

# The Basics of Radio Wave Propagation

## Current Solar Terrestrial Activity Report

### *Radio Wave Propagation*

**Aurora:** A favorite propagation. When more than the usual levels of charged particles arrive at the earth (i.e., increased solar wind), as a result of a CME or coronal stream, many of these charged particles penetrate the weakest parts of the GMF near the polar regions. This is because the GMF field lines guide these charged particles into these regions; at these polar regions, extreme ionization can result at altitudes up to 1000km. Due to this increased ionization, a dynamic curtain shaped layer develops instead of the more typical horizontal shaped F2-layer. This auroral layer may reflect radio waves from the HF-band (3-30MHz) all the way up to and including the entire UHF-band (300-3000MHz). However, due to its very irregular shape and constant movement, heavy fading (QSB) is common in the reflected radio signals. This QSB can also result from multiple reflections within these auroral layers, causing rapid phase shifting. An auroral signal is easily recognized at 30MHz as a bubbling sounding modulation or "under-water-like" modulation. Finally, because of the extreme and sudden phase shifts, narrow band modes such as CW and digital are the most reliable modes for DX contacts.

**Backscatter:** A useful form of propagation which mostly occurs when the maximum usable frequency (MUF) rises above 30MHz. During these conditions, when radio waves reach the ionosphere (usually the F2-layer), they are reflected towards the earth's surface at a larger detectable continuum of angles than usual. In other words, a detectable fraction of a radio signal is now reflected at a very sharp angle back into region just surrounding the transmitting station but usually beyond the range of ground wave communications (i.e., blind zone). Therefore, backscatter signals are heard within a radius of 2000km from the transmitting station. Backscatter signals are generally weaker than the normal reflected radio waves and during periods of low solar flux, only radio stations using directional antennas can produce readable signals. However, during periods of very high solar flux, even small stations using 10 Watts and vertical ground plane antennas may produce readable signals. Backscatter signals are generally very stable and rarely influenced by QSB. Finally, backscatter signals are easily recognized as a "hollow" or "barrel-like" sound originating from the expected blind zones of a radio station.

**Blind Zone:** The blind zone is the area around a radio station which cannot normally be worked by either ground waves or normal ionospheric sky waves. Usually stations in the blind zone can only be worked via intermittent backscatter propagation.

**E<sub>s</sub>:** A mode of propagation producing well known short skip radio contacts off the E-layer of the ionosphere. This propagation usually occurs during the summer months and results in high signal levels. Finally, the skip distances are generally around 1000 statute miles.

**F2:** The most common mode of propagation is sky waves reflected off the F2-layer of the ionosphere; these reflections are responsible for most DX contacts.

**Gray-line:** The area occurring along the sunset and sunrise zones (i.e. also called the terminator in astronomy) is known as the gray line and it has special significance to radio communications. Signals which travel along this gray line region often experience significant improvements in received signal strengths as compared to the direct shortest distance communications. This is because the radio wave absorbing D-layer disappears faster than the higher altitude radio wave propagating F2-layer around the time of sunset (and vice versa for sunrise). Because the F2-layer of the ionosphere remains strongly ionized along this gray line, HF signals often have less attenuation when they travel along the gray line as compared to the more direct shorter route.

**LUF:** Lowest usable frequency.

**Meteor scatter:** A remarkable type of propagation caused by the ionization by meteors (also known as "shooting stars") entering the earth's atmosphere. Meteors are small rocks orbiting in space and every year on certain dates, the earth passes through streams of these meteors. When the earth crosses an orbit of meteors, meteors hit the earth's atmosphere at a speeds of over 10.000km/h causing them they burn up at extremely high temperatures. The resulting high temperatures leave traces of ionized air behind them at 80-150km in altitude. Fortunately for radio operators, this trace of ionized air can reflect radio waves up to 500MHz and sometimes beyond. It can also reflect HF signals in the range of 30MHz. Each meteor entry results in a radio wave scatter that can be categorized into either a "ping" or "burst". Pings are short openings lasting a few seconds and bursts are openings lasting for minutes. During meteor storms (i.e., when meteors occur at high rates), both pings and bursts can occur so regularly that long QSO's are possible. The most famous meteor shower is called the Perseids and it occurs when the earth crosses the Perseid meteor orbit around August 12th of each year. This particular shower is known to

have up to 120 meteors per hour. For instance, in 1994 the Perseids supported radio conversations having strong signal strengths for several hours and the skip distances ranged from 200 to 1800km. However, meteor scatter contacts are usually more brief; and as a result, APRS and VHF packet radio is considered to be a good means of communication during meteor showers due to the mode's short packets of data containing useful information such as the transmitting station's callsign as well as location in each packet sent.

**MUF: Maximum Usable Frequency.**

**TA: Trans-Atlantic.** A mysterious and rare type of propagation named after the mysterious openings that occur between Europe and North America during the summer months, at a sunspot minimum, and well after sunset. In theory, openings such as these are unlikely, but there have been many occasions in 1995, 1996, and 1997 when such openings like these have occurred which allowed DX contacts across the Atlantic when DX seemed impossible. Even more mysterious is the fact that TV-amateurs received signals across the Atlantic well into the VHF-band during these openings. The mechanism of propagation is still unclear, but one proposed theory suggests that a gigantic  $E_s$ -cloud forms above the entire Atlantic resulting in sky wave propagation.

**TEP: Trans-Equatorial Propagation.** This is another form of mysterious radio wave propagation which occurs during the spring and fall months during the sunspot minimum. This form of propagation allows two stations at nearly identical middle latitudes on opposite sides of the geomagnetic equator to communicate at frequencies up to 150 MHz. For example, communications can occur between Italy and South-Africa or between the West Indies and South America. Like Trans-Atlantic propagation, there is no widely accepted scientific explanation for this type of propagation.

**Tropospheric scatter:** The only form of propagation that is directly influenced by the surface weather of the earth. Our troposphere (0-10km altitude) is composed of layers of air having different temperatures and moisture contents. When a sharp transition, called an inversion, appears between a cold dry layer and a warm moist layer of air, this transition causes refraction of radio waves. This is analogous to the refraction caused by the transition between water and air. For instance, when you put a stick into the water, it looks like it is bent. This same type of refraction occurs when a radio wave travels through a climate inversion; if the inversion is strong enough, radio waves can be refracted back to the surface of the earth after traveling significant distances (up to several hundred kilometers on the 6m band). Finally, this propagation effect is seen most often in the VHF and UHF bands, especially the 6m band.

**Ducting:** On rare occasions, two or more inversions may appear at different altitudes. Sometimes certain radio waves can be transported between these two inversions. Therefore, this type of propagation is called "ducting" (or "tunnelling"). Records of over 2500km have been set due to such ducting on VHF and UHF. Unfortunately, the effect is usually confined to 2m, but it can occur as high as 1.2 GHz (usually along frontal systems), and it almost never occurs below frequencies of 50MHz. When ducting does occur on these frequencies, communication distances are typically in the range of ~400km. Inversions usually develop under the influence of high pressure weather systems when there is very little air movement. Also, low pressure systems may produce an inversion when a cold air mass collides with a warmer air mass (called a frontal system in meteorology). Inversions that occur along frontal systems support propagation along a line parallel to the weather front, and radio amateurs using frontal inversion often point their antennas parallel to the frontal system to take advantage of this form of propagation.

### *The Ionosphere*

**Ionosphere:** A collection of ionized particles and electrons in the uppermost portion of the earth's atmosphere which is formed by the interaction of the solar wind with the very thin air particles that have escaped the earth's gravity. These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies with these critical frequencies varying with the degree of ionization. As a result, radio waves having frequencies higher than the lowest usable frequency (LUF) but lower than the maximum usable frequency (MUF) are propagated over large distances. Finally, predictions for the LUF and MUF at different times and regions around the world can be found by searching the world wide web for propagation forecasts.

**D-Layer:** The lowest part of the ionosphere, the D-layer appears at an altitude of 50-95km. This layer has a negative effect on radio waves because it only absorbs radio-energy, particularly those frequencies below 7MHz. It develops shortly after sunrise and disappears shortly after sunset. This layer reaches maximum ionization when the sun is at its highest point in the sky and this layer is also responsible for the complete absorption of sky waves from the 80m and 160m amateur bands as well as the AM broadcast band during the daytime hours.

**E-layer:** This part of the ionosphere is located just above the D-layer at an altitude of 90-150km. This layer can only reflect radio waves having frequencies less than 5MHz. It has a negative effect on frequencies above 5MHz due to the partial absorption of these higher frequency radio waves. The E-layer develops shortly after sunrise and it disappears a few hours after sunset. The maximum ionization of this layer is reached around midday and the ions

in this layer are mainly  $O_2^+$ .

**E<sub>s</sub>-layer:** Also called the sporadic E-layer. This layer is characteristically very different from the normal E-layer. Its altitude may vary anywhere between 80km and 120km. This extraordinary part of the ionosphere is capable of reflecting radio waves well into the VHF-band (30-300 MHz) and even into the lower parts of the UHF-band (300-3000 MHz). It is still a mystery as to how this layer actually develops, but, it is clear that this layer appears mostly during the summer months and briefly at mid-winter, with the peak occurring in the early summer. Furthermore, it can appear at any time of the day, with a preference for the late morning and early evening. The sporadic E-layer may produce skip distances ranging from 400km to 2000km, with unusually high signal strengths. Even with a fraction of a Watt and a small ground plane antenna, long range contacts are very common.

**F-layer:** Highest part of the ionosphere. The F-layer appears a few hours after sunset, when the F1- and F2-layers merge. The F-layer is located between 250km and 500km in altitude. Even well into the night, this layer may reflect radio waves up to 20 MHz, and occasionally even up to 25 MHz. Ions in the lower part of the F-layer are mainly  $NO^+$  and are predominantly  $O^+$  in the upper part.

**F1-layer:** The F1-layer is located between 150km and 200km in altitude and it occurs during daylight hours. Just before sunrise, the sun begins to shine on the upper part of the atmosphere containing the F-layer. Due to an unclear physical mechanism, the sunlight causes this F-layer to split into two distinct layers called the F1- and F2-layers. The maximum ionization of the F1-layer is reached at midday; this layer merges with the F2-layer a few hours after sunset to reform the F-layer. Finally, this layer reflects radio waves only up to about 10MHz.

**F2-layer:** This important layer of the ionosphere is the upper most part of the earth's atmosphere and it is located between 250km and 450km in altitude with occasional altitudes extending beyond 600km. At the higher latitudes north or south of the equator, this layer is located at lower altitudes. Near the equator, this layer can be located at twice the altitude as compared to the higher latitudes. About an hour before sunrise, this layer starts to develop as the F-layer begins to split (see F1-layer above). The maximum ionization of the F2-layer is usually reached one hour after sunrise and it typically remains at this level until shortly after sunset. However, this layer shows great variability with peaks in the maximum ionization occurring at any time during the day, displaying its sensitivity to rapidly changing solar activity and major solar events. In contrast to all other layers of the ionosphere, the maximum ionization of the F2-layer usually peaks during the winter months. Most importantly, this layer can reflect radio waves up to 50MHz during a sunspot maximum and maximum usable frequencies (MUF) can extend beyond 70MHz on rare occasions.

**Geomagnetic field (GMF):** The magnetic field which originates from the rotation of the molten iron core of our planet. This magnetic field produces the well known magnetic flux lines which run between the two magnetic poles allowing us to navigate by use of a compass. The shape of the geomagnetic field, GMF, is very similar to a water drop, with the tail pointing away from the sun. This shape is formed by a constant stream of charged particles originating from the sun (i.e. solar wind) and exerting a constant "pressure" on the side facing the sun. The GMF plays a major role in the dynamics of the earth's atmosphere and without the protection of our GMF, which traps charged particles before they reach the earth's surface, our planet's surface would be undergoing a constant bombardment of these charged particles. Furthermore, without this charged particle trap, the ionosphere would cease to exist and without an ionosphere, sky wave propagation would not exist and neither would DX contacts! Finally, the GMF is weakest near the polar regions and strongest near equatorial regions and on the night side of the earth opposite the sun, the GMF can extend millions of kilometers into space. Because of the importance of the GMF in trapping charged particles necessary for sky wave propagation, the short term variability of the GMF influences propagation; therefore, these short term variations are included in propagation forecasts. These forecasts categorize the GMF into the following categories: quiet, unsettled, active, minor storm, major storm, severe storm, very severe storm (very rare).

### [Additional information on the structure of the ionosphere.](#)

#### *Solar Events*

**Active Region:** A region of enhanced activity on the sun's surface that is associated with a complex magnetic field. An active region may be spotless (plage) or have one or more spots. Active regions are designated by a number when they appear on the visible part of the sun (the visible disk). They are also categorized by their complexity with a rating ranging from alpha (simple) to gamma-delta (multiple complexes). The more complex a region, the more activity (M- and X-flares, etc.) that region produces.

**Coronal Mass Ejections (CME):** Ejection of a large mass of plasma, including electrons, which are mostly caused by large solar flares. CME's directed towards the earth usually impact the planet between 36 and 96 hours after the ejection. CME's are responsible for increased A- and K-indices by increasing the solar wind velocities. These solar wind velocities may vary from 200km/h (small flares) to 900km/h (large flares).

