Field Description

Dataset Identifier: Total Global Greenhouse Gas Emissions

- URL: https://climatedata.imf.org/datasets/b84a7e25159b4c65ba62d3f82c605855/explore
- Title: Change in Mean Sea Levels
- Authors: National Oceanic and Atmospheric Administration (NOAA)
- Publication Date: 2024-09-30
- Text Type: Text/Value
- Unit of Measure: Millimeters (mm)
- Accessible: Yes
- Accessibility: API
- Preprocessing requirement: None
- Live Data: No
- Summary: 39617 records

1. **Measure** (Type: Text): This is the name of the sea or ocean.
2. **Date** (Type: Date): This is the date the sea level measurement was taken.
3. **Value** (Type: Decimal): This is the sea level measurement that was taken.

The dataset has eight other fields: Country, ISO3, Indicator, Unit, Source, CTS Code, CTS Name, and CTS Full Descriptor. These eight fields are not used because they all have the same values in all the dataset records.

Country	ISO3	Indicator	Unit	Source	CTS Code	CTS Name	CTS Full Descriptor	Measure	Date	Value
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Sea Okhotsk	D12/16/1992	10.11
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Adriatic Sea	D12/17/1992	32.73
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Andaman Sea	D12/17/1992	-14.88
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Arabian Sea	D12/17/1992	-9.76
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Atlantic Ocean	D12/17/1992	-13.66
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Baltic Sea	D12/17/1992	213.45
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Bay Bengal	D12/17/1992	-1.57
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Bering Sea	D12/17/1992	-10.19
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Caribbean Sea	D12/17/1992	-7.43
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Gulf Mexico	D12/17/1992	-2.52
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Indian Ocean	D12/17/1992	-26.92
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Indonesian	D12/17/1992	-14.93
World	WLD	Change in mean sea level: Sea lev...	Millimeters	National Oceanic and Atmospheric...	ECCL	Change in Mean Sea Level	Environment, Climate Change, Cli...	Mediterranean	D12/17/1992	48.86

Data Context

The dataset provides the sea level values for some seas and oceans from 1992 to 2024. It includes comprehensive data on some seas and oceans in the world. This dataset is broken down by sea/ocean and their level values at different times of the year.

Key Features of the Dataset:

4. **Temporal Coverage**: The dataset spans 1992 to 2024, capturing over five decades of emissions data.
5. **Geographical Coverage**: It includes data on seas and oceans, providing a global perspective on sea level.
6. **Data Sources**: The data is compiled from various reputable sources, including national inventories, scientific studies, and international organizations.

3.4 Data Conditioning

1. Data Collection

- **Sources**: Emission National Oceanic and Atmospheric Administration (NOAA)
- **Variables**: Ensure the dataset includes variables like Measure, Date, and the sea level values recorded for the dates.

2. Data Cleaning

- **Missing Values**: Handle missing values by interpolation or using statistical methods to estimate them.
- **Outliers**: Identify and address outliers that may skew the analysis. This can be done using statistical tests or visual inspection.
- **Consistency**: Ensure consistency in units (e.g., mm) and formats (e.g., date formats).

3. Data Transformation

- **Normalization**: Normalize the data to ensure comparability across countries and years.
- **Aggregation**: Aggregate data to the desired level of granularity (e.g., annual totals for each country).
- **Log Transformation**: Apply log transformation if the data spans several orders of magnitude to stabilize variance.

4. Feature Engineering

- **Temporal Features**: Add temporal features like year-on-year changes and moving averages to capture trends.

5. Data Integration

- **Merging Datasets**: If using multiple sources, merge datasets, ensuring alignment on key variables like country and year.
- **Harmonization**: Harmonize data from different sources to ensure consistency in definitions and methodologies.

6. Validation

- **Cross-Validation**: Use cross-validation techniques to ensure the reliability of the dataset.
- **Comparison with Benchmarks**: Compare the dataset with benchmark datasets to validate accuracy.

7. Documentation

- **Metadata**: Document the dataset thoroughly, including sources, methodologies, and any assumptions made.
- **Versioning**: Maintain version control to track changes and updates to the dataset.

8. Function Calling Preparation

- **API Readiness**: Format the dataset for API calls, ensuring it is in a machine-readable format like JSON or CSV.
- **Schema Definition**: Define a schema for the dataset to facilitate easy integration with function calls.

