Is This Solar Minimum Better or Worse Than the Last Solar Minimum on 160m?

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Introduction

In late April 2009 I posted the following message to the topband reflector (then moderated by Bill Tippett, W4ZV):

There's no doubt we're experiencing the deepest solar minimum period of our lifetimes. The previous five solar minimums roughly lasted only two years, and here we are now halfway through year three of the solar minimum period between Cycle 23 and Cycle 24. This solar minimum period shouldn't be too much of a surprise, though, as our historical data suggested this is likely where we are headed.

I've seen scattered comments about this solar minimum (2006 onward) not being as good as the previous solar minimum (1995, 1996, 1997) with respect to 160m propagation. I'd like your comments on this issue. Specifically, does your experience on topband indicate this solar minimum period is worse than the last solar minimum period? Better than? The same?

What criteria is this based on? Quantity and duration of European contacts? Quantity and duration of extremely long distance contacts? Signal strengths? Something else?

This paper summarizes the results of this request and analysis.

Caveat

Right up front I'll admit that this study is very subjective, as several respondents rightfully pointed out. There are many external factors that muddy the root question – is 160m propagation during this solar minimum better or worse? Two issues that would sway the answer to a better 2006-2009 solar minimum period are more stations available to work nowadays and better stations nowadays. An issue that would sway the answer to a better 1995-1997 solar minimum period is generally more man-made noise nowadays.

Results

I received 23 responses to my request. Twenty were from W/VE stations and 3 were from European stations. Those who responded include N6TR, K0CS, W7DRA, K7FL, N7UA, K4DLI, K1GUN, KK9K, SM2LIY, K5UO, K8RYU, WK3N, K1ZM, N4XM, W8JV, K5RX, N5UL, K6XT, NI6T, VE7DXR, IV3PRK, OZ8ABE, and W4ZV (his input was verbal). Additionally, IV3PRK provided long-term QSO data, and VE7DXR provided long-term signal strength data (although at medium frequencies – not 160m).

Not all respondents answered my questions – some commented on this being too subjective (as noted earlier), some commented that they've only been on during this solar minimum period, and some just wanted to be put on the list if I ever did something with this data. Of all the responses, the following table summarizes what I consider to be the most ‘valid’ responses (these are all from the W/VE respondents):

	1995-1997 better	2006-2009 better	Equal
Paths to EU	7	1	2
Other paths (including long path)	5	2	1

Note that the responses are broken down into paths to Europe and other paths including long path. I felt this was initially necessary because of auroral zone issues on paths to Europe from W/VE introducing an additional variable into the mix compared to other paths that didn’t go through the auroral zone.

Regardless of the subjective nature of this study and small sample size, there appears to be a general consensus that the 1995-1997 solar minimum period was better than the current solar minimum period (at least so far).

Interestingly, there actually may be an ionospheric explanation for why the 1995-1997 solar minimum period was better. Let’s review some basic ionospheric physics, and follow that effort up with a look at the data from IV3PRK and VE7DXR to see if it tends to confirm the above conclusions.

Some Propagation Basics

The laws of ionospheric physics on 1.8 MHz apply to HF and even VHF – the issue is just ‘to what degree’.

For example, the physics of refraction says the amount of bending is inversely proportional to the square of the frequency. Thus an electromagnetic wave on 160m will be bent more by a given electron density profile than on 80m – thus it doesn’t get as high into the ionosphere, with the result being a shorter hop. And an electromagnetic wave on 80m will be bent more than on 40m – and so forth. This tells us that 160m propagation is via shorter hops than on our HF bands.

Another example is the physics of absorption, which says the amount of absorption is also inversely proportional to the square of the frequency. Thus an electromagnetic wave on 160m will incur more absorption per hop than on 80m. And an electromagnetic wave on 80m will incur more absorption per hop than on 40m – and so forth. This, along with the refraction issue in the previous paragraph, tells us that 160m propagation occurs via short lossy hops compared to the higher bands.