**Coronal Stream:** A stream of charged particles originating from the sun's corona. Coronal streams have similar effects as CME's by increasing the A- and K-indices but usually to a lesser extent. However, a few coronal holes may cause major storm levels at the higher latitudes on earth resulting in total propagation fade-out at these latitudes.

**Filament:** A slow moving "cord-like" mass of plasma which moves across the sun's surface. Since most filaments are darker in color than the surrounding surface they are often visible in optical telescopes.

**Prominence:** A slow moving large mass of plasma on the sun's surface. Prominences are larger than filaments and are constantly changing in shape.

**Proton Flares:** An eruption of protons (positively charged nuclear particles) from the sun's surface. Protons usually reach the earth within an hour after the flare and they usually impact the earth at the polar regions where the magnetic field lines converge attracting these charged particles. Protons cause the ionosphere to absorb radiowaves at the polar regions.

**Solar Flares:** Solar flares are large eruptions of energy and charged particles from the sun's surface. They are usually accompanied by coronal mass ejections and/or proton flares. Solar flares may last from minutes to hours.

**Solar Wind:** The constant stream of charged particles originating from the sun. The solar wind has speeds ranging from 200km/s to 700km/s, but under certain circumstances such as fast moving CME's or coronal streams, the solar wind speed may increase to around 900km/s.

**Sunspot:** A small spot on the sun's visible surface where the magnetic flux lines converge. Sunspots appear darker than the surrounding surface area because they are relatively cooler in temperature.

### *Fluxes & Indices Used For Forecasting*

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**A- and K-index:** Geomagnetic activity indices, high indices (K:>5 or A:>20) means stormy conditions with an active geomagnetic field. The more active, the more unstable propagation with possible periods of total propagation fade-out. Especially around the higher latitudes and especially at the polar regions, where the geomagnetic field is weak, propagation may disappear completely. Extreme high indices may result in aurora propagation, with strongly degraded long distance propagation at all latitudes. Sporadic-E is strongest during low indices. Low indices result in relative good propagation, especially noticeable around the higher latitudes, when transpolar paths may open up. Maximum K-index is 9, and the A-index can exceed well over 100 during very severe storm conditions, with no maximum. The ARRL often reports the K-index from the Alaskan station where this index is known as the College K-index. Other stations reporting K-indices include Planetary and Boulder. In contrast, the A-indices are usually reported for the Planetary station only.

The higher the K-index, the more unstable propagation becomes, the effect is stronger at high latitudes, but weaker near low latitudes.

When storm level is reached, propagation strongly degrades, possibly fade out at high latitudes.

Classification of K-indices are as follows:

K0=Inactive  
K1=Very quiet  
K2=Quiet  
K3=Unsettled  
K4=Active  
K5=Minor storm  
K6=Major storm  
K7=Severe storm  
K8=Very severe storm  
K9=Extremely severe storm

As with the K-index, the higher the A-index, the more unstable propagation becomes.

Classification of A-indices are as follows:

A0 - A7 = quiet  
A8 - A15 = unsettled  
A16 - A29 = active  
A30 - A49 = minor storm

A50 - A99 = major storm  
A100 - A400 = severe storm

**Background X-ray level:** This may vary from B (very low), C (low to moderate), M (moderate to high) to X (high to extremely high), the higher the number after the letter, the stronger the X-ray radiation. So an X0.1 is stronger than an M9.9. High amounts of X-ray radiation causes intense ionization of the D-layer, resulting in strong absorption of HF-signals. Solar flares are commonly measured in the amount of X-ray radiation.

**Solar Flux:** This flux number is measured from the amount of radiation on the 10.7cm band (2800MHz). It is closely related to the amount of ultraviolet radiation, which is needed to create an ionosphere. The lowest possible number for this solar flux is 63.75. Single hop propagation already starts at 70 in lower latitude areas. Worldwide long distance propagation (DX) may turn up already with a solar flux at 120. From experience, a minimum solar flux of 160 seems to be ideal for 10m-20m band QRP DX with good possibilities during these conditions to reach every possible part of the globe with a simple dipole running as low as 5 Watts!

**T-index:** This index is used and developed by IPS Radio & Space Services in Australia. In this index, all other indices are used, so it's a very general index for forecasting propagation.

## GLOSSARY OF SOLAR/PROPAGATION TERMINOLOGY

### A

**a index.** See ak index.

**aa index.** A daily and half daily index of geomagnetic activity determined from the k indices scaled at two nearly antipodal stations at invariant magnetic latitude 50 degrees (Hartland, England, and Canberra, Australia). The aa values are in units of 1 nT. The index is available back to 1868, and is provided by the Institut de Physique du Globe de Paris, France.

**absorption line.** In spectroscopy, and in particular the solar Fraunhofer spectrum, a characteristic wavelength of emitted radiation that is partially absorbed by the medium between the source and the observer. (See H alpha.)

**active.** A descriptive word specifically meaning (1) a probability of  $\geq 50\%$  for an M-class x-ray flare (see x-ray flare class) in a sunspot region; (2) disturbed geomagnetic levels such that  $16 \leq Ak$  index  $< 30$ .

**active dark filament (ADF).** A filament displaying motion or changes in shape, location, or absorption characteristics.

**active longitude.** The approximate center of a range of heliographic longitudes in either the northern or southern solar hemisphere (seldom both at the same time) containing one or more large and complex active regions formed by the frequent, localized emergence of new magnetic flux. Individual sunspot groups within the complex can have relatively short lifetimes (a week or two); the complex may persist for several solar rotations because additional spot groups form as earlier ones decay.

**active prominence.** A prominence moving and changing in appearance over a few minutes of time.

**active prominence region.** A portion of the solar limb displaying active prominences; typically associated with an active region.

**active region (AR).** A localized, transient volume of the solar atmosphere in which plages, sunspots, facula, flares, etc., may be observed. Active regions are the result of enhanced magnetic fields; they are at least bipolar and may be complex if the region contains two or more bipolar groups.

**active surge region (ASR).** An active region that exhibits a group or series of spike-like surges that rise no higher than 0.15 solar radii above the limb. (See bright surge on the limb.)

**ADF.** See active dark filament.

**AE index.** A geomagnetic index of the auroral electrojet, which characterizes the maximum range of excursion (both positive and negative) from quiet levels; measured at a given universal time by using the combined data from a worldwide ring of high-latitude magnetic observatories. AU (A upper) refers to the greatest positive deviation from the quiet time reference and AL (A lower) to the most negative. By definition  $AE = AU - AL$ . AO refers to the mean of AU and AL:  $AO = 1/2 (AU + AL)$ . The AE and companion indices are provided by the Data Analysis Center for Geomagnetism and Spacemagnetism of Kyoto University, Kyoto, Japan.

**AFR.** The Ak index observed at Fredericksburg, Virginia.

**AFS.** See arch filament system.

**ak index.** A 3-hourly "equivalent amplitude" index of geomagnetic activity for a specific station or network of

stations (represented generically here by k) expressing the range of disturbance in the horizontal magnetic field. "ak" is scaled from the 3-hourly K index according to the following table:

K	ak
0	0
1	3
2	7
3	15
4	27
5	48
6	80
7	140
8	240
9	400

At SESC these values are used directly for operational purposes. But to convert the ak values to nanoteslas (nT), a local (station-dependent) conversion factor must be found by dividing the station's lower limit for K=9 by 250. For example, at Boulder and Fredericksburg the lower limit for K=9 is 500 nT so the factor is 2; therefore the ak values for these stations are in units of 2 nT. (To obtain an equivalent amplitude in nanoteslas for Boulder or Fredericksburg, the index value must be doubled).

**Ak index.** A daily index of geomagnetic activity for a specific station or network of stations (represented generically here by k) derived as the average of the eight 3-hourly ak indices in a Universal Time day.

**Alfven wave.** A transverse wave in magnetized plasma characterized by a change of direction of the magnetic field (rather than a change of intensity).

**am index.** A mean, 3-hourly "equivalent amplitude" of geomagnetic activity based on standardized K index data from a global network of 23 Northern and Southern Hemisphere stations by the Institut de Physique du Globe de Paris, France; am values are given in units of 1 nT.

**Am index.** The daily Ak index determined from the eight daily am indices.

**An index.** The daily Ak index determined from only the Northern Hemisphere stations of the am index network. anomaly. In typical SESC use, an unexpected response of a spacecraft.

**ap index.** A mean, 3-hourly "equivalent amplitude" of magnetic activity based on K index data from a planetary network of 11 Northern and 2 Southern Hemisphere magnetic observatories between the geomagnetic latitudes of 46 degrees and 63 degrees by the Institut fur Geophysik at Gottingen, F.R. Germany; ap values Ap index. Formally the daily Ak index, determined from the eight daily ap indices. However, for daily operational uses (since several weeks are required to collect the data and calculate the index), Air Force Space Forecast Center estimates the value of the Ap index by measuring the geomagnetic field in near-real time at several Western Hemisphere magnetometer stations and statistically weighting the data to represent the Gottingen Ap. The value of this estimated Ap index is reported in SESC daily and weekly summaries of geophysical activity.

**aphelion.** That point on the path of a sun-orbiting object most distant from the center of the sun. Compare perihelion.

**apogee.** That point on the path of an earth-orbiting satellite most distant from the center of the earth. Compare perigee.

**APR.** See active prominence region.

**AR.** See active region.

**arcade.** A series of magnetic loops, overlying a solar inversion line.

**arch filament system (AFS).** A system of small, arched linear-absorption features connecting bright, compact plage of opposite polarity. An AFS is a sign of emerging bipolar magnetic flux and possibly rapid or continued growth in an active region.

**As index.** The daily Ak index determined from only the Southern Hemisphere stations of the am index network.

**ASR.** See active surge region.

**atmospherics.** Also known as "sferics," transient radio waves produced by naturally occurring electric discharges

(e.g., lightning) in the earth's atmosphere.

**AU.** The mean distance between the earth and sun, equal to 214.94 solar radii or 1.496E+11m.

**aurora.** A sporadic, faint visual phenomenon associated with geomagnetic activity that occurs mainly in the high-latitude night sky. Auroras occur within a band of latitudes known as the auroral oval, the location of which is dependent on geomagnetic activity. Auroras are a result of collisions between atmospheric gases and precipitating charged particles (mostly electrons) guided by the geomagnetic field from the magnetotail. Each gas (oxygen and nitrogen molecules and atoms) gives out its own particular color when bombarded, and atmospheric composition varies with altitude. Since the faster precipitating particles penetrate deeper, certain auroral colors originate preferentially from certain heights in the sky. The auroral altitude range is 80 to 1000 km, but typical auroras are 100 to 250 km above the ground; the color of the typical aurora is yellow-green, from a specific transition of atomic oxygen. Auroral light from lower levels in the atmosphere is dominated by blue and red bands from molecular nitrogen and molecular oxygen. Above 250 km, auroral light is characterized by a red spectral line of atomic oxygen. To an observer on the ground, the combined light of these three fluctuating, primary colors produces an extraordinary visual display. Auroras in the Northern Hemisphere are called the aurora borealis or "northern lights." Auroras in the Southern Hemisphere are called aurora australis. The patterns and forms of the aurora include quiescent arcs, rapidly moving rays and curtains, patches, and veils.

**auroral electrojet.** See electrojet.

**auroral oval.** An elliptical band around each geomagnetic pole ranging from about 75 degrees magnetic latitude at local noon to about 67 degrees magnetic latitude at midnight under average conditions. It is the locus of those locations of the maximum occurrence of auroras and widens to both higher and lower latitudes during the expansion phase of a magnetic substorm.

**autumnal equinox.** The equinox that occurs in September. Compare vernal equinox.

## **B**

**B-angle.** As viewed from the earth, the heliographic latitude of the center of the solar disk. The center of the solar disk usually does not coincide with the heliographic equator, due to a tilt of the solar axis with respect to the ecliptic. (See *Bo* under solar coordinates).

**Bartels' rotation number.** The serial number assigned to 27-day rotation periods of solar and geophysical parameters. Rotation 1 in this sequence was assigned arbitrarily by Bartels to begin in January 1833, and the count has continued by 27-day intervals to the present. (For example, rotation 2000 began on 12 November 1979, rotation 2030 on 30 January 1982.) The 27-day period was selected empirically from the observed recurrence of geomagnetic activity attributed to co-rotating features on the sun. The sun has an average rotation period (as seen from the earth) of 27.27 days; therefore, solar longitude slowly drifts with respect to the Bartels rate. Compare Carrington longitude.

**bipolar magnetic region (bmr).** A region of the solar photosphere containing at least two areas of enhanced magnetic fields of opposing polarity.

**birefringent filter.** An optical device that passes a narrow range of wavelengths near a selected optical wavelength. Used especially in solar telescopes to pass selected lines (usually H alpha) in the Fraunhofer spectrum.

**bow shock.** A collisionless shock wave in front of the magnetosphere arising from the interaction of the supersonic solar wind with the earth's magnetic field.

**bright point.** A short-lived brightening of flare intensity, less than ten millionths of the solar hemisphere in area.

**bright surge on the disk (BSD).** A bright (high temperature) stream of gas (surge) seen against the solar disk. BSDs are often flare related and commonly fan out from the flare site. See also bright surge on the limb, and dark surge on the disk.

