SOLAR MAX AND THE RADIO WAVE
MIT Haystack Observatory's Multi-faceted Approach to Space Weather Outreach

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1. ABSTRACT

Most modern communication technologies depend on radio waves to transmit information. As consumers of this information - using radios, cell phones, GPS, etc, - the general public is heavily dependent on radio waves, yet most people have little idea of the devastating effects that a large solar storm can have on this technology. Space weather as a means of predicting solar events and their effect on Earth's upper atmosphere will become increasingly important to us as we approach the next period of solar maximum, when the Sun's activity level rises. In recent years, scientists at MIT Haystack Observatory have worked on a multi-faceted approach to introduce the public to space weather and how it can affect us. This presentation will discuss projects with a local children's museum and local teachers, and the use of video podcasts to make space weather a more common concept. Full-text resources that have been created and are available on the Internet will be discussed.

2. INTRODUCTION

As we begin to approach the most active point of solar cycle 24 (solar maximum or solar max) our society finds itself in an historically unique and technologically critical position due to our dependence on radio waves for the transmission of information. Never before have there been so many satellites in operation, so many people who rely exclusively on cell phones, so many ways that GPS technology has been integrated into commercial and personal activities, and so many uses for radio waves in our daily lives. Yet most people have little idea that these technologies can be susceptible to the blasts of plasma that can slam into the ionosphere when the Sun is in its most active state. Depending on their strength, the clouds of energetic charged particles that create the magnificent displays called aurora at the northern and southern poles can also knock out the equipment on a satellite, disrupt communications, or shut down an electrical grid (as happened in Canada's Quebec province in March 1989).

Today, the study of these variable energy bursts from the Sun and how they affect Earth and the near space environment is called *space weather*. Just as meteorologists have for years studied how tropospheric pressure fronts move across the Earth causing weather that can disrupt our daily lives, atmospheric scientists are studying space weather to learn to predict when a solar storm will affect Earth. For more than 50 years, scientists at MIT Haystack Observatory have been conducting research into the interaction of the Sun and the Earth's upper atmosphere. Their studies are helping to discover and define space weather 'storm fronts' of charged upper atmospheric particles, and how these large scale structures affect our technology.

With the potential effects that space weather can have on daily technologies, the MIT Haystack Observatory outreach program has focused attention in the last few years on introducing students and the general public to the science of space weather. Several different approaches have been used in this effort – working with teachers in traditional classrooms, working with museum specialists to create an exhibit on space weather, and producing video podcasts (vodcasts) that will present the subject of space weather to the public through an attractive, popular, and current medium. Important considerations in the construction of an effective educational program include the questions of where people get their information, how can this subject be made relevant to the person's daily life, and how does a scientific research group best use its resources to reach out to the public.

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3. THE CLASSROOM APPROACH

MIT Haystack Observatory has a long and exceptional record in its program of educational outreach. For many years scientists have given their time to speak to school groups visiting the Observatory, gone to schools to work with teachers in the classroom, worked with middle school students in the Haystack Young Scholars Program, and given talks at local civic and open house events. When the Research Experiences for Teachers (RET) program was initiated by the National Science Foundation, Haystack became one of the first to welcome teachers to their research center for the summer. Working closely with one of the teacher participants during that first summer, Haystack atmospheric scientists began to see how the complex subject of space weather could be broken down into understandable and age-appropriate concepts useful for building a basic understanding of space weather in a student's mind.

One of the first things that was learned from the RET participants was the need to make the science relevant to the students – i.e. why should they care about space weather? The strategy of connecting the effects of the Sun's activities to the technology that students use on a daily basis creates a "hook" to catch the student's attention. In one instance, students are given an assignment to listen to an AM radio station at night over the weekend, and issued a challenge to see who can find a station from the farthest location. They are then asked to find the station again at school during daytime hours, when AM propagation through the ionosphere changes and reception is mainly local. This day/night difference launches them into a discussion of radio waves and the ionosphere. In another unit, students read a solar mystery about young people at a summer camp who suddenly discover that their power is off, their GPS units don't work, and, most terrible of all, their cell phones don't work either! This tends to grab a student's attention.

Through their work with the participants of the RET program, Haystack scientists have helped teachers to develop several excellent lessons and units that are now available on the Web for classroom use. These materials have been tested in the classroom, and include presentations, games, Web-quests and hands-on activities among other materials. These units can be found at:
http://www.haystack.mit.edu/edu/pcr/resources/lessonplans.html

The AM Radio Lesson Plan is a one-week investigation that explores basic wave principles (wavelength, frequency, and speed) and how electromagnetic waves interact with the Earth's ionosphere. Space weather and the aurora are also examined.

Solar and Geomagnetic Investigations is a six-week program focusing on the Sun-Earth connection and combines on-line data collection with the optional use of a Small Radio Telescope. This unit contains an extensive introduction to electromagnetic waves, activities that help students better understand the Sun, and the effects of solar activity that are felt here on Earth.

Demystifying Scientific Data introduces high school students and their instructors to one of the vital aspects of science: the essential skills of data analysis and interpretation. The lessons are based on scientific research in radio astronomy, geodesy, and space weather, and lead to understanding a critical process of science: transforming raw data into explanatory theories. It includes an introduction to space weather and the analysis of atmospheric science data.

