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Managing the Anthropocene marine transgression to the year 2100 and beyond in the State of Florida U.S.A.

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Abstract We simulate the vulnerability of all 35 Florida coastal counties to the ongoing Anthropocene marine transgression using a bathtub model unconstrained by the artificial end date of year 2100. Our projections are based upon the association between rising sea level and atmospheric temperature; a 2.3 m rise per each 1 °C increase (Levermann et al., Proc Natl Acad Sci 10.1073/pnas.1219414110, 2013). Results are organized into seven regions based upon an assessment of hypsographic and geologic attributes. Each represents an area of common vulnerability characterized in this study as high (10 to 29 % average land loss), higher (15 to 77 % average land loss), and highest (43 to 95 % average land loss). This regional approach is designed to facilitate the implementation of effective adaptation activities by providing a logical basis for establishing or re-enforcing collaboration based upon a common threat and the utility of shared technical and financial resources. The benefits of a regional perspective in formulating an actionable response to climate change have already been demonstrated in south Florida. It is our intent to facilitate regional adaptation activities in other parts of the state and adjacent southern and southeastern seaboard.

1 Introduction

The State of Florida is especially vulnerable to climate change and concomitant sea level rise. Elevations in the coastal zone and southern peninsula are low (Fig. 1) and already subject to flooding during intense rainfall events, exceptional tides, and storm surge. The near-surface

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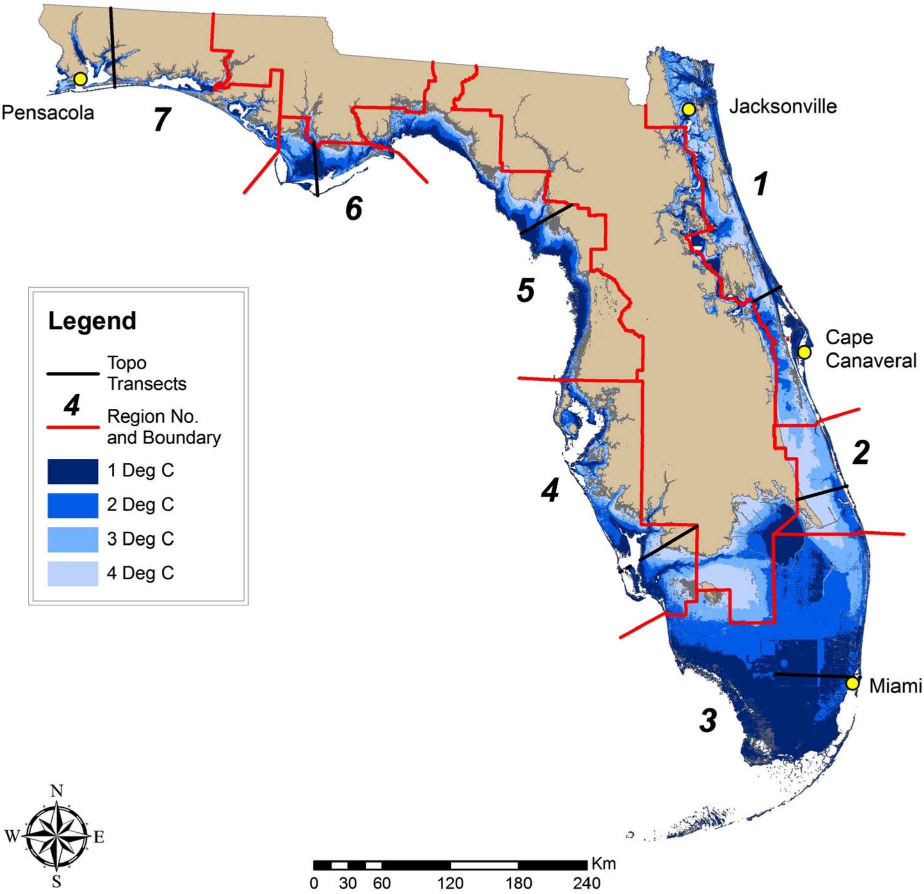

Fig. 1 Florida base map showing extent of submergence associated with an atmospheric temperature increase of between 1 °C (*darkest blue*) and 4 °C (lightest blue). For each one degree rise in temperature, sea level was elevated 2.3 m (Levermann et al. 2013). *Red lines* depict boundaries of seven regions with common vulnerability to sea level rise as defined in this study. *Black* shore-perpendicular *lines* indicate location of representative topographic profiles shown in Fig. 2

geology of coastal counties consists primarily of unconsolidated sand and porous limestone through which water is easily transmitted, further exacerbating the magnitude and extent of coastal and inland flooding. The extensive barrier island system, upon which much of the tourism-based economy relies, is vulnerable to erosion.