**bright surge on the limb (BSL).** A bright stream of gas (surge) emanating from the chromosphere that moves outward more than 0.15 solar radius above the limb. It may decelerate and return to the sun. Most BSLs assume a linear radial shape but can be inclined and/or fan shaped because they apparently follow magnetic lines of force.

**brightness temperature.** The equivalent blackbody temperature at a specified wavelength of a uniform source filling the resolution element of the telescope.

**BSD.** See bright surge on the disk.

**BSL.** See bright surge on the limb.

**burst.** A transient enhancement of the solar radio emission, usually associated with an active region or flare.

**butterfly diagram.** A plot of observed solar active region latitudes vs. time. This diagram, which resembles a butterfly, shows that the average latitude of active region formation drifts from high to low latitudes during a sunspot cycle.

## C

**C index.** A subjective daily character figure (index) of geomagnetic activity for a single observatory; for each UTC day the figure is 0 for very quiet magnetic conditions, 1 for moderately disturbed conditions, and 2 for severely disturbed conditions.

**Carrington longitude.** A system of fixed solar longitudes rotating at a uniform synodic period of 27.2753 days (a sidereal period of 25.38 days). Carrington selected the meridian that passed through the ascending node of the sun's equator at 1200 UTC on 1 January 1854 as the original prime meridian. The daily Carrington longitude of the central point of the apparent solar disk is listed (with other solar coordinates in *The Astronomical Almanac* published annually by the U.S. Naval Observatory. Compare Bartels' rotation number.

**Castelli U.** See U burst.

**celestial equator.** The projection of earth's geographic equator onto the celestial sphere.

**celestial sphere.** An imaginary spherical shell around the earth and concentric with it.

**centimeter burst.** A solar radio burst in the centimeter wavelength range (1 to 10 cm or 0.01 to 0.1 m), or 30 000 to 3000 MHz in the frequency range.

**central meridian passage (CMP).** The rotation of an active region or other feature across the longitude meridian that passes through the apparent center of the solar disk.

**CFI.** See comprehensive flare index.

**chromosphere.** The layer of the solar atmosphere above the photosphere and beneath the transition region and the corona. The chromosphere is the source of the strongest lines in the solar spectrum, including the Balmer alpha line of hydrogen and the H and K lines of calcium, and is the source of the red (chromium) color often seen around the rim of the moon at total solar eclipses.

**Ci index.** The daily international magnetic character figure formed by taking the arithmetic mean of the C index values from all reporting observatories.

**cleft.** See cusp.

**CMD.** Central Meridian Distance. (See solar coordinates).

**CME.** See coronal mass ejection.

**CMP.** See central meridian passage.

**comprehensive flare index (CFI).** A method of evaluating the significance of a complex flare event. The  $CFI = A + B + C + D + E$ . The value of each component is given below; a value of zero is assigned if the effect did not occur. The CFI values range from 1 to 17 (non-occurrence gives a zero value); values  $>10$  indicate flares with unusually strong electromagnetic radiation.

**A-**Originally the importance of ionizing radiation as indicated by the importance of associated SID, scale 1-3; but currently scaled from the x-ray flare class, class C being 1, class M being 2, and class X being 3.

**B-**Importance of H alpha flare; scale 1-3 (3 includes flare importance classes 3 and 4).

**C-**Log of 10.7-cm peak radio flux in units of  $10E-22$  W/sq m/Hz.

**D-**Effects associated with the dynamic radio spectrum: Type II burst = 1, continuum storm = 2, Type IV burst = 3.

**E-**Log of 200-MHz flux in same units as C. The CFI was devised and documented by Helen Dodson Prince and Ruth Hedeman at the McMath-Hulbert Observatory.

**conjugate points.** Two points on the earth's surface at opposite ends of a geomagnetic field line.

**continuum.** Optical radiation arising from broadband emission from the photosphere.

**continuum storm (CTM).** General term for solar noise lasting for hours and sometimes days, in which the intensity varies smoothly with frequency over a wide range in the meter and decimeter wavelengths.

**convection.** The bulk transport of plasma (or gas) from one place to another, in response to mechanical forces (for example, viscous interaction with the solar wind) or electromagnetic forces.

**Coordinated Universal Time (UTC).** By international agreement, the local time at the prime meridian, which passes through Greenwich, England. It was formerly known as Greenwich Mean Time, or sometimes simply Universal Time. There are 24 time zones around the world, labeled alphabetically. The time zone centered at Greenwich has the double designation of A and Z. Especially in the military community, Coordinated Universal Time is often referenced as Z or Zulu Time.

**corona.** The outermost layer of the solar atmosphere, characterized by low densities ( $<10E+9$  per cubic cm or  $10E+15$  per cubic m and high temperatures ( $>10E+6$  K).

**coronagraph.** An optical device that makes it possible to observe the corona at times other than during an eclipse. A simple lens focuses the sun onto an occulting disk that prevents the light from the solar disk from proceeding farther along the optical path, effectively providing an artificial eclipse.

**coronal hole.** An extended region of the corona, exceptionally low in density and associated with unipolar photospheric regions having "open" magnetic field topology. Coronal holes are largest and most stable at or near the solar poles, and are a source of high-speed solar wind. Coronal holes are visible in several wavelengths, most notably solar x-ray s, but at SESC, coronal holes are determined from solar images in He 1083 nm provided by the Kitt Peak National Solar Observatory.

**coronal loops.** A typical structure of enhanced corona observed in EUV lines and soft x-rays. They are sometimes related to H alpha loops. Coronal loops represent "closed" magnetic topology. coronal mass ejection (CME). A transient outflow of plasma from or through the solar corona. CMEs are often but not always associated with erupting prominences, disappearing solar filaments, and flares.

**coronal rain (CRN).** Material condensing in the corona and appearing to rain down into the chromosphere as observed in H alpha at the solar limb above strong sunspots.

**coronal streamer.** A large-scale structure in the white-light corona often overlying a principal inversion line in the solar photospheric magnetic fields. (See helmet streamer ).

**coronal transients.** A general term for short-time-scale changes in the corona.

**corrected geomagnetic coordinates.** A nonspherical coordinate system based on a magnetic dipole axis that is offset from the earth's center by about 450 km toward a location in the Pacific Ocean (15.6 N 150.9 E). This "eccentric dipole" axis intersects the surface at 81N 85 W, and 75 S 120 E.

**cosmic noise.** The broad spectrum of radio noise arriving at the earth from sources outside the solar system.

**cosmic ray.** An extremely energetic (relativistic) charged particle primarily originating outside the earth's magnetosphere.

**Cp index.** A daily index of geomagnetic activity analogous to the Ci index, obtained from the sum of the eight daily values of the ap index. The range of Cp is 0.0 to 2.5, 2.5 representing the most disturbed.

**critical frequency.** In ionospheric radio propagation, that frequency capable of penetration just to the layer of maximum ionization with vertical propagation. Radiowaves of lower frequencies are refracted back to the ground; higher frequencies pass through.

**CRN.** See coronal rain.

**crochet.** A sudden deviation in the sunlit geomagnetic field H component (see geomagnetic elements ) associated with extraordinary solar flare x-ray emission. The effect can be as much as 50 nT and last up to 30 minutes. The event is also known as an SFE (solar flare effect).

**CTM.** See continuum storm.

**cusps(s).** In the magnetosphere, two regions near magnetic local noon and approximately 15 degrees of latitude equatorward of the north and the south magnetic poles. The cusps mark the division between geomagnetic field lines on the sunward side (which are approximately dipolar but somewhat compressed by the solar wind ) and the field lines in the polar cap that are swept back into the magnetotail by the solar wind. The term cusp implies conical symmetry around the axis of the bundle of converging (Northern Hemisphere) or diverging (Southern Hemisphere) field lines. In practice, "cusp" and "cleft" are often used interchangeably. However, "cleft" implies greater extension in longitude (local time) and hence a wedge-shaped structure.

**D**

**D component of the geomagnetic field.** See geomagnetic elements.

**D region.** A daytime region of the earth's ionosphere beginning at approximately 40 km, to 90 km altitude. Radiowave absorption in layers in this region can be significantly increased in response to increased ionization associated with solar activity.

**dark surge on the disk (DSD).** Dark gaseous ejections on the sun visible in H alpha. They usually originate from small subflare-like brightenings. Material is usually seen to be ejected, to decelerate at a gravitational rate, and to flow back to the point of origin. DSDs can occur intermittently for days from an active region.

**dB (decibel).** A unit used to express the ratio between two levels of power. By definition  $dB = 10 \log (P2/P1)$ . (Doubling the power ratio is approx an increase of 3 dB).

**DB.** disparition brusque. See disappearing solar filament.

**declination.** (1) The angular distance of an astronomical body north (+) or south (-) of the celestial equator. (2) In geomagnetic applications, the angle between true north and the horizontal component of the local geomagnetic field.

**differential charging.** The charging of different areas of a spacecraft or satellite to different potentials in response to sunlight, the charged particle environment, and the design and composition of the structural materials themselves. Discharge may occur through arcing and generally is detrimental.

**differential particle flux.** The differential particle directional flux  $j(E,w)$  denotes the number of particles of energy  $E$  per unit energy interval, per unit area, per unit time, per unit solid angle of observation, passing through an area perpendicular to the viewing direction; the angle  $w$  is the angle between the viewing direction and the local magnetic field. It is approximately obtained from the count rate of a physical detector measuring the flux of particles between energy  $E$  and  $E + dE$ , geometric factor  $G$ , and solid angle of view  $dW$  through the relationship  $j(E,w) = C/(G * dE * dW * dt)$ , where  $C$  is the number of detector counts in time  $dt$ .

**differential rotation.** The change in solar rotation rate with latitude. Low latitudes rotate at a faster angular rate (approx. 14 degrees/day) than do high latitudes (approx. 12 degrees/day).

**dip.** The geomagnetic inclination angle. See geomagnetic elements.

**dip equator.** An irregular, imaginary line around the earth where the geomagnetic inclination angle is measured to be zero. It lies near the geographic equator.

**disappearing solar filament (DSF).** A solar filament (prominence) that disappears suddenly (on a time scale of minutes to hours). The prominence material is often seen to ascend but is also seen to fall into the sun or just fade. (Historically, DSFs have been called disparitions brusques because they were first studied by French astronomers.) DSFs are a possible indicator of coronal mass ejections.

**disk.** The visible surface of the sun (or any heavenly body) projected against the sky.

**disparition brusque (DB).** See disappearing solar filament.

**Doppler shift.** A change in the perceived frequency of a radiated signal caused by motion of the source relative to the observer.

dose rate. The rate at which radiation energy is absorbed in living tissue, expressed in centisieverts per unit time.

DSD. See dark surge on the disk.

DSF. See disappearing solar filament.

Dst index. A measure of variation in the geomagnetic field due to the equatorial ring current. It is computed from the H-components at approximately four near-equatorial stations at hourly intervals. At a given time, the Dst index is the average of variation over all longitudes; the reference level is set so that Dst is statistically zero on internationally designated quiet days. An index of -50 or deeper indicates a storm-level disturbance, and an index of -200 or deeper is associated with middle-latitude auroras. Dst is determined by the World Data Center C2 for Geomagnetism, Kyoto University, Kyoto, Japan.

## E

E region. A daytime region of the earth's ionosphere roughly between the altitudes of 90 and 160 km. E region characteristics (electron density, height, etc.) depend on the solar zenith angle and solar activity. The ionization in the E layer is caused mainly by x-rays in the range 0.8 to 10.4 nm. (See also sporadic E).

eccentric dipole. See corrected geomagnetic coordinates.

eclipse. The obscuring of one celestial body by another.

(1) A Solar Eclipse occurs when the moon comes between the earth and the sun. In a total eclipse, the solar disk is completely obscured; in a partial eclipse the solar disk is only partly obscured. An annular eclipse occurs when the moon is near its apogee and the apparent diameter of the moon is less than that of the sun so that the sun is never completely obscured. "First and last contacts" are defined as the times of tangency of the solar and lunar disks. A central eclipse (which can be total or annular) has two additional times of tangency: "second contact," when maximum eclipse begins, and "third contact," when it ends. The last glimpses of the sun through the lunar valleys, just before second contact, are known as Baily's beads.

(2) A lunar eclipse occurs when the moon enters the shadow cast by the earth.

(3) Spacecraft in the earth's shadow are said to be in eclipse.

ecliptic. The great circle made by the intersection of the plane of the earth's orbit with the celestial sphere. (Less properly, the apparent path of the sun around the sky during the year.)

EFR. See emerging flux region.

EHF. See extremely high frequency.

electrojet. (1) Auroral: A current that flows in the ionosphere in the auroral zone. (2) Equatorial: A thin electric current layer in the ionosphere over the dip equator at about 100 to 115 km altitude.

electrostatic discharge (ESD). An abrupt equalization of electric potentials. In space, ESD can occur between objects or portions of a single object (see differential charging); ESD may occur locally within a dielectric or cable. The consequences may include material damage, a spacecraft anomaly, phantom commands, disrupted telemetry, and contaminated data.

ELF. See extremely low frequency.

emerging flux region (EFR). An area on the sun where new magnetic flux is erupting. An EFR is a bipolar magnetic region that first produces a small bipolar plage visible in the chromosphere, which may develop an arch filament system and the initial spots of a sunspot group. An EFR may be isolated from other solar activity or may occur within an active region.

emission line. In spectroscopy, a particular wavelength of emitted radiation, more intense than the background continuum.

emission measure. The integral of the square of the electron density over volume; the units are inverse volume (per cubic m).

ephemeris. An astronomical almanac listing solar coordinates and the positions of the sun and other heavenly bodies at regular intervals in time.

