ACENET - ISP

Climate Change in the Stephenville area over 30 years

Presented by: Jamie Goosney

Introduction

This presentation analyzes climate data trends, in the Stephenville, NL, area, including temperature, wind speed, precipitation, and snow on the ground, using data from 1994 to 2024. We will examine the statistical significance of these trends and their correlations with each other.

The original intent of the ISP included the use of this data to determine coastline erosion rates in the Stephenville, NL, area. However, there is limited and sporadic information on this subject available. Any representations in the project are extrapolations of a very small data set.

Purpose of ISP

1. Quantifying Climate Change Impact: Analyzing historical climate data will clarify if climate change had an effect on the Stephenville area over the past 30 years.
2. Predicting Future Trends: Understanding past trends in climate change and predicting future changes in erosion rates.

Programming Flowchart

- Start
- Import Libraries
- Load Climate Data
  - Read CSV file into DataFrame
- Data Preprocessing
  - Check and handle missing values
  - Convert the date column to datetime and set it as index
  - Calculate average wind speed
- Coastal Erosion Data Calculation
  - Compute daily erosion rates
  - Create and save coastal erosion DataFrame
- Data Visualization
  - Plot temperature trends
  - Plot precipitation trends
- Summary Statistics and Linear Regression
  - Display summary statistics
  - Perform and plot linear regression for:
    - Temperature
    - Average wind speed
    - Precipitation
    - Snow on ground
  - Correlation Analysis
    - Load and merge coastal erosion data
    - Calculate and visualize the correlation matrix
  - Future Trend Forecasting using Prophet
    - Define forecast function
    - Forecast and plot trends for:
      - Temperature
      - Precipitation
      - Average wind speed
      - Coastal erosion
- End

Data Preparation and Initial Analysis

- Import Necessary Packages:
  - Import libraries: pandas for data manipulation, matplotlib.pyplot and seaborn for plotting, scipy.stats. linregress for linear regression, and prophet for time series forecasting.
- Load and Display Data:
  - Load climate data from a CSV file into a DataFrame (df).
  - Display the first few rows of the DataFrame to understand its structure.
- Handle Missing Values:
  - Check for missing values in the DataFrame.
  - Drop rows with missing values for simplicity.
- Convert Date Column:
  - Convert the 'date' column to datetime format.
  - Set the 'date' column as the index of the DataFrame.
- Calculate Average Wind Speed:
  - Calculate average wind speed from “max_wind_speed_s” and “min_wind_speed_s” columns and add it as a new column “avg_wind_speed”.

Coastal Erosion Data Calculation

- Calculate Daily Erosion Rates:
  - Compute cumulative erosion based on an average rate of 0.20 meters per year, converted to a daily rate.
- Create Coastal Erosion DataFrame:
  - Create a new DataFrame (coastal_erosion_data) with dates and cumulative erosion values.
- Save Coastal Erosion Data:
  - Save the coastal erosion DataFrame to a CSV file.

Data Visualization

- Plot Temperature Trends:
  - Plot temperature trends over time using the “max_temperature_s” column.
- Plot Precipitation Trends:
  - Plot precipitation trends over time using the “rain_s” column.

Summary Statistics and Linear Regression

- Summary Statistics:
  - Display summary statistics of the DataFrame.
- Temperature Trend Analysis:
  - Perform linear regression analysis on temperature trends.
  - Plot the temperature trend with a fitted regression line.
- Average Wind Speed Trend Analysis:
  - Perform linear regression analysis on average wind speed trends.
  - Plot the average wind speed trend with a fitted regression line.
- Precipitation Trend Analysis:
  - Perform linear regression analysis on precipitation trends.
  - Plot the precipitation trend with a fitted regression line.
- Snow on Ground Trend Analysis:
  - Perform linear regression analysis on snow on the ground trends.
  - Plot the snow on ground trend with a fitted regression line.

Correlation Analysis

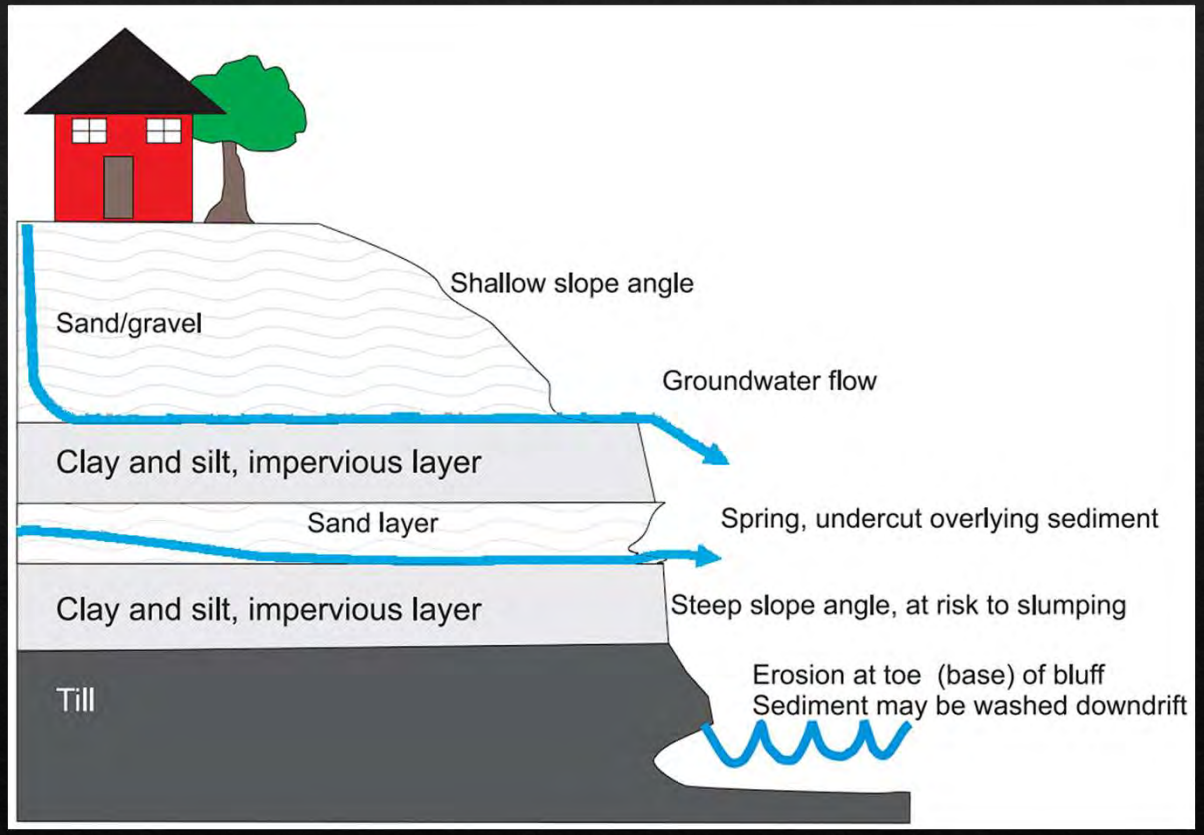
- Load and Merge Coastal Erosion Data:
  - Load coastal erosion data from a CSV file.
  - Merge climate data with coastal erosion data based on dates.
- Calculate and Visualize Correlation:
  - Calculate the correlation matrix of the merged DataFrame.
  - Visualize the correlation matrix using a heatmap.

