

Name and Date:

Astronomy 122

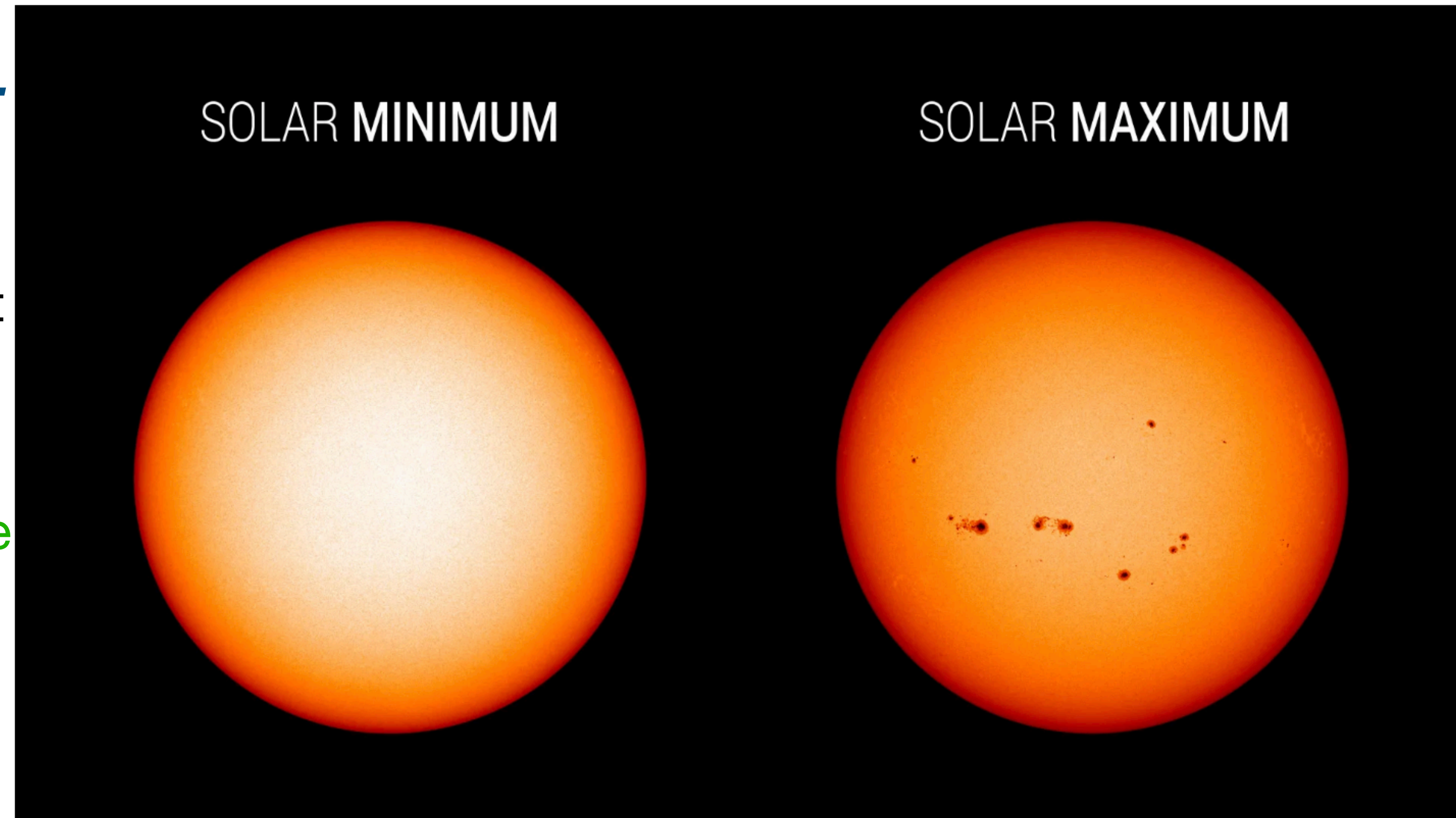
Homework 1: Wolf Numbers and the Sun as a Variable Star

Due: by the end of January 26, 2024

I. We will find Wolf numbers for the Sun.

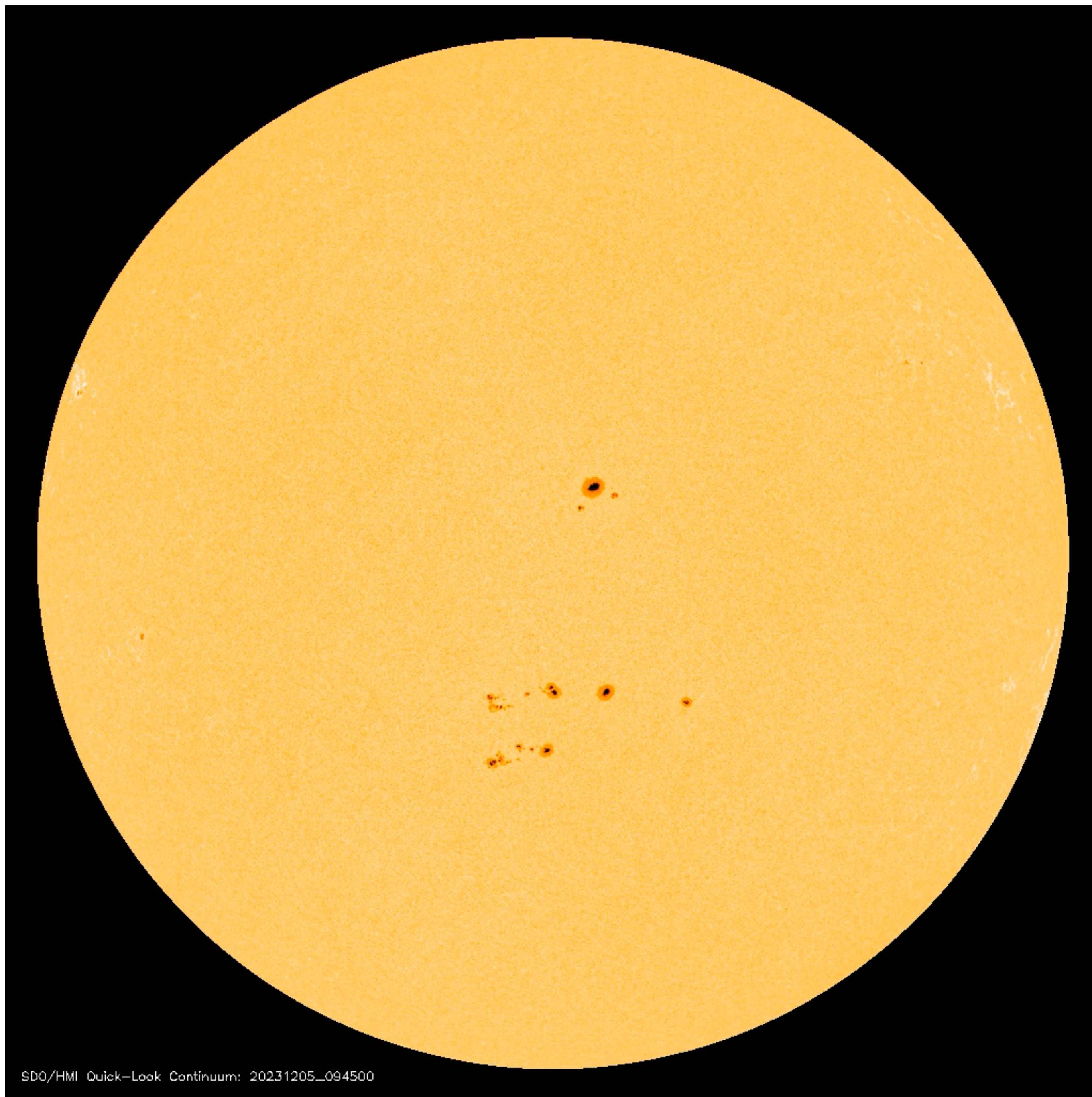
To the right are shown two snapshots of the Sun, the left taken in April 2014, and the right taken in December 2019. Find the Wolf number for each image. (1) Count the number of sunspots on the image. (2) Count the number of sunspot groups. The Wolf number is $R = k[(\# \text{ of sunspots}) + 10 \times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

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 $R = 10 \times (1 \text{ group}) + (1 \text{ sunspot}) = 11$, $k = 1$.

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



The video at left (https://pages.uoregon.edu/imamura/122/homeworks/20231206_1024_HMI.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.

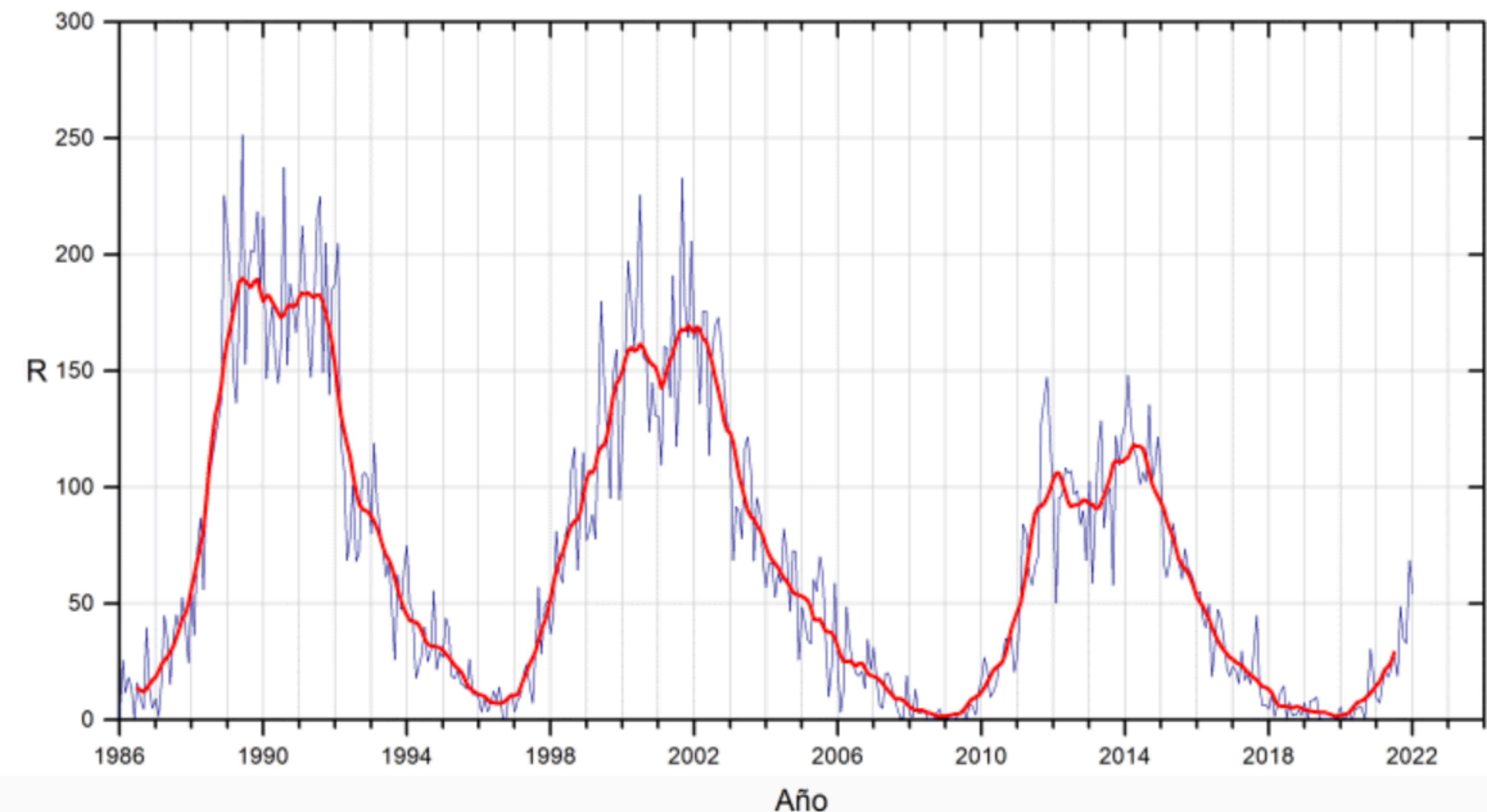
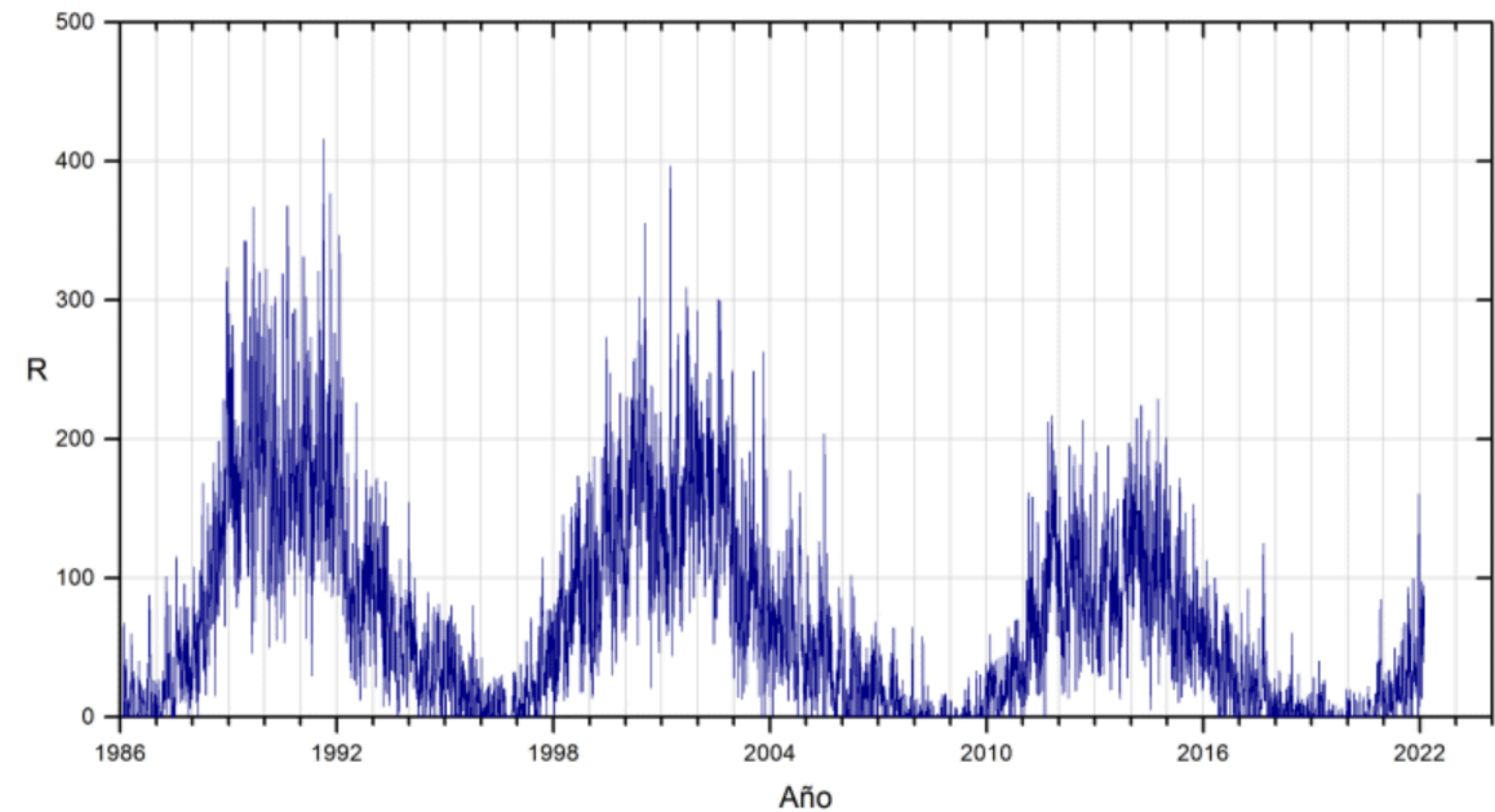
2. What are the Wolf numbers for the beginning and end of the sequence? Add to table on slide 3

| 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)

View Zoom 125% Add Category Pivot Table Insert Table Chart Text Shape Media Comment Share Format Organize

Sheet 1

Sheet

Sheet Name
Sheet 1

Background 

Duplicate Sheet

Delete Sheet

| Number | Year | Wolf Number | | |
|--------|--------------------|---------------------|--------------------|--------------------|
| 1 | 1700.5000000000000 | 8.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 2 | 1701.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 3 | 1702.5000000000000 | 26.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 4 | 1703.5000000000000 | 38.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 5 | 1704.5000000000000 | 60.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 6 | 1705.5000000000000 | 96.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 7 | 1706.5000000000000 | 48.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 8 | 1707.5000000000000 | 33.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 9 | 1708.5000000000000 | 16.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 10 | 1709.5000000000000 | 13.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 11 | 1710.5000000000000 | 5.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 12 | 1711.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 13 | 1712.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 14 | 1713.5000000000000 | 3.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 15 | 1714.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 16 | 1715.5000000000000 | 45.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 17 | 1716.5000000000000 | 78.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 18 | 1717.5000000000000 | 105.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 19 | 1718.5000000000000 | 100.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 20 | 1719.5000000000000 | 65.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 21 | 1720.5000000000000 | 46.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 22 | 1721.5000000000000 | 43.300000000000000 | -1.000000000000000 | -1.000000000000000 |

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

The screenshot shows a spreadsheet application window titled "SN_y_tot_V2.0 (2)". The top toolbar includes icons for View, Zoom (125%), Add Category, Pivot Table, Insert, Table, Chart, Text, Shape, Media, Comment, Share, Format, and Organize. The "Chart" icon is highlighted with an arrow from the text above. Below the toolbar is a sheet tab labeled "Sheet 1". The main area contains a table with the following data:

| Number | Year | Wolf Number | | |
|--------|--------------------|---------------------|--------------------|--------------------|
| 1 | 1700.5000000000000 | 8.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 2 | 1701.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 3 | 1702.5000000000000 | 26.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 4 | 1703.5000000000000 | 38.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 5 | 1704.5000000000000 | 60.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 6 | 1705.5000000000000 | 96.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 7 | 1706.5000000000000 | 48.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 8 | 1707.5000000000000 | 33.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 9 | 1708.5000000000000 | 16.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 10 | 1709.5000000000000 | 13.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 11 | 1710.5000000000000 | 5.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 12 | 1711.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 13 | 1712.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 14 | 1713.5000000000000 | 3.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 15 | 1714.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 16 | 1715.5000000000000 | 45.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 17 | 1716.5000000000000 | 78.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 18 | 1717.5000000000000 | 105.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 19 | 1718.5000000000000 | 100.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 20 | 1719.5000000000000 | 65.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 21 | 1720.5000000000000 | 46.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 22 | 1721.5000000000000 | 43.300000000000000 | -1.000000000000000 | -1.000000000000000 |

The right-hand sidebar, titled "Sheet", contains the following options:

- Sheet Name: Sheet 1
- Background:
- Duplicate Sheet
- Delete Sheet

We will plot columns 1 and 2 using the Chart option

The screenshot shows a spreadsheet application window titled "SN_y_tot_V2.0 (2)". The spreadsheet contains a table with 19 rows and 4 columns. The first two columns are "Number" and "Year", and the last two are "Wolf Number" and an unlabeled column. A chart selection menu is open over the spreadsheet, showing various chart options under "2D", "3D", and "Interactive" tabs. The "2D" tab is selected, and a scatter plot option is highlighted. An arrow points from the text "We will plot columns 1 and 2 using the Chart option" to the chart selection menu. Another arrow points from the text "Choose scatter plot option" to the scatter plot option in the menu.

| Number | Year | Wolf Number | |
|--------|--------------------|---------------------|--------------------|
| 1 | 1700.5000000000000 | 8.300000000000000 | -1.000000000000000 |
| 2 | 1701.5000000000000 | 18.300000000000000 | -1.000000000000000 |
| 3 | 1702.5000000000000 | 26.700000000000000 | -1.000000000000000 |
| 4 | 1703.5000000000000 | 38.300000000000000 | -1.000000000000000 |
| 5 | 1704.5000000000000 | 60.000000000000000 | -1.000000000000000 |
| 6 | 1705.5000000000000 | 96.700000000000000 | -1.000000000000000 |
| 7 | 1706.5000000000000 | 48.300000000000000 | -1.000000000000000 |
| 8 | 1707.5000000000000 | 33.300000000000000 | -1.000000000000000 |
| 9 | 1708.5000000000000 | 16.700000000000000 | -1.000000000000000 |
| 10 | 1709.5000000000000 | 13.300000000000000 | -1.000000000000000 |
| 11 | 1710.5000000000000 | 5.000000000000000 | -1.000000000000000 |
| 12 | 1711.5000000000000 | 0.000000000000000 | -1.000000000000000 |
| 13 | 1712.5000000000000 | 0.000000000000000 | -1.000000000000000 |
| 14 | 1713.5000000000000 | 3.300000000000000 | -1.000000000000000 |
| 15 | 1714.5000000000000 | 18.300000000000000 | -1.000000000000000 |
| 16 | 1715.5000000000000 | 45.000000000000000 | -1.000000000000000 |
| 17 | 1716.5000000000000 | 78.300000000000000 | -1.000000000000000 |
| 18 | 1717.5000000000000 | 105.000000000000000 | -1.000000000000000 |
| 19 | 1718.5000000000000 | 100.000000000000000 | -1.000000000000000 |

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

The screenshot shows a spreadsheet application window titled "SN_y_tot_V2.0 (2)". The spreadsheet has columns labeled "Number", "Year", "Wolf Number", and a fourth unlabeled column. The data rows contain numerical values. A chart selection menu is open, showing various chart types under "2D", "3D", and "Interactive" tabs. A scatter plot option is highlighted. On the right, a "Table" style panel is visible, showing options for "Table Options", "Headers & Footer", "Rows", "Columns", "Table Font Size", and "Table Outline".

| | Number | Year | Wolf Number | |
|----|--------|--------------------|---------------------|--------------------|
| 1 | 1 | 1700.5000000000000 | 8.300000000000000 | -1.000000000000000 |
| 2 | 2 | 1701.5000000000000 | 18.300000000000000 | -1.000000000000000 |
| 3 | 3 | 1702.5000000000000 | 26.700000000000000 | -1.000000000000000 |
| 4 | 4 | 1703.5000000000000 | 38.300000000000000 | -1.000000000000000 |
| 5 | 5 | 1704.5000000000000 | 60.000000000000000 | -1.000000000000000 |
| 6 | 6 | 1705.5000000000000 | 96.700000000000000 | -1.000000000000000 |
| 7 | 7 | 1706.5000000000000 | 48.300000000000000 | -1.000000000000000 |
| 8 | 8 | 1707.5000000000000 | 33.300000000000000 | -1.000000000000000 |
| 9 | 9 | 1708.5000000000000 | 16.700000000000000 | -1.000000000000000 |
| 10 | 10 | 1709.5000000000000 | 13.300000000000000 | -1.000000000000000 |
| 11 | 11 | 1710.5000000000000 | 5.000000000000000 | -1.000000000000000 |
| 12 | 12 | 1711.5000000000000 | 0.000000000000000 | -1.000000000000000 |
| 13 | 13 | 1712.5000000000000 | 0.000000000000000 | -1.000000000000000 |
| 14 | 14 | 1713.5000000000000 | 3.300000000000000 | -1.000000000000000 |
| 15 | 15 | 1714.5000000000000 | 18.300000000000000 | -1.000000000000000 |
| 16 | 16 | 1715.5000000000000 | 45.000000000000000 | -1.000000000000000 |
| 17 | 17 | 1716.5000000000000 | 78.300000000000000 | -1.000000000000000 |
| 18 | 18 | 1717.5000000000000 | 105.000000000000000 | -1.000000000000000 |
| 19 | 19 | 1718.5000000000000 | 100.000000000000000 | -1.000000000000000 |

Choose scatter plot option

SN_y_tot_V2.0 (2) — Edited

View Zoom 125% Add Category Pivot Table Insert Table Chart Text Shape Media Comment Share Format Organize

Sheet 1

Chart Axis Series Arrange

Chart Styles

Chart Options

- Title
- Caption
- Border
- Legend
- Hidden Data

Chart Font

Helvetica Neue

Regular A A

> Background & Border Style

> Shadow

SN_y_tot_V2.0 (2)

| Number | Year | Wolf Number | | |
|--------|--------------------|--------------------|--------------------|--------------------|
| 1 | 1700.5000000000000 | 8.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 2 | 1701.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 3 | 1702.5000000000000 | 26.700000000000000 | -1.000000000000000 | -1.000000000000000 |
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| 6 | 1705.5000000000000 | 96.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 7 | 1706.5000000000000 | 48.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 8 | 1707.5000000000000 | 33.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 9 | 1708.5000000000000 | 16.700000000000000 | -1.000000000000000 | -1.000000000000000 |
| 10 | 1709.5000000000000 | 13.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 11 | 1710.5000000000000 | 5.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 12 | 1711.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 13 | 1712.5000000000000 | 0.000000000000000 | -1.000000000000000 | -1.000000000000000 |
| 14 | 1713.5000000000000 | 3.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 15 | 1714.5000000000000 | 18.300000000000000 | -1.000000000000000 | -1.000000000000000 |
| 16 | 1715.5000000000000 | 45.000000000000000 | -1.000000000000000 | -1.000000000000000 |

Wolf Number

300.0000000000000000

225.0000000000000000

150.0000000000000000

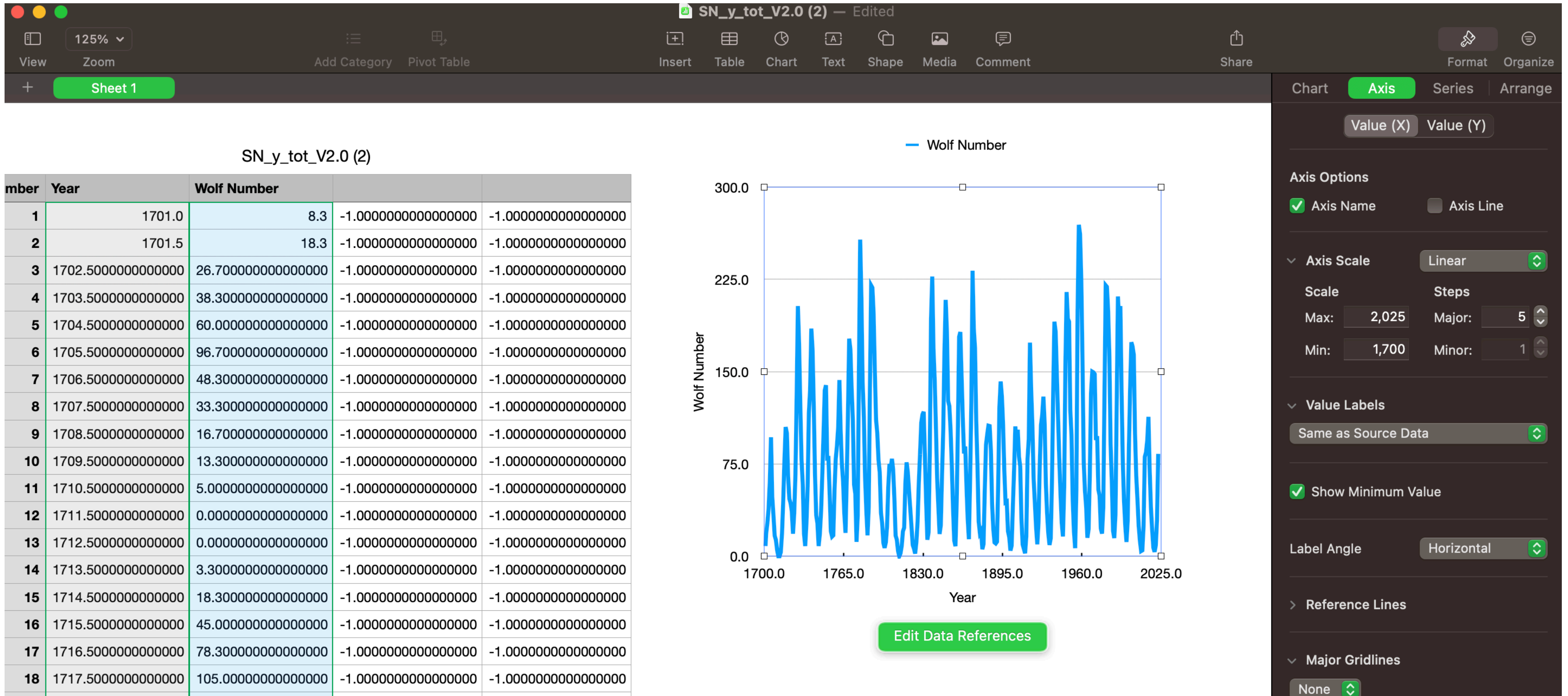
75.0000000000000000

0.0000000000000000

1700.0000000000000 1900.0000000000000 2100.0000000000000

Edit Data References

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



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.

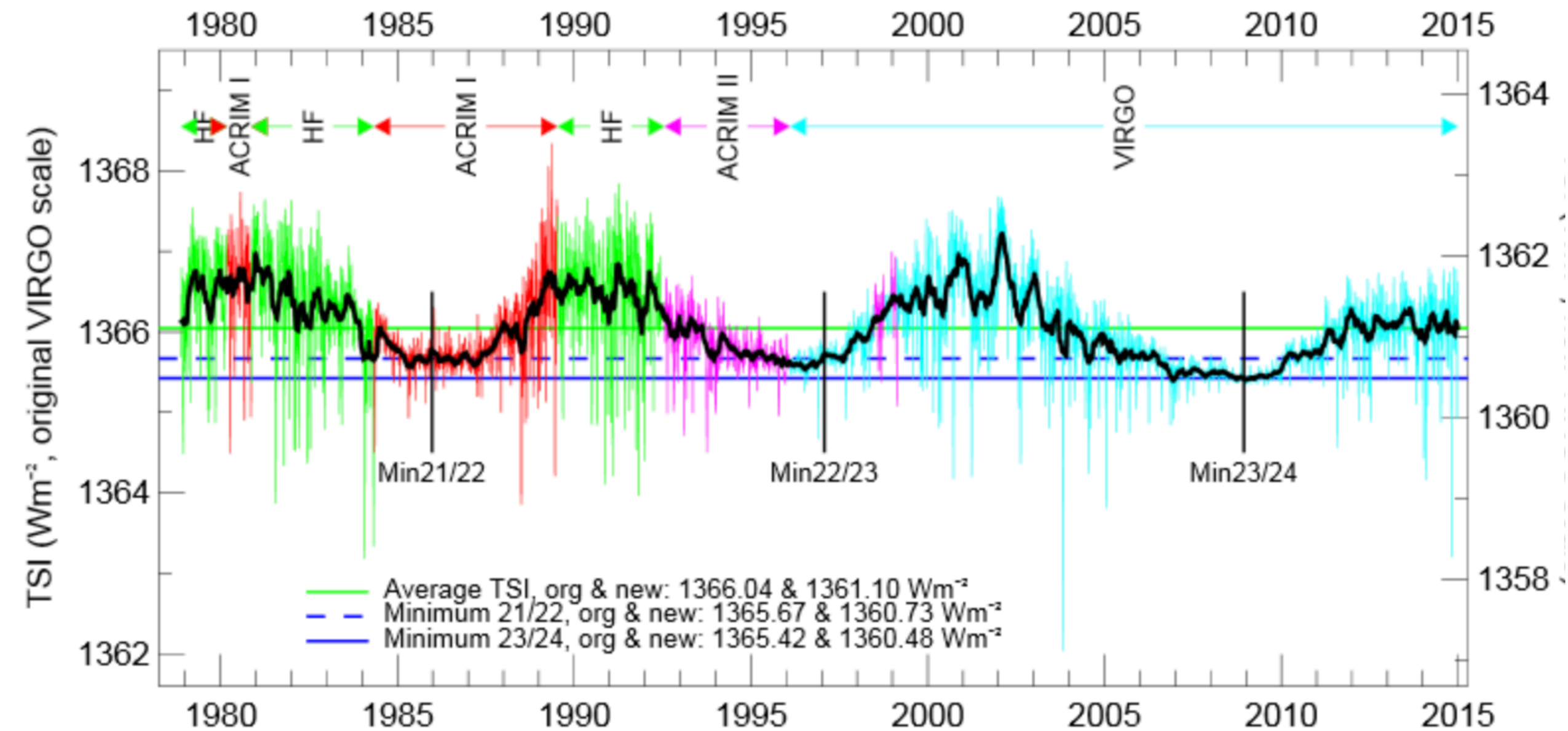


Figure 1. Composite daily values of the Sun's Total Solar Irradiance (TSI) from radiometers on different space platforms since November 1978: HF on Nimbus7, ACRIM 1 on SMM, ERBE on ERBS, ACRIM II on UARS, VIRGO on SOHO, and ACRIM III on ACRIM_Sat. The values of the average and the minima values are also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

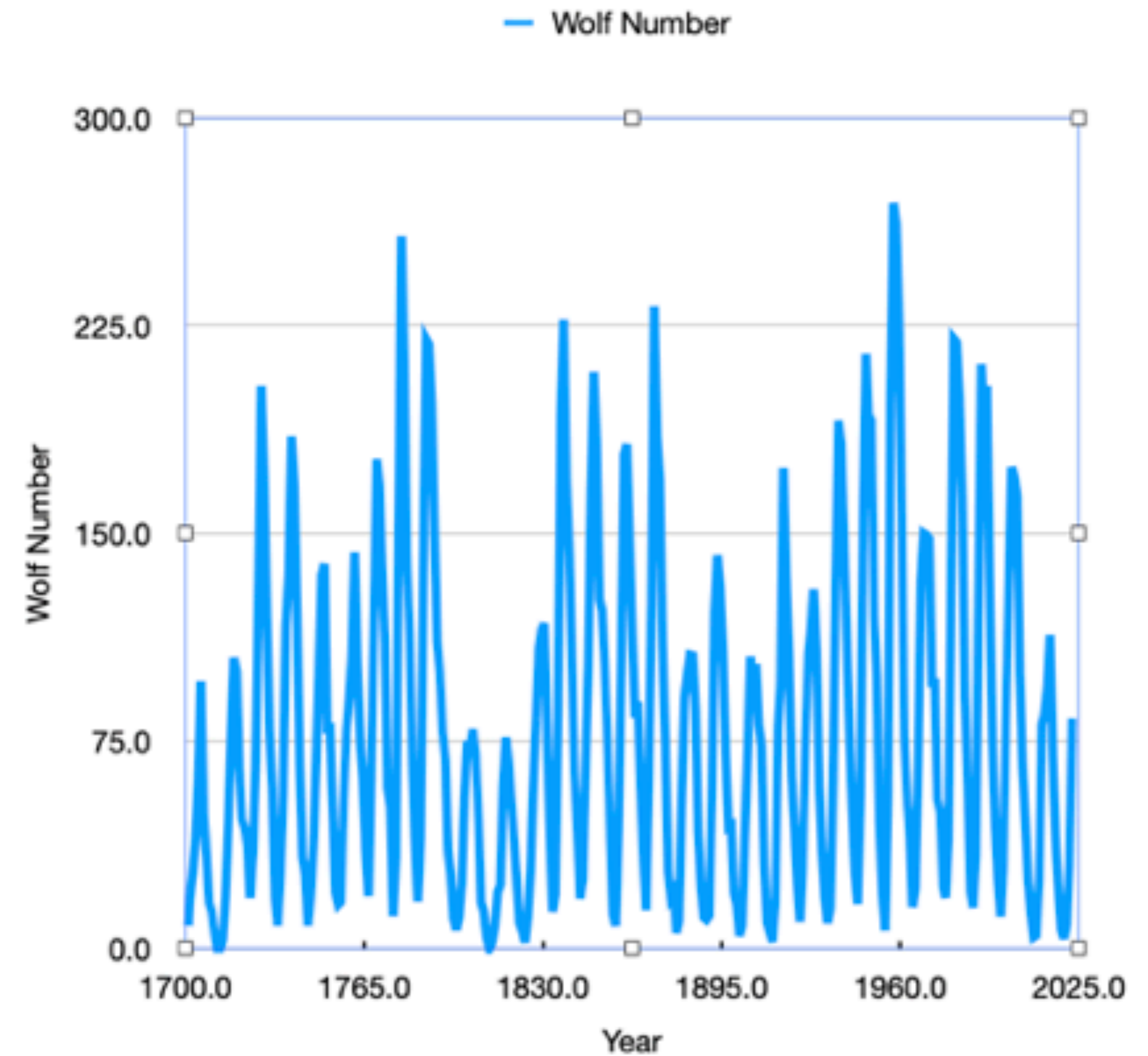
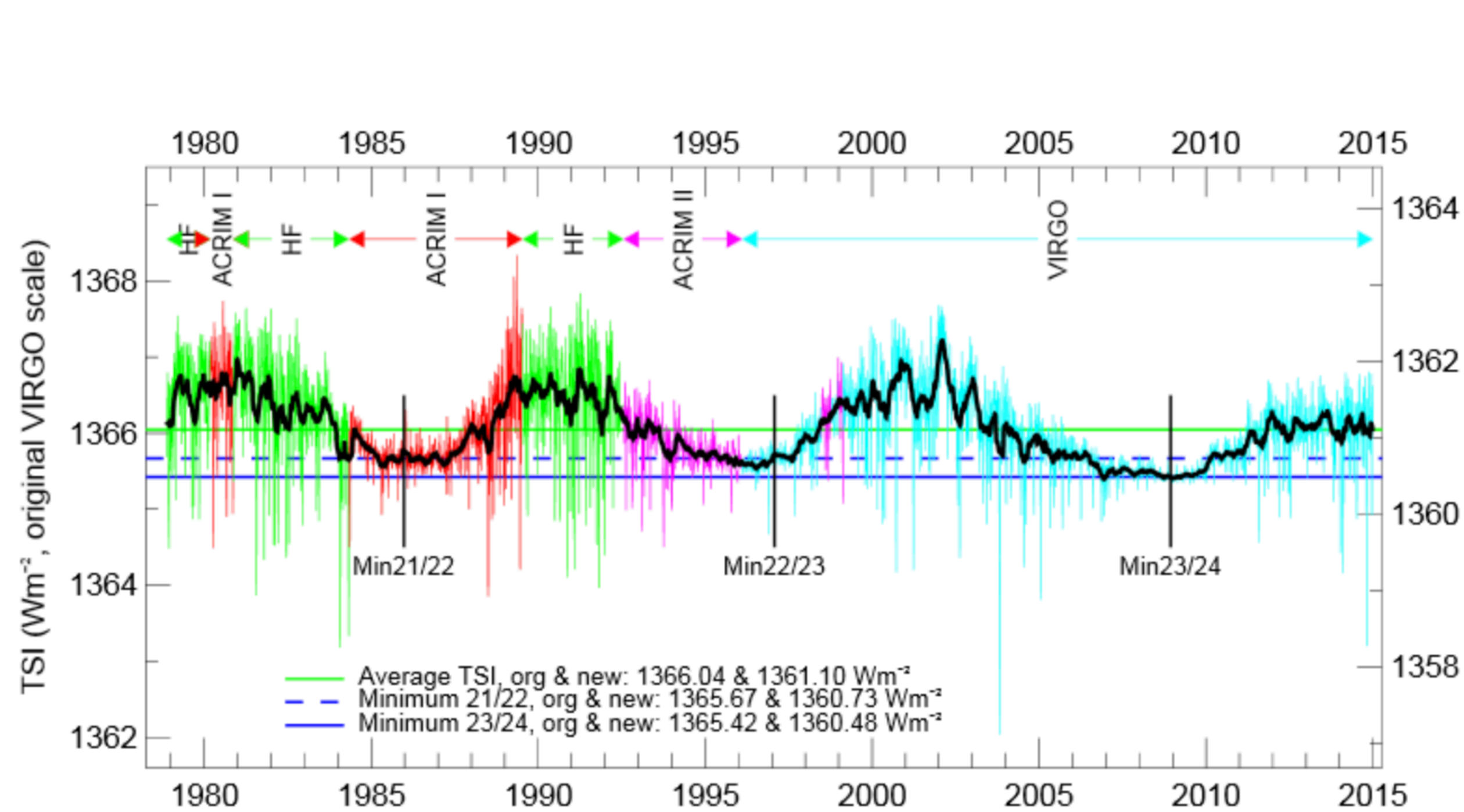


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Material prepared by John Kennewell and Andrew McDonald

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?