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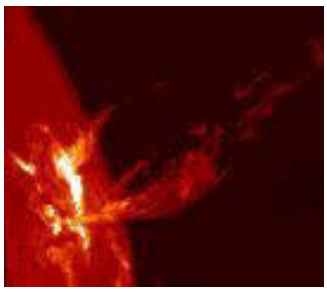

KN4LF
MEDIUM FREQUENCY
RADIO PROPAGATION THEORY NOTES

Layman Level Explanations Of "Seemingly" Mysterious Medium Frequency Occurrences

Current Time:

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KN4LF DAILY SOLAR SPACE WX AND GEOMAGNETIC DATA ARCHIVE HOME

Note! For those that would like to chat with me about solar, space weather and geomagnetic goings on I'm on Yahoo IM and my ID is thomasgiella.

This website is permanently under construction as I add new data and research information continuously. If you see any spelling or sentence structure errors I've overlooked "please" feel free to advise me, thanks! Also feel free to ask for inclusion on this website of "legitimate" propagation theory. Remember that the definition of "theory" means that the concept has not or can not be definitively proven in a laboratory setting but can be inferred via systematic study.

Note these theory notes are primarily for medium frequencies (300-3000 KC) only.

I have attempted to keep the propagation theory explanations in simple to understand layman terms, because long complicated technical explanations can be boring and make one's eyes glaze over. Unfortunately though sometimes while trying to keep

things simple, certain definitions, meanings and technical aspects can get watered down or even lost, which tends to open me up to criticism from certain fellow space weather scientists that just don't understand the educational and public relations concept of the keep it simple stupid (KISS) principle.

I choose to use W6SAI's (SK) "KISS" method of writing and communicating. I have found that this method works best whether it be in teaching about Space or Atmospheric Weather. I do have an extensive teaching background in Space and Atmospheric Weather.

Unfortunately I'm not be able to answer all propagation questions from either the layman or scientific community at this moment, due to ongoing federal government reasons (one of my peers found this explanation humorous). I'm the only scientist on the planet with a command of high and medium frequency radio wave propagation theory as a Space Plasma Physicist and also of atmospheric weather as a Meteorologist. However because of the nature of my employment with "Uncle Sam", I'm not well known within typical civilian government and academic circles involving space weather forecasting nor within the Amateur Radio community, so have been looked upon with suspicion and/or indifference. I am however well known within atmospheric weather consulting circles. I do hold basic and advanced degrees in Meteorology and Space Plasma Physics courtesy of the cold war era "Uncle Sam University".

In 2003 I was in the research and data collection mode for a new book concerning MF and LF wave propagation modes and their interaction with Stratospheric and Troposphere meteorological effects, including lightning, Internal Buoyancy/Gravity Waves, temperature and moisture discontinuities (cold frontal inversions), etc. Unfortunately virtually all in depth research data on the subject is still bottled up within the federal government and it will stay there for an indefinite period of time because of government reaction to the 09/11/2001 terrorist attacks. The book was to be based on the research that was to become available in 2003 through the U.S. FOIA. Actually a good amount of very valuable research data on MF and LF frequency propagation period is still in a "not to be released to the general public" form. I was to publish the data in G & A and also in book form in approximately one year but basically the book has gone the way of Polar Cap absorption so to speak.

Recently I also became involved in a propagation research project of sorts on 10, 6 and 2 meters. I have set up a propagation beacon on 10 meters, the frequency is 28131 kc USB +1500 hz using 25 watts. Actually there is a group of hams running the propagation beacons in the U.S. and around the world. Basically it's a marriage between digital PSK31 and APRS technology, actually software's run on a computer that is interfaced to a transceiver. Beacon transmission will commence on 20 meters in the future, with the ultimate aim of all HF bands and even 160 meters. It's been very interesting so far watching F2 propagation openings on 10 meters, when conventional propagation wisdom says that the opening should not be occurring. A knowledgeable observer can also pick out Sporadic-E (Es) openings. You can learn more about the concept by clicking here for HF PropNET.

We hams are a curious lot with inquiring minds. A good number of us have a keen interest in low, medium, high and very high frequency radio wave propagation mechanisms and this website conglomeration is directed at this cutting edge group.

We also have a segment in our radio service that is basically disinterested in radio propagation and don't feel it necessary to understand it in order to successfully work DX, which is certainly okay.

Then we have a third and smaller group with gigantic runaway egos that insist that they are omniscient by virtue of their license class, ARRL DXCC entity totals and "possible" electrical engineering backgrounds. Anal Retentives? They spend their time arguing with ignorance (Alchemists) against explanations put forth via this and other scientists, with solid backgrounds in atmospheric and/or space weather physics.

Other experts within our great radio service include our own NM7M, K9LA, N4XX, W3ASK, NW7US and others unintentionally left out of this list!

Back To The Top

1.) MF Propagation Overview-

a.) Medium frequencies encompass 300 to 3000. The simplest way to look at medium frequencies with respect to propagation issues from a layman's point of view, is to accept the fact propagation is poor the majority of the time. (See definition #6. Electron Gyro Frequency Absorption), especially past approximately 1250 miles (one refraction off of the E-layer), with occasional short-lived good periods as far as 3200 miles.

Medium frequency radio waves possess elliptical polarization, with the signal splitting into ordinary and extra-ordinary rays. These rays can propagate in or out of phase, mainly out of phase. The out of phase extra-ordinary ray represents a 50% power loss on the receive end of a path.

b.) Why? D-layer absorption! At daytime the D-layer, which is at an approximate height of 30-60 miles in the mesosphere, totally absorbs medium frequency RF signals most of the time. I say most of the time because at high latitudes, during the winter season and especially at the low part of a sunspot cycle, daytime penetration of RF signals through the weakened D-layer and then refraction via the E-layer does occur. Another issue is the fact that the D-layer does not totally disappear at night. Many books that deal with wave propagation erroneously state that the D and E-layers disappear after sunset, totally incorrect thanks to Galactic X-Rays and Cosmic Rays.

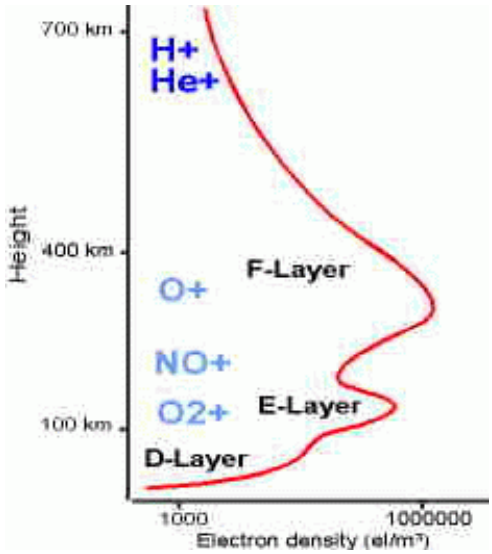
c.) Background electromagnetic radiation in the 1 to 10 Angstrom range (Hard X-Rays) is the main source of ionization of the day time D-layer, with our Sun as the source of Cosmic Rays, also playing a role.

The following paragraph was contributed by Carl Luetzelschwab K9LA.

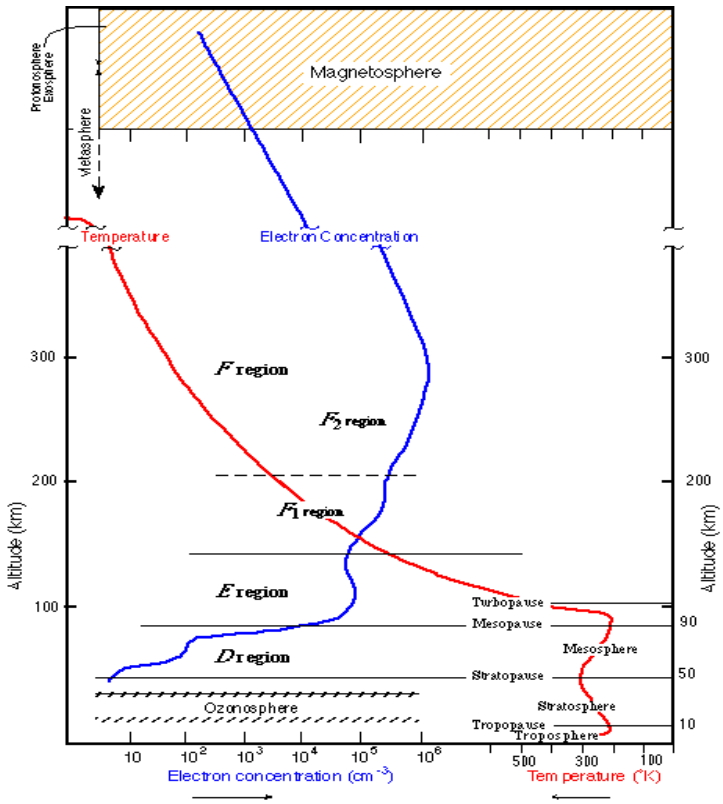
A couple years ago I was playing with Proplab Pro on a one-hop 936km path on 160m during daylight. I plotted absorption versus sunspot number. I expected a nice monotonic increase as the sunspot number increased. But the plot showed that absorption started at about 60dB at zero sunspots and was constant out to a sunspot number of about 50. Then it started climbing, reaching 100dB at a sunspot number of 150. This suggested that there was something other than hard x-rays and cosmic rays as the source of daytime D region absorption. So I dug into Davies 1990 (page 61),

Hunsucker and Hargreaves (page 31), and Brekke (page 233). They all seem to point to the Lyman-alpha line of the solar spectrum at 1215 Angstroms ionizing NO as the main source of the quiet daytime D region. So in terms of my absorption versus sunspot number plot, the flat portion up to a sunspot number of 50 is probably due to the Lyman-alpha line ionizing NO. Then above a sunspot number of 50 the hard x-rays start contributing as the Sun becomes more active.

Speaking of Carl K9LA, he produced two really good .pdf files on 160 meter propagation in 2004 and Disturbances To Propagation in 2003. Read them here: 160 Meter Propagation Disturbances To Propagation



Ionosphere Ion Types



Ionosphere Profile
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While I'm visiting the subject of electromagnetic radiation, our Sun emits electromagnetic radiation and matter, as a result of the nuclear fusion process. Electromagnetic radiation at wavelengths of 100 to 1000 Angstroms (Ultraviolet) ionizes the F region, radiation at 10 to 100 Angstroms (Soft X-rays), as well as Cosmic Rays ionize the E region. Galactic X-rays and Cosmic Rays are the reason that the E-layer is "always" present at night time, the D-layer also.

Cosmic rays are not rays at all, but particles. They are ionized atoms, atoms with missing electrons ranging from a single proton up to an iron nucleus and beyond but typically protons and alpha particles, which have 2 protons and 2 neutrons. They originate from deep space, being produced by a number of different sources, such as other stars, and more exotic objects, such as supernova, which are exploding stars and their remnants, neutron stars, black holes, and distant galaxies. Cosmic Ray particles travel very close to the speed of light, and are highly energetic.

While on the subject of distant galactic objects on 12/27/2004 more than a dozen spacecraft recorded the brightest event from outside the solar system ever observed in the history of astronomy. This gamma and X-ray producing super flare was emitted by a Magnetar star named SGR 1806–20. This star is an estimated 50,000 light years distant in the constellation Sagittarius on the far side of the Milky Way galaxy and obscured behind dense interstellar clouds.

Upon arrival at Earth the X-rays were powerful enough to increase absorption in the D layer of our ionosphere and create a dayside Sudden Ionospheric Disturbance (SID) and

a blackout of radio signals, amazing!!! To read more about this rare event check out this link at: http://skyandtelescope.com/news/article_1464_1.asp .

d.) Recently I saw a post on the Topband Reflector E-List, lamenting the seemingly unexplainable differences in 160 propagation on certain paths from night-to-night. A reasonable explanation? Yes, unfortunately small increases in the density of the night time D-layer over short periods of time, caused by smaller solar flares and also the general variability of the solar background X-Ray flux level, can have a profound negative impact on propagation in the form of increased absorption of high and even mid-latitude medium-frequency signal paths, both on the MF broadcast band, 160 and 120 meters. Why? It only takes 10 electron volts (ev) of energy to ionize the atmosphere and 1-10 Angstrom X-ray photons energize the atmosphere at a factor of 100. This translates into D layer absorption of medium frequency signals. The lower half of the MF broadcast is always affected first followed by the upper half of the AM broadcast band, then 160 and 120 meters. If you learn nothing else on this website, remember this simple explanation and pass the word.

e.) After much personal observational research over a 30 year period, I've come to the conclusion that high and mid latitude TA and TP propagation paths tend to open up only after a significant period of time passes with an energetic proton event of no greater then (10+0) on 160 meters and no greater then (10-1) on the medium frequency broadcast band. Openings also occur when the average solar background X-ray level falls back to or below C1 for 160 meters and B9 for the AM broadcast band, with A9 or less best.

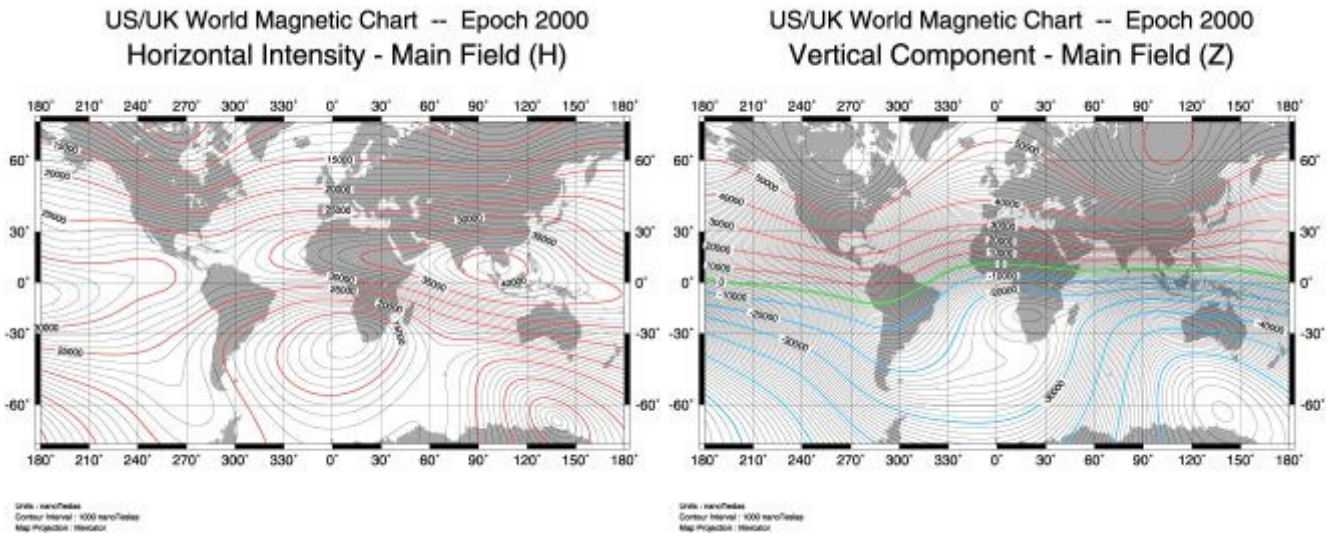
f.) Remember though that there are daily extremes of the Background X-ray flux level. So even though the daily average might have been good at say B2.2, the daily "extreme" maximum could have been C1.5, which would have been bad and have cause a short period of increased D layer absorption.

g.) Though high latitude paths on the day light side of the Earth are primarily effected, night time high latitude paths can also be impacted by higher intensity energetic proton events. This fact is still stubbornly opposed by some otherwise very knowledgeable space weather physicists hung up on high latitude threshold riometer data tied to Polar Cap Absorption (PCA).

h.) Another wrench in the gears preventing consistent good propagation on medium frequencies is related to Sporadic-D (Ds) absorption. Sporadic-D (Ds) occurrences have an inter-relationship with brief but intense Sun based and Galactic Cosmic Rays, huge positive cloud to ground lightning strokes and interrelated Elves and Sprites. Very large bursts of Gamma Rays have also been observed to occur in conjunction with Sprites.

i.) Also there is another unavoidable problem, Magneto Ionic Power Coupling. Antenna polarization plays a large role in the success of a long haul DX contact. As a medium frequency RF signal traverses Earth's magnetic lines of force in a perpendicular manner on high and mid latitude paths say between W3 land and SM, higher angle horizontally polarized signals are more readily absorbed then lower angle vertically polarized signals. On other propagation paths on the globe opposite results can be found, i.e. horizontally polarized signals suffer less absorption on a propagation path between VK6 and W6 or S9 and W4.

Magneto Ionic Power Coupling expert Bob Brown NM7M has a good educational thread on this bugaboo on the May 2002 Topband Reflector. The thread can read in it's entirety by going to this link Topband Reflector May 2002 Archives Layer



Horizontal & Vertical Components Of Earths Geomagnetic Field
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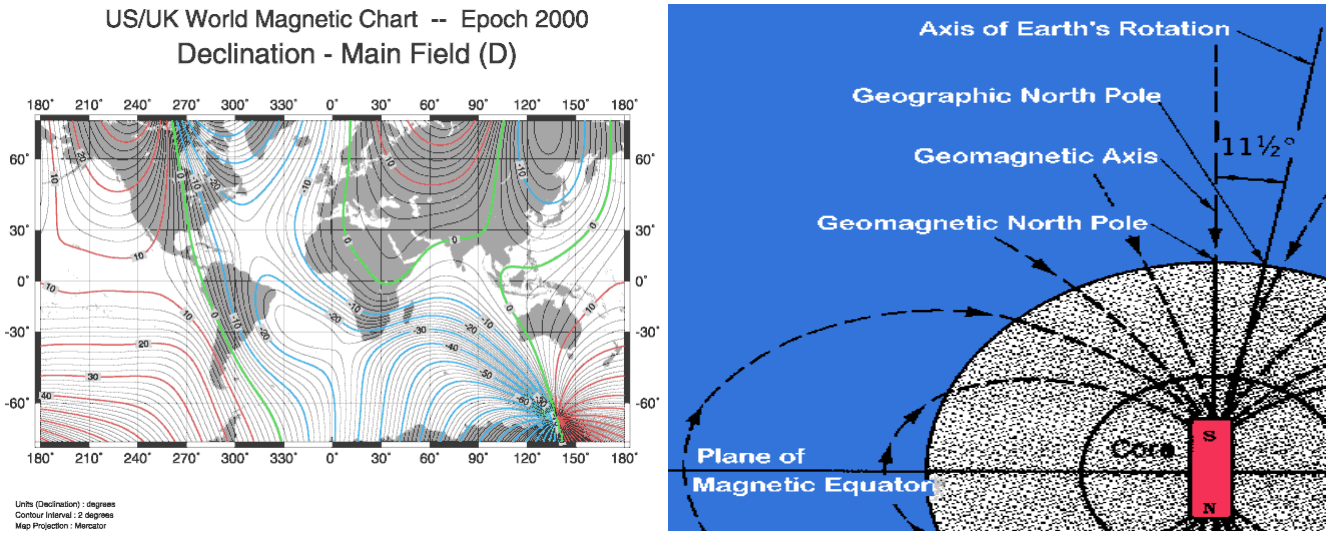

Earth's Geomagnetic Field
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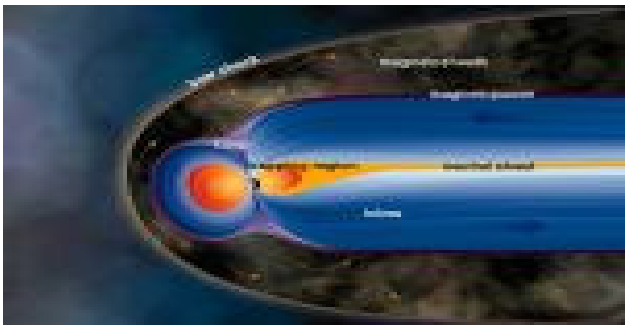

Earth's Magnetosphere
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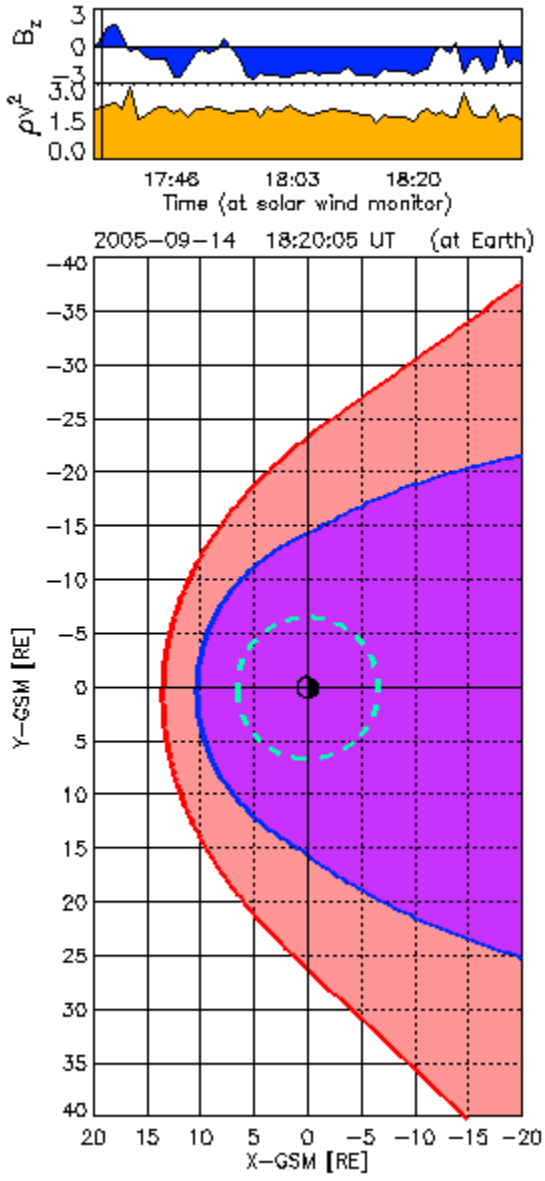


Profile Of Earth's Bow Shock & Magnetopause

j.) Geological effects such as earthquakes and volcanic eruptions, as well as meteorological effects such as troposphere originating Internal Buoyancy/Gravity Waves (IBGW), stratospheric level Quasi-Biennial Oscillations (QBO) and stratospheric warming (See definition #20 on Stratospheric Warming) have a negative effect on MF RF signals in the form of small to medium increased absorption variations of MF RF signals via the D layer caused by traveling ionospheric disturbances (TID's). Also temperature and moisture discontinuities (frontal inversions) can refract/scatter MF radio signals in unpredictable ways, most notably on high transmitted RF power levels.

k.) The Quasi-Biennial Oscillation (QBO) is a wind shift in the equatorial stratosphere, an oscillation from easterly to westerly and back on the time scale of approximately two years (26 months) and is a source of Internal Buoyancy/Gravity Waves (IBGW's) which create absorptive perturbations in the D and E layers and even in the F-1&2 layers.

l.) A note, the E-valley/Flayer ducting propagation mechanism does not exist only during gray line periods. Internal Buoyancy/Gravity Waves (IBGW's) are a source of the ducting mechanism and allow for occurrences of ducting along any propagation path in total darkness. Measurement of the timing of arrival of propagated MF RF signals demonstrates the existence of the ducting mechanism, versus conventional numerous E layer land/ocean surface hops.

m.) Yet another mechanism to deal with that impacts medium frequency radio wave propagation in a negative fashion is the D-Region Mid Winter Anomaly. It is a period of increased MF radio wave absorption at high and mid latitudes occurring in mid winter and is associated with sudden stratospheric warming and the Quasi Biennial Oscillation (QBO).

n.) The HAARP ionospheric program, earthquakes, volcanic eruptions, thunderstorms, lightning (especially positive cloud to ground strokes), elves, sprites, tornadoes, hurricanes and even man made activities such as rocket launches including the space shuttle, are all sources of (IBGW's). Many times I've heard ham's lament that propagation was going to go to crap due to another space shuttle launch, in a sense they are correct. Much more research is needed on MF and LF radio wave propagation.

o.) Another issue facing MF AM broadcast Band DXers and 160 meter operators is lower latitude propagation path absorption due to the Equatorial Ring Current. This phenomenon acts as a repository for precipitated electrons and the end result is unpredictable MF RF signal blockage absorption and refraction. Absorption is similar to higher latitude Auroral absorption.

p.) Here are some interesting website links concerning LF and VLF radio propagation theory.

LF PROPAGATION THEORY INFO BY ALAN MELIA G3NYK

PROPAGATION OF LONG RADIO WAVES BY J.A. ADCOCK VK3ACA

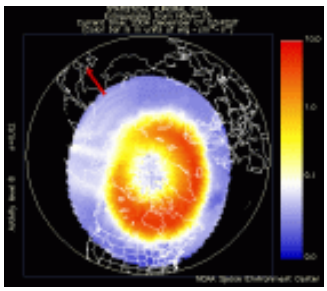
RADIO WAVES BELOW 22 KC

2.) Aurora Oval Blockage, Absorption And Refraction-

The aurora ovals "generally" have a negative impact on medium-frequency propagation. If the path over which you are communicating lies along or inside one of the Aurora Ovals, you will experience degraded propagation in one of several different forms; strong signal absorption, brief periods of strong signal enhancement, which is mainly caused by tilts in the ionosphere that allow signals to become focused at your location or very erratic signal behavior in the form of strong and rapid fading, etc., caused by a variety of effects such as multi-pathing, anomalous and rapid variations in absorption, non-great-circle propagation, horizontal or side refraction and/or scatter (skewing) due to changes in electron density and polarization changes. (See definition #7. Propagation Path Skewing).

When the Aurora Oval zones are contracted and latitudinally-thin coinciding with low geomagnetic activity, it is possible for a medium-frequency transmitted signal to propagate through the Aurora Oval zone without being heavily absorbed by skirting underneath it.

During periods of very low geomagnetic activity, areas of the Aurora Oval zones may only have a latitudinal thickness of approximately 300 miles. But radio signals reflected from the E-layer can travel over distances of as much as 300 to 1250 miles at heights below the ionosphere for low take-off angles of between 10 and 25 degrees. When the geometry is just right, the medium-frequency transmitted signal can literally propagate underneath and through the Aurora Oval zones into the polar ionosphere which is less disturbed and from the polar ionosphere back into the middle latitude ionosphere, without ever coming in contact with the highly absorptive Aurora Ionosphere. This type of propagation is not as rare as you might think and it can provide unusually stable polar region path openings to (TA) Transatlantic and (TP) Transpacific regions. But because the Aurora Oval zone expands and contracts constantly, such conditions often do not last very long. (See definition #3. Equatorial Ring Current).



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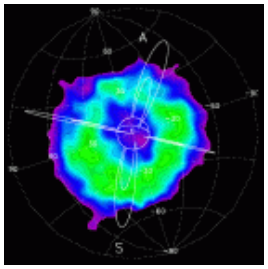
Back To The Top

3.) Equatorial Ring Current- A phenomena that acts as a repository for precipitated electrons in the vicinity of the magnetic equator. The electrons travel by spiraling around north south magnetic field lines at a frequency called the 'gyro frequency. The

end result is lower latitude propagation path medium frequency transmitted RF signal blockage absorption via the D layer. Absorption is similar to higher latitude Aurora Oval absorption and is inter-related with same.

A reliable gauge for measuring the up to three day lingering post geomagnetic storming medium frequency transmitted RF absorption is the Dst index, measured in nT's. It is an estimated value from Kyoto Japan and is based on a formula. Large negative values after a major geomagnetic storm indicates a high Equatorial Ring Current level. (See definition #2. Aurora Oval Blockage, Absorption And Refraction). Here is a website link to the Kyoto, Japan Dst Index http://swdcdb.kugi.kyoto-u.ac.jp/dstdir and the U.C. Berkeley website link http://sprg.ssl.berkeley.edu/dst_index and a NASA GSFC website link http://sprg.ssl.berkeley.edu/dst_index . (See definition #2. Aurora Oval Blockage, Absorption And Refraction).



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4.) Coronal Mass Ejection (CME)-

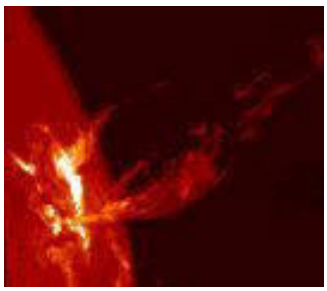
A Coronal Mass Ejection is the name given to an ejection of a large amount of matter from the Sun's outer atmosphere or corona. These ejections typically comprise millions of tons of material in the form of charged particles, and can be seen because the material reflects sunlight. When one of these ejections is directed towards the Earth (or conversely, directly away from the Earth), it looks like a roughly circular "halo" surrounding the Sun.

The "Halo CME's" then are those CME's which are more likely to impact the Earth than those which are shot out at right angles to the Earth-Sun line. Energetic protons emitted during CME's play a major role in increased day time and night-time D-layer absorption of medium frequencies.

Coronal Mass Ejections were once thought to be completely initiated by solar flares. However it is now known that many (CME's) are not associated with Solar Flares but instead with Solar Filaments. If a (CME) collides with the Earth, it can excite a Geomagnetic Storm if the polarity of the IMF has a negative sign. We must be vigilant in watching for geo-effective (CME's), in order to not be caught by surprise with a seemingly sudden and unexpected Geomagnetic Storm. (See definition #6. Solar Filament). (See definition #11. Geomagnetic/Ionospheric Storm). (See definition #16. Solar Flare).

Coronal mass ejections are not random meaningless eruptions but instead a process by

which the Sun expels complex magnetic signatures enroute to changing it's magnetic polarity or said a different way the swapping of the Sun's magnetic poles. Basically the Sun swapped it magnetic polarity at the peak of present solar cycle 23 somewhere between July 2000 and December 2001. The next polarity swap will occur during solar cycle 24 somewhere around 2010-2011.



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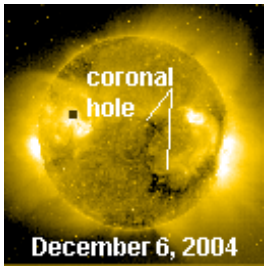
5.) Coronal Hole-

The corona is not part of the Sun's surface. It is instead part of the Sun's atmosphere, much like Earth's troposphere. Coronal holes are low density areas associated with open magnetic field lines and are found near the Sun's poles at the bottom of a sunspot cycle and everywhere during a cycle maximum. A coronal hole is a dark region where a breakdown in the magnetic field structure in the solar corona has occurred. From these regions stream the high velocity solar wind and are a source of geomagnetic storming on Earth.

Coronal holes occur most often on the downside of a solar cycle and their absence at the bottom of a solar cycle and at the beginning of the next, allow for the best LF and MF radio propagation conditions. Many think it's the lower solar flux values seen at the bottom of a solar cycle that accounts for improved propagation conditions but it's actually pretty much a lack of coronal holes and geomagnetic storming. (See definition #11. Geomagnetic/Ionospheric Storm).

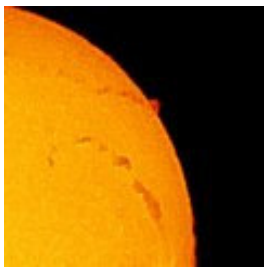
One thing to keep in mind is that the high velocity solar wind stream emanating from a coronal hole is a neutral phenomena with respect to the Bz (magnetic component) of the interplanetary magnetic field (IMF). If the Bz component is negative (southward) prior to arrival of the solar stream, there will exist a tendency to see a larger swing negative after the disturbance arrives. If the Bz component is positive (northward) prior to arrival of the solar stream, there will exist a tendency to see a larger swing positive after the disturbance arrives.



Courtesy Of SOHO

6.) Solar Filament-

A relatively cool and dense ribbon of gas held together by solar magnetic fields. From Earth they usually appear as dark lines across the face of the Sun. At times the magnetic lines holding the filament open up creating a tremendous eruption similar in size and impact of a Coronal Mass Ejection (CME). (See definition #4. Coronal Mass Ejection). (See definition #11. Geomagnetic/Ionospheric Storm).



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7.) Correlation Of Energetic Protons, Solar Flux and Ap & Kp Indices With Medium Frequencies-

I've been observing energetic proton levels, as well as the Ap & Kp indices for 30 years and see a direct correlation between high energetic proton levels above 10 MeV (10+0) and poor propagation on high and at times mid latitude MW paths at day AND night, where as A & K don't as readily correlate. (See paragraph three of definition #2. Aurora Oval Blockage, Absorption And Refraction and definition #7. High Latitude Path Skewing), for a further explanation on the lack of correlation of Ap & Kp indices with medium frequency propagation conditions.

High solar flux values are "incorrectly" considered to be detrimental to medium-frequency signals both domestic and TA/TP, as more absorption can be present as the transmitted signal makes two trips through the D layer, near sunrise and sunset. However most medium wave frequency RF signals in excess of 3100 miles are propagated via the E valley/F layer ducting and/or Chordal Hop/Pederson Ray propagation mechanism and a high solar flux value ensures a strong E and F-layer duct mechanism. Actually a solar flux of at least 100 is needed for the E valley/F layer

ducting mode.

The main reason that MF radio radio propagation "seems to be better" at the bottom of a sunspot cycle is not so much due to lower solar flux levels BUT due to much less geomagnetic activity.

Keep in mind though that the 10.7 cm (2800 mhz) solar flux index is not a "reliable" gauge of ionization in our atmosphere, as the energy of photons at this frequency is to low on the order of one million times. However most are used to solar flux and sunspot number and it's a hard habit to break. A better indicator is the interrelated background x-ray flux. See #1e & f above.

An elevated energetic proton flux level greater then (10+0) on 160 meters and greater then (10-1) on the medium frequency broadcast band creates noticeably increased winter time day and year round night time D layer absorption of medium wave frequencies, especially on high latitude propagation paths but it can also negatively impact mid latitudes, depending on the intensity of the event.

Elevated energetic proton events too small to be categorized as a Polar Cap Absorption event (PCA) can still impact high and at times mid latitude medium frequency propagation paths in the form of excessive D layer absorption.

((((Note, high latitude medium frequency radio propagation paths can still be disturbed for days and up to weeks, following the end of an official >10 MeV (10+0) proton event.))))

Here are some general guidelines concerning correlation of MF propagation indices to actual expected propagation conditions.

1.) Dropping indices numbers are better.

2.) For medium frequencies a solar flux under 150, under 100 better, 70 is best for E layer multi hop.

Keep in mind though that the 10.7 cm (2800 mhz) solar flux index is not a "reliable" gauge of ionization in our atmosphere for F layer MF frequency refractions, as the energy of photons at this frequency is to low on the order of one million times. However most are used to solar flux and sunspot number and it's a hard habit to break. A better indicator is the background x-ray flux. See #7 below.

3.) Solar flux of at least 100 for E valley-F layer ducting mechanism.

4.) Previous 24 hour Ap index under 10, under 7 for several days consecutively is best.

5.) Previous 3 hour Kp index under 3 for mid latitude paths, under 2 for high latitude paths, 0-1 for several days consecutively is best.

6.) Energetic protons no greater then 10 MeV (10+0) for 160/120 meters and no greater then (10-1) on MF broadcast band.

7.) Background x-ray flux levels less than C1 for several days consecutively for 160/120 meters and less then B9 for MF broadcast band, A9 or less is best.

8.) No current STRATWARM alert.

9.) IMF Bz with a (positive number) sign, indicates a lesser chance of high latitude path auroral absorption/unpredictable refraction or scattering of MF RF signals, when the Kp is above 3.

10.) A -50 or better towards a positive number Dst index during the recovery time after a geomagnetic storm, as related to the Equatorial Ring Current.

8.) E Valley-F Layer Propagation Ducting Mechanism/Chordal Hop Propagation-

Antenna polarization plays a large role in the success of a long haul DX contact. As a medium frequency RF signal traverses our planets magnetic lines of force in a perpendicular manner on high and mid latitude paths say between W3 land and SM, higher angle horizontally polarized signals are more readily absorbed then lower angle vertically polarized signals. On other paths on the globe opposite results can be found, i.e. horizontally polarized signals suffer less absorption on a propagation path between VK6 and W4.

You would expect a true long path QSO on 160 to be theoretically possible but improbable on most paths during any season. However a G to VK long path might be possible if the E-valley/F-layer ducting propagation mechanism or the Chordal Hop propagation mechanism is involved. A 160 meter signal can traverse a daylight path via these propagation modes if the transmitted signal enters/exits at each end of the path at or near sunrise/sunset when the D layer ionization is weak (ionospheric tilting).

The downward tilt of ionospheric layers is eastward at sunrise. As a result, signals coming from the west are refracted downward at steeper angles and are therefore heard better on higher angle antennas. The opposite is true at local sunset.

A note though, the E-valley/Flayer ducting propagation mechanism does not exist only during gray line periods. Internal Buoyancy/Gravity Waves (IBGW's) are a source of the ducting mechanism and allow for occurrences of ducting along any propagation path in total darkness. Measurement of the timing of arrival of propagated MF RF signals demonstrates the existence of the ducting mechanism, versus conventional numerous E layer land/ocean surface hops.

The majority of the time medium frequency RF signals in excess of approximately 3200 miles propagate via the E-valley/F-layer propagation mechanism or via the Chordal Hop (mostly on HF) propagation mechanism. High solar flux values can aid in long haul medium frequency propagation, as high solar flux values ensure a strong F-layer half of the E-Valley/F-layer duct mechanism. Typically the majority of transmit antenna's radiation must be focused between 40-60 deg. to enter the E-Valley/F-layer duct.

If one is lucky enough to be on the receive end of a ducted medium frequency signal due to an IBGW or two, a change in the vertical and/or horizontal electron gradient will

allow the RF to drop out of the duct at your QTH.

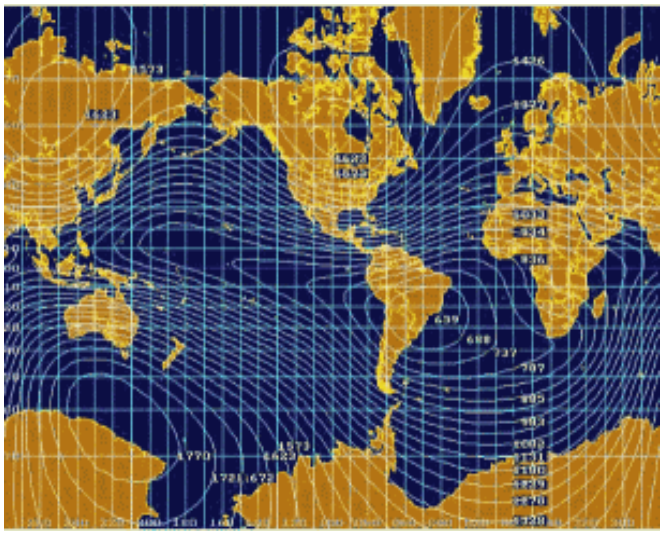
A note, high solar activity in the form of increased ionization created by ultraviolet and X-ray radiation, can fill in the E-Valley/F-layer ducting region with medium frequency absorptive ionization and interfere with the E- Valley/F-layer ducting mechanism. In a sense the E/F layer duct is shut down and the medium frequency RF signal can only propagate between the E-layer and land/ocean surface, at a higher angle and with more signal loss. This closing of the duct can be reciprocal on each end of the propagation path or one way only. (((((When closing of the duct occurs the advantage of a low angle vertical radiator is lost, with a higher takeoff angle horizontal dipole making the contact still possible, albeit maybe weaker.)))))

Medium frequency radio waves possess elliptical polarization, with the signal splitting into ordinary and extra-ordinary rays. These rays can propagate in or out of phase, mainly out of phase. The out of phase extra-ordinary ray represents a 50% power loss on the receive end of a propagation path.

9.) Electron Gyro Frequency Absorption-

Unfortunately medium frequencies fall within or very near the electron gyro-frequency which is in the approximate range of 630 to 1630 kHz and of course the AM broadcast band and 160 meter band is very close to these electron gyro-frequencies. There is a direct correlation between the strength Earth's magnetic field lines and electron gyro frequencies.

Basically, the electron gyro-frequency is a measure of the interaction between an electron in the Earth's atmosphere and the Earth's magnetic field. The closer a transmitted a medium frequency carrier or sideband wave frequency is to the electron gyro-frequency, the more energy that is absorbed by the gyro electrons from that carrier wave frequency. This is especially true for medium frequency signals traveling perpendicular to the Earth's magnetic field, meaning high latitude NW and NE propagation paths. Unfortunately this form of medium frequency signal absorption is ALWAYS present.



Electron Gyro-frequency Map From Proplab Pro Software
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Back To The Top

10.) Horizontal Propagation Path Skewing-

Basically the simplest way to look at medium frequency signal propagation path skewing is that the transmitted RF signal will "always" seek to propagate along the path with least absorption, which almost always means via a darkness path. As an example a signal transmitted from Norway to New England, which is a polar great circle path, will be directly absorbed most of the time by the Aurora Oval, with the remaining medium frequency signal skirting south and then west on the darkness path, arriving in New England from say the SE rather then the expected NE path. Also medium frequency skewed propagation paths are the norm rather then the exception, especially past approximately 3200 miles.

Unfortunately this simplified explanation has been resoundingly rejected but I stand by it 100%. Borrowing from definition #2. Aurora Oval Blockage, Absorption And Refraction, I will add horizontal or side scatter propagation due to electron gradient changes, as a more complex explanation of signal path skewing around the Aurora Oval.

11.) Geomagnetic/Ionospheric Storm-

A worldwide disturbance of the Earth's magnetosphere and or ionosphere, induced by direct connection to the Sun's interplanetary magnetic field (IMF), distinct from regular diurnal variations. Basically it's a precipitation of electrons trapped within our magnetosphere, as the electrons collide. The end result is a reduction of the MUF of the F2 layer. (See definition #3. Equatorial Ring Current). (See definition #4. Coronal Mass Ejection). (See definition #5. Coronal Hole). (See definition #6. Solar Filament).

Geomagnetic Storm Levels

Planetary K Indices	Geomagnetic Storm Level
K = 5	G1 Minor
K = 6	G2 Moderate
K = 7	G3 Strong
K = 8	G4 Severe
K= 9	G5 Extreme
Active K = 4	K- 0= A- 0
Unsettled K = 3	K- 1= A- 3
Quiet K= 0, 1, 2	K- 2= A- 7

A= 100-400 Severe	**K- 3= A- 15**
A= 50-99 Major	**K- 4= A- 27**
A= 30-49 Minor	**K- 5= A- 48**
A= 16-29 Active	**K- 6= A- 80**
A= 8-15 Unsettled	**K- 7= A- 140**
A= 0-7 Quiet	**K- 8= A- 240**
	K- 9= A- 400

Solar Radiation Storm Levels

Flux Level of ≥ 10 MeV Particles	Solar Radiation Storm Level
10	S1 Minor
10^2	S2 Moderate
10^3	S3 Strong
10^4	S4 Severe
10^5	S5 Extreme

MF Radio Blackout Levels

Peak X-Ray Level And Flux	Radio Blackout Level
M1 and (10^{-5})	R1 Minor
M5 and (5×10^{-5})	R2 Moderate
X1 and (10^{-4})	R3 Strong
X10 and (10^{-3})	R4 Severe
X20 and (2×10^{-3})	R5 Extreme

((((Note! Unfortunately elevated Kp indices of as little as a 3 will create absorptive conditions for medium frequency signal propagation on higher propagation paths)))).

Initial phase of a geomagnetic storm is that period when there may be an increase of the middle latitude horizontal intensity.

Main phase of a geomagnetic storm is that period when the horizontal magnetic field at

middle latitudes is generally decreasing.

Recovery phase of a geomagnetic storm is that period when the depressed northward field component returns to normal levels.

By the way effects of the solar wind on the magnetosphere decreases as we approach the Summer/Winter solstice and increase at the Fall/Spring Equinox. Why? Basically it's the orientation of Earth's magnetic field with respect to the Interplanetary Magnetic Field within the Solar Wind. When solar material and shock waves reach Earth their effects may be enhanced or dampened depending on the angle at which they arrive. READ ABOUT IT HERE.

The Wang-Sheeley Interplanetary Magnetic Field (IMF) Model is used to predict Sun's IMF polarity. When the polarity of the IMF is negative a visible mid latitude Aurora display is likely as a Coronal Mass Ejection (CME) strikes the Earth's magnetic field.

12.) Geological/Meteorological Effects On MF Propagation-

Geological effects such as earthquakes and volcanic eruptions, as well as meteorological effects such as troposphere originating Internal Buoyancy/Gravity Waves (IBGW's), stratospheric level Quasi Biennial Oscillations (QBO) and warming (STRATWARM) have a negative effect on MF RF signals in the form of small to medium increased absorption variations of MF RF signals via the D layer, due to traveling ionospheric disturbances (TID's).

Also temperature and moisture discontinuities involved with cold frontal inversions and air mass triple points involved with extra-tropical low pressure systems can refract, diffract or scatter MF radio signals in unpredictable ways, most notably on high transmitted RF power levels. This is another concept that a fellow Physicist and expert in optics took me to task over.

As far as MF refraction it's more significant at say 3000 kc, then 1850 kc or 1500 kc. But it's also more noticeable with higher transmitted RF powers, i.e. WSAI 1530 50 KW and even more so with BSKA 1521 KC 1000 KW and now defunct 2000 kc region 100 KW marine stations.

We know that the MF spectrum is defined as 300-3000 kc but the differences in refractive properties between 300 and 3000 is very significant significant. At 3000 kc refraction is a good description, on 160 scattering, at 300 kc diffraction.

Using the strictest definition of RF refraction, it's effect on 160 meters is small but it has been measured by government researchers as significant enough to impact 160 but near the air mass triple point. In my opinion scattering is actually the more consistent propagation medium for 160 meters along a cold front, away from the extra-tropical cyclone center.

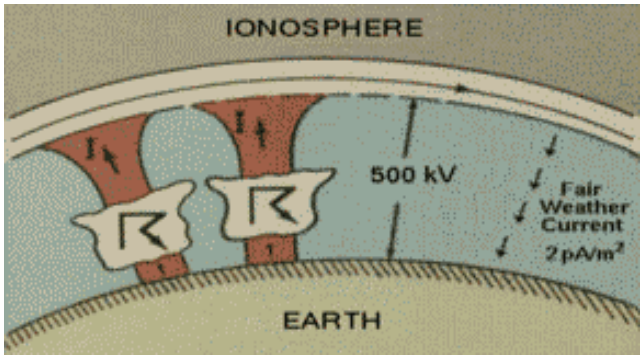
However the temperature and moisture discontinuities in the vicinity of a triple point air mass structure such as seen with a mature extra-tropical cyclone is very complex and fluid. The NW quadrant of the extra-tropical cyclone is the location that the original

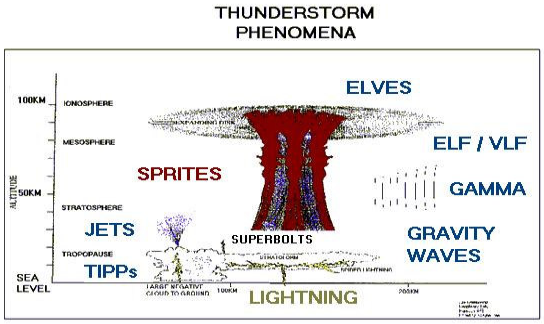
government researchers identified as the region of existence for the complex temperature/moisture discontinuity structure that allows for refraction of RF signals as low as 1500 kc. I have not been successful at garnering data from the federal government that can be released to the general public. NOAA has been similarly stymied and therefore is now conducting similar research.

The QBO is a wind shift in the equatorial stratosphere, an oscillation from easterly to westerly and back on the time scale of approximately two years (26 months) and is a source of Internal Buoyancy/Gravity Waves (IBGW) which create absorptive perturbations in the D and E-layers and even possibly the F 1/2 layer. A note, the E-valley/Flayer ducting propagation mechanism does not exist only during gray line periods. Internal Buoyancy/Gravity Waves (IBGW's) are a source of the ducting mechanism and allow for occurrences of ducting along any propagation path in total darkness. Measurement of the timing of arrival of propagated MF RF signals demonstrates the existence of the ducting mechanism, versus conventional numerous E layer land/ocean surface hops.

The HAARP ionospheric program, earthquakes, volcanic eruptions, thunderstorms, lightning (especially positive cloud to ground strokes), elves, sprites, tornadoes and hurricanes and even man made activities such as rocket launches including the space shuttle, are all sources of (IBGW's).

Many times I've heard ham's lament that propagation was going to go to crap due to another space shuttle launch, in a sense they are correct. Much more research is needed on the subject.





Lightning And Thunderstorms And Their Interaction With The Ionosphere
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Back To The Top

13.) Polar Cap Absorption (PCA)-

An anomalous condition of the polar ionosphere whereby MF (300-3000 kc) radio waves are absorbed, and LF and VLF (3-300 kHz) Radio waves are wave guided at lower altitudes than normal. In practice, the absorption is inferred from the proton flux at energies greater than 10 MeV (10+0), so that PCA's, Polar Radio Blackouts and Proton

Events are interrelated and often simultaneous.

((((NOTE!!! high latitude radio propagation paths may still be disturbed for days, up to weeks, following the end of an official proton event.)))) This fact is still stubbornly opposed by some otherwise very knowledgeable space weather physicists, hung up on threshold Riometer readings.

-----

14. Sunspot Group-

Sunspot groups are bipolar magnetic concentration regions on the photosphere of the Sun where magnetic field strengths many thousands of times stronger than the Earth's magnetic field reside. Sunspots appear as dark spots on the surface of the Sun because temperatures in the dark centers of sunspots drop to approximately 3700 K compared to 5700 K for the surrounding photosphere. The difference in temperature makes the spots appear darker than elsewhere. Sunspots typically last for several days to several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually come in groups with two sets of spots. One set will have a positive or north magnetic field while the other set will have a negative or south magnetic field. The magnetic field is strongest in the darker parts of the sunspots called the umbra and weaker and more horizontal in the lighter part called the penumbra.

The twisted magnetic fields associated with sunspot groups are one source of the solar flares, coronal mass ejections and geomagnetic storms that wreak havoc with the ionosphere here on Earth.

15.) Short Wave Fadeout (SWF)-

During a Solar Flare event or Sudden Ionospheric Disturbance (SID), abrupt increased ionization of the D-layer results in reduced to total absorption of MF circuits which are reflected by the ionosphere on the sunlit hemisphere of the earth. This is known as a Shortwave Fadeout (SWF).

Solar flares produce copious amounts of electromagnetic radiation including energetic protons which increase the ionization of the daytime D-layer. MF communication depends on the reflection of signals from the higher E and F2 layers and these signals must travel through the D layer at least twice.

Lower frequencies are affected first and higher frequencies last. The stronger the event, the stronger the ionization of the D layer, the higher the frequency effected via absorption.

Daytime E-layer propagation of the AM broadcast band and 160 meters (See definition #1. Overview) usually only occurs during the winter season and especially at higher latitudes with a lower sun angle and at the low part of a sunspot cycle, therefore SWF's rarely are rarely noticed. The 80/75 meter and 40 meter bands are most noticeably

affected, with the higher bands least affected.

An SWF can last from several hours on the lower frequencies to minutes on the higher frequencies. (See definition #16. Solar Flare).

16.) Solar Flare-

A day side earthward bound solar filament and/or approximate C5 class or higher solar flare can move the proton flux >10 MeV (10+0) and initiate large scale high latitude propagation path absorption but even smaller C4 class flares and weaker are the culprit behind hour-to-hour and night-to-night variations in signal strength on the AM broadcast band and 160 meters, both stateside and DX. This transfer of increased density and RF signal absorption from the day-side D-layer to night-side of the ionosphere occurs through high level neutral winds.

X-Ray Class Solar Flare. The rank of a solar flare based on its X-ray energy output. Flares are classified by the order of magnitude of the peak burst intensity (I) measured at the earth in the 1 to 10 angstrom band as follows:
Class (in Watt/sq. Meter)
B- I less than (l.t.) 10.0E-06
C- 10.0E-06 l.e.= I l.t.= 10.0E-05
M- 10.0E-05 l.e.= I l.t.= 10.0E-04
X- I g.e.= 10.0E-04

Background radiation in the 1 to 10 Angstrom range (Hard X-Rays), as well as Solar and Galactic Cosmic Rays is the source of ionization of the D-layer.

Basically a C-class solar flare possesses energy 1/10 the level of an M- class solar flare and an M-class solar flare possesses energy 1/10 the level on an X-class solar flare. (See definition #15. Shortwave Fadeout).

Solar flares are not random meaningless explosions but instead a process interelated with coronal mass ejections (CME's) by which the Sun expels complex magnetic signatures enroute to changing it's magnetic polarity or said a different way the swapping of the Sun's magnetic poles. Basically the Sun swapped it magnetic polarity at the peak of present solar cycle 23 somewhere between July 2000 and December 2001. The next polarity swap will occur during solar cycle 24 somewhere around 2010-2011.

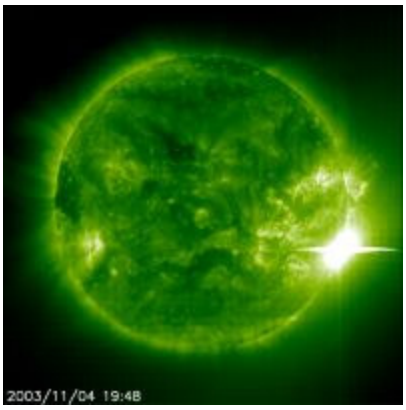
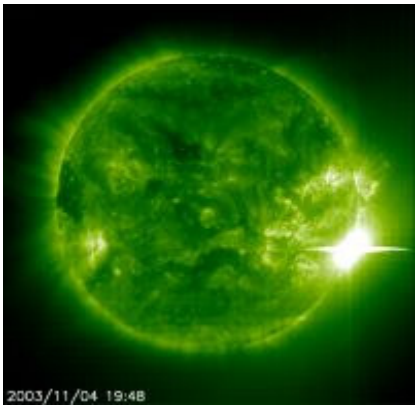


Image Of An X45 Class Solar Flare Click To Enlarge



Click for X45 Super Solar Flare Movie

Back To The Top

17.) Sporadic-D (Ds) Absorption & Wave Guiding-

Sporadic-D (Ds) occurrences have an inter-relationship with brief but intense Sun based and Galactic X-rays and Cosmic Rays, huge positive cloud to ground lightning strokes and interrelated Elves and Sprites. Very large bursts of Gamma Rays have also been observed to occur in conjunction with Sprites.

Sporadic-D (Ds) absorption occurs both at day and night. Much of the night time occurrence of Sporadic-D (Ds) absorption is often masked by lightning QRN, as well as a lack of radio operation during thunderstorm events due to the lightning strike hazard and/or high QRN levels and also due to the operator not being able to recognize the mode due to unfamiliarity with it. It's doubtful that you will read about the Sporadic-D (Ds) phenomena anywhere else other then on this website.

While on the topic of lightning and propagation, an ionized lightning channel which normally has a maximum diameter of approximately a silver dollar, can reflect RF much like meteor trails do. I've personally noticed it on the 70 cm band, as a single propagation burst lasting 1/4 to 1/2 second. (See definition #20. D Region Mid Winter Absorption Anomaly).

18.) Sporadic-E (Es) Absorption, Blocking & Refraction-

Just as the E-layer is the main refraction medium for medium frequency (300-3000 kc) signal propagation within approximately 5000 km/3100 mi, so is Sporadic-E (Es). Sporadic-E clouds occur at approximately 100 km/60 miles in altitude and generally move from west to east but at times east to west.

Like stratospheric level warming and troposphere level temperature and moisture discontinuities, Sporadic-E can depending on the circumstances absorb, block and refract medium, high and very high frequency RF signals in an unpredictable manner.

The main source for high latitude Sporadic E is radio aurora activity.

The main sources for mid latitude Sporadic-E include wind shear, internal buoyancy/gravity waves (IBGW's), and traveling ionosphere disturbances (TID's), most of which are produced by severe thunderstorm cell complexes. The tie in between Sporadic-E and a severe thunderstorm is the sprite and elve.

The main sources for low latitude Sporadic-E include wind shear, internal buoyancy/gravity waves (IBGW's), and traveling ionosphere disturbances, most of which are produced by severe thunderstorm cell complexes tied to tropical cyclones.

The forecasting of Sporadic-E has long been considered to be impossible. However it is possible to identify certain troposphere level meteorological conditions that can lead to the formation of Sporadic-E. One is as mentioned above the severe thunderstorm cell complex.

Sporadic-E have been observed to occur within approximately 150 km/90 mi to the left of a severe thunderstorm cell complex in the northern hemisphere, with the opposite being observed in the southern hemisphere. To complicate matters is the fact that Sporadic-E clouds not only have been observed to move from west to east but at times also east to west. So one has to look for Sporadic-E on either side of a severe thunderstorm cell complex.

Not all thunderstorm cell complexes reach severe levels and not all severe thunderstorm cell complexes produce Sporadic-E. This is where knowledge in tropospheric physics and weather forecasting is necessary. Coincidentally I have a B.S. in Meteorology and an M.S. in Space Plasma Physics and am qualified to identify which severe thunderstorm complexes are most likely to produce Sporadic-E.

Some but not all key elements in identifying which severe thunderstorm cell complexes have the potential to produce Sporadic-E via wind shear, internal buoyancy/gravity waves, traveling ionosphere disturbances, sprites and elves include:

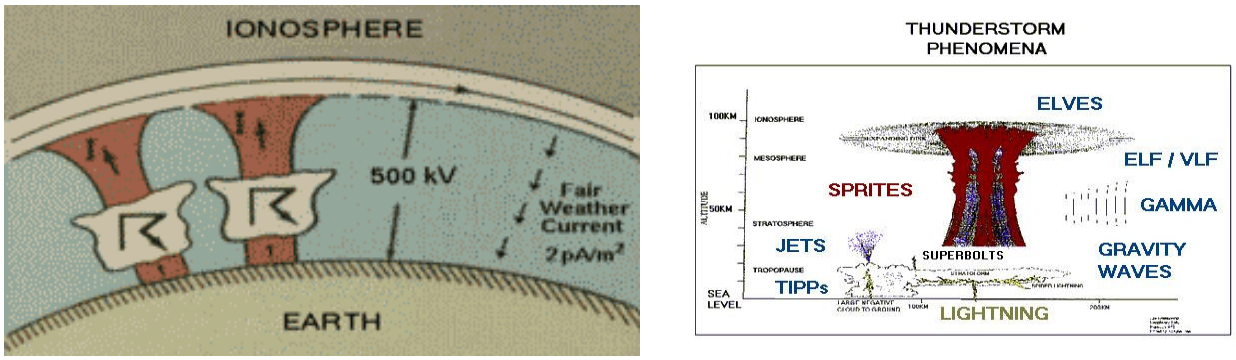
1.) Negative tilted mid level long wave troughs.

2.) Approximate 150 knot/170 mph jet stream jet maxes that produce divergence and therefore create a sucking vacuum effect above thunderstorm cells, that assist thunderstorm cells in reaching and penetrating the tropopause into the stratosphere.

3.) 500 mb temperatures of -20 deg. C or colder, which produce numerous positive and negative lightning bolts and inter-related sprites and elves.

4.) Approximate 150-175 knot/172-200 mph updrafts within thunderstorm cells that create overshooting tops that penetrate the tropopause into the stratosphere (See definition #20 on Stratospheric Warming), launching upwardly propagating internal buoyancy/gravity waves, traveling ionosphere disturbances and wind shear.

More to come.



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19.) Long Delayed Echo (LDE)-

A fairly common propagation mechanism by which an RF transmitted signal returns to the sender within 1.25-5 seconds and in rare cases of up to 30 seconds. Research in the 1980's with HF OTHR discovered one propagation mechanism which involves ducting of the transmitted signal in the E-valley-F layer region of the ionosphere. A signal traveling along a magnetic field line much like a lightning induced whistler is another possibility.

The best time to observe an LDE is during the Fall/Spring equinox period when conditions are more balanced in the ionosphere. LDE's are very noticeable on amateur and SW broadcast signals between 17-28 mc with a peak near the maximum usable frequency (MUF). As recently as fall 2003 I did my own brief experiments using Morse code (CW) on the 15 meters band. I personally observed LDE's of my own transmitted signal of approximately 1.5-3 seconds and I could hear a mushy kind of doppler shift on my returned signal frequency.

Claims of very long delayed echo's (VLDE) on the order of hours and even days have been reported since the beginning of radio. Time periods of this magnitude would point to the "seeming possibility" of a refracting ionospheric type medium outside of Earth's own ionosphere, possibly somewhere past Pluto in the Oort Cloud. However no evidence so far has been found of such a medium and 99% of reported VLDE's are "probably" hoaxes.

20.) Sudden Stratospheric Warming (STRATWARM ALERT)-

Sudden stratospheric warming is a major temperature change of the winter time polar and middle atmosphere from the Tropopause (where the troposphere transitions into the stratosphere) to the base (D-layer) of the ionosphere, lasting for many days at a time and characterized by a warming of the stratospheric temperature by some tens of degrees (temperature inversion), in unison with adjacent tropospheric cooling.

Another way to explain stratospheric warming is a major disturbance of the winter polar middle atmosphere from the Tropopause to D-region which is at the base of the Mesosphere resulting from a breakdown of the polar vortex into two circulation cells. Air trapped in the vortexes is mixed by the new meridional flow and is exposed to sunlight. Solar lyman alpha ionizes the nitric oxide gasses resulting in an increase in electron density and producing strong MF absorption.

A little related Troposphere Meteorology:

Interrelated with the splitting and shifting of the Arctic Circumpolar Vortex, is a Troposphere level negative North Atlantic Oscillation (NAO) and Pacific-North America Anomaly (PNA), mid and upper air height anomaly pattern. This equates to a large high pressure ridge in Western North America extending northward all the way into the Yukon region of Canada and a deep trough in the Eastern North America, from the eastern U.S. extending down into the Yucatan region of Mexico, with a second ridge in the western North Atlantic Ocean. This pattern is also called a dual blocking ridge and taps Siberian Arctic air, sending it across the North Pole into the eastern 2/3's of Canada and the U.S. providing for very cold surface temperatures.

As the stratosphere lies below the ionosphere, which is at mesosphere and thermosphere height, you would not expect to see stratospheric warming effect medium frequency propagation in any way BUT medium frequency signals do propagate off of temperature inversions and moisture discontinuities and a temperature inversion is involved with stratospheric warming. So it's probable that a medium frequency signal could do any number of things when scattering off of a temperature inversion, at any height. Unfortunately though some otherwise very knowledgeable Physicists stubbornly resist this concept.

You can almost always correlate the coldest weather occurrences with poor medium frequency propagation conditions.

Also Stratospheric Warming (STRATWARM) has a negative effect on medium frequency propagation, due to increasing medium frequency radio wave absorption by the D layer, via upward propagating Internal Buoyancy/Gravity Waves (IBGW's).

This phenomenon also occurs in southern hemisphere winter but is less pronounced.

Click Here For The U. Of Berlin Germany Stratospheric Research Group Layer

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21.) D Region Mid Winter Absorption Anomaly-

A period of increased MF radio wave absorption at high and mid latitudes occurring in mid winter and is associated with sudden stratospheric warming and the Quasi Biennial Oscillation (QBO). If you look in your radio logs for 160 meters you will notice that most of your good DX contacts are in the fall and spring. This is due to the D Region Mid Winter Absorption Anomaly. (See definition #17. Sporadic-D (Ds) Absorption & Wave Guiding). (See definition #19. Sudden Stratospheric Warming (STRATWARM ALERT).

Click Here For A Abstract By Gian-Carlo Rumi Concerning the Mid Winter Anomaly And Click Here For "Weather In The Upper Atmosphere"

22.) F3 Ionospheric Layer-

Click Here For A PDF Article Via IPS Australia About The Long Suspected But Only Recently Verified F3 Ionospheric Layer
Click Here For PDF Article #2 Via IPS Australia About The Long Suspected But Only Recently Verified F3 Ionospheric Layer

The F3 layer primarily seems to exist only in the vicinity of the Earth's magnetic equator. This may be an explanation for (TEP) Trans Equatorial Propagation.

Contact Info:

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Note! I have attempted to keep the propagation theory explanations in simple to understand layman terms, because long complicated technical explanations can be boring and make one's eyes glaze over. Unfortunately though sometimes while trying to keep things simple, certain definitions, meanings and technical aspects can get watered down or even lost. Therefore use these definitions at your own risk with no guarantee or warranty implied.

Also I use "RAW" and error prone public domain data from the NOAA Space Environment Center, as well as other U.S. Government organizations, to produce my "not for profit" propagation forecast outlooks. This data is gathered and made public by the U.S. Government using taxpayer $$$. However the forecast outlooks that I produce from the "RAW" public domain data, is my personal intellectual property. Therefore the propagation outlooks contained herein is copyrighted © 1988-2005 by Thomas F. Giella, KN4LF, all rights reserved. Reproduction of information herein is allowed as long as proper credit is given.

Space weather forecasting is still an inexact science. The discussions, forecasts and

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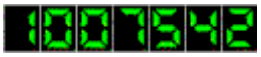
Back To The Top



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