To complicate matters, the state's population grew nearly 20 % during the last decade (Ingram et al. 2013). New residents and businesses have generally settled in low lying coastal areas and this trend is unlikely to change anytime soon (Dow and Carter 2013). More than half of the state's population now lives within 5 miles of the coastline (Murley et al. 2003).

Planning for the effects of climate change and sea level rise in the state requires the successful completion of a sequence of five adaptation activities: (1) identification of specific risks, (2) assessment of vulnerability, (3) development and (4) implementation of an adaptive management plan, and thereafter (5) plan updates and revisions as new information becomes available (c.f. Dow and Carter 2013). Most adaptation activities have focused on the first two; the identification of risk and assessment of vulnerability (c.f. Treasure Coast Regional

Planning Council 2005; Deyle et al. 2007; Harrington and Walton 2007; Stanton and Ackerman 2007; Beever III et al. 2009a, 2010a; Parkinson and McCue 2011; Zhang et al. 2011). The subsequent development and implementation of adaption plans has been slow however, and there are currently few examples in the state of Florida (c.f. Beever III et al. 2009b, 2010b; Southeast Florida Regional Climate Change Compact 2012; Monroe County 2013). This is in part a consequence of serious 'science gaps' in which decision makers lack the appropriate information or the means to implement adaptive planning recommendations (Moss et al. 2013). Furthermore, applicable science is frequently delivered in a format that does not facilitate comprehension by decision makers. This 'usability gap' must be closed by delivering adaptation science in a decision-relevant context (Parkinson 2009; Moss et al. 2013).

To be sure, developing effective adaptation strategies to reduce the risks associated with sea level rise and sustain resiliency of the built and natural coastal environment presents an enormous challenge (Williams and Gutierrez 2009). Current options include: protect and defend, accommodate, strategic withdrawal or do nothing (c.f. Deyle et al. 2007). But suppose you are a planner who is asked to include the potential impact of climate change or sea level rise in your risk management and planning efforts. What are the first steps towards ensuring resiliency of your coastal community? What information would you need? How can social and economic decisions like these be made by local, regional, or even state government agencies? One thing is clear, failing to adapt is not a viable option (Hallegatte et al. 2013).

We simulate Florida's vulnerability to the ongoing Anthropocene (c.f. Syvitski 2012) marine transgression applicable beyond the year 2100 using a bathtub model. The focus on an end date of 2100 is problematic because it encourages people to take the estimated result as an indication of what humanity faces. This is untrue because the rate and magnitude of sea level rise during the next century will be much larger than that experienced this century, especially if emissions continue to increase (Hansen et al. 2013). Our projections are based upon the association between rising sea level and atmospheric temperature; a 2.3 m rise per each 1 °C increase (Levermann et al. 2013).

The results of our analysis are organized into seven regions. Each region represents an area of common risk and vulnerability. This approach was designed to facilitate effective adaptive management planning and implementation by providing a logical basis for establishing or re-enforcing regional collaboration based upon a common threat and the utility of shared technical and financial resources. The benefits of a regional perspective to help formulate an actionable response to climate change have already been demonstrated in south Florida. It is our intent to facilitate the expansion of regional collaboration to other parts of the state and adjacent southern and southeastern seaboard.

2 Background

Increasing carbon dioxide from fossil fuel emissions is now the main cause of changes in the Earth's atmospheric composition and thus future climate (Solomon et al. 2009). A doubling of pre-Industrial Revolution (IR) levels (i.e., 280 ppm) is now likely within the next 20 years and concentrations may pass 1000 ppm by the end of this century (IPCC 2013). Even under a zero emissions scenario, the adverse and irreversible climate changes triggered by elevated anthropogenic atmospheric carbon dioxide levels are not expected to be completely neutralized for several millennia (Archer 2005; Solomon et al. 2009; Armour and Roe 2011).

