International Civil Aviation Organization

THE FIFTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/4)

Ishigaki, Japan, 16 – 18 February 2015

A Follow-up of ISTF AI 4/2: To develop guidelines about how to generate data in GTEX

GUIDELINES OF GTEX DATA GENERATION

(Presented by Japan)

SUMMARY

This information paper presents the guidelines about how to generate data in GTEX format from GNSS receiver data in RINEX format in response to the Action Item 4/2 identified by the Fourth Meeting of the Ionospheric Studies Task Force (ISTF/4).

1. Introduction

1.1 The fourth meeting of the Ionospheric Studies Task Force (ISTF/4) held in New Delhi, India from 5 to 7 February 2014 identified an Action Item:

ACTION ITEM 4/2: To develop guidelines about how to generate data in GTEX.

1.2 This information paper presents the guidelines about how to generate data in GTEX format from GNSS receiver data in RINEX format using a software "RNX2GTEX".

2. Discussion

2.1 The latest version of RNX2GTEX for Linux/Unix (version 1.1.3) is available from the website:

http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX.tgz

The tar file includes manuals and a set of programs written in fortran 77 and shell scripts in RNX2GTEX directory. Details of installation and usage of RNX2GTEX for Linux/Unix are described in the manual (see Appendix 1).

2.2 The latest version of RNX2GTEX for Windows Vista/7/8.1 (version 2.1) is available from the website:

http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX_WIN.zip

RNX2GTEX for Windows is an application for creating GTEX data files from RINEX data using explorer-like GUI. Details of installation and usage are described in the manual "RNX2GTEX_manual_en.pdf" (see Appendix 2) included in the zip file.

Appendix 1.
User Guide of RNX2GTEX for Linux/Unix (ver 1.1.3)

Prepared by NICT, Japan

Jan. 6, 2015

RNX2GTEX for Linux/Unix is an application for creating total electron content (TEC) data files in GNSS-TEC Exchange (GTEX) format from RINEX observation files. This document describes how you can use RNX2GTEX for Linux/Unix.

Version Information

RNX2GTEX for Linux/Unix 1.1.3

Supported format

This application supports the following data formats.

Input data: RINEX(Receiver INdependent EXchange format) version 2.

Output data: GTEX(GNSS-TEC EXchange format) version 1.0.

How to install RNX2GTEX

1. Download the source file (tar+gz), "RNX2GTEX.tgz", from the website:
   http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX.tgz
2. Extract source files
   % tar zxvf RNX2GTEX.tgz
3. Change directory
   % cd RNX2GTEX
4. Edit "RNX2GTEX.sh"
   4.1. RINEX_DIR: Root directory name of the RINEX files(*).
        e.g., "/data/RINEX"
   4.2. TEC_DIR: Root directory name of the GTEX files .
        e.g., "/data/TEC"
   4.3. ORBIT_DIR: Root directory name of the satellite orbit files.
        e.g., "/data/ORBIT"
   4.4. work_DIR: Temporary working directory.
        e.g., "/data/tmp"
   4.5. EXEC_DIR: Directory where the program is.
        e.g., "/work/RNX2GTEX"

4.6. ORBIT_TYPE: ORBIT data type to use convert.
Only "igs"(final) or "igr"(rapid) are selectable.

4.7. GROUP: User group of converted GTEX files.

(*) The directory tree for the RINEX files is assumed to be in the following manner:

e.g., RINEX_DIR/YEAR/DOY/

YEAR: Four digit year

DOY : Three digit day of year

```
-------------------------
[ROOT_DIRECTORY]
  |-...
  |-[2012]
  |-[2013]
     |-...
     |-[005]
     |-[006]
        |-abcd0060.13o.gz
        |-...
-------------------------
```

5. Create GTEX (TEC_DIR), working (work_DIR), and orbit (ORBIT_DIR) directories if necessary.

```
% mkdir <TEC_DIR> <ORBIT_DIR> <work_DIR>
```

6. Compile the source files

```
% make
```

If the compilation is carried out successfully, "RNX2GTEX" is created.

7. FTP setting

To download GPS orbit data from IGS FTP server, FTP client software is needed.

7.1. Installation FTP (if necessary)

If FTP client is not installed, install FTP client software.

e.g., Scientific Linux

```
% su
% yum install ftp
```

7.2. FTP default setting

For FTP automatic anonymous FTP login, ".netrc" file should contain "igscb.jpl.nasa.gov".

How to use the RNX2GTEX for Linux/Unix

RNX2GTEX for Linux/Unix converts a daily RINEX file to the corresponding daily GTEX file. The orbit file (*.igs or *.igr) for the corresponding day is required for the conversion. Date-setting and file-overwriting options are available as follows.

Date-setting options :

[no option] <YEAR> <DOY>

To convert the RINEX files of the specified day (ex. 2013 032),
type as below:

```
% RNX2GTEX.sh 2013 032
```

-r <Number>

This option is used to convert the RINEX files of <Number> days before the current day. If you want to convert the RINEX files of yesterday, type as below:

```
% RNX2GTEX.sh -r 1
```

-b <YEAR1> <DOY1> <YEAR2> <DOY2>

This option is used to convert the RINEX files from <DOY1> of <YEAR1> to <DOY2> of <YEAR2> as below:

```
% RNX2GTEX.sh -b 2013 365 2014 003
```

File-overwriting option:

-o

To overwrite a GTEX file if the GTEX file already exists in TEC_DIR directory.
This option is used with any date-setting option as below:

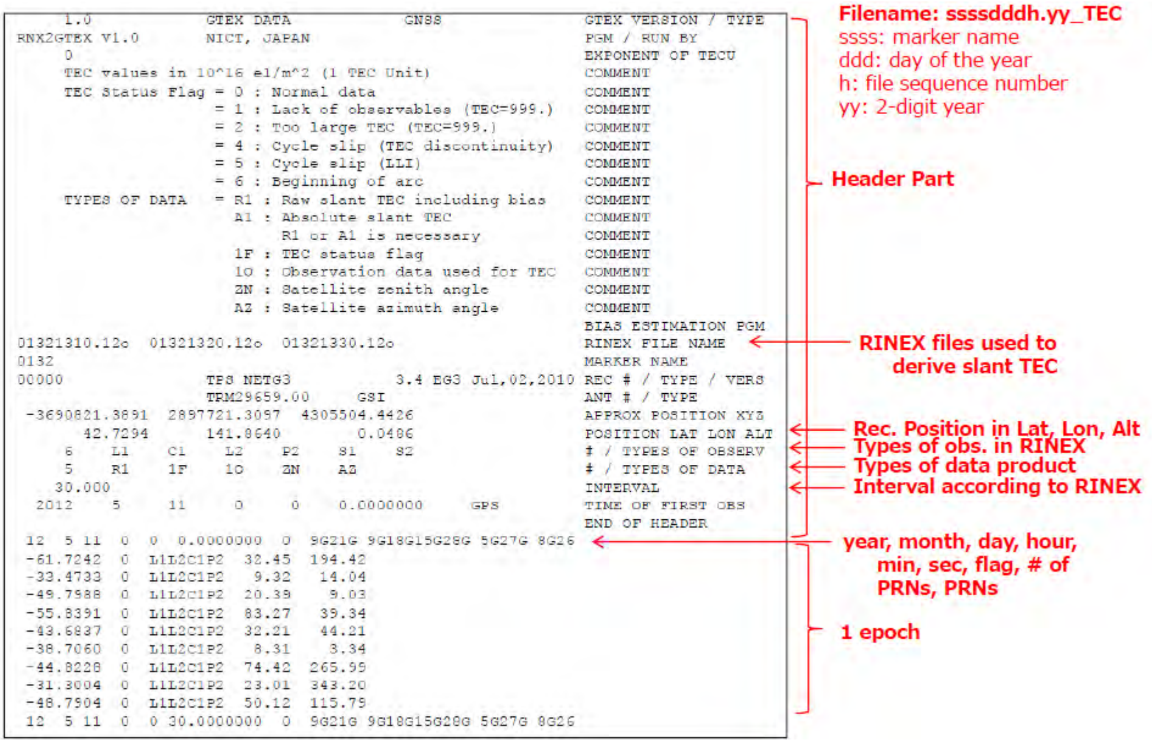
```
% RNX2GTEX.sh 2013 365 -o
% RNX2GTEX.sh -r 1 -o
% RNX2GTEX.sh -b 2013 365 2014 003 -o
```

References:

RINEX version 2.11 format

http://igscb.jpl.nasa.gov/igscb/data/format/rinex211.txt

GTEX version 1.0 format



Appendix 2.
User Guide of RNX2GTEX for Windows (ver 2.1)

Prepared by NICT, Japan

Jan. 6, 2015

RNX2GTEX is an application for creating total electron content (TEC) data files in GNSS-TEC Exchange (GTEX) format from RINEX observation files. This document describes how you can use RNX2GTEX for Windows.

Operation Environment

Microsoft Windows Vista 32bit/64bit

Microsoft Windows 7 32bit/64bit

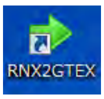
Microsoft Windows 8.1 32bit/64bit

Version Information

RNX2GTEX 2.1

How to install RNX2GTEX

1. Download “RNX2GTEX_WIN.zip” from the website:
   http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX_WIN.zip
2. Unzip the downloaded file and run “Setup.exe” in the folder.
3. Follow the on-screen instructions to complete the installation.



Note: Please input a mail address during installation.
This is used in order to download satellite's orbit data required for TEC calculation from an FTP site (Anonymous FTP).
Note: After the installation is complete, a shortcut icon for RNX2GTEX is placed on your desktop.

How to uninstall RNX2GTEX

For Windows 7 and Vista users:

1. Click on the Start button and select Control Panel.
2. Open Programs and then Programs and Features (for Windows 7 and Vista users).
3. Select RNX2GTEX in the Programs list.

