Slide 1

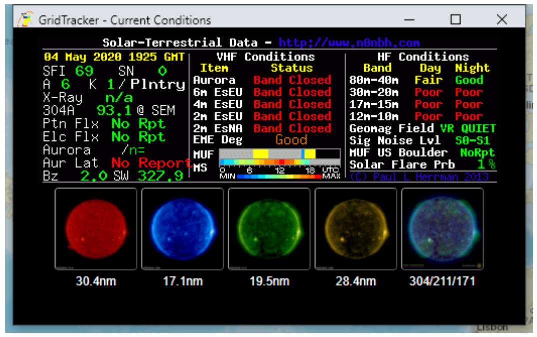
INTERPRETING THE SOLAR DATA FOR HF PROPAGATION

A TECHNICAL TOPIC DISCUSSION

SEM ARC
AMATEUR RADIO
MINNESOTA

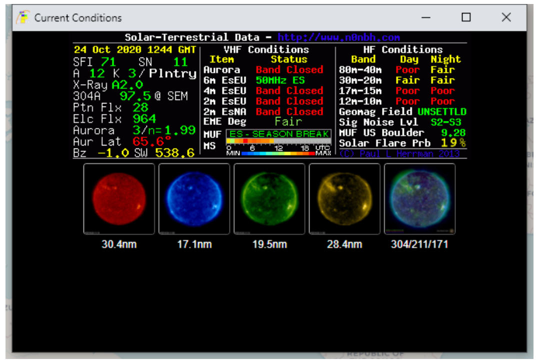
October 27, 2020
Moderator: Joe KCØOIO

Slide 2



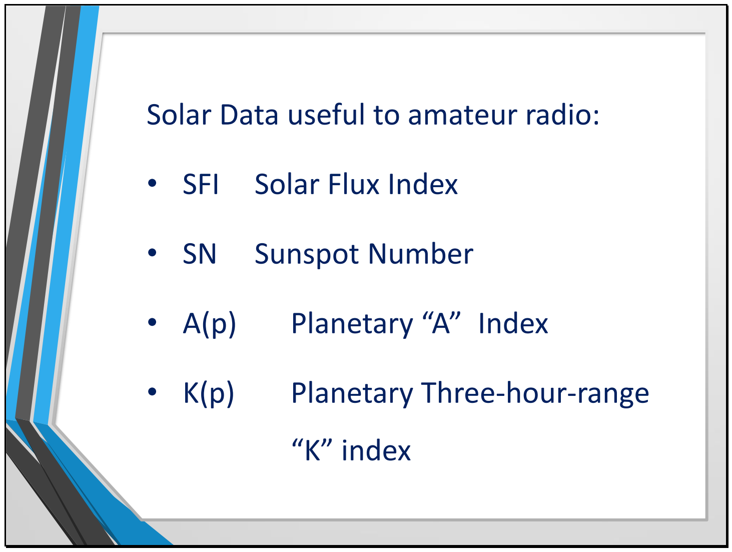
AT THE BOTTOM?

Slide 3



SOLAR CYCLE 25 BEGAN DEC 2019 – NUMBERS ARE GOING UP!

Slide 4


Solar Data useful to amateur radio:
• SFI Solar Flux Index
• SN Sunspot Number
• A(p) Planetary "A" Index
• K(p) Planetary Three-hour-range "K" index