Future Trend Forecasting using Prophet

- Define Forecast Function:
  - Define a function (forecast_future_trend) to forecast future trends using Prophet. This function:
    - Renames columns to 'ds' (dates) and 'y' (values).
    - Fits a Prophet model.
    - Makes future predictions for a specified number of periods.
  - Forecast Future Temperature Trends:
    - Forecast temperature trends from 2024 to 2054 (30 years) and plot the forecast with confidence intervals.
  - Forecast Future Precipitation Trends:
    - Forecast precipitation trends from 2024 to 2054 and plot the forecast with confidence intervals.
  - Forecast Future Average Wind Speed Trends:
    - Forecast average wind speed trends from 2024 to 2054 and plot the forecast with confidence intervals.
  - Forecast Future Coastal Erosion Trends:
    - Forecast coastal erosion trends from 2024 to 2054 and plot the forecast with confidence intervals.

Coastal bluffs

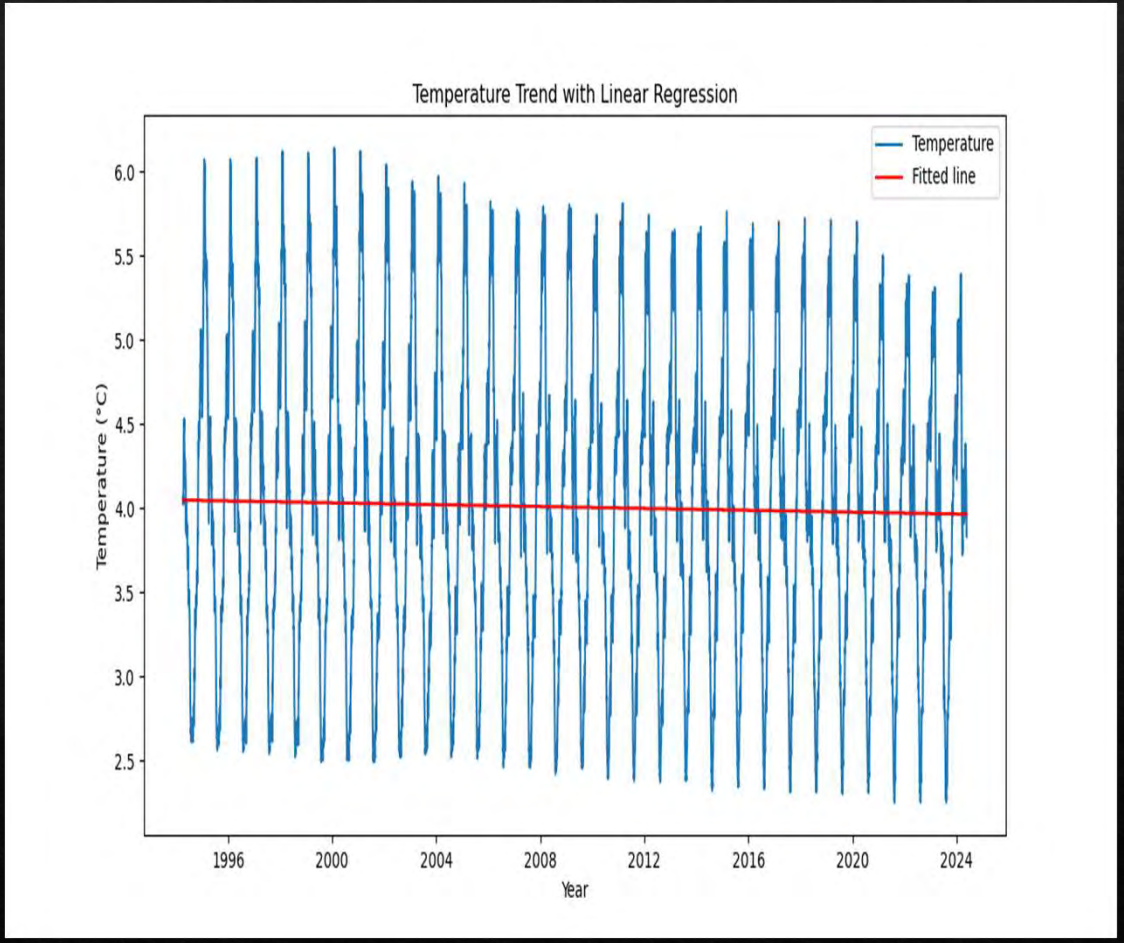
Coastal bluffs in Newfoundland and Labrador consist of various materials. Water percolates through sand and gravel but moves laterally upon reaching an impervious clay/silt layer, exiting through seepage or springs. Sand and gravel layers have shallower slopes and erode easily, while cohesive clays and silts form steeper slopes but slump when saturated or undercut. Waves at the base remove sediment, undercutting the cliff.



