As winter approaches, "Magic Band" fans look forward to a seasonal increase in E-layer propagation on 6 meters. But is it really the same as much more intense summertime Sporadic-E? HamSCI's K1YOW has been investigating and says weather plays a big role.

Winter Sporadic-E-Like Propagation on 6 Meters

A HamSCI Citizen Science Investigation

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WITH A FOREWORD BY DR. PHILIP J. ERICKSON,# W1PJE

The Ham Radio Science Citizen Investigation, HamSCI <http://hamsci.org>, is an organization connecting professional ionospheric and atmospheric researchers with the worldwide amateur radio community. HamSCI was started by ham-scientists who study upper atmospheric and space physics, and the group is dedicated to enabling amateurs' ability to make and contribute truly scientific observations through pursuit of the hobby we all enjoy. K1YOW has been making just such a set of detailed science experiments as described in this article using his powers of observation. It represents a great example of not only the power of "what if?" curiosity but also of the strength of merging science and amateur radio to help advance knowledge of Earth's ionosphere. In the end, we hope this article encourages many others to be curious during their own operations, to connect with the scientific community, and to use their keen observation skills for the benefit of all. – W1PJE

What started this investigation? In a previous article entitled "Upper-Level Lows and 6-Meter Sporadic E,"[1] I looked at the main causes of Sporadic-E (E_S), why there were many more E_S openings in Europe than we see in North America and some of the causes that allowed 6-meter transatlantic communications. The question then arose: Could similar weather events that allowed transatlantic E_S 6-meter communications also be behind 6-meter winter E_S-like band openings in North America?

Sporadic-E Review

For purposes of this article, we define E_S conditions as existence of some kind of ionospheric structure that allows long-distance communication at VHF frequencies, and in particular, the 6-meter ham band.

A general overview of E_S ionospheric features is in order:

- E_S layers are phenomena occurring in the ionospheric E region approximately 90 to 120 kilometers (56-75 miles) altitude. (Remember that the F region is typically much higher than this altitude — 200+ kilometers, or 125+ miles, during the day).
- E_S layers consist of enhanced electron density when compared to the background ionization created each day by the sun's extreme ultraviolet rays.
- The E_S layers appear mainly at daytime in mid-latitudes and mostly in the hemisphere experiencing summer.
- The layers usually have a vertical thickness of 0.5-5.0 kilometers (0.31-3.1 miles) and a horizontal extent of 10-1,000 kilometers (6.21-621 miles).

From my initial investigations into E_S, I made the following further conclusions:

- E_S is not random — it just has many variables — and we still can't predict it … yet.

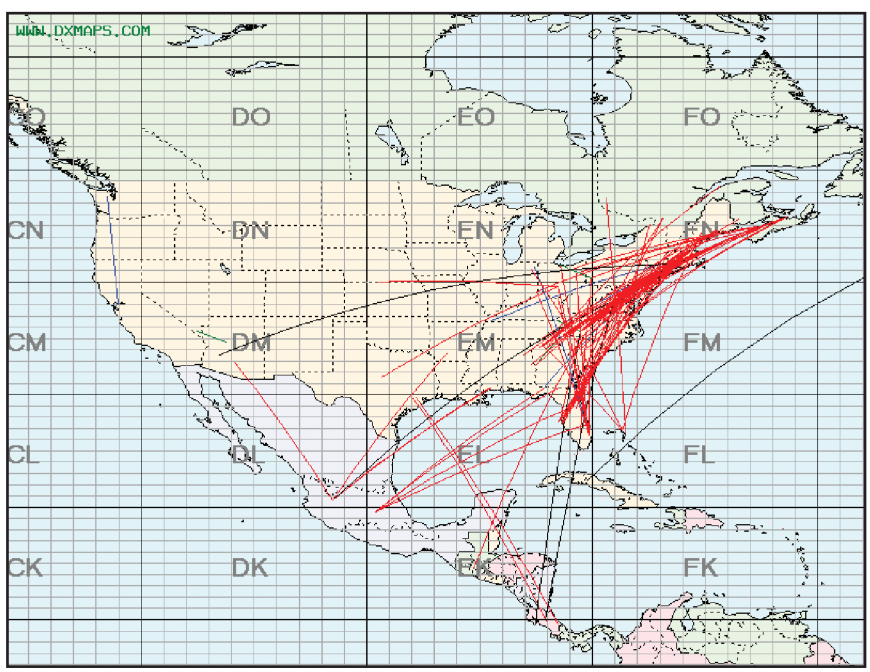

Figure 1: December 13, 2017 E_S opening (Courtesy DXmaps.com)

