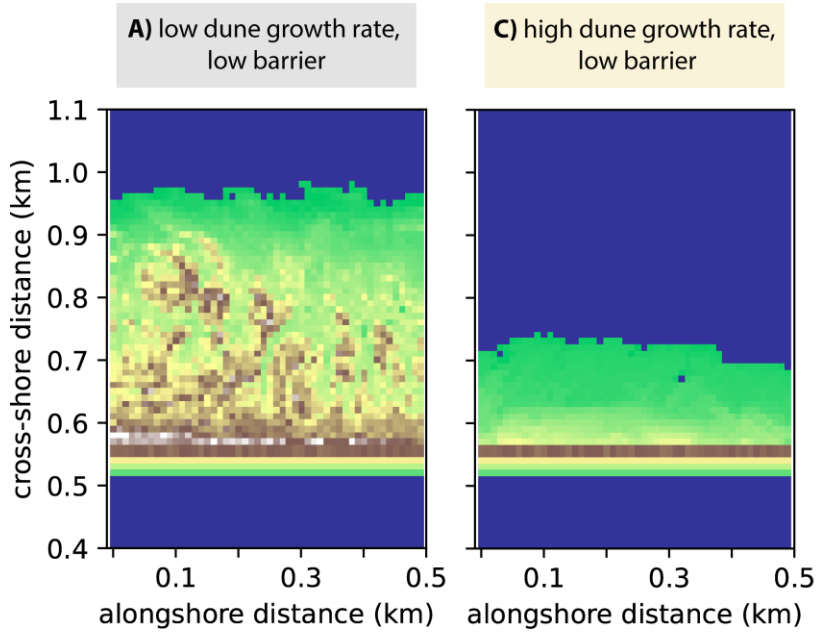
Initial Conditions

- Two initial configurations: both low topography (developed using actual topography)
  - A: dunes naturally recover slowly
  - C: dunes naturally recover quickly
- Storms add randomness to the system: here use a single sequence of synthetic storms
- Two SLR scenarios: linear (0.004 m/yr) and accelerated

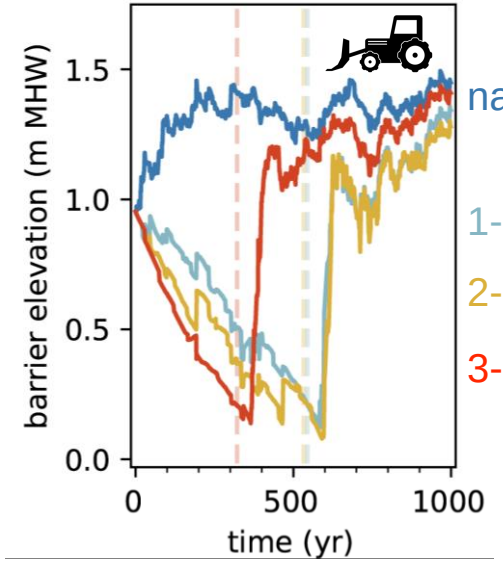




Simplest scenario: one barrier segment, linear SLR



Consistently high dunes ➡ less overwash ➡ earlier road abandonment



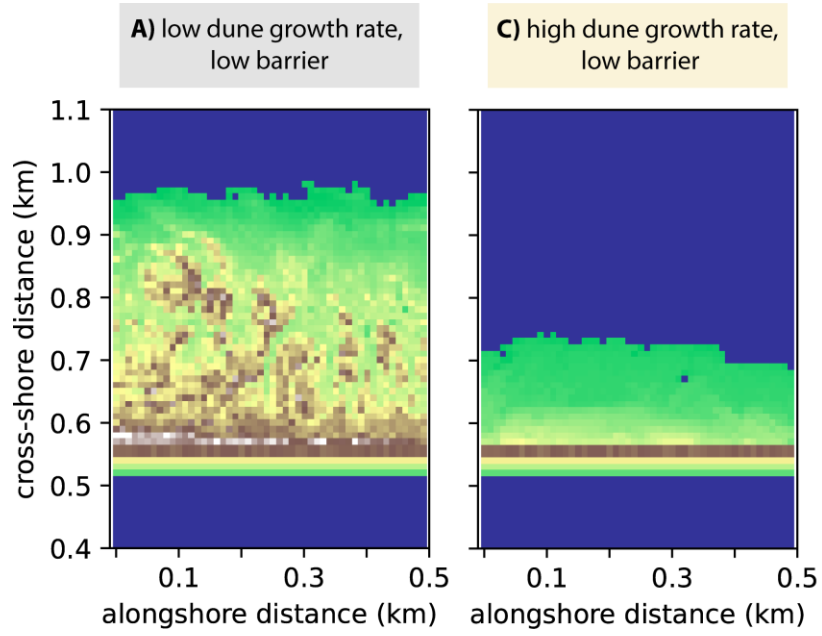
natural scenario

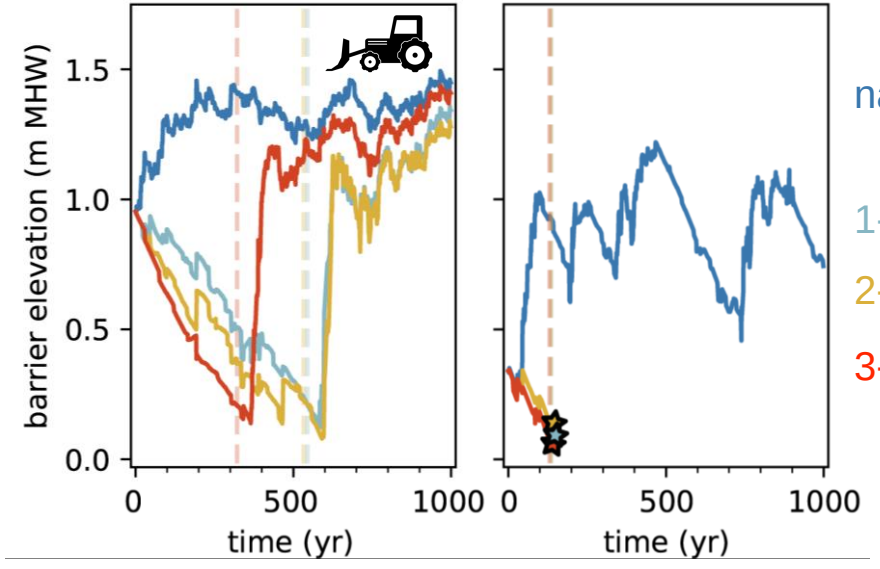
1-m dune, road abandoned after 544 yrs

2-m dune, road abandoned after 533 yrs

3-m dune, road abandoned after 322 yrs

Simplest scenario: one barrier segment, linear SLR





Consistently high dunes ➡ less overwash ➡ earlier road abandonment

post-abandonment:
- drowning (★) depends on storm stochasticity

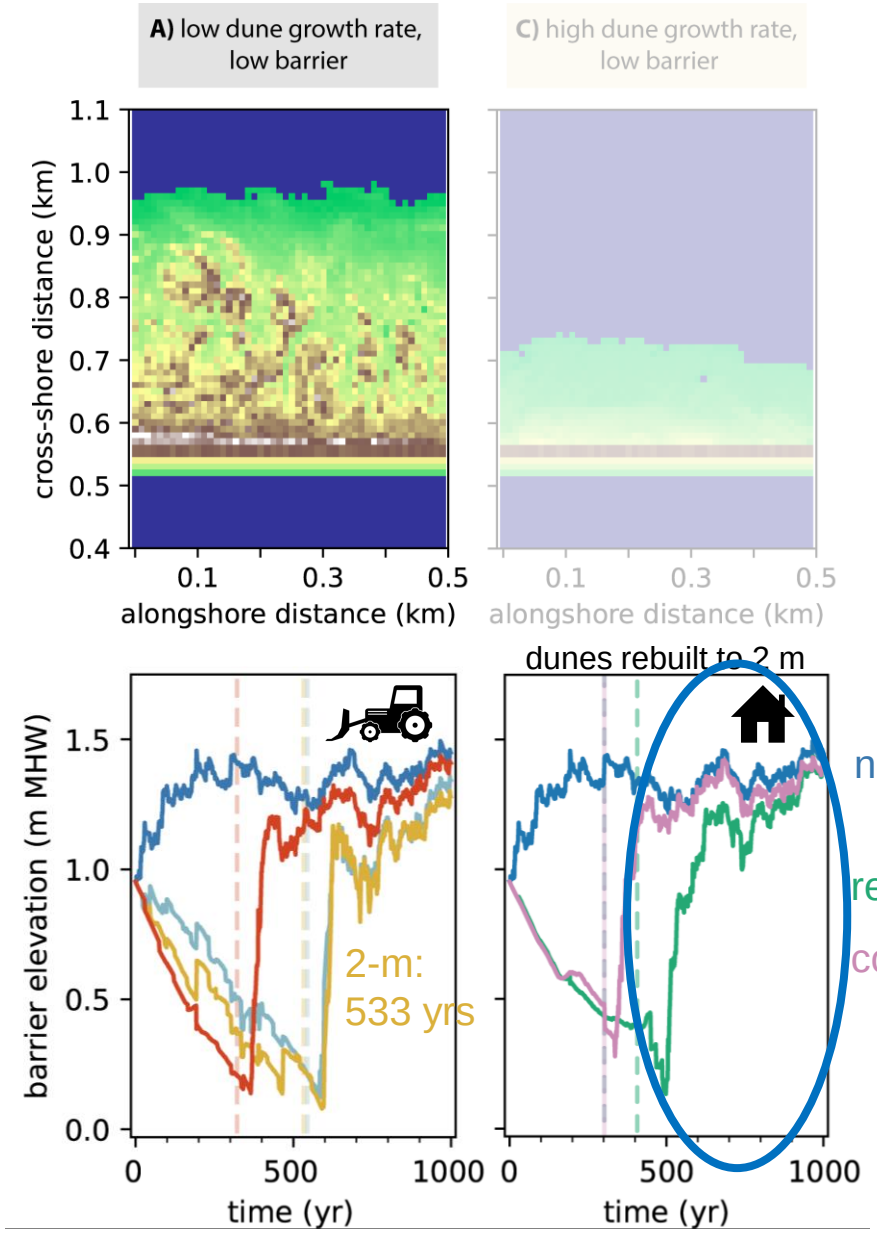
natural scenario

1-m dune, road abandoned after 136 yrs

2-m dune, road abandoned after 136 yrs

3-m dune, road abandoned after 132 yrs

Simplest scenario: one barrier segment, linear SLR



Consistently high dunes ➡ less overwash ➡ earlier road abandonment

post-abandonment:
- drowning (★) depends on storm stochasticity
- barriers can rebound within decades

