BUREAU CENTRAL DE MAGNÉTISME TERRESTRE
France

Bureau Central de Magnétisme Terrestre

Strategic plan 2010-2012

Prepared by: Arnaud Chulliat (IPGP)

And the other members of the BCMT Management Committee: Aude Chambodut (EOST), Vincent Courtillot (IPGP), Michel Granet (EOST), Gilbert Juste (IRD), Xavier Lalanne (IPGP), Michel Menvielle (IPSL).

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1. Introduction

The "Bureau Central de Magnétisme Terrestre" (BCMT) is in charge of organizing and coordinating the French observations of the Earth's magnetic field. It was founded by a decree in 1921 and attached to the Institut de Physique du Globe de Paris (IPGP).

Three French institutions are currently operating magnetic observatories: the IPGP, the École et Observatoire des Sciences de la Terre (EOST) and the Institut de Recherche pour le Développement (IRD). A fourth institution, the Observatoire Versailles Saint Quentin (OVSQ), attached to Institut Pierre Simon Laplace (IPSL) and Université Versailles Saint Quentin (UVSQ), hosts the International Service of Geomagnetic Indices (ISGI), which provides data products derived from magnetic observatory data. Additional funding and staffing is provided to the BCMT by the Institut National des Sciences de l'Univers (INSU) (which is one of the institutes of the Centre National de la Recherche Scientifique, CNRS), the Institut Polaire Français Paul-Émile Victor (IPEV), the Centre National d'Études Spatiales (CNES) and the Commissariat à l'Énergie Atomique (CEA). BCMT operations are made possible by collaborations with eight foreign institutions worldwide.

In 2009, the Director, BCMT, Prof Vincent Courtillot established an international Scientific Council of nine members, whose inaugural meeting took place on 6 April 2009 at the IPGP. In its report, the Scientific Council, chaired by Dr David Kerridge, made the following recommendation:

> "Ideally there would be a strategy document setting out the longer-term vision for the BCMT operations and a series of delivery plans and annual reports providing measureable evidence of progress towards the long term objectives. The annual reports would include information on the staff and other resources used to achieve the deliverables."

Following this recommendation, the BCMT embarked in the definition and writing of a strategy for the period 2010-2012. This time interval was chosen in order to put the BCMT strategy in phase with that of the IPGP, its leading institution (whose strategy is known as "rapport quadriennal" and covers the period 2009-2012).

The general and specific objectives of the strategy were adopted during a BCMT Management Committee meeting on 25 January 2010 in Paris. External feedbacks were received from INSU's Observatory Committee on 18 June 2010. A first version of the present document was written in July 2010 and then circulated and discussed by electronic mail among the members of the Management Committee. The present version was adopted on 30 September 2010.

Note that ISGI is one of the permanent services of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) and has its own scientific council nominated by the International Association of Geomagnetism and Aeronomy (IAGA).

This document has several purposes:

a. It will be used as a reference document for the upcoming funding and staffing requests to participating and funding institutions, particularly the yearly

requests to INSU/CNRS, IPEV and CNES. These requests will provide the annual reports mentioned by the Scientific Council, including the information on budgeting and staffing.

b. The BCMT Scientific Council will use it as a reference document in its future reviews of the BCMT operations.
c. It will provide a framework for the BCMT management team to prioritize among the various projects and activities.

In order to fulfill purpose b, the present document is written in English.

The mission and vision of the BCMT are articulated in section 2. A summary of the current status of the BCMT is provided in section 3, including a brief description of the current observation infrastructure, data products and data users. The general and specific objectives of the strategy are given in section 4.

2. Mission and vision

The BCMT Management Committee, recognizing the need of having a statement defining the fundamental purpose of the BCMT in a more modern and more precise way than its founding decree, adopted the following mission statement:

The mission of the BCMT is to provide ground-based geomagnetic observations and data products of the highest quality, addressing the needs of the French and international geosciences research community, and those of the French administrations, businesses and citizens.

One of the main challenges for the BCMT (and similar geomagnetic observatory programs throughout the world) is to combine traditional activities where procedures should remain mostly unchanged for decades, with activities addressing new and emerging uses of geomagnetic data. This preoccupation is central to the BCMT's vision statement:

The vision of the BCMT is to be one of the key components of the global geomagnetic observation system, combining a high level of consistency and robustness in its long-term operations and an ability to quickly innovate as a response to new scientific and societal needs.

3. Current status

This section briefly presents the current observational infrastructure of the BCMT, its data products and main data users. It aims at laying the ground for the presentation of the strategic objectives developed in section 4, not at providing a detailed and exhaustive account of recent BCMT activities and achievements.

3.1. Observational infrastructure

The BCMT currently operates a network of 18 observatories throughout the world and a network of 30 repeat stations in metropolitan France. In addition, the BCMT develops, builds and calibrates its own lines of vector and scalar magnetometers, providing significant flexibility to its operations.

3.1.1. Observatories

The Earth's magnetic field has been continuously recorded in the Paris area since 1883, first in Parc St Maur (1883-1900), then in Val Joyeux (1901-1935) and now in Chambon le Forêt (since 1936). The Chambon le Forêt magnetic observatory, located 100 km south of Paris, in the Loiret department, is the National Magnetic Observatory and the headquarter of the IPGP technical team (Figure 1).

Figure 1: Absolute pavilions (left) and magnetometer vault (right) at the Chambon la Forêt magnetic observatory.

