All Things Digital

Amateur Radio for the 21st Century

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THE GREAT AMERICAN SOLAR ECLIPSE

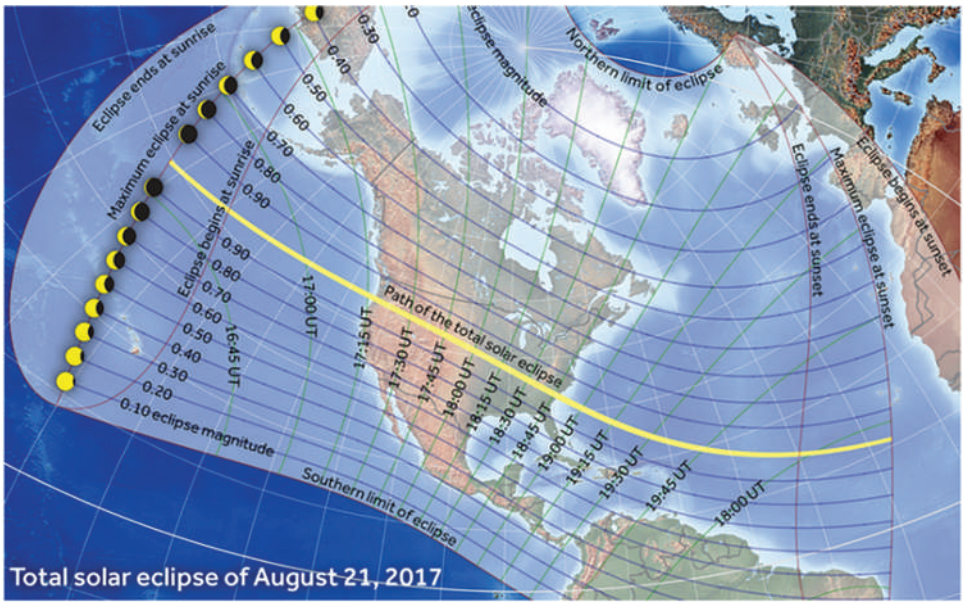

Figure 1: The Great American Total Solar Eclipse. It created a fast moving 115 kilometre-wide band of a few minutes of night, within the path of totality, while other areas had varying degrees of partial eclipse. Courtesy: Michael Zeiler, http://www.GreatAmericanEclipse.com

INTRODUCTION

On August 21, 2017, the sun and moon tangoed together as they raced across the Americas (see Figure 1). This allowed tens of millions of ground observers to see either a total or partial eclipse (if the sky was clear) – right up to the North Pole!

Thousands of radio hobbyists and scientists also conducted various experiments from the surface using solar-filtered eyes, various types of telescopes, radio (voice and data modes), up to near-space flying high-altitude balloons (see Figure 2), to outer space using satellite telemetry.

Total solar eclipses over heavily populated parts of the world are infrequent, and the last time there was a transcontinental one like this was in 1918. This was a truly once-in-a-lifetime event!

MY OBJECTIVES

1) Visually observing and photographing the eclipse.

2) Taking measurements of any effects it may have on the visual light spectrum and/or ambient air temperatures.

3) Monitoring low band frequencies below 40 metres (data and voice) to see if there were any changes in normal mid-day propagation patterns.

Figure 2: Chasing the Moon's Shadow. The view of the eclipse from the edge of space as snapped by a digital camera flying onboard one of many high altitude balloons launched within the path of totality. Courtesy: "The Eclipse Ballooning Project"

Figure 3: Solar Viewing Telescope Setup. My telescope, digital camera, plus white light solar filter sitting on a manual tracking tripod (eclipses are slow moving). A right-angle viewfinder allowed me to see what the camera was "seeing".

Because it was a westerly to easterly transit, cutting across equal lines of longitude, it would allow for easy comparisons with stations just west and east of my longitude (same solar time zone).

