

INTERMAGNET

Technical Reference Manual

version : 5.3.2 (2025)

TABLE OF CONTENTS

1	INTERMAGNET	1
1.1	Introduction	1
1.2	INTERMAGNET Vision, Mission and Objectives	1
1.3	History and Status of INTERMAGNET	2
1.4	The INTERMAGNET Principles and Conditions	2
1.5	Participation	3
1.6	Products	3
1.7	Conditions of Use	4
1.8	INTERMAGNET Management	4
1.8.1	Executive Council	4
1.8.2	Operations Committee	5
2	INTERMAGNET Magnetic Observatories - One Minute IMOs	7
2.1	Description	7
2.2	Environment/Location	8
2.3	Instrumentation/Specifications	8
2.3.1	Definitive Data	9
2.3.2	Absolute Measurements	9
2.3.3	Vector Magnetometer	9
2.3.4	Scalar Magnetometer	9
2.3.5	Clock Timekeeping	9
2.3.6	Recorder	9
2.3.7	Transmission	9
2.3.8	Other	10
2.3.9	Proton Gyromagnetic Ratio	10
2.4	Data Sampling and Filtering	10
2.5	Missing Data	11
2.6	Data Quality Control	12
3	INTERMAGNET Magnetic Observatories - One Second IMOs	13
3.1	Description	13
3.2	Environment/Location	14
3.3	Instrumentation/Specifications	14
3.3.1	Definitive Data	15
3.3.2	Absolute Measurements	15
3.3.3	Vector Magnetometer	15
3.3.3.1	General Specifications	15
3.3.3.2	Pass Band Specifications [DC to 8mHz (120s)]	15
3.3.3.3	Pass Band Specifications [8mHz (120s) to 0.2Hz]	16
3.3.3.4	Stop Band Specifications [0.5 Hz]	16

3.3.4	Scalar Magnetometer	16
3.3.5	Auxiliary Measurements	16
3.3.6	Recorder	16
3.3.7	Transmission	16
3.3.8	Other	16
3.4	Data Sampling and Filtering	17
3.5	Missing Data	17
3.6	Data Quality Control	18
4	Absolute Measurements	19
4.1	Definition and Frequency	19
4.2	Instrumentation/Specifications	19
4.3	Measurement Method	20
4.4	Data Quality Control	20
4.5	Observatory Operations	20
4.6	Variometer Operations	21
4.7	Baseline Calculation	21
4.8	Calculation of the Difference Between F Pillar and Absolute Pillar	21
4.9	Training	22
4.10	References	22
5	Processing Data	23
5.1	Introduction	23
5.2	Data Quality Control & Processing Tasks	23
5.2.1	Daily Data Quality Tasks	23
5.2.2	Weekly Data Quality Tasks	24
5.2.3	Monthly Data Quality Tasks	24
5.2.4	Annual Data Quality Tasks	25
5.2.5	Despiking and Removal of Artificially Disturbed Data	25
5.2.6	Absolute Quality Control	26
5.3	Computation of Baseline Values	26
5.4	Baseline Adoption	27
5.5	The Computation of Total Field Differences	27
5.6	Producing Quasi-Definitive Data	28
5.7	Summary	28
6	Submitting Data	29
6.1	Introduction	29
6.1.1	Data Formats	29
6.1.1.1	IMFV1.23 GIN Dissemination Format	29
6.1.1.2	IMFV2.83 Satellite Transmission Format	30
6.1.1.3	IAGA-2002	30
6.1.1.4	INTERMAGNET Archive Format	30
6.1.1.5	ImagCDF	30
6.1.1.6	IYF INTERMAGNET Year-Mean File	30
6.1.1.7	IBF INTERMAGNET Baseline File	31
6.1.2	Data Types	31
6.1.3	Geomagnetic Components (or Elements)	32
6.1.4	Near Real-Time Preliminary Data	33
6.1.5	Geomagnetic Information Nodes	33
6.1.5.1	GIN Manager Addresses	34
6.1.5.2	GIN Email Addresses	35
6.1.5.3	INTERMAGNET GIN Types	35
6.2	Submission of Preliminary Data	35

6.2.1	Update Frequencies and Formats for Preliminary Data	36
6.2.2	Types of Preliminary Data	36
6.2.3	Submission via WEB Service	37
6.2.4	Submission via Email	38
6.2.5	Satellite Transmission	39
6.2.5.1	Geostationary Satellites	39
6.2.5.2	METEOSAT	39
6.2.5.3	GOES	39
6.2.5.4	Transmission Access	39
6.2.5.5	Satellite Operators	40
6.2.5.6	Satellite Services	41
6.2.6	Transferring Data from GINs to WEB Site	41
6.2.7	How to Check if Your Data Has Been Received	42
6.2.8	Common Problems with Data Transmission	42
6.2.9	Data Publication Delays	42
6.3	Submission of Quasi-Definitive Data	43
6.3.1	Update Frequencies and Formats for Quasi-Definitive Data	43
6.3.2	Submission via WEB Service	43
6.3.3	Submission via Email	43
6.3.4	How to Check if Your Data Has Been Received	43
6.3.5	References	43
6.4	Definitive 1-Minute Data	44
6.4.1	Checking Procedure	45
6.4.2	Obtaining the Checking Software	46
6.4.3	Data Encoding for Publication	46
6.4.3.1	General Features	46
6.4.3.2	IAF INTERMAGNET Archive Format	47
6.4.3.2.1	IAFV2.11 (2014 and after)	47
6.4.3.3	INTERMAGNET Reference Data Set and Physical Media Directory Structure	48
6.4.3.4	INTERMAGNET Reference Data Set and Physical Media Software	49
6.5	Definitive Data Calculation Based on Most Common Orientations	50
6.6	Standards for Calculating Hourly, Daily and Annual Means	52
6.6.1	Hourly Mean Values	52
6.6.2	Daily Mean Values	52
6.6.3	Annual Mean Values	52
6.6.4	Rule for Missing 1-minute Values	52
6.7	Definitive 1-Second Data	53
7	Using INTERMAGNET Data	55
7.1	INTERMAGNET WEB Site	55
7.1.1	WEB Site Address	55
7.1.2	Online Technical Reference Manual	56
7.1.3	Downloading Data	56
7.1.3.1	Downloading Data Using DOIs	57
7.1.3.2	Downloading Data Using the WEB Interface	58
7.1.4	Geomagnetic Activity	58
7.2	Data Viewer	58
7.3	Condition Use	59
7.3.1	Acknowledgment of Data from Observatories Participating in INTERMAGNET	59
8	How to Apply for Membership	61
8.1	Application	61
8.2	INTERMAGNET Participation Policy	62
8.2.1	Observatory Application to the INTERMAGNET Network	62

8.2.2	Ongoing Participation in the INTERMAGNET Network	63
8.2.3	Withdrawal of INTERMAGNET Status	63
A	INTERMAGNET Terminology	65
B	Observatories Participating in INTERMAGNET	67
C	Archive Data Formats	69
C.1	INTERMAGNET Archive Format : IAF	69
C.1.1	IAFV2.11 Binary Data Structure Format-32 Bit Words	69
C.1.2	IAFV2.10 Binary Data Structure Format-32 Bit Words	70
C.1.2.1	IAFV2.10 (2010 to 2013)	71
C.1.3	IAFV2.00 Binary Data Structure Format-32 Bit Words	72
C.1.3.1	IAFV2.00 (2009)	73
C.1.4	IAFV1.10 Binary Data Structure Format-32 Bit Words	74
C.1.4.1	IAFV1.10 (2008)	75
C.1.5	IAFV1.00 Binary Data Structure Format-32 Bit Words	75
C.1.5.1	IAFV1.00 (2007 and before)	76
C.2	INTERMAGNET Physical Media Directory Structure	78
C.2.1	Structure of the USB (2014)	78
C.2.2	Structure of (2011) DVD	79
C.2.3	Structure of first (1991) CD-ROM	80
C.2.4	INTERMAGNET Physical Media Directory Structure	81
C.2.5	List of Changes to the Structure since the first (1991) CD-ROM	81
C.3	INTERMAGNET Format for Yearmean File : IYF V1.02	85
C.3.1	Description of the Header Block	85
C.3.2	Description of the Footer	86
C.3.3	Sample of a Yearmean File	86
C.3.4	Sample of Missing Values	88
D	Contacts	89
D.1	INTERMAGNET Executive Council	89
D.2	INTERMAGNET Operations Committee	90
E	Data Formats	93
E.1	INTERMAGNET Satellite Transmission Format : IMFV2.83	93
E.1.1	IMFV2.83 Header Encoding	94
E.1.2	IMFV2.83 Data Value Encoding	95
E.2	Satellite Coding Examples	99
E.2.1	Coding Example for Goes Satellite	99
E.2.2	Coding Example for Meteosat Satellite	100
E.2.3	Coding Example for GMS Satellite	103
E.2.4	Time Framing for GMS	104
E.2.4.1	Base-44 Coding for GMS	104
E.3	INTERMAGNET Gin Dissemination Format for Minute Values : IMFV	106
E.3.1	IMFV1.23	106
E.3.1.1	Description of the Header Block (64 characters including CrLf)	106
E.3.1.2	Description of Data Space (64 characters per line including CrLf)	107
E.3.2	IMFV1.22	108
E.3.2.1	Description of the Header Block (64 characters including CrLf)	108
E.3.2.2	Description of Data Space (64 characters per line including CrLf)	109
E.4	INTERMAGNET Baseline Format : IBF	110
E.4.1	IBFV2.00 (2009 and after)	110
E.4.2	IBFV1.20 (2008 and before)	112
E.5	IAGA2002 INTERMAGNET Exchange Format (Spreadsheet compatible)	113

E.5.1	The 12 Mandatory File Header Records	113
E.5.2	The Optional Comment Header Records	114
E.5.3	The Mandatory Data Header Record	114
E.5.4	The Data Records	115
E.5.5	Recommended File Name Procedure	115
E.5.6	Sample of IAGA-2002 Format July 2003 Revision	116
E.5.6.1	Sample Data Header and Data Record for 1-minute Values	116
E.5.6.2	Sample Data Header and Data Record for Hourly Values	117
E.5.6.3	Sample Data Header and Data Record for Monthly Values	117
E.5.6.4	Sample Data Header and Data Record for 1-second Values	118
E.5.6.5	Sample Data Header and Data Record for 5-Millisecond Values	118
E.6	IMAGCDF INTERMAGNET Exchange Format	119
E.6.1	Design Details and CDF Concepts	119
E.6.1.1	General Design Details	119
E.6.1.2	Data Types Used for Variables and Attributes	119
E.6.1.2.1	Real Numbers	119
E.6.1.2.2	Dates / Times	120
E.6.1.2.3	Strings	120
E.6.1.3	Compression	120
E.6.2	Where to Obtain the CDF Software	120
E.6.3	ImagCDF Data	120
E.6.4	ImagCDF Version 1.2	121
E.6.4.1	ImagCDF Global Attributes (V1.2)	121
E.6.4.1.1	Attributes that Describe the Data Format (V1.2)	122
E.6.4.1.2	Attributes that Uniquely Identify the Data (V1.2)	122
E.6.4.1.3	Attributes that Describe the Observatory (V1.2)	123
E.6.4.1.4	Attributes that Relate to Data Standards and Quality (V1.2)	123
E.6.4.1.5	Attributes that Relate to Publication of the Data (V1.2)	124
E.6.4.1.6	Valid Codes for Elements Recorded (V1.2)	124
E.6.4.1.7	Relevant Data Standards (V1.2)	125
E.6.4.2	ImagCDF Variable Attributes (V1.2)	126
E.6.4.3	ImagCDF File Names (V1.2)	127
E.6.4.3.1	Format of Date/Time Portion of Filename and Examples (V1.2)	128
E.6.5	ImagCDF Version 1.3	128
E.6.5.1	ImagCDF Global Attributes (V1.3)	128
E.6.5.2	ImagCDF Variable Attributes (V1.3)	129
E.6.5.3	ImagCDF File Names (V1.3)	129
E.6.5.3.1	ISO 8601 Duration Strings for Common Geomagnetic Sample Periods (V1.3)	129
E.6.5.3.2	Format of Date/Time Portion of Filename and Examples (V1.3)	129
E.6.6	Tools to Look at CDF Data	130
E.6.7	Example Data File	131
F	Filter Coefficients	135
F.1	Filter Coefficients to Produce One Minute Values	135
F.2	Filter Coefficients to Produce One Second Values	136
G	Acknowledgements	137

This document has been prepared by the INTERMAGNET Operations Committee and Executive Council. Every effort has been made to ensure that the information is accurate and current. The document is distributed in the hope that it will be a useful reference not only for those participating formally in INTERMAGNET, but also for the greater geomagnetic community.

ACKNOWLEDGMENTS

We gratefully acknowledge the many significant contributions and comments provided by our colleagues.

Cite as:

Bracke, S. (Ed.), INTERMAGNET Operations Committee and Executive Council, 2025, INTERMAGNET Technical Reference Manual, Version 5.3.2

The INTERMAGNET Office :

INTERMAGNET
c/o British Geological Survey
The Lyell Centre
Research Avenue South
Edinburgh EH14 4AP
UK

QUICK REFERENCES

- **INTERMAGNET web site**

<https://www.intermagnet.org/>

- **GIN internet addresses**

Ottawa: charles.blais@canada.ca

Paris: vmaury@ipgp.fr

Golden: bgeels@usgs.gov

Edinburgh: e_gin@mail.nmh.ac.uk

Kyoto: wdc_service@kugi.kyoto-u.ac.jp

- **INTERMAGNET PHYSICAL MEDIA (IPM) distribution office**

INTERMAGNET Physical Media distribution office

Observatoire Magnétique National

Carrefour des 8 routes

45340 Chambon la Forêt

FRANCE

TEL: 33 (0) 2-38-33-95-01

INTERNET: intermagnet@ipgp.fr

- **General inquiries**

Andrew Lewis

INTERMAGNET Operations Committee

c/o Geoscience Australia

Cnr Jerrabomberra Avenue and Hindmarsh Drive

Symonston ACT

GPO Box 378

Canberra ACT 2601

Australia

TEL: +61 2 6249 9764

FAX: +61 2 6249 9999

INTERNET: andrew.lewis@ga.gov.au

- **INTERMAGNET membership application**

Information on how to apply for membership can be found in **Chapter 8**. The application form can be downloaded from

<https://intermagnet.org/membership.html>

More information can be obtained from the INTERMAGNET Observatories Subcommittee chair:

Chris Turbitt

INTERMAGNET

c/o British Geological Survey

The Lyell Centre

Research Avenue South

Edinburgh EH14 4AP

United Kingdom

TEL: 44-131-667-1000

FAX: 44-131-667-1877

INTERNET: c.turbitt@bgs.ac.uk

INTERMAGNET

1.1 Introduction

The Genesis of INTERMAGNET resulted from a convergence of scientific need and emerging technology. The growing interest and importance of space weather fostered a need for “near real-time” magnetic data, and the semi-automation of some of the world’s major networks in the late 1980s made it possible to provide data in a timely fashion. However, no standards or guidelines existed to ensure that, as other observatories converted from analogue to digital recording, their data would be of comparable quality to data from existing automated observatories; nor was there any guarantee that their data would be compatible with data from existing digital systems. INTERMAGNET was founded both to develop standards for the acquisition and transmission of observatory data and to encourage the establishment of digital magnetic observatories in all parts of the world. Although the near real-time transmission of data is a major focus of INTERMAGNET activity, much effort is also spent ensuring that INTERMAGNET observatories provide data of sufficient accuracy to meet the needs of scientists who study the magnetic field of internal origin.

By any measure INTERMAGNET has been a resounding success. In three decades it has grown from a pilot project to an internationally recognized organization that includes approximately 50 institutes and over 100 observatories. In 2017, more than 9 million observatory-days of data are distributed to users. These are used in a variety of ways: magnetic reference field model production; space weather forecasts; directional drilling; magnetic surveying; and scientific research.

However, user needs change, and to maintain its relevance INTERMAGNET must evolve accordingly. To ensure the continued success of the organization, INTERMAGNET liaises with users to make certain that the observatories provide data that meet the needs of all its users, now and into the future.

1.2 INTERMAGNET Vision, Mission and Objectives

The main objective of INTERMAGNET is to establish a global network of cooperating digital magnetic observatories, adopting modern standard specifications for measuring and recording equipment, in order to facilitate data exchange and the production of geomagnetic products in a timely manner.

In more detail, INTERMAGNET has a specific vision, mission and strategy, which are as follows.

The INTERMAGNET vision is of

A global, real-time, permanent geomagnetic observatory network, which is recognized as a key Earth observation system that provides data, which serve scientific research into the Earth, from its deep interior to space, and support operational services benefiting society.

The INTERMAGNET mission is to

Establish and maintain an organization with a worldwide membership drawn from institutes operating geomagnetic observatories that is dedicated to building a network of geomagnetic observatories supplying consistent data, with the geographical coverage, quality, and timeliness of delivery required to meet the evolving needs of research and applied science.

The INTERMAGNET strategy is to

1. Set mandatory standards for measurement, data processing, formats and transmission for network membership, and to support geomagnetic observatory operators in achieving these standards by providing technical assistance.
2. Provide advice on the establishment of new observatories, to help co-ordinate initiatives taken by member institutes and to optimize the scientific value of the global network.
3. Support data services, as a member of the World Data System, by maintaining an infrastructure for geomagnetic observatory data collection and dissemination.
4. Communicate with data users to promote the use of INTERMAGNET data and to understand their requirements, feeding this information into the definitions of operating standards.
5. Work closely with the International Association of Geomagnetism and Aeronomy and other organizations concerned with magnetic observatory operations.
6. Maintain a dialog with technology providers to take advantage of new developments in instrumentation and data acquisition, and to advise them of user demands for data in order to inform their system developments.

This manual therefore describes the global near real-time magnetic observatory network, known as INTERMAGNET. Throughout the document, the term “magnetic observatory” will mean a recording station where absolute measurements of the geomagnetic field are made on a regular basis over many years and which produces data of the requisite quality for secular variation studies.

1.3 History and Status of INTERMAGNET

The possibility of worldwide data communication between magnetic observatories was first raised seriously at the Workshop on Magnetic Observatory Instruments, held in Ottawa, Canada, in August 1986. Further discussions, particularly between the British Geological Survey (BGS) and the U.S. Geological Survey (USGS) took place in May 1987 at the Nordic Comparison Meeting held at Chambon la Forêt, France. A pilot scheme between BGS and USGS was described at the sessions of Division V of IAGA during the XIXth General Assembly of IUGG in Vancouver, Canada, in August 1987, with the proposal that the geomagnetic community should adopt automatic observatories with satellite communications as its mode of operation for the future. INTERMAGNET embodies the proposal to extend worldwide the network of observatories communicating in this way. A successful pilot scheme operated during 1989, with the UK, USA, and Canada transmitting and receiving at 12 minute or 1 hour intervals geomagnetic data recorded every minute. As a result of the pilot scheme, the IAGA Executive Committee endorsed INTERMAGNET. The Study of the Earth's Deep Interior (SEDI) Steering Committee has also endorsed INTERMAGNET.

At present the observatories shown in *APPENDIX B* are transmitting daily over the Internet, or through satellites to Geomagnetic Information Node (GINs). More stations are coming online rapidly. GINs are now operating in Edinburgh (BGS), Golden (USGS), Kyoto (Kyoto U.), Ottawa (GSC), and Paris (IPGP).

1.4 The INTERMAGNET Principles and Conditions

INTERMAGNET is operated according to principles and conditions (listed below) which are accepted as necessary and desirable for maintaining a service of rapid magnetic observatory data exchanges for the international scientific community and for commercial users.

1. INTERMAGNET is a non-exclusive program of worldwide data exchange between magnetic observatories.
2. An INTERMAGNET aim is the establishment and maintenance of observatories in remote areas where local support is lacking.
3. INTERMAGNET encourages the establishment and maintenance of digital observatories in developing countries, with the involvement and enhancement of local science and technology.
4. Each participating country/institution is expected to bear the costs of its participation in INTERMAGNET.

5. Data will be transmitted from observatories or operating institutes to regional geomagnetic information nodes (GINs) by satellites, computer networks or by other near real-time means, using standard INTERMAGNET formats.
6. Regional geomagnetic information nodes will exchange data and data products globally as rapidly as appropriate, and will maintain data files for all contributing observatories for a period commensurate with the immediate usefulness of the product.
7. The collected data will be made available to the scientific community and to participating observatories on the INTERMAGNET web site or on media and in formats approved by the INTERMAGNET Executive Council.
8. All data are supplied on the condition that they are not used for commercial gain (media, transcription and other costs may be charged to the user).
9. The INTERMAGNET Executive Council recognizes the value to commerce of geomagnetic data and derived products which are available in near real-time, and accepts the right of participating institutions to recover costs for services and to levy charges where possible and as necessary. Participating institutions will undertake to safeguard the interests of fellow participants concerning the commercial usage of their data.
10. Each INTERMAGNET GIN will provide annually to each participating institution or observatory a statement of data received by the GIN. Each week, INTERMAGNET will provide data download statistics to the community.
11. Participating institutes will co-operate to facilitate the production of globally representative data products, such as the official IAGA indices.
12. Participating institutions will agree to submit definitive data annually for inclusion in the INTERMAGNET data set.

1.5 Participation

INTERMAGNET membership is available to institutions who wish to operate one or more INTERMAGNET Magnetic Observatories (IMOs). Members agree to allow distribution of their IMO data in accordance with INTERMAGNET guidelines. In return for participation, Institutional membership provides: access to near real-time data from any IMOs for all members of the Institution; access to the best in magnetic observatory technologies and assistance in implementing them. There are, at present, no membership fees. An application to become a member is submitted to the INTERMAGNET office for approval by the Executive Council, subject to technical evaluation by the Operations Committee. Information on how to apply for membership can be found in [Chapter 8](#).

1.6 Products

Values of geomagnetic components along with other INTERMAGNET products may be retrieved from the website (<https://www.intermagnet.org/>) under Data. Values are kept on-line permanently to allow comparisons between preliminary and definitive data and to give data sets that can be used to test software that works with preliminary data. When available, definitive data should preferably be used. Before 2017, a physical media containing definitive data from INTERMAGNET observatories was created annually. After 2016, definitive data will not be published on a physical media and will be available for download on the INTERMAGNET website. The INTERMAGNET physical medias are available at no charge to participating institutes and to bona fide scientists for academic purposes only. Technical help for operators of IMOs may also be available by special arrangements through the INTERMAGNET office.

1.7 Conditions of Use

Unless otherwise noted, INTERMAGNET data are provided to users under a Creative Commons Attributions-NonCommercial 4.0 International Licence (CC BY-NC 4.0). Some institutes contributing data to INTERMAGNET may do so under different licence arrangements.

- If data are required for commercial use, sale or bulk distribution you must obtain written permission directly from the institute operating the observatory. Check the INTERMAGNET web site (<https://www.intermagnet.org/>) for contact details and any specific institute licence conditions.
- Any report or publication making use of INTERMAGNET data should acknowledge the relevant institutes as the source of data. The preferred method for acknowledgement is to cite the relevant Digital Object Identifier (DOI). DOIs are not yet available for some older data so INTERMAGNET provides two suggested forms of acknowledgement for those data, see [Section 7.3.1](#).
- We ask that either an electronic link to, or paper copy of, each report or publication is sent to those institutes whose data you use.
- We also ask that a citation reference is sent to the INTERMAGNET Secretary secretary_intermagnet@gfz-potsdam.de.

Your email address, which you provide to INTERMAGNET when requesting data, may be given to the institute supplying the data so that it can monitor data usage.

By accessing data from INTERMAGNET you signify your acceptance of these terms and conditions. For commercial applications of observatory data, you must contact the operating institute directly.

INTERMAGNET accepts no liability in respect of loss, damage, injury or other occurrence arising from the provision of these data.

1.8 INTERMAGNET Management

1.8.1 Executive Council

The Executive Council establishes policy for INTERMAGNET, deals with questions of international participation and data exchange, and communicates with national agencies and international scientific and funding agencies.

Table 1.1: Executive Council membership

David Boteler	Canada (Chair)
Ellen Clarke	United Kingdom
Gauthier Hulot	France
Kristen Lewis	United States of America
Andrew Lewis	Australia
Jürgen Matzka	Germany

1.8.2 Operations Committee

The Operations Committee advises the Executive Council on matters relating to magnetic sensors, data capture and data processing, and on communications options, protocols, etc. The Operations Committee is also responsible for establishing and maintaining standards of operation and uniform data formats and transmission characteristics which optimize global data exchange.

The Operations Committee is led by:

- Jürgen Matzka, Chair
- Andrew Lewis, Secretary

Table 1.2: Operations Committee Structure

Name	Definitive Data	GINS	IMO applications and Standards	Technical Manual	Instrumentation and Data acquisition
András Csontos				Member	
Andrew Lewis			Deputy Chair	Member	
Benoit Heumez	Deputy Chair		Member		
Brendan Geels		Member			
Charles Blais		Member			
Chris Turbitt			Chair	Deputy Chair	
David Calp			Member		
Emmanuel Nahayo	Member				
Igor Mandic	Member				
Jan Reda	Co-Chair				
Jürgen Matzka			Member		
Kusumita Arora	Member				
Manjula Lingala	Member				
Marcos Vinicius da Silva	Member				
Matthew Gard	Member		Member		
Orsi Baillie	Member				
Roman Leonhardt	Co-Chair				
Seiki Asari				Member	
Shun Imajo		Member			
Simon Flower	Member	Chair			
Stephan Bracke		Member		Chair	
Tero Raita	Member		Member		
Virginie Maury		Member			

INTERMAGNET MAGNETIC OBSERVATORIES - ONE MINUTE IMOS

2.1 Description

An INTERMAGNET Magnetic Observatory (IMO) is a magnetic observatory with full absolute control, making continual data recordings at a minimum rate of one minute. One minute magnetic field values should be measured using a vector magnetometer and, optionally, a scalar magnetometer. Vector measurements performed by a continually recording magnetometer are typically variation measurements and variation data, transmitted as reported data, can be accepted by INTERMAGNET GINs from existing member observatories. However, it has been considered best practice since Technical Manual V4.0 (1999) that variometer data are corrected to near absolute values using the best available baseline estimates at the time of transmission. Observatories making new applications for INTERMAGNET membership will be required to transmit data with best available baseline estimates applied.

IMOs are required to transmit preliminary data in an INTERMAGNET recognized format (see [Section 6.1.1](#)) to one of the INTERMAGNET Geomagnetic Information Nodes (GIN) by electronic means within 72 hours of recording. Data are typically transmitted over the Internet or through satellite such that preliminary data can be made available on the INTERMAGNET web site. Note that, for the time being, GINs also accept reported data from observatories that have historically transmitted such data.

Within 3-months, observatories may transmit quasi-definitive data to one of the INTERMAGNET GINs provided these data meet the provisional baseline conditions outlined in [APPENDIX A](#). Quasi-definitive data submission is by the same method as preliminary data submission (described in [Section 6.2](#)). Observatories may submit quasi-definitive data in place of preliminary data if this meets the requirement of being received within 72 hours of recording, but ideally faster (see [Section 6.1.4](#)).

At the end of a calendar year, data are to be prepared using final baselines and submitted as definitive data for inclusion in the INTERMAGNET Reference Data Set (IRDS). The deadline for submission will be communicated by INTERMAGNET.

An observatory intending to participate in INTERMAGNET as an IMO must be able to meet the INTERMAGNET standards for one-minute data detailed below and agree to the conditions for data transmission detailed in the INTERMAGNET Participation Policy. The Participation Policy is included in [Chapter 8](#) along with instruction for observatories wishing to make an IMO application. Further information is also available from the INTERMAGNET Observatories Subcommittee chair.

2.2 Environment/Location

There are a number of factors that determine the quality of data recorded at an observatory and whether the recorded data conform to the INTERMAGNET standards for one-minute data. Such factors include the types of instrument, the operating environment, the quality and frequency of absolute observations and the method used to apply baseline measurements to the vector magnetometer data.

The type of instrument varies greatly from observatory to observatory, but generally, vector magnetometers must be housed in a clean, dry, shelter with a stable pillar (preferably on bed rock), where there is low magnetic gradient and no man-made magnetic contamination. Since in general, vector magnetometers have a significant temperature coefficient, the vector magnetometer shelter should ideally maintain a constant temperature throughout the year as well as protecting the instrument from the elements. This may be achieved through thermal insulation and damping and may also include regulated heating or cooling.

Generally, scalar magnetometers, have an extremely small temperature coefficient and may be housed in non-temperature regulated housing, but they must still be protected from the elements. Instruments should be separated by a few meters to avoid cross-contamination.

The Manual on Magnetic Measurements and Observatory Practice (Jankowski and Sucksdorff, 1996) suggests establishing a magnetic observatory on a piece of land which is large enough not only to house the buildings, but also to limit the magnetic contamination from surrounding infrastructure or activity. In order to resolve the long period components of the natural magnetic field, care must be taken to select a site that is free from sources of man-made magnetic contamination over time-scales of many years. Contamination can come from nearby roads, buildings, power distribution infrastructure (transformers or cables), transmitters (radio or communication), local land use (e.g. housing, farm machinery, etc.) or from electric train lines. DC train lines can cause interference for tens of kilometers.

Other desirables are:

- The site should have as low a magnetic gradient as possible, particularly in the location of the instruments and between the variometers, scalar magnetometer and the absolute pillar.
- The observatory buildings should be located on a flat, well-drained, solid foundation. Buildings, lighting and heating systems should be made of non-magnetic materials. Electricity supplies to variometer and absolute buildings for lighting and heating should be AC.
- There should be access to a reliable mains electricity supply to the site, preferably with some form of back-up power, so that power outages are kept to a minimum.
- The site should offer good visibility to distance reference objects for absolute observations.
- There should be access to local telephone or network communications for data transfer.
- There should be an existing clean, dry environment nearby to house the data recording equipment.
- The site should be easily accessible by observatory staff.

2.3 Instrumentation/Specifications

INTERMAGNET does not specify the type of magnetometer that must be used (although a list of instrument suppliers can be provided on request), however an IMO must try to meet the recommendations listed below. These specifications are used by INTERMAGNET as a guideline for reviewing data quality when data are either submitted for an IMO application, or when definitive data are submitted for inclusion in the INTERMAGNET archive. A scalar magnetometer is not mandatory, but is recommended for data quality monitoring.

2.3.1 Definitive Data

Accuracy	$\pm 5\text{nT}$
----------	------------------

2.3.2 Absolute Measurements

See Chapter 4

2.3.3 Vector Magnetometer

Resolution	0.1nT
Dynamic Range	$\pm 4000\text{nT}$ High Latitude $\pm 3000\text{nT}$ Mid/Equatorial Latitude
Band pass	D.C. to 0.1Hz
Sampling rate	1Hz
Thermal stability	0.25nT/ $^{\circ}\text{C}$
Long term stability	5nT/year

2.3.4 Scalar Magnetometer

Resolution	0.1nT
Accuracy	1nT
Sampling rate	0.033Hz (30 sec)

2.3.5 Clock Timekeeping

Observatory data logger	5 seconds centered on UTC minute (mm:00)
Data collection platform	± 1.5 sec GOES, GMS ± 1.0 sec METEOSAT

2.3.6 Recorder

An on-site recorder is necessary so data are not lost as a result of data transmission outages.

2.3.7 Transmission

Transmission to a Geomagnetic Information Node (GIN) must be over the Internet or by satellite, within 72 hours of acquisition or sooner (see Section 6.1.4).

Note: Keeping within the time slot for satellite transmission is an important duty of an IMO operator. When advised by a GIN of a time drift, the IMO operator must make the necessary corrections within 24 hours.

2.3.8 Other

Preliminary data	transmitted in IAGA2002 format (IMFV2.83 for satellite)
Definitive data	to be submitted annually for inclusion in the IRDS in IAFV2.11 format
Instrument baseline data	to be submitted annually for inclusion in the IRDS in IBFV2.00 format
Annual means	to be submitted annually for inclusion in the IRDS in IYFV1.02 format
Filtering	to INTERMAGNET standard (Section 2.4)

For more information see Section 6.1.1 for Data Formats and Section 6.1.2 for Data Types.

2.3.9 Proton Gyromagnetic Ratio

In 2009, INTERMAGNET adopted the new proton gyromagnetic ratio (for H₂O, sphere, 25°C) published by the CODATA group in 2006 (see https://physics.nist.gov/cuu/pdf/all_2006.pdf):

$$g_p = 2.675153362 * 10^8 .T^{-1}S^{-1}$$

This ratio divided by 2 pi relates the magnetic field strength in T to the output frequency (Larmor frequency) of a proton magnetometer in Hz. For example, a field strength of 50000.00 nT gives a Larmor frequency of 2128.819 Hz.

2.4 Data Sampling and Filtering

In its Resolution 12 from the 1979 Assembly in Canberra, IAGA noted the desirability of digital magnetic observatories using a sampling rate no slower than once every 10 seconds. In that resolution, IAGA also stated that the one-minute means must be centered on the minute (mm:00).

To minimize aliasing of higher frequency signals into the pass-band of the final minute data series, anti-aliasing filters should be included in the analogue portions of magnetometers before analogue-to-digital conversion. The filter responses should be matched to the chosen primary digital sampling rate. Subsequent to the digital sampling, INTERMAGNET requires that a numerical filter be applied in order to obtain the final minute data series.

One digital filter that is widely used by INTERMAGNET can be achieved by applying the following coefficients (for a Gaussian filter) to a series of 19 samples of 5-second data :

Table 2.1: filter 5 sec

C0	0.00229315
C1	0.00531440
C2	0.01115655
C3	0.02121585
C4	0.03654680
C5	0.05702885
C6	0.08061140
C7	0.10321785
C8	0.11972085
C9	0.12578865
C10	0.11972085
C11	0.10321785
C12	0.08061140
C13	0.05702885
C14	0.03654680
C15	0.02121585
C16	0.01115655
C17	0.00531440
C18	0.00229315

For a filter output value to be centered on the minute, coefficient C0 is applied 45 seconds before this minute and coefficient C18 is applied 45 seconds after the minute.

In addition to the attenuation provided by the numerical filter, a “natural filter” applies, estimated at -9 to -18 dB/Octave typically, caused by the decrease in energy of the natural field with increasing frequency.

Examples of other acceptable sets of filter coefficients, for use with various sampling rates of properly anti-aliased signals are presented in [APPENDIX F1](#).

A scalar magnetometer must provide a sample centered on the same time as the output of the digital filter used with the vector magnetometer. INTERMAGNET recommends that the scalar magnetometer is sampled at the highest possible rate and that the data are filtered to one-minute values using the filter specified in this section.

2.5 Missing Data

When mean or filtered values are to be calculated, the question of how to handle missing data arises. For a number of reasons it is difficult to devise a simple objective rule that can be applied to all cases. INTERMAGNET recommends a simple and pragmatic approach: mean or filtered values may be calculated when 90% or more of the values required for calculation are available. This can be interpreted as either 90% of the values or 90% of the weight of the filter. When fewer than 90% of the required values are available the value should be assigned the value used to flag missing data. INTERMAGNET recommends adoption of this rule for both simple mean and weighted mean calculations. For example, a simple daily mean value may be computed when 1296 or more one-minute values are available for the day. Similarly, if a one-minute value is constructed from one-second samples, the one-minute value may be computed when 54 or more one-second samples are available. In either case the weights applied to each sample in the mean or the filter must be re-normalized to account for the reduced number of samples available. In practice, this means dividing the sum of samples by the number of available samples in the case of a simple mean or normalizing to unity those coefficients that have been used in a filter calculation. INTERMAGNET observatories are expected to provide high levels of data continuity, so this rule is expected to be applied only rarely. To avoid the propagation of missing values into higher level means, it is recommended to calculate all higher level means using the method described in [Section 6.6](#).

2.6 Data Quality Control

Variometer drift should be monitored regularly through frequent absolute observations. [Chapter 4](#) describes absolute measurements and [Chapter 5](#) describes the derivation of continuous variometer baselines from spot measurements and the calculation of baseline corrected data.

Continual recordings of the variometer temperature should also be made as temperature recordings can be of benefit when determining the source of baseline variations. Many observatories monitor both the variometer electronics and sensor separately as the electronics and the sensor typically have differing temperature coefficients.

Although the use of a continually recording scalar magnetometer is not mandatory, it is highly recommended. Since proton precession magnetometers and Overhauser effect magnetometers generally have a very low temperature coefficient and output near-absolute values without the need for baseline measurements, they provide a high quality reference data set against which baseline-corrected vector variometer data can be compared, albeit only the scalar component. Such comparisons can identify baseline drift in the variometer or changes in the local field gradient. In addition, as the variometer and the scalar magnetometer are spatially separated, such comparisons can also serve to identify local magnetic contamination.

The first derivative of the variometer and scalar data can be a good indicator for spikes and noise. Where there is another observatory in relatively close proximity, comparisons of the two sets of vector data can frequently highlight scaling or alignment errors and also steps, spikes or drifting in a variometer data set that are not necessarily evident when observing a single data set.

It is good practice to maintain good written records of instrument changes, site changes or changes in personnel. Where there is a major change of instrument that differs significantly from the original IMO application, this should be communicated to the INTERMAGNET secretary.

INTERMAGNET MAGNETIC OBSERVATORIES - ONE SECOND IMOS

3.1 Description

Because of recent developments in instrumentation, data acquisition, and data dissemination, an increasing number of observatories have begun to produce a filtered one-second data product in addition to traditional one-minute data, hourly means, daily means, monthly means, and annual means. An INTERMAGNET survey of the user community carried out in 2005 concluded that there is a desire for one-second data, that they should be made available through the INTERMAGNET network, and that, as is the case for one-minute data, a standard of instrument performance and data quality should be set. The INTERMAGNET Observatories & Standards Subcommittee has developed one-second data standards which were adopted in 2012¹. These standards are discussed in the following sections.

A one-second INTERMAGNET Magnetic Observatory (1s-IMO) is a magnetic observatory with full absolute control, making continual data recordings at a minimum rate of once per second using a vector magnetometer and at a minimum rate of once every 30 seconds using a scalar magnetometer. Since vector measurements performed by a continually recording magnetometer are typically variation measurements, they are to be corrected to quasi-absolute using the best available baseline measurements prior to transmission.

1s-IMOs are required to transmit preliminary data in an INTERMAGNET recognized format (see [Section 6.1.1](#)) to one of the INTERMAGNET Geomagnetic Information Nodes (GIN) by electronic means within 72 hours of recording. Data are typically transmitted over the Internet such that preliminary data can be made available on the INTERMAGNET web site. Note that, for the time being, GINs also accept reported data from observatories that have historically transmitted such data.

