Evidence coastal sea level changes along the east coast of United States associated with the Florida Current transport and heat content using satellite altimetry and hydrographic observations

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High-tide Flooding Events in Miami

Credit: Grant Rawson (NOAA/AOML)

High-tide Flooding Events in Miami: September-October 2015

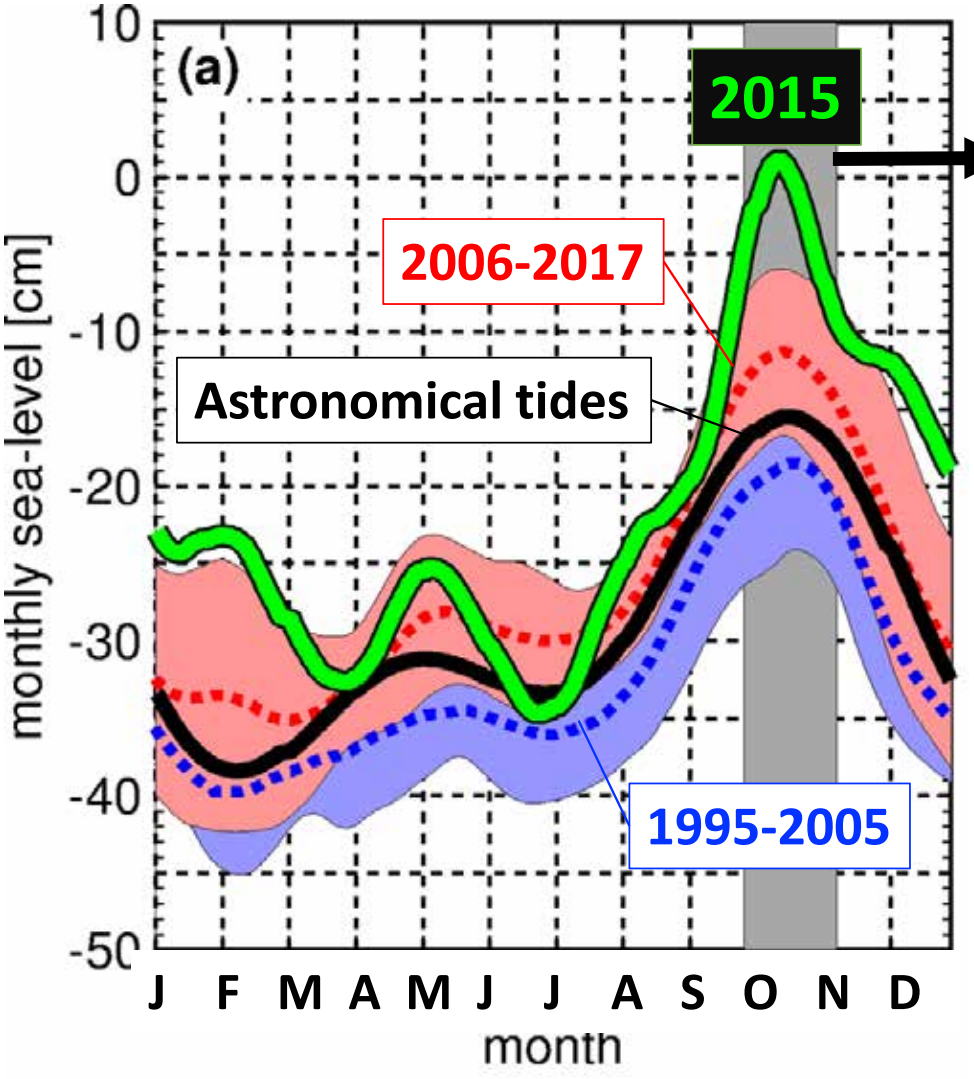
Credit: Miami New Times


Credit: New York Times

Estimated return period of 6 years (Sweet et al., 2016)

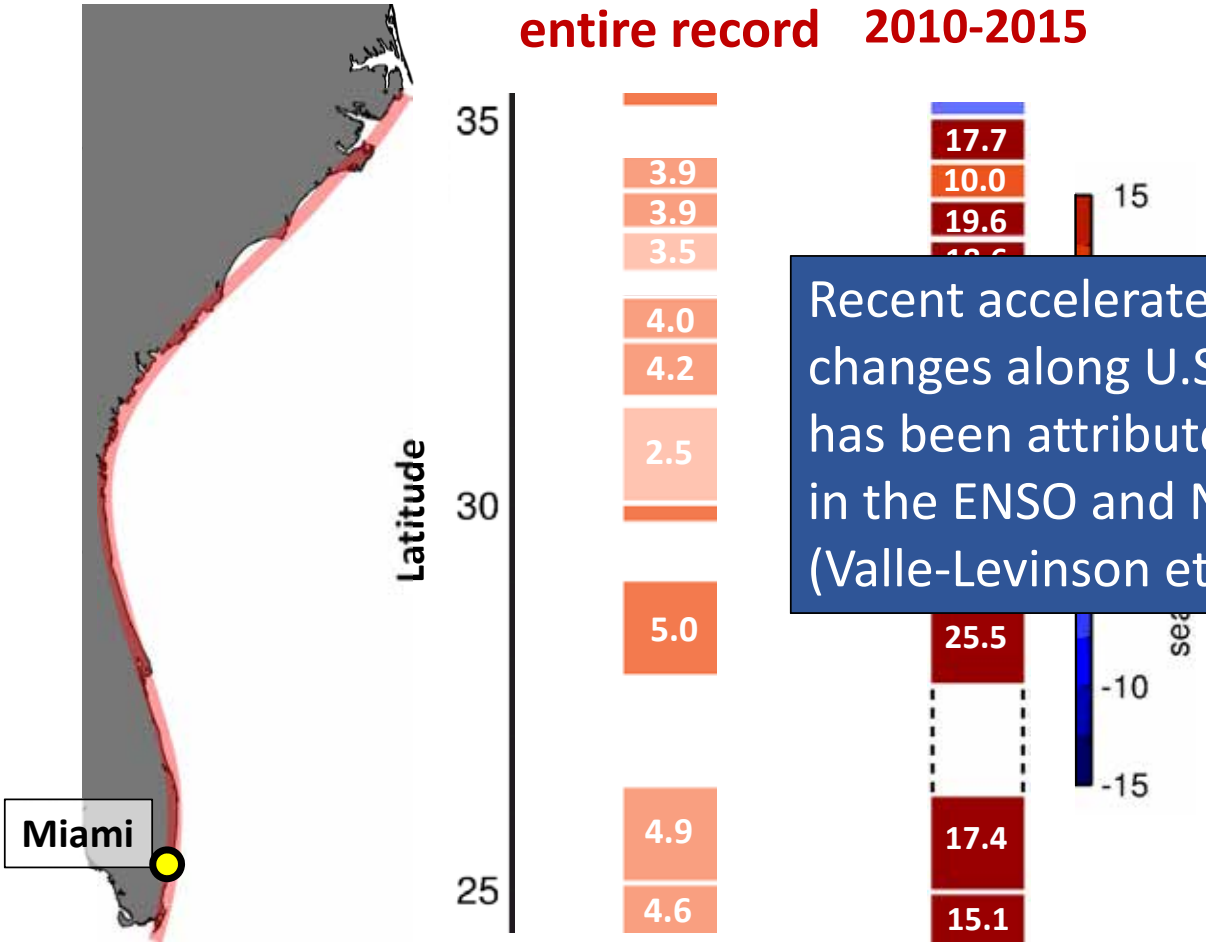
High-tide Flooding Events in Miami: September-October 2015

Monthly sea-level observed in Miami
(NOAA/NOS Virginia Key Tide Gauge)



