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Evaluation of the Geomagnetic Reference Field Models in North-Western Pacific Region

by

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Abstract

The GSI (Geographical Survey Institute) model, the MSA (Maritime Safety Agency) model and the IGRF proposed by the Edinburgh resolution of IAGA are compared with data in 1980 at permanent observatories in the north-western Pacific region. As a result, evaluation indicates that the GSI model can be used only in the Japanese main islands (Hokkaido, Honshu, Shikoku and Kyushu) and that the MSA model is acceptable in the Japanese main islands and in its surrounding region. The IGRF in 1980 is acceptable in the whole region but it has discrepancies of about 100 nT~200 nT for F, H and Z and about 10 minutes for D from observed data in Japanese main islands. Since the difference between IGRF and observation is not more than about 100 nT during 1965–1980 in this region for the geomagnetic total intensity, a magnetic anomaly chart of total force based on the IGRF has accuracy of about 100 nT when the data employed are measured in this term.

1. Introduction

Based on the International Geomagnetic Reference Field model, Fujita and Kawamura (1984) presented a magnetic anomaly chart of the geomagnetic total intensity for the area of 120°-160°E and 15°-50°N (the north-western Pacific region) with maritime geomagnetic data measured in 1961-1979. Here, we will evaluate three geomagnetic field models including the IGRF, which are applied in the north-western Pacific region. The three are the model compiled by Geographical Survey Institute (the GSI model), the model by Hydrographic Department of Maritime Safety Agency (the MSA model) and the International Geomagnetic Reference Field (IGRF). This report is a companion paper of Fujita and Kawamura (1984).

The GSI model is based on results of land magnetic surveys in Japan conducted by GSI. This model represents values of three geomagnetic components (H, D and Z) with a quadratic expression of latitude and longitude and does not give their secular

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variations. GSI makes it every 10 years. The model employed here presents geomagnetic values at 1980.5.

The MSA model presents geomagnetic values and their secular variations for the three components (H, D and Z) and total intensity (F) with a cubic expression of latitude and longitude. This is made every 5 years using data observed at permanent observatories in and around the Japanese main islands (Hokkaido, Honshu, Shikoku and Kyushu). Details are described in Series of Magnetic Survey, No. 4 of Data Report of Hydrographic Observation (1983). The model employed here presents the values and their secular variation rates at 1980.0.

The IGRF gives coefficients of a spherical harmonic expression of the geomagnetic field. The IGRF is composed of three DGRFs (Definitive International Geomagnetic Reference Fields for 1965.0, 1970.0 and 1975.0) and PGRF (Provisional International Geomagnetic Field for 1980.0), and secular variation of the coefficients during 1980.0-1985.0. There were three proposed models for the IGRF from the groups in U.S. National Aeronautics and Space Administration [Langel, et al., 1982], in U.K. Institute of Geological Science [Barraclough, et al., 1982] and in U.S. Geological Survey [Peddie and Fabiano, 1982]. The IGRF employed in this paper, the third generation of the IGRF, was determined as weighted means of coefficients of the three proposed models at the Fourth Scientific Assembly of IAGA at Edinburgh [IAGA Working Group I–1, 1981; Peddie, 1982]. The coefficients up to the 14th degree are shown in Table 2 of Peddie's paper (1982).

The third generation of the IGRF is believed to represent the geomagnetic field better than the previous generations of the IGRF do. Since evaluation of the IGRF has not been executed in the north-western Pacific region [Xu, et al. (1985) evaluated the IGRF for 1975.0 only in and near China], it is necessary to evaluate the model with observed data when we apply it for scientific purpose, for example, to find magnetic anomalies in the maritime geomagnetic total intensity [Fujita and Kawamura, 1984]. As for other two models (GSI and MSA models), evaluation is also important before application of the models to an actual problem.

2. Evaluation

The three field models will be evaluated here using 11 observatories in and around the Japanese main islands. Observatories used are listed in Table 1. In the first part of this section, the absolute values calculated with the three models will be employed for evaluation. Since a local magnetic anomaly possibly introduces large difference between a calculated value and an observed value, it is doubtful whether large difference between the two values is always attributed to poor achievement of a model. On the other hand, a local anomaly of secular variation is not generally contained in the geomagnetic field because an anomalous field by a magnetized rock in the crust is

Table 1. List of Observatories Employed

Name	Symbol	Geographic latitude	Geographic longitude
Yuzhno-Sakhalinsk	YSS	46°57′N	142°43′E
Memambetsu	MMB	43 55	144 12
Vladivostok	VLA	43 41	132 10
Kakioka	KAK	36 12	140 11
Kanoya	KNY	31 25	130 53
Zo-Se	ZSC	31 06	121 11
Chichijima	CBI	27 06	142 11
Lunping	LNP	25 00	121 10
Honolulu	HON	21 19	202 00
Muntinlupa	MUT	14 23	121 10
Guam	GUA	13 35	144 52

generally very stable comparing with the main field. Therefore, the IGRF and the MSA model will be also evaluated employing secular variation rates offered by these models. (Unfortunately, the GSI model does not present the secular variation rate.)

2-1. Absolute values

Graphic representations of difference between model and observation for each permanent observatory are illustrated for H, D, Z, and F in Fig. 1. The epoch is 1980.0 for MSA and IGRF and 1980.5 for GSI. The observed value at 1980.0 is defined as an arithmetic mean of annual means in 1979 and in 1980. Characteristics of these differences are as follows:

(1) The GSI model, when it applied at MMB, KAK and KNY, is most suitable than other models as a whole; this is reasonable because this model is based on results of land magnetic surveys in the Japanese main islands. Therefore, this model is possibly useful as a base field for local magnetic anomalies within Japanese main islands.

