J Geophys (1984) 55:37–40

Journal of Geophysics

Some characteristics of the horizontal field variations around the geomagnetic jerk of 1970

H. Nevanlinna

University of Helsinki, Department of Geophysics, Fabianinkatu 24 A, SF-00100 Helsinki 10, Finland

Abstract. This paper describes some details of the geomagnetic secular variation connected with the secular variation acceleration phenomenon (jerk) observed in 1970. In Europe and Asia, the acceleration was most prominent in the *D* and *Y* components of the geomagnetic field. The direction of the drift of the zero isoporic line of $\dot{Y}$, i.e. $\dot{Y}=0$, was found to reverse in Europe and Asia in 1970. The typical drift rate in Europe was 5°/year. Before 1970, the drift was westward and after 1970, up to 1980; the direction was to the east. In other regions of the world the $\dot{Y}=0$ lines were rather stable during 1956–1978, the period studied here. The shape and orientation of (*X*, *Y*)-vectograms of annual means in Eurasian observatories indicate that the wave-like variation observed in the vector horizontal field was due to changes in a regional source (focal point at 45° N, 85° E) near the maximum area of the large Siberian non-dipole *Z* anomaly.

Key words: Geomagnetic secular variation – Jerk of 1970

Introduction

There have been many papers in recent years on the impulsive acceleration feature (jerk) in the secular variation in 1970 (e.g. Courtillot et al., 1978; Ducruix et al., 1980; Malin et al., 1983). Malin et al. (1983) showed that the jerk signal was worldwide, but over large areas it was most pronounced in one of the field components *X*, *Y* or *Z*. In Europe, the jerk was most clearly observed in the secular variation of declination (*D*) and in the east component (*Y*) (which is closely associated with *D*). Typical curves of annual changes of *Y* and *D* were V-shaped and the peak coincided with the year 1970. Using spherical harmonic analysis (SHA) with internal and external coefficients, Malin and Hodder (1982) showed that the jerk was of internal origin. The result of a SHA by Malin et al. (1983) showed that the secular variation acceleration field around 1970 was mostly confined to low-order harmonics, that is, to quadrupole and octupole fields. However, the internal origin of the jerk was questioned by Alldredge (1979, 1983) who interpreted the acceleration of secular variation around 1970 as a part of the well-known 11-year solar cycle effect due to magnetospheric ring current and polar electrojets.

Later in the 1970s (1977–1979) there was a rather intense impulse in the global secular variation, lasting roughly 2 years. Nevanlinna and Sucksdorff (1981) and Nevanlinna (1983) showed that this impulse was of solely external origin.

Both external and internal geomagnetic impulses are useful for determinations of the electrical conductivity of the Earth's mantle. Ducruix et al. (1980) found that the jerk of 1970, if it is of internal origin, implies conductivities which do not exceed 100–200 S/m in the lower mantle. On the other hand, if the jerk is of external origin, the high conductivity value (10^4 S/m) found by Alldredge (1977) is also possible.

In this paper, a contribution to the morphology of the jerk phenomenon is presented by a global study of the drift of the zero isoporic line of $\dot{Y}$ from 1956 to 1978. Characteristics of the wave-like variations in the vector horizontal field in Europe and Asia are also given.

Data and methods to calculate isoporic charts

Yearly secular variation values (the curves of which have been smoothed by three running yearly means) of the *X*, *Y* and *Z* components for 12 epochs between 1956 and 1978 from 48 worldwide observatories were used as input data in calculations for the isoporic charts. The secular variation model consisted of four changing radial dipoles at a constant distance of $0.25\,R_e$ from the geocentre (for details, see Nevanlinna, 1980). The isoporic charts, calculated from least-squares fits of the four-dipole model, had a mean vector rms error of 9 nT/year, corresponding in accuracy to charts calculated from a 5th degree SHA. The isoporic charts were of the greatest accuracy in Europe, North America and Asia, where the geomagnetic observatory network density is highest. For example, the isoporic charts of $\dot{Y}$ from which the lines of $\dot{Y}=0$ were calculated (see Figs. 2–4) had a mean rms error of 3.5 nT/year in Europe for the time interval studied.

