The Earth's Magnetic Field Attracts Confusion

Carl Luetzelschwab K9LA   March 2019

On February 6, Frank W3LPL sent an e-mail to the PVRC (Potomac Valley Radio Club) and copied ten other individuals (including me). The subject was confusion about the recent reports of the movement of the Earth's magnetic poles.

W3LPL pointed out that the confusion stems from the fact that the Earth's magnetic field is not a simple bar magnetic. It is more complicated than that, and this can cause confusion.

For example, due to the field being more complicated than a simple bar magnetic, there are two 'magnetic poles' that are important to Amateur Radio operators. The first is known as the magnetic pole and the second is known as the geomagnetic pole.

The magnetic pole is a measure of the dip angle of the Earth's magnetic field. For example, at the equator the magnetic field is horizontal and thus the needle doesn't need to point up or down from the horizontal – it just needs to point in the horizontal direction of the field. At the high latitudes, the magnetic field is approaching vertical. If a compass needle could also point down, it would do so at the high latitudes. This magnetic pole is where the field is exactly vertical – thus the magnetic pole is also called the dip pole, with 'dip' referring to how far down in the northern hemisphere (or up in the southern hemisphere) the needle would point away from (or towards) the equator.

The geomagnetic pole is the location on which the auroral oval is centered. The geomagnetic pole is constantly changing and the auroral zone will move as the part of the plasma sheet that generates the aurora moves to different field lines. More importantly, the geomagnetic pole isn't in the same location as the magnetic (dip) pole.

Having said all the above, we have to realize that these two definitions are purely semantic devices used to talk about the different ways we model the field---different fits produce different pole locations.

With the definitions of the magnetic (dip) pole and geomagnetic pole in place, let's get to the heart of this month's column – which is to correct a figure in my June 2009 column in WorldRadio On-Line. In that column I showed (in Figure 2) the movement of the northern auroral oval from 1948 to 2015. But due to my confusion with the different 'magnetic poles', I had the movement of the northern auroral oval tied to the north magnetic (dip) pole. Wrong!

Thus I went through my numerous books and technical papers and looked for an early northern auroral oval picture, a more recent northern auroral oval picture and a current northern auroral oval. I did this to show the movement of the geomagnetic pole.

For the early northern auroral oval, I found a 1963 picture in the International Auroral Atlas, Edinburgh 1963, Bond. The 2017 northern auroral oval comes from https://en.wikipedia.org/wiki/North_Magnetic_Pole. The 2019 northern auroral oval comes from the current Space Weather Prediction Center web site at https://www.swpc.noaa.gov/.

Estimating the center of each northern auroral oval (green x's) results in the following image.

