BY ORDER OF THE COMMANDER
AIR FORCE WEATHER AGENCY

AIR FORCE WEATHER AGENCY MANUAL 15-1

5 DECEMBER 2013

Incorporating Change 1, 6 May 2014

Weather

SPACE ENVIRONMENTAL OBSERVATIONS SOLAR OPTICAL OBSERVING TECHNIQUES

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: Publications and Forms are available on the e-publishing website at www.e-Publishing.af.mil.

RELEASABILITY: There are no releasability restrictions on this publication.

OPR: HQ AFWA/A3N

Certified by: HQ AFWA/A3 (Col David Andrus)

Pages: 89

This manual is applicable to all Solar Observing Optical Network (SOON) observatories. It provides solar optical telescope equipment descriptions, operational procedures, and data collection and analysis guidance. SOON observatories gather solar photospheric, chromospheric, and coronal data in either computer assisted (automatic) or non-computer (semiautomatic) mode. Use this manual in conjunction with Air Force Weather Agency Instruction (AFWAI) 15-2, *Solar Optical and Radio Observing*, all applicable Technical Orders (TOs) and the SOON Software Users Manual (SOONSUM). Send comments, suggested changes, or improvements through channels to Headquarters Air Force Weather Agency Scientific Services, Training, and Standards Division (HQ AFWA/A3N), 101 Nelson Drive, Offutt AFB NE 68113-1023. Ensure that all records created as a result of processes prescribed in this publication are maintained IAW Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of IAW the Air Force Records Information Management System (AFRIMS) Records Disposition Schedule (RDS). Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR). This publication does not apply to the Air National Guard or Air Force Reserve commands. The reporting requirements in this publication are exempt from licensing in accordance with AFI 33-324, The Information Collections and Reports Management Program; Controlling Internal Public and Interagency Air Force Information Collections, paragraph 2.11.12.

SUMMARY OF CHANGES

This interim change revises AFWAMAN 15-1 by (1) changing the Title from SPACE ENVIRONMENTAL OBSERVATIONS SOLAR RADIO OBSERVING TECHNIQUES to SPACE ENVIRONMENTAL OBSERVATIONS SOLAR OPTICAL OBSERVING TECHNIQUES.

Chapter 1

SOON EQUIPMENT DESCRIPTION AND OBSERVING CONSIDERATIONS

1.1. Telescope System.

1.1.1. The AN/FMQ-7 Solar Observing Optical Network (SOON) telescope system provides the capability to observe, analyze, and report visible solar phenomena such as solar flares, sunspots, magnetic fields, and disk and limb activity. The system is divided into four functional areas: automatic data processing, tracking and light acquisition, automatic flare detection, and spectral analysis. However, the AN/FMQ-7 equipment nomenclature includes all equipment subsystems (the overall facility, telescope, birefringent filter, spectrograph, television, computer, etc). The telescope has two modes of operation: automatic (computer performs flare detection) and semiautomatic/manual (analyst performs flare detection using either television monitors or the SOON Rehost client software components). A general description of the telescope is presented below. For a complete description, see TO 31M1-2FMQ7-1.

1.1.2. Telescope Tube Assembly and Optical Bench. The telescope tube assembly has a 10-inch objective lens mounted at the forward end, a 210-inch focal length, and operates in a partial vacuum to minimize image distortion and damage to the internal optics. A field lens with a focal length of 36 inches is at the optical bench end of the tube, providing a 2-inch diameter solar image. Translational image motion caused by the apparent motion of the sun across the sky is offset by an image rotator, which moves with the telescope tube, but at half the speed. The beam splitters and scanner mirrors receive the image from the collimator lens and direct it to upper and lower light paths in the lens interchange box. The birefringent filter in the upper light path supports both the Hydrogen alpha (Hα) and Magnesium b2 (Mg-b2) subsystems. The lower light path supports the spectrograph subsystem. About one-third of the light goes to the upper light path, and about two-thirds goes to the lower light path. The exact division of light between the upper and lower light paths depends on the beam splitter position and wavelength. For example, in beam splitter position 2, 70% of the Hα wavelength and 95% of the Mg-b2 wavelength is sent to the upper light path; the remainder goes to the lower light path.

1.1.2.1. A series of lenses in the upper light path lens interchange box define image viewing size. In “large scale”, a single lens passes the full 2-inch diameter image to the birefringent filter. At this scale, which is used for automatic flare analysis, an image of only about one-fifteenth of the solar disk displays on the monitor. In “full disk”, the image size is reduced by a factor of 6 to a 0.33-inch diameter image, which allows full disk display on the monitor.

1.1.2.2. Visual observations are available through the Hα and spectrograph eyepieces, including a sunspot projection board. Real-time video is available on various monitors. A SOON Rehost Solar Image Movie Console allows continuous Hα or Mg-b2 observations, including review of stored data.

1.1.2.3. The telescope optics cause large scale and full disk images to have different display orientations. Standard solar cardinal directions are in clockwise direction: North/West/South/East. The mirror image is in clockwise direction:

North/East/South/West. The following indicates orientation for each display type. Only the SOON Rehost provides P-angle correction.

1.1.2.3.1. Television Monitors.

1.1.2.3.1.1. Hα, Mg-b2, and Spectrograph white light display standard solar cardinal directions:

1.1.2.3.1.1.1. Large scale: North up; East left.

1.1.2.3.1.1.2. Full disk: North down; East right.

1.1.2.3.1.2. Spectrograph spectra and Spectrohelioscope display standard solar cardinal directions:

1.1.2.3.1.2.1. Large scale: North left; East down.

1.1.2.3.1.2.2. Full disk: North right; East up.

1.1.2.3.2. Monocular Eyepiece (Hα/Mg-b2) display standard solar cardinal directions:

1.1.2.3.2.1. Large scale: North down; East right.

1.1.2.3.2.2. Full disk: North up; East left.

1.1.2.3.3. Spectrograph Eyepiece (white light) display mirror image of standard solar cardinal:

1.1.2.3.3.1. Large scale: North right; East down.

1.1.2.3.3.2. Full disk: North left; East up.

1.1.2.3.4. White Light Sunspot Projection Board display mirror image of standard solar cardinal directions: North right; East down.

1.1.3. Hα Subsystem. This upper light path subsystem produces a solar image at the Hα wavelength (6562.8 Angstroms). The Hα line reveals chromospheric features such as plage (see 5.1.3.), flares, prominences, and filaments. Since the Hα birefringent filter assembly is very temperature sensitive, it has its own temperature control unit.

1.1.4. Mg-b2 Subsystem. This upper light path subsystem uses the same birefringent filter as the Hα subsystem, but employs different prefilters and polaroids to produce a solar image at the Mg-b2 wavelength (5172.3 Angstroms). It reveals photospheric features such as sunspots and faculae.

1.1.5. White Light and Guider/Tracking Subsystems. The white light beam-splitter divides incoming light into separate light paths. The front and rear surfaces reflect 8% of the light upward to an optical wedge, which in turn sends 4% to a white light (or sunspot) projection board and 4% to a guider assembly. The guider assembly measures light intensity using photoelectric cells and, if sufficient light is received, commands the telescope drive modules to track the sun automatically. At low light intensity, the modules track at a fixed rate.

1.1.6. Spectrograph (SG) Subsystem. The SOON spectrograph provides adjustable wavelength analysis from 3,700 to 10,830 Angstroms. This subsystem employs the lower light path within the lens interchange box. It can be operated concurrently with Hα patrol, since at beam splitter position 2, it continuously receives about two-thirds of the total light.

The exact percentage varies with wavelength: about 30% for Hα, 10% for Mg-b2, and nearly 100% for Iron 8468 and Helium 10,830. The imaging optics is similar to the Hα subsystem (large scale and full disk), except the spectrograph's full disk image is 0.66 inches versus 0.33 inches for Hα. The spectrograph consists of a slit carriage assembly, Littrow lens, and dispersing element (diffraction grating), and has three major subsystems:

1.1.6.1. Basic Spectrograph Components.

1.1.6.1.1. Slit Carriage Assembly. The spectrograph slit is a narrow opening through which light passes on its way to the dispersing element. A micrometer can manually adjust the width of the slit opening. Although it is the diffracted angle of the light in the dispersing element that isolates a specific spectral line, the slit width determines the fraction of the spectrum passed at the central wavelength. The slit carriage assembly has three positions: spectra/white light (S-WL), spectrohelioscope (SHS), and photoelectric (PE).

1.1.6.1.2. Littrow Lens. This lens is located on a worm gear track inside the grating assembly box between the Doppler cube and the dispersing element. It serves two purposes: it collimates (makes parallel) the light and focuses the returning dispersed light at the exit slit plane. Since focal length is wavelength dependent, the analyst can manually adjust the location of the Littrow lens to focus the desired wavelength.

1.1.6.1.3. Dispersing Element. This element is a diffraction grating and produces several duplicate images of the solar spectrum (known as "orders") through diffraction and interference of light waves. The spectrograph has two diffraction gratings located back-to-back on a common pivot, each having a different groove spacing and groove angle ("blaze angle"). These different grating parameters favor different wavelengths and order intensities depending on the angle the light strikes the grating ("angle of incidence").

1.1.6.2. Major Spectrograph Subsystems.

1.1.6.2.1. Spectra/White Light Subsystem. Setting the function control knob on the front of the slit carriage assembly to "WL" while the carriage is in the "S-WL" position can facilitate white light observations. In this position, a series of prisms reduce light intensity and prevents it from going to the grating. Also, a 200 Angstrom band-pass filter in front of the prisms further reduces light intensity and sharpens the image. This white light imagery can be used to supplement the white light projection board and Mg-b2 subsystem for sunspot and photospheric observations.

1.1.6.3. Magnetograph (or Photoelectric) Subsystem.

1.1.6.3.1. This subsystem includes the photodiodes; the power supply and chopping circuitry; the KD*P crystal and phase plate circuitry; the calibration Polaroid; the objective focusing (or calibration) lens; and a Doppler cube. It is selected by moving the slit carriage to the PE position and provides maps of magnetic field information called magnetograms. . This capability is one of the SOON system's greatest assets, since solar flare occurrence is closely linked to magnetic field strengths, gradients, complexity, and structural changes.

1.1.6.3.2. The magnetograph uses the Zeeman effect, the splitting of selected solar spectral lines on the basis of magnetic field strength in the material emitting the light. The SOON magnetograph uses the iron spectral line at 8468 Angstroms, which splits into three lines when observed in the presence of active region or sunspot. Two lines are displaced on either side of the central line and are analyzed to determine the longitudinal (line-of-sight) component of magnetic field strength. The separation of these two lines determines total magnetic field strength. Emission polarization gives magnetic polarity (north or south).

1.1.6.3.3. The two displaced spectral lines are respectively right and left circularly polarized, which means the electric field portion of the light wave precedes or follows the magnetic field portion by one quarter of a wavelength. To analyze these lines, the circular polarization must be phased to plane polarization, which is when the light wave's electric and magnetic field components match. Polarization introduced by the telescope must also be eliminated. The KD*P crystals accomplish this by adding or subtracting (depending on whether the spectral line is right or left polarized) one quarter wavelength to phase the line emission to plane polarization. Since electric charge in the KD*P crystals affects the phase change of light waves passing through, two charges corresponding to phase corrections of right and left polarized light is alternately applied to the crystal.. Results are imaged onto two photodiodes in the spectrograph carriage. The output signal is amplified and sent to the computer for analysis. Each measurement is compared to the quiet sun reference. Deviations from this reference yield magnetic field strength and direction.

1.2. Computer System.

1.2.1. The AN/FMQ-7 SOON telescope's computer system includes many peripheral devices. Further information on the SOON computer system and its operational use is found in the SOONSUM and TO 31M1-2FMQ7-1. Major components of the computer system are presented below.

1.2.2. SOON Rehost Client subsystem is a standalone desktop PC based computer that provides the Graphical User Interface (GUI) functionality for the analyst. It allows the analyst the ability to view solar images and perform flare, DALAS, and magnetogram analyses. It provides screens to aid solar activity analyses, and telescope control, which allows the analyst to accomplish required solar patrol. Other screens facilitate system maintenance, diagnostics, and calibration.

1.2.3. SOON Rehost Server subsystem is a rack-mounted server that provides archival and storage capability for solar images and histograms. It provides communication to and from the SOON Rehost Client and Embedded Controller. It passes messages, images, and other products to the SEON Operations Secure Server (SOSS) for distribution, using Secure File Transfer Protocol (SFTP).

1.2.4. Embedded Controller interfaces with the telescope system, providing control logic to position the telescope. It receives live video to capture images from the telescope cameras. It creates histograms and accomplishes flare analysis on the histogram data.

1.2.5. SOSS application provides the user the ability to send, receive, forward, print, and store weather messages and images.

1.2.6. SEON WINDS provides a graphic user interface to transmit and receive alphanumeric solar weather data.

1.3. Solar Coordinate Systems.

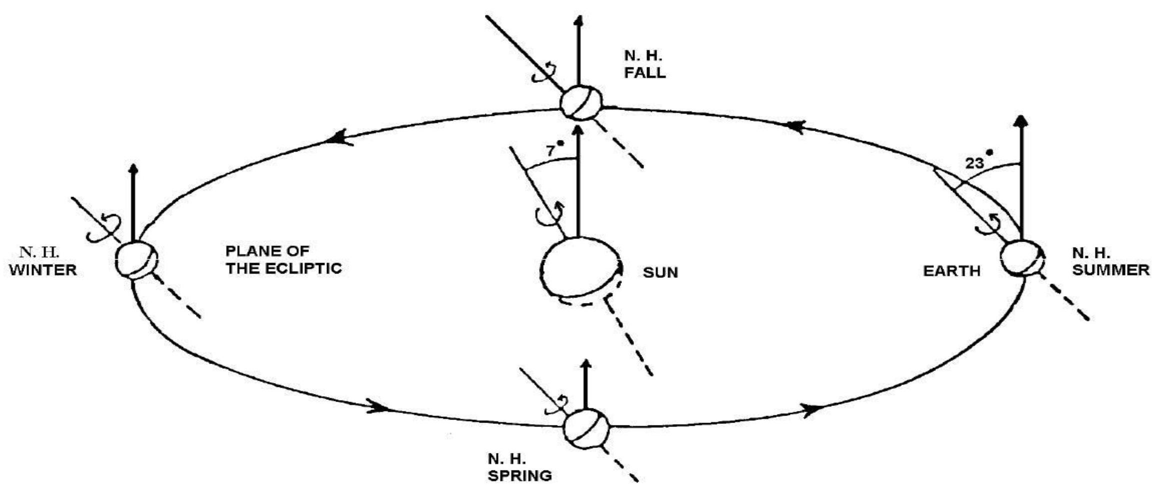
1.3.1. Earth-Sun Orbital Relationships.

1.3.1.1. The earth's orbit around the sun is a slightly eccentric ellipse with a mean distance to the sun of 150 million kilometers (93 million miles), which is also defined as one astronomical unit (1 AU). Perihelion, when the earth is closest to the sun, occurs in early January at a distance of 0.984 AU (147 million km, 91.4 million miles). Aphelion, when the earth is farthest from the sun, occurs in early July at a distance of 1.016 AU (152 million km, 94.6 million miles). The ecliptic plane is defined as the plane the earth orbits the sun.

1.3.1.2. The earth's axis of rotation is tilted 23.5° from a line perpendicular to the ecliptic plane (Figure 1.1). This tilt defines the limits of solar declination, namely ± 23.5°.

1.3.1.3. The sun rotates about its own axis in the same sense as the earth rotates around the sun (i.e., counterclockwise as viewed from the north side of the ecliptic plane). The solar axis of rotation axis is tilted 7.23° from a line perpendicular to the ecliptic plane (Figure 1.1). The sun rotates faster at its equator than it does at its poles. On average, the sun takes 25.35 days to rotate (at 26° solar latitude); however, because the earth orbits the sun in the same direction as the solar rotation, the sun averages 27. 2753 days to rotate with respect to an observer on the earth.

Figure 1.1. Earth-Sun Orbital and Axial Rotation Relationships.



1.3.2. Geocentric Coordinates. This coordinate system is based on the perspective of an observer standing on the surface of the earth. It is used to determine solar position and orientation in the earth's sky as well as establish the location of features on the solar disk.

1.3.2.1. In the northern hemisphere, the north-south (N-S) reference line is perpendicular to the earth's horizon with north toward the zenith when looking due south at local noon (Figure 1.2). In this case, the east horizon is to the left and the west horizon is to the right.

This orientation defines the “east” (left) and “west” (right) limbs (or edges) of the sun as viewed from the northern hemisphere. Conversely, in the southern hemisphere, the sun appears “upside down”—that is, the south end of the N-S reference line is toward zenith when looking due north at local noon. In this case, the east horizon is to the right and the west horizon is to the left. Regardless of which hemisphere one observes the sun, at sunrise the west limb always appears first, and at sunset it sets first (Figure 1.3). The sun’s 27-day rotation period causes persistent solar features to appear on its east limb and disappear around its west limb about two weeks later.

1.3.2.2. Geocentric coordinates consist of Position Angle (PA) and Radius Vector (Rv) (Figure 1.4).

1.3.2.2.1. PA is the angle formed between the N-S reference line and a ray from the center of the observed solar disk to the desired point. PA ranges *counterclockwise* from 0º to 360º, with north at 0º, east at 90º, south at 180º, and west at 270°.

1.3.2.2.2. The magnitude of Rv measures the distance from the center of the observed solar disk to the desired point in fractions of one solar radius. Features observed on the disk range from Rv = 0.0 (sun’s center) to Rv = 1.0 (solar limb), while features observed beyond the disk have an Rv value greater than 1.0.

1.3.2.3. The magnitude of the Rv is particularly useful in computing geometric foreshortening corrections. The spherical sun is observed as a projected disk on a flat image plane. The further a feature is from the center of the solar disk, the more distorted the projected image appears. This distortion foreshortens the image along a radial line. This effect makes features close to the solar limb appear compressed and parallel to the limb.

1.3.2.3.1. This foreshortening effect causes the observed (i.e., apparent or measured) area of a solar feature to be smaller than its true area by an amount related to the magnitude of the feature’s Rv. Application of a foreshortening correction permits conversion of measured areas (Am) to true—or Corrected—areas (Ac).

For sunspots:

$$Ac = \frac{Am}{\sqrt{1-(Rv)^2}}$$

For flares (allowing for the height of flares above solar surface):

$$Ac = \frac{Am}{0.2Rv+\sqrt{1-(Rv)^2}}$$

Figure 1.2. Orientation of Solar Directions (as seen looking south from northern hemisphere on the Earth).

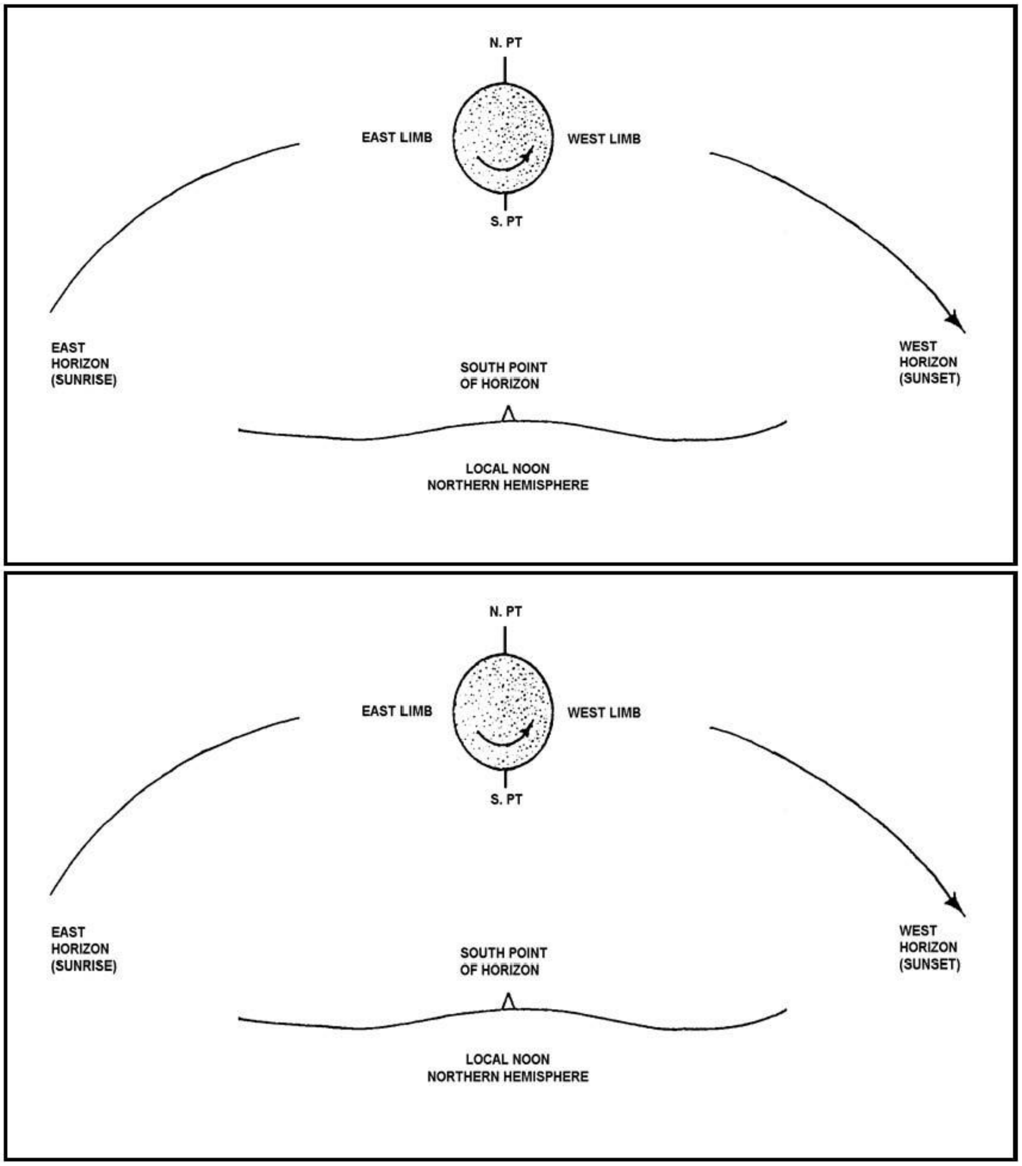


Figure 1.3. Solar Orientation at Sunset (as seen looking west from anywhere on the Earth).

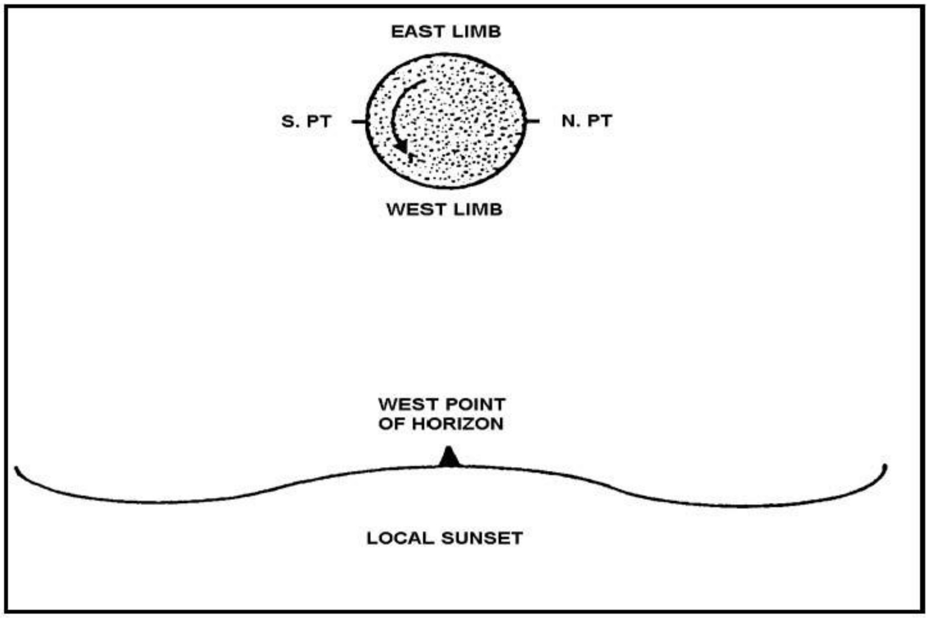
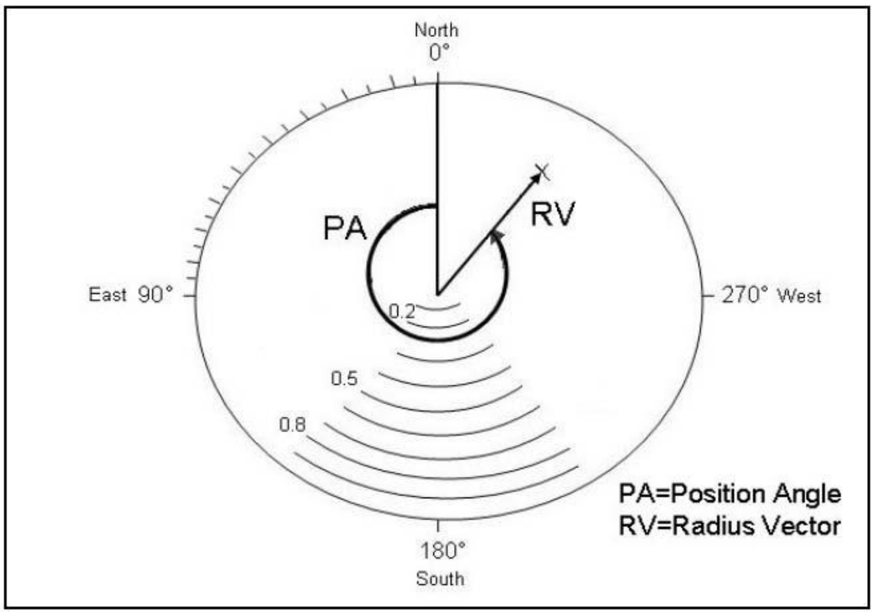


Figure 1.4. Geocentric Coordinates (note the counter clockwise determination of PA).



1.3.2.3.2. In the equations above, both Ac and Am are in units of "millionths of the solar disk". To convert Ac to "millionths of the solar hemisphere", use the relationship:

$$Ac(millionths\ of\ hemisphere) = \frac{Ac(millionths\ of\ disk)}{2}$$

1.3.2.3.3. All area measurements reported by United States Air Force (USAF) observatories are expressed in millionths of the solar hemisphere. The scientific community also uses square heliographic degrees to express corrected areas, which is calculated as follows:

$$One\ square\ heliographic\ degree = 48.5\ millionths\ of\ solar\ hemisphere$$

$$One\ millionth\ of\ solar\ hemisphere = 0.0206\ square\ heliographic\ degrees$$

1.3.3. Heliographic Coordinates. This coordinate system is based on the sun's axis of rotation, rather than the N-S reference line in the earth's sky (Figure 1.5). . It is used to measure and report the size and location of solar features. Charts using heliographic coordinates are published in one degree increments for B angle (see 1.3.3.2.) and are also called Stonyhurst Disks.

1.3.3.1. The P-angle (P) is the angle formed between the sun's North Pole rotation axis and the N-S reference line in the earth's sky. P-angle ranges from P = +26.31º (westward tilt, clockwise) in October to P = –26.31º (eastward tilt, counterclockwise) in April, with P = 0º occurring in July and January.

1.3.3.2. "Heliographic Latitude (B)" is measured from the solar equator (B = 0º) to +90º at the solar North Pole and -90º at the solar South Pole. The heliographic latitude that coincides with the center of the sun's visible disk is defined as "B_o", also called the "B-angle". Since the sun's axis is inclined 7.23° to a perpendicular line through the ecliptic plane, at times the sun's north pole may be visible, and at other times not visible (beyond the north solar limb). During the present epoch, B_o ranges from B_o = +7.23º in September to B_o = -7.23º in March, with B = 0º occurring in June and December. If B is positive, the solar North Pole is tilted toward the earth and is visible; if B_o is negative, the South Pole is tilted toward the earth and is visible.

1.3.3.3. Heliographic Longitude may be expressed as either "Central Meridian Distance (CMD)" or "Carrington Longitude (L)".

1.3.3.3.1. CMD is only applicable to the visible disk of the sun. It fixed with respect to an observer on earth. The line through the solar North and South Poles (not through the N-S reference line in the earth's sky) is defined as the central meridian and is assigned a CMD value of 0º. CMD from 0º to 90ºE corresponds to locations on the sun's eastern hemisphere. CMD from 0º to 90ºW corresponds to locations on the sun's western hemisphere.

