

Analyzing the Space Weather Data

As you might have surmised, the information obtained from the Millstone Hill IS Radar is complex and often difficult for even experts to interpret. We have compiled a set of data and placed them in Excel files for you to use.

The first data set consists of a year by year compilation of radar data by day. We combined and averaged all the data points for a specific day. This data found on the CD ROM or downloaded from the Haystack website:

<http://www.haystack.mit.edu/edu/pcr/downloads/>

in files named:

[SpaceWeatherfiles_yearly.xls](#)

The Millstone IS radar data for each year from 1984 to 2006 were compiled using the software program, Madrigal. The IS radar was looking:

- directly overhead,
- around noon,
- at a fixed altitude of around 300 km, and
- at parameters, T_e and T_i , the temperatures of the electrons, and positive ions in Kelvin respectively.

Examine the data files and answer the worksheet on the next page.

As you might suspect, there are giant holes in the daily and monthly coverage from year to year. And even this is deceptive because in some cases the radar was run continuously for a short period of time, accumulating lots of data but over a short time span.

Name_____ Period_____ Date_____

Worksheet: Analyzing the Space Weather Data

Answer the following questions:

1. What do we see, if anything, if we examine the data from year to year?
2. Are there any seasonal trends?
3. Do we find any solar cycles?

4. Can we detect abnormal space weather?

5. What does the number of points indicate about the radar coverage from year to year?

6. For the number of data points, what years seem to have the best coverage? What years seem to have the least?

Year	Points
1984	1026
1985	1332
1986	1076
1987	851
1988	1215
1989	1741
1990	2088
1991	1463
1992	1657
1993	2032
1994	6583
1995	3040
1996	5002
1997	4524
1998	5217
1999	3857
2000	3224
2001	3055
2002	3224
2003	1875
2004	25258
2005	2881
2006	3234

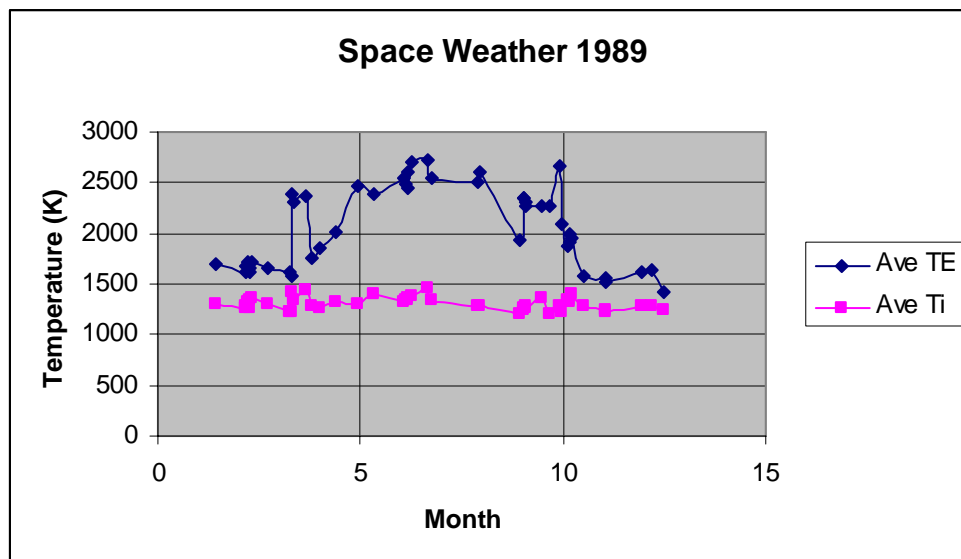
Activity 1: Examining a Year

Student should form teams of two or three. Each team should select a specific year and make a scatter diagram of the year. It is best if the years are consecutive, but if there is a choice, select the mid 80's to 2002. This data found on the CD ROM or downloaded from the Haystack website, Education and Outreach:

<http://www.haystack.mit.edu/edu/pcr/downloads/>

- First select the year, and open the [SpaceWeatherfiles_yearly.xls](#) file. Find an empty box on the spreadsheet and click there.
- Click on the Graphing icon "Chart Wizard" and select "XY (Scatter)" and select the second box from the top on the left with the lines joining dots. Hit: "Next>."
- Drag over the headings, Ave Time, Ave T_e , Ave T_i and then drag down to the bottom of data set. Then Hit: "Next>."
- Enter the titles:
 - ❖ "Chart title: Space Weather 1989" In the example: Space Weather 1989
 - ❖ "Value (X) axis: Month"
 - ❖ "Value (Y) axis: Temperature (K)"
- Select "Gridlines" and make sure that the major gridlines are selected on both axes.
- Hit: "Next>" and the "Finish."

