TEACHER PAGE – *Trial Version*

** After completion of the lesson, please take a moment to fill out the feedback form on our web site (https://www.cresis.ku.edu/education/k-12/online-data-portal)**

Lesson Title: Data Series – The Role of Solar Radiation in Climate Change
Grade: 9-12

Question: How has the variance in solar irradiance changed over time and how do those changes relate to global temperature?

Time:
Two 45 minute class periods plus additional time for instruction on Excel if necessary. Lesson can be structured to 20-30 minute segments or as stand-alone activities.

Scope of the Lesson:
This lesson contains basic graphing components, interpretation of information and communication to others of findings depicted on their graph. You may choose to use either the total lesson or bits and pieces depending on student abilities and time constraints. The lesson is also designed so that it can be expanded for advanced students and used as an enrichment activity or a remedial activity.

Use of Microsoft Excel or another computerized graphing program will speed the activity and allow for more than one set of data to be examined. Graph paper and calculator can also be used by the students to get the same results.

If groups are given different data sets, the graphs can be printed or displayed so that the entire class or several groups can merge their information to come up with findings.

Objectives:
Given a set of data students will be able to:

- Create, using Microsoft Excel or another graphing program, an appropriate graph.
- Using the graph they construct, be able to answer questions related to the data.
- Interpret the information found on the graph, and present their findings either orally or in a written format.

Standards:

- National 9-12: A1, 2; B6; D1, 3; E2; F4, 5, 6; G1, 2, 3

Vocabulary:

- Solar irradiance: the amount of radiation received at the top of the earth's atmosphere, per unit area

Background:
Regardless of species, all living organisms on earth are affected continually by their surrounding environment, and are hence dependent upon the state of the climate at any given moment. Such dependence causes local, regional, and global climate to play a large role in our lives. This makes any climate changes which occur noticeable, especially over long periods of time. Due to the relationship between changes in climate and our everyday lives, as well as the potential future impacts that these changes can have on the global community, it is important to understand the factors which cause climate change to take place. One important aspect, which has been linked to climate change by scientists and

used by climate change skeptics as an argument against human-induced climate change, is the amount of radiation or energy received by the planet from the sun—a term known as **solar irradiance**. Analysis of such values has allowed scientists to determine the role which deviations in solar energy have in dictating atmospheric processes and facilitating changes in climate.

The first direct measurements of solar irradiance began in 1978 with the launch of the Active Cavity Radiometer Irradiance Monitor (**ACRIM**) satellite. After several years of ACRIM observations, certain cycles in irradiance values began to emerge, showing that the energy emitted by our nearest star does not remain constant but varies between maxima and minima on an eleven year basis. This variance was later found to coincide with changes in sunspot abundance, known as Schwabe Cycles, establishing a relationship between the measured strength of the sun and the number of sunspots visible upon its surface. Being the product of an increased magnetic field, sunspots are usually most abundant at times of high solar activity and less numerous when solar activity is low. This direct relationship implies that a large number of visible sunspots correspond to greater emission of solar radiation, and fewer sunspots to reduced solar emissions. Using the correlation between Schwabe Cycles and solar irradiance, scientists were able to recreate past irradiance values based on sunspot observations and establish a closer relationship between climate change and solar emissions.

Since solar irradiance is defined as the amount of radiation received at the top of the earth's atmosphere, and radiation warms our planet, it is reasonable to think that an increase in irradiance values would correspond to a subsequent increase in global temperature, and vice versa. However, although past irradiance values, recreated through Schwabe Cycle analysis, show a long term correlation with climate changes, this trend has not been observed in more recent times. Despite the fact that nearly two and a half irradiance cycles have been completed since 1978, continual temperature increase has been observed in many regions of our planet, suggesting that changes in solar irradiance are not the sole cause of climate change. Through this activity, students will examine this relationship, using actual data obtained by the ACRIM satellite to determine the irradiance cycle for actual and averaged values. In addition, students are asked to compare plots of temperature and irradiance values and predict future trends based on each plot.

