Weakening of Geomagnetic field: Implication to our life and climate

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Planet Earth possesses a strong magnetic field that originates in its fluid outer core by a process called Geodynamo. This intrinsic field contributes more than 95% to the magnetic energy of the Earth. The geomagnetic field is similar to that of a bar magnet means it has two magnetic poles, where the field strength is higher as compared to that in the equatorial regions. This field has fundamental importance as it acts like a protective magnetic shield around the planet Earth, which safeguards its inhabitants from harmful highly energetic particles emitted from the Sun that can cause damage to living organisms, orbiting satellites, astronauts, and space crafts. Although it protects us from the majority of energetic charged particles, still some particles manage to enter the Earth's atmosphere and get trapped along the geomagnetic field lines. The motions of these particles are responsible for the generation of intense electric currents in the Earth's upper atmosphere, which in turn can damage our power systems during severe space weather conditions. In general, it is shown that long-term changes in the Earth's climate are controlled by the cosmic ray flux. Cosmic ray particles are highly energetic atomic nuclei or other charged particles traveling through space with a speed approaching that of the speed of light. As cosmic rays are charged particles, the geomagnetic field can potentially control their entry into the near-Earth environment. The geomagnetic field is an important driving component to the variations of the climate. Therefore, in this modern time understanding the changes in the Earth’s magnetic field is essential.

This geomagnetic field varies slowly on different timescales, which reflects changes deep within the Earth. The Earth's magnetic field over the globe is depicted in Figure 1(a) as a function of geographic latitude and longitude. The strength of the geomagnetic field varies between 25000-70000 nT. This magnetic field is obtained from the thirteenth generation of the International Geomagnetic Reference Field model (www.ngdc.noaa.gov/geomag). The most distinct feature is the extended low magnetic field area (see blue patch), known as South Atlantic Anomaly (SAA). It is widely referred to as a dent in the magnetic field and it is a favorite gateway for the energetic particles to enter the Earth's magnetosphere. The geomagnetic field is weakest over SAA, and it is continuously growing in size and moving westward from the equator to southern latitudes. The long-term observations revealed that the geomagnetic field in the SAA region is decreasing continuously over the past several years. Another feature is the strong magnetic field in the Polar Regions.

If we compare the two poles, the average magnetic field in the southern polar region was invariably stronger as compared to the northern polar average magnetic field. But over the past few decades, the magnetic field in the southern polar region has experienced a considerable decrease such that presently it is weaker than the northern polar region. If we track minimum and maximum magnetic field on the globe then it invariably falls in the SAA and southern polar region, respectively.

The time variation of the minimum magnetic field and the maximum magnetic field is shown in Figures 1(b) and (c), respectively. In the SAA region, the field is decreasing at 30 nT/year and in the southern polar region, the field decreases at the rate of 13 nT/year. Overall, one can see that in the SAA and polar region the magnetic field has steadily weakened over the last two centuries. This weakened polar magnetic field can affect the flux of energetic charged particles and cosmic rays entering the Earth's atmosphere. In general, precipitation of energetic particles in a relatively confined region of the atmosphere can influence atmospheric dynamics, which subsequently play a crucial role in the long-term climate variations. Moreover, the weakening of the magnetic field in the SAA region has major consequences for the operation and protection of surface instruments and satellites over that region. In the present article, glims of the geomagnetic field over the past 200 years are presented. Increased radiation dose due to weakening of the magnetic field is dangerous to life and to our satellites. Though the weakening of the geomagnetic field is not an impulsive phenomenon but can invoke serious concerns to our life, satellites, and climate in near future.

