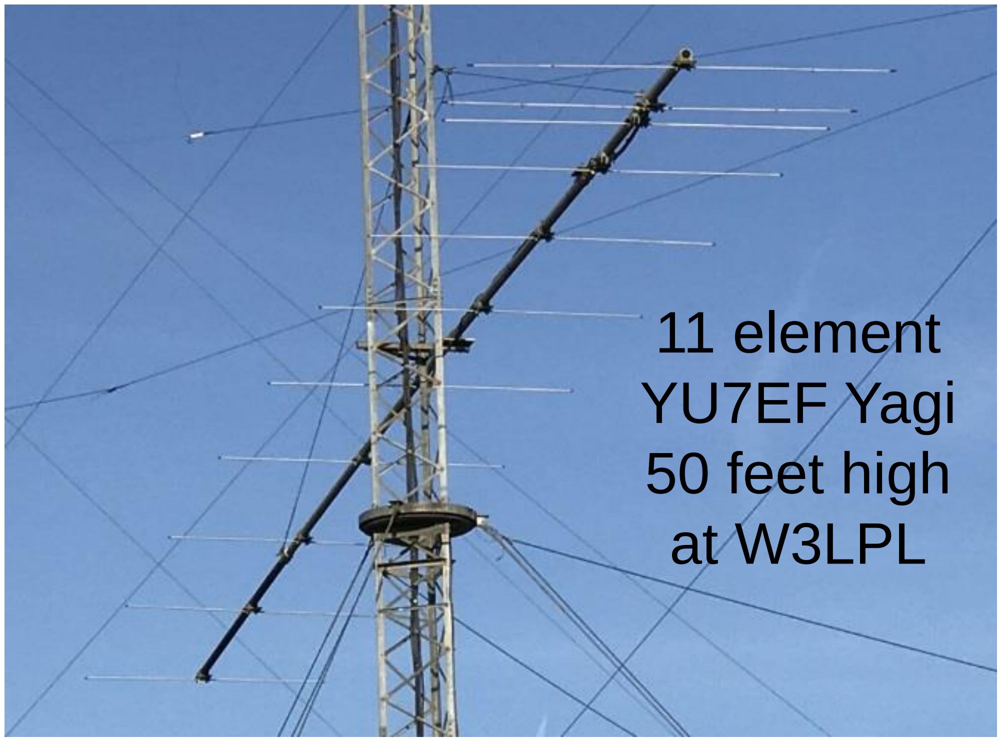
6 Meter Long Distance Propagation During the Next Four Years Near Solar Maximum



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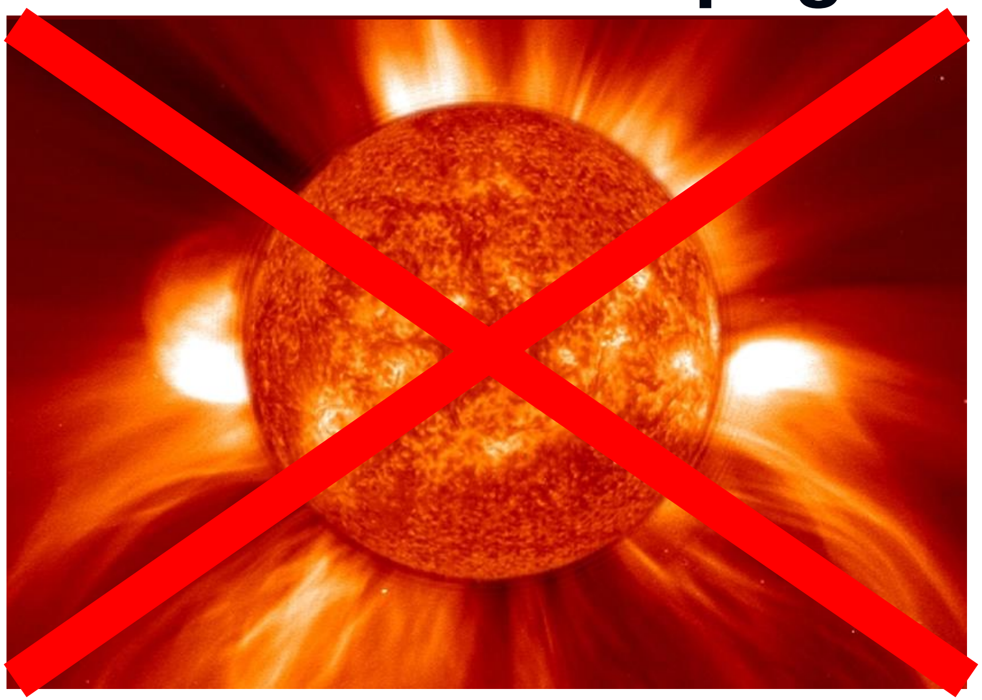
Forget Everything You Know about HF Propagation

6 Meter Mid-Latitude Sporadic-E (E_s) Propagation and F_2 Trans-Equatorial Propagation (TEP) are Fundamentally Different Than Almost All HF Propagation



Experience the Wonders of Solar Cycle 25's Solar Maximum

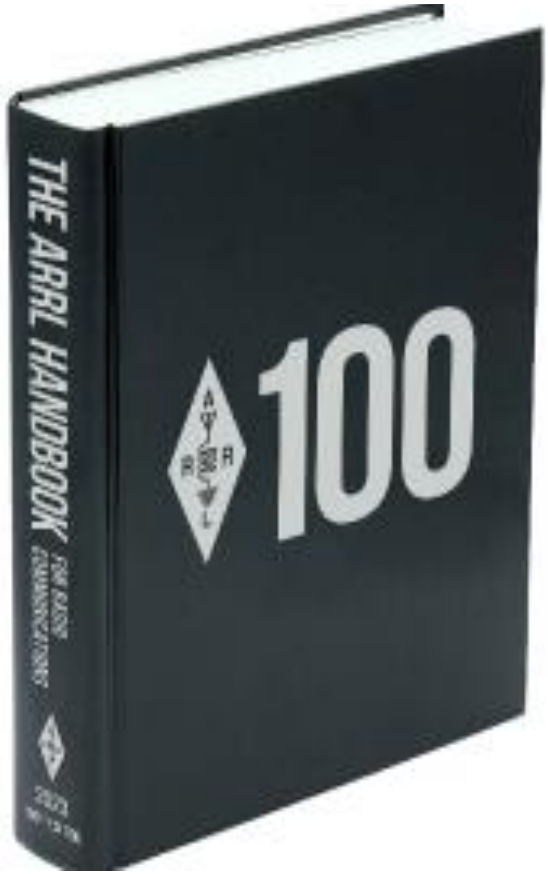
The next 4 years of this solar cycle are forecast to produce the best HF and 6-meter DX propagation in 20 years

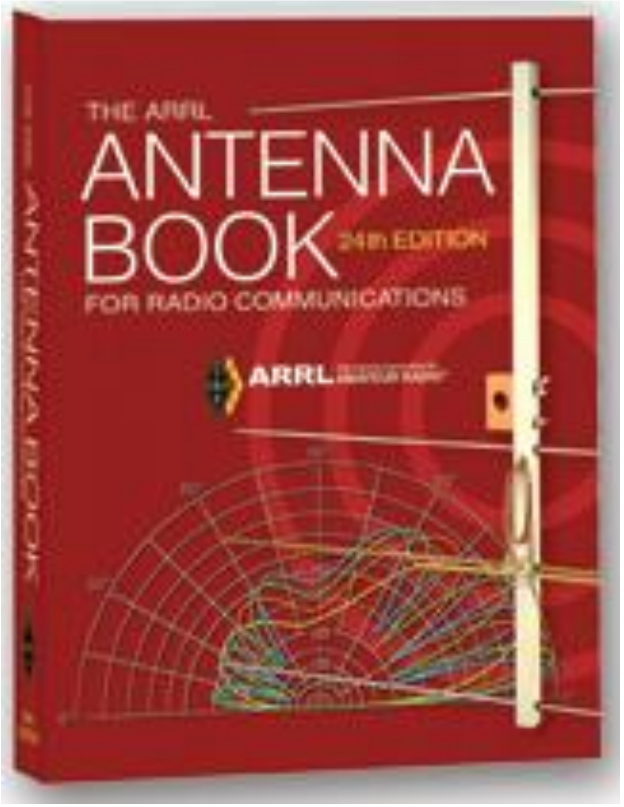
Frank Donovan W3LPL

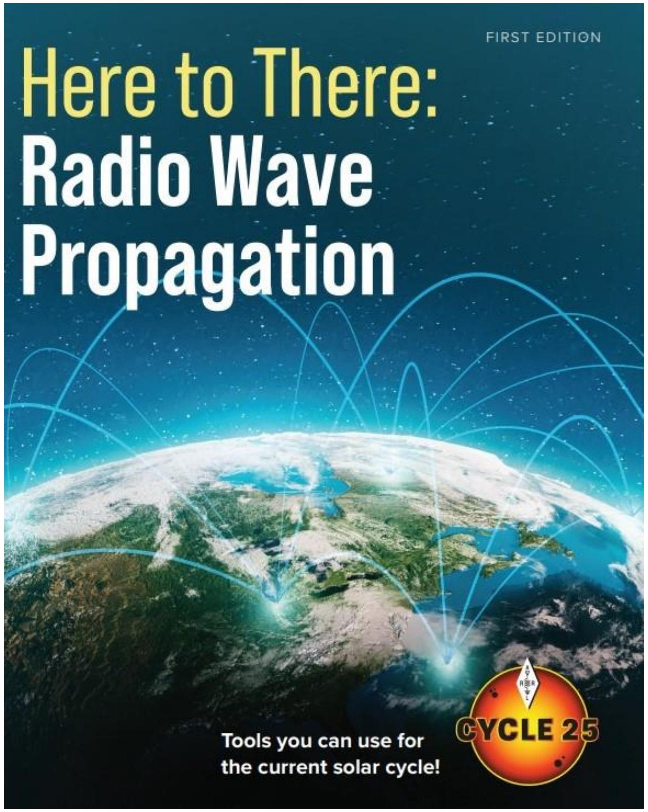
May 2023 QST

arrl.org/qst

The Three Most Valuable Investments to Greatly Improve Radio Amateur's Understanding of Antennas and Propagation







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home.arrl.org/action/Store/Product-Details/productId/114288

CQ Magazine Propagation Column

PROPAGATION

BY TOMAS HOOD,* NW7US

April Propagation Revisited

Quick Look at Current Cycle 25 Conditions: (Data rounded to nearest whole number)	One Year Ago: (Data rounded to nearest whole number)
Sunspots:	Sunspots:
Observed Monthly, January 2023: 144	Observed Monthly, January 2022: 57
12-month smoothed, July 2022: 87	12-month smoothed, July 2021: 32
10.7-cm Flux:	10.7-cm Flux:
Observed Monthly, January 2023: 182	Observed Monthly, January 2022: 104
12-month smoothed, July 2022: 130	12-month smoothed, July 2021: 83

NW7US was unable to produce his column this month, so we are reprising his April 2022 column, which offered a general look at what to expect on the bands in this month of "equinoctial" propagation. Sunspot numbers have been updated. For the Last-Minute Forecast, please visit Tomas's website at <https://SunSpotWatch.com>. – W2VU

As we move into spring in the Northern Hemisphere, the Sun is mostly overhead above the equator this month. This creates equal day and night periods in both hemispheres, which leads to improved DX conditions around the world on HF.

The Vernal Equinox in mid-March marks the day when the hours of daylight and darkness are about equal around the world. This creates an ionosphere of similar characteristics throughout more of the world than is possible during other times when it is summer in one hemisphere and winter in the other, and there are extreme differences in the ionosphere.

This equalization of the ionosphere during the equinoctial periods (autumn and spring) is responsible for optimum DX conditions starting late in February and lasting through late April. The improvement in propagation is most noticeable on long circuits between the Northern and Southern hemispheres. During this season, conditions are optimum for long-path as well as short-path openings, and during gray-line twilight periods associated with sunrise and sunset.

