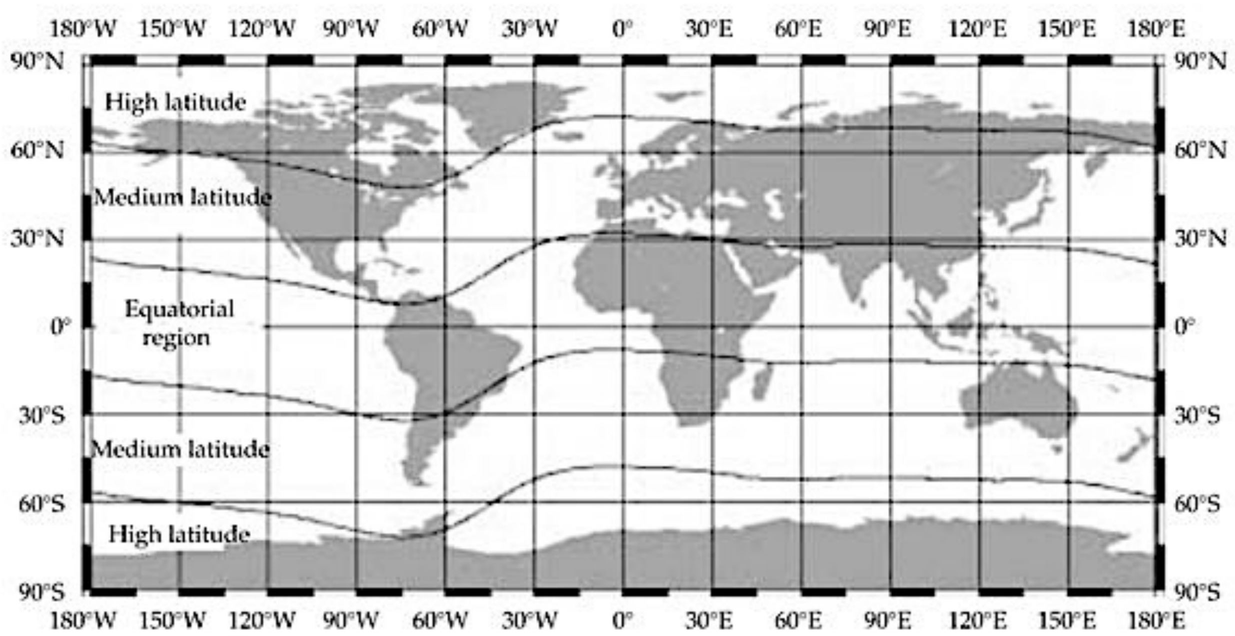
Equatorial Ionosphere

Ken Larson KJ6RZ
November 2022
www.skywave-radio.org

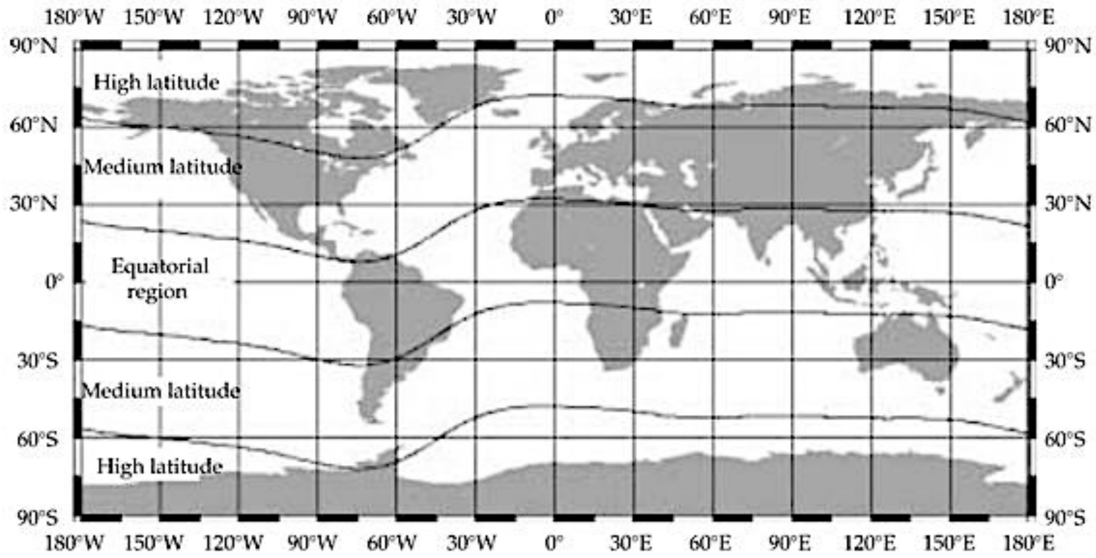
Ionosphere Changes With Latitude



ResourceGate.net

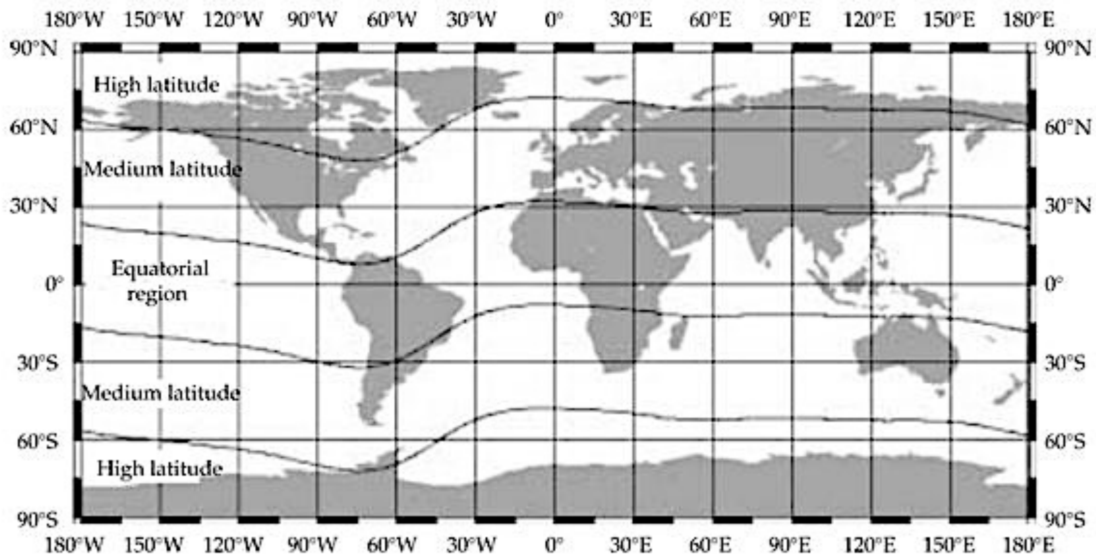
- The Earth's magnetic field exerts a considerable influence over the ionosphere, separating the ionosphere into three broad regions.
  - The low-latitude (equatorial) region,
  - Mid-latitude region (the most studied and well understood), and
  - The high-latitude (polar) region