VISUAL ECLIPSE

The weather on August 21 was perfect and the sky remained clear for most of the eclipse. If you were stuck inside you could also watch it live on television and/or the Internet. Those lucky people in the path of totality with a clear sky also saw the brightest stars and planets become visible for a few minutes. I stayed outside for the entire partial eclipse (74% of totality) over Thunder Bay, used a handheld optical solar filter giving nice views of what looked like "Pac-Man" (Google it if you're under 40). But my solar-filtered telescope setup (see Figure 3) provided far more impressive images because there were

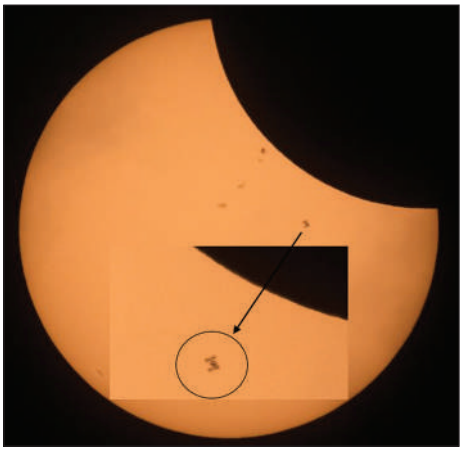

Figure 4: ISS Photobombs the Sun! The ISS transits the face of the sun at over 8 kilometres per second early in the eclipse. Courtesy: NASA.

several prominent sunspot groups adding to the spectacle. A digital camera was attached to the scope for both visual viewing/imaging, but I shot nothing compared with a NASA photographer who caught the international space station (ISS) transiting the sun (see Figure 4)!

LIGHT AND TEMPERATURE EFFECTS

After reading several accounts as to whether or not solar eclipses have any effect on air temperatures, I noticed a slight problem with how measurements were being made by those saying "Not." They tended to rely on airport weather and/or personal weather stations (PWS) for their conclusion, but the problem is that those weather stations are designed to take average temperature readings of the ambient air surrounding them. They are also sheltered inside Stevenson screens (or versions of) to shield them from direct sunlight and wind effects.

A better alternative is to use a technique similar to the photographic spot metering method, and collimate (to make waves or particles parallel) a vertical column of light (and air) straight up to the top of the atmosphere, or until we hit clouds. Collimators are sometimes sophisticated devices like telescopes and parabolic reflectors, but sometimes they are just a length of black tubing. A deep, black plastic Halloween treats pail was used for my collimator; it also blocked internal reflections and any side lighting and wind.

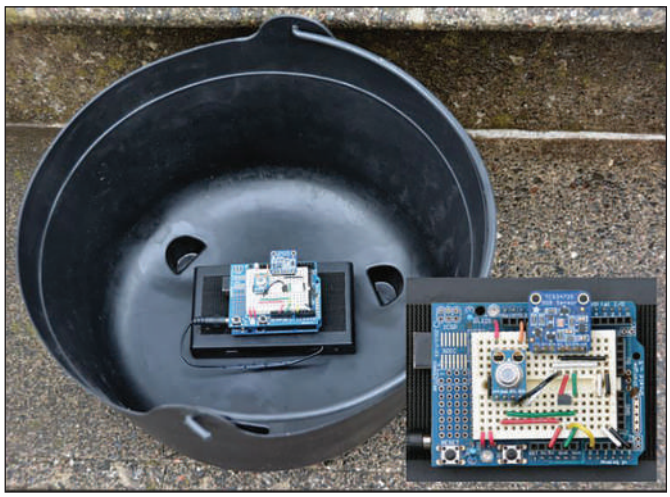

Figure 5: Collimated Arduino Sensor Gadget. Looking straight up into a collimated column of light and air, this gadget has red, green, blue (RGB) light and temperature sensors. Readings were automatically taken and saved at two-minute intervals for later retrieval and analysis.

An Arduino Uno light/temperature sensors gadget (see Figure 5) was put inside the pail/collimator (see my "The Arduino Uno MCU" parts "Uno" and "Duo" in the November-December 2014 and January-February 2015 issues of TCA). The pail was placed in the shadow of my house (north side) to add more protection from direct sunlight hitting the sensors.

Figure 6 depicts graphical results of measurements taken during the partial eclipse. It was no great surprise that lux (light) levels slowly dropped and then slowly rose during the eclipse. Neither was the fact that both my PWS and airport weather stations recorded only a slight linear increase in mid-day summer temperatures, but perhaps the eclipse slowed down the increase? The Arduino temperature sensor showed that something different was going on inside the collimated light/air column. Exposed skin is also very sensitive – it's our largest sensory and body organ.

After mid-eclipse I wrote in my notes: "Feel a definite chill in the air".

