

Barrier islands: naturally-dynamic landforms



NOAA ERI: <https://storms.ngs.noaa.gov/>

NC STATE
UNIVERSITY

Katherine Anarde
Assistant Professor, Coastal Engineering

THE NORTH CAROLINA NATIONAL ESTUARINE RESEARCH'S COASTAL TRAINING
PROGRAM PRESENTS:

Living on a Barrier Island – A Workshop for Real Estate Professionals

Barrier islands: naturally-dynamic landforms

Developed barriers: highly-vulnerable landforms

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Agenda for today

- **What are barrier islands and how did they form in North Carolina?**
- **Dynamics on natural vs developed barrier islands**
- **The future of developed barrier islands:**
 - *How are they changing?*
 - *How can we respond?*





2149 barrier islands worldwide

300 ring the Atlantic and Gulf coasts of the US



Low-lying

Ecologically diverse and important

Protect mainland from waves and surge



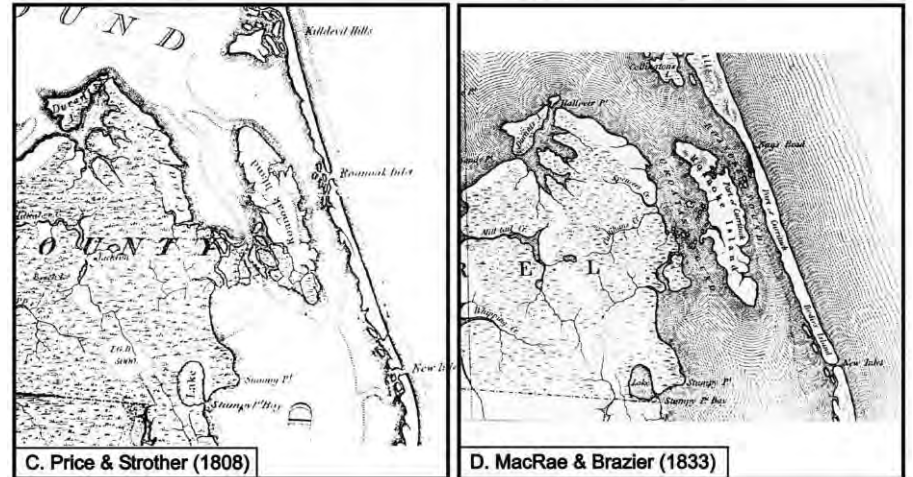
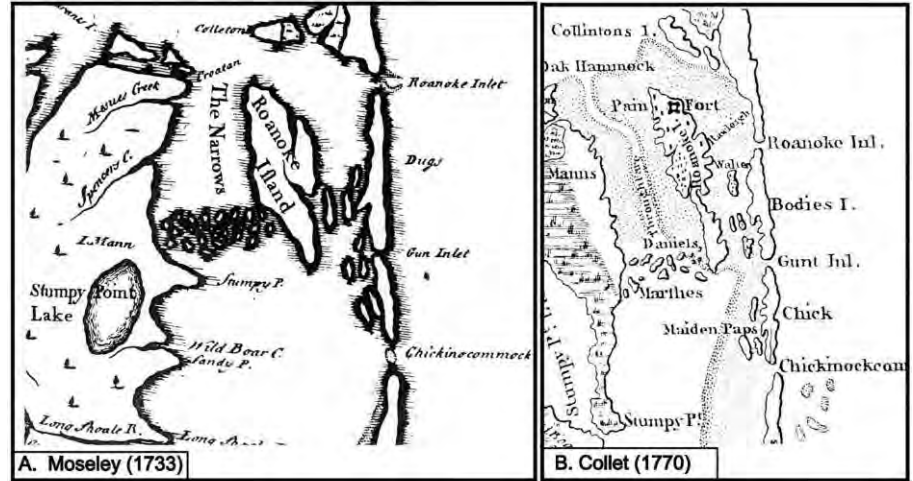
Long, narrow offshore sand deposits

Parallel to the coast

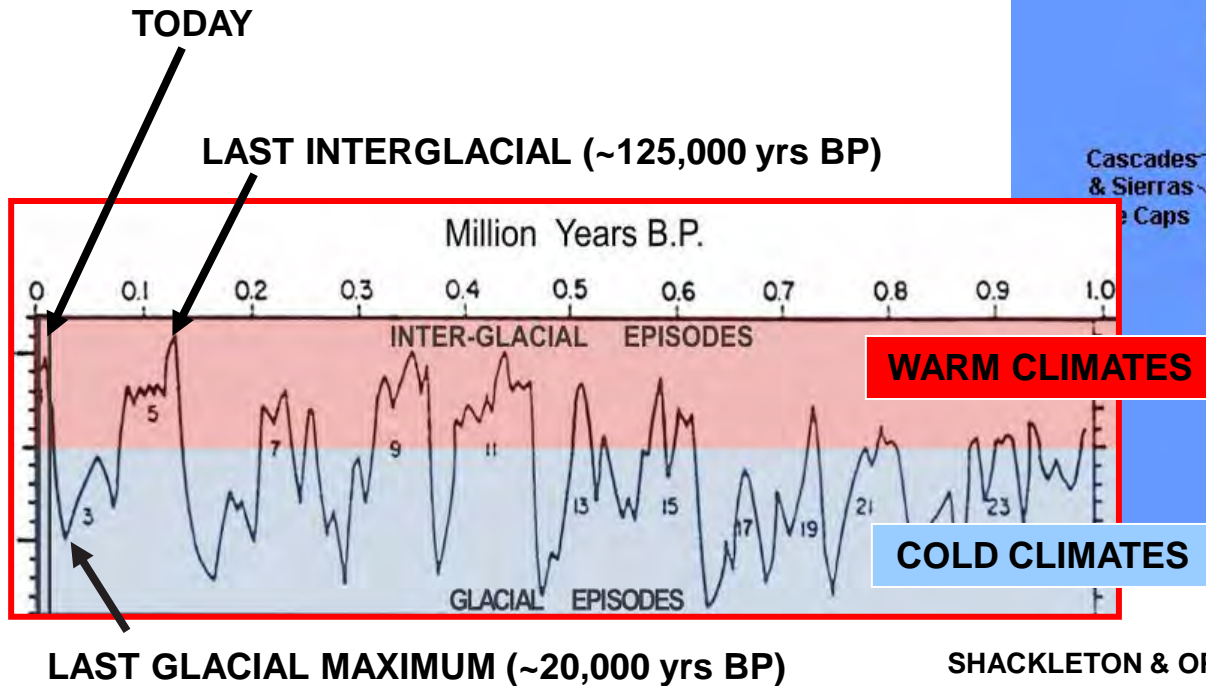
Separated from mainland by a bay/lagoon/sound

Separated from each other by tidal inlets

NC barriers have been dynamically changing since they emerged....