Within 3-months, observatories may transmit quasi-definitive data to one of the INTERMAGNET GINs provided these data meet the provisional baseline conditions outlined in [APPENDIX A](#). Quasi-definitive data submission is by the same method as preliminary data submission (described in [Section 6.2](#)). Observatories may submit quasi-definitive data in place of preliminary data if this meets the requirement of being received within 72 hours of recording.

At the end of a calendar year, until the production of a global one-second data archive, one-second data are to be prepared using final baselines and submitted as definitive data for inclusion in the INTERMAGNET archive. The deadline for submission will be communicated by INTERMAGNET. Definitive data archives are made available on the INTERMAGNET web site. For definitive data processing, it is recommended that the same variometer baselines computed for the one minute be used for the one second, if the same variometer is producing both data sets.

An observatory intending to participate in INTERMAGNET as a 1sIMO must agree to these conditions for data transmission and be able to meet the INTERMAGNET standards for one-second data detailed in this chapter. [Chapter 8](#) provides instruction for observatories wishing to make a 1s-IMO application. Further information is also available from the INTERMAGNET Observatories Subcommittee chair.

¹ C. Turbitt, J. Matzka, J. Rasson, B. St-Louis, D. Stewart, 2013. An Instrument Performance and Data Quality Standard for Intermagnet One-Second Data Exchange. Proceedings of the XVth IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing, Extended Abstract Volume. Real Instituto y Observatorio de la Armada en San Fernando, Boletín Roa N.º 3/2013 pp186-188, ISSN: 1131-504029

3.2 Environment/Location

There are a number of factors that determine the quality of data recorded at an observatory and whether the recorded data conform to the INTERMAGNET standards for one-second data. Such factors include the types of instrument, the operating environment, the quality and frequency of absolute observations and the method used to apply baseline measurements to the vector magnetometer data.

The instrument's operating environment varies greatly from observatory to observatory, but generally, vector magnetometers must be housed in a clean, dry, shelter with a stable pillar (preferably on bed rock), where there is low magnetic gradient and no man-made magnetic contamination. Since in general, vector magnetometers have a significant temperature coefficient, the vector magnetometer shelter should ideally maintain a constant temperature throughout the year as well as protecting the instrument from the elements. This may be achieved through thermal insulation and damping and may also include regulated heating or cooling.

Generally, scalar magnetometers, have an extremely small temperature coefficient and may be housed in non-temperature regulated housing, but they must still be protected from the elements. Instruments should be separated by a few meters to avoid cross-contamination.

The Manual on Magnetic Measurements and Observatory Practice (Jankowski and Sucksdorff, 1996) suggests establishing a magnetic observatory on a piece of land which is large enough not only to house the buildings, but also to limit the magnetic contamination from surrounding infrastructure or activity. In order to resolve the long period components of the natural magnetic field, care must be taken to select a site that is free from sources of man-made magnetic contamination over time-scales of many years. Contamination can come from nearby roads, buildings, power distribution infrastructure (transformers or cables), transmitters (radio or communication), local land use (e.g. housing, farm machinery, etc.) or from electric train lines. DC train lines can cause interference for tens of kilometers.

Other factors for consideration are:

- The site should offer good visibility to distant target(s) to be used as an horizontal direction reference in absolute observations.
- The observatory buildings should be located on a flat, well-drained, solid foundation. Buildings, lighting and heating systems should be made of non-magnetic materials. Electricity supplies to variometer and absolute buildings for lighting and heating should be AC.
- There should be access to a reliable mains electricity supply to the site, preferably with some form of back-up power, so that power outages are kept to a minimum.
- The site should offer good visibility to distance reference objects for absolute observations.
- There should be access to local telephone or network communications for data transfer.
- There should be an existing clean, dry environment nearby to house the data recording equipment.
- The site should be easily accessible by observatory staff.

3.3 Instrumentation/Specifications

The parameters listed below describe the specifications of a complete observatory system for a one-second vector data set including recording environment, magnetometer, and data processing procedure. INTERMAGNET does not specify the type of magnetometer that must be used (although a list of instrument suppliers can be provided on request), however a 1s-IMO must meet the specifications listed below. These specifications are used by INTERMAGNET as a guideline for reviewing data quality when data are either submitted for an IMO application, or when definitive data are submitted for inclusion in the archive. A scalar magnetometer is mandatory as well as temperature measurements of the vector magnetometer electronics and sensor with a resolution of 0.1°C.

3.3.1 Definitive Data

Due to advances in instrumentation and observatory practice, the INTERMAGNET requirements for one-second definitive data are more stringent (and defined more comprehensively) than those for one-minute data described in [Chapter 2](#). The parameters listed below describe the specifications of a complete observatory system for a one-second vector data set including recording environment, magnetometer, and data processing procedure. These specifications are designed such that definitive one-minute data may be derived from definitive one-second data by means of a suitable filter.

The absolute accuracy of one-second definitive data is specified below as a maximum offset error of ± 2.5 nT. This is the maximum low frequency error between absolute observations. In general, the largest source of offset error is instrumental or thermal drift of the variometer, therefore the frequency of absolute observations can be determined by the observer based on the stability of the variometer, its operating environment and its baselines.

The definitive one-second data standard is described in more detail in INTERMAGNET Technical Note TN6.

3.3.2 Absolute Measurements

The requirements are the same as for 1 minute data. See [Chapter 4](#)

3.3.3 Vector Magnetometer

3.3.3.1 General Specifications

Time-stamp accuracy	0.01s centered on UTC second
Phase response	Maximum group delay ± 0.01 s
Maximum filter width	25 seconds
Dynamic Range	± 4000 nT High Latitude ± 3000 nT Mid/Equatorial Lat.
Data resolution	1pT
Pass band	DC to 0.2Hz
Thermal stability	0.25nT/°C
Long term stability	5nT/year

3.3.3.2 Pass Band Specifications [DC to 8mHz (120s)]

Noise level	100pT RMS over 10 min
Maximum offset error (cumulative error between absolute observations)	± 2.5 nT
Maximum component scaling & linearity error	1%
Maximum component orthogonality error	2mrad
Maximum Z-component verticality error	2mrad

3.3.3.3 Pass Band Specifications [8mHz (120s) to 0.2Hz]

Noise level	10pT/ Hz at 0.1Hz
Maximum gain/attenuation	3dB

3.3.3.4 Stop Band Specifications [0.5 Hz]

Minimum attenuation in the stop band (0.5 Hz)	50 dB
---	-------

3.3.4 Scalar Magnetometer

Resolution	0.01nT
Accuracy	1nT
Sampling rate	0.033Hz (30 sec)

3.3.5 Auxiliary Measurements

Compulsory vector magnetometer electronics and sensor temperature measurements with a resolution of 0.1°C at a minimum sample period of one minute.

3.3.6 Recorder

An on-site recorder is necessary so data are not lost as a result of data transmission outages.

3.3.7 Transmission

Transmission by electronic means to a Geomagnetic Information Node (GIN) must be within 72 hours of acquisition or sooner (see Section 6.1.4).

3.3.8 Other

Data format	IAGA2002 or ImagCDFV1.30 (or later)
Definitive data	to be submitted for inclusion in the INTERMAGNET archive
Baseline data	each component to be submitted for inclusion in the INTERMAGNET archive
Filtering	to INTERMAGNET standard (Section 3.4)

For more information see Section 6.1.1 for Data Formats and Section 6.1.2 for Data Types.

The consensus of the scientific community survey was that one-second data should be accurately timestamped and the instruments should have linear phase response. Hence, a maximum time-stamp error has been specified and the phase response quoted in terms of a maximum group delay, which limits the non-linearity of the phase. Data samples may be time-shifted to correct for latency (e.g. instrument response and filter delay) provided that the system phase response is met. The quoted instrument ranges are inherited from the INTERMAGNET one-minute specification, while a data

format resolution is specified to reduce quantization noise and a maximum filter width is set to minimize the time extent of the system response to a step input i.e. filter ringing.

Observatories moving from one-minute recordings to one-second recordings having definitive data quality will need to monitor over both a larger frequency band and, due to the spectrum of the natural magnetic field, a larger dynamic range. To meet these stringent measurement requirements while ensuring that the instrumentation standards are realistic, the pass band has been split into two bands with different specifications:

1. the existing INTERMAGNET one-minute data band (DC to 120s) and
2. the extended high frequency band (8mHz to 0.2Hz)

For the low frequency band (DC to 120s), there is a higher system noise level limit than for the high frequency band, but more constraints on parameters affecting the absolute accuracy, such as sensor orthogonality errors, scale and offset errors. The offset error is expressed as a maximum error from all sources (including instrument and thermal drift) between absolute observations.

In the high frequency band of the pass band (8mHz to 0.2Hz), the noise level is set at a lower level to ensure sufficient resolution of low amplitude fluctuations in the geomagnetic field that may occur in this frequency range. Since absolute signal amplitude is not as critical in this band as it is in the low frequency band, and to allow for instrument roll-off with sufficient attenuation in the stop band, the maximum signal gain/attenuation is specified at a less stringent 3dB in the high frequency band.

The stop band starts at the Nyquist frequency, allowing for a sufficiently wide transition band to set a high stop band attenuation. This is necessary to attenuate typical natural signals in order to avoid errors due to aliased signal in the pass band and meet the noise specification. However, this specification alone will not sufficiently attenuate large amplitude artificial signals, such as 50/60 Hz mains interference. Hence it is recommended to separately attenuate non-natural, large-amplitude signals above the Nyquist frequency.

3.4 Data Sampling and Filtering

INTERMAGNET requires that the one-second filtered data values be centered on the second. To minimize aliasing of higher frequency signals into the pass-band of the final second data series, anti-aliasing filters should be included in the analogue portions of magnetometers before analogue-to-digital conversion. The filter responses should be matched to the chosen primary digital sampling rate. Subsequent to the digital sampling, INTERMAGNET requires that a numerical filter be applied in order to obtain the final one-second data series. INTERMAGNET does not specify the use of a particular filter although the chosen filter must provide adequate attenuation to meet the required specifications in [Section 3.3](#).

Examples of acceptable sets of filter coefficients, for use with various sampling rates of properly anti-aliased signals are presented in [APPENDIX F2](#).

A scalar magnetometer must provide a sample centered on the same time as the output of the digital filter used with the vector magnetometer.

3.5 Missing Data

When mean or filtered values are to be calculated, the question of how to handle missing data arises. For a number of reasons it is difficult to devise a simple objective rule that can be applied to all cases. INTERMAGNET recommends a simple and pragmatic approach: mean or filtered values may be calculated when 90% or more of the values required for calculation are available. This can be interpreted as either 90% of the values or 90% of the weight of the filter. When fewer than 90% of the required values are available the value should be assigned the value used to flag missing data. INTERMAGNET recommends adoption of this rule for both simple mean and weighted mean calculations. For example, a simple daily mean value may be computed when 1296 or more one-minute values are available for the day. Similarly, if a one-minute value is constructed from one-second samples, the one-minute value may be computed when

54 or more one-second samples are available. In either case the weights applied to each sample in the mean or the filter must be re-normalized to account for the reduced number of samples available. In practice, this means dividing the sum of samples by the number of available samples in the case of a simple mean or normalizing to unity those coefficients that have been used in a filter calculation. INTERMAGNET observatories are expected to provide high levels of data continuity, so this rule is expected to be applied only rarely. To avoid the propagation of missing values into higher level means, it is recommended to calculate all higher level means using the method described in [Section 6.6](#).

3.6 Data Quality Control

Variometer drift should be monitored regularly through frequent absolute observations. [Chapter 4](#) describes absolute measurements and [Chapter 5](#) describes the derivation of continuous variometer baselines from spot measurements and the calculation of baseline corrected data.

It is mandatory that continual recordings of the variometer temperature are also made as temperature recordings can be of benefit when determining the source of baseline variations. It is important to monitor both the variometer electronics and sensor separately as the electronics and the sensor typically have differing temperature coefficients.

The use of a continually recording scalar magnetometer is mandatory for one-second IMO. Since proton precession magnetometers and Overhauser effect magnetometers generally have a very low temperature coefficient and output near-absolute values without the need for baseline measurements, they provide a high quality reference data set against which baseline-corrected vector variometer data can be compared, albeit only the scalar component. Such comparisons can identify baseline drift in the variometer or changes in the local field gradient. In addition, as the variometer and the scalar magnetometer are spatially separated, such comparisons can also serve to identify local magnetic contamination.

The first derivative of the variometer and scalar data can be a good indicator for spikes and noise. Where there is another observatory in relatively close proximity, comparisons of the two sets of vector data can frequently highlight scaling or alignment errors and also steps, spikes or drifting in a variometer data set that are not necessarily evident when observing a single data set.

It is good practice to maintain good written records of instrument changes, site changes or changes in personnel. Where there is a major change of instrument that differs significantly from the original IMO application, this should be communicated to the INTERMAGNET secretary.

ABSOLUTE MEASUREMENTS

4.1 Definition and Frequency

Absolute control at a magnetic observatory requires periodic measurements of the absolute value of the geomagnetic field. At present, this requires manually operated instruments; a single observation takes several minutes.

Absolute control is required in order to correct for the long-term instability in the variometer installation, and thereby enabling the determination of very long-term changes in the magnetic field. The frequency with which these measurements should be made depends on several factors: the intrinsic and thermal stability of the variometer electronics, sensor, and piers; the method of temperature stabilization and monitoring; the accessibility of the observatory; availability of staff; and other considerations.

The choice of period between measurements should be influenced by:

- the change in baseline values from measurement to measurement,
- the consistency between primary and alternative variometers (including intermediate Reference Measurements),
- the consistency between total field derived from the vector variometer F_v , and those measured using a recording absolute scalar magnetometer F_s , and
- known disruptive events.

INTERMAGNET recommends a maximum period of one week between absolute measurements.

Observations should be obtained for different levels of magnetic activity and for different magnetic field values.

4.2 Instrumentation/Specifications

INTERMAGNET recommends the use of a

- Proton Precession Magnetometer or Overhauser Magnetometer (both will be abbreviated as PPM in the following), and a
- Declination/Inclination Magnetometer (DIM, also called DI-flux, i.e. a fluxgate mounted on a theodolite).

Other combinations of instrumentation are in use for absolute determinations at some IMOs, but a new observatory should use the above pair of instruments.

Absolute instruments should be periodically compared, within an organization and internationally, for consistent operation. Bi-annual IAGA workshops offer an opportunity to make such comparisons.

4.3 Measurement Method

This manual will not describe how to make absolute observations. This information is given in two comprehensive manuals that every magnetic observatory should have:

- Guide for Magnetic Repeat Station Surveys Newitt, Barton, and Bitterly (1996), and the
- Guide for Magnetic Measurements and Observatory Practice Jankowski and Sucksdorff (1996).

Additional information can be found in Wienert (1970) and Stuart (1984).

4.4 Data Quality Control

Many factors are involved in achieving good baseline control at a magnetic observatory. Some suggestions are presented in the following sections.

A good adopted baseline shows a low scatter of individual baseline determinations, and has small drifts and few offsets. However this is dependent on the stability of the variometer installation, how well its parameters (scale-values, orientation, temperature coefficients, etc.) are known, and other factors as well as the quality of the absolute observations. It should also be remembered that a large long-term variation in a baseline does not mean that the baseline observations were poorly made. The change could be real, the result of seasonal temperature changes or possibly pier tilt, for example. Scatter on a shorter time scale could be an indication of poor observations, but it could also indicate problems with the magnetic environment, poor temperature control, or problems with the magnetometer.

If possible, calibrate the variometer parameters in a controlled environment before installation, if this has not already been done by the manufacturer.

INTERMAGNET recommends to put effort into determining the adopted baselines, e.g. by the use of curve-fitting algorithms to fit time-dependent adopted baselines to the series of absolute observations. A statistical estimation of the quality-of-fit of the adopted baselines should be made. The adoption of the baseline should also take into account known sudden disruptive events, and estimations of the uncertainty of absolute observations (partly derived from the individual observations and corresponding variometer values, and perhaps partly derived from other factors such as an estimate of the experience of the observer).

4.5 Observatory Operations

INTERMAGNET recommends:

1. Making weekly absolute observations, avoiding intervals of magnetic activity. If any baselines are changing rapidly increase the frequency of observations.
2. Making regular physical inspections of all observatory buildings to ensure that no magnetic materials which would cause jumps in baselines are present, inside or outside the absolute or variometer buildings.
3. Ensuring that absolute instruments and their supporting piers are free from contaminating magnetic materials.
4. Establishing an external-reference-site in an undisturbed area outside the absolute building; determining the absolute vector difference between that site and the main absolute pier. INTERMAGNET recommends annual comparison to check for magnetic contamination of either site. The external-reference-site may be a permanent pier, or a tripod site. If a tripod site is used, the location of the absolute instruments must be repeatable in latitude, longitude and height. The relocation precision depends on the distance to the azimuth mark and on the magnetic gradients at the site. Aim for a precision of 1mm in all three coordinates.
5. Ensuring that piers and azimuth marks are physically stable. Do not lean on piers during observations.
6. Comparing periodically the angles between multiple (non-collinear) azimuth marks to check that both the pier and marks are stable. If there is any change in any of the angles redetermine the azimuth to the primary azimuth mark independently (by means of astronomical observation, or differential-GPS for example). INTERMAGNET recommends annual checks.

7. Maintaining an up-to-date diary of absolute measurements, visits, repairs and other actions at the observatory.
8. Periodically reviewing procedures for absolute observations and adopting best practices; this may be facilitated by visiting other institutes and by attending the biannual IAGA observatory workshop.

4.6 Variometer Operations

INTERMAGNET recommends:

1. Operating two variometers at the observatory and comparing their data records as often as data are downloaded so that problems are noticed and can be rectified as soon as possible.
2. Keeping variometers, interconnecting cables, and control electronics at constant temperatures.
3. Monitoring continually and recording the temperatures of all sensors, cables, and electronics units.

4.7 Baseline Calculation

The magnetic field will vary during an absolute observation. This is unavoidable since an absolute observation may take several minutes, and the magnetic field may vary tens of nT or more during that time, especially at high latitudes. To achieve sub-nT estimation of the instantaneous vector baseline:

- the timing accuracy of the clock used for the absolute measurements should be 1 second and each single observation with e.g. the DIM and PPM should be reported with 1 second timing accuracy

Generally, use variometer spot-readings or one-second means or means over a few seconds (and not minute means) for reducing the absolute measurements.

Accurate formula (as those presented in [Section 6.5](#)) should be used. If approximate formulas are used, then one has to be clear about the assumptions they are based on (some formula currently used at observatories only work under certain conditions, e.g. for constant geomagnetic field during the absolute measurement or for variations of the H component being small compared to the size of the H component, or assume a certain sign of the vertical component (i.e. depend on hemisphere)).

Careful synchronization between the absolute measurements and variometer data, becomes more important as the magnetic field activity increases.

Ideally all component measurements are made on the same pier. For various reasons, some observatories measure components on different piers. For example, D and I may be made on a primary pier, and total field may be measured on an auxiliary pier; possibly the variometer F may be used, or a dedicated scalar F may be used on a separate pier. Some instruments such as a proton vector magnetometer cannot be moved and the use of an auxiliary pier is unavoidable.

If more than one pier is used, vector pier correction(s) should be measured and applied to reduce all measurements to a primary pier. It may be sufficient to treat scalar component pier corrections, such as F, as a simple scalar correction, but this is not always the case as described in [Section 4.8](#).

4.8 Calculation of the Difference Between F Pillar and Absolute Pillar

If F_v is the magnitude of the magnetic vector at the primary absolute pillar, and $p = F_v - F_s$ is the constant magnetic vector difference between the primary pillar and auxiliary pillar used to measure scalar F, then:

$$F_v^2 - F_s^2 = (F_s + p) \cdot (F_s + p) - F_s \cdot F_s = 2F_s \cdot p + p \cdot p$$

If we set $F_s = F_s^0 + \delta$, where F_s^0 is constant typical value and the δ is time-dependent variation

$$F_v^2 - F_s^2 = 2F_s^0 \cdot p + p \cdot p + 2\delta \cdot p$$

or

$$(F_v - F_s)(F_v + F_s) = (2F_s^0 \cdot p + p \cdot p) + 2\delta \cdot p$$

$F_v - F_s$ is the scalar pier difference at any moment in time. The variable terms are $(F_v + F_s)$ and $2\delta \cdot p$. In some situations, such as auroral observatories on highly-magnetic volcanic rock, δ and/or p may be large, and $F_v - F_s$ may show a measureable variation. In this case a simple scalar pier correction is not sufficient. This can be tested by measuring the total field at both locations for some time with some variation in δ . If there is no variation in $F_v - F_s$ outside the measurement noise then a simple scalar correction is acceptable. Otherwise a vector pier correction needs to be determined and applied. The simplest determination of p is by direct vector measurement using variometer corrections. If this is not possible or convenient, then it may be possible to determine p by a multi-linear regression of $(F_v^2 - F_s^2)$ against δ as measured by a variometer.

The application of this vector pier correction then requires reasonably calibrated variometer data to remove the first order changes in $F_v - F_s$.

4.9 Training

There are several opportunities for improving techniques and basic training in absolute measurements. IAGA workshops on Geomagnetic Observatory Instruments, Data Acquisition and Processing are held biannually.

Observatory groups may establish inter-observatory absolute instrument comparisons, similar to the concept of the Scandinavian inter-observatory comparisons. These activities also encourage the exchange of ideas on instrumentation and observatory practice.

Regularly review the observatory procedures, including those in use for absolute measurements, and consider if they can be improved.

Provide meaningful information to observers about how their work contributes to local and worldwide research projects, and how baseline quality can affect the research. Provide regular feedback on the quality of absolute observations to observers.

4.10 References

Jankowski, J. and Sucksdorff, C. 1996. Manual on Magnetic Measurements and Observatory Practice, International Association of Geomagnetism and Aeronomy, Boulder, Co., 235 p.

Newitt, L.R., Barton, C.E., and Bitterly, J. 1996. Guide for Magnetic Repeat Station Surveys, International Association of Geomagnetism and Aeronomie, Boulder, Co., 112 p.

Stuart, W.F.(ed.) 1984. Geomagnetic observatory and survey practice; reprinted from Geophysical Surveys, Vol. 6, nos. 3/4; D. Reidel, Dordrecht/Boston, 464 p.

Wienert, K.A. 1970. Notes on geomagnetic observatory and survey practice; UNESCO, Paris, 217 p.

PROCESSING DATA

5.1 Introduction

Quality control methods should be employed in the production of reported, adjusted and definitive data. Total field intensity values that are recorded using a proton precession magnetometer are an excellent tool for monitoring the measurement process that produces component values. The total field values may also be used to estimate the maximum likely range of error for component values. Baseline values are used to adjust component values for long-period, non-random error. A baseline adoption process may be used that provides confidence limits for component 1-minute and 1-second values. A tabular listing of annual baseline values and a description of baseline adjustments accompany the absolute data contained in the INTERMAGNET Reference data set (IRDS). A graphic display of baselines and differences in computed and recorded total field values are available to users.

5.2 Data Quality Control & Processing Tasks

Routines and procedures for inspecting and processing observatory data will vary between observatories and institutes so there is no set method or list of tasks that precisely detail how quality control is to be managed. However, to meet the standards for definitive one-minute and one-second data as specified by INTERMAGNET, an observatory is best advised to adopt a routine of data inspection, inter-comparison, data cleaning and baseline estimation. By regularly performing these tasks, many data problems can be identified and rectified quickly, thus maintaining the quality of the near real-time data published by an observatory, but also the quality of the definitive data produced at the end of the year. Tasks, such as baseline fitting on a weekly or monthly basis, will simplify the production of definitive data as well as improve its quality. As a general guide, typical quality control tasks have been listed here according to how often they are performed.

5.2.1 Daily Data Quality Tasks

Most observatories will have a daily routine for assessing the performance of instruments and identifying any artificial signal in the recorded data. Tasks such as collecting data, applying instrument scale values, filtering to one-second/one-minute and plotting magnetograms are normally performed automatically, leaving the observer to:

- Manually inspect magnetograms (and optionally power spectra) to identify both natural signal and artificial disturbance
- Plot inter-comparisons between instruments
- Plot inter-comparisons with data from nearby observatories
- Perform cross-correlation between instruments to detect timing inconsistencies
- Identify noise (steps, spikes, etc.) and correct by either flagging, filling or performing an interim baseline adjustment
- Record observatory changes and events in the observatory diary
- Transmit reported data within 72 hours of recording with approximate adopted baselines
- Optionally transmit observatory indices

Instrument comparisons (both vector-vector comparisons and the vector-scalar comparisons described in [Section 5.5](#)) are a very useful quality control tool, particularly when all data are corrected to a common point i.e. the absolute pillar. In comparing two or more instruments, the observatory is operating a magnetic gradiometer that is very sensitive to instrument problems or changes in the measuring environment. In comparing three or more systems, it is often possible to detect problems and also identify the source of the problem. In a similar way, inter-comparisons with nearby observatories are a convenient way to detect localised problems, particularly over long time series.

Observatories are advised to maintain a detailed observatory diary, recording significant events and changes that may have an influence on data quality. Similarly, any manual changes to the data, such as removing spikes or filling data of one instrument from another, should be logged for future reference. Procedures for editing data vary between observatories, but it is considered good practice to preserve all original data in an unedited state, with edits applied either on a copy of the data or using a separate flagging system. Either way, maintaining an edit log and version control should allow information on data edits to be preserved and edits rolled back where required.

5.2.2 Weekly Data Quality Tasks

Observatories will have specific tasks associated with making and processing absolute observations and baseline modelling that are performed at least weekly. This is an opportune time to make a more accurate assessment of the applied baselines and to optionally transmit adjusted data with an improved level of data quality to the reported data. Weekly tasks typically include:

- Performing absolute observations
- Making a scalar site difference measurement between the scalar instrument and the absolute pillar
- Reducing the absolute observations and the variometer data to observed baselines
- Plotting and inspecting observed baselines, identifying and evaluating steps and drifts
- Approximately modelling the adopted baseline for application to reported and adjusted data
- Transmitting adjusted data with approximate adopted baselines (plus spikes removed and gaps filled) within 7 days of recording

5.2.3 Monthly Data Quality Tasks

It is also good practice to re-evaluate data after a period of time when there are a number of observed baselines available before and after that data point. This allows for a more accurate adopted baseline to be calculated at a time when outlying observations can more easily be identified and removed and when there is a clearer view of instrument drifts or steps. If this process is performed within three months of the data being recorded, then these improvements to baselines (and therefore the resulting data) may be sufficient to re-submit the data to INTERMAGNET as quasi-definitive as described in [Section 5.6](#) .

An additional data quality task than can be a useful reference for definitive data processing is the production of monthly bulletins i.e. a catalogue daily magnetograms plus a record of the approximate baselines adopted at that time. Monthly bulletins can also be used to log information that is of use to annual definitive data processing such as significant observatory events and natural signal identified in the data during the month.

5.2.4 Annual Data Quality Tasks

Following the end of each calendar year, observatories are required to finalise baselines and produce a definitive data set to submit to INTERMAGNET, including observatory metadata and derived data products (such as hourly, daily, annual means and optionally K-indices). This process is typically scheduled at least a month into the following year to allow baselines to be finalised with sufficient absolute observations after the year boundary. If routine tasks such as data cleaning and continuous baseline adoption have been maintained throughout the year, then producing a definitive data set can be relatively straight forward. Observatories may also consider publishing data to an observatory yearbook as this provides an opportunity to preserve additional metadata to those required by INTERMAGNET. The process for submitting data to INTERMAGNET (definitive or otherwise) is described in [Chapter 6](#).

5.2.5 Despiking and Removal of Artificially Disturbed Data

Single data points that are further away from the true signal than the typical noise of the time series are referred to as spikes. In the variometer data, their origin are typically analogue signals that are short compared to the sampling rate, e.g. voltages in cables or magnetic fields arising from lightning strikes) or a single error in the analogue-digital conversion in the ADC, or single errors arising in the transmission of digital data. Spikes are best identified and removed from the original spot readings, in any subsequently filtered time series (like minute means) they are smoothed and hence difficult to identify, but still lead to degradation of the data. Spikes can also occur in absolute scalar magnetometer (e.g. proton magnetometers) data.

Spikes with an offset from the signal that significantly exceeds the maximum natural variation between two consecutive data points can be easily identified by computer algorithms and automatically removed from the spot-reading time series. For example, a change of say 100 nT per second will not be reached by natural geomagnetic field variations and consequently, an algorithm that removes data points that are more than 100 nT away from the previous and consecutive data point can safely be used.

Other short-term artificial disturbances in the data could arise from magnetic objects passing by the magnetometer sensors or from interference of the magnetometer with radio wave or voltage variations in the power supply. Typical problems of the first type occur if cars get too close to an observatory or the grass is cut around a magnetometer hut, or if a magnetometer hut is entered with magnetic objects.

When two magnetometers are operated in an observatory, such spikes usually don't occur simultaneously. Also, moving magnetic objects usually affect the magnetometers differently because of the differences in distance and/or direction they are with respect to the two magnetometers. Therefore, spikes and disturbances can best be recognized by looking at the difference between these two magnetometers, as this will eliminate the natural geomagnetic field variations that are identical at both magnetometers, but not the signal from moving magnetic objects. For two scalar magnetometers, calculating the total field difference is simple. For a vector and a scalar magnetometer, the total field difference between the two magnetometers can be calculated (see [Section 5.5](#) computation of total field differences) or between two scalar magnetometers. For two vector magnetometers, one can calculate the difference between the individual components (but note that the sensor orientation might not be identical for the two variometers).

Another good way to facilitate the visual identification of spikes and other short term artificial disturbances, especially in the absence of a second magnetometer, is to plot the first difference of a time series (e.g. a component of the variometer, or total field). This acts like a high-pass filter and the slow natural field changes give almost no signal in the first difference. Spikes appear always and artificial disturbances appear often prominently due to their high rate of field change. Such first differences can be compared with first differences from observatories many hundreds or thousands of kilometers away. The time derivative of natural signals appears often as very similar (though not identical) over large areas. Thus, spikes and short term artificial signals (appearing only at one station) can be distinguished from natural signals (appearing at neighboring stations).

Once a spike or artificially disturbed data is identified, it should not be used for calculating calibrated data. Often, such corrupted data was deleted and thus removed from the archive. A more modern approach would be to keep the corrupted raw data in the archive and to flag it such that it is replaced by data from a back-up system or flag it such that it is not used for the calculation of calibrated data (possibly leading to a data gap).

5.2.6 Absolute Quality Control

Absolute measurement (often also referred to as ‘absolutes’) quality is important for geomagnetic observatories. Typical reasons for low quality absolutes are instrument malfunction, errors by the observer (e.g. misreading, typos, insufficient levelling, and issues with magnetic cleanliness), timing errors, and errors in the software used for calculating results. Here we look especially at the declination and inclination absolute measurements with a fluxgate theodolite (DI-flux).

One way to judge the quality of the absolute measurements is to look at the scatter of the baselines determined from them. This is very helpful, but the baselines always depend on the quality of the absolutes and the quality of the variometer, therefore it is desirable to have quality parameters that are (as much as possible) independent from the variometer quality.

If an erroneous absolute measurement occurs in a series of correct absolutes, it can be identified firstly by an erroneous value in the baseline. Secondly, it often can be identified by erroneous fluxgate parameters, these are sensor offset and sensor alignment with the theodolite telescope. More information on these is given in Jankowski and Sucksdorff (1996)¹, but note the sign error identified by Matzka and Hansen (2007)². The fluxgate parameter are largely independent of the variometer data and are very sensitive to single misreading or typos. Also, they are indicative for mechanical or magnetic faults of the DI-fluxgate.

To identify operator problems, you can compare the absolutes from different observers. To identify instrument problems, one can test the instrument against other absolute instruments, like done at IAGA workshops or more regional instrument comparisons.

Finally, erroneous absolutes should not be reported to INTERMAGNET and should not be used for the baseline adoption.

5.3 Computation of Baseline Values

The component baseline values are calculated as described in Section 6.5 and reported in the format described in APPENDIX E4.

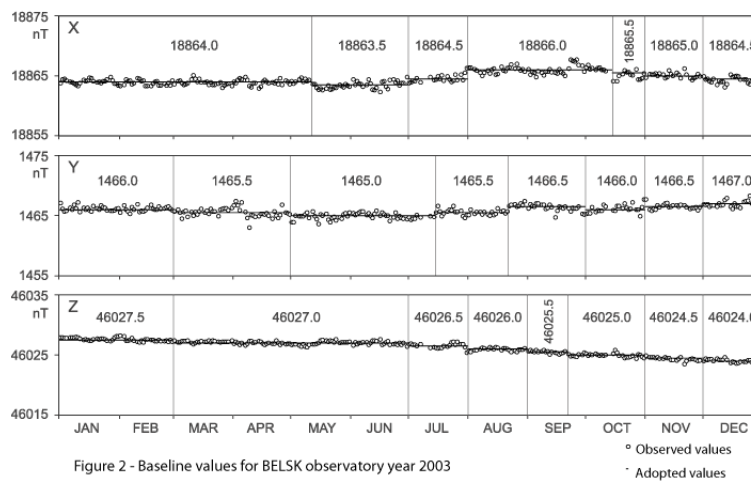


Fig. 5.1: Baseline values for Belsk observatory 2003

¹ Jankowski, J. and Sucksdorff, C.: Guide for magnetic measurements and observatory practice, IAGA, Warsaw, p. 235,1996: <http://www.iaga-aiga.org/data/uploads/pdf/guides/iaga-guide-observatories.pdf>

² Matzka, J. and Hansen, T. L.: On the various published formulas to determine sensor offset and sensor misalignment for the DI-flux, *Publ. Inst. Geophys. Pol. Acad. Sci.*, C-99, 298–303, 2007: <https://pub.igf.edu.pl/files/Pdf/Pubs/37.pdf?t=1702373167>

5.4 Baseline Adoption

A number of methods are used in observatory data processing procedures to adopt baselines from observed baseline values. An adopted baseline may be fitted to the baseline values by hand or by a computer algorithm. The baseline values obtained from the adopted baseline for each day are written to a file in the INTERMAGNET baseline format IBFV2.00, (*APPENDIX E4*). The format includes a section for comments pertaining to dates and times of baseline adjustments or changes in instrumentation. These files must be transmitted annually to INTERMAGNET along with 1-minute data for the IRDS production.

Statistics of the difference between the adopted and observed baseline can be generated to verify that confidence limits for the adopted baseline meet the INTERMAGNET specifications.

Fig.5.1 shows observed values (circles) and adopted baseline values (dots) for magnetic field components X, Y, and Z for Belsk observatory during 2003. The time series of F-P total field differences, defined in *Section 5.5*, corresponds to the time series of adopted baseline values.

Often the baseline changes smoothly due to seasonal changes in temperature or humidity, or from ageing of magnetometer components. The constant segments used to adopt the baseline shown in *Fig.5.1* are just one example for the adoption method. In order to avoid jumps in the calibrated data (at the times between segments of constant baselines), the baseline could be adopted using continuous, linear segments or curves. For the latter, often polynomials or splines of various degrees are used, and can be fitted to the observed baselines by automatic algorithms. Significant jumps in the baseline can still occur (e.g. during maintenance work at the variometer), and these should be reflected by the adopted baseline. Then the computer algorithms for baseline fitting should be used separately to fit the baselines before and after such a jump. The timing of a baseline jump caused by maintenance often coincides with artificially disturbed variometer data. Then the timing of the baseline jump can conveniently be set into the time interval where data from the variometer is not used as it is disturbed during maintenance.

Once the baseline is adopted, the variometer can be calibrated. To check the quality of the variometer data and the adopted baseline, it is helpful to plot the total field differences. For a well-adopted baseline, the total field differences ideally should be small (e.g. smaller than 0.5 to 1 nT), and should not depend on the shape of the baseline too much. If there is an error in the adopted baselines, or in the subsequent calibration procedure, then this will likely show up in total field differences. Also, this will show up when you calculate the differences between the absolute field values determined in the absolute measurements minus the calibrated data from the final data product (e.g. from the IAF files, see *APPENDIX C1*) at the time of absolute measurements.

5.5 The Computation of Total Field Differences

Whenever possible, observatories should measure the scalar field intensity *S* (*Section 6.1.3*) in addition to the vector components of the magnetic field. The total field component *F* (*Section 6.1.3*) can be calculated from the vector components of the field using simple mathematical relationships. *F* and *S* thus provide two independent values of the total field intensity from two different instruments at different locations within the observatory. Calculating the difference between these two values (*F - S*) is a powerful tool for quality control of the magnetic time series data.

Where both instruments are stable and functioning correctly the value (*F - S*) is expected to be a constant (within the noise envelope of the instrumentation) and by accounting for the difference in the magnetic field between the two locations where *F* and *S* are measured the (*F-S*) value can be reduced to close to zero. Any variations in the value of (*F - S*) which are beyond the expected noise envelope of the two instruments can indicate contamination or instability in either the vector or scalar instrument. (*F - S*) is often the only measure of the vector variometer baseline stability during the periods between absolute observations.

The (*F - S*) value can be computed from adjusted, quasi-definitive or definitive 1 minute or 1-second data and used to monitor data quality and instrument stability as part of routine daily quality checks.

The value of this technique as a quality control tool is diminished when the calculated total field (*F*) is dominated by one component of the magnetic field. In this case changes in *F* can be relative insensitive to the component which contributes

least to the value of F.

5.6 Producing Quasi-Definitive Data

The production of quasi-definitive data is similar to the process for definitive data, the difference being that quasi-definitive data are submitted within 3 months of acquisition. Provided quasi-definitive data are produced using the best available baselines such that data meet the specification given in *APPENDIX A*, any method can be used. Observatories typically adopt the same process to produce quasi-definitive data as they do for definitive data as this simplifies the production of definitive data at the end of the year. Examples of processes used by some institutes are listed in *Section 6.3.5*.

5.7 Summary

Tools that might be used for quality control of reported, adjusted and definitive data have briefly been described. INTERMAGNET is establishing standards of comparison such as the graphs of baselines and F-P values. Participating observatories may evaluate the performance of their operations relative to the results of other observatories. Participants communicate with other members on instrumentation procedures to improve the quality of INTERMAGNET observatory data.

SUBMITTING DATA

6.1 Introduction

Observatories send their data to INTERMAGNET via two different routes. For preliminary data products (all types of non-definitive data including quasi-definitive), each observatory is assigned to a Geomagnetic Information Node (GIN). Observatories send their preliminary data to their assigned GIN in ‘near real-time’, i.e. as soon as possible after recording. The process is designed to be automated, so that observatories can upload data to INTERMAGNET as part of their automatic data recording or processing systems. Multiple transmissions of preliminary data are possible, where an observatory is refining the quality of the data shortly after recording. The GIN is responsible for forwarding this data to the INTERMAGNET web site for onward distribution to users. The INTERMAGNET web site is the only place where users have access to data from INTERMAGNET observatories. Observatories send their definitive data to the ftp site of the Paris GIN. This process is expected to be manual and only done once a year (unless there are problems with the data that require resubmission).

