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Evidence for a geomagnetic jerk in 1990 across Europe

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Abstract
The analysis of geomagnetic data from magnetic observatories demonstrated the existence of very rapid changes, or jerks, in the secular variation, especially the occurrence of the well known geomagnetic jerks of 1969 and 1978. A new geomagnetic jerk seems to have appeared around 1990 and is clearly visible at a selection of European magnetic observatories as a rapid and sudden change in the secular variation pattern. The comparison between all day and quiet day means for two different observatories, respectively at high and middle latitude, suggests that this phenomenon, as stated by many authors for the other jerks, could be generated by an internal source.

Key words *geomagnetic field – secular variation – jerks*

1. Introduction

Natural magnetic time variations can be divided into two groups: a) external origin (essentially caused by the interaction of solar wind and electromagnetic radiation with the Earth's magnetic field), and b) internal origin. The internal origin part is called secular variation and can be observed usually only when long term running magnetic observatory data are inspected. This data set is in fact generally considered the most reliable source for secular variation studies. The typical secular variation pattern can be observed by successive observatory annual mean values plotted versus time and can be computed by the differences between them. The general behaviour of these curves, and then of secular variation, is a smooth slowly changing pattern that reflects the corresponding motions of the Earth's fluid core (see for example, Bloxham and Jackson, 1991; Constable *et al.*, 1993; Gubbins, 1989). In recent years, however, several papers have reported on the existence of rapid and sudden changes in the secular variation pattern. Among the others: Courtillot *et al.*, 1978; Ducruix *et al.* 1980; Nevanlinna and Sucksdorff, 1981; Malin *et al.*, 1983; Nevanlinna, 1983; Courtillot and Le Mouël, 1984; McLeod, 1985, reported on a so called jerk at the end of the Sixties.

This discovery gave rise to a very interesting debate on this peculiar impulsive phenomenon in secular variation for its scientific consequences. A geomagnetic jerk can be exactly defined as a rapid change, taking place in a year or two, in the slope of the curve of annual secular variation and in a step function in the secular acceleration. Such a change was observed in the European observatories as a V-shaped curve in declination secular variation with the peak coinciding with the year 1969. Malin and Hodder (1982) examined the data of eighty-three observatories and using spherical harmonics analysis were able to separate the internal and external contributions to the field and concluded that most of the jerk is of internal origin (although these analyses do not allow separation of the main field from the part induced in the conducting mantle by external sources). On the other hand, Alldredge (1979, 1985) noted that in many sites in the world the jerk was not at all evident. He also stressed possibility that some external signal might contribute to sharpen the change. He also claimed that the apparent rapidity of the field change is an artifact of the mathematical assumptions used. Almost all the other authors, however, remain convinced of the jerk's global and internal nature (see also Backus and Hough, 1985; Backus *et al.*, 1987).

Other jerks were identified after the reported 1969 event, such as the jerk in 1912-1913 and 1978 for example (see Golovkov *et al.*, 1989; Alexandrescu *et al.*, 1995). We will discuss in this paper the evidence of a new jerk in 1990 as observed in many observatories over Europe.

Table I. Geographic coordinates and symbols of the selected European geomagnetic observatories.

Symbol	Observatory	Latitude	Longitude
TRO	Tromso	69.663°N	18.948°E
NUR	Nurmijarvi	60.508°N	24.655°E
MOS	Kr. Pakhra	55.280°N	37.190°E
ESK	Eskdalemuir	55.190°N	356.480°E
WNG	Wingst	53.743°N	9.073°E
NGK	Niemegk	52.072°N	12.675°E
BEL	Belsk	51.837°N	20.792°E
HAD	Hartland	50.995°N	355.517°E
KIV	Dymer	50.717°N	30.300°E
DOU	Dourbes	50.097°N	4.595°E
FUR	Furstenfeldbruck	48.165°N	11.277°E
AQU	L'Aquila	42.383°N	13.317°E