1.3.3.3.2. Carrington longitude (L) rotates with the sun according to its 27.2753-day rotation period (as originally measured using sunspots). Longitude is measured from 0º to 360º in the direction of rotation (i.e., westward, counterclockwise as viewed from solar North Pole). As time passes, successively lower Carrington longitudes will occupy the central meridian. The Carrington longitude that occupies the center of the sun's visible disk (i.e., central meridian) is defined as L_o, which is published (along with P angle and B_o) daily at 0000 UT in the Astronomical Almanac and is calculated by the SOON computer system. L_o decreases by 360º every 27.2753 days at a rate of 13.2º per day or 0.55º per hour.

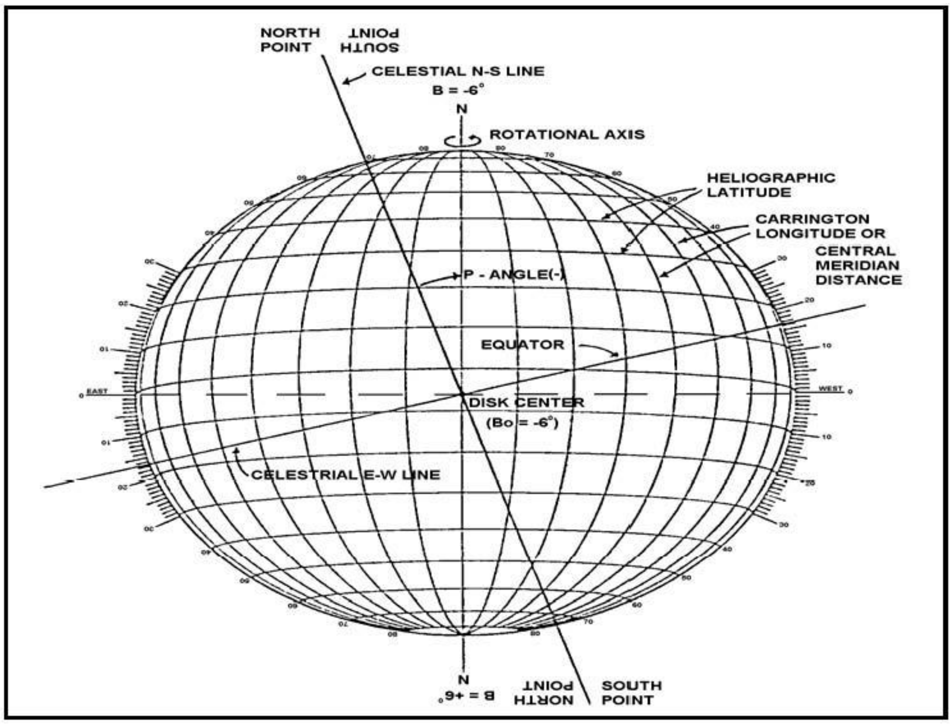
1.3.3.3.3. Carrington Rotation Number. The Carrington longitude reference system allows positional continuity of solar features over periods of many solar rotations.

Each time L_o = 0º passes the central meridian, the Carrington Rotation Number increases by one. This occurs every 27.2753 days. Carrington Rotation #1 started at 0000 UT, 9 November 1853, when L_o = 0º was defined as being at the central meridian.

1.3.3.3.4. The CMD of a solar feature can easily be converted to Carrington longitude.

EXAMPLE: A sunspot is located at 15ºN, 40ºE (CMD) at 1000 UT on 14 May 1991. What is the spot's Carrington longitude? The almanac lists L_o = 238.94º at 0000 UT on that date. Ten hours later L_o = 238.9° – 10hrs (0.55° per hr) = 233.4º. Since the spot is 40º east of the central meridian, the Carrington longitude L = 233.4 – 40 = 193.4º.

Figure 1.5. Heliographic Coordinates and Stonyhurst Disk (Example showing B = –6°).



1.4. Quality of Observation.

1.4.1. Seeing quality is the degree to which the observed solar image resembles the actual solar disk. The "quality of observation"—as reported in a Plain Language code (PLAIN), FLARE, Solar Disk and Limb Activity Summary code (DALAS), Sunspot code (SPOTS), or other data messages—combines the impact of atmospheric effects, observing continuity, and telescope condition. The analyst subjectively assesses overall quality and reliability of data being transmitted based on observing conditions. Quality of observation is scaled from 1 (very poor) to 5 (excellent) for both white light and Hα observations.

1.4.2. Poor atmospheric observing conditions decrease image resolution and stability. Most image degradation is caused by variations in the refractive properties of the earth's atmosphere between the telescope and the sun. Refractive index variations result from density irregularities, which cause convective currents, primarily in the lowest 1,000 feet in the earth's atmosphere. Such turbulence tends to exaggerate solar area measurements, while decreasing peak brightness measurements. Seeing conditions are generally best during the first two hours after sunrise, over water, or under a temperature inversion. Once atmospheric mixing in the boundary layer has begun, the shortest path through the turbulent layer produces the best seeing conditions (i.e., near local noon). Also, the presence of thin clouds can drastically influence both area and brightness measurements.

1.4.3. Equipment condition affects image quality. Problems that can degrade image quality include a poor vacuum in the telescope tube, poorly focused lenses, or smudges on the white light projection mirror.

1.4.4. Qualities of observation categories are listed in paragraph 4.2 for white light observations and in paragraph 5.2 for Hα observations.

1.5. Semiautomatic Operations.

1.5.1. When in semiautomatic operations, there are several common physiological and psychological factors that affect an analyst's ability to visually conduct patrol using the Hα video.

1.5.1.1. Analyst attention decreases after just a couple minutes of continuous viewing. Therefore, frequent short breaks from viewing help to relieve the monotony of continuous observing or detailed disk analysis.

1.5.1.2. When scanning the solar image, analysts tend to bias their scan toward the center of the image or toward a specific feature. Eyes focus on sharply contrasted regions, follow contours, or jump from one feature to another in a chain. This results in uneven scanning and missed information. To offset these tendencies, analysts must be aware of these natural inclinations and discipline themselves to perform a systematic and thorough scanning sequence.

1.5.2. During extended periods of low solar activity, certified SOON analysts must work at least one shift per quarter in semiautomatic operation mode. Frequent short periods of semiautomatic operations necessitated by poor observing conditions may satisfy this training requirement.

1.6. Observing and Analysis Aids. Each SOON site shall maintain the following:

1.6.1. A current copy of an ephemeris or Astronomical Almanac or internet source.

1.6.2. A complete set of 18cm clear plastic Stonyhurst overlays. A complete set consists of eight overlays constructed for $B_o = -7°$ to $+7°$, in one degree increments.

1.6.3. Monitor overlay grids.

1.6.4. Radius Vector overlays.

1.6.5. Sunspot area overlay.

1.6.6. Limb foreshortening overlay.

Chapter 2

SOON EQUIPMENT POWER-UP AND SHUTDOWN

2.1. General.

2.1.1. Types of equipment, equipment configuration, and power sources may vary with each observatory. Consult applicable SUMs when establishing local procedures. Use guidance provided in this chapter to develop local equipment and computer procedures to cover the following situations:

2.1.1.1. Normal Power-Up and Normal Shutdown (sunrise and sunset)

2.1.1.2. Complete Power-Up and Complete Shutdown during the observing day (e.g., during severe weather, such as lightning within 5 nautical miles; or when room environmental limits exceed safe/proper thresholds for computer or telescope equipment)

2.1.1.3. Emergency Power-Up and Emergency Shutdown during the observing day (e.g., when hazardous conditions exist or are imminent such as severe weather, flood, fire, electrocution, etc.)

2.2. Normal Power-Up Procedures.

2.2.1. Follow local procedures to preset all hardware and software to operate in either Semi-Automatic or Automatic patrol, depending on available light conditions during power-up. The following settings assume Normal Start-up occurs during light conditions suitable for Semi-Automatic patrol.

2.2.1.1. Ensure the vacuum pump is operational, the valve handle on the telescope tube is open (parallel to the vacuum line), and vacuum levels are within the normal range (check with maintenance for values). Do not open the telescope if the vacuum is not within the specified range.

2.2.1.2. Turn off the objective lens heater (if applicable).

2.2.1.3. Turn on the SOSS/SOON/WINDS server, if applicable.

2.2.1.4. Ensure the servo modules are set to the following positions.

2.2.1.4.1. RA and DEC: Manual (values should be set to normal stow position per local procedures).

2.2.1.4.2. Beam Selector: Position 1.

2.2.1.4.3. Flare Alarm: Computer.

2.2.1.4.4. Hα and SG: Full Disk

2.2.1.4.5. Hα B: B

2.2.1.4.6. All other Potentiometers: Manual and set to 500

2.2.1.4.7. SHS: Down position

2.2.1.5. Turn on the television and telescope power.

2.2.1.6. Turn on all TV cameras and monitors.

2.2.1.7. Turn on the SOON Rehost client monitors.

2.2.1.8. Open the guider lens cover (if necessary).

2.2.1.9. Ensure the guider threshold is set to "ENABLE" and is not set below an acceptable value (2.0 volts minimum).

2.2.1.10. Ensure the Scanner Box beam splitter is in Position "2".

2.2.1.11. Turn on any small computers (e.g., PCs) as needed.

2.2.2. Launch SOON/WINDS/SOSS consoles on the Rehost client.

2.2.3. Manually acquire the sun using the "RA" and "DEC" servo modules. (**CAUTION:** Avoid looking down the light path.).

2.3. Normal Shutdown Procedures - Tailor these listed actions as needed to meet local requirements:

2.3.1. Complete daily SACCT totals.

2.3.2. With the Polaroid removed, stow the telescope using the "RA" and "DEC" servo modules (set the "RA" potentiometer to approximately 900 and "DEC" potentiometer to approximately 100; these values may be slightly different at each SOON observatory due to variations in "DEC" and "RA" drive calibrations). Visually ensure the lens is seated in its cover.

2.3.3. Set Servo modules to the following positions. The following settings are for setting up for Semi-Automatic patrol. Adjust as necessary for local conditions.

2.3.3.1. RA and DEC: Manual (values should be set to normal stow position per local procedures).

2.3.3.2. Beam Selector: Position 1

2.3.3.3. Flare Alarm: Computer

2.3.3.4. Hα and SG: Full Disk

2.3.3.5. Hα B: B

2.3.3.6. All other Potentiometers: Manual and set to 500

2.3.3.7. SHS: Down position

2.3.4. Ensure Scanner Box Beam splitter in Position "2".

2.3.5. Close the guider lens cover.

2.3.6. **Important**: Prior to shutting down the Rehost client computer, analyst must perform a SOON data archival by clicking File>Archive Settings. Additional details are located in the SOONSUM and/or local SOPs. Power off Rack monitors, H camera, SPEC camera, SOON Telescope and Television power switches, and all computer monitors.

2.3.7. Turn off any small computers (e.g., PCs) as appropriate.

2.4. Develop and Publish Complete Power-Up and Power Down Procedures. Due to site and configuration differences, procedures will vary at each observatory. Develop these procedures to safeguard equipment from severe weather events (lightning within 5 nautical miles, tropical cyclones, departure from normal room environmental limits, etc.). Observatories will coordinate with maintenance personnel when developing these procedures to maintain safety and accomplish proper equipment configuration. Procedures will include step-by-step directions on how to restore power and re-establish patrol after complete shutdown is achieved.

2.4.1. Issue patrol status (STATS) messages to “down” and “up” the equipment as applicable (analysts will issue the “down” message prior to shutdown) and call the SPACEWOC (2WS/WXZ) to inform them of equipment status.

2.5. Emergency Shutdown/Emergency Power-Up Procedures. Due to site and configuration differences, emergency procedures will vary at each observatory. Regardless, local procedures will specify actions in case of severe weather, flooding, fire, electrocution, etc. The procedures will highlight which buildings, power sources (e.g., 110V/60 Hz or 250V/50 Hz), and circuit panels will be affected by each shutdown action. The procedures will also include step-by-step directions on how to restore power and re-establish patrol after the emergency is over.

Chapter 3

SOLAR OPTICAL OBSERVING

3.1. Opening Procedures.

3.1.1. Arrival on Site.

3.1.1.1. Arrive early enough to accomplish all opening procedures before sunrise. For SOON operations, local optical sunrise is defined as the first full minute the entire disk is above the apparent horizon, which is based on a smooth oblate spheroid earth adjusted to reflect permanent local obstructions such as ridge lines or buildings.

3.1.1.2. Review notes from the previous shift, latest Daily Operational Summary (NWXX60) message, overnight WINDS traffic from other sites (e.g., region additions or changes and solar activity messages), and equipment outage logs.

3.1.1.3. Perform an environmental check. Observe the hygrothermograph or its equivalent. When either the room temperature or relative humidity exceed environmental limits (listed below) for more than 30 minutes, perform a "Complete Shutdown" of the computer and/or telescope equipment (as appropriate). Use local "Complete Shutdown" procedures developed with the aid of guidance in AFWAMAN 15-1, TO 31M1-2FMQ7-1, and the SOONSUM. Periodically perform an environmental check throughout the observing day.

3.1.1.3.1. Telescope room: 60° to 80° F and 30% to 60% relative humidity.

3.1.1.3.2. SOON/SOSS Server room: 50° to 90° F with a max graduation of 10° F per hour and 20% to 80% relative humidity with a max graduation of 10% per hour.

3.1.2. Power Up. Power up equipment and boot the computer using local "Normal Power-Up" procedures developed with guidance from chapter 2 and TO 31M1- 2FMQ7-1.

3.1.3. If FLARE or DALAS activity is in progress when patrol is acquired (at sunrise or after a break in patrol), perform the following:

3.1.3.1. If possible, prepare a FLARE or DALAS code message IAW AFMAN 15-124. Use the start time of patrol as the FLARE or DALAS start time, using appropriate time and data qualifiers.

3.1.3.2. If enough reliable data could not be collected for a meaningful FLARE or DALAS coded message, send a PLAIN message instead. This PLAIN will advise the 2WS SPACEWOC (2WS/WXZ) that some activity occurred, but not enough to initiate a FLARE or DALAS report.

3.1.3.3. If the activity is event-level, the analyst has two options:

3.1.3.3.1. If it is known that the activity has been reported by another observatory more than 15 minutes earlier, do not send an EVENT code message. Instead, use routine (AXXX61) Manual of Operations (MANOP) headers for the FLARE or DALAS code message. A common example is a long duration Loop Prominence System (LPS).

3.1.3.3.2. If it is not known whether the activity has been reported by another observatory more than 15 minutes earlier, respond as if it were a new event. Send an event (SXXX61) MANOP header for the FLARE or DALAS code message. Also, append a PLAIN indicating you just acquired the sun and that the event may or may not be new activity.

3.2. Patrol Procedures.

3.2.1. Region Definitions and Analyses Boxes.

3.2.1.1. Maintain updated region definitions and region acquisitioning using Region Definition tables, Region Display Console, Sequence Table Editor, and the lead site's latest analyses boxes (BXOUT) message. The lead site is the SOON site that is "on the sun" when an observatory first comes up. The lead site may transfer lead status to another site because of weather, equipment problems, etc.

3.2.1.1.1. Video sequences must contain the "regions of special interest" from the Space Weather Prediction Center (SWPC) Data Acquisition Request bulletin (AXXX05 KWNP), the active regions listed in the SWPC Region Summary bulletin (AXXX02 KWNP), newly spotted regions, and other active regions considered to have flare potential. **NOTE:** The SWPC invites inputs and suggested changes from SOON analysts concerning the regions of special interest.

3.2.1.1.2. At a minimum, sample each region of special interest every 30 seconds and other active regions every minute.

3.2.1.1.3. Set up sequences to minimize scanner mirror movements. Place significant regions last in each sequence, so they will be visible for a longer period of time.

3.2.1.1.4. Ensure automated hourly histogram history (HSTRY) reports are transmitted for the regions of special interest.

3.2.1.2. Intersite analysis box procedures.

3.2.1.2.1. All SOON sites will use identical Magnetic Reference Region (MAGR) analysis boxes.

3.2.1.2.2. All SOON sites will use similar analysis boxes for any given active region. Region center coordinates will be within ±10 arc seconds in box height and width, and ±5° in box center location.

3.2.1.2.3. During operating hours, whether you are actually on patrol or not, review and, as appropriate, load all box changes or additions received from other sites Check overnight WINDS traffic for any added SN/DL (serial numbered/disk or limb) regions after auto-BXOUTs are transmitted. The latest auto-BXOUT may not be the most current BXOUT. Updating boxes as required ensures automatically generated BXOUT messages will pass the most current information to the next site. Use the Region Display Console to display how the boxes look on the disk, and to check for duplications.

3.2.1.2.4. Coordinate locally assigned box numbers with other operating observatories to prevent more than one number being used for the same region, or the same number being used for different regions.

3.2.1.3. Periodically check analysis boxes (including MAGR) to ensure they are producing good data. *Modify boxes only when necessary.* When boxes are changed or added, or when a region is updated or added, transmit a BXOUT message. Ensure automated BXOUT reports are transmitted every three hours.

3.2.2. Patrol Status (STATS) Reports. Transmit an initial STATS message as soon as feasible after optical sunrise, whether or not patrol is acquired. During the day, report each interruption in observation that exceeds 5 minutes as a break in patrol. Conversely, report periods of observation exceeding 2 minutes as patrol. Report all transitions between automatic and semiautomatic patrol. Transmit a final STATS message as soon as feasible after the end of the observing day.

3.2.2.1. Patrol is possible when the telescope displays an image that will permit collection and analysis of flare data in either semiautomatic or automatic mode. Maintain patrol as long as flare data can be collected even if the data must be qualified "Very Poor".

3.2.2.2. If unable to acquire the sun at sunrise (e.g., power outage, clouds, severe weather, etc), do not delay transmitting an initial STATS message showing which solar sensors are "inoperative at sunrise". If unable to transmit messages, telephone the SPACEWOC, and inform them of the problem and when patrol is expected to begin. If appropriate, ask the 2WS SPACEWOC to inform SWPC and other SOON observatories.

3.2.2.3. All patrol times reported represent actual times patrol was lost or regained. This may not be the current time, transmission time, or the time equipment is logged out for maintenance.

3.2.2.4. If the reported expected outage time is later changed or exceeded, transmit as soon as practical a new STATS message to extend downtime.

3.2.3. Observing Routine.

3.2.3.1. Initiate semiautomatic patrol, IAW paragraph 3.4 below, whenever automatic patrol cannot be established or maintained (e.g., computer or equipment outage, clouds, or light levels too low for automatic flare detection).

3.2.3.2. At least daily, run optical calibration checks and perform alignment checks to ensure the optical system is properly calibrated.

3.2.3.3. Check daily and adjust, if needed, the image rotator value by performing an image drift in full disk using an Hα feature displayed on a monitor. Incorporate guidance from applicable TOs to create local procedures for this adjustment. At least once a week, check the drift of a sunspot on the white light projection board. Weekly white light checks ensure greater consistency between observatories.

3.2.3.4. At least hourly, scan the sunspot image board, including the Hα disk and limb (whether in automatic or semiautomatic mode) to detect changes in active regions, filaments, prominences, or other features. During event-level flares, check more frequently to detect flare-induced changes or white light flares. Use Movie Console images to detect filament changes or disappearances. In semiautomatic mode, make TV monitor Hα observations at least every 3 minutes for flare patrol.

3.2.3.5. Make a magnetic field analysis (using Spectrograph Analysis or manual method), whether in automatic or semiautomatic operations, for at least:

3.2.3.5.1. All regions of special interest listed in the SWPC Data Acquisition Request bulletin (AXXX05)

3.2.3.5.2. All spotted regions with a suspected magnetic class of Beta-Gamma or greater.

3.2.4. Forms and Data Reporting.

3.2.4.1. Use AFWA IMT 17, *Solar Optical Worksheet*, Attachment 2, to record flare, DALAS, and patrol data, whether in automatic or semiautomatic operations. Use AFWA Form 21, *Sunspot Analysis Worksheet*, Attachment 3, to draw and analyze sunspots.

3.2.4.2. Transmit data reports as soon as possible, not to exceed time limits stated in this chapter and summarized in Attachment 4.

3.2.5. PLAIN Reports.

3.2.5.1. Transmit scheduled (AXXX60 MANOP header) PLAIN messages by the prescribed file times. Include a detailed description of each SWPC numbered region, or interesting locally numbered region, at least once each observing day for regions with a magnetic complexity of Beta or greater. Include Beta-Gamma or more complex regions in each report. Concentrate on changes or information not previously reported in a PLAIN or coded message. Avoid using program names or other terms in a PLAIN that may not be known or clear to all recipients. Use the format and content described in Attachment 5. **NOTE:** If no patrol was possible during the period due to weather or maintenance, send an abbreviated PLAIN that covers the requirements of the first section. As applicable, include any scheduled maintenance in the abbreviated PLAIN.

3.2.5.2. Transmit unscheduled PLAIN messages as needed to clarify information in coded data reports or to report information not reported in any other message. These PLAIN messages may be appended to coded data messages, or sent separately using an AXXX61 MANOP header.

3.2.6. FLARE Reports.

3.2.6.1. Report sampled activity as a flare when it meets the following criteria:

3.2.6.1.1. In automatic mode: The sampled activity increases in brightness, in two minutes or less, to an intensity at least 50% above the surrounding background, *and* the area at or above this intensity level has a corrected area of at least 10 millionths of the solar hemisphere. **NOTE:** Normally the histogram flare threshold is set at 160%, which represents a brightness level of about 60% above the surrounding background intensity. Variations in background plage intensity (see 5.1.3.) or observing conditions may require an analyst to set the threshold as low as 140% or as high as 220%.

3.2.6.1.2. In semiautomatic mode: The sampled activity increases in brightness, in two minutes or less, to an intensity that produces brightening over a total Hα line width (red shift plus blue shift) of at least 0.8 Angstroms, *and* the corrected area which displays this brightening is at least 10 millionths of the solar hemisphere.

Examples: a 0.4 red shift and a 0.4 blue shift, a 0.8 red shift alone, or a 0.8 blue shift alone.

3.2.6.2. For event-level flares, transmit preliminary report within 2 minutes of flare meeting event threshold in automatic mode (15 minutes if in semi-automatic) using the SXXX61 MANOP header. Transmit final event-level flare reports within 10 minutes after flare ends in automatic mode (20 minutes if in semiautomatic) using the AXXX61 MANOP header. For non-event flares, preliminary reports are optional, but are encouraged if time permits; transmit final reports within 15 minutes after flare end in automatic mode (30 minutes if in semiautomatic) using an AXXX61 MANOP header..

3.2.6.3. If a computer-generated FLARE message appears to be incorrect, evaluate the data and correct the message if necessary. If data collected by the SOON computer is used to produce a new data report, the method/type of observation should still be coded (using T in the TIBcc group) as "electronic" (i.e., automatic). If the SOON computer was not used to produce the new data report and any of the following parameters are changed, the method/type of observation should be coded as "visual" (i.e., semiautomatic):

3.2.6.3.1. Time groups (start, peak, or end).

3.2.6.3.2. Flare importance, location, or corrected area.

3.2.6.3.3. Flare brightness. **NOTE:** Encode FBBbb as "/////".

3.2.7. DALAS Reports.

3.2.7.1. Use AWS TR 75-252 and this guidance to identify and analyze DALAS activity. DALAS phenomena are not limited to the disk or limb, but may extend beyond the limb, such as a surges or prominences.

3.2.7.2. Report Disappearing Solar Filaments (DSFs) equal to or greater than 5 square heliographic degrees as soon as detected. It is optional, but encouraged, to report DSFs less than 5 square heliographic degrees. Reporting DSFs are second in importance to flare reporting. The DALAS code 22222 data continuation line is mandatory for a DSF report.

3.2.7.2.1. If the exact DSF start time is not observed, use the last time the filament was observed as the start time and use the time qualifier s = 3, "Activity started after GGgg". If the exact end time is not observed, use the time the filament was first observed to be absent as the DSF end time and use the time qualifier e = 2, "Activity ended before GGgg". Report the location of the DSF at the time the filament was last visible. In all cases, ensure the date in the “YMMDD” group in line three of the code relates to the start time of the activity.

3.2.7.2.2. Overnight DSFs. Report DSFs that occur between the end of patrol on the previous day and the start of patrol on the current day. Use the DALAS code if the period between "start time" (i.e., the last time the filament was observed) and the "end time" (i.e., the time the filament was first observed to be absent) does not exceed 24 hours. If the period exceeds 24 hours, the DALAS code cannot be used. In this case, report relevant information about the DSF in the next scheduled PLAIN or in an unscheduled PLAIN. Analysts should coordinate with other observatories to narrow the period between "start time" and "end time" for overnight DSFs (i.e., the analyst need not base the DSF report on only what was observed at the local observatory).

3.2.7.3. Transmit non-event final reports no later than in the final (AXXX62) patrol message at the end of the observing day. Use an AXXX61 MANOP header for all nonevent DALAS reports.

3.2.8. Interrupted Patrol. If patrol is lost (due to clouds, power outages, etc.) and flare or DALAS activity was in progress at that time:

3.2.8.1. Keep the flare (or DALAS activity) in progress if it can be seen intermittently through breaks in the clouds, even though official patrol cannot be maintained.

3.2.8.2. If no observations are possible after 45 minutes for a flare, or 2 hours for a DALAS phenomenon, issue a final message using the time the activity was last seen as the end time, with the appropriate qualifiers. **NOTE:** Use good judgment when applying the 45 minute or 2 hour criteria. Flare and DALAS duration is roughly correlated with flare size or DALAS type, but consider other data sources such as bulletins from other observatories, radio burst information, etc.

3.2.8.3. Issue the final message immediately if there is no reason to expect patrol to be reacquired. However, if patrol is later reacquired and the activity is still in progress, transmit a correction to the final (use report status S = 3) and replace the end time group with /////. Append a PLAIN to indicate what you did and why you did it. Append the “AMD” modifier to the end of the message DTG. When the activity does end, the final message must be sent as a correction (S = 3) or it will fail to be accepted in the SPACEWOC database, since only a correction or deletion can replace an existing correction.

3.2.9. SPOTS reports.

3.2.9.1. Perform sunspot analysis daily during the best viewing available, normally within two hours after sunrise.

3.2.9.2. Transmit one sunspot data report each GMT day. Sites (excluding Learmonth) that change GMT dates during their observing day will transmit their SPOTS message before the end of the initial GMT day. If no sunspots were seen, or no observations were possible, by the end of a GMT day, transmit a truncated SPOTS report IAW AFMAN 15-124, *Meteorological Codes*. **NOTE:** The SWPC forecaster must receive a SPOTS report by 2300Z in order to include the data in their Solar Region Summary.

3.2.9.3. Before transmission, review the SPOTS report for consistency by checking it against reports from other observatories and SWPC. **CAUTION:** The SWPC classification of a region, listed in the Solar Region Summary, is a weighted average based on reports from several observatories and should be used only as a guide. The analyst should not change observations to match these other reports.

3.2.10. Adverse Weather.

3.2.10.1. Protect the telescope objective lens from blowing dust, sand, other potentially abrasive materials, and precipitation by stowing it in right ascension and declination. Ensure the lens is sealed within its protective cover. For brief periods, it may be sufficient to lower the lens in declination into its lens cover, while the telescope continues to track the sun in right ascension.

3.2.10.2. If thunderstorms or lightning occur within 5 nautical miles of the site, perform a computer and telescope "Complete Shutdown" using local procedures developed with guidance outlined in Chapter 2, TO 31M1-2FMQ7-1, and the SOONSUM.

3.2.10.3. If winds greater than or equal to 50 knots (sustained or gusts) are imminent or forecast to impact the observatory, perform a computer and telescope "Complete Shutdown" using local procedures developed with guidance outlined in Chapter 2, TO 31M1-2FMQ7-1, and the SOONSUM.

3.2.11. Emergency Shutdown. When severe weather, fire, flooding, electrocution, or other hazard immediately threatens the facility, equipment, or personnel, use local "Emergency Shutdown" procedures developed with guidance outlined in Chapter 2, TO 31M1-2FMQ7-1, and the SOONSUM.

3.2.12. Complete Power Up Procedures. After a "Complete Shutdown" of the computer and/or telescope systems (e.g., due to thunderstorms or exceeding room environmental limits), or an "Emergency Shutdown", perform a computer and telescope “Complete Power Up” using local procedures developed with guidance outlined in Chapter 2, TO 31M1-2FMQ7-1, and the SOONSUM.

3.2.13. Shift-Change Briefings. As a minimum, include:

3.2.13.1. Recent or current activity (both optical and radio), observed locally or at another site using information gleaned from the latest SWPC bulletins, include active regions due to return within the next several days.

3.2.13.2. Equipment, power, communications, or computer outages/problems. Include anticipated PMI and other problems or outages.