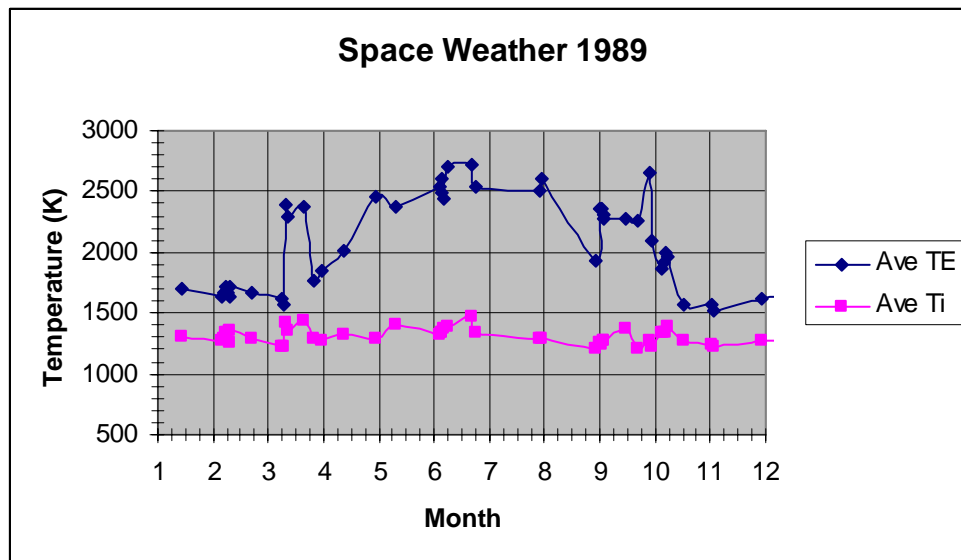
You should see the following chart:



Now you should make the graph better looking.

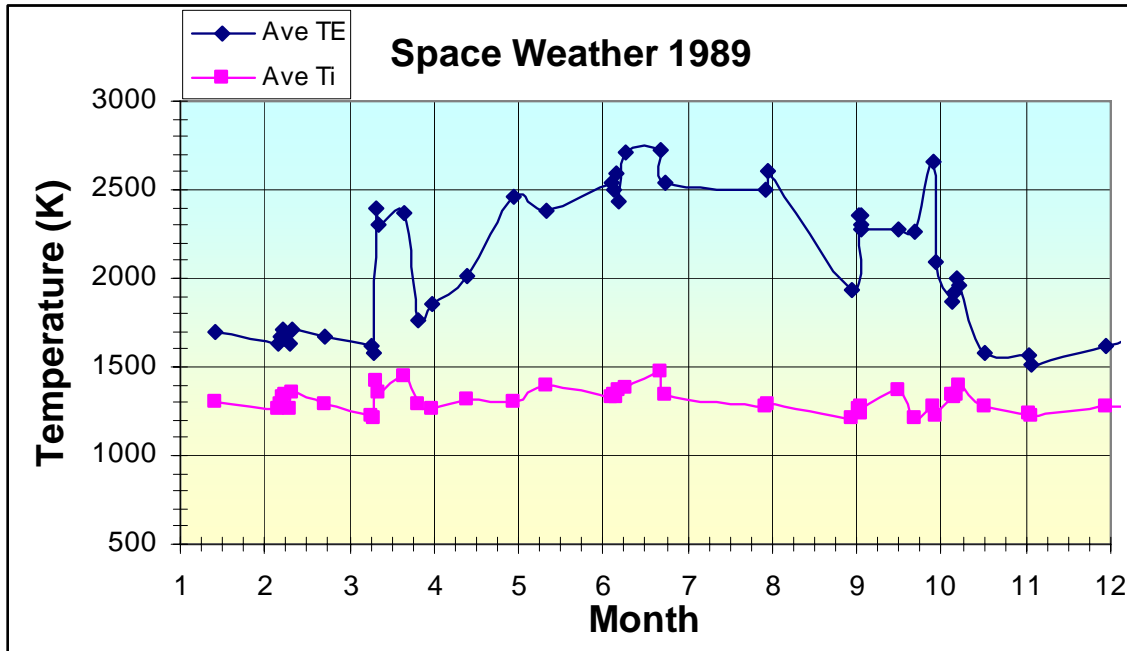
- Double click on any number on the X-axis. Select the "Scale" tab and change the Minimum = 1, the Maximum = 12.99, the Major unit = 1, Minor unit = .2
- Select "Patterns" and in the middle box select "Cross." Hit "OK."
- Click on any number on the Y-axis. Select "Scale" and change the Minimum = 500, the Maximum = 3000, the Major unit = 500, Minor unit = 100.
- Select "Patterns" and in the middle box select "Cross." Hit "OK."

