Investigating the U.S. East Coast sea level change

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Abstract

Since 1993, global mean sea level has risen by approximately 100 mm (~3.9 inches), as estimated by NASA. However, this increase is not spatially uniform, as sea level change exhibits significant variability across different regions and timescales, ranging from hours to decades. Understanding the patterns and underlying mechanisms of regional sea level variability is essential for improving future projections and mitigating the associated impacts on coastal communities. This project focuses on quantifying the sea level variability along the US East Coast using observational data.

To assess long-term trends in coastal sea level change, linear analysis was performed on the sea level time series from five tide gauge stations spanning Florida to North Carolina. The results show a consistent rise in sea level at all locations. A review of existing literature was also conducted to place these findings in the broader context of sea level change research.

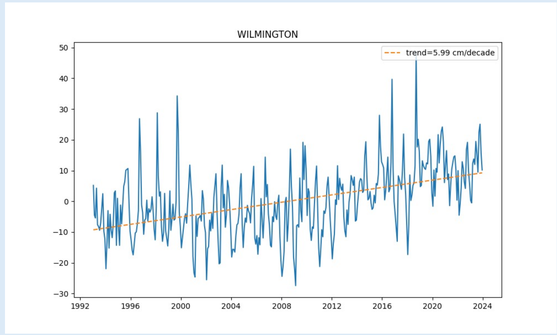
Preliminary results confirm a persistent rise in sea level along the U.S. East Coast, indicating potential roles of the Gulf Stream change, melting glaciers, and other climate-related processes in the sea level change. These findings highlight the increasing impact of greenhouse gas accumulation in the atmosphere, which contributes to the acceleration of global and coastal sea level rise. This study underscores the urgent need for strategic measures to mitigate the effects of climate change, particularly for vulnerable coastal regions.

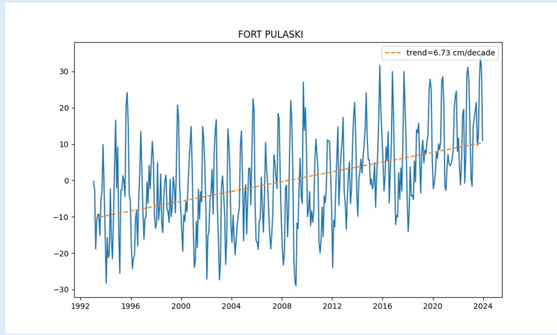
Methods

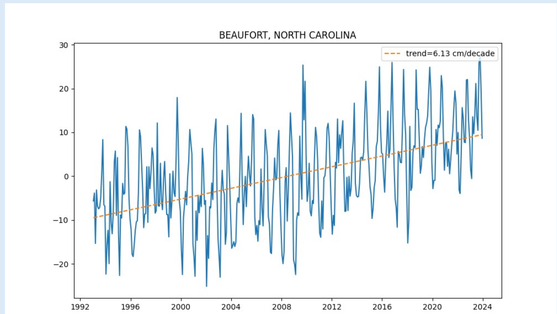
Sea level data from multiple U.S. East Coast tide gauge stations were analyzed using Python in Jupyter Notebook. The dataset includes sea level records, timestamps, and station metadata. Time values were converted into a readable format using the datetime module, and the data were structured in an xarray.DataArray to facilitate efficient handling and analysis.

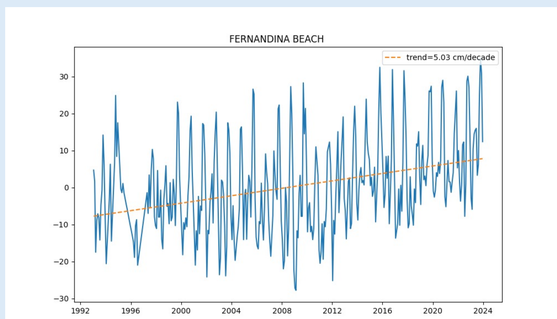
Before analysis, tide gauge records were processed to remove two effects:
1.Inverted Barometer Effect: The static response of sea level to atmospheric pressure, where low pressure allows sea level to rise, and high pressure depresses it. Since this effect is not relevant to the ocean's dynamic response to atmospheric forcing, it was removed using ERA5 reanalysis data (Hersbach et al., 2023; Ponte, 2006).

