Exploratory Glider Deployments Reveal Changes in the Upper Oceanic Water Masses of the Caribbean Through-Flow

Ocean Circulation Dynamics, Water Masses, Climate Change, Autonomous Underwater Vehicles, Ocean Observing

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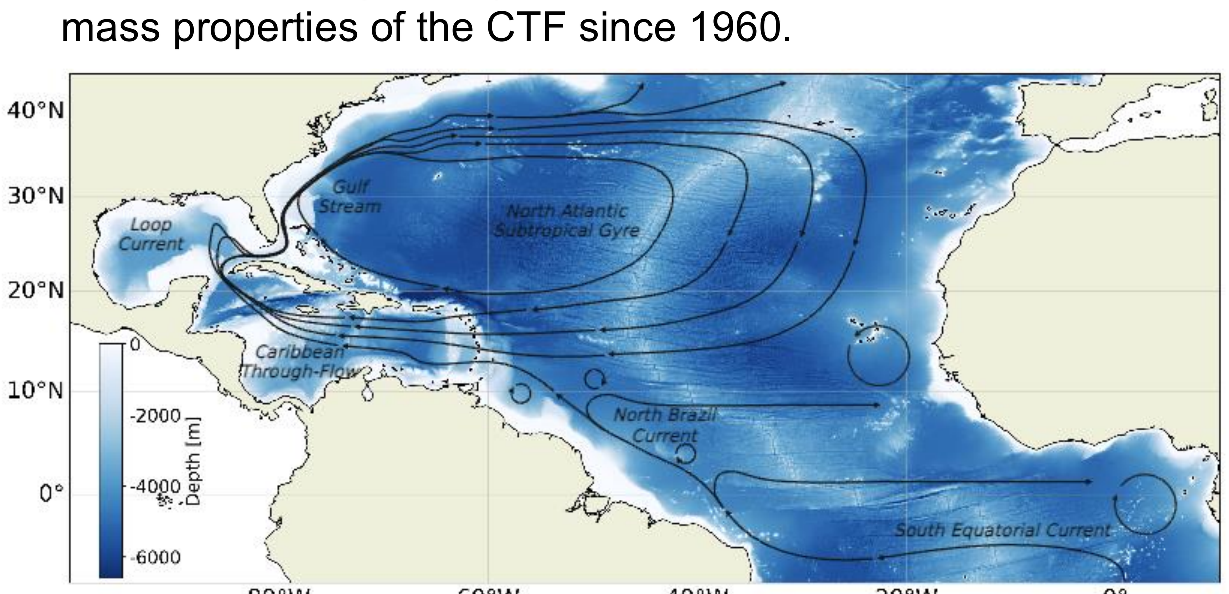
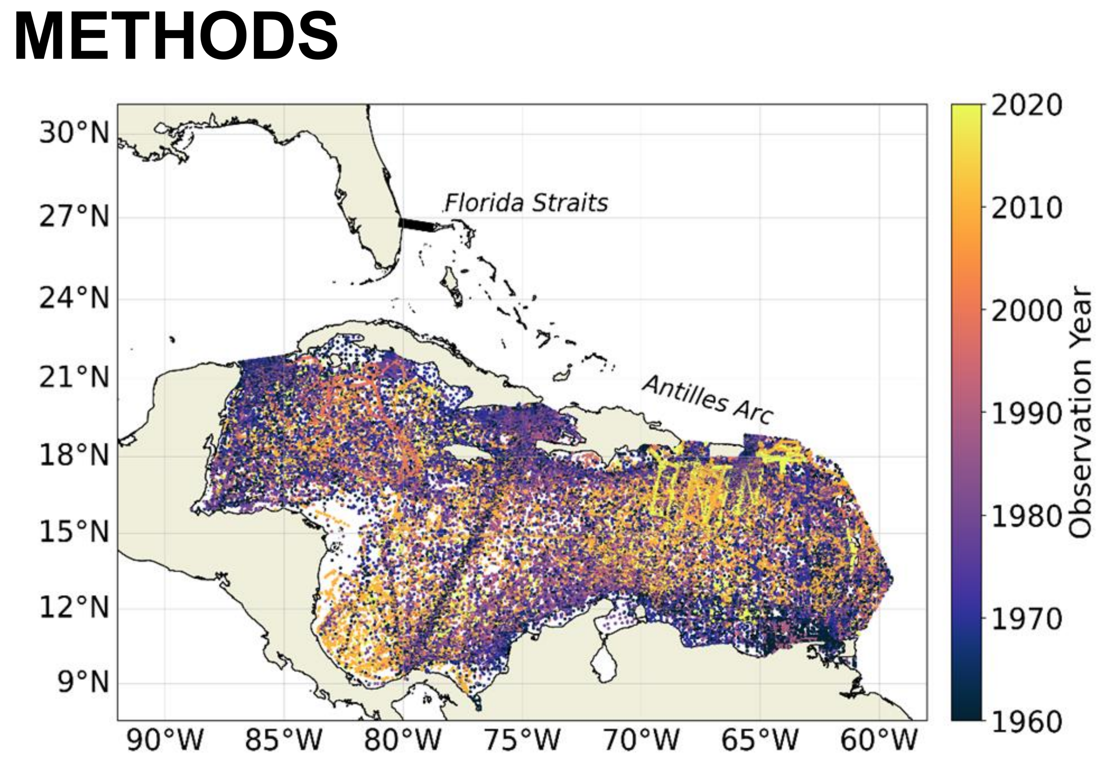
INTRODUCTION