3.5 Data Quality Assessment

Completeness

The dataset does not cover all seas and oceans from 1992 to 2024. This could be due to data not being available for certain regions.

Uniqueness

Each record is unique based on the combination of sea/ocean and date. No known duplicate records exist for the same sea/ocean and date.

Accuracy

The accuracy of the data can be assessed by comparing it with other reliable sources, such as reports from the Intergovernmental Panel on Climate Change (IPCC) or the National Oceanic and Atmospheric Administration (NOAA). Ensure that the data aligns with known benchmarks and standards.

Atomicity

Each record represents a single data point for a specific sea/ocean and date. The dataset does not combine multiple data points into one record.

Conformity

The dataset conforms to a consistent format for seas/oceans, dates, sea level values (e.g., millimeters), and standardized sea/ocean names.

Overall Quality

Overall, we classify this dataset as high quality. The dataset is as complete as possible, unique, accurate, atomic, and conform to standards.

Use Cases and Functions Performed on the Dataset

1. Temporal Patterns and Anomalies

Use Case: Identify outliers in sea level data for a specific region to detect irregularities or unusual events.

Function: temporal_patterns_and_anomalies(region)

Description: This function filters data for the specified region and calculates Z-scores for sea level values. Any value with a Z-score above 2.5 or below -2.5 is flagged as an anomaly.

Return Value: A dictionary with the region name and a data frame of anomalies, including dates and values where unusual patterns were detected.

A **Z-score** measures how far a data point is from the mean in terms of standard deviations. A Z-score of 0 indicates a value equal to the mean, while positive or negative values indicate how many standard deviations a value is above or below the mean.

In the context of your function:

- A Z-score **between -2.5 and 2.5** suggests that the sea level measurement is within a "normal" range, close to the average, given typical variability in the dataset.
- Z-scores **beyond ±2.5** (outside -2.5 and 2.5) indicate that a sea level measurement is unusually high or low, lying over 2.5 standard deviations away from the mean.

Values outside this range are flagged as **anomalies** because they deviate significantly from the average pattern, suggesting unusual sea level events in the specified region. This threshold helps to identify outliers, which could be the result of extreme weather events, seasonal shifts, or other significant environmental changes impacting sea levels.

2. Comparative Analysis of Variability

Use Case: Compare variability across regions to determine which regions have the most or least sea level fluctuation.

Function: compare_variability()

Description: This function calculates the standard deviation of sea level values for each region, which serves as a measure of variability.

Return Value: A sorted Series of regions by their sea level variability, allowing easy comparison.

In this context, **variability** refers to the extent to which sea level measurements fluctuate over time within each region. It measures how spread out or inconsistent the sea level data is for a given area.

When the function calculates the **standard deviation** for each region's sea level values, it assesses the amount of **dispersion** around the average sea level for that region:

- A **high standard deviation** means high variability, indicating that sea levels in that region fluctuate significantly over time, with values that often deviate far from the mean. This might suggest exposure to irregular weather patterns, seasonal influences, or other dynamic environmental factors.
- A **low standard deviation** means low variability, showing that sea levels in the region tend to stay relatively close to the average, suggesting a more stable or predictable sea level trend.

In summary, variability here quantifies how stable or unstable sea levels are in each region based on the range and consistency of recorded measurements.

3. Correlation Between Neighboring Regions

Use Case: Examine the correlation between sea levels in two regions to assess potential inter-regional influence or similarity.

Function: correlation_between_regions(region1, region2)

Description: Computes the Pearson correlation coefficient between two regions' sea-level data. A high positive correlation indicates synchronized trends, while a negative correlation shows inverse trends.

Return Value: The correlation coefficient, a float ranging from -1 to 1, or a message indicating insufficient data overlap for calculation.

A strong positive correlation between two regions may suggest that they are influenced by similar environmental or climatic factors (e.g., ocean currents, global weather patterns).

Identifying these correlations can help researchers understand how changes in one region might impact another, which is valuable for regional planning and forecasting.

High correlations in sea levels between distant regions could indicate shared climate drivers, such as El Niño or La Niña events, which influence global weather patterns. Recognizing these patterns helps understand the impact of large-scale climate phenomena on sea level changes.