Ionosphere Changes With Latitude



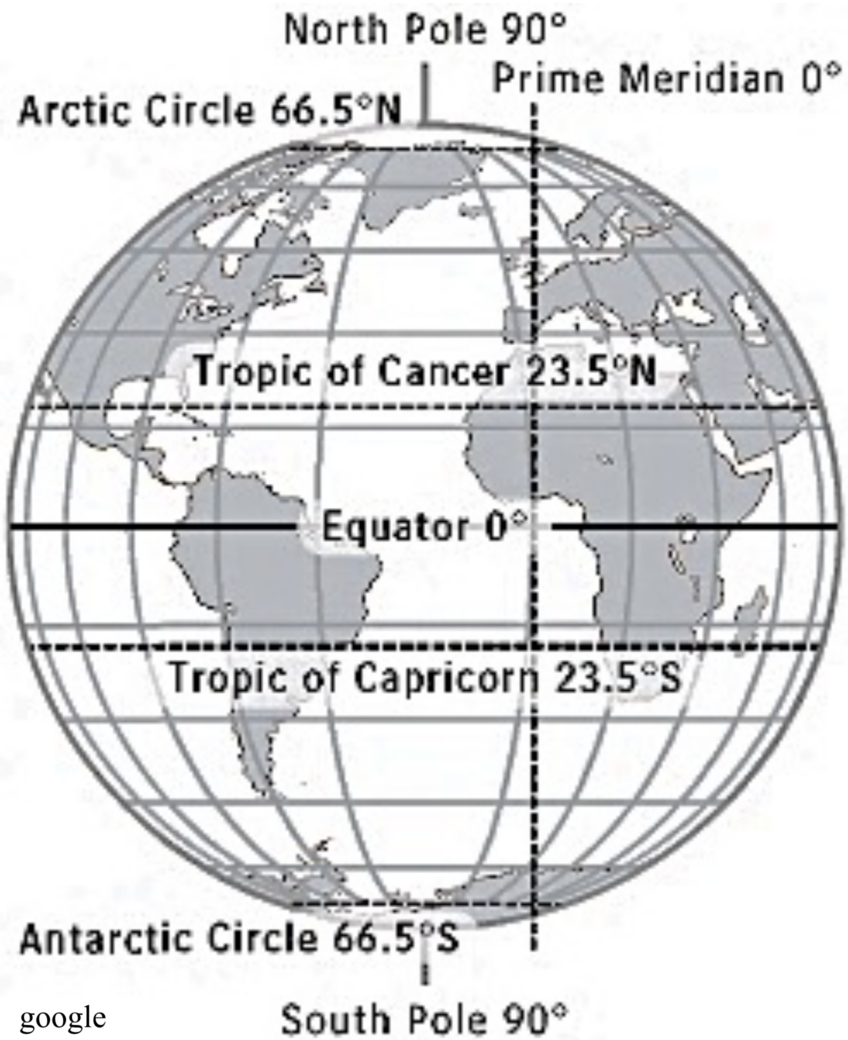
- The phenomena that occur at mid-latitudes also occur at both the high and low latitudes, including:
  - Ionization by solar Extreme Ultra-Violate (EUV) radiation,
  - Diurnal and seasonal variation,
  - Changes created by the 11 year solar cycle

Ionosphere Changes With Latitude



- In addition the low and high latitudes each have phenomena that are unique to their particular regions.
- Consequently, the high-latitude ionosphere bears little resemblance to the low latitude region, and both are considerably different from the mid-latitude ionosphere.

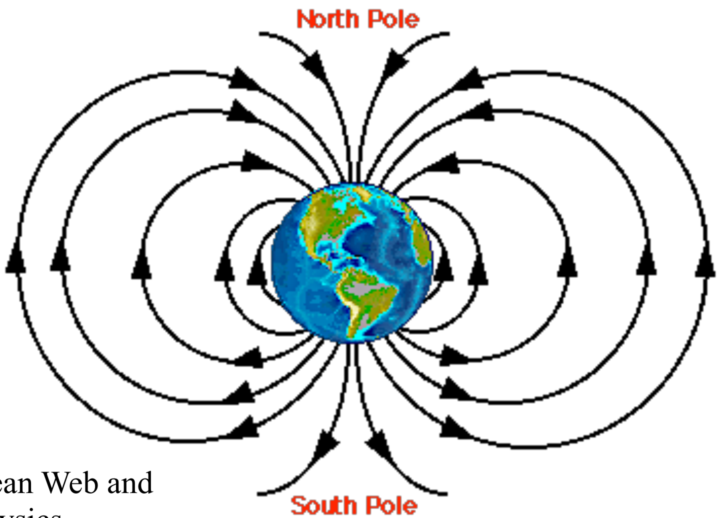
Low Latitude Equatorial Ionosphere



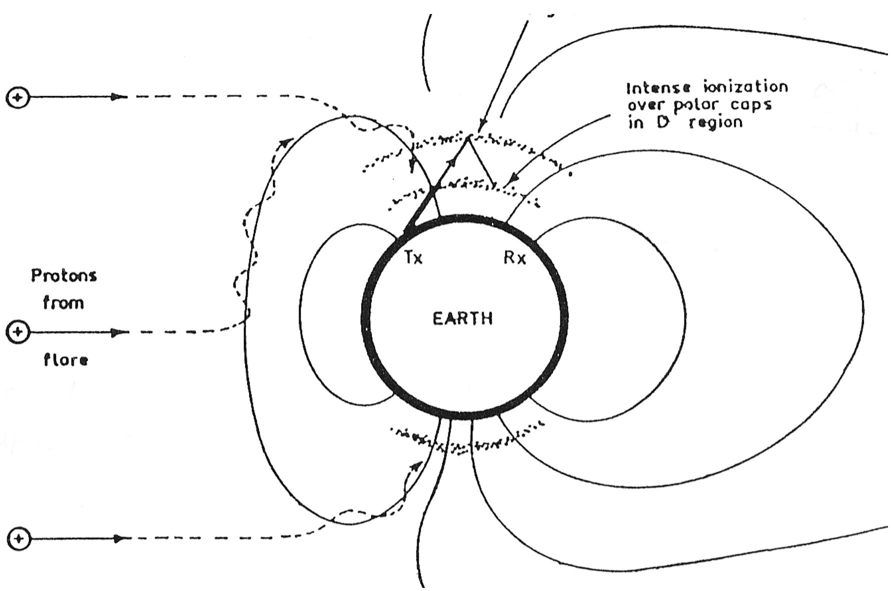
google

- The low latitude equatorial region is the zone between the Tropic of Cancer and the Tropic of Capricorn 23.5 degrees either side of the equator.

