

## EXECUTIVE SUMMARY

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Florida's climate has been and continues to be one of its most important assets. It has enabled the growth of many major industries, including tourism and agriculture, which both rank at the top of Florida's diverse economic activities. Florida's weather and the natural beauty of its native ecosystems—including more than 11,000 miles of rivers, streams, and waterways and 663 miles of beaches—attract visitors and new residents from other states and around the world. The Sunshine State's dependency on climate is widely recognized and generally taken for granted. However, as we observe climate around the world changing, questions arise about whether or not Florida's climate is changing as well, how rapidly these changes might occur, how Florida might adapt to anticipated changes, and how Floridians might support efforts to reduce the rates of change. This includes questions about how the state's major economic activities might be affected by climate change, how they might adapt, and how they might contribute to reducing human activities' influence.

Although many scientific papers and books have been written on climate trends and changes at global, national, or regional scales, this book focuses on Florida—its climate, changing sea levels, the impacts of these changes, and how our societal and natural systems may adapt to anticipated changes. It addresses the unique conditions in our state and provides a thorough review of the current state of research on Florida's climate, including physical climate benchmarks; climate prediction, projection, and attribution; and the impacts of climate and climate change on the people and natural resources in the state. Over ninety researchers from universities across the state and beyond have contributed to this volume, summarizing important topics such as sea level rise, water resources, and how climate affects various sectors, including energy, agriculture, forestry, tourism, and insurance. Authors of each chapter summarize key messages to help readers understand important risks associated with climate change and societal responses that would be beneficial to Florida's economy, its natural resources, and the well-being of its citizens.

The purpose of this book is to provide accessible, accurate information to a broad audience, to serve as a reference on Florida's climate and its influences on important sectors, and to introduce the various approaches that Floridians are considering for adapting to pending changes in climate and sea levels. It is intended for use by a broad audience that includes: students and educators, both at the secondary school level and at universities; policymakers; business and industry planners; and the general public. It focuses on the unique characteristics of Florida's natural and built environments, including its peninsular features and highly active economic activities, how these characteristics are influenced by our climate systems, how changes have influenced these current and past features, and how they are likely to affect these features in the future. Furthermore, it provides information on how various components of our state's natural and built systems may be able to adapt to future changes.

Climate change poses significant challenges to a wide range of economic activities in Florida, some of which are more critical to our state's economy than others; for example, tourism,

agriculture, forestry, fisheries and the infrastructures that support those activities. The science that addresses these changes in climate and oceans is offered, not as an afterthought, but rather as key evidence that supports the societal impacts and responses to the anticipated changes presented in earlier chapters. The book is therefore divided in three sections: societal challenges associated with climate and climate change, economic activity challenges associated with climate change, and past, current and future physical climate.

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## Societal Challenges Associated with Climate and Climate Change in Florida

There are many societal challenges associated with climate variability and climate change in Florida. These challenges include human health impacts, the availability of and access to essential resources such as water and energy, changes in land use, and the need for new laws and policies associated with all of these issues. Although many direct effects of climate change on Florida are of major concern, it is clear that sea level rise, and its impacts on coastal communities, infrastructure, ecosystems, and businesses, is the state's most immediate climate-related threat.

The interaction between Florida's climate and societal systems is bidirectional: climate change affects social systems *and* social systems influence climate change. Furthermore, communicating this can instigate social action and facilitate (or obstruct) adaptive responses. But unfortunately, while scientists develop skills for communicating with other scientists, many lack the necessary skills to effectively communicate with the broader public. This is particularly true and problematic in scientists' discussions of climate change, in part due to the complexity and potential impacts of the issue. In particular, there is a nationwide organized effort embraced by some Florida politicians to reject climate change science, which makes it difficult to consider practical and rational policies at the state level. However, as this book points out, Florida has a wide array of response capabilities for imminent threats, and they must be improved if we are to address longer-term challenges such as climate change and sea level rise.

