The Economic Impact of Climate Change in Coastal Areas in Florida

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Florida State University
The Florida State University Center for Economic Forecasting and Analysis (CEFA) specializes in applying advanced, computer-based economic models and techniques to examine and help resolve pressing public policy issues across a spectrum of research areas.
The Florida State University Beaches and Shores Research Center was created in 1982 to assist the State of Florida in establishing a recommended Coastal Construction Control Line for each of Florida’s 24 coastal counties with sandy beaches. The Center actively seeks to understand how beaches can be better designed to protect upland property from coastal storms while protecting the native flora and fauna of this delicate ecosystem. Types of research include:

- Analytical shoreline modeling
- Bay/wetland response to tide
- Impacts due to natural or man-made construction
- Inlet stability
- Water level extreme and distributional analysis
- Short-term storm surge forecasting
- Inlet modeling for improved storm surge estimates
General Framework

- Six County (Escambia, Duval, Dade, Wakulla, Dixie and Monroe - Demographics

- Sea Level Rise (SLR) – Eustatic Estimates (IPCC) and SLR Estimates and Methodology Performed by FSU Beaches and Shores Resources Center, Todd Walton for Years 2030, 2080.

- Property at Risk – Examples and Adaptation Measures in Florida

- Cost Damage Assessment Model Based on Flood Insurance Studies, and Hurricane Damage Assessments for Two Years in 2006 Dollars

- Economic Impact – Yohe Model
Demographics
Dade County

Area

Total 6,297 km² (2,431 mi²)
Land 5,040 km² (1,946 mi²)
Water 1,257 km² (485 mi²) 19.96%

Population

Year 2000 2,253,362
Density 447/km²
Demographics
Dixie County

Area
- Total 2,237 km² (864 mi²)
- Land 1,824 km² (704 mi²),
- Water 413 km² (160 mi²) 18.49%

Population
Year 2000 13827
Density 8/km²
Demographics
Duval County

Area

Total 2,378 km² (918 mi²)
Land 2,004 km² (774 mi²)
Water 374 km² (145 mi²), 15.74%

Population

Year 2000 778,879
Density 389/km²
Demographics
Monroe County

**Area**
- Total 9,679 km² (3,737 mi²)
- Land 2,582 km² (996.9 sq mi)
- Water 7,097 km² (2,740 mi²), 73.32%

**Population**
- Year 2000 79,589
- Density 30.8/km²
Demographics

Escambia County

Area

Total 2,268 km² (876 mi²)
Land 1,715 km² (662 mi²)
Water 552 km² (213 mi²), 24.35%

Population

Year 2000   294,410
Density 172/km²
Demographics
Wakulla County

Area

Total 1,906 km² (736 mi²)
Land 1571 km² (607 mi²)
Water 334 km² (129 mi²), 17.54%

Population

Year 2000  22,863
Density  15/km²
Global average sea level rise (1990 - 2100) for the six SRES Scenarios

Sea level rise (metres)

Ranges in 2100

- All SRES envelope including land-ice uncertainty
- Several models all SRES envelope
- Model average all SRES envelope

Scenarios:
- A1
- A1T
- A1FI
- A2
- B1
- B2

Bars show the range in 2100 produced by several models

Source: IPCC Climate Change 2001: The Scientific Basis
Reasons for Data Based Approach

• Based on Global Models of Climate Change (physics uncertain… i.e. can’t predict El Nino’s)

• Need Relative Sea Level Rise (for local damage estimates)
Fernandina Beach Tide Station
<table>
<thead>
<tr>
<th>Station Name</th>
<th>Station Number</th>
<th>Record Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernandina, FL</td>
<td>8720030</td>
<td>1941-2005</td>
</tr>
<tr>
<td>Key West, FL</td>
<td>8724580</td>
<td>1941-2005</td>
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<tr>
<td>St. Petersburg, FL</td>
<td>8726520</td>
<td>1947-2005</td>
</tr>
<tr>
<td>Cedar Key, FL</td>
<td>8727520</td>
<td>1941-2005</td>
</tr>
<tr>
<td>Pensacola, FL</td>
<td>8729840</td>
<td>1941-2005</td>
</tr>
</tbody>
</table>
Data Based Methods of Forecasting

