AM 5-610

UNDERSTANDING SOLAR METRICS DATA

MAKING SENSE OF THE SOLAR METRICS

September 2015

Version 0

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DEPARTMENT OF THE ARMY
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Contents

IMPROVEMENTS

Suggested corrections, or changes to this document, should be submitted through your State Director to the Regional Director. Any Changes will be made by the National documentation team.

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References:

The following references apply to this manual:

MARS Technical Documents:

(1) AM 5-303 Basic Propagation Theory

CONTRIBUTORS

This document has been produced by the Army MARS Technical Writing Team under the authority of Army MARS HQ, Ft Huachuca, AZ. The following individuals are subject matter experts who made significant contributions to this document.

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Acronyms and Abbreviations:

Abbreviations	Definition
ALE	Automatic Link Establishment
AM	Amplitude Modulation
C	Centigrade
CME	Coronal Mass Ejection
GFZ	German Research Centre for Geosciences
MHz	1 Mega Hertz 2 One Million Hertz
MUF	Maximum Usable Frequency
NOAA	National Oceanic Atmospheric Administration
NRCAN	Natural Resources Canada
R Scale	
SFI	Solar Flux Index
SN	Son Spot Number
UV	Ultra Violent
HF	High Frequency
SW	Solar Wind
PT	Proton Flux
EF	Electron Flux
MUF BDR	Maximum usable frequency as measured at Bolder Colo.
SFI	Solar Flux Index
UV	Ultra Violet
SWF	sweep frequency (radio) events
Bz	Interplanetary Magnetic Field
SW	Solar Wind
EME DEG	Earth – Moon – Earth Degradation
CME	Coronal Mass Ejection

1 BACKGROUND

1.1 INTRODUCTION:

We all know that the Sun is overwhelmingly important to life on Earth, but few of us have been given a good description of our star and its variations. The Sun is an average star, similar to millions of others in the Universe. It is a prodigious energy machine, manufacturing about 3.8 x 1023 kilowatts (or kilojoules/sec). In other words, if the total output of the Sun was gathered for one second it would provide the U.S. with enough energy, at its current usage rate, for the next 9,000,000 years. The basic energy source for the Sun is nuclear fusion, which uses the high temperatures and densities within the core to fuse hydrogen, producing energy and creating helium as a byproduct. The core is so dense and the size of the Sun so great that energy released at the center of the Sun takes about 50,000,000 years to make its way to the surface, undergoing countless absorptions and re-emissions in the process. If the Sun were to stop producing energy today, it would take 50,000,000 years for significant effects to be felt at Earth.

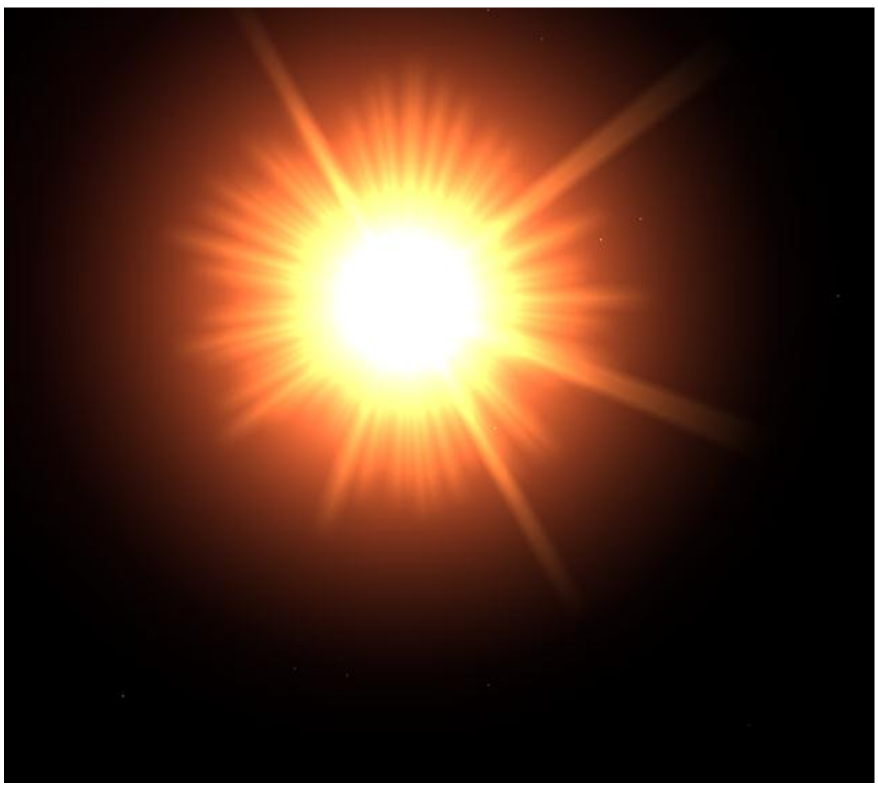


Figure 1-1
Our Sun

The Sun has been producing its radiant and thermal energies for the past four or five billion years. It has enough hydrogen to continue producing for another hundred billion years. However, in about ten to twenty billion years the surface of the Sun will begin to expand, enveloping the inner planets (including Earth). At that time, our Sun will be known as a red giant star. If the Sun were more massive, it would collapse and re-ignite as a helium-burning star. Due to its average size, however, the Sun is expected to merely contract into a relatively small, cool star known as a white dwarf.

It has long been known that the Sun is neither featureless nor steady. (Theophrastus first identified sunspots in the year 325 B.C.) Some of the more important solar features are explained in the following sections.

1.2 SUNSPOTS:

Sunspots, dark areas on the solar surface, contain strong magnetic fields that are constantly shifting. Reference Figure 1-2. A moderate-sized sunspot is about as large as the Earth. Sunspots form and dissipate over periods of days or weeks. They occur when strong magnetic fields emerge through the solar surface and allow the area to cool slightly, from a background value of 6000 ° C down to about 4200 ° C; this area appears as a dark spot in contrast with the Sun. The rotation of these sunspots can be seen on the solar surface; they take about 27 days to make a complete rotation as seen from Earth.