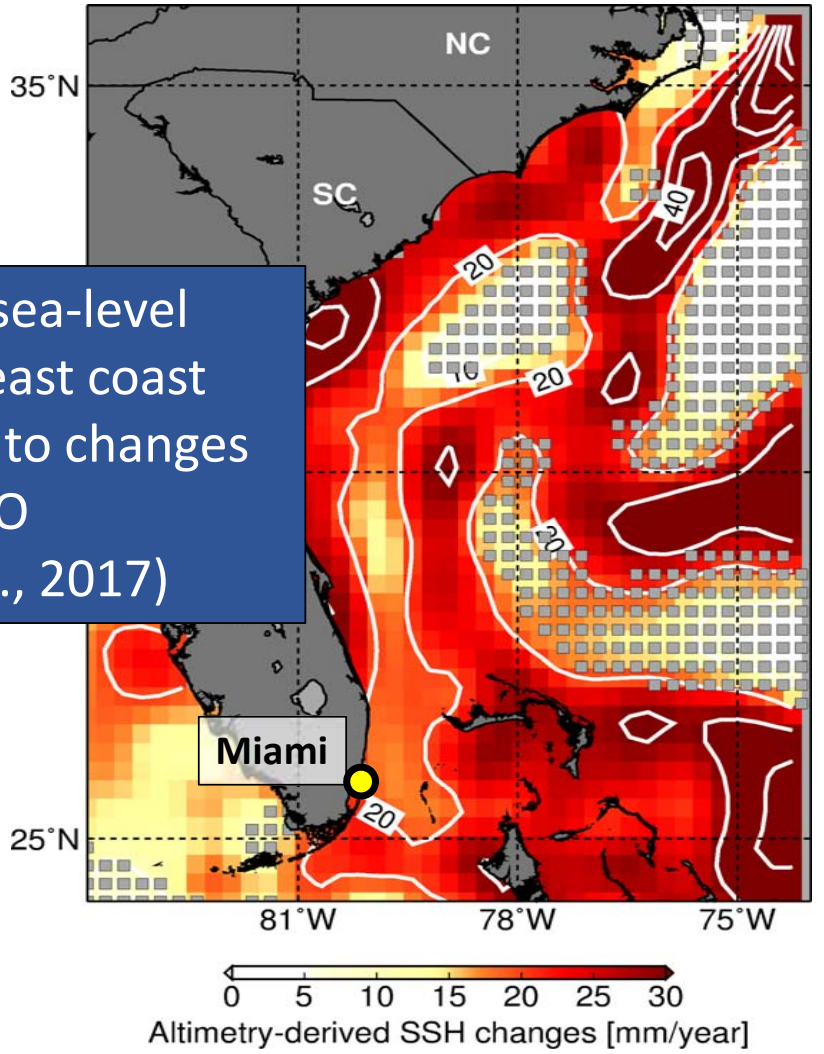
Sea Level Changes Along U.S. East Coast

Tide Gauges



Recent accelerated sea-level changes along U.S. east coast has been attributed to changes in the ENSO and NAO (Valle-Levinson et al., 2017)

Satellite-Altimetry: 2010-2015



Sources of Sea Level Changes

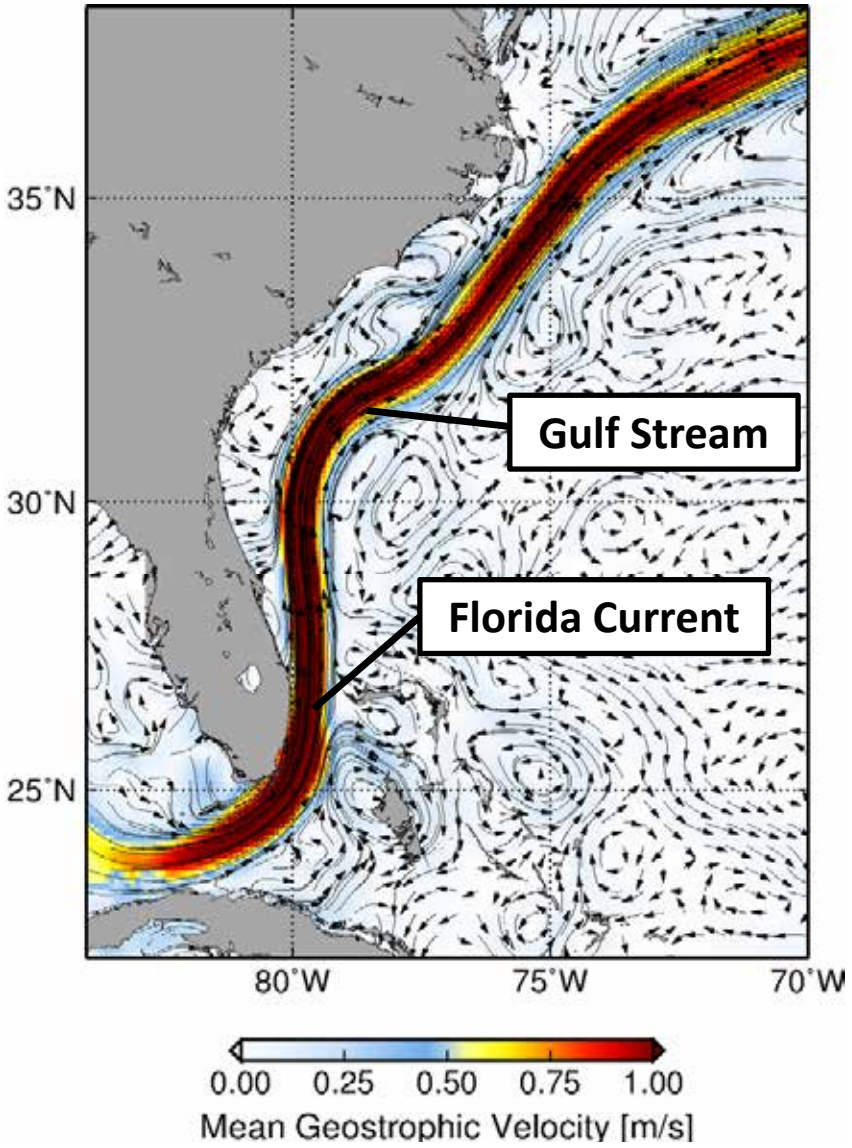
$$\mathbf{Obs.\,SL} = \overline{\mathbf{SL}} + \Delta\mathbf{SL_{tides}} + \Delta\mathbf{SL_{waves}} + \Delta\mathbf{SL_{weather}} + \Delta\mathbf{SL_{land}} + \Delta\mathbf{SL_{GL}} + \Delta\mathbf{SL_{Ocean\ Currents}}$$

$\overline{\mathbf{SL}}$	mean sea level
$\Delta\mathbf{SL_{tides}}$	effect of astronomical tides
$\Delta\mathbf{SL_{waves}}$	local effect of waves
$\Delta\mathbf{SL_{weather}}$	effect of local winds and atm. pressure changes
$\Delta\mathbf{SL_{land}}$	effect of land subsidence
$\Delta\mathbf{SL_{GL}}$	effect of global changes in ocean mass and density
$\Delta\mathbf{SL_{Ocean\ Currents}}$	effect of Ocean Currents in sea level changes

