

# Influence of Solar Activity on Earth's Climate

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# Research Question

Is there any relationship between solar activity (Solar Flares) and climate change on Earth?



# Introduction

## Importance of Study

- Understanding the influence of solar activity on Earth's climate is important for predicting weather patterns and long-term climate change.
- Solar activity, including phenomena like solar flares, can impact Earth's atmosphere, potentially affecting temperature and atmospheric composition

## Objectives

- Assess whether there is a relationship between solar activity (specifically solar flares) and changes in Earth's climate, focusing on temperature and CO2 concentration.
- Utilize statistical methods to analyze the significance of solar flare data in relation to climate variables.
- Use advanced data engineering methods to Extract, Transform, and Load the data for analysis.

# Data Used



**Solar Flare Data**



**CO2 Concentration  
Data**



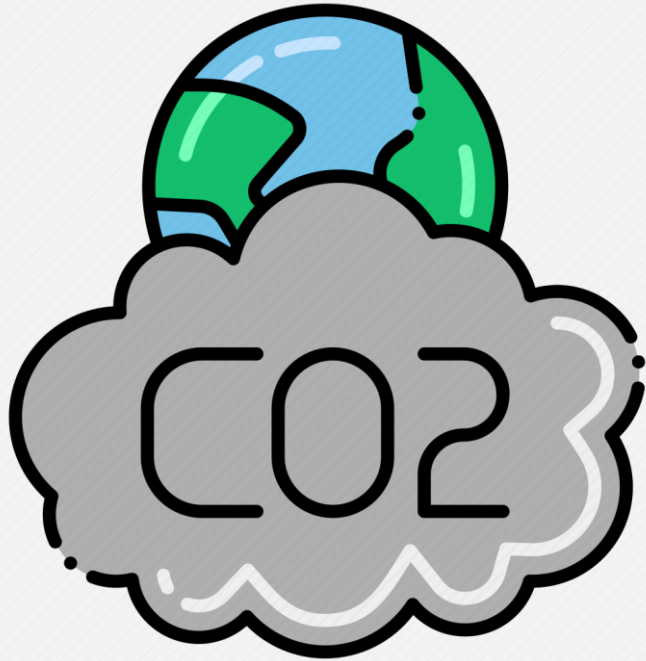
**Temperature Change  
Data**



# Data Used

- **Solar Flare Data**
  - **Source:** Zenodo
  - **Used features:** Date, FlareNumber, TOTUSJH, TOTBSQ, TOTPOT, TOTUSJZ, ABSNJZH, SAVNCPP, USFLUX
  - **Description:** Comprising 8,874 records spanning from May 2010 to December 2019, provides crucial insights derived from vector magnetic field data.
  - **Data Structure and Quality:** Tabular format (CSV), sourced from reliable JSOC and SWPC
  - **Licensing:** MIT License

