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A historical declination curve for Munich from different data sources

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Abstract

Long series of geomagnetic field changes are important for studying processes in the Earth's core. We have compiled 635 historical declination values for southern Germany and surrounding areas. Indirect estimations, including the oldest ones from back in the 15$^{\text{th}}$ century, come from 185 sundials and compasses with declination information, and 15 historical maps. Measurements carried out by monks in the time interval 1668 to 1854 amount to 122 annual mean values and data related to the orientation of mine shafts contributes by 313 annual values for several locations. All these data can be useful to improve historical geomagnetic field models. Previously compiled German church orientations, however, are shown to be no reliable sources of the past declination. The compiled new declination curve for Munich shows general agreement with previously published curves for London and Paris and allows to detect geomagnetic jerks with a temporal uncertainty of ±10yrs. More or less regular impulses, on a decadal time-scale ranging from 30 to 60 years, are identified for most of the time interval 1400 to 2000, but the century from about 1760 to 1860 seems to be devoid of sudden secular variation changes.

Key words: Geomagnetism, declination, historical data, geomagnetic jerks

1. Introduction

The Earth's magnetic field generated by dynamo processes in the core varies on a broad range of time-scales, from years to millions of years, known as secular variation. A highly detailed picture of the current secular variation is obtained from satellite magnetic vector measurements (Ørsted and CHAMP satellite), available since 1999. Systematic vector measurements at locations all over the world, leading to the present network of geomagnetic observatories, started in the early 19th century with the initiative of Alexander von Humboldt and Carl Friedrich Gauss. Moreover, a major improvement was the developement of a method to determine the absolute field intensity by Gauss (Gauss, 1833). Time series longer than 200 years are, however, desirable to study decadal to centennial secular variation processes. Archaeo- and paleomagnetic data provide information on longer intervals, but mostly with limited time resolution and lower accuracy than direct measurements. Magnetic data from historical sources are then an important complement to study the field evolution of the past centuries.

The first measured geomagnetic field element was the declination, linked to the early use of compasses. The magnetic compass has been known in Europe since the 12th century (e.g. Merrill et al., 1996), but it is not clear when its deviation from geographic north, i.e. declination, became known there. In China, both the compass and declination had been known some centuries before. The earliest known European declination measurements start with an observation by Hartmann in Rome in 1510 (Hellmann, 1899). The discovery of declination in the European area has often been ascribed to Christopher Columbus in 1492, but Chapman and Bartels (1962) describe evidence from ancient sundials and compasses indicating that the deviation of a compass needle from geographic north was known in Europe at least since the early 15th century. This knowledge, however, might not have been widely distributed. Moreover, some of the first observed deviations might have been interpreted as resulting either from the construction of specific instruments (see e.g. Wolkenhauer, 1904) or from different magnetisation directions of the loadstone, used to magnetise the needle, depending on its location of origin (see e.g. Balmer, 1965; Körber, 1965). The oldest declination value given by a magnetic compass known to us dates from 1451 (Zinner, 1939). This instrument was made by Peuerbach in Vienna. However, it is not clear if Peuerbach understood the deviation from geographic north as a property of the magnetic field or as one of the specific instrument. Three more compasses made by him at the same location between 1451 and 1456 indicate different declination values, although the discovery of change of declination with time (i.e. secular variation) is generally assumed to lie only in the early 17th century. It has first been described by Henry Gellibrand in 1634 and probably been noticed before by Edmund Gunter in 1622 (Chapman and Bartels, 1962). It is generally assumed that inclination was discovered in 1544 by Georg Hartmann at Nuremberg but probably first measured correctly by Robert Norman in 1576 (e.g. Chapman and Bartels, 1962).

Measurements of the two field directions, declination and inclination, date back further than full vector observations. Frequent measurements were taken particularly from shipboard for navigational purposes from the late 16th century on, and Jonkers et al. (2003) compiled a large global set of such data. Their database also contains a few land measurements prior to the start of systematic observations. Individual time series of declination and sometimes inclination have been compiled by Malin and Bullard (1981); Cafarella et al. (1992); Barraclough (1995); Alexandrescu et al. (1996) and Soare et al. (1998) for London, Rome, Edinburgh, Paris and Romania, respectively.

When we noticed a historical declination curve for southern Germany based on declination information from sundials (Wagner, 1997) and a number of historical measurements carried out at monasteries and not included in the Jonkers et al. (2003) database, we started new efforts of finding historical data over Germany and surrounding areas. In the course of this work we noticed even more largely unexploited sources of declination data: compass roses printed on old maps (Mandea and Korte, 2007), declination measurements used for mining activities and probably even orientations of churches. These data sources have also been mentioned by Knothe (1987, 1988), who actually compiled declination data from mining activities in Europe, but only published and preserved resulting curves and not the values.

Here, we first give an overview of the previously published data compilations for the German region from 1300 on. Then, we discuss the different data sources explored in this study and present the new data compilation for (southern) Germany. We compare the data to predictions from the *gufm1* global geomagnetic field model (Jackson et al., 2000), which covers the time interval from 1590 to 1990, and to the archeomagnetic data from earlier times. A smoothed declination curve for Munich is obtained. Its similarities and differences to the declination curves for London and Paris are shown and the occurence of geomagnetic jerks from 1400 to present is investigated.

2. Existing German declination data since 1400

2.1. Geomagnetic observatories

Started in the early 19th century and initiated by Alexander von Humboldt, regular measurements of the geomagnetic field were carried out on a daily basis at fixed times at a growing number of geomagnetic observatories . At the Sternwarte Berlin such measurements were carried out from 1836 to 1865 (Encke, 1840, 1844, 1848, 1857, 1884). The annual mean values are included in the supplementary data file. In the late 19th and early 20th century the magnetic field was recorded at several locations in and nearby Germany, and annual mean values are archived at the World Data Center (WDC) Edinburgh (http://www.wdc.bgs.ac.uk). The time series of three active geomagnetic observatories go back to the 19th century when they are combined with data from one or two predecessing stations located not far away from the present observatories. Table 1 indicates them with their location changes. The data are published in the yearbooks of the observatories and are also available from the WDC Edinburgh. We only consider the MNH-MAS-FUR time series in the following, as most of our newly compiled data come from southern Germany and our aim is to construct a regional declination curve from all values adjusted to Munich.

2.2. Gufm1 and its data basis

A global compilation of historical geomagnetic data has been published by Jonkers et al. (2003). It spans the times from 1510 to 1930 and consists mainly of measurements made on ships for navigational purposes during the voyages over the oceans, but also some measurements on land. From that database, we have extracted declination values for the region 47-55°N, 6-15°E, covering the present day German territory and parts of some

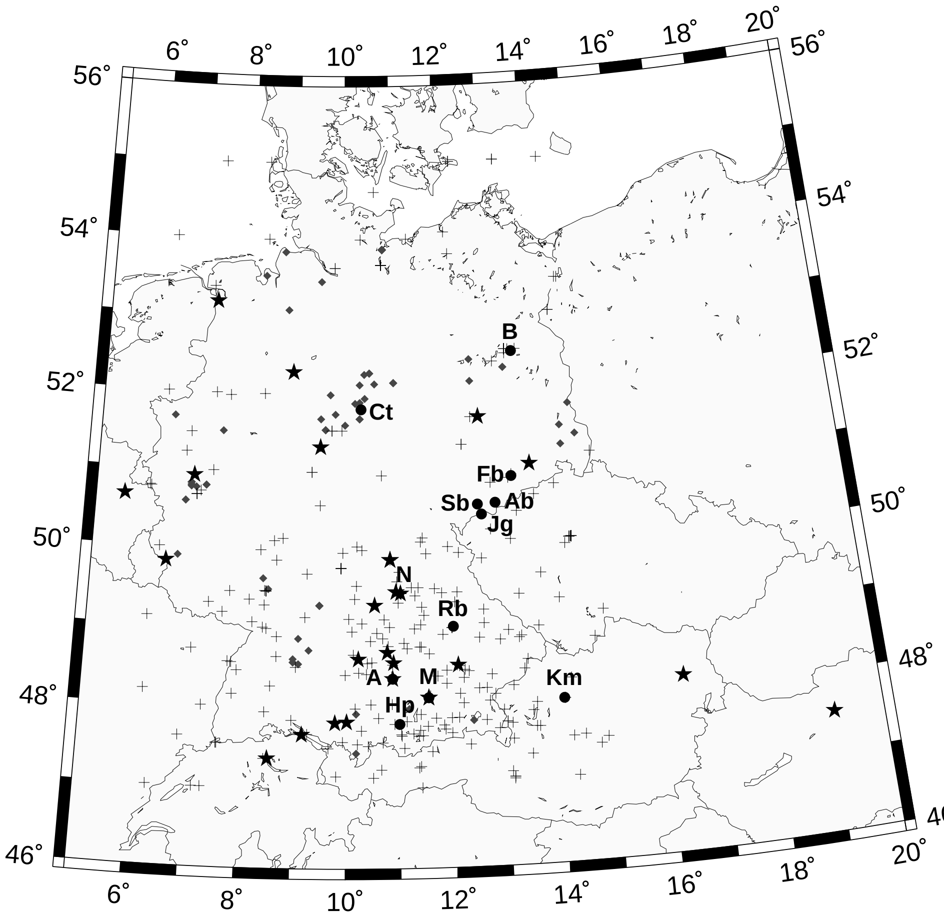

Figure 1: Locations of declination data sources. Stars mark locations of found declination values from sundials, compasses and historical maps. Direct measurements at mines and monasteries are marked by black dots. Crosses mark the locations of historical data available from the Jonkers et al. (2003) database (region 47-55°N,6-15°E) and gray diamonds of archeomagnetic data compiled for Germany by Schnepp et al. (2004). Labels (letters) are given for some locations referred to in the text.

