Solar Eclipse 2017 DX from Western America

by Nick Hall-Patch (VE7DXR)

1. Introduction

For a brief period during a solar eclipse, the moon's shadow stops the arrival of most radiation from the sun, creating a patch of darkness in the middle of the day over a small portion of the Earth's surface. That patch is surrounded by a substantial amount of twilight as well, in locations where the solar eclipse would be seen as partial (Figure1).

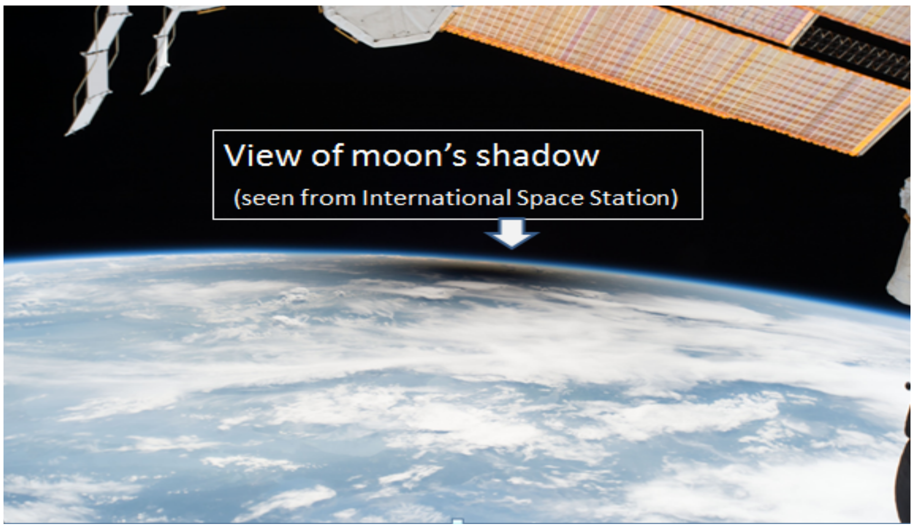

Figure 1 -- ISS view of 21 August 2017 solar eclipse shadow (NASA)

Because Extreme Ultraviolet (EUV) radiation from the sun energizes various layers of the ionosphere, and that radiation ends at sunset, medium wave propagation conditions change markedly at night, as the ionosphere reconfigures itself. So, do night-time conditions exist on the medium wave band during the duration of a solar eclipse?

In fact, it has been long been accepted that solar eclipses affect radio reception, and that normal daytime propagation can take on nighttime characteristics for a brief period of time at locations near the path of the eclipse. Indeed, the first recorded instance of such an observation took place during the 17 April 1912 solar eclipse across northern Europe, when William Eccles in London documented the increase in the number of clicks and crackles created by distant lightning discharges as the eclipse progressed, while he listened to radio equipment tuned to near 50kHz. (Eccles, 1912) (This was referenced in http://hamsci.org/sites/default/files/publications/2017_IES_Liles.pdf which covers the subject of studying the ionosphere using solar eclipses.)

Since 1912, there have been many solar eclipses and many studies of the influence of eclipses on radio reception. Some of these studies were done in the tradition of what we now call "citizen science", because historically, AM radio was a principal source of entertainment, and many listeners were aware that more distant stations could be heard at night. For example, in 1925, the magazine, Scientific American, organized about 2000 AM radio listeners in the USA to record their observations of the changes in reception during the eclipse of that year. These observations were then used by academics to help verify the existence of skywaves. (Lane & Walsh, 1925)

In 1999, Dr. Ruth Bamford of the Rutherford Appleton laboratory in the UK reported the effects of the solar eclipse of 11 August 1999 upon radio reception in the paper "Radio and the 1999 UK Total Solar Eclipse" (Bamford, 2000, https://arxiv.org/abs/1703.01491). The table of contents of that paper speaks to the medium wave DXer, with such headings as "General public medium wave experiment" and "Propagation at 1440kHz".