Temperature Trends

The temperature trends over time show seasonal variations with a slight but statistically significant.

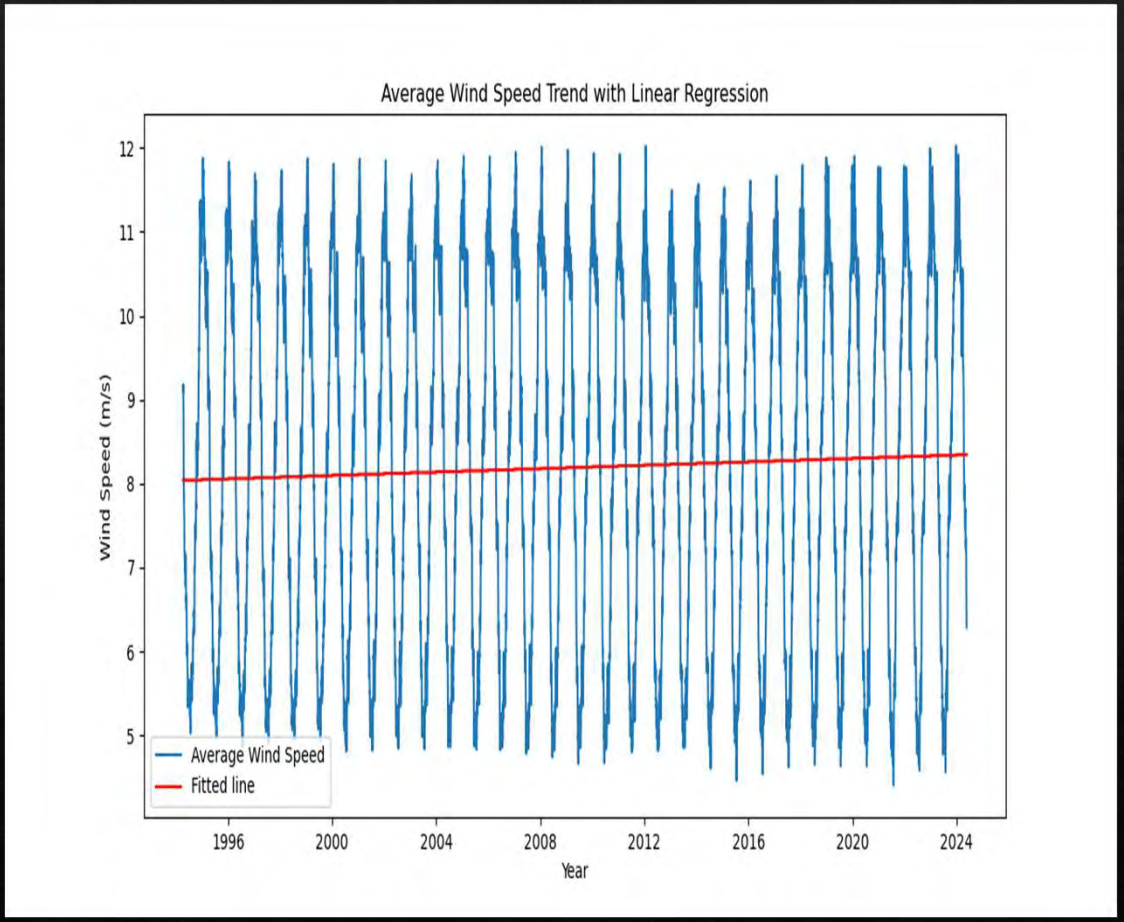
Slope: -0.0028°C per year



Wind Speed Trends

The average wind speed trends over time show seasonal variations with a statistically significant upward trend.

