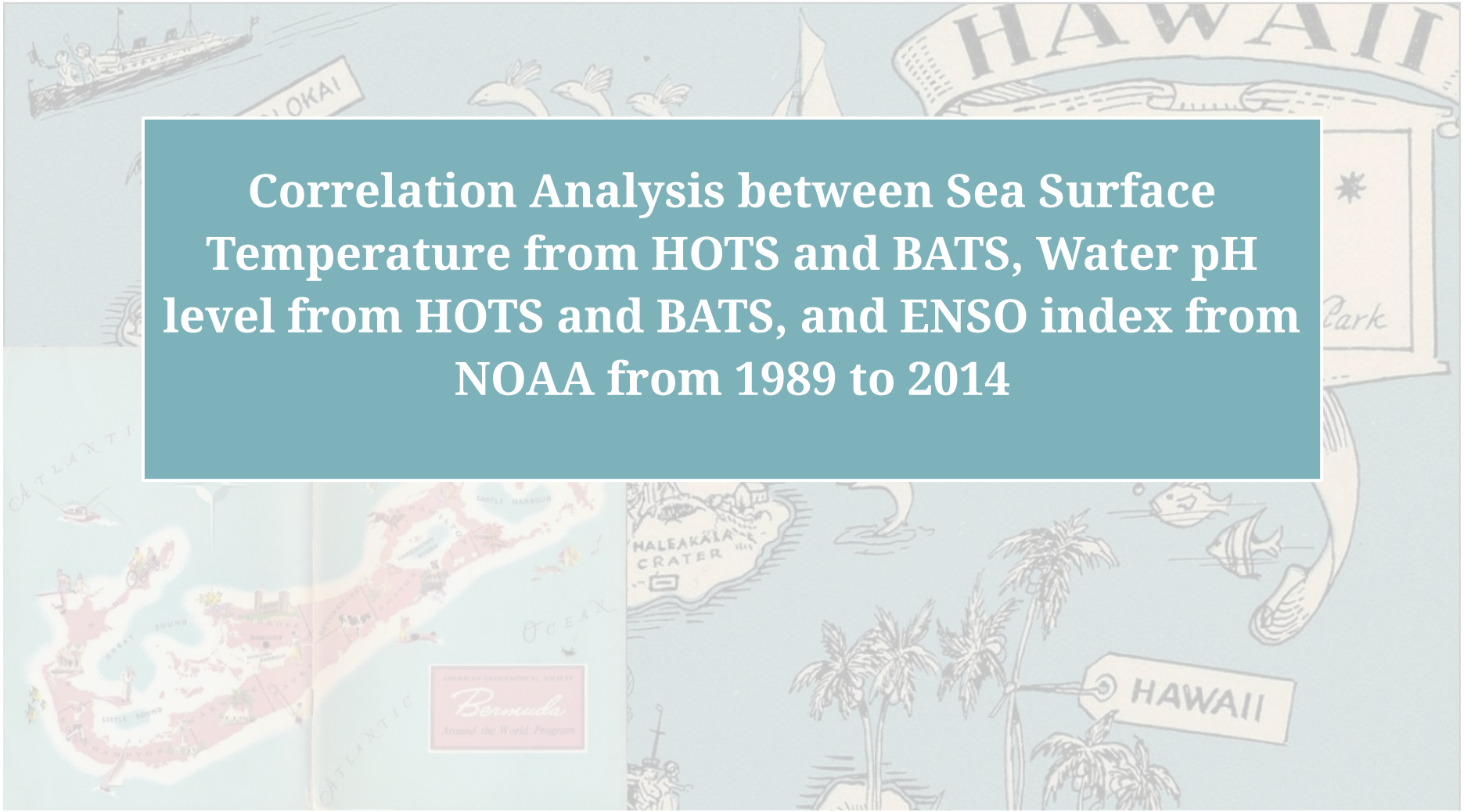
Correlation Analysis between Sea Surface Temperature from HOTS and BATS, Water pH level from HOTS and BATS, and ENSO index from NOAA from 1989 to 2014



Background Information

Temperature Effect:

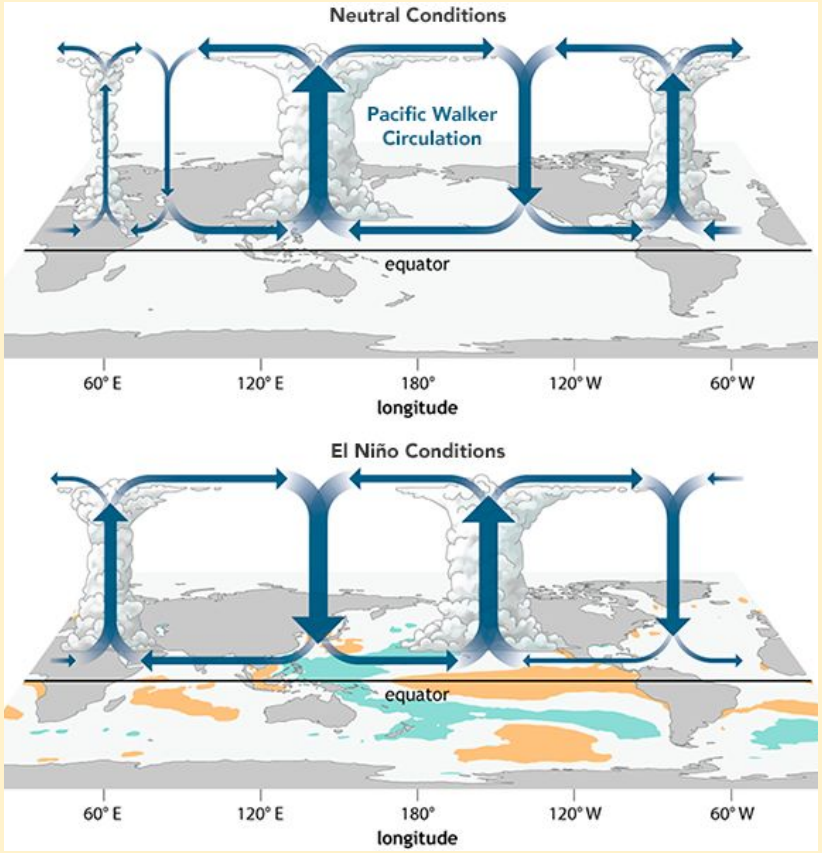
- El Niño is a climate pattern that describes the warming of surface water in the eastern tropical Pacific Ocean. It is the warm phase of a larger phenomenon called ENSO (El Nino-Southern Oscillation)
- An El Niño reduces the upwelling of cold nutrient-rich water off the coast of the Americas
- Reduction in upwelling causes low productivity on the surface water
- La Nina is the cool phase of ENSO