...~12,000 yrs ago,
after the last glacial
maximum

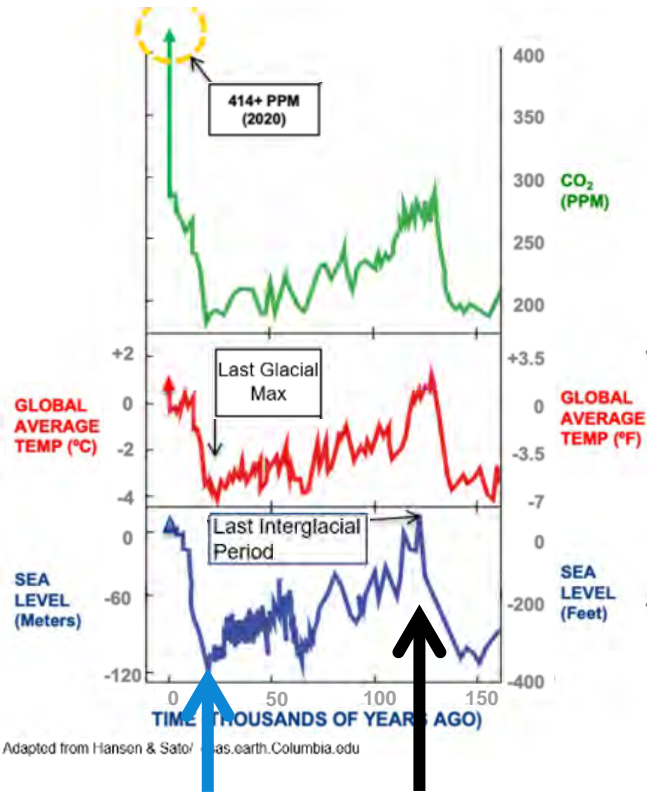


**Extent of continental glaciation
at the peak of the last Ice Age**

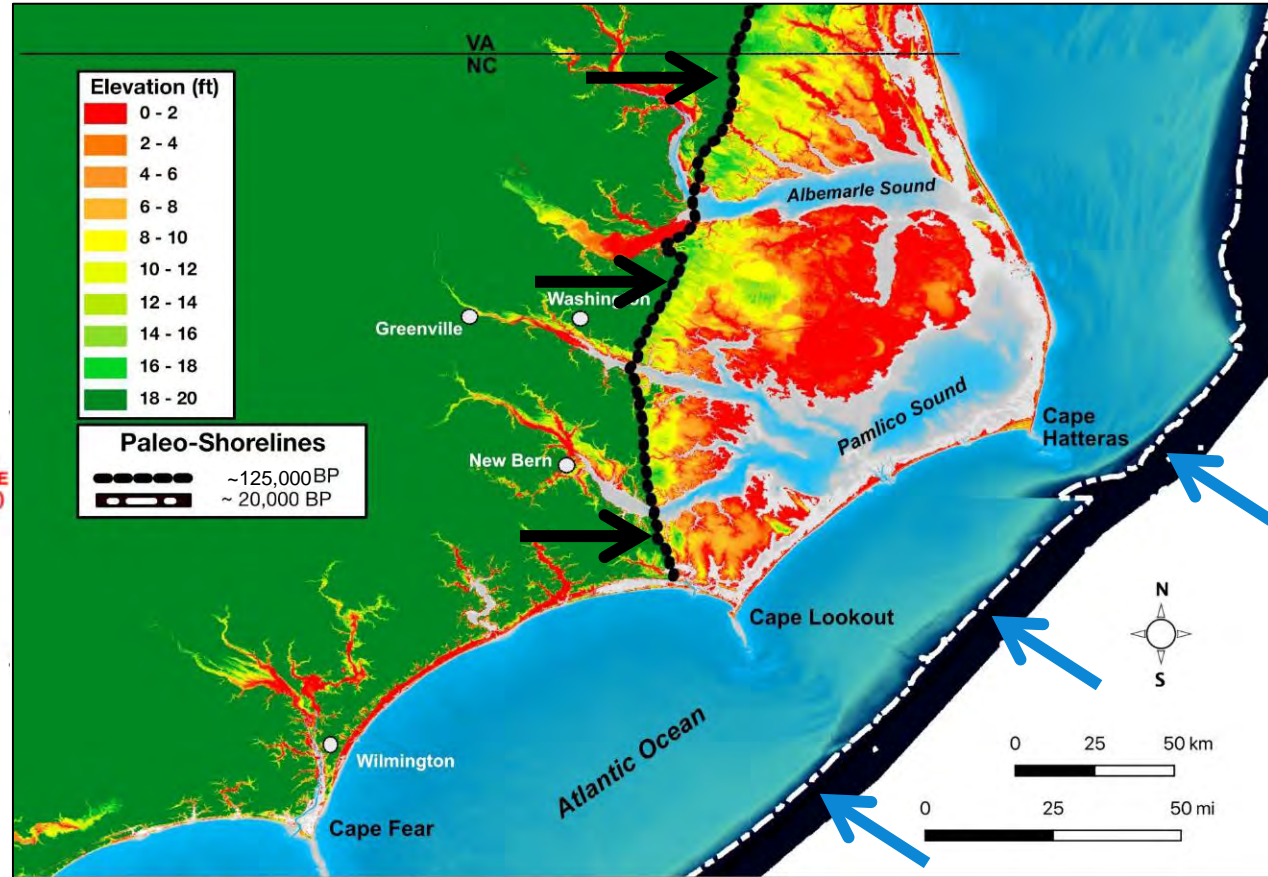


SHACKLETON & OPDYKE (1973)

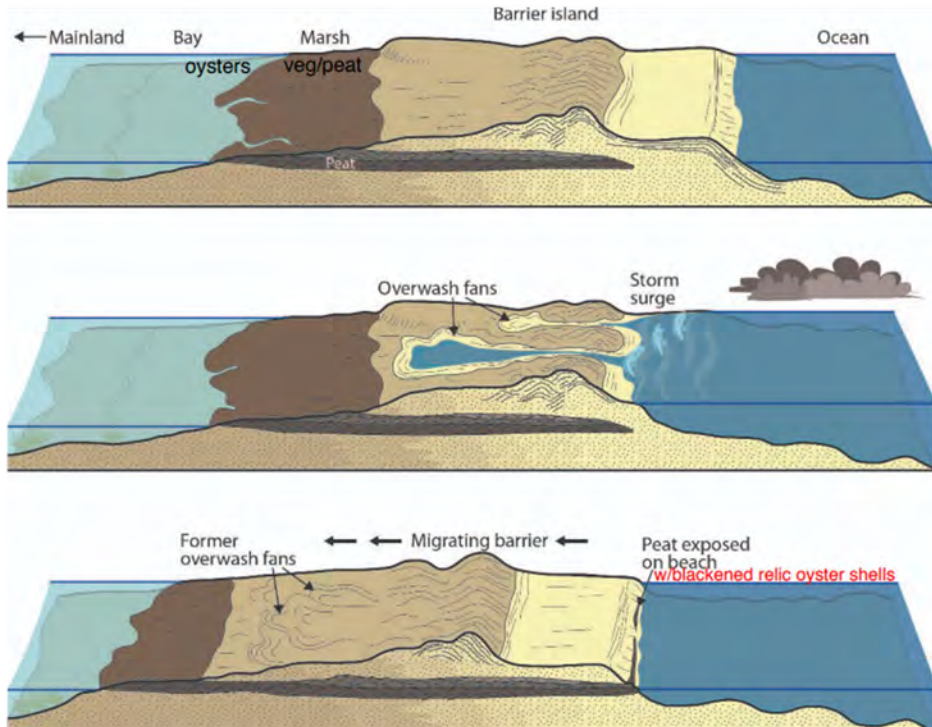
North Carolina's Shorelines of the PAST



Glacial Interglacial



Barrier islands build new land, keep pace with sea-level rise through storm overwash



- Once formed, barriers are maintained by **overwash**: landward directed flux of water and sand during storms
- Over decades the barrier island marches landward