The expansion of the BCMT network outside metropolitan France started in 1952, with the installation of the MBour observatory in Senegal. Today, the BCMT is in charge of 18 observatories throughout the world, including 10 observatories in other countries (Table 1 and Figure 2). Eight of these observatories are cooperated with foreign institutions. The typical cooperation agreement stipulates that the BCMT provides the instruments, trains the observers and prepares the final data products, while the local institution operates the observatory on a day-to-day basis and performs regular calibration measurements.

IAGA code	Observatory name	Institutions	Country	Starting date
AAE	Addis Ababa	IPGP / GO AAU	Ethiopia	1997 (1957)
AMS	Martin de Viviès	EOST / IPEV	France	1981
BNG	Bangui	IRD	Central African Rep.	1955
BOX	Borok	IPGP / BGO IPERAS	Russia	2004 (1976)
CLF	Chambon la Forêt	IPGP	France	1883
CZT	Port Alfred	EOST / IPEV	France	1974
DMC (*)	Dôme C	EOST / INGV / IPEV / PNRA	Antarctica	2005

DRV	Dumont d'Urville	EOST / IPEV	Antarctica	1957
IPM (*)	Isla de Pascua Mataveri	IPGP / DMC	Chile	2009
KOU	Kourou	IPGP / CNES	France	1995
LZH	Lanzhou	IPGP / LIS CEA	China	2001 (1959)
MBO	Mbour	IRD	Senegal	1952
PAF	Port-aux-Français	EOST / IPEV	France	1957
PHU	Phu Thuy	IPGP / IG VAST	Vietnam	1993 (1961)
PPT	Pamatai	IPGP / CEA	France	1968
QSB	Qsaybeh	IPGP / NCGR	Lebanon	2000
TAM	Tamanrasset	IPGP / CRAAG	Algeria	1993 (1932)
TAN	Antananarivo	EOST / IOGA	Madagascar	1983 (1889)

Table 1: List of the 18 magnetic observatories affiliated to the BCMT and of the French and foreign institutions operating them (see Appendix A for a list of acronyms). Dates indicate when observatories joined the BCMT network (dates in parenthesis indicate when observatories were founded, if different). Asterisks (*) indicate non-INTERMAGNET status.

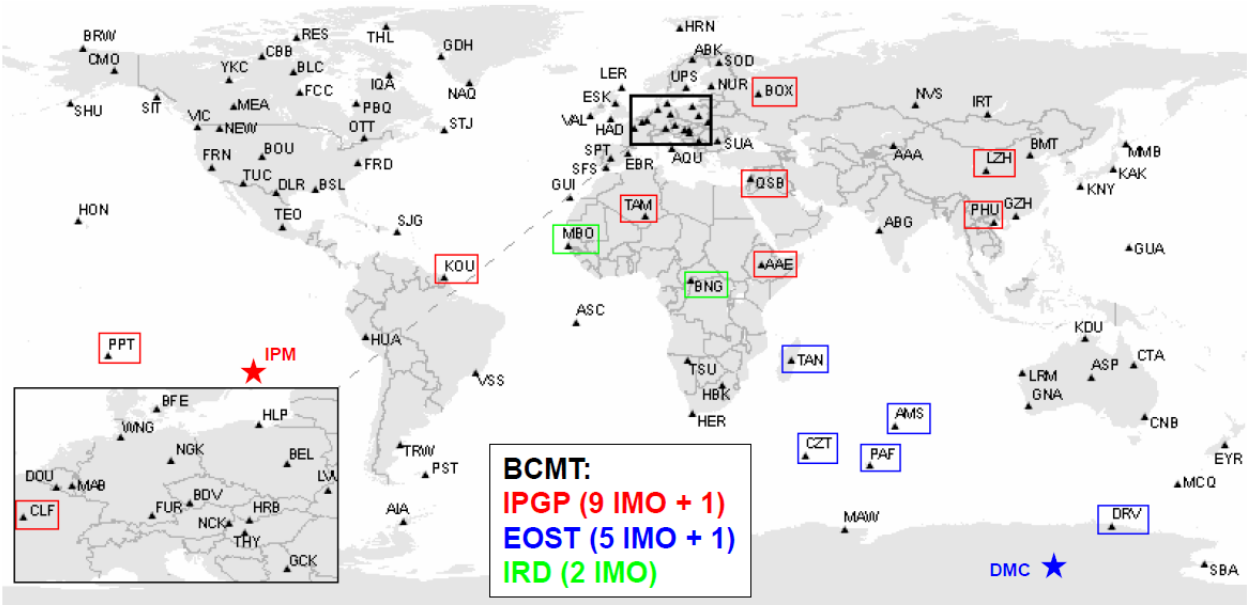

Figure 2: Map of the 110 INTERMAGNET magnetic observatories (IMO) in 2010 (black triangles). Among these, 16 are affiliated to the BCMT (colored boxes). The localization of the two newly installed observatories in Easter Island and Dome C are also shown (colored stars).

Sixteen BCMT observatories belong to INTERMAGNET, the global network of magnetic observatories transmitting their data in near real time and fulfilling high quality standards. This represents about 15% of the current INTERMAGNET network (Figure 2). The two latest installed observatories (Isla de Pascua and Dôme C) are expected to join INTERMAGNET soon. The BCMT's contribution to INTERMAGNET is significant, not only due to its size but also to its wide geographic coverage. BCMT observatories cover all magnetic latitudes, from the equatorial zone (with one observatory, Addis Ababa, at the dip-equator) to the polar caps. Several BCMT observatories are very isolated and cover areas where no other magnetic observatory program is operating, particularly in Northern and Central Africa, in the Southern Indian Ocean, in the Southern Pacific Ocean

and in Antarctica. The Isla de Pascua observatory, located more than 4000 km from the closest observatory, Huancayo (Peru), is the most remote magnetic observatory in the world.

