The study of change in the location of the geomagnetic north pole for the epoch (1900-2005) by using spherical harmonic coefficient.

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Abstract:

In this paper we study the nature of the location change of geomagnetic north pole (GMNP) for epoch (1900-2005). Using the spherical harmonic coefficient defining the International Geomagnetic Reference Field Model (IGRF) for the (22) epochs (1900-2005), the coordinates of the (GMNP) (longitude and latitude) were computed. Also, I study the secular variation of total intensity (F) and declination (D) (the angle between the horizontal component of the geomagnetic field and true geographic north) at the geomagnetic north pole location (lat 79.73°N, long 71.82°W , year 2005), we found that the rate of change of field intensity (F) is roughly (0.04-0.06% per year).The declination change from (14° west) to (25° east).

Introduction:

The geomagnetic poles, sometimes referred to as the geomagnetic dipole poles are the tow points on the earth's surface formed by the axis of an inclined dipole placed at the centre of the earth. Because the dipole is centered, the geomagnetic poles are situated exactly opposite each other. If the geomagnetic field were exactly that of an inclined geocentric dipole, then the geomagnetic poles would exactly coincide with the dip poles.(1). The geomagnetic north pole (GMNP) position can be calculated from the first three coefficients of the International Geomagnetic Reference Field Model (IGRF).IGRF, providing spherical harmonic coefficients up to degree and order 10 for the year between 1900 to 2005. The first order coefficients $\left(g_1^0, g_1^1, h_1^1\right)$ for this model define the position of the centered tilted dipole.(2)

Geomagnetic Coordinates System:

The first three Gauss coefficients are all that is required to describe an Earth-centered dipole. It has been found quite useful to establish a coordinate system using such a centered dipole field, this system is called Geomagnetic Coordinate System (GCS). The (GCS) is completely defined by one pole location (because of symmetry, either the north or south pole will suffice),and a selection of a prime meridian of geomagnetic longitude.. The dipolar central model is used to define the geomagnetic coordinates (they are the coordinates from the dipole's axis) :

1) Geomagnetic latitude, θ_M , measured from the geomagnetic equator , define as the plane normal to the dipole's axis and passing through the center of the earth .
2) Geomagnetic longitude, φ_M , measured eastwards from the meridian half-plane containing the geographical south pole. (3)

International Geomagnetic Reference Field (IGRF):

The (IGRF) is a series of mathematical models describing the earth's main field and its secular variation. For points located near the earth's surface, it is possible to calculate the geomagnetic field B using the scalar magnetic potential V , were:

$$B = -\nabla V \qquad [1]$$

The scalar magnetic potential can be expanded in terms of the geographical coordinates as:

$$V(r,\theta,\varphi) = a\sum_{n=1}^{N}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^{n+1}\left(g_n^m \cos m\varphi + h_n^m \sin m\varphi\right)P_n^m(\cos\theta) \qquad [2]$$

Where a is the mean radius of the earth {6371.2km}, r is the radial distance from the centre of the earth, φ is the longitude eastward from Greenwich, θ is the geocentric colatitude, and $P_n^m(\cos\theta)$ is the associated Legendre function of degree n and order m. N is the maximum spherical harmonic degree of the expansion, { g_n^m, h_n^m } set of spherical harmonic coefficients.(4)

Geomagnetic Dipole:

The main contribution in the spherical harmonic expansion comes from the terms with $(n = 1, m = 0,1)$ in the spherical harmonic representation of (V),the total dipole potential (V^{dipole}), becomes

$$V^{dipole}(r,\theta,\varphi) = \frac{a^3}{r^2}\left[\{g_1^0 \cos(0) + h_1^0 \sin(0)\}P_1^0(\cos\theta) + \{g_1^1 \cos\varphi + h_1^1 \sin\varphi\}P_1^1(\cos\theta)\right] \qquad [3]$$

but

$P_1^0(\cos\theta) = \cos\theta$ and $P_1^1(\cos\theta) = \sin\theta$, equation 3 becomes:

$$V^{dipole}(r,\theta,\varphi) = \frac{a^3}{r^2}\left(g_1^0 \cos\theta + g_1^1 \cos\varphi \sin\theta + h_1^1 \sin\varphi \sin\theta\right) \qquad [4]$$