DXers (those who seek out signals from across the world) love April because the seasonal change this month plays out on HF: Activity (propagation) moves up from the 40-meter band and down from the 10-meter band, with stronger, more stable openings on paths on frequencies from 30 meters through 17 meters. Propagation on the higher HF frequencies (20 through 10 meters) begins to suffer late in April and into the summer months due to lower MUFs (Maximum Usable Frequencies) in the Northern Hemisphere, but the mid-HF bands are very usable, especially late in the day when MUFs peak.

Summertime MUFs are lower due to solar heating which causes the ionosphere to expand. An expanded ionosphere produces lower ion density, which results in lower MUFs.

Short-path propagation between countries in the Northern Hemisphere will drop out entirely. Higher frequency propagation peaks in the fall, north of the Equator.

April and May are autumnal months in the Southern Hemisphere, resulting in enhanced long-path DXing. At the same time, short-path propagation from South America, the South Pacific, and other areas south of the equator to points in the Northern Hemisphere will be strong and reliable when open. However, these do not happen every day on the higher frequencies—but do on mid-HF frequencies such as in the 20-meter band.

From April to June, excellent propagation occurs on both daytime and nighttime paths. The strongest propagation occurs on paths that span areas of both day and night, following the MUF. During April, peaking in May, and still in June, the 16-meter broadcast and the 15-meter amateur bands may offer 24-hour DX to all parts of the world, with both short- and long-path openings occurring, sometimes at the same time! If you hear a lot of echo on a signal, you might be beamed in the wrong direction. Try the opposite azimuth. Propagation on frequencies from the 30-meter band through 17 meters is more stable at night, with propagation following gray-line and nighttime paths.

Low-band propagation is still hot on 40 meters, with Europe in the evening and Asia in the mornings. Occasional DX openings will occur on 90 and 75 meters around sunrise.

VHF Conditions

The Lyrids meteor shower occurs in mid-April, peaking on the UTC night of April 21/22. The hourly visual meteor rate is expected to be low, with average meteor velocities of about 48 kilometers per second with broad outbursts. However, this shower's peak lasts for several days.

The debris expelled by comet Thatcher as it moves through its orbit causes the Lyrids. It is a long period comet that visits the inner solar system every 415 years or so. Despite this long period, there is activity every year at this time, so it is theorized that the comet must have been visiting the solar system for quite a long time. Over this long period, the debris left with each pass into the inner solar system has been evenly distributed along the path of its orbit.

This material isn't quite evenly distributed however, as there have been some years with outbursts of higher than usual meteor activity. The most recent of these outbursts occurred in 1982, with others occurring in 1803, 1922, and 1945. These outbursts are unpredictable, and one could occur this year. The best time to work this shower should be from midnight to early morning.

The unpredictability of the shower in any given year always makes the Lyrids worth watching, since we cannot say when the next unusual return may occur. If this year's event is average or better, this should make possible meteor-scatter type openings on the VHF bands.

A seasonal increase in sporadic-E (E_s) ionization usually begins during April and continues through the spring and summer months. Expect an increase in short-skip openings on both the 15- and 10-meter bands during April, as well as a possible occasional opening on 6 meters. While sporadic-E openings may occur at any time, they tend to peak between 8 a.m. and noon, and again between 5 and 9 p.m. local time.

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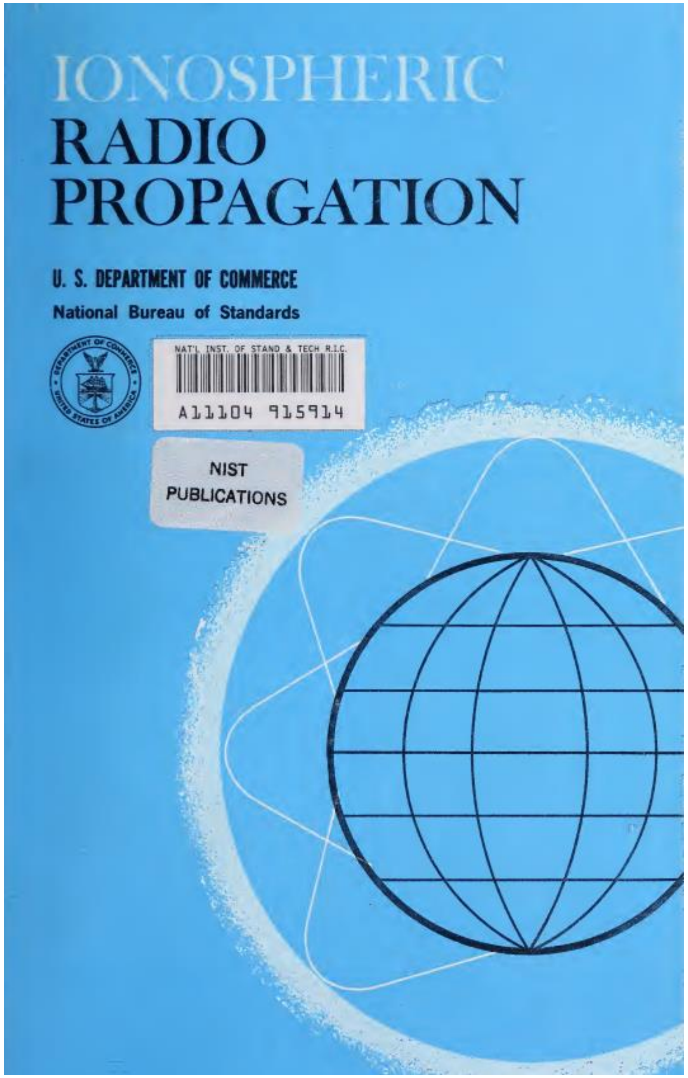
An Excellent Free Technical Reference for Scientifically Inclined Amateurs



nvlpubs.nist.gov/nistpubs/Legacy/MONO/nbsmonograph80.pdf

Why does Sporadic-E Propagation Continue to be Very Important on 6 Meters During the Solar Maximum Years?

Unless there's an unexpected major upsurge in solar cycle 25 sunspot activity (solar flux more than 200 almost every day) then reliable transatlantic F_2 propagation in not likely

Only the southern tier of the lower 48 US states has occasional direct access to F_2 trans-equatorial propagation (TEP) without an additional ionospheric hop

Almost everyone in the lower 48 US states needs an additional ionospheric hop
- usually a sporadic-E (E_s) hop
- only rarely an F_2 hop

6 Meter Sporadic-E (E_s) Propagation to/from the Lower 48 US States

E_s propagation in this presentation focuses *exclusively* on 6 meter E_s propagation to/from the lower 48 US states

- southern Canada E_s is similar but not as frequent or reliable

Southern hemisphere mid-latitude 6 meter E_s propagation is very similar in almost all respects

- it has some unique characteristics not covered in this presentation

Two other forms of 6 meter E_s propagation also have unique characteristics not covered in this presentation

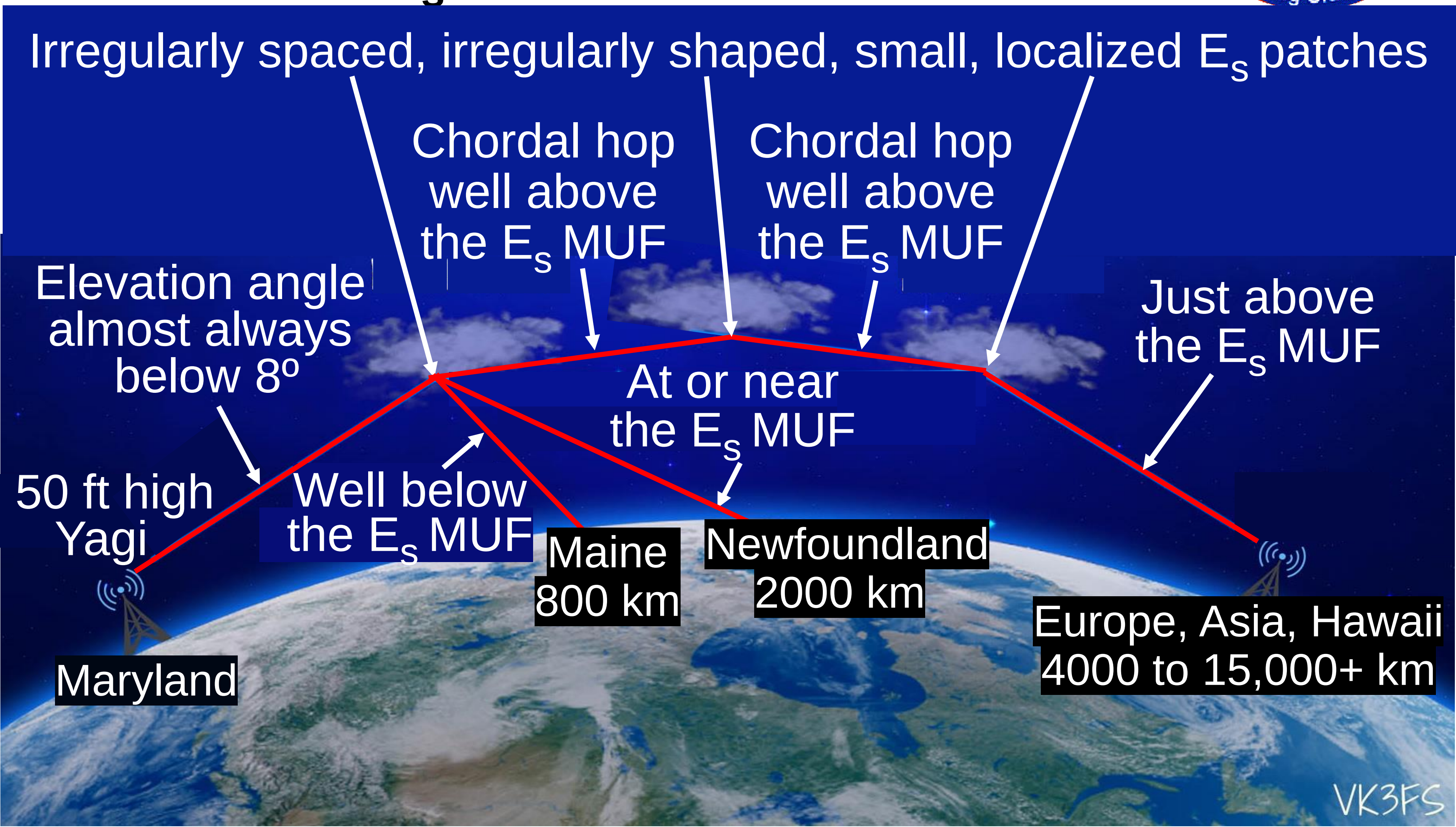
- equatorial-E propagation occurs <u>every day</u> within about 600 miles of magnetic dip equator
- auroral E_s (auroral-E) occurs mostly during severe geomagnetic storms
    - auroral E_s is NOT the same as auroral backscatter

