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THE NORMAL GEOMAGNETIC FIELD AND THE I.G.R.F. OVER ALBANIA

Abstract. For the epochs 1942.0, 1960.0, 1990.4 the *normal geomagnetic field (N.G.F.) in the form* of a first order polynomial in latitude and longitude, is *computed and its mean secular variation is found.* The field secular variation is also computed according to I.G.R.F.. *The N.G.F. and I.G.R.F. over Albania* are compared.

INTRODUCTION

The earliest geomagnetic observations over Albania were carried out in 1942, within the framework of Europe's magnetic declination Atlas for the 1944.5 epoch published by R. Bock.

Later on, in 1961, an expedition from the Potsdam Geomagnetic Institute performed geomagnetic surveying over part of Albania.

Finally, for the Albanian magnetometric network, an expedition by Tirana Geophysics Enterprise performed geomagnetic surveying throughout Albania for the 1990.4 epoch.

Using measurements of the three epochs (1942.0, 1961.0, 1990.4), the normal geomagnetic field (N.G.F.) and its mean secular variation is computed and described. Then N.G.F. is compared with the International Geomagnetic Field (I.G.R.F.) over Albania.

THE N.G.F.

On a limited middle-latitude area, sufficiently restricted to be considered flat, every element E of the geomagnetic field (H, Z, D, I or total field T) can be approximated by a second-order polynomial of the form

$$E_{normal}=E_0+M\cdot\Delta\varphi+N\cdot\Delta\lambda+O\cdot(\Delta\varphi)^2+P\cdot(\Delta\lambda)^2+Q\cdot\Delta\varphi\cdot\Delta\lambda, \qquad (1)$$

where $\Delta\varphi$, $\Delta\lambda$ are latitude and longitude differences with respect to a reference point, chosen in order to be near the centre of the area (e.g. Demetrescu and Anghel, 1970).

Preliminary calculations show that since Albania is small and with few data, the errors in the second-order coefficient determinations (O, P, Q) are larger than the coefficient values. For this reason we took into consideration only the first order terms:

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$$E_{normal}=E_0+M\cdot\Delta\varphi+N\cdot\Delta\lambda \tag{2}$$

From measured field values, E_0, M, N coefficients were determined by the least squares method. Using this algorithm (e.g. Press et al., 1987) we computed the coefficient values and the associated estimated errors. We excluded the measuring points where differences r_i between normal field and observed field are

$$r_i>2\cdot\sigma \quad \left(\sigma=\sqrt{\frac{\sum_{i=1}^{N} r_i}{N-3}}\,,\quad N=\text{number of measuring points}\right). \tag{3}$$

"Tirana 1" station ($\varphi=48.626°$, $\lambda=19.876°$) was selected as reference point.

1942.0 Epoch

From the measurement of D, H, I elements carried out at 65 points, in 1942, H. Bolz (1963) calculated the N.G.F. for this epoch:

$$\begin{aligned}
D_{1942.0}&=-1.478+0.09\cdot\Delta\varphi+0.31\cdot\Delta\lambda,\\
H_{1942.0}&=24056\,nT-537.3\cdot\Delta\varphi+43.9\cdot\Delta\lambda,\\
Z_{1942.0}&=37332\,nT+671.5\cdot\Delta\varphi+95.3\cdot\Delta\lambda,
\end{aligned}\tag{4}$$

($\Delta\varphi$ and $\Delta\lambda$ units are in degrees).

Actually Bolz did not give the observed values for 1942 in his article, but the interpolated ones for the 1961 epoch, according to the secular variation given by M. Rossinger (Bolz, 1963) with the Niemek Observatory reference point.

Inverting Bolz's transformation, we recovered the observed values for the 1942.0 epoch. Using the above mentioned algorithm, we computed the N.G.F. for the 1942.0 epoch, which changes little from (4):

$$\begin{aligned}
D_{1942.0}&=(-1.496°\pm0.005)+(0.038\pm0.0072)\cdot\Delta\varphi+(0.327\pm0.015)\cdot\Delta\lambda,\\
H_{1942.0}&=(24064\pm3.5)\,nT+(-537.3\pm5.6)\cdot\Delta\varphi+(53.1\pm8.5)\cdot\Delta\lambda,\\
Z_{1942.0}&=(37281\pm11.8)\,nT+(670.7\pm18)\cdot\Delta\varphi+(94.5\pm29.6)\cdot\Delta\lambda.
\end{aligned}\tag{5}$$

1961.0 Epoch

For this epoch, the N.G.F. was determined with less accuracy, because few measurements (13 points) are available, and they are distributed over a limited area of Albania (Bolz, 1963). We have exluded three measurements, whose deviation from the trend is large, and which are not in a local anomaly area. In order to enlarge the measurement area, we considered Bolz's field values reduced from 1942 to 1961; for 1961.0, we computed the following N.G.F.:

$$\begin{aligned}
H_{1961.0}&=(24248.71\pm3.13)\,nT+(-565.86\pm5.36)\cdot\Delta\varphi+(42.23\pm8.18)\cdot\Delta\lambda,\\
Z_{1961.0}&=(38041.84\pm14.71)\,nT+(650.87\pm23.73)\cdot\Delta\varphi+(121.87\pm39.48)\cdot\Delta\lambda.
\end{aligned}\tag{6}$$

1990.4 Epoch

Making use of data from the 34 measuring stations, the N.G.F. for this epoch is computed. The measurement reduction due to daily variation was done using the variation recorded at Tirana 1 station (Frasheri et al., 1990).

At every station, the total field T was measured with a proton magnetometer MP—2 (1 nT accuracy), and the relative vertical component Z (refering to Tirana 1 station) with a Flux-Gate magnetometer (1 nT accuracy). In order to measure the vertical field component at Tirana 1 station, Helmholz's coils were used to compensate for the horizontal field component. The vertical component was found to be

$$Z_{Tirana\ 1}=38855\pm 70\ nT. \tag{7}$$

In this way, the Z absolute values were calculated at 34 points, with a systematic error of 70nT, which does not influence the M, N coefficients.

All measured values were reduced to sea-level considering only dipol field terms (Meloni et al., 1988).

Thus, the N.G.F. for the 1990.4 epoch was determined:

$$\begin{aligned} T_{1990.4}&=(45989.72\pm 3.93)\ nT+(321.79\pm 5.04)\cdot\Delta\varphi+(77.57\pm 10.1)\cdot\Delta\lambda, \\ Z_{1990.4}&=(38925.94\pm 11.16)\ nT+(738.42\pm 14.04)\cdot\Delta\varphi+(78.56\pm 25.42)\cdot\Delta\lambda. \end{aligned} \tag{8}$$

Fig. 1 presents the T isolines of N.G.F. (straight lines). In this figure, the local anomalies (T isodifferences between observed values and N.G.F. values) are also presented (curved lines).

I.G.R.F. OVER ALBANIA

As is well known, the geomagnetic field components on the Earth's surface can be expressed in spherical harmonic series (e.g. Parkinson, 1986):

$$\begin{aligned} X&=\sum_{n=1}^{N}\sum_{m=0}^{n}\left[(b_n^m+g_n^m)\cos(m\lambda)+(c_n^m+h_n^m)\sin(m\lambda)\right]\frac{d}{d\theta}P_n^m(\cos\theta), \\ Y&=\sum_{n=1}^{N}\sum_{m=0}^{n}\left[m(b_n^m+g_n^m)\sin(m\lambda)-m(c_n^m+h_n^m)\cos(m\lambda)\right]P_n^m(\cos\theta), \\ Z&=\sum_{n=1}^{N}\sum_{m=0}^{n}\left\{[nb_n^m-(n+1)g_n^m]\cos(m\lambda)+[mc_n^m-(n+1)h_n^m]\sin(m\lambda)\right\}P_n^m(\cos\theta), \end{aligned} \tag{9}$$

where $\theta=\frac{\pi}{2}-\varphi$ and $P_n^m(\cos\theta)$ are the Schmidt quasi-normalised associated Legendre functions.

Gauss coefficients b_n^m, c_n^m represent the contribution from field sources outside the Earth; these coefficients can be neglected because they are much smaller than g_n^m, h_n^m which represent the contribution of internal sources. In various spherical harmonic models compiled to determine the Gauss coefficients g_n^m, h_n^m, the number of terms N is chosen so as to include the contribution from the Earth's core, but excluding the ones from the Earth's crust (Quinn et al., 1986). Coefficient values for the 1945, 1950, 1955, 1960, 1965, 1970, 1975, 1980 epochs were taken from Barraclough (1988) with N=10, while the ones for the 1985 epoch (N=13) were taken from Quinn et al. (1986), adding to them the predicated secular variation in order to obtain the coefficient values for the 1990 epoch.

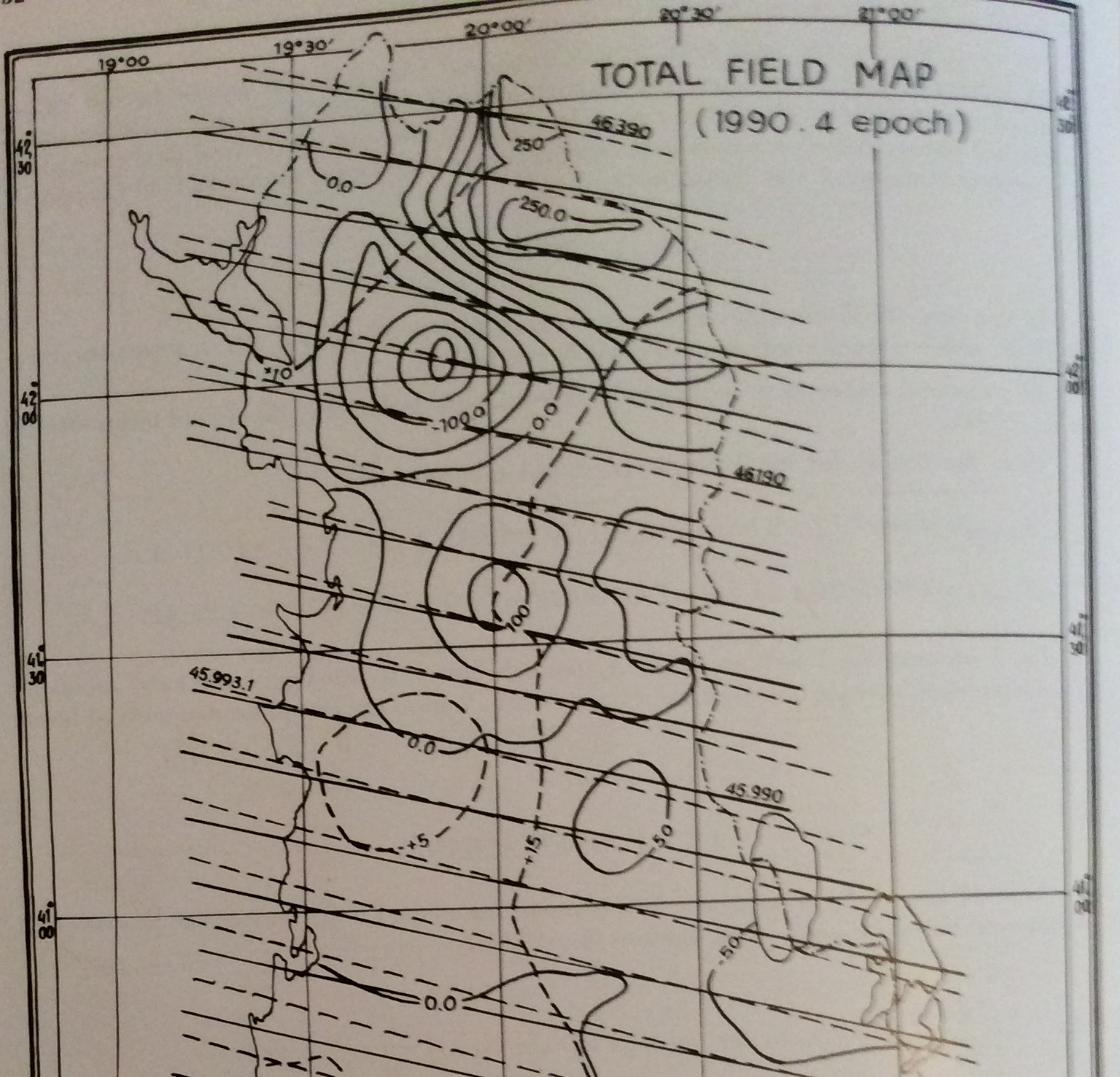

Fig. 1 — Total field maps (1990.4 epoch): N.G.F. isolines, I.G.R.F. isolines, local anomalies map, N.G.F. and I.G.R.F. differences map.

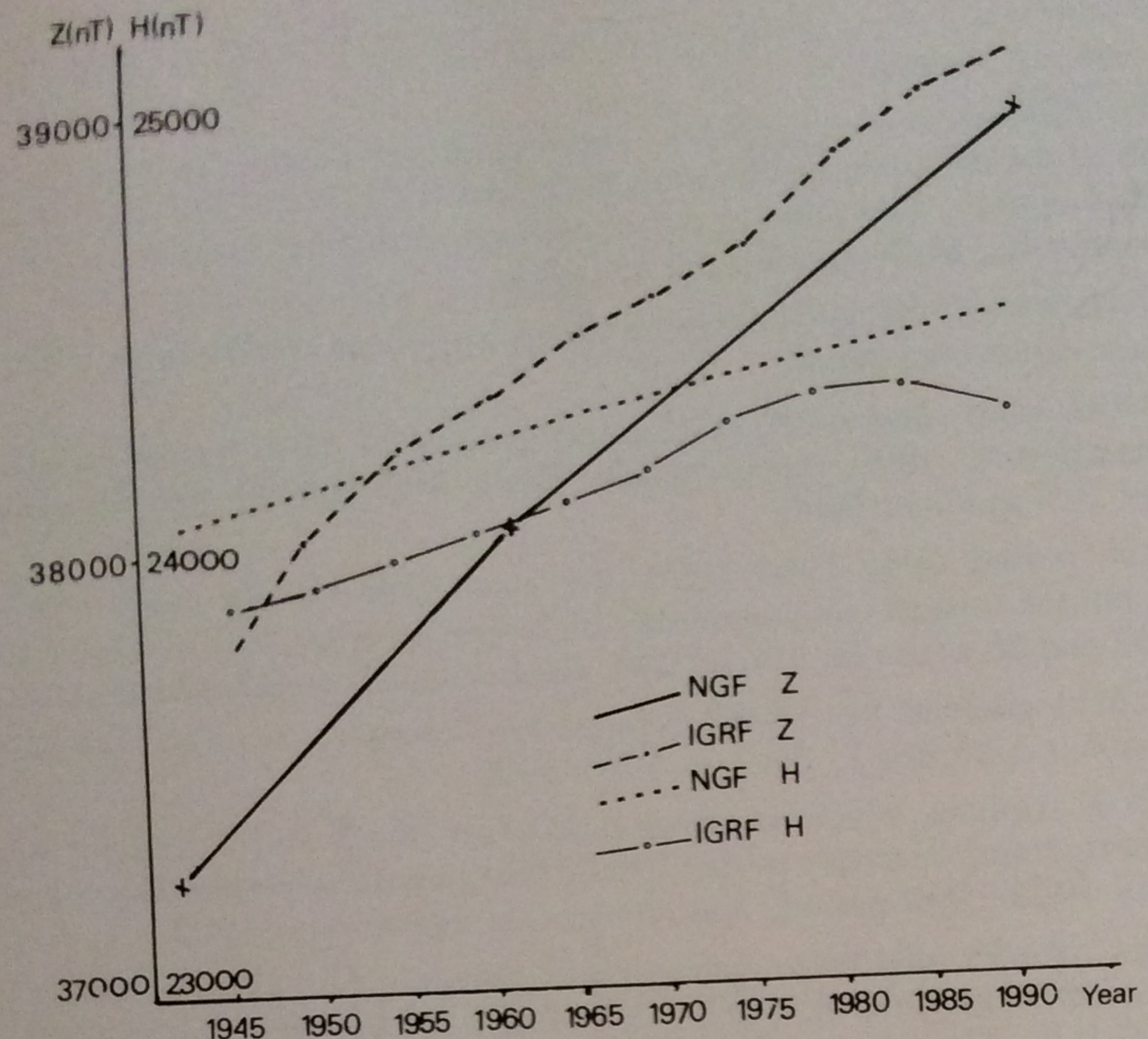

Fig. 2 – Secular variation of the mean over the Albanian territory field (Z and H component), according to N.G.F. (three epochs) and fitted I.G.R.F. (every 5 years).

The associated Legendre functions are generated by means of recurrence formulae (Press et al., 1987) and their derivates are expressed by the recurrence:

$$\frac{d}{d\,\theta}\,P_n^m = n.\,\frac{\cos\theta}{\sin\theta}P_n^m + (2n+3)\cdot P_{n+1}^m - P_{n+2}^m\,. \tag{10}$$

On the basis of this algorithm, the I.G.R.F. values at any point with φ, λ coordinates and at each epoch can be calculated. The I.G.R.F. T values on the points of the 1990.4 network (34 stations) were fitted by a first degree polynomial, as in eqn. (3). Polynomials were computed using I.G.R.F. values for the 1945, 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985 and 1990 epochs. For each epoch, the fit was very good (rms residual < 1.6 nT). Isolines of fitted I.G.R.F. (T component for 1990 epoch) are presented in Fig. 1 (straight dashed lines).

So as to compare the N.G.F. and I.G.R.F. secular variation, the time dependencies of coefficients E_0, M, and N were drawn (in Fig. 2 we have shown only E_0 for the Z and H components).

Differences between N.G.F. and I.G.R.F. were computed and plotted (curved dashed lines in Fig. 1). Seeing that these differences are of the same order as those among the various I.G.R.F. (Molina et al., 1985), the above mentioned values can't be considered to be the crustal component contained in the normal field (Molina et al., 1985).

CONCLUSIONS

Several problems had to be faced in order to determine the N.G.F. and its secular variation. Firstly, the measuring stations are not satisfactorily distributed. As Albania is rather extended in the north. the density of measuring stations should be greater in the W-E than in the S-N direction. In addition, a more dense measuring grid is necessary in the north-east area, where local anomalies are stronger.

Secondly, different measuring points were considered for the three epochs, and different field elements at the different epochs were measured (I, H, D at 1942.0; Z, H at 1961.0 and T, Z at 1990.4 epoch). The other components were computed making use of them, but the inaccuracy in the E_0, M, N coefficients increases.

Thirdly, the most of the 1961.0 epoch values are transferred from the 1942.0 epoch, so the values have some uncertainty.

Nevertheless, some conclusions can be drawn about the mean secular variation, especially for the E_0 coefficient, which represents the mean field and for the M coefficient, which represents the S-N gradient field.

During the period 1942-1961-1990, the mean field has increased (Fig. 2) for both components, but the vertical component has the largest increase, with average about 40 nT/Yr for 1942-1961 and 38 nT/Yr for 1961-1990. The horizontal component increased more slowly.

The S-N field gradient has small changes. For example, (for Z) $-1\ nT.deg.^{-1}\ Yr^{-1}$ in 1942-1961 and $+3\ nT.deg.^{-1}\ Yr^{-1}$ in 1961-1990.

For the W-E gradient, which has more inaccuracy, the T and Z gradient increase in the 1942-1961 period and decrease in the 1961-1990 period, while the H gradient decreases throughout the 1942-1990 period, and changes its sign around 1985.

Having few data for only three epochs (three points in Fig. 2), it is difficult to know the N.G.F. secular variation in detail, and it is even more difficult to compare it with the secular variation of I.G.R.F.. We may say that both fields have in general the same time dependence (Fig. 2). The curve showing the secular variation of the I.G.R.F. Z component is above the curve showing the secular variation of the N.G.F. Z component. The curve showing the secular variation of the I.G.R.F. H component is below the curve showing the secular variation of the N.G.F. H component. Thus, the T components ($T=\sqrt{Z^2+H^2}$) of both fields are quite equal at the reference point (as shown in Fig. 1).

Comparing N.G.F. with I.G.R.F., it seems that the spherical harmonic models of geomagnetic fields approch N.G.F. better at the actual epoch when the data used are more numerous and more accurate.

REFERENCES

Barraclough D.R.; 1988: *International geomagnetic reference field revision 1987*. Geophysical Journal, **93**, 187-189.

Bök H.; 1963: *Ergebnisse geomagnetischer Feldmessungen in Albanien*. Gerlands Beitrage zur Geophysik, **72**, 266-271.

Demetrescu C. and Anghel M.; 1970: *Some aspects of the calculation of the normal field in limited areas*. Revue Roumaine de geologie, geophysique et geography, **14**, 81-93.

Frashëri A., Bushati S. and Duka B.; 1990: *Luhatjet e fushes gjeomagnetike jane dukuri krahinore me karakteristika te njejta ne kuadrin Albanideve*. Buletini i shkencave gjeologjike, Submitted.

Meloni A., Arca S., Battelli O., Dominici G. and Marchetti A.; 1988: *Italian magnetic network at 1985.0*. Boll. Geod. Sc. Aff., **4**, 339-349.

Molina F., Meloni A., Battelli O. and De Santis A.; 1985: *Comparison of geomagnetic planetary reference fields over Italy*. Physics of the Earth and Planetary Interior, **37**, 35-45.

Parkinson W.D.; 1986: Vvedenie v geomagnetizm. Mir, Moskva, 107 pp.

Press W.H., Flannery B.P., Teukolsky S.A. and Vetterling W.T.; 1987: *Numerical recipes*. Cambridge university press, 509-513 pp.

Quinn J.M., Kerridge D.J. and Barraclough D.R.; 1986: *World magnetic charts for 1985.0 sperical harmonic models of the geomagnetic field and its secular variation*. Geophy. J.R. astr. Soc., **87**, 1143-1157.