Walker Circulation

- Describes air flow circulation
- It is caused by pressure gradient force
- Affects upwelling of cold water, and has a greater influence in the pacific region

MEI Index:

- Large positive MEI indicates the occurrence of El Niño
- Large negative MEI indicates the occurrence of La Niña



Research Question

Is the impact of ENSO on sea surface temperature and pH more significant in the subtropical pacific or subtropical atlantic?

Hypothesis

The impact of ENSO will be more significant in the subtropical pacific because the walker circulation air patterns is greater in the pacific region.

Why Does It Matter?

- Impact of pH: Acidification of the ocean

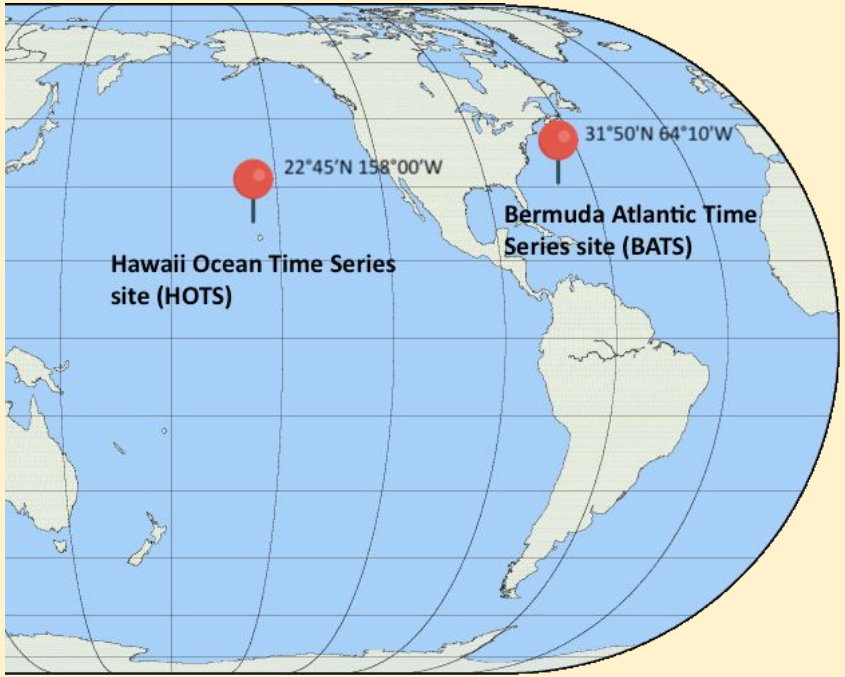
CO2 in atmosphere is increasing
Absorbed into surface ocean
Can become carbonate/bicarbonate/co2
Figure shows that by adding co2, lowers pH which adds bicarbonate in the ocean lowering carbonate and affects carbon availability for ocean species

Co2 forcing is lowering pH due to more hydrogen molecules

Acidification Affect:

- Acidification of the ocean negatively affect marine life
- It causes organisms' shells and calcium materials to dissolve
- Corals reefs provides an important ecosystem for maine life, they are also a course of food and new medicines for people.
- Corals are made up of soft-bodied polyp; a hard outer skeleton of limestone which has composition of calcium carbonate

Map of HOTS and BATS station



HOTS (Hawaii Ocean Time-series) - ALOHA Station
- Located at the Pacific Ocean
- Continuous low iron and low productivity

BATS (Bermuda Atlantic Time Series) - Sargasso Sea
- Located at the Atlantic Ocean
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Similarities
- Located at northern gyres
- Low nutrient environments

Methodology

Correlation analysis was used to determine the strength of relationship between two quantitative variables:

- Hawaii SST vs Hawaii ocean pH
- Hawaii SST vs ENSO
- Hawaii pH vs ENSO
- Bermuda SST vs Bermuda ocean pH
- Bermuda SST vs ENSO
- Bermuda pH vs ENSO

Pearson's correlation coefficient was used to measure the strength and direction of a linear association between the variables.

We used the following guideline to interpret the coefficients:

Table 1. Pearson's correlation coefficient interpretation

Strength of Association	Coefficient r
Negligible	0 ~ (+/-) 0.3
Weak	0.3 ~ (+/-) 0.5
Moderate	0.5 ~ (+/-) 0.7
Strong	0.7 ~ (+/-) 1.0

