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INTER-PROGRAMME COORDINATION TEAM ON SPACE WEATHER

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FORMATS FOR GNSS TEC AND OTHER DATA

(Submitted by I. Stanislawska)

Summary and Purpose of Document

This document provides details on RINEX and IONEX formats for GNSS TEC data.

The Appendix contains additional information on:
- ISO standard for ionosphere specification;
- ISO standard for dosimetry aboard civilian aircraft;
- INAG format for ionosonde data;
- ISES formats;
- Radio-occultation.

ACTION PROPOSED

The Inter-Programme Coordination Team is invited to comment on the usefulness of the presented formats.

APPENDIX: Additional background on codes and format issues

REFERENCES:

A. RINEX Version 3.02 (ftp://igscb.jpl.nasa.gov/pub/data/format/rinex302.pdf)

B. IONEX Version 1 Format (http://igscb.jpl.nasa.gov/igscb/data/format/ionex1.pdf)

C. GNSS-TEC exchange (GTEX) format : See ICTSW-4/Doc. 8.2(2)

DISCUSSION

1. INTRODUCTION

1.1 Background

The Receiver Independent Exchange Format (RINEX) is a data exchange format for raw satellite navigation system data. This allows the user to post-process the received data to produce a more accurate solution — usually with ancillary data unavailable to the original receiver such as better models of the atmospheric conditions at the time of measurement.

Processing of GNSS signals enables the recovery of the total electron content (TEC) presented in IONEX format. The proposed GTEX format presents TEC data in a simpler and more friendly manner than IONEX.

1.2 Scope of the document

This document provides a brief description of the proposed formats for evaluation and seeks the endorsement of ICTSW to proceed with the utilization of these formats

2. PROPOSED FORMATS

2.1 GNSS data

An important task of the CDDIS (The Crustal Dynamics Data Information System) (See: http://cddis.nasa.gov/cddis.html) and other GNSS services such as the International GNSS Service (IGS) (See: http://igscb.jpl.nasa.gov/) or the EUREF Permanent Network (EPN) (See: http://www.epncb.oma.be/) is to provide the GNSS data as well as products such as precise GNSS orbits, satellite clocks corrections, ionospheric TEC maps. That data is worldwide used in many research projects and is for the profit of the entire space weather community. The GNSS data is stored and disseminated in open format specially prepared for all GNSS users and independent from the type of GNSS receivers. That format is called The Receiver Independent Exchange Format (RINEX). Its subsequent versions included the development of the GNSS systems. The first proposal for the Receiver Independent Exchange Format RINEX was developed by the Astronomical Institute of the University of Berne for the easy exchange of Global Positioning System (GPS) data to be collected during the first large European GPS campaign EUREF 89, which involved more than 60 GPS receivers of 4 different manufacturers.

The newest version 3.02 (see RINEX 3.02.IGS.RTCM.doc, RINEX The Receiver Independent Exchange Format Version 3.00, Werner Gurtner and Lou Estey in Reference 1) supports GNSS observations from GPS, GLONASS, Galileo, SBAS, QZSS, BeiDou.

The RINEX version 3 format consists of three ASCII file types:
1. Observation data File
2. Navigation message File
3. Meteorological data File

The data stored in RINEX format is easy to use and clear to understand by users from different disciplines. See details in Reference A.

Total Electron Content Grid (TEC Grid) have a specified resolution, e.g. 5° longitude x 2.5° latitude (current IGS specification) in IONEX files. Time resolution, 1 or 2 hr, and file size are dependent on the spatial and temporal resolutions.

Daily files from IGS with two-hour temporal and 5°x2.5° spatial resolution are approximately 1 MB large.

Efforts to minimize RINEX file size without losing information has been done by Yuki Hatanaka (hatagsi.go.jp) (GSI) He wrote and maintains rnx2crx and crx2rnx, which allows the user to compress/decompress a RINEX OBS file into a smaller ASCII format. The Hatanaka-compressed ASCII format version of a RINEX OBS file is frequently used in conjunction with the UNIX compress,zip, gzip or other generalized compression utilities to create a very small file for Internet transfer.

2.2 Ionospheric data

This product is part of the offer of permanent GNSS services for wide scientific community. It provides the ionospheric TEC global maps. They are stored in IONEX format containing Ionospheric delay parameters (one file per day) containing hourly maps of TEC values. They are prepared as daily files with two-hour temporal and 5°x2.5° spatial resolution in UT x Longitude x Latitude. The final IGS global maps are computed with a latency of about 11days while the Rapid products are generated with latency below 24 hours. Related to the ionosphere product is the estimation of the differential code biases (DCB). The TEC is computed with a precision better than 10 TECU in post-processing (IGS on its webpage at http://igscb.jpl.nasa.gov/components/prods.html: 2-8 TECU for final TEC grid, 2-9 TECU for rapid TEC). On those maps TEC is presented as values computed from many stations and because of spatial resolution some, especially small, disturbances could be lost.

