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Climate Change and Security: The Case of Florida

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Abstract

The low-lying subtropical Florida Peninsula, surrounded on three sides by the sea, is highly vulnerable to the manifestations of climate change. Rising sea levels are already responsable for significant coastal erosion that threatens infrastructure, real estate, and Florida's subtropical habitats. The State lies in the path of hurricanes whose winds and storm surges pose great threats to life and property. Rising temperatures are likely to impact the most vulnerable sectors of the population, adversely impact agriculture, and threaten the health of Florida's coral reef ecosystems. Some local governments are beginning to address the threats. However, the State of Florida irresponsibly continues to take a "business-as-usual" path.

Ecosecurity

When hearing the phrase "national security" we often think about protection of the nation from terrorism, foreign enemies, drugs, and criminal activities. A broader consideration of "security" also includes the welfare of a society and its people that depend on and benefit from environmental goods and services. One responsibility of government should be to protect its citizens from threats, such as those mentioned above, but also including disease, poverty, ignorance, air and water pollution, and damage to ecosystems that provide numerous goods and services.

This short article examines some of the threats from global climate change that challenge the southeastern United States, particularly the State of Florida. The manifestations of climate change all bear some degree of uncertainty, yet the international community of scientists and policymakers has reached consensus about the reality of climate change and its anthropogenic drivers. This article examines some of the unique vulnerabilities that Florida faces due to climate change and urges the State's leaders to take clear responsibility for implementing adaptive actions that will mitigate the risks to Florida's population, infrastructure, and environment.

Environmental Changes and Climate Change in Florida

The emission of greenhouse gases (carbon dioxide, carbon monoxide, methane, among others) to the global atmosphere via the burning of fossil fuels and biomass, as well as deforestation, has resulted in the elevation of global atmospheric temperatures. Since the Industrial Revolution, the concentration of atmospheric carbon dioxide has increased 35 percent from 280 ppm in 1750 to more than 400 ppm today. If these trends continue, CO_2 concentrations may well reach 600 to 700 ppm by the end of the twenty-first century. Greenhouse gases trap infrared radiation emitted from the earth's surface causing an increase in atmospheric temperatures. Land and ocean surface temperatures have already increased about 0.85^0C—the range lies between 0.65 to 1.06^0C—from 1880 to 2012.[1] Predictions of the range of temperature increases, of course, contain a degree of uncertainty. Panels of scientific experts organized by the Intergovernmental Panel on Climate Change (IPCC) have created various models that project global mean surface temperature increases during the twenty-first century that range between 0.3^0 and 4.8^0C depending on future global emissions of greenhouse gases and mitigation measures that societies implement.[2] Heat waves will become more intense with longer duration in much of the United States.[3] Scientists reported that 2015 global temperatures were the highest on record and the second highest in the continental U.S. (after 2012).[4] Atmospheric temperature increases cause a number of other environmental and, ultimately socioeconomic, impacts.

As global temperatures rise, glacial and polar ice caps melt. The volumen of surface seawater also expands with increasing temperature (thermal expansion). Taken together, these factors produce an elevation of sea level. The IPCC estimates that by the end of the twenty-first century sea levels will rise between 25 and 195 cm with the most reasonable estimate being 60 cm.[5] The Sea Level Rise Work Group of the Southeast Florida Regional Climate Change Compact Steering Committee has estimated sea level rise for the region using data from reports of the IPCC, the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration (NOAA).[6] Using 1992 as a baseline, sea levels may increase from 15 to 25 cm by 2030, 36 to 66 cm by 2060, and 79 to 155 cm by 2100.

