

BS ISO 16695:2014



BSI Standards Publication

Space environment (natural and artificial) — Geomagnetic reference models

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This British Standard is the UK implementation of ISO 16695:2014.

The UK participation in its preparation was entrusted to Technical Committee ACE/68/-/4, Space systems and operations - Space environment (natural and artificial).

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2014. Published by BSI Standards Limited 2014

ISBN 978 0 580 73121 1

ICS 49.140

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2014.

Amendments issued since publication

Date	Text affected
------	---------------

INTERNATIONAL STANDARD

ISO
16695

First edition
2014-02-15

Space environment (natural and artificial) — Geomagnetic reference models

*Environnement spatial (naturel et artificiel) — Modèles de référence
du champ magnétique terrestre*



Reference number
ISO 16695:2014(E)
Documents
Document Sharing Hub
© ISO 2014



COPYRIGHT PROTECTED DOCUMENT

© ISO 2014

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Reference frames	1
2.1 General	1
2.2 Geocentric reference frame	2
2.3 Geodetic reference frame	2
2.4 Geodetic to geocentric coordinate transform	3
3 Specification of the geomagnetic field vector	3
3.1 General	3
3.2 Magnetic vector components in the geocentric frame	4
3.3 Magnetic elements in the geodetic reference frame	4
3.4 Transform of magnetic vector components from geocentric to geodetic frame	6
4 Specification of the geomagnetic reference model	6
4.1 Potential of the magnetic field	6
4.2 Geomagnetic reference radius	8
4.3 Epoch of a sub-model	8
4.4 Validity of a sub-model	8
4.5 Time-dependence of Gauss coefficients	8
4.6 Calculation of magnetic vector components in the geocentric reference frame	9
4.7 Spatial wavelength	10
4.8 Root-mean-square difference between two model fields	10
5 Examples of the use of geomagnetic reference models	11
5.1 Compute reference magnetic elements near the Earth's surface	11
5.2 Compute reference magnetic vector in near-Earth space	11
5.3 Compute reference magnetic vector in magnetosphere	12
Annex A (informative) Available geomagnetic reference models	13
Bibliography	18

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

For centuries, geomagnetic reference models have been used to describe the vector field (for example, by its direction and strength) as a function of position and date. Such models are widely used in upper-atmospheric, ionospheric, and magnetospheric research, and in characterizing the near-Earth space environment. They further provide an essential reference for navigation, heading, and attitude determination and control subsystems of spacecraft and ground-based systems.

Earth's magnetic field is represented in such models as a spherical harmonic expansion of the equivalent scalar magnetic potential. This representation was proposed by Karl Friedrich Gauss (1777-1855) and has been used ever since to describe the geomagnetic field. The spherical harmonic coefficients of the geomagnetic field are commonly called Gauss coefficients. In 1969, the International Association for Geomagnetism and Aeronomy (IAGA) introduced the International Geomagnetic Reference Field (IGRF), which uses the Gauss representation to describe Earth's magnetic field. This International Standard closely mirrors the established specification of such models, including formulae and computational procedure.

There are several internal and external sources contributing to the observed magnetic field. All of these sources affect a scientific or navigational instrument, but only some of them are represented in geomagnetic reference models. The strongest contribution, by far, is the magnetic field produced by motions in the Earth's liquid-iron outer core, which is called the core field. This core field changes perceptibly from year to year. When extrapolating the temporal evolution of the field into the future, a linear extrapolation of the Gauss coefficients is used. Geomagnetic reference models specify the Gauss coefficients for a start date (epoch) and provide their linear change over time as a set of so-called secular variation (SV) coefficients. Due to unpredictable nonlinear changes in the core field, predictive geomagnetic reference models are valid only for a limited period, and users subsequently have to update to a newer version.

Other sources also contribute to the magnetic field. Magnetic minerals in the crust and upper mantle give rise to magnetic anomalies which can be significant locally. Electric currents induced by the flow of conducting sea water through the ambient magnetic field make a further, albeit weak, contribution to the observed magnetic field. Time-varying electric currents in the upper atmosphere and near-Earth space generate an external magnetic field. The external field does not average to zero over time. Its steady contribution can therefore be included in a geomagnetic reference model using external Gauss coefficients with linear secular variation. Time-varying external magnetic fields further induce electric currents in the Earth and oceans, producing secondary internal magnetic fields. Since there is no general consensus on how to separate these various internal and external sources, it is left to the producer of a geomagnetic reference model to specify which of these internal and external sources are included in their model, and any radial limitation to the validity of the external part of their model.

Space environment (natural and artificial) — Geomagnetic reference models

1 Scope

This International Standard defines reference models representing the geomagnetic field. It closely mirrors and clarifies specifications which have been in use for many decades.

The approach is to represent the corresponding scalar magnetic potential by a spherical harmonic expansion having specified numerical coefficients, called Gauss coefficients. This International Standard covers models in which, at any one time, changes of the magnetic field are modelled by a linear time-dependence of each Gauss coefficient. A model might consist of a succession of sub-models, in each of which the coefficients change linearly with time. For such a step-wise linear model, the coefficients are continuous in time. This International Standard provides the formulae and a step-by-step computational procedure to evaluate a geomagnetic reference model for any desired location and date.

This International Standard does not specify the interpretation of the geophysical content of a geomagnetic reference model. It is left to the producer of a model to specify which internal and external magnetic sources are included in (or excluded from) their model.

2 Reference frames

2.1 General

For positions remote from the Earth, it is customary to use a geocentric reference frame and to resolve the magnetic field vector into components based on this geocentric frame. For positions on and near the Earth's surface, it is customary to use a geodetic reference frame, based on the standard World Geodetic System (WGS84) ellipsoid of rotation approximating the Earth's surface, and to resolve the magnetic field vector into components based on this geodetic frame.

The down axis in the geodetic frame is perpendicular to the surface of the WGS84 ellipsoid. Deflections of the vertical caused by local gravity anomalies have to be taken care of by the user and are not covered by this International Standard (see [5.1](#)). Geocentric and geodetic coordinates are illustrated in [Figure 1](#).