Variations of declination and horizontal field components

Typical curves of annual means of *D* from 1953 to 1975 in Europe and Asia can be seen in the *lower part* of Fig. 1. In the north-west part of Europe [for which the Lerwick observatory ($\phi=60.1°$ N, $\lambda=358.8°$ E) was chosen to represent secular variation of that region], declination has been increasing during the last 30 years. The yearly secular variation of *D* slowed down over a couple of years before the jerk of 1970. This can be seen as a change in the slope of the *D* curve at Lerwick and also in recordings from

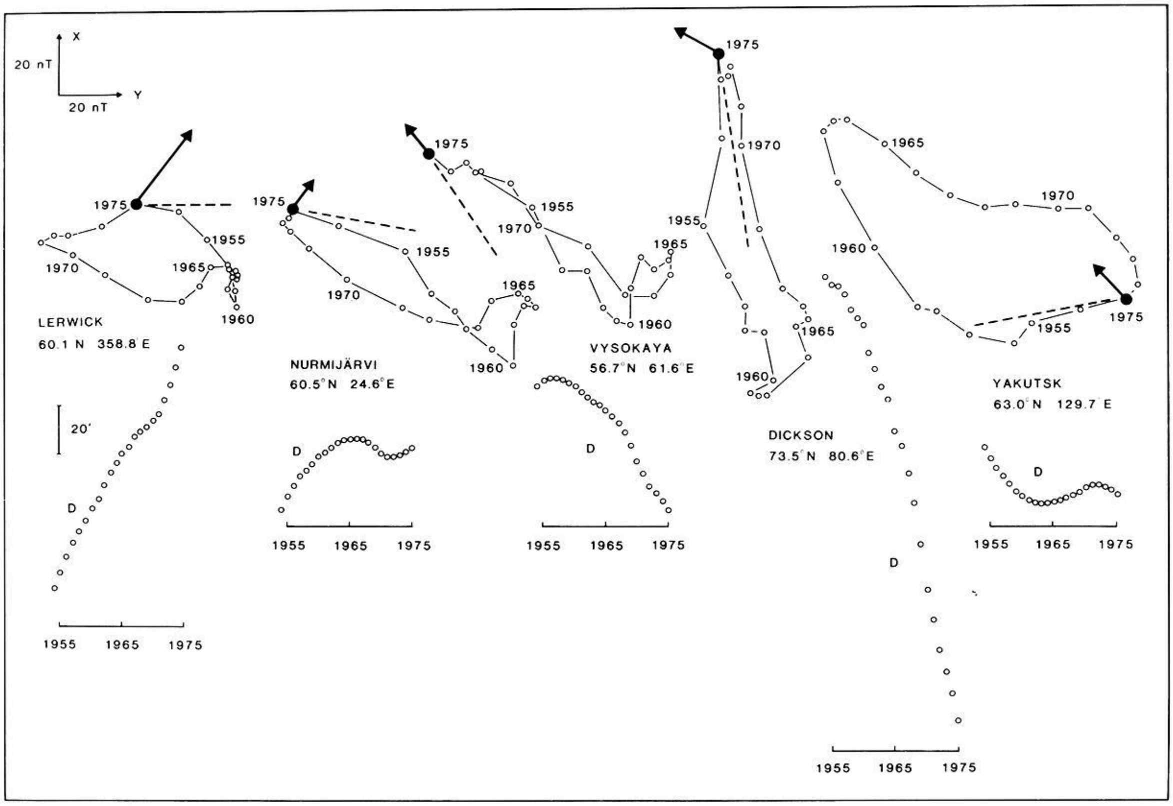

Fig. 1. *Upper part: Open circles* show the end point of the residual horizontal field vector of annual means from Lerwick, Nurmijärvi, Vysokaya Dubrova, Dickson and Yakutsk during 1953–1975. The yearly linear part, shown by *arrows*, were determined by using the annual means of X and Y for 1953 and 1975. The *dotted line* for each observatory depicts the direction of the horizontal vector field caused by a stationary dipole source with a focal point at 45° N, 85° E. *Lower part*: annual means of declination (D)

