

# Space Environment TOPICS



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SE-13

## Solar Maximum

**T**he Greek scientist Theophrastus first identified sunspots in the year 325 B.C., showing that the Sun is neither featureless nor steady. Sunspots that are visible with a simple projection of the Sun have been counted and charted for centuries. Over the last 300 years, the average number of sunspots has regularly waxed and waned in an approximately 11-year sun-spot cycle (see figure 1). The Sun, like the Earth, has its seasons—but its “year” equals 11 of ours.

While some other aspects of the Sun vary differently over the years (for example, coronal holes tend to be most numerous in the years following sunspot maximum), the sunspot cycle is a useful way to mark the changes in the sun. Solar Minimum refers to the several Earth years when the sunspot numbers are lowest; Solar Maximum occurs in the years when sunspots are most numerous.

During Solar Maximum, activity on the Sun and its effects on our terrestrial environment

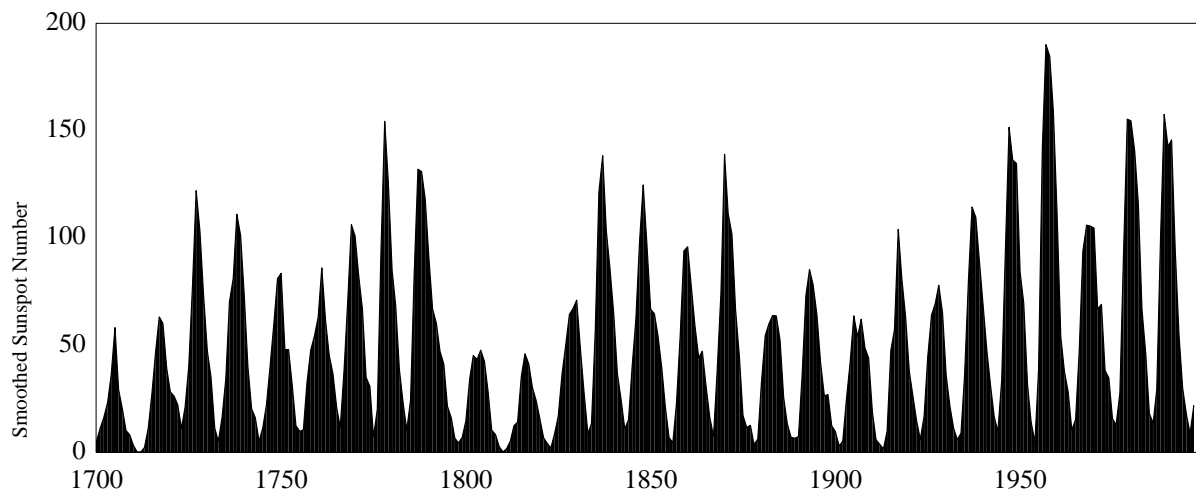


Figure 1. The Sunspot Cycle, well documented over the last 300 years, reveals a 10-11 year pattern of solar activity.

are high. Dynamic outbreaks of geomagnetic storms and radiation showers at the Earth occur sporadically but with increasing intensity and frequency during the years around maximum (see figure 2).

### The Severest Geomagnetic Storms

During the current solar maximum period, we expect the aurora borealis (the northern lights) to appear dramatically several times per year over the continental U.S.; it will likely reach as far south as the Gulf of Mexico at least once during this period. At these times the aurora will appear as brilliant red clouds, bands, or curtains in the sky; they often prompt calls to police and emergency officials for an explanation of the dynamic visual displays.

The electric currents that flow during auroral displays disturb the ionosphere and wreak considerable havoc on long distance radio communications and on satellite-to-ground connections. These effects may last for several days.

Other effects include the loss of signals and accuracy in worldwide navigation systems such as the Global Positioning System (GPS). These effects can include the strange propagation of radio signals that prompt the random reception of local police radio signals and mysterious openings of garage doors.

It is likely that at least one electric power system operator will lose some of their power grid and be challenged to avoid triggering a widespread blackout sometime during solar maximum. When the aurora is visible overhead, it causes earth currents to flow through the ground underneath. The currents will leak into power systems, pipelines and other long metal conductors.

The auroral currents also heat the atmosphere and cause it to expand upward. This increases the atmospheric drag on low altitude satellites, and that is sufficient to change their orbital pat-

terns. Space centers that maintain catalogs of satellites and space debris will have to recalculate the new orbits of the satellites and “space junk” in their catalogs after these events.