Most people at that time were familiar with AM radio broadcasts, and Dr. Bamford used television and newspaper coverage to encourage the average person to assist with what otherwise would have been strictly an academic experiment. On the day of the solar eclipse, 1700 people listened in the UK for RNE-639kHz during the solar eclipse, a radio station located in La Coruña, Spain, that would not normally have been heard in most of the UK in the daytime. Up to 25% of listeners did hear it, with some areas having more success than others. In addition, radio amateurs used receiver S-meters to record the strength of various signals, including those of medium wave broadcasters in Europe, and professional monitoring stations recorded signal strength from the Luxembourg broadcaster on1440kHz at various British sites as well.

All saw signal strength increases during the eclipse, and Dr. Bamford published preliminary results from the experiment a month later in a major British newspaper, continuing the publicity about distant radio reception that she had started before the eclipse.

2. Radio monitoring during the 21 August 2017 solar eclipse

Fast forward to the total solar eclipse of 21 August 2017, the first to cross the North American mainland since 1979. Did anything like the 1999 study occur that was relevant to the medium wave DXer? The answer, unfortunately, is "not really". HamSCI, a group of radio amateurs collaborating with researchers, investigated eclipse effects on the amateur bands and on WWVB-60kHz. Amateur radio results have been reported in the academic literature (Frissell et al., 2018, https://doi.org/10.1029/2018GL077324) and include findings for the 160m (1.8MHz) amateur band. This, as well as numerous ionospheric eclipse results, are published as part of a special eclipse issue of *Geophysical Research Letters* (https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1944-8007.SOL_ECLIPSE2017). All of these may have relevance for the medium wave DXer. There are also some HamSCI datasets directly relevant to the MW DXer: https://zenodo.org/record/897048/ and https://zenodo.org/record/851575/ , for example.

Sky and Telescope magazine asked readers of their website to monitor AM broadcasters during the eclipse, but they had responses from only 6 listeners. That was really unfortunate, as AM radio stations, which use a strong, steady carrier transmission, are ideal for monitoring fine details of changes in signal strength, going beyond reports of "heard" / "not heard", or rough descriptions of audio volume.

It's not as if medium wave DXers didn't listen during the eclipse; it was just that practically no-one had really planned any co-ordinated listening beforehand; contributing unusual loggings to a local hobby group seemed to be the extent of interest. There were a couple of medium wave reports to SWLing.com (https://swling.com/blog/tag/eclipse/), plus the International Radio Club of America list had a fair number of contributions about unusual DX around the time of the eclipse (https://www.mail-archive.com/irca@hard-core-dx.com/maillist.html)

According to those reports, there were indeed nighttime conditions during the eclipse. For example, very unusual and enhanced summer daytime receptions were described, such as:

- Mexico (XEPE-1700) was heard in Victoria, BC, for example, as well as in Vancouver, WA, and Grants Pass, OR
- in Seattle, California, Nevada and Utah were heard, as well as closer states
- California, Nevada, Utah, Colorado, Kansas were heard in southern Alberta
- further east, Florida and other deep south states were heard in Michigan

There is no doubt that such anecdotal reports have value to anyone who is attempting to understand radio wave propagation during a solar eclipse. However, the irony of the situation is that medium wave DXers are now more capable of documenting propagation effects than they have ever been before. This solar eclipse was possibly the first time that a number of DXers were able to use wideband recording software defined radios (SDRs) across a wide geographical area. Several DXers in Canada and the United States did, in fact, use their SDRs to listen during the eclipse, and made recordings to play back afterwards, primarily to hear more DX than would have been possible during the few minutes of enhanced conditions.

3. Using SDR recordings to monitor radio propagation during the eclipse

Given the serious firepower that SDRs now provide in their ability to record the entire MW band, it seemed possible to try to emulate some of the work done in 1999 by using some of these DXers' recordings. This article will discuss a small amount of work done with SDR recordings made by four DXers in western North America, Dave Aichelman in Grants Pass, Oregon, Mark Durenberger in Upsala, Minnesota, Nigel Pimblett near Medicine Hat, Alberta, and myself in Victoria, British Columbia. None of these DXers were under the path of totality, though all saw partial eclipses at their locations.