Table 1: German geomagnetic observatories with long data series

	location 1	location 2	location 3
Name	Wilhemshaven	Wingst	
IAGA Code	WLH	WNG	
Time interval	1884-1932	since 1939	
Name	Potsdam	Seddin	Niemegk
IAGA Code	POT	SED	NGK
Time interval	1890-1907	1908-1931	since 1932
Name	Munich	Maisach	Fürstenfeldbruck
IAGA Code	MNH	MAS	FUR
Time interval	1841-1926	1927-1935	since 1939

surrounding countries. The locations of the resulting 326 declination values from 1523 to 1895 are shown in Fig. 1.

Jackson et al. (2000) constructed a global, time-varying magnetic field model spanning the time 1590 to 1990, named *gufm1*. Predictions of declination for the area of Germany from the *gufm1* model, in 100 year intervals, are shown in Fig. 2a, complemented by the declination prediction of the International Geomagnetic Reference Field (IGRF) for 2000 (Macmillan et al., 2003). In Fig. 2b the declination curves from the *gufm1* model for the four corners of the considered region and its center (51.0°N, 10.5°E) are shown. A strong change of the declination gradient with time in east-west direction is very clear. Around 1700, declination values all over Germany are on the order of -8°, while around 1900 they range from -13° (western part) to -9° (eastern part). The epoch without strong spatial declination gradient around 1700 also marks a change in the isogonic lines over Germany, from more easterly declination values in the west than the east to more westerly declination values in the west than the east (see Fig. 2b).

2.3. Archeomagnetic data

A catalogue of German archaeomagnetic data has been compiled by Schnepp et al. (2004). Among others, this catalogue contains a consecutive time series of data from a

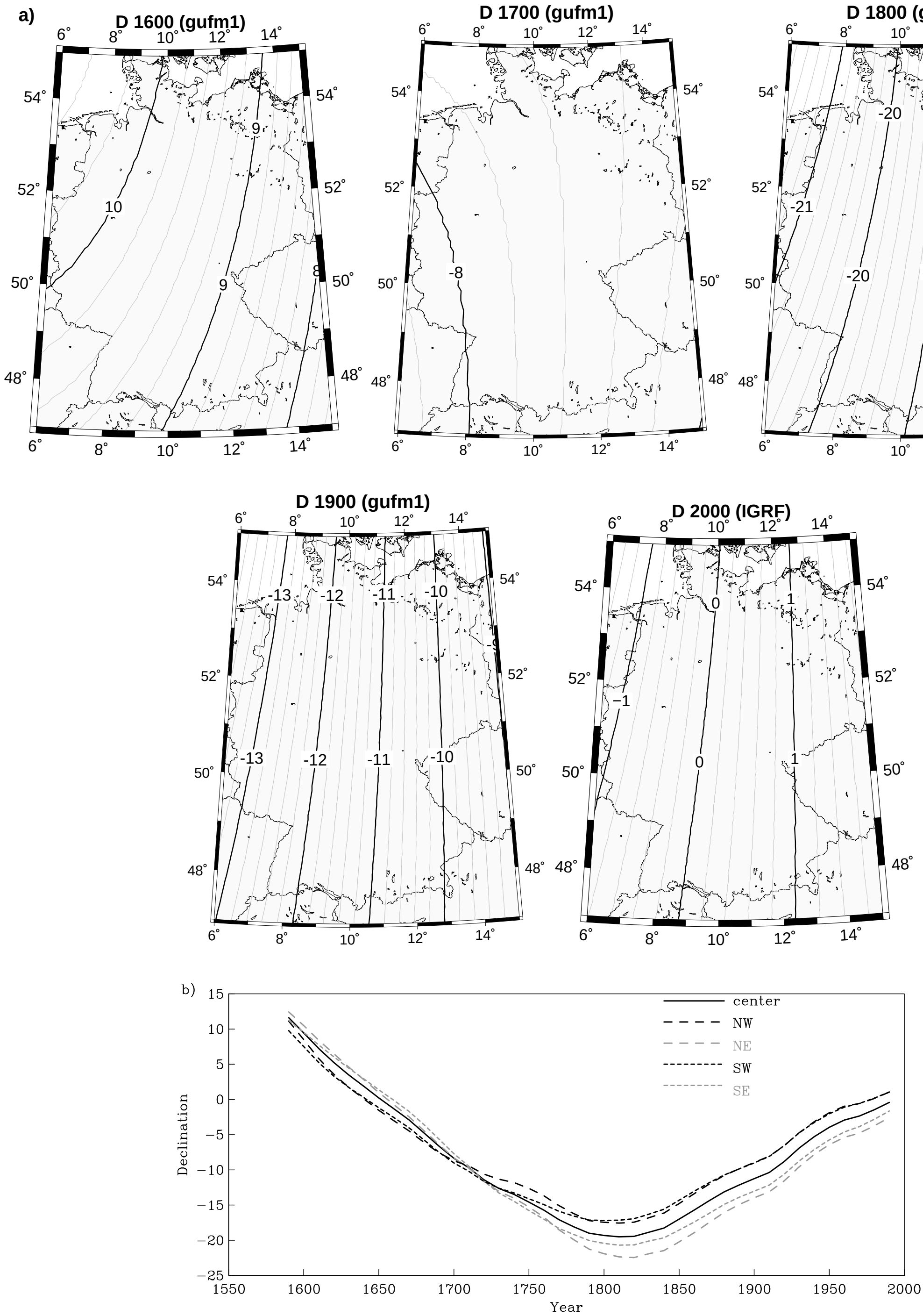

Figure 2: a) Declination distribution over Germany from 1600 to 2000 according to global models *gufm1* and IGRF. b) Declination predictions from *gufm1* for the center and four corners of the region shown in a).

bread oven-floor sequence in Lübeck (Schnepp et al., 2003), spanning approximately the time interval 1300 to 1800. The locations of 51 declination values available since 1300 from that catalogue are also shown in Fig. 1. The mean age uncertainty of these archeomagnetic data is 75 yrs, and the mean declination data uncertainty we computed based on the given $\alpha95$ uncertainties is 3.6°. Both the previous historical and archaeomagnetic data are discussed together with the newly compiled data in section 4.

3. Newly compiled declination data

Reports of direct declination observations are the most reliable sources of information about this magnetic element. However, additional historical sources of declination exist. Here, we describe the different sources we have explored during this study, and discuss their accuracy and reliability. The new data are supplied in the supplemental data file. The locations of the newly compiled declination data are shown in Fig. 1.

3.1. Sundials and compasses

Portable sundials have to be oriented in the right direction in order to show the correct time. The easiest way to achieve this is by means of a magnetic compass. The manufacturers of sundials obviously were aware of the deviation of the compass needle from the true north since the 15^{th} century (Hellmann, 1899; Zinner, 1939). Ancient sundials or compasses often have a mark of declination angle (Körber, 1965), and this information can generally be found in books and catalogues describing collections of historical sundials (e.g. Körber, 1964; Gouk, 1988; Wagner, 1997). The southern German cities Nuremberg and Augsburg (N and A in Fig. 1) were centers of sundial manufacturing from the 15^{th} to 18^{th} century. For many of the ancient sundials an indication about the place and the epoch when they were made is included in the descriptions. Wagner (1997) compiled a list of declination values given by well-dated historical sundials mainly produced at Nuremberg.

Wagner (1997) only included data from instruments of which the exact years of manufacturing were known. Here, we also include values from instruments that were only approximately dated. The assigned age error estimates depend on the accuracy of the dating. If a time interval was given we assigned the mean time ± the difference between mean and interval borders. A dating of, e.g., 16$^{\text{th}}$ century became 1550±50, of , e.g., first half of 16$^{\text{th}}$ century became 1525±25, and datings like "about 1670" became 1670±5. Note that these are not statitical error estimates and probably not even completely consistent within the dataset due to the many different formulations for the age estimates by different authors. In general, they should be close to the maximum age uncertainties and like that useful when error bars are used to decide on data consistency and reliability.

We do not have a clear idea what uncertainty to expect as we do not know by which method exactly and under which conditions the values were determined. In general the values are given as full degrees. Körber (1965) notes that the values might have been given according to a 32- or 36-parts wind rose, where approximately 6° or 5° is half a mark on the rose. We assume that 1° to 3° is a reasonable estimate for the general uncertainties of these data.

Appendix A lists the declination values obtained from sundials and compasses, together with the references, and data are plotted in Fig. 3a for comparison with other data. Fig. 4 is an enlargement of that panel with error bars when the year of manufacturing is unknown. Interestingly, the ages of the older instruments, in general, are better known than of those from 18th and 19th century. The older declination data with known manufacturing dates are much more consistent than the most recent ones. Unless the declination has not been taken into account properly for those instruments, either several of the estimated ages are not correct, or those sundials have been built for significantly different locations. The number of data from sundials amounts to 133 values from instruments with known locations, plus 52 values from unknown locations.

