

Guide

Guide to Reference and Standard Atmosphere Models

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Guide to Reference and Standard Atmosphere Models

Sponsored by

American Institute of Aeronautics and Astronautics

Approved October 2010

Abstract

This standard provides guidelines for selected reference and standard atmospheric models for use in engineering design or scientific research. The guide describes the content of the models, uncertainties and limitations, technical basis, data bases from which the models are formed, publication references, and sources of computer code where available for over seventy (70) Earth and planetary atmospheric models, for altitudes from surface to 4000 kilometers, which are generally recognized in the aerospace sciences. This standard is intended to assist aircraft and space vehicle designers and developers, geophysicists, meteorologists, and climatologists in understanding available models, comparing sources of data, and interpreting engineering and scientific results based on different atmospheric models.

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Foreword

This *Guide to Reference and Standard Atmosphere Models* has been sponsored by the American Institute of Aeronautics and Astronautics (AIAA) as part of its Standards program. Since the mid 19th century there has been considerable effort devoted to the development of standards and reference atmosphere models. The first “Standard Atmospheres” were established by international agreement in the 1920s. Later some countries, notably the United States, also developed and published Standard Atmospheres. The term *reference atmospheres* is generally used to identify atmosphere models for specific geographical locations or globally.

The proliferation of atmospheric models and the lack of documentation have hindered general knowledge of their availability as well as information on their relative strengths, weaknesses, and limitations. The intent of this guide is to compile in one reference practical information about some of the known historical and available atmospheric models—those which describe the physical properties and chemical composition of the atmosphere as a function of altitude. The inclusion in this Guide of information on the various reference and standard atmosphere models is not meant to imply endorsement by the AIAA of the respective model. Also, inputs provided on the models were based on the information available at the time the entry was originally prepared.

The included Earth and other planetary models are those intended for general purpose or aerospace applications. The information provided, while deemed current at time of inclusion in the summary write-ups, may or may not still be current at the time of this version of the Guide is published. Therefore, the reader should further research the information before making decisions on usage of the model(s) of interest. The models extend to heights ranging from as low as the surface to as high as 4000 km. Models describing exclusively low altitude phenomena are not included. Possible examples of the latter are particulate aerosols or pollutants in the boundary layer and cloud properties as a function of altitude in the troposphere. Dynamical models such as the Earth Troposphere-Stratosphere General Circulation Models (GCM), the Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIME-GCM), and research reports on measurements made by satellite, aircraft, and ground systems of the atmosphere are also not included in this guide.

The guide summarizes the principal features of the models to the extent the information is available:

- Model content
- Model uncertainties and limitations
- Basis of the model
- Publication reference
- Dates of development, authors, and sponsors
- Model codes and sources

The models are listed in the table of contents according to whether they are primarily global, middle atmosphere, thermosphere, range, or regional (i.e., applying only to a specific geographic location). This division is admittedly somewhat arbitrary because many of the models embody elements of several of the categories listed.

With few exceptions, there is no information on standard deviations from the mean values or frequencies of occurrence of the variables described by these models. This lack of information prohibits quantitative assessments of uncertainties, and it is a serious deficiency in nearly all reference and standard atmospheric models.

Candidate models for inclusion in this guide have been solicited by means of advertisements in several publications including *AIAA/Aerospace America*, *AGU/EOS*, *WMO Bulletin*, *Physics Today*, and *Bulletin of the American Meteorological Society*.

Announcements have also been made at meetings of the Committee on Space Research (COSPAR), the AIAA, American Meteorological Society, and the American Geophysical Union. Despite this effort, this collection of models is far from complete, particularly in the international sphere. It is hoped that future editions will include more models from Europe, Asia, and the Southern Hemisphere. Recommendations for models to include in subsequent revisions will be welcomed.

We are indebted to those authors who submitted their models for inclusion, to those who offered encouragement and valuable advice, and especially to the original Guide reviewers: Kenneth R. W. Champion (Air Force Geophysics Laboratory), Richard Jeck (Naval Research Laboratory), Gerald M. Keating (NASA Langley Research Center), Billy M. McCormac (Lockheed Missiles and Space Co.), and Richard P. Turco (Department of Atmospheric Sciences, University of California, Los Angeles). The 1996 edition incorporated changes provided by William W. Vaughan (University of Alabama in Huntsville) including review comments by Dale L. Johnson (NASA Marshall Space Flight Center), C. G. Justus (Computer Sciences Corporation), and Stephen Pravelity (Sverdrup Technology, Inc.). The 2004 and 2010 editions of the *Guide to Reference and Standard Atmosphere Models* were prepared under the direction of William W. Vaughan (University of Alabama in Huntsville). The Guide will be further modified when additional data become available.