All of these locations were able to hear KSL-1160kHz from Salt Lake City during the eclipse, at distances of up to 1400km away, though normally this station would have been inaudible late on an August morning, due to daytime absorption in the ionosphere. I was able to go through the files kindly supplied by each of the DXers, and extract the signal strength of KSL as the eclipse progressed across the U.S.A.

Figure 2 shows a NASA provided graphic of the eclipse path superimposed with the paths from KSL to each of the DXers' locations. Three of the paths crossed the path of the eclipse, one was parallel to it

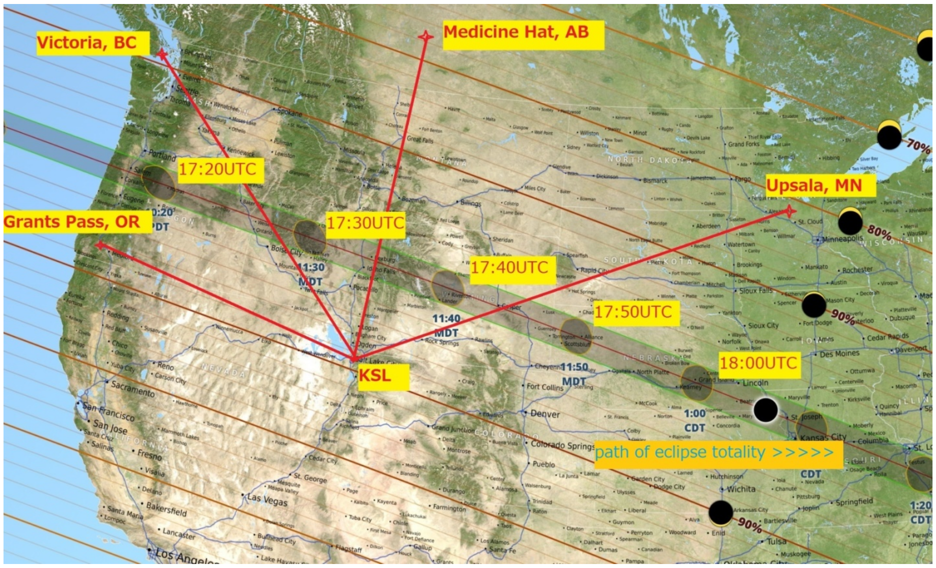

Figure 2-- KSL-1160kHz and the four reception sites. . The dark circles superimposed on the dark band representing the eclipse path are the positions of totality at various locations, with the time of totality in UTC pasted near each circle.

So, what did KSL's signal strengths look like from each location? Figures 3 through 6 are charts of KSL's recorded signal strength at the four locations during the course of the eclipse. X-axis in all cases is time UTC, and the Y-axis is signal strength at the input to the SDR in dBm.