3.2.13.3. Status of other sites.

3.2.13.4. Any special support requirements.

3.2.13.5. Any shift duties not accomplished.

3.3. Closing Procedures.

3.3.1. Termination of Patrol.

3.3.1.1. Maintain automatic patrol as long as light levels allow accurate flare detection and analysis. Each site will establish a minimum threshold for analysts, and redefine that value when equipment adjustments are made. Never adjust the guider threshold below 2.0 volts in an attempt to maintain automatic patrol.

3.3.1.2. Continue semiautomatic patrol as long as conditions allow reasonably accurate flare detection and analysis, even if the data must be qualified "Very Poor".

3.3.1.3. Transmit a final patrol (STATS) message (using an AXXX62 MANOP header), and the End of Day Summary (NWXX60) message, using the appropriate file time. A combined summary message with STATS, FLARE, and DALAS (DALAS ended earlier and/or in progress at sunset) may be sent.

3.3.2. Flare or DALAS Activity in Progress at Optical Sunset.

3.3.2.1. Prepare a final FLARE or DALAS code message IAW AFMAN 15-124. Use the end time of patrol as the FLARE or DALAS end time, using appropriate time and data qualifiers.

3.3.2.2. If enough reliable data could not be collected before sunset for a meaningful FLARE or DALAS coded message, send a PLAIN message that informs the 2WS SPACEWOC that some activity occurred.

3.3.2.3. Send any FLARE, DALAS, and/or PLAIN messages generated by the Rehost client, if applicable, after ending patrol.

3.3.3. Data Archival. Prior to shutting down the Rehost client computer, perform a SOON data archival by clicking File>Archive Settings. Additional details are located in the SOONSUM and/or local SOPs.

3.3.4. Final Closing Actions.

3.3.4.1. After terminating patrol, enter solar patrol data using guidance in Chapter 2.

3.3.4.2. Turn off equipment using locally developed "Normal Shutdown" procedures. If thunderstorms are forecast overnight or observed nearby at sunset, follow computer and telescope "Complete Shutdown" procedures instead.

3.3.4.3. As necessary, leave notes for the next day's early shift addressing topics normally covered in a shift briefing. **EXAMPLE:** If a "Complete Shutdown" was performed at sunset, inform the morning analyst that extra power up steps will be necessary.

3.4. Semiautomatic Operations.

3.4.1. Attempt semiautomatic operations whenever automatic operations cannot be established or maintained (e.g., computer or equipment outage, clouds, or low light levels). Follow observing routines, analysis techniques, and reporting requirements specified elsewhere in this chapter.

3.4.2. Initiation. Notify the field (SPACEWOC, SWPC, and other SOON observatories) via a patrol (STATS) message whenever semiautomatic patrol is initiated or terminated. If unable to transmit messages, telephone the 2WS SPACEWOC. If applicable, ask the SPACEWOC to inform SWPC or other observatories.

3.4.3. Flare Analysis.

3.4.3.1. Use the Monitor Overlay method or SOON Rehost for making flare area measurements.

3.4.3.1.1. Check and recalculate, if required, the Monitor Overlay site correction factor anytime an adjustment is done which could affect the TV image (e.g., Hα light path or vidicon alignment). Check and recalculate, if required, the monitor overlay site correction anytime an Hα light path alignment is performed (except for minor focus adjustments).

3.4.3.1.2. Do not adjust the height or width controls, since this will affect the accuracy of the site correction factor.

3.4.3.2. As an aid to making brightness (intensity) measurements, each site will develop local Doppler shift tables, which list the correct Automatic Gain Control (AGC), 1-Angstrom, and 1/2-Angstrom settings for each off-band measurement. Use these tables to determine a flare's intensity category as described in Chapter 6. You can also use the DALAS off-band measurement capabilities located in the Analysis Console Window.

3.4.3.3. In automatic mode, a flare must attain a corrected area of at least 10 millionths of the solar hemisphere above intensity thresholds before it can be categorized as an F, N, or B flare. In semiautomatic mode, this requirement is waived for the N and B thresholds, when off-band measurements are sufficient. However, the sampled activity must still meet the criteria of total corrected area (equal to or greater than 10 millionths of the solar hemisphere) to be declared a flare.

3.5. Event-level Activity.

3.5.1. Optical Event Thresholds.

3.5.1.1. All 2B, 3F, 3N, 3B, 4F, 4N, 4B flares.

3.5.1.2. Impulsive limb activity (spray, surge, eruptive prominence, etc) which attains a radial extent of 0.15 solar radius or greater above the limb (or from the point of origin for combined disk/limb activity).

3.5.1.3. Disk or limb Loop Prominence System (normally a post-flare phenomenon), whether or not the causative flare was observed.

3.5.2. Reports. Send required data reports as soon as possible, not to exceed time limits specified below and summarized in Attachment 4.

3.5.3. Event-level Flares.

3.5.3.1. Transmit a preliminary event-level FLARE message within 2 minutes after event threshold start if in automatic mode (15 minutes if in semiautomatic). **Note:** A new preliminary message must be sent anytime an in-progress, event-level FLARE increases in either area or brightness to a higher threshold. This will enable SPACEWOC to maintain situational awareness throughout the FLARE life-cycle and issue warnings accordingly.

3.5.3.2. Transmit a final FLARE message within 10 minutes of flare end if in automatic mode (20 minutes if in semiautomatic).

3.5.4. Event-level DALAS Activity.

3.5.4.1. Transmit a preliminary event-level DALAS message within 10 minutes after event identification, whether in automatic or semiautomatic mode. **NOTE:** Extra preliminary DALAS code messages may be appropriate.

3.5.4.2. Transmit a final DALAS code message within 20 minutes of activity end, whether in automatic or semiautomatic mode.

3.5.5. Hard Copies. After an event-level flare, analysts must run Flare Analysis tools and make hard copies for post-analysis, quality assurance, and training purposes. Contractor-operated sites shall forward these hard copies monthly to the AFWA Contract Office Representative (COR).

3.6. Common Event Procedures.

3.6.1. MANOP Headers. Select the appropriate event (SXXX60 EVENT or SXXX61 prelim) or routine (AXXX61 optical) MANOP header IAW guidance provided in this manual, AFMAN 15-124, and AFWAI 15-2. For event-level activity in progress when patrol is acquired (either at sunrise or after a break in patrol), consult paragraph 3.1.3.

3.6.2. Event-Level Messages. Between sunrise and sunset, transmit an event-level preliminary message within timeliness criteria when:

3.6.2.1. Any event threshold is reached at the observatory.

3.6.2.2. Another observatory sends an initial (SXXX61) event-level FLARE, DALAS, BURST or SWEEP message and you have criteria meeting event thresholds. If no thresholds are met or observation is not possible due to clouds etc. respond with the appropriate EVENT code message.

3.6.2.3. An event is in progress and another event threshold is reached at the observatory or at another site.

3.6.3. Event Message Acknowledgment. The SPACEWOC decodes all BURST, SWEEP, DALAS, FLARE, EVENT SXXX60, and SXXX61 prelim MANOP header messages in real-time.

3.6.3.1. If the solar event exceeds supported operator established criteria (optical flare 2B, 3B, 4B, 3F, 4F, 3N and 4N), the SPACEWOC issues a warning.

3.6.3.1.1. The SPACWOC issues a WOXX51 KGWC bulletin for optical flares equal to or greater than 3B.

3.6.3.1.2. The SPACEWOC issues a WOXX50 KGWC bulletin when solar x-ray flux (as measured by GOES spacecraft) equals or exceeds M1. When x-ray data is unavailable, the SPACEWOC issues a WOXX50 KGWC if an optical flare equal to or greater than 2B occurs.

3.6.3.2. If the observatory does not receive a warning within 3 minutes of event transmission, call the SPACEWOC and retransmit the event message.

3.6.3.3. If transmission of an event-level message is precluded for any reason, phone the SPACEWOC immediately.

3.6.3.4. Continue attempts to make rapid event notifications until the warning is received, a phone call is completed, or 15 minutes have elapsed from the time when event criteria or maximum was reached.

3.6.3.5. Retransmit any activity messages issued but not included in the summary reports. Include a PLAIN remark stating the reason for the retransmission.

3.6.3.6. Review summary bulletins throughout the day, at least once per observing shift.

3.6.4. REQST Message. When responding to a REQST message (TXXX50) from the SPACEWOC, observatories will respond with observed data within 2 minutes using the appropriate EVENT code IAW guidance in AFMAN 15-124, Chapter 6.

Chapter 4

SUNSPOT ANALYSIS TECHNIQUES

4.1. Sunspot Properties.

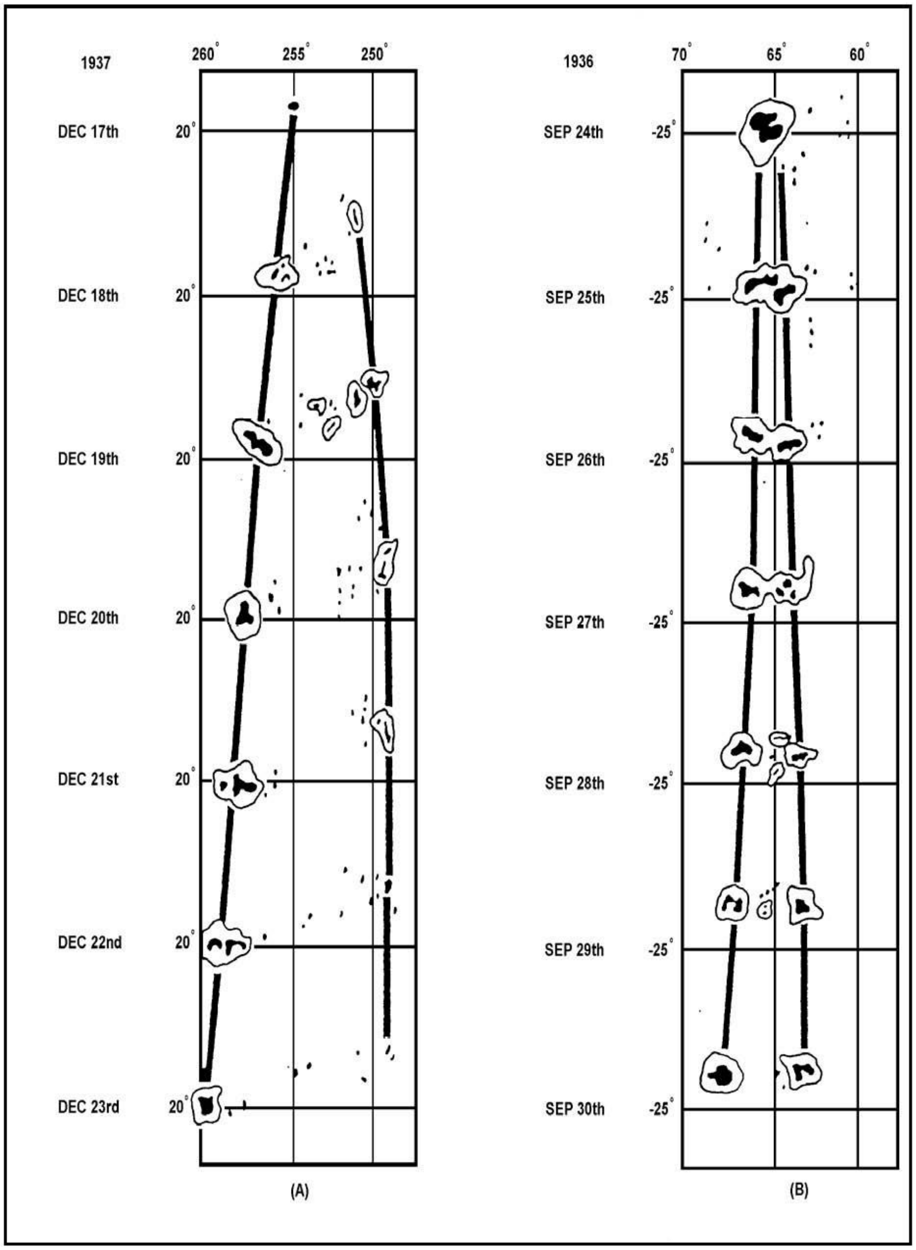
4.1.1. Sunspots. Sunspots are relatively dark patches on the solar photosphere. This is because strong vertical magnetic fields cool photospheric gases (from about 5800 K to 3800 K) and decreases radiation output. This darker area is called *umbra* (Latin for "shadow"). Sunspots are not black; they would still be bright to human eyes; however, when photospheric brightness is filtered, sunspot umbrae appear very dark. Larger sunspots are often surrounded by a less dark striated fringes called penumbra ("next to shadow"), where the vertical magnetic fields in the umbra branch out more horizontally near the edges of the sunspot. Sunspot diameters vary in size up to 100,000 kilometers (about 2500 millionths of the solar hemisphere).

4.1.2. Sunspot Groups. A sunspot exhibits a magnetic polarity: north or south. Sunspots tend to form in what are called sunspot groups, which contains spots of both polarities, connected by magnetic fields looping upward into the solar atmosphere. Spot groups rotate with the sun from east to west (left to right on the solar disk, north being up). In a group, there are normally two dominant sunspots, one of each magnetic polarity, roughly oriented on an east-west line. Of these, the leading spot (also called the *leader*, *preceding*, or *western* spot) usually is the first to form, is the first to develop penumbra, becomes the largest, has the strongest magnetic field, and is the last to dissipate in the group. The leader is normally situated closer to the equator than the trailing spot (also called the *trailer*, *following*, or *eastern* spot). This "tilt" in the group's major axis is evident in both solar hemispheres. When there exists a sunspot group with only one magnetic polarity ("unipolar"), its magnetic field that loops back into the surrounding photosphere is too weak to cause visible spots of the opposite polarity.

4.1.3. Sunspot Motion. Sunspot groups rotate with the sun; however, individual spots also move with respect to each other. Such relative motion is measured with respect to the rotating Carrington coordinate system (see 1.3.3.3.2.) and is called "proper motion". The proper motion of sunspots is caused by magnetic flux emerging from the photosphere and by *differential solar rotation*. The sun does not rotate as a solid body like the earth. Instead, it rotates as a fluid: slowest at the solar poles and fastest at the solar equator, with a gradual change in speed in between described as *differential rotation*. . Because the leader sunspot in a group usually lies at lower solar latitude than the trailer spot, differential rotation slowly widens the longitudinal separation between these spots (Figure 4.1). Once a sunspot group reaches its maximum longitudinal width, its proper motion usually stabilizes, or the group decays as its magnetic fields weaken. Sunspots within a region will occasionally converge or revolve around each other), or a major individual spot may rotate about its own axis. These relative motions tend intensify magnetic fields, gradients, or shear, which increases the potential for flare activity (sudden releases of magnetic tension).

4.1.4. Spot Growth and Decay. Individual spots may last a few hours to a few weeks, while a sunspot group may persist several months. Sunspot formation begins as short-lived tiny spots called "pores". Excellent or good seeing conditions are required to see such small features. If the magnetic fields strengthen and continue to emerge, pores become more persistent and mature into sunspots.

Figure 4.1. Proper Motion of Sunspots



4.1.4.1. The growth and decay rate of individual spots in a group varies. Growth (or decay) is identified by an increase (or decrease) in umbral darkness, in umbral/penumbral area, or in the number of intermediate spots. Growth rate is generally more significant in portending flare activity than an equivalent decay rate. The more rapid the growth or decay, the more significant its reflection of flare activity. Growth in one segment of a group accompanied by decay in another segment is equally significant.

4.1.4.2. "Light bridges" appear as bright material extending across an umbra. They usually form slowly and may last up to several days. Rapid formation of light bridges often precedes rapid spot fragmentation and increased flare activity.

4.2. White Light Seeing Categories.

4.2.1. Seeing = 1 (Very poor).

4.2.1.1. Extreme limb movement observed. Faculae (see 5.1.1.) are not visible.

4.2.1.2. Sunspots on the disk appear blurry with no definite shape. Separation between umbral areas in large spots is not detectable. Penumbrae are ill-defined.

4.2.1.3. No pores, granulation (cellular brightness pattern in the photosphere), or small sunspots are visible.

4.2.2. Seeing = 2 (Poor).

4.2.2.1. Moderate limb movement observed. Faculae and spots near the limb lack definite outlines.

4.2.2.2. Spots on the disk are badly blurred. Small spots are visible, but those closely spaced seem to merge. No details are detectable in penumbral areas, and umbrae lack definite outlines.

4.2.2.3. No pores or granulation are visible.

4.2.3. Seeing = 3 (Fair).

4.2.3.1. Image movement is observed on the limb and disk. Faculae near the limb have definite outline but are slightly blurred.

4.2.3.2. Small spots are blurred, large spots are only slightly blurred. Umbrae and penumbrae are well separated, but with very little fine structure visible.

4.2.3.3. Pores and granulation are occasionally visible.

4.2.4. Seeing = 4 (Good).

4.2.4.1. Only slight limb movement is noticeable. Faculae near the limb are sharply defined. Small umbrae near the limb are detectable.

4.2.4.2. Small details are visible within the large penumbral areas on the disk. Boundaries of penumbral and umbral areas are well-defined. Light bridges, if any, are detectable.

4.2.4.3. Spots, pores, and granulation are visible, but show slight movement.

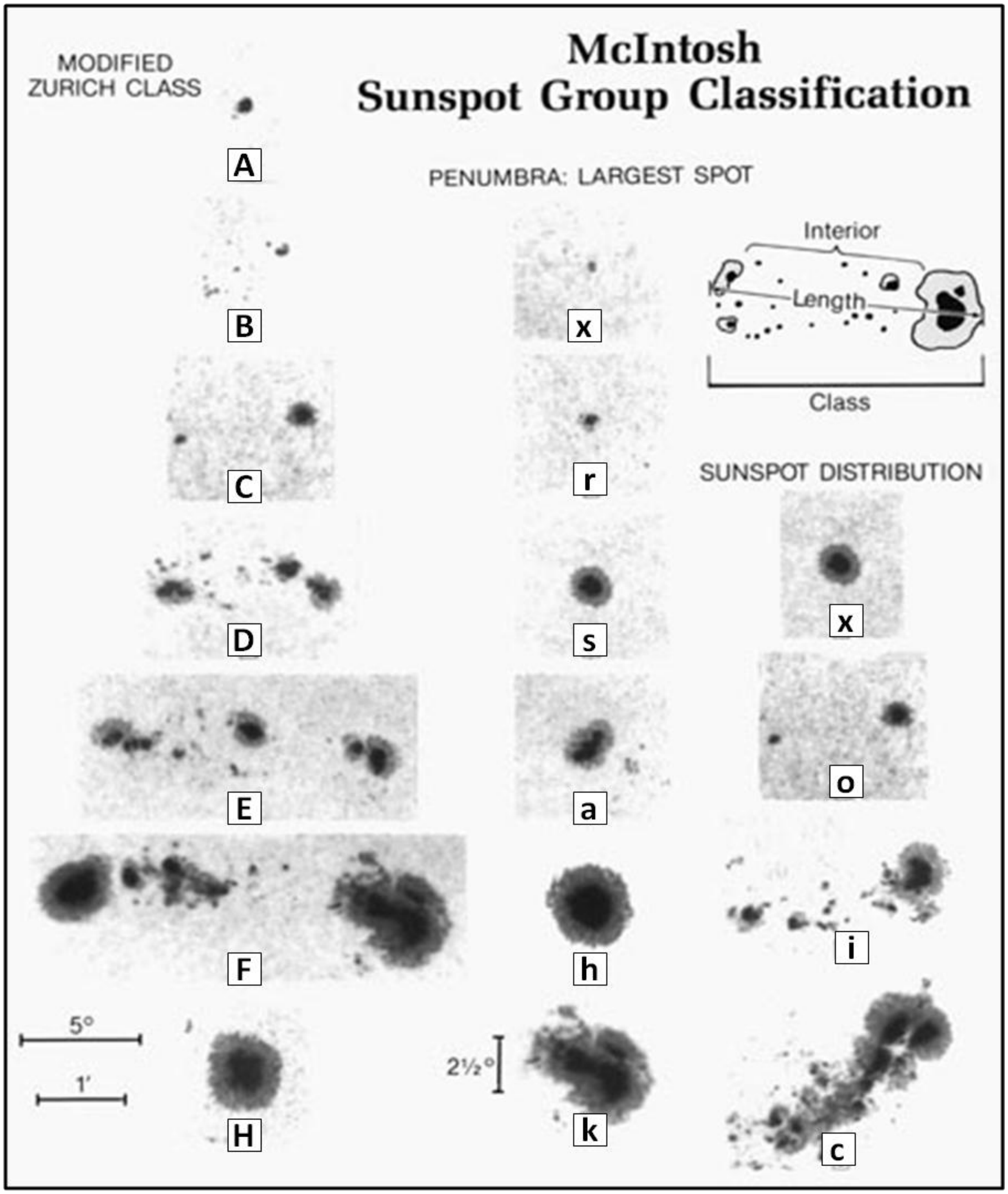
4.2.5. Seeing = 5 (Excellent).

4.2.5.1. Limbs are extremely stable (show no movement). Faculae and small spots near the limb are clearly defined and stable.

4.2.5.2. Boundaries of penumbrae and umbrae are sharply defined and show no motion. Very fine detail is observable within penumbral areas on the disk.

4.2.5.3. Small spots, pores, and granulation are sharply defined.

Figure 4.2. Modified-Zurich Sunspot Classification System.



4.3. Modified-Zurich Sunspot Classification System. This classification system, developed by Patrick McIntosh while he was at the National Oceanic and Atmospheric Administration's Space Environment Laboratory, is based on a sunspot group's appearance in white light. There are three components to the system: sunspot class, penumbral class, and sunspot distribution (Figure 4.2 previous page).

4.3.1. Unipolar and Bipolar Groups.

4.3.1.1. A unipolar group matches only one magnetic field polarity. It is defined as a single spot (Class H) or a compact cluster of spots (Class A) with the greatest separation between spots less than 3º. In the case of a group with a single encompassing penumbra greatest separation is defined as the distance between the center of the largest umbra and the nearest edge of its penumbra. Due to the width of the principal spot, such a group may have an overall length (along its major axis) of up to 5º. **NOTE:** degree distances are assumed to be heliographic degrees.

4.3.1.2. A bipolar group contained both magnetic polarities. It is defined as two or more spots forming a group with a major axis length of 3º or greater. Often there is a space near the middle of the group that defines the separation of opposite magnetic polarities.

4.3.1.3. The definitions above are based on traditional white light observations. Magnetograph inversion line analysis may indicate that a group is unipolar even though its length is 3º or greater, or bipolar even though its length is less than 3º. In such cases, report the sunspot class based on the magnetograph or inversion line analysis and flag the unusual situation with a PLAIN language remark appended to the coded SPOTS report.

4.3.2. Sunspot Class. There are seven classes in this component of the system. Each class represents an evolutionary stage a sunspot group may exhibit during the course of its development and decay. When determining sunspot class, use the length of a sunspot group between the outermost extremities of the group's leading and trailing ends. Measure this length along the group's major axis (Figure 4.3). **NOTE:** The overall length of a spot group is often called “longitudinal extent”; however, this term is misleading because it implies a strictly east-west measurement, since the group’s major axis may not be parallel to latitude lines.

4.3.2.1. **A** - Unipolar group with no penumbra; length is normally less than 3°. Exceptions are supported by magnetographic analyses.

4.3.2.2. **B** - Bipolar group with no penumbra; length is normally 3° or greater. Exceptions are supported by magnetographic analyses.

4.3.2.3. **C** - Bipolar group with penumbra on spots of one polarity only, usually the spots at one end of an elongated group.

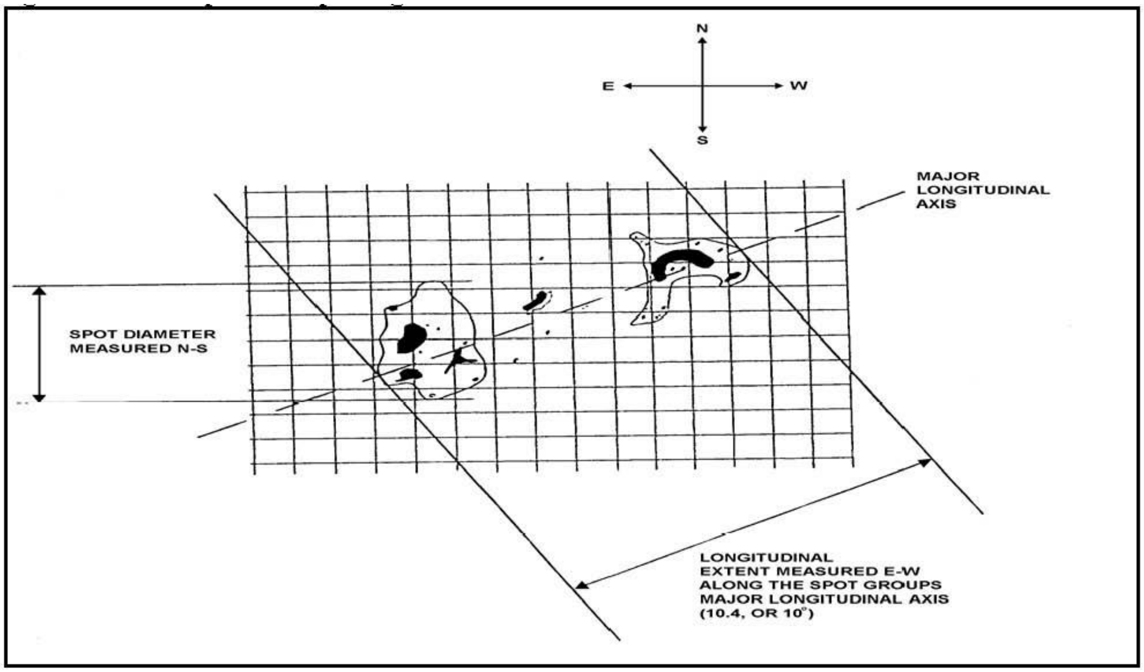
4.3.2.4. **D** - Bipolar group with penumbra on spots of both polarities. The group's length is less than or equal to 10°.

4.3.2.5. **E** - Bipolar group with penumbra on spots of both polarities. The group's length is greater than 10°, but less than or equal to 15°.

4.3.2.6. **F** - Bipolar group with penumbra on spots of both polarities. The group's length exceeds 15°.

4.3.2.7. **H** - Unipolar group with penumbra. The principal spot is usually the leader spot remaining from an old bipolar group.

Figure 4.3. Sunspot Group Length and Penumbral Diameter.



4.3.3. Penumbral Class. Penumbra appears as the gray area surrounding the umbra. If an apparent gray area is too indistinct to be drawn, do not report it. To determine penumbral class, use symmetry and size of the largest penumbra of a sunspot in the group. When using the penumbral diameter criteria below, measure the N-S axis of the spot. **NOTE:** A N-S measurement standardizes the effect of geometric foreshortening, which increases the closer a spot is to the solar limb in any radial direction from the sun's center. Since most sunspot groups are located less than 40º latitude, N-S spot diameter ensures foreshortening effects remain constant as the group rotates across the solar disk

4.3.3.1. **x** - No penumbra.

4.3.3.2. **r** - Rudimentary penumbra. Incomplete, irregular penumbra. It is brighter than mature penumbra. Its fine structure is mottled or granular instead of filamentary.

4.3.3.3. **s** - Small symmetric penumbra. Mature, dark, circular or elliptical penumbra with filamentary fine structure. The N-S diameter of the penumbra is 2.5° or less. This class includes penumbrae that appear elliptical due to the effect of geometric foreshortening. Symmetric penumbrae usually contain either a single umbra or a compact cluster of umbrae near the center.

4.3.3.4. **a** - Small asymmetric penumbra. Mature, dark, irregular (clearly not circular or elliptical) penumbra with filamentary fine structure. The N-S diameter of the penumbra is 2.5° or less. The asymmetry is "real", not just due to foreshortening effects. Asymmetric penumbrae usually contain two or more umbrae scattered within it.

4.3.3.5. **h** - Large symmetric penumbra. Has the same characteristics as a small symmetric (s) penumbra, but with a N-S diameter greater than 2.5° (normally corresponding to an area greater than about 250 millionths of the solar hemisphere).

4.3.3.6. **k** - Large asymmetric penumbra. Has the same characteristic as a small asymmetric (a) penumbra, but with an N-S diameter greater than 2.5° (normally corresponding to an area greater than about 250 millionths of the solar hemisphere).