Atmospheric temperature projections caused by rising carbon dioxide concentrations have continuously increased and are not expected to decrease significantly over the next several centuries even if carbon emissions were to completely cease today (Solomon et al. 2009). Temperature change will likely exceed +2 °C relative to pre-IR levels by the end of this century and an increase of 4 °C is now considered possible (Nicholls et al. 2011; IPCC 2013; Sherwood et al. 2014; Sanford et al. 2014).

In response to ever increasing atmospheric temperature, global mean sea level is forecast to rise at an accelerating rate. By the year 2100 most projections suggest it will rise by as much as 2 m, with low estimates averaging about 0.5 m above present (c.f. Rahmstorf 2007; Vermeer and Rahmstorf 2009; Parris et al. 2012; IPCC 2013). It is virtually certain that global mean sea level will continue to rise beyond 2100 as new and residual carbon dioxide emissions further elevate atmospheric temperatures. Depending upon the scenario, sea level could potentially rise 3 m or more during the next century (Goelzer et al. 2012; Jevrejeva et al. 2012; Schaeffer et al. 2012; Horton et al. 2013; Rohling et al. 2013).

3 Methods

3.1 Vulnerability simulation

The effect of rising sea level was simulated in all 35 Florida coastal counties using a bathtub model (c.f. NOAA 2010). The model assumes the shoreline migrates across a static landscape in response to sea level rise with minimal change in the physical and biological materials being transgressed. All features at or below the selected sea level elevation are submerged.

Four vulnerability simulations were conducted, each representing the extent of submergence associated with an atmospheric temperature increase of between 1 and 4 °C. For each one degree rise in temperature, sea level was elevated 2.3 m (Levermann et al. 2013). The extent of submergence, and hence vulnerability of each coastal county, was initially illustrated on a base map and further quantified by construction of hypsographic curves depicting the cumulative percent of total land area (x axis) submerged by increasing sea level elevation (y axis). The vertical datum used in this study was NAVD88.

3.2 Regional grouping

The grouping of adjacent coastal counties into regions of similar vulnerability was based primary upon visual inspection of their respective hypsographic curves. Curves from adjacent counties were added or removed from a common plot until a cluster of similarly shaped curves was optimized. This initial grouping into regions was further evaluated by geologic analysis; i.e., inspection of geologic features (c.f. Scott et al. 2001) and corresponding topographic profiles associated with all coastal counties within a proposed region.

Six geologic features were identified as indicators of potential vulnerability to rising sea level and organized into two categories: Holocene and relict (Table 1). Holocene features are typically less than a few thousand years old, rarely rise more than a few meters above sea level, and associated with the modern coastline. These include barrier islands, coastal wetlands, and estuarine embayments. *Barrier islands* (i.e., Miami Beach, St. Petersburg Beach, Pensacola Beach) are low-relief features generally less than a few kilometers wide and separated from the mainland by a shore parallel shallow lagoon or estuary. *Coastal wetlands* (i.e., Ten Thousand Islands, St. Marks Wildlife Refuge) refer to segments of the Florida mainland shoreline hosting extensive tidal and/or freshwater wetland environments. *Estuarine embayments* (i.e. Charlotte Harbor, St. Andrew Bay) are hydraulically coupled with the ocean and extend inland at

Table 1 Summary of Florida coastal county attributes associated with the seven regions of similar vulnerability to sea level rise forecast to accompany a 1 to 4 °C rise in atmospheric temperature