The oceanic conditions of the Caribbean Sea have profound impacts on the broader Intra-Americas Sea region, driving tropical cyclone generation and rapid intensification as well as sea level rise, both which are increasingly devastating coastal communities. The Caribbean Through-Flow (CTF) , is an important component of Earth's climate system as it organizes and transports significant heat and salt fluxes from two major circulation systems, the North Atlantic Subtropical Gyre (NASTG) and the Atlantic Meridional Overturning Circulation (AMOC). Once these flows combine, the CTF is transported through the Yucatán Straits to feed the Florida Current and eventually forms an important component of the Gulf Stream. Mass conservation requires that the sum of the CTF inflow pathways from the Atlantic through the complex bathymetry of the Antilles Island arc is equal to the transport of the Florida Current. In this sense, it is the CTF that represents a chokepoint for climatically important water masses. As recent evidence indicates the NASTG is changing[1] and the AMOC may be slowing[2], here we combine targeted glider observations with all available hydrographic data from the EN4 database to investigate the how these changes may have impacted upper ocean water mass properties of the CTF since 1960.



METHODS



Processing steps:

- Subset profiles to CTF shapefile
- Linearly interpolate onto a common vertical grid with 5-m resolution in the upper 100 m, 25-m resolution above 250 m and 50-m resolution above 1000m
- To avoid giving disproportionate weight to profiles collected close together in space and time, means of profiles in the same month in a given year in a 0.5º latitude x 0.5º longitude spatial grid are calculated[3]
- Anomaly profiles calculated by subtracting the all-time mean profiles from each individual monthly mean profile at the same spatial grid cell
- Yearly mean and decadal mean anomaly profiles calculated by averaging the individual anomaly profiles
- All-time mean profiles are added back to the yearly mean and decadal mean anomalies to calculate yearly mean and decadal mean profiles