- Noise in data
- Missing observations
Filtering Approaches

• Monthly Means
• Low Pass
• Band Pass
• Singular Spectral Analysis (SSA)
Low Pass Filtering

- fcutoff = 1/48 (magenta)
- fcutoff = 1/24 (green)
Low Pass Filtering Forecast to 2080

The graph shows the Monthly index along the x-axis and Filtered MSL (m) along the y-axis. The data extends from monthly index 0 to 1800, with Filtered MSL values ranging from -0.2 to 0.5. The trend line indicates an increasing filtered MSL over time, with a significant rise towards the year 2080.
Figure 1. Fernandina – Forecast Filtered Sea Level Rise

Monthly index
Forecasting Approaches

• Linear
• Linear with Second Order Acceleration Term
• Non-Linear
• Autoregressive Series (Unstable)
Linear

\[ y(t) = a + b \cdot t + \varepsilon \]

Linear with Second Order Term (for acceleration/deceleration of slr)

\[ y(t) = a + b \cdot t + c \cdot t^2 + \varepsilon \]
Non-Linear Exponential

\[ y(t) = p_1 + p_2 \cdot e^{(p_3 \cdot t)} + \text{error} \]

\[ y(t) = p_1 + p_2 \cdot (1 + p_3 \cdot t + \frac{p_3 \cdot t^2}{2} + \ldots \text{hot}) + \text{error} \]
## Forecast Relative Sea Level Rise from 2006 to 2080

<table>
<thead>
<tr>
<th>Station</th>
<th>Relative SLR (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernandina, FL</td>
<td>0.25</td>
</tr>
<tr>
<td>Key West, FL</td>
<td>0.31</td>
</tr>
<tr>
<td>St. Petersburg, FL</td>
<td>0.35</td>
</tr>
<tr>
<td>Cedar Key, FL</td>
<td>0.27</td>
</tr>
<tr>
<td>Pensacola, FL</td>
<td>0.34</td>
</tr>
</tbody>
</table>
## Forecast Relative Sea Level Rise from 2006 to 2080

<table>
<thead>
<tr>
<th>Station</th>
<th>Relative Sea Level Rise (in Meters)</th>
<th>1st Order</th>
<th>2nd Order</th>
<th>Exponential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernandina, FL</td>
<td>0.16</td>
<td>0.25</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Key West, FL</td>
<td>0.15</td>
<td>0.31</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>St. Petersburg, FL</td>
<td>0.18</td>
<td>0.35</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Cedar Key, FL</td>
<td>0.11</td>
<td>0.27</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Pensacola, FL</td>
<td>0.13</td>
<td>0.34</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

*parameter estimation convergence problems
SLR Estimation Conclusions

"Predictions are risky, especially when they're about the future."

- Linear (straight line) Trend Forecasts do not allow for sea level acceleration.
- A small sea level rise acceleration is noted in the Florida data.
- Sea level rise trends using (straight line) linear trends underestimate the sea level rise to be realized (for Florida and the time span considered).
- Sea level rise trends found using data are within the band of IPCC findings using global climate models.

"The future ain't what it used to be." ---Yogi Berra
Property at Risk

• How will your Coastal Property be Effected in the Year 2080?

According to the IPCC estimate of a 65cm scenario SLR, and with respect to the six counties, it appears that although a number of properties along the coast will be considered to not be inundated, it doesn’t assure that these coastal properties are safe from the effects of SLR. Numerous coastal parcels are predicted to be affected due to hurricane damage up to the year 2080.
Data Limitations and Benefits

Limitations

1. Lidar data was only available for 3 counties: Duval, Escambia, and Dade. Flyover only included the coastal areas.
2. Lidar data did not include “Bare Earth” estimation, i.e., structures were “not” removed.
3. Lidar data has a 0.5 foot accuracy, so if we use the 34 cm estimate, it’s similar to the range of error.
4. Northern Duval County has no private parcels, and Southern Duval County has parcels but the coast is controlled by an Erosion Control Line (ECL).
5. Approximately 90% of Escambia County is publicly owned coast. Most of the private parcels are behind the ECL.