Sunspots remain more or less in place on the Sun. Near the solar equator the surface rotates at a faster rate than near the solar poles.

Groups of sunspots, especially those with complex magnetic field configurations, are often the sites of flares. Over the last 300 years, the average number of sunspots has regularly waxed and waned in an 11-year sunspot cycle. The Sun, like Earth, has its seasons but its “year” equals 11 of ours. This sunspot cycle is a useful way to mark the changes in the Sun. Solar Minimum refers to the several Earth years when the number of sunspots is lowest; Solar Maximum occurs in the years when sunspots are most numerous. During Solar Maximum, activity on the Sun and its effects on our terrestrial environment are high.

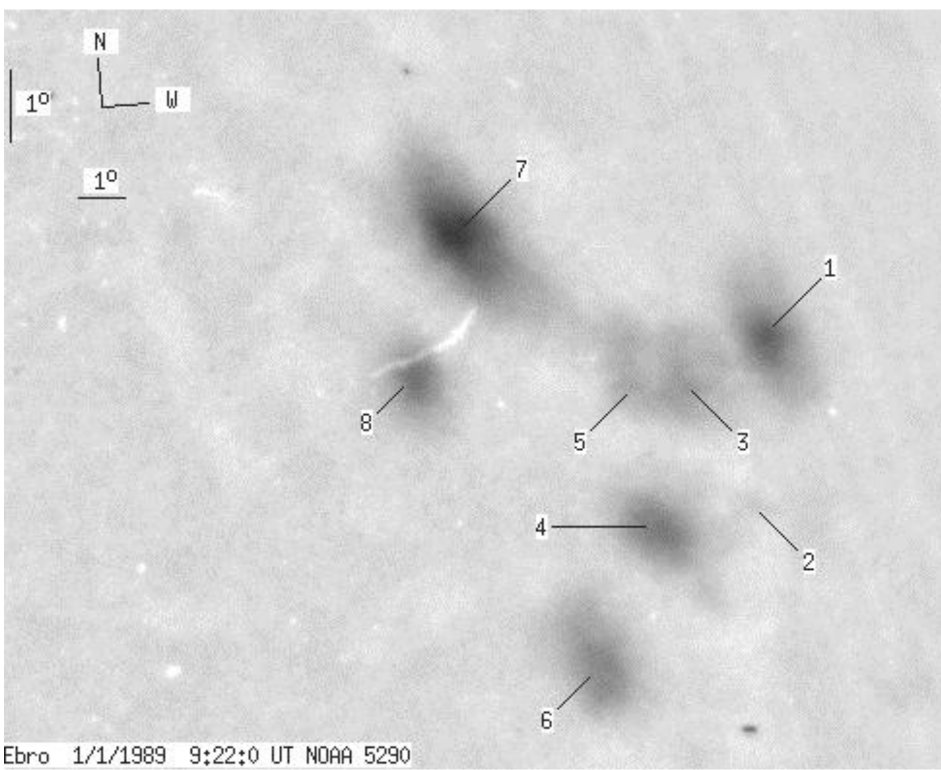


Figure 1-2
Sunspots

1.3 CORONAL MASS EJECTION (CME):

The outer solar atmosphere, or corona, is structured by strong magnetic fields. Where these fields are closed, often above sunspot groups, the confined solar atmosphere can suddenly and violently release bubbles or tongues of gas and magnetic fields called coronal mass ejections. A large CME can contain 10^{16} grams (ten billion tons) of matter accelerated to several million MPH in a spectacular explosion. Solar material streaks out through the interplanetary medium, impacting any planet or spacecraft in its path. CMEs are sometimes associated with flares but usually occur independently.

A CME is a gigantic eruption from the sun. When the sun's rotation places this eruption at a point where the mass is sent toward Earth, it becomes a danger to the Earth. The ejected plasma travels at up to 621 miles per second. The CME is a fiery plasma eruption that sends a cloud of energized electrons, protons, and other particles hurtling through space. When (not if) that energy travels to the earth, it will be trapped in Earth's magnetic field. That will be a massive amount of energy that will initiate magnetic storms, which look ethereal but will likely have a disastrous effect causing vary dangerous or even fatal accidents to occur. A CME can cause massive power grid failure, fires and other disastrous reactions possibly causing the infrastructure to collapse in some areas.

1.4 FLARES:

Solar flares are intense, short-lived releases of energy. Reference Figure 1-3. They are seen as bright areas on the Sun in optical wavelengths and as bursts of noise in radio wavelengths; they can last from minutes to hours. Flares are our solar system's largest explosive events. The primary energy source for flares appears to be the tearing and reconnection of strong magnetic fields. They radiate throughout the electromagnetic spectrum, from gamma rays to x-rays, through visible light out to kilometer-long radio waves.

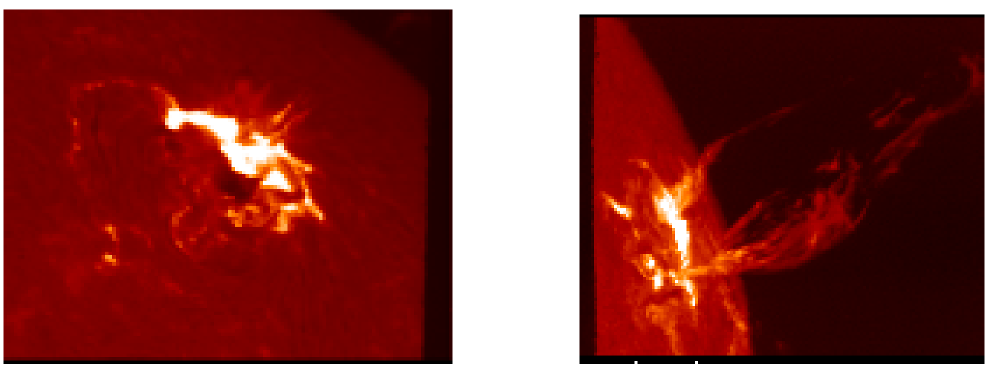


Figure 1-3
Typical Sun Flares

Flares are caused by magnetic reconnection associated with large-scale **CME**s. Solar flares occur in a large range of strengths and are classified on a logarithmic scale based on their intensity in the 1-minute averaged NOAA/GOES XRS instrument's 0.1 -- 0.8 nm spectral band, with the being labeled as **A, B, C**, **M** or **X**.

