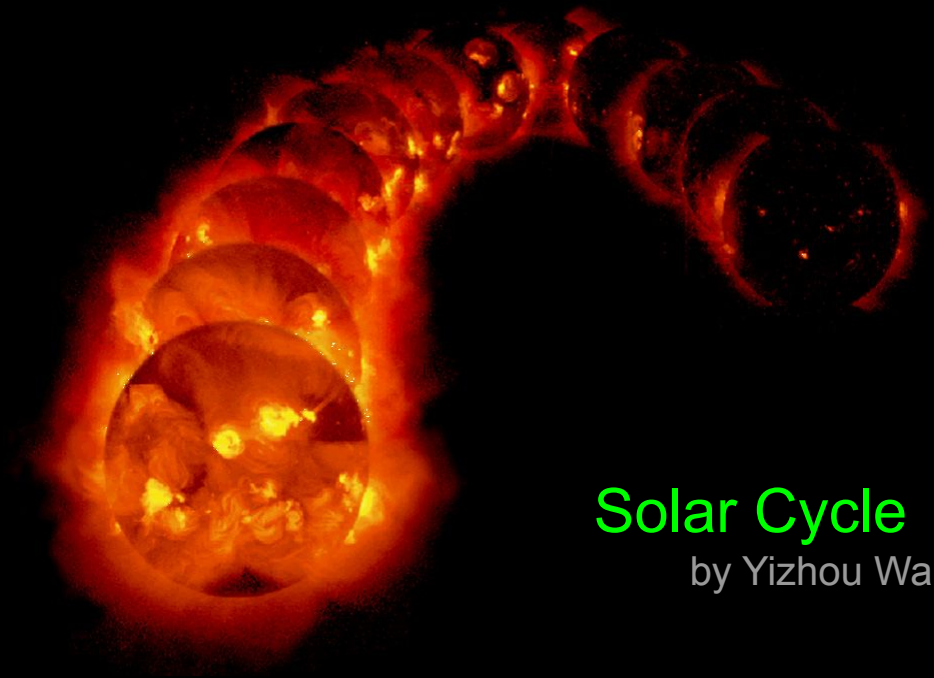
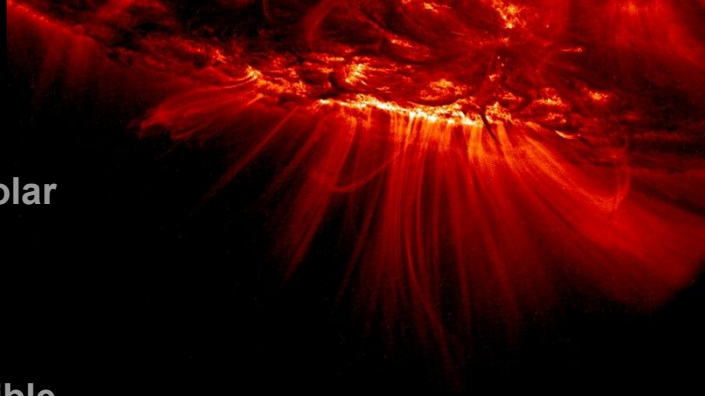


Solar Cycle

by Yizhou Wan, Anni Zheng



Abstract + Platform

Sunspots are regions where magnetic field influx suppresses solar convections.

Sunspot data are important because they comprehend the characteristics of the Sun and similar stars, and provide a possible way to classify them.

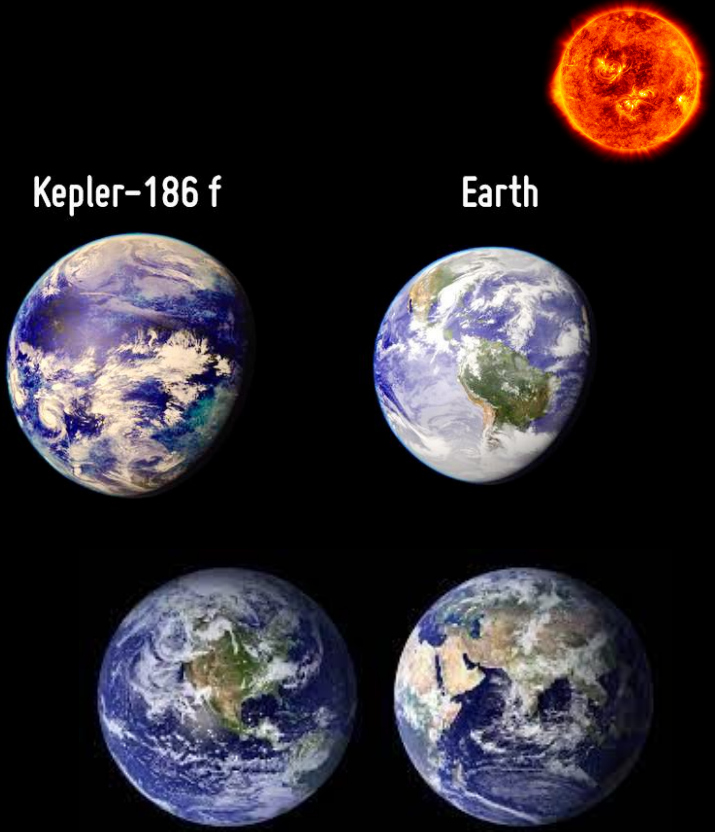
The project further prove the correspondence between solar magnetic field strength and sunspot number.

