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Guide

Guide to Reference and Standard Ionosphere Models

Approved American National Standard

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Guide to Reference and Standard Ionosphere Models

Sponsored by

American Institute of Aeronautics and Astronautics

Approved May 2014

American National Standards Institute

Abstract

This guide assists in the selection of ionospheric models for engineering design or scientific research. It describes the content of the models, uncertainties and limitations, technical basis, databases from which the models are formed, publication references, and sources of computer codes for 46 ionospheric models. The models cover the altitude range from the Earth's surface to approximately 10,000 kilometers. This guide is intended to assist communication and space system designers and developers, geophysicists, space physicists, and climatologists in understanding available models, comparing sources of data, and interpreting engineering and scientific results based on different ionospheric models.

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Foreword

This *Guide to Reference and Standard Ionosphere Models* is sponsored by the American Institute of Aeronautics and Astronautics (AIAA) as part of its Standards Program.

The proliferation of ionospheric models and the lack of documentation have hindered general knowledge of their availability as well as their relative strengths, weaknesses, and limitations. The intent of this guide is to compile, in one reference, practical information about known and available ionospheric models—those that describe the physical properties and practical effects of the ionosphere as a function of altitude, latitude, and other key parameters. At this writing, the included models are those intended for general purpose, scientific, or aerospace applications and therefore extend to heights ranging from 50 to 10,000 km. Dynamical models of the ionosphere are included in this guide, as the dynamics are essential to many applications.

The guide summarizes the principal features of the models:

- Model content
- Model uncertainties and limitations
- Basis of the model
- Database or model input parameters
- Publication references
- Dates of development, authors, and sponsors
- Model codes and sources.

The models are grouped according to whether they describe primarily global, regional, or special properties.

There is limited information on standard deviations from the mean values or frequencies of occurrence of some of the variables described by these models. This limits quantitative assessments of uncertainties. Correlation distances for electron densities and statistics on scintillation are well defined. These and other statistics are discussed in the body of the guide. Candidates for inclusion in this guide have been solicited by means of advertisements in publications including announcements at national and international meetings of URSI, IAGA, AGU, COSPAR, AIAA, and scientific community newsletters. This collection of models is not exhaustive. It is hoped that future editions will include additional models from the international community.

We are indebted to those authors who submitted their models for inclusion, to those who offered valuable advice, to Jared Fulgham for notable assistance, and to the editors/reviewers: W. Kent Tobiska (Editor), Robert W. Schunk, Herbert C. Carlson, and Ludger Scherliess.

The first revision was prepared and approved in 1998. The second revision was initiated in 2010 and approved in March 2014 by the AIAA Atmospheric and Space Environments Committee on Standards (ASE CoS). At the time this document was balloted, the AIAA Atmospheric and Space Environments CoS included the following members:

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David J. Youker	General Electric Aviation

NOTE The cooperation of all those who provided input, both for the updates and new entries, is sincerely appreciated. Without their contributions, this significant revision of the *AIAA Guide to Reference and Standard Ionosphere Models* would not have been possible.

The ASE CoS acknowledges the following individuals who contributed to this guide: William H. Bauman, Craig D. Fry, Mike Newchurch, Fred Proctor, Andrew Shapiro, and John Wise.

This 2014 revision of *Guide to Reference and Standard Ionosphere Models* contains updated information on several models relative to information on references, sources, and so forth. In addition, a few of the models in the previous edition that are now obsolete have been replaced with updated versions. The model for which updated information is provided is the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM).

Some new models that have been added include the following:

1. The Assimilative Mapping of Ionospheric Electrodynamics (AMIE)
2. Global Assimilation of Ionospheric Measurements–Full Physics (GAIM-FP)
3. Global Assimilation of Ionospheric Measurements–Gauss-Markov (GAIM-GM)
4. JPL/USC GAIM: The Jet Propulsion Laboratory/University of Southern California Global Assimilative Ionospheric Model
5. Ionosphere Forecast Model (IFM)
6. Ionosphere-Plasmasphere Model (IPM)

7. Ionosphere-Polar Wind Model (IPWM)
8. Ionosphere-Polar Wind-PIC (IPW-PIC)
9. Thermosphere-Ionosphere Forecast Model (TIFM)
10. NRL SAMI2/SAMI3 Models
11. Texas Reconfigurable Ionosphere-Plasmasphere-Logarithmic Data Assimilator (TIPL-DA)
12. Weimer Electric Potential, Current, and Joule Heating Models
13. Incoherent Scatter Radar Ionospheric Models (ISRIMs)
14. Probabilistic Topside Ionosphere Model
15. PBMOD Time-Dependent Model of the Global Low-Latitude Ionosphere and Radio Scintillation

NOTE Every attempt has been made to obtain information from modelers in the community. However, ASETC CoS is aware that new models may have recently been developed and older models exist but may not have been incorporated into this document. We appreciate any information that could lead to reporting of models that are not included here.

