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THE SUN AND SOLAR ECLIPSES IN THE CLASSROOM

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Abstract. Educators in the United States are working hard to meet the challenges of the *No Child Left Behind* initiative signed by George Bush in 2002. The ultimate goal of this initiative is to improve the performance of America's elementary and secondary schools. In Massachusetts this has, in part, resulted in standardized testing (known as the MCAS exam) at various times throughout a child's schooling and a drive to provide professional development opportunities for teachers. In the physics department at Bridgewater State College (in Bridgewater, Massachusetts), we offer graduate level courses that count toward professional development for K-12 teachers. My goal is to develop a graduate course centered on the Sun that not only educates teachers, but also provides them with curricular material that prepares their own students for the MCAS exam.

Key words: solar physics education, eclipses

1. Introduction

In 2002, President G.W. Bush signed the *No Child Left Behind (NCLB)* initiative into law (www.ed.gov/nclb). The ultimate goal of this initiative is to improve the performance of America's elementary and secondary schools and close the achievement gap between students. The four main principles of this initiative are:

1. *Stronger accountability for results*: states must have a plan for closing gaps in student achievement and have ways to assess their plan.
2. *Freedom for states to use federal funds*: states can use federal funding to address particular needs, helping them reach their goals of closing the student achievement gap.
3. *Using proven education methods*: schools receive federal funding to employ good teaching practices that are based on research studies.
4. *Choices for parents*: parents have access to more information that helps them make informed decisions about their child's education and even have options to move their child to other schools.

As a result of this federal directive, each state has the flexibility to deal with disparities in student achievement in their own way. Massachusetts has chosen to address the first pillar of accountability by implementing the Massachusetts Comprehensive Assessment System (MCAS) (www.doe.mass.edu/mcas) and requiring that teachers be Highly Qualified (www.doe.mass.edu/nclb/hq).

1.1. The MCAS exam

The MCAS is an exam administered to students at various points in their studies between the 3rd and 10th grades. These exams cover topics including arts, English, foreign languages, math, history and social sciences, health education, and the sciences (including Earth and Space Science and Physics.)

MCAS exams are designed to test material that is based on a well defined and documented set of standards (www.doe.mass.edu/frameworks). These standards identify material that students - and teachers - are expected to be proficient in. Several of the Earth and Space Science and physics content standards are directly related to the Sun. Examples include solar energy, the electromagnetic spectrum, the Sun/Earth/moon connections (including solar eclipses), the Doppler effect, methods of energy transfer, and magnetic fields. In addition, for all the sciences, students should have proficiency in mathematical skills as well as *Scientific Inquiry Skills*. Specifically, these skills include:

- Make observations, raise questions, and formulate hypotheses.
- Design and conduct scientific investigations.
- Analyze and interpret results of scientific investigations.
- Communicate and apply the results of scientific investigations.

In 2005 Shadia Rifai Habbal, Munir Nayfeh and I wrote a National Science Foundation grant to observe total solar eclipses in 2006, 2008, and 2009. We incorporated an education and public outreach component for which I am primarily responsible. One of my goals with our grant is to develop a graduate level course for in-service teachers that makes connections between the Sun and MCAS content areas as well as provide learning opportunities that specifically address the *Scientific Inquiry Skills*.

1.2. Highly Qualified Teachers

In order for a teacher to be highly qualified in her/his discipline, she/he must maintain her/his teaching certification and meet one of the following qualifications:

- Pass the state licensure test in subject area
- Undergraduate major or equivalent coursework in subject area
- Graduate degree in subject area

Bridgewater State College (BSC) in Bridgewater, Massachusetts, USA, is well known for its teacher preparation programs. In addition, BSC has become one of the premier centers in southeastern Massachusetts for teachers working toward becoming highly qualified. As a result, BSC is an ideal place to offer our graduate course on incorporating the Sun into the classroom. Not only do teachers learn about new materials for their classrooms, they also work on their own professional development.

2. Educational Material based on the Sun

Several educational materials related to the Sun have already been developed and are readily available - two comprehensive lists can be found at eo.nso.edu/resources.html and umbra.nascom.nasa.gov/outreach.html. My goal is to incorporate some of these materials into my course as well as develop new ones, some of which are directly related to our eclipse expeditions. All material and activities will be geared toward the content standards and skills that the teachers are responsible for helping students learn. Therefore, such a course will not only help teachers earn credits toward becoming highly qualified, but also help them prepare their students for the MCAS exam.

Many of the individual standards mentioned above have obvious connections with the Sun - e.g. the electromagnetic spectrum and Sun/moon/earth relationships. My plan is to develop material based on the Sun that directly addresses *scientific inquiry skills* and gives students some sense of what it is like to do scientific research. Following are two examples of such activities that I have used with students - one utilizing free, online data and another utilizing data taken during a total solar eclipse.

2.1. Activity 1: Sunspot patterns

This activity was done with a group of students in an introductory astronomy course during the Summer of 2006. The class was made up of 8 college and 2 high school students. My goals with this activity were to have students access and look at data, analyze and interpret their observations, and share their results in an informal setting as well as in writing. Prior to this activity, students had learned about the structure of sunspots, but not about the solar sunspot and magnetic cycles.

