"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 77 - 80, 2007

Polar Geophysical Institute

DEPENDENCE OF CORRECTED GEOMAGNETIC COORDINATES OF HIGH-LATITUDE OBSERVATORIES ON SEASON OF A YEAR, UNIVERSAL TIME AND GEOMAGNETIC ACTIVITY LEVEL

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Abstract. Calculation of CGM-coordinates of any point on the Earth's surface is based on the magnetic field line tracing from a specified point up to the magnetic equator plane by using one of the magnetospheric magnetic field models and tracing back to the ionosphere by using the dipole magnetic field only. The magnetic field model and coordinates are usually presented in GSM coordinate system, therefore the CGM-coordinates of any point depend on season of a year, UT, and the used magnetic field model, which continuously change in time and depend on the geomagnetic activity level. The geomagnetic activity level defined by indices of geomagnetic activity or parameters of Interplanetary Magnetic Field/Solar Wind (IMF/SW) is one of input parameters of any magnetic field model. Besides, variations of activity level causes changes of the magnetospheric boundaries geometry. Modern tables and computation procedures of GCM-coordinates of geomagnetic observatories do not inform about CGM temporal variations. We demonstrate variations of CGM-coordinates of high-latitude magnetic observatories, for which temporal variations are the most appreciable. The CGM-coordinates are calculated by using IGRF, Tsyganenko's and Paraboloid models of the magnetospheric magnetic field.

Introduction

Solar magnetospheric (GSM) and Corrected GeoMagnetic (CGM) coordinate systems are used to analyze geophysical phenomena at the Earth's surface and in the Earth' s environment. Corrected Geomagnetic Coordinates was introduced by *Hultquist and Gustafsson* [1960]. According to *K Stasiewicz* [1991] the classical algorithm of the geomagnetic corrected coordinates calculation looks as following:

- Step 1: The magnetic field line tracing from point belonging to the Earth's surface or the satellite position (limited by 6 R_E) up to magnetic equatorial plane using IGRF magnetic field model.
- Step 2: Tracing back from the point produced at Step 1 to the Earth's surface by using the dipole magnetic field.
- The corrected geomagnetic latitude and longitude of the original point are equal to the dipole latitude and longitude of the point produced at the Step 2.

CGM coordinates of any point can be calculated at *Nssdc.gsfc.nasa.gov/space/cgm/*. Input parameters of the computation procedure are geocentric latitude and longitude, altitude above the 1-Re (6371.2 km) surface, year for IGRF models. Below, the CGM coordinates calculated by using this procedure will be named as *standard* CGM coordinates.

The Earth's magnetosphere is an electrodynamic system that couples the northern and southern polar ionospheres, each with different geophysical and electrodynamic properties. The unique physical characteristics of the northern and southern polar regions must be considered in models of the fully coupled, global, dynamic geospace system. For example, the separation of geomagnetic and rotation poles, magnetic field strength, and conductivity structures are different in the two polar regions. Further, the solar wind electrodynamic coupling to the northern and southern hemispheres can be very different depending upon the IMF orientation and solar wind parameters. Investigations of these differences and their consequences is a focus of the International Polar Year and the associated ICESTAR program. In addition, considerable new data should be available from various sources such as ground/satellite conjunctions (Double Star, Cluster) and the coordinated THEMIS experiment. These programs along with other national and international efforts produce new instrument arrays and methods for combining and synthesizing global data sets to investigate the fully coupled solar wind – magnetosphere – ionosphere system including inter-hemispheric coupling. The CGM coordinates are used to analyze geophysical information, and we notice that coordinates of any high-latitudinal point of observation are not fixed and vary depending on a season of a year, UT, and geomagnetic activity.

CGM coordinates of some high-latitudes geomagnetic observatories depending on day, UT and geomagnetic activity level

We have calculated the CGM coordinates of some high-latitudes geomagnetic observatories taking into account that geomagnetic field line can cross the magnetosphere boundary, and spatial distribution of the magnetic field can change depending on day of a year and universal time (Solar magnetospheric coordinate system) and on IMF condition (geomagnetic activity).

The magnetosphere form is assigned as a paraboloid of revolution in solar-magnetosphric system of coordinates, the paraboloid vertex is located in the subsolar point of the magnetopause at the geocentric distance R1

[*Feldstein et al.*, 2005]. The magnetic field in the near-Earth's space is determined as superposition of the main magnetic field of the Earth and the magnetic field of the magnetospheric current systems. To calculate the main magnetic field the IGRF-2000 has been used ([*Olsen et al.*, 2000]), the magnetospheric magnetic field has been modeled by Tsyganenko's model T96 ([*Tsyganenko and Stern*, 1996]).