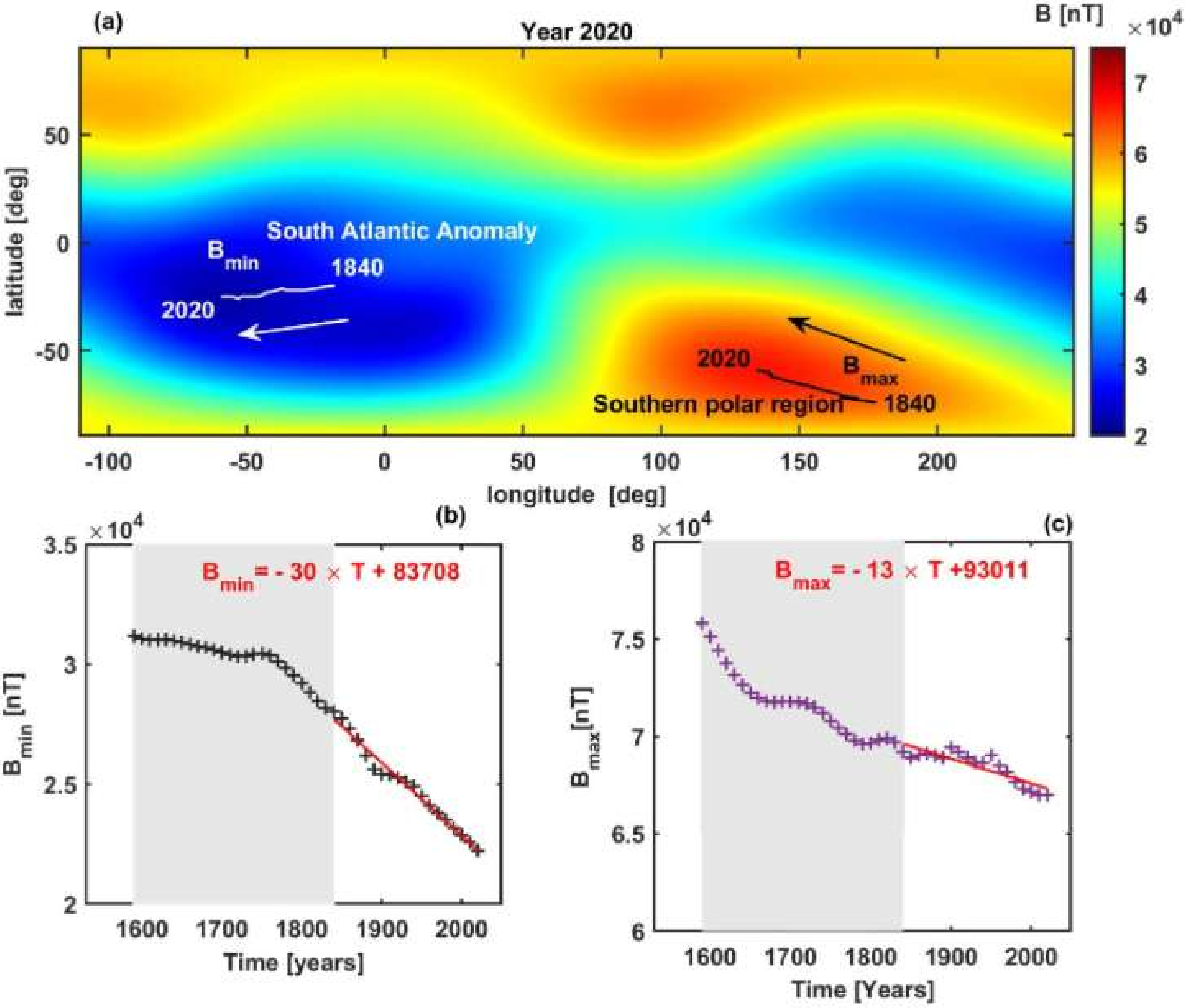

Figure 1: The figure shows the (a) magnetic field strength on the surface of the Earth for the year 2020. The South Atlantic anomaly and Southern polar region are shown and their movement from 1840-to 2020 is superimposed. (b) variation of the minimum magnetic field in the SAA region (c) time variation of the maximum magnetic field in the southern polar region.