Low Latitude Equatorial Ionosphere



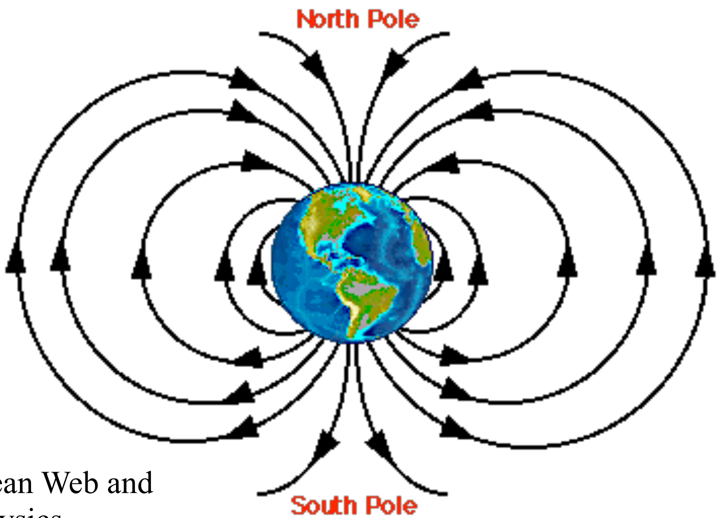
The Ocean Web and hyperphysics



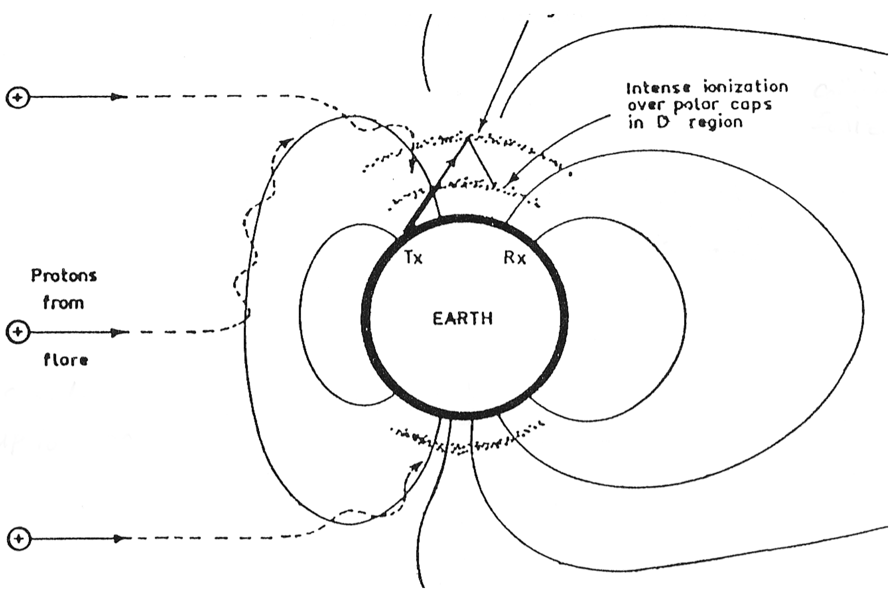
McNamar

- The geomagnetic field over the equatorial region is parallel to Earth's surface
- The horizontal field shields the low latitude region from harsh solar winds & high energy particles from the Sun.
- The equatorial ionosphere is much thicker than elsewhere
- In addition the Sun is nearly over head every day throughout the year.
- Thus critical frequencies are higher than at mid-latitudes with little seasonal difference between summer and winter.
- Based on this we would expect the low latitude region to be a quiet zone.
- To an extent our assumptions are true.

Low Latitude Equatorial Ionosphere



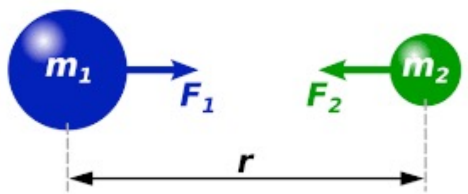
The Ocean Web and hyperphysics



McNamar

- However, strong electromagnetic forces are present in the equatorial zone.
- These forces result from:
  - The horizontal north-south magnetic field over the magnetic equator, and
  - High concentrations of free electrons resulting from extensive photo-ionization
- High electron concentrations produce abnormally high upper atmosphere electrical conductivity throughout the equatorial region

