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Space environment (natural and artificial) — Geomagnetic reference models

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

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Foreword

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

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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.

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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.

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