The total dipole magnetic field $B^{dipole} = -\nabla V^{dipole}$, has components:

$$B_r^{dipole} = \frac{2a^3}{r^3}\left(g_1^0 \cos\theta + \sin\theta\left(g_1^1 \cos\varphi + h_1^1 \sin\varphi\right)\right) \qquad [5]$$

$$B_\theta^{dipole} = \frac{a^3}{r^3}\left(g_1^0 \sin\theta - \cos\theta\left(g_1^1 \cos\varphi + h_1^1 \sin\varphi\right)\right) \qquad [6]$$

$$B_\varphi^{dipole} = \frac{a^3}{r^3}\left(g_1^1 \sin\varphi - h_1^1 \cos\varphi\right) \qquad [7]$$

The magnetic dipole pierces the surface of the earth at the latitude (θ) and longitude (φ) , given by the following equations :

$$\varphi_M = \tan^{-1}\left(h_1^1 / g_1^1 \right) \quad [8]$$

$$\theta_M = \tan^{-1}\left(\left(g_1^1 \cos\varphi + h_1^1 \sin\varphi \right) / \ g_1^0 \right) \quad [9]$$

were (φ_M, θ_M) are the longitude and latitude of the geomagnetic north pole respectively , and g_1^0, g_1^1, h_1^1 , represent the first three coefficient of a magnetic reference field model.(5,6).

Geomagnetic secular variation:

The magnetic field of the Earth is not a constant over time. Various changes occur in intensity and direction. Although the magnetic field is sustained by dynamo within the Earth's core, part of the field threads its way through the mantle and up to the surface. The same convection motion that drives the geodynamo also causes the field, measured at the surface, to be time-dependent over historical timescales, phenomenon known as secular variation (s.v).(1).The origins of geomagnetic secular variation can be crudely subdivided into two contributions with overlapping periodicities: 1) nondipole changes dominating the shorter periods and 2) changes of the dipolar field with longer periods. The dipole portion of the geomagnetic field (90% of the surface field) changes direction and amplitude. In addition to changes in geomagnetic pole position the amplitude of the geomagnetic dipole also changes with time .The (s.v) is very small, but after a few years their accumulation is enough to make the geomagnetic field models out dated. So, magnetic models and charts must be periodically updated to accommodate the continual (s.v) of the filed. (7).

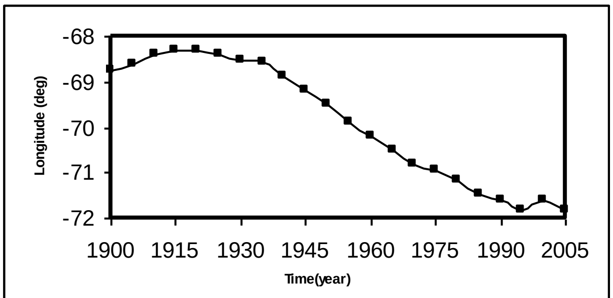
Data source:

In this paper, we get on data of total intensity (nano Tesla) of geomagnetic field and declination (deg) from the International Geomagnetic Reference Field Model (IGRF10) at geomagnetic north pole location for year 2005.

Results and discussion:

1) In fig {1}, we plot the longitude of the geomagnetic north pole as a function of the time for epoch (1900-2005). We can see that (GMNP) move towards west about (0.04^o per year).This refer to that the geomagnetic north pole performing a random walk about the north geographic.

Table 1.data of the longitude vs. time.



