Amateur Radio Observations and The Science of Midlatitude Sporadic E

Joe Dzekevich, K1YOW

K1YOW@ARRL.NET

Outline

1. Introduction
2. What Started This Investigation?
3. Causes of Sporadic E (Es)
4. Es and 6M Low Pressure Observations using Amateur Radio
5. Winter Es-Like Observations
6. Conclusions and Observations
7. Biography
8. References

K1YOW

Joe Dzekevich, FN42, Harvard, MA, USA

Retired Reliability Engineering Fellow

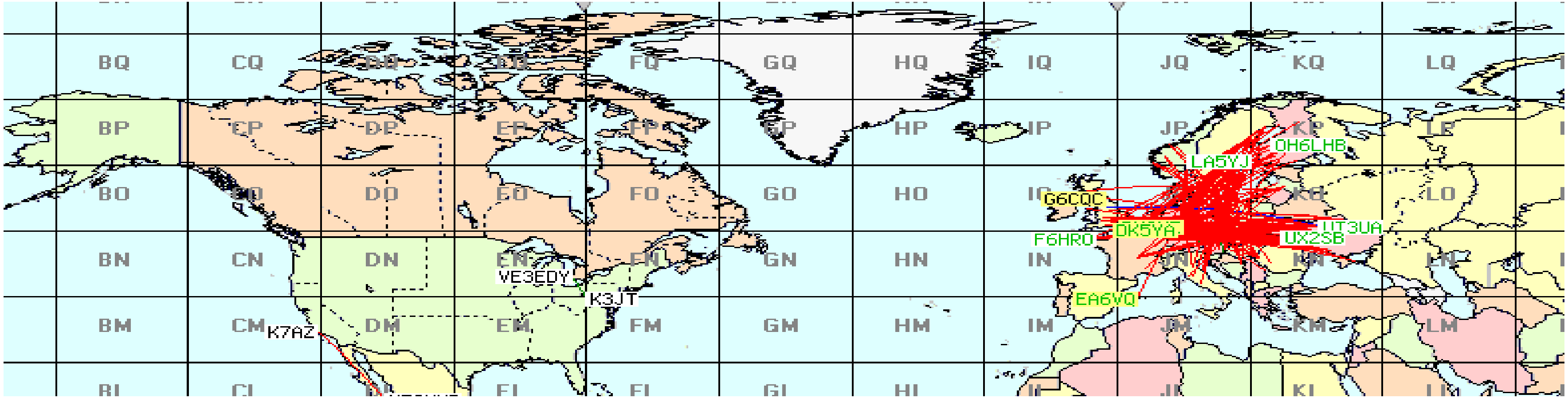
Licensed in 1962

Station is modest: TS-950SG or IC-746-PRO, 100W, into a 7 band OCF dipole (added a VHF/UHF LP antenna late 2017)

Interests: Propagation (Es, F2, Geomagnetic Storms, PCA, Tropo Ducts, Gray Line, Auroras), Astronomy, Science

Used CRPL Predictions way back in the 60's.

What Started This Investigation?



Typical 6M Day for the Spring of 2016
European 6M Es, NA – Nothing!
What then are the causes of Es?

German Es Study using GPS

A Global Survey of Sporadic E Layers based on GPS Radio Occultations by CHAMP, GRACE and FORMOSAT–3 / COSMIC

Christina Arras

Scientific Technical Report STR10/09

ISSN 1610-0956

September 2010

A Landmark Paper!

- Excellent overview of radio wave propagation
- Chapters 2, 6, 7 and 8 are of the main interest to hams on Sporadic E (Es)
- It is 35 MB is size as a PDF file
- You may need a few mugs of coffee to get through the paper. It is long, but well written.
- It is up to date and not 60 yr old IGY data and uses modern GPS techniques.

Use GNSS to Detect Global Es

- GNSS satellites emit electromagnetic waves on L Band frequencies
- The signals are affected by strong electron density gradients at altitudes above approximately 80km and by atmospheric density, pressure and water vapor content in the troposphere and stratosphere (not discussed here)

Ionization Layers

20 *CHAPTER 2. THE IONOSPHERE AS PART OF EARTH'S ATMOSPHERE*

Layer	Altitude range	Prevalent ions	Typical electron density
Plasmasphere	400 km – 3 - 7 Earth's radii	H^+	$\sim 10^8\,m^{-3}$
F layer	170 – 1000 km	O^+	$\sim 10^{11} - 10^{12}\,m^{-3}$
E layer	90 – 170 km	O_2^+, NO^+	$\sim 10^{11}\,m^{-3}$
D layer	$\leq$90 km	H_3O^+, NO_3^-	$\sim 10^8 - 10^{11}\,m^{-3}$

Table 2.1: Main properties of the ionospheric layers.

Solar radiation is the major factor in ionization densities.

Generally, the electron content is on average higher at low latitudes compared to high latitudes.

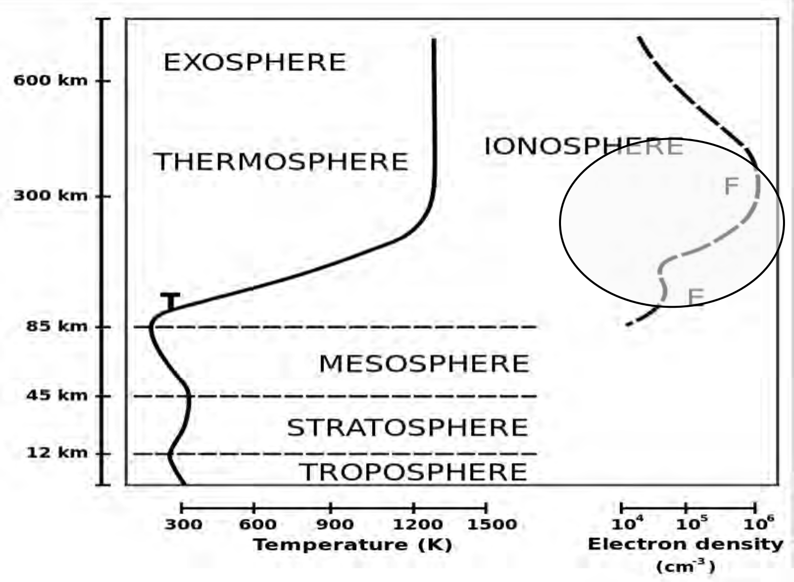
The ionosphere varies on different time scales that follow daily, seasonal and solar sunspot cycle (11 years) changes.

Daily variations in the ionosphere are a result of the 24 hour rotation of the Earth around its axis

- Sporadic E layers are phenomena of the ionospheric E region.
- The Es layers appear mainly at daytime in mid latitudes in the summer hemisphere.
- Sporadic E layers = enhanced electron density compared to the background ionization.
- They occur between 90 and 120 km altitude with a thickness of usually 0.5 – 5.0 km and a horizontal extent of 10 – 1000 km.
- Electron Density Scale 10^4 to 10^6 cm^-3

Neutrals

Ions/Electrons (radio wave propagation effects)



Ions/Electrons

Radio Occulation

3.1. ATMOSPHERIC OBSERVATIONS BASED ON GPS 37

Figure 3.1: GPS Radio occultation principle. The LEO satellites CHAMP (top), GRACE (middle) and the COSMIC constellation (bottom) observe a rising or setting GPS satellite (left) behind Earth's limb. The key observable is the bending angle, α, which is induced by ionospheric and neutral atmospheric refraction.

Sporadic E

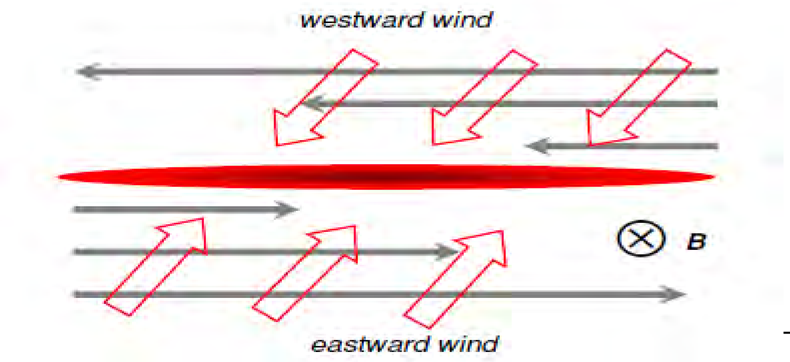
- Es is subject to coupling processes between the neutral atmosphere and ionosphere.
- Es occurrence is oriented along Earth’s magnetic field
- Es altitudes are subject to tidal winds and that its annual cycle varies with meteor influx.

Mid Latitude Es Causes

- Solar Inputs (Solar Tides in Neutral Upper Atmosphere from Heating Effect)
- Upper Level Vertical Wind Shear (Main Cause) from Solar Tides
- Meteor Inputs (long life metallic ions)
- Horizontal Component of Magnetic Field

Mid Latitude Wind Shear

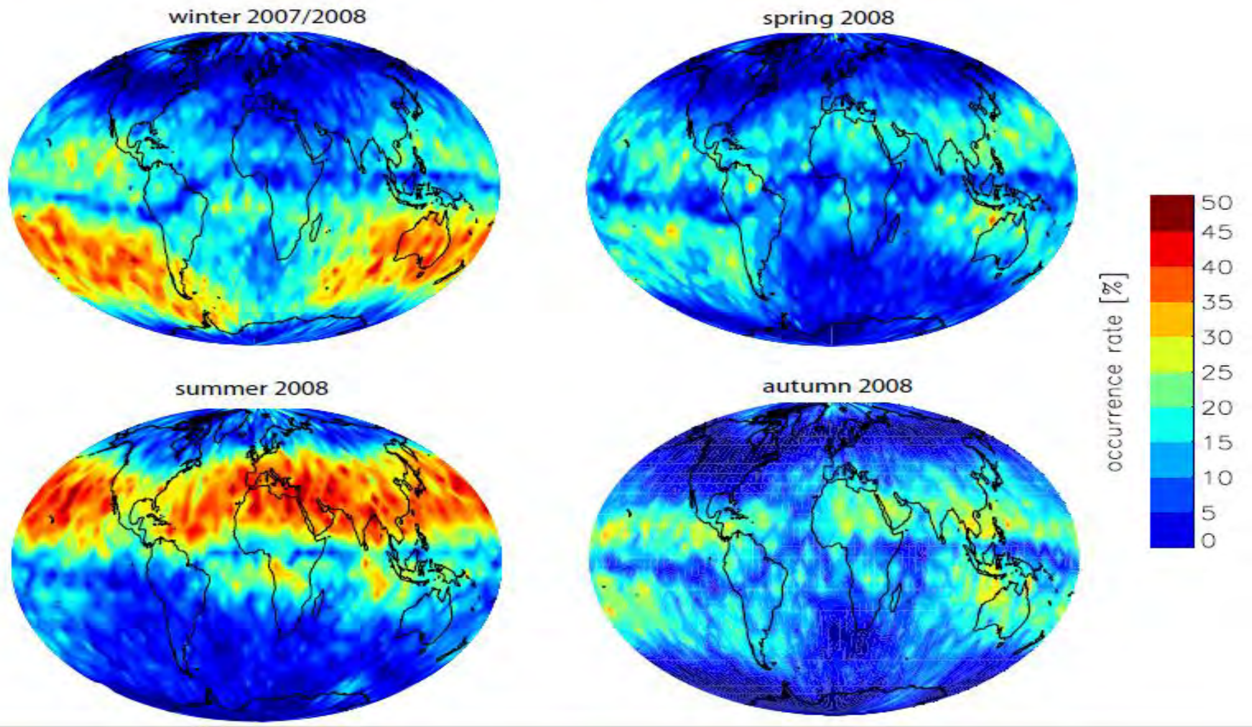
Ionospheric plasma of large volume is swept together into a thin layer by the combined action of vertical wind shears, mainly produced by atmospheric tides, ion–neutral collision coupling and geomagnetic Lorentz forcing (somewhat like the right and left hand rule).
The process works well in mid-latitudes at altitudes between 95 and 120 km.



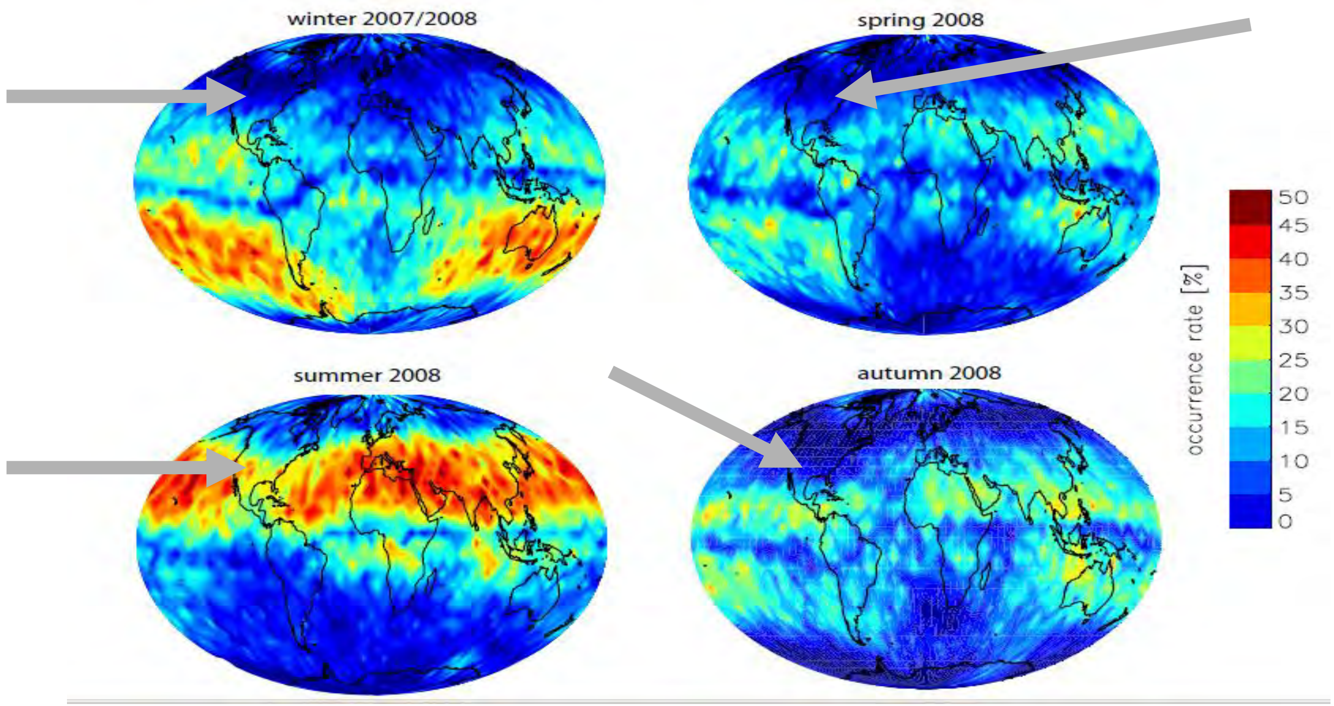
Mid Latitude Wind Shear

- The wind shear process works only in mid-latitudes.
- In polar and equatorial regions, electric fields become too strong for effective Es formation and cannot be neglected.
- Then why do we see some good propagation at the equator? More sun, better E and F2 MUFs, but stronger D absorption as well.

