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DATA AND PRODUCT EXCHANGE IN THE CONTEXT OF WIS

ITU discussions on ionospheric products and formats

(Submitted by the WMO Secretariat)

Summary and Purpose of Document

The appendix to this document is a working document communicated to the Secretariat by the International Telecommunications Union (ITU), which relates to the definition of new digital products for trans-ionospheric propagation. It contains draft high-level product specification and format proposals.

It is emphasized that the material in appendix is a working document which does not reflect the official position of ITU.

ACTION PROPOSED

The Inter-Programme Coordination Team is invited to take note of the material in appendix and to consider the opportunity to provide comments to ITU.

Radiocommunication Study Groups

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Annex 2 to
Document 3L/63-E
1 July 2013
English only

Annex 2 to Working Party 3L Chairman's Report

WORKING DOCUMENT TOWARDS THE DEFINITION OF NEW DIGITAL PRODUCTS FOR TRANSIONOSPHERIC PROPAGATION

During the last WP 3L meetings, a number of contributions related to digital products for transionospheric propagation have been submitted by a number of administrations evidencing the lack of a number of digital products, in particular reference datasets and Study Group 3 data formats for model verification and prediction of propagation characteristics. Other digital products exist for the prediction methods in tropospheric propagation, multipath and radio noise (Rec. ITU-R P.311 and Study group 3 databanks and DGSG3). It is considered that statistical experimental data and related tables would be beneficial for Study Group 3 in the area of (trans)-ionospheric propagation.

It is important to remark that the aim of Study Group 3 is not to archive raw data from individual experiments, but instead relevant statistical parameters and reference datasets for prediction and evaluation of propagation models.

In this document, the work plan for the establishment of relevant digital products on transionospheric propagation is described. The following workplan is defined:

1) The definition of new Study Group 3 table formats incorporating statistics relevant analysis, at least for the following types of experimental data and products:
   - a) Global and regional Vertical Total Electron Content (VTEC) grid maps.
   - b) Ground-based location specific Vertical or Slant Total Electron Content (STEC) from GNSS experiments or inverted from ionosondes.
   - c) Space-based TEC for specific tracks/passes (from altimeters or radio-occultation experiments).
   - d) TEC variability for the type of experiments (as Rate-of-TEC along arc, temporal gradient, etc…).
   - e) Ionospheric scintillation fading and phase variation statistics.
2) The draft revision of Recommendation ITU-R P.311 in order to reflect the new table formats.
3) The publication of WP 3L Fascicle including the requirements for experimental data relevant for analysis and generation of new tables, description of statistical analysis procedures to fill the tables, testing variables for testing quality of data and models.
4) The inclusion of Tables in DBSG3 database and the population of such tables with reference relevant data.

A first draft of the Fascicle is described in Appendix 1.

APPENDIX 1

Draft new fascicle on "Definition, experimental requirements, analysis and testing variables for SG 3 tables on transionospheric propagation"

Scope

This fascicle provides the definition of parameters of in SG 3 tables for transionospheric propagation, the experimental requirements and recommended exchange formats, the description of procedures of statistical analysis for populating SG3 tables and the testing variables to be used.

[Remark: This document is prepared as a draft document.]

1 Definition of parameters and association with tables

Global and regional Vertical Total Electron Content (VTEC) and VTEC rate grid maps

– Monthly median for different solar activity periods including its variability.

– Seasonal, annual and solar cycle statistics. Inter-solar cycle variability.

Location-specific Vertical, Slant or Horizontal TEC and TEC rates

– Total statistics and as a function of time of day, elevation and azimuth/solar zenith angle for ground-based and space-based experiments.

Electron-density profile

– Statistical description of profile characteristics for the testing of electron density and mapping function models.

Ionospheric scintillation fading and phase variation statistics

– Statistics as a function of frequency, location, solar activity, season and time-of-day.

2 Experimental requirements for extraction of parameters for tables and recommended exchange formats

Global and regional Vertical Total Electron Content (VTEC) and VTEC rate grid maps

For this type of data, the following complementary information needs to be provided:

1) Measure of the quality per grid point needs to be provided.

2) Description of reference data and method used for generation of map.

3) Range of heights for the map (bottomside, topside, all).

4) Temporal and spatial resolution.

