Current Climate Science and Climate Scenarios for Florida

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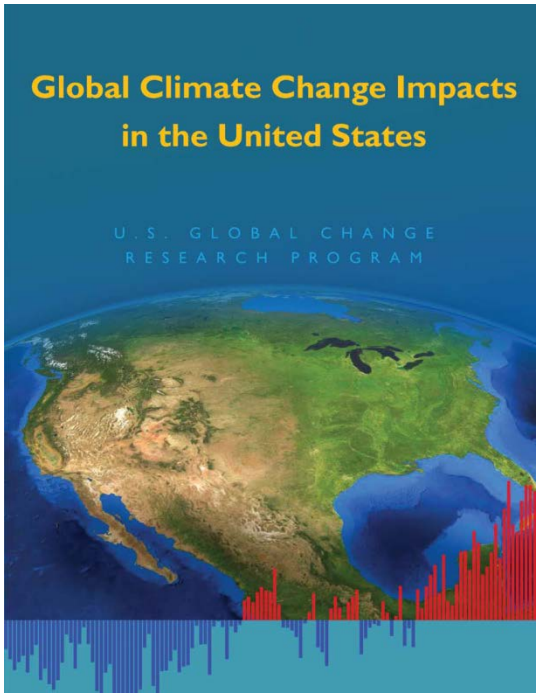
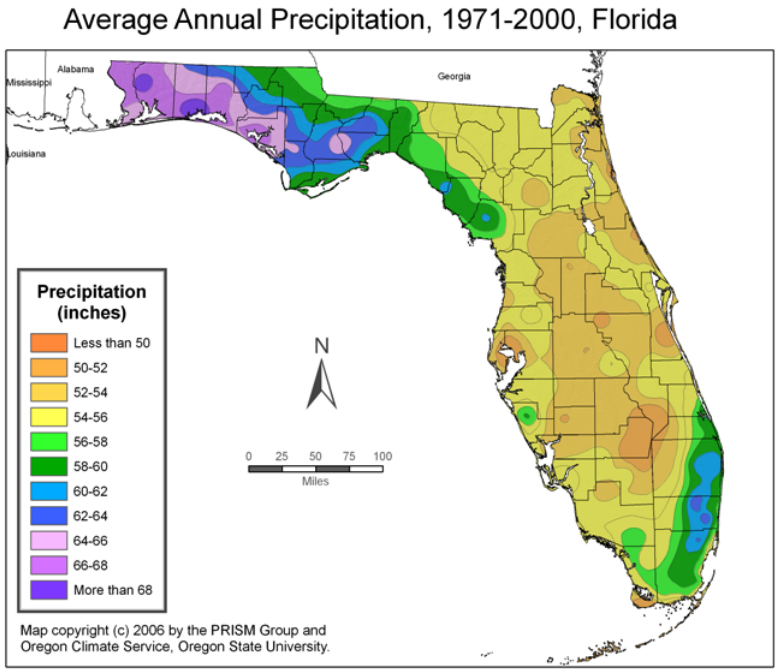
State of the Science

- International/National
  - IPCC 4th Assessment Report (2007)
  - IPCC 5th Assessment Report (2013)
  - USGCRP Climate Impacts Report (2009)
- State/Regional
  - Florida Climate Action Plan released in 2008