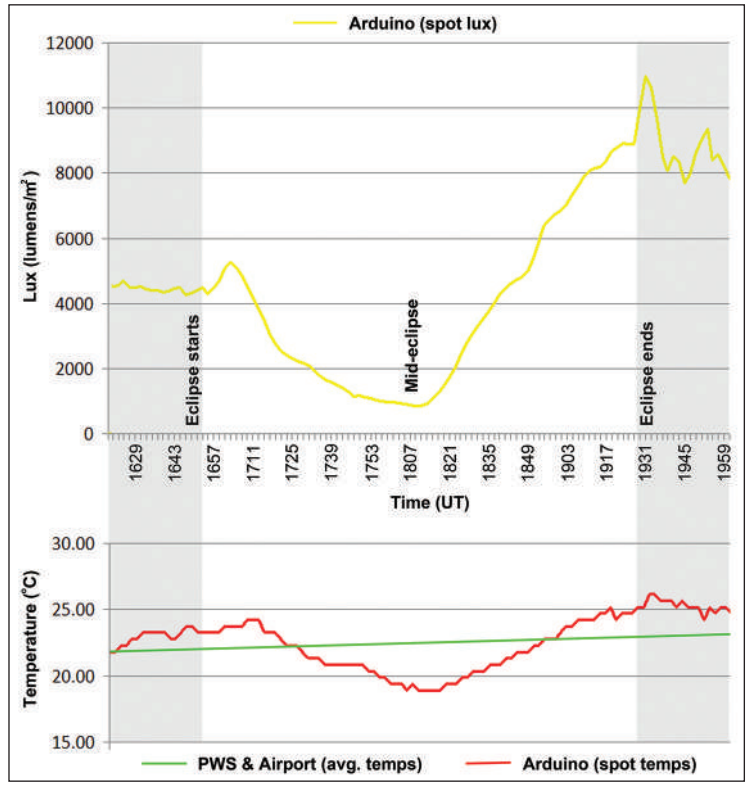

Figure 6: VA3ROM Eclipse Lux and Temperatures. Noticeable changes in lux levels and ambient air temperatures were detected by the Arduino sensor gadget. My PWS and local airport temperatures remained fairly constant.

PROPAGATION EFFECTS

Maximum solar UV irradiation of the upper atmosphere (ionosphere) occurs between 1200 and 1400 local time. This is called solar noon when the sun is at its highest point in the sky, and it varies with the time of year, geographical location, and if Daylight Saving Time (DST) is used. Thunder Bay is one of many wonky time zone exceptions because geographically we're well inside the Central Time Zone, but we use "Toronto time" (Eastern Time Zone) instead of "Winnipeg time". This creates late evening DST mid-summer sunsets (around 2200 local), and solar noon (year round) always occurs an hour after civil or by the clock noon.

The cooling cycle of "my" ionosphere serendipitously started at the same time as the eclipse did, and it appeared to accelerate the cooling, creating low band openings after mid-eclipse (see Figure 7). Notice how all the WSPR stations lie close to my line of longitude, and south towards the path of totality. This opening lasted nearly an hour as stations slowly faded, from west to east, back into the atmospheric noise. However, one very small data set is not enough because appearances can be deceiving ("lies, damned lies, and statistics").

