A low-power data acquisition system for geomagnetic observatories and variometer stations

Morschhauser Achim[1], Haseloff Jürgen[1], Bronkalla Oliver[1], Müller-Brettschneider Carsten[1], and Matzka Jürgen[1]

[1]GFZ German Research Centre for Geosciences

Correspondence to: Achim Morschhauser (mors/at/gfz-potsdam.de)

Abstract. A modern geomagnetic observatory must provide data of high stability, continuity, and resolution. The INTER-MAGNET network has therefore specified quantitative criteria to ensure a high quality standard of geomagnetic observatories. Here, we present a new data acquisition system which was designed to meet these criteria, in particular with respect to 1 Hz data. This system is based on a Raspberry Pi embedded PC and a modern 24 bit analog-to-digital converter and runs a C++ data
5 acquisition software which is compatible with the POSIX standard. As a result, the data acquisition system is modular, cheap, flexible, and can be operated in remote areas with limited power supply. In addition, the system is capable of real-time data transmission, using a reverse SSH tunnel to work with any network available. We have successfully tested the system hardware at the Niemegk observatory for a period of one year and subsequently installed at the Tatuoca observatory in Brazil.

1 Introduction

10 Geomagnetic observatories are known for providing continuous and high-quality geomagnetic field data (Matzka et al., 2010). These data are essential to understand the geomagnetic field, its sources and its temporal variations (Chulliat et al., 2016). Amongst many other examples, geomagnetic observatories are an important source of reliable long-term data to resolve secular variation over several decades to centuries (e.g., Wardinski and Holme (2006); Jackson et al. (2000)), and they are essential to derive indices of geomagnetic activity (e.g., Menvielle et al. (2011)) due to their fixed position on Earth. The main disad-
15 vantage, however, is their sparse spatial global coverage (Macmillan, 2007; Rasson et al., 2010). The reason is the dependence on infrastructure such as a reliable power supply and facilities for continuous data transmission as well as their dependence on human resources for maintenance tasks and manual absolute measurements. In particular, the availability of power and continuous data transmission remains a challenge in remote areas whereas the lack of absolute measurements might be acceptable for some applications such as magnetospheric studies or short-period magnetotellurics.

20 Since the digitization of geomagnetic observatories, efficient and reliable data acquisition systems had to be developed. Such a system is responsible for digitizing the analogue output signal of the sensors, precisely timestamping the readings, and for filtering, storing, and transmitting the data. Due to the long life cycle of geomagnetic observatory installations, many of the currently used data acquisition systems have been developed in the eighties and nineties. In consequence, spare parts are more and more difficult to obtain, and modern requirements with respect to power consumption, resolution, and timestamping

accuracy can hardly be fulfilled. For example, the MAGDALOG data acquisition system developed at the GFZ German Research Centre for Geosciences (Linthe et al., 2009) runs on DOS, usually requires two additional PCs which increase power consumption, and its sampling rate of 2 Hz limits the use of digital filtering. For the above reasons, existing data acquisition systems are being modernized, including G-DAS used by BGS (Riddick et al., 2009), the system used by the Polish Academy

5 of Sciences (Reda and Neska, 2016), and ENO3 used by IPGP (Chulliat et al., 2009), or newly developed such as the system MARCOS/MARTHA of the Conrad observatory and the commercially available MAGREC-4 by MinGeo Ltd.

