Users Guide to

The Preliminary Report and Forecast of Solar Geophysical Data

August 2012

The *Preliminary Report and Forecast of Solar Geophysical Data* (referred to hereafter as the Weekly) is compiled and issued every Monday. This publication is produced in Boulder, Colorado, jointly by the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center, formerly the Space Environment Center, and the Air Force Weather Agency (AFWA). It is a continuation of the weekly reports that began in 1951 and were issued by the High Altitude Observatory and NOAA and/or its predecessors. The current series began with serial number PRF 001 on 09 September 1975. The contents of the Weekly have no copyright or other restrictions. Comments concerning the content or improvements to the Weekly are invited.

The Weekly begins with space weather highlights from the previous week and an outlook for the following 27 days, and includes tables and plots of solar and geophysical indices, data, activity and reports of special events and missing data that were not included previously. For information on terms used in this document, refer to the Glossary of Solar-Terrestrial Terms. The Weekly is a technical publication. Another product, the NOAA Scales http://www.swpc.noaa.gov/NOAAscales/ gives information in a different context for a more general audience.

The Weekly is based on data that is available at the time of publication. It is intended for rapid distribution, and to be especially useful to real-time operations and research organizations. Many of the data in the Weekly are subject to later revision or refinement, and therefore cannot be cited reliably for reference purposes. Archival-quality data, suitable for more extensive studies, are published monthly in *Solar-Geophysical Data* and can be obtained from: National Geophysical Data Center, http://www.ngdc.noaa.gov/stp/. Many of the data are also published in the *IAU Quarterly Bulletin of Solar Activity*.

Questions about the content of the Weekly should be sent to RWC.Boulder@noaa.gov.

The Weekly is made possible through the combined efforts of several groups providing timely data. A complete list of data sources is given in Appendix A. Appendix B is an explanation of SWPC data sets.

HIGHLIGHTS AND OUTLOOK

Page 1 of the Weekly summarizes the solar activity, energetic particle enhancements to include protons and electrons, and geomagnetic activity observed during the previous Monday through Sunday. It also provides an outlook of solar-geophysical conditions expected during the next 27 days, beginning on Monday. In the activity summary and outlook, solar active regions are identified by the region number, heliographic latitude and longitude. It also provides the modified Zurich (McIntosh) sunspot classification/sunspot area in millionths of the solar hemisphere on the date of maximum sunspot area; for example, Region 4421 (N16, L=115, class/area, Dki/710 on 27 February). Significant solar activity is discussed in terms of the characteristics of the region of origin, x-ray flare class (C, M, or X), optical classification (Sn, 1b, etc.), radio emission, associated energetic particle emission, the general character of the solar wind and geophysical effects. The characteristics of near-Earth energetic proton and electron events as detected by satellites and ground-based sensors are discussed, and geomagnetic storms and disturbances are described. Observations of visual aurora are included when available, and whenever feasible, solar and geomagnetic activity is summarized and forecast using standard terms.

Terms Used to Describe Solar Activity

Very Low: x-ray events less than C-class.

Low: C-class x-ray events.

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

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

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

The letter classification of solar flares used in these definitions (Table 1) was initiated on 01 January 1969. This classification ranks solar activity by its peak x-ray intensity in the 0.1-0.8 nm band as measured by the Geostationary Operational Environmental Satellites (GOES). This x-ray classification offers at least two distinct advantages compared with the standard optical classifications: it gives a better measure of the geophysical significance of a solar event, and it provides an objective means of classifying geophysically significant activity regardless of its location on the solar disk.

Table 1. The SWPC x-ray flare classification

	Peak Flux Range (0.1-0.8 nm)	
Classification	mks system (W m^{-2})	cgs system (erg $cm^{-2}s^{-1}$)
A	$\Phi < 10^{-7}$	$\Phi < 10^{-4}$
B	$10^{-7} \leq \Phi < 10^{-6}$	$10^{-4} \leq \Phi < 10^{-3}$
C	$10^{-6} \leq \Phi < 10^{-5}$	$10^{-3} \leq \Phi < 10^{-2}$
M	$10^{-5} \leq \Phi < 10^{-4}$	$10^{-2} \leq \Phi < 10^{-1}$
X	$10^{-4} \leq \Phi$	$10^{-1} \leq \Phi$

The letter designates the order of magnitude of the peak value and the number following the letter is the multiplicative factor. A C3.2 event for example, indicates an x-ray burst with $3.2x10^{-6}Wm^{-2}$ peak flux. Solar flare forecasts are usually issued only in terms of the broad C, M, and X categories. Since x-ray bursts are observed as a full-Sun value, bursts below the x-ray background level are not discernible. The background drops to class A level during solar minimum; only bursts that exceed B1.0 are classified as x-ray events. During solar maximum the background is often at the class M level, therefore class A, B, or C x-ray bursts cannot be discerned. Data are measured by the NOAA GOES satellites, monitored in real time in Boulder (Grubb 1975).

Terms Used to Describe Geomagnetic Activity

The following adjectives are used to describe geomagnetic activity. *A* refers to the 24-hour A-index observed at a geomagnetic observatory such as Fredericksburg, VA (middle latitude), and College, AK (high latitude). A-index values range from 0 (very quiet) to 400 (extremely disturbed). *K* refers to a 3-hour index derived from the most disturbed horizontal component of the local geomagnetic field. *K* is a quasi-logarithmic index ranging from 0 (very quiet) to 9 (highly disturbed). Please refer to the detailed description in the Geomagnetic Indices section in Appendix B.

Category	A-index range	Typical values
Quiet:	$0 \leq Ap < 10$	usually no Kp indices > 2+
Unsettled:	$10 \leq Ap < 20$	usually no Kp indices > 3+
Active:	$20 \leq Ap < 35$	a few Kp indices of 4
Minor Storm:	$35 \leq Ap < 60$	Kp indices mostly 4 and 5
Moderate Storm:	$60 \leq Ap < 100$	some Kp indices of 6
Strong Storm:	$100 \leq Ap < 160$	some Kp indices of 7
Severe Storm:	$160 \leq Ap < 310$	some Kp indices of 8 and 9-
Extreme Storm:	$310 \leq Ap$	some Kp indices of 9

DAILY SUMMARIES

Three different daily summaries are provided. The column headings for each table are defined below.