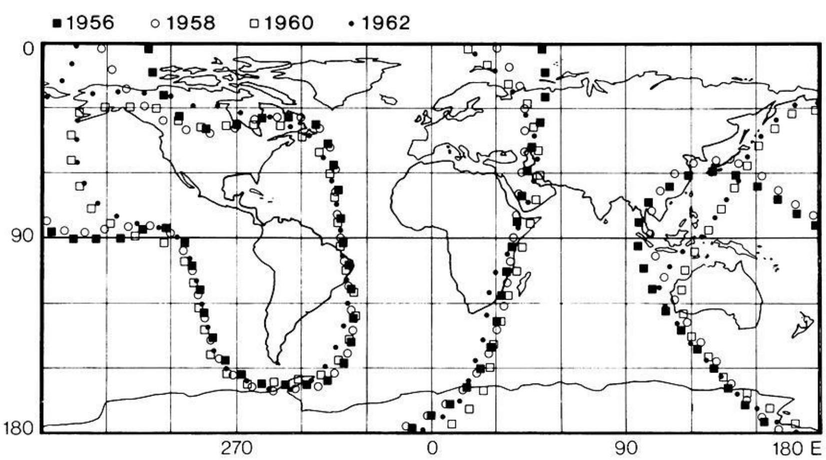

Fig. 2. Zero lines of $\dot{Y}$ isopors ($\dot{Y}=0$) for the epochs 1956, 1958, 1960 and 1962

observatories in the west of Europe. In the northern part, which is represented by the Nurmijärvi observatory ($\phi=60.5°$ N, $\lambda=24.6°$ E), we can see a local maximum in the D-curve in 1965 instead of only a small change in the slope, and a minimum 7 years later. Thus there were two epochs at which $\dot{D}=0$ and also $\dot{Y}=0$. This wave-like character of D (and Y) variation was typical of observatories in the east and west of Europe, located between 20°–45° E. Further east there was a region of rather linear decreasing change in D, for example in Vysokaya Dubrova ($\phi=56.7°$ N, $\lambda=61.6°$ E) and in Dickson ($\phi=73.5°$ N, $\lambda=80.6°$ E); see Fig. 1. In the east of Asia, from roughly 100° E eastwards, D varied as it did in the north of Europe. For example, regarding its two local extreme points, the D curve recorded at Yakutsk ($\phi=63.0°$ N, $\lambda=129.7°$ E) resembles that of Nurmijärvi.

The wave-like character of D was further studied by calculating the lines of $\dot{Y}=0$, using the isoporic charts described in the last section. Figures 2–4 show the global distribution of $\dot{Y}=0$ lines for 12 epochs between 1956 and 1978. Observatories located in areas over which the $\dot{Y}=0$ line has drifted back-and-forth have recorded a wave-like variation of Y (and D). As can be seen in Figs. 2–4, the north and east of Europe and eastern Asia are regions in which this type of variation has occurred.

