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World Monthly Means Database Project

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Abstract

Observatory monthly means are widely used for studying geomagnetic secular variation. They provide a better time resolution than annual means and are well suited for investigating the so-called geomagnetic jerks. While annual and hourly means have been compiled for a long time within the WDC system, no such tradition exists for monthly means. This project aims at filling the gap by building a publicly available monthly means database. It is also motivated by the need to resolve occasional inconsistencies between annual and hourly means present in WDCs. To begin with, we computed monthly means for all INTERMAGNET observatories from WDC hourly means. We stored them in a data format providing information on data discontinuities ("jumps"), as well as data components, quality and sources. Then we assessed the quality of the data by systematically comparing them with WDC annual means and with predictions of the CM4 geomagnetic model (Sabaka *et al*. 2004). Although most of the data are valid, some serious discrepancies arise, requiring that some observatories correct their data.

1. Introduction

Observatory monthly means are used for modeling the geomagnetic secular variation (e.g., Wardinski and Holme 2006), generated by fluid flows at the top of the Earth's core (e.g., Chulliat and Hulot 2000). Averaging over one month is a powerful and easy-to-implement way to remove most magnetic variations of external origin, while keeping variations of internal origin. More rapid variations of internal origin are filtered out by the lowly conducting mantle. Annual means are also used for studying the secular variation, but they do not provide enough time resolution for investigating sudden changes of the core field variation trend, called geomagnetic jerks (e.g., Mandea *et al*. 2000).

There are various public archives of old magnetic observatory data throughout the world (see the list in Table 1). Unfortunately, none of them compiles observatory monthly means.

Table 1

Public archives of old observatory data

Data type	WDC
Annual means	Edinburgh (BGS)
Monthly means	None
Hourly means	Copenhagen (DMI)*, Kyoto
Minute values	Copenhagen (DMI)*, Kyoto
Second values	Kyoto

*As of April 2007, the Geomagnetic Data Master Catalogue previously hosted by DMI has been transferred to the WDC in Edinburgh.

One could think of simply computing monthly means from hourly means whenever they are needed. However, it is not such an easy task to compute consistent monthly means series from WDC data. One is faced with two difficulties:

1. Data discontinuities, or “jumps”, are treated differently in the various public archives. For example, jumps are not integrated yet documented in the Edinburgh WDC, while they are neither documented nor integrated (in general) in the Copenhagen WDC.
2. There are occasional inconsistencies between data from different WDCs. Possible reasons are that data were not simultaneously sent by observatories to each WDC, or that data were not updated in all WDCs after a revision.

Several monthly means databases have been built by individual researchers in recent years. Some years ago, Mioara Mandea built such a database and made it publicly available (Alexandrescu 1998). However, this database was not always consistent with data in WDCs. As data discontinuities were integrated without being documented, it was more difficult to track down the origin of inconsistencies.

Here we propose a new method for archiving monthly means, to apply this method to INTERMAGNET observatories and systematically check the consistency of the obtained monthly means series. This is the first step toward a new, publicly available monthly means database.

2. Data Format

The IAGA-2002 format is not convenient for our purpose because it forces each year of data to be stored in a different file. Moreover, some of the information in the IAGA-2002 header is not relevant to monthly means (for example digital sampling rate) while some potentially more useful information (for example data quality) cannot be included in data records.

Thus, we designed a new, specific file format for archiving monthly means, with the following properties (see Fig. 1):

- Usual information on observatory is given in a IAGA-2002 like 5-line header.
- Information on data discontinuities is provided in the rest of the header.
- Information on observed elements, data quality and the origin of the data is provided in data records using codes (L, M and R) similar to those used by the Edinburgh WDC to store observatory annual means.
- All data for a given observatory are stored in the same file (except when the name of the observatory changes) with time counted in decimal years.

```
 Station Name                 Chambon La Foret                            |
 IAGA Code                    CLF                                         |
 Geodetic Latitude [deg]      48.017                                      |
 Geodetic Longitude [deg]     2.266                                       |
 Elevation [m]                145                                         |
 # This data file is part of the IPGP monthly means database.             |
 # Data last verified by the observatory: December 2006                   |
 # Conditions of use: these data are for scientific/academic use.         |
 # NOTES:                                                                 |
 # 1936 Site differences Val Joyeux - Chambon                             |
 # 1957 New proton magnetometer                                           |
 # 1968 Theodolite and absolute pier change                               |
 # 1983 Absolute pier change                                              |
TIME          X      Y      Z L M R
1936       -387    -96    278 9 9 1
1936.042  19724  -3323  41342 2 1 1
1936.124  19733  -3317  41351 2 1 1
1936.206  19739  -3313  41344 2 1 1
1936.290  19733  -3305  41355 2 1 1
```

Fig. 1. Header of the CLF monthly means data file in the proposed format.