A. DAILY SOLAR DATA

Radio Flux 10.7 cm: The 10.7 cm (2800 MHz) full Sun background radio flux is reported by the Dominion Radio Astrophysical Observatory (DRAO) at Penticton, B.C., Canada on the date indicated. Measurements are made at local noon (approximately 2000UT). Values are in units of 10^{-22} Wm^{-2} Hz^{-1} and are not corrected for the variable Sun-Earth distance that results from the eccentric orbit of the Earth around the Sun.

Sunspot No: The SWPC sunspot number for the indicated date is from the daily Solar Region Summary issued by SWPC. The SWPC sunspot number is computed according to the Wolf Sunspot Number formula $R=k(10g+s)$, where g is the number of sunspot groups (regions), s is the total number of individual spots in all the groups, and k is a variable scaling factor (usually <1) that indicates the combined effects of observing conditions, telescope, and bias of the solar observers. A sunspot number of zero indicates there were no visible sunspots on that date; a blank indicates that no observations were taken. The sunspot region information used to compute the daily sunspot number incorporates reports from as many as six observatories. These reports are used to form a composite picture of each individual region, including the sunspot number, area and classification and taking into account such factors as the time of observation and the quality of seeing. This composite information is the daily average obtained from the reporting observatories and may not represent the latest data. It is reported daily in the Solar Region Summary and listed in the Region Summary section of the Weekly.

Sunspot Area: The sum of the corrected area of all observed sunspots, in units of millionths of the solar hemisphere.

X-ray Background: The daily average background x-ray flux as measured by the GOES satellite. To better reflect mid day values, the average is the lower of (a) the average of 1-minute data between 0800UT to 1600UT, or (b) the average of the 0000UT to 0800UT and the 1600UT to 2400UT data. The value is given in terms of x-ray class (Donnelly 1982); (Bouwer, et al.1982). X-ray flux values below the B1 level can be erroneous because of energetic electron contamination of the x-ray sensors. At times of high electron flux at geosynchronous altitude, the x-ray measurements in the low A-class range can be in error by 20-30 percent. Measurements taken during periods of low energetic electron fluxes are much more accurate.

Flares: The tally of the number of x-ray events and flares by classification observed during the day.

B. DAILY PARTICLE DATA

Proton Fluence: The daily integrated particle fluxes measured at geosynchronous altitudes by the GOES spacecraft for protons of energies >1 MeV, >10 MeV, and >100 MeV in units of protons cm^{-2} day^{-1} sr^{-1}.

Electron Fluence: The daily integrated electron fluxes measured at geosynchronous altitudes by the GOES spacecraft for energies of >.6, >2, and >4 MeV in units of electrons cm^{-2} day^{-1} sr^{-1}. (*Note*: The >.6 and >4 MeV electrons are not currently available.)

C. DAILY GEOMAGNETIC DATA

Fredericksburg, College, and Estimated Planetary A and K Indices: The daily 24-hour A index and eight 3-hourly K indices from the Fredericksburg (middle-latitude) and College (high-latitude) geomagnetic stations. The estimated planetary 24-hour A index and eight 3-hourly K indices are derived from magnetometers reporting data to SWPC in near real-time. These indices may differ from the final Kp and Ap values derived by the GeoForschungsZentrum, Potsdam, Germany, using an alternative network of magnetometers. K indices range from 0 (very quiet) to 9 (extremely disturbed). A-indices range from 0 (very quiet) to 400 (extremely disturbed). An A-index of 35 or greater indicates local geomagnetic storm conditions. See Appendix B for further explanation.

ALERTS, WARNINGS, AND WATCHES ISSUED

This section lists all SWPC real-time alerts (observed disturbances), warnings (imminent conditions), and watches (expected conditions) that are issued during the previous week. The first column lists the date and time that the alert, warning or watch was issued. The second column lists the type of alert or warning observed, and the third column indicates the date and UT time the event occurred, or is expected to occur, e.g., 29 April 0159 or a time-frame such as 06-09 (0600-0900UT). Units are defined in Appendix B.

SWPC notifies customers when the event reaches specific thresholds. The Alert, Warning and Watch categories are listed on our website at http://www.swpc.noaa.gov/alerts/index.html.

Note: 245 MHz bursts and Radio Noise Storms are issued as a summary product rather than Alerts, but continue to include the information in the Alerts list. This listing will contain information on the number of 245 MHz bursts and noise storms that occur on any given date.

TWENTY-SEVEN DAY OUTLOOK

This section of the Weekly is a quantitative complement to the 27-day forecast described on page 1. Values are given for the next 27 days beginning on Monday of the current week. These 27-day forecasts are based primarily on the persistence of patterns of solar and/or geophysical activity from one 27-day solar rotation to the next. Solar-terrestrial predictions on time scales of 27 days to several years (medium term) are less developed than short-term (days) or long-term solar cycle scale predictions. Recurrence of solar phenomena varies throughout the solar cycle, and therefore the accuracy of these forecasts is partly a function of the strength of recurrent activity. For example, geomagnetic activity resulting from stable coronal holes is most prevalent in the declining portion of the solar cycle, and the accuracy of 27-day geomagnetic forecasts based on recurrence is better during that time. The 10.7 cm flux forecast is likely to be less accurate during the rising phase of the cycle, when there are no long-lived active regions and active longitudes have yet to form. The outlook contains predicted 10.7cm Radio Flux, planetary A index (A_p) and the largest expected K_p index; these values are intended for guidance only.

ENERGETIC EVENT SUMMARY

This section of the Weekly is a summary of all events with an x-ray burst of class M or greater. The summary includes the following:

Date: Month and day the event began.

