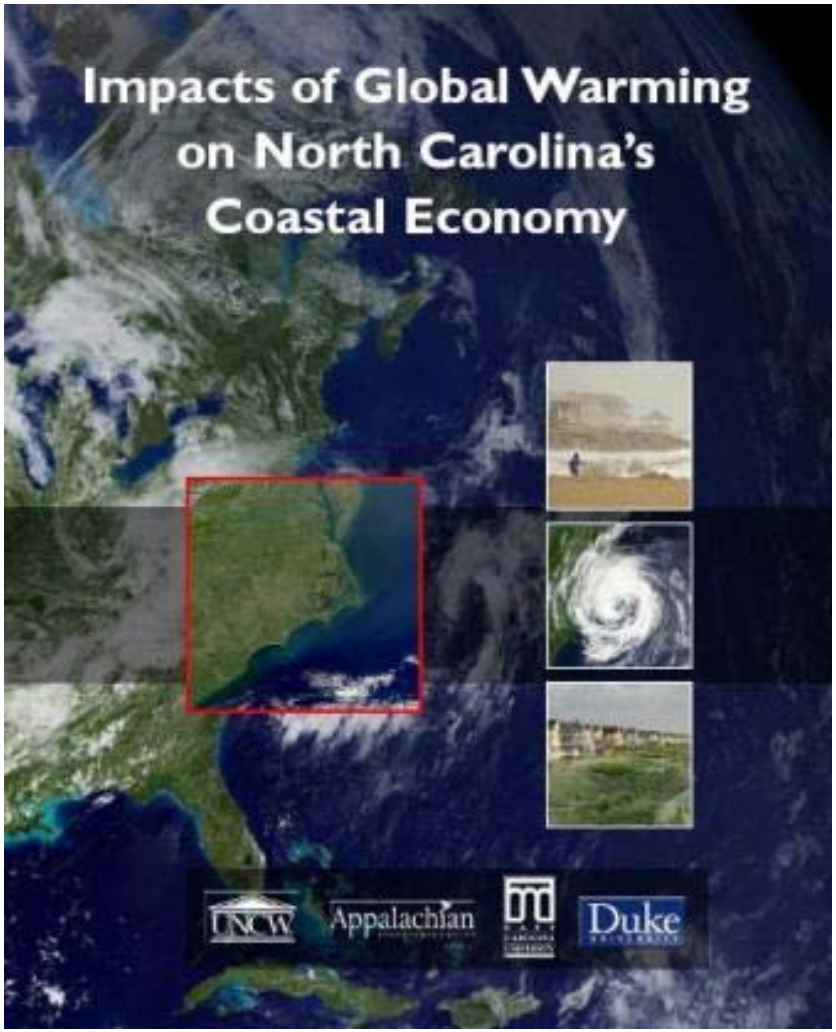

National Commission on Energy Policy

East Carolina University

University of North Carolina Wilmington

Duke University

Appalachian State University

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This research was supported by a grant from the William and Flora Hewlett Foundation to the Bipartisan Policy Center, Inc.

National Commission on Energy Policy Projects on Climate Change Impacts and Adaptation

In addition to the North Carolina project:

- Impacts of permafrost melt on infrastructure in Alaska
- Impacts on water resources in New Mexico & adaptation policy
- Impacts on forests & air quality in Tennessee
- Risks to Florida coastal property & adaptation policy
- Impacts on water supplies in Idaho
- Impacts on forests in the upper Rocky Mountains

Problem

- Climate change may have significant impacts on North Carolina coastal resources due to sea level rise, increased erosion, and increased hurricane activity and intensity.
- Extensive development in the coastal zone in recent decades has put more people and property at risk.

Climate change in coastal North Carolina

- Sea-level rise
  - Complete loss of many beaches
  - Lost property values
  - Lost recreational benefits
- Hurricane intensity increases
  - Business & tourism interruption
  - Agricultural losses
  - Greater damage to forests
  - Commercial fishing losses

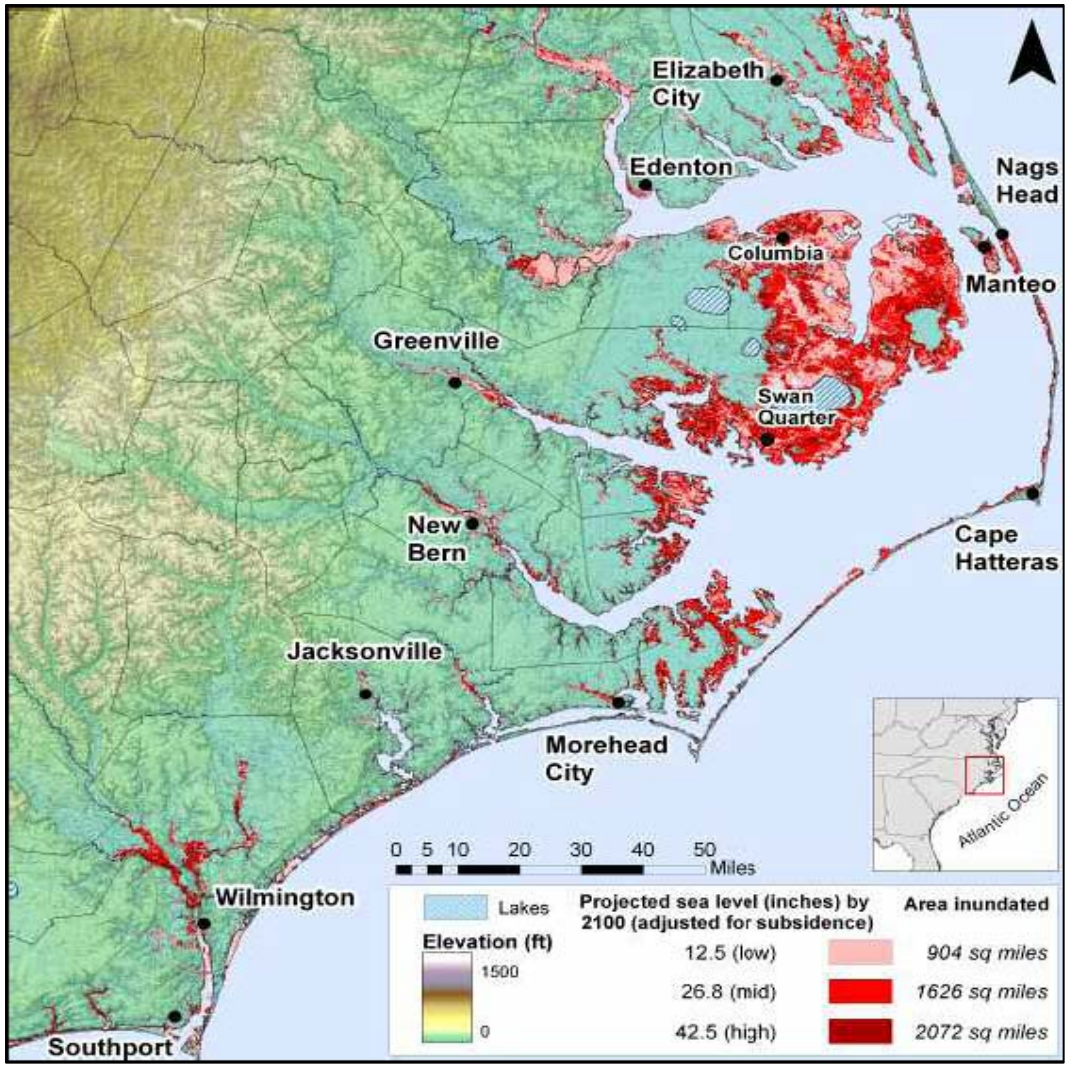
Climate Models Behind the Analysis

- Climate model results from IPCC Third Assessment Report. (Fourth Assessment was not ready yet.)
  - Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, D. Xiaosu, and K. Maskell (eds.) 2001. Climate Change 2001: The Scientific Basis. New York: Cambridge University Press.
- Used mid-range numbers from results of over 20 global climate models covered in the IPCC report. (cccma cccma.t63 cnrm csiro gfdl0 gfdl1 giss.aom giss.eh giss.er iap inmcm3 ipsl miroc.hires miroc.medres echo echam mri ccsm pcm hadcm3 hadgem1)
- Sea Level Rise inundation model using 8-side rule for connectivity (see Poulter and Halpin, in review)
  - i. Uses lidar elevation data (±25 cm vertical accuracy)
  - ii. Generated binary flooded/not-flooded raster surface

Sea-level Rise and Coastal Inundation

- A one-foot rise in sea level can cause inland movement of the shoreline by 2,000 to 10,000 feet along the relatively flat North Carolina coast.