The NASA Technical Standards Program provided assistance in the preparation of this 2010 edition of AIAA G-003C.

The original document was approved by the AIAA Reference and Standard Atmosphere Models Working Group membership in May 1989. The AIAA Atmospheric Environment Committee on Standards approved the document in June 1989. The AIAA Standards Technical Council approved the document in November 1989. The AIAA Standards Executive Council approved the document in January 1990.

The first revision was prepared and approved in 1996. The second revision was initiated in 2002 and approved in 2004 by the AIAA Atmospheric and Space Environments Committee on Standards (ASE CoS).

At the time of this 2010 revision, the AIAA Atmospheric and Space Environments CoS included the following members:

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William H. Bauman	AFNSCO
Andy Broeren	NASA Glenn Research Center
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W. Kent Tobiska	Space Environment Technologies
William W. Vaughan	University of Alabama in Huntsville
John Wise	Air Force Research Laboratory
David J. Youker	General Electric Aviation

The committee acknowledges the assistance of William Freiss, independent consultant, on the development of this standard.

This 2010 revision of *Guide to Reference and Standard Atmosphere 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.

Some of the models for which updated information is provided include the following:

1. NRLMSISE-00 Thermosphere Model, 2000
2. U. S. Air Force High Accuracy Satellite Drag Model, 2004
3. 22 Range Reference Atmospheres (RRA), 2006
4. COSPAR International Reference Atmosphere (CIRA), 1986
5. AFGL Atmospheric Constituent Profiles, 1986
6. U. S. Standard Atmosphere, 1976

Some new models that have been added include the following:

1. NASA/MSFC Venus Global Reference Atmospheric Model (Venus-GRAM), 2003
2. IGO Global Reference Atmosphere Model, 2004
3. International Reference Ionosphere (IRI), 2007
4. Drag Temperature Model-Thermosphere Model, 2001
5. Jacchia-Bowman Empirical Thermosphere Density Model, 2006

6. Jacchia-Bowman Empirical Thermosphere Density Model, 2008
7. Russian Earth's Upper Atmosphere Density Model For Ballistic Support of the Flight of Artificial Earth Satellites, 2004
8. China National Standard Atmosphere, 1980
9. The Mars Climate Database, 2008
10. Horizontal Wind Model (HWM), 1993 (with note regarding HWM07)
11. Exosphere Hydrogen Model, 1994
12. COSPAR International Reference Atmosphere (CIRA), 2008
13. SHARC/SAMM Atmosphere Generator, SAG-2, 2003
14. NASA/MSFC Earth Global Reference Atmosphere Model (Earth-GRAM-07), 2007
15. NASA Marshall Engineering Thermosphere Model Version 2007 (MET-2007), 2007
16. Russian Direct Density Correction Method (DDCM), 2004

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

The AIAA Atmospheric and Space Environments Committee on Standards (W. Kent Tobiska, Chairperson) approved this document for publication in November 2009.

The AIAA Standards Executive Council (Wilson Felder, Chairman) accepted this document for publication in October 2010.

The AIAA Standards Procedures provide that all approved Standards, Recommended Practices, and Guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any AIAA standards publication and no commitment to conform to or be guided by a standards report. In formulating, revising, and approving standards publications, the Committees on Standards will not consider patents which may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents or copyrights, or both.

1 Scope

This standard provides guidelines for selected reference and standard atmospheric models for use in engineering design or scientific research. The 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 code where available for over seventy (70) Earth and planetary atmospheric models, for altitudes from surface to 4000 kilometers, which are generally recognized in the aerospace sciences. This standard is intended to assist aircraft and space vehicle designers and developers, geophysicists, meteorologists, and climatologists in understanding available models, comparing sources of data, and interpreting engineering and scientific results based on different atmospheric models.

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Recommendations for models to include in subsequent revisions will be welcomed.

2 Applicable Documents

The following document contains provisions which, through reference in this text, constitute provisions of G-003C. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

AIAA-2003-0894 Atmospheric Models for Engineering Applications

3 Terms and Definitions

For the purposes of AIAA-G-003C, the following terms and definitions apply.

3.1

reference atmospheres

defined by the vertical temperature profiles for each latitude and season; atmosphere models for specific geographical locations or globally