Global Es: Red/Yellow = Es Areas



North America is Not an Es Hot Spot!



What Else is Going On?

- If then North America is not an Es hot spot, then why do we see good Es at times?
- Amateurs over the years have also noticed that Es openings seem to happen near hurricanes and storms as well as the regular Es openings.

K1YOW's Hypothesis

- The hypothesis to be tested is: besides the normal random Es, Es openings are enhanced by strong storms like hurricanes and upper level low pressure systems for the mid latitudes.
- Are somehow lower atmosphere, low pressure systems, affecting upper level tidal wind shear?
- Can we see this using Amateur Radio?

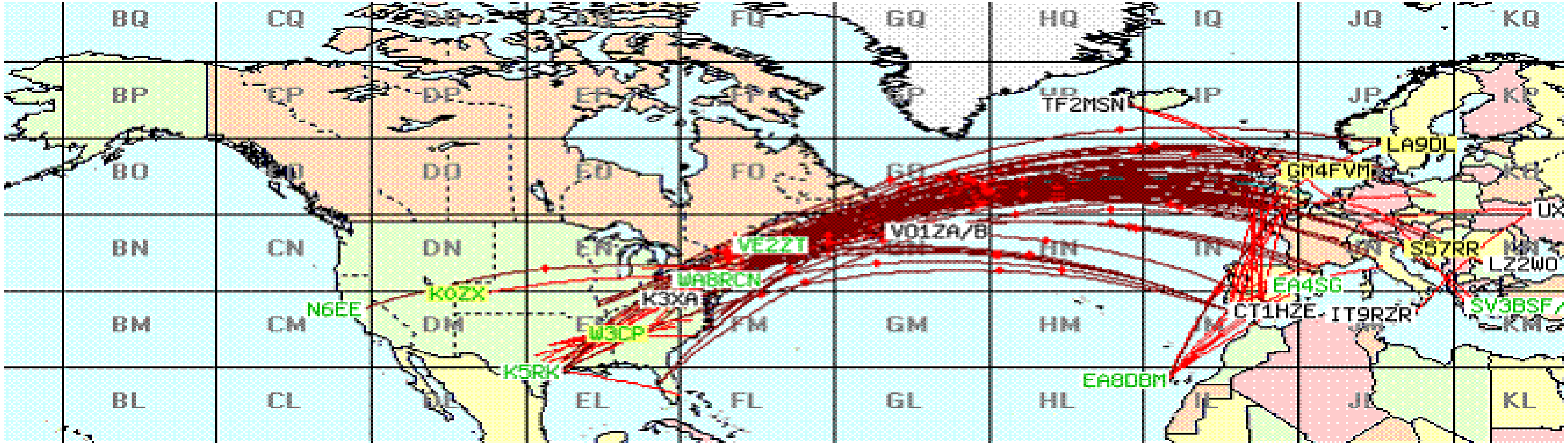
Low Pressure and T-Storms

2nd Paper Found: A statistical analysis on the relationship between thunderstorms and Sporadic E Layer over Rome V. BartaP1,2P, UC. ScottoUP3P, M. PietrellaUP3P, V. Sgrigna P4, G. SátoriP2P, L. Conti 5

Low Pressure and T-Storms

- Internal atmospheric gravity waves (AGWs) are often generated by thunderstorms in the troposphere but they are also generated by strong atmospheric fronts irrespective of lightning.
- They found no ionospheric response to low-pressure systems without lightning, consequently this localized intensification of the sporadic E layer can be attributed to lightning.
- A statistical analysis on the relationship between thunderstorms and Sporadic E Layer over Rome V. Barta et Al. 2013

June 13, 2016 6 Meter Double Hop Trans Atlantic Es DX Map



The VHF Gods Were Smiling on us this Day!

K1YOW General Rules of Thumb for Radio Circuit Paths

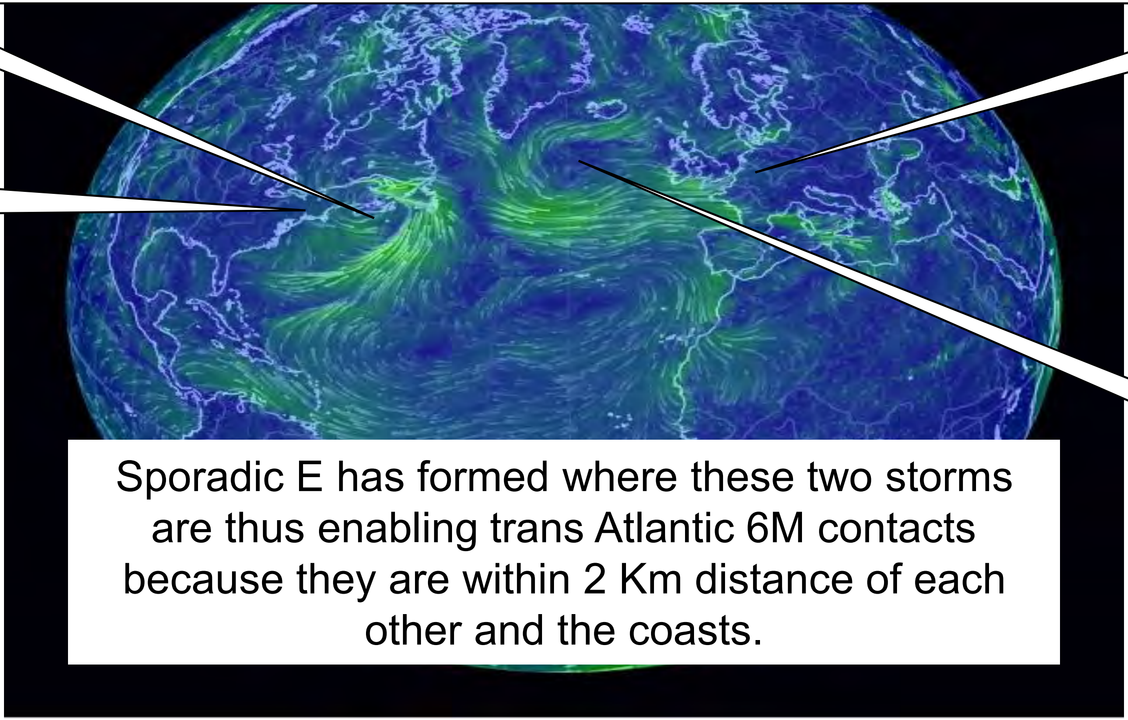
- 2000 Km path use .85 of the E layer MUF (80m, 40m, 30m, etc)
- 4000 Km path use .85 of the F2 layer MUF (20m, 17m, 15m or higher per conditions)
- 4000 Km path can also use E layer if multi hop
- Greater than 4000 Km path can use F2 layer multi hop BUT the MUF must be looked at 2000 Km from each circuit end point and at the middle of the path
- Note the 2000 Km distance – critical for weather storm spacing

June 13 2016

Two Upper Level Lows during 50 Mhz Trans-Atlantic Es Double Hop

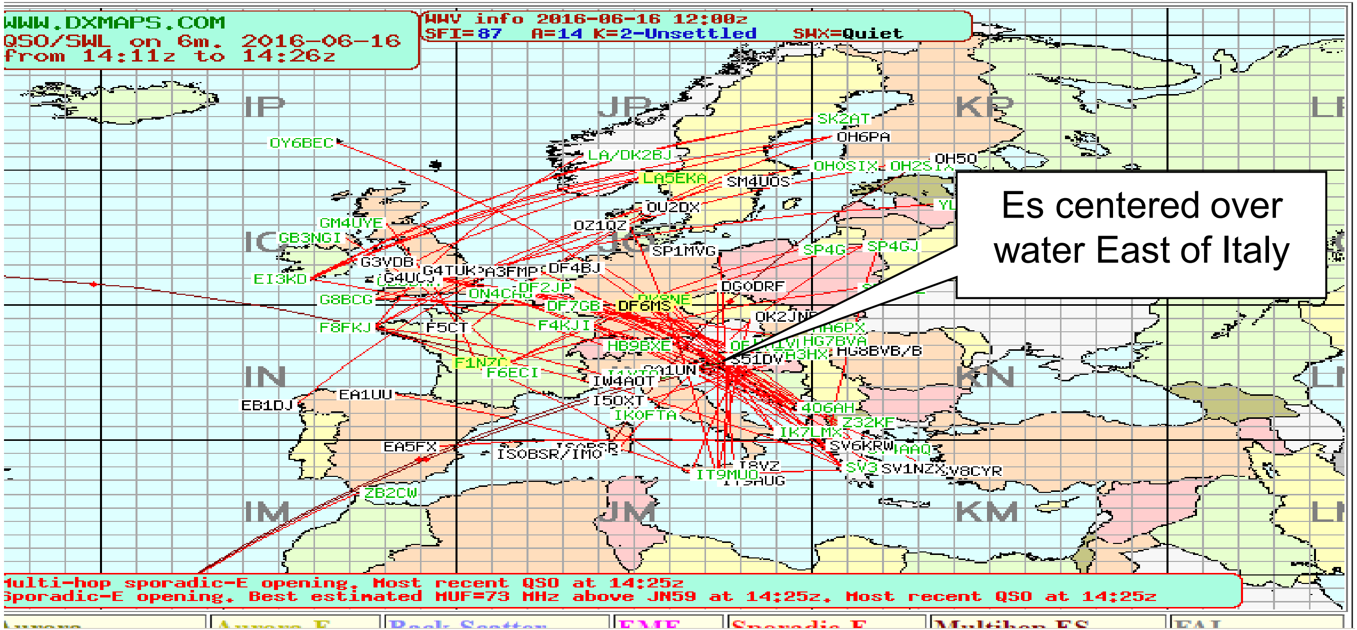
Note: Views are surface level winds just to make things easier to see. Viewing high level winds make things very hard to see what is going on.

June 13, 2016 – Two Atlantic Storms



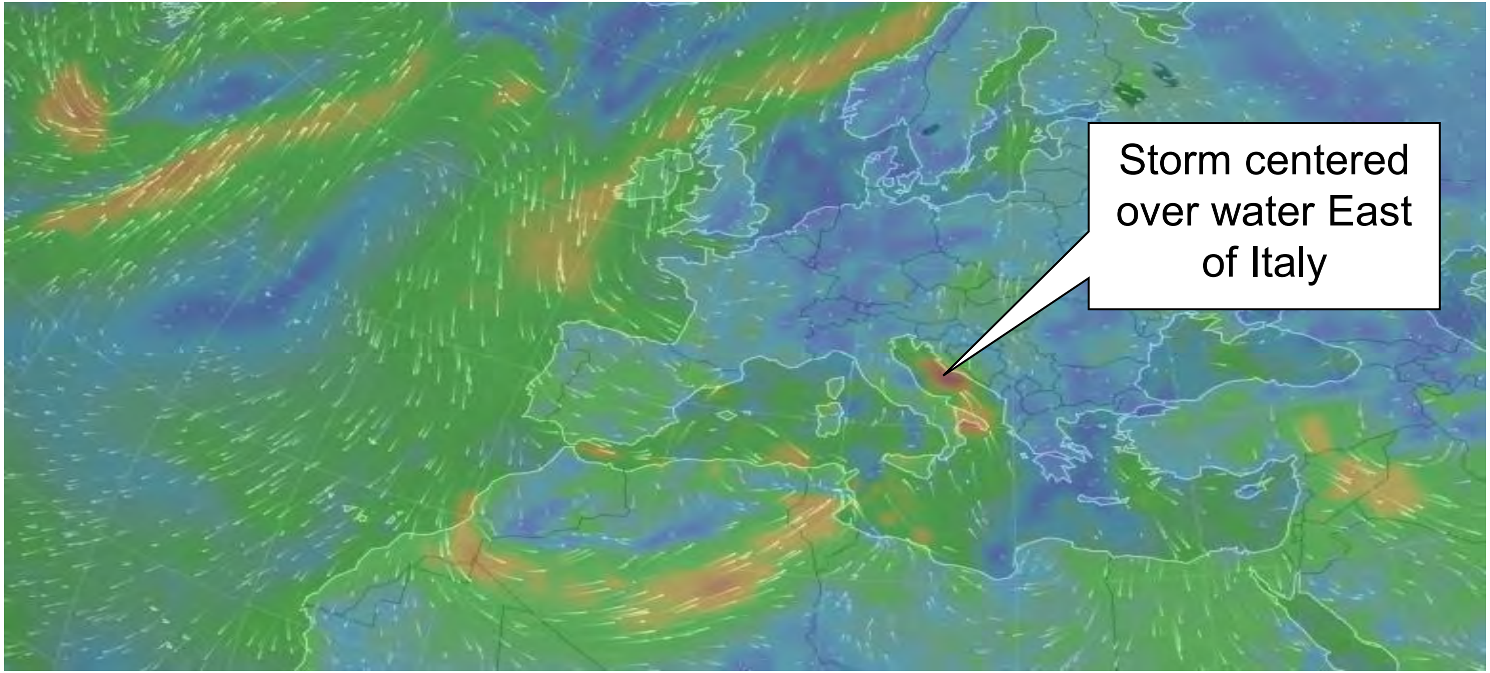
Sporadic E has formed where these two storms are thus enabling trans Atlantic 6M contacts because they are within 2 Km distance of each other and the coasts.

Europe 06/16/2016 14:30Z



Es centered over water East of Italy

Europe 06/16/2016 14:30Z



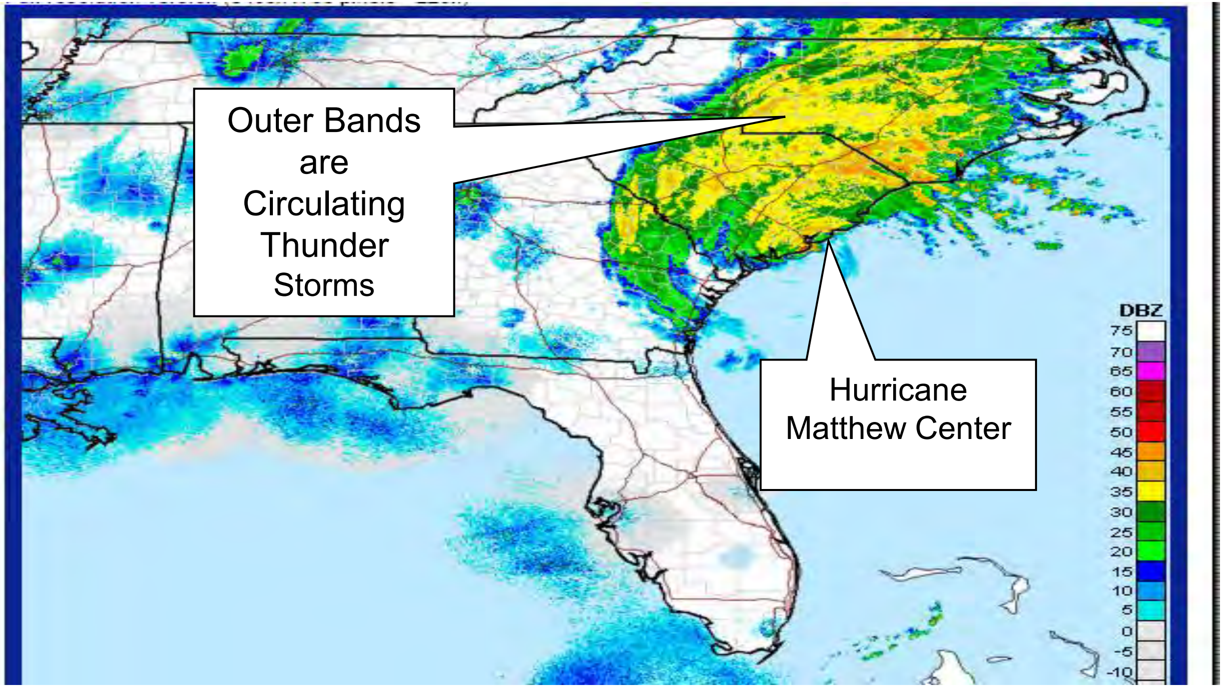
What About Hurricanes?