1. "**A**" flares, smallest flares
2. "**B**" flares are (10 times) larger
3. "**C**" flares next larger
4. "**M**" flares are fairly large
5. "**X**" flares are the largest

The history of this lettering scheme is that **C** flares are fairly "***Common***" during solar sunspot activity, **M** flares are "***Medium***" in size, and X flares are "***Extreme***" in size. It became necessary to add **A** and **B** categories below **C** flares to recognize that smaller flares occur very frequently during any given solar magnetic cycle.

1.5 CORONAL HOLES:

Coronal holes, as shown in Figure 1-4, are variable solar features that can last for weeks to months. They are large, dark areas when the Sun is viewed in x-ray wavelengths, sometimes as large as a quarter of the Sun's surface. These holes are rooted in large cells of unipolar magnetic fields on the Sun's surface; their field lines extend far out into the solar system. These open field lines allow a continuous outflow of high-speed solar wind. Coronal holes have a long-term cycle, but the cycle doesn't correspond exactly to the sunspot cycle; the holes tend to be most numerous in the years following sunspot maximum. At some stages of the solar cycle, these holes are continuously visible at the solar north and south poles.

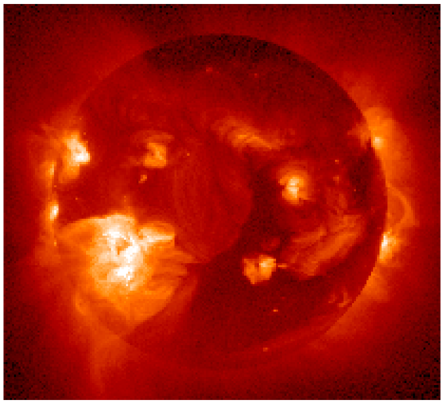


Figure 1-4
Coronal Holes

1.6 AURORA:

The aurora, as shown in Figure 1-5, is a dynamic and visually delicate manifestation of solar-induced geomagnetic storms. The solar wind energizes electrons and ions in the magnetosphere. These particles usually enter the Earth's upper atmosphere near the Polar Regions. When the particles strike the molecules and atoms of the thin, high atmosphere, some of them start to glow in different colors. Aurora usually begins between 60 and 80 degrees latitude. As a storm intensifies, the aurora spread toward the equator. During an unusually large storm in 1909, an aurora was visible at Singapore, on the geomagnetic equator. The aurora does provide pretty displays, but they are just a visible sign of atmospheric changes that may wreak havoc on technological systems.

Figure 1-5
Aurora

2 SPACE WEATHER:

2.1 INTRODUCTION:

In order for us to understand what Solar Flux is we first need to understand something of the conditions on the sun that cause the Solar Flux. Disturbances on the sun can cause problems on earth and they can be serious if the sun has a major coronal mass ejection.

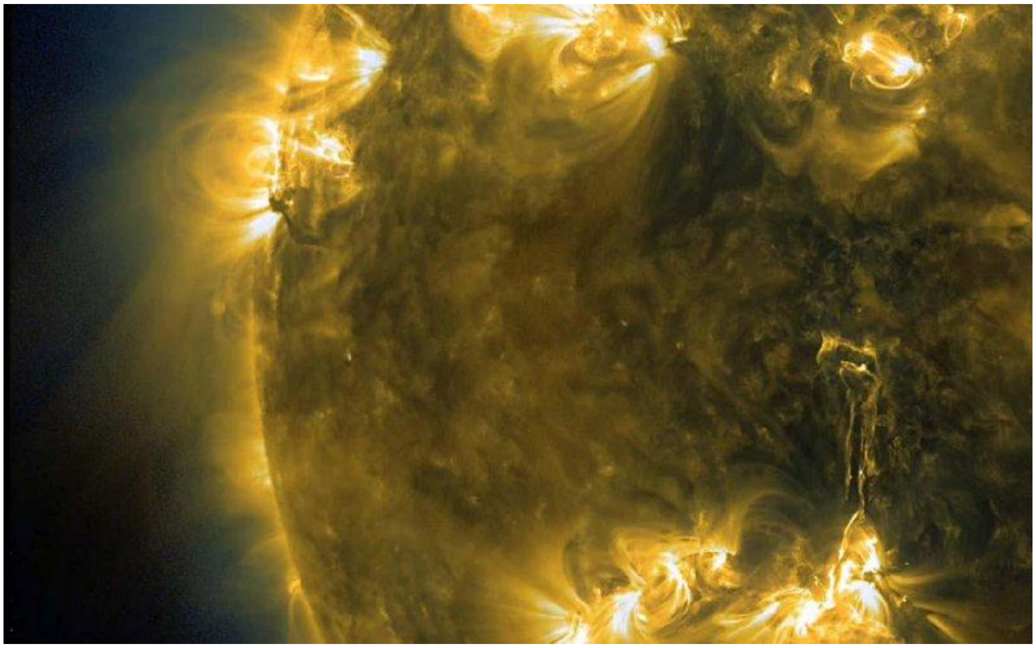


Figure 2-1
Surface of the Sun

Space weather is a term that scientists use to describe the violent changes in energy and magnetism on the solar surface, and how these changes travel through the solar system to affect the Earth and other planets.

The Sun gives off a very strong wind from its outer layers, and this wind flows past Mercury, Venus and the rest of the planets in the solar system. In fact, you can even say that Earth goes around the Sun while still being INSIDE the atmosphere of the Sun.

The surface of the Sun is very complicated and full of very hot gases that are sometimes shot away from the Sun. Astronomers call one type of these events 'Solar Flares' or CMEs'.