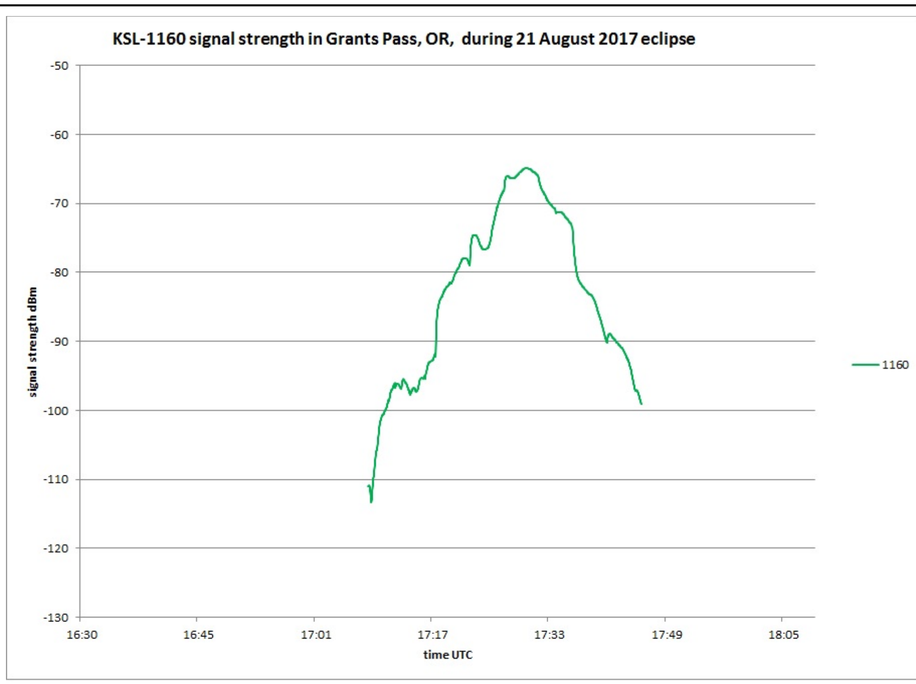

Figure 3 -- Signal recorded at Grants Pass, OR, using RFSpace Cloud-IQ and Wellbrook 1530LN Loop. Peak signal strength occurred at 1729:40UT, after a 45dB increase in KSL's strength over about 20 minutes, followed by a decline that was cut off by the end of the recording.

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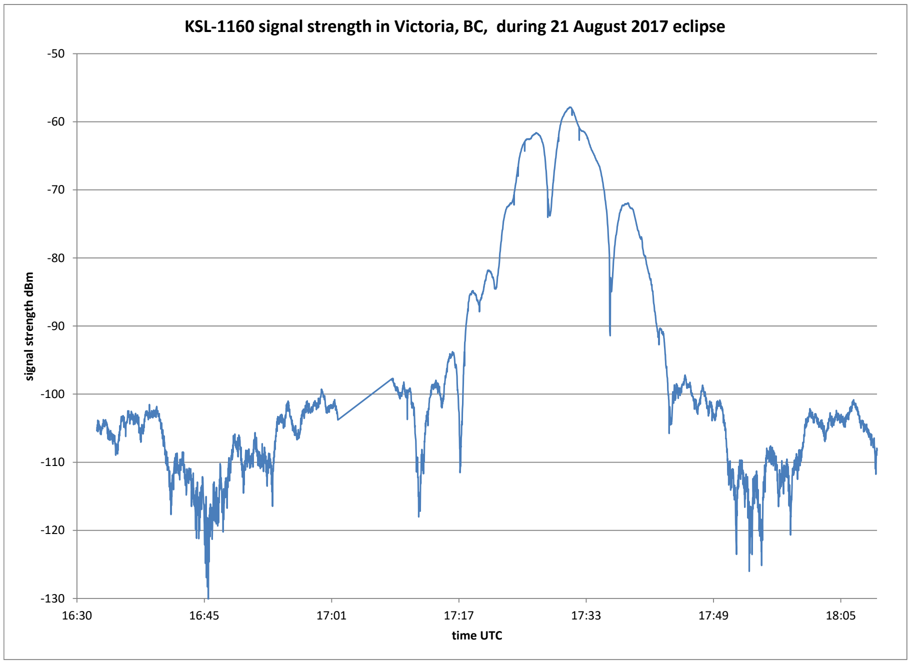

Figure 4 -- Signal recorded at Victoria, BC, using RFSpace NetSDR and Wellbrook ALA100 Loop. Peak signal strength occurred at 1729:40UTC, a minute later than at Grants Pass, but with a similar rate of increase to near normal night-time levels