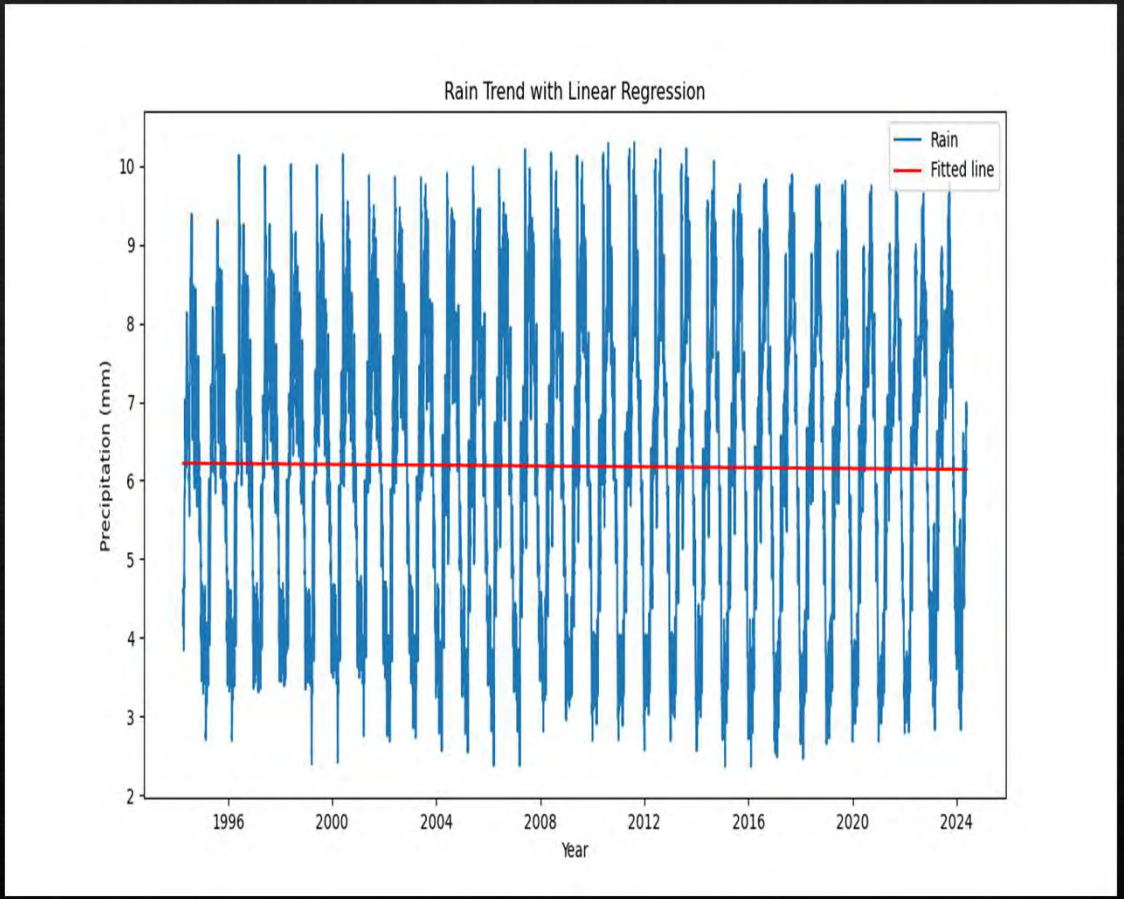
Slope: 0.0102 m/s per year



Rain Trends

The rain trends over time show seasonal variations with a slight downward trend.

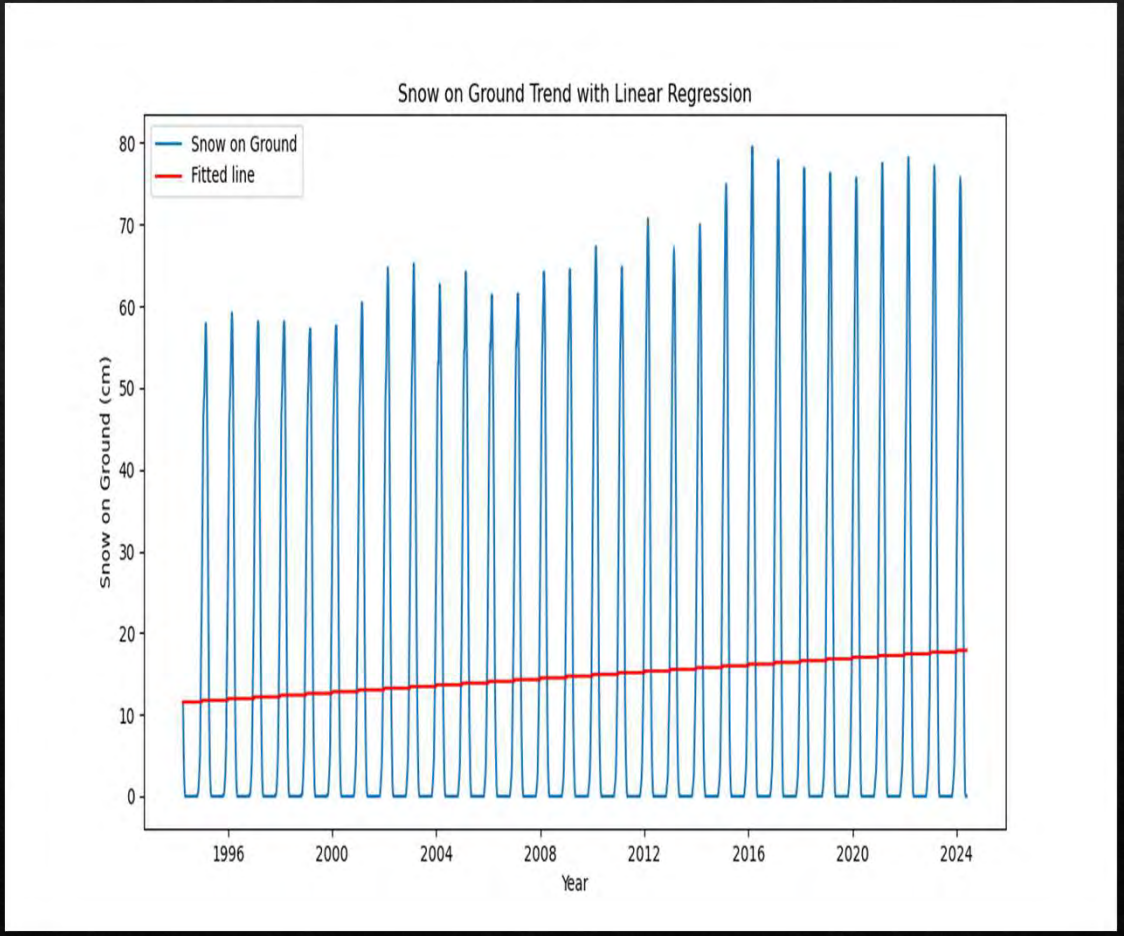
Slope: -0.0026 mm per year



Snow on Ground Trends

The snow on the ground trends over time show seasonal variations with a statistically significant upward trend.

