PROPOSED STANDARD PLASMASPHERE–IONOSPHERE MODEL FOR ISO

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ABSTRACT

To produce Standard Plasmasphere–Ionosphere Model, the working group on Space environment (natural and artificial) of the International Standardization Organization, ISO, has recommended that the International Reference Ionosphere electron temperatures and electron density profiles below 1000 km have been extended towards 20,000 km with SMI plasmasphere model. Further developments of the ISO standard are planned to combine the IRI electron density at low and mid-latitudes with SMI high latitude peak electron density and effective collision frequency models. While IRI and SMI present morphology of the ionosphere-plasmasphere structure in a statistical sense, proper ingestion of the past history of magnetic activity, foF2 and/or TEC observations makes ISO standard model capable to provide forecast of magnetic indices, 3-D electron density profile and TEC three hours ahead. Results of TEC forecast are illustrated with GPS observations.

INTRODUCTION

Currently, the navigational Global Positioning System (GPS) satellites transmitting signal through the plasmasphere and ionosphere from 20,000 km over the Earth to the ground receivers become an important source of information for terrestrial, trans-ionospheric and satellite-to-satellite communications. For specification of structure and dynamics of plasma in the both areas, the theoretical, semi-empirical and fully empirical models are being developed by different groups (see, e.g. [1-6]). With a variety of models the potential users are often make preference by simple criteria, such as model availability, easy to use, non-commercial conditions of model access, etc. To meet increasing demands of the users for modeling and forecasting of the space weather through the ionosphere and plasmasphere the internationally agreed standard model for such evaluation is initiated by the International Standardization Organization, ISO.

The ISO/TC20, Technical Committee on Aircraft and Spacecraft, ISO/TC20/SC14 Subcommittee on Space Systems and Operations, and ISO/TC20/SC14/WG4 Working Group on Space Environment (Natural and Artificial) has initiated the Project of the international standard entitled (ISO Working Draft WD 16457): "Space environment (natural and artificial). Earth's Ionosphere and Plasmasphere. Model of distribution of density, temperature and effective collision frequency of electrons". In the framework of the ISO Project the International Reference Ionosphere, IRI [1] is complemented with the plasmasphere option and the effective collision frequency model of the Russian Standard Model of the Ionosphere, SMI [2]. Proposed international standard is aimed to define distribution of density, temperature, and effective collision frequency of electrons in the Earth's ionosphere and plasmasphere for the height range from 65 km to 20,000 km (or to the plasmapause if it is greater than 20,000 km) at any longitude, geographic latitudes from 80°N to 80°S, for any time of day, day of year, and wide range of the solar and magnetic activity indices. The 1st software package of the standard model called ISOMAIN2 has been released in September, 2001 [3].

The IRI is one of the internationally agreed standard models initiated by Karl Rawer, Freiburg, Germany, under patronage of Committee on Space Research (COSPAR) and International Union of Radio Science (URSI). The IRI software is maintained and permanently improved by Dieter Bilitza at the National Space Science Data Center, Greenbelt, MD, USA, with the deliberate contributions of many authors world-wide. ISO_IRI part describes the electron density, total electron content, electron and ion temperatures at the altitude range from 50 km to 1000 km. It provides monthly averages in the non-auroral ionosphere for magnetically quiet conditions. On a short-term scale ISO_IRI selection includes storm-time updating procedure [7] with input of geomagnetic ap-indices.

The classical way in which geophysicists normally construct models, namely in so-called “quiet” conditions implies an assumption that these conditions would only occasionally abandonned. Yury Chasovitin however built a model in which the disturbance activity is a leading variable [2]. Apart from a probably more adequate model of the plasmasphere the SMI construction opened at the same time a way to assess ionospheric disturbances by their plasmaspheric origin [8]. Instead of describing variation of plasma in the plasmasphere along the field lines [4-5], the SMI code similar to [6] is based on an analytical description of empirical vertical electron density profile distribution with height from the bottom of the ionosphere to the plasmapause.

COMPOSITION OF ISO STANDARD MODEL SOFTWARE

The components of the IRI and SMI models of distribution of Ne and Te are developed directly using experimental data. The major data sources are the worldwide network of ionosondes, the incoherent scatter radars, the ISIS, Alouette, ISSb and Interkosmos-19 topside sounders, whistler observations through the plasmasphere, and in situ instruments on satellites and rockets. The total electron content TEC measurements have not been used as a data source in constructing the models so they can serve as a tool for the model testing and applications. In particular, the GPS observations can provide unique TEC database for evaluating and update of the ISO model [9].

A number of different public domain models are included in the ISO standard. In particular, COSPAR Reference Atmosphere Model is used for producing the neutral temperature [10]. The model of distribution of the effective collisions frequency, Nu, is calculated with the models of Ne, Te and neutral atmosphere parameters by the formulae of gas-kinetic theory. Geomagnetic Reference Field models are used to produce the ionosphere – plasmasphere driving parameters including modified dip latitude [11] and corrected magnetic latitudes and longitudes [12]. CCIR predictions of the F2 layer peak parameters [13] are used.