3.2. Historical maps

Printed historical maps occasionally show compass roses with an indication of declination. Assuming that geographic north is at the top of the map, the declination can be read from the orientation of the printed compass needle. The accuracy to which the declination can be estimated is in the order of 1° to 5° and 15 declination values from historical maps have been compiled here. Further values, including earlier ones (Wolkenhauer, 1904,

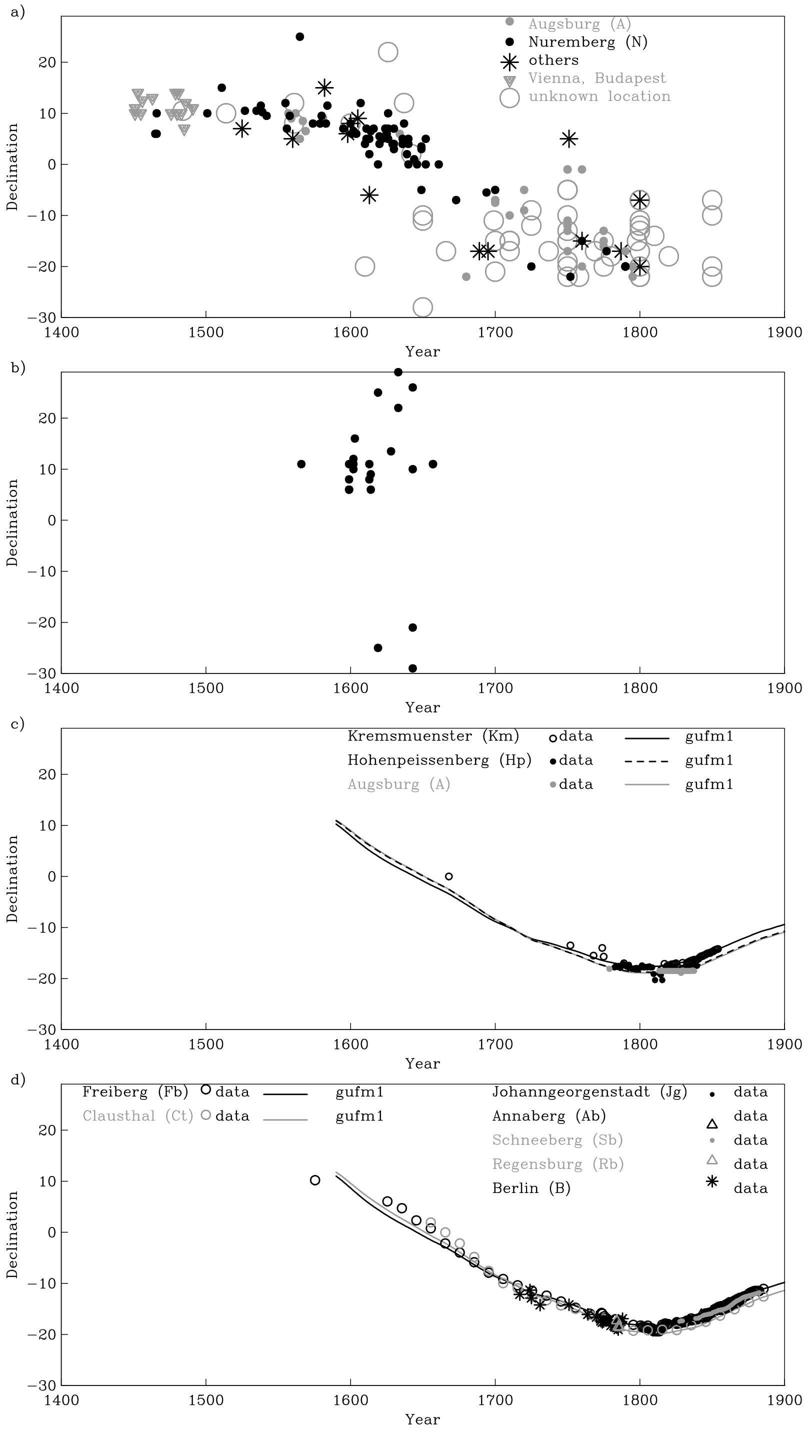

Figure 3: Declination data for the indicated locations provided by several sources: a) from sundials and compasses b) from historical maps; c) from measurements in monasteries and d) from measurements in mines (due to the close agreement several of the mine data are hardly distinguishable). In c) and d) predictions from the *gufm1* model for the same locations are shown. Abbreviation letters refer to those shown in Fig. 1.

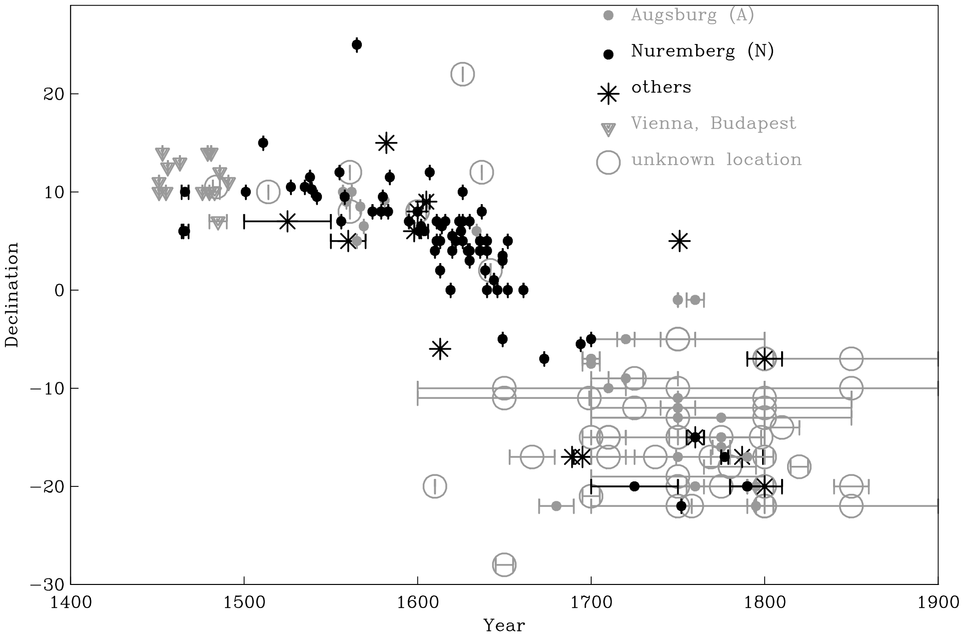

Figure 4: Declination data from sundials and compasses from Fig. 3a with estimated error bars when the year of manufacturing is unknown.

1907), certainly exist, but as it will be discussed in the following this kind of data seems less reliable than the sundial data. Here, we limited our work to the easily verifiable values published by Körber (1965) and Kleinschmidt (1989). Indeed we found some discrepancies between the values provided by these two sources and confirmed all values from the atlas of historical maps (Bachmann, 1941, 1942, 1961). All these values, including differing published ones, are listed in Appendix B and plotted in Fig. 3b. All declination values compiled here come from within one century. The figure clearly shows a large scatter among these values, indicating a much lower reliability of these data compared to those obtained from sundials. Apparently the printed compass roses do not represent very exact declination values or the maps themselves are not oriented accurately to geographic north. The three strongly westward declination values even suggest that declination has been applied with the wrong sign to these maps.

3.3. Monasteries and meteorological stations

During the 18th and 19th centuries, measurements of declination were carried out at several places in southern Germany and Austria by monks.

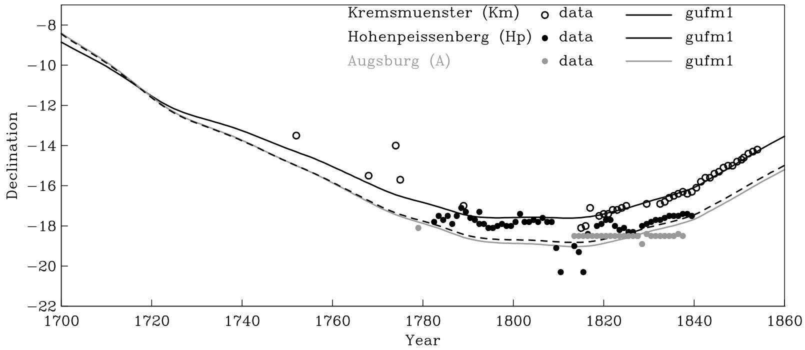

Figure 5: Declination data measured at monasteries from Fig. 3 enlarged to show the differences in detail.

At Hohenpeissenberg, magnetic declination measurements were initiated together with meteorological measurements in 1781 by the Societas Meteorologica Palatina, the Academy of the Palatinate. Declination measurements were conducted three times a day by monks and local priests until 1839. Annual means from these measurements, published in yearbooks (e.g. Hemmer, 1783) and a later compilation by Lamont (1851) have been digitized.

Results from magnetic observations carried out at monasteries at Augsburg and Kremsmünster (Austria) are published in a series of yearbooks, like Stark (1814) and Reslhuber (1857), respectively. Monthly mean values based on at least three measurements a day exist for Augsburg from 1813 to 1837, and we computed annual means based on them. The time series for Kremsmünster consists of single data points between 1740 and 1790. From 1815 on the digitized values are means of several measurements per year and from 1832 several measurements per month with a declinatorium manufactured by Brander in Augsburg. This is the same instrument as was used in Hohenpeissenberg and Augsburg. Around 1840 a gradual shift to classic geomagnetic observatory intruments and routines with regular daily observations started.

The locations and time series of these observations are included in Figs. 1 and 3c. Fig. 5 shows the same data on an enlarged scale to visualize the detailed differences between these data mainly coming from the time interval 1750 to 1850. The data show a good internal consistency and generally good agreement with the *gufm1* model. The Augsburg data, however, present somewhat suspect values as they are nearly constant over the whole time span they cover.

