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When the K Index Goes Up, Do the Higher Bands Always Get Worse?

The June 2, 2017, ARRL Propagation Bulletin, edited by Tad Cook, K7RA, included comments from two West Coast operators — K6CTW and N6GP. Both had participated in the CQ WPX CW contest over the May 27-28 weekend. K6CTW logged contacts with YB, ZL, JA, and KHØ on 15 meters and on 20 meters from 0440 UTC to 0540 UTC on Sunday, May 28. On the same day, N6GP logged contacts with JA and KH2 on 10 meters at around 0400 UTC.

K6CTW commented that it was usually not worthwhile for stations such as his — running low power and simple antennas — to even check out conditions on the higher bands during a geomagnetic storm — especially a major storm like the one that occurred during the WPX weekend. "Be great to find out how this happened, because isn't it a given that major geomagnetic storms totally disrupt the higher bands?" he asked.

K7RA sought my input on these observations, and I explained to him that this was an excellent example of how we take a very complicated and dynamic process — the effect of a geomagnetic storm on the ionosphere — and try to simplify it with one general statement. I pointed out that these observations simply tell us that the question, "Isn't it a given that major geomagnetic storms totally disrupt the higher bands?" is not entirely true. Let's dig deeper to try to understand what happened.

A coronal mass ejection (CME) several days prior to the WPX weekend arrived in the vicinity of Earth around midday UTC on Saturday, May 27, the first day of the WPX contest. After this the K index began increasing. K indices greater than or equal to 5 occurred during the first half of Sunday (with a maximum of K = 9 during the 0300-0600 UTC period), and at College diminished throughout the rest of the day.

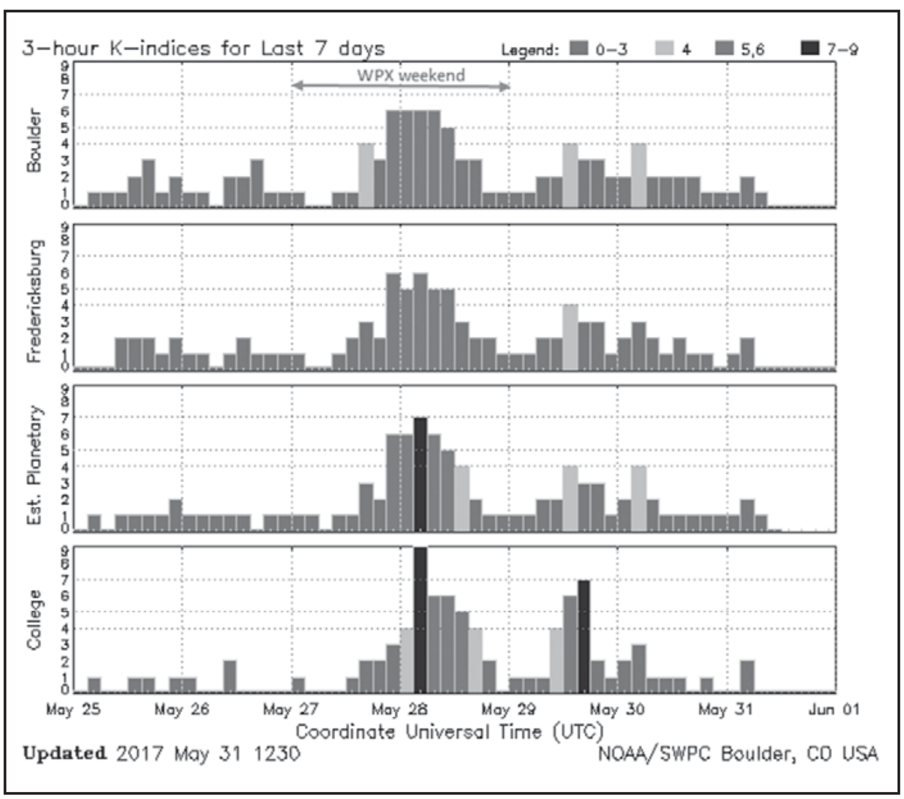

Figure 1 — The K indices from May 25 through May 31.

