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Testing Geomagnetic Reference Field models for 1990-2000 with data from the Trelew Geomagnetic Observatory, Argentina

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RESUMEN

En los relevamientos magnéticos realizados sobre la superficie de la Tierra se utiliza el Campo Geomagnético Internacional de Referencia (IGRF) para sustraer la contribución del campo principal de la Tierra. Cada cinco años se publica un nuevo modelo de IGRF y la variación secular del período previo debe ser actualizada, generándose el denominado modelo DGRF.

Una vez que el DGRF es publicado, las anomalías magnéticas calculadas previamente deben ser recalculadas. La actualización de las anomalías podría ser particularmente importante para relevamientos magnéticos regionales o para compilaciones de datos magnéticos adquiridos en diferentes épocas.

En este trabajo se muestra la importancia de esta corrección, particularmente para el periodo 1995-2000, en el cual la diferencia DGRF-IGRF es llamativamente apreciable. Se documenta la validez de la corrección utilizando datos del Observatorio Geomagnético Permanente de Trelew, Argentina.

PALABRAS CLAVE: IGRF, variación secular, Observatorio Trelew (Argentina).

ABSTRACT

Every five years a new International Geomagnetic Reference Field (IGRF) model is released and the secular variation for the previous period is updated, producing the definitive DGRF model. Once a DGRF is released, the previously calculated magnetic anomalies are updated. We show the importance of this correction for the 1995-2000 period, in which the DGRF-IGRF difference is anomalously large. We document the validity of the correction by using data from the permanent geomagnetic Observatory of Trelew, Argentina.

KEY WORDS: IGRF, secular variation, Trelew observatory (Argentina).

INTRODUCTION

The International Geomagnetic Reference Field (IGRF) is a model of the Earth's internal magnetic field defined by the International Association of Geomagnetism and Aeronomy (IAGA, 2000). It is constituted by a set of coefficients representing the main field at a particular epoch. The IGRF model is released every 5 years. Once the IGRF is updated using new data, it is called a Definitive Geomagnetic Reference Field (DGRF). For dates between epochs, secular variation coefficient values are given by linear interpolation. For five years after the most recent epoch, there is a linear secular variation model for forward extrapolation.

Each model is defined by a set of spherical harmonic coefficients, $g_n^m h_n^m$ called Gauss coefficients in a truncated series expansion up to 10th degree of a geomagnetic potential function of internal origin (Chapman and Bartels, 1940; Merrill *et al.*, 1996; Parkinson, 1983):

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

where a is the mean radius of the Earth and r, φ, θ are the spherical coordinates. The $P_n^m(\cos\theta)$ are the associated Schmidt-modified Legendre polynomials of degree n and order m given by

$$P_n^m(\cos\theta) = \left\{E_m \ \frac{(n-m)!}{(n+m)!}\right\}^{1/2}$$

$$sen^m\theta \, \frac{d^m P_n(\cos\theta)}{d\left(\cos\theta\right)^m} \qquad with: \ E_m = \begin{cases} 1 & for \ \ m \neq 0 \\ 2 & for \ \ m = 0 \end{cases} \tag{2}$$

The temporal dependence of the Gauss coefficients is:

$$g_n^m(t) = g_n^m(T_0) + (t - T_0)\dot{g}_n^m(T_0) \quad ;$$

$$h_n^m(t) = h_n^m(T_0) + (t - T_0)\dot{h}_n^m(T_0), \quad (3)$$

where $\dot{g}_n^m(T_0)$ and $\dot{h}_n^m(T_0)$ represent the secular variation for the Gauss coefficients , the first time derivative of $g_n^m(T_0)$ and $h_n^m(T_0)$, T_0 is the epoch of the main-field model, and t is the year for which model values are required ($T_0 \le t \le T_0 + 5$) (Mandea and Macmillan, 2000).

The secular variation is approximately continuous and smooth, although some types of short term variations, such as jerks, occasionally occur. A detailed description of the geomagnetic field time variations is given by Courtillot and Le Mouël (1988).

