Ocean Acidification insights through Geospatial Visualizations and Time Series Forecasting for New York Harbor

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Introduction

Since the beginning of the industrial revolution humans have produced an estimated 1.5 trillion tons of CO2 emissions. The side effects of these emissions produced, which today are classified as Green House Gas Emissions, have had detrimental effects on the natural ecosystems of the earth. From a significant increase in extreme weather patterns to the rise in temperatures across the globe, the limits of the earth's capacity to support this exponential increase in Green House Gas emissions before the destabilization of the earth's natural climate cycle has been predicted to soon come to a close within the following decades (RCP 8.5). Combined with the destabilization of earth's climate, the average hydrogen ion concentration of the earth's surface waters has risen by 30% (-0.1 pH) increasing the level of acidification. With the production and release of anthropogenic carbon dioxide emissions into the atmosphere, the oceans chemistry has changed significantly and the organisms present within the earth's bodies of water have been at the forefront of facing the detrimental side effects of ocean acidification. The pH level in the New York Harbor as of today has come to a vulnerable state where the possibility of negative impacts on the health of the oyster and reproduction capability are bound to be prominent. By gaining insights into the New York Harbors water quality data through Geospatial Analysis and Time Series forecasting, I am proposing methodologies and strategies for conducting citizen science in an accessible and efficient manner to create actionable insights for conducting future Oyster restoration operations.

