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Time-of-Day Effects in Six-Meter Multi-hop Sporadic E Propagation

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Introduction

Sporadic E-layer propagation (E_s) occurs when E-layer winds, the Earth's magnetic field, and other effects conspire to compress low-density ionization, from a large volume of space, down into a very thin, localized, high-density layer. These thin layers may be only tens of meters thick and lead to nearly specular reflections, with MUF's at times higher than 150 MHz.

There are several forms of E_s, with important differences in behavior at different latitudes. In polar regions, *Auroral* E_s is a nightly effect, virtually independent of season. In equatorial regions, *Equatorial* E_s is a daytime effect, also with little seasonal variation. These two phenomena are related to the auroral and equatorial electrojets, respectively.

Temperate Zone E_s (e.g. North America) is quite different. Ionograms and operating experience show that it peaks strongly in the early summer, with a minor peak in the winter. There is also a strong time-of-day dependence. Ionograms[1] (and long experience[2]) show that a strong daily peak at 0900-1200 Local Standard Time (LST). There is a minor peak about 1800-1900 LST and sometimes another about 2100-2200 LST.

A key point here is that long multi-hop circuits involve large latitudinal or longitudinal extents. As a result, their great circle paths may well traverse, or impinge on, the realm of more than one form of the E_s phenomena, perhaps resulting in variations in the favored times of day.

A related point is that ionogram times are at the path *midpoint* and *not* at the *ends* of the circuit. For single-hop paths, the midpoint time rarely will be more than an hour different from the end points. However, multi-hop endpoint times can be very different. In order to compare timing data from different multi-hop paths, some eastbound and some westbound, this study examines the time-of-day effects with reference to the time of day at the path midpoints, and *not* the ends.

This study is somewhat less than rigorously scientific. No attempt has been made to control for data "observing effects", that is, to adjust for times when no observer was present (like late at night). On the other hand, the data represent the times of day that three active, well-equipped, six-meter operators, spaced roughly evenly over 5,000 miles east to west, actually found the band open for a total of 3,204 contacts. Thus, we regard the results presented here to be good practical information, in the context of amateur operations.

The Data

The data are from the logs of K1SIX in New Hampshire, K6QXY in Northern California, and K6MIO/KH6 on the Big Island. K1SIX records 2,537 contacts or beacon signals with stations in Europe between 1985 and 2000. The K6QXY data provide 277 contacts with Japan, Alaska, and northwestern Canada, and Hawaii from 1979 to 2000. The K6MIO/KH6 data represent 390 contacts with stations across North America (NA) during 1999 and 2000. All the contacts were at least double hop; many were three to four hops; a few were probably five hops.

The data were first grouped according to the paths involved: NA-Europe, NA-Alaska/Canada, NA-Japan, and NA-Hawaii. Then the observed times were corrected to the nominal path mid-point times. Then, the times were sorted, plotted, and compared. Some paths had very similar characteristics, and were then combined. Still others were similar among themselves but different from others, and these have been contrasted.

North America to Europe, Alaska/Canada, and Japan

Although some of these paths go *east* from North America and others go *west*, they actually have a lot in common. They start near a coast and proceed over water in great-circle arcs that pass near arctic regions before coming back south again, one via the Atlantic and the other the Pacific.