natural scenario

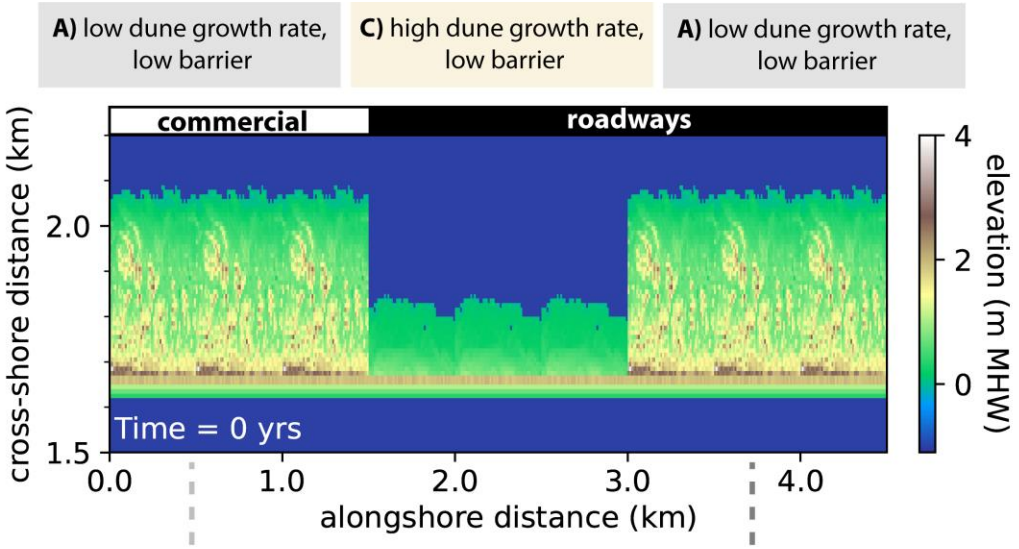
residential, abandoned after 407 yrs

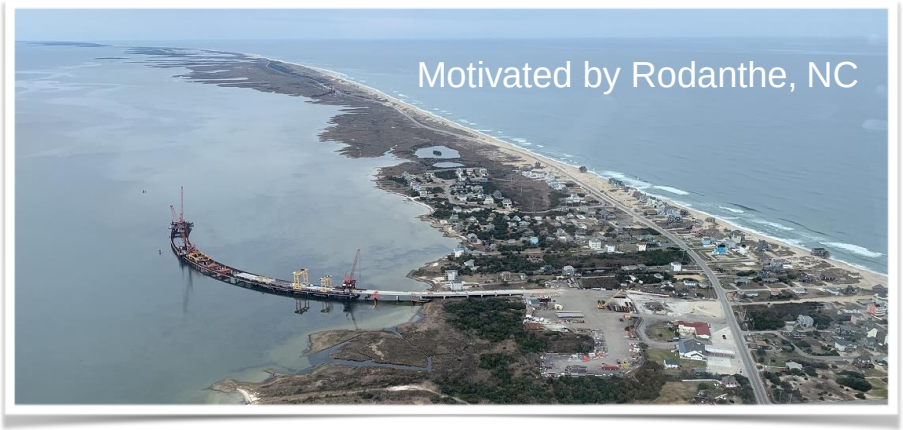
commercial, abandoned after 302 yrs

Increase complexity…
alongshore-varying management

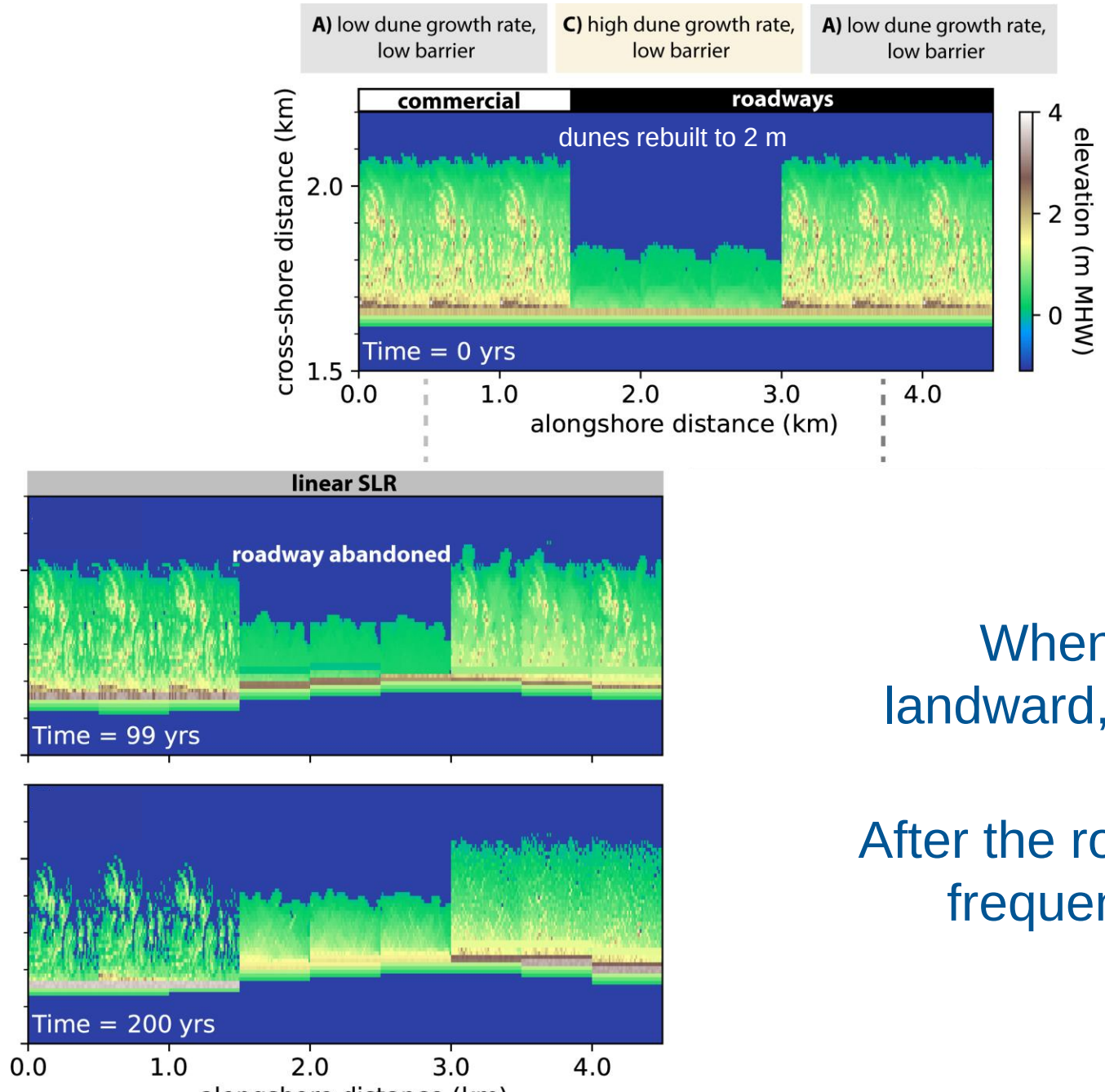
Image: NC-DOT

2022 - Rodanthe, NC



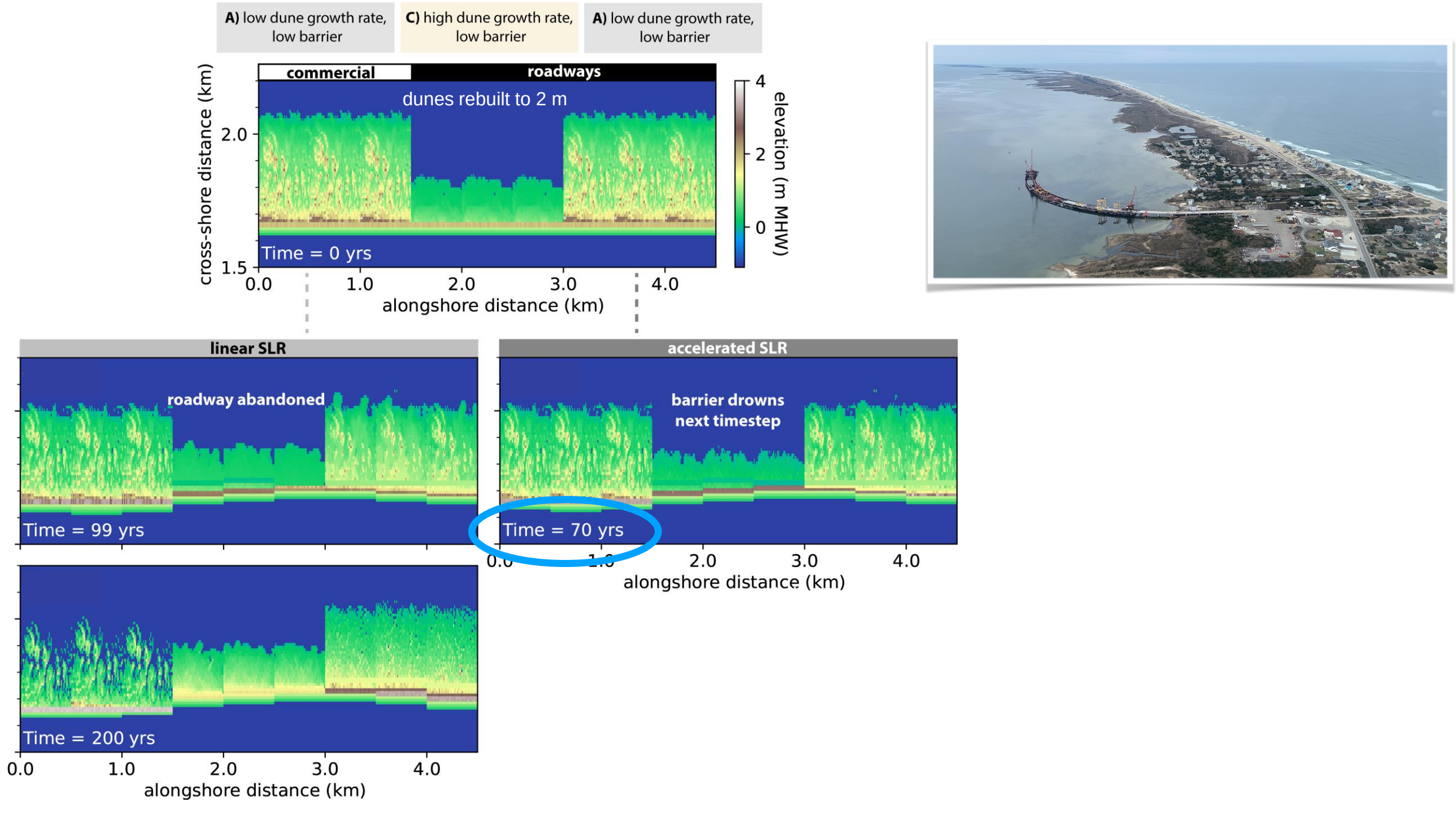


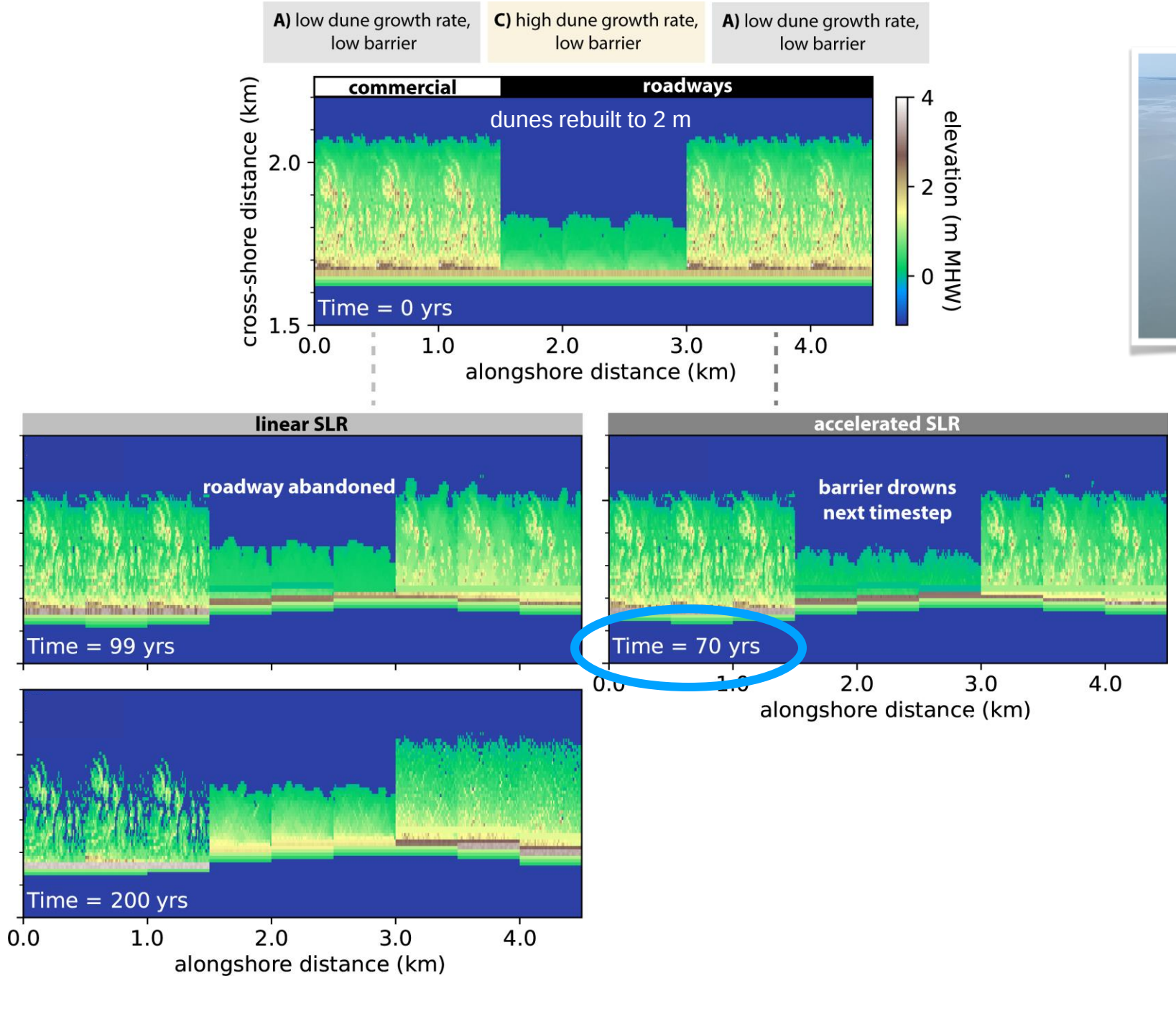
Exploratory simulations: not meant to simulate specific barriers, but to explore general behaviors.