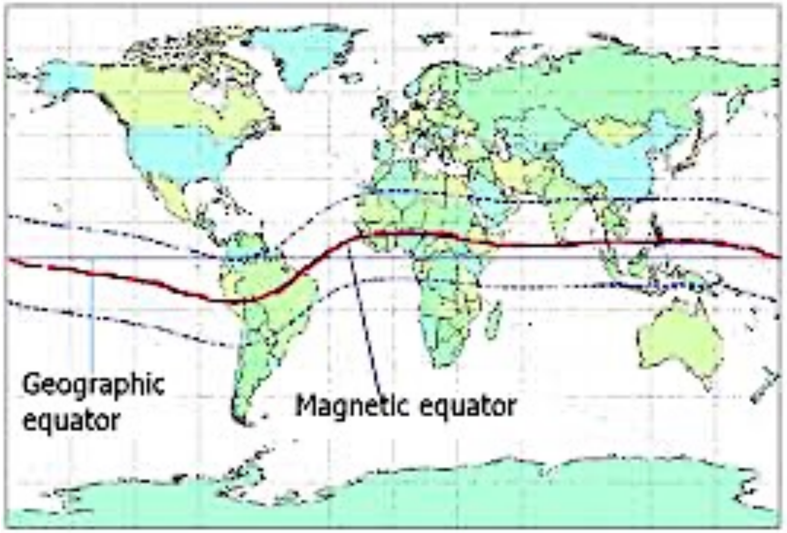
Development of Eastward Electric Field



www.edumple.com

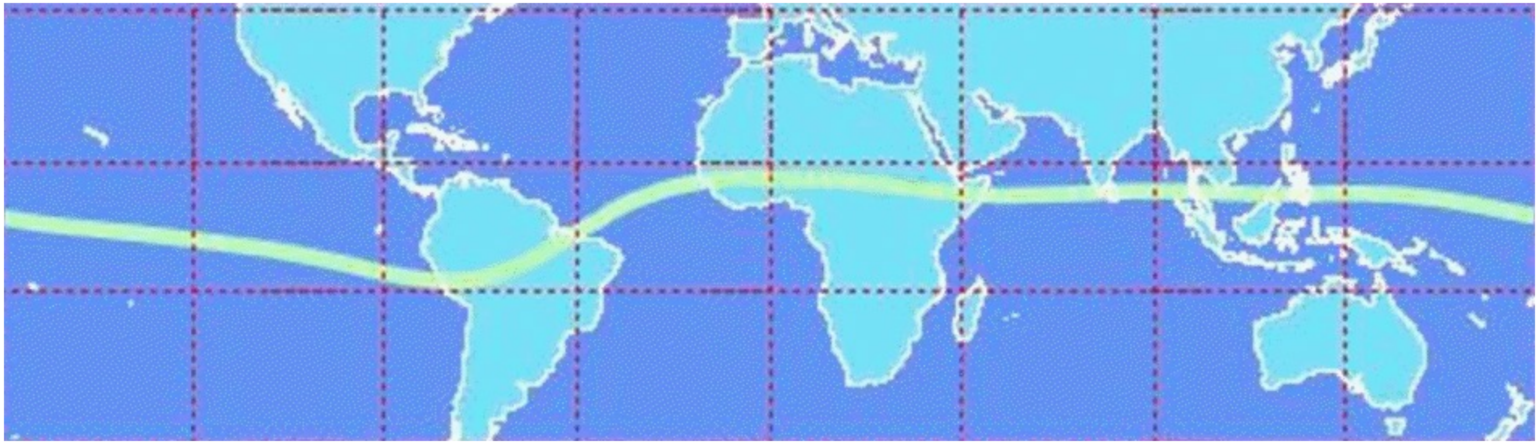
Charge Separation

indico.ictp.it



- During the day, as the Sun warms Earth's equatorial atmosphere, temperature and pressure differences develop creating upper atmosphere winds blowing eastward
- Ionospheric plasma is blown along with the wind
- But motion of the large heavy ions is impeded by constant collisions with equally large and heavy neutral air particles
- However, tiny electrons move with considerable freedom.
- A charge separation develops between the free moving electrons and relatively immobile ions producing a horizontal eastward equatorial electric field

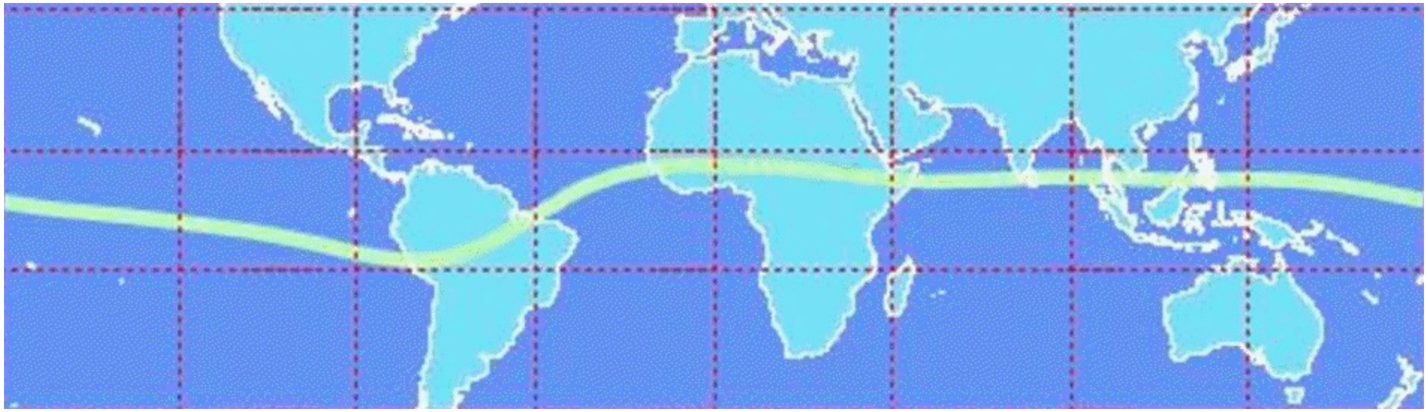
Low Latitude Electrojet



gfz-potsdam.de

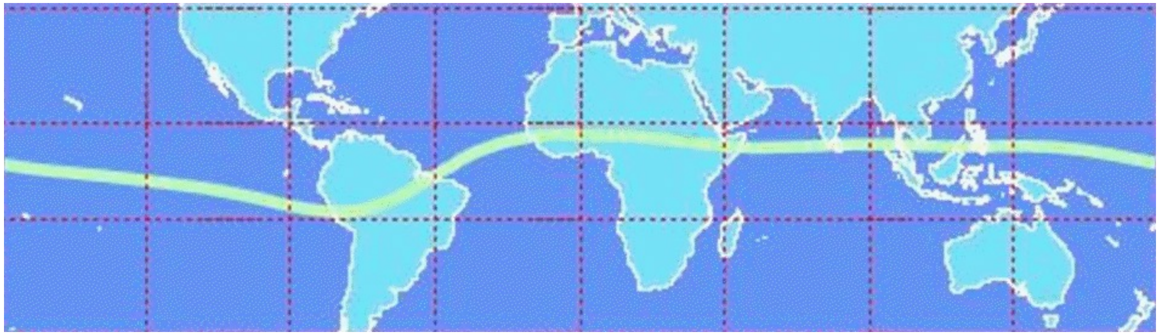
- High ionospheric conductivity,
- Along with the eastward electric field,
- Plus the north-south magnetic field
- Combine through a complex process to produce a very strong horizontal electrical current flowing eastward along the magnetic equator
- This electrical current, known as the Equatorial Electrojet, flows in the E region of the ionosphere at an altitude of 90 to 130 km