Time (UT): *Begin, Max,* and *½ Max* are the begin, peak, and ½ peak times of the x-ray burst. The begin time is defined as the first minute in a sequence of 4 minutes of a steep monotonic increase in 0.1-0.8 nm x-ray flux. X-ray maximum is taken as the minute of the peak x-ray flux. X-ray ½ Max is the time when the flux level decays to a point halfway between the maximum flux and the pre-flare background level. See Appendix B for further explanation.

X-ray: Class, as defined in Table 1 on page 2.
Integ Flux is the integrated flux from start to ½ max, in joule m^{-2}

Optical Information: The optical classification and location of an associated flare, observed in Hα.

Imp/Brtns

Importance is the corrected area of the flare in heliospheric square degrees at maximum brightness, observed in the Hα line (656.3 nm).

- S - Subflare (area ≤ 2.0 $deg.^2$)
- 1 - Importance 1 (2.1 ≤ area ≤ 5.1 $deg.^2$)
- 2 - Importance 2 (5.2 ≤ area ≤ 12.4 $deg.^2$)
- 3 - Importance 3 (12.5 ≤ area ≤ 24.7 $deg.^2$)
- 4 - Importance 4 (area ≤ 24.8 $deg.^2$)

Brightness is the relative maximum brightness of flare in Hα.

F – faint N – normal B – brilliant

Location (ºLat. ºCMD) gives the spherical, heliographic coordinates of the solar flare in Hα as a distance in degrees from the solar equator (heliographic latitude), and distance in degrees from a line extending from the north solar rotational pole to the south solar rotational pole through the center of the solar disk as viewed from Earth (central meridian). The field is blank for x-ray events with no optical correlation (no optical flare observed or no optical patrol at the time) and for flares that occasionally occur in unassigned regions).

Rgn # - SWPC-assigned region number.

Peak Radio Flux is the peak value above pre-burst background of associated radio bursts at frequencies of 245 and 2695 MHz in (sfu.) solar flux units (1 flux unit = $10^{-22}\,Wm^{-2}\,Hz^{-1}$).

Sweep Frequency Intensity

The intensity is a relative scale from 1 (minor) to 3 (major) of any sweep radio event associated with the energetic event, as follows (see Figure 1):

Type II: Slow drift burst.

Type IV: Broadband smooth continuum burst.

Solar Radio Burst Classifications

TYPE	CHARACTERISTICS	DURATION	FREQUENCY RANGE	ASSOCIATED PHENOMENA
II	Slow drifting bursts, often accompanied by second harmonic.	5-30 minutes	Fundamental: 20-150 MHz	Flares, proton emission, megnetohydro-dynamic shock waves
IV	Stationary Type IV Broad-band continua emission with fine structure.	Hours – days	20 - >1000 MHz	Flares, proton emission
	Moving Type IV Broad-band, slow drifting, with a smooth continua.	30 min. – 2 hrs.	20-400 MHz	Eruptive prominence and magnetohydro-dynamic shock waves

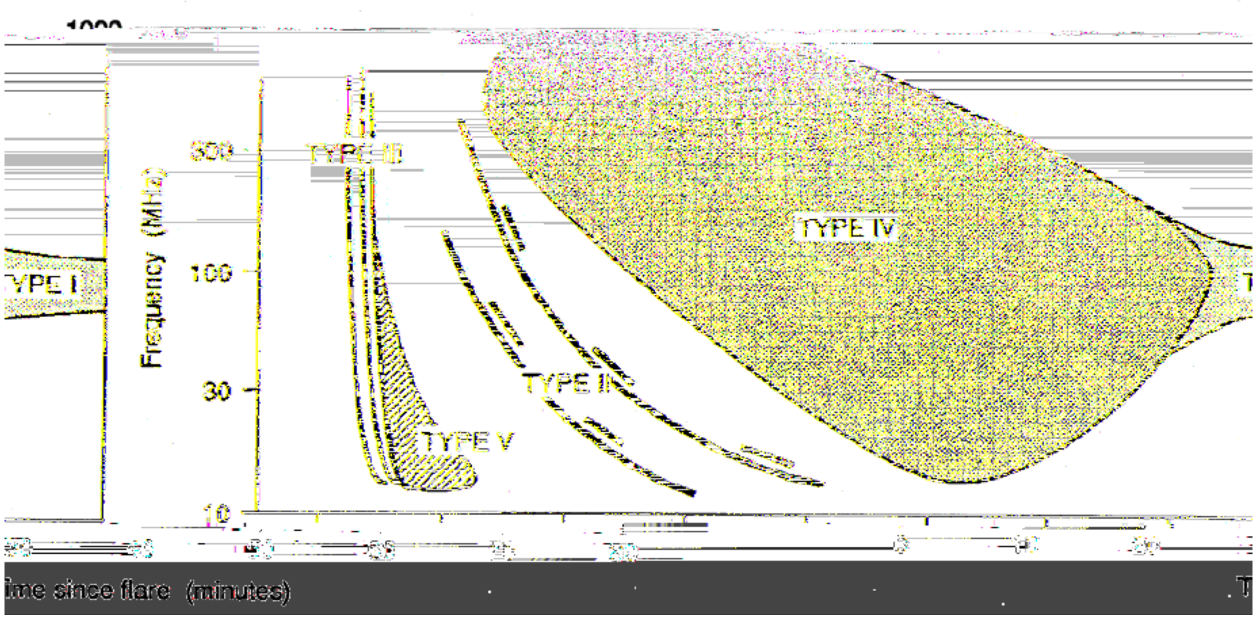

Figure 1. Schematic Radiospectrogram of Events Following a Large Solar Flare. This diagram illustrates each major type of solar radio burst in a typical configuration following a large flare. It should be noted that not all of these features are observed following every flare. (Source: *The New Culgoora Radiospectrograph Technical Report* IPS-TR-93-03, June 1993.)

FLARE LIST

This section lists all solar flares reported in near real time (see list of observatories in Appendix A), including their optical importance and/or x-ray class. In the event of multiple reports of the same event, the quality of observation (how good the observing conditions were and whether the flare was observed in its entirety) and the type of report (preliminary or final) are used to determine which report, or combination of reports, will be listed. The entries include the following information:

Date: Month and day the event began.