For coastal planning and development, understanding which regions experience synchronized sea level changes can improve resilience against flooding, erosion, and extreme weather events. This information helps prioritize areas that might experience sea level shifts concurrently, posing a compounded risk.

Knowing correlations between sea level trends can guide where and when to build infrastructure, especially in coastal cities and ports. Governments can use this data to make informed decisions on adaptation and mitigation strategies based on the potential ripple effects across regions.

In summary, this correlation analysis can reveal interconnected sea-level data patterns, offering valuable insights for climate modeling, risk management, and sustainable planning.

4. Impact of Extreme Events on Trend

Use Case: Analyze the effect of extreme events on a region's overall sea level trend.

Function: trend_with_outliers(region)

Description: The function calculates linear trends with and without extreme values by comparing the slope of sea levels over time. This comparison reveals how significantly outliers affect the long-term trend.

Return Value: A dictionary containing two slopes, one including outliers and one excluding them, highlighting the impact of extreme events on trend analysis.

This comparison helps researchers understand the **robustness** of the observed trend. A significant difference between the two slopes suggests that outliers significantly impact the trend, which could mean that the data is sensitive to rare, extreme events.

In climate studies, a robust trend (one that remains similar with and without outliers) increases confidence in long-term projections.

Outliers in sea level data often correspond to extreme weather events (e.g., hurricanes, tsunamis) or unusual climate phenomena. Comparing trends helps researchers assess how much these events skew the overall trend.

If extreme events strongly influence the trend, this insight can guide additional analysis to understand the frequency and impact of such events on sea levels.

5. Seasonal Peaks and Troughs

Use Case: Identify seasonal highs and lows in sea level data to understand the cyclical nature of sea levels.

Function: seasonal_peaks_troughs(region)

Description: The function calculates monthly averages for a region and identifies months with the highest and lowest average sea levels.

Peaks are the months with the **highest average sea levels**.

Troughs are the months with the **lowest average sea levels**.

Return Value: A dictionary with the region, the month with the seasonal peak, and the month with the seasonal trough.

This seasonal_peaks_troughs function is designed to identify **seasonal patterns** in sea level data for a specified region. Calculating the monthly average sea levels and pinpointing the months with the highest (peak) and lowest (trough) average values helps reveal cyclical fluctuations that may correspond to seasonal changes in the region's environment.

Seasonal sea level changes affect ecosystems, particularly in coastal regions where variations can influence salt marshes, mangroves, and other habitats. Understanding the timing of peak and low sea levels can help conservationists monitor these habitats, predicting periods of stress or growth.

6. Annual Rate of Change

Use Case: Calculate the year-over-year rate of sea level change to observe the overall trend.

Function: annual_rate_of_change(region)

Description: Using linear regression, this function calculates the slope of yearly average sea levels, providing an estimated annual rate of change.

Return Value: A dictionary with the region and the annual rate of change, reflecting whether sea levels are generally rising or falling each year.

A **positive** rate of change in this context means that the average sea level in the region is rising each year.

A **negative** rate of change in this context means that the average sea level in the region is decreasing each year.

7. Positive vs. Negative Changes

Use Case: Determine the balance of rising versus falling sea levels in a region over time.

Function: positive_negative_ratio(region)

Description: The function calculates the ratio of positive to negative changes in sea level, providing insight into whether sea levels are more frequently increasing or decreasing.

Return Value: A dictionary with the region and the ratio of positive to negative changes, revealing any directional bias in sea level trends.

A **high positive-to-negative ratio** (above 1) indicates that sea levels in the region are more often increasing than decreasing.

A **low positive-to-negative ratio** (below 1) means sea levels tend to decrease more often than they increase in that region.

The positive-to-negative ratio summarizes whether sea levels are generally on an upward or downward trend over time. This is especially useful for regions with variable sea levels, where individual increases and decreases might otherwise mask the overall direction.

Persistent increases in sea levels (reflected in a high positive-to-negative ratio) can signal long-term climate change, such as glacial melt or thermal expansion due to global warming. Monitoring this ratio over time can help researchers track these changes more effectively.

For coastal communities, knowing that a region's sea levels are more frequently rising than falling (a high positive-to-negative ratio) can support risk assessments and planning. For instance, regions with consistently positive sea level trends may need to invest in flood defenses or other protective infrastructure.