- Did Hurricane Matthew cause any Es?
- Don’t forget – these observations depend on Amateur Radio types being on the air.
- Hams won’t be on the air if they are being flooded and/or have no power (no backup batteries or generators) or if they sustain antenna damage from winds and fallen trees.

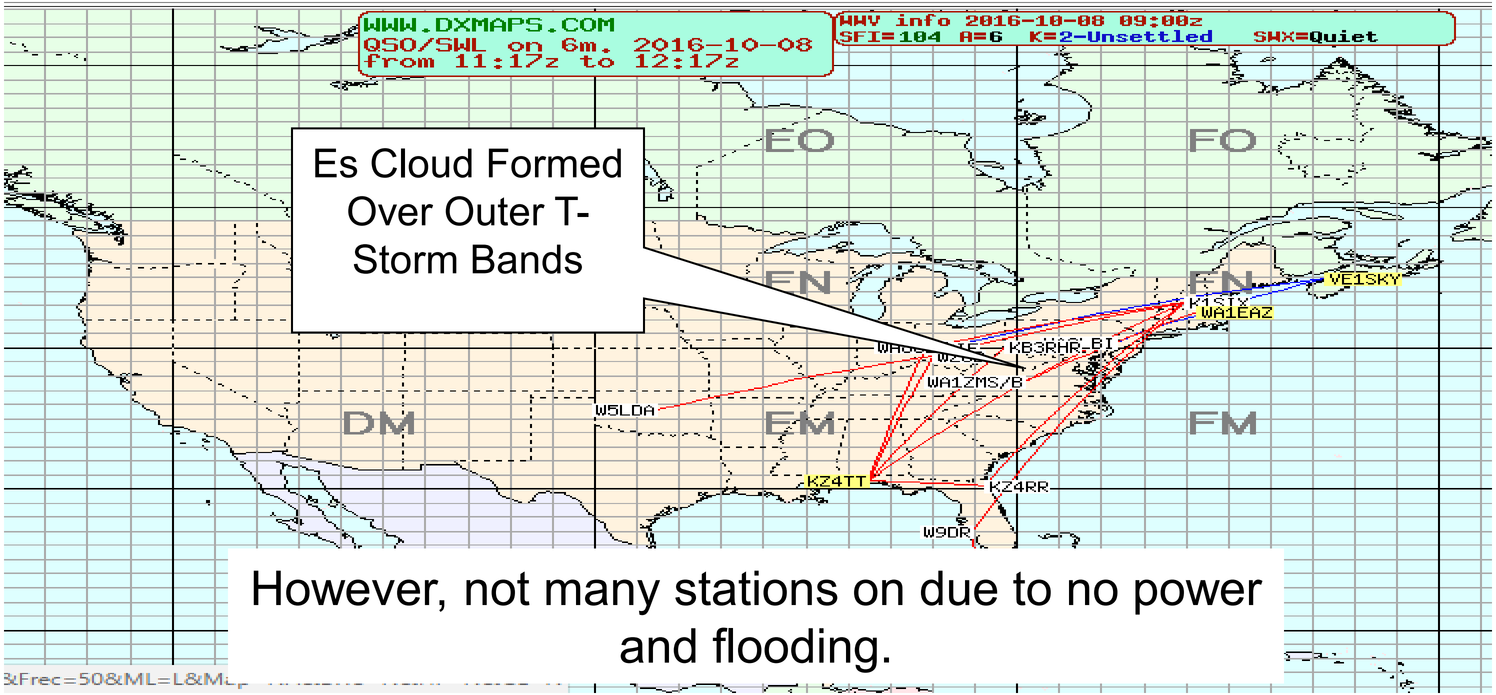
Lightning and Sprites

- Hurricanes spawn bands of thunderstorms.
- T-Storms spawn lightning and sprites.
- Italian paper: lightning can enhance Es and also probably sprites can enhance Es as well.

Hurricane Matthew 10/08/2016 12:20 GMT



Hurricane Matthew 10/08/2016 12:20 GMT



Es Cloud Formed Over Outer T-Storm Bands

However, not many stations on due to no power and flooding.

Equatorial Electrojet Fountain – Key Slide!

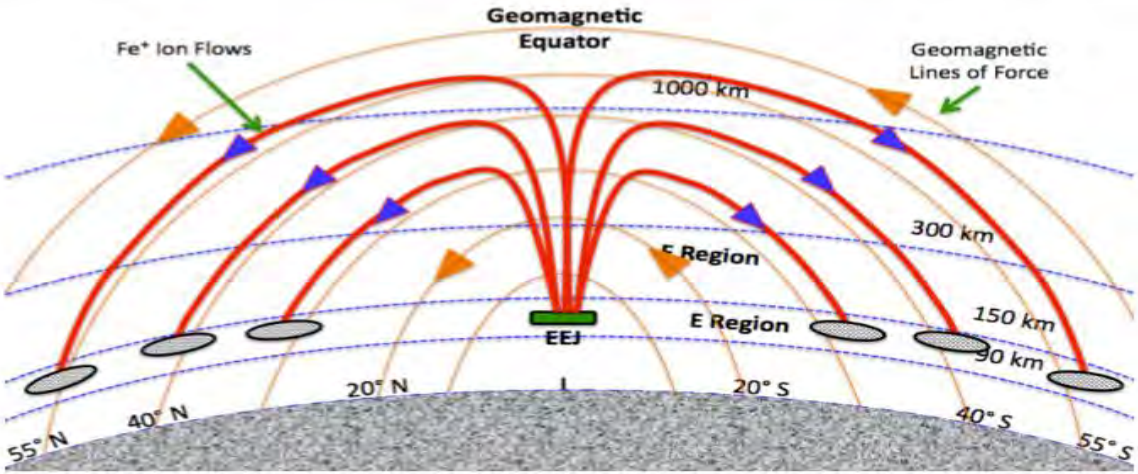
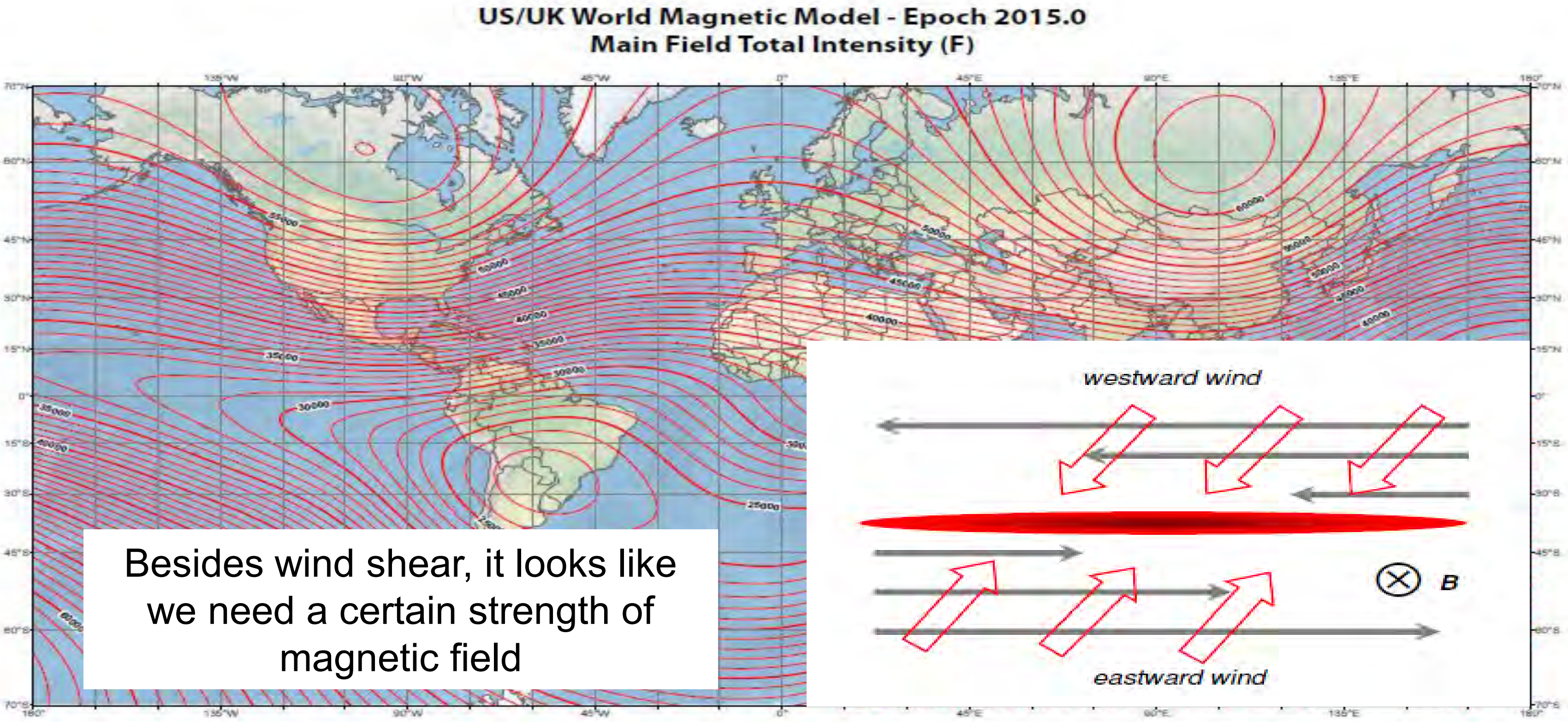


Figure 3: Looking eastward along the EEJ, the **ExB** effect causes both positive ions and free electrons to drift upward. The iron ions reach extreme F-region heights. Then, they fall downward along the Earth's magnetic field lines, until they reach the *midlatitude* E region. There they enhance the locally produced Fe^{+}, and add more free electrons, raising the Es MUF.

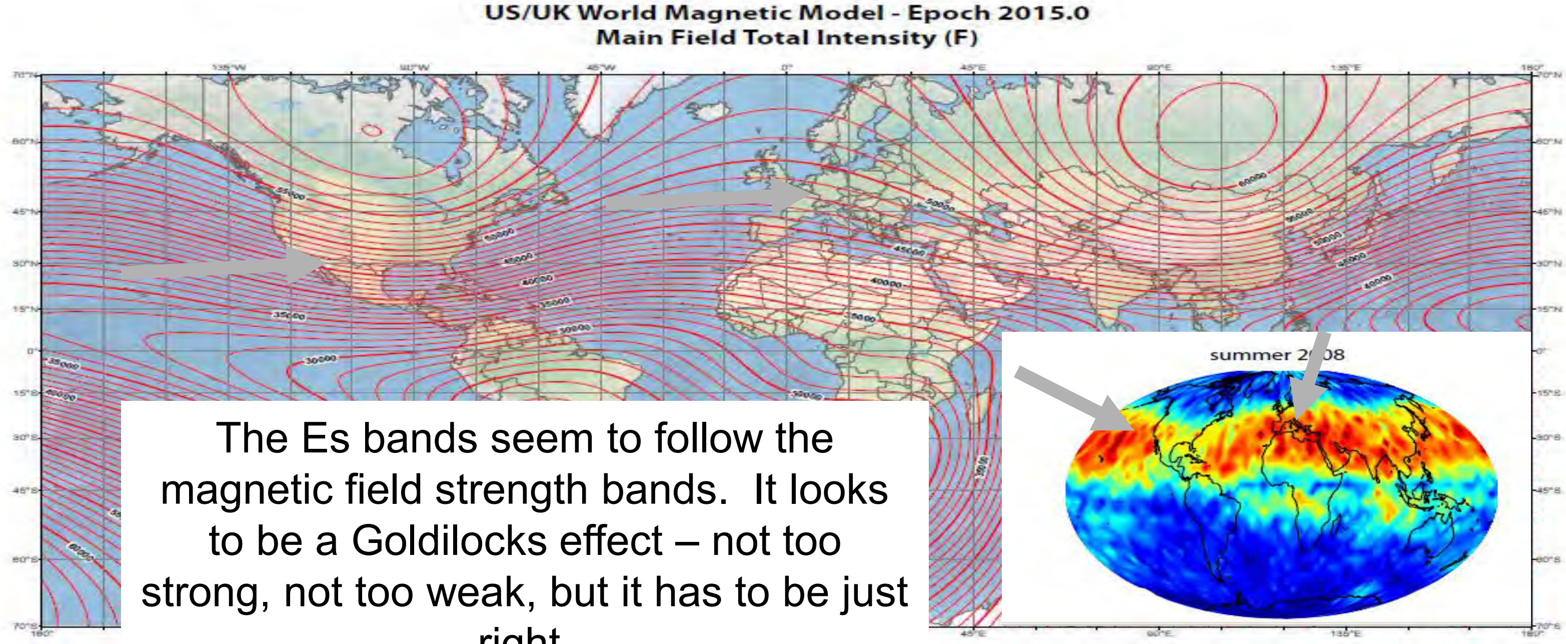
Figure Credit: Jim Kennedy, K6MIO/KH6

World Magnetic Field



Besides wind shear, it looks like we need a certain strength of magnetic field

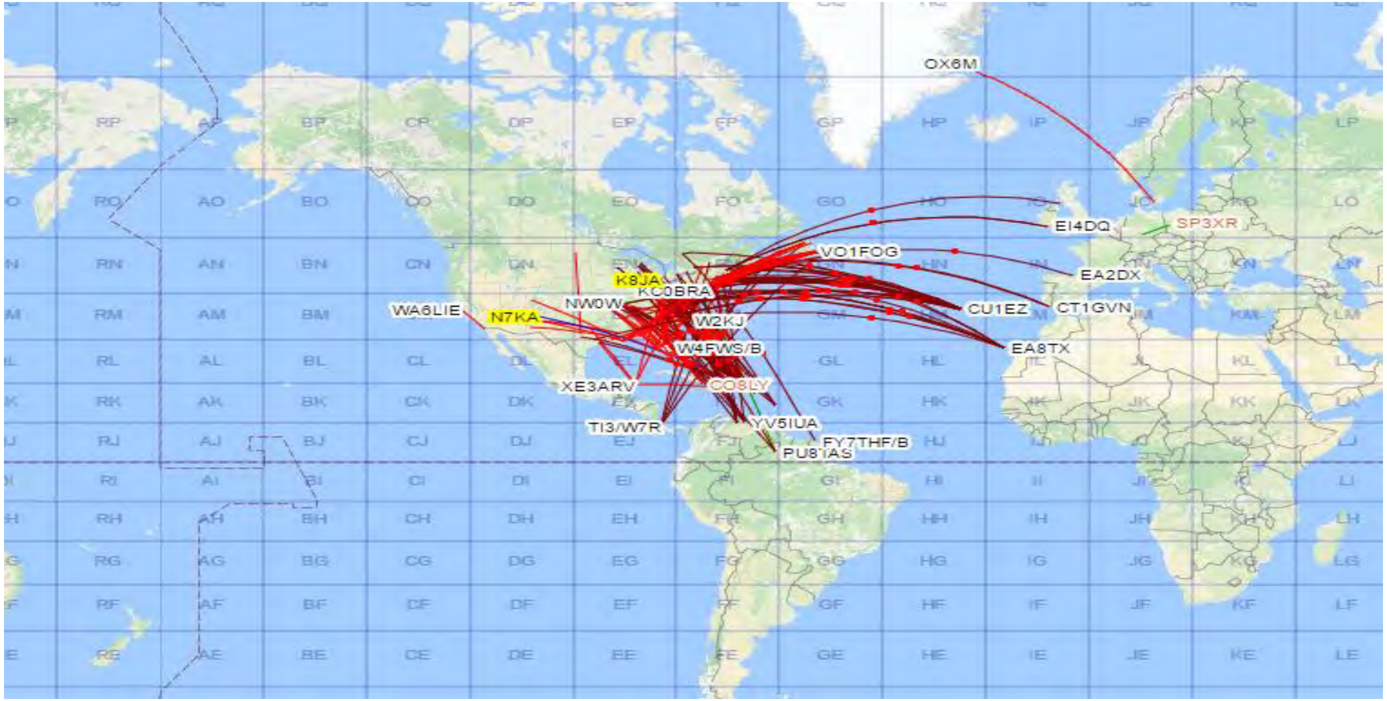
European and SW NA Mag Field Strengths the Same and Similar Es