It mainly demonstrates the relationship between solar magnetic field strength and sunspot number.

We are going to use Hadoop MapReduce and Hive (both in NYU Peel Cluster) to organize data, and Excel to visualize the Solar Cycle.

Motivation + User Target + Importance

The Sun is the closest star to our Earth. It is one of the main factors why Earth is formed in its own unique way of providing a suitable environment for organisms and even civilizations to exist. It is even set as one of the requirements of finding a twin Earth or new Earth. So, to study the characteristics of the Sun is important, and to examine the polar reversal (solar cycle) of the Sun is crucial. **Knowing this trait of the Sun, astronomers can detect similar stars without looking closely at them. They can even detect a "second Earth" through the locality of "a second Sun".**

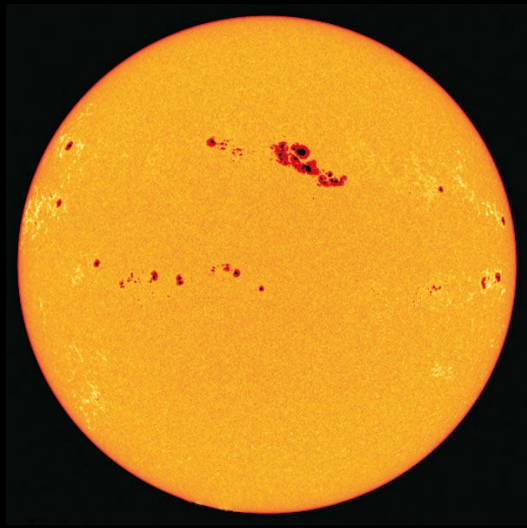


Goodness + Steps taken to access the goodness of analytic

The goodness of fit of the result of our project is high due to that **it is almost an universal acknowledgement to use sunspot number as a way to demonstrate Solar Cycle**, and solar magnetic field is the cause of sunspot area.

Here are some related works that are published in authoritative websites

- The Solar Flux and Sunspot Number; A Long Trend Analysis
- On Polar Magnetic Field Reversal in Solar Cycle 21, 22, 23, and 24
- Wikipedia: Solar cycle
- Stanford Solar Center: Solar Eclipse



Data Source: Sunspot Number Data

Source Link:
http://wso.stanford.edu/#MeanField

Original Data Format:
year, month, day, date, sunspot number,
standard deviation, number of observations,
provisional indicator

Normalized Data Format:
year, month, day, sunspot number

What does it demonstrate:
Sunspot number per day

SN_d_tot_V2.0.txt

```
1991 12 31 1991.999   222   14.7    16
1992  1 01 1992.001   186   14.3    19
1992  1 02 1992.004   190    8.2    21
1992  1 03 1992.007   234   18.3    21
1992  1 04 1992.010   243   14.8    20
1992  1 05 1992.012   242   13.8    18
1992  1 06 1992.015   245   18.7    14
1992  1 07 1992.018   251   20.9    14
1992  1 08 1992.020   270   19.2    20
1992  1 09 1992.023   255   18.2    10
1992  1 10 1992.026   242   12.4    18
1992  1 11 1992.029   205    9.5    20
1992  1 12 1992.031   189   11.0    16
1992  1 13 1992.034   188    8.9    18
1992  1 14 1992.037   143    7.6    17
1992  1 15 1992.040   141    7.3    17
1992  1 16 1992.042   115    4.8    14
1992  1 17 1992.045   100    7.0    22
1992  1 18 1992.048    94   10.8    24
1992  1 19 1992.051   116    7.9    15
1992  1 20 1992.053   152    8.7    18
1992  1 21 1992.056   188    6.8    22
```

Data Source: Solar Magnetic Field Strength Data

Source Link:
http://wso.stanford.edu/#MeanField

Original Data Format:
day, month (January - December) / year

Normalized Data Format:
year, month, day, number

What does it demonstrate:
Magnetic field strength (if recorded) of the Sun per day

Stanford Mean Solar Magnetic Field (microTesla)

1992

day	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
01	-97	-6	73	53	7	14	8	39	88	.	19	-16
02	-78	25	.	25	0	17	17	60	67	.	-5	.
03	-45	72	61	10	-1	23	13	58	43	.	-24	.
04	.	8	78	0	21	47	.	58	-22	.	-41	-39
05	53	28	.	-14	25	52	33	46	-27	.	-57	-38
06	.	.	.	-13	32	17	39	38	-18	.	-47	.
07	.	.	27	11	43	-5	21	37	13	4	-48	-20
08	104	.	19	21	43	-12	18	-4	24	-17	.	.
09	101	.	-3	1	33	-18	29	-45	19	-40	-29	.
10	125	.	15	-7	15	-18	39	-44	29	-68	-7	.
11	145	.	17	.	-13	-2	.	-10	-18	-57	-1	.
12	126	7	8	.	-19	20	.	-2	-25	-31	-5	-50
13	102	.	28	-34	-30	20	-55	10	-53	-38	-16	-41
14	54	.	.	-61	-44	18	-46	9	-46	-29	-24	-15
15	37	.	.	4	-50	6	-16	34	-33	-33	-23	8
16	12	.	.	-81	-14	-18	2	14	-30	-14	-19	11
17	-21	.	-31	-138	25	-13	8	-19	-26	-5	20	.
18	-43	.	-54	-121	.	-19	24	-4	-26	-13	57	6
19	-46	.	.	-59	21	12	25	11	-9	.	.	-9
20	-20	-33	.	-42	28	35	-31	-14	-13	-5	.	.
21	.	.	.	-19	39	23	-56	-12	-22	24	-2	-3
22	-6	-34	.	-9	35	10	-55	-17	-23	34	.	11
23	-16	-75	-50	3	62	-21	-59	-3	-1	66	-9	42
24	0	-64	13	20	88	-50	-55	-6	17	65	.	57
25	-46	-11	40	46	85	-45	-42	1	54	47	.	49
26	-36	75	40	70	50	-36	-26	4	79	20	.	40
27	-113	58	39	72	-64	-11	-5	25	85	-7	60	.
28	-126	63	55	49	-51	.	1	55	60	.	62	.
29	-115	.	.	42	-27	.	4	.	39	.	55	.
30	-74		.	27	-13	17	-1	101	7	-14	11	-59
31	.		82		8		-5	97		22		.

Data Source: Solar Corona Data

Source Link:
http://wso.stanford.edu/#MeanField

Original Data Format:
day, month (January - December) / year

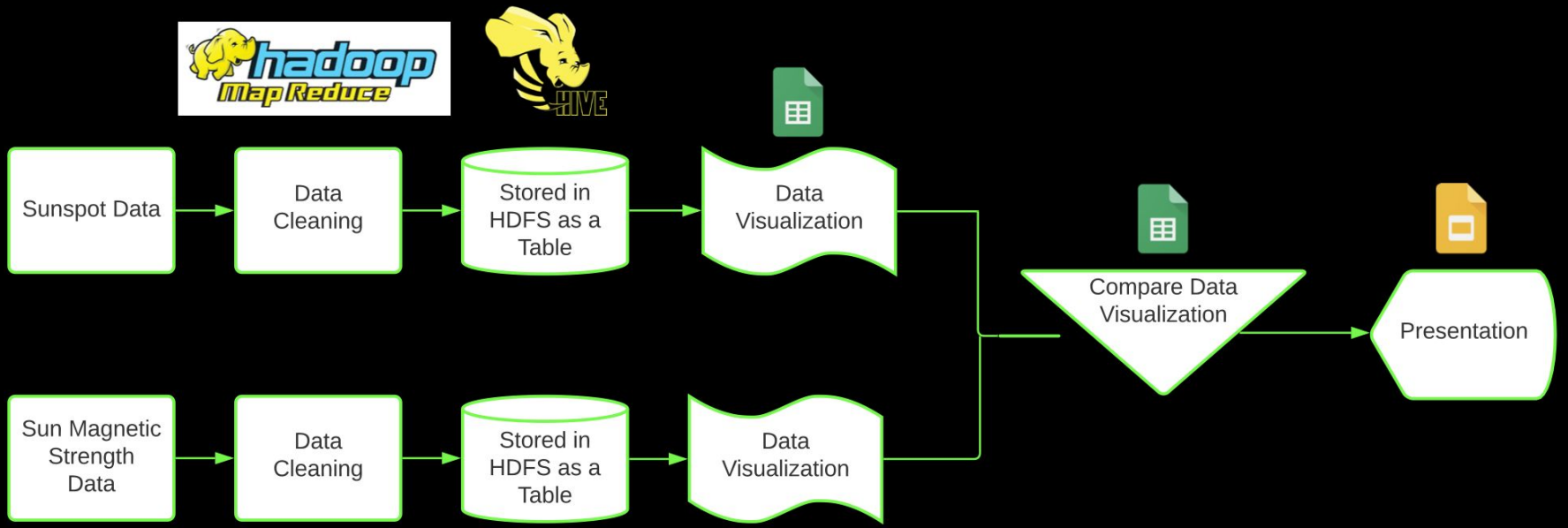
Normalized Data Format:
year, month, day, number

What does it demonstrate:
Solar coronal index change

1992 CORONAL INDEX OF SOLAR ACTIVITY 1992
Slovak Academy Fill-Disk Fe Emission (530.3 nm) Units=10**16 W/sr

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	16.04	14.26	14.23	13.62	12.18	9.58	8.45	8.48	8.79	8.36	8.88	10.68
2	15.91	13.08	14.33	12.60	12.06	9.58	8.39	9.18	9.00	8.91	8.33	8.88
3	16.99	12.76	14.26	13.28	11.63	9.94	8.81	9.17	8.93	9.17	8.49	9.84
4	17.90	13.02	14.12	12.97	11.19	9.98	8.86	10.10	8.79	9.03	8.13	9.61
5	17.22	12.74	14.25	12.62	10.94	9.75	9.51	10.36	8.55	8.85	8.43	9.49
6	16.18	12.82	14.32	12.38	10.41	10.20	11.20	10.15	8.75	9.03	8.33	9.63
7	15.46	12.87	13.88	12.11	11.19	11.12	11.57	10.95	8.41	9.18	8.31	10.20
8	14.96	13.25	13.86	11.45	11.55	9.91	11.63	11.16	8.47	9.38	8.22	9.45
9	14.92	14.08	13.77	11.86	12.00	11.21	10.66	9.92	8.43	8.86	9.49	9.53
10	14.78	14.64	13.92	11.53	12.43	11.86	11.44	10.38	8.69	8.57	8.50	9.04
11	14.02	13.64	13.81	11.53	12.98	11.32	11.41	10.36	9.03	8.44	9.71	10.20
12	13.34	12.66	13.40	12.08	12.83	11.63	11.41	10.17	8.63	8.59	8.66	10.66
13	12.98	12.85	12.65	12.68	13.65	12.06	10.93	10.89	8.26	8.42	8.81	10.69
14	12.71	13.01	12.80	12.77	14.02	11.56	10.65	11.28	8.55	8.21	8.94	11.20
15	11.93	12.81	13.00	13.08	14.30	11.24	10.30	10.26	8.59	8.28	8.91	11.10
16	11.98	12.24	13.68	13.26	13.22	10.50	10.38	9.84	9.04	7.99	8.91	9.69
17	11.60	11.66	13.91	13.77	14.07	10.49	9.97	9.42	9.64	7.89	9.21	12.00
18	12.00	12.02	14.26	14.11	13.51	10.47	10.14	9.10	9.49	7.80	9.69	11.86
19	11.98	12.76	13.79	15.23	13.83	10.54	10.08	9.61	9.32	7.79	9.31	11.35
20	11.93	13.22	14.65	14.49	13.45	10.21	9.08	8.40	9.53	7.65	9.11	11.28

Design Diagram



Code Challenge

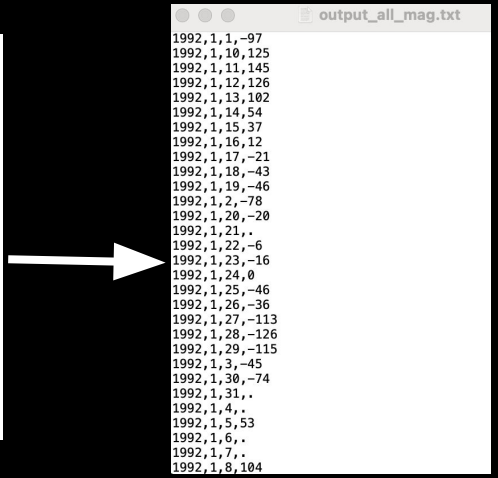
MapReduce Formatting

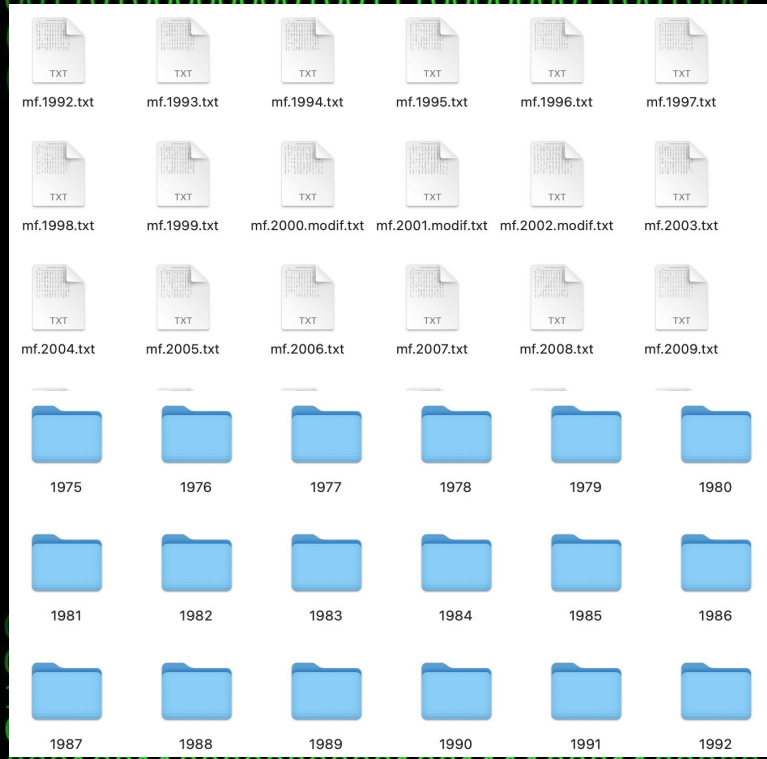
mf.1992.txt

Stanford Mean Solar Magnetic Field (microTesla)

1992

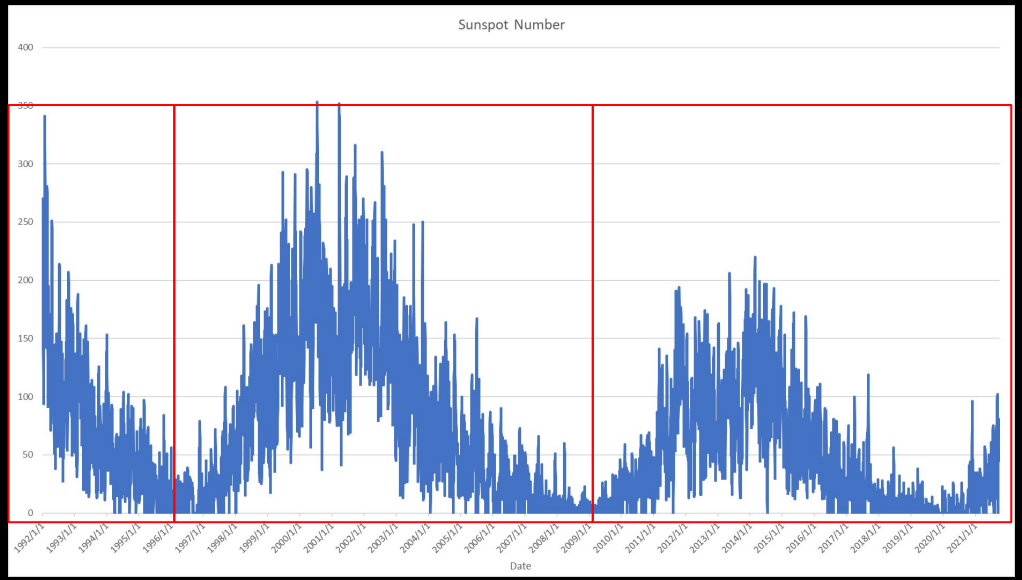
day	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
01	-97	-6	73	53	7	14	8	39	88	.	19	-16
02	-78	25	.	25	0	17	17	60	67	.	-5	.
03	-45	72	61	10	-1	23	13	58	43	.	-24	.
04	.	8	78	0	21	47	.	58	-22	.	-41	-39
05	53	28	.	-14	25	52	33	46	-27	.	-57	-38
06	.	.	.	-13	32	17	39	38	-18	.	-47	.
07	.	.	27	11	43	-5	21	37	13	4	-48	-20
08	104	.	19	21	43	-12	18	-4	24	-17	.	.
09	101	.	-3	1	33	-18	29	-45	19	-40	-29	.
10	125	.	15	-7	15	-18	39	-44	29	-68	-7	.
11	145	.	17	.	-13	-2	.	-10	-18	-57	-1	.
12	126	7	8	.	-19	20	.	-2	-25	-31	-5	-50
13	102	.	28	-34	-30	20	-55	10	-53	-38	-16	-41
14	54	.	.	-61	-44	18	-46	9	-46	-29	-24	-15
15	37	.	.	4	-50	6	-16	34	-33	-33	-23	8
16	12	.	.	-81	-14	-18	2	14	-30	-14	-19	11
17	-21	.	-31	-138	25	-13	8	-19	-26	-5	20	.
18	-43	.	-54	-121	.	-19	24	-4	-26	-13	57	6
19	-46	.	.	-59	21	12	25	11	-9	.	.	-9
20	-20	-33	.	-42	28	35	-31	-14	-13	-5	.	.

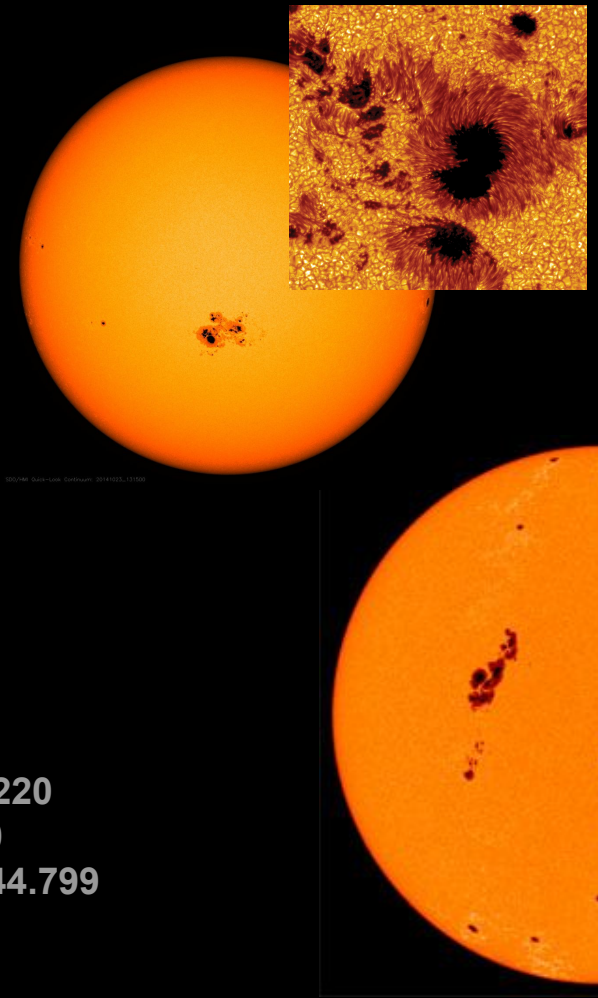




Concatenation of files

Visualization Sunspot Number



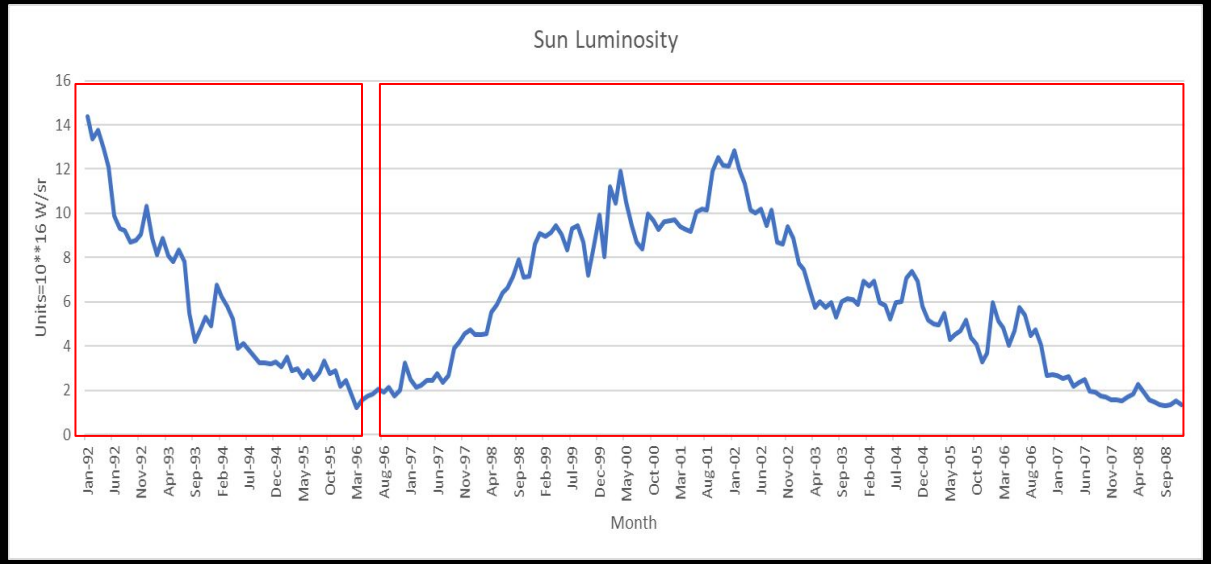


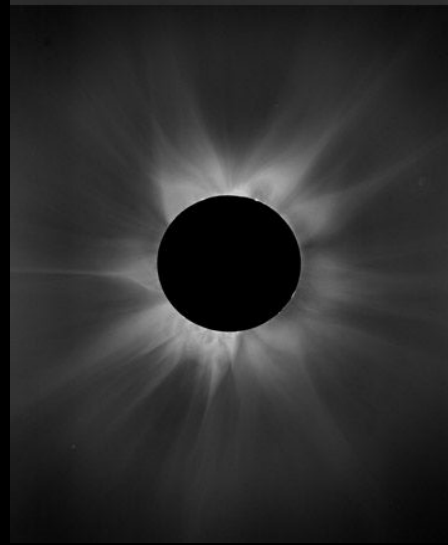
Cycle 23 Max: 341
Cycle 23 Min: 0
Cycle 23 Avg: 58.104

Cycle 24 Max: 353
Cycle 24 Min: 0
Cycle 24 Avg: 84.153

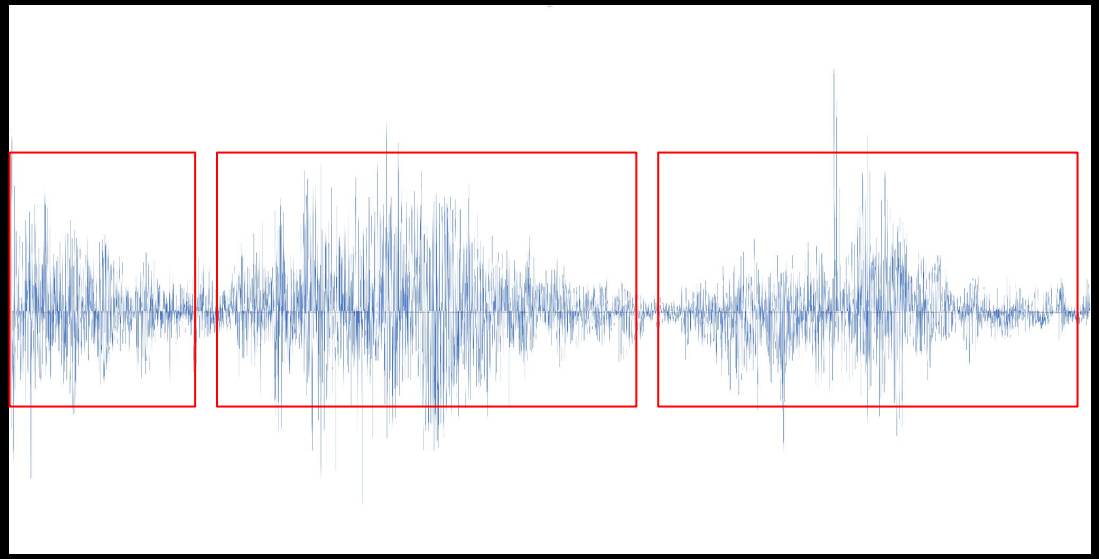
Cycle 25 Max: 220
Cycle 25 Min: 0
Cycle 25 Avg: 44.799

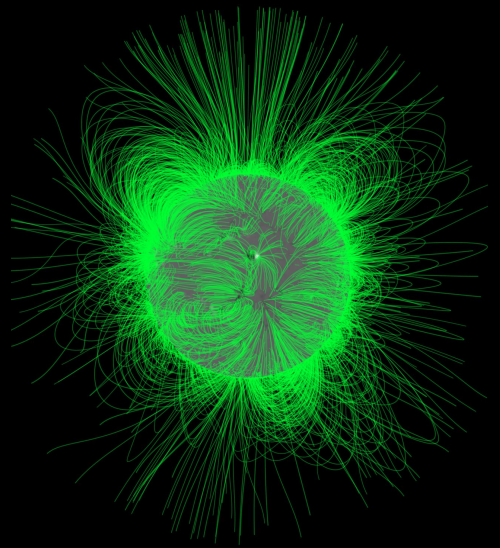
Visualization: Luminosity





Visualization: Solar Magnetic Field Strength



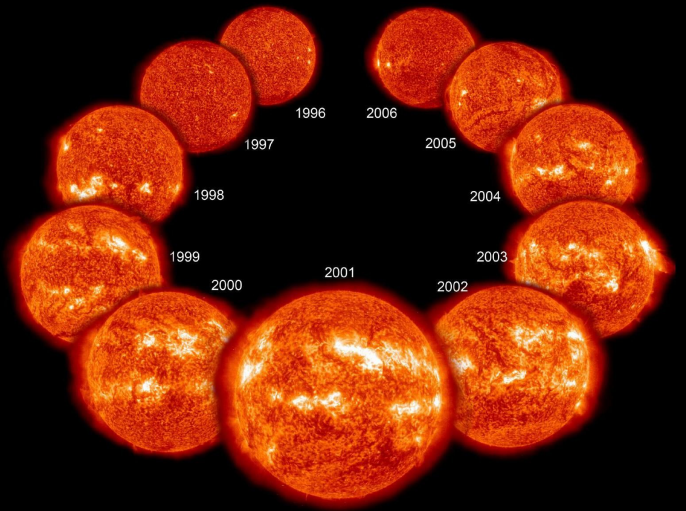


Cycle 23 Max: 174	Cycle 24 Max: 120	Cycle 25 Max: 200
Cycle 23 Min: -159	Cycle 24 Min: -117	Cycle 25 Min: -107
Cycle 23 Avg: 2.723	Cycle 24 Avg: -2.749	Cycle 25 Avg: 2.785

Obstacle

Missing year data (1985 - 1992; 2008 to 2021) for constructing correct sunspot number and luminosity trend for Cycle 23, 24, 25

Fail to predict future since Cycle 24 is anomalous as it had way less number of solar influx (and we still don’t know why)



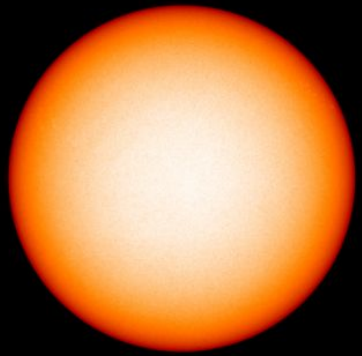
Summary

Solar Cycle happens every 10-11 years

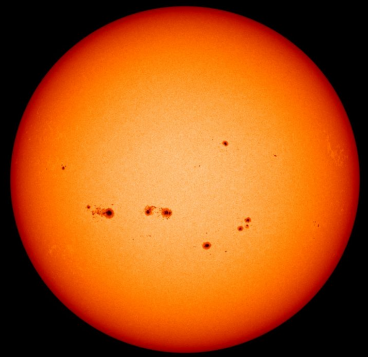
There exists a **positive relationship** between **sunspot number and solar magnetic field strength**, and a **negative relationship** between **sunspot number and solar luminosity** (i.e. coronal index)

> Specifically, the stronger the magnetic field force, the weaker the solar influx, therefore the more possible that there is a sunspot (or “cool region”) present
>
> Since the number of solar influx has a negative relationship with the sunspot number while having a positive relationship with the luminosity, we may also deduce that the greater the sunspot number, the “darker” the Sun’s surface (the weaker the Sun’s luminosity)

SOLAR **MINIMUM**



SOLAR **MAXIMUM**



Acknowledgement

We'd like to express our greatest gratitude to **Professor Malavet** for her teaching of Big Data tools and giving us this opportunity to work on our interest, and **NYU HPC Peel** platform administrators for providing us a convenient way for data analysis.

We would also like to thank **Royal Observatory of Belgium** for publishing sunspot number data. **The Wilcox Solar Observatory** for solar magnetic field data, and **National Centers for Environmental Information** for solar coronal index data.

Reference

- The Solar Flux and Sunspot Number; A Long Trend Analysis
- On Polar Magnetic Field Reversal in Solar Cycle 21, 22, 23, and 24
- Wikipedia: Solar cycle
- Stanford Solar Center: Solar Eclipse
- Sunspot Number Data
- Solar Magnetic Field Data
- Solar Coronal Index Data