**EPL.** See eruptive prominence on limb.

**equatorial electrojet.** See electrojet.

**equinox.** One of the two points of intersection of the celestial equator and the ecliptic. The sun passes through the vernal equinox on about 21 March and through the autumnal equinox on about 22 September.

**eruptive.** With regard to solar flare predictions, a probability of >50% that an active region will produce C class x-ray flares. (See x-ray flare class.)

**eruptive prominence on limb (EPL).** A solar prominence that becomes activated and is seen to ascend from the sun; sometimes associated with a coronal mass ejection. (See also disappearing solar filament).

**ESD.** See electrostatic discharge.

**estimated hemispherical power input.** For the earth, an estimate made from NOAA/TIROS particle measurements of the instantaneous power dissipated daily in a single auroral zone by auroral particle precipitation. The power ranges from approximately 5 gigawatts during quiet intervals up to more than 100 in very active times. The magnitude of this power input corresponds closely to the level of geomagnetic activity.

**EUV.** See extreme ultraviolet.

**Evershed effect.** Horizontal motion of the solar atmosphere near a sunspot, having velocities of a few kilometers per second. In the photosphere, matter streams away from the umbra. In the chromosphere, the direction of flow is toward the umbra.

**exosphere.** The earth's atmosphere above 500-600 km.

**expert system.** A computer program intended to simulate human logic for analyzing a complex situation on the basis of a sequence of behavior rules supplied by a human expert. (See Theophrastus).

**extraordinary mode.** One of the two modes of propagation of electromagnetic waves in a magnetic plasma. For propagation along the direction of the magnetic field, it is the mode in which the electric vector rotates in the same sense that an electron gyrates freely about the field. For propagation perpendicular to the magnetic field, the electric vector oscillates perpendicular to the primary magnetic field. (See also ordinary mode.)

**extreme ultraviolet (EUV).** A portion of the electromagnetic spectrum from approximately 10 to 100 nm.

**extremely high frequency (EHF).** That portion of the radio frequency spectrum from 30-300 GHz.

**extremely low frequency (ELF).** That portion of the radio frequency spectrum from 30 to 3000 Hz.

## F

**F corona.** Of the white-light corona (the corona seen by the eye at a total solar eclipse), that portion which is caused by sunlight scattered or reflected by solid particles (dust) in interplanetary space. The same phenomenon produces zodiacal light.

**F region.** The upper region of the ionosphere, above approximately 160 km altitude. F region electron densities are highly variable, depending on the local time, solar activity, season, and geomagnetic activity. The F region contains the F1 and F2 layers. The F2 layer is more dense and peaks at altitudes between 200 and 600 km. The F1 layer, which forms at lower altitudes in the daytime, has a smaller peak in electron density.

**f-spot.** See follower spot.

**facula.** White-light plage—a bright region of the photosphere seen in white light, seldom visible except near the solar limb. Corresponds with concentrated magnetic fields that may presage sunspot formation.

**fibril.** A linear feature in the H alpha chromosphere of the sun, occurring near strong sunspots and plage or in filament channels. Fibrils parallel strong magnetic fields, as if mapping the field direction.

**filament.** A mass of gas suspended over the chromosphere by magnetic fields and seen as dark ribbons threaded

over the solar disk. A filament on the limb of the sun seen in emission against the dark sky is called a prominence. Filaments occur directly over magnetic-polarity inversion lines, unless they are active.

**filament channel.** A broad pattern of fibrils in the chromosphere, marking a portion of a magnetic polarity inversion line where a filament may soon form or where a filament recently disappeared. Filament channels interconnect separate filaments and active regions on a common inversion line.

**flare.** A sudden eruption of energy in the solar atmosphere lasting minutes to hours, from which radiation and particles are emitted. Flares are classified on the basis of area at the time of maximum brightness in H alpha.

Importance 0 (Subflare):  $\leq 2.0$  hemispheric square degrees

Importance 1: 2.1-5.1 square degrees

Importance 2: 5.2-12.4 square degrees

Importance 3: 12.5-24.7 square degrees

Importance 4:  $\geq 24.8$  square degrees

[One square degree is equal to  $(1.214 \times 10^4 \text{ km})^2 = 48.5$  millionths of the visible solar hemisphere.] A brightness qualifier F, N, or B is generally appended to the importance character to indicate faint, normal, or brilliant (for example, 2B). fluence. Time integrated flux. In SESC use, a specified particle flux accumulated over 24 hours. flux. The rate of flow of a physical quantity through a reference surface.

**fmin.** The lowest frequency at which echo traces are observed on an ionogram. It increases with increasing D region absorption.

**foEs.** The maximum ordinary mode radiowave frequency capable of vertical reflection from the sporadic E layer of the ionosphere.

**foF2.** The maximum ordinary mode radiowave frequency capable of vertical reflection from the F2 layer of the ionosphere. (See F region.)

**follower spot.** In a magnetically bipolar or multipolar sunspot group, the main spot in that portion of the group east of the principal inversion line is called the follower or f-spot. Leader and follower describe the positions of spots with respect to apparent motion due to solar rotation. (Compare leader spot.)

**Forbush decrease.** An abrupt decrease, of at least 10%, of the background galactic cosmic ray intensity as observed by neutron monitors. It is associated with major plasma and magnetic field enhancements in the solar wind at or beyond the earth.

**Fraunhofer spectrum.** The system of dark lines superposed on the continuous solar spectrum formed by the absorption of photons by atoms and molecules in the solar and terrestrial atmospheres.

## G

**gamma rays.** High-energy radiation (energies in excess of 100 keV) observed during large, extremely energetic solar flares.

**GEOALERT.** An IUWDS special message summarizing by code the current and predicted levels of solar activity and geomagnetic activity.

**geocorona.** The outer region of the earth's atmosphere lying above the thermosphere and composed mostly of hydrogen.

**geomagnetic activity.** Natural variations in the geomagnetic field classified quantitatively into quiet, unsettled, active, and geomagnetic storm levels according to the observed a index:

Category Range of index

quiet 0 - 7

unsettled 8 - 15

active 16 - 29

minor storm 30 - 49

major storm 50 - 99

severe storm 100 - 400

**geomagnetic elements.** The components of the geomagnetic field at the surface of the earth. These elements are usually denoted thus in the literature:

X-the geographic northward component

Y-the geographic eastward component

**Z**-the vertical component, reckoned positive downward

**H**-the horizontal intensity, of magnitude  $\sqrt{(X)^2 + (Y)^2}$

**F**-the total intensity  $\sqrt{(H)^2 + (Z)^2}$

**I**-the inclination (or dip) angle,  $\arctan (Z/H)$

**D**-the declination angle, measured from the geographic north direction to the H component direction, positive in an eastward direction.  $D = \arctan (Y/X)$

However, in SESC use, the geomagnetic northward and geomagnetic eastward components are called the H and D components. The H axis direction is defined by the mean direction of the horizontal component of the field; the D component is expressed in nanoteslas and is related to the direction of the horizontal component relative to geomagnetic north by using the small-angle approximation. Thus the D component = H (the horizontal intensity) multiplied by  $\Delta D$  (the declination angle relative to geomagnetic north, expressed in radians).

**geomagnetic field.** The magnetic field in and around the earth. The intensity of the magnetic field at the earth's surface is approximately 32,000 nT at the equator and 62,000 nT at the north pole (the place where a compass needle points vertically downward). The geomagnetic field is dynamic and undergoes continual slow secular changes as well as short-term disturbances (see geomagnetic activity). The geomagnetic field can be approximated by a centered dipole field, with the axis of the dipole inclined to the earth's rotational axis by about 11.5 degrees. Geomagnetic dipole north is near geographic coordinate 78.3 N 69 W (Thule, Greenland), and dipole south is near 79 S 110 E (near Vostok, Antarctica). The observed or dip poles, where the magnetic field is vertical to the earth's surface, are near 76 N 101 W, and 66 S 141 E. The adopted origin of geomagnetic longitude is the meridian passing through the geomagnetic poles (dipole model) and the geographic south pole. (See also corrected geomagnetic coordinates.)

**geomagnetic storm.** A worldwide disturbance of the earth's magnetic field, distinct from regular diurnal variations. A storm is precisely defined as occurring when the daily  $A_p$  index exceeds 29. (See geomagnetic activity).

**Initial Phase:** Of a geomagnetic storm, that period when there may be an increase of the middle-latitude horizontal intensity (H) (see geomagnetic elements) at the surface of the earth. The initial phase can last for hours (up to a day), but some storms proceed directly into the main phase without showing an initial phase.

**Main Phase:** Of a geomagnetic storm, that period when the horizontal magnetic field at middle latitudes is generally decreasing, owing to the effects of an increasing westward-flowing magnetospheric ring current. The northward component can be depressed as much as several hundred nanoteslas in intense storms. The main phase can last for hours, but typically lasts less than 1 day.

**Recovery Phase:** Of a geomagnetic storm, that period when the depressed northward field component returns to normal levels. Recovery is typically complete in one to two days, but can take longer.

**geomagnetic time.** See magnetic local time.

**geosynchronous.** Term applied to any equatorial satellite with an orbital velocity equal to the rotational velocity of the earth. The geosynchronous altitude is near 6.6 earth radii (approximately 36 000 km above the earth's surface). To be geostationary as well, the satellite must satisfy the additional restriction that its orbital inclination be exactly zero degrees. The net effect is that a geostationary satellite is virtually motionless with respect to an observer on the ground.

**GLE.** See ground-level event.

**GMT.** Greenwich Mean Time. (See Coordinated Universal Time.)

**GPS.** Global Positioning System: a network of earth-orbiting satellites used for precise position-finding in surveying and navigation.

**gradual commencement.** The commencement of a geomagnetic storm that has no well-defined onset. (See also sudden commencement.)

**granulation.** Cellular structure of the photosphere visible at high spatial resolution. Individual granules, which represent the tops of small convection cells, are 200 to 2000 km in diameter and have lifetimes of 8 to 10 minutes.

**Greenwich Mean Time (GMT).** See Coordinated Universal Time.

**green line.** A coronal emission line at 530.3 nm from Fe XIV (an iron atom from which 13 electrons have been stripped). The green line is one of the strongest (and first-recognized) visible coronal lines. It identifies moderate-temperature regions of the corona; it is enhanced in coronal streamers above inversion lines, and diminished in coronal holes.

**ground-level event (GLE).** A sharp increase in ground-level cosmic ray count to at least 10% above background, associated with solar protons of energies greater than 500 MeV. GLEs are relatively rare, occurring only a few times each solar cycle. When they occur, GLEs begin a few minutes after flare maximum and last for a few tens of minutes to hours. Intense particle fluxes at lower energies can be expected to follow this initial burst of relativistic

particles. GLEs are detected by neutron monitors, e.g., the monitor at Thule, Greenland.

## H

**H component (of the geomagnetic field ).** See geomagnetic elements.

**H alpha.** The first atomic transition in the hydrogen Balmer series; wavelength = 656.3 nm. This absorption line of neutral hydrogen falls in the red part of the visible spectrum and is convenient for solar observations. The H alpha line is universally used for patrol observations of solar flares, filaments, prominences, and the fine structure of active regions.

**Hale boundary.** A large-scale magnetic inversion line of a particular magnetic orientation in the solar photosphere or across a sector boundary in the solar wind. If the polarity of the western (leading) side of the boundary is the same as that of the nearer solar pole at the start of a sunspot cycle, the boundary is said to be "Hale." If the polarity is opposite, the boundary is "anti-Hale." At the beginning of Cycle 22 (1987), the northern solar pole was negative; therefore, in the northern hemisphere a Hale boundary separates a leading negative polarity region from a following positive one. The boundary between the leader spot and follower spot of a typical sunspot group in either hemisphere is a Hale boundary.

**heliographic.** Referring to coordinates on the solar surface referenced to the solar rotational axis.

**heliopause.** The boundary surface between the solar wind and the external galactic medium.

**heliosphere.** The magnetic cavity surrounding the sun, carved out of the galaxy by the solar wind.

**helmet streamer.** A feature of the white light corona (seen in eclipse or with a coronagraph) that looks like a ray extending away from the sun out to about 1 solar radius, having an arch-like base containing a cavity usually occupied by a prominence.

**hemispherical power input (HPI).** See estimated hemispherical power input.

**HF.** See high frequency.

**high frequency (HF).** That portion of the radio frequency spectrum between 3 and 30MHz.

**high latitude.** With reference to zones of geomagnetic activity, 50 degrees to 80 degrees geomagnetic latitude. The other zones are equatorial, polar, and middle latitude.

**high-speed stream.** A feature of the solar wind having velocities exceeding approximately 600 km/s (about double average solar wind values). High-speed streams that originate in coronal holes are less dense than those originating in the average solar wind.

**homologous flares.** Solar flares that occur repetitively in an active region, with essentially the same position and with a common pattern of development.