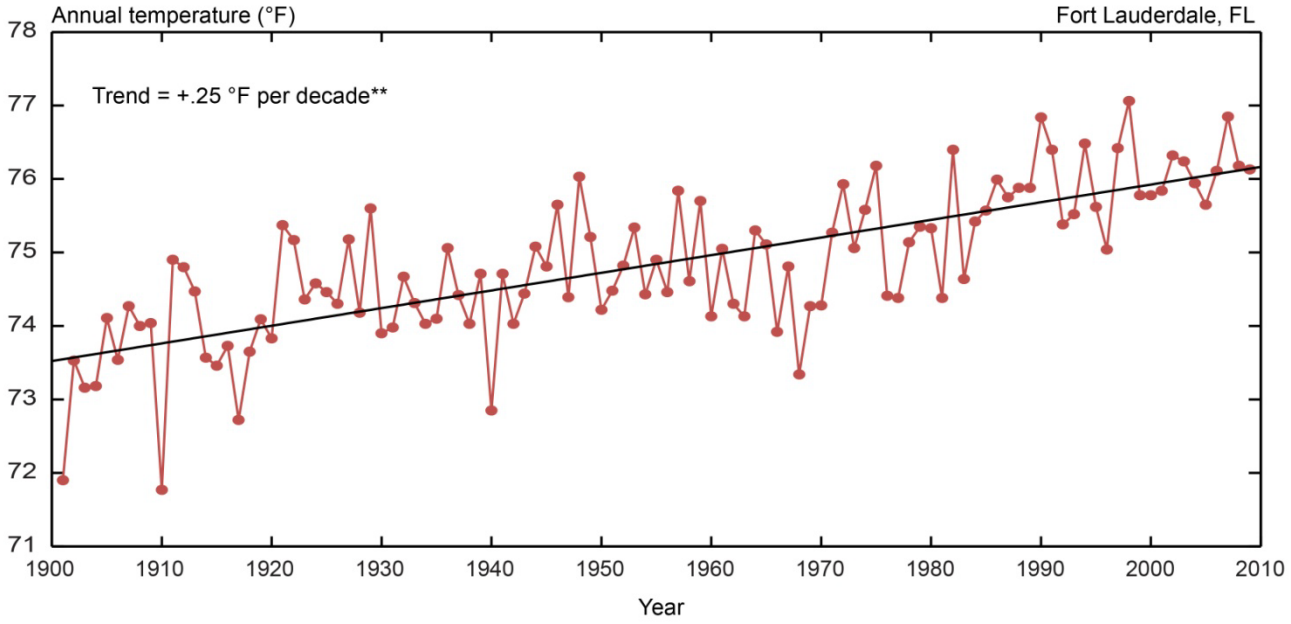


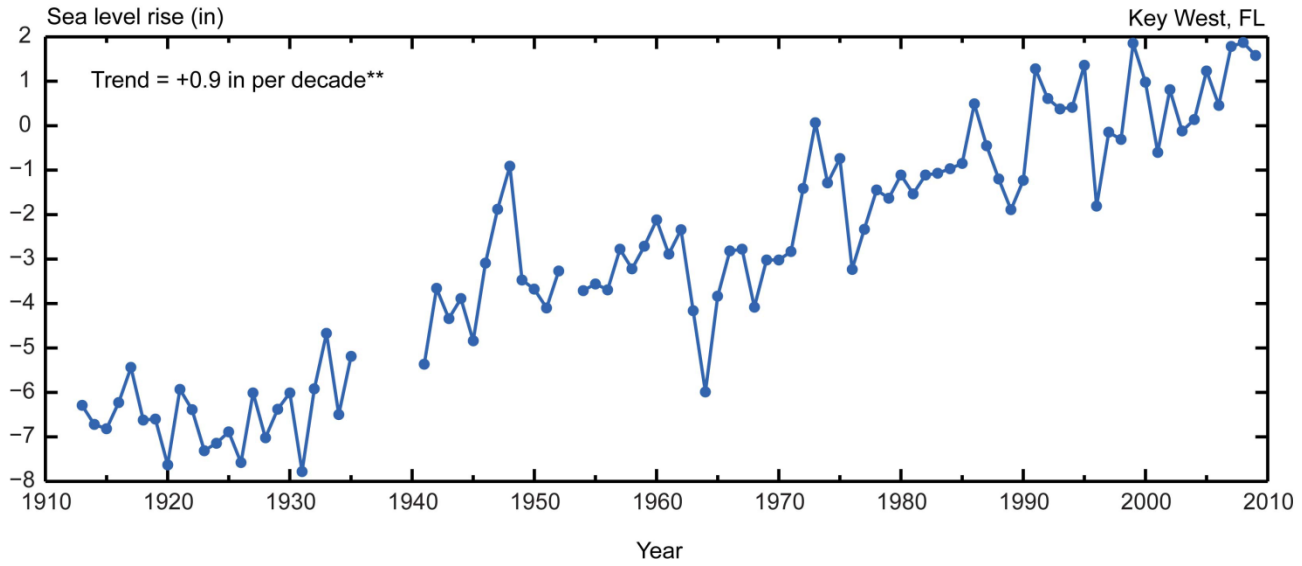
Southeast Florida Climate

- Temperature
  - Range from an average of 67 °F in January to 83 °F in August
- Precipitation
  - Annual average of 56 in
  - Pronounced rainy and dry season
- Local climate features
  - Thunderstorms
  - Tropical cyclones