The ratio can indicate the dominant trend in sea level changes, providing inputs for predictive models. It may help refine models used in forecasting, particularly in regions where sea levels exhibit seasonal or irregular patterns.

8. Consistency Over Time

Use Case: Measure the stability of sea levels over time by analyzing year-to-year fluctuations.

Function: consistency_over_time(region)

Description: Calculates the standard deviation of annual sea level averages, providing a measure of inter-annual consistency or volatility in the region.

Return Value: A float indicating the standard deviation of yearly averages, with lower values suggesting greater consistency.

In sea-level studies, smaller values (e.g., 5-10 mm) often suggest stability, while values above 20 mm suggest greater fluctuations, which could be driven by environmental factors.

9. Decadal Shifts

Use Case: Detect decade-level trends in sea level changes for long-term analysis.

Function: decadal_shifts(region)

Description: This function calculates average sea level changes for each decade, providing insights into broad shifts in sea levels over time. A negative value indicates a drop in sea level, and a positive value means rising sea levels.

Return Value: A Series indexed by decade, containing average sea levels, highlighting long-term trends in the region.

10. Ranking by Average Annual Change

Use Case: Identify and rank regions by their average annual sea level change.

Function: rank_by_average_annual_change()

Description: Computes the average yearly change in sea levels across regions, ranking them to show which areas experience the fastest changes.

Return Value: A sorted Series of regions by average annual change, from the highest to the lowest rate of sea level change.

11. Seasonal Consistency Year-to-Year

Use Case: Determine if a region follows a consistent seasonal pattern year-to-year in its sea level changes.

Function: seasonal_consistency(region)

Description: Calculates the standard deviation of seasonal averages over multiple years, providing a measure of how consistently the sea level changes by season.

Return Value: A float indicating seasonal variation consistency, with lower values showing more consistent seasonal patterns. It returns four values (1,2,3 and 4 representing Winter, Spring, Summer, and Fall, respectively).

This function helps determine if a region's sea-level patterns are stable during each season over the years or vary significantly. Stable seasonal patterns can help forecast and identify normal seasonal fluctuations.

For coastal management, knowing if a particular season consistently brings higher sea levels or if those levels vary unpredictably can guide infrastructure planning and disaster preparedness efforts. For instance, regions with high seasonal sea-level variability may need flexible or adaptive planning to address potential fluctuations.

12. Identification of "Sea Level Hotspots"

Use Case: Find regions with the most significant average sea level increases, highlighting at-risk areas.

Function: sea_level_hotspots()

Description: This function calculates the average change in sea levels for each region and identifies the top regions with the highest average increases.

Return Value: A Series of the top regions with the highest average sea level changes, ranked to show "hotspots."

13. Trend Reversal Detection

Use Case: Identify points where the trend in sea levels changes direction in a region.

Function: trend_reversal_detection(region)

Description: Analyzes changes in the direction of sea level data over time, detecting trend reversals.

The trend_reversal_detection function identifies reversals in the direction of sea level changes over time for a specified region. A trend reversal occurs when the direction of change switches, for instance, from rising sea levels to falling, or vice versa.

Trend reversals provide insight into the stability or volatility of sea levels in a region. A high number of reversals indicates that sea levels frequently change direction, while a low number of reversals suggests more consistent trends (either steadily rising, falling, or stable).

Return Value: A dictionary with the region and the number of trend reversals detected, revealing periods of directional change in sea levels.

Trend reversals may point to cyclical patterns where sea levels rise and fall periodically. For instance, if reversals happen frequently and correspond with specific times of the year, this could indicate a seasonal cycle.

An increase in trend reversals over time could signal environmental shifts or climate-related events. For example, rising variability with frequent trend reversals may suggest changing weather patterns or the impact of periodic climate phenomena (like El Niño and La Niña) on sea levels.

In coastal planning and risk management, knowing how frequently sea level trends reverse can inform predictive models and preparedness efforts. Regions with stable trends may require different approaches than those with frequent, unpredictable reversals.

This function identifies how often sea levels in a region change direction, providing insights into sea level stability, potential cyclic patterns, and environmental dynamics. It benefits climate research, coastal risk assessment, predictive modeling, and adaptation planning by helping determine whether sea level changes are stable or frequently shifting.