4.3.4. Sunspot Distribution. This component of the Modified-Zurich Sunspot Classification System indicates the density of a group's internal spot population. The "o", "i", and "c" distribution classes are limited to bipolar groups (Classes B through F). The “x” distribution class is reserved for unipolar groups (Classes A and H). Such logical restrictions on combining sunspot class, penumbral class, and sunspot distribution limit the number of possible classifications in the Modified-Zurich Sunspot Classification System to a total of 60 combinations. Table 4.1 summarizes allowed combinations.

4.3.4.1. **x** - Undefined distribution; used to classify a single spot or unipolar spot group.

4.3.4.2. **o** - Open. Few, if any, spots exist between the leader and trailer spots. Any interior spots are very small umbral spots or pores.

4.3.4.3. **i** - Intermediate. Many spots lie between the leading and trailing portions of the group, but none of them possesses a mature, well-defined penumbra.

4.3.4.4. **c** - Compact. The area between the leading and trailing ends of the spot group is populated with many strong spots, with at least one interior spot possessing mature penumbra. An extreme case has the entire spot group enveloped in one continuous penumbral area.

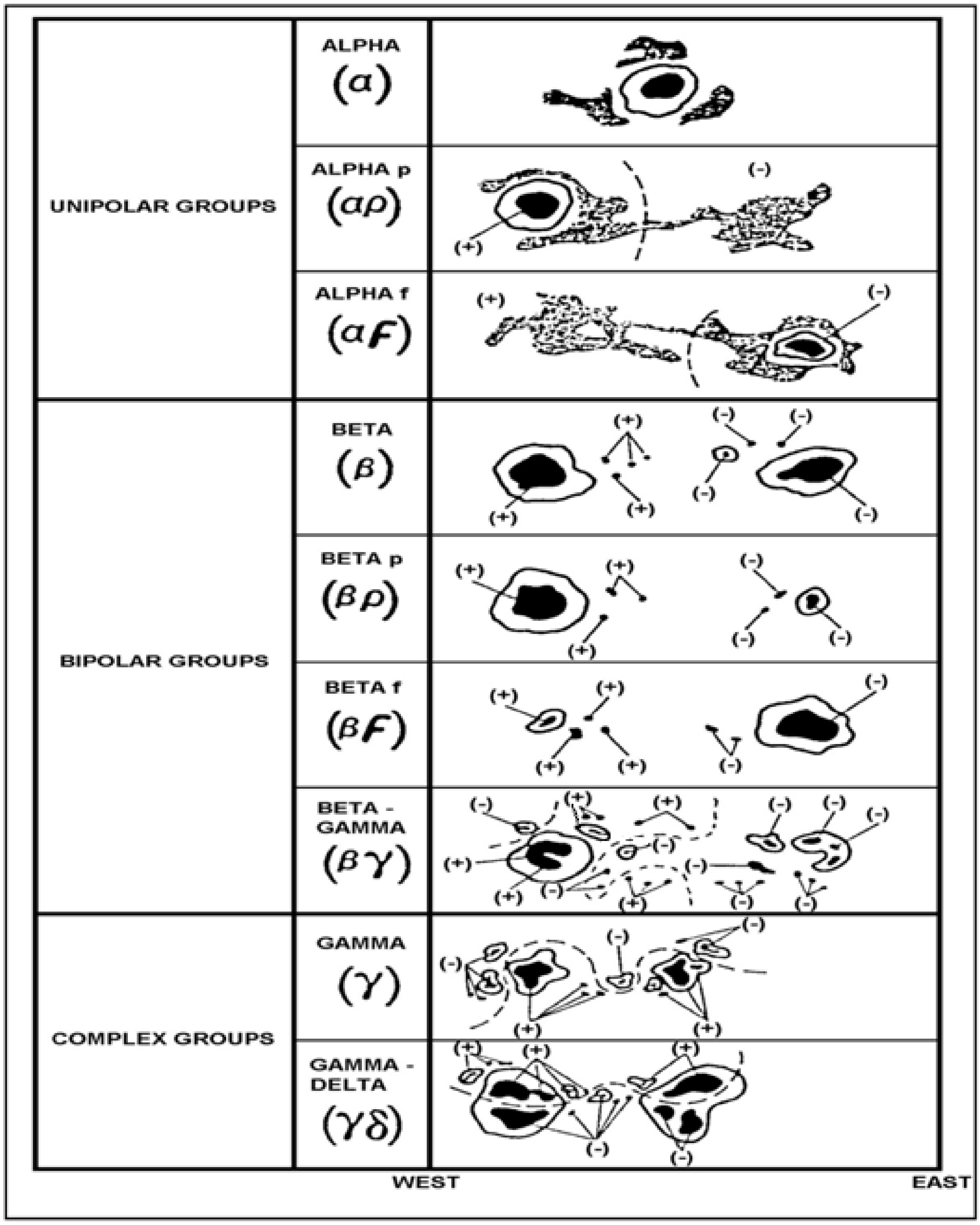
Table 4.1. Allowed Types of Groups in the Modified-Zurich System.

Sunspot Class	Penumbral Class	Spot Distribution	Number of Combinations
A	X	x	1
B	X	o, i	2
C	r, s, a, h, k	o, i	10
D, E, F	r	o, i	6
D, E, F	s, a, h, k	o, i, c	36
H	r, s, a, h, k	x	5
		Total Allowed Types:	60

4.4. Mount Wilson Magnetic Classification System.

4.4.1. Information to help determine a Mount Wilson magnetic class is obtained from computer generated magnetic maps, manual inversion line analyses, or other approved observing techniques. The magnetic polarities of individual sunspots in a group and the distribution of surrounding plage (see 5.1.3.) form the basis for this system. The three major classes are Alpha (unipolar), Beta (bipolar), and Gamma (complex). A special magnetic sub-classification, Delta , exists when an inversion line separates umbrae of opposite polarity within the same penumbral area. An example of each class is shown in Figure 4.4.

Figure 4.4. Mount Wilson Magnetic Classification System.



4.4.2. **Alpha (α)**. A single spot or unipolar spot group, around which the distribution of plage (see 5.1.3.) is fairly symmetrical. Magnetic field measurements show that unipolar groups are often accompanied by an area of opposite polarity where sunspots are not visible. This class is reported by USAF observatories.

4.4.2.1. **Alpha (αp)** . The magnetic field polarity in and around the spot(s) corresponds to the expected polarity for leader spots in the hemisphere for the current solar cycle. The spot(s) and adjacent plage are followed by an elongated area of plage or faculae of the opposite polarity. This subclass is not reported by USAF observatories.

4.4.2.2. **Alpha (αf)**. The magnetic field polarity in and around the spot(s) corresponds to the expected polarity for trailer spots in the hemisphere for that cycle. The spot(s) and adjacent plage are preceded by an elongated area of plage or faculae of the opposite polarity. This subclass is not reported by USAF observatories.

4.4.3. **Beta (β)**. A bipolar group where magnetic field strengths and spot areas indicate a balance between the leader and trailer spots. The polarities show a clear separation. This class is reported by USAF observatories.

4.4.3.1. **Beta p (βp)**. A bipolar group in which the magnetic field strengths and spot areas indicate that the leader spots are dominant. This subclass is not reported by USAF observatories.

4.4.3.2. **Beta (βf)**. A bipolar group in which the magnetic field strengths and spot areas indicate that the trailer spots are dominant. This subclass is not reported by USAF observatories.

4.4.4. **Beta-gamma (βγ)**. A spot group that has Beta (bipolar) characteristics, but is lacking a well defined dividing line between regions of opposite polarity. This class includes cases in which spots of the opposite or "wrong" polarity accompany the leader or trailer regions. This subclass is reported by USAF observatories.

4.4.5. **Gamma (γ)**. A spot group in which the polarities are completely intermixed. This class is reported by USAF observatories.

4.4.6. **Beta-delta (βδ)**. A spot group, which has Beta characteristics, but has umbrae of opposite polarity inside the same penumbra. This subclass is reported by USAF observatories.

4.4.7. **Beta-gamma-delta (βγδ)**. A spot group, which has Beta-gamma characteristics, but has umbrae of opposite polarity inside the same penumbra. This subclass is reported by USAF observatories.

4.4.8. **Gamma-delta (γδ)**. A spot group, which has Gamma characteristics, but has umbrae of opposite polarity inside the same penumbra. This subclass is reported by USAF observatories.

4.5. Sunspot Drawing Procedures.

4.5.1. Complete the legend block of the AFWA Form 21 and align the worksheet on the white light projection board for the correct P-angle.

4.5.2. Check the focus and size of the projected solar image prior to starting the drawing. **NOTE:** If necessary, adjust the white light focusing knob and projection board position to ensure an 18 cm diameter image is in focus on the board. There is a seasonal variation in image size due to changes in the earth-sun distance. These adjustments may be required as often as daily around solar perihelion (early January) and as infrequently as 2-3 weeks around aphelion (early July). Movement of the white light focusing knob may also affect image dimension at the guider assembly. To ensure accurate tracking and positioning, run the Optical Calibration program.

4.5.3. Use a short, finely pointed, hard lead pencil. Ensure the pencil has a good eraser. Avoid hitting the surface of the mirror with the pencil since the eraser will leave a mark.

4.5.4. Annotate drawing start time on the form. Carefully outline each umbra and penumbra with a fine line. Precisely blacken in the umbrae.

4.5.5. Move a white card back and forth over the worksheet to help define sunspots and eliminate effect of tiny imperfections in the worksheet. This also allows comparison between the actual and drawn images. Place an “X” over imperfections that could be mistaken for sunspots.

4.5.6. Annotate drawing finish time on the form. The time of the observation is the midpoint of the drawing process.

4.6. Data Reduction Procedures.

4.6.1. Assign local and SWPC sunspot numbers.

4.6.1.1. Start the local number sequence with 001 for the first new sunspot group observed after the beginning of a new calendar year.

4.6.1.2. Carefully maintain numbering continuity from day-to-day. However, use a new local number when a previously numbered spot group disappears, then later reforms.

4.6.1.3. Include SWPC assigned region numbers, when available. **NOTE:** Check other spot reports and all SWPC messages for information on newly-assigned SWPC regions.

4.6.2. Assign a seeing quality of the observation. Refer to the white light seeing categories in paragraph 4.2.

4.6.3. Determine each sunspot group's location and length using the appropriate Stonyhurst overlay. When selecting a Stonyhurst overlay, round the B-angle (B_o) up if it is x.5º or greater, and round it down if it is x.4º or less.

4.6.3.1. The sunspot group's location is defined as the geometric center of the group (latitude and longitude). Label the coordinates for each sunspot group on the sunspot analysis worksheet.

4.6.3.2. Measure the length of a group (often called "longitudinal extent") between the outermost extremities of the group's leading and trailing ends. Express the results in heliographic degrees. Make the measurement along the group's major axis (Figure 4.3). **NOTE:** The overall length of a spot group is often called “longitudinal extent”; however, this term is misleading because it implies a strictly east-west measurement, since the group’s major axis may not be parallel to latitude lines.

4.6.3.2.1. If the major axis of a spot group is inclined *more* than about 45º to latitude lines: Visualize a right triangle formed by the major axis, the latitude lines, and the longitude lines. Measure the change in latitude in degrees, and the change in longitude in degrees. Compute the group's length in degrees:

$$Group\ Length = \sqrt{(Latitude\ Change)^2 + (Longitude\ Change)^2}$$

4.6.3.2.2. If the major axis of a spot group is inclined *less* than about 45º to latitude lines: Lay a ruler or the straight edge of a piece of paper along the major axis and note its length or mark the length on the paper. Rotate the ruler (or paper edge) around the center of the group, so the ruler (or paper edge) is parallel to the latitude lines. Read the group's (approximate) length directly off the Stonyhurst overlay in heliographic degrees.

4.6.4. Determine the total (penumbral and umbral) uncorrected area of each sunspot group using the sunspot area overlay.

4.6.4.1. Place the sunspot area overlay on top of a drawn spot. Select the overlay circle or ellipse whose outline best matches the outline drawn for penumbral areas or encloses individual umbra without penumbra. For very irregular penumbra, it may be necessary to break it down into imaginary circles or ellipses to make the measurement. If the area is less than 10 millionths, determine the area by estimating the fraction of the 10 millionths circle it fills.

4.6.4.2. Repeat the step above for each spot in a group. Add the areas of all the spots in the group to get the total uncorrected group area.

4.6.5. Determine the total corrected area of each sunspot group using the limb foreshortening overlay.

4.6.5.1. Center the limb foreshortening overlay on the sunspot drawing and rotate it so that the N/S line of the overlay corresponds with the N/S line of the form and runs from the sun center through the geometric center of the group. The "hash mark" across the group's center represents a limb foreshortening correction factor.

4.6.5.1.1. If the group's center is between two hash marks use the smaller correction factor (i.e. the hash mark closer to the disk center) no matter which hash mark is closest to the group’s center.

4.6.5.1.2. If the group's center lies below the 1.1 hash mark, give it a correction factor of 1.

4.6.5.1.3. If the group's center lies beyond the 3.0 hash mark, give it a correction factor of 3.

4.6.5.2. To calculate a group's corrected spot area (in millionths of the solar hemisphere) multiply the total uncorrected spot area by the foreshortening correction factor. Report each group's area in whole increments of 10 millionths of the solar hemisphere rounded up or down as appropriate.

4.6.5.2.1. Round corrected spot areas whose last digit is 5 or higher up to the nearest 10 millionth of the solar hemisphere. (i.e. a corrected sunspot area of 66 millionths would be rounded up to 70 millionths and encoded as 007).

4.6.5.2.2. Round corrected spot areas whose last digit is 4 or lower down to the nearest 10 millionth of the solar hemisphere. (i.e. a corrected sunspot area of 123 millionths would be rounded down to 120 millionths and encoded as 012).

4.6.5.2.3. Spot groups who’s corrected spot area is 4 millionths of the solar hemisphere or less will be encoded as 000.

4.6.6. The number of spots in a sunspot group is the number of distinct umbrae (or dark cores) visible, for example, two umbrae surrounded by the same penumbral area count as two spots.

4.6.7. Determine the Modified-Zurich Classification (spot class, penumbra type, and distribution) from the spot drawing. Use the length of the sunspot group (measured as specified in this chapter) in determining spot class.

4.6.8. Determine the magnetic classification using any means of magnetic field analyses available. Particularly useful is the technique of overlapping a magnetic map on an Mg-b2 image.

4.6.9. As a final check before transmitting an encoded Sunspot Code (SPOTS) report IAW AFMAN 15-124, compare the sunspot locations against data from other observatories and the AXXX02 KWNP Joint United States Air Force / National Oceanic and Atmospheric Administration (USAF/NOAA) Solar Region Summary bulletin. If a significant deviation exists, recheck the location with the white light projection board and Stonyhurst overlay (correct P-angle and B_o used). Serious errors can result if Hα and white light imaging systems are not colinear. To detect lack of colinearity, perform two image rotator checks: one at the white light board, and the other on the Hα monitor. Lack of colinearity can be detected by comparing the sunspot analysis worksheet coordinates for a particular spot with the coordinates obtained by the DALAS Analysis Console.

Chapter 5

ACTIVE REGION AND MAGNETIC ANALYSIS TECHNIQUES

5.1. Active Region Analysis.

5.1.1. A solar active region is an area where strengthening of magnetic fields has concentrated atmospheric plasma to make it denser, hotter, and brighter than the surrounding atmosphere. These regions are observed in the upper photosphere as white light faculae, in the chromosphere as plage, and often in the corona as coronal condensations (see 5.8). The enhanced magnetic fields in active regions often become complex and are responsible for nearly all flare activity and most disk and limb activity.

5.1.2. Faculae. Faculae (plural of facula, Latin for “little torch”) are bright patches (also known as "white light plage") in the upper photosphere, located in areas of enhanced magnetic fields, and are associated with existing sunspots or possible sunspot development. They are normally visible only near the limb, where limb darkening provides favorable contrast. Since magnetic fields associated with active regions diverge with height, facular structure has finer detail than chromospheric plage.

5.1.3. Plage. Plage (“beach” in French) is chromospheric indication of an active region and is visible in Hα imagery. Tables 5.1 and 5.2 list criteria to determine plage compactness and intensity. **NOTE:** Plage normally takes no plural (sort of like the word “turf”).

5.1.3.1. Each class of plage compactness roughly corresponds to a stage in the development and decay of an active region. New, young regions tend to be compact. As the region ages, magnetic fields and associated plage tend to spread over a wider area.

5.1.3.2. Since weaker magnetic fields can produce plage and faculae than can form a sunspot, plage and faculae generally develop before and dissipate after any associated sunspots. In fact, not all plage or faculae develop sunspots. In Hα observations, plage can obscure underlying sunspots.

Table 5.1. Plage Compactness Descriptions.

Compactness	% Area of an Enclosed Circle
Widely Scattered	< 20
Scattered	≥ 20 to < 40
Scattered to Broken	≥ 40 to < 60
Broken	≥ 60 to < 80
Compact	≥ 80 to 100

Table 5.2. Plage Intensity Descriptions.

Intensity	Description
1	Faint Plage. Barely visible with diffuse edges; i.e., just above the contrast sensitivity detection threshold.
2	Moderate Faint. Clearly visible and moderately distinct with good seeing and light level. Visible to about ± 0.2 Angstrom off-band.
3	Normal. Visible to about ± 0.35 Angstrom off-band.
4	Bright. Visible to about ± 0.5 Angstrom off-band. Generally associated with new emerging regions with strong magnetic gradients along complex neutral lines. May reach intensities equal to faint flares in strong or rapidly emerging regions.
5	Flare Bright. Generally visible to ± 0.5 Angstrom off-band. Distinguished from flares by slow rise time and long duration. Normally confined to only points or segments within a region.

5.1.3.3. Point Brightenings. Very localized point enhancements in plage intensity that collectively, at any one moment, do not reach the minimal area needed to declare a flare (i.e., their total corrected area is less than 10 millionths of the solar hemisphere). Point brightenings may be of faint, normal, or brilliant intensity. They generally rise in intensity and return to their pre-enhanced level in a short period of time, typically 10 minutes or less. They may occur as single points, or as a series of continuously rising and falling points. At times, they may brighten rapidly and remain at, or near, flare intensity for up to several hours. **NOTE:** "Point brightenings" are a plage—not flare—characteristic. As such, they are reported in a PLAIN—not FLARE—code report. Do not confuse point brightenings with the flare characteristics "brilliant points", "bright points", or "several eruptive centers". These flare characteristics are defined in chapter 6.

5.1.3.4. Plage Fluctuations. Plage fluctuations exhibit lower intensities than flares (seldom greater than 50% above background), have slower rates of intensity change (no flash phase), are usually less defined than flares, and are not identifiable beyond about +0.5 Angstrom off-band in Hα. Occasionally they slowly rise to flare intensity and may remain near that level for several hours. Portions of these fluctuations can exhibit flash phase characteristics and should be classified as flares. The most enhanced, extensive, and long-lived plage fluctuations occur in magnetically intense, complex areas, and their effects (x-ray and radio emissions, etc.) can be similar to those of a flare.

5.2. Hα Seeing Categories.

5.2.1. Seeing = 1 (Very Poor).

5.2.1.1. Image movement is usually obvious with rippling waves sweeping across the disk.

5.2.1.2. Only sizeable features such as plage and large filaments are visible. Plage brightness appears as homogeneous blob. Only major changes may be detected in large prominences.

5.2.1.3. Small (around 10 millionths of the solar hemisphere) faint and normal subflares (importance of 0) are usually not discernible.

5.2.1.4. When viewing off-band, the observer cannot distinguish between umbrae and penumbrae, even in large spots.

5.2.2. Seeing = 2 (Poor).

5.2.2.1. Image movement is observed.

5.2.2.2. Brightness variations between plage areas may be seen. Point brightenings may be observed, but appear as small, ill-defined patches of fluctuating plage.

5.2.2.3. Filament channels begin to appear. Minor limb activity, such as small Active Surge Regions (ASRs), may not be observed.

5.2.2.4. Small, faint subflares may not be observed.

5.2.3. Seeing = 3 (Fair).

5.2.3.1. Some image movement may be observed on both the disk and limb.

5.2.3.2. Arch Filament Systems (AFS) are plainly visible. Narrow active region filaments may be seen.

5.2.3.3. Filament channels are generally well-defined. Minor limb activity is visible.

5.2.3.4. Fibril structure is moderately distinct around strong spots. When viewing off-band, umbrae and penumbrae can be distinguished.

5.2.4. Seeing = 4 (Good).

5.2.4.1. AFSs are well defined. Narrow active region filaments are sharply defined. Plage point brightenings appear as sharp, well-defined points.

5.2.4.2. Individual spikes in small ASRs are clearly separated from each other.

5.2.4.3. Chromospheric fine structure is moderately distinct at Hα line center and off-band.

5.2.5. Seeing = 5 (Excellent).

5.2.5.1. No limb movement is observed.

5.2.5.2. Fine hairline filaments are sharply visible.

5.2.5.3. Active region fibril structure and chromospheric fine structure are sharply defined.

5.2.5.4. When viewing off-band, both umbrae and penumbrae are sharply defined.

5.3. Computer Generated Magnetic Maps.

5.3.1. Use the SOON telescope's magnetograph subsystem to generate magnetic maps (called magnetograms) for use in analyzing the magnetic complexity of active regions (i.e., inversion line locations; field polarities, intensities, gradients, and Mount Wilson sunspot classifications). Use the Spectrograph program to acquire magnetograms.

5.3.2. The magnetograph exploits the Zeeman Effect (see 1.1.6.3.2.). Since magnetograms display only the line-of-sight portion of the magnetic field, geometric foreshortening decreases resolution and accuracy nearer the limbs. Thus, even if a region's magnetic field strength remains constant throughout its disk transit, it would seem to strengthen as it crosses the central meridian and then weaken as it moves toward the west limb.

5.3.3. Preliminary steps required before running the Spectrograph.

5.3.3.1. Ensure a good magnetic reference region (MAGR) analysis box exists. Locate MAGR as near as possible to disk center with a minimum 150 x 150 arc seconds in size and is as devoid of features (e.g., plage, filaments, etc) as possible. The Spectrograph uses this region for magnetic calibrations, initial Doppler cube centering, and phase plate optimization.

5.3.3.2. Determine those regions on which to perform magnetic analysis using the Spectrograph program.

5.3.3.3. Place the calibration polaroid over the objective lens.

5.3.3.4. Ensure the following are properly adjusted:

5.3.3.4.1. The right hand edge of the large scale SG lens is at its proper setting. **Note:** Analysts should not adjust the SG lens setting. The correct setting is determined by local maintenance personnel. If setting is suspect, contact local maintenance personnel for assistance.

5.3.3.4.2. The slit-jaw micrometer is set at 1.25 mm (125 microns).

5.3.3.4.3. The slit carriage assembly is in the PE position, and "NORM" is selected on the slit function knob.

5.3.3.4.4. The Grating, Focus, and Shift dial is set to locally established values. **NOTE:** The final rotation of the Grating dial should be a counterclockwise move to compensate for any play in the linkage.

5.3.3.4.5. Spectrograph filter wheel is set at filter 11.

5.3.3.4.6. Magnetograph slide assembly beam-splitter lever is in the "up" position, and the 10830 Angstrom beam-splitter is pulled out.

5.3.3.4.7. Magnetograph slide assembly is in the full "in" position (toward the optical bench).

5.3.3.5. Ensure all servo modules are in the "AUTO" position, and the SG lens control is in the "COMP" position. Set the DZA gain to the locally determined value in order to achieve a proper photodiode plot.

5.3.4. Run the Spectrograph program IAW guidance contained in the SOONSUM.

5.3.4.1. Initiate centering so that the calibration polaroid lies over the junction of the slit and the photodiodes, as seen on the monitor.

5.3.4.2. Execute the Diode Plot profile. If there is not a dip in the profile on each side of the vertical line, do the following:

5.3.4.2.1. Move the slit carriage assembly to the Spectral/White Light (S-WL) position. Place the trinocular TV/Eyepiece switch to the TV position. Route the SG output to monitor 4 by selecting "SG" on the "Master" switcher. A split image of the spectral line, with lateral horizontal displacement, should be visible. **NOTE:** If it is not visible, adjust the scanner mirrors to send light to the SG, check the function knob on the slit carriage, check the filter wheel in front of the SG TV camera, and check the prism in the SG front end.

5.3.4.2.2. Move the slit carriage until one side of the slit jaw opening is visible. Use the SG zoom optics to bring the slit image into sharp focus. Then use the Focus dial to focus the spectral line in relation to the slit.

5.3.4.2.3. Set the Doppler "CUBE" servo module to "MANUAL" and its potentiometer to "500".

5.3.4.2.4. Adjust the 8468 Angstrom spectral line position with the grating dial so the spectral line in the top half of the split image lies on one side of the slit and the line in the bottom half lies on the other side of the slit. It will be necessary to move the slit carriage so that one edge of the slit jaw opening is first seen, and then the other is seen. The spectral line segments should be positioned as equally as possible on each side of the slit.

5.3.4.2.5. Return the "CUBE" servo module to the "AUTO" position, and the slit carriage to the "PE" position.

5.3.4.2.6. Run the Spectrograph program again.

5.3.4.2.7. If the dips in the profile plot now appear on each side of the vertical line, proceed to the next paragraph. If not, repeat the above steps for executing the diode plot profile.

5.3.4.3. Select regions for Automatic Magmap analysis.

5.3.5. After all magnetograms are acquired remove the calibration polaroid from the objective lens.

5.4. Magnetic Inversion Line Analysis.

5.4.1. A magnetic inversion line (also called a *transition*, *dividing*, *zero*, or *neutral* line) indicates the division between areas of opposite line-of-sight magnetic polarity vertical to the solar surface. The terms *zero* or *neutral* line are misleading since they imply an absence of magnetic field, when in fact there exists a "transverse" field (horizontal or parallel to the sun's surface), often a strong one. Use inversion lines to determine magnetic complexity of active regions (and thus flare potential), or to locate boundaries between large solar areas with predominately positive or negative polarity (i.e., footings of solar sector boundaries (SSBs)).

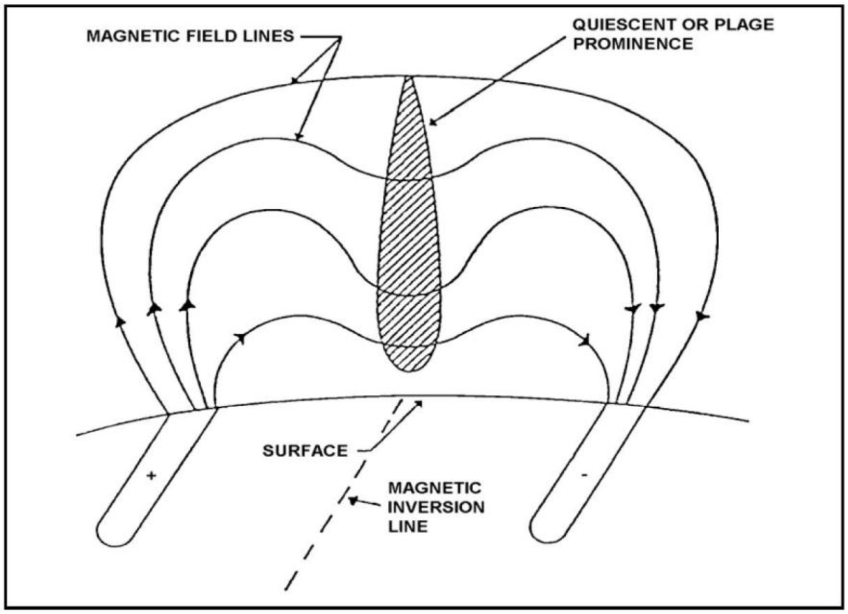
5.4.2. Use manual analysis of magnetic inversion lines, based on inference techniques to supplement computer magnetograph analysis when: the magnetograph is inoperative, in areas where the magnetic field strength is below the detection threshold of the magnetograph, or when features are smaller in scale than can be resolved by the magnetograph. For example, magnetograph accuracy declines with increasing radial distance from the sun's center because the vertical magnetic fields in the solar atmosphere become less line-of-sight. In addition, magnetograph analysis is often ineffective for full disk analyses. Excellent background material can be found in AWS-TR-76-262, *Development and Decay Potential of Active Solar Regions from a Full-Disk Neutral-Line Analysis*.

5.4.3. Inference Techniques. In the absence of magnetograms, use Hα features such as filaments, fibril structure, AFSs, and plage corridors to infer the location of magnetic inversion lines. These features, and their relationship to inversion lines, are discussed below.