Region	Counties	Number of topo graphic profiles evaluated	Geologic features						Cumulative land loss (%)				FRPC
			Holocene			Relict							
			1 Barrier Island	2 Coastal Wetland	3 Estuarine Embayment	4 Ridge	5 Interior Lowland	6 Exposed Limestone	1 °C	2 °C	3 °C	4 °C	
Region 1 North Atlantic Coast	Nassau	1	•			•	•		18	32	52	58	NE
	Duval	2	•			•	•		21	35	56	67	
	St Johns	2	•			•	•		24	38	51	77	
	Flagler	1	•			•	•		14	33	59	94	
	Volusia	3	•			•	•		24	33	43	65	EC
	Brevard	5	•			•	•		21	43	75	96	
Region 2 Central Atlantic Coast	Indian River	2	•			•			5	8	45	91	TC
	St Lucie	3	•			•			5	17	50	95	
	Martin	3	•			•			15	38	54	90	
Region 3 South Florida	Palm Beach	6	•			•	•		22	74	97	100	
	Broward	2	•			•	•		42	99	100	100	SF
	Dade	5	•			•	•	•	90	100	100	100	
	Monroe	3		•			•	•	99	100	100	100	
	Collier	5	•	•			•	•	34	82	94	100	SWF
Region 4 South Gulf Coast	Lee	2	•		•				29	52	81	99	
	Charlotte	2	•		•				24	32	42	66	
	Sarasota	2	•						8	33	51	76	
	Manatee	1	•		•	•			7	13	23	31	TB

Table 1 (continued)

Region	Counties	Number of topo graphic profiles evaluated	Geologic features						Cumulative land loss (%)				FRPC
			Holocene			Relict							
			1 Barrier Island	2 Coastal Wetland	3 Estuarine Embayment	4 Ridge	5 Interior Lowland	6 Exposed Limestone	1 °-C	2 °-C	3 °-C	4 °-C	
	Hillsboro	2			•	•			7	12	18	25	
	Pinellas	3	•		•	•			29	55	68	74	
Region 5 Big Bend	Pasco	2		•		•		•	4	7	11	15	
	Hernando	1		•		•		•	13	17	20	23	W
	Citrus	1		•		•		•	22	28	31	34	
	Levy	3		•		•		•	18	30	37	47	
	Dixie	1		•		•		•	18	35	48	62	NCF
	Taylor	3		•		•		•	12	19	26	41	
	Jefferson	1		•		•		•	4	9	13	19	A
	Wakulla	1		•		•		•	15	30	45	55	
Region 6 East Panhandle	Franklin	3	•				•		30	62	82	95	
	Gulf	2	•				•		27	52	74	84	
Region 7 West Panhandle	Bay	2	•		•	•			11	22	31	38	WF
	Walton	2	•		•	•			6	10	14	18	
	Okaloosa	1	•		•	•			2	5	7	9	
	Santa Rosa	2	•		•	•			6	12	16	19	
	Escambia	1	•		•	•			6	11	15	19	

Regional associations based upon similarity of county hypsographic curves and geologic attributes (i.e., topographic profiles, geologic features numbered 1–6). See also Fig. 2. Counties listed clockwise from northeast corner of state. Also shown are Florida Regional Planning Council (FRPC) county affiliations (*NE* Northeast, *EC* East Central, *TC* Treasure Coast, *SF* South Florida, *SWF* Southwest Florida, *TB* Tampa Bay, *W* Withlacoochee, *NCF* North Central Florida, *A* Apalachee, *WF* West Florida) relatively high angle to the coastline along depressions in the mainland's antecedent topography. The magnitude of risk to rising sea level is directly proportional to the presence of one or more of these features.

Relict features are elements of Florida's terrain formed more than 100,000 years ago during a period when sea level was at or above its present elevation. These include ridges, interior lowlands, and exposed limestone. *Ridges* (i.e. Atlantic Coastal Ridge, Brooksville Ridge, Western Highlands) are linear, high relief (5+ m) deposits of sand or limestone oriented roughly parallel to the adjacent modern coastline. In contrast, *interior lowlands* (i.e., St. Johns River Basin, Florida Everglades, Yellow River Basin) are low areas in the mainland's antecedent topography which contain extensive freshwater wetland environments. *Exposed limestone* (i.e., Miami Limestone, Ocala Limestone) is present at or very near (<0.5 m) the land surface along some segments of the Florida coastal zone. Their elevation is typically within a few meters of present sea level. The magnitude of risk to rising sea level is inversely proportional to the presence of relict ridges. The magnitude of risk is directly proportional to the presence of interior lowlands and exposed limestone features.