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• We hams make E_S contacts in polar and equatorial regions, even though some research studies say that there is no E_S there. But are these contacts caused by E_S or something else? More work is needed.

• Upper level low-pressure systems appear to influence the high-level tidal wind shear effects on E_S via thunderstorms, hurricanes, strong fronts, and especially lightning. Looking at tools like DX Maps, we see that E_S often forms at the same locations as storms and strong weather fronts.

• Results demonstrate that we can use amateur radio to see and document these occurrences.

• North America is not the best E_S spot in the world.

• If there are also low-pressure systems that generate effects such as lightning and higher altitude sprites / jets, they can *enhance* the E_S field up to the 6- or 2-meter frequencies.

• In Europe, the magnetic field strength is the same as in southern North America and we see more E_S openings in southern North America than in other parts of the continent, somewhat like we see more E_S in Europe. It looks to be a Goldilocks effect — the magnetic field strength must be not too strong nor too weak, but must be "just right" (like Goldilocks's porridge), although we are not going so far here as to describe a physical mechanism for this dependence. By "Goldilocks effect," we mean here that Europe, the southern U.S., and Caribbean all should have similar background magnetic field strength ranges of between 40,000 and 50,000 nT (nanoTesla).

• E_S is like one big DOE (Design of Experiment)[2] with many variables.

• For transatlantic communications via 6 meters over the North Atlantic, evidence showed that storm systems and / or strong frontal systems had to be spaced within 2,000 miles of each other and of North America and European land (where the amateur radio stations are). This effect seemed *not* to hold true for transatlantic 6-meter communications as one approached the equator.

With these previous conclusions, let's turn to the newer part of my investigations: Winter E_S conditions.

Winter E_S-Like Propagation

If E_S is mainly a summertime event, where we have long daylight hours with long UV exposure to the ionosphere, why do we see E_S during the winter at