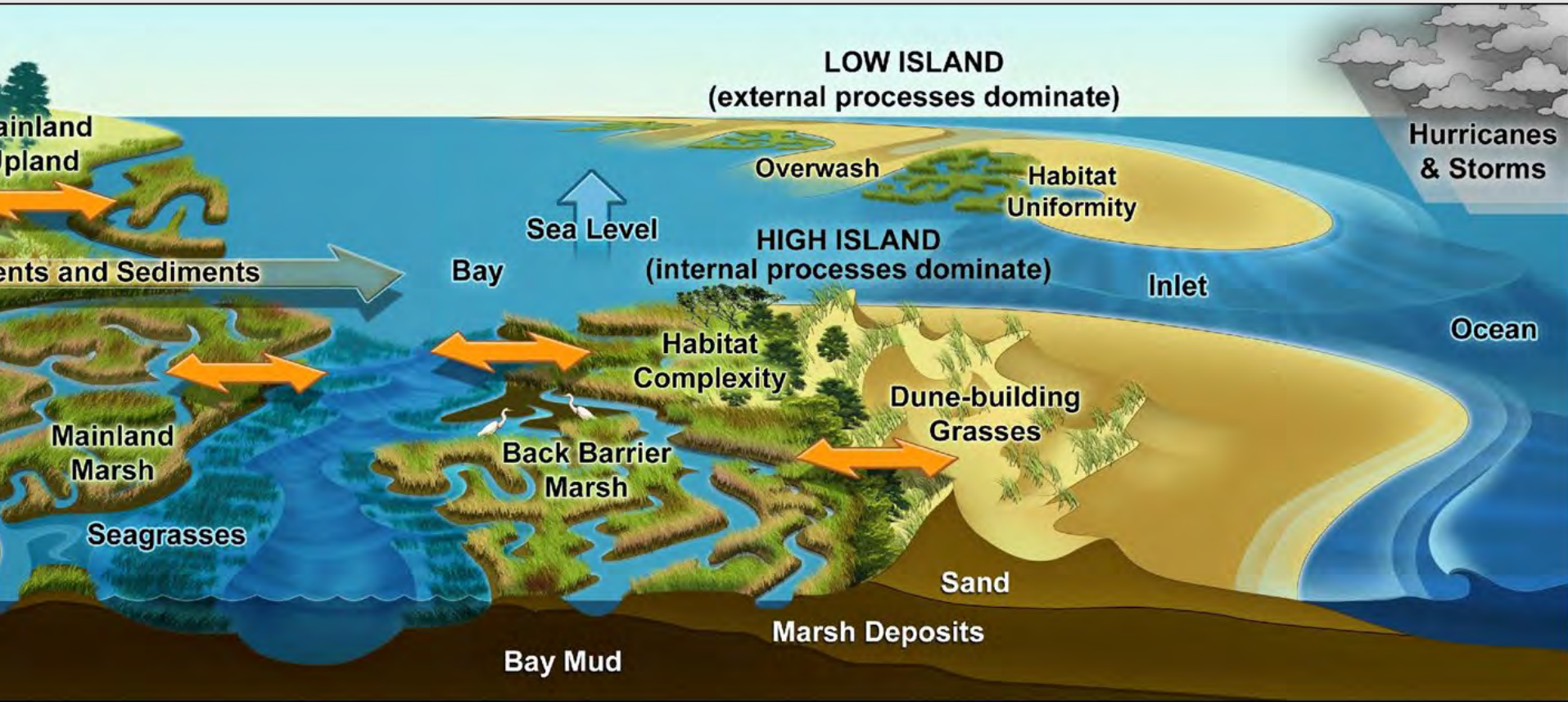
Dunes regulate overwash delivery to the barrier interior

Slow growth rates: prone to overwash Fast growth rates: resistant to overwash



Durán & Moore 2015; Durán et al. 2021

Couplings across the landscape affect the state of the barrier system



Humans alter couplings across barrier systems





Rogers et al., 2015
Lazarus et al., 2021

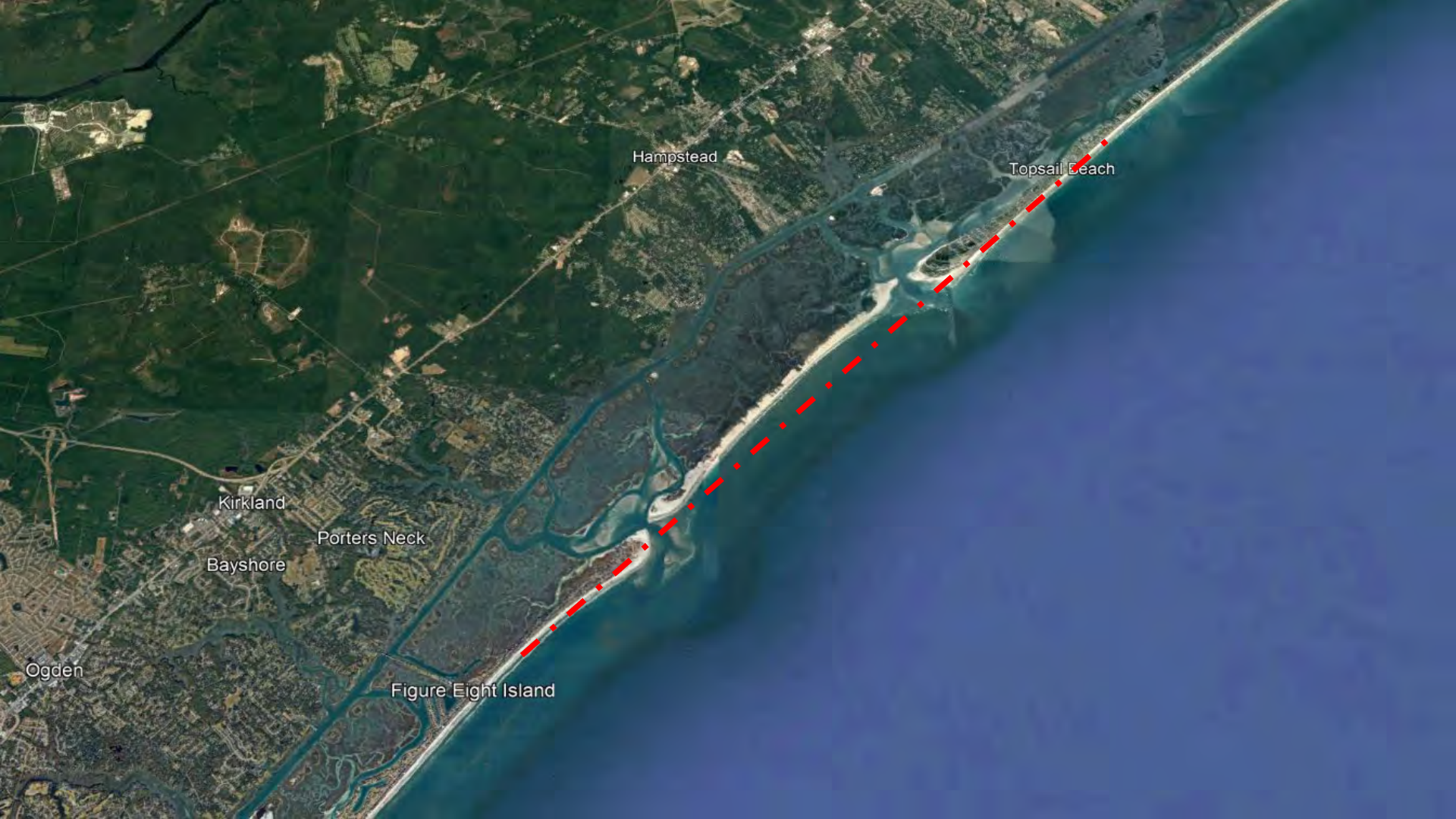
Limit overwash delivery to the
barrier interior and marsh