Topographic profiles were constructed on approximately 15 km centers along transects perpendicular to the Florida coastline and extended to each county's inland boundary. The shape of each profile is indicative of specific geologic features (i.e., Holocene barrier island, relict ridge) and associated sedimentological processes (i.e., deposition, erosion, cementation) responsible for the formation and subsequence evolution of the landscape through which each transect was constructed. The construction of topographic profiles thus compliments the analysis of geologic features previously described. The shape of each profile is also a proxy for vulnerability because it provides information regarding when and *where* submergence will occur. A graph containing all profiles within a proposed region was constructed to evaluate similarity of geomorphic form. Again, plots from adjacent counties were added or subtracted to optimize similarity within a proposed region. One topographic profile was ultimately selected by visual comparison as 'representative' of each region.

4 Results

Based upon our analysis of 35 county hypsographic curves, six geologic features, and 81 topographic profiles, the state of Florida is logically devisable into seven regions (Figs. 1 and 2, Table 1). These regional associations translate to areas of similar vulnerability to sea level rise characterized in this study as high (10 to 29 % average land loss), higher (15 to 77 % average land loss), and highest (43 to 95 % average land loss) (Fig. 3, Table 1).

4.1 High vulnerability

Regions 5 and 7 are included in the high vulnerability category. Region 5 includes Pasco, Hernando, Citrus, Levy, Dixie, Taylor, Jefferson, and Wakulla Counties. In contrast to adjacent regions, Holocene barrier islands are not present along this segment of the Florida coast. This region is host to coastal wetlands and exposed limestone, however significant relief associated with relict ridges (i.e., Brooksville Ridge) reduces risk and yields a 'high' vulnerability classification.

Region 7 consists of Bay, Walton, Oskaloosa, Santa Rosa, and Escambia counties. A mixture of Holocene barrier islands and expansive estuarine embayments (i.e.,