Materials:

- Computer w/Microsoft Excel (or other graphing software)
- Data Set – Global Solar Irradiance Values
    - http://www.acrim.com/Data%20Products.htm
- Student Worksheet

Engage: http://www.qwiki.com/q/#!/Solar_variation

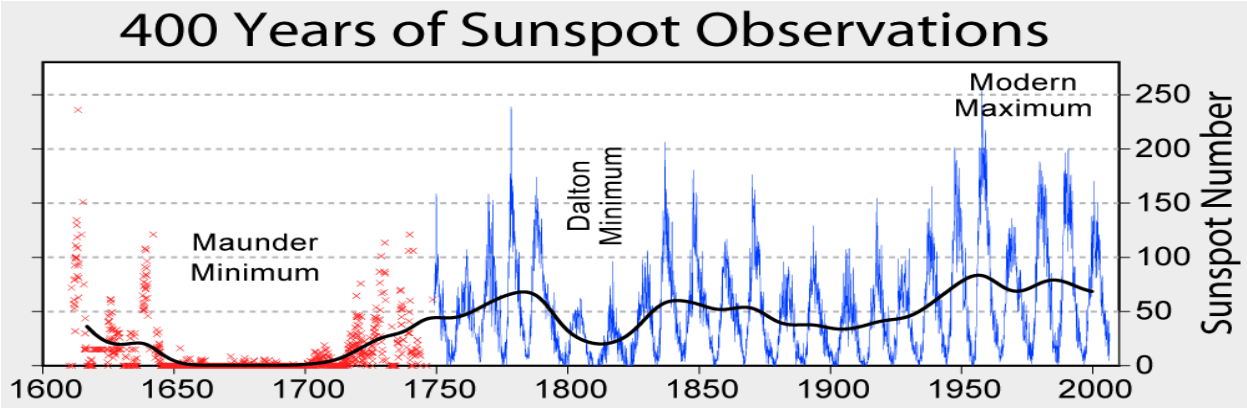

Figure 1 – Image created by Robert A. Rohde / Global Warming Art

Q1) What appears to be the length of a complete sunspot cycle (Figure 1)?

Q2) The black line in Figure 1 illustrates the annual average number of sunspots. Describe the shape or trends in this line.

Explore:

- Download the data set (see materials section).
- Plot a graph of the actual solar irradiance measurements versus time.

Q3) What are the noticeable trends in this graph?

Q4) What are some advantages or disadvantages of such a highly populated (dense time scale) graph?

- Irradiance is defined as the power, per unit area, of electromagnetic radiation incident upon a surface. Keeping this definition in mind, describe what is meant by solar irradiance (see example questions below):

Q5) Where does the radiation come from?

Q6) What is the surface the radiation is incident upon?

Explore:

- Using the average values given for each year, plot a graph of the average solar irradiance versus time.

Q7) Discuss what trends you can interpret from these averages.

Q8) Discuss if any patterns seem to emerge from your graph.

Elaborate:

- Climate records from the past quarter century indicate a warming trend throughout this time period, as shown by the temperature anomaly graph from East Anglia University (Figure 2).

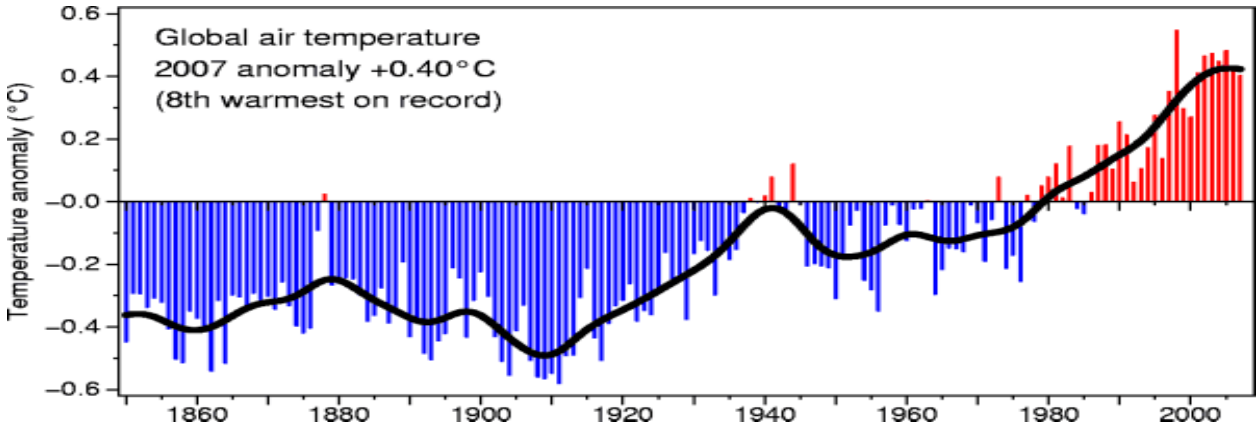

Figure 2 – Climatic Research Unit at University of East Anglia

Q9) Describe any relationship between the temperature anomaly graph (Figure 2) and the graph of average solar irradiance.