Although there are many specific areas where climate change will impact the daily lives of Floridians across different sectors, several are of concern to all residents of the state. For instance, the chapters in this section address connections between climate change and human health. Research has demonstrated that increased risks to human health are likely to occur due to heat waves and temperature-related illnesses, waterborne and vector-borne diseases, and direct human exposure to stronger hurricanes, storm surge, intensive rainfall and flooding, and other extreme events. There are also societal challenges associated with land use, particularly those related to population growth and the possible inward migration from coastal areas due to climate change and sea level rise.

The availability and accessibility of essential resources are likely to become more limited as our climate continues to change. For example, competition for water and energy resources will continue to increase, intensified by greater demands under expected temperature increase. Policies and investment decisions will be essential to address these growing needs. Another key

societal issue affecting property, infrastructure, and businesses is the changing risk levels, particularly along the coasts where vulnerabilities to climate change and sea level rise are highest. Climate change and sea level rise increase the risks of losses, thus increasing the cost of insurance and making it very likely that consumers will see substantial changes in the insurance products available to them; some of these modifications are already being made. Finally, the authors in this section point out that some policies and laws, which were developed under more stable climate and sea level conditions, have now become obsolete. New policies and laws are needed to ensure that our social support systems adapt to climate change and sea level rise and to address these societal challenges in order to make communities and infrastructure more resilient to anticipated changes.

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## Economic and Environmental Challenges Associated with Climate Change in Florida

Florida has one of the most vibrant state economies in the US, and all its economic sectors benefit from the pleasant climate and abundant natural resources in the state. Economic growth in Florida is predicted to outpace national trends. However, Florida's economic activities may be severely impacted by higher sea levels and projected climate conditions, including the potential for more powerful hurricanes. To achieve the predicted economic growth, business leaders must address the serious threats associated with climate change and sea level rise and develop technological and policy solutions that ensure that the state's potential is achieved. Fortunately, Florida has highly educated scientists backed by nationally acclaimed research universities as well as political and business leaders, and we have the human, physical, and natural resources necessary to address these threats.

Currently, the state's two largest economic sectors are tourism and agriculture. Both are highly dependent on climate conditions and both are vulnerable to the projected changes. The tourism industry in Florida accounts for about 2.5 million jobs, either directly or indirectly, and serves more than 106 million tourists per year, generating nearly \$90 billion in economic impact annually. Because much of the state's economic activity and projected growth are in coastal areas, solutions to overcome risks associated with sea level rise, storm surge, wind damage, and other detrimental events must be developed. And, if projected increases in temperature and the frequency of intense rainstorms disrupt many tourism activities, these risks must also be addressed.

Similarly, Florida's agricultural and forestry industries are highly vulnerable to climate, most notably to the availability of water and energy resources that are likely to be negatively impacted by climate change. Together, these two industries contribute more than \$120 billion to the state's economic revenues and support more than 2 million jobs. Fortunately, Florida agriculture has a successful history of adapting to the vagaries of weather. But climate change is occurring at an unprecedented rate, thus increasing the challenges of continuing or increasing the economic

contributions of the state's agriculture sector. In the case of forestry, projected increases in temperature and atmospheric CO<sub>2</sub> concentration in Florida may actually result in increased plantation production *if*, as projected, rainfall remains constant or increases slightly. Forestry provides a number of positive ecosystem services and withdraws more carbon dioxide from the atmosphere than it requires for production. Thus, this "carbon sequestration" could contribute even more to a reduction in greenhouse gases in the atmosphere. That said, science-based management approaches are essential for society to fully benefit from forest ecosystem services in the future.

Urban infrastructure is also crucial to our economic activity, supporting many businesses and contributing to the state's economic activity through construction, revitalization, and maintenance. Similar to agriculture and tourism, Florida's urban development and populations are concentrated in the coastal areas. This means that infrastructure is also highly vulnerable to sea level rise and climate change, particularly near the coasts, where we continue to see increasing coastal development and population densities. Thus, a large portion of Florida's urban infrastructure is susceptible to damage due to storm surge, flooding, and wind. New technologies, policies, and strategies are needed at the individual and community-level that will lead to the development of a more resilient and sustainable urban infrastructure.