The overall number of data from these sources amounts to 122 values spanning the time 1668 to 1854.

3.4. Mining activities

Since the 13th century, compasses were also used in mining to determine the direction of the mine legs (Ludwig and Schmidtchen, 1997). Christian Doppler first realized that declination information can be gained either by comparing old mining maps with newer ones or that declination values are given in mining publications (Doppler, 1849). Knothe (1987, 1988) compiled several data from differnt European locations, but only plots and no values are published or have been preserved by the author (Knothe, pers. comm.). Schreyer (1886) compiled a large number of declination measurements carried out for mining purposes in Saxony (at that time Kingdom of Saxony) from 1575 to 1885. A number of measurements in Berlin and Regensburg between 1717 and 1788 are included.

For two main mining areas in Freiberg and Clausthal 10 year interval data series from 1545 to 1885 are given by Schreyer (1886). All found data within each decade have been reduced to the central epoch by a simple assumption of secular variation and averaged "taking into account their reliability" (Schreyer, 1886), but details of this averaging are not given. A few measurements reported by Schreyer (1886) from Freiberg between 1773 and 1790 come from different, insufficiently documented sources and are averages of 9 to 24 measurements over the year or individual measurements.

Annual data for several locations for the 19th century are best documented. Those values had mostly been published annually in a series of mining calendars, e.g. Königl. Bergakademie zu Freiberg (1850), which have been scanned by the Technical University Bergakademie Freiberg and today are available on a website (http://www.tu-freiberg.de/ ub/el-bibl/jb_sachsen/jb_sachsen.html). Schreyer (1886) reports that if several observations existed within a year, they have been reduced to the middle of the year by an estimate of secular variation for that time and averaged. Moreover, if the time of observation was given the values had first been reduced to the daily mean by rules determined by Johann von Lamont for Munich. The values are rounded to 0.1'. The individual measurements on which these averages are based were done by means of mine surveyors' compasses and their accuracy is estimated as 10' for the earlier and 3-5' for the later years by Schreyer (1886). Note, that the signs of all these values in our digital supplement are opposite to the ones in the Schreyer (1886) publication, in order to agree with today's convention of positive sign for eastern declination and negative for western.

Time series of all these 313 declination measurements are shown in Fig. 3d. A good accuracy of these data with very good agreement to *gufm1* from 1700 onward can be seen. The long data series from Clausthal (Ct in Fig. 1) further west and Freiberg (Fb) further east clearly reflect the change in declination gradient around 1725 again. Assuming that the accuracy of these averaged declination data is nearly equally high throughout the 17th century, these data have the potential to improve details of models like *gufm1*, which fits the earlier data less well.

3.5. Church orientations

A few publications describe church orientations as a possible source of magnetic declination values. Motivated by historical documents proving the use of a compass for church orientation in 1516, Wehner (1905) studied the deviation from the geographic east of the axes of some 300 churches. He concluded that several churches were oriented by magnetic compass and provides a list of 45 German churches with orientations. However, his claim that most of them were oriented by magnetic compass is based on the assumption that the declination varies strictly periodically. Figure 6 shows the declination values resulting from the deviation of church orientations from the geographic east. The associated ages are the years of the church foundation and error bars of 50 years are shown when the year is not exactly known. Nippold (1916) supports Wehner's conclusion (Wehner, 1905) by direct comparison of church axes deviations and geomagnetic field data, however, for lack of available data, again under the assumption of periodicity. Today we know from archeo- and paleomagnetism that we cannot expect a strictly periodic declination variation. Abrahamsen (1985) picked up the topic again by studying Romanesque churches in Denmark

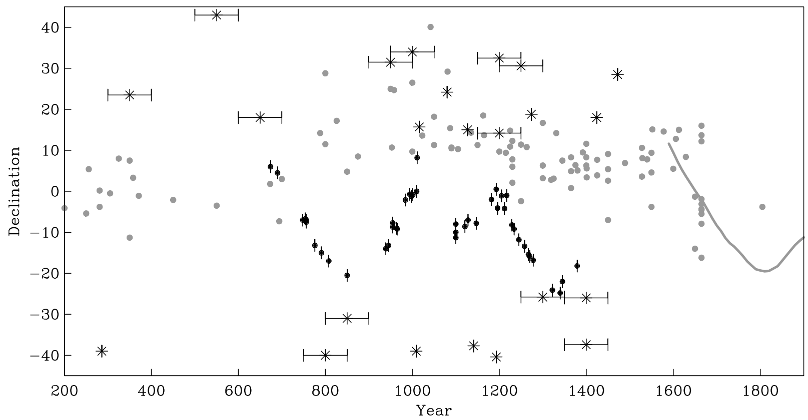

Figure 6: Declinations for 45 locations in Germany, as determined from church axes deviations from the geographic east under the assumption that orientation was done by magnetic compass. Black dots are the values presumed to represent magnetic declination by Wehner (1905), stars are the ones he considered not in agreement with orientation by magnetic compass. Archeomagnetic declination data (gray dots, see sec. 2.3) and the *gufm1* model prediction for the center of Germany (gray line) are also shown for comparison.

in the 12^{th} century. From a statistical analysis of orientation of more than 500 churches he concluded that about 25% of all Danish Romanesque churches were oriented by means of a magnetic compass (Abrahamsen, 1990).

The declination values obtained from church orientations published by Wehner (1905) are based on an a priori assumption about the geomagnetic field. Apart from the fact that the assumption is most likely wrong, as e.g. a comparison with the archaeomagnetic data described in section 2.3 (Fig. 6) suggests, the values are not independent and cannot be used to study past declination. A rigorous statistical analysis of all German churches from a given epoch might provide true information on past declination, but a complete dataset is not readily available and such a study is outside the scope of this work. We did not consider the values from church orientations any further in this work.

4. A declination curve for southern Germany

All new and previous historical and archeomagnetic data from the German region, spanning the time interval 1300 to 1950 are combined in Fig. 7a on their original locations. Then the values D have been adjusted to the location $M = (11.57E, 48.13N)$ of Munich (M in Fig. 1) from their original locations $x = (longitude, latitude)$ (Fig. 7b) by using adjustment values ΔD determined from the *gufm1* model for the respective epoch t:

$$D(M,t) = D(x,t) + \Delta D(t) \tag{1}$$

with

$$\Delta D(t) = Dg(M,t) - Dg(x,t), \tag{2}$$

where $Dg(M,t)$ and $Dg(x,t)$ are *gufm1* model predictions at time t for locations M and x, respectively. For data prior to the validity of the model, i.e. $t < 1590$, the adjustment values were computed with $t = 1590$. Data from the sundials without known location have not been considered and are omitted in Fig. 7b and in the following determination of a smoothed curve. From the historical map data, only the values determined/confirmed by us have been used. Most of the adjusted data are consistent within 10°, but some outliers exist among the sundials and maps data.

A smooth declination curve for Munich for the time span 1400 to 2000 has been created by fitting a smoothing spline (Constable and Parker, 1988) to 1105 reduced data. In order to avoid any artificial end effects of the spline function the archaeomagnetic data have been considered from 1300 on and the combined annual declination means from the geomagnetic observatories at Munich-Maisach-Fürstenfeldbruck from 1840 to 2000 and reduced to Munich have been included (147 values). We do not have good uncertainty estimates for the data and for this reason no weighting has been applied. The knot-point spacing of the spline function has been set to 25 years. The minimum root mean square (rms) misfit of this spline curve is 2.89°. The residuals between data and curve are not normally distributed, but show a symmetric distribution with good fit to the majority of the data and some significant outliers. In order to avoid an influence from obviously erroneous data we rejected several outliers. As the residuals are not truly normally distributed and we have no information on the uncertainty distribution of the data, we somewhat arbitrarily rejected all data lying further than three standard deviations away from this initial curve (26 rejected values). We fit a new smoothing spline to the remaining declination values, which can achieve a new minimum rms misfit of 1.45°. In order to keep the variability of the whole curve comparable with the recent end, the fit to the observatory values, we