The important questions is, "What did the ionosphere do during this geomagnetic storm?" It would be nice to have an ionosonde along one of the paths cited above, but we're out of luck there. So I looked at the Boulder (Colorado) ionosonde (See FIgure 2). It should be somewhat representative of what other ionosondes saw during this geomagnetic storm. Additionally, it took data every 5 minutes, so the time resolution is very good for most applications. (During an eclipse, though, it would be nice to take data every 15 seconds or so.)

The first observation is the sinusoidal-like diurnal variation of the F_2 region. During the day, the noontime (1800 UTC) MUF (maximum usable frequency) for a 3000-kilometer path with the midpoint over the Boulder ionosonde was around 20 MHz until the K index started increasing due to the geomagnetic storm. Then, the noontime MUF decreased to 18 MHz on May 27, to 16 MHz on May 28 and 29, and started returning to normal on May 30.

During the night, the midnight (0600 UTC) MUF was around 10 MHz until the May 28, when it dropped to 5 MHz due to the geomagnetic storm. The midnight MUF remained around 5 MHz on May 29, again due to the geomagnetic storm, and began returning to normal the next day.

The second observation is the many random and short periods of significantly increased MUFs. What we're seeing here is the short-term, day-to-day variation of the F_2 region due to minor perturbations from geomagnetic field activity and events in the lower atmosphere coupling up to the ionosphere. I believe the much more organized MUF increase early on during May 28 — generally corresponding to the periods cited by K6CTW and N6GP — was an enhancement due to this specific major geomagnetic storm. As I mentioned earlier, it would be nice to have an ionosonde along one of the N6GP paths to confirm that 10 meters could have been supported.

Now we can answer the question, "When the K index goes up, do the higher bands always get worse?" The answer is, "No, the higher bands do not necessarily *always* get worse when the K index goes up." Although it might be tempting to say that the higher bands always get worse at the high latitudes, interesting things still can happen that suggest we should exercise caution in saying "always." On the other hand, I think it's safe to say that there can be periods of F_2 region enhancements at the mid latitudes and low latitudes when the K index rises.

As for what happens in the ionosphere to cause an electron density enhancement during a geomagnetic storm, let's quickly review a technical paper that analyzed this specific scenario.[1] The authors looked at the geomagnetic storm of April 3, 2004. Their measurements are shown in Figure 3.

The top plot is the solar wind pressure, the second plot is the B_z component of the interplanetary magnetic field, the third plot is the K_p index, the fourth plot is the D_{st} index and the bottom plot is the F_2 region electron density. This geomagnetic storm began at around 1400 UTC on April 3 (indicated by the vertical dotted line), with an enhancement in electron density of approximately two to four times the normal daytime diurnal peak in the 1400-2400 UTC period on April 3.

From the above measurements and incoherent scatter radar measurements, the authors found that during the enhanced electron density period, the F region electron temperature decreased by about 1000° K — a 40% decrease, the eastward electric field increased, and the poleward meridional wind decreased.

The authors suggested that the major factor in the enhanced electron density for this geomagnetic storm (others may be different) was the enhanced eastward electric field, which caused an upwelling of the ionospheric plasma particles to altitudes with lower recombination. They also hypothesized that the reduction in the poleward wind may have helped by changing the composition of the mid-latitude atmosphere to less molecular species, resulting in reduced electron loss.

In summary, keep your ears open during geomagnetic storms — and at all other times, too. You may be pleasantly surprised by an unexpected contact. The F_2 region is very dynamic, and we do not yet fully understand nor have the ability to predict short-term events in the F_2 region. When we are able to predict short-term events, we'll be closer to having daily propagation predictions — not the monthly median propagation predictions we have now.