Time (UT): Begin, Max, and End: Begin, maximum, and the ½ max times of the optical flare often consolidated from several reports. If no optical flare can be correlated, x-ray event times as described in Appendix B are used. If the start of the flare was not observed, "B" precedes the begin time, indicating that the flare started before that time. If the maximum was not observed, "U" precedes the maximum time, indicating that the flare maximum time is uncertain (estimated). If the end of the flare was not observed, an A precedes the end time, indicating that the flare ended after the time given.

X-ray Class: X-ray classification as defined in Table 1.

Optical Information: Importance and Brightness as defined for Energetic Event Summary Optical Information, location (ºLat. ºCMD) defined for the Energetic Event Summary (see pg. 5) and the Region Number as assigned by SWPC. The field is blank for x-ray events with no optical correlation (no optical flare observed or no optical patrol at the time) and for flares that occasionally occur in unassigned regions.

REGION SUMMARY

This is a history-to-date summary for each active region visible on the solar disk during the preceding 7 days. The sunspot characteristics of a region for each date are based on observations made during the 24-hour UT day, and the location is adjusted to 2400UT on the date indicated. The information is taken from the daily Solar Region Summary, which is a composite picture of each region from all sunspot reports received at Boulder during the UT day. Regions are assigned SWPC region numbers if one of the following conditions exists: (1) the region has a sunspot group with a first digit spot class of C, D, E, F or H (see figure 2), (2) two or more reports confirm the presence of class A or B spot group, (3) the region produces a solar flare, or (4) the region is "bright" in Hα and exceeds 5 heliographic degrees in either latitude or longitude.

Solar magnetic field measurements are used to assist in defining bipolar areas and to determine the approximate boundaries of each active area. It is not uncommon to have widely separated small spots within an extended bipolar region during an active region's declining phase. This phenomenon occasionally leads to assignment of two or more different numbers to spots that actually originate within the same region.

The Region Summary contains the following information:

Region: SWPC-assigned region number.

Date: Day and month.

Location: Location of the midpoint of the latitudinal and longitudinal extremities of the white-light sunspot group in absolute heliographic coordinates corrected to 2400UT on the date reported. The position of the center of Hα plage associated with the region is given if sunspots were not visible. ºLat. ºCMD is defined for Energetic Event Summary location Information (see pg. 6). Helio. Longitude is the heliographic longitude of a solar feature in the coordinate system that rotates with the Sun.

The solar rotation rate for the heliographic longitude is the average rate determined by R. Carrington from central meridian transits of sunspots (27.2753 days as seen from Earth) and so, this term is often referred to as Carrington longitude.

Sunspot Characteristics:

Area: The corrected area of the sunspot group in millionths of the solar hemisphere. Extent: Extent of the major axis of the region in heliographic degrees.

Spot Class: The three letter modified Zurich sunspot group classification (McIntosh) in the general form of Zpc (see Figure 2).

Z - Modified Zurich class, A through F plus H.

p - Penumbra type of largest spot in group:

x = no penumbra,
r = rudimentary,
s = small symmetric,
a = small asymmetric,
h = large symmetric,
k = large asymmetric.

c - Relative sunspot distribution or compactness of group:

x = single spot,
o = open,
i = intermediate,
c = compact.

Spot Count: Total number of individual sunspots in the group or region.

Magnetic Class: Mount Wilson magnetic classification (Bray and Loughhead, 1964) as follows:

A - Alpha (single polarity spot).
B - Beta (bipolar spot configuration).
G - Gamma (atypical mixture of polarities).
BG - Beta-Gamma (mixture of polarities in a dominantly bipolar configuration). D - Delta (opposite polarity umbrae within single penumbra).
BD - Beta with a Delta configuration.
BGD - Beta-Gamma with a Delta configuration.

Flares:

x-ray - Number of C, M, and X-class events detected with concurrent optical observation.

Optical - Number of S (sub), and importance 1, 2 and 3 optical flares observed in Hα with classification according to corrected area at time of peak brightness.

The summary for each region includes its average absolute heliographic longitude, the tally of the number of x-ray events and flares by class for the region, and the status at the end of the reporting period. The status is either:

Still on Disk - an active region, still in transit across the disk.

Crossed West Limb - still extant at or beyond Central Meridian Distance (CMD) of W78.

Died on Disk - sunspots and chromospheric plage in Hα disappeared before the region rotated to the west limb.