The IONEX format has been described in IONEX: The IONosphere Map Exchange Format by Stefan Schaer and Werner Gurtner. The product is already available on line. See details of format description in Reference B

Another proposal, unfortunately still weakly documented is the GTEX format presented by Takuya Tsugawa from National Institute of Information and Communications Technology (NICT), Japan. It describes the TEC values observed by a single receiver. NICT have developed the database of “GTEX” data for more than 5,000 GNSS receivers in the world. These data are available via the NICT science cloud, OneSpaceNet (OSN). This format is not popular now for data sharing, but it has the potential to be widely used in the future. It opens possibility for user to analyze TEC changes in epoch to epoch interval. It is possible to compute ionospheric TEC data from each RINEX file. More detailed information on that format is necessary. See details in Reference C.

3. CONCLUSION

The described formats (RINEX and IONEX) are widely used by the Space Weather community, end users and other interested parties. It is necessary to obtain more information about GTEX format. It seems to be more useful for raw ionospheric data exchange than IONEX, which present TEC data in development of spherical harmonics. We should mention that the GNSS data and products distributed by permanent services CDDIS, IGS and EPN are free of charge and a huge database of archive files is available.

ADDITIONAL BACKGROUND ON CODES AND FORMAT ISSUES

Data formats should follow standards

What is a standard?

A standard is “a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose” (From International Organization for Standardization).

1. Standards developed by the International Organization for Standardization (ISO)

1.1 ISO/TS 16457:2009

Space systems -- Space environment (natural and artificial) -- The Earth's ionosphere model: international reference ionosphere (IRI) model and extensions to the plasmasphere.

- **Edition** 1
- **Stage**90.92
- **TC**ISO/TC 20/SC 14
- **ICS**49.140; 07.060
- **Documentavailable as of** 2009-02-03

Abstract : ISO/TS 16457:2009 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.

1.2 ISO 20785-1:2012

Dosimetry for exposures to cosmic radiation in civilian aircraft -- Part 1: Conceptual basis for measurements

- **Edition** 2
- **Stage**60.60
- **TC**ISO/TC 85/SC 2
- **ICS**49.020; 13.280
- **Document available as of** 2012-12-14

Abstract: ISO 20785:2012 gives the conceptual basis for the determination of ambient dose equivalent for the evaluation of exposure to cosmic radiation in civilian aircraft and for the calibration of instruments used for this purpose.

2. Standards accepted by the Ionosonde Network Advisory Group (INAG)

INAG, a Working Group of URSI Commission G, is responsible for:

- collecting together information on the analysis of ionograms,
- maintaining conventions for the reduction of ionograms,
- providing a forum for people interested in obtaining reliable data from ionograms,
- preserving the Global ionospheric climate record.

The standardized format endorsed by INAG for ionospheric sounding measurements is the SAOXML 5 elaborated on the basis of the Standard Archiving Output (SAO) format in eXtensible Markup Language (XML). It is a format of exchange data not its storage. It contains variable amount of metadata. Format is supported by various software libraries.

Description and examples can be found at: http://ulcar.uml.edu/SAOXML/

SAO Record Info

Format Version	5.0
Start Time UTC	2009-04-06 -096 05:00:00.000
URSI Code	HE13N
Station Name (UMLCAR ID 934)	HERMANUS
GeographicLatitude	-34.42
GeographicLongitude	19.22
Source	Ionosonde
Source Type	DPS-4D
ScalerType	auto

FrequencyStepping

Start Frequency	0.3 MHz
Stop Frequency	12.0 MHz
LinearStepping	0.025MHz

RangeStepping

Start Range	80.0 km
Stop Range	1360.0 km
LinearStepping	2.5km

Autoscaler	Artist5
Version	500200
Artist Flags	1 2 0 0 0 0 0 0 0 11 0 0 0 0 0 0 0 0 0 0
Comments	AR.5002.31, NH 4.32 Confidence: 95% PACIFIC flags: Multiple candidates fo
Start Time	2009.04.06 (096) 05:00:00
Format	yyyy.MM.dd (DDD) HH:mm:ss
Time Zone	Coordinated Universal Time

Solar Terrestrial Data

GyroFrequency	Value: 0.67 Model: IGRF Altitude: 300
Dip Angle	Value: -64.40 Model: IGRF Altitude: 300
Sun Spot Number	Value: -1.0 Status: predicted

3. Standard endorsed by the International Space Environment Service (ISES)

It is an answer to the need of fast distribution of large amount of data between partners of that are able to construct and direct their services to meet the specific needs of their own customers mostly in coded format. Users of the RWC services are very diverse and in fact vary quite substantially from centre-to-centre according to the needs of the nation in which the RWC resides. The standard in this case is verified by the number of subscribers and their commercial interest and benefit.

Occultation - Summary

A GNSS receiver on a Low Earth Orbit satellite can determine temperature and water vapour profiles when measuring GNSS links in occultation geometry. Additionally, a positioning antenna is required. This type of data has a large impact in Numerical Weather Prediction and big potential for climate monitoring (main limitation is that the current data record covers only about 10 years).

The processing requires knowledge of the GNSS orbits and clocks in near real time. However, operational radio occultation measurements are not widely used, but carry a certain potential, and together with ground based observations can be applied to meteorological and climate applications.