Let’s predict a Coronal Mass Ejection

Educational Scenario

Metadata

General information

Title: Let's predict a Coronal Mass Ejection

Short description: Students learn about Coronal Mass Ejections (CMEs) and their effects on human civilization. In their attempt to predict if they will observe a Coronal Mass Ejection, they use scientific data to construct a diagram of the number of Coronal Mass Ejections over time and they try to spot a pattern. They also compare this diagram with various diagrams of sunspots over time linking CMEs with the solar cycle. They discuss about the scientific practices that they implemented and the importance of expressing a prediction by using possibilities.

Keywords: Sun, Coronal Mass Ejection, diagram, observation

Educational Context

Connection to the Greek Curricula: Physics 3rd grade of Junior High school-Magnets and Earth's magnetic field, Math 2nd grade of Junior High school-Cartesian coordinates and function graph

Age: 15-16

Prerequired: Basic information about the Sun, the position of the Earth at the Solar System and the magnets/magnetic fields

Duration: 2.5-3 school hours

Educational objectives

Cognitive

- To know that the activity of the Sun is changing according to the 11 year cycle.
- To know that the Coronal Mass Ejections and the sunspots are phenomena occurring at the Sun.
- To know that phenomena occurring at the Sun can affect our lives on Earth.
- To know that the Corona Borealis is related to the Sun.
- To understand that there is always some uncertainty to a scientific prediction.
- To identify a Coronal Mass Ejection when looking at the solar disk (at an appropriate filter).
- To realize the complexity of making a prediction.
- To realize that there are many factors in organizing and implementing an observation.

Affective

- To wonder about the credibility of a prediction.
- To improve their attitude towards science.

Phycomotor

- To be able to construct and read a table.
- To be able to construct and read a diagram.
- To improve their cooperation skills.

Orienting & Asking Questions

Orienting: Provide Contact with the content and/or provoke curiosity

How important do you think the Sun is for our life on Earth? Could we survive without it? Discuss this topic with the rest of the classroom.

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Write a few phenomena that you think are related to the Sun.

Watch the following video

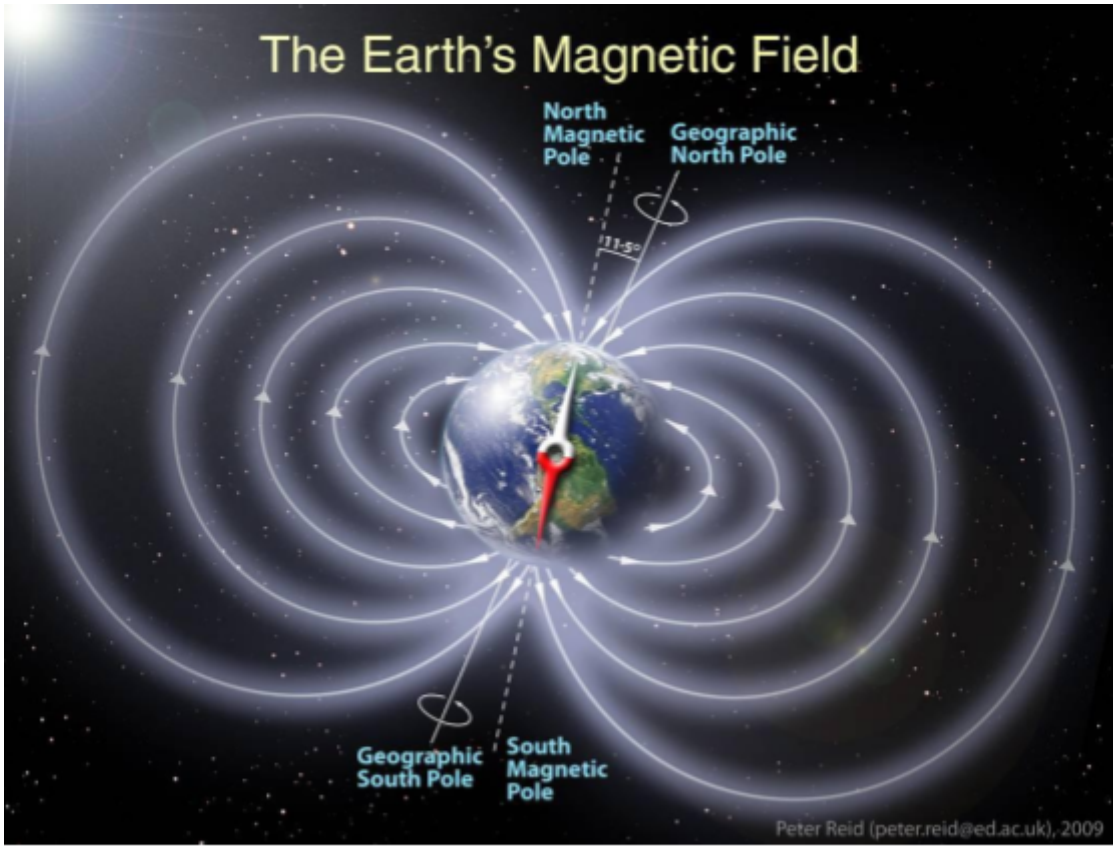
https://www.youtube.com/watch?v=SUhK7WzprU4