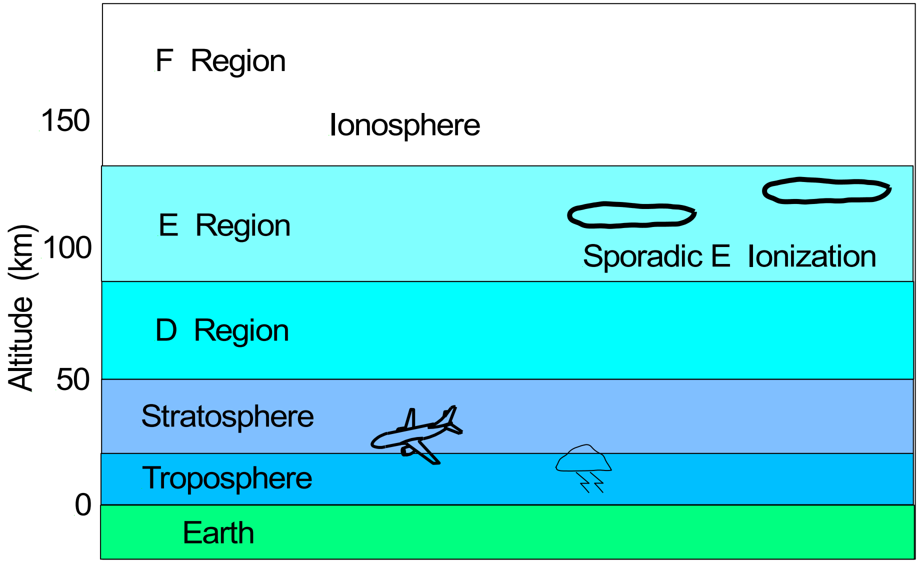
Low Latitude Electrojet



- The conditions producing the Equatorial Electrojet occur only during daylight hours in a narrow zone approximately 600 km in width above the magnetic equator
- The electrojet is most intense around local noon
- All electrical currents produce magnetic fields.
- The magnetic field produced by the electrojet induces significant diurnal variations in Earth's geomagnetic field along the magnetic equator

Equatorial Sporadic E

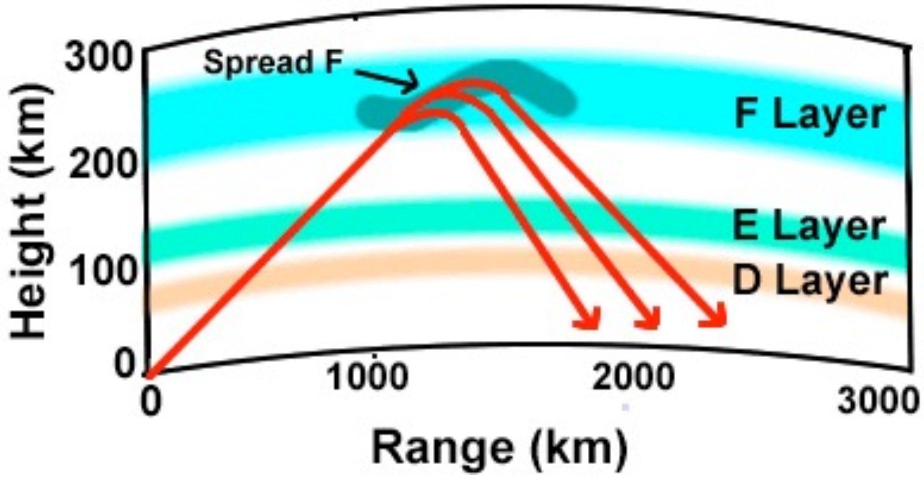




author

- At low latitudes, ionization irregularities resulting from the electrojet are responsible for creating equatorial sporadic E zones.
- The equatorial sporadic E is essentially a daytime phenomenon with little seasonal variation.

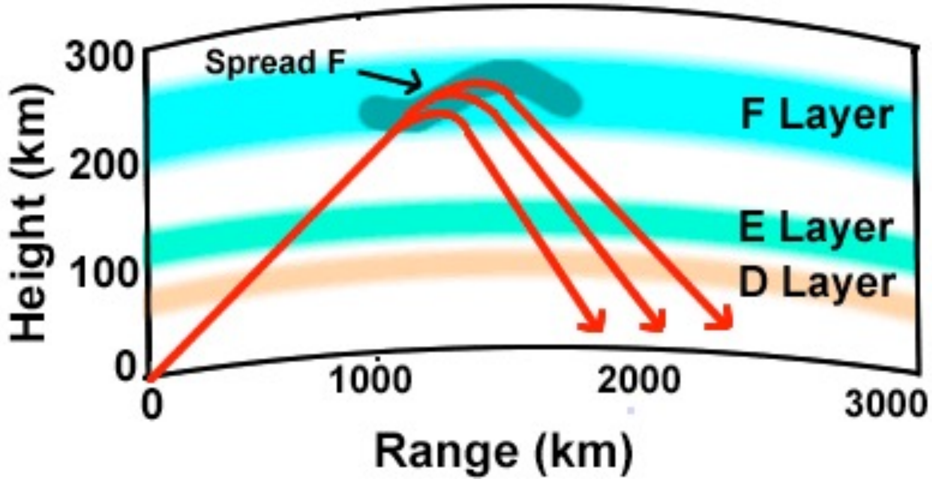
Spread F Irregularity



www.met.nps.edu

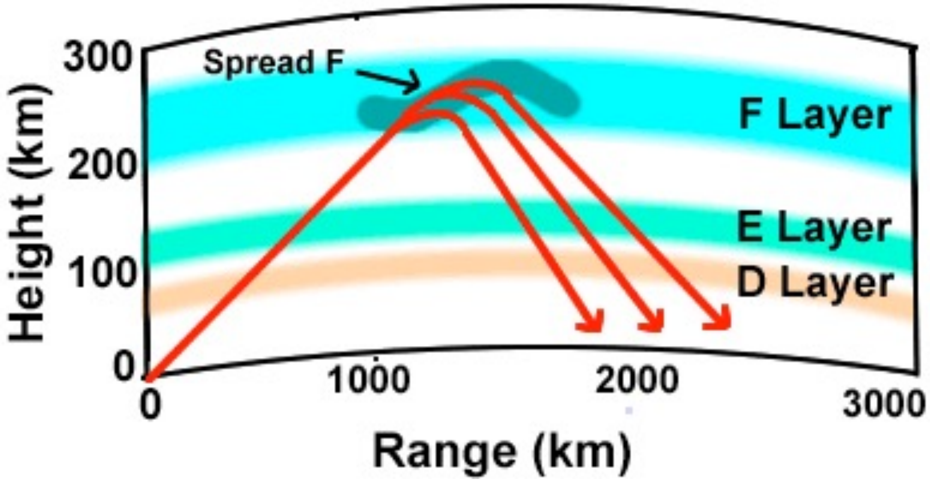
- Signal scattering due to field aligned irregularities results in the spread F phenomena
- Spread F occurs most frequently in the equatorial and high latitude regions.
- Spread F causes an HF signal to be reflected from different heights within the F layer.
- Received spread F signals are spread in time and space, making frequency resolution difficult and producing garbled messages
- Received digital data pulses can be up to 10 times wider than the transmitted pulses limiting the data rate of signals that can be successfully transmitted. This type of distortion is known as range spread.