Here, we present a new low-power data acquisition system which was developed for geomagnetic observatories which intend to fulfill the INTERMAGNET 1 Hz data standard (Turbitt et al., 2014). This system is designed to be highly modular and flexible, allowing its adaptation to a particular location, exisiting infrastructure, and existing instrumentation. Also, easily

10 available hardware such as the Raspberry Pi embedded PC (Upton and Halfacree, 2016) has been used whenever possible, and no custom-made electronic circuit boards are necessary. The system hardware was tested at the Niemgk geomagnetic observatory and installed at the Tatuoca geomagentic observatory in Brazil (Morschhauser et al., 2017). These systems run a previous version of the data acquisition software which is mainly based on shell and Perl scripts along with C code for serial communication. The new software package is based on object-oriented C++ and was tested in Niemegk, but more development

15 and testing is necessary to be used in a productive system. We believe that an efficient and versatile data acquisition system can only be developed with the support and experience of the community, and therefore encourage active participation in the project by publishing the source code at a GFZ GitLab server under the creative commons license for non-commercial use.

Details of the design criteria and functionality of the data acquisition system are presented in Sec. 2. Subsequently, the hardware is described in Sec. 3 and the data acquisition software is presented in Sec. 4. Finally, we will conclude with discussions

20 and conslusions in Sec. 5.

2 Design Criteria and Functionality

A modern data acquisition system for geomagentic observatories should meet a variety of requirements. Many of these requirements are included in the INTERMAGNET 1 Hz data standard (Turbitt et al., 2014), others result from operational conditions in remote areas.

25 INTERMAGNET secifies that the timestamping accuracy for 1 Hz data should be better than 10 ms and that the deviation from a linear phase response should be less than 10 ms (Turbitt et al., 2014). This can be achieved by precise GPS or radio controlled clocks in combination with good knowledge of the inherent time delays of the data acquisition system. In addition, the characteristics of the used analog and digital filters should have a linear phase response and be well characterized. Also, INTERMAGNET requires a noise level of less than 10 pT $Hz^{-1/2}$ at 0.1 Hz. Amongst good sensors, this requires efficient

30 anti-aliasing whilst the employed low-pass filter should not damp power in the passband. Indeed, INTERMAGNET requires at least 50 dB attenuation in the stop band, less than 3 dB attenuation in a transition pass band of 8 mHz (120 s) to 0.5 Hz (2 s), and minimum attenuation in a passband of DC to 8 mHz (Turbitt et al., 2014). Therefore, specifically designed digital filters should be used along with high sampling rates, ideally faster than 120 Hz. Further, an analog filter is recommended in order to avoid

aliasing of frequencies above the Nyquist frequency corresponding to half the sampling rate. Third, INTERMAGNET demands a resolution of 1 pT along with a dynamic range of ± 3000 to 4000 nT depending on latitude (Turbitt et al., 2014). Still, the suggested dynamic range may be exceeded during extreme geomagnetic events (Thomson et al., 2011). In consequence, analog to digital converters (ADC) with high resolution are necessary. For example, a DTU FGE with the largest available dynamic

5   range ±10000 nT requires at least a 20 bit ADC in order to resolve 1 pT.

Other important design criteria which are not the subject of the INTERMAGNET 1Hz data standard, but which have been considered here, are described in the following. First, a fully operating geomagnetic observatory must guarantee long-term stability of its data product. Therefore, calibration constants of the analogue output of the instruments must be stable and remain unchanged even after loss of power. In addition, the capability for real time data transmission becomes more and more

10   important, in particular for applications in geohazard monitoring and space weather, e.g. ground-induced currents (Viljanen et al., 2014; Barbosa et al., 2015). Finally, data gaps in operation should be avoided, requiring a system that is easy to operate, safely survives power losses, close-by lightning strikes, and automatically restarts data acqusition as soon as power is available after power loss. Continuous operation also requires that spare parts should be accessible without large delays and can be replaced with commonly available tools following simple procedures. As well, low consumption of power of the whole system

15   is essential for continuous operation, particularly in remote areas with an unreliable or no power grid.

In the following sections, we will present our approach to implement these design criteria with a modern C++ software package, a low-power and widely available embedded PC (Raspberry Pi), a modern A/D converter developed for geomagnetic observatories, and a flexible and modular system for backup and remote connectivity.