Fig(1).Longitude of the (GMNP) location derived from the

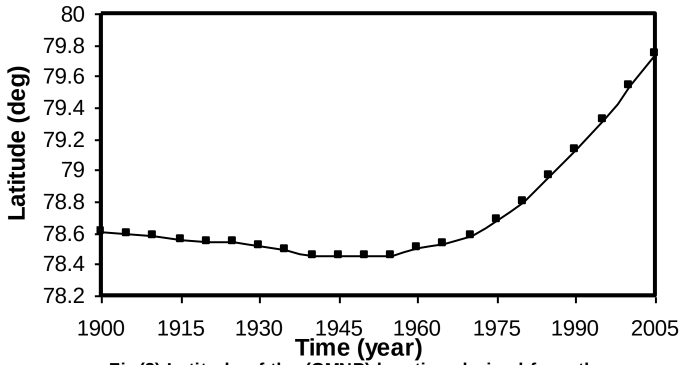
Time(year)	g_1^0	g_1^1	h_1^1	φ(deg)
1900	-31543	-2298	5922	-68.8264
1905	-31464	-2298	5909	-68.7839
1910	-31354	-2297	5898	-68.7562
1915	-31212	-2306	5875	-68.6042
1920	-31060	-2317	5845	-68.411
1925	-30926	-2318	5817	-68.308
1930	-30805	-2316	5808	-68.2945
1935	-30715	-2306	5812	-68.3932
1940	-30654	-2292	5821	-68.5429
1945	-30594	-2285	5810	-68.5657
1950	-30554	-2250	5815	-68.882
1955	-30500	-2215	5820	-69.199
1960	-30421	-2169	5791	-69.502
1965	-30334	-2119	5776	-69.8892
1970	-30220	-2068	5737	-70.213
1975	-30100	-2013	5675	-70.5055
1980	-29992	-1956	5604	-70.795
1985	-29873	-1905	5500	-70.9317
1990	-29775	-1848	5406	-71.1635
1995	-29692	-1784	5306	-71.4524
2000	-29619.4	-1728.2	5186.1	-71.6063
2005	-29556.8	-1671.8	5080.0	-71.8203

2) In fig {2}, we plot the latitude of the geomagnetic north pole as a function of the time for epoch (1900-2005). We can see that (GMNP) move towards north about (0.02^o per year), and the geomagnetic field has an angle (10.27^0) with the rotation axis.

Table 2. data of the latitude vs. time.

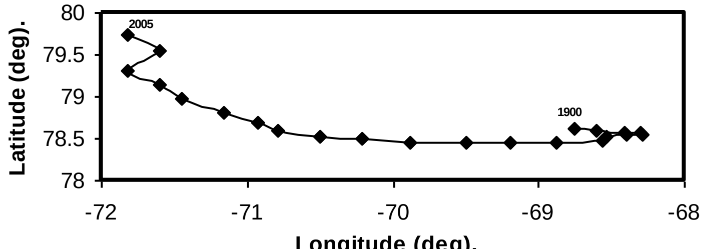
Time	g1,0	g1,1	h1,1	θ(deg)
1900	-31543	-2298	5922	78.6081012
1905	-31464	-2298	5909	78.6014628
1910	-31354	-2297	5898	78.5811682
1915	-31212	-2306	5875	78.5626009
1920	-31060	-2317	5845	78.5504292
1925	-30926	-2318	5817	78.5478031

1930	-30805	-2316	5808	78.5202784
1935	-30715	-2306	5812	78.4874996
1940	-30654	-2292	5821	78.4594154
1945	-30594	-2285	5810	78.4604124
1950	-30554	-2250	5815	78.4602311
1955	-30500	-2215	5820	78.4545511
1960	-30421	-2169	5791	78.5038534
1965	-30334	-2119	5776	78.5288257
1970	-30220	-2068	5737	78.5852451
1975	-30100	-2013	5675	78.6816858
1980	-29992	-1956	5604	78.7998849
1985	-29873	-1905	5500	78.9688201
1990	-29775	-1848	5406	79.1327628
1995	-29692	-1784	5306	79.3178363
2000	-29619.4	-1728.2	5186.1	79.5380152
2005	-29556.8	-1671.8	5080.0	79.7386418



Fig(2).Latitude of the (GMNP) location derived from the spherical harmonic coefficient for each epoch (1900-2005)

3) Fig {3}, shows the drift of the geomagnetic north pole location for epoch (1900-2005) for the twenty tow models comprising the latest version of the International Geomagnetic Reference Field. We can see from this figure that the (GMNP) is slowly drifting by the geomagnetic secular variation, which is caused by the slow variation of the electric currents flowing in the earth's core.