When rising sea levels are projected horizontally, many low-lying coastal areas will be flooded. Predicted areas that will be inudated are site-specific and depend on coastal topography, land subsidence or emergence, drainage patterns, and society's ability to defend the coastline. The World Resources Institute estimates that by 2060 sea levels on the Floridian coastline could increase between 23 and 61 cm over levels in 2012.[7] Moreover, it appears that the rate of sea level rise is increasing.[8]

Atmospheric warming will also lead to changes in rainfall patterns and tropical storm intensity and frequency. Although climate predictions have inherent uncertainties, models forecast that some regions will experience increased rainfall while others will become drier. The dry southwestern U.S. will have even drier conditions throughout this century. While the variation in net rainfall in the southeastern U.S. may not be significant, extreme rainfall events will become more frequent, intense, and irregular—as will be the case in most of the U.S.[9] Predictive models also suggest that tropical storms will increase in intensity and precipitation during this century.[10]

The global ocean is an important sink for some of the increasing levels of atmospheric carbon dioxide. Dissolved carbon dioxide alters the ocean's carbonate-bicarbonate equilibrium leading to more acidic conditions of surface seawater (ocean acidification).[11] Even relatively small decreases in the pH of seawater (more acidic conditions) can make it more difficult for calcareous marine fauna to form their carbonate exoskeletons. Four IPCC scenarios predict decreases in surface seawater acidity between 0.06 and 0.31 (an increase in acidity between 15 and 109 percent) by the end of the twenty-first century.[12] Of particular concern are mollusks and coral reefs; the latter are already experiencing a number of threats from increasing seawater temperatures caused by global warming and El Niño-ENSO events, viral diseases, nutrient enrichment of coastal waters leading to algae blooms, damage from unsustainable fishing practices and physical damage from vessels and divers.

The Case of Florida

Demography

According to the 2010 U.S. Census, Florida's population was 18,801,310 persons, the fourth largest state. Population estimates of July 1, 2015 were 20,271,272—a percentage change of 7.8 in that five-year period.[13] Population growth rates in Florida are among the highest in the country. In fact, Florida ranks sixth in growth rates among U.S. states.[14]

Florida's shoreline and coastal amenities are great attractions for visitors and residents alike. The U.S. Census Bureau defines counties bordering saltwater as "coastal". Using this definition, just under 14 million persons resided in Florida's coastal counties in 2008—about 78 percent of Florida residents (compared to about 29 percent of the U.S. population).[15] Almost 16 percent of the U.S. coastal population resides in Florida, second only to California.[16] The population in Florida's coastal counties increased by 12.9 percent from 2000 to 2008, yet percentage increases for all U.S. coastal counties only reached 6.5 percent, while that of the entire country was 8.0 percent.[17]

Florida's population is large, fast growing, coastal, and also relatively old. The State has the highest percentage of residents over 65 years of age of any state in the country—about 18.3 percent.[18] The percentage of seniors in Florida's population should reach 21 percent by 2020 and will continue to subsequently increase.

Economy

Tourism is the primary economic industry in Florida, and the State received about 90 million visitors in 2012.[19] Miami-Dade County is one of the State's primary tourist destinations accounting for about 30 percent of the $71.8 billion that visitors to Florida spend each year. Florida's beaches and nearshore and coastal environments are the principal attraction for tourists.

Agriculture also plays an important role in Florida's economy. The agricultural sector is the largest in the southeastern U.S. with citrus playing a principal role. Citrus is a $9.3 billion industry in Florida.[20] The State produces more than two-thirds of the country's citrus production and almost half of the global supply of orange juice. Tomatoes follow citrus in economic contribution with sugar cane and nursery and ornamental plants also making significant contributions to Florida's economy.

Environment

Florida's natural environment is closely linked to the sea. The state is a peninsula bordered on three sides by the ocean. Florida has the greatest length of coastline of any state in the continental U.S.,[21] as well as 1,200 miles of sandy beaches and 1,800 miles

of coastline.[22] The State's elevation is relatively low—the highest point reaching only 96 meters—and its water table is high.[23] Florida's Coastal Management Program defines the entire State as the coastal zone. However, for planning purposes, only the 35 coastal counties (of 67 in the State) are treated as "coastal".[24] Few points in the State are more than 100 km from either the Gulf of Mexico or the Atlantic Ocean. The State's unique position in the subtropics, as well as its exposure to the sea make it highly vulnerable to strikes from hurricanes. Of the Category three to five hurricanes that made landfall on the Atlantic Coast of the U.S. between 1851 and 2008, some 39 percent struck Florida.[25]

Florida's subtropical environment hosts the northernmost reach of shallow coral reef ecosystems and mangrove forests with their associated flora and fauna and is the only state in the continental U.S. with extensive areas of these ecosystems.