**Hyder flare.** A filament -associated two-ribbon flare, often occurring in spotless regions. The flare is generally slow (30-60 minutes rise time in H alpha and x-ray) and follows the disappearance of a quiescent filament. The flare presumably results from the impact on the chromosphere of infalling filament material. The Hyder flare is named for Dr. C. Hyder, who published studies of such flares in 1967.

## I

**IMF.** See interplanetary magnetic field.

**inclination of the geomagnetic field.** The angle between the local geomagnetic field direction and the horizon. (See geomagnetic elements.)

**initial phase.** See geomagnetic storm.

**integral particle flux.** The integral directional particle flux  $J(E,w)$  is literally the mathematical integral, with respect to the energy  $E$ , of the differential particle flux  $j(E,w)$ . It denotes the number of particles of energy equal to or

greater than E, per unit area, per unit solid angle, per unit time, passing through an area perpendicular to the viewing direction.

interplanetary magnetic field (IMF). The magnetic field carried with the solar wind.

INTERMAGNET. An international consortium of magnetic observatories that exchange data in near-real time by satellite relay.

invariant magnetic latitude. The geomagnetic latitude at which a particular line of force of the geomagnetic field, characterized by L (the altitude of the field line at the equator), intersects the earth. The relationship is given by  $L(\cos)^2 = 1$  L is expressed in earth radii and the geomagnetic field is approximated by a dipole model.

inversion line. The locus of points on the solar surface where the radial magnetic field vanishes. Inversion lines separate regions of opposing polarity and are often superposed by thin, dark filaments, which can be used as tracers. Inside active regions, the areas close to and along inversion lines are preferred places of flare occurrence. Filament channels, plage corridors, arch-filament systems, and fibril patterns surrounding active regions can be used to infer the positions of inversion lines.

ion-acoustic waves. Longitudinal waves in a plasma similar to sound waves in a neutral gas. Amplitudes of electron and ion oscillations are not quite the same, and the resulting Coulomb repulsion provides the potential energy to drive the waves.

ionogram. A plot (record) of the group path height of reflection of ionospherically returned (echoed) radio waves as a function of frequency.

ionosphere. The region of the earth's upper atmosphere containing free electrons and ions produced by ionization of the constituents of the atmosphere by solar ultraviolet radiation at very short wavelengths (<100 nm) and energetic precipitating particles. The ionosphere influences radiowave propagation of frequencies less than about 300 MHz. (See D region, E region, F region.)

ionospheric storm. A disturbance in the F region of the ionosphere, which occurs in connection with geomagnetic activity. In general, there are two phases of an ionospheric storm, an initial increase in electron density (the positive phase) lasting a few hours, followed by a decrease lasting a few days. At low latitudes only the positive phase is usually seen. Individual storms can vary, and their behavior depends on geomagnetic latitude, season, and local time. The phases of an ionospheric storm are not related to the initial and main phases of a geomagnetic storm.

## K

K (kelvin). A unit of absolute temperature. One kelvin is equal to 1 degree C, but zero on the kelvin scale corresponds to absolute zero (-273.15 degrees C).

K corona. Of the white-light corona (that is, the corona seen by the eye at a total solar eclipse), that portion which is caused by sunlight scattered by electrons in the hot outer atmosphere of the sun. This is the "true" corona. Corona graphs are specifically constructed to separate the K corona from the F corona.

K index. A 3-hourly quasi-logarithmic local index of geomagnetic activity relative to an assumed quiet-day curve for the recording site. Range is from 0 to 9. The K index measures the deviation of the most disturbed horizontal component (see geomagnetic elements).

Kelvin-Helmholtz instability. A mechanism often invoked to explain phenomena at the magnetopause (and sometimes the plasmopause), especially the observed magnetic pulsations.

Km index. A 3-hourly planetary index of geomagnetic activity calculated by the Institut de Physique du Globe de Paris, France, from the K indices observed at a large, symmetrically located network of stations. The Km indices are used to determine the am indices.

Kp index. A 3-hourly planetary index of geomagnetic activity calculated by the Institut für Geophysik der Gottingen Universität, F.R. Germany, from the K indices observed at 13 stations primarily in the Northern Hemisphere. The Kp indices, which date from 1932, are used to determine the ap indices.

## L

**L.** Heliographic longitude of a solar feature. (See solar coordinates.)

**latchup.** With reference to the effect of energetic particles on spacecraft microcircuits, a serious type of single event upset in which the microcircuit is either permanently stuck or cannot be reset without being turned off and on.

**LDE.** See long duration (or decay) event.

**leader spot.** In a magnetically bipolar or multipolar sunspot group, the main spot in that portion of the group west of the principal inversion line ; also called the preceding or p-spot. Leader and follower describe the positions of spots with respect to apparent motion due to solar rotation. (Compare follower spot.)

**LEO.** Among satellite operators, a common abbreviation for Low Earth Orbit.

**LET.** See linear energy transfer.

**LF.** See low frequency.

**light bridge.** Observed in white light, a bright tongue or streaks penetrating or crossing sunspot umbra e. Light bridges typically develop slowly and have lifetimes of several days. The appearance of a light bridge is frequently a sign of impending active region division or dissolution. The more brilliant forms occur with overlying bright plage and often occur during the most active phase of the sunspot group.

**light curve.** A plot of intensity in a particular wavelength or band of wavelengths against time, especially with reference to a solar flare; for example, the time history of the x-ray output of a flare.

**limb.** The edge of the solar disk, corresponding to the level at which the solar atmosphere becomes transparent to visible light.

**limb darkening.** For certain solar spectral lines, a lessening of the intensity of the line from the center of the solar disk to the limb, caused by the existence of a temperature gradient in the sun and the line-of-sight through the solar atmosphere.

**limb flare.** A flare at the edge (limb) of the solar disk ; the elevated portions of the flare are seen with particular clarity against the dark sky background.

**linear energy transfer (LET).** The energy per unit path length that an ionizing particle loses to the medium through which it is traveling. The greater the LET, the more damaging the particle.

**lobes.** In the magnetotail, the two regions (north and south) separated by the neutral sheet.

**long duration ( or decay) event (LDE).** With reference to x-ray events, those events that are not impulsive in appearance. The exact time threshold separating impulsive from long-duration events is not well defined, but operationally, any event requiring hours (1 or more) to return to background levels would probably be regarded as an LDE. It has been shown that the likelihood of a coronal mass ejection increases with the duration of an x-ray event, and becomes virtually certain for durations of 6 hours or more.

**longitudinal component.** That component of magnetic field vector parallel to the direction of view, radial from the solar surface at disk center.

**loop prominence system (LPS).** A system of prominences in the form of loops associated with major flares, bridging the magnetic inversion line. The lifetime of an LPS is a few hours.

**Loop prominences observed in H alpha** are distinctly brighter than other prominences, and material typically flows downward along both legs from condensation "knots" near the top of the loop. LPSs show a high correlation with proton flares.

**low frequency (LF).** That portion of the radio frequency spectrum from 30 to 300 kHz.

**lowest usable frequency (LUF).** The lowest frequency that allows reliable long-range HF radio communication by ionospheric refraction.

**LPS.** See loop prominence system.

**LUF.** See lowest usable frequency.

## M

**M(3000).** The ratio of the maximum frequency reflected once from an ionospheric layer over a 3000-km range to the critical frequency of the layer.

**magnetic bay.** A relatively smooth excursion of the H (horizontal) component (see geomagnetic elements ) of the geomagnetic field away from and returning to quiet levels. Bays are "positive" if H increases and "negative" if H decreases.

**magnetic cloud.** In general, any identifiable parcel of solar wind. More specifically, a region of about 0.25 AU in radial dimension in which the magnetic field strength is high and the direction of one component of the magnetic field changes appreciably by means of a rotation nearly parallel to a plane. Magnetic clouds may be one manifestation of coronal mass ejections in the interplanetary medium.

**magnetic local time (MLT).** On earth, analogous to geographic local time; MLT at a given location is determined by the angle subtended at the geomagnetic axis between the geomagnetic midnight meridian and the meridian that passes through the location. 15 degrees = 1 h. The geomagnetic meridian containing the sub-solar point defines geomagnetic local noon, and the opposite meridian defines geomagnetic midnight. (See geomagnetic field.)

**magnetic sunspot classifications.** See Mount Wilson magnetic classification.

**magnetogram.** A plot showing the amplitude of one or more vector components of a magnetic field versus space or time. Solar magnetograms are a graphic representation of solar magnetic field strengths and polarity.

**magnetohydrodynamics (MHD).** The study of the dynamics of an electrically conducting fluid in the presence of a magnetic field.

**magnetopause.** The boundary surface between the solar wind and the magnetosphere, where the pressure of the magnetic field of the object effectively equals the dynamic pressure of the solar wind.

**magnetopause current sheet.** An electric current sheet that more or less coincides with the magnetopause.

**magnetosheath.** The region between the bow shock and the magnetopause, characterized by very turbulent plasma. For the earth, along the sun-earth axis, the magnetosheath is about 2 earth radii thick.

**magnetosphere.** The magnetic cavity surrounding a magnetized body, carved out of the passing solar wind by virtue of the magnetic field, which prevents, or at least impedes, the direct entry of the solar wind plasma into the cavity.

**magnetotail.** The extension of the magnetosphere in the antisunward direction as a result of interaction with the solar wind. In the inner magnetotail, the field lines maintain a roughly dipolar configuration. But at greater distances in the antisunward direction, the field lines are stretched into northern and southern lobes, separated by a plasmashet. There is observational evidence for traces of the earth's magnetotail as far as 1000 earth radii downstream.

**MAGSTORM.** A telegraphic abbreviation used to denote a geomagnetic storm.

**main phase.** See geomagnetic storm.

**Maunder minimum.** An approximately 70-year period, centered near 1670, during which practically no sunspots were observed.

**maximum usable frequency (MUF).** The highest frequency that allows reliable HF radio communication over a given ground range by ionospheric refraction. Frequencies higher than the MUF penetrate the ionosphere and become useful for extraterrestrial communications.

**MDP.** See mound prominence.

**medium frequency (MF).** That portion of the radio frequency spectrum from 0.3 to 3 MHz.

**mesosphere.** The region of the earth's atmosphere between the upper limit of the stratosphere (approximately 30 km altitude) and the lower limit of the thermosphere (approximately 80 km altitude).

**MHD.** See magnetohydrodynamics.

micropulsation. See pulsation.

microwave burst. A radiowave signal associated with optical and/or x-ray flare s. Microwave bursts occur mostly at centimeter wavelengths (6 cm = 4995 MHz) but are generally broadband, often extending into the millimeter and decimeter domains. (See also U - burst.)

microwaves. Generically, any radio frequency of 500 MHz or more.

middle latitude. With reference to zones of geomagnetic activity, 20 degrees to 50 degrees geomagnetic latitude. Other zones are equatorial, polar, and high latitude.

Moreton wave. A wave disturbance (also known as a flare blast wave) generated by large flares, which is seen to propagate horizontally across the disk of the sun at a typical velocity of about 1000 km /s. Its presence is more visible in wings of the H alpha line. It can cause filaments to erupt as the wave apparently disturbs supporting magnetic fields.

mound prominence (MDP). H alpha structure at the solar limb that is the elevated top of numerous small surges and/or a dense, low-lying prominence. Mount Wilson magnetic classification. Classification of the magnetic character of sunspot s according to rules set forth by the Mount Wilson Observatory in California:

alpha. A unipolar sunspot group.

beta. A sunspot group having both positive and negative magnetic polarities (bipolar), with a simple and distinct division between the polarities.

gamma. A complex active region in which the positive and negative polarities are so irregularly distributed as to prevent classification as a bipolar group.

beta-gamma. A sunspot group that is bipolar but which is sufficiently complex that no single, continuous line can be drawn between spots of opposite polarities delta. A qualifier to magnetic class (see below) indicating that umbra e separated by less than 2 degrees within one penumbra have opposite polarity.

beta-delta. A sunspot group of general beta magnetic classification but containing one (or more) delta spot(s).

beta-gamma-delta. A sunspot group of beta-gamma magnetic classification but containing one (or more) delta spot (s).

gamma-delta. A sunspot group of gamma magnetic classification but containing one (or more) delta spot(s).

multipath. Describing a degraded condition of radio propagation in which the radio wave splits and arrives at the receiver via different paths. Because each path will generally have different lengths, arrival times, and phases, the signal received will suffer fading.

## N

network. (1) Chromospheric: a large-scale brightness pattern in chromospheric (see chromosphere ) and transition region spectral lines, which is located at the borders of the photospheric (see photosphere ) supergranulation and coincides with regions of local magnetic enhancement. These cellular patterns are typically  $3 \times 10^4$  km across.

(2) Photospheric: a bright pattern that appears in spectroheliograms in certain Fraunhofer spectrum lines. It coincides in gross outline with the chromospheric network. neutral line. The line that separates solar magnetic fields of opposite polarity, typically determined from solar magnetograms recording the longitudinal magnetic component. Neutral lines are, more properly, inversion line s).

neutron monitor. A ground-based detector that counts secondary neutrons generated by processes originating with the impact of atmospheric molecules and atoms by very energetic particles (galactic or solar cosmic rays).

nm (nanometer). A unit of length,  $10^{-9}$ m.

noise storm. A transient enhancement of solar radio emission, particularly at 245 MHz, consisting of an elevated background emission (radiation) and Type I radio bursts.

non-great-circle propagation. Describing a degraded condition of radio propagation caused by horizontal gradients in the ionospheric electron density. The radio wave is refracted away from its normal great-circle path, which is the shortest distance between two points on the earth. Strong horizontal gradients are associated with the equatorward boundary of the auroral oval (especially in the night sector) and the sunrise terminator.

nT (nanotesla ).  $10^{-9}$  tesla or 0.00000001 tesla.