(2) Difference between the values of the MSA model and the observed one is not so large in the Japanese main islands and in its surrounding area (all of rest observations except HON) for F. At HON, the value calculated from this model is very different from the observed one for F. This very large discrepancy can be regarded as an indication of inability of this model at HON for F. This model does not seem to be applicable at MUT, GUA and HON for H, D and Z as well.

(3) The IGRF is acceptable in the whole area concerned. However, discrepancies between calculated and observed values are generally about 100 nT~200 nT for F, H and Z and 10 minutes for D in the Japanese main islands (except for F of MMB). These discrepancies cannot be attributed to local magnetic anomalies at those observatories because the GSI and MSA models do not show large discrepancies.

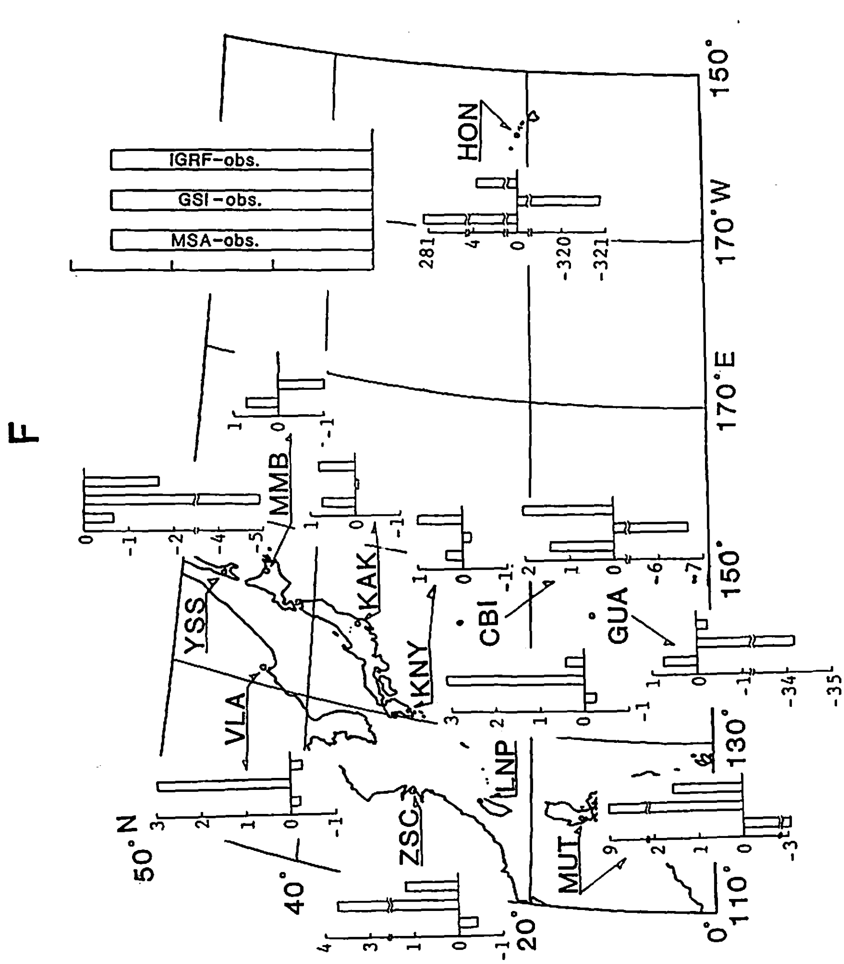


Fig. 1. Differences between geomagnetic values of model and those of observation at permanent observatories at the epoch of 1980.0 for MSA and IGRF and 1980.5 for GSI. Units of bar charts are 100 nT for F, H and Z and 10 minutes for D.