Vulnerabilities of Sectors to these Climate Changes

Coastal Infrastructure

Recent reports from the World Resources Institute (WRI) have projected initial vulnerabilities of Florida to sea level rise.[26] Florida is the state that is most vulnerable to sea level rise with large populations residing at low elevations, and thus, highly exposed to tropical storms and storm surges. These WRI reports focus on the State's four southeastern counties (Monroe, Miami-Dade, Broward, and Palm Beach) that are the most urbanized, have the highest population concentration in Florida (almost 6 million persons in the four county area), and only lie several meters above sea level. Miami-Dade County has more people living less than 1.3 meters above sea level than any state except Louisiana (and of course, Florida itself). About 25 percent of the county's land is less than one meter above sea level. Estimates of the value of Miami-Dade's beachfront properties range to about $15 billion. Evaluation of cities most vulnerable to losses from flooding rank Miami, Florida in sixth place of global cities and first place of U.S. cities. The same evaluation ranks Tampa-St. Petersburg, Florida as 16th in the world and fourth among U.S. cities.[27]

A recent study published in *Nature Climate Change* estimated the number of people that will be affected by sea level rises of 90 and 180 cm in 2100—also taking population growth into account.[28] The lower sea level rise value will place 1,221,837 persons at risk in Florida out of 4,310,983 in the U.S., while the higher value will affect 6,057,419 Floridians out of 13,115,250 in the entire country. Similarly, the WRI estimates that about 40 percent of properties in the U.S. that are vulnerable to sea level rise are in Florida. These estimates place Florida as the state most at risk from sea level rise. The *Nature Climate Change* report mentions the extreme risk faced by four Florida counties—Monroe, Miami-Dade, Broward, and Pinellas (Tampa-St. Petersburg).

Several cities in South Florida are already experiencing flooding during high tide events, as well as extreme rainfall events. Several streets on the west side of the City of Miami Beach flood about six times per year during high tides ("king tides"). Using U.S. Army Corps of Engineers estimates for sea level rise, the Union of Concerned Scientists predicts that Miami Beach streets will flood about 380 times per year by 2045.[29] To confront this threat, Miami Beach is conducting an overhaul of its stormwater system, installing 70 one-way pumps, and elevating some of the streets that are most vulnerable to flooding. The City is spending $500 million on these initial adaptation measures. Ft. Lauderdale and Hollywood in Broward County are experiencing similar flooding during king tides.[30] However, protection of coastal areas from flooding and storm surges will be extremely difficult in many parts of Florida because of the State's geology. Porous limestone substrate in much of Florida suggests that protection of lowlying areas from storm surges and sea level rise by seawalls will not be feasible.

Florida is clearly a target for hurricanes that may approach from the Gulf of Mexico or the Atlantic Ocean bringing high winds, storm surges, high energy wave action, coastal flooding, coastal erosion, loss of coastal wetlands, and saltwater intrusion. On average from 1900 to 2007 a hurricane struck Florida once every two years, and a strong hurricane every four years. Eight of the ten most expensive hurricanes in the U.S. have affected Florida. Studies suggest that the State can expect a ten percent chance of property and infrastructure losses that exceed $5.8 billion annually and a five percent chance of loss of $19.6 billion.[31] Many experts predict that global warming will increase the size and intensity of hurricanes. Increased storm intensity compounded with Florida's rapid coastal development and population increases suggest that potential losses to property from tropical storms will

be extremely high.

Sea level rise, historical shoreline armoring (groins, seawalls, and bulkheads), jetties, destruction of dunes, and the buildout of much of Florida's coastline have resulted in severe beach erosion. Loss of sandy beaches means loss of defense against storms, habitat loss, and decreased tourism revenues. In response to the loss of Florida's natural beaches, the U.S. Army Corps of Engineers, the State of Florida, and in some cases local governments have funded beach renourishment projects. Essentially all of the beaches in South Florida have been renourished during the past 30 years at a cost of approximately a million dollars per mile of renourished beach. While these projects produce benefits, they also have adverse environmental impacts and are costly and often temporary. One wonders how long we will be willing to fund expensive sand replacement to protect low-lying barrier islands on which large-scale building should never have been allowed in the first place.