6.1.1 Data Formats

A number of data formats are in use in INTERMAGNET. In some cases this diversity exists to support handling of different types of data, in other cases a new format has superseded (or partially superseded) an older one.

6.1.1.1 IMFV1.23 GIN Dissemination Format

Data type supported	Notes
Minute mean values	GINs continue to support this format, but INTERMAGNET no longer distributes data in IMFV1.23. Observatories are encouraged to use the IAGA-2002 format instead.

This format is fully defined in *APPENDIX E3*.

6.1.1.2 IMFV2.83 Satellite Transmission Format

Data type supported	Notes
Minute mean values	A format designed to transport compressed data via GOES and METEOSAT satellites.

This format is fully defined in *APPENDIX E1*.

6.1.1.3 IAGA-2002

Data type supported	Notes
Any regular time-series geomagnetic data	The preferred format for submission of preliminary data.

This format is fully defined in *APPENDIX E5*.

6.1.1.4 INTERMAGNET Archive Format

Data type supported	Notes
Definitive and quasi-definitive minute, hourly, daily values and K-indices	The required format for submission of definitive data. Primarily used in the annual INTERMAGNET Reference Data Set (IRDS).

This format is fully defined in *APPENDIX C1*.

6.1.1.5 ImagCDF

Data type supported	Notes
High precision 1-second data	A new (2016) format for submission of 1-second definitive data.

This format is fully defined in *APPENDIX E6*.

6.1.1.6 IYF INTERMAGNET Year-Mean File

Data type supported	Notes
Annual mean values	Primarily used in the IRDS.

This format is fully defined in *APPENDIX C3*.

6.1.1.7 IBF INTERMAGNET Baseline File

Data type supported	Notes
Baseline values and absolute observation data	Primarily used in the IRDS.

This format is fully defined in *APPENDIX E4*.

6.1.2 Data Types

Geomagnetic data is refined over time as the various sources from which it is composed are recorded, combined and verified. Data type in this context describes the state that a set of data values have reached in the process of being published, from raw data which is read directly from one or more sensors to definitive data which is the final product of an observatory to which no further changes are expected. The data formats used with time-series geomagnetic data include (or imply) a data type field in their metadata. This data type field is explained below.

Data type	Formats where it can be used	What it means
Reported	IMFV1.23 (as a metadata field) IMFV2.83 (implied – data in this format can only be ‘Reported’).	Preliminary data from an observatory that has not had any baseline corrections applied. It may contain spikes and may have missing values.
Variation	IAGA-2002 (as a metadata field)	The data type is not defined in the format definition. It is assumed to contain data to the same definition as the ‘Reported’ data type.
Adjusted	IMFV1.23 (as a metadata field)	Adjusted data may have modifications made to raw data to apply baselines, remove spikes or fill gaps.
Provisional	IAGA-2002 (as a metadata field)	The data type is not defined in the format definition. It is assumed to contain data to the same definition as the ‘Adjusted’ data type.
Quasi-definitive	IMFV1.23, IAGA-2002 and IAFV2.11 (as a metadata field)	Quasi-definitive data are defined as data that have been corrected using provisional baselines. Produced soon after data acquisition, their accuracy is intended to be very close to that of an observatory’s definitive data product. 98% of the differences between quasi- definitive and definitive data monthly mean values should be less than 5nT in (X, Y, Z) orientation.
Definitive	IMFV1.23, IAGA-2002 and IAFV2.11 (as a metadata field) and IAF version prior to V2.11 (implied - data in this format can only be ‘Definitive’).	Observatory data which have been corrected for baseline variations, have had spikes removed and gaps filled where possible. No further change is expected and the quality of the data is such that they would be used for inclusion in observatory year books and for input to the World Data Centers and the IRDS.

Where software is used to convert between formats (e.g. at GINs):

- The Reported data type is assumed to be interchangeable with the Variation data type.
- The Adjusted data type is assumed to be interchangeable with the Provisional data type.

The use of data types to describe more than the state of data in the publication process is prone to error. INTERMAGNET is moving to a system of describing the standard that a data set meets and including this description alongside the data to which it applies.

6.1.3 Geomagnetic Components (or Elements)

Geomagnetic data can be described in a number of different orientations. Component codes are used to describe the individual elements of the geomagnetic vector.

- $X = H \cdot \cos(D)$
- $Y = H \cdot \sin(D)$
- $Z = F \cdot \sin(I)$
- $H = F \cdot \cos(I)$
- $H = \text{SQRT}(X^2 + Y^2)$
- $F = \text{SQRT}(X^2 + Y^2 + Z^2)$
- $\tan(D) = Y/X$
- $\tan(I) = Z/H$

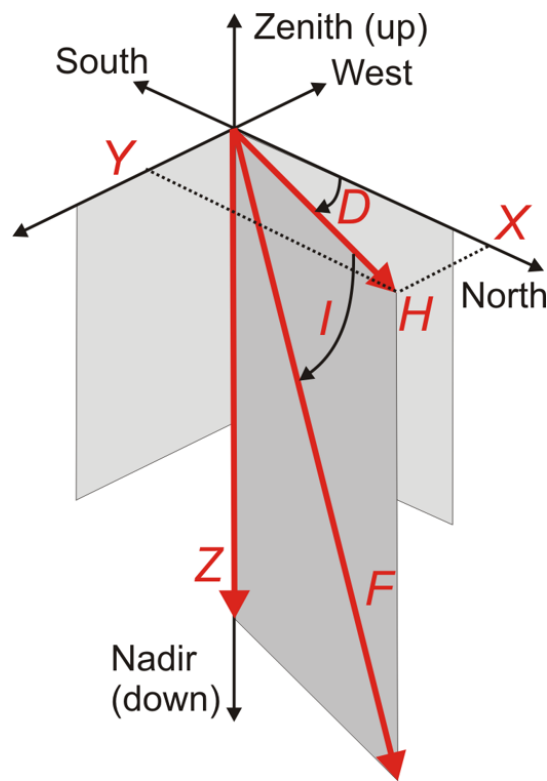


Fig. 6.1: Geomagnetic components

Code	Description
X	North Component. The strength of the magnetic field vector in the geographic north direction (northerly values are positive).
Y	East component. The strength of the magnetic field vector in the geographic east direction (easterly values are positive).
Z	Vertical intensity. The strength of the magnetic field vector in the vertical direction (Z is positive down and hence negative south of the geomagnetic equator).
H	Horizontal intensity. The strength of the magnetic field vector in the horizontal plane along the magnetic meridian.
D	Declination or variation. The angle between the magnetic vector and true north (positive east).
I	Inclination. The angle between the magnetic vector and the horizontal plane, in degrees of arc (positive below the horizontal).
F	Total field intensity. The geomagnetic field strength, calculated from and consistent with XYZ or HDZ field elements.

6.1.4 Near Real-Time Preliminary Data

INTERMAGNET wishes to make data available to users as soon as possible after it is recorded. Observatories who are members of INTERMAGNET are required to submit their preliminary data within 72 hours of recording. This requirement has been in place since INTERMAGNET was created and was a challenging target in the days before the INTERNET. It is now a minimum requirement. INTERMAGNET wishes to improve its near real-time performance and has set these goals for near real-time performance:

- 1-second data: Available to users within 30 seconds.
- 1-minute data: Available to users within 2 minutes.

These are challenging targets and at present (2018) the INTERMAGNET infrastructure is not able to support these targets; the best possible performance is around 15-20 minutes. However observatories are encouraged to submit preliminary data to their assigned GIN as near to real-time as possible. The best way to achieve this is using the web interface to submit data in IAGA-2002 format.

6.1.5 Geomagnetic Information Nodes

INTERMAGNET has a two stage approach to collection and dissemination of non-definitive data. Observatories send their data to one of 5 Geomagnetic Information Nodes (GINs). The GINs then forward data to the INTERMAGNET web site for distribution to users, where it is made available via a web service and a data download application on the web site. GINs may make provision for observatories to access their own data once it has been sent to the GIN, but there is no public access to data at the GINs – all public access to data is via the INTERMAGNET web site. Both GINs and the web site keep a permanent copy of all data sent to them – no data is deleted (though it may be overwritten if an observatory sends an update).

INTERMAGNET will not edit any data that an observatory has sent, though it may contact an observatory if problems are detected and may also remove spikes for the purposes of plotting the data. GINs will send monthly reports of the ‘completeness’ of the data received from observatories. The INTERMAGNET web site will send monthly reports to observatories on the requests users have made for their data. The manager at each GIN acts as a point of contact for IMOs to resolve any data transmission and formatting problems.

6.1.5.1 GIN Manager Addresses

Any enquiries to individual GINs should be made to the INTERMAGNET GIN Manager at the following addresses:

USGS - USA:

Brendan Geels
U.S. Geological Survey
Box 25046 MS 966
Denver Federal Center
Denver, Colorado 80225-0046
USA
Email: bgeels@usgs.gov

GSC - Canada:

Charles Blais
Canadian Hazards Information Service
Natural Resources Canada
7 Observatory Cr.
Ottawa, Ontario
CANADA
K1A 0Y3
Email: charles.blais@canada.ca

BGS - Scotland:

Simon M. Flower
Geomagnetism Team
British Geological Survey
The Lyell Centre
Research Avenue South
Edinburgh EH14 4AP
UK
Email: e_gin@mail.nmh.ac.uk

IPG - France:

Virginie Maury
Institut de Physique du Globe de Paris
Observatoires magnétiques - Bureau 110
1, rue Jussieu
75238 Paris Cedex 05
France
Email: vmaury@ipgp.fr

Kyoto University - Japan:

Shun Imajo

Data Analysis Center for Geomagnetism and
 Space Magnetism
 Graduate School of Science, Bldg #4
 Kyoto University
 Oiwake-cho, Kitashirakawa, Sakyo-ku
 Kyoto 606-8502
 JAPAN
 Email: wdc_service@kugi.kyoto-u.ac.jp

6.1.5.2 GIN Email Addresses

- Ottawa: charles.blais@canada.ca
- Paris: vmaury@ipgp.fr
- Golden: bgeels@usgs.gov
- Edinburgh: e_gin@mail.nmh.ac.uk
- Kyoto: wdc_service@kugi.kyoto-u.ac.jp

6.1.5.3 INTERMAGNET GIN Types

The five INTERMAGNET GINs can be classified into two types, depending on the observatories they handle and the services they offer.

Type	Description	GIN
1	<ul style="list-style-type: none"> • Handles data from observatories run by its own institute (and maybe a few others with which it has close relationship). • Uses its own mechanisms to collect data from observatories 	Golden, Ottawa
2	<ul style="list-style-type: none"> • Handles data from many IMOs not associated with its own institute. • Uses INTERMAGNET defined mechanisms to collect data from observatories. 	Edinburgh, Kyoto, Paris

New observatories not run by USGS or GSC would normally be assigned to one of the Type 2 GINs.

6.2 Submission of Preliminary Data

An observatory sends preliminary (non-definitive) data to its assigned GIN via email, web upload or satellite transmission. INTERMAGNET encourages observatories to send data as close to real-time as possible. The best way to achieve this is using the web interface to submit data in IAGA-2002 format. Observatories are also encouraged to make regular submissions of quasi-definitive data using the same methods for submitting data.

6.2.1 Update Frequencies and Formats for Preliminary Data

GINs can receive data in IAGA-2002 and IMFV1.23 formats. These formats are fully defined and described in [APPENDIX E3](#) and [APPENDIX E5](#). GINs also support IMFV2.83 format, but only where an observatory is transmitting via satellite. IMFV2.83 is defined in [APPENDIX E1](#). Preliminary data cannot be accepted by GINs in other formats (except where a GIN makes arrangements to receive data from its own observatories in a private format – in these cases the data must be converted to IAGA-2002 before forwarding to the INTERMAGNET web site).

GINs can receive ‘fragments’ of a day file – that is day files that are incomplete – in any of these formats and recombine the fragments into a day file in IAGA-2002 format. In this way observatories can send multiple short data files that contain only the data from the end of the previous transmission up to what has been most recently recorded. This allows an observatory to update the INTERMAGNET web site in near real-time for the current day as the day progresses.

GINs will overwrite data if they receive data that has previously been sent. This allows observatories to send data in close to real-time, then correct that data at a later date (e.g. after manual gap filling or spike removal).

IAGA-2002 is the preferred format for observatories to send data to INTERMAGNET. The format is flexible enough to allow very small fragments of day files to be transmitted easily, whereas IMFV1.23 format requires a minimum of 1-hour of data to be encoded in a file (though where a fragment is smaller than an hour, the remainder of the 1-hour block could be coded as missing values). Observatories sending data in IMFV1.23 should be aware that the GIN will convert their data to IAGA-2002 format. INTERMAGNET intends to stop supporting the IMFV1.23 format at some point in the future. The smallest fragment of data that should be encoded into an IAGA-2002 file is 2 samples, since some software using this format calculates the sample rate from time difference between the first pair of samples in the file.

There are a number of ways that observatories can combine the different transmission methods that INTERMAGNET offers to achieve reliable throughput of data in near real-time. Two of the most successful have been:

1. To use the web interface to submit small data fragments to the GIN. The web interface returns a code indicating successful upload of data. If this code is not received, the observatory can flag that this data was not uploaded and attempt to upload it again (along with any new data) on a subsequent upload.
2. It is not always easy to keep track of whether data has been successfully uploaded (and it is likely to be only a small number of occasions where there is a problem). An alternative is to submit regular small fragments of a day file throughout the day via the web interface, without tracking their successful upload, then submit a complete day file via email shortly after the day has ended, which will have the effect of filling any gaps that occurred from unsuccessful transmission via the web interface.

Other combinations of data transmission are possible if they suit and observatory’s working practice. As at 2016, the fastest rate at which data is being sent using these techniques is every 3 minutes (i.e. files of 1-minute data with 3 samples per file).

6.2.2 Types of Preliminary Data

In the past INTERMAGNET has collected Reported (or Variometer) data - preliminary data without a baseline. New observatories are not allowed to send data of this type and existing INTERMAGNET observatories are encouraged to stop sending this data and instead send baseline corrected data using the Adjusted (or Provisional) data type.

Observatories should send Adjusted (or Provisional) data as close to real-time as possible.

Observatories are encouraged to send quasi-definitive data to the GIN as well as adjusted data, unless they are producing quasi-definitive data in near real-time, in which case it is sufficient to just send quasi-definitive data. Quasi-definitive data need not be produced in near real-time – some methods of producing this type of data do not allow for near real-time production. However where possible observatories are encouraged to send quasi-definitive data in near real-time.

6.2.3 Submission via WEB Service

Data can be submitted to INTERMAGNET GINs using a web service. The web was chosen as a delivery medium because it provides the best chance of avoiding issues with firewalls between two institutes. The http: 'file upload' mechanism is used, as described in RFC1867 "Form-based File Upload in HTML" - see <http://www.ietf.org/rfc/rfc1867.txt>. The web service responsible for receiving data from INTERMAGNET observatories works as follows:

1. Observatories upload their data to the web service.
2. The web service indexes and caches the data, making it available for download by the GIN.
3. The web service provides a search mechanism by which a GIN can find out what data is in the cache.
4. The web service provides a download form which allows the GIN to download data files that observatories have uploaded to the cache.
5. The responses which the web service makes to these actions are standardised, making it easy to automate the processes of uploading and downloading data.

In this way, issues with firewalls are avoided, since both observatories and the GIN access the web service using a standard http: connection.

Observatories connect to the web service in one of three ways:

1. Manually using a standard web browser. Once connected the file upload is very simple, similar to the method used by online mail services to upload files as attachments when sending mail.
2. Automatically using a command line based tool that supports file upload. One such tool is CURL <http://curl.haxx.se/> . which is available for SUN Solaris, Linux and Windows.
3. Automatically using their own software. File upload to a web server is supported by Java and other languages.

The web service will accept data in the following formats:

1. One-second data in IAGA 2002 format.
2. One-minute data in IAGA 2002 format.
3. One-minute data in IMF V1.23.

Data files may contain a maximum of 24 hours data. There is no minimum quantity of data, but an IMO may not make more than 1440 uploads per day. The same file may not be uploaded more than once. These limits are imposed to help prevent Denial Of Service (DOS) attacks.

The first operation that the web service performs when a file is uploaded is to parse the file to check that the file name and contents are correct and that the file conforms to the maximum data size and maximum number of file upload rules. Once a file has been verified it is assigned a unique ID number (implemented as a 64-bit integer to ensure it cannot 'run out'). The ID number increments for each new file uploaded. The ID number never gets smaller. ID numbers can be used to sort files by their time of arrival on the server.

The web service will respond to an attempt to upload a file using a formatted response in either HTML or plain text (the format is under control of the user). The HTML response is designed to be easy for an interactive user to understand, the plain text response is designed to be easy to process from software. The first line of the response indicates whether the attempt was successful. It will contain one of the following words:

Word	Description
Success	The operation succeeded.
Information	The operation succeeded and there is some additional information.
Warning	The operations succeeded, but there was a problem with a peripheral part of the system.
Error	The operation failed.
Exception	The operation failed with an unforeseen problem. A full description of the software fault is included.
Fatal	The entire web service is not working.

The second line of the response is a message further describing what happened. The response may include subsequent lines with further detail.

On successful upload, the following message will be returned:

```
Success
Data loaded OK, data file id = <ID>
```

Capturing the ID of the transaction from the response allows you to confirm that the upload was successful and to download and view the file that you uploaded at a later date. Note that successful delivery of data to the web service does not mean that the data has been loaded to the GIN. The GIN's operating software needs to download the data from the web service and insert it into the GIN data store. This may take a few seconds to minutes following the upload. In exceptional circumstances a file may be successfully loaded to the web service, but fail to load on the GIN – these occurrences are very rare.

An example of the web service (as implemented at the Edinburgh GIN) can be seen here:

<https://gin-upload.bgs.ac.uk/GINFileUpload/>

Detailed descriptions of the interface to the web service along with some example software to upload data to the web service are available here:

<https://gin-upload.bgs.ac.uk/GINFileUpload/HelpAutomate.html>

Note that this web site is password protected – for access apply to the GIN manager.

For more detailed information see INTERMAGNET Technical Note 9: https://intermagnet.org/docs/technical/im_tn_9_WebDataDelivery.pdf.

6.2.4 Submission via Email

All GINs support receipt of data by email. An entire day of data may be sent by email, or a smaller 'fragment' of data may be sent (an hour, or even a few minutes) if an observatory is sending updates more than once a day. In this case, the GIN is responsible for reassembling the data fragments into a day file.

Data may be sent by email in the following formats:

1. One-second data in IAGA 2002 format.
2. One-minute data in IAGA 2002 format.
3. One-minute data in IMF V1.23.

Whatever format is used, data may be submitted in one of two ways:

1. The data may be put directly into the body of the email. In this case the 'subject' field for the mail message must contain the filename for the data, formatted according to the filename rules for the data format used. So, for example, if data is sent in the IMFV1.23 format for Boulder observatory on 15th March 1992, the mail subject line would be:
Subject: MAR1592.BOU
For 1-minute provisional Canberra data on 1st January 2002 in IAGA2002 format the subject line would be:
Subject: bou20020101pmin.min
The body of the mail message should contain the data, formatted according to the rules of the format used. The body of the message should not contain anything else (e.g. automatic signatures) - there must be no additional text before or after the data. The data must be in 'plain text' with no formatting. The requirement for plain text transmission is becoming increasingly problematic, as modern email clients don't make it easy to guarantee that email is not formatted using HTML or Rich Text. If the email client you use makes it difficult to guarantee sending plain text emails, consider sending the data as an attachment instead.
2. The data may be attached to a mail message. The data must be contained in a file, correctly formatted for the chosen data format and attached to the mail message using the MIME (Multipurpose Internet Mail Extensions) standard. The attached file must be named according to the filename rules for the chosen data format. When data is attached to an email, the subject field and body of the mail message are ignored.

A list of GIN Internet addresses can be found in [Section 6.1.5.1](#)

6.2.5 Satellite Transmission

In preparation for transmitting data to one of several possible satellites, an IMO will first prepare its data in INTERMAGNET format IMFV2.83 or later. This format, which is fully described in *APPENDIX E1*, imposes a common structure on the data files, ensuring that all necessary information is included so that the data may be properly decoded at a GIN. Once data are in IMFV2.83, a supplementary encoding step is applied to make the data stream, as transmitted to satellites, exactly compatible with the requirements of the satellite operators. *APPENDIX E2* shows the supplementary encoding steps for the GOES and Meteosat satellites along with examples using a specific data set. `lapp_sat_codl` also provides provisional information about encoding for the GMS satellite.

6.2.5.1 Geostationary Satellites

Orbiting the earth, 36,000 km above the equator with approximately 72E of longitude between them are four geostationary satellites, METEOSAT, GOESEast, GOES-West, and GMS. The primary function of these satellites is to provide regular updates, to meteorological agencies, of cloud and infra-red image data which they use to produce forecasts of weather conditions worldwide. Along with these imaging facilities the satellites can, at regular time intervals, relay data collected from remote ground based transmitters to users equipped with suitable receiving and decoding equipment.

6.2.5.2 METEOSAT

Each Data Collection Platform (DCP) that transmits through METEOSAT is allocated a one-minute transmission slot every hour. During this time, the DCP encodes and transmits to the satellite any data input to it during the previous 60 minutes. From the satellite, the data are relayed to the EUMETSAT operations center at Darmstadt, Germany, where they are checked and temporarily stored. The GIN automatically collects the data from the EUMETSAT web site. For more information please contact the Paris GIN manager.

6.2.5.3 GOES

Observatories transmitting through the GOES East/West satellites output their data every 12 minutes to the satellite; there is no secondary retransmission stage, as is the case with METEOSAT. In the GOES system, the data are transmitted directly to a receiving GIN where they are transferred to the INTERMAGNET web site. This form of communication is simpler, but the GOES link does require a much larger receiving antenna as signals transmitted directly from a geostationary satellite are at a very much lower power than those relayed using the METEOSAT retransmission facility. To overcome the necessity for a large 3-5m receiving dish antenna, users in or near the United States may also access GOES East and West transmissions using a DOMSAT (DOMestic SATellite) receiving station. This is a retransmission facility similar to that used with METEOSAT, providing users with a much stronger signal and hence a considerable reduction in the size of the receiving antenna required (1.2 - 1.8m in diameter).

6.2.5.4 Transmission Access

The use of satellites and the timed-transmission slots on any of the geostationary satellites is very closely controlled. Before an observatory can transmit data using a satellite, an application must be made to the relevant controlling body. All transmission equipment used must be checked and certified to be of an acceptable standard before a licence and a transmission slot can be granted. Also, although it may be possible to gain free access to geostationary satellites, depending on the institute and the use to which the data is being put, the satellite operators may charge users for access.

Two different types of transmission authority may be necessary before an observatory can transmit its data through a satellite to a GIN:

1. Authority to transmit to an Earth orbiting apparatus. This is a licence issued by the government of a particular country which gives an institute permission to operate radio transmission equipment. This type of licence may not

be necessary, but prospective participants should check with the appropriate regulatory authorities in their country to ensure that they are not contravening any transmission laws in force in their country.

2. Application must be made to the operators of whichever satellite is accessible from the observatory. *APPENDIX B* shows the footprints of geostationary satellites and from this users can decide which satellite should provide the best transmission path. Since satellite positions are sometimes changed, those intending to operate an IMO near the edge of a footprint should contact the satellite operators for more detailed information concerning the satellite accessibility. Most satellite operators have a standard application form. A prospective user should write to the operator giving details of the proposed use to which the transmitted data is to be put, a brief description of the project and a request for a transmission slot application form.

If an application form has to be completed, it may include many questions about the operator, site location, and technical questions about the type of DCP, transmission power and whether or not the proposed DCP has been certified for use on this satellite by the satellite operators. To answer these questions, it is usually necessary to contact the DCP supplier.

The completed form is then sent to the respective satellite operator, who, after due deliberation will hopefully issue the applicant with a satellite identification number, a transmission frequency/channel and a specific time slot on the allocated channel.

Alternatively, if the user or the organization to which the user belongs is a member of the World Meteorological Organization (WMO), access to a specific satellite and a transmission slot may be granted simply by quoting an identification number which has been issued by the respective satellite operators to the member state or country.

The length of the time slots allotted to the applicant depends on the satellite which is being accessed. A METEOSAT time slot is 1 minute every hour. On GMS it is 90 seconds every 12 minutes and on GOES, 20 seconds every 12 minutes. During these times users transmit their data. It is essential that the DCP clocks maintain accurate timing, as any transmission outside the allocated time slot will result not only in corruption of the data being transmitted, but also of data transmitted by users on adjacent time slots.

6.2.5.5 Satellite Operators

METEOSAT

EUMETSAT

AM Kavalleriesand 31

D-64295

Darmstadt

Germany

Telephone: 49 61 51 80 77

Fax: 49 61 51 80 75 55

Internet: ops@eumetsat.de

Web: www.eumetsat.de

Those whose potential IMOs would be serviced by METEOSAT are advised to first contact the PARIS GIN operators for timely information on access to METEOSAT.

GOES East and West

Letecia Reeves

NOAA Satellite Operations Facility

(NSOF), RM 1646

1315 East West Hwy

Silver Spring, MD 20746

USA

Telephone: 1-301-817-4563
Fax: 1-301-817-4569
Internet: GOES.DCS@noaa.gov

Those whose potential IMOs would be serviced by GOES are advised to first contact the GOLDEN GIN operators for timely information on access to GOES.

6.2.5.6 Satellite Services

Other methods of obtaining permission to transmit via METEOSAT and GOES East and West are:

1. Through MAEDS (Multisatellite Applications Extended Dissemination Service), which is a commercial organization based in France. This company undertakes to arrange a satellite transmission slot on METEOSAT and GOES.

CLS Service MEADS
18, Av. Edouard Belin
Toulouse Cedex 31055
FRANCE

2. Through North American Collection and Location Service (NACL), which is a company providing similar services to those provided by MAEDS.

Mr. Peter Griffith
North American Collection & Location by
Satellite
9200 Basil Court, Suite 306
Landover, MD 20785
USA
Telephone: 1-301-341-1814
Fax: 1-301-341-2130

These companies have been given the right by EUMETSAT to market environmental data gathering services.

6.2.6 Transferring Data from GINs to WEB Site

GINs receive non-definitive data from observatories in either IAGA-2002, IMFV1.23 or IMFV2.83 format. They forward this to the INTERMAGNET web site in IAGA-2002 format only (data in other formats will be converted to IAGA-2002 format at the GIN). Data is transmitted frequently (e.g. every 5 minutes) between GINs and the web site using the rsync protocol. It is received into a 'staging area' at the web site, and then copied to the data store (so not available to the public until a short while after it has been received).

Different GINs have different practices over how far back in time to go when transferring data to the web site, since transferring the entire data set would be a time consuming operation. There may be different rules for transferring the different data types. For example a GIN may transfer Quasi-Definitive data less frequently than Adjusted or Reported data, but over a longer time span, since Quasi-Definitive data is not required to be delivered within 72 hours. If there are problems with the transfer of data from your observatory to the INTERMAGNET web site, contact your GIN manager.

6.2.7 How to Check if Your Data Has Been Received

The web interface to the GIN provides a mechanism to verify that your data has been successfully delivered (via the ‘Success’ code response to a file upload and the transaction ID that goes with it). Email and satellite transmission, although generally reliable, do not guarantee delivery and do not provide a mechanism for verifying the arrival of your data.

One simple method to check whether your data has been received is to look for the data at the INTERMAGNET web site. The delay time from receipt of data at the GIN to data becoming available at the web site can be as much as 10 minutes, so you need to allow time for the data to arrive. If your data does not arrive, contact the manager of the GIN you have sent data to and they will investigate where the problem lies.

The Edinburgh GIN provides a ‘handshake’ for incoming data. An email can be sent from the GIN to the observatory contact at the start of each day describing the amount of data sent the previous day (or a longer time back if the observatory is not sending in near real-time). This allows the observatory to fill in any gaps due to transmission problems.

GINs send statistics describing the amount of data received from all observatories registered on the GIN. These statistics are sent out to the observatory email contact once a month, shortly after the 72 hour period following the end of the month to which they refer (72 hours after the end of the month, all data should have been received). They contain summary information on the completeness of the previous month’s data.

The INTERMAGNET web site keeps data that describes, on a minute by minute basis, the difference between the current time and the time stamp of the most recently received data from each observatory – the observatory’s lag time. These files are useful for analysing an observatory’s near real-time performance. These files are available from the “statistics” section of the INTERMAGNET data portal.

6.2.8 Common Problems with Data Transmission

The two most common problems are in incorrectly implemented data formats and missing email.

When you first connect to INTERMAGNET your observatory will be assigned a GIN. The GIN manager will work with you to set up regular transmissions of data from your observatory. It is helpful if you can supply a sample of the data you will submit. This will give the GIN manager a chance to check the format you are using before you start regular transmissions.

An increasing problem with email transmission is the filtering of emails for unwanted and malicious messages. Whilst these filtering systems are necessary to protect users of email systems, they do frequently block data messages of the type exchanged in INTERMAGNET. Getting to the bottom of this type of problem may take a little time as GIN managers do not have direct control of mail filtering systems. When investigating this type of problem you will need to provide the GIN manager with the full email address that you send mail from and the date and time of a message that was sent. This will allow the administrators of the filtering system to track your message and describe what happened to it.

6.2.9 Data Publication Delays

INTERMAGNET understands that some institutes would like to restrict their data for the public within a defined time period. Although INTERMAGNET encourages institutes to deliver their data within 72 hours, the INTERMAGNET website can enforce these rules to secure their data.

By default, if the institute does not request a data publication delay, it will be published once received by INTERMAGNET.

Two data publication delays can be requested:

- Plotting delay
- Download delay

For example, an institute can request that their data be plotted (image) as soon as received by INTERMAGNET but prevent the data files from being downloaded until the following day.

To request a data delay, the institute can contact the webmaster at nrcan.geomag-webmaster-geomag-webmaster.rncan@canada.ca .

- **Plotting delay**

The INTERMAGNET website offers online plotting utilities. https://intermagnet.org/data_download.html . A delay (in days) can be added to prevent the user from plotting the data.

- **Download delay**

Data can be download via the website. https://intermagnet.org/data_download.html . A delay (in days) can be added to prevent the user from downloading the data.

- **Exception**

There is, however, an exception to this feature. No matter the delay requested by the institute, INTERMAGNET will generate hourly range values from the data and will use these values for the INTERMAGNET Geomagnetic Activity Map. It was determined by INTERMAGNET that hourly range values are too low resolution to be of any use.

6.3 Submission of Quasi-Definitive Data

An observatory can send quasi-definitive data to its assigned GIN via email or web upload. Quasi-definitive data should be sent within 3 months of acquisition, however INTERMAGNET encourages observatories to submit quasi-definitive data as soon as possible, preferably in IAGA-2002 data format with the file name and data type set to quasi-definitive.

6.3.1 Update Frequencies and Formats for Quasi-Definitive Data

Typical update frequencies are updates on a daily or monthly basis. For the formats, please refer to [Section 6.2.1](#).

6.3.2 Submission via WEB Service

Please refer to the description for preliminary data in [Section 6.2.3](#).

6.3.3 Submission via Email

Please refer to the description for preliminary data in [Section 6.2.4](#).

6.3.4 How to Check if Your Data Has Been Received

Please refer to the description for preliminary data in [Section 6.2.7](#) .

6.3.5 References

Please refer to the following references for more information on creating Quasi-Definitive Data.

- What is the BGS method for creating Quasi-Definitive Data:
<https://intermagnet.org/faq/08.bgs-quasi.html>
- What is the IGP method for creating Quasi-Definitive Data:
<https://intermagnet.org/faq/09.ipgp-quasi.html>

- Matzka, J., 2013. Preparation of Quasi-Definitive (QD) data for the observatories Narsarsuaq, Qeqertarsuaq, and Tristan da Cunha. Boletín ROA, No. 03/13, pp 50 - 53.
[publication xvth iaga workshop](#)

6.4 Definitive 1-Minute Data

In January 1992 the Executive Council and Operations Committee decided to produce a CD-ROM of definitive minute data values from observatories of participating institutions, beginning with 1991 data and continuing annually thereafter. Users thus have access to global magnetic observatory data near real-time values and also the final, definitive data. The institution responsible for an IMO must deliver a complete set of definitive data (this includes de-spiking, filling gaps where possible, correcting baselines, and applying other processing procedures). The baselines for one-minute definitive data must also be included in the annual definitive data submissions to INTERMAGNET.

The definitive data volume only contains data from participating observatories. Participating observatories are those that meet the INTERMAGNET standards, have been accepted by the INTERMAGNET operations committee and also report their data to a GIN within 72 hours of recording. The data from all contributing observatories are provided by the institutions responsible for those observatories.

One of the main objectives of INTERMAGNET is to process definitive data as fast as possible and to make these data available to users. To facilitate this, institutes should send their definitive data in the INTERMAGNET binary data format as well as accompanying files (e.g. baseline files) by ftp to the Paris GIN's ftp server as soon as possible and before the data submission deadline which is set by INTERMAGNET operations committee:

- Host name: par-gin.ipgp.fr
- User name: userint
- Password can be obtained from Virginie Maury (vmaury@ipgp.fr) or Jan Reda (jreda@igf.edu.pl)

Once the data have been put on this server, INTERMAGNET then:

- Checks the data for problems.
- Transfers the data to the INTERMAGNET Web server.
- Transfers the data to the World Data Centre Edinburgh
- Publishes the data (CD-ROM up to 2005, DVD to 2013, USB memory to 2015, on-line publication after 2015).
The annual data volume includes definitive data from all IMOs.

Institutes must prepare definitive data with extreme care. The data are distributed widely. Publishing corrections to this data set is a very difficult task.

Inspection of definitive data should be done carefully. The method of inspection is left to each individual institute. However software tools are available which can help in the preparation and checking of data. These tools are available from the Internet (see [Section 6.4.2](#) for details). The most important program to control the data is the `imagedview` Java browser which is also available on the annual data media and on the INTERMAGNET web site: <https://intermagnet.org/software.html>

Usually, after the end of the calendar year, INTERMAGNET officers send an email to IMOs titled "Call For Data". This email informs, among other things, about the delivery deadline of definitive data. For this, the email list imocontact@gfz-potsdam.de is used. The subject of this email starts traditionally with the words "Call for Data". The request always includes a submission date by which data must be received at the Paris GIN ftp server (usually this deadline is six months after the end of the year in which the data were recorded). If an IMO misses the deadline:

- Only definitive data accepted before the publication deadline (specified by the Operations committee) will be included in the annual data publication.
- Definitive data delivered after this publication deadline will be published on the INTERMAGNET web site and subsequent data publications.
- Any corrections to definitive data will also be published on the INTERMAGNET web site and subsequent data publications.

Each INTERMAGNET observatory should put the following data and information on the Paris ftp server:

- A. Twelve files of definitive binary data, oriented XYZG.
- B. One baseline file.
- C. One readme file for the observatory.
- D. One yearmean file listing annual mean values for the observatory.
- E. Information about the readme-country file.
- F. Information concerning the About-screen for the country.
- G. Information concerning the Map of the institutes country.

For each of options E, F, and G, please state whether you want:

1. To use the same file as the previous year.
2. To make changes to the previous year's file (in which case please describe the changes).
3. To use a new file (in which case please put the new file on the server).

Please note the following:

- The total field element F_s included in the binary file, used to calculate $G=F_v-F_s$, should come from an absolute scalar magnetometer. INTERMAGNET is not accepting total field data calculated from a vector magnetometer.
- K-indices should be included in the binary files only. DKA files are created by INTERMAGNET from the binary data. Any DKA file provided by an institute will be ignored.
- INTERMAGNET needs information about changes (or lack of changes) to country files. The publication of data cannot be finished before receiving all country information (points E,F,G above). So delivery of country information before the deadline is very important.
- In cases when a country has several IMOs, the country information should be delivered by a single representative of the given country.

6.4.1 Checking Procedure

In order to check the data for publication, it is necessary to create a directory structure on disk similar to the structure of the IRDS - this will allow the user to use the imcdview software to view the data (imcdview is the Java software). In order for imcdview to recognize that a directory contains INTERMAGNET data, the subdirectories `ctry_inf` and `yyyymaps` are needed even if they are empty.

A complete annual INTERMAGNET data structure includes the following files (the following example is for the year 2010):

1. `x:\mag2010\sss\sss10mmm.bin` (12 binary files in format IAF)
2. `x:\mag2010\sss\readme.sss` (1 readme file)
3. `x:\mag2010\sss\sss2010.blv` (1 baseline file)
4. `x:\mag2010\sss\yearmean.sss` (1 annual means file)
5. `x:\mag2010\2010maps\country_id.xxx` (1 map for each country (xxx = png or pcx))
6. `x:\mag2010\ctry_inf\readme.country_id` (1 readme-file for each country)
7. `x:\mag2010\ctry_inf\country_id+srn.xxx` (1 about-screen for each country (xxx = png or pcx))

sss is 3-letter observatory code, mmm is the month, `country_id` is the country code. The same structure is also required by most of the other programs used to check data.

Before putting INTERMAGNET files on the Paris GIN ftp server, institutes must perform the following as a minimum set of tests:

1. Review the whole year of binary data. Software for this action:
 1. **imcdview, imagplot.exe**
The imcdview browser is written in Java and allows users to display data in both graphics (plots) and text modes.
 2. **imagplot.exe**
The imagplot.exe works under Windows and allows users to create PostScript plots.

2. Check for any discrepancies between Fvector (Fv total field calculated on the basis of XYZ elements) and Fscalar (Fs recorded by means of proton magnetometer) for minute values. The resource that can be used to make this check is imcdview Java browser.
3. Check the binary data headers and the consistency of the binary data with the yearmean baseline, and readme files.

Software for this action: check1min.exe

The program check1min.exe checks the headers of the binary data. It also checks whether recent yearly mean values included in the yearmean.sss file are consistent with the 12 binary files, i.e. whether annual means included in the yearmean file agree with annual means calculated from the binary data. Please remember that for XYZG orientation the D-conversion factor should be set to exactly 10000.

This program checks for discrepancies between elements XYZFIDH, and also detects format errors.

1. K-numbers Software: Java browser IMCDVIEW, which is equipped, among other things, with a “K index Viewer”.

Note: Program Kasm.exe available on INTERMAGNET web enables to include K-numbers to binary files generated according to the Adaptive Smoothing method.