From our current understanding of the lower ionosphere, absorption on 160m at night does not go to zero – it minimizes around 10 dB per hop. This suggests that multi-hop propagation on 160m is limited to something around 10,000 km with legal limit stations employing antennas of several dBi gain in a quiet noise environment.

Since QSOs significantly greater than 10,000 km occur on 160m, it is believed that an alternate mode of propagation on 160m is ducting. The nighttime E region peak and the nighttime F region, in conjunction with the nighttime electron density valley in between, form a natural lower and upper boundary for ducting – which means successive refractions without intermediate transits through the absorbing region and without intermediate ground reflections. See Figure 1.

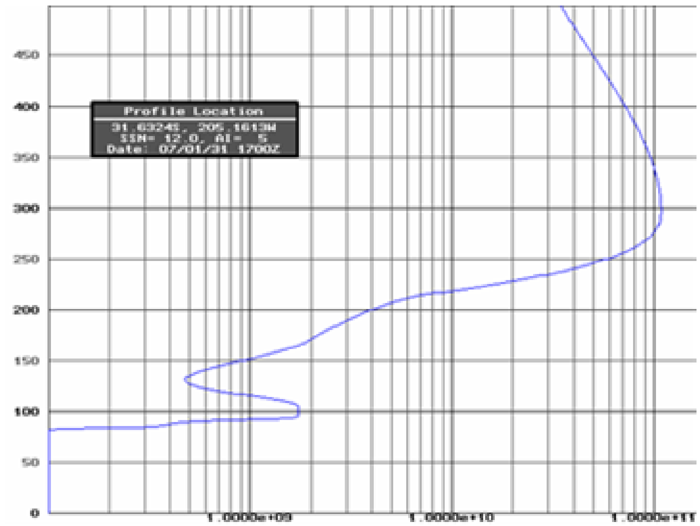

Figure 1 – The Nighttime Valley That Likely Supports Ducting on 160m

<u>The Role of Galactic Cosmic Rays</u>

Although solar radiation is the main instigator of ionization in the atmosphere, there are other processes that contribute and ultimately determine the electron density in a given geographical area.

For example, electron precipitation in the auroral zone due to geomagnetic field activity can significantly add to the high latitude ionization produced solely by solar radiation. Another example is in the equatorial region, where clumps of high electron densities form on either side of the geomagnetic equator. These two examples are processes that contribute significantly to the background solar radiation ionization, and they are geographically localized. If this isn't enough, there's another source of ionization, and it is essentially omni-directional in nature. That source is galactic cosmic rays.

Galactic cosmic rays (GCRs) are protons of extremely high energy. They arrive at Earth from all directions day <u>and night</u>. Since GCRs are of extremely high energy, their impact on the ionosphere is at low altitudes. Figure 2 (which is Figure 6.5 of Whitten and Poppoff, *Physics of the Lower Ionosphere*, Prentice-Hall) shows that GCRs cause ionization at D and lower E region altitudes – where absorption occurs on 160m.

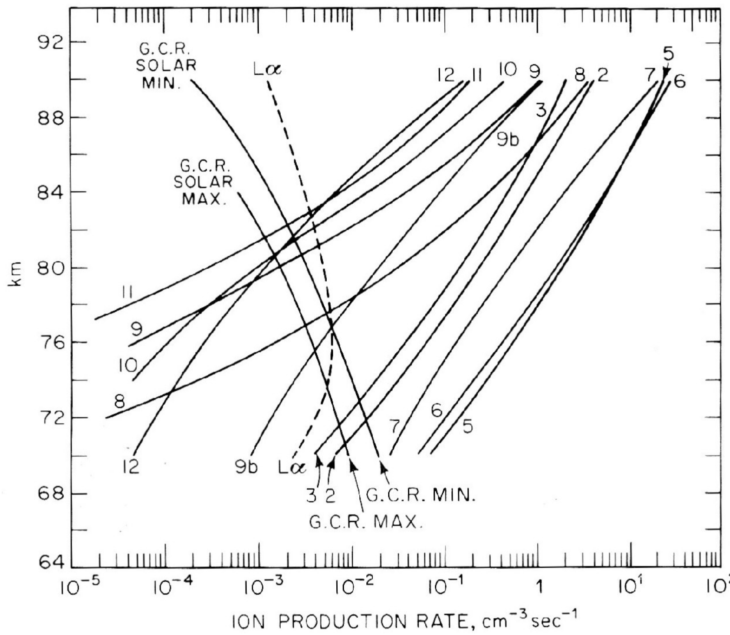

Figure 2 – GCR Ionization Rates

Note from Figure 2 that the ion production rate from GCRs is more at solar minimum than at solar maximum. That's because at solar minimum geomagnetic field activity is minimum, and this 'lets in' all those GCRs to cause more ionization at low altitudes (which shows up as a higher count rate on neutron monitors). At solar maximum, the increased geomagnetic field activity 'sweeps away' GCRs and results in less ionization at low altitudes (and a lower count rate on neutron monitors). Whether GCRs impact absorption (by causing more), impact ducting (by filling in the valley as surmised by Bob Brown, NM7M), or impact both is still an open question. But the result appears to be the same – the possibility of worse 160m propagation at solar minimum from too much ionization at low altitudes. This is seen in Figure 3 (from data compiled by NM7M).

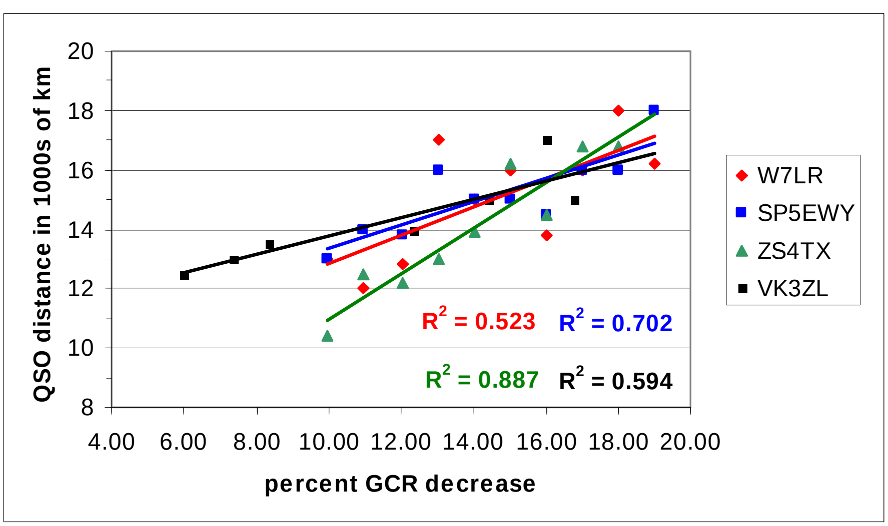

Figure 3 – QSO Distance versus Percent GCR Decrease

The x-axis is the percent decrease from the baseline of the neutron monitor count rate (which is a very high value established by a calibrated radiation source). A percent GCR decrease of 0 is around solar minimum, and a percent GCR decrease of 20 is around solar maximum. As the percent decrease gets bigger (more geomagnetic field activity that shields us from GCRs), the log data in Figure 3 from several 160m operators indicates they can communicate farther. In other words, the trend lines of this data suggest that solar maximum is better for extremely long distance DXing on 160m due to the effect of galactic cosmic rays. Of course this has to be tempered with the fact that too much geomagnetic field activity is generally a detriment to 160m propagation.

This Solar Minimum Period

It shouldn't be tough to figure out where this analysis is headed. With a very deep solar minimum period going on, could it be that we are seeing more GCRs than during the 1995-1997 solar minimum? And the result is more deleterious ionization at low altitudes?

Figure 4 compares count rates from the Kiel neutron monitor for 1995-1998 and 2006-2009 (ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/COSMIC_RAYS/kiel.tab).

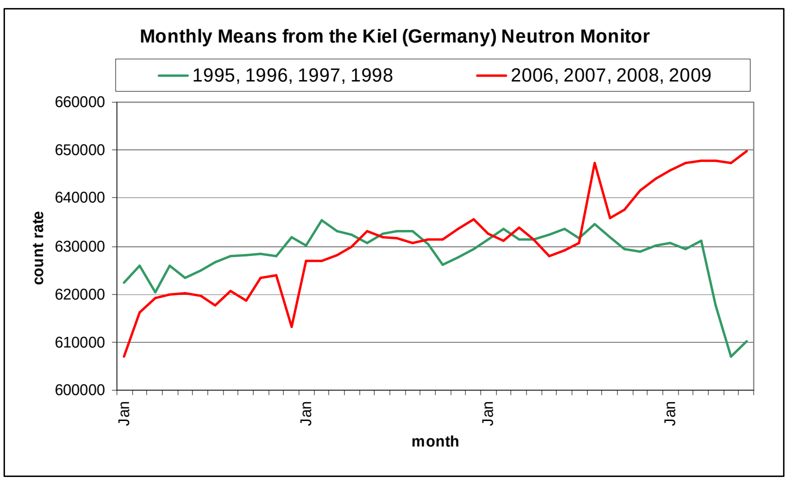

Figure 4 – GCR Activity For 1995-1998 and 2006-2009

The green line in Figure 4 is data from January 1995 through June 1998. The red line is data from January 2006 through June 2009. Indeed, we are now seeing higher count rates, which means more galactic cosmic rays are getting down to low altitudes during this solar minimum period to cause more ionization.

Data from IV3PRK and VE7DXR

Luis Mansutti, IV3PRK, has been keeping records of his QSOs with North America since 1993. From this data he constructed the following two plots of his QSOs to California (Figure 5) and to the state of Washington and VE7 (Figure 6).

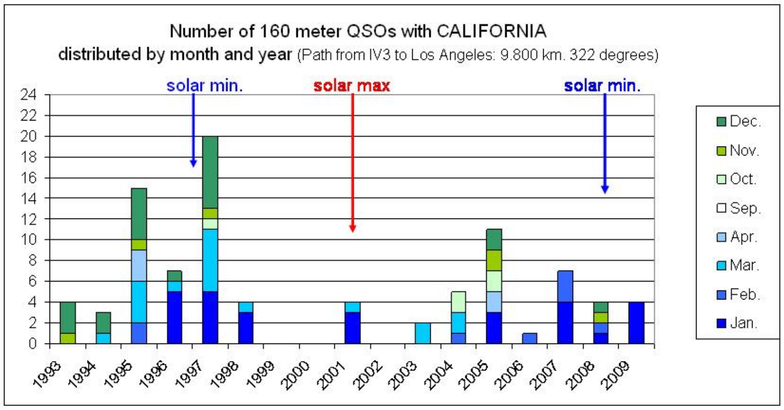

Figure 5 – IV3PRK to W6

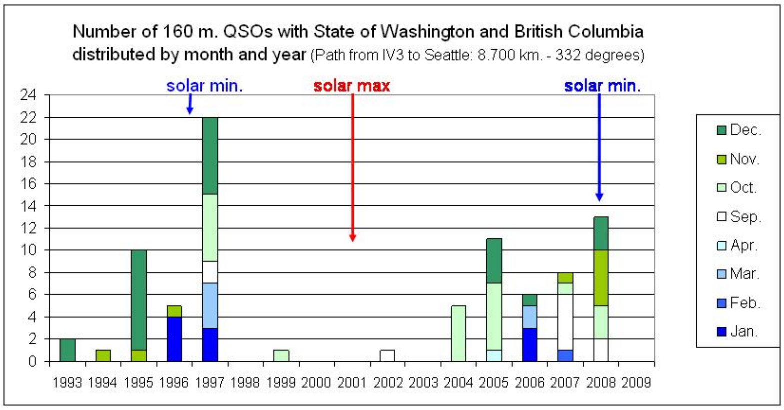

Figure 6 – IV3PRK to W7 Washington and VE7

IV3PRK's data, especially Figure 5, appears to support the general consensus that this solar minimum isn't as good as the last one.