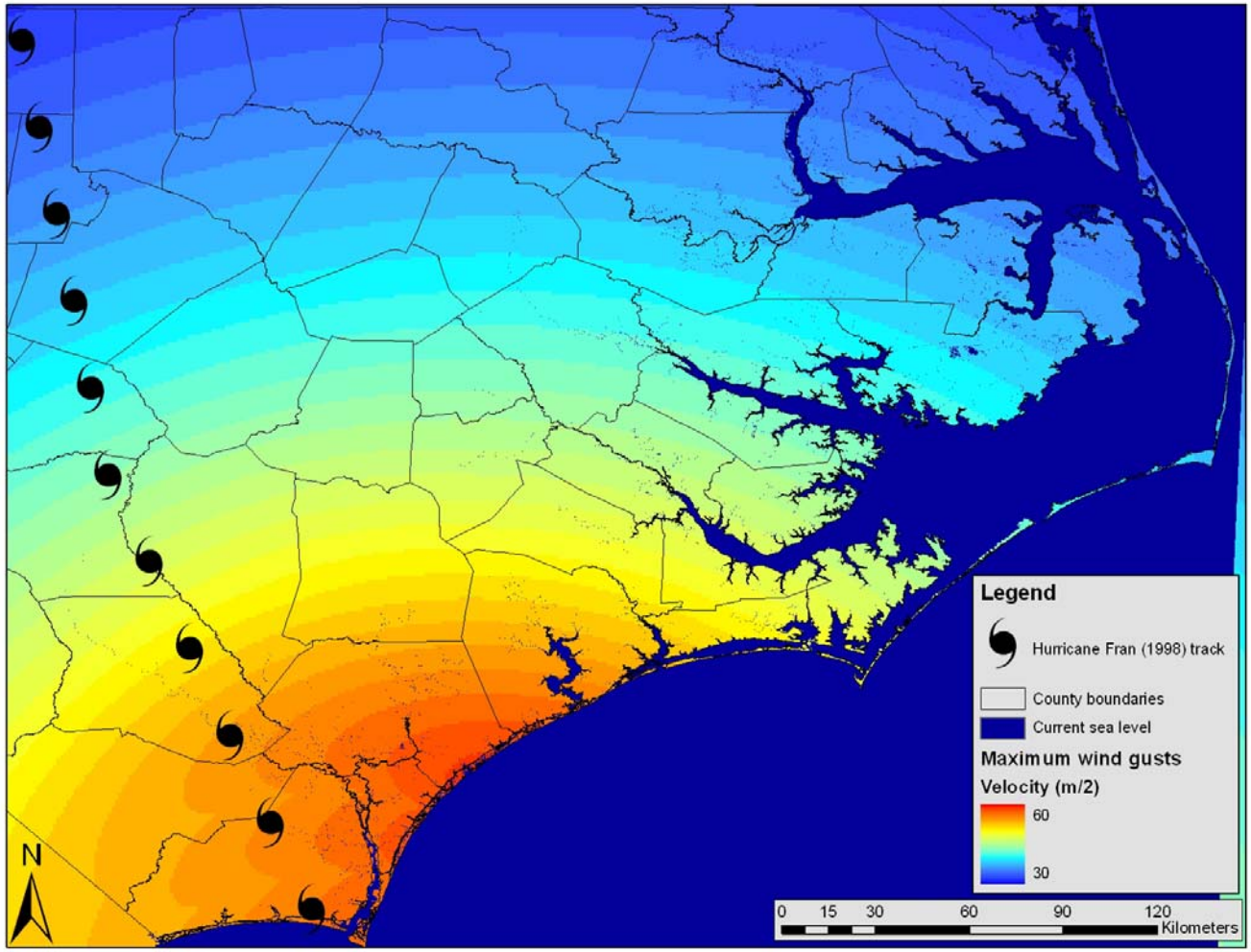
Land at risk due to sea level rise by 2100



Hurricane Intensity (Wind Speeds)

- Modified Hurrecon (Boose and Foster 2001) wind speed model
- Ran Hurrecon with track from Fran (1996) download from NOAA HURDAT website
  - Interpolated 3-hourly measurements from NOAA to 1-hourly intervals
  - Approximately 14 time points of Fran track recorded across NC
  - Generated maximum wind gust maps and maximum sustained wind velocity maps for each time point
  - Calculated maximum wind gust map for entire storm track (m per second)
- The scenarios are based on estimated changes in hurricane intensity by Knutson and Tuleya (2004). K&T examined estimated changes in hurricane formation in the Atlantic and Pacific oceans from nine climate models. They calculated a range of changes in sea surface temperature, intensity, wind speed, and precipitation
- Estimates of wind speed increases from MAGICC/SCENGEN for 2030 and 2080. The original 1996 wind speed map was multiplied by these percent increases to simulate a climate-change influenced Fran hurricane.

Hurricane Fran (Cat 3, 1996) Case Study



Changes in Hurricane Intensity

Hurricane categories for baseline and climate change scenarios

	Category 3 Hurricane (Hurricane Fran Track) Baseline Scenario	Climate Change Scenarios	
	1996	2030	2080
County	MAX	MAX	MAX
Bertie	TS	TS	TS
Carteret	1	2	2
Dare	TS	1	1
New Hanover	2	2	3

