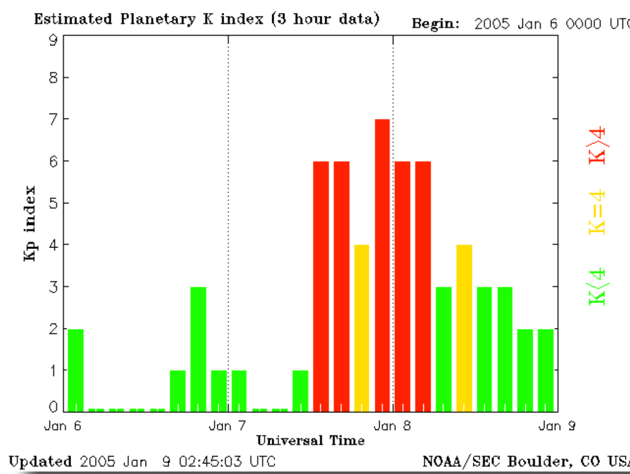
Activity 14 – Magnetic Storms

In this exercise, students will become familiar with a very common indicator of magnetic storminess: the Kp index. This index is assembled every three hours based on the level of the disturbances detected in dozens of magnetometer installations located at latitudes north of 50 degrees. It is a 9-point scale in which '9' is the most severe, largest disturbance, and '0' is the least severe, smallest to no disturbance. Typically, there are only one or two Kp=9 storms every year. Kp index plots, like the one below, can be obtained for this activity from the NOAA archive at:
http://www.sec.noaa.gov/ftpdir/warehouse
For this lesson, we have created a website using 2005 data from the NOAA archive, which can be found here: http://ds9.ssl.berkeley.edu/themis/classroom_kp2005.html

GOALS

1. Students will learn that strong magnetic storms are not as common as weaker ones.
2. Students will analyze plots of the Kp index and create a histogram of the number of days in the year that magnetic storms exceed a specific level on the Kp scale.



PROCEDURE

1. Students visit http://ds9.ssl.berkeley.edu/themis/classroom_kp2005.html
2. Students select one of the plot files and open it in the browser.
3. From the archive of Kp, students note the **maximum Kp reached each day**. This will give the number of days that magnetic storminess reached the following levels out of 90 days:

Calm storm conditions:	Kp = 4
Minor storm conditions:	Kp = 5
Moderate storm conditions:	Kp = 6
Strong storm conditions:	Kp = 7
Severe storm conditions:	Kp = 8
Extreme storm conditions:	Kp = 9

4. Students create a histogram of the tallies for at least one month's worth of Kp plots.

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5. At the conclusion of the assignment, consult the NOAA Space Weather site to compare. http://www.sec.noaa.gov/NOAAscales/#GeomagneticStorms

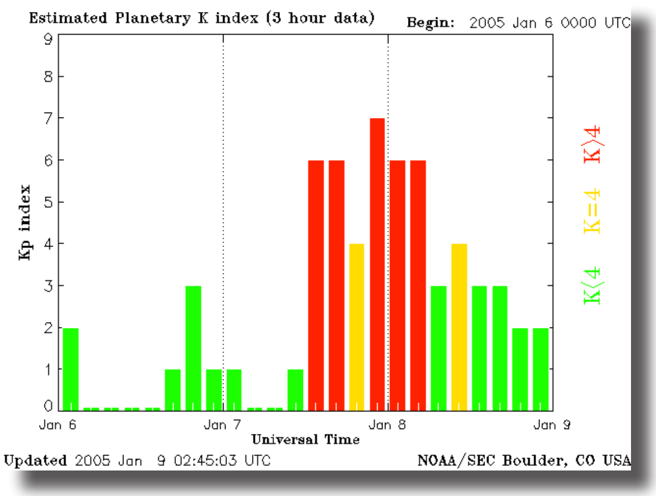
GOING FURTHER

- Have the students enter the data into a computer datasheet so they can perform additional calculations on the data and plot the data using the computer program.
- Every 3 days print out the most recent Kp index from NOAA's website http://www.sec.noaa.gov/rt_plots/kp_3d.html and post it on the wall in the classroom. Post other relevant space-weather data from NASA's Student Observation Network, http://son.nasa.gov/tass/ such as sunspot, radio wave data, or magnetometer data, underneath the Kp data. Have students compare datasets to notice the connection between the Sun and Earth's Magnetosphere.

Student Name ______________________________ **Date** ________

Magnetic Storms

Below is a plot of the Kp index for a storm obtained from the NOAA data archive and put on the following website: http://ds9.ssl.berkeley.edu/themis/classroom_kp2005.html Scientists use the Kp index to identify the strength of magnetic storms. The bar graph shows the Kp index from January 6, 7, and 8, 2005. On January 7th, there was a strong magnetic storm with Kp=7. In this activity, you will examine similar plots from an on-line data archive and determine how common it is to find storms at various levels of the Kp index, beginning January 1, 2005. **See the example below for an explanation for how to tally.**



From the Kp website above, tally **the maximum Kp reached each day.** This will give you the number of days that magnetic storminess reached the following levels during 90 days:

Calm Conditions:	Kp = 4
Minor storm conditions:	Kp = 5
Moderate storm conditions:	Kp = 6
Strong storm conditions:	Kp = 7
Severe storm conditions:	Kp = 8
Extreme storm conditions:	Kp = 9

Example: The plot shows one bar for every 3-hour interval starting at midnight on January 6. There are 8 bars for each day. The tally for the above plot would indicate for January 6, no counts. For January 7, one count for Kp=7, and for January 8, one count for Kp=6.