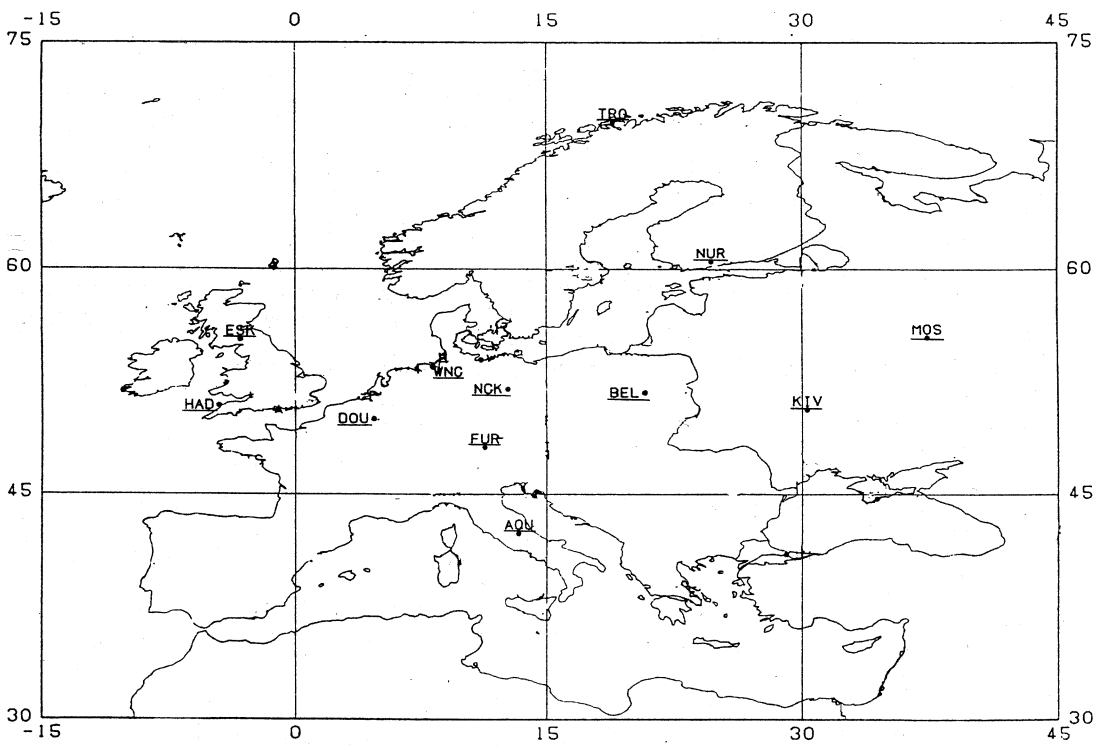

Fig. 1. Locations of the European observatories considered in the analysis of the 1990 magnetic jerk. Symbols and geographic coordinates are reported in table I.

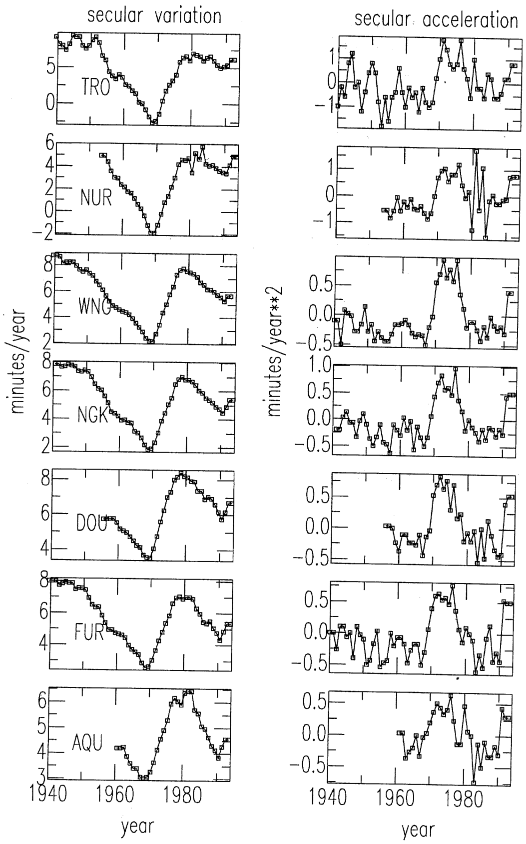

Fig. 2. Secular variation and secular acceleration defined respectively as first and second derivative of the annual mean values of declination as recorded at the selected geomagnetic observatories. Observatories are ordered in increasing latitude from bottom to top of the figure.

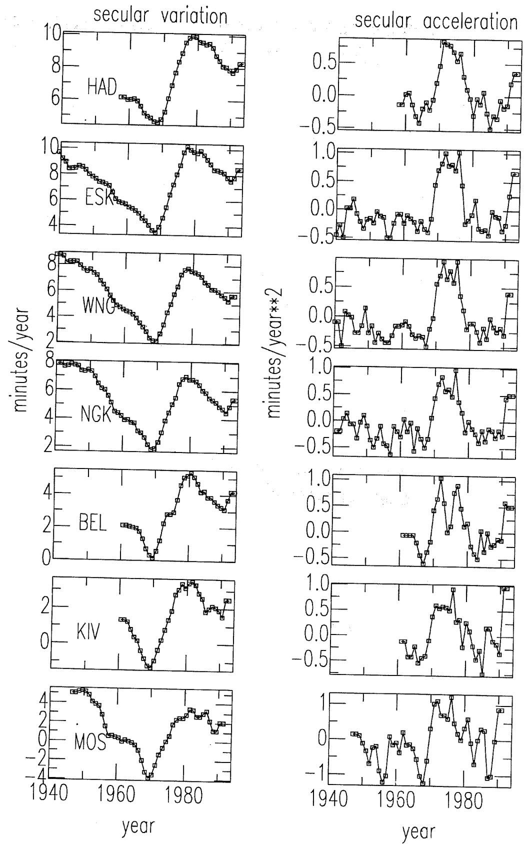

Fig. 3. Secular variation and secular acceleration defined respectively as first and second derivative of the annual mean values of declination as recorded at the selected geomagnetic observatories. Observatories are ordered in increasing longitude.