2.Vertical Land Motion (VLM): Tide gauges are fixed to land, meaning measurements are influenced by vertical movements of the land itself due to changes in Earth's shape and size. Although relatively small, this effect was removed using GPS-derived VLM trends referenced to the International Terrestrial Reference Frame, obtained from the Nevada Geodetic Laboratory (Hammond et al., 2021; http://geodesy.unr.edu/vlm.php).



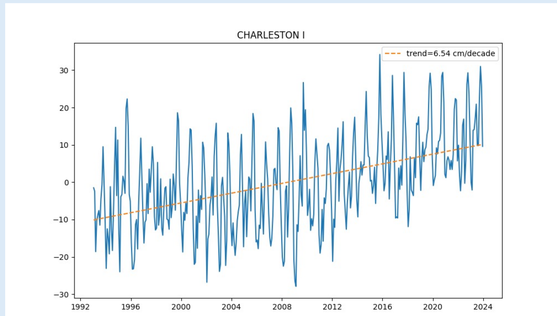






Sea level anomalies were calculated by subtracting each station's mean sea level from recorded values. Time series plots were generated using matplotlib.pyplot, with linear regression models (numpy.polyfit) applied to quantify long-term trends. The resulting slopes were converted to cm/decade, and trendlines were overlaid on each graph to visualize long-term changes.

Standard deviation calculations were performed to assess the temporal variability at each station. The analysis was conducted using key Python libraries, including numpy, xarray, matplotlib.pyplot, and scipy.io.loadmat. To enhance clarity, gridlines and legends were incorporated into the visualizations, and all figures were saved as PNG files for presentation.



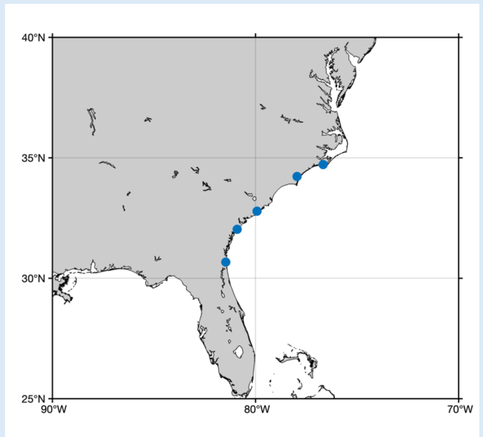


Figure: The dots show the stations' locations.

Table: What the data originally looks like, with about 400 data points for each station.

FERNANDINA BEACH	FORT PULASKI	CHARLESTON I	WILMINGTON	BEAUFORT, NORTH CAROLINA
7335	7221	7152	7245	7094
7305	7197	7143	7148	7112
7113	7035	6981	7139	6997
7198	7111	7064	7236	7119
7217	7130	7079	7117	7082
7207	7130	7091	7111	7076
7146	7072	7052	7099	7079
7241	7169	7122	7123	7100
7281	7194	7161	7172	7158
7430	7322	7262	7218	7234
7348	7203	7158	7096	7085
7210	7078	7061	7071	7082
7082	6941	6936	6974	6927
7140	7066	7042	7059	6994
7198	7011	7018	7163	7027
7256	7020	6975	7041	6951
7351	7200	7155	7151	7138
7143	7060	7042	7099	7045
7213	7008	6984	7075	7019
7284	7127	7091	7120	7067
7354	7267	7213	7221	7183
7537	7389	7314	7227	7208
7372	7203	7131	7050	7061
7463	7316	7280	7203	7193
7403	7072	7042	7108	7019
7344	6968	6927	7050	6924
7284	7197	7128	7181	7062

Results and implications

- Our results suggest a persistent rise in sea levels along the East Coast, underscoring the significant impact of the Gulf Stream change, melting glaciers, and other climate-related processes .
- Linear regression shows that sea level rise trends range from 5.03 to 6.73 cm/decade, with the highest rate observed in Fort Pulaski.
- Standard deviations of the sea level reveal notable temporal variability, with increased fluctuations in regions influenced by oceanic and atmospheric processes such as mean currents and strong wind.
- These findings highlight the urgent implications of greenhouse gas emission and its role in driving global and regional sea level rise. The study emphasizes the need for comprehensive strategies to mitigate the effects of climate change on vulnerable coastal regions.

Resources

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