Figure 5 shows the drift velocity of the $\dot{Y}=0$ line along

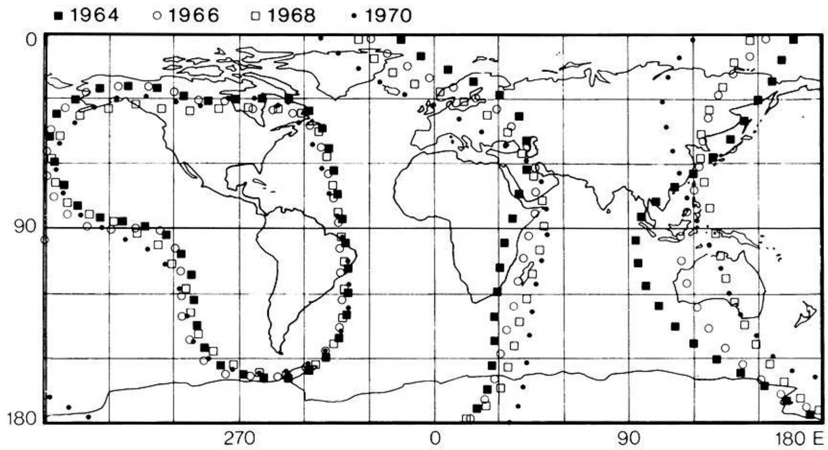

Fig. 3. Zero lines of $\dot{Y}$ isopors ($\dot{Y}=0$) for the epochs 1964, 1966, 1968 and 1970

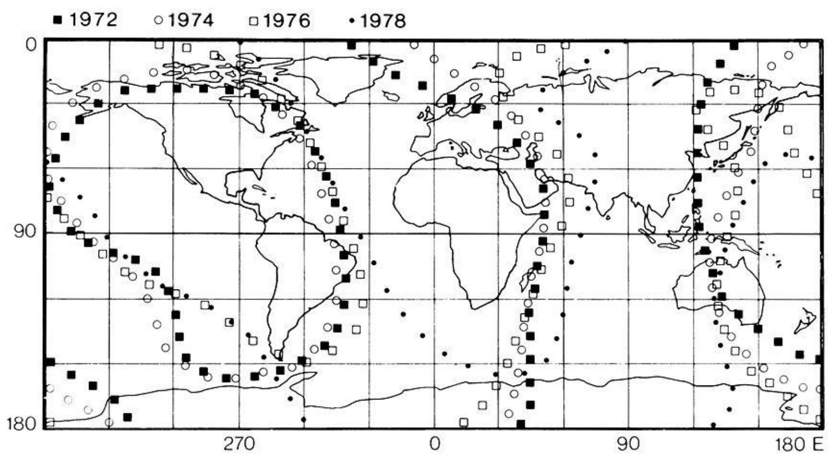

Fig. 4. Zero lines of $\dot{Y}$ isopors ($\dot{Y}=0$) for the epochs 1972, 1974, 1976 and 1978. Note that in this figure the drift direction in Europe and in the east of Asia is eastwards, whereas it is westwards in Figs. 2 and 3

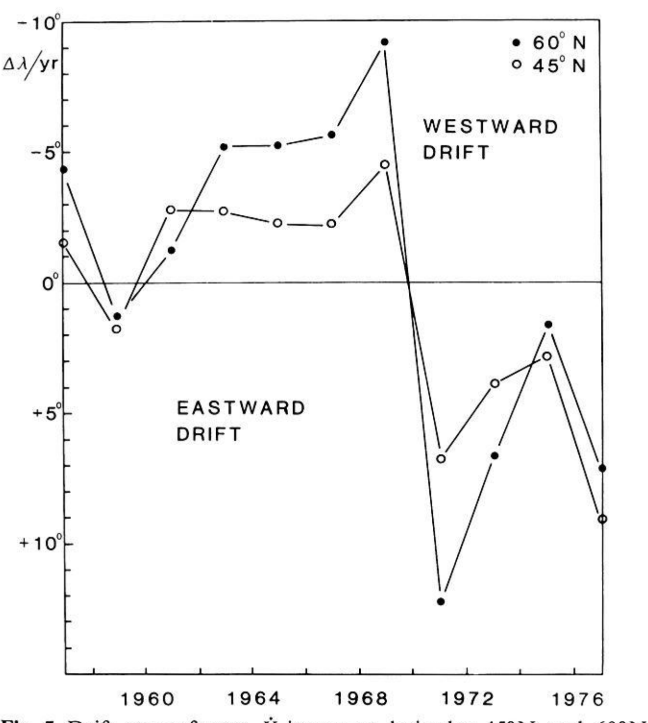

Fig. 5. Drift rate of zero $\dot{Y}$ isopor at latitudes 45° N and 60° N in Europe, as calculated from Figs. 2–4. Note the abrupt change in drift direction in 1970, the year of the global geomagnetic jerk

