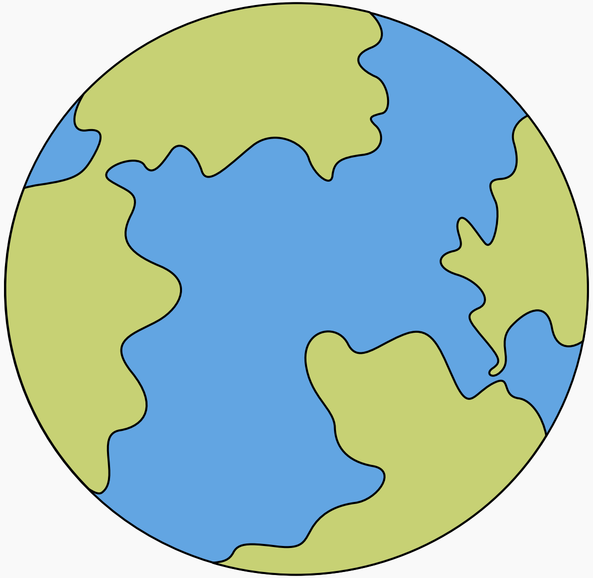

EMP Resilience and Prediction Initiative:

MISSA Data Analytics Team

Our Team

Nathan Leung

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Richwei Chea

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01 Background & Intro

Background

EMP Threat

EMPs pose a risk to electrical grids, as they can induce currents in power lines, potentially **damaging transformers** and causing **widespread power outages**. The initial damage can lead to cascading failures across multiple critical infrastructure sectors, expanding beyond the initial area to affect millions of households and businesses.

What are EMPs?

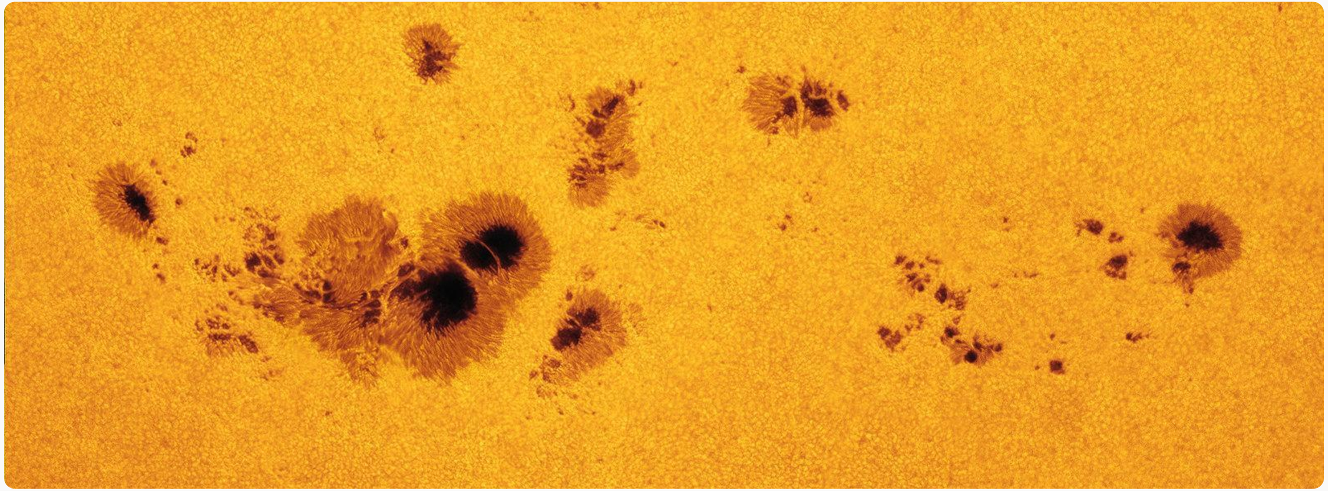
1. Brief burst of electromagnetic energy
2. Short circuits wide range of electronic equipment
3. EMPS can be artificial or natural
4. Reach earth fairly quickly (4 hours - 15 days)

EMP Effects

Cripples wiring and circuitry

Permanent loss of data

Costly Extensive Damage



02 Research Question & Objectives

Research Question

How can correlating EMPs with environmental and solar phenomena enhance SoCal Edison's preparedness for potential disruptions?

Research Objectives

01 To identify patterns between EMP events and specific environmental conditions or solar activities

02 To explore predictive measures that can be derived from these correlations

03 To recommend strategies for improving EMP resilience based on the analysis

Data Source

Our data compilation includes information sourced from various **scientific institutions** and **national databases**, covering diverse domains such as sunspot numbers, historical drought conditions, and earthquake occurrences spanning different time periods.

Main Variables

- Sunspots
- 6.0+ Magnitude
- Total Earthquake
- Solar Flare Value
- Climate Change
- Fracking
- Droughts
- Power Outages

Differences between Earthquake Data?

Old Earthquake Data

- Earthquake data of magnitude 6 and above
- Only went up to the year 2014

Total Earthquake Data

- Earthquake data of all magnitudes
- Went up until 2023

Data Cleaning

	A	B	C	D	E	F	G	H
1	Year	Month	OutagesCount	Total Daily Sunspots	Northern Total Daily Sunspots	Southern Total Daily Sunspot	Earthquakes	Magnitude
98	2000	1	-0.8067081867	1.076998656	0.7748322918	1.211398047	0.5350732407	-0.778159001
99	2000	2	0	1.457998978	0.7117958947	1.969653472	-0.7525036835	-1.045695979
100	2000	3	-0.8067081867	2.551548575	1.649987604	3.051554504	-1.074397915	1.665345396
101	2000	4	-0.8067081867	1.986791461	1.684657622	1.985065167	-1.074397915	-0.903009591
102	2000	5	-0.2492269195	1.648499139	1.670999736	1.379899253	-0.4306094525	0.495317013
103	2000	6	-0.6952119333	1.928348933	2.779389718	0.807611622	1.98359728	0.478194646
104	2000	7	-0.9182044402	3.014593214	3.237454203	2.345698845	0.0522318941	-0.492511828
105	2000	8	-0.4722194264	1.901937407	2.185796979	1.339828844	0.3741261251	0.466779735
106	2000	9	0	1.388879451	1.625823652	0.9493992217	-0.4306094525	-1.730590642
107	2000	10	0	1.224790817	0.8179071631	1.439491142	0.5350732407	-0.296592441
108	2000	11	0	1.423720188	1.828590729	0.8148037467	1.500755934	1.36700113
109	2000	12	-1.029700694	1.254574028	1.684657622	0.6463025412	0.2131790096	-0.495334196
110	2001	1	-0.9182044402	1.242773133	1.551230582	0.7552118569	0.5350732407	2.127292578
111	2001	2	0	0.6695868074	0.7569719793	0.483966014	0.5350732407	0.077959328
112	2001	3	-0.4722194264	1.646813297	1.613216373	1.433326464	-0.7525036835	-1.366740353
113	2001	4	0	1.484410505	1.429360214	1.316197577	-0.269662337	-0.461978937
114	2001	5	-0.8067081867	1.233781975	1.903183799	0.3945781794	-0.591556568	-0.712761073
115	2001	6	-0.8067081867	2.179539411	3.156557494	0.898026903	0.2131790096	0.177330205
116	2001	7	0	0.9005471797	0.906158119	0.7603490888	-0.269662337	0.658757785
117	2001	8	-1.029700694	1.572074296	1.415702328	1.489836015	-0.9134507991	0.360784133
118	2001	9	0	2.773517789	2.338134939	2.784418447	-0.591556568	-1.283506626
119	2001	10	0	2.1390792	2.23517549	1.725121235	-0.1087152214	0.880570261
120	2001	11	0	1.735039035	1.846451042	1.36654245	0.0522318941	-0.683492071
121	2001	12	0	2.476247627	2.175290913	2.400153503	-0.1087152214	-0.18957765

1. Merged datasets together within to allow for analysis and visualizing
2. Transformed Dataset to have every month for every year in our dataset
3. Normalized variables to a common scale using Z-score transformation

Data Analysis

Implemented ML models with Python to find predictive patterns with variables and find metrics such as R-squared, P-value, Correlation Coefficients between data

Analyzed visualizations created in Tableau and Python to draw conclusions about correlations

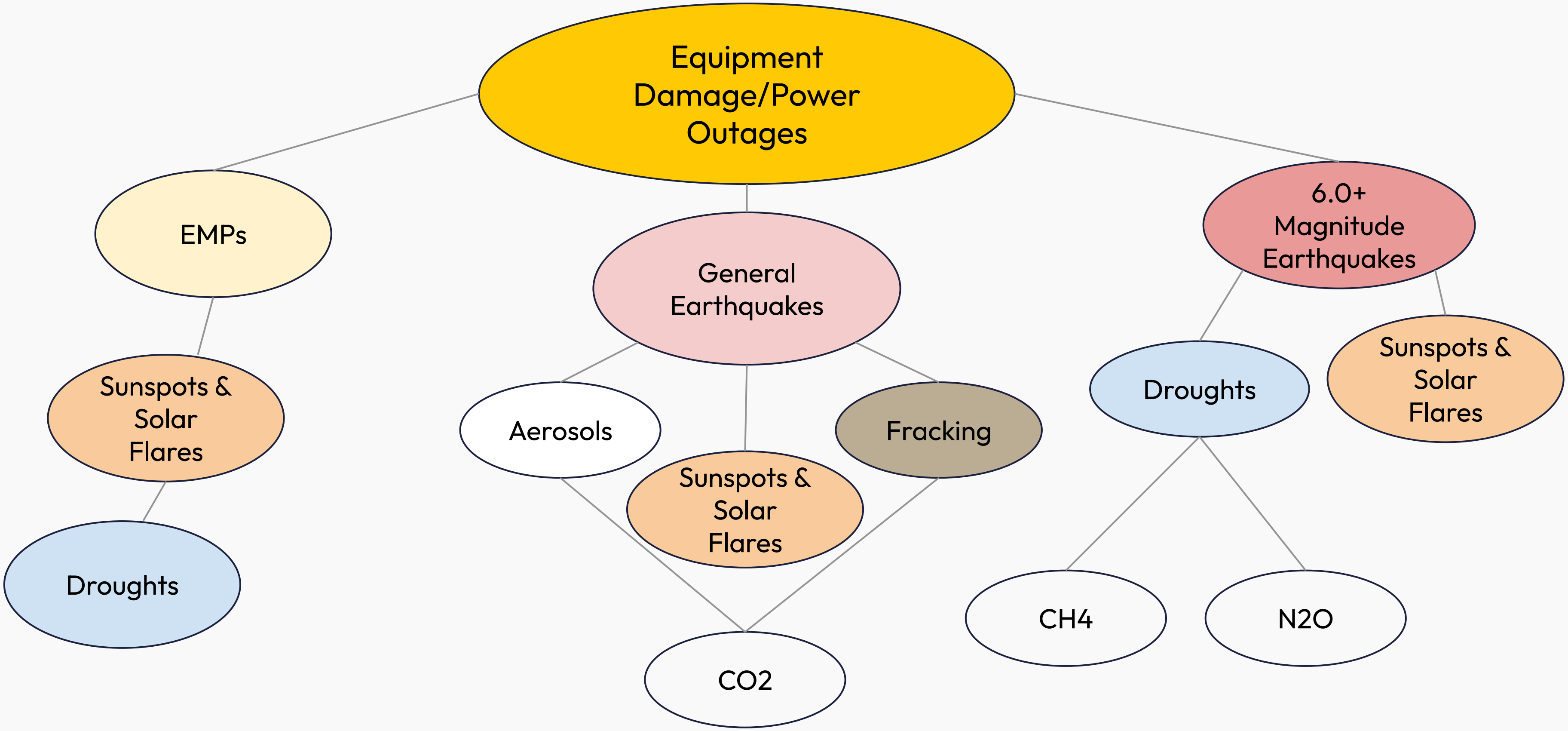
Compared attributes of different variables contributing to equipment destruction

Data Visualization

Utilized Tableau and Python libraries to craft compelling visual representations.
Produced visualizations derived from in-depth analysis and exploration
Visualized Correlations to identify key outcomes and trends
Generated conclusions and useful insights based on visual representations

03 Research & Analysis

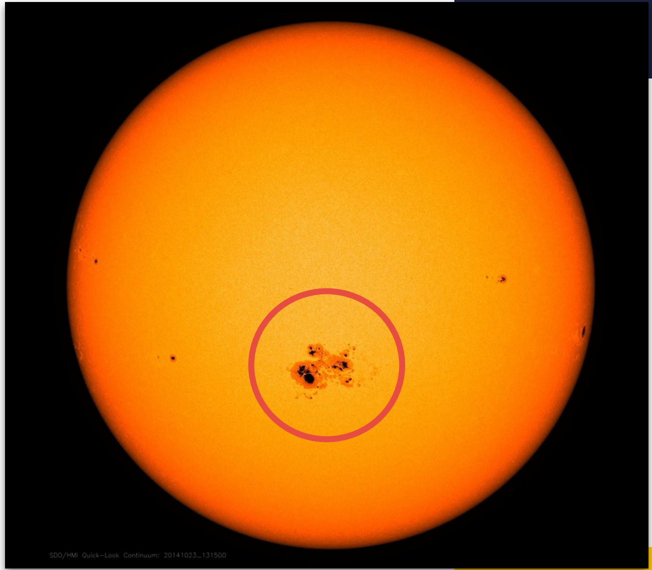
Correlation Research Diagram



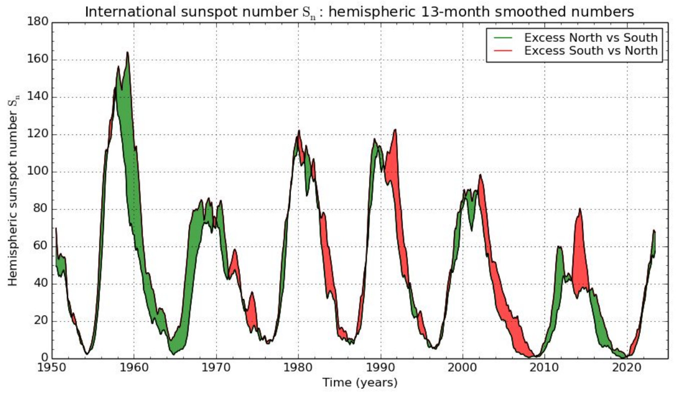
Sunspots

What are Sunspots?

Sunspots are darker regions of the Sun that are much cooler than the regions nearby. They are caused by large concentrations of strong magnetic fields pushing energy away from those spots.



Daily Sunspots



Mean

Total	North	South
65.470	31.620	33.985

Median

Total: 49
North: 20
South: 23

Standard Deviation

Total: 61.968
North: 35.643
South: 36.970

Minimum

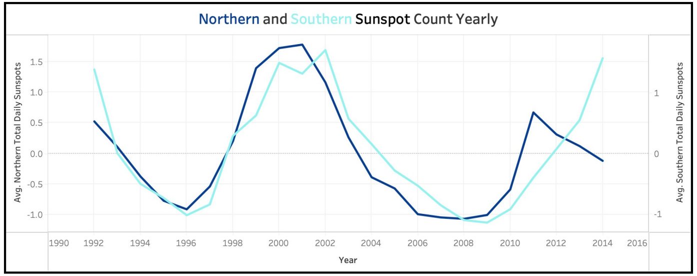
Total: 0
North: 0
South: 0

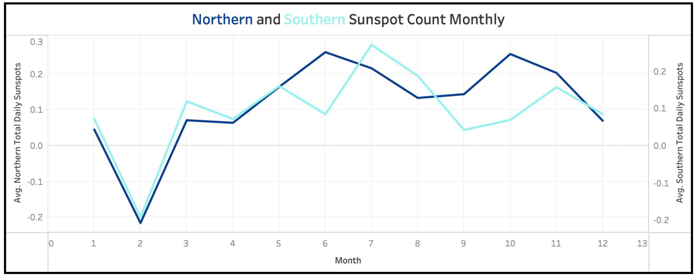
Maximum

Total: 353
North: 259
South: 245

Solar Cycle

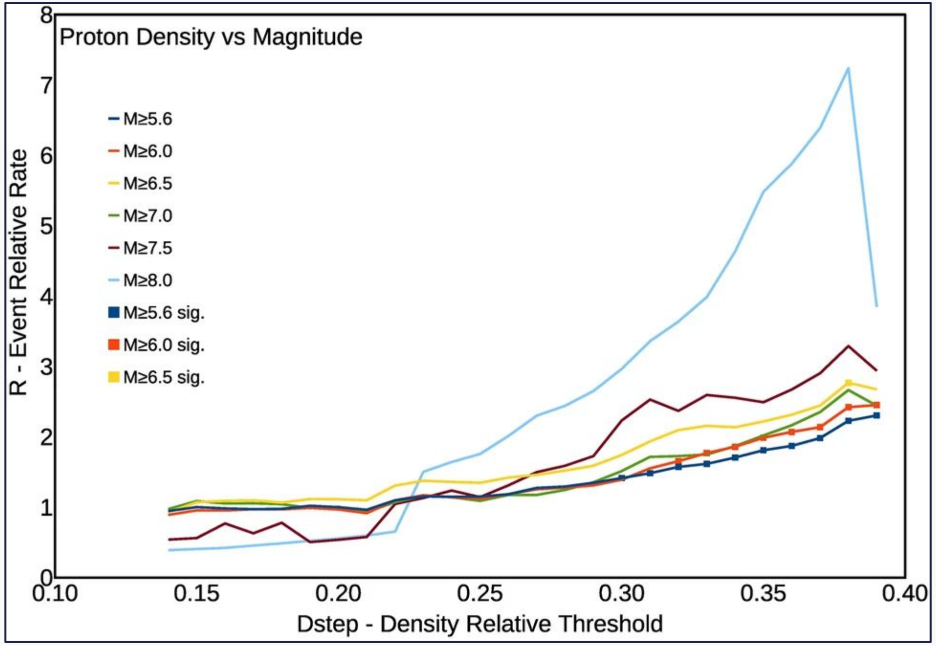
The **solar cycle**, an approximately 11-year cycle of solar activity, causes changes in the number of sunspots and other solar phenomena. It includes periods of increased activity **(solar maximum)** and decreased activity **(solar minimum)** driven by the Sun's magnetic dynamo process. This cycle affects space weather and can impact Earth's atmosphere and technological systems.





Earthquakes and Sunspots

As proton density in the magnetosphere rises, so does the frequency and intensity of seismic activity across all magnitudes



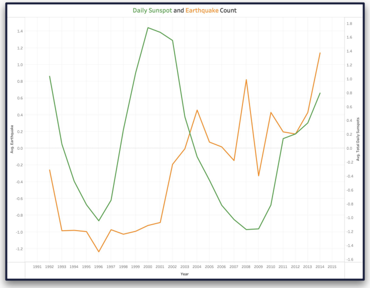
MLR

MLR performs better for 6+ Magnitude Data

Predictors

Total Earthquakes
Year

→ **Adjusted R Square :** 0.203



6 + Magnitude Earthquakes
Year

→ **Adjusted R Square :** 0.406

Solar Flares & Geomagnetic Storms

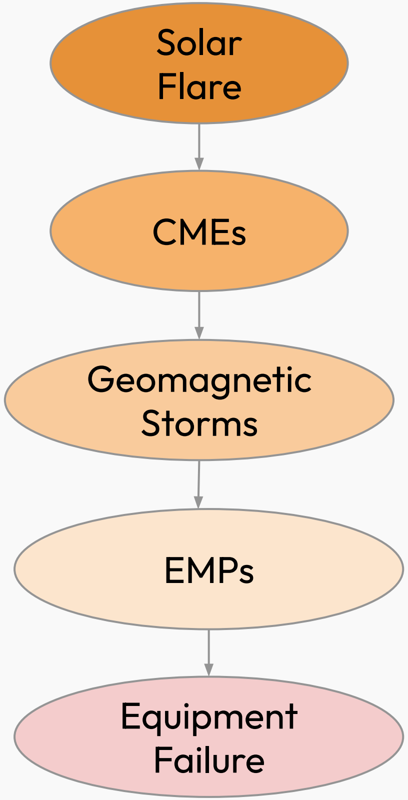
Why Solar Flare Values?

Utilizing solar flare value to investigate potential correlations with EMP occurrences helps to explore the impact of solar activity on Earth's electromagnetic environment, offering insights into predicting disruptive electromagnetic phenomena.

Can Solar Flares Cause EMPs?

Solar flares, which are intense radiation bursts from sunspot-associated magnetic energy, can lead to coronal mass ejections (CMEs) - massive releases of solar wind and magnetic fields into space

When CMEs reach Earth, they interact with the magnetosphere, potentially causing geomagnetic storms by transferring solar wind energy into Earth's space environment, altering its magnetic currents and fields, and potentially inducing EMP-like effects on electrical systems.



Solar Flare Data Source

- **Solar H-alpha Kandilli Flare Index** Flare index data compiled from the **Kandilli Solar Observatory**. This dataset was prepared by the Kandilli Observatory and Earthquake Research Institute at the Bogazici University, and made available through the NOAA National Geophysical Data Center (NGDC).

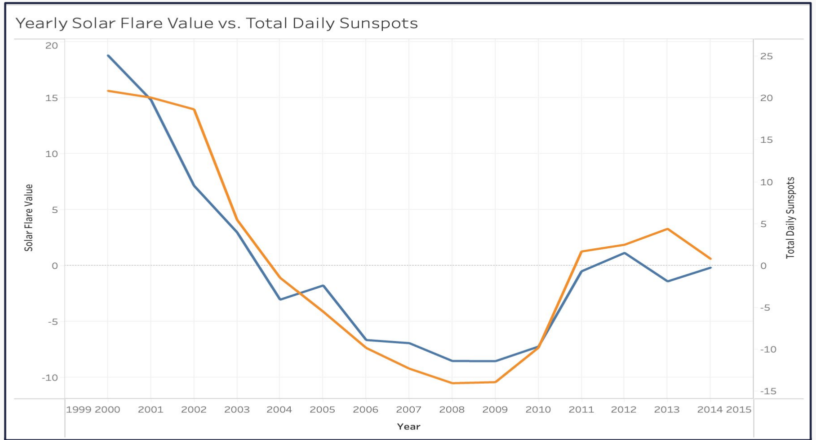
- The Value measured is the intensity of the solar flare, measures total energy emitted by solar flare.

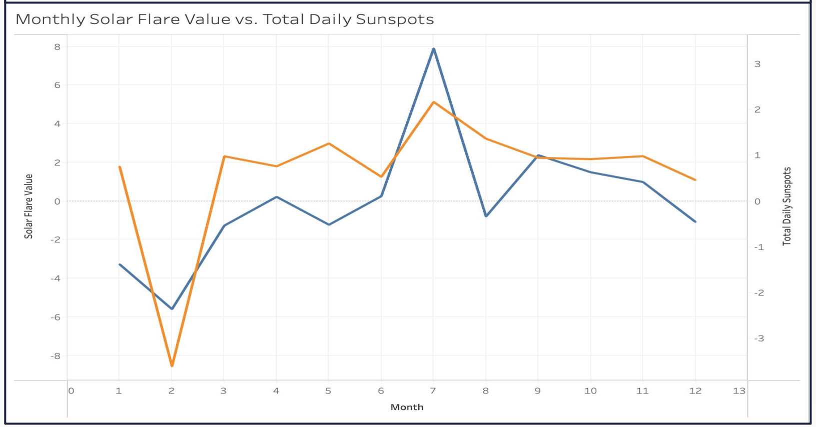
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.17	0.19	2.82	16.44	2.27	9.20	2.92	0.48	2.12	15.14	1.98	2.67
2	0.39	0.09	14.67	7.66	2.35	29.57	4.71	2.23	4.77	9.16	0.72	1.07
3	1.03	0.78	13.37	5.12	0.00	18.87	1.37	1.27	3.91	2.38	8.33	0.64
4	0.62	4.92	2.29	25.45	5.06	8.04	9.44	2.55	9.46	1.88	1.78	0.49
5	0.00	11.58	6.78	3.62	1.54	10.12	1.19	0.89	1.00	3.16	3.95	0.40

Correlation Analysis

Feature	Correlation Coefficient
Total Daily Sunspots	0.743
Magnitude	0.226
Year	-0.438
Earthquakes	-0.365
6+ Magnitude Earthquakes	-0.065

Solar Flares x Total Daily Sunspots





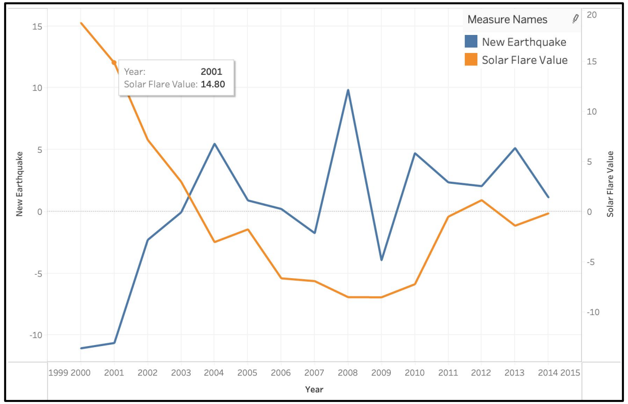
- **Direct Solar Activity Link:** Demonstrates the intrinsic connection between sunspots and solar flares as indicators of solar magnetic activity.
- **Predictive Value for Space Weather:** Crucial for forecasting geomagnetic storms that affect Earth's technological systems.
- **Risk Assessment for Space Missions:** Vital for evaluating solar radiation risks, particularly for manned space missions beyond Earth's protective magnetosphere.
- **Solar Cycle:** Follows same yearly solar cycle just like sunspots

Solar Flares x Earthquakes

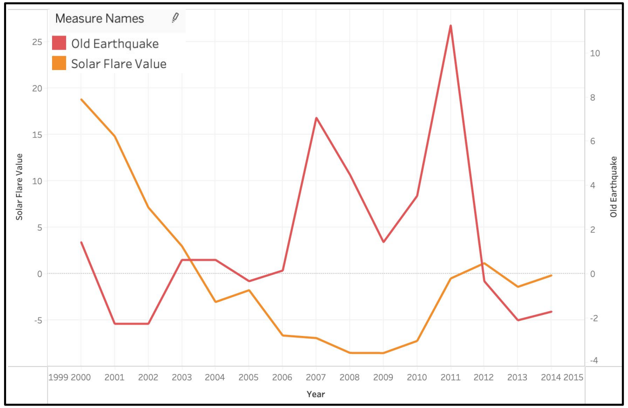
- **What we know now:**
  - The hypothesis that solar flares directly influence earthquake activity remains speculative and is **a topic of ongoing research.**

- **What is the difference from sunspots vs. earthquakes?**
  - Analyzing sunspots in relation to earthquakes focuses on broader, cyclical patterns of solar activity, whereas analyzing solar flare values **targets specific incidents and their immediate aftermath**, offering a different perspective on solar-terrestrial interactions.

Total Earthquakes



6.0+ Earthquakes



Multiple Linear Regression

Predictors

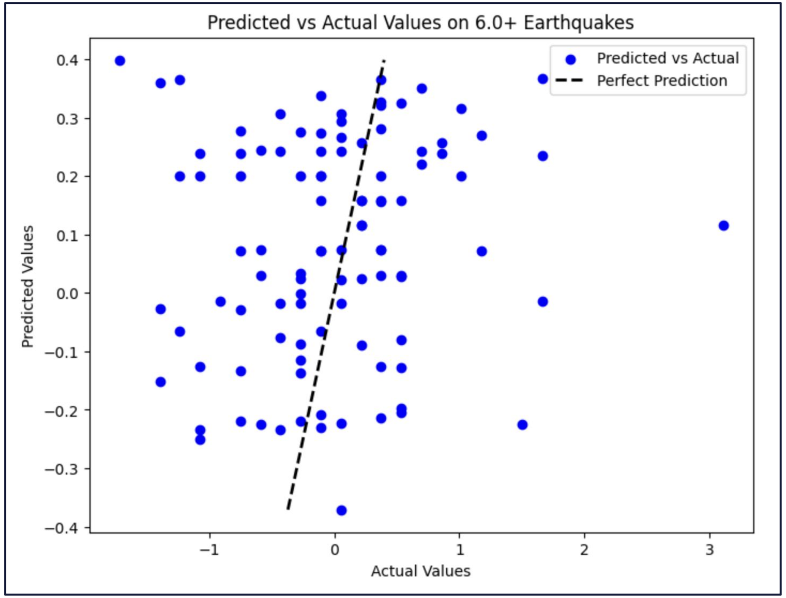
6+ Magnitude Earthquakes
Year

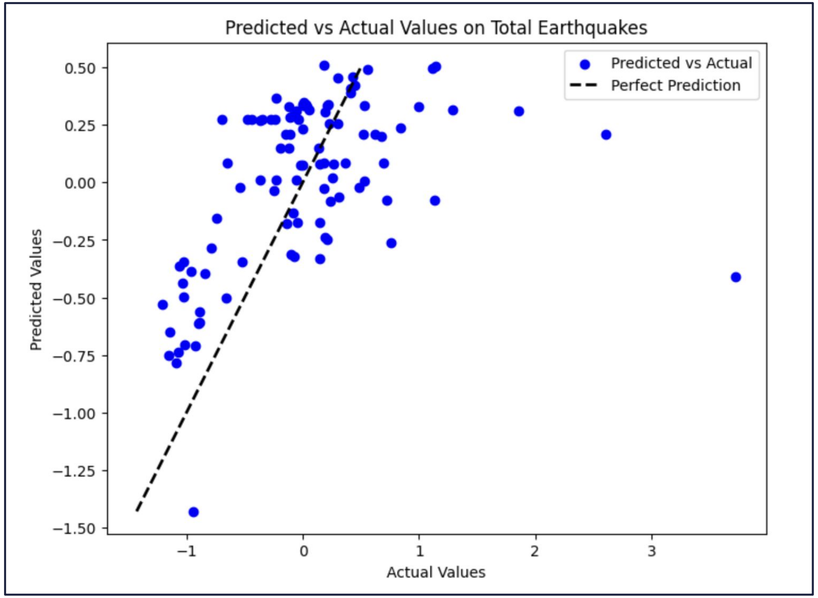
Adjusted R Square : 0.004
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 1.2033
Mean Absolute Error (MAE) : 0.6619

Total Earthquakes
Year

Adjusted R Square : 0.220
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.6674
Mean Absolute Error (MAE) : 0.4448

Predicted vs Actual Values





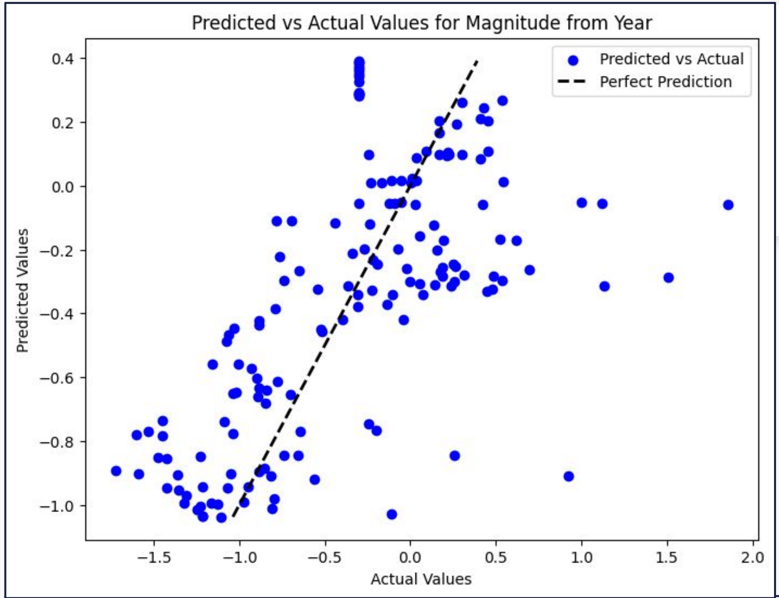
	coef	std err	t	P>|t|	[0.025	0.975]
const	-31.3982	46.700	-0.672	0.502	-123.601	60.804
Solar Flare Value	-0.0453	0.094	-0.480	0.632	-0.232	0.141
Year	0.0157	0.023	0.675	0.501	-0.030	0.062

	coef	std err	t	P>|t|	[0.025	0.975]
const	-113.2654	28.765	-3.938	0.000	-170.058	-56.473
Solar Flare Value	-0.1749	0.058	-3.005	0.003	-0.290	-0.060
Year	0.0565	0.014	3.938	0.000	0.028	0.085

Adjusted R Square : 0.004

Adjusted R Square : 0.22

Lag by 24 rows



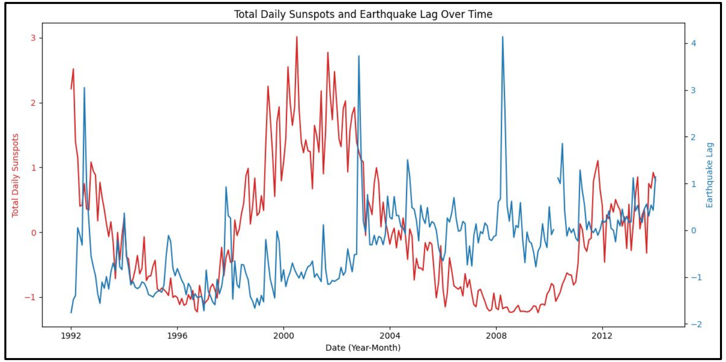
Adj. R-squared = 0.38

Achieved with a 2 year lag

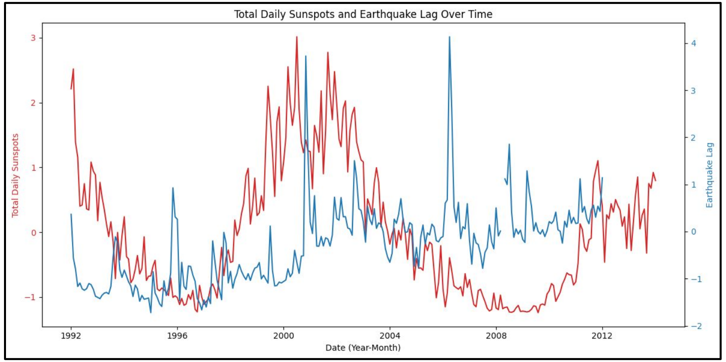
This suggests a potential temporal correlation where solar activity could influence geological processes on Earth, with a notable delay

	coef	std err	t	P>|t|	[0.025	0.975]
const	-120.2926	14.176	-8.486	0.000	-148.206	-92.379
Year	0.0599	0.007	8.459	0.000	0.046	0.074
Total Daily Sunspots	-0.1413	0.045	-3.132	0.002	-0.230	-0.052

No Earthquake Lag



2 Year Earthquake Lag



- Need for more data across multiple solar cycles to test validity
- Enhance earthquake prediction models incorporating solar cycle data
- Potential for improved disaster preparedness and infrastructure planning

What does this mean?

An increase in model performance through a 2 year lag suggests a delayed relationship between sunspots and earthquakes

Because the 6.0 + Earthquake dataset does not have other magnitude occurrences to compare by, **further research is needed** to better understand why solar flare does fairly well as a predictor for Total Earthquake Counts.

Higher model fit for **total earthquake data** suggests more analysis needed to show correlation with higher magnitudes

Magnitude Predictability

Magnitude Analysis w Solar Flare

	coef	std err	t	P>|t|	[0.025	0.975]
const	307.6351	32.605	9.435	0.000	243.259	372.012
Year	-0.1534	0.016	-9.438	0.000	-0.185	-0.121
New Earthquake	-0.1833	0.084	-2.178	0.031	-0.349	-0.017
Solar Flare Value	-0.1047	0.065	-1.616	0.108	-0.233	0.023

Solar Flare Value is **NOT** statistically significant

Multiple Linear Regression

Predictors

Solar Flare Value
Year

Adjusted R Square : 0.470
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.7260
Mean Absolute Error (MAE) : 0.5630

Not a good model

Magnitude Analysis w Sunspots

	coef	std err	t	P>|t|	[0.025	0.975]
const	350.8737	32.139	10.918	0.000	287.418	414.329
Year	-0.1749	0.016	-10.920	0.000	-0.207	-0.143
New Earthquake	-0.2379	0.080	-2.967	0.003	-0.396	-0.080
Total Daily Sunspots	-0.2764	0.061	-4.510	0.000	-0.397	-0.155

Sunspot Value is **IS** statistically significant

Multiple Linear Regression

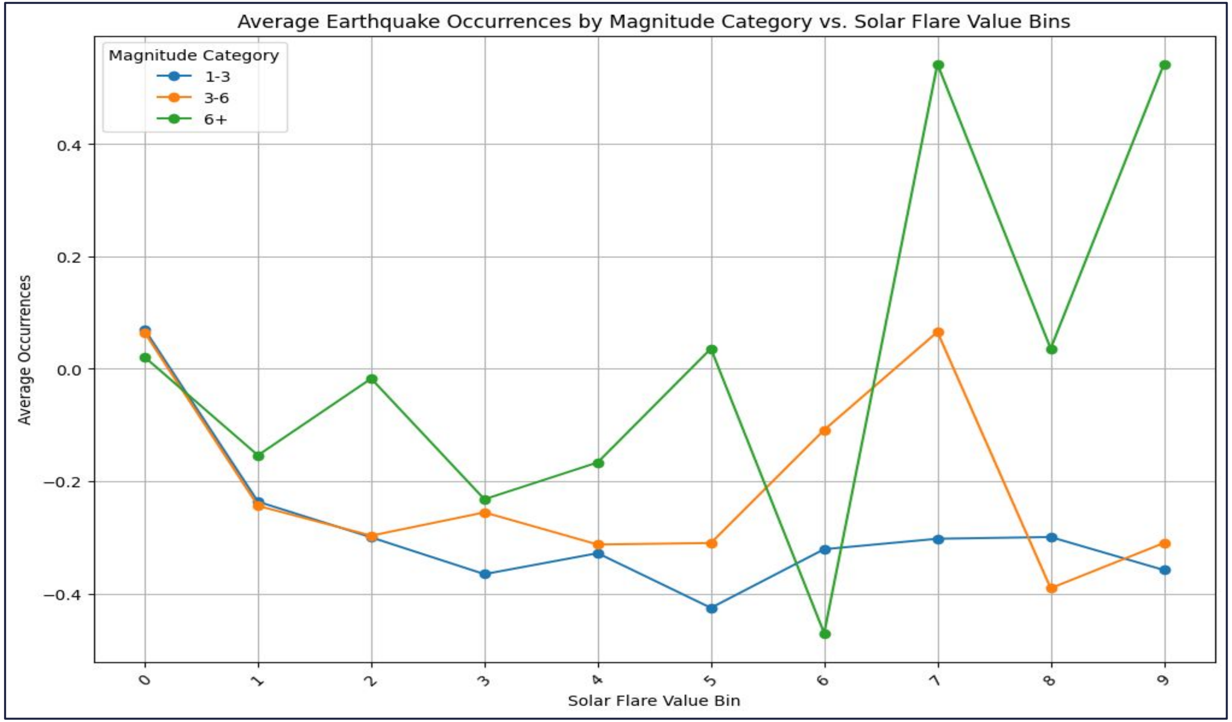
Predictors

Total Daily Sunspots
Year

Adjusted R Square : 0.508
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.7024
Mean Absolute Error (MAE) : 0.5262

Potentially good model

Different Magnitude Bins

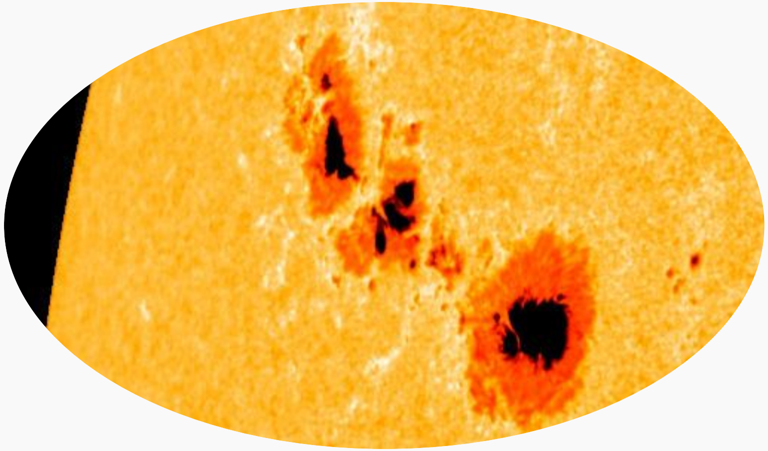


This visual confirms that 6.0+ Magnitude Earthquakes increases as the solar flare value increases.

Why Sunspots a Better Predictor for Magnitude than Solar Flare Value?

- **Longer Duration:** Sunspots can persist for days to weeks, offering a more prolonged and stable measure of solar activity compared to the **transient** nature of solar flares.

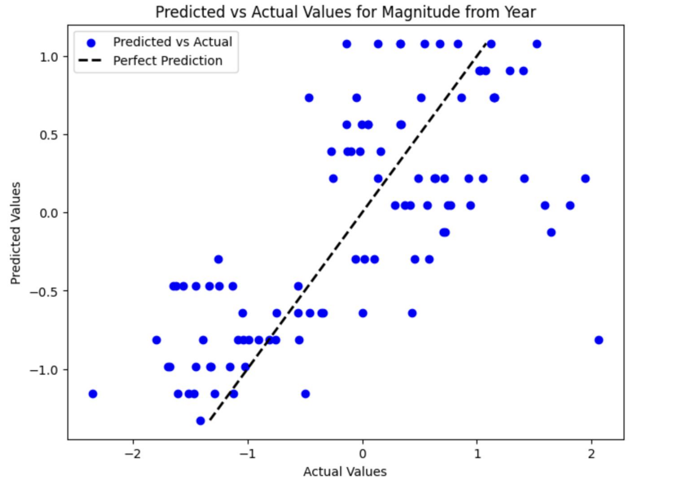
- **Indicative of Solar Cycle:** Sunspots are a key indicator of the solar cycle's phase and intensity, potentially correlating better with **long-term** geophysical processes on Earth.

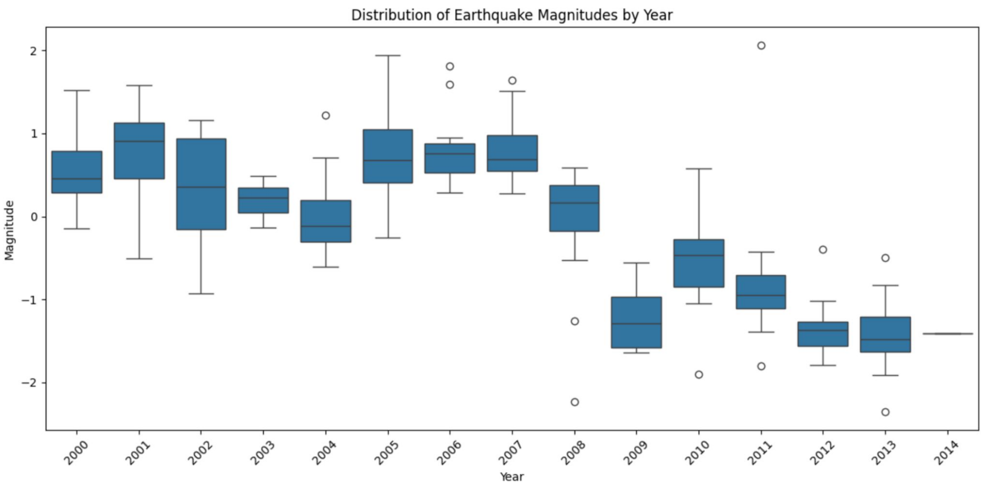


Sunspots might offer a more consistent, statistically significant, and theoretically plausible predictor for earthquake magnitude

Magnitude and Year

	coef	std err	t	P>|t|	[0.025	0.975]
const	312.6010	28.338	11.031	0.000	256.653	368.549
Year	-0.1558	0.014	-11.034	0.000	-0.184	-0.128



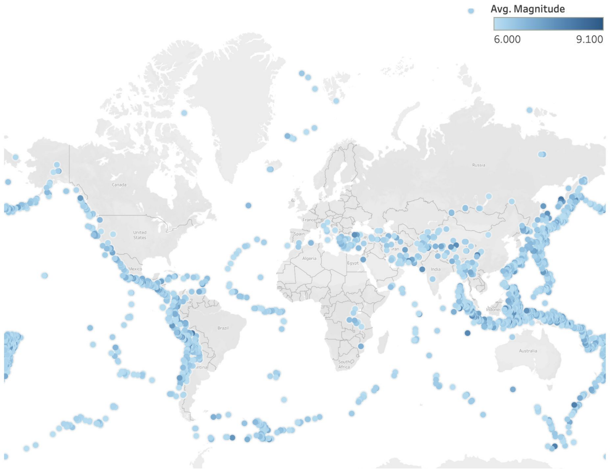


Adjusted R Square : 0.478
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.7282
Mean Absolute Error (MAE) : 0.5672

Earthquakes

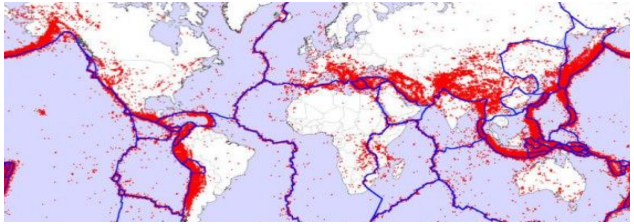
Why Earthquakes?

Earthquakes can indirectly cause EMPs by damaging power infrastructure lines and transformers. This damage can lead to power disruptions, especially in areas with high-voltage lines or substations, potentially causing EMPs that affect electronic devices and systems.

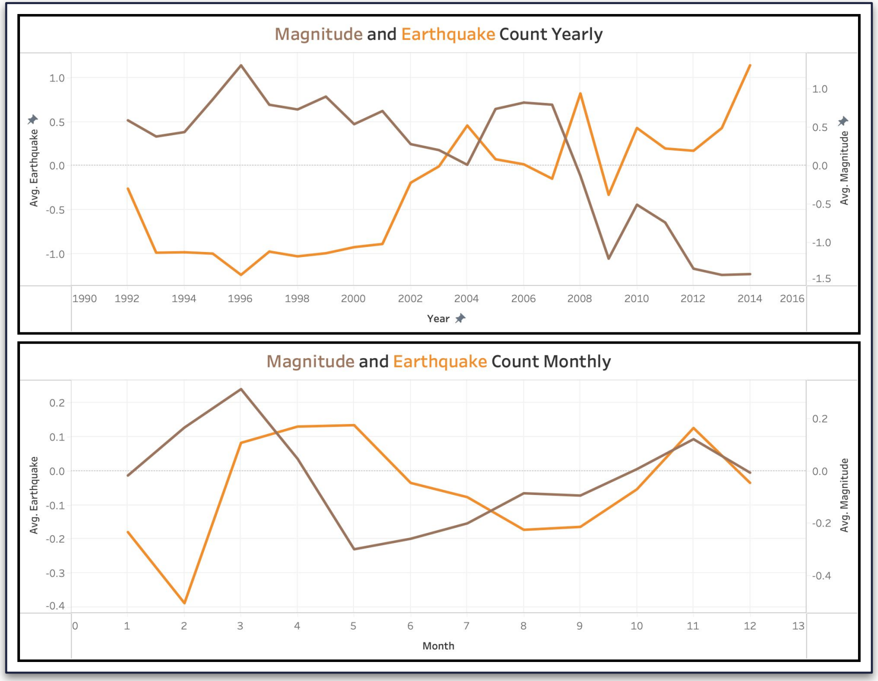


Earthquake Coordinates and Fault Lines

Earthquake coordinates are found along fault lines, where tectonic plates meet and move. Most earthquakes occur in these areas, signaling the release of accumulated stress between the plates.



Magnitude x Earthquakes



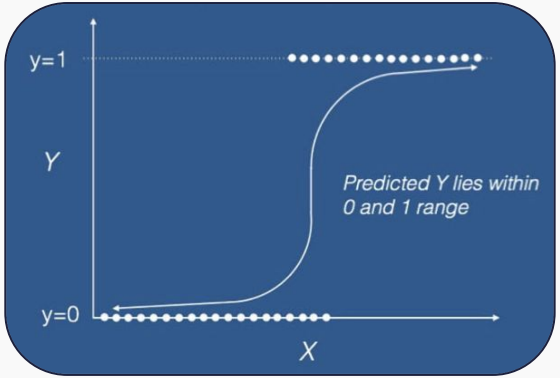
Inverse relationship

Feature	Correlation Coefficient
Magnitude vs. Earthquakes	-0.36

Logistic Regression

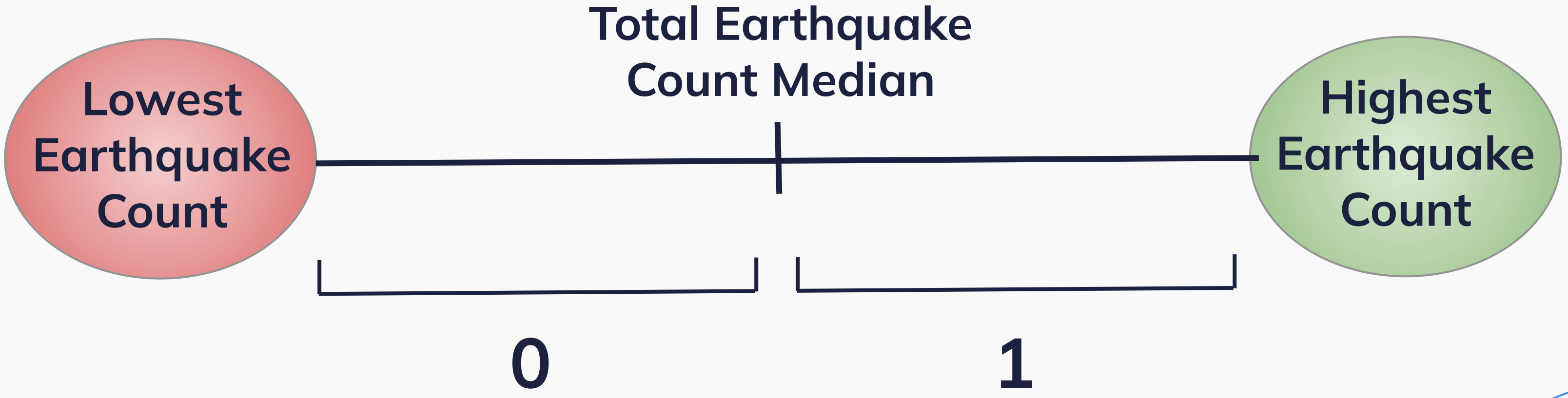
Logistic Regression

- Can capture nonlinear relationships
- Classification provides broader outcome, tests to see if predictors can see certain range rather than exact amount



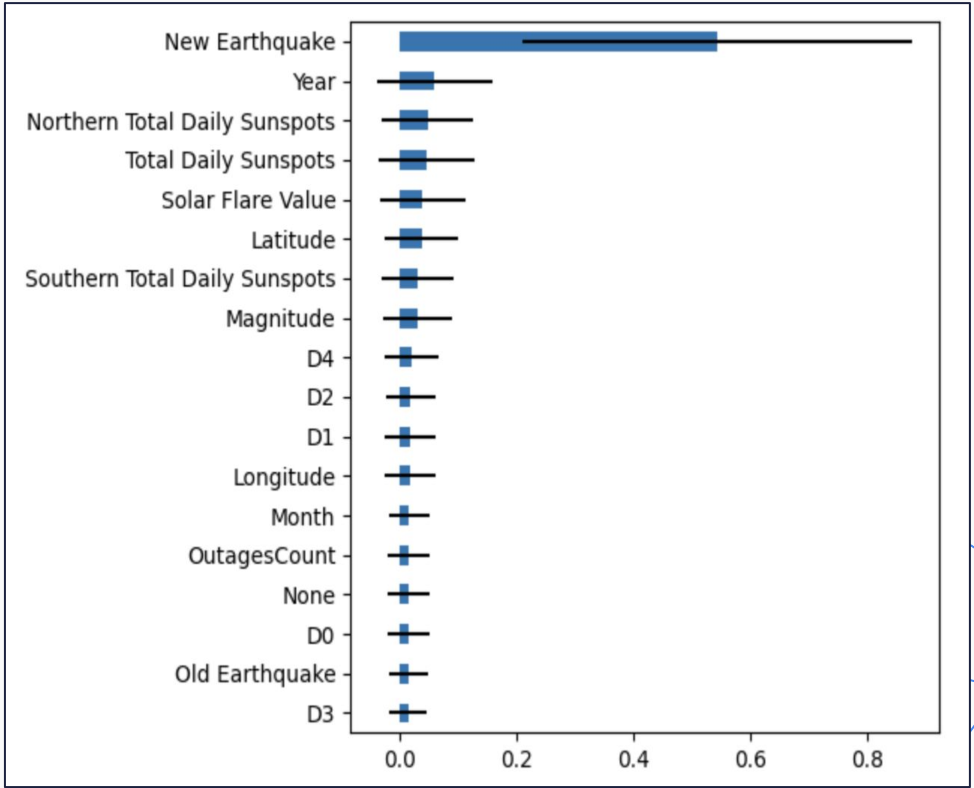
What factors are the best predictors that can help determine the range of earthquake counts, whether it be below or above the Earthquake Count Median?

How it will work



Classification Model Importance

feature	importance	std
D3	0.014112	0.032027
Old Earthquake	0.014440	0.032819
D0	0.015521	0.036770
None	0.015593	0.035237
OutagesCount	0.016156	0.035651
Month	0.016310	0.034841
Longitude	0.017736	0.043230
D1	0.017841	0.042598
D2	0.018419	0.042223
D4	0.019987	0.046035
Magnitude	0.030155	0.059608
Southern Total Daily Sunspots	0.030796	0.061196
Latitude	0.037138	0.063637
Solar Flare Value	0.039386	0.073172
Total Daily Sunspots	0.045900	0.081772
Northern Total Daily Sunspots	0.047558	0.078360
Year	0.059895	0.098359
New Earthquake	0.543056	0.333528



Independent Variables

Year

Score = 75% | CV = 57%

Accuracy: 0.7450980392156863
Classification Report:

	precision	recall	f1-score	support
0	0.70	0.88	0.78	26
1	0.83	0.60	0.70	25
accuracy			0.75	51
macro avg	0.77	0.74	0.74	51
weighted avg	0.76	0.75	0.74	51

Northern Sunspots

Score = 63% | CV = 63%

Accuracy: 0.6274509803921569
Classification Report:

	precision	recall	f1-score	support
0	0.67	0.54	0.60	26
1	0.60	0.72	0.65	25
accuracy			0.63	51
macro avg	0.63	0.63	0.63	51
weighted avg	0.63	0.63	0.62	51

Total Sunspots

Score = 49% | CV = 60%

Accuracy: 0.49019607843137253
Classification Report:

	precision	recall	f1-score	support
0	0.50	0.42	0.46	26
1	0.48	0.56	0.52	25
accuracy			0.49	51
macro avg	0.49	0.49	0.49	51
weighted avg	0.49	0.49	0.49	51

Solar Flare Value

Score = 55% | CV = 56%

Accuracy: 0.5490196078431373
Classification Report:

	precision	recall	f1-score	support
0	0.54	0.73	0.62	26
1	0.56	0.36	0.44	25
accuracy			0.55	51
macro avg	0.55	0.55	0.53	51
weighted avg	0.55	0.55	0.53	51

Independent Variables

D4

Score = 65% | CV = 57%

Accuracy: 0.6470588235294118

Classification Report:

	precision	recall	f1-score	support
0	0.64	0.69	0.67	26
1	0.65	0.60	0.63	25
accuracy			0.65	51
macro avg	0.65	0.65	0.65	51
weighted avg	0.65	0.65	0.65	51

Magnitude

Score = 55% | CV = 58%

Accuracy: 0.5490196078431373

Classification Report:

	precision	recall	f1-score	support
0	0.56	0.58	0.57	26
1	0.54	0.52	0.53	25
accuracy			0.55	51
macro avg	0.55	0.55	0.55	51
weighted avg	0.55	0.55	0.55	51

Power Outages

Score = 63% | CV = 45%

Accuracy: 0.6274509803921569

Classification Report:

	precision	recall	f1-score	support
0	0.62	0.69	0.65	26
1	0.64	0.56	0.60	25
accuracy			0.63	51
macro avg	0.63	0.63	0.63	51
weighted avg	0.63	0.63	0.63	51

Southern Sunspots

Score = 63% | CV = 55%

Accuracy: 0.6274509803921569

Classification Report:

	precision	recall	f1-score	support
0	0.61	0.73	0.67	26
1	0.65	0.52	0.58	25
accuracy			0.63	51
macro avg	0.63	0.63	0.62	51
weighted avg	0.63	0.63	0.62	51

Best Combinations

Classification

Predictors

Solar Flare Value
Year

Accuracy: 76%
CV: 66%

Classification

Predictors

Northern Total Sunspots
Year

Accuracy: 73%
CV: 70%

Solar Flares/Sunspots remain best predictor in determining high or low Earthquake counts

Climate Change

Greenhouse Gases

Nitrous Oxide (N20)

A potent greenhouse gas from agriculture and industry, contributes to environmental harm, including crop damage, health risks, and ozone layer depletion, affecting human health and ecosystems.

Carbon Dioxide (CO2)

Vital for Earth's carbon cycle but human activities, like burning fossil fuels and deforestation, have drastically raised CO2 levels, worsening the greenhouse effect and global warming.

Methane (CH4)

A potent greenhouse gas, contributing significantly to climate change, primarily from human activities like agriculture and fossil fuel production.

Trichlorofluoromethane (CFC-11)

A man-made compound that was commonly used as a refrigerant and propellant. It is also a potent greenhouse gas, contributing to ozone depletion in the upper atmosphere.

Correlation Analysis

Feature	Correlation Coefficient
Nitrous Oxide (N20)	0.51
Carbon Dioxide (CO2)	0.50
Methane (CH4)	0.30
Trichlorofluoromethane (CFC-11)	-0.57

Multiple Linear Regression

Predictors

Nitrous Oxide (N20)
Carbon Dioxide (CO2)
Methane (CH4)
Trichlorofluoromethane (CFC-11)

Adjusted R Square : 0.336
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.6468
Mean Absolute Error (MAE) : 0.4457

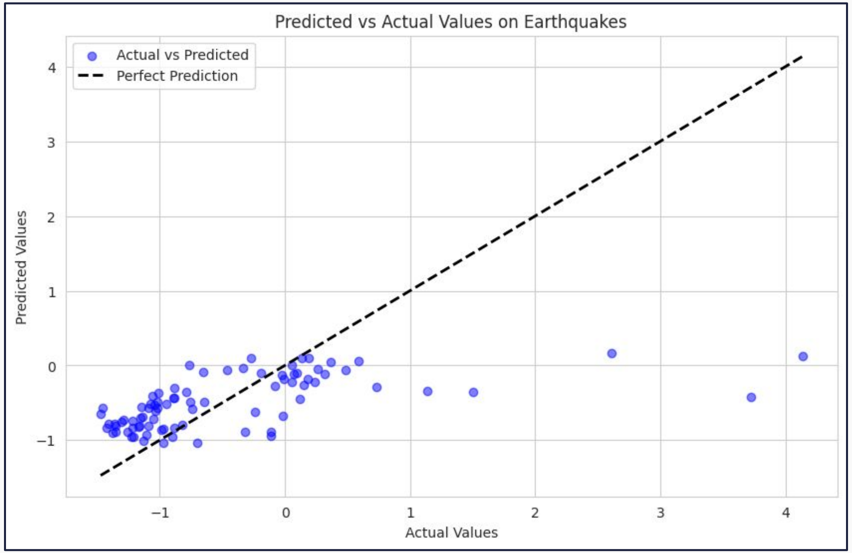
	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.4906	0.060	-8.154	0.000	-0.610	-0.371
CO2	-0.1030	0.244	-0.422	0.674	-0.586	0.381
CH4	-0.0421	0.117	-0.360	0.720	-0.274	0.190
N2O	-0.7679	0.427	-1.797	0.075	-1.614	0.078
CFC-11	-1.2971	0.327	-3.965	0.000	-1.945	-0.649

These values are **NOT** statistically significant

Not a good model

Predicted vs Actual Values

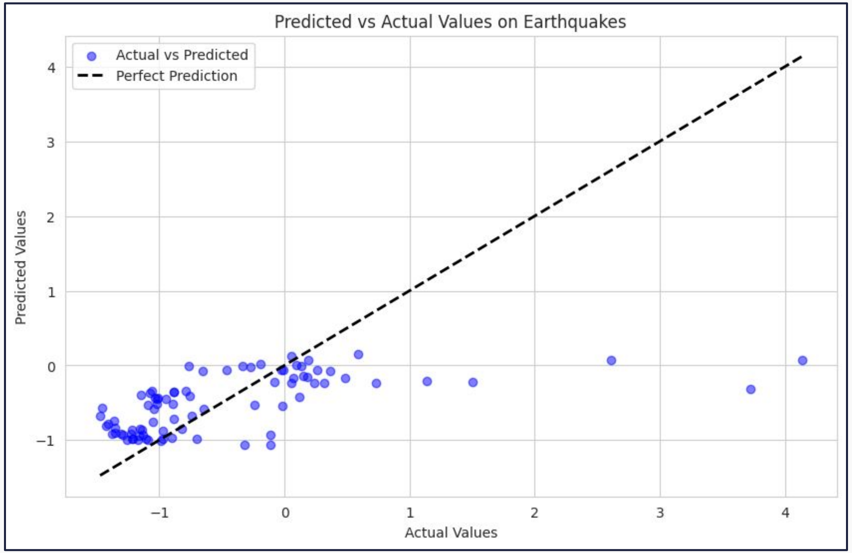
Carbon Dioxide (CO2)



	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.4978	0.065	-7.614	0.000	-0.627	-0.368
CO2	0.3423	0.065	5.229	0.000	0.213	0.472

Adjusted R Square : 0.179

Nitrous Oxide (N2O)

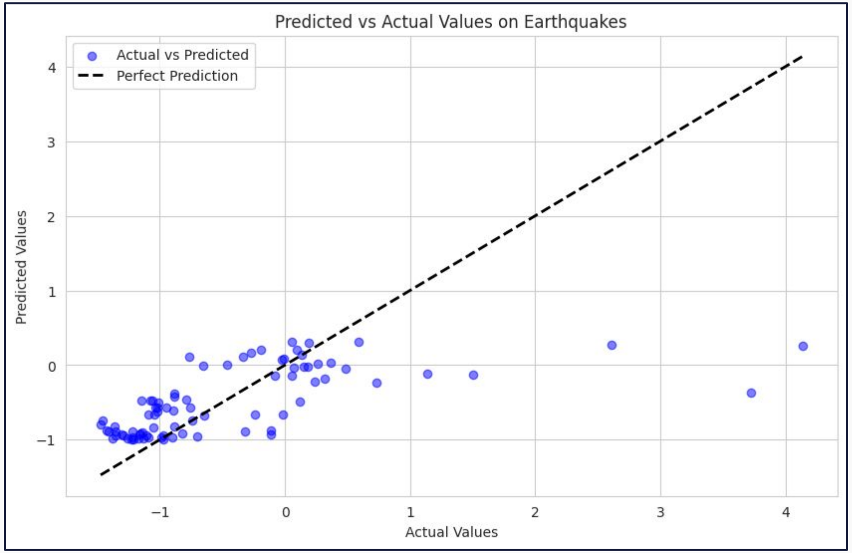


	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.5013	0.065	-7.710	0.000	-0.630	-0.373
N2O	0.3579	0.067	5.381	0.000	0.226	0.490

Adjusted R Square : 0.188

Predicted vs Actual Values

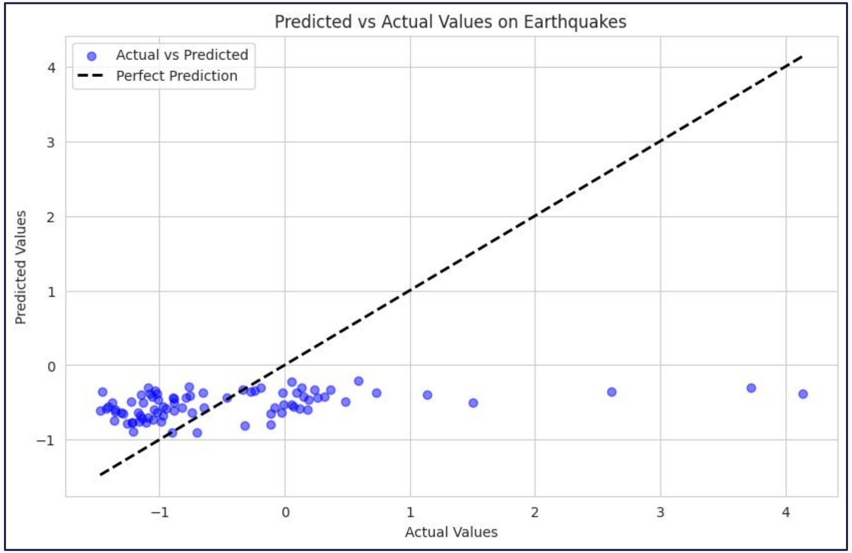
Trichlorofluoromethane (CFC-11)



	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.4984	0.062	-8.021	0.000	-0.621	-0.375
CFC-11	-0.4178	0.064	-6.559	0.000	-0.544	-0.292

Adjusted R Square : 0.258

Methane (CH4)



	coef	std err	t	P>|t|	[0.025	0.975]
const	-0.5109	0.071	-7.197	0.000	-0.652	-0.370
CH4	0.1661	0.071	2.329	0.022	0.025	0.307

Adjusted R Square : 0.035

What does this mean?

The combined analysis of N2O, CO2, CFC-11, and CH4 suggests that these gases **together do not contribute** significantly to earthquakes. However, there may be **individual connections** between N2O, CO2, and CFC-11 and earthquake activity. **Further research is needed** to explore these potential links.

Preventative Measures

N2O

Reducing emissions involves using fertilizers more efficiently in agriculture, **managing manure better**, optimizing industrial processes, and **promoting sustainable practices**.

CO2

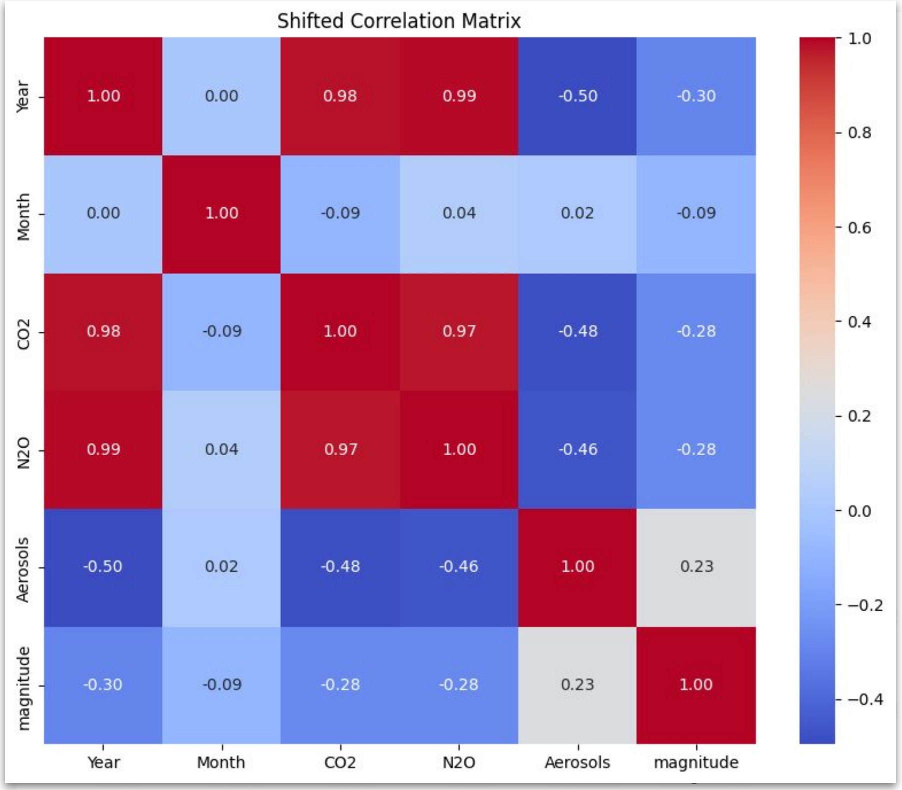
Reducing emissions involves transitioning to **renewable energy** sources, improving energy efficiency, promoting sustainable transportation, and implementing carbon capture and storage technologies.

CFC-11

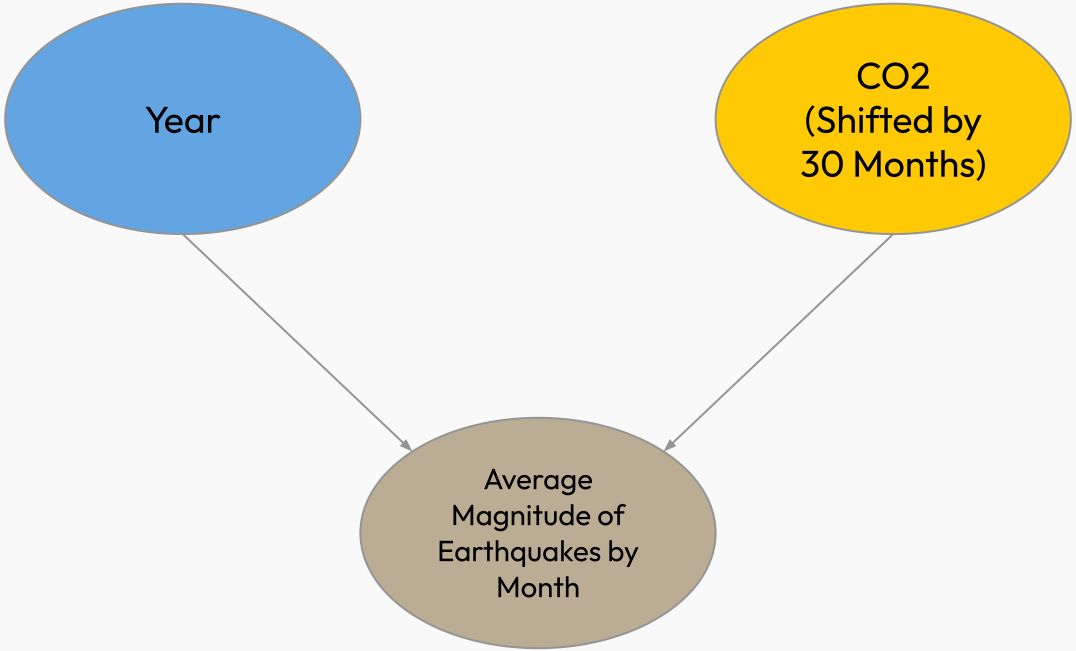
Since it is a **man made material** as long as we stop manufacturing it we should be alright however it can still appear as it was still used in old appliances. Steadily declining after 2018

Correlation Matrix

Climate-related factors are all highly correlated with each other, meaning multicollinearity

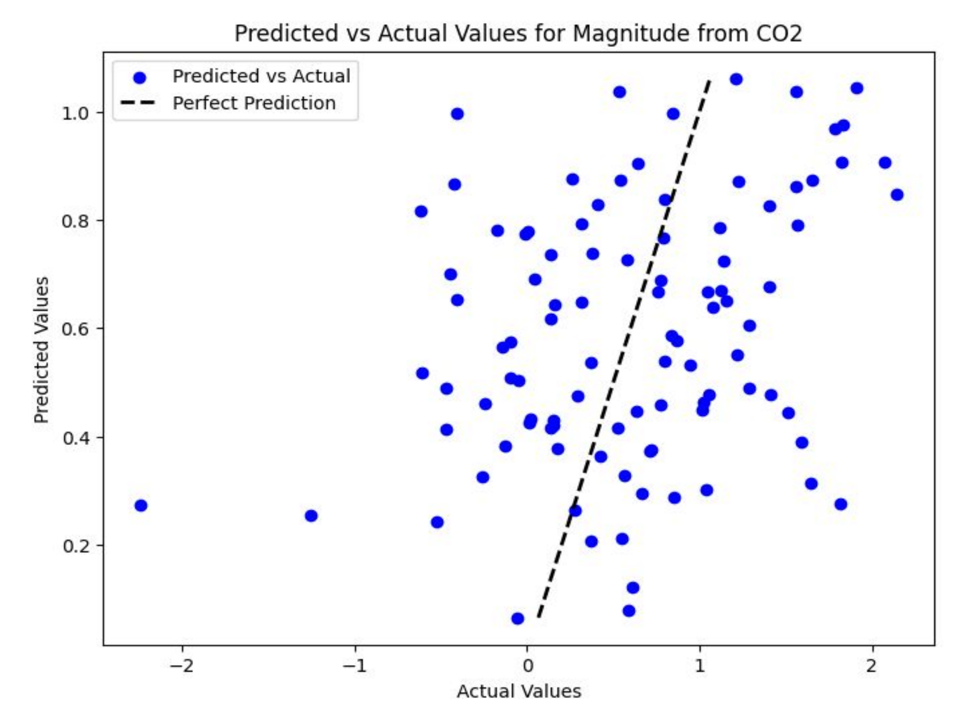


Multiple Linear Regression



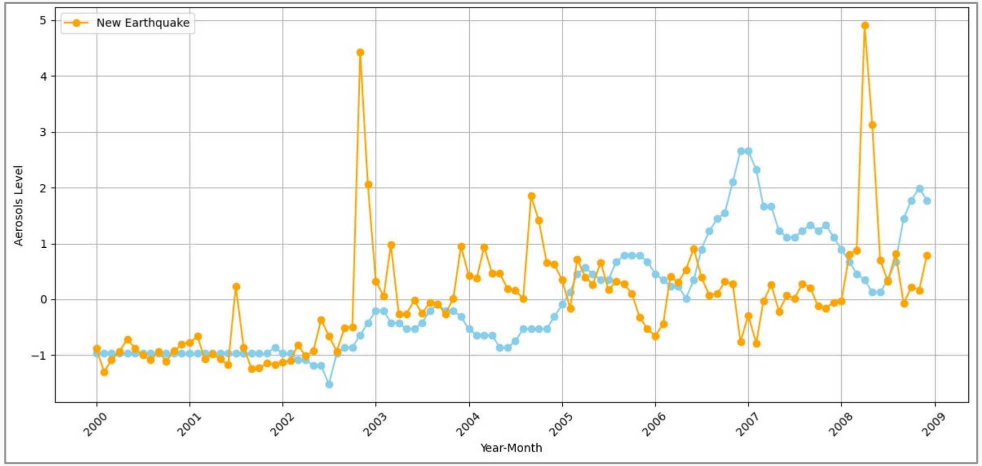
Adjusted R Square : 0.093

Multiple Linear Regression

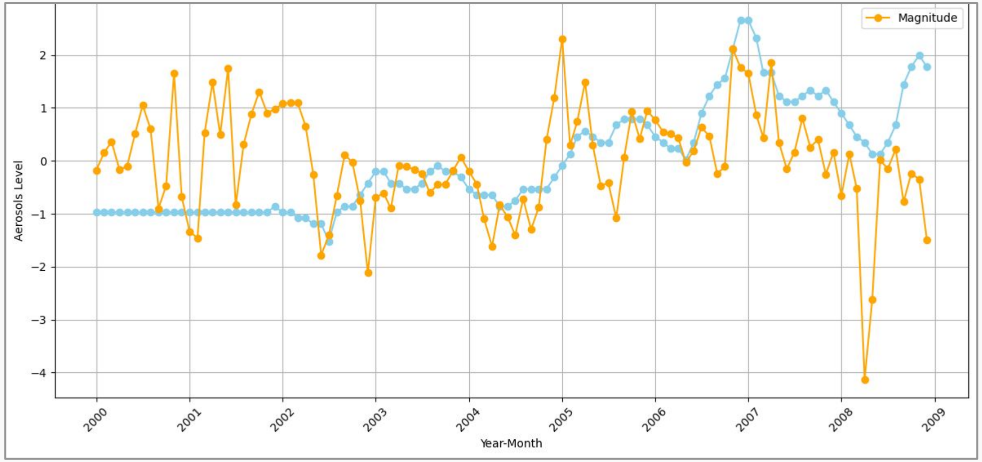


Aerosols

- **Aerosols:** Particles or droplets in the air and includes airborne dusts, mists, fumes or smoke
- **Examples:** Sea spray, mineral dust, smoke, fog, and volcanic ash
- Possible correlation between, Earthquake and Magnitude:
    - **Aerosol Induced Seismicity**



Aerosol Level vs. Earthquake Counts

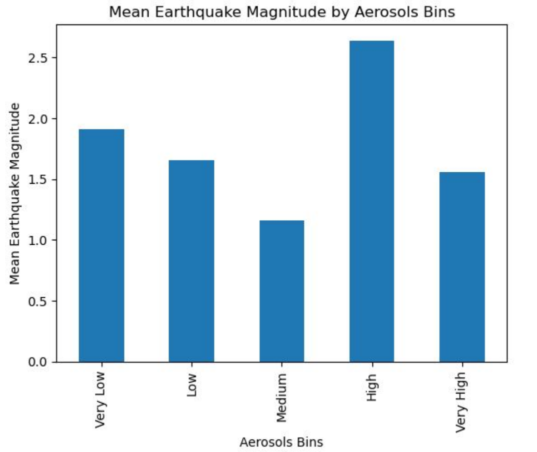


Aerosol Level vs. Magnitude

Aerosol Analysis

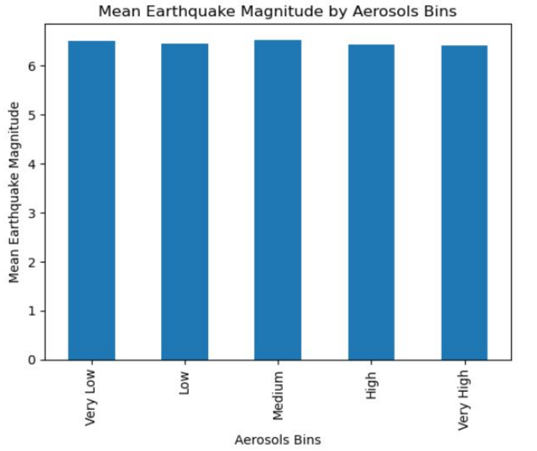
Aerosol Levels comparing with Magnitude < 6

```
Aerosols_bins
Very Low     1.907611
Low          1.653333
Medium       1.157500
High         2.640000
Very High    1.557143
Name: earthquake_magnitude, dtype: float64
```

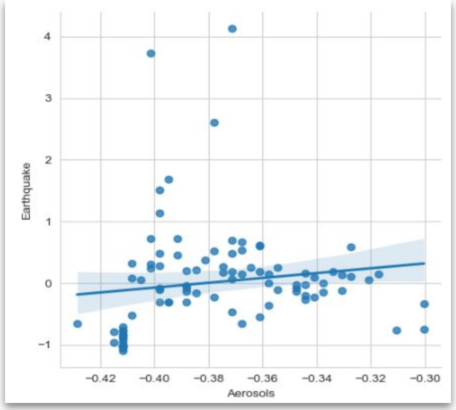


Aerosol Levels comparing with Magnitude > 6

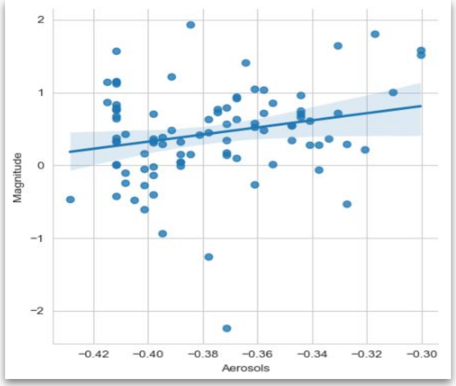
```
Aerosols_bins
Very Low     6.506111
Low          6.444444
Medium       6.525000
High         6.425000
Very High    6.400000
Name: over_six, dtype: float64
```



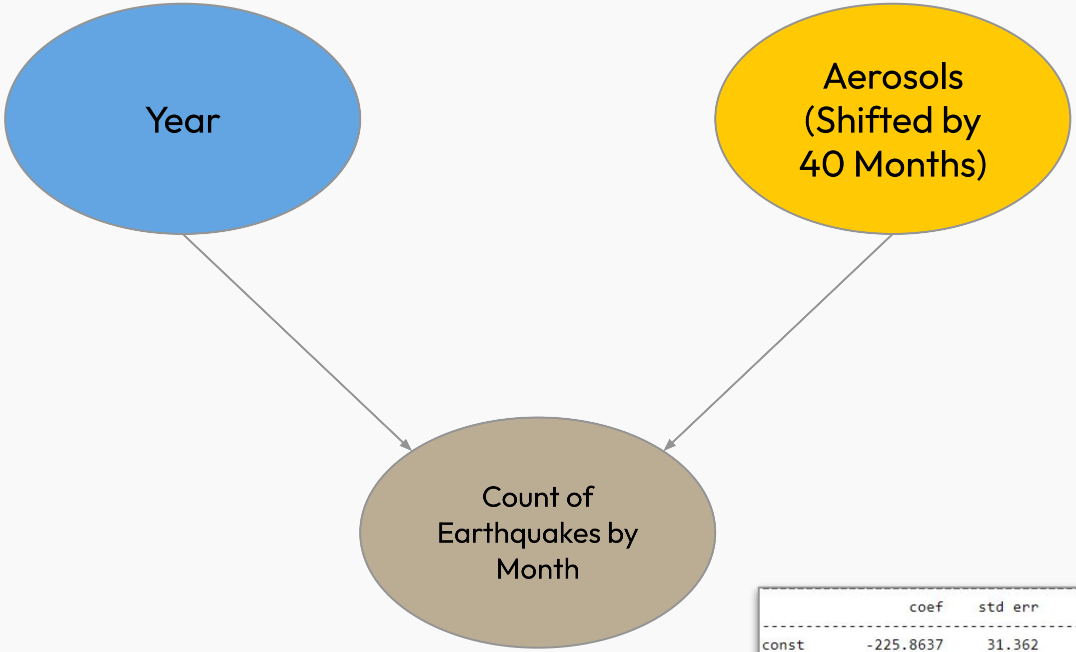
Earthquake vs Aerosols



Magnitude vs Aerosols



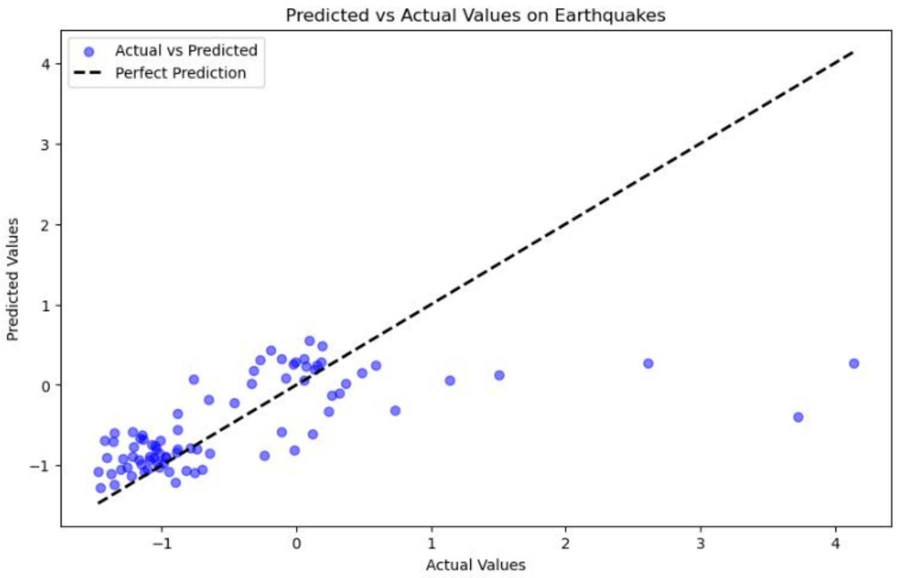
Multiple Linear Regression



Adjusted R Square : 0.417

	coef	std err	t	P>|t|	[0.025	0.975]
const	-225.8637	31.362	-7.202	0.000	-287.970	-163.757
Aerosols	0.3081	0.068	4.518	0.000	0.173	0.443
Year	0.1126	0.016	7.181	0.000	0.082	0.144
Month	0.0246	0.017	1.450	0.150	-0.009	0.058

Predicted Vs Actual Values on Earthquakes - Aerosols



Multiple Linear Regression - Aerosols and Magnitude

Dependent Variable: Magnitude
Predictors:

CO_2
N_2O
Year
Month

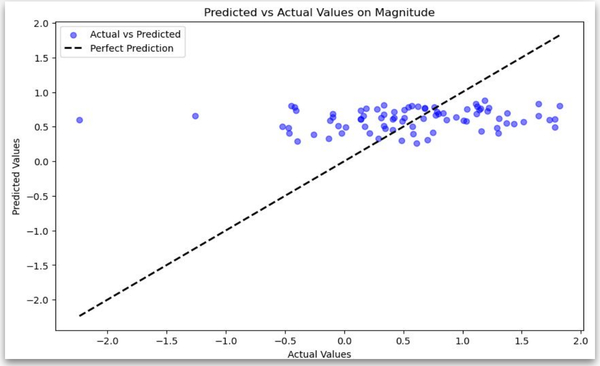
Adjusted R Square : 0.010

Mean Error (ME) : 0.0000

Root Mean Squared Error (RMSE) : 0.6484

Mean Absolute Error (MAE) : 0.5133

	coef	std err	t	P>|t|	[0.025	0.975]
const	664.9222	423.253	1.571	0.119	-173.385	1503.229
Aerosols	-0.1836	0.099	-1.858	0.066	-0.379	0.012
CO2	0.4833	0.359	1.346	0.181	-0.228	1.194
N2O	1.0205	0.872	1.171	0.244	-0.706	2.747
Year	-0.3321	0.212	-1.569	0.119	-0.751	0.087
Month	-0.0289	0.023	-1.256	0.212	-0.074	0.017



Aerosols What-if?

Dependent Variable: Earthquake
Predictors:

new_mult (Aerosol what-if)
Year
Month

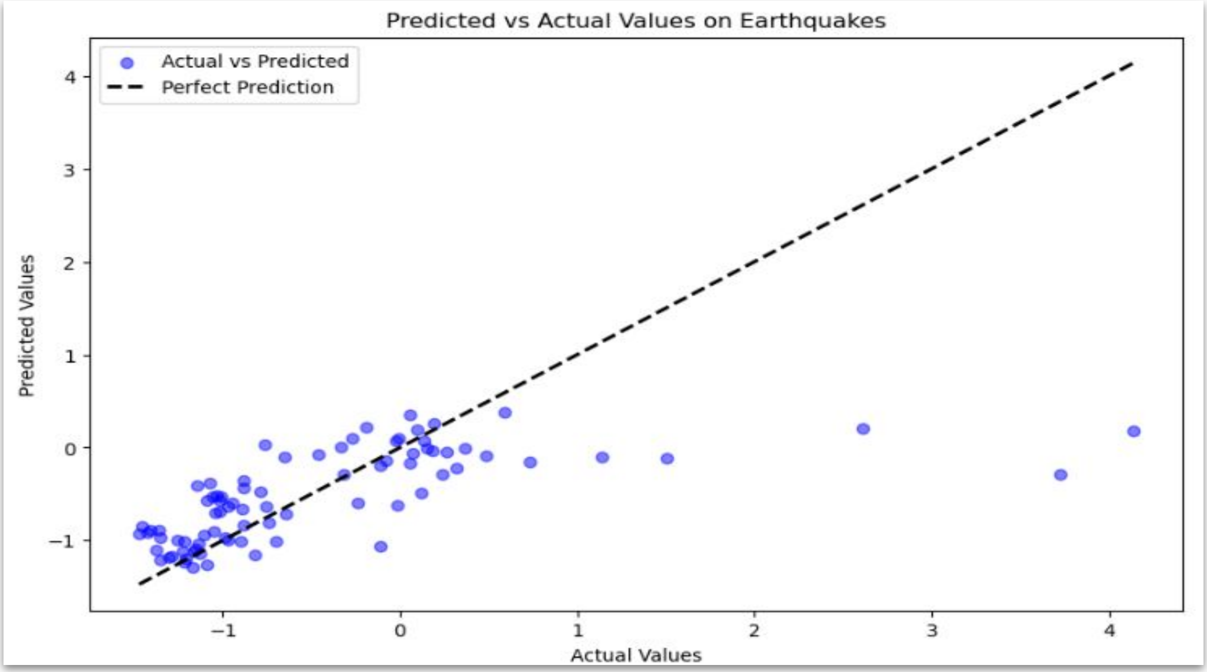
Adjusted R Square : 0.301

Multiplied the top highest Aerosol levels by a factor of 5.

Tested MLR with the new Aerosol columns on Earthquake

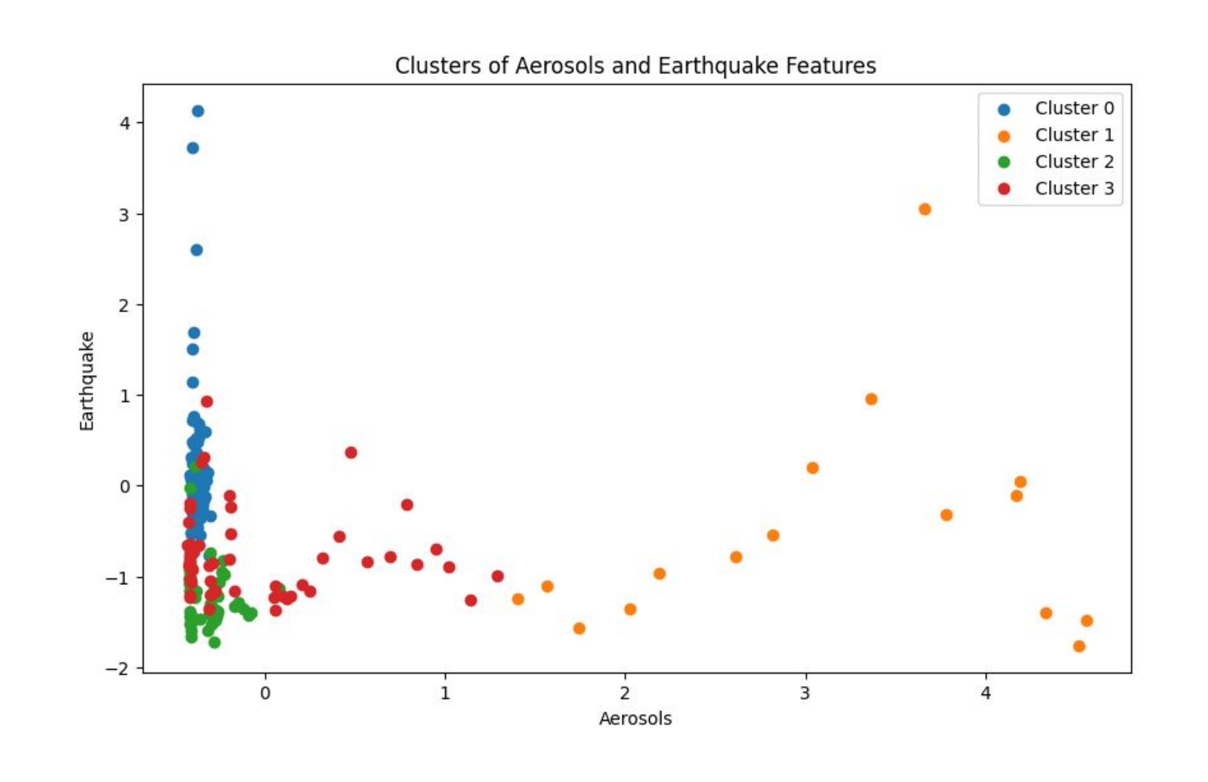
	coef	std err	t	P>|t|	[0.025	0.975]
const	-212.1998	30.369	-6.987	0.000	-272.339	-152.060
new_mult	0.0154	0.004	4.250	0.000	0.008	0.023
Year	0.1057	0.015	6.965	0.000	0.076	0.136
Month	0.0244	0.017	1.423	0.157	-0.010	0.058

Predicted vs Actual of Aerosol What-if



Cluster Analysis

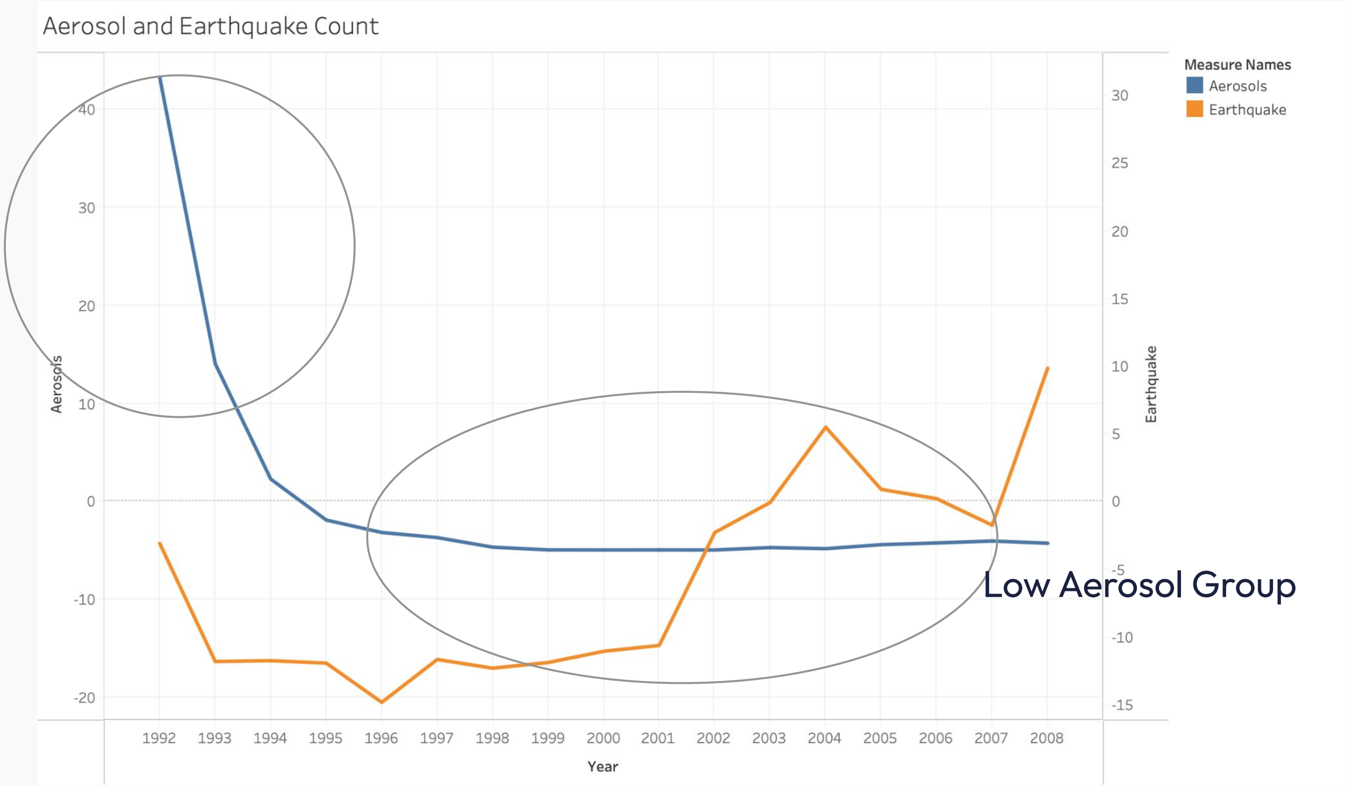
Cluster



Clusters of Aerosols and Earthquake Features
Cluster 0
Cluster 1
Cluster 2
Cluster 3
Earthquake
Aerosols
4
3
2
1
0
−1
−2
0
1
2
3
4


Aerosol Distribution by Cluster
Cluster (group)
Avg. Aerosols
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
1
2
3
Magnitude Distribution by Cluster
Cluster (group)
Avg. Magnitude
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
Earthquake Count Distribution by Cluster
Cluster (group)
Avg. Earthquake
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
0
1
2
3
During Solar Peak

Aerosol and Earthquake Count



What does this mean?

There is **potential** for the predictors all for except to CO_2 to be **statistically significant** as P-Values are less than 0.05. As with Aerosols, there is a possible chance that Aerosols and Earthquakes are **correlated** with one another.

With Aerosols and Magnitudes, there is **little correlation** as it is likely that Aerosol levels do not impact Magnitude levels as much. It seems that Aerosol levels have more of an impact with magnitudes that are of magnitude < 6. Elevated Aerosol levels have been seen before seismic activity but does **not necessarily correlate** to any Magnitude level.

Why Aerosols can be a possible predictor:

Atmospheric Loading:

- Injecting reflective aerosols, such as sulfur dioxide particles, into the stratosphere to scatter sunlight and reduce global temperature

- Researchers have hypothesized that it could potentially alter atmospheric dynamics and pressure distribution, leading to changes in seismic activity

Hydrological Cycle:

- Aerosols can affect cloud formation and precipitation patterns, influencing the distribution of water in the Earth's crust

- Changes in pore pressure within the crust due to variations in groundwater levels could potentially affect the stability of fault zones

Preventative Measures

Environmental Monitoring:
Install monitoring systems to track environmental conditions around transformers, including aerosol levels, humidity, temperature, and pollution. This data can help identify areas with high contamination levels and inform maintenance decisions.

Oil Filtration and Treatment:
Maintain filtration systems to remove contaminants from transformer oil and maintain its dielectric properties. Periodically treat oil to mitigate the effects of contamination and extend the lifespan of transformers.

Insulation Upgrades:
Upgrading transformer insulation materials can improve resistance to contamination and enhance performance under adverse environmental conditions. Using advanced insulation materials with better resistance to moisture and chemical degradation can help mitigate the effects of aerosols and extend the service life of transformers.

Droughts

Why Droughts

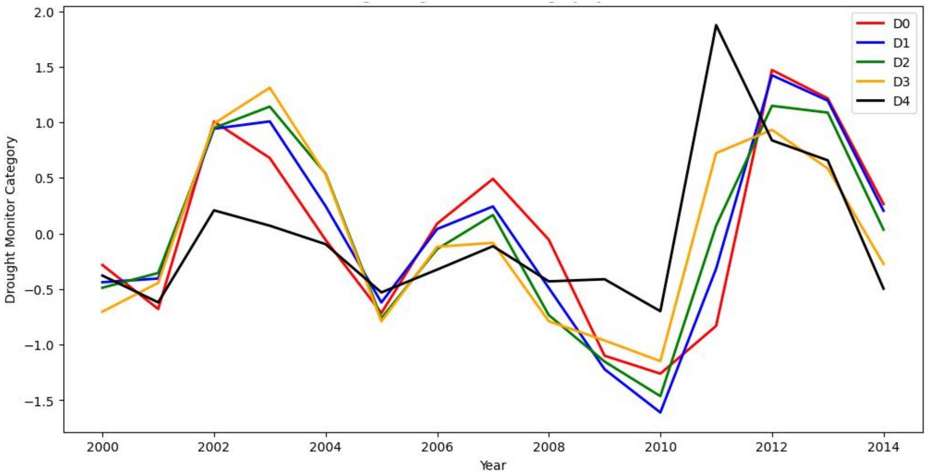
Relationship with Earthquakes

Although not directly linked, some studies suggest that prolonged droughts can alter stress distribution in the Earth's crust, potentially increasing seismic activity in fault zones

Relationship with Sunspots

Sunspots can indirectly influence Earth's climate by affecting atmospheric circulation, potentially leading to changes in precipitation patterns and drought conditions

Avg. Drought Monitor Category



U.S. Drought Monitor Category	% of U.S.
D0 - Abnormally Dry	**18.4%**
D1 - Moderate Drought	**14.9%**
D2 - Severe Drought	**7.3%**
D3 - Extreme Drought	**5.9%**
D4 - Exceptional Drought	**2.29%**
Total Area in Drought (D1–D4)	**30.39%**

Drought levels categorized from D0 - D4 follow the same pattern

Independent Variables

D4

Score = 65% | CV = 56%

```
Accuracy: 0.6470588235294118
Classification Report:
              precision    recall  f1-score   support

           0       0.64      0.69      0.67        26
           1       0.65      0.60      0.63        25

    accuracy                           0.65        51
   macro avg       0.65      0.65      0.65        51
weighted avg       0.65      0.65      0.65        51
```

D2

Score = 51% | CV = 54%

```
Accuracy: 0.5098039215686274
Classification Report:
              precision    recall  f1-score   support

           0       0.52      0.62      0.56        26
           1       0.50      0.40      0.44        25

    accuracy                           0.51        51
   macro avg       0.51      0.51      0.50        51
weighted avg       0.51      0.51      0.50        51
```

D3

Score = 49% | CV = 49%

```
Accuracy: 0.49019607843137253
Classification Report:
              precision    recall  f1-score   support

           0       0.50      0.46      0.48        26
           1       0.48      0.52      0.50        25

    accuracy                           0.49        51
   macro avg       0.49      0.49      0.49        51
weighted avg       0.49      0.49      0.49        51
```

D1

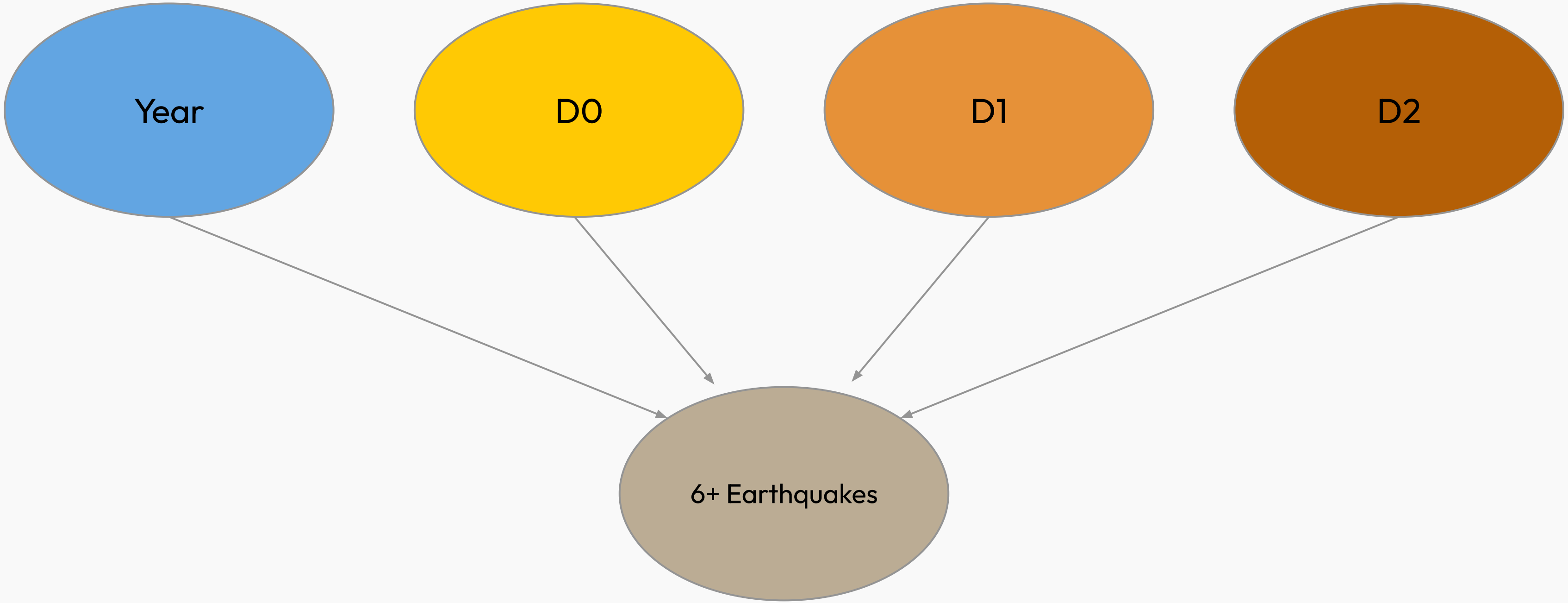
Score = 58% | CV = 47%

```
Accuracy: 0.5882352941176471
Classification Report:
              precision    recall  f1-score   support

           0       0.62      0.50      0.55        26
           1       0.57      0.68      0.62        25

    accuracy                           0.59        51
   macro avg       0.59      0.59      0.59        51
weighted avg       0.59      0.59      0.59        51
```

Drought-Earthquake Relationship

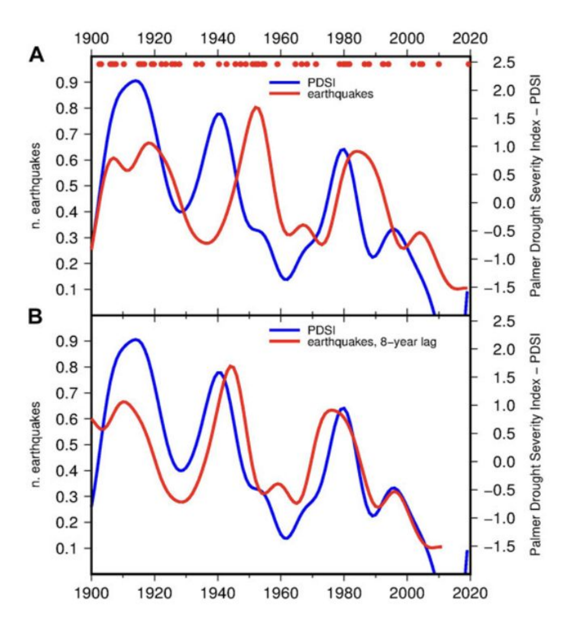
Research indicates a potential relationship between droughts and earthquakes, especially for seismic events of magnitude 6 or higher. Many significant earthquakes have been preceded by extended periods of drought, suggesting a "drought-earthquake relationship."

Drought Levels vs 6+ Earthquakes



Adjusted R Square : 0.076

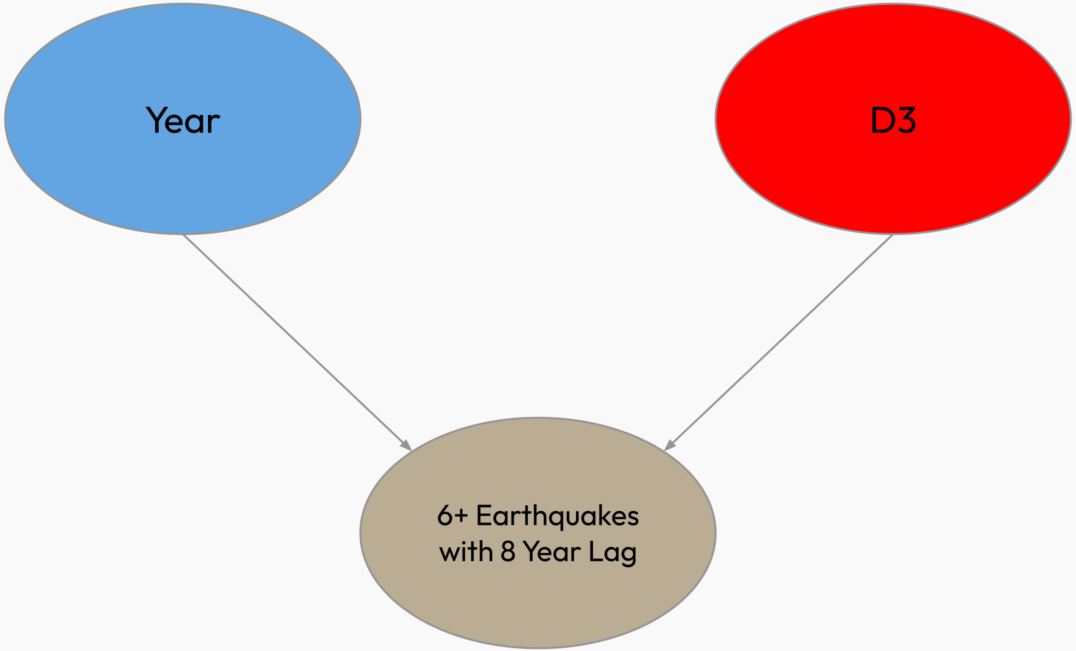
Palmer Drought Severity Index (PDSI)



The PDSI is a standardized index that measures drought severity using precipitation, temperature, and soil moisture data

Panel (B) compares Southern California earthquakes (red) with PDSI for climate zones 6–7 (blue), showing earthquakes leading PDSI by 8 years, hinting at a drought-seismic activity link

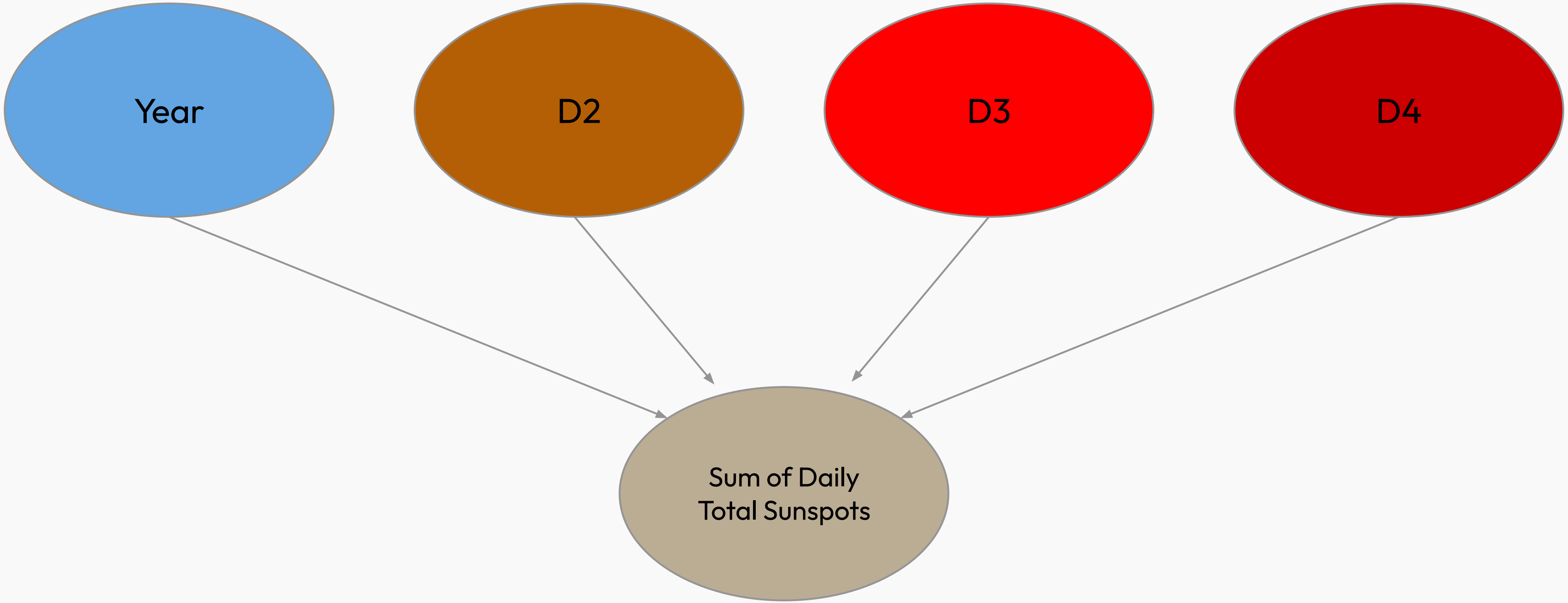
Droughts vs 6+ Earthquakes (8 Year Lag)



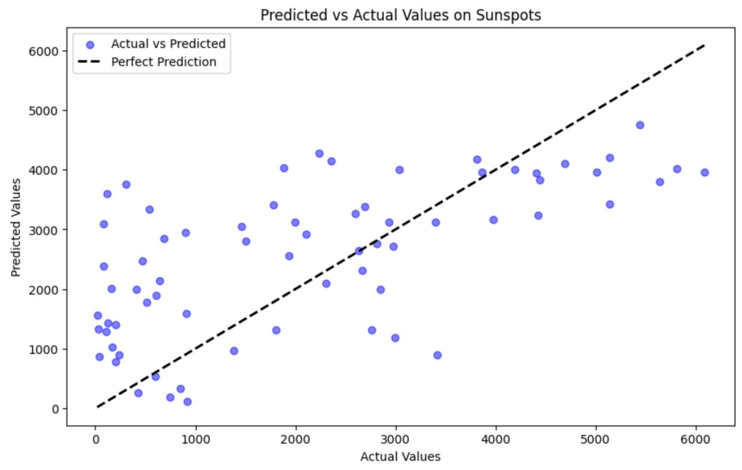
Adjusted R Square : 0.104

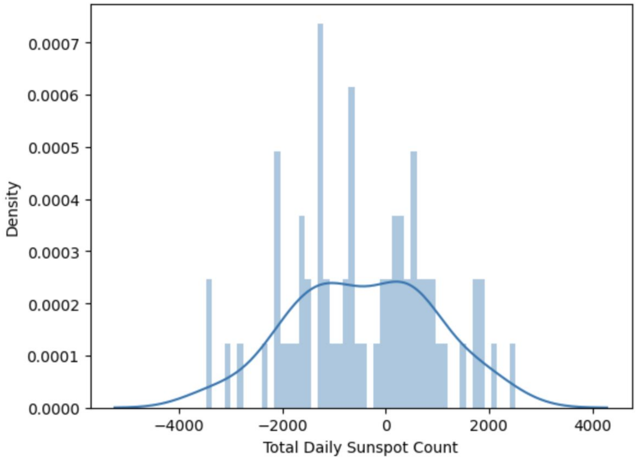
Droughts vs. Sunspots

Droughts vs Sunspots

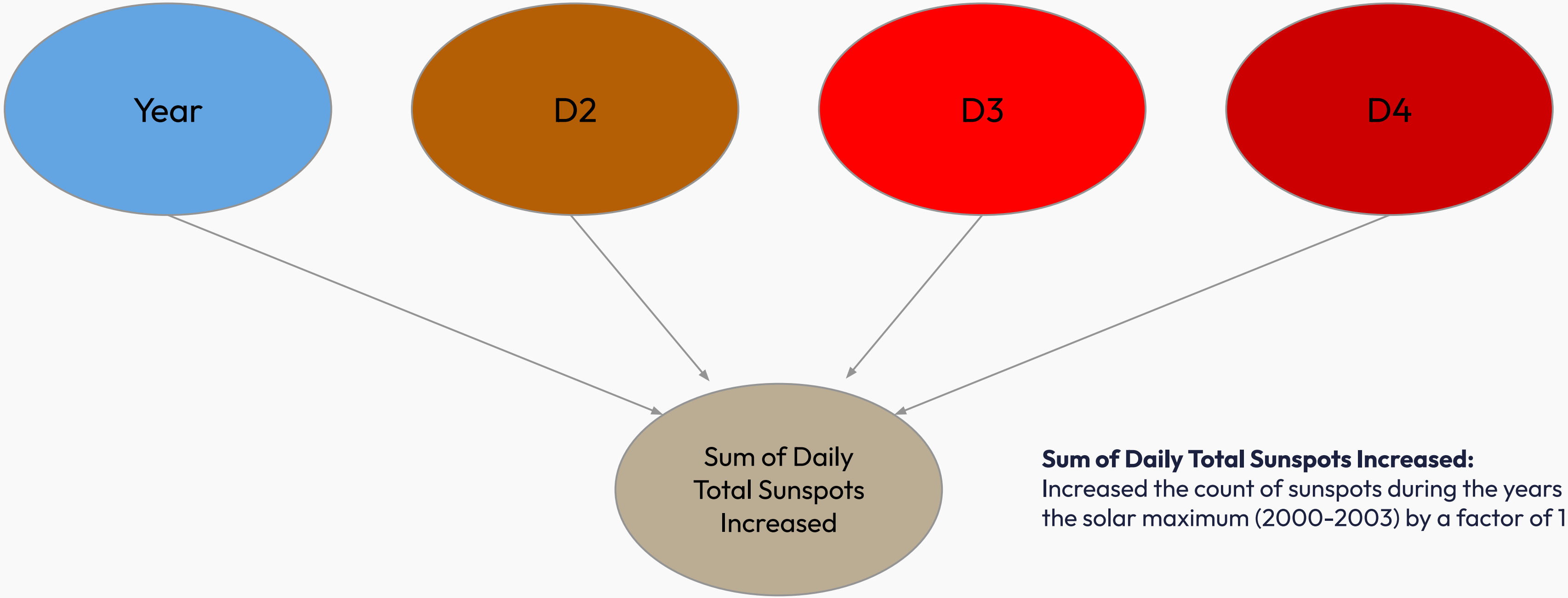


Adjusted R Square : 0.431


Predicted vs Actual Values on Sunspots
Actual vs Predicted
Perfect Prediction
Predicted Values
Actual Values
0
1000
2000
3000
4000
5000
6000


Density
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
−4000
−2000
0
2000
4000
Total Daily Sunspot Count

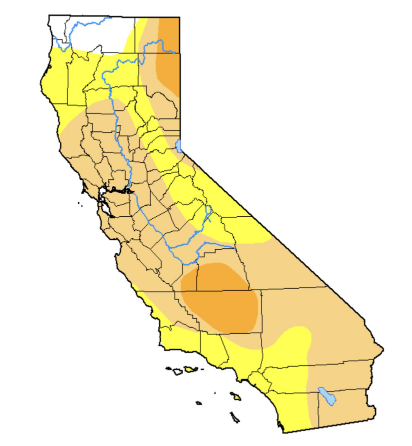
Droughts vs Sunspots (What if?)



Adjusted R Square : 0.516

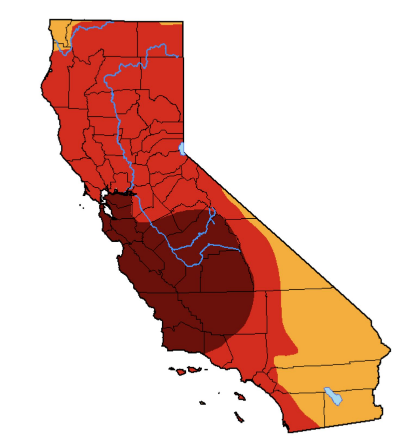
Sum of Daily Total Sunspots Increased:
Increased the count of sunspots during the years of the solar maximum (2000-2003) by a factor of 1.5

Solar Cycle Effects on Droughts



Solar Minimum

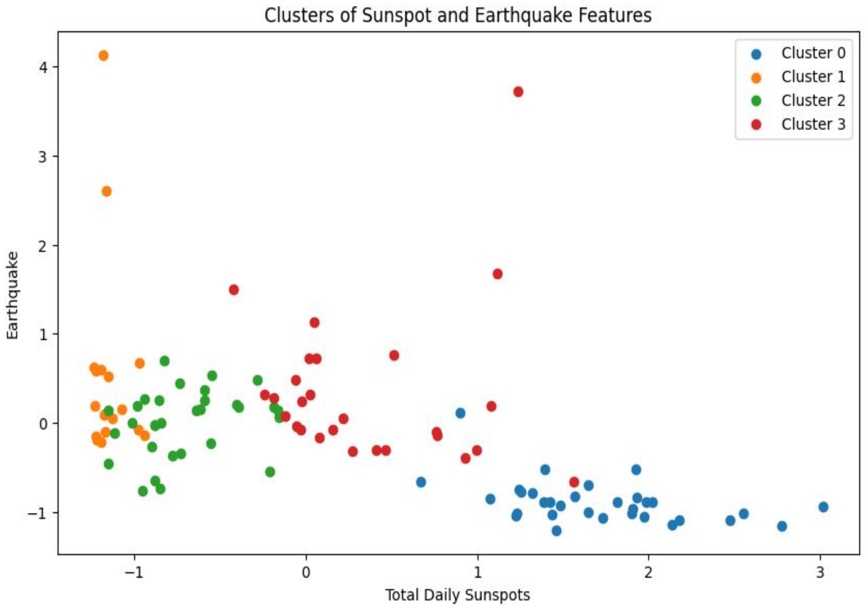
June 10, 2008
Avg. Daily Sunspot Count: 4.2



Solar Maximum

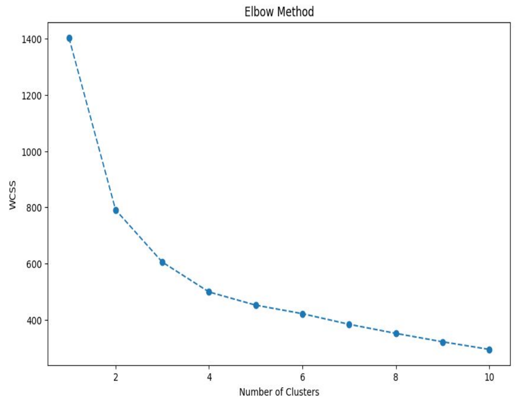
June 10, 2014
Avg. Daily Sunspot Count: 113.3

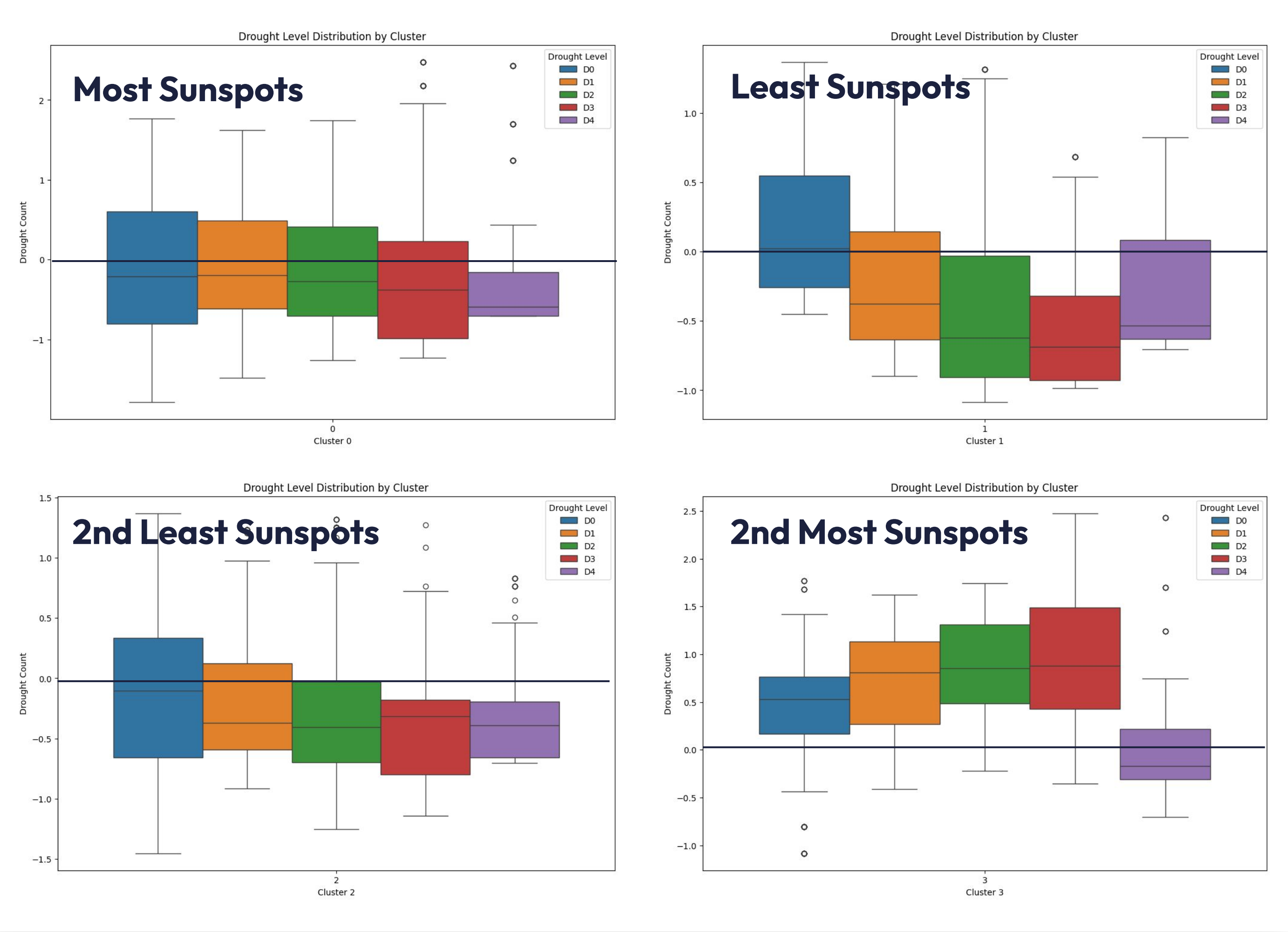
Cluster Analysis



Separated Sunspots into **4** clusters, each representing different sunspot count range

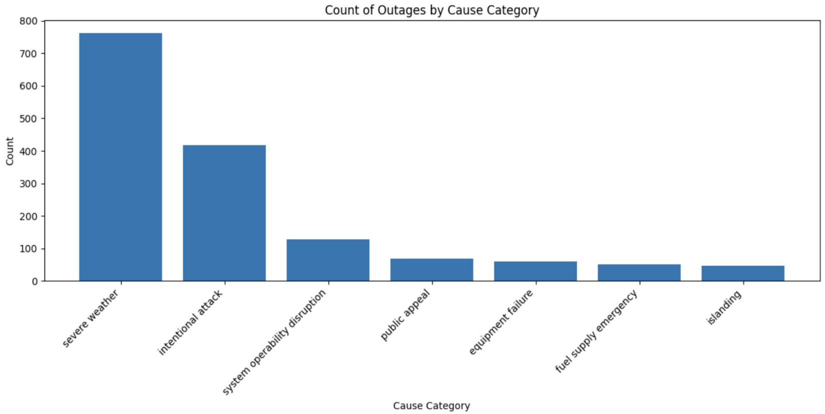
Utilized **PCA** to reduce complexity of other variables





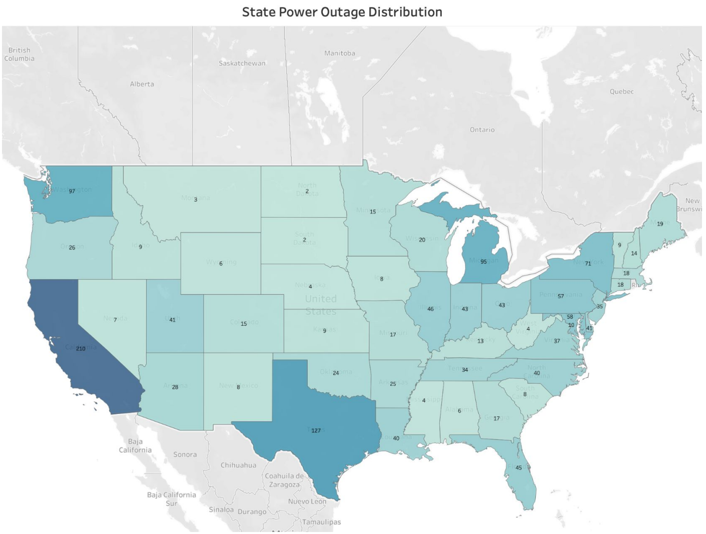
The Higher the sunspots, the more Droughts that occur at all levels. **Cluster 3** (2nd most sunspots) is only sign of increasing drought intensity counts

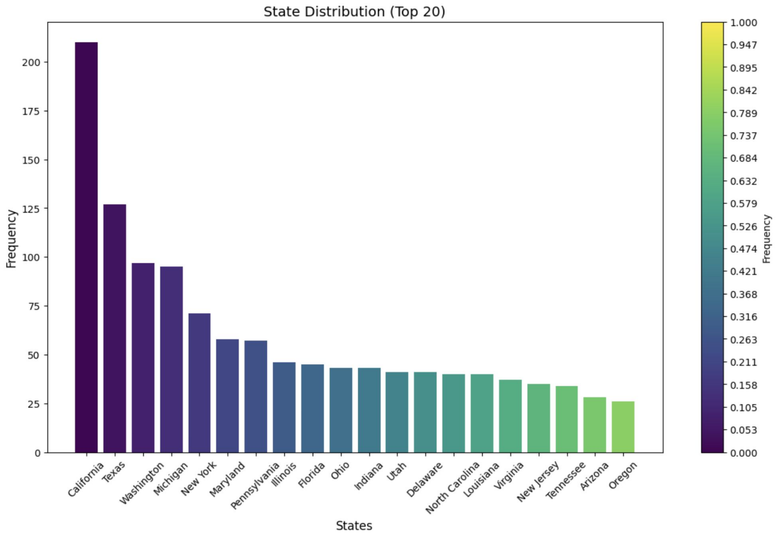
Power Outages

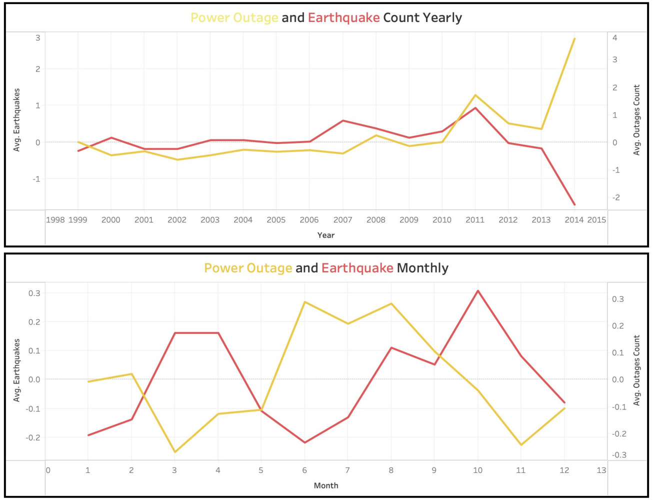


Power Outages

EMPs, from natural or human-made sources, can damage electronics and disrupt power grids, highlighting the need for protective measures and contingency plans


State Power Outage Distribution
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
United States
Baja California
Sonora
Chihuahua
Coahuila de Zaragoza
Nuevo León
Baja California Sur
Sinaloa
Durango
Tamaulipas

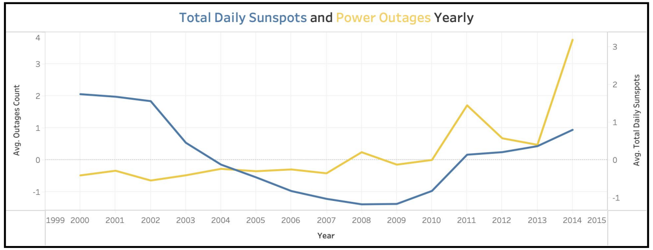

State Distribution (Top 20)
Frequency
0
25
50
75
100
125
150
175
200
California
Texas
Washington
Michigan
New York
Maryland
Pennsylvania
Illinois
Florida
Ohio
Indiana
Utah
Delaware
North Carolina
Louisiana
Virginia
New Jersey
Tennessee
Arizona
Oregon
States
1.000
0.947
0.895
0.842
0.789
0.737
0.684
0.632
0.579
0.526
0.474
0.421
0.368
0.316
0.263
0.211
0.158
0.105
0.053
0.000
Frequency

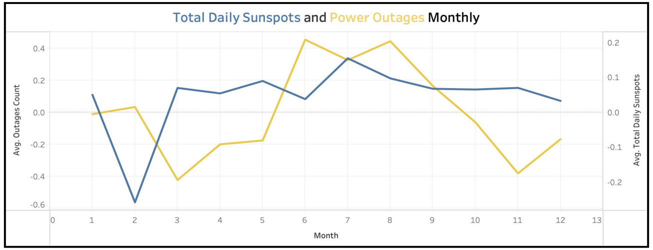


Power Outages and Earthquakes

Yearly: There is an upward trend in both earthquake count and power outage count from 1998 to 2013

Monthly: Inverse relationship between earthquakes and power outages and higher count of power outages in the summer months



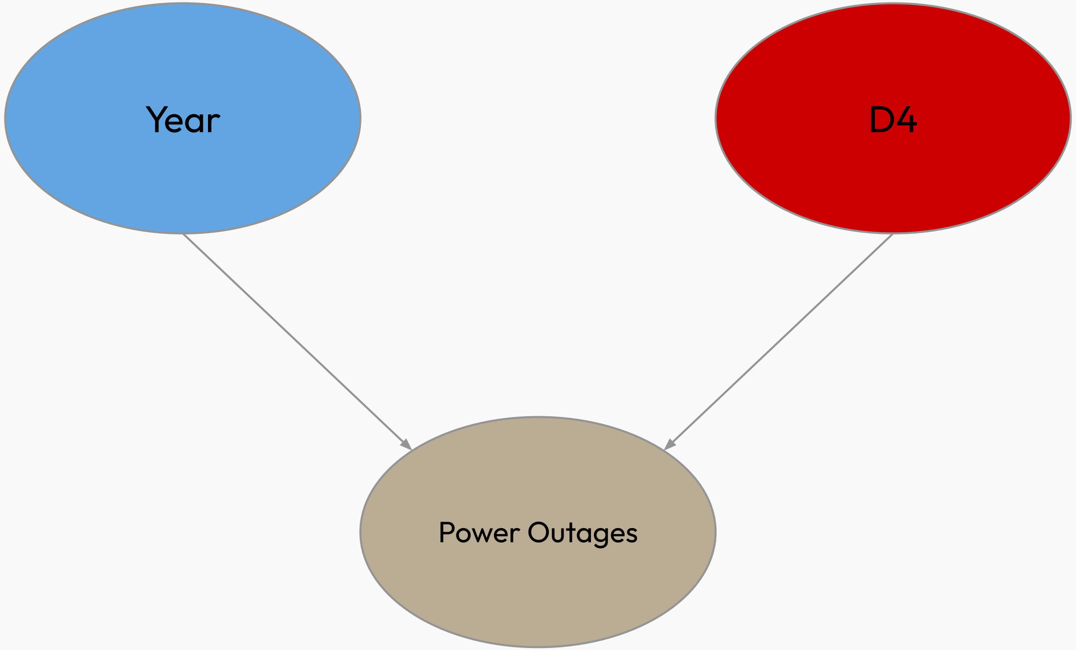


Power Outages and Sunspots

Yearly: From 2000 to 2008, both sunspot activity and power outages declined. After 2008, sunspot activity increased, while power outages fluctuated, indicating other factors influencing outages

Monthly: Sunspot activity peaks mid-year, while power outages spike in January and June

Droughts vs Power Outages



Adjusted R Square : 0.342

Sunspots

Solar maximum increases solar radiation, leading to increased drought conditions

Droughts

Droughts can strain power generation resources, leading to an increased risk of power outages

Power Outages

Take preventative measures during a solar maximum

Preventative Measures

Inspect and Maintain Infrastructure

Increase inspections and maintenance of critical infrastructure, like power lines and transformers, after droughts to withstand potential earthquake impacts

Prepare for Droughts

Develop drought response plans considering sunspot activity. Increase water storage, implement conservation measures, and collaborate with local authorities

Invest in Solar Power

Expand solar capacity to leverage increased production during high sunspot activity, offsetting potential energy supply challenges from droughts

Next Solar Maximum: Between late 2024 and early 2026

Fracking

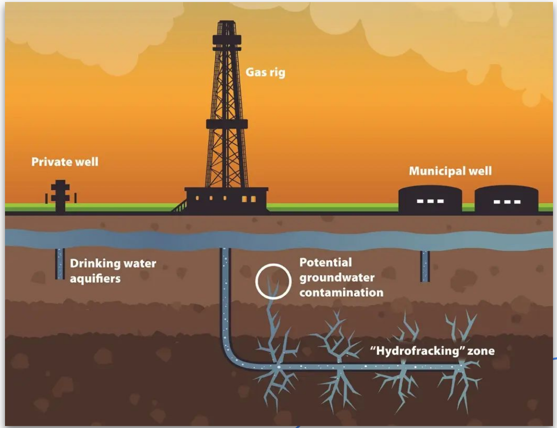
Why Fracking?

- Fracking: Used to extract oil, natural gas, or water by injecting highly pressurized liquid deep underground

- Fracking activities is linked to the cause in earthquakes
  - Injection of wastewater into deep wells can increase underground pressure, leading to the destabilization of faults

- Induced earthquakes from fracking activities are generally low in magnitude and less frequent

- Understanding relationship with fracking and earthquake can help with other locations involved with fracking as well when developing preventative measures



Data Source

- Fractracker Alliance: https://www.fractracker.org/data/data-resources/

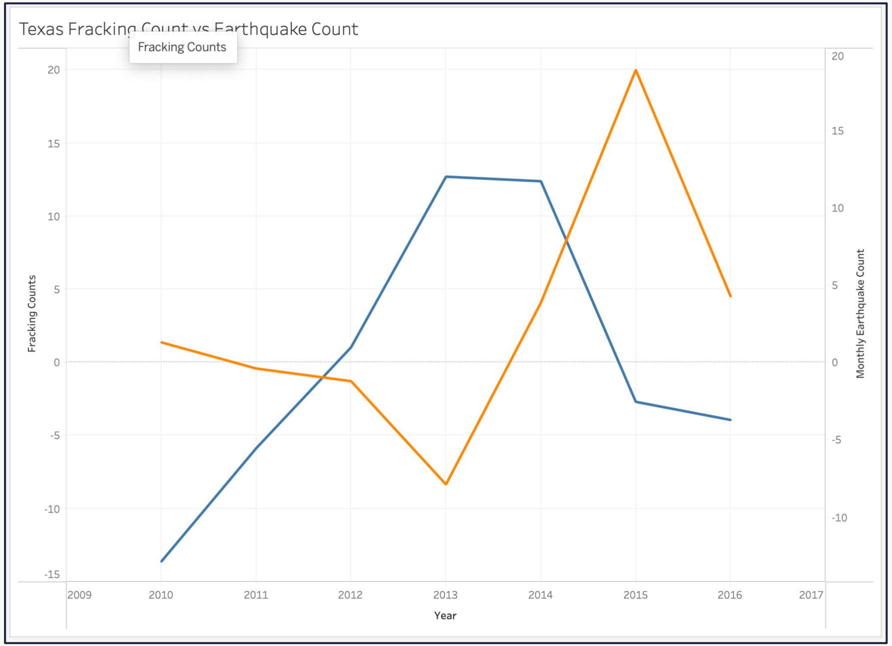
- Filtered National Data of Fracking occurrences to find possible correlations with earthquakes

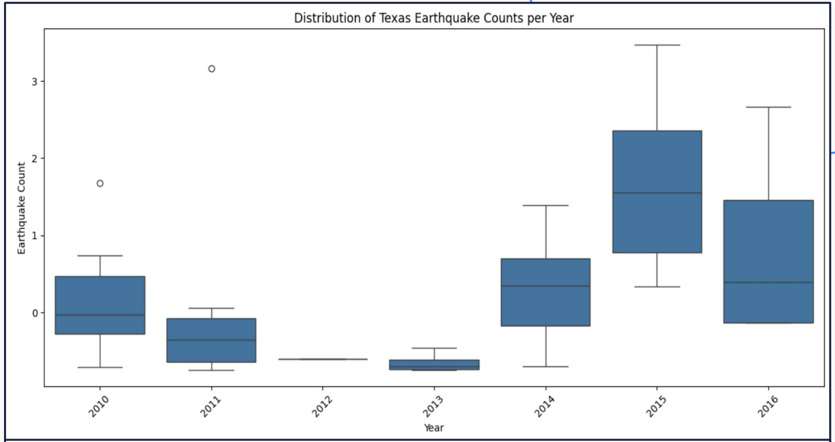
- Used Texas from 2010-2016 as sample since it has the most occurrences and utilized Texas Earthquake Data for improved accuracy

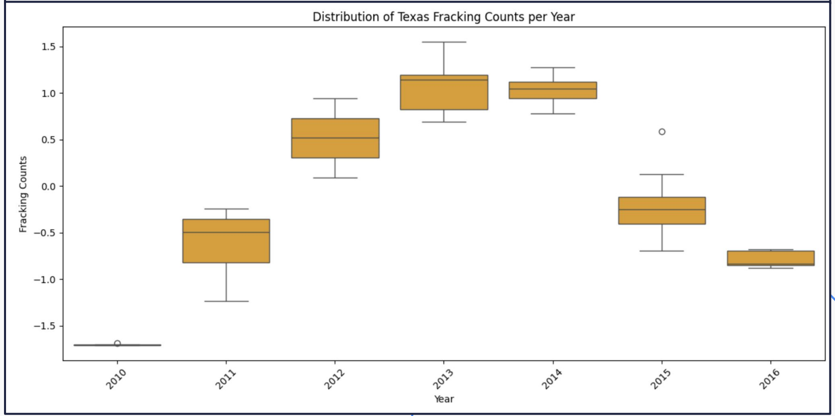
Fracking occurrences by State

Texas	105703
Colorado	20291
Oklahoma	18888
North Dakota	16653
New Mexico	12094
Pennsylvania	10901
Wyoming	6435
Utah	5745
Louisiana	4378
California	3826

Fracking Count vs Earthquake Count







Can fracking count help predict the amount of Earthquakes that occur?

MLR

	coef	std err	t	P>|t|	[0.025	0.975]
const	-674.5656	136.974	-4.925	0.000	-948.749	-400.383
Fracking Counts	-0.4770	0.129	-3.703	0.000	-0.735	-0.219
Year	0.3352	0.068	4.927	0.000	0.199	0.471

Multiple Linear Regression

Predictors

Fracking Count
Year

Adjusted R Square : 0.132
Mean Error (ME) : 0.0000
Root Mean Squared Error (RMSE) : 0.7260
Mean Absolute Error (MAE) : 0.5630

About 13% of the variance of Earthquakes in Texas are explained by Year and Fracking Count

Current State of Fracking

Incoming Regulations

- California plans to ban fracking by the end of 2024
- Public and legislative pressure has led to increased scrutiny and regulatory oversight.

Relation with SoCal Edison

- Limited fracking operations within Southern California compared to other regions.
- Focus on renewable energy initiatives aligns with state environmental policies
- Investment in renewable energy and sustainable practices as part of risk mitigation strategies

04 Conclusions

What Can Be Improved?

More Data

More data would help validate our findings further as well as uncover insights that were not clear in our analysis

Complex Models

Techniques such as vector autoregression (VAR) or machine learning models that can handle complex nonlinear relationships might be more effective

Non Stationary Models

11 year solar cycles were the only clear seasonal data we have which was limited

Geographical Analysis

Daily measurements or finer geographic distinctions could uncover patterns not visible in coarser data.

What we Learned

Droughts & Sunspots

During solar maximums, increased sunspot activity can intensify drought conditions, emphasizing the interconnectedness of solar phenomena and Earth's climate

6.0+ Earthquakes

Higher magnitude earthquakes are influenced by sunspot activity and greenhouse gases have an independent impact on earthquakes

Aerosols as Predictors

Identified aerosols as a significant predictor for earthquake counts, suggesting a potential linkage between atmospheric conditions and seismic activities

Sunspot - Earthquake Lag

Sunspot activity exhibits a delayed (lagged) effect on earthquake occurrences, indicating a complex interaction between solar activity and tectonic movements

High Level Droughts - Power Outages

The relationship between exceptional drought conditions and power outages highlights the critical need for strategic planning and adaptation measures

CO2 Impact

Our research suggests that increases in CO_2 levels are correlated with earthquake activities, possibly due to the influence of CO_2 on atmospheric and terrestrial dynamics

Closing Remarks

A Holistic View

This project highlights the interconnectedness of atmospheric, solar, and terrestrial phenomena, urging a holistic approach to environmental and earth sciences.

Call to Action

Continued monitoring and collaboration across scientific disciplines are essential to harness these insights for practical applications in EMP preparedness and climate adaptation strategies.

Thank You for Listening!

Data Sources

Daily total and hemispheric sunspot numbers:

https://www.sidc.be/SILSO/infosndhem

Historical Data & Conditions:

https://www.drought.gov/historical-information?dataset=0&selectedDateUSDM=20120124

Earthquake Data 1970-2014:

https://data.humdata.org/dataset/catalog-of-earthquakes1970-2014/resource/10ac8776-5141-494b-b3cd-bf7764b2f964

Earthquake Data 1990-2023
https://www.kaggle.com/datasets/alessandrolobello/the-ultimate-earthquake-dataset-from-1990-2023/data

Drought Data
https://www.drought.gov/historical-information?dataset=0&selectedDateUSDM=20120124

Ecology icon pack

Introduction

Do you know what helps you make your point crystal clear?
Lists like this one:

- They're simple
- You can organize your ideas clearly
- You'll never forget to buy milk!

And the most important thing: the audience won't miss the point of your presentation

01 About us

You can enter a subtitle here if you need it

About us

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon. The planet's name has nothing to do with the liquid metal, since Mercury was named after the Roman messenger god

Our history

2005

Jupiter is the biggest planet of them all

2008

Venus is the second planet from the Sun

2010

Despite being red, Mars is very cold

Our history

2012
Earth is the third planet from the Sun

2018
Mercury is the closest planet to the Sun

2022
Neptune is very far away from the Sun

Our goals

Mercury

Mercury is the closest planet to the Sun and the smallest one

Venus

Venus has a beautiful name, but also high temperatures

Our philosophy

Mission

Despite being red, Mars is actually a very cold place. It's full of iron oxide dust, which gives the planet its reddish cast

Vision

Jupiter is a gas giant and the biggest planet in the Solar System and the fourth-brightest object in the night sky

Values

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon

"This is a quote, words full of wisdom that someone important said and can make the reader get inspired."

—Someone Famous

To reinforce the concept, try using an image

Images reveal large amounts of data, so remember: use an image instead of a long text. Your audience will appreciate it

Office locations

Jupiter

Jupiter is the biggest planet of them all

Mars

Despite being red, Mars is very cold

Find out where all our offices around the world are located

Awesome words

Our services

Mercury

Mercury is the closest planet to the Sun

Venus

Venus is the second planet from the Sun

Mars

Despite being red, Mars is very cold

Saturn

Saturn is a gas giant and has several rings

Neptune

Neptune is very far away from the Sun

Jupiter

It’s the biggest planet in the Solar System

Best sellers

Mars

Despite being red, Mars is very cold

Venus

Venus is the second planet from the Sun

Saturn

Saturn is a gas giant and has several rings

Our strengths

Efficiency

Saturn is not the only planet with rings

Economy

Venus is the second planet from the Sun

Productivity

Despite being red, Mars is a really cold place

Commitment

Neptune is the farthest planet from the Sun

Our target

Gender

50%
Women

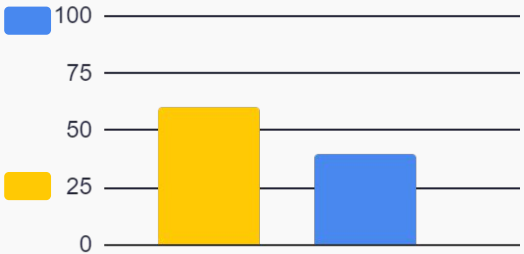
65%
Men

25%
Other

Age

60%
20-30

40%
31-40



To modify this graph, click on it, follow the link, change the data and paste the new graph here, replacing this one

Interests

Mercury is small

2/10

Mars is red

6/10

Our numbers

25%
Mars
Mars is cold

75%
Jupiter
Jupiter is big

Budget

Mars | Jupiter | Earth

25% | 50% | 75%

To modify this graph, click on it, follow the link, change the data and paste the new graph here, replacing this one

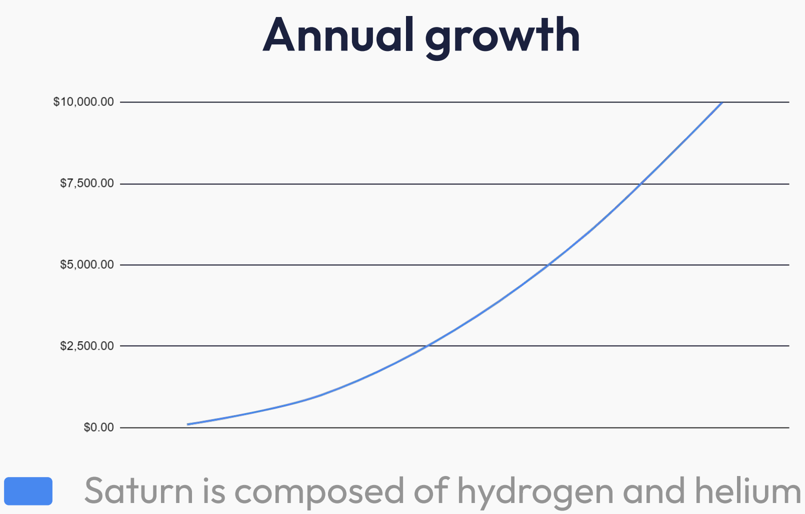
$28,000
Jupiter is big

6 months
Mars is very cold

45 panels
Earth has life

1 M units
Venus is very hot

Our growth



$20,000

Expected income for 2020

100

New employees next year

To modify this graph, click on it, follow the link, change the data and paste the new graph here, replacing this one

Future projects

Venus
Venus is the second planet from the Sun

2024

Mars
Despite being red, Mars is a cold place

2028

Saturn
Saturn is a gas giant and has several rings

2032

Earth
Earth is also known as the blue planet

2036

Customer testimonials

"Mercury is the closest planet to the Sun and the smallest one of them all"

—Helena James

"Venus has a beautiful name and is the second planet from the Sun"

—John Patterson

"Neptune is the fourth-largest planet in the Solar System"

—Jenna Doe

Awards we got

Mercury

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon

Venus

Venus has a beautiful name and is the second planet from the Sun. It's terribly hot, even hotter than Mercury

Jupiter

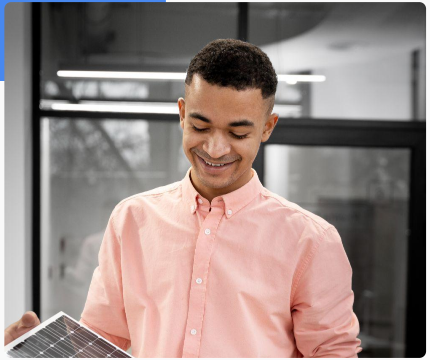
Despite being red, Mars is actually a very cold place. It's full of iron oxide dust, which gives the planet its reddish cast

Our team

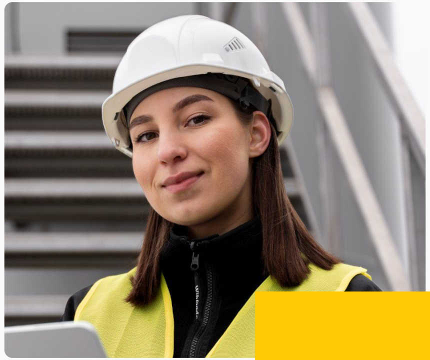
John James

Jenna Doe

Jane Patterson



You can replace the image on the screen with your own



You can replace the image on the screen with your own

You can replace the image on the screen with your own

Our services

Service	Description	Price
Venus	Venus has a beautiful name and is a hot planet	$120-$250
Jupiter	Jupiter is the biggest planet in the Solar System	$400-$800
Neptune	Neptune is the farthest planet from the Sun	$1,000-$2,600

150,000

Big numbers catch your audience's attention

9h 55m 23s

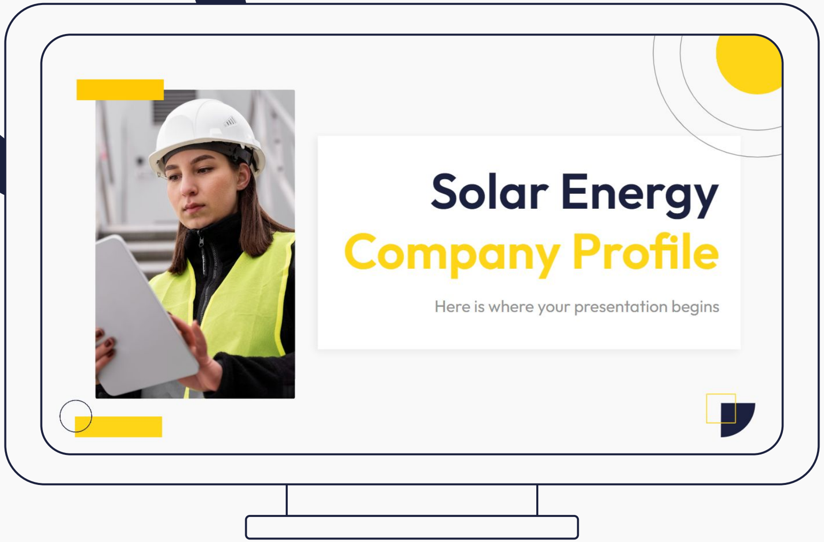
Jupiter's rotation period

333,000

The Sun's mass compared to Earth's

386,000 km

Distance between Earth and the Moon



PC mockup

You can replace the image on the screen with your own work. Just right-click on it and select “Replace image”

Thanks

Do you have any questions?

addyouremail@freepik.com
+91 620 421 838
yourwebsite.com

Please keep this slide for attribution

References

https://frontiersin.org/articles/10.3389/feart.2021.790412/full
https://yaleclimateconnections.org/2023/05/climate-change-and-droughts-whats-the-connection/#:~:text=Warmer%20temperatures%20lead%20to%20drying&text=For%20that%20reason%2C%20hotter%20weather,will%20increase%20in%20some%20regions.

Icon pack