You should see:



- Click on the box on the right and then "Format" and change the font to 8. Then drag the Box to the upper right hand corner.
- Click on the plot area, right click it and select "Fill Effects." Select "two colors" The first color should be the lightest blue, the second the lightest yellow. With the horizontal blue on top, select "OK" twice.
- Make the areas as large as possible by clicking on the plot area and then grabbing the sides and dragging them to fill the square. You may have to reformat the font on the X- and Y-axis numbers.

Your graph should look like the one on the next page.



Make a duplicate graph for the group and keep one graph for your notebook.

Each group should answer the following questions concerning their own graph in the following worksheet.

Name_____ Period_____ Date_____

Worksheet: Activity 1 Analyzing a Year

Answer the following questions. Explain your answers. A negative response is all right if your graph justifies it—but you must state why.

1. In examining the graph, describe what you see from month to month.

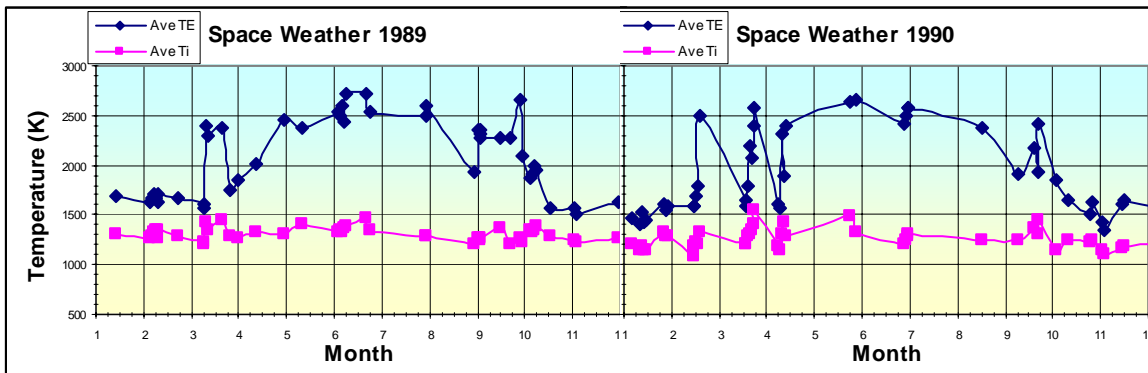
2. Are there any seasonal trends?

3. Do you see any solar cycles?

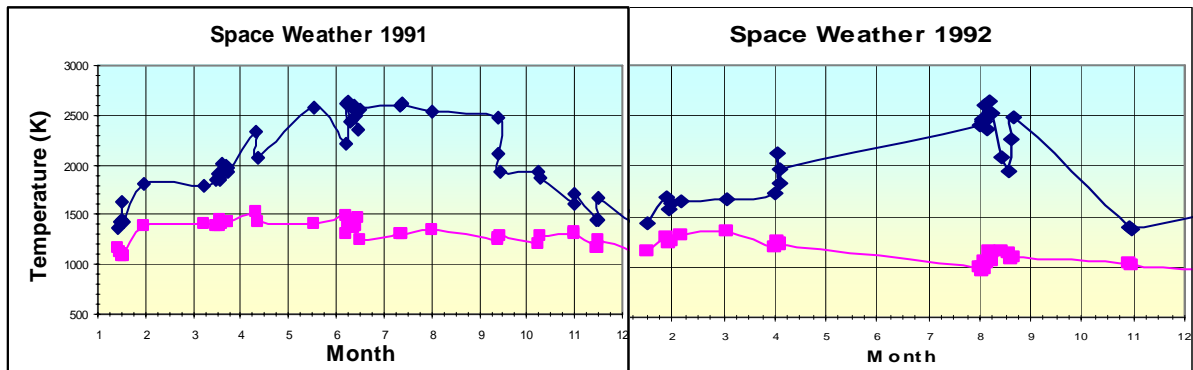
4. Can you detect abnormal space weather?

Activity 2: Examining a Continuous Number of Years

Take the graphs from each group, cut the vertical ends off at the Y-axis lines and tape them together. It should be continuous like this. In the example below, graphs from 1989 to 1990 are joined into a single graph.



In another example, 1991 and 1992 are joined.



Answer the questions on the following worksheet concerning the continuous years.

6. Can you detect abnormal space weather? Use the Internet and "Google" search on something like "severe solar weather." List your sources. (Hint: Check out March 1989, March 1991, November 1991 and May 1992.)

7. So, what do you think of the Millstone Hill data? Is there anything about the graphs which causes you doubt? (It's OK to feel this way. In your high school labs everything is nice and tidy.)