These multiple threats to coastal lands, property, and infrastructure in Florida (roads, bridges, wastewater treatment plants, stormwater drainage systems, nuclear power plants, etc.) present grave risks to the millions of Florida's coastal residents, as well as to Florida's coastal tourism industry. A study published by the University of Florida estimated the economic impacts of climate change in Florida using two cases: rapid stabilization of greenhouse gas emission and a business-as-usual model.[32] The study predicts that by 2050 the average annual losses from hurricane damages will range between $24 and $49 billion. By 2100 real estate at risk from sea level rise will have a value between $10 and $66 billlion. Tourism losses will reach $40 billion by 2050 and $167 billion by 2100 or between 1.2 percent and 2.4 percent of the Gross State Product.

Agriculture

Climate change in Florida may mean rainfall variability, increased droughts, greater incidence of extreme rainfall events instead of more consistent smaller rainfall events, and higher temperatures.[33] These factors may increase stress for comercial crops and also create greater susceptibility to diseases.

Citrus fruits are the largest contributor to Florida's agriculture. The State produces about 69 percent of the U.S. citrus crop.[34] Some researchers suggest that yields of citrus in South Florida may decrease with global warming due to higher winter temperatures.[35] The major challenge that Florida's citrus industry faces today is Citrus Greening, an insect-spread bacterial infection that is now present throughout the State. This citrus disease impacts fruit color, size, and flavor and eventually kills the tree. The warmer temperatures may also favor reproduction and the spread of insects that spread the Citrus Greening bacteria.

Intensification of hurricanes could mean greater losses to Florida agriculture—not only from physical damage to plants and infrastructure but also because of salinization and salt water intrusion. Hurricanes also may facilitate insect movement that is responsable for Citrus Greening.

Fisheries and Marine Ecosystems

Coral reef ecosystems are one of the most biologically diverse on the planet. Barrier reefs provide numerous ecosystem services, including attenuation of wave energy and shoreline protection. They offer habitat for numerous species of fish and other marine organisms that are important for commercial and recreational fisheries—including different species of grouper, snapper, and lobster. The U.S. Commission on Ocean Policy noted that about 50 percent of the country's federally managed commercial fish species depend on coral reefs for part of their life cycle.[36] The economic contribution from diving on Florida's coral reefs is also significant. The contribution of 8 million visitor-days annually from divers and snorkelers in Florida is close to $1 billion per year.[37]

Coral reefs in Florida are already stressed from diseases, pollution, bleaching, direct damage from divers and boat groundings, and urban and port development. The Florida Department of Environmental Protection reported that between 1996 and 2005, coral cover in the Florida Keys declined by 44 percent.[38] In 2006, NOAA's National Marine Fisheries Service listed two emblematic coral species (Elkhorn and Staghorn corals) as "threatened" under the Endangered Species Act. In 2014, this federal agency listed 20 more coral species as "threatened"—five of which are found in the Caribbean. The two drivers directly related to climate change—ocean warming and ocean acidification—could mean the death blow to Florida's coral reef ecosystems.

The connectivity between coral reefs ecosystems, seagrass beds, mangroves, and other coastal wetlands in Florida is well understood. Coastal wetlands serve as

nursery grounds and homes for many species of Florida's coastal fish during some stage of their life. They trap sediments, are crucial to shoreline protection, and help build the shoreline. Coastal wetlands host many endangered species and are home to diverse avifauna, including many migratory bird species.

Florida has experienced great losses of coastal wetlands during the past century due to coastal development and urban expansion. Sea level rise poses an additional threat. Mangroves might gradually retreat inland with rising sea levels.[39] However, because of coastal infrastructure development in Florida (roads, bulkheads and seawalls, buildings, and reclaimed land), coastal wetlands may not have the necessary space to migrate inland with sea level rise.

Some studies suggest that ocean warming favors the growth and reproduction of introduced (exotic) species over native marine species and could lead to dominance of invasive species in some marine ecosystems.[40]

Public Health

Climate change also may impact human health in several ways. Rising temperatures and extreme heat waves have the potential to increase the mortality of the most sensitive group in the population—the elderly.[41] The percentage of Florida residents over 65 years is higher than that of any state in the U.S.—suggesting a high risk for many Floridians.

Higher average temperatures and rainfall may also increase the incidence of certain vector-borne diseases, such as dengue and the Zika epidemic, the later which is linked to microcephaly and temporary paralysis. Perhaps the range of these diseases will also extend further northward in the U.S. with global warming. Higher temperatures may also speed up the life cycle of mosquitos and decrease the incubation period of the virus living in *Aedes aegypti* mosquitos, the vector for both of these diseases.[42] The first cases of Zika in the continental U.S. contracted from local mosquitos have been confirmed in Miami in July 2016,[43] and although the spread of this disease cannot be linked directly to global warming, in the future we may well discover some relationship.

Increased coastal flooding resulting from sea level rise and storm surges also creates a number of potential public health issues for Florida. Direct damage to infrastructure may cause injuries, make access to hospitals and health care facilities more difficult, and contaminate water supplies. Increased standing water will also increase breeding habitats for mosquitos.

Water Resources

Changes in precipitation patterns and an increase in short term rainfall events may lead to greater dependence on groundwater resources for irrigation. This could increase competition for this resource with public water supplies and also lead to overutilization of groundwater resources.

Southeastern Florida counties depend on groundwater from the Biscayne Aquifer for the vast majority of their drinking water. Wells providing the municipal water supply that once were close to Biscayne Bay have already been abandoned because of saltwater intrusion and have been moved further westward.

Response From The State Of Florida

Despite the State of Florida's vulnerability to climate change impacts in many areas, at the State level, planning for response and adaptation to climate change has left much to be desired. In a 2012 evaluation of states' preparation planning for climate change, the Natural Resources Defense Council (NRDC) ranked Florida in Category three out of four categories; the 29 states in Categories three and four are "largely unprepared and lagging behind."[44] The NRDC Report stressed the importance that the Governor has in planning for climate change: "[w]ithout a top-down directive from the executive level, there is unlikely to be sufficient action by all necessary government agencies within a state on climate change issues."[45]

Recent responses to climate change impacts from the Governor of the State of Florida have not been energetic to say the least. The current Governor Rick Scott, a Republican who was first elected in November 2010, remains skeptical about climate change and claims not to be a scientist. He has established an unwritten policy that State of Florida agencies not use the phrases "climate change" and "global warming" in their documents. Reports of this policy come from Florida´s Department of Environmental Protection, the Department of Transportation, the Department of Health, and the South Florida Water Management District.[46] Such a policy stance from the executive of the State most vulnerable to climate change impacts is unconscionable.

While the State of Florida continues to ignore climate change risk, Florida's counties and municipalities

have taken the lead in climate change preparation. The County Commissions of the four southeastern counties (Broward, Miami-Dade, Monroe, and Palm Beach) approved the Southeastern Florida Regional Climate Change Compact (SEFRCCC) in January 2010 to create a united front to face regional climate change. Since then the SEFRCCC Steering Group has adopted consistent methodologies and assessed the vulnerabilities from sea level rise in the four county region based on one, two, and three foot rises. In October 2012, the SEFRCCC produced a Regional Action Plan with 110 Action Items related to reduction of greenhouse gas emissions, water supply systems, sustainable communities, transportation infrastructure, and emergency management that decisionmakers at the county and city levels can adopt to mitigate and adapt to climate change.[47] Although it will take many years to adopt and implement the recommendations, these are important planning steps for local governments.

Conclusion

The high vulnerability of Florida to climate change across so many economic, social, and environmental sectors demands unified responses from various levels of government—national, state, and local. The on-the-ground adaptive responses will be implemented at the county and city levels. The federal government may offer broad policy guidelines, scientific information, and funding for programs. The State must provide guidance for land use planning at the local level, funding for programs, guidance for local decisionmakers, and coordination of State programs. Today, the inability of Florida's leaders to internalize scientific information and their lack of comprehensive response to the high vulnerability of the State to environmental, economic, and social harm is truly irresponsible and will be remembered by future generations of Floridians who will ask why their leaders delayed so long before accepting reality and taking action to proactively address the climate change challenge.

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