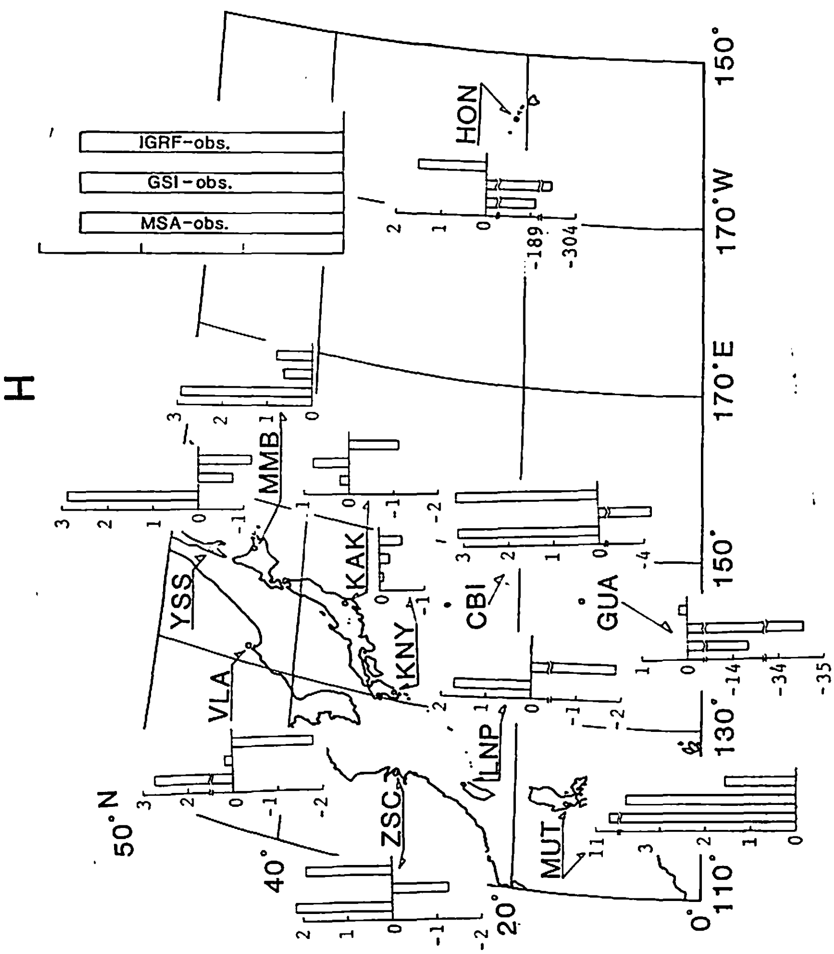
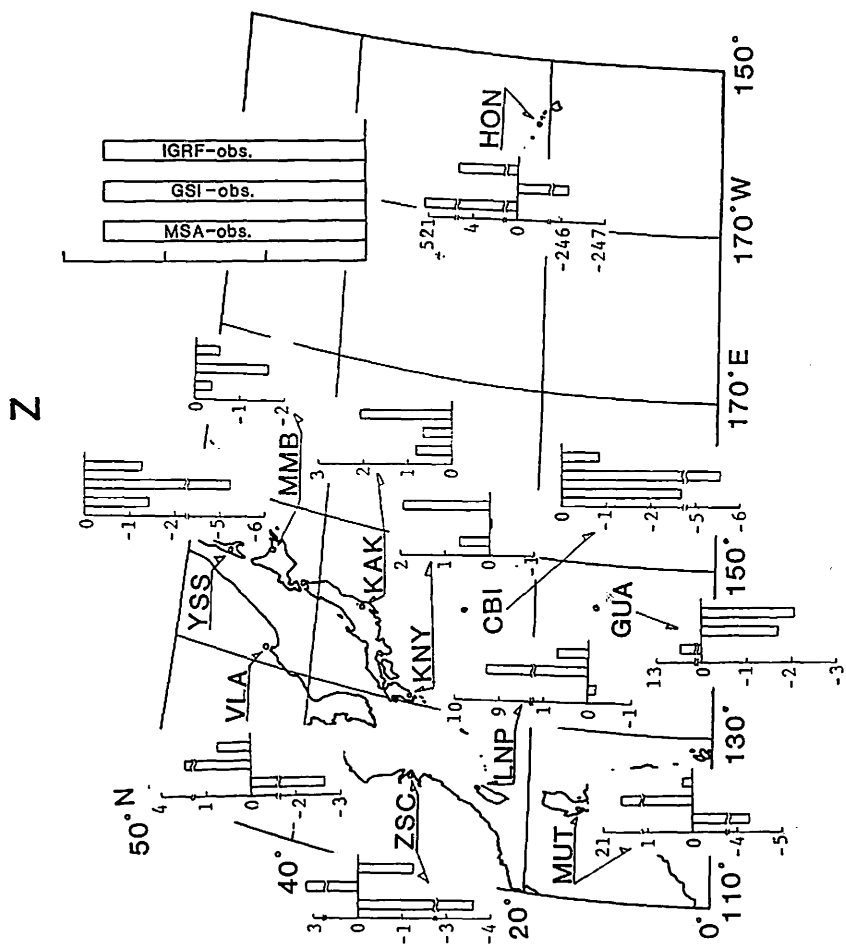


Fig. 1. (Continued)



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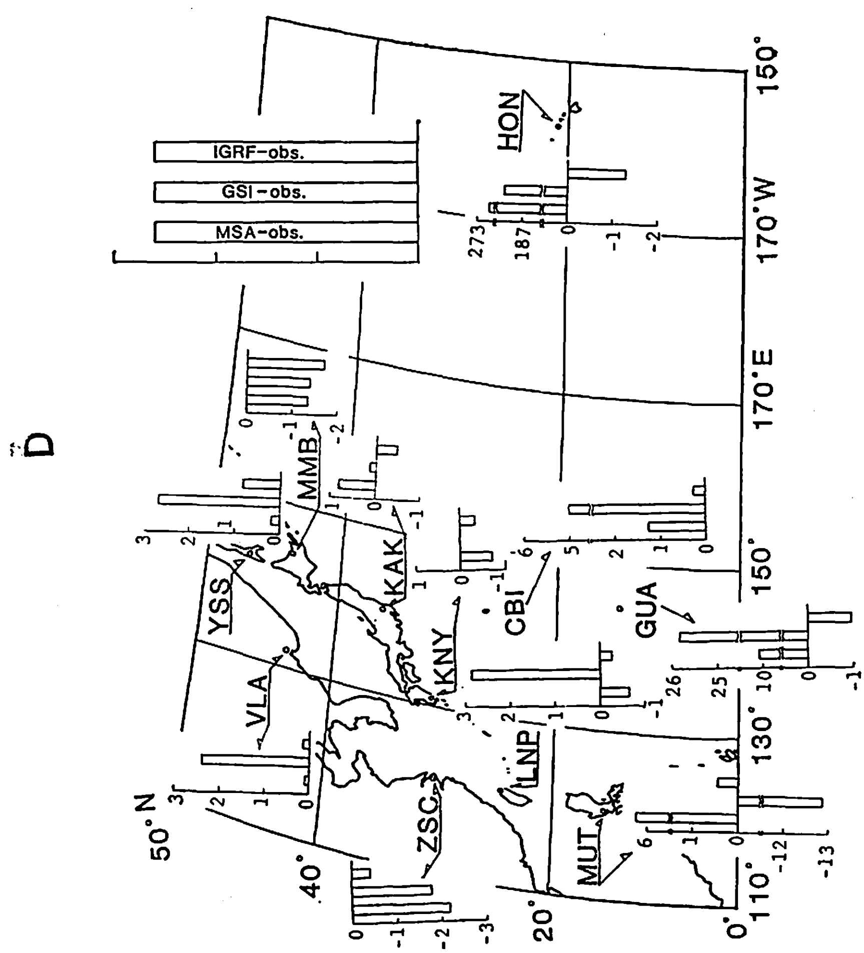