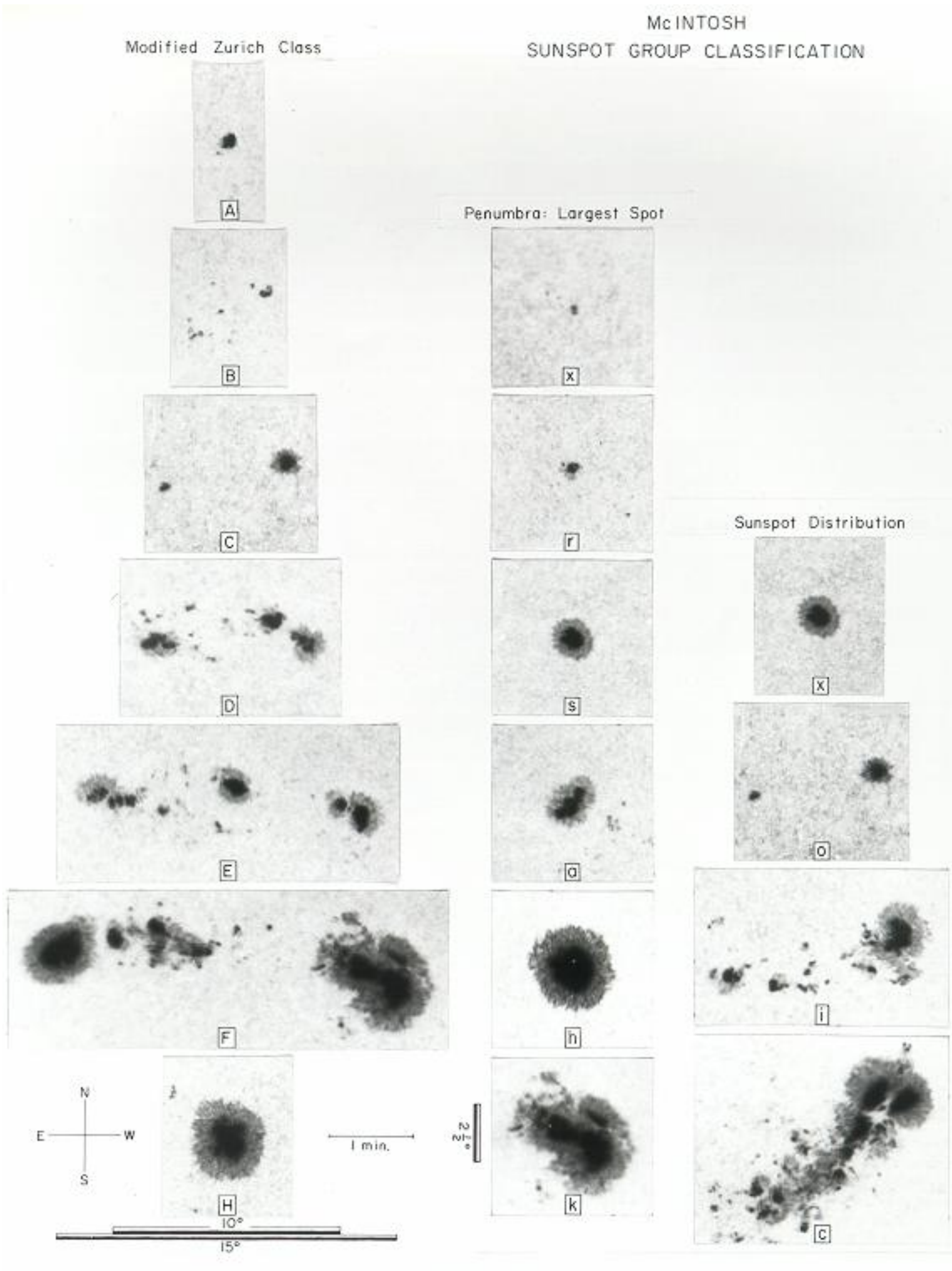

Figure 2. The Modified Zurich Sunspot Group Classification

RECENT SOLAR INDICES (preliminary)

This is a listing of monthly preliminary solar indices for the past 2 years. The final RI (International Sunspot Number), Penticton 10.7 cm flux, and A_p values are provided by the National Geophysical Data Center (NGDC). Observed numbers are simple averages of the daily values for the month. Smooth values are an average of 13 monthly observed values centered on the month of concern (the 1^{st} and 13^{th} months are given a weight of 0.5). A note at the bottom of the page indicates preliminary and finalized values.

Sunspot Numbers:

SEC refers to the monthly mean of the daily SEC sunspot numbers listed in the Daily Solar Data section.

RI is the official monthly sunspot number (formerly the Zurich sunspot number) provided by the Sunspot Index Data Center, *Observatoire Royal de Belgique*, in Brussels, under the sponsorship of the International Astronomical Union.

Ratio RI/SEC is the ratio of the International sunspot number to the SWPC sunspot number. It can be used to determine a SWPC correction factor. (Similar to the *k* factor described in The Daily Solar Data section on page 3).

Smooth values are the smoothed SWPC and RI sunspot numbers.

Radio Flux: The monthly mean value of the observed daily Penticton (formerly Ottawa) 10.7 cm radio flux. This reading is provided by the Dominion Radio Astrophysical Observatory, Canada. Radio flux values adjusted to 1 AU are published in *Solar-Geophysical Data*.

Geomagnetic: The preliminary estimated A_p values are estimated by the SWPC. The final monthly mean and smoothed Planetary A_p values are provided by *GeoForschungsZentrum*, *Potsdam*, Germany.

WEEKLY GEOSYNCHRONOUS SATELLITE ENVIRONMENT SUMMARY

This is a graphic representation of parameters and indices that may be associated with anomalies on satellites. The plot consists of four panels that cover the previous 7 days. They are described below:

The proton flux plot contains the five-minute averaged integral proton flux (protons/cm -sec -sr) as measured by the SWPC Primary GOES satellite, near West 75, for each of three energy thresholds: greater than 10, 50, and 100 MeV.

The electron flux plot contains the five-minute averaged integral electron flux (electrons/cm -sec -sr) with energies greater than 2 MeV by the SWPC Primary GOES satellite.

The Hp plot contains the five minute averaged Hp magnetic field component in nanoteslas (nT) as by the SWPC Primary GOES satellite. The Hp component is parallel to the spin axis of the satellite, which is nearly parallel to the Earth's rotation axis.

The Estimated 3-hour Planetary Kp-index is derived at the NOAA Space Weather Prediction Center using data from the following ground-based magnetometers: Boulder, Colorado; Chambon la Foret, France; Fredericksburg, Virginia; Fresno, California; Hartland, UK; Newport, Washington; Sitka, Alaska. These data are made available thanks to the cooperative efforts between SWPC and data providers around the world, which currently includes the U.S. Geological Survey, the British Geological Survey, and the Institut de Physique du Globe de Paris.
Development and negotiations are in progress to add Jeju, Korea (Korea Communications Commission); Canberra, Australia (Geoscience Australia); Ottawa and Meanook, Canada (Geological Survey of Canada).

The data included here are those now available in real time at the SWPC and are incomplete in that they do not include the full set of parameters and energy ranges known to cause satellite operating anomalies. The proton and electron fluxes and Kp are 'global' parameters that are applicable to a first order approximation over large areas. H parallel is subject to more localized phenomena and the measurements generally are applicable to within a few degrees of longitude of the measuring satellite.

GOES SATELLITE X-RAY AND PROTON PLOTS

The x-ray plots contains five-minute averages x-ray flux (Watt/m) as measure by the SWPC primary GOES X-ray satellite, usually at West 105 longitude, in two wavelength bands, 0.05 - 0.4 and 0.1 - 0.8 nm. The letters A, B, C, M and X refer to x-ray event levels for the 0.1 - 0.8 nm band.