For Windows 8.1 users:

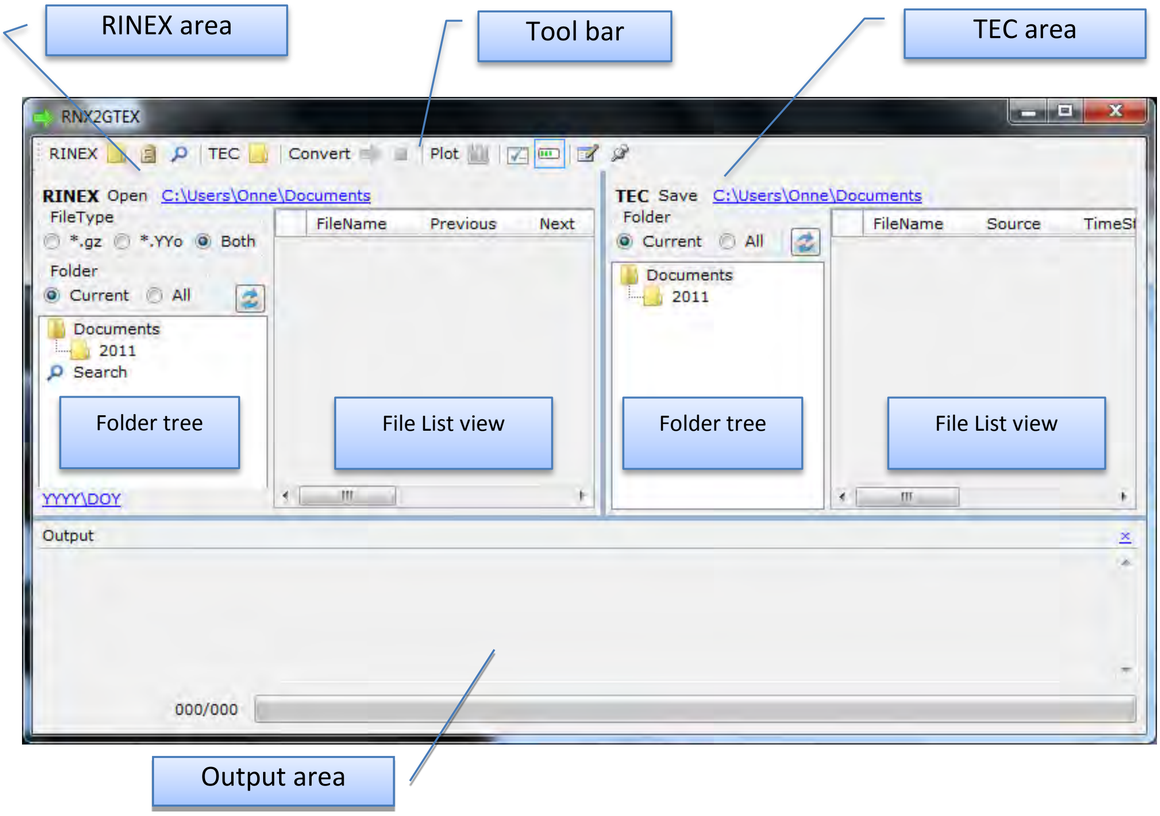
1. Right click on RNX2GTEX icon on the Start Screen.

2. Click Uninstall on the toolbar at the bottom of the screen.
3. Click Uninstall in the **Programs and Features** window.

How to start up RNX2GTEX

To start RNX2GTEX, double-click the RNX2GTEX shortcut icon on your desktop; otherwise, click the Windows Start menu and select All Programs, NICT and then RNX2GTEX.

Main Screen



Tool bar

 Selects a root folder for RINEX files.

 Specifies the folder structure where RINEX files are stored.

 Searches for RINEX files

 Selects a root folder in which to store the converted TEC file.

 Converts the RINEX file.

 Stops the file conversion process.

Plots a TEC file.

Customizes column display in File List view.

Shows/Hides the Output area.

Displays conversion history logs.

Displays the version information of RNX2GTEX.

Before using RNX2GTEX

A. File name of RINEX file

The file name format for an uncompressed file is as follows: **{SSSS}{DOY}0.{YY}o**; where SSSS is the four-character marker name, DOY is the day of year and YY is two-digit year.

The file name format for a compressed file is as follows: **{SSSS}{DOY}0.{YY}o.gz**; where SSSS is the four-character marker name, DOY is the day of year and YY is two-digit year.

For example when a marker name is ssss and a RINEX file has the data that is dated January 12, 2012, the file name is ssss0120.12o or ssss0120.12o.gz.

B. Folder structure of TEC file

TEC files are automatically located under "< Specified Root Folder > \<YYYY>\<DOY >".

C. File name of TEC file

The file name format is as follows: **{SSSS}{DOY}0.{YY}_TEC** ; where SSSS is the four-character marker name, DOY is the day of year and YY is two-digit year.

For example when a marker name is ssss and a RINEX file has the data that is dated January 12, 2012, the file name is ssss0120.12_TEC.

D. Converting program RINEX files to TEC files

The RNX2GTEX application is developed for Windows by National Institute of Information and Communications and Technology (NICT), Japan. The original Fortran code was developed by GNSS ionospheric observation team of NICT, Kyoto University, and Nagoya University. Carrier phase and pseudorange in a RINEX file are used to derive TEC value for each epoch. The slant TEC derived from the carrier phase is adjusted to that derived from the corresponding pseudorange of the satellite-receiver pair. This procedure requires satellite orbit information. The derived TEC values are slant values including satellite and receiver biases. The TEC data are output in the GTEX format (ASCII format) for each marker and day, similar to the RINEX observation file.

E. About satellite orbit data

RNX2GTEX application requires satellite orbit data for calculating TEC values. Satellite orbit data have a Final level (a file prefix character begins in "igs") and a Rapid level (a file prefix character begins in "igr"), and this application user can select type of orbit data for calculating TEC values. RNX2GTEX downloads satellite orbit data automatically from the following FTP site.

ftp://igscb.jpl.nasa.gov/igscb/product/

And so, basically, you can use this application under environment can use internet connection. But, if you download satellite orbit data in advance

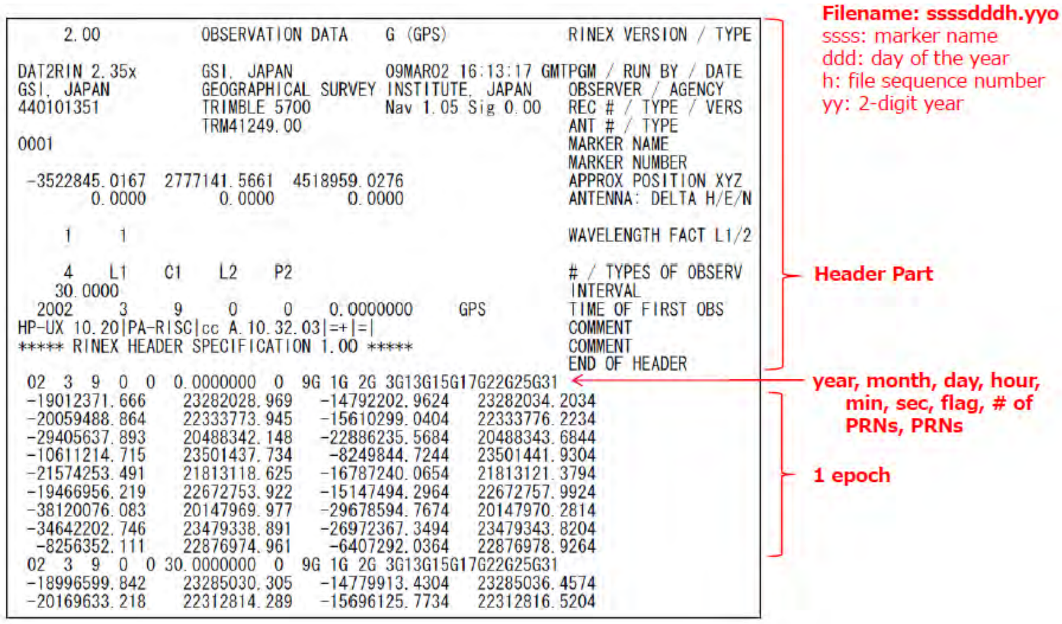
Downloaded satellite orbit data (UNIX Compress(*.Z) form) is uncompressed and saved below.

< ORBIT Folder > \YYYY\MM\ig[sr]<WOY ><DOW>.sp3

(*) “YYYY” is Year, “MM” is Month, “WOY” is Week of year, “DOW” is Day of week

(*) Default value of “<ORBIT Folder>” is “%USERPROFILE%\Documents”

The input file: RINEX observation file (ASCII format)



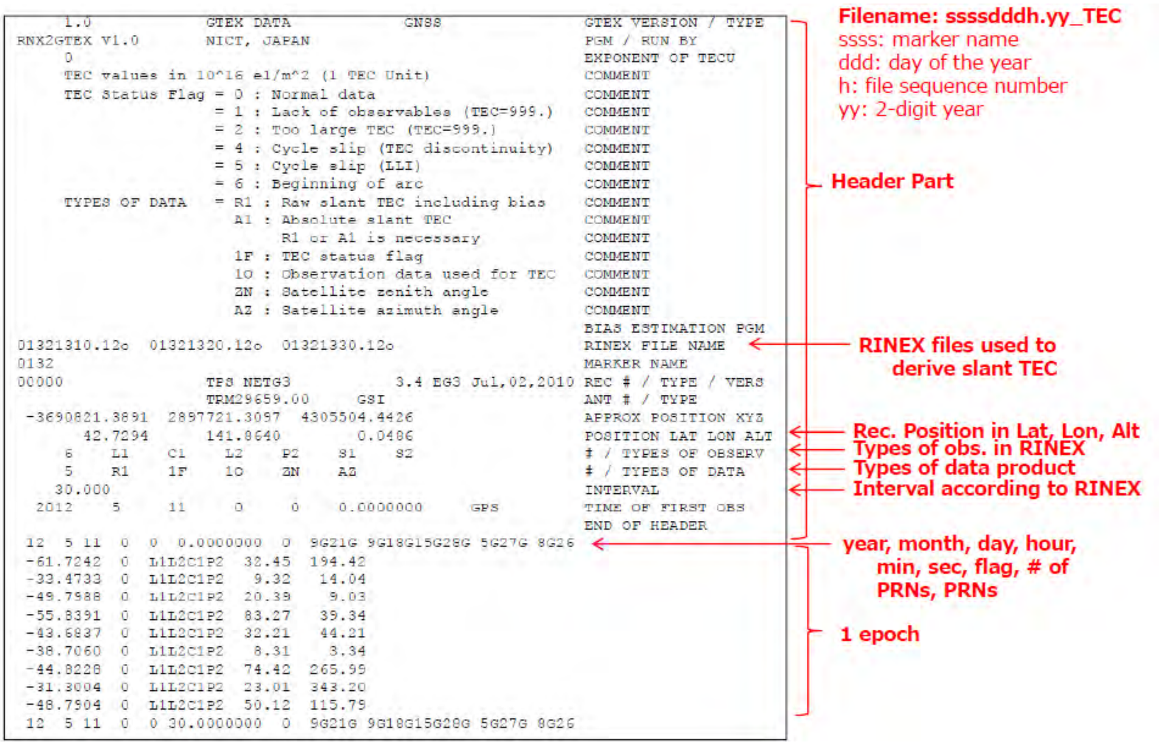
```
     2.00           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE

DAT2RIN 2.35x       GSI, JAPAN          09MAR02 16:13:17 GMTPGM / RUN BY / DATE
GSI, JAPAN          GEOGRAPHICAL SURVEY INSTITUTE, JAPAN    OBSERVER / AGENCY
440101351           TRIMBLE 5700        Nav 1.05 Sig 0.00   REC # / TYPE / VERS
                    TRM41249.00                             ANT # / TYPE
0001                                                        MARKER NAME
                                                            MARKER NUMBER
 -3522845.0167  2777141.5661  4518959.0276                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N

     1     1                                                WAVELENGTH FACT L1/2

     4    L1    C1    L2    P2                              # / TYPES OF OBSERV
    30.0000                                                 INTERVAL
  2002     3     9     0     0    0.0000000     GPS         TIME OF FIRST OBS
HP-UX 10.20|PA-RISC|cc A.10.32.03|=+|=|                     COMMENT
***** RINEX HEADER SPECIFICATION 1.00 *****                 COMMENT
                                                            END OF HEADER
 02  3  9  0  0  0.0000000  0  9G 1G 2G 3G13G15G17G22G25G31
 -19012371.666     23282028.969    -14792202.9624    23282034.2034
 -20059488.864     22333773.945    -15610299.0404    22333776.2234
 -29405637.893     20488342.148    -22886235.5684    20488343.6844
 -10611214.715     23501437.734     -8249844.7244    23501441.9304
 -21574253.491     21813118.625    -16787240.0654    21813121.3794
 -19466956.219     22672753.922    -15147494.2964    22672757.9924
 -38120076.083     20147969.977    -29678594.7674    20147970.2814
 -34642202.746     23479338.891    -26972367.3494    23479343.8204
  -8256352.111     22876974.961     -6407292.0364    22876978.9264
 02  3  9  0  0 30.0000000  0  9G 1G 2G 3G13G15G17G22G25G31
 -18996599.842     23285030.305    -14779913.4304    23285036.4574
 -20169633.218     22312814.289    -15696125.7734    22312816.5204
```