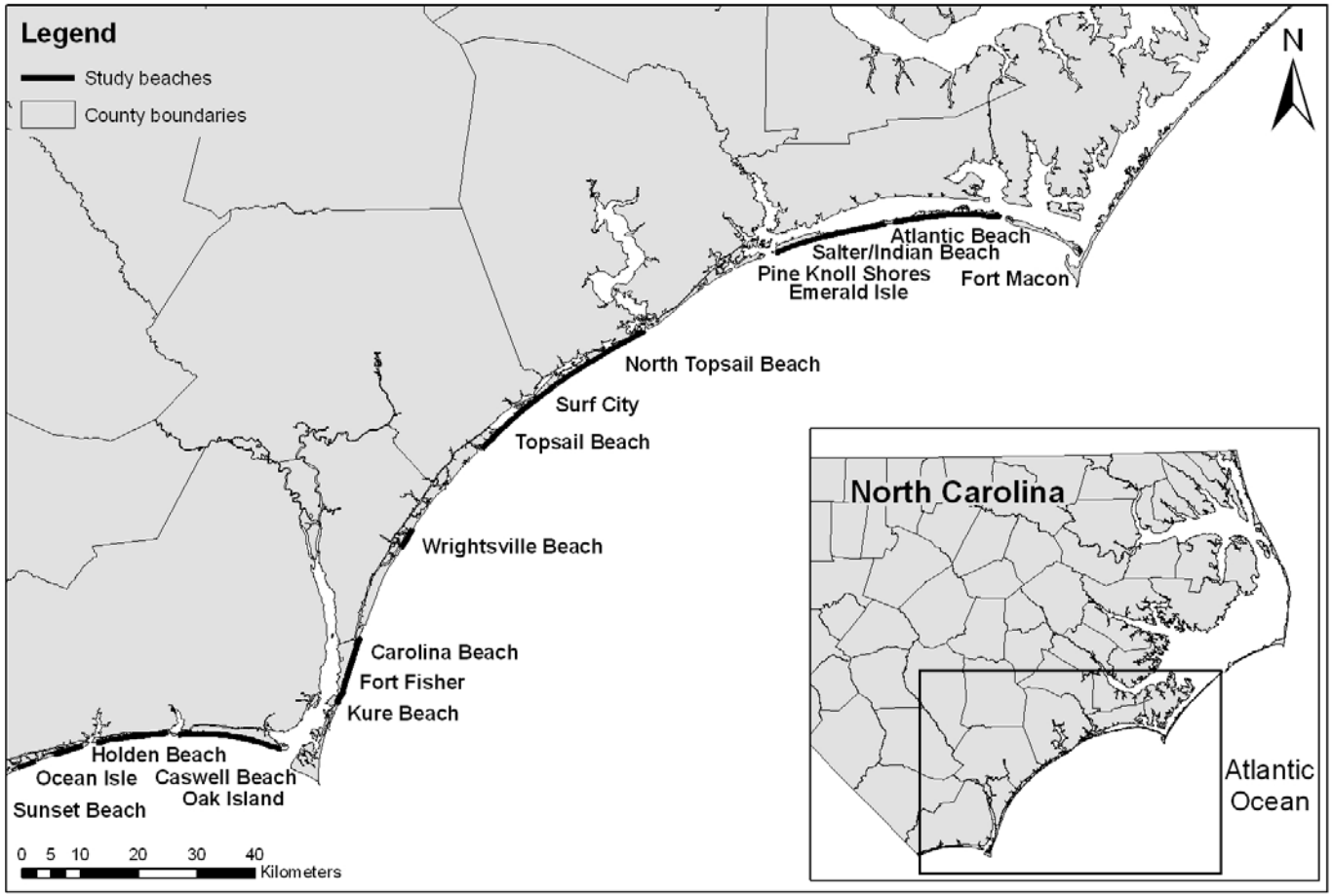
TS = tropical storm, 1 = category 1 hurricane, 2 = category 2 hurricane, etc.

Within this physical science context, this study …

- Considers the impacts of climate change on the
  - coastal real estate market
  - coastal recreation and tourism
  - business activity, agriculture and forestry
- Utilizes a range of mid-range assumptions for sea-level rise and hurricane intensity increases, not best- or worst-scenarios.
- Assumes no mitigation/adaptation—presents “What costs might be if no mitigation/adaptation is undertaken.” Benefits of mitigation/adaptation activities are the avoidance of these costs.
- Is limited in geographic scope and types of impacts considered due to budget and time constraints.

Recreation Impacts

Study Beaches



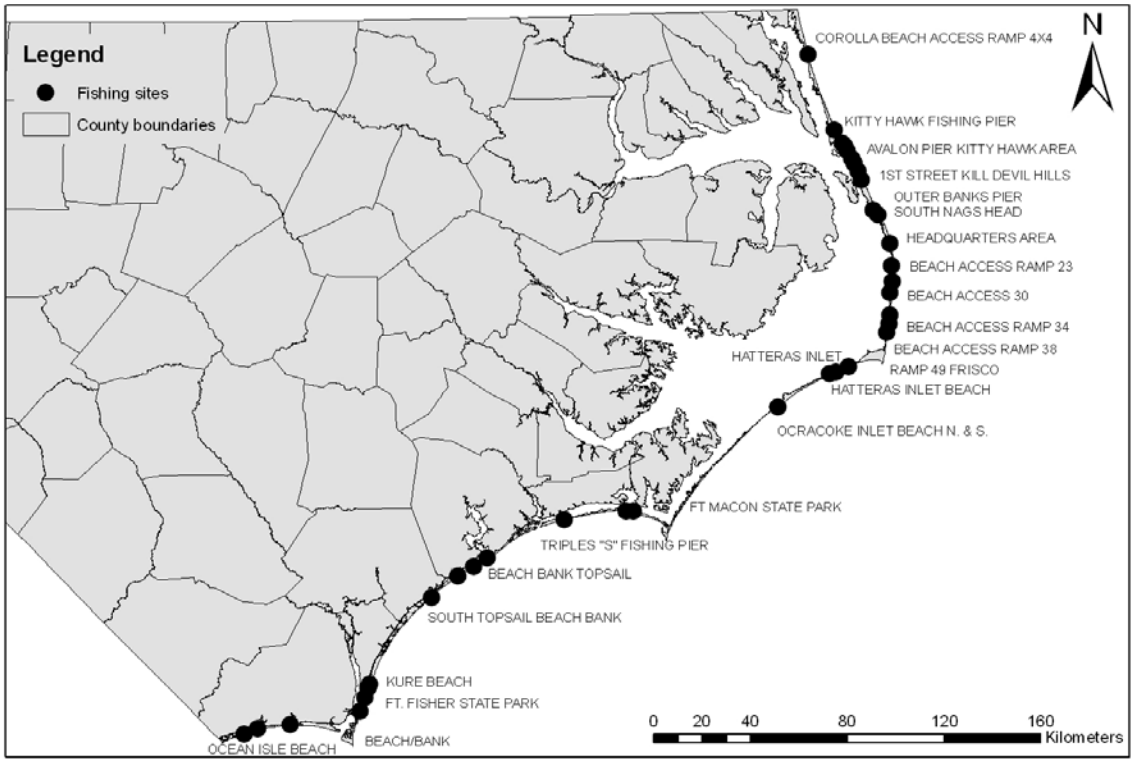
Beach Width (Assuming no mitigation)

County	Beach	2003	2030	2080
Carteret	Fort Macon	90	40	0
Carteret	Atlantic Beach	135	85	0
Carteret	Pine Knoll Shores	110	60	0
Carteret	Indian Beach / Salter Path	90	40	0
Carteret	Emerald Isle	130	80	0
Onslow-Pender	North Topsail Beach	82	32	0
Onslow-Pender	Surf City	90	40	0
Onslow-Pender	Topsail Beach	110	60	0
New Hanover	Wrightsville Beach	160	110	3
New Hanover	Carolina Beach	185	135	28
New Hanover	Kure Beach	130	80	0
New Hanover	Fort Fisher	400	350	243
Brunswick	Caswell Beach	80	30	0
Brunswick	Oak Island	120	70	0
Brunswick	Holden Beach	90	40	0
Brunswick	Ocean Isle Beach	85	35	0
Brunswick	Sunset Beach	115	65	0

Impacts on Recreation and Tourism

- Lost recreation value to local southern NC beach goers:
  - $93 million a year by 2030
  - $223 million a year by 2080
- Reduction in annual spending by non-local beach tourists visiting southern NC beaches:
  - 16% decline by 2030
  - 48% decline by 2080.
- Note: These are impacts for southern NC beaches only. Necessary data were not available for northern NC beaches.