60° N and 45° N latitude circles. During the years before 1970, the zero isopor, as observed along the 60° N latitude, drifted rapidly westwards with a mean velocity of 5°/year. The mean velocity at 45° N was 3°/year. The total drift of the $\dot{Y}=0$ line in Europe was roughly 60°.

In 1970, the year of the global geomagnetic jerk, the westward drift of the $\dot{Y}=0$ line suddenly changed its direction eastwards, and up to 1978 the velocity of the eastward drift was some 7°/year. This eastward drift in Europe now seems to be over, because in the latest world magnetic charts (IGRF 1980; Peddie, 1982) the zero isopor of $\dot{Y}$ runs approximately along the 60° E longitude line, which is roughly the same as in Fig. 4 for the epoch 1978.

Note that the drifting character of the $\dot{Y}=0$ line in eastern Asia was very similar to that observed in Europe. In northern Canada and Alaska there seems to have been a slight north-south movement of the zero $\dot{Y}$ isopor.

Secular variations of the horizontal field were also studied using annual means of X and Y. Five observatories (shown in Fig. 1) located between roughly 0°–130° E longitude and 56°–75° N latitude were selected to demonstrate, by means of (X, Y)-vectograms, variations in the annual vector horizontal field in Europe and Asia. The vectograms were constructed so that first a linear part, defined by a straight line through the 1953 and 1975 annual means of X and Y, respectively, were subtracted from all annual means. The end points of (X, Y) residual vectors depicting the yearly linear part for each of the five observatories are shown in the *upper part* of Fig. 1.

In a first approximation, the varying residual part of the vector horizontal field can be analytically represented by a simple sinusoidal wave. The linear and varying parts of the secular variation of Y recorded at an observatory, can be written as follows:

$$\dot{Y}(t) = A + B \sin(2\pi t/T),$$

where A and B are constants and T is the period ($\simeq 20$ years) of the varying part. If the absolute magnitude of the constant part (A) of the secular variation is smaller than the amplitude (B) of the varying part, an observatory, like Nurmijärvi in Fig. 1, will record two epochs (t_1, t_2) when $\dot{Y}=0$. On the other hand, if $|A|>B$, then $\dot{Y}\neq 0$ and no local maximum or minimum can be recorded, as can be seen at Dickson in Fig. 1.

Because A and B are different for different observatories, the time (t) when $\dot{Y}=0$ will also be different, causing the drift of the $\dot{Y}=0$ line. In Europe, for example, the constant part (A) was much greater in the western part of Europe than in the eastern part, but the amplitude (B) was rather constant over the whole of Europe (see Fig. 1). It is, therefore, clear that during the growing phase of the varying field, t_1 occurred first in the east, but during the diminishing phase t_2 was observed earlier in the west than in the east.

As can be seen in Fig. 1, the end points of the (X, Y) residual vectors form ovals which are all rather similar in shape. The major axis of an oval represents the mean direction from the observatory to the focus of the residual (X, Y) vector field. At the focus, $X=Y=0$, but $|Z|$ is at its maximum. The direction of the major axis of the vectogram oval is in the east-west direction at the most westerly observatory (Lerwick). The direction changes gradually to an almost north-south direction (Dickson) and then again to the east-west direction (Yakutsk). This 180° change in the orientation of the ovals indicate that the source of the wave-like variation is a regional one. The dotted lines in Fig. 1 show the calculated directions of the oval axis if the regional source is approximated by a single radial dipole located at a distance of 0.25 R_e from the geocentre at the point 45° N and 85° E. The calculated directions of the oval axis coincide rather well with the actual directions.