Florida Current and Gulf Stream Effect on Sea Level Along East U.S. coast

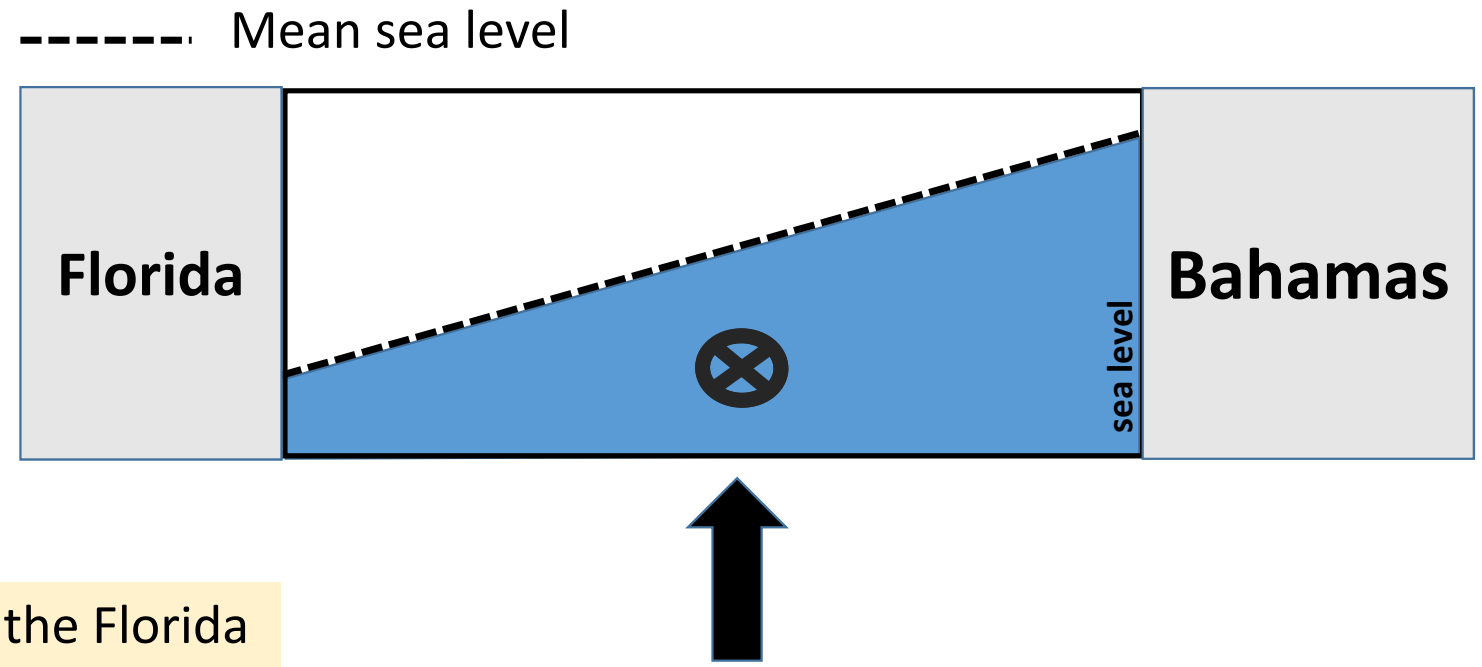
$\Delta SL_{Ocean\ Currents}$

The Florida Current sustain a sea level difference between south Florida and the Bahamas of almost **1m**



Florida Current and Gulf Stream Effect on Sea Level Along East U.S. coast

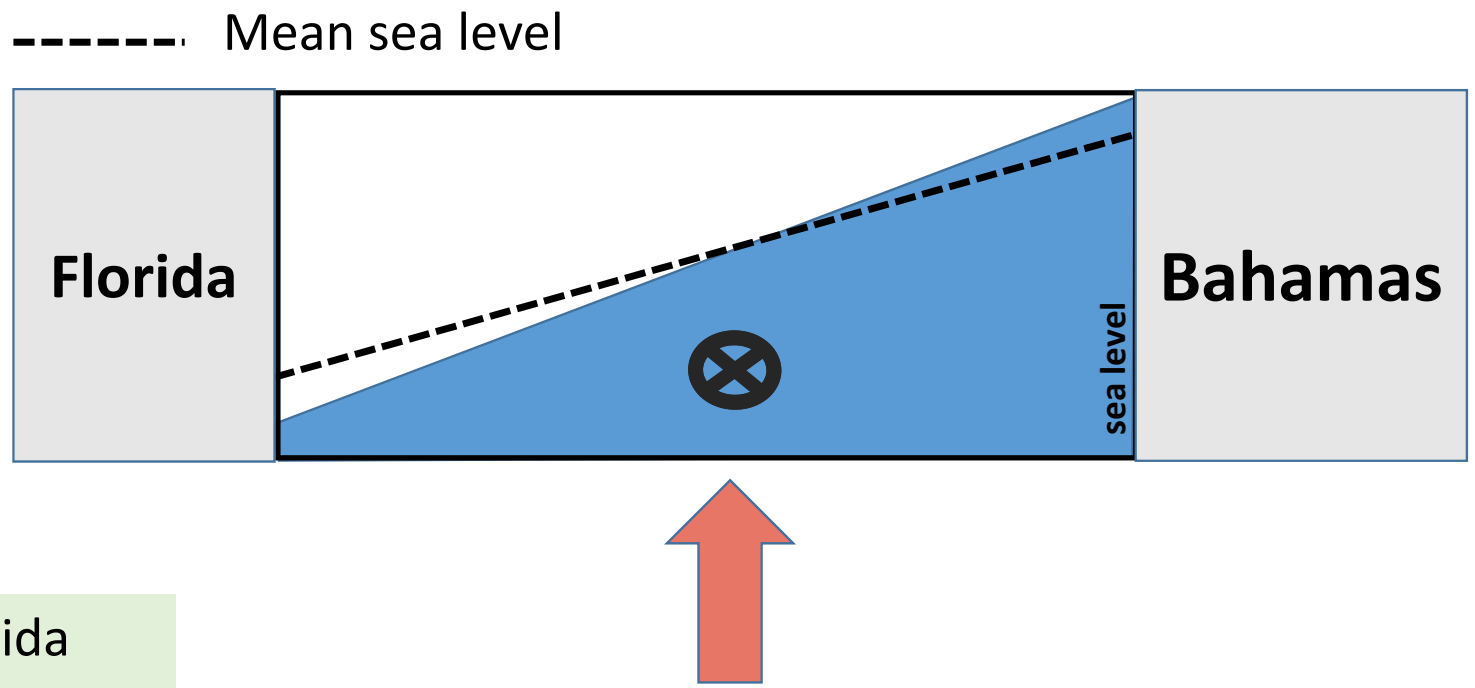
$\Delta SL_{Ocean\ Currents}$



Changes in the intensity of the Florida Current and Gulf Stream are, therefore, associated with sea level changes along the east coast of U.S.