Impacts on Shore Fishing--Fishing Sites



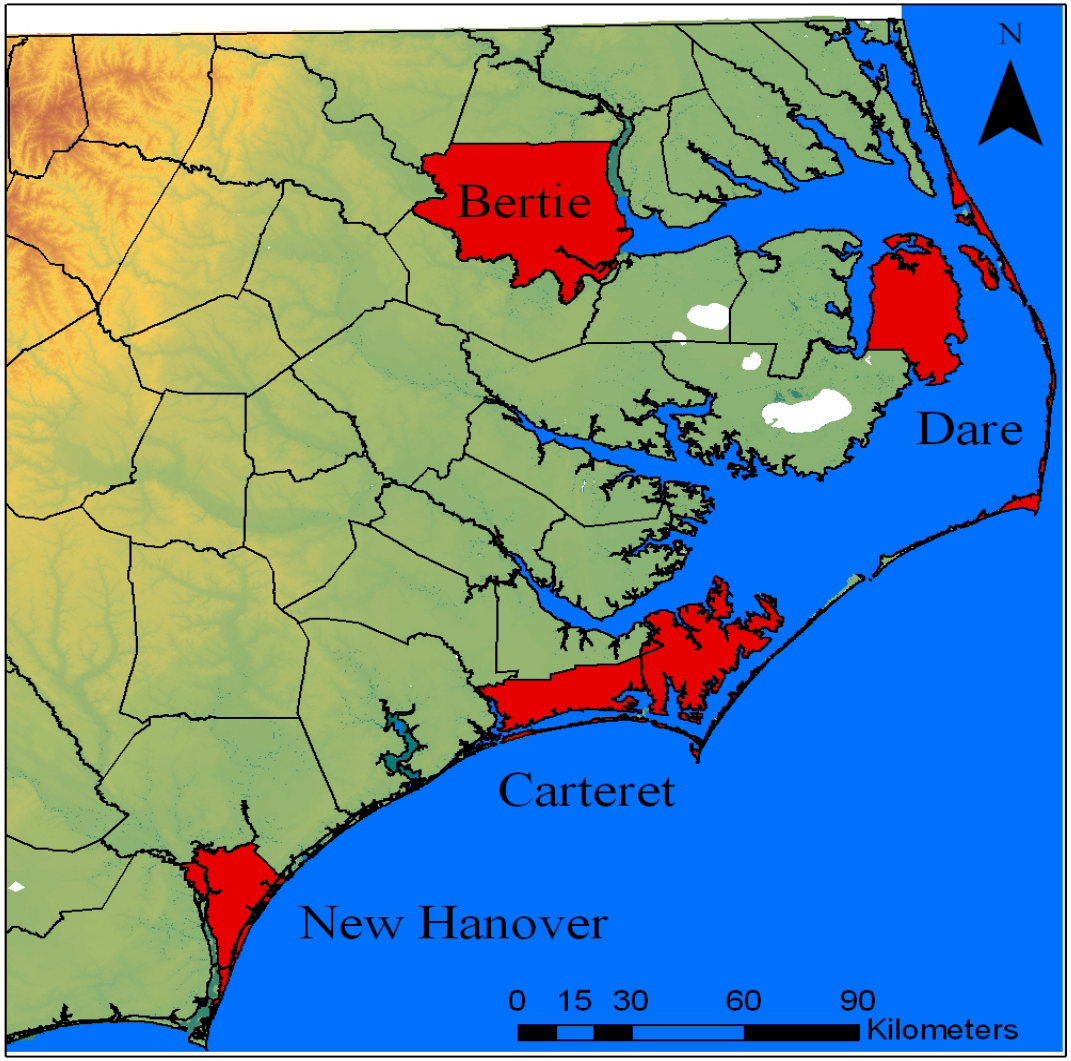
- 22 Piers
- 28 Beach

Impacts on Shore Fishing

- Based on MRFSS angler intercept data.
- The lost recreation value to local shore anglers (all NC beaches):
  - $15 million a year by 2030
  - $17 million a year by 2080
- Note: These are impacts for all NC beaches.