Solar flares are pretty spectacular. Within an hour or less, an area of the Sun the size of Earth suddenly lets loose a blast of X-rays and other powerful radiations. Traveling at the speed of light, which can go 7 times around Earth in only one second, it still takes 8 1/2 minutes for these X-rays to get to Earth from the Sun. During some of the most powerful solar flares, an astronaut in a spacesuit could actually get killed if he or she happened to be doing a spacewalk at the time. NASA, and astronomers, has been studying solar flares for over 50 years to learn more about what causes them, and to make it easier to forecast when the next one will happen so that astronauts won't be injured by them accidentally.

Fortunately, the atmosphere of Earth is so thick that we never have to worry about even the most powerful solar flare here on the ground. The only thing that solar flares do is to knockout short-wave radio communication during the daytime. These blasts of X-rays damage a part of the atmosphere called the Ionosphere, and this lets radio signals from the ground get reflected like light is reflected from a mirror.

The second type of storm from the Sun is the Coronal Mass Ejection, also called the CME. For reasons that astronomers don't fully understand yet, the sun occasionally 'burps' and send out huge clouds of gas into space. By the time they reach the orbit of Earth, they grow to be millions of miles across. Most of the time, these clouds are sent out in other directions than where Earth is in its orbit, but every few weeks they come charging right at us. They travel at about a million miles an hour and take 2-3 days to get here.

Now it just so happens that Earth has a pretty stiff magnetic field, and a very thick atmosphere, so we never have to worry about these solar storm clouds as they sweep by Earth on their way to Pluto and beyond. The Earth's magnetic field, which looks kind of like a bar magnet, pushes most of the particles in these clouds away from us so they never really hit the planet at all. But even so, the CME material can make lots of trouble in other ways too.

As the material streams past Earth, it stretches Earth's magnetic field. This makes Earth's magnetic field look like a comet with Earth at the head of it. The tail of Earth's field trembles and shakes, and sometimes it can even snap. When that happens, space weather becomes more than just some invisible storm between the planets.

In a region of the tail nearly halfway to the Moon, there are charged particles trapped in the magnetic field - mostly electrons and protons. When the field snaps, these particles pick up energy from the magnetic field, and they begin to move at very high speeds. Within a few minutes, they travel towards Earth along the magnetic field. They get funneled into the polar regions where they collide with atoms of oxygen and nitrogen. These collisions give off light and we se this from the ground as the famous aurora borealis and aurora australis - the northern and southern lights. People have worried about them for centuries, but they really are harmless. They can't get any closer to the ground than 70 miles or so, but optical illusions can fool the eye into thinking they get much lower and even touch the ground.

If aurora were the only things that space weather causes, we wouldn't have much to really worry about, but unfortunately it is not that simple. We rely on communications satellites, military satellites, and a reliable electrical service to power our computers, televisions, air conditioners and to run our industries. Space weather can knock out satellites and cause blackouts.

In March 1989, the Canadian province of Quebec experienced a blackout that affected millions of people for a half a day. People were stuck in dark elevators; heating systems would not work to heat homes during the Canadian winter, and if it hadn't been for a bit of old fashioned good luck, many states from Maine to Georgia would have had electrical problems too! What happened was that a huge solar storm caused currents to flow in the ground under Canada. These currents of electricity found their way into the Quebec electrical power system. In 90 seconds, the engineers went from normal operation to full blackout.

It isn't just blackouts that can happen. The most common way that space weather affects us is by damaging or disrupting communications satellites. When was the last time you used a cell phone or a pager? When did you stop at a gas station and use your credit card at the pump to buy gas? Have you used the internet to visit web sites in Europe or elsewhere? Chances are pretty good that you or your family have relied on one or more satellites every day to handle your communications or other needs. These satellites are very expensive and they orbit Earth far enough out in space that they aren't as well shielded from space weather storms as you and I are here on the ground. Since 1996, 14 satellites have been affected by space weather events and nearly $2 billion has been lost in satellite technology from some kind of space weather event.

There are many good introductions to space weather to be found on the Internet. Here are a few recommendations:

- NASA Lithograph Set - Describes the key ingredients to space weather in ten steps from the solar surface to aurora.
- NASA Sun-Earth Viewer - This is a Flash-oriented viewer of space weather data.
- Passport to Knowledge - Includes interviews with scientists describing various aspects of space weather.
- Solar Storms - This Washington Post newspaper article was published on March 10, 1999 and gives a short account of the various phenomena and their human impacts.

In addition to direct measurements of the sun, the results of items and their effect on communications have been summarized into a scale called the "**R**" scale. As the K-Index increases we can expect to see disruptions in communications as it also correlates with an increase in UV and X ray emissions.

As K-Index exceeds 4, Watches, Warnings and Alerts are issued using a "**G**" scale. In addition to **G** scale, an **S** scale indicates Radiation storms by their intensity in X ray energy reaching earth.