# Data Used



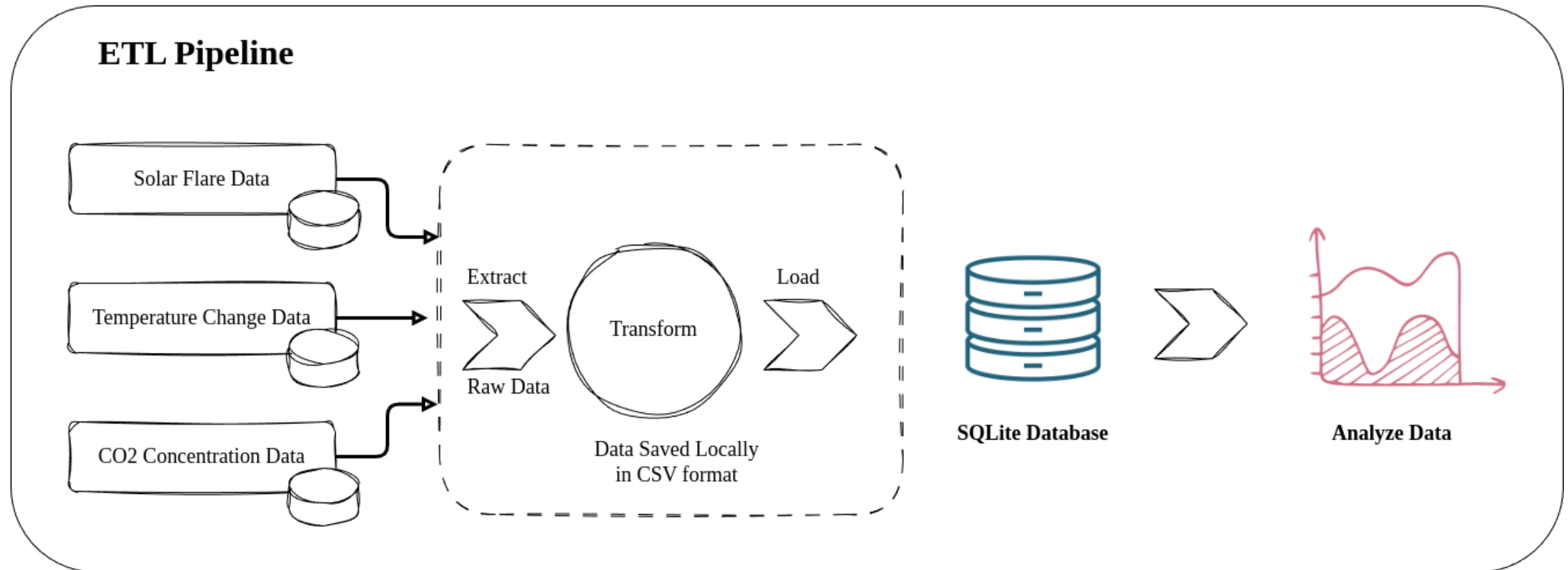
- **CO2 Concentration Data**
  - **Source:** Atmospheric CO2 Concentrations from IMF
  - **Used features:** Date, CO2\_Concentration\_PPM
  - **Description:** The Atmospheric CO2 dataset offers monthly and yearly records of carbon dioxide levels in the air dating back to 1958, enabling users to track changes over time.
  - **Data Structure and Quality:** Tabular format (CSV), sourced from FAOSTAT
  - **Licensing:** IMF License

# Data Used



- **Temperature Change Data**
  - **Source:** Annual Surface Temperature Change from IMF
  - **Used features:** Date, Temp\_Change
  - **Description:** Shows how Earth's average surface temperature has changed from 1961 to 2021 compared to temperatures between 1951 and 1980, using data from NASA GISS
  - **Data Structure and Quality:** Tabular format (CSV), sourced from reliable JSOC and SWPC
  - **Licensing:** IMF License

# Data Pipeline (ETL)





# Project Structure

```
project
├── ETL
│   ├── __init__.py
│   ├── extract
│   │   ├── __init__.py
│   │   ├── csv_extractor.py
│   │   └── extractor.py
│   ├── load
│   │   ├── __init__.py
│   │   ├── loader.py
│   │   └── sqlite_loader.py
│   └── transform
│       ├── __init__.py
│       ├── co2_concentration_data_transformer.py
│       ├── solar_flare_data_transformer.py
│       ├── temperature_data_transformer.py
│       └── transformer.py
├── config
│   └── pipeline_config.yaml
├── data
│   ├── raw
│   ├── sink
│   └── transformed
├── logger
│   ├── __init__.py
│   ├── base_logger.py
│   ├── console_logger.py
│   ├── file_logger.py
│   └── logger.py
├── logs
│   └── 20240701_043653.log
```

```
├── logs
│   └── 20240701_043653.log
├── tasks
│   ├── __init__.py
│   └── task.py
├── tests
│   ├── __init__.py
│   ├── mock
│   │   ├── __init__.py
│   │   ├── data
│   │   │   ├── __init__.py
│   │   │   ├── raw
│   │   │   ├── sink
│   │   │   ├── co2_concentration_mock_data.py
│   │   │   ├── solar_flare_mock_data.py
│   │   │   └── temperature_change_mock_data.py
│   │   └── transformed
│   │       └── mock_logger.py
│   ├── test_system.py
│   └── test_transform.py
├── utils
│   ├── __init__.py
│   ├── config.py
│   └── converters.py
├── pipeline.py
├── tests.py
└── requirements.txt
```