14. Acceleration Analysis

Use Case: Detect acceleration or deceleration in sea level changes.

Function: acceleration_analysis(region)

Description: Fits a quadratic model to determine whether sea-level changes are accelerating or decelerating.

Return Value: A dictionary with the region and the acceleration rate, with positive values indicating acceleration and negative values showing deceleration.

Identifying acceleration in sea level rise is crucial for understanding long-term trends. A positive acceleration value can be a warning sign of intensifying impacts, such as increased flooding risks, faster shoreline erosion, and more rapid loss of coastal habitats.

Sea level acceleration is often associated with climate change, specifically with factors like the melting of glaciers and polar ice and the thermal expansion of seawater. A positive acceleration in sea levels could be strong evidence of such climate impacts in the region.

The acceleration_analysis function assesses whether sea levels in a region are rising at an accelerating or decelerating rate, offering critical insights into long-term trends, climate impacts, risk assessment, and planning needs. Detecting acceleration in sea level change can inform predictive models, coastal defenses, and proactive adaptation strategies in response to climate-driven sea level changes.

15. Leading and Lagging Indicators

Use Case: Identify if one region's sea level changes lead or lag another's.

Function: leading_lagging_indicators(region1, region2)

Description: Uses cross-correlation to detect lead-lag relationships between two regions.

Return Value: The lag in days between the regions, with positive values indicating a lead-lag relationship.

A **positive lag** suggests that changes in region1 lead changes in region2. For example, if the lag is 2 months, this means that shifts in sea levels in region1 are reflected in region2 about 2 months later.

A **negative lag** implies that changes in region2 lead those in region1.

A **lag of zero** suggests that both regions' sea levels change in sync, with no detectable lead-lag relationship.

Understanding whether sea level changes in one region tend to lead or lag those in another can reveal interconnectedness or influence. For example, upstream river or ocean systems, currents, or atmospheric patterns could cause changes in one region to affect another after a certain period.

If one region's changes are known to lead another's, this insight can be used to predict sea level changes in the lagging region. For example, knowing that region1 consistently leads region2 by a few months can enable early warnings and better preparedness in region2.

The leading_lagging_indicators function identifies time-delayed relationships in sea level changes between regions, uncovering potentially synchronized patterns or cause-and-effect dynamics. This analysis aids in climate research, forecasting, coastal management, and environmental planning, enhancing understanding of regional dependencies and improving preparedness for sea level changes.

16. Forecasting with ARIMA

Use Case: Forecast future sea levels for a region.

Function: forecast_sea_level(region, periods=12)

Description: Uses ARIMA to generate sea level forecasts based on historical data.

Return Value: A Series of forecasted sea level values for the specified period, showing future sea level predictions.

The forecast_sea_level function provides sea level forecasts for a specified region using an ARIMA (AutoRegressive Integrated Moving Average) model. This approach uses historical data to predict future sea level changes, helping to estimate what sea levels might look like over a given number of periods.

17. Monthly vs. Annual Rate of Change

Use Case: Compare the volatility of monthly versus annual changes.

Function: monthly_vs_annual_fluctuations(region)

Description: Calculates and compares the standard deviation of monthly and annual changes in sea levels.

Monthly Fluctuations:

- **Low**: Less than **10 mm –** Indicates high stability, with minimal month-to-month variation. Typical for sheltered regions or areas with limited tidal influence.
- **Moderate**: Between **10 mm** and **30 mm –** Suggests moderate variability. It may reflect seasonal or minor tidal influences.
- **High**: Above **30 mm –** Indicates high variability, likely due to strong seasonal effects, tides, or weather patterns.

Annual Fluctuations:

- **Low**: Less than **20 mm (2 cm) –** Indicates stable sea levels year-to-year, common in regions with minimal climate-related fluctuations.
- **Moderate**: Between **20 mm** and **50 mm (2-5 cm) –** Suggests typical variability for many regions, accounting for mild seasonal or climatic changes.
- **High**: Above **50 mm (5 cm) –** Indicates significant year-to-year changes, potentially due to strong climate influences, seasonal patterns, or environmental events.

Return Value: A dictionary showing monthly and annual fluctuations.