Florida Current and Gulf Stream Effect on Sea Level Along East U.S. coast

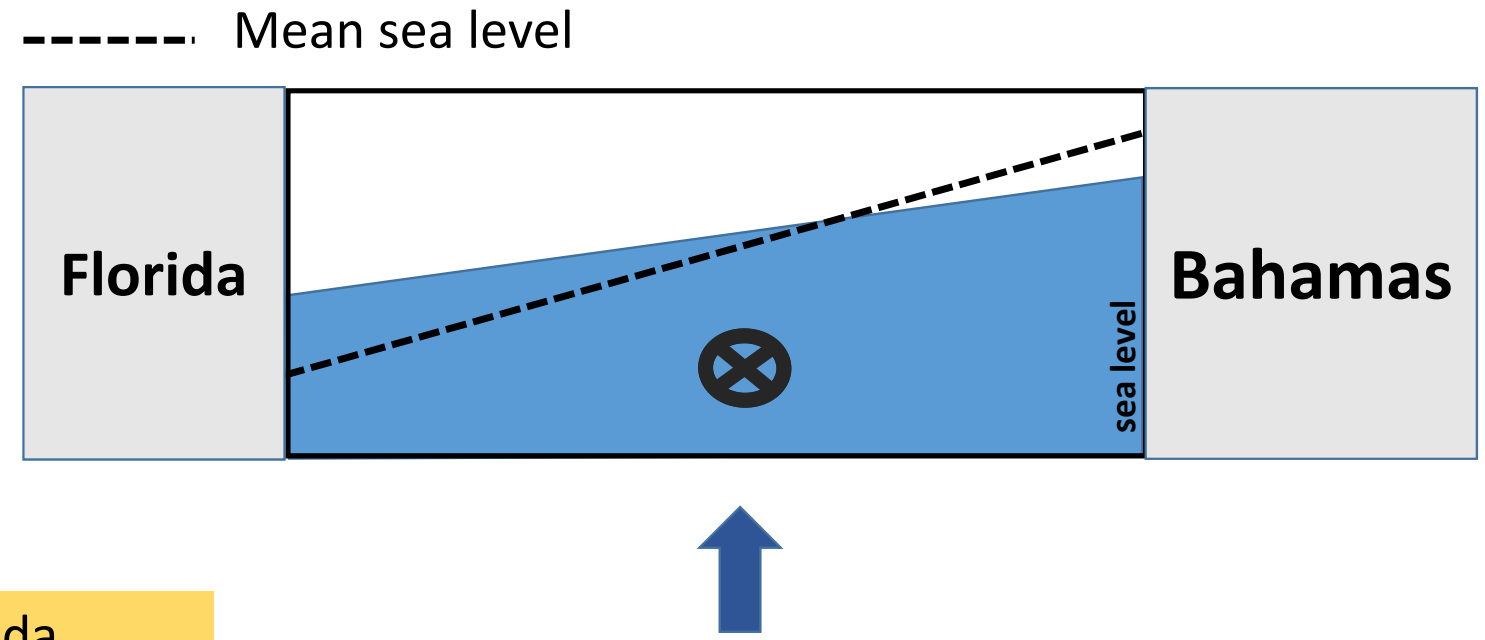
$\Delta SL_{Ocean\ Currents}$



Decrease in sea level at Florida
Increase sea level at the Bahamas

Florida Current and Gulf Stream Effect on Sea Level Along East U.S. coast

$\Delta SL_{Ocean\ Currents}$

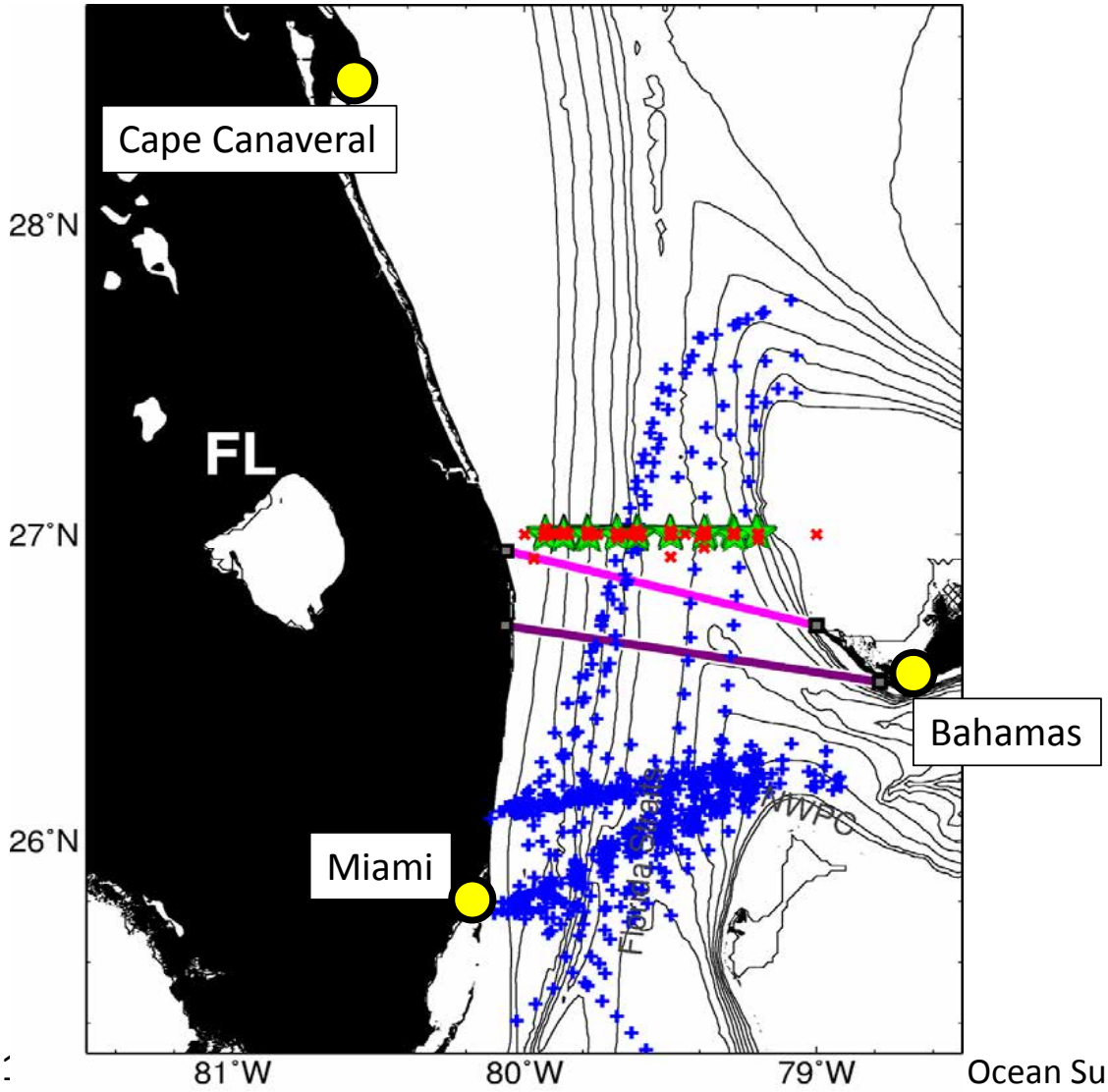


Increase in sea level at Florida
Decrease sea level at the Bahamas

Weak Florida Current flow

Ratio: 1-3 cm change in FL coastal sea-level per 1 Sv change in the Florida Current transport

Current efforts by NOAA/AOML to monitor the Florida Current



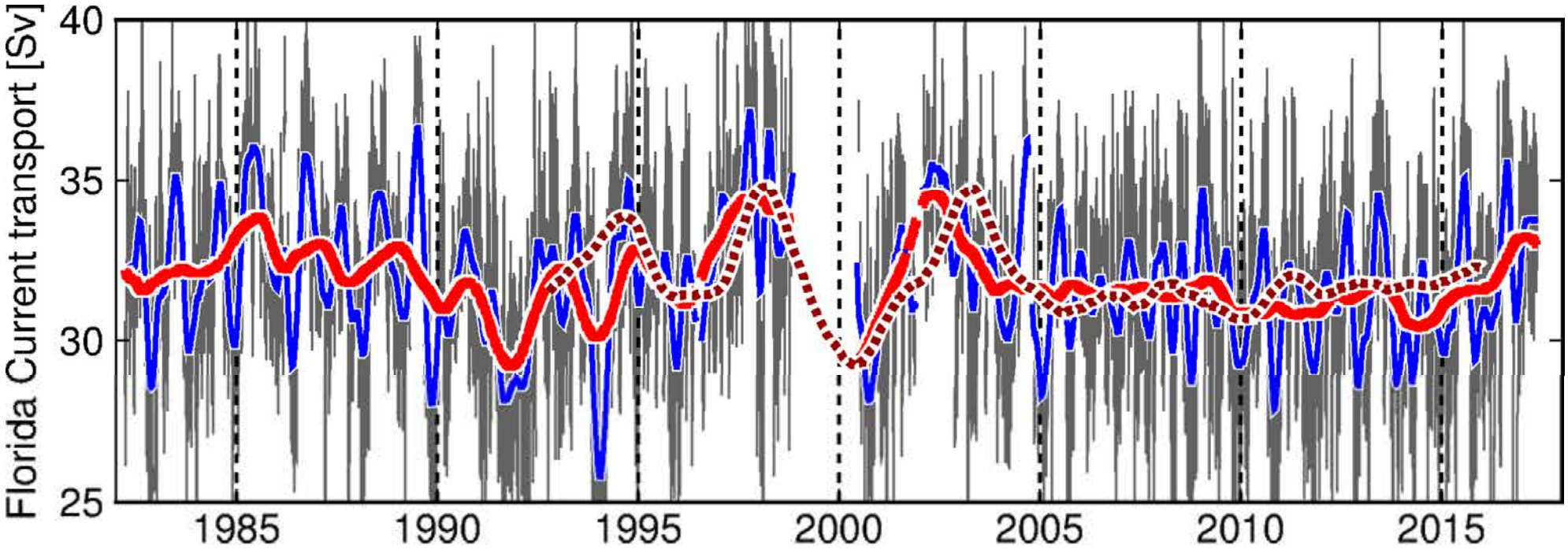
isobaths every 100m
27N CTD profiles (2001-2016)
27N XBT profiles (1995-2016)
AX7 XBT profiles (1995-2016)