Observed Climate Trends

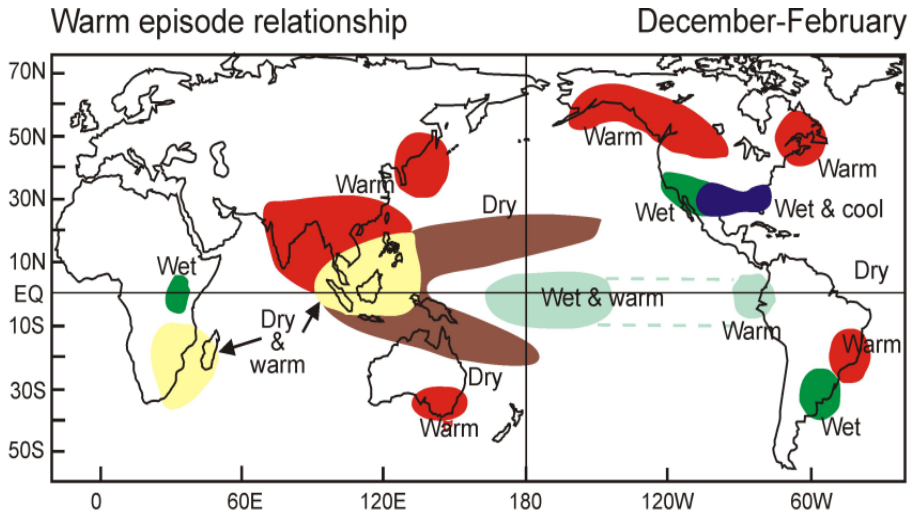


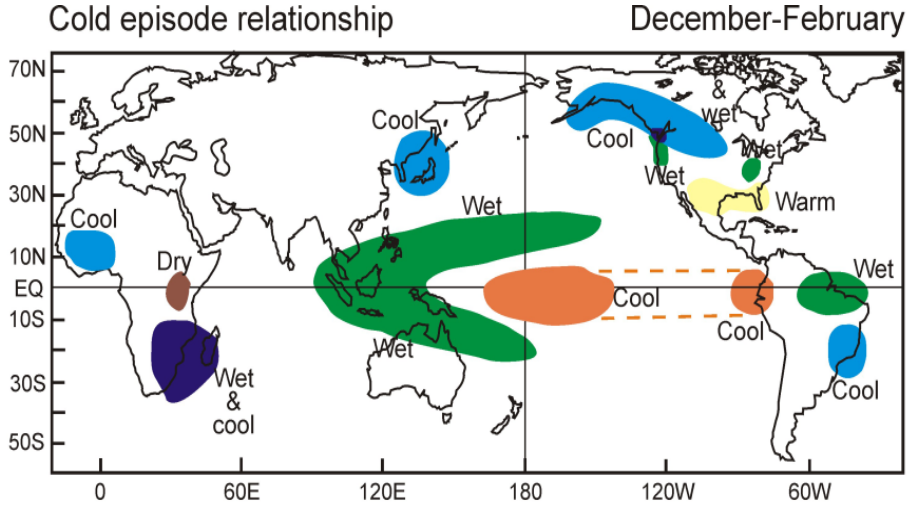


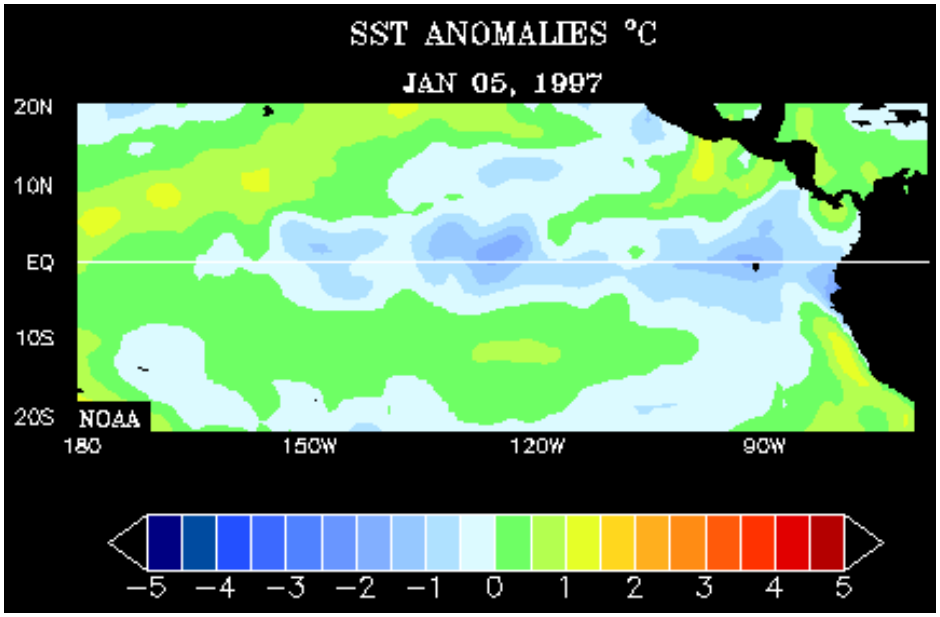
Temperature and sea level are rising in South Florida

Temperature data from NOAA NCDC. Sea level data from NOAA Tides and Currents. Source: Columbia University Center for Climate Systems Research

El Niño Southern Oscillation (ENSO)