2. Inspection of the BLV file
Software for this action is also imcdview Java browser.
The program imcdview makes it possible to produce PNG or PDF plots of baseline values. The plots are created from the SSSYYYYY.BLV files
3. Inspection of readme files
Readme files can be checked using any text editor, though an editor which can display non-printing characters (except Cr Lf), which should not be in readme and other text files, and gives easy control of line length is preferred. The contents of readme files can also be seen using imcdview.

6.4.2 Obtaining the Checking Software

See the following web page to download the checking software: <https://intermagnet.org/software.html>

6.4.3 Data Encoding for Publication

1-minute definitive data for an IMO are to be provided to INTERMAGNET shortly after the end of each calendar year for inclusion in the annual data publication. INTERMAGNET will send out a “call for data” to each observatory, specifying the deadline for providing data. Observatories should provide data in the INTERMAGNET Archive Format (IAF) which is described in *APPENDIX C1*. Data can be converted to IAF using INTERMAGNET’s “imcdview” viewing software, which can be obtained from <https://intermagnet.org/software.html> Baseline data will accompany the definitive data, and will be provided in format IBFV2.00 as described in *APPENDIX E4*.

6.4.3.1 General Features

The first INTERMAGNET CD-ROM contains data from 41 observatories provided by 11 countries for the year 1991. The 1992 and subsequent IPMs also contain baseline data for the year for each observatory in the form of text and plots. *APPENDIX B* of this manual provides a list of observatories currently contributing to the data publication.

6.4.3.2 IAF INTERMAGNET Archive Format

The INTERMAGNET IRDS and IPM contain a variety of metadata, including contact information and quality control records. The geomagnetic data is held in INTERMAGNET Archive Format. This format holds minute, hourly and daily mean values as well as K indices.

The data are coded as 32-bit (long integer) binary words, with 5888 words comprising a day-long record. Each file contains one month of day-records (so files are variable length, from 28 to 31 records). Each day of data has a header and data section, the data being subdivided into minute means, hourly means, daily means and a set of K-indices. To date, five versions of this format have been used: IAFV1.00 being the original description of the format. It was only designated as version 1.00 in 2007. Minor undocumented changes were made to how the header was used over the lifetime of this version. IAFV1.10 was defined in 2008 to add the publication date, encoding of the format version number and to reserve word 16 in the header, affecting words 14, 15 and 16. In 2009, delta-F was introduced in IAFV2.00 affecting words 6, 8 and 15 in the header, and words 4337 to 5776, words 5849 to 5872 and word 5876 in the data section. Also in IAFV2.00, space padding was specified to be at the left most position affecting word 13 in the header and words 5885 to 5888 in the data section were made available for each contributing institution. In 2010, IAFV2.10 was defined to allow for a missing instrument designator affecting words 6 and 15 in the header, and words 4337 to 5776 in the data section. In 2014, IAFV2.11 was introduced to add a data type flag in word 15 to indicate whether the data is definitive or quasi-definitive. [APPENDIX C1](#) provides a schematic representation of the record structure.

Each 1-day record requires 23,552 bytes, so a month-file for January would require 730,112 bytes of storage. A year of observatory data requires almost 8.6 Megabytes (Mb) of storage. The storage capacity of a CD-ROM is about 640 Mb. A single sided, single layer DVD holds about 4.7 Gb, a single sided, double layer DVD about 8.5Gb. Following the increase of observatories within INTERMAGNET and the evolution of the physical media, definitive data were published on one CD from 1991 to 1999, two CDs from 2000 to 2005, one DVD from 2006 to 2013 and on one USB drive thereafter.

Observatories should provide new definitive data to INTERMAGNET in IAF V2.11, which is described here. In order to allow users of historic CD-ROM/DVD/USB data to understand the format of the data for each year of production, previous versions (and the years they are associated with) are fully described in [APPENDIX C1](#).

6.4.3.2.1 IAFV2.11 (2014 and after)

Words 1 to 16 comprise the header section containing a mixture of text and numeric fields, including a 3-letter observatory identification preceded with a space [hex20] (ID) code, the year concatenated with the day of the year, co-latitude, longitude, elevation, reported orientation, originating organization, a D-conversion factor, data quality, instrumentation, K-9, sampling rate, sensor orientation, publication date and format version/data type. Latitude, longitude/colatitude and elevation must be given using the WGS-84 datum. From 2014 onward, a field was added to indicate whether the data is definitive or quasi-definitive. This field is a single bit flag in the second byte of word 15. It will be encoded as 0x00 to indicate definitive data, 0x01 to indicate quasi-definitive data. From 2010 onward, the orientation codes “XYZ” and “HDZ” have been added to “XYZG” and “HDZG” where “G” represents ΔF (see description below). These new codes indicate that the observatory is recording 3 elements only (no scalar instrument). The D-conversion factor is a fixed value used only in the graphics portion of the access software to allow Declination to be plotted in minutes of arc and equivalent nanoteslas (nT). It is given as $H/3438 \times 10000$, where H is the annual mean value of the horizontal intensity. Example: If H is 16500 D will be 47993(Integer). When XYZG or XYZ is used, the D-conversion factor should be set to 10000.

ASCII values, such as the observatory ID and orientation, are also stored as 32-bit words, but are coded as the hexadecimal byte-string corresponding to the ASCII string. For example, the string “HDZF” is coded as the sequence “48 44 5A 46”. Where a string is shorter than four bytes, it is padded to the left with spaces. For example, the string “ESK” is coded as the sequence “20 45 53 4B”.

Word 11 is the K-9 value for the observatory in nT, word 12 is the digital sampling rate in msec, and word 13 is the sensor orientation. Sensor orientation could be XYZF, DIF, UVZ, HDZ, HDZF etc. and should indicate which components are actually measured. If a three component sensor orientation is used, a space must be added to the left. Word 14 is the publication date encoded as 4 ASCII bytes “YYMM” provided by INTERMAGNET. The high byte (left most) of word 15 is the INTERMAGNET Archive Format version number code provided by the IMO. It takes the form of a binary

single byte number ranging from 0 to 255. Zero (0x00) represents version 1.00, one (0x01) represents version 1.10, two (0x02) represents version 2.00, three (0x03) represents version 2.10 and four (0x04) represents version 2.11. The second byte in word 15 will be encoded as 0x00 to indicate definitive data, 0x01 to indicate quasi-definitive data. The other two bytes of word 15 are reserved for future use and padded with zeros. Word 16 is reserved for future use.

Words 17-5776 contain the minute values of the 4 geomagnetic elements (successively X,Y,Z,G or H,D,Z,G or X,Y,Z, or H,D,Z) for the day. From 2009 onward, the 4th element contains the difference between the square root of the sum of the squares of the variometer components, $F(v)$, and the total field from an independent scalar recording, $F(s)$. This difference, ΔF , is defined as $F(v) - F(s)$. Both $F(v)$ and $F(s)$ must be corrected to the location in the observatory where absolute geomagnetic observations are made. When $F(s)$ is missing or both $F(s)$ and $F(v)$ are missing, ΔF must be set to 999999. When $F(v)$ only is missing, ΔF must be set to $-F(s)$. The values of the 4 elements are stored in tenth-units with an implied decimal point. Thus, an H value of 21305.6 is stored (in tenth-nT) as 213056 with a decimal point implied between the last and next-to-last digits. Words 5777-5872 are used for the hourly mean values of the successive 4 elements. From 2009 onward, words 5849-5872 always record 999999 (missing value), this is done because the 4th element in the data is a quality check for minute mean data and this quality check is meaningless for hourly means. Words 5873-5876 store the 4 daily mean values. From 2009 onward, word 5876 always record 999999 (missing value) because the quality check for daily means is also meaningless. From 2009 onward, the last 4 words (5885-5888) are available for each contributing institution. Missing data for minute, hour, and day values are stored as “999999”. From 2010 onward, if a scalar instrument is not used (so no data is recorded in the fourth element) the value “888888” should be used instead of “999999”. Missing K-Index values are stored as “999”.

6.4.3.3 INTERMAGNET Reference Data Set and Physical Media Directory Structure

This section describes the structure of the DVD (2011). The structure of the INTERMAGNET Reference Data Set (IRDS), which is also the structure of the data on the INTERMAGNET Physical Media (IPM) at the example is described in [APPENDIX C2](#).

The files are set up in a particular directory structure. The root directory contains a “README.TXT” file, which is an ASCII file describing the DVD and where to obtain information about it, the software, and documentation;

On the 2011 DVD there are also three directories and a further file. The directory called “ERRATA” contains a file “ERRATA.TXT”. This file lists errors on previous IPMs. A second folder, called “SOFTWARE”, holds the “imcdview” programme, software, for visualizing and working with the data. This software is described in [Section 6.4.3.4](#) The file “imcdview_install.txt” describes how to install the imcdview software.

The final directory, MAG2011, contains a sub-directory for each observatory identified by its 3-letter ID code. In addition, there are sub-directories labeled “2011MAPS”, “CTRY_INF”, and “OBSY_INF”. The 2011MAPS directory contains the *.PNG files that are the map images of each country for use in the access software. These are labeled by a 3-letter country ID with the PNG extension, and one labeled “ALL.PNG” for all countries. The CTRY_INF directory contains a *.PNG file for each country (and one for ALL) that are the images used to show the flag and organizational Logo for the different countries, and the README files that pertain to each country’s geomagnetism program (including a README for the ALL option). The OBSY_INF subdirectory is empty, but is required to identify to software that the this folder holds data in the IRDS structure.

The individual sub-directories (e.g. BFE for Brorfelde, TUC for Tucson, etc.) contain the 12 months of data labeled with the 3-letter ID, 2-character year, 3-letter month abbreviation, and a “BIN” extension indicating they are binary files in the IAF format (see [Section 6.4.3.2.1](#)). For example, “BFE91AUG.BIN” is a file of 31 sequential day-records for Brorfelde, for 1991, for August. In addition, there are “README.XXX” files for the individual observatory, a YEARMEAN.XXX containing annual mean data in plain text format for all years that the observatory has operated (see [APPENDIX C3](#) for details of the format) and an XXX2011.BLV file that contains absolute observation and baseline data in the INTERMAGNET baseline format (see [APPENDIX E4](#)) where XXX indicates the 3-letter observatory ID.

This sub-directory may also contain a file labeled XXXYRK.DKA, where XXX is the 3-letter observatory ID, YR is the 2-character year value and K indicates a K-Index file. Originally the DKA extension was used to indicate that the data were generated from a digital algorithm in an ASCII format, however subsequently these files have been used to hold both digitally derived and hand-scaled K indices. Since the 2005 CD-ROM the DKA files have been created by

INTERMAGNET using data from the binary IAF file (before 2005 these files were provided by the observatories). These ASCII K-Index files are used, even though the data are in the binary records, because they are much faster to access than paging through the binary records.

6.4.3.4 INTERMAGNET Reference Data Set and Physical Media Software

INTERMAGNET provides software to work with the data. This software can be installed from the IPM, or downloaded from <https://intermagnet.org/software.html> . The software is designed to be simple and easy to use. When the software starts for the first time on a new computer, a dialog is displayed describing how to tell the software where to find data. This same information, on how to find data, is available from the “Help” menu under “Help for New Users”.

The program has 3 main windows. The window that you see when the program starts shows a view of the World. The observatories that the program has discovered in its database(s) are shown as red dots on the world map. If you move your mouse over an observatory its name will be displayed. If you click on an observatory using the left mouse button then a popup-menu will appear with a list of data that you can view. If you use the right mouse button you will get the same menu, but in a permanent window that will not close when you select an item from the menu. The World Map window also holds the program’s menu bar. The World Map window is always present while the software is running. If you close this window, the program will exit.

There is also an Explorer window, available from the “View” menu. This window gives you an alternative view of data. The view of the data that the window presents is similar in structure to the directory structure used to hold the data on the IPM. To view an object in the Explorer window, double click the object. For example, to plot data from an observatory using the Explorer window, expand the tree until the observatory is listed, expand the observatory, select and expand the data file that you want to view then double click the “Data Plot” icon. The Explorer window also shows you which databases the program is using. For more information about databases see the online help system.

The third main window, also available from the “View” menu, is the Export Window. This window allows you to create data files in IAGA 2002 and other data formats from the INTERMAGNET archive data. The window has been designed so that you can convert as much data as you want with the minimum of work. Further details are available in the online help system.

The software also includes an import function, allowing you to convert data from IAGA 2002 and other data formats into the INTERMAGNET Archive Format. This function is available from the “Database” menu. Using this software, observatories can convert their own data into IAF for delivery to INTERMAGNET. It’s also possible to use the import and then export functions to convert between data formats (e.g. to convert INTERMAGNET minute mean format to IAGA-2002), but please note that between import and export the data will always be stored in IAF format and so the precision of the data will be that provided by the IAF format (1/10th nT and 1/10th minute of arc). For most modern data this precision is unacceptably low, particularly for angular measurements.

Prior to the current software, INTERMAGNET distributed a DOS-based program for working with the IPM data.

Copies of INTERMAGNET Physical Media may be obtained from:

INTERMAGNET Physical Media (IPM) distribution office
Observatoire Magnétique National
Carrefour des 8 routes
45340 Chambon la Forêt
FRANCE
Tel: 33 (0) 2-38-33-95-01
Internet: intermagnet@ipgp.fr

From 2015 onward, INTERMAGNET stopped the production of physical medias. Definitive data is now published yearly with a Digital Object Identifier (DOI) see [Section 7.1.3.1](#). Individual (monthly) IAF data files are available from

the INTERMAGNET web site.

6.5 Definitive Data Calculation Based on Most Common Orientations

Fluxgate variometers usually have 3 orthogonal fluxgate sensors. These sensors can be oriented in various ways. Most variometers are designed such that two sensors are horizontal and a third sensor is vertical. If the two horizontal sensors are oriented towards geographic north and east, respectively, then the orientation is often referred to as XYZ. If they are approximately oriented towards magnetic north (i.e. approximately along the local H component) and magnetic east, then the orientation is called HDZ. There exist other orientations, but these are less frequently used. One example is to mount two horizontal sensors approximately 45° on either side of geomagnetic north and one sensor along Z. Another example is to align one sensor approximately along the field vector, one sensor horizontal towards east, and one sensor perpendicular to the other two sensors, in which case the three fluxgates will sense magnetic field variations that approximately reflect changes in field strength F, declination D and inclination I.

There are two types of fluxgate sensors. One type is quasi-absolute and measures the full field component (up to 70000 nT) or more. As every fluxgate, it has an unknown sensor offset which typically is small (a few nT). The other type is a variation-type fluxgate with a limited measurement range (typically 6000 nT to 20000 nT). The variation-type requires bias fields to be applied along the fluxgate in order to compensate for geomagnetic field components that exceed the measurement range. The bias field can be very large (up to 70000 nT or more) and adds to the small sensor offset. Both bias field and sensor offset are not known accurately, but are assumed to be stable between absolute measurements.

Here, we first describe the calculation of definitive data based on the HDZ orientation and later for the XYZ orientation, as this is one of the most commonly used orientations. In particular, we consider a variometer-type instrument with selectable bias fields for the individual channels. The HDZ orientation was also the typical orientation for classical instruments with suspended magnets and photographic recordings. With the classical instruments, often simple, linear formulas were used to calculate absolute data from variations and baselines. For this procedure to be sufficiently accurate, the classical instruments required reorientation with changing declination (typically every few years). With the non-linear formulas given here, it is not necessary to reorient the fluxgate variometer with changing declination (as long as the magnetic field stays within the measuring range of the fluxgates, which is typically the case for decades).

The horizontal sensor directions do not exactly correspond to the magnetic field components H and D. In order not to confuse the sensor directions with the magnetic field components HDZ, we label the sensors N for horizontally north, E for horizontally east and V for vertically down. We denote N_{var} , E_{var} and V_{var} the fluxgate output in nT, positive towards north, east and down, respectively. We denote N_0 , E_0 and V_0 the sum of the (stable) bias fields necessary to compensate field components, the sensor offsets and the pillar differences (between the main absolute pillar and the variometer pillar, see below) for the sensors N, E and V, respectively. The angle between geographic north and sensor N is labelled D_0 .

We begin with reviewing the assumptions that are made for the formulas that we use here to be valid:

1. The three fluxgates N, E, V have to be orthogonal.
2. The fluxgates N and E have to be horizontal, the fluxgate V has to be vertical.
3. Fluxgate E points roughly towards magnetic east. It requires a negligibly small sensor offset and a zero bias field, i.e., E_0 can be assumed to be zero.
4. Fluxgate N points roughly towards magnetic north, i. e., D_0 is similar to declination D.
5. We assume that the magnetic north direction (declination D) at the variometer is identical to the magnetic north direction at the main pillar of the observatory, where declination is measured.

Fig.6.2 depicts this situation for horizontal fluxgate sensors E and N and their output in nT, N_{var} and E_{var} . D_0 is now the baseline of declination, its physical meaning is the orientation of the fluxgate variometer, expressed as the angle from geographic (true) north to the N sensor. N_0 is the baseline of the H component, its physical meaning is the bias plus offset of the fluxgate sensor N. Likewise, V_0 is the baseline of the vertical component and its physical meaning is the bias and offset of that sensor.

While the relationship between the absolute values Z, baselines V_0 and variations V_{var} for Z component is simply linear (1a), the relationship for H (1b) and D (1c) can be derived from Fig.6.2:

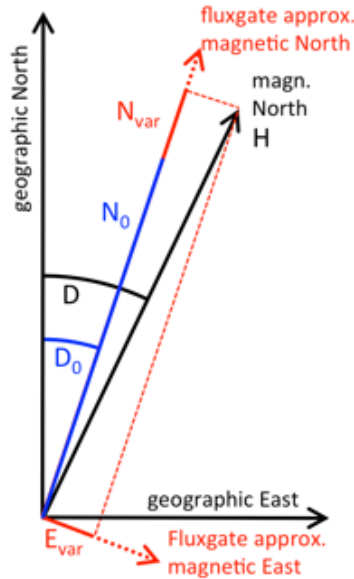


Fig. 6.2: Horizontal field component H and horizontal sensors of the variometer for the HDZ orientation.

$$(1a) \quad Z(t) = V_0(t) + V_{var}(t)$$

$$(1b) \quad H(t) = \sqrt{(N_0(t) + N_{var}(t))^2 + E_{var}^2(t)}$$

$$(1c) \quad D(t) = D_0(t) + \text{atan}\left(\frac{E_{var}(t)}{N_0(t) + N_{var}(t)}\right)$$

with N_0 being the baseline of the horizontal component and D_0 being the baseline of declination. N_{var} and E_{var} are variations in nT. Note that the definitive values at the absolute pillar can be calculated for any time t , for which both final adopted baselines and checked and cleaned variation recordings are available. Note also, that if either E_{var} or N_{var} is missing, then neither H nor D can be calculated.

For completeness, we give the formulas that are necessary to calculate baselines from absolute measurements that have been performed at a point in time t_1 . These can easily be derived from (1a) to (1c):

$$(2a) \quad V_0(t_1) = Z(t_1) - V_{var}(t_1)$$

$$(2b) \quad N_0(t_1) = \sqrt{H^2(t_1) - E_{var}^2(t_1)} - N_{var}(t_1)$$

$$(2c) \quad D_0(t_1) = D(t_1) - \text{atan}\left(\frac{E_{var}(t_1)}{N_0(t_1) + N_{var}(t_1)}\right)$$

Note that in the case of the absolute values $H(t_1)$, $D(t_1)$ and $Z(t_1)$ all appropriate pillar differences have to be included such that the absolute values represent the magnetic field at the observatory's main pillar. Since the observed baseline values $N_0(t_1)$, $D_0(t_1)$ and $V_0(t_1)$ are determined as a difference between measurements on two pillars, they also incorporate the pillar difference between the main pillar and the variometer pillar. From the resulting observed baseline values $N_0(t_1)$, $D_0(t_1)$ and $V_0(t_1)$ the continuous final baselines $N_0(t)$, $D_0(t)$ and $V_0(t)$ are adopted and used for the calculation of definitive data as described above in formula (1a) to (1c).

If the XYZ-orientation is used, we label the fluxgates X, Y and Z.

Note: To avoid confusion, that these are the identical symbols as used for the geomagnetic components X, Y and Z, and that you have to determine from the context whether the sensors or the geomagnetic components are being referenced. We also refer to the vertical sensor as V before.

We assume the sensors X, Y and Z are aligned exactly along the magnetic components X (North), Y (East) and Z (vertical). It is thus not trivial to physically set up a magnetometer exactly in this direction. Then, all formula become linear: $X(t) = X_0(t) + X_{var}(t)$ with X_0 being the baseline (bias plus offset in nT) and $X_{var}(t)$ being the variometer output of the X sensor; $Y(t) = Y_0(t) + Y_{var}(t)$ with Y_0 being the baseline (bias plus offset in nT) and $Y_{var}(t)$ being the variometer output of the Y sensor; $Z(t) = Z_0(t) + Z_{var}(t)$ with Z_0 being the baseline (bias plus offset in nT) and $Z_{var}(t)$ being the variometer output of the Z sensor.

6.6 Standards for Calculating Hourly, Daily and Annual Means

INTERMAGNET requires that all mean values be calculated using the rules described in the next sections.

6.6.1 Hourly Mean Values

The hourly mean values must be produced following the IAGA rules:

- Arithmetic average of the 1-minute data
- Centered on the center of the hour (HH:29:30, HH=hour) using 1-minute data 00-59 of the hour

6.6.2 Daily Mean Values

The daily mean values must be produced using the following rules:

- Arithmetic average of the 1-minute data
- Centered on the center of the day (11:59:30) using 1-minute data 00:00-23:59 of the day

6.6.3 Annual Mean Values

The annual mean values must be produced using the following rules:

- Arithmetic average of the 1-minute data
- Centered on the center of the year (02 July 11:59:30 for a regular year, 01 July 23:59:30 for a leap year) using 1-minute data 01 January 00:00- 31 December 23:59 of the year

6.6.4 Rule for Missing 1-minute Values

When mean values are to be calculated the question of how to handle missing data arises. For a number of reasons it is difficult to devise a simple objective rule that can be applied to all cases. INTERMAGNET recommends a simple and pragmatic approach: mean or filtered values may be calculated when 90% or more of the values required for calculation are available. This can be interpreted as either 90% of the values or 90% of the weight of the filter. When fewer than 90% of the required values are available the value should be assigned the value used to flag missing data.

6.7 Definitive 1-Second Data

Since 2014 INTERMAGNET has requested observatories to provide 1-second definitive data if they are able to do so. Calls for 1-second definitive data will be made at the same time as calls for 1-minute definitive data. It is not a requirement of INTERMAGNET membership that an observatory is able to provide 1-second data. Where possible, observatories should produce data that complies with the INTERMAGNET 1-second data standard (see [Chapter 3](#)). At present observatories are requested to provide baseline corrected 1-second definitive data whether or not it conforms to the standard, though this is likely to change in the future as more observatories become able to meet the standard. INTERMAGNET is currently developing recommendations on how to produce 1-second definitive data that will conform to the standard.

INTERMAGNET has created a format for 1-second data (see [APPENDIX E6](#)) based on NASA's Common Data Format (CDF) software. Observatories are asked to supply data in the new INTERMAGNET CDF format. Software for conversion to the new format is available. For the most up to date details of what software is available please see <https://intermagnet.org/software.html>

USING INTERMAGNET DATA

7.1 INTERMAGNET WEB Site

The INTERMAGNET web site provides background information about INTERMAGNET, its structure, and participating organizations, countries and IMOs (INTERMAGNET Magnetic Observatories).

The web site offers access to various data products:

- The annual definitive data published with a Digital Object Identifier (DOI).
- Magnetograms and data files of reported and adjusted minute values from all the IMOs.
- The Online Technical Reference Manual.
- The INTERMAGNET application form.

INTERMAGNET moved away from in-house maintained servers towards free cloud-based possibilities to deploy the web site.

The following underlying technologies were selected for the web site :

- a GitHub repository for all software, web site development and discussion forums : <https://github.com/INTERMAGNET>
- The INTERMAGNET web site has been designed using GitHub Pages (<https://pages.github.com/>).
- The Online Technical Reference Manual is produced using the [sphinx framework](#) making it possible to generate both pdf and html versions of the manual The manual is automatically built and deployed using the services offered by readthedocs.org.

The metadata and online data are hosted by the British Geological Survey (BGS). The annual definitive data are deployed on the servers of the German Research Centre for Geosciences (GFZ).

7.1.1 WEB Site Address

The INTERMAGNET web site address is: <https://www.intermagnet.org/>. This gives access to the home page from where required information about INTERMAGNET is available. The source code is available on the INTERMAGNET GitHub.

7.1.2 Online Technical Reference Manual

The Online Technical Reference manual can be found on the subdomain <https://tech-man.intermagnet.org/>. It is also possible to download the manual in different formats.

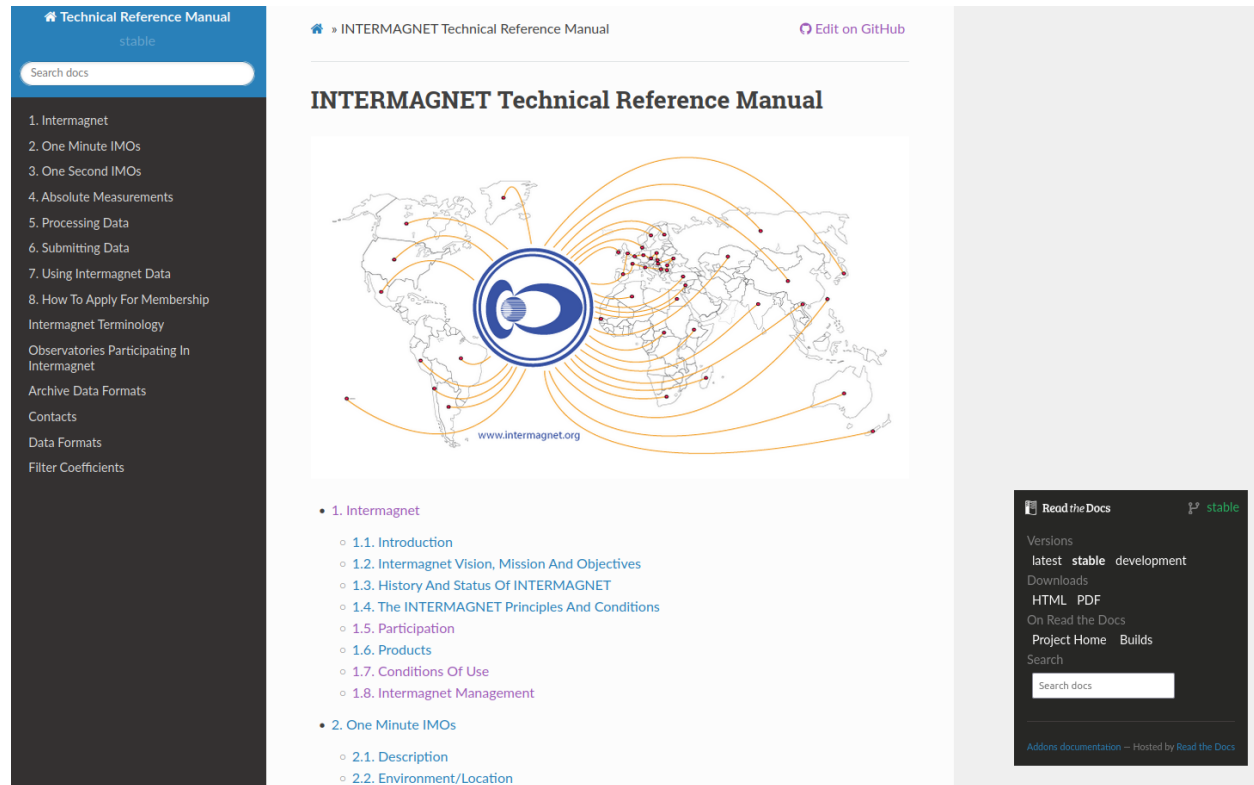


Fig. 7.1: Online Technical Reference manual

On the right side, you will find links to download the manual in PDF or HTML format.

There are three versions available:

1. stable : The latest official release (the most up to date version to be used as a reference).
2. latest : The current working version with accepted changes but not ready for an official release.
3. development : This version may contain errors and/or proposed changes not yet accepted.

The stable version should be the only one used as reference.

7.1.3 Downloading Data

Geomagnetic observatory data can be downloaded using a web browser by either using DOIs for definitive data or using the web data distribution interface for all data types including definitive data. Until 2015, the annual definitive data was released on a physical media (see *APPENDIX C2*). From 2015 onward, the intermagnet definitive data is published yearly with a Digital Object Identifier (DOI) which includes all definitive data since 1991 to the publication year.

7.1.3.1 Downloading Data Using DOIs

Beginning with the publication of the definitive data for 2015, INTERMAGNET stopped publishing individual years of data and started publishing the entire, cumulative definitive data set since INTERMAGNET's first recorded definitive data in 1991.

This DOI-referenced annual data set is known as the “INTERMAGNET Reference Data Set” (IRDS). The IRDS comprises all INTERMAGNET one-minute definitive data since 1991 and is annually updated with a new year and occasional corrections to previous releases. The different releases of the IRDS can be found on the INTERMAGNET web site :https://intermagnet.org/data_download.html.

The IRDS are deployed on the servers of the GFZ German Research Centre for Geosciences. File names for IRDS data are formatted in the form mag<year>_def<year>.zip. The mag<year> section of the filename describes the year in which the data was recorded. The def<year> section of the filename describes the most recent annual INTERMAGNET publication in which the data was updated. Files where mag<year> = def<year> have had no corrections since their original publication. For example, “mag2015_def2016” indicates that this file is different from the first release “mag2015_def2015”.

The zip archive is organized in a number of subdirectories. Most of them are named with observatory IAGA codes, they contain information regarding a particular observatory. Further subdirectories provide country information about national operators of magnetic observatories. A complete set for one observatory consists of the following files (this example is for the year 2010):

1. x:\mag2010\sss\sss10mmm.bin (12 binary files in IAF format)
2. x:\mag2010\sss\readme.sss (1 readme file)
3. x:\mag2010\sss\sss2010.blv (1 baseline file)
4. x:\mag2010\sss\yearmean.sss (1 annual means file)
5. x:\mag2010\sss\sss10k.dka (1 text file of K-indices)
6. x:\mag2010\2010maps\country_id.xxx (1 map for each country (xxx = png or pcx))
7. x:\mag2010\ctry_inf\readme.country_id (1 readme-file for each country)
8. x:\mag2010\ctry_inf\country_idsrn.xxx (1 about-screen for each country (xxx = png or pcx))

Where:

- sss is the 3-letter observatory IAGA code
 - mmm is the month
 - country_id is the three-letter country code
1. A binary file in IAF format (described in detail in [Section 6.4](#) and [APPENDIX C1](#)) includes minute values as well as other accompanying data such as: metadata headers W01-W16, K indices, hourly and daily mean values.
 2. A text file readme.sss contains meta-data and information about the observatory such as location, parent institute, personnel, equipment and instrumentation etc.
 3. A text file sssyyy.blv includes results of absolute control of geomagnetic observations and adopted baseline values. The format of this file is described in [APPENDIX E4](#). Baseline data are considered by many experts as an indicator of data quality, especially with regard to observation of secular variation.
 4. A text file yearmean.sss includes a listing of annual mean values for the observatory. The format of this file is described in [APPENDIX C3](#). Most observatories publish all annual means, i.e. since the beginning of their activity. Some observatories also publish annual means for international geomagnetic quiet-days and disturbed-days.
 5. A text file sssyyk.dka includes K-indices. DKA files are created by INTERMAGNET from the K index data included in binary IAF files. If K-indices are not scaled by the IMO there is no DKA file.
 6. The image file country_id.xxx shows the location of observatories of a given country.
 7. The text file readme.country_id provides information about parent institute(s) in a given country.
 8. The image file country_idsrn.xxx provides information about parent institute(s) managing IMOs in a given country in graphical form.

After unzipping the archive data can be accessed using INTERMAGNET's IMCDViewer software available for download from the web site : <https://intermagnet.org/software.html>. See [Section 7.2](#) for more info on the usage of this Data Viewer.

7.1.3.2 Downloading Data Using the WEB Interface

Reported and adjusted intermagnet data are available for many IMO's in near real-time. The availability of data files is dependent on the publishing delay and data embargo policy of participating institutes. If there is no publishing delay, data are available within 10 to 20 minutes after being placed on the server. The data covers the period from 1991 to present. In addition to data of reported and adjusted quality, quasi-definitive and definitive data may also be available for one-minute or one-second sampling rates in various data formats. Data are available via web services. For further details and to download data, you can consult the INTERMAGNET web site: https://intermagnet.org/data_download.html

Plots of magnetic observatory data and information derived from the data are also available. These include:

- Plots of X, Y, Z magnetic field components
- Plots of H, D, Z magnetic field components
- Plots of declination and inclination

7.1.4 Geomagnetic Activity

A map of geomagnetic activity is currently under development. The magnetic activity maps will show the range of the magnetic variation in each hour at INTERMAGNET observatories around the world. For recent events only those observatories with fast reporting capabilities can be presented.

7.2 Data Viewer

INTERMAGNET provides software to work with the data from the DOIs, web downloads and from the INTERMAGNET Physical Media (IPM). This software can be installed from the Physical Media, or downloaded from <https://intermagnet.org/software.html>. The software is designed to be simple and easy to use. When the software starts for the first time on a new computer, a dialog is displayed describing how to configure the software to find data. This same information, on how to find data, is available from the "Help" menu under "Help for New Users".

The program has 3 main windows. The window that you see when the program starts shows a view of the world. The observatories that the program has discovered in its database(s) are shown as red dots on the world map. If you move your mouse over an observatory its name will be displayed. If you click on an observatory using the left mouse button then a popup-menu will appear with a list of data that you can view. If you use the right mouse button you will get the same menu, but in a permanent window that will not close when you select an item from the menu. The World Map window also holds the program's menu bar. The World Map window is always present while the software is running. If you close this window, the program will exit.

There is also an Explorer window, available from the "View" menu. This window gives you an alternative view of data on the IPM. The view of the data that the window presents is similar in structure to the directory structure used to hold the data on the IPM. To view an object in the Explorer window, double click the object. For example, to plot data from an observatory using the Explorer window, expand the tree until the observatory is listed, expand the observatory, select and expand the data file that you want to view then double click the "Data Plot" icon. The Explorer window also shows you which databases the program is using. For more information about databases see the online help system.

The Data Catalogue option from the "View" menu displays a colour-coded graphical view of available observatories and data from the program's database. Data can be accessed via sub-menus by clicking within the graphic.

The third main window, also available from the "View" menu, is the Export Window. This window allows you to create data files in IAGA 2002 and other data formats from the INTERMAGNET archive data. The window has been designed so that you can convert as much data as you want with the minimum of work. Further details are available in the online help system.

The software also includes an import function, allowing you to convert data from IAGA 2002 and other data formats into the INTERMAGNET Archive Format. This function is available from the "Database" menu. Using this software, observatories can convert their own data into IAF for delivery to INTERMAGNET. It's also possible to use the import

and then export functions to convert between data formats (e.g. to convert INTERMAGNET minute value format to IAGA-2002), but please note that between import and export the data will always be stored in IAF format and so the precision of the data will be that provided by the IAF format (1/10th nT and 1/10th minute of arc). For most modern data this precision is unacceptably low, particularly for angular measurements.

Prior to the current software, INTERMAGNET distributed a DOS-based program for working with the DVD/CD-ROM data.

7.3 Condition Use

Please refer to [Chapter 1.7](#) for the INTERMAGNET conditions of use.

7.3.1 Acknowledgment of Data from Observatories Participating in INTERMAGNET

Publications making use of INTERMAGNET data should include an acknowledgement statement of the form given below. The first form is for cases where data from many observatories have been used and it is not practical to list them all, or each of their operating institutes. The second is for cases where research results have been produced using a smaller set of observatories.

Suggested Acknowledgement Text (template 1):

The results presented in this paper rely on data collected at magnetic observatories. We thank the national institutes that support them and INTERMAGNET for promoting high standards of magnetic observatory practice. (<https://www.intermagnet.org/>)

Suggested Acknowledgement Text (template 2):

The results presented in this paper rely on the data collected at <observatory name>. We thank <institute name>, for supporting its operation and INTERMAGNET for promoting high standards of magnetic observatory practice (<https://www.intermagnet.org/>).

HOW TO APPLY FOR MEMBERSHIP

8.1 Application

Any observatory wishing to become a member of the INTERMAGNET network is invited to submit an application to the INTERMAGNET Operations Committee along with a minimum of twelve months of one-minute definitive data. The Committee will assess an application against the data quality standards as described in this manual ([Chapter 2](#) and [Chapter 3](#)) before granting INTERMAGNET membership.

Observatories submitting an application should note that a condition of acceptance is that the observatory agrees to comply with the INTERMAGNET Observatory Participation Policy as described below.

Applications forms are available on the [INTERMAGNET web site](#) and forms should be sent to the IMO Applications and Standards Subcommittee chair:

Chris Turbitt
INTERMAGNET
c/o British Geological Survey
The Lyell Centre
Research Avenue South
Edinburgh EH14 4AP
United Kingdom
TEL: 44-131-667-1000
FAX: 44-131-667-1877
c.turbitt@bgs.ac.uk

It is not a prerequisite of INTERMAGNET membership that an observatory makes one-second recordings nor is it currently a prerequisite that one-second recordings meet the INTERMAGNET One-second Definitive Data Standard in order to be transmitted to INTERMAGNET. Please contact the IMO Applications and Standards Subcommittee chair for further information.

The IMO Applications and Standards Subcommittee chair can also be contacted at any stage of the application process for further information on the application form, data transmission or for assistance in producing the data files listed on the application form.

8.2 INTERMAGNET Participation Policy

INTERMAGNET is a global near real-time network of absolute geomagnetic observatories with a common data quality standard and common data publication platforms. Observatories wishing to become a member of the INTERMAGNET one-minute data network are required to submit an application to the IMO Applications and Standards Subcommittee chair that demonstrates that the INTERMAGNET requirements on data quality and data delivery are currently being and will continue to be met. Applications are assessed by the INTERMAGNET Operations Committee against a set of documented standards and the Committee will recommend that the chair of the INTERMAGNET Executive Council accepts the application if:

- The institute abide by the INTERMAGNET Principles and Conditions (Section 1.4).
- The observatory is meeting and will continue to meet the documented standards on data quality and data formats.
- The observatory transmits and will continue to transmit data in near real-time to the INTERMAGNET network.
- If using satellite communication, the institute must keep its DCPs operating within allotted transmission time 'windows'. Upon receipt of notification from a Geomagnetic Information Node (GIN) that a DCP is transmitting outside of its allotted time window, the responsible Institute agrees to stop the transmission or correct the timing of transmission within 24 hours.
- The observatory will submit definitive data and accompanying files for publication in the INTERMAGNET data set every year.
- The institute must communicate any instrument or practice change to the IMO Applications and Standards Subcommittee chairman.

