# A Review of Magnetic Indices

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Over the years Amateur Radio operators have become very familiar with the A and K magnetic indices. These two indices have crept into our vocabulary, into space weather reports and into our propagation prediction programs.

The A and K indices start with the 3-hour K index, which is a measure of the variation of the Earth's magnetic field relative to quiet day conditions. The K index ranges from 0 to 9, and it is a quasi-logarithmic function ('quasi' means 'very close to'). Once the eight K indices are known for an entire day, each individual 3-hour K index is converted to a linear scale, and is called an 'a' index. When these eight 'a' indices are averaged, we end up with the daily A index. Note that little 'a' indicates the linear equivalent to a 3-hour K index, while a capital A indicates the daily A index. For more details on theses indices, visit **http://k9la.us** and read the paper "Where Do the A and K Indices Come From?" in the General link. The K index is available back to 1932.

The planetary A and K indices (Ap and Kp) are worldwide measurements of currents flowing at E region altitudes as measured by observatories mostly at mid latitudes. Thus they don't necessarily cover the high latitudes and low latitudes, and they don't directly tell us anything about the F2 region. Although our propagation prediction programs may allow the input of a K index, this is a very simplistic approach to a very complicated process. I've always said that an elevated K index may result in lower MUFs (maximum useable frequencies) at mid and high latitudes, and may result in higher MUFs at low latitudes. Note that I used "may" instead of "will".

How the F2 region reacts depends on how the K index develops over a longer period of time than just 3 hours. For example, the STORM model (**http://www.swpc.noaa.gov/products/storm-time-empirical-ionospheric-correction**) is an empirical ionospheric correction model. It uses the last 11 values of the K index to predict how the F2 region is deviating from quiet conditions. Figure 1 shows the K index for February 16-18, 2015, along with the resulting STORM prediction for the F2 region on February 17 and 18.

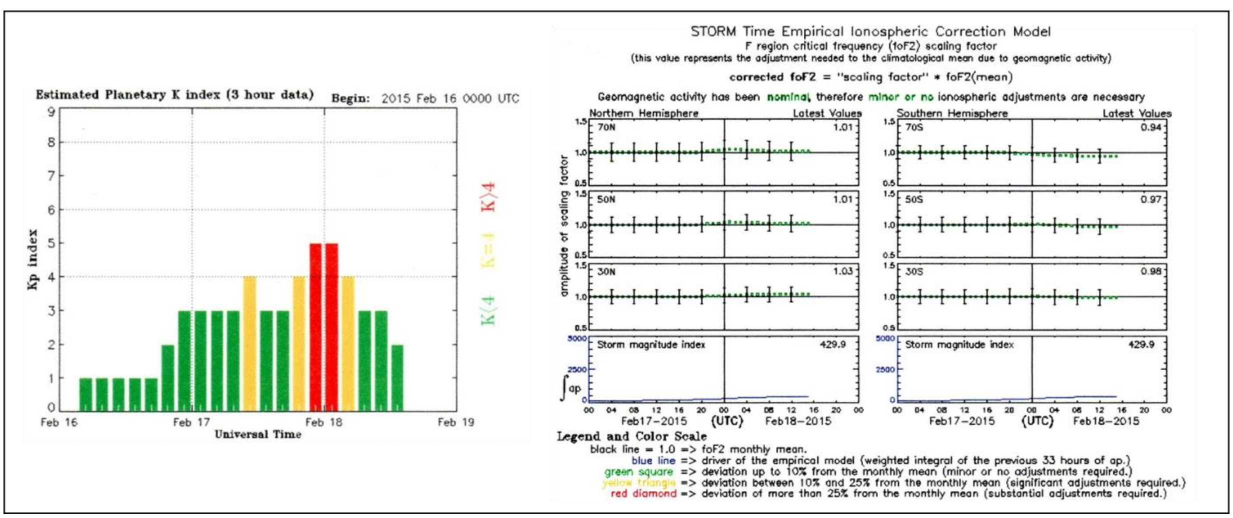


**Figure 1 – K indices and STORM prediction**

Although the K index shot up to 5 for two 3-hour periods, this activity was not predicted to cause any significant deviation of the F2 region from quiet conditions. Note that the STORM model makes predictions for the two hemispheres and for high, mid and low latitudes in each hemisphere. The take-away here is to use caution when plugging in a single value of K into your favorite propagation prediction program – the result may not be an accurate depiction of what's going on. You should at least follow up with the current prediction from STORM.