8. In the natural world data collection is often governed by chance. For example, the radar is off when you wish it were on. What influences this? Consider the following in your answer:
 - a) Human resources, for example, the time necessary to run the radar around the clock and the drain on manpower to do it.
 - b) Cost. It is expensive to run the radar—who pays for it?
 - c) Probability (Bad Luck!) We might suspect that a storm is coming but we don't know when.
 - d) Rotten Luck! Interferences from outside sources or instrument malfunctions.


Activity 3: Literature Review and Report—Examining a Severe Solar Storm

Severe space storms have occurred many times during Millstone Hill's history. The ones we examined in detail are found on:

[SpaceWeatherfiles Special Months.xls](#) or
[SpaceWeatherfiles Special Months2.xls](#)

Here are the months we examined and a description of what occurred:

Date	Description
March 1989	<p>The HydroQuebec Blackout of March 13, 1989 at 2:44 am</p> <p>Recent storms associated with Solar Cycle 22 (the 11-year sunspot cycle that began in 1986) have had an unprecedented impact on electric power systems. The great geomagnetic storm of March 13, 1989, plunged the entire HydroQuebec system, which serves more than 6 million customers, into a GIC-triggered blackout. Most of Hydro Quebec's neighboring systems in the United States came close to experiencing the same sort of outage. http://www.agu.org/sci_soc/eiskappenman.html</p>
March 1991	<p>The recent impacts on Jupiter by the fragments of comet Shoemaker-Levy are a sobering reminder of the violent forces that exists in space that are released now and then in spectacular fashion. A violent event of a different type occurred in March 1991, when a powerful interplanetary shock wave hit the Earth's magnetic field and created a new radiation belt. Nothing like that had happened since July 1962, when the US Air Force exploded a hydrogen bomb above the atmosphere, creating a belt of trapped radiation which lasted five years and caused the demise of three spacecraft.</p> <p>http://www-spof.gsfc.nasa.gov/Education/wbirthrb.html</p>
October 2002	<p>Summary: On Oct. 23rd, Earth glided into a solar wind stream flowing from a large an unusually long time. Solar wind gusts triggered auroras off-and-on from Oct. 23rd until Oct. 31st..</p> <div data-bbox="1273 1163 1528 1419" data-label="Image"> </div> <p>http://science.nasa.gov/spaceweather/aurora/gallery_23oct02.html</p>
Oct-Nov 2003	<p>November 12, 2003: What if...you're in California in July, the middle of summer. The sun rises early; bright rays warm the ground. It's a great day to be outside. Suddenly, it begins to snow--not just a little flurry, but a swirling blizzard that doesn't stop for two weeks.</p> <p>That's what forecasters call unseasonable weather. It sounds incredible, but "something like that just happened on the Sun," says David Hathaway, a solar physicist at NASA's Marshall Space Flight Center.</p> <p>Only a few weeks ago solar activity was low. The face of the sun was nearly blank--"very few sunspots," says Hathaway--and space weather near Earth was mild. "Mild is just what we expect at this point in the 11-year solar cycle," he explains. "The most</p>

	<p>recent maximum was in 2001, and solar activity has been declining ever since."</p> <p>Then, suddenly, in late October the sun began to behave strangely. Three giant sunspots appeared, each one larger than the planet Jupiter. In California where smoke from wildfires dimmed the sun enough to look straight at it, casual sky watchers were startled by the huge blotches on the sun.</p> <p>One of them, named "sunspot 486," was the biggest in 13 years.</p> <p>Below: Astrophotographer Bob Sandy of Virginia took this picture of giant sunspot 486 emerging over the sun's limb on Oct. 23, 2003. It is preceded by another giant spot, numbered 484.</p>  <p>http://sohowww.nascom.nasa.gov/hotshots/2003_11_04/</p>
<p>September 2005</p>	<p><u>Power Outrages ... Colorful Skies</u></p> <p>Monday, September 12th, 2005: It's interesting to see the various news outlets report (speculate) on the large power outages in Los Angeles today, though I recalled reading about something last week that might be a factor. My turn.</p> <p>I am wondering, Could it possibly be due to the very large and strong Solar Storms and flares in recent and coming days? Some of the biggest ever recorded?</p> <p>Giant Solar Flare Hits U.S., Canada (September 12, 2005)NOAA Issues Another Space Weather Warning; Powerful Solar Flare Erupts. Spaceweather.com [Sept. 12]</p> <p>Maybe sun storms are causing the outages; I had read that they can, maybe not, though it will be interesting to see what may have caused the big outages in California. eruptions in the act.</p> <p>http://hm-ad.com/?m=200509</p>
<p>April 2006</p>	<p>4/27/06</p> <p>CRACKLING SUNSPOT: Big sunspot 875 is crackling with solar flares. Earlier today it unleashed an M8-flare, almost an X-class event. The sun's rotation is turning</p> <p>SOLAR FLARE ALERTS: Ham radio operators and solar photographers, would you like to know when X-flares are happening? Instant solar flare alerts from SpaceWeather PHONE (http://spaceweatherphone.com) allow you to catch solar the spot toward Earth, raising the possibility of Earth-directed eruptions in the days ahead.</p> <p>http://cse.ssl.berkeley.edu/secnews/s-a-news.html</p>

Select one of the months above and describe the space weather events in your month. Do an Internet research paper or a multimedia presentation such as a poster or PowerPoint. In your paper or multimedia presentation, be sure to include color images.