The INTERMAGNET Operations Committee will continually assess the near real-time data delivery and submitted annual definitive data from participating observatories against the definition of near real-time and data quality standards for one-minute definitive data in the INTERMAGNET Technical Manual.

It is recognised that any near real-time network is potentially subject to temporary operational issues leading to a degradation of data quality or loss of data. If required, the INTERMAGNET Operations Committee may be able to offer advice or technical support to resolve such problems. However, an observatory that is not able in the long-term to meet the data delivery and/or data quality specifications defined in the Technical Manual may ultimately have INTERMAGNET status withdrawn.

For operational purposes, INTERMAGNET may occasionally need to modify data formats or the method of data delivery but these changes will not be applied retrospectively.

8.2.1 Observatory Application to the INTERMAGNET Network

Observatories intending to join the INTERMAGNET network are requested to submit an application and sample data to the IMO Applications and Standards Subcommittee chair using the [application form](#) on the INTERMAGNET web site. The application will then be reviewed by the INTERMAGNET Operations Committee against the standards defined in the Technical Manual. If these standards are met, and once near real-time data are being transmitted to the network, the INTERMAGNET Executive Council chair will communicate to the observatory that the application was successful and that the observatory is now able to participate as an INTERMAGNET observatory. Observatories are accepted into INTERMAGNET on the condition that the data quality and data delivery standards will continue to be met.

Applications may be rejected on the grounds that the data quality or data delivery standards are not judged to have been met, in which case the Operations Committee will communicate this and the reason for the decision to the observatory making the application. There is no restriction on re-application.

8.2.2 Ongoing Participation in the INTERMAGNET Network

On a regular basis, the Operations Committee will monitor the delivery of one-minute, near real-time data of all participating observatories against the requirements outlined in the Technical Manual.

Where an observatory does not transmit near real-time, one-minute data to the INTERMAGNET network for a continuous period of one-year, this will be considered to be a breach of the INTERMAGNET data delivery requirements and the observatory will be notified of the breach by the Operations Committee.

The Operations Committee will also assess definitive data submitted for inclusion in the INTERMAGNET Reference Data Set (IRDS) against the data quality standards for one-minute data as defined in the Technical Manual. The deadline for submission of definitive data will be communicated by the Operations Committee in advance and sufficient time will be provided for final processing following the year end. In the case where data not judged to meet the data quality standards or where the data formats do not comply with those defined in the Technical Manual, the Operations Committee will establish a communication with the observatory to resolve the issue.

Where no definitive data have been submitted prior to the submission deadline, this will be considered to be a *breach* of the INTERMAGNET data delivery requirements and the observatory will be notified of the breach by the Operations Committee.

Where definitive data have been submitted, but where data quality or format issues have not been resolved prior to the INTERMAGNET data publication date, definitive data will not be published under the assigned INTERMAGNET DOI, this will be considered to be a *breach* of the INTERMAGNET data quality requirements and the observatory will be notified of the breach by the Operations Committee.

8.2.3 Withdrawal of INTERMAGNET Status

Under certain circumstances and on the recommendation of the INTERMAGNET Operations Committee, the INTERMAGNET Executive Council chair may withdraw INTERMAGNET status from a participating observatory. An Operations Committee recommendation of withdrawal will be made if a participating observatory:

- Does not respond to a communication from the Operations Committee notifying that the observatory has breached INTERMAGNET standards or
- Does not transmit near real-time, one-minute data to the INTERMAGNET network for two consecutive years or
- Does not submit or does not have definitive one-minute data accepted for publication for two consecutive years.

Where an observatory has had INTERMAGNET status withdrawn, the observatory will be required to submit a further application to the INTERMAGNET Observatories Subcommittee chair before INTERMAGNET status can be reinstated.

INTERMAGNET TERMINOLOGY

ADJUSTED Data

Each observatory or its parent institute is allowed to modify REPORTED data files to produce ADJUSTED data, with a goal of 7 days after transmission. These adjustments may be to modify baselines, remove spikes, fill gaps etc. on any day file. When data are missing from an ADJUSTED data file, these data may be input to a GIN in a later message. This new message file can be transmitted to a GIN with the data type set to ADJUSTED (See [APPENDIX E1](#)). ADJUSTED data are maintained online until the annual INTERMAGNET Reference Data Set (IRDS) is available. They are then archived by the GIN and only available thereafter by special arrangement.

DEFINITIVE Data

This describes the final publication stage of observatory data. DEFINITIVE data have been corrected for baseline variations, have had spikes removed and gaps filled where possible. DEFINITIVE data are recorded and transmitted in files with the data type set to DEFINITIVE ([APPENDIX E1](#), [APPENDIX E5](#)). The quality of DEFINITIVE data is such that in this form they would be used for inclusion into Observatory Year Books, input to World Data Centers and included in the INTERMAGNET Reference Data Set (IRDS).

Flags

Flags are reserved data values that are typically used to indicate that a data sample is missing. This can be the result of a fault with an instrument; where data have been removed due to poor quality; or where a particular component is not observed when the necessary instrument is not operated. The value of a data flag is specific to the data format. See ([APPENDIX E1](#), [APPENDIX E5](#)).

GIN

Geomagnetic Information Nodes are data centers, organized on a regional basis, which INTERMAGNET observatories send their provisional data to. GINs forward this data to the INTERMAGNET web site. GIN managers will help INTERMAGNET observatories with the technical details of establishing reliable data flow. GINs do not distribute data to users – this task is done by the INTERMAGNET web site.

IMO

An INTERMAGNET Magnetic Observatory (IMO) is a magnetic observatory equipped with magnetometers, clock, control electronics, transmitting equipment and a data collection platform (DCP), residing at the magnetic observatory site. The operation and equipment must meet INTERMAGNET standards and specifications.

IPM

INTERMAGNET Physical Media, this term collectively describes the INTERMAGNET CDs, INTERMAGNET DVDs and INTERMAGNET USBs.

IRDS

INTERMAGNET Reference Data Set contains all definitive data and metadata from the first Intermagnet publication in 1991 up to the current year, including any corrections that have been made. Published with a DOI, for example the INTERMAGNET Reference Data Set, 2015: <https://doi.org/10.5880/INTERMAGNET.1991.2015>.

Magnetic observatory

A permanent installation of magnetometers capable of providing magnetic field values with an absolute accuracy of better than 5 nT over a period ranging from DC to approximately 1 Sec.

NESS binary

This term is specific to the data transmission format used by the GOES satellite. For GOES transmissions, each 16-bit binary word is encoded as 3 pseudo ASCII bytes, so that the 126 bytes of IMFV2.83 data are encoded as 189 bytes NESS binary (see [APPENDIX E2](#)).

Offset

A fixed-value change applied to an instrument or data set. An offset can be inherent in an instrument but is often used to bring an instrument into its operating range, or to reduce the magnitude of a data point for storage or transmission. For example, offsets are used to reduce the size of data blocks where bandwidth is limited, such as in satellite telemetry. The IMFV2.83 format has provisions for offset values for one-minute data per component ([APPENDIX E1](#)).

QUASI-DEFINITIVE Data

As the name implies, the data should be close to the expected definitive value, but is to be delivered more rapidly than an observatory's annual definitive data. This initiative will be useful for a number of scientific activities, where timely and close-to-definitive data is essential. For example, quasi-definitive data will be particularly useful in joint analyses of geomagnetic and other phenomena, together with data measured by satellites. Quasi-definitive data are 1-minute or 1-second data (observatories are encouraged to produce both minute and second data) that can be submitted to INTERMAGNET as (H, D, Z) or (X, Y, Z) and have the following properties:

- A. Corrected using temporary baselines
- B. Made available less than 3 months after their acquisition
- C. Such that the difference between the quasi-definitive and definitive (X, Y, Z) monthly means are less than 5 nT in any component for every month of the year

Point C is checked a posteriori by comparing quasi-definitive and definitive data from the previous year. Observatories are strongly encouraged to submit quasi-definitive data that is thoroughly controlled, i.e. de-spiked, free from corrupted data, data gaps filled in from back-up systems, and with the best possible baseline at the time of submission. Submission of quasi-definitive data should not be seen as having satisfied the requirements for definitive data. The annual definitive data, again thoroughly controlled and with a baseline based on a full year of absolute measurements, shall be submitted in the formats for definitive data at latest by the deadline agreed by INTERMAGNET.

Reference Measurement (RM)

RMs are optional values provided by an IMO as additional quality control information. RM values have historically been derived automatically from variometer data and an independent, stable vector instrument, often sampling at a slower cadence. RMs transmitted in data formats such as IMFV2.83 ([APPENDIX E1](#)) can be applied to reported data to produce adjusted data and to supplement baseline control.

REPORTED Data

Data as output by an observatory, transmitting through a satellite or using email. REPORTED data have not had any baseline corrections applied, may contain spikes and may have missing values. When ADJUSTED data are available, REPORTED data are removed from online access.

Time stamp

The precise date and time of acquisition of a data sample. Timestamp are recorded and transmitted alongside the data. In the IMFV2.83 format, a timestamp is recorded for the first sample of each 12-minute data block only due to bandwidth constraints (see [APPENDIX E1](#) and [APPENDIX E2](#)).

OBSERVATORIES PARTICIPATING IN INTERMAGNET

Up-to-date observatory information is available on the INTERMAGNET website: <https://intermagnet.org/metadata/#/imos>.

ARCHIVE DATA FORMATS

C.1 INTERMAGNET Archive Format : IAF

C.1.1 IAFV2.11 Binary Data Structure Format-32 Bit Words

Section	Word	Field Name	Comment
Header	1	Station ID	eg: BOU = HEX(20 42 4F 55)
	2	Year and day number	eg: 1989001; year 1989, day January 01
	3	Co-latitude	(90° - Latitude) * 1000, to WGS-84 datum
	4	Longitude	East Longitude * 1000, to WGS-84 datum
	5	Elevation	elevation in meters above sea level, to WGS-84 datum
	6	Orientation	eg: XYZG = HEX(58 59 5A 47); HDZG = HEX(48 44 5A 47); XYZ = HEX(20 58 59 5A); and HDZ = HEX(20 48 44 5A)
	7	Source	eg: DMI = HEX(20 44 4D 49)
	8	D conversion	H/3438*10000 where H=annual mean of H (set to 10000 for XYZG)
	9	Data Quality	IMAG = HEX (49 4D 41 47)
	10	Instrumentation	eg: LC(Linear Core) = HEX(20 20 4C 43) (or RC(Ring Core))
	11	K9 value in nT	eg: 750
	12	Sampling rate (ms)	eg: 125
	13	Sensor orientation	eg: XYZF, DIF, UVZ, HDZ, HDZF etc.
	14	Publication Date	eg: YYMM = 0806 (June 2008) HEX (30 38 30 36)
	One minute data	15	IAF version number and data type
16		Reserved for future use	
17		1440 mean minute values - element 1 (one day)	Missing value = 999999
...		1440 mean minute values - element 2 (one day)	Missing value = 999999
...		1440 mean minute values - element 3 (one day)	Missing value = 999999
5776	1440 mean minute values - element 4 (one day)	Missing value = 999999 Scalar not recorded = 888888	

continues on next page

Table 3.1 – continued from previous page

Section	Word	Field Name	Comment
Mean hourly data	5777	24 mean hourly values - element 1	Missing value = 999999
	...	24 mean hourly values - element 2	Missing value = 999999
	...	24 mean hourly values - element 3	Missing value = 999999
	5872	24 mean hourly values - element 4	Missing value = 999999
Daily means	5873	daily mean value element 1	Missing value = 999999
	5874	daily mean value element 2	Missing value = 999999
	5875	daily mean value element 3	Missing value = 999999
	5876	daily mean value element 4	Missing value = 999999
K indices	5877	8 K-values	Missing value = 999
Reserved	5885 - 5888	Reserved for each contributing institution	

See Section 6.4.3.2.1 for details.

C.1.2 IAFV2.10 Binary Data Structure Format-32 Bit Words

Section	Word	Field Name	Comment
Header	1	Station ID	eg: BOU = HEX(20 42 4F 55)
	2	Year and day number	eg: 1989001; year 1989, day January 01
	3	Co-latitude	(90° - Latitude) * 1000, to WGS-84 datum
	4	Longitude	East Longitude * 1000, to WGS-84 datum
	5	Elevation	elevation in meters above sea level, to WGS-84 datum
	6	Orientation	eg: XYZG = HEX(58 59 5A 47); HDZG = HEX(48 44 5A 47); XYZ = HEX(20 58 59 5A); and HDZ = HEX(20 48 44 5A)
	7	Source	eg: DMI = HEX(20 44 4D 49)
	8	D conversion	H/3438*10000 where H=annual mean of H (set to 10000 for XYZG)
	9	Data Quality	IMAG = HEX (49 4D 41 47)
	10	Instrumentation	eg: LC(Linear Core) = HEX(20 20 4C 43) (or RC(Ring Core))
	11	K9 value in nT	eg: 750
	12	Sampling rate (ms)	eg: 125
	13	Sensor orientation	eg: XYZF, DIF, UVZ, HDZ, HDZF etc.
	14	Publication Date	eg: YYMM = 0806 (June 2008) HEX (30 38 30 36)
	15	IAF version number	HEX(03 00 00 00) version 2.10
One minute data	16	Reserved for future use	
	17	1440 mean minute values - element 1 (one day)	Missing value = 999999
	...	1440 mean minute values - element 2 (one day)	Missing value = 999999

continues on next page

Table 3.2 – continued from previous page

Section	Word	Field Name	Comment
Mean hourly data	...	1440 mean minute values - element 3 (one day)	Missing value = 999999
	5776	1440 mean minute values - element 4 (one day)	Missing value = 999999 Scalar not recorded = 888888
	5777	24 mean hourly values - element 1	Missing value = 999999
	...	24 mean hourly values - element 2	Missing value = 999999
	...	24 mean hourly values - element 3	Missing value = 999999
Daily means	5872	24 mean hourly values - element 4	Missing value = 999999
	5873	daily mean value element 1	Missing value = 999999
	5874	daily mean value element 2	Missing value = 999999
	5875	daily mean value element 3	Missing value = 999999
	5876	daily mean value element 4	Missing value = 999999
K indices	5877	8 K-values	Missing value = 999
Reserved	5885 - 5888	Reserved for each contributing institution	

C.1.2.1 IAFV2.10 (2010 to 2013)

Words 1 to 16 comprise the header section containing a mixture of text and numeric fields, including a 3-letter observatory identification preceded with a space [hex20] (ID) code, the year concatenated with the day of the year, co-latitude, longitude, elevation, reported orientation, originating organization, a D-conversion factor, data quality, instrumentation, K-9, sampling rate, sensor orientation, publication date and format version/data type. Latitude, longitude/colatitude and elevation must be given using the WGS-84 datum. From 2010 onward, the orientation codes “XYZ” and “HDZ” have been added to “XYZG” and “HDZG” where “G” represents ΔF (see description below). These new codes indicate that the observatory is recording 3 elements only (no scalar instrument). The D-conversion factor is a fixed value used only in the graphics portion of the access software to allow Declination to be plotted in minutes of arc and equivalent nanoteslas (nT). It is given as $H/3438 \times 10000$, where H is the annual mean value of the horizontal intensity. Example: If H is 16500 D will be 47993(Integer). When XYZG or XYZ is used, the D-conversion factor should be set to 10000.

ASCII values, such as the observatory ID and orientation, are also stored as 32-bit words, but are coded as the hexadecimal byte-string corresponding to the ASCII string. For example, the string “HDZF” is coded as the sequence “48 44 5A 46”. Where a string is shorter than four bytes, it is padded to the left with spaces. For example, the string “ESK” is coded as the sequence “20 45 53 4B”.

Word 11 is the K-9 value for the observatory in nT, word 12 is the digital sampling rate in msec, and word 13 is the sensor orientation. Sensor orientation could be XYZF, DIF, UVZ, HDZ, HDZF etc. and should indicate which components are actually measured. If a three component sensor orientation is used, a space must be added to the left. Word 14 is the publication date encoded as 4 ASCII bytes “YYMM” provided by INTERMAGNET. The high byte (left most) of word 15 is the INTERMAGNET Archive Format version number code provided by the IMO. It takes the form of a binary single byte number ranging from 0 to 255. Zero (0x00) represents version 1.00, one (0x01) represents version 1.10, two (0x02) represents version 2.00 and three (0x03) represents version 2.10. The other three bytes of word 15 are reserved for future use and padded with zeros. Word 16 is reserved for future use.

Words 17-5776 contain the minute values of the 4 geomagnetic elements (successively X,Y,Z,G or H,D,Z,G or X,Y,Z, or H,D,Z) for the day. From 2009 onward, the 4th element contains the difference between the square root of the sum of the squares of the variometer components, $F(v)$, and the total field from an independent scalar recording, $F(s)$. This difference, ΔF , is defined as $F(v) - F(s)$. Both $F(v)$ and $F(s)$ must be corrected to the location in the observatory where

absolute geomagnetic observations are made. When F(s) is missing or both F(s) and F(v) are missing, ΔF must be set to 999999. When F(v) only is missing, ΔF must be set to -F(s). The values of the 4 elements are stored in tenth-units with an implied decimal point. Thus, an H value of 21305.6 is stored (in tenth-nT) as 213056 with a decimal point implied between the last and next-to-last digits. Words 5777-5872 are used for the hourly mean values of the successive 4 elements. From 2009 onward, words 5849-5872 always record 999999 (missing value), this is done because the 4th element in the data is a quality check for minute mean data and this quality check is meaningless for hourly means. Words 5873-5876 store the 4 daily mean values. From 2009 onward, word 5876 always record 999999 (missing value) because the quality check for daily means is also meaningless. From 2009 onward, the last 4 words (5885-5888) are available for each contributing institution. Missing data for minute, hour, and day values are stored as “999999”. From 2010 onward, if a scalar instrument is not used (so no data is recorded in the fourth element) the value “888888” should be used instead of “999999”. Missing K-Index values are stored as “999”.

C.1.3 IAFV2.00 Binary Data Structure Format-32 Bit Words

Section	Word	Field Name	Comment
Header	1	Station ID	eg: BOU = HEX(20 42 4F 55)
	2	Year and day number	eg: 1989001; year 1989, day January 01
	3	Co-latitude	(90° - Latitude) * 1000, to WGS-84 datum
	4	Longitude	East Longitude * 1000, to WGS-84 datum
	5	Elevation	elevation in meters above sea level, to WGS-84 datum
	6	Orientation	eg: XYZG = HEX(58 59 5A 47); and HDZG = HEX(48 44 5A 47)
	7	Source	eg: DMI = HEX(20 44 4D 49)
	8	D conversion	H/3438*10000 where H=annual mean of H (set to 10000 for XYZG)
	9	Data Quality	IMAG = HEX (49 4D 41 47)
	10	Instrumentation	eg: LC(Linear Core) = HEX(20 20 4C 43) (or RC(Ring Core))
	11	K9 value in nT	eg: 750
	12	Sampling rate (ms)	eg: 125
	13	Sensor orientation	eg: XYZF, DIF, UVZ, HDZ, HDZF etc.
	14	Publication Date	eg: YYMM = 0806 (June 2008) HEX (30 38 30 36)
	One minute data	15	IAF version number
16		Reserved for future use	
17		1440 mean minute values - element 1 (one day)	Missing value = 999999
...		1440 mean minute values - element 2 (one day)	Missing value = 999999
Mean hourly data	...	1440 mean minute values - element 3 (one day)	Missing value = 999999
	5776	1440 mean minute values - element 4 (one day)	Missing value = 999999
	5777	24 mean hourly values - element 1	Missing value = 999999
		values - element 2	999999
	...	24 mean hourly values - element 3	Missing value = 999999

continues on next page

Table 3.3 – continued from previous page

Section	Word	Field Name	Comment
Daily means	5872	24 mean hourly values - element 4	Missing value = 999999
	5873	daily mean value element 1	Missing value = 999999
	5874	daily mean value element 2	Missing value = 999999
	5875	daily mean value element 3	Missing value = 999999
	5876	daily mean value element 4	Missing value = 999999
K indices	5877	8 K-values	Missing value = 999
Reserved	5885 - 5888	Reserved for each contributing institution	

C.1.3.1 IAFV2.00 (2009)

Words 1 to 16 comprise the header section containing a mixture of text and numeric fields, including a 3-letter observatory identification preceded with a space [hex20] (ID) code, the year concatenated with the day of the year, co-latitude, longitude, elevation, reported orientation, originating organization, a D-conversion factor, data quality, instrumentation, K-9, sampling rate, sensor orientation, publication date and format version/data type. Latitude, longitude/colatitude and elevation must be given using the WGS-84 datum. From 2009 onward, the orientation must be “XYZG” or “HDZG” where “G” represents ΔF (see description below). The D-conversion factor is a fixed value used only in the graphics portion of the access software to allow Declination to be plotted in minutes of arc and equivalent nanoteslas (nT). It is given as $H/3438*10000$, where H is the annual mean value of the horizontal intensity. Example: If H is 16500 D will be 47993(Integer). When XYZG is used, the D-conversion factor should be set to 10000.

ASCII values, such as the observatory ID and orientation, are also stored as 32-bit words, but are coded as the hexadecimal byte-string corresponding to the ASCII string. For example, the string “HDZF” is coded as the sequence “48 44 5A 46”. Where a string is shorter than four bytes, it is padded to the left with spaces. For example, the string “ESK” is coded as the sequence “20 45 53 4B”.

Word 11 is the K-9 value for the observatory in nT, word 12 is the digital sampling rate in msec, and word 13 is the sensor orientation. Sensor orientation could be XYZF, DIF, UVZ, HDZ, HDZF etc. and should indicate which components are actually measured. If a three component sensor orientation is used, a space must be added to the left. Word 14 is the publication date encoded as 4 ASCII bytes “YYMM” provided by INTERMAGNET. The high byte (left most) of word 15 is the INTERMAGNET Archive Format version number code provided by INTERMAGNET. It takes the form of a binary single byte number ranging from 0 to 255. Zero (0x00) represents version 1.00, one (0x01) represents version 1.10 and two (0x02) represents version 2.00. The other three bytes of word 15 are reserved for future use and padded with zeros. Word 16 is reserved for future use.

Words 17-5776 contain the minute values of the 4 geomagnetic elements (successively X,Y,Z,G or H,D,Z,G) for the day. From 2009 onward, the 4th element contains the difference between the square root of the sum of the squares of the variometer components, F(v), and the total field from an independent scalar recording, F(s). This difference, ΔF , is defined as $F(v) - F(s)$. Both F(v) and F(s) must be corrected to the location in the observatory where absolute geomagnetic observations are made. When F(s) is missing or both F(s) and F(v) are missing, ΔF must be set to 999999. When F(v) only is missing, ΔF must be set to -F(s). The values of the 4 elements are stored in tenth-units with an implied decimal point. Thus, an H value of 21305.6 is stored (in tenth-nT) as 213056 with a decimal point implied between the last and next-to-last digits. Words 5777-5872 are used for the hourly mean values of the successive 4 elements. From 2009 onward, words 5849-5872 always record 999999 (missing value), this is done because the 4th element in the data is a quality check for minute mean data and this quality check is meaningless for hourly means. Words 5873-5876 store the 4 daily mean values. From 2009 onward, word 5876 always record 999999 (missing value) because the quality check for daily means is also meaningless. From 2009 onward, the last 4 words (5885-5888) are available for each contributing institution. Missing data for minute, hour, and day values are stored as “999999”. Missing K-Index values are stored as “999”.

C.1.4 IAFV1.10 Binary Data Structure Format-32 Bit Words

Section	Word	Field Name	Comment	
Header	1	Station ID	eg: BOU = HEX(20 42 4F 55)	
	2	Year and day number	eg: 1989001; year 1989, day January 01	
	3	Co-latitude	(90° - Latitude) * 1000, to WGS-84 datum	
	4	Longitude	East Longitude * 1000, to WGS-84 datum	
	5	Elevation	elevation in meters above sea level, to WGS-84 datum	
	6	Orientation	eg: XYZF = HEX(58 59 5A 46); and HDZF = HEX(48 44 5A 46)	
	7	Source	eg: DMI = HEX(20 44 4D 49)	
	8	D conversion	H/3438*10000 where H=annual mean of H (set to 10000 for XYZF)	
	9	Data Quality	IMAG = HEX (49 4D 41 47)	
	10	Instrumentation	eg: LC(Linear Core) = HEX(20 20 4C 43) (or RC(Ring Core))	
	11	K9 value in nT	eg: 750	
	12	Sampling rate (ms)	eg: 125	
	13	Sensor orientation	eg: XYZF, DIF, UVZ, HDZ, HDZF etc.	
	14	Publication Date	eg: YYMM = 0806 (June 2008) HEX (30 38 30 36)	
	One minute data	15	IAF version number	HEX(01 00 00 00) IAFV1.10
16		Reserved for future use		
17		1440 mean minute values - element 1 (one day)	Missing value = 999999	
...		1440 mean minute values - element 2 (one day)	Missing value = 999999	
Mean hourly data	...	1440 mean minute values - element 3 (one day)	Missing value = 999999	
	5776	1440 mean minute values - element 4 (one day)	Missing value = 999999	
	5777	24 mean hourly values - element 1	Missing value = 999999	
	...	24 mean hourly values - element 2	Missing value = 999999	
	...	24 mean hourly values - element 3	Missing value = 999999	
	5872	24 mean hourly values - element 4	Missing value = 999999	
	Daily means	5873	daily mean value element 1	Missing value = 999999
		5874	daily mean value element 2	Missing value = 999999
5875		daily mean value element 3	Missing value = 999999	
5876		daily mean value element 4	Missing value = 999999	
K indices	5877	8 digitally derived K-values	Missing value = 999	
Reserved	5885 - 5888	Reserved for future use = 0		

C.1.4.1 IAFV1.10 (2008)

Words 1 to 16 comprise the header section containing a mixture of text and numeric fields, including a 3-letter observatory identification preceded with a space [hex20] (ID) code, the year concatenated with the day of the year, co-latitude, longitude, elevation, reported orientation, originating organization, a D-conversion factor, data quality, instrumentation, K-9, sampling rate, sensor orientation, publication date and format version/data type. Latitude, longitude/colatitude and elevation must be given using the WGS-84 datum. The orientation must be “XYZF” or “HDZF”. If the F element is not measured, it must be filled with 999999 in the data section. The D-conversion factor is a fixed value used only in the graphics portion of the access software to allow Declination to be plotted in minutes of arc and equivalent nanoteslas (nT). It is given as $H/3438 \times 10000$, where H is the annual mean value of the horizontal intensity. Example: If H is 16500 D will be 47993(Integer). When XYZF is used, the D-conversion factor should be set to 10000.

ASCII values, such as the observatory ID and orientation, are also stored as 32-bit words, but are coded as the hexadecimal byte-string corresponding to the ASCII string. For example, the string “HDZF” is coded as the sequence “48 44 5A 46”.

Word 11 is the K-9 value for the observatory in nT, word 12 is the digital sampling rate in msec, and word 13 is the sensor orientation. Sensor orientation could be XYZF, DIF, UVZ, HDZ, HDZF etc. and should indicate which components are actually measured. If a three component sensor orientation is used, a space must be added at the end. Word 14 is the publication date encoded as 4 ASCII bytes “YYMM” provided by INTERMAGNET. The high byte (left most) of word 15 is the INTERMAGNET Archive Format version number code provided by INTERMAGNET. It takes the form of a binary single byte number ranging from 0 to 255. Zero (0x00) represents version 1.00 and one (0x01) represents version 1.10. The other three bytes of word 15 are reserved for future use and padded with zeros. Word 16 is reserved for future use.

Words 17-5776 contain the minute values of the 4 components (successively X,Y,Z,F or H,D,Z,F) for the day. The 4th component “F” should be included only if it is measured from a scalar instrument independent of the other 3 components otherwise it must be filled with 999999. The values of the 4 components are stored in tenth-units with an implied decimal point. Thus, an H value of 21305.6 is stored (in tenth-nT) as 213056 with a decimal point implied between the last and next-to-last digits and a D value of 527.6 is stored (in tenth-minutes) as 5276 also with a decimal point implied between the last and next-to-last digits. Words 5777-5872 are used for the hourly mean values of the successive 4 components. Words 5873-5876 store the 4 daily mean values. Words 5877-5884 contain the K-Index*10. The last 4 words (5885-5888) are reserved for future use and padded with zeros. Missing data for minute, hour, and day values are stored as “999999”. Missing K-Index and Ak values are stored as “999”.

C.1.5 IAFV1.00 Binary Data Structure Format-32 Bit Words

Section	Word	Field Name	Comment
Header	1	Station ID	eg: BOU = HEX(20 42 4F 55)
	2	Year and day number	eg: 1989001; year 1989, day January 01
	3	Co-latitude	(90° - Latitude) * 1000, to WGS-84 datum
	4	Longitude	East Longitude * 1000, to WGS-84 datum
	5	Elevation	elevation in meters above sea level, to WGS-84 datum
	6	Orientation	eg: XYZF = HEX(58 59 5A 46); and HDZF = HEX(48 44 5A 46)
	7	Source	eg: DMI = HEX(20 44 4D 49)
	8	D conversion	$H/3438 \times 10000$ where H=annual mean of H
	9	Data Quality	IMAG = HEX (49 4D 41 47)
	10	Instrumentation	eg: LC(Linear Core) = HEX(20 20 4C 43) (or RC(Ring Core))
	11	K9 value in nT	eg: 750
	12	Sampling rate (ms)	eg: 125

continues on next page

Table 3.5 – continued from previous page

Section	Word	Field Name	Comment
One minute data	13	Sensor orientation	eg: XYZF, DIF, UVZ, HDZ, HDZF etc.
	14	Reserved for future use	
	15	IAF version number	HEX(00 00 00 00) IAFV1.00
	16	Reserved for each contributing institution	
	17	1440 mean minute values - element 1 (one day)	Missing value = 999999
Mean hourly data	...	1440 mean minute values - element 2 (one day)	Missing value = 999999
	...	1440 mean minute values - element 3 (one day)	Missing value = 999999
	5776	1440 mean minute values - element 4 (one day)	Missing value = 999999
	5777	24 mean hourly values - element 1	Missing value = 999999
	...	24 mean hourly values - element 2	Missing value = 999999
Daily means	...	24 mean hourly values - element 3	Missing value = 999999
	5872	24 mean hourly values - element 4	Missing value = 999999
	5873	daily mean value element 1	Missing value = 999999
	5874	daily mean value element 2	Missing value = 999999
	5875	daily mean value element 3	Missing value = 999999
K indices	5876	daily mean value element 4	Missing value = 999999
	5877	8 digitally derived K-values	Missing value = 999
Reserved	5885 - 5888	Reserved for future use = 0	see Section 6.4.3.2 for details on word 5885

C.1.5.1 IAFV1.00 (2007 and before)

Words 1 to 16 comprise the header section containing a mixture of text and numeric fields, including a 3-letter observatory identification preceded with a space [hex20] (ID) code, the year concatenated with the day of the year, co-latitude, longitude, elevation, reported orientation, originating organization, a D-conversion factor, data quality, instrumentation, K-9, sampling rate and sensor orientation. Latitude, longitude/colatitude and elevation must be given using the WGS-84 datum. From 1991 to 2005, the fourth component is the total field from either a scalar (independent) instrument or the total field calculated from the main observatory instrument. INTERMAGNET has a list of which observatories supplied which type of total field value between 1991 and 2005 and this list is available as a spreadsheet in the archive viewer software. The D-conversion factor is a fixed value used only in the graphics portion of the access software to allow Declination to be plotted in minutes of arc and equivalent nanoteslas (nT). It is given as H/3438*10000, where H is the annual mean value of the horizontal intensity. Example: If H is 16500 D will be 47993(Integer). This conversion factor only applies to HDZ observatory data supplied before 2005.

ASCII values, such as the observatory ID and orientation, are also stored as 32-bit words, but are coded as the hexadecimal byte-string corresponding to the ASCII string. For example, the string “HDZF” is coded as the sequence “48 44 5A 46”.

Word 11 is the K-9 value for the observatory in nT, word 12 is the digital sampling rate in msec, and word 13 is the sensor orientation. Sensor orientation could be XYZF, DIF, UVZ, HDZ, HDZF etc. and should indicate which components are actually measured. If a three component sensor orientation is used, a space must be added at the end. Word 14-15 are reserved for future use and padded with zeros. In version 1.10 and later, word 15 have been defined to represent the version number. Previously, it should have been coded to zero by IMOs, that is the reason this word was chosen for the

version number (zero represents version 1.00). Word 16 is set aside for each contributing institution to use as they wish, provided it is coded as a 32-bit binary value.

Words 17-5776 contain the minute values of the 4 components (successively X,Y,Z,F or H,D,Z,F) for the day. Until 2005, the 4th component could contain "F" from either a scalar or calculated from the vector instrument. From 2006 onward, the 4th component contains "F" only if it is measured from a scalar instrument independent of the other 3 components otherwise it must be filled with 999999. The values of the 4 components are stored in tenth-units with an implied decimal point. Thus, an H value of 21305.6 is stored (in tenth-nT) as 213056 with a decimal point implied between the last and next-to-last digits and a D value of 527.6 is stored (in tenth-minutes) as 5276 also* with a decimal point implied between the last and nextto- last digits. Words 5777-5872 are used for the hourly mean values of the successive 4 components. Words 5873-5876 store the 4 daily mean values. Prior to the 1994 CD-ROM, words 5877-5884 held the 8 (K-Index*10) values for the day. The true IAGA K-Index could be obtained from these K-Index*10 values by truncating the second (least significant) digit. From 1994 onward, words 5877-5884 contain the K-Index*10. Until 1998, word 5885 contained the equivalent daily amplitude index (Ak). From 1999 onward, word 5885 is reserved for future use and padded with zeros. The last 3 words (5886-5888) are reserved for future use and padded with zeros. Missing data for minute, hour, and day values are stored as "999999". Missing K-Index and Ak values are stored as "999".

C.2 INTERMAGNET Physical Media Directory Structure

The structure of files and folders on the INTERMAGNET Physical Media (IPM) has remained broadly the same since its inception in 1991, however there have been some differences. This appendix documents the structure for the USB (2014), then describes the structure of the DVD (2011) and the first CD-ROM (1991) and lists year by year differences in the files and folders on the INTERMAGNET Physical Media (IPM).

C.2.1 Structure of the USB (2014)

```

.
├── errata
│   └── errata.txt
├── mag2014
│   ├── 2014maps
│   │   ├── alg.png
│   │   ├── all.png
│   │   ├── aus.png
│   │   └── ...
│   ├── ctry_inf
│   │   ├── algsrn.png
│   │   ├── aussrn.png
│   │   ├── ...
│   │   ├── readme.alg
│   │   ├── readme.arg
│   │   └── ...
│   ├── aaa
│   │   ├── aaa14jan.bin
│   │   ├── aaa14feb.bin
│   │   ├── ...
│   │   ├── aaa14k.dka
│   │   ├── aaa2014.blv
│   │   ├── readme.aaa
│   │   └── yearmean.aaa
│   └── ...
├── obsy_inf
├── imcdview_install.txt
├── readme.txt
├── software
│   └── Disk1
│       └── InstData
│           ├── GenericUnix
│           │   └── IMCDView.bin
│           ├── Linux_32
│           │   ├── NoVM
│           │   │   └── IMCDView.bin
│           │   └── VM
│           │       └── IMCDView.bin
│           ├── Linux_64
│           │   ├── NoVM
│           │   │   └── IMCDView.bin
│           │   └── VM
│           │       └── IMCDView.bin
│           └── MacOSX

```

(continues on next page)

└─ README.EXE

C.2.4 INTERMAGNET Physical Media Directory Structure

The files on the INTERMAGNET Physical Media are set up in a particular directory structure. The root directory contains a “README.TXT” file, which is an ASCII file describing the INTERMAGNET Physical Media and where to obtain information about it, the software, and documentation; CD-ROMs from 1991-2004 also hold a “README.EXE” file, which is an executable version of the README.TXT file that allows the user to scroll back and forth through the information. DVDs and USBs do not contain README.EXE.

On the 1991 CD-ROM there are also two sub-directories. One is labelled “XTRAS”, and the other “MAG1991”. The XTRAS directory contains one file labeled “STRUCTUR.DAT”, and another “PRNSTRUC.EXE”. The STRUCTUR.DAT file provides a schematic of the data structure for the records on the CD-ROM and the PRNSTRUC.EXE file enables the user to obtain a printout of that record structure.

The MAG1991 directory contains a sub-directory for each observatory identified by its 3-letter ID code. In addition, there are sub-directories labeled “1991MAPS”, “CTRY_INF”, and “OBSY_INF”. The 1991MAPS directory contains the *.PCX files that are the map images of each country for use in the access software. These are labeled by a 3-letter country ID with the PCX extension, and one labeled “ALL.PCX” for the “All Countries” option. The CTRY_INF directory contains a “CTRYLIST.IDX” file that is used internally, *.PCX files for each country (and one for ALL) that are the images used to show the flag and organizational Logo for the different countries, and the README files that pertain to each country’s geomagnetism program (including a README for the ALL option). The OBSY_INF subdirectory contains a “91OBSYDAT.DBF” file that is used internally in the software. Since 2006 .pcx and .gif graphic files have been replaced with .png files. It concerns both maps in YYYYMAPS and About-screen images in CTRY_INF, where YYYY is the 4-character year value.

The individual sub-directories (e.g. BFE for Brorfelde, TUC for Tucson, etc.) contain the 12 months of data labeled with the 3-letter ID, 2-character year, 3-letter month abbreviation, and a “BIN” extension indicating they are binary files. For example, “BFE91AUG.BIN” is a file of 31 sequential day-records for Brorfelde, for 1991, for August. In addition, there are the “README.XXX” files for the individual observatory, where the XXX indicates the 3-letter observatory ID.

This sub-directory may also contain a file labeled as XXXYRK.DKA, where the XXX is the 3-letter observatory ID, the YR is the 2-character year value and the K indicates a K-Index file. Originally the DKA extension was used to indicate that the data were generated from a digital algorithm in an ASCII format, however subsequently these files have been used to hold both digitally derived and hand-scaled K indices. Since 2005 the DKA files have been created by INTERMAGNET, using data from the binary IAF file (before 2005 these files were provided by the observatories). The consequence is that DKA ASCII files provided by IMO are ignored during final compilation of INTERMAGNET Physical Media. These ASCII K-Index files are published on, even though the data are in the binary records, because they are much faster to access than paging through the binary records on the INTERMAGNET Physical Media.