The Space Station and the Space Shuttle will probably have to maneuver to avoid space debris that has been shifted into a collision path with the station.

### The Most Frequent Storms

Storms that are less intense but still rated severe will occur frequently, probably several times per year. These storms will also challenge electric power system operators to keep their grids in operation, will likely cause interruptions in the use of some or all GPS navigation systems, will degrade satellite-to-ground signals, interfere with most long distance radio communications and force more avoidance maneuvers on the space station.

The aurora associated with these storms will frequently cover the northern half of the continental United States. Travelers, campers, and others outside on nights when these storms occur will see brilliant light shows off to the north and even reaching overhead. During the solar

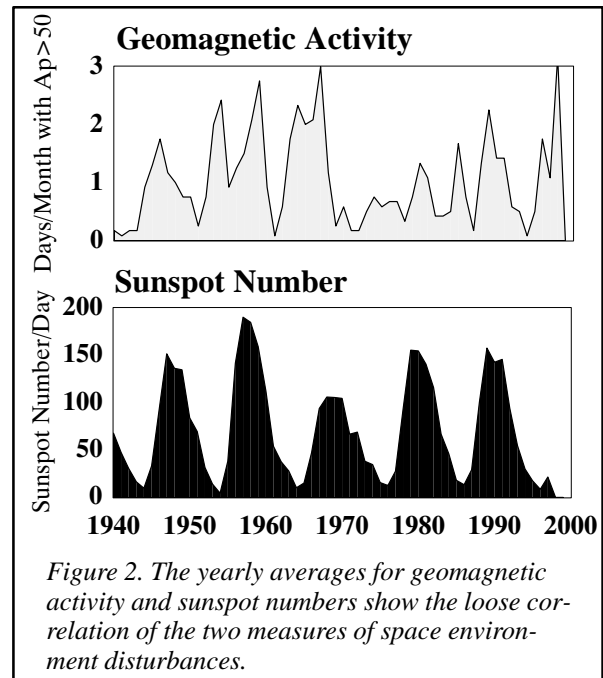


Figure 2. The yearly averages for geomagnetic activity and sunspot numbers show the loose correlation of the two measures of space environment disturbances.

maximum years, there is typically a double peak in the frequency of these storms, first early in the maximum period and then after the maximum in sunspot numbers.

### Particle Showers

Proton radiation showers in the space around Earth are also expected to become more frequent and more intense during the period of solar maximum, but like the distribution of geomagnetic storms, the peak year may occur any time in the 1999-2002 era (see figure 3). Some of the super energetic protons will pass through satellites and cause satellite electronics to experience bit flips or latch-ups and solar power cells that drive the satellites will be degraded. Space missions such as the Hubble Space Telescope and many others will note the activity, will more closely monitor the health of their systems, and will be prepared to take corrective action. Depending on the phase of the space station orbits and the activities of the astronaut crews, they will be subjected to increased radiation doses. Scheduling the crew for EVA (Extra-Vehicular Activity) during assembly of the

space station must consider radiation levels as part of the planning during the assembly missions. The construction schedule calls for over 100 EVA's by American astronauts, extending over 34 missions between 1999 and 2004 (see figure 4). These activities coincide very well

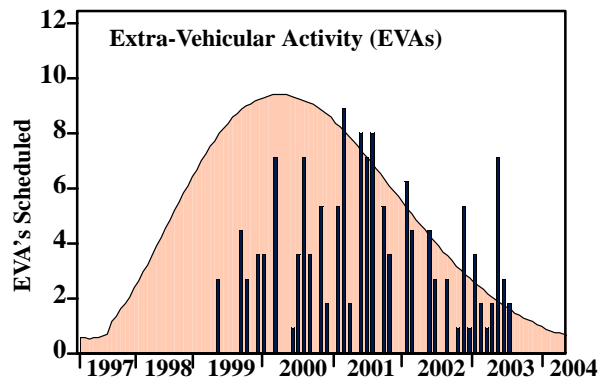


Figure 4. The construction of the space station will occur during the peak of solar activity.

with periods of high solar radiation event activity. NASA personnel will be working with the NOAA Space Environment Center to monitor the radiation events, as they do many other affected space activities, and they will use NOAA forecasts and data to manage activities to keep radiation doses low and within pre-set limits.