- Describe what happened on the Sun and when,
- Detail the events that occurred on Earth because of the events.

Multimedia Presentation Rubrics

Students enjoy working together to make a multimedia presentation and our choice of presentation is a PowerPoint. Go to "Google" and select "science presentation rubrics." Here are some rubrics we recommend to use:

- Science PowerPoint Presentation Evaluation Rubric
www.howe.k12.ok.us/~jimaskew/education/evalppt.htm
- Rubrician.Com PowerPoint rubrics: www.rubrician.com/technology.htm
- Multimedia: <http://www.ncsu.edu/midlink/rub.mm.st.htm>
- Presentation Rubric: <http://www.ncsu.edu/midlink/rub.pres.html>

Analyzing the Monthly Data

For the monthly data, the parameters were the same as previously selected along with the log of the electron density.

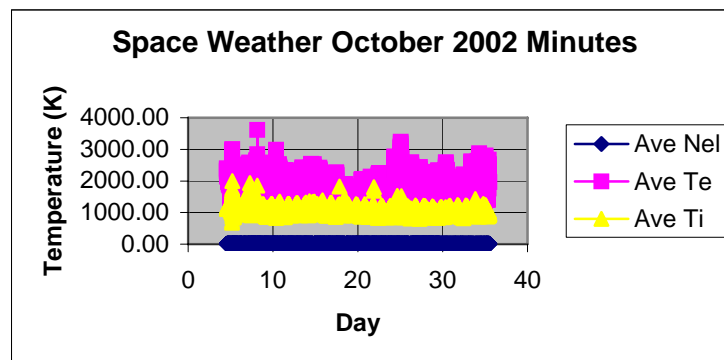
The best set of data is for October 2002. This was the first time that **any** IS radar was run around the clock for one continuous month. Consequently, this information was in demand worldwide. Other sets of monthly data are also excellent but you will see missing data when the radar was turned off at night or when the radar was not operating. There are gaps, particularly in the 1980s and 1990s. We suggest that you look at the October 2002 data and then compare it with the other sets.

Each team should select a specific month and make a graph of that month.

1. First select the year and open the [SpaceWeatherfiles Special Months.xls](#) or [SpaceWeatherfiles Special Months2.xls](#) file.

2. Find an empty box on the spreadsheet and click there.
3. Click on the Graphing icon and select "XY (Scatter)" with the lines joining dots. Hit "Next>."
4. Drag over the headings, Ave Time, Ave Te, Ave Ti and then drag down to the bottom of the data set. Then Hit "Next>."
5. Enter the titles:
Chart title: "Space Weather Month Year Data Span." In the example:
Space Weather October 2002 Minutes
Value (X) axis: Month
Value (Y) axis: Temperature (K)
6. Select "Gridlines" and make sure major gridlines for both axes are selected. Hit "Next>" and "Finish."

You should see the following chart:

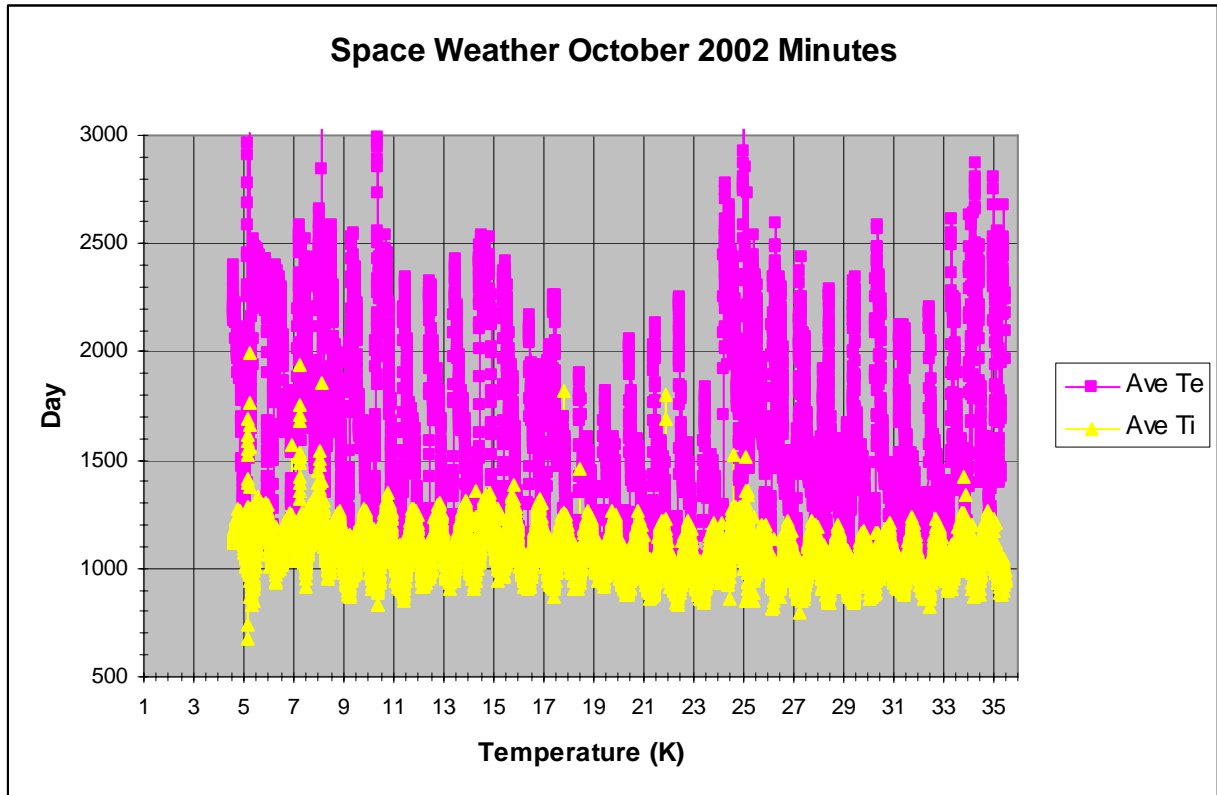


Now you should make the graph better looking.

1. Put the pointer in the white area of the graph and right click. Select "Source Data." Choose "Series" and then Remove "Ave Nel." Click "OK."
2. Click on any number on the X-axis. Select "Scale" and change the minimum = 1, the maximum = 36, the major unit = 2, minor unit = .5. Select "Font" and change the size to "8."
3. Select "Patterns" and in the middle box select "Cross." Hit "OK"

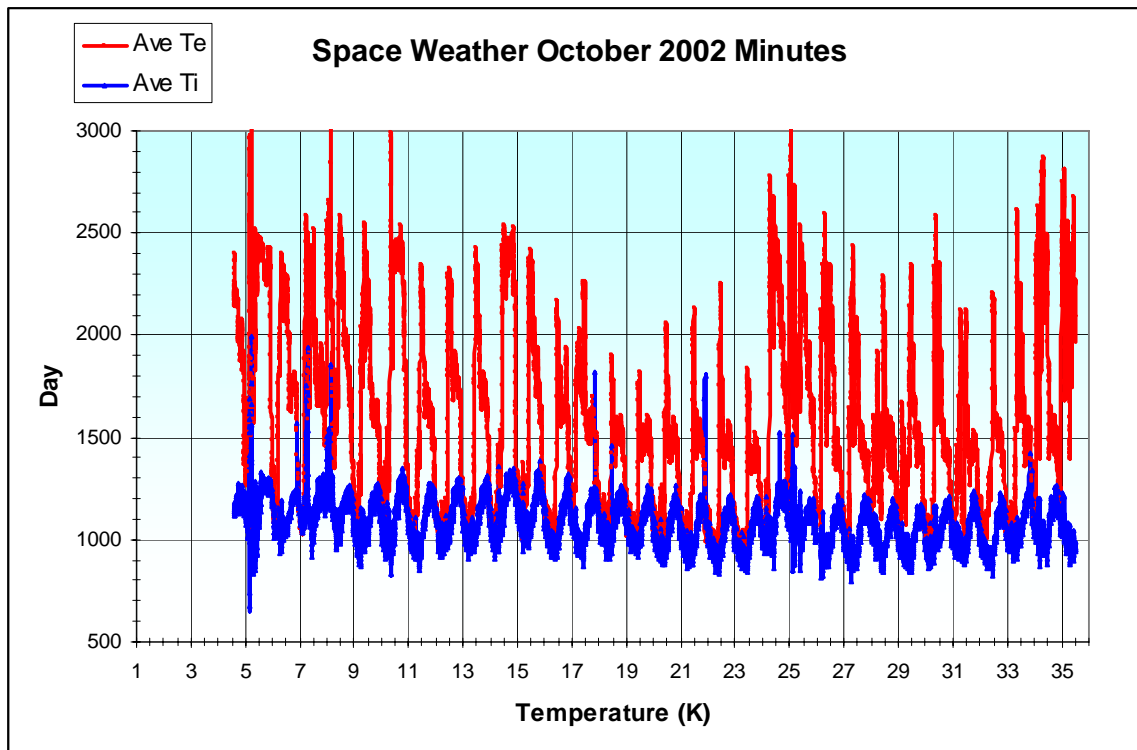
4. Click on any number on the Y-axis. Select "Scale" and change the minimum = 500, the maximum = 3000, the major unit = 500, minor unit = 100. Select "Font" and change the size to "8."
5. Select "Patterns," on the middle box "Cross." Hit "OK."

