Building a magnetic declination maps and its anomalies for the Isthmus of Panama during 2010 to 2014
Construyendo mapas de declinación magnéticas y sus anomalías para el Istmo de Panamá desde el 2010 hasta el 2014

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Resumen– *El objetivo de este trabajo se focaliza en presentar una actualización del mapa de declinación magnética del istmo de Panamá para un lapso temporal comprendido entre los años 2010 a 2014. Para tal propósito se utilizó el modelo IGRF-11 de la International Association of Geomagnetism and Aeronomy, cuya revisión se lleva cabo cada cinco años. Este modelo toma en consideración el constante cambio que experimenta el campo magnético terrestre y su influencia en la declinación magnética; estos elementos son de vital importancia para la determinación de la dinámica, y por ende la actualización de los niveles de exactitud de la cartografía que posteriormente pueda servir de soporte a sistemas de navegación aéreo o marítimo y a la determinación del Geoide. Los resultados obtenidos en este trabajo muestran que la declinación magnética experimenta un desplazamiento hacia el sector occidental del istmo de Panamá.*

Palabras claves– *Campo de referencia geomagnética, carta magnética, declinación magnética, modelo IGRF-11, Panamá.*

Abstract– *This work presents an updated magnetic declination map of the Isthmus of Panama for the years 2010 to 2014 based on the IGRF-11 model from the International Association of Geomagnetism and Aeronomy. This model takes into account changes in the Earth's magnetic field and its influence on the magnetic declination. These elements are important for determining accurate mapping which may be used to support systems of sea or air navigation. The results obtained show that the magnetic declination lines in Panama have shifted westwardly during these years.*

Keywords– *Reference geomagnetic field, magnetic map, magnetic declination, IGRF-11 model, Panama.*

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1. Introduction

At any particular point on the surface of our planet, the geomagnetic field and its scalar potential can be expressed in spherical polar coordinates (r, θ, ζ) where r is the distance from the center of our planet, θ is the colatitude and ζ the longitude. This scalar potential can be given by:

$$\Phi\left(r,\theta,\varsigma,t\right) = R\sum_{n=1}^{n_{\max}}\left(\Lambda_n r^n + \frac{\Theta_n}{r^{n+1}}\right)\sum_{k=0}^{k=n}\aleph_n^k\left(\theta,\varsigma\right) \quad (1)$$

Here R denotes the Earth's radius. The term Λ_n represents part of the potential linked to the magnetic field sources outside the Earth and Θ_n is associated to the internal magnetic sources. In this equation $\aleph_n\left(\theta,\varsigma\right)$ is the spherical harmonic function and describes the changes or variations of the magnetic potential when the distance r is constant.

The summation signs show that the total potential is made up of an infinity number of terms with different values of n and k [1].

To understand the geomagnetic field caused by internal sources of Earth, we need to omit the term Λ_n of equation (1); according to [1], the spherical harmonic functions $\aleph_n(\theta,\varsigma)$ (linked to the variation of potential on a spherical surface) are expressed in some polynomial functions that depend on time. Equation (1) can be represented by:

$$\Phi(r,\theta,\varsigma,t) = R\sum_{n=1}^{n_{\max}}\left(\frac{R}{r}\right)^{n+1}\sum_{k=0}^{k=n}\left[\kappa_n^k(t)\cos(k\varsigma)+ +\tau_n^k(t)\sin(k\varsigma)\right]\Gamma_n^k\cos(\theta) \quad (2)$$

In the equation (2), $\kappa_n(t)$ and $\tau_n(t)$ are the numerical Gauss coefficients at time *t* and $\Gamma_n\cos(\theta)$ are the Schmidt semi-normalized associated Lagrange functions of degree *n* and order *k* [2, 3].

This means that at any particular point on the Earth the geomagnetic field presents variations in time. In decades or centuries of observations these variations are significant and they are called secular variations [1]; this means that magnetic North does not always coincide in location with the real geographic North (the Earth's rotational axis); the horizontal angle between these elements is known as magnetic declination. If there are secular variations, the magnetic declination values can change. According to [4, 5] this parameter is important for all map users because the cartography of magnetic anomalies as a basic component to define the geoid in geodesy.

The need to calculate the magnetic declination lies in the annual variations of this angle which affects air and maritime navigation systems for global positioning and mapping works done with compass system. In addition the study of magnetic declination is one of the important components of the national magnetic map necessary for the study of magnetism and its applications in Geodesy and Geophysics for searching of a geoid model for Panama.