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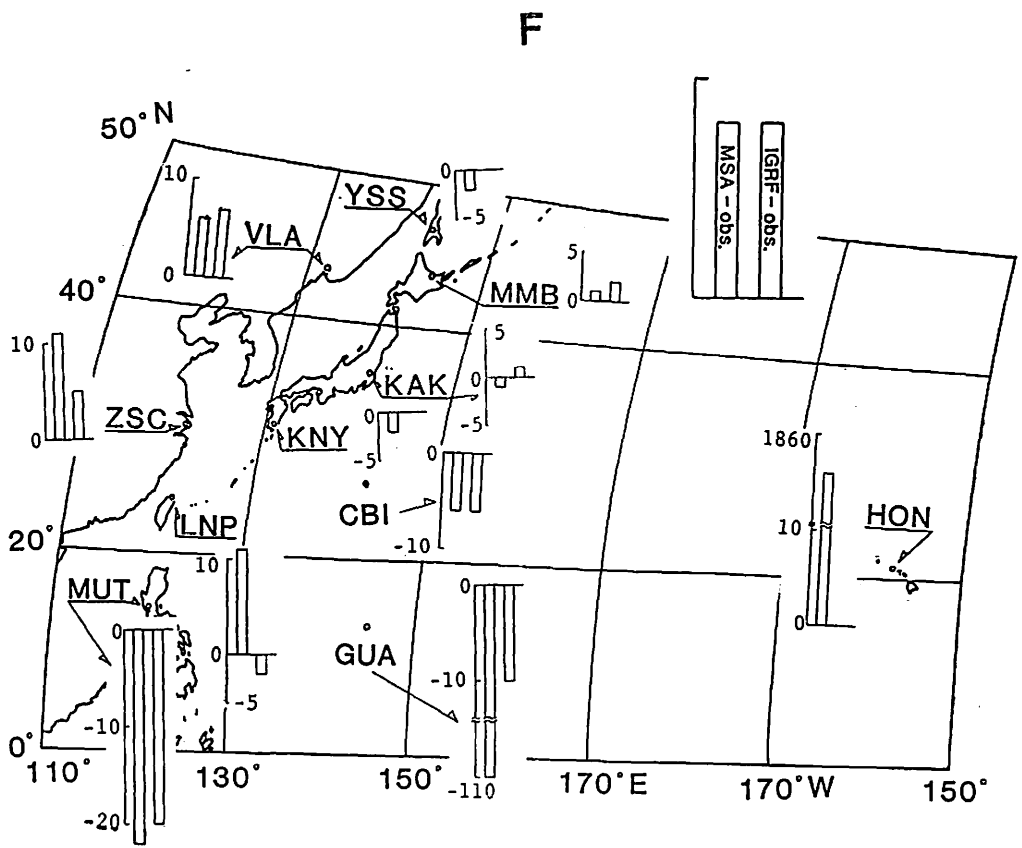
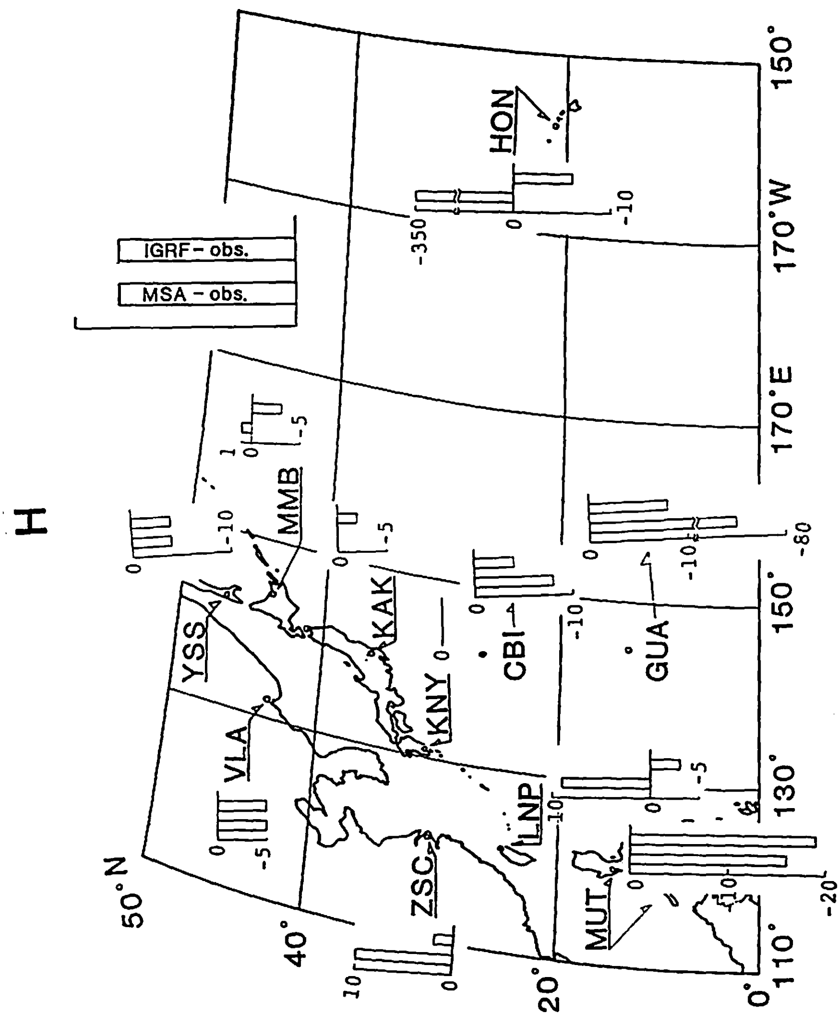