You should see:

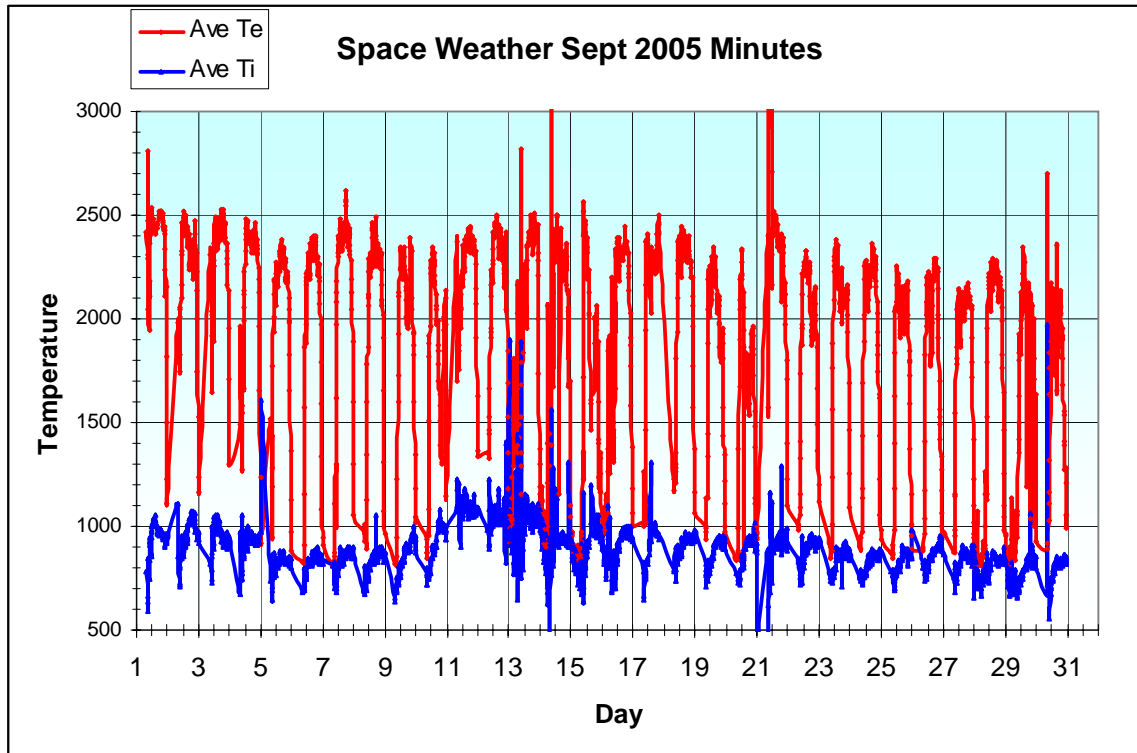


6. Now make the dots more visible. For the T_i series, right click on the set of data points Select "Format data series" and change their size to 2 and the color for both "Foreground" and "Background" to blue. Change the lines to the same blue color and select the next highest "Weight" line.
7. For the T_e series, right click on the set of data points. Select "Format data series" and change their size to 2 and the color for both "Foreground" and "Background" to red. Change the next highest "Weight" line and its color to red.
8. Drag the Box on the right to the upper left hand corner.