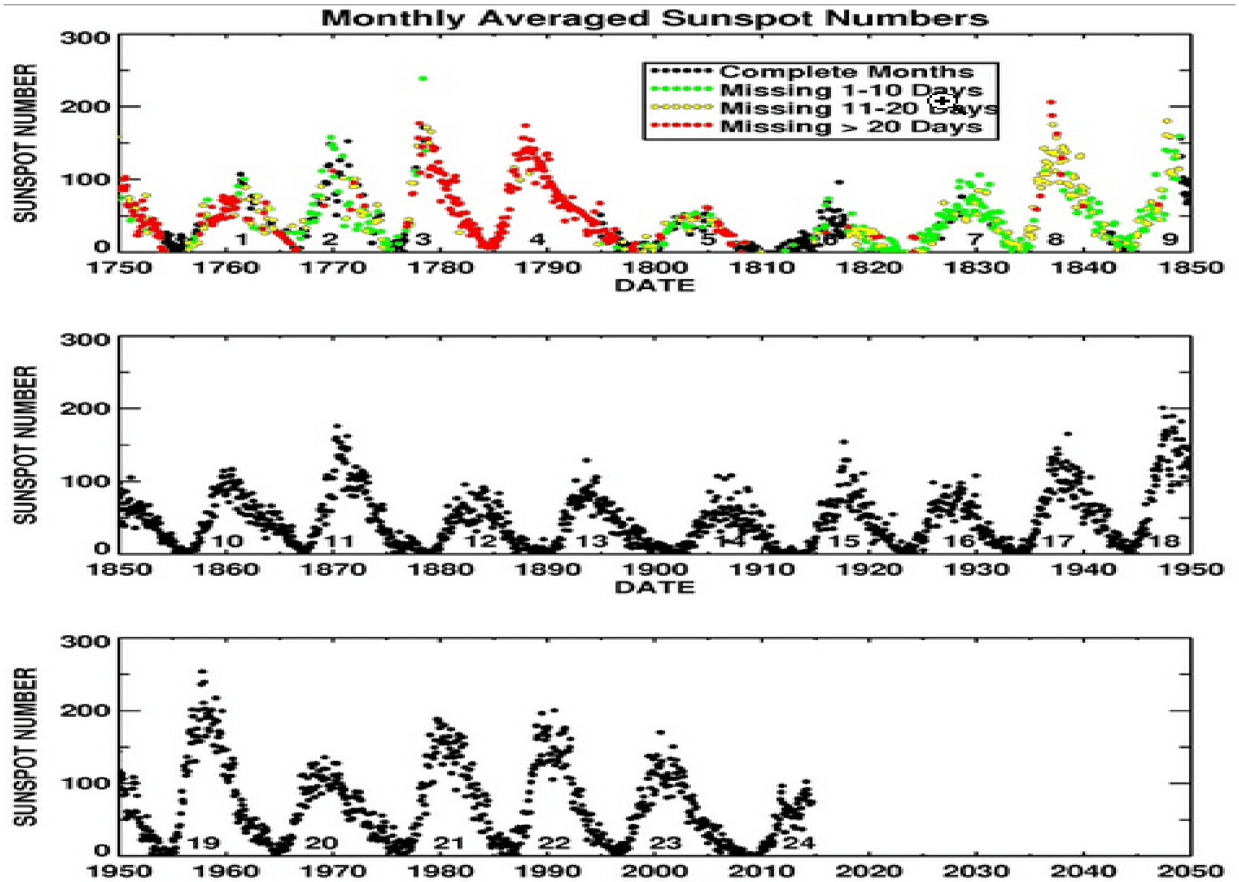


Figure 2-2
Sun Spot Numbers from 1790 to Present
The Numbers Indicate the Cycle

3 SOLAR FLUX REPORT COMPONENTS

3.1 EXAMPLE SOLAR REPORT:

The following example is a typical Solar Flux Report. A solar report is made up of several components:

1. **Current Solar Flux report:**
   - *SFI: 145 A-index: 13 K-Index: 1*
   - *Report last updated: 09:11utc 14 Sep 14*
   - *Current Sunspot Count: 157*
2. ***Highs for Cycle***
   - *Sunspots: FOR A CERTAIN DATE*
3. ***Summary for the past 24 hours:***
   - *pace weather for the past 24 hours has been minor.*
   - *Radio blackouts reaching the R1 level occurred.*
4. ***Forecast for the next 24 hours:***
   - *Space weather for the next 24 hours is predicted to be minor.*
   - *Radio blackouts reaching the R1 level are likely.*

3.2 SOLAR FLUX INDEX (SFI):

Solar Flux Index (**SFI)**, is an indirect measurement of **UV** and **X** rays generated by the Sun. This is a measurement of Suns radiation at 2800 MHz and is taken daily. You can see the number in the typical report shown above is 145. In Cycle 19 (1957), the November numbers reached 380 and during the lows dropped to just above 200. In cycle 24 we have had a high of 237 in January. The range is normally 0 to 350 and the larger the number the better for communications. A simplification at this point, an increase in the **SFI** can be correlated with an increase in **UV** and **X** rays. This increase indicates greater ionization of the **D**, **E** and **F** layers causing the increase in the Maximum Usable Frequency (MUF).

3.3 THE A AND K INDEX:

A-Index and **K**-Index are interconnected. The **K**-Index is derived from measurements taken from various stations around the globe every three hours and averaged together to get a picture of the disturbance to the earth's magnetic field. The value range is displayed on a Quasi-logarithmic scale of 0 to 9 with anything above 4 indicating a geomagnetic storm. The **K**-Index shows what is happening now.

3.3.1 A Index:

The ***A-Index*** is a compilation of ***K-Index values*** that have been massaged and displayed on a linear scale of 0 – 400. This ***A-Index*** is always a historical look at the previous twenty four (24) hours prior to the report

3.3.1.1 K Index Codes:

These codes apply to the previous 24 hours to the report. This Code will give you a very good ides as to the general status of the **A**-index

- K = 0 Inactive
- K = 1 Very quiet
- K = 2 Quiet
- K = 3 Unsettled
- K = 4 Active

- K = 5 Minor storm
- K = 6 Major storm
- K = 7 Severe storm
- K = 8 Very severe storm
- K = 9 Extremely severe storm

3.3.1.2 The A Index Completion:

The A index is linear number computed from the eight K index values. It ranges from 0 (quiet) to 400 (severe storm):

- A = 0 - 7 Quiet
- A = 8 - 15 Unsettled
- A = 16 - 29 Active
- A = 30 - 49 Minor storm
- A = 50 - 99 Major storm
- A = 100 - 400 Severe storm

Generally, propagation conditions are best when the **A** index is 15 or lower, and the K index is 3 or lower. Besides causing aurora activity, high geomagnetic field conditions can affect the electrons in the ionosphere, reducing the maximum usable frequency (MUF).

3.3.1.3 Example of K-Index Data Charted:

Figure 3-1 provides a graphic picture of the **K**-Index for the previous 24 hour period and is updated every 15 minutes at 1, 16, 31, and 46 minutes past the hour.

The Estimated 3-hour Planetary **Kp**-index is derived at the NOAA Space Weather Prediction Center using data from the following ground-based magnetometers:

1. Sitka, Alaska
2. Meanook, Canada
3. Ottawa, Canada
4. Fredericksburg, Virginia
5. Hartland, UK
6. Wingst, Germany
7. Niemegk, Germany
8. Canberra, Australia

This data are made available thanks to the cooperative efforts between SWPC and data providers around the world, which currently includes:

1. U.S. Geological Survey,
2. Natural Resources Canada (NRCAN),
3. British Geological Survey,
4. German Research Centre for Geosciences (GFZ),
5. Geosciences Australia.