Model R1 and the magnetospheric magnetic field modeled by T96a are parameterized by IMF components (Bz and By), SW (velocity V and density N) and Dst index of geomagnetic activity. Depending on geomagnetic activity level and IMF/SW conditions the input parameters were arranged into groups according to quiet, weakly disturbed, and disturbed states of geomagnetic activity (Table 1).

Table 1. Interplanetary Magnetic Field/Solar Wind parameters and Dst index for different states of geomagnetic activity.

	Quiet state	Weakly disturbed state	Disturbed state
Bz, nT	2.5	- 2.5	-10
By, nT	4	4	8
N, cek^{-1}	4	8	15
V, km/cek	400	500	700
Dst, nT	-10	-40	-100

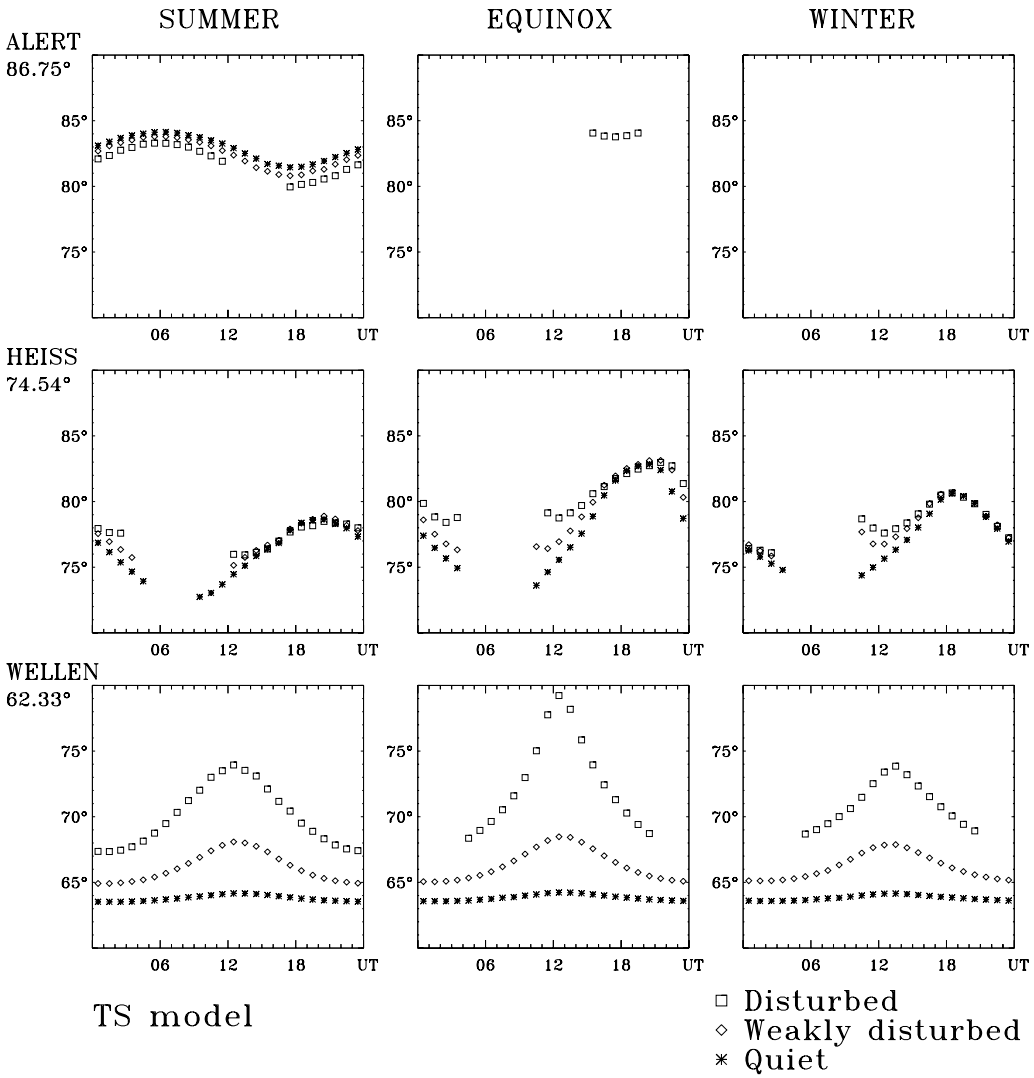

Figure 1. (from top to bottom) Variations of CGM latitudes of high latitude observatories Alert, Heiss, Wellen depending on UT, season, and geomagnetic activity level. *Standard* CGM latitude of each observatory is presented below of the observatory names.