Caught in the Solar Wind is a unit that has a goal of introducing students to the source, mechanisms and impacts of space weather. It focuses on ionospheric data, auroras, coronal holes, coronal mass ejections and sunspot graphing. (This unit is currently being tested in the classroom and will be on the Haystack Web site in the Summer of 2008.)

4. *SOLAR STORMS TO RADIO WAVES*

One of the practical public outreach challenges encountered by scientists working with complex subjects is developing effective strategies to break the subjects down to the simplest form so that they can be understood by as young an audience as possible. This is particularly desirable in light of the insatiable curiosity that some children have for science. Stepping outside of the laboratory to work with young children and explain your science to them can be a truly exhilarating experience.

While the scientists at Haystack Observatory had previously worked with elementary students on an individual basis, there had been no focused attempt to introduce the subject of space weather to young students until Haystack began a collaboration with The Discovery Museums in Acton, MA. Through a grant from the National Science Foundation, Haystack scientists and museum specialists spent two years finding effective ways to introduce radio waves and space weather to a very young audience. This work resulted in an exhibit, *Solar Storms to Radio Waves*, which opened in May 2007.

For this project, an approach was selected to start from concepts that the students are familiar with in order to teach them about space weather. To make the exhibit as simple as possible, four central statements were developed: radio waves are all around us all the time; we use radio waves in all different sizes; radio waves carry information for us; and activities on the Sun can disrupt radio waves.

The first three stations of the *Solar Storms to Radio Waves* exhibit are about tools that use radio waves. Radios, iPods, and video cameras were used to engage the students. To demonstrate the use of radio waves, it was necessary to find an effective Faraday cage that could be used time and again, and would completely block radio waves from being received by objects located inside the cage. A simple metal spatter screen and metal colander turned out to be a very effective and easily obtainable Faraday cage. By interchanging the metal colander with a plastic one, students were led to inquiries on the interaction of radio waves with different materials. Another part of the exhibit used a high frequency wireless security camera. Here, the antenna for the receiving portion of the wireless camera was covered alternately with metal and plastic tubes to demonstrate the same radio wave interference effects for a different kind of receiver. (Construction details of all of the exhibit components are on the Web for duplication by other museums, or for use in the classroom. http://www.haystack.mit.edu/edu/poa/index.html)

The final station of the exhibit contains a SpinBrowser – a mechanical video device that allows the museum visitor to slowly spin backwards and forwards through a series of images. A thirty minute video with images of the Sun, of coronal mass ejections, and of the effects solar storms have on the Earth was generated specifically for the project, designed to encourage the student to consider hidden connections between radio waves and space weather.

5. *SPACE WEATHER FX*

One only has to watch people commuting on a train, walking on the sidewalk, or sitting in a coffee house to notice that handheld personal devices (e.g. MP3 players, iPods) are becoming a prime way to disseminate information in today's society and are an ideal way to reach a large general audience. Funded by a grant from NASA for public outreach, the *Space Weather FX* vodcast series is aimed at helping the general public understand the phenomena involved with space weather. Through short episodes downloaded to one of these devices, the series will let viewers explore Earth's coupled ionosphere and inner magnetosphere using Haystack scientists as guides. The series is aimed at both educational and general public audiences, and has been carefully scripted to hold their interest as well as inform.

The vodcast format is particularly appealing for this project due to its flexibility in forms of dissemination. While planned for a handheld personal device and independent learning, vodcasts can also be used in other ways in educational and informal settings. Episodes can be used in classrooms, watched on PCs, or downloaded for projection in a variety of venues such as planetariums, museum displays and on information kiosks. The episodes can be widely and easily distributed through services such as iTunes, GoogleVideo, and YouTube.

To leverage the budgeted funds to the best advantage, the programs use existing video material from the NASA GSFC Science Visualization Lab, still photos from such sources as NOAA and the University of Alaska-Fairbanks, animations from the large NASA Sun-Earth Connection resource, and animations and visuals (including on-camera interviews with Haystack scientists) created specifically as part of the analysis of data from Haystack's space weather research projects. Scripts are initially written by Carolyn Collins Petersen in collaboration with Haystack scientists, and are reviewed by local teachers. Episode production is being handled by Loch Ness Productions, Groton, MA.

At this time, the first episode, which is an introduction to space weather, has been completed and is available on the Haystack Web site, www.haystack.mit.edu/swfx, on iTunes, and on YouTube. Other episodes are currently in production, and a total of 8-9 vodcasts is planned for the series. Other topics to be explored include *The Mysterious Magnetic Fields of Earthspace, Connecting the Sun and Earth, When Space Weather Attacks,* and *GPS – a Space Weather Twist on Navigational Technology*.

6. CONCLUSION

By reaching out to students and the public in the places where they learn – schools, museums, and on the Internet – and by carefully selecting highlights from the latest research on Earth's upper atmosphere with the aim of simplifying messages for general public understanding, scientists are better able to communicate their science and share their excitement of research with the public at large. MIT Haystack Observatory scientists have made a concerted and long-term public outreach effort to explain not only their science but also the reasons that their science is pertinent to the everyday lives of people. By using a multifaceted approach, these strategies have been able to reach a wide audience with messages crafted to different age and comprehension levels. As society approaches 2010-2012, when the peak of the next solar cycle, or solar maximum, is expected to occur, it is hoped that these efforts will have produced a greater awareness of the scientific event itself as well as the social effects that might occur.