Spread F Irregularity



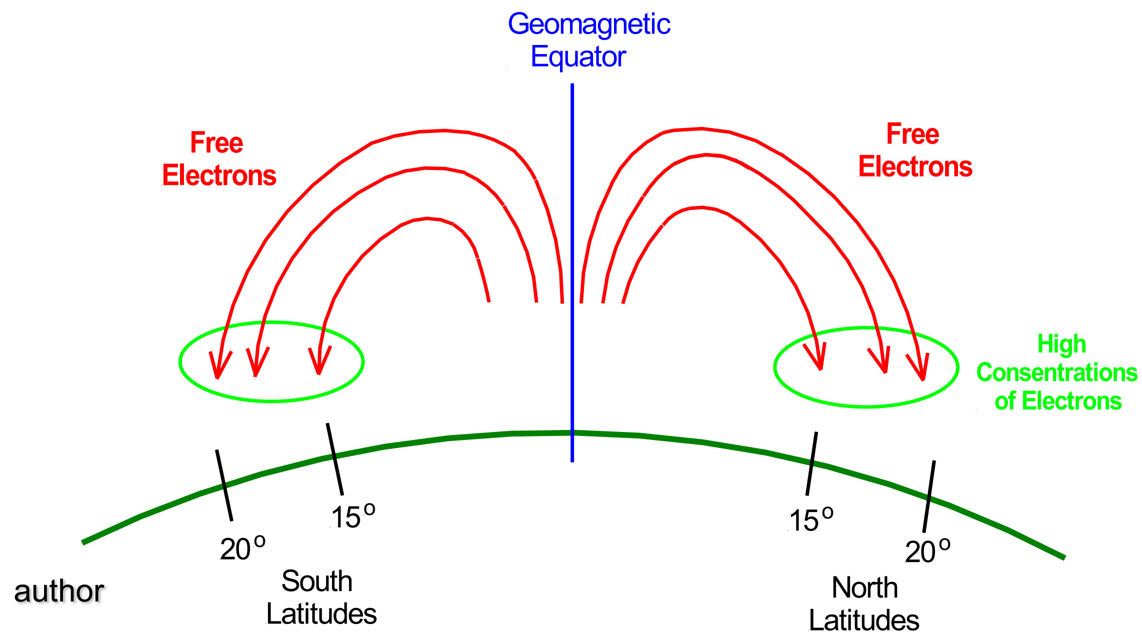
- In addition, spread F produces high fading rates.
- Field aligned irregularities producing spread F are highly variable in size ranging from roughly a 100 km to several thousand kilometers in length & about a kilometer thick.
- Near the equator, the irregularities drift eastward.

Equatorial Spread F



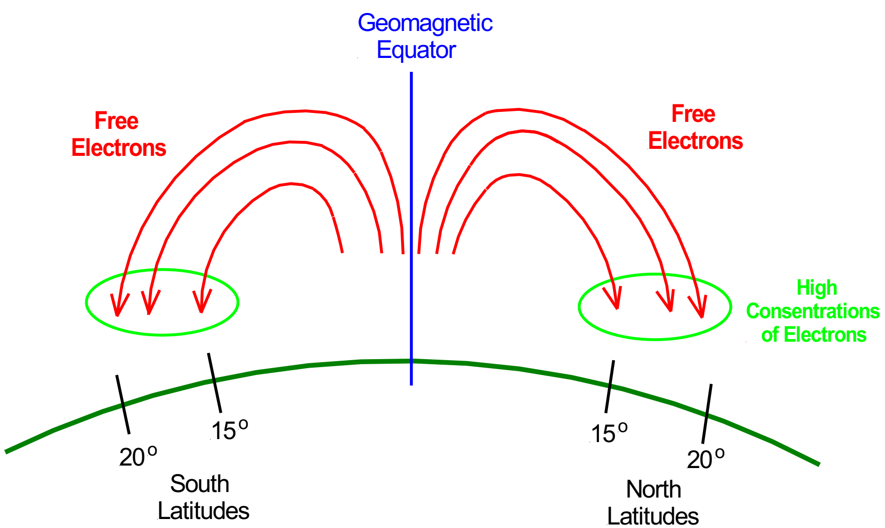
- In the equatorial regions spread F occurs mainly at night, during magnetically quiet days, in a zone straddling the geomagnetic equator from approximately 20^{o} south to 20^{o} north latitude.
- They begin appearing near sunset, in conjunction with the nightly upward drifting F region, peak around midnight, and then generally decrease.
- Equatorial spread F can occur at any time but tends to be more intense and more numerous at solar maximum, during the winter & equinoxes, and during the summer in South America where the magnetic and geographic equators are furthest apart.
- Equatorial spread F disappears with the onset of a magnetic storm.

The Fountain Effect



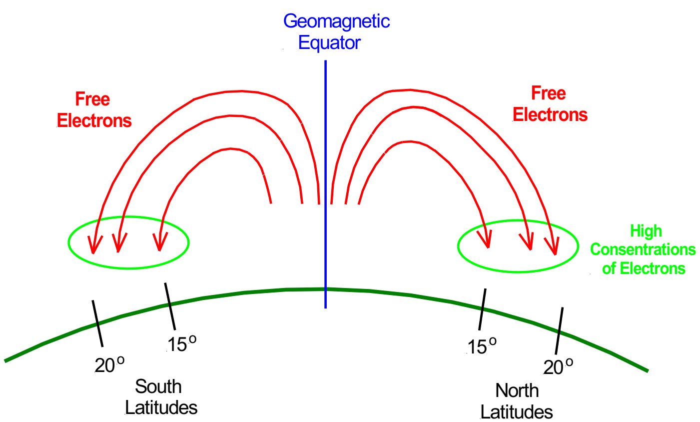
- Along the magnetic equator, the horizontal eastward electric field is perpendicular to the horizontal north-south magnetic field.
- The two perpendicular fields cause free electrons to drift upward away from the equator reducing electron concentrations in the area.