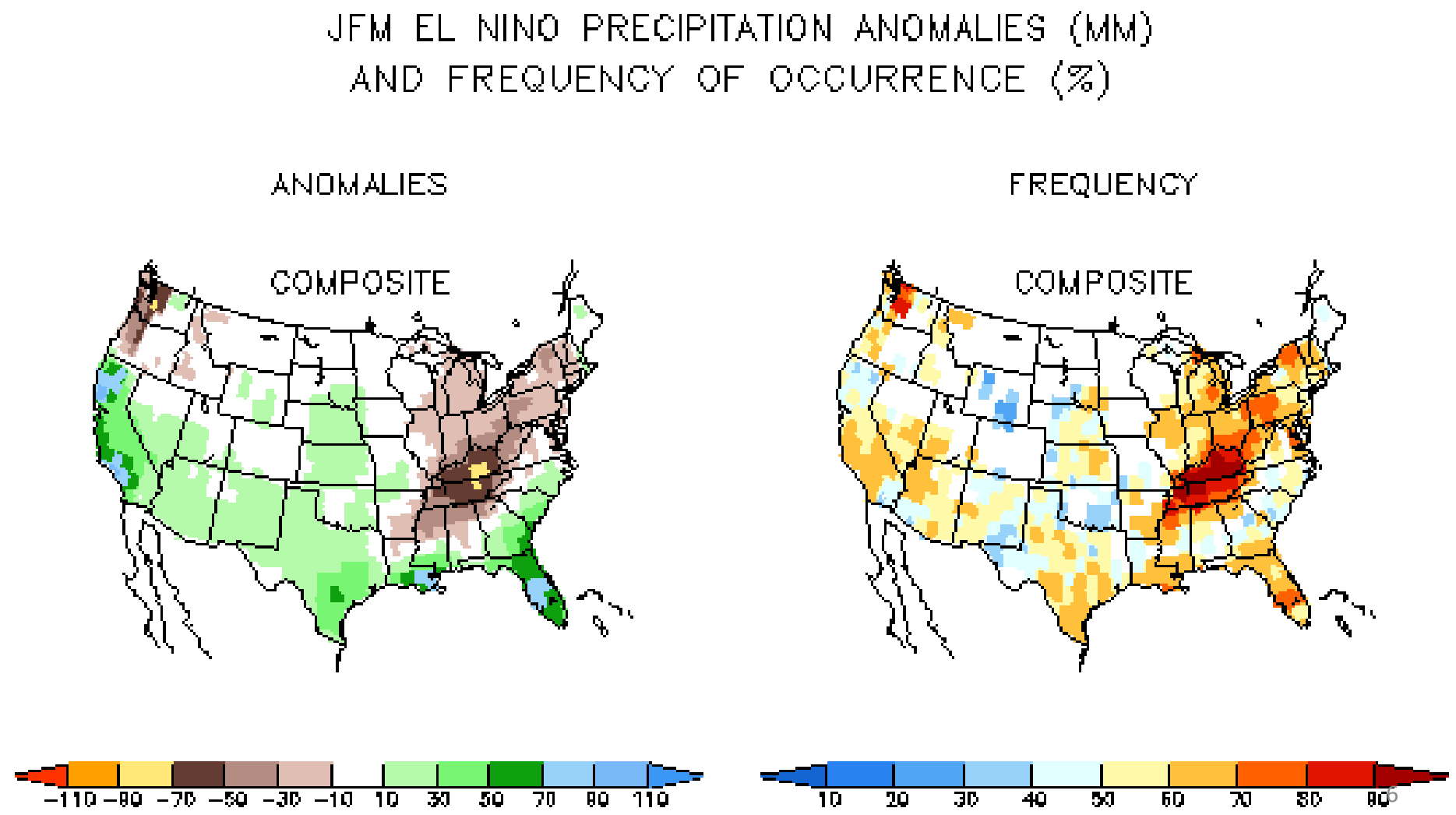






SST Anomalies from 1998 El Niño

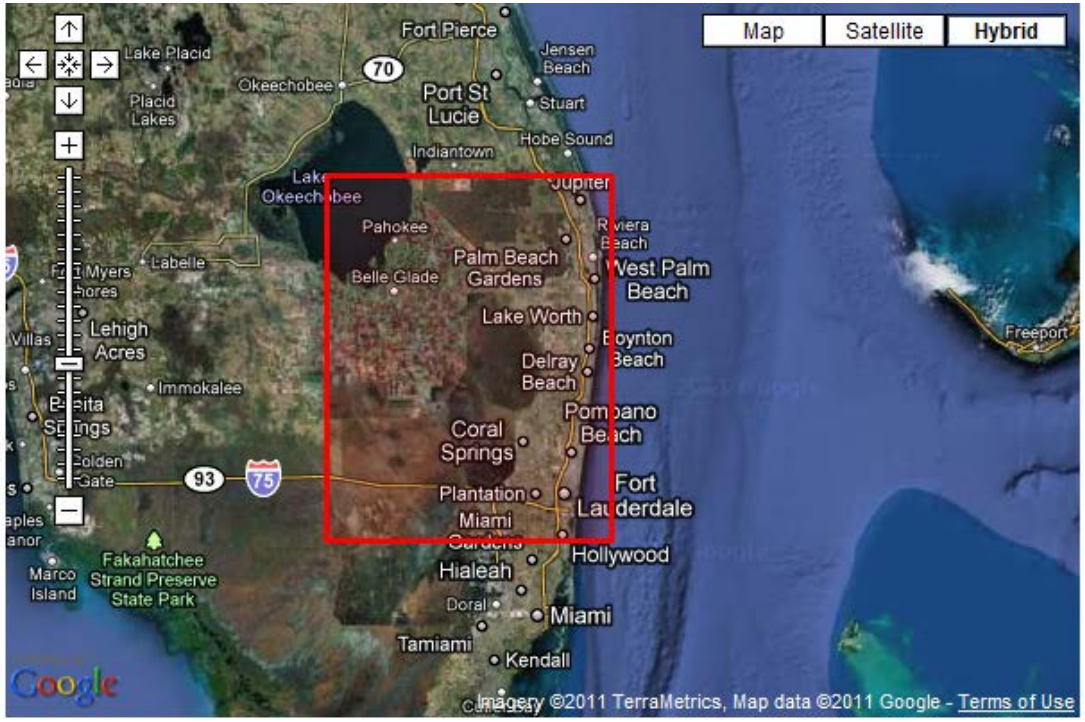
El Niño Southern Oscillation (ENSO) Teleconnections – Seasonal Averages



Source: NOAA CPC

Downscaling

- Statistical downscaling produces finer scale features than Global Climate Models (GCMs) using historical relationships between the large and small spatial scales
- Dynamical downscaling achieved by running a Regional Climate Model (RCM) RCM at high resolution over a small spatial domain driven by GCM output



Mean Annual Changes

	Baseline	2020s	2050s	2080s
Air Temperature	76 ˚F	1.0 to 2.0 ˚F	2.0 to 3.5 ˚F	3.0 to 5.5 ˚F
Precipitation	56 in	-5 to 5 %	-10 to 5 %	-10 to 5 %

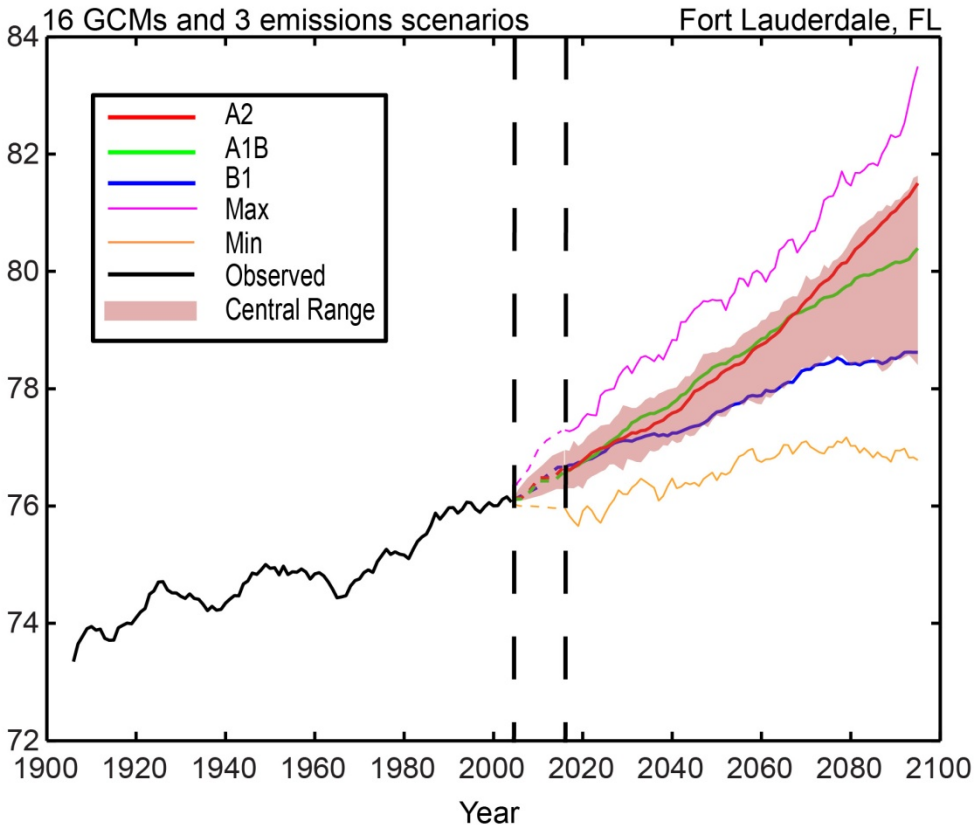
Based on 16 GCMs and three emissions, downscaled to ~12 km resolution

Shown are the central range (middle 67%) of model-based values

Temperature and precipitation changes reflect a 30-year average centered on the specified decade. The baseline for temperature and precipitation is the most complete 30-year data period centered around the 1980s. The baseline value is an average of baseline data from the Miami, Miami Beach, Fort Lauderdale, Palm Beach, and Belle Glade stations. Temperatures are rounded to the nearest half degree, precipitation to the nearest 5%. Data are from NOAA.

Bias-corrected and spatially downscaled CMIP3 data:
http://gdodcp.ucllnl.org/downscaled_cmip3_projections/, Maurer et al (2007).
Source: Columbia University Center for Climate Systems Research