## O

ordinary mode. One of the two modes of propagation of electromagnetic waves in a magnetic plasma. For

propagation along the direction of the magnetic field, it is the mode in which the electric vector rotates opposite to the direction of an electron gyrating freely about the field. For propagation perpendicular to the magnetic field, the electric vector oscillates parallel to the primary magnetic field. (See also extraordinary mode.)

**P**

**P-angle.** See solar coordinates.

**p-spot.** See leader spot.

**PCA.** See polar cap absorption.

**particle flux unit (p.f.u.).** 1 p/sq cm/s/sr(steradian).

**penumbra.** The sunspot area that may surround the darker umbra or umbrae. In its mature form it consists of linear bright and dark elements radial from the sunspot umbra.

**perigee.** That point on the orbit of an earth-orbiting satellite nearest to the earth. Compare apogee.

**perihelion.** That point on the orbit of a sun-orbiting body nearest to the sun. Compare aphelion.

**persistence.** Continuation of existing conditions. When a physical parameter varies slowly, the best prediction is often persistence.

**p.f.u.** See particle flux unit.

**phantom command.** An apparent (but unintended) spacecraft command caused by the natural environment. (See single event upset or electrostatic discharge.)

**photosphere.** The lowest visible layer of the solar atmosphere; corresponds to the solar surface viewed in white light. Sunspots and faculae are observed in the photosphere.

**pitch angle.** In a plasma, the angle between the velocity vector of a charged particle and the direction of the ambient magnetic field.

**plage.** On the sun, an extended emission feature of an active region that is seen from the time of emergence of the first magnetic flux until the widely scattered remnant magnetic fields merge with the background. Magnetic fields are more intense in plage, and temperatures are higher than in surrounding, quiescent regions.

**plage corridor.** A low-intensity division in chromospheric (see chromosphere ) plage coinciding with a polarity inversion line and marked by narrow filament segments and/or fibrils spanning the corridor.

**plasma.** A gas that is sufficiently ionized so as to affect its dynamical behavior.

**plasma frequency.** The characteristic frequency of free plasma oscillations, determined by the balance between electron kinetic energy and ion Coulomb attraction.

**plasmopause.** The outer surface of the plasmasphere.

**plasmashet.** In the magnetosphere, the core of the magnetotail in which the plasma is hotter and denser than in the tail lobes north and south of it. The plasmashet is thought to be separated from the tail lobes by the sheet of the "last closed field lines" and it typically lies beyond geosynchronous orbit.

**plasmasphere.** In the magnetosphere, a region of relatively cool (low energy) and dense plasma that may be considered an outer extension of the ionosphere with which it is coupled. Like the ionosphere, the plasmasphere tends to co-rotate with the earth.

**polar cap absorption (PCA).** An anomalous condition of the polar ionosphere whereby HF and VHF (3-300 MHz) radiowaves are absorbed, and LF and VLF (3-300 kHz) radiowaves are reflected at lower altitudes than normal. PCAs generally originate with major solar flares, beginning within a few hours of the event and maximizing within a day or two of onset. As measured by a riometer, the PCA event threshold is 2 dB of absorption at 30MHz for daytime and 0.5 dB at night. In practice, the absorption is inferred from the proton flux at energies greater than 10 MeV, so that PCAs and proton events are simultaneous. However, the transpolar radio paths may still be disturbed for days, up to weeks, following the end of a proton event, and there is some ambiguity about the operational use of the term PCA.

**polar crown.** A nearly continuous ring of filaments occasionally encircling either polar region of the sun (latitudes higher than 50 degrees).

**polar plumes.** Fine, ray-like structures of the solar corona, best observed in the solar polar regions during solar minimum.

**polar rain.** In the earth's upper atmosphere, a weak, structureless, near-isotropic flux of electrons precipitating into the polar caps.

**pore.** A feature in the photosphere, 1 to 3 arc seconds in extent, usually not much darker than the dark spaces between photospheric granules. It is distinguished from a sun spot by its short lifetime, 10 to 100 minutes.

**post-flare loops.** A loop prominence system often seen after a major two-ribbon flare, which bridges the ribbons. Lifetimes are several hours.

**preheating.** A slow brightening of an active region, both optically and in x-rays, that sometimes precedes moderate and larger solar flare events by some tens of minutes.

**PRESTO.** An alert issued by a Regional Warning Center to give rapid notification of significant solar or geophysical activity in progress or just concluded.

**prominence.** A term identifying cloud-like features in the solar atmosphere. The features appear as bright structures in the corona above the solar limb and as dark filaments when seen projected against the solar disk. Prominences are further classified by their shape (for example, mound prominence, coronal rain ) and activity. They are most clearly and most often observed in H alpha.

**proton event.** The measurement of proton flux reaching and sustaining  $\geq 10$  p.f.u. for at least 15 min at energies  $> 10$  MeV by the primary SESC geosynchronous satellite. (See polar cap absorption.) The start time of the event is defined as the earliest time at which event thresholds have been reached. There are two event thresholds, namely p10 and p100. (p10, a proton event reaching 10 p.f.u. at  $> 10$  MeV and p100 reaching 100 p.f.u. at  $> 100$  MeV).

**proton flare.** Any flare producing significant counts of protons with energies exceeding 10 MeV in the vicinity of the earth.

**pulsation.** A rapid fluctuation of the geomagnetic field having periods from a fraction of a second to tens of minutes and lasting from minutes to hours. There are two main patterns: Pc (a continuous, almost sinusoidal pattern), and Pi (an irregular pattern). Pulsations occur at magnetically quiet as well as disturbed times. Pc's are grouped, according to their physical and morphological properties, into five categories:

Pc1 - periods 0.2-5 s. May occur in bursts ("pearls"), or in consecutive groups of pulsations with sharply decreasing frequency.

Pc2 - periods 5-10 s. Do not seem to be physically related to Pc1 or Pc3.

Pc3 - periods 10-45 s. Are observed over a wide range of latitudes.

Pc4 - periods 45-150 s. Are also known as Pc II or Pc.

Pc5 - periods 150-600 s. Are sometimes called giant micropulsations.

## Q

**Q index.** A 15-minute index of geomagnetic activity intended for high-latitude (auroral) stations. After quiet diurnal variations are removed, Q is the largest deviation scaled from the undisturbed level for the two horizontal components. (This differs from the K index, which is scaled from the largest relative deviation.) The 15-minute periods are centered on the hour and at 15, 30, and 45 minutes past each hour. The range of Q is from 0 to 11; the upper limit, in nanoteslas, for each index value is given below.

Q nT

0 10

1 20

2 40

3 80

4 140

5 240

6 400

7 660

8 1000

9 1500

**QDC.** See quiet day curve.

**quiescent prominence.** A long, sheet-like prominence nearly vertical to the solar surface. Except in an occasional activated phase, shows little large-scale motion, develops very slowly, and has a lifetime of several solar rotations. Quiescent prominences form within the remnants of decayed active regions, in quiet areas of the sun between active regions, or at high solar latitudes where active regions seldom or never form. (See filament).

**quiet.** A descriptive word specifically meaning (1) a probability of less than 50% for a C-class flare (see x-ray flare class ) in a sunspot region; (2) geomagnetic activity levels such that  $A_k < 8$ . quiet day curve (QDC). Especially in connection with the components of the geomagnetic field (see geomagnetic elements ), the trace expected in the absence of activity. The K index and Q index are measured from deviations relative to a QDC. Riometer and neutron monitor deviations are also measured relative to a QDC.

**R**

**R-number.** See sunspot number.

**radar aurora.** Radar returns from electron density irregularities in auroral regions. The strength of radar auroral returns is aspect dependent.

**radiation belts .** Regions of the magnetosphere roughly 1.2 to 6 earth radii above the equator in which charged particles are stably trapped by closed geomagnetic field lines. There are two belts. The inner belt is part of the plasmasphere and corotates with the earth; its maximum proton density lies near 5000 km. Inner belt protons are mostly high energy (MeV range) and originate from the decay of secondary neutrons created during collisions between cosmic ray s and upper atmospheric particles. The outer belt extends on to the magnetopause on the sunward side (10 earth radii under normal quiet conditions) and to about 6 earth radii on the nightside. The altitude of maximum proton density is near 16 000-20 000 km. Outer belt protons are lower energy (about 200 eV to 1 MeV) and come from the solar wind. The outer belt is also characterized by highly variable fluxes of energetic electrons. The radiation belts are often called the "Van Allen radiation belts" because they were discovered in 1968 by a research group at the University of Iowa led by Professor J. A. Van Allen.

**radio burst.** See radio emission.

**radio emission.** Emission of the sun in radio wavelengths from centimeters to dekameters, under both quiet and disturbed conditions. Some patterns, known variously as noise storms, bursts, and sweeps, are identified as described below. These types of emission are subjectively rated on an importance scale of 1 to 3, 3 representing the most intense.

**Type I.** A noise storm composed of many short, narrow-band bursts in the meter wavelength range (300-50 MHz), of extremely variable intensity. The storm may last from several hours to several days.

**Type II.** Narrow-band emission (sweep) that begins in the meter range (300 MHz) and sweeps slowly (tens of minutes) toward dekameter wavelengths (10 MHz). Type II emissions occur in loose association with major flares and are indicative of a shock wave moving through the solar atmosphere.

**Type III.** Narrow-band bursts that sweep rapidly (seconds) from decimeter to dekameter wavelengths (500-0.5 MHz). They often occur in groups and are an occasional feature of complex solar active regions.

**Type IV.** A smooth continuum of broad-band bursts primarily in the meter range (300-30MHz). These bursts occur with some major flare events; they begin 10 to 20 minutes after the flare maximum and can last for hours.

**Type V.** Short-duration (a few minutes) continuum noise in the dekameter range usually associated with Type III bursts.

**Rayleigh-Taylor instability.** A fluted or ripple-like instability that can develop on a fluid or plasma boundary surface and propagate along it. This instability is often invoked to explain phenomena in the ionosphere and magnetosphere.

**reconnection.** A process by which differently directed field lines link up, allowing topological changes of the magnetic field to occur, determining patterns of plasma flow, and resulting in conversion of magnetic energy to kinetic and thermal energy of the plasma. Reconnection is invoked to explain the energization and acceleration of the plasma s that are observed in solar flares, magnetic substorms, and elsewhere in the solar system.

**recurrence.** Used especially to express a tendency of some solar and geophysical parameters to repeat a trend and sometimes the actual value of the parameter itself every 27 days (the approximate rotation period of the sun).

**red line.** An intense coronal emission line at 637.4 nm from Fe X (an iron atom from which nine electrons have been

stripped). It identifies relatively cooler regions of the corona.

region number. A number assigned by SESC to a plage region or sunspot group if one of the following conditions exists: (1) the region is a group of at least sunspot classification C; (2) two or more separated optical reports confirm the presence of smaller spots; (3) the region produces a solar flare; (4) the region is clearly evident in H alpha and exceeds 5 heliographic degrees in either latitude or longitude. (See also active region.)

regression. A functional relationship between two or more correlated variables that is often empirically determined from data and is used especially to predict values of one variable when values of the others are given.

RI. The international standard relative sunspot number.

right ascension. The angular distance measured eastward along the celestial equator from the vernal equinox. It is expressed in hours, minutes, and seconds (the circumference of the celestial equator is defined as 24 hours).

rigidity. A measure of how easily a particle is deflected by a magnetic field, expressed in megavolts (MV) per nucleon. It is the momentum per unit charge. The integral proton spectrum of a flare can be expressed as an exponential function of rigidity rather than a power function of energy.

ring current. In the magnetosphere, a region of current that flows in a disk-shaped region near the geomagnetic equator in the outer of the Van Allen radiation belts. The current is produced by the gradient and curvature drift of the trapped charged particles. The ring current is greatly augmented during magnetic storms because of the hot plasma injected from the magnetotail. The ring current causes a worldwide depression of the horizontal geomagnetic field during a magnetic storm.

riometer (Relative Ionospheric Opacity meter). A specially designed ground-level radio receiver for continuous monitoring of cosmic noise. The absorption of cosmic noise in the polar regions is very sensitive to the solar low-energy cosmic ray flux. Absorption events are known as PCA s (polar cap absorption) and are primarily associated with major solar flares.

rudimentary. A type of sunspot penumbra characterized by granular (rather than filamentary) structure, brighter intensity than the umbra, and narrow extent, and possibly only partially surrounding the umbra. Penumbrae are typically rudimentary during the sunspot formative and decay phases.

## S

Satellite Anomaly. The usually undesirable response of spacecraft systems to variations in the space environment. High energy particles cause detector noise and/or physical damage to solar cells, electronics, and memory devices (single event upsets or "bitflips"). Large and varying low-to-medium energy particle fluxes can result in a charge buildup between spacecraft components, especially during the eclipse season and during spacecraft maneuvers. Atmospheric drag on spacecraft below approximately 1,000 km can increase during geomagnetic storms, resulting in cross-track and in-track orbit errors and orientation problems. Various communication interference problems result during solar radio bursts from flares when the Sun is within the field of view of the ground tracking dish. Ionospheric irregularities during geomagnetic storms can cause radio telemetry scintillation and fading S-band. Radio frequencies between 1.55 and 5.20 GHz. For satellite communication, the term usually refers to frequencies used for earth-space communication near 2.2 GHz.