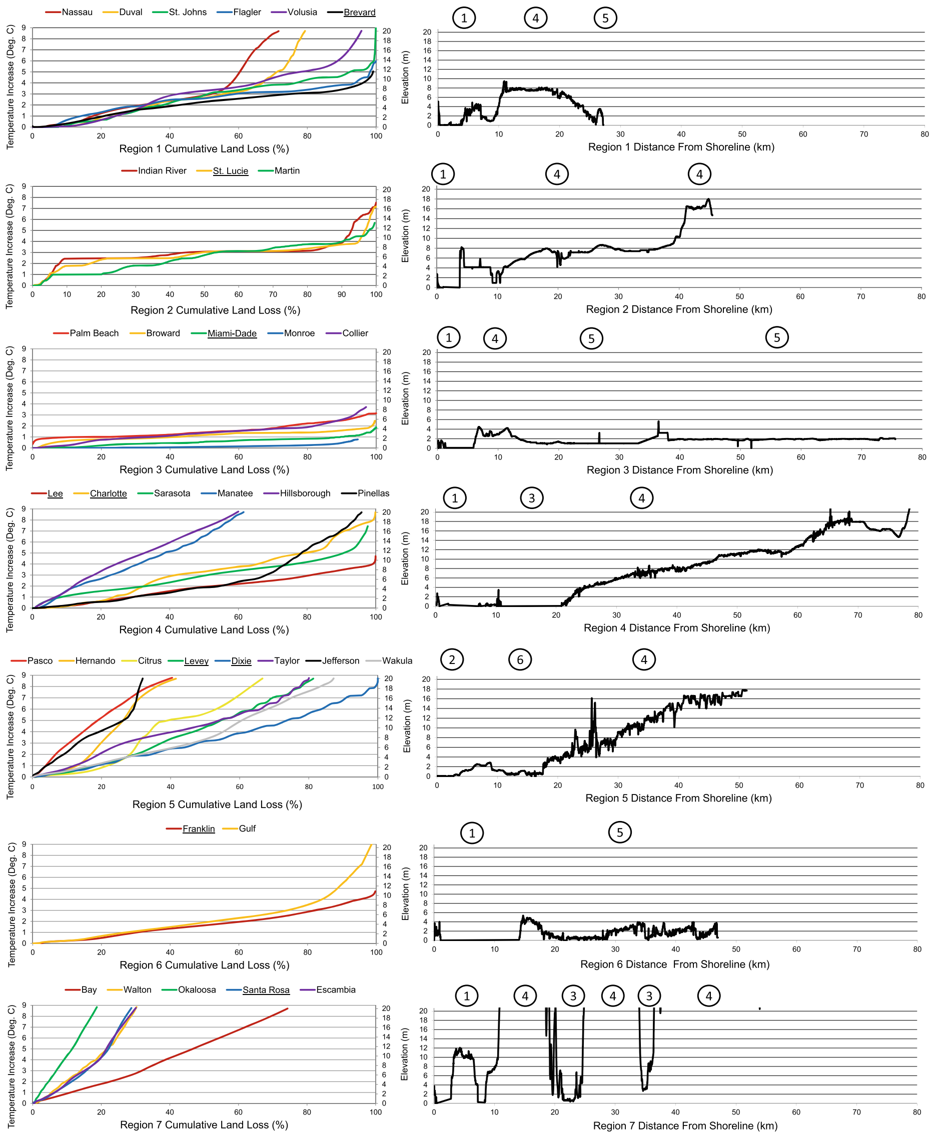

Fig. 2 Florida coastal county hypsographic curves (*left panel*) and representative topographic profiles (*right panel*) associated with the seven regions of similar vulnerability to rising sea level forecast to accompany a 1 to 4 °C rise in atmospheric temperature. *Underlined* hypsographic curve series label in left panel identifies county from which the representative topographic profile was generated. All elevations truncated at 20 m to retain common scale. See Fig. 1 for profile locations and Table 1 for key to geologic features numbered 1 through 6

Pensacola Bay) are the distinguishing features of this region of the Florida coastline. However, Region 7 is placed in the 'high' vulnerability category because of the presence of regionally significant relict ridges (i.e., Western Highlands) and associated high elevations unmatched by any other Florida coastal county.

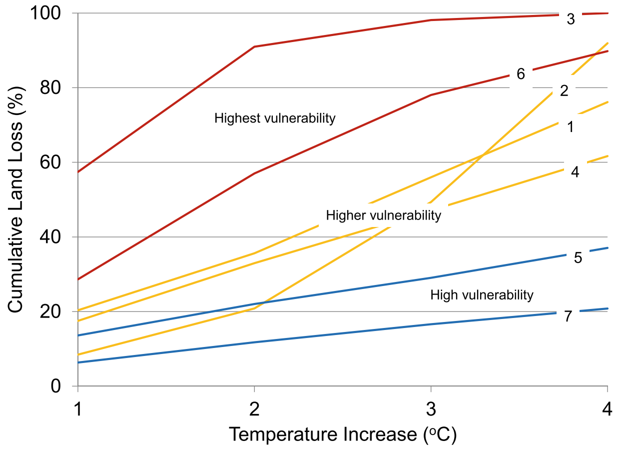

Fig. 3 Vulnerability of Regions 1 through 7 to sea level rise associated with a 1 to 4 °C increase in atmospheric temperature

4.2 Higher vulnerability

Regions 1, 2, and 4 are included in the higher vulnerability category. Region 1 consists of Nassau, Duval, St. Johns, Flagler, Volusia, and Brevard counties. It is distinguished from the adjacent Region 2 by the presence of extensive shore parallel interior lowlands associated with the St. Johns River basin. Its classification in the 'higher' vulnerability category reflects a geomorphic landscape consisting of a mixture of both low lying features (i.e., Holocene barrier islands, St. Johns River basin) and relict high relief ridges (i.e., Atlantic Coastal Ridge).

Region 2 consists of Indian River, St. Lucie, and Martin counties. The geomorphology of this region is similar to Region 1 because it includes a mixture of both low lying coastal features (i.e., Holocene barrier islands) and an elevated topography associated with relict ridges. However, the expansive, shore parallel interior lowlands of the St. Johns River basin are not present. Although classified in the 'higher' vulnerability category, the absence of the St. Johns River basin makes the region less vulnerable to the initial 2 °C temperature increase and associated rise in sea level than Region 1 (Fig. 3).

Region 4 includes Lee, Charlotte, Sarasota, Manatee, Hillsborough, and Pinellas counties. It is distinguished from adjacent regions by the presence of well-developed barrier islands and large estuarine embayments (i.e., Caloosahatchee River, Charlotte Harbor, Tampa Bay). Like the other two regions in this vulnerability category, it is classified as 'higher' because the geomorphic landscape consists of a mixture of both low lying coastal terrain and an elevated topography associated with relict ridges.