FC Telephone Cable

Present day cable
Sanford (1982) cable

The Florida Current Cable Transport Time-series

Daily record of the Florida Current flow since 1982



Seasonal Changes in the Florida Current Flow

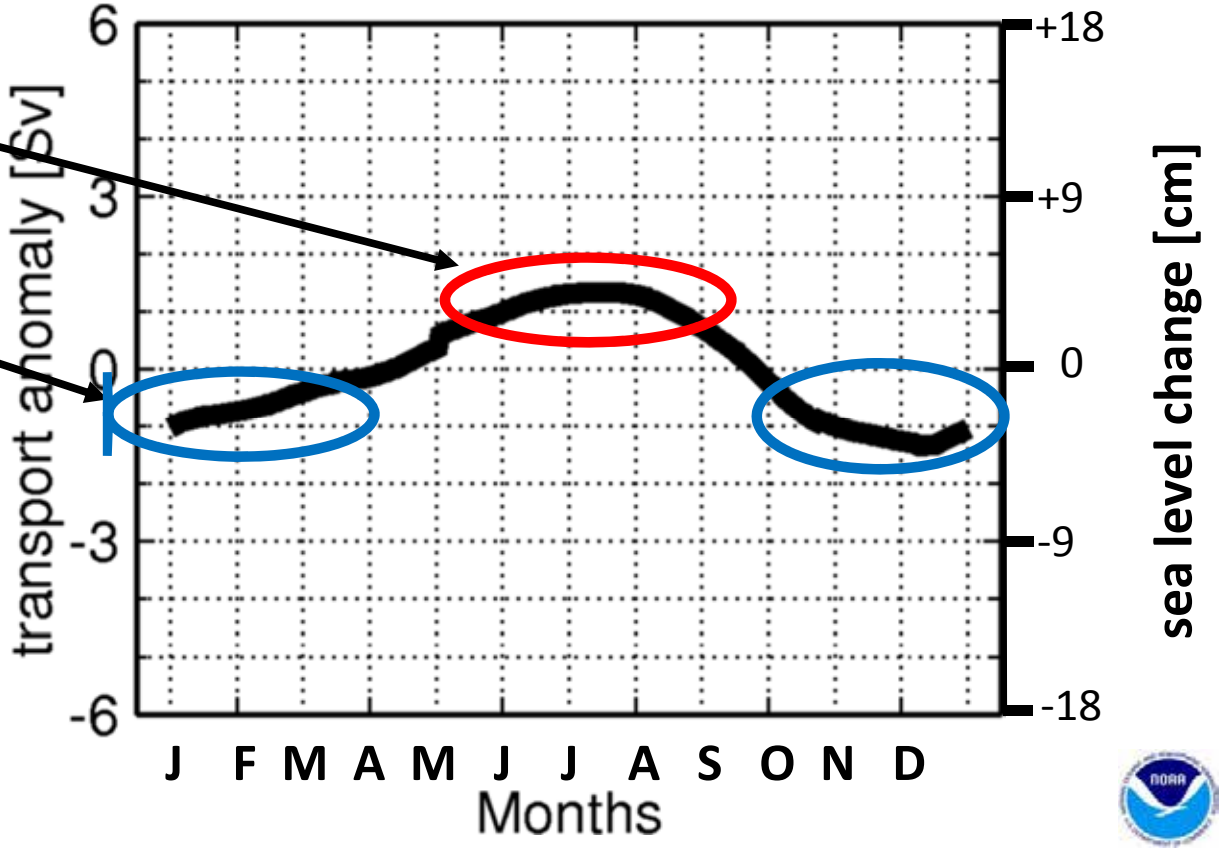
High during late spring to summer

Low during fall to winter

Niiler and Richardson (1973);
Leaman et al. (1987)
Schott et al., (1988)
Baringer and Larsen (2001);
Meinen et al., (2010)