Q10) Describe whether any changes in solar irradiation appear to be directly causing the observed warming.

Q11) What predictions can you make about future solar irradiance and temperature trends?

Q12) How might solar irradiance values affect the rate of future temperate changes?

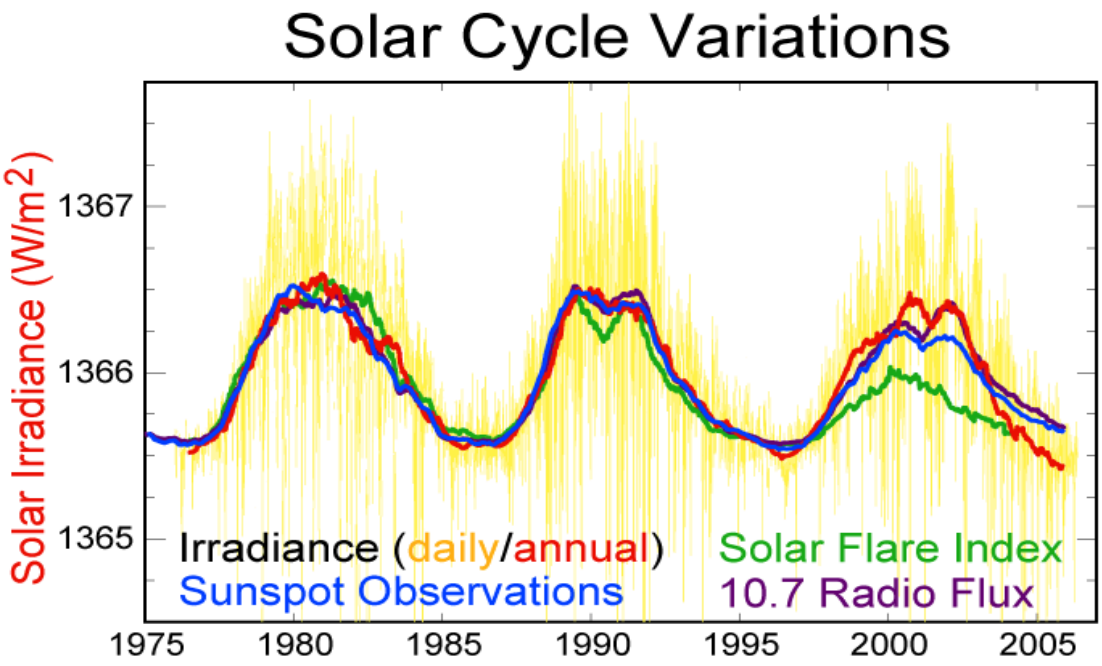

Figure 3 – Image created by Robert A. Rohde / Global Warming Art

Evaluate:

Q11) What predictions can you make about future solar irradiance and temperature trends?

Q12) How might solar irradiance values affect the rate of future temperate changes?

*** * *NOTE* * ***

There are ACRIM data for 1978-2011 contained in the accompanying Excel Workbook. The web site in the materials section contains additional data in a little rougher format. Assign students different time periods or divide students into groups to analyze different scenarios. The same questions will apply. Examples and answers are provided for the data supplied in the workbook (1978-2007).

References:

- Activity Cavity Radiometer Irradiance Monitor - http://www.acrim.com/Index.htm

STUDENT PAGE

Lesson Title: Data Series – The Role of Solar Radiation in Climate Change

Question: How has the variance in solar irradiance changed over time and how do those changes relate to global temperature?

Objectives:
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- Interpret the information found on the graph, and present their findings either orally or in a written format.