3. Database Construction

To begin with, we restricted ourselves to INTERMAGNET observatories, as a first step toward a larger database. For each INTERMAGNET observatory, monthly means were calculated as far back in time as possible from hourly values retrieved from the WDC in Copenhagen, or directly from our own recently revised digital archive in case of French observatories. Information on data discontinuities was obtained from the WDC in Edinburgh, as well as information on observed elements and data quality (whenever available).

4. Checking Method

Three tests were systematically applied to each monthly means series:

1. Internal consistency of the series was checked by visual inspection of various plots. Particular attention was paid to data discontinuities.
2. Consistency between the series and that of annual means was checked by re-

calculating annual means from the monthly means. Although this is clearly not the best method to compute annual means (which should be computed from daily means), the error associated with the unequal number of days in each month is negligible for the purpose of the checking.

3. Consistency between the series and those at other observatories was checked by comparing it with the secular variation predicted by the CM4 model (Sabaka et al. 2004) from 1960 to present time. It is expected that the CM4 misfit becomes larger at an anomalous observatory provided it is not too far from other non-anomalous observatories.

5. Results of the Tests

Most tested monthly means series have no problem. However, about 10% of them fail at one test at least. It is not the purpose of this paper to list problematic observatories, since most problems should be easily corrected in the near future. Here we want to show how very simple consistency tests can be useful for improving the overall quality of data stored in public archives. Therefore, the following examples should be seen as illustrations only.

Figure 2 shows two examples of anomalies in monthly means series. The first one is an artificial offset of about 120 nT in monthly means from January to October 1984, coming from a corresponding offset in hourly values retrieved from the Copenhagen WDC. Error of that kind can be easily corrected by coming back to the original raw data. The second example of anomaly is a series of oscillations of amplitude 100-200 nT between 1950 and 1960. The cause of this observation is unknown, but it is suspicious since it is not observed in neighboring observatories.

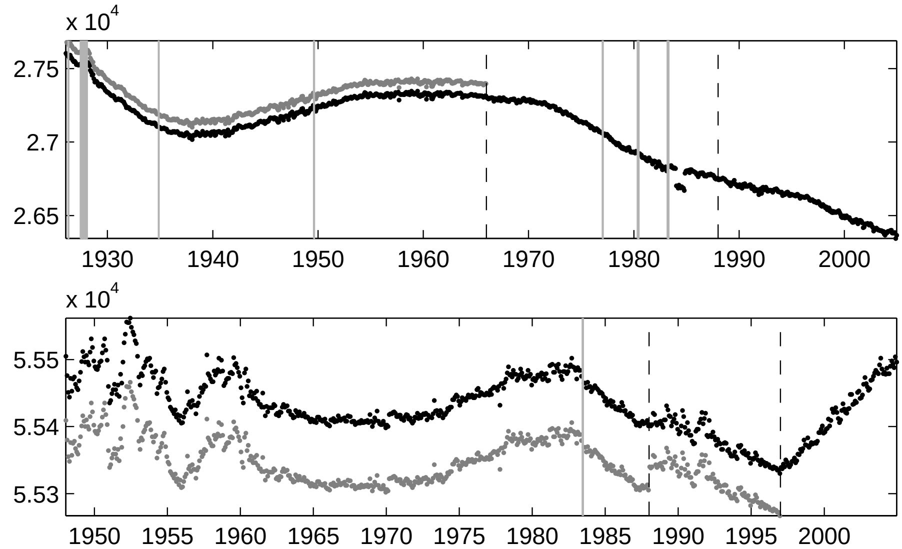

Fig. 2. Two examples of anomalies in monthly means series. The grey (resp. black) dots represent monthly means before (resp. after) integrating jumps. Jumps are indicated by vertical dashed lines. Grey rectangles show data gaps. Vertical scale in nT.

Figure 3 shows two examples of inconsistencies between monthly means (calculated from hourly values retrieved from the Copenhagen WDC) and annual means (retrieved from the Edinburgh WDC). In the first example, the 1973 jump has been integrated in annual means instead of being simply documented there. There is also an undeclared jump in 1967. Although an approximate correction of these errors is possible, a precise determination of the jump values would require having access to the original observatory data. In the second example, there is an undeclared, uncorrected jump in the annual means in 1977, which has been corrected in the hourly values (hence the absence of jump in the monthly means series).