3   Hardware Layout

20   The overall system layout can be divided into the power supply chain and the data acquisition chain (Figs. 1 and 3). With respect to power supply, we required that the system should be easy to integrate in the existing observatory electronics which has previously been installed by GFZ in a number of observatories worldwide (e.g. Korte et al., 2009). Still, we made sure that this requirement does not interfere with the flexibility and easy integrability in other existing systems.

3.1   Data Acquisition

25   The schematics of the data acquisition chain is presented in **Fig. XX**. The heart of this chain is a Raspberry Pi embedded PC (Upton and Halfacree, 2016) which is responsible for communication with the geomagnetic instruments or the corresponding analogue-to-digital converters (ADC), for timestamping, digital filtering, and buffering of the data. This equipment is usually housed in the variometer house in order to reduce cable lengths. Therefore, it must be assured that the geomagentic instruments will not be influenced by the electronics when installing the system. The Raspberry Pi temporarilly buffers geomagnetic data,

30   and an external HDD or SSD may be attached to increase storage capacity in case extended loss of connectivity is expected or in case the data should be kept as a backup.
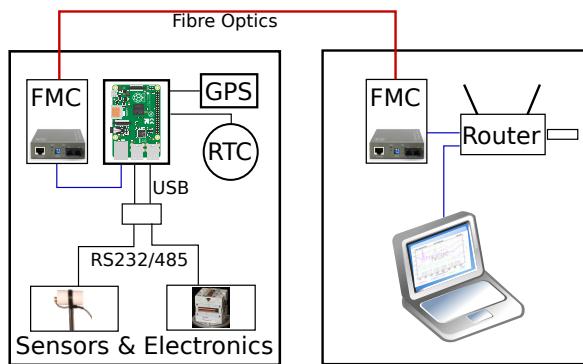
Figure 1. Schematic illustration of the data acquisition chain. On the right hand side, the electronics in the variometer house is shown. These include the Raspberry Pi embedded computer as the central processing unit, the attached GPS sensor and real-time clock (RTC) for timekeeping, a fibre optics media converter (FMC), USB to RS232/485 converters, and the magnetometer sensors and electronics. On the right hand side, the electronics hut is shown where another FMC, an optional laptop or Raspberry Pi, and an optional router are located. See text for more details.

Ideally, any additional electronics should be kept in a separate building which we will refer to as the electronics hut. Data transmission between the variometer and electronics hut should be established via a fibre optical cable for two reasons: First, larger distances of up to 2 km (multi mode) and 20 km (single mode) can be bridged with fibre optics cables compared to only a few hundred meters with twisted-pair copper cables. Second, the optical transmission line serves as a galvanic isolation,

5   avoiding e.g. induced currents during close-by lightning strikes. For transmitting the data to remote location, it is recommended to use a dedicated router to access the internet either via the mobile network or any local infrastructure, if available. In this way, a firewall can protect the observatory system, and a local UMTS USB modem can easily be integrated without having to worry about UMTS settings and modem drivers. Such a router is usually cheap, and consumes typically less than five watts of power. If an even lower power consumption is required, this task may still be integrated into the Raspberry Pi datalogger. Optionally,

10   a laptop or second Raspberry Pi may be installed in the electronics hut to backup the data on a local hard disk drive. As well, the incoming data may be graphically displayed on a dedicated screen in order to provide real-time feedback of the correct operation of the system to the local observatory staff. In addition, the laptop can also be used to store and transmit the absolute measurements.