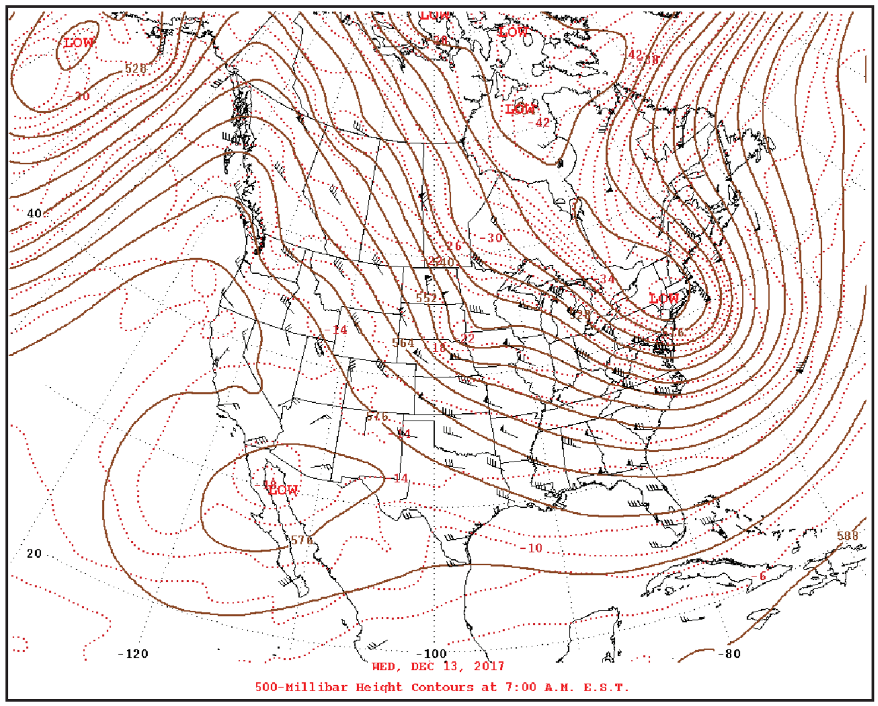

Figure 2: December 13, 2017 NOAA Isobar Map (NOAA image)

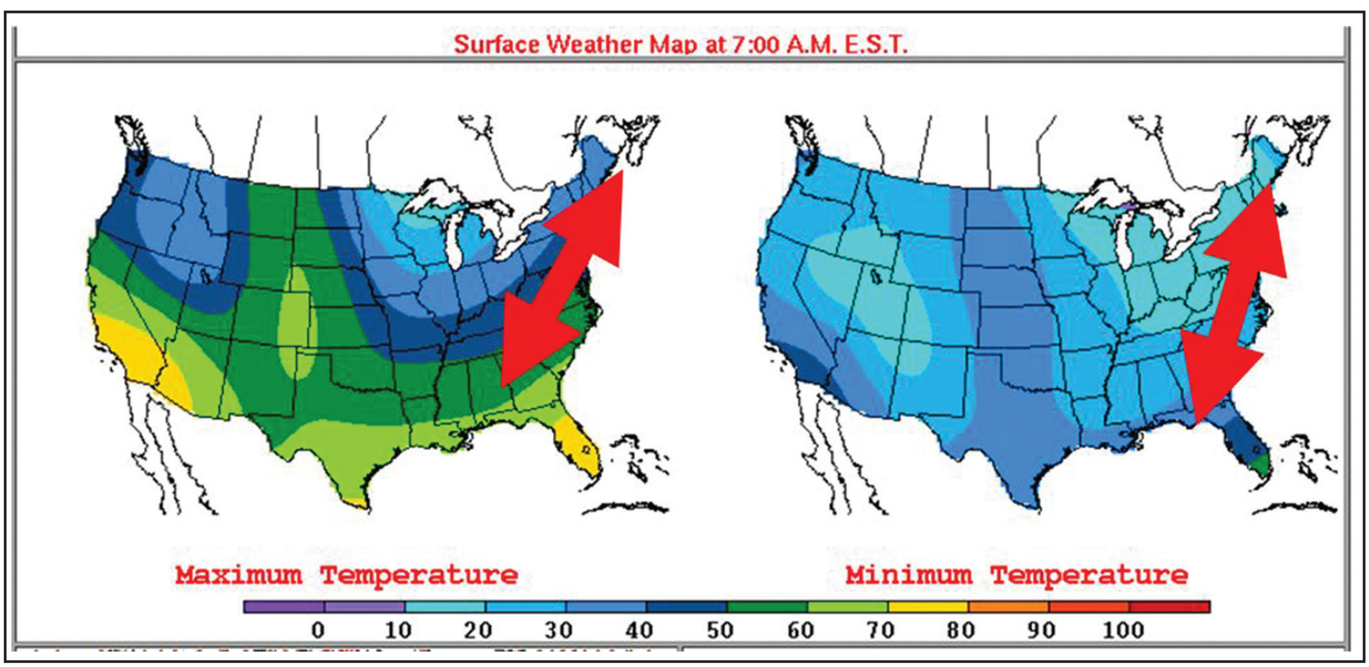

Figure 3: December 13, 2017 E_S paths overlaid onto NOAA jet stream surface temperatures

all, with winter's very short daylight hours, and thus minimal UV exposure to the ionosphere? In fact, could winter E_S be related to tropospheric weather such as storm and frontal systems, and can we use amateur radio to investigate this? The answer at the present appears to be "yes" to both questions from my ham radio-based data studies.