Larson et al., 2003

Alter patterns of alongshore
sediment transport





Hampstead

Topsail Beach

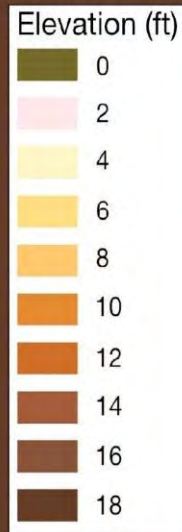
Kirkland

Porters Neck

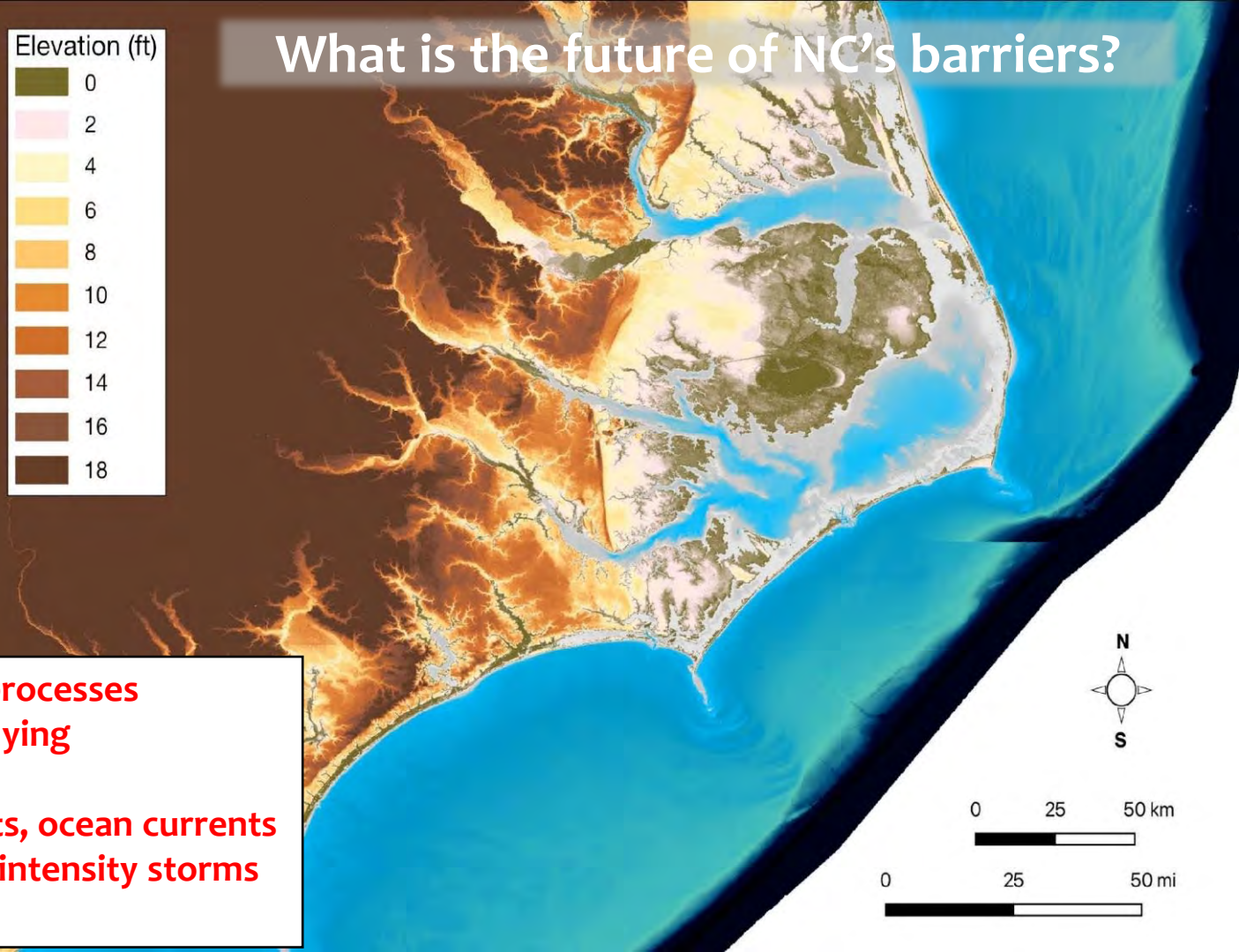
Bayshore

Ogden

Figure Eight Island



What is the future of NC's barriers?



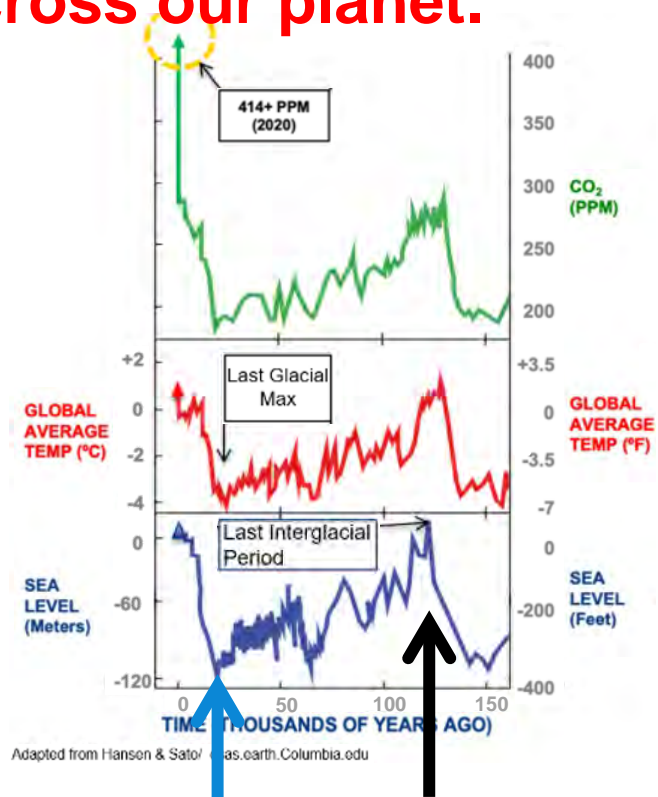
0 25 50 km

0 25 50 mi



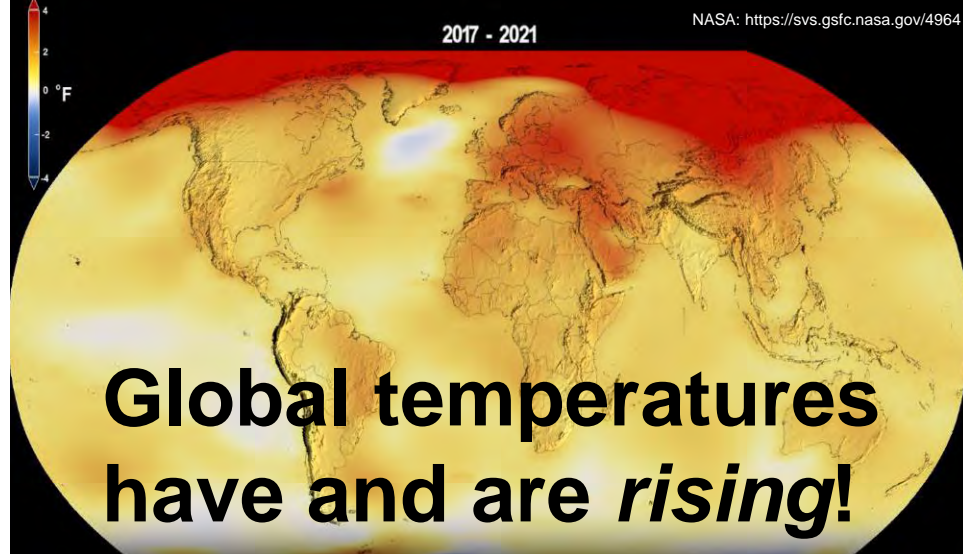
- Humans modify natural processes
- NC barriers are very low lying
- Dynamic setting
 - Changing river outputs, ocean currents
 - Increasing frequency/intensity storms
 - Sea-level rise

Global temperatures are a significant driver of change across our planet.