± 3 cm expected sea level change associated with the mean FC annual cycle

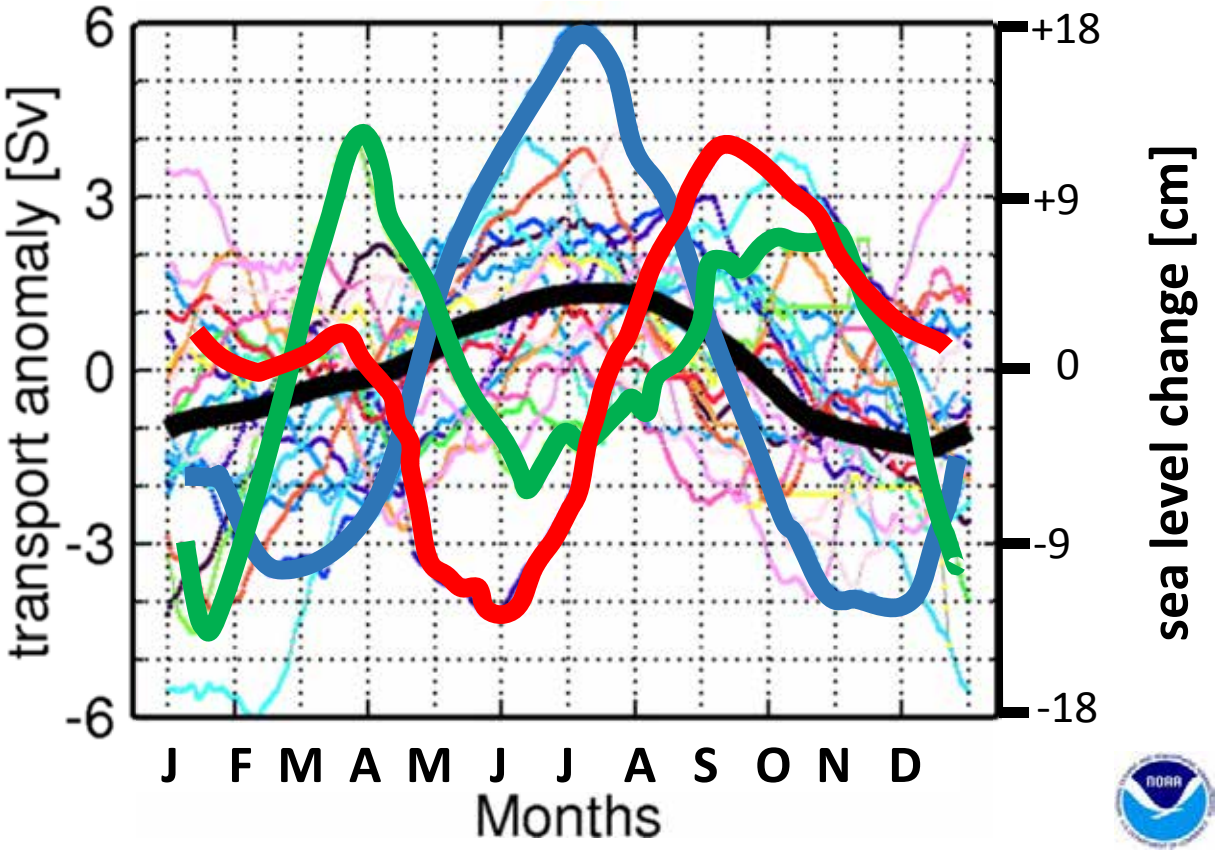
The FC annual variability



Seasonal Changes in the Florida Current Flow

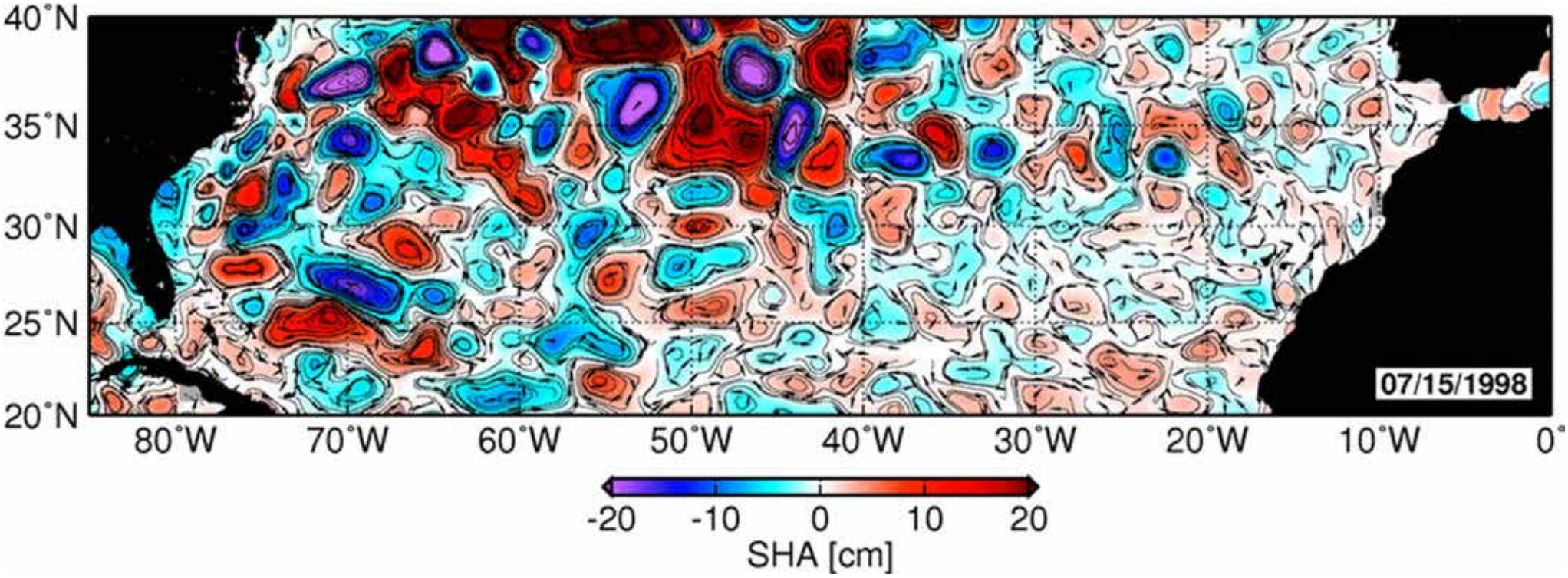
Significant changes in the Florida Current annual variability from one year to the next

The FC annual variability



Sources of Seasonal Changes in the Florida Current Flow

Filtered Satellite Altimetry Sea Height Anomaly



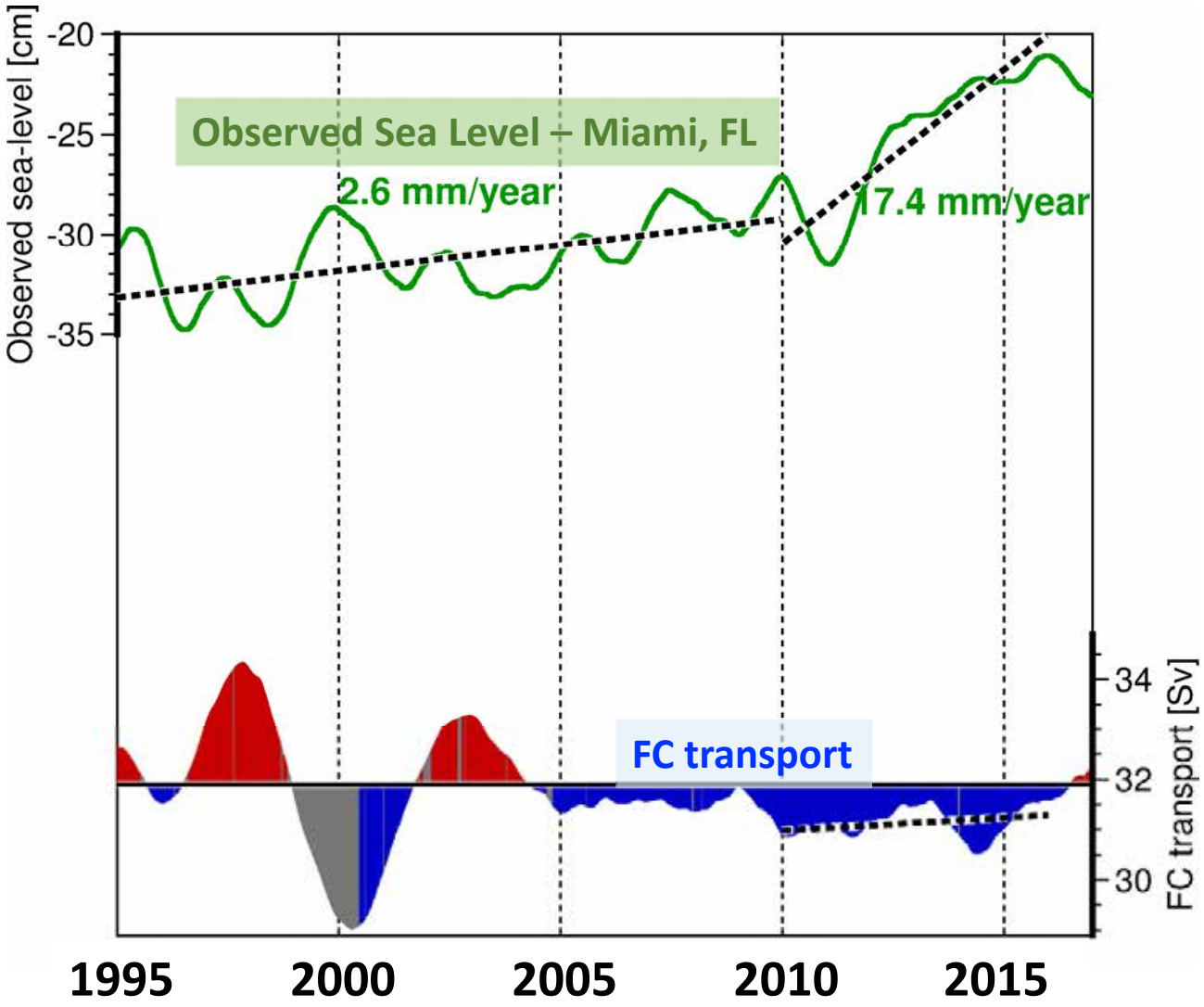
~ ±10 cm coastal sea level changes usually associated with the seasonal FC flow

