Is The Worldwide Ionosphere "In Step"?

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If you take a simplistic view of atmospheric and ionospheric processes, it would be easy to talk yourself into thinking that the worldwide ionosphere is "in step" – in other words, what happens at a given time anywhere in the world is exactly what happens elsewhere at the same time. For example, if the F_2 region ionization decreases at a given time on a certain date over one ionosonde, then it would also decrease over a nearby ionosonde.

This hypothesis easy to check out by comparing data from two ionosondes that are close to each other. Figure 1 does this for Millstone Hill (42N/72W) and Wallops Island (37N/76W) on October 5, 2003 (which is a very typical one-day period). These two ionosondes are only 653 km (408 miles) apart. The MUF (maximum usable frequency) plotted is the MUF over each ionosonde assuming it is the mid point of a 3000 km hop.

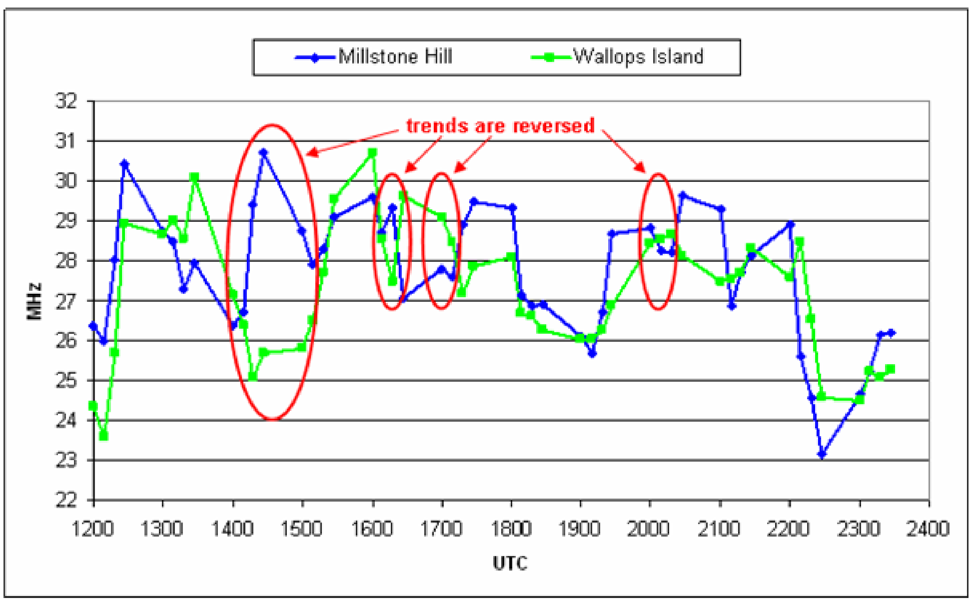

Figure 1 – Millstone Hill MUF and Wallops Island MUF on October 5, 2003

Figure 1 only includes data for the daytime in the area of Millstone Hill (Massachusetts) and Wallops Island (Virginia), when solar radiation is directly impinging on the atmosphere in that area of the world.

At sunrise just after 1200 UTC, as expected both ionosondes show a significantly increasing MUF. Both ionosondes generally track until 1400 UTC, after which the Millstone Hill ionosonde shows the beginning of a big increase while the Wallops Island ionosonde continues to show a significant decrease. Around 1500 UTC we again see opposite trends, with Millstone Hill decreasing and Wallops Island increasing. This entire area of opposing trends is enclosed in the big red circle.

Three other periods (also circled in red) show more opposite trends – around 1630 UTC, around 1700 UTC, and around 2030 UTC. From this data, and supported by volumes of other similar data, we conclude that the worldwide ionosphere is not necessarily "in step". That is unfortunate, as it highlights the problem scientists had when they developed the model of the ionosphere used in our propagation prediction programs.

With armloads of solar data and armloads of ionospheric data, scientists would have loved nothing better than to have developed a model that took today's sunspot number (or today's solar flux) and used it to predict what the ionosphere was doing today. But that specific correlation was very poor. You can understand this problem from the data of Figure 1 – the 10.7 cm solar flux on October 5, 2003 (reported to be 110) would have had trouble predicting what each ionosonde was doing in the red circled periods – or at any other times for that matter, since the MUFs are not constant throughout the day.

So what's the problem here? Is it the fact that we're trying to just use one value of 10.7 cm solar flux for the entire day? Would we get better results if we knew how 10.7 cm solar flux varied throughout the day? To check this out, we'll go one step farther than using 10.7 cm solar flux and use data that is in the band of wavelengths (and thus energy) of the true ionizing radiation of the F_2 region – which is radiation at wavelengths from 10 to 100 nanometers.

We'll use radiation at 30 nanometers, and it is measured by the Solar Extreme Ultraviolet Monitor that is onboard SOHO (Solar and Heliospheric Observatory). Figure 2 plots the 10-minute average of 30 nm radiation for the daylight hours of October 5, 2003.