Note that the focal point (45° N, 85° E) of the source dipole field coincides with the focus of $\Delta\ddot{Z}$ isolines of the jerk of 1970 (see Fig. 10 by Malin et al. (1983) and Fig. 2 by Madden and LeMouël (1982)) and also with the maximum area of the large Siberian non-dipole Z anomaly (see e.g. Yukutake and Tachinaka (1968)).

Discussion

The global analysis of the drift of the zero isopors of $\dot{Y}$ during 1956–1978 showed that the westward movement of the $\dot{Y}=0$ lines in Europe and Asia was abruptly changed to an eastward one in the same year (1970) as the global geomagnetic jerk was observed. In other parts of the globe the zero lines of $\dot{Y}$ were rather stable during the time interval studied.

On the basis of the directions of (X, Y)-vectogram ovals, it is concluded that the drift of the $\dot{Y}=0$ line and the subsequent wave-like variation of Y (and D) annual mean curves from observatories in Europe and the east of Asia may be connected with changes in the large Siberian non-dipole anomaly. Both the long-term wave-like variation reported here and the much more rapid secular acceleration field (jerk) have the same geometry and hence the same source in Europe and in Asia.

References

Alldredge, L.R.: Deep mantle conductivity. J. Geophys. Res. **82**, 5427–5431, 1977

Alldredge, L.R.: Commentaire sur: "Sur une accèlèration récente de la variation séculaire du champ magnétique terrestre" de V. Courtillot, J. Ducruix et J.-L. LeMouël. C. r. Hebd. Séanc. Acad. B289, 169–171, 1979

Alldredge, L.R.: Impulses and jerks in the geomagnetic field. IAGA Bull. No. 48, 100–101, 1983

Courtillot, V., Ducruix J., LeMouël, J.-L: Sur une accélération récente de la variation séculaire du champ magnétique terrestre. C. r. Hebd. Séanc. Acad. Sci. Paris, D287, 1095–1098, 1978

Ducruix, J, Courtillot, V., LeMouël, J.-L.: The late 1960s secular variation impulse, the eleven year magnetic variation and the electrical conductivity of the deep mantle. Geophys. J. R. Astron Soc., **61**, 73–94, 1980

Madden, T., LeMouël, J.-L: The recent secular variation and the motion at the core surface. Phil. Trans. R. Soc. London, A306, 271–280, 1982

Malin, S.R.C., Hodder, B.M.: Was the 1970 geomagnetic jerk of internal or external origin? Nature, **296**, 726–728, 1982

Malin, S.R.C., Hodder, B.M., Barraclough, D.R.: Geomagnetic secular variation: a jerk in 1970. In: Contribuciones cientificas para conmemorar el 75 aniversario del observatorio del Ebro, Publicaciones del Observatorio del Ebro Memoria No. 14, 239–256, 1983

Nevanlinna, H.: Global geomagnetic secular variation from 1956 to 1976 as described by a four-dipole model. Geophysica, **16**, 109–133, 1980

Nevanlinna, H.: The 1977–1979 geomagnetic impulse: its induction effect and dependence on magnetic activity. J. Geophys., **53**, 149–154, 1983

Nevanlinna, H., Sucksdorff, C.: Impulse in global "secular variation", 1977–1979. J. Geophys., **50**, 68–69, 1981

Peddie, N.W.: International geomagnetic reference field: the third generation. J. Geomagn. Geoelectr., **34**, 309–326, 1982

Yukutake, T. Tachinaka, H.: The non-dipole part of the Earth's magnetic field. Bull. Earthq. Res. Inst. (Tokyo), **46**, 1027–1074, 1968

Received January 26, 1984; Revised March 19, 1984
Accepted March 21, 1984