SHA – sea height anomaly measured by satellite altimetry

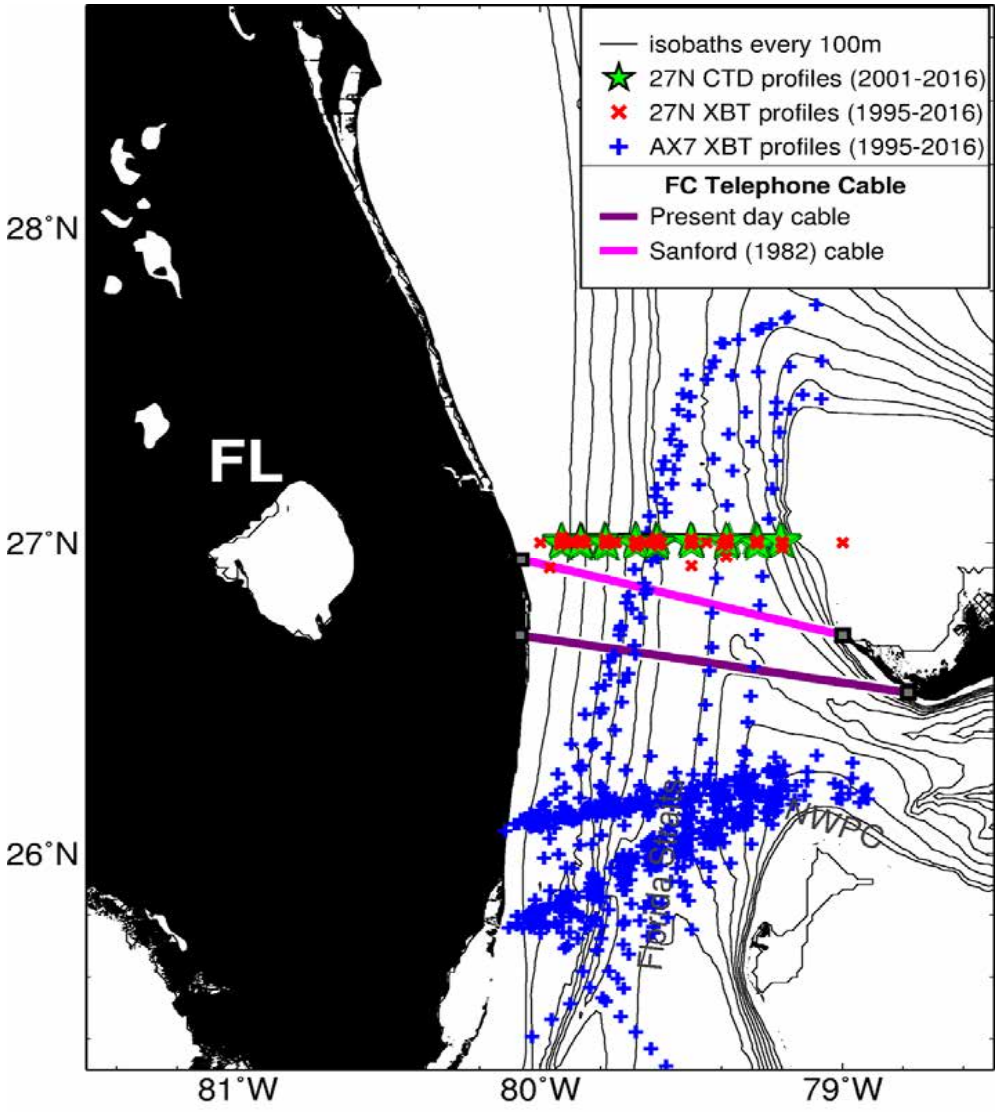
*displayed data is filtered for the 73-525 days band, after removal of average annual cycle

Domingues et al., (2016). Remote sources for year-to-year changes in the seasonality of the Florida Current transport. Journal of Geophysical Research-Oceans

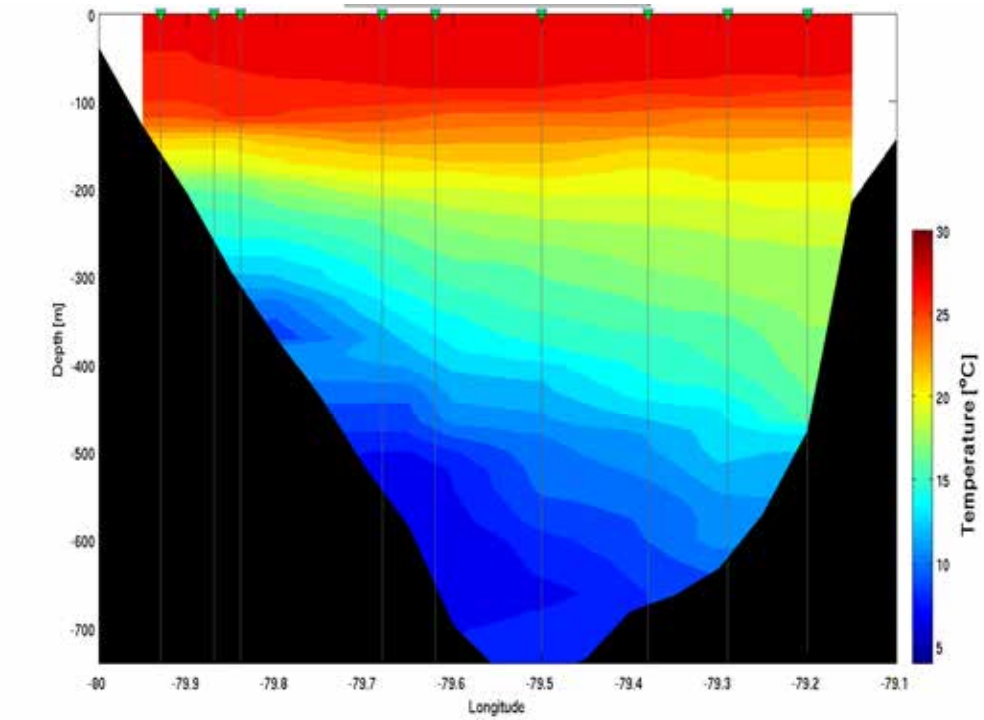
The Florida Current Flow and Sea Level Changes During 2010-2015