There are two methods that are used to map the magnetic declination: by field observations with magnetometers and by geomagnetic models [5-13]. Today two models are used: (a) the WMM model (World Magnetic Model) that was developed jointly by the British Geological Survey and the National Geophysical Data Center. This model uses the geomagnetic field for altitude and navigation for example and was published in January 2000, and (b) the IGRF (International Geomagnetic Reference Field) of the International Association of Geomagnetism and Aeronomy that is based in equation (2); in other words, we can say that this model is an established numerical model or series of global spherical harmonic models of the geomagnetic field whose sources are in the Earth's core. The model is produced and maintained by a group of geomagnetic field modelers who review it every five years [2, 3]. This model has been used by some authors as computational method [5, 8, 10, 12, 14]. The usefulness of modelling the behavior of the magnetic field lies in the dynamics of the magnetic poles, but it is important to know that the geomagnetic field has important elements that are nondipolar [15].

As Panama lacks geomagnetic stations, then we can use a geostatistical method from the IGRF-11 model which has shown satisfactory results with respect to field data. Some authors refer to the magnetic declination fluctuations in different geographical latitudes; according to [16] refers to changes that occur long time period in Europe, meanwhile according to [11] the geomagnetic forces are dynamics. This work is focused on updating the map of the magnetic declination of the Isthmus of Panama between periods of five years (2010-2014) for understand the dynamics of this important geomagnetic parameter and its impact of the data for navigation purposes.

2. Materials and methodology

The first step is to define the mesh points, in this work we have located these points every thirty minutes (30') from the point of origin 7°00' N, -77°00' W to 10°00' N, -83°00' W. Figure 1 shows the distribution of these points on the map of the Isthmus of Panama.

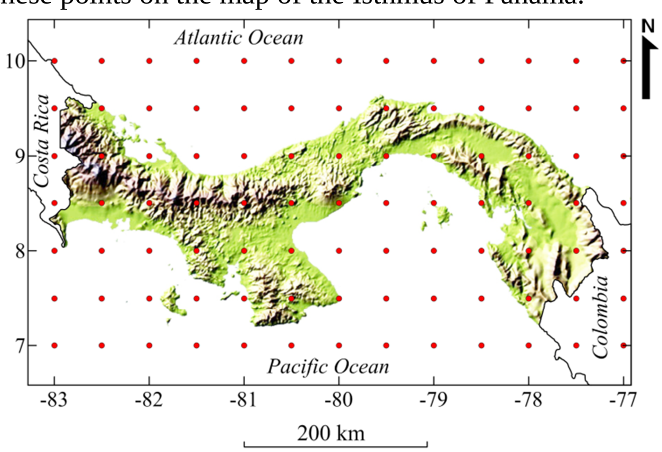

Figure 1. Coordinates of sampling points of IGRF-11 model.

For these geographical coordinates WGS-84 was used as a geographical reference. In second step, elevations for each sampling point was determined using the digital terrain model of NASA SHUTTLE (1:100000 scale). Finally, the IGRF-11 model was then applied to each sampling point for the first day of January of the years 2010 to 2014. The coefficients of the main field model in the period established and secular variations values are computed.

The results obtained were processed in Geographic Information System where isogonic interpolation of lines for each date mentioned was done; this process is made by geostatistical methods according to [8, 10] and then, a regional geographical analysis of temporal variations of isogonic lines was performed.

3. Results

The results of five maps of magnetic declination for these dates are presented in figure 2. These maps show that the magnetic declination changes in western direction of the Isthmus of Panama, but another important feature is that this displacement is not systematic.

For the time interval between 2010 and 2014, areas with magnetic declination fluctuations that can affect navigation systems, have been identified according to the coefficients of variation estimated from the developed model.

According to estimated data obtained from the IGRF-11 model the areas with highest annual variations of magnetic declination are: (1) the southern part of the Azuero Peninsula continuing for the area around Coiba Island in the Veraguas province, (2) the central mountain in Veraguas, Coclé provinces and Western Panama, (3) the western part of Chiriquí province, (4) the eastern Gulf of Chiriquí, (5) the southern part of Las Perlas archipelago and (6) the coastal area of the Bocas del Toro province. Figure 3 presents magnetic variation coefficients map between 2010 and 2014.