5.4.3.1. Filaments and Prominences. Filaments are long, relatively dark, cloud-like structures that are suspended by magnetic fields (usually forming shallow saddle configuration) in the sun's atmosphere. They can develop where magnetic field lines are transverse (i.e., horizontal or parallel to the sun's surface) and can support relatively high density plasma. These transverse fields are normally found over magnetic inversion lines (Figure 5.1). Filaments may develop between large scale areas (solar sectors) of opposite polarity ("quiescent filaments") or between areas of opposite polarity within an active region ("plage filaments"). Plage filaments are much shorter, narrower, and lower in the sun's atmosphere than quiescent filaments. Since magnetic field structure in an active region changes relatively quickly, plage filaments vary in size, shape, and darkness (i.e., density) more rapidly than quiescent filaments. Against the bright solar disk, filaments appear as dark absorption features; however, filaments seen above the limb appear bright against the black background of space and are called "prominences". Because of their relatively large size and ready identification, filaments can be a most useful feature to locate magnetic inversion lines

5.4.3.1.1. Filaments located some distance from the center of the disk are actually viewed at an angle from the side. Because of this perspective, filaments often display "legs" or "feet", which connect the filament to the sun's surface. Current flows along the feet, interacts with the magnetic field, and provides the buoyancy needed to suspend the filament material. The inversion line, therefore, is located at the base of these feet, not at the smooth, unscalloped side of the filament (Figure 5.2).

Figure 5.1. Magnetic Field Support for a Prominence (Filament).



5.4.3.1.2. Near a large, well-developed sunspot a filament may curve toward and point directly toward the spot. In this case, the inversion line departs from the path of the filament near the ends of the radial fibril structure and extends around the spot at right angles to the fibrils (Figure 5.3).

5.4.3.2. Fibril Structure and Filament Channels. Fibrils are narrow, linear absorption features visible in Hα. Near filaments and sunspots with strong magnetic fields they align with the horizontal magnetic field lines near the sun's surface (much like iron filings near a magnet). Overall fibril patterns show little change over a period of hours, although the lifetime of an individual fibril is only 10 to 20 minutes.

5.4.3.2.1. Patterns of parallel, curving fibrils typically connect closely-spaced regions of opposite polarity, giving the impression that the regions are "stitched" together. Fibrils may also extend radially from large sunspots with strong magnetic fields, forming extensions of the radial pattern seen in the penumbra. In this situation, the magnetic inversion line often lies perpendicular to the outer edge of the radial fibril pattern (Figure 5.3).

5.4.3.2.2. Fibrils are often aligned at an angle to the filament, forming a feather-like pattern, with the magnetic inversion line along its rib (Figure 5.3). A "filament channel" is an extension of this feather-like pattern into an area where a filament could be supported, but no filament is observed. A filament channel normally develops before the filament appears and often persists long after the filament disappears.

Figure 5.2. Full Disk Magnetic Inversion Lines

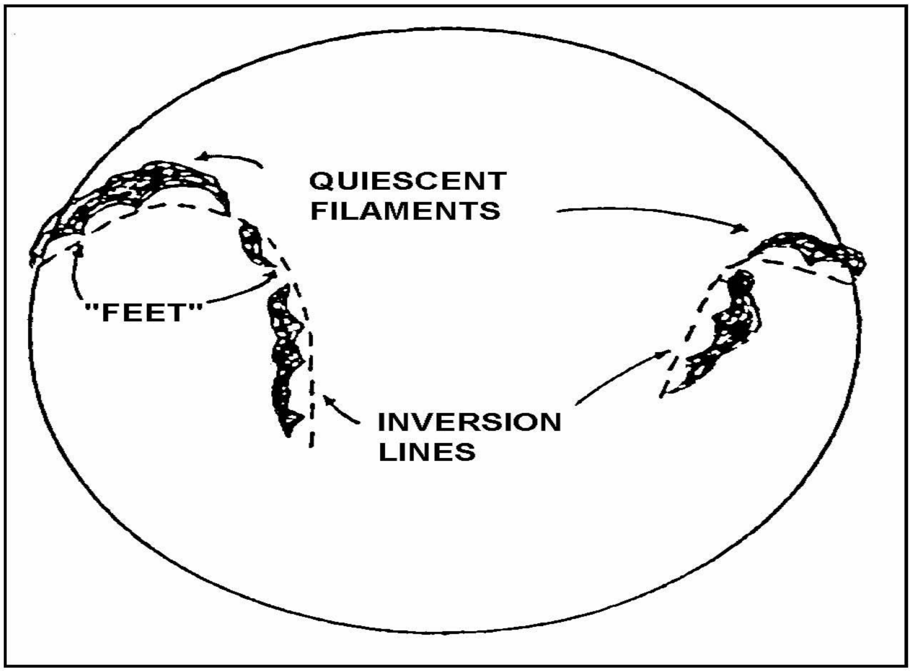
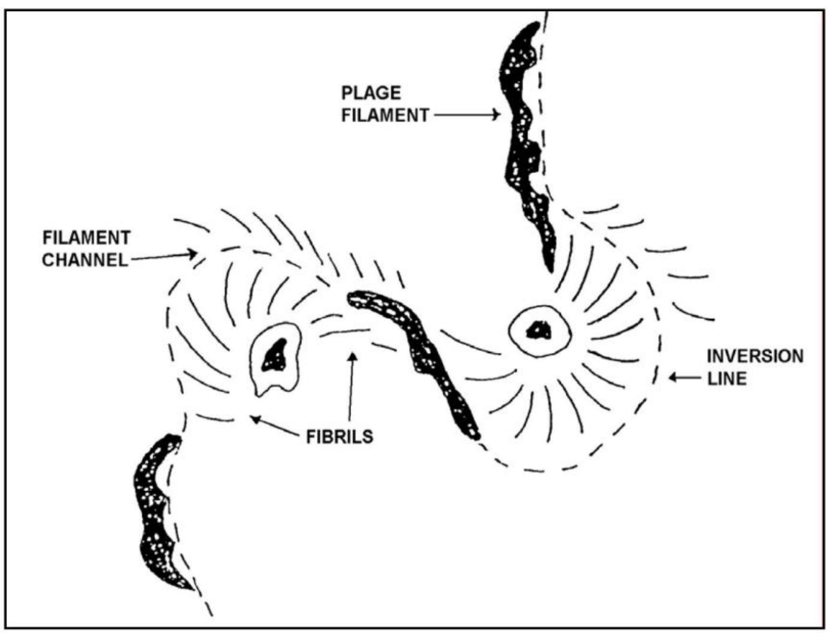


Figure 5.3. Active Region: Magnetic Inversion Line, Fibrils, and Filament Channel.



5.4.3.3. Arch Filament Systems (AFS). These are dark, linear absorption features usually observed only in young, developing bipolar plage regions, or in Emerging Flux Regions (EFR). An AFS appears as a series of dark, parallel arches connecting plage of opposite polarity (Figure 5.4). The legs of individual arch filaments are inclined less than 30º to the sun's surface and the tops of the arches lie at a relatively low altitude, rarely more than 10,000 km. Since arch filaments, like fibrils, align with horizontal magnetic fields near the sun's surface, an AFS is parallel to the underlying fibril pattern, but perpendicular to filament channels and plage filaments. Arch filaments are not "true" filaments, since they lie across (rather than along) magnetic inversion lines, and are lower in the chromosphere than plage filaments (Figure 5.5). The inversion line therefore bisects the AFS at right angles.

5.4.3.4. Plage Corridors. Polarity changes normally do not occur within an area of bright plage. Usually there is a distinct division (a dark lane) between plage segments of opposite polarity. The division is called a "plage corridor", and an magnetic inversion line often lies along this corridor (Figure 5.6). Plage filaments and filament channels may lie along a plage corridor, while arch filaments would lie across it. The width of a plage filament, filament channel, or plage corridor *increases* as the magnetic field gradient across the inversion line *decreases*. Thus, in young active regions (with abrupt polarity changes) plage corridors are narrow and often difficult to observe. They are noticeably wider in old active regions, where magnetic fields have weakened.

Figure 5.4. Arch Filament System (AFS), Plage, Sunspots, and Magnetic Inversion Line.

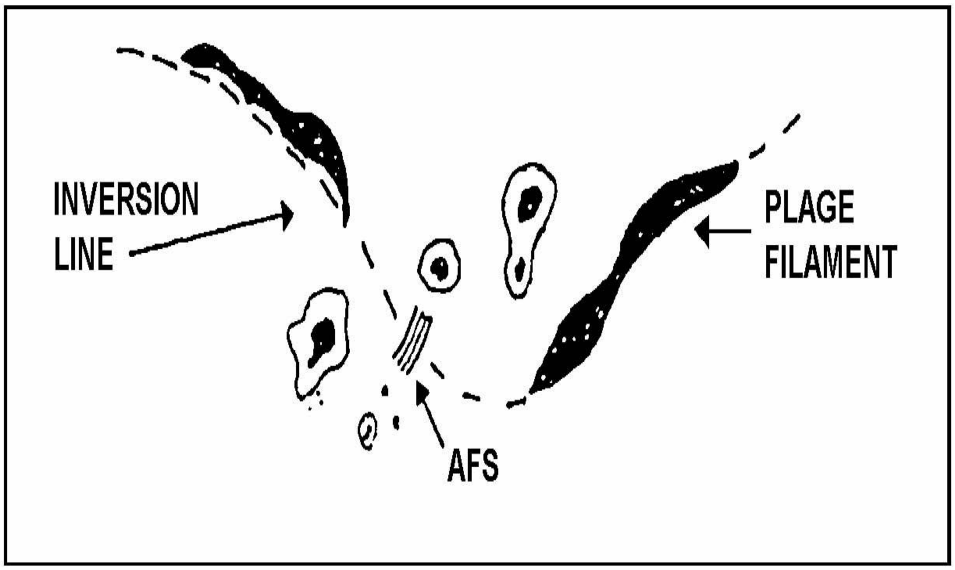


Figure 5.5. Arch Filament System Structure

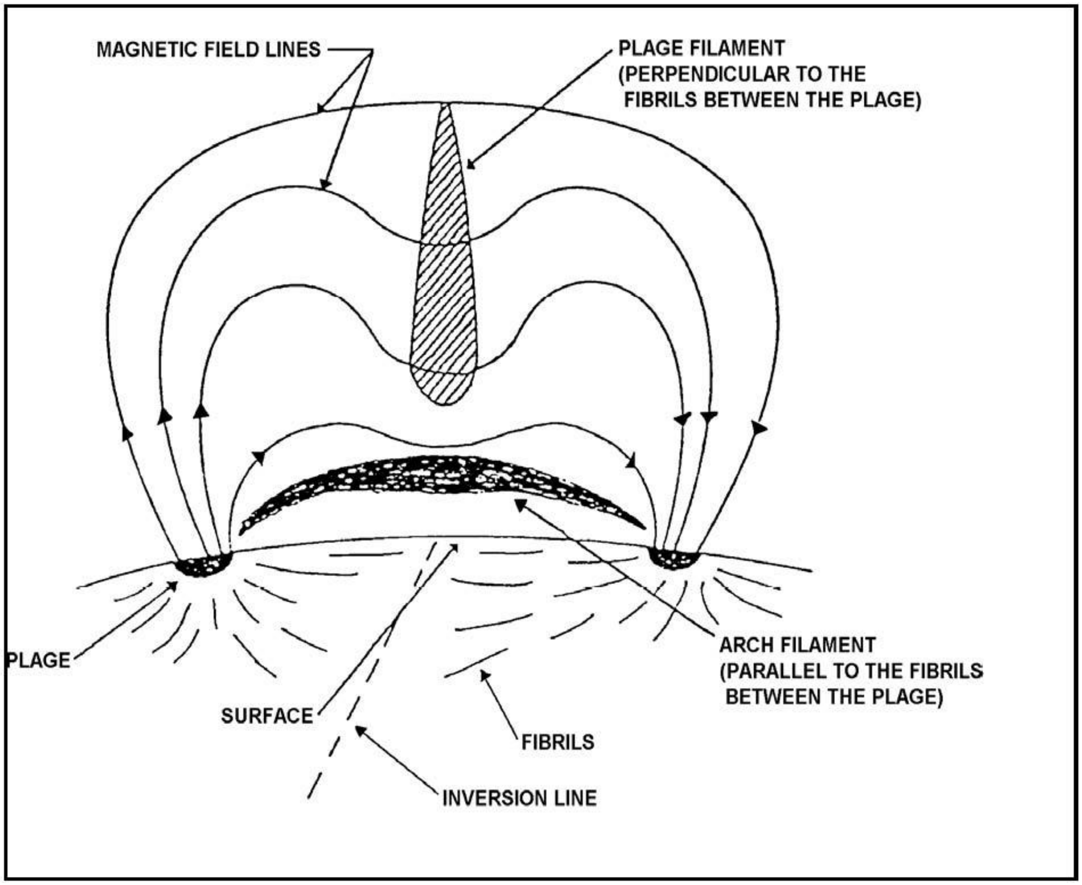
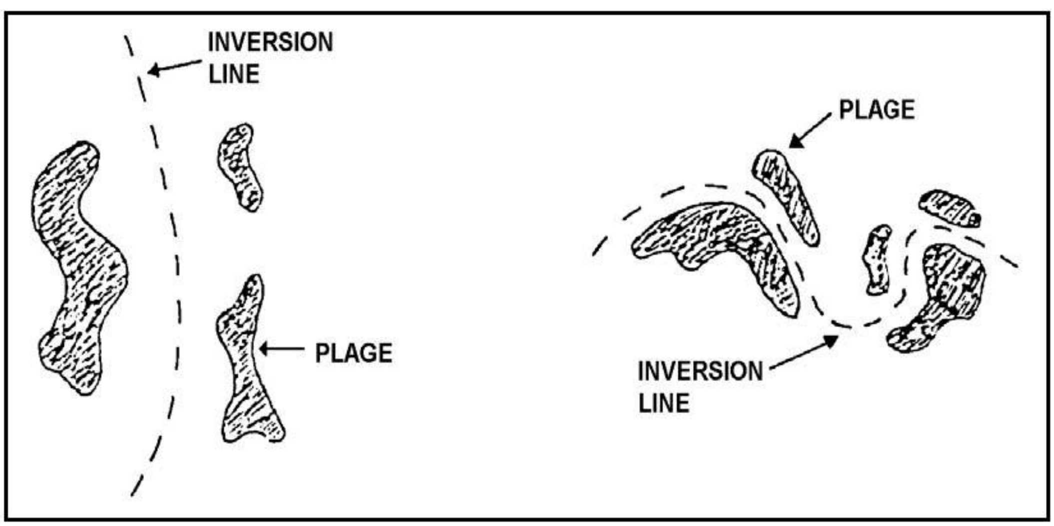


Figure 5.6. Plage Corridors.



5.5. Magnetic Polarities in Active Regions.

5.5.1. Active regions are magnetically bipolar, just like associated sunspot groups that may form (although individual sunspots exhibit only one magnetic polarity). The positive and negative magnetic field strengths within an active region or spot group are usually *not* equal in intensity or area. This explains why EFRs and old regions appear unipolar: the opposite polarity in an EFR has not yet achieved a detectable intensity, while the opposite polarity in an old region has declined below detectability. As stated above in Chapter 4, the leader spot is usually larger and has a stronger magnetic field.

5.5.2. The overall solar magnetic field is fairly weak: about 1.0 Gauss (compared to the surface of the earth's average magnetic field of about 0.5 Gauss). This solar magnetic field is rather consistent and stable around the solar Polar Regions. Unlike the earth's magnetic field, which is generated by electric currents in the molten iron portion of the Earth's core, the sun's overall magnetic field is thought to be the net result of turbulent motion of plasma beneath the photosphere, complicated by convoluted electric current systems associated with active regions, sunspots, and other phenomena.

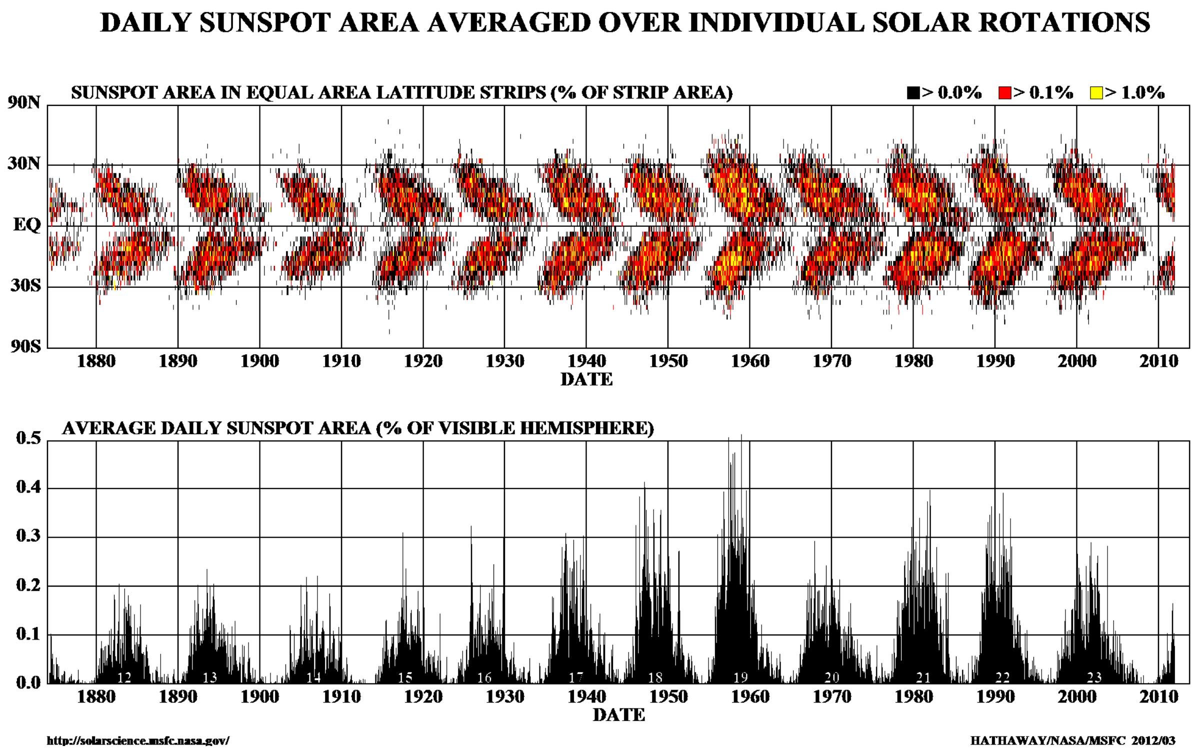
5.5.2.1. Also, unlike the earth, the sun rotates as a fluid (i.e., low latitudes rotate faster than high latitudes). The effect of this differential rotation on the overall solar magnetic field imbedded in its surface causes active regions and sunspot groups to erupt with a frequency that follows a cycle lasting an average of 11 years (as short as 9, as long as 14). This cycle is called the Solar Cycle (or the Sunspot Cycle because the number of sunspots corresponds with solar activity). Solar "minimum" is marked by little or no development of active regions and associated sunspots. Solar "maximum" is marked by the almost continuous development of active regions and sunspots. Solar activity from minimum to maximum takes about 4 years, while the decline back to minimum takes about 7 years.

5.5.2.2. Another curious aspect of the solar magnetic field is that it reverses its global magnetic polarities sometime during high solar activity, so that a return to the original magnetic polarity takes two complete cycles. This longer cycle is called the "Hale" 22-year cycle. The leader spots in a sunspot group will almost always match the polarity that the nearer pole had at the start of the 11-year Solar Cycle.

5.5.2.3. Solar cycles have been numbered since the mid 1700s. The current Solar Cycle (#24) began its minimum in January 2008, is expected to peak sometime in 2013, and will likely end sometime between 2018 and 2022. At the start of this Cycle (#24), the solar North Pole was magnetically negative (the South Pole was positive). Cycle 25 would then have a positive North and a negative South leader.

5.5.2.4. Another consequence of differential rotation and that the sun's emerging magnetic field is imbedded in the photosphere is that sunspot formation prefers certain latitudes. At the start of a cycle (solar minimum), active regions and their associated sunspots tend to form near 40º north and south latitude. As the cycle progresses, active regions and sunspots form progressively closer to the solar equator, about 15° north and south latitude around solar maximum. As the solar cycle winds down towards minimum, active regions and sunspots form within 5° of the equator. Graphing the latitude of sunspots over many cycles produces the famous Maunder Butterfly Diagram (Figure 5.7). It is common during solar minimum years that old cycle spots near the equator will coexist with new cycle spots at higher latitudes. New versus old sunspot groups are also identified by their leader spot polarity.

Figure 5.7. Maunder's Butterfly Diagram. (Latitudinal variation in distribution of sunspots with time).



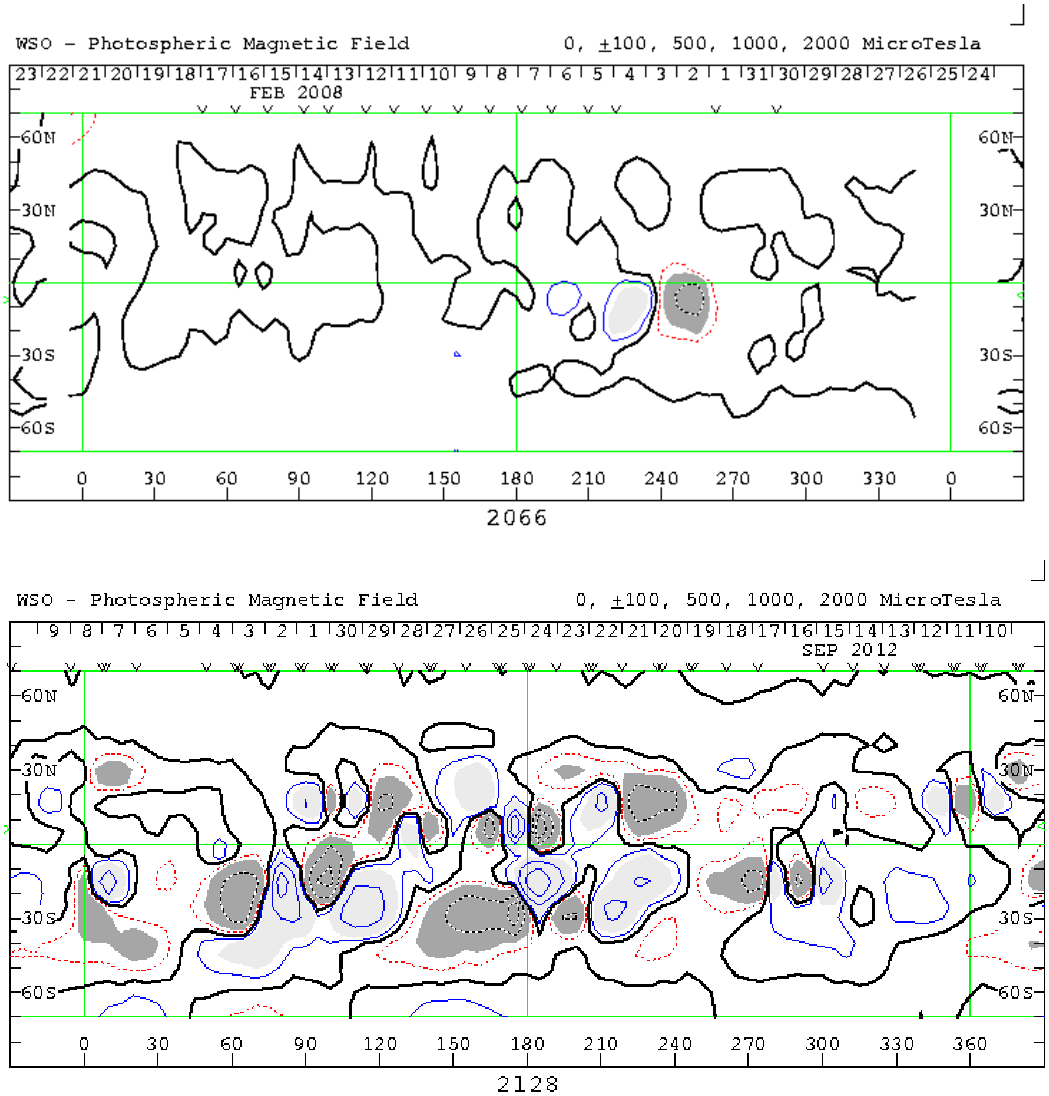
5.5.3. Computer generated magnetograms indicate the polarity of the various portions of an active region. To substantiate computer accuracy, an analyst can compare the computer-assigned polarities to what is expected based on the Cycle. For example, Cycle 24 active regions in the northern hemisphere should lead with negative polarity plage or spots and trail with positive polarity plage or spots. The opposite is true for the southern hemisphere.

5.5.4. If a leader spot is observed to have a magnetic polarity opposite to what is expected, recheck the magnetic field analysis. True leader spot polarity reversals rarely occur; however, when they do occur, they often involve complex or unusual region configurations. Their occurrence is significant and should be brought to the attention of the forecast centers.

5.6. Solar Sector Boundaries.

5.6.1. In general, opposing magnetic polarities at the solar Poles are consistent and stable; however, during solar maximum years, these polarities weaken, become disorganized, and re-strengthen with the opposite polarity through the next solar minimum. These magnetic polarities extend from the solar poles toward, and even cross, the equator in expansive areas that are punctuated by the magnetic complexities of active regions and sunspots. The magnetic field strength of these large areas is relatively weak (1 to 2 Gauss). Because of differential rotation, these broad areas stretch longitudinally to an average width of about 100°. The northern and southern sector polarities commonly dovetail into a rough arrowhead pattern, which points westward (Figure 5.8). The solar sector boundary (SSB) represents the magnetic inversion line that separates these expansive areas of opposite magnetic polarity. **NOTE:** SSBs are currently not reported by USAF Solar Observatories.

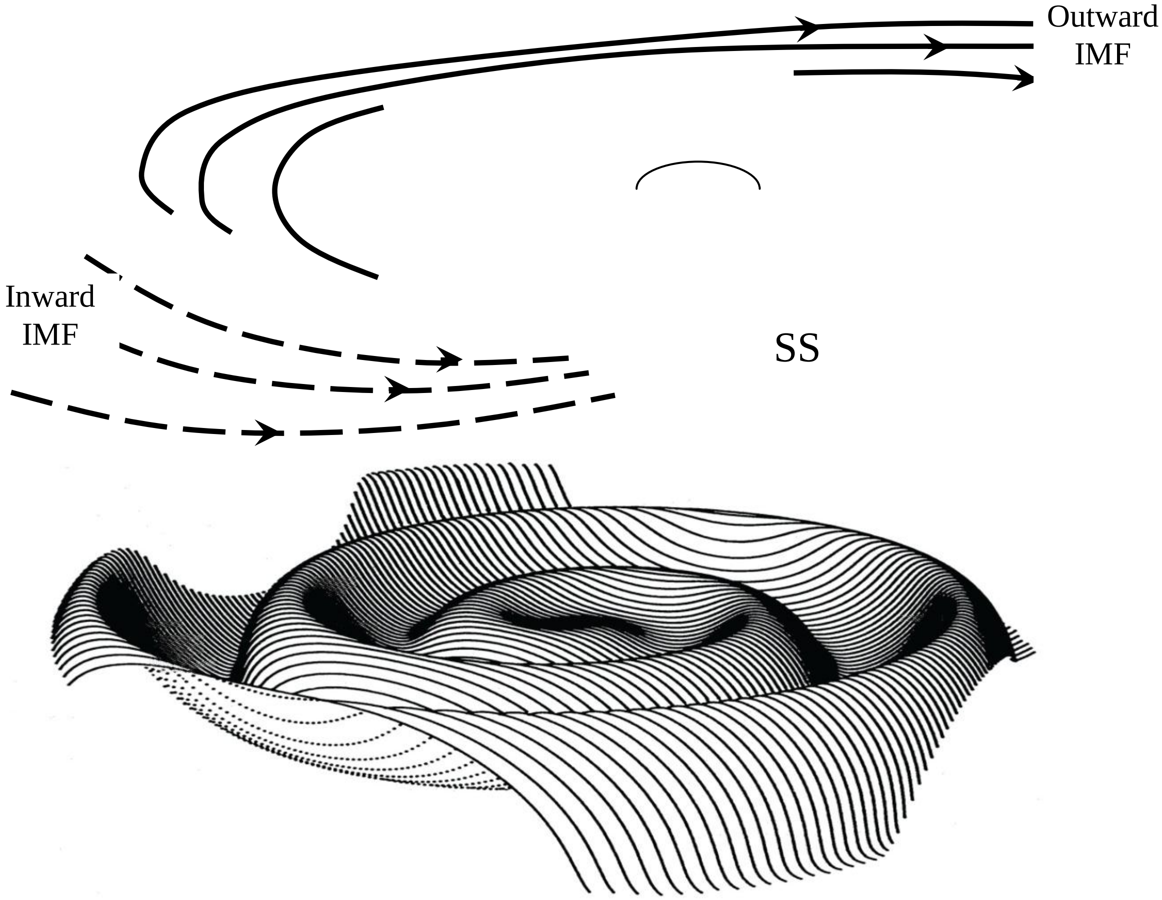
Figure 5.8. Solar Sectors.