Nick Hall-Patch, VE7DXR, has kept signal strength records of medium frequency broadcast stations for many years. Figure 7 is a representative plot comparing September 1997 and September 2008.

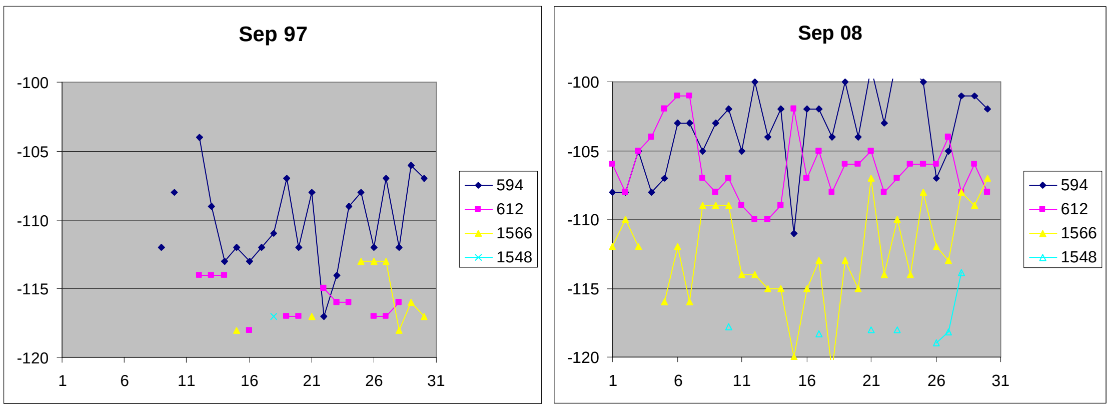

Figure 7 – VE7DXR Comparison of MF Signal Strength

The x-axis is the day of the month, and the vertical axis is the sunrise peak signal strength in dBm on the indicated day. All of VE7DXR's data indicates that this solar minimum is better than the last solar minimum, which is contradictory to the general consensus. But note that the stations monitored are below 160m – they are at 594 KHz (Tokyo), 612 KHz (Brisbane in Queensland, Australia), 1566 KHz (South Korea), and 1548 KHz (Emerald, also in Queensland, Australia). Frequencies lower than 1.8 MHz don't get as high into the ionosphere as 160m signals, so the effects of this have to be analyzed to see if these contradictory results are indeed applicable to 160m or they simply reflect a big enough change in absorption and ducting to warrant being treated separately.

Conclusion

From admittedly subjective comments, from a small amount of QSO quantity data, and from an analysis of galactic cosmic rays for this solar minimum compared to the last solar minimum, there appears to be evidence that this solar minimum may be worse than the previous solar minimum on 160m. It should be noted that there is contradictory evidence on frequencies below 1.8 MHz.

In essence this solar minimum may be too quiet for 160m – which results in more deleterious ionization at low altitudes from galactic cosmic rays. That either causes more absorption or fills in the valley to negate ducting or does both.

Since 160m signal levels are typically at or near the noise floor of our receiving systems, it seems reasonable to assume that a small change in absorption or ducting either way will have a significant impact to propagation on 160m.

Having said all the above, it is also very possible that a little geomagnetic field activity on the ascent of Cycle 24 will 'sweep away' enough GCRs to give us some good 160m propagation. We'll just have to wait and see if this happens. If it does, it may be further proof that galactic cosmic rays impact our DXing efforts on 160m. If it doesn't happen, then 160m may continue to be reluctant in revealing some of its secrets.