4.3 Highest vulnerability

Regions of highest vulnerability include 3 and 6. Region 3 consists of Palm Beach, Broward, Miami-Dade, Monroe, and Collier counties. It is distinguished from adjacent regions by the presence of extensive low lying areas associated with Holocene coastal wetlands, relict interior lowlands (i.e., the Everglades), and exposed limestone. The absence of significant geomorphic relief results in this region being placed in the 'highest' vulnerability category.

Region 6 includes Franklin and Gulf counties. This region is distinguished by the presence of low lying Holocene barrier islands, interior lowlands (i.e., Apalachicola River basin), and absence of relict ridges. This geomorphology places Region 6 in the ‘highest’ vulnerability category.

5 Discussion

5.1 Utility of submergence simulations

The internet is now replete with maps depicting the extent of Florida’s vulnerability to predicted sea level rise that are based upon the bathtub model of submergence (c.f. Weiss et al. 2011). However, geologic studies of past and present shorelines indicate it may not be that simple; the rate of rise can be as important as the magnitude when predicting coastal response to sea level rise (c.f. Parkinson 1989). At slower rates of rise, wetlands may accrete vertically to keep pace with rising water levels and barrier islands or sandy coastlines may migrate inland while retaining their general geomorphic form. To determine the utility of the bathtub model as a representative simulation of Florida’s response to future sea level rise, we generated a summary of Florida’s coastal response to varying rates of sea level rise over the last 14,000 years (Table 2). These data clearly demonstrate predicted rates of sea level rise will result in widespread submergence by erosional shoreface retreat or overstep. The rate of rise will be too fast to be offset by the stabilizing forces of biogenic (i.e., vertical peat accretion) or physical (i.e., formation of coastal dunes or beach ridges) sediment accumulation. Hence the magnitude of land loss and associated shoreline retreat in each of the seven regions will be largely a function of topographic elevation and can be reasonably forecast using a bathtub model.

5.2 Management applications

Managing the consequence of sea level rise to reduce risk and sustain resiliency of the built and natural environment presents an enormous challenge. Current options include: protect and defend, accommodate, strategic withdrawal, or do nothing (c.f. Deyle et al. 2007). According to

Table 2 Observed and predicted Florida coastal response to sea level rise

Period	Time interval	Average rate of sea level rise (mm/yr)	Coastal response
Late Pleistocene to early Holocene	14,000 to 7000 ybp	>10	Coastal submergence via overstep
Mid Holocene	7000 to 3000 ybp	1 to 2	Coastal submergence via erosional shoreface retreat
Late Holocene	3000 to present	<1	Shoreline stabilization, aggradation and progradation
20th Century	1900 to 2000	2	Coastal submergence via erosional shoreface retreat
Recent	1993 to 2012	3.2	Coastal submergence via erosional shoreface retreat
Predicted	1990 to 2100+	5 to 20	Coastal submergence via erosional shoreface retreat and overstep (with increasing rate)

After Parkinson 1989; Parkinson and White 1994; Parkinson et al. 1994; Wanless et al. 1994; Parkinson and Donoghue 2010; Donoghue 2011

Titus et al. (2009), most of the Atlantic coast is developed to the extent the likely response to sea level rise will be construction of shore protection projects (i.e., dune and wetland restoration, beach nourishment, construction of seawalls and dikes). However, these traditional 'protect and defend' strategies will not be effective in the long term. For example, existing coastal wetlands may initially provide a short-term or temporary buffer to rising water levels. But these habitats will not keep pace and over time (decades) convert to open water as the rate of sea level rise increases (c.f. Parkinson et al. 1994; Table 2). Hence, focus should shift from protection, restoration, and management of *extant* habitat (c.f. Arkema et al. 2013) to the management of *potential* habitat along existing conservation corridors and acquisition of undeveloped buffer zones in adjacent upland areas (c.f. Erwin 2009; Beever III et al. 2012; Vargas et al. 2014).