Large and medium scale photospheric magnetic fields are evident in these magnetic synoptic charts provided by Wilcox Solar Observatory. Top chart shows Solar Cycle 24 solar minimum conditions (February 2008); bottom chart shows Cycle 24 solar maximum conditions (September 2012). Blue lines and light shading indicate positive magnetic fields; red dashed lines and darker shading indicate negative magnetic polarities. The thick black line shows where the magnetic inversion line indicates the SSB. During solar minimum (top), note that magnetic polarity of solar North Pole is completely negative (connected to the red dashed area near the solar equator). During solar maximum (bottom), note that the magnetic polarity of the Poles are mixed. Red dashed is negative; blue is positive; black line in SSB

5.6.2. Position of solar sectors on the sun and associated SSBs translate large-scale magnetic structure directly into the interplanetary magnetic field (IMF). The solar wind—a constant flow of thin plasma escaping the sun—drags a portion the solar magnetic field outward through the solar system and stretches it so that the field is oriented either toward or away from the sun (corresponding to the positive and negative sectors on the sun). The SSB can be traced outward from the solar surface and represents the thin boundary where the IMF reverses direction. Because the sun rotates, the IMF exhibits a spiral shape, and the SSB takes on a similar spiral shape whose ripples and waves correspond to the shape of the SSB at the sun's surface (Figure 5.9). In general, an IMF sector boundary passage at the earth tends to follow the solar central meridian passage (CMP) of a SSB observed on the sun by about four to six days.

Figure 5.9. Solar Sectors and IMF



5.6.3. The IMF and the associated SSB that separates the magnetic field directions is all but invisible as it sweeps past the earth; however, forecasters can infer its ever-changing shape by following activity and features on the sun. The shape of the IMF and the location of the SSB is important because it interacts with solar particle output much like a waving flag interacts with the wind. Also, the orientation of the IMF as it sweeps past the earth's magnetic field has important implications for geomagnetic activity.

5.6.4. Knowing the shape of the IMF and the position of the moving SSB helps forecasters determine whether solar events will strike the earth or entirely miss it. For example, if the sun discharges a stream particles or a batch of plasma that differs substantially from the speed, density, or magnetic orientation of the solar wind, the IMF shape and position of the SSB can direct the motion of such discharges.

5.6.5. Quiescent filaments are the most useful solar feature for identifying portions of an inversion line associated with a SSB observed at the solar surface. The disappearance of a filament that previously defined a SSB may indicate changes in the strength, position, or size of adjacent sectors. It does not necessarily indicate the SSB has also disappeared. In fact, the filament may reform in or near the original location since the underlying magnetic field structure may not have changed.

5.7. Coronal Holes.

5.7.1. Coronal Holes. Coronal holes are regions of low density and low temperature, where the solar magnetic field lines open and diverge directly into space. This allows the ready escape of hot solar particles, adding high-speed, low-density particle streams to the solar wind. The SOON telescope can observe coronal holes using the infrared Helium emission line at 10830 Angstroms. Hot helium emits at 10830 Angstroms, so a lack of emission—a "hole"—indicates cooler or less helium. If this feature appears in the vicinity of a SSB, it might be a quiescent filament, which would consist of cooler helium (and other imagery would confirm this). However, if this 10830 feature appears well within a solar sector (where magnetic polarity is constant), it is likely a coronal hole.

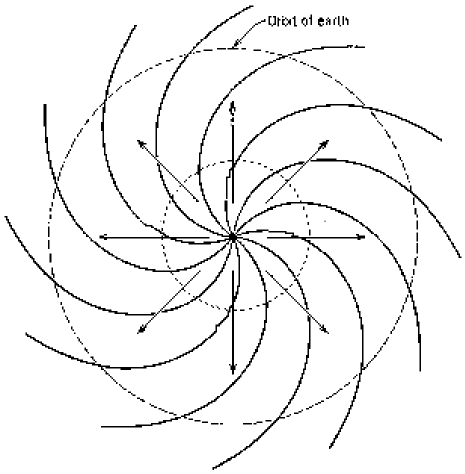
5.7.2. Coronal holes are related to expansive photospheric areas (solar sectors) of predominately single magnetic polarity. A coronal hole may form inside a solar sector when the sector has grown to at least 30º in longitude, and it generally disappears when the longitudinal extent of the sector decreases to less than about 30º. Only those sectors possessing the same polarity as the nearer pole are possible source regions for coronal holes (Figure5.8).

5.7.3. Coronal holes are perhaps the most persistent solar feature. They are semi-permanent features of the sun's polar caps. At lower latitudes they persist for months.

5.7.4. Near solar cycle maximum, coronal holes tend to be more numerous, at lower solar latitudes, and are also much smaller and shorter-lived. Near solar minimum, coronal holes are fewer and dominate high solar latitudes for years. During the years of solar minimum, high speed streams emanating from solar coronal holes are the dominant cause of recurrent geomagnetic storms (disruptions of the earth's magnetic field).

5.7.5. It is important to understand that the solar wind and high-speed streams associated with coronal holes move *radially* from the solar surface nearly in a straight line; however, the magnetic field it pulls with it is warped into a *spiral*, due to the sun's rotation. Also, a snapshot of a high speed stream is also spiral-shaped due to solar rotation; however, at each point in the stream, particles are moving *radially* away from the sun. Think of a spinning lawn sprinkler; each water drop moves in a straight line from the hose (as viewed from above), yet the succession of water droplets exiting the rotating hose gives a spiral pattern. When a coronal hole passes the central meridian as viewed from the earth, high-speed particles are being shot directly toward the earth. During the next several days (while the particles are traveling to the earth), the coronal hole rotates past the central meridian into the solar western hemisphere, at which point the stream strikes the earth. This gives the false impression that the stream is following a spiral from the current location of the coronal hole to the earth. The SOON telescope is not presently used to report coronal holes.

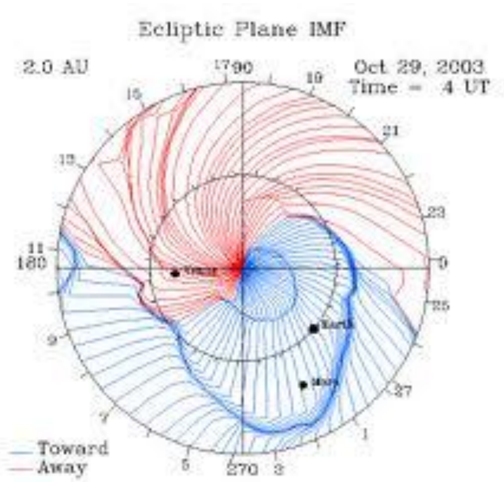
Figure 5.10. Radial vs.



5.8. Coronal Condensations. The corona above solar active regions often exhibit large-scale closed magnetic field loops that tend to concentrate hot plasma in streaks (at the top of the field loops) called coronal condensation. These features are bright enough to be seen in visible, ultraviolet, and x-ray imagery, especially on the solar limb. Coronal condensations are long-lived features, and can persist for a month or more after underlying photospheric sunspots and chromospheric plage have dissipated. The SOON telescope is not presently used to report coronal condensations.

5.9. Corona Mass Ejections (CMEs). Sometimes a sudden rearrangement of magnetic fields in the solar corona can eject a large cloud of plasma into space. Such an event is called a coronal mass ejection (CME). The plasma cloud is denser than the solar wind it plows into and has a stronger magnetic field than the IMF, which is distorted as the CME progresses forward (Figure 5.11.). If a CME strikes the earth, it generates a geomagnetic storm. Disappearing filaments, eruptive prominences, and flares are strong indicators that a CME has occurred (but not always).

Figure 5.11. IMF distorted by CMEs



Chapter 6

FLARE ANALYSIS TECHNIQUES

6.1. Solar Flares.

6.1.1. A solar flare is a sudden, intense, transient brightening in a localized area of the chromosphere. A flare is an explosive release of energy previously stored in the strong, complex magnetic fields found in an active region. Flares tend to occur along magnetic inversion lines in an active region. The more bends or kinks exhibited by an active region's inversion line (a strong indicator of magnetic complexity), the greater the flare potential.

6.1.2. A flare's initial energy release is called the "flash phase", since there is typically a rapid rise to maximum flare brightness. The flash phase is followed by a gradual intensity leveling off and declines to pre-flare brightness within tens of minutes to many hours. In larger flares, the flash phase may occur in different segments of the flare at different times, resulting in multiple intensity maxima. A typical flare's energy output across the full electromagnetic spectrum is only about 1/100,000th of the total solar output. However, flares are important because their output at certain wavelengths where solar output is normally low (ultraviolet, x-ray, and radio) may exceed normal solar emissions by a factor of 100 or more.

6.1.3. Sampled activity is declared to be a flare if it meets the following brightness and area criteria:

6.1.3.1. In Automatic Mode. The sampled activity increases in brightness, in two minutes or less, to an intensity at least 50 percent above the surrounding background. The area at or above this intensity level has a corrected area of at least 10 millionths of the solar hemisphere. **NOTE:** Normally, the histogram flare threshold is set at a bin value of 16, which represents a brightness level of about 60 percent above the surrounding background intensity. Variations in background plage intensity or observing conditions may require an analyst to set the threshold as low as about bin 14 (40 percent above background) or as high as about bin 22 (120 percent above background).

6.1.3.2. In Semiautomatic Mode. The sampled activity increases in brightness, in two minutes or less, to an intensity that produces brightening over a total Hα line width of at least 0.8 Angstroms, and the corrected area which displays brightening over a line width of 0.8 Angstroms or greater is at least 10 millionths of the solar hemisphere.

6.1.4. A flare's Hα emission does not necessarily reflect its emission at other wavelengths or its ability to produce energetic charged particles. However, statistically, the size and brightness in Hα is a good indicator of a flare's x-ray, radio, and particle emissions. In general, the larger and/or brighter a flare is in Hα, the more energetic it is, the less frequently it will occur, and the longer is its duration.

6.1.5. Chromospheric brightenings may be categorized as "flares", "point brightenings", or "plage fluctuations". Point brightenings and plage fluctuations (defined in Chapter 5) are plage characteristics. They should not be confused with "brilliant (or bright) points" and "several eruptive centers", which are flare characteristics defined later in this chapter.

6.2. Flare Location.

6.2.1. A flare's location is the geometric center of the flaring area at the time of maximum flare brightness, expressed as central meridian distance and heliographic latitude. The geometric center is often not the same location as the brightest portion of the flare or where the flaring segments are concentrated. **NOTE:** If the maximum brightness is not observed (due to clouds, power outage, etc), report the location at the time of the brightest intensity actually observed.

6.2.2. In Automatic Mode. The computer warns the analyst of a flare by turning on the flare alarm as a three second steady tone for routine flares and a series of three interrupted tones for event level flares. Use the Flare Location tool to locate the flare's geometric center. This process allows the analyst to visually confirm or reject the automated analysis. If accepted, the geomagnetic center location is input into the flare message (QXXYY) group. If Flare Location is not run, the region center is input as the flare location. As needed, rerun this program to refine the flare's location as the activity progresses (up to the time of maximum flare brightness). **NOTE:** The DALAS Analysis Console may be used to obtain a location; however, it will not update the location in the flare analysis program.

6.2.3. In Semiautomatic Mode.

6.2.3.1. SOON Rehost may be used to determine the location of a flare if there is a recently acquired large scale image of the flaring region available within the image database of images acquired during automatic patrol. It also may be possible to acquire a new image using the DALAS program within the SOON analysis console. SOON Rehost can be used to locate the flare’s geometric center by roaming the cursor over a full disk image using the Region definition function.

6.2.3.2. If unable to use SOON Rehost, one can estimate the location of a flare by its relation to a nearby solar feature (e.g., 2º south of a leader spot).

6.2.3.2.1. Determine the location of the reference feature (e.g., the spot) using the appropriate Stonyhurst overlay (adjusted for P-angle) and as many of the following tools as is required: the white light projection board, a sunspot drawing, recent Region Definition table printout, and current BXOUT message from your site or another site. The analyst must select the best sources suited for the current situation to determine the most accurate flare location.

6.2.3.2.2. Determine the flare's latitude and longitude from the reference feature's location.

6.2.3.2.3. Unless the reference image used is real-time, the flare's current position is actually west of the location due to solar rotation. To compute a correction factor for the flare's longitude: multiply the rotation rate of 0.55º per hour to the time difference (in hours and tenths of hours) between when the flare occurred and when the reference image was made (Use a rate of 0.50º per hour for flares at high latitudes.)

6.3. Flare Area and Importance.

6.3.1. Flare area is measured at the time of maximum flare brightness. If the maximum brightness is not observed (due to clouds, power outage, etc), report the area measured at the time of the brightest intensity actually observed, and qualify the overall report and the time of observed maximum brightness appropriately. Flare area tend to spread after maximum brightness is reached, so the reported area may not necessarily be the largest area obtained by a flare. Flare Importance is defined in terms of corrected flare area at time of maximum brightness. Corrected area is the area a flare would have if viewed from directly above the flare (Table 6.1).

Table 6.1. Flare Importance.

Importance	Corrected Flare Area (millionths of the solar hemisphere)
0 (subflare)	≥ 10 to < 100
1	≥ 100 to < 250
2	≥ 250 to < 600
3	≥ 600 to < 1200
4	≥ 1200

6.3.2. To obtain corrected flare area, the apparent area measured on a projected image of the solar disk must be corrected for both geometric foreshortening and the vertical height of the flare (which may be as much as 10,000 km) above the photosphere. The magnitude of both effects increases with Rv (distance from the disk's center). The foreshortening correction formula used for sunspot areas is modified by adding a 0.2 Rv term to statistically account for the vertical height of flares. The formula below (from Smith and Smith, *Solar Flares*, The MacMillian Co, NY, 1963) is based on a statistical study of 4,700 flare observations at Sacramento Peak Observatory. This formula can only approximate the true vertical correction required for any given flare, and its results become increasingly less accurate the further a flare is from the disk center. Near the limb, the formula tends to give corrected areas that are too large for small flares, and too small for large flares. The foreshortening correction is embedded in the automatic flare analysis software, and in the area correction table(s) used during semiautomatic operations.

For flares:

$$Ac = \left[\frac{Am}{0.2Rv + \sqrt{1-(Rv)^2}}\right] \times .5$$

Where: Ac is the Corrected Area, Am is the Measured (or apparent) Area, Rv is the Radius Vector (see 1.3.2.3.2.)

6.3.3. In Automatic Mode. The computer will calculate corrected flare areas automatically. **CAUTION:** Automatic measurements may include flare-bright plage and any bright surges accompanying a flare.

6.3.4. Semiautomatic Mode.

6.3.4.1. Using SOON Rehost.

6.3.4.1.1. Use the Flare Analysis Console to determine the area of a flare if there is a recently acquired large scale image of the flaring region available within the image database.

6.3.4.2. If unable to use a SOON Rehost image, use the TV Monitor Overlay method for measuring flare areas.

6.3.4.2.1. Measure the flare area, observed on a large scale Hα image, in grid squares to the nearest 0.1 square (for the overlay method). SOON Rehost console enables rapid conversion of grid squares to corrected flare area using the Monitor Overlay Correction tool. Given the number of grid squares and the Rv, the program provides a corrected flare area and flare importance. Alternatively, use a locally completed version of Table 6.2 to convert the measured (apparent) area to corrected area in millionths of the solar hemisphere.

6.3.4.2.2. To use a local version of Table 6.2, the Rv to the current location of the flare's geometric center is needed.

Table 6.2. 18 cm Image Millimeter-to-Rv Conversion Table.

mm = Rv	**mm = Rv**	**mm = Rv**	**mm = Rv**	**mm = Rv**
01 = .01	19 = .21	37 = .41	55 = .61	73 = .81
02 = .02	20 = .22	38 = .42	56 = .62	74 = .82
03 = .03	21 = .23	39 = .43	57 = .62	75 = .83
04 = .04	22 = .24	40 = .44	58 = .64	76 = .84
05 = .06	23 = .26	41 = .46	59 = .66	77 = .86
06 = .07	24 = .27	42 = .47	60 = .67	78 = .87
07 = .08	25 = .28	43 = .48	61 = .68	79 = .88
08 = .09	26 = .29	44 = .49	62 = .69	80 = .89
09 = .10	27 = .30	45 = .50	63 = .70	81 = .90
10 = .11	28 = .31	46 = .51	64 = .71	82 = .91
11 = .12	29 = .32	47 = .52	65 = .72	83 = .92
12 = .13	30 = .33	48 = .53	66 = .73	84 = .93
13 = .14	31 = .34	49 = .54	67 = .74	85 = .94
14 = .16	32 = .36	50 = .56	68 = .76	86 = .96
15 = .17	33 = .37	51 = .57	69 = .77	87 = .97
16 = .18	34 = .38	52 = .58	70 = .78	88 = .98
17 = .19	35 = .39	53 = .59	71 = .79	89 = .99
18 = .20	36 = .40	54 = .60	72 = .80	90 = 1.00

6.3.4.2.2.1. To determine the Rv, use any of the following tools (if available): SOON Rehost; the white light projection board; a sunspot drawing; 18 cm Rv overlay; a recent Region Definition table printout; and current BXOUT message from your site or another site. **NOTE:** When given the number of grid squares, the Monitor Overlay Correction tool provides the corrected radial extent (for limb activity).

6.3.4.2.2.2. For a Stonyhurst overlay, use a ruler to measure the distance in millimeters from the disk center to the flare's center. The Rv value (in hundredths of the solar radius) equals the number of millimeters divided by 90 for an 18 cm disk (or see Table 6.2). **NOTE:** If the image is not a real-time image, the flare's current position is actually west of its measured location due to solar rotation. To correct the flare's longitude, see 6.2.3.2.3.

6.4. Flare Brightness.

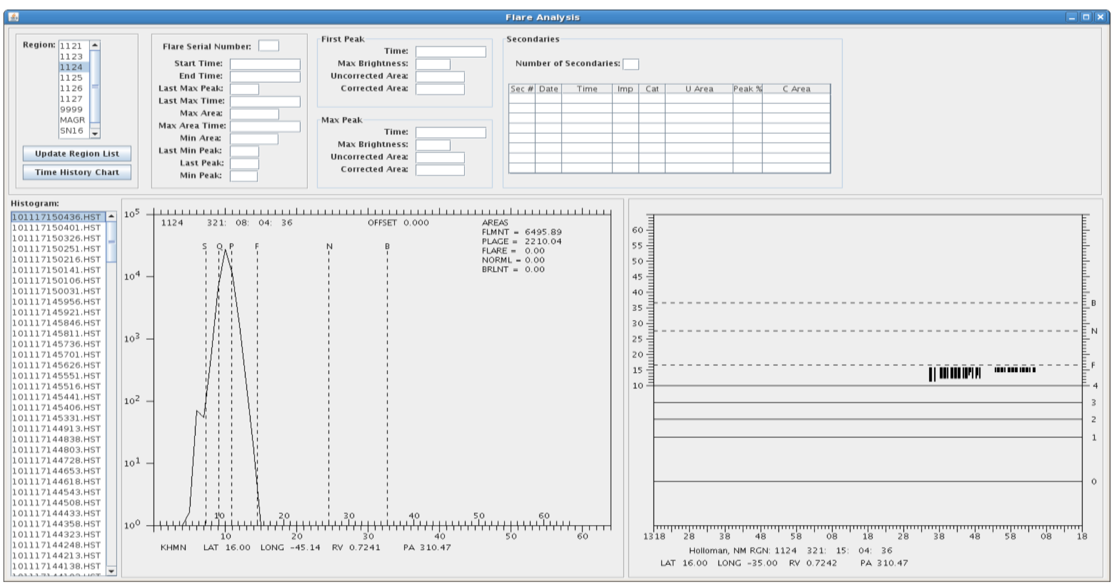
6.4.1. Flare brightness is a measure of a flare's enhancement over the quiet sun's (or background) intensity. The three categories of flare brightness (Faint, Normal, and Brilliant) combine with flare Importance (correlated to flare area) to create fifteen Hα flare classifications (0F through 4B).

6.4.2. In Automatic Mode.

6.4.2.1. The computer determines flare brightness by electronically scanning the area within a analysis box. Peak and current flare intensities, including flare areas, are continuously updated on the system console display. The analyst must graphically display data for flaring regions using the flare Histogram display tools (Figure 6.1).

6.4.2.2. To report a flare as faint (F), normal (N), or brilliant (B), it must reach the brightness level corresponding to that category. The corrected area at or above that intensity level must be at least 10 millionths of the solar hemisphere.

Figure 6.1. Flare Analysis Histogram Plot.



6.4.3. In Semiautomatic Mode.

6.4.3.1. The analyst must estimate brightness based on the total Hα line width over which the flare enhancement is distinctly visible. When off-band capability is not available, a subjective evaluation must be made using low intensity TV Hα observations.

6.4.3.1.1. **Faint (F).** Plage definitely enhanced, but flaring area edges are diffuse. Distinctly visible as an enhanced area over a line width of 0.8 Angstroms or greater, but less than 1.2 Angstroms. Example: a 0.4 red shift plus a 0.4 blue shift, or solely 0.8 red or 0.8 blue shift.

6.4.3.1.2. **Normal (N).** Flaring area distinctly visible as an enhanced area over a line width of 1.2 Angstroms or greater, but less than 1.0 Angstroms in either wing. Example: 0.6 red shift plus a 0.6 blue shift.

6.4.3.1.3. **Brilliant (B).** Flaring area distinct at 1.0 Angstroms off line center in either the red or blue wing.

6.4.3.2. In automatic mode, each flare brightness level (F, N, or B) must attain at least 10 millionths of the solar hemisphere before it is reported. To expedite reporting in semiautomatic mode this requirement is waived for N and B thresholds and the off-band measurement is sufficient. **NOTE:** The overall flare area must still meet the 10 millionths of the solar hemisphere criteria to be declared a flare and reported.

6.4.3.3. Each site shall develop local Doppler shift tables, which list the correct AGC, 1-Angstrom, and 1/2-Angstrom settings for each off-band measurement. To determine a flare's brightness: Adjust the AGC, 1-Angstrom, and 1/2-Angstrom Polaroids to the values in the tables. Step through the off-band settings, in both the red and blue wings, until the flare is no longer distinctly visible, i.e., a significant decrease in intensity is observed. These are the off-band values, and their sum is the Hα line width. **NOTE:** Determining "distinctly visible" is subjective. During automatic patrol, analysts should occasionally analyze flares with off-band techniques to develop reliable accuracy.

6.4.3.4. If in semiautomatic mode, but the computer is operating (e.g., low light levels), use the DALAS Analysis Console to perform off-band measurements.

6.5. Flare Characteristics.

6.5.1. Flares show considerable variability in structure and associated activity. The FLARE code permits reporting of up to two out of ten flare characteristics. Appended PLAIN language comments can be used to expand on reported flare characteristics or to discuss phenomena not covered by the code.

6.5.2. White Light Flare (c = 0). During the flash phase of an extremely energetic flare, it may be visible in white light for a short time (normally 10 minutes or less). A white light flare can be significantly brighter than the white light background. It may have a red or blue cast due to chromatic aberration caused by the fact that refracting telescopes tend to focus different colors at different distances from a lens. On the average, white light flares may occur perhaps once or twice per year during years of solar maximum.

6.5.3. Umbral Coverage of 20% or more (c = 1). In order for flaring material to intrude over a sunspot's umbra it must have sufficient energy to penetrate the strong vertical magnetic fields over the spot. Thus coverage of major umbra (e) is indicative of a very energetic flare.

6.5.4. Parallel (c = 2) and Y-shaped (c = 4) Ribbons. Both these characteristics usually indicate complex magnetic field structures and energetic events. In particular, a parallel ribbon flare suggests that material from a plage filament may have slid down magnetic field lines on either side of an inversion line, impacted the sun's surface, and released additional energy. **NOTE:** Hyder flares, as described later, also appear as parallel ribbon flares, but are not energetic events. Even so, the characteristic c = 2 should still be reported for a Hyder flare.

6.5.5. Associated Loop Prominence System (c = 3). Loops are post-flare coronal phenomena, which may start to form while the flare is still in progress, but will persist well after the flare ends. A Loop Prominence System is caused by material thrown into the corona by the flare. This material condenses into knots, and then rains down curved magnetic field lines to the surface. Loops are another indicator of an energetic (usually 2B or greater) flare. Loop Prominences are best seen at the limb.

6.5.6. Several Eruptive Centers (c = 5). During a flare, several separate areas may rise to faint, normal, or brilliant intensity. These areas tend to grow as the flare develops and may merge. Eruptive centers differ from "brilliant points" in that eruptive centers need not be of brilliant intensity, are larger in area, and tend to expand as the flare progresses.

6.5.7. Brilliant Points (c = 6). One or more points of brilliant intensity (exceeding 360% of the quiet sun) are occurring during a faint, normal, or brilliant flare. Brilliant points (also called "bright points") are generally small and do not increase in size as the flare progresses. The collective area of the brilliant points must be considered when determining a flare's overall brightness classification. For example, if the total corrected area of the entire brilliant points equals or exceeds 10 millionths of the solar hemisphere, a brilliant flare must be reported. However, it would still be appropriate to carry a code c = 6 characteristic.

6.5.8. Associated Dark or Bright Surge on the Disk (c = 7). These are additional indicators of a possibly energetic flare. Surges are described in Chapter 7.

6.5.9. Flare followed a Disappearing Filament (c = 8). Flares represent a rapid release of energy stored in the complex magnetic fields within an active region. These same fields may support plage filaments above the active region. Consequently, in response to the disruption of the supporting field, a flare may be preceded by, or accompanied by, a disappearing plage filament (filament material being thrown off the sun). **NOTE:** Hyder flares, which occur outside active regions, are associated with disappearing *quiescent* filaments.

6.5.10. Hα emission greater in the blue than red wing (c = 9). A Doppler shift toward the blue end of the spectrum indicates material is moving toward the observer may have sufficient outward speed to impact the solar corona.

6.6. Special Flare Types.

6.6.1. Some flares are “special” in the sense that they appear to follow a pattern, or may be triggered by relatively observable mechanisms.

6.6.2. Homologous Flares. Occasionally, an active region will produce a series of flares with similar location, size, shape, and pattern of development. Such “homologous” flares reflect the tendency for chromospheric magnetic fields to return to pre-flare configuration under the influence of stronger magnetic fields imbedded in the photosphere below. **NOTE:** For the same reason, filaments disrupted during a flare may reform with the same orientation and density within a few tens of minutes to several hours (for plage filaments) or a few hours to several days (for quiescent filaments).

6.6.3. Sympathetic Flares. Sometimes a flare, especially if large and energetic, appears to trigger a flare in another part of the active region, or in a neighboring region. The mechanism for causing the second, “sympathetic” flare is a shock wave (called a “Moreton” wave) generated by the first flare. As the shock wave propagates horizontally away from the flare, it disturbs the magnetic field structure in active regions in its path, possibly inducing a flare in a region whose magnetic complexity already indicates flare potential. The shock wave can also cause oscillatory motions in distant plage or quiescent filaments. These filaments may tend to wink in and out of Hα visibility as they are Doppler shifted in and out of the Hα line center. The shock wave may also propagate vertically, causing a Type II swept frequency radio event.

6.6.4. Impact Flares.

6.6.4.1. "Impact, infall, or Hyder" flares are relatively rare, and often occur in spotless—even plageless—areas. A large quiescent filament, triggered by some change in its supporting magnetic field structure, can be lifted upward into the corona. As this occurs, the filament will disappear in Hα because its motion causes a Doppler shift away from Hα line center. (A prominence would appear to erupt). Most of the filament's material will then spill back along magnetic field lines and impact the chromosphere in two parallel bands on either side of the original filament's location. The result is chromospheric heating and a parallel ribbon flare. The separation between the ribbons tends to widen with time because as the magnetic field loops supporting the original filament continue to rise, their "feet" diverge.

6.6.4.2. Impact flares typically show a slow rise time to maximum brightness (about 30 - 60 minutes), exhibit faint to normal brightness, cover large areas (importance 3 or 4), and last for hours. Impact flares are not particularly energetic phenomena, and are rarely associated with X-ray events or significant high-energy particle emissions. However, escaping material from the erupting, disappearing filament itself can produce a geomagnetic disturbance. Impact flares should not be confused with the parallel ribbon flares that occur in active regions, often in association with disappearing plage filaments. Such active region parallel ribbon flares are associated with energetic particle (proton) events.