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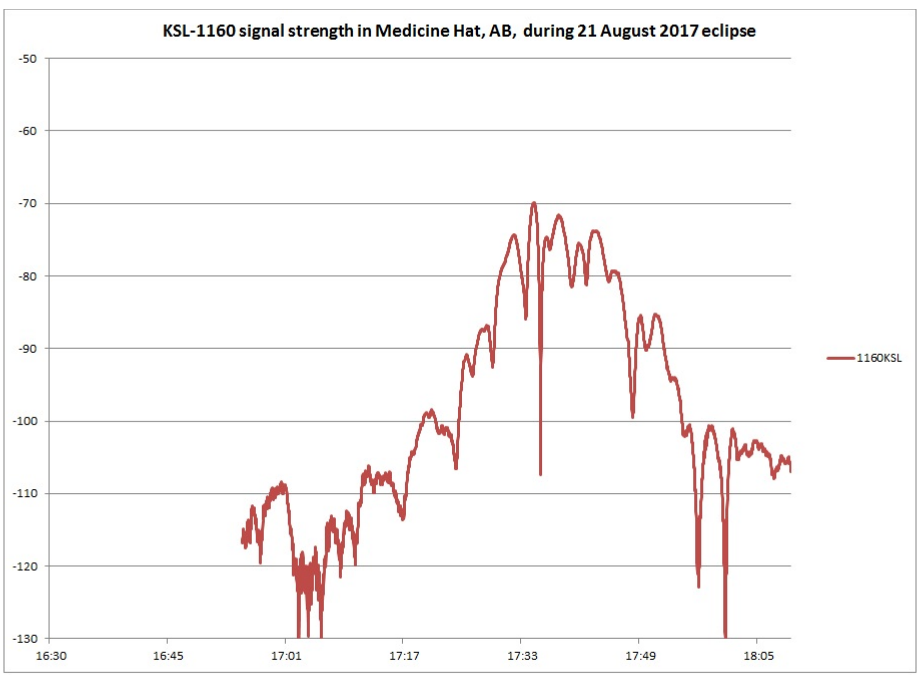

Figure 5 -- Signal recorded near Medicine Hat, AB, using Microtelecom Perseus and Beverage antenna, with the peak signal strength at 17:34:45UTC , after a 40 dB increase.

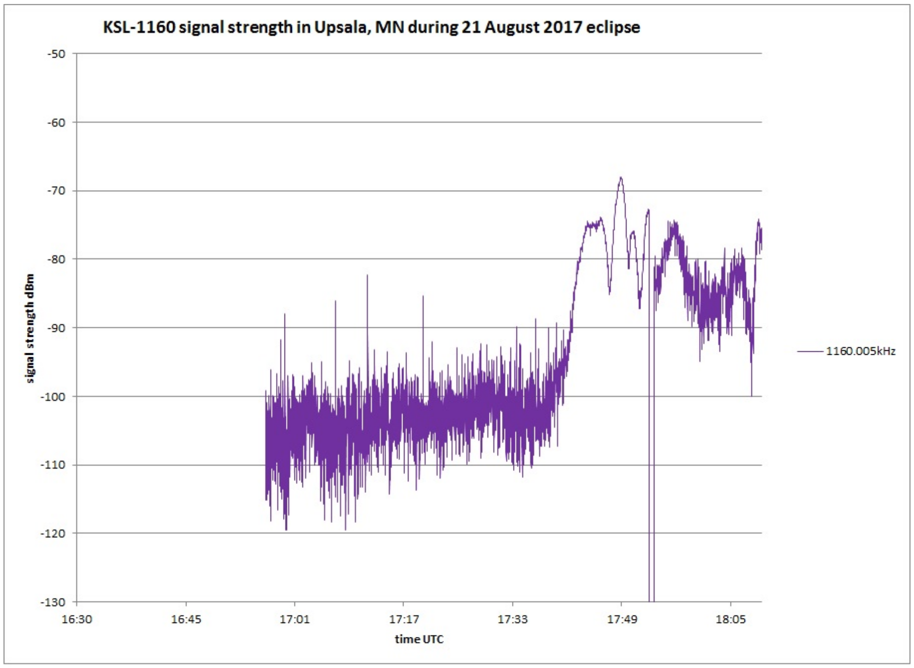

Figure 6 -- Signal recorded at Upsala, MN, using Microtelecom Perseus and Wellbrook ALA100 Loop. This is a rather "furry" signal trace due to a high level of lightning static at the site but there was around a 30dB increase in KSL's signal level above the noise over a 15 minute period, peaking at 17:48:45UTC.