Mean Hawaii Sea Surface Temperature (C) Annual Time Series

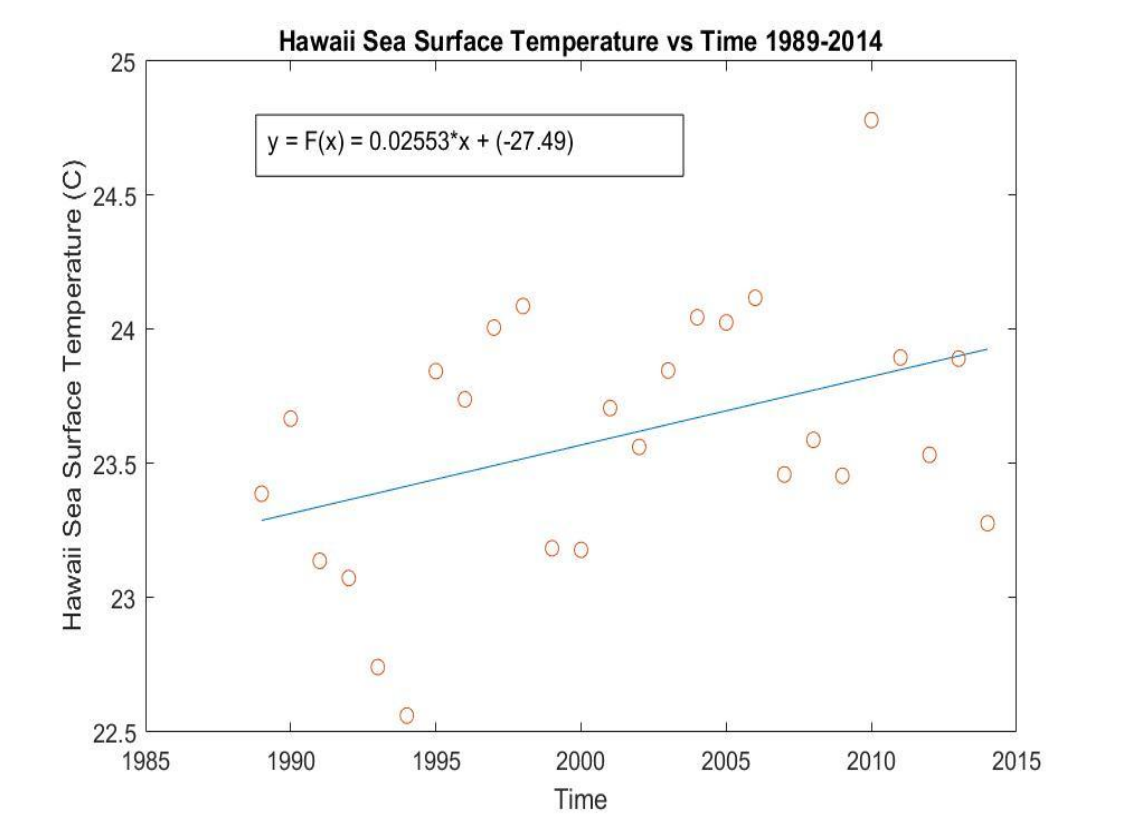

Figure 1. Mean Sea Surface Temperature (C) annual time series at Hawaii from 1989 to 2014. The data was obtained from the Environmental Research Division of National Oceanic and Atmospheric Administration (NOAA) website.

- **R-squared: 0.17, p-value = 0.0366**
- Statistically significant (p value < 0.05)
- Increasing sea surface temperature over time

Mean Bermuda Sea Surface Temperature (C) Annual Time Series

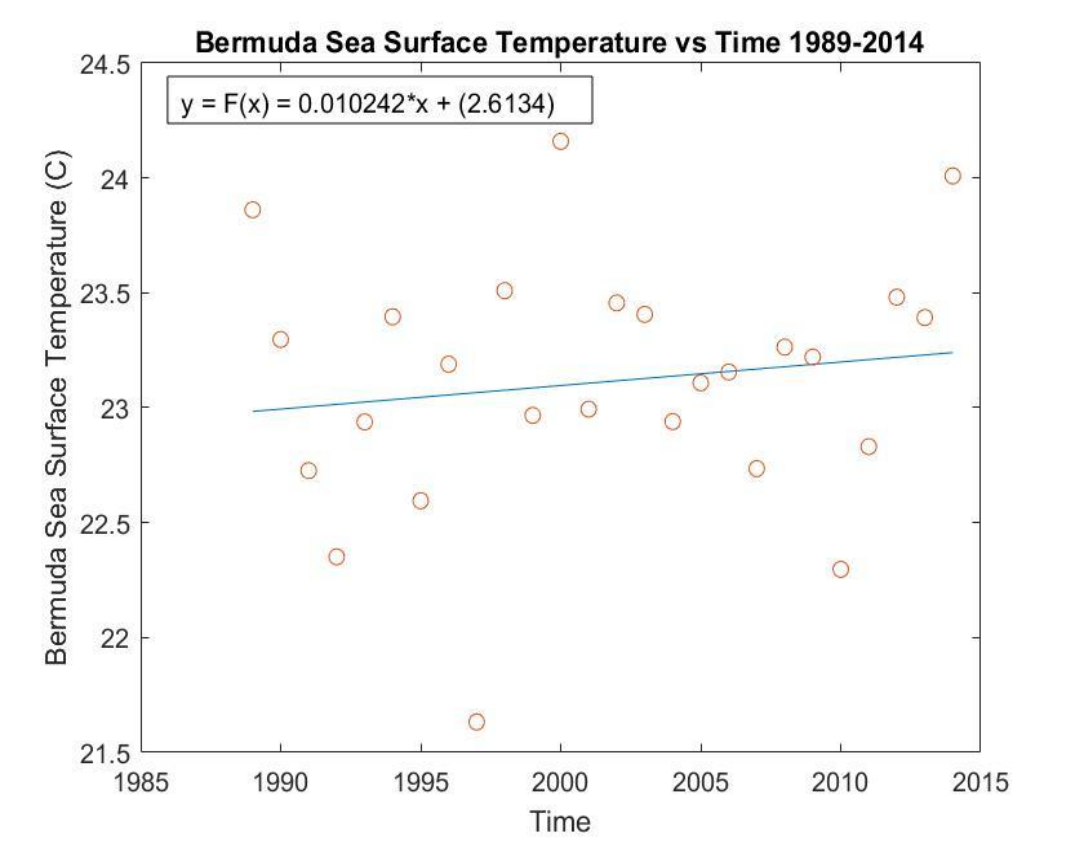

Figure 2. Mean Sea Surface Temperature (C) annual time series at Bermuda from 1989 to 2014. The data was measured at a depth of a few meters from Bermuda, St. Georges Island Station and was obtained from the Bermuda Atlantic Time-series Study (BATS) website

- **R-squared: 0.0208, p-value = 0.482**

- Statistically insignificant (p value > 0.05).
- Cannot conclude that the sea surface temperature at Bermuda increases or decreases over time.