Mid-Latitude E_s Propagation

Well below the E_s MUF: 800 to 1200 km

Near or at the E_s MUF: 1200 to 2000 km

Above the E_s MUF: 2000 to 15,000+ km



Propagation via a Single E_s Patch

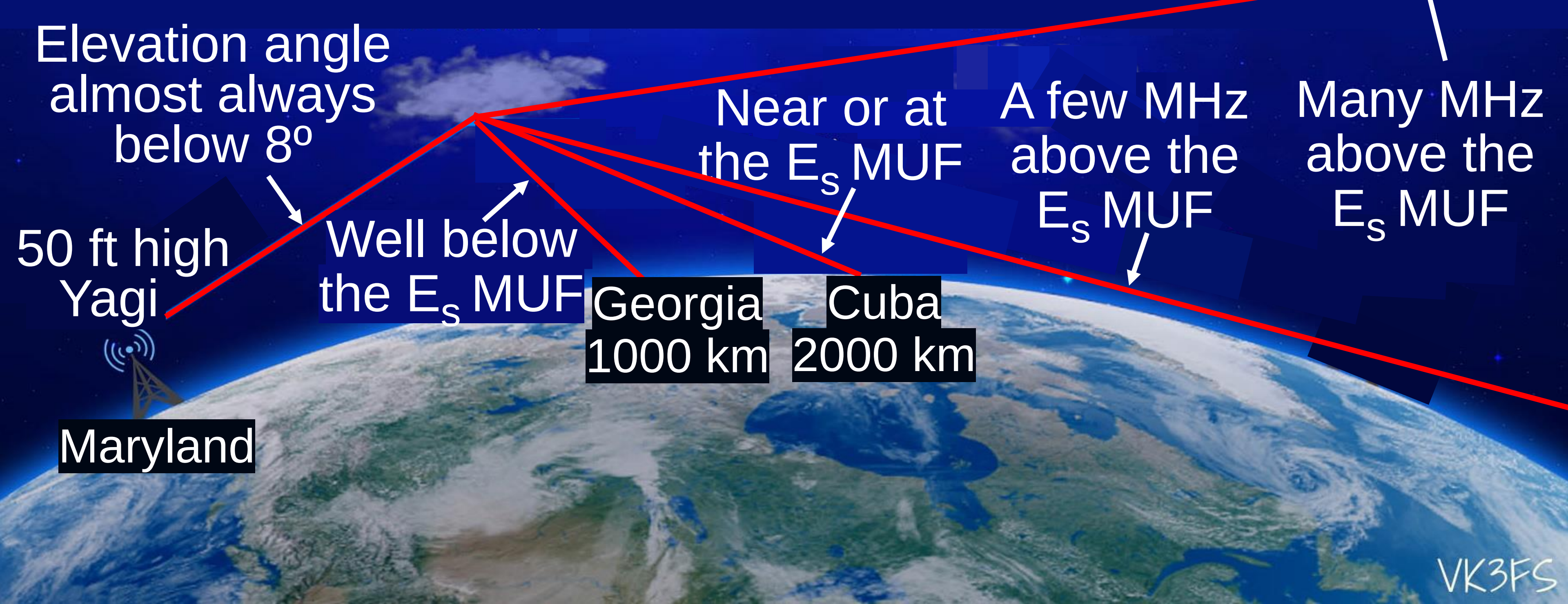
By far the most common E_s propagation

Usually about 1500 to 2000 km (1000 to 1200 miles)

Occasionally about 800 to 2400 km (500 to 1500 miles)

Below and at the MUF for reflection from one E_s ionization patch

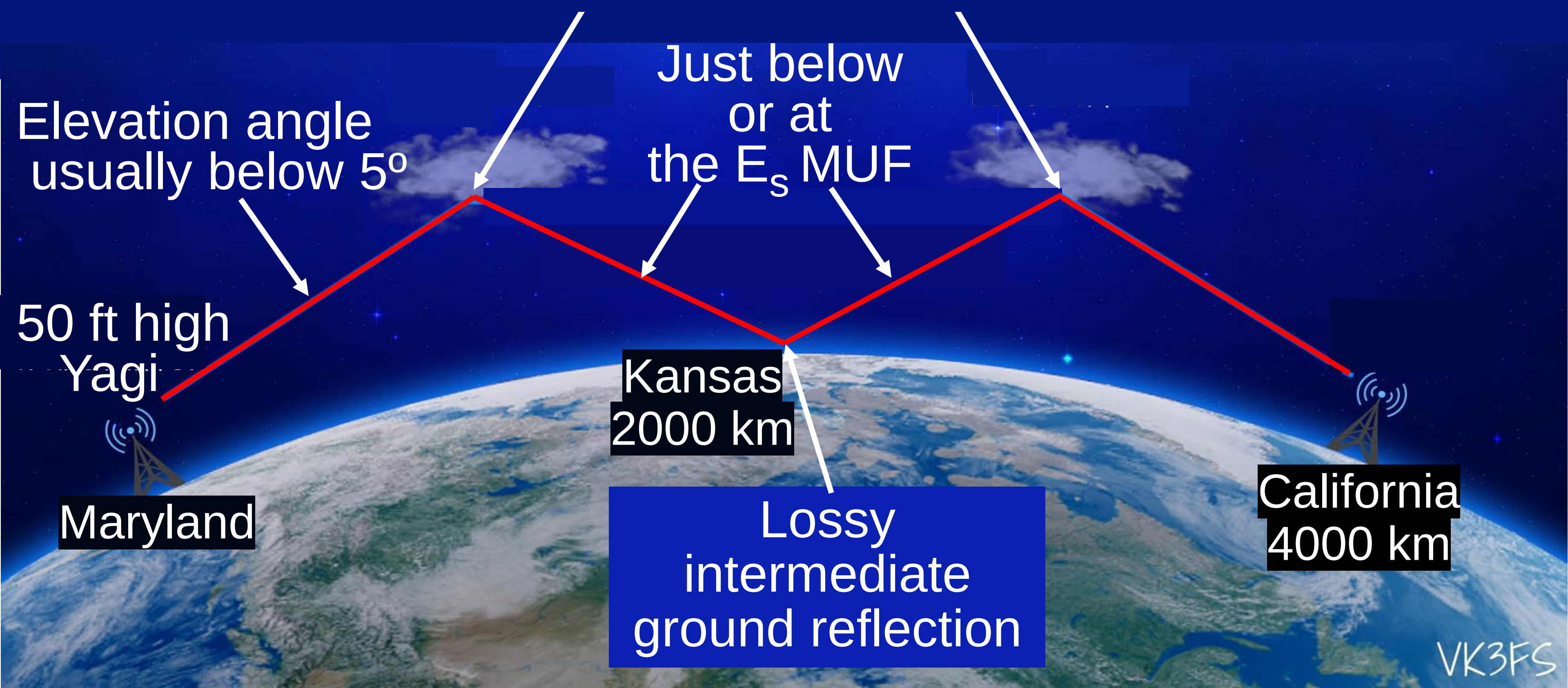
- E_s patches are about 100-115 km (60-70 miles) above the Earth
- 50 km north-south patch width but <u>usually much less</u>
- 500 km east-west patch length but <u>usually much less</u>



Simple Double Hop E_s Propagation

Usually about 2800 to 4000 km (1600-2400 miles)
Sometimes as short as 2200 km (1400 miles)
Almost every day from early June through mid-July

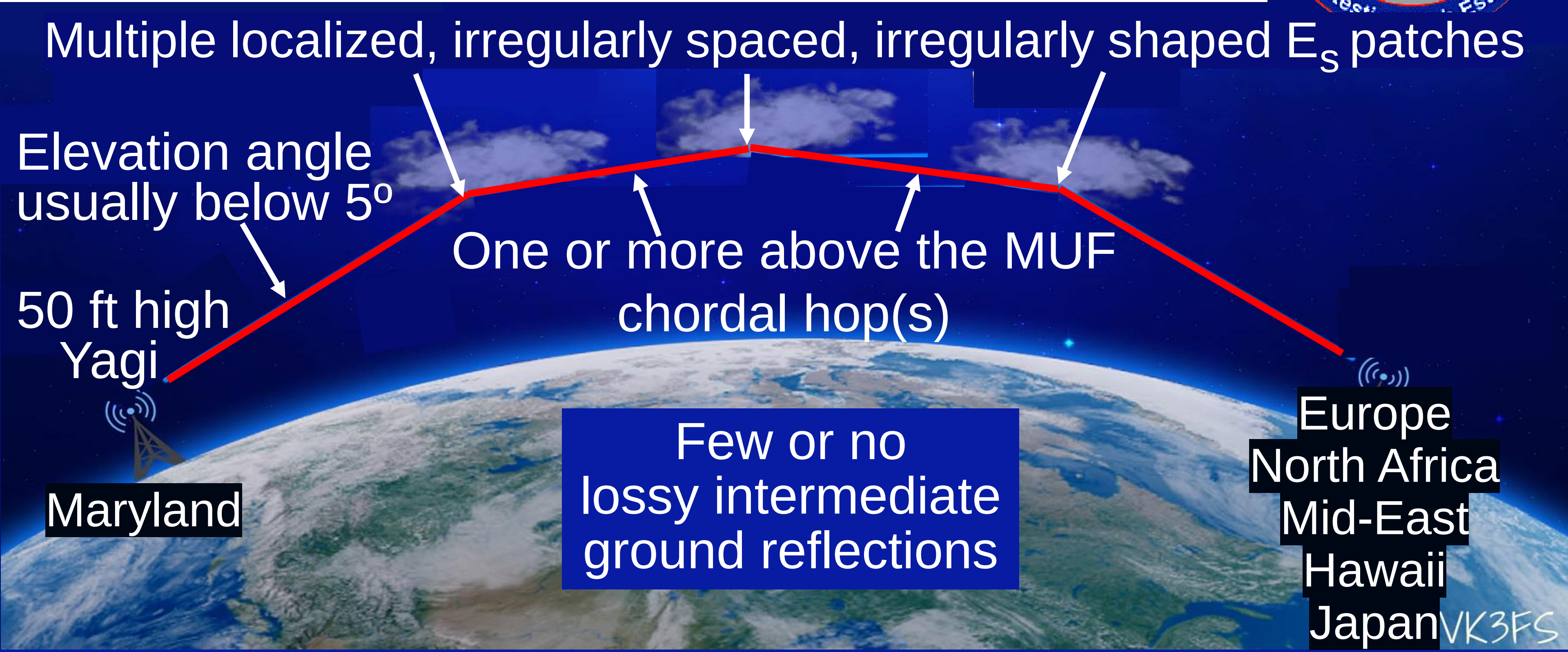
Two localized, irregularly spaced, irregularly shaped E_s patches
50 km north-south patch width but <u>usually much less</u>
500 km east-west patch length but <u>usually much less</u>



Above-the-MUF Partial Reflections via Chordal Hops between E_s Patches

2200 km (1400 miles) to 15,000+ km (9000+ miles)

Occurs frequently from early June to mid-July

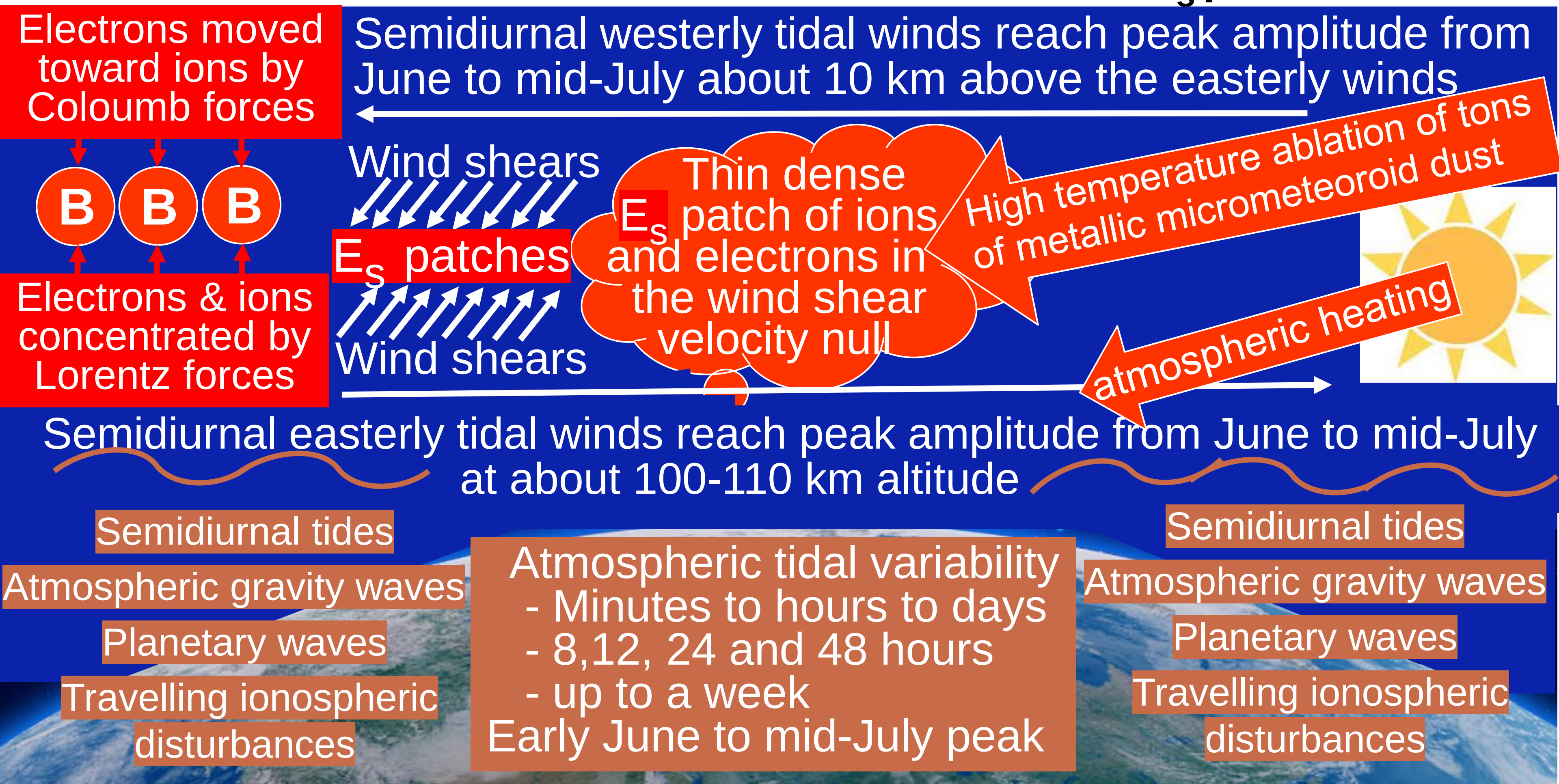


E_s ionization patches are frequently capable of efficient above-the-MUF partial reflection at higher frequencies than reflections returning to Earth