   The Raspberry Pi is developed and distributed by the Raspberry Pi Foundation. It was originally developed as a tool to teach

15   basic computer science in schools (Severance, 2013), but has found wide applications also in science (e.g. Cox et al., 2013). Here, we use the Raspberry Pi model B+, which runs on a system-on-chip Broadcom BCM2835 with an ARM processor clocked at 700 MHz, and 512 Mb of shared memory. Four USB 2.0 ports are available along with a 100 Mbit/s 8P8C ethernet connector for connectivity, and the module consumes a maximum of 3 W of power at 5 V (Upton and Halfacree, 2016). We
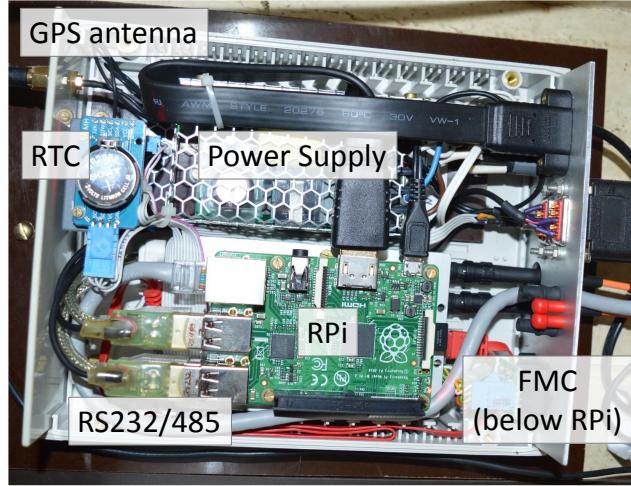
Figure 2. The Raspberry Pi in its housing as installed in Tatuoca (TTB). The most important components are labeled, i.e. the connector for the GPS antenna, the real time clock (RTC), the power supply, the Raspberry Pi (RPi), the USB to RS232/485 converters, and the fibre optics media converter (FMC).

have enclosed the Raspberry Pi along with its peripherals in an industrial plastic case for protection (Fig. 1). Unfortunately, the Raspberry Pi does not possess an integrated real-time clock (RTC) which is necessary to quickly restore the correct system time after power-loss, but an external RTC is readily available (e.g., DS3231/AT24C32) and can easily be added. Further, a GPS module (Microstack L80) is integrated into the system in order to guarantee precise timekeeping even in remote areas.

5   Moreover, most geomagnetic instruments and ADCs are equipped with RS-232 or RS-485 for serial communication. Although one serial port is readily available on the Raspberry's general purpose input/output (GPIO) pins, we decided to use small serial to USB converters (FTDI USB-RS232-PCBA and FTDI USB-RS485-PCBA) for more flexibility. Finally, it was necessary to include a fibre media converter (FMC) to connect the fibre optics network cable to the Raspberry Pi 8P8C ethernet port.

Most geomagnetic instrumentation is either already equipped with a serial port, or provides an analogue output of its mea-
10 sured signal. In the latter case, an ADC is required in order to digitally process the readings. In principle, the proposed system and software can be adapted to work with any ADC as long as it can be connected to the Raspberry Pi, but we recommend to use an ADC with at least 24 bit and 128 Hz sampling rate. Ideally, the ADC should allow for external triggering in order to ensure high timing accuracy. In our setup, we have used a Technical University of Denmark (DTU) FGE variometer and a MinGeo ObsDAQ 24-bit ADC. The DTU FGE has been proven to be very reliable and stable in geomagnetic observatories.
15 In addition, it complies with the new INTERMAGNET 1 Hz standard, except for its level of noise (Pedersen and Merenyi, 2016). Also, the ObsDAQ is well suited for geomagnetic observatories, as it provides three independent input channels (non-multiplexed), capabilities for external triggering, and allows to save pre-defined calibration constants. In addition, it is able to record housekeeping values such as voltage and temperature.
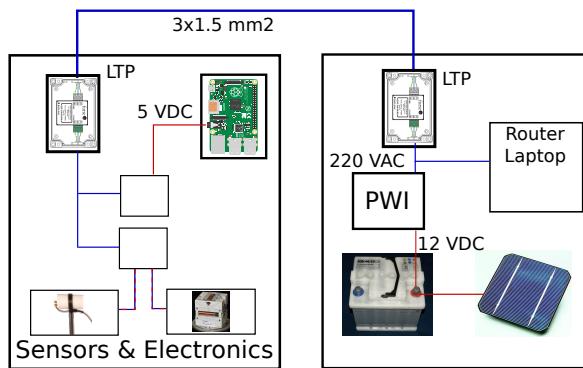
Figure 3. Schematic illustration of the power supply. On the right hand side, the electronics hut is shown. The system is powered by solar cells and/or the power grid or generators. A power inverter (PWI) transforms 10 VDC of the buffer batteries to 220 VAC for transmission to the variometer hut. Also, the laptop and router are powered by 220 VAC. On the left hand side, the variometer hut is shown where the Raspberry Pi, the sensors and the electronics are powered via appropriate transformers and AC-DC converters. A lightning protection (LTP) is installed in both the variometer and electronics hut.