In particular, looking at *Figure 1*, we see on DX Maps that we had a nice 6-meter E_S opening in the eastern U.S. on December 13, 2017. What was the tropospheric weather doing at the time? Looking at *Figure 2*, we see a strong jet stream dip occurred in the same location as the 6-meter E_S event as measured by QSO rates. Strong jet stream troughs also have sharp temperature and wind speed boundaries. *Figure 3* shows the E_S path overlaid onto that day's temperature boundaries. The E_S cloud was above the eastern edge of the jet stream trough as that trough moved eastward with the steering currents.

Now, this is only one data point which could have happened at random, so did this pattern repeat itself? The answer is "yes." *Figure 4* shows three E_S paths later in that same month on December 31st, and *Figure 5* shows that the detected VHF propagation paths were again on strong jet stream temperature and wind boundaries. *Figure 6* shows a nice east-west E_S path on DX Maps. Sure enough, *Figure 7* shows that there was a strong jet stream trough in the same area.

Note that I show the E_S path also going east-west, as if the E_S cloud may have been over the center of the trough, but this is an assumption and may not have been the case. For example, there could have been two E_S clouds, one over the eastern edge of the trough's eastern ascending front and one on the eastern side of its descending western front. It is not possible to distinguish the possibilities precisely from this data alone, but it remains clear that a jet stream trough occurred in the same area as presumed E_S and happened at the same time. *Figures 8* and *9* show a similar pattern a few weeks later on January 6, 2018, except in this case, as the jet stream trough became shallower, the E_S paths stayed more on the edges of each side of the trough.

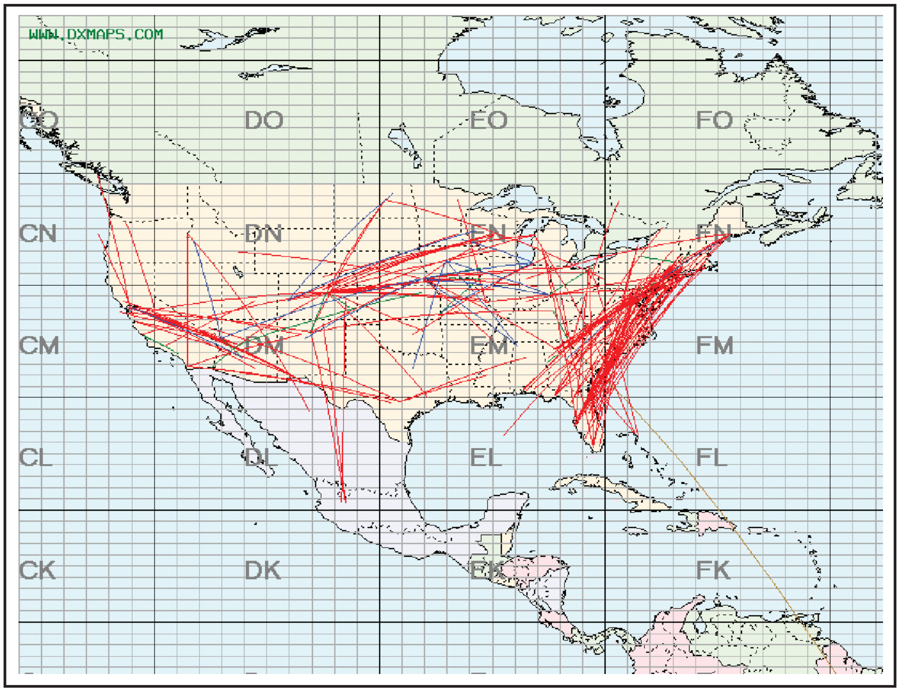

Figure 4: December 31, 2017 E_S shown on DX Maps

Initial Conclusions

So we can sum up trends consistent with our findings so far:

• E_S could be strongly favored to form

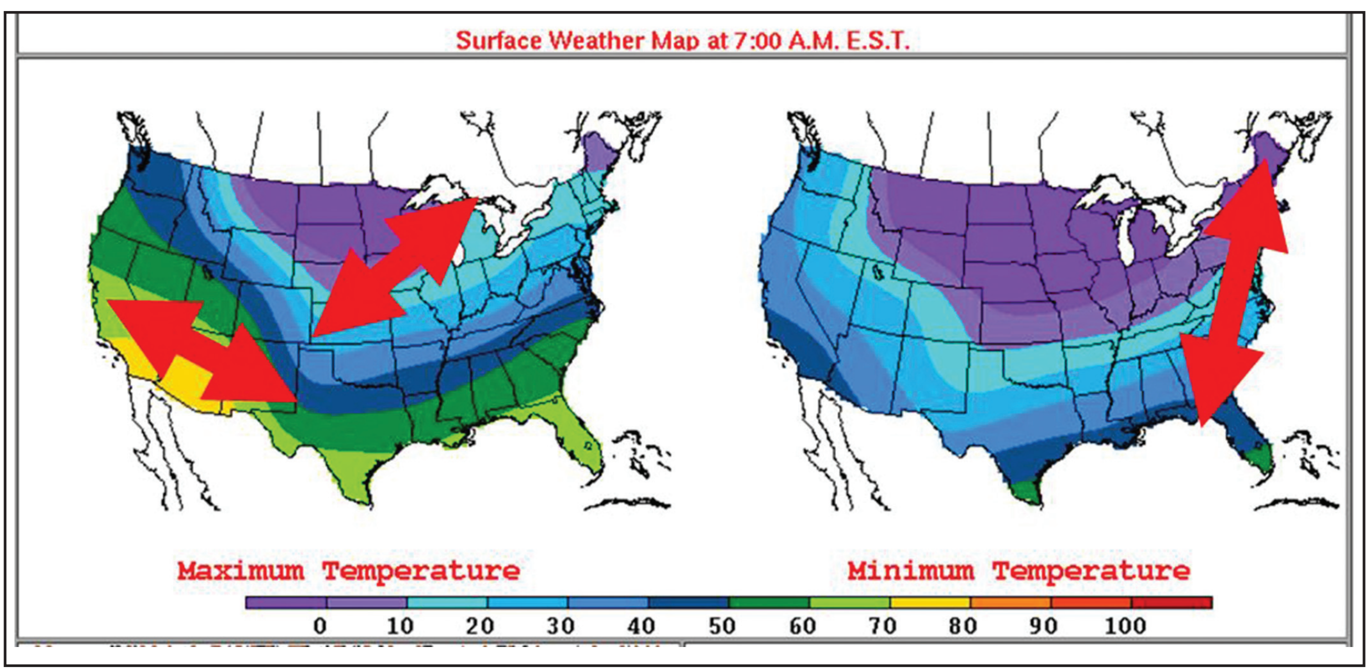

Figure 5: December 31, 2017 E_S paths shown on the NOAA jet stream temperature map