Vocabulary:

- solar irradiance: _____

Background:
Regardless of species, all living organisms on earth are affected continually by their surrounding environment, and are hence dependent upon the state of the climate at any given moment. Such dependence causes local, regional, and global climate to play a large role in our lives. This makes any climate changes which occur noticeable, especially over long periods of time. Due to the relationship between changes in climate and our everyday lives, as well as the potential future impacts that these changes can have on the global community, it is important to understand the factors which cause climate change to take place. One important aspect, which has been linked to climate change by scientists and used by climate change skeptics as an argument against human-induced climate change, is the amount of radiation or energy received by the planet from the sun—a term known as **solar irradiance**. Analysis of such values has allowed scientists to determine the role which deviations in solar energy have in dictating atmospheric processes and facilitating changes in climate.

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Materials:

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Engage:

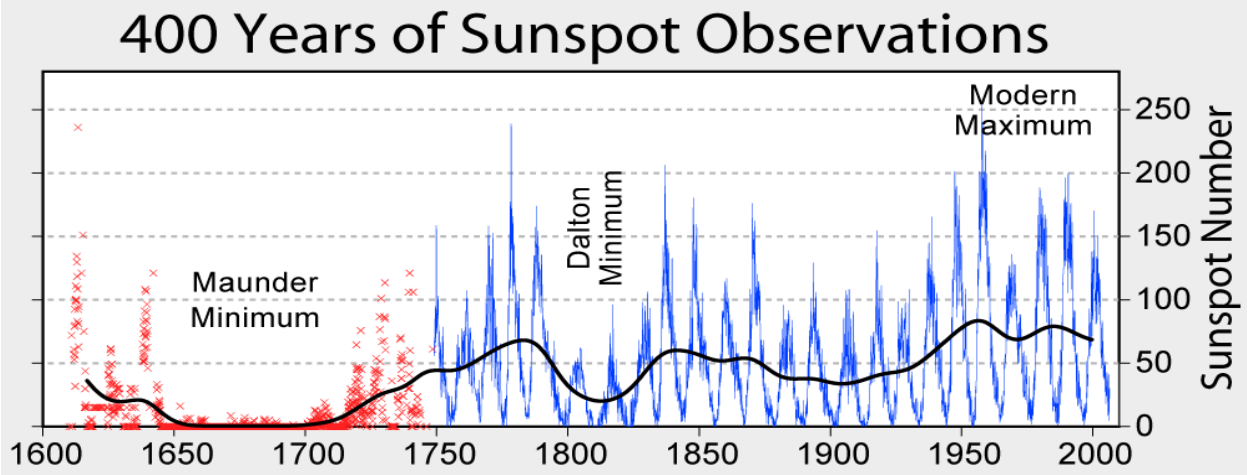


Figure 4 - Image created by Robert A. Rohde / Global Warming Art

Q1) What appears to be the length of a complete sunspot cycle (Figure 4)?

Q2) The black line in Figure 4 illustrates the annual average number of sunspots. Describe the shape or trends in this line.

Explore:

- Download the data set (see materials section).
- Plot a graph of the actual solar irradiance measurements versus time.

Q3) What are the noticeable trends in this graph?

Q4) What are some advantages or disadvantages of such a highly populated (dense time scale) graph?

- Irradiance is defined as the power, per unit area, of electromagnetic radiation incident upon a surface. Keeping this definition in mind, describe what is meant by solar irradiance (see example questions below):

Q5) Where does the radiation come from?

Q6) What is the surface the radiation is incident upon?

Explore:

- Using the average values given for each year, plot a graph of the average solar irradiance versus time.

Q7) Discuss what trends you can interpret from these averages.

Q8) Discuss if any patterns seem to emerge from your graph.

Elaborate:

- Climate records from the past quarter century indicate a warming trend throughout this time period, as shown by the temperature anomaly graph from East Anglia University (Figure 5).

