Reconstructing Florida Current Transport from Paleo Data

Prepared by:

Barbara Lorenzo

Under mentorship of:

Dr. Marlos Goes,

Dr. Denis Volkov

In partnership with:

Cooperative Institute For Marine And Atmospheric Studies (CIMAS)

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Introduction

The Florida Current is a major component of the Atlantic Meridional Overturning Circulation (AMOC), transporting heat and salt from the subtropical North Atlantic toward higher latitudes. Originating in the Gulf of Mexico and passing through the Florida Straits before merging with the Gulf Stream, it plays a crucial role in regulating weather patterns, sea level, and ecosystems along the eastern seaboard of the United States.

Recent climate model projections and observational studies indicate the potential for a weakening of the AMOC within the coming decades, with profound implications for regional environmental stability. Understanding how the Florida Current has varied over the past 10,000 years can provide important context for present-day changes. Paleoceanographic proxy records, particularly oxygen isotope ratios in the form of delta eighteen oxygen ($\delta^{18}O$) preserved in the shells of marine foraminifera, offer a way to reconstruct past ocean conditions and infer historical current transport strength.

This project aimed to reconstruct the Florida Current's transport history by integrating modern observational data, ocean reanalysis products, and paleo proxy records, using statistical calibration techniques to observe similarities of past and present relationships.

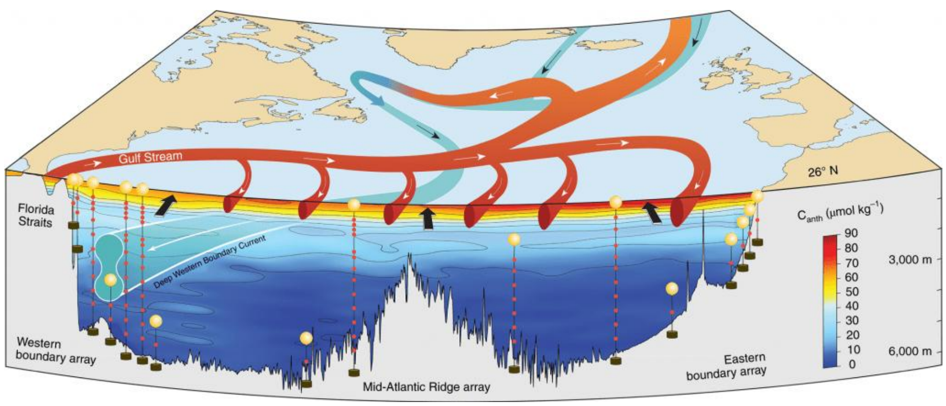

***Figure 1** Schematic of the RAPID/MOCHA/WBTS Array in relation to meridional overturning circulation pattern from aoml.noaa.gov. Image credit: University of Miami*

Motivation

Recent studies have raised urgent concerns about the weakening of the AMOC, which could lead to abrupt climate shifts including disrupted weather patterns, coastal sea level rise, and altered marine ecosystems. Reconstructing the history of the Florida Current, a key upper limb of the AMOC, provides insight into how ocean circulation has responded to past climate changes. This can improve the reliability of future climate projections and refine the performance of global climate models.

Data

This project utilized a combination of modern observational data and paleo proxy records. Modern datasets consisted of CTD profiles including temperature, salinity, oxygen, and density, long-term Florida Current cable transport records, and the GLORYS (Global Ocean Reanalysis and Simulation) - a high-resolution product that integrates in-situ and satellite observations with ocean models to provide realistic estimates of ocean state variables over time. Paleo data were based on $\delta^{18}O$ measurements from foraminifera in sediment cores, which were collected across the Florida Straits and used to estimate past temperatures and therefore infer salinity, allowing for the reconstruction of seawater density over time.

Methodology

All analysis was conducted in MATLAB using both modern and paleo datasets. The workflow began by identifying relationships between observed Florida Current transport and seawater properties using modern hydrographic observations. Conductivity-Temperature-Depth (CTD) profiles of temperature, salinity, and density were paired with concurrent Acoustic Doppler Current Profiler (ADCP) transport measurements and long-term submarine cable records.

A correlation analysis was performed across depth and longitude to assess which variables most strongly related to transport. Density emerged as the most reliable predictor, particularly at depths between 200 and 400 meters.