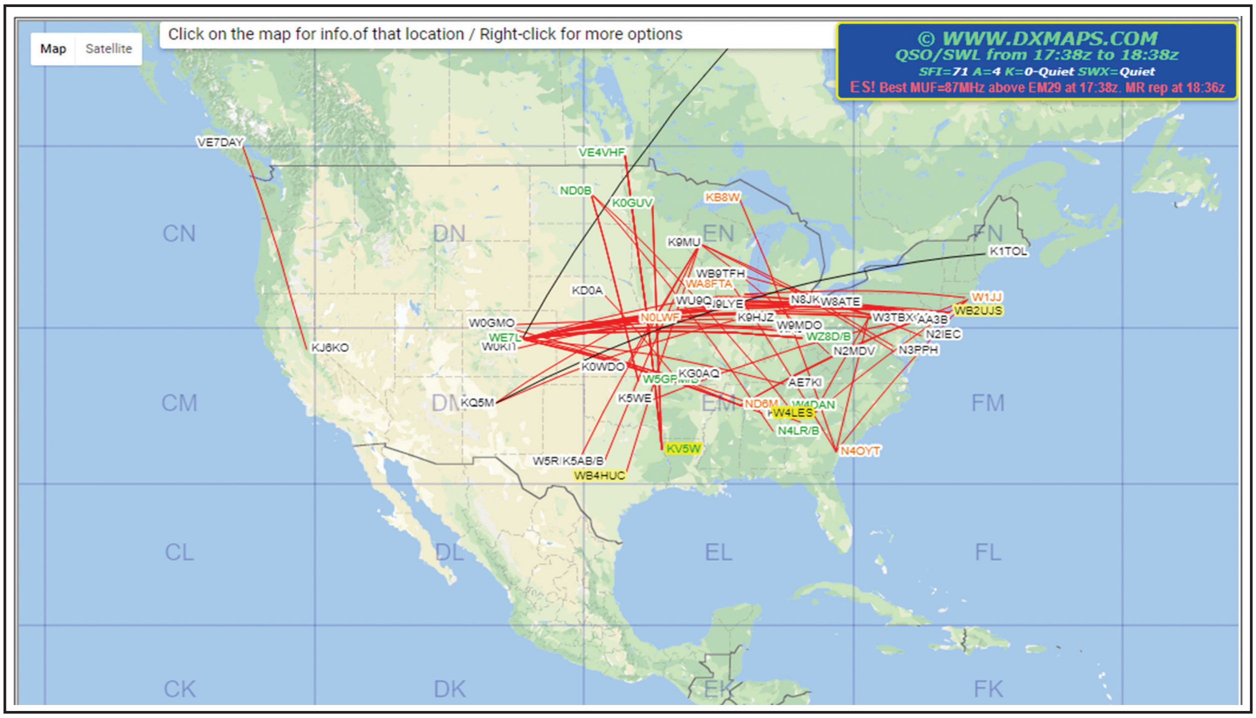

Figure 6: January 04, 2018 DX Maps image showing an east-west E_S path

above strong winter jet stream boundaries, where there are strong wind shears and strong temperature gradients.

• E_S seems to form above the eastern edge of either the eastern or western boundary of the winter jet stream trough.

• E_S also can form across the jet stream dip, but seems to form more often on the eastern side of a boundary on the side where the air currents are heading. Note that our North American jet stream flows west-to-east in the overall pattern.

But as in typical science studies … with E_S there is *always* a counter example. *Figure 10* shows the January 14, 2018 NOAA wind speed, with an extraordinarily strong jet stream trough on the eastern coast of the U.S. I went to the shack during this period expecting a nice 6-meter E_S opening, but found the band was completely closed with no widespread VHF propagation. Interestingly, there also happened to be a level G1 geomagnetic storm in progress at the time.

Can we reconcile this failure of my E_S prediction based on meteorological conditions? Many possibilities exist:

• Perhaps the jet stream was not fast enough to trigger the proposed mechanism.

• Perhaps the temperature difference boundaries were not strong enough.

• Perhaps geomagnetic activities interrupted the proposed lower-upper atmospheric connection. In particular, the sun was quiet for four previous studies, but this time we had a short G1/K5 set of moderate intensity geomagnetic storm conditions. These could have negated the connection.

• Perhaps the frontal boundary pushed off the eastern U.S. coast very quickly, and didn't linger in one spot as did the previous four jet stream-connected E_S events. If so, this would point to a minimum "residence time" needed for jet stream forcing.

• Perhaps none of these factors occurred, but instead an unknown additional mechanism happened.

Regardless of this latter case, the results of my studies show us something that both the ham and professional com-