Mean Hawaii Ocean pH Annual Time Series

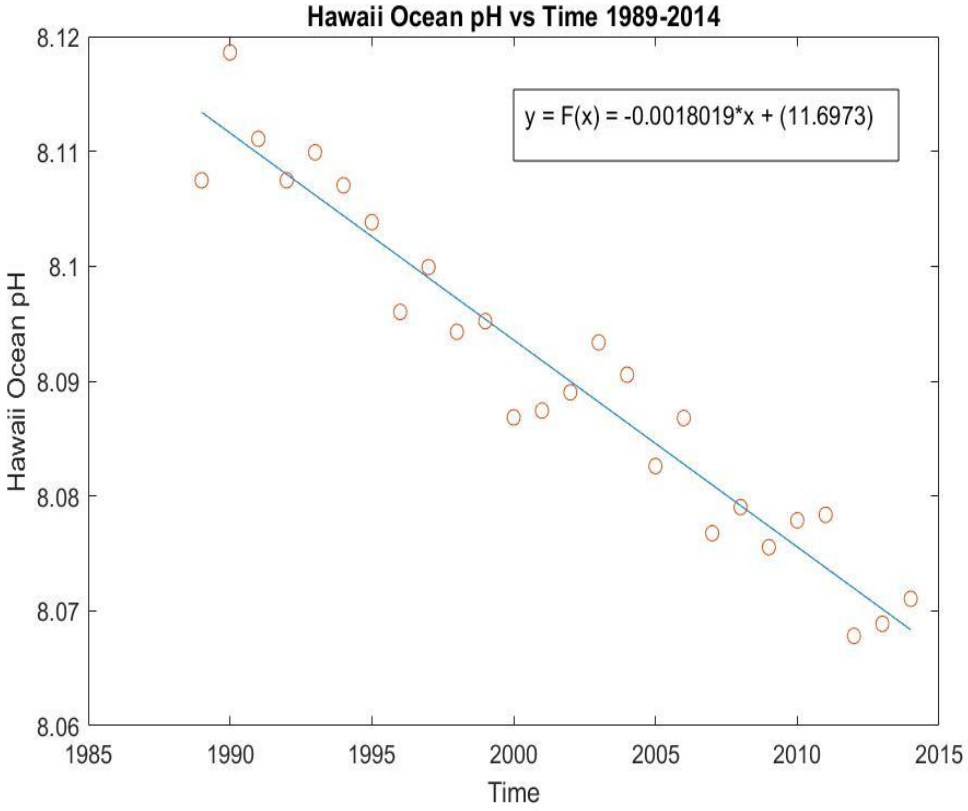

Figure 3. Mean ocean pH annual time series at Hawaii from 1989 to 2014. The data was collected at Station ALOHA and obtained from the Hawaii Ocean Time-series (HOT) website

- **R-squared: 0.932, p-value = 1.5e-15**

- Statistically significant (p value < 0.05).
- Decreasing ocean pH over time.

Mean Bermuda Ocean pH Annual Time Series

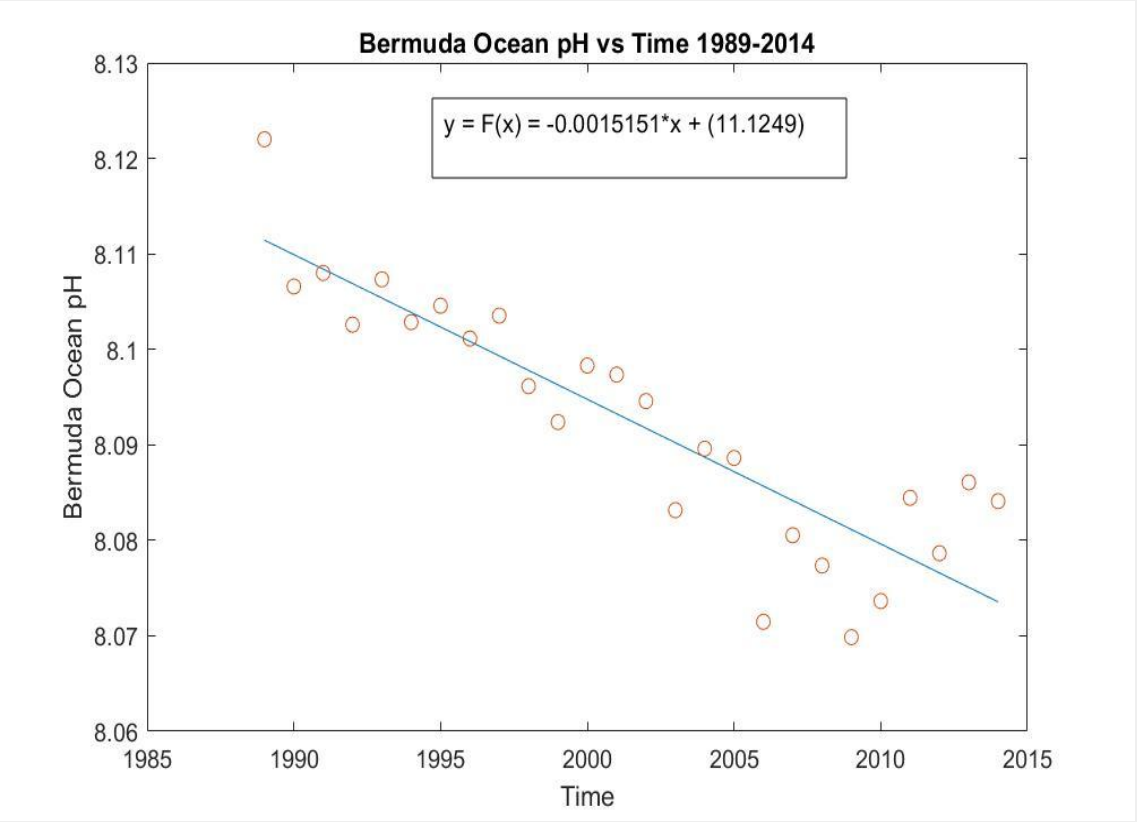

Figure 4. Mean ocean pH annual time series at Bermuda from 1989 to 2014. The data was obtained from the Bermuda Atlantic Time-series Study (BATS) website

- **R-squared: 0.778, p-value = 2.64e-09**

- Statistically significant (p value < 0.05).
- Decreasing ocean pH over time.