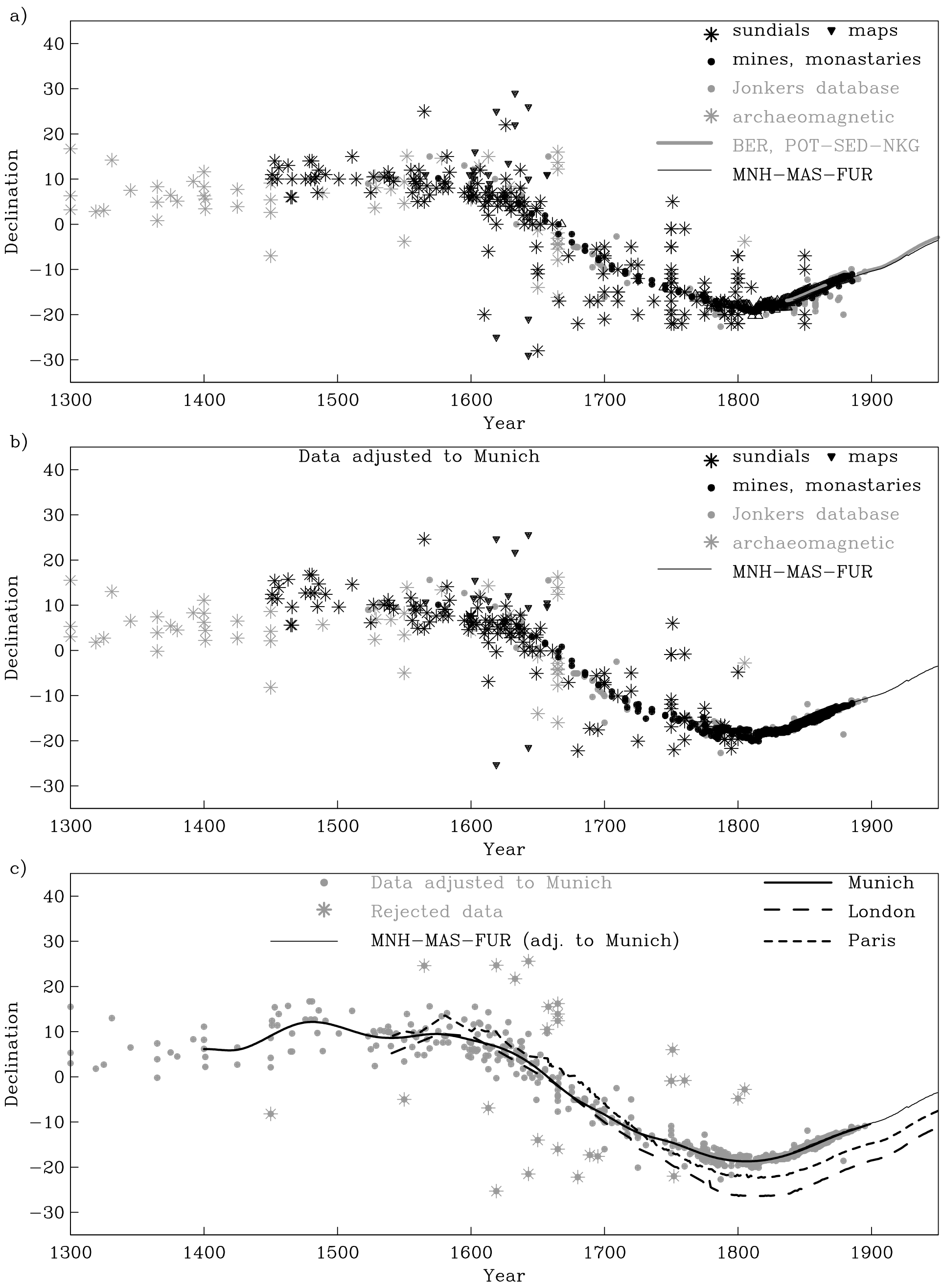

Figure 7: All new (black symbols) data presented in Fig. 3a to d together with previously published historical and archeomagnetic data (gray symbols) on a) their original locations and b) adjusted to Munich (11.57E 48.13N). c) Historical declination curves for Munich (thick black line, see text), London (long dashed line, Malin and Bullard (1981)) and Paris (short dashed line, Alexandrescu et al. (1996)). The data used and rejected for the Munich curve are shown here as gray dots and stars, respectively. The time series from the observatories in Munich, Maisach and Fürstenfeldbruck (adjusted to Munich) is given as thin black line.

applied a slight smoothing. Our preferred curve has an rms misfit of 1.48° and is shown as thick solid line in Fig. 7c. The curve is also provided in the supplemental data file.

5. Comparison to other declination curves

The declination curves by Malin and Bullard (1981) and Alexandrescu et al. (1996) for London and Paris, respectively, are included in Fig. 7c. The agreement in general shape of European declination variation is obvious. The intersection between the Munich and Paris curves confirms again the change from more easterly declination further west (Paris) to more westerly declination there than further east (Munich) in the early 18^{th} century. The new Munich curve shows a somewhat different variability in the 16^{th} and 17^{th} century than the previous curves. Geomagnetic jerks, characterised by a sharp extrema of secular variation like the 1969 event, can be identified as rather broad minimum or maxima in the curve. The well-known 1978 and 1990 geomagnetic jerks, however, are not detected as they occur near the very end of the investigated period. Moreover, a comparison of secular variation in form of the first derivative of the spline function with first differences of the MNH-MAS-FUR data series (Fig. 8a), slightly smoothed by an 11-yr running average, to minimise the solar cycle related variations, shows that for the recent decades the spline function is not able to represent the very short time-scale changes, recently defined as "rapid secular variation fluctuations" by Mandea and Olsen (2009).

The occurrence time of maxima and minima of the curve, representing geomagnetic jerks, can be determined more easily by looking for changes of sign in the second derivative, secular acceleration, which is also shown in Fig. 8a. Note that the sharp angles in this secular acceleration curve are a consequence of the 25 year knot-point spacing of the cubic spline basis functions, but the zero crossings accurately represent the times where maxima and minima occur in the secular variation curve. Indeed, the sign changes of the Munich secular acceleration around 1932, 1889 and 1861 roughly agree with the known geomagnetic jerks in 1925, 1901 and 1870 described by Alexandrescu et al. (1995, 1997). The comparison between the observatory data and the smoothed historical curve around 1925 suggests that the uncertainty in dating these jerks lies in the smoothed representation and we consequently should adopt an uncertainty of about ±10 yrs for all earlier events shown by our curve. The new Munich curve suggests events at 1763, 1741, 1708, 1693, 1661, 1558, 1508, 1448 and 1410, although the two earliest have to be regarded with caution because they are constrained only by few data. Two more geomagnetic jerks might have occured around 1598 and 1603, but are less clearly resolved.

Alexandrescu et al. (1997) describe five possible jerks between 1680 and 1870, based on their study of the Paris data series. They are dated 1700, 1730, 1750, 1770 and 1785. Considering the data noise and some baseline problems for the first two centuries of the Paris curve, Alexandrescu et al. (1997) conclude that none of these jerks is deeply supported by their data and the presence of any geomagnetic jerk between 1680 and 1870 could be doubted. Comparing their and our geomagnetic jerk occurrence times, the sign change of secular acceleration (maximum or minimum of secular variation), and taking into account the significant temporal uncertainties, the events dated 1700/1708, 1730/1741 and 1750/1763 could represent the same events. On the other hand, our compilation identifies no events in 1770 and 1785.

The identification of geomagnetic jerks by Alexandrescu et al. (1997) was carried out on a significantly less smoothed data series. We applied a similar spline fit to the Paris data series for a more direct comparison to our analysis. We used the annual data presented by Alexandrescu et al. (1996), which go back to 1541, and added 26 archeomagnetic declination values from France for the time span 1300 to 1540, mainly compiled by Bucur (1994) and digitally available from the global compilation by Korte et al. (2005) or the GEOMAGIA V.2 database (http://www.geomagia.ucsd.edu). The declination series by Alexandrescu et al. (1996) is adjusted to the location of Chambon-la-Forêt (2.27E, 48.02N), the location of the present observatory near Paris. We adjusted the archeomagnetic data to the same location using the *gufm1* model as described for the German data in section 4. The data were fit by smoothing splines for the same time interval (1300 to 2000) and with the same knot-point spacing (25 yrs) as the Munich curve. A comparable variability of the curve was obtained by applying weak smoothing and fitting the data to an rms misfit of 0.69°. Secular variation and acceleration at Paris are represented by the first and second derivative of this curve in Fig. 8b.

The comparison of the smoothed Munich and Paris secular variation is best described in three time intervals: 1400 – 1580, 1580 – 1770 and 1770 – 2000. During the recent time interval, from about 1770 onwards, secular variation and acceleration at both locations broadly agree, with the jerk seen in 1901 in the original French data also represented slightly earlier by the smooth Paris curve, but agreeing within our estimated dating uncertainty of ±10 yrs due to the smoothing. The earliest time interval from 1400 to about 1580, least well supported by data particularly in the Paris curve, also shows surprisingly consistent secular variation and acceleration between the smoothed curves from the two locations. Larger time lags between similar patterns in this case might be influenced by relatively large dating uncertainties associated with the archeomagnetic data, but artificial oscillations in the spline fit resulting from the sparse data until 1550 can also not be ruled out.

Significant differences between the two locations are seen in the time interval between 1580 and 1770. The geomagnetic jerks suggested between 1580 and 1680 by the Munich curve are not confirmed by the Paris curve. During this interval, however, the Paris curve might lack some information as it is based only on 25 annual values derived from 35 individual measurements, while 128 data points support the Munich curve within this interval. After 1680, when a reasonable amount of data exists for both locations, the smoothed Paris curve only shows one of the five jerks suggested by Alexandrescu et al. (1997) based on the original data (at 1700). However, no deceleration (i. e. secular acceleration ¡ 0) appears in the smoothed curve for nearly two centuries after that event. The existence and tentative link between suggested jerks about 1700/1708, 1730/1741 and 1750/1763 thus neither can be confirmed nor excluded by this comparison. Both analyses agree, however, that the century from about 1765 to about 1865 is devoid of strong rapid secular variation changes. This is the time when the declination in Europe has reached its most western values and changes its trend, i.e. the minimum seen in the declination curve (Fig. 7c).