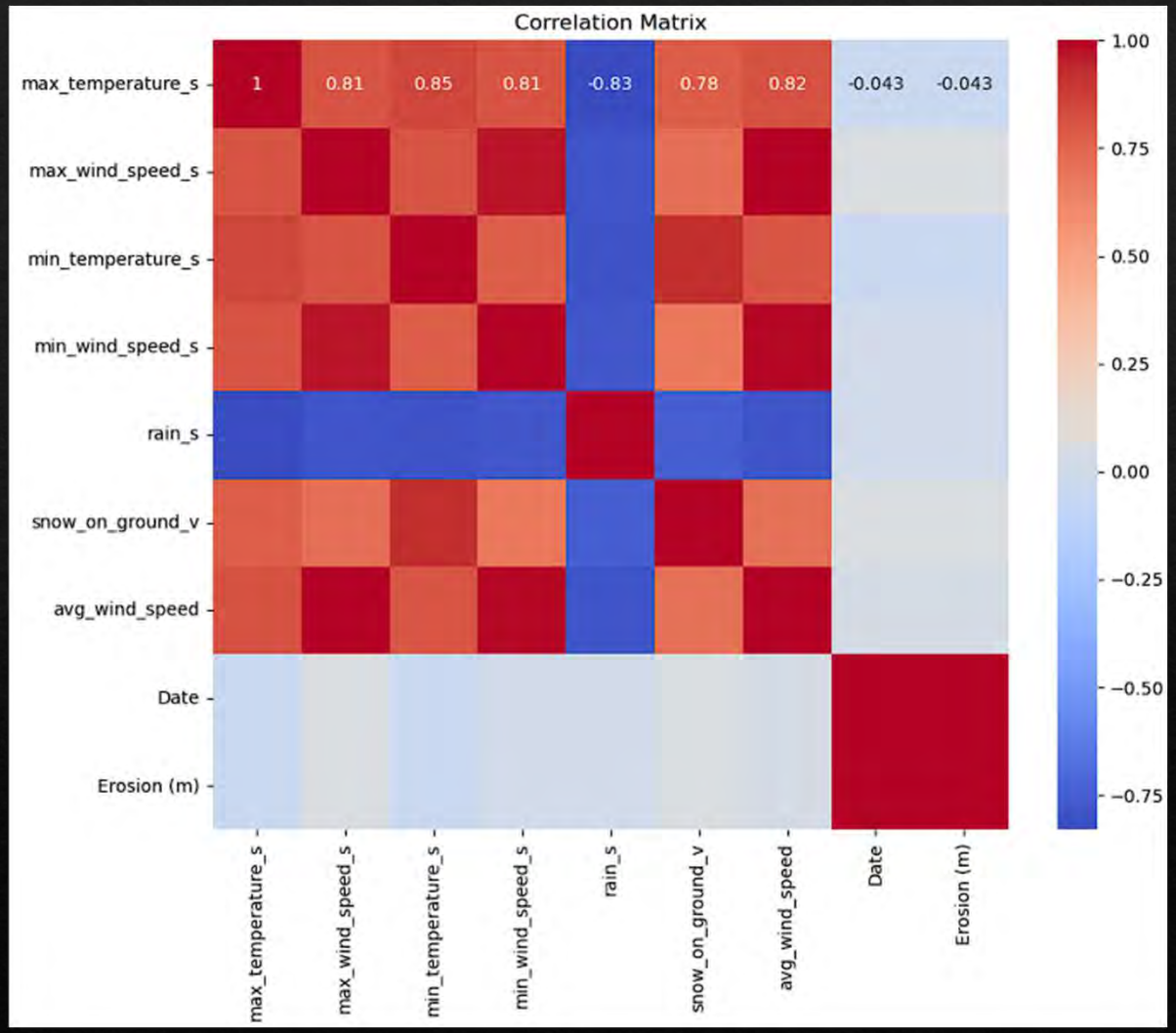
Slope: 0.2109 cm per year



Correlation Matrix

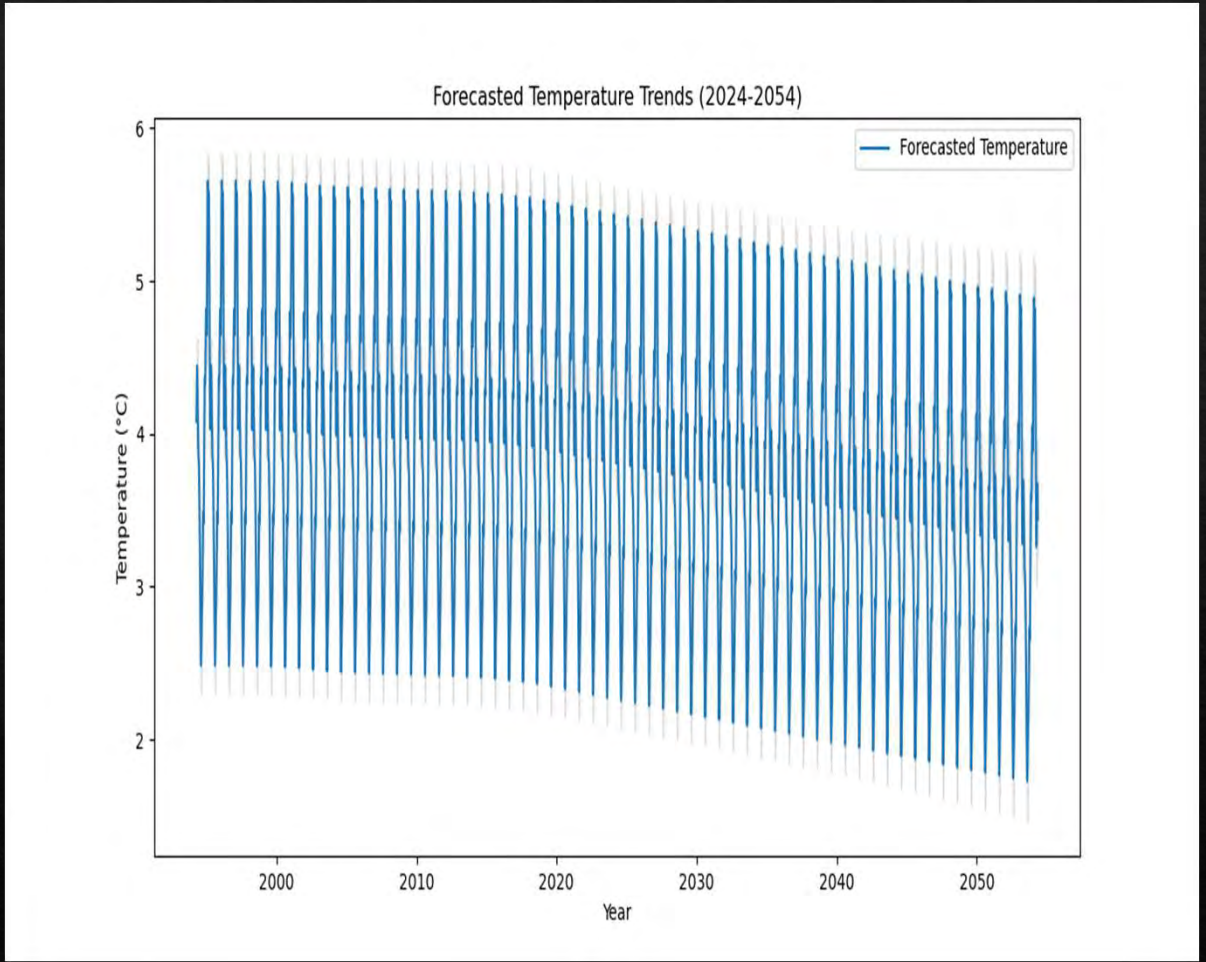
The correlation matrix shows the relationships between different climate variables:

- Temperature is negatively correlated with rain and positively correlated with snow.
- Wind speeds (max, min, and average) are highly correlated.
- Rain is negatively correlated with temperature and snow.
- Snow is positively correlated with lower temperatures and negatively with rain.



Forecasted Temperature Trends 2024 - 2054

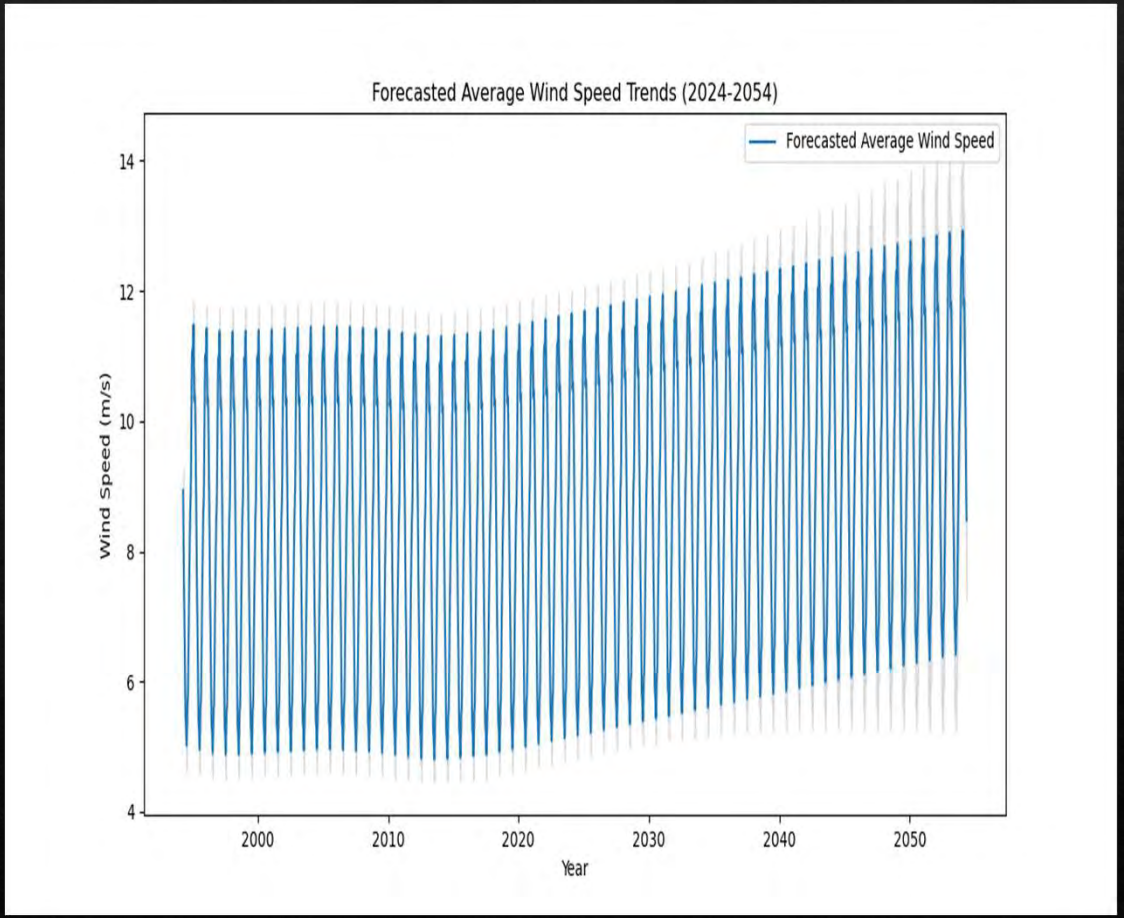
The average air temperature trends downward over the next 30 years will continue to drop. This may be due to shorter, colder winters, but we may also see increased summer temperature spikes.