Mean MEI Annual Time Series

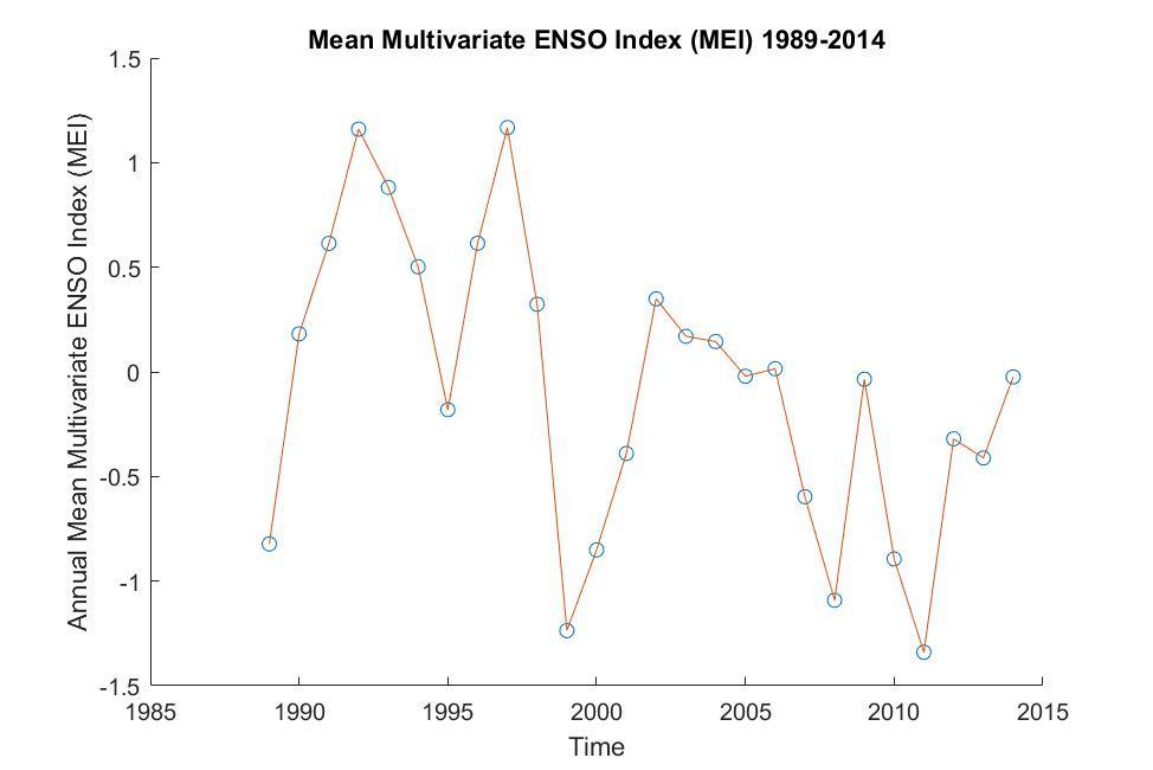

Figure 5. Mean Multivariate ENSO Index (MEI) annual time series from 1989 to 2014. The data was obtained from the National Oceanic and Atmospheric Administration (NOAA) website.

- **R-squared: 0.224, p-value = 0.0146**
- Statistically significant (p value > 0.05).
- ENSO pointing toward El Nino

Hawaii Mean SST vs Hawaii Mean pH

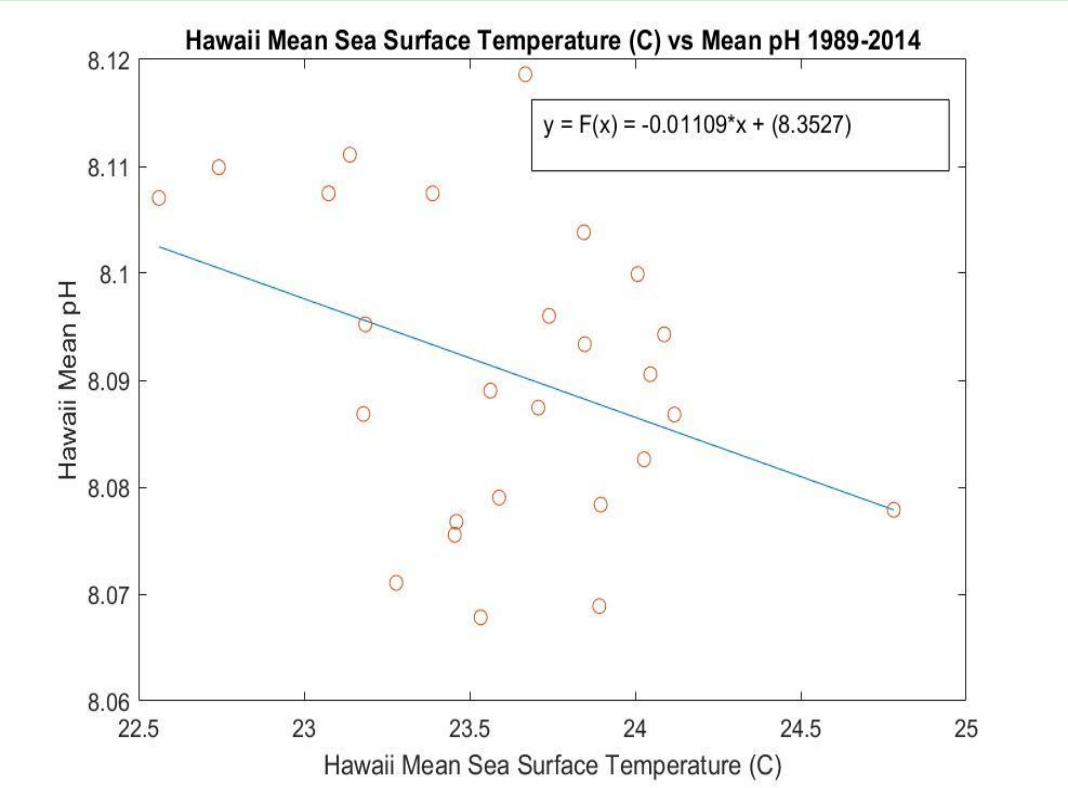

Figure 6. Hawaii Mean Sea Surface Temperature vs Hawaii Mean Surface Ocean pH

- **R-squared: 0.136, p-value = 0.064**
- Statistically insignificant p-value > 0.05
- Cannot conclude that there is a statistically significant correlation between the two variables
- Weak negative correlation (r value = between +/-0.3 ~ +/-0.5) based on the Pearson's correlation coefficient measuring the strength of a linear association