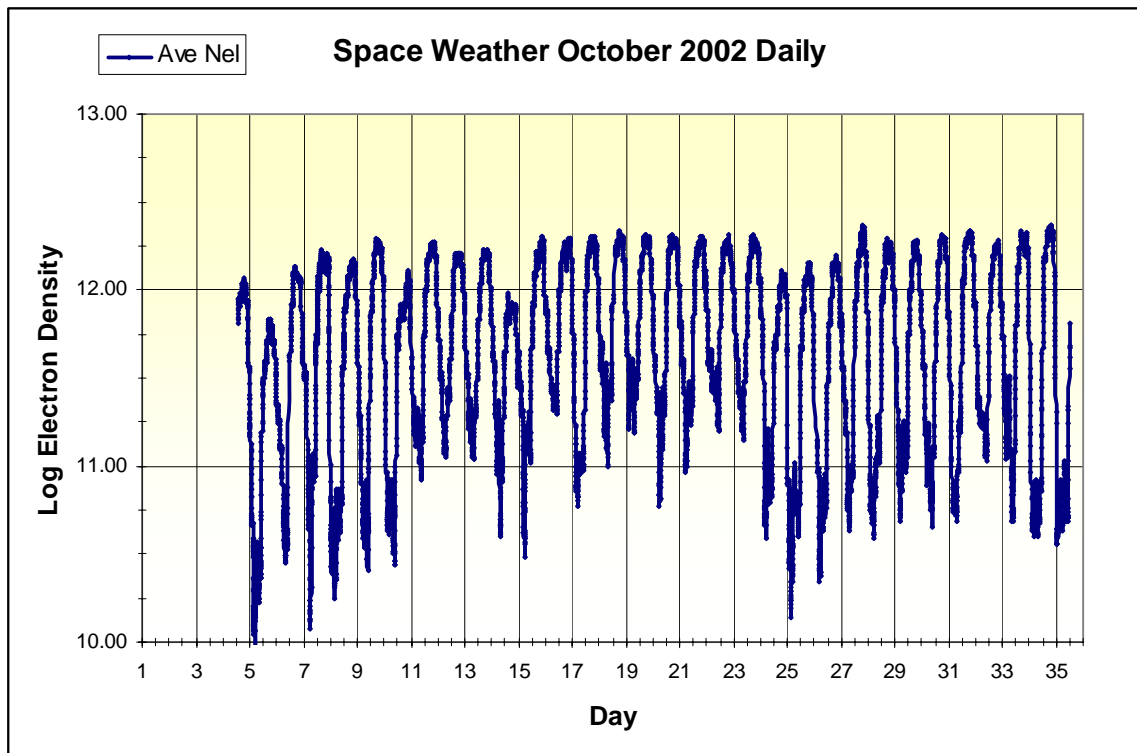
9. Right click on the plot area and select "Fill Effects." Select "two colors." The first color should be the lightest blue, and the second should be white. The horizontal blue should be on top, select "OK" and then "OK."
10. Make the areas as large as possible by clicking on the plot area and then grabbing the sides and dragging them to fill the square. You may have to reformat the font on the x- and y-axis numbers. What you should have is:



Below is the monthly run for September 2005.



Below is the log of the electron density in m^3 for October 2002.



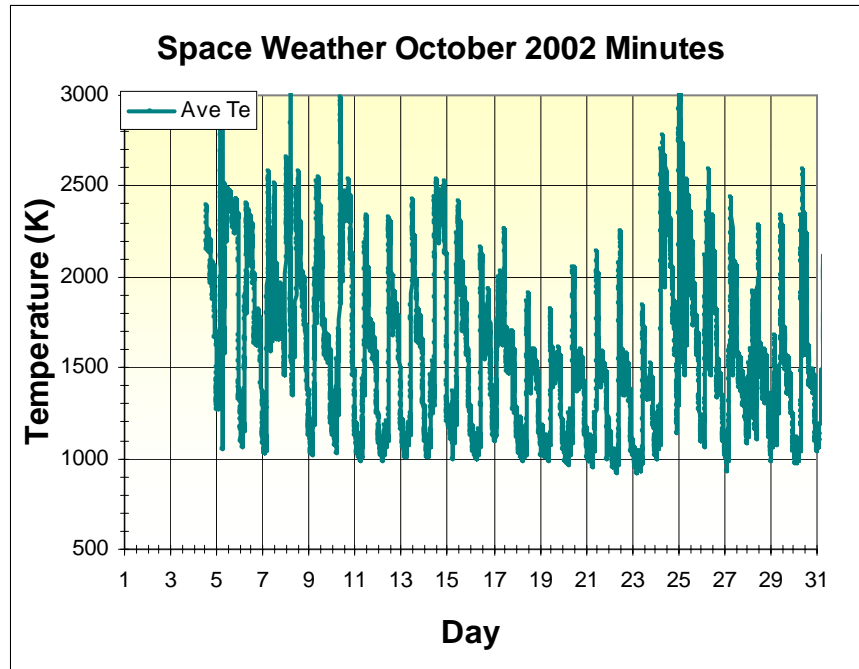
Name _____ Period _____ Date _____

Activity 5: Analysis of the Monthly Data

Using your graphs, answer the following questions:

1. From your Internet search, list the dates and type of event that occurred when the solar storms affected the Earth.
2. Explain the periodic trends in this graph in terms of the physical phenomena occurring between the Earth and Sun.
3. Using question #1, can you tell from the graph when a solar storm was occurring? If you can, describe what is happening to the electron density.

11. Finally, look at only the T_e verses time graph.



There is something about this graph which seems different. Where is it? Speculate what is happening.