

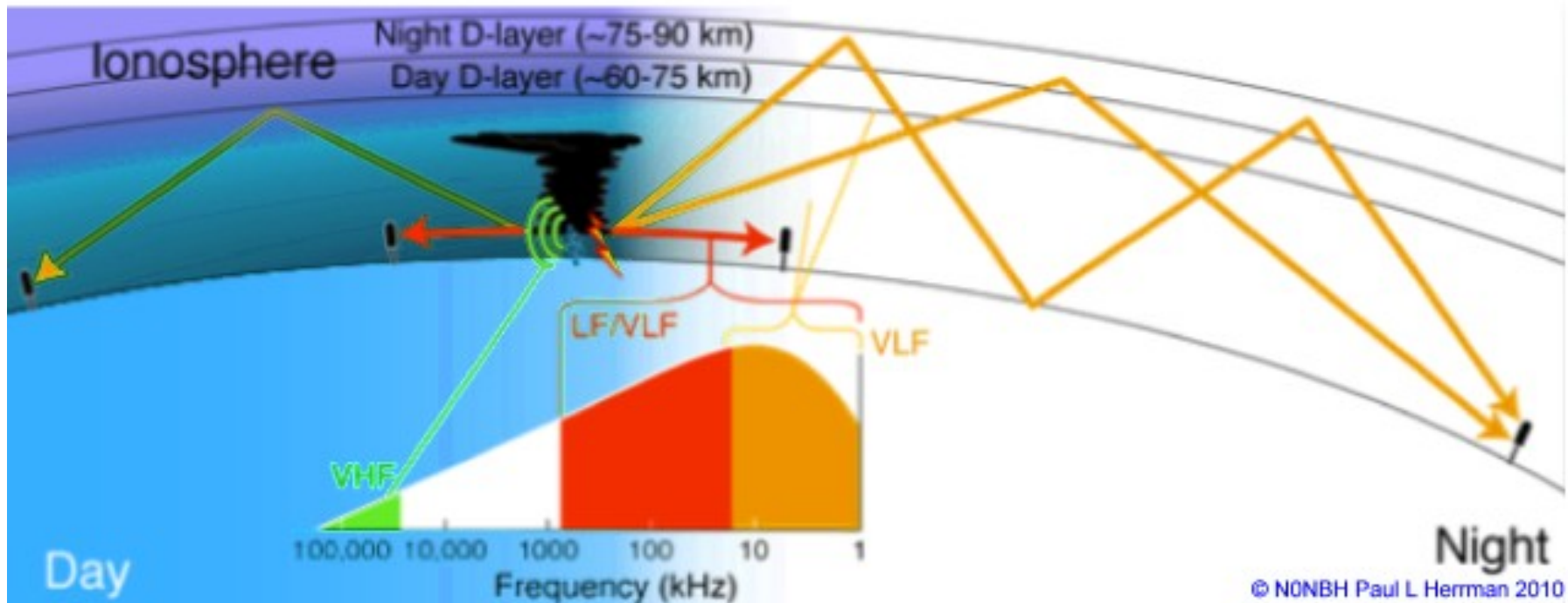
***Understanding HF/VHF/UHF/SHF  
Propagation relative to Guided  
Wave, Ground Wave, Direct Wave,  
Ionosphere, Troposphere, Aurora,  
Meteor Scatter, and Earth-Moon-  
Earth (EME or Moon Bounce)***

Paul L Herrman N0NBH 11 July 2010

# Propagation Modes

Image by soest

| Band | Frequency   | Primary Mode of Propagation                                                                                                                                                                                                           |
|------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VLF  | 3-30kHz     | Guided between the earth & ionosphere                                                                                                                                                                                                 |
| LF   | 30-300kHz   | Guided between the earth & D layer of ionosphere. Also surface waves                                                                                                                                                                  |
| MF   | 300-3000kHz | Surface waves. E, F layer ionospheric refraction at night, when D layer absorption weakens                                                                                                                                            |
| HF   | 3-30MHz     | E layer ionospheric refraction. F1, F2 layer ionospheric refraction. Auroral reflection. Meteor scatter                                                                                                                               |
| VHF  | 30-300MHz   | Infrequent E ionospheric refraction (Es). Extremely rare F1,F2 layer ionospheric refraction during high sunspot activity up to 80MHz. Direct wave. Auroral reflection. EME reflection. Meteor scatter. Sometimes tropospheric ducting |
| UHF  | 300-3000MHz | Direct wave. EME reflection. Tropospheric ducting. Meteor scatter                                                                                                                                                                     |
| SHF  | 3-30GHz     | Direct wave. EME reflection. Tropospheric ducting                                                                                                                                                                                     |
| EHF  | 30-300GHz   | Direct wave limited by absorption. EME reflection                                                                                                                                                                                     |



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# Guided/Ground/Direct Wave

Image by NIST

## Guided Wave:

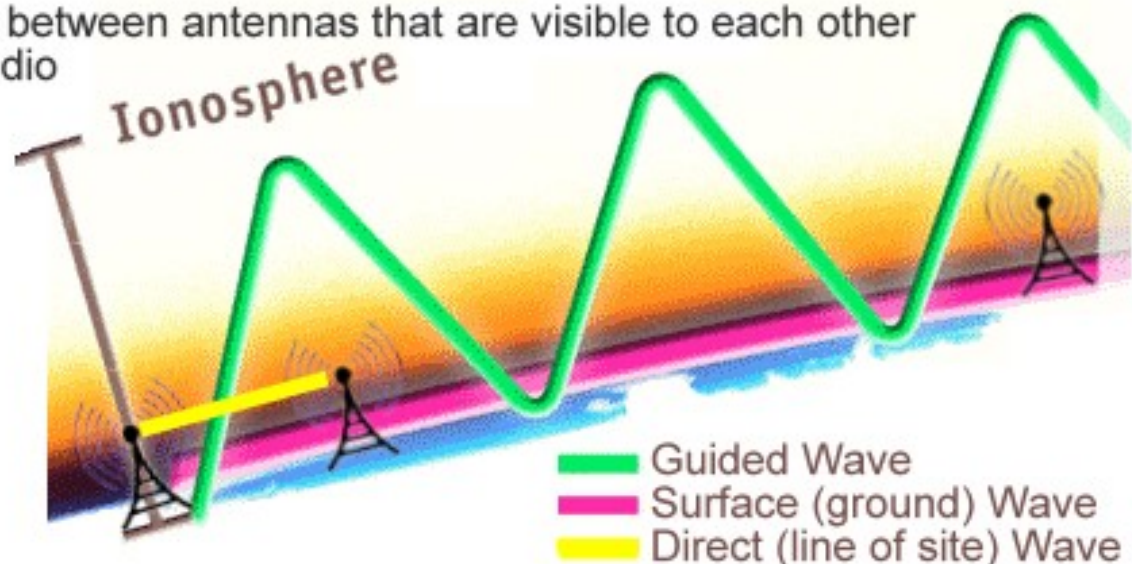
- Most VLF & LF propagation occurs via guided wave (due to long wavelength)
- Ground/water surface and ionosphere are highly conductive at these frequencies
- Form the “walls” of a spherical waveguide.
- Vertical Polarization always used:
  - Horizontal antennas not practical (due to extremely long wavelength)
  - Alleviates short circuiting the electric field through the conductivity of the ground

## Surface (Ground) Wave:

- Low/medium frequencies travel efficiently as a surface waves
- Property of following the curvature of the earth
- Conductivity of the surface affects the propagation of ground waves (more conductive surfaces such as water providing better propagation and result in less dissipation)
- Since the ground is not a perfect electrical conductor, ground waves are attenuated as they follow the earth's surface
- Ground waves do not include ionospheric and tropospheric waves

## Direct Wave (line-of-sight):

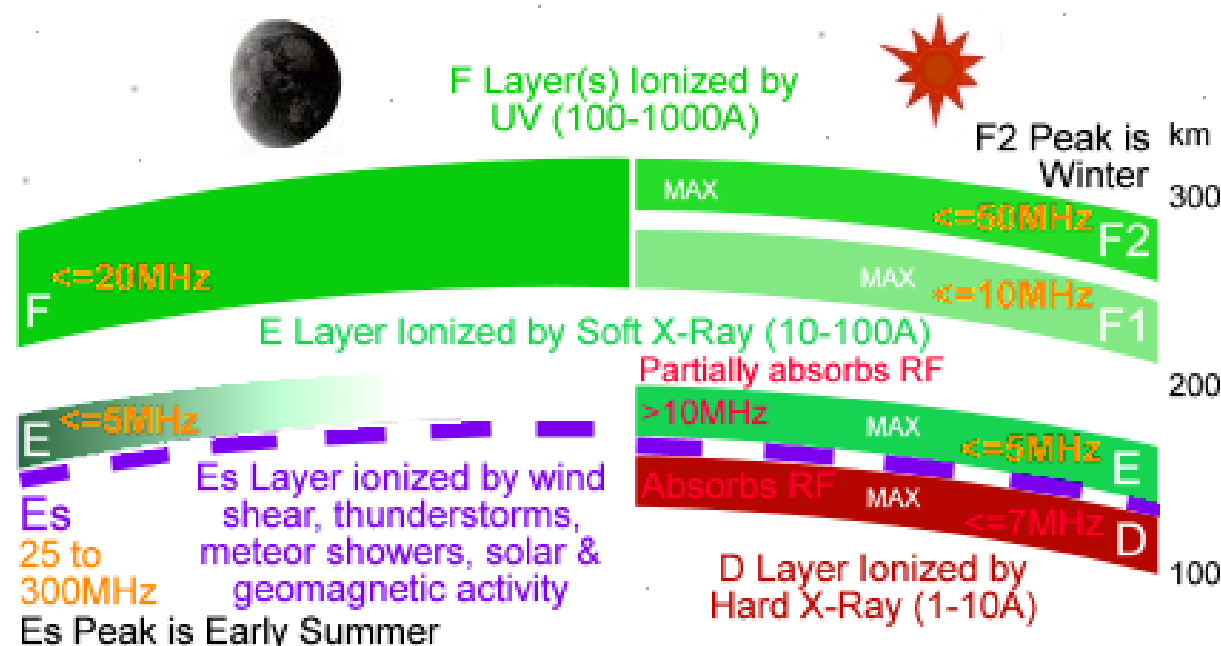
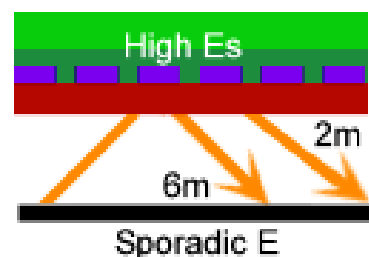
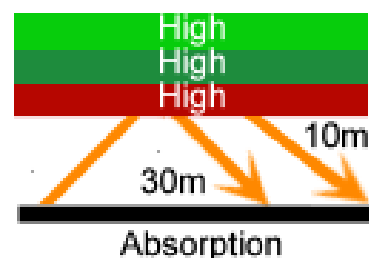
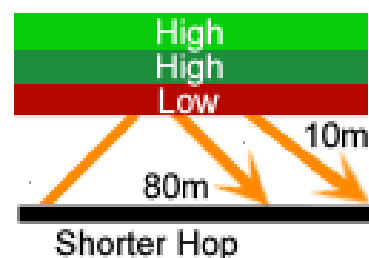
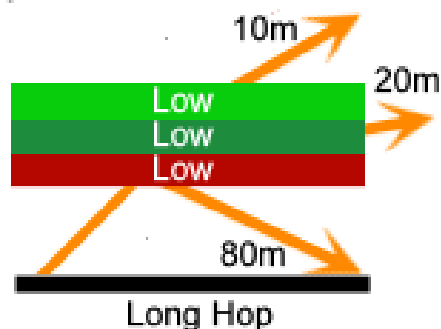
- Propagation of radio waves between antennas that are visible to each other
- The most common of the radio propagation modes at VHF and higher frequencies
- Includes radio signals that travel through non-metallic objects (like walls)
- Ground plane reflection effects are an important factor in line of sight propagation



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# Ionospheric Propagation

## Layer Ionization Levels



So what causes the layers in the ionosphere to reflect RF energy:

- When a radio wave reaches the ionosphere, the signal's electric field forces the ionosphere electrons into oscillation at the same frequency
- Some RF is given up to this resonant oscillation
- Oscillating electrons will then either be lost to recombination or re-radiate at the original signal energy
- If the transmitted frequency is higher than the layer's plasma frequency, then the electrons cannot respond fast enough, and do not re-radiate the signal

Other factors about the layers in the ionosphere:

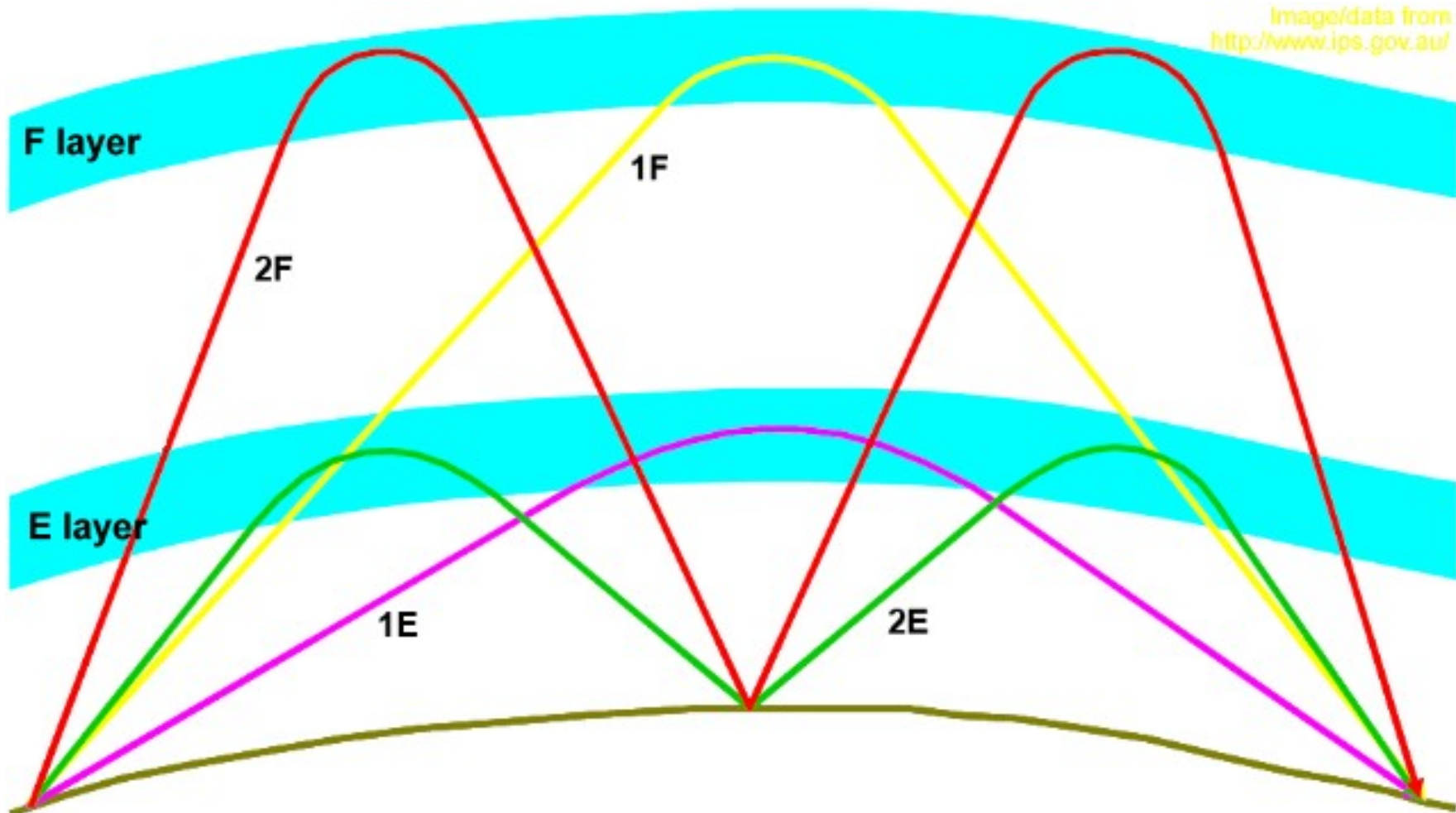
- X-Rays and Gamma Rays ionize the layers in the Ionosphere
- 10cm Solar Flux provides a good indication of current F layer ionization
- During geomagnetic storms the F2-layer becomes unstable, fragments, & may even disappear completely
- At night the E layer begins to disappear and solar wind drags it higher
- Flares can highly ionize D Layer to the point it absorbs everything to 30MHz
- Solar Wind can ionize high latitudes impacting Aurora
- Solar proton events can ionization the D-layer over high and polar latitudes creating Polar Cap Absorption (PCA)

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# Simple Propagation

Image/data from  
<http://www.ips.gov.au/>



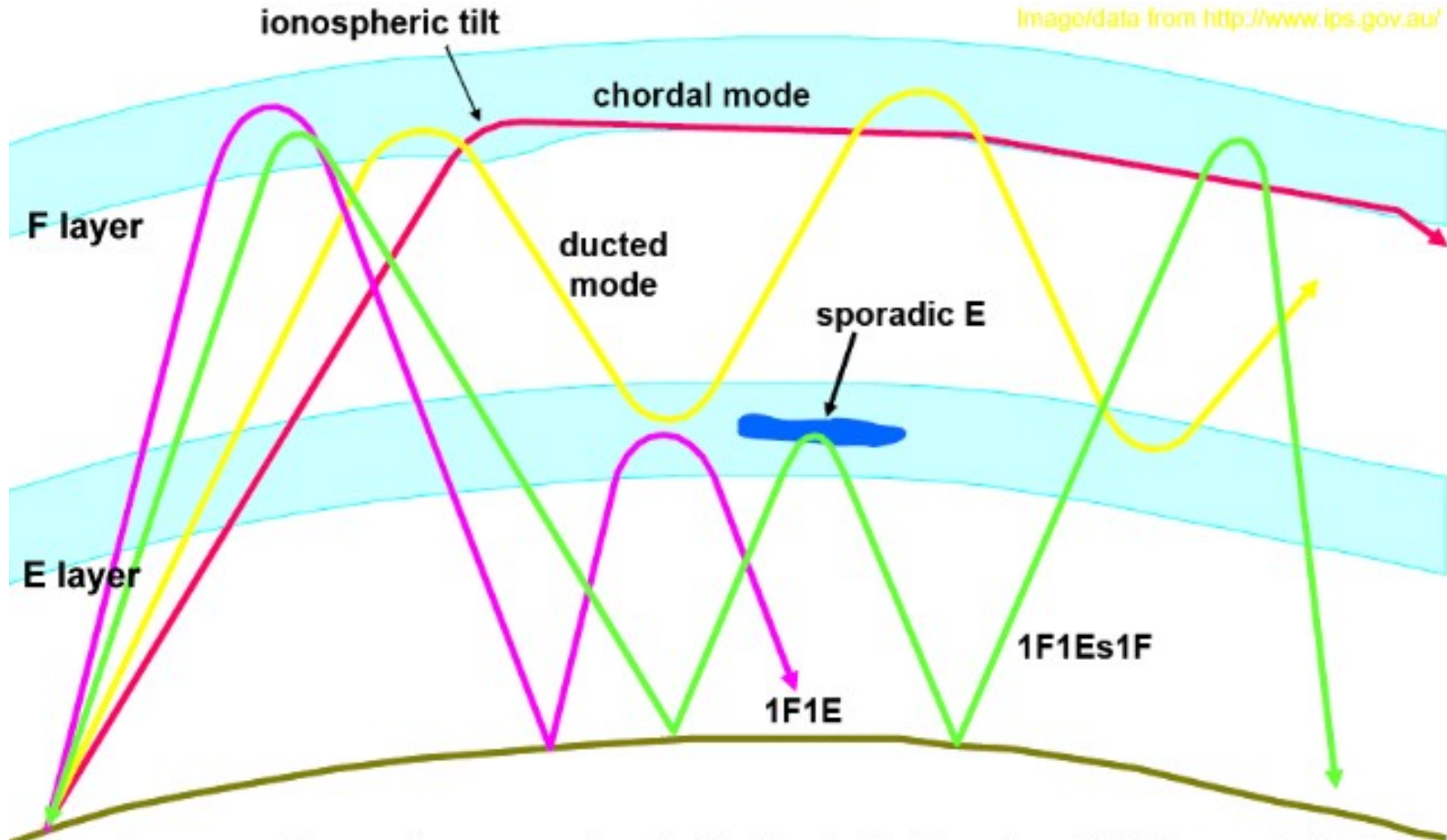
## Simple Propagation Mode:

- RF propagated by one layer
- Can be more than one single hop (reflection from Earth)
- Most (if not all) propagation predictions use simple mode
- Multiple paths by which RF travels
  - \* 1st order mode (1X) RF reflected by a layer requiring least number of hops
  - \* 2nd order mode (2X) requires one extra hop....(etc)

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# Complex Propagation

Image/data from <http://www.ips.gov.au/>

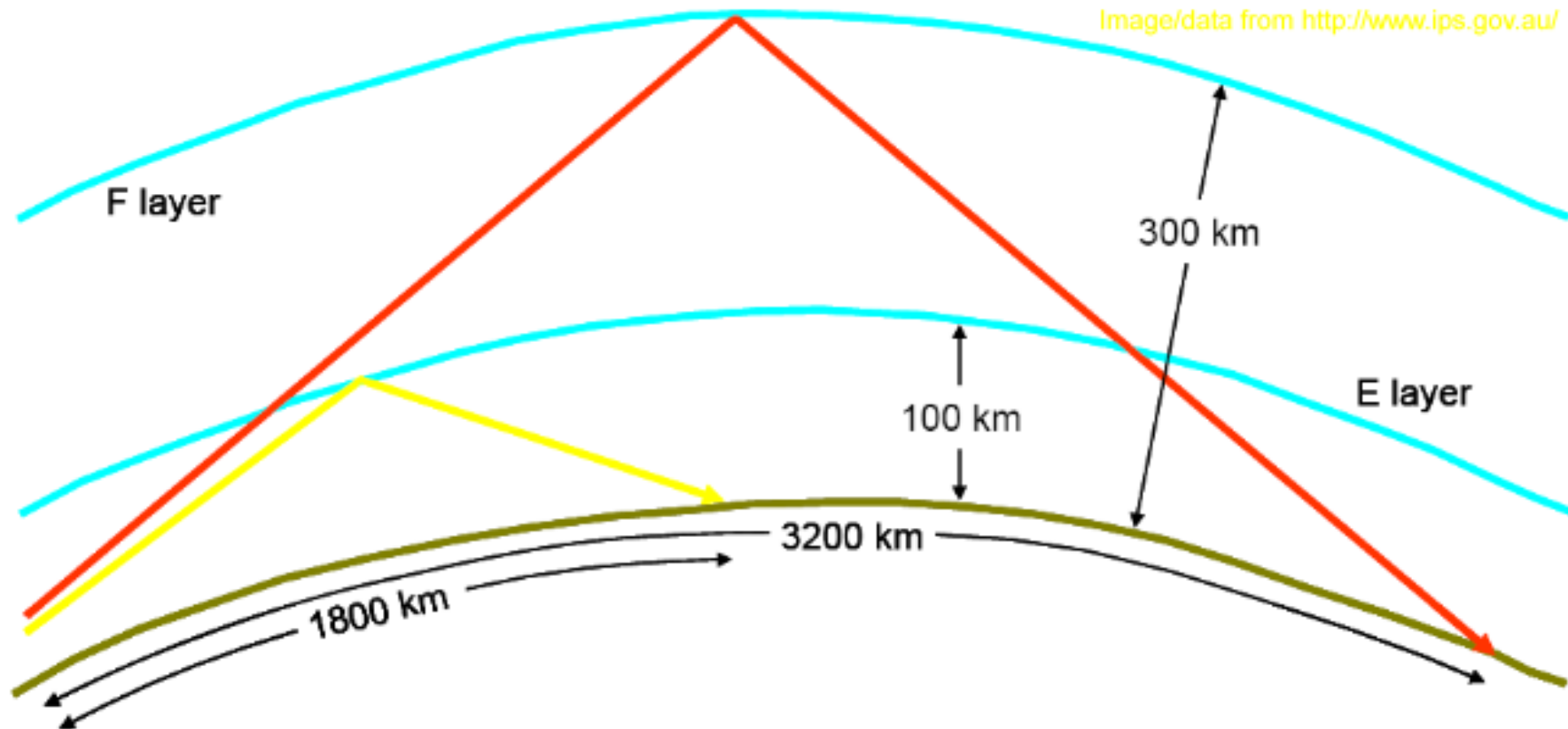


Complex propagation modes are combo of reflections/refractions from E & F layers & Earth  
Layers of the ionosphere are not always smooth which affects the reflections/refractions of RF  
- Most likely near equatorial anomaly, mid-latitude trough, and sunrise/sunset sectors of globe  
When ionospheric layers tilt chordal and ducted modes may occur:

- Ducted mode is reflections/refractions between layers in the ionosphere
- Chordal mode is ducting within a single ionosphere layer
- Signals strong since RF not attenuated by D layer/ground

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# Propagation Distances



Hop length is the ground distance covered by RF after it has been reflected once from the ionosphere and returned to Earth

Maximum hop length is set by the height of the ionosphere and curvature of the Earth

The maximum hop lengths shown:

- Assumes antenna radiation angle of  $4^\circ$  (shorter with larger antenna elevation angles)
- Assumes E/F layer heights as specified

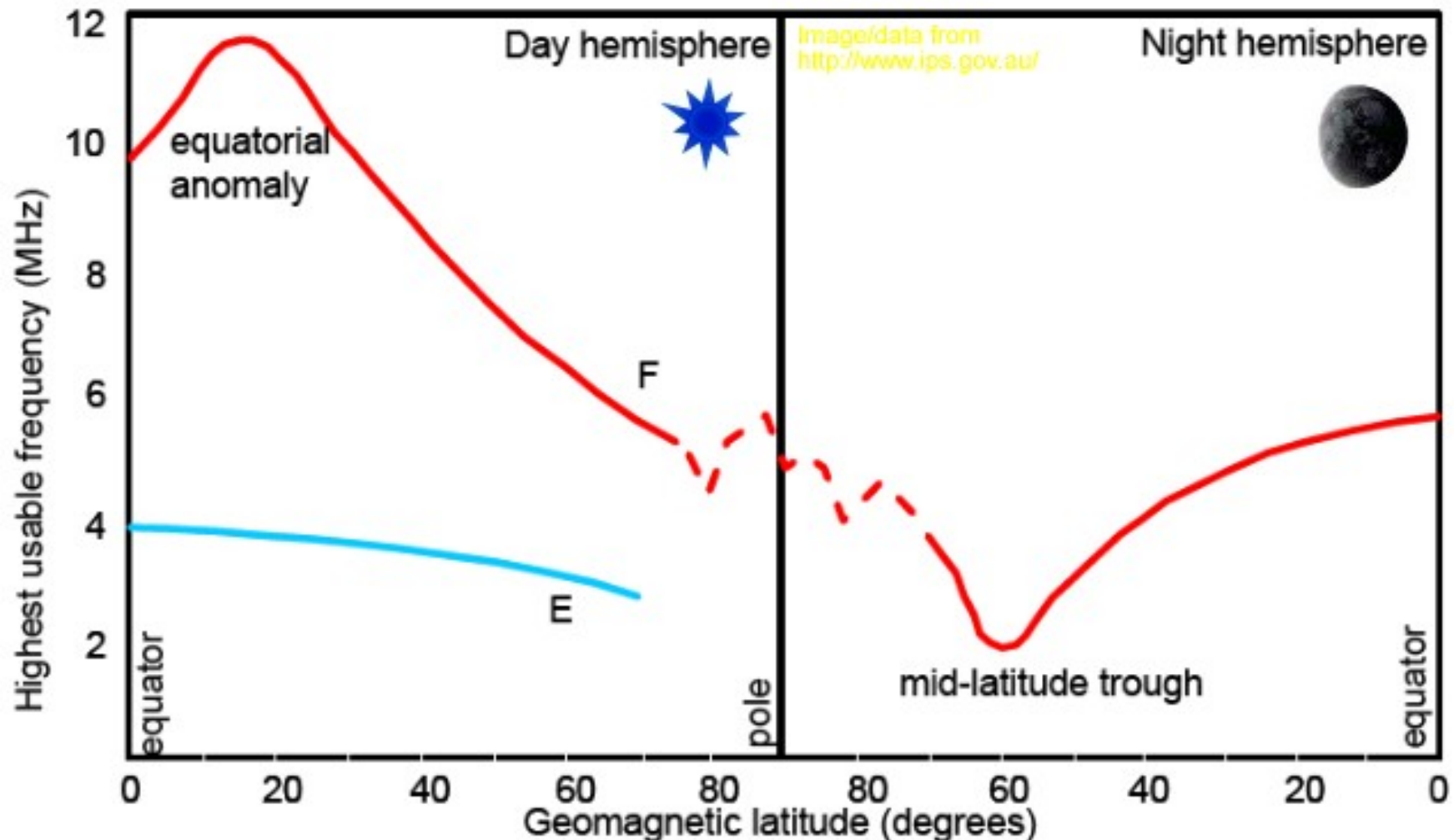
Distances greater than shown will require more than one hop

- Results in weaker RF signal at the receiver (RF is attenuated by multiple passes through D layer absorption and ground reflection)

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# Latitude Variations

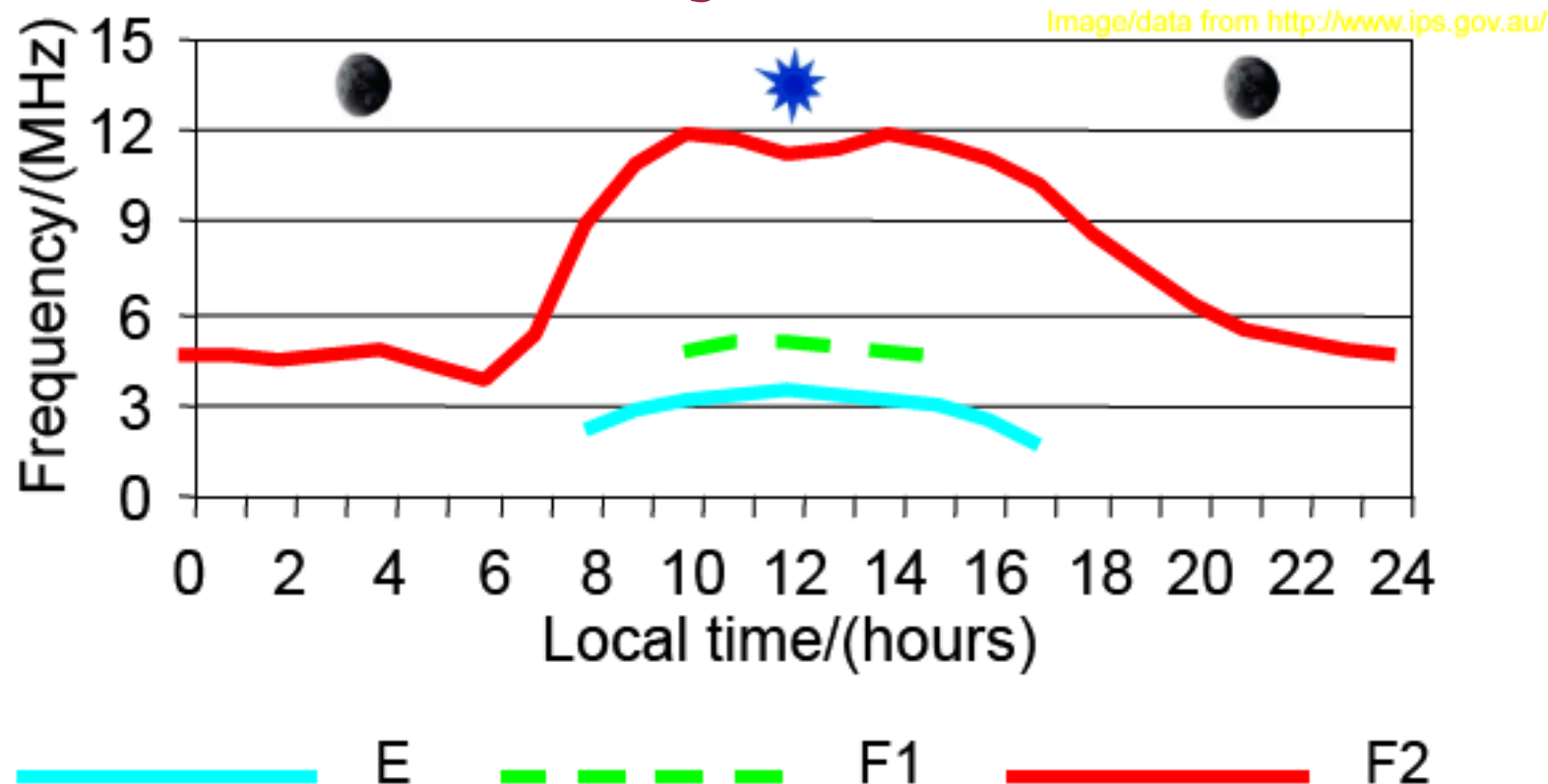


- During the day solar radiation strikes the atmosphere more obliquely with increasing latitude. Intensity of radiation and daily production of free electrons decreases with increasing latitude.
- F region latitude variation persists throughout the night due to the action of upper atmospheric wind currents from day-lit to night-side hemispheres
- Deviations from the low to high latitude decrease are:
- Equatorial anomaly-daytime F layer peak 15 to 20° N/S latitude
  - Mid-latitude trough-nighttime minimum around 60° N/S latitude

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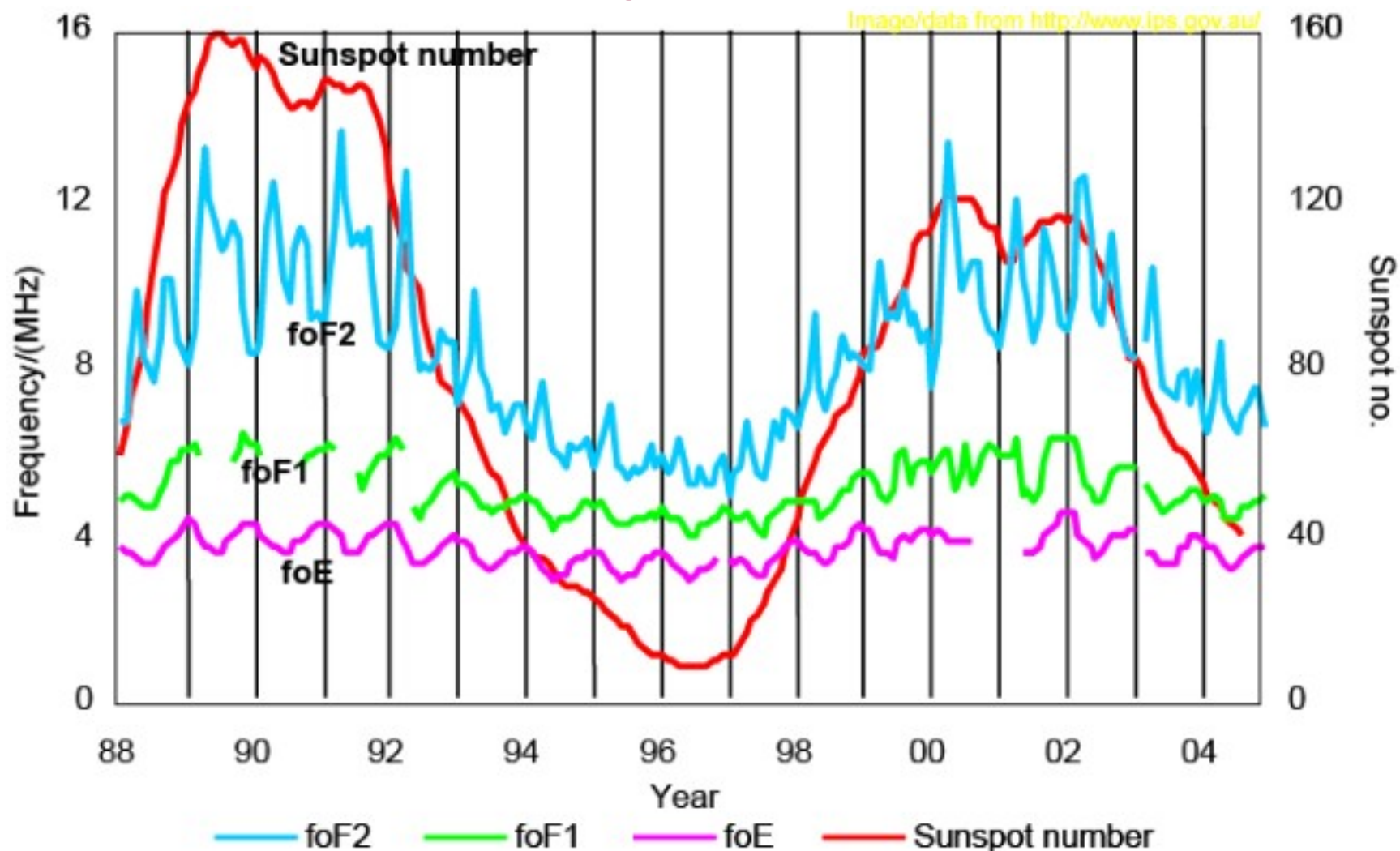
# Time-of-Day Variations



Frequencies are normally higher during the day and lower at night  
After dawn, solar radiation causes electrons to be produced in the ionosphere and frequencies increase rapidly to a maximum around noon  
During the afternoon, frequencies begin falling due to electron loss and with darkness the D, E and F1 layers disappear  
Communication during the night is by the F layer only and attenuation is very low  
Through the night, maximum frequencies gradually decrease, reaching their minimum just before dawn

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# Sunspot Cycle Variations



Solar Cycle is periodic rise and fall in activity which affects HF communications (9-14 years)  
The higher the activity, the more radiation being emitted from the Sun producing more electrons in the ionosphere which allows the use of higher frequencies.  
At solar minimum, only the lower frequencies of the HF band will be reflected by ionosphere  
At solar maximum the higher frequencies will successfully propagate

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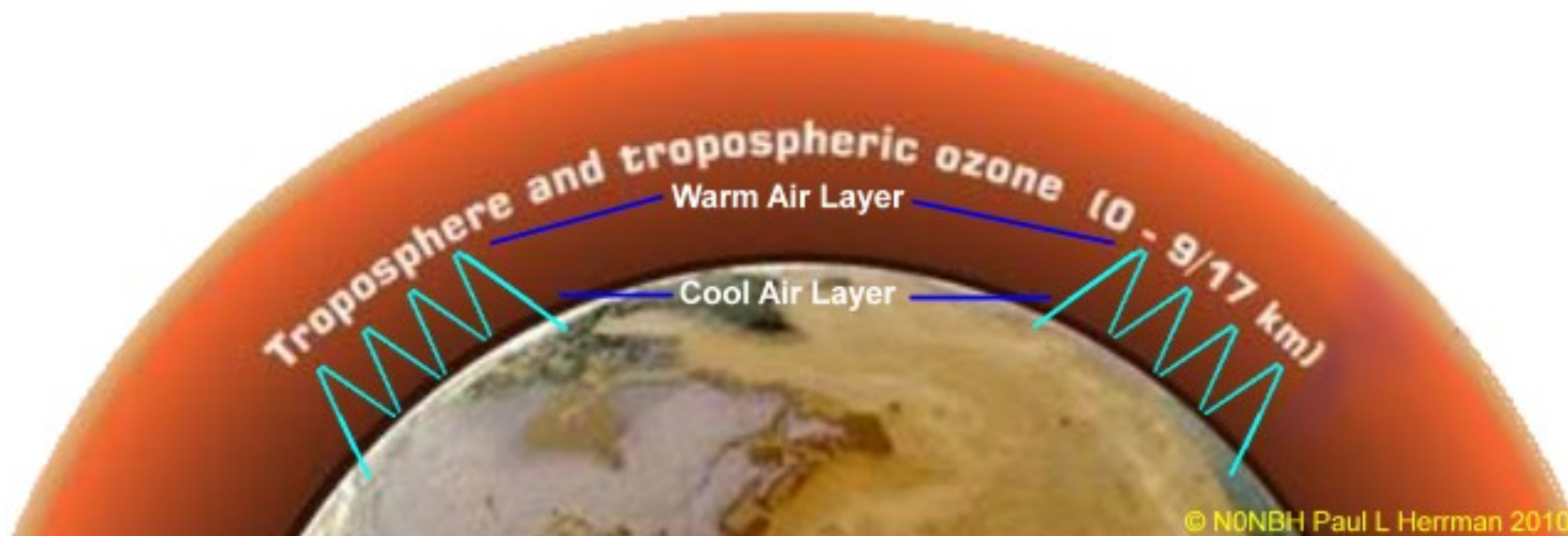
# *Tropospheric Propagation*

What causes Tropospheric Propagation:

- Weather causes the condition
- When a large mass of cold air is overrun by warm air (temperature inversion)
- Typically found along a stationary weather front
- Most frequently along coastal areas bordering large bodies of water
- Also in the morning when the rising sun warms the upper layers

Additional Information on Tropospheric Ducting:

- The boundary between the two air masses may extend for 1,000 miles (1,600 km)
- Frequencies above 90MHz are more favourably propagated
- Signals exhibit a slow cycle of fading with occasional strong signal levels
- High mountainous areas and undulating terrain between the transmitter and receiver can block tropospheric signals
- A relatively flat land path between the transmitter and receiver is ideal for tropospheric ducting
- Sea paths also tend to produce superior results



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# Auroral Propagation

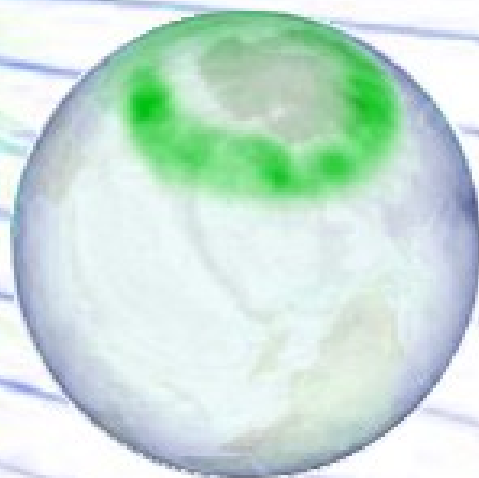
Artist K Endo

What causes radio-auroral events?

- Primarily an increase in solar wind caused by solar flares, coronal holes, SIDs & CMEs
- High energy particles enter the Earth's atmosphere along the magnetic lines at the poles
- They collide with atmospheric molecules & release positive ions & negative electrons
- HF bands then close for a short while, but soon recover (increase in SFI)
- 20 - 30 hours after the solar activity the solar wind shock wave hits the earth.
- This causes a magnetic storm & the HF bands fail as the full auroral event starts
- At this point VHF radio propagation is enhanced over distances of a several hundred km
- Having reached a peak the aurora ends and the HF bands slowly recover, lower freq 1st
- Can take a week before HF bands are back to the state they were before the storm

Time from Sun to Earth:

- Electromagnetic Radiation: 8 min
- High Energy Charged Particles: 15 min- 2 hours
- Enhanced B Field/Plasma Clouds: 2-3 days



Radio-auroral event:

- Ionization at 100 km altitudes
- Usually coupled with Sporadic E events
- Reflection angle is approx 90 deg
- Increase in noise (also doppler freq shift [5kHz at 2m])
- Usually at >60deg Latitude
- Voice very difficult to copy, SSB best voice mode, CW better

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# Meteor Scatter

Artist unknown

## What enables Meteor Scatter Communications:

- When a meteor enters the atmosphere it burns up and creates a trail of ionized particles along its path
- The same way solar events impact ionosphere layers, ionized particles enable brief comm paths to open
- Path distance (typ 2,250 km max) is determined by:
  - Altitude at which ionization occurs (where meteor burns up)
  - Location over Earth surface where the meteor is falling
  - Angle of entry into atmosphere
  - Locations of stations attempting to communicate
- Frequency of reflected RF (typ 20-500MHz) depends on intensity of ionization (meteor size)
- Communications typically only persist for up to several seconds
- Remember, there are 10's of thousands of meteors entering the atmosphere every day (more during known meteor showers)

## How to work Meteor Scatter:

- Normally an advanced planned schedule with the other station is used
- Typically, transmission and receptions are recorded/automated computer programs due to unpredictability of this mode of communications
- Any form of communications mode can be used for meteor scatter
  - Single sideband audio transmission is popular
  - Morse code is better, at transmission speeds up to 800 wpm (played back at a slower speed to copy)
  - Several digital mode (computer programs) are available (check out WSJT's program)

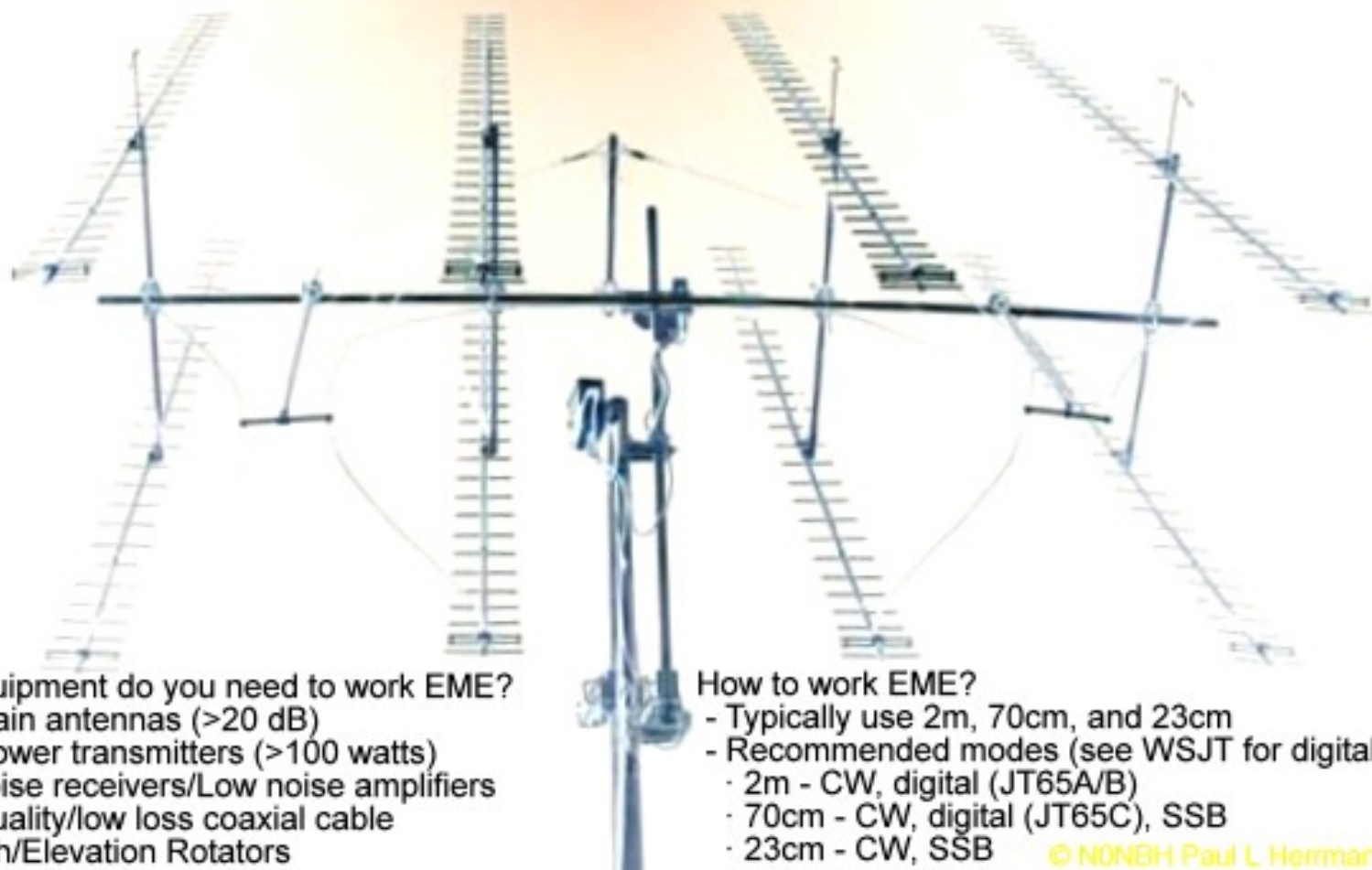
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# EME/Moon Bounce

AR4Q Photo

How do Earth-Moon-Earth (EME or moon bounce) communications work:

- RF propagation from an Earth-based transmitter to receiver via reflection from the moon surface
- Moon must be visible at TX/RX sites
- Roundtrip distance is 770,000 km
- Path loss 250-310dB depending on:
  - VHF/UHF/Microwave band used
  - Modulation format & Doppler shift
- RF reflectivity low (7% typ/12% max)
- Doppler +300Hz Moonrise/-300Hz Moonset
- Moon orbit is not perfectly circular:
  - Varies from 406,700km to 356,400km
  - Results in 2.25dB difference in path loss



What equipment do you need to work EME?

- High-gain antennas (>20 dB)
- High power transmitters (>100 watts)
- Low noise receivers/Low noise amplifiers
- High quality/low loss coaxial cable
- Azimuth/Elevation Rotators

How to work EME?

- Typically use 2m, 70cm, and 23cm
- Recommended modes (see WSJT for digital):
  - 2m - CW, digital (JT65A/B)
  - 70cm - CW, digital (JT65C), SSB
  - 23cm - CW, SSB

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# Parts of the Sun (for next slide)

Artist Pbroks13

## Parts of the Sun:

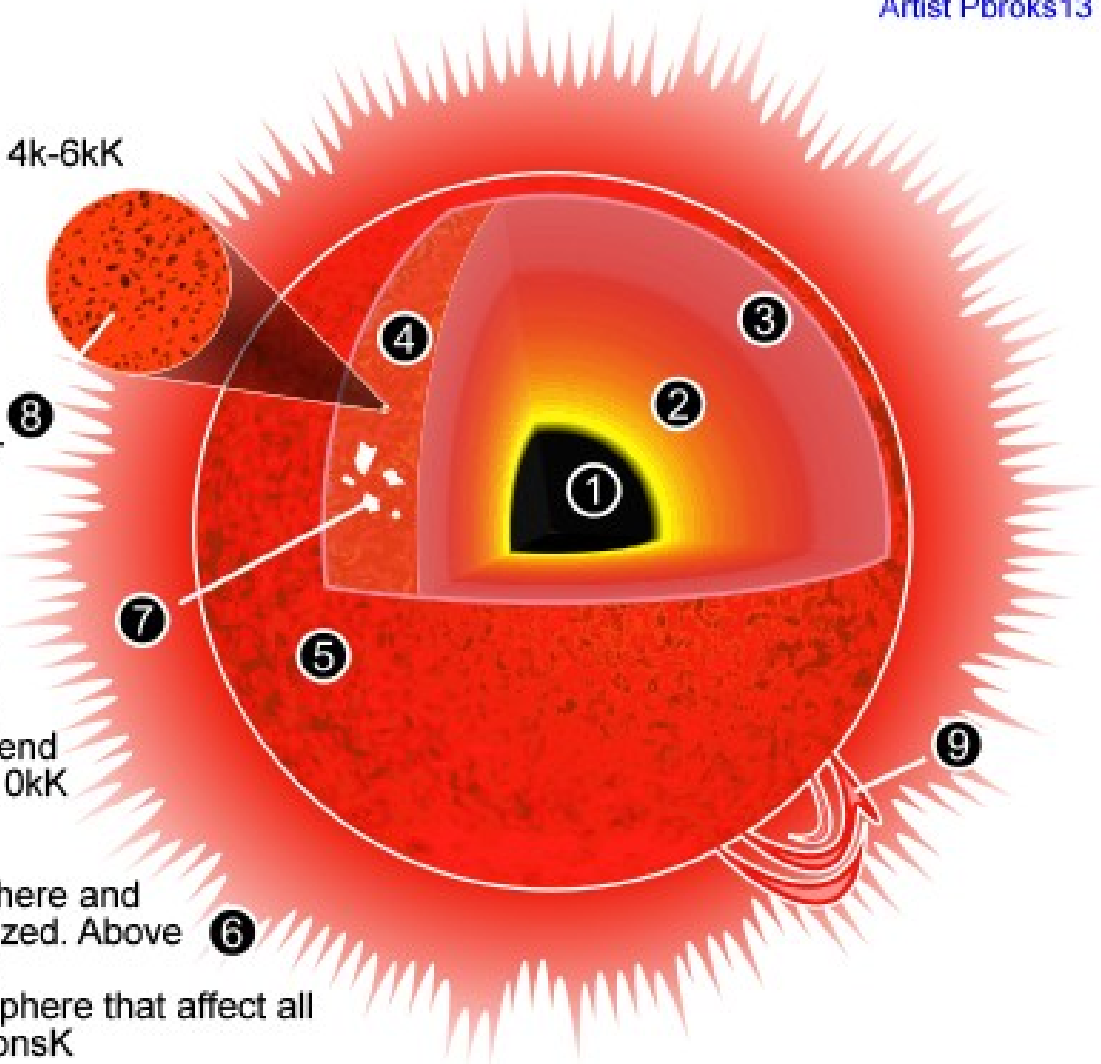
- 1-Core. Temp ~15MK
- 2-Radiative zone. Temp ~7MK
- 3-Convective zone. Temp ~2MK
- 4-Photosphere. Sun's visual surface. Temp 4k-6kK
- 5-Chromosphere. ~2,000km deep. Primarily hydrogen. Temp 4k-20kK
- 6-Corona. Plasma "atmosphere" of Sun. Spectral features traced to highly ionized Iron. Temp in excess of 1MK
- 7-Sunspots. Concentrations of magnetic flux (0.4 to >1.0 tesla) in photosphere, typically 2,500-50,000 km across. Appear dark because 1.5k-2.5kK cooler than surrounding area. ~5,000km deep
- 8-Granules. On photosphere. Caused by convection currents of plasma within Sun's convective zone. 1,000-30,000 km dia. Life 8 minutes to 24 hours
- 9-Prominence. Large, bright loop, spray, or surge. Anchored to photosphere, and extend into corona, but much cooler plasma by 10kK

## Not shown:

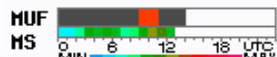
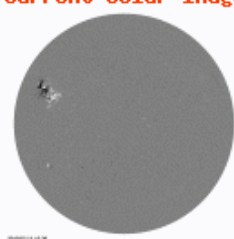
- Solar transition region. Between chromosphere and corona. Below region, helium not fully ionized. Above region it is fully ionized. Temp 60k- 80kK
- Solar flare. Large explosion in Sun's atmosphere that affect all solar layers. Heats plasma to tens of millionsK

## Definitions for the images:

- EIT = Extreme Ultraviolet (EUV) Imaging Telescope. Provides images of transition region and inner corona
- MDI = Michelson Doppler Imager measures underlying magnetic fields & gas flow patterns on solar surface
- VSM = Vector Spectromagnetograph provides magnetic field observations in photosphere & chromosphere
- SH = Spectroheliograph provides photographic image of Sun's visible surface in light of a single wavelength
- LASCO=Large Angle and Spectrometric Coronagraph



# Putting the Solar Data to Use

| Current Solar-Terrestrial Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Category                                                                     | Radio Blackouts<br>Use X-Ray                                             | Solar Radiation Storms<br>Use Proton Flux                                                                                     | Geomagnetic Storms<br>Use K-Index/K-nT/<br>Aurora/Solar Wind/Bz                                                    | Band Openings<br>Use Solar Flux (SN)                        | Electron Alert<br>Use Electron Flux |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------|---------|------|------|---------|------|------|---------|------|------|---------|-------------------------------------------------------------------------------|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------------------------|
| <b>Solar-Terrestrial Data</b><br><b>2010 Jul 11 1206 UTC</b><br>SFI: 80 SN: 18<br>A-Index: 2<br>K-Index: 1 / 8 nT<br>X-Ray: B2.8<br>304A: 121.8 @ SEM<br>Ptn Flx: 1.54e-01<br>Elc Flx: 1.06e+03<br>Aurora: 3 / n=0.93<br>Mag (Bz): 2.8<br>Solar Wind: 266.4<br><br><b>HF Conditions</b><br><table><tr><td>Band</td><td>Day</td><td>Night</td></tr><tr><td>80n-40n</td><td>Fair</td><td>Good</td></tr><tr><td>30n-20n</td><td>Fair</td><td>Fair</td></tr><tr><td>17n-15n</td><td>Poor</td><td>Poor</td></tr><tr><td>12n-10n</td><td>Poor</td><td>Poor</td></tr></table><br><b>VHF Conditions</b><br>Aur Lat 65.6°<br>Aurora Band Closed<br>6n EsEU Band Closed<br>4n EsEU Band Closed<br>2n EsEU Band Closed<br>2n EsNA Band Closed<br><br><br><b>Geomag Field VR QUIET</b><br><b>Sig Noise Lvl S0-S1</b><br><br><b>Current Solar Image</b><br><br><br><a href="http://www.n0nbh.com">http://www.n0nbh.com</a><br>Copyright Paul L Herrman 2010 | Band                                                                         | Day                                                                      | Night                                                                                                                         | 80n-40n                                                                                                            | Fair                                                        | Good                                | 30n-20n | Fair | Fair | 17n-15n | Poor | Poor | 12n-10n | Poor | Poor | Extreme | X20 (1 per cycle)<br>Complete HF blackout on entire sunlit side lasting hours | 1.0e+06 (1 per cycle)<br>Complete HF blackout in polar regions | K=9 (nT=>500) [Aur=10+] (SW=>800) [Bz=-40 -50] (4 per cycle)<br>HF impossible. Aurora to 40°. Noise S30+. | 200-300 (SN=160-250)<br>Reliable communications all bands up through 6m | >1.0e+03 Alert<br>Partial to complete HF blackout in polar regions |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Band                                                                         | Day                                                                      | Night                                                                                                                         |                                                                                                                    |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 80n-40n                                                                      | Fair                                                                     | Good                                                                                                                          |                                                                                                                    |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 30n-20n                                                                      | Fair                                                                     | Fair                                                                                                                          |                                                                                                                    |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 17n-15n                                                                      | Poor                                                                     | Poor                                                                                                                          |                                                                                                                    |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 12n-10n                                                                      | Poor                                                                     | Poor                                                                                                                          |                                                                                                                    |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Severe                                                                       | X10 (8 per cycle)<br>HF blackout on most of sunlit side for 1 to 2 hours | 1.0e+05 (3 per cycle)<br>Partial HF blackout in polar regions                                                                 | K=8 (nT=330-500) [Aur=10+] (SW=700-800) [Bz=-30 -40] (100 per cycle)<br>HF sporadic. Aurora to 45°. Noise S20-S30. |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
| Strong                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | X1 (175 per cycle)<br>Wide area HF blackout for about an hour on sunlit side | 1.0e+04 (10 per cycle)<br>Degraded HF propagation in polar regions       | K=7 (nT=200-330) [Aur=10] (SW=600-700) [Bz=-20 -30] (200 per cycle)<br>HF intermittent. Aurora to 50°. Noise S9-S20.          | 150-200 (SN=105-160)<br>Excellent conditions all bands up through 10m w/6m openings                                |                                                             |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
| Moderate                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | M5 (350 per cycle)<br>Limited HF blackout on sunlit side for tens of minutes | 1.0e+03 (25 per cycle)<br>Small effects on HF in polar regions           | K=6 (nT=120-200) [Aur=9] (SW=500-600) [Bz=-10 -20] (600 per cycle)<br>HF fade higher lats. Aurora to 55°. Noise S6-S9.        | 120-150 (SN=70-105)<br>Fair to good conditions all bands up through 10m                                            | <1.0e+03 Active<br>Degraded HF propagation in polar regions |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
| Minor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | M1 (2000 per cycle)<br>Occasional loss of radio contact on sunlit side       | 1.0e+02 (50 per cycle)<br>Minor impacts on HF in polar regions           | K=5 (nT=70-120) [Aur=8] (SW=400-500) [Bz=0 -10] (1700 per cycle)<br>HF fade higher lats. Aurora to 56°. Noise S4-S6.          | 90-120 (SN=35-70)<br>Fair conditions all bands up through 15m                                                      | <1.0e+02 Active<br>Minor impacts on HF in polar regions     |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
| Active                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | C1 Moderate Flare<br>Low absorption of HF signals                            | 1.0e+01 Active<br>Very minor impacts on HF in polar regions              | K=3-4 (nT=20-70) [Aur=6-7] (SW=200-400) [Bz=0-+50] Unsettled/Active<br>Minor HF fade higher lats. Aurora 60-58°. Noise S2-S3. | 70-90 (SN=10-35)<br>Poor to fair conditions all bands up through 20m                                               | <1.0e+01 Normal<br>No impacts on HF                         |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |
| Normal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | A1-B9 No/Small Flare<br>No or very minor impact to HF signals                | 1.0e+00 Normal<br>No impacts on HF                                       | K=0-2 (nT=0-20) [Aur=<5] (SW=200-400) [Bz=0-+50] Inactive/Quiet<br>No impacts on HF. Aurora 67-62°. Noise S0-S2.              | 64-70 (SN=0-10)<br>Bands above 40m unusable                                                                        | <1.0e+00 Normal<br>No impacts on HF                         |                                     |         |      |      |         |      |      |         |      |      |         |                                                                               |                                                                |                                                                                                           |                                                                         |                                                                    |

### VHF Conditions

**Aur Lat (Auroral Latitude):** Indicates lowest latitude from the current Aurora Activity measurement. Text color coded for low activity, hi-latitude, & mid-latitude.

**Aurora (Northern Auroral Activity):** Band Closed = No/Low Auroral activity. High LAT AUR = Auroral activity >60°N. MID LAT AUR = Auroral activity 60° to 30°N.

**EsEU (Sporadic E - Europe):** Band Closed = No Sporadic E (ES) activity. High MUF (2M only) = Cond support 2M ES 50/70/144MHz ES = Respective band open

**EsNA (Sporadic E - North America):** Band Closed = No Sporadic E (ES) activity. High MUF = Cond support 2M ES 144MHz ES = ES reported @ 2M

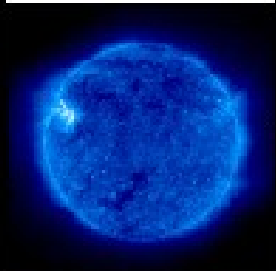
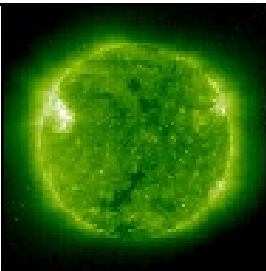
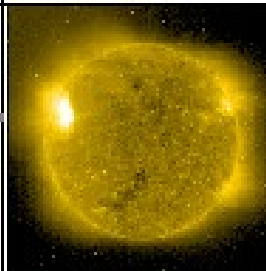
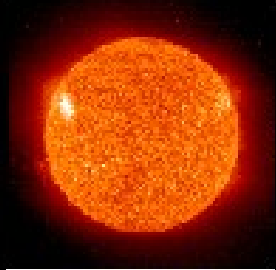
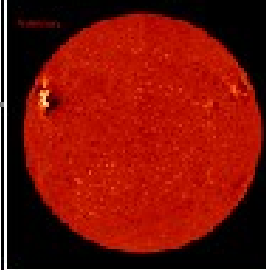
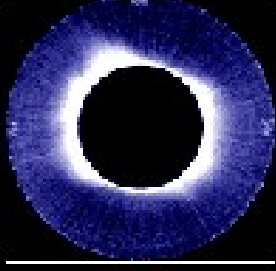
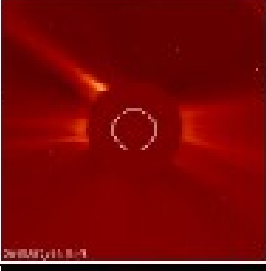
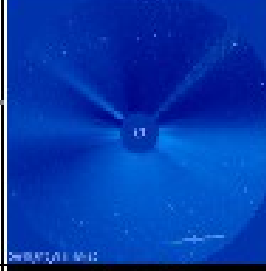
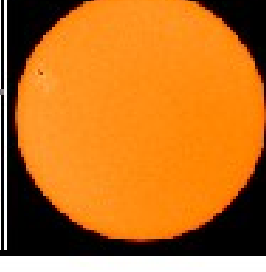
**MUF (Max Usable Frequency Bar Color):** No Sporadic E (ES) activity / ES reported @ 6M / ES reported @ 4M / Cond support 2M ES / ES reported @ 2M

**MS (Meteor Scatter Bar):** Use color code below bar to determine relative activity.

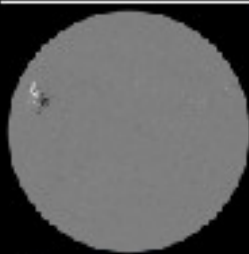
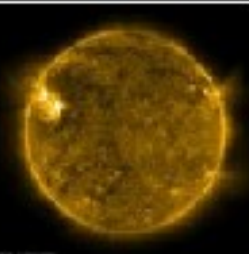
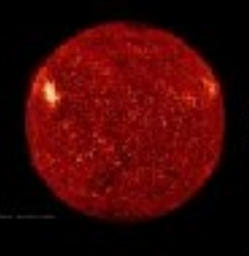
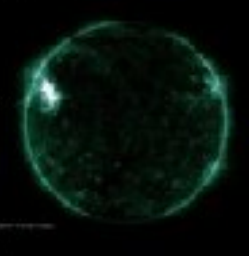
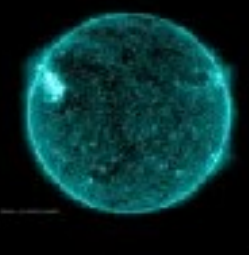
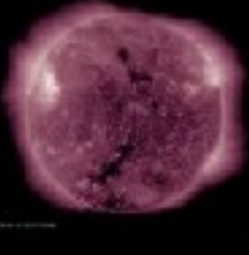
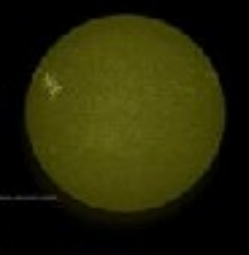
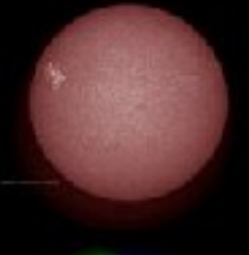
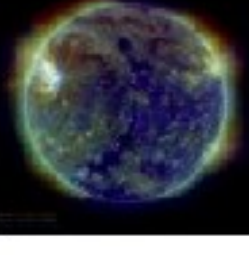
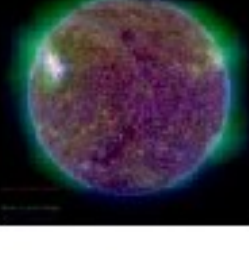
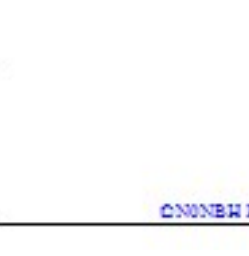
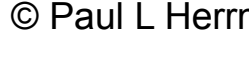
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# Putting the Solar Images to Use (1)

| SoHo/SDO/Other Image                                                                | λ nm<br>?image=             | TempK<br>Temp°C<br>Temp°F                              | SoHo/SDO/Other Image                                                                 | λ nm<br>?image=            | TempK<br>Temp°C<br>Temp°F                | SoHo/SDO/Other Image                                                                  | λ nm<br>?image=              | TempK<br>Temp°C<br>Temp°F                   |
|-------------------------------------------------------------------------------------|-----------------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------|------------------------------------------|---------------------------------------------------------------------------------------|------------------------------|---------------------------------------------|
|                                                                                     | Spectral Line & Ionization  | Best used to see                                       |                                                                                      | Spectral Line & Ionization | Best used to see                         |                                                                                       | Spectral Line & Ionization   | Best used to see                            |
|    | 171 Å<br>17.1 nm<br>eit171  | 1,000,000K<br>999,727°C<br>1,799,540°F                 |    | 195 Å<br>19.5 nm<br>eit195 | 1,500,000K<br>1,499,727°C<br>2,699,540°F |    | 284 Å<br>28.4 nm<br>eit284   | 2,000,000K<br>1,999,727°C<br>3,599,540°F    |
|                                                                                     | Iron (Fe) 8-9 times ionized | Tran-reg, sunspots, low temp loops                     |                                                                                      | Iron (Fe) 11 times ionized | Tran-reg, sunspots, corona, flares       |                                                                                       | Iron (Fe) 14 times ionized   | Tran-reg, sunspots, corona, high temp loops |
|    | 304 Å<br>30.4 nm<br>eit304  | 80,000K<br>79,727°C<br>143,540°F                       |    | 6302 Å<br>630.2 nm<br>vsm1 | 5,800K<br>5,527°C<br>9,980°F             |    | 8542 Å<br>854.2 nm<br>vsm2   | 10,000K<br>9,727°C<br>17,540°F              |
|                                                                                     | Helium (He) 1 times ionized | Chromosphere, Tran-reg, Prominence, sunspots, Granules |                                                                                      | Iron (Fe) 0 times ionized  | Photosphere, sunspots                    |                                                                                       | Calcium (Ca) 1 times ionized | Photosphere, Chromosphere, sunspots         |
|   | 9500 Å<br>950 nm<br>corona  | 2,000,000K<br>1,999,727°C<br>3,599,540°F               |   | NA<br>NA<br>c2             | 2,000,000K<br>1,999,727°C<br>3,599,540°F |   | NA<br>NA<br>c3               | 2,000,000K<br>1,999,727°C<br>3,599,540°F    |
|                                                                                     | White Light                 | Corona                                                 |                                                                                      | White Light                | Corona, CME, Flare                       |                                                                                       | White Light                  | Corona, CME, Flare                          |
|  | 10830 Å<br>1083 nm<br>sh    | 20,000K<br>19,727°C<br>35,540°F                        |  | 6562.8 Å<br>656.28nm<br>ha | 20,000K<br>19,727°C<br>35,540°F          |  | 6767 Å<br>676.7 nm<br>mdi    | 6,000K<br>5727°C<br>10,340°F                |
|                                                                                     | Helium (He) 0 times ionized | Chromosphere, Tran-reg, sunspots, Granules             |                                                                                      | Hydrogen (H) Hα-Line       | Chromosphere, Tran-reg, sunspots, flares |                                                                                       | Nickel (Ni) 0 times ionized  | Photosphere, sunspots                       |

# Putting the Solar Images to Use (2)

|                                                                                     |                                       |                                          |                                                                                      |                                   |                                             |                                                                                       |                                     |                                            |
|-------------------------------------------------------------------------------------|---------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------|--------------------------------------------|
|    | Magnetogram<br>N/A<br>mag             | N/A<br>N/A<br>N/A                        |    | 171 Å<br>17.1 nm<br>sdo_171       | 1,000,000K<br>999,727°C<br>1,799,540°F      |    | 193 Å<br>19.3 nm<br>sdo_193         | 1,500,000K<br>1,499,727°C<br>2,699,540°F   |
|    | N/A<br>N/A                            | Sunspots                                 |    | Iron (Fe) 8<br>times<br>ionized   | Quiet corona,<br>upper transition<br>region |    | Iron (Fe)<br>11/23 times<br>ionized | Corona and hot<br>flare plasma             |
|    | 335 Å<br>33.5 nm<br>sdo_335           | 5,000,000K<br>5,000,000°C<br>9,000,000°F |    | 304 Å<br>30.4 nm<br>sdo_304       | 80,000K<br>79,727°C<br>143,540°F            |    | 94 Å<br>9.4 nm<br>sdo_094           | 9,000,000K<br>9,000,000°C<br>16,000,000°F  |
|   | Iron (Fe) 15<br>times ionized         | Active-region<br>corona                  |   | Helium (He)<br>1 times<br>ionized | Chromosphere,<br>transition region          |   | Iron (Fe) 17<br>times<br>ionized    | Flaring regions                            |
|  | 131 Å<br>13.1 nm<br>sdo_131           | 1,000,000K<br>999,727°C<br>1,799,540°F   |  | 211 Å<br>22.1 nm<br>sdo_211       | 2,000,000K<br>1,999,727°C<br>3,599,540°F    |  | 1600 Å<br>160.0 nm<br>sdo_1600      | Unknown                                    |
|  | Iron (Fe)<br>7/19/22 times<br>ionized | Flaring regions                          |  | Iron (Fe) 13<br>times<br>ionized  | Active-region<br>corona                     |  | Carbon (C)<br>3 times<br>ionized    | Transition<br>region, upper<br>photosphere |
|  | 1700 Å<br>170.0 nm<br>sdo_1700        | Unknown                                  |  | 4500 Å<br>450.0 nm<br>sdo_4500    | 2,000,000K<br>1,999,727°C<br>3,599,540°F    |  | 211/193/<br>171 Å<br>sdo_comp1      | Unknown                                    |
|  | Continuum                             | Temperature<br>minimum,<br>photosphere   |  | White Light                       | Photosphere                                 |  | 94/193/<br>335 Å<br>sdo_comp3       | Unknown                                    |
|  | 304/211/<br>171 Å<br>sdo_comp2        | Unknown                                  |  | Composite<br>Image                | See above                                   |  | Composite<br>Image                  | See above                                  |
|  | Composite<br>Image                    | See above                                |  | Composite<br>Image                | See above                                   |  | Composite<br>Image                  | See above                                  |

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## ***N0NBH Solar Web Pages***

- ◆ I hope the information in this presentation helps you with Ham Radio DX on all the bands
- ◆ Additional data, tools, and even Solar banners/widgets for your webpages and computer devices are available at <http://www.hamqsl.com/solar.html>
- ◆ Please feel free to contact me with any questions, comments, or additional ideas at [n0nbh@cox.net](mailto:n0nbh@cox.net)
- ◆ 73 all and good DX de Paul N0NBH