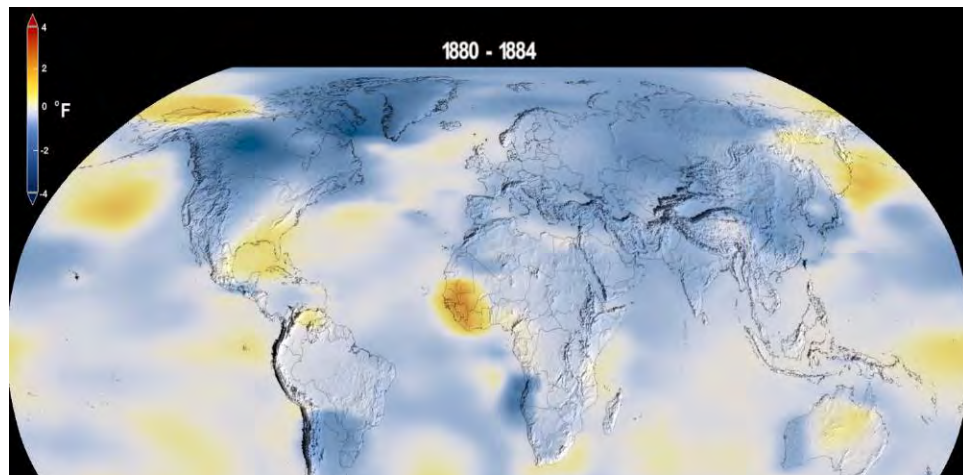


Glacial

Interglacial

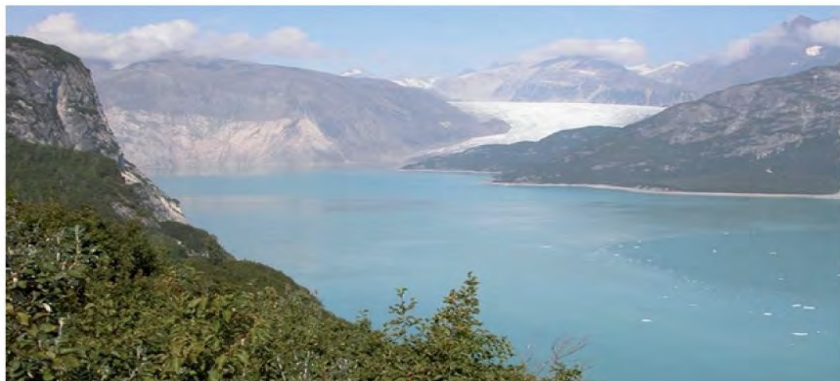


"Normal" temperatures are calculated over the 30-year baseline period 1951-1980

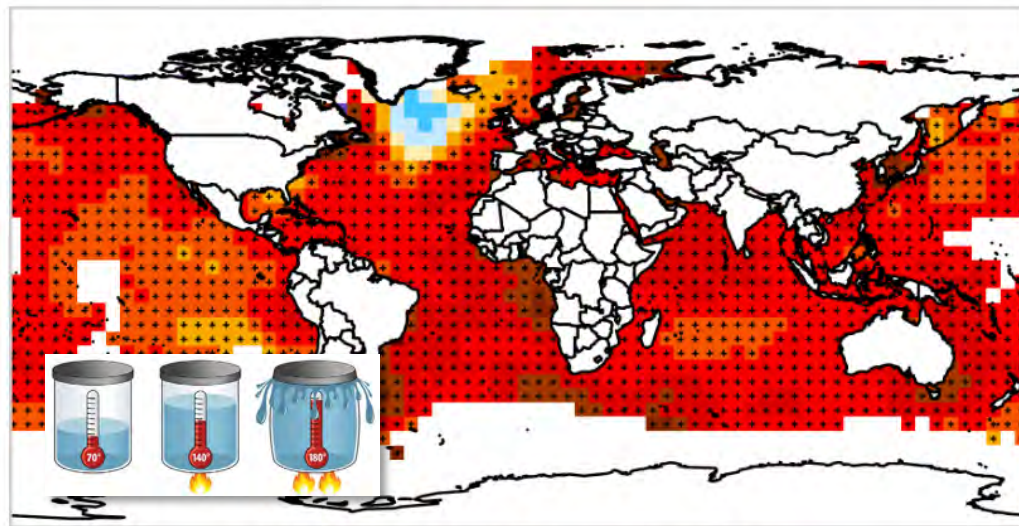


Melting land-based ice

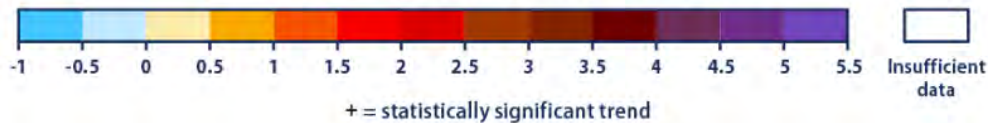
Muir Glacier, Alaska, 1941 and 2004



Rising ocean temperatures



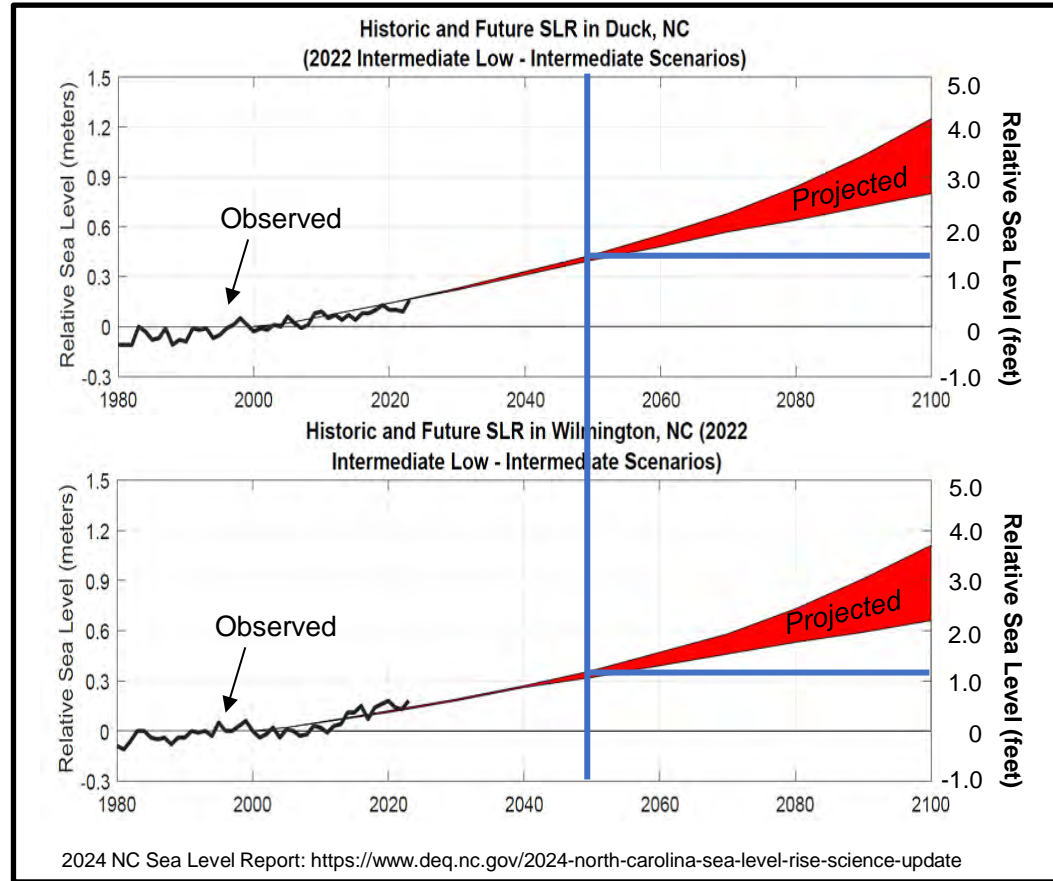
Change in sea surface temperature (°F):



Data source: IPCC, 2013; NOAA, 2021

What does the latest science say about future SLR in NC?