# Test Automation with GitHub actions

night-fury-me / Methods-of-Advanced-Data-Engineering

Code Issues Pull requests Actions Projects Security Insights Settings

**Actions** New workflow

All workflows

Exercise Feedback

**Project CI**

Management

Caches

Attestations

Runners

**Project CI** project-ci.yml

37 workflow runs

Filter workflow runs

Event	Status	Branch	Actor
✓	Removed intentional bug.	main	15 minutes ago ...
	Project CI #37: Commit <a href="#">62163af</a> pushed by night-fury-me		27s
✗	Added a minor fix in the test.py class t...	main	16 minutes ago ...
	Project CI #36: Commit <a href="#">2c98e94</a> pushed by night-fury-me		28s
✓	Added intentional test fail case to chec...	main	23 minutes ago ...
	Project CI #35: Commit <a href="#">c868df4</a> pushed by night-fury-me		30s
✓	Fixed minor bug in project-ci.yml fie	main	26 minutes ago ...
	Project CI #34: Commit <a href="#">a9cb970</a> pushed by night-fury-me		30s
✗	Updated readme.md for testing slack ...	main	29 minutes ago ...
	Project CI #33: Commit <a href="#">72a62ec</a> pushed by night-fury-me		Startup failure

# Test Automation with GitHub actions

The screenshot shows a Slack workspace for 'night-fury'. The left sidebar contains navigation options: Home, DMs, Activity, and More. The main panel displays the '#made-ci-cd' channel. At the top of the channel, there is a search bar and a 'Canvas' button. Below the channel name, there is a section for 'Channels' with options like '# general', '# made-ci-cd', and '# random'. There is also a section for 'Direct messages' and 'Apps' with a user 'Redwanul Karim' and the 'made-ci-cd' app. The main message area shows three messages from the 'made-ci-cd' app, each titled 'Test result of repo night-fury-me/Methods-of-Advanced-Data-Engineering'. The first two messages indicate 'Tests passed!' and provide a link to a GitHub Actions run. The third message indicates 'Tests failed!' and provides a link to a GitHub Actions run. The bottom of the screen shows a message input area with a text box and various formatting and action buttons.

night-fury

Upgrade subscription

Channels

- # general
- # made-ci-cd
- # random
- + Add channels

Direct messages

- Redwanul Karim you
- + Add colleagues

Apps

- made-ci-cd
- + Add apps

# made-ci-cd

+ Add a bookmark

Today

made-ci-cd APP 18:36

**Test result of repo night-fury-me/Methods-of-Advanced-Data-Engineering**

Tests passed!

Please check the details at <https://github.com/night-fury-me/Methods-of-Advanced-Data-Engineering/actions/runs/9860859590>

**Test result of repo night-fury-me/Methods-of-Advanced-Data-Engineering**

Tests passed!

Please check the details at <https://github.com/night-fury-me/Methods-of-Advanced-Data-Engineering/actions/runs/9860908679>

made-ci-cd APP 18:45

**Test result of repo night-fury-me/Methods-of-Advanced-Data-Engineering**

Tests failed!

Please check the details at <https://github.com/night-fury-me/Methods-of-Advanced-Data-Engineering/actions/runs/9860991039>

**Test result of repo night-fury-me/Methods-of-Advanced-Data-Engineering**

Tests passed!