3.2 Power Supply

A reliable supply of electric power is mandatory for the operation of a geomagnetic observatory. In some areas, however, frequent power failures or the lack of access to the power grid require options to generate and store power. a landline require special precautions, usually in the form of large battery packs. However, batteries are expensive, and have to be replaced

5   frequently. With the low power consumption of the proposed system, the overall required battery capacity can be drastically reduced. Also, these batteries may be charged solely by solar cells. Additionally, a hybrid solar charger may be attached which accepts different types of power sources such as solar cells, the power grid or various kinds of generators.

3.2.1 Power supply chain

An overall schematic overview of the power supply chain is shown in Fig.3. The battery pack and generators will usually be

10   situated in a separate housing far enough from the geomagentic instrumentation in the variometer and absolute houses. For the effective transmission of electric energy, the 12 V DC output of the batteries will be transformed to higher-voltage AC power, usually 220 - 240 V. In addition, a suitable lightning protection needs to be installed at both ends of this power line in order to prevent induced currents due to close lightning strikes. In the variometer house, we rely on a well-tested and simple system of transformers that has been developed in NGK in order to provide the required voltages for the operation of the proton and

15   fluxgate magnetometers.

Concerning the central data acquisition unit including the Raspberry Pi and the fibre optics media converter, the required 5 V DC power is provided by a commercial AC-DC power converter which is embedded in the data acquisition unit (Fig. 2).

Table 1. Power consumption of a typical installation of the proposed data acquisition system.

Instrument	I [mA] / U [V]	Power [W]	Comment
DTU FGE		1.5	
GSM90F1	250 / 12 DC	3	
Raspberry Pi	1000 / 5 DC	5	
Router		5	
Netbook		20	
Power Inverter		6	$\phi > 88\%$
Cable Loss		0.05	200 m / 1.5 mm^2

The overall power consumption of a typical system with a DTU FGE as vector fluxgate magnetometer, a GEMSystem GSM-90F1 as scalar magentometer, and an optional laptop is shown in Tab. 1. In addition to these numbers, we add 10 % to account for losses in the transformers and AC-DC converters for the laptop and the Raspberry Pi data processing unit. Overall, this results in a maximum power consumption of 45 W. By replacing the netbook with a second Raspberry Pi and a small TFT screen, this number may be further decreased to 35 W. Optionally, the netbook may also be completely removed without substitution.

3.2.2 Photovoltaic system

The required size B_S of the batteries can be calculated depending on the number of required days N_D the system can survive without sunshine and the overall power consumption P by

$$B_S[Ah] = 110\% \frac{P[W]N_D[d]}{0.3} \frac{24[h/d]}{12[V]} \tag{1}$$

when a maximum discharge depth of 30% is assumed. For $N_d = 5$, $B_S \approx 37$ Ah are hence necessary for each Watt of system power. For our system, this would require batteries of at least 1665 Ah. Please note that N_d should at least be sufficient to survive the night. Concerning the solar panels, the necessary daily power production P_{SD} should at least balance the daily power consumption, i.e. $P_{SD}[Wh/d] = P[W]24[h/d]$. In addition, larger solar arrays are necessary in order to recharge empty batteries within N_R days due to successive days without sunshine, i.e.