Year-to-year Changes in the Florida Current Temperature



Over 250 in situ surveys since 1995



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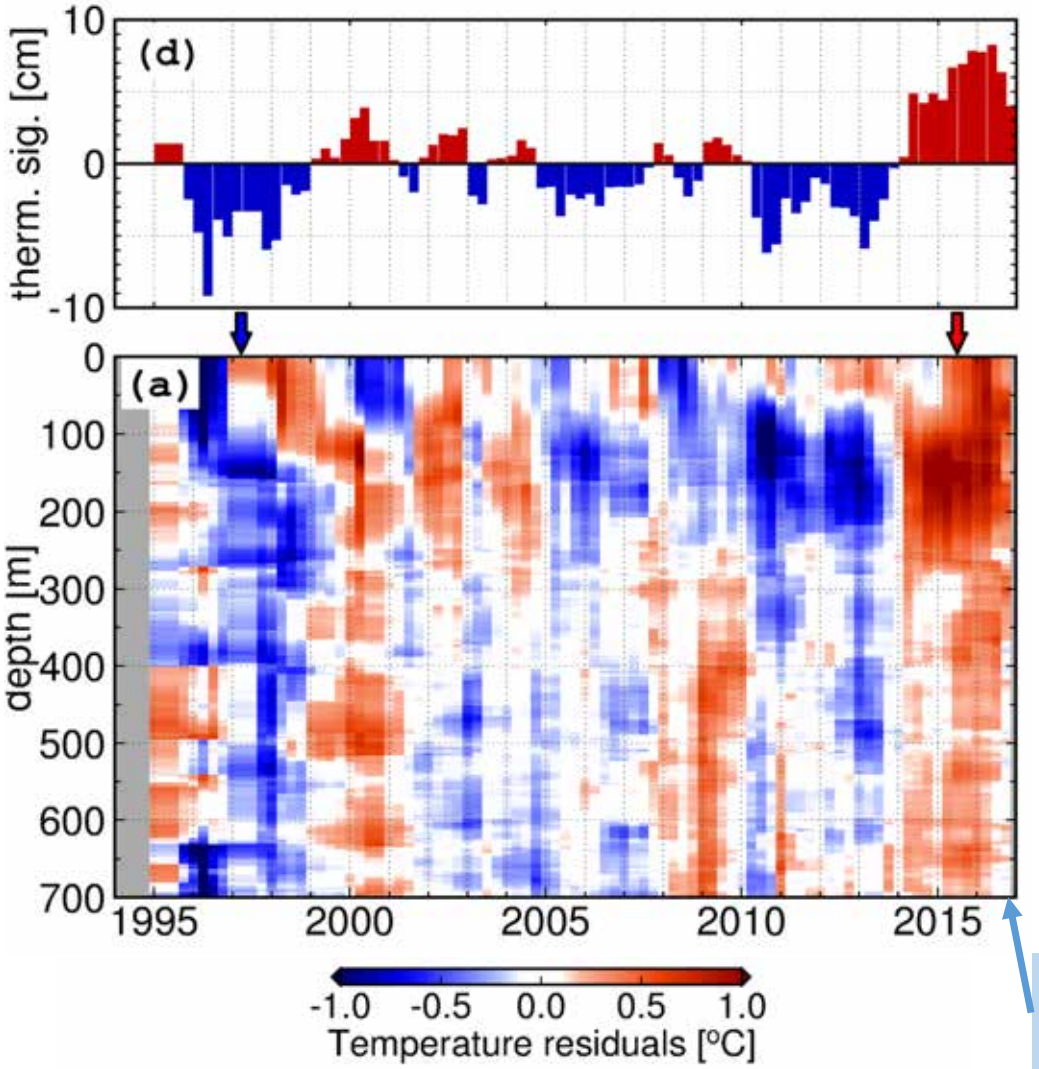


Temperature anomalies associated with:

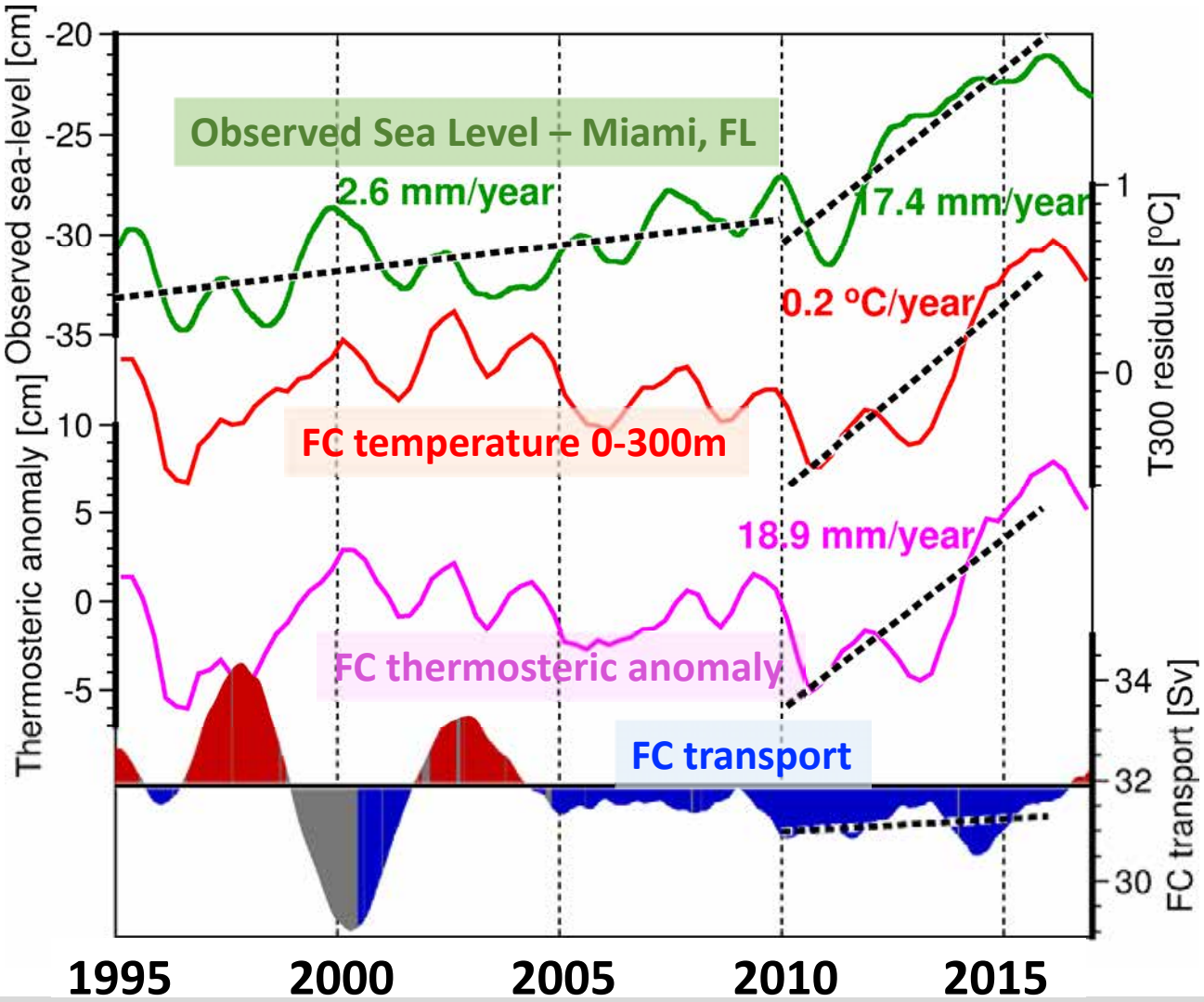
- **Thermosteric height anomalies ranging between:**
  - -10 and 10 cm
  - Trend of 2 cm / decade
- **The 2010-2015 event:**
  - Florida Current temperature shifted from a cold regime during 2010-2013 to a warm regime during 2014-2015
  - The observed peak in late 2015 coincided with observed flooding events

Temperature anomalies with respect to the annual cycle, and averaged for the Florida Straits

Domingues et al., (in preparation). Accelerated sea level changes in the United States east coast: links with recent warming of the Florida Current

The Florida Current Temperature and Sea Level Changes During 2010-2015

FC temperature and transport changes likely contribute independently to coastal sea-level variability



Domingues et al., (in preparation). Accelerated sea level changes in the United States east coast: links with recent warming of the Florida Current

Conclusions

- **Changes in the Florida Current transport and temperature cause sea-level variability along the east coast of U.S.**

- **On seasonal time-scales, changes in the Florida Current flow are largely associated with westward propagating signals originated in the open ocean, which cause sea level changes of ±10 cm**

- **On year-to-year time-scales, changes in the Florida Current temperature can also account for ±10cm in coastal sea-level due to thermal expansion of the water column**

- **Accelerated sea-level changes observed during 2010-2015 along the U.S. east coast is consistent with the warming of the Florida Current for the period**

- **Flooding events in Miami during the very large King Tide from September-October 2015 coincided with:**
    - **Lower than average Florida Current transport -> ~5cm increase in sea-level**
    - **Warmer than average Florida Current - > ~10 cm increase in sea-level**

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Ocean Surface Topography Science Team Meeting, Miami, FL, October 2017