C.2.5 List of Changes to the Structure since the first (1991) CD-ROM

Year	Change
1992	No change
1993	No change
1994	First CD-ROM with an ERRATA folder in the root of the disk IMAG21.EXE and INSTALL.EXE added to the root of the CD-ROM
1995	Annual means included in a YEARMEAN.obs file in each observatory folder

continues on next page

Table 3.6 – continued from previous page

Year	Change
1996	IMAG22.EXE replaces IMAG21.EXE PLOTUTIL folder added to the root of the CD-ROM containing plotting source code and executables (for DOS)
1997	No change
1998	Replication of some data (folders in root of CD-ROM): <ul style="list-style-type: none"> • CLF 1996 • PPT, THY 1991
1999	No change
2000	1st year of distribution on 2 CD-ROMs (the number of observatories meant that the data was too large to fit on a single CD-ROM) IMAG23.EXE replaces IMAG22.EXE INTRO00A.PCX and INTRO00B.PCX are include in CTRY_INF folder – these are splash screens for individual disks
2001	Replication of some data (folders in root of 1st CD-ROM only): <ul style="list-style-type: none"> • ABG 2000 Removed INTRO00A.PCX and INTRO00B.PCX from CTRY_INF
2002	IMAG24.EXE replaces IMAG23.EXE Replication of some data (folders in root of both CD-ROMs): <ul style="list-style-type: none"> • TAN 2001 INTRO1.PCX and INTRO2.PCX are included in CTRY_INF folder
2003	Replication of some data (folders in root of both CD-ROMs): <ul style="list-style-type: none"> • FRN, HON 1993 • HON 2001, 2002 • PPT 2002
2004	Replication of some data (folders in root of both CD-ROMs): <ul style="list-style-type: none"> • 2003 ABG, IQA, SJG A new UTILITY folder is put into the root of the CD-ROM. It holds software for working with the data, including the first distributed version (V1.1) of the imcdview viewing software in CDVIEWER/CDVIEWER.JAR V1.1 The OBSY_INF folder includes a file OBS_V101.CSV – a list of observatories used by imcdview
2005	Replication of some data (folders in root of both CDs): <ul style="list-style-type: none"> • 2003 NVS • 2004 WNG Filenames on the CD-ROMs are now lowercase (this documentation will continue to show filename in uppercase for clarity) GIF files are used for some graphics files (alongside PCX) The UTILITY folder is removed A SOFTWARE folder is added to the root of the CD-ROM. It contains the CD viewer software, imcdview.jar V1.2 and associated installer software An AUTORUN.INF file is added to the root of the CD-ROM to run the imcdview installer when the disk is inserted (only works on Windows operating systems) The following files are removed from the CTRY_INF folder: INTRO.PCX, INTRO1.PCX, INTRO2.PCX, CTRYLIST.IDX The OBSY_INFO folder is retained, but is empty The IMAG24.EXE viewing software and its associated files are removed from the root of the disk The XTRAS folder is removed

continues on next page

Table 3.6 – continued from previous page

Year	Change
2006	Publication moves from two CD-ROMs to a single DVD All graphics files are in PNG format The root of the DVD contains the following folders and files: <ul style="list-style-type: none"> • AUTORUN.INF • ERRATA • MAG2006 • README.TXT • SOFTWARE The software folder contains the imcdview visualisation software along with a simple installer
2007	A multi-OS “Install Anywhere” installer is included for the imcdview visualisation software. A Java Virtual Machine is no longer required to run the software, as this is include on the DVD
2008	No change
2009	A major republication of data from years 2005, 2006, 2007 and 2008 The AUTORUN.INF file is removed from the root of the DVD The IMCDVIEW_INSTALL.TXT file is added to the root of the DVD
2010	No change
2011	Publication physical maps instead of political country maps
2012	No change
2013	No change
2014	Publication moves from DVD to USB drive
2015	Final physical publication including all data from 1991 to 2015

Note: Unless otherwise noted, where a change is shown in the structure, the change affects all years subsequent to the year where the change is described. The exception to this is republished data.

Republished data is put into a folder at the root of the INTERMAGNET Physical Media. It is only put on for one year – the republished data is not repeated on subsequent INTERMAGNET Physical Medias. Because the data is not under the MAGyyyy folder, it will not be recognised by the imcdview viewing software (where a number of years where republished in a form that the software can access).

The OBSY_INF folder is present on all INTERMAGNET Physical Medias, though it may be empty. It is used by software (along with the CTRY_INF and yyyyMAPS folders) to indicate the presence of an INTERMAGNET Physical Media folder structure.

The .com and .exe files on earlier CD-ROMs are programs that were designed to run on Microsoft DOS operating system. They will not work on more recent versions of Microsoft Windows.

The IMAGxx.EXE files on earlier CD-ROMs contained software to view the data on the CD-ROM. This software only ran on Microsoft DOS operating system. This has been superseded by a multi-operating-system program for viewing the data (imcdview, the INTERMAGNET CD viewer).

The .PCX files, that preceded the current .GIF and .PNG files, are graphics files. PCX stands for PiCture eXchange, a format created by the ZSoft corporation. PCX is no longer in widespread use. Convertors from PCX to more modern formats are available online.

The CTRYLIST.IDX file (no longer used on the DVD/USB) is a text list of countries and their 3 letter codes.

The yyOBSDAT.DBF file (no longer used on the DVD/USB) is a database listing the contents of the CD-ROM. This was used by the DOS-based IMAGxx software (but is not used by the more recent imcdview software). The database is

in Dbase format.

C.3 INTERMAGNET Format for Yearmean File : IYF V1.02

Magnetic data with 1nT or 0.1min of arc resolution are organized on a year file basis. One file contains all annual mean values of the geomagnetic field components that are available from the observatory.

File name: “YEARMEAN” and the three-letter observatory ID code as an extension. eg: YEARMEAN.BOU for Boulder.

Each file may have from 1 to 3 tables containing annual mean values. The file must contain a table of annual means for ALLDAYS, but may also contain tables of annual means for QUIET-DAYS and DISTURBED-DAYS.

C.3.1 Description of the Header Block

The header contains information on observatory name, ID-code, Colatitude, Longitude and Elevation to WGS-84 datum. It further contains the headers for each data columns.

eg: The header for Wingst is:

```

                                ANNUAL MEAN VALUES

                                WINGST, WNG, GERMANY.

COLATITUDE:  36.26           LONGITUDE:   9.07 E           ELEVATION:   50 m

YEAR         D           I           H           X           Y           Z           F * ELE Note
Deg. min Deg. min           nT           nT           nT           nT           nT
    
```

Description of data space (75 characters per line including CrLf)

All data fields are right-justified. The field width must be maintained, either by zero-filling or space-filling. The ‘+’ sign for positive values is optional.

```

_YYYY.yyy_DDD_dd.d_III_ii.i_HHHHHH_XXXXXX_YYYYYY_ZZZZZZ_FFFFFFF_A_EEEE_NNNCrLf
....
....
    
```

YYYY.yyy	Epoch is given with 3 decimals
DDD_dd.d	Declination is given in degrees and decimal minutes of arc
III_ii.i	Inclination is given in degrees and decimal minutes of arc
HHHHHH	H-component is given in nT
XXXXXX	X-component is given in nT
YYYYYY	Y-component is given in nT
ZZZZZZ	Z-component is given in nT
FFFFFF	F-component is given in nT
A	Type of annual means. May be “A”ll, “Q”uiet, “D”isturbed, “I”ncomplete or “J”ump. The “J” is not an annual mean value, but indicates a jump in the observatory recordings, which should be described in a note.
EEEE	recorded elements. eg:”XYZF” or “HDZF”
NNN	Note number
CrLf	Indicates a Carriage return Line feed
–	Represents a space

- Missing angular values must be coded as three 9 digits, a space, two 9 digits, a dot and one 9 digit: 999 99.9

- Missing component values must be coded as six 9 digits: 999999
- Angular values are written as degrees and minutes. Values may be written in the range 0 to 360 or -180 to 180. Observatories may choose which range to use. Negative values must always have the minus sign before the degree field, never before the minute field (including values between 0 and -1 degrees, for example “-0 59” means a value of minus zero degrees fifty nine minutes). This applies to all types of records, including jump records.

C.3.2 Description of the Footer

At the end of the file is added a footer describing the data. The footer contains notes on jumps, incomplete data sets etc. A sample footer looks like this:

```
* A = All days
* Q = Quiet Days
* D = Disturbed Days
* I = Incomplete
* J = Jump: jump value = old site value - new site value

ELE = Recorded elements from which the annual means were derived.
If an independent total field measurement is not made at an
observatory, this field should not include an 'F' code. For
example, an observatory using a three component fluxgate with one
horizontal sensor aligned along the magnetic meridian and a proton
magnetometer would put 'HDZF' in this field. An observatory using
only the fluxgate would put 'HDZ'.
```

Notes:

1. The jump in the values from 1988 to 1989 is due to establishment of a new absolute pillar during 1988.
2. The jump in the values from 1993 to 1994 is due to a change in the difference delta-F between the PPM pillar and the absolute pillar. The change happened between spring 1989 and autumn 1993. Why and when is unknown.

C.3.3 Sample of a Yearmean File

ANNUAL MEAN VALUES										
NARSARSUAQ, NAQ, GREENLAND										
COLATITUDE: 28.84			LONGITUDE: 314.56 E				ELEVATION: 4 meters			
YEAR	D	I	H	X	Y	Z	F	*	ELE	Note
	Deg.	'	Deg.	'	nT	nT	nT	nT	nT	
1983.500	326	41.6	77	15.8	12152	10156	-6673	53764	55120	A DHZ
1984.500	326	55.7	77	14.3	12171	10199	-6642	53736	55097	A DHZ
1985.500	327	11.1	77	12.9	12187	10242	-6604	53706	55071	A DHZ
1986.500	327	26.8	77	11.7	12201	10284	-6565	53679	55048	A DHZ
1987.500	327	44.5	77	09.9	12223	10336	-6524	53647	55022	A DHZ
1988.500	328	00.5	77	09.0	12235	10377	-6482	53633	55011	A DHZ
1989.000	0	02.6	0	00.7	-4	2	10	30	28	J DHZ 1
1989.500	328	13.8	77	07.2	12254	10418	-6452	53592	54975	A DHZ
1990.500	328	29.9	77	05.9	12271	10463	-6412	53571	54959	A DHZ

(continues on next page)

(continued from previous page)

1991.500	328	45.6	77	04.9	12284	10503	-6371	53555	54946	A	DHZ	
1992.500	329	01.3	77	03.4	12302	10547	-6332	53525	54920	A	DHZ	
1993.500	329	17.9	77	01.6	12323	10596	-6292	53495	54896	A	DHZ	
1994.000	0	00.0	0	00.0	-1	-1	0	-2	-3	J	DHZ	2
1994.500	329	34.3	77	00.7	12335	10636	-6247	53476	54880	A	DHZ	
1995.500	329	53.6	76	58.3	12366	10698	-6203	53444	54856	A	DHZ	
1996.500	330	13.6	76	56.0	12395	10759	-6155	53409	54828	A	DHZ	
1997.500	330	33.9	76	54.0	12423	10819	-6105	53381	54807	A	DHZ	
1998.500	330	55.6	76	52.2	12446	10878	-6048	53361	54793	A	DHZ	
1999.500	331	17.3	76	50.2	12473	10939	-5992	53332	54771	A	DHZ	
2000.500	331	39.0	76	48.4	12497	10998	-5934	53311	54756	A	DHZ	
2001.500	332	01.3	76	46.1	12527	11063	-5877	53278	54731	A	DHZ	
2002.500	332	23.6	76	44.2	12553	11124	-5817	53254	54714	A	DHZ	
2003.500	332	45.2	76	43.3	12564	11170	-5752	53237	54699	A	DHZ	
2004.500	333	07.8	76	40.5	12600	11240	-5695	53202	54674	A	DHZ	
2005.500	333	29.3	76	38.7	12624	11296	-5635	53176	54654	A	DHZ	
2006.500	333	50.4	76	36.2	12656	11360	-5580	53140	54626	A	DHZ	
2007.500	334	10.9	76	34.0	12686	11420	-5525	53113	54607	A	DHZ	
1983.500	326	42.3	77	15.1	12164	10167	-6677	53765	55124	Q	DHZ	
1984.500	326	56.3	77	13.3	12186	10213	-6648	53734	55098	Q	DHZ	
1985.500	327	11.6	77	12.0	12202	10256	-6611	53704	55073	Q	DHZ	
1986.500	327	27.4	77	10.8	12215	10297	-6571	53676	55048	Q	DHZ	
1987.500	327	44.9	77	09.4	12232	10345	-6527	53648	55025	Q	DHZ	
1988.500	328	00.8	77	08.2	12246	10387	-6487	53631	55011	Q	DHZ	
1989.000	0	02.6	0	00.7	-4	2	10	30	28	J	DHZ	1
1989.500	328	14.4	77	06.6	12263	10427	-6455	53591	54976	Q	DHZ	
1990.500	328	30.0	77	05.3	12279	10470	-6416	53567	54956	Q	DHZ	
1991.500	328	46.1	77	04.0	12297	10515	-6376	53551	54945	Q	DHZ	
1992.500	329	01.6	77	02.7	12312	10556	-6336	53521	54919	Q	DHZ	
1993.500	329	18.2	77	00.9	12335	10607	-6297	53491	54895	Q	DHZ	
1994.000	0	00.0	0	00.0	-1	-1	0	-2	-3	J	DHZ	2
1994.500	329	35.4	76	59.2	12357	10657	-6255	53470	54879	Q	DHZ	
1995.500	329	54.2	76	57.5	12380	10711	-6208	53443	54858	Q	DHZ	
1996.500	330	13.6	76	55.5	12403	10766	-6159	53407	54828	Q	DHZ	
1997.500	330	34.2	76	53.4	12431	10827	-6108	53380	54808	Q	DHZ	
1998.500	330	55.5	76	51.6	12456	10886	-6053	53359	54793	Q	DHZ	
1999.500	331	17.9	76	49.6	12483	10949	-5995	53330	54771	Q	DHZ	
2000.500	331	39.3	76	47.8	12507	11007	-5938	53308	54755	Q	DHZ	
2001.500	332	01.5	76	45.6	12535	11070	-5880	53278	54733	Q	DHZ	
2002.500	332	23.7	76	43.6	12562	11132	-5821	53252	54714	Q	DHZ	
2003.500	332	45.9	76	42.0	12584	11189	-5759	53234	54701	Q	DHZ	
2004.500	333	08.1	76	39.7	12613	11252	-5700	53200	54675	Q	DHZ	
2005.500	333	29.6	76	37.8	12640	11311	-5641	53177	54659	Q	DHZ	
2006.500	333	50.5	76	35.5	12669	11371	-5585	53141	54630	Q	DHZ	
2007.500	334	11.0	76	33.5	12694	11427	-5528	53114	54610	Q	DHZ	
1983.500	326	40.4	77	17.7	12121	10128	-6659	53763	55112	D	DHZ	
1984.500	326	54.6	77	16.5	12136	10168	-6626	53744	55097	D	DHZ	
1985.500	327	10.1	77	14.7	12158	10216	-6592	53707	55066	D	DHZ	
1986.500	327	25.6	77	13.7	12169	10255	-6552	53683	55045	D	DHZ	
1987.500	327	43.9	77	11.0	12205	10320	-6516	53645	55016	D	DHZ	
1988.500	327	59.5	77	10.9	12204	10349	-6469	53636	55007	D	DHZ	
1989.000	0	02.6	0	00.7	-4	2	10	30	28	J	DHZ	1
1989.500	328	12.2	77	08.9	12228	10393	-6443	53598	54975	D	DHZ	

(continues on next page)

(continued from previous page)

1990.500	328	30.0	77	07.3	12249	10444	-6400	53577	54959	D	DHZ	
1991.500	328	45.1	77	06.5	12258	10480	-6359	53560	54945	D	DHZ	
1992.500	329	00.8	77	05.6	12268	10517	-6316	53539	54927	D	DHZ	
1993.500	329	16.8	77	03.5	12295	10570	-6281	53502	54897	D	DHZ	
1994.000	0	00.0	00	00.0	-1	-1	0	-2	-3	J	DHZ	2
1994.500	329	33.2	77	02.9	12300	10604	-6233	53481	54877	D	DHZ	
1995.500	329	52.6	76	59.7	12344	10677	-6195	53445	54852	D	DHZ	
1996.500	330	12.9	76	57.1	12378	10743	-6149	53411	54827	D	DHZ	
1997.500	330	33.7	76	54.8	12409	10807	-6099	53382	54805	D	DHZ	
1998.500	330	54.7	76	54.2	12416	10850	-6036	53371	54796	D	DHZ	
1999.500	331	17.0	76	51.9	12446	10915	-5980	53336	54769	D	DHZ	
2000.500	331	37.8	76	50.1	12472	10974	-5926	53317	54756	D	DHZ	
2001.500	332	00.3	76	47.0	12512	11048	-5873	53276	54726	D	DHZ	
2002.500	332	23.3	76	45.3	12536	11108	-5810	53256	54711	D	DHZ	
2003.500	332	44.1	76	45.7	12526	11134	-5738	53245	54698	D	DHZ	
2004.500	333	06.5	76	42.6	12567	11208	-5684	53206	54670	D	DHZ	
2005.500	333	29.1	76	40.1	12600	11275	-5625	53174	54647	D	DHZ	
2006.500	333	50.1	76	37.7	12631	11337	-5570	53140	54621	D	DHZ	
2007.500	334	10.9	76	34.9	12672	11407	-5519	53113	54604	D	DHZ	

* A = All Days
 * Q = Quiet Days
 * D = Disturbed Days
 * J = Jumps jump value = old site value - new site value

ELE = Recorded elements from which the annual mean values were derived

Notes: 1. The jump in the values from 1988 to 1989 is due to establishment of a new absolute pillar during 1988.
 2. The jump in the values from 1993 to 1994 is due to a change in the difference delta-F between the PPM pillar and the absolute pillar. The change happened between spring 1989 and autumn 1993. Why and when is unknown.

C.3.4 Sample of Missing Values

YEAR	D	I	H	X	Y	Z	F	* ELE Note	
	Deg.	'	Deg.	'	nT	nT	nT	nT	
1983.500	999	99.9	999	99.9	999999	999999	999999	999999	A DHZ
1984.500	999	99.9	77	14.3	12171	999999	-6642	53736	55097 A DHZ

CONTACTS

D.1 INTERMAGNET Executive Council

Name	Organization & Address	Email
David Boteler	Natural Resources Canada Canadian Hazards Information Service 2617 Anderson Rd. Ottawa Ontario K1A OE7 CANADA	David.Boteler@canada.ca
Ellen Clarke	British Geological Survey The Lyell Centre Research Avenue South Edinburgh EH14 4AP UK	ecla@bgs.ac.uk
Gauthier Hulot	Institut de Physique du Globe de Paris Observatoires magnétiques - Bureau 110s 1, rue Jussieu 75238 Paris Cedex 05 FRANCE	gh@ipgp.fr
Kristen Lewis	U.S. Geological Survey Box 25046 MS 966 Denver Federal Center Denver, Colorado 80225-0046 USA	klewis@usgs.gov
Andrew Lewis	Geoscience Australia Cnr Jerrabomberra Avenue and Hindmarsh Drive Symonston ACT GPO Box 378 Canberra ACT 2601 AUSTRALIA	andrew.lewis@ga.gov.au
Jürgen Matzka	GFZ Helmholtz Centre for Geosciences A.-Schmidt-Observatory for Geomagnetism Lindenstr. 7 14823 Niemegk GERMANY	juergen.matzka@gfz.de

D.2 INTERMAGNET Operations Committee

Name	Organization & Address	Email
Seiki Asari	Japan Meteorological Agency Kakioka Magnetic Observatory Technical Division Kakioka 595, Ishioka, 315-0116 JAPAN	asari@kakioka-jma.go.jp
Kusumita Arora	National Geophysical Research Institute Uppal Road Hyderabad 500 007 Andhra Pradesh INDIA	karora_ngri@yahoo.co.uk
Orsi Baillie	British Geological Survey The Lyell Centre Research Avenue South Edinburgh EH14 4AP UK	orba@bgs.ac.uk
Charles Blais	Natural Resources Canada Canadian Hazards Information Service 7 Observatory Cr. Ottawa, Ontario K1A OY3 CANADA	charles.blais@canada.ca
Stephan Bracke	Royal Meteorological Institute of Belgium Geophysical Centre Rue du Centre de Physique 4 B-5670 Dourbes BELGIUM	stbracke@meteo.be
András Csontos	HUN-REN Institute of Earth Physics and SPace Science Tihany Geophysical Observatory Kossuth utca 91 8237 Tihany HUNGARY	csontos.andras@epss.hun-ren.hu
David Calp	Natural Resources Canada Canadian Hazards Information Service 2617 Anderson Rd. Ottawa Ontario K1A OE7 CANADA	david.calp@nrca-nrcan.gc.ca
Matthew Gard	Geoscience Australia 101 Jerrabomberra Avenue Symonston ACT 2609 AUSTRALIA	Matthew.Gard@ga.gov.au
Simon M. Flower	British Geological Survey The Lyell Centre Research Avenue South Edinburgh EH14 4AP UK	s.flower@bgs.ac.uk

continues on next page

Table 4.2 – continued from previous page

Name	Organization & Address	Email
Brendan Geels	U.S. Geological Survey Box 25046 MS 966 Denver Federal Center Denver, Colorado 80225-0046 USA	bgeels@usgs.gov
Benoit Heumez	Observatoire Magnétique National Carrefour des 8 routes 45340 Chambon la Forêt France	heumez@ipgp.fr
Shun Imajo	Data Analysis Center for Geomagnetism and Space Magnetism Graduate School of Science, Bldg #4 Kyoto University Oiwake-cho, Kitashirakawa, Sakyo-ku Kyoto 606-8502 JAPAN	imajo@kugi.kyoto-u.ac.jp
Roman Leonhardt	Conrad Observatorium ZAMG - Zentralanstalt für Meteorologie und Geodynamik 1190 Wien, Hohe Warte 38 AUSTRIA	roman.leonhardt@zamg.ac.at
Andrew Lewis	Geoscience Australia 101 Jerrabomberra Avenue Symonston ACT 2609 AUSTRALIA	andrew.lewis@ga.gov.au
Manjula Lingala	Geomagnetism group CSIR-NGRI Uppal Road Hyderabad 500 039 Telangana INDIA	manjulalingala@gmail.com
Igor Mandic	Department of Geophysics Faculty of Science University of Zagreb Horvatovac 95 10000 Zagreb CROATIA	mandici@gfz.hr
Jürgen Matzka	GFZ Helmholtz Centre for Geosciences A.-Schmidt-Observatory for Geomagnetism Lindenstr. 7 14823 Niemegk GERMANY	juergen.matzka@gfz.de
Virginie Maury	Institut de Physique du Globe de Paris Observatoires magnétiques - bur 110 1, rue Jussieu 75238 Paris Cedex 05 FRANCE	vmaury@ipgp.fr

continues on next page

Table 4.2 – continued from previous page

Name	Organization & Address	Email
Emmanuel Nahayo	SANSA Space Science Hospital Street Hermanus 7200 Western Cape SOUTH AFRICA	enahayo@sansa.org.za
Tero Raita	Sodankyla Geophysical Observatory University of Oulu Tahtelantie 62 FI-99600 Sodankyla FINLAND	tero.raita@sgo.fi
Jan Reda	Institute of Geophysics PAS Central Geophysical Observatory 05-622 Belsk POLAND	jreda@igf.edu.pl
Marcos Vinicius da Silva	GFZ Helmholtz Centre for Geosciences A.-Schmidt-Observatory for Geomagnetism Lindenstr. 7 14823 Niemegk GERMANY	mvsilva@gfz.de
Christopher W. Turbitt	British Geological Survey The Lyell Centre Research Avenue South Edinburgh EH14 4AP UK	c.turbitt@bgs.ac.uk

DATA FORMATS

E.1 INTERMAGNET Satellite Transmission Format : IMFV2.83

The INTERMAGNET satellite data transmission format IMFV2.83 defines the structure of 126 bytes of magnetic observatory information. METEOSAT users, who must transmit once per hour, will send five 12-minute IMFV2.83 data blocks. GOES users transmit at 12-minute intervals one IMFV2.83 data block encoded in NESS-BINARY (189 bytes). The order of transmission to the satellite will be in byte sequence low-byte first, then high-byte. Refer to [APPENDIX E2](#) for satellite coding examples. REFERENCE MEASUREMENT (RM) or FREE SPACE

HEADER 12 BYTES	Day of first sample (1-365/366)	12 Bits	1 - 3 ¹
	Minute of the day of first sample (0 - 1439)	12 Bits	1 - 3 ¹
	Offset for C1	8 Bits	4
	Offset for C2	8 Bits	5
	Offset for C3	8 Bits	6
	Offset for C4	8 Bits	7
	Flag #1	8 Bits	8
	Flag #2	8 Bits	9
	Colatitude in 1/10 degrees (0 - 1800)	12 Bits	10 - 12 ¹
	Flag #2	12 Bits	10 - 12 ¹
08 BYTES	FREE SPACE	64 Bits	13 - 20
10 BYTES	REFERENCE MEASUREMENT (RM) or FREE SPACE	80 Bits	21 - 30
MIN VALUES 96 BYTES	C1 for Sample 1	16 Bits	31 - 32
	C2 for Sample 1	16 Bits	33 - 34
	C3 for Sample 1	16 Bits	34 - 35

	C1 for Sample 12	16 Bits	119 - 120
	C2 for Sample 12	16 Bits	121 - 122
	C3 for Sample 12	16 Bits	123 - 124
	C4 for Sample 12	16 Bits	125 - 126

¹ See section *IMFV2.83 Header Encoding*.

Table 5.1: Flag#1

MSB	Description																									
8	<table border="1"> <thead> <tr> <th>Orientation Code</th> <th>Component 1</th> <th>Component 2</th> <th>Component 3</th> <th>Component 4</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>X</td> <td>Y</td> <td>Z</td> <td>F</td> </tr> <tr> <td>1</td> <td>H</td> <td>D</td> <td>Z</td> <td>F</td> </tr> <tr> <td>2</td> <td></td> <td>D</td> <td>I</td> <td>F</td> </tr> <tr> <td>3</td> <td colspan="4">Other</td> </tr> </tbody> </table>	Orientation Code	Component 1	Component 2	Component 3	Component 4	0	X	Y	Z	F	1	H	D	Z	F	2		D	I	F	3	Other			
Orientation Code		Component 1	Component 2	Component 3	Component 4																					
0		X	Y	Z	F																					
1		H	D	Z	F																					
2		D	I	F																						
3	Other																									
7																										
6	Scale factor for X or H																									
5	Scale factor for Y or D																									
4	Scale factor for Z or I																									
3	Scale factor for F																									
2	Filtering - 0: INTERMAGNET approved filtering, 1: non-approved filtering. See INTERMAGNET terminology "filtering".																									
1	Alert capability - The IMO has the ability to detect magnetic events if the flag is set to 1. 0: not active 1: active																									

Table 5.2: Flag#2

MSB	Description
8	Sudden storm commencement detected
7	Storm in progress A storm is in progress if the level of magnetic activity is equivalent to $K > 4$ for past one-hour period. The flag will be reset to zero when the equivalent level of activity drops to $K \leq 4$.
6	0: No Reference Measurement (RM) capability bytes 13-30 are user free space 1: Base Reference Measurement data available in bytes 21-30. Bytes' 13-20 are user free space.
5	Free (user defined)
4	Free (user defined)
3	Free (user defined)
2	Free (user defined)
1	Free (user defined)

E.1.1 IMFV2.83 Header Encoding

In IMFV2.83 format, the time stamp and site identification code are encoded in 3-byte strings formed from two 12-bit fields combined as described below:

Time Stamp Input	Encoded Output
Least sig. 8 bits of day	Byte 1
Most sig. 4 bits of day	Byte 2, four least sig. bits
Least sig. 4 bits of minute	Byte 2, four most sig. bits
Most sig. 8 bits of minute	Byte 3

Site Identification Code Input	Encoded Output
Least sig. 8 bits of colatitude	Byte 10
Most sig. 4 bits of colatitude	Byte 11, four least sig. bits
Least sig. 4 bits of east longitude	Byte 11, four most sig. bits
Most sig. 8 bits of east longitude	Byte 12

Example:

The time stamp for day 30, minute 684 would be encoded as:

Table 5.3: Input fields

Bit (MSB to LSB)	11	10	9	8	7	6	5	4	3	2	1	0	Hex
Day 30 (first item)	0	0	0	0	0	0	0	1	1	1	1	0	01E
Minute 684 (second item)	0	0	1	0	1	0	1	0	1	1	0	0	2AC

Table 5.4: Output Encoded field

	Byte 0		Byte 1		Byte 2	
Byte	0001	1110	1100	0000	0010	1001
Hex	1	E	C	0	2	A
Value	8 LSB Day		4 LSB Minute	4 MSB Day	8 MSB Minute	

E.1.2 IMFV2.83 Data Value Encoding

Constraints on the bandwidth of a GOES satellite communications channel dictate a maximum transmission block of 126 bytes of data once every 12 minutes from an INTERMAGNET Magnetic Observatory (IMO). To conserve bytes, each measurement of a magnetic component is represented using only 2 bytes which, upon reception, are interpreted together with header information to produce a resultant 3-byte representation at the Geomagnetic Information Node (GIN). All magnetic field values in this encoding description are expressed in tenths of nanoTeslas (tnT) unless otherwise noted. The resolution of the measurements is 1 tnT and so a 16-bit representation allows a $2^{16} = 65536$ tnT (6553.6 nT) dynamic range within a 12-minute IMFV2.83 block. This is inadequate to accommodate magnetic storms at some locations, and so the encoding scheme produces measurements at reduced sensitivity when extremely large excursions are present. The INTERMAGNET data encoding produces an Offset (OFF) value and a Scale Factor (SF) flag bit for each component, as well as the encoded individual minute values (see diagram at end of appendix). The OFF and SF apply to all measurements of a component within an IMFV2.83 data block.

We define the terms used in encoding as follows:

Table 5.5: Input fields

Data(i)	Set of minute values measured in tnT
D _{pos} (i)	Minute values shifted by 1048576 to be always positive
D _{max}	Largest D _{pos} (i) of a given component in IMFV2.83 block
D _{min}	Smallest D _{pos} (i) of a given component in IMFV2.83 block
OFF	Offset value
BF	Bias Factor = 8192
SM	Scale Multiplier for sensitivity of encoded data
SF	Scale Factor flag for sensitivity of encoded data
E(i)	Set of encoded minute values

Numbers used in this encoding algorithm have been chosen to permit simple binary arithmetic operations:

- 8192 = 213
- 57344 = 216 · 213
- 1048576 = 220
- 2097151 = 221 · 95

Encoding of a 12-minute IMFV2.83 data block begins by adding a constant 1048576 tnT to the minute values Data(i) to produce a new data set $D_{pos}(i)$ whose values are always positive.

$$D_{pos}(i) = Data(i) + 1048576$$

The limiting values of these $D_{pos}(i)$ are 0 and 2097151tnT. An Offset value (OFF) is next computed from the $D_{pos}(i)$ for each component by using the minimum value of the component, D_{min} .

$$OFF = INT(D_{min}/BF)$$

where INT means the truncated integer after the division. The OFF value for each component may be anywhere in the range of 0 to 255 and the OFF values for the four components are stored in bytes 4,5,6,7 of the header for use in decoding the data after reception at a GIN. A Scale Multiplier (SM) for each component is now computed:

$$SM = INT((D_{max} - OFF * BF)/57344) + 1$$

The encoding algorithm produces an SM whose value is governed by the range of $D_{pos}(i)$ within a data block. In this application to format IMFV2.83, however, SM can in practice be limited to values of either 1 or 2. Format IMFV2.83 reserves only one flag bit per component for storing scale information. These flags are bits 6,5,4,3 of byte 8 in the header, labelled Scale Factor (SF). Flag bit SF=0 represents SM=1, where the encoded data are considered at normal sensitivity (1 tnT/bit). At SM=1, the dynamic range available in the data block is at least 49152 tnT (= 57344-BF) and at most 57344 tnT, depending upon where the D_{min} value sits relative to the quantity OFF*BF. Flag bit SF=1 represents SM=2, where the encoded data are considered as half sensitivity (2 tnT/bit). At SM=2, the dynamic range in the data block is at least 106496 tnT (= 2*57344-BF) and at most 114688 tnT (= 2*57344) depending again upon where D_{min} is relative to the quantity OFF*BF. Encoded data values are now computed as:

$$E(i) = INT((D_{pos}(i) - OFF * BF)/SM)$$

and are stored in bytes 31 to 126. Upon reception at the GIN, encoded data are reconstituted using the expression:

$$Data(i) = E(i) * SM + OFF * BF - 1048576$$

This reconstitution is exact for SM=1 but rounded down by no more than 2 tnT on those infrequent occasions when SM=2. In summary, the expressions defining each of the encoding and reconstitution steps are:

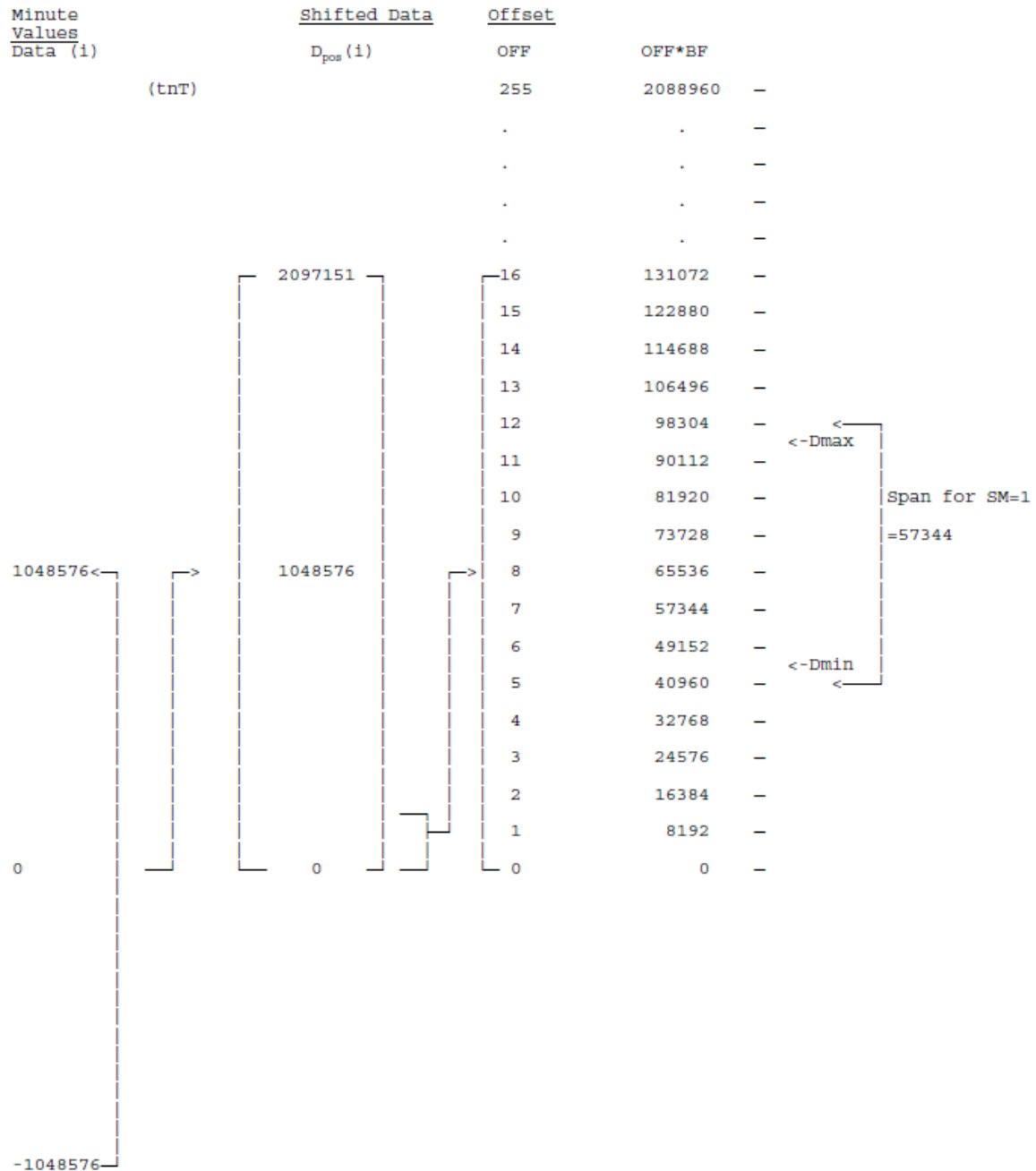
1. $D_{pos}(i) = Data(i) + 1048576$
2. $OFF = INT(D_{min}/BF)$

3. $SM = INT((D_{max} - OFF * BF) / 57344) + 1$
4. $E(i) = INT((D_{pos}(i) - OFF * BF) / SM)$
5. $Data(i) = E(i) * SM + OFF * BF - 1048576$

Scale Factor flags are set

SF	SM
0	1
1	2

Note: E(i) set to 65535 (FFFF hex) indicates missing or invalid data.



E.2 Satellite Coding Examples

E.2.1 Coding Example for Goes Satellite

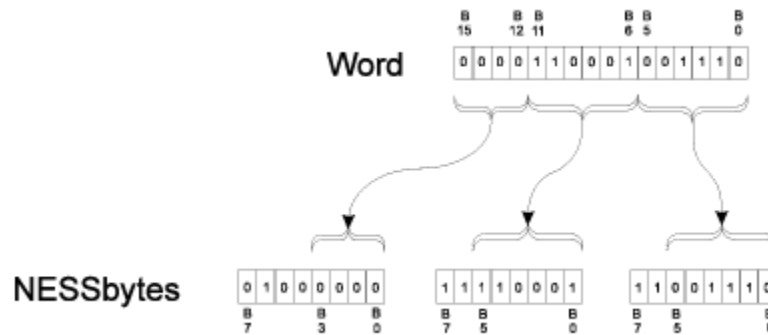
Each block of 126 bytes in IMFV2.83 must be encoded in 189 NESS-BINARY bytes (NESSbytes). NESSBINARY breaks each pair of source bytes (word) into 3 NESSbytes. If the bits of the source word are B15-B0 with B15 the most significant, then these are placed right-justified in NESSbytes as follows: B15-B12 are in the first NESSbyte, B11-B6 are in the second NESSbyte and B5-B0 are in the third NESSbyte. Within NESSbytes, bit 6 is always set to 1 and bit 7 is set for odd parity. In the first NESSbyte, bits 5 and 4 are filled by sign extension, i.e. they take the same value as bit 3. As an example, consider the 16-bit source word h0C4E, d3150.