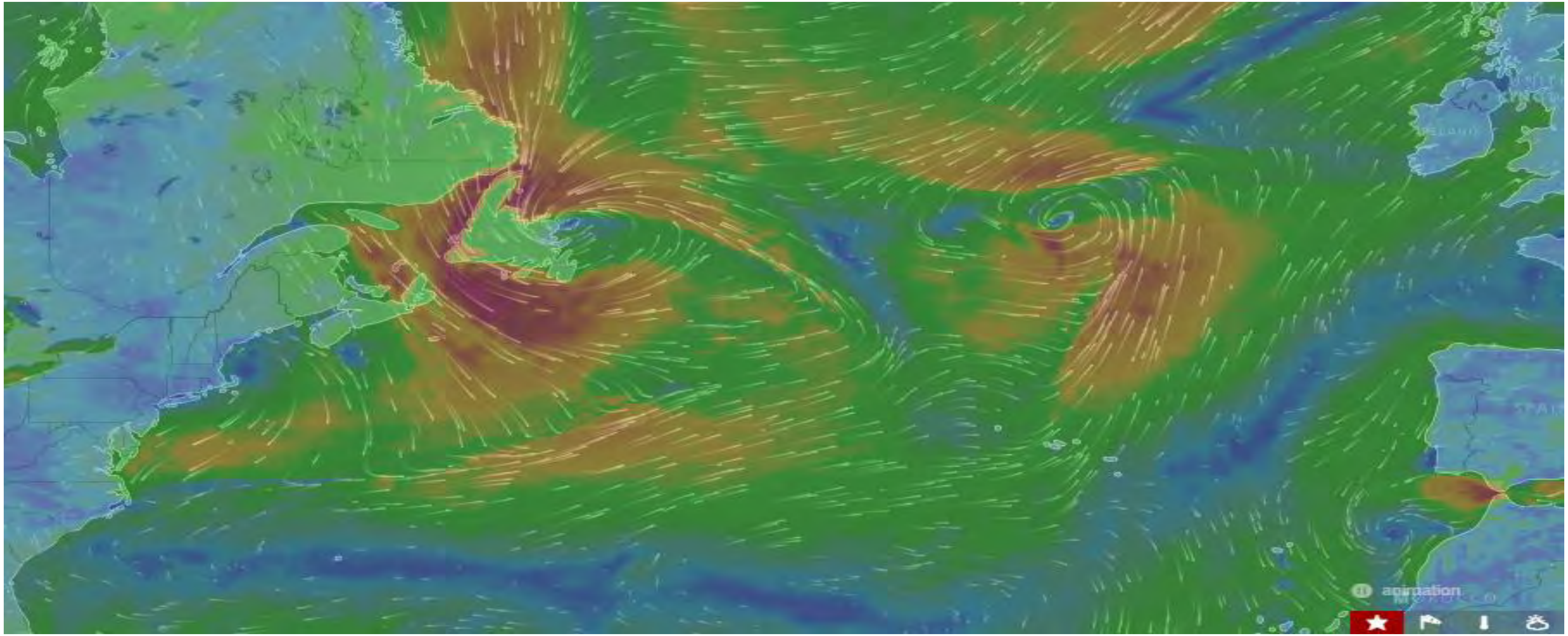
The Es bands seem to follow the magnetic field strength bands. It looks to be a Goldilocks effect – not too strong, not too weak, but it has to be just right.

What About 2017?

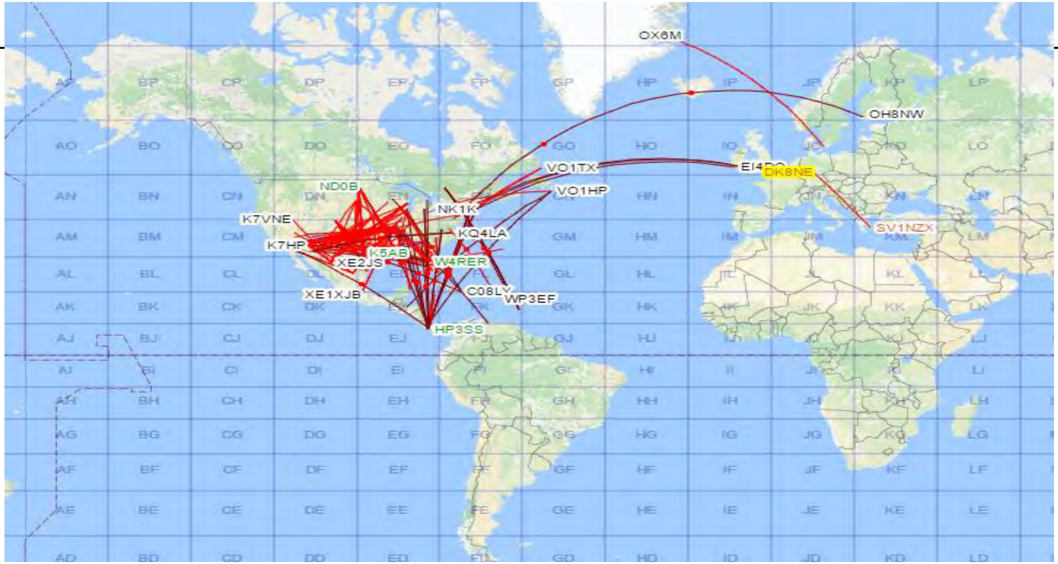
05/20/2017 22:25 GMT 6M



05/20/2017 22:25 GMT 6M



05/21/2017 00:05 GMT 6M



Es over central USA vortex in jet stream trough; Es over Georgia formed on jet stream trough shear line for paths to Caribbean; three low pressure systems in Atlantic allowing trans Atlantic paths NA to extreme Western Europe and North America to Scandinavia.

05/21/2017 00:05 GMT 6M

Es over central USA vortex in jet stream trough; Es over Georgia formed on jet stream trough shear line for paths to Caribbean; three low pressure systems in Atlantic allowing trans Atlantic paths NA to extreme Western Europe and Iceland and North America to

06/05/2017 22:30 GMT 6M

What is Going-On Here – We Do Not Know!

2x 3x 4x Es hops? Almost world-wide many Es clouds coverage?

Polar enhanced Es over the North Pole path?

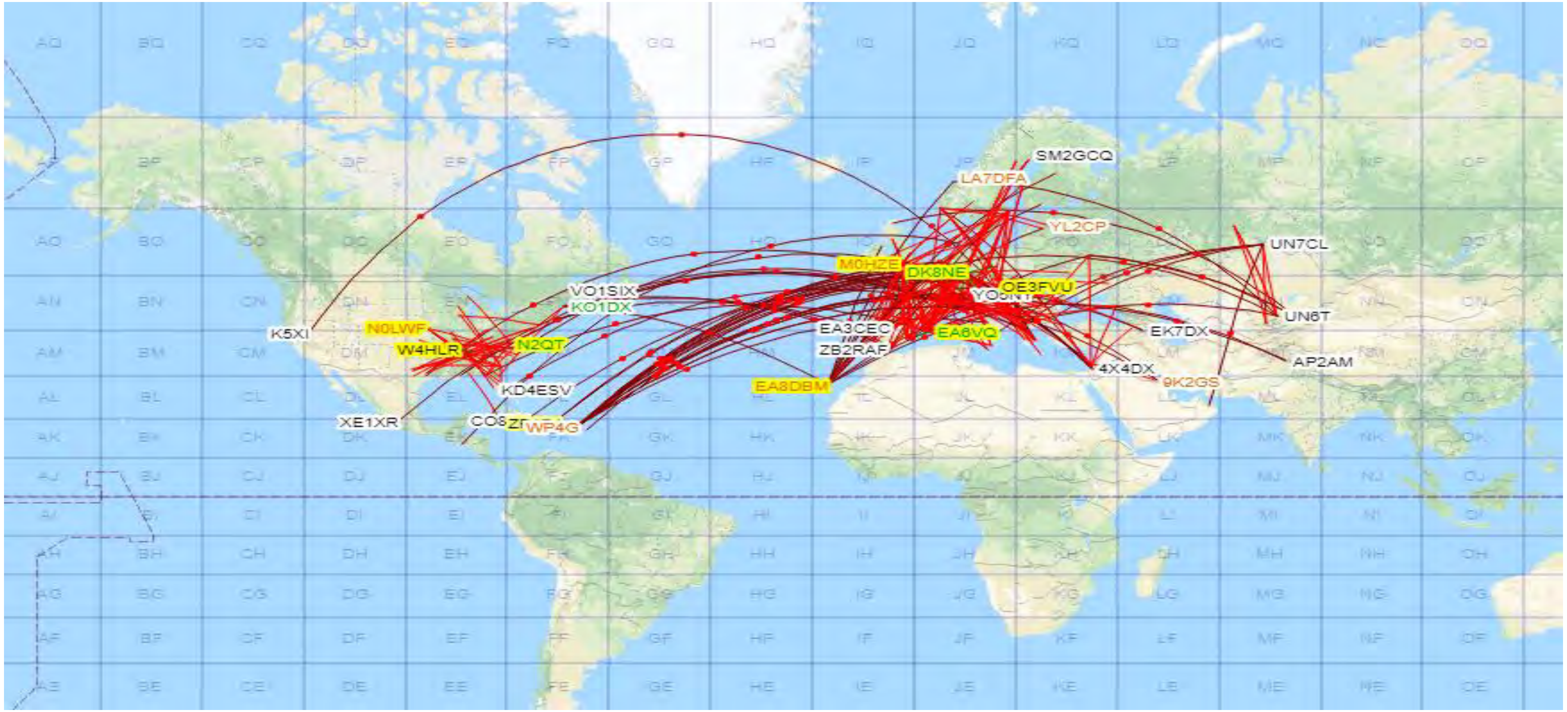
Es scattering into a F2 duct?

East/West paths via the Equatorial Anomaly?

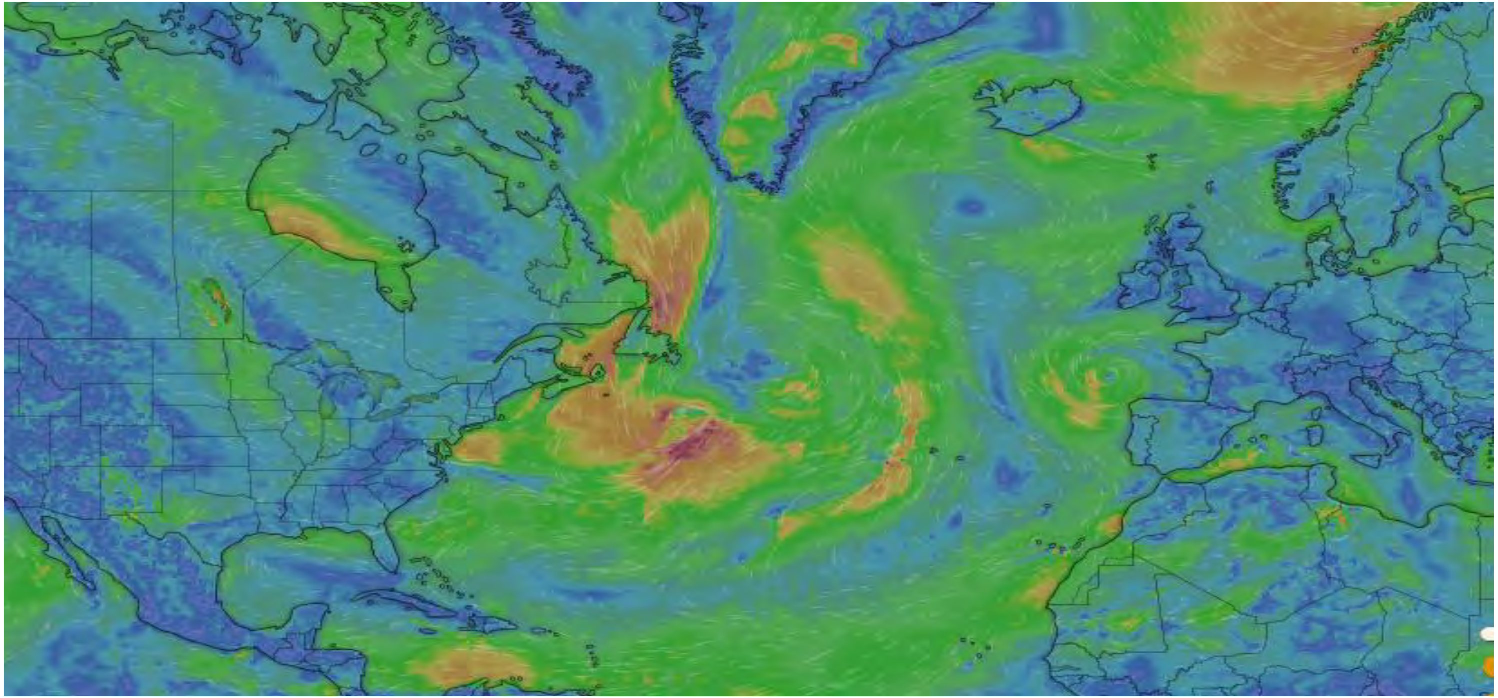
We just do not know! No storms observed over the Pacific.

What About 2018?