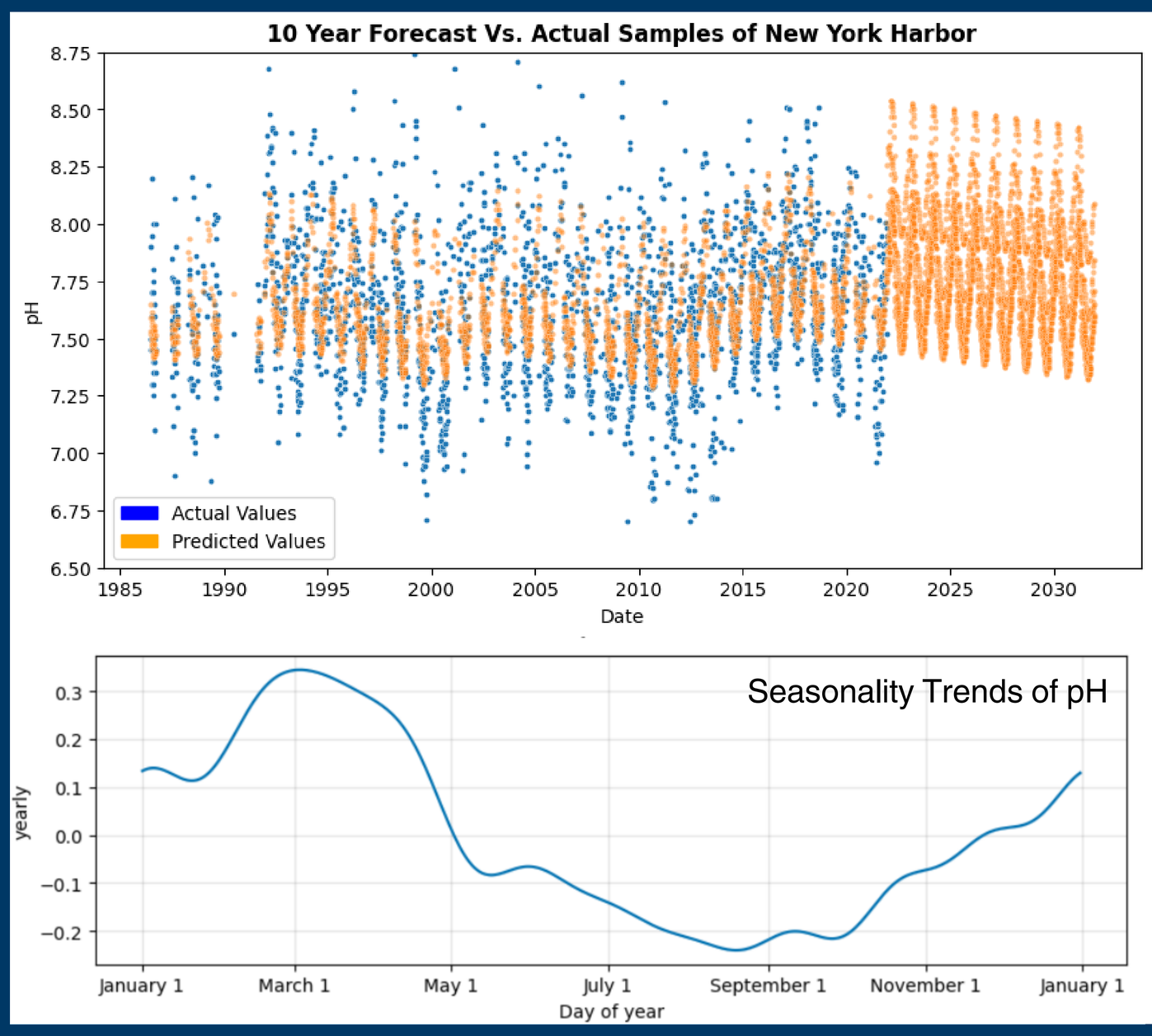
Research Objectives

My research objective is to effectivley demonstrate the concept of pH and it's impacts in the context of Ocean Acidfication. This research project explores ways to visualize and further increase the accessibility to Water Quality data to further understand New York Harbors waters.

Understanding pH

pH is the concentration of Hydrogen ions in an aqueous solution. It is measured on a logarithmic scale, which means for every per unit increase in pH, the hydrogen ion concentration is 10 fold. It ranges on a scale from 1-14 where 7 is neutral, pH < 7 is acidic, and pH > 7 is alkaline or “basic”. In the context of Ocean Acidification, pH and the level of “acidity” in a body of water is determined by the concentration of hydrogen ions which is the process of naturally occurring or anthropogenic CO2 emissions from the atmosphere dissolving into the water. This forms into a carbonic acid (H2CO3) that dissociates into hydrogen ions (H+) and bicarbonate ions. When CO2 dissolves it lowers pH and decreases carbonate ion concentration and increases bicarbonate concentration. This is due to the decreased likelihood of dissociation from bicarbonate to carbonate ions because of the excessive amounts of CO2 producing a high concentration of hydrogen ions. With a body of water that has a high concentration of hydrogen ions, hydrogen ions bond with carbonate ions and effectively remain as bicarbonate instead of becoming carbonate ions. For aquatic organisms such as Oysters and Coral, when the pH decreases due to the increase in the presence of hydrogen ions, the process of forming the Calcium Carbonate ($CaCO_3$) structures (shells, skeletons) becomes more difficult.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO\bar{3} \rightleftharpoons 2H^+ + CO\bar{3}$$



Forecast Analysis

Time series forecasting is the prediction of future values based on the understanding of previous data. Prophet, an additive model created by Facebook Open Source, is a model that simplifies the process of producing effective time series forecasts with resilience to common data abnormalities such as outliers and missing data. Prophet as an additive model consists of 3 primary components to make forecasts: Trend, Seasonality, and Events (Holidays). In our univariate time series forecasting model, consisting of pH sampled at low depths as our target value to predict, a decrease in pH was predicted. In addition, as a dataset affected by the natural climate cycle on the east coast of the United States, seasonality changes in the data were prominent. In a cross-validation test of the model, in a 2 year forecast the Mean Absolute Percentage Error (MAPE) was 4.82%, in a 5 year forecast the MAPE was 7.6%, and in a 10 year forecast the MAPE was 9.7%. With understanding the average percentage difference between predictions and their intended target (MAPE) in the context of the problem domain of forecasting Ocean Acidification, forecasting around 2-5 years outwards from the current timeline for ORS sites could be utilized as an effective tool to measure which sites are most at risk of falling into moderate to severe pH levels.

Effects of OA

The Eastern Oyster *(Crassostrea virginica)* that resides in the depths of New York Harbor has been a core species at risk of the impacts of Ocean Acidification. Studies have shown that at pH level of 7.1 and below that reproducibility rates of Oysters are negatively impacted. With the process of reproduction being the most sensitive to variability in pH, maintaining pH levels which have a high margin above severe levels is critical to the success of an estuary. When the pH decreases in a body of water due to the excessive amount of CO2 concentration the energy needs of Oysters increase due to oxidative stress increasing the metabolism rate to maintain a healthy state. In effect to this increased level of energy usage, because the gametogenesis of the Eastern oyster is dependant on energy available for sperm production the entirety of the reproduction capability of the oyster becomes significantly reduced. For the past 10 years the average pH during Spring and Summer months in the New York Harbor has been measured at 7.64. Although this is higher than the severe levels mentioned prior, Oysters during the reproduction season in the Spring and Summer months when there is reduced pH are still potentially susceptible to performance degradation at certain sites within the city. The case of anthropogenic emissions that dissolve into the Harbors bodies of water remains a serious threat to the success of Oyster Estuaries.

References

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