Fig. 2. Differences between geomagnetic secular variation rates derived from models (MSA and IGRF) and those observed at permanent observatories at the epoch of 1980.0. The observed variation rate is defined as a difference of an annual mean in 1980 from that in 1979. Units of bar charts are 1 nT/year for F, H and Z and 1 minute/year for D.



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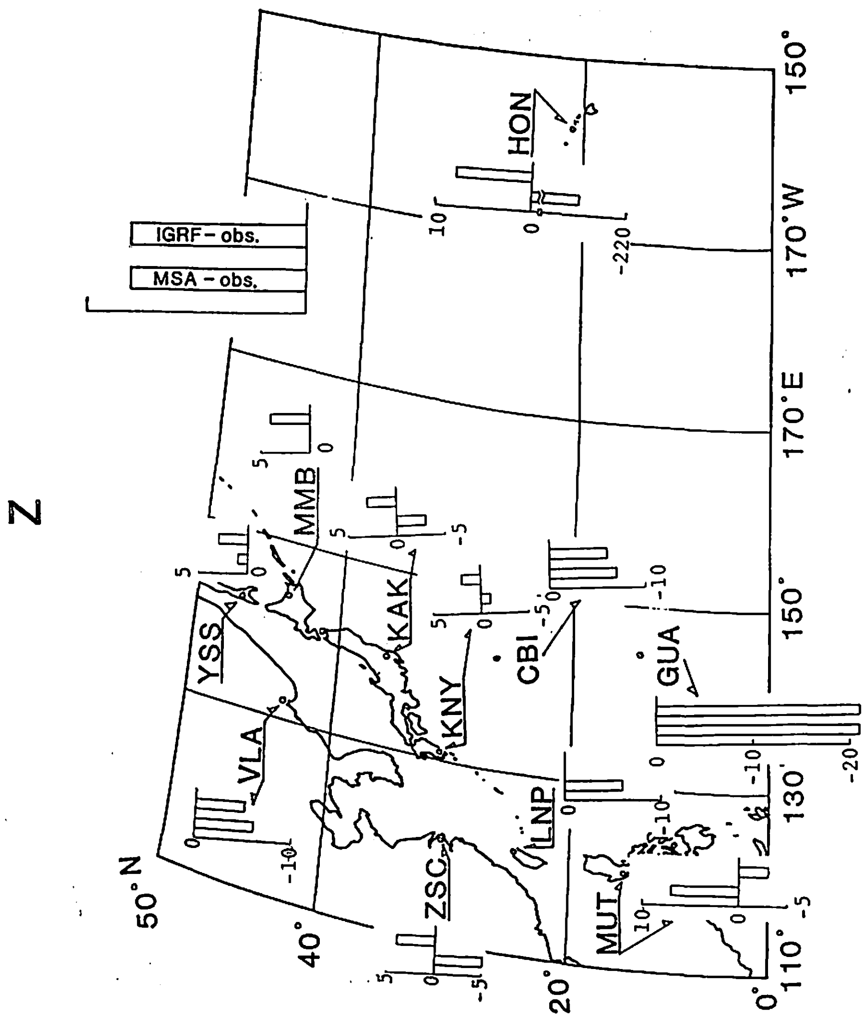

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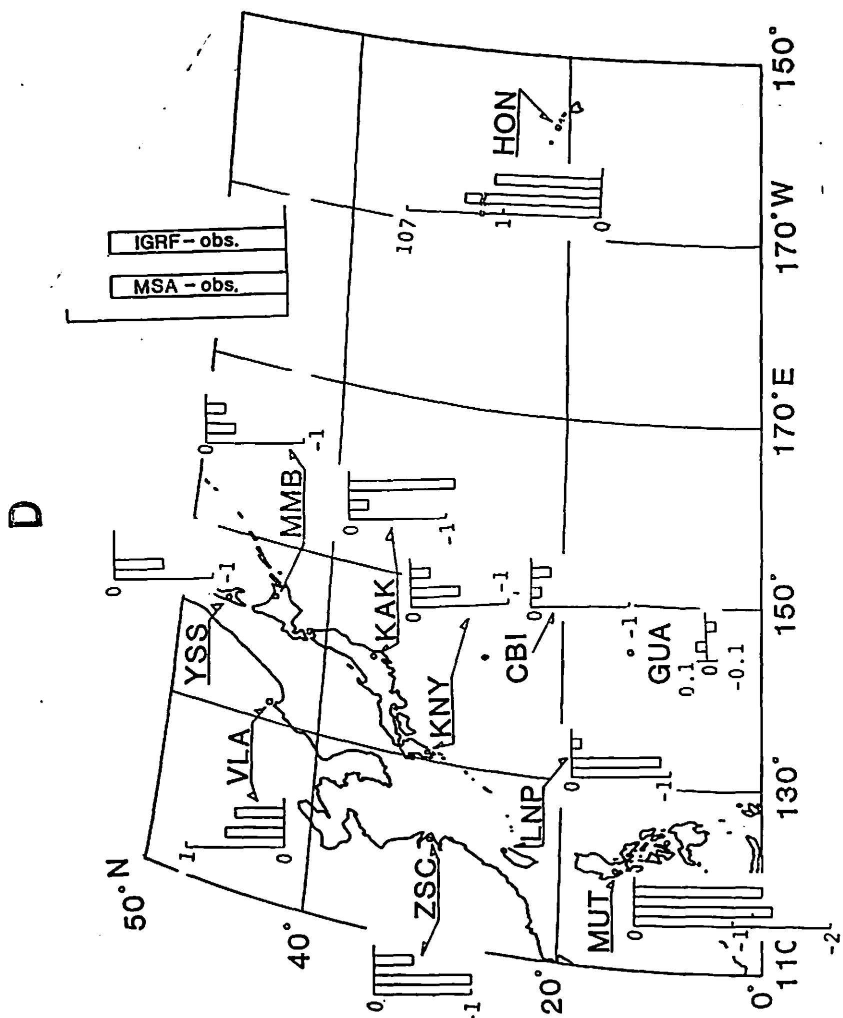