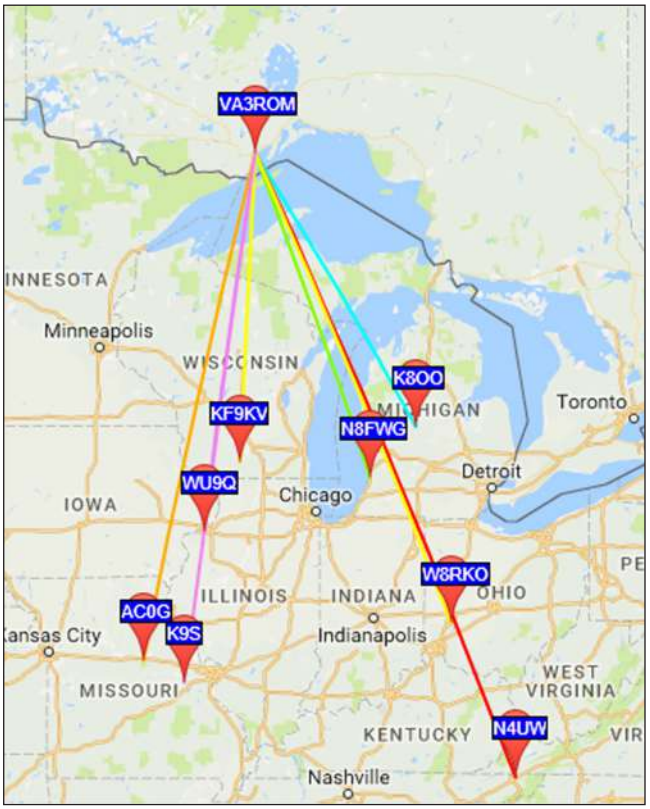

Figure 7: VA3ROM WSPR Mid-eclipse 80m Band Opening. Courtesy: WSPRnet.org

Results from many other independent sources are needed to prove/disprove any hypothesis.

Figure 8A is a graphical analysis of the Reverse Beacon network (RBN) Morse code data, as compiled by the Ham Radio Science Citizen Investigation (HamSCI) group, during the eclipse. One of the HamSCI founders, is newly minted PhD Nathaniel Frissell, W2NAF, who wrote his dissertation on using Amateur Radio data networks to assist scientists, like himself.

In this case, thousands of real-time reports (spots) clearly showed what happened during the eclipse: the 20 metre band behaved like it would during late night, and signals were no longer being refracted back to earth because they now travelled up and out to the stars, while the low bands displayed typical night-time propagation by travelling farther up into the ionosphere before being refracted. But there's a slight problem with this graph – dramatic as it is – you can't get any empirical values from it. There appears to be some kind of reciprocal relationship going on with the data set, but how do we quantify it as a number, preferably in dB, for any time during the eclipse?

I decided to analyze the corresponding WSPR beacon data because these automatons generate reliable, regular repeating signals with embedded digital data (call, grid and power). Steve Franke, K9AN's impressive 24/7 WSPR streaming station was used as the data source because he's almost due south of me (same solar time zone) and was just north of the path of totality.

K9AN's eclipse spots were extracted from the WSPRnet (archives go back to 2008), and stations beyond 2000 kilometres (km) were removed, but all beacons, regardless of power levels, were kept. The beacons' received signal-to-noise ratios (SNR or S/N), as determined by K9AN, were analyzed with a scatter plot, which is used to identify the type of relationship (if any) between two quantitative variables. The results produced less spectacular looking graphs (see Figure 8B), but now they can give us comparative dB values. Their (blue horizontal) trend lines, showing the general direction a group of points seem to be heading, indicate the 20 metre band had about a 6 dB decrease in SNR, while the 80 metre band had about a 6 db increase (a power factor of four).

Voice only operators would (probably) say this is only a 1 S-unit increase/decrease and barely noticeable (perhaps), but in the data world it's a HUGE number – the digital equivalent of SHOUTING! Ask any Morse code operator if a 6 dB SNR change up/down makes any difference to them.

As for commercial broadcast AM radio band reception – quoting from my notes – "Four stations received between 900 and 1000 kHz after mid-eclipse, but identified only one across Lake Superior (100 miles southeast) – WMPL 920 Hancock, Michigan. The others weren't readable enough to make out any station details because they were riding the atmospheric noise, fading in and out. Most likely Great Lakes region stations to my south southeast."

EXPLANATION

So why did this particular solar eclipse affect propagation right across North America? First, it was a transcontinental eclipse; and second, propagation is affected by something called the total electron count (TEC) high above your head in the ionosphere. It's created by solar UV (ionizing) radiation literally blasting electrons free from atoms in the upper atmosphere – turning atoms into positive ions (hence the name). The freed electron particles interact with the Earth's magnetic field (magnetosphere) creating negatively charged clouds of varying densities, "lumpiness", energy levels and tilt angles that refract (or not) radio waves (photons) of specific wavelengths travelling though them.

The TEC changed by an amazing 40%, creating low band openings and high band closings following along the path of totality. The propagation effects expanded outwards, but weakened with increasing distance, to well over 1000 kilometres.

TEC is affected by the Earth's diurnal cycle (higher on daylight side), solar cycle (higher with more sunspots), and geomagnetic storms (solar "wind" interaction with the magnetosphere).