Partial reflections may propagate between two or more E_s ionization patches via chordal hops with no lossy intermediate ground reflections

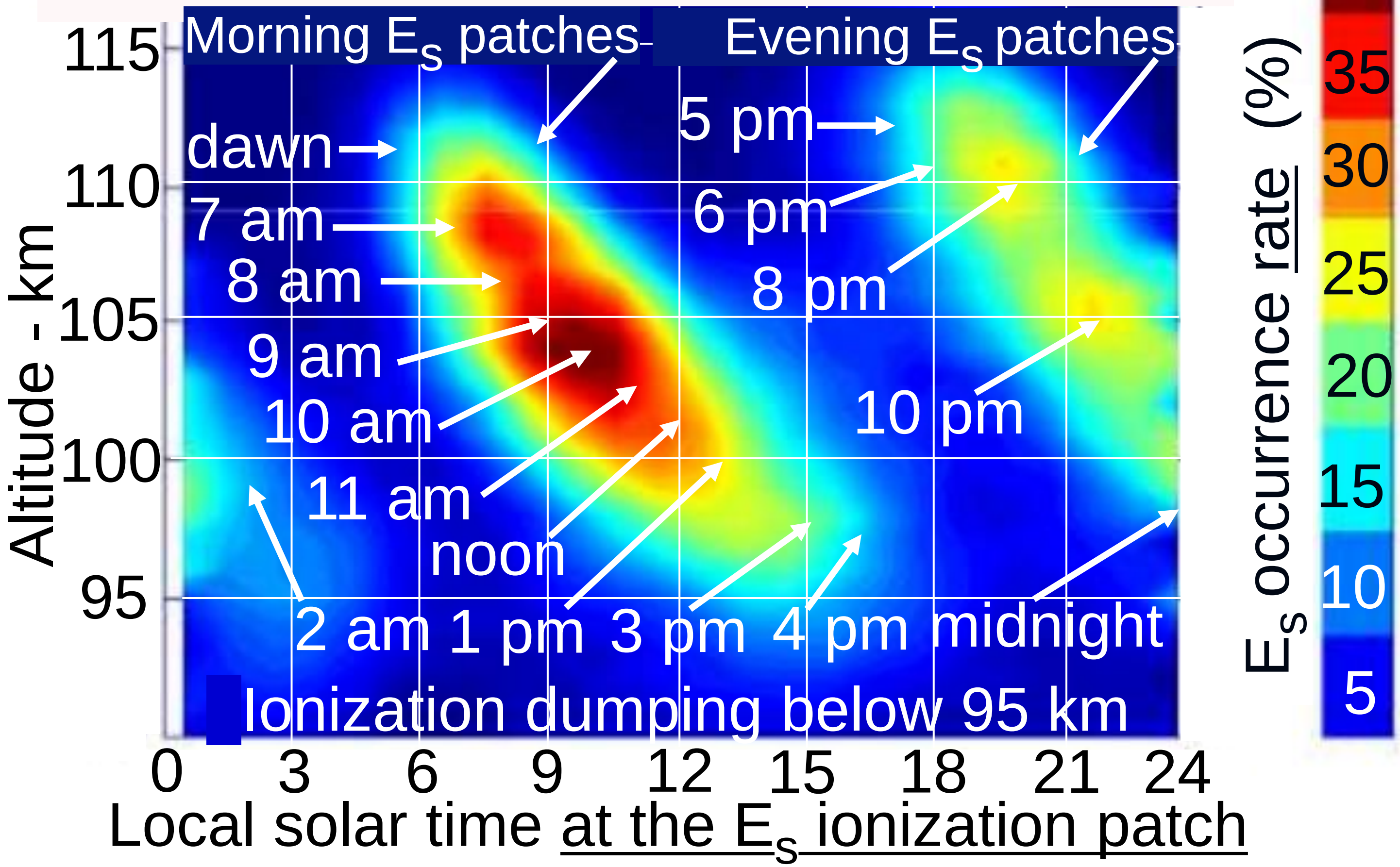
Why is Mid-Latitude E_s Very Different?

High temperature ablation ionizes the daily influx of many tons of metallic meteoroid dust. Vertical wind shears between east/west semidiurnal winds concentrate ions into dense patches. Coloumb forces move electrons toward positive charged ions. Lorenz forces concentrate electrons and ions into dense E_s patches.



researchgate.net/publication/227207773_A_Tutorial_Review_on_Sporadic_E_Layers

Observed Semidiurnal Variability of June-July E_s Patch Occurrence Rate at 50° to 55° North Latitude



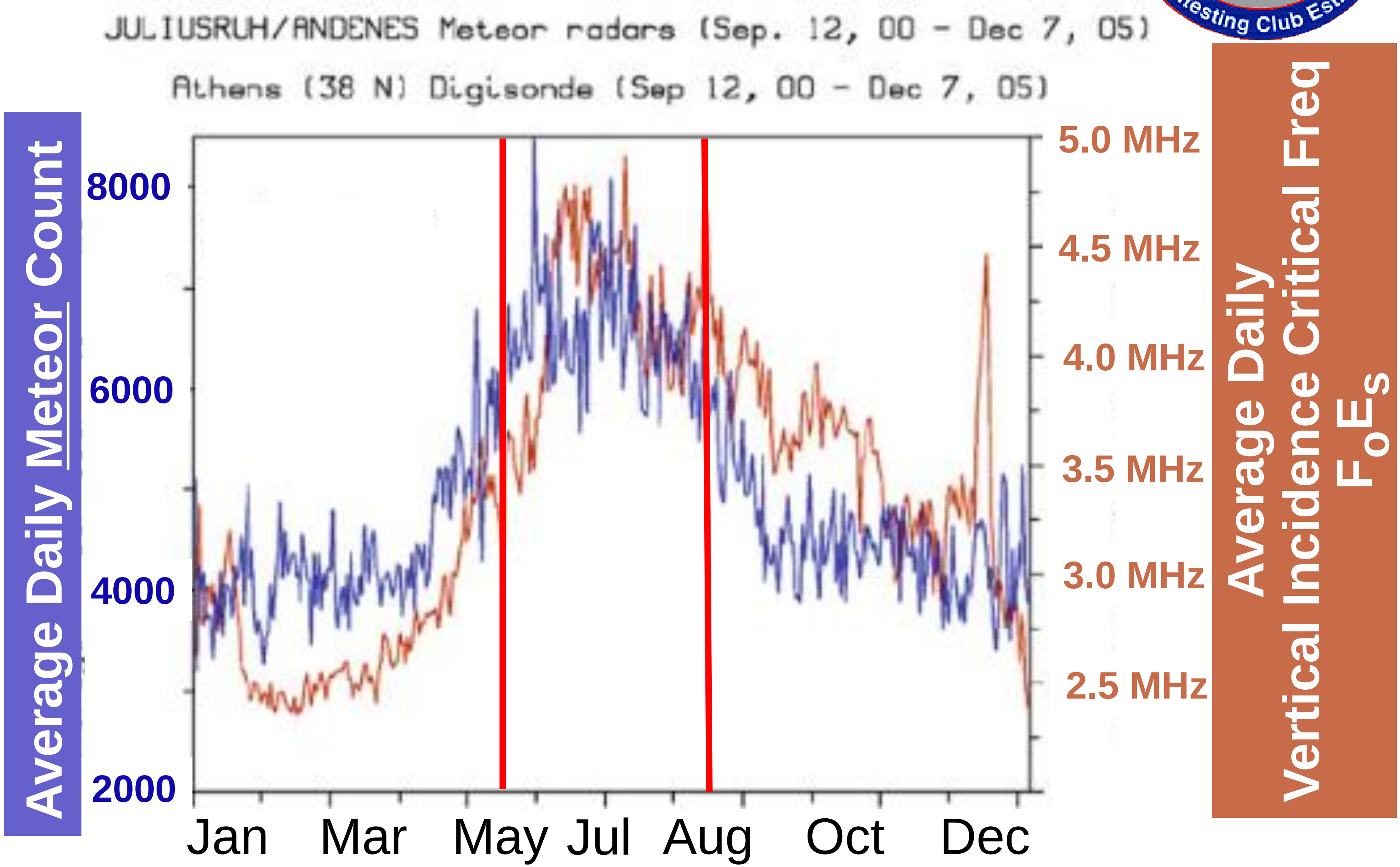
E_s becomes less and less frequent after mid-July and vanishes almost completely by mid-August

12 hour variability of June-July E_s *occurrence rate* is caused by the downward drift of semidiurnal tidal winds towards the D region.

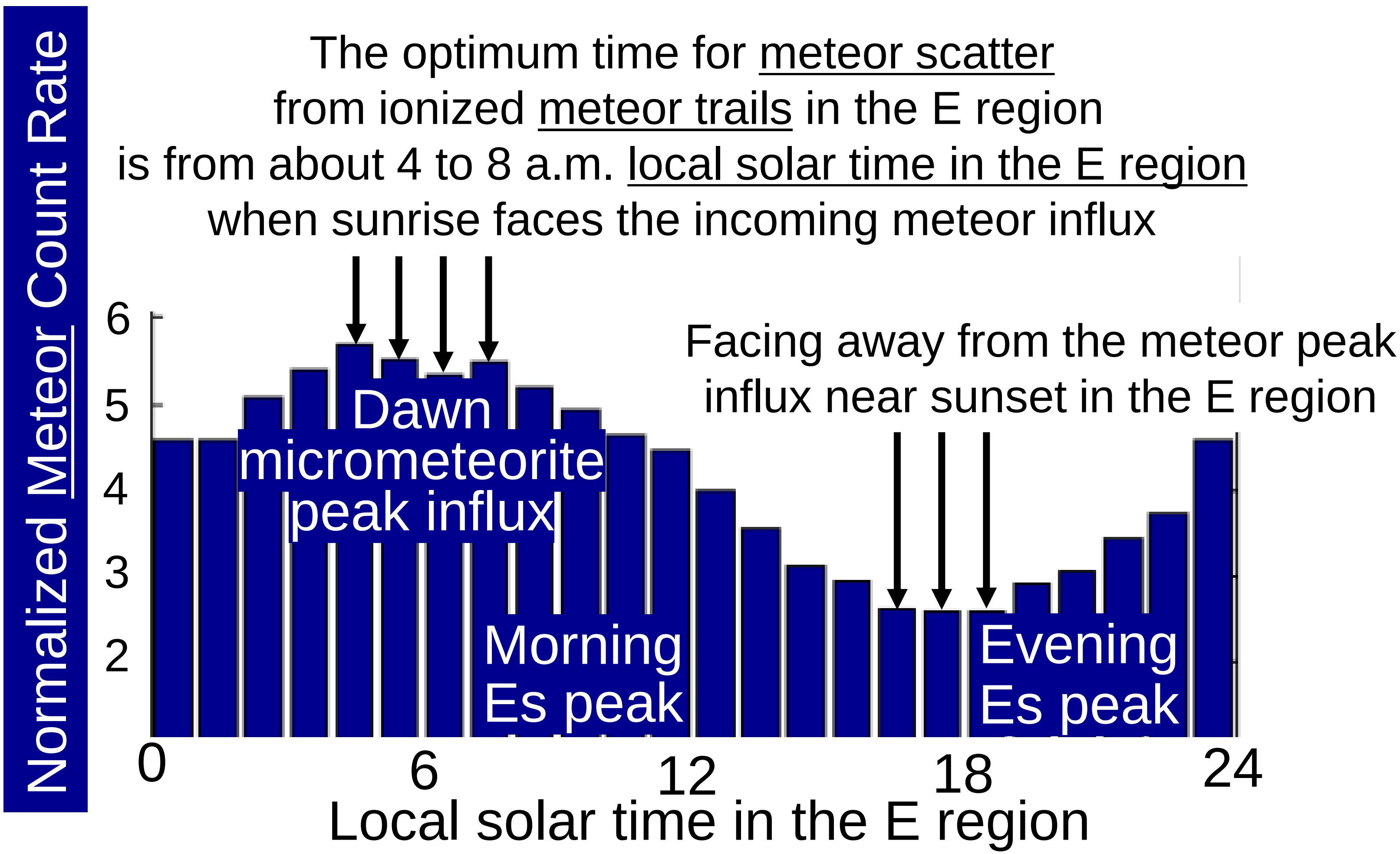
E_s is most frequent from 7 a.m to 1 p.m. local solar time at the patch