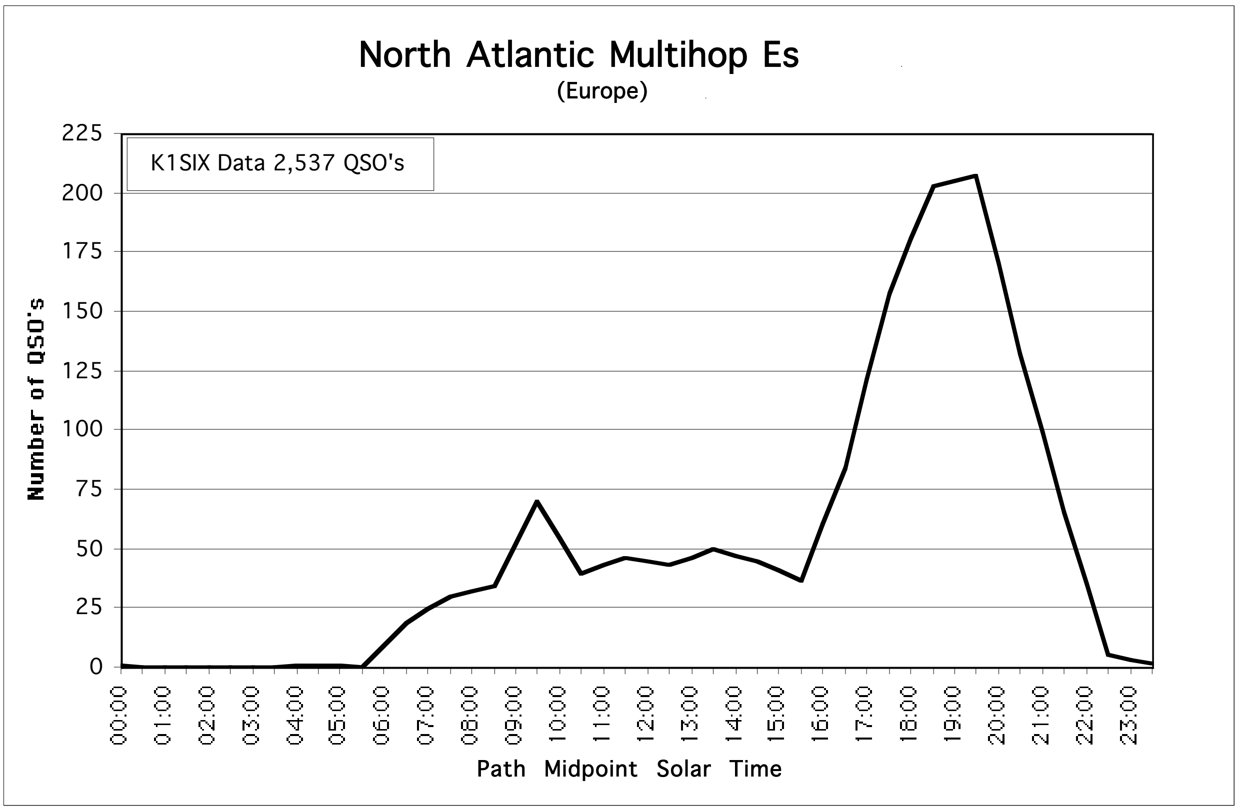

Figure 1. The path to Europe shows a strong peak 1630-2030 LST at the path midpoint.

The K1SIX data set is the most extensive of all those presented here. While it is difficult to estimate the statistical significance of the features, the early evening peak is obvious and the peak about 0930 LST may well be real also. It will be noted that the times are roughly consistent with the ionogram data that suggest peaks in the mid morning and early evening. However, what is different is that Temperate-Zone ionograms show the *morning* peak as the dominant one and the evening peak as a minor one – which is just exactly the *opposite* of what is shown in Figure 1.

At first glance, it was not obvious how to handle the Japan and Alaskan data. The paths are very similar in that the Alaska path is somewhat north of the first 40% of the Japan path. Nevertheless, the two paths were processed separately to see if they were correlated.