Step 1 - break into 3 formative NESSbytes.

- byte 1: XXXX0000
- byte 2: XX110001
- byte 3: XX001110

Step 2 - sign extend in byte 1, bit 6=1, bit 7=odd parity.

- NESSbyte 1:01000000
- NESSbyte 2:11110001
- NESSbyte 3:11001110



After encoding, the 12-minute block is sent to the data collection platform (DCP) to be transmitted.

(continued from previous page)

```
No alert capability
No RMs
Flag #1: 00000000
Flag #2: 00000000
```

Minute values of C1, C2, C3, C4**Block #1: minute 0-11**

```
209062 -56 423216 472036
209062 -52 423218 472038
209058 -46 423220 472038
209053 -49 423219 472035
209052 -51 423214 472030
209054 -55 423214 472031
209061 -56 423215 472035
209066 -55 423217 472039
209062 -52 423214 472034
209055 -54 423212 472030
209055 -52 423213 472030
209056 -50 423213 472031
```

Block #2: minute 12-23

```
209059 -45 423215 472034
209057 -45 423214 472032
209059 -40 423216 472035
209057 -42 423214 472032
209054 -40 423213 472030
209053 -42 423214 472030
209048 -45 423214 472028
209046 -47 423217 472030
209045 -45 423217 472030
209044 -46 423217 472029
209043 -44 423214 472026
209045 -43 423215 472028
```

Block #3 : minute 24-35

```
209050 -44 423215 472030
209056 -45 423217 472035
209064 -45 423218 472039
209072 -43 423217 472042
209073 -41 423216 472041
209069 -39 423216 472039
209063 -37 423215 472036
209059 -36 423216 472035
209054 -37 423216 472033
209051 -42 423215 472030
209046 -47 423215 472028
209045 -50 423216 472029
```

Block #4: minute 36-47

```
209041 -56 423214 472025
209044 -58 423215 472027
209044 -60 423215 472027
```

(continues on next page)

E.2.3 Coding Example for GMS Satellite

The GMS satellite system requires that DCP data transmission use a long preamble, recommends that the length of time for data block be at least 63 seconds, and that transmitted data conform to a specified character set. A base-44 coding algorithm was developed for converting binary data to the GMS character set. The coded data format follows:

HEADER 21 BYTES				
Field	Length (bit)	Length (word)	Position	Frame
Time Day of the year	12 Bits	3/4 word	0 word - 0.75	
Minute of the day	12 Bits	3/4 word	0.75 word - 1.5	
Offset for C1	8 Bits	1/2 word	1.5 word - 2.0	
Offset for C2	8 Bits	1/2 word	2.0 word - 2.5	
Offset for C3	8 Bits	1/2 word	2.5 word - 3.0	
Offset for C4	8 Bits	1/2 word	3.0 word - 3.5	
Flag #1 & #2	16 Bits	1 word	3.5 word - 4.5	
Station colatitude	12 Bits	3/4 word	4.5 word - 5.25	
Station longitude	12 Bits	3/4 word	5.25 word - 6.0	-18 byte (CR-CR-LF)-21 byte
FREE SPACE 27 BYTES CODED				
Field	Length (bit)	Length (word)	Position	Frame
D1 Indices and Baseline control	8 Bits	1/2 word	6.0 word - 6.5	
...				
D18 Indices and Baseline control	8 Bits	1/2 word	15.5 word - 15.0	-48 byte
				(CR-CR-LF)-51 byte
MINUTE VALUES 157 BYTES CODED				
Field	Length (bit)	Length (word)	Position	Frame
C1 for t+0 minute	16 Bits	1 word	15.0 word - 16.0	-54 byte
C2 for t+0 minute	16 Bits	1 word	16.0 word - 17.0	-57 byte
C3 for t+0 minute	16 Bits	1 word	17.0 word - 18.0	-60 byte
C4 for t+0 minute	16 Bits	1 word	18.0 word - 19.0	-63 byte
...				
C4 for t+4 minute	16 Bits	1 word	34.0 word - 35.0	-111 byte (CR-CR-LF)-114 byte
C1 for t+5 minute	16 Bits	1 word	35.0 word - 36.0	-117 byte
...				
C4 for t+9 minute	16 Bits	1 word	54.0 word - 55.0	-174 byte (CR-CR-LF)-177 byte
C1 for t+10 minute	16 Bits	1 word	55.0 word - 56.0	-180 byte
...				
C1 for t+11 minute	16 Bits	1 word	59.0 word - 60.0	-192 byte
C2 for t+11 minute	16 Bits	1 word	60.0 word - 61.0	-195 byte
C3 for t+11 minute	16 Bits	1 word	61.0 word - 62.0	-198 byte
C4 for t+11 minute	16 Bits	1 word	62.0 word - 63.0	-201 byte
CRC	16 Bits	1 word	63.0 word - 64.0	-204 byte (CR-CR-LF)-208 byte

E.2.4 Time Framing for GMS

A multiple data transmission (12-minute data block repeated 3 times) may be used to satisfy the GMS minimum block transmission time of approximately 63 seconds. The time framing for GMS would be:

no-signal carrier	5.0 second	: 5.0 sec
bit synchronization	2.5	: 7.5
word synchronization	0.15	: 7.65
address	0.31	: 7.96
first (64*3+16-1)*8/100	16.56	:24.52 (177 bytes)
second (64*3+16-1)*8/100	16.56	:41.08 (177 bytes)
last (64*3+16)*8/100	16.64	:57.72 (178 bytes)
EOT-EOT-EOT	0.24	:57.96

The following table shows time slots assigned to DCPs. Each table line represents 60 seconds, the station ID is placed at the beginning of a data transmission block, '....' is for the no-signal (carrier only) period, '- -' is for synchronization sequence, and '==' is for the data block.

Assigned time slots for the GMS coding would allow 58 seconds per transmission and 7 seconds guard time. This would allow 11 observatories to transmit every 12 minutes.

```

min sec0....*....1....*....2....*....3....*....4....*....5....*....
12*(n)  ....--M01=====
+01     .....--M02=====
+02     ===.....--M03=====
+03     =====.....--M04=====
+04     =====.....--M05=====
+05     =====.....--M06=====
+06     =====.....--M07=====
+07     =====.....--M08=====
+08     =====.....--M09=====
+09     =====.....--M10=====
+10     =====.....--M11=====
+11     =====.....
12(n+1) .....--M01=====
    
```

E.2.4.1 Base-44 Coding for GMS

The characters used on the GMS system are: LF CR SP ' () + , - . / 0 1 2 3 4 5 6 7 8 9 : = ? A B C D E F G H I J K L M N O P Q R S T U V W X Y Z (TOTAL 50). The base-44 character set is shown in the table below.

Each IMFV2.83 data block is encoded by dividing the data block into 16-bit integers. Signed integers are represented by 2's complement. Each integer value is converted to 3 base-44 numbers, <n1,-n2,n3>, the most significant being n1 and the least significant n3. Each base-44 number may be represented by a base-44 character from Table 1. Example conversions are shown below:

decimal number	base-44 number	base-44 char
0	< 0, 0, 0 >	000
1	< 0, 0, 1 >	001
43	< 0, 0, 43 >	00?
44	< 0, 1, 0 >	010
32767	<16, 40, 31 >	G-V

(continues on next page)

(continued from previous page)

-1	<43, 43, 43>	???
-44	<43, 43, 0>	??0
-1935	<43, 0, 1>	?01
-32768	<27, 3, 12>	R3C

DIGIT	BASE-44	DIGIT	BASE-44
0	0	22	M
1	1	23	N
2	2	24	O
3	3	25	P
4	4	26	Q
5	5	27	R
6	6	28	S
7	7	29	T
8	8	30	U
9	9	31	V
10	A	32	W
11	B	33	X
12	C	34	Y
13	D	35	Z
14	E	36	(
15	F	37)
16	G	38	+
17	H	39	, (comma)
18	I	40	- (hyphen)

E.3 INTERMAGNET Gin Dissemination Format for Minute Values : IMFV

E.3.1 IMFV1.23

Magnetic data, with tenth-nanotesla resolution, are organized on a day file basis. One file contains 24 one-hour blocks, each containing 60 minutes worth of values. Blocks of 60 minutes of data are transmitted. Blocks are padded with 9's if incomplete. Information is coded in ASCII.

File name: To remain compatible with all operating systems, the file name is limited to 8 characters and will contain the date and the three-letter code as an extension. eg: MAR1591.BOU for Boulder, March 15, 1991; and JUN2391.OTT for June 23, 1991 at Ottawa.

E.3.1.1 Description of the Header Block (64 characters including CrLf)

IDC_DDDDDDD_DOY_HH_COMP_T_GIN_COLALONG_DECBAS_RRRRRRRRRRRRRRRRCrLf

Field	Description
IDC	Indicates the IAGA three letter observatory identification (ID) code eg: BOU for Boulder, OTT for Ottawa, LER for Lerwick, etc.
DDDDDDD	Indicates the date, eg: FEB1591 for February 15, 1991.
DOY	Indicates day of the year (1-366)
HH	Indicates the Hour (0-23). The first line following the header will contain the values corresponding to minute 0 and 1 of this hour. The first value of the day file is hour 0 minute 0.
COMP	Order in which the components are listed, can be HDZF, HDZG, XYZF, XYZG. G represents the difference between a measured 'Scalar' F and a computed 'vector' F: $G = F(\text{vector}) - F(\text{scalar})$. All components excluding D must be in tenths of nT. D must be in hundredths of minutes, east. The F or G component should be included only if it is measured from a scalar instrument independent of the other 3 components otherwise it must be filled with 999999.
T	One-letter code for data type. R=Reported, A=Adjusted, Q=Quasi-definitive, D=Definitive data. Reported data are defined as: the raw data obtained from the IMO, either by satellite, computer link, or other means. It will be formatted in either version IMFV2.8N (binary) or IMFV1.2N (ASCII,) without any RM (Reference Measurements), or other modifications applied to it. Adjusted data are defined as: the Reported data with RM, spike removal, timeshifts, and/or other modifications applied to it. It is emphasized that only one (1) adjusted version of the data would be allowed, to be completed within 7 days of receipt of the Reported data to prevent the proliferation of multiple versions of the Adjusted data. Quasi-definitive data are defined as data that have been corrected using provisional baselines. Produced soon after their acquisition, their accuracy is intended to be very close to that of an observatory's definitive data product. 98% of the differences between quasi-definitive and definitive data (X, Y, Z) monthly mean values should be less than 5nT. Definitive data are defined as the final adopted data values. Definitive data will only be distributed by the institution responsible for the observatory.
GIN	Three-letter code for GIN responsible for processing the station (IMO) data eg: EDI(Edinburgh), GOL(Golden), OTT(Ottawa), PAR(Paris).
COLALONG	Colatitude and east longitude of the observatory in tenths of degrees, to WGS-84 datum.

continues on next page

Table 5.7 – continued from previous page

DECBAS	Baseline declination value in tenths of minutes East (0-216,000). Declination baseline values to be provided annually. If components are X,Y,Z then DECBAS=000000. The DECBAS value is used to allow declination data to exceed 166.66 degrees (which is the limit of the declination elements in each data record without any offset). If the declination is > 166 degrees at an observatory then a DECBAS value should be selected such that the minute samples lie between 0 and 166 degrees. The declination baseline DECBAS should be subtracted from the minute data samples before coding them.
RRR..RRR	Reserved 16 bytes of R-characters for future use.
_	Indicates a space character.
CrLf	Indicates a Carriage return, Line feed.

Missing values for a vector component must be coded as a space (for the sign bit) followed by six 9 digits: _999999.

Missing values for the scalar component must be coded as six 9 digits: 999999

E.3.1.2 Description of Data Space (64 characters per line including CrLf)

Component values are coded as signed integers, right-justified with a field width of 7. Total field (F) values are coded as unsigned integers, right-justified with a field width of 6. The field widths must be maintained, either through zero-filling or space-filling. The '+' sign for positive values is optional.

Two (2) minutes of data are concatenated on the same line

```

AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFFF__AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFFFCrLf
(values for minute 0) (values for minute 1)
. .
. .
. .
AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFFF__AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFFFCrLf
(values for minute 58) (values for minute 59)
    
```

Field	Description
AAAAAAAA	Indicates Component 1 data field (H,X, etc.).
BBBBBBB	Indicates Component 2 data field (D,Y, etc.).
CCCCCC	Indicates Component 3 data field (Z,I, etc.).
FFFFFF	Indicates Total Field data field.
_	Indicates space character.
CrLf	Indicates Carriage Return and Line Feed.

Sample of missing values

```
_999999__999999__999999_999999__999999__999999__999999_999999CrLf
```

This example represents all components as missing for the first two minutes of the hour.

“_” indicates a space character.

E.3.2 IMFV1.22

Magnetic data, with tenth-nanotesla resolution, are organized on a day file basis. One file contains 24 one-hour blocks, each containing 60 minutes worth of values. Blocks of 60 minutes of data are transmitted. Blocks are padded with 9's if incomplete. Information is coded in ASCII.

File name: To remain compatible with all operating systems, the file name is limited to 8 characters and will contain the date and the three-letter code as an extension. eg: MAR1591.BOU for Boulder, March 15, 1991; and JUN2391.OTT for June 23, 1991 at Ottawa.

E.3.2.1 Description of the Header Block (64 characters including CrLf)

```
IDC_DDDDDDD_DOY_HH_COMP_T_GIN_COLALONG_DECBAS_RRRRRRRRRRRRRRRR_CrLf
```

Field	Description
IDC	Indicates the IAGA three letter observatory identification (ID) code eg: BOU for Boulder, OTT for Ottawa, LER for Lerwick, etc.
DDDDDDD	Indicates the date, eg: FEB1591 for February 15, 1991.
DOY	Indicates day of the year (1-366)
HH	Indicates the Hour (0-23). The first line following the header will contain the values corresponding to minute 0 and 1 of this hour. The first value of the day file is hour 0 minute 0.
COMP	Order in which the components are listed, can be HDZF, XYZF. All components excluding D must be in tenths of nT. D must be in hundredths of minutes, east. The F component should be included only if it is measured from a scalar instrument independent of the other 3 components otherwise it must be filled with 999999.
T	One-letter code for data type. R=Reported, A=Adjusted, D=Definitive data. Reported data are defined as: the raw data obtained from the IMO, either by satellite, computer link, or other means. It will be formatted in either version IMFV2.8N (binary) or IMFV1.2N (ASCII,) without any RM (Reference Measurements), or other modifications applied to it. Adjusted data are defined as: the Reported data with RM, spike removal, timeshifts, and/or other modifications applied to it. It is emphasized that only one (1) adjusted version of the data would be allowed, to be completed within 7 days of receipt of the Reported data to prevent the proliferation of multiple versions of the Adjusted data. Definitive data are defined as the final adopted data values. Definitive data will only be distributed by the institution responsible for the observatory.
GIN	Three-letter code for GIN responsible for processing the station (IMO) data eg: EDI(Edinburgh), GOL(Golden), OTT(Ottawa), PAR(Paris).
COLALONG	Colatitude and east longitude of the observatory in tenths of degrees, to WGS-84 datum.
DECBAS	Baseline declination value in tenths of minutes East (0-216,000). Declination baseline values to be provided annually. If components are X,Y,Z then DECBAS=000000.
RRR..RRR	Reserved 16 bytes of R-characters for future use.
_	Indicates a space character.
CrLf	Indicates a Carriage return, Line feed.

Missing values for a vector component must be coded as a space (for the sign bit) followed by six 9 digits: _999999.

Missing values for the scalar component must be coded as six 9 digits: 999999

E.3.2.2 Description of Data Space (64 characters per line including CrLf)

Component values are coded as signed integers, right-justified with a field width of 7. Total field (F) values are coded as unsigned integers, right-justified with a field width of 6. The field widths must be maintained, either through zero-filling or space-filling. The '+' sign for positive values is optional.

Two (2) minutes of data are concatenated on the same line

```

AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFF__AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFCrLf
(values for minute 0) (values for minute 1)
. .
. .
. .
AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFF__AAAAAAAA_BBBBBBBB_CCCCCC_FFFFFFCrLf
(values for minute 58) (values for minute 59)
    
```

Field	Description
AAAAAAAA	Indicates Component 1 data field (H,X, etc.).
BBBBBBB	Indicates Component 2 data field (D,Y, etc.).
CCCCCC	Indicates Component 3 data field (Z,I, etc.).
FFFFFF	Indicates Total Field data field.
_	Indicates space character.
CrLf	Indicates Carriage Return and Line Feed.

Sample of missing values

```

_999999__999999__999999_999999____999999__999999__999999_999999CrLf
    
```

This example represents all components as missing for the first two minutes of the hour.

“_” indicates a space character.

E.4 INTERMAGNET Baseline Format : IBF

E.4.1 IBFV2.00 (2009 and after)

This file format is to be used to provide baselines for use in examining equipment and environmental quality (mainly thermal stability of the variometers). This format makes room for all published components, including a baseline to scalar data. After a one-line header, the first section contains the observed baseline values on the days when they are measured. Consequently the number of entries will depend upon the schedule for absolute measurements at the observatory. The second section contains adopted baseline values, representing each day of the year. The third section for comments is mandatory. This comment section must include a brief description of the baseline adoption method.

```

COMP_HHHHH_FFFFF_IDC_YEARCrLf
DDD_aaaaaa.aa_bbbbbbb.bb_zzzzzz.zz_ssssss.ssCrLf
. . .
. . .
. . .
DDD_aaaaaa.aa_bbbbbbb.bb_zzzzzz.zz_ssssss.ssCrLf
*CrLf
001_AAAAAA.AA_BBBBBB.BB_ZZZZZZ.ZZ_SSSSSS.SS_DDDD.DD_mCrLf
002_AAAAAA.AA_BBBBBB.BB_ZZZZZZ.ZZ_SSSSSS.SS_DDDD.DD_mCrLf
003_AAAAAA.AA_BBBBBB.BB_ZZZZZZ.ZZ_SSSSSS.SS_DDDD.DD_mCrLf
. . .
. . .
. . .
366_AAAAAA.AA_BBBBBB.BB_ZZZZZZ.ZZ_SSSSSS.SS_DDDD.DD_mCrLf
*CrLf
Comments:CrLf
.....CrLf
.....CrLf

```

Component values are coded as signed float numbers, right justified with format (1X,F9.2). DeltaF values (denoted as DDDD.DD) are coded as signed float numbers, right justified with format (1X,F7.2). The field widths must be maintained, either through zero-filling or space-filling in order to have records of fixed length: every line is 43 characters long in section one, and 53 characters long in section two excluding terminator CrLf or Lf. Comment lines should not exceed 53 characters long.

Field	Description
COMP	Order of components XYZF, DIF_, HDZF, UVZF (see Note 1).
HHHHH	Annual mean value of H component in nT.
FFFFF	Annual mean value of F component in nT.
IDC	Official IAGA three-letter station code in capital letters.
YEAR	4-digit Year: eg, 2009.
DDD	Day of the year.
aaaaaa.aa	Observed baseline of X, D, H or U in nT or minutes (absolute - variometer)
bbbbbb.bb	Observed baseline of Y, I, D or V in nT or minutes (absolute - variometer)
zzzzz.zz	Observed baseline of Z or F in nT (absolute - variometer)
sssss.ss	Observed baseline of Scalar F in nT (absolute - scalar, See Note 5)
AAAAAA.AA	Adopted baseline value of X, D, H or U in nT or minutes.
BBBBBB.BB	Adopted baseline value of Y, I, D or V in nT or minutes.
ZZZZZ.ZZ	Adopted baseline value of Z, or F in nT.
SSSSSS.SS	Adopted baseline value of Scalar F in nT. (absolute - scalar, See Note 5)
DDDD.DD	Representative value of Delta F for this day (see Note 2).
m	Discontinuity marker (valid values c or d - see Note 3).
*	Section separator.
_	Space character.
CrLf	Indicates Carriage Return and Line Feed.

File name convention is IAGYEAR.BLV e.g. BFE2008.BLV where:

- IAG = 3-letter observatory IAGA code
- YEAR = 4-digit year

Note:

1. The codes XYZF, DIF_, HDZF, UVZF are the only supported codes of the components which must be listed in specified order within sections one and two.
2. Delta F is defined as:

$$\text{Delta F} = F(v) - F(s)$$
 Where F(v) represents the total field value calculated from the main observatory instrument ('vector F') and F(s) represents the total field from an independent instrument ('scalar F'). Both F(v) and F(s) must be corrected to the location in the observatory where geomagnetic absolute observations are made.
3. Discontinuity marker: c indicates that the baselines for all components form a continuous series with the previous day, d indicates a discontinuity in the baseline of one or more components (i.e. step) between the current day and the preceding one. This is to allow the baselines to be plotted at an appropriate scale. A discontinuity is defined as a known operational change such as an instrument re-alignment.
4. Missing values must be replaced by 99999.00 for D, H, X, Y, Z, F and by 999.00 for Delta F. Components that are not observed, which may include Scalar F (SSSSSS.SS) and Delta F (DDDD.DD), must be coded 88888.00 and 888.00 respectively.
5. The observed and adopted F baselines represent the DIFFERENCE in the F component between the absolute position and the continuously recording scalar instrument. Pier corrections are not applied to the data before computing the baselines.

E.4.2 IBFV1.20 (2008 and before)

This format is to be used to provide baselines for use in examining equipment performance and for inclusion on the INTERMAGNET DVD. The first section contains the observed baseline values on those days on which they were measured. Consequently the number of entries will depend upon the schedule for absolute measurements at that observatory. The second section contains adopted baseline values representing each day of the year. A comment section is also provided.

```

COMP_HHHHH_IDC_YEARCrLf
DDD_AAAAAA_BBBBBB_ZZZZZZ CrLf.
. . . . .
. . . . .
. . . . .
DDD_AAAAAA_BBBBBB_ZZZZZZ CrLf.
*
001_AAAAAA_BBBBBB_ZZZZZZ_FFFFF CrLf.
002_AAAAAA_BBBBBB_ZZZZZZ_FFFFF CrLf.
003_AAAAAA_BBBBBB_ZZZZZZ_FFFFF CrLf.
...
366_AAAAAA_BBBBBB_ZZZZZZ_FFFFF CrLf.
*
Comments:
    
```

Component values are coded as signed integers, right-justified with a field width of 7. Total field (Delta F) values are coded as signed integers, right-justified with a field width of 5. The field widths must be maintained, either through zero-filling or space-filling. The '+' sign for positive values is optional.

Field	Description
COMP	Order of components HDZF, XYZF, DIF, UVZF
HHHHH	Annual mean value of H component in nT.
IDC	IAGA three-letter observatory ID code eg: BOU for Boulder, OTT for Ottawa, LER for Lerwick, etc.
YEAR	4-digit Year: for example, 1991.
DDD	Day of the year.
AAAAAAA	Signed value of H, D, U or X in 0.1 nT
BBBBBBB	Signed value of D, I, V or Y in 0.1 nT or 0.1 min of arc for D
ZZZZZZZ	Signed value of Z or F in 0.1 nT
FFFFF	Signed value of Delta F, the difference between calculated and observed value of F (by a proton magnetometer) in 0.1 nT
*	Section separator.
-	Space character.
CrLf	Indicates Carriage Return and Line Feed.

Missing values must be replaced by 999999 for D, H, X, Y, Z and by 9999 for F.

File name convention is IAGYR.BLV where:

- IAG = 3-letter observatory IAGA code
- YR = 2-digit year

E.5 IAGA2002 INTERMAGNET Exchange Format (Spreadsheet compatible)

This ASCII Exchange Format, adopted in August 2001 and revised in December 2001, July 2003 and in August 2011, is intended as a data exchange format for geomagnetic data (samples and means) from observatories and variometer stations at time intervals from millisecond up to and including monthly means. The format comprises:

- Twelve (12) mandatory file header records.
- Unlimited optional comment records.
- One (1) mandatory data header record.
- A series of data records.
- **Every record is 70 characters long** plus the machine-dependent carriage return/line feed.

Pad records with spaces if needed. Data records report exactly 4 magnetic field elements (DHIF, DHZF, XYZF, or DHIG, DHZG, XYZG where G = DF).

Use missing data values (8's or 9's) if fewer than 4 elements are available.

E.5.1 The 12 Mandatory File Header Records

Mandatory header and optional comment records begin with a space character in column 1 and end with the vertical bar | (ASCII 124) in column 70. Content labels begin in column 2 and descriptions begin in column 25.

- This **format** is designated IAGA-2002.
- **Source of Data** is the name of the institute responsible for collecting the data.
- Please spell the entire **station name**; do not use abbreviations. Capitalize the first letter.
- The **IAGA Code** is the official IAGA 3-letter station code. It should be in capital letters and correspond to the IAGA list of magnetic observatories.
- Location of the station is reported to the one thousandth degree in **geodetic latitude** (positive north) from -90 to 90 degrees and in **geodetic longitude** (positive east) -180 to 180 or 0 to 360 degrees. Geographic location is reported using WGS-84 datum
- Report **elevation** in meters above mean sea level.
- **Reported** refers to the magnetic field elements contained in the data record, **in the order recorded in data record**. Valid values are DHIF, DHZF, and XYZF (or DHIG, DHZG, and XYZG where G = DF). Use E/V instead of D/I for declination/inclination given in intensity units (ONLY if data type is variation).
- **Sensor Orientation** is the physical orientation of the observing instruments, i.e. XYZF, HDZ.
- **Digital Sampling** is the rate (in seconds) of the data sampling of the magnetic field sensor (instrument) or the digitizing interval for analogue data.
- **Data interval** type is the mean or instantaneous time interval of the data. Common values include 1-minute (00:30-01:29), 1-minute (00:00-00:59), 1-hour (00-59), 1-day (00-23) and 1-month (01-31); the last day could also be 30, 29, or 28. There are many possible intervals, including a fraction of a second (instant value), averages by 1-second (501-1500), 1-second (0-1000), 10 second, or 2.5 minute. **Define the type of mean and how values are centered in the comment section.**
- **Data type** is provisional (P), definitive(D), quasi-definitive (Q), or variation (V).
- **Publication date** (optional) is the date when the data is published. This was added in June 2015. The inclusion of this line is (#13) optional but desirable for the modern data. The old data files cannot be modified (e.g. Publication date 2014-10-20).

E.5.2 The Optional Comment Header Records

Use these records to record important information concerning the data that is not contained in the defined fields. Types of information may include the type of means and how the mean values are centered, important gaps in the data record, or explanations of missing values (9 filled element field).

- Every record begins with a space character in column 1 and # (hash or number sign) in column 2.
- The end of each record is indicated with a vertical bar | (ASCII 124) in column 70.
- For transmission of incomplete day files include two additional optional comment headers stating the start time and duration in seconds. These records must have the form:
 - Start Time hh:mm:ss
 - Duration-in-seconds sssss
- If the data file contains absolute values (Data Type provisional or definitive), include the formula for computing the missing (non-reported) magnetic elements. For example, if an observatory reports XYZF, the comments should contain the formula for computing HDI (see sample data header and data record for 1-minute values).
- If the data file contains variometer values without considering base line values (Data Type variation), formula and constants are to be given to convert the recorded magnetic elements into others or to convert angular units into nT or vice versa. The possible conversions are:
 - $E = D * Ha * \text{arc}(1')$
 - $V = I * Fa * \text{arc}(1')$
 - $X = H * \cos(Da) - E * \sin(Da)$
 - $Y = H * \sin(Da) + E * \cos(Da)$
 - $Z = F * \sin(Ia) + V * \cos(Ia)$
 - $F = Z * \sin(Ia) + H * \cos(Ia)$
 - $H = X * \cos(Da) + Y * \sin(Da) = F * \cos(Ia) - V * \sin(Ia)$
 - $E = Y * \cos(Da) - X * \sin(Da)$
 - $V = Z * \cos(Ia) - H * \sin(Ia)$

X, Y, Z, H, F, E, V in nT; D, I in minutes of arc

$\text{arc}(1') = 2.9089\text{E-}04 = 0.00029089$

Ha, Fa, Da, Ia : approximate values of H, F, D, I (eg the most recent annual mean value or a value from the IGRF)

The formula and constants are to be given in additional optional comment header lines (see sample data header and data record for 1-second values).

E.5.3 The Mandatory Data Header Record

The mandatory data-header record contains column headers useful for multi-station analysis. Elements, both type and order, are indicated in the file-header field Reported.

- The date and time headers are DATE, TIME, and DOY (day of year).
- The magnetic element headers comprise 4 letters: 3 letters for the observatory IAGA code and 1 letter for the magnetic element reported. Valid values are H, D (or E), I (or V), X, Y, Z, F (or G). The column headers are space delimited.
- The end of each record is indicated with a vertical bar | (ASCII 124) in column 70.

E.5.4 The Data Records

The data records contain the date, time, and magnetic field elements reported. Report data to the least significant digit. Indicate missing data with 99999 to the corresponding accuracy for a given component (e.g., 99999.00). If an element is not observed, please record (to the corresponding accuracy for a given component) 88888 in that field. The format for field elements is 4(1X, F9.2). Each record is exactly 70 characters long plus the machine dependent carriage return / line feed.

- DATE is the calendar date in ISO YYYY-MM-DD format (4-digit year, month as 01-12, day as 01-31).
- TIME is in ISO hh:mm:ss.sss format (hour as 0-24, minute as 0-59, second as 0-59 Note: if the hour is 24, the minute and second must be 0). Values beyond the time interval of the means being reported must be zero-filled. i.e. 14:01:00.000 for 1 minute data for the 14th hour, first minute. Describe the method of average, i.e., centered to the hour for hourly means, in the comments area.
- DOY is the day of the year, from 1 - 365 (or 366 for leap years).
- D and I are reported in angular units of minutes of arc to the precision of the instruments. F, H, X, Y, Z, E, G, and V are reported in nanotesla and a fraction of nT.

E.5.5 Recommended File Name Procedure

To improve the ease with which data are exchanged and recognized, IAGA recommends the following guidelines and style for naming files containing magnetic observatory data. The recommendations closely follow the current International Standards Organization (ISO) Level II recommendations, and are fully compliant with both the Joliette extension to Level II and to the proposed modifications for the ISO standard. These recommendations are for data exchange and do not necessarily apply to data archive. Some changes have been made in this section in July 2003 to allow for existence of multiple fragments of data starting at different times (which is a possibility for some data transmission systems) and to ease usage with compression programs.

- File names are composed of two parts, the base name and a three-character extension. A full stop (period) separates the base from the extension. The base name may be up to 27 characters long. The extension is exactly three characters (total file name length not to exceed 31 characters). This format is sometimes referred to as the “27.3” format. BASENAME (1 to 27 characters) “.” EXTENSION (3 characters). Ex. my_file_name.dat
- File names are composed of lower case a-z, 0-9, underscore “_”, and dash “-” characters. No spaces, unusual characters (i.e. *, /, \, :, ;, ?) or upper case characters allowed.
- File names must begin with the IAGA 3-Letter Code, Date, and Type of data. The Extension defines the Data Interval (monthly, daily, hourly, minute, or second data). The Extension is duplicated in the last three characters of the base name, so that if the Extension is stripped on compression the Data Interval is not lost. The file name only indicates the general data interval, specific information is contained in the file header Data Interval field (i.e. 2.5 and 1-minute averages are both “minute” data, 10 second averages and 1 second instantaneous are both “second” data).
- The first several characters in the base name are strictly defined. Files may be further defined with the remaining characters by using an underscore “_” to separate the standard name. For example, naq20020101d.min and naq20020101d_2-5.min are both acceptable names for 2.5 minute definitive data from Narsarsuaq.

General format: iagyyymmddtint.int

Where:

- iag = IAGA 3-letter observatory code
- yyyy = four digit year (i.e. 2002)
- mm = two digit month (i.e. 01 for January, 12 for December)
- dd = two digit day of month (01-31)
- t = type of data (p - provisional, d - definitive, q - quasi-definitive v - variation)
- int = data interval (mon - monthly, day - daily, hor - hourly, min - minute, sec - second)

Comment	Data Interval	Files	File name pattern	Example name
1	Monthly	Year	iagyyyytint.int	naq2002dmon.mon
2	Daily	Year	iagyyyytint.int	naq2002dday.day
3	Hourly	Month	iagyyyymmtint.int	naq200201phor.hor
4	Minute	Day	iagyyyymmddtint.int	naq20020101pmin.min
5	Second	Day	iagyyyymmddtint.int	naq20020211vsec.sec

1. File contains 1 year of definitive monthly data for 2002 from Narsarsuaq.
2. File contains 1 year of definitive daily data for 2002 from Narsarsuaq.
3. File contains 1 month of provisional hourly data for January 2002 from Narsarsuaq.
4. File contains 1 day of provisional minute data for 1 January 2002 from Narsarsuaq.
5. File contains 1 day of variation second data for 11 February 2002 from Narsarsuaq.

Additional format to handle multiple fragments of data starting at different times:

iagyyyymmddhhMMsstint.int

Where:

- iag = IAGA 3-letter observatory code
- yyyy = four digit year (i.e. 2002)
- mm = two digit month (i.e. 01 for January, 12 for December)
- dd = two digit day of month (01-31)
- hh = hour at which data starts (00-23)
- MM = minute at which data starts (00-59)
- ss = second at which data starts (00-59)
- t = type of data (p - provisional, d - definitive, v - variation)
- int = data interval (mon - monthly, day - daily, hor - hourly, min - minute, sec - second)

Comment	Data Interval	Files	File name pattern	Example name
1	Minute	Part-day	iagyyyymmddhhMMstint.int	clf200306121320vmin.min
2	Second	Part-day	iagyyyymmddhhMMsstint.int	clf20030612132000vsec.sec

1. File contains part-day of 1-minute variation data from CLF for 12 June 2003, starting at 13:20
2. File contains part-day of 1-second variation data from CLF for 12 June 2003, starting at 13:20:00

E.5.6 Sample of IAGA-2002 Format July 2003 Revision

E.5.6.1 Sample Data Header and Data Record for 1-minute Values

Format	IAGA-2002	
Source of Data	Danish Meteorological Institute	
Station Name	Narsarsuaq	
IAGA Code	NAQ	
Geodetic Latitude	61.160	
Geodetic Longitude	314.560	
Elevation	4	
Reported	XYZF	
Sensor Orientation	DIF	
Digital Sampling	0.01 seconds	
Data Interval Type	Filtered 1-minute (00:30 - 01:29)	
Data Type	Definitive	
# This area is where the data source or distributor can include		

(continues on next page)

(continued from previous page)

```
# any additional information needed for proper use of data. For
# example, the observers name and contact, notes on a change of
# instrumentation, reasons for missing data values, definition of
# observed values, geomagnetic location of the observatory, etc.
# This area should also contain the formula for computing the non-
# reported elements and components of the INTERMAGNET binary
# format which do not fit elsewhere. These include:
# D-conversion:
# = H/3438*10000.
# which is word 8 in the INTERMAGNET binary format and is used
# to convert variations of D in minutes of arc <-> nT. Please
# note that all of the header records and comment records begin
# with a space in column 1, end with a | (ASCII 124), and are
# padded with spaces - never with tabs.
#  $H = \sqrt{X^2 + Y^2}$ ,  $\cos D = X/H$ ,  $\sin I = Z/F$ 
DATE      TIME      DOY      NAQX      NAQY      NAQZ      NAQF      |
2001-03-13 00:00:00.000 072      10800.11 -6100.23  53381.51  54801.12
2001-03-13 00:01:00.000 072      10800.31 -6100.20  53381.51  54801.12
2001-03-13 00:02:00.000 072      10801.11 -6101.23  99999.00  54801.12
2001-03-13 00:03:00.000 072      10803.12 -6100.23  99999.00  54801.12
```

E.5.6.2 Sample Data Header and Data Record for Hourly Values

The header record for Data Interval Type might read:

Data Interval Type 1-hour (00 - 59). Note filler for non-reported element.

```
DATE      TIME      DOY      NAQX      NAQY      NAQZ      NAQF      |
2001-03-13 00:00:00.000 072      10800.11 -6100.23  53381.51  88888.00
2001-03-13 01:00:00.000 072      10800.31 -6100.20  53381.51  88888.00
2001-03-13 02:00:00.000 072      10801.11 -6101.23  53381.50  88888.00
2001-03-13 03:00:00.000 072      10803.12 -6100.23  99999.00  88888.00
```

E.5.6.3 Sample Data Header and Data Record for Monthly Values

The header record for Data Interval Type might read:

Data Interval Type 1-month (01 - 31). Note filler for non-reported element.

```
DATE      TIME      DOY      NAQX      NAQY      NAQZ      NAQF      |
2001-01-15 00:00:00.000 015      10800.11 -6100.23  53381.51  88888.00
2001-02-14 00:00:00.000 045      10800.31 -6100.20  53381.51  88888.00
2001-03-15 00:00:00.000 074      10801.11 -6101.23  53381.50  88888.00
2001-04-15 00:00:00.000 105      10803.12 -6100.23  99999.00  88888.00
```

E.5.6.4 Sample Data Header and Data Record for 1-second Values

```

Format                IAGA-2002
Source of Data        Danish Meteorological Institute
Station Name          Narsarsuaq
IAGA CODE              NAQ
Geodetic Latitude     61.160
Geodetic Longitude    314.560
Elevation             4
Reported              HEZF
Sensor Orientation    HEZF
Digital Sampling      1 seconds
Data Interval Type    1-second instantaneous
Data Type             Variation
# This area should contain additional information needed
# in order to transform the reported elements. For the data in this
# sample information about the declination at the observatory is
# needed in order to transform the variation data from HEZ to the
# widely used XYZ orientation. Also information about the value of
# horizontal field H can be useful to convert E-variations in nT to
# variations in minutes of arcs.
# E = D * Ha * 0.00029089
# Ha = 17123.45
# X = H * cos(Da) B E* sin(Da)
# Y = H * sin(Da) + E* cos(Da)
# Da = 312.89 minutes of arc
DATE      TIME      DOY      NAQH      NAQE      NAQZ      NAQF
2001-03-13 00:00:00.000 072      800.11    -100.23    381.51    54801.12
2001-03-13 00:00:01.000 072      800.31    -100.20    381.51    54802.32
2001-03-13 00:00:02.000 072      801.11    -101.23    99999.00    54803.22
2001-03-13 00:00:03.000 072      803.12    -100.23    99999.00    54803.43
    
```

E.5.6.5 Sample Data Header and Data Record for 5-Millisecond Values

The header record for Data Interval Type might read:

Data Interval Type 5-millisecond (instantaneous values). Note filler for missing element.

```

DATE      TIME      DOY      NAQX      NAQY      NAQZ      NAQF
2001-03-13 00:00:00.000 072      10800.11  -6100.23  53381.51  99999.00
2001-03-13 00:00:00.005 072      10800.31  -6100.20  53381.51  99999.00
2001-03-13 00:00:00.010 072      10801.11  -6101.23  53381.50  54801.12
2001-03-13 00:00:00.015 072      10803.12  -6100.23  99999.00  54801.12
    
```

E.6 IMAGCDF INTERMAGNET Exchange Format

This document describes how NASA's Common Data Format (CDF - <http://cdf.gsfc.nasa.gov/>) is used to store geomagnetic data. This format is called ImagCDF.