$$P_{SD}[Wh/d] = \left(110\% \frac{N_D[d]}{N_R[d]} + 1\right) P[W]24[h/d]. \tag{2}$$

For $N_R = 2$, this results in $P_{SD} \approx 4$ kWh/d. Now, the nominal peak power P_{Wp} of the solar cells can be calculated from the minimum daily solar radiation G (e.g. Paulescu et al., 2012) at the given location, the inclination and azimuth of the solar panels, and the ambient temperature (e.g. Almonacid et al., 2011).
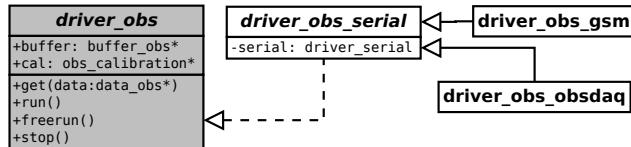
Figure 4. UML diagram of driver classes for communication with geomagentic instrumentation, see text for details.

4   Software Layout

The datalogger software is running on the Raspberry Pi under a Raspbian (Debian-derivate) Linux operating system. Still, it may be compiled with any C++11 ANSI compiler on different platforms as long as the underlying operating system is POSIX compatible.

5   The software contains different abstraction layers, from more generic classes defining interfaces to more specialized classes. Further, the implemented classes can be grouped according to their functionality. First, we will describe the classes providing functionality to communicate with the geomagnetic instrumentation. Then, we will describe the timestamping of the incoming data, followed by a section on the filtering, storing and internal transmission of the data. Finally, we will describe our current solution for data transmission to external servers.

10   4.1   Communication with instruments

An overview of the different classes to communicate with instrumentation at an observatory is shown in Fig. 4 in the form of an UML diagram. At the most abstract level, the software package provides an abstract class *<driver_obs>* which defines some compulsatory interface methods such as taking a single measurement (*get(data*:data_obs)*), taking continuous measurements in freerun mode (*freerun()*), taking continuous measurements in triggered mode (*run()*), and stopping the measurements

15   (*stop()*). In freerun mode, the software will passively listen to incoming data. In triggered mode, the software will actively trigger the measurements at a specified frequency. Depending on the instrument, the active trigger may also be a PPS which is directly attached to the instrument. The data are written to a buffer of class *<buffer_obs>* (Fig. 5), and single measurement can also directly be returned as an instance of class *<data_obs>*. In addition, calibration constants of the instrument can be passed to the driver using the generic abstract class *<obs_calibration>*. An implementation for vector data is provided by the class

20   *<obs_calibration_vector>*.

For communication using serial ports, we have implemented a generic serial driver class *<driver_serial>* (not shown in Fig. 4) which provides a convenient wrapper for POSIX serial communication functionality using *termios*. For example, a termination character as used by many instruments can be set for receiving data on the serial port. Also, the system time of the first character received can be passed for timestamping purposes.

25   Based on these classes, a generic class *<driver_obs_serial>* for communication with observatory instruments using the serial port has been developed. For example, this class provides functionality to automatically set the correct baud rate. Up to now, drivers for the MinGeo ObsDAQ ADC (*<driver_obs_obsdaq>*) and the GEMSystem GSM-90 and GSM-19 families

(*<driver_obs_gsm90>* and *<driver_obs_gsm19>*) have been implemented. For these drivers, arbitrary sampling rates can be requested by the user, and the driver will automatically test if it is supported by the instrument. Further, additional drivers can be added in the future.