The proton plot contains the five-minute averaged integral flux units (pfu = protons/cm -sec -sr) as measured by the primary SWPC GOES Proton satellite for each of the energy thresholds: >1, >10, >30, and >100 MeV. The P10 event threshold is 10 pfu at greater than 10 MeV.

Eclipse periods at geosynchronous orbit occur during Equinox periods each year. Any of the plots described above that contain data from the GOES satellites are subject to data dropouts due to eclipse periods. Eclipse periods occur March-April and again in September-October each year.

ISES SOLAR CYCLE PROGRESSION PLOTS

Updates to the progression of Solar Cycle 23 are included once a month, usually in the first issue. The updates include plots and tabular data relating to the progress and forecast of the International Sunspot Number (RI) and 10.7 cm Radio Flux. Progress of the magnetic A_p index is also included.

The plots show monthly values, 13 month running smoothed values and the forecast where appropriate. Tabular values include a combination of smoothed and forecast values. Forecasts are shown in boldface, with an error bound in parentheses. Official values are used when available, otherwise preliminary or estimated values are given.
See the *RI and 10.7 cm Flux Prediction* in Appendix B for further information concerning the forecast method.

PLOTS

Twelve different plots, each depicting a different measure of the progress of the solar cycle (one each month), will be included according to the following schedule:

January - Sunspot Number (RI)
February - Sudden Storm Commencements and Impulses
March - Solar Radio Flux (10.7 cm)
April - Quiet ($A_p \leq 7$) Geomagnetic Conditions
May - Cosmic Ray Ground-level Events
June - Severe Storm ($A_p \geq 100$) Geomagnetic Conditions
July - M5 or greater X-ray Flares
August - Proton Events
September - Solar Terrestrial Indices
October - Optical Flares
November - Active Regions
December - Geomagnetic Activity (A_p)
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APPENDIX A: EXPLANATORY NOTES

All times used within the Weekly are Universal Time (UT), which is the same as Greenwich Mean Time (GMT). The terms x-ray event, x-ray burst, and x-ray flare are used interchangeably. SWPC, SWO, and SESC are also used interchangeably.

The highlights and all data listings cover the 7-day period Monday through Sunday. The 27-day forecast period begins on the following Monday.

Most data listings are generated by computer. Occasionally, inaccurate data will be included as reported. Notification of any data found to be questionable is appreciated.

Reports from the following stations are included in the SWPC data base and may be used for preparing the Weekly:

Station	WMO*	URSI†	Location
Big Bear, California, USA	-----	-----	N34W117
Boulder, Colorado, USA	72469	20401	N40W105
College, Alaska, USA	70261	25602	N64W147
Culgoora, Australia	94300	85303	S30E149
Fredericksburg, Virginia, USA	72405	18403	N38W77
GOES 10 (geostationary satellite)	-----	-----	W135 (variable)
GOES 12 (geostationary satellite)	-----	-----	S75 (variable)
Holloman AFB, New Mexico, USA	72269	21305	N33W106
Kitt Peak National Obs., Arizona, USA	-----	21304	N32W111
Learmonth, Australia	94302	81202	S22E114
Penticton, B.C., Canada	72889	22501	N49W120
Palehua, Hawaii, USA	91178	26204	N21W158
Sacramento Peak National Obs., Sunspot, New Mexico, USA	-----	21301	N32W105
Sagamore Hill, Massachusetts, USA	72509	17401	N42W70
San Vito, Italy	16320	32404	N41E18
Sydney, Australia	94768	85304	S34E151
Thule, Greenland	04202	17801	N76W68

*World Meteorological Organization identification
†International Union of Radio Science identification

APPENDIX B: EXPLANATION OF SWPC DATA SETS

Data Averaging

Data sets with finer than 1-minute resolution are often averaged. For example, 3-second GOES x-ray data with time tags between 16:40:00UT and 16:40:59UT are averaged to produce the 16:40UT data point in the GOES x-ray 1-minute average data set. The same procedure is used for the 5-minute, hourly, daily, and monthly averages. Note that not all of the data points available are necessarily used in calculating the averages. For example, GOES data points during calibration are eliminated. The averaged values are calculated by summing all of the "good" data values for the averaging period, and then dividing by the number of samples used. It is theoretically possible (though highly unlikely) that an hourly average could be calculated from a single data point.

The Smoothing Function

The monthly smoothed numbers are calculated by the following method:

s*j* is the monthly number or average for month *j*

S*n* is the 13 month smoothed number for month *n*

$$S_n = \left[\ .5(s_{n-6} + s_{n+6}) + \sum_{j=n-5}^{n+5} s_j\ \right] / 12.$$

This smoothing function is used on several time series data sets at SWPC, including the International Relative Sunspot Number (RI), the SWPC sunspot number, the monthly averaged planetary geomagnetic index Ap, and the monthly- averaged 10.7-cm. solar radio flux.

The production of the "Derived" Data Sets

The GOES spacecraft have 11 proton channels, measuring proton flux in the following energy ranges:

P1 : 00.6 to 04.2 MeV	P7 : 110.0 to 500.0 MeV
P2 : 04.2 to 08.7 MeV	P8 : 370.0 to 480.0 MeV
P3 : 08.7 to 14.0 MeV	P9 : 480.0 to 640.0 MeV
P4 : 15.0 to 44.0 MeV	P10 : 640.0 to 850.0 MeV
P5 : 39.0 to 82.0 MeV	P10 : 640.0 to 850.0 MeV
P6 : 84.0 to 200.0 MeV	P11 : >850.0 MeV

Where P*n* represents the proton count rate in $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ for channel *n*. The GOES particle channels are multiplexed, and so the time resolution for the particle data varies from 5 to 30 samples per minute, depending on the particular channel.