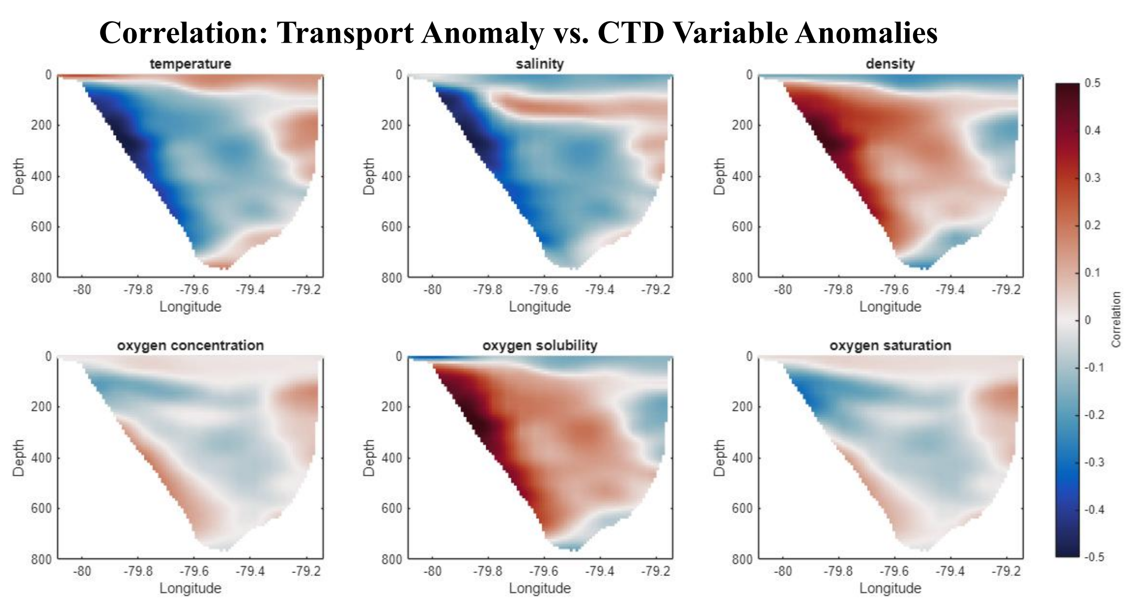

Figure 2 *Correlation between Florida Current transport anomalies and CTD variable anomalies across depth and longitude. Positive and negative correlations are shown for seawater properties named. Strongest correlations with transport were observed for subsurface density and temperature, particularly between 200 and 400 m depth.*

To quantify this relationship, east–west density gradients across the Florida Straits were calculated at approximately 250 m depth and regressed against observed cable transport using simple linear regression ($Y = a^*x + b$). The resulting regression coefficients provided a calibration model to estimate transport from density anomalies.

	temperature (t)	**salinity (s)**	**density (d)**
correlation	0.43	0.18	0.49
Coefficients (a,b) **Y = a*x + b**	0.8662, 26.7532	2.0241, 29.9144	6.6628, 27.6007

To assess the model's ability to replicate modern variability, reconstructed transport values were directly compared with observed cable transport data. The reconstructed index was derived from the calibrated density gradient, while the observed values came from submarine cable records. This side-by-side comparison allowed visual validation of the reconstruction method's accuracy.

Comparison of Reconstructed and Observed Florida Current Transport

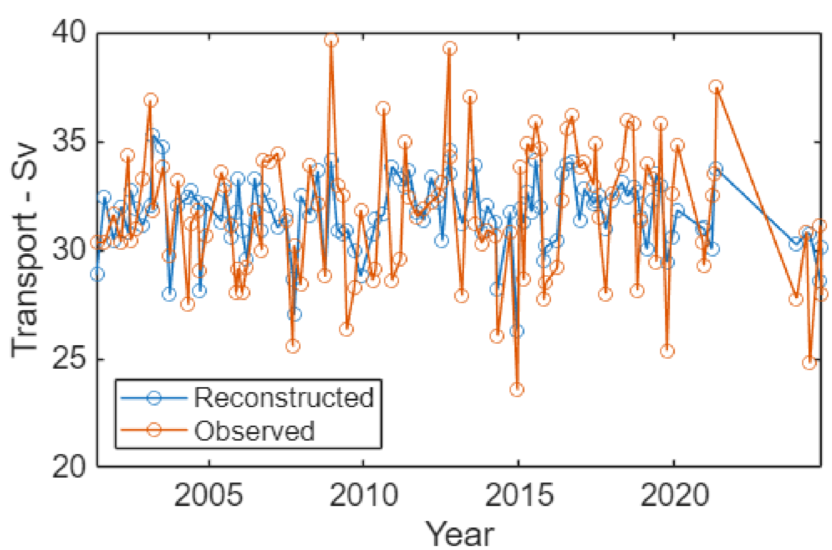

Figure 3 *Comparison of reconstructed and observed Florida Current transport. The reconstructed transport index (blue) was derived from east–west density gradients at ~250 m depth using CTD data and regression coefficients calibrated from modern observations. Observed transport (orange) corresponds to direct measurements from the Florida Current submarine cable system. The close alignment between the two series demonstrates the effectiveness of the reconstruction method in capturing monthly-scale transport variability.*

The reconstruction method was applied to the GLORYS ocean reanalysis dataset to validate its performance. East–west gradients in temperature, salinity, and density were calculated at a comparable depth of approximately 220 meters. These gradients were smoothed to highlight low-frequency variability and then used in linear regression against GLORYS transport data. The resulting regression coefficients allowed a reconstructed transport time series to be generated for each variable. These were then compared to the original GLORYS transport values to evaluate performance.

