

For the Teacher

The Technology Monitoring Space Weather

(Excerpt from *NOAA Watch* at <http://www.noaawatch.gov/themes/space.php>)

Technology is evolving at an incredible rate, especially our space-based technology. Many of these systems are vulnerable to hazardous space weather. The health of this Nation's technological infrastructure will depend heavily on our understanding of the space environment and our ability to predict hazardous solar storms. With the rising sophistication of our technologies, and the number of people that use technology, vulnerability to space weather events has increased dramatically.

SOHO Satellite

(Excerpts from the SOHO Fact Sheet at http://sohowww.nascom.nasa.gov/about/docs/SOHO_Fact_Sheet.pdf)

SOHO, the Solar and Heliospheric Observatory, is a project of international cooperation between ESA (European Space Agency) and NASA to study the Sun, from its deep core to the outer corona, and the solar wind.

SOHO was designed to answer the following three fundamental scientific questions about the Sun:

- What is the structure and dynamics of the solar interior?
- Why does the solar corona exist and how is it heated to the extremely high temperature of about 1 000 000°C?
- Where is the solar wind produced and how is it accelerated?

Clues on the solar interior come from studying seismic waves that are produced in the turbulent outer shell of the Sun and which appear as ripples on its surface.

SOHO was launched on December 2, 1995.

The satellite orbits the sun at the First Lagrangian Point, or L1 point. This position is approximately 1.5 million kilometers away from the Earth in the direction of the sun. The L1 point orbit allows the satellite to orbit the sun with the same period as the earth. This occurs due to the combined gravitational effects of the Earth and the sun. Two activities have been included (Orbiting the Sun, The SOHO satellite and the Lagrange Point L1) for students to investigate orbits and specifically the L1 point. For further information on the L1 point orbit, visit http://www.esa.int/esaSC/SEMM17XJD1E_index_0.html.

The satellite contains 12 scientific instruments. Of particular interest are the Extreme ultraviolet Imaging Telescope (EIT), the Large Angle and Spectrometric Coronagraph (LASCO), and the Michelson Doppler Imager/Solar Oscillations Investigation (MDI/SOI).

Extreme ultraviolet Imaging Telescope (EIT)

EIT provides full disc images of the Sun at four selected colors in the extreme ultraviolet, mapping the plasma in the low corona and transition region at temperatures between 80 000 and 2 500 000°C.

Large Angle and Spectrometric Coronagraph (LASCO)

LASCO observes the outer solar atmosphere (corona) from near the solar limb to a distance of 21 million kilometers, that is, about one seventh of the distance between the Sun and the Earth. LASCO blocks direct light from the surface of the Sun with an occulter, creating an artificial eclipse, 24 hours a day, 7 days a week.

Michelson Doppler Imager/Solar Oscillations Investigation (MDI/SOI)

MDI records the vertical motion (“tides”) of the Sun's surface at a million different points for each minute. By measuring the acoustic waves inside the Sun as they perturb the photosphere, scientists can study the structure and dynamics of the Sun’s interior. MDI also measures the longitudinal component of the Sun’s magnetic field.

Visit the SOHO website <http://sohowww.nascom.nasa.gov/home.html> for the latest images from the satellite, archives, and more detailed background information.

ACE Satellite

The Advanced Composition Explorer (ACE) spacecraft, carrying six high-resolution sensors and three monitoring instruments, samples low-energy particles of solar origin and high-energy galactic particles.

ACE was launched on August 25, 1997 from the Kennedy Space Center in Florida. It orbits the sun at the L1 point.

The solar wind density and velocity measurements found at the Spaceweather.com website are measured by the ACE satellite.

More detailed information about the satellite and its scientific mission can be found at <http://www.srl.caltech.edu/ACE/>.

STEREO Satellite

(Excerpts from http://www.nasa.gov/mission_pages/stereo/main/index.html)

STEREO (Solar TERrestrial RELations Observatory provides a unique and revolutionary view of the Sun-Earth System. The two nearly identical observatories - one ahead of Earth in its orbit, the other trailing behind – will trace the flow of energy and matter from the Sun to Earth as well as reveal the 3D structure of coronal mass ejections and help us understand why they happen. STEREO will also provide alerts for Earth-directed solar ejections, from its unique side-viewing perspective.

CME’s are the most powerful drivers of the Sun-Earth connection. Yet despite their importance, scientists don’t fully understand the origin and evolution of CMEs, nor their

structure or extent in interplanetary space. STEREO's unique stereoscopic images of the structure of CMEs will enable scientists to determine their fundamental nature and origin.

The NASA's STEREO website, http://www.nasa.gov/mission_pages/stereo/main/index.html, contains more detailed information about the mission, as well as 3D images and movies from the satellites.

Studying the Ionosphere

(Excerpts from http://www.windows.ucar.edu/spaceweather/sun_earth9.html)

Basic Facts About the Ionosphere

- Invisible layers of ions and electrons are suspended in the Earth's atmosphere above about 60 kilometers in altitude.
- The main source of these layers is the Sun's ultraviolet light which ionizes atoms and molecules in the Earth's upper atmosphere. During this process, called photoionization, an electron is knocked free from a neutral atmospheric particle, which then becomes an ion.
- Because the Sun's light is responsible for most of the ionization, the ionosphere reaches maximum densities just after local noon. In this region at altitudes where the highest densities occur, about one in every 1000 air particles is ionized. Resulting ionospheric densities are ~ a million ions and electrons per cubic centimeter.
- Ion - electron pairs are also created during collisions of high velocity electrons and ions with the neutral atmosphere mostly at polar and auroral latitudes.
- Flares and other energetic events on the Sun produce increased ultraviolet, x-ray and gamma-ray photons that arrive at the Earth just 8 minutes later and dramatically increase the density of the ionosphere on the dayside. These solar events also can produce high velocity protons and electrons (arriving at Earth hours to days later) that precipitate into the ionosphere in the polar regions producing large increases in the density of the ionosphere at low altitudes.
- Ions and electrons in the ionospheric layer are constantly being lost and replenished. The lifetime of a given ion is only a fraction of a day and decreases with decreasing altitude. Lower altitude ions have shorter lifetimes.
- The low-altitude portion of the ionosphere (D and E-layers) rapidly reaches low densities at night because ion and electron lifetimes are very short at these altitudes and the major source of new ion-electron pairs (solar photons) is absent.

Points of Interest

- The atmosphere's ionization layers make possible long distance radio communication by reflecting the radio waves back to Earth. They also are home to the aurora and the mega-ampere currents that heat the atmosphere at high latitudes during geomagnetically active times. During storms depletions and enhancements of ionization occur depending on the local time and geographical location. Depletions are particularly effective at causing problems with the normal operation of radio communications.
- Any radio wave communication that needs to pass through the ionosphere can be affected if the properties of the ionosphere change. The wave speed can change affecting the accuracy of satellite navigational systems. Gradients within the ionosphere can corrupt satellite communications.

GPS Satellites and Ionospheric Mapping

By analyzing data from high quality GPS receivers located around the world, TEC (total electron count) maps of the ionosphere can be generated. A TEC map illustrates variations in the make-up of the ionosphere. These maps can be used to detect ionospheric storms and monitor their behavior. This data is used to improve the accuracy of GPS units.

Details on the operation of GPS can be found at

<http://electronics.howstuffworks.com/gps.htm>

GPS satellite tracking website <http://www.n2yo.com/gps.php>

Incoherent Scatter Radar (ISR)

ISR is another tool in studying the conditions of the ionosphere. These radar systems can measure the electron and ion temperature, composition and velocity. See the attachment on ISR for more detailed information.