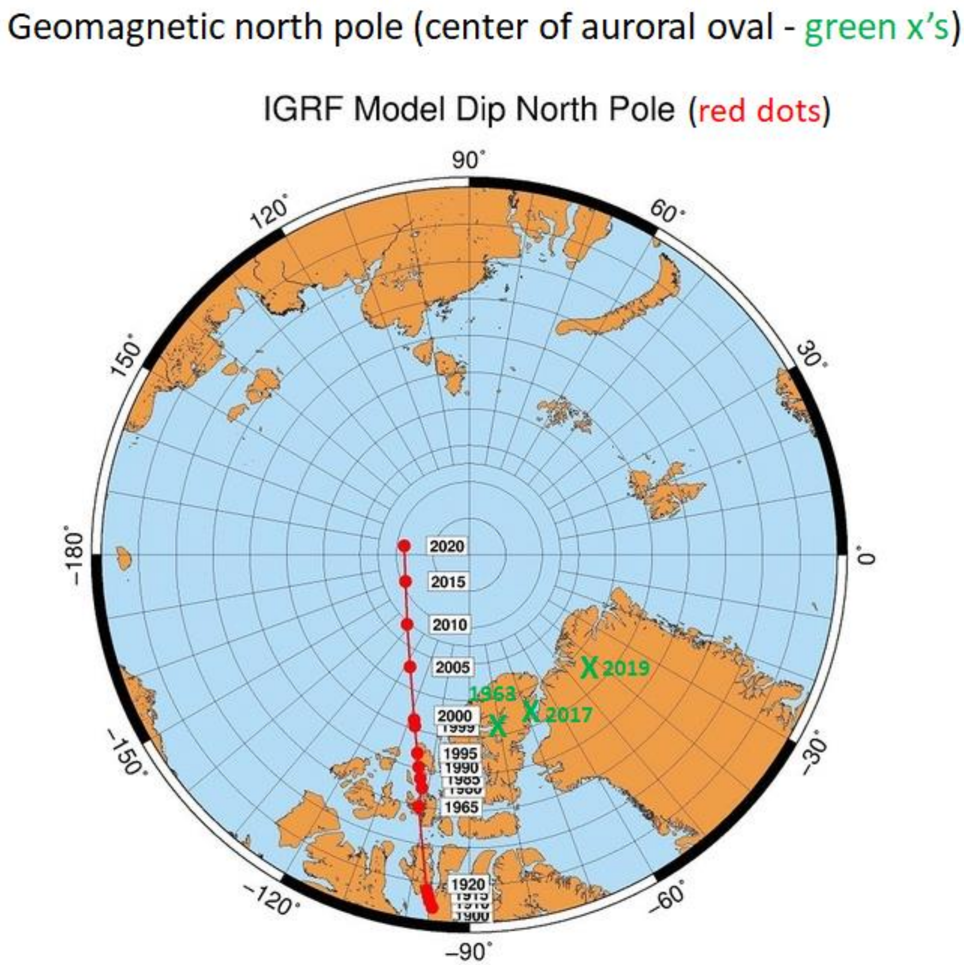

Figure 1 – Movement of the Two Poles

Two conclusions can be reached. First the northern magnetic (dip) pole is moving faster than the northern geomagnetic pole. Second, the northern geomagnetic pole is moving kind of perpendicular to the movement of the northern magnetic (dip) pole. Thus the northern auroral oval is not moving out of the way of the North America West Coast path to Europe as shown in Figure 2 of the June 2009 column.

The discussion in the remainder of the 2009 column of the changes in the Earth's magnetic field strength in relation to the impact on the ionosphere is still valid. This discussion is repeated here between the dashed lines.

With respect to strength, the variation of the Earth's magnetic field is very subtle due to the small changes involved. Figure 2 plots the strength (in nanoTeslas) in 1957 on the left and the change in 1997 compared to 1957 on the right. This figure is from I. Cnossen and A. D. Richmond, *Modeling the effects of changes in the Earth's magnetic field from 1957 to 1997 on the ionospheric hmF2 and foF2 parameters*, Journal of Atmospheric and Solar-Terrestrial Physics, 70, 2008, pages 1512-1524.

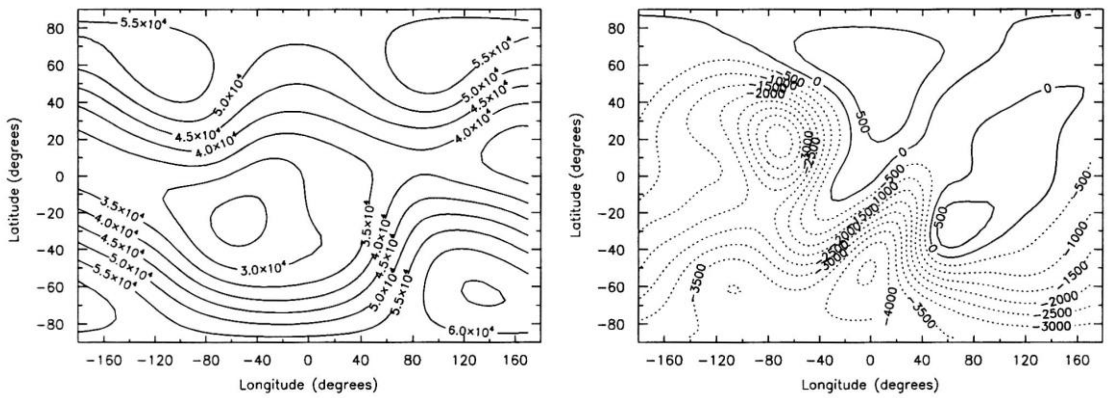

Figure 2 – Field Strength in 1957 and Changes in 1997

The dashed contours in the right plot represent negative values, and solid contours are positive values. Overall, the Earth's magnetic field strength has been decreasing over the past half century.

The Earth's magnetic field affects the ionosphere in four major ways. First, it structures the path of energetic particles entering the terrestrial system. Second, it influences the transport of ionospheric plasma by neutral winds. Third, it affects the generation of dynamo electric fields that induce additional plasma drift. Fourth, it influences ion drag.

Thus we would expect a changing magnetic field strength to re-order the distribution of electrons. Indeed, the study from which Figure 2 came modeled h_mF_2 (height of the F_2 region electron density peak) and f_oF_2 (ordinary wave F_2 region critical frequency) over 35 worldwide ionosondes. The results of the modeling effort showed predicted trends in those parameters over the 40-year period between 1957 and 1997. As one might expect, though, the trends were small – less than a 1.5 km change in h_mF_2 and less than a 0.5 MHz change in f_oF_2. The trends at some stations were positive, and were negative at the other stations.

Remember the January 2008 column that discussed long-terms trends in the ionosphere allegedly due to increased greenhouse gases? In light of the results from the magnetic field modeling above, it is likely that those long-term trends are contaminated with ionospheric changes due to changes in the magnetic field. Thus the impact of greenhouse gases on the ionosphere may not be as strong as originally thought. Granted the changes due to the magnetic field are a small contribution, but nonetheless they have to be included in any conclusion.

Because of W3LPL's initial e-mail, I'm sure we'll see more discussion of this topic in the Amateur Radio literature.