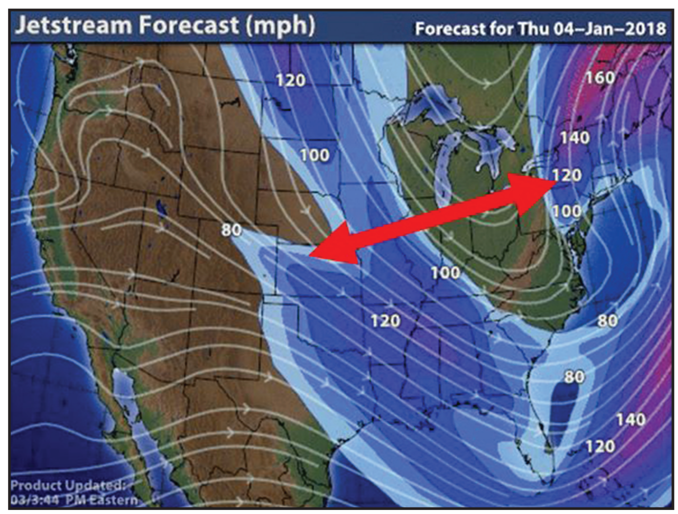

Figure 7: January 04, 2018 E_S path shown on NOAA jet stream wind speed map

munities has been puzzling over for many years: E_S can have multiple driving causes due to many variables.

An appropriate analogy views this situation, as in much of geophysics, as one big DOE (Design Of Experiment) with very few variables under control.

A vast number of these variable conditions exist: 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, and atmospheric weather (fronts, thunderstorms, lightning, sprites, thermal boundaries).

Conclusion: A Role for Weather

A considerably surprising conclusion nevertheless can be reached: Local tropospheric weather has more E_S effects than I would have previously thought. In the end, as the pro-