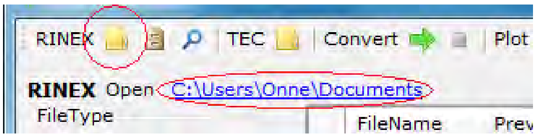
The output file: TEC file in the GTEX format (ASCII format)



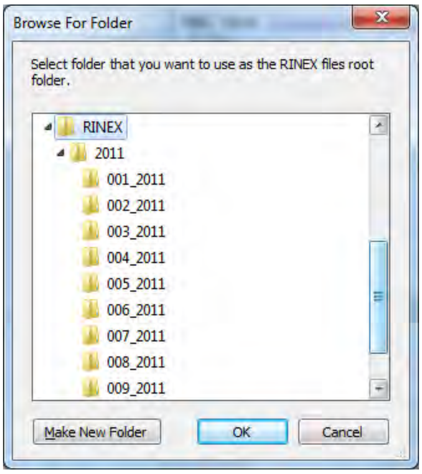
```
     1.0           GTEX DATA           GNSS                GTEX VERSION / TYPE
RNX2GTEX V1.0      NICT, JAPAN                             PGM / RUN BY
     0                                                     EXPONENT OF TECU
     TEC values in 10^16 el/m^2 (1 TEC Unit)               COMMENT
     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
```

Basic operations

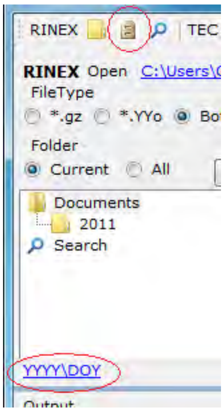
1. Select a root folder for RINEX files.



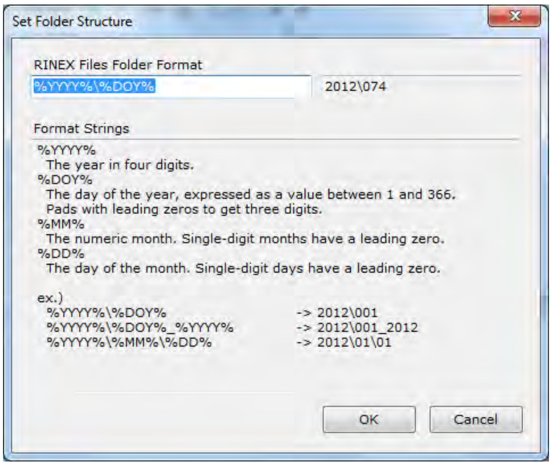
→



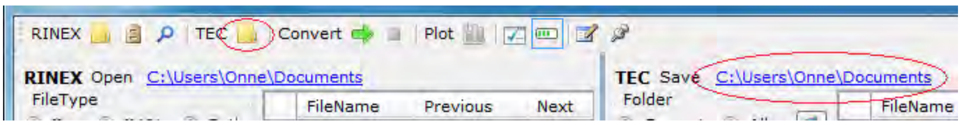
2. Specify the folder structure where RINEX files are stored.



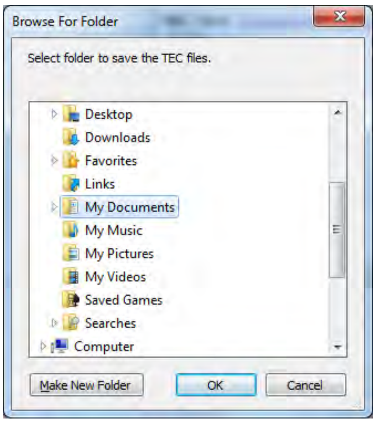
→



3. Select a root folder in which to store the converted TEC file.

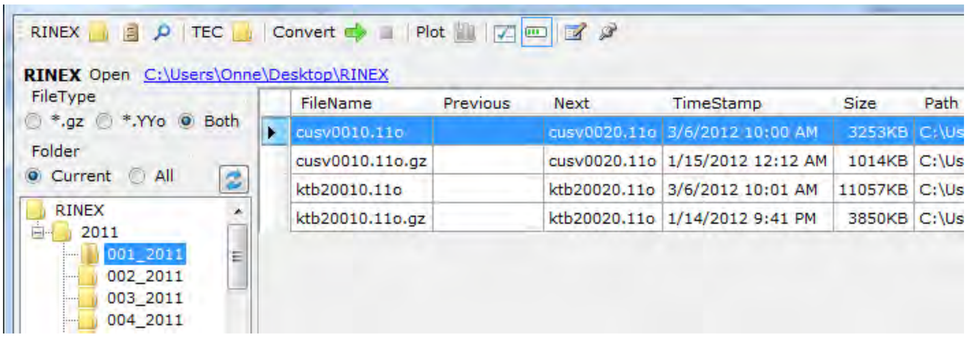


→

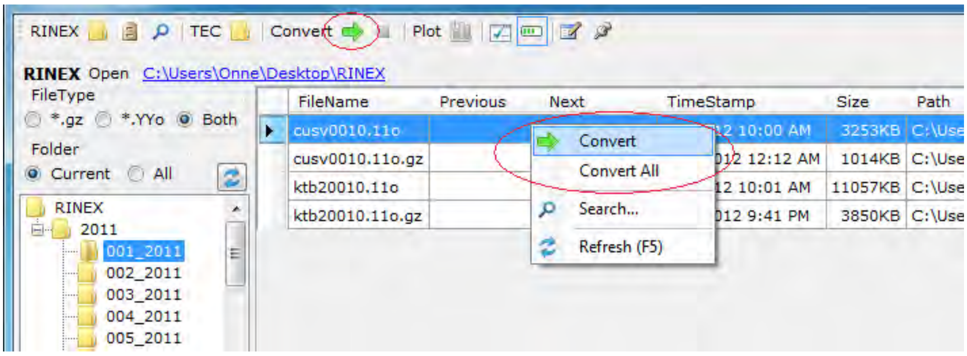


4. In the RINEX folder tree, select the folder where the RINEX file you want to convert is stored.

   In the RINEX File List view, select the RINEX file you want to convert.



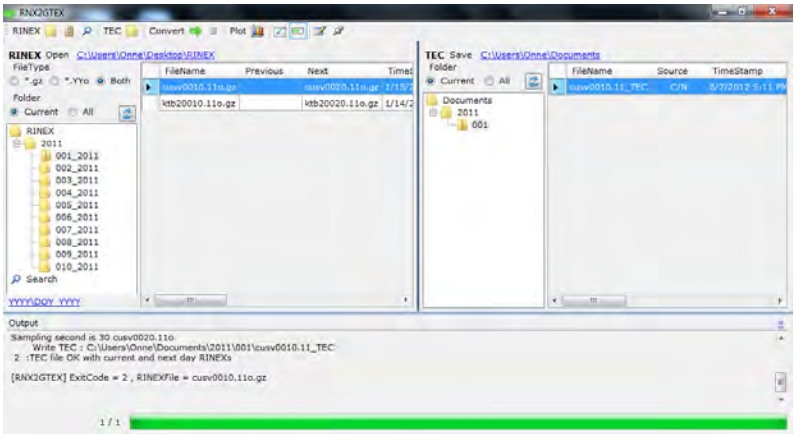
5. Convert the RINEX file.



To convert the RINEX file, perform one of the following:

- Click the Convert button in the toolbar.
- Double-click the RINEX file you want to convert.
- Right-click on the RINEX area, and then click [Convert]. [Convert All] allows you to convert all of the RINEX files currently displayed.

6. When the file conversion is complete, the created TEC files are displayed in the TEC File List view. Logs during conversion are displayed in the Output area.

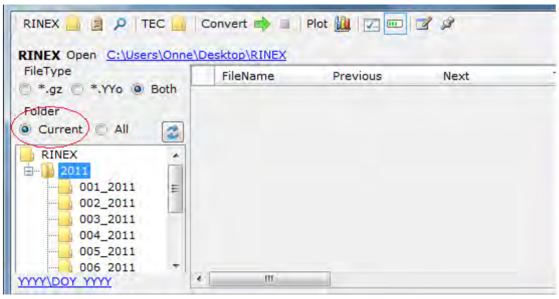


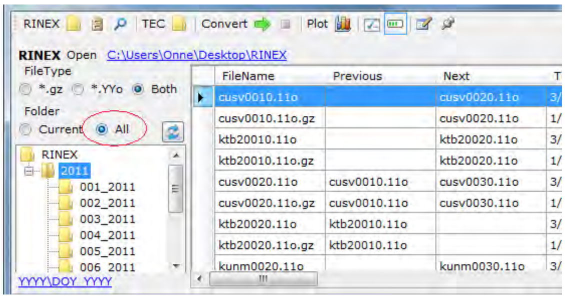
Optional Functions

✧ Specifying files to display in the File List view

You can specify the files you want to display in the File List view using the following radio buttons:

- [Current] Displays the files stored directly under the folder you selected on the folder tree.
- [All] Displays all the files stored under the folder you selected on the folder tree (including subfolders).

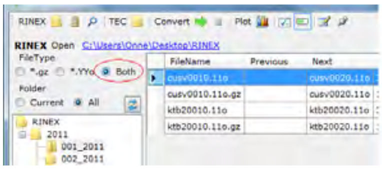


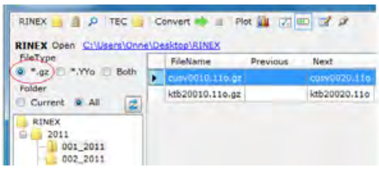


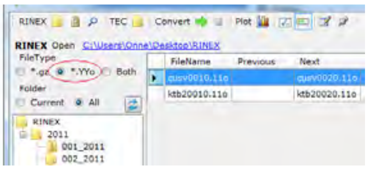
✧ Specifying RINEX files to be displayed

You can specify the RINEX file you want to display in the RINEX File List view.

- [Both] Displays both uncompressed files and compressed files.
- [*.gz] Displays only compressed files.
- [*.YYo] Displays only uncompressed files.