The AIAA Atmospheric and Space Environments Committee on Standards (W. Kent Tobiska, Chairperson) approved this document for publication in March 2014.

The AIAA Standards Executive Council (Laura McGill, Chairperson) accepted this document for publication in April 2014.

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1 Scope

This guide describes the content of the models, uncertainties and limitations, technical basis, databases from which the models are formed, publication references, and sources of computer codes for 46 ionospheric models (see Table 1). The models cover the altitude range from the Earth's surface to approximately 10,000 km. It is intended to assist communication and space system designers and developers, geophysicists, space physicists, and climatologists in understanding available models and comparing sources of data, and interpreting engineering and scientific results based on different ionospheric models.

Table 1 — Summary of reference and standard ionospheres

Model (Page No.)	Geographic Region	Altitude Range (km)	Parameters	Species Included	Temporal Variation	Output Data Presentation	Principal Application
USU (5)	global	90–1000	N_e, N_i, T_e, $T_{i\parallel}$, $T_{i\perp}$, u_e, u_i	NO^+, O_2^+, N_2^+, N^+, O^+, H^+	10–100 sec	3D grid	scientific studies
NCAR/ TIE-GCM (7)	global	97–500	T_n, T_i, T_e, neutrals U, V, W	CO_2, O, O_2, $N(^4S)$, $N(^2D)$, O^+, O_2^+, NO^+, $N_e(cm^{-3})$	120 sec	tables, plots	scientific studies
CTIM (10)	global	80–10,000	N_e, N_i neutrals U, V, W T_n, T_e, T_i	O^+, H^+, NO^+, $O_2N_2^+$, N^+, O, O_2^+, N_2, NO, $N(^2D)$, $N(^4S)$	1–6 min	tables, plots	scientific studies
CTIP (12)	global	80–10,000	N_e, N_i neutrals U, V, W T_n, T_e, T_i, T_e	O^+, H^+, NO^+, O_2^+, N_2^+, N[illegible], O, O_2, N_2, NO, N(2D), N[illegible]	[illegible]15 min	tables, plots	scientific studies
GTIM (13)	global	90–22,000	N_e, N_i	NO^+, O_2^+, [illegible] H^+, He^+	diurnal with resolution of 15 min	tables, plots	theoretical climatology and development of parametric models such as PIM
PIM (15)	global	90–22,000	N[illegible], TE[illegible] [illegible]F_2, [illegible]$_mF_2$, [illegible], h_mE	O^+, NO^+, O_2	diurnal with resolution of 30 min	tables	theoretical climatology, systems design
IRI (17)	global	N_e: 50–20[illegible] T: 120–3[illegible] N_i: 1[illegible]–20[illegible]	N_e, T_e, T_i, N_i	O^-, H^+, He^-, NO, O_2^-, N_2^- cluster	diurnal (LT, UT, solar zenith angle), seasonal solar cycle	tables, interactive on WWW	spacecraft instrument design, satellite tracking, radio wave propagation, altimeter data analysis ray-tracing, education, etc.
EMI (20)	global coverage ([illegible]at)	50–4000	H^+, He^+, N_2^+, NO^+	N^+, O^+, O_2^+, N_e	diurnal seasonal solar activity	figures, tables	scientific studies
SU[illegible] ([illegible])	global	90–22,000	N_e, N_i, T_e, T_i	O^+, O_2^+, NO^+, H^+, He^+	diurnal with resolution of 15 min	tables	theoretical studies and climatology
F[illegible]P (25)	mid-lat	90–22,000	N_e, N_i, T_e, T_i	H^+, He^+, O^+, N^+, NO^+, O_2^+, $^+(^2D)$, $O^+(^2P)$, $N(^2D)$, $N(S^4)$, NO, $O(^1D)$, $N_2(vib)$	diurnal 1–30 min resolution	tables, plots	mid-latitude ionosphere-plasmasphere single ground comparison