5) For VTEC rate calculation, a sampling rate below 60 seconds is expected.

6) Related solar and geomagnetic activity for the period of experiments.

7) For exchange of VTEC data, the IONEX format is proposed (see Annex 1).

Location-specific Vertical, Slant or Horizontal TEC and TEC rates

For this type of data, the following complementary information needs to be provided:

1) Absolute or relative calibration, expected calibration errors and calibration method.

2) Range of heights covered by the data (bottomside, topside, all).

3) Temporal and spatial resolution.

4) For VTEC rate calculation, a sampling rate below 60 seconds is expected.

5) Related solar and geomagnetic activity for the period of experiments.

6) For exchange of STEC data, the GTEX format is proposed (see Annex 1).

Electron-density profile

For this type of data, the following complementary information needs to be provided:

1) Absolute or relative calibration or measure of quality. Details of estimation or inversion method.

2) Range of heights for the map (bottomside, topside, all).

3) Temporal and height resolution.

4) Related solar and geomagnetic activity for the period of experiments.

Ionospheric scintillation fading and phase variation statistics

– Accuracy of estimation (phase and amplitude).

– Method for index estimation (including detrending).

– Geometrical description. Sampling rate.

– Temporal resolution.

– Related solar and geomagnetic activity for the period of experiments.

– For exchange of ionospheric scintillation indices, the SCINTEX format is proposed (see Annex 1).

3 Procedures for statistical analysis

(*This section will be completed once the table formats are defined.)*

4 Testing variables

(*This section will be completed once the table formats are defined.)*

ANNEX 1

Formats for exchange of experimental data and products.

1 IONEX

A *de facto* standard widely used by various scientific communities is proposed for the format of the provided VTEC maps. Such format is the IONEX (IONosphere map EXchange) format, see details in: http://igscb.jpl.nasa.gov/igscb/data/format/ionex1.pdf.

IONEX map file example:

```
     1.0            IONOSPHERE MAPS     MIX                 IONEX VERSION /
         TYPE
ionex_mean v0        ESA/ESTEC          12-Jun-12 15:46     PGM / RUN BY /
         DATE
ionex file containing IGS 30-DAY average maps                COMMENT
global ionosphere maps for day 079,    0                     DESCRIPTION
IONEX file containing the 30-DAY average IGS MAP and st.dev DESCRIPTION
  2002     3    20     1     0     0                        EPOCH OF FIRST
         MAP
  2002     3    20    23     0     0                        EPOCH OF LAST
         MAP
  7200                                                      INTERVAL
     0                                                      # OF MAPS IN
         FILE
  COSZ                                                      MAPPING
         FUNCTION
     0.0                                                    ELEVATION
         CUTOFF
   000                                                      # OF STATIONS
    00                                                      # OF SATELLITES
  6371.0                                                    BASE RADIUS
     2                                                      MAP DIMENSION
   450.0 450.0   0.0                                       HGT1 / HGT2 /
         DHGT
    87.5 -87.5  -2.5                                       LAT1 / LAT2 /
         DLAT
  -180.0 180.0   5.0                                       LON1 / LON2 /
         DLON
    -1                                                      EXPONENT
                                                            END OF HEADER
     1                                                      START OF TEC
         MAP
  2002     3    20     1     0     0                        EPOCH OF
         CURRENT MAP
   -87.5-180.0 180.0   5.0 450.0
         LAT/LON1/LON2/DLON/H
  322  320  318  315  314  313  313  313  318  317  316  317  318  319  319
         318
  317  317  317  314  311  309  307  306  307  307  307  306  305  302  297
         290
  289  293  297  296  296  297  299  300  301  302  304  307  308  309  311
         313
  316  317  319  320  322  324  327  329  330  331  332  333  333  334  335
         336
  336  336  336  334  332  328  326  326  322
   -85.0-180.0 180.0   5.0 450.0
         LAT/LON1/LON2/DLON/H
```

```
335  330  328  325  322  318  317  316  322  319  318  318  319  319  320
       318
315  311  307  302  297  291  289  286  285  283  280  277  275  274  273
       274
272  273  274  275  276  277  279  283  287  291  296  300  302  305  308
       312
315  318  321  324  327  331  335  338  341  344  346  348  350  351  352
       352
352  352  351  349  347  343  340  336  335
 -82.5-180.0 180.0   5.0 450.0
       LAT/LON1/LON2/DLON/H
347  345  343  337  334  331  328  325  324  324  322  321  321  321  322
       316
303  295  291  285  281  279  276  271  266  262  257  255  253  253  252
       253
253  253  252  253  256  259  262  265  269  275  281  288  294  298  303
       308
313  317  322  327  332  337  342  347  351  355  358  361  363  366  367
       368
368  368  367  365  362  359  356  351  347
 -80.0-180.0 180.0   5.0 450.0
       LAT/LON1/LON2/DLON/H
363  358  354  353  346  344  341  337  335  332  332  332  329  323  320
       308
293  278  271  271  269  262  254  249  244  238  237  234  232  233  233
       231
231  232  233  234  237  241  245  248  253  259  267  272  281  288  295
       301
307  313  320  326  333  340  347  353  359  364  368  372  376  379  381
       383
383  383  382  380  379  376  371  367  363
```