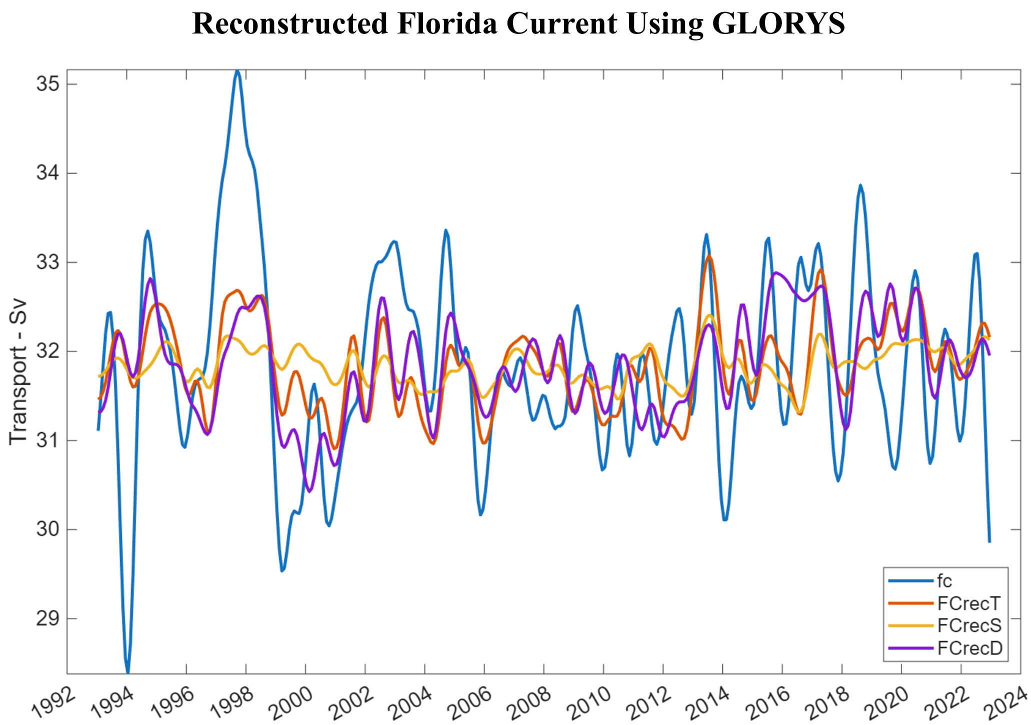

Figure 4 *Reconstructed Florida Current transport using GLORYS reanalysis gradients at ~220 m depth. The blue line ("fc") represents smoothed Florida Current transport estimated from GLORYS data. Reconstructed transport estimates using linear regression are shown for temperature (FCrecT – orange), salinity (FCrecS – red), and density (FCrecD – purple) gradients across the Florida Straits.*

For the paleo reconstruction, oxygen isotope data ($\delta^{18}O$) from foraminifera in sediment cores were converted to temperature using the paleotemperature conversion method described by Gaskell & Hull's paper from 2023, *Technical note: A new online tool for δ18O–temperature conversions*. Salinity was inferred from temperature following the empirical method in Goes et al's paper from 2018, *An updated estimate of salinity for the Atlantic Ocean sector using Argo observations*. From the reconstructed temperature and salinity values, density was calculated, and the calibrated regression model from the modern analysis was interpolated to derive estimates of past Florida Current transport.

