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Space environment (natural and artificial) — The Earth's ionosphere model — International reference ionosphere (IRI) model and extensions to the plasmasphere

Environnement spatial (naturel et artificiel) — Modèle de l'ionosphère de la Terre — Modèle de l'ionosphère internationale de référence (IRI) et extensions à la plasmasphère

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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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles,* Subcommittee SC 14*, Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 16457:2014), which has been technically revised.

The main changes are as follows:

— adding a description of the newly developed real-time IRI (Clause 9);

— replacing one of the plasmaspheric extension models (GPID) that is no longer available with the option to extrapolate the standard IRI to plasmaspheric altitudes;

— providing more detail and newer references for the IMAGE/RPI and IZMIRAN plasmaspheric extensions of IRI.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to identify a set of management guidelines for dealing with space systems engineering activities and is intended to define the minimum existing processes on the subject seeking to reach an international agreement on the topic.

Guided by the knowledge gained from empirical data analysis, this document provides guidelines for specifying the global distribution of electron density, electron temperature, ion temperature, ion composition, and total electron content through the Earth's ionosphere and plasmasphere. The model recommended for the representation of these parameters in the ionosphere is the international reference ionosphere (IRI).

IRI is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). These organizations formed a working group in the late 1960s to produce an empirical standard model of the ionosphere based on all available data sources. The IRI Working Group consists of more than 60 international experts representing different countries and different measurement techniques and modelling communities. The group meets annually to discuss improvements and additions to the model. As a result of these activities several steadily improved editions of the model have been released [18],[19],[20],[5],[6],[1],[2],[3],[53],[72],[73]. The homepage of the IRI project at http://irimodel.org/ provides access to the computer code (FORTRAN) of the latest version of the model and to earlier versions and to links to several related sites that use IRI for various applications.

For a given location over the globe, time, and date, IRI describes the monthly averages of electron density, electron temperature, ion temperature, and the percentage of O^+, H^+, He^+, N^+, NO^+, O_2^+, and cluster ions in the altitude range from 50 km to 1 500 km. In addition, IRI provides the electron content by numerically integrating over the electron density height profile within user-provided integral boundaries. IRI is a climatological model describing monthly average conditions. The major data sources for building the IRI model are the worldwide network of ionosondes, the powerful incoherent scatter radars, the topside sounders and in situ instruments flown on several satellites and rockets. This document also presents several empirical and semi-empirical models that can be used to extend the IRI model to plasmasphere altitudes.

One advantage of the empirical approach is that it solely depends on measurements and not on the evolving theoretical understanding of the processes that determine the electron and ion densities and temperatures in the Earth's ionosphere. A physical model can help to find the best mathematical functions to represent variations of these parameters with altitude, latitude, longitude, time of day, day of year, and solar and magnetic activity.

IRI is recommended for international use by COSPAR and URSI. The IRI model is updated and improved as new data and new sub-models become available. This document provides a common framework of the international standard of the Earth's ionosphere and plasmasphere for the potential users.

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1 Scope

This document provides guidance to potential users for the specification of the global distribution of ionosphere densities and temperatures, as well as the total content of electrons in the height interval from 50 km to 1 500 km. It includes and explains several options for a plasmaspheric extension of the model, embracing the geographical area between latitudes of 80°S and 80°N and longitudes of 0°E to 360°E, for any time of day, any day of year, and various solar and magnetic activity conditions.

A brief introduction to ionospheric and plasmaspheric physics is given in Annex A. Annex B provides an overview over physical models, because they are important for understanding and modelling the physical processes that produce the ionospheric plasma.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
ionosphere
region of the Earth's atmosphere in the height interval from 50 km to 1 500 km containing weakly ionized cold plasma

3.2
plasmasphere
torus of cold, relatively dense (> 10 cm^{-3}) plasma of mostly H^+ in the inner magnetosphere, which is trapped on the Earth's magnetic field lines and co-rotates with the Earth

Note 1 to entry: Cold plasma is considered to have an energy of between a few electronvolts and a few dozen electronvolts.

3.3
plasmapause
outward boundary of the *plasmasphere* (3.2) located at between two and six Earth radii from the centre of the Earth and formed by geomagnetic field lines where the plasma density drops by a factor of 10 or more across a range of *L*-shells of as little as 0,1

Note 1 to entry: The *L*-shell is a parameter describing a particular set of planetary magnetic field lines, often describing the set of magnetic field lines which cross the Earth's magnetic equator at a number of Earth-radii equal to the *L*-value, e.g. "*L* = 2" describes the set of the Earth's magnetic field lines which cross the Earth's magnetic equator two Earth radii from the centre of the Earth.