2 GTEX

GNSS-TEC data, GNSS-TEC Exchange Format (GTEX) is a data format proposed for international exchange and sharing, which is available for various ionospheric studies including dense and wide-coverage TEC mapping. The main concept of the GTEX is to include slant TEC data from each receiver. By sharing slant TEC data which are not converted to vertical TEC, various ionospheric studies may be possible without affected by specific analysis procedures such as satellite/receiver bias estimation, or different mapping heights. Thus, slant TEC values described in the GTEX can include biases arising from inter-frequency bias of satellites and receivers. The structure of GTEX is designed in such a way that the structure is as close to the format of GNSS observation data, RINEX (version 2) (Gurtner 2013), as possible, because RINEX (Receiver Independent Exchange Format) is a *de facto* standard in exchanging GNSS observation data and potential users of GTEX would be familiar with RINEX. GTEX also include additional information useful to TEC analysis, such as GNSS satellite zenith/azimuth angles, and information of RINEX observable combination (ex. L1L2C1P2) to derive slant TEC values. GTEX may include more data relevant to TEC analysis in the later revisions. The format is designed to allow future extension.

The GTEX data file consists of two parts, the header and the TEC data blocks.

- The header block structure is similar to that of RINEX. All the header items defined in RINEX can be used in GTEX as well. The main data type descriptor, “R1” for slant TEC including bias (“raw TEC”) or “A1” for absolute slant TEC is necessary for GTEX. The other data type descriptors “1F” for TEC status flag, “1O” for RINEX observable

combination, “ZN” for satellite zenith angle, and “AZ” for satellite azimuth angle are included in GTEX. There are additional header items to describe the unit of TEC, approximated GNSS receiver position (latitude, longitude, and altitude), bias estimation program name, etc.

- The TEC data block starts from a line(s) with a time stamp and list of satellites with the same format as “EPOCH/SAT” field of RINEX. Following the EPOCH/SAT field, TEC and additional information data as defined in “# / TYPES OF DATA” in the header part are recorded. After the record of TEC data for all the satellites, data set of the next epoch follows.

An example of TEC data in GTEX is shown below. The sampling rate is 30 sec. The file name format is similar to the RINEX and defined as follows: ssssdddh.yy_TEC; where “ssss” is the four-character station name defined in “MARKER NAME”, “ddd” is the day of year, and “yy” is two-digit year. “h” is file sequence number and “0” means daily data. In this case, we used the daily data and the file name is 01321320.12_TEC. First 29 lines (to the line of “END OF HEADER”) describe the header part. Five data, raw slant TEC, TEC status flags, RINEX observable combination, satellite zenith angle, and satellite azimuth angle are recorded in the data blocks. The TEC data block starts from the 30th line. The first epoch is 00:00:00 GPS Time on 11 May 2012. 9 GPS satellites (PRN 21, 9, 18, 15, 28, 5, 27, 8, and 26) were tracked. Following this epoch line, 9 lines describe the five data. Some negative values of slant TEC data are caused by satellite and receiver biases. All the TEC flags are 0, meaning that all the slant TEC data are normal. Meaning of TEC status flag is described in the header part. Because the GTEX format has a similar look as the RINEX, which is commonly used in GNSS related works to record GNSS data, it would be friendly to those who have been involved in GNSS related studies as well as those because the data are human readable and meanings of data fields are clearly defined.