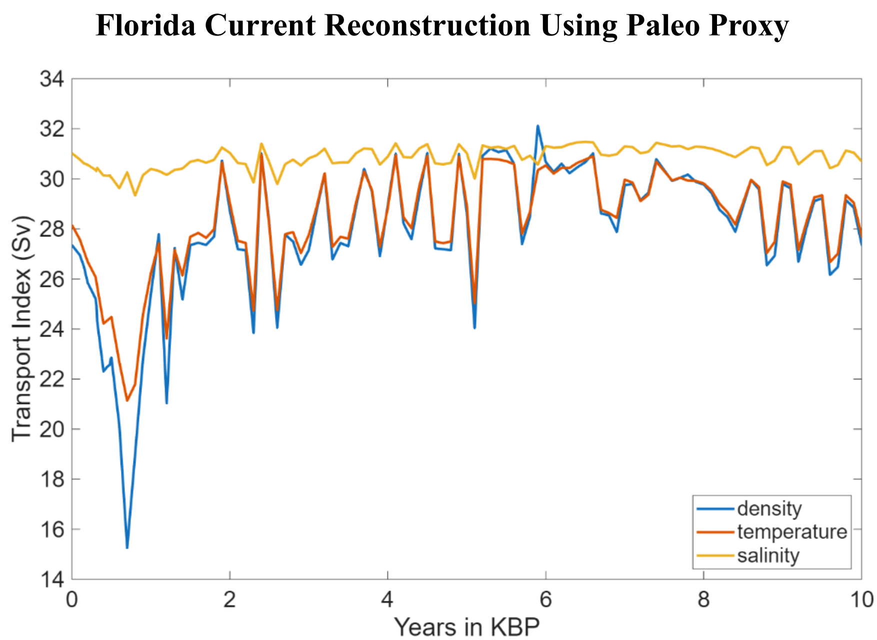

Figure 5 *Paleo reconstruction of Florida Current transport over the past 10,000 years using proxy data derived from foraminifera $\delta^{18}O$ records. Transport estimates were reconstructed from temperature (orange), salinity (yellow), and density (blue), calculated from sediment core isotopic records. All variables were converted to transport values using regression coefficients calibrated from modern GLORYS data displayed in SV or "Sverdrups" by KBP or "thousands of years before present".*

4. Results

The modern calibration confirmed that density gradients explain a meaningful fraction of Florida Current variability, with GLORYS reanalysis showing that these gradients account for approximately 25% of the observed variance. The regression coefficients derived from MATLAB analysis provided a robust calibration, enabling the density-gradient index to closely replicate observed transport trends.

The paleo reconstruction revealed substantial variability in the past Florida Current strength, ranging from approximately 16 to 32 Sverdrups (Sv). A significant decline in transport was observed around 700 years ago, possibly coinciding with the onset of cooler climatic conditions during the Little Ice Age, followed by a recovery toward present-day values.

Conclusion

This study demonstrates that subsurface density is the most reliable modern predictor of Florida Current transport. Through correlation analysis and regression modeling, density anomalies, particularly between 200 and 400 meters depth, were shown to have the strongest relationship with transport variability. By calibrating this relationship using GLORYS ocean reanalysis and applying it to $\delta^{18}O$ records preserved in foraminifera shells, we were able to reconstruct a continuous record of Florida Current strength over the past 10,000 years. These $\delta^{18}O$-based reconstructions proved to be a viable and informative method for inferring past oceanographic conditions. The results revealed substantial variability throughout the Holocene, including a pronounced decline in transport approximately 700 years ago, possibly coinciding with the onset of the Little Ice Age.

Discussion

The reconstructed record offers valuable insight into long-term variability of the Florida Current and its link to broader Atlantic circulation changes. The decline observed ~700 years ago coincides with climatic events such as the Little Ice Age, suggesting potential sensitivity to hemispheric-scale climate forcing. Further research of this decline may add value and understanding of transport behavior.

Further investigation could integrate additional paleo proxies, extend geographic coverage, and incorporate machine learning approaches for improved reconstruction accuracy. Such advancements would refine our understanding of Florida Current variability and its implications for future climate projections.

Reflection

Participating in this research project through the CIMAS/NOAA internship has been an incredibly rewarding and formative experience. This work challenged me to apply both technical and theoretical knowledge from interpreting complex oceanographic datasets to developing statistical models in MATLAB, all within the context of real-world marine research.

One of the most valuable aspects of this project was learning how to integrate modern observations with paleo proxy records to draw meaningful conclusions about long-term changes in the Florida Current. Before this study, I hadn't considered that data analysis could offer a window not just into forecasting the future but also into *reconstructing the past*. This realization was eye-opening. The idea that we can use present-day relationships to better understand historical variability, and in doing so, improve the accuracy of future projections, gave me a new appreciation for the power of data science in marine research.

Working under the guidance of my mentors, Dr. Marlos Goes and Dr. Denis Volkov, has given me deeper insight into the collaborative nature of oceanographic research. This experience has not only strengthened my interest in marine and climate science but has also affirmed my commitment to pursuing graduate studies in systems-oriented research.

Overall, this project has equipped me with a deeper understanding of the scientific process, from data to insights, and has shown me how even historical records can help answer critical questions about our changing environment. I look forward to building on this experience as I continue my academic and professional journey.

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