Each observatory is equipped with two sets of instruments:

- a tri-axis fluxgate magnetometer and a scalar magnetometer located in a thermally insulated vault, pavilion or box, and recording the geomagnetic field variations on a continuous basis;
- a "DI-flux" (i.e., a non-magnetic theodolite with a mono-axis fluxgate magnetometer mounted on top of it) and, often, a second scalar magnetometer located in a pavilion or hut where weekly calibration measurements ("absolute measurements") are performed.

A data acquisition system collects the data from the continuously recording magnetometers and sends them via the internet or a satellite link to the BCMT data center and INTERMAGNET Geomagnetic Information Node (GIN) located in Paris. The instruments and data acquisition system are powered by a local power supply, by solar panels, or both.

The BCMT observatories are operated according to the standard procedures recommended by IAGA and INTERMAGNET. In particular, weekly absolute measurements are performed by a trained operator in order to frequently recalibrate the vector magnetometer. These measurements are extremely important, as all existing vector magnetometers unavoidably drift in time (over only a few weeks) and there currently exists no automatic system able to replace a human operator. In order to meet the high quality standards set by INTERMAGNET, BCMT observers are trained on a regular basis, either on-site, at the Chambon-la-Forêt observatory (IPGP and IRD) or at the Welschbruch geophysical station (EOST). This time consuming and sometimes underappreciated activity is a critical part of operating a global network of magnetic observatories.

3.1.2. Repeat stations

Magnetic repeat stations are places where the Earth's magnetic field is measured on a regular basis (using a DI-flux and a portable scalar magnetometer), although not continuously (typically every few years), in order to improve the spatial resolution of secular variation data. The BCMT is in charge of the French magnetic repeat stations network, which today consists of 30 stations in metropolitan France (Figure 3). This network was created in 1947 and has been reoccupied every five years since then. The last measurement campaign took place in the summer 2007.

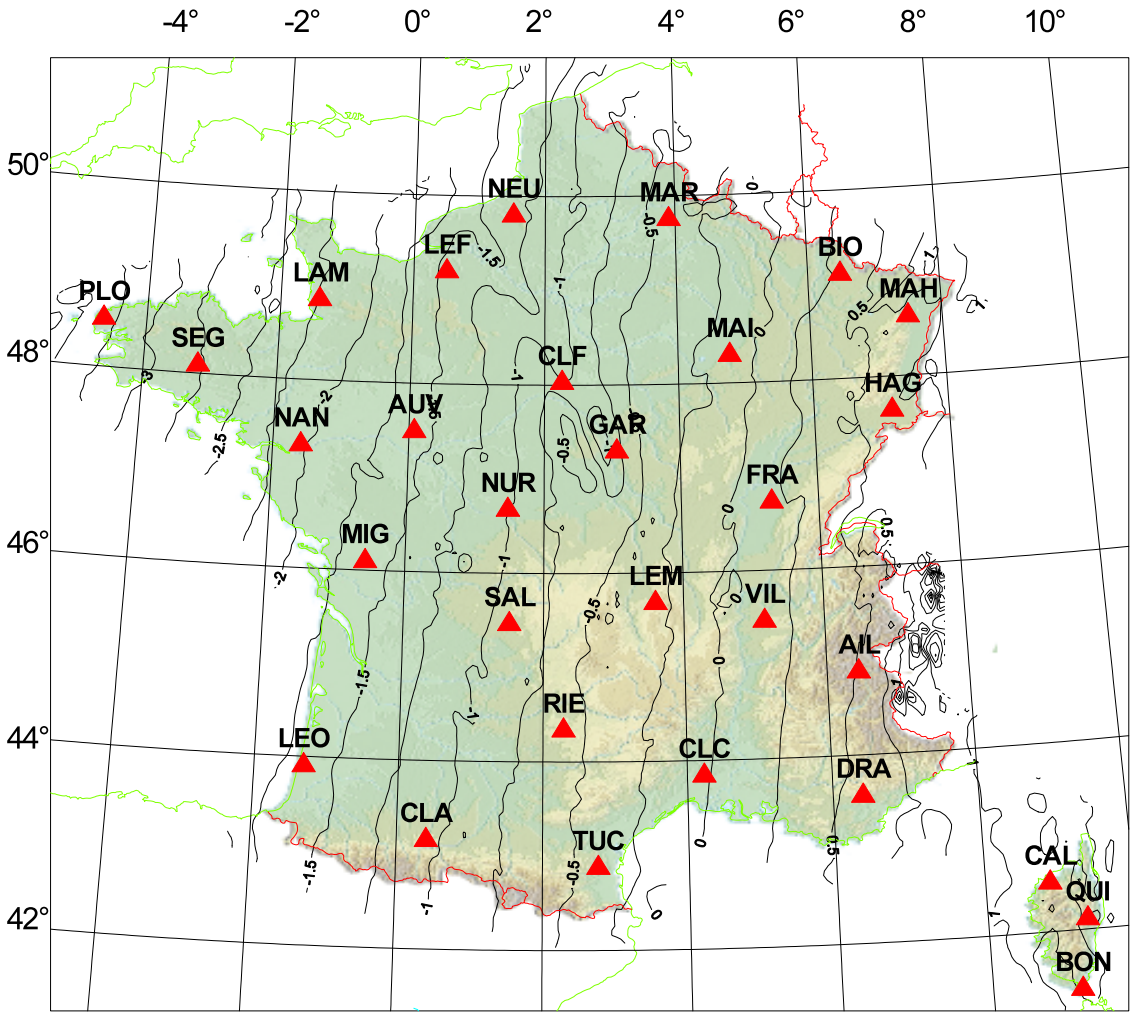

Figure 3: Map of the BCMT repeat stations network reoccupied in 2007, superimposed on the obtained declination map (level curves every 0.25°) at epoch 2007.5.