- The report projects **1.0 – 1.4 ft of sea level rise by 2050** (Intermediate-Low & Intermediate Scenarios) **in the Southeast**, relative to 2000.
- Emissions are **on track for a sea level rise of 2 – 4 feet by 2100** (Intermediate-Low – Intermediate Scenarios).
- RSLR in NC varies, with higher rates in the north relative to the south, largely due to differences in vertical land motion.

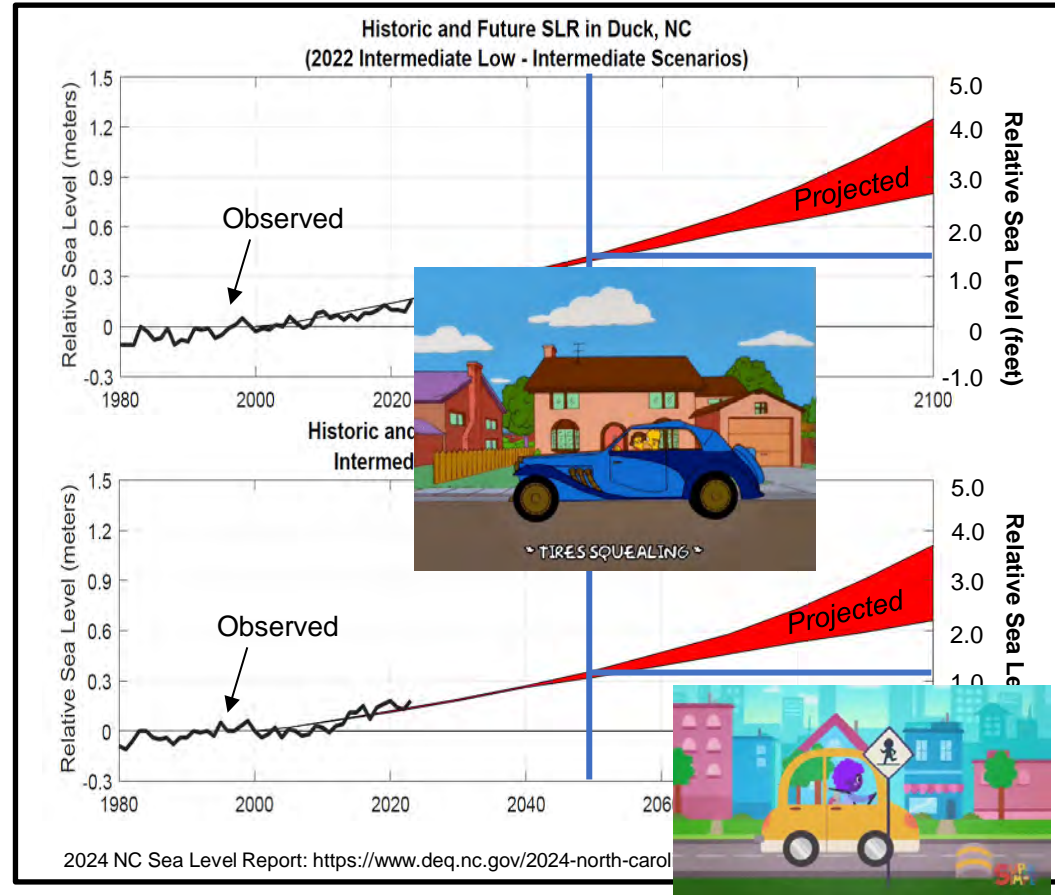


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Best case: future emissions are low or decreasing, and sea level rise is relatively gradual

Worst case: future emissions are high or increasing, and sea level rise occurs relatively quickly



May 2023-April 2025: it flooded 60 days in CB

communications earth & environment

Article | [Open access](#) | Published: 02 June 2025

Land-based sensors reveal high frequency of coastal flooding

Miyuki Hino , Katherine Anarde, Tessa Fridell, Ryan McCune, Thomas Thelen, Elizabeth Farquhar, Perri Woodard & Anthony Whipple

THE DROWNING SOUTH

ANATOMY OF A FLOOD

The Post installed cameras along the main road of one N.C. town to document the many ways rising seas exacerbate high-tide flooding.

Scroll to continue >



Nearest tide gauge: 1 flood day



What might sea-level rise look like on Canal Drive? 2022 to 2030

We expect <i>this much</i> SLR by:	2030	2040	2050	2070	2100
3 inches (from 2020)	All cases				



Baseline: 2022 flood

+ 3 inches =



2030 flood

What might sea-level rise look like on Canal Drive? 2022 to 2040-2050

We expect <i>this much</i> SLR by:	2030	2040	2050	2070	2100
7 inches (from 2020)		Worst case	Best case		



Baseline: 2022 flood

+ 7 inches =



2040 to 2050 flood

What might sea-level rise look like on Canal Drive? 2022 to 2050-2070

We expect <i>this much</i> SLR by:	2030	2040	2050	2070	2100
12 inches (from 2020)			Worst case	Best case	



Baseline: 2022 flood

+ 12 inches =



2050 to 2070 flood

What might sea-level rise look like on Canal Drive? 2022 to 2070-2100

We expect <i>this much</i> SLR by:	2030	2040	2050	2070	2100
24 inches (from 2020)				Worst case	Best case