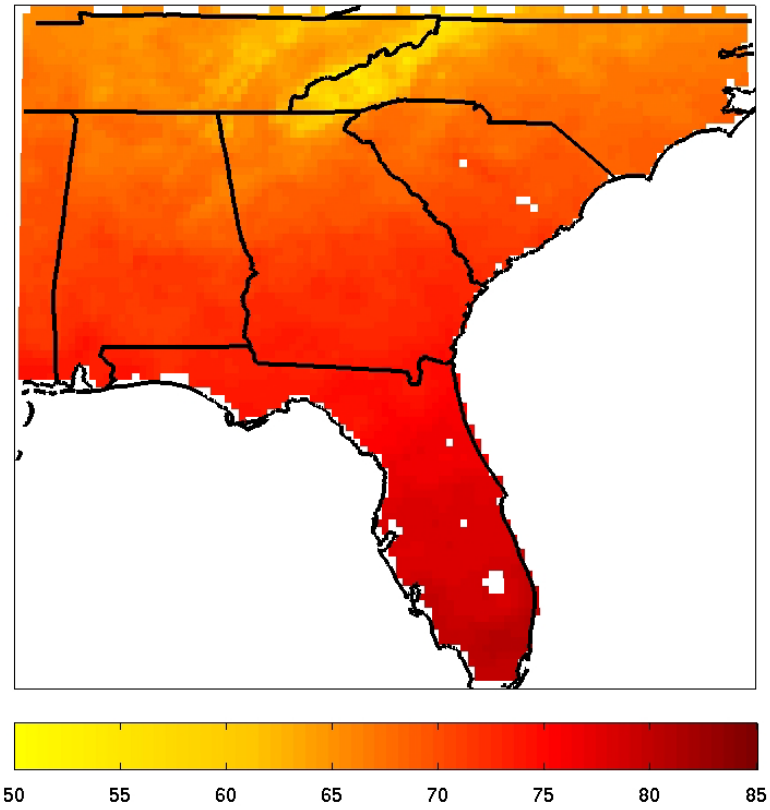
Mean Annual Changes



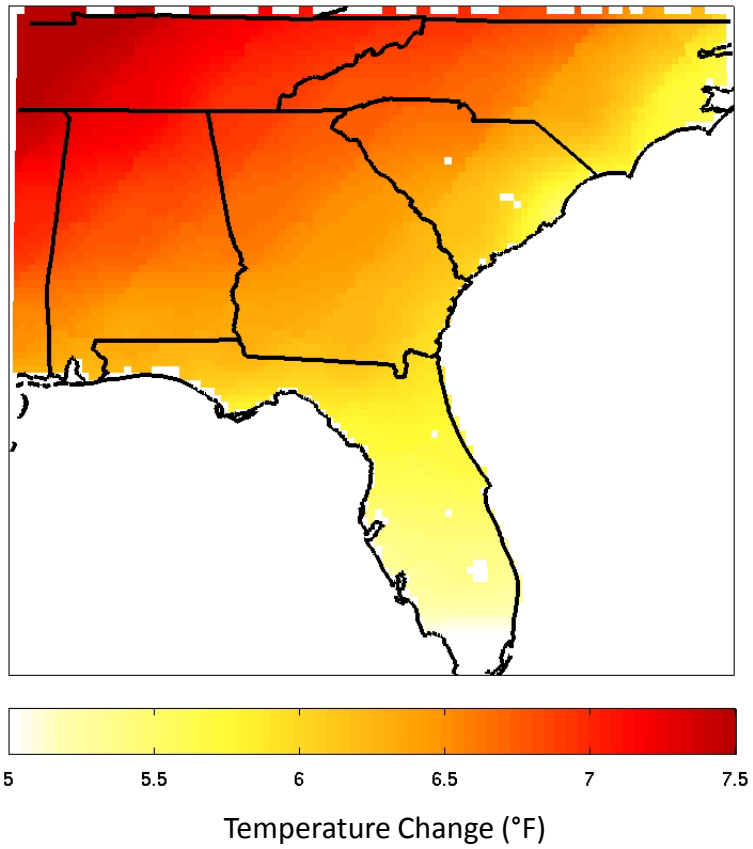
Combined observed (black line) and projected precipitation. Projected model changes through time are applied to the observed historical data. The three thick lines (green, red, and blue) show the average for each emissions scenario across the 16 GCMs from the BCSD dataset. Shading shows the central range. The bottom and top lines, respectively, show each year's minimum and maximum projections across the suite of simulations. A ten-year filter has been applied to the observed data and model output. The dotted area between 2005 and 2015 the period that is not covered due to the smoothing procedure. Source: CCSR

Regional Temperature Projections

16 A2 GCM Annual Temperature
2070 – 2099 (°F)



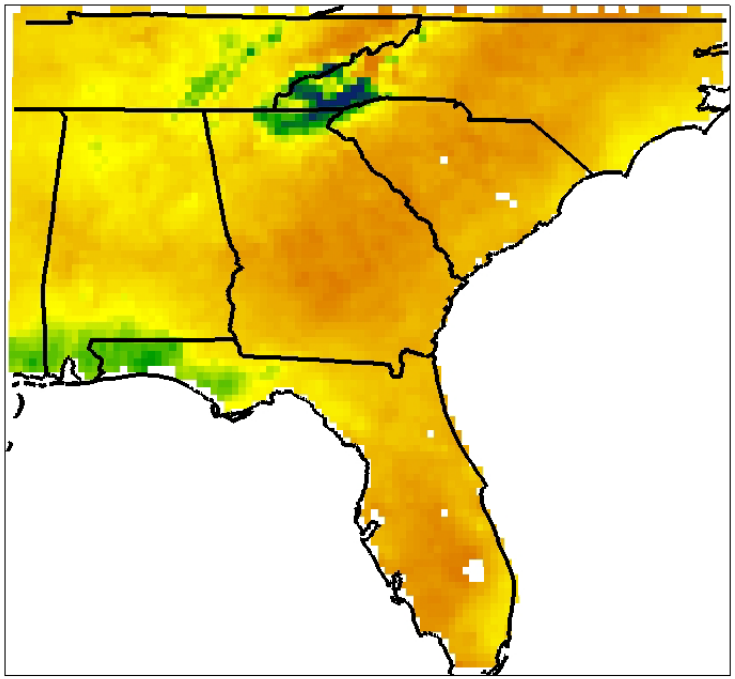
A2 2080s 16 GCM Annual Temperature
Change (°F), relative to 1970-1999

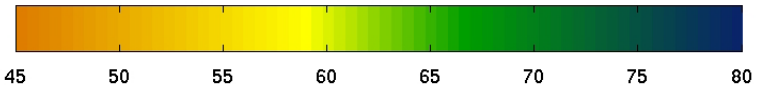


Bias-corrected and spatially downscaled CMIP3 data:
http://gdodcp.ucllnl.org/downscaled_cmip3_projections/, Maurer et al (2007).
Source: Columbia University Center for Climate Systems Research