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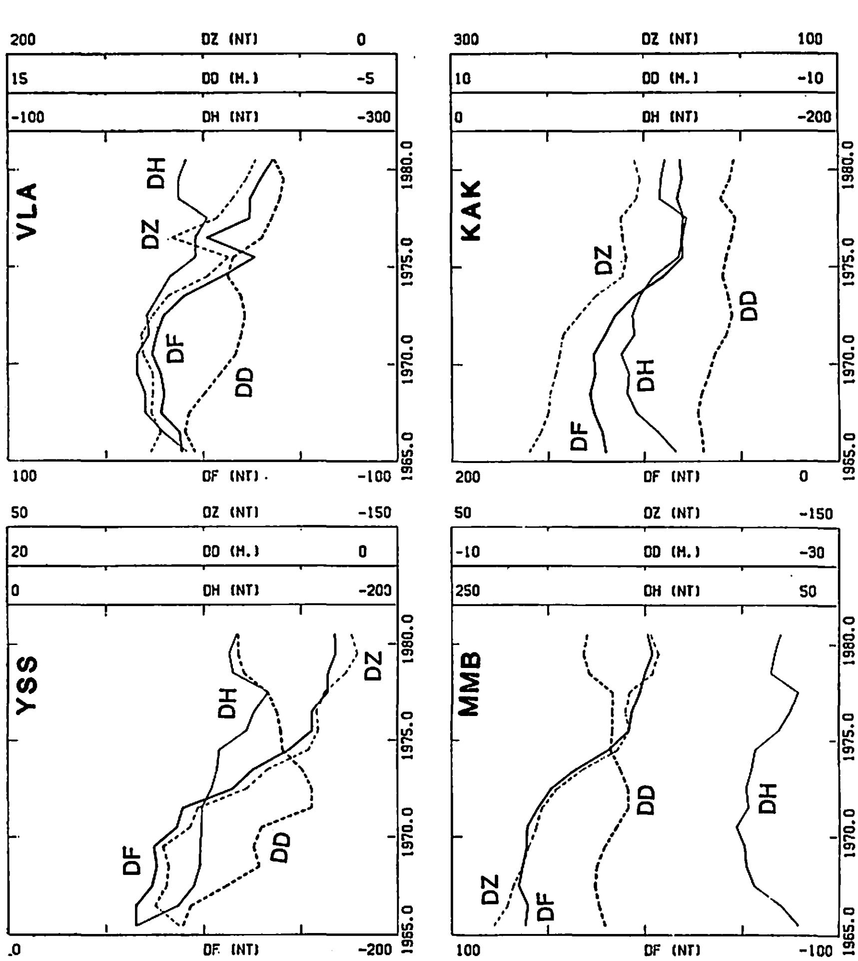

Fig. 3. Variations of the difference between geomagnetic values of IGRF and observation in 1965.5–1980.5. See the text for detail.