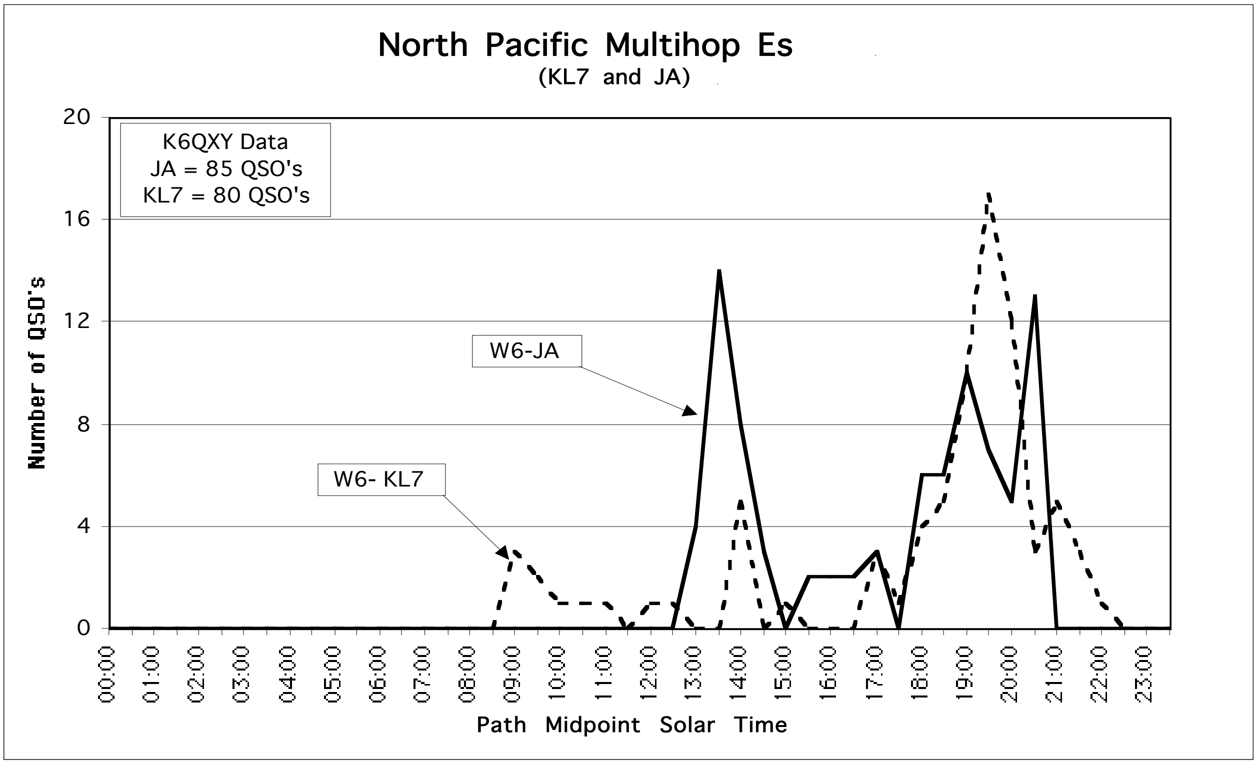

Figure 2. Like the Europe path, the Alaska and Japan circuits also show a dominant evening peak centered on 1930 LST. There is also minor peak around 1330 LST not seen for Europe.