3.1.3. Instruments, data acquisition systems and calibration facilities

The BCMT is among the very few (less than five) organizations in the world building tri-axis vector magnetometers stable enough for long-term magnetic observatory operations. This situation results from developments initiated in the 1980s in collaboration with industrial partners. BCMT vector magnetometers were an essential part of the "Observatoire Magnétique Planétaire" project which led to the installation or modernization of several observatories in partnership with foreign institutions in the 1990s. The latest version of the BCMT vector magnetometer is named IPGP VM391 (Figure 4). It is installed in all BCMT magnetic observatories operated by IPGP and IRD (12 in total, see Table 1).

In the last few years, the BCMT has also been developing of a new, optically pumped helium magnetometer providing scalar measurements of the geomagnetic field. This instrument is at the prototype stage and has not yet been deployed in observatories.

Figure 4: The IPGP VM391 tri-axis fluxgate magnetometer.

BCMT magnetometer developments are carried out by IPGP's technical team based at the Chambon la Forêt observatory, where testing and calibrating facilities are available, including an amagnetic room and a set of Helmholtz coils. These facilities have been used to test magnetometers for various space and satellite missions (for example, the CNES Demeter mission), as well as by the industry.

Data acquisitions systems are also being developed by BCMT. New systems have been developed in recent years by IPGP and EOST in order to acquire data every second, as opposed to every minute which was the previous international standard. These developments took into account the various characteristics of the BCMT observatories and are now completed.

All instruments and data acquisition systems, whether manufactured by the BCMT or acquired, are fully tested and calibrated before being installed in magnetic observatories. These tests are made either at the Chambon la Forêt observatory (IPGP and IRD) or at the Welschbruch geophysical station (EOST), close to Strasbourg.

3.2. Data products

3.2.1. Preliminary data

The data sampling frequency at BCMT observatories has regularly increased since the 1950s, from hourly to 1-minute and now 1-second measurements (Figure 5). This evolution was made possible by advances in instrument and data transmission technologies. Today, 1-second data are produced at 12 BCMT observatories, while 1-minute data are still produced at the other six observatories (Table 2).

Data acquired at the BCMT observatories (either 1-minute or 1-second) are typically transmitted to the Paris GIN every hour. Once on the GIN server, they are immediately made available on the BCMT website (www.bcmt.fr) and sent to INTERMAGNET's central website in Ottawa, Canada (www.intermagnet.org). This first type of data is called *preliminary data*. At the moment, INTERMAGNET does not yet have the capability to distribute 1-second data and for that reason only 1-minute data (either calculated from 1-second data or directly acquired) are sent to Ottawa. However, this situation is expected to change soon.

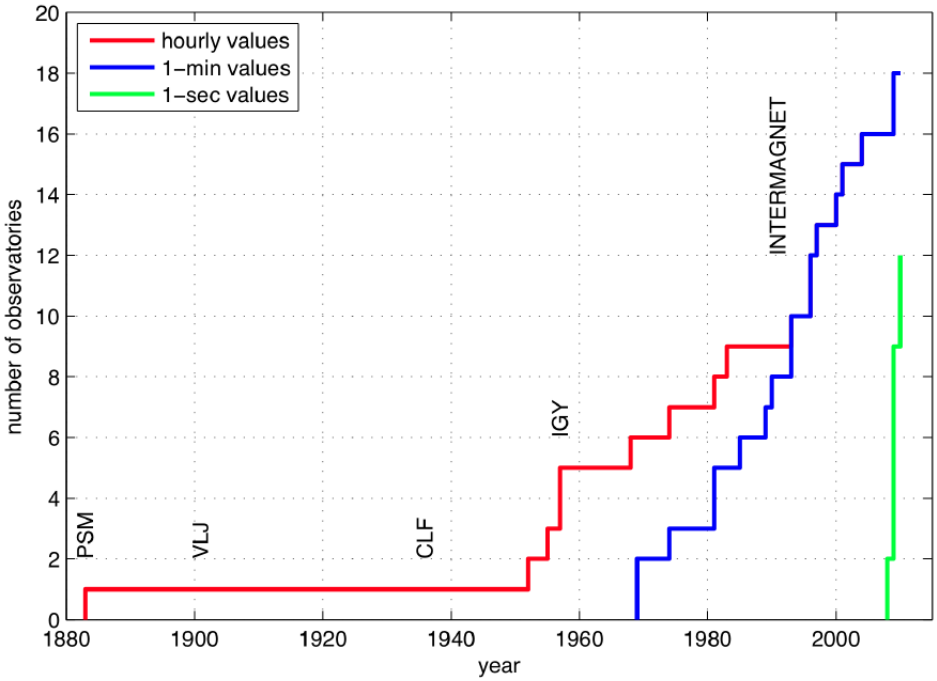

Figure 5: Evolution of the number of BCMT observatories producing hourly, one-minute and one-second data since 1883.

IAGA code	1-second data	Quasi-definitive data
AAE	yes	yes
AMS	yes	no
BNG	no	no
BOX	no	yes
CLF	yes	yes
CZT	yes	no
DMC (*)	yes	no
DRV	yes	no
IPM (*)	yes	yes
KOU	no	yes
LZH	yes	yes
MBO	yes	yes
PAF	yes	no
PHU	yes	yes
PPT	yes	yes
QSB	no	no
TAM	no	yes
TAN	no	no

Table 2: Availability of recently launched BCMT data products as of July 2010.