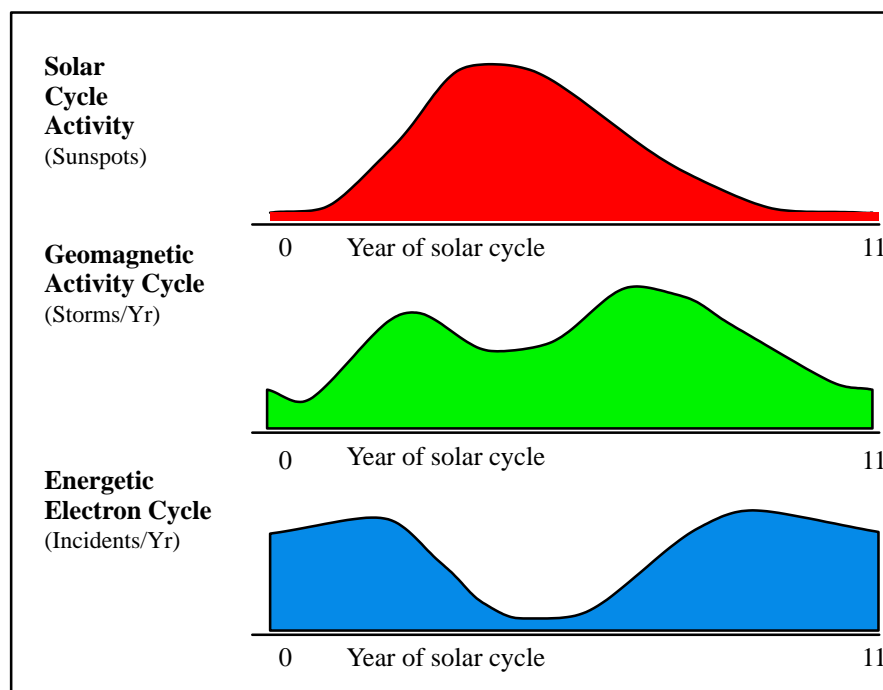


Figure 3. Solar activity and its effects at Earth occur in several variations around the approximately 11-year sunspot cycle. Energetic electron events, featuring high fluxes of "killer electrons," actually peak in the years around solar minimum. These electrons bury themselves in satellites and when enough have accumulated, a high-voltage discharge can upset the satellite processors or permanently damage memory chips and other components.

## A Disturbed Ionosphere

The most rapidly growing sector of the communications market is satellite based. Broadcast television and radio signals, long-distance telephones, cellular phones and pagers are often dependent on satellites for transmission (see figure 5).

Many communication systems use the ionosphere to reflect radio signals over long distances. Ionospheric storms affect radio communications at all latitudes. Some radio frequencies are absorbed and others are reflected, leading to rapidly fluctuating signals and unexpected propagation paths.

Broadcast television and radio signals, long-distance telephones, cellular phones, pagers and GPS signals are all dependent on transmission to and from satellites, and their signals transmit through the ionosphere. They are im-

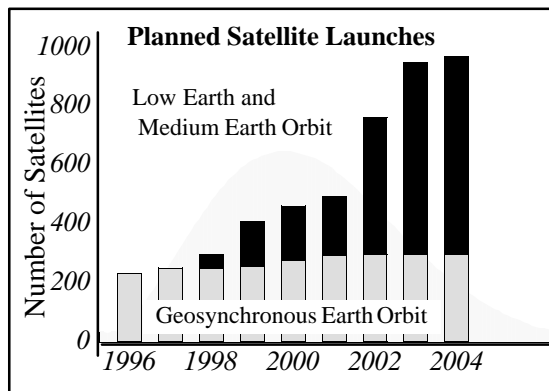


Figure 5. The number of geosynchronous satellites in orbit will grow slightly; the number of low and medium earth orbit satellites will quadruple compared with 1996 numbers.

pected when the ionosphere between the satellite and the user becomes turbulent and irregular; the signal may “scintillate” and prove difficult to track. If a GPS signal is abnormally delayed because the electron content of the ionosphere is far from normal, the position will be in error.

## Many Little Problems Possible

Scientific experiments that probe the Earth environment will be affected in subtle and complex ways. Ozone measurements will have to account for depletions from particle showers. Radiation dosimeters used by aircraft crews may register small, additional increases in their dose after flights to high latitudes during a radiation shower. Sensitive magnetic sensors will experience high noise levels during geomagnetic storms. These include sensors to measure motion along crustal faults of the Earth, to guide deep drilling projects, to map subsurface resources, and to chart the ocean floor. The high noise levels interfere with accurate readings.

As new technologies are developed and brought into use, the list of effects of solar maximum continues to grow. NOAA Space Environment Center will continue to track and list these effects, and alert new and current customers to disturbances.



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