Earlier I mentioned that the Kp and Ap indices were essentially for mid latitudes as those are where most of the observatories are that contribute to the planetary indices. Are there indices specifically for the high latitudes and the low latitudes? Yes, there are. Perhaps you've heard of them – the auroral electrojet index (AE) for high latitudes and the storm-time disturbance index (Dst) for low latitudes.

The AE index was defined in 1966, and is primarily a high latitude measure of auroral zone magnetic activity produced by enhanced ionospheric currents flowing below and within the auroral oval. The AE index has been employed in studies of geomagnetic substorm morphology and of the coupling between the interplanetary magnetic field and the Earth's magnetosphere. Visit **https://catalog.data.gov/dataset/auroral-electrojet-ae-al-ao-au-a-global-measure-of-auroral-zone-magnetic-activity** for more information about the auroral electrojet. The AE index is measured every minute.

The Dst index was introduced in 1964, and is primarily a near-equatorial measure of the ring-current magnetic field. Similar to the auroral electrojet, Dst is also known as the equatorial electrojet since it uses near-equatorial observatories to measure ionospheric currents near the equator. See **https://www.ngdc.noaa.gov/stp/geomag/dst.html** for more details about the Dst index. The Dst index is also measured every minute.

A good question to ask is "how are these three indices related?" Since Ap/Kp, AE and Dst are measured at different intervals, one must baseline them to the same interval for meaningful comparisons. With Ap/Kp the longest at 3 hours, we need to take 3-hour averages of AE and Dst. Also, AE and Dst are linear measures – thus we'll use ap (little a, little p – the linear equivalent of the 3-hour Kp index). Figure 2 shows the correlation between these three indices for the first 19 days of January 1979. For the record, Figure 2 comes from Saba, Gonzalez and Clúa de Gonzalez, *Relationships between the Ae, ap and Dst indices near solar minimum (1974) and at solar maximum (1979)*, **Annales Geophysicae**, 15, 1265-1270, 1997.