3.2.2. Quasi-definitive and definitive data

Geomagnetic data require a significant amount of processing before they can be used for studying the geomagnetic secular variation and other slowly varying phenomena. The BCMT produces two types of processed data, classified according to their latency (Figure 6):

- *quasi-definitive data*, released a few days after the end of each month, after having checked all data for spikes, jumps and other anomalies, collected all absolute measurements for that month and used them to recalibrate the vector magnetometer data;
- *definitive data*, released a few months after the end of each civil year, after having thoroughly checked the processing made at the quasi-definitive stage, and solved the problems that were too complicated to be solved at that stage.

Note that quasi-definitive data are a new data product, launched in July 2009 at 10 BCMT observatories (Table 2).

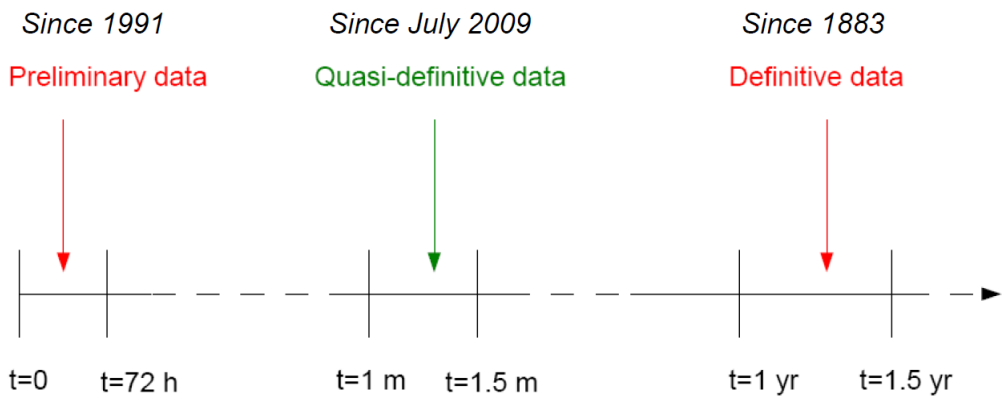

Figure 6: Latencies of the BCMT data products.

Once definitive data are ready (at the 1-minute and 1-second sampling rates, when available), averages over longer periods of time are prepared: hourly means, daily means, monthly means and annual means.

All quasi-definitive and definitive data products are made available on the BCMT website. Definitive (1-minute) data are then sent to INTERMAGNET where they are one more time checked by a dedicated team of data experts before being distributed on INTERMAGNET website and annual DVD. INTERMAGNET is currently building the capability to also distribute quasi-definitive data on its website.

3.2.3. Repeat stations data products

After each measurement campaign, repeat stations data are processed according to standard practices in the field, using the field variations recorded at Chambon la Forêt. Final data are made available on the BCMT website and sent to the World Data Center (WDC) in Edinburgh. Two products derived from repeat stations data are also prepared after each campaign at year Y:

- a regional declination map covering metropolitan France at epoch Y.5 (1st July Y);
- a software (named "IPGP Caldec") providing estimates of the declination in metropolitan France over the time interval from year Y to year Y+5.

3.2.4. Geomagnetic indices

In accordance with the current observatory practice recommended by IAGA, K indices are calculated for each BCMT observatory. These indices are made available through the yearly BCMT bulletins and INTERMAGNET DVDs.

ISGI plays a reference role at the international level in the field of geophysical indices. One of the contributions of OVSQ to ISGI activities is the computation of *am* and *aa* planetary geomagnetic indices:

- Quick-look values of *aa* and *am* indices are routinely made available on line through the ISGI website (http://isgi.latmos.ipsl.fr) 30 minutes after the end of the 3-hour interval (since 2003), and on day D+2 (since 1996), respectively. The quick-look values are computed using minute values transmitted by about 20 INTERMAGNET observatories, including four BCMT observatories (AMS, CLF, CZT, PAF). Besides, the Chambon la Forêt observatory is the Hartland backup station in the computation of *aa* quick look values, and of quick-look values of new 15-minute interval rms-based indices that will be made routinely available on ISGI's website in 2011.
- Provisional values of *aa* and *am* indices are made available six to eight weeks after the end of the month. They are computed on the basis of K indices transmitted to ISGI by that time. The K indices from four BCMT observatories (AMS, CLF, CZT, PAF) are used in the computation of the *am* indices. Provisional values of K indices from these stations are sent to ISGI on a 2-week basis (AMS, CZT, PAF), or a monthly basis (CLF).
- Definitive values of *am* and *aa* indices are computed when definitive K indices are published in the annual INTERMAGNET DVD.

3.2.5. Global databases

In addition to its activity as a data producer, the BCMT maintains two global geomagnetic databases:

- ISGI is in charge of distributing geomagnetic indices and lists of remarkable events prepared by various institutions. These data are routinely transmitted to ISGI and made available through its website, which is a worldwide reference website for geomagnetic indices and remarkable events.

- The World Monthly Means Database (WMMD), managed by IPGP and available on the BCMT website (www.bcmt.fr), contains quality-checked monthly means from INTERMAGNET observatories, going as far back in time as possible. This database complements hourly and annual means databases at the WDCs.

3.3. Data users

BCMT data are used by research scientists as well as various organizations and businesses. Main uses can be categorized as follows. (The following categories are assigned a code, for example, S1, which will be referenced in section 4.)

3.3.1. Scientific research

Magnetic observatory data are used to investigate temporal variations of the Earth's magnetic field having time scales from a few seconds to several decades. They have been the basic observational data used in geomagnetism research for more than a century.