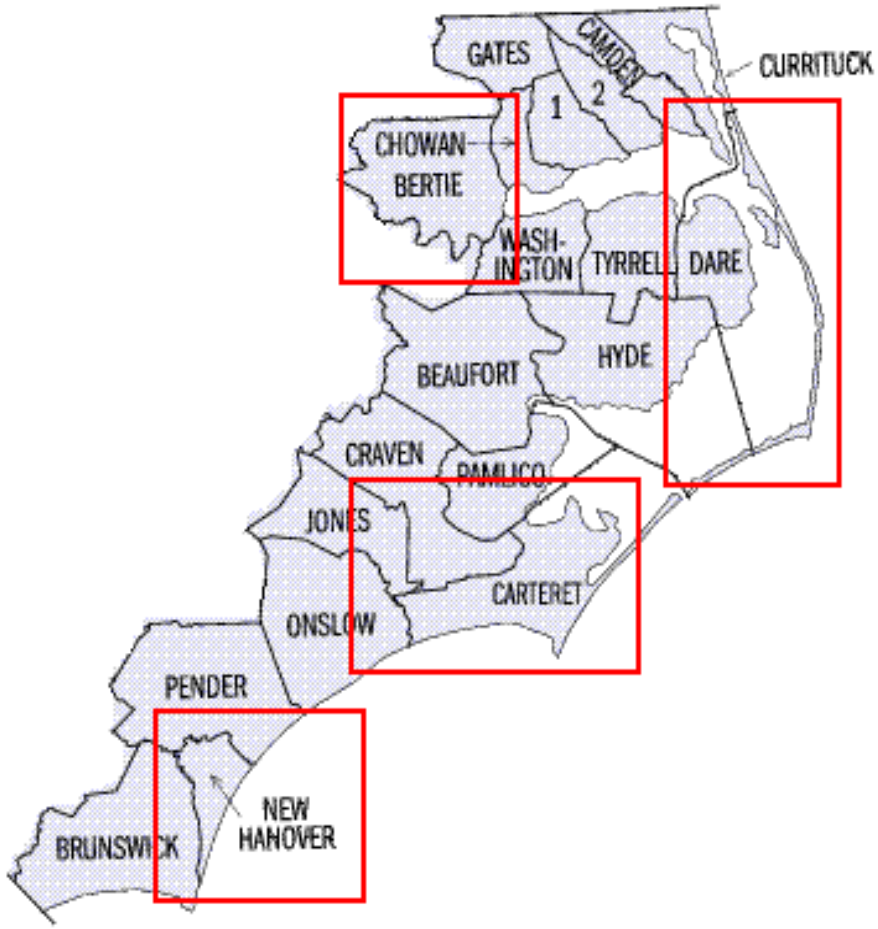
Coastal Real Estate

Study Area



Data

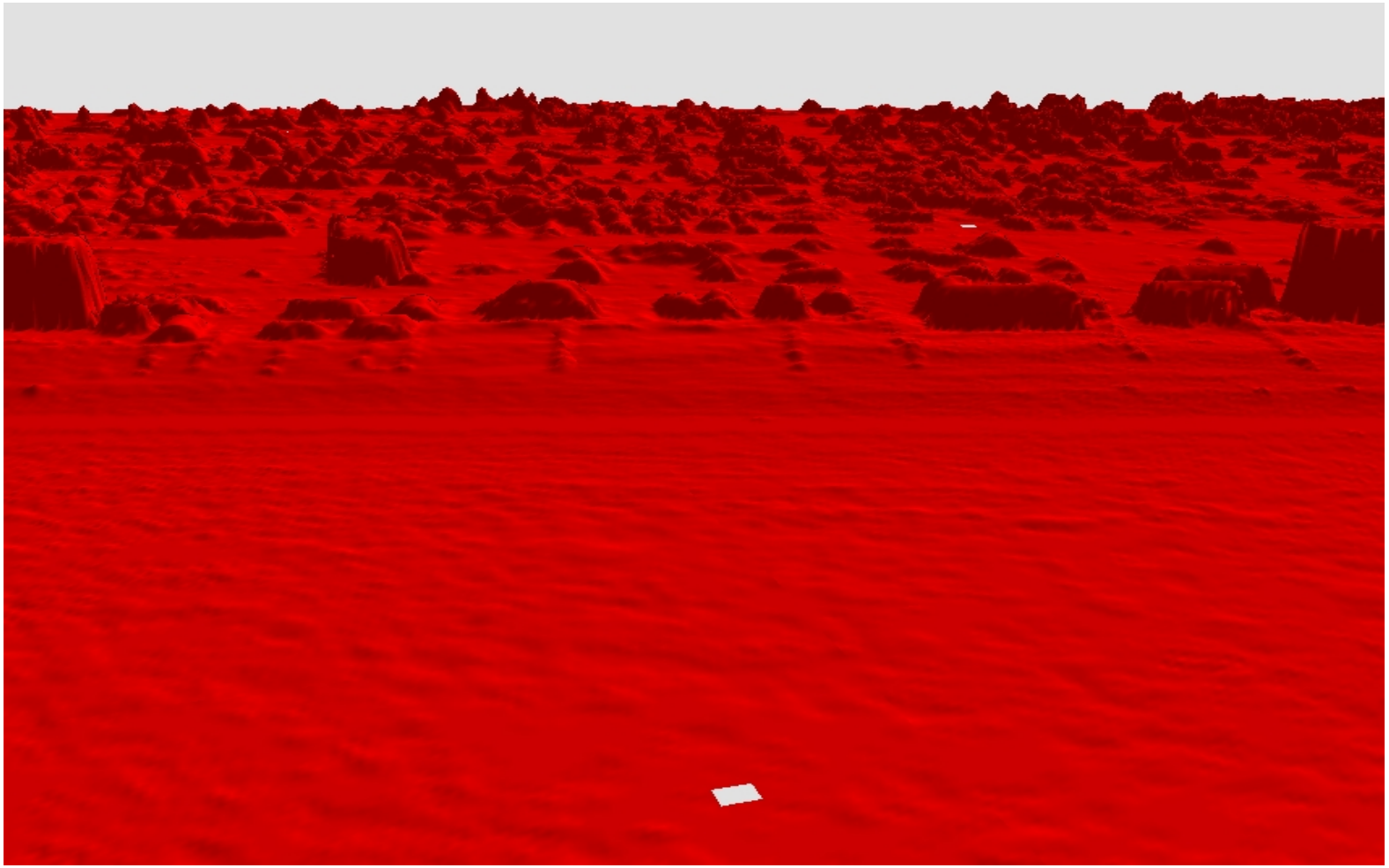
- Data on property values come from the county tax office.
- High-resolution LIDAR elevation data are utilized to identify the inundation areas.
- Other spatial amenities (e.g., distance to the shore) are measured using GIS.



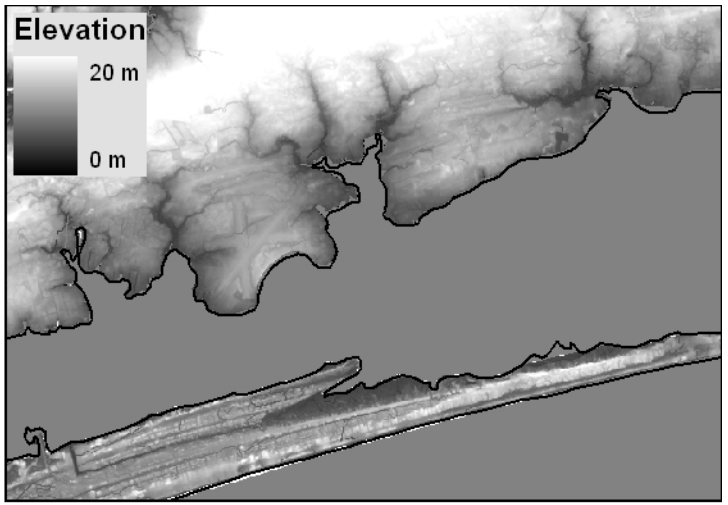
Data for New Hanover County

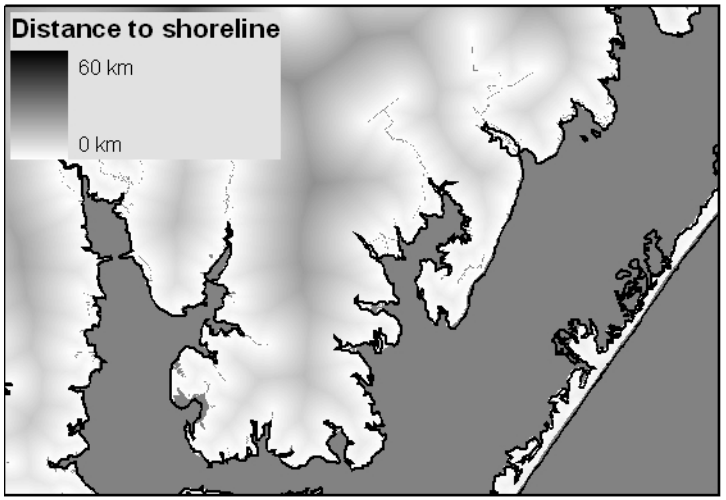
Variable	Description	Mean	Standard Deviation
AV	Real assessed property value as of May 2006	176,554.01	152,684.14
WRIGHTS	Wrightsville Beach township (= 1)	0.02	0.13
CAROLINA	Carolina Beach township (= 1)	0.04	0.20
KURE	Kure Beach township (= 1)	0.03	0.16
FIGEIGHT	Castle Hayne township (=1)	0.02	0.15
LOTSIZE	Total lot size measured in square feet	16,375.63	23,106.41
SQFT	Total structure square footage	1,786.05	798.79
AGE	Age of house	25.46	23.12
BATHRM	Number of bathrooms	2.23	0.85
AIRCOND	Central air conditioning (= 1)	0.90	0.30
FIREPLCE	Fireplace (= 1)	0.64	0.48
MULTISTR	Multistory house (= 1)	0.30	0.46
DETGAR	Detached garage (= 1)	0.07	0.26
OCEAN	On ocean front (= 1)	0.01	0.08
SOUND	On sound front (= 1)	0.02	0.12
DIST	Distance to nearest shoreline measured in feet	1,811.87	1,273.46
ELEV	Elevation of property measured in feet	26.21	12.14