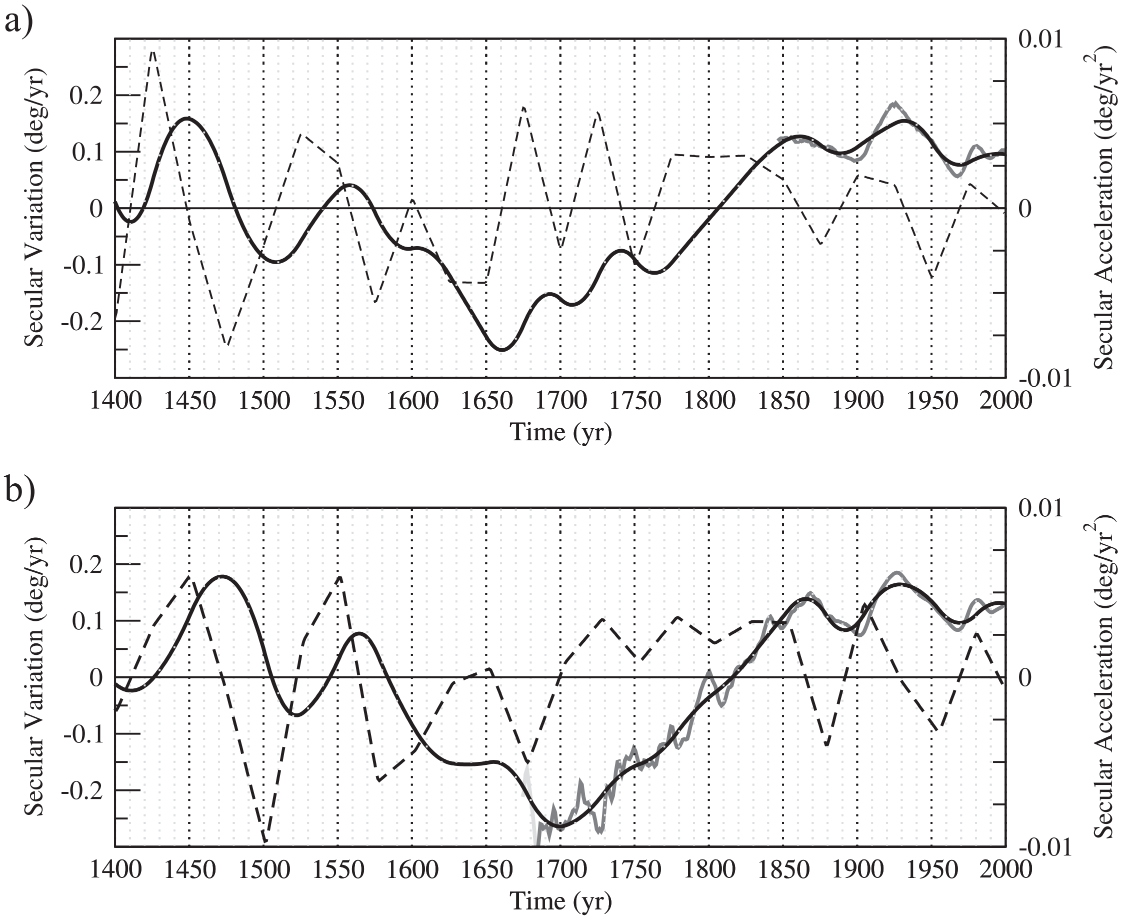

Figure 8: Secular variation and acceleration for Munich (a) and Paris (b). Secular variation is given by the first temporal derivative of the smoothed curves fit to the declination data (black) and by first differences of the data series smoothed by 11-yr running averages (gray, MNH-MAS-FUR (a) and of the declination data from Alexandrescu et al. (1996) (b), respectively). Secular acceleration (dashed lines) of the declination curves is shown with right-side label axes.

6. Conclusions

We have compiled 635 historical declination values from southern Germany and surrounding areas from different sources. The accuracy of declination values determined from sundials and old compasses from the 15th to 19th century are in the same order as that of the available archeomagnetic data. Measurements in mines and those made by monks from the 17th to 19th century show an accuracy better than 1°. All these data can be useful to improve historical geomagnetic field models and to link archeomagnetic and historical field reconstructions. Declination values obtained from church orientations, however, have to be taken with caution. They require more comprehensive statistical investigations than currently available for Germany in order to be considered as a source of historical declination information.

The compiled data have been adjusted to the location of Munich together with available archeomagnetic and previously published historical data. A smooth declination curve has been fit to the data, extending the existing observatory record from MNH-MAS-FUR backward to AD 1400. The comparison to declination curves for Paris and London shows a broadly uniform European declination variation, but with a significant spatial gradient change in the early 18th century.

The smooth secular variation description provided by the Munich declination curve indicates several geomagnetic jerks with an uncertainty of about ±10 years, as can be estimated for the well-known jerks of the 20th century. The geomagnetic jerk shown by the Munich curve around 1861 is presumably the one proposed around 1870 based on data from Paris and four other European locations by Alexandrescu et al. (1997). Three jerks suggested by Alexandrescu et al. (1997) from the Paris data over the 18th century might be confirmed by this new compilation: 1750/1763, 1730/1741 and 1700/1708 (first date is based on the Paris original data, the second one is based on the smoothed Munich curve). However, the two more recent events are not seen in the Paris curve smoothed in the same way as the Munich one. Going back in time, several earlier events are suggested by the Munich curve around the following epochs: 1693, 1661, 1558, 1508, and perhaps, but less clearly resolved or supported by data, in 1603, 1598, 1448 and 1410. An analysis of the similarly smoothed, sparse Paris data over the 17th and 16th century, however, suggests significantly different secular variation and acceleration during these times and does not support the suggested jerks.

More data are necessary and regional or global modelling might help to resolve whether true small-scale field structure or insufficient data cause the observed differences. Note also that jerks in relatively quick succession, like e.g. the 1979 and 1990 events, can in general not be resolved by a smoothed declination reconstruction. In summary, our study suggests that geomagnetic jerks, as defined by Mandea and Olsen (2009), occurred more or less regularly on a decadal time scale (from some three to six decades) during most of the studied six centuries. However, the time span from about 1760 to 1860 seems to have been devoid of sudden secular variation changes.

We expect that this new data compilation will be useful to improve historical geomagnetic field models and to better track the different temporal variations revealed by the Earth's magnetic field. We also hope that our work will encourage the search for unknown ancient geomagnetic field data from all around the world.

Acknowledgements

We thank Klaus Eichholz for information on sundials and historical compass scales, and Nils Olsen for drawing our attention to the work of Nils Abrahamsen. We thank P. Amand Kraml (Kremsmünster) and P. Gregor Helms (Augsburg) for support in their monasteries and Peter Winkler for support at Hohenpeissenberg and helpful discussions. We particularly acknowledge efforts by Hannelore Podewski, Francesca Overbeck and Martin Feller for documenting and digitizing all the data from the literature. We also thank two anonymous reviewers for constructive comments which helped us to improve the original manuscript.

A. Declination from sundials and compasses

[h]

Year	ΔT	D (deg.)	Location	Manufacturer	Reference	Ref. No.	Given Age
1451	0	10.0	Vienna	G. Peuerbach	Wagner (1997), Zinner (1979)		
1451	0	11.0	Vienna	G. Peuerbach	Wagner (1997), Zinner (1979)		
1453	0	14.0	Vienna	G. Peuerbach	Wagner (1997), Zinner (1979)		
1455	0	10.0	Vienna	G. Peuerbach	Zinner (1979)	4525	
1456	0	12.5	Vienna	G. Peuerbach	Wagner (1997), Zinner (1979)		
1463	0	13.0	Budapest	J. Regiomontan	Zinner (1979)	122	
1465	0	6.0	Nuremberg	J. Regiomontan	Wagner (1997), Zinner (1979)		
1466	2	6.0	Nuremberg	J. Regiomontan	Zinner (1979)	WI 7	1464-1467
1466	2	10.0	Nuremberg	J. Regiomontan	Zinner (1979)	F 1361	1464-1467
1476	0	10.0	(Budapest)	C. Dorn	Zinner (1979)	12364	
1479	0	14.0	(Budapest)	C. Dorn	Zinner (1979)	288	
1480	0	10.0	(Budapest)	C. Dorn	Zinner (1979)		
1481	0	14.0	(Budapest)	C. Dorn	Zinner (1979)	G 425	
1483	3	10.0	(Budapest)	C. Dorn	Zinner (1979)		1480-1486
1484	2	14.0	unknown	W. Faber	Zinner (1979)		presum. 1484
1485	5	7.0	(Budapest)	C. Dorn	Zinner (1979)	1893	1480-1490
1486	0	12.0	(Budapest)	C. Dorn	Zinner (1979)		
1491	0	11.0	Vienna	C. Dorn	Zinner (1979)	94	
1501	0	10.0	Nuremberg	E. Etzlaub	Wagner (1997), Gouk (1988)		
1511	0	15.0	Nuremberg	E. Etzlaub	Zinner (1979)	WI 28	
1514	0	10.0	unknown	unknown	Körber (1964)	DI 65	
1525	25	7.0	Kassel	B. Emck	Hamel (2000), Mackensen	Mat U 24	1^{st} half $16.^{th}$ cent.
1527	0	10.5	Nuremberg	G. Hartmann	Zinner (1979)		
1535	0	10.5	Nuremberg	G. Hartmann	Wagner (1997), Gouk (1988)		
1538	0	11.5	Nuremberg	G. Hartmann	Wagner (1997), Gouk (1988)		
1539	0	10.25	Nuremberg	G. Hartmann	Zinner (1979)	Rar 434	
1539	0	10.25	Nuremberg	G. Hartmann	Zinner (1979)	WI 182	
1542	0	9.5	Nuremberg	G. Hartmann	Wagner (1997), Gouk (1988)		
1555	0	12.0	Nurmeberg	G. Reimann	Zinner (1979)	WI 267	
1556	0	7.0	Nuremberg	J. Gebhard	Wagner (1997), Bryden (1988)	1681	
1557	0	10.0	Augsburg	C. Schissler	Wagner (1997)		
1558	0	9.5	Nuremberg	H. Reimann	Wagner (1997), Syndram (1989)	N. 12	
1559	0	9.0	Augsburg	C. Schissler	Wagner (1997), Zinner (1979)		
1560	10	5.0	Dresden	Göbe	Kleinschmidt (1989), Körber (1964)	DI 63	about 1560
1561	0	8.0	unknown	unknown	Hamel (2000), Zinner (1979)	MATB75	
1561	0	12.0	unknown	unknown	Wagner (1997),Körber (1964)	DI 12	
1562	0	10.0	Augsburg	C. Schissler	Wagner (1997), Körber (1964)	DI 37	
1565	0	5.0	Augsburg	(C. Schissler)	Wagner (1997), Körber (1964)	DI 22	
1565	0	25.0	(Nuremberg)	C. Heiden	Hamel (2000), Zinner (1979)	MAT B 29	
1567	0	8.5	Augsburg	C. Schissler	Wagner (1997), Zinner (1979)		
1569	0	6.5	Augsburg	C. Heiden	Wagner (1997), Zinner (1979)		
1574	0	8.0	Nuremberg	H. Tucher	Wagner (1997), Zinner (1979)		