At present, for given location, time and date, and wide range of the solar and magnetic activity indices the ISOMAIN2 software provides 3-D image of the ionosphere and plasmasphere up to the plasmapause. Further developments of ISO standard are planned using SMI sub-auroral trough and polar cap models and the effective collision frequency calculations. Figure 1 presents an example of future extension of ISO standard to produce night-time trough model of TEC under moderately disturbed magnetosphere conditions (kp=3) for the low solar activity. When compared with GPS-driven NTCM2 map of TEC (Figure 1a) the sub-auroral trough of ionization (Figure 1b) is reproduced with original SMI code at the interface between the middle and auroral latitudes [14].

The IRI, SMI, and ISO standard model present morphology of the ionosphere-plasmasphere structure in a statistical sense. However, these are often unable to represent in a realistic way the spatial structure and temporal development of even the large-scale features in electron density present on any given day. For allowance of daily-hourly variability of the ionosphere, the ISO_IRI storm-time update [7] describes changes in the F2 layer peak electron density NmF2 in terms of Api index integrated from 3-hourly ap-indices for 39 hours preceding given time.The ISOMAIN2 plasmapause altitude is driven by Kpm index presenting forecast of planetary kp-index 3 hours in advance based on the history of kp-indices for preceding 12 hrs ranked by decreasing order [15]. Forecast of magnetic activity yields the foF2, Ne(h) profile and TEC forecast if CCIR quiet prediction is improved by foF2 observed quiet reference median (or TEC-derived an artificial F2 layer critical frequency) based on the past history of the ionosonde (or GPS-TEC) observations [16].

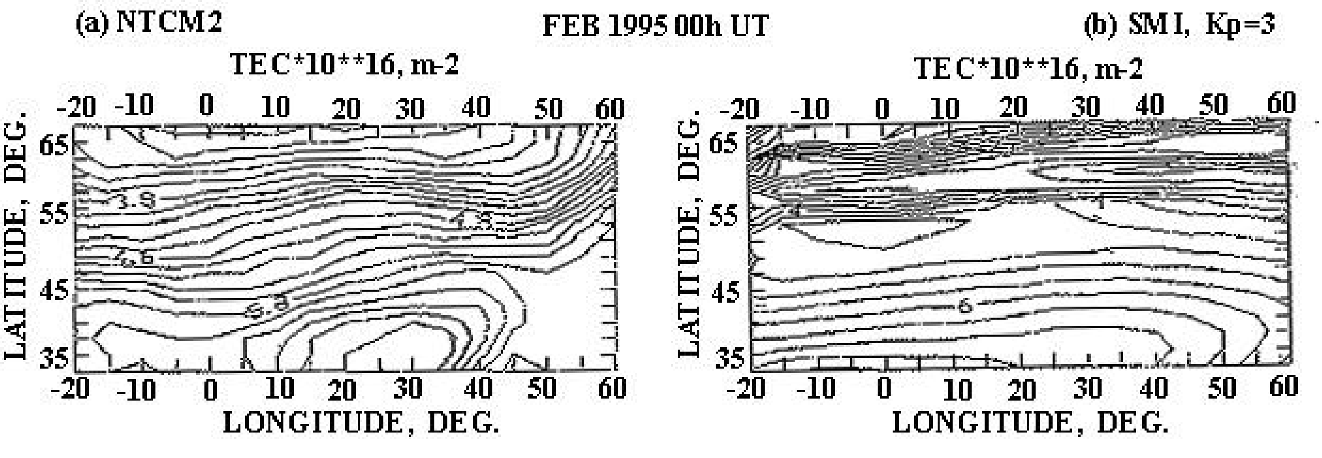

Fig.1. (a) GPS-derived TEC map NTCM2, and (b) SMI produced map of winter nighttime high latitude trough of ionization at moderate magnetosphere disturbance (kp=3), low solar activity (Rz=30), February, 1995.