6.7. Preparation for Automatic Flare Analysis. Accurate flare analysis is sensitive to SOON system alignments and calibrations. To prepare for flare patrol and to resolve intersite differences, analysts should:

6.7.1. Check and, if needed, correct the image rotator alignment.

6.7.2. Verify image calibrations and area conversion factors using the system Calibration and Maintenance programs.

6.7.3. Verify proper birefringent filter transmission using the transmission calibration SOON Rehost Calibration and Maintenance programs.

6.7.4. Occasionally check alignments using the SOON Rehost Calibration and Maintenance programs.

6.7.5. Check the overall data collection system e.g., AGC, video, and computer by examining a Histogram plot of MAGR.

6.7.6. Minimize scanner mirror movements to reduce equipment wear and allow more time for images to stabilize for sampling. Putting regions in close proximity within the same sequence can minimize mirror movements. In addition, mirror movements between sequences should not exceed one solar radius, unless it is unavoidable. **NOTE:** It is also useful to place significant regions last in each sequence, so they will be visible for a longer time.

6.8. Analysis Boxes.

6.8.1. Analysts establish areas in the solar image to be sampled for flare detection by constructing analysis boxes. The computer controlled SOON telescope can automatically scan and analyze the area in a box to determine 64 brightness levels. When a pre-set threshold is exceeded for three successive reads in any box, the computer will declare a flare to be in progress.

6.8.2. General rules for ensuring a "good" MAGR box.

6.8.2.1. Locate the box as close as possible to the disk center.

6.8.2.2. Make the box at least 150 x 150 arc-seconds in size.

6.8.2.3. Ensure the box is as completely devoid of features (plage, filaments, etc) as possible.

6.8.3. General rules for “good” flare detection boxes.

6.8.3.1. Ensure at least two-thirds of the box is quiet sun (i.e., not plage, filaments, etc).

6.8.3.2. When practical, center a region in its box.

6.8.3.3. Minimize “sky” area in boxes near the limb by making tall, narrow boxes. Offset the region in the box if necessary, and periodically check the box's location relative to the limb. Do not move region center when adjusting boxes near limb; only move the box center. This will ensure regions rotate off the limb as expected. **NOTE:** Wide boxes near the limb can cause inaccuracy in flare analysis when the limb darkening correction is applied.

6.8.3.4. Quiet sun boxes may overlap.

6.8.3.5. Avoid overlap with adjacent active regions (i.e., have plage from only one region in each box).

6.8.3.6. Coordinate locally assigned box numbers with other operating observatories, to prevent more than one number being used for the same region, or the same number being used for different regions.

6.9. Data Analysis.

6.9.1. The stored data for any analysis box can be graphically displayed as a histogram plot (Figure 6.1). Histogram programs are particularly valuable as tools for evaluating flare thresholds, brightness and area measurements, and for reconstructing entire flare events.

6.9.1.1. Use Histograms to verify start, peak, or end times, as well as secondary maxima. Also use Histograms to identify suspect samples (spikes, dropouts, or data gaps) in order to qualify flare reports.

6.9.1.2. As an analytical tool, use Histograms to cross-check measurements and to assist in trouble-shooting where bad samples are involved (e.g., too much "sky" in an analysis box, video malfunction, etc.).

6.9.2. The position of the faint flare threshold in relation to the quiet sun level is a major determinant in flare start time, end time, and area measurement.

6.9.2.1. The Flare Threshold program automatically reads the last 10 to 20 minutes worth of histograms for each region being sampled. It then computes a best-fit line for the histogram peak intensities. If the slope of that line is close to zero and no peak varies from the line by more than 20%, the faint flare threshold is automatically adjusted. Flare Threshold, however, becomes ineffective during intermittent observations or when fluctuating plage or point brightenings are present. During periods when Flare Threshold has difficulty assigning a valid flare threshold setting, use Histograms to verify a region's peak brightness and current flare threshold setting. If the stable peak intensity (or average peak for fluctuating plage/point brightenings) is above or below the current setting, the analyst may manually adjust the faint flare threshold using the Flare Threshold program. If possible, avoid adjusting it below the 160% level (bin 16). **NOTE:** Do not adjust the faint flare threshold during a flare, unless: it is a "false" flare caused by the threshold being set too low, or the flare will not end because the plage remains enhanced at a level above the threshold.

6.9.2.2. During fluctuating background conditions, any faint flare threshold setting may be a compromise between many "false" flares (when the threshold is set too low) and under-measuring flare area (when the threshold is set too high). During these times, post analysis is the only way to ensure accuracy and inter-site consistency. To perform a post analysis:

6.9.2.2.1. Examine the Histogram plot for a correct faint flare threshold. The threshold is set correctly when the average pre-flare peak intensity readings are representative of the faint flare threshold value (Figure 6.1).

6.9.2.2.2. If the Histogram plot indicates that an incorrect threshold was set prior to automated flare analysis, reset the faint flare threshold. Use the new values and times obtained from this new Histogram plot to correct the final FLARE message. The Histogram program will plot single histograms and should be used to confirm data at flare maximum for correct classification. Remember, in order to classify a flare's brightness, three consecutive brightness readings must have a corrected area of at least 10 millionths of the hemisphere. **NOTE:** In the FLARE message, leave the “method or type of observation” T = 4 (Electronic) in the TIBcc group, since the computer is still your data source.

6.9.2.2.3. Occasionally, the plage field may remain enhanced above the pre-flare threshold value for an extended period (up to two hours) after the flare ends. During this period, the computer may incorrectly continue the flare. The analyst must again use post analysis to correctly end the flare. Once it is determined from the Histogram plot that the flare has ended but the plage field has remained enhanced, raise the flare threshold to force an end to the flare. Assign a flare end time that is no later than ten minutes after the plage brightness became stable. Transmit a final FLARE message, or a correction, with the correct end time taken from the Histogram.

6.10. Equipment Setup for Semiautomatic Operations. The following suggested setups might be varied to meet local needs:

6.10.1. Beam Selector in position “1” for TV monitor observations.

6.10.2. Hα/B2 switch in “Hα” position.

6.10.3. Hα Lens Interchange in “FULL DISK”.

6.10.4. Guider Module switch in “ENABLE”.

6.10.5. All Servo Module switches (except for RA and DEC) in “Manual”, with all potentiometers (except AGC) set to “500”. Adjust AGC to a suitable light level.

6.10.6. Master monitor switcher in either “Hα HIGH” or “Hα LOW”.

6.10.7. Analysis Monitor switcher in “Hα LOW”; monitor overlay secured in place. Do not change monitor adjustments in any way that would alter image dimensions.

6.11. Preparing Flare Area Correction Tables.

6.11.1. In Semiautomatic Mode.

6.11.1.1. Update tables using the SOON Rehost Monitor Overlay Correction tool. Optionally provide a hard copy of the conversion table for use when Rehost is not available.

6.11.1.2. Flare areas, observed on a large scale Hα image, are measured in grid squares to the nearest 0.1 square (for the monitor overlay method). Then a locally completed version of Table 6.3 is used to convert this measured (apparent) area to corrected area in millionths of the solar hemisphere.

6.11.2. The Site Correction (Sc) factor is the number of millionths of the solar disk contained in a square grid (for the overlay method). Sc is independent of Rv, but will differ depending on which TV monitor is used, or whether an eyepiece is used. As a result, at each observatory a separate table is required for each display device that might be used during semiautomatic operations.

Table 6.3. Sample Flare Area Correction Table.

Rv	Sc	CF	TC	Rv	Sc	CF	TC	Rv	Sc	CF	TC
.00-.42:		x.50=		.77:		x.63=		.90:		x.81=	
.43-.48:		x.51=		.78:		x.64=		.91:		x.84=	
.49-.53:		x.52=		.79:		x.65=		.92:		x.87=	
.54-.57:		x.53=		.80:		x.66=		.93:		x.90=	
.58-.60:		x.54=		.81:		x.67=		.94:		x.94=	
.61-.63:		x.55=		.82:		x.68=		.95:		x1.00=	
.64-.65:		x.56=		.83:		x.69=		.96:		x1.06=	
.66-.67:		x.57=		.84:		x.70=		.97:		x1.14=	
.68-.69:		x.58=		.85:		x.72=		.98:		x1.27=	
.70-.71:		x.59=		.86:		x.73=		.99:		x1.47=	
.72-.73:		x.60=		.87:		x.75=		1.00:		x2.50=	
.74:		x.61=		.88:		x.77=					
.75-.76:		x.62=		.89:		x.79=					

6.11.3. The Sc factor is computed by dividing the area of the solar disk expressed in units of millionths of the solar disk by the area of the solar disk expressed in square grids for the overlay method.

6.11.3.1. For the Overlay Method: Move a large scale image of the sun across the TV monitor under the overlay grid. Count the number of grids from limb to limb, i.e., across the solar diameter. Divide the result by two to get the solar radius (r) in units of grid width. Then use the following equation:

$$Sc = \frac{10^6}{3.14 \times r^2} = \text{millionths of the disk per square grid}$$

6.11.4. Each time an observatory changes a Sc factor, a new table listing the Total Correction (TC) factors must be prepared. Check and (if necessary) recalculate the Monitor Overlay Sc factor anytime an adjustment is done which could affect the TV image (e.g., Hα light path or vidicon alignment). Avoid unnecessary adjustments to the TV monitor used for measurements. In particular, changes in the height or width controls will affect the accuracy of a previously computed Sc factor. Check and (if necessary) recalculate the Eyepiece Sc factor anytime an Hα light path alignment is performed (except for minor focus adjustments). **NOTE:** It is recommended that the flare area correction tables be maintained in a spreadsheet to facilitate easy re-computation. Where:

Rv = Radius Vector (Rv = 0.0 at disk center, and Rv = 1.0 at limb)

Sc = Site Correction Factor; the number of millionths of the disk contained in a square grid (for the overlay method) or in a square millimeter (for the eyepiece method). Sc is the same for all Rv values.

CF = Conversion Factor:

$$CF = \frac{0.5}{0.2Rv + \sqrt{1-(Rv)^2}}$$

NOTE: CF accounts for foreshortening, vertical height of flares, and the Sc.

TC = Total Correction Factor; the final number desired from the table above for use in the equation:

$$Corrected\ Area = \text{TC} \times Measured\ Area$$

Chapter 7

DALAS ANALYSIS TECHNIQUES

7.1. Disk and Limb Activity Summary (DALAS) Analysis.

7.1.1. Since the SOON telescope's primary function is flare detection; it is not configured to automatically detect other forms of solar activity. Furthermore, much of the reportable non-flare activity occurs outside areas being monitored for flares.

7.1.2. For these reasons, identifying and reporting non-flare DALAS information is up to the analyst’s discretion. Use AWS TR 75-252 (*A Solar Optical Observer's Guide*, R. Agee, September 1975), and this chapter to identify and analyze DALAS activity.

7.2. Filaments and Prominences (Active Dark Filament (ADF), Active Prominence Region (APR), Disappearance of Solar Filament (DSF), Eruptive Prominence on Limb (EPL)).

7.2.1. The terms filament and prominence refer to the same phenomena: a long, narrow, cloud-like structure in the chromosphere or corona where the solar plasma is cooler and denser than its surroundings, and is supported by the interaction of horizontal magnetic fields and electric currents within the filament/prominence. Against the relatively intense Hα emitting disk they appear as dark absorption features (filaments). At the limb, they appear as relatively bright features (prominences), since their weaker Hα emission is evident when compared to the black background of space. The coronal gas surrounding these features is so hot that *all* its hydrogen is ionized and does not produce any Hα emission. On the other hand, the material in filaments and prominences is partially ionized, so solar magnetic fields shape the material and control its flow. There are two general classes of filaments/prominences: quiescent and plage (associated with active regions).

7.2.2. Quiescent Filaments and Prominences.

7.2.2.1. Development: These structures are supported by horizontal magnetic fields (about 3 to 8 Gauss) lying between large photospheric magnetic sectors. Since their supporting magnetic structure changes slowly, quiescent filaments/prominences are stable features with lifetimes that often last several months. These filaments/prominences may disappear in three ways: Material may diffuse into the surrounding corona, material may flow down into the chromosphere and not be replaced, or material may erupt as supporting magnetic fields are suddenly altered by an external disturbance such as a major flare.

7.2.2.2. Active Phases: Quiescent filaments/prominences may experience periods of activity as changes occur in there supporting magnetic fields. When a filament/prominence varies in darkness/brightness (corresponding to a change in density), size, and/or shape, it is called an ADF (active dark filament) or APR (active prominence region). The activity may also involve a violent eruption. On the disk, such an eruption is observed as a sudden DSF (disappearing solar filament) as its material is Doppler-shifted out of Hα line center. On the limb, the motion is mostly across the line-of-sight, so the Doppler Effect is small and an EPL (eruptive prominence on limb) is seen to lift away from the sun. During an EPL, the lifting action generally starts slowly, and then rapidly accelerates; an EPL often achieves escape velocity and reaches "event" criteria (radial extent of 0.15 solar radius or greater). A day or so after a DSF or EPL occurs, the filament/prominence may reform in roughly the same shape and location. This tendency indicates that the underlying magnetic field configuration (anchored below the sun's surface) is basically unchanged by the disturbance.

7.2.2.3. Relation to Flare Activity. When a quiescent filament/prominence becomes a DSF or EPL, it may cause a flare to occur. Conversely, a flare may cause filament/prominence activity or trigger a DSF or EPL.

7.2.2.3.1. During a DSF or EPL, some of the material may escape the sun, more material dissipates into the corona, but most of the material returns to the chromosphere along magnetic field lines down either side of the ascending filament/prominence. The returning material may induce a parallel ribbon flare. For a quiescent filament/prominence, this parallel ribbon flare is called a “Hyder (infall-impact)” flare, which is a low-energy flare that typically shows a slow rise time, faint to normal brightness, and a large area. Although the flare itself is not an energetic particle producer, the escaping filament/prominence material may lead to a geomagnetic disturbance.

7.2.2.3.2. A major flare may precede, rather than follow, the disappearance or eruption of a quiescent filament/prominence (DSF or EPL). However, flares more often cause activation, rather than actual disappearance/eruption of a filament/prominence. A filament may wink in and out of visibility (Hα line center) in response to Doppler shifts caused by oscillatory motions induced by the passage of a Moreton shock wave from the flare. A prominence can display changes in brightness, size, and/or shape during such oscillatory motions.

7.2.3. Plage (or Active Region) Filaments and Prominences.

7.2.3.1. Development. These structures are supported by stronger horizontal magnetic fields (up to about 100 Gauss) lying above magnetic inversion lines in, or at the border of, active regions. Since plage filaments/prominences are associated with active region magnetic fields, compared to quiescent filaments/prominences they are: smaller, shorter and narrower, lower in the solar atmosphere, shorter-lived (days vice months), and subject to more frequent periods of activation. Plage filaments/prominences may disappear through any of the same three mechanisms as quiescent filaments/prominences (see 7.2.2.1).

7.2.3.2. Active Phases. The terms ADF, APR, DSF, and EPL apply equally well to plage and quiescent filaments/prominences. In fact, since the supporting magnetic structure in an active region involves higher field strengths and can change over a short time scale, plage filaments/prominences tend to vary in darkness/brightness (density), size, and shape more rapidly and frequently than do quiescent filaments/prominences. Like quiescent filaments /prominences, disappearing or erupting plage filaments/prominences tend to reform in roughly the same shape and location since the underlying magnetic field configuration (anchored below the sun's surface) is basically unchanged by the disturbance. However, plage filaments/prominences tend to reform quicker, in a matter of hours, vice a day or more.

7.2.3.3. Relation to Flare Activity. Active region filament activity is traditionally considered a flare precursor, even a prerequisite; however, observations do not always support this. Plage filament/prominence activity (especially a DSF or EPL) indicates significant magnetic restructuring in an active region that may lead to a flare. Conversely, a flare is very likely to cause plage filament/prominence activation (possibly even a DSF or EPL).

7.2.3.3.1. Preflare activation of a plage filament/prominence (ADF or APR) indicates changes in the surrounding magnetic field, which may increase the potential energy of an upcoming flare. In the extreme case of a DSF or EPL, most of the material falls back to the surface along magnetic field lines on either side of the ascending filament/prominence. The returning material may induce a parallel ribbon flare (Hyder flare). For a plage filament/prominence, an associated parallel ribbon flare is typically a fast-rise, high-energy flare often associated with significant x-ray, radio, and energetic particle (proton) emissions.

7.2.3.3.2. The rapid restructuring of a region's magnetic field structure during a flare will temporarily influence the stability of an associated filament or prominence. In addition, the flare may generate a Moreton shock wave, which would likely activate plage filament/prominence, possibly resulting in a DSF or EPL, within the region. In fact, the shock wave from a flare may even induce changes in plage filaments/prominences in neighboring regions or quiescent filaments/prominences.

7.2.4. Active Dark Filaments (ADF).

7.2.4.1. An ADF generally exhibits one or more of the following characteristics: change in absorption (darkness, brightness, dissipation), change in shape (moves, displacement), and/or increased internal motions (Doppler shifts of 0.6 Angstroms or greater in either wing).

7.2.4.2. All three characteristics involve some temporal change. When used alone, off-band measurements do not necessarily indicate a change. So, off-band measurements should be used conservatively as a sole criterion for ADF identification. If a filament fades from sight within ±0.5 Angstroms and does not exhibit other characteristics, it is quiescent, not active. However, if the filament is definitely visible to a full 1.0 Angstroms off-band it may be considered a legitimate ADF regardless of other characteristics.

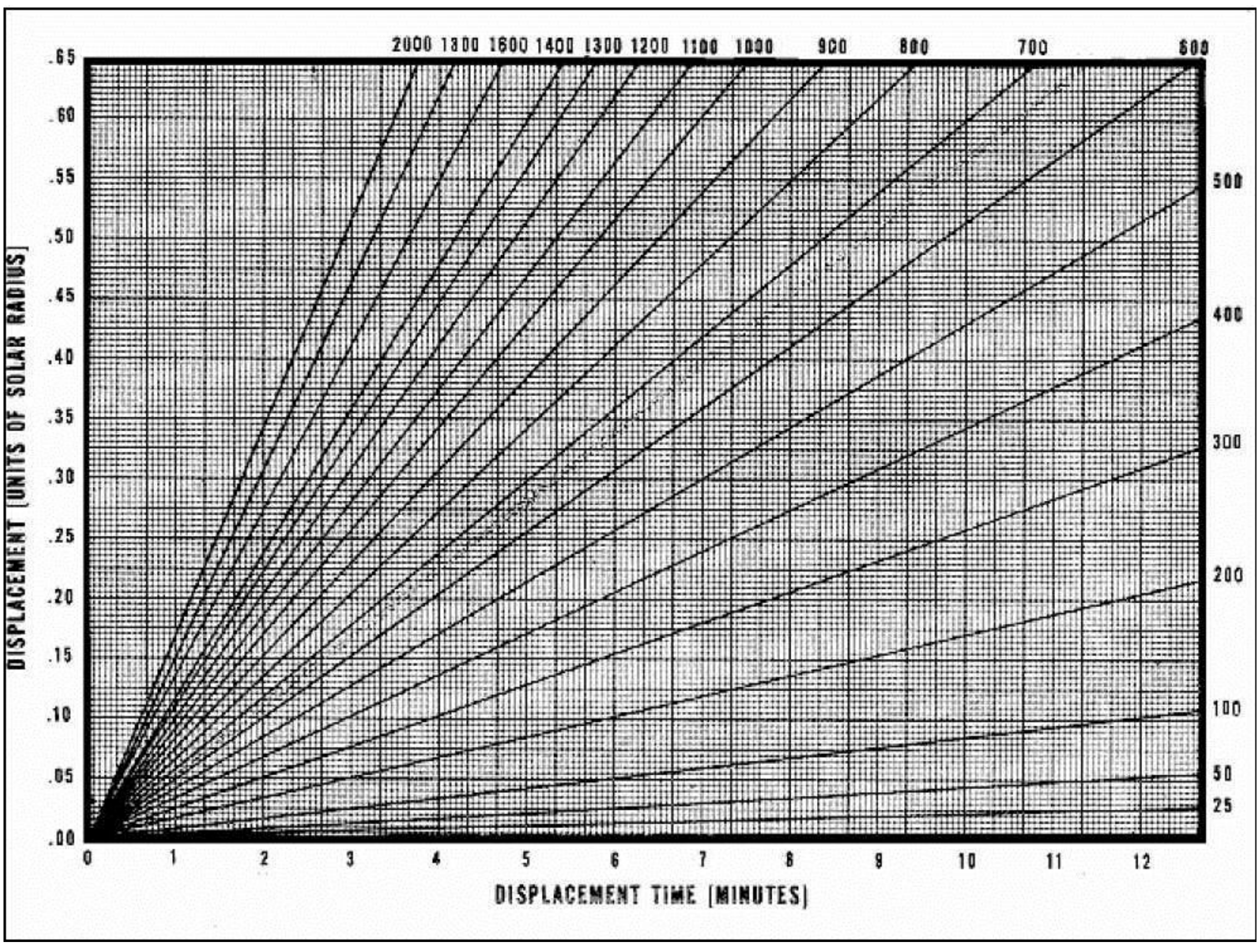
7.2.5. DSFs and EPLs.

7.2.5.1. As mentioned earlier, filaments/prominences may disappear in three ways. Material may diffuse into the surrounding corona, material may flow down into the chromosphere and not be replaced, or material may erupt as supporting magnetic fields are suddenly altered by an external disturbance such as a major flare. Diffusion into the corona represents a generally slow fade or breakup in about 3 to 10 hours and is not normally accompanied by any motion. Eruption generally represents a sudden disappearance of a filament or prominence within a few minutes to a couple hours. Only a filament or prominence that erupts is likely to cause a geomagnetic disturbance at the earth. The difference between the dissolution and eruptive process is sufficiently important to justify appending a PLAIN language remark to the coded DALAS report if the analyst can clearly distinguish which process occurred.

7.2.5.2. A filament/prominence eruption does not guarantee a geomagnetic disturbance. Three factors must be considered: The filament/prominence must be sufficiently large. It is generally accepted that filaments of at least 10 to 20 square heliographic degrees are likely to have enough material to cause a geomagnetic disturbance. However, since we are unable to view filaments in three dimensions, it is difficult to assess their volume, density, and therefore total mass. This is why it is not possible to set a minimum size threshold for a geo-effective DSF. For USAF observatories, reporting "very small" DSFs (loosely defined as less than about 5 square heliographic degrees) is optional. An analyst must evaluate the circumstances on a case-by-case basis to determine if such a DSF should be reported using the DALAS code. Analysts may find it helpful to crosscheck with other sites. **NOTE:** The loosely defined threshold between reportable and non-reportable DSFs is similar to the more sharply defined threshold between bright points and a zero-faint flare.

7.2.5.2.1. Second, the ejected material may not have entirely escaped the sun. If the supporting magnetic fields do not support continued travel away from the sun, most of the plasma will fall back. To determine the velocity of material being ejected from the sun perpendicular to the line-of-sight, use Figure 7.1.

Figure 7.1. Solar Velocity Estimation Graph (km/sec as displayed on right/top edge).



7.2.5.2.2. Finally, the ejected material may miss the earth. The earth is a tiny target at 93 million miles from the sun; most solar mass ejections will simply pass above, below, ahead, or behind the earth.

7.2.5.3. If portions of an ADF disappear, report those sections as DSF activity, and reevaluate the remaining filament structure to determine if the ADF should be terminated or continued.

7.3. Active Surge Regions (ASR): Bright Surge on Limb (BSL), Bright Surge on Disk (BSD), Dark Surge on Disk (DSD).

7.3.1. A surge is an outward ejection of material, often from the vicinity of an active region. The material follows magnetic field lines outward, but does not have the continued magnetic support to escape the sun. The material either fades into the corona falls back along the same path, or follows a magnetic loop that returns to the solar surface. Most surges are not flare related and achieve speeds of 50 to 200 km/sec. Although individual surges may last tens of minutes, a region may continue to produce surging for up to several days.

7.3.2. Surges that *are* flare related tend to have the highest speeds (up to several hundred km/sec) and reach the greatest heights. Seen on the limb, such a flare related surge is classified as a BSL if it reaches or exceeds a radial height of 0.15 solar radius. Surging that reaches less than 0.15 solar radius is classified as an ASR. On the disk, most surges appear dark, a DSD, but some surges may appear bright, a BSD, especially in the initial phase of surging. If a surge exhibits both BSD and DSD characteristics, report which aspect was most representative during the lifetime of the surge. Disk surges usually show blue Doppler shifts in their early phase (indicating rising material), and red shifts in their later phase (falling material). When not flare associated, a DSD area may last for hours up to a day or more and represents the disk counterpart of an ASR.

7.4. Other DALAS Types: Spray (SPY), Loop Prominence System (LPS), Coronal Rain (CRN), Arch Filament System (AFS).

7.4.1. Spray (SPY). A spray is a rare, very energetic, flare-related ejection of material off the solar limb. Sprays appear as outward moving clumps of material, moving with speeds of about 400 km/sec or greater. Some of the material falls back to the surface, but much of it dissipates into the corona or entirely escapes the sun. Sprays often reach event criteria (0.15 solar radius or greater). Sprays favor no particular direction and are frequently not directed radially outward from the limb. **NOTE:** For comparison, a BSL is a continuous stream of material, has a lower speed, and is usually directed radially outward. Sprays are almost never observed on the disk because they last for a short time and their high speed causes a large Doppler shift (well out of Hα line center).

7.4.2. Loop Prominence System (LPS). Loop-shaped prominences occasionally develop during the post-maximum phase of energetic, non-Hyder parallel ribbon flares, and may persist for several hours after the flare subsides. Since such loops indicate that the flare is associated with extreme particle (proton) acceleration in the corona, these features are always considered event-level activity. LPS features are observed on the limb, with the responsible flare sometimes partly or completely hidden by the limb. The loops initially form in the corona as small, suspended condensations (knots, beads, or arcs). For the solar analyst, these "top knots" can be an important identifying feature of an LPS. As material high in the corona flows down magnetic field lines, arched legs form below the top knots, another feature that distinguishes true loop prominences from a loop-shaped surge. Loop-shaped surges have upward motion in one leg and downward motion in the other leg, generally lie lower in the atmosphere, and do not persist as long as an LPS. Loop prominences tend to form in striated patterns, either a fan of loops whose feet converge at two points within or near the active region that has just flared, or a tunnel of loops whose feet connect to the regions that had just supported a parallel ribbon flare. Disk loops usually appear as thin dark absorption features and are not easily observed; they may be better seen in the red wing of Hα, as loop material is draining down, away from the observer.

7.4.3. Coronal Rain (CRN). While this feature is not reported by USAF observatories, it is important analysts recognize coronal rain so they will not mistake it for another type of reportable activity (such as an LPS). Coronal rain is magnetically unsupported material that condenses in the corona and flows downward along magnetic field lines as luminous streamers. It often appears as a faint fan or funnel-like structure in which material falls with noticeable speed. CRN can be distinguished from a dissipating prominence by the high speed of its material and its luminosity. CRN may last a few hours and can recur in the same location over several days. It is usually associated with mature or decaying active regions, or it may herald the approach of an energetic active region by up to several days. **CAUTION:** Observed in profile, CRN may resemble weak, half loops, but are distinguished from a LPS by no curvature at the top.

7.4.4. Arch Filament System (AFS). These are dark, linear absorption features usually observed only in young, developing bipolar plage regions, or in emerging flux regions (EFR). An AFS appears as one or more short, dark, parallel arches connecting plage of opposite polarity (Figures 5.4 and 5.5). A single arch filament element lasts only 20 to 30 minutes, although an arch filament system may persist for several days. The legs of individual arch filaments are inclined less than 30° to the sun's surface and the tops of the arches lie at a low altitude, rarely more than 10,000 km. Since AFS normally occur in young, maturing active regions, they are usually associated with subflares (importance of 0). The disappearance of AFSs at spot group maturity is one indicator that stronger flares may soon follow. While significant flare activity is typically inhibited in the immediate vicinity of AFS, the presence of AFS near an existing mature region indicates increased magnetic field complexity, which may lead to greater flare activity in the mature region later on.

7.4.4.1. Due to their low altitude, arch filaments, like fibrils, represent only the horizontal component of the magnetic field near the sun's surface. As a result, an AFS is aligned parallel to the fibril pattern between the plage of opposite polarity. Arch filaments are not "true" filaments, since they lie across (rather than along) magnetic inversion lines, and are lower in the chromosphere than plage filaments (Figure 5.5).

7.4.4.2. Material flows downward in both legs of an arch filament, as is the case with flare loops. However, arch filaments are distinguished from loop prominences by being much lower in the atmosphere, being about ten times smaller in size, and having a lack of flare history. In fact, AFSs lie so low in the atmosphere that they are usually not visible on the limb.