Baseline: 2022 flood



+ 24 inches = 2070 to 2100 flood

Continued and increasing long-term shoreline erosion rates

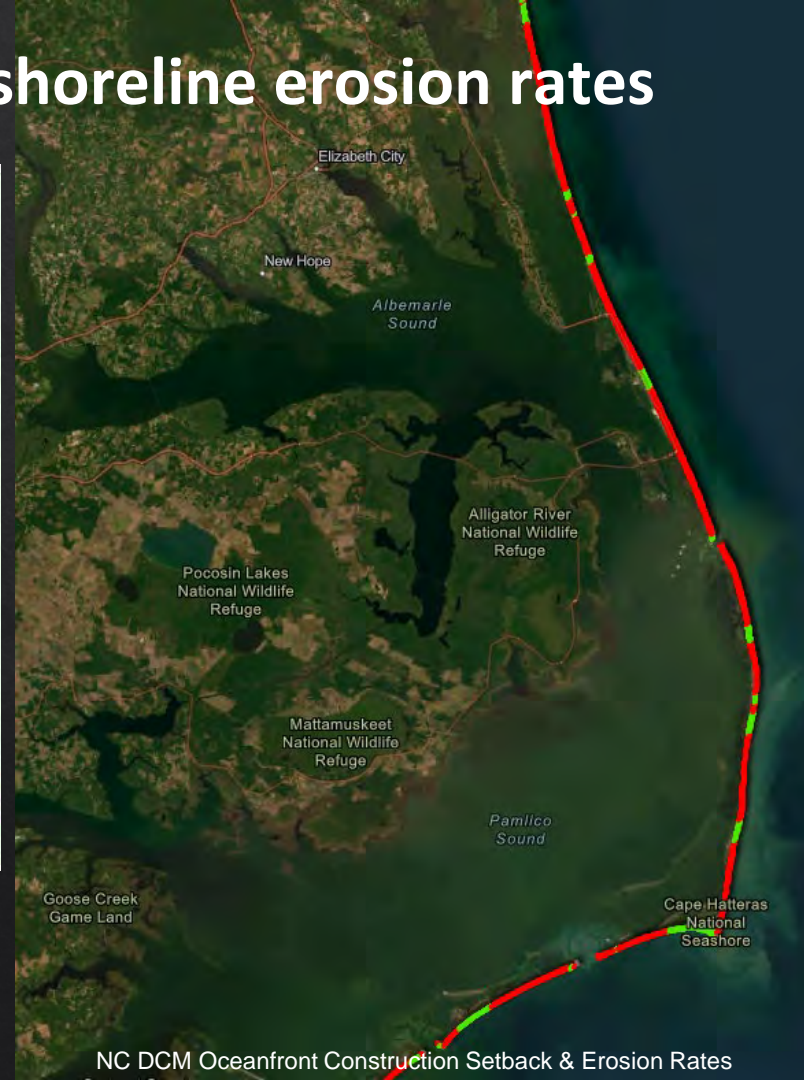


- The ocean shoreline erodes over time where more sand is lost from the shoreline than supplied.
- Losses related to sea level rise will increase and so background, long-term erosion rates will increase.

Credit: USGS; Google Maps; Paul Horn/InsideClimate News

S. Nags Head

Continued and increasing long-term shoreline erosion rates



Credit: USGS; Google Maps; Paul Horn/InsideClimate News

S. Nags Head

NC DCM Oceanfront Construction Setback & Erosion Rates

Coastal residents on climate change: "The ocean's coming for you"



"The ocean has become an increasingly greedy neighbor. Storms are more frequent, and more fierce. Parts of these Barrier Islands have retreated more than 200 feet in the last two decades. Some beaches are now losing about 13 feet a year."



Imelda, Humberto Wreak Havoc On North Carolina Beach Homes

Rising water table

Stormwater Runoff Backup → Increased Flooding During Storms

Ponding Water during Rain Events



Credit: Island Free Press

Manteo, NC 2018, Stormwater Drainage



Credit: Outer Banks Voice

Exacerbated by...

Outfalls becoming submerged



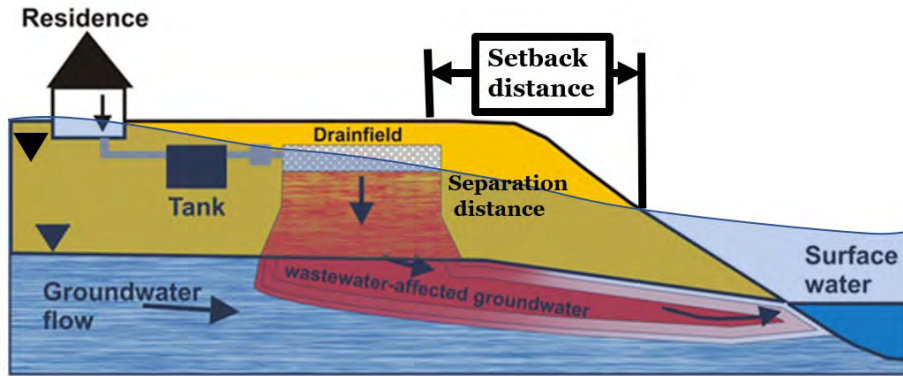
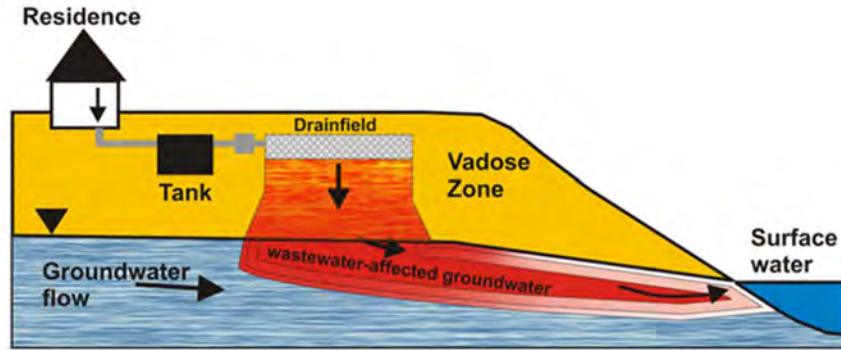
Credit: <http://jockeysridge.blogspot.com/v>

Loss of wetlands to development



Credit: DEQ

Septic system failure

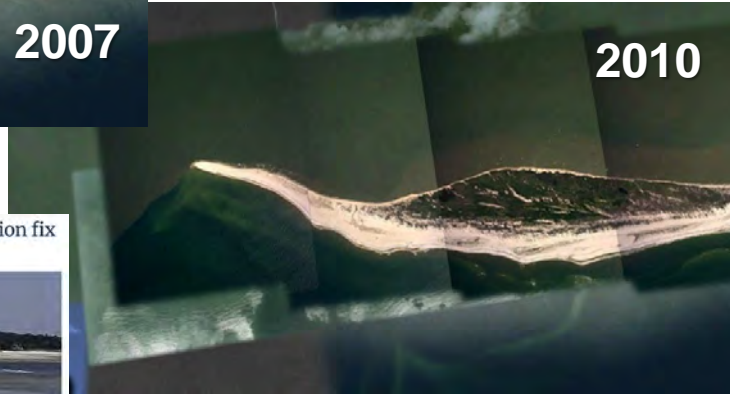


- High-tide flooding, extreme precipitation and sea level rise result in “immediate and long-term losses of on-site wastewater system functionality”
- These factors reduce unsaturated soils underneath the drainfield; lead to poor treatment, backing up, and **pollution**.

From Harrison, Edwards, Humphrey, O'Driscoll, Hill & community partners

Shifting inlets (and new structures)

Longshore currents can move sand towards the ends



Sand is vanishing on east side of Ocean Isle's \$11M erosion fix

09/30/2025 by Trista Talton



A view looking east of Ocean Isle Beach's terminal groin, where sandbags hold off beachfront erosion. Photo: Trista Talton



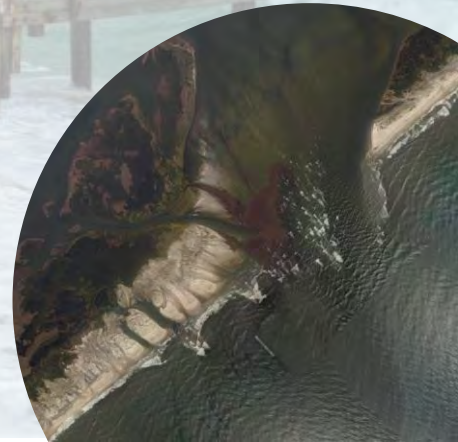
CoastalReview.org

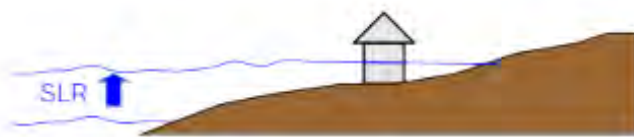
A Daily News Service of the North Carolina Coastal Federation





What can we do?