From the point of view of observatory operations, two types of scientific uses are to be distinguished:

(S1) Scientific research requiring very high quality baselines on all components, i.e., making use of quasi-definitive or definitive data only. This includes investigations of the secular variation originating in the Earth's core, core field modeling as well as some geomagnetic indices calculations. The core magnetic field is one of the very few geophysical observables available for the study of the core dynamics and the geodynamo.

(S2) Scientific research not requiring high quality baselines, i.e., that could be performed using preliminary data only. This is the case for most rapidly varying geomagnetic phenomena originating in the magnetosphere (ultra-low frequency waves, magnetic storms), ionosphere (equatorial electrojet, Sq currents, auroral electrojets, solar flare effects), oceans (magnetic fields induced by tidal flows, tsunamis) and the Earth's mantle (magnetic fields induced by external current systems).

It should be noted, however, that all scientific users benefit from the generally much higher quality of quasi-definitive and definitive data with respect to the preliminary data.

Over the last decade, global geomagnetic field modeling has made huge progress thanks to high-precision magnetic data from the Ørsted and CHAMP low-Earth orbiting satellites. Magnetic observatories have greatly contributed to these advances, by providing high-precision ground data that were included in model calculations or used for independent model validations. Ground based and satellite data are complementary and for this reason magnetic observatories will be critical during the upcoming European Space Agency (ESA) Swarm mission, to be launched in 2012.

Geomagnetic indices are widely used in geomagnetic modeling (for data selection and parameterization of external magnetic fields), as well as in the field of solar-terrestrial physics (either academic research or operational activities). They are one of the basic data used in space weather activities.

3.3.2. Societal applications

Although historically the BCMT has mostly emphasized the scientific part of its mission, several organizations and businesses are already using BCMT data products on a regular basis for the following applications:

(A1) Applications centered on orientation and navigation, which require global or regional geomagnetic models. Two French organizations are regular users of the declination map and IPGP Caldec software derived from repeat stations measurements: the Institut Géographique National (IGN) and the Direction Générale de l'Aviation Civile (DGAC). Also, BCMT quasi-definitive and definitive data are used for calculating and validating the International Geomagnetic Reference Field (IGRF) model, which is prepared by an international group of scientists under the auspices of IAGA and used by hundreds of users in the world.

(A2) Applications centered on space weather (such as space weather monitoring, directional drilling), which require rapid variations in close to real time. The BCMT currently does not distribute its magnetic observatory data in real time, but several potential users for such data have been identified (see section 4).

(A3) Other applications, such as reduction of aeromagnetic surveys, which generally require preliminary 1-second or 1-minute data.

4. Objectives

As indicated by its mission statement, the BCMT has various stakeholders and data users, coming with very different needs and objectives. On one end of the spectrum, the core field scientific community needs high-quality data recorded in a consistent manner and without interruption over very long time scales, from years to decades and even centuries, in order to investigate the geomagnetic secular variation and the geodynamo. In this case, the main emphasis should be put on the long-term durability and stability of the observation system and on archiving capabilities. On the other end of the spectrum, real-time monitoring of geomagnetic variations requires very efficient and robust data transmission systems, but no archiving.

The BCMT strategy for the period 2010-2012 addresses the needs of all data users identified in subsection 3.3, while setting priorities. It builds on existing strengths and addresses the current limitations of the BCMT operations. In the present section, the context of the strategy, its general goals and its specific goals are presented, as well as some general considerations on how the strategy will be implemented.

4.1. Context

The BCMT strategy takes into account the following contextual elements:

- The BCMT is part of a global observational enterprise and has international commitments: towards observatory programs in other countries, with which BCMT developed rich and fruitful collaborations throughout years and even decades; towards INTERMAGNET, the global network of digital magnetic observatories, of which France is a founding member; towards IAGA, the international organization that coordinates all ground magnetic observations worldwide.

- The BCMT is an 89 year old organization which accumulated significant know-how in various areas, including instrumentation and installation of remote magnetic observatories. In particular, the three French institutions operating magnetic observatories (IPGP, EOST and IRD) have specialized in different geographical areas (Western and Central Africa for IRD, Southern Indian Ocean and Antarctica for EOST, mid and low-latitude countries for IPGP), each of them presenting some specific challenges.

- According to its mission statement, the BCMT is not directly involved in satellite observation of the Earth's magnetic field. However, the BCMT strategy must be consistent with scientific objectives of satellite programs such as Ørsted, CHAMP and the upcoming ESA Earth Explorer Mission Swarm. It should also reflect the strong involvement of the French research community into satellite geomagnetism as well as theoretical, numerical and experimental studies of the Earth's core dynamics and the geodynamo.

- Societal applications and technology transfer to the business sector ("valorization") are becoming important goals of French universities and academic organizations. This situation requires that the BCMT realigns its priorities, following the path laid out by similar organizations in the world (for example, the American, British and Canadian geomagnetism programs).

4.2. General objectives

The BCMT has the following general objectives for the period 2010-2012:

- To maintain and reinforce the BCMT know-how and production capabilities in observatory instrumentation, by modernizing existing magnetometers and data acquisition systems.

- To extend and improve the long-term durability of the BCMT observatory network, i.e., the French contribution to INTERMAGNET.

- To develop new data products as a response to emerging and/or currently unaddressed scientific and societal needs.

- To improve the long-term durability and scientific relevance of the BCMT repeat stations network.

- To increase the number of data users and improve the visibility of the BCMT at the national and international level.