Important magnetometer observations are also contributed by the “Institut de Physique du Globe de Paris” and the Korean Space Weather Center

There are three basic types of K-Index data issued:

- **K-index Watches:** A K Index watch is issued when the highest predicted K-index for a day is K = 5, 6, 7, or >= 8 and is reported in terms of the NOAA G scale.
- **K-index Warnings:** A K Index Warning is issued when NOAA K-indices of 4, 5, 6, and 7 or greater is expected.
- **K-index Alerts:** A K Index Alert is issued when the NOAA K-index reaches 4, 5, 6, 7, 8, or 9 in a 3-hour period.

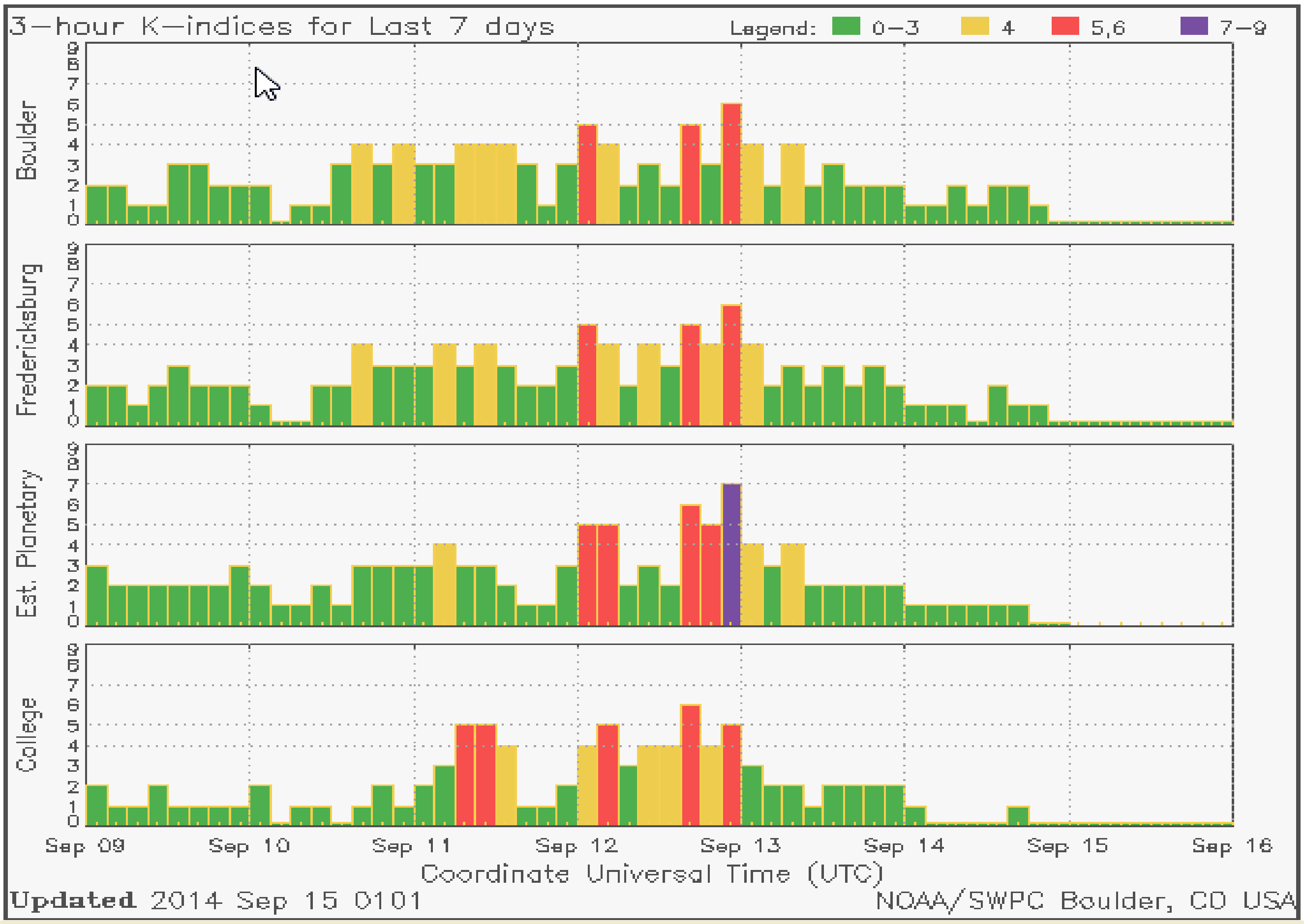


Figure 3-1
Typical Chart of the K-Indices for Previous 24 Hours

3.4 RADIO BLACKOUT CODES:

Radio Blackout is the is considered the inability to communicate on High Frequency bands in the 5 to 35 Mega Hertz spectral ranges. However lower frequency radio communications may also be significantly degraded during a Radio Blackout event.

Radio Blackouts are classified by a five-level NOAA scale based on the solar flare X-ray scale. Table 3-1 provides a relationship between Radio Blackouts, Solar Flares, Solar radiant energy flux in Watts per square meter, and designated Severity of the event.

Table 3-1
Radio Blackout Codes

Radio Blackout	X Ray Flare	Flux (W/m2)	Severity
R1	M1	0.0000	Minor
R2	M5	0.00005	Moderate
R3	X1	0.0001	Strong
R4	X10	0.001	Severe
R5	X20	0.002	Extreme

Radio Blackouts			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	**Extreme**	**HF Radio:** Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Less than 1 per cycle
R 4	**Severe**	**HF Radio:** : HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	**Strong**	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	**Moderate**	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	350 per cycle (300 days per cycle)
R 1	**Minor**	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

Figure 3-2
HF Radio Blackout R Codes

G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

Figure 3-3
Solar Flux G Codes

Ver. 0

Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** Satellite operations: infrequent single-event upsets possible. Other systems: effects on HF propagation through the polar regions, and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·$ster^{-1}$·cm^{-2} Based on this measure, but other physical measures are also considered.