GTEX file example:

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---
|---8|
     1.0            GTEX DATA            GNSS                GTEX VERSION /
TYPE
RNX2GTEX V1.0       NICT, JAPAN                              PGM / RUN BY
     0                                                       EXPONENT OF
TECU
     TEC values in 10^16 el/m^2 (1 TEC Unit)                 COMMENT
     TEC Status Flag = 0 : Normal data                       COMMENT
                     = 1 : Lack of observables (TEC=999.)    COMMENT
                     = 2 : Too large TEC (TEC=999.)          COMMENT
                     = 4 : Cycle slip (TEC discontinuity)    COMMENT
                     = 5 : Cycle slip (LLI)                  COMMENT
                     = 6 : Beginning of arc                  COMMENT
     TYPES OF DATA   = R1 : Raw slant TEC including bias     COMMENT
                       A1 : Absolute slant TEC               COMMENT
                            R1 or A1 is necessary            COMMENT
                       1F : TEC status flag                  COMMENT
                       1O : Observation data used for TEC    COMMENT
                       ZN : Satellite zenith angle           COMMENT
                       AZ : Satellite azimuth angle          COMMENT
                                                             BIAS ESTIMATION
PGM
01321310.12o  01321320.12o  01321330.12o                     RINEX FILE NAME
0132                                                         MARKER NAME
00000               TPS NETG3           3.4 EG3 Jul,02,2010 REC # / TYPE /
VERS
                    TRM29659.00     GSI                      ANT # / TYPE
 -3690821.3891  2897721.3097  4305504.4426                  APPROX POSITION
XYZ
       42.7294      141.8640        0.0486                  POSITION LAT
LON ALT
     6    L1    C1    L2    P2    S1    S2                  # / TYPES OF
OBSERV
     5    R1    1F    1O    ZN    AZ                        # / TYPES OF
DATA
    30.000                                                   INTERVAL
  2012    5     11     0     0    0.0000000     GPS         TIME OF FIRST
OBS
                                                             END OF HEADER
 12  5 11  0  0  0.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
 -61.7242  0  L1L2C1P2  32.45  194.42
 -33.4733  0  L1L2C1P2   9.32   14.04
 -49.7988  0  L1L2C1P2  20.39    9.03
 -55.8391  0  L1L2C1P2  83.27   39.34
 -43.6837  0  L1L2C1P2  32.21   44.21
 -38.7060  0  L1L2C1P2   8.31    3.34
 -44.8228  0  L1L2C1P2  74.42  265.99
 -31.3004  0  L1L2C1P2  23.01  343.20
 -48.7904  0  L1L2C1P2  50.12  115.79
 12  5 11  0  0 30.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
```

3 SCINTEX

A receiver independent ionospheric scintillation format named as SCINTEX is proposed. It is based on RINEX v3 (ftp.igs.org/igscb/data/format/rinex300.pdf). It contains the following observables:

- S_4 and σ_φ for all available frequencies.
- Carrier-to-Noise-Density Ratio C/No.
- (Optional) Real-time TEC and Differential TEC estimation.
- Code Carrier Divergence.
- Elevation and Azimuth of the satellite.
- Lock signal time.

An example of a SCINTEX file is presented below:

scintex_example.11s (~\My Documents\ESA\Congres-meetings\Galileo Colloquium 2011) - GVIM

File Edit Tools Syntax Buffers Window Help