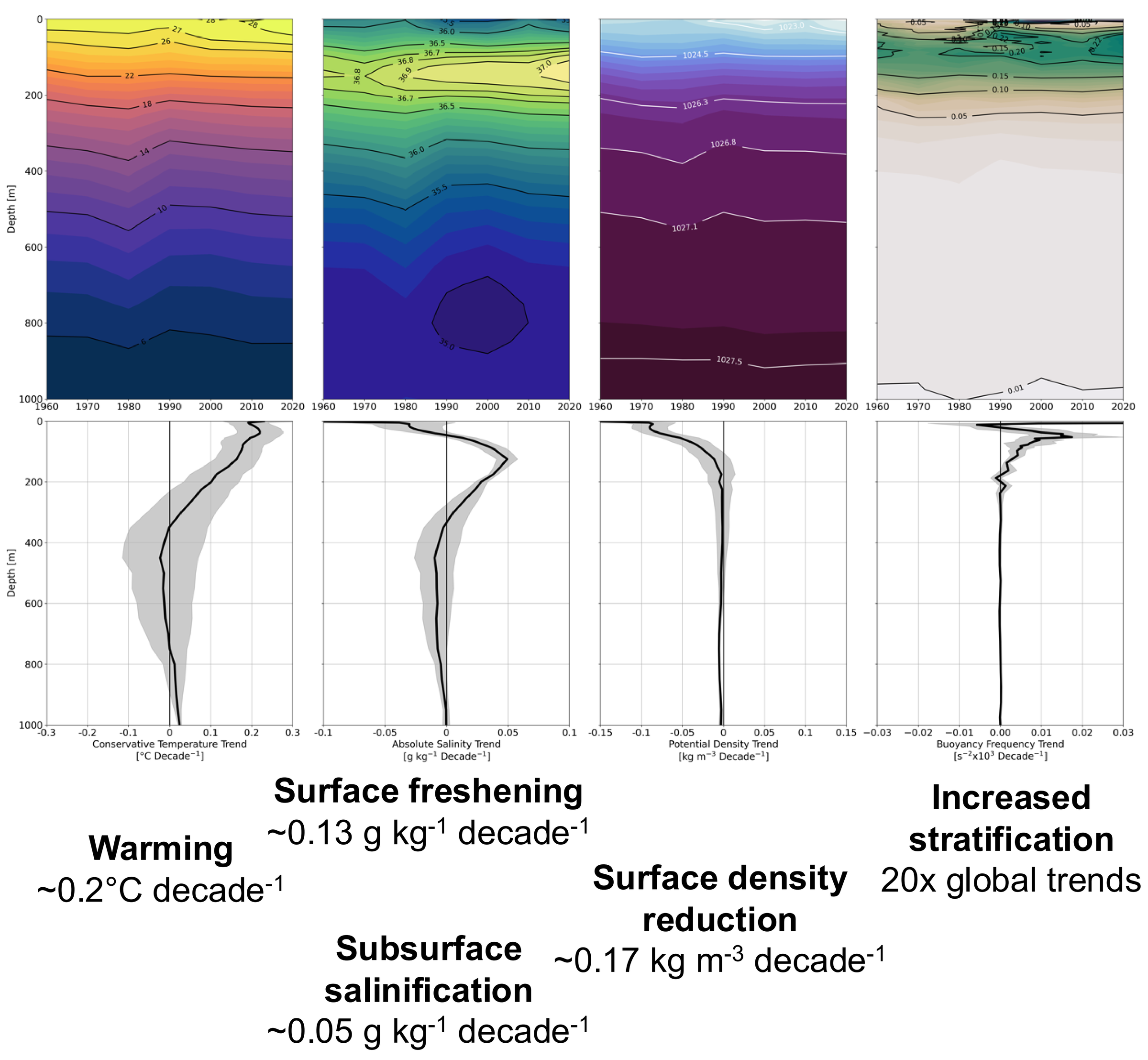
- **Tropical Cyclone Heat Potential** (TCHP):