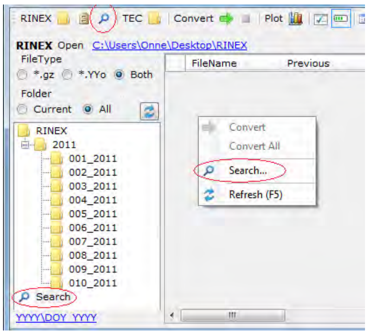




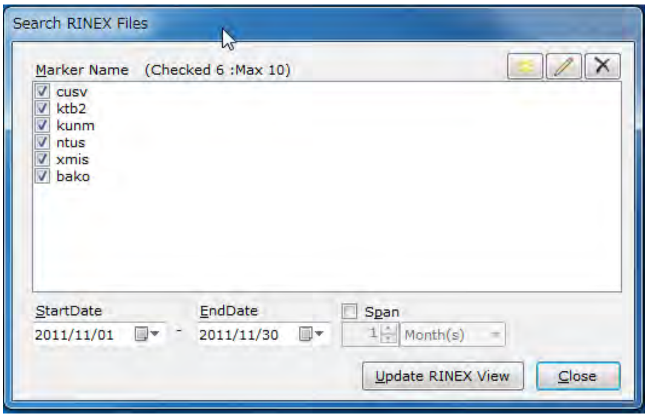
✧ Searching for RINEX files

To search for RINEX files, perform one of the following:

・Click the Search button on the toolbar.
・Click the Search node on the RINEX folder tree.
・Right-click on the RINEX area, and then click Search.



→



[Marker Name]

Select the marker name by which you want to search for RINEX files.

The three buttons shown in the upper right corner allow you to add a marker name, change the name of a marker name and delete a marker name, respectively.

[Start Date]
To search for RINEX files by the RINEX file date range, specify the start date.

[End Date]

To search for RINEX files by the RINEX file date range, specify the end date.

[Span]

When you want to specify a time span instead of the end date, click this checkbox.

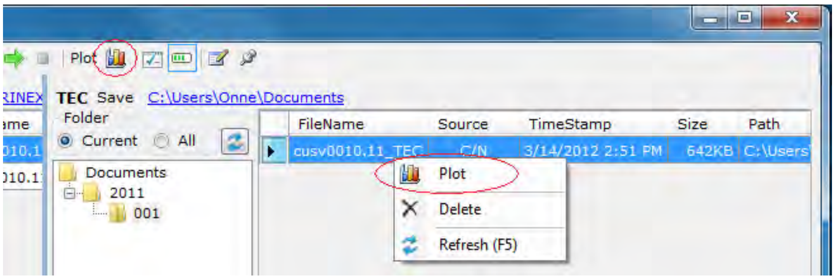
[Update RINEX View]

The RINEX files that meet the specified conditions（marker name and Date） are displayed in the RINEX File List view.

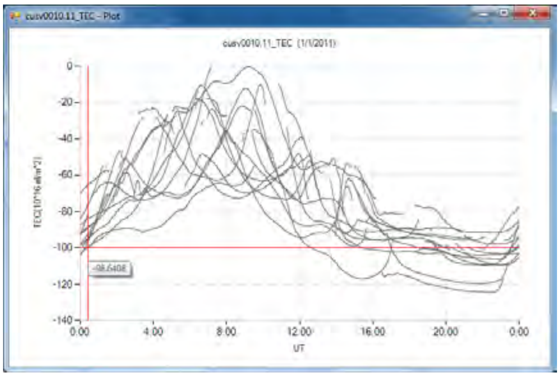
Note: When you uncheck all the checkboxes of marker name, you can search for RINEX files only based on the specified date range or time span.

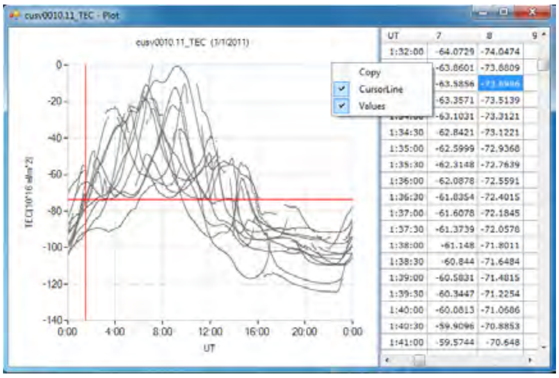
✧ Plotting TEC file

You can plot the data of the TEC file created by converting.



1. From the TEC File List view, select the TEC file you want to plot.
2. Click the Plot button on the toolbar ; otherwise, right-click on the TEC file, and then click Plot.





When you right-click on the screen, the following options are available:

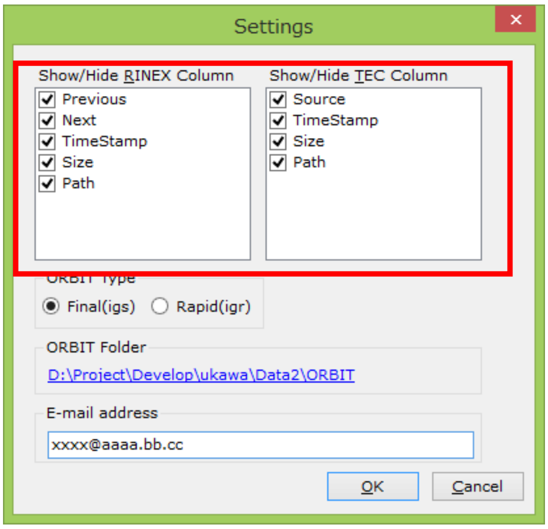
- [Copy] Copies the plot to the clipboard.
- [Cursor Line] Chooses to show or hide the cursor line.
- [Values] Displays the data values. Note that this operation can take some time depending on the environment.

The cursor line on the plot and the current cell where the data value is displayed are synchronized.

✧ **Customizing column display in File List view**

You can choose to show or hide the column in the File List view.

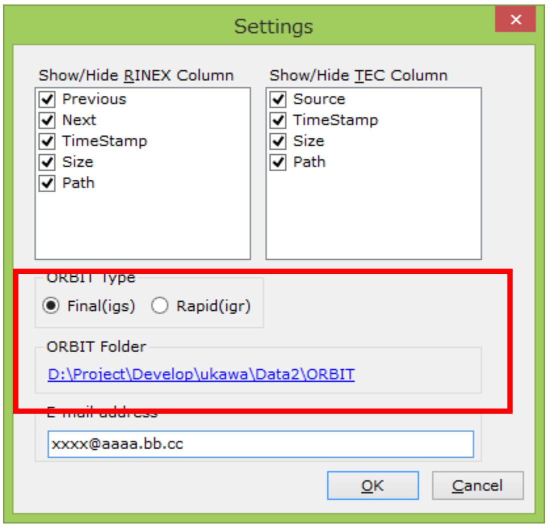
↓



✧ **Change satellite orbit data type and specify orbit folder**

You can choose satellite orbit data type (Final [Default] or Rapid). and specify a folder save the satellite orbit data by file chooser window.

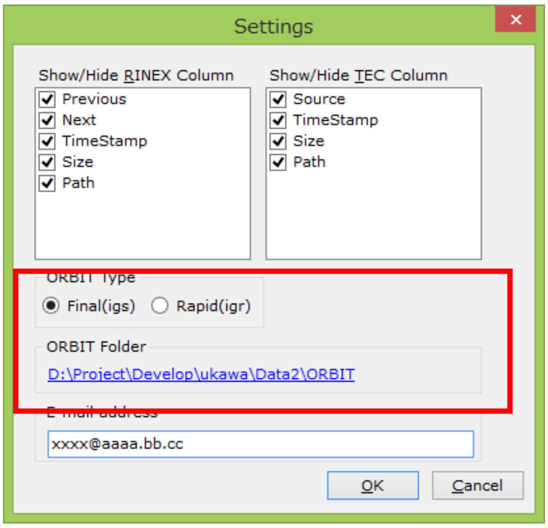
↓



✧ Preference of your e-mail address

You can change your e-mail address (used by download of satellite orbit data from FTP site) when you installed this application.

↓

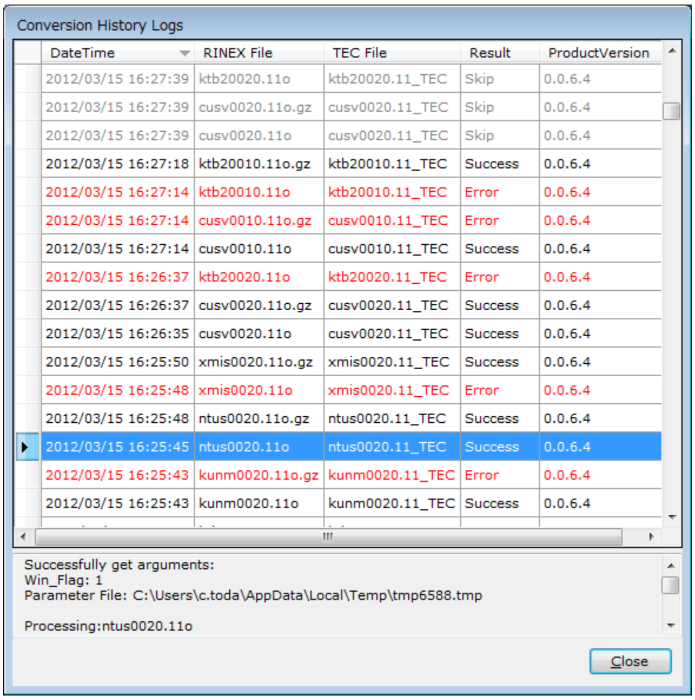


✧ Conversion history logs

The logs generated during conversion are displayed.

The conversion logs are kept for the most recent one-month period. Even after one month has passed, at least 100 conversion logs are kept.

These logs may be helpful, when a problem occurs.

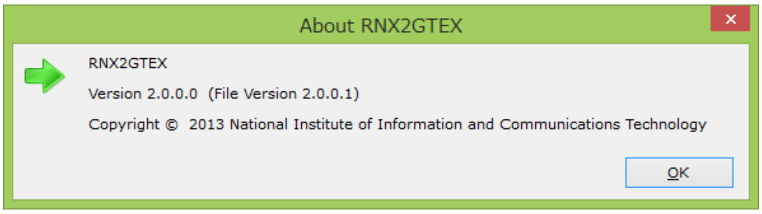


DateTime	RINEX File	TEC File	Result	ProductVersion
2012/03/15 16:27:39	ktb20020.11o	ktb20020.11_TEC	Skip	0.0.6.4
2012/03/15 16:27:39	cusv0020.11o.gz	cusv0020.11_TEC	Skip	0.0.6.4
2012/03/15 16:27:39	cusv0020.11o	cusv0020.11_TEC	Skip	0.0.6.4
2012/03/15 16:27:18	ktb20010.11o.gz	ktb20010.11_TEC	Success	0.0.6.4
2012/03/15 16:27:14	ktb20010.11o	ktb20010.11_TEC	Error	0.0.6.4
2012/03/15 16:27:14	cusv0010.11o.gz	cusv0010.11_TEC	Error	0.0.6.4
2012/03/15 16:27:14	cusv0010.11o	cusv0010.11_TEC	Success	0.0.6.4
2012/03/15 16:26:37	ktb20020.11o	ktb20020.11_TEC	Error	0.0.6.4
2012/03/15 16:26:37	cusv0020.11o.gz	cusv0020.11_TEC	Success	0.0.6.4
2012/03/15 16:26:35	cusv0020.11o	cusv0020.11_TEC	Success	0.0.6.4
2012/03/15 16:25:50	xmis0020.11o.gz	xmis0020.11_TEC	Success	0.0.6.4
2012/03/15 16:25:48	xmis0020.11o	xmis0020.11_TEC	Error	0.0.6.4
2012/03/15 16:25:48	ntus0020.11o.gz	ntus0020.11_TEC	Success	0.0.6.4
2012/03/15 16:25:45	ntus0020.11o	ntus0020.11_TEC	Success	0.0.6.4
2012/03/15 16:25:43	kunm0020.11o.gz	kunm0020.11_TEC	Error	0.0.6.4
2012/03/15 16:25:43	kunm0020.11o	kunm0020.11_TEC	Success	0.0.6.4

✧ **Version information**

You can determine the version of RNX2GTEX.