Proton Flux

The algorithm for calculating the proton differential and integral fluxes from measurements obtained on GOES spacecraft has three features. First, the average background counting rate is subtracted from the measured counting rate. Second, a calculation is made to determine the average spurious component (particles counted by a given channel that have initial energies outside the stated energy window for the channel) and it is subtracted from the measured counting rate. The spurious component can be large during the onset of energetic particle events containing high energy particles (E > 50 MeV). Third, the integral flux calculation uses a power law approximation between neighboring channels ($j=j_0E^{-g}$).

Particle Fluence

Fluence is flux integrated over time. In SWPC use, the daily particle fluence is the integral particle flux accumulated over the UT day. It is calculated by summing all of the 5-minute-averaged integral particle flux values for the day, and then multiplying the sum by 300 (300 seconds in 5 minutes).

Geomagnetic Components

Modern magnetometers are typically three axis instruments and are oriented in two types of configurations: the X, Y, Z configuration and the H, D, Z configuration. In the X, Y, Z configuration, the axes are geographically aligned with X- North, Y-East, and Z vertically down. In H, D, Z configuration, the instrument is leveled and aligned such that one horizontal axis is parallel to the natural magnetic field during quiet geomagnetic conditions, and the second horizontal axis is perpendicular to the quiet geomagnetic field. The second axis, therefore, will measure zero-level field intensity under quiet conditions. The third axis is oriented vertically downwards, just as it was in the X, Y, Z configuration. The absolute value for H is measured as the intensity along the first horizontal axis, and the absolute declination is measured as the angle between the first horizontal axis and true north. Denote these baseline, quiet-level readings as H_0 (in nanoTesla), and D_0 (in degrees).

In the H, D, Z configuration, the magnetometer measures small variations of the geomagnetic field intensity along mutually orthogonal, fixed directions. Conventionally, the first axis of the magnetometer is referred to as the 'H-axis' and the second axis is referred to as the 'D-axis'. The measured variation along the H-axis, δh, is referred to as the variation in the H- component of the field, and the measured variation along the second axis, δd, is called the variation in the D-component of the field. Note that this convention is not strictly consistent with the definitions for H and D given above. However, we shall show that it is valid for practical purposes because the variations are much smaller than the absolute field intensity.

Given the initial absolute measurements of H_0 and D_0, consider the calculation of instantaneous values for H and D, given the measured variations δh and δd from the baseline values. These variations are quite small compared to the strength of the intrinsic field: typically 10-20 nT (but up to several hundred nT in severe storms) compared with an intrinsic field of about 60,000 NT (and intrinsic H values of 20,000 at a mid-latitude station). The mathematical relationships between H, D and δh, δd are as follows:

$$H = \sqrt{(H_0 + \delta h)^2 + (\delta d)^2} = H_0\left[1 + 2(\delta h / H_0) + (\delta h^2 + \delta d^2) / H_0^2\right]^{1/2}$$
$$\tan(D - D_0) = \delta d / H_0$$

Using the fact that the variations are much smaller than H0, the first equation can be expanded using Taylor series:

$$H = H_0 + \delta h + (\delta h^2 + \delta d^2) / 2H_0$$

This equation shows that δh is an excellent approximation for H - H_0, the variation of H: the correction term will typically be less than 1% of δh for realistic values of δh, δd, and H_0. Because δd is much smaller than H_0, the angle (D - D_0) must be small. This permits simplification of the second equation by use of the small angle approximation:

$$\delta d = H_0 * (D - D_0)$$

The fractional error introduced by the small angle approximation is about $(\delta d/H_0)^2 \sim 0.5\%$, hence δd is an accurate way of telling us the variation of D relative to the baseline declination D_0. As an example, consider a geomagnetic storm with a δh reading of +100nT and a δd reading of ±100 nT. The instantaneous value for H would be:

$$H = \sqrt{(20000+100)^2 + 100^2} = 20100.25$$

so that H - H_0 = 100.25, and the error introduced by using δh = 100 for the variation of H instead of the strictly correct value of 100.25 is 0.25%, well within the instrument limitations. Likewise, the instantaneous value for the change in D in such an instance would be such that:

$$\tan(D-D_0) = (\delta d / H_0) = (100/20000),$$

leading to an angular fluctuation of 17.2 arc minutes (0.286 degrees), compared to an intrinsic D_0 of about 11 degrees. The approximate formula for (D-D_0) would lead us to the following calculation:

$$(D-D_0) = (100/20000) \text{ radians} = 5 \times 10^{-3} \times 57.296 \times 60 = 17.2 \text{ arc-minutes.}$$

The absolute measurements and the instrument orientation are updated from time to time due to the slow secular change of the geomagnetic field. If required the maintainers of the instrument will rotate the sensor to insure proper H, D, Z configuration.

RI and 10.7 cm Flux Prediction

An international panel developed the SWPC solar cycle prediction, for both RI and 10.7 cm flux. In advance of the panel meeting, held in September 1996, forecasts of solar and geomagnetic activity were requested from the scientific community. Replies were considered by the panel along with forecasts published in the open literature. To place all forecasts on the same footing, 10.7 cm flux values were converted to an equivalent sunspot number. The resulting 28 forecasts were separated into 6 classes according to the nature of the prediction technique used. The predictions in each class were considered in detail and a "representative" prediction was selected. These values are given in Table 1 in descending order of the predicted maximum. In the table, "Recent Climatology" considers only Cycles 18 and later, but the mean characteristics of all (or nearly-all) known cycles are considered in "Climatology (all)."

Table 1: Combined forecasts of maximum smoothed sunspot number for classes of prediction techniques

Technique	**Low End of Range**	**Maximum**	**High End of Range**
Even/Odd behavior	165	200	235
Precursor	140	160	180
Spectral	135	155	185
Recent Climatology	125	155	185
Neural Networks	110	140	170
Climatology (all)	75	115	155

While four of the six techniques are in general agreement, the panel gave the greatest weight to precursor methods, since they have proved to be the most successful technique for solar activity predictions in the past. These methods utilize the concept of an "extended solar cycle" the idea that the imminent solar cycle actually starts in the declining phase of the previous cycle.

The representative predictions in Table 1 were combined to obtain a consensus prediction for the panel. Combining such different techniques was a difficult process, and the panel made use of its experience and knowledge of the techniques and their success in predicting previous cycles especially Cycles 21 and 22. For a more complete discussion of the prediction procedures, please see *http://www.swpc.noaa.gov/SolarCycle/index.html*.