Figure 6 shows that a baseline signal was difficult to derive at the Upsala receiver, due to lightning static. This signal trace is further confused at 17:54UTC by a change of antenna, pointing in a different direction, meaning that any further signals on1160kHz after that time are more likely to be from WYLL in Chicago rather than KSL. The signal heard earlier than 17:54UTC was weak and noisy, but was verified to be KSL by comparing the Minnesota audio recordings with what was being heard in Medicine Hat at the same time with much better quality, and containing a call letter identification.

Of note are sudden dropouts in KSL's signal strength, particularly in the Victoria and Medicine Hat recordings. While not pretending to offer any explanation, it is intriguing to speculate whether ionospheric bow waves or some other sort of traveling ionospheric disturbance (TID) might have caused these dropouts. (see https://news.mit.edu/2018/solar-eclipse-caused-bow-waves-earths-atmosphere-0119). There was also a C-class X-ray flare observed by GOES at 1755UTC that may have had some effect.

Dr. Bamford's paper included two different observations concerning the time of peak signal strength on medium wave during a total solar eclipse. One set was for a path from Paris on 864kHz to a radio amateur in Cornwall, and peak strength occurred at the time when totality was occurring about half way between receiver and transmitter. However, observations were also made of the peak signal strength of Luxembourg-1440kHz at six professional receiving sites in the UK, and those seemed to indicate that peak signal strength occurred when totality was close to the transmitter site.

Which of these observations were more pertinent to the recordings made of KSL's signal strength. If the signal strengths recorded for the Luxembourg 1440KHz signal in 1999 were most relevant to our 2017 observations, then the peaks that we all observed for KSL's signal should have occurred around 17:33:39UTC when the sun at KSL's transmitter site was at its greatest (92%) occultation.

Table 1 shows that our observed maximum signal strengths in Grants Pass, Victoria, and Medicine Hat were not exactly at that time of maximum solar occultation at KSL, but perhaps there was a few minutes room for error. However, KSL peaked in Minnesota a full 15 minutes later than maximum occultation in Salt Lake City. If it wasn't maximum darkness at the transmitter that was defining the receptions, what was?

It can be seen in Table 1 that the signal maximum definitely did not occur at the point of maximum solar occultation at the receiver. However, the time of maximum solar occultation at the half way point along the signal path from transmitter to the receiver (derived from Figure 2) looks more promising, especially for the paths to Medicine Hat, AB and to Upsala, MN, as both locations saw KSL's signal peak within a minute of that time. The delay in maximum signal strength at Victoria, BC and at Grants Pass, OR from maximum solar occultation half way along the signal path might be explained by the fact that not enough solar occultation had yet occurred at the KSL transmitter to dissipate the normal daytime signal absorption, even though the path to those more westerly receivers had already started to open.

Receiver Location	Time of KSL Max. Signal Strength (UTC)	Time of Max. Solar Occultation (UTC)	Time of Max Occultation 1/2 Way Between xmtr and rcvr (UTC)	Time of Max. Signal vs. Time of Max. Occultation SLC (min:sec)	Time of Max. Signal vs. Time of Max. Occultation at Receiver (min:sec)	Time of Max. Signal vs. Time of Max. Occultation 1/2 Way Between xmtr and rcvr (min:sec)
Grants Pass, OR	**17:29:40**	17:16:20	17:26	-03:59	13:20	03:40
Victoria, BC	**17:30:42**	17:20:15	17:26	-02:57	10:27	04:42
Medicine Hat, AB	**17:34:45**	17:37:24	17:34	01:06	-02:39	00:45
Upsala, MN	**17:48:45**	18:03:50	17:48	15:06	-15:05	00:45
Salt Lake City, UT	N/A	17:33:39	N/A	N/A	N/A	N/A

Table 1

A comparison of the times of the peaks observed at each receiver, along with Salt Lake City's time of maximum occultation. In addition, the approximate time of maximum solar occultation at the receiver, and also at the point where the signal paths were half way between KSL and our receivers are noted. Documenting the times at the half way point along the path assumes that each reception of KSL involved a single ionospheric hop between its transmitter and the four receivers.