S component. The slowly varying (weeks or longer) fluctuation observed in solar radio emission at microwave frequencies (wavelengths from 3 to 100 cm).

SC. See sudden commencement.

scintillation. Describing a degraded condition of radio propagation characterized by a rapid variation in amplitude and/or phase of a radio signal (usually on a satellite communication link) caused by abrupt variations in electron density anywhere along the signal path. It is positively correlated with spread F and to a lesser degree, sporadic E. Scintillation effects are the most severe at low latitudes, but can also be a problem at high latitudes, especially in the auroral oval and over the polar caps.

sector boundary. In the solar wind, the area of demarcation between sectors, which are large-scale features distinguished by the predominant direction of the interplanetary magnetic field, toward the sun (a negative sector), or away from the sun (a positive sector). The sector boundary separating fields of opposite polarity is normally narrow, passing the earth within minutes to hours as opposed to the week or so needed for passage of a typical sector. The solar wind velocities in the boundary region are typically among the lowest observed.

**SEU.** See single event upset.

**SFE.** Solar flare effect. (See [crochet](#).)

**s.f.u.** See solar flux unit.  $10E-22$  W/sq m/Hz = 10 000 jansky.

**SHF.** See super high frequency.

**shock.** A discontinuity in pressure, density, and particle velocity, propagating through a compressible fluid or plasma.

**short wave fade (SWF).** An abrupt decrease of HF radio signal strength, lasting from minutes to hours, caused by increased day-side ionization from some solar flares. An SWF is one effect under the broad category of sudden ionospheric disturbances (SIDs).

**SI.** See sudden impulse.

**SID.** See sudden ionospheric disturbance.

**sidereal.** Referring to a coordinate system fixed with respect to the distant stars.

**simultaneous flares.** Unrelated solar flares that occur at nearly the same time. Compare sympathetic flares.

**single event upset (SEU).** With reference to the effects of energetic particles on spacecraft microcircuits, an unexpected change in the logic state of a single digital bit. SEUs can be either "soft" (the microcircuit is not damaged and can be rewritten to either state), or a latchup, which cannot easily be reset.

**smoothed sunspot number.** An average of 13 monthly RI numbers, centered on the month of concern. The 1st and 13th months are given a weight of 0.5.

**solar activity.** Transient perturbations of the solar atmosphere as measured by enhanced x-ray emission (see [x-ray flare class](#) ), typically associated with flares. Five standard terms are used to describe the activity observed or expected within a 24-h period:

Very low - x-ray events less than C-class.

Low - C-class x-ray events.

Moderate - isolated (one to 4) M-class x-ray events.

High - several (5 or more) M-class x-ray events, or isolated (one to 4) M5 or greater x-ray events.

Very high - several (5 or more) M5 or greater x-ray events.

**solar constant.** The total radiant energy received vertically from the sun, per unit area per unit of time, at a position just outside the earth's atmosphere when the earth is at its average distance from the sun. Radiation at all wavelengths from all parts of the solar disk is included. Its value is approximately  $2.00$  cal/sq cm/min =  $1.37$  kW/sq m and it varies slightly (by approximately 0.1%) from day to day in response to overall solar features.

**solar coordinates.** Specifications for a location on the solar surface. The location of a specific feature on the sun (for example, a sunspot ) is complicated by the fact that there is a tilt of 7.25 degrees between the ecliptic plane and the solar equatorial plane as well as a true wobble of the solar rotational axis. (Only twice a year are the solar north pole and the celestial north pole aligned.) Consequently, to specify a location on the solar surface, three coordinates (P, B, L) are necessary to define a grid. Daily values for the coordinates in Coordinated Universal Time (UTC) are listed in *The Astronomical Almanac* published annually by the U.S. Naval Observatory. The terms used to refer to the coordinates are defined as follows:

**P-angle (or P):** The position angle between the geocentric north pole and the solar rotational north pole measured eastward from geocentric north. The range in P is +/- 26.31 degrees.

**Bo:** Heliographic latitude of the central point of the solar disk; also called the B-angle. The range of Bo is +/- 7.23 degrees, correcting for the tilt of the ecliptic with respect to the solar equatorial plane.

**Example:** If (P,Bo) = (-26.21 degrees, -6.54 degrees), the heliographic latitude of the central point on the solar disk is -6.54 degrees (the north rotational pole is not visible), and the angle between the projection onto the disk of the geocentric north pole and the solar north rotational pole is 26.21 degrees to the west.

**Lo:** Heliographic longitude of the central point of the solar disk. The longitude value is determined with reference to a system of fixed longitudes rotating on the sun at a rate of 13.2 degrees /day (the mean rate of rotation observed from central meridian transits of sunspots). The standard meridian on the sun is defined to be the meridian that passed through the ascending node of the sun's equator on 1 January 1854 at 1200 UTC and is calculated for the present day by assuming a uniform sidereal period of rotation of 25.38 days.

Once P, Bo, and Lo are known, the latitude, central meridian distance, and longitude of a specific solar feature can be determined as follows:

**Latitude.** The angular distance from the solar equator, measured north or south along the meridian.

**Central meridian distance (CMD).** The angular distance in solar longitude measured from the central meridian. This

position is relative to the view from earth and will change as the sun rotates; therefore, this coordinate should not be confused with heliographic positions that are fixed with respect to the solar surface.

**Longitude.** The angular distance from a standard meridian (0 degrees heliographic longitude), measured from east to west (0 degrees to 360 degrees) along the sun's equator. It is computed by combining CMD with the longitude of the central meridian at the time of the observation, interpolating between ephemeris values (for 0000 UT) by using the synodic rate of solar rotation (27.2753 days, 13.2 degrees per day).

**solar cycle.** See sunspot cycle.

**solar flare effect (SFE).** See *crochet*.

**solar flux unit (s.f.u.).** See *s.f.u.*

**solar maximum.** The month(s) during the sunspot cycle when the smoothed sunspot number reaches a maximum. A recent solar maximum occurred in December 1979.

**solar minimum.** The month(s) during the sunspot cycle when the smoothed sunspot number reaches a minimum. A recent solar minimum occurred in September 1986.

**solar radio emission.** See *radio emission*.

**solar rotation rate.** (1) synodic:  $13.39 \text{ degrees} - 2.7 \text{ degrees} \sin^2(\text{solar latitude})/\text{day}$ . (2) sidereal:  $14.38 \text{ degrees} - 2.7 \sin^2(\text{solar latitude})/\text{day}$ . The difference between sidereal and synodic rates is the earth orbital motion of 0.985 degrees/day.

**solar sector boundary (SSB).** The boundary between large-scale unipolar magnetic regions on the sun's surface, as determined from inversion lines mapped using filaments and filament channels, or large-scale magnetograms. The supposed solar signature of an interplanetary sector boundary.

**solar wind.** The outward flow of solar particles and magnetic fields from the sun. Typically at 1 AU, solar wind velocities are near 375 km/s and proton and electron densities are near 5 per cubic centimeter. The total intensity of the interplanetary magnetic field is nominally 5 nT.

**solstice.** A point on the ecliptic where the sun reaches its greatest absolute declination. There are two of these points, halfway between the equinoxes; they mark the beginning of summer and winter.

**South Atlantic anomaly (SAA).** A region of the earth centered near 25 degrees S 50 degrees W (geographic coordinates, near the Atlantic coast of Brazil) of low geomagnetic field intensity owing to the fact that the geomagnetic field axis is offset from the center of the earth (see corrected geomagnetic coordinates.) One consequence of the SAA is that trapped particles in the plasmasphere drift closer to the earth's surface and can more easily be lost into the atmosphere. The result is that the F region (see ionosphere ) is highly variable in this region, and satellites in low earth orbits suffer greater radiation doses when they pass through the SAA. There is a corresponding location of maximum geomagnetic field intensity in Southeast Asia.

**spacecraft charging.** A term that encompasses all the charging effects on a spacecraft due to the environment in space. Occasionally this term is used in a more limited sense to mean surface charging.

**spicules.** Rapidly changing, predominantly vertical, spike-like structures in the solar chromosphere observed above the limb. Spicules appear to be ejected from the low chromosphere at velocities of 20 to 30 km/s reaching a height of about 9000 km and then falling back or fading. The total lifetime is 5 to 10 minutes.

**sporadic E ( $E_s$ ).** Transient, localized patches of relatively high electron density in the E region of the ionosphere, which significantly affect radiowave propagation. Sporadic E can occur during daytime or nighttime, and it varies markedly with latitude.  $E_s$  can be associated with thunderstorms, meteor showers, solar activity and geomagnetic activity.

**spray (SPY).** Luminous material ejected from a solar flare with sufficient velocity to escape the sun (675 km/s). Sprays are usually seen in H alpha with complex and rapidly changing form. There is little evidence that sprays are focused by magnetic fields. Compare *surge*.

**spread F.** A condition of the F region of the ionosphere caused by patches of ionization that scatter or duct radio signals, characterized on ionograms by a wide range of heights of reflected pulses. In equatorial latitudes spread F is most commonly observed at night and may be negatively correlated with geomagnetic activity; at high latitudes spread F occurs throughout the daytime and is positively correlated with magnetic activity. The latitude of minimum occurrence of spread F is near 30 degrees magnetic latitude.

**SPY.** See spray.

**Sq.** The diurnal variation of the geomagnetic field. The Sq variation is explained in terms of solar tidal motions of the ionosphere and thermally driven ionospheric winds.

**SSB.** See solar sector boundary.

**SSC.** See sudden commencement.

**storm.** See geomagnetic storm.

**stratosphere.** That region of the earth's atmosphere between the troposphere and the mesosphere. It begins at an altitude of temperature minimum at approximately 13 km and defines a layer of increasing temperature up to about 50 km.

**STRATWARM.** A code word designating a major disturbance of the winter, polar, middle atmosphere from the tropopause to the ionosphere, lasting for several days at a time and characterized by a warming of the stratospheric temperature by some tens of degrees. There is no evidence that stratwarms are caused by solar events, or that they affect the lower atmosphere. (In fact, the disturbance may be generated by tropospheric conditions).

**subflare.** See flare.

**substorm.** A geomagnetic perturbation lasting 1 to 2 hours, which tends to occur during local post-midnight nighttime. The magnitude of the substorm is largest in the auroral zone, potentially reaching several thousand nanoteslas. A substorm corresponds to an injection of charged particles from the magnetotail into the auroral oval.

**sudden commencement ( SC, or SSC for Storm Sudden Commencement).** An abrupt increase or decrease in the northward component (see geomagnetic elements) of the geomagnetic field, which marks the beginning of a geomagnetic storm. SCs occur almost simultaneously worldwide but with locally varying magnitudes.

**sudden impulse (SI + or SI -).** A sudden perturbation, positive or negative, of several nanoteslas in the northward component (see geomagnetic elements ) of the low-latitude geomagnetic field, not associated with a following geomagnetic storm. (An SI becomes an SC if a storm follows.)

**Sudden ionospheric disturbance (SID).** Any of several radio propagation anomalies due to ionospheric changes resulting from solar flares. Anomalies include short wave fades, enhancements of atmospherics, phase shifts, cosmic noise absorptions, and signal enhancements.

**sudden ionospheric disturbance (SID).** Any of several radio propagation anomalies due to ionospheric changes resulting from solar flares. Anomalies include short wave fades, enhancements of atmospherics, phase shifts, cosmic noise absorptions, and signal enhancements.

**sunspot.** An area seen as a dark spot, in contrast with its surroundings, on the photosphere of the sun. Sunspots are concentrations of magnetic flux, typically occurring in bipolar clusters or groups. They appear dark because they are cooler than the surrounding photosphere. Larger and darker sunspots sometimes are surrounded (completely or partially) by penumbrae. The dark centers are umbrae. The smallest, immature spots are sometimes called pores.

**sunspot classification (Modified Zurich Sunspot Classification).** As devised by McIntosh, a 3-letter designation of the optical, white-light characteristics of a sunspot group. The general form of the designation is Zpc. One letter is chosen from each of the following three categories.

**Z (the modified Zurich class of the group):**

**A -** A small single sunspot or very small group of spots with the same magnetic polarity, without penumbra.

**B -** Bipolar sunspot group with no penumbra.

**C -** An elongated bipolar sunspot group. One sunspot must have penumbra, and penumbra does not exceed 5 degrees in longitudinal extent.

**D -** An elongated bipolar sunspot group with penumbra on both ends of the group; longitudinal extent of penumbra is more than 5 degrees, but does not exceed 10 degrees.

**E -** An elongated bipolar sunspot group with penumbra on both ends. Longitudinal extent of penumbra exceeds 10 degrees but not 15 degrees.

**F -** An elongated bipolar sunspot group with penumbra on both ends. Longitudinal extent of penumbra exceeds 15 degrees.

**H -** A unipolar sunspot group with penumbra. Class H sunspot groups become compact Class D or larger when the penumbra exceeds 5 degrees in longitudinal extent.