Please check the details at <https://github.com/night-fury-me/Methods-of-Advanced-Data-Engineering/actions/runs/9861012341>

B I S | | | | | | | |

Message #made-ci-cd

+ Aa ☺ @ | | | |

# Methodology



Determining the common time window of the datasets

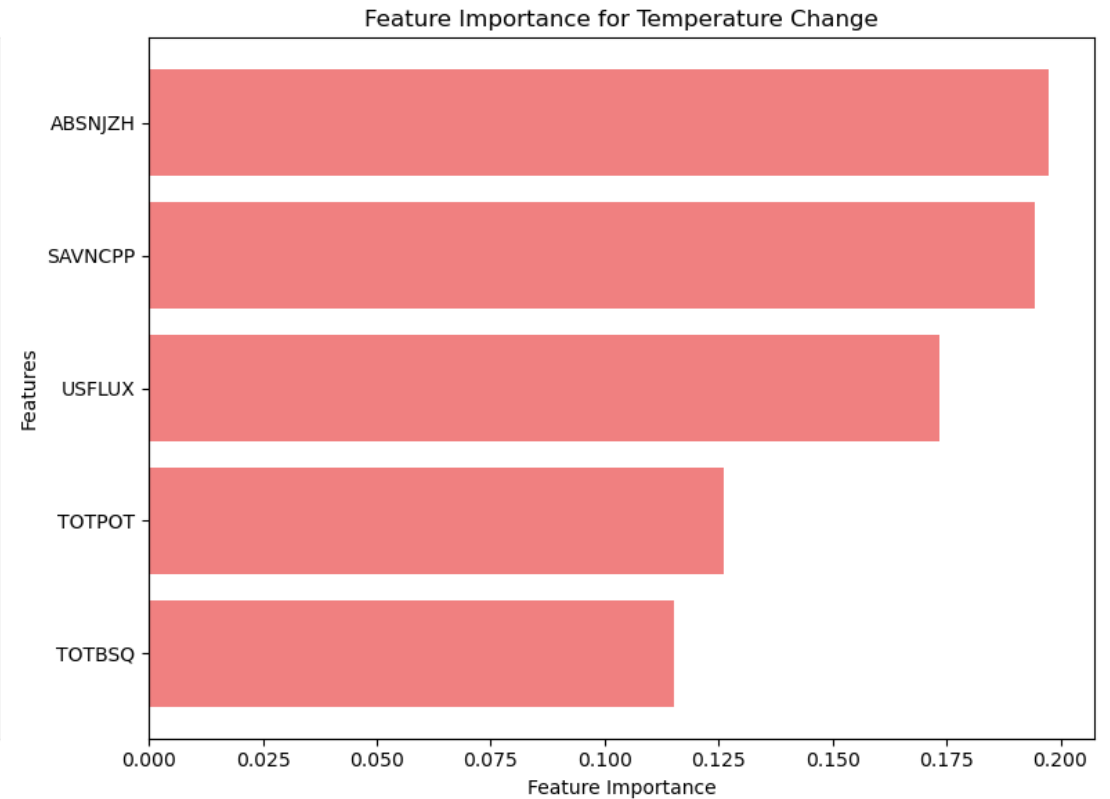
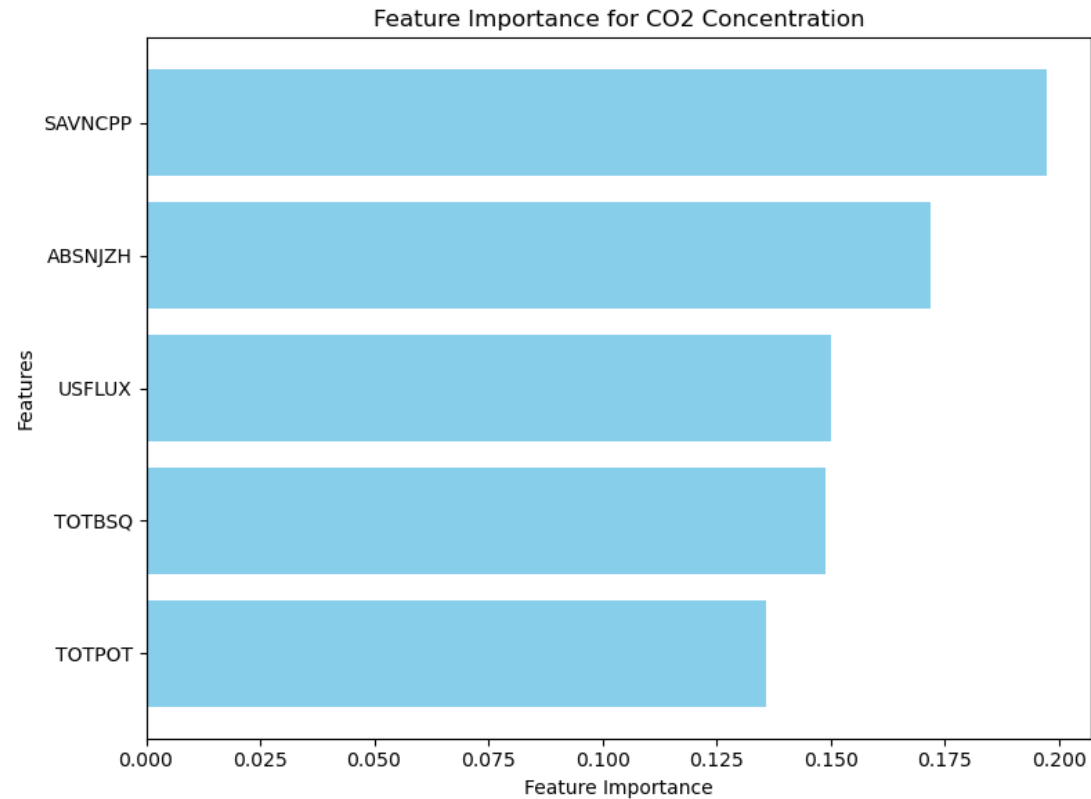