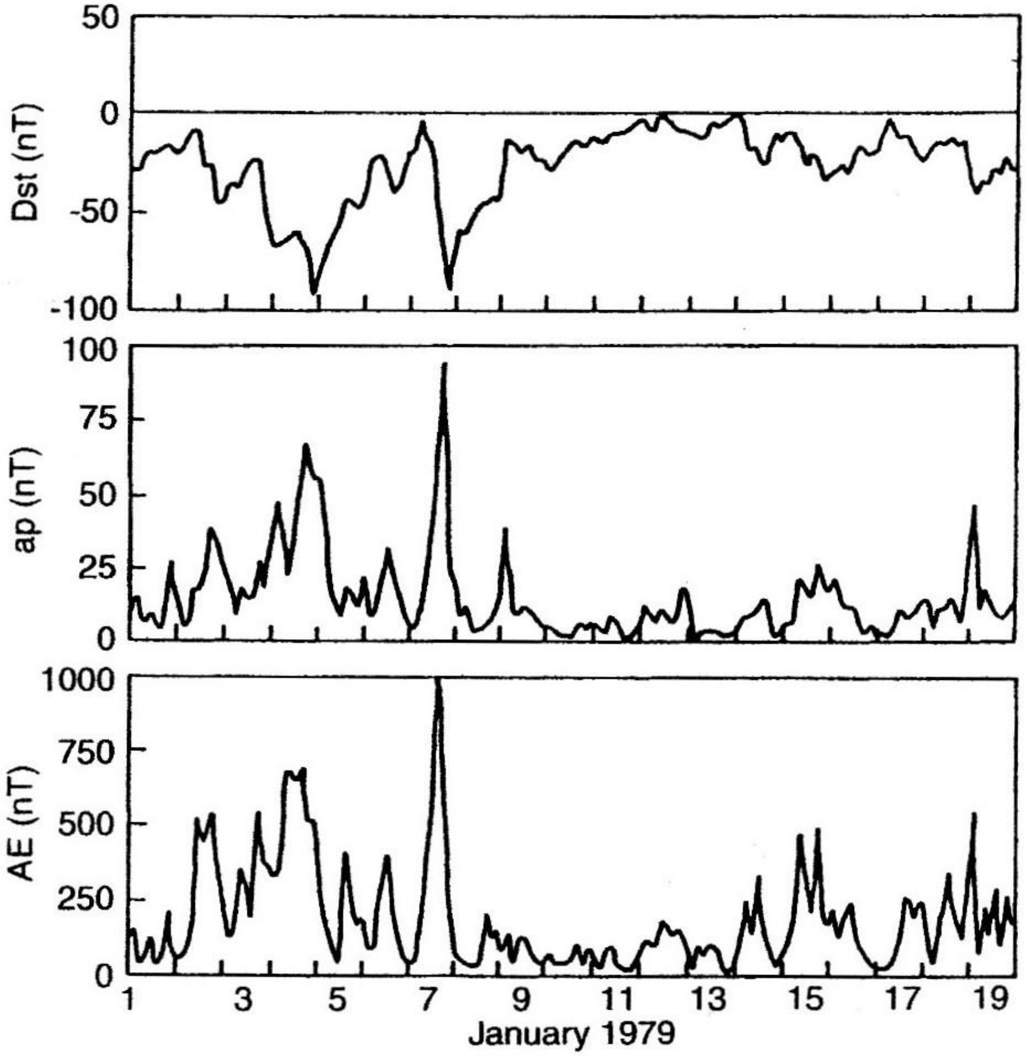


**Figure 2 – Comparison of the three magnetic indices**

Note that all three measurements are in nT (nanoTeslas), which is the unit of measurement for the Earth's magnetic field. Dst is measured as the actual deviation from the quiet-time condition, whereas ap and AE are measured as the maximum deviation from the quiet-time condition in their respective measurement interval.

From Figure 2 it is quite obvious that there is correlation between all three magnetic indices. When Dst is at its largest negative values, ap and AE are generally at their largest deviation values. And when Dst is near zero, the maximum deviations of ap and AE are small. This is somewhat intuitive since processes occurring at high and low latitudes as monitored by the AE index and by the Dst index, respectively, are expected to influence equally the mid latitudes where the ap index is recorded.

But if we dig deeper we'll find discrepancies. For example, there is a time-lag between Dst and AE and between Dst and ap, but there is no time-lag between AE and ap. No time-lag between AE and ap is probably due to the similar nature of these two indices. Dst monitors a bulky and low-rate dissipating current, whereas AE and ap respond to ionospheric currents with a faster response time to external variations.

Other observations noted include:

1) The yearly average of AE is greater at solar minimum than at solar maximum (indicating that coronal holes play more of a role in geomagnetic field activity at solar minimum than do coronal mass ejections at solar maximum), whereas the inverse seems to be true for the yearly average of Dst
2) The seasonal variation of Dst is higher than that of ap, and is almost negligible in AE
3) The ap-AE correlation is in general the highest value overall, and is surpassed only by the ap-Dst correlation during geomagnetic storms

So what does all this mean? We have three measurements of the geomagnetic field. Although they are correlated, they each tell a slightly different story depending on the latitude band in which they are measured.

With respect to affecting F2 region propagation, we know that a large negative Dst index and high-value Ap and AE indices tell of geomagnetic field activity that can be detrimental to propagation. But the only index that gives enough detail to tell how much the F2 region is affected is the ap index (and the related Ap and Kp indices) used by the STORM model. It's always good to know about other magnetic indices (and who knows – maybe someday there will be a model tying them to the F2 region), but right now I personally believe the best index to use is Ap/Kp.