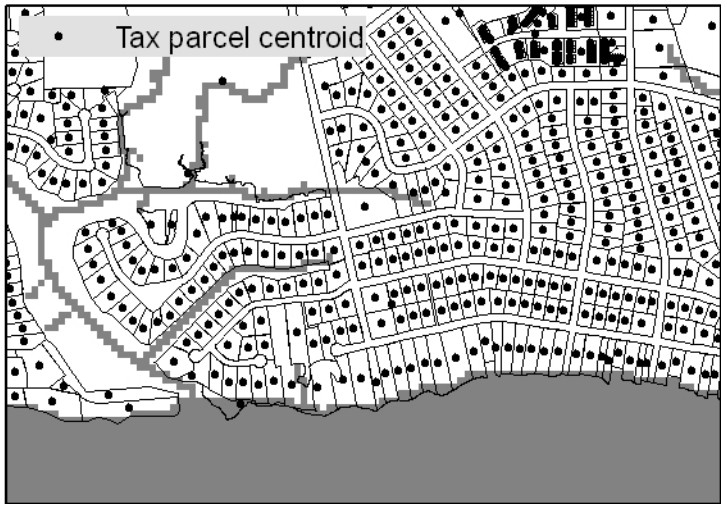
LIDAR Data



GIS Real Estate Data



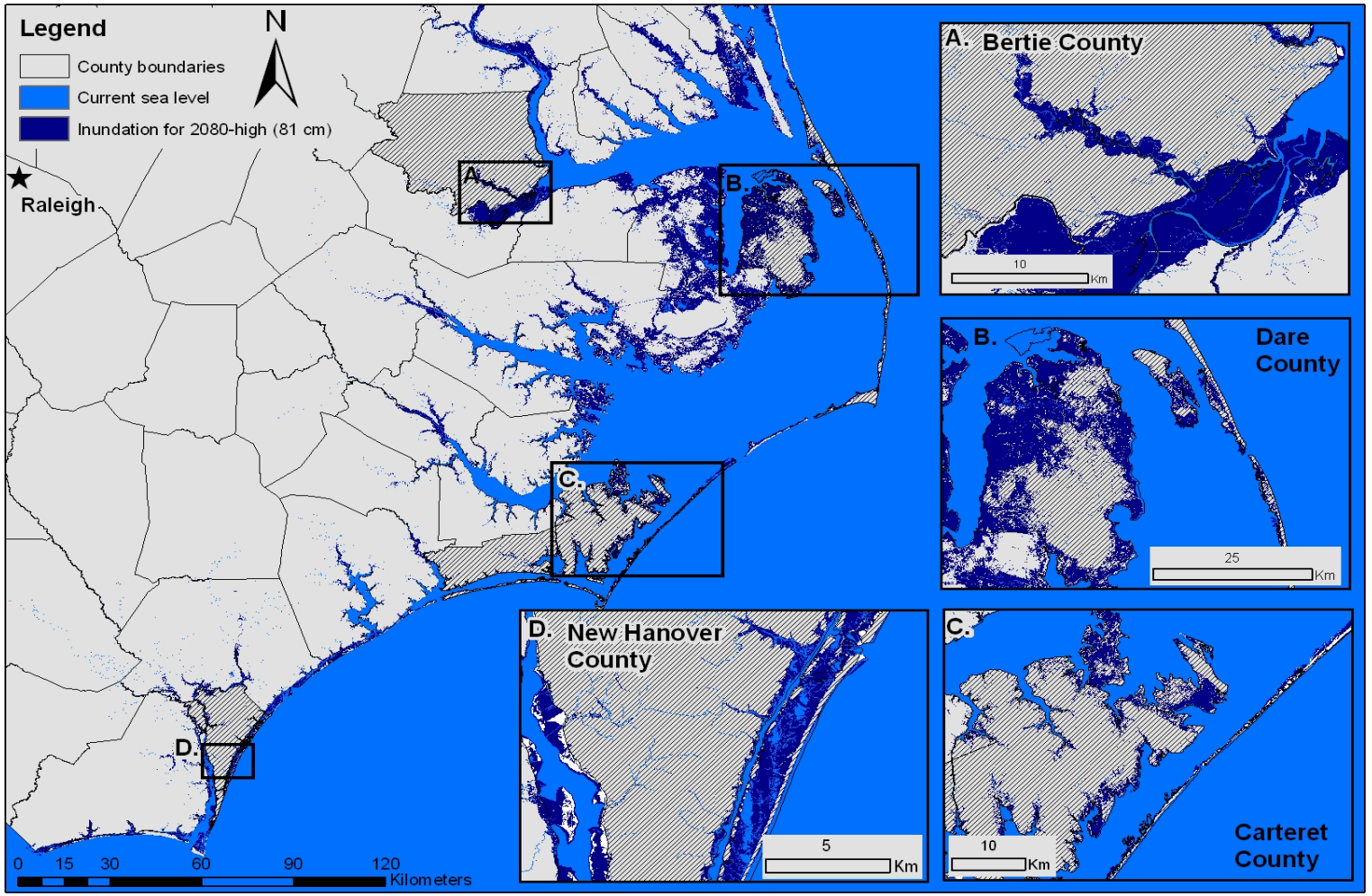




Sea Level Rise Scenarios

Year	Scenario	Projected sea level rise (m)
2030	Low	0.11
	Mid	0.16
	High	0.21
2080	Low	0.26
	Mid	0.46
	High	0.81

Inundation for 2080-High



Hedonic Property Value Models

- Loss of property values due to SLR is estimated by a simulation approach based on the hedonic method.
- This approach links property value to structural, location, and environmental characteristics.
- Assume no adaptation that coastal communities and property owners may undertake as they observe sea level rise over time.

Estimation Methods

- The baseline hedonic models are estimated for residential & nonresidential properties.

$$\ln \boldsymbol{R} = \alpha + \sum_i \beta_i \boldsymbol{S}_i + \sum_j \gamma_j \boldsymbol{N}_j + \sum_k \phi_k \boldsymbol{E}_k + \boldsymbol{\varepsilon}$$

- The net loss in property values from sea level rise in year *t* is estimated by

$$Net\ \mathrm{Loss}_t = \delta \cdot \left\{ \boldsymbol{R}_{LOST,t} - A_{LOST,t} + \Delta \boldsymbol{R}_{INV,t} \right\}.$$

Current Property Values subject to SLR - New Hanover

	Property Values ($mil)	Lost Property Values for Various Sea Level Rise Scenarios					
		2030-Low	2030-Mid	2030-High	2080-Low	2080-Mid	2080-High
Total	$16,154.42	$80.36	$84.42	$88.87	$95.19	$123.01	$227.70
(n)*	85,786	495	516	544	574	680	1,063
(%)*		0.50%	0.52%	0.55%	0.59%	0.76%	1.41%
Residential	$11,688.36	$62.15	$66.20	$70.59	$72.85	$90.72	$167.40
(n)	74,984	345	360	385	403	476	773
(%)		0.53%	0.57%	0.60%	0.62%	0.78%	1.43%
Nonresidential	$4,466.06	$18.21	$18.21	$18.28	$22.34	$32.29	$60.31
(n)	10,802	150	156	159	171	204	290
(%)		0.41%	0.41%	0.41%	0.50%	0.72%	1.35%

Current Property Values subject to SLR - Dare

	Property Values ($mil)	Lost Property Values for Various Sea Level Rise Scenarios					
		2030-Low	2030-Mid	2030-High	2080-Low	2080-Mid	2080-High
Total	$18,800.01	$1,142.87	$1,241.80	$1,332.87	$1,623.00	$2,224.75	$3,544.75
(n)*	38,780	1,506	1,725	1,965	2,331	4,004	7,716
(%)*		6.08%	6.61%	7.09%	8.63%	11.83%	18.86%
Residential	$12,262.76	$365.99	$410.84	$461.92	$521.55	$906.67	$1,801.99
(n)	27,006	825	927	1,051	1,225	2,143	4,371
(%)		2.98%	3.35%	3.77%	4.25%	7.39%	14.69%
Nonresidential	$6,537.25	$776.88	$830.97	$870.95	$1,101.45	$1,318.07	$1,742.76
(n)	11,774	681	798	914	1,106	1,861	3,345
(%)		11.88%	12.71%	13.32%	16.85%	20.16%	26.66%