Annual mean ENSO index vs Hawaii Mean SST

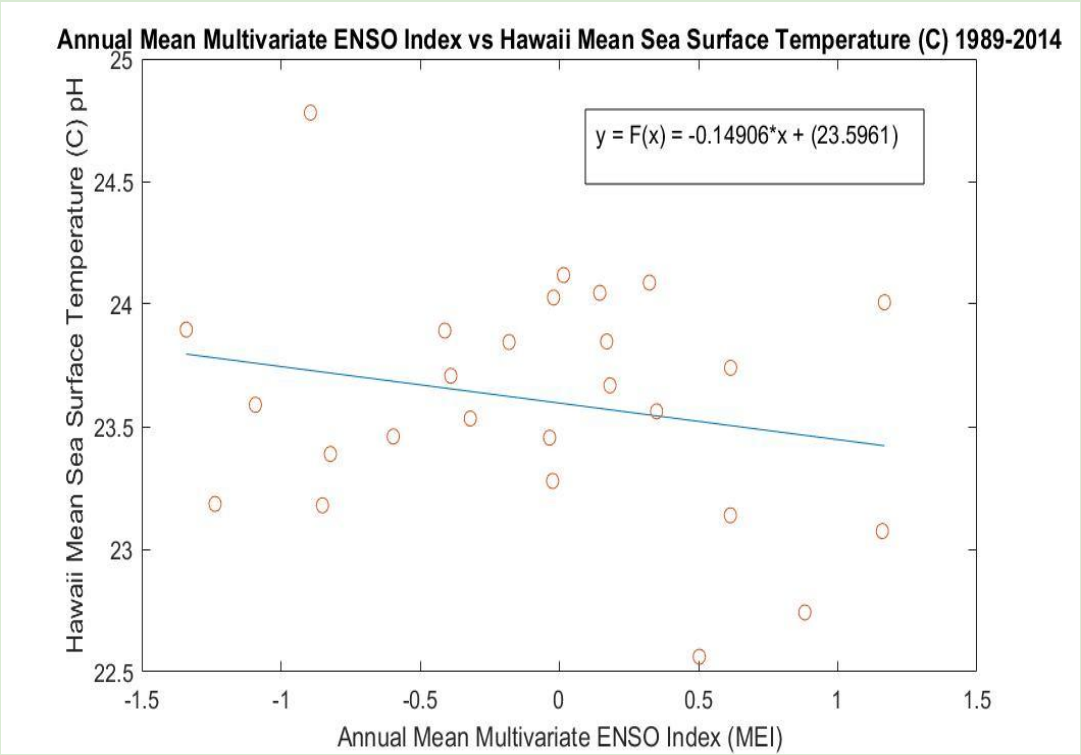

Figure 7. Annual mean MEI vs Hawaii Mean Sea Surface Temperature .

- **R-squared: 0.0481, p-value = 0.282**
- Statistically insignificant p-value > 0.05
- Cannot conclude that there is a statistically significant correlation between the two variables
- Negligible correlation (r = between 0 ~ +/-0.3) , based on the Pearson's correlation coefficient measuring the strength of a linear association

Annual mean ENSO index vs Hawaii Mean pH

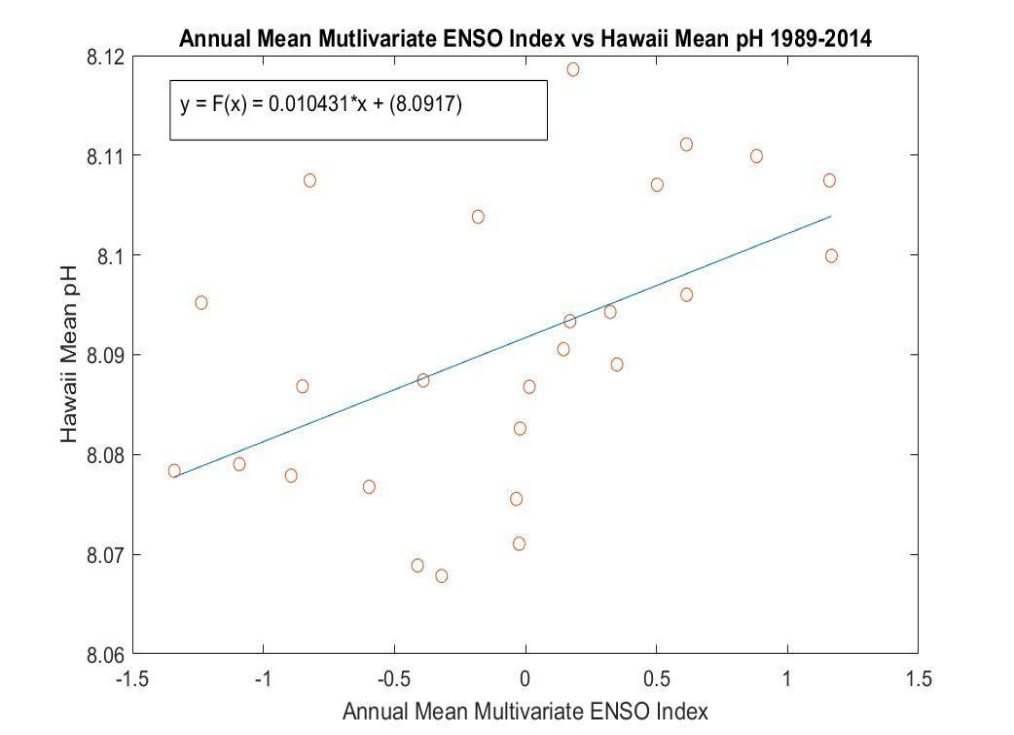

Figure 8. Annual mean MEI vs Hawaii Mean Surface Ocean pH.