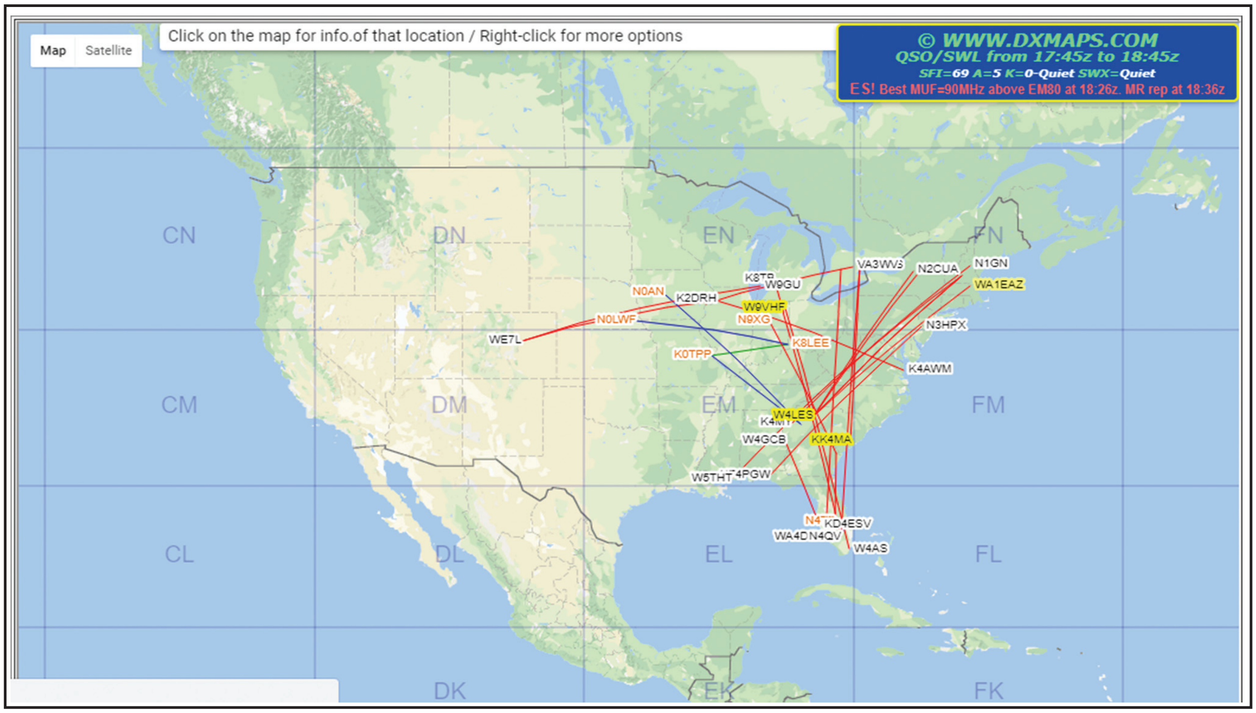

Figure 8: January 06, 2018 E_S shown on DX Maps

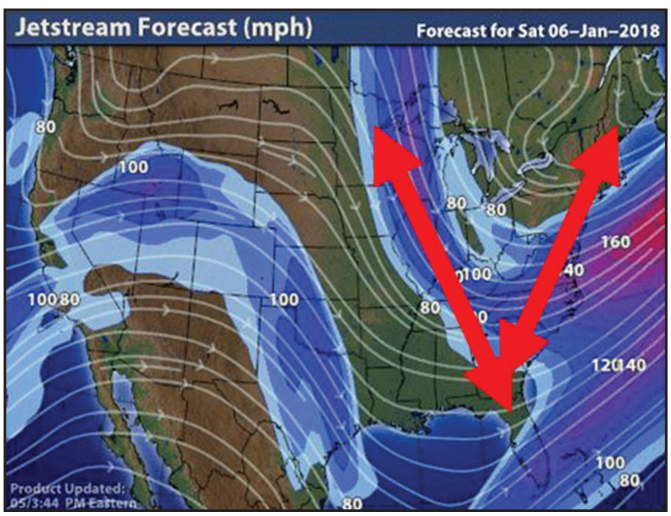

Figure 9: January 06, 2018 E_S shown on NOAA weather map

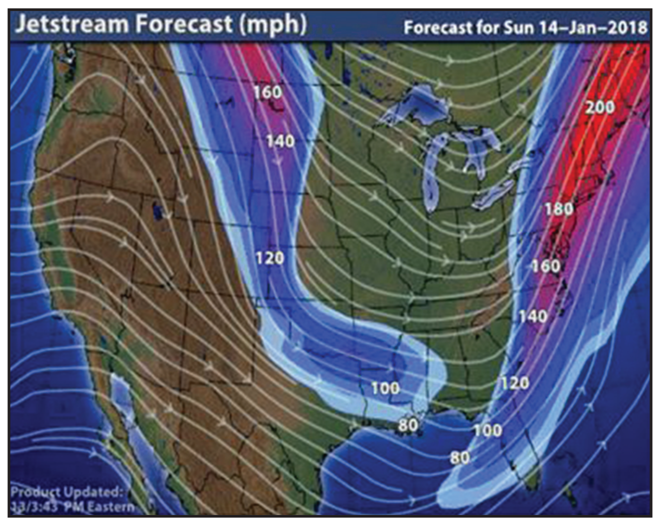

Figure 10: January 14, 2018 jet stream — but no E_S — a G1 magnetic storm was in progress (NOAA Wind Map)

fessional community has realized for its work, it is clear that simply looking at what the sun's ultraviolet and geomagnetic output is doing at the moment (space weather "from above") is just not sufficient to predict ionospheric variations. Internal atmospheric processes can have a large effect and must be considered as well.

Citizen Science and Amateur Radio

In the end, this citizen science study is another example how amateur radio can contribute to science and illustrates the great potentials for studies using ham radio data. We have many amateur radio stations on the air, using modes like FT8 which make contacts on propagation paths that we thought were previously impossible. Furthermore, many fine reporting tools like DX Maps, PSK Reporter, and various spotting networks exist and can provide unlocking keys for combination of the results with other scientific tools such as the NOAA weather maps. Pursuing these studies in the ham and professional communities can really help us start to understand what is going on, and contribute not only to human knowledge of space, but also directly to the enjoyment of our hobby, especially if you like the Magic Band!

Notes:

1. Dzekevich, J. (2017), "Upper-Level Lows and 6-Meter Sporadic E", QST, December 2017

2. According to the National Institute of Standards and Technology's *Engineering Statistics Handbook*, "Design of experiments (DOE) is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions. In addition, all of this is carried out under the constraint of a minimal expenditure of engineering runs, time, and money." (See <https://tinyurl.com/y434ref5>)