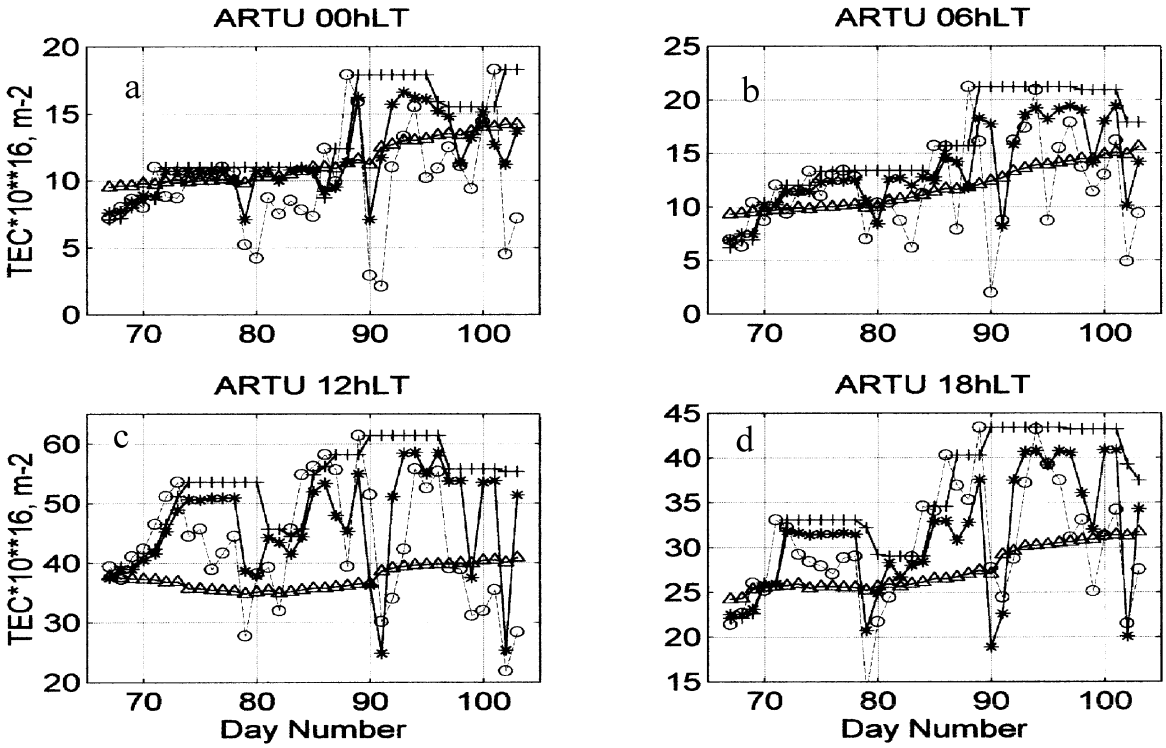

Fig. 2. Comparison of GPS-derived TEC at Artu (58.6°N, 56.4°E), at four selected local times for a period of 8 March to 13 April 2001 (high solar activity, sunspot number Rz = 95) with ISOMAIN2 model forecast. Daily observations (circles), CCIR median predictions (triangles), reference TECmax during 7 preceding days (crosses), TEC forecast with ISOMAIN2 storm update adjusted to 7-days peak TEC (stars).

Example of TEC forecast is given in Figure 2. Algorithm for TEC evaluation [8] is applied here to differences of simultaneous dual-frequency code and carrier phase GPS observations at Artu (Sverdlovsk). GPS-based measurements during March – April 2001 are provided by Grigory Steblov, Institute of Physics of the Earth, Moscow, Russia. The instrumental differential delays and carrier phase TEC inversion show negligible differences in TEC so only results of the carrier phase inversion are shown here. Four selected frames refer to local midnight, sunrise, noon, and sunset hours for the days of 8 March to 13 April, 2001, with an intense magnetic storm on 31 March 2001. The 1st iteration of ISOMAIN2 code with CCIR predictions of foF2 yields CCIR-TEC (triangles) for the monthly average conditions failing to represent time-corresponding day-to-day TEC variations (circles). Replacing CCIR-TEC by peak TEC for 7 days preceding any given day (crosses) the 2nd iteration of ISOMAIN2 code producing forecast of magnetic activity 3 hrs ahead yields TEC forecast (stars) resembling GPS-derived TEC.

The input data file for ISOMAIN2 code includes: geodetic or geomagnetic latitude and longitude, the date (year, month, day), local or universal time, sunspot number (optional), magnetic kp-index (optional), the F2 layer critical frequency (optional) and/or F2 layer peak height (optional). IRI-based IG_RZ.dat, ap.dat, CCIR.asc data files, and SMI-based BIN12 file are used as the input. Output of the full electron density profile up to the plasmapause is accompanied by series of standard output parameters: year, day, UT and LT times, solar zenith angle, sunspot number, solar radio flux, geomagnetic Kpm and Api indices, geodetic and geomagnetic coordinates, modified dip latitude, foF2, hmF2, NmF2, electron density at the upper boundary of the ionosphere (hs=1000km), the plasmapause altitude and electron density, TEC up to the plasmapause and its parts in the bottomside and topside ionosphere and the plasmaspheric electron content.

CONCLUSION

For a model to be approved as the internationally agreed standard for the users, a number of open issues should be resolved: the best produced results, easy to use, availability of the source model, compatibility with application software, adoption by model developing community, relation to other standards, drawbacks of the model. In this respect the International Reference Ionosphere is better familiar to the users as the standard ionosphere model.

However to meet modern communication needs the ionosphere model alone is not sufficient. The spatial extension of IRI above 1000 km with SMI plasmasphere option is reasonable solution for combined Standard Plasmasphere-Ionosphere Model. On the temporal scale, the stormtime updating procedure of IRI complemented with forecast of magnetic activity 3 hrs in advance provides step forward from the climatological monthly-mean IRI and SMI models towards the dynamic space weather forecasting capability. The software package of the 1st Issue of the ISO proposed standard model producing electron density profile and the total electron content through the ionosphere and plasmasphere is available for the users. Amendments with SMI high latitude ionosphere subroutines and the effective collision frequency model are planned for the next generations of the ISO software. It is hoped that the proposed model could be considered by ISO as a potential model standard.

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