4.3. Specific objectives

Specific objectives of the BCMT may be divided in four main categories:

a. Instruments development, manufacturing and calibrating
b. Observatories installation and operation
c. Data processing, management and distribution
d. Repeat stations installation and operation

In what follows, these categories are simply referred to as "Instruments", "Observatories", "Data" and "Repeat stations". For each objective, the data users (categorized from S1 to A3, see subsection 3.3) and participating institutions (among the BCMT core institutions) are listed. A priority level is also assigned to each objective, from high (A) to medium (B) and low (C).

4.3.1. Instruments

INST-1: *To develop a robust, manufacturable version of the IPGP scalar helium magnetometer*

Data users: All – Participants: IPGP – Priority: B

Scalar magnetometers currently available on the market either suffer from a low reliability compared to other observatory instruments (which increases maintenance costs) or cannot be exported (due to classified technologies). In order to improve this situation, the BCMT launched the development of a new, optically pumped helium magnetometer in 2008. This magnetometer is designed to fill the observatories' needs of an instrument (a) able to measure the scalar field in an almost constant direction at the 1 Hz sampling rate for quality control purposes, (b) robust on the long term, and (c) low-cost. The electronics is digital and is being jointly developed with that of the new fluxgate magnetometer (see project INST-2). A prototype of this new instrument is currently being tested.

INST-2: *To develop a low-noise and digital version of the IPGP vector "fluxgate" magnetometer*

Data users: All – Participants: IPGP – Priority: A

The IPGP VM391 "fluxgate" magnetometer had its electronics entirely redesigned in 2007-2008 in order to being able to record 1-second data. However, only a limited amount of sensors for this magnetometer were built in the 1990s (when the magnetometer was designed) and only about 15 of them are currently available to the BCMT, i.e., less than the total number of BCMT affiliated observatories. In addition, these sensors (like most sensors available on the market) have an intrinsic noise of the same order of magnitude as the geomagnetic signal around 1 Hz, thus limiting the accuracy of 1-second data. This project aims at addressing these limitations by developing a new

generation of "fluxgate magnetometers", having a low-noise sensor around 1 Hz and a fully digital electronics (which helps reducing the noise as well as the long-term drifts). Once the development will be completed, it is planned that at least 30 pieces of this new magnetometer will be built in the coming years.

4.3.2. Observatories

OBS-1: *To complete the BCMT network extension*

Data users: S1, S2 (A1, A2, A3) – Participants: IPGP, EOST, IRD – Priority: B

The BCMT has recently completed the installation of two new observatories in very challenging locations (Easter Island and Dome C, Antarctica). The installation of two other observatories in relatively easier locations was planned several years ago: Dalat, in Vietnam, as part of the ongoing BCMT collaboration agreement with the IG VAST; Noumea, in New Caledonia, on one of the premises of the IRD and with contributions from the local IRD staff. Both projects are expected to significantly improve the coverage of the BCMT network (under the equatorial electrojet and in the Pacific Ocean, respectively) for a relatively low installation cost. After completing these projects, it is expected that the BCMT will mark a pause in the extension of its network, unless a very interesting opportunity arises.

OBS-2: *To consolidate the existing BCMT network, including the deployment of the 1-second data acquisition systems*

Data users: All – Participants: IPGP, EOST, IRD – Priority: A

A magnetic observatory runs the risk of quickly producing lower quality data if regular and sustained efforts are not made to maintain and improve its infrastructures, equipments and instruments. Fragile parts include internet connection, thermally insulating devices and power supply (particularly in countries where thunderstorms are frequent and electric networks unreliable). As in previous years, the installation of 1-second data acquisition systems in observatories still producing 1-minute data (see Table 2) will be used to upgrade the whole observatory equipment.

OBS-3: *To save and rescue the observatories in danger of ceasing operations*

Data users: All – Participants: IPGP, EOST, IRD – Priority: A

Three observatories of the BCMT network are in danger of definitely ceasing operations, due to difficulties in maintaining regular absolute measurements and/or data transmission, or human disturbances at the observatory site: Qsaybeh (Lebanon), Bangui (Central African Rep.) and Antananarivo (Madagascar). The situation at each observatory is unique and requires a specific approach. Due to the very long data series involved at BNG and TAN, this project is of the highest priority.

OBS-4: *To implement real time data transmission*

Data users: S2, A2 – Participants: IPGP, EOST, IRD – Priority: A

Real-time monitoring of the Earth's electromagnetic environment is becoming essential, as our societies are increasingly reliant on technologies affected by space weather. Ground geomagnetic data are one of the key geophysical parameters providing direct information on the state of this environment, provided they are available in real time (less than 2-3 min data latency). Today, the typical data latency of preliminary data from the BCMT observatories is one hour. This project aims at transmitting in real time the preliminary data from the BCMT observatories, in order to make them useful for the space weather community. It should bring a large number of new data users, both from the academic world and from the governmental and business sectors. The first step will be to implement real time data transmission at observatories having a good Internet connection, starting with the Chambon la Forêt observatory.

OBS-5: *To install the newly developed scalar and vector magnetometers*

Data users: All – Participants: IPGP, EOST, IRD – Priority: C

This is a follow-up to projects INST-1 and INST-2. As the development of the new instruments is expected to take at least one or two years, its implementation will only start at the end of the 2010-2012 period. As for the recent deployment of the 1-second data acquisition systems, it will be coupled with a consolidation of the network (see OBS-2).

4.3.3. Data

DATA-1: *To produce and distribute quasi-definitive data at all observatories*

Data users: S1, A1 (S2, A3) – Participants: IPGP, EOST – Priority: A

Quasi–definitive data are data corrected using temporary baselines shortly after their acquisition and very near to being the final data of an observatory (see section 3.2.2). They have recently emerged as a new observatory data product and are recommended by IAGA and INTERMAGNET. The BCMT has been among the first institutions to produce quasi-definitive data on a regular basis and its data have been used for validating candidate models to the 11th generation of the IGRF model. The goal of this project is to extend to all BCMT observatories (see Table 2) the monthly production of quasi-definitive data. This will require a better coordination of data processing procedures between IPGP and EOST and is expected to improve the overall efficiency of the data processing.