Florida's biodiversity and ecology are central to most of the state's economic activities and valued greatly by its residents. The rich biodiversity of Florida is the product of climate conditions, geographic position, and geology, all of which contribute to the unique ecosystems that exist. This biodiversity and the resulting ecosystems are highly vulnerable to changes in climate and local hydrology; they are dependent upon society's willingness and ability to protect them. They may disappear if coastal populations continue to grow, causing development that displaces coastal habitats, and if projected increases in sea level lead to coastal habitat inundation. Some of this is already happening. Migration of wildlife from affected areas may also be threatened due to loss of habitats, making the biodiversity of coastal ecosystems extremely vulnerable. Adaptive capacity to climate change must be improved to avoid unwanted losses in these critical areas.

Florida's extensive shorelines support a diverse marine life that contributes significantly to the economy of the state in a variety of ways. This section also deals with potential impacts of climate change on the vast marine habitat of Florida, such as coral bleaching, warming of the Gulf of Mexico, and ocean acidification, which can affect larval and nutrient transport and fisheries production and lead to harmful algal blooms.

Finally, marine and freshwater fisheries and other large aquaculture industries contribute about \$15 billion annually to Florida's revenue. These types of industries are also highly vulnerable to higher temperatures, more frequent severe storms, and sea level rise. The interactions between climate change and fish production/catches are complex, making it difficult to accurately assess the impacts. However, it is likely that there will be negative effects from

climate change in Florida that will need to be addressed to help sustain the viability of these industries.

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## Florida's Physical Climate: Past, Current, and Future

The peninsular geography of Florida is an outcome of tectonic movements that took place some ~200 million years ago with the simultaneous creation of the Gulf of Mexico and the Caribbean Sea. Consequently, Florida, surrounded by water, has a unique climate characterized by sea breezes that bring moist air to both the east and west coasts and by a strong seasonality in rainfall. The cyclic growth and retreat of huge ice sheets in the Northern Hemisphere lead to strong fluctuations in sea level, alternatively exposing or covering the Florida Peninsula. A paleoclimate analysis of Florida reveals clearly the interglacial cycles punctuated by the glacial periods, which make detection of regional climate change trends non-trivial. To compound this intricate entanglement, Florida's climate is dependent upon phases of the El Niño and the Southern Oscillation (ENSO), the Atlantic Multi-decadal Oscillation (AMO), and the Pacific Decadal Oscillation (PDO).

Despite this complexity of regional climate variations, significant progress has been achieved in the seasonal prediction of winter climate over Florida on the basis of the persistence of large-scale variations of ENSO. However, regional climate predictions are daunting and challenge our current understanding and state-of-the-art climate models to account for the correct balance of influences including remote large-scale climate drivers (e.g., ENSO), local feedback (e.g., land-biosphere-atmosphere interactions), and climate change.

There is undeniable evidence linking increased greenhouse gas emissions to sea level rise. The discussion of sea level rise presents this evidence and shares an in-depth discussion on the challenges of arriving at quantitative sea level rise estimates for Florida. There is also the issue of climate and weather extremes affecting Florida that increases the vulnerability profile of the state and makes it a focus of the risk insurance market. This section gives a thorough review of events such as droughts, land-falling tropical cyclones, tornadoes, severe thunderstorms, and lightning, which cause collateral damage and human fatality periodically across Florida. Finally, the variations and triggers of such extreme events are discussed in this book, providing a complete picture of the physical (earth, ocean, and atmosphere) climate system of Florida.

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## Conclusion

There is no doubt that development, climate change, vulnerability, and risk go hand in hand, particularly in Florida. These vulnerabilities and risks exist in all segments of Florida, but they are particularly severe along our coastline where negative impacts are already being felt. Understanding these linkages is important and will help in the development of effective mitigation and adaptation strategies to address the impacts of climate change. The purpose of this book is to share knowledge about this linkage that has been gathered over years of research from

experts around the state, and to provide candid views on the known, unknown, and the unknowable. There is no silver bullet to eliminate the risks imposed on Florida by climate change. But making informed decisions in light of potential future climate evolution would go a long way toward mitigating at least some of future vulnerabilities and risks. It is our sincere hope that the contents of this book will help move us in this direction.

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Eric P. Chassignet, Florida State University  
James W. Jones, University of Florida  
Vasubandhu Misra, Florida State University  
Jayantha “Obey” Obeysekera, South Florida Water Management District

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