During a solar storm, solar flares and Coronal Mass Ejections occur on the Sun's surface. Watch the following video to learn what they are and to understand the differences between the two phenomena.

https://www.youtube.com/watch?v=TWjtYSRlOUI

Describe in a few words a day on Earth without technology.

Below you can see some representations of Earth's magnetic field. Magnetic fields are not visible but we observe them through the phenomena caused by them and the way charged particles move in magnetic fields.



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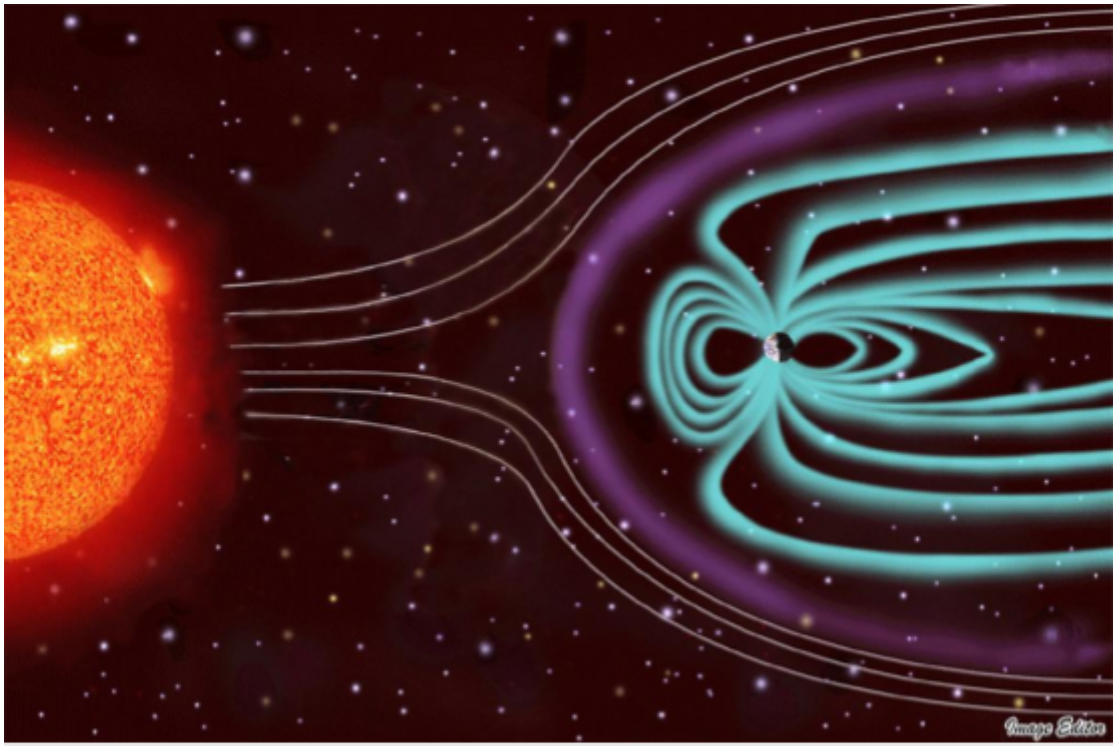

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See how Earth's magnetic field is affected by a Coronal Mass Ejection.

Click on the links below and observe a Coronal Mass Ejection through 5 different filters.

https://svs.gsfc.nasa.gov/4659

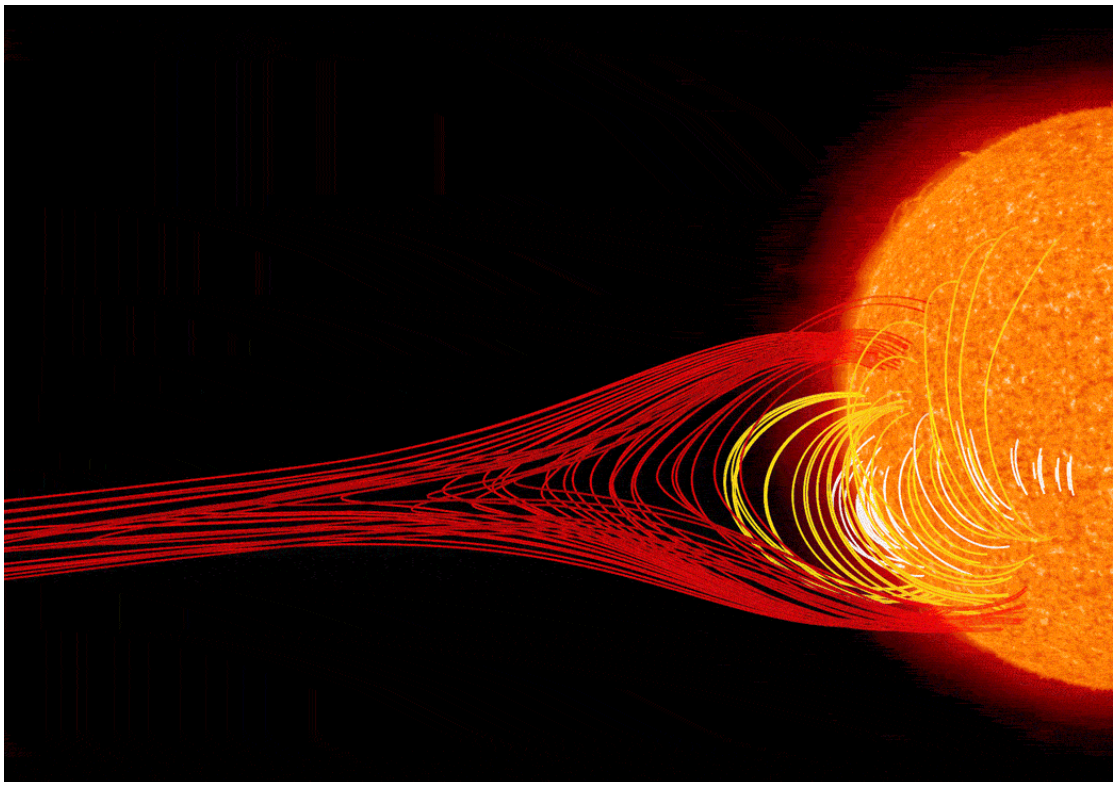
https://svs.gsfc.nasa.gov/4352

https://svs.gsfc.nasa.gov/3840

https://svs.gsfc.nasa.gov/3839

https://svs.gsfc.nasa.gov/3841

See on the following GIF how the Sun's magnetic field changes during a Coronal Mass Ejection (CME).



©NASA's Goddard Space Flight Center/ARMS/Joy Ng, producer, source

Define Goals and/or questions from current knowledge

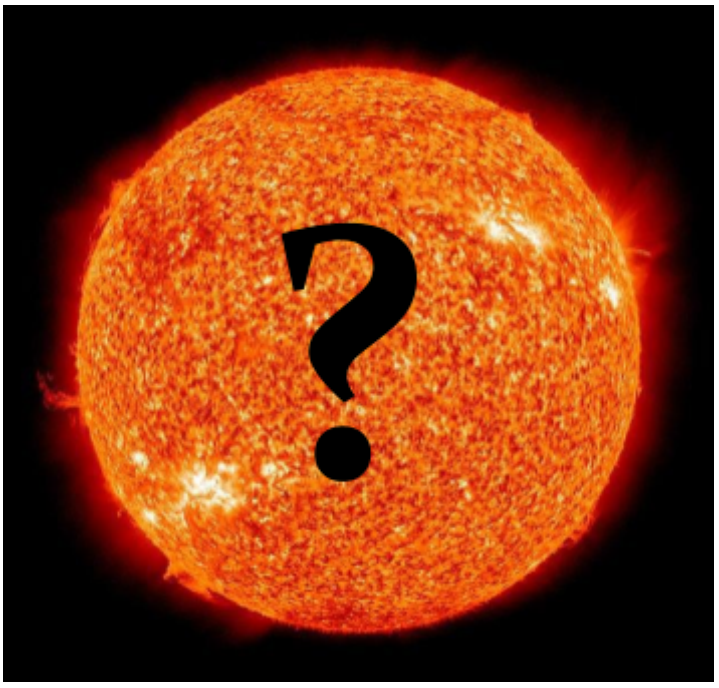
If you would like to observe a Coronal Mass Ejection which of the above filters would you choose? Is the CME visible to all 5 filters?

Can we predict when a Coronal Mass Ejection will occur in order to protect Earth's electronic grid and our everyday activities?

Hypothesis Generation and Design

Generation of Hypotheses or Preliminary Explanations

Do you think a CME will occur tomorrow? Where do you base your answer? Can you argument on that?



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When would you observe the Sun in order to see a CME?

How can you improve this prediction? Discuss the topic with the rest of your classroom.

Design/Model

Every year in Greece during December there are low temperatures and during August there are high temperatures. This is attributed to the seasons, but we know that it happens from our everyday experience because it is something that occurs every year. We can therefore predict, with high certainty, that during August it will be hot, as it is something that repeats regularly. The appearance of a phenomenon at regular basis makes its prediction much easier.

In the same way, in Greece, the Sun rises in the morning and sets after a few hours. This way we have light and darkness. The phenomenon of day and night is also repeated regularly allowing us to predict that tomorrow the Sun will rise and set after a few hours.

Can you do something similar in order to predict when a CME will occur at the Sun? Discuss this topic with the rest of the classroom.

Planning and Investigation

Plan Investigation

To improve your prediction you can study the records of observed CMEs trough time and try to spot a pattern.

Within the following links you can find how many CMEs have been recorded since 1996.

https://cdaw.gsfc.nasa.gov/CME_list/

https://cdaw.gsfc.nasa.gov/CME_list/UNIVERSAL/text_ver/

By clicking on a month, the recorded CMEs appear in the form of a table. Each line of the table represents a CME. Based on these data fill out the empty slots of the following table.

Month-Year	Number of month	Number of CMEs
January-08	1	97
February-08	2	65
March-08	3	100
April-08	4	80
May-08	5	73
June-08	6	70
July-08	7	76
August-08	8	52
September-08	9	56
October-08	10	67
November-08	11	57
December-08	12	70
January -09	13	62
February -09	14	51
March -09	15	61
April -09	16	60
May -09	17	
June -09	18	72
July -09	19	47
August -09	20	46
September -09	21	107
October -09	22	65
November -09	23	51
December -09	24	77
January -10	25	64
February -10	26	76
March -10	27	91
April -10	28	86
May -10	29	99
June -10	30	101
July -10	31	94
August -10	32	85
September -10	33	77
October -10	34	78
November -10	35	144
December -10	36	122
January -11	37	
February -11	38	89
March -11	39	179
April -11	40	205
May -11	41	202
June -11	42	187
July -11	43	140

August -11	44	136
September -11	45	190
October -11	46	227
November -11	47	178
December -11	48	173
January -12	49	155
February -12	50	118
March -12	51	152
April -12	52	172
May -12	53	164
June -12	54	229
July -12	55	241
August -12	56	203
September -12	57	184
October -12	58	136
November -12	59	196
December -12	60	227
January -13	61	227
February -13	62	192
March -13	63	180
April -13	64	206
May -13	65	261
June -13	66	169
July -13	67	136
August -13	68	147
September -13	69	143
October -13	70	254
November -13	71	196
December -13	72	227
January -14	73	211
February -14	74	177
March -14	75	208
April -14	76	226
May -14	77	238
June -14	78	259
July -14	79	191
August -14	80	167
September -14	81	156
October -14	82	211
November -14	83	225
December -14	84	209
January -15	85	178
February -15	86	135
March -15	87	189

April -15	88	200
May -15	89	197
June -15	90	150
July -15	91	179
August -15	92	167
September -15	93	165
October -15	94	168
November -15	95	167
December -15	96	163
January -16	97	172
February -16	98	161
March -16	99	130
April -16	100	123
May -16	101	142
June -16	102	114
July -16	103	112
August -16	104	
September -16	105	77
October -16	106	89
November -16	107	99
December -16	108	84
January -17	109	70
February -17	110	61
March -17	111	56
April -17	112	92
May -17	113	64
June -17	114	64
July -17	115	72
August -17	116	
September -17	117	68
October -17	118	71
November -17	119	51
December -17	120	52
January -18	121	37
February -18	122	33
March -18	123	46
April -18	124	48
May -18	125	47
June -18	126	36
July -18	127	39
August -18	128	48
September -18	129	38
October -18	130	40
November -18	131	

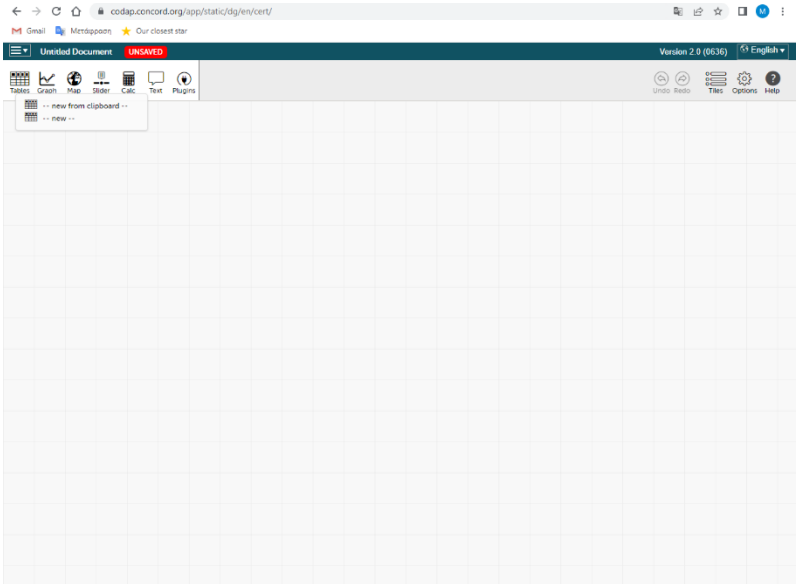
December -18	132	32
January -19	133	48
February -19	134	31
March -19	135	58
April -19	136	39
May -19	137	75
June -19	138	39
July -19	139	57
August -19	140	32
September -19	141	34
October -19	142	48
November -19	143	34
December -19	144	54
January -20	145	43
February -20	146	37
March -20	147	38
April -20	148	33
May -20	149	44
June -20	150	47
July -20	151	
August -20	152	67
September -20	153	47
October -20	154	56
November -20	155	103
December -20	156	82
January -21	157	63
February -21	158	55
March -21	159	45
April -21	160	66
May -21	161	77
June -21	162	77
July -21	163	87
August -21	164	82
September -21	165	130
October -21	166	91
November -21	167	82

Perform Investigation

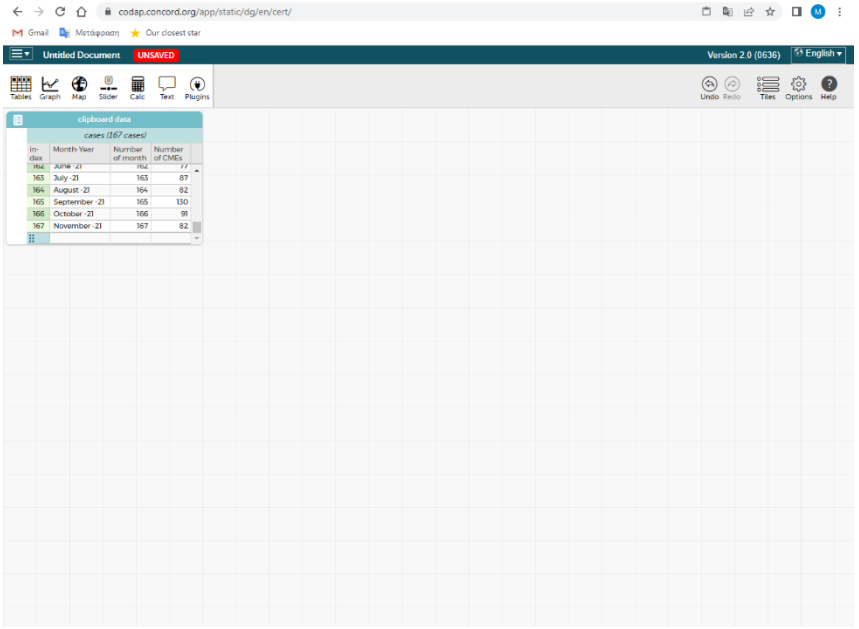
According to this table construct a diagram that shows the number of CMEs over time. To do that click on the following link that leads to an online program called CODAP that allows you to process data.

https://codap.concord.org/app/static/dg/el/cert/index.html

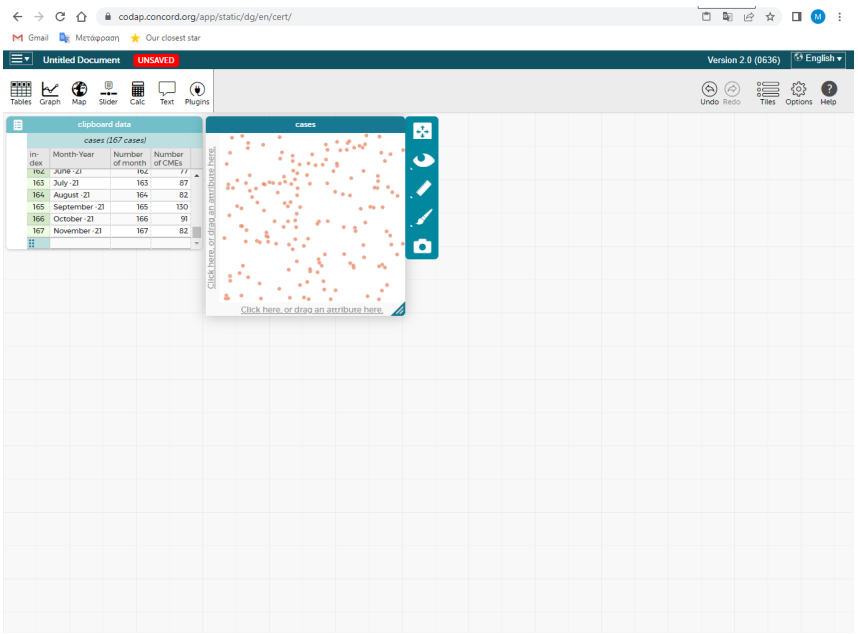
Choose the entire table that you filled out before and choose copy (after doing a right click). After that go to CODAP and click on the tab “Tables” and choose “new from clipboard”.



The table you filled out before will appear in the following form.



Click on the tab “Graph”. You will see the following image.



In order to construct your graph you have to choose the data you will put to the two axis. Which data would you choose for the x axis and the y axis in order to study how the number of CMEs changes over time? Discuss this topic with the rest of the classroom.

When you decide on this matter you can then click and drag the data you have chosen to the respective axis. The data will enter the axis and the graph will be created automatically.

Part of the graph can be constructed on paper for the students to practice on designing a graph.

Analysis & Interpretation

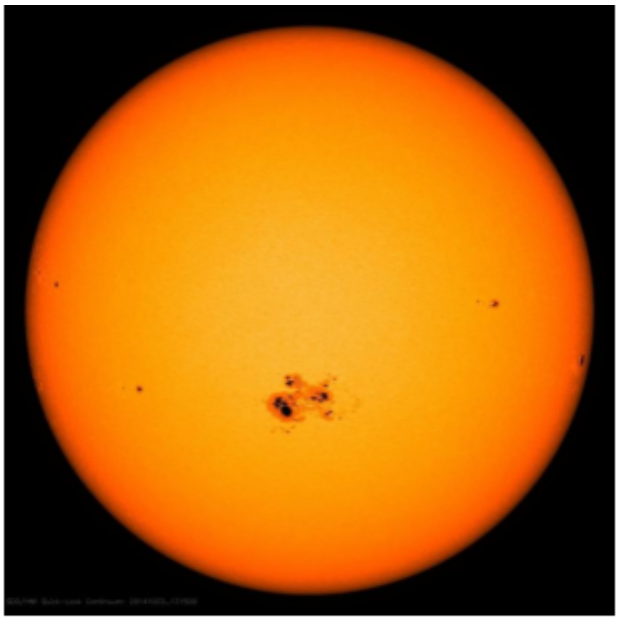
Analysis and interpretation : Gather result from data

What do you observe? How does the number of recorded CMEs change over time? Can you distinguish a repeating pattern? Discuss these questions with the rest of the classroom.

Let's study how another phenomenon occurring at the Sun changes over time...

In the following photograph you can see the Sun and a few dark areas on its surface. These dark areas are called sunspots and they are a phenomenon occurring at one of Sun's layers called photosphere. The number of sunspots is

linked with the Sun's activity and magnetic field. The more "active" the Sun, the more sunspots we observe.



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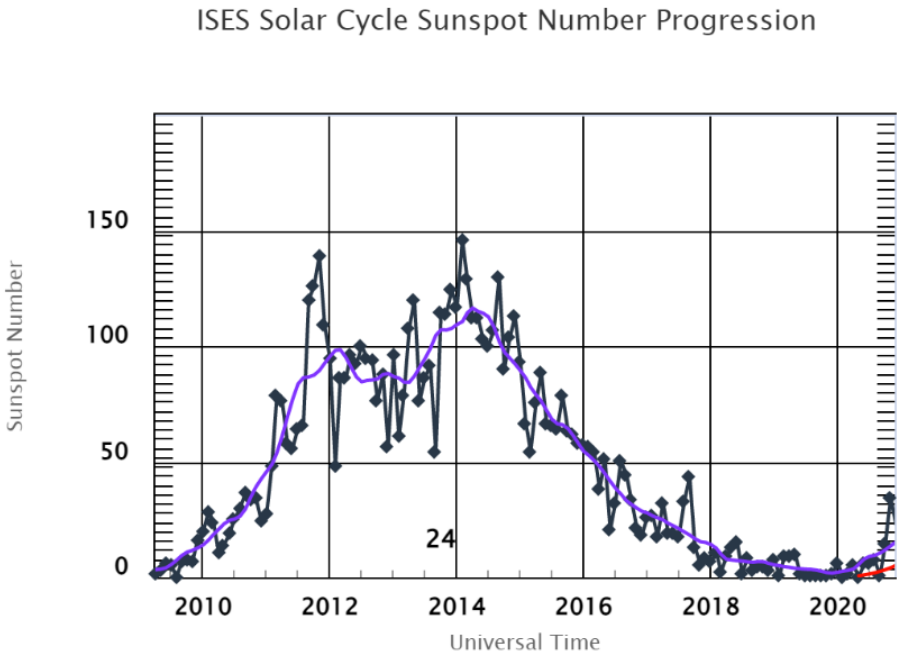
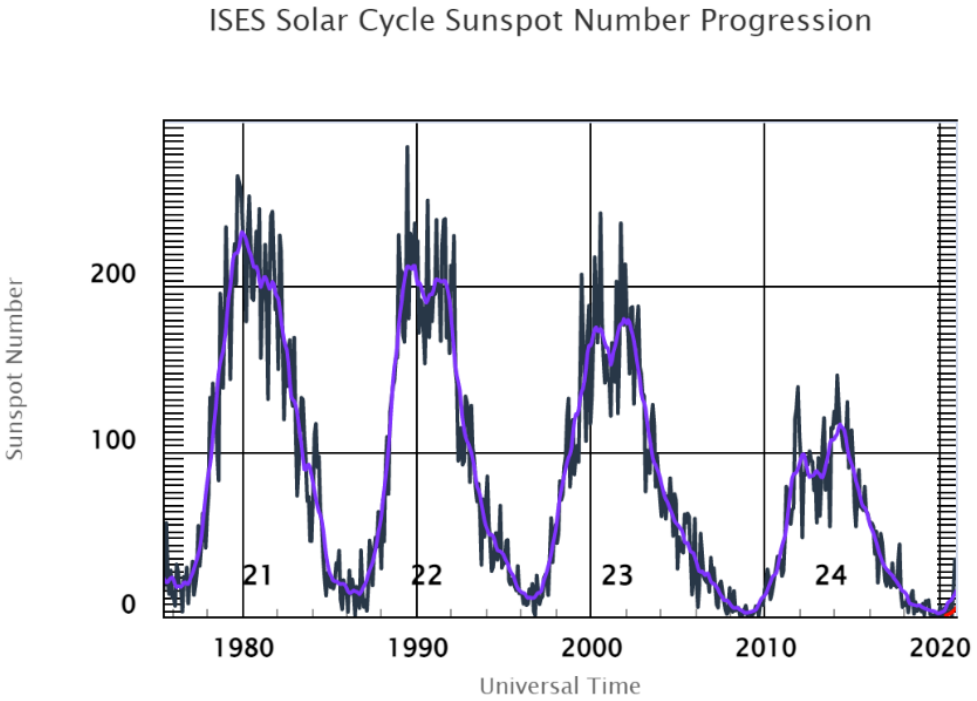
The diagram bellow represents the number of sunspots overtime for the same period as the CMEs' diagram you created before. What do you observe? Are there any similarities between the two diagrams?



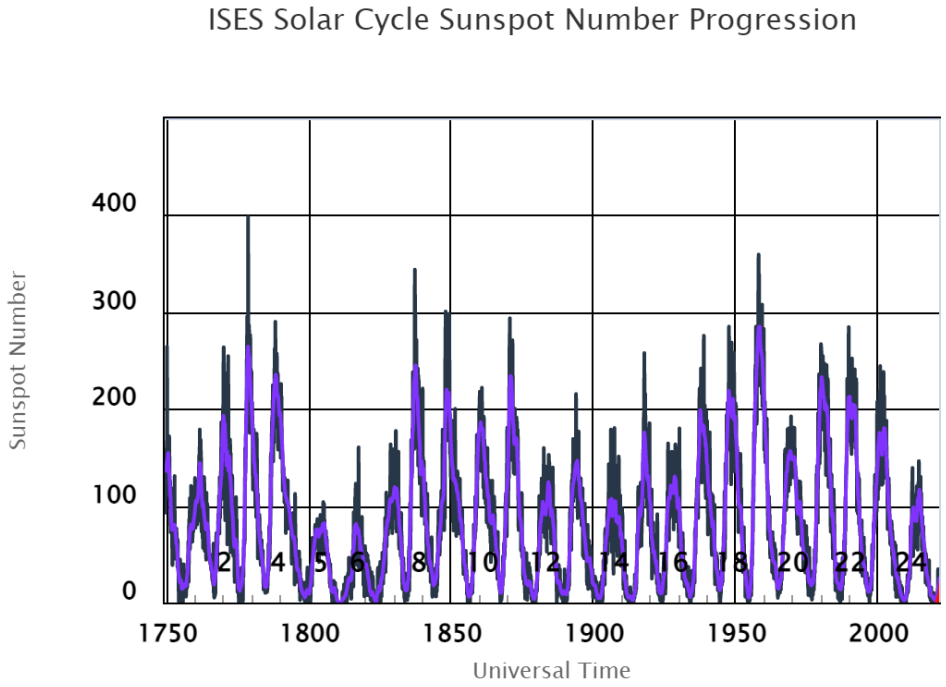
The dots represent the real data and the purple line their mean.

Observe the following changes to the number of sunspots overtime that have been seen on the Sun's surface. In this case the time period is larger. What do

you observe? Can you spot a pattern? Discuss this topic with the rest of the classroom.



Lastly in the following diagram you can see the number of sunspots overtime since their recording began.



What pattern do you observe? Is there a repetition to the way the number of sunspots changes? If the answer is yes, how long does this repetition lasts? Could you distinguish that just by looking at the numbers of the table?

This "repetition" is otherwise called the 11 year solar cycle. It represents the way Sun's activity and magnetic field changes overtime. This change is also observed indirectly through phenomena taking place on Earth (and not on the Sun) that are cause by the Sun, like Corona Borealis.

Conclusion & Evaluation

Conclude and communicate result/explanation

What is your conclusion? Do you think yesterday (a few days have passed since the previous lesson) a CME occurred at the Sun? How certain are you about this answer? Can you be 100% certain? Present your opinion to the classroom.

Evaluation/Reflection

Enter the online platform SOHO Movie Theater . At the "Image" dropdown choose a filter that will allow you to see a CME. Choose a 512 resolution and the dates for which you have made a prediction (you must choose two dates, but you can check your prediction for one of them in the video that will be created). Click on the "Generate" button and then on the "play" button to watch the created video?

What do you observe? How many CMEs do you see? Was your prediction correct?

How certain can scientists be when making a prediction?

Consider other explanations

If your school has a solar telescope or special filters go out, observe the Sun and discuss about what you see.

Solar cycle and sunspots (video): https://svs.gsfc.nasa.gov/10804

Are there any other phenomena or formations that we can see on the Sun?
https://www.nasa.gov/mission_pages/sunearth/the-heliopedia

CMEs and solar flares:
https://earthsky.org/space/is-a-solar-flare-the-same-thing-as-a-cme/

Watch the following video (from 6.48).

https://www.youtube.com/watch?v=b22HKFMIfW0