The monthly_vs_annual_fluctuations function analyzes the variability in sea levels by comparing the standard deviation of monthly changes to that of annual changes within a specified region. Examining fluctuations over these two-time scales provides insight into short-term (monthly) versus long-term (annual) variability in sea levels.

18. Frequency and Duration of Extreme Events

Use Case: Identify how often extreme sea level events occur in a region and measure the duration of these events.

Function: extreme_event_frequency_duration(region, threshold=2.5)

Description: This function identifies extreme events by calculating Z-scores for each data point in the specified region. Events with Z-scores exceeding the threshold (default 2.5) are considered extreme. It counts the number of such events and computes the duration (in consecutive data points) of each event, revealing how long these extreme events persist.

A value of 25 means that there were 25 extreme events detected based on the Z-score threshold (2.5), where sea level measurements were significantly higher or lower than the average for the Adriatic Sea.

A maximum duration of 25 implies that one or more of these extreme events persisted for 25 consecutive data points

Return Value: A dictionary with the following keys:

- **"Frequency"**: The number of extreme events detected.
- **"Max Duration"**: The longest duration of consecutive extreme events.
- This information provides insight into the frequency and persistence of extreme sea level fluctuations, which can be critical for assessing environmental impact and risk.

19. Dominant Trends for Rising vs. Falling Sea Levels by Region

Use Case: Classify each region by its dominant sea level trend, identifying whether the region has a rising, falling, or stable sea level pattern.

Function: dominant_trends(region)

Description: This function uses linear regression on annual sea level averages to calculate the slope of change. Based on the slope, it categorizes the region's trend as "Rising" (positive slope), "Falling" (negative slope), or "Stable" (near-zero slope).

Return Value: A dictionary with:

- **"Region"**: The region analyzed.
- **"Trend"**: A classification of the trend as "Rising," "Falling," or "Stable." This helps identify regions most affected by increasing sea levels or regions experiencing a decrease.

20. Long-Term Stabilization Events

Use Case: Detect periods where sea levels remained within a specific range for a prolonged period, indicating stabilization.

Function: stabilization_events(region, threshold=5)

Description: This function uses a rolling window to calculate the range of sea levels over a set number of days. It identifies periods where the range remains below the threshold (default is five units), indicating stability.

Return Value: A data frame with dates and values during stabilization periods. This helps identify times of reduced fluctuation, which could indicate temporary equilibrium or stability in sea levels and helps understand natural buffering processes.

21. Seasonal vs. Non-Seasonal Variation Classification

Use Case: Classify regions based on whether their sea level variations are predominantly seasonal or non-seasonal.

Function: seasonal_vs_non_seasonal_variation(region)

Description: The function applies seasonal decomposition to the time series data for a region and calculates the ratio of variance explained by the seasonal component relative to total variance. A high seasonal component ratio indicates predominantly seasonal variation.

The seasonal_vs_non_seasonal_variation function analyzes the strength of seasonal patterns in sea level data for a specified region. By applying seasonal decomposition to the time series and calculating the proportion of total variance explained by the seasonal component, this function helps determine whether sea level changes in the region are primarily driven by seasonal factors (like recurring monthly or annual cycles) or non-seasonal factors (such as long-term trends or irregular variations).

Return Value: A dictionary with:

- **"Region"**: The region analyzed.
- **"Seasonal Variation"**: Classification as either "Seasonal" or "Non-Seasonal" based on the dominance of seasonal variation. This categorization aids in understanding which regions are primarily driven by seasonal cycles versus those with more irregular or trend-driven fluctuations.

22. Peak-to-Trough Analysis

Use Case: Measure the range between the highest and lowest sea levels within each specified period (e.g., annually or monthly) to assess fluctuation magnitudes.

Function: peak_to_trough_analysis(region, period="YE")

Description: The function resamples sea level data by the specified period (yearly or monthly) and calculates the difference between maximum and minimum values within each period.

Return Value: A dictionary where each key is a period (e.g., "2024-12-31" for yearly), and each value is the peak-to-trough range within that period. This range provides a measure of fluctuation intensity over the period, helping to understand how drastically sea levels change within a specific timeframe.

The peak-to-trough analysis results for the Adriatic Sea provide insights into the annual range of sea level fluctuations over multiple years. Each value represents the difference between the maximum and minimum sea levels within each year, highlighting how much sea levels vary from their highest to lowest points annually.