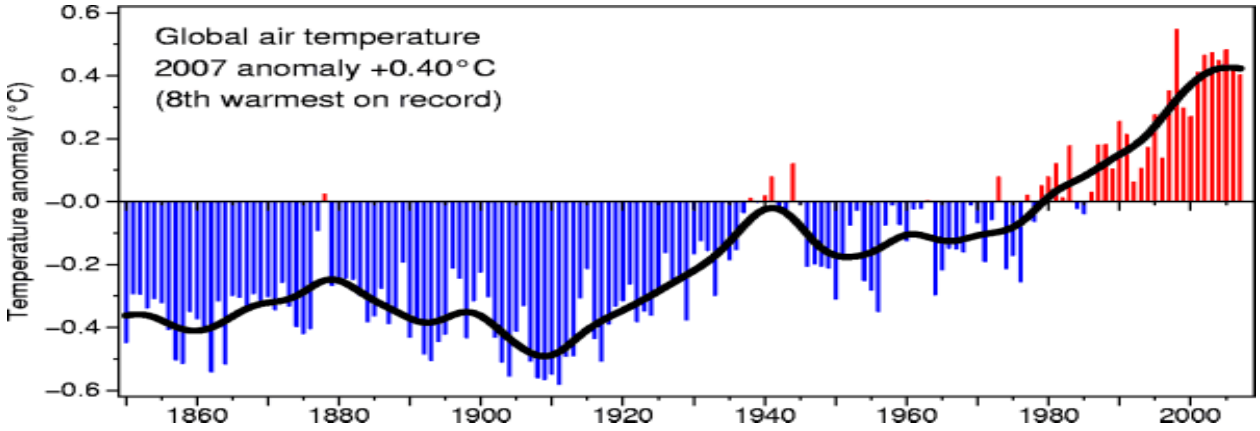


Figure 5 – Climatic Research Unit at University of East Anglia

Q9) Describe any relationship between the temperature anomaly graph (Figure 5) and the graph of average solar irradiance.

Q10) Describe whether any changes in solar irradiation appear to be directly causing the observed warming.

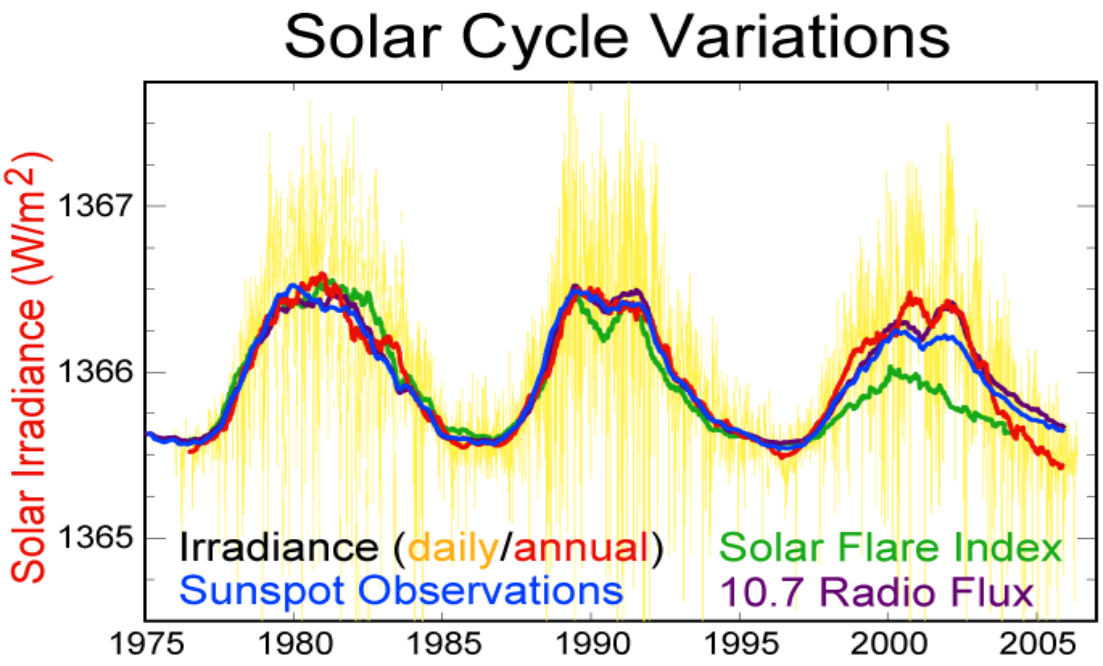


Figure 6 – Image created by Robert A. Rohde / Global Warming Art

Evaluate:

Q11) What predictions can you make about future solar irradiance and temperature trends?

Q12) How might solar irradiance values affect the rate of future temperate changes?