```
     1.0           SCINTILLATION DATA  MIX                 SCINT VERSION / TYPE
scintex_sept_v0    ESA                 28-aug-11 15:39     PGM / RUN BY / DATE
scintex file containing scintillation information          COMMENT
ESTE                                                       MARKER NAME
Unknown                                                    MARKER NUMBER
Unknown            Unknown                                 OBSERVER / AGENCY
9999999            Septentrio PolaRxS  0.0.0               REC # / TYPE / VERS
Unknown            Unknown                                 ANT # / TYPE
  5760940.0104 -1556238.7358  2276652.7023                 APPROX POSITION XYZ
       0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
E   18 SS41 S4C1 SPH1 CN01 LKT1 CCD1 SCD1 SS47 S4C7 SPH7   SYS / # / OBS TYPES
CN07 LKT7 CCD7 SCD7 TECI DTEC ELEV AZIM                    SYS / # / OBS TYPES
G   18 SS41 S4C1 SPH1 CN01 LKT1 CCD1 SCD1 SS42 S4C2 SPH2   SYS / # / OBS TYPES
CN02 LKT2 CCD2 SCD2 TECI DTEC ELEV AZIM                    SYS / # / OBS TYPES
S   11 SS41 S4C1 SPH1 CN01 LKT1 CCD1 SCD1 TECI DTEC ELEV   SYS / # / OBS TYPES
AZIM                                                       SYS / # / OBS TYPES
    60.000                                                 INTERVAL
  2011     8    28    21    11     0.0000000     GPS       TIME OF FIRST OBS
  2011     8    28    21    59    59.0000000     GPS       TIME OF LAST OBS
    21                                                     # OF SATELLITES
                                                           END OF HEADER
> 2011 08 28 21 11  0.0000000  0 21
E10 0.04  0.04    0.00 49.10  187.00   -0.10    0.10    0.03 0.03   0.00  51.30  187.00    0.
E19 0.04  0.04    0.00 48.60  311.00  -88.39   87.65    0.03 0.03   0.00  50.80  311.00  -90.
E12 0.04  0.04    0.00 49.20  185.00 -123.46  143.93    0.03 0.03   0.00  51.40  185.00    0.
E11 0.04  0.03    0.00 49.70  257.00    0.09    0.10    0.03 0.03   0.00  51.90  257.00    0.
E06 0.04  0.04    0.00 48.70  196.00  -11.36   22.57    0.03 0.03   0.00  50.90  196.00    0.
E07 0.86  0.04    0.00 47.60  194.00  -13.79   56.72    0.86 0.03   0.00  49.80  194.00    0.
E25 0.04  0.04    0.00 48.60  228.00    0.21    0.20    0.03 0.03   0.00  50.80  228.00    0.
E26 0.31  0.03    0.00 49.30  226.00  -61.96  115.60    0.31 0.03   0.00  51.50  225.00    0.
E27 0.74  0.04    0.00 48.40  224.00    0.25    0.18    0.74 0.03   0.00  50.60  223.00    0.
E08 0.53  0.04    0.00 48.20  266.00  -62.16  115.70    0.53 0.03   0.00  50.40  266.00    0.
G26 0.28  0.04    0.00 48.00  333.00    0.01    0.06    0.00 0.00   0.00   0.00    0.00    0.
G07 0.04  0.05    0.00 46.50  381.00    0.01    0.06    0.00 0.00   0.00   0.00    0.00    0.
G08 0.51  0.04    0.00 47.20  380.00    0.01    0.08    0.00 0.00   0.00   0.00    0.00    0.
G10 0.72  0.05    0.00 46.50  380.00    0.02    0.08    0.00 0.00   0.00   0.00    0.00    0.
G27 0.11  0.04    0.00 46.90  332.00    0.20    0.06    0.00 0.00   0.00   0.00    0.00    0.
G28 0.05  0.04    0.00 47.60  332.00    0.20    0.05    0.00 0.00   0.00   0.00    0.00    0.
G21 0.04  0.05    0.00 46.80  302.00    0.21    0.06    0.00 0.00   0.00   0.00    0.00    0.
G15 0.84  0.05    0.00 45.80    0.00   -0.17    0.17    0.00 0.00   0.00   0.00    0.00    0.
G24 0.04  0.04    0.00 46.90  299.00    0.19    0.06    0.00 0.00   0.00   0.00    0.00    0.
S20 0.14  0.04    0.00 48.30 3407.00    3.57    0.59    0.00   +0.00+41.00+121.00
S24 0.14  0.05    0.00 46.20 3379.00    0.01    0.75    0.00   +0.00+39.00+124.00
> 2011 08 28 21 12  0.0000000  0 21
E10 0.04  0.03    0.00 49.40  247.00   -0.09    0.09    0.03 0.03   0.00  51.10  247.00    0.
E19 0.04  0.04    0.00 48.90  371.00 -148.47  141.90    0.03 0.03   0.00  50.60  371.00    0.
```