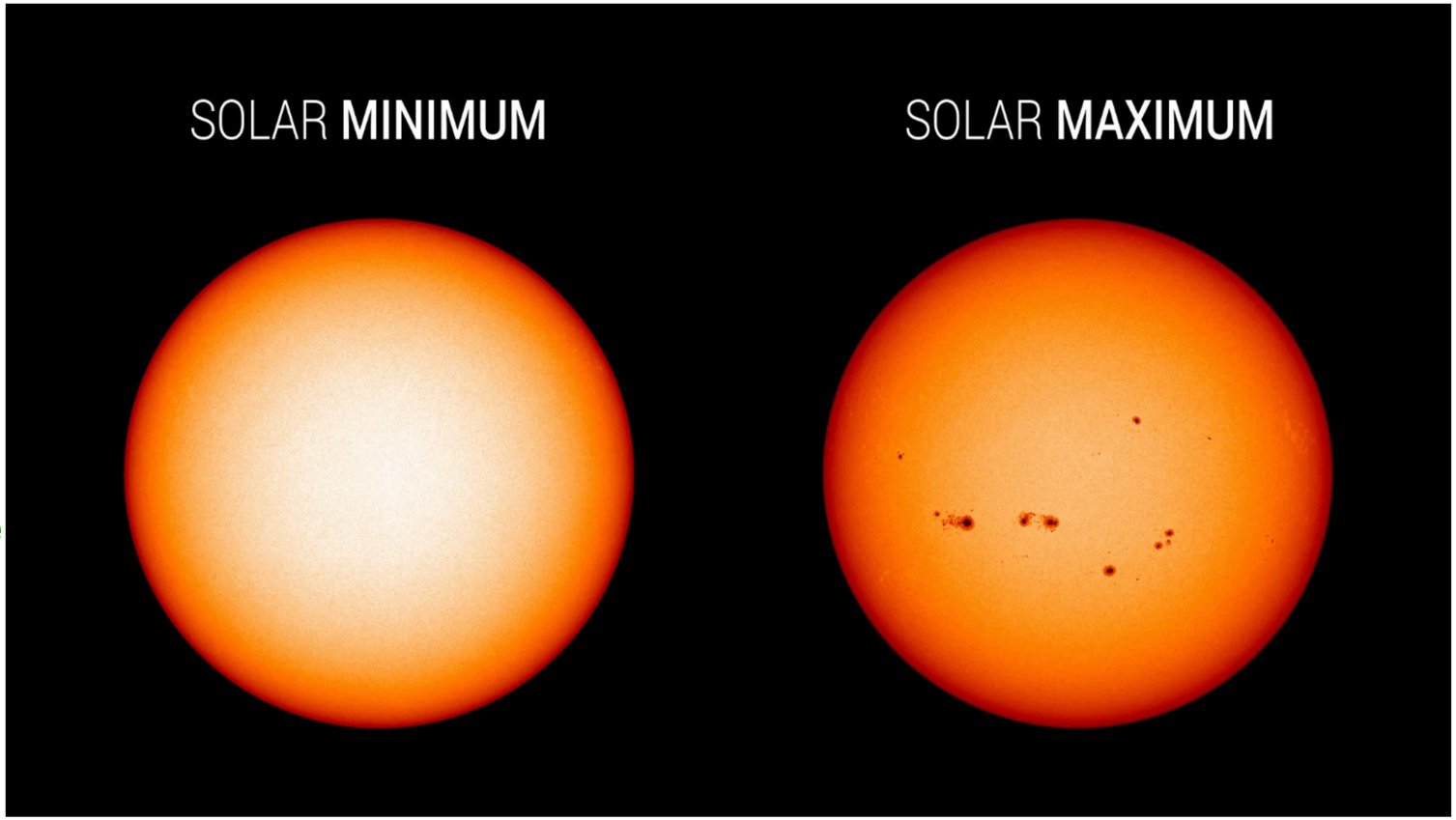
Name and Date:

Astronomy 122
Homework 1: Wolf Numbers and the Sun as a Variable Star
Due: by the end of January 26, 2024

I. We will find Wolf numbers for the Sun.

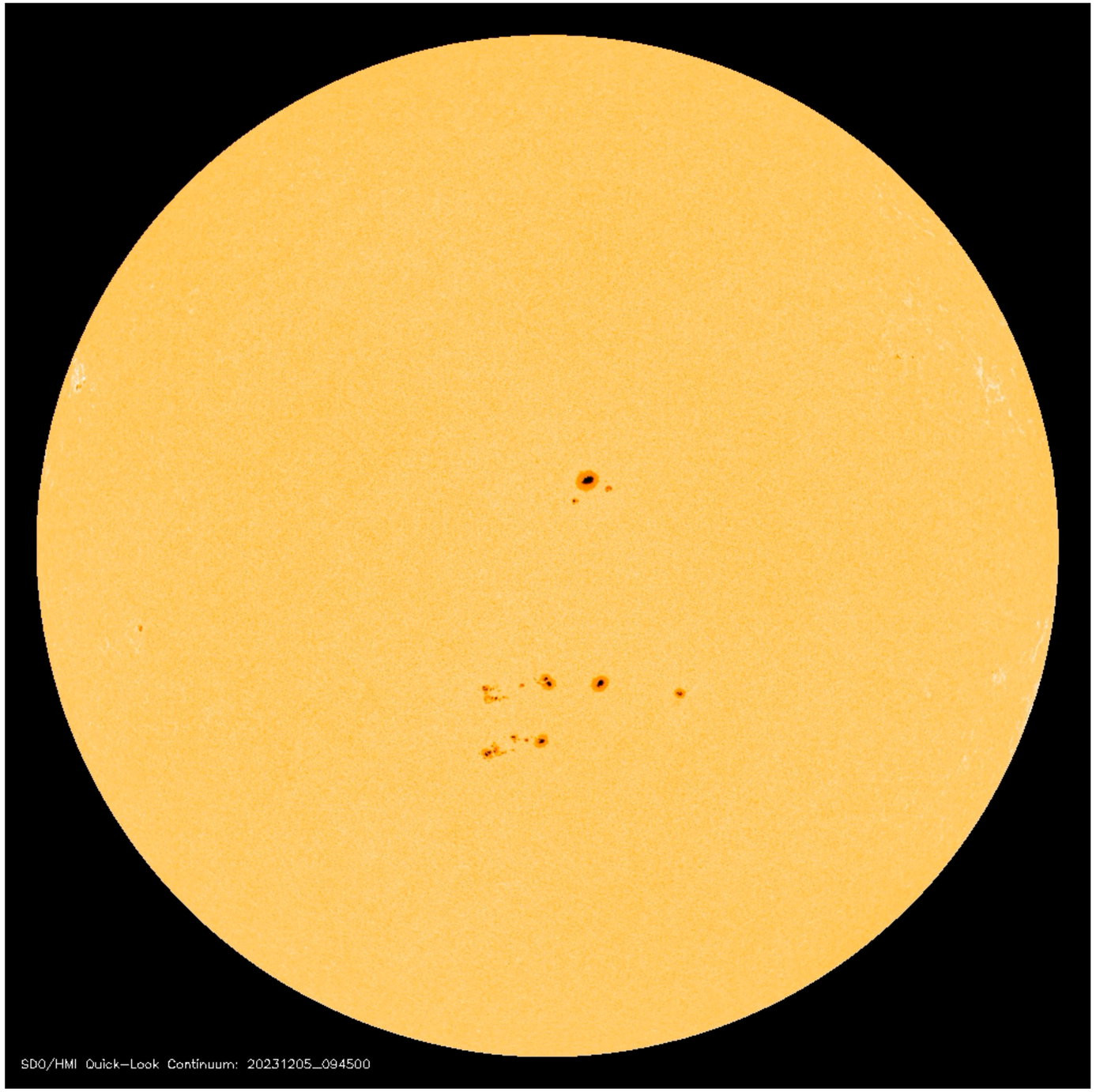
To the right are shown two snapshots of the Sun, the left taken in April 2014, and the right taken in December 2019. Find the Wolf number for each image. (1) Count the number of sunspots on the image. (2) Count the number of sunspot groups. The Wolf number is R = ***k***[(# of sunspots) + 10 x (# of sunspot groups)] Recall ***k*** is a fudge factor.



Visible-light images from NASA's Solar Dynamics Observatory show the Sun at solar minimum in December 2019 and the last solar maximum in April 2014. Sunspots freckle the Sun during solar maximum; the dark spots are associated with solar activity.
Credits: NASA's Solar Dynamics Observatory/Joy Ng

1. What are the Wolf numbers for each image? Use k = 1. Use table on Slide 3

If I see one sunspot, the Wolf number is R = 10 x (1 group) + (1 sunspot) = 11, $k = 1$.



The video at left (https://pages.uoregon.edu/imamura/122/homeworks/20231206_1024_HMII.mp4) was made on 2023 Dec 6 and 7 by the Solar Dynamics Observatory (SDO: https://sdo.gsfc.nasa.gov/mission/, NASA's Living With a Star Program). SDO is designed to help understand the Sun's influence on Earth and Near-Earth space. SDO was launched on 2010 February 11, 2010 from Cape Canaveral.

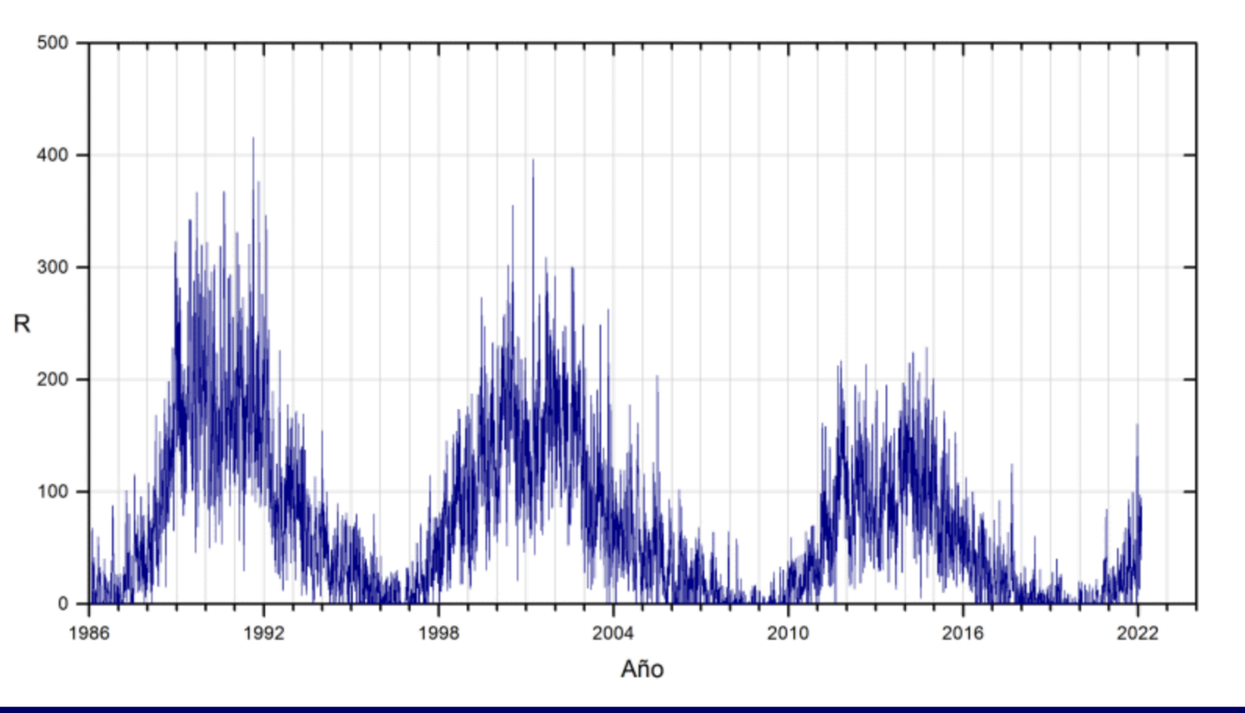
2. What are the Wolf numbers for the beginning and end of the sequence? Add to table on slide 3

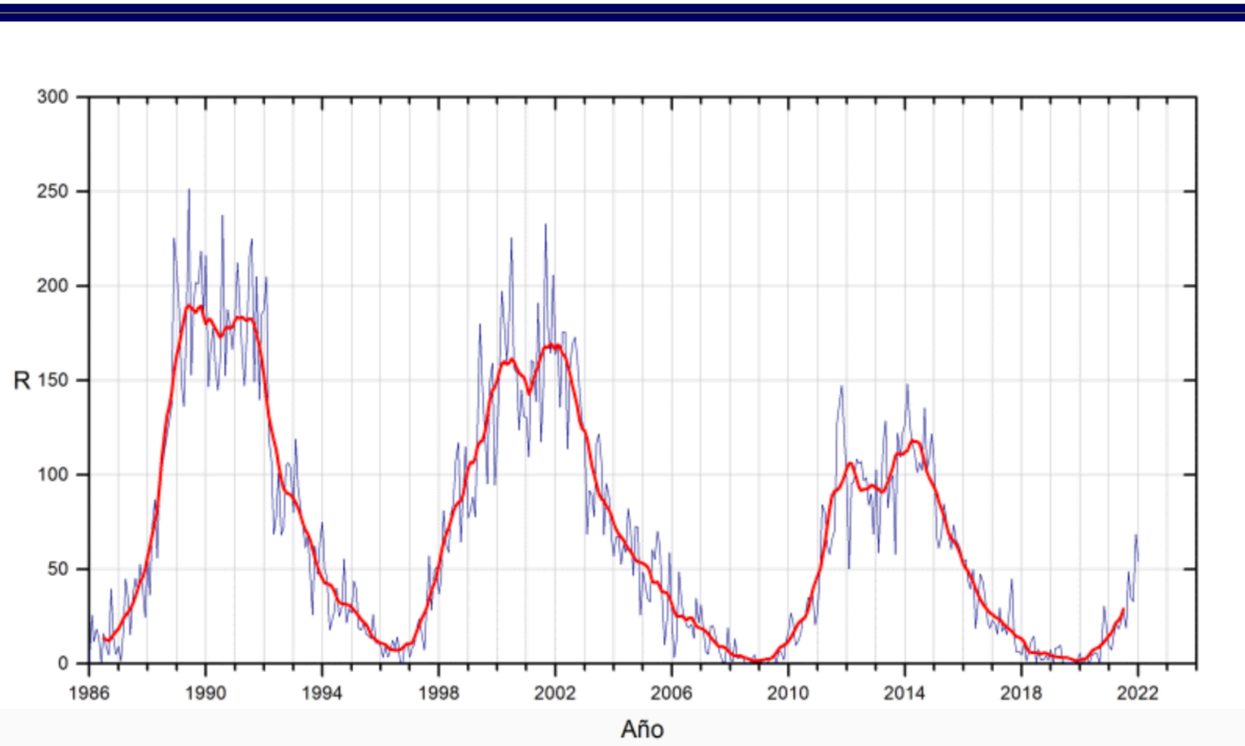
Time	# of Sunspots	# of Sunspot Groups	Wolf Number, R
Solar Minimum			
Solar Maximum			
Dec 6/7 Sequence			

The two plots show recent Wolf numbers for Solar Cycles 23 and 24, and the start of Cycle 25. The plots show daily, monthly, and annual averages.

3. On both the upper and lower plots, mark your measured Wolf numbers.

4. How much does it matter that you used snapshots to find Wolf numbers for your plots rather daily, monthly, or annual averages? What kind of errors does your technique introduce? Was using k = 1 reasonable?



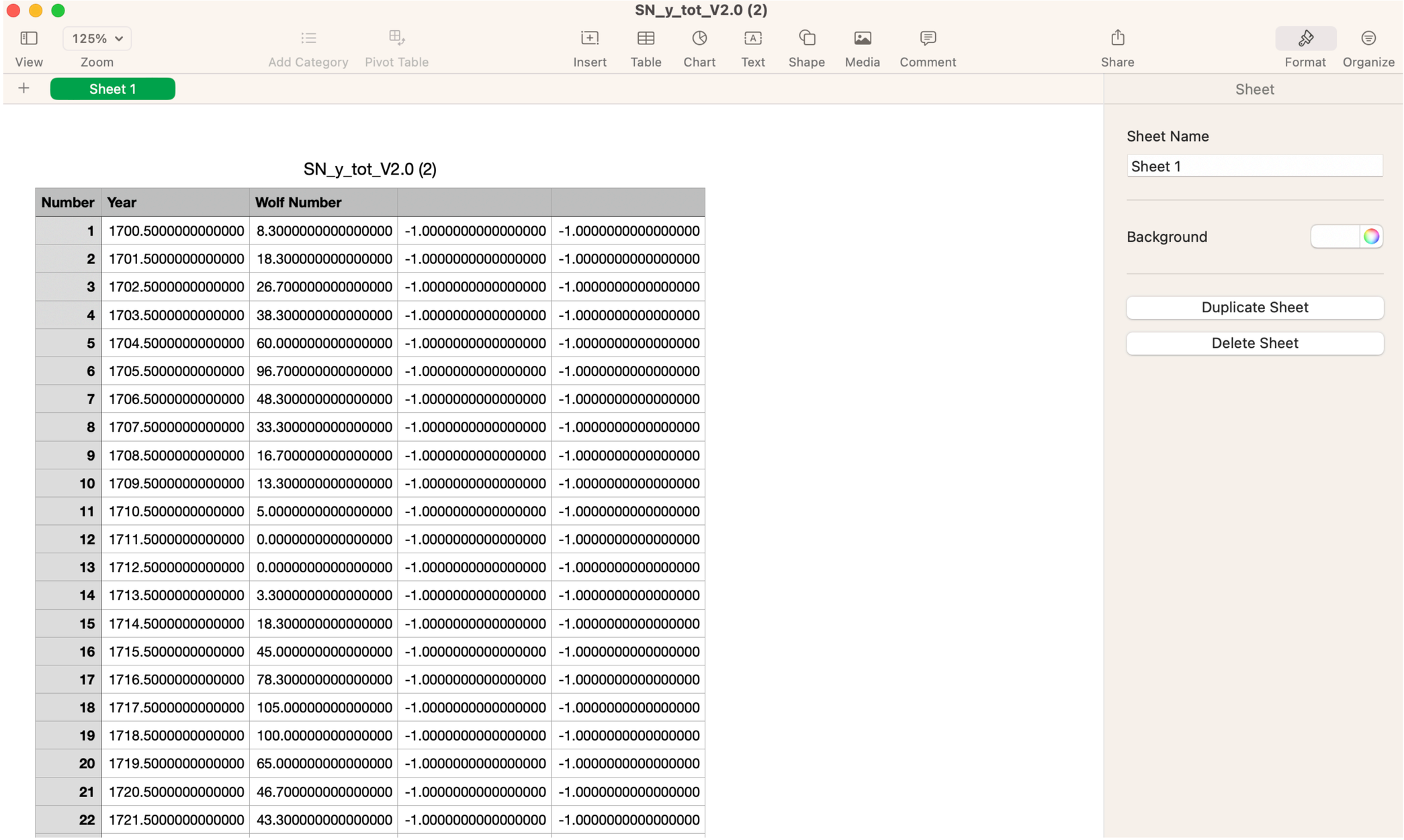


II. For this part of the assignment, you will make a plot of the Wolf numbers since 1700 to get a feel for how Solar activity has varied over time.

A listing and links to tables of Wolf Numbers from the 1700s to present is given in linked webpage:

https://pages.uoregon.edu/imamura/122/homeworks/wolf_numbers.html

I used the data in the files and the Apple version of Microsoft's Excel to make plots. I describe how I made the plots in the following pages.You may make the plot in the way (and/or software) you find easiest.

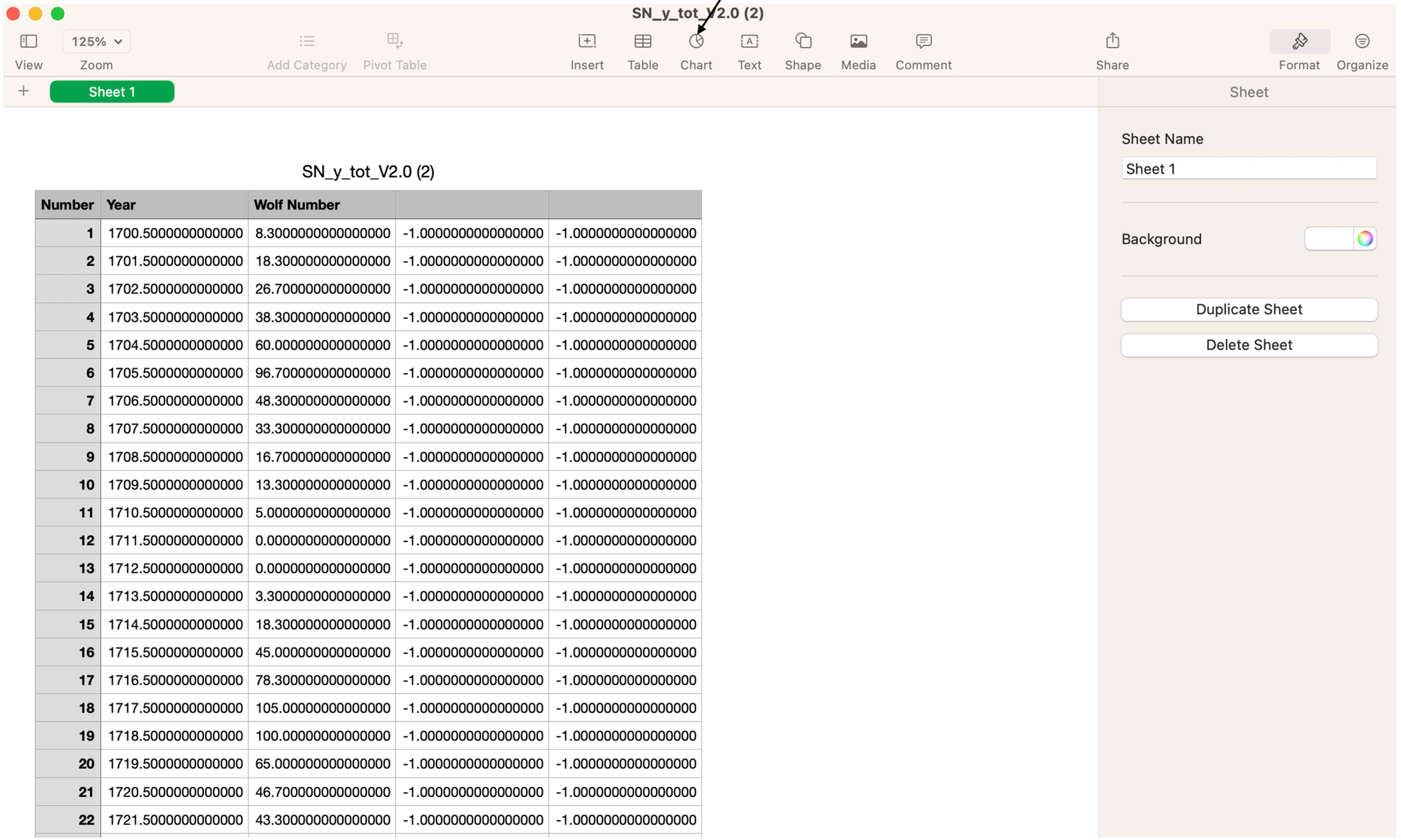


SN_y_tot_V2.0 (2)

Number	Year	Wolf Number		
1	1700.5000000000000	8.3000000000000000	-1.0000000000000000	-1.0000000000000000
2	1701.5000000000000	18.300000000000000	-1.0000000000000000	-1.0000000000000000
3	1702.5000000000000	26.700000000000000	-1.0000000000000000	-1.0000000000000000
4	1703.5000000000000	38.300000000000000	-1.0000000000000000	-1.0000000000000000
5	1704.5000000000000	60.000000000000000	-1.0000000000000000	-1.0000000000000000
6	1705.5000000000000	96.700000000000000	-1.0000000000000000	-1.0000000000000000
7	1706.5000000000000	48.300000000000000	-1.0000000000000000	-1.0000000000000000
8	1707.5000000000000	33.300000000000000	-1.0000000000000000	-1.0000000000000000
9	1708.5000000000000	16.700000000000000	-1.0000000000000000	-1.0000000000000000
10	1709.5000000000000	13.300000000000000	-1.0000000000000000	-1.0000000000000000
11	1710.5000000000000	5.0000000000000000	-1.0000000000000000	-1.0000000000000000
12	1711.5000000000000	0.0000000000000000	-1.0000000000000000	-1.0000000000000000
13	1712.5000000000000	0.0000000000000000	-1.0000000000000000	-1.0000000000000000
14	1713.5000000000000	3.3000000000000000	-1.0000000000000000	-1.0000000000000000
15	1714.5000000000000	18.300000000000000	-1.0000000000000000	-1.0000000000000000
16	1715.5000000000000	45.000000000000000	-1.0000000000000000	-1.0000000000000000
17	1716.5000000000000	78.300000000000000	-1.0000000000000000	-1.0000000000000000
18	1717.5000000000000	105.00000000000000	-1.0000000000000000	-1.0000000000000000
19	1718.5000000000000	100.00000000000000	-1.0000000000000000	-1.0000000000000000
20	1719.5000000000000	65.000000000000000	-1.0000000000000000	-1.0000000000000000
21	1720.5000000000000	46.700000000000000	-1.0000000000000000	-1.0000000000000000
22	1721.5000000000000	43.300000000000000	-1.0000000000000000	-1.0000000000000000

The above is a screenshot of the *Numbers* page in which I opened the csv file

We will plot columns 1 and 2 using the Chart option



SN_y_tot_V2.0 (2)

Number	Year	Wolf Number		
1	1700.5000000000000	8.3000000000000000	-1.0000000000000000	-1.0000000000000000
2	1701.5000000000000	18.300000000000000	-1.0000000000000000	-1.0000000000000000
3	1702.5000000000000	26.700000000000000	-1.0000000000000000	-1.0000000000000000
4	1703.5000000000000	38.300000000000000	-1.0000000000000000	-1.0000000000000000
5	1704.5000000000000	60.000000000000000	-1.0000000000000000	-1.0000000000000000
6	1705.5000000000000	96.700000000000000	-1.0000000000000000	-1.0000000000000000
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8	1707.5000000000000	33.300000000000000	-1.0000000000000000	-1.0000000000000000
9	1708.5000000000000	16.700000000000000	-1.0000000000000000	-1.0000000000000000
10	1709.5000000000000	13.300000000000000	-1.0000000000000000	-1.0000000000000000
11	1710.5000000000000	5.0000000000000000	-1.0000000000000000	-1.0000000000000000
12	1711.5000000000000	0.0000000000000000	-1.0000000000000000	-1.0000000000000000
13	1712.5000000000000	0.0000000000000000	-1.0000000000000000	-1.0000000000000000
14	1713.5000000000000	3.3000000000000000	-1.0000000000000000	-1.0000000000000000
15	1714.5000000000000	18.300000000000000	-1.0000000000000000	-1.0000000000000000
16	1715.5000000000000	45.000000000000000	-1.0000000000000000	-1.0000000000000000
17	1716.5000000000000	78.300000000000000	-1.0000000000000000	-1.0000000000000000
18	1717.5000000000000	105.00000000000000	-1.0000000000000000	-1.0000000000000000
19	1718.5000000000000	100.00000000000000	-1.0000000000000000	-1.0000000000000000
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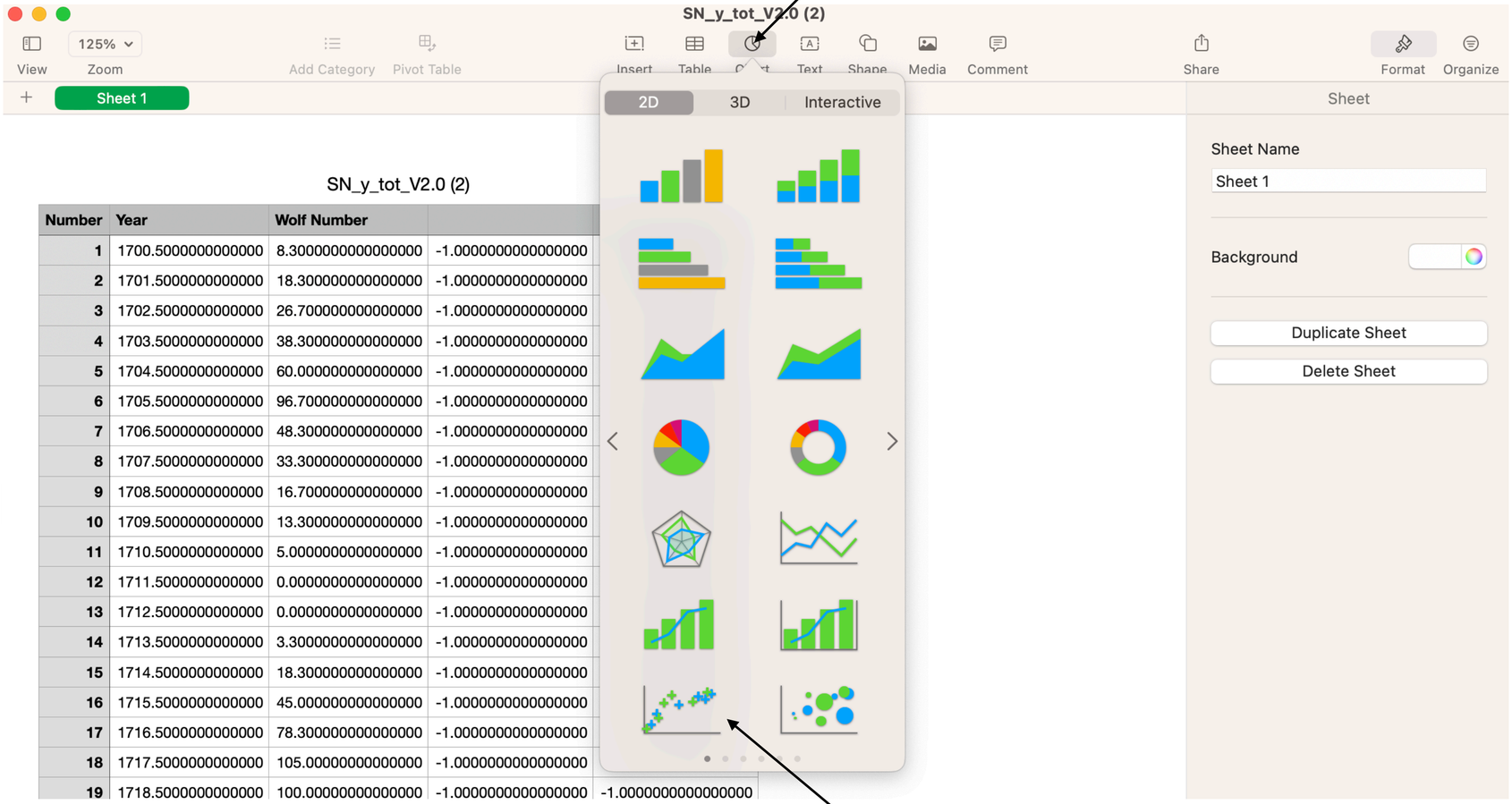
22	1721.5000000000000	43.300000000000000	-1.0000000000000000	-1.0000000000000000

We will plot columns 1 and 2 using the Chart option



SN_y_tot_V2.0 (2)

Number	Year	Wolf Number		
1	1700.5000000000000	8.3000000000000000	-1.0000000000000000	
2	1701.5000000000000	18.300000000000000	-1.0000000000000000	
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4	1703.5000000000000	38.300000000000000	-1.0000000000000000	
5	1704.5000000000000	60.000000000000000	-1.0000000000000000	
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11	1710.5000000000000	5.0000000000000000	-1.0000000000000000	
12	1711.5000000000000	0.0000000000000000	-1.0000000000000000	
13	1712.5000000000000	0.0000000000000000	-1.0000000000000000	
14	1713.5000000000000	3.3000000000000000	-1.0000000000000000	
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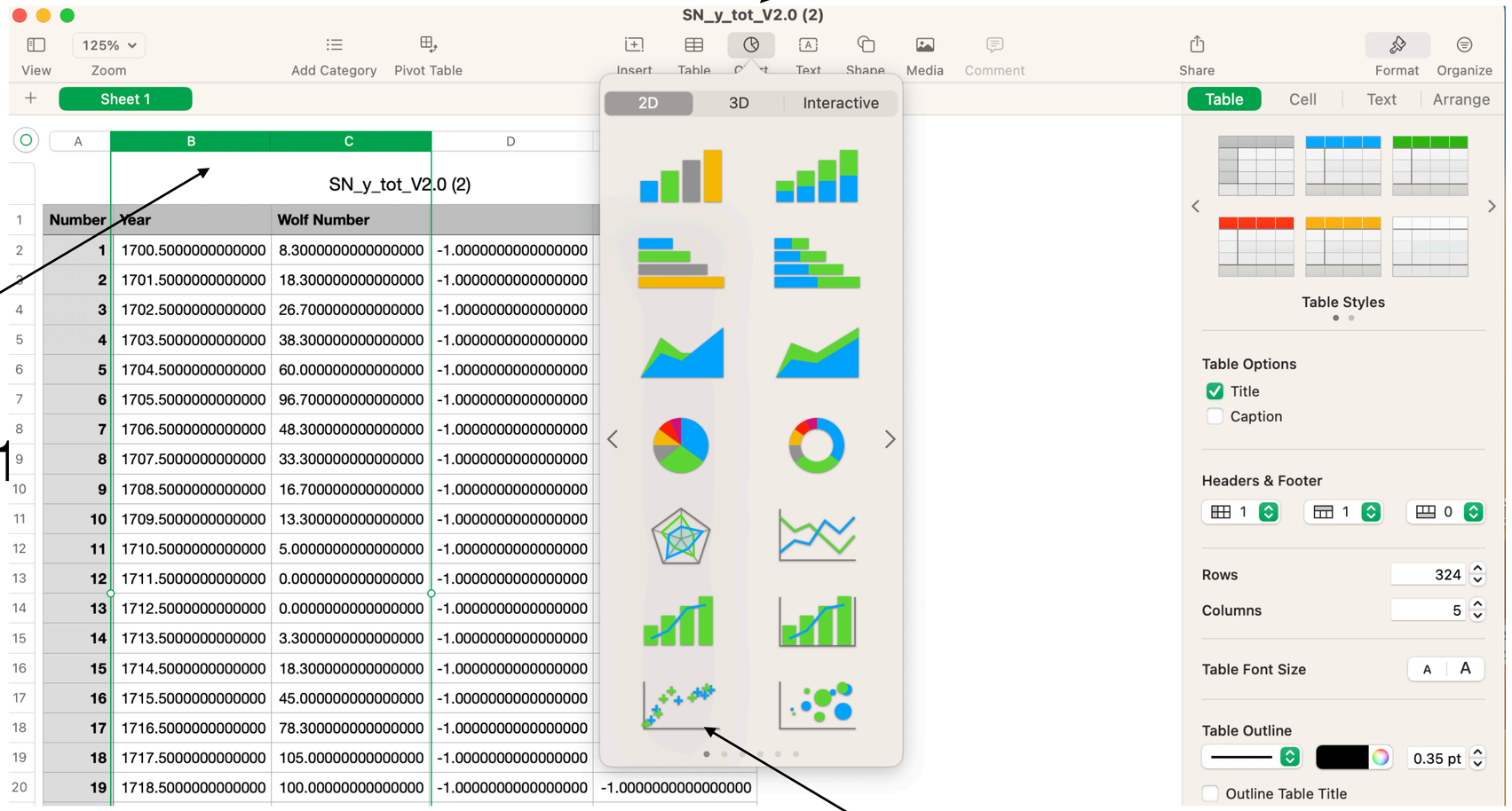
16	1715.5000000000000	45.000000000000000	-1.0000000000000000	
17	1716.5000000000000	78.300000000000000	-1.0000000000000000	
18	1717.5000000000000	105.00000000000000	-1.0000000000000000	
19	1718.5000000000000	100.00000000000000	-1.0000000000000000	-1.0000000000000000

Select columns 1 and 2

Choose scatter plot option

We will plot columns 1 and 2 using the Chart option

Select columns 1 and 2



	Number	Year	Wolf Number		
1	1	1700.5000000000000	8.3000000000000000	-1.0000000000000000	
2	2	1701.5000000000000	18.300000000000000	-1.0000000000000000	
3	3	1702.5000000000000	26.700000000000000	-1.0000000000000000	
4	4	1703.5000000000000	38.300000000000000	-1.0000000000000000	
5	5	1704.5000000000000	60.000000000000000	-1.0000000000000000	
6	6	1705.5000000000000	96.700000000000000	-1.0000000000000000	
7	7	1706.5000000000000	48.300000000000000	-1.0000000000000000	
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10	10	1709.5000000000000	13.300000000000000	-1.0000000000000000	
11	11	1710.5000000000000	5.0000000000000000	-1.0000000000000000	
12	12	1711.5000000000000	0.0000000000000000	-1.0000000000000000	
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16	16	1715.5000000000000	45.000000000000000	-1.0000000000000000	
17	17	1716.5000000000000	78.300000000000000	-1.0000000000000000	
18	18	1717.5000000000000	105.00000000000000	-1.0000000000000000	
19	19	1718.5000000000000	100.00000000000000	-1.0000000000000000	-1.0000000000000000

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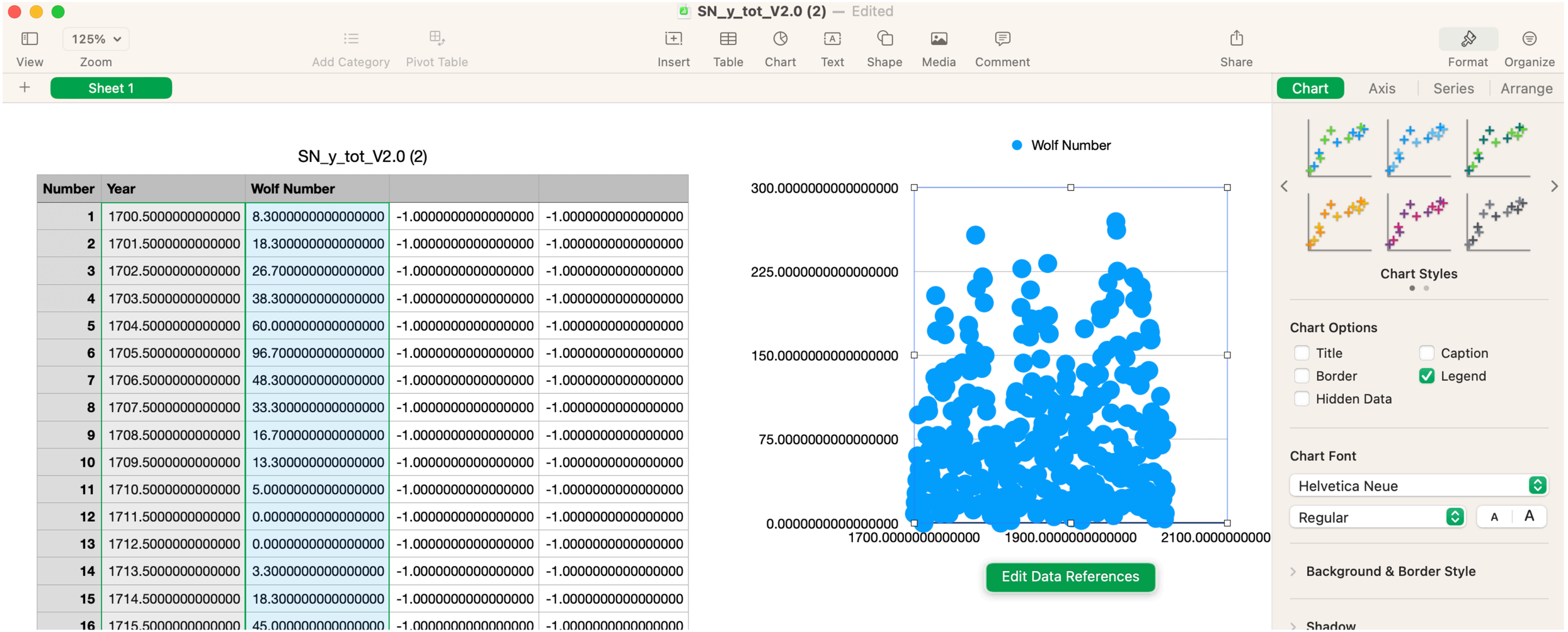

The initial plot is shown above. Click Edit Data References to bring up the panel to the right, use tabs to change plot appearance.

SN_y_tot_V2.0 (2)

mber	Year	Wolf Number		
1	1701.0	8.3	-1.0000000000000000	-1.0000000000000000
2	1701.5	18.3	-1.0000000000000000	-1.0000000000000000
3	1702.5000000000000	26.700000000000000	-1.0000000000000000	-1.0000000000000000
4	1703.5000000000000	38.300000000000000	-1.0000000000000000	-1.0000000000000000
5	1704.5000000000000	60.000000000000000	-1.0000000000000000	-1.0000000000000000
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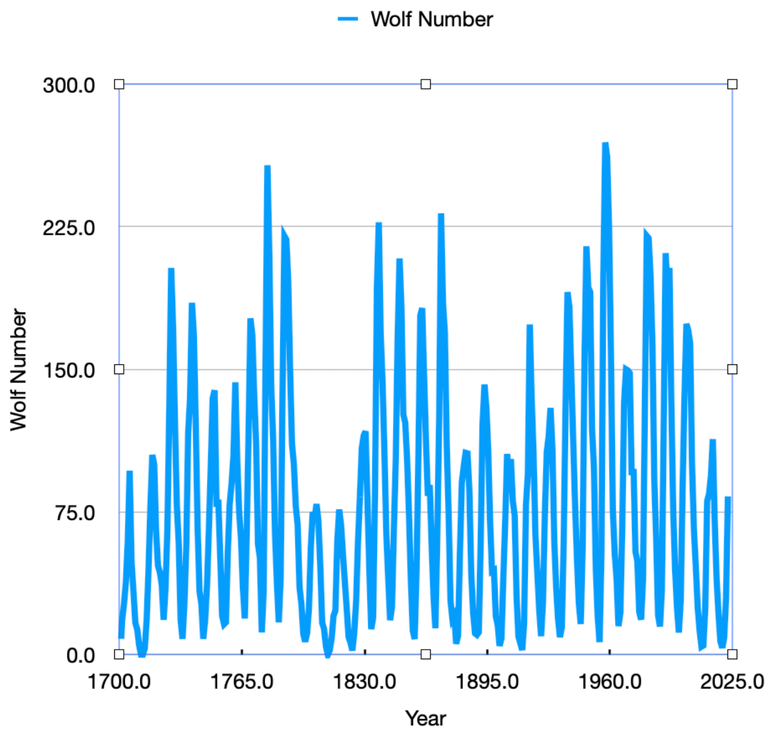
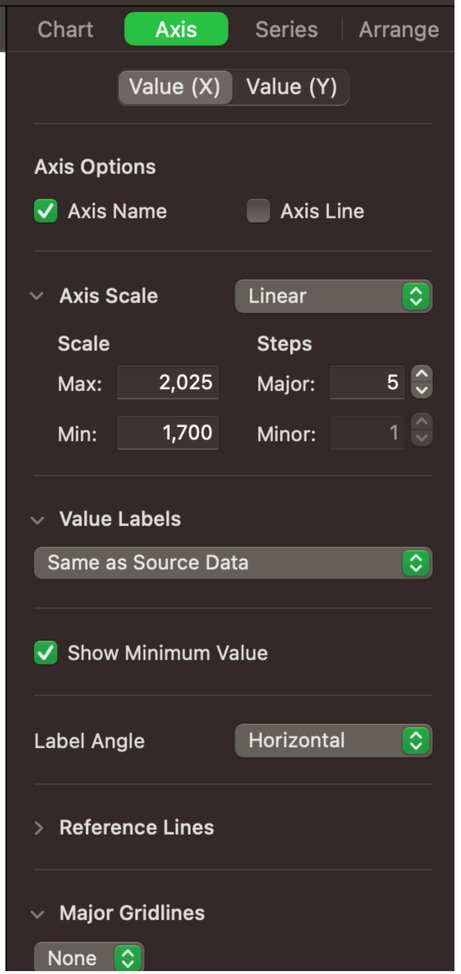




I changed appearance of the plot using Tools in Numbers. ***5. Circle the Dalton Minimum on the plot. Describe how the Terrestrial climate changed during the Dalton Minimum.***

III. How does the Solar output change over the Solar Activity Cycle? The luminosity of the Sun has been measured for the last 45 years (covering several Solar Cycles) using space-based telescopes. The Solar energy which reaches the top of the Earth's atmosphere defines the Solar constant. The Solar constant varies over time. The quantity plotted is the energy in Watts (Joules per second) per square meter which strikes the atmosphere of the Earth.

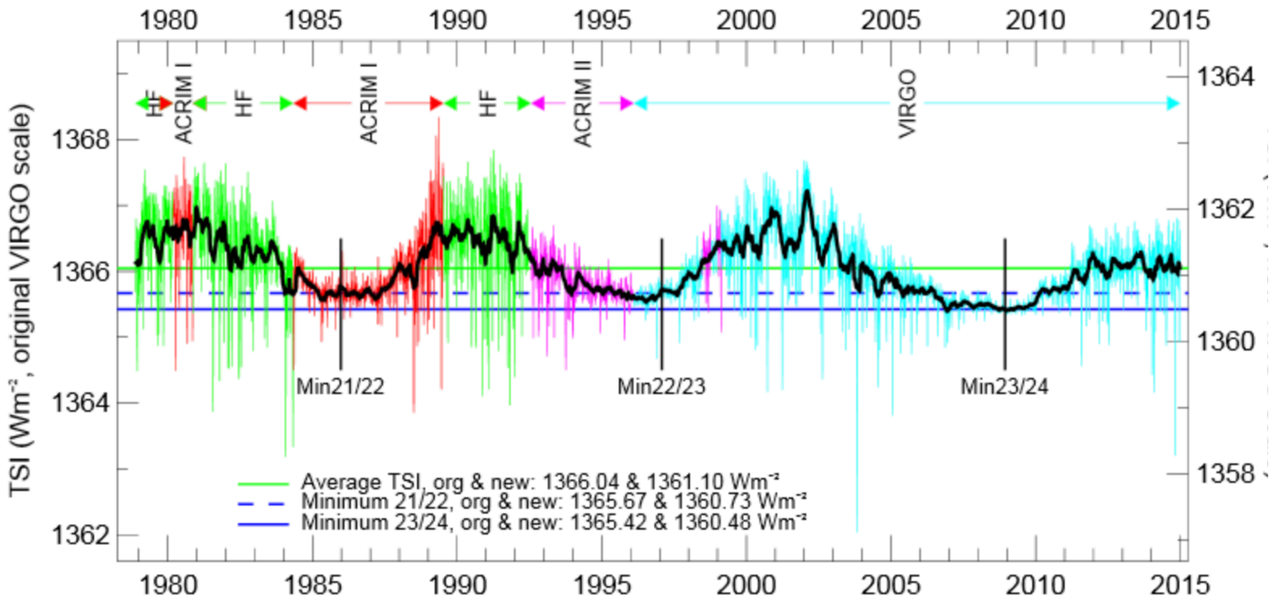


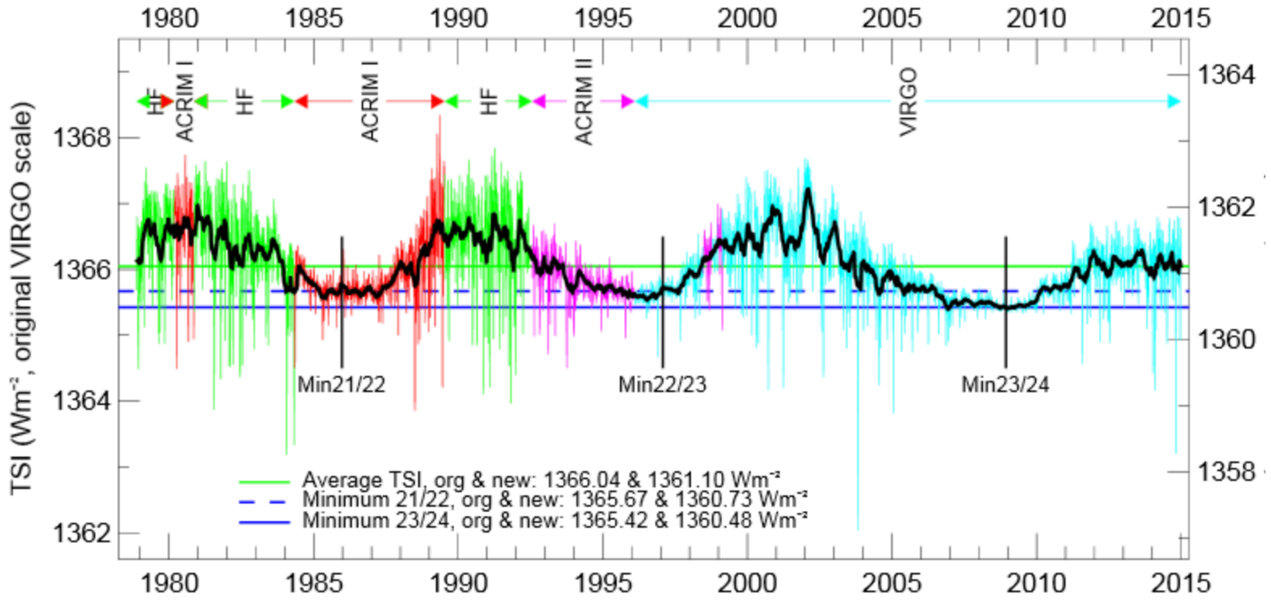
Figure 1. Composite daily values of the Sun's Total Solar Irradiance (TSI) from radiometers on different space platforms since November 1978: HF on Nimbus7, ACRIM 1 on SMM, ERBE on ERBS, ACRIM II on UARS, VIRGO on SOHO, and ACRIM III on ACRIM_Sat. The values of the average and the minima values are also given in the original VIRGO and new absolute VIRGO scales.

The variation in the solar constant has been about 0.1% over a period of about 30 years. Some researchers have tried to reconstruct this variation, by correlating it to sunspot numbers, back over the last 400 years, and have suggested that the Sun may have varied in its power output by up to one percent. It has also been suggested that this variation might explain some terrestrial temperature variations. It is interesting to note that the average G-type star (the class of star the Sun falls into) typically shows a much larger variation of about 4%.

Material prepared by John Kennewell and Andrew McDonald

6. According to the plot, what is average Solar constant (the cyan line)?

7. According to the plot, what is the percentage difference in the Solar constant, over a Solar cycle?



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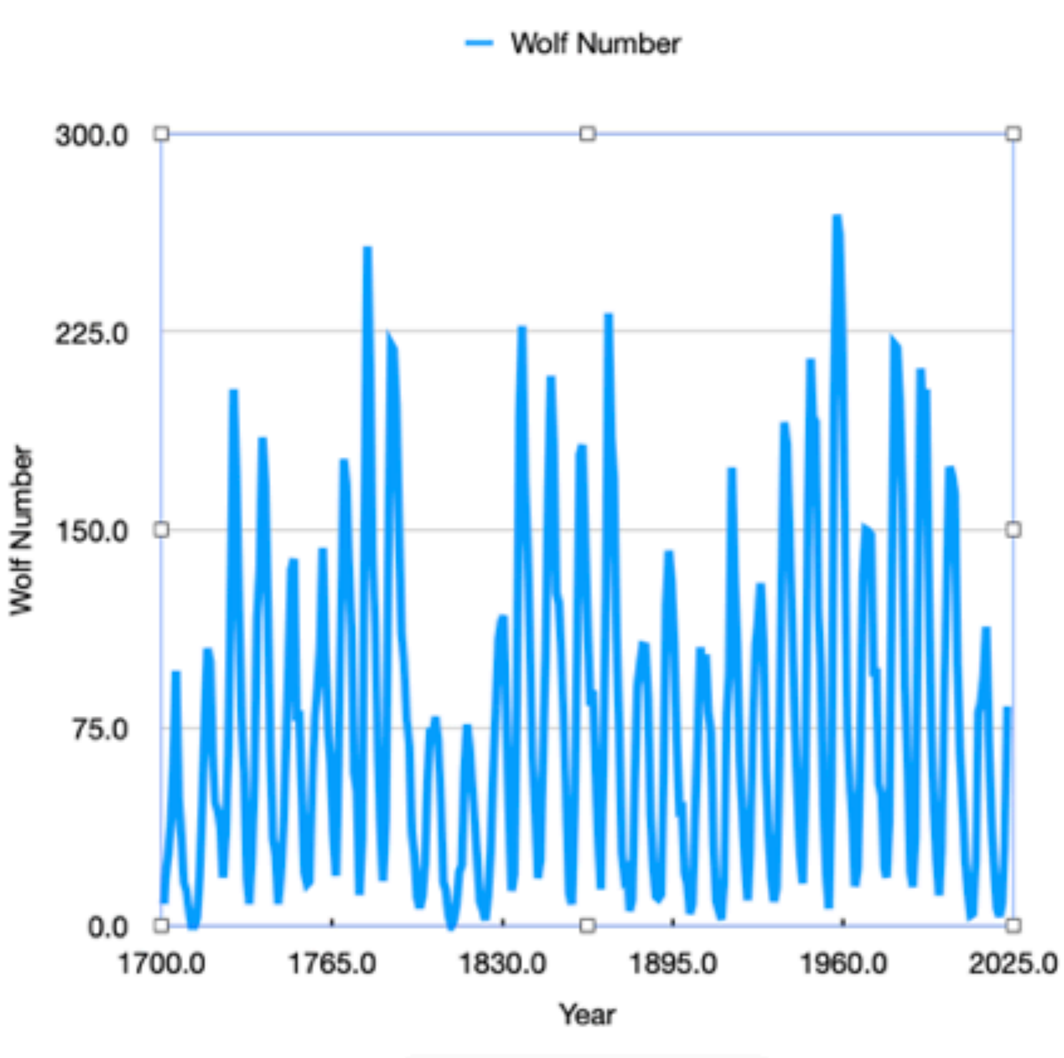

8. During the Maunder Minimum (1645-1715) there was essentially zero sunspot activity. Roughly how much smaller was the average Solar Constant then than say, from around 1935-1960?

9. During the Dalton Minimum, what was the average Solar Constant?