7.5. DALAS Locations.

7.5.1. The location of DALAS features, expressed by their CMD and heliographic latitude, are determined using the same general methods described in Chapter 6 for flare locations. The CMD of a limb feature is defined as 90º, unless a portion of the feature clearly originates from a point on the disk (i.e., a combined disk/limb feature).

7.5.2. In Automatic Mode. Use SOON Rehost tools to locate specific points on the sun's disk. As needed, rerun tools to refine the location as the activity progresses.

7.5.3. In Semiautomatic Mode.

7.5.3.1. Using SOON Rehost. SOON Rehost may be used to determine the location of DALAS activity if there is a recently acquired large scale image of the region available within the image database or it is possible to acquire a current image.

7.5.3.2. If unable to use SOON Rehost, estimate location of the feature by its relation to a nearby solar feature (e.g., 2° south of a leader spot).

7.5.3.2.1. Determine the location of the reference feature (e.g., the spot) using the appropriate Stonyhurst overlay (adjusted for P-angle), and as many of the following tools as is required: the white light projection board, a sunspot drawing, Region Definition table printout, or current BXOUT message from your site or another site.

7.5.3.2.2. Determine the DALAS feature's latitude and longitude from the reference feature's location.

7.5.3.2.3. Unless the reference image used is real-time, the DALAS feature's current position is actually west of the location due to solar rotation. To compute a correction factor for the longitude: multiply the rotation rate (0.55° per hour) to the time difference (in hours and tenths of hours) between when the DALAS feature occurred and when the reference image was made. (A rate of 0.50º per hour is more accurate for features at high latitudes.)

7.5.4. The procedure for reporting DALAS activity varies with the type of feature.

7.5.4.1. SPY, BSL, DSD, or BSD: The location is the base, or point of origin, of the spray or surge.

7.5.4.2. ASR, APR, EPL, AFS, ADF, CRN, or DSF: The location of a feature of 5º or less in length may be reported by its center or midpoint. For a feature greater than 5º in length, use the feature's endpoints. For unusually shaped features, the analyst may report additional intermediate points. However, if more than a total of three points are needed, the analyst must either report the additional points in an appended PLAIN language message, or divide the feature into sections and report them as part of the same feature in separate DALAS messages.

7.5.4.3. LPS. The location of limb loops is the point on the limb midway between the legs. For disk loops, the location is the apparent center of mass on a line midway between the legs. Normally there are two distinct legs or set of legs; however, a complex array may be present. This can indicate that several sets of loops exist. Use judgment in coding location, and report several sets of loops only if they are well apart from each another.

7.5.4.4. Further guidance on reporting locations for combined disk/limb activity is provided later in this chapter.

7.6. Off-Band Measurements.

7.6.1. Use SOON Rehost to make off-band measurements when in automatic mode. The DALAS program can also be used while in semiautomatic mode (e.g., during low light levels).

7.6.2. In semiautomatic mode, make DALAS off-band measurements in much the same way as for semiautomatic flare brightness measurements. Use locally developed Doppler shift tables, which list the correct AGC, 1-Angstrom, and 1/2-Angstrom settings for each off-band measurement. Adjust the AGC, 1-Angstrom, and 1/2-Angstrom Polaroids to the values listed in the tables. Step through the off-band settings, in both the red and blue wings, to determine the amount of Doppler shift in each wing.

7.7. Heliographic Extent and Radial Extent.

7.7.1. The RR group in the DALAS code reports the "heliographic extent" (i.e., length) for disk activity, and the "radial extent" for limb or combined disk/limb activity.

7.7.2. Disk Activity. Report the "heliographic extent" of a feature in whole degrees. This measurement represents a total length from one endpoint of the feature to its other endpoint, following every kink or bend in the feature (Figure 7.2).

7.7.2.1. Determine the heliographic extent using the SOON Rehost Analysis Console to find the endpoint locations. Use Pythagorean Theorem ($c^2 = a^2 + b^2$) to compute lengths, where "a" and "b" correspond to increments in latitude and longitude, expressed in degrees:

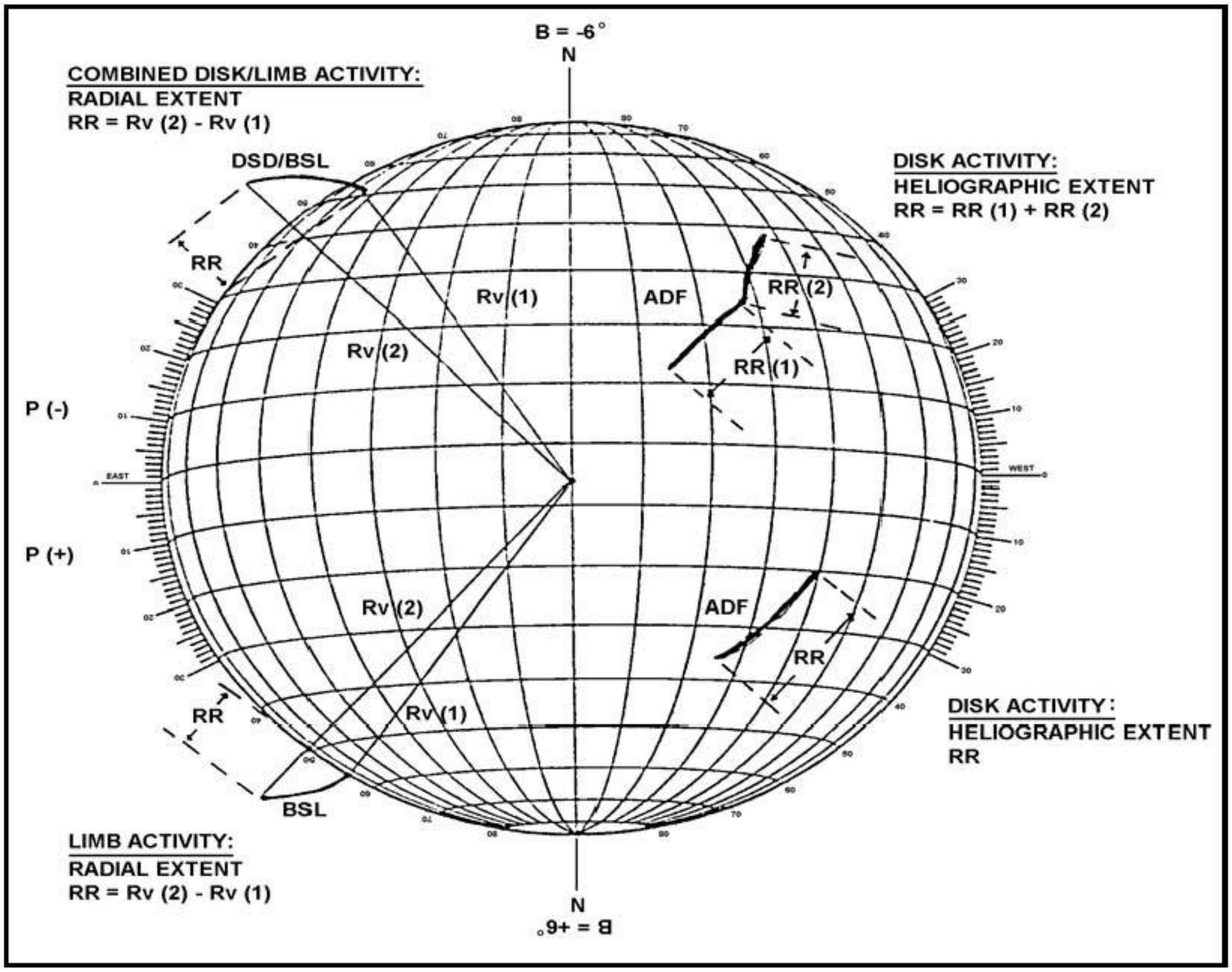
$$Total\ Length = \sqrt{(Latitude\ Change)^2 + (Longitude\ Change)^2}$$

7.7.2.2. If computer-derived coordinates are unavailable, the length can be estimated by comparing the feature with other nearby features of known length, such as sunspot groups. When comparing with other features at different Rv values, remember to allow (at least qualitatively) for the effect of geometric foreshortening.

7.7.3. Limb, or Combined Disk/Limb, Activity.

7.7.3.1. Report the "radial extent" of a feature in hundredths of the solar radius. For activity only on or above the limb, radial extent is the difference between the Rv of the limb (Rv = 1.0) and the Rv of the outermost extent of the phenomena (Figure 7.2). For combined disk/limb activity, radial extent is the difference between the Rv of the point of origin (Rv < 1.0) and the Rv of the outermost extent of the phenomena. Take measurements periodically until the maximum radial extent is reached.

Figure 7.2. Heliographic Extent and Radial Extent (RR Group).



7.7.3.2. To determine the Rv of a particular point, use any of the following tools (if available): SOON Rehost; the white light projection board; a sunspot drawing; an 18 cm Rv overlay; recent Region Definition table printout; or current BXOUT message from your site or another site. Alternatively, use a TV monitor overlay.

7.7.3.2.1. If using an image, apply the appropriate Stonyhurst overlay, and use a ruler to measure the distance in millimeters from the disk center to the point of interest. The Rv value (in hundredths of the solar radius) equals the number of millimeters divided by 90 for an 18 cm disk (or see Table 6.2). **NOTE:** If the image is not a real-time image, the point's current position is actually west of its measured location due to solar rotation. To correct the point's longitude: multiply the time difference (in hours and tenths of hours) between when the DALAS occurred and the time of the image by a rotation rate of 0.55º per hour (A rate of 0.50º is more accurate for features at high latitudes).

7.7.3.2.2. If using a TV monitor overlay, align the grids so they are perpendicular to a line connecting the disk center and the point whose Rv is desired. Count the number of grid squares to the nearest tenth grid. Then multiply the number of grids by the applicable (normally large scale image) local conversion factor (see section 6.11.3. for details).

7.7.3.3. Since features are frequently not exactly aligned along a line connecting the center of the disk with the endpoint of the feature, radial extent is not a measure of the true length of the feature. Furthermore, due to the effect of projecting a feature onto the image plane perpendicular to the observer's line-of-sight, radial extent is a poor measure of the height that a feature has reached into the corona. This projection inaccuracy is especially relevant for DALAS features, which originated either on the disk or from behind the limb. However, reporting radial extent, as defined above, is an accepted approximation.

7.8. Combined Disk/Limb Activity.

7.8.1. Some DALAS phenomena are not limited exclusively to the disk or limb. If a combined disk/limb feature has a radial extent (from its point of origin) of 0.15 solar radius or greater, it meets the requirement for a limb "event" (e.g., Limb East (LIMBE) or Limb West (LIMBW)). The projection inaccuracy mentioned above (7.7.3.3.) suggests that this event definition is not accurate for all features; however, it is an accepted approximation.

7.8.2. To avoid over-reporting limb events, consider this rule-of-thumb: Hesitate to report a combined disk/limb feature as a limb event if more than about a third of its radial extent from its point of origin lies on the disk. The reason for this is that in order for a combined disk/limb feature whose point of origin is well inside the limb to achieve such a large radial extent, the feature's true spatial orientation must be mostly perpendicular to the observer's line-of-sight. In other words, its motion was likely more parallel to the sun's surface (not as significant) than upward into the corona (more significant). If an analyst believes a particular phenomenon is an event, despite this guidance, it should be reported as an event.

7.8.3. Surge Combinations.

7.8.3.1. Types.

7.8.3.1.1. DSD (or BSD)/ASR. A dark (or bright) gaseous stream of material originating from a point on the disk which, due to its proximity to the limb extends beyond the limb. The radial extent (from the point of origin) is less than 0.15 solar radius.

7.8.3.1.2. DSD (or BSD)/BSL. A dark (or bright) gaseous stream of material with characteristics similar to a DSD (or BSD)/ASR combination; however, in this case the surge is more impulsive and achieves a radial extent (from the point of origin) of at least 0.15 solar radius.

7.8.3.2. Reporting.

7.8.3.2.1. Encode the name of the limb feature (ASR = 01 or BSL = 04), and the location of the point of origin of the surge. Encode the radial extent (RR) as the difference between the Rv of the point of origin and the Rv of the outermost extent of the phenomena (Figure 7.2). If the radial extent is at least 0.15 solar radius, it is a limb "event" (e.g., 456123 or LIMBW).

7.8.3.2.2. Use of a PLAIN language message appended to the coded DALAS report is highly encouraged to clarify the situation or provide additional information.

EXAMPLE #1: COMBINATION DSD/BSL WITH TOTAL RADIAL EXTENT FROM POINT OF ORIGIN OF 0.17 SOLAR RADIUS.

EXAMPLE #2: COMBINATION DSD/ASR HAS BECOME A DSD/BSL, SINCE RADIAL EXTENT FROM POINT OF ORIGIN HAS INCREASED TO 0.16 SOLAR RADIUS.

7.8.4. Filament/Prominence Combinations.

7.8.4.1. Types.

7.8.4.1.1. ADF/APR. The activation of a quiescent filament/prominence, which has a portion of its active material on the disk and a portion extending beyond the limb.

7.8.4.1.2. DSF/EPL. A filament on the disk erupts, and the displaced filament material becomes visible as a prominence as it moves beyond the limb.

7.8.4.2. Reporting.

7.8.4.2.1. Encode the name of the limb feature (APR = 02 or EPL = 05), and the location of the feature's endpoints and, if appropriate, intermediate points. Report enough points to allow the feature to be accurately redrawn from the report. For combined limb and disk activity, encode radial extent from the feature’s point of origin to the outermost extent of the feature, expressed in hundredths of the solar radius. If the radial extent is 0.15 solar radius or greater, it is a limb "event" (e.g., LIMBE or LIMBW). **NOTE:** The feature's heliographic extent, or length, can be determined after-the-fact from the feature's reported location. However, the analyst can assist the forecast centers by reporting the heliographic extent in an appended PLAIN language message.

7.8.4.2.2. Use of a PLAIN language message appended to the coded DALAS report is highly encouraged to clarify the situation or provide additional information.

LOUIS ZUCCARELLO, Colonel, USAF
Commander

Attachment 1

GLOSSARY OF REFERENCES, ABBREVIATIONS, AND ACRONYMS

References

AFMAN 15-124, *Meteorological Codes*, 28 October 2009

AFMAN 33-363, *Management of Records*, 1 March 2008

AFWAI 15-2, *Space Environmental Observations Solar Optical and Radio Observing*

AFWAMAN 15-2, *Space Environmental Observations Solar Radio Observing Techniques*

AWS-TR-75-252, *A Solar Optical Observer's Guide,* September 1975

AWS-TR-76-262, *Development and Decay Potential of Active Solar Regions from a Full-Disk Neutral-Line Analysis*, April 1976

T.O. 31M1-2FMQ7-1 *Operations and Maintenance Instruction for the Solar Observing Optical Network (SOON) AN/FMQ-7*, 22 October 2008

Abbreviations and Acronyms

Ac—Corrected Area

ADF—Active Dark Filament

AFI—Air Force Instruction

AFS—Arch Filament System

AFWA—Air Force Weather Agency

AFWAI—Air Force Weather Agency Instruction

AFWAMAN—Air Force Weather Agency Manual

AGC—Automatic Gain Control

Am—Measured Area

AN/FMQ-7—Field Meteorological Equipment (SOON telescope)

APR—Active Prominence Region

ASR—Active Surge Region

AU—Astronomical Unit

AWS—Air Weather Service

AWS-TR—Air Weather Service Technical Report

B-angle—Heliographic Latitude

B—Brilliant (flare brightness category)

Bo—Heliographic Latitude (B) occurring at center of visible disk

BSD—Bright Surge on the Disk

BSL—Bright Surge on the Limb

BXOUT—Box-Out Program

CF—Conversion Factor

CMD—Central Meridian Distance

CME—Coronal Mass Ejection

cm—centimeters

CMP—Central Meridian Passage

CRN—Coronal Rain

DALAS—Solar Disk and Limb Activity Summary Code

DEC—Declination

DL—Disk or Limb (locally-defined region)

DSD—Dark Surge on Disk

DSF—Disappearance of a Solar Filament

DZA—Doppler Zeeman Analyzer

EFR—Emerging Flux Region

EPL—Eruptive Prominence on Limb

EVENT—Solar Event Code

F—Faint (flare brightness category)

FLARE—Solar Flare Code

GMT—Greenwich Mean Time

GUI—Graphical User Interface

Hα—Hydrogen (H) alpha emission line

HSTRY—Histogram History Code

Hz—Hertz

IAW—In Accordance With

IMF—Interplanetary Magnetic Field

IMT—Information Management Tool

K—Kelvin temperature scale

KD*P—Potassium (K) Dideuterium Phosphate

km—kilometers

L—Carrington Longitude

LIMBE—Limb East

LIMBW—Limb West

LPS—Loop Prominence System

MAGR—Magnetic Reference Region

MANOP—Manual of Operations

Mg-b2—Magnesium (Mg) b2 emission line

mm2—square millimeters

N—Normal (flare brightness category)

NOAA—National Oceanic and Atmospheric Administration

N-S—North-South

OPR—Office of Primary Responsibility

P angle—Position Angle

PA—Position-Angle

PC—Personal Computer

PE—Photoelectric

PLAIN—Plain Language Code

PMI—Preventive Maintenance Inspection

RA—Right Ascension

REQST—Request Message

RGN—Solar Region

RR—Radial Extent

Rv—Radius Vector

SACCT—SOON Account Program

Sc—Site Correction

SEON—Solar Electro-Optical Network

SFTP—Secure File Transfer Protocol

SG—Spectrograph Subsystem

SHS—Spectrohelioscope

SN—Serial Number (locally-defined region)

SOON—Solar Observing Optical Network

SOONSUM—Solar Observing Optical Network Software Users Manual

SOP—Standard Operating Procedure

SOSS—Solar Optical Secure Server

SPOTS—Sunspot Code

SPY—Spray

SSB—Solar sector Boundary

SPACEWOC—Space Weather Operations Center (2WS/WXZ)

STATS—Patrol Status Code

SUM—Software Users Manual

S-WL—Spectral White Light

SWPC—Space Weather Prediction Center

TC—Total Correction

TO—Technical Order

TR—Technical Report

TV—Television screen

USAF—United States Air Force

UT—Universal Time

WINDS—Weather Information Network Distribution System

WL—White Light

WS—Weather Squadron

Attachment 2

SAMPLE AFWA IMT 17, SOLAR OPTICAL WORKSHEET

Sample AFWA IMT 17, Solar Optical Worksheet

SOLAR OPTICAL WORKSHEET

STATION: KHM	DATE: 29 May 2005	JULIAN DATE: 149	SUNRISE: 1213 SUNSET: 0157
HSTRY RGNS: 8103 8108	LS RGN OF INT: 8108	MAG ANAL RGN: 8103 8108	

AUTOMATIC PATROL — REMARKS

72269 (IIiii) 50529 (YMMDD) ____ (STOnn)

11111	/1305	31817	/ 1830	10049	/ 0055	10117	/		
22222	/		/		/		/		
22222	/		/		/		/		
22222	/		/		/		/		99999

SEMI AUTOMATIC PATROL — REMARKS

12269 (IIiii) 70529 (YMMDD) ____ (STOnn)

11111	/1218	61305	/0117	10151					
22222	/		/		/		/		
22222	/		/		/		/		
22222	/		/		/		/		99999

FLARE

72269 (IIiii) 70529 (YMMDD) 3// ____ (nn)

11111 / 22222	qSJJJ / IBGgg	GGggL / 7AAAA	QXXYY /	TIBcc	GGggL	7AAAA	GGggL	9NNNN	FBBbb	TRNS#	INIT
11111	12002	12182	14406	1087/	12172	70052	12451	98103	/////	511	ll
11111	32003	13111	23608	4075/	13121	70053	13241	98108	92435	517	kp
11111	32004	15461	23408	42914	16001	70501	17371	98108	93844	554	kp
22222	08701	70064									
11111	32005	16141	14303	40756	16191	70043	16311	98103	92440	530	kp
11111											
11111											
11111											

DALAS

72269 (IIiii) 70529 (YMMDD) 3// ____ (nn)

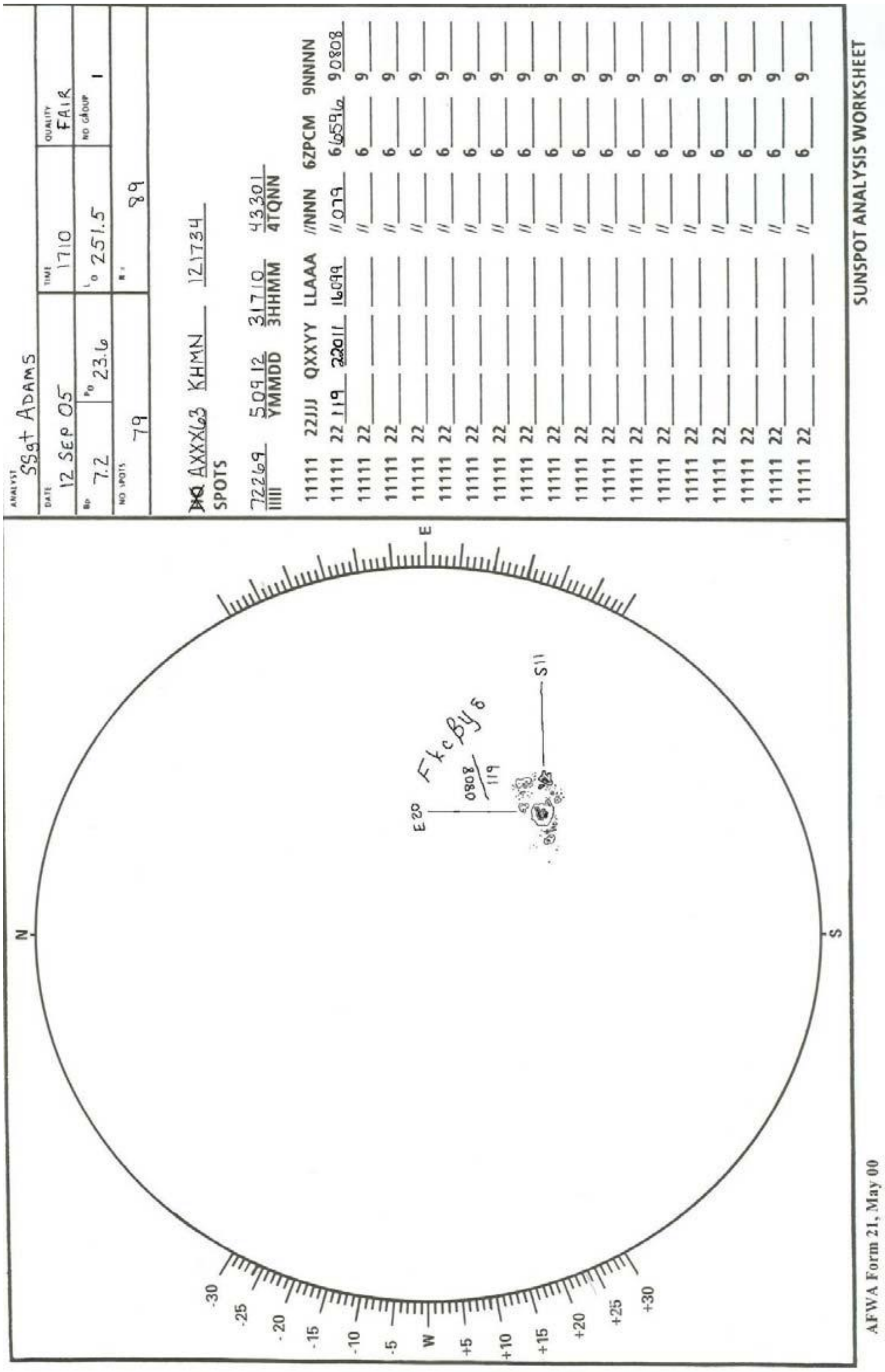
11111 / 22222	qSJJJ / WWWD	EEIRR / 3qFFF	GGggs	GGgge	TBRAA	9NNNN	QXXYY	QXXYY	QXXYY	TRNS#	INIT
11111	22001	11/15	12192	13032	19910	98103	15213			530	ll
11111	22002	11/02	12502	13372	199//	98108	41818			532	ll
11111											
11111											
11111											
11111											
11111											
11111											

AFWA IMT 17, 20040720 *V1* — Page 1 of 2

Attachment 3

SAMPLE AFWA FORM 21, SUNSPOT ANALYSIS WORKSHEET

Sample AFWA Form 21, Sunspot Analysis Worksheet



Attachment 4

TIMELINESS CRITERIA

1. Automatic Operations: (Transmit as soon as possible, but not to exceed these limits.)

CODE TYPE	EVENT LEVEL	NON-EVENT LEVEL
EVENT	2 min after event start or notification	Not Applicable
FLARE		
-Preliminary	2 min after meeting, or increasing to a higher (area or brightness), event threshold	Optional
-Final	10 min after end	15 min after end
DALAS		
-Preliminary	10 min after event identification	Optional
-Final	20 min after end	NLT end of day (AXXX72) message
BURST		
-Preliminary	2 min after meeting event threshold	Optional (30 min after start for an NSM)
	2 min after crossing reportable threshold	
	5 min after peak on each frequency (may be combined for near simultaneous peaks)	
-Final	10 min after end	15 min after end (45 min for an NSM)
SWEEP		
-Preliminary	2 min after type identification	Optional. (EXCEPTION: 30 min after type identification for a Type 6, 7, or 8)
-Final	30 min after end data availability	45 min after end data availability

NOTE: NSM = Noise Storm

2. Semiautomatic Operations: (Transmit as soon as possible, but not to exceed these limits.)

CODE TYPE	EVENT LEVEL	NON-EVENT LEVEL
EVENT	5 min after event start or notification	Not Applicable
FLARE		
-Preliminary	15 min after meeting, or increasing to a higher (area or brightness), event threshold	Optional
-Final	20 min after end	30 min after end
DALAS		
-Preliminary	Same as automatic operations	Same as automatic operations
-Final	Same as automatic operations	Same as automatic operations

Attachment 5

SCHEDULED PLAIN MESSAGE FORMAT

A5.1. First section: Indicate observing conditions, initial or changed equipment status, and an outlook for the next period or next day.

A5.2. Second section: Report analyses of solar active regions.

A5.2.1. Put each region in a separate paragraph, with one number symbol (#) at the start, and two number symbols (##) at the end, of each paragraph. Use the contraction RGN, the region's number, and the location (at the time of the PLAIN) in parentheses. Including the location is mandatory only for any SN, DL, or recently numbered region not listed in the most current daily AXXX02 KWNP, Solar Region Summary bulletin. Do not put a space between the latitude and longitude. **EXAMPLES:** #RGN 7901 (S12E23), #RGN SN91 (N23W71).

A5.2.2. Include a detailed description of each SWPC-numbered region, or locally numbered region of interest (i.e., SNs or DLs) at least once each observing day for regions with a magnetic complexity of Beta or less. Include Beta Gamma or more complex regions in every report. Concentrate on changes or information not previously reported in a PLAIN or coded message. Examples:

A5.2.2.1. Sunspot classification changes. Development of new spots, penumbra, or light bridges. Sunspot dynamics such as spot rotation, relative spot motion, and merging of spots within an active region or with another region.

A5.2.2.2. Plage compactness and intensity. Plage fluctuations or point brightenings (see Table 5.1 and 5.2 for definitions). Of particular interest are:

A5.2.2.2.1. An increase or decrease in the intensity, number, or frequency of plage fluctuations or brightenings along a complex magnetic inversion line.

A5.2.2.2.2. Bright plage encroachment on a strong sunspot, which is often accompanied by an inversion line filament encircling or pointing into the spot.

A5.2.2.3. Inversion line filament activity (i.e., active dark filaments or their limb counterpart, active prominence regions). Report changes in size, darkness/brightness (i.e., density), or Doppler shift measurements.

A5.2.2.4. Magnetic classification changes. Magnetic gradients and trends. Inversion line kinks and orientation (e.g., basically NE-SW, closed or isolated pole, or mostly circular). Also report possible crossing of a large penumbra, causing a delta configuration.

A5.2.2.5. Comments related to structure, growth (e.g., Arch Filament System formation), decay, or interaction of solar features.

A5.2.2.6. Special characteristics or features of flares or DALAS activity during the period.

A5.2.2.7. Impression of the region's flare potential (optional item; subject to analyst experience).

A5.3. Third section: Report features and activity not associated with a SWPC or locally assigned numbered region (e.g., disappearing filaments and limb activity). Start this portion with "#OTHER ACTIVITY:" and use two number symbols (##) as the end characters.