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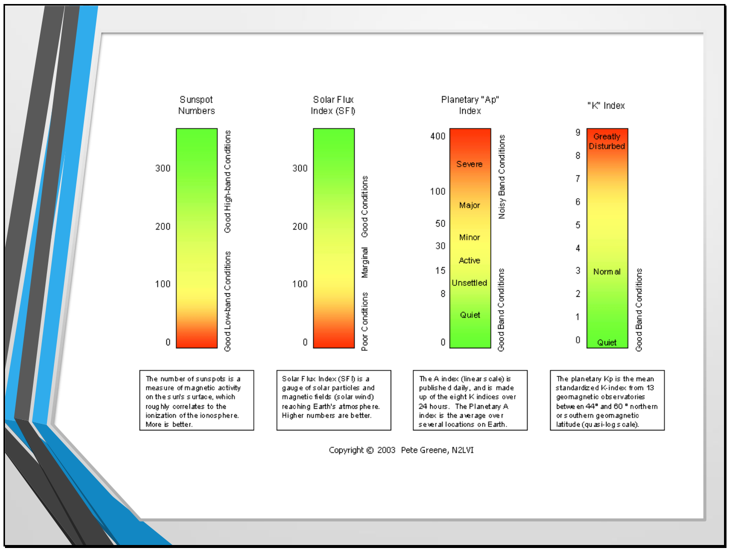
Sunspot Numbers
Solar Flux Index (SFI)
Planetary "Ap" Index
"K" Index
Good High-band Conditions
Good Low-band Conditions
Good Conditions
Marginal
Poor Conditions
Severe
Major
Minor
Active
Unsettled
Quiet
Noisy Band Conditions
Good Band Conditions
Greatly Disturbed
Normal
Quiet
Good Band Conditions
The number of sunspots is a measure of magnetic activity on the sun's surface, which roughly correlates to the ionization of the ionosphere. More is better.
Solar Flux Index (SFI) is a gauge of solar particles and magnetic fields (solar wind) reaching Earth's atmosphere. Higher numbers are better.
The A index (linear scale) is published daily, and is made up of the eight K indices over 24 hours. The Planetary A index is the average over several locations on Earth.
The planetary Kp is the mean standardized K-index from 13 geomagnetic observatories between 44° and 60 ° northern or southern geomagnetic latitude (quasi-log scale).
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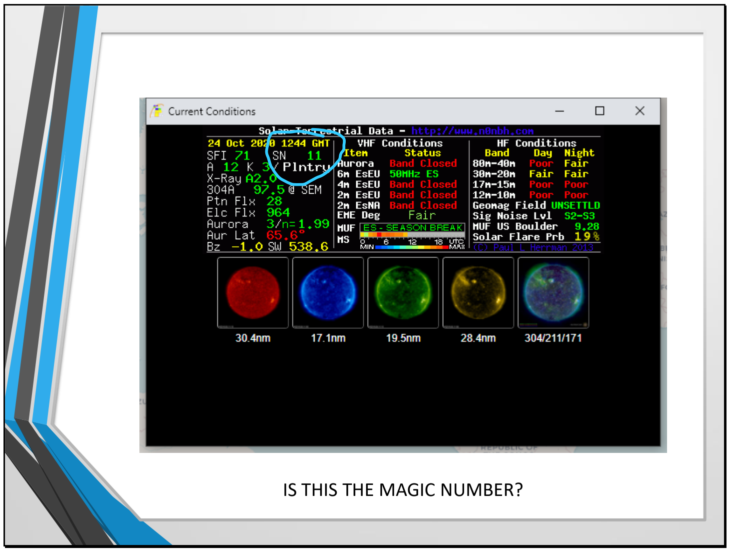
Current Conditions
Solar-Terrestrial Data - http://www.n0nbh.com
24 Oct 2020 1244 GMT
SFI 71 SN 11
A 12 K 3 / Plntry
X-Ray A2.0
304A 97.5 @ SEM
Ptn Flx 28
Elc Flx 964
Aurora 3/n=1.99
Aur Lat 65.6°
Bz -1.0 SW 538.6
VHF Conditions
Item Status
Aurora Band Closed
6m EsEU 50MHz ES
4m EsEU Band Closed
2m EsEU Band Closed
2m EsNA Band Closed
EME Deg Fair
MUF ES - SEASON BREAK
MS
0 6 12 18 UTC
MIN MAX
HF Conditions
Band Day Night
80m-40m Poor Fair
30m-20m Fair Fair
17m-15m Poor Poor
12m-10m Poor Poor
Geomag Field UNSETTLD
Sig Noise Lvl S2-S3
MUF US Boulder 9.28
Solar Flare Prb 19%
(C) Paul L Herrman 2013
30.4nm
17.1nm
19.5nm
28.4nm
304/211/171
IS THIS THE MAGIC NUMBER?

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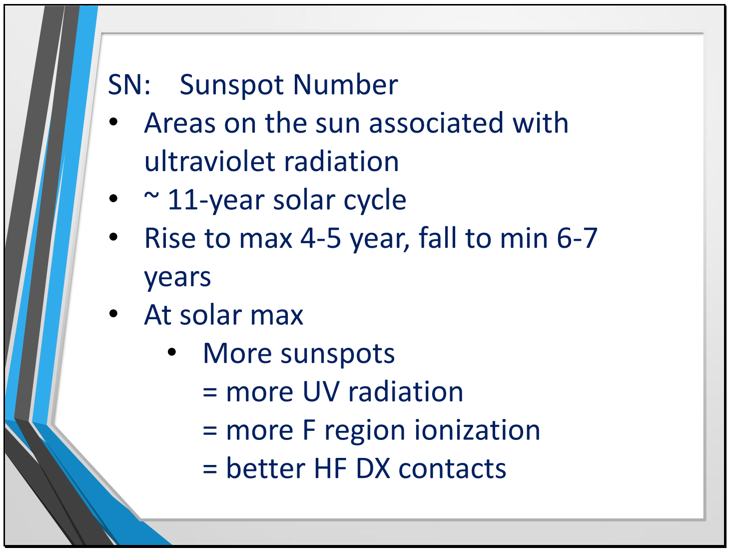

Sunspots are areas on the sun associated with ultraviolet radiation. They have been tied to ionization of the F region. The daily sunspot number, when plotted over a month time frame, is very spiky. Averaging the daily sunspot numbers over a month results in the monthly average sunspot number, but it is also rather spiky when plotted.