- **R-squared: 0.26, p-value = 0.0078**
- Statistically significant p-value < 0.05
- There is a statistically significant correlation between the two variables
- Moderate positive correlation (r = between 0.5-0.7) based on the Pearson's correlation coefficient

Bermuda Mean SST vs Bermuda Mean pH

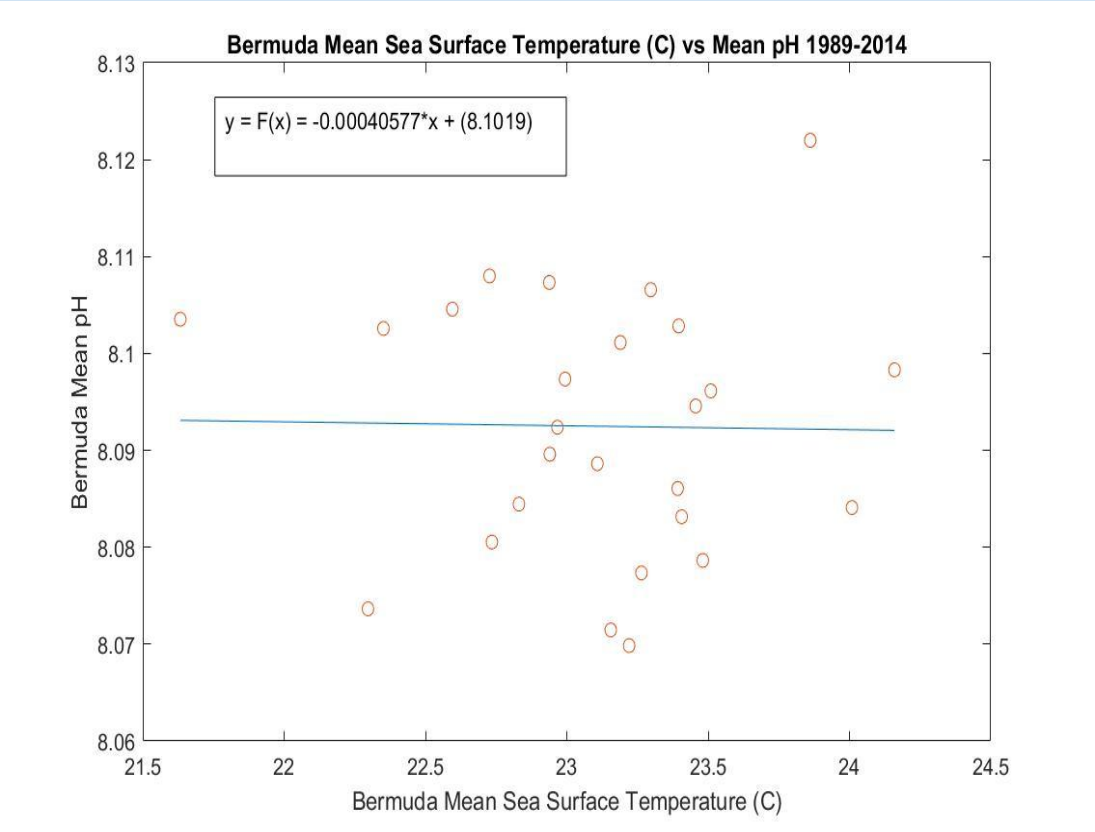

Figure 9. Bermuda Mean Sea Surface Temperature vs Bermuda Mean Ocean pH .

- **R-squared: 0.000281, p-value = 0.935**
- Statistically insignificant p-value > 0.05
- Cannot conclude that there is a statistically significant correlation between the two variables
- Negligible correlation (r value < +/-0.3), based on the Pearson's correlation coefficient measuring the strength of a linear association