4.2 Timestamping and Timekeeping

5   There are two different modes of timekeeping that can be used depending on the capabilities of the attached instrument: A basic mode which works with any instrument and a triggered mode. In basic mode, the timestamp of incoming data is set according to the system time when the first byte is received. In this case, the timestamp critically depends on the accuracy of the system time. Also, the timestamp includes a delay due to the transmission time of the data from the instrument to the datalogger, and due to the processing time of the operating system on the datalogger. For higher timing accuracy, a geomagnetic instrument or

10   ADC is recommended that can directly be synchronized to some precise pulse by, e.g., an attached GPS.

Concerning the accuracy of the Raspberry Pi system time, the network time protocol (NTP) is used to manage and evaluate different time sources. Based on the quality, scatter, and delay of these time sources, the system time is set accordingly. Also, detailed logfiles are recorded that can be used to reconstruct the offset between the individual time sources and the system time. As a primary source of time, we recommend a GPS receiver or radio controlled clock. Secondary time sources may include

15   any close-by time servers.

4.3 Datalogging and Filtering

The instrument drivers described above store the data in a generic data class *<data_obs>* (Fig. 5). This generic class can hold timestamps only, and is extented by the classes *<data_obs_scalar>* and *<data_obs_vector>* to work with scalar and vector data, respectively. In addition to storing the data, all data classes also provide methods for calculating the weighted mean and

20   the median for a given data set.

For further processing, the data can be stored in a buffer that collects incoming data. For this purpose, a generic class *<buffer_obs>* is available, providing methods to push and pop objects of type *<data_obs>*. Such a buffer may be implemented in various ways. An easy and convenient solution is to use an ASCII representation of the data and to write to STDOUT. Now, STDOUT can be connected to STDIN of a processing program via the pipe command. This approach is implemented in the

25   class *<buffer_obs_pipe>*. Also, STDOUT may be split using the *tee* command to store raw data at high sampling frequency in separate files. A more sophisticated approach to implement *<buffer_obs>* could consist of using a queue along with threaded processes to take the measurements and to process the data.

Up to now, a finite impule response (FIR) digital filter and a median filter have been implemented in a class *<filter_obs>* for further processing the data. Also, we have implemented the filter suggested by the PLASMON project which fullfills the

30   INTERMAGNET specifications. This filter is a two-stage FIR filter that downsamples the data from 128 Hz or 640 Hz to 1 Hz (Merényi et al., 2013). For input and output, the class *<filter_obs>* continuosly reads the data from an input buffer and writes the filtered data to an output buffer, both of type *<buffer_obs>*. Now, the data can be written to an ASCII file if an output
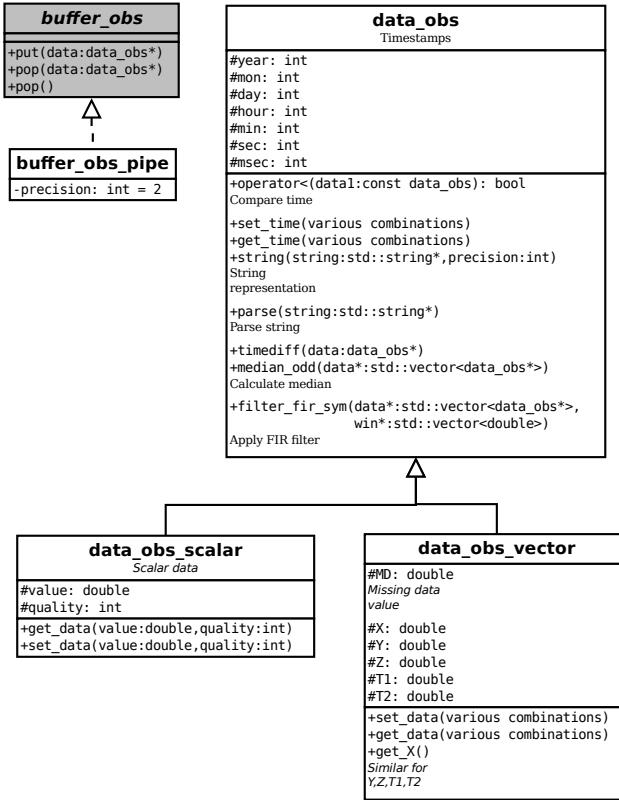
Figure 5. UML diagram of data and buffer classes, see text for details.

buffer of type <*buffer_obs_pipe*> is used. In case the data should be written to a binary file, or even transmitted via Internet in realtime (e.g. using MQTT), a suitable class of type <*buffer_obs*> can be added.