Students visited the website www.solarmonitor.org and studied two magnetogram images 6 years apart (one during solar minimum, the other during solar maximum.) They were asked to make and record observations of patterns in the sunspots. This particular group of students noticed a difference in the number of the spots on the two dates, the range of latitudes where sunspots were located, the different polarity of the leading spots in the northern and southern hemispheres, and that the sunspots came in pairs. Students shared their observations and made a comprehensive list of things that need to be explained by any sunspot model. This then led into a discussion of the Babcock model.

In addition, students were asked to estimate the rotational period of the Sun using two different spots - one at a high latitude during solar maximum, the other near the equator during solar minimum. Students shared their data, discussed their methods and range in their answers, and ways to reduce errors. My hope was that students would be able to observe differential rotation, but interestingly enough, there was no statistical difference in the rotational rate as a function of latitude based on these two spots. This disparity generated an excellent conversation about what happens during research, ways to check answers, and the benefits of multiple observations and data points.

This activity hit upon nearly all of the *scientific inquiry skill* standards, and let the students work with real data and notice patterns on their own that connect with well established patterns such as the sunspot and magnetic cycles and the Maunder butterfly diagram. They also got a sense for how long it can take to analyze data, and the value of making many observations to observe trends.

2.2. Activity 2: Eclipse conditions

Before the 2002 solar eclipse in South Africa, I met with over 100 middle school students in Plymouth, Massachusetts. We discussed solar eclipses, how they happened, and what our research team hoped to learn from them. During my time with them, students asked how temperature and light intensity changed during a total eclipse. I had no quantitative answer for them, so I asked the students to hypothesize what would happen; they predicted it would get colder and much darker. Using equipment they had access to in their classrooms, we designed a simple experiment to quantify the changes during the eclipse. A temperature probe would be left in the shade to monitor the temperature throughout the eclipse. In addition, a light sensor would measure the amount of light reflected off a piece of white paper. Figure 1 shows the light probe on the day of the eclipse (the temperature probe is on the other side of the tree.)

Fig. 1. Middle School students helped design an experiment to measure changes in light intensity and temperature during totality. A light sensor attached to a tree and trained on a white piece of paper measures the reflected light throughout the eclipse. The temperature probe was kept in the shade on the other side of the tree.

When I returned from the eclipse, I brought the students their data, shown in figure 2, and we spent time together interpreting it. They noted interesting properties like the numerous dips in light intensity (which they correctly determined were due to clouds) and the time delay in intensity and temperature minima (perhaps due to the high heat capacity of the Earth.)

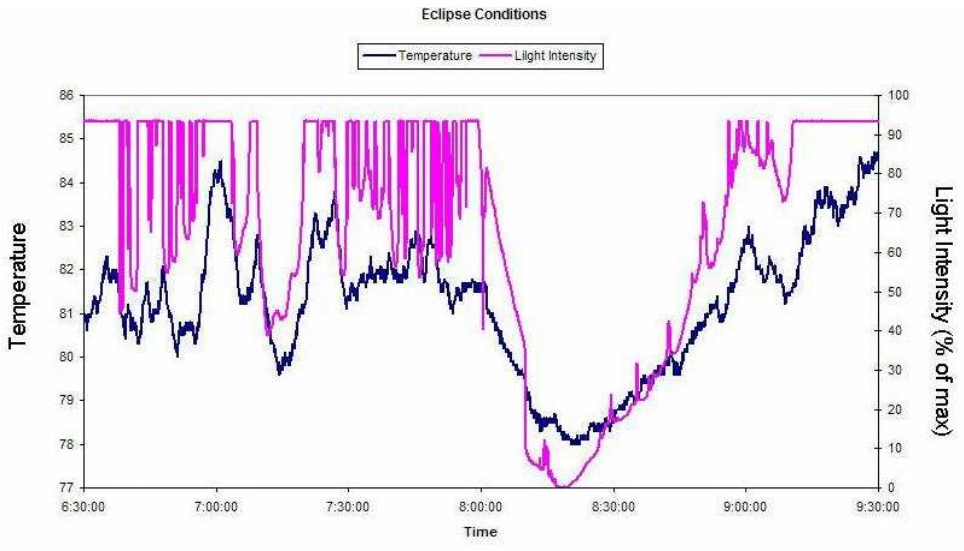

Fig. 2. Light intensity (pink) and temperature data (purple) during the 2002 eclipse. Interesting features include numerous dips in the data (due to clouds) and time delays in temperature and light intensity minima(likely due to the high heat capacity of the Earth.)

This activity engaged students in experimental design as well as data analysis and interpretation. They had a sense of ownership of the experiment and they learned how to find answers to their original questions, and check their hypotheses. Interestingly enough, when I share figure 2 with students in college level courses and groups of amateur astronomers, it always generates lively and useful discussions. This may be because the concepts behind the data and experimental setup are accessible at many levels.

3. Future work

The two examples above are only the beginning, and more work needs to be done. My goal is to offer this graduate level course during the summer of 2007. In addition to developing new materials myself, I plan to utilize the experience of the teachers and have them contribute as well. All materials will be made available to the public at www.bridgew.edu/physics.

In addition, we hope to include a middle or high school teacher in our research team during the 2008 and 2009 eclipses. The teacher would be responsible for conducting any student designed experiments as well as maintaining a journal and web page documenting the experience. Our goal is to provide the teacher with a research experience that will ultimately impact her/his students through not just content, but also the excitement that comes with doing research on total solar eclipses.

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