Annual mean ENSO index vs Bermuda Mean SST

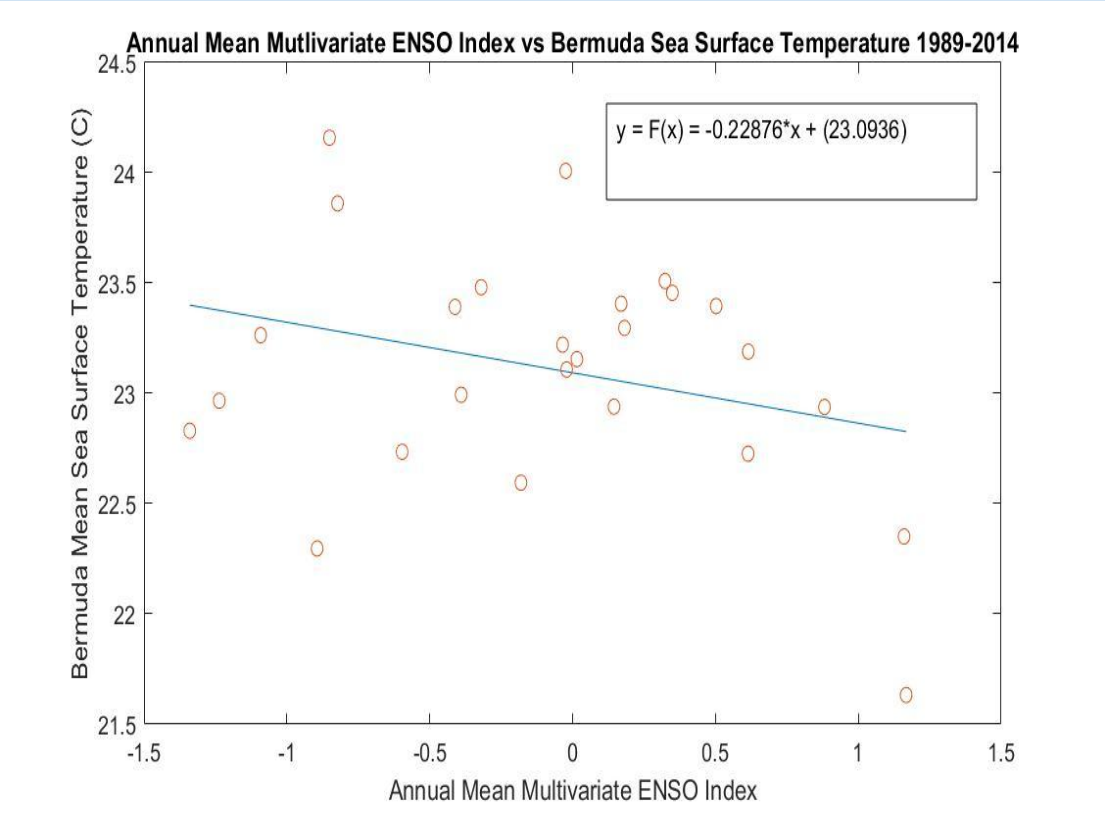

Figure 10. Annual mean MEI vs Hawaii Mean Sea Surface Temperature

- **R-squared: 0.0865, , p-value = 0.145**
- Statistically insignificant p-value > 0.05
- Cannot conclude that there is a statistically significant correlation between the two variables
- Negligible correlation (r value < +/-0.3), based on the Pearson's correlation coefficient measuring the strength of a linear association

Annual mean ENSO index vs Bermuda Mean pH

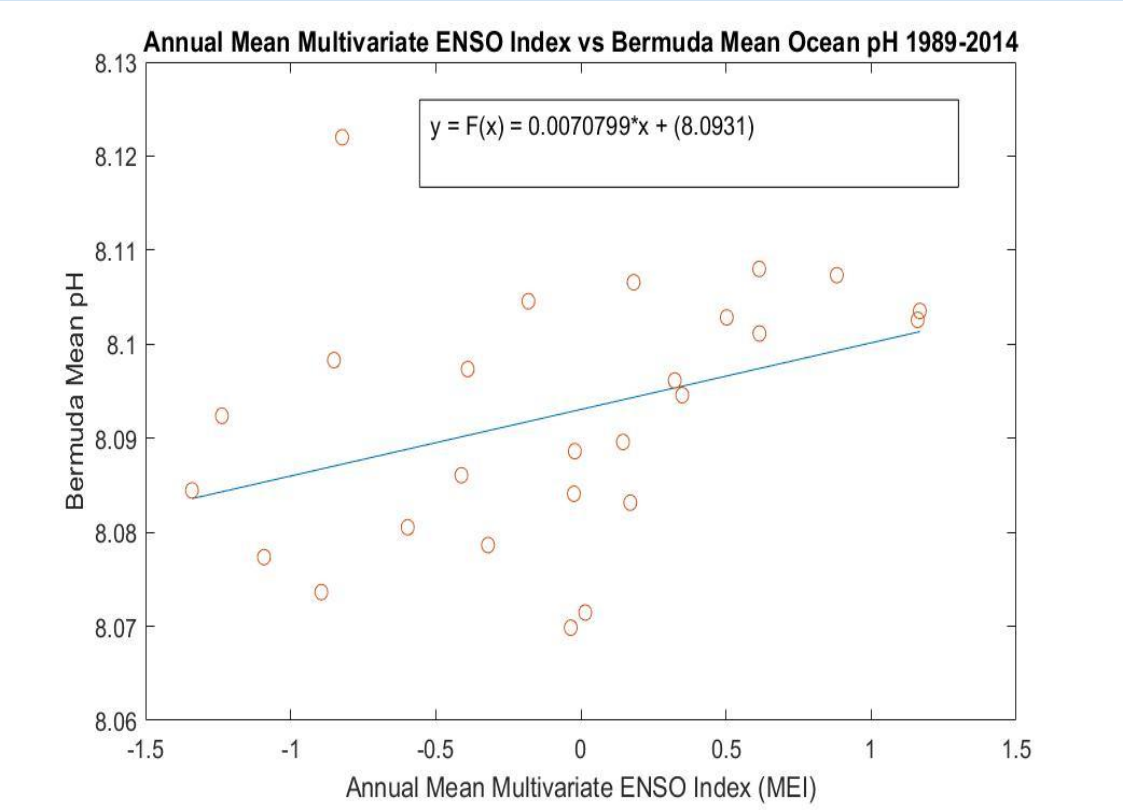

Figure 11. Annual mean MEI vs Bermuda Mean Surface Ocean pH.

- **R-squared: 0.141, p-value = 0.0585**
- Statistically insignificant p-value > 0.05
- Cannot conclude that there is a statistically significant correlation between the two variables
- Weak positive correlation (0.3 < r < 5) based on the Pearson's correlation coefficient

Summary of Results

	Hawaii (Pacific)	**Bermuda**
SST annual time-series	Slope: 0.025 (Steeper)	Slope: 0.01
pH annual time-series	Slope: -0.0018 (Steeper)	Slope: -0.0015
SST vs pH	Weak negative correlation	Negligible correlation
SST vs ENSO	Negligible correlation	Negligible correlation
pH vs ENSO	Moderate positive correlation	Weak positive correlation

Discussion

1) Explain our expected findings about Bermuda

The results we collected from the Hawaii data did not match the knowledge that we know about El Nino/La Nina, and how it affects ocean circulation.

Here are the two contradictory results:

1) Figure 8: It says the pH increase during El Nino
2) The ENSO vs SST correlation is negative but insignificant in both Hawaii and Bermuda.

Here is why our results doesn't make sense: (By explaining what we know)

ENSO vs SST: We're expecting to see a positive correlation because High ENSO index (El Nino) means surface water should be warmer.

-> Why doesn't our data match our prediction?

Conclusion

- Is the impact of ENSO on sea surface temperature and pH more significant in the subtropical pacific or subtropical atlantic?

- Our findings:
  - The impact of ENSO on sea surface temperature was insignificant at both locations however the impace of ENSO on pH was more significant in the subtropical pacific

References