As the model magnetospheric magnetic field depends on a day of a year and the dipole angle, CGM coordinates of geomagnetic observatories were calculated for every UT of summer and winter solstice days (June, 22 and December, 22) and vernal and autumnal equinox days (March, 22 and September, 22).

Figure 1 presents dependencies of CGM latitudes of observatories Alert (*standard* CGM latitude is 86.75°), Heiss (*standard* CGM latitude is 74.54°), Wellen (*standard* CGM latitude is 62.33°) on UT, seasons (Summer, Equinox, Winter) and geomagnetic activity level (Quiet, Weakly disturbed, Disturbed). It is shown that model magnetic field lines mapping from the near-polar point (Alert) are unclosed during the most part of a year. Magnetic field lines of the point located near the polar cap boundary (Heiss) are unclosed during 6-8 hours. The CGM coordinates of any high-latitudinal point at the Earth's surface depend on geomagnetic activity in accord with the southward shift of the polar oval during geomagnetic activity increase.

Tables 2-3 demonstrate the model CGM coordinates of auroral observatories (Barrow, Murmansk, Dixon) deriving AE (AU, AL)-index and observatories located in the polar cap (Godnawn, Baker Lake, Heiss) for the disturbed geomagnetic state and for different seasons of the year (Winter and Summer). The tables show *standard* CGM coordinates (Corrected geomagnetic coordinates) and model coordinates (Model corrected geomagnetic coordinates) of the observatories. The model coordinates are absent in a table if magnetic field line mapping from point of the observatory location is unclosed for given UT, season and geomagnetic activity state.

Table 2. Corrected geomagnetic coordinates of AE-index observatories during disturbed state of geomagnetic activity.

	BARROW		MURMANSK		DIXON	
Geographic coordinates (latitude, longitude)	71.30º	–156.75º	68.25º	33.08º	73.55º	80.57º
Standard corrected geomagnetic coordinates (latitude, longitude)	69.51º	247.89º	63.98º	114.39º	67.73º	155.85º
WINTER	MODEL CORRECTED GEOMAGNETIC COORDINATES					
UT	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
00	---	---	72.23º	127.22º	---	---
04	---	---	---	---	---	---
08	73.53º	257.98º	---	---	---	---
12	77.10º	253.36º	---	---	---	---
16	75.80º	235.43º	71.66º	112.30º	77.37º	168.57º
20	---	---	75.31º	116.95º	77.07º	153.78º
SUMMER	MODEL CORRECTED GEOMAGNETIC COORDINATES					
UT	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
00	---	---	74.11º	105.80º	73.64º	137.41º
04	---	---	70.75º	102.93º	---	---
08	76.01º	276.48º	---	---	---	---
12	77.62º	254.92º	---	---	---	---
16	74.43º	231.68º	70.87º	124.84º	74.57º	169.34º
20	---	---	74.12º	118.50º	75.96º	147.04º

Thus, we demonstrated that modern models of the magnetospheric magnetic field allow to calculate the CGM coordinates taking into account the day of a year, universal time, and IMF conditions. There are some conditions when magnetic field line mapping from a point location is unclosed, so we have no possibility to calculate the CGM coordinates for given UT, season and geomagnetic activity state.

Table 3. Corrected geomagnetic coordinates of high-latitudinal observatories during the disturbed state of geomagnetic activity.

	GODHAWN		BAKER LAKE		HEISS	
Geographic coordinates (latitude, longitude)	69.23º	–53.52º	64.33º	-96.03º	80.62º	58.05º
Standard corrected geomagntic coordinates (latitude, longitude)	76.82º	42.15º	74.80º	323.25º	74.54º	145.32º
WINTER	MODEL CORRECTED GEOMAGNETIC COORDINATES					
UT	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
00	76.89º	60.01º	76.26º	26.48º	76.43º	116.53º
04	75.19º	34.51º	74.72º	343.80º	---	---
08	76.47º	353.54º	75.57º	325.41º	---	---
12	---	---	76.57º	293.42º	77.60º	206.67º
16	---	---	---	---	79.80º	173.35º
20	78.44º	98.48º	---	---	79.83º	141.75º
SUMMER	MODEL CORRECTED GEOMAGNETIC COORDINATES					
UT	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
00	80.06º	58.44º	76.25º	20.25º	77.95º	103.89º
04	81.34º	23.18º	80.25º	354.44º	---	---
08	78.38º	351.41º	80.80º	321.61º	---	---
12	---	---	76.51º	294.00º	75.98º	206.84º
16	---	---	---	---	76.99º	170.58º
20	76.15º	87.98º	---	---	78.49º	137.59º

Acknowledgments. The research was supported by INTAS grant 03-51-5359 and RFBR grants 05-05- 65196 and 04-05-64890.

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