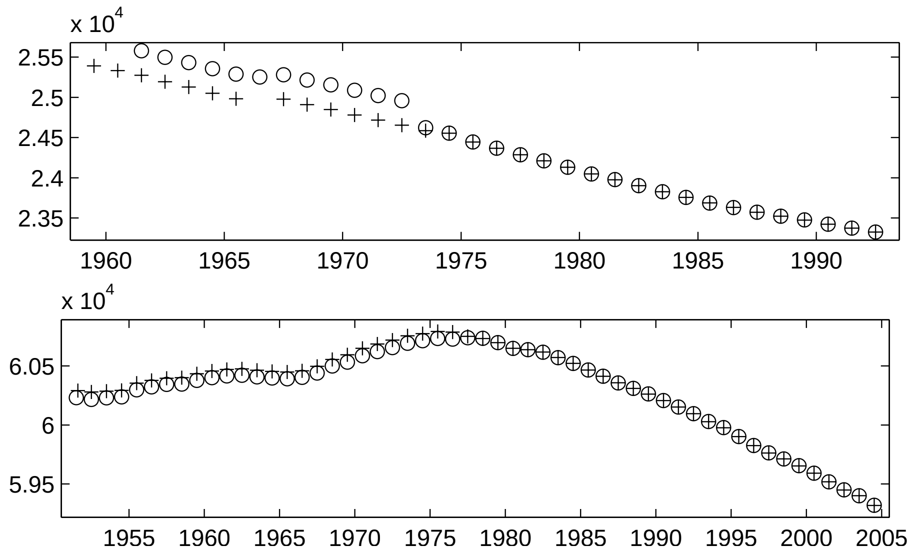

Fig. 3. Two examples of inconsistencies between monthly means and annual means. Crosses represent annual means from the Edinburgh WDC; circles represent annual means calculated from monthly means. The values are after correction of jumps. Vertical scale in nT.

Although not represented here, systematic comparison of monthly means and annual means series also reveal inconsistencies between data time spans. Quite frequently, there is at least one year with an annual mean available but without hourly value. The opposite also occurs, but less frequently.

Additional anomalies can be detected by comparing monthly means and field values predicted by the CM4 model. One such anomaly is shown in Fig. 4: there is a decreasing difference between CM4 and the monthly means of the considered observatory from 1970 to 1980. As several other observatories are located within a few thousand kilometers from this observatory, and the spatial scale of the detectable core field at the Earth's surface is about 3000 km, the core field predicted by CM4 is well constrained in the area of this observatory. Therefore, the difference between CM4 and the observatory monthly means indicates some anomaly of unknown origin in the observatory data.

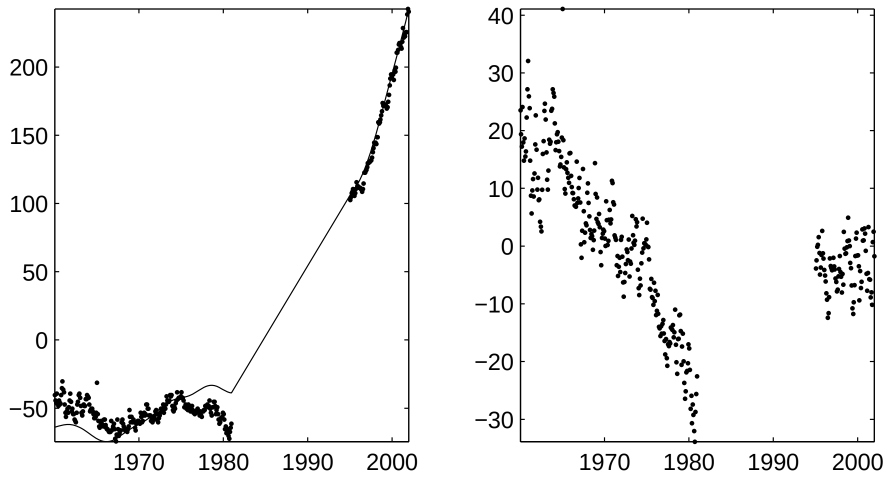

Fig. 4. An example of inconsistency between monthly means and the CM4 model. Left side graph: monthly means (dots) versus values predicted by CM4 (core field part, corrected for crustal bias) at the observatory location (line). Right-side graph: differences between the two. Vertical scale in nT.

6. Conclusion

We computed monthly means for all INTERMAGNET observatories from hourly values retrieved from the Copenhagen WDC, and archived them using a specifically designed file format. Like annual means archived at the Edinburgh WDC, we did not integrate data discontinuities but instead documented them in the header of the file.

After performing systematic tests, we found that about 10% of the monthly means series have inconsistencies, either internal or with respect to the annual means archived in Edinburgh or the CM4 model. Some of the inconsistencies can easily be corrected by the user or the relevant WDC, while others require that some observatories investigate their old original data.

The work presented here is a first step toward a new, publicly available monthly means database. The success of this project depends on the willingness of world observatories to send their old data and to investigate potential discrepancies.

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