Many property owners and government agencies have been engaged in coastal engineering and construction projects designed to protect and defend upland property. In the short term, sea level rise may simply increase the cost of these projects. However, this approach is not sustainable over the long term because rising sea level will ultimately exceed the tipping point between 'cost effective' strategies designed to mitigate shoreline erosion and reduce coastal flooding, and irreversible geomorphic change (Williams and Gutierrez 2009; Table 2). Furthermore, this type of construction does not address the increasing frequency and magnitude of flooding in low lying *inland* areas that will accompany rising seas given the permeability of Florida's coastal geology. Engineered shore protection projects can be used in the short-term, but only as a means of transitioning to long term adaptation activities like accommodation and ultimately strategic withdrawal (c.f. Parkinson and Donoghue 2010; Parkinson and McCue 2011; Kousky 2014).

5.3 Utility of regional approach

To date, successful efforts to develop and implement adaptation plans are typically conducted at a relatively small scale (i.e., individual communities; Parkinson and McCue 2011). However, effective adaptation activities to reduce the vulnerability of infrastructure (i.e., transportation, storm water and sewer systems), natural resources, water supplies, and so on, will require the implementation of plans that extend well beyond the geopolitical boundaries of individual municipalities and counties.

Each of the seven regions identified in this study share a common vulnerability to sea level rise. By combining resources and integrating adaptation into existing decision-making systems, the probability of ensuring resilience of the built and natural environments in each region are greatly enhanced. Certainly the co-benefits and synergies of multi-county collaboration are demonstrated by the continued progress being made in south Florida (c.f. Beever III et al. 2012; Southeast Florida Regional Climate Change Compact 2012).

While our focus is on coastal counties, we recognize in some regions the effects of sea level rise will extend further inland (c.f. Region 1). Hence, the boundaries proposed herein could be expanded inland in those areas. However, differences in the perception of risk and associated vulnerability of coastal and inland counties may complicate timely collaboration.

We also considered the contribution existing Florida Regional Planning Councils (FRPC) could make by providing a logical basis for initiating or re-enforcing regional collaboration. The FRPC were established in the 1970s to *improve the quality of life by coordinating growth management, protecting regional resources, promoting economic development and providing technical services to local governments*. So their involvement seems appropriate. However, the counties grouped into each of the seven regions proposed in this study are typically not the same as those assigned to each of the FRPC (Table 1). This may require a realignment of FRPCs boundaries if they are to effectively contribute towards the formulation and implementation of regional adaptation activities to reduce the vulnerability of Florida's coastal counties to rising sea level.

6 Concluding remarks

It is increasingly unlikely an increase in atmospheric temperature can be limited to less than 2 °C by the end of this century because the emissions gap (UNEP 2013) between targeted and expected levels of carbon dioxide will likely not be closed anytime soon. Furthermore, the longevity or residence time of existing carbon dioxide in the atmosphere dictates warmer temperatures and concomitant sea level rise for millennia to come (Solomon et al. 2009). The last time the earth's atmosphere was a couple of degrees warmer than today, sea level was at least 5 m higher than present (Kopp et al. 2009).

The Anthropocene marine transgression is already impacting major metropolitan areas in south Florida. The City of Miami Beach is now subject to frequent flooding during astronomic high tides (aka nuisance flooding; see Sweet et al. 2014) and intense rainfall events. City Commissioners voted in February 2014 to stop an *ongoing* stormwater construction project in favor of a redesign that factored in the short-term consequences of a changing climate. This work stop and subsequent construction was expected to cost an additional $200 million (Veiga 2014).

Implementing strategies to adapt to rising sea level is proving to be enormously challenging as it requires society to incur costs now for the benefit of future generations (Borisova et al. 2008). To facilitate progress, the appropriate science must be delivered in a decision-relevant context (c.f. Parkinson 2009; Moss et al. 2013). Otherwise, as time progresses it will become increasingly difficult to adequately prepare and implement adaptation activities.

Towards that end, we simulate Florida's vulnerability to sea level rise applicable beyond the year 2100 and provide forecasts unconstrained by this artificial end date that has masked the true magnitude of risk. The results are organized into seven regions, each representing an area of common vulnerability characterized in this study as high, higher, and highest. The benefits of a regional perspective in formulating an actionable response to climate change have already been demonstrated in south Florida. It is our intent to facilitate adaptation activities in other parts of the state and adjacent southern and southeastern seaboard by providing a logical basis for establishing or re-enforcing regional collaboration to reduce the risk posed by the ongoing Anthropocene marine transgression.

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