Forecasted Wind Speed Trends 2024 - 2054

The average wind speed will continue to increase for the next 30 years. This will result in more sustained winds and more damaging wind gusts.

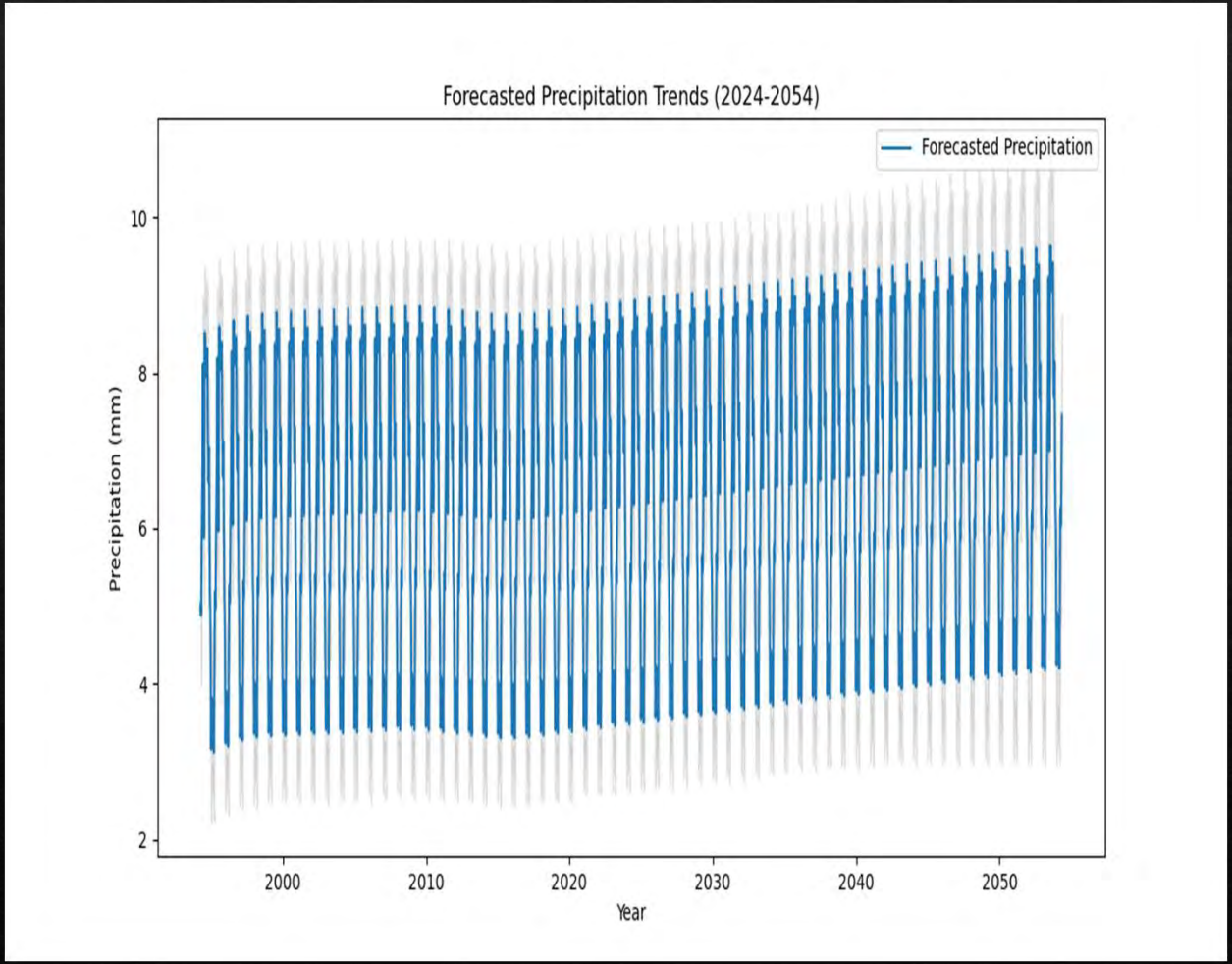
As warmer temperatures occur to the south more storms and sustained winds will push from the south to the north.



Forecasted Precipitation Trends 2024 - 2054

The amount of rain has trended downward in the past 30 years. However, snow on the ground has an upward trend, increasing by approximately 0.2109 cm per year. This finding shows a growing accumulation of snow over the years, which can impact water resources, ecosystems, and winter weather patterns.