Year	ΔT	D (deg.)	Location	Manufacturer	Reference	Ref. No.	Given Age
1579	0	8.0	Nuremberg	H. Tucher	Wagner (1997),Körber (1964)	1	
1580	0	9.5	Nuremberg	H. Ducher	Wagner (1997), Syndram (1989)	N. 14	
1581	0	9.13	Augsburg	T. Klieber	Zinner (1979)		
1582	0	15.0	(Kassel)	J. Bürgi	Zinner (1979)		
1583	0	8.0	Nuremberg	P. Reinmann	Wagner (1997), Zinner (1979)		
1584	0	11.5	Nuremberg	P. Reinmann	Wagner (1997), Zinner (1979)		
1595	0	7.0	Nuremberg	H. Tucher	Wagner (1997), Lloyd (1992)		
1598	0	6.0	(Antwerpen)	unknown	Wagner (1997), Syndram (1989)	Nr. 17	
1600	0	8.0	Bamberg	J. Bonius	Glasemann (1999)	Nr. 53	
1600	0	8.0	Nuremberg	H. Troschel	Wagner (1997), Lloyd (1992)		
1600	5	8.0	unknown	"R"	Hamel (2000), Zinner (1979)	MAT B 72	about 1600
1601	0	6.0	Nuremberg	Troschel	Wagner (1997), Körber (1964)	2	
1602	0	6.5	Nuremberg	P. Reimann	Wagner (1997), Zinner (1979)		
1604	2	6.0	Nuremberg	unknown	Kleinschmidt (1989), Körber (1964)		after 1602
1605	2	9.0	Dresden	unknown	Kleinschmidt (1989), Körber (1964)	AI 44	after 1603
1607	0	12.0	Nuremberg	P. Reimann	Wagner (1997), Zinner (1979)		
1610	0	4.0	Nuremberg	Lösel	Wagner (1997), Körber (1964)	4	
1610	0	-20.0	(Augsburg)	L. Miller	Zinner (1979)		
1611	0	5.0	Nuremberg	H. Troschel	Wagner (1997), Lloyd (1992)	7534	
1611	0	7.0	Nuremberg	H. Tucher	Wagner (1997), Lloyd (1992)	7577	
1613	0	-6.0	Kassel	J. Bürgi	Zinner (1979)		
1613	0	2.0	Nuremberg	L. Miller	Wagner (1997), Gouk (1988)	1684	
1613	0	5.0	Nuremberg	L. Miller	Wagner (1997), Lloyd (1992)	7459	
1614	0	6.5	Nuremberg	H. Tucher	Wagner (1997)	H 5820	
1616	0	7.0	Nuremberg	L. Miller	Wagner (1997), Lloyd (1992)	7565	
1619	0	0.0	Nuremberg	G. Karner	Wagner (1997), Zinner (1979)		
1620	0	4.0	Nuremberg	C. Karner	Wagner (1997), Lloyd (1992)	7542	
1620	0	5.5	Nuremberg	C. Trechsler	Wagner (1997), Syndram (1989)	N. 37	
1622	0	5.0	Nuremberg	C. Karner	Wagner (1997), Lloyd (1992)	7552	
1624	0	7.0	Nuremberg	H. Tucher	Wagner (1997), Zinner (1979)		
1625	0	6.0	Nuremberg	L. Miller	Wagner (1997)		
1625	0	6.0	Nuremberg	L. Miller	Wagner (1997), Zinner (1979)		
1626	0	5.0	Nuremberg	H. Troschel	Wagner (1997), Lloyd (1992)	7458	
1626	0	7.0	Nuremberg	C. Karner	Hamel (2000), Zinner (1979), Gouk (1988)		
1626	0	10.0	Nuremberg	H. Troschel	Hamel (2000), Zinner (1979), Gouk (1988)		
1626	0	22.0	changed	C. Karner	Hamel (2000), Zinner (1979), Gouk (1988)		
1629	0	4.0	Nuremberg	L. Miller	Wagner (1997),Lloyd (1992)	7560	
1630	0	3.0	Nuremberg	C. Karner	Wagner (1997),Lloyd (1992)	7553	
1630	0	4.0	Nuremberg	C. Karner	Wagner (1997),Lloyd (1992)	7554	
1630	0	7.0	Nuremberg	L. Miller	Wagner (1997),Lloyd (1992)	7567	
1634	0	6.0	Augsburg	L. Miller	Wagner (1997), Körber (1964)	5	
1636	0	4.0	Nuremberg	J. Karner	Wagner (1997), Lloyd (1992)	7550	
1636	0	4.0	Nuremberg	L. Miller	Wagner (1997), Syndram (1989)	N. 19	
1636	0	5.0	Nuremberg	L. Miller	Wagner (1997), Lloyd (1992)	7568	
1637	0	8.0	Nuremberg	L. Miller	Hamel (2000), Gouk (1988), Zinner (1979)		
1637	0	12.0	changed	L. Miller	Hamel (2000), Gouk (1988), Zinner (1979)		

Year	ΔT	D (deg.)	Location	Manufacturer	Reference	Ref. No.	Given Age
1639	0	2.0	Nuremberg	J. Karner	Wagner (1997), Gouk (1988)	634	
1640	0	0.0	Nuremberg	L. Miller	Wagner (1997), Gouk (1988)	1684	
1640	0	4.0	Nuremberg	L. Miller	Wagner (1997), Lloyd (1992)	7562	
1640	0	5.0	Nuremberg	L. Miller	Wagner (1997), Gouk (1988)	1683	
1642	0	2.0	South Ger.	L. Hartmann	Wagner (1997)		
1644	0	1.0	Nuremberg	L. Miller	Wagner (1997), Lloyd (1992)	7563	
1646	0	0.0	Nuremberg	L. Miller	Wagner (1997), Gouk (1988)	184	
1649	0	3.0	Nuremberg	N. Miller	Wagner (1997), Lloyd (1992)	1770	
1649	0	3.5	Nuremberg	N. Miller	Wagner (1997), Syndram (1989)	N. 21	
1649	0	-5.0	Nuremberg	N. Miller	Wagner (1997), Gouk (1988)	1686	
1650	5	-28.0	unknown	unknown	Hamel (2000)	MAT B 81	about 1650
1650	50	-10.0	unknown	unknown	Körber (1964)	7	ca. 17th cent.
1650	50	-11.0	unknown	unknown	Körber (1964)	compass	ca. 17th cent.
1652	0	0.0	Nuremberg	L. Miller	Wagner (1997), D.M.Mnchen	69503	
1652	0	5.0	Nuremberg	A. Karner	Wagner (1997), Lloyd (1992)	7540	
1661	0	0.0	Nuremberg	N. Miller	Wagner (1997), Zinner (1979)		
1666	13	-17.0	unknown	J. Koch	Zinner (1979)	1880-36	
1673	0	-7.0	Nuremberg	unknown	Wagner (1997), Zinner (1979)		
1680	10	-22.0	Augsburg	J. Martin	Körber (1964)	11	approx. after 1670
1689	0	-17.0	(Kassel)	J.W. Schulze	Hamel (2000), Zinner (1979)	MATB23	
1694	0	-5.5	Nuremberg	M. Karner	Wagner (1997)		
1695	5	-17.0	Cologne	S. Krigner	Hamel (2000), Zinner (1979)	MAT 1997-6	1690-1700
1699	0	-11.0	unknown	Richardus	Wagner (1997), Körber (1964)	26	
1700	0	-5.0	Nuremberg	G. Karner	Wagner (1997), Lloyd (1992)	7525	
1700	5	-7.0	Augsburg	J. Martin	Hamel (2000), Zinner (1979)	MAT B 25	about 1700
1700	5	-7.0	Augsburg	J. Martin	Hamel (2000), Zinner (1979)	MAT	about 1700
1700	5	-7.5	Augsburg	J. Martin	Hamel (2000), Zinner (1979)	MAT B 62	about 1700
1700	5	-15.0	changed	J. Martin	Hamel (2000), Zinner (1979)	MAT B 62	about 1700
1700	5	-21.0	unknown	(Krigner)	Körber (1964)	DI 80	
1750	50	-11.0	Augsburg	Höldrich	Körber (1964)	DI 64	
1750	50	-13.0	unknown	unknown	Körber (1964)	DI 88	
1750	50	-13.0	Augsburg	A. Braunmüller	Zinner (1979)	6625	
1710	10	-10.0	Augsburg	J. Willebrand	Glasemann (1999)		beg. 18^{t}h cent.
1710	10	-15.0	German	unknown	Glasemann (1999)	Nr. 38	early 18th cent.
1710	10	-15.0	unknown	H.G. Wellingen	Hamel (2000), Hausmann	MAT A 27	beg. 18^{t}h cent.
1710	10	-17.0	German	unknown	Glasemann (1999)	Nr. 37	early 18th cent.
1720	5	-5.0	Augsburg	J. Willebrand	Hamel (2000), Zinner (1979)	MAT B 49	about 1720
1720	10	-9.0	Augsburg	J. Willebrand	Körber (1964)	DI 94	about 1720
1725	25	-9.0	unknown	unknown	Hamel (2000)	MAT B 21	1st half 18th cent.
1725	25	-12.0	(Hessen)	unknown	??	MAT B 26	1st half 18th cent.
1725	25	-20.0	Nuremberg	L.A. Karner	Hamel (2000), Gouk (1988), Zinner (1979)	MAT B 78	1st half 18th cent.
1737	12	-17.0	unknown	unknown	Glasemann (1999)	Nr. 25	2nd quarter 18th cent.
1750	0	-14.0	Augsburg	L.T. Müller	Hamel (2000), Zinner (1979)	MATB59	
1750	0	-17.0	Augsburg	L.T. Müller	Hamel (2000), Zinner (1979)	MATB84	
1750	5	-15.0	unknown	unknown	Hamel (2000)	MAT B 61	about 1750
1750	10	-5.0	unknown	unknown	Hamel (2000)	MAT B 82	middle 18th cent.