Calculate Feature Importance using Random Forest Regressor



Perform hypothesis testing using t-tests

# Feature Importance

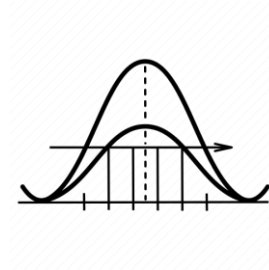


# Results

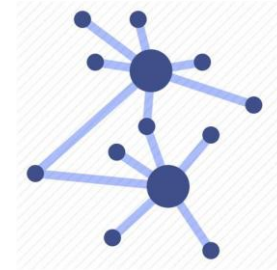
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Statistically significant p-values for both CO<sub>2</sub> concentration and temperature change suggest a potential relationship between solar flare events and climate variables on Earth.



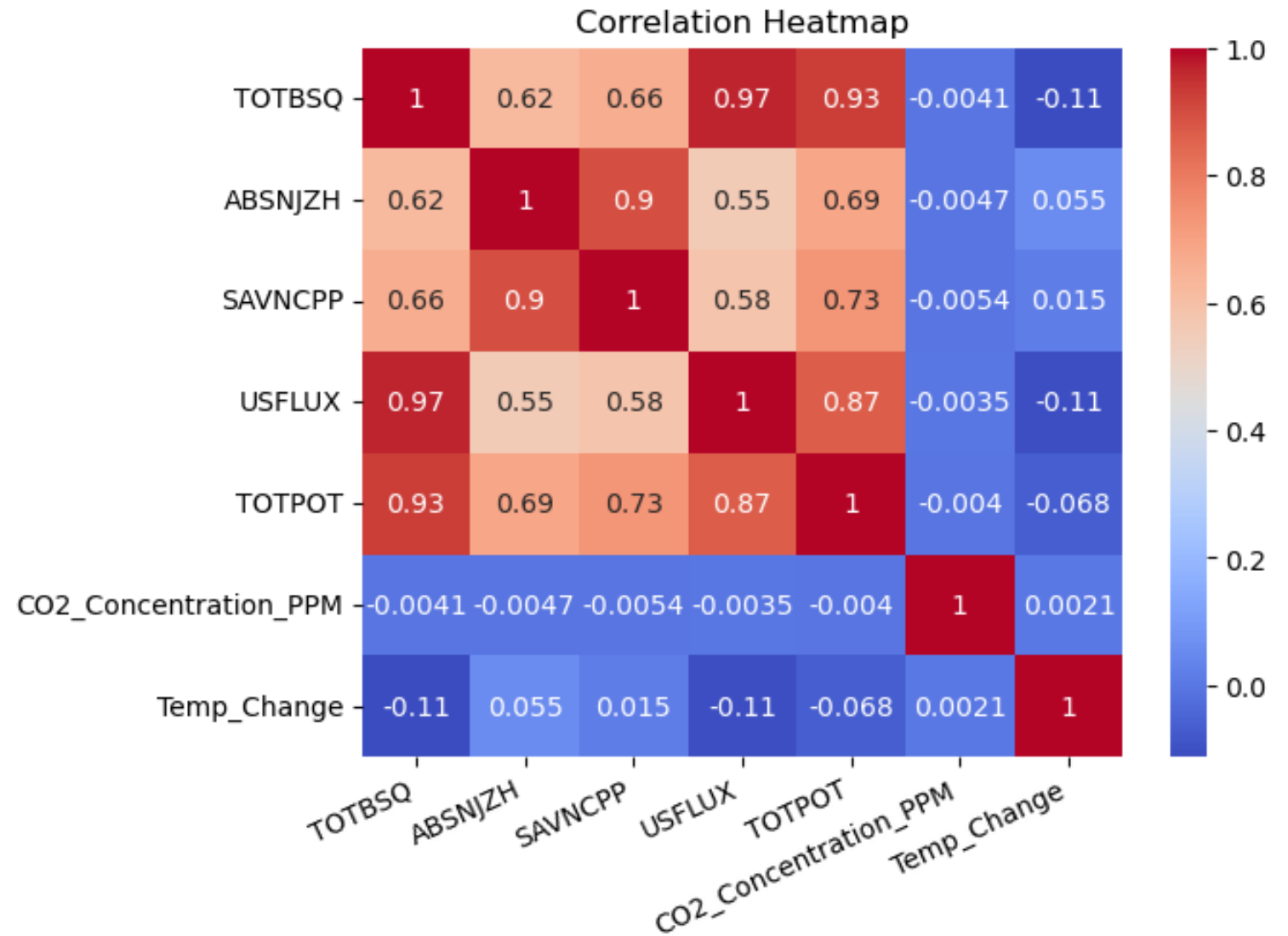
However, none of the datasets are normally distributed, indicating violations of the underlying assumptions of normality.



Also, the issue of autocorrelation among data points violates the assumption of homogeneity of variance, raising concerns about the reliability of our hypothesis test results.

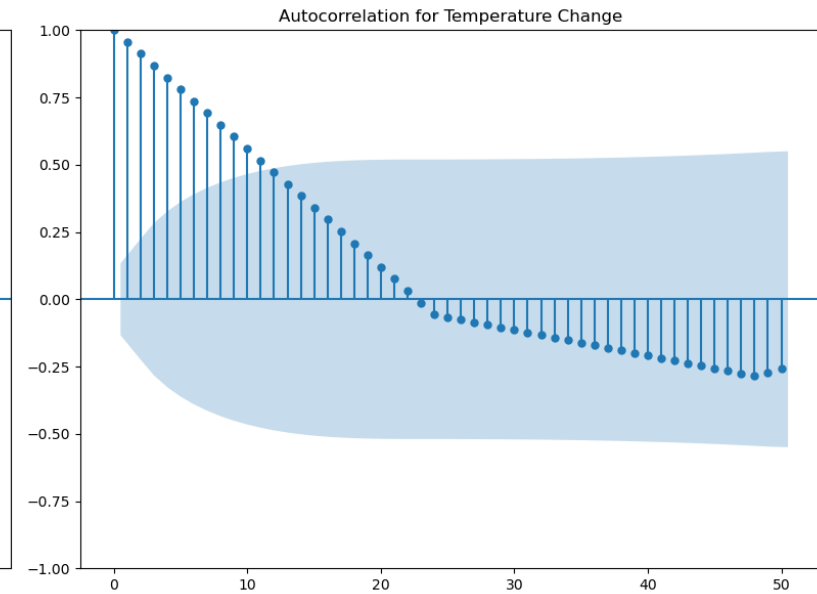
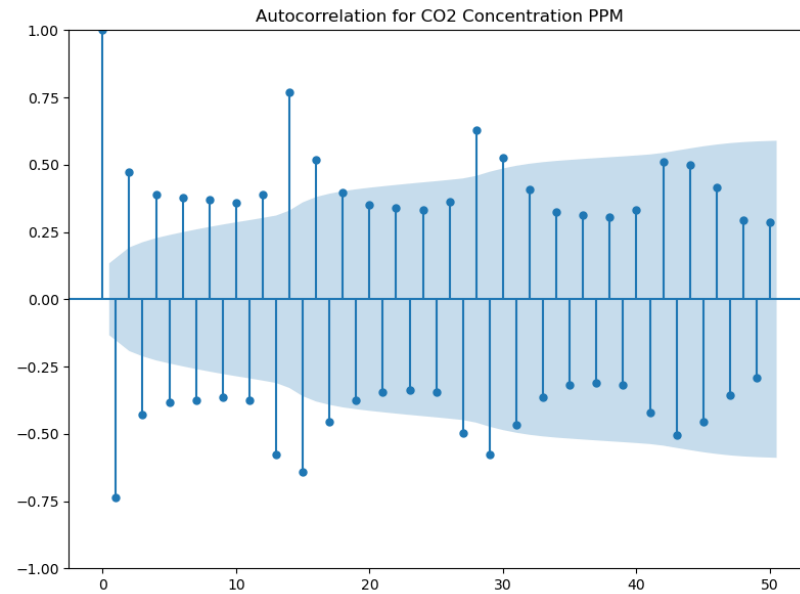
# Results: Correlation Coefficient Heatmap