Notes

[1] Huang, Foster, Goncharenko, Erickson, Rideout and Coster; *A strong positive phase of ionospheric storms observed by the Millstone Hill incoherent scatter radar and global GPS network*; Journal of Geophysical Research, Vol 110, A06303, doi:10.1029/2004JA010865, 2005

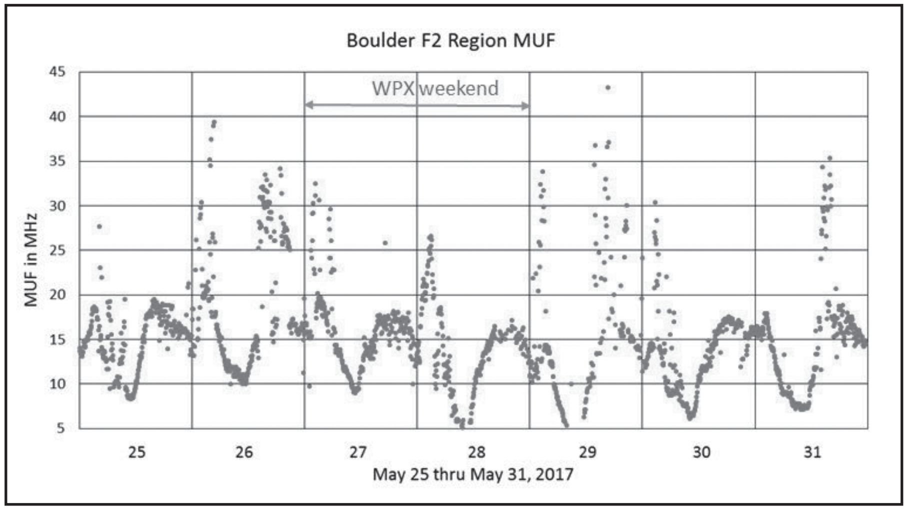

Figure 2 — The Boulder F_2 region data for May 25 through May 31.

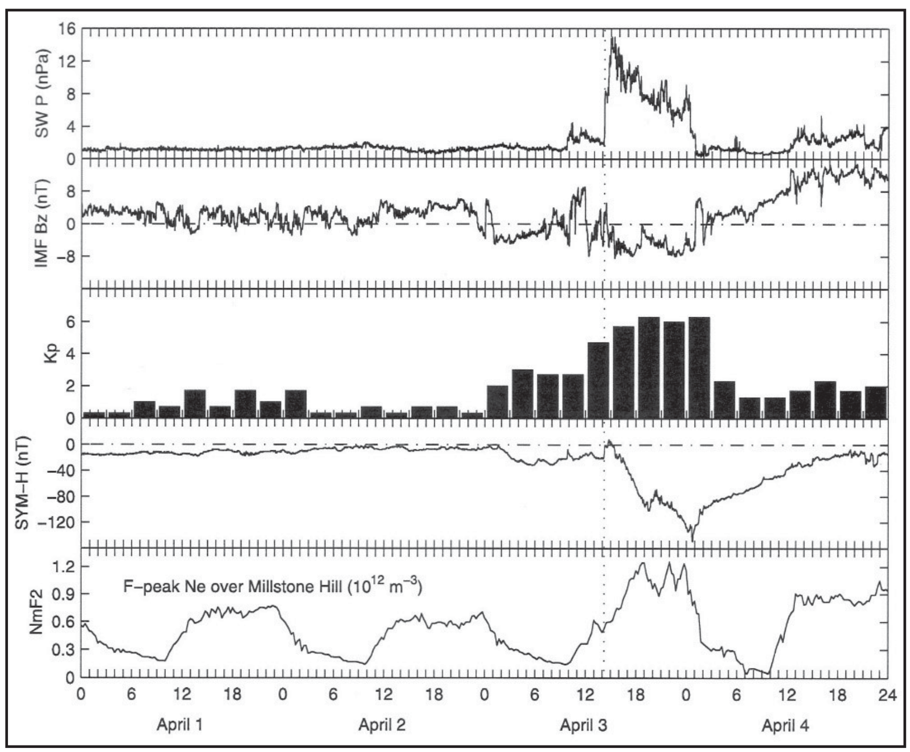

Figure 3 — The geomagnetic storm of April 3, 2004.