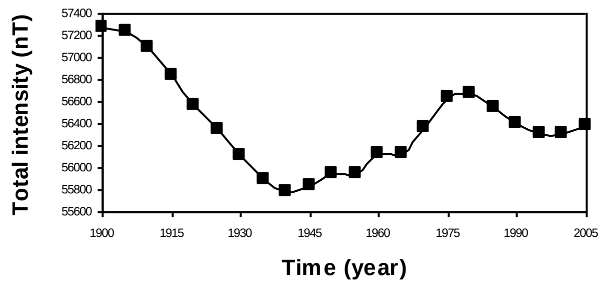
Fig(3).Drift of (GMNP) for epoch (1900-2005).

4) In fig {4} we plot the total intensity (F) in nano Tesla unit as a function of the time for the (1900-2005) at the (GMNP) point. We can see from this curve that the field intensity decrease with the time during the epoch (1900-1940) and the rate of the change in field intensity is about (0.06 % per year) . Then for epoch (1940-1980) , we

can see that the field intensity increase with the time and the rate of the change is about (0.04 % per year) .After the year (1980) , the field intensity returning to decrease with the time.

Table 3. . data of the total intensity vs. time.

Time	F(nT)
1900	57276
1905	57241.9
1910	57090.2
1915	56833.9
1920	56561.3
1925	56354
1930	56105.1
1935	55893.2
1940	55774.7
1945	55828.6
1950	55948.8
1955	55938.3
1960	56119.9
1965	56125.8
1970	56372
1975	56631.4
1980	56677.7
1985	56543.3
1990	56393.4
1995	56316.9
2000	56303.3
2005	56383.6



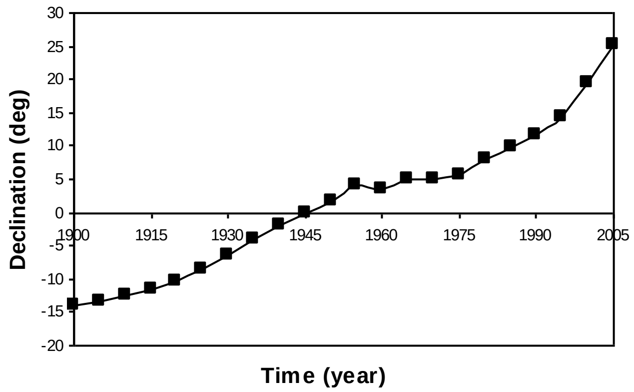
Fig(4).Change in total field at (GMNP) POINT.

5) In fig {5} we plot the declination (D) as a function of the time for the (1900-2005) at the (GMNP) point. We can see from this curve that the declination has changed from approximately 14^o west to 25^o east.

Table 4. data of the declination vs. time.

Time	D (deg)
1900	-14.116
1905	-13.285
1910	-12.559
1915	-11.529

1920	-10.355
1925	-8.624
1930	-6.459
1935	-4.108
1940	-2.047
1945	0.028
1950	1.63
1955	3.998
1960	3.635
1965	4.855
1970	5.104
1975	5.522
1980	8.099
1985	9.824
1990	11.771
1995	14.398
2000	19.407
2005	25.278



Fig(5).Change in declination at (GMNP) point.

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دراسة التغير في موقع القطب الجيومغناطيسي الشمالي للفترة (1900-2005) باستخدام المعاملات التوافقية الكروية.

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الخلاصة:

تناولنا في هذا البحث دراسة طبيعة تغير موقع القطب الشمالي الجيومغناطيسي للفترة (1900-2005).باستخدام المعاملات التوافقية الكروية والمعرفة بواسطة النموذج الدولي المرجعي للمجال المغناطيسي الأرضي خلال (22) فترة من 1900 إلى 2005. تم حساب المواقع الجغرافية لخطي الطول والعرض للقطب الجيومغناطيسي الشمالي. تمت أيضا دراسة التغير في كل من الشدة الكلية (F) وقيمة الميل (D)(الزاوية المحصورة بين المركبة الأفقية للمجال المغناطيسي الأرضي والقطب الشمالي الجغرافي) عند موقع القطب الشمالي الجيومغناطيسي لسنة 2005 (خط عرض 79.73 درجة شمالا، خط طول 71.82 درجة غربا).وقد وجدنا بان نسبة التغير في الشدة الكلية يبلغ حوالي (0.04 -0.06 % لكل سنة) ، وان الميل يتغير من 14 درجة غربا إلى 25 درجة شرقا.