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# Results: Auto correlations

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# Limitations and Future Direction



This study relies on publicly available datasets, which may have inherent biases or limitations in data quality and completeness.



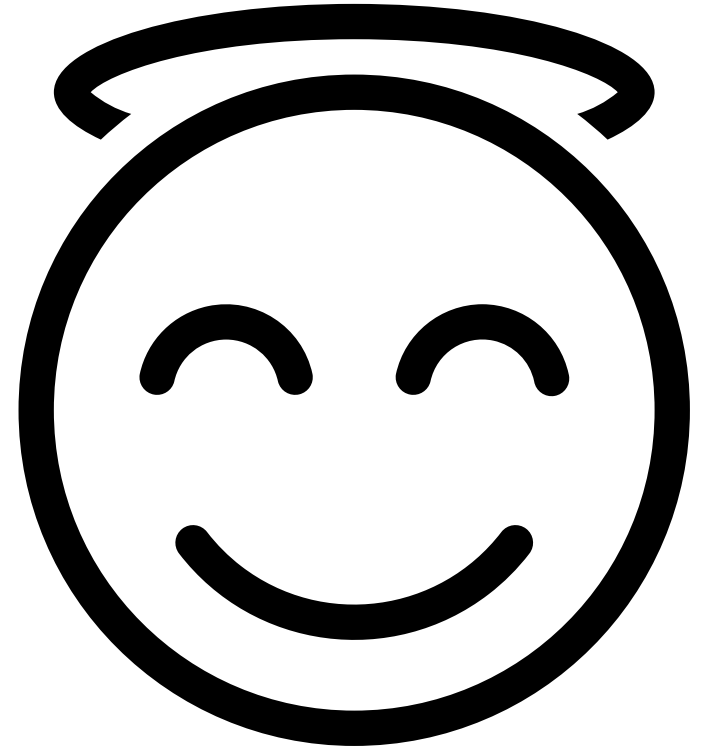
The use of traditional statistical tests assumes linear relationships and strict adherence to assumptions like normality, which may not fully capture complex interactions in climate and solar data.



Employ advanced machine learning techniques that can handle non-linear relationships and complex data interactions to refine our understanding of the relationship between solar activity and climate change.

Thank you for your  
attention!

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# Reference

- Solar Flare Data by Zenodo  
<https://zenodo.org/records/4603412>
- Temperature Change Data by IMF  
<https://climatedata.imf.org/datasets/4063314923d74187be9596f10d034914/explore>
- CO2 Concentration Data by IMF  
<https://climatedata.imf.org/datasets/9c3764c0efcc4c71934ab3988f219e0e/explore>