Kp Index	Number of days in January	Number of days in February	Number of days in March
9			
8			
7			
6			
5			
4			

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Student Name ___________________________ ***Date*** _______

Magnetic Storms

Question 1: From your 90-day sample, what percentage of days had either Severe or Extreme magnetic storm conditions?

Question 2: From your answer to Question 1, what is the chance (in percent) that your magnetometer will see at least a moderate magnetic storm tomorrow?

Question 3: What percentage of days are considered "stormy" during this period?

Inquiry Problem - 2005 was near sunspot minimum.

1. Find a year of sunspot maximum.
2. Repeat your tabulations of stormy days in a new chart, using the data from http://www.sec.noaa.gov/ftpdir/warehouse.
3. Compare your answers during sunspot maximum and sunspot minimum.

Teacher Answer Key

Kp Index	Number of days in January	Number of days in February	Number of days in March
9			
8	|		
7	|||		
6	|||	|	|
5	||||||	|||	|||||
4	|||||||||| (10)	||||||	|||||||| (8)

Note: To simplify the calculations, only tally the maximum Kp reached in a given day. For example, in the Kp plot above, we count one day with Kp=7, which occurred on January 7, and one day with Kp=4 on January 8.

Question 1: From your 90-day sample, what percentage of days had either Severe or Extreme magnetic storm conditions?

Answer: There was only one day (in January) that reached at least Kp= 8 'Severe Storm', so the percentage is (1/90) x 100% = 1% of the time.

Question 2: From your answer to Question 1, what is the chance (in percent) that your magnetometer will see at least a moderate magnetic storm tomorrow?

Answer: There were 10 days where Kp was at 6 or higher, so the chance is (10/90) x 100% = 11%.

Question 3: What percentage of days are considered 'stormy' during this period?

Answer: Stormy days are days where Kp exceeds 4. There were 24 days in January, 10 in February, and 14 in March for a total of 48 days, so the percentage of days is (48/90) x 100% = 53%. During this period of time, about every other day had stormy conditions.

How is the Kp index actually determined?

Geomagnetic disturbances can be monitored by ground-based magnetic observatories called magnetometers. The global Kp index is obtained as the mean value of the disturbance levels in the two horizontal magnetic field components Bx and By, observed at 13 selected, subauroral stations. The name Kp originates from "planetarische Kennziffer" (planetary index). Kp was introduced as a magnetic index by physicist J. Bartels in 1949 and has been derived since then at the Institut für Geophysik of Göttingen University, Germany.

The following definition of K variations has been given by Siebert (1971):

> "K *variations are all irregular disturbances of the geomagnetic field caused by solar particle radiation within the 3-h interval concerned. All other regular and irregular disturbances are non K variations. Geomagnetic activity is the occurrence of K variations.*"

To calculate the Kp index from the K index, here's what you have to do:

1. Local disturbance levels which lead to a value for the K index are determined by measuring the range (difference between the highest and lowest values) during three-hourly time intervals for the most disturbed horizontal magnetic field component.
2. The quiet-day variation pattern has to be removed from the magnetometer data, a somewhat subjective procedure. The range is then converted into a local **K index** for the Niemegk Magnetic Observatory near Potsdam, taking the values 0 to 9 according to a quasi-logarithmic scale, which is station-specific; this is done in an attempt to normalize the frequency of occurrence of the different sizes of disturbances because smaller disturbances are so common compared with larger disturbances.
3. According to the geographic and geomagnetic coordinates of the observatories, each observatory still has an annual cycle of daily variations. Using statistical methods J. Bartles generated conversion tables to eliminate these effects. By applying the conversion tables, a standardized **Ks index** for each of the 13 selected observatories is determined. In contrast to the K values, the Ks index is expressed in a scale of thirds (28 values): 0-, 0, 0+, 1-, 1, 1+, 2-, 2, 2+, ... , 8, 8+, 9-, 9
4. The main purpose of the standardized index Ks is to provide a basis for the global geomagnetic **Kp index** which is the average of a number of the Ks index from the "Kp stations," originally 13. The Ks data for the two stations Brorfelde and Lovö are combined, as are the data from Eyrewell and Canberra. With these four stations combined into two stations, the total number of stations used for the Kp index is 11.

The official Kp indices are available since 1932 at:

http://swdcwww.kugi.kyoto-u.ac.jp/kp/

Additional Web Resources

Space Weather terms

- Solar Terrestrial Dictionary - http://stp.gsfc.nasa.gov/stp_program/stp_dictionary.htm
- Space Physics Textbook - http://www.oulu.fi/~spaceweb/textbook/

Space Weather primers

- NASA-IMAGE - http://sunearth.gsfc.nasa.gov/sechtml/tut.html

Space Weather websites

- NOAA-Space Environment Center - http://www.noaa.sec.gov/SWN
- Spaceweather.com - http://www.spaceweather.com
- The Human Impacts of Space Weather - http://www.solarstorms.org

Space Weather books

- *The 23rd Cycle - Learning to Live with a Stormy Star* by Sten Odenwald, (Columbia University Press, 2001)
- *Sentinels of the Sun: Forecasting Space Weather* by Barbara Poppe and Kristen Jordan (Johnson Books, 2006)

Space Weather magazine and newspaper articles

- "Solar Storms" Sten Odenwald (*Washington Post* March 10, 1999) http://solar.physics.montana.edu/press/WashPost/Horizon/196l-031099-idx.html
- "Solar Storms: The Silent Menace" Sten Odenwald (*Sky and Telescope*, March 2000)
- "Storm Watch" C. Renee James (*Sky and Telescope*, July 2007)