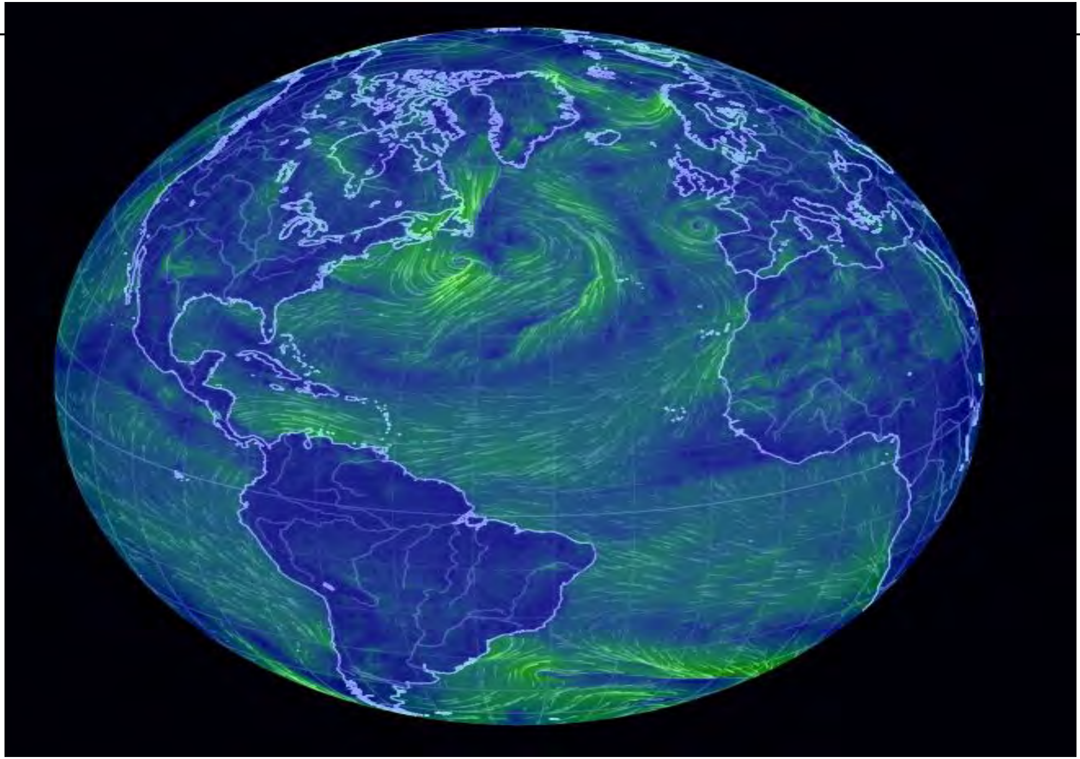
June 03 2018 6M 12:00 UTC



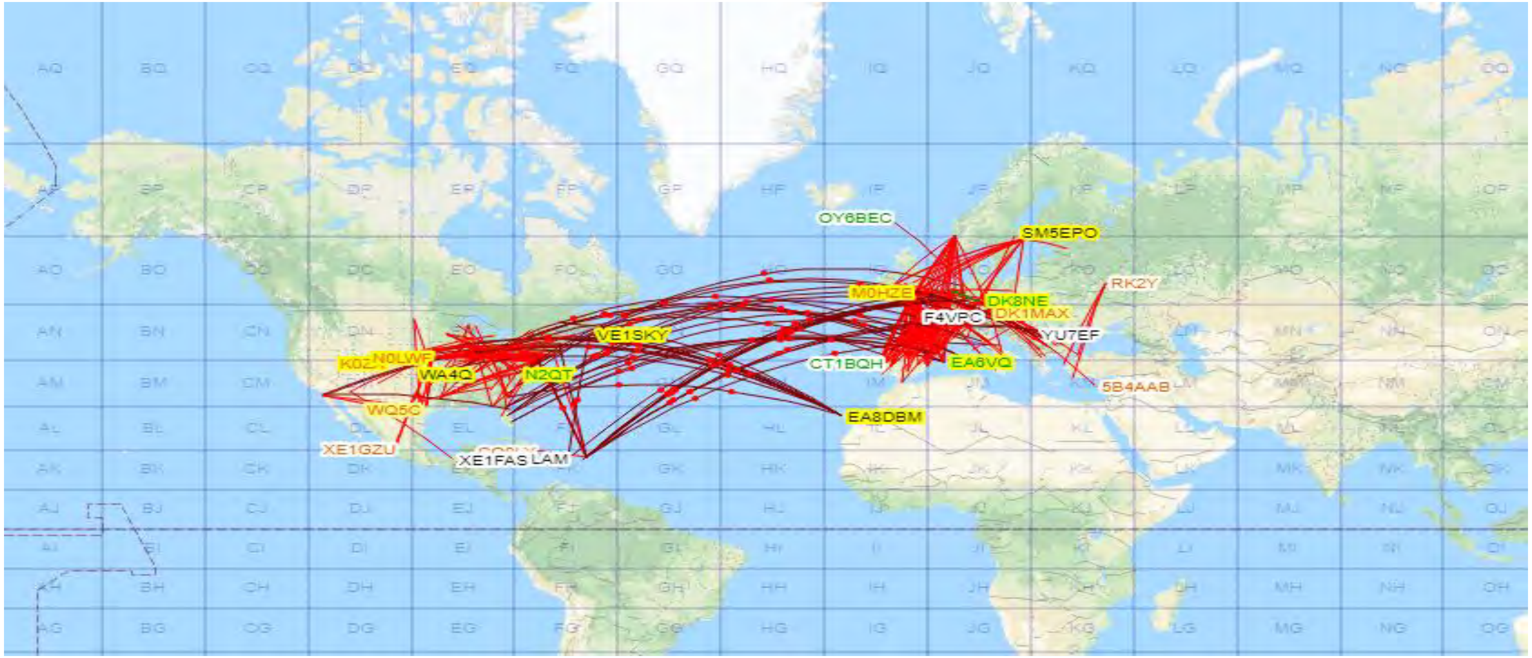
June 03 2018 6M 12:00 UTC



June 03 2018 6M 12:00 UTC



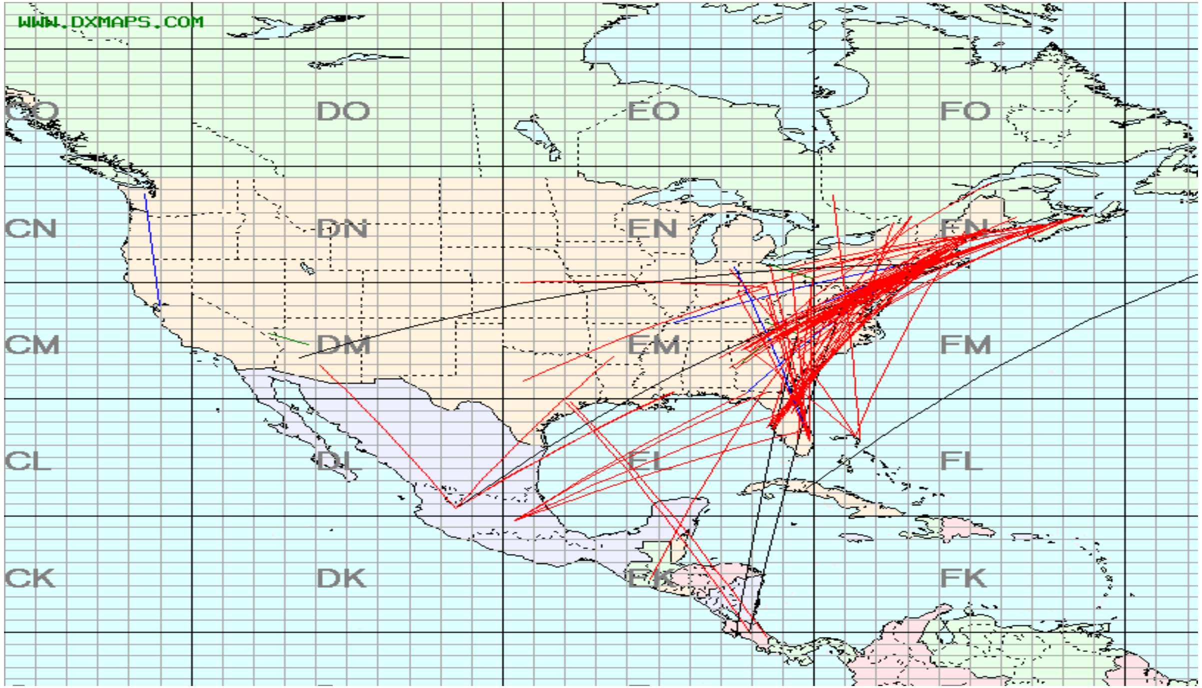
June 03 2018 6M 14:00 UTC



Winter 2017 into 2018

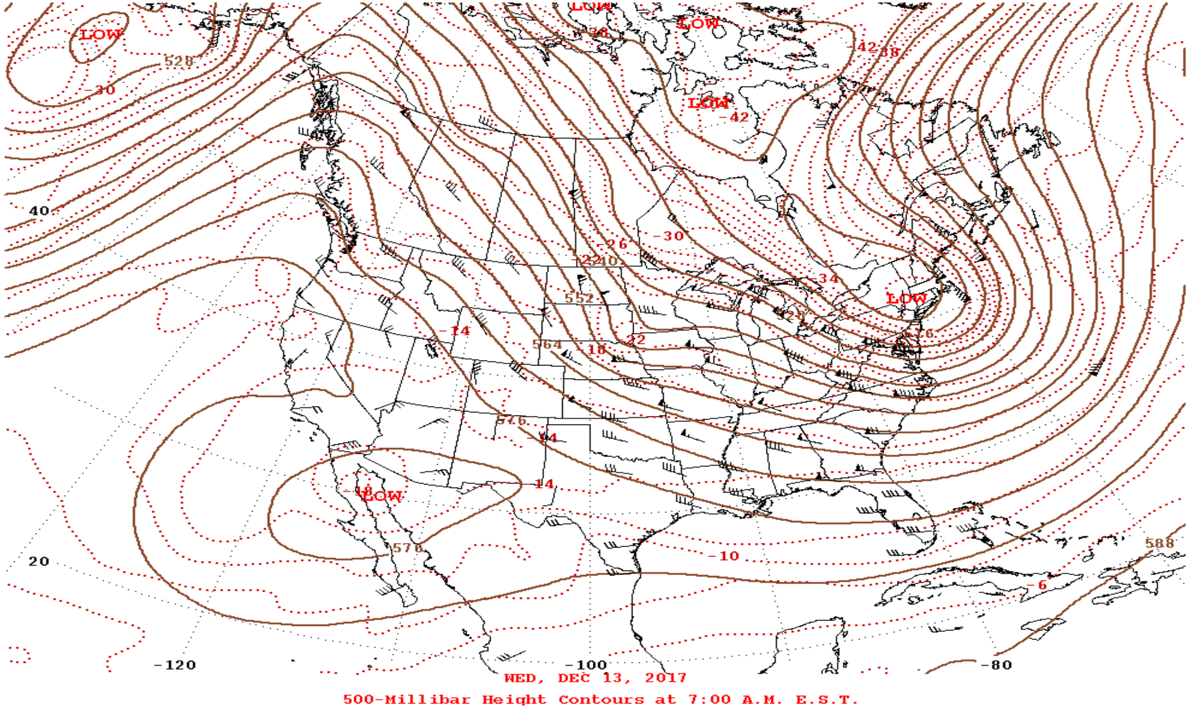
- In 2018 we had some nice winter Es-Like openings
- What possibly could cause this?
- Low sun angles and exposure
- Cold temperatures
- Summer is usually the “hot” Es season