Year	ΔT	D (deg.)	Location	Manufacturer	Reference	Ref. No.	Given Age
1750	10	-12.0	Augsburg	J.P. Bihler	Syndram (1989)	H-W 70	middle 18th cent.
1750	50	-5.0	unknown	"B"	Körber (1964)	19	about 18th cent.
1750	50	-10.0	unknown	unknown	Hamel (2000)	MAT B 32	18th cent.
1750	50	-15.0	unknown	unknown	Körber (1964)	49 compass	about 18th cent.
1750	50	-17.0	Augsburg	A. Vogler	Hamel (2000), Zinner (1979)	MAT B 87	18th cent.
1750	50	-19.0	unknown	Pfersich	Körber (1964)	12	about 18th cent.
1750	50	-20.0	unknown	unknown	Körber (1964)	17	about 18th cent.
1750	50	-22.0	unknown	"K"	Körber (1964)	23	about 18th cent.
1751	0	5.0	Lüttich	Vineron	Körber (1964)	compass	
1752	0	-22.0	Nuremberg	L.A. Karner	Wagner (1997)		
1758	0	-22.0	unknown	A.F.	Wagner (1997),	22	
1760	5	-15.0	Augsburg	L.T. Miller	Wagner (1997), Körber (1964)		about 1760
1760	5	-15.0	Augsburg	L.T. Mller	Glasemann (1999) Körber (1964)	Nr. 32	ca. 1760
1760	5	-15.0	Nuremberg	D. Beringer	Kleinschmidt (1989), Körber (1964)	DI 94	about 1760
1760	5	-15.0	Reinharz	J.G. Zimmer	Kleinschmidt (1989), Körber (1964)	DI 7	about 1760
1760	5	-20.0	Augsburg	J.G. Vogler	Kleinschmidt (1989), Körber (1964)	DI 96	about 1760
1769	0	-17.0	unknown	unknown	Wagner (1997), D.M.Mnchen	80/239	
1775	5	-16.0	Augsburg	L. Grassl	Kleinschmidt (1989), Körber (1964)	DI 89	about 1775
1775	25	-13.0	Augsburg	A. Vogler	Glasemann (1999)	Nr. 30	2nd half 18th cent.
1775	25	-15.0	Augsburg	L. Grassl	Glasemann (1999)	Nr. 33	2nd half 18th cent.
1775	25	-15.0	German	unknown	Glasemann (1999)	Nr. 41	2nd half 18th cent.
1775	25	-20.0	German	unknown	Glasemann (1999)	Nr. 40	2nd half 18th cent.
1777	2	-17.0	Nuremberg	D. Beringer	Hamel (2000), Zinner (1979)	MAT B 93	1775-1780
1780	15	-18.0	German	unknown	Syndram (1989)	H-W	last third 18th cent.
1787	12	-17.0	Ansbach	K.C. Keller	Glasemann (1999)	Nr. 35	last quarter 18th cent.
1790	10	-17.0	Augsburg	J.N. Hölderich	Hamel (2000), Zinner (1979)	MAT B 63	end 18th cent.
1790	10	-20.0	Nuremberg	D. Beringer	Hamel (2000), Zinner (1979)	MAT B 110	end 18th cent.
1790	10	-20.0	Nuremberg	D. Beringer	Hamel (2000), Zinner (1979)	MAT B 67	end 18th cent.
1790	10	-20.0	Nuremberg	J.B. Bauer	Glasemann (1999)	Nr. 81	late 18th cent.
1790	10	-20.0	Nuremberg	P.P. Beringer	Hamel (2000), Zinner (1979)	MAT B 113	end 18th cent.
1790	10	-20.0	Nuremberg	P.P. Beringer	Hamel (2000), Zinner (1979)	MAT B 68	end 18th cent.
1795	5	-20.0	Augsburg	J. Schretteger	Kleinschmidt (1989), Körber (1964)		ca. after 1790
1795	5	-22.0	Augsburg	J. Schretteger	Kleinschmidt (1989), Körber (1964)	DI 91	ca. after 1790
1798	0	-15.0	unknown	I.C.R.	Wagner (1997),Körber (1964)	DI 95	
1800	5	-7.0	unknown	unknown	Hamel (2000)	MAT B 3	about 1800
1800	5	-7.0	unknown	unknown	Hamel (2000)	MAT B 6	about 1800
1800	5	-17.0	unknown	unknown	Hamel (2000)	MAT B 65	about 1800
1800	5	-20.0	unknown	unknown	Hamel (2000)	MAT B 71	about 1800
1800	5	-22.0	unknown	unknown	Hamel (2000)	MAT B 69	about 1800
1800	5	-22.0	unknown	unknown	Hamel (2000), Zinner (1979)	MAT B 70	about 1800
1800	10	-7.0	Cologne	E. Schmaldt	Hamel (2000), Zinner (1979)	MAT B 88	about 1800
1800	10	-20.0	Fürth	Stockkert	Hamel (2000), Zinner (1979)	MAT B 66	about 1800
1800	50	-11.0	unknown	unknown	Körber (1964)	24	about 18/19th cent.
1800	50	-12.0	unknown	unknown	Körber (1964)	DI 85	18/19th cent.
1800	50	-13.0	unknown	unknown	Körber (1964)	DI 86	18/19th cent.

Year	ΔT	D (deg.)	Location	Manufacturer	Reference	Ref. No.	Given Age
1810	10	-14.0	unknown	unknown	Hamel (2000)	MAT B 14	begin. 19th cent.
1820	5	-18.0	unknown	unknown	Kleinschmidt (1989), Körber (1964)	DI 82	about 1820
1850	10	-20.0	German	unknown	Glasemann (1999)	Nr. 35	middle 19th cent.
1850	50	-7.0	unknown	unknown	Hamel (2000)	MAT B 16	19th cent.
1850	50	-22.0	unknown	unknown	Körber (1964)	25	about 19th cent.
1850	50	-10.0	unknown	unknown	Körber (1965)	DI 77	19th cent.

B. Declination from maps

Differing declination estimates by different authors are given in one line of the table. All values with references Bachmann (1941, 1942, 1961) are the values taken from these reproductions of the original maps by us.

Year	D (deg.)	Location	Reference
1566	11	Zürich	Körber (1965)
1599	6 / 11 / 8	Nuremberg	Körber (1965) / Kleinschmidt (1989) / Bachmann (1942)
1599	6	Munich	Wagner (1997)
1602	11 / 10 / 12	Bamberg	Körber (1965) / Kleinschmidt (1989) / Bachmann (1942)
1603	16	Konstanz	Kleinschmidt (1989) (Bodenseekarte by J.G. Tibian)
1613	8 / 11 / 11	Munich	Körber (1965) / Kleinschmidt (1989) / Bachmann (1942)
1614	6 / 9	Landshut	Körber (1965) / Bachmann (1942)
1619	25	Thierhaupten	Kleinschmidt (1989), Bachmann (1942)
1619	-25	Donauwörth	Kleinschmidt (1989), Bachmann (1942)
1628	13.5	Bunde	Kleinschmidt (1989) (map by J. Sems)
1633	22 / 29 / 22	Bamberg	Körber (1965) / Kleinschmidt (1989) / Bachmann (1942)
1643	-29 / -21	Wolfegg	Kleinschmidt (1989) / Bachmann (1961)
1643	10	Leutkirchen	Kleinschmidt (1989), Bachmann (1961)
1643	26	Giengen	Kleinschmidt (1989), Bachmann (1961)
1657	11	Minden	Körber (1965), Bachmann (1941)

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