Image credit: GFZ German Research Centre for Geosciences

Increased Meteor Count at Northern Latitudes from Mid-May to Mid-August Correlates to Increased E_s Vertical Incidence Critical Frequency



In the thin E region, heavy metallic ions recombine much more slowly than lighter atmospheric gas ions and persist <u>for many hours to a day or more</u> after the dawn peak micrometeoroid influx and the morning E_s peak



Easily Observable **Basic Characteristics** of Mid-Latitude 6 Meter E_s Propagation

Spotlight propagation	~ 50 to 300 mile east-west width ~ 50 mile north-south width
MUFs	>50 MHz MUFs every day in June and July **-- but not everywhere and every day**
4000 to 15,000+ km propagation	Many days from early June to mid-July - a few days in late May and early August - a few days in late December/early January
Azimuth to DX target	True great circle azimuth, rarely skewed
Preferred antenna	3 to 6 (or more) element horizontal Yagi
Preferred polarization	Horizontal polarization is strongly preferred
Optimum heights	50 to 60 feet (70 feet only for DX)
Compromise height can be degraded by dense housing and dense forests within 1500 feet	25 feet: only about 3 dB worse at 1000 km about 6 dB worse beyond 2000 km compared to optimum 50 foot height

Easily Observable Extreme Variability of Mid-Latitude E_s Patch Occurrence Rates and Locations

Seasonal variability of E_s occurrence rate	Every day during June and July **- but not everywhere and every day** Many days during late May and early August Some days in December, January and April Uncommon in February (+/-) and September (+/-)
Daily occurrence	Dawn until 2 a.m. local solar time at the E_s patch
Daily maximum occurrence rate	7 a.m. to 1 p.m. local solar time at the E_s patch June-July peak rate is from 9 a.m. to noon
Short term variability	E_s varies from seconds to minutes to hours
South to north drift	E_s drifts south to north along magnetic field lines
East/West extent	E_s patches form along east-west zonal winds
E_s patch locations	E_s locations vary in seconds to minutes to hours
Day-to-day variability	Extreme E_s occurrence and location variability
Morning-to-evening	Extreme E_s occurrence and location variability

6 Meter F_2 Propagation
-- Its Not What You Think It Is --

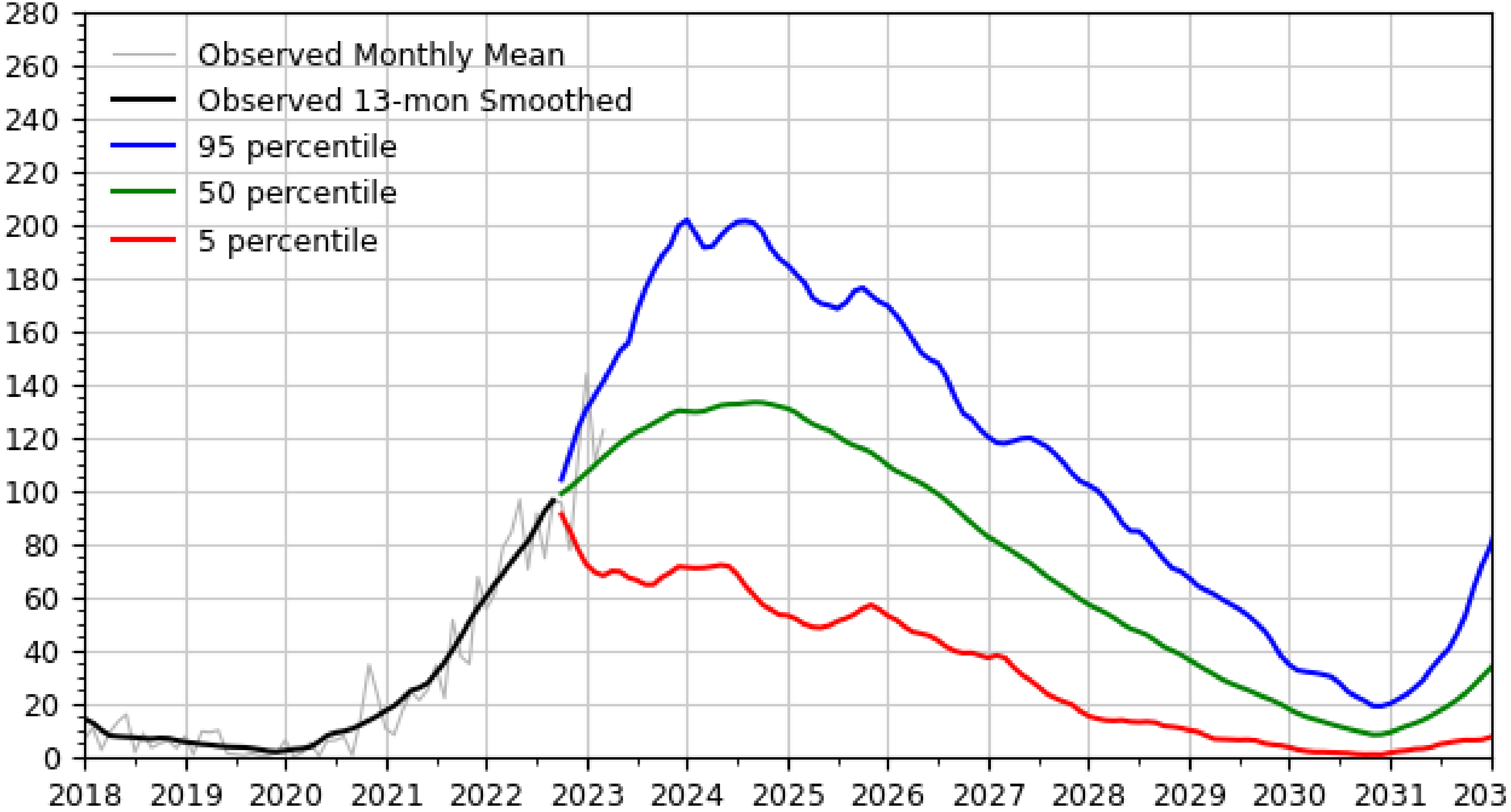
Reliable transatlantic and transpacific F_2 propagation **is not likely** unless there's an unexpected major upsurge in solar cycle 25 sunspot activity
- the solar flux index must exceed 200 almost every day

E_s will continue to support frequent propagation to Europe, north Africa, the Mideast and Asia from early June to mid-July

F_2 trans-equatorial propagation (TEP) and TEP-related F_2 propagation became much more frequent in 2022 and 2023
- caused by increased solar cycle 25 sunspot activity

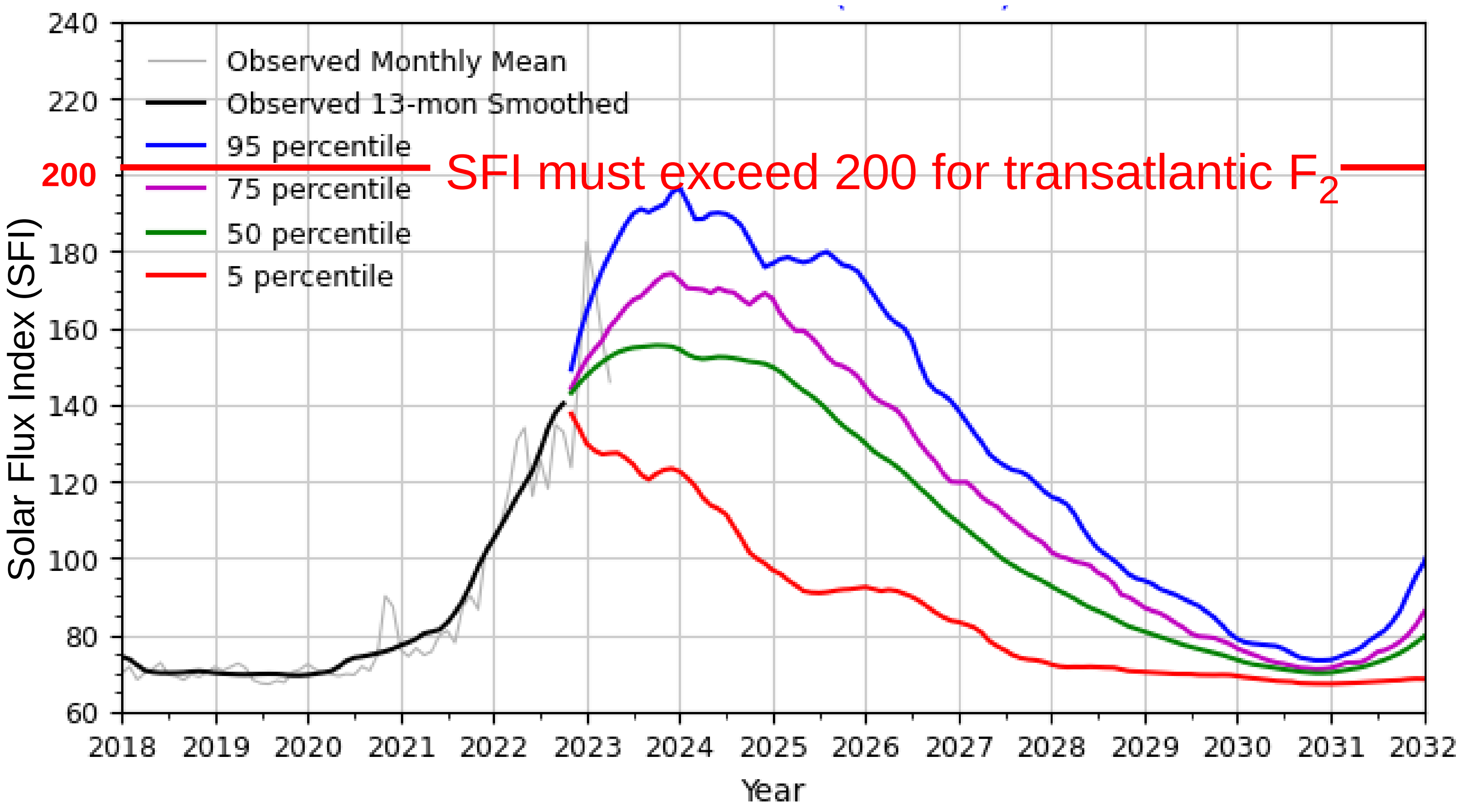
TEP will continue to occur frequently through at least 2026
- TEP occurs sporadically and not every day, very similar to E_s
- north-south TEP to the southern cone of South America
- less frequent east-west oblique-TEP to the south Pacific
- occasional TEP-related propagation to equatorial Africa