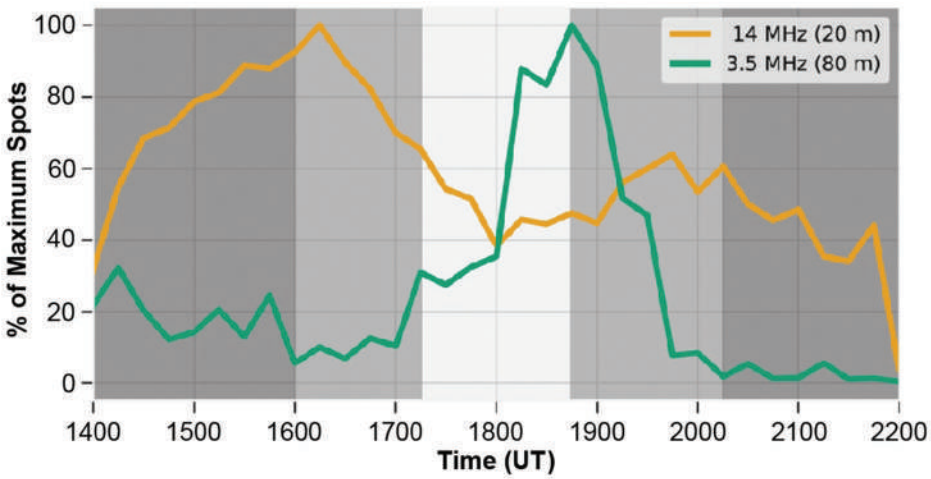

Figure 8A: HamSCI North American Eclipse Effects. RBN graph depicting percentage of maximum spots per band received during the Solar Eclipse QSO Party (SEQP). Shaded areas represent the eclipse level: dark – no eclipse; light gray – partial eclipse; white – total eclipse. Courtesy: ARRL (QST, December 2017, p. 39)

It's measured continuously in two ways: by using the Global Navigation Satellite System (GNSS), colloquially called "GPS" (see Figure 9), and by incoherent scatter radar (ISR) from ground stations transmitting pulses straight up. The Madrigal web server database network continuously collects and stores TEC values from worldwide reporting stations – archives go back nearly 20 years.

MY FINAL

Radio hobbyists can do real science, have fun, learn a lot, and contribute invaluable data on solar-terrestrial events to help scientists figure out what really goes on "up there". Early results are being published and there are two excellent articles in the December 2017 issue of *QST* magazine. The next total solar eclipse will be in April 2024, with eastern Canada in the path of totality, albeit it's a southwest to northeast transit coming up from Mexico. There's also an annular (ring) solar eclipse in June 2021 for most of North America.

In closing, here's one easy way you can help while you sleep: leave your computers and radios turned on at night (subject to area thunderstorms), monitoring any radio data bands and streaming data to one of the Amateur Radio web sever database networks (most software is free). Any person, group, organization, classroom, and so on, can contribute and/or access collected data. – 73