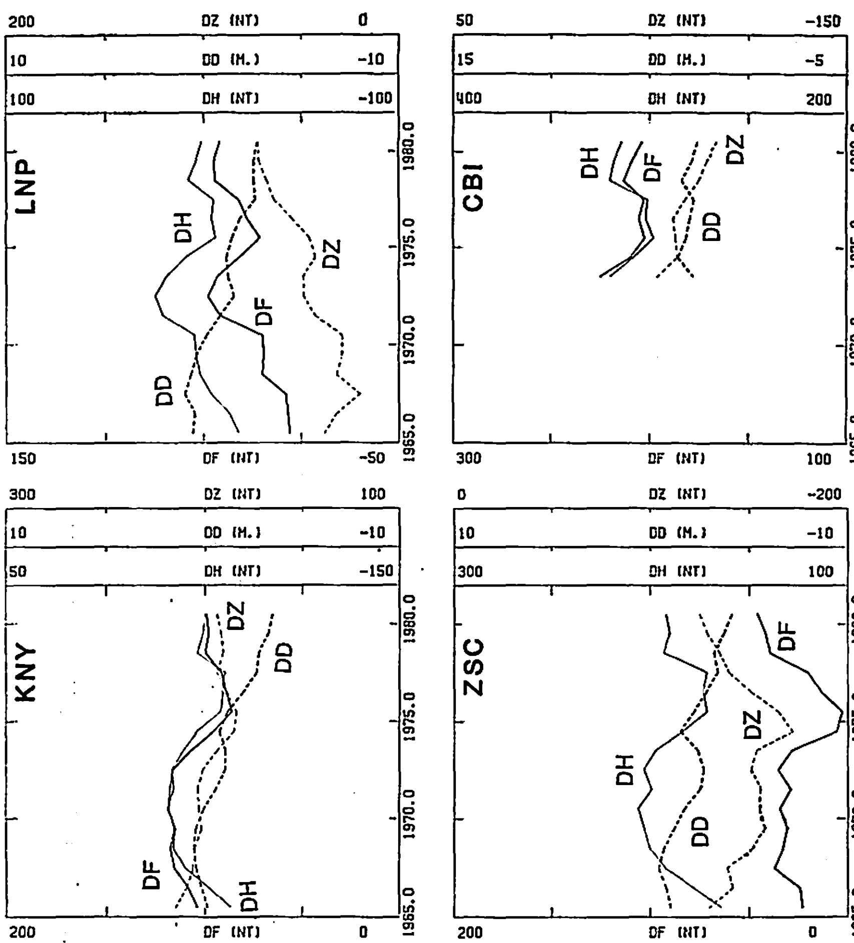

Fig. 3. (Continued)

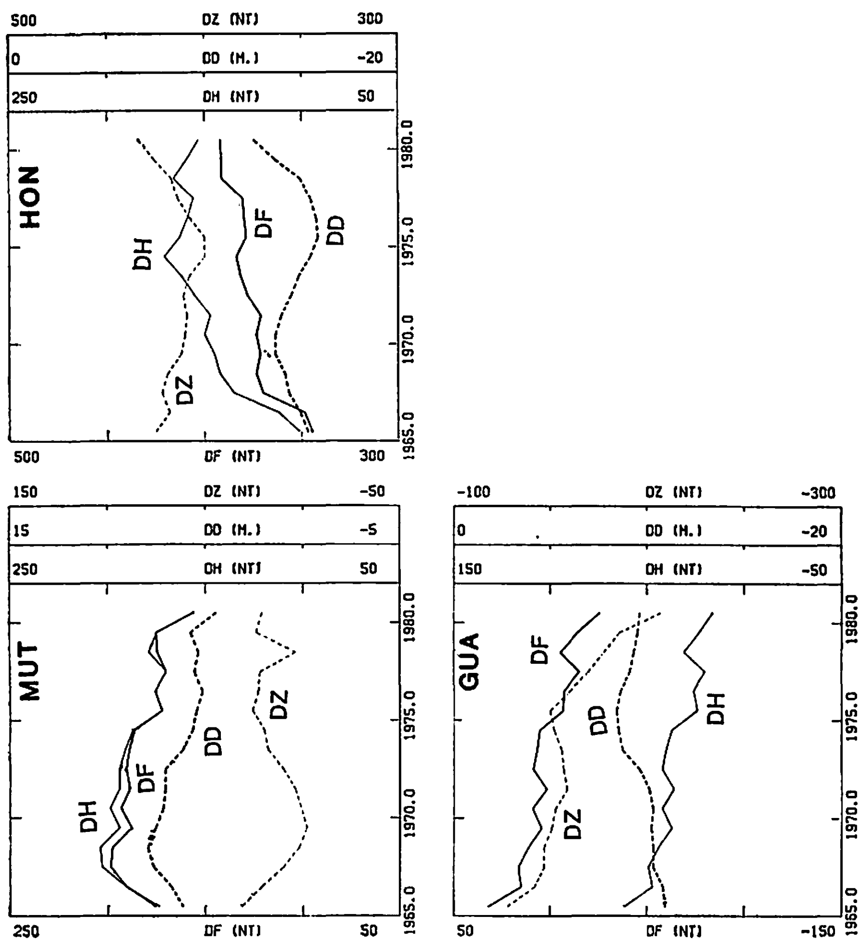

Fig. 3. (Continued)

It is noticeable that the IGRF has large discrepancy at HON as compared with those at other observatories for all components. This seems to be attributed to sparse distribution of magnetic observatories in the central Pacific region.

2-2. Secular variation rates

A secular variation rate observed at 1980.0 is defined as a difference of the annual mean value in 1980 from that in 1979. Discrepancy between MSA model and observation is not so large at all observatories except MUT, GUA and HON and so is for IGRF at all observatories.

2-3. The IGRF as a base field for magnetic anomalies

This model has DGRF's for 1965.0, 1970.0 and 1975.0 and PGRF for 1980.0. The geomagnetic total intensity of this model was used by Fujita and Kawamura (1984) as a base field for calculation of magnetic anomalies of maritime geomagnetic data measured in 1961–1979. (Most of all data were aquired in 1965–1979.) In this report let us consider differences between values based on the IGRF and observed ones in 1965–1980 at observatories in and around the Japanese main islands.

Fig. 3 presents variations of discrepancies of the IGRF (DF, DH, DD and DZ stand for the respective components). The IGRF at an intervening year is obtained with linear interpolation of the coefficients of neighboring DGRF's or PGRF. DF decreases with time at all observatories except LNP and HON. The largest difference between DF at 1965.5 and DF at 1980.5 is about 100 nT at YSS. Generally, this

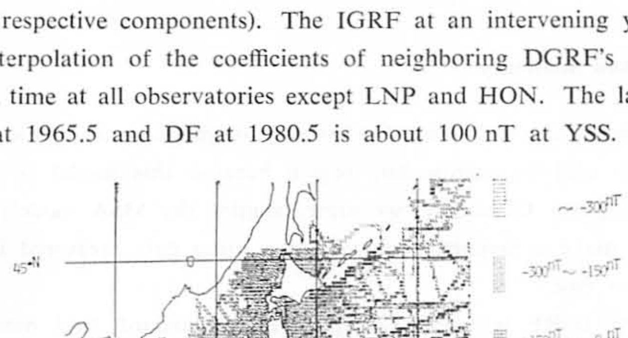

Fig. 4. A magnetic anomaly chart of maritime geomagnetic total intensity observed in 1961–1979 based on the IGRF mcdel. [A reproduction of Fig. 2 of Fujita and Kawamura (1984)].

difference is not larger than 50 nT for other observatories. We notice that variation in DF in 1970.5–1975.5 is as a whole larger than those in 1965.5–1970.5 and in 1975.5–1980.5 at YSS, MMB, VLA, KAK and KNY. This feature can be explained by the fact that the IGRF defined in a period of 5 years cannot precisely represent an actual change in geomagnetism with a period shorter than 5 years. F at these observatories decreasing in intensity before the years of 1970–1975 abruptly turned to increase after that (turning time depends on a site of an observatory).