Current Property Values subject to SLR - Carteret

	Property Values ($mil)	Lost Property Values for Various Sea Level Rise Scenarios					
		2030-Low	2030-Mid	2030-High	2080-Low	2080-Mid	2080-High
Total	$8,217.34	$172.08	$176.38	$185.82	$202.38	$260.33	$433.40
(n)*	55,509	1,077	1,140	1,225	1,322	1,977	3,890
(%)*		2.09%	2.15%	2.26%	2.46%	3.17%	5.27%
Residential	$5,960.24	$42.83	$45.53	$49.41	$56.12	$92.29	$208.05
(n)	34,073	192	207	228	261	468	1,204
(%)		0.72%	0.76%	0.83%	0.94%	1.55%	3.49%
Nonresidential	$2,257.10	$129.25	$130.85	$136.41	$146.26	$168.05	$225.35
(n)	21,436	885	933	997	1,061	1,509	2,686
(%)		5.73%	5.80%	6.04%	6.48%	7.45%	9.98%

Current Property Values subject to SLR - Bertie

	Property Values ($mil)	Lost Property Values for Various Sea Level Rise Scenarios					
		2030-Low	2030-Mid	2030-High	2080-Low	2080-Mid	2080-High
Total	$1,001.18	$5.25	$6.06	$6.63	$6.75	$8.45	$12.57
(n)*	17,502	72	81	93	99	126	174
(%)*		0.52%	0.61%	0.66%	0.67%	0.84%	1.26%
Residential	$727.09	$3.22	$3.73	$3.92	$4.04	$4.99	$7.66
(n)	15,777	55	61	68	73	91	126
(%)		0.44%	0.51%	0.54%	0.56%	0.69%	1.05%
Nonresidential	$274.09	$2.03	$2.33	$2.71	$2.71	$3.46	$4.91
(n)	1,725	17	20	25	26	35	48
(%)		0.74%	0.85%	0.99%	0.99%	1.26%	1.79%

Residential Property Values at Risk (NHC)

Residential	Discount Rate							
	No Discounting		2%		5%		7%	
SLR Scenario	$ (millions)	%	$ (millions)	%	$ (millions)	%	$ (millions)	%
2030-Low	$61.82	0.35%	$36.94	0.21%	$17.39	0.10%	$10.64	0.06%
2030-Mid	$65.49	0.37%	$39.14	0.22%	$18.42	0.10%	$11.28	0.06%
2030-High	$69.72	0.39%	$41.66	0.23%	$19.61	0.11%	$12.00	0.07%
2080-Low	$151.56	0.41%	$90.57	0.24%	$42.62	0.11%	$26.10	0.07%
2080-Mid	$194.37	0.52%	$116.15	0.31%	$54.66	0.15%	$33.47	0.09%
2080-High	$354.14	0.96%	$211.63	0.57%	$99.60	0.27%	$60.98	0.16%

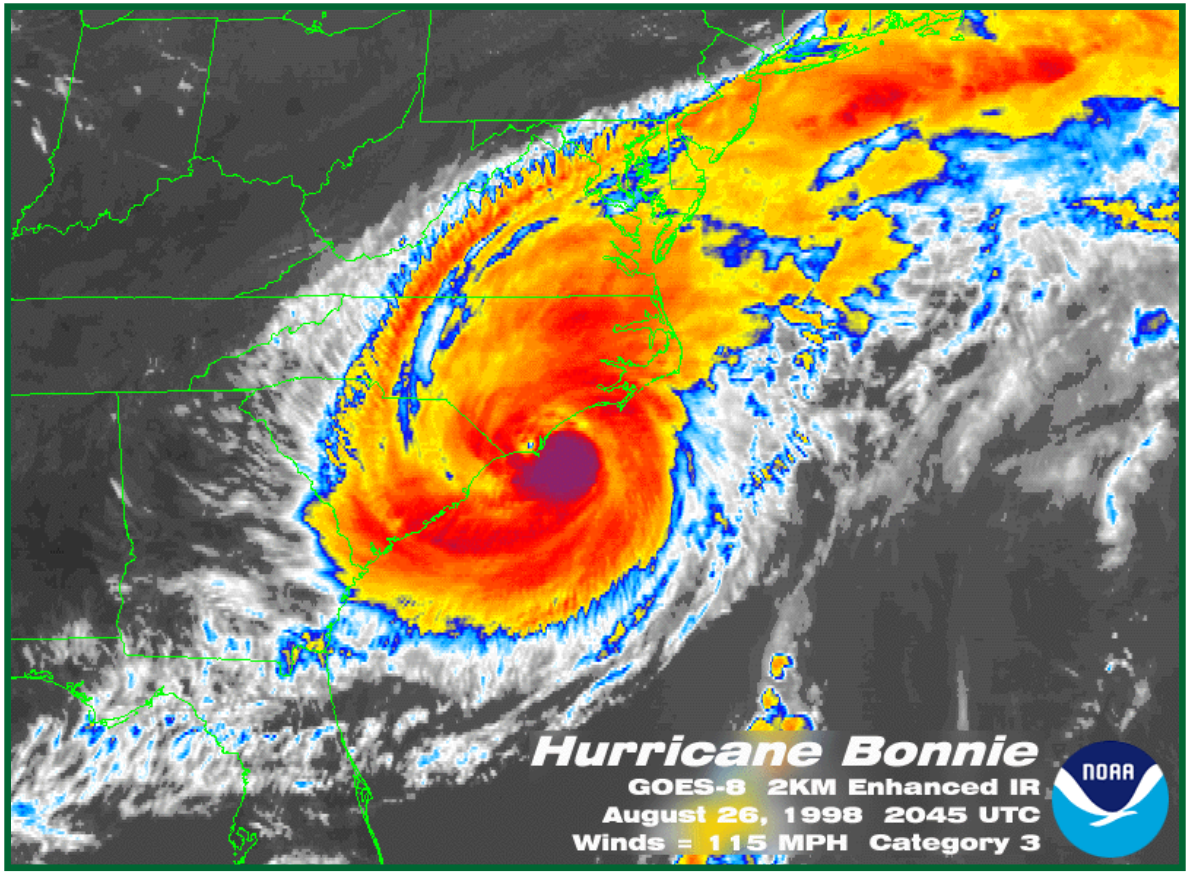
Summary

- We estimate the loss of property values due to sea level rise using a simulation approach based on hedonic property value models.
- The impacts of sea level rise on coastal property values vary across different portions of the North Carolina coastline.
- The northern part of the North Carolina coastline is comparatively more vulnerable to the effect of sea level rise than the southern part. The residential property value at risk in Dare County ranges from 1.3% to 6.9% of the total residential property value.