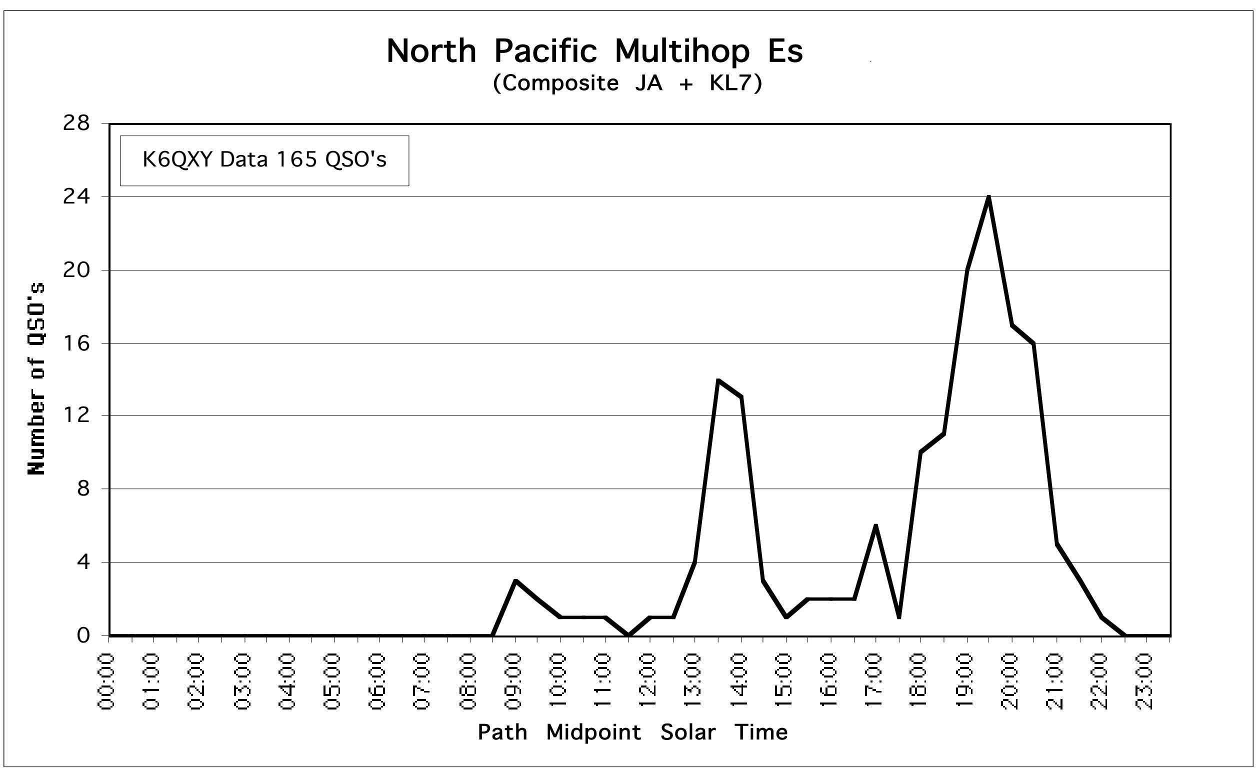

Figure 3. The composite of the Japan and Alaska/Canada data shows their same basic features.

Both data sets are relatively small, though nearly the same size. This makes it reasonable to compare them without adjustments. The overlay in Figure 2 shows that they agree well in their major features, an early evening peak – that matches the Europe peak very well, and they both show an early afternoon peak at about 1430 LST – that has no counterpart in the Europe data.

Given that there is a good indication that these two paths are, in fact very similar, when referenced to the solar time at their (different) path midpoints. We have taken the liberty of combining the two data sets to produce a composite set representing the North Pacific path in Figure 3.

The final step has been to compare these two North Oceanic data sets. Figure 4 shows that there is indeed good agreement between the path across the North Atlantic and its counterpart across the North Pacific.

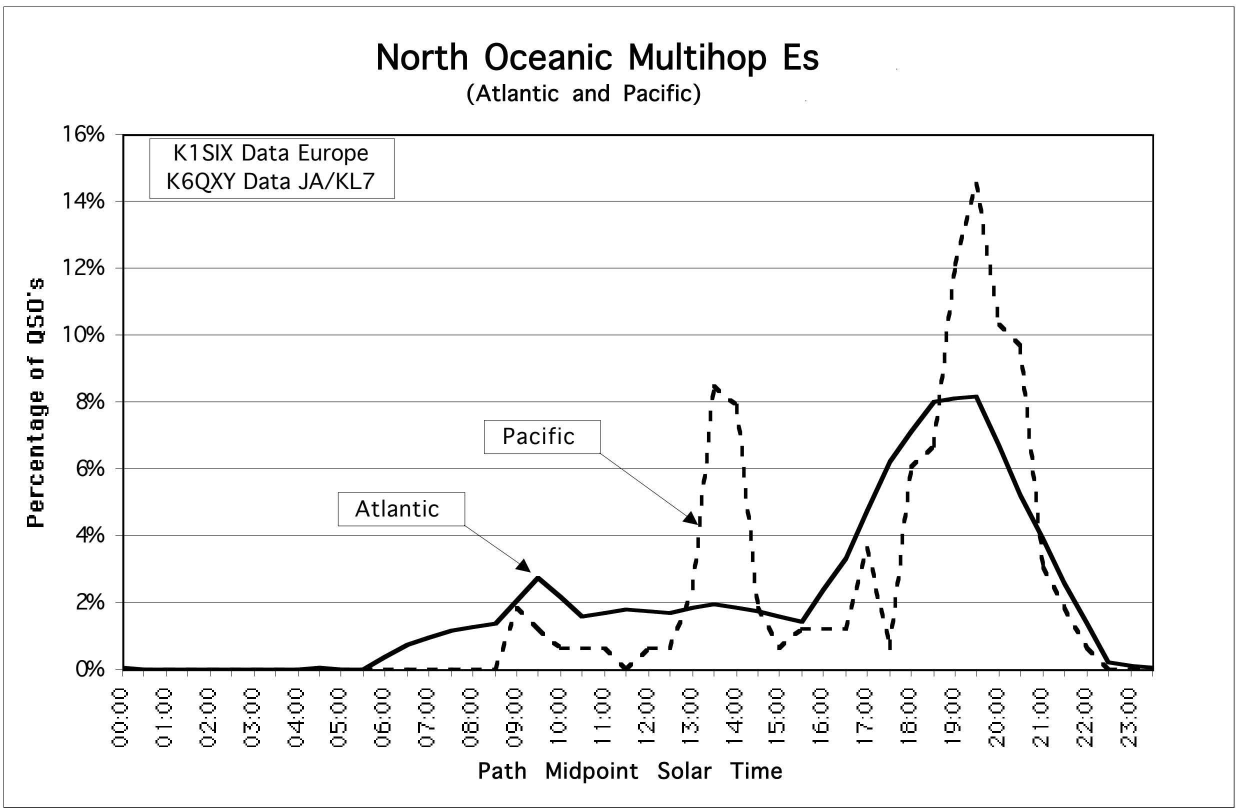

Figure 4. This overlay shows the similarity of the two North Oceanic Path sets.

Both paths show substantially the same major peak in the early evening, although arguably the centroid of the Atlantic peak is 30 to 45 minutes earlier than the Pacific peak. Both data sets show the minor peak at 0900 LST. The principal difference between the two data sets is the Pacific peak around 1330 LST. There is no indication of a counterpart in the Atlantic.

It is important to note that there is a large difference in the size of the Atlantic and Pacific data sets. With well over 2,500 data points, one can be reasonably confident about the reality of the *absence* of the 1330 LST peak in the Atlantic data. With only 165 points in the North Pacific data, the significance of the afternoon peak in those data is a bit more of an issue. Nevertheless, when the Pacific data set is broken down into the Japan and Alaska components, they both seem to show the effect. It is reminiscent of the mid-day peaks seen in the Hawaii data below.

Mid-Latitude Pacific

The path to Hawaii presents some special challenges to interpreting the data. Though there are 390 points in the K6MIO/KH6 data set, slightly more than half of them (196) come from a single opening on 2 July 2000. Thus, those data trace very well the progress of one (particularly spectacular) opening. Nevertheless, it is hard to say how well that characterizes *all* openings.

By contrast, the K6QXY data sample many years of observations, but only represent 112 points. As a result we have plotted the 2 July data separately from the "other" K6MIO/KH6 data and the K6QXY data. This makes Figure 5 a rather busy graph, but it does allow the viewer the discretion to draw their own conclusions.

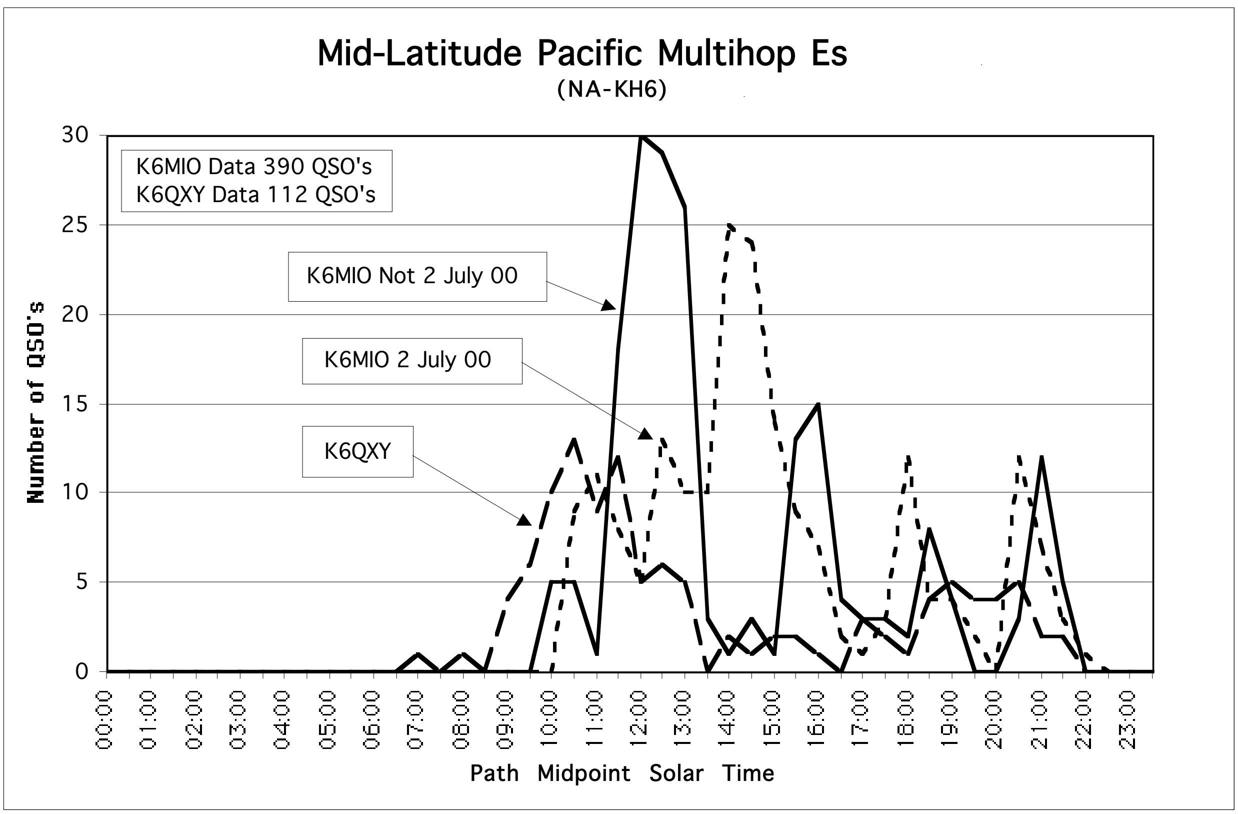

Figure 5. This overlay shows that all three Hawaii data sets have the dominant peak in the late morning to early afternoon. Correlated peaks also occur around 1800 LST and 2100 LST.

In the broadest terms (and in contrast to the North Oceanic paths), all three data sets show the basic characteristics of the mid-latitude ionograms. That is to say, the dominant activity peaks occur in the late morning to early afternoon, and the minor peaks around 1800 and 2100 LST.

Having said that, however, there is a large discrepancy in the exact time of the major peak particularly for the 2 July data. The band opened at least thirty minutes earlier on 2 July than the data indicate. The operator was not on the air at that time. All three data sets show significant activity by 1000 LST. The K6QXY data show it peaking at 1000 LST, the "Not 2 July" data show the peak at 1200 LST, while the 2 July data show the peak at about 1400 LST.

It is also interesting that all three data sets show minor peaks around 1800 LST and 2100 LST. This is in very good agreement with ionogram observations. While the trends indicated here certainly favor the early dominant peak view for the mid-latitude path, it will be interesting to see how the *details* of this picture evolve as additional data are added over the next few years.

Summary and Conclusions

There are three characteristic forms of E_s associated with the latitude of the path: Auroral E_s, Temperate-Zone E_s, and Equatorial E_s. The latitudinal extent of the paths discussed here clearly includes the Temperate and Auroral zones for the two Northern Oceanic paths, and the Temperate and Equatorial zones for the Hawaii path. One would expect, then, to see a superposition of characteristics on these paths that pass through more than one region. Both the North Oceanic and Mid-Latitude Pacific paths have significant footing in the Temperate Zone. The observations show that peaks in the 0900-1200 LST and 1800-2100 LST period occur in all cases.

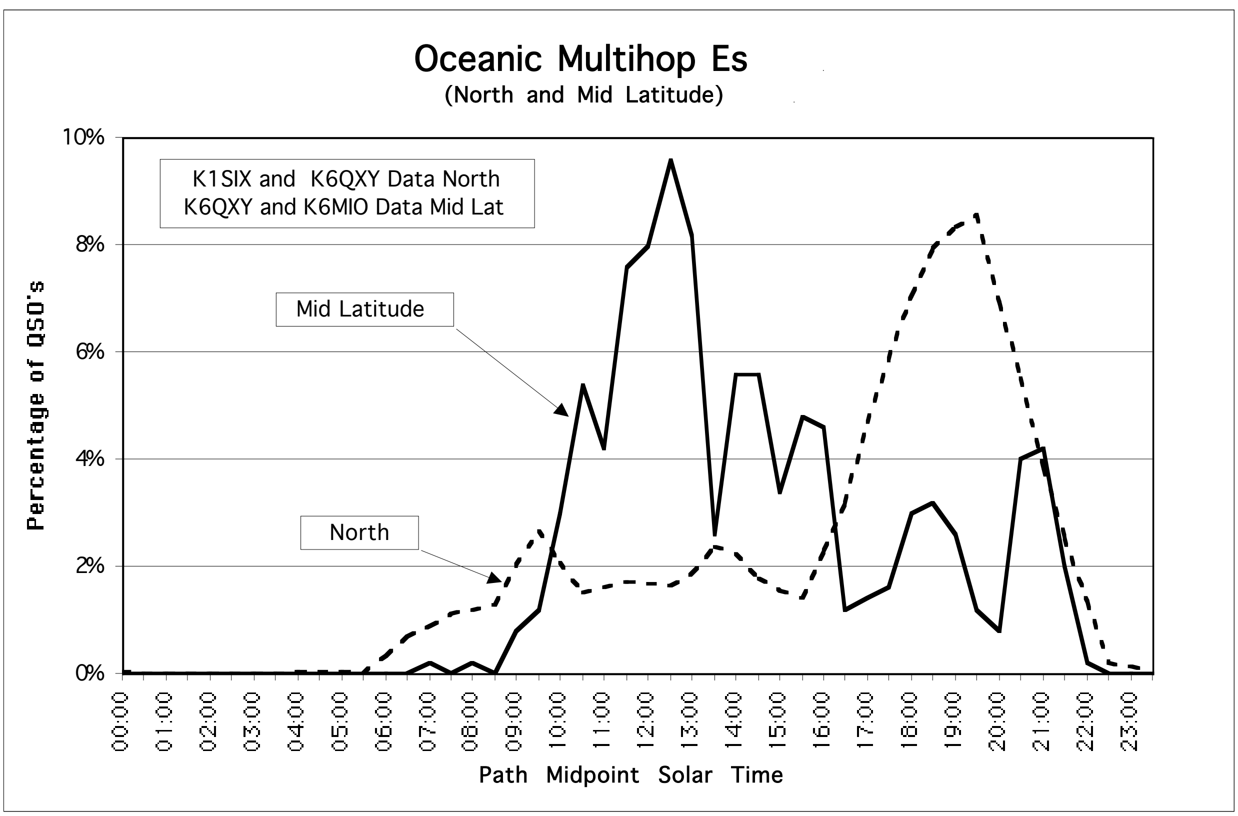

Figure 6. A composite of the Hawaii and North Oceanic data shows the mirroring of the dominant and minor peaks between the northern and Hawaii paths.

North Oceanic Paths – Starting and ending in the Temperate Zone, the North Oceanic paths also encroach on the Auroral zone. It appears that the evening enhancement of the path by Auroral E_s has the effect of turning the overlapping Temperate E_s evening peaks from minor peaks into the *dominan*t peaks for the whole path. If this is a correct conclusion, then the ion contribution made by Auroral E_s process is a significant factor in making the bulk of the contacts on this path.

Mid-Latitude Path – Much of the Hawaii path is in the Temperate Zone, but it definitely encroaches on the Equatorial zone. It appears likely that the daytime nature of the Equatorial E_s (an effect that peaks between 0900-1700 LST) is enhancing the basic characteristics of Temperate E_s. This leads to a more-or-less normal pattern of dominant morning peaks and minor evening peaks. However, it is entirely possible that the variability of the Equatorial E_s component is causing the dominant peak to move around between 1000 and 1400 LST on a day-to-day basis, and being smeared out in the average. If this conclusion is correct, then the Equatorial E_s ionization appears to be a real factor in most of these contacts.

Implications for Operations Planning – It is central to recall that the times in these plots represent the path-midpoint times. If one wanted to use these data to project the optimum time to listen for a particular path, one must first choose the path, note the time difference between one's own location and the path midpoint, then adjust the plots to one's own local time. For example, the data here suggest that stations on the West Coast (one hour east of the path midpoint) wishing to work Hawaii have the best chance between 1100 and 1700 PST (1200-1800 PDT) with the very best chance around 1300 PST (1400 PDT).

The authors thank the operators who were the far ends of the thousands of contacts that made this study possible.

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[1] Kenneth Davies, 1990, *Ionospheric Radio*, Peter Peregrinus Ltd. pg. 145
[2] William Orr and H.G. Johnson, 1956, *VHF Handbook*, Radio Publications, pg. 33