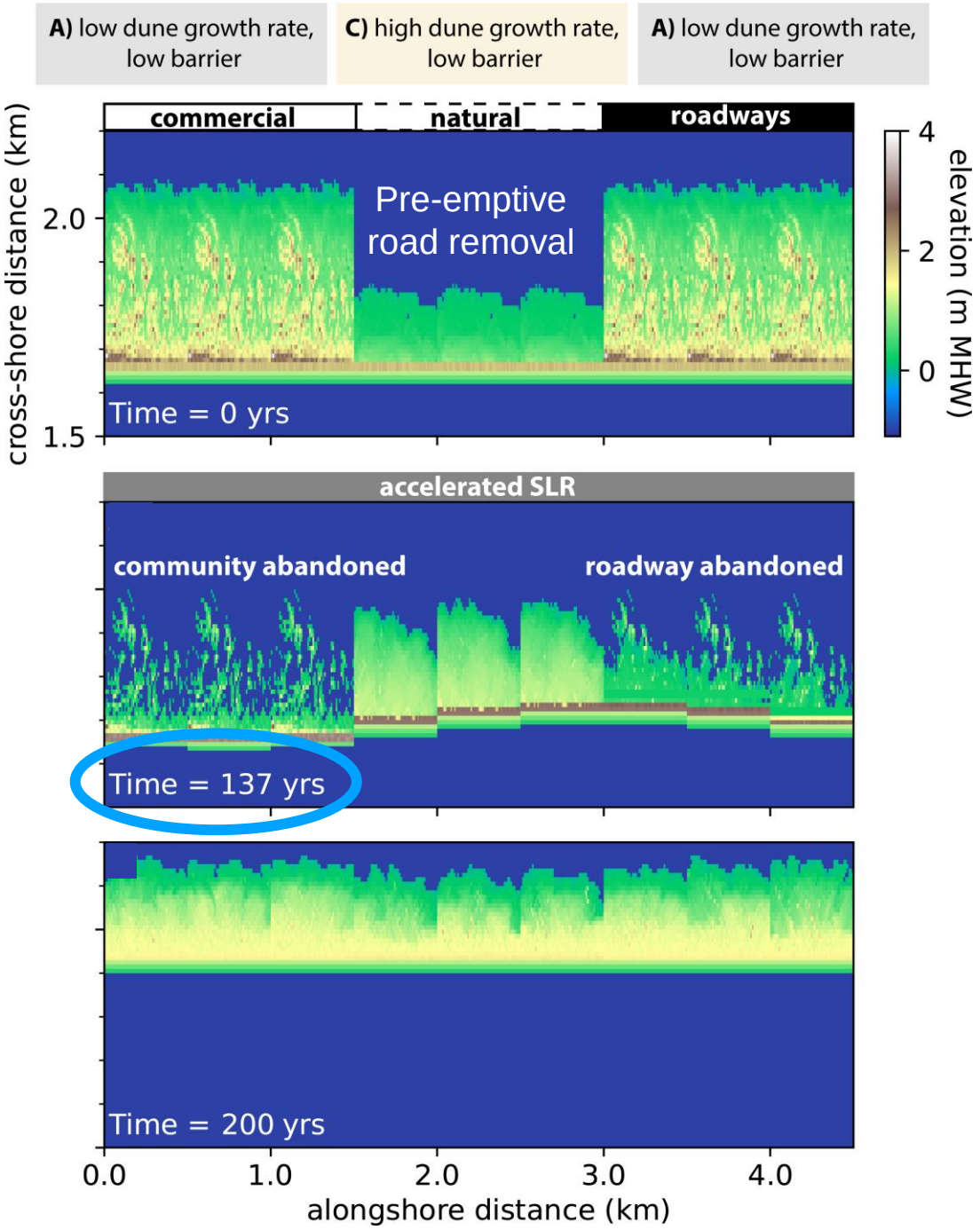
When part of the barrier moves landward, effects will be felt alongshore

After the roadway is abandoned, nourishment frequency increases in the community


A) low dune growth rate, low barrier
C) high dune growth rate, low barrier
A) low dune growth rate, low barrier
commercial
roadways
dunes rebuilt to 2 m
Time = 0 yrs
cross-shore distance (km)
2.0
1.5
0.0
1.0
2.0
3.0
4.0
alongshore distance (km)
4
2
0
elevation (m MHW)
linear SLR
roadway abandoned
Time = 99 yrs
accelerated SLR
barrier drowns next timestep
Time = 70 yrs
Time = 200 yrs
0.0
1.0
2.0
3.0
4.0
alongshore distance (km)



“status quo” scenarios

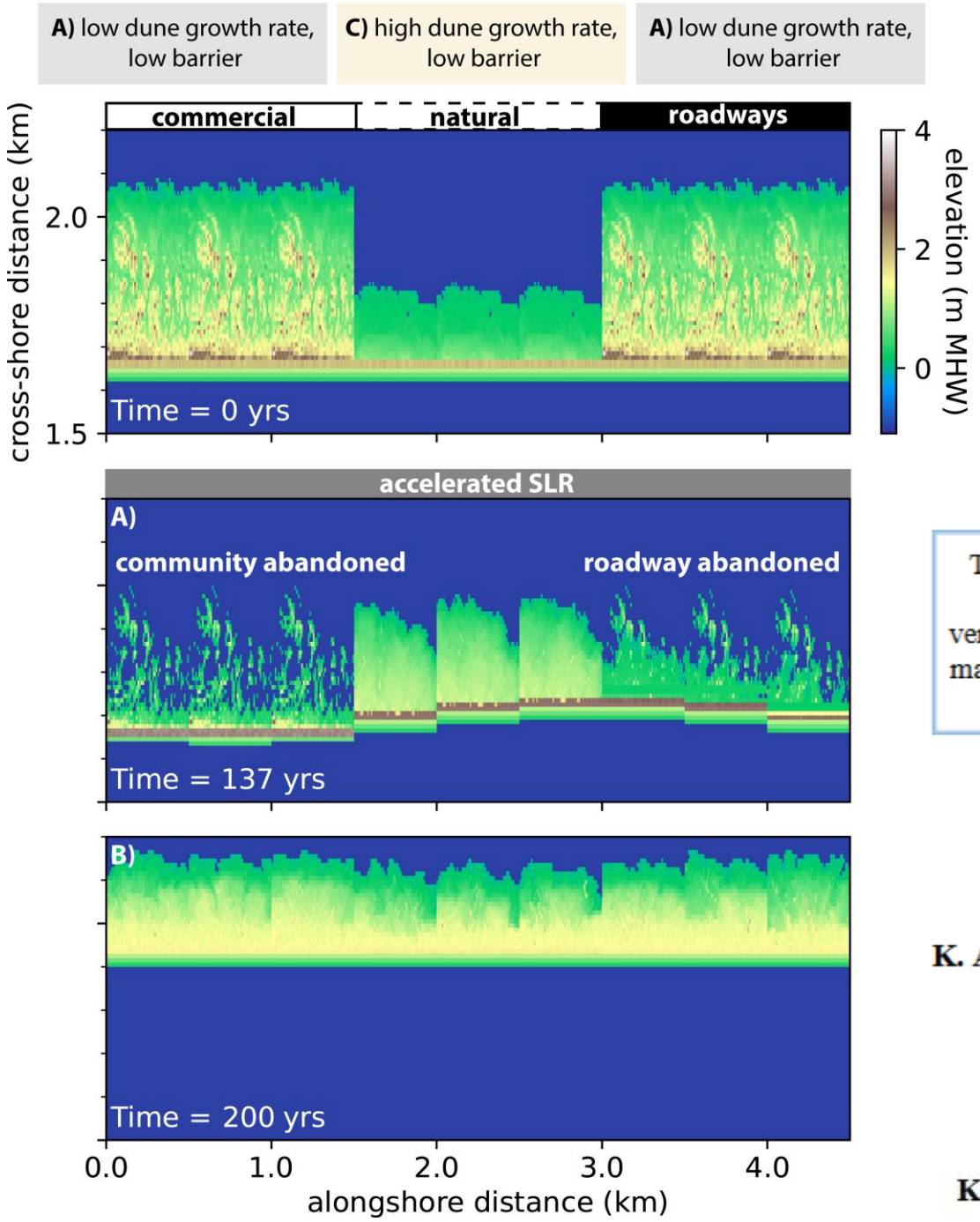


Adaptation Scenario

Transitions to less vulnerable barrier configurations may be possible through partial, early abandonment of developed barriers, even under extreme SLR

Average of 100 storm sequences:

- ✶Status quo - 81% drown
- ✶Preemptive road removal - 54% drown



Adaptation Scenario

Transitions to less vulnerable barrier configurations may be possible through partial, early abandonment of developed barriers, even under extreme SLR

The Future of Developed Barrier Systems - Part I: Pathways Toward Uninhabitability, Drowning, and Rebound

K. A. Anarde[1,2], L. J. Moore[1], A. B. Murray[3], and I. R. B. Reeves[1*]

The Future of Developed Barrier Systems - Part II: Alongshore Complexities and Emergent Climate Change Dynamics

K. A. Anarde[1,2], L. J. Moore[1], A. B. Murray[3], and I. R. B. Reeves[1*]

Key takeaway #1 – By modifying natural overwash pathways, management leads to barrier lowering and narrowing, and sometimes drowning.

Key takeaway #2 - Early, partial abandonment of management actions could facilitate transitions to less vulnerable system states. Barriers recover within decades after management ends.

Decisions made now affect future habitability

Short-term Options

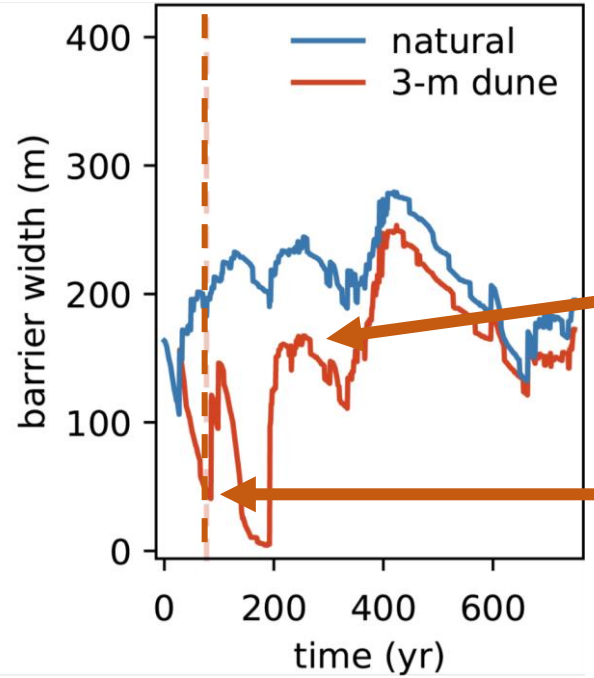
Allow overwash/island elevation increase (e.g., causeway)

Maintain dunes to protect road

Possible Future in 50 yrs

Wide and sometimes overwashed But moving landward…

Too narrow for road; requires roadway alternative.



Island recovers, after management ceases.

Too narrow for road

Understanding how decisions play out in the longer term (30 yrs+) informs planning, leads to more resilient futures.

Credit: DOT

CASCADE participatory modeling project underway…

Ocracoke Ferry Terminal and Roadway Challenges

- Funded by Cooperative Agreement
- Project team includes NPS staff, representatives from NC DOT, Hyde Co.
- Customize the model; calibrate using hindcasts
- Project decadal-scale effects of management strategies on landscape change for different SLR and storminess scenarios.

NATIONAL PARK SERVICE

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

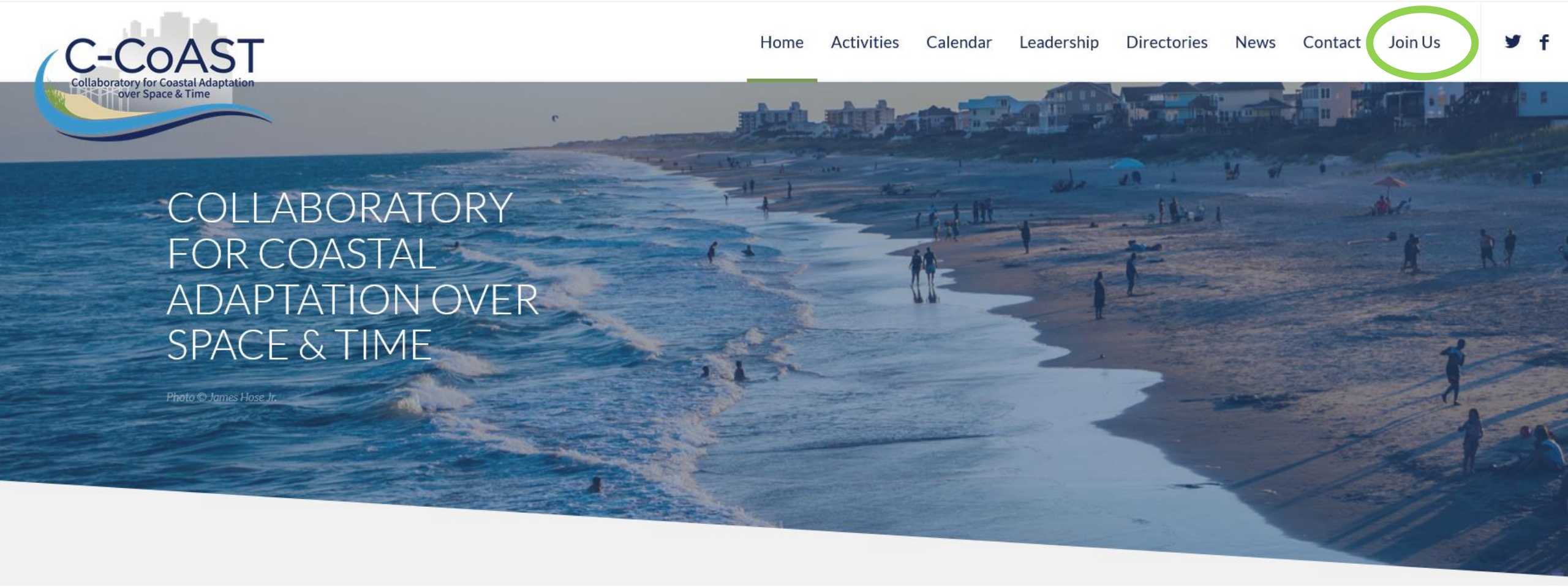
THE COUNTY OF HYDE 1712

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Duke UNIVERSITY

NC STATE UNIVERSITY

Cape Hatteras erosion hotspots; Topsail Island oceanfront roadway mitigation soon to follow…



More C-CoAST activities and projects to come…

c-coast.org

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c-coast@unc.edu

Get Involved

Become a participant by joining the C-CoAST Network.