E.6.1 Design Details and CDF Concepts

E.6.1.1 General Design Details

Geomagnetic data is held in CDF variables, one variable per geomagnetic element. Additional variables hold time stamp data. A single time stamp variable may be used if all time series data uses the same sample rate. Alternatively one time stamp variable may be for the vector magnetometer data, a second variable for the scalar magnetometer data, if data from these two instruments are recorded at different sample rates.

Each variable (data or time stamp) has one or more records, an individual record holding a single sample value. The index numbers of the records in the data variables correspond with the index numbers in the appropriate time stamp variable's records. A typical file might contain 6 variables: 3 geomagnetic elements (such as HDZ or XYZ); one scalar element (F); and two timing variables, one for the vector data, the other for the scalar. The format does not mandate that these variables are present – there may be fewer (for example only scalar data) or more (for example additional temperature data).

Metadata is held in CDF attributes in two ways: global attribute entries concern all the data in a file; variable attributes have entries that concern a single variable (e.g. the geomagnetic data 'H' variable). An entry holds an individual item of metadata. An attribute name (whether global or variable) must be unique, so when an attribute needs to be used more than once (e.g. the element type for a geomagnetic variable must be used once for each geomagnetic element), then multiple entries are created in a single attribute. Global attributes in ImagCDF will have only one entry (with two exceptions). Variable attributes may have an entry for each of the relevant variables in the file. For variable attributes, the multiple entries are indexed using the variable's numeric identifier, so that the metadata 'belongs' to the variable. For example, in an ImagCDF file holding HDZF data, the attribute Units will have four entries (in this order): "nT"; "Degrees of arc"; "nT"; "nT".

E.6.1.2 Data Types Used for Variables and Attributes

E.6.1.2.1 Real Numbers

ImagCDF uses double precision CDF_DOUBLE (8-byte) floating point numbers (to the IEEE 754 standard) for all numeric values. These numbers provide about 14.5 (decimal) digits of precision - <http://flint.cs.yale.edu/cs422/doc/art-of-asm/pdf/CH14.PDF>. In order to use floating point numbers successfully, the dynamic range of the quantity being represented (ratio of smallest to largest value) must be smaller than 14.5 digits. For geomagnetic field strengths, assume that the ratio of smallest difference to largest value that we need to represent in geomagnetic field data is 0.1pT in 80,000nT. This equates to 1 part in 80,000 x 1,000 x 10, or 1 part in 800,000,000, or 9 digits of precision, so is within the dynamic range available.

E.6.1.2.2 Dates / Times

All date / time values in ImagCDF are held as CDF TT2000 dates, which are based on 8-byte integers. TT2000 uses an epoch (midday on 1st January 2000) to store dates and times, has a precision of 1 nanosecond which gives a range in excess of ± 280 years from the epoch date. The TT2000 type can correctly handle leap seconds.

E.6.1.2.3 Strings

Text data is held using CDF_CHAR variables in ImagCDF.

E.6.1.3 Compression

The CDF library allows the user to specify whether all, part or none of a CDF file is compressed at the time it is written. Once this choice has been made, the CDF library handles compression and decompression of the data in the file automatically (reading and any further writing to the file will decompress or compress as required). Choosing whether or not to compress a file is simply a matter of specifying which (if any) compression method to use when the file is created. ImagCDF allows any of the compressions provided by CDF.

Significant compression is achieved using the CDF compression option. A day file of four element minute data can occupy under 15Kb.

E.6.2 Where to Obtain the CDF Software

Before you can use any of NASA or INTERMAGNET's tools for working with ImagCDF, you will need to download and install the CDF software from NASA: http://cdf.gsfc.nasa.gov/html/sw_and_docs.html . Software that has been written to work with CDF is likely to need the libraries that are installed. For details of other software that may be useful see section *Tools to Look at CDF Data*.

E.6.3 ImagCDF Data

All variables holding geomagnetic data have the following features:

- Units used must be nT for geomagnetic field values, degrees for angles or celsius for temperatures.
- Lengths of time series are arbitrary (e.g. a file may be used to store an entire day of data or a small fragment of a day down to a single sample).

Geomagnetic data is held in variables called GeomagneticField <E> where <E> represents the code for the geomagnetic element recorded - see section *Valid Codes for Elements Recorded (V1.2)* for a list of valid codes (in version 1.2). The variable has 0 dimensions, each consecutive record holding individual consecutive data samples in CDF double data type, starting at record 1. Missing data values are represented by a data sample that contains the same number as is present in the FILLVAL metadata attribute. The FILLVAL must exceed any valid geomagnetic field strength or angle. Typically this would be 99999.0. The variable attribute FIELDNAM must be set to "Geomagnetic Field Element <E>".

An ImagCDF file must include a set of geomagnetic field variables that describe the vector field in a recognised orientation (such as 'HDZ', 'XYZ' or 'DIF'). All vector variables must have the same number of records. An ImagCDF file may also include an additional field element from an independent scalar instrument, with an element code of 'G' or 'S'.

Temperature data is optional (unless otherwise stated in the data standard that the data conforms to, for example, temperature is mandatory for data that conforms to the INTERMAGNET 1-second data standard). The first temperature variable is called Temperature1, then Temperature2 and so on. The FIELDNAM attribute describes, in free text, for each temperature variable, the location at which the temperature was recorded.

Time stamps for the data are held in separate variables. Time stamps must represent a regular time series with no missing values in the series.

If all data in the CDF file (including non-geomagnetic data) has the same sample rate, a single time stamp variable called *DataTimes* should be used. If all geomagnetic data has the same sample rate (but other data has different sample rates), a time stamp variable called *GeomagneticTimes* should be used for the geomagnetic data, and time stamps for temperature data should be called *TemperatureTimes* (if all temperature data has the same sample rate) or *Temperature1Times*, *Temperature2Times*, ... (for temperature data with different sample rates). If the geomagnetic vector and scalar data have different sample rates, time stamp variables *GeomagneticVectorTimes* and *GeomagneticScalarTimes* should be used (time stamp variables for temperature data should follow the rules already described).

All time stamp variables have 0 dimensions and must have the same number of records as the data variables that they apply to. Each record in a time stamp variable holds a CDF TT2000 epoch time. Time stamps must always refer to the start of each sample period (e.g. for minute data, the seconds and milliseconds will always be set to zero).

Whatever time stamp variables are used, every data variable must have an entry in the *DEPEND_0* variable attribute containing the name of the time stamp variable that is to be used with that data variable.

Names for time stamp variables are:

Situation	Names
The same time stamps can be used for all data in the file (i.e. there is a single time stamp variable in the file)	<i>DataTimes</i>
The same time stamps can be used for all geomagnetic data, a single different time stamp is used for all temperature data	<i>GeomagneticTimes</i> , <i>TemperatureTimes</i>
Different time stamps for vector, scalar and temperature data	<i>GeomagneticVectorTimes</i> , <i>GeomagneticScalarTimes</i> , <i>Temperature1Times</i> , <i>Temperature2Times</i> , ...

Additional variables and metadata may be carried in an *ImagCDF* (e.g. it may be convenient to include meteorological data in the same file). The format of these variables and metadata is left to the user to define. The CDF system means that these variables can be included without causing problems to software reading *ImagCDF* files. Software writing *ImagCDF* files should preserve additional variables and attributes read from an *ImagCDF* file.

E.6.4 *ImagCDF* Version 1.2

The descriptions in this section apply to version 1.2 of *ImagCDF*.

E.6.4.1 *ImagCDF* Global Attributes (V1.2)

The following attributes apply to all the data in an *ImagCDF* file. The “Entries” column shows whether the attribute has:

- A single mandatory entry (number of entries is exactly 1)
- A single optional entry (number of entries may be 0 or 1)
- Multiple mandatory entries (number of entries is between 1 and N¹)
- Optional mandatory entries (number of entries is between 1 and N²)

Superscript numbers following the attribute name show:

1. That the attribute is a recommended attribute for use with NASA’s CDF tools
2. That the attribute is part of the ISTEP/IACG guidelines - http://spdf.gsfc.nasa.gov/istp_guide/gattributes.html

E.6.4.1.1 Attributes that Describe the Data Format (V1.2)

These are ‘constant’ values that will be the same for all ImagCDF files. They allow ‘generic’ CDF programs to understand and process the data correctly.

Attribute Name	Type	Entries	Description
FormatDescription	String	1	Always set to “INTERMAGNET CDF Format”
FormatVersion	String	1	Set to the current version of the format – “1.2”
Title	String	1	Always set to “Geomagnetic time series data”

E.6.4.1.2 Attributes that Uniquely Identify the Data (V1.2)

The attributes in this section are sufficient, along with the start date and duration of the time series, to uniquely identify a piece of geomagnetic data.

Attribute Name	Type	Entries	Description
IagaCode	String	1	The IAGA code for the observatory
ElementsRecorded	String	1	A string consisting of single character codes, each describing one of the geomagnetic field elements that is recorded in this data file. This might typically be a three or four digit code such as HDZ, XYZG or DIFG. The codes in this attribute determine the names of the data variables (see the section on geomagnetic data). Valid codes are defined in section <i>Valid Codes for Elements Recorded (V1.2)</i>
PublicationLevel	String	1	Choose one of the following codes to describe the level that the data has been processed to: <ul style="list-style-type: none"> • 1: The data is unprocessed and as recorded at the observatory with no changes made. • 2: Some edits have been made such as gap filling and spike removal and a preliminary baseline added. • 3: The data is at the level required for production of an initial bulletin or for quasi-definitive publication. • 4: The data has been finalised and no further changes are intended Only these values are allowed. This field provides a quick description of the point the data has reached in the publication process. For detailed information on the standards that the data conforms to see section <i>Attributes that Relate to Data Standards and Quality (V1.2)</i>
PublicationDate	Date/time	1	Date and time on which the data was published. This attribute is used to distinguish multiple publications of the same data.

E.6.4.1.3 Attributes that Describe the Observatory (V1.2)

These attributes are available from other metadata systems (given an IAGA code), but are included for convenience of the user.

Attribute Name	Type	Entries	Description
ObservatoryName	String	1	The full name for the observatory
Latitude	Double	1	The latitude of the observing position in degrees, to WGS-84 datum
Longitude	Double	1	The longitude of the observing position in degrees, to WGS-84 datum
Elevation	Double	1	The height of the observing position in metres above sea level, to WGS-84 datum. Set to 99999.0 if not known.
Institution	String	1 or more	The name of the responsible institute.
VectorSensOrient	String	0 - 1	The orientation code of the sensor at the original recording of the vector data. A string consisting of single character codes, each describing one of the geomagnetic field elements that was recorded by the vector instrument. Valid codes are the same as for the ElementsRecorded attribute.

E.6.4.1.4 Attributes that Relate to Data Standards and Quality (V1.2)

These attributes describe the standards, if any, that the data meets.

Attribute Name	Type	Entries	Description
StandardLevel	String	1	Describe whether the data conforms to a standard. Choose from one of the following codes: <ul style="list-style-type: none"> • <i>None</i>: The data does not conform to any standards. When using this, the StandardName attribute does not need to be set. • <i>Partial</i>: The data partially conforms to the relevant standard for this data product. • <i>Full</i>: The data fully conforms to the relevant standard for this data product. Only these values are allowed. If <i>StandardsLevel</i> is set to <i>Partial</i> , then the <i>PartialStandDesc</i> attribute must also be set.
StandardName	String	0 - 1	The name of the relevant standard. See section Relevant Data Standards (V1.2)
StandardVersion	String	0 - 1	If the standard has a version, put its version number in this attribute.
PartialStandDesc	String	0 - 1	See section Relevant Data Standards (V1.2)

E.6.4.1.5 Attributes that Relate to Publication of the Data (V1.2)

These attributes are needed when that data is published.

Attribute Name	Type	Entries	Description
Source	String	1	Set to one of: “institute” (if the named institution provided the data- see section <i>Attributes that Describe the Observatory (V1.2)</i> for the institution); “INTERMAGNET” (if the data file has been created by INTERMAGNET from another data source); “WDC” (if the World Data Centre has created the file from another data source)
TermsOfUse	String	0 – 1	The terms of use for the data. This could be text describing the terms of use or a link to a web page. INTERMAGNET has a recommended wording for data provided through INTERMAGNET.
UniqueIdentifier	String	0 – 1	A string that can be used to uniquely identify this data. This could be a Digital object identifier or could be an identifier created according to local rules. Note this is optional and will not be present if this data is not covered by an identifier.
ParentIdentifiers	String	0 or more	The unique identifiers of the parent data sets (if any), one identifier per entry. The parent data set is the data set from which this data set’s values have been derived. E.g. if a one minute data set has been created from a one second data set, the one second data set is the parent. Another example is where definitive data is created from provisional data.
ReferenceLinks	String/URL	0 or more	URLs pointing to (e.g.) information about the data creator, information about the data repository... One URL per entry.

E.6.4.1.6 Valid Codes for Elements Recorded (V1.2)

- ‘X’, ‘Y’, or ‘Z’ indicate that the variable holds the strength of the magnetic field vector in the standard geographic coordinates in nT.
- ‘H’ indicates that the variable holds the strength of the magnetic field vector in the horizontal plane along the magnetic meridian in nT.
- ‘D’ indicates that the variable holds the angle between the magnetic vector and true north, in degrees of arc, positive east.
- ‘E’ indicates that the variable holds a field strength in the horizontal plane perpendicular to ‘H’ in nT. ‘E’ is only valid for data that is not baseline corrected.
- ‘V’ indicates that the variable holds the field strength along the direction of the inclination.
- ‘I’ indicates that the variable holds the angle between the magnetic vector and the horizontal plane, in degrees of arc, positive below the horizontal.
- ‘F’ indicates that the variable holds the geomagnetic field strength in nT, calculated from and consistent with XYZ or HDZ field elements.
- ‘S’ indicates that the variable holds the geomagnetic field strength in nT, measured by an independent scalar instrument
- ‘G’ indicates that the variable holds delta- F values, defined as F(vector) –S(scalar) in nT. When calculating values for the G element, if F(vector) is missing, G is set to –S (scalar)

Other codes are allowed, but may lead to data not being understood.

E.6.4.1.7 Relevant Data Standards (V1.2)

Different geomagnetic data products have different standards associated with them. This table shows what standards are being referred to in the StandardsLevel attribute and describes what to put into the StandardName attribute in the case where StandardsLevel is set to Partial or Full. The table also shows what to put in the PartialStandDesc attribute in the case where the StandardsLevel attribute is set to Partial.

Data product	Relevant Standard	Contents of StandardName
One second definitive data	INTERMAGNET Definitive One-second Data Standard ²	INTERMAGNET_1-Second
One minute definitive data	INTERMAGNET magnetic observatory – specifications ³	INTERMAGNET_1-Minute
One minute quasi-definitive data	INTERMAGNET magnetic observatory – specifications ³ , modified for baseline accuracy ⁴	INTERMAGNET_1-Minute_QD
Hourly means	No relevant standard	
Daily means	No relevant standard	
Monthly means	No relevant standard	
Annual means	No relevant standard	

If a standard is met in full or not met at all, PartialStandDesc can be omitted. Where a standard is partially met (e.g. the time stamp accuracy is within tolerance, but the data is not baseline corrected), the name of the relevant standard should be put in the StandardName attribute, StandardLevel should be set to Partial and the PartialStandDesc attribute should be filled in with a comma separated list of the sub-sections from the standard that the data meets. E.g. if the data meets the time stamp accuracy and thermal stability sections of the 1-minute data standard, enter IMOM-01,IMOM-16 in PartialStandDesc.

Value to put in PartialStandDesc	Description
	One-minute Definitive Data: General specifications
IMOM-01	Time-stamp accuracy (centered on the UTC minute): 5s
	One-minute Definitive Data: Vector Magnetometer specifications
IMOM-11	Absolute Accuracy: ± 5 nT
IMOM-12	Resolution: 0.1nT
IMOM-13	Dynamic Range: $\geq \pm 4000$ nT High Lat., $\geq \pm 3000$ nT Mid/Equatorial Lat.
IMOM-14	Band pass: D.C. to 0.1Hz
IMOM-15	Minimum sampling rate: 1Hz
IMOM-16	Thermal stability: 0.25nT/°C
IMOM-17	Long term stability: 5nT/year
IMOM-18	Filtering to one-minute data: INTERMAGNET Gaussian
	One-minute Definitive Data: Scalar Magnetometer specifications
IMOM-21	Resolution: 0.1nT
IMOM-22	Absolute Accuracy: ± 1 nT
IMOM-23	Minimum sampling rate: 0.033Hz (30 sec)
	One-second Data: General Specifications
IMOS-01	Time-stamp accuracy (centered on the UTC second): 0.01s
IMOS-02	Phase response: Maximum group delay: ± 0.01 s

continues on next page

² INTERMAGNET Technical Note 6

³ Section 2.1

⁴ Quasi-definitive definition on the INTERMAGNET web site: <https://intermagnet.org/faq/04.what-is-quasi.html>

Table 5.9 – continued from previous page

IMOS-03	Maximum filter width: 25 seconds
IMOS-04	Instrument amplitude range: $\geq \pm 4000$ nT High Lat., $\geq \pm 3000$ nT Mid/Equatorial Lat.
IMOS-05	Data resolution: 1pT
IMOS-06	Pass band: DC to 0.2Hz
	One-second Data: Specifications in the Pass Band [DC to 8mHz (120s)]
IMOS-11	Noise level: ≤ 100 pT RMS
	Maximum offset error (cumulative error between absolute observations): ± 2.5 nT
IMOS-13	Maximum component scaling plus linearity error: 0.25%
IMOS-14	Maximum component orthogonality error: 2mrad
IMOS-15	Maximum Z-component verticality error: 2mrad
	One-second Data: Specifications in the Pass Band [8mHz (120s) to 0.2Hz]
IMOS-21	Noise level: ≤ 10 pT/ $\sqrt{\text{Hz}}$ at 0.1 Hz
IMOS-22	Maximum gain/attenuation: 3dB
	One-second Data: Specifications in the Stop Band [≥ 0.5 Hz]
IMOS-31	Minimum attenuation in the stop band (≥ 0.5 Hz): 50dB
	One-second Data: Auxiliary measurements:
IMOS-41	Compulsory full-scale scalar magnetometer measurements with a data resolution of 0.01nT at a minimum sample period of 30 seconds.
IMOS-42	Compulsory vector magnetometer temperature measurements with a resolution of 0.1°C at a minimum sample period of one minute.

E.6.4.2 ImagCDF Variable Attributes (V1.2)

The following attributes apply to individual variables - there is an attribute entry for each geomagnetic field element or temperature in an ImagCDF file and the value of that entry applies only to that field element or temperature. The “Entries” column shows whether the attribute is:

- Mandatory (number of entries per variable is exactly ¹)
- Optional (number of entries per variable may be ⁰ or ¹)

None of these attributes are required for the time stamp variables `GeomagneticVectorTimes` and `GeomagneticScalarTimes`.

Attribute Name	Type	Entries	Description
FIELDNAM ⁵	String	1	Set to “Geomagnetic Field Element ” + the element code (e.g. H, D, Z,... - see section <i>Valid Codes for Elements Recorded (V1.2)</i> for a list of valid codes); or set to “Temperature ” + the name of the location where the temperature was recorded.
UNITS ⁵	String	1	Must be one of “nT”, “Degrees of arc” or “Celsius”
FILLVAL ⁵	Double	1	The value used to show that a data sample is missing. Set to 99999.0 for compatibility with other formats. The values must either less than VALIDMIN or greater than VALIDMAX.
VALIDMIN ⁵	Double	1	The smallest allowed numeric value for the data in the corresponding variable.
VALIDMAX ⁵	Double	1	The largest allowed numeric value for the data in the corresponding variable.
DEPEND_0 ⁶	String	0 - 1	For geomagnetic data, set this to the name of the variable that holds time stamps for this time series. For records containing time stamps, do not set this variable.
DISPLAY_TYPE ⁶	String	1	Set to “time_series”
LABLAXIS ⁶	String	1	Set to the element code (as defined in section <i>Valid Codes for Elements Recorded (V1.2)</i>)

E.6.4.3 ImagCDF File Names (V1.2)

ImagCDF files are named using the convention:

```
[iaga-code]_[date-time]_[publication-level].cdf
```

- Iaga-code is the three letter IAGA code for the observatory that the data is from. This should match the IAGA code in section *Attributes that Uniquely Identify the Data (V1.2)*.
- Date-time describes the data interval (or period) of the data along with the date/time of the data in the file. The format for the date/time is described below.
- Publication-level is the PublicationLevel attribute from section *Attributes that Uniquely Identify the Data (V1.2)*.

Filenames are in lower case. Files may contain arbitrary amounts of data, however the amount of data is not coded into the filename.

⁵ The attribute is a recommended attribute for use with NASA’s CDF tools

⁶ The attribute is part of the ISTEP/IACG guidelines - http://spdf.gsfc.nasa.gov/istp_guide/vattributes.html

E.6.4.3.1 Format of Date/Time Portion of Filename and Examples (V1.2)

The date/time portion of the filename is formatted differently for different data with different data intervals:

Data Interval	Date/time format	Example filename
Annual means	YYYY	esk_2000_4.cdf – final annual mean data from Eskdalemuir starting in the year 2000
Monthly means	YYYYMM	ott_201401_4.cdf – final monthly mean data from Ottawa starting in January 2014
Daily means	YYYYMMDD	gua_20100101_4.cdf – final daily mean data from Guam starting at the beginning of 2010
Hourly means	YYYYMMDD_HH	naq_20020201_00_4.cdf – final hourly mean data from NAQ in February 2002
Minute means	YYYYMMDD_HHMM	naq_20020120_0000_3.cdf – ‘bulletin’ or quasi-definitive minute mean data from NAQ for 20th January 2002 starting at midnight
Second	YYYYMMDD_HHMMSS	naq_20020120_012300_1.cdf – raw 1-second data from NAQ for 20th January 2002 starting at 01:23:00

- YYYY = four digit year (i.e. 2002)
- MM = two digit month (01 for January - 12 for December)
- DD = two digit day of month (01-31)
- HH = two digit hour (0-23)
- MM = two digit minute (0-59)
- SS = two digit second (0-59)

E.6.5 ImagCDF Version 1.3

The descriptions in this section apply to version 1.3 of ImagCDF.

Version 1.3 only changes the format of the ImagCDF filenames. The documentation for version 1.2 should be used for the contents of these files:

E.6.5.1 ImagCDF Global Attributes (V1.3)

The following changes have been made to global attributes since version 1.2:

1. The “FormatVersion” global attribute should be set to “1.3”.
2. An additional optional variable “LeapSecondLastUpdated” may be used to describe when the CDF Leap Second table was last updated. NASA CDF libraries specify this value as part of CDF file metadata, but some third party libraries do not set the value in the metadata. Where libraries are used that do not set this value, data providers are encouraged to use this global attribute. The contents of the attribute should be the same as the CDF file metadata, which is the date of the day following the last leap second, coded as an integer: (year * 10000) + (month * 100) + day.

See the global attributes documentation for [version 1.2](#) for a description of the other global attributes.

E.6.5.2 ImagCDF Variable Attributes (V1.3)

There are no changes to the variable attributes in the format since version 1.2. See the variable attributes documentation for *version 1.2*.

E.6.5.3 ImagCDF File Names (V1.3)

Version 1.3 fixes some errors and omissions in the format of ImagCDF filenames.

ImagCDF files are named using the convention:

```
[iaga-code]_[date-time]_[cadence]_[publication-level].cdf
```

- Iaga-code is the three letter IAGA code for the observatory that the data is from. This should match the IAGA code in section *Attributes that Uniquely Identify the Data (V1.2)*.
- Date-time describes the time coverage of the data (i.e. how much data is in the file) along with the date/time of the data in the file. The format for the date/time is described below.
- Cadence refers to the data sample period and is formatted as an ISO 8601 duration. Some sample ISO 8601 durations are given below.
- Publication-level is the PublicationLevel attribute from section *Attributes that Uniquely Identify the Data (V1.2)*.

Filenames are in lower case. Files may contain any amount of data. The date/time string may be used to indicate the amount of data in the file - more information on this is given in the description of the date/time format.

E.6.5.3.1 ISO 8601 Duration Strings for Common Geomagnetic Sample Periods (V1.3)

Sample Period	ISO 8601 duration
1 second	PT1S
1 minute	PT1M
Hourly means	PT1H
Daily means	P1D
Monthly means	P1M
Annual means	P1Y

The table above is a set of examples. Other sample periods may be used provided that the sample period used represents the vector data and conforms to ISO 8601.

E.6.5.3.2 Format of Date/Time Portion of Filename and Examples (V1.3)

The date/time portion of the filename is formatted differently, depending on the amount of data the file contains (the data coverage).

E.6.7 Example Data File

The data in this example was extracted from a monthly file containing 1-second definitive data from Abisko observatory for January 2019. Only the first two data records are shown for each variable.

```
File Info
=====
CDF File:      abk_201901_PT1S_4.cdf
Version:      3.7.0

Common Data Format (CDF)
https://cdf.gsfc.nasa.gov
Space Physics Data Facility
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771 USA
(User support: gsfc-cdf-support@lists.nasa.gov)

Format:       SINGLE
Encoding:     IBMPC
Majority:     ROW
NumrVars:     0
NumzVars:     5
NumAttrs:     29 (21 global, 8 variable)
Compression:  GZIP.1
Checksum:     None
LeapSecondLastUpdated: 20170101

Global Attributes (21 attributes)
=====
FormatDescription (num:0) (1 entry):
  0 (CDF_CHAR/22):      "INTERMAGNET CDF format"
FormatVersion (num:1) (1 entry):
  0 (CDF_CHAR/3):       "1.3"
Title (num:2) (1 entry):
  0 (CDF_CHAR/28):      "Geomagnetic time series data"
IagaCode (num:3) (1 entry):
  0 (CDF_CHAR/3):       "ABK"
ElementsRecorded (num:4) (1 entry):
  0 (CDF_CHAR/4):       "XYZG"
PublicationLevel (num:5) (1 entry):
  0 (CDF_CHAR/1):       "4"
PublicationDate (1 entry):
  0 (CDF_TT2000/1):     2022-10-08T12:19:06.088000000
ObservatoryName (num:7) (1 entry):
  0 (CDF_CHAR/6):       "Abisko"
Latitude (num:8) (1 entry):
  0 (CDF_DOUBLE/1):     68.358
Longitude (num:9) (1 entry):
  0 (CDF_DOUBLE/1):     18.823
Elevation (num:10) (1 entry):
  0 (CDF_CHAR/5):       "380.0"
Institution (num:11) (1 entry):
  0 (CDF_CHAR/27):      "Geological Survey of Sweden"
VectorSensOrient (num:12) (1 entry):
  0 (CDF_CHAR/3):       "XYZ"
StandardLevel (num:13) (1 entry):
  0 (CDF_CHAR/7):       "Partial"
StandardName (num:14) (1 entry):
```

(continues on next page)

(continued from previous page)

```

    0 (CDF_CHAR/20):          "INTERMAGNET_1-Second"
PartialStandDesc (num:15) (1 entry):
    0 (CDF_CHAR/87):          "IMOS-03, IMOS-04, IMOS-05, IMOS-06, IMOS-11, IMOS-12, IMOS-
↪14, IMOS-15, IMOS-22, IMOS-41, IMOS-42"
Source (num:16) (1 entry):
    0 (CDF_CHAR/9):           "institute"
TermsOfUse (num:17) (1 entry):
    0 (CDF_CHAR/62):          "http://www.intermagnet.org/data-donnee/data-eng.php
↪#conditions"
LeapSecondUpdated (num:18) (1 entry):
    0 (CDF_CHAR/8):           "20170101"
ParentIdentifiers (num:19) (1 entry):
    0 (CDF_CHAR/13):          "ABKsec_4_0001"
SamplingRate (num:20) (1 entry):
    0 (CDF_CHAR/7):           "1.0 sec"

Variable Attributes (8 attributes)
=====
DEPEND_0 (num:21)
DISPLAY_TYPE (num:22)
LABLAXIS (num:23)
FILLVAL (num:24)
VALIDMIN (num:25)
VALIDMAX (num:26)
FIELDNAM (num:27)
UNITS (num:28)

Variable Information (0 rVariable, 5 zVariables)
=====
DataTimes          CDF_TT2000/1      0:[]    T/
GeomagneticFieldX  CDF_DOUBLE/1      0:[]    T/
GeomagneticFieldY  CDF_DOUBLE/1      0:[]    T/
GeomagneticFieldZ  CDF_DOUBLE/1      0:[]    T/
GeomagneticFieldG  CDF_DOUBLE/1      0:[]    T/

Variable (5 variables)
=====

DataTimes (No: 0) (Recs: 2678400) (Compression: GZIP.6 BlockingFactor: 8192)
-----
Data Type:          CDF_TT2000
Dimensionality:     0:[]      (T/)
Compression:        GZIP.6
Pad value:          0000-01-01T00:00:00.000000000
Written Records:    2678400/2678400 (max)
Allocated Records:  2678400/2678400 (max)
Blocking Factor:    8192 (records)
Attribute Entries:
Variable Data:
  Record # 1: 2019-01-01T00:00:00.000000000
  Record # 2: 2019-01-01T00:00:01.000000000
  ...

GeomagneticFieldX (No: 1) (Recs: 2678400) (Compression: GZIP.6 BlockingFactor: 8192)
-----
Data Type:          CDF_DOUBLE
Dimensionality:     0:[]      (T/)

```

(continues on next page)

(continued from previous page)

```

Compression:          GZIP.6
Pad value:            -1.0e+30
Written Records:     2678400/2678400 (max)
Allocated Records:   2678400/2678400 (max)
Blocking Factor:     8192 (records)
Attribute Entries:
  DEPEND_0           (CDF_CHAR/22): "DataTimes"
  DISPLAY_TYPE       (CDF_CHAR/11): "time_series"
  LABLAXIS           (CDF_CHAR/1): "X"
  FILLVAL            (CDF_DOUBLE/1): nan
  VALIDMIN           (CDF_DOUBLE/1): -88880.0
  VALIDMAX           (CDF_DOUBLE/1): 88880.0
  FIELDNAM           (CDF_CHAR/27): "Geomagnetic Field Element X"
  UNITS              (CDF_CHAR/2): "nT"
Variable Data:
  Record # 1: 11283.1
  Record # 2: 11283.0
  ...

```

GeomagneticFieldY (No: 2) (Recs: 2678400) (Compression: GZIP.6 BlockingFactor: 8192)

```

-----
Data Type:           CDF_DOUBLE
Dimensionality:      0:[] (T/)
Compression:         GZIP.6
Pad value:           -1.0e+30
Written Records:     2678400/2678400 (max)
Allocated Records:   2678400/2678400 (max)
Blocking Factor:     8192 (records)
Attribute Entries:
  DEPEND_0           (CDF_CHAR/22): "DataTimes"
  DISPLAY_TYPE       (CDF_CHAR/11): "time_series"
  LABLAXIS           (CDF_CHAR/1): "Y"
  FILLVAL            (CDF_DOUBLE/1): nan
  VALIDMIN           (CDF_DOUBLE/1): -88880.0
  VALIDMAX           (CDF_DOUBLE/1): 88880.0
  FIELDNAM           (CDF_CHAR/27): "Geomagnetic Field Element Y"
  UNITS              (CDF_CHAR/2): "nT"
Variable Data:
  Record # 1: 1806.72
  Record # 2: 1806.67
  ...

```

GeomagneticFieldZ (No: 3) (Recs: 2678400) (Compression: GZIP.6 BlockingFactor: 8192)

```

-----
Data Type:           CDF_DOUBLE
Dimensionality:      0:[] (T/)
Compression:         GZIP.6
Pad value:           -1.0e+30
Written Records:     2678400/2678400 (max)
Allocated Records:   2678400/2678400 (max)
Blocking Factor:     8192 (records)
Attribute Entries:
  DEPEND_0           (CDF_CHAR/22): "DataTimes"
  DISPLAY_TYPE       (CDF_CHAR/11): "time_series"
  LABLAXIS           (CDF_CHAR/1): "Z"
  FILLVAL            (CDF_DOUBLE/1): nan
  VALIDMIN           (CDF_DOUBLE/1): -88880.0

```

(continues on next page)

(continued from previous page)

```

VALIDMAX      (CDF_DOUBLE/1): 88880.0
FIELDNAM      (CDF_CHAR/27): "Geomagnetic Field Element Z"
UNITS         (CDF_CHAR/2): "nT"
Variable Data:
  Record # 1: 52087.4
  Record # 2: 52087.4
  ...

GeomagneticFieldG (No: 4) (Recs: 2678400) (Compression: GZIP.6 BlockingFactor: 8192)
-----
Data Type:           CDF_DOUBLE
Dimensionality:      0:[] (T/)
Compression:         GZIP.6
Pad value:           -1.0e+30
Written Records:    2678400/2678400 (max)
Allocated Records:  2678400/2678400 (max)
Blocking Factor:    8192 (records)
Attribute Entries:
  DEPEND_0          (CDF_CHAR/22): "DataTimes"
  DISPLAY_TYPE      (CDF_CHAR/11): "time_series"
  LABLAXIS          (CDF_CHAR/1): "G"
  FILLVAL           (CDF_DOUBLE/1): nan
  VALIDMIN          (CDF_DOUBLE/1): -88880.0
  VALIDMAX          (CDF_DOUBLE/1): 88880.0
  FIELDNAM          (CDF_CHAR/28): "Geomagnetic Field Element DF"
  UNITS             (CDF_CHAR/2): "nT"
Variable Data:
  Record # 1: 0.0254182
  Record # 2: 0.0189378
  ...

```

FILTER COEFFICIENTS

F.1 Filter Coefficients to Produce One Minute Values

Time in second (s)	One Second Data	Five Second Data	Ten Second Data
t ₀	0.0251958	0.12578865	0.25100743
t ₁	0.02514602		
t ₂	0.02499727		
t ₃	0.02475132		
t ₄	0.02441104		
t ₅	0.0239804	0.11972085	
t ₆	0.02346437		
t ₇	0.02286881		
t ₈	0.02220039		
t ₉	0.02146643		
t ₁₀	0.0206748	0.10321785	0.20596804
t ₁₁	0.01983377		
t ₁₂	0.01895183		
t ₁₃	0.01803763		
t ₁₄	0.01709976		
t ₁₅	0.01614667	0.0806114	
t ₁₆	0.01518651		
t ₁₇	0.01422707		
t ₁₈	0.01327563		
t ₁₉	0.01233892		
t ₂₀	0.01142303	0.05702885	0.11379931
t ₂₁	0.01053338		
t ₂₂	0.0096747		
t ₂₃	0.0088509		
t ₂₄	0.0080653		
t ₂₅	0.0073204	0.0365468	
t ₂₆	0.0066181		
t ₂₇	0.0059596		
t ₂₈	0.0053454		
t ₂₉	0.0047755		
t ₃₀	0.0042496	0.02121585	0.04233562
t ₃₁	0.0037667		
t ₃₂	0.0033254		
t ₃₃	0.0029243		
t ₃₄	0.0025614		

continues on next page

Table 6.1 – continued from previous page

Time in second (s)	One Second Data	Five Second Data	Ten Second Data
t ₃₅	0.0022347	0.01115655	
t ₃₆	0.0019419		
t ₃₇	0.0016809		
t ₃₈	0.0014492		
t ₃₉	0.0012445		
t ₄₀	0.0010645	0.0053144	0.01060471
t ₄₁	0.000907		
t ₄₂	0.00077		
t ₄₃	0.000651		
t ₄₄	0.000548		
t ₄₅	0.000459	0.0022932	
t ₄₆			
t ₄₇			
t ₄₈			
t ₄₉			
t ₅₀			0.0017886

F.2 Filter Coefficients to Produce One Second Values

ACKNOWLEDGEMENTS

We gratefully acknowledge the many and significant contributions provided by past members of the Executive Council, the Operations Committee and the Data Checking Team.

- **EXCON**

William F. Stuart (UK)
Arthur W. Green Jr. (USA)
Richard L. Coles (Canada)
Jean-Louis LeMouël (France)
Larry Newitt (Canada)
Jeff Love (USA)
David Kerridge (UK)
Arnaud Chulliat (France)
Carol Finn (USA)
Alan Thomson (UK)

- **OPSCOM**

Lanny Wilson (USA)
Doug Trigg (Canada)
Francois-Xavier Lalanne (France)
Gerrit Jansen van Beek (Canada)
Michèle Bitterly (France)
Jacques Bitterly (France)
Volodya Papitashvili (USA)
John Riddick (UK)
Edward A. Sauter (USA)
Jennifer Parmelee (Canada)
Toyohisa Kamei (Japan)
Ole Rasmussen (Denmark)
Lee Pankratz (USA)
Donald Herzog (USA)
Laszlo Hegymegi (Hungary)
Danielle Fouassier (France)
Jean-Jacques Schott (France)
Manabu Kunitake (Japan)
Luc Decker (France)
Peter Crosthwaite (Australia)

Hans-Joachim Linthe (Germany)
Masahito Nosé (Japan)
Duff Stuart (USA)
Jean Rasson (Belgium)
Tim White (USA)
Sergey Khomutov (Russia)
Hiroaki Toh (Japan)
Benoit St-Louis (Canada)
Achim Morschhauser (Germany)
Margaret Pueringer (USA)

- **Data Checking Team**

Jennifer Parmelee (Canada)
Don Herzog, (USA)
Larry Newitt, (Canada)
Toyo Kamei, (Japan)
Danielle Fouassier, (France)
Jean Rasson, (Belgium)
Peter Crosthwaite, (Australia)
Jill Caldwell, (USA)
Ellen Clarke, (UK)
Sergey Khomutov, (Russia)
Lorne McKee, (Canada)
Nose Masahito, (Japan)
Juergen Matzka, (Germany)
Jake Morris, (USA)
Anca Isac, (Romania)
Hannelore Podewski, (Germany)
Achim Morschhauser (Germany)
Bill Worthington, (USA)
Kusumita Arora, (India)
Margaret Pueringer, (USA)