A more averaged, or smoothed, measurement is used to measure solar cycles. This is the smoothed sunspot number (SSN). The SSN is calculated using six months of data before and six months of data after the desired month, plus the data for the desired month. Because of this amount of smoothing, the official SSN is one-half year behind the current month. Unfortunately, this amount of smoothing may mask any short-term unusual solar activity that may enhance propagation.

This explains why the start of Cycle 25 back in December was just recently determined and announced.

Sunspots come and go in an approximate 11-year cycle. The rise to maximum (4 to 5 years) is usually faster than the descent to minimum (6 to 7 years). At and near the maximum of a solar cycle, the increased number of sunspots causes more ultraviolet radiation to impinge on the atmosphere. This results in significantly more F region ionization, allowing the ionosphere to refract higher frequencies (15, 12, 10, and even 6 meters) back to Earth for DX contacts.

At and near the minimum between solar cycles, the number of sunspots is so low that higher frequencies go through the ionosphere into space. Commensurate with solar minimum, though, is less absorption and a more stable ionosphere, resulting in the best propagation on the lower frequencies (160 and 80 meters). Thus, in general, high SSNs are best for high-frequency propagation, and low SSNs are best for low-frequency propagation.

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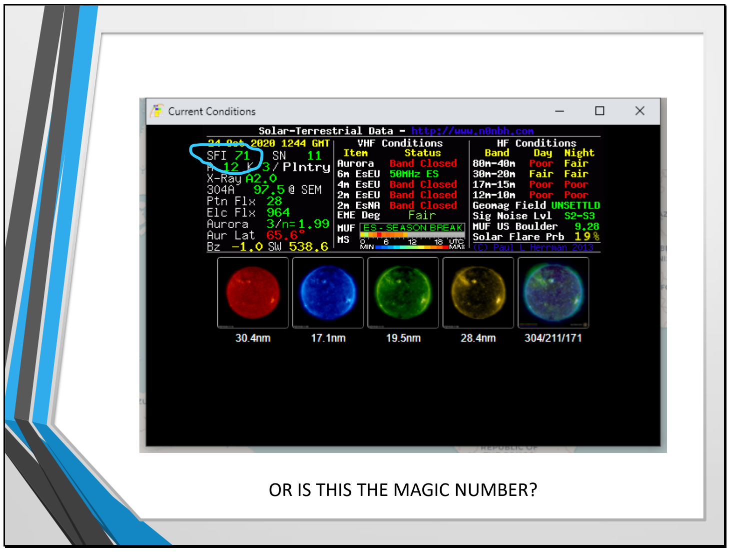

A measure known as the solar flux is used as the basic indicator of solar activity, and to determine the level or radiation being received from the Sun.

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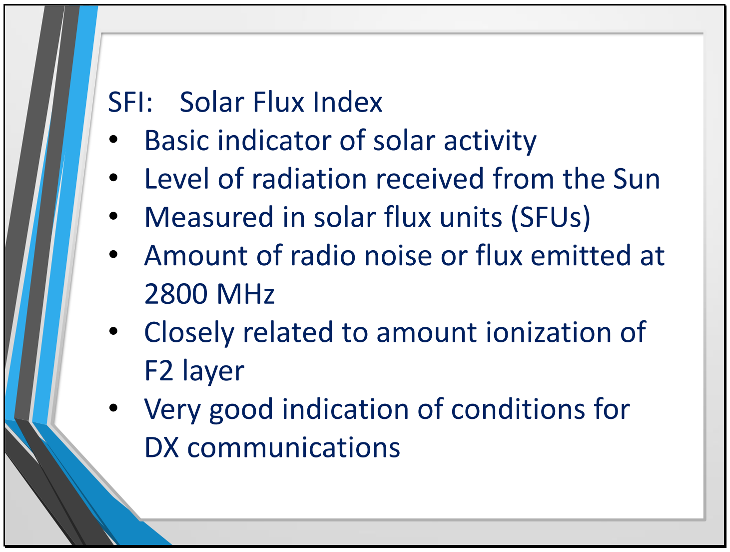

The solar flux is measured in solar flux units (SFU) and is the amount of radio noise or flux that is emitted at a frequency of 2800 MHz (10.7 cm). The Penticton Radio Observatory in British Columbia, Canada reports this measure daily. The solar flux is closely related to the amount of ionization and hence the electron concentration in the F2 region. As a result it gives a very good indication of conditions for long-distance communication. The figure for the solar flux can vary from as low as 50 or so to as high as 300. Low values indicate that the maximum useable frequency will be low and overall conditions will not be very good, particularly on the higher HF bands.

Conversely, high values generally indicate there is sufficient ionization to support long-distance communication at higher-than-normal frequencies. However, remember that it takes a few days of high values for conditions to improve. Typically values in excess of 200 will be measured during the peak of a sunspot cycle with high values of up to 300 being experienced for shorter periods.

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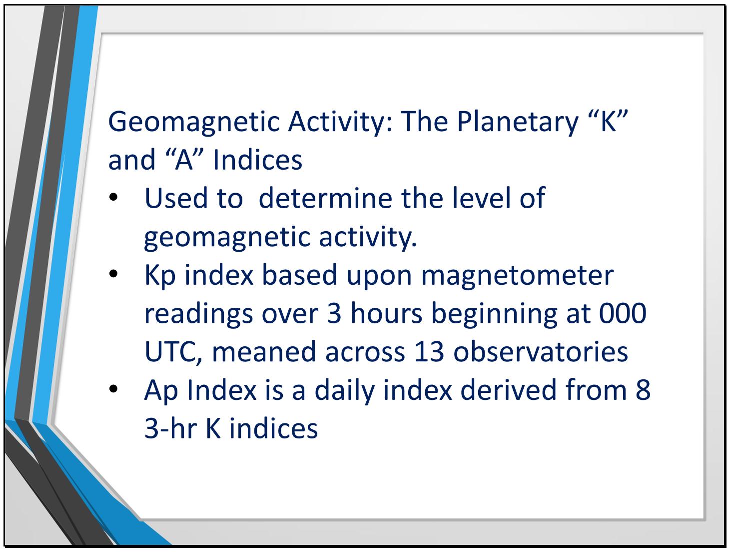

There are two indices that are used to determine the level of geomagnetic activity: the A index and the K index. These give indications of the severity of the magnetic fluctuations and hence the disturbance to the ionosphere.

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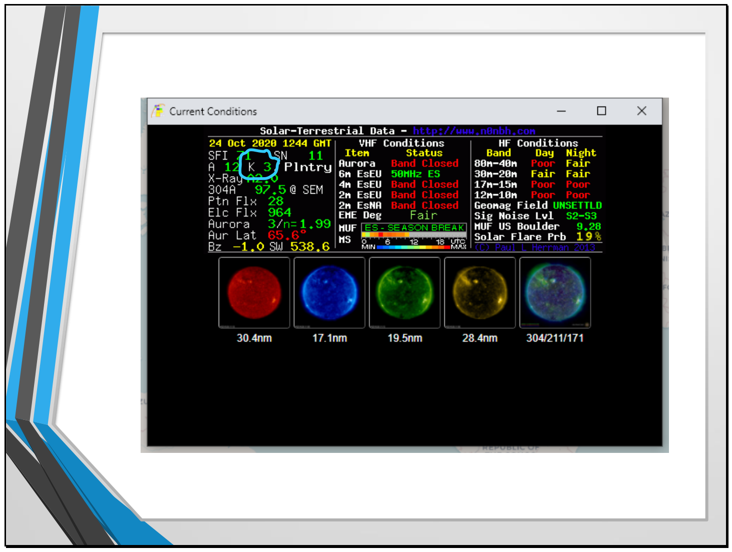

The first of the two indices used to measure geomagnetic activity is the K index. Each magnetic observatory calibrates its magnetometer so that its K index describes the same level of magnetic disturbance, no matter whether the observatory is located in the auroral regions or at the Earth's equator. At three hourly intervals starting at 0000 UTC each day, the maximum deviations from the quiet day curve at a particular observatory are determined and the largest value is selected. This value is then manipulated mathematically and the K index is calculated for that location.

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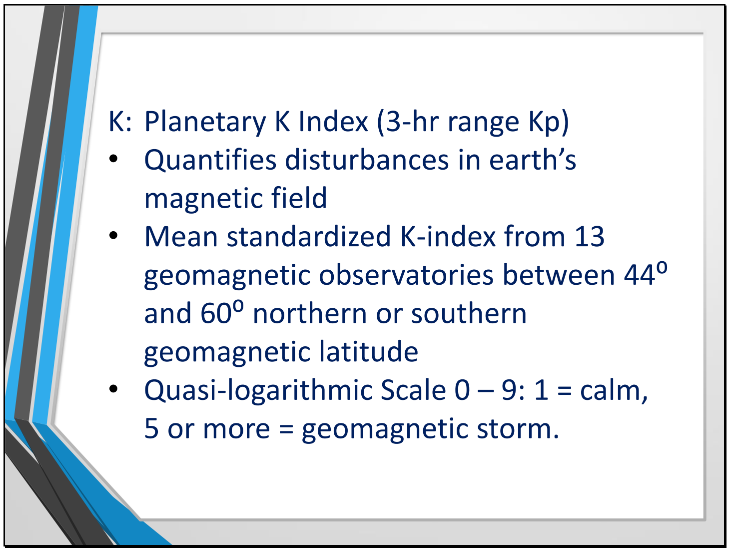

The Kp index is the planetary average of all the K indices at observatories around the globe. Values between 0 and 1 represent quiet magnetic conditions and this would indicate good HF band conditions, subject to a sufficient level of solar flux. Values between 2 and 4 indicate unsettled or even active magnetic conditions and are likely to be reflected in a degradation of HF conditions. Moving up the scale, 5 represents a minor storm, 6 a larger storm and 7 through 9 represents a very major storm that would result in a blackout of HF communications.

The K index is a "quasi logarithmic" number and as such cannot be averaged to give a longer-term view of the state of the Earth's magnetic field.

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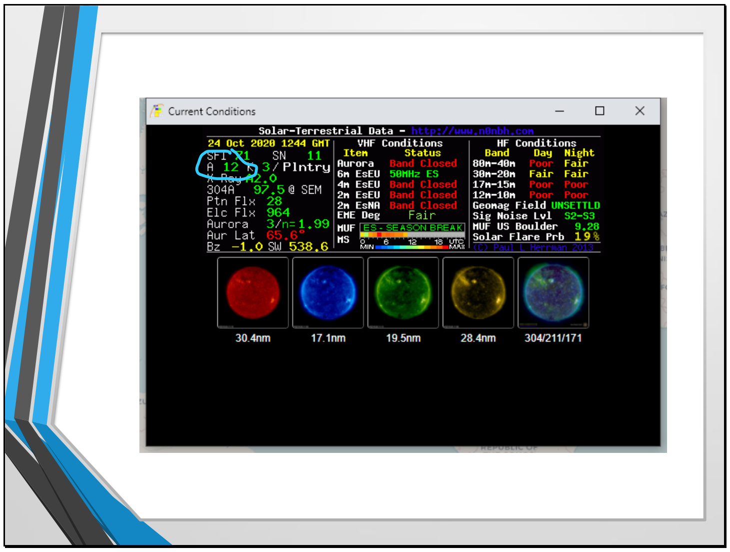

Thus was born the A index, a daily average.

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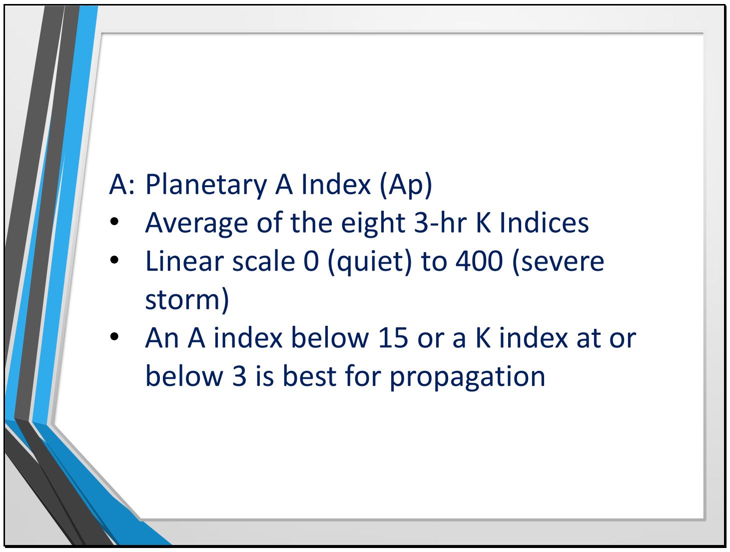

At each 3-hour increment the K index at an observatory is converted to an equivalent “a” index using Table 1, and the 8 a-index values are averaged to produce the A index for that day. It can vary up to values around 100. During very severe geomagnetic storms it can reach values of up to 200 and very occasionally more. The A index reading varies from one observatory to the next, since magnetic disturbances can be local. To overcome this, the indices are averaged over the globe to provide the Ap index, the planetary value.

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Relationship between A and K Values		
A	K	Comment
0	0	Quiet
2	1	Quiet
3	1	Quiet
4	1	Quiet to Unsettled
7	2	Unsettled
15	3	Active
27	4	Active
48	5	Minor Storm
80	6	Major Storm
132	7	Severe Storm
208	8	Very Major Storm
400	9	Very Major Storm

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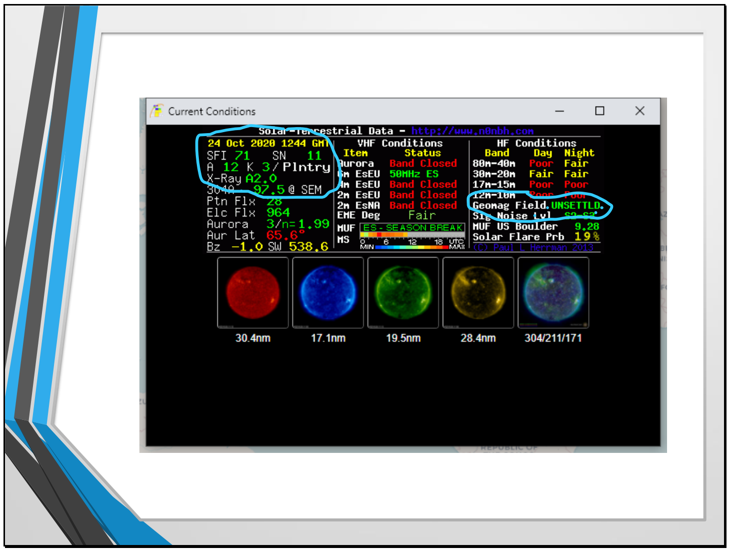
Current Conditions
Solar-Terrestrial Data - http://www.n0nbh.com
24 Oct 2020 1244 GMT
SFI 71 SN 11
A 12 K 3/ Plntry
X-Ray A2.0
97.5 @ SEM
Ptn Flx 28
Elc Flx 964
Aurora 3/n=1.99
Aur Lat 65.6°
Bz -1.0 SW 538.6
VHF Conditions
Item Status
Aurora Band Closed
EsEU 50MHz ES
EsEU Band Closed
2m EsEU Band Closed
2m EsNA Band Closed
EME Deg Fair
MUF ES - SEASON BREAK
MS
0 6 12 18 UTC
MIN MAX
HF Conditions
Band Day Night
80m-40m Poor Fair
30m-20m Fair Fair
17m-15m Poor Poor
12m-10m
Geomag Field UNSETTLD
Noise Lvl
MUF US Boulder 9.28
Solar Flare Prb 19%
(C) Paul L Herrman 2013
30.4nm
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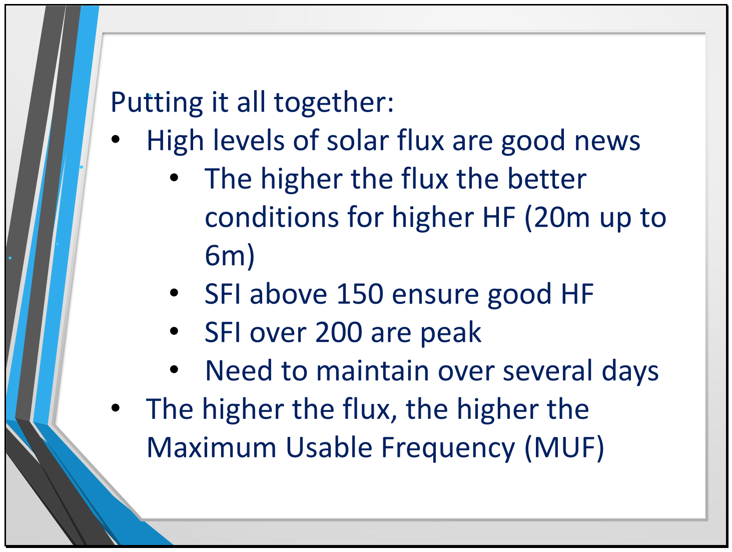
28.4nm
304/211/171

Slide 17



The easiest way to use these figures is to enter them into a propagation prediction program. This will provide the most accurate prediction of what might be happening. These programs will take into account factors such as signal paths because some will cross the poles and they will be far more affected by storms than will those across the equator.

If you don't own propagation software, it is still possible to gain a good insight into what the figures mean purely by assessing them mentally. Obviously, high levels of solar flux are good news. Generally, the higher the flux the better the conditions will be for the higher HF frequencies and even 6 meters. However, the levels need to be maintained for some days. In this way the overall level of ionization in the F2 layer will build up. Typically values of 150 and more will ensure good HF band conditions, although levels of 200 and more will ensure they are at their peak. In this way the maximum usable frequencies will rise, thereby providing good conditions.

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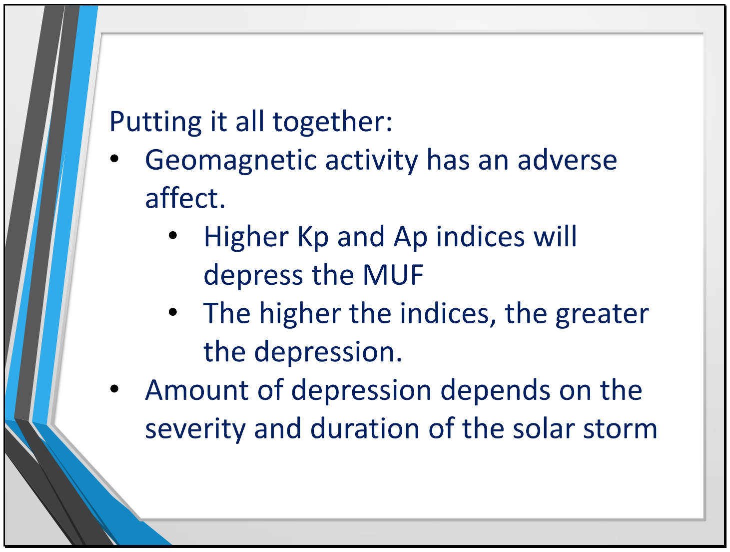

The level of geomagnetic activity has an adverse effect, depressing the maximum usable frequencies. The higher the level of activity as reflected in higher Ap and Kp indices, the greater the depression of the MUFs. The actual amount of depression will depend not only on the severity of the storm, but also its duration.

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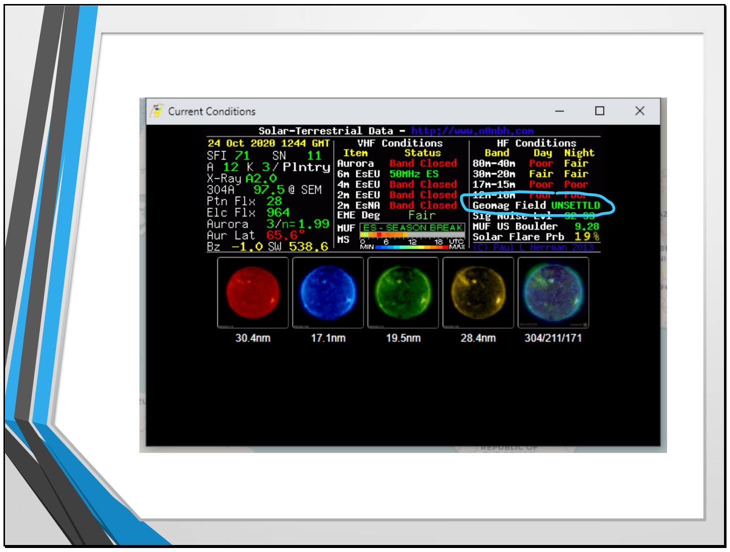
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304A 97.5 @ SEM
Ptn Flx 28
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VHF Conditions
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EME Deg Fair
MUF ES - SEASON BREAK
MS
HF Conditions
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80m-40m Poor Fair
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17m-15m Poor Poor
Geomag Field UNSETTLD
MUF US Boulder 9.28
Solar Flare Prb 19%
(C) Paul L Herrman 2013
30.4nm
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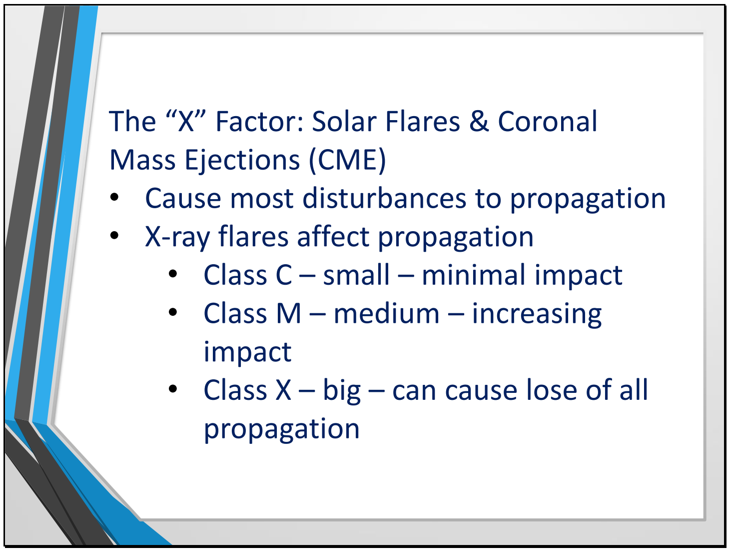
Slide 20



Most of the disturbances to propagation come from solar flares and coronal mass ejections (CMEs). The solar flares that affect propagation are called X-ray flares due to their wavelength being in the 1 to 8 Angstrom range. X-ray flares are classified as C (the smallest), M (medium size), and X (the biggest). Class C flares usually have minimal impact to propagation. Class M and X flares can have a progressively adverse impact to propagation.

The electromagnetic radiation from a class X flare in the 1 to 8 Angstrom range can cause the loss of all propagation on the sunlit side of Earth due to increased D region absorption. Additionally, big class X flares can emit very energetic protons that are guided into the polar cap by Earth's magnetic field. This can result in a polar cap absorption event (PCA), with high D-region absorption on paths passing through the polar areas of Earth.

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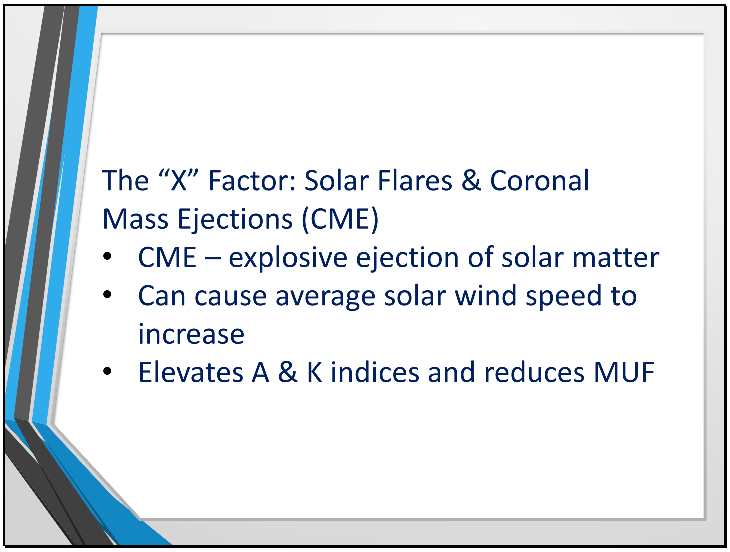

A CME is an explosive ejection of a large amount of solar matter and can cause the average solar wind speed to take a dramatic jump upward - kind of like a shock wave heading toward Earth. If the polarity of the sun's magnetic field is southward when the shock wave hits Earth's magnetic field, the shock wave couples into Earth's magnetic field and can cause large variations in Earth's magnetic field. This is seen as an increase in the A and K indices.

In addition to auroral activity, these variations to the magnetic field can cause those electrons spiraling around magnetic field lines to be lost into the *magnetotail*. With electrons gone, maximum usable frequencies (MUFs) decrease, and return only after the magnetic field returns to normal and the process of ionization replenishes lost electrons. Most of the time, elevated A and K indices reduce MUFs, but occasionally MUFs at low latitudes may increase (due to a complicated process) when the A and K indices are elevated.

Solar flares and CMEs are related, but they can happen together or separately. Scientists are still trying to understand the relationship between them. One thing is certain, though - the electromagnetic radiation from a big flare traveling at the speed of light can cause short-term radio blackouts on the sunlit side of Earth within about 10 minutes of eruption. Unfortunately we detect the flare visually at the same time as the radio blackout, since both the visible light from the flare and the electromagnetic radiation in the 1 to 10 Angstrom range from the flare travel at the speed of light - in other words, we have no warning. On the other hand, the energetic particles ejected from a flare can take up to several hours to reach Earth, and the shock wave from a CME can take up to several days to reach Earth, thus giving us some warning of their impending disruptions.

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A short cut to interpreting the solar date and picking your operating bands: The HF Conditions information column shows predictions of propagation characteristics on given bands from 80M to 10M. The VHF Conditions column shows E-skip conditions and EME propagation.

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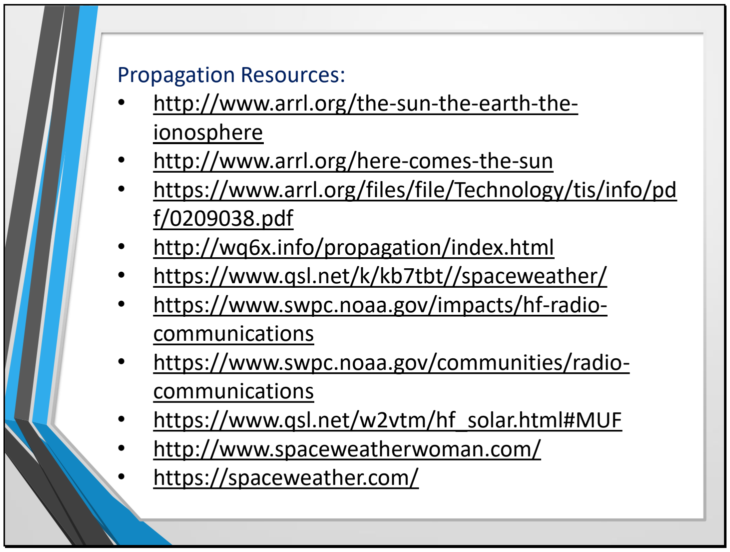
Propagation Resources:
• http://www.arrl.org/the-sun-the-earth-the-ionosphere
• http://www.arrl.org/here-comes-the-sun
• https://www.arrl.org/files/file/Technology/tis/info/pdf/0209038.pdf
• http://wq6x.info/propagation/index.html
• https://www.qsl.net/k/kb7tbt//spaceweather/
• https://www.swpc.noaa.gov/impacts/hf-radio-communications
• https://www.swpc.noaa.gov/communities/radio-communications
• https://www.qsl.net/w2vtm/hf_solar.html#MUF
• http://www.spaceweatherwoman.com/
• https://spaceweather.com/