Perhaps this is not the only possible explanation of what was observed, however. Because the ionospheric layers would have been pretty dynamic during the passage of the eclipse, there could have been some rather unusual propagation modes available. On the other hand, it does seem telling that the simple single hop hypothesis did seem to line up pretty well for at least two of the data sets.

This might be a good place to discuss at least one of the possible pitfalls of "citizen science" and "found data", such as these recordings. To make useful observations about the times of maximum signal strength of a certain signal, and then draw conclusions from them, one needs to be confident about such simple things as the accuracy of everyone's computer clock at the time that the recordings were made. After over a year has passed, how many DXers could be certain that their clocks had been set properly, unless they had specifically noted it down on the day of the eclipse? At the time, no one had planned to be part of a research project; they were just going to record DX. Fortunately, many domestic radio stations still give accurate time checks at the top of the hour, and by listening to each DXer's files, it is possible to say that everyone's computer clock was within a few seconds of each other.

4. Conclusion

It is hoped that those who are more knowledgeable about medium wave propagation will be able, by using this data, to develop firmer conclusions about the effects of the solar eclipse. In that vein, all the solar eclipse SDR data used in this article has been uploaded to the HamSCI long term repository. In addition, Tim Tromp's SDR recordings from western Michigan, and Brandon Jordan's from Mt. Juliet, TN, have also been archived. This data is for use by academics, but also by interested amateurs, and will be found by going to https://zenodo.org/communities/hamsci , and if the data is not immediately obvious, then search for "Solar Eclipse 2017 recordings". Appropriate software for playback of the recordings is available with each data set, as well as instructions, for those interested, on how to use the software to analyze signal strengths, similar to what has been done in this article.

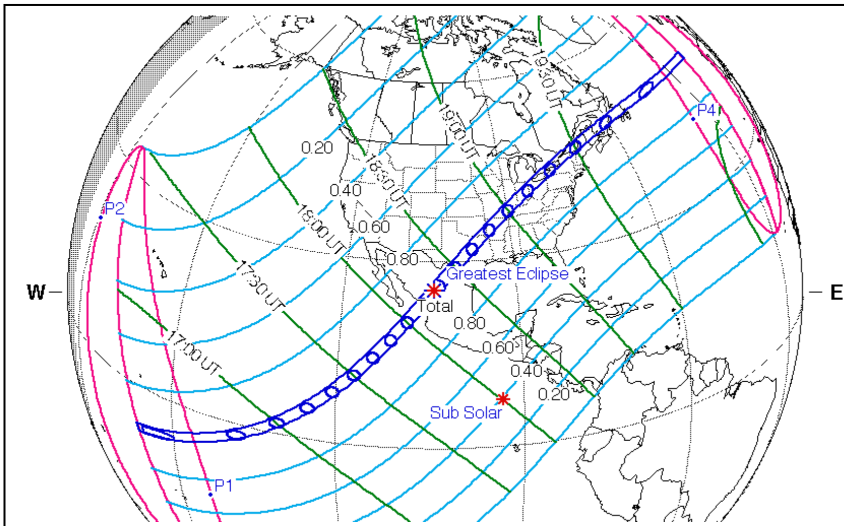

Figure 7-- 2024 solar eclipse path (NASA)

It's probably not too early to start thinking about radio reception for the 2024 total solar eclipse that will cross Mexico, the USA, and Maritime Canada (Fig 7). Perhaps this time we can do some proper planning for some extraordinary MW eclipse recordings.

This article is based on a presentation given at the International Radio Club of America's 2018 convention in St. Louis, MO, and first appeared in IRCA's bulletin, *DX Monitor*.

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