**p (the penumbra type of the largest spot in the group):**

**x -** no penumbra

r - rudimentary  
s - small ( $\leq 2.5$  degrees north-south diameter), symmetric  
a - small, asymmetric  
h - large ( $> 2.5$  degrees north-south diameter), symmetric  
k - large, asymmetric  
c (the compactness of the group):  
x - a single spot  
o - open  
i - intermediate  
c - compact

**sunspot cycle.** The approximately 11-year quasi-periodic variation in the sunspot number. The polarity pattern of the magnetic field reverses with each cycle. Other solar phenomena, such as the 10.7-cm solar radio emission, exhibit similar cyclical behavior.

**sunspot number.** A daily index of sunspot activity (R), defined as  $R = k(10g + s)$  where s = number of individual spots, g = number of sunspot groups, and k is an observatory factor (equal to 1 for the Zurich Observatory and adjusted for all other observatories to obtain approximately the same R number). The standard number, RI, once derived at Zurich (see Wolf number), is now being derived at Brussels and is denoted by RI. Often, the term "sunspot number" is used in reference to the widely distributed smoothed sunspot number.

**super high frequency (SHF).** That portion of the radio frequency spectrum from 3 GHz to 30 GHz.

**supergranulation.** A system of large-scale velocity cells that does not vary significantly over the quiet solar surface or with phase of the solar cycle. The cells are presumably convective in origin with weak upward motions in the center, downward motions at the borders, and horizontal motions of typically 0.3 to 0.4 km/s. Magnetic flux is more intense along the borders of the cells.

**surge.** A jet of material from active regions that reaches coronal heights and then either fades or returns into the chromosphere along the trajectory of ascent. Surges typically last 10 to 20 minutes and tend to recur at a rate of approximately 1 per hour. Surges are linear and collimated in form, as if highly directed by magnetic fields. Compare spray.

**SWF.** See short wave fade.

**sympathetic flares.** Solar flares in different active regions that apparently occur as the common result of activation of a coronal connection between the regions. Compare simultaneous flares.

**synodic.** Referring to a coordinate system fixed on the earth.

**synoptic chart.** A map of the whole sun in absolute heliographic coordinates, displaying an integrated view of solar features observed during a Carrington rotation.

## T

**TEC.** See total electron content.

**TED.** Total (particle) Energy Deposition. The TIROS/NOAA instrument used to estimate the hemispherical power input. (See estimated hemispherical power input.)

**tenflare.** A solar flare accompanied by a 10-cm radio noise burst of intensity greater than 100% of the pre-event 10-cm flux value.

**Theophrastus (Theo).** The name of the rule-based expert system used to assist SESC solar region analysis and solar flare prediction.

**thermosphere.** That region of the earth's atmosphere where the neutral temperature increases with height. It begins above the mesosphere at about 80-85 km and extends to the exosphere.

**total electron content (TEC).** The number of electrons along a ray path between a transmitter and a receiver. Units are electrons per square meter. This number is significant in determining ionospheric effects such as refraction, dispersion, and group delay on radio waves, and can be used to estimate critical frequencies. The TEC is strongly

affected by solar activity and geomagnetic activity.

**transition region.** That region of the solar atmosphere lying between the chromosphere and the corona where the temperature rises from 10000 K to 1000000 K. The transition region is only a few thousand kilometers thick.

**transverse.** Component of magnetic field vector perpendicular to direction of view, parallel to solar surface at disk center.

**troposphere.** The lowest layer of the earth's atmosphere, extending from the ground to the stratosphere at approximately 13 km of altitude.

**two-ribbon flare.** A flare that has developed as a pair of bright strands (ribbons) on both sides of an inversion line of the solar magnetic field.

Type I, II, III, IV, V. See radio emission.

## U

**U-burst.** A radio noise burst associated with some flares. It has a U-shaped appearance in an intensity-vs.-frequency plot. The minimum intensity falls roughly between 500 and 2000 MHz. A U-burst is sometimes called a Castelli U.

**UHF.** See ultrahigh frequency.

**ultrahigh frequency (UHF).** That portion of the radio frequency spectrum from 300 MHz to 3 GHz.

**ultraviolet (UV).** That part of the electromagnetic spectrum between 5 and 400 nm.

**umbra.** The dark core or cores (umbrae) in a sunspot with penumbra, or a sunspot lacking penumbra.

**UMR.** See unipolar magnetic region.

**unipolar magnetic region (UMR).** A large-scale photospheric region where the magnetic elements are predominantly of one polarity (for example, the solar polar regions).

**Universal Time (UT).** A shortened form of the more correct Coordinated Universal Time (UTC).

**unsettled.** With regard to geomagnetic activity, a descriptive word between quiet and active specifically meaning that the Ak index is between 8 and 16.

**upsets.** See single event upsets.

**UT or UTC.** See Coordinated Universal Time.

**UV.** See ultraviolet.

## V

**Van Allen radiation belts.** See radiation belts.

**vernal equinox.** The equinox that occurs in March. Compare autumnal equinox.

**very high frequency (VHF).** That portion of the radio frequency spectrum from 30 to 300 MHz.

**very low frequency (VLF).** That portion of the radio frequency spectrum from 3 to 30 kHz.

**VHF.** See very high frequency.

**VLF.** See very low frequency.

## W

**white light (WL).** The sum of all visible wavelengths of light (400-700 nm) so that all colors are blended to appear white to the eye. No pronounced contribution from any one spectral line (or light-emitting element) is implied.

**white-light flare.** A major flare in which small parts become visible in white light. This rare continuum emission is caused by energetic particle beams bombarding the lower solar atmosphere. Such flares are usually strong x-ray, radio, and particle emitters.

**wing.** Portion of a spectroscopic absorption (or emission) line between the core of the line and the continuum adjacent to the line.

**WL.** See white light.

**Wolf number.** An historic term for sunspot number. In 1849, R. Wolf of Zurich originated the general procedure for computing the sunspot number. The record of sunspot numbers that he began has continued to this day.

**WWV.** Call letters of the radio station over which National Institute of Standards and Technology broadcasts time-standard signals at 2.5, 5, 10, 15, and 20 MHz. Solar-terrestrial conditions and forecasts are broadcast at 18 minutes past the hour.

## X

**X-band.** Designates those radio frequencies between 5.2 and 10.9 GHz.

**x-ray.** Radiation of extremely short wavelength (generally less than 1 nm).

**x-ray background.** A daily average background x-ray flux in the 0.1 to 0.8 nm range. It is a midday minimum given in terms of x-ray flare class.

**x-ray burst.** A temporary enhancement of the x-ray emission of the sun. The time-intensity profile of soft x-ray bursts is similar to that of the H alpha profile of an associated flare. Soft x-rays are those of energies less than 20 keV, or wavelengths longer than 0.05 nm.

**x-ray flare class.** Rank of a flare based on its x-ray energy output. Flares are classified by the Space Environment Services Center according to the order of magnitude of the peak burst intensity (I) measured at the earth in the 0.1 to 0.8 nm band as follows:

Class Peak, 0.1 to 0.8 nm band, W/square m ergs/square cm/s

B  $I < 10.0E-06$   $I < 10.0E-03$

C  $10.0E-06 \leq I < 10.0E-05$   $10.0E-03 \leq I < 10.0E-02$

M  $10.0E-05 \leq I < 10.0E-04$   $10.0E-02 \leq I < 10.0E-01$

X  $I \geq 10.0E-04$   $I \geq 10.0E-01$

**x-ray flare termination.** The end time is defined as the time the flux has decayed to 1/2 the peak flux of the event.

## Y

**yellow line.** A coronal emission line at 569.4 nm from Ca XV (a calcium atom from which 14 electrons have been stripped). It identifies the hottest regions of the corona.

## Z

**Z.** Zulu Time. (See Coordinated Universal Time.)

**Z component of the geomagnetic field.** See geomagnetic elements.

**Zeeman effect.** The splitting of spectral emission lines due to the presence of a strong magnetic field. Briefly, the lines split into three or more components of characteristic polarization; the components are circular if the local

magnetic field is parallel to the line of sight, and linear if the field is perpendicular to the line of sight. The amount of splitting is proportional to the strength of the field.

Zurich sunspot classification. See sunspot classification.

Zurich sunspot number. See sunspot number.

## APPENDIX A: ACRONYMS AND INITIALISMS

AFB - Air Force Base  
AFGL - Air Force Geophysics Laboratory (at Hanscom AFB, MA)  
AFSFC - Air Force Space Forecast Center (at Colorado Springs, CO)  
ALMEDS - ALaskan MEteorological Data System  
AMSAT - Radio Amateur Satellite Corporation  
ARRL - American Radio Relay League  
ASCII - American Standard Code for Information Interchange  
AUTODIN - AUTOMATIC Digital Network  
AWS - Air Weather Service (USAF)  
COMEDS - CONUS MEteorological Data System  
CONUS - CONTinental United States  
DALAS - Disk And Limb Activity Summary  
DMS - data management system  
DMSP - Defense Meteorological Satellite Program  
DOC - Department Of Commerce  
DOD - Department Of Defense  
EOS - Earth Observing System  
ERL - Environmental Research Laboratories  
ESA - European Space Agency  
GMS - Geostationary Meteorological Satellite (Japan)  
GOES - Geostationary Operational Environmental Satellite (Also called SMS/GOES)  
GSFC - Goddard Space Flight Center (Greenbelt, MD)  
HAO - High Altitude Observatory  
HEPAD - High Energy Proton and Alpha Detector (on GOES and TIROS)  
HLMS - High Latitude Monitoring Station  
HST - Hubble Space Telescope  
IAG - International Association of Geomagnetism and Aeronomy  
ICE - International Cometary Explorer (formerly ISEE-3)  
IGY - International Geophysical Year  
IMP - Interplanetary Monitoring Platform  
IMS - International Magnetospheric Study  
INTERMAGNET - An International Consortium of Magnetic Observatories  
ISEE-3 - International Sun Earth Explorer-3.  
ISTP - International Solar-Terrestrial Program  
IUGG - International Union of Geodesy and Geophysics  
IUWDS - International Ursigram and World Days Service  
JPL - Jet Propulsion Laboratory  
JSC - Johnson Space Center (Houston, TX)  
KPNO - Kitt Peak National Observatory  
MEPED - Medium Energy Proton and Electron Detector (on GOES and TIROS)  
MSFC - Marshall Space Flight Center (Huntsville, AL)  
NAG - Naval Astronautics Group  
NASA - National Aeronautics and Space Administration  
NBS - National Bureau of Standards  
NCAR - National Center for Atmospheric Research  
NESDIS - National Environmental Satellite, Data, and Information Service  
NESS - National Environmental Satellite Service  
NGDC - National Geophysical Data Center  
NGSDC - National Geophysical and Solar-Terrestrial Data Center (Boulder, CO)  
NIST - National Institute of Standards and Technology  
NOAA - National Oceanic and Atmospheric Administration  
NOAO - National Optical Astronomy Observatories

**NORMEDS - Northern Meteorological Data System**  
**NOSC - Naval Ocean Systems Center**  
**NRL - Naval Research Laboratory**  
**NSF - National Science Foundation**  
**NSO - National Solar Observatories (combines Sacramento Peak Observatory and the Solar Section of Kitt Peak Observatory)**  
**NSSDC - National Space Science Data Center (Greenbelt, MD)**  
**OLDS - On-Line Data Systems**  
**PL - Phillips Laboratory (Air Force)**  
**RGON - Remote Geophysical Observing Network**  
**RSTN - Radio Solar Telescope Network (USAF)**  
**RWC - Regional Warning Center**  
**Sci - Science Institute (Space Telescope)**  
**SEL - Space Environment Laboratory (ERL)**  
**SELDADS- Space Environment Laboratory Data Acquisition and Display System**  
**SELSIS - Space Environment Laboratory Solar Imaging System**  
**SEM - Space Environment Monitor (on GOES and TIROS)**  
**SEON - Solar Electro-Optical Network (USAF)**  
**SESC - Space Environment Services Center**  
**SFC - Space Forecast Center (at Falcon AFB, Colorado)**  
**SGAS - Solar Geophysical Activity Summary**  
**SMM - Solar Maximum Mission**  
**SMS - Synchronous Meteorological Satellite**  
**SOON - Solar Observing Optical Network (USAF)**  
**SPAN - Space Physics Analysis Network**  
**SXI - Solar X-ray Imager**  
**TDRS - Tracking and Data Relay Satellite (NASA)**  
**TED - Total (particle) Energy Detector (on TIROS)**  
**TIROS - Television and Infrared Radiation Observation Satellite**  
**TMO - Table Mountain Observatory**  
**URSI - Union Radio Scientifique Internationale (thus, URSIgram: message from URSI).**  
**USAF - United States Air Force**  
**USGS - United States Geological Survey**  
**USSFC - United States Space Forecast Center**  
**WDC - World Data Center**  
**WMO - World Meteorological Organization**  
**WWA - World Warning Agency**  
**WWV - call letters of the standard time and frequency radio station**

## **APPENDIX B: UNITS**

The preferred system of physical units for publications of the U.S. Department of Commerce is the International System of Units (SI). In this system, the base units of length, mass, and time are the meter, the kilogram, and the second, respectively. In this appendix, various other common and historical measurement units are listed with appropriate conversion factors.

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