** These events can last more than one day.

*** High energy particle (>100 MeV) are a better indicator of radiation risk to passenger and crews. Pregnant women are particularly susceptible.

Figure 3-4
Solar Radiation Storm Ratings

3-7

3.5 BANNERS:

3.5.1 Examples of Banners:

Banners that are found on various internet sites such as Figure 3-6 is a good example of how the data that can be presented.

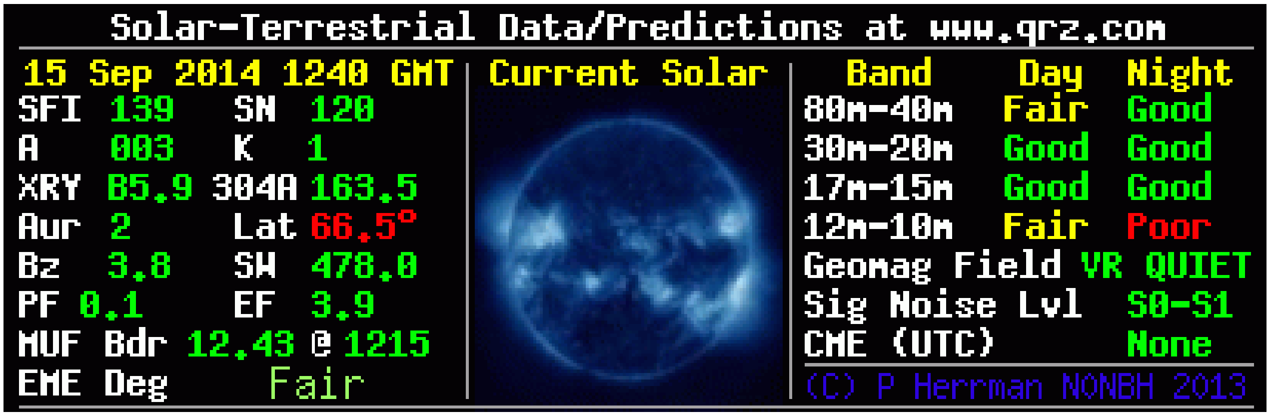


Figure 3-6
Example Solar Terrestrial Data/Prediction

Using the banner of Figure 3-6 found on QRZ.com, we will go over each piece of data and define what it means and how it affects propagation. We will find that many of the new items are subsets or a finer breakout of the metrics we have studied to this point.

The first items on the left are our old friend **SFI** (Solar Flux Index), **SN** (Sun Spot Numbers), **A**-Index and **K**-Index.

3.5.2 X Ray:

The next metric **X RAY** is followed by the value **B5.9** is the intensity of **X** rays and requires reference to another table as shown in Table 3-1, to make sense of it.

Table 3-1
X-Ray Matrix

Class	*Peak (W/m^2)between 1 and 8 Angstroms*
B	$I < 10^{-6}$
C	$10^{-6} <= I < 10^{-5}$
M	$10^{-5} <= I < 10^{-4}$
X	$I >= 10^{-4}$

The **B** selects the class and in this case the 5.9 is the multiplier. Looking at the table we see the intensity of a standard **B** is less than 10^{-6}. Multiplying 10^{-6} X 5.9 = Watts/Meter^2 of the **X** rays between 1 and 8 Angstroms reaching the Earth's surface. On their trip they pass through the **F layer** and then Ionize the **D layer** and to some extent the **E layer**. The **D layer** normally absorbs the 160 meter and 80 meter signals during the daytime. Actually this extends to some degree up to 10 MHz during daylight hours. A high level of **X** rays as seen in the **M** and **X** classes can enhance the **D**

layer and cause it to absorb all frequencies we have access to and we can have a full blackout of communications.

3.5.3 304A :

This is just a further breakout of the **SFI** that affects the **D layer** Data component. with a value of 163.5, this is radiation of the Sun at 304 Angstroms which is **UV** (Ultra Violet) This is a portion of the Solar Flux Index but breaks out the portion that enhances the **F layer** propagation. Like the SFI, this metric indicates enhanced propagation.

3.5.4 2 AUR and LAT:

AUR is Aurora and **LAT** is latitude, Ready for this? The number 2 indicates the on a scale of 1 to 10 the number of GIGAWATTS of power reaching the poles. This is the energy that causes the Northern Lights and the Latitude is the lower limit of the event. This will affect us if we are trying to use an over the pole path. Or live in the Northern regions i.e. Alaska or Sweden.

3.5.5 Bz (Interplanetary Magnetic Field):

The value of +3.8 indicates the **IMF** is aiding the Earth's magnetic field. A negative value would indicate it opposes the Earth's magnetic field making it weaker and allowing other disturbances to have a greater effect. While this banner shows it as a number other banners show it as a half circle with an arrow vector. The value is from -50 to +50.

3.5.6 SW (Solar Wind):

The value of 478.1 is the speed in Kilometers per second. A normal value is 350- 375 and as the speed increases it imparts greater pressure on the Ionosphere. At the faster speeds it disturbs the magnetic field causing a disturbance of the F layer resulting in poor HF conditions. The values are between 0 and 2000 with about 500 and above being the point where it has an effect on propagation. This is another value where some banners use an arrow type presentation.

3.5.7 PF (Proton Flux):

The value of .1 represents the proton density with in the Earth's magnetic field. We can associate this back to the **S levels** we covered earlier and levels of **S4** or **S5** will make a path over the pole impossible.

3.5.7.1 EF (Electron Flux):

The value of 3.9 is the level of electrons in the magnetic field, and takes significant numbers > 1000 to act similar to PF.

3.5.7.2 MUF BDR (Maximum Usable Frequency as measured at Bolder Colorado):

it is followed by a time in **UTC** that the measurement was taken, the value "***FAIR***" is the expected dB additional attenuation along the **EME** path per the following table.