Benefits

1. Parcel ID (property value) database has distinct variables for land value and for structure value.
2. Parcel ID data was available for all six counties.
Parcels are close to mean high water (MHW)

Storm surge in a Category 4 (20.132ft) hurricane would likely hit structures and inundate those adjacent properties by the year 2080.
Properties located behind the possible line of the Hurricane Category 4 (HC4) contour will likely experience reduced damage costs in 2080.
Escambia County
(West Side)

- Land parcels susceptible to SLR and highly likely that properties will be inundated by a HC4
Escambia County (East Side)

- Properties do not immediately face inundation; however, there is a risk that the lower areas (pink contours) could flood if surge crosses the summit of the frontier of the property
Adaptation Measures in Florida

- **Retreat**: no effect to protect the land from the sea
- **Accommodation**: continue to use land at risk
- **Protection**: involves hard structure such as sea walls and dikes
- **Nourishment**: consists of the placement of good quality sediment along the water’s edge to advance the shoreline seaward.
## Comparisons of Alternative Measures

<table>
<thead>
<tr>
<th>Pros:</th>
<th>Retreat</th>
<th>Accommodation</th>
<th>Protection</th>
<th>Beach Nourishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The most appropriate option in areas of high erosion and in the presence of small economic revenue base</td>
<td>• Provides the opportunities for inundated land to be used for new purposes</td>
<td>Effective Defense</td>
<td>• Reduces Water Power Slowly</td>
<td></td>
</tr>
<tr>
<td>Cons:</td>
<td>Can be costly</td>
<td>• Requires hefty insurance premiums</td>
<td>• Erosion</td>
<td>• Necessary to regularly nourish a beach</td>
</tr>
<tr>
<td></td>
<td>• Frequent maintenance</td>
<td>• Costly Solution</td>
<td>• Visually Unattractive</td>
<td>• Dredging may cause short-term direct mortality to sessile organisms, modifies seafloor habitats and sedimentary character</td>
</tr>
</tbody>
</table>

Resource: Report Of The Coast Management Subgroup
Cost Damage Assessment Model

Regression Model

- **Elevation_Return Years** \(^1\)  \(Y = a + b \log X\)
  \(Y = \text{surge (ft)}\),  \(X = \text{year}\)

- **Damage Cost\(^2\)_Storm Surge** \(^3\)  \(Y = c + d \ M\) \(^4\)
  \(Y = \text{surge (ft)}\),  \(M = \text{damage cost ($ in 2006)}\)

Damage cost and return years of the storm event associated with storm surge are simulated by linear interpolation and regression.
This approach was developed by CEFA, FSU to project damage cost and return year period.

1. *Flood Insurance Study, FEMA, 2000*
2. *Hurricane Summary Data, Florida Office of Insurance Regulation, 2006; 2006 Dollars*
4. *Regression with 95% confidence*
Cost Damage Assessment

There are Two Approaches\textsuperscript{1} to Measure the Damage Associated with SLR.

\begin{itemize}
  \item Increase of the Damage Cost
  \item Reduction of Hurricane Return Years
\end{itemize}

In Dade County, the return year for a Category 2 hurricane with a storm surge of 8 feet will be reduced from 412 years to 12 years for a 65 cm SLR scenario. The associated damage cost will increase from $2.4 Billion to $3.3 billion.\textsuperscript{2}

\textsuperscript{1} CEFA, Florida State University
\textsuperscript{2} Linear Regression with 95\% confidence
Wakulla County
Elevation (ft)

Dennis ($6.9, 11.132 ft)
Dennis ($4.59, 9 ft)

Damage Cost¹ (Million)
Return Period² (Years)

1 Hurricane summary data, Florida Office of Insurance Regulation, 2006
2 Flood Insurance study, FEMA, 2000
Wakulla County Elevation (ft)

Damage Cost¹ (Million) Return Period² (Years)

1 Hurricane summary data, Florida Office of Insurance Regulation, 2006
2 Flood Insurance study, FEMA, 2000
Dade County
Elevation (ft)

C2: 10.132 65CM SLR

Wilma ($2.9, 9.132 ft)

Wilma ($2.1, 7.132 ft)

1.0168 (31 cm)

2.132 (65 cm)

Damage Cost (Billion) vs. Return Period (Years)

1 Hurricane summary data, Florida Office of Insurance Regulation, 2006
2 Flood Insurance study, FEMA, 2000
Dixie County Elevation (ft)

Damage Cost¹ (Thousand) vs. Return Period² (Years)

- C3 14.132 Ft 65CM SLR
- C3 12.91 Ft 28CM SLR

- Dennis ($85,11.32 ft)
- Dennis ($61.8,9 ft)

¹ Hurricane summary data, Florida Office of Insurance Regulation, 2006
² Flood Insurance study, FEMA, 2000
Damage Cost (Thousand) vs. Return Period (Years) for Duval County, Florida

- C1: 5.82 Ft 25CM SLR
- C1: 7.132 Ft 65CM SLR

1 Hurricane summary data, Florida Office of Insurance Regulation, 2006
2 Flood Insurance study, FEMA, 2000
Damage Cost\(^1\) (Million) vs. Return Period\(^2\) (Years)

- Dennis ($95, 14.132 ft)
- Dennis ($73, 12 ft)
- C2: 10.132 Ft 65CM SLR
- C2: 9.1152 Ft 34CM SLR

\(^1\) Hurricane summary data, Florida Office of Insurance Regulation, 2006
\(^2\) Flood Insurance study, FEMA, 2000
Monroe County
Elevation (ft)

Damage Cost¹ (Million)  Return Period² (Years)

1.0168 (31 cm)
2.132 (65 cm)

C1: 7.132 Ft 65CM SLR
C1: 6.0168Ft 31CM SLR

Wilma ($370, 4.89 ft) o
Wilma($233, 2.76 ft) o

Hurricane summary data, Florida Office of Insurance Regulation, 2006
1 Flood Insurance study, FEMA, 2000
# Event Totals by County of Loss Occurrence - CY 2004 in 2006 Dollars

<table>
<thead>
<tr>
<th>County</th>
<th>Charley</th>
<th>Frances</th>
<th>Ivan</th>
<th>Jean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dade</td>
<td>$3,008,721</td>
<td>$70,468,075</td>
<td>$2,865,950</td>
<td>$16,170,268</td>
</tr>
<tr>
<td>Dixie</td>
<td>$36,408</td>
<td>$4,945,128</td>
<td>$63,237</td>
<td>$971,682</td>
</tr>
<tr>
<td>Duval</td>
<td>$5,906,950</td>
<td>$72,322,498</td>
<td>$1,649,646</td>
<td>$22,404,237</td>
</tr>
<tr>
<td>Escambia</td>
<td>$1,001,182</td>
<td>$12,980,961</td>
<td>$2,010,001,983</td>
<td>$19,105,056</td>
</tr>
<tr>
<td>Monroe</td>
<td>$663,804</td>
<td>$4,945,128</td>
<td>$363,295</td>
<td>$133,665</td>
</tr>
<tr>
<td>Wakulla</td>
<td>$14,047</td>
<td>$1,854,422</td>
<td>$214,588</td>
<td>$193,451</td>
</tr>
</tbody>
</table>

## Event Totals by County of Loss Occurrence- CY 2005 in 2006 Dollars

<table>
<thead>
<tr>
<th>County</th>
<th>Dennis</th>
<th>Katrina</th>
<th>Rita</th>
<th>Wilma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dade</td>
<td>$5,976,177</td>
<td>$585,157,998</td>
<td>$4,396,620</td>
<td>$2,152,438</td>
</tr>
<tr>
<td>Dixie</td>
<td>$59,559</td>
<td>$1,742</td>
<td>$661</td>
<td>$33,104</td>
</tr>
<tr>
<td>Duval</td>
<td>$361,426</td>
<td>$831,764</td>
<td>$151,072</td>
<td>$1,055,752</td>
</tr>
<tr>
<td>Escambia</td>
<td>$70,706,486</td>
<td>$11,341,048</td>
<td>$150,867</td>
<td>$283,996</td>
</tr>
<tr>
<td>Monroe</td>
<td>$4,400,998</td>
<td>$27,907,960</td>
<td>$11,329,370</td>
<td>$215,335,831</td>
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<tr>
<td>Wakulla</td>
<td>$4,418,483</td>
<td>$588,457</td>
<td>$1,274</td>
<td>$28,279</td>
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