Regional Precipitation Projections

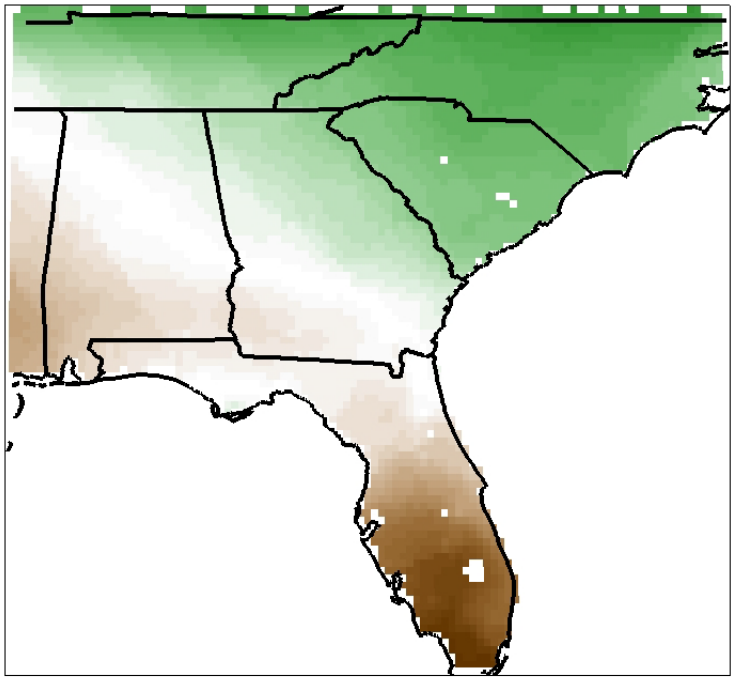
16 GCM A2 Annual Precipitation
2070 – 2099 (in)

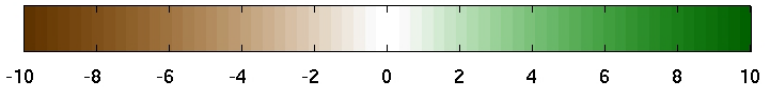




Annual Precipitation (in)

A2 2080s 16 GCM Annual Precipitation
Change (%), relative to 1970-1999





Percentage change in precipitation (%)

Bias-corrected and spatially downscaled CMIP3 data:
http://gdodcp.ucllnl.org/downscaled_cmip3_projections/, Maurer et al (2007).
Source: Columbia University Center for Climate Systems Research

Extreme Events

Daily Temperatures	Baseline	2020s	2050s	2080s
Max temperature at or above 90˚F (days/year)	60	84 to 98	107 to 139	130 to 174
Min temperature at or below 45˚F (days/year)	9	6 to 7	4 to 6	3 to 5
Precipitation at or above 1 inch (days/year)	18	17 to 19	16 to 19	15 to 19

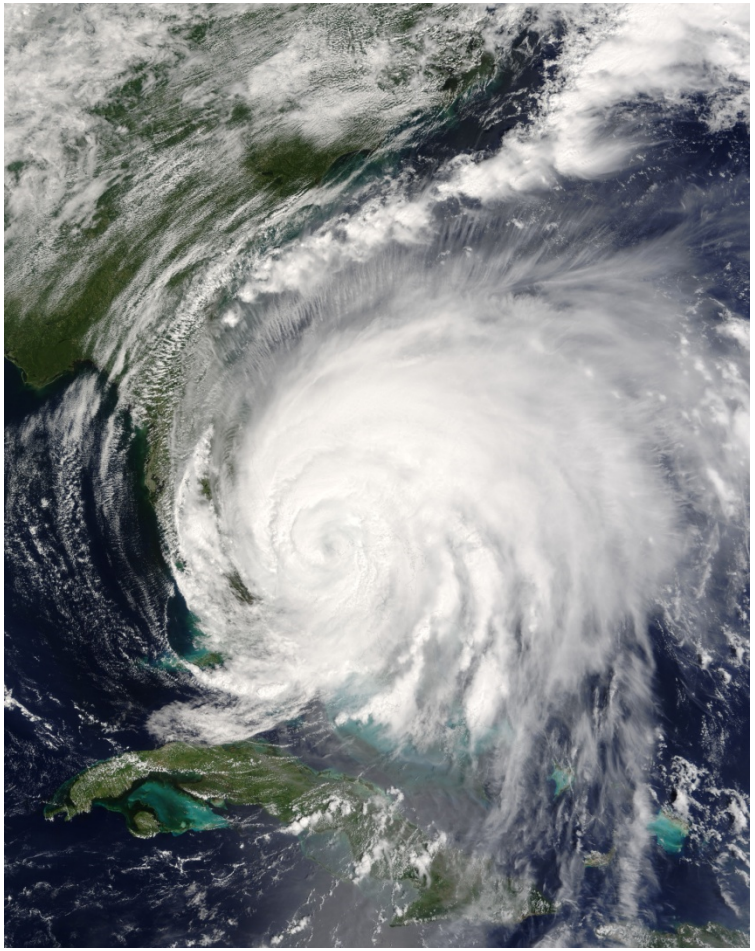
The number of days per year exceeding 90°F is projected to rise in the coming century, and the number of days with temperatures below 45°F is projected to decrease.

*** For Fort Lauderdale, FL**

Baseline data from NOAA
Source: Columbia University Center for Climate Systems Research

Tropical Cyclones

- Teleconnections
  - El Niño / La Niña
  - Atlantic Multidecadal Oscillation
- 2011 Seasonal Forecast
  - 12 to 18 names storms
  - 6 to 10 hurricanes
  - 3 to 6 major hurricanes
- Future Projections
  - No concrete evidence global warming will have an impact on hurricane strength and frequency
  - Warming may increasing hurricane intensity (Emanuel, 2005)
  - Other factors that influence hurricane development (i.e. wind shear) may also change with warming



Hurricane Frances

Source: NASA, 2004

Qualitative Extremes

Qualitative Changes in Extreme Events During this Century		
Event	Direction of Change	Likelihood
Heat Stress	⇧	Very Likely
Downpours	⇧	Likely
Intense storms	⇧	More likely than not
Drought*	⇧	More likely than not
Extreme winds	⇧	More likely than not

Likelihood categories based on IPCC WG1, 2007.