↓



A new data format to promote international exchange and share of GNSS-TEC data

T. Tsugawa[1], S. Saito[2], M. Nishioka[1], A. Saito[3],
Y. Otsuka[4], and M. Ishii[1]

[1] NICT, [2] ENRI, [3] Kyoto University, [4] Nagoya University

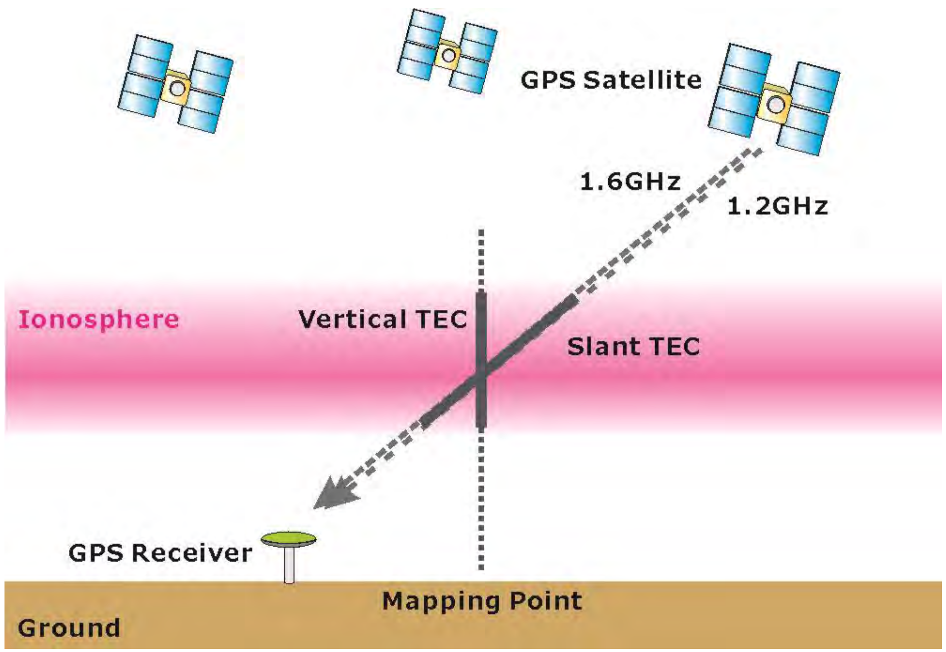
GNSS-TEC Observations

- Total electron content (TEC) can be derived by comparing the pseudorange/phase delays of the two GPS signals.

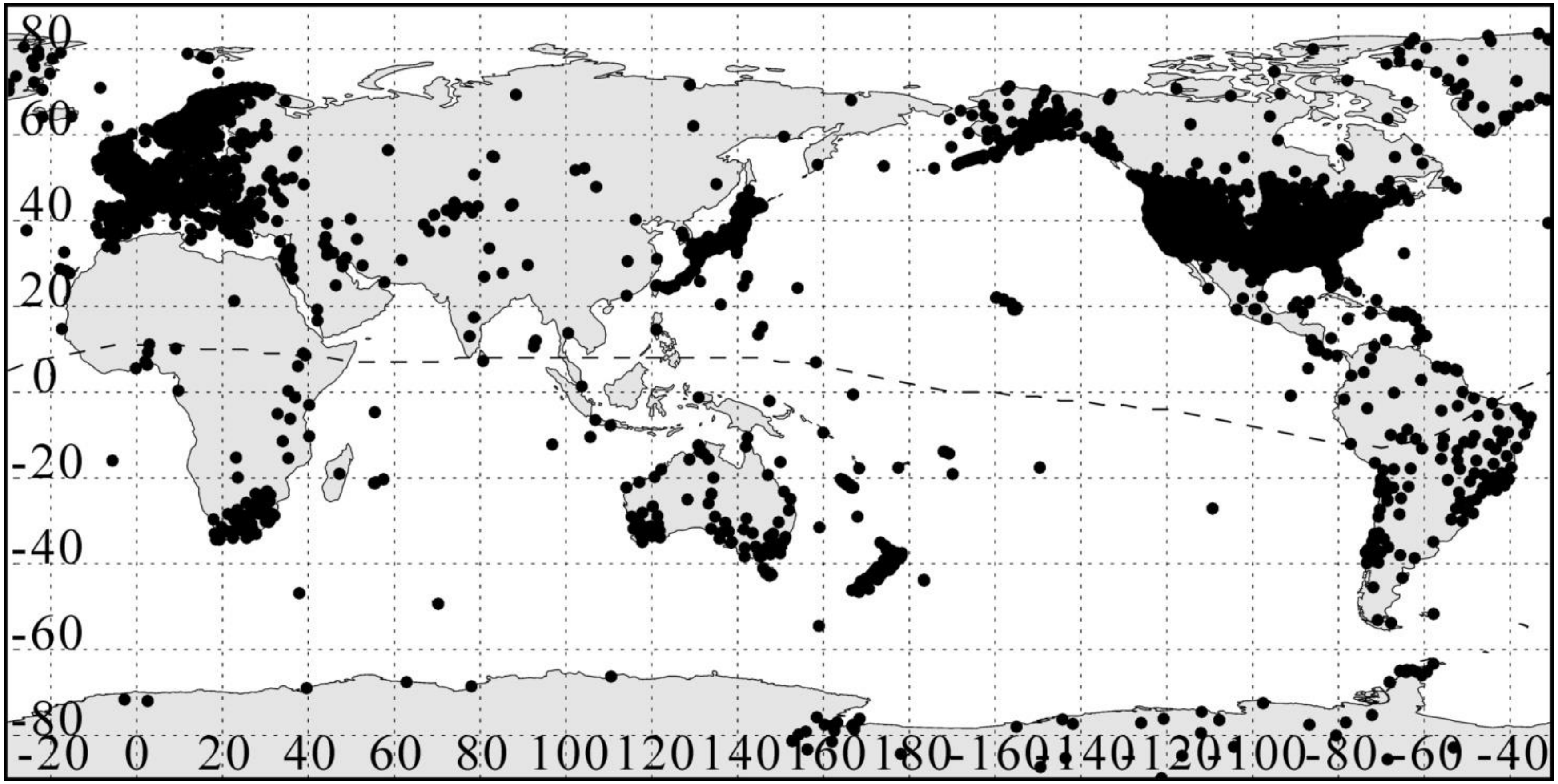
$$
\begin{aligned}
P_1 &= \rho + I/f_1^2 + \tau_1^r + \tau_1^s \\
P_2 &= \rho + I/f_2^2 + \tau_2^r + \tau_2^s \\
L_1 &= \rho - I/f_1^2 + \lambda_1 n_1 + \epsilon_1^r + \epsilon_1^s \\
L_2 &= \rho - I/f_2^2 + \lambda_2 n_2 + \epsilon_2^r + \epsilon_2^s
\end{aligned}
$$

P_1 P_2: Pseudorange
L_1 L_2: Carrier phase
I: Total electron content
f_1, f_2: Frequency
ρ: True range between the GPS satellite and receiver

- TEC is a measure of integrated electron density in 1m² column.
- Spatial resolution of TEC map depends on the number of GNSS satellites and GNSS receivers distribution.



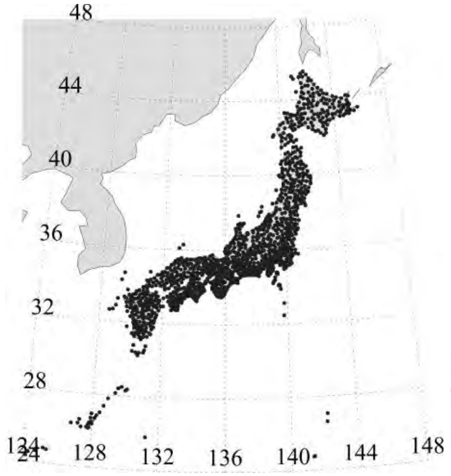
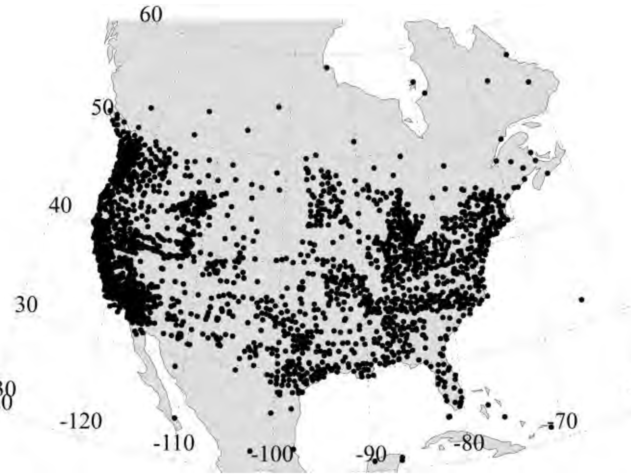
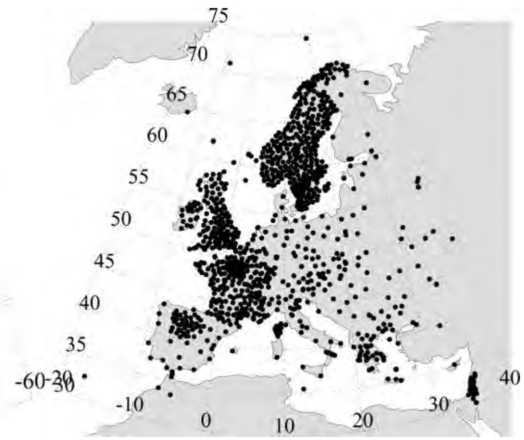
GNSS Receiver Networks



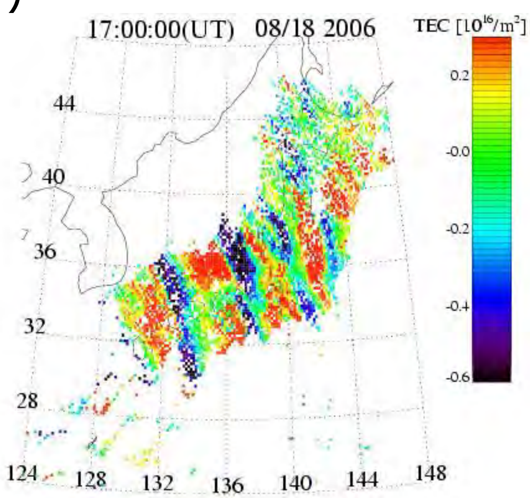
- GNSS receiver networks whose data is available online (more than 6,000 receivers as of Jan. 2013).

High resolution GPS-TEC maps

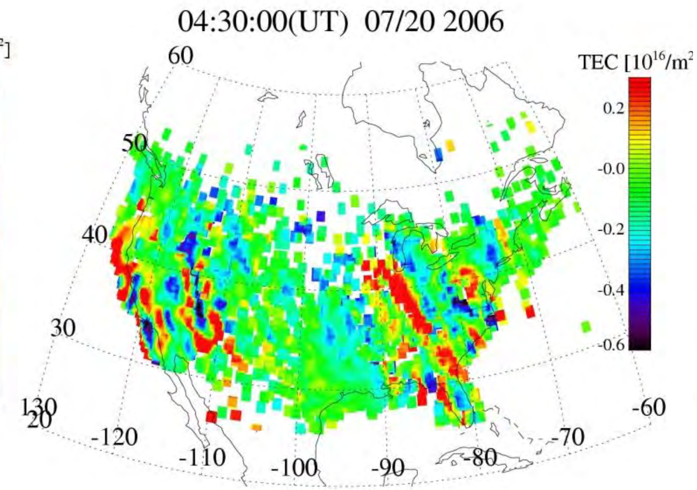
Region	JAPAN	N. America	Europe
# of GPS Rec.	~1,200 receivers	~2,700 receivers	~1,200 receivers

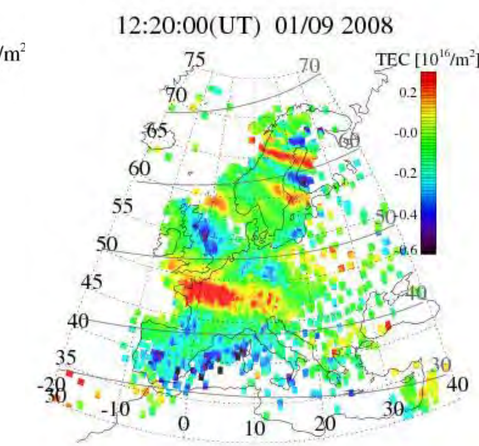
Detrended TEC Map (60-min Window)



[Tsugawa et al., 2011].

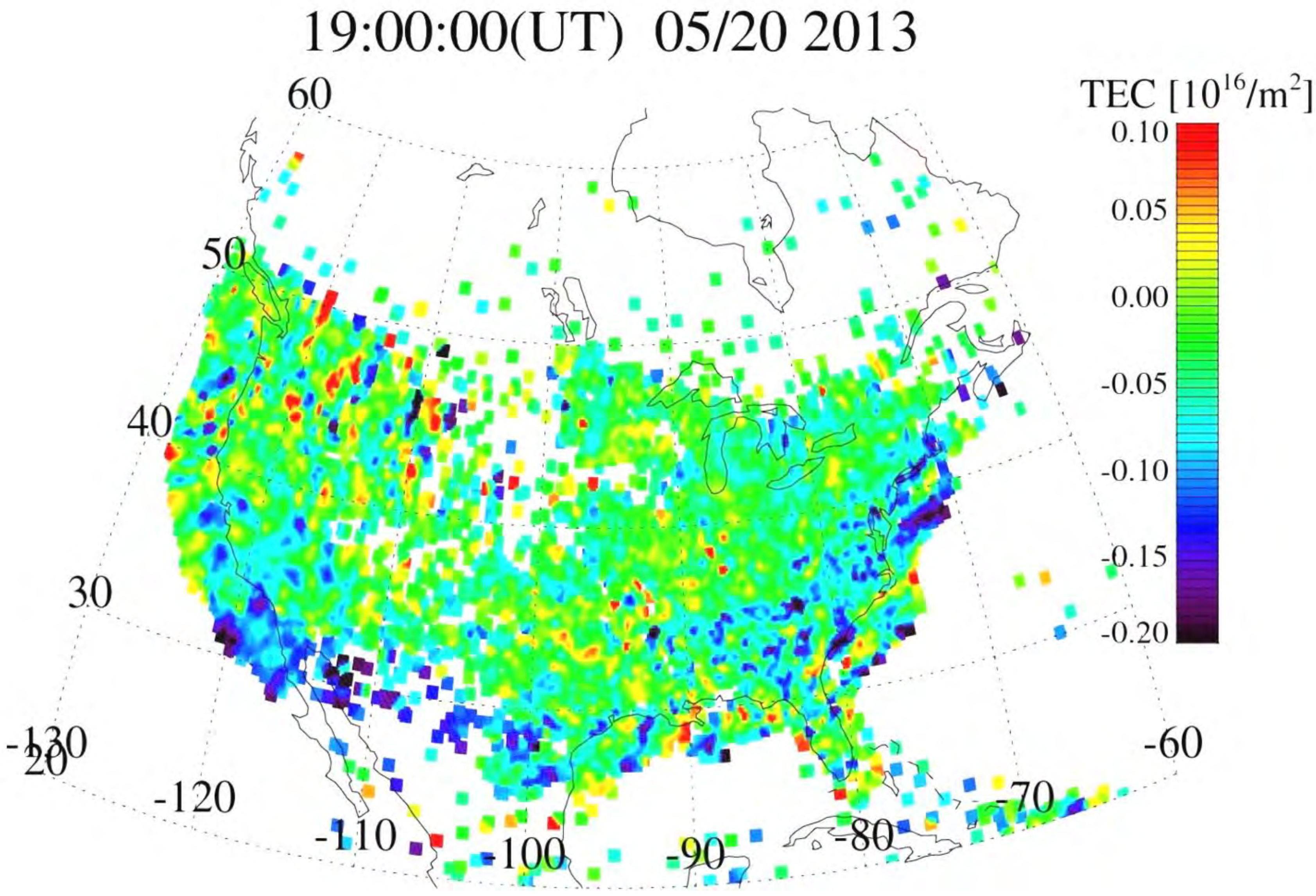


[Tsugawa et al., 2007].

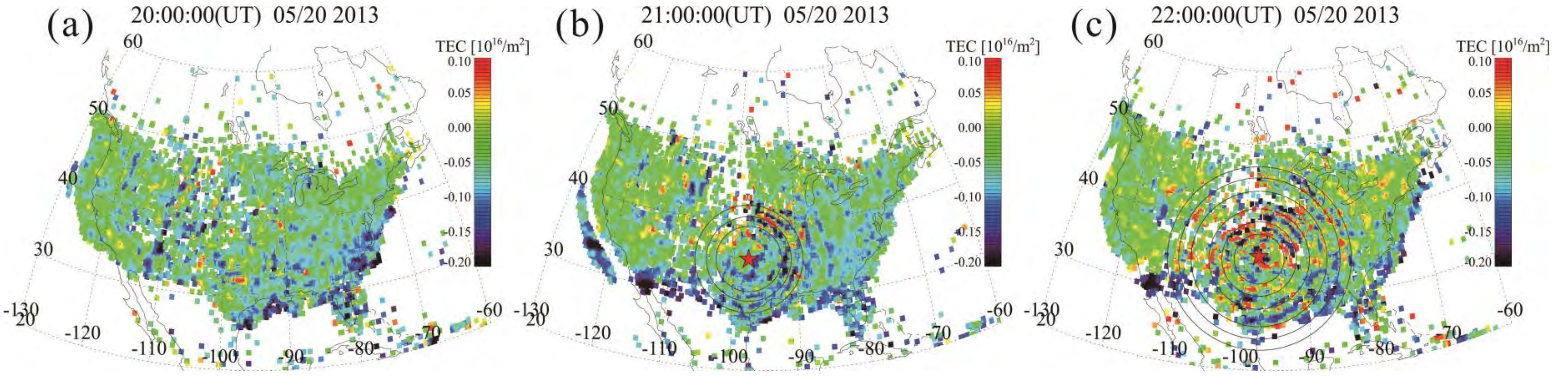


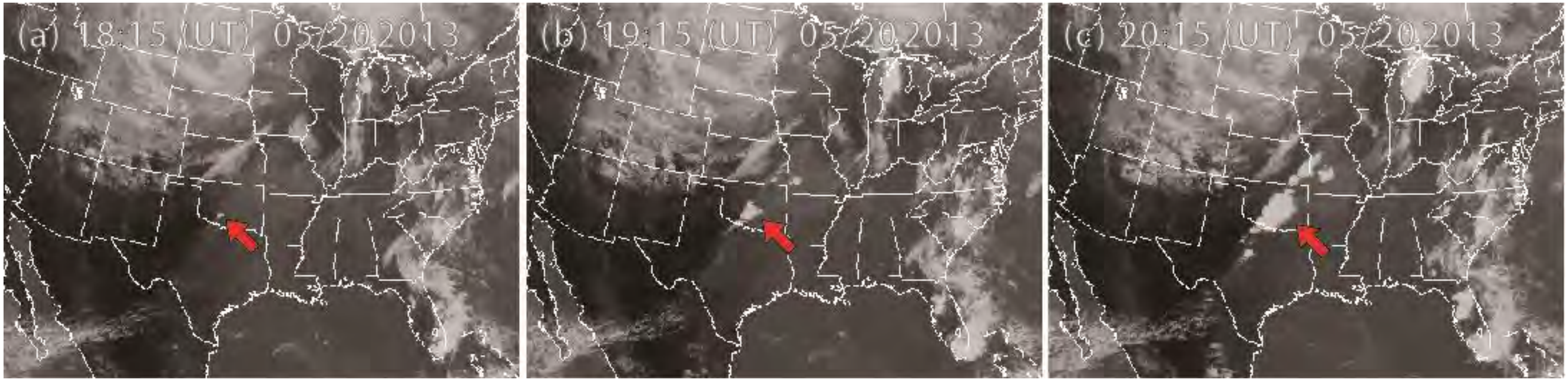
[Otsuka et al., 2012].

Ionospheric variations after massive tornados



Ionospheric variations after massive tornados





[Nishioka et al., GRL, 2013]

- Clear long-lasting concentric waves detected by the high-resolution TEC maps after massive tornados in North America.
- The peak-to-peak amplitude was ~1% of the background TEC.

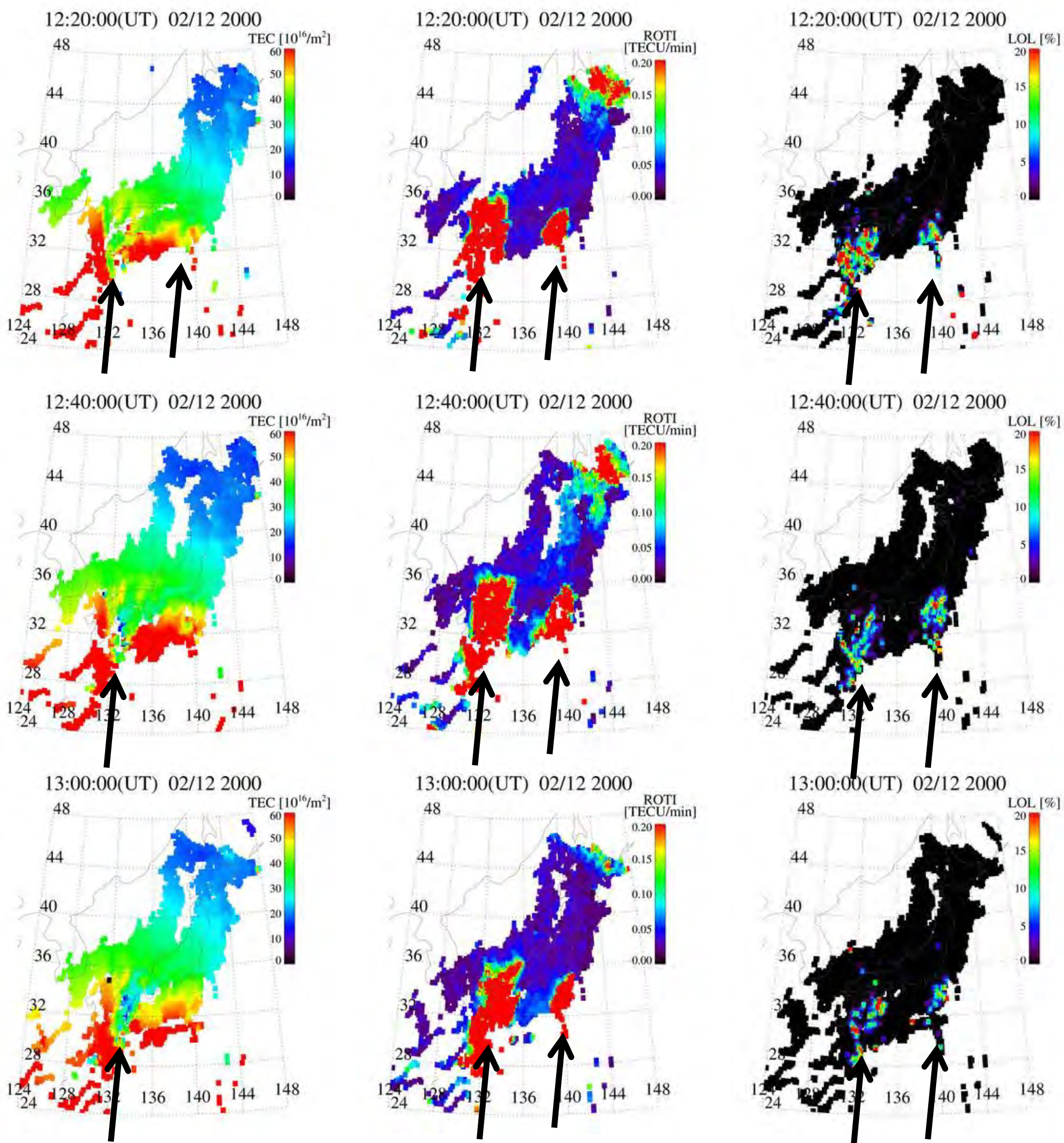
GPS-TEC Observations for Space Weather

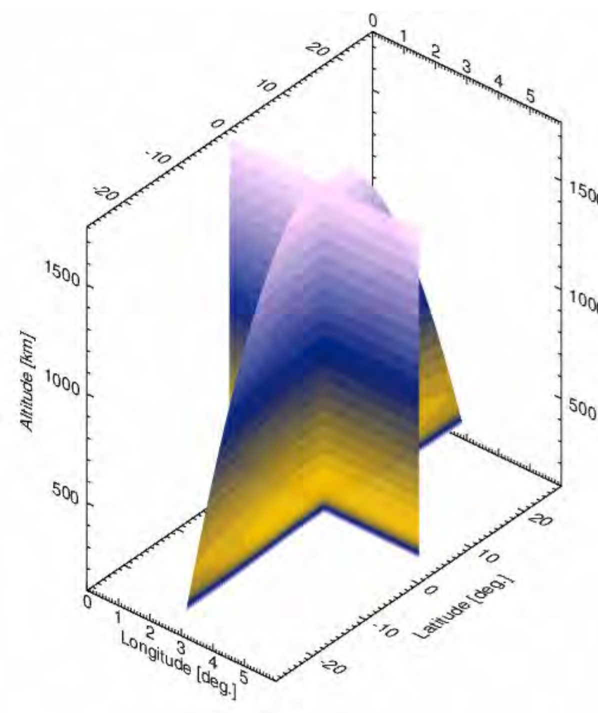
Absolute TEC | ROTI (~10km scale irregularity) | Loss-of-Lock (~100m scale irregularity)

12:20 UT (21:20 JST)

12:40 UT (21:40 JST)

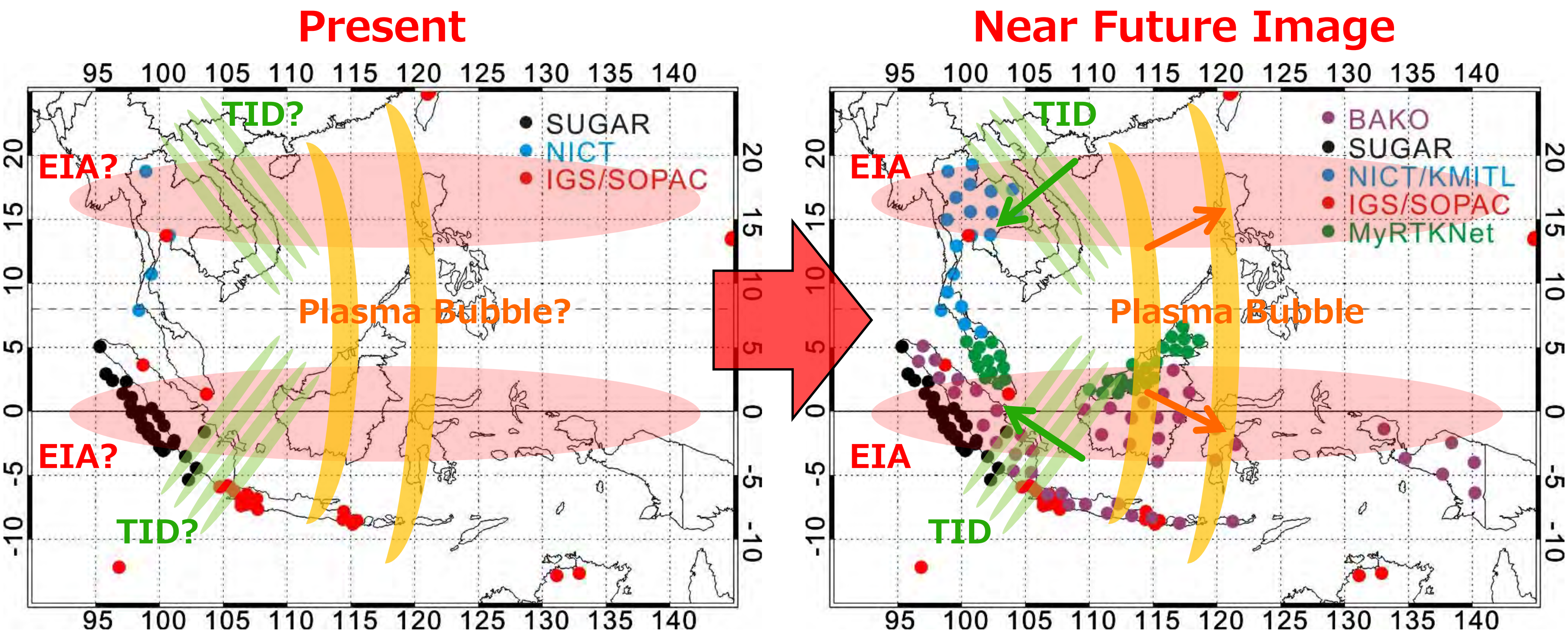
13:00 UT (22:00 JST)





3D simulation of plasma bubble [Courtesy of Dr. T. Yokoyama (NICT)]

Southeast Asian GNSS Networks Available for Ionospheric Researches



- The GPS-TEC maps greatly contribute to the ionospheric researches and the nowcast/forecast of space weather.
- However, it is difficult for a government and/or a data provider to provide the original GNSS receiver data abroad due to political and/or economic reasons because the raw data of GNSS receiver including multi-frequency carrier phase and psuedorange information are important and valuable

GPS Observation Data （RINEX ver.2 format）

```
     2.00           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE

DAT2RIN 2.35x       GSI, JAPAN          09MAR02 16:13:17 GMTPGM / RUN BY / DATE
GSI, JAPAN          GEOGRAPHICAL SURVEY INSTITUTE, JAPAN    OBSERVER / AGENCY
440101351           TRIMBLE 5700        Nav 1.05 Sig 0.00   REC # / TYPE / VERS
                    TRM41249.00                             ANT # / TYPE
0001                                                        MARKER NAME
                                                            MARKER NUMBER
 -3522845.0167  2777141.5661  4518959.0276                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N

     1     1                                                WAVELENGTH FACT L1/2

     4    L1    C1    L2    P2                              # / TYPES OF OBSERV
    30.0000                                                 INTERVAL
  2002     3     9     0     0    0.0000000     GPS         TIME OF FIRST OBS
HP-UX 10.20|PA-RISC|cc A.10.32.03|=+|=|                     COMMENT
***** RINEX HEADER SPECIFICATION 1.00 *****                 COMMENT
                                                            END OF HEADER
 02  3  9  0  0  0.0000000  0  9G 1G 2G 3G13G15G17G22G25G31
 -19012371.666     23282028.969   -14792202.9624   23282034.2034
 -20059488.864     22333773.945   -15610299.0404   22333776.2234
 -29405637.893     20488342.148   -22886235.5684   20488343.6844
 -10611214.715     23501437.734    -8249844.7244   23501441.9304
 -21574253.491     21813118.625   -16787240.0654   21813121.3794
 -19466956.219     22672753.922   -15147494.2964   22672757.9924
 -38120076.083     20147969.977   -29678594.7674   20147970.2814
 -34642202.746     23479338.891   -26972367.3494   23479343.8204
  -8256352.111     22876974.961    -6407292.0364   22876978.9264
 02  3  9  0  0 30.0000000  0  9G 1G 2G 3G13G15G17G22G25G31
 -18996599.842     23285030.305   -14779913.4304   23285036.4574
 -20169633.218     22312814.289   -15696125.7734   22312816.5204
```

Filename: ssssdddh.yyo
ssss: marker name
ddd: day of the year
h: file sequence number
yy: 2-digit year

Header Part

year, month, day, hour, min, sec, flag, # of PRNs, PRNs

1 epoch

- 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.

GNSS-TEC exchange (GTEX) format (v1.0)

```
     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
```

Filename: ssssdddh.yy_TEC
ssss: marker name
ddd: day of the year
h: file sequence number
yy: 2-digit year

Header Part

RINEX files used to derive slant TEC

Rec. Position in Lat, Lon, Alt

Types of obs. in RINEX

Types of data product

Interval according to RINEX

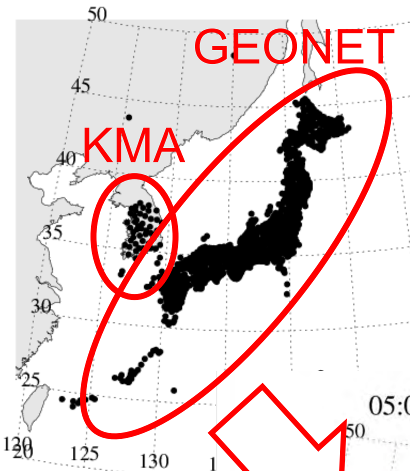
year, month, day, hour, min, sec, flag, # of PRNs, PRNs

sTEC, TEC flag, Used RINEX observation data, sat. zenith angle, azimuth angle for PRN21

1 epoch

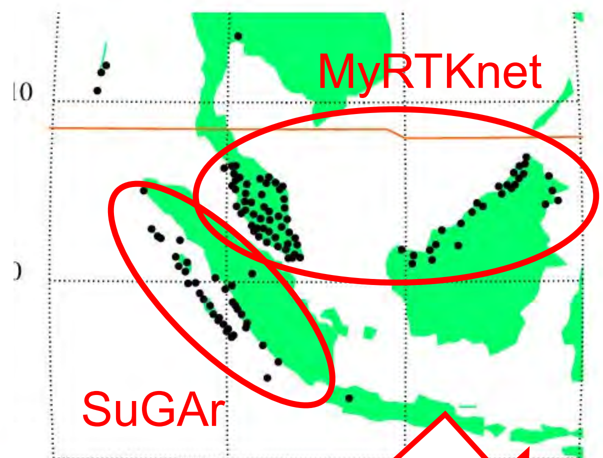
GNSS-TEC data sharing based on GTEX

- NICT have developed the database of “GTEX” data for more than 6,000 GNSS receivers in the world. These data are available via the NICT science cloud.
- Since the 1st AOSWA workshop, we started sharing the GTEX data among some countries.



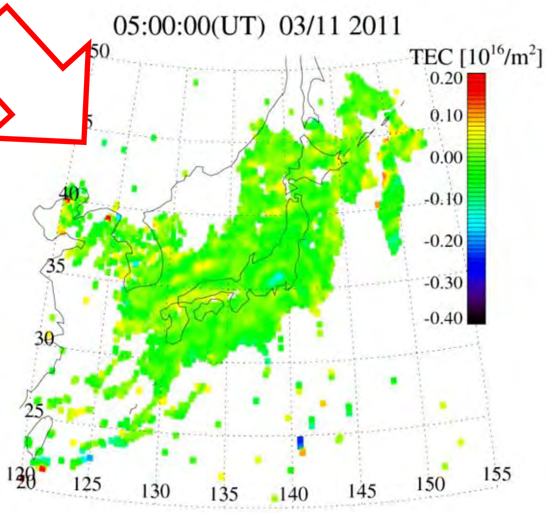
GPS receiver network in Japan and South Korea.

GTEX data in South Korea were provided by KMA.

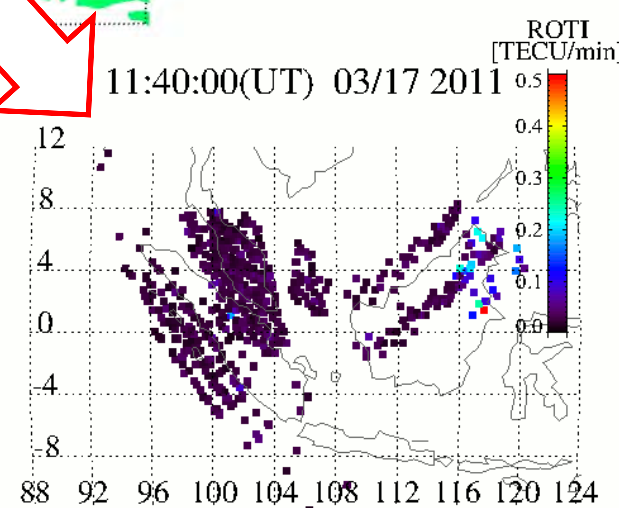


GPS receiver network from which UKM derived GTEX data

[Courtesy of Suhaila M Buhari (UKM, Malaysia)]



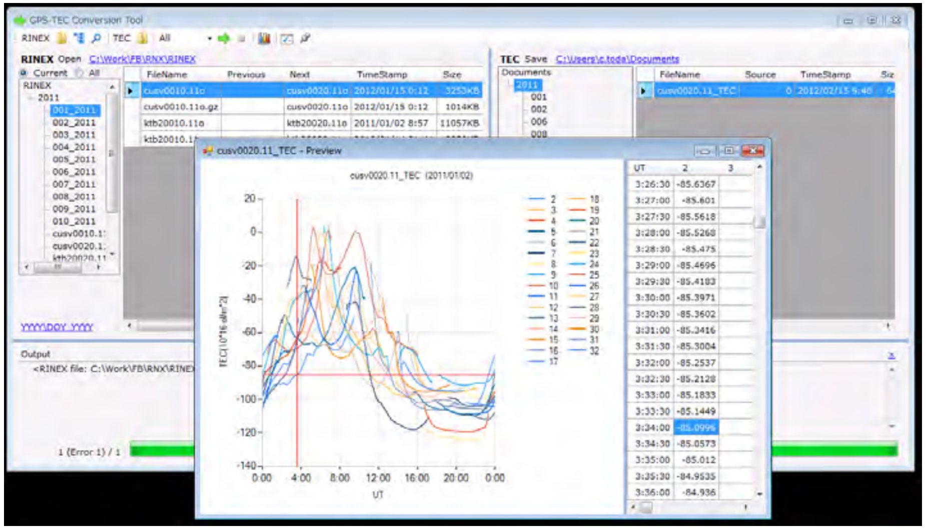
TEC maps detected concentric structures after the 2011 Tohoku EQ.



ROTI maps detected plasma bubble structures and propagations.

RINEX-to-GTEX Data conversion tool: RNX2GTEX

- We have developed software products to convert RINEX data to GTEX data.
- RNX2GTEX (ver. 0.1) for Linux/Unix consists in a set of programs written in fortran 77 and a shell script. The RNX2GTEX for Linux/Unix is available from the website: http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX.tgz
- RNX2GTEX for Windows XP/Vista/7 is also available from the website: http://seg-web.nict.go.jp/GPS/DRAWING-TEC/software/RNX2GTEX_WIN.zip
- NICT has developed the database of GTEX (ver. 0.1) derived from all the available online GNSS receiver data from 2000 to the current. This database is available via NICT Science Cloud (http://sc-web.nict.go.jp/) .



RNX2GTEX for Windows is an application for creating GTEX data files from RINEX data using explorer-like GUI.

Asia-Oceania Space Weather Alliance: AOSWA

http://aoswa.nict.go.jp

- Objective: make a regional linkage of information of space weather for operations and researches
- GTEX data sharing is one of important topics.

The 1st AOSWA workshop at Chiang Mai, Thailand during 22-24 February 2012.
- 10 countries, 30 organizations, 76 participants
- 41 oral presentations, 21 poster presentations, 1 tutorial lecture

The 2nd AOSWA workshop at Kunming, China will be held in 4-7 Nov 2013, hosted by CSERF and CAS.

ICAO Asia and Pacific Ionospheric studies task force (ISTF)

- ICAO plans to use aviation navigations based on GNSS, such as GBAS and SBAS. ICAO recognizes a necessity to evaluate the ionospheric effects on such navigations.
- ICAO Asia and Pacific have discussed about the effect of low-latitude ionospheric disturbances such as plasma bubble since 2009 and established the ionospheric studies task force (ISTF) in July 2011.

- In the 2nd meeting of ISTF held at Bangkok in Oct. 2012, the ionospheric data format for data sharing among countries were discussed.
- The GTEX format proposed by Japan (ENRI, NICT) were adopted as the sharing format in ISTF.

International Telecommunication Union Radiocommunication Sector (ITU-R)

- NICT, as a delegate of Japan, proposed “GTEX” as a format to promote international exchange and sharing of GNSS-TEC data in an input document to a meeting of Working Party 3L (ionospheric propagation and radio noise), Study Group 3 (radiowave propagation) of International Telecommunication Union Radiocommunication Sector (ITU-R) in June 2013 at Geneva, Switzerland.
- The document was discussed in the larger context of the need to incorporate new digital products and SG3DB tables (Study Group 3 databanks of radiowave propagation measurement data) .
- The definition and explanation of GTEX format was included in a Chairman’s report towards the definition of new digital products for transionospheric propagation. The Chairman’s report also included “IONEX” and “SCINTEX” format. The definition of digital products was added to the list of future work programme in Working Party 3L.

Summary

- High-resolution TEC observations using dense GNSS receiver networks can be a powerful tool to monitor and research medium-scale (~100-1,000 km) ionospheric disturbances such as plasma bubble.
- We propose a data format, GTEX, to promote international exchange and sharing GNSS-TEC data to expand observation area of high-resolution TEC maps.
- We have discussed about GTEX data sharing at AOSWA and started data sharing among some countries.
- The GTEX has been adopted as the basis of ionospheric data sharing by ICAO/ISTF and included in a Chairman's report of ITU-R WP3L.

SCINTEX

SCINtintillation and **T**EC **EX**change Format

Version 0.2

Raul Orus Perez, Roberto Prieto-Cerdeira
Wave interaction and Propagation Section
ESA/ESTEC

Takuya Tsugawa
Space Weather and Environment Informatics Laboratory,
Applied Electromagnetic Research Institute,
National Institute of Information and Communications Technology

Table of contents

I. Revision History

01 Apr 2014 (v0.0)	- Creation of the document
14 Apr 2014 (v0.1)	- Adding ROTI observable. - Added comments of Dr. Tsugawa concerning: - Naming of files - Multi-constellation Examples -Missing INTERVAL format on APPENDIX
22 Apr 2014 (v0.2)	- Suggestions of ISTG included. - IRNSS included (Surendra Sunda)

II. REFERENCES

[1] Werner Gurtner and Lou Estey "RINEX/ The RInex Independent Exchange Format, version 3.01"

III. INTRODUCTION

The SCINTEX Format originates from the necessity to harmonize the different vendor and future scintillation and total electron content (TEC) files.

The format is extensively based on the RINEX v3.01 format, see [1], trying to keep as much features as possible to allow the *compatibility* and easy adoption of it. The reason behind is that RINEX coped before with the problems of sharing large amounts of data between different multichannel systems and it is the standard for exchange of GNSS data.

IV. GENERAL FORMAT DESCRIPTION

The SCINTEX version 0.0 format consists of a single ASCII file containing all necessary information:

1. Observation data File

The file consists of a header section and a data section. The header section contains global information for the entire file and is placed at the beginning of the file. The header section contains header labels in columns 61-80 for each line contