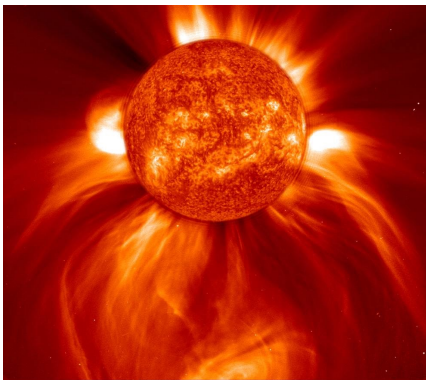
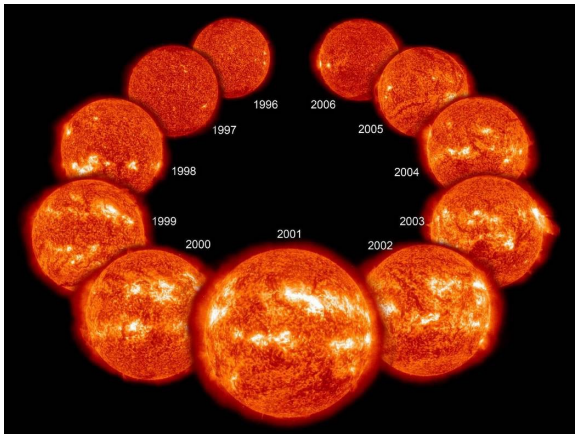


You Be the Solar Scientist!
Student Worksheet
Name: _____

Sarah Gibson is an astrophysicist at the National Center for Atmospheric Research. She is a solar scientist, a scientist who studies the Sun. She looks at how space weather, flares or ejections of material that begin on the Sun millions of miles away could affect life on Earth. Extreme space weather can harm satellites in orbit around Earth, threaten astronauts on the International Space Station, affect power grids on Earth's surface (think blackout!), can take down air traffic control at your airport (think no transport of people or packages), it could even affect your cell phone and internet service (think no social media!).

Today, you'll learn some important skills that are used by solar scientists. Who knows, maybe someday, you'll be in charge of a satellite research project that will track space weather and will help protect life on Earth!

Skill #1 - Understanding the Sunspot Cycle
Solar activity is linked to the number of sunspots on the Sun. The higher the number of sunspots, the more likely there is to be solar activity that might affect the Earth. Near solar maximum, when sunspot numbers are the highest, the Sun produces about three CMEs every day. Near solar minimum, when sunspot numbers are the lowest, there is about one CME every five days. A CME (coronal mass ejection) is just one type of solar storm where the outer layer of the Sun quickly spews out a lot of material into the solar wind.



On graph paper, graph the number of sunspots versus the year with year on the x-axis and the number of sunspots on the y-axis.

Sunspot number data is from the WDC-SILSO, Royal Observatory of Belgium, Brussels

Year	Number of Sunspots	Year	Number of Sunspots
1965	22	**1970**	148
1966	67	**1971**	94
1967	133	**1972**	98
1968	150	**1973**	54
1969	149	**1974**	49

Year	Number of Sunspots	Year	Number of Sunspots
1975	23	**1998**	88
1976	18	**1999**	136
1977	29	**2000**	174
1978	100	**2001**	170
1979	220	**2002**	164
1980	219	**2003**	99
1981	199	**2004**	65
1982	162	**2005**	46
1983	91	**2006**	25
1984	61	**2007**	13
1985	21	**2008**	4
1986	15	**2005**	46
1987	34	**2006**	25
1988	123	**2007**	13
1989	211	**2008**	4
1990	192	**2009**	5
1991	203	**2010**	25
1992	133	**2011**	81
1993	76	**2012**	85
1994	45	**2013**	94
1995	25	**2014**	113
1996	12	**2015**	70
1997	29		

1. Connect the points you've plotted with a smooth curve. You'll notice that there are very clear peaks (maximums) and valleys (minimums). Which years are the maximums and which years are minimums?
   Years that are maximums _____
   Years that are minimums _____

Label these years on your graph with a capital M and lower case m, respectively.

2. Is there is a regular pattern for sunspot numbers? To answer this question, take note of what scientists call the solar cycle, i.e., how many years are there between a solar maximum, a solar minimum and the next solar maximum? For example, in 1968 there is a solar maximum, followed by a solar minimum in 1976, followed by another maximum in 1979. So the solar cycle would be 11 years for that first set of data (1979 minus 1968).

Find the next solar cycle starting in 1979.

Solar maximum=1979
Next solar minimum=
Next solar maximum=

Solar cycle (time between a solar maximum, solar minimum, and next solar maximum)=

Find the next solar cycle starting with 1989.
Solar maximum=1989
Next solar minimum=
Next solar maximum=

Solar cycle (time between a solar maximum, solar minimum, and next solar maximum)=

Find the next solar cycle starting with 2000.
Solar maximum=2000
Next solar minimum=
Next solar maximum=

Solar cycle (time between a solar maximum, solar minimum, and next solar maximum)=

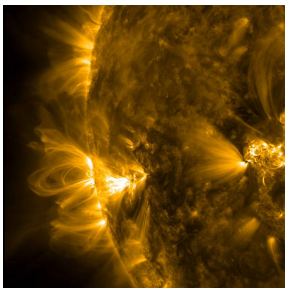
You should have four solar cycles calculated (one was done for you).
a) If you had to guess at the average solar cycle length, what would it be from 1968-2014?

b) Now find the average solar cycle length from 1968-2014 with a calculator:

3. If you had to make a prediction for the years 2019 and 2025, would the years be maximums or minimums?

4. How many sunspots were there during the year you were born? Predict whether it will be closer to a maximum or a minimum when you graduate from high school and for when you turn 30 years old.

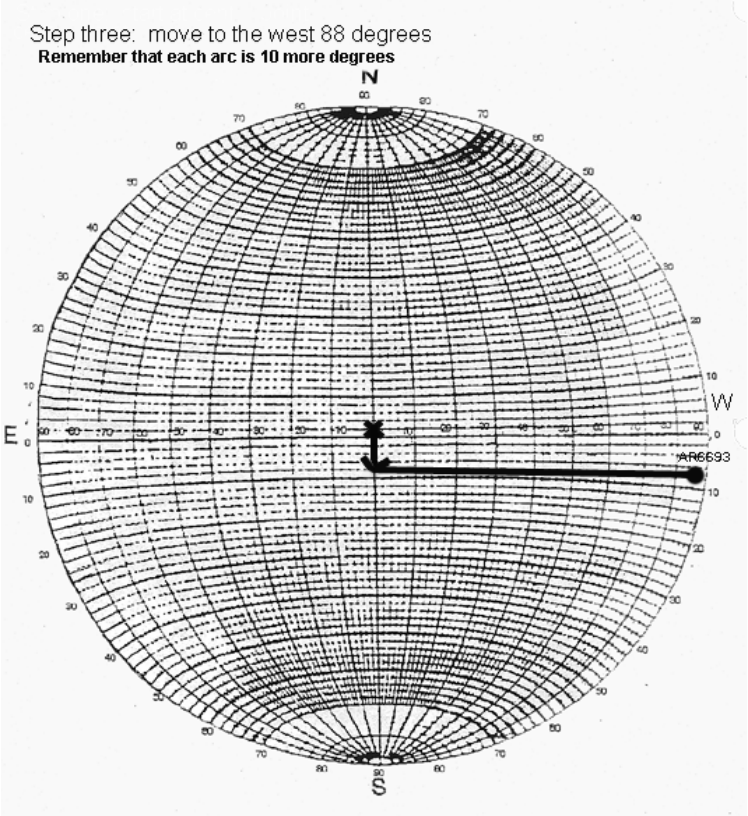
Check your understanding: The number of sunspots on the Sun is not constant. The number of sunspots varies with an ~11 year cycle. Space weather definitely increases with an increased number of sunspots, so it's important for everyone on Earth to know where we are in the solar cycle (near a maximum? or near a minimum?).



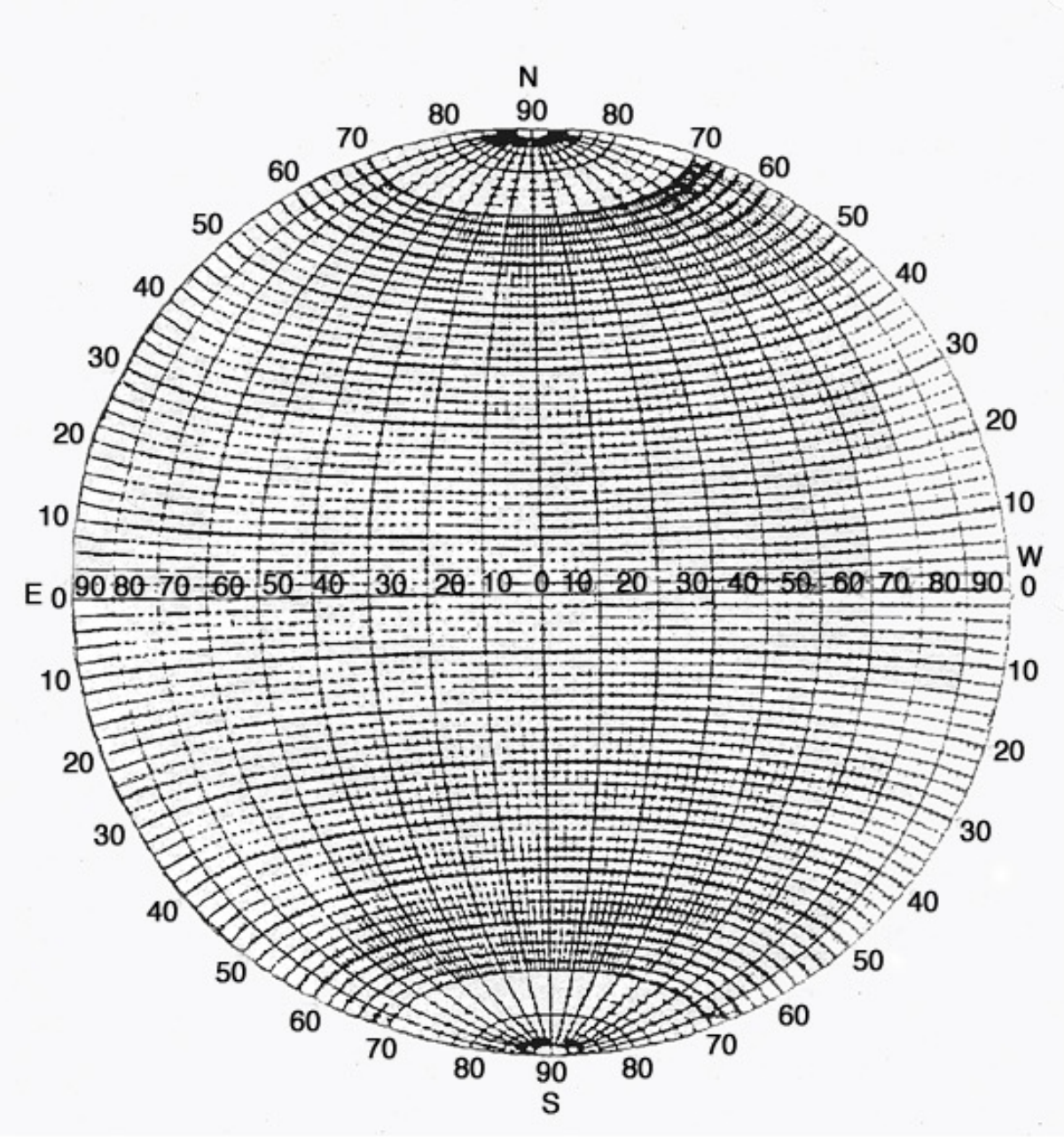
Skill #2 Tracking How an Active Region Moves Across the Sun
In order for scientists to determine if a solar flare or CME will affect life on Earth, they need to know where the flare or ejection came from. In fact, they are always tracking "active regions" (AR) on the Sun. An active region on the Sun is an area with an especially strong magnetic field. Sunspots frequently form in active regions. Solar activity, in the form of solar flares and coronal mass ejections (CMEs), is often associated with active regions.

How to graph an active region:
In general, choose your starting point as (0,0). This is the center point of the circle. Always move north or south first (the number of degrees that comes after the S or N in the AR number). The horizontal lines are in degree increments of 2's. Then move east or west (the number that comes after the E or W in the AR number). These east/west arcs are in degree increments of 10's. Here's an example for an AR6693 located at S07W88.

- step one: locate the starting point
- step two: move south by seven degrees
- step three: move west 88 degrees (or right 88 degrees)



Now you try it! Use the table below to plot the location of the active region AR7220 on the solar graph as it moves across the face of the Sun. To distinguish each new plot of AR7220, place the date by the plot. Unlike the example above, you will *not* want heavy lines drawn in pencil. If necessary, draw the vertical/horizontal lines very lightly in pencil, plot the dated point, and then erase the pencil lines before continuing to plot the next point. (Otherwise, your graph could get messy!)



Active sunspot region data from Rice University-Houston Museum of Natural Sciences, Summer Solar Institute

Date	Location of AR7220
July 5	S11E73
July 6	S12E63
July 7	S11E50
July 8	S12E38
July 9	S11E25
July 10	S12E11
July 11	S12W01
July 12	S12W14
July 13	S11W28
July 14	S12W41
July 15	S13W55
July 16	S12W69

Question for the Students

1. What pattern do you notice about the movement of AR7220?

2. Do you see much motion in the north-south range? On average, how many degrees west does the active region move in one day?

3. Scientists are tracking another active region on the Sun. The first day that AR7216 was seen, its location was N13E75. After 12 days where would you expect AR7216 to be?

Skill #3 Alerting People to Fact That a CME is Coming…
One final skill that solar scientists need to be successful is the ability to communicate their research or findings to other scientists and to the general public.

You know that happenings on the Sun, like a solar flare or CME, can affect life on Earth. In your groups, use the internet (like this page http://www.windows2universe.org/space_weather/sw_intro/sw_affect_us.html) to research how space weather affects life on Earth.

Create one of the following announcements to alert people to an incoming CME:
1. radio announcement (not to exceed 2 minutes of recording)
2 tv announcement (not to exceed 2 minutes of video)
3. PowerPoint slides that will be presented at "town hall meeting" (your classroom) alerting public to incoming CME (not to exceed 3 slides)

Your announcement must be creative and it will be about a hypothetical solar storm, but should include the follow scientific information about the incoming CME:
1. When the CME occurred and when it will arrive at Earth (CMEs typically reach Earth one to five days after leaving the Sun.)
2. The location on the Sun your CME originated from (use the active region notation from skill #2, for example, N13E75).
3. What places on Earth can expect to be affected. (remember that polar regions are more likely affected by space weather, not locations near the equator)
4. At least 2 threats to human society that this hypothetical CME poses.
5. One precaution that your listeners can take (examples, make sure generator is working in case of electrical blackout, make final post on Facebook in case cell service/internet goes down, put all of your homing pigeons in secure cages so they don't get lost, power down satellites that might be in storm's path, etc.)

Note: The first solar image on this worksheet is from the SOHO spacecraft. The image was voted into first place during SOHO's recent (December 2015) 20th anniversary/birthday celebration. This picture, captured on January 8, 2002, shows an enormous eruption of solar material, called a coronal mass ejection, spreading out into space.

The second solar image is also from the SOHO spacecraft and shows eleven years in the life of the Sun, as it progressed from solar minimum to maximum conditions and back to minimum (upper right) again. This solar cycle is seen as a collage of ten full-disk images of the lower corona.

The last image shows an active region of the sun just rotating into the view of NASA's Solar Dynamics Observatory. It gives a profile view of coronal loops over a two-day period, from February 8-10, 2014. Coronal loops are found around sunspots and in active regions. These structures are associated with the closed magnetic field lines that connect magnetic regions on the solar surface. Many coronal loops last for days or weeks, but most change quite rapidly. This image was taken in extreme ultraviolet light.