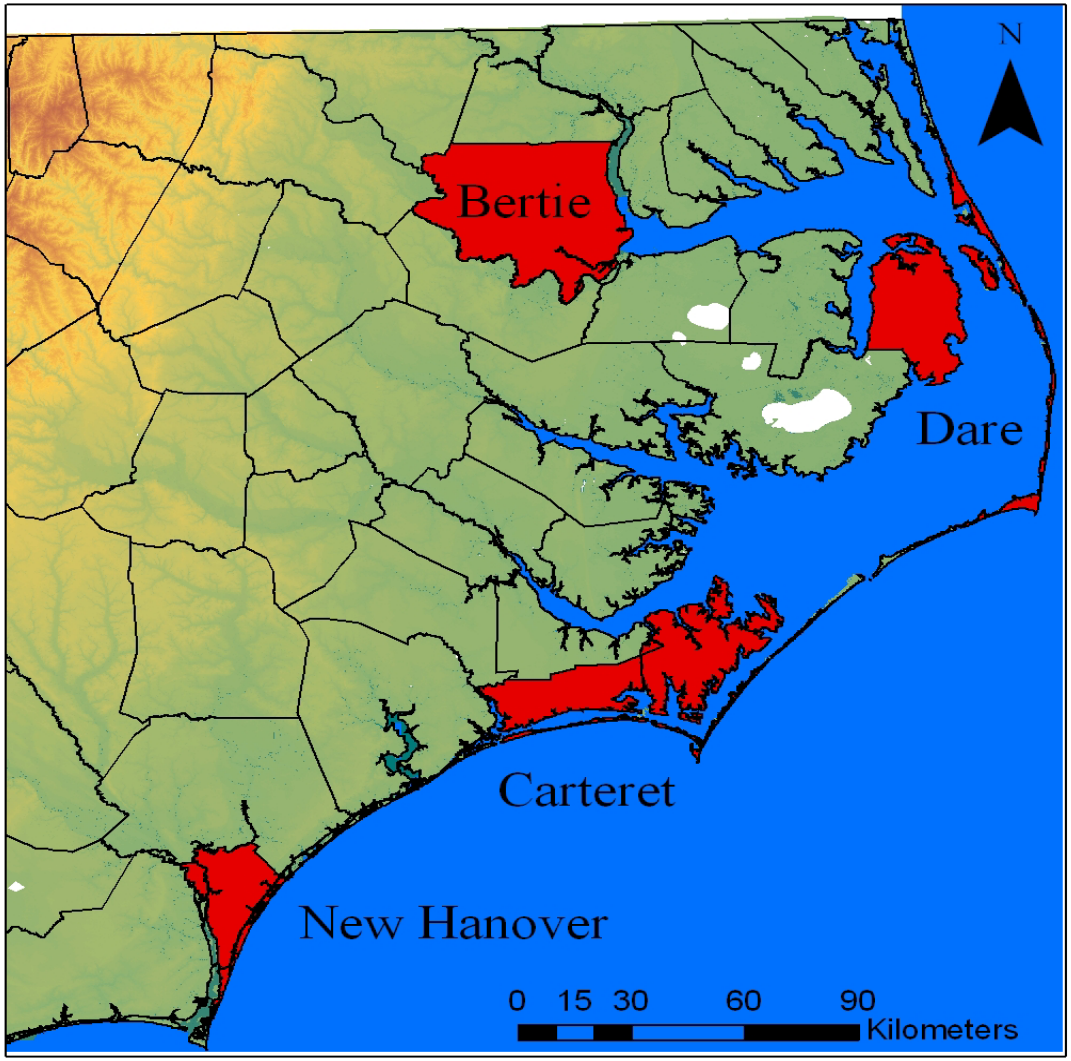
Summary

- The value of property at risk to sea-level rise in just four counties over the next 75 years is $6.9 billion.
- The present value of lost residential property value in 2080 is $3.2 billion discounted at a 2% rate.
- The present value of lost nonresidential property value in 2080 is $3.7 billion at a 2% rate.

Storm Impacts



Study Area



Changes in Hurricane Intensity

Hurricane categories for baseline and climate change scenarios

	Category 3 Hurricane (Hurricane Fran Track) Baseline Scenario	Climate Change Scenarios	
	1996	2030	2080
County	MAX	MAX	MAX
Bertie	TS	TS	TS
Carteret	1	2	2
Dare	TS	1	1
New Hanover	2	2	3

TS = tropical storm, 1 = category 1 hurricane, 2 = category 2 hurricane, etc.

Assume No Changes in Hurricane Frequency

Observed annual hurricane strike frequencies

Hurricane Category	1	2	3	4	5
Number of Strikes in North Carolina 1851-2006	23	13	11	1	0
Annual Frequency	0.1474	0.0833	0.0705	0.0064	0.0000

Full Business Day Equivalents Lost

Source: Burrus, Dumas, Farrell and Hall (Natural Hazards Review 2002)

Industry Name	Bertha (Cat 1)	Bonnie (Cat 2)	Fran (Cat 3)
Boat Building and Repairing	6.54	32.21	104.46
Amusement and Recreation Services	9.94	17.78	89.03
Food Stores	12.92	27.08	23.25
New Residential Structures	12.96	6.33	34.25
Electrical Repair Service	1.00	4.00	42.50
Furniture & Home Furnishings Stores	8.58	4.92	31.58
Real Estate	10.74	8.24	11.72
Miscellaneous Retail	8.02	4.19	14.27
Banks	6.31	2.88	14.35
Radio and TV Broadcasting	2.00	8.75	12.38
Hotels and Lodging Places	0.83	0.60	21.35
Weighted Means Over ALL Sectors	3.75	4.66	12.61

Business Interruption Impacts

- Business interruption losses in just four NC counties
  - Dare, Bertie, Carteret, New Hanover
  - Allows industry mix to vary across counties
  - Does not include agriculture, forestry, or comm. fisheries
- Due to increases in category 3 hurricane severity ONLY
  - $34 million increase per storm by 2030
  - $157 million increase per storm by 2080
- Cumulative impact 2004-2080
  - $373 million assuming no pop or income growth
  - $1.44 billion assuming proj. state pop and per capita income growh

Impacts on Agriculture

- Based on historical NC Agri. Stats. Service data:
  - Cat 1 hurricane -- $50 million in agricultural damage
  - Cat 2 -- $200 million
  - Cat 3 -- $800 million.

- Increases in storm intensity, even for low-intensity hurricanes, could have serious impacts on agriculture.

Impacts on Forestry

- Less data available for forest sector.
- Based on historical NC Forest Service Timber Damage Assessment data:
  - Cat 2 hurricane (Isabel 2003) – $578 million statewide ($2004)
  - Cat 3 hurricane (Fran 1996) -- $1.496 billion statewide ($2004)
- Based on this limited data, an increase in storm severity from category 2 to category 3 can increase forest damage by $900 million.
  - Caveat: Fran may have “cleared out” weaker trees, leaving fewer trees for Isabel to damage. If so, incremental impacts of severity increases would be smaller.

Potential Impacts of Climate Change on NC's Coastal Economy

- Potential Impacts over the next 75 years:
  - Lost recreational benefits total $3.9 billion
  - The value of property at risk to sea-level rise in just four counties is $6.9 billion
  - Business interruption, agriculture and forestry losses are also substantial
  - Assumes no increase in storm frequency – look forward to new results from climate and weather modelers that would allow us to update our impact estimates
- These are *potential* impacts, assuming no adaptation or mitigation.
- These results facilitate comparison of policy costs and benefits. *Avoiding these potential impacts is a measure of the benefits of adaptation and mitigation policies*.

Additional Research Underway:

- UNC Research Competitiveness Fund has approved funding for additional research on “NC Coastal Hazards: Economic Implications of Severe Storms and Sea-Level Rise”
- $288K
- Joint work: ECU-lead (Steve Culver & Stan Riggs), WCU, ASU, UNCW, CSI.
- Report due this summer.

http://econ.appstate.edu/climate

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Measuring the Impacts of Climate Change on North Carolina Coastal Resources

Okmyung Bin, East Carolina University, **Chris Dumas**, University of North Carolina at Wilmington; **Ben Poulter**, Duke University and Potsdam Institute for Climate Impact Research; and **John Whitehead**, Appalachian State University

Global warming is projected to have significant impacts on North Carolina coastal resources as sea level rises and hurricanes become more intense. Extensive development in the coastal zone in recent decades has put more people and property at risk for these impacts. In this context, a scientific study was undertaken by researchers at four North Carolina universities to consider three important aspects of the coastal economy and their vulnerability to a changing climate: the impacts of sea-level rise on the coastal real estate market, the impacts of sea-level rise on coastal recreation and tourism, and the impacts of stronger tropical storms and hurricanes on business activity.

The study used a range of moderate assumptions, not best- or worst-case scenarios. Its focus was only the specific economic impacts mentioned above, and as such, it does not attempt to provide a comprehensive analysis of all potential impacts, such as the possible loss of species or the natural ecosystems in which they live.

Download the summary:
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