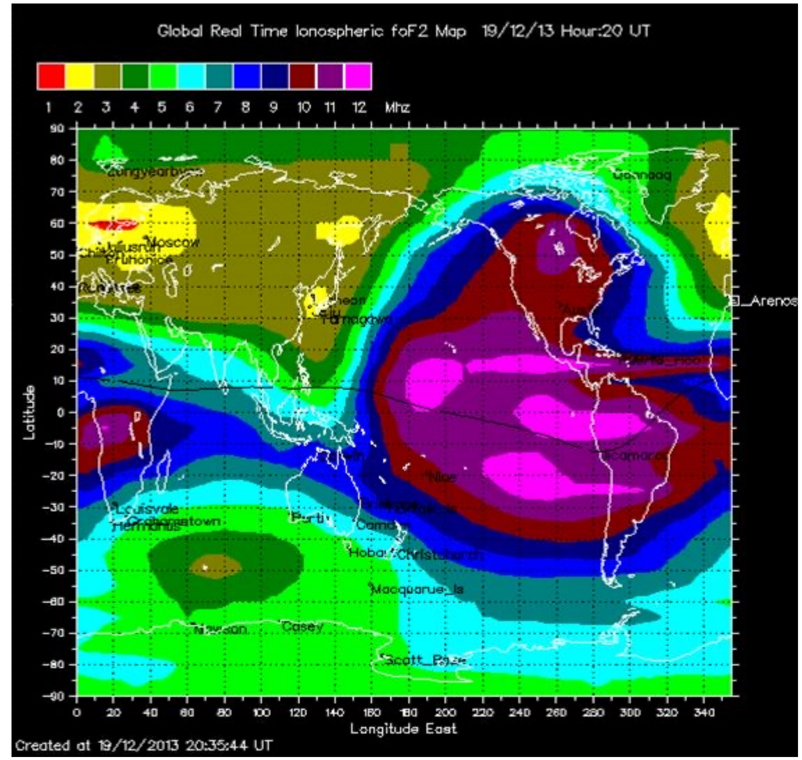
The Fountain Effect



- At an altitude of around 800 km the diminishing electric field finally disappears causing electrons to travel under the influence of gravity and pressure gradients along magnetic field lines curving back to Earth
- The electrons reenter the mid F2 region 15 to 20 degrees either side of the magnetic equator.
- The electrons transported from the equator combine with electrons already in the region creating a peak or crest in electron concentrations.
- This process is called the fountain effect.

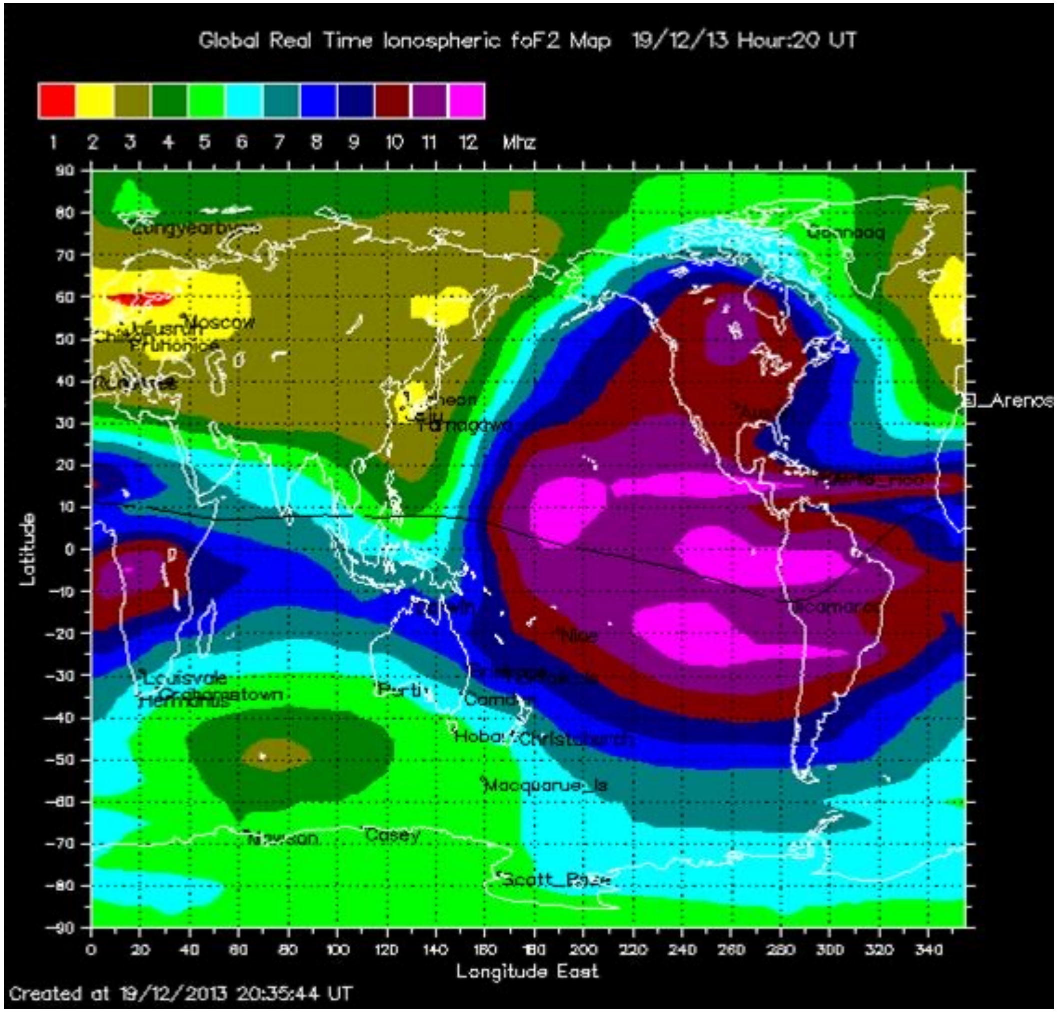
The Appleton / Equatorial Anomaly





- Before the fountain effect was understood, high concentrations of electrons appearing at latitudes between 15 to 20 degrees was known as the equatorial or Appleton anomaly.
- It was believed to be an anomaly since the highest electron concentrations were expected to occur over the equator.