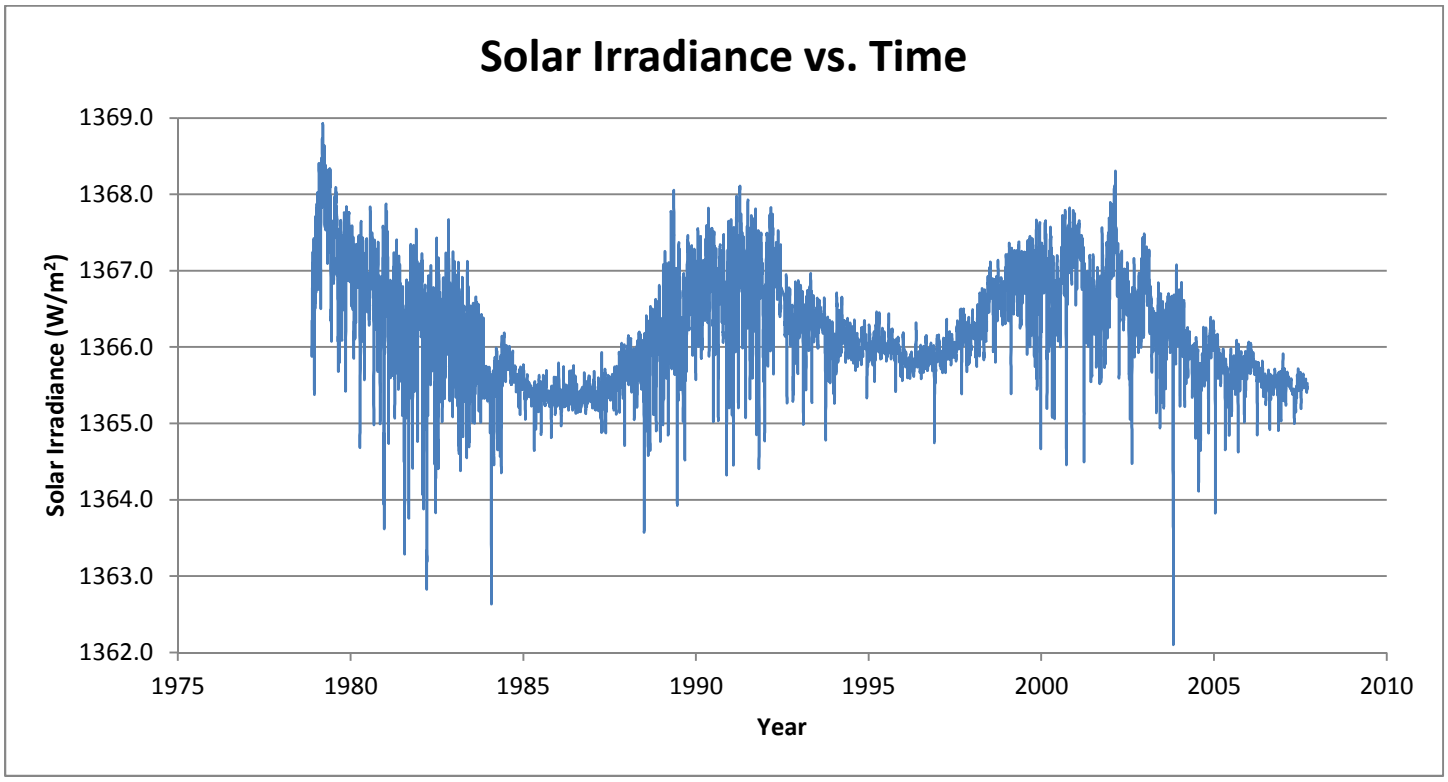
References:

- Activity Cavity Radiometer Irradiance Monitor - http://www.acrim.com/Index.htm

ANSWER KEY

Q1) A complete sunspot cycle occurs every ~11 years.

Q2) There is considerable variability with some periods having a higher annual average number of sunspots and others having a lower annual average.