2. Data analysis

A jerk in 1990 was clearly observed in magnetic declination and all over Europe. Twelve observatories were selected to demonstrate in detail the secular variation behaviour in the 1960-1994 time interval and particularly around the geomagnetic jerk of 1990. The considered observatories are reported in table I with their latitude and longitude and their locations are shown in fig. 1. Figures 2 and 3 show the secular variation defined as the first time derivative of annual mean values and the secular acceleration for the selected magnetic observatories, ordered in latitude (fig. 2) and longitude (fig. 3). Many of the irregularities that can mask the possible effects present in the second and third differences of annual means, were removed applying a simple 3-year running mean on the curves.

The well known and debated 1969 jerk is quite evident as a V-shaped structure, in the first derivative at all observatories and as a step in the second derivative. Latitudinal and longitudinal secular variation effects across the observatory network show up as a different amplitude range for the observed phenomenon. A second V-shaped structure in the first derivative and a step function in the second derivative, although less evident, appears in 1978 as reported by several authors; we claim that one more possible jerk also appears at 1990. We should say, however, that the irregular variation present especially in the second time derivative tends to mask the reported phenomenon especially at 1990 since the number of available years after the suspected jerk is at this time very low.

Since the jerk occurrence was also interpreted as a secondary effect given by the increase in magnetic activity on the Earth around solar maxima (Alldredge, 1985), in order to better investigate the nature of the possible new jerk around 1990 two categories of declination annual means have also been used to determine its secular variation: all-day means (reported in figs. 2 and 3) and quiet-day means which are based only on the means of five international quiet days of each month (see for example Nevanlinna, 1985). Figure 4 shows the secular variation and secular acceleration calculated only on quiet days for two observatories AQU and NUR respectively at high and low magnetic latitude. As expected, the secular variation based on all-day annual means has the greatest scatter from year to year, especially during the years of high solar activity; the curves of only quiet day annual means and their derivatives are quite smooth with respect to all day mean curves indicating that, using only quiet days, most external contributions to the magnetic field should be eliminated. Looking at fig. 4, where dashed lines indicate all day means and solid lines indicate quiet day values, it is clear that there was an external part in the jerk in 1978 while the scatter of the two curves around 1990 appears quite small.

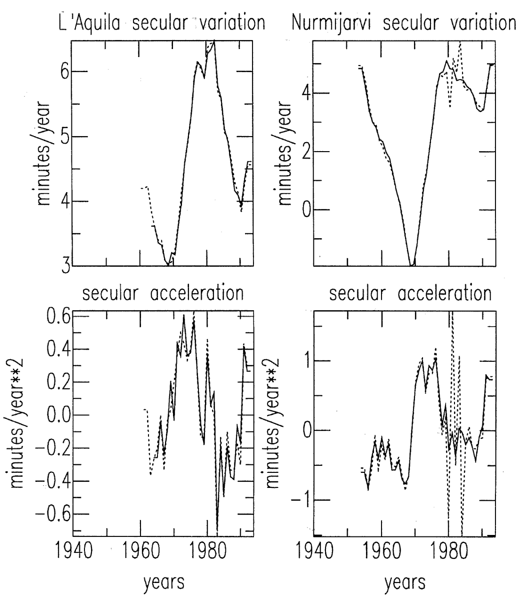

Fig. 4. Secular variation and secular acceleration in the D element at AQU and NUR observatories computed on all day means (dashed lines) and only on quiet day means (solid line).

3. Conclusions

This paper briefly presented the evidence for a new possible geomagnetic jerk around 1990. Twelve observatories over Europe were analysed to show the phenomenon and its dependence on latitude and longitude and some peculiarities in all stations were disclosed. Only declination data were presented because jerks across Europe were clearly observed in this element. The data were presented starting from 1940, when available, and the jerks in 1969 and 1978 are also clearly visible in the figures. Also a jerk in 1958, as reported by a few authors (see for axample Golovkov *et al.*, 1989) appears in some plots. Latitudinal and longitudinal secular variation effects across Europe were revealed as a different amplitude range for the observed phenomena.

An analysis undertaken on all-day means and only on quiet day mean values of declination for two observatories seems to confirm that the new reported jerk around 1990 should be of internal origin. A more complete analysis using the spherical harmonic method will give more precise information on the origin of this phenomenon. A larger data set around 1990 should be available reasonably soon.

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