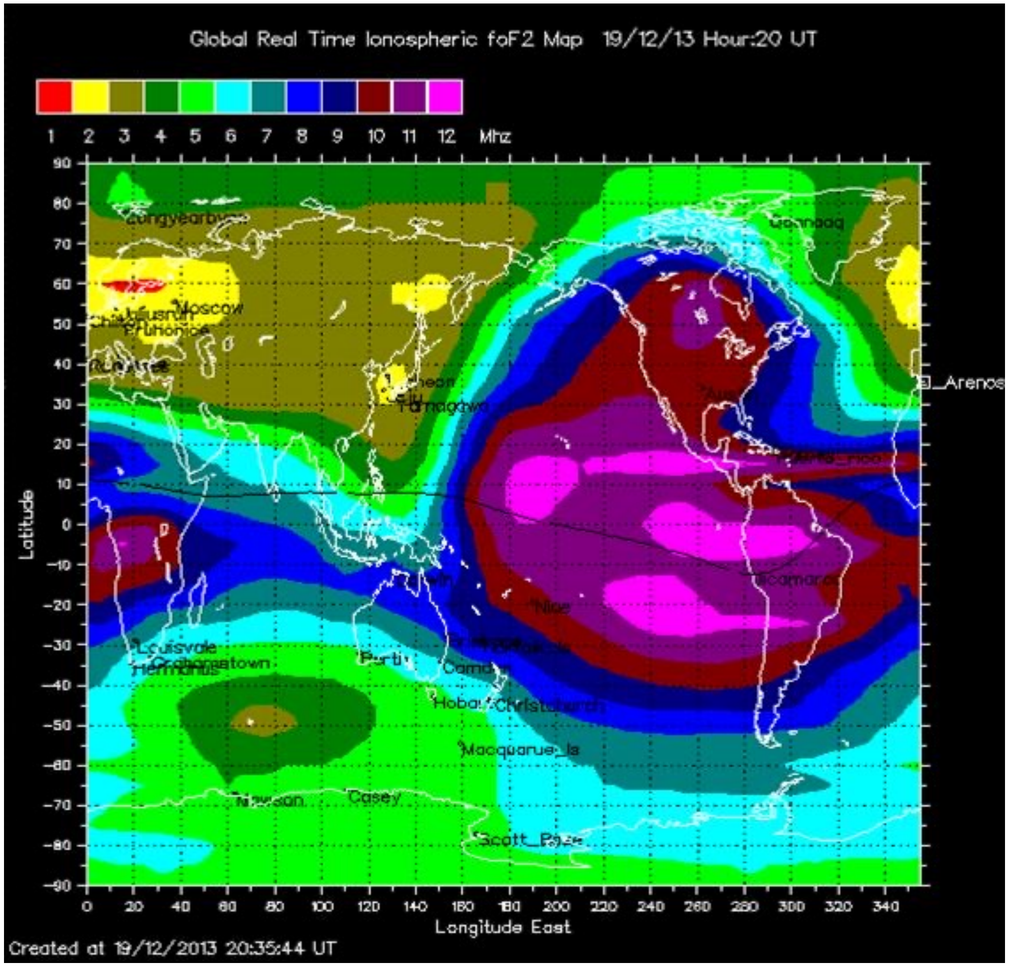
The Appleton / Equatorial Anomaly



Commonwealth of Australia

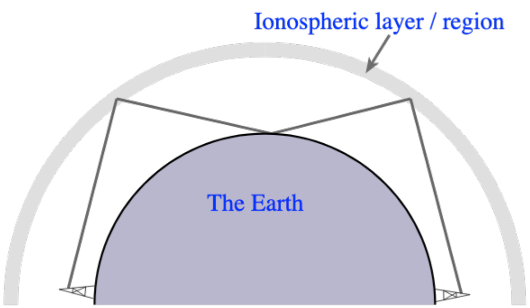
- The fountain effect is clearly visible in the F2 critical frequency map.
- The black line dipping through South America is the geomagnetic equator
- The bright pink zones on either side of the black line are the crests in electron concentrations
- These concentrations usually form in late afternoon and early evening.
- While the crests vary from day-to-day and seasonally, they are most pronounced during solar maximum.

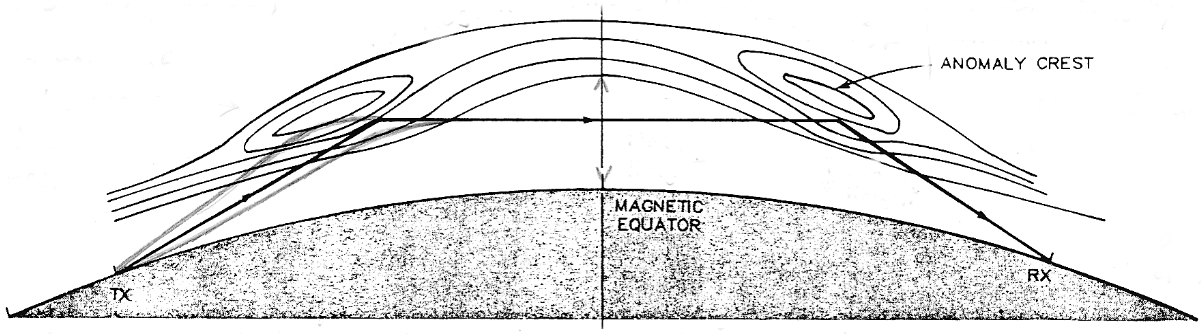
Critical Frequencies Within the Crest Zones



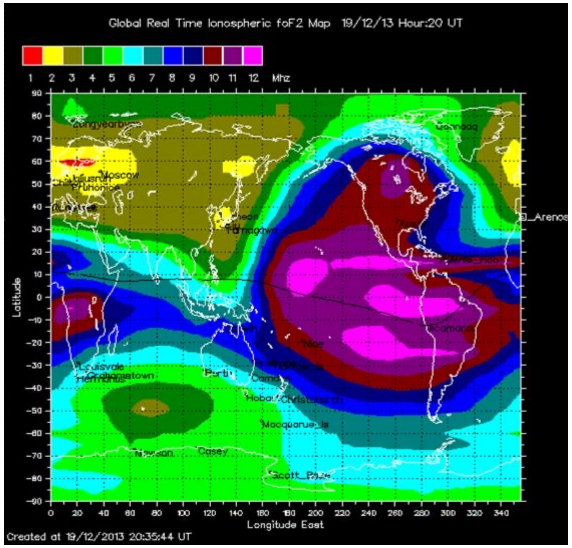
- F2 critical frequencies within the crests can often reach 15 MHz or higher during solar maximum.
- In contrast, critical frequencies along the magnetic equator will typically be several MHz less.
- The altitude at which the F2 peak electron density occurs is also different between the equator and the crests
- The peak electron density altitude along the equator is higher than the corresponding peak in the crests.

Transequatorial HF Propagation





McNamara



- The fountain effect distorts the general form of the ionosphere throughout the low latitude region making possible Transequatorial HF propagation
- Instead of multiple hops & associated signal attenuation
- A radio signal reflects off one anomaly crest
- Travels across the equator to the second crest
- Then refracts back to Earth
- Traversing the distance from transmitter to receiver in one hop with minimal signal loss