Solar Cycle 25 Smoothed Sunspot Number Forecast NASA Marshall Space Flight Center – 9 May 2023



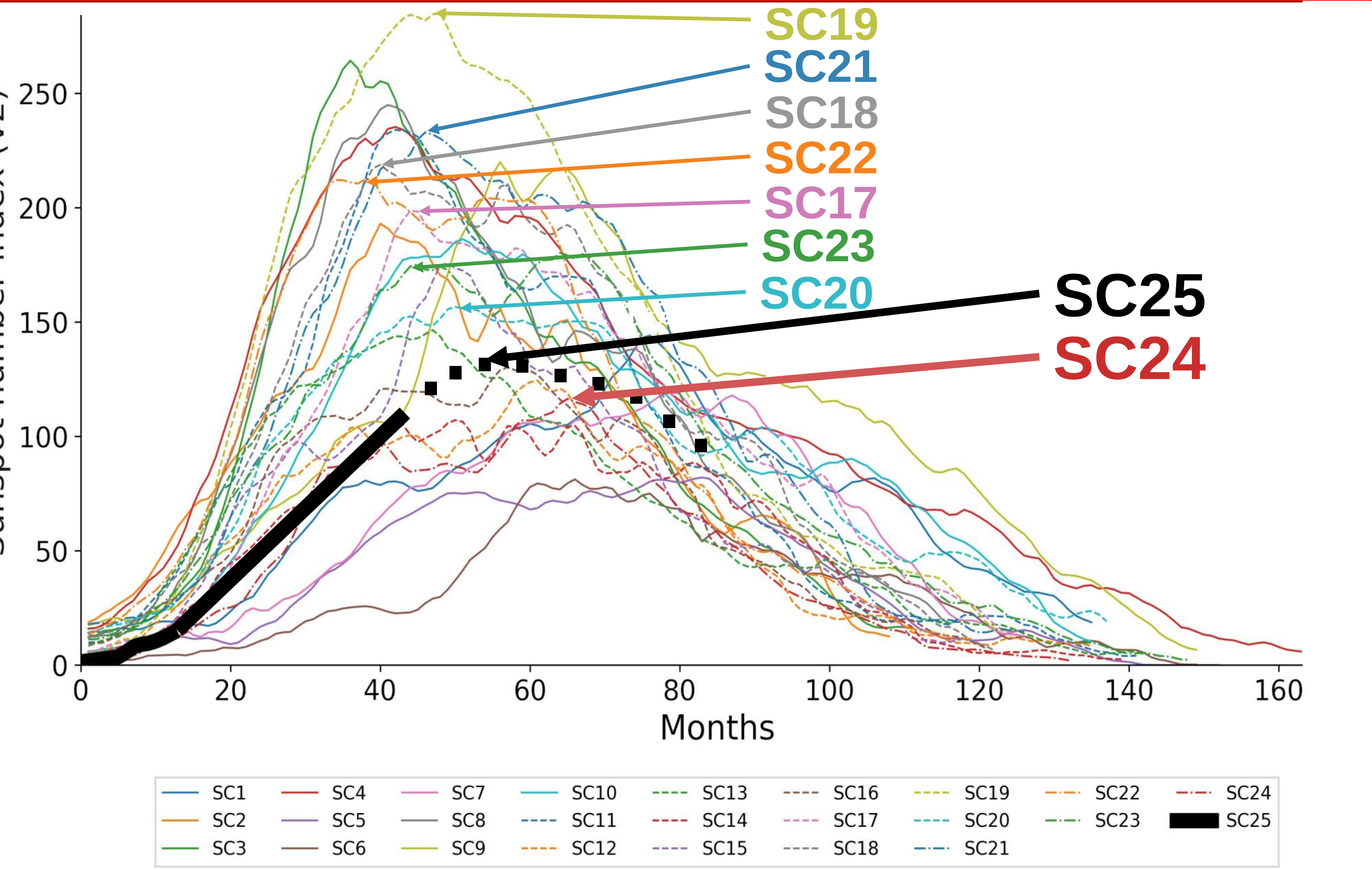
www.nasa.gov/msfcsolar

Solar Cycle 25 Solar Flux Index Forecast
NASA Marshall Space Flight Center – 9 May 2023



www.nasa.gov/msfcsolar

Solar Cycles 24 and 25 Sunspot Activity Increased Much More Slowly Than Stronger Cycles 17 to 23



6 Meter F_2 Trans-Equatorial Propagation (TEP) to/from the Lower 48 US States

TEP propagation in this presentation focuses *exclusively* on propagation to/from the lower 48 US states

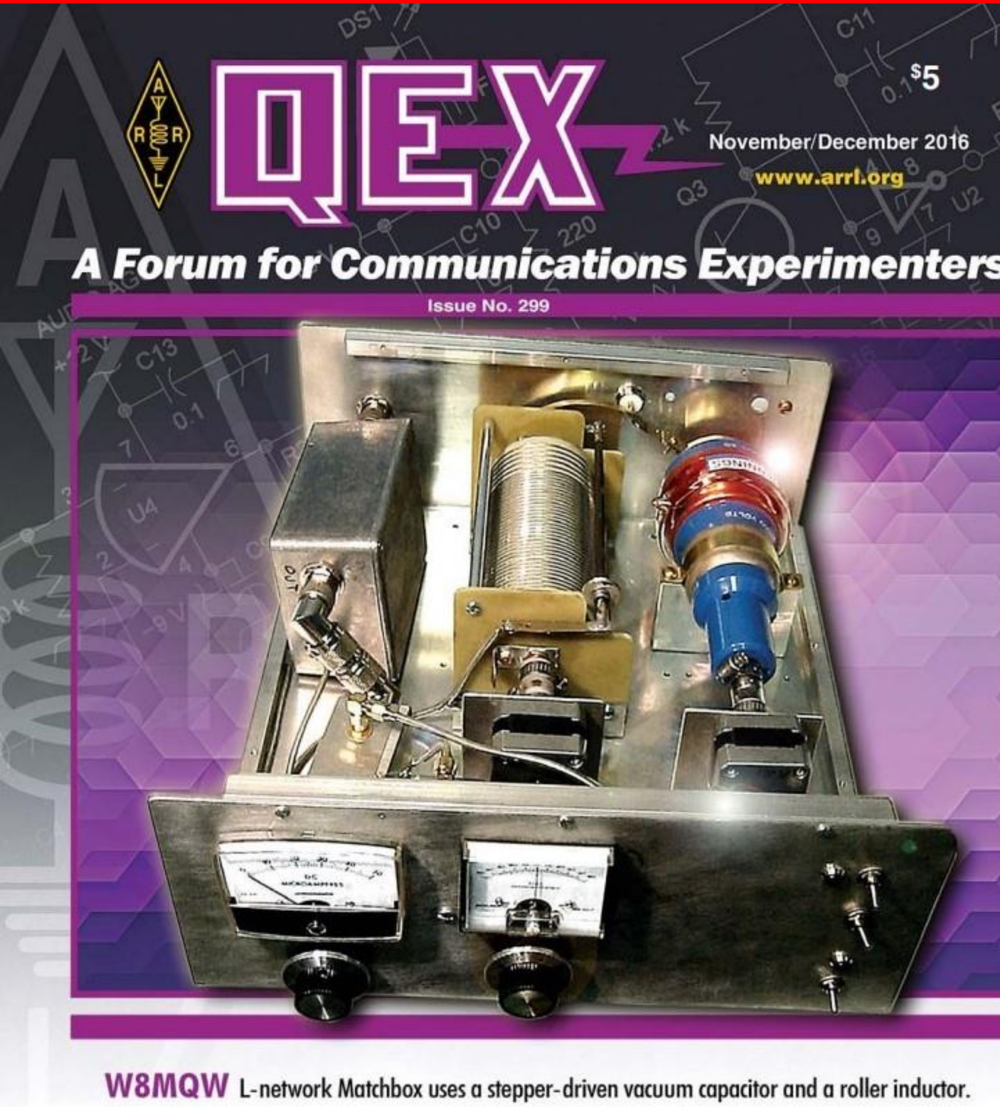
TEP propagation much above the F_2 MUF occurs sporadically
- similar to the sporadic minutes-to-hours behavior of E_s

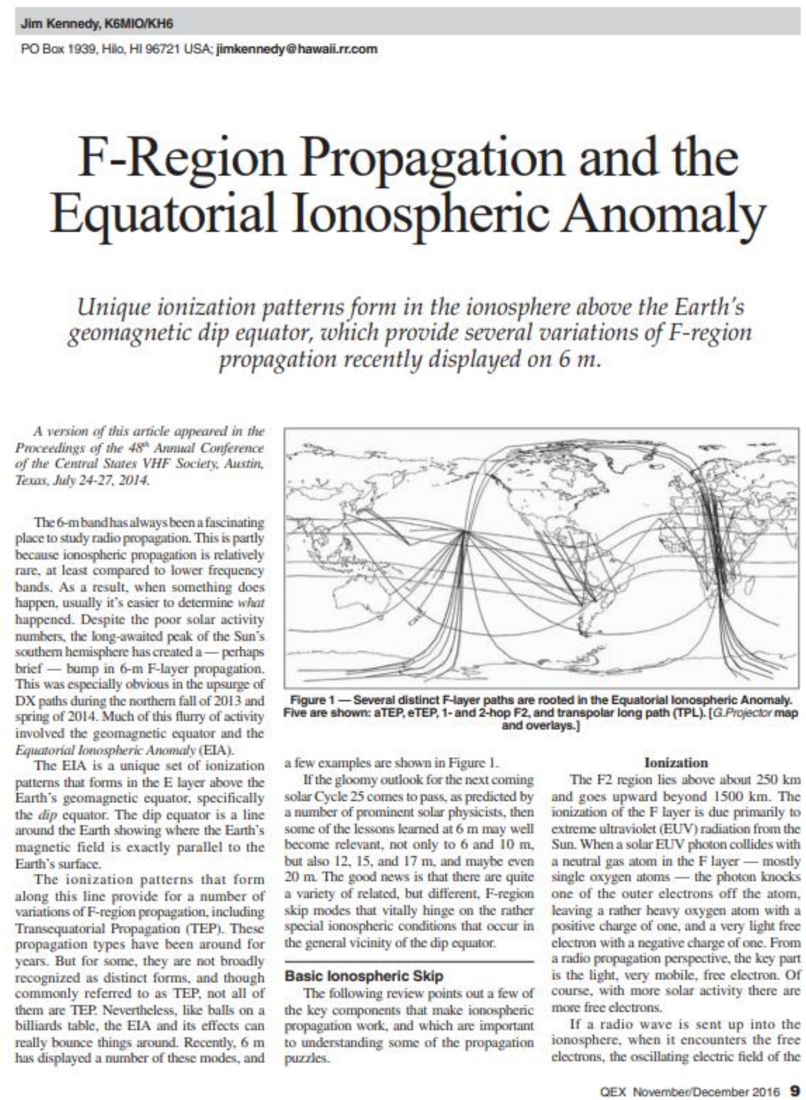
E_s hops linking southern Canada to TEP are not as reliable as in most of the lower 48 US states

TEP propagation to/from the Caribbean is greatly enhanced
- its unique characteristics are not covered in this presentation

TEP propagation to/from Europe and Japan is similar in most respects to TEP to/from the lower 48 US states
- its unique characteristics are not covered in this presentation
- southern Europe does not require an E_s hop to link into TEP
- southern Japan does not require an E_s hop to link into TEP

One of the Most Useful Articles About F_2 Trans-Equatorial Propagation





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F-Region Propagation and the Equatorial Ionospheric Anomaly

Unique ionization patterns form in the ionosphere above the Earth's geomagnetic dip equator, which provide several variations of F-region propagation recently displayed on 6 m.

A version of this article appeared in the Proceedings of the 48th Annual Conference of the Central States VHF Society, Austin, Texas, July 24-27, 2014.

The 6-m band has always been a fascinating place to study radio propagation. This is partly because ionospheric propagation is relatively rare, at least compared to lower frequency bands. As a result, when something does happen, usually it's easier to determine *what* happened. Despite the poor solar activity numbers, the long-awaited peak of the Sun's southern hemisphere has created a — perhaps brief — bump in 6-m F-layer propagation. This was especially obvious in the upsurge of DX paths during the northern fall of 2013 and spring of 2014. Much of this flurry of activity involved the geomagnetic equator and the *Equatorial Ionospheric Anomaly* (EIA).

The EIA is a unique set of ionization patterns that forms in the E layer above the Earth's geomagnetic equator, specifically the *dip* equator. The dip equator is a line around the Earth showing where the Earth's magnetic field is exactly parallel to the Earth's surface.

The ionization patterns that form along this line provide for a number of variations of F-region propagation, including Transequatorial Propagation (TEP). These propagation types have been around for years. But for some, they are not broadly recognized as distinct forms, and though commonly referred to as TEP, not all of them are TEP. Nevertheless, like balls on a billiards table, the EIA and its effects can really bounce things around. Recently, 6 m has displayed a number of these modes, and a few examples are shown in Figure 1.

Figure 1 — Several distinct F-layer paths are rooted in the Equatorial Ionospheric Anomaly. Five are shown: aTEP, eTEP, 1- and 2-hop F2, and transpolar long path (TPL). [*G.Projector* map and overlays.]

If the gloomy outlook for the next coming solar Cycle 25 comes to pass, as predicted by a number of prominent solar physicists, then some of the lessons learned at 6 m may well become relevant, not only to 6 and 10 m, but also 12, 15, and 17 m, and maybe even 20 m. The good news is that there are quite a variety of related, but different, F-region skip modes that vitally hinge on the rather special ionospheric conditions that occur in the general vicinity of the dip equator.

Basic Ionospheric Skip

The following review points out a few of the key components that make ionospheric propagation work, and which are important to understanding some of the propagation puzzles.

Ionization

The F2 region lies above about 250 km and goes upward beyond 1500 km. The ionization of the F layer is due primarily to extreme ultraviolet (EUV) radiation from the Sun. When a solar EUV photon collides with a neutral gas atom in the F layer — mostly single oxygen atoms — the photon knocks one of the outer electrons off the atom, leaving a rather heavy oxygen atom with a positive charge of one, and a very light free electron with a negative charge of one. From a radio propagation perspective, the key part is the light, very mobile, free electron. Of course, with more solar activity there are more free electrons.

If a radio wave is sent up into the ionosphere, when it encounters the free electrons, the oscillating electric field of the

http://www.oh3ac.fi/QEX-2016-11.pdf

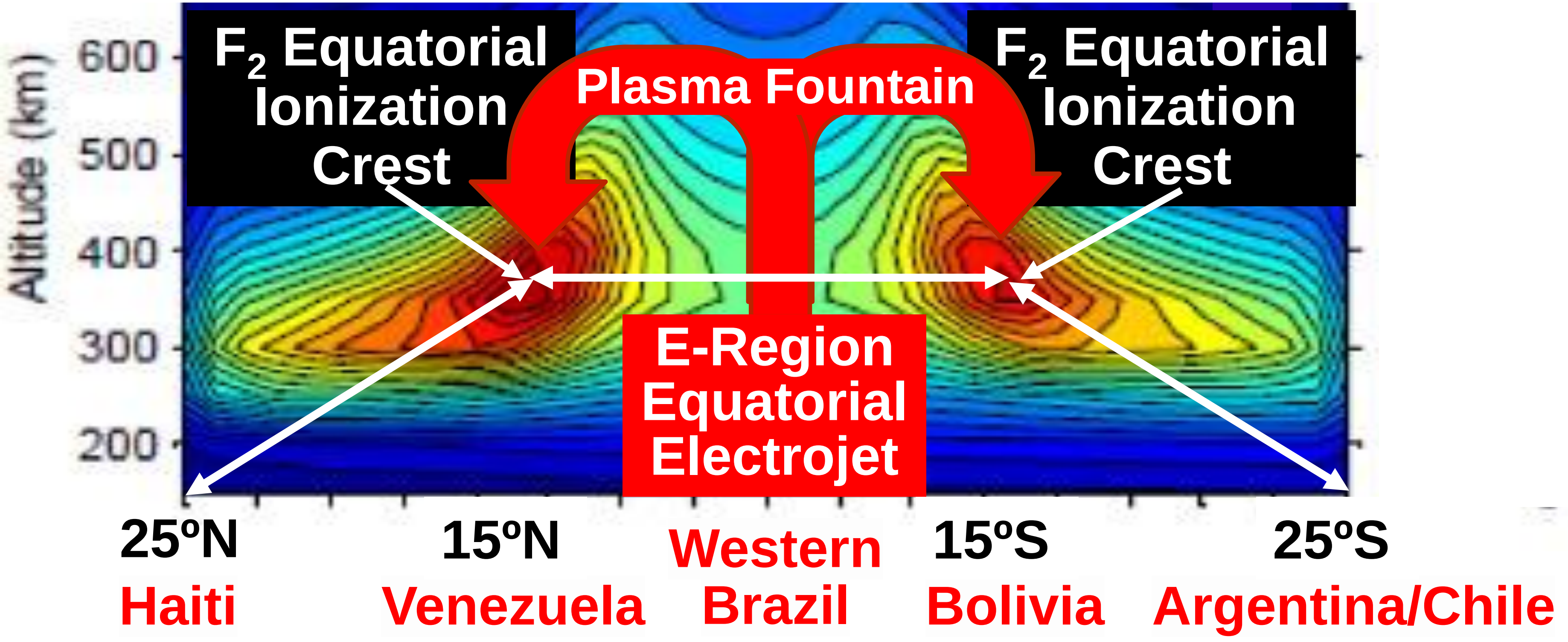
6 Meter Trans-Equatorial Propagation (TEP) via the F_2 Equatorial Ionization Crests

The longest duration and most frequent TEP usually occurs during March - shorter duration and less frequent during April, May and October

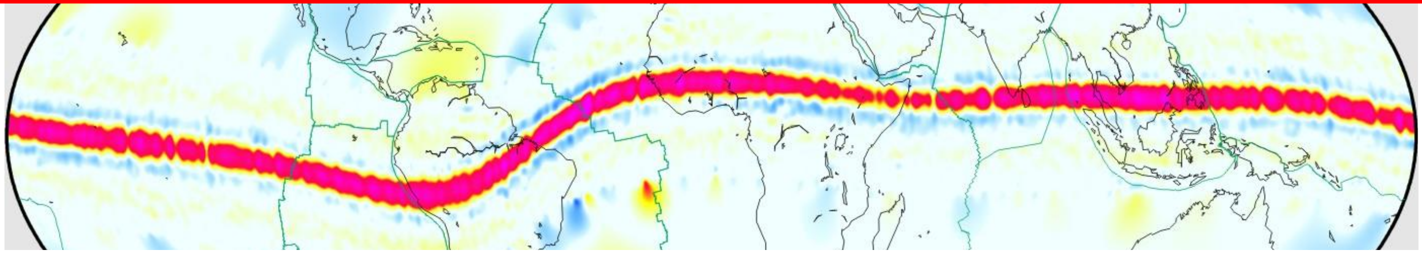
Occurs most frequently from 1500 to 1900 local solar time at the crests

Longest duration and most frequent propagation is between locations 2000 to 2400 miles north and south of the ***magnetic*** **dip equator**

Stations in the 48 states need an additional E_s or F_2 hop to link to TEP



E Region Equatorial Electrojet Peak Current Density is from 1100 to 1300 Local Solar Time Everywhere on the Magnetic Dip Equator



Neutral winds in the E region start at sunrise and continue until sunset
- under the strong influence of **extremely variable** atmospheric tides with **longitudinal and time** variability (minutes, hours, days to many days)
- sets up an electric field that forms the **Daytime Dynamo Current System**

The daytime enhanced electric field in the E region together with Earth's horizontal magnetic field perpendicular to the magnetic dip equator causes upward drift of electrons and ions in the E region at about 70 MPH creating:
- negative electric charge at the top of the E region, and
- positive electric charge at the bottom of the E region
- similar to formation of negative/positive charge in thunderstorm clouds

The opposing E region electric charges produce strong west-to-east electric current flow within about 150 miles of the magnetic dip equator in the E region at 100-110 km altitude called the **Equatorial Electrojet**

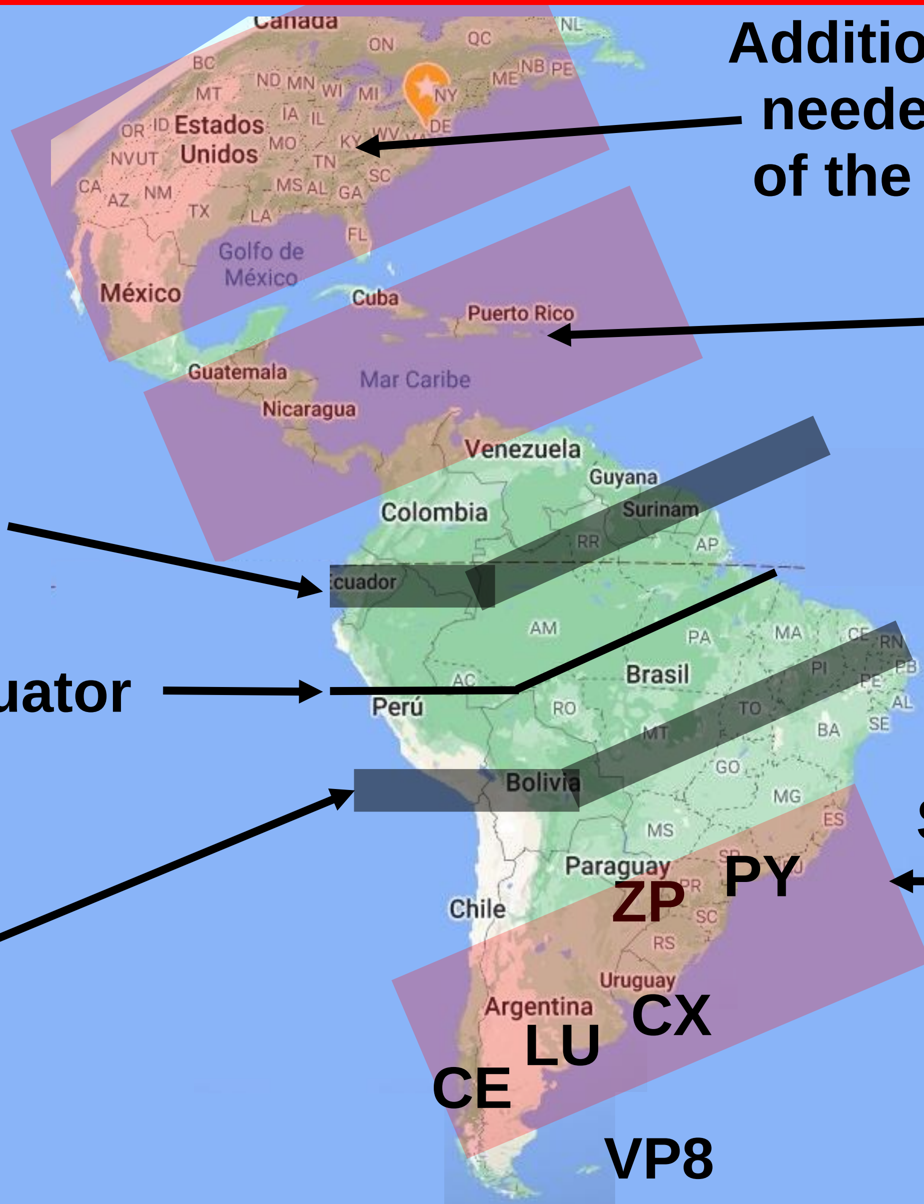
F_2 Trans-Equatorial Propagation to/from the Southern Cone of South America

Additional E_S or F_2 hop needed to/from most of the lower 48 states

Caribbean TEP Zone

Northern F_2 Equatorial Ionization Crest

Magnetic Dip Equator



South American TEP Zone

Southern F_2 Equatorial Ionization Crest

F_2 Propagation to/from the Equatorial Region of South America is Enhanced by the Northern Ionization Crest

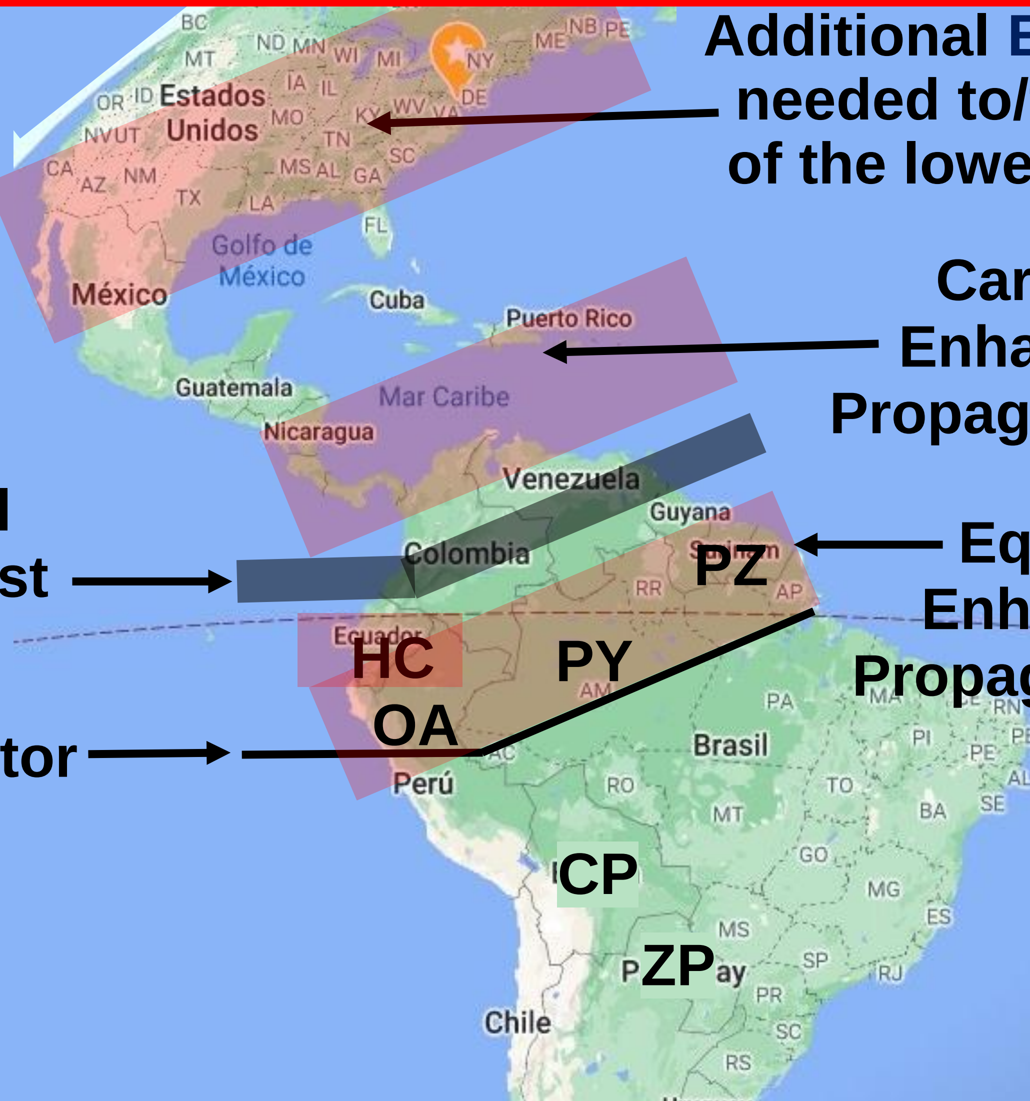
Additional E_s or F_2 hop needed to/from most of the lower 48 states

Caribbean Enhanced F_2 Propagation Zone

Northern F_2 Equatorial Ionization Crest

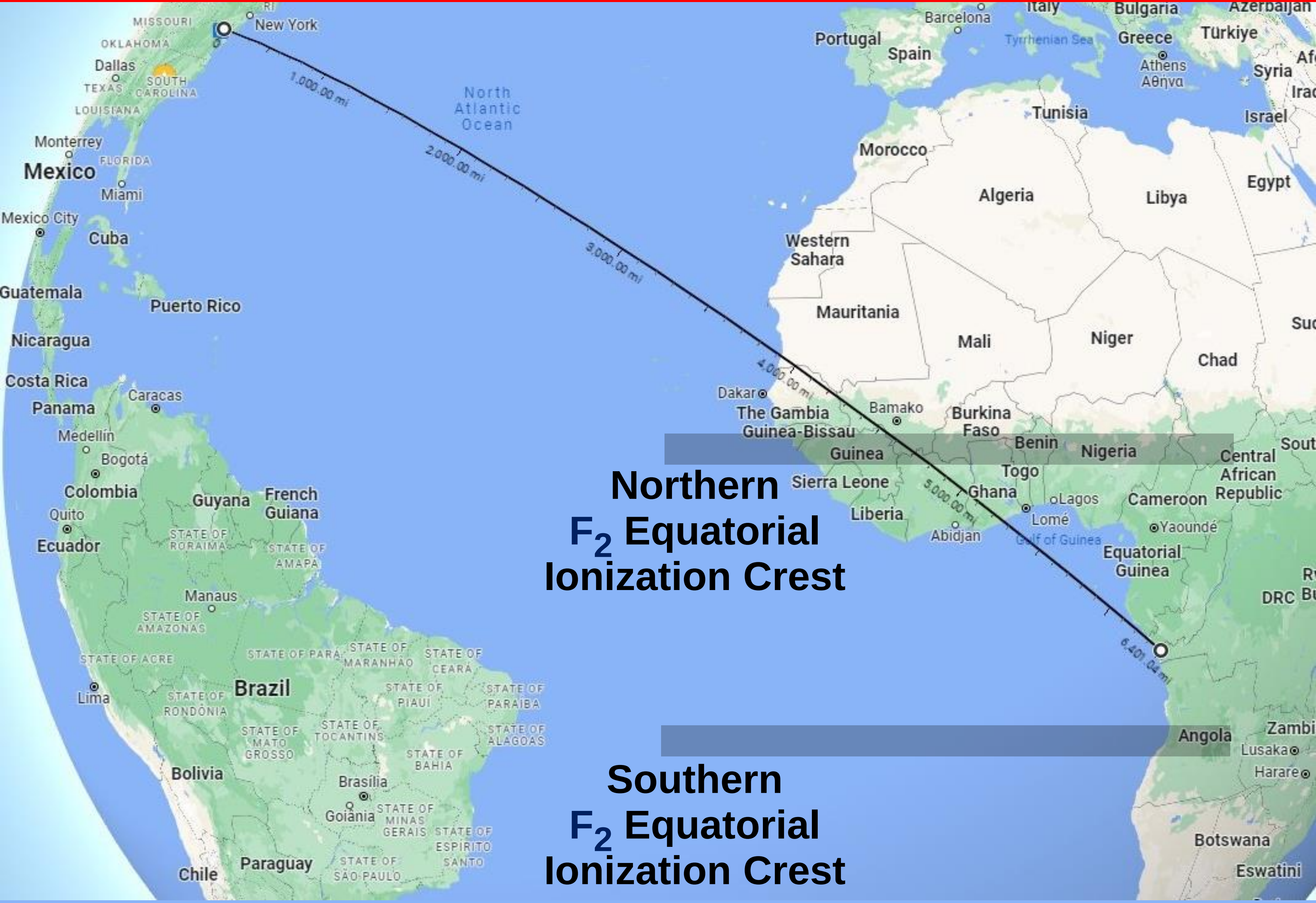
Equatorial Enhanced F_2 Propagation Zone

Magnetic Dip Equator



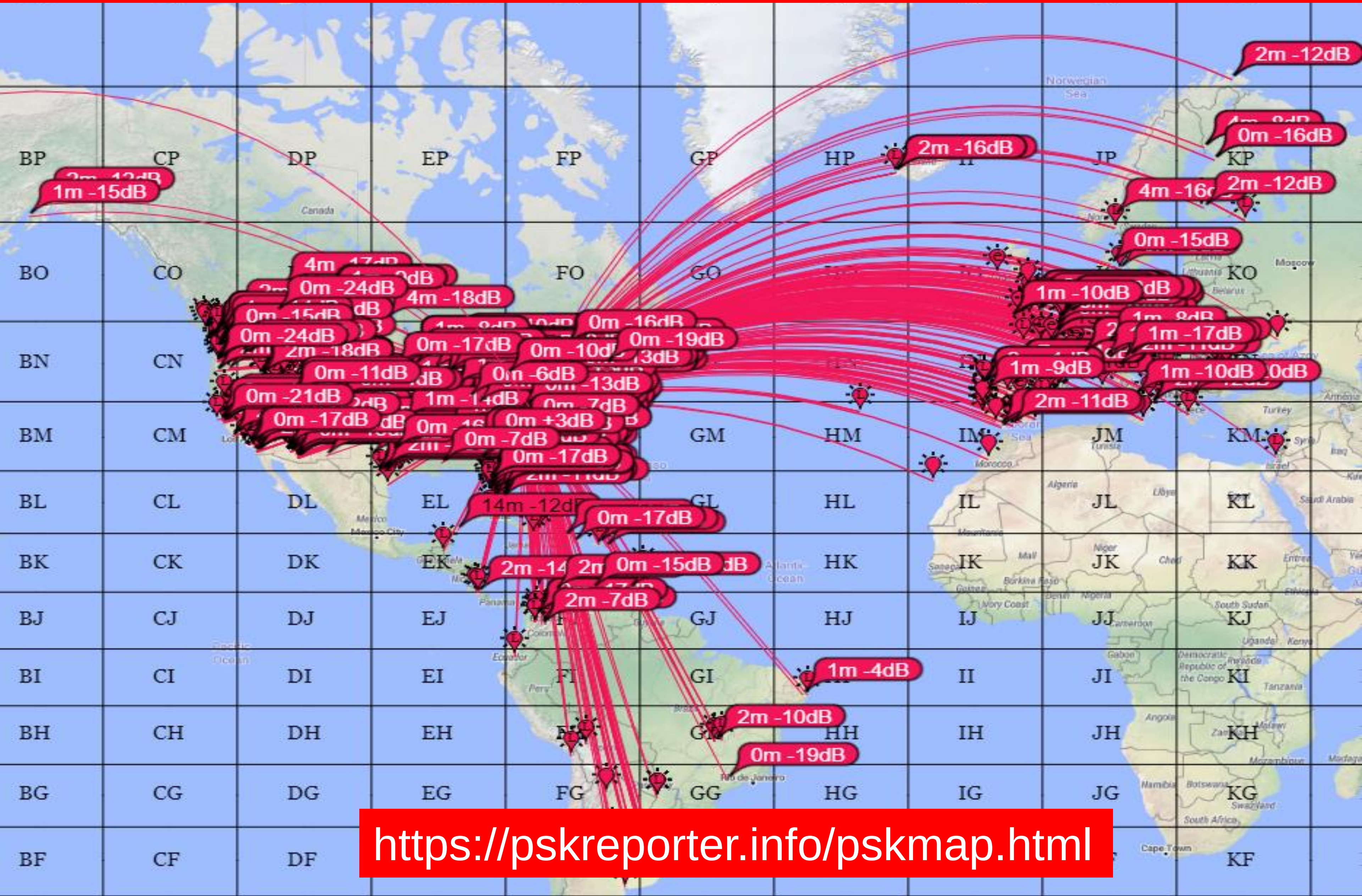
W3LPL 6 Meter Oblique-TEP QSO with 3D2AG

W3LPL 6 Meter Enhanced F_2 QSO with D2UY



Nowcasting using PSK Reporter

20 Meters Worldwide PSK heard in North America 2200Z



https://pskreporter.info/pskmap.html

6 Meter TEP without E_s Hops