DATA-2: *To develop tools enabling the semi-automatic data processing of 1-second data*

Data users: S2, A3 – Participants: IPGP, EOST – Priority: B

As more and more BCMT observatories are being upgraded to produce 1-second data (see Table 2), it has been realized that some observatories are subject to artificial disturbances in 0.01-1 Hz frequency range. The 1-minute data averaging previously masked these disturbances. Producing definitive 1-second data with the same high quality standards as 1-minute data requires that these disturbances be removed from the recordings. However, this can be a grueling task for some observatories where several spikes occur everyday. This project aims at developing new spike detection and

removal tools in order to streamline the data processing of 1-second data. The new software(s) will be integrated into MAGIS, the existing data processing platform. It will also be used locally at EOST observatories where high-speed Internet is not available.

DATA-3: *To design, develop and launch a new website for the BCMT*

Data users: All – Participants: IPGP, EOST, IRD – Priority: A

The current BCMT website (www.bcmt.fr) was developed in the early 2000s and both its design and functionalities have become largely outdated. As the website is one of the main BCMT data distribution tools (together with the INTERMAGNET website and DVD), as well as the main information source on BCMT activities, improving this situation has become a high priority. The new website will have a modern look and will provide information and data products relevant to BCMT participants, data users and the general public.

4.3.4. Repeat stations

RS-1: *To install new repeat stations / to transfer old repeat stations on airports*

Data users: S1, A1 – Participants: IPGP – Priority: C

The French repeat station network was designed in the late 1940s, with new stations being added until the late 1970s. Its scientific relevance is becoming less clear at a time when low-Earth orbiting satellites provide high precision and high spatial resolution measurements of the geomagnetic field. Only the best repeat stations measurements (best sites, best observers) can be used for global and/or regional secular variation modeling, and even this is questionable. This important question will have to be addressed by the BCMT scientific council before the next measurement campaign, scheduled in 2012. Reducing the size of the network while focusing on achieving the highest data precision is among the considered options. Also, the possibility of transferring some stations on regional airports in partnership with the DGAC (the main non-scientific user of repeat station data) is currently being investigated.

RS-2: *To calculate a regional model of the geomagnetic field in metropolitan France from satellite, observatory and repeat station data*

Data users: S1, A1 – Participants: IPGP – Priority: B

The current declination map (Figure 3) derived from repeat station measurements could be improved by calculating a regional field model using the latest regional modeling techniques such as R-SCHA. This project is already well advanced and a regional field model based upon the 2007 data should be released soon.

4.4. Implementation

The core institutions listed in subsection 4.3 will implement each objective of the BCMT strategy. It should be stressed that the workload associated to these projects will be added to that of regular activities performed by the BCMT staff, such as calibration

measurements, instrument manufacturing, observatory maintenance and data processing. Detailed implementation plans and status reports will be provided in annual funding and staffing requests to INSU/CNRS, IPEV and CNES.

Most objectives are achievable within the current level of annual funding provided by the core institutions, as well as INSU/CNRS, IPEV, CNES and CEA. However, it is expected that additional funding will be needed for objectives INST-2 and OBS-4 to be completed in a timely manner. Other funding sources are currently being sought for these two projects.

The implementation of the BCMT strategy will also require an adequate staffing of all core institutions. There has been an ongoing staffing crisis at the BCMT since the mid-2000s, putting a lot of pressure on the present BCMT staff. Specific requests for staffing will be put to the Conseil National des Astronomes des Physiciens (CNAP) and INSU/CNRS.

Appendix A: List of abbreviations and acronyms

BCMT	Bureau Central de Magnétisme Terrestre
BGO IPERAS	Borok Geophysical Observatory, Institute of Physics of the Earth of the Russian Academy of Sciences
CEA	Commissariat à l'énergie atomique et aux énergies renouvelables
CNAP	Conseil National des Astronomes et Physiciens
CNES	Centre National d'Études Spatiales
CNRS	Centre National de la Recherche Scientifique
CRAAG	Centre de Recherche en Astronomie, Astrophysique et Géophysique
DGAC	Direction Générale de l'Aviation Civile
DMC	Dirección Meteorológica de Chile
EOST	École et Observatoire des Sciences de la Terre
ESA	European Space Agency
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
GIN	Geomagnetic Information Node
GO AAU	Geophysical Observatory, Addis Ababa University
IAGA	International Association of Geomagnetism and Aeronomy
IGN	Institut Géographique National
IGRF	International Geomagnetic Reference Model
IG VAST	Institute of Geophysics, Vietnamese Academy of Science and Technology
IMO	INTERMAGNET Magnetic Observatory
INGV	Istituto Nazionale di Geofisica e Vulcanologia
INSU	Institut National des Sciences de l'Univers
IOGA	Institut et Observatoire Géophysique d'Antananarivo
IPEV	Institut polaire français Paul-Émile Victor
IPGP	Institut de Physique du Globe de Paris
IPSL	Institut Pierre Simon Laplace
IRD	Institut de Recherche pour le Développement
ISGI	International Service of Geomagnetic Indices
LIS CEA	Lanzhou Institute of Seismology, China Earthquake Administration
NCGR	National Center for Geophysical Research
OVSQ	Observatoire Versailles Saint Quentin
UVSQ	Université Versailles Saint Quentin
WDC	World Data Center
WMMD	World Monthly Means Database