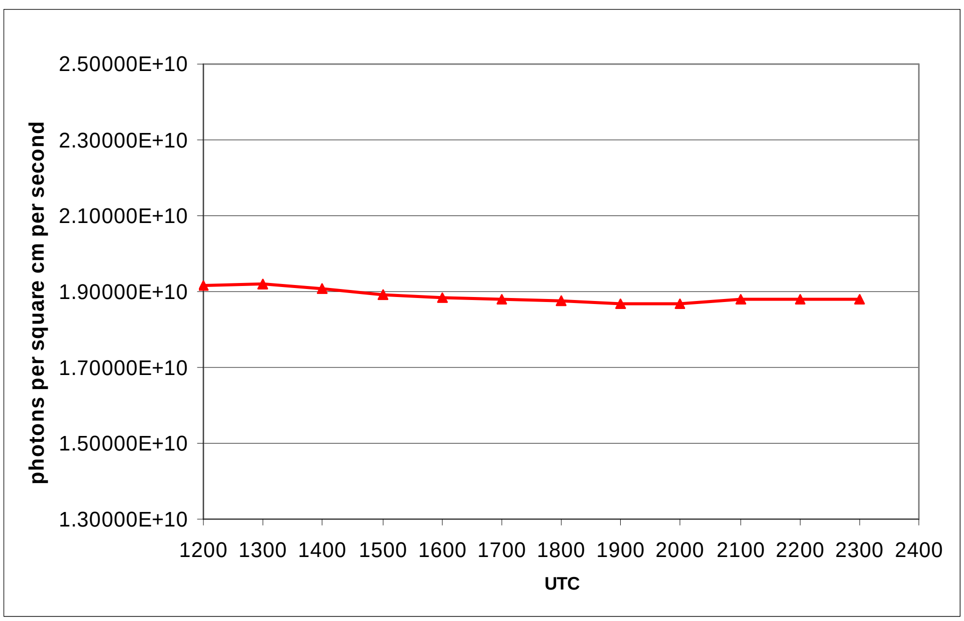

Figure 2 – 10-Minute Average of 30 Nanometer Flux on October 5, 2003

For all intents and purposes, the 30 nanometer flux is constant throughout the daylight hours. It does not show any variation that would explain the significant ups and downs of the MUF data in Figure 1. Our only conclusion is that processes other than ionization by solar radiation contribute to the ionization at any given location at any given time.

This variation in MUF under conditions of constant solar radiation is also very obvious around solar minimum. For example, let's look at the 3000 km MUF over the Millstone Hill ionosonde for the month of August 2008. There were no sunspots at all during this month, and the solar flux varied between 65 and 68. Figure 3 shows the MUF data at 1630 UTC for each day for these extreme solar minimum conditions.

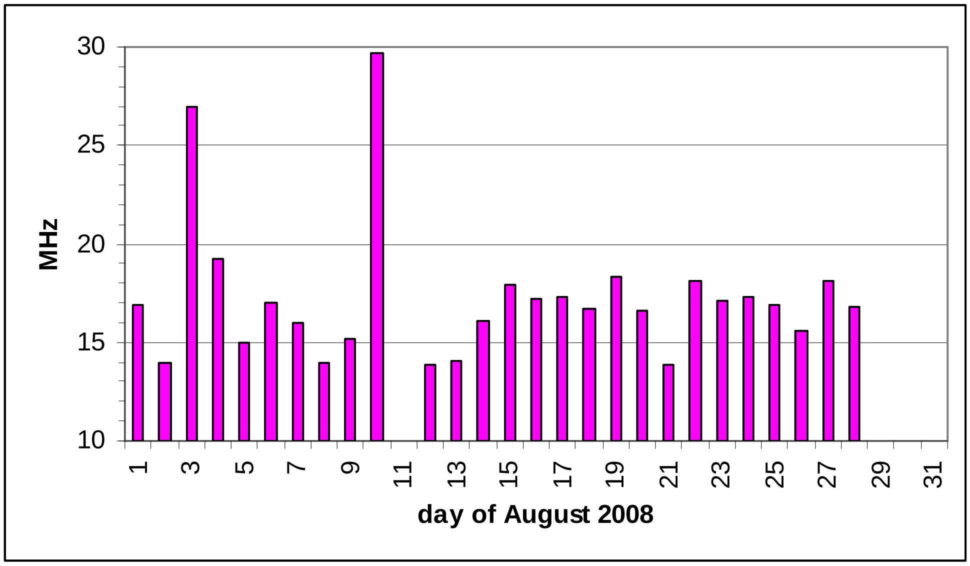

Figure 3 – MUF for 3000 km Hop Over Millstone Hill at 1630 UTC

The MUF varied from a low of 13.9 MHz to a high of 29.7 MHz. Even if we throw out those two high-MUF days (one of which was likely due to geomagnetic field activity), the MUF still hit a high of 19.2 MHz. 13.9 MHz to 19.2 MHz is still quite a spread.

Why does the MUF vary so much even though the ionizing radiation (or even the 10.7 cm solar flux) is constant? One process that causes this was given in the previous paragraph – geomagnetic field activity. The other process is an event in the lower atmosphere coupling up to the ionosphere. Interestingly, each of these two processes contributes about equally to the variation of the daytime F_2 region of the ionosphere – and each of these contributions is almost an order of magnitude greater than the contribution to the variation by ionizing radiation. For more details on this interesting topic, visit **mysite.verizon.net/k9la**, go to the "General articles" link, and read the article *Day-to-Day Variability of the F2 Region*.

In summary, the worldwide ionosphere is not "in step" – even for locations separated by only several hundred miles. More importantly, it's tough to predict what the ionosphere is doing today at a given time. The result of all this unpredictable variation is a model of the ionosphere (which is used in our propagation prediction programs) that correlates monthly median ionospheric parameters to smoothed sunspot numbers (or smoothed solar flux). Until we have a better understanding of all this, that's what we have to work with.