No response



Protect



Accommodate



Advance



Deconstruct or Move



Ecosystem-based adaptation



No silver bullet: modeled 2050-2070 flooding comes from North End marsh, bypassing bulkheads

**Modeled “protect” strategy:
minimum bulkhead elevation**



A survey to understand chronic flooding impacts, responses, and preferred adaptations



Flooding survey mailer

Have you ever experienced any of the following due to flooding outside of hurricanes or tropical storms? You may select multiple options.

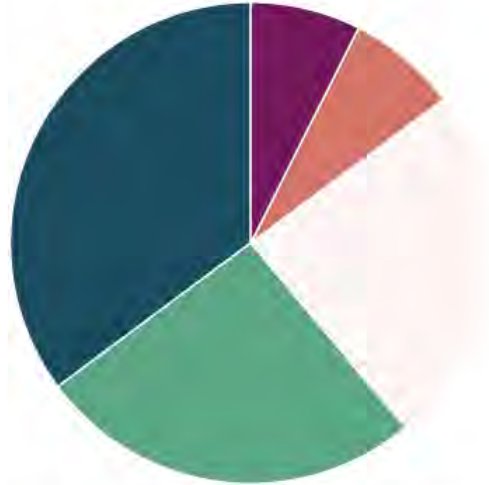
- ☐ Difficulty commuting to work or school
- ☐ Difficulty reaching or canceling doctor and other appointments
- ☐ Inability to leave your house
- ☐ School delays and closures
- ☐ Business delays and closures
- ☐ Trash can tipped over or trash collection disrupted
- ☐ Concerns about health and safety due to water quality
- ☐ Damage to personal vehicle
- ☐ Property damage
- ☐ Negative impact on home value
- ☐ Difficulty obtaining homeowner's insurance
- ☐ Neighbors selling homes and moving out
- ☐ Neighbors moving out and renting their homes
- ☐ Complaints from renters
- ☐ Lost rental income

The survey respondents most impacted by flooding are more willing to move

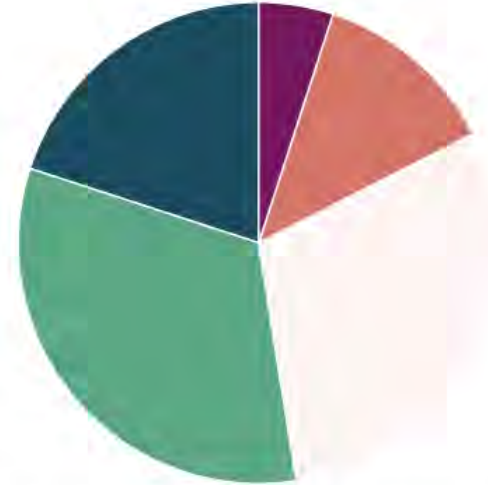
0-2 flood impacts
n = 41



3-6 flood impacts
n = 54



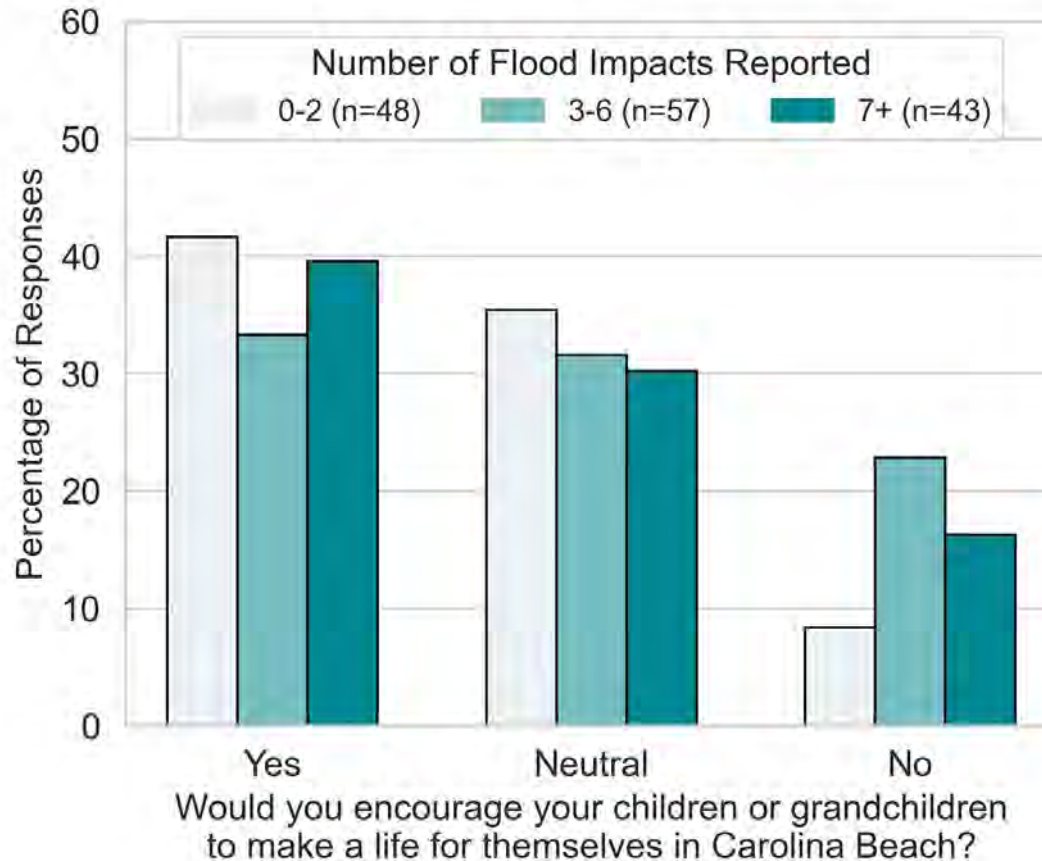
7+ flood impacts
n = 40



If a good opportunity for you or your family arose to move to a less flood-prone location within Carolina Beach, what is the chance you would take it?

- Definitely would not move (0% chance)
- Prefer not to move (1-39% chance)
- Might move (40-59% chance)
- Prefer to move (60-99% chance)
- Definitely would move (100% chance)

Respondents are positive or neutral about the next generation, more "No" for 3+ impacts



Takeaways

- Developed barrier islands, and properties on them, are increasingly vulnerable to storm and climate hazards.
- There are emerging sound-side (high tide flooding) and groundwater hazards (septic and water quality issues), which may not make it to flood disclosures, but influence property livability.
- These emerging hazards may also influence whether people stay or go.

C.J. Schuberth (1970) in the article "Barrier beaches of eastern America," in the Natural History magazine:




"If man wishes to build his works on the fringes of such a battleground (the coast), he must understand that the rules of this ancient battle require the beach, the berm, and the dunes to shift constantly before the assault of the sea. If man tries to change these rules, he can only fail; and in his failure he may even undermine the fragile hold of these outposts against the powerful sea."



What are My Options Right Now?

Homeowner Costs/Financial Assistance for Home Deconstruction



	Homeowner Can Pay Full Cost	Potential for Insurance Funding?	Potential for FEMA (HMGP) Funding?
Let the home collapse 	Yes Homeowner will be required to pay for debris cleanup (costs vary, estimate upwards of \$50K)	Maybe But an insurance payout is not guaranteed (up to \$250K for the home, up to \$100K for belongings)	No
Deconstruct the home 	Yes (~\$30K-50K)	Maybe One homeowner was successful in 2025	Likely FEMA will need to award Dare County the grant
Purchase a new lot and move the home – backward on the same lot or to a new lot 	Yes New lot: There are a limited number of available land parcels in the Outer Banks	No	At-Risk Oceanfront Structures Dare County Public Meeting