The IGRF predictive model for the secular variation is truncated at n =8 because a higher order would involve larger uncertainties (Lowes, 2000) and the high-degree coefficients in the IGRF are not well determined (Xu, 2000). Lowes (2000) observed that the n=7 and 8 terms contribute about 5 nT/yr to the secular variation and considered that by using these coefficients we are adding more errors than when we make those coefficients zero, i.e. truncate the models at n=6. He affirms that, although the satellite data can reduce the errors of the n=7 and 8 coefficients, there is still the problem of extrapolation into the future due to the secular acceleration. In general, the secular variation models allow exclusively extrapolation/interpolation of the main-field model and they are not necessarily good models of the real secular variation.

Comparisons of geomagnetic observatory data with IGRF models permits evaluating the goodness of fit of IGRF, and local crustal anomaly effects or departures from the smoothed regional/global IGRF data (Urrutia and Campos, 1993). Crustal anomalies in Mexico have been also investigated by studying the IGRF90 model and regional magnetic anomaly data (Campos *et al*., 1994).

Large areas of the oceans at low latitudes and in the southern hemisphere lack permanent observatory data although satellite magnetometers have been successful in providing complete global coverage. For the 1995-2000 period there has been little or no satellite coverage, and a good approximation of the International Geomagnetic Reference Field cannot be guaranteed in those areas (Golovkov *et al*., 2000).

THE TRELEW MAGNETIC OBSERVATORY

The Observatory of Trelew (TRW) is located at 43° 16.1' S, -65° 22.9' W and +15m above mean sea level. It employs magnetic instruments of different generations. The oldest generation instrument has been active from September 1957 to the present, producing a permanent analogue magnetogram of three elements of the geomagnetic field as a function of time: declination (D), vertical (Z) and horizontal (H) components. A quartz horizontal magnetometer for D and H and a balance meter of zero for Z are used to define the baseline of these records.

An absolute instrument, the theodolite fluxgate magnetometer, has been measuring the absolute values of D and I since 1993 to the present. These measurements are used for the evaluation of the base line for the digital variometers.

A digital variometer was installed in 1993 to record D, the inclination (I), and the total intensity (F) of the magnetic field. During the year 2000 a second digital variometer was installed.

All digital instruments were developed at the Royal Meteorological Institute of Belgium. Since July 2001 the magnetic Observatory of Trelew is part of the International net INTERMAGNET whose World Data Center is located in Edinburgh and collects digital data.

The Trelew Magnetic Observatory is located beneath the southern focus of the ionospheric current system. It is affected by the South Atlantic magnetic anomaly where the absolute total intensity field values are low.

Any extended geomagnetic time series contains perturbed and calm periods. The calm periods are especially required for studies of the Earth's internal geomagnetic field. These periods are selected by the joint analysis of worldwide observations, rendering a list of magnetically quiet days.

In this paper we consider the values of F for quiet days at the Trelew Observatory. To avoid enhanced variations produced by solar activity we work with the nocturnal values of F (Reference Nocturnal Level). They are shown in Figure 1 for the 1990-2000 period.

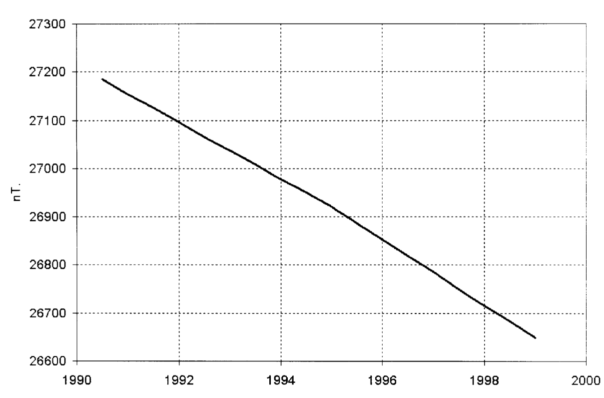

Fig. 1. Nocturnal values of F for quiet days at Trelew Observatory.

The objective is to calculate the magnetic anomaly (ΔF=total magnetic field – daily variation – IGRF) using both IGRF and DGRF models to analyze the differences.

SECULAR VARIATION IN 1990-2000 PERIOD

We calculated the average secular variation for 1990-1995 and 1995-2000 using both IGRF and DGRF models and the corresponding differences. Figure 2 shows two contour maps that display those differences.

The maps cover the southern part of South America as a regional framework for the Trelew location.

We can observe a significant change between the two maps: the differences are positive in the 1990-1995 period and they increase from NE to SW, whereas, on the other hand, for the 1995-2000 period they change from negative to positive increasing to the NE. The major difference displays a local minimum of –20 nT in the 5 nT contour interval map.

RESULTS

We calculated the total Intensity values using IGRF and DGRF models for the periods 1990-1995 and 1995-2000 (Figure 3) for the Trelew site. There are differences between the DGRF and IGRF results, and the differences are more important and increasing with time for the 1995-2000 period. Figure 4 displays the differences. We notice that they change sign after 1995.

We used the nocturnal F observations at Trelew to calculate the local magnetic anomaly for the two cases: a) using IGRF and b) using DGRF to subtract from the main field (Figure 5). The local magnetic anomaly using DGRF yields a practically time-independent anomaly of over 20 nT, which is a reasonable result. When using IGRF the anomaly varies between –60 and 60 nT indicating that IGRF is a not very representative in the area of the Trelew Geomagnetic Observatory.

CONCLUSIONS

This study displays and documents the DGRF - IGRF difference for the 1900-2000 time period in a regional framework near the Trelew Observatory location. The results (Figure 2 and 5) indicate that the secular variation predicted by the IGRF model was notably erroneous in this region for the second half of the decade.

Despite the fact that these results could only be obtained after the release of IGRF 2000, after the correction was available worldwide, we consider that it is nevertheless important to call attention to the anomalous behavior of IGRF 1995,

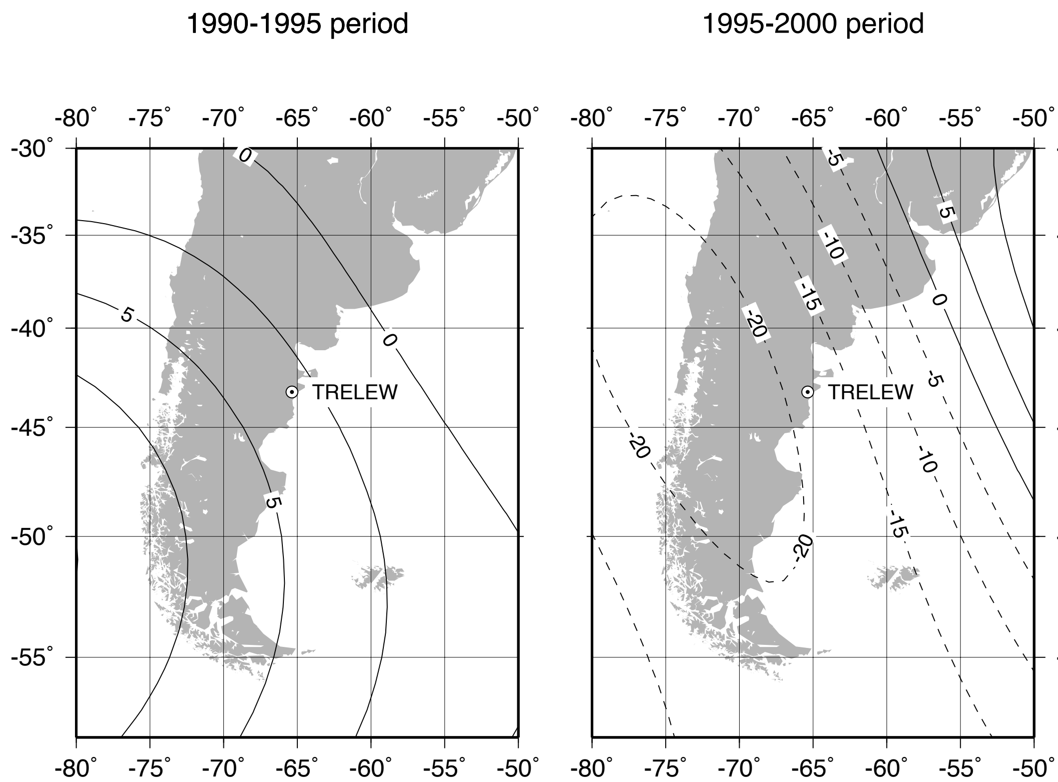

Fig. 2. Difference in secular variation between IGRF and DGRD models in the 1990-1995 and 1995-2000 period.

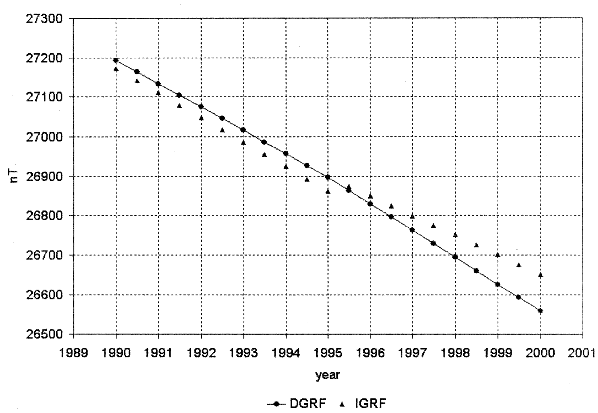

Fig. 3. Geomagnetic reference field using DGRF and IGRF models at Trelew Observatory.

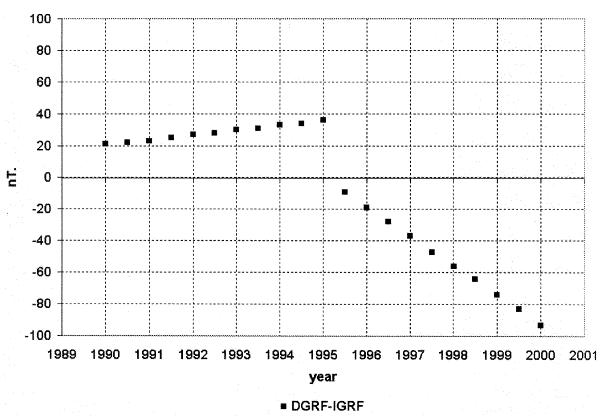

Fig. 4. Differences between DGRF and IGRF (DGRF - IGRF) for F at Trelew Observatory.

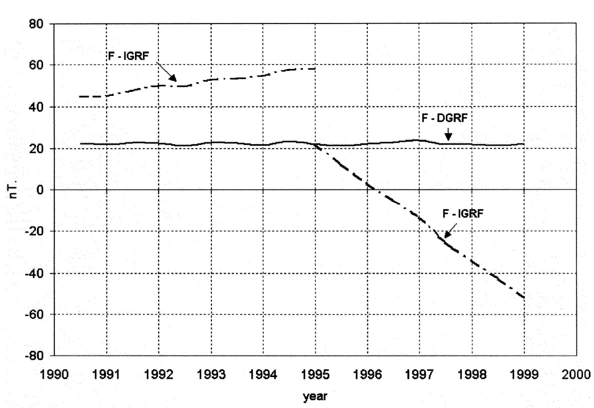

Fig. 5. The magnetic anomaly at Trelew Observatory using the IGRFs and DGRFs models.

for the case of magnetic anomaly compilations involving surveys that were performed and reduced in different epochs. The magnetic anomalies need to be recalculated to avoid abnormal disparity between surveys. This is true for the general case, but is particularly important for the 1995 2000 period.

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