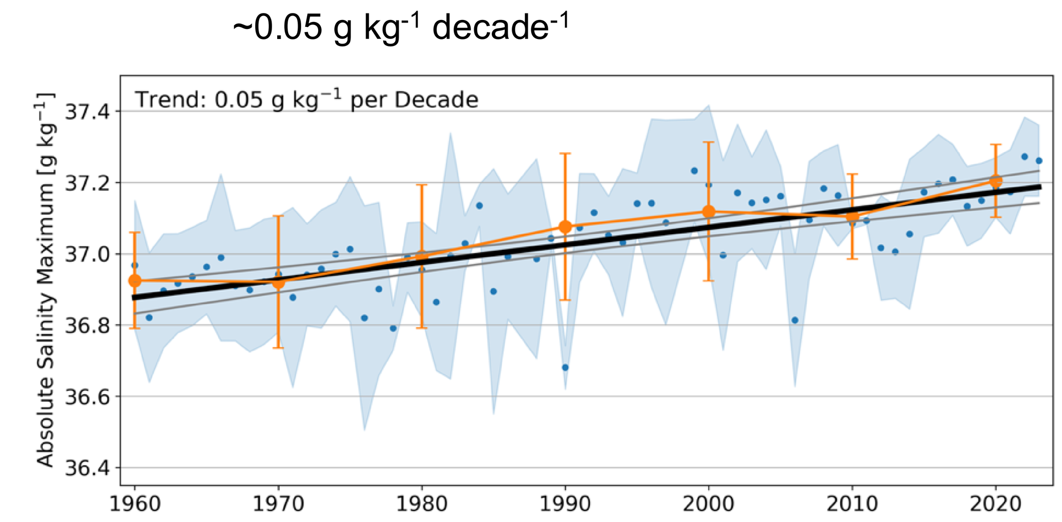
$$Q = \rho C_p \Delta T \Delta z$$

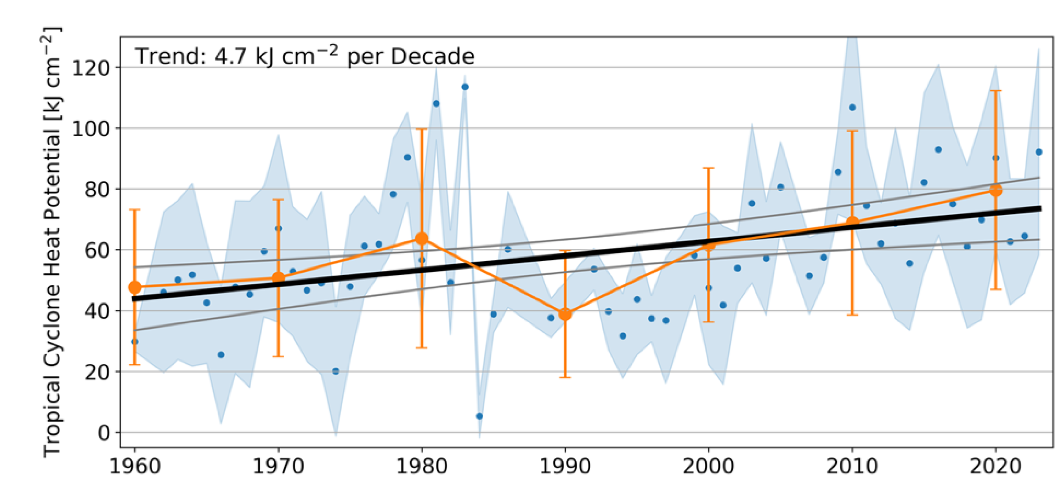
- **Potential Energy Anomaly** (PEA):

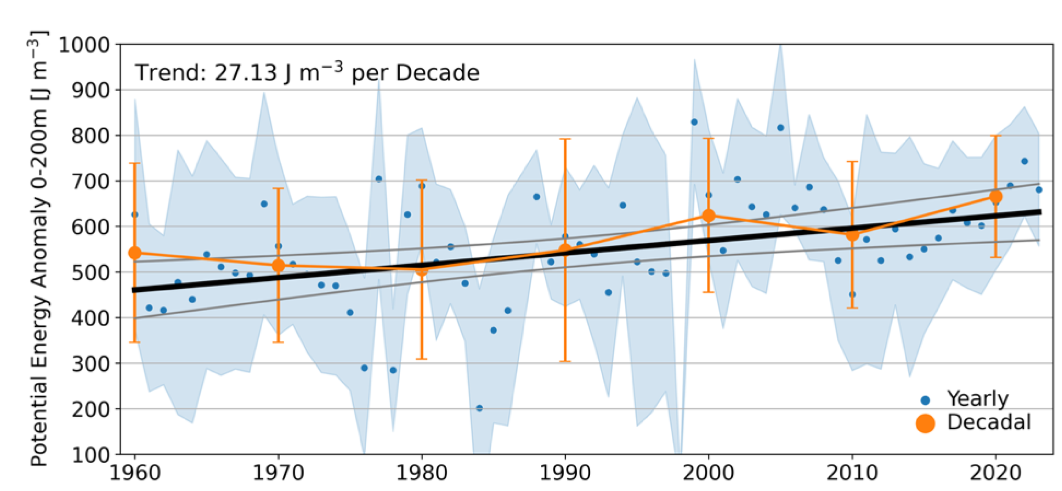
$$\varphi = \frac{1}{H}\int_{-H}^{0} (\bar{\rho} - \rho) g z \, dz$$