Source: Columbia University Center for Climate Systems Research

Very likely = >90% probability of occurrence

Likely =>66% probability of occurrence

More likely than not =>50% probability of occurrence

*The scenarios presented here can be used to produce quantitative estimates of drought frequency

Causes of Sea Level Change

Land water storage

Groundwater mining, impoundment in reservoirs, urban runoff, deforestation, seepage into aquifers

Vertical land motions

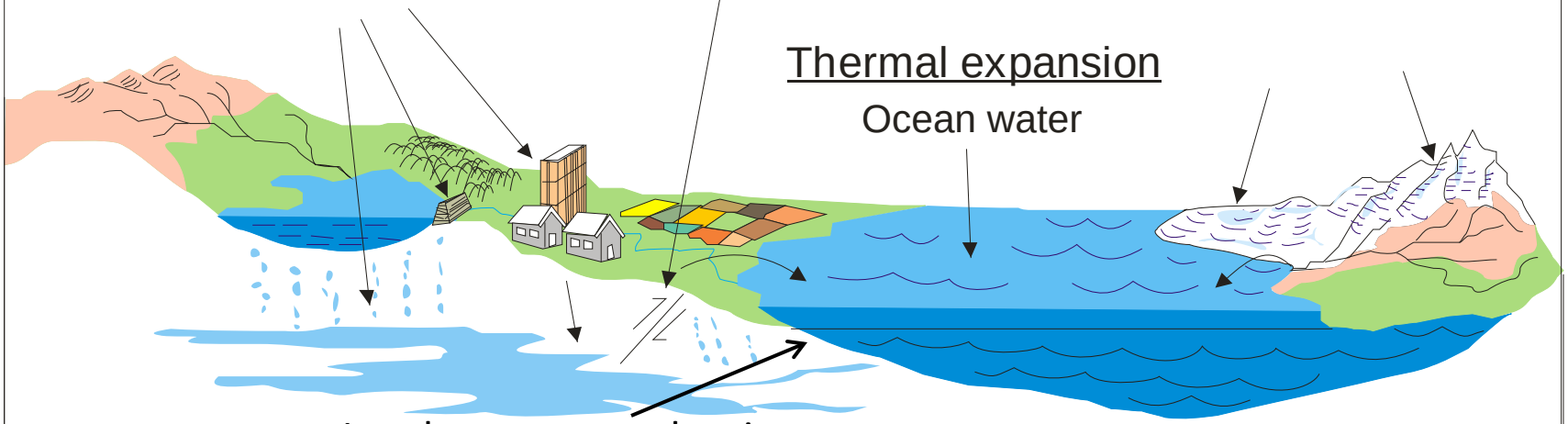
Subsidence/uplift due to glacial isostatic adjustment, tectonics

Mass changes

Glaciers and ice sheets

Thermal expansion

Ocean water



Local water mass density

Temperature, salinity, ocean currents

Sea Level Rise Methods

- IPCC-based approach
  - Global thermal expansion
  - Local land subsidence (GIA)
  - Meltwater from glaciers, ice caps, and ice sheets
  - Local water surface elevation
- Rapid ice-melt approach
  - Based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets and paleoclimate studies
  - Rationale:
    - Observed sea level slightly above high end IPCC projections
    - Climate models cannot yet fully capture processes such as:
      - Surface ponding and basal lubrication of glaciers
      - Thinning of ice shelves that buttress land ice
      - Thinning of ice at grounding lines

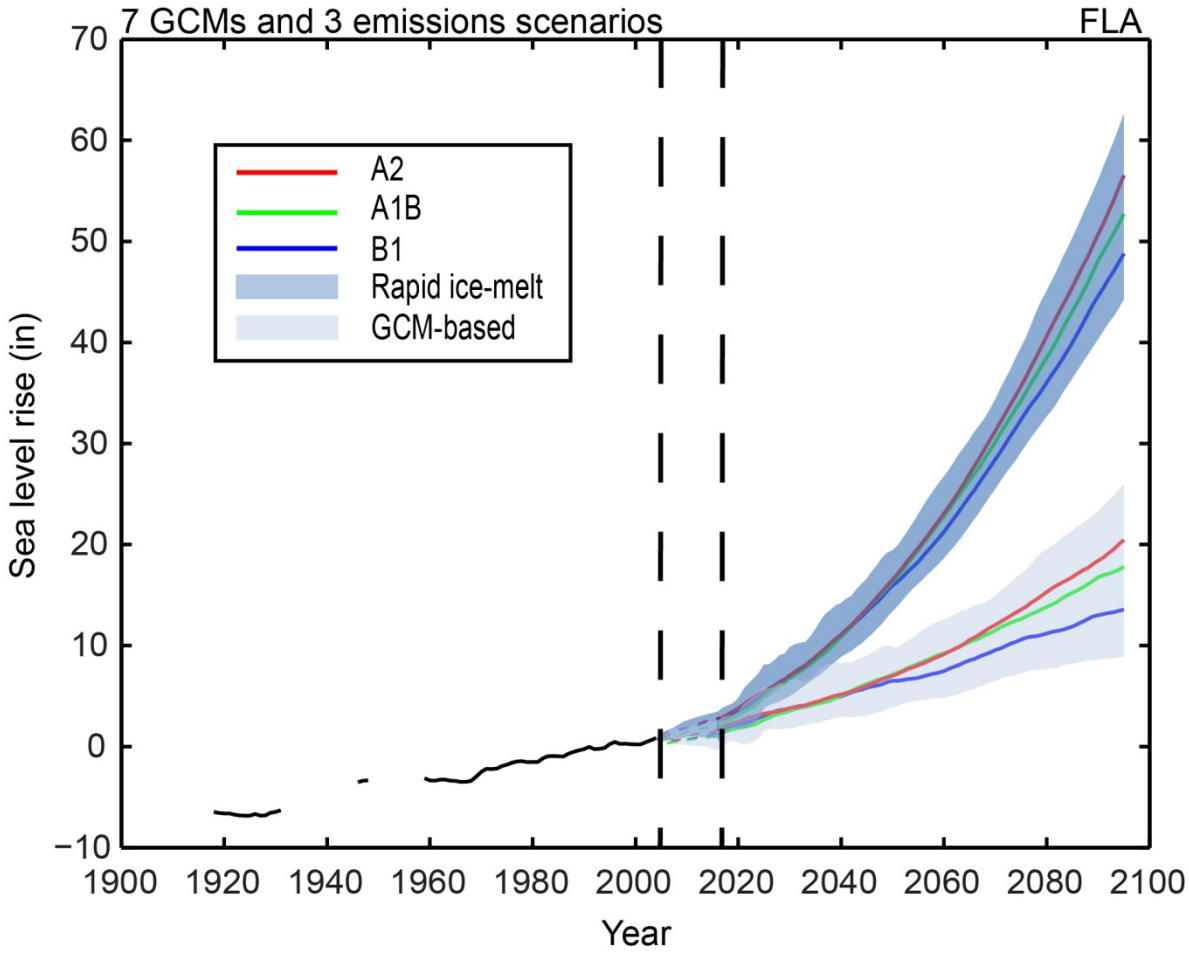
Sea Level Rise Projections Southeast Florida