Table 3-2
Attenuation along the EME path

Description	dB Attenuation of the EME Path
Excellent	<= 1.5 dB
Good	>1.5 dB
Fair	> 2.5 dB
Poor	> 4.5 dB
Very Poor	> 5.5 dB

3.5.7.3 EME DEG (Earth – Moon – Earth Degradation):

3.5.7.3.1 Geomagnetic Field:
Previously covered

3.5.7.3.2 Signal to Noise Level:
The value S0 - S1 indicates the noise generated by the solar wind as it interacts with the magnetic field in S-Units.

3.5.8 CME (Coronal Mass Ejection):

The value of "***None***" indicates no expected **CME's**, had one been predicted, the time in **UTC** would be shown as well.

Now that we have seen all the values on this banner we can see on the next banner the data is rearranged somewhat but essentially the same.

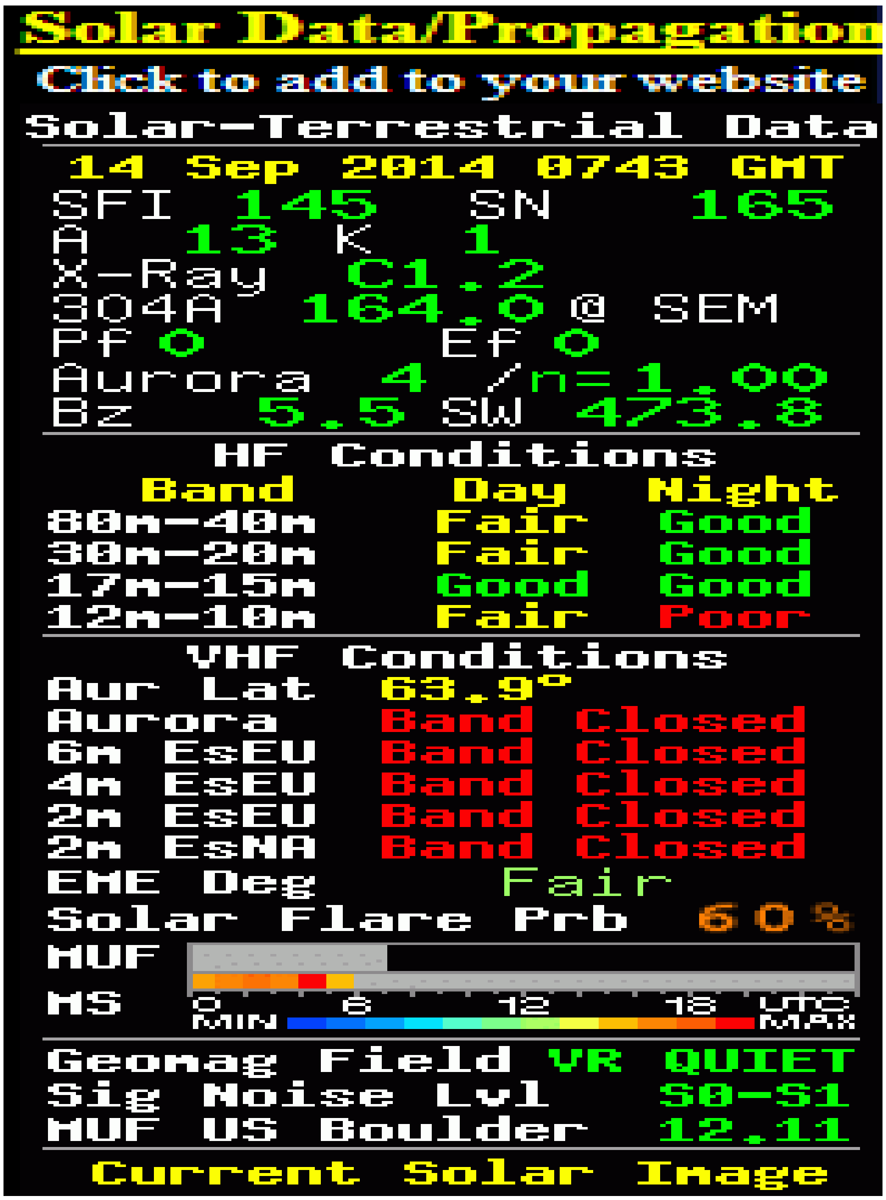
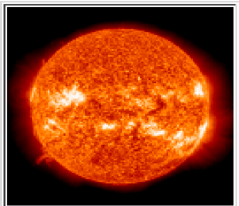


Figure 3-7
Solar Data Propagation Banner

 **Current Solar Image from SOHO**	**Current Solar Flux report:** SFI: **133** A-index: **3** K-Index: **2** Report last updated: 03:11utc 16 Sep 14 **Current Sunspot Count: 120**	**Highs for Cycle 24** **Flux: 237 - 7 Jan 2014** **Sunspots: 296 - 17 Apr 2014**
	Summary for the past 24 hours: No space weather storms were observed for the past 24 hours.	
	Forecast for the next 24 hours: No space weather storms are predicted for the next 24 hours.	

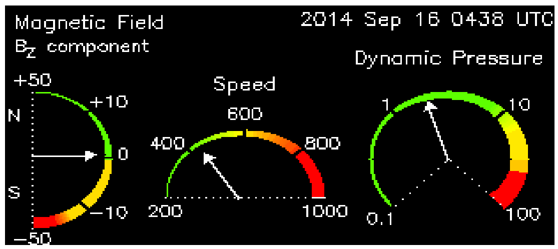


Figure 3-8

Note:

This BANNER uses the vector pointers

4 SUMMARY:

While we have touched on the basic there is more learn. What can you do with the information you have learned so far? After a period of time you will note what conditions must exist for you to successfully pass a message on a long haul net or an adjacent state on a particular frequency. This has become a lost art over the years and is one of the reasons **ALE** was developed. You can either have experienced old hands that understand propagation or develop a system that tries all the combinations until it locates a frequency that will work at a specific time and existing conditions.

A rule of thumb is the further you wanted to talk the higher the frequency you should use, it is a great rule if old Sol will cooperate.

You have seen and now understand the meanings of the various metrics and have the tools to allow you to delve deeper in this interesting field or simply to take a quick look at the banner to determine likely band conditions.

NOTES: