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Assessment of IGRF Candidate Models over the Indian Region

B. P. SINGH[1], Mita RAJARAM[1], N. BASAVAIAH[1], V. K. NAGAR[2], and B. S. RAJAL[2]

[1]*Indian Institute of Geomagnetism, Colaba, Bombay 400 005, India*
[2]*Survey of India, Dehradun 248 001, India*

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The five candidate models for DGRF 1985 and IGRF 1990 developed by IZMIRAN, US/UK, USGS and two models of GSFC, are assessed over the Indian region, using observatory and repeat survey stations data for period 1985–1990. The results indicate that no model is dramatically better than the other. However, as depicted by error calculation, the DGRF model proposed by USGS for the year 1985 and the IGRF model of GSFC-S for the year 1990, are the best individual models over the Indian sub-continent. The large crustal anomalies seen over the subcontinent are probably responsible for large RMS errors.

1. Introduction

The candidate models of DGRF for the year 1985 and the IGRF for the year 1990, have been submitted by five groups: the model IZMIRAN by the Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN) in the USSR; the joint US/UK model by the U.S. Naval Oceanographic Office (USNOO) in the U.S.A. and the British Geological Survey (BGS) in the U.K.; the model USGS by U.S. Geological Survey (USGS) in the U.S.A.; and the two models, GSFC-S and GSFC-DS, by the Goddard Space Flight Center, U.S.A. All these models have been tested for selecting the best model for each epoch of 1985 and 1990 over the Indian region.

To conduct such test, we need data collected during the period 1985–1990 over the Indian region. The data from the permanent magnetic observatories and repeat survey stations conducted by Survey of India, form the representative values for this assessment. The data set comprises values from eight magnetic observatories and 139 repeat survey stations. Location of data points used are shown in Fig. 1. The data have a good spatial coverage ensuring its utility in making this test.

Further, India has had a unique history in the realm of geology and tectonics, with rock formations ranging in age from Archean to Neogene. This geologic-tectonic divergent nature has resulted in a magnetically complex region—an ideal region to test various models. With the geomagnetic equator passing through the southern tip and the northern limit attaining a dip of 45°, the Indian region covers both the equatorial and low latitude belts for testing the efficacy of various reference field models. The approach adopted to test the various proposed models is discussed below.

2. Data Analysis and Discussion

The test requires comparison of observed field values against computed values from

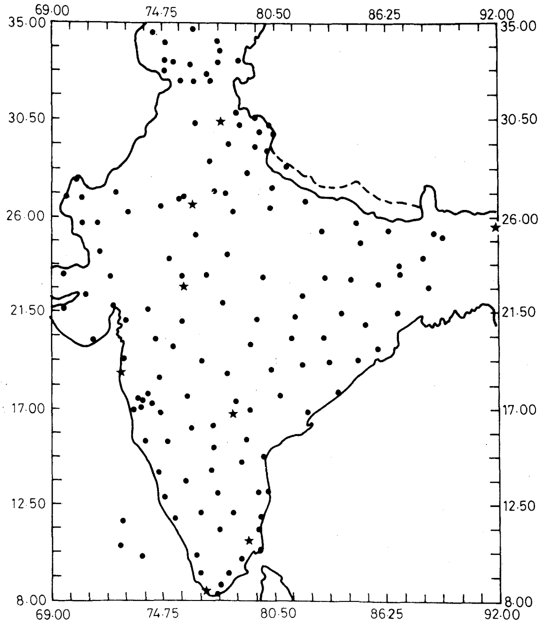

Fig. 1. Geographical distribution of permanent geomagnetic observatories (stars) and repeat survey stations (dots) over India, used in the present analysis.

different models for the epochs 1985 and 1990. We computed the differences of the observed and calculated H- and Z-components for the five models. For the present discussion, we designate such differences as "range". The observed differences were separated in groups with each group covering a range of 100 nT. Figure 2 shows the histogram of the number of points against range. The distribution for different models are shown by different symbols. There were a few points having a range more than 800 nT. These points have been excluded from the present analysis assuming that they may be due to measurement errors or local anomalies. As expected, almost all the models have the largest number of points with differences in the range 0–100 nT for both epochs. Also, the number of points gets drastically reduced when the difference exceeds 400 nT. It appears that these differences above 400 nT are attributed to local anomalies or measurement errors.

We then computed the RMS differences between the measurements (M_{obs}) and the corresponding calculated field values (M_{cal}) for all the models. The RMS errors are calculated using the relationship (BEVINGTON, 1969)

$$\text{RMS error} = \left\{ \sum_{i=1}^{N} \left(M_{i(\mathrm{obs})} - M_{i(\mathrm{cal})} \right)^2 / N \right\}^{1/2}$$

where N = total number of observations.

The RMS errors thus calculated are shown in Table 1. Two entries are made in the table:

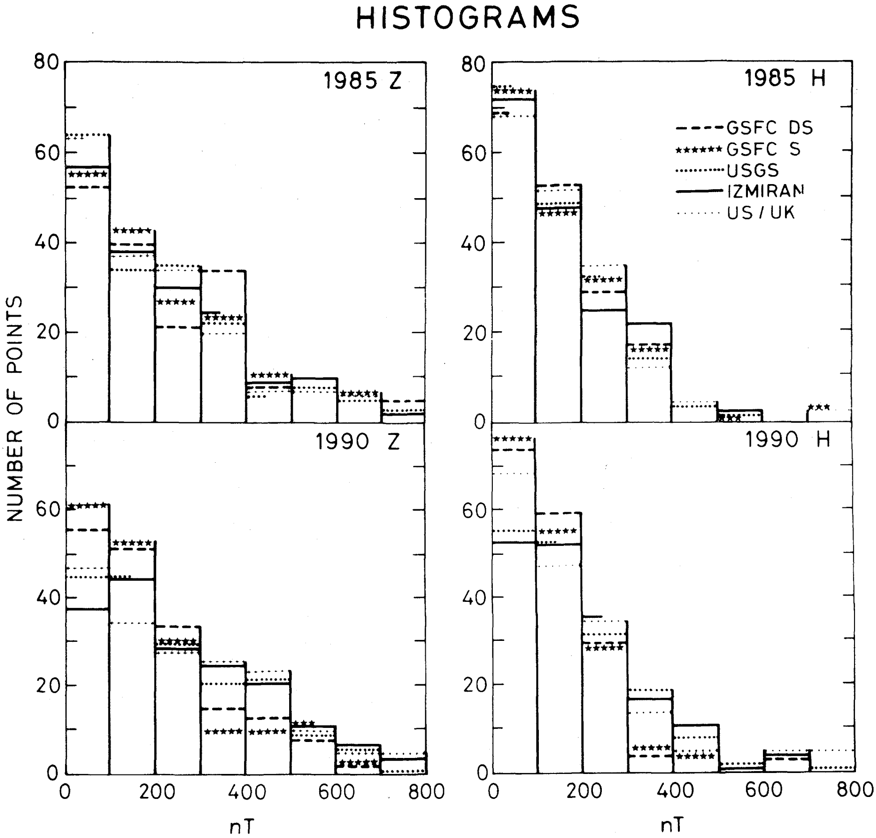

Fig. 2. A histogram showing the distribution of number of observation points of different ranges of H and Z increasing in steps of 100 nT for all five models. The two histograms on the top corresponds to 1985 epoch and those below are for 1990 epoch. The left and right plots are for Z and H respectively.

the top entry corresponds to the RMS value for the whole data set. As mentioned earlier, differences greater than 400 nT are suspect and therefore, we recalculated the RMS errors including only those data points whose differences from model values were less than 400 nT. The bottom entry in Table 1 corresponds to the RMS error obtained after removing the differences exceeding 400 nT. As is evident from Table 1, exclusion of points with ranges greater than 400 nT drastically reduces the RMS errors of all models. Also, no model is drastically better than the other. However, on the whole, the models USGS-85 for epoch 1985 and GSFC-90S for epoch 1990 appear to be better for the Indian region. For these two models, we then recomputed the RMS errors for ranges increasing in steps of 100 nT. Figure 3 gives a plot of the RMS error versus range for H and Z for these two models. An interesting aspect is that up to a range of 400 nT, the RMS errors for H and Z are very close for both the models. The RMS error in Z continues to rise with the range of deviation while in H a saturation limit is reached by range 500 nT. We further note that if we retain ranges up to 300 nT only, then all the RMS errors for H and Z for both the models are almost equal with a value of about 140 nT.

Table 1. The RMS errors, for H and Z components of the magnetic field, for all the five candidate models for epochs 1985 and 1990. The numbers on the top are computed using all data whereas those at the bottom are computed using only those points whose ranges are within 400 nT.

Model name	1985 H	1985 Z	1990 H	1990 Z
IZMIRAN	193.9 178.8	282.3 194.1	243.1 181.6	324.7 211.8
GSFC-DS	186.8 175.3	304.4 209.2	188.7 152.9	250.9 182.0
GSFC-S	200.1 173.8	285.3 202.9	167.3 153.9	247.9 161.0
US/UK	199.5 171.5	269.3 186.5	216.2 176.6	324.7 201.1
USGS	182.0 165.7	269.4 168.6	235.3 183.4	296.1 135.3

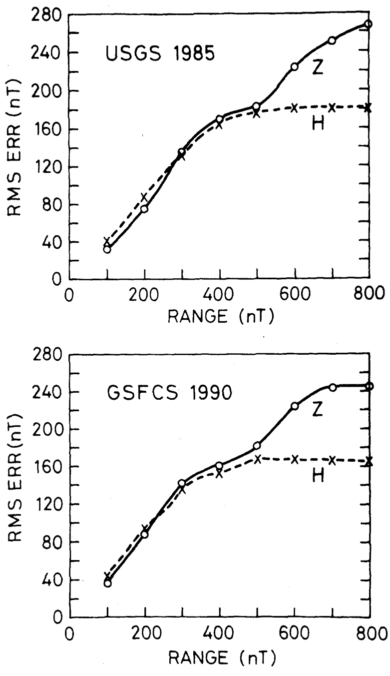

Fig. 3. The plot of RMS error calculated using points, whose difference, from the best two models fall in different ranges. The top diagram is for USGS-1985 and the bottom for GSFC-1990S. Full lines are for Z and dashed for H values.

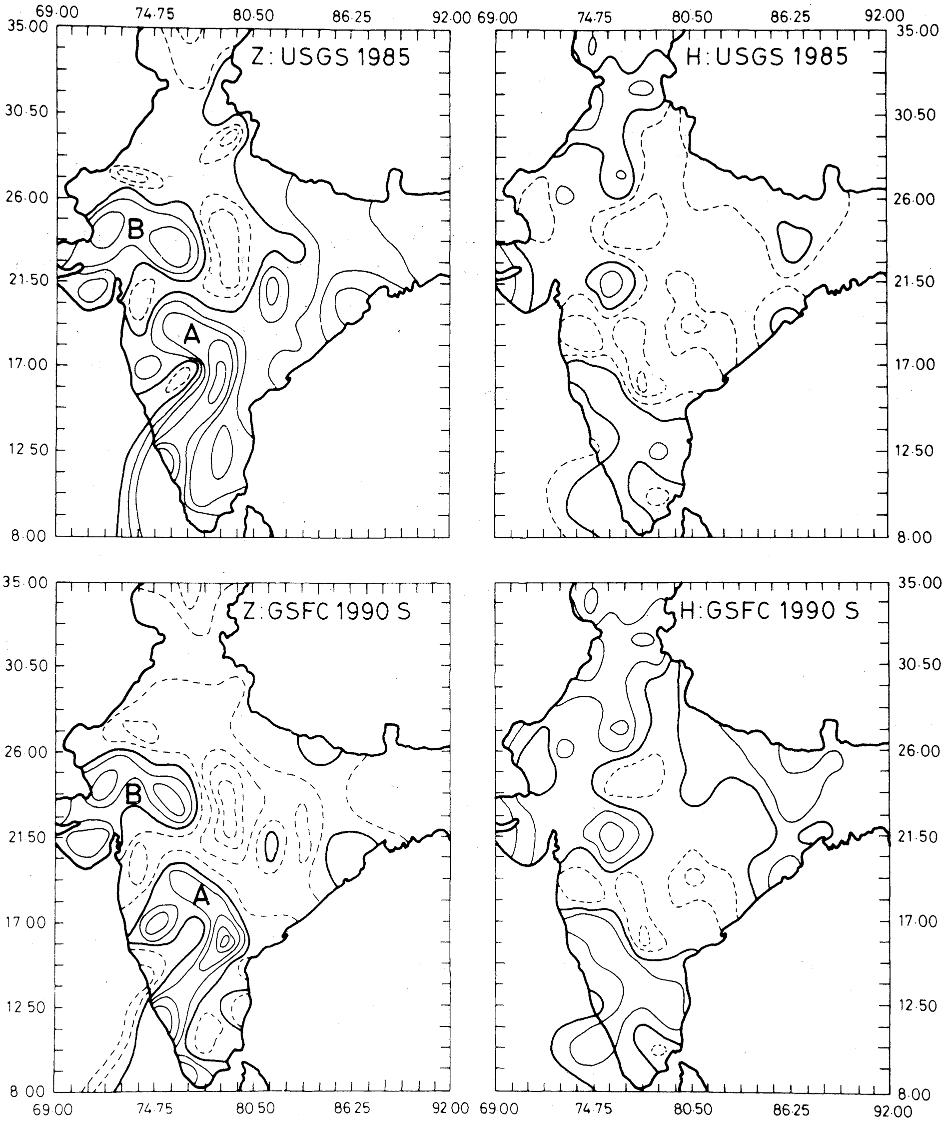

Fig. 4. Anomaly maps for Z and H obtained using USGS-1985 model (top) and GSFC model (bottom) over the Indian region. Contour interval is 100 nT. The solid and dashed contour lines represent the positive and negative values respectively.

Figure 4 is a difference map (anomaly) of observed and calculated field components from the two best models for H and Z components. The upper maps are for USGS-85 and the lower for GSFC-90S. As seen in Fig. 1, there are no observational points in the surrounding oceanic regions of India, except three observations which are taken in the Lakshadweep Islands. As a consequence, we have not extrapolated all these plots into the nearby oceanic region. The H

anomaly plots have smaller magnitudes than Z. Further, the H anomalies for the two models agree quite well. The gross features in Z anomalies are also reasonably comparable. In particular, the large positive anomalies present in the South with negative anomalies in the North, are seen in both the models for Z. These can be attributed to the presence of large crustal fields in these regions. These anomaly trends also have been observed in all the five models for both the epochs, substantiating our conjecture. This observation also, explains the large RMS errors in the Indian region.

Large positive deviation in Z-maps (A and B in Fig. 4) also coincide with large Z-anomalies in the Magsat derived maps (SINGH and RAJARAM, 1990). These are suggested to be associated with local crustal geology. Their wavelengths are such that a reference model with $n = 10$ can not incorporate them. Overall deviations in H are less than deviations in Z (Fig. 4). Nonetheless, the large anomaly regions here, too, coincide with anomalous regions of H in the Magsat maps, again suggesting a local crustal feature.

3. Conclusions

The assessment of the five candidate models for the DGRF 1985 and IGRF 1990 over the Indian region reveals that no model is better than the other. However, the USGS-85 and GSFC-90S models are marginally better suited over the Indian region for epochs 1985 and 1990 respectively. Lack of marine data around the Indian peninsula restricts the accuracy of the test. The fit in general is better for the H-component, at least in the low latitude and equatorial regions. Deviations, if any, are due to crustal geology of wavelength that can not be incorporated in a reference field model of $n = 10$.

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