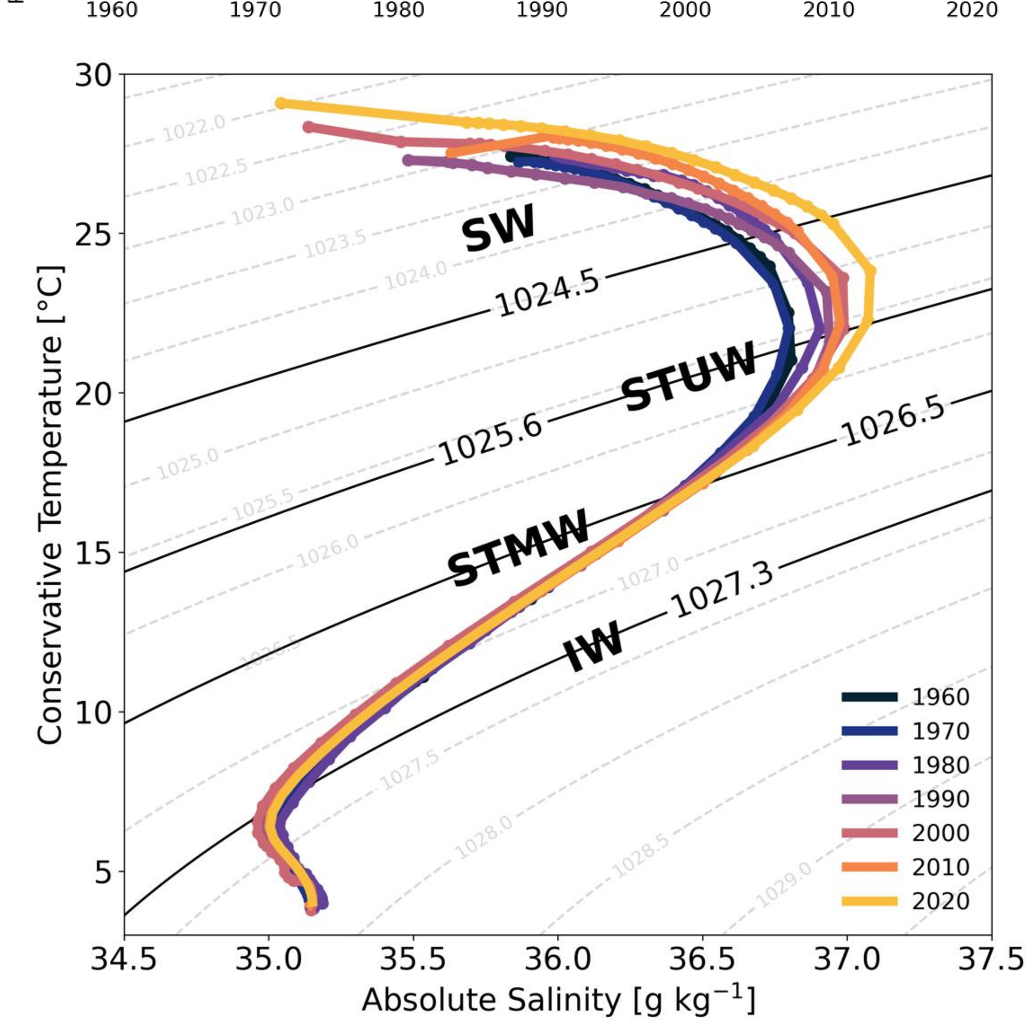
RESULTS







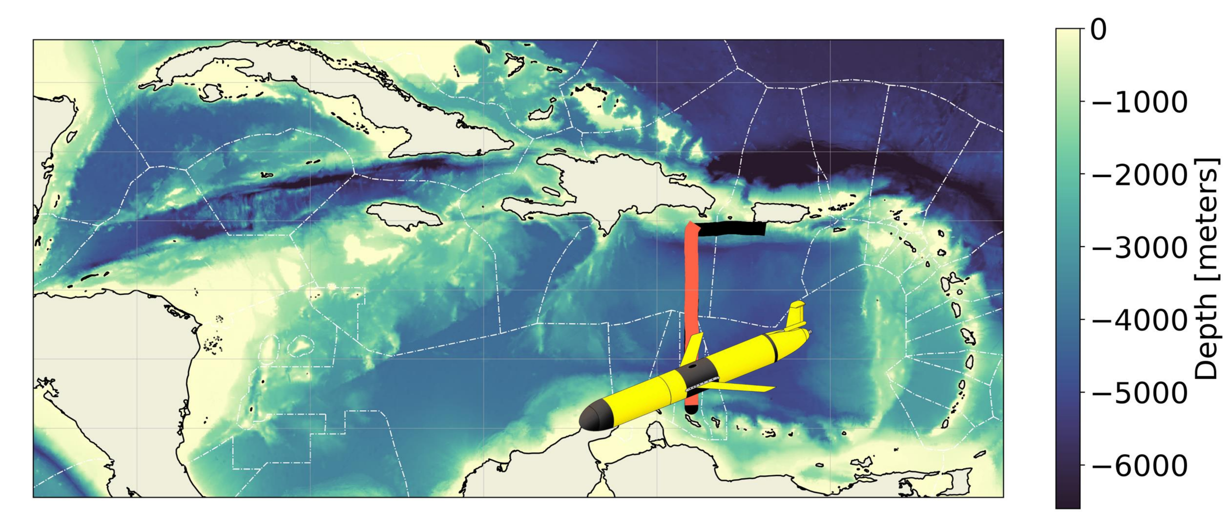


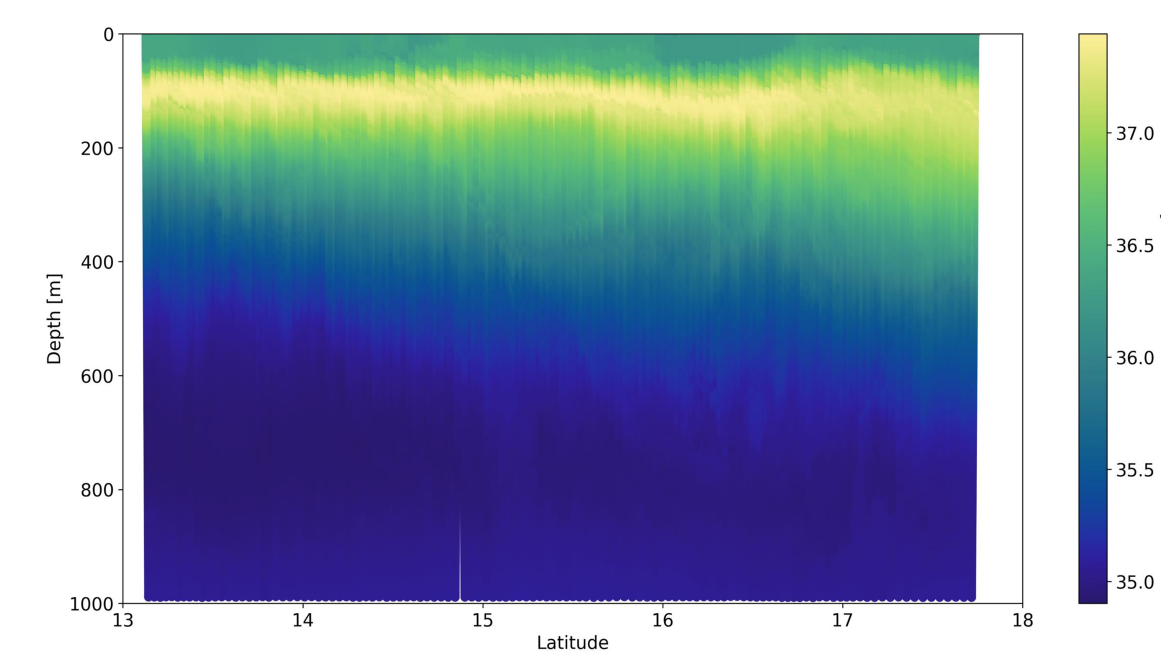


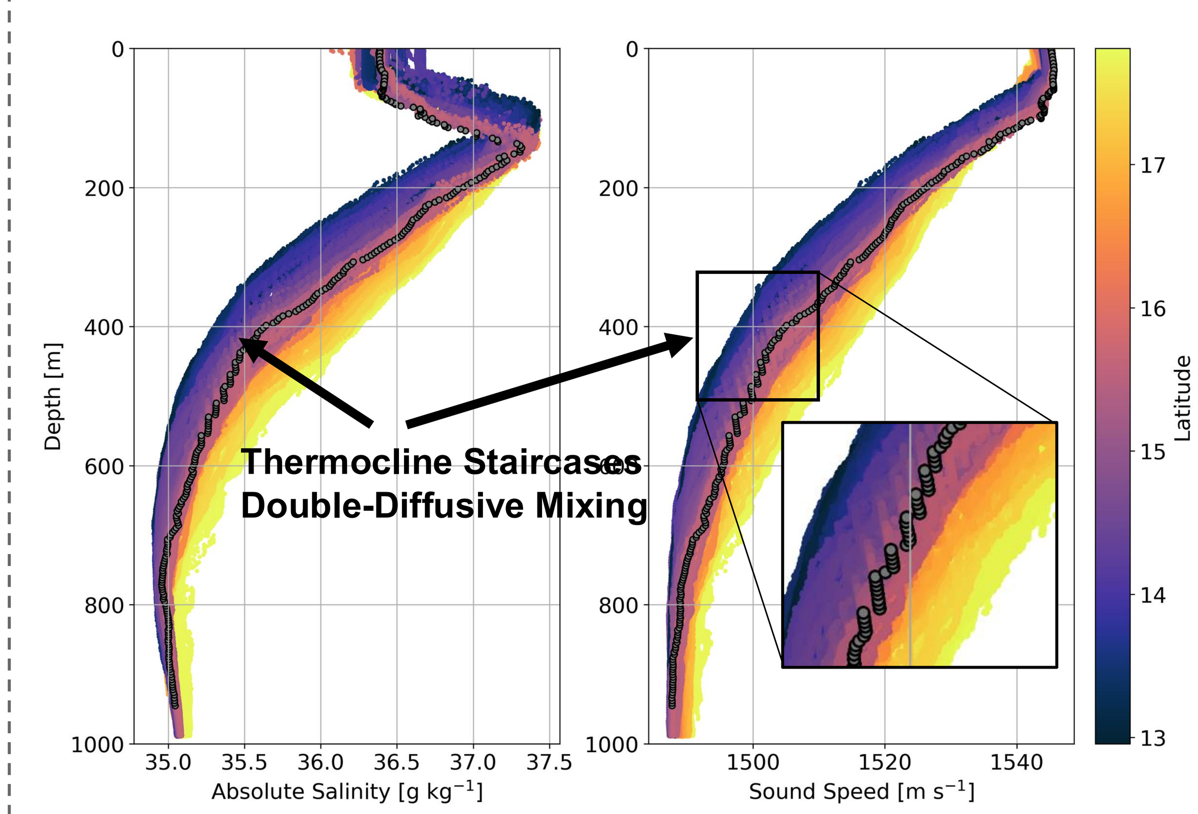
Decadal mean temperature and salinity profiles in the CTF from 1960 to 2023. Water masses labeled where SW: Surface Waters above 1024.5 kg m-3, STUW: Subtropical Under Water core at 1025.6 kg m-3, STMW: Subtropical Mode Water core 1026.5 kg m-3, and IW: Intermediate Water core at 1027.3 kg m-3.

RESULTS

Results motivated an unprecedented glider campaign: the ABC2DR (Aruba, Curaçao, Bonaire to Dominican Republic) line. Intentionally designed to sample a gradient in water mass properties/mixing regimes and bulk of CTF transport







CONCLUSION

- In the upper 0-200 m, the CTF is now warmer, less dense, and more stably stratified
- These changes have implications for tropical cyclone activity, sea level rise, marine ecosystems, and downstream water mass formation
- Temperature and stability increases are nearly 3 times[4] and 20 times[5] larger than globally averaged trends
- These findings highlight the CTF as experiencing amplified climate impacts driven by global processes and emphasize the need for sustained observations in this region

REFERENCES

Theses findings are published as:

Gradone, J. C., Miles, T. N., Palter, J. B., Glenn, S. M., & W. D. Wilson. Warming and salinity changes of the upper ocean Caribbean Through-Flow since 1960. Nature Scientific Reports, 5, 23157 (2025). https://doi.org/10.1038/s41598025-05494-z

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