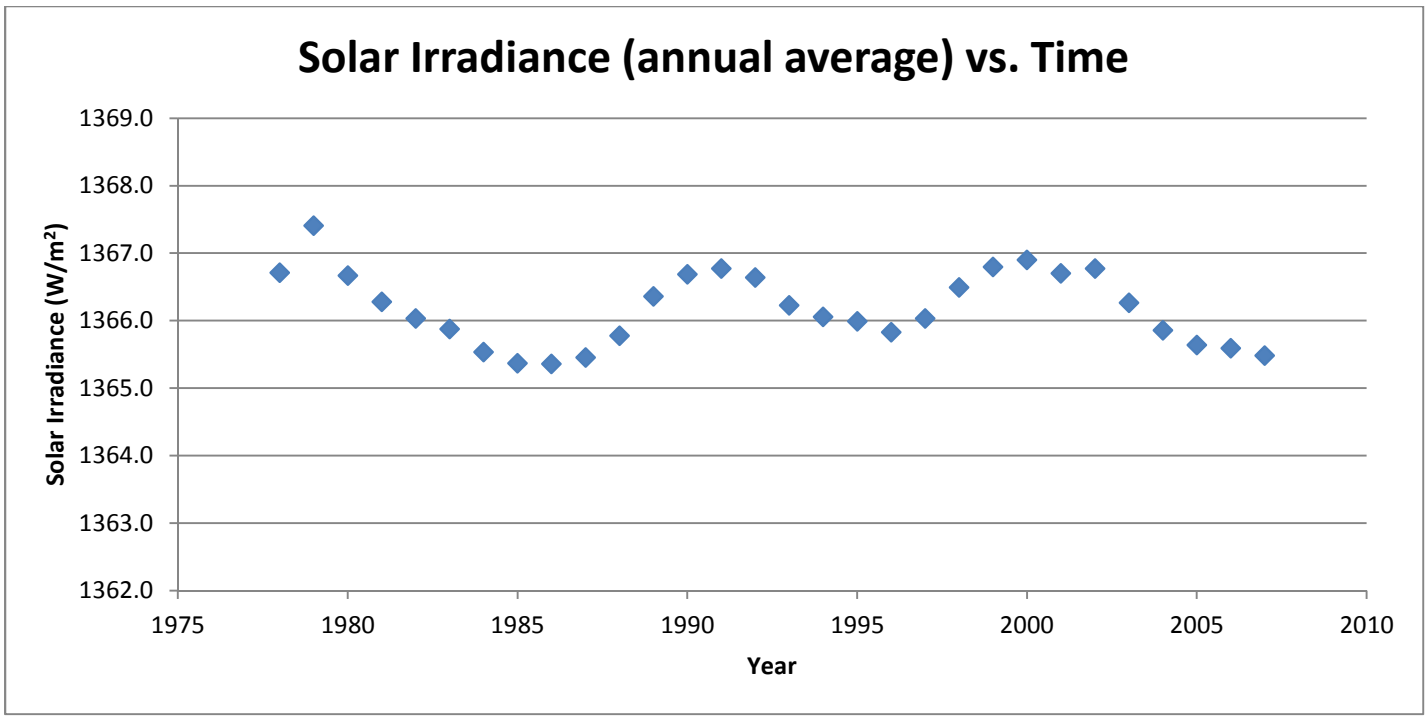


Q3) A repeating cycle of alternating irradiance maxima and minima occurs about every 10 to 11 years. This phenomenon is due to the gradual increase and decrease of the number of sunspots over an 11-year period, and is known as the Schwabe Cycle.

Q4) Graphing such highly populated raw data can lead to poor resolution making it more difficult to discern actual trends and data measurements for particular time periods.

Q5) Radiation comes from the sun.

Q6) Solar irradiance can be defined as the amount of the sun's radiation incident on the top of Earth's atmosphere, per unit area. This globally averaged value is often referred to as the "solar constant", although small variations in its value exist, as shown by the graph.



Q7) The average maximum and minimum which occurred in the mid-1990s and early-2000s, respectively, appear to be slightly higher than their mid-1980s and early-1990s counterparts.

Q8) The average solar irradiance values exhibit a similar pattern as the actual irradiance values, with an 11-year alternating maxima and minima.

Q9) Although the average global temperature increases steadily after about 1970, average solar irradiance values continue to increase and decrease in 11 year cycles. These two graphs show that a direct correlation between solar irradiance and global temperature values does not exist. If this were the case, global temperature values would exhibit a similar cyclic pattern.

Q10) Since no correlation can be established, it can be concluded that changes in solar irradiance are not a direct cause of observed global temperature increases.

Q11) Solar irradiance values are currently at an 11 year minimum, in accordance with the Schwabe Cycle. Over the next few years the amount of solar radiation reaching the top of the earth's atmosphere will begin to increase.

Q12) Global temperature, as indicated by the temperature anomaly graph, will continue to increase as well. However, increases in solar irradiance should help to amplify the temperature increase, causing global temperatures to rise at a more pronounced rate over the next 10 to 11 years.