Dec 13 2017

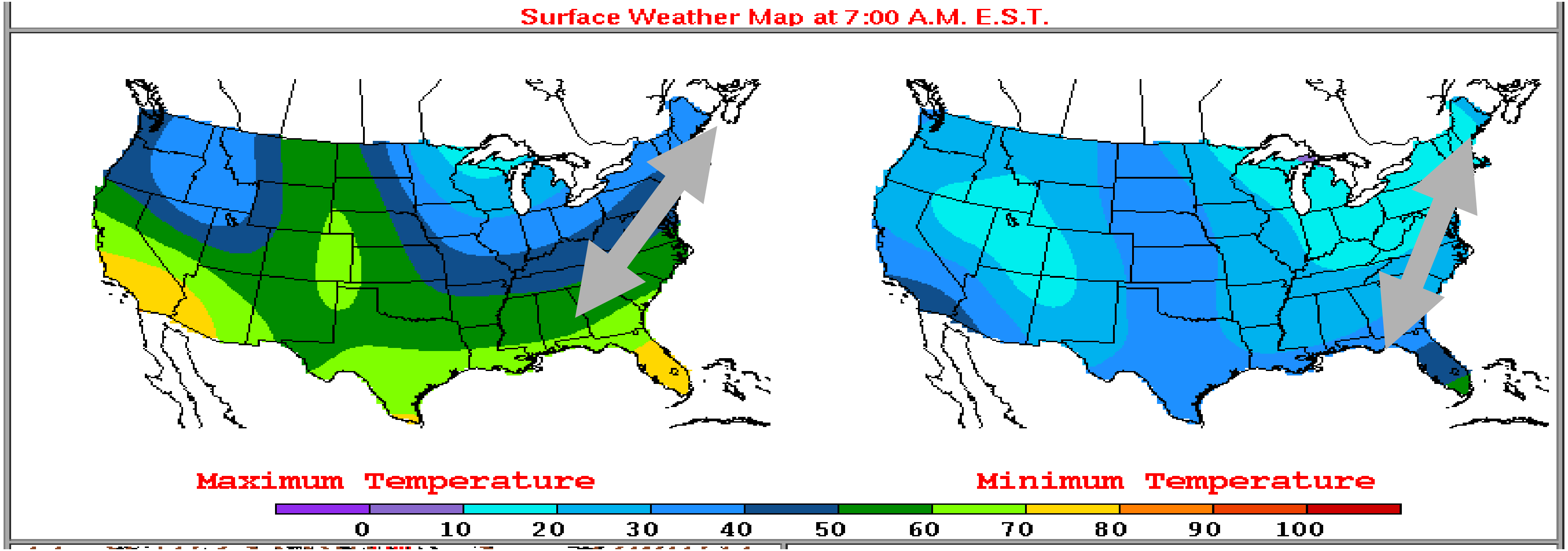


WWW.DXMAPS.COM
DO
EO
FO
CN
DN
EN
FN
CM
DM
EM
FM
CL
DL
EL
FL
CK
DK
EK
FK

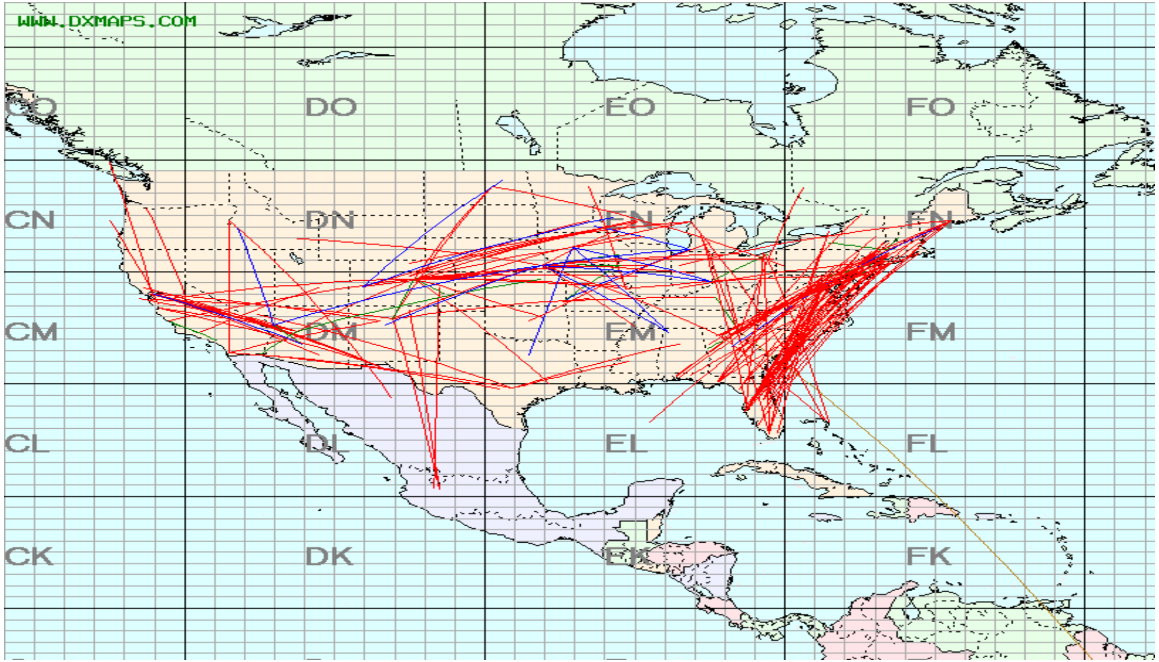
Dec 13 2017



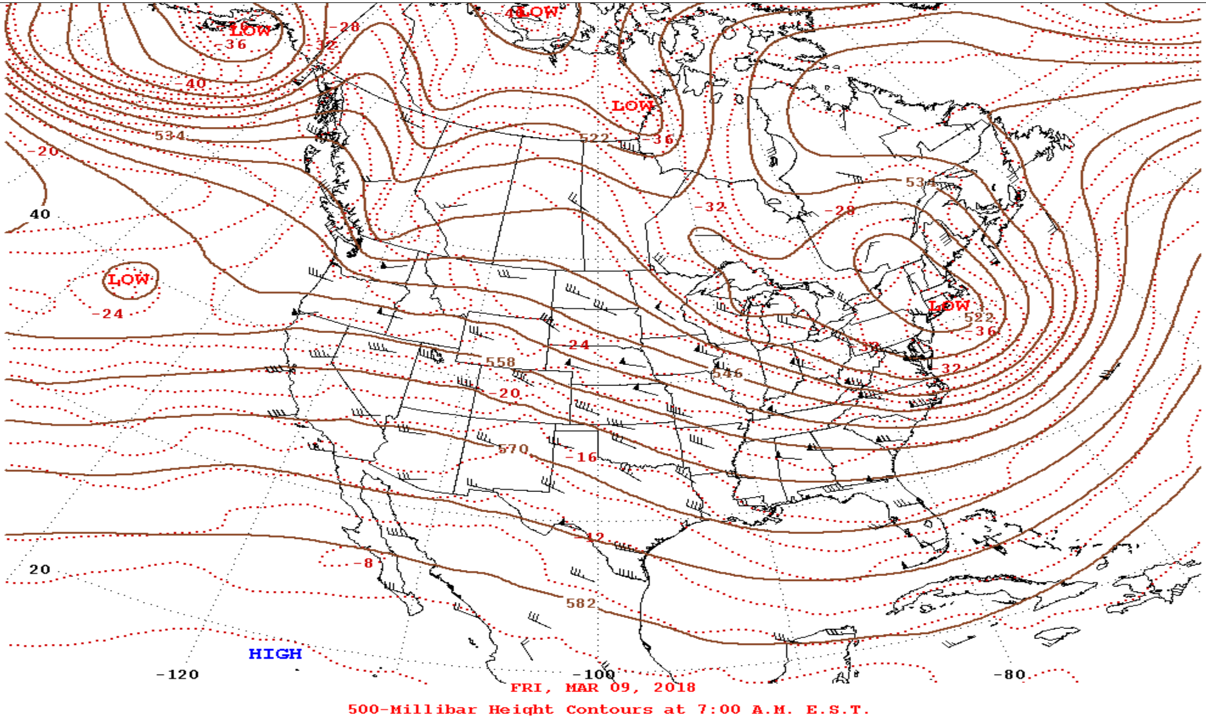
Dec 13 2017 Es on Jet Stream Boundary



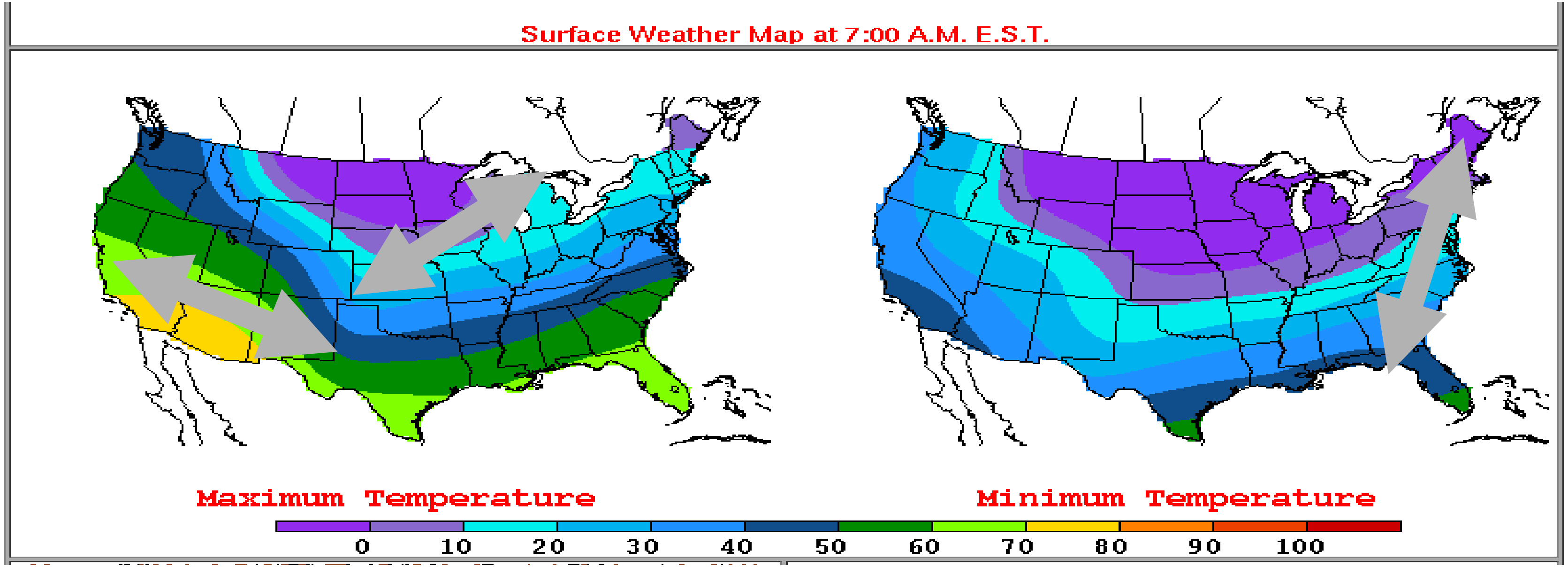
Dec 31 2017


WWW.DXMAPS.COM
DO
EO
FO
CN
DN
EN
FN
CM
DM
EM
FM
CL
DL
EL
FL
CK
DK
EK
FK

Dec 31 2017



Dec 31 2017 Es on Jet Stream Boundaries



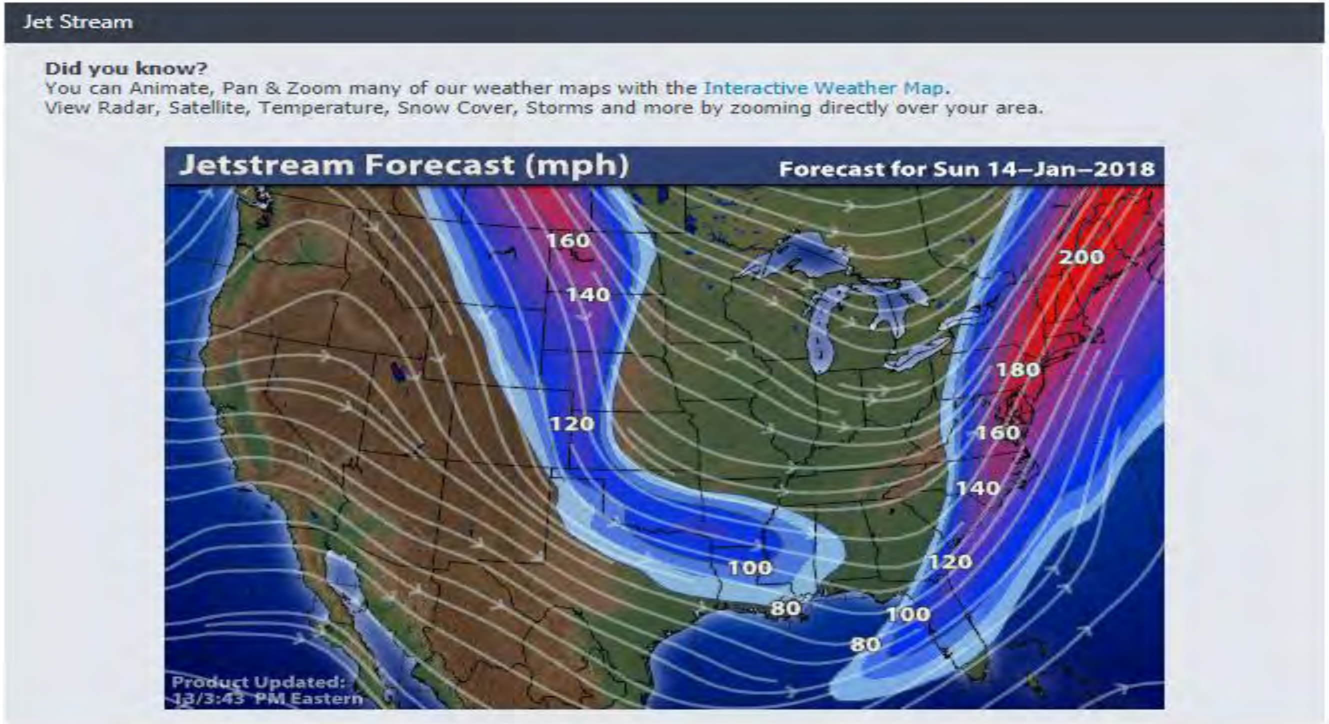
Notice the Trend?

- Es is forming on strong Jet Stream boundaries where there are strong wind shears and strong temperature gradients.
- It seems to form on the Eastern edge of either the Eastern or Western boundary of the Jet Stream trough.
- Es also can form across the trough dip but seems to form more often on the Eastern side of a boundary on the side where the air currents are heading – our NA Jet Stream flows West to East in the overall pattern.
- But…with Es there is ALWAYS a BUT:

Jan 14 2018

Well, even with a similar Jet Stream this weekend (Jan 13/14, 2018) to the four past Es openings that happened over Jet Stream boundaries, it really didn't happen that way this time, which in itself, is a useful data point. This time, the sun did hiccup with a short G1 K5 storm, and there was Es in other parts of the world like in Australia, unlike the pervious winter North American openings in December and January. On Saturday there was some Es in NA but it was fairly scattered around and not the very strong SW to NE along the Jet Stream pattern that we saw with the previous openings. Also, many of the 6M hams were staying on meteor scatter as well and not moving to FT8.

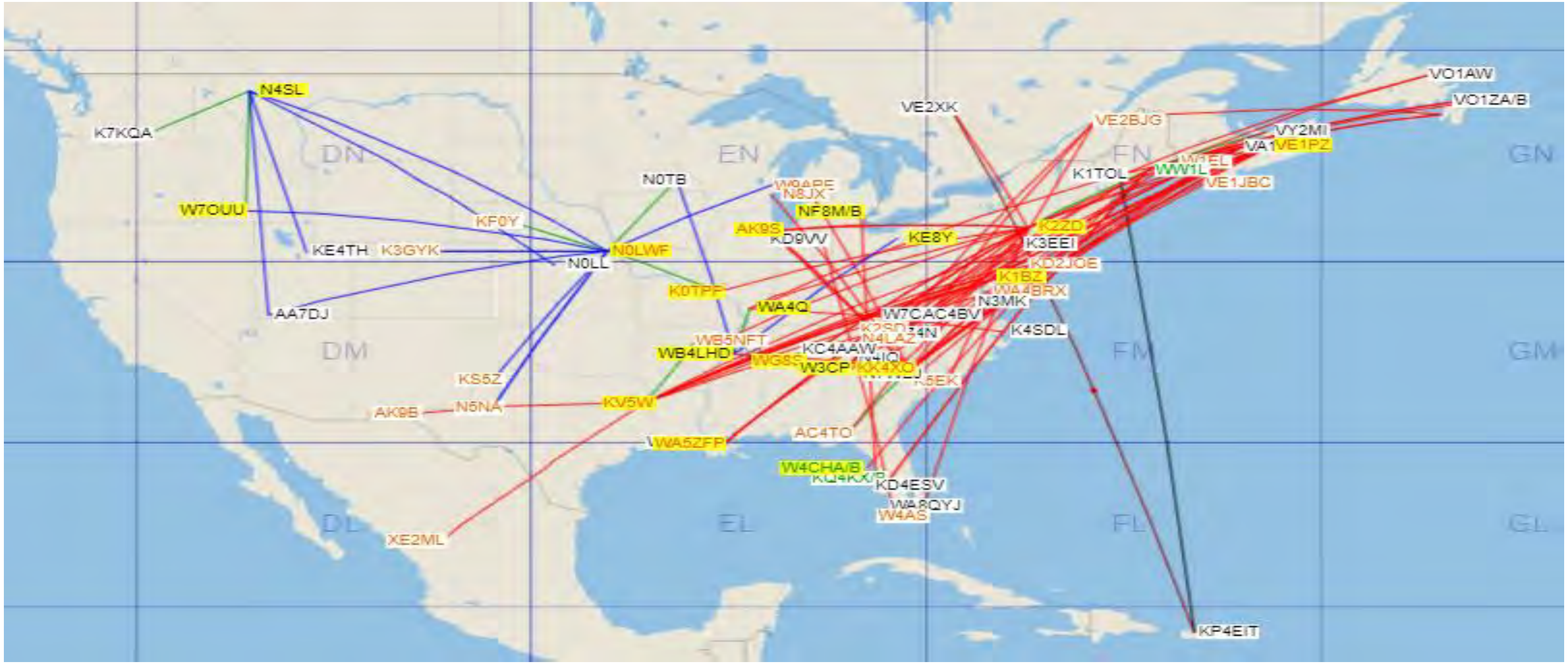
Jan 14 2018 Strong Jet Stream but also G1/K5 Storm – No Es



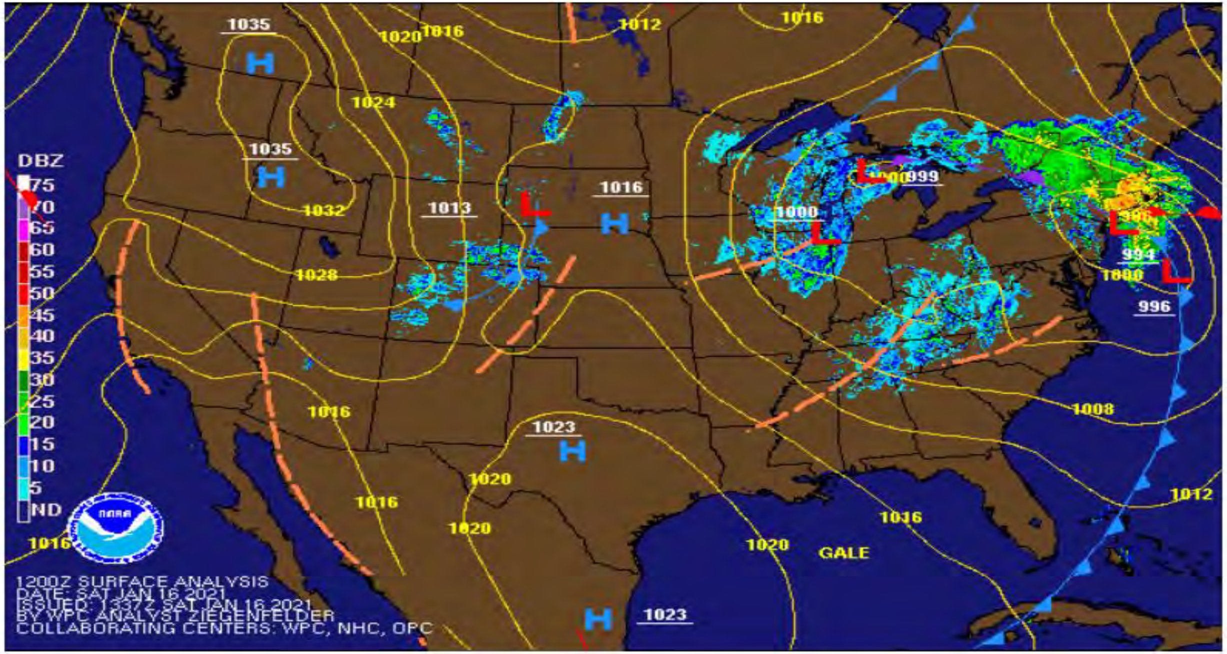
No Jet Stream Es This Time

- Maybe the stream was not fast enough
- Maybe the temperature difference boundaries were not strong enough
- Maybe because the sun was quiet the last four times and this time we had a short G1/K5 set of conditions to negate the effect
- Maybe the frontal boundary pushed-off the eastern USA coast very fast and didn't linger per the previous four Jet Stream Es events
- Maybe, maybe, maybe, maybe…..

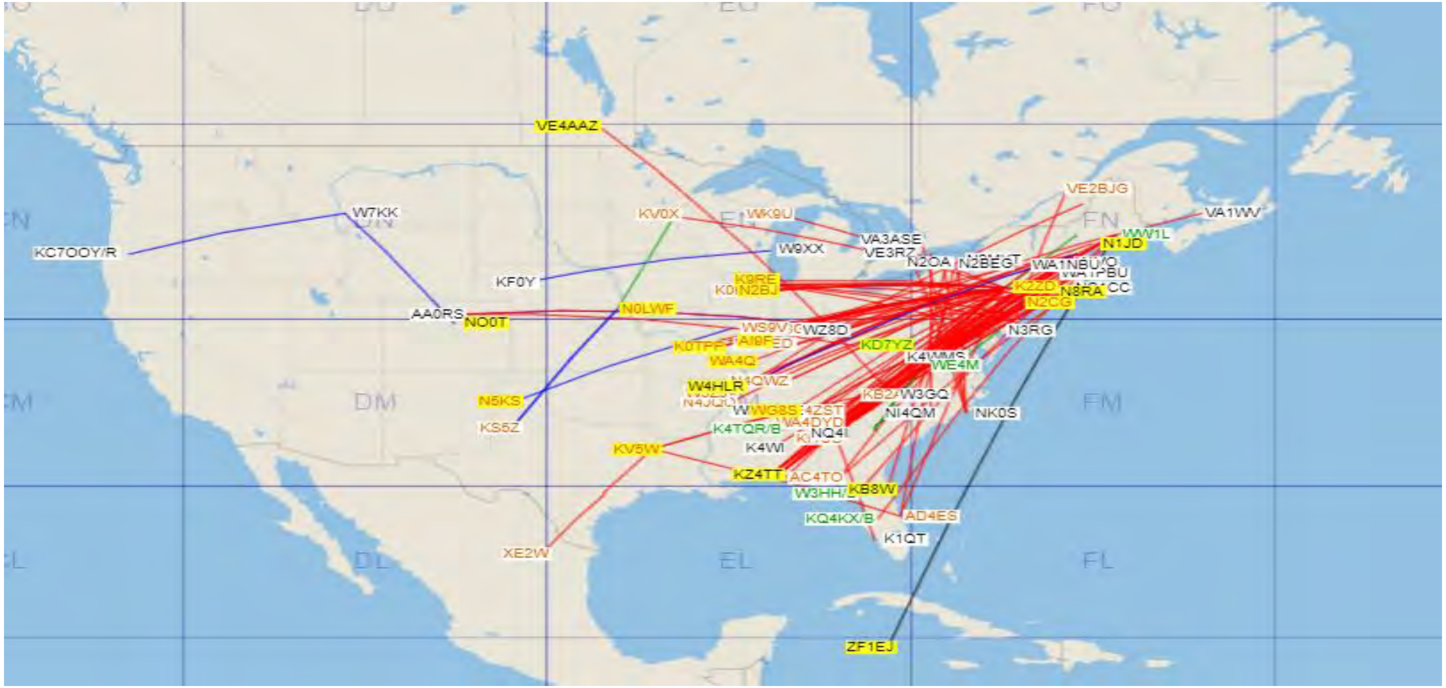
Jan 16 2021 14:00 UTC – 6M Opening on Northeast Coast



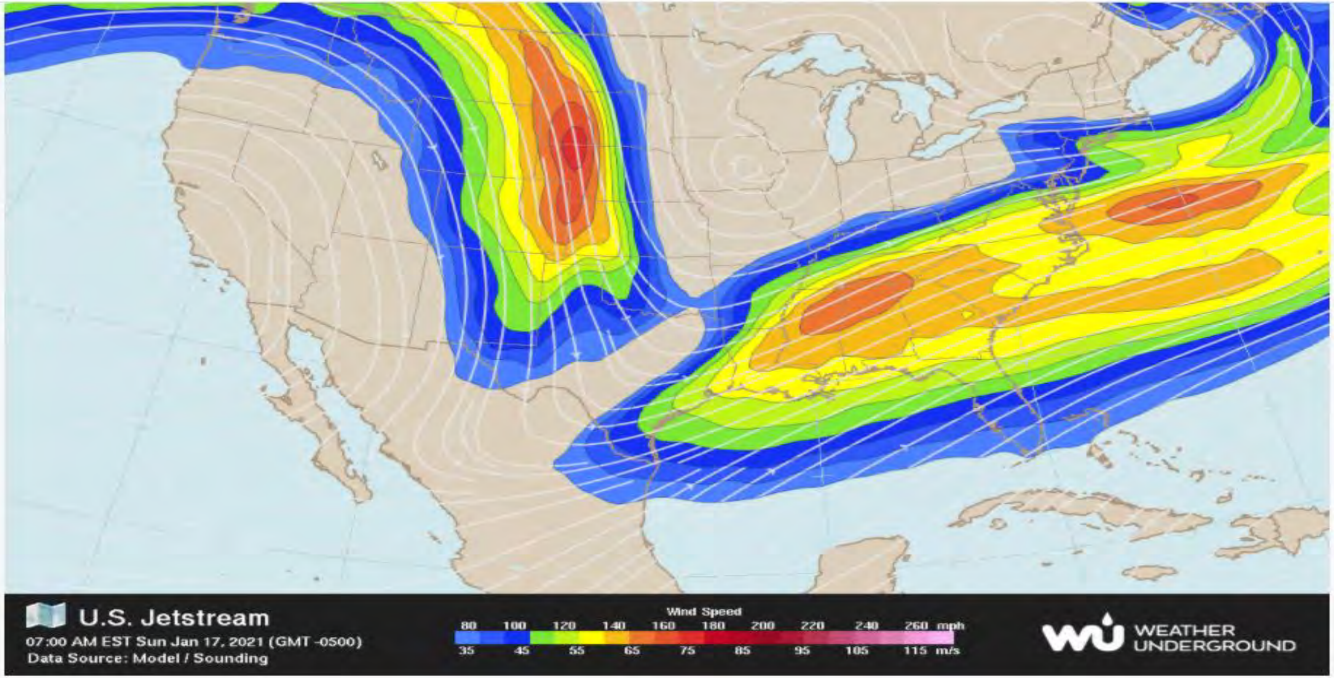
Jan 16 2021 14:00 UTC Surface Map – Large Storm over New England and a Long Front



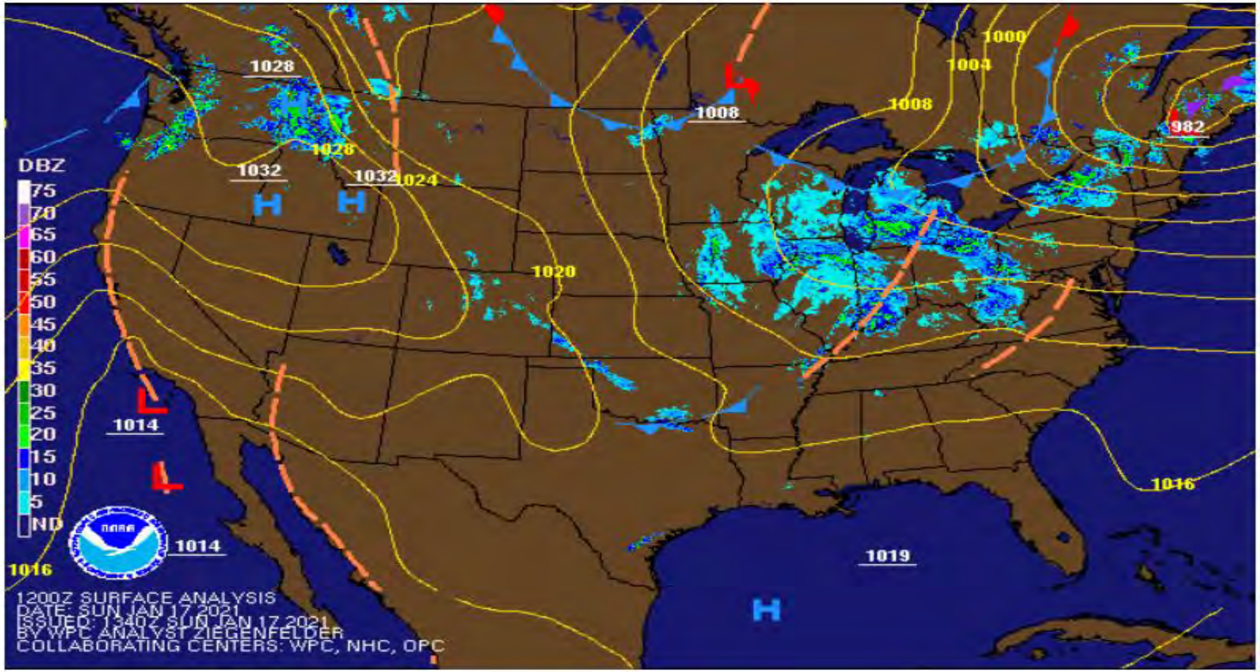
Next Day: Jan 17 2021 13:30 UTC – 6M Band Opening Again



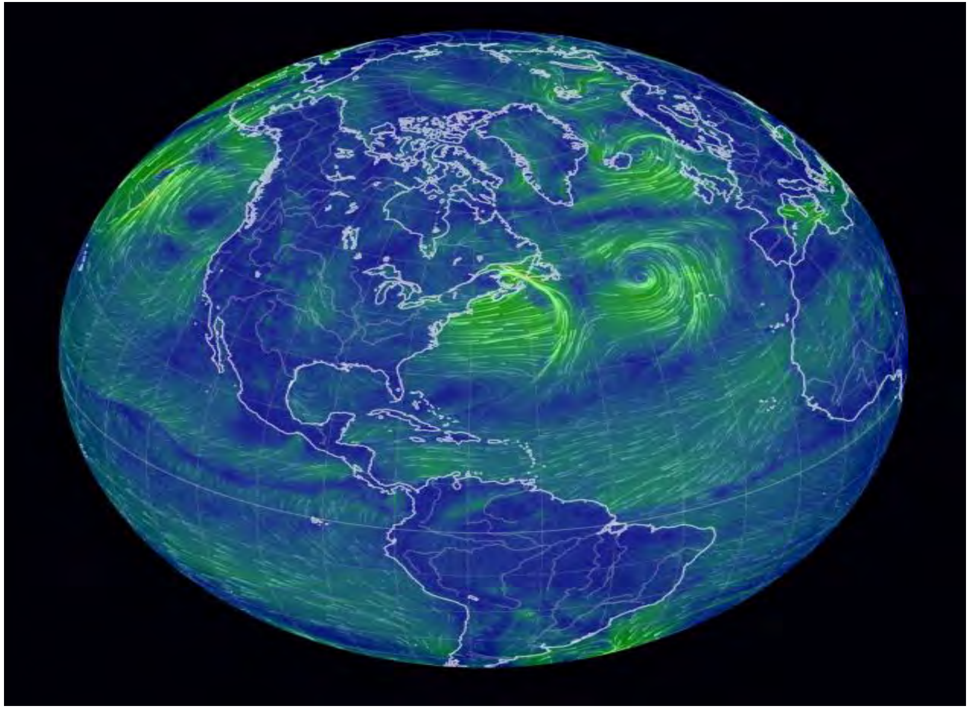
Jan 17 2021 13:30 UTC – Strong Jet Stream Trough on the East Coast



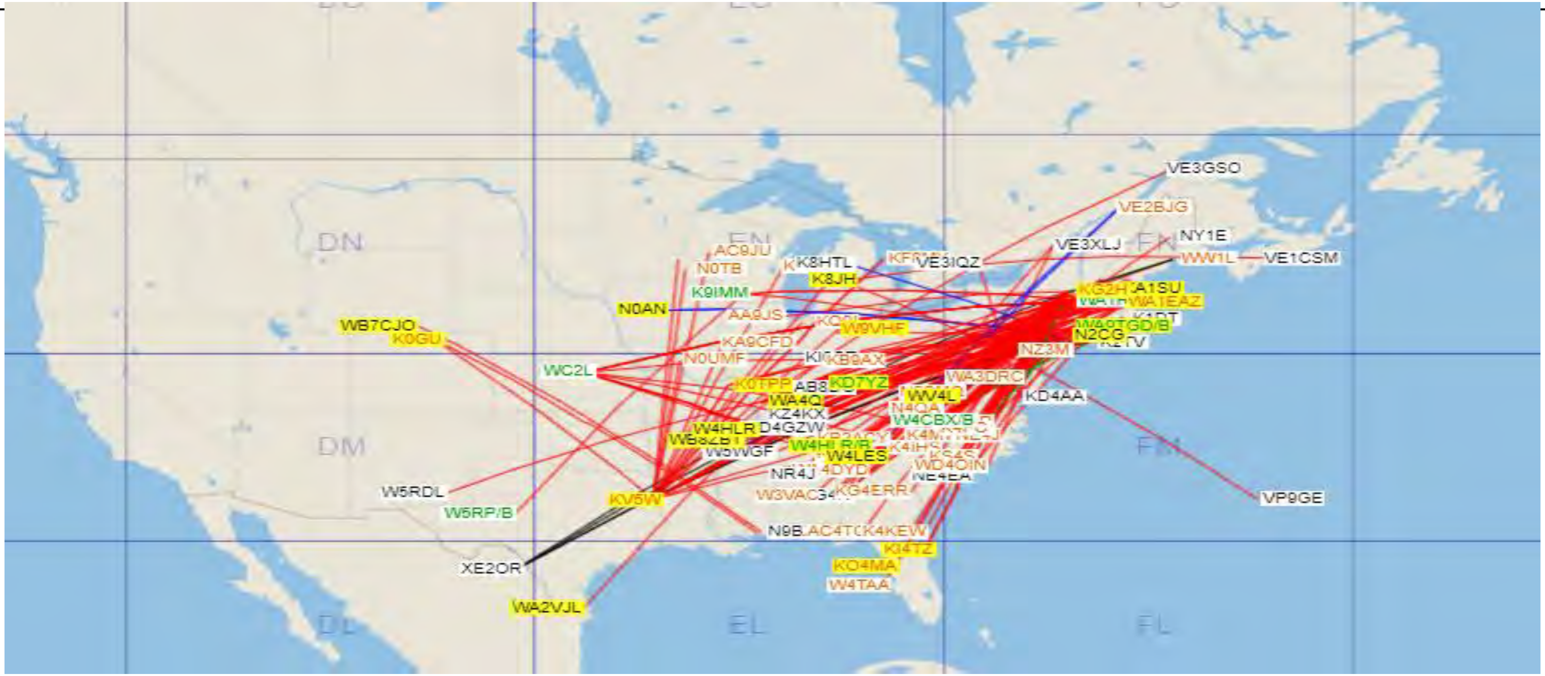
Jan 17 2021 13:30 UTC – Surface Map



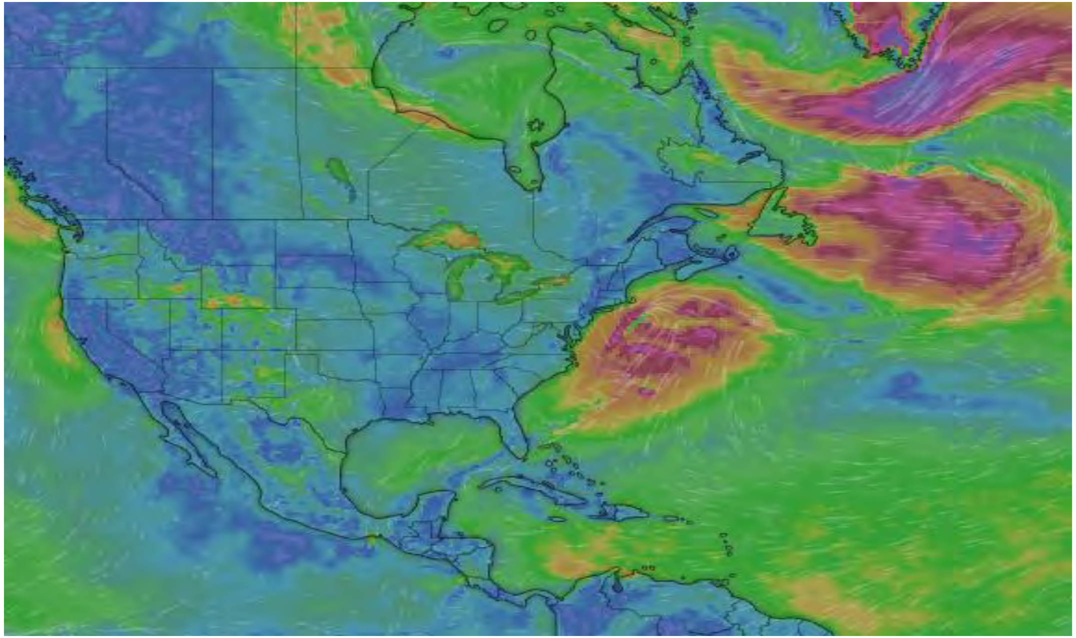
Jan 17 2021 15:30 UTC – Global Surface Model Showing Strong Wind Fields Just East of the Es-Like Opening



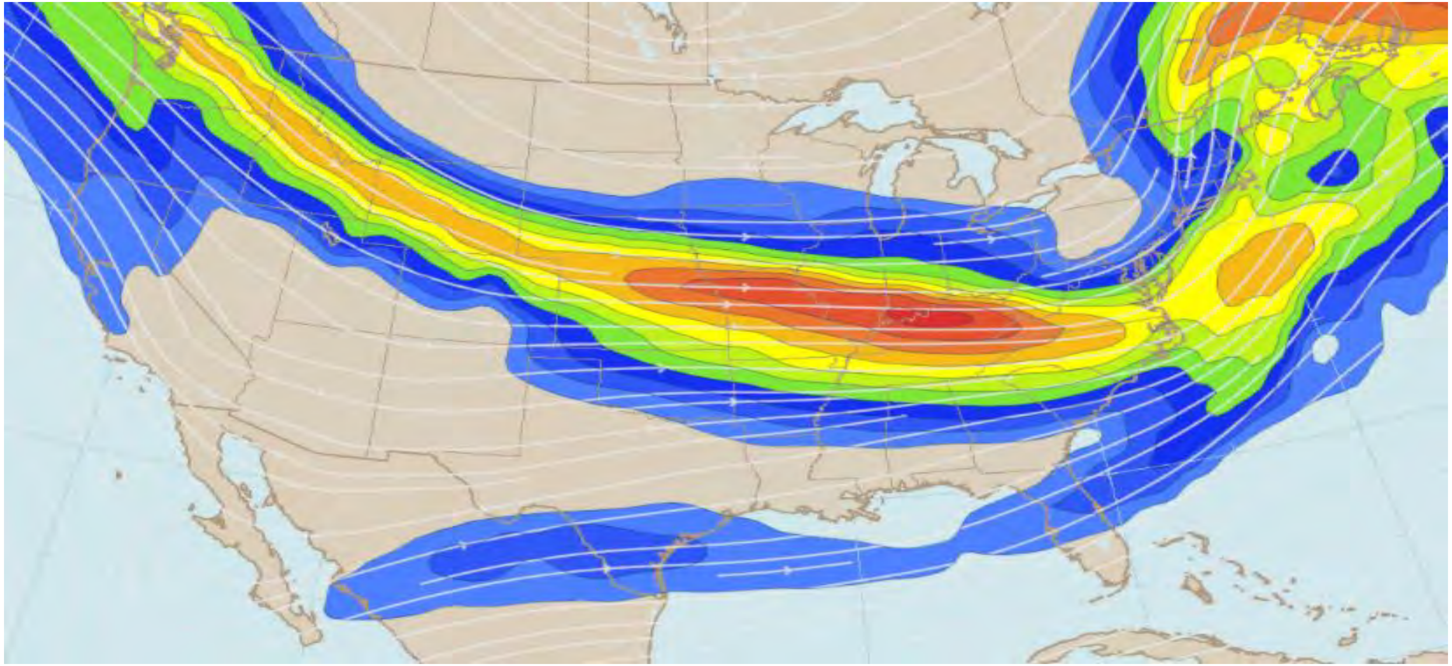
Feb 07 2021 21:20 UTC 6M



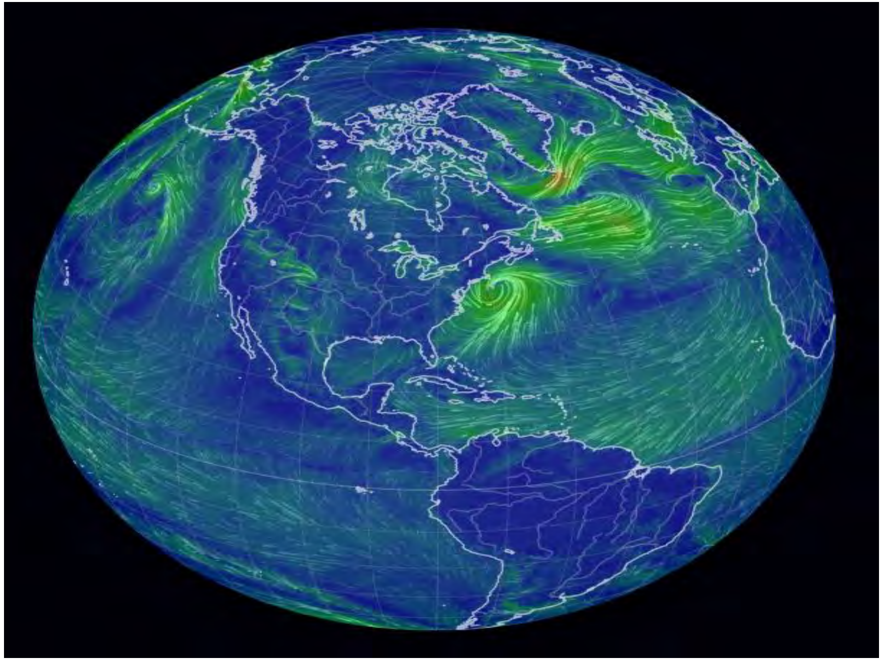
Feb 07 2021 21:20 UTC 6M



Feb 07 2021 21:20 UTC 6M

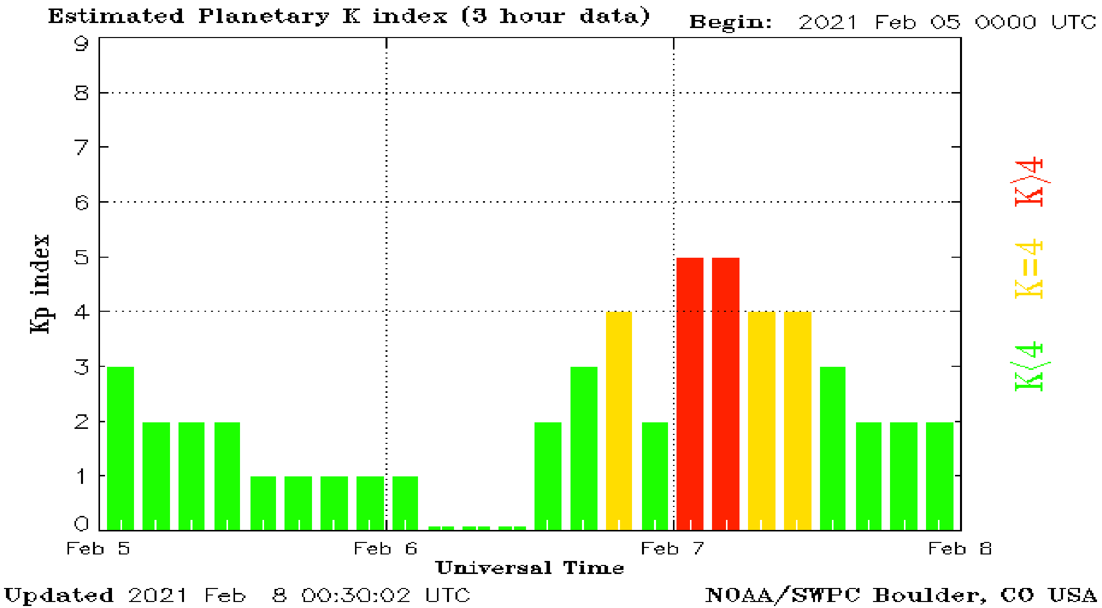


Feb 07 2021 21:20 UTC 6M



Feb 07 2021 22:04 UTC 6M

No Es Until Magnetic Storm Subsides and Then Es Forms Near The Wx Storm



Es – Many Variables, Many Causes

- Like one big DOE (Design Of Experiment) with no variables under control
- Variables: Solar UV, magnetic fields (Goldilocks levels, anomalies, disturbances), upper neutral atmosphere shears and tides, solar storms (flares, CMEs, coronal hole particle streams), time of year, location on Earth, atmospheric weather (fronts, thunder storms, lightning, sprites, thermal boundaries, strong jet streams), AND NO magnetic storms at the same time
- For me the surprise is: local weather has more Es effects than I would have thought – it is not just what the sun is doing at the moment

K1YOW Ham Radio Conclusions

- Es over storms in the North Atlantic spaced within 2000 Km allow transatlantic VHF communications.
- Fast Winter jet stream boundaries seems to be giving us our Winter Es season.
- Es also seems to form over strong Winter storms.
- Geomagnetic storms of level G1 or higher negate the above effects.
- Many amateur radio stations using WSJT-X digital communications along with excellent DX spotting Internet sites now give us excellent tools to make ionosphere observations!

K1YOW@ARRL.NET

Reference Links

http://www.dxmaps.com/spots/map.php
http://www.accuweather.com/en/world/satellite
https://earth.nullschool.net/
https://www.windyty.com/?42.753,-71.584,4
http://gfzpublic.gfz-potsdam.de/pubman/item/escidoc:23022:5/component/escidoc:23021/1009.pdf
https://www.weather.gov/oun/sfcmaps
https://www.wunderground.com/maps/wind/jet-stream
https://www.weather.gov/ffc/mapslast

A statistical analysis on the relationship between thunderstorms and Sporadic E Layer over Rome V. BartaP1,2P, UC. ScottoUP3P, M. PietrellaUP3P, V. Sgrigna P4, G. SátoriP2P, L. Conti 5

F-Region Propagation and the Equatorial Ionospheric Anaomaly, Jim Kennedy, K6MIO/KH6, QEX Issue No. 299 November/December 2016

Thunderstorm connected with Sporadic E propagation, Flavio Egano, ik3xtv documento n. 128 del 5 Settembre 2008

Biography

Joe Dzekevich, K1YOW, was first licensed in 1962 and currently holds an Amateur Extra Class license. He graduated from Northeastern University in 1977 with a B.S. in Industrial Technology and holds a M.B.A. from Clark University (1985). Joe is currently a retired Reliability Engineering Fellow who has worked for Bell Telephone Labs, Digital Equipment Corporation, Chipcom/3Com and Raytheon. Joe is also a senior member of the IEEE Reliability Society, where he held various offices in the local IEEE Boston Reliability Chapter and developed and taught many of the chapter's courses. He is a member of NVARC (Nashoba Valley Amateur Radio Club), the ARRL, and HamSCI. He has always been interested in radio propagation, starting back in 1965 where he subscribed to the CRPL (Central Radio Prediction Lab) Ionospheric Predictions, where one used monthly CRPL prediction maps to chart predicted E-Layer and F-Layer radio paths.

Title