JOIN US

C-CoAST
Collaboratory for Coastal Adaptation over Space & Time

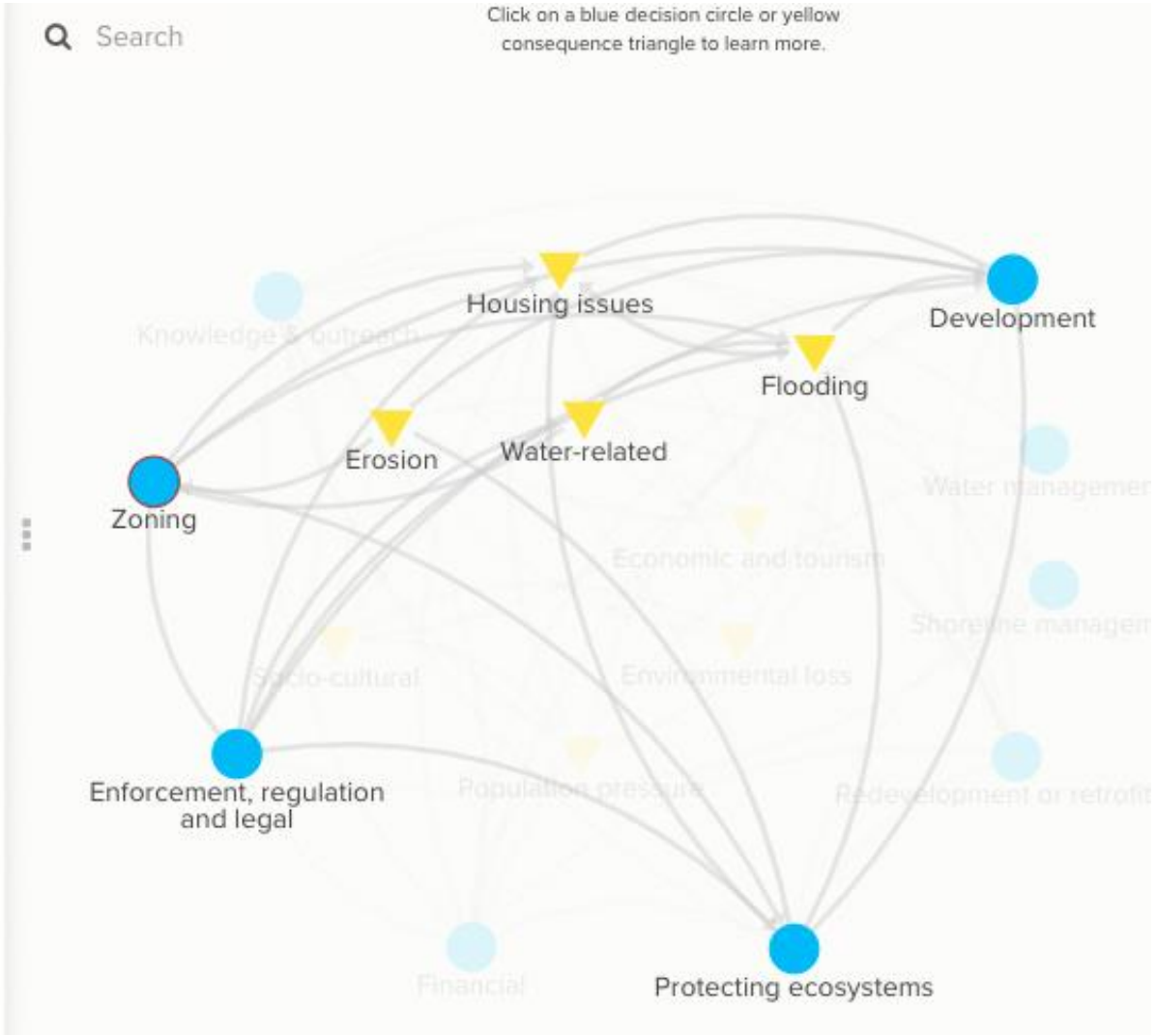
NSF

Gallery Walk: Self-guided Tour

Zoning

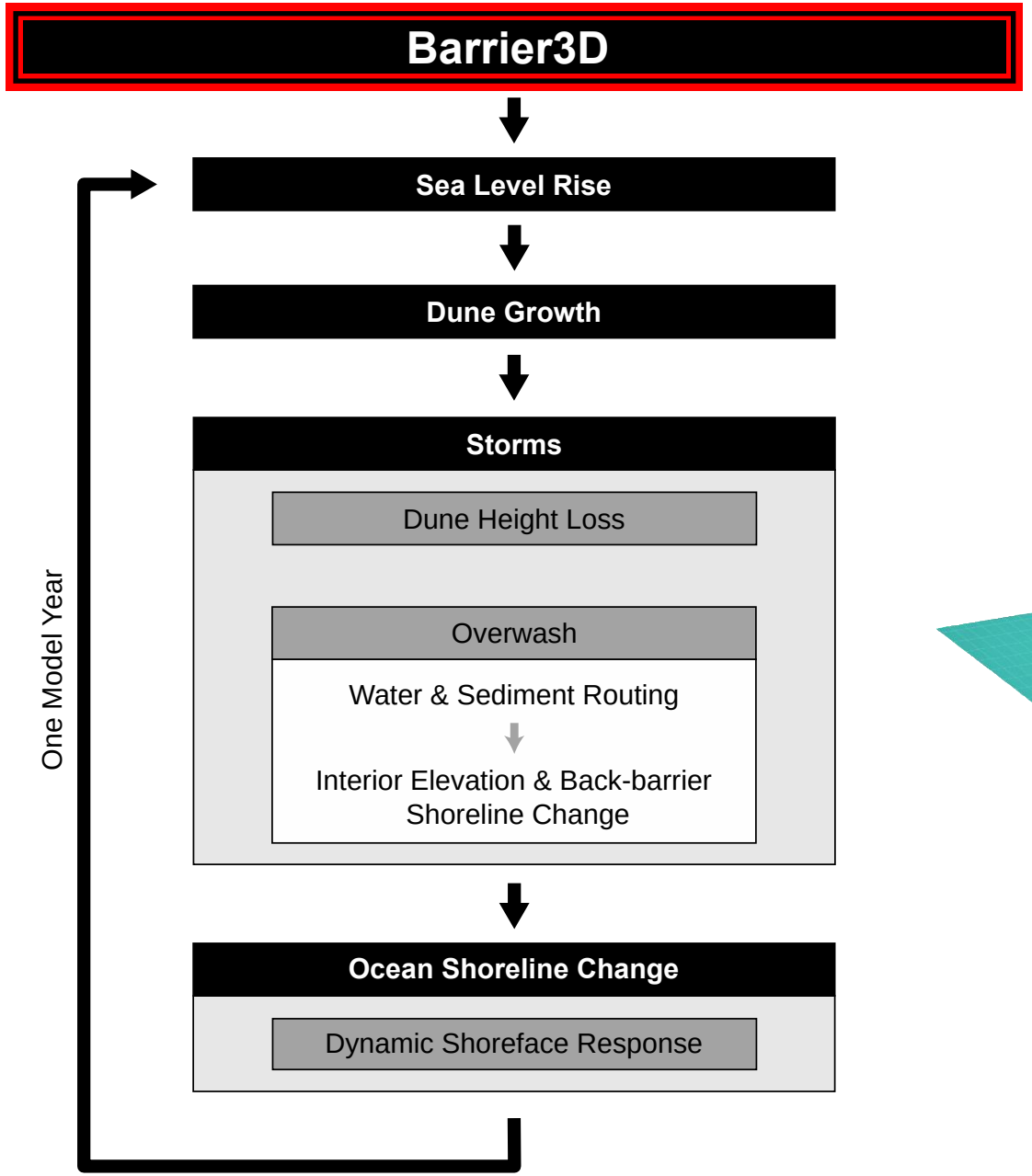
DECISION

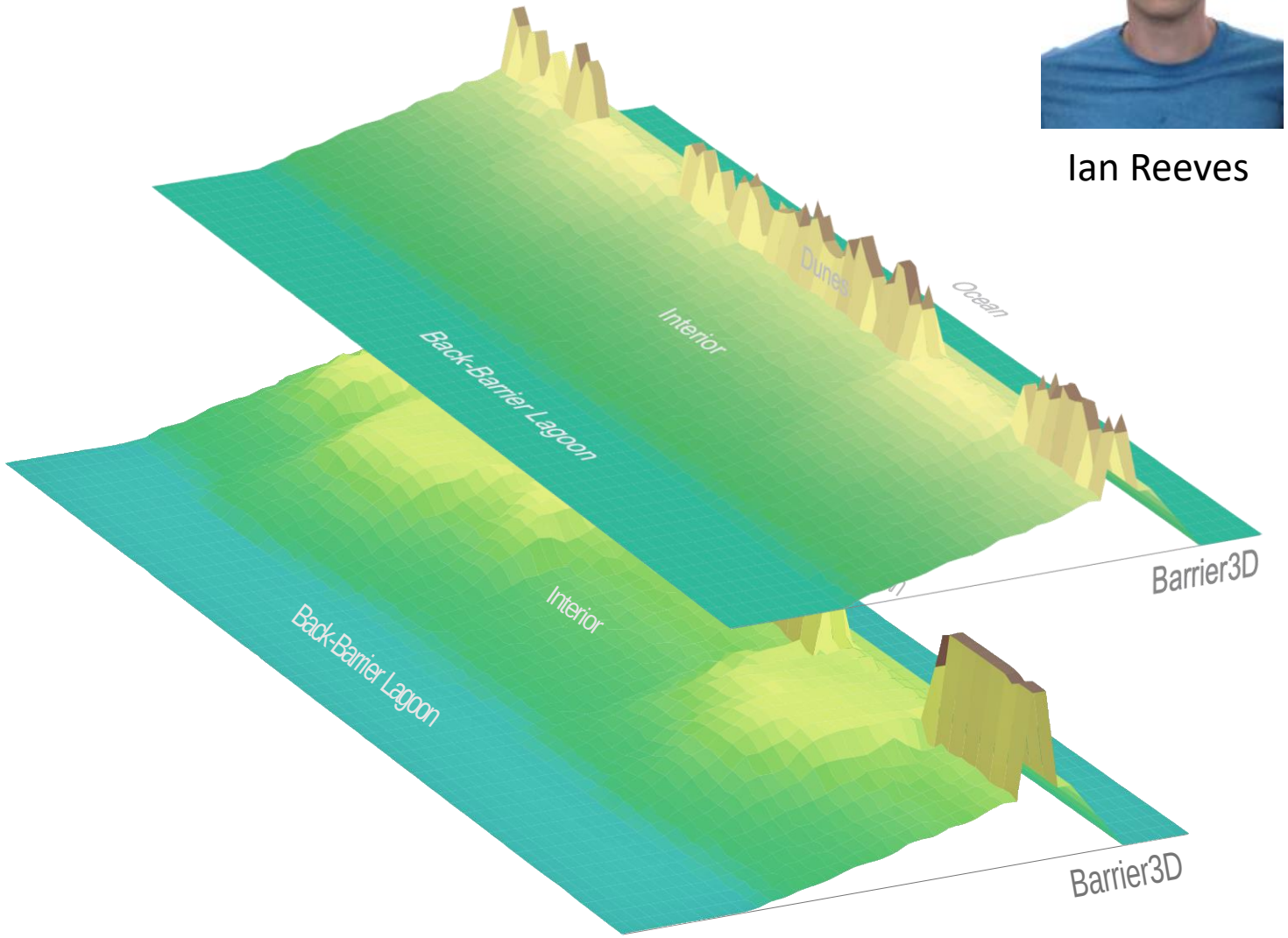
Decisions about zoning were often deeply connected to other decisions and consequences. Much of the conversation around zoning centered around the necessity of zoning more areas for ecosystem protection. Participants mentioned this as necessary for marsh migration, and *"developing a UDO [Unified Development Ordinance] that encourages protection of natural environments over more harmful development practices."* UDOs could *"specify things—whether it's residential, and then the density, or commercial, or it can be designated as a conservation area. Those kinds of things. And I also believe that a UDO can get into things like low-impact development requirements."*



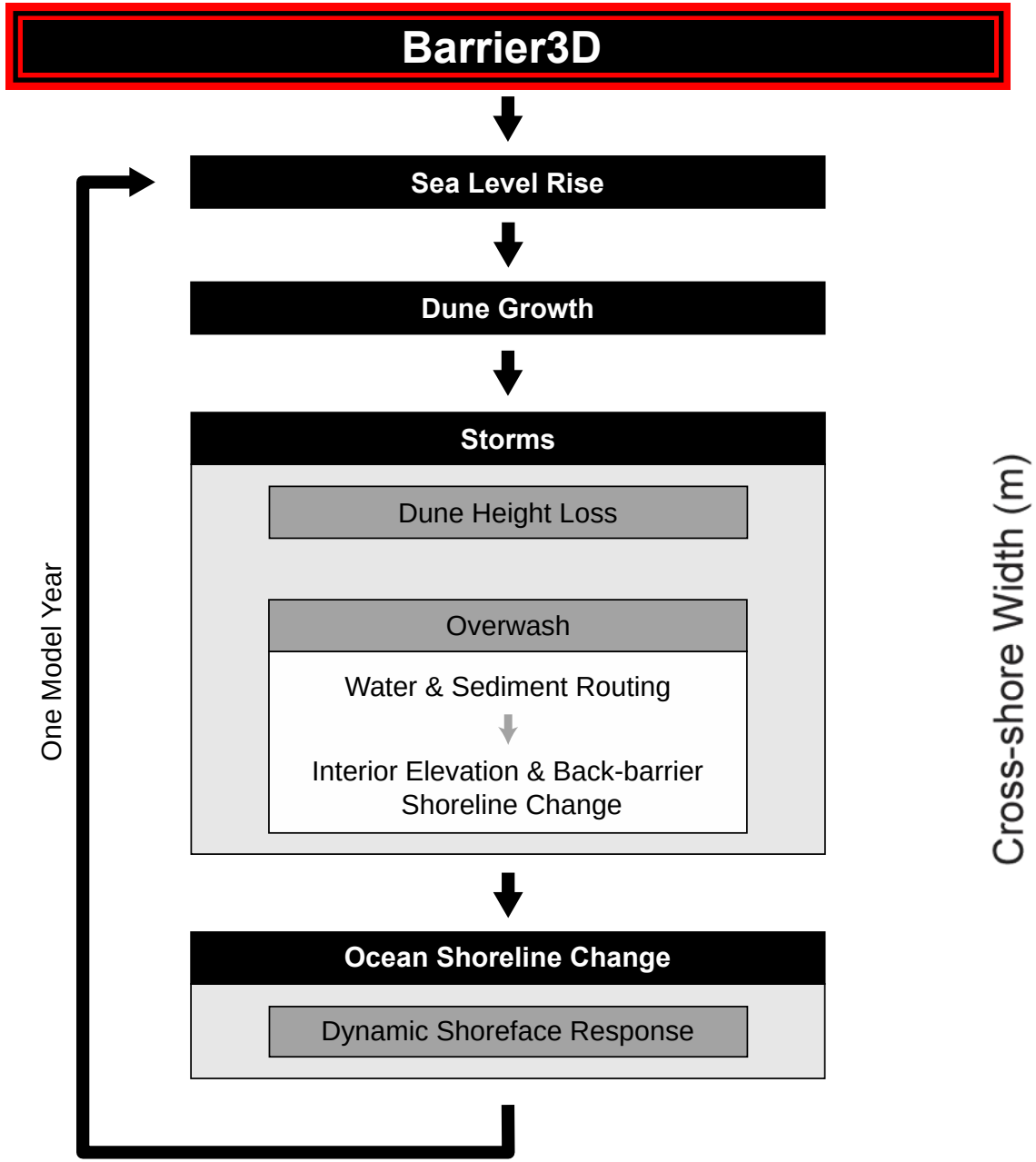
New exploratory model Barrier 3D

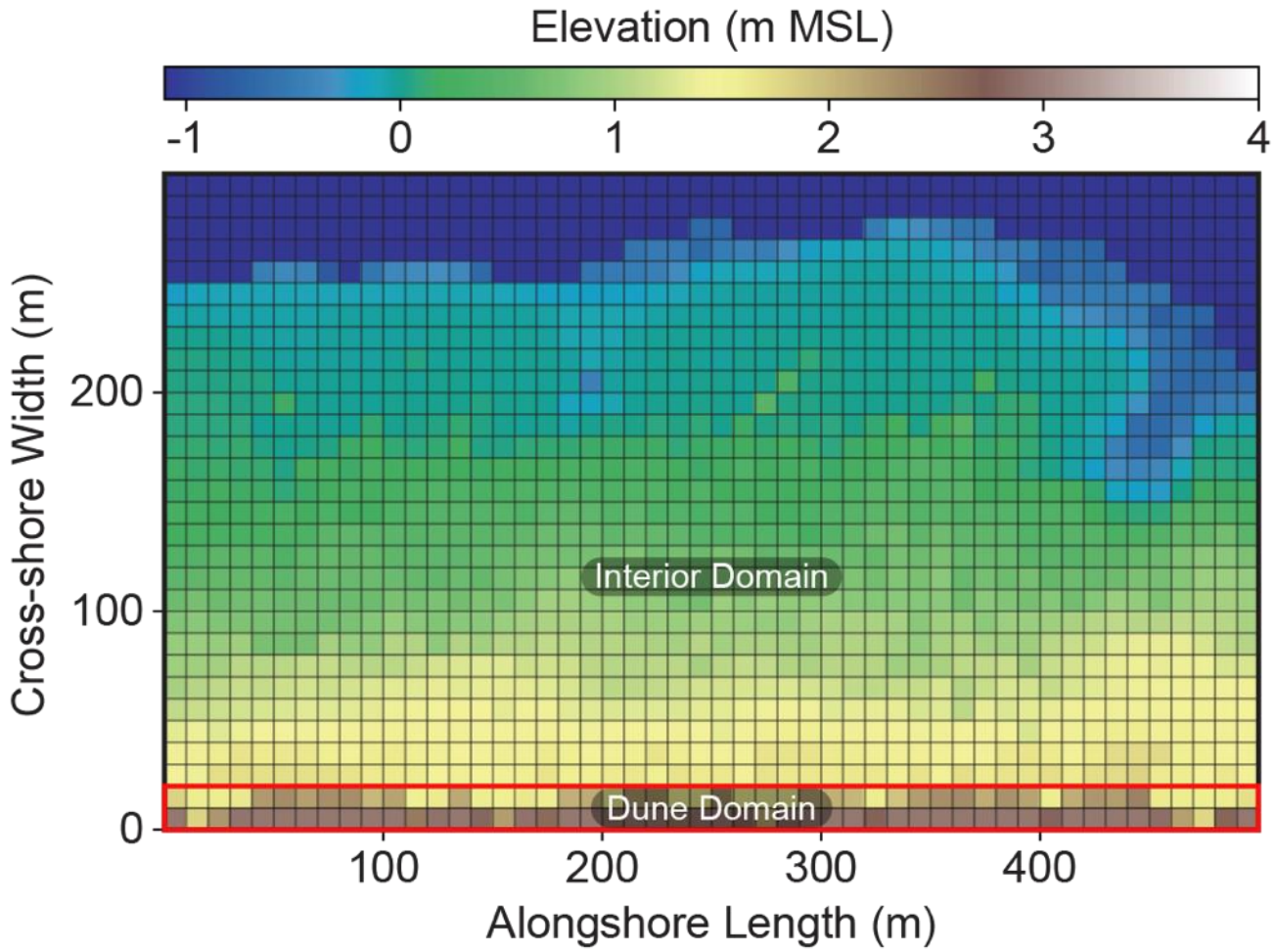
Ian Reeves

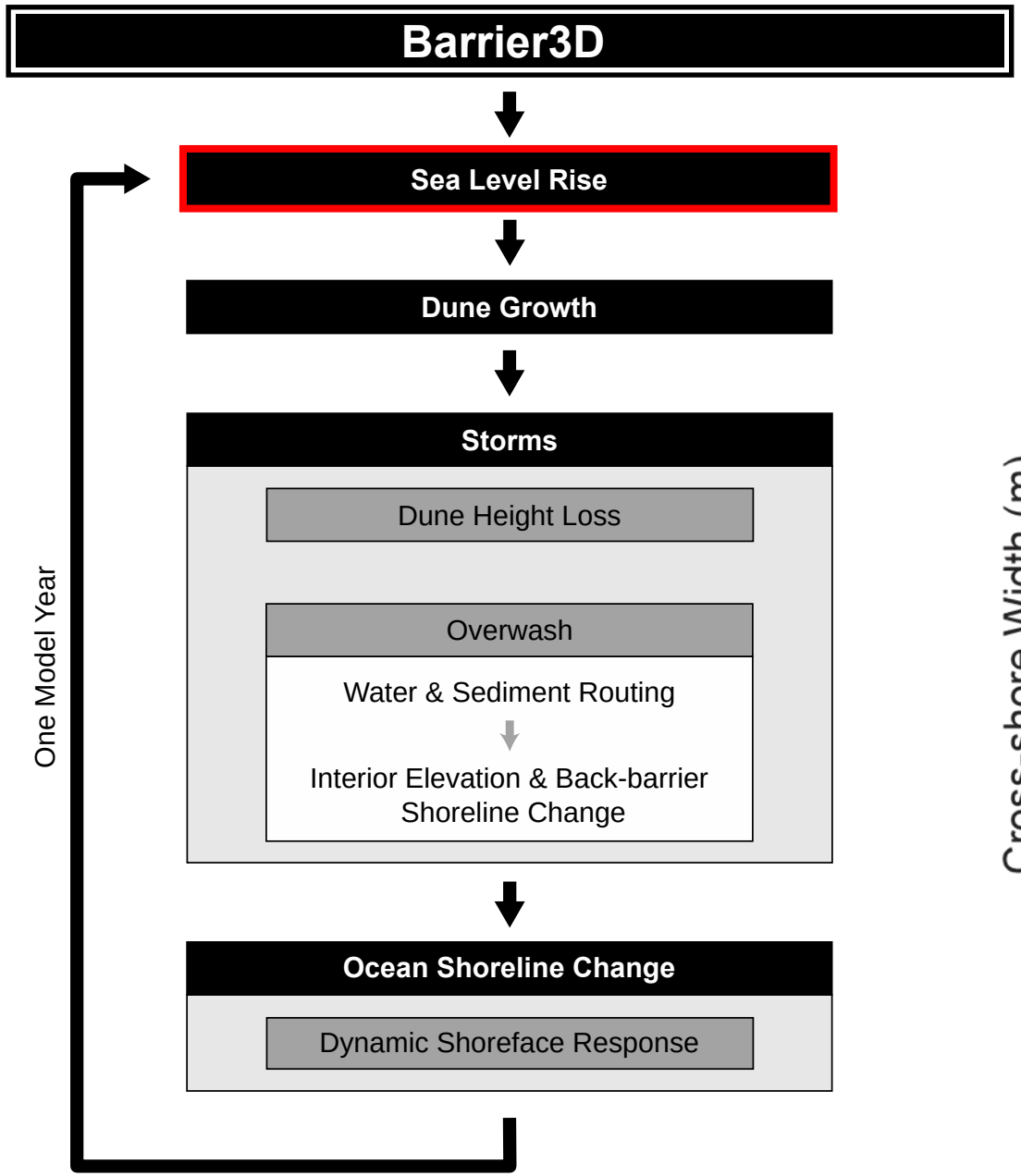




Reeves, Moore, Murray, Anarde, and Goldstein, 2021


Barrier3D
Sea Level Rise
Dune Growth
Storms
Dune Height Loss
Overwash
Water & Sediment Routing
Interior Elevation & Back-barrier Shoreline Change
Ocean Shoreline Change
Dynamic Shoreface Response
One Model Year


Elevation (m MSL)
-1
0
1
2
3
4
Cross-shore Width (m)
200
100
0
Interior Domain
Dune Domain
100
200
300
400
Alongshore Length (m)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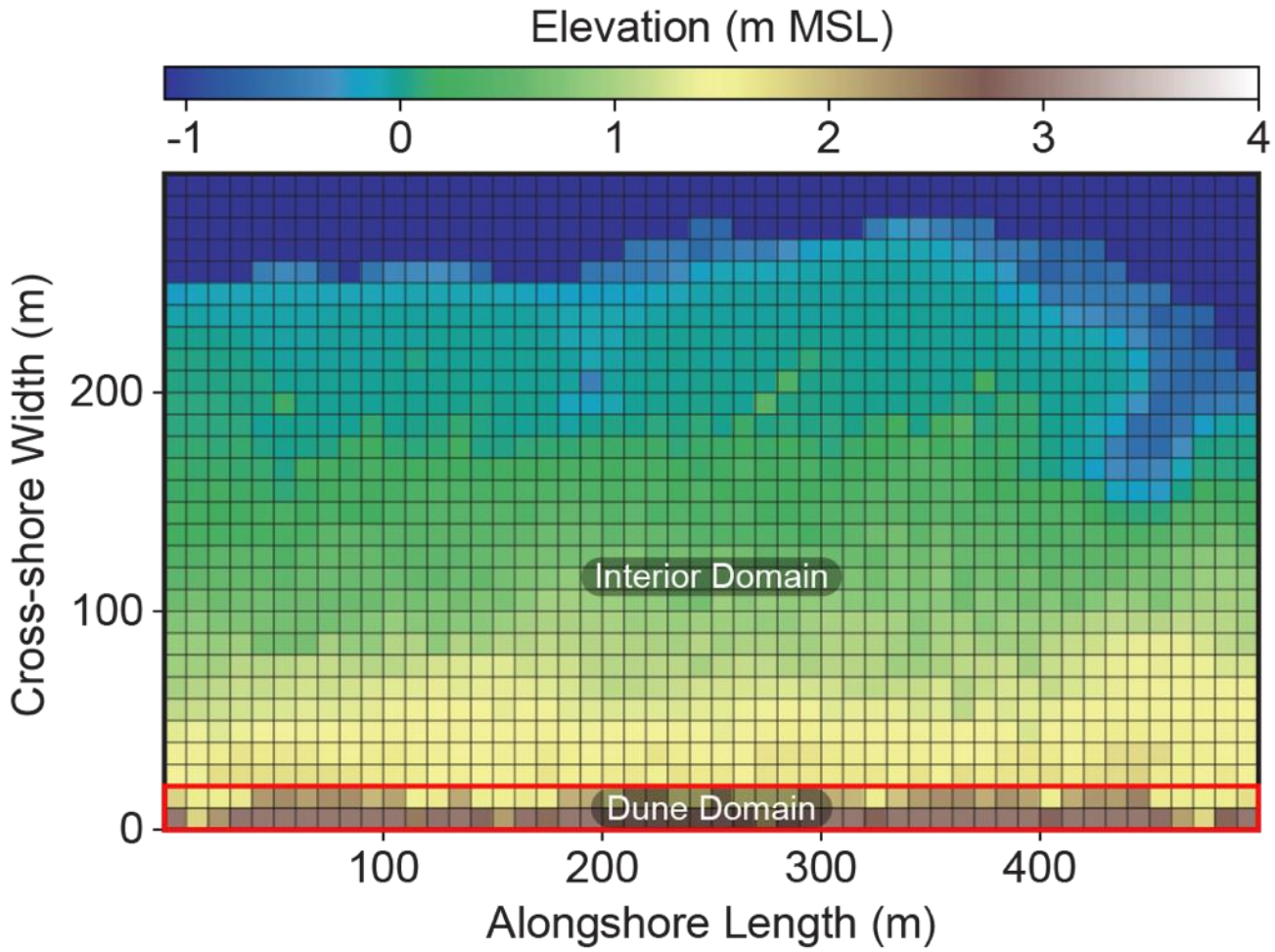
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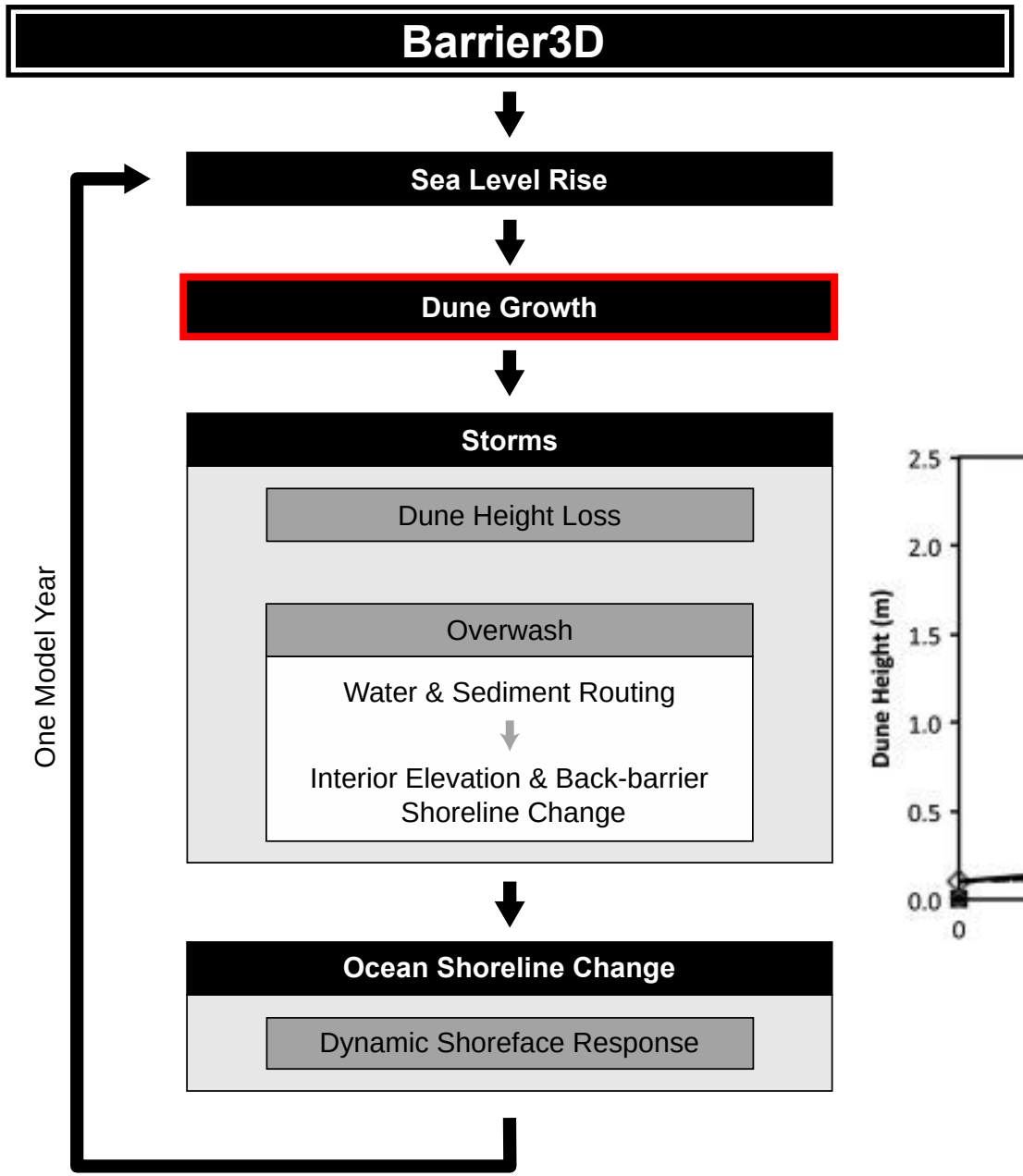
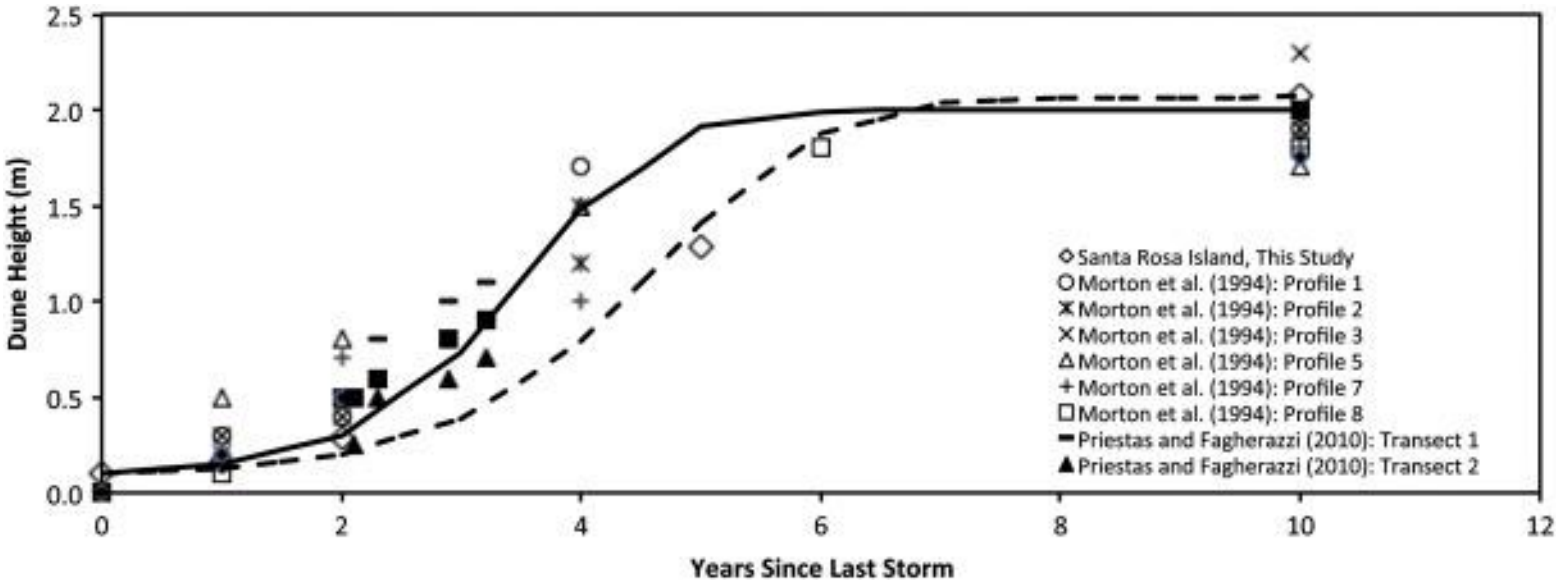
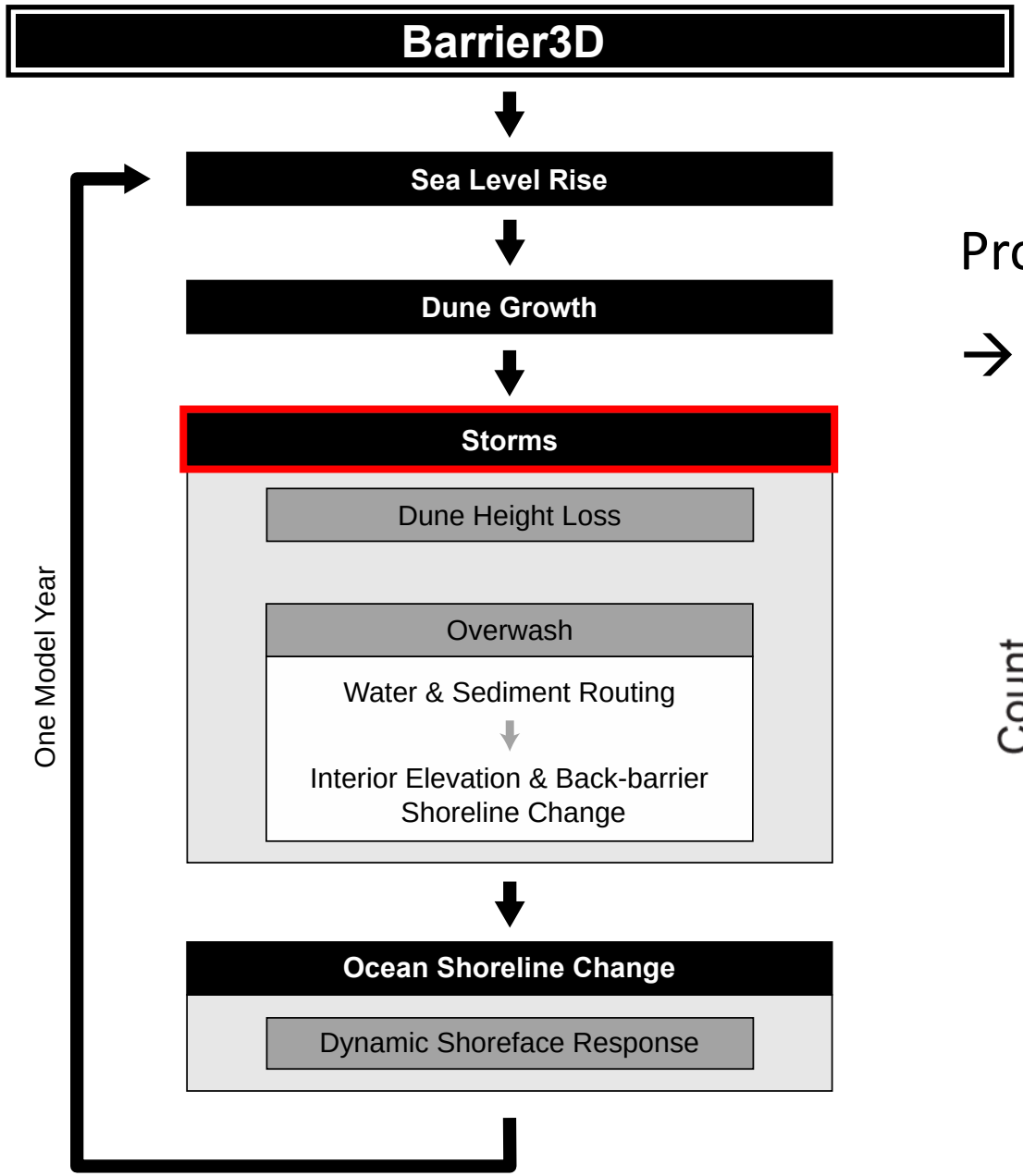


Logistic dune growth

[Houser et al., 2015]

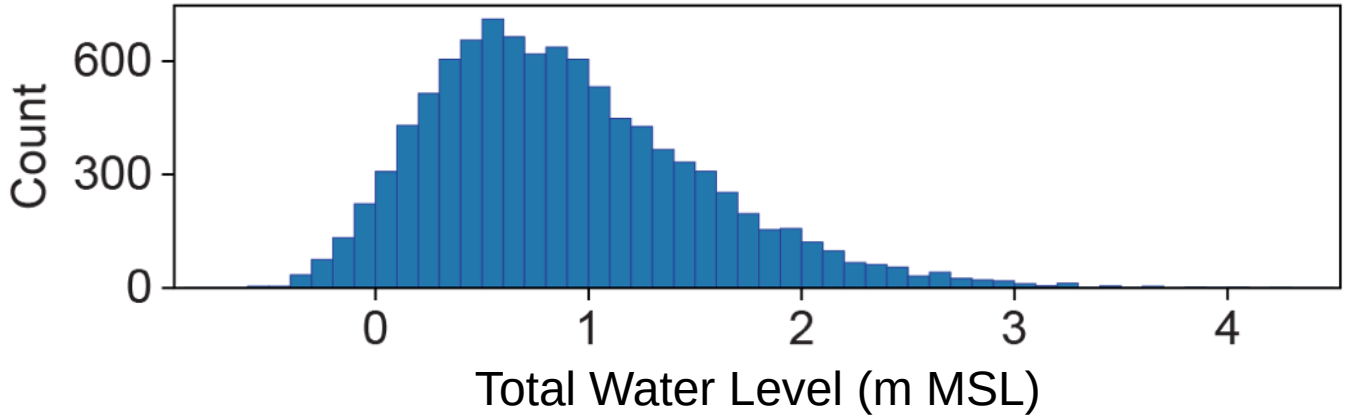


$\bar{r}$: characteristic dune growth rate

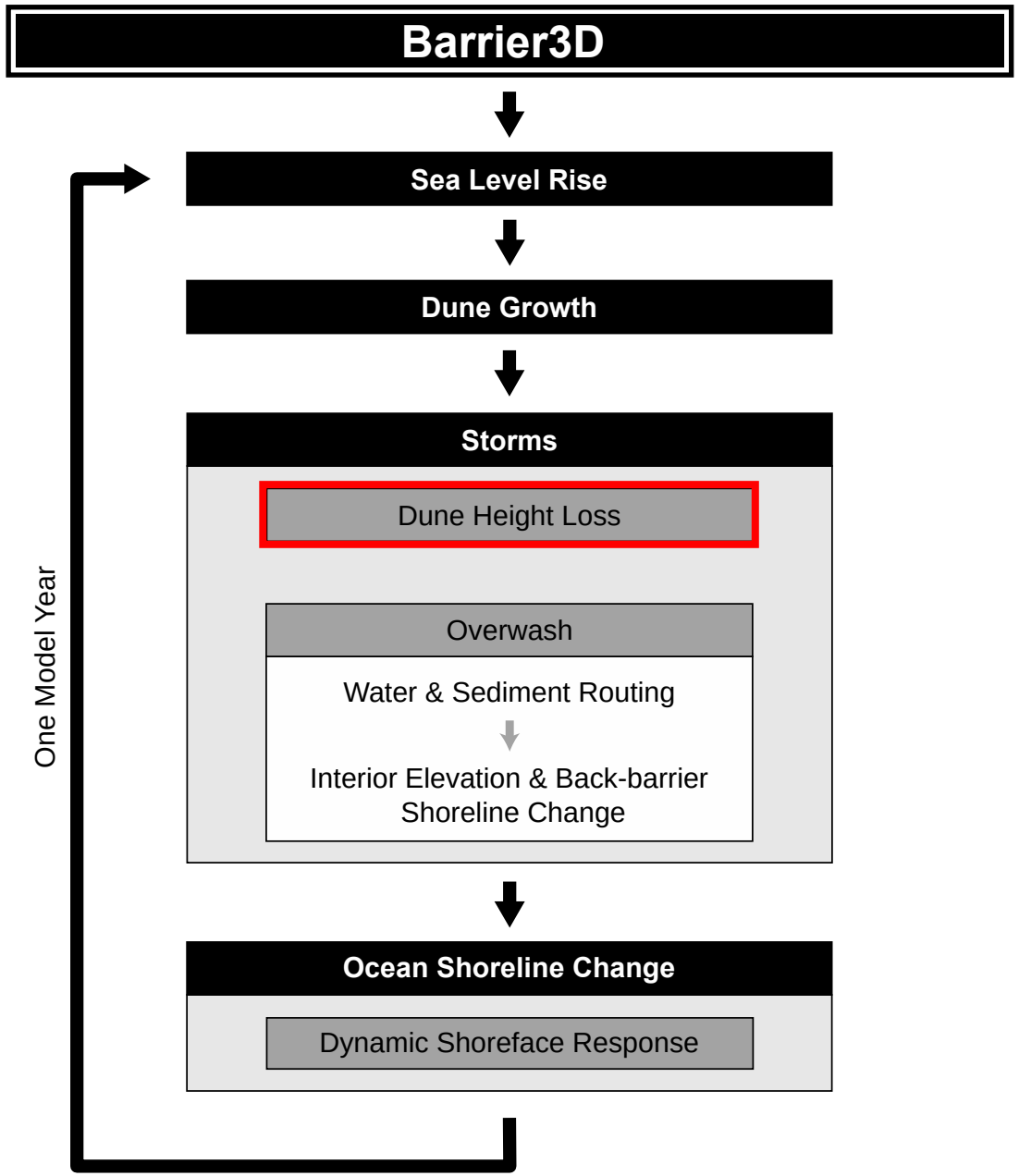


Probabilistically simulated storm environment

→ 10,000 synthetic storms (following Wahl et al., 2016)

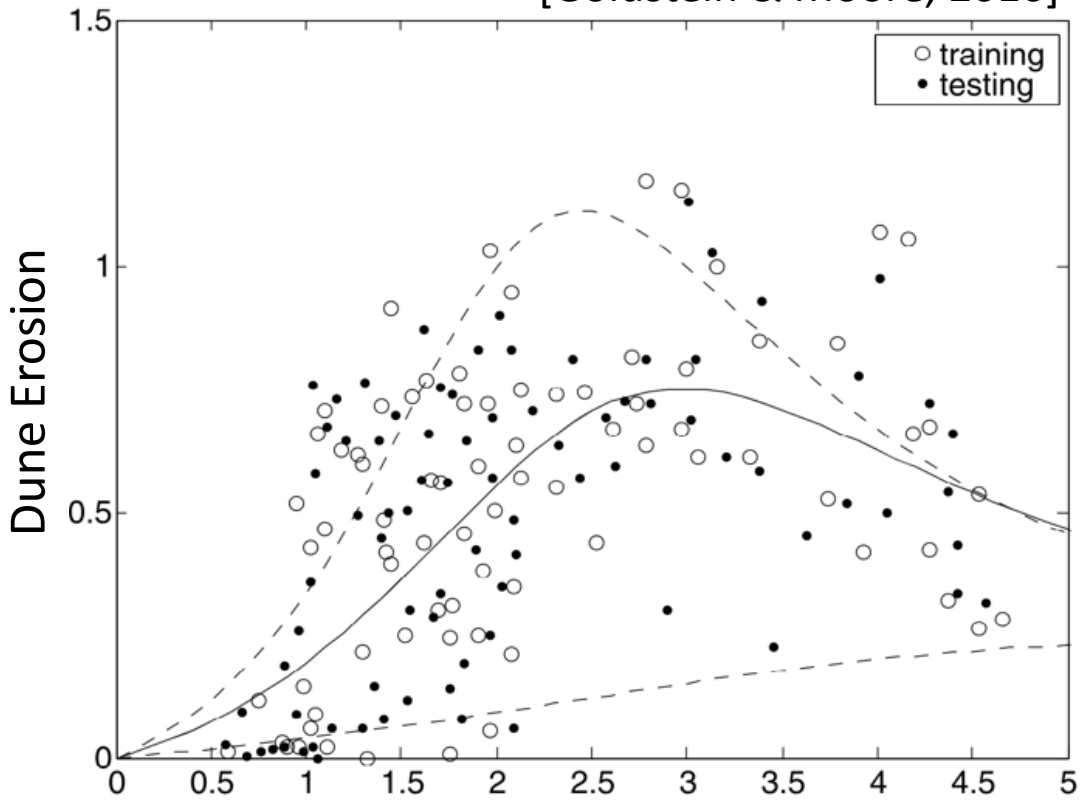


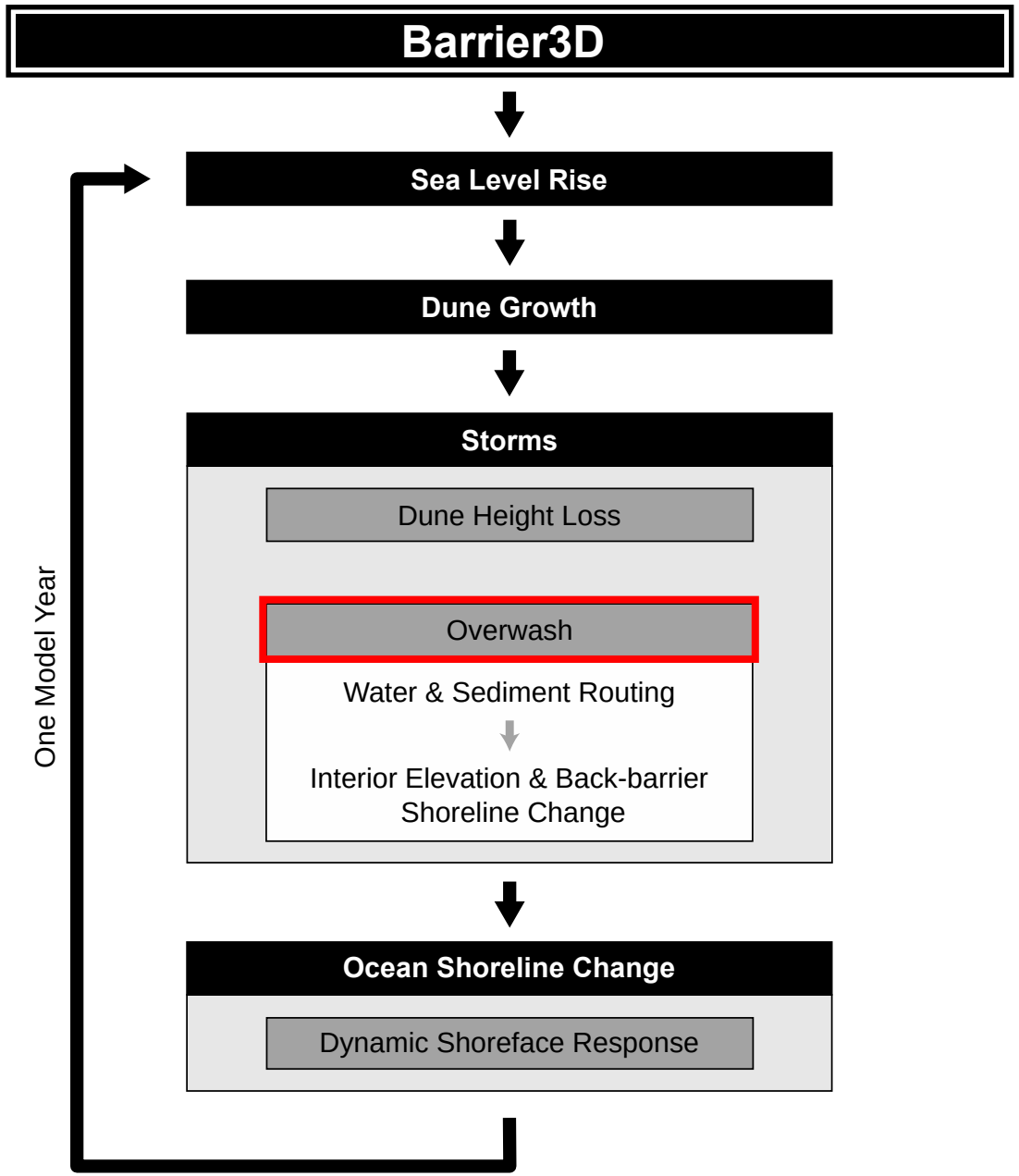
$\overline{N}$: average storms per year



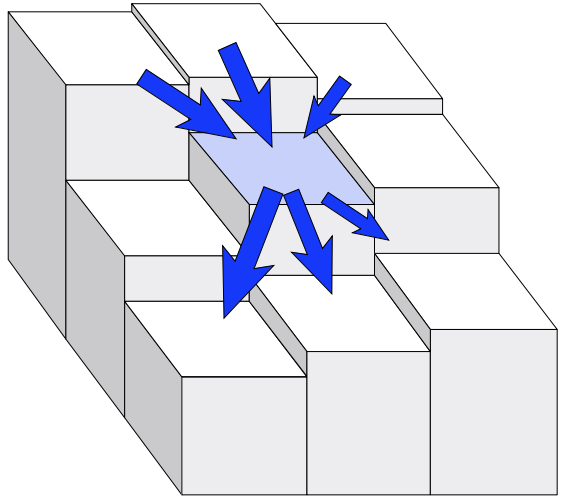
Empirical predictor of dune erosion

[Goldstein & Moore, 2016]

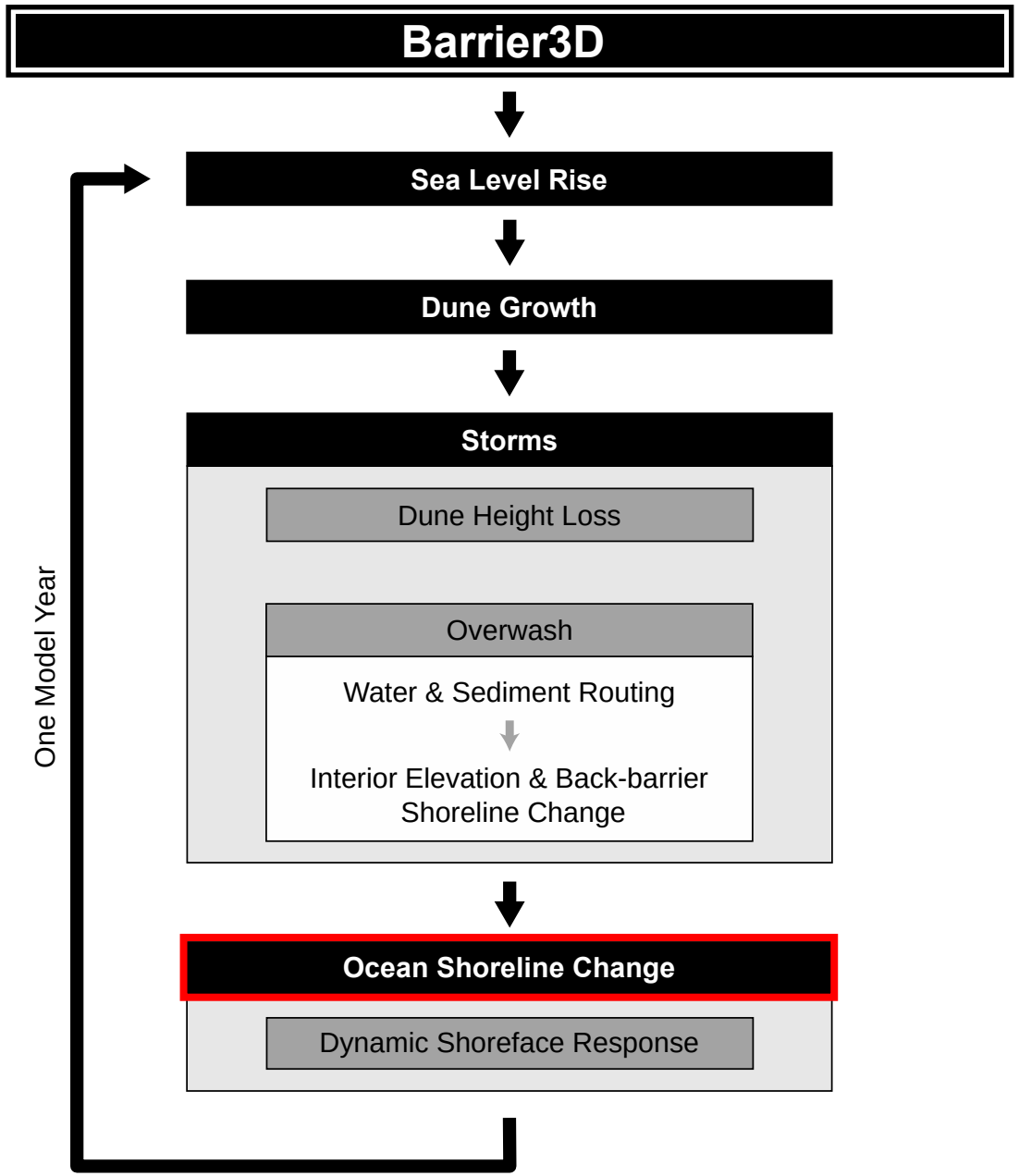




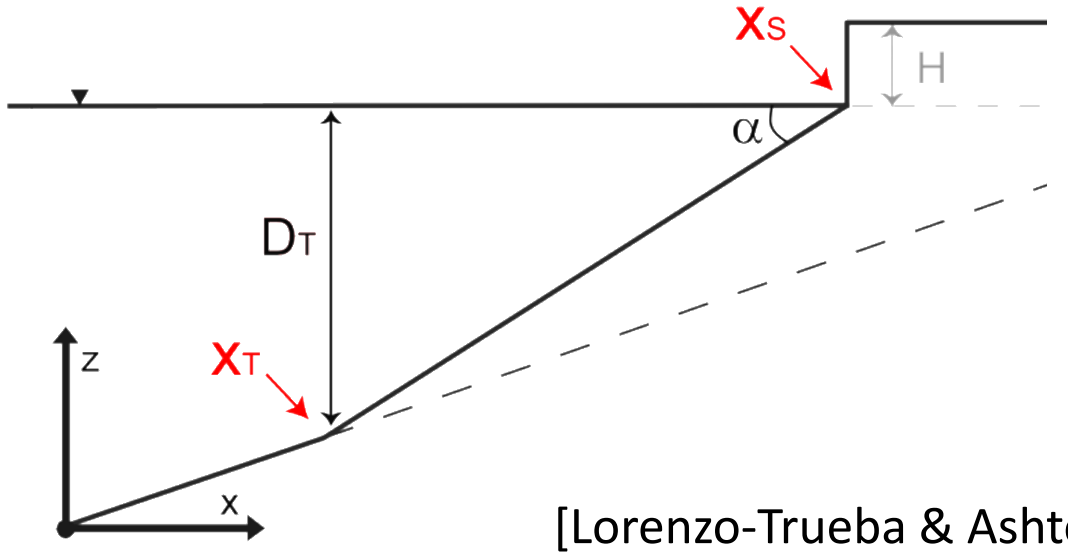
Spatially explicit cellular routing of water and sediment



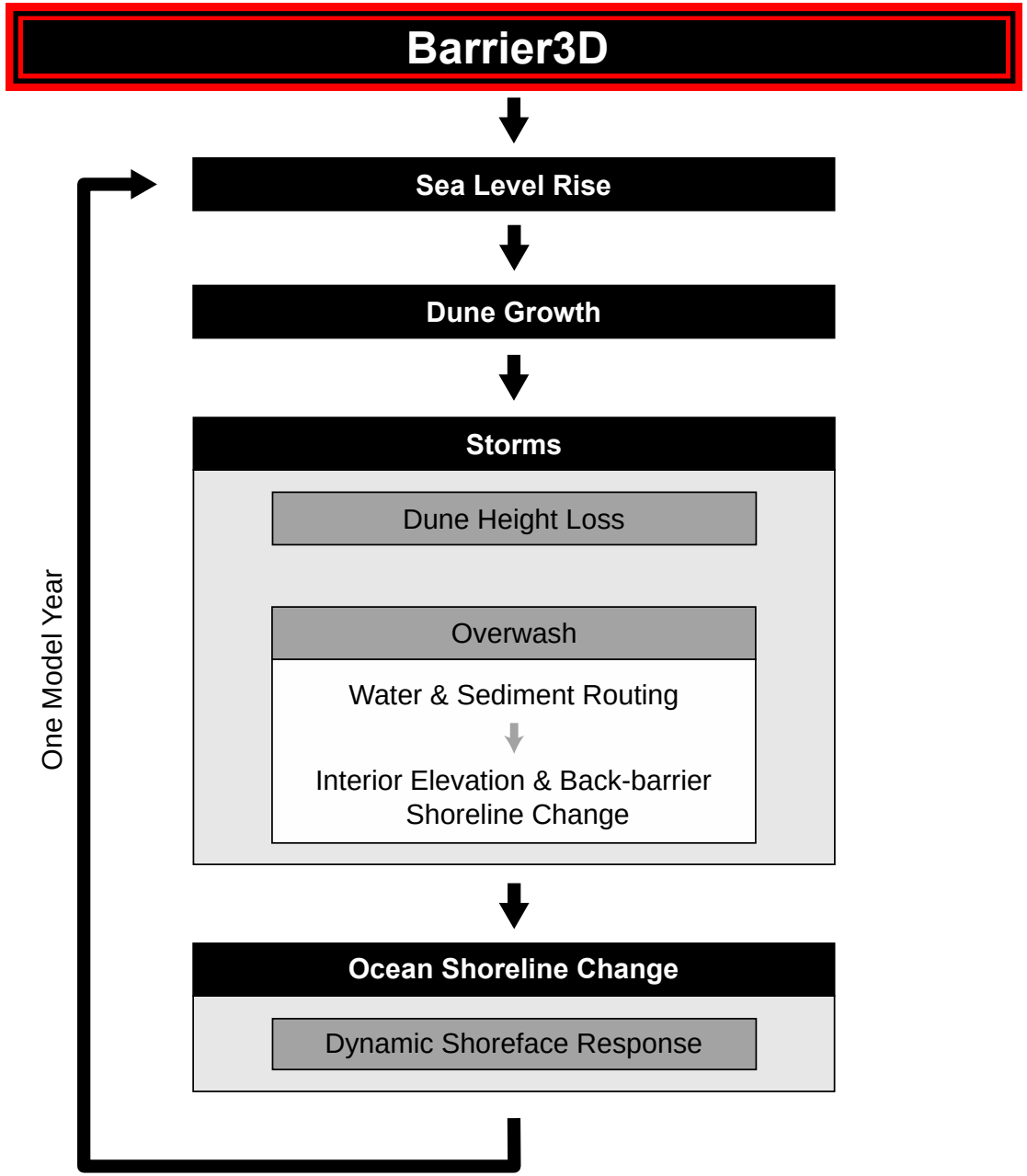
[Murray & Paola, 1994]

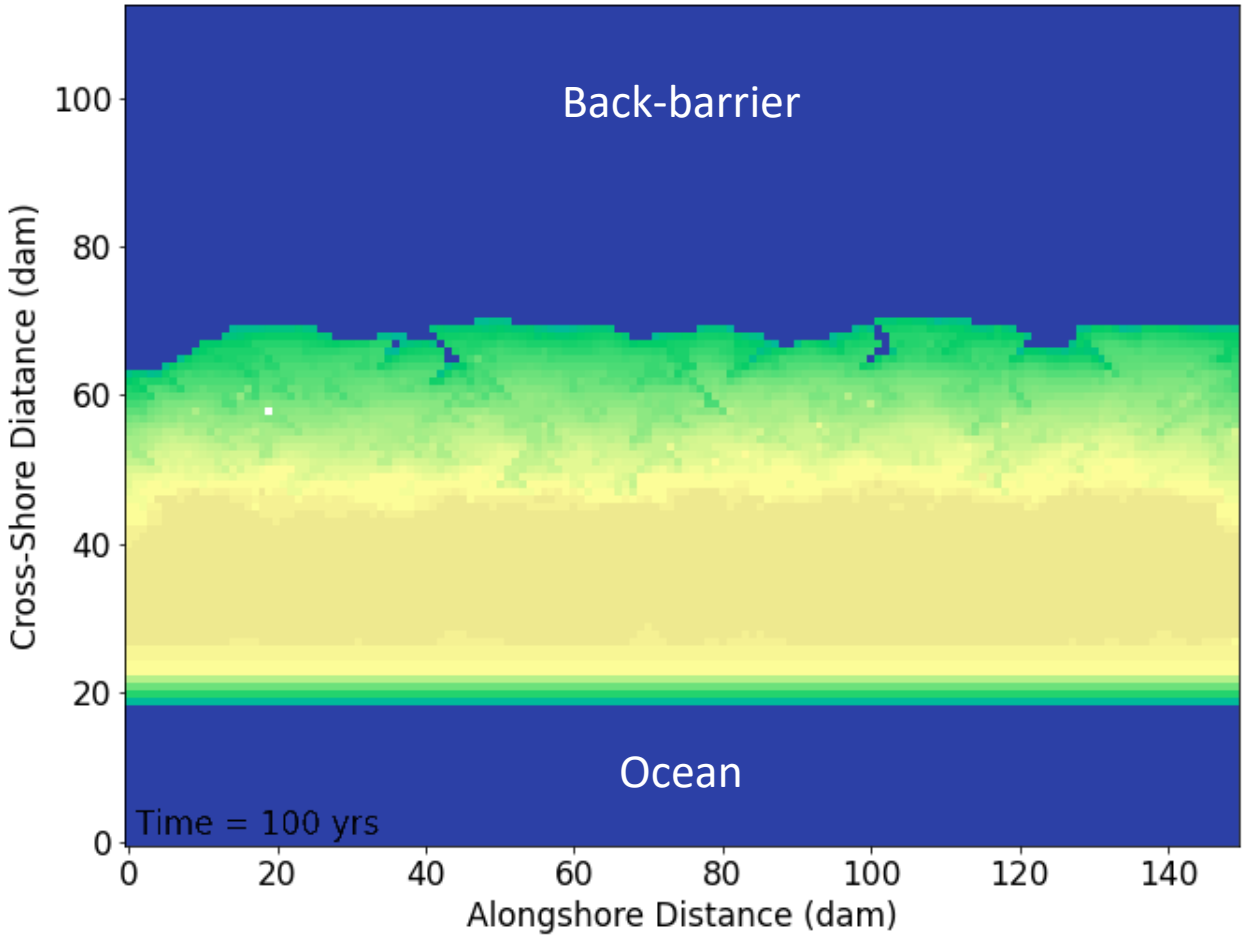


$$\Delta x_s = f\left(Q_{RSLR} + Q_{Overwash} + Q_{Shoreface}\right)$$



[Lorenzo-Trueba & Ashton, 2014]





Reeves, Moore, Murray, Anarde, and Goldstein, *GRL*, 2021