4. Conclusions

Understanding of Earth magnetic field dynamics in the Isthmus of Panama is a topic of remarkable interest in marine and aerial navigation systems and for some migratory species, and therefore update magnetic declination map is necessary to understand the impact in Cartography and Ecology.

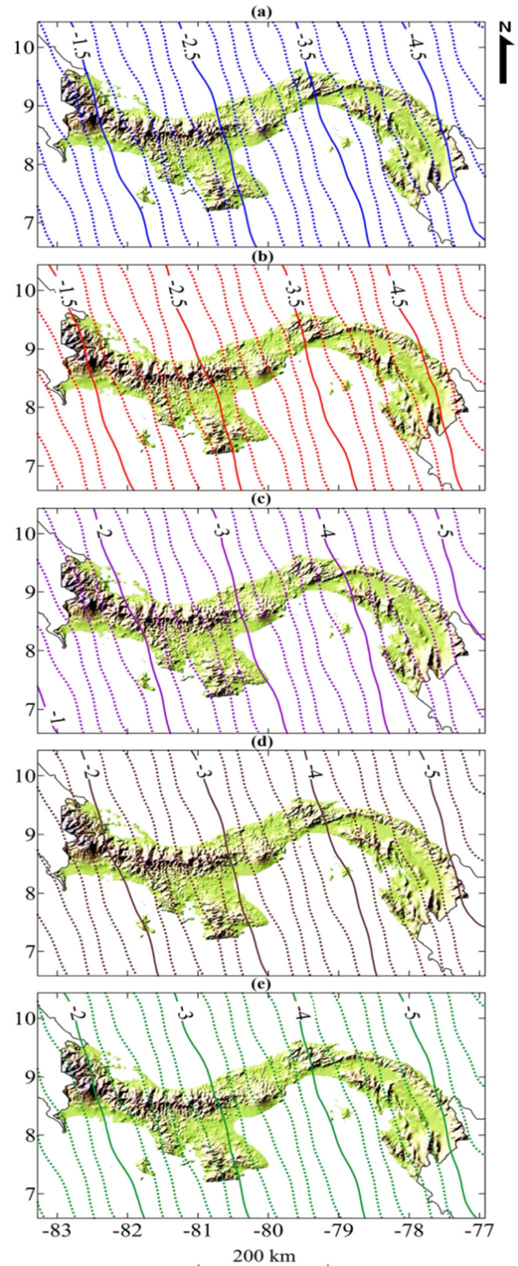

Figure 2. Magnetic declination maps to January 1 of the years: (a) 2010, (b) 2011, (c) 2012, (d) 2013 y (e) 2014.

The magnetic declination of Panama for the period 2010-2014 remains displacing to the western part of the isthmus; it should also be noted that this displacement is not systematic. The analysis of the annual variations in isogonic lines during the 2010-2014 periods shows a total of six areas where magnetic declination changes are large.

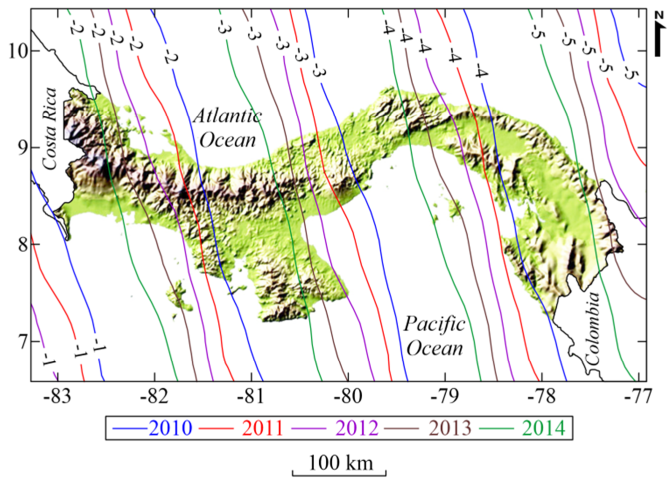

Figure 3. Variability of magnetic declination between 2010 and 2014.

The identification of these zones of magnetic declination variations can justify the aim to amplify the period to determinate all variation of the magnetic field and its impact on Cartography, Geophysics and Ecology. In near surface magnetic prospection, the knowledge of these parameters can play an important role.

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