4.4 Integration in operating system

The software package has to be integrated in the running operating system. For this purpose, a number of bash scripts and
5 cronjobs are responsible. Amongst others, these make sure to automatically start data acquisition at reboot and after power loss, backing up and compressing transmitted data, and to log any events such as starting and stopping the datalogging software, NTP time information, or disk space availability.

On the optional laptop or Raspberry Pi in the electronics house, a number of scripts may also be active to show daily magnetograms, or any other system-relevant information.

10 ### 4.5 Data Transmission

A simple and reliable approach for secure data transmission is a file-based method where data is transmitted to a central server via *rsync* and *scp*. In addition, a reverse SSH tunnel may be necessary if the datalogger is protected by a firewall or assigned a

dynamic IP address. On the side of the central server, a scheduler such as *cron* can then be used to contact the datalogger and to transmit the data on a regular basis.

Alternatively, and if realtime data access is an issue, a messaging protocol such as MQTT can be used. Also, the data may be temporarily transferred to a central database in order to quickly extract, access, and process the latest data.

5 Conclusions and Outlook

We have presented a datalogging system for use at geomagnetic observatories and described its hardware design and software package. It is based on a Raspberry Pi embedded PC as the central data acquisition unit, without the need for any custom-made circuit boards. The software package is written in object-oriented C++ and runs on any POSIX-compliant operating system. Advantages of the system include its versatility and flexibility, its relatively low power consumption, and its compatibility with the INTERMAGNET 1 Hz standard. We encourage the community to participate in its use and further development by making the C++ source code freely available at *https://gitext.gfz-potsdam.de/mors/GeomagLogger.git* under the creative commons license.

The hardware setup was successfully tested at the Niemegk geomagnetic observatory for about one year. During this time, the Raspberry Pi was almost continuously running and we haven't observed any problems concerning its reliability and stability in continuous operation. Also, we succcessfully tested safe rebooting after sudden loss of power. In addition, the system was installed at the Tatuoca observatory in Brazil (Morschhauser et al., 2017), where it was continuously running from November 2015 until a lightning strike in December 2016, and is operational again since February 20, 2017. Up to now, the Raspberry Pi datalogger provides a reliable platform, but the system should be further tested in the future.

The described C++ software package is under development, and requires thorough testing before it can be installed routinely at geomagnetic observatories. The modular design will make it easy to implement more elaborate configuration files for, e.g., calibration constants, and to implement a triggered mode option for the MinGEO ObsDAQ analog-to-digital converter. Anticipated hardware improvements include a battery powered shutdown procedure. Also, the inherent time delay of the system needs to be fully characterized.

The objective of the development is to install it the proposed system will be successfully installed in many of the geomagnetic observatories operated by GFZ or in cooperation with other institutes. Also, we would like to welcome contributions from other institutes and observatories, and strongly support a community-based effort towards a modern, affordable, flexible, and reliable data acquisition system.

6 Code availability

The C++ software is freely available for non-commercial use under the creative commons license at *https://gitext.gfz-potsdam.de/mors/Geo...* Contributiors are welcome and should contact the author for access to the developer branch.

Author contributions. AM wrote the manuscript and implemented the C++ data acquisition software described here, OB developed previous versions of the data acquisition and transmission software, JH and CMB designed the hardware layout, JH installed the test system, and JM coordinated the activities.

Competing interests. No competing interests.

5 *Acknowledgements.* Achnowledgements.

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