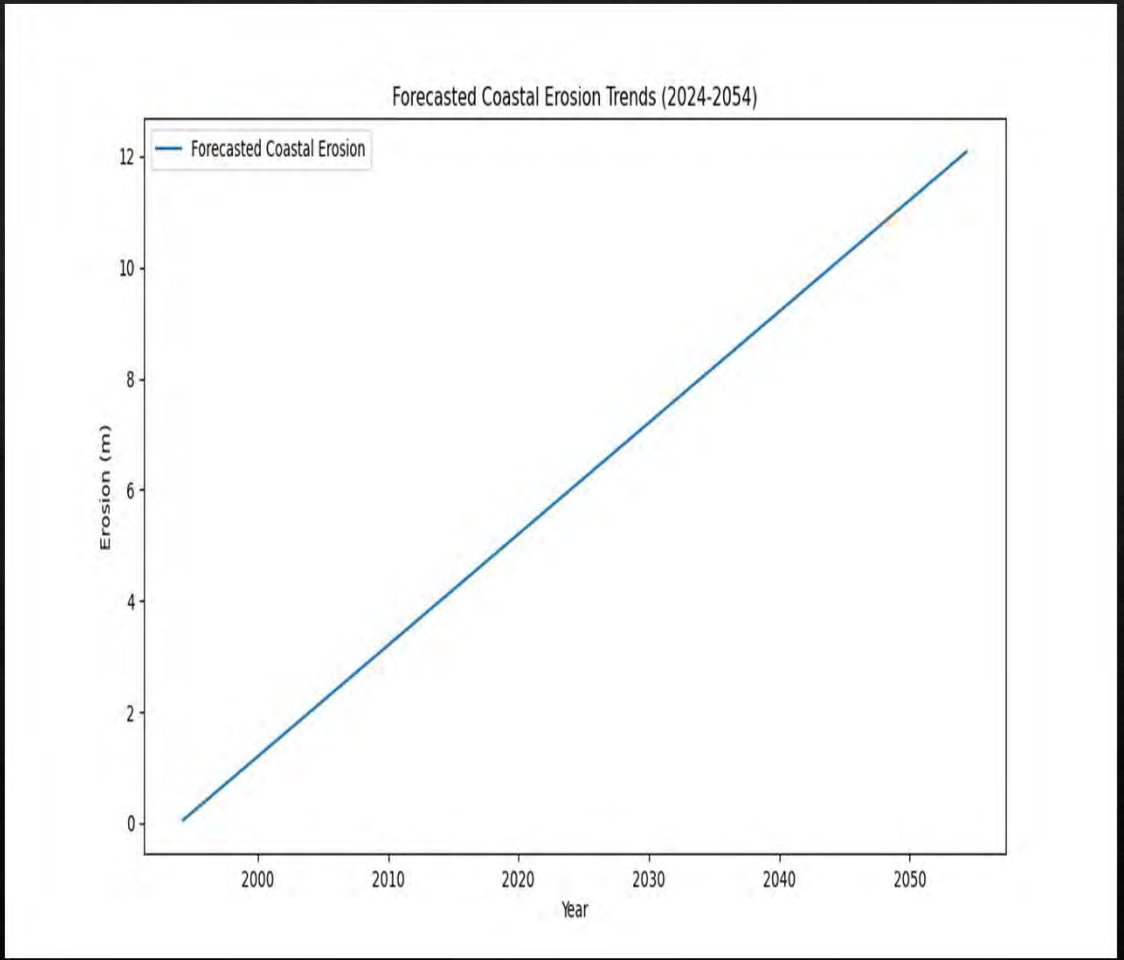
Combining these two precipitations we see an increasing precipitation rate for the next 30 years, with snowmelt being the dominant form of surface runoff. The downward trend in rain is concerning as it will lead to draughts in mid to late summer, and fall.



Forecasted Coastal Erosion Trends 2024 - 2054

Coastal erosion data in Newfoundland consists primarily of GIS data, mostly in the form of shapefiles, rather than numerical data. The average erosion rate at the Kippens (Seaside Drive) Coastal Monitoring Site is approximately 20 cm per year. Therefore, the forecasted coastal erosion trend will use that rate.

Erosion Rate: 0.20 cm per year



Discussion

The analysis indicates significant trends in temperature, wind speed, and snow on the ground, while the trend in rainfall is not statistically significant. The downward trend in temperature and upward trends in wind speed and snow accumulation have important implications for regional climate adaptation strategies. Coastal erosion, influenced by climatic factors, remains a critical concern. The average erosion rate at Kippens (Seaside Drive) is approximately 20 cm per year. Historical surveys conducted in 1991, 1993, 1994, 2000, 2012, 2013, 2016, and 2017 indicate that groundwater seepage and the composition of the coastline, which includes silt, clay, sand, and gravel, contribute to the erosion process. The increasing impact from storms and sea-level rise is likely to exacerbate these erosion rates. Although minimal data is available other than GIS shapefiles, this analysis highlights the importance of addressing coastal erosion in the context of climate change.

Conclusion

This analysis of climate data from 1994 to 2024 provides valuable insights into the trends and relationships among various climatic variables, including temperature, wind speed, precipitation, and snow on the ground. The results indicate a slight but statistically significant downward trend in temperature over the years, with a decrease of approximately 0.0028°C per year. This subtle trend suggests long-term climate changes in the region. Wind speed shows a statistically significant upward trend, increasing by approximately 0.0102 m/s per year, which has implications for weather patterns, energy production, and environmental conditions. Precipitation trends reveal a slight decrease of approximately 0.0026 mm per year, indicating no strong evidence of meaningful change. Snow on the ground shows a statistically significant upward trend, increasing by approximately 0.2109 cm per year, indicating growing snow accumulation that impacts water resources, ecosystems, and winter weather patterns.

The correlation analysis highlights several important relationships among the climatic variables. Temperature is negatively correlated with rainfall and positively correlated with snow, suggesting that higher temperatures are linked to less rainfall and more snow, during winter months. Wind speeds, including maximum, minimum, and average, are highly correlated, indicating that they tend to vary together.

Coastal erosion is another critical issue examined in this study. The average erosion rate at Kippens (Seaside Drive) is approximately 20 cm per year. Historical surveys conducted in 1991, 1993, 1994, 2000, 2012, 2013, 2016, and 2017 indicate that groundwater seepage and the composition of the coastline, which includes silt, clay, sand, and gravel, contribute to the erosion process. The increasing impact from storms and sea-level rise is likely to exacerbate these erosion rates.

The period from 2024 to 2054 forecast shows a continuation of the slight downward trend in temperature. Precipitation patterns are expected to maintain current trends with slight variability, with rain showing no significant changes and snow continuing to increase, affecting water resources and winter weather patterns. Wind speeds are projected to continue increasing, which may impact energy production and environmental conditions. Coastal erosion rates are expected to rise due to increased storm activity and sea-level rise.

In summary, these findings provide an overview of climatic trends and their interrelationships in the Stephenville area of Newfoundland and Labrador. Understanding these patterns is crucial for developing effective strategies for climate adaptation and mitigation, as well as for informing policy decisions and environmental best management practices (BMPs).