REFERENCES AND RESOURCES

Amateur Radio Science Citizen Investigation

http://hamsci.org/

Eclipse Ballooning Project

http://eclipse.montana.edu/

Eclipse Time/Date Calculator

http://tinyurl.com/y8earrwh

How GPS "saw" the Solar Eclipse

http://tinyurl.com/y7wzrby7

http://tinyurl.com/yb6c4wu8

How ISS Astronauts saw the Solar Eclipse

http://tinyurl.com/yd7vrvwq

Measuring Solar Energy during an Eclipse

http://tinyurl.com/yccbey3z

NASA Eclipse Support

https://eclipse.gsfc.nasa.gov/eclipse.html

Madrigal

http://tinyurl.com/y9do3sz8

TEC

http://tinyurl.com/y9r9ndac

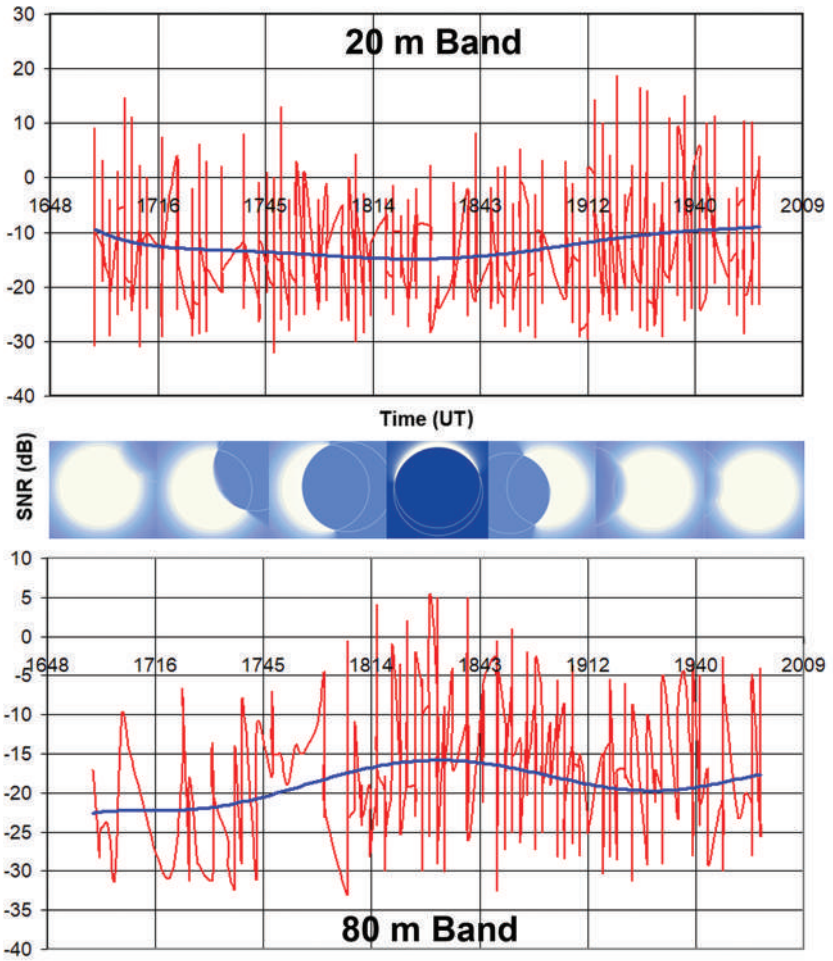

Figure 8B: K9AN WSPR North American Eclipse Results. Courtesy: WSPRnet.org

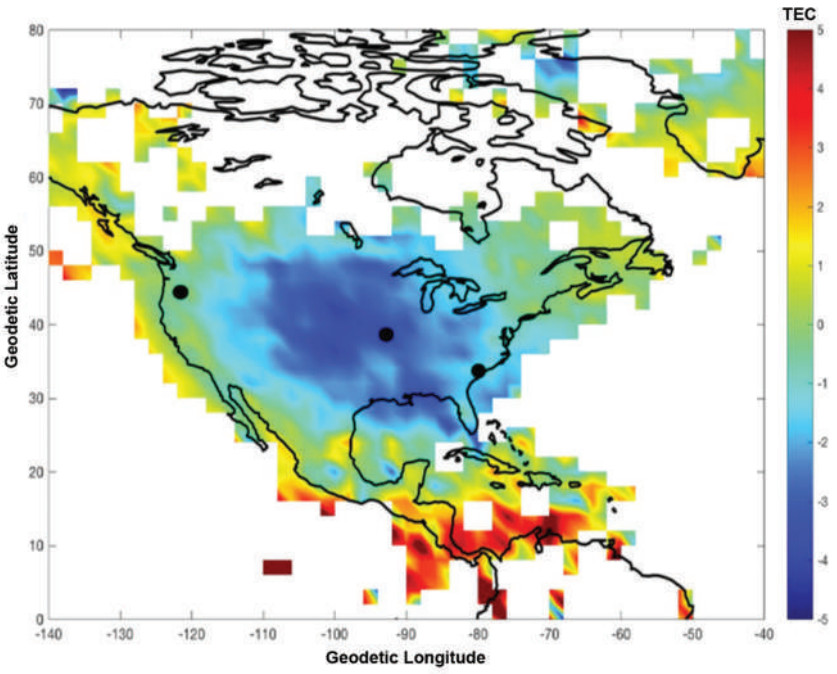

Figure 9: How GPS "saw" the Solar Eclipse. GPS geodetic map showing the amount of change in the ionosphere's TEC by mid-eclipse (1815 UT) as compared to eclipse start (1615 UTC). Varying levels of the TEC cause varying delays in satellite microwave signals travelling down to earth. Negative change (towards blue) means better low band propagation; positive change (towards red) means better high band propagation. Courtesy: National Oceanic and Atmospheric Administration (NOAA)