The discussion on the characteristic feature of DF leads to the conclusion: when we applied the IGRF in the north-western Pacific region to derive magnetic anomalies of total intensity from data measured in 1965–1980, individual patterns in a magnetic anomaly may are meaningless if the contours of the map are drawn with an interval of less than 100 nT. The magnetic anomaly map presented in Fig. 4 is an example [a reproduction of Fig. 2 of Fujita and Kawamura (1984], which avoids presentation of the fictitious feature because the contours are drawn with an interval of 150 nT.

It is natural that DZ behaves in a similar manner to DF at the observatories far from the magnetic equator (YSS, MMB, VLA, KAK, KNY and LNP). Variation in DH is naturally similar to that in DF in the equatorial region (ZSC, MUT, GUA and HON). Ranges of variations in DH and in DZ are not larger than 50 nT as a whole and those in DD are also smaller than 5 minutes at all observatories.

3. Discussions and Summary

The MSA model can be a base field model for magnetic anomalies in the Japanese main islands and its surrounding region because this model is acceptable as a whole in this region. Of course, we must examine the MSA models for different epochs when we make a magnetic anomaly map using data measured in an interval of one decades or two.

Although the IGRF is widely accepted as a standard field model by many scientists in the world, it fails to reproduce the actual geomagnetic field with accuracy of several 10s nT in north-western Pacific region. This weak point is inevitable because density of magnetic observatories is large in Europe and in North America but small in the Pacific Ocean.

Summarizing results described in this paper, we have the followings:

(1) The GSI model seems to be the best model among three as a whole in the Japanese main islands but it is not acceptable in the region out of the Japanese main islands.

(2) The MSA model is acceptable in the Japanese main islands and its surrounding region. This model cannot be applied in a regoin far from Japan such as MUT, GUA and HON.

(3) The IGRF can be used in the whole area concerned. However, accuracy

of reproduction is 100 nT~200 nT (F, H and Z) and about 10 minutes (D) in the Japanese main islands. Thus, the accuracy is worst among the three there.

(4) A magnetic anomaly chart of the total intensity based on the IGRF has accuracy of about 100 nT when the total intensity is observed in 1965–1980 in the north-western Pacific region.

(5) The MSA model is a candidate for a base field for magnetic anomalies near Japan.

Acknowledgement

Annual mean values of ZSC, LNP, HON, MUT and GUA are obtained from the data book published by WDC-B for secular variation.

References

Barraclough, D. R., Hodder, B. M. and Malin, R. S. C. (1982): The IGS proposal for the new international geomagnetic reference field. J. Geomag. Geoelectr., **34**, 351–356.

Fujita, S. and Kawamura, M. (1984): Regional magnetic anomaly around the Japanese Islands revealed in maritime data. J. Geomag. Geoelectr., **36**, 483–486.

IAGA Working Group I-1 (1981): Analysis of the main field and secular variations, International Geomagnetic Reference Field 1980. IAGA News, No. 200, 100–102.

Langel, R. A., Estes, R. H. and Mead, G. D. (1982): Some new methods in geomagnetic field modelling applied to the 1960–1980 epoch. J. Geomag. Geoelectr., **42**, 327–349.

Maritime Safety Agency (1983): Data Report of Hydrographic Observation, Series of Magnetic Survey, No. 4.

Peddie, N. W. (1982): International geomagnetic field: The third generation. J. Geomag. Geoelectr., **34**, 309–326.

Peddie, N. W. and Fabiano, E. B. (1982): A proposed international geomagnetic reference field for 1965–1985, J. Geomag. Geoelectr., **34**, 357–364.

WDC-B for Secular Variation (1983): The summary of the annual mean values of magnetic elements at the world magnetic observatories, issue XVI.

Xu, Y., Sun, F. and An, C. (1985): Some characteristics of the geomagnetic field and its secular variation in and near China in the last 20 years. Phys. Earth Planet. Int. **37**, 52–64.

北西太平洋域における磁場モデルの評価

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概　　要

北西太平洋域で提案されている，3つの磁場モデル，即ち，国土地理院モデル（GSI モデル），海上保安庁モデル（MSAモデル），国際標準磁場（IGRF）を，日本及びその付近の固定観測所のデータを用いて有効性を評価した。その結果，GSI モデルは日本のみで有効であること，MSA モデルは日本及びその周辺で有効なこと，IGRF は全域で有効であることがわかった。しかし，IGRF は日

本において，F, H, Z については 100nT～200nT 程度，Dについては10分程度の誤差があり，これは，ヨーロッパ・北米に偏在している観測所のデータから決められた IGRF が，日本付近では十分に地球磁場を表わせないからであると考えられる。又，1965年から1980年にわたる全磁力に対する IGRF の値と観測値の間の差の変動は，この期間に 100nT 程度になるので，IGRF を基準としたこの期間に得られた全磁力値を用いた磁気異常図は 100nT程度の誤差を含んでいる。

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