	Baseline	2020s	2050s	2080s
IPCC-based	NA	+ 2 to 4 in	+ 6 to 9 in	+ 10 to 19 in
Rapid ice-melt scenario	NA	~ 4 to 6 in	~ 18 to 21 in	~ 39 to 48 in

Source: Columbia University Center for Climate Systems Research

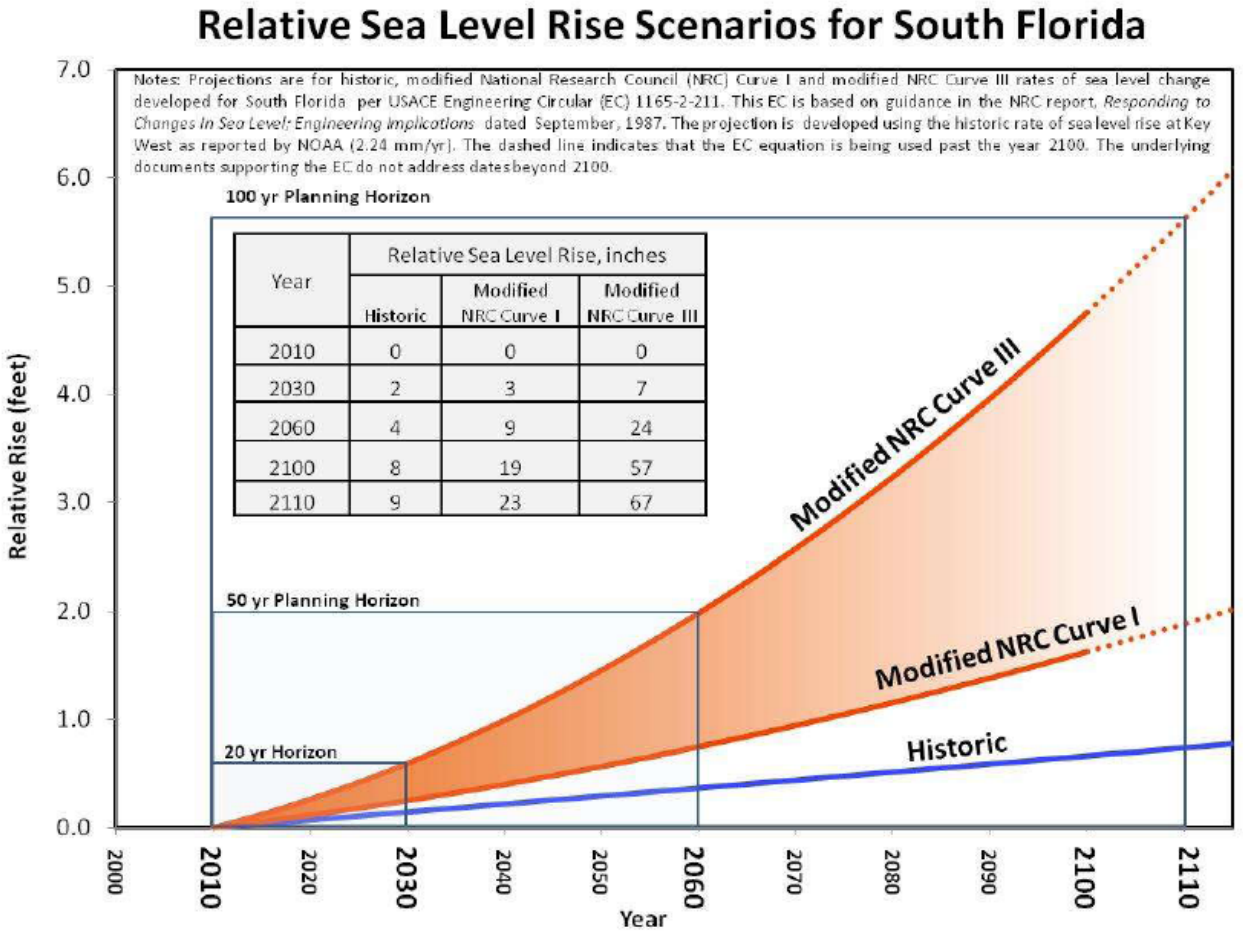
Sea levels are averages for the specified decade. Changes are relative to the 2000 to 2004 base period. The central range (middle 67% of values from model-base probabilities) across the 7 GCMs and 3 GHG emissions scenarios is shown; sea level rise rounded to the nearest inch. "Rapid ice melt scenario" is based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets and paleoclimate studies. The scenario assumes a 1 meter rise in sea level due to ice melt alone.

Sea Level Rise Projections



Combined observed (black line) and projected sea level rise for two future sea level rise scenarios. Projected model changes through time are applied to the observed historical data. The darker shaded blue shows the full range of projections for the rapid ice-melt scenario while the lighter shade of blue shows the full range of projections for the GCM-based sea level rise approach. The three thick lines (green, red, and blue) within each sea level rise scenario show the average for each emissions scenario across the 7 GCMs A ten-year filter has been applied to the observed data and modeled output. The dotted area between 2004 and 2015 the period that is not covered due to the smoothing procedure. Source: CCSR

Sea Level Rise Comparison



Year	Relative Sea Level Rise, inches		
	Historic	Modified NRC Curve I	Modified NRC Curve III
2010	0	0	0
2030	2	3	7
2060	4	9	24
2100	8	19	57
2110	9	23	67

Sea Level Rise Comparison

Year	Relative Sea Level Rise, inches				
	Historic	Modified NRC Curve I	Modified NRC Curve II	IPCC-based	Rapid ice-melt
2010	0	0	0	Up to 4	Up to 4
2030	2	3	7	1 to 6	5 to 10
2060	4	9	24	4 to 13	19 to 28
2100	8	19	57	10 to 29	49 to 70
2110	9	23	67	NA	NA