Geomagnetic Indices

Natural variations in the Earth's magnetic field are measured continuously at a number of locations around the globe. These variations are indexed at the end of specified 3-hour periods by measuring the maximum deviation, in nT, of the actual field from quiet field conditions. The measured variation, which can be either positive or negative relative to a "quiet day", is converted to a K index (a number from 0 to 9) by using a look-up table appropriate to that particular observing site. This is done to correct for some of the natural differences between observing sites. The K index is quasi-logarithmic and open-ended. For example, at Boulder, Colorado a measured deviation between 0 and 4 nT results in a K index of 0; between 70 and 119 nT is a K index of 5, and a measurement of 500 nT or greater is a K index of 9.

In order to combine the eight daily K indices into one number representing overall activity for the day each K is converted to an ak index as shown below, and then the eight ak indices are averaged to yield the daily A index.

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

The a_k indices for a particular station may be converted into units of nT by multiplying them by a station-specific conversion factor. The conversion factor can be found by dividing the station's lower limit for a K=9 by 250. Example: At Boulder, the lower limit for a K index of 9 is a maximum deviation of 500 nT, and so 500/250 = 2. Therefore, a K index of 4 has an associated K index of 27, which has an equivalent amplitude of 27*2 = 54 nT.

The A_k index for a station is simply the average of the eight a_k indices for that station for the UT day. The subscript $_k$ used on the A_k and K_k refers to an individual station, e.g. A_B for example is the Boulder A-index.

X-ray Events

The start of an x-ray event is defined as the first minute in a sequence of 4 minutes of steep monotonic increase in 0.1-0.8 nm flux. The time of x-ray maximum is defined as the time tag of the peak 1-minute averaged value x-ray flux. The end time is the time when the flux level decays to a point halfway (1/2 peak) between the maximum flux and the pre-flare background level.

Sudden Commencements

See *Geomagnetic Storms* description.

Proton Events

A proton event starts when the integrated proton flux (5-minute average) rises above a specific threshold for at least three points. The two alert thresholds are: >10 MeV ≥10 pfu. and >100 MeV ≥ 1 pfu. (1 pfu. = particle $cm^{-2}s^{-2}s^{-1}sr^{-1}$). The time of maximum is the time tag of the 5 minute averaged flux value that has the greatest value.

Electron Events

An electron event begin is defined as when the greater than 2 MeV GOES electron flux exceeds 1 x 10^3 pfu level in a day when no values on the previous day were above that threshold. The event continues for each subsequent day where the flux meets or exceeds the threshold. Event end occurs when a complete UT day passes where the electron flux never meets the threshold.

Geomagnetic Storms

Geomagnetic storm conditions are characterized by an intensification of equatorial 'ring' current (at 2-7 Earth radii above the ground) and an expansion of the auroral oval region to lower latitudes (see Gonzalez et al, 1994, JGR, 99, A4, pg. 5771 for details). A geomagnetic storm is caused by the interaction of the Earth's magnetosphere with unusual conditions in the solar wind. Frequently the strongest geomagnetic storms will begin suddenly with the arrival at Earth of a shock front in the solar wind, which compresses the front of the magnetosphere. On ground magnetometers at middle and low latitudes the shock arrival is observed as a sudden discontinuous jump in the horizontal magnetic field component. When this signature is seen simultaneously at several observatories the event is called a sudden impulse. If the sudden impulse is followed by a geomagnetic storm, then the sudden impulse may also be referred to as a sudden storm commencement. Note that not all sudden impulses are followed by geomagnetic storms, nor are all geomagnetic storms preceded by a sudden storm commencement. If a storm is not preceded by a sudden storm commencement, it is customary to review the magnetometer records and attempt to identify a point in time where the conditions transitioned from calm to disturbed levels. This type of storm begin time is referred to as a gradual commencement and is typically reported to the nearest hour.

SWPC defines geomagnetic storms based on the running estimated planetary A-index. If the index is greater than or equal to 35, a storm is in progress. The running A-index is calculated using the K indices in a running 24-hour window, rather than using fixed days. Storms are minor, major, or severe as defined below.

Minor: Ap between 35 and 59
Moderate: Ap between 60 and 99
Strong: Ap between 100 and 159
Severe: Ap between 160 and 309
Extreme: Ap between 310 and 400

However, the level of storm conditions can vary throughout a day. Regardless of the running A-index, it is permissible to say that periods of minor, moderate, strong, severe, or extreme storm levels occurred, based on the observed K index. The following table identifies K indices with storm levels.

Minor storm conditions: Kp=5
Moderate storm conditions: K=6
Strong storm conditions: K=7 or greater
Severe storm conditions: Kp=8 or 9-
Extreme storm conditions: Kp=9

In general, the point in time when the running A_p index falls below 35, it is taken to be the end of storm conditions for SWPC operational purposes.

Edited Events

All energetic event reports received are automatically stored in the computer database. The system checks the *begin* and *max* times of each event to sort them into bins. For every bin, the system picks the "best" of each type of report that occurs in the particular bin. The selection of the "best" report is based on a number of criteria, including report quality, accuracy of event times, report completeness, etc. The duty solar forecaster then reviews the event list, and may "rebin" reports, select different best reports, or create best reports by combining information from several different reports. The edited list becomes the operational event list as used by SWPC for forecast center products and operations. At the beginning of a new week, the Weekly staff proofs the edited events lists for the previous week, and then incorporates them into the Weekly.

Explanation of Units

PARAMETER	UNITS
Solar Radio Flux	1 sfu (solar flux unit) = 10 -22 W m -1 Hz -1
Solar Area	millionths of the solar hemisphere (1 millionth of solar hemisphere=3 million km2)
Integrated x-ray flux	Joules.
Particle Fluence	particles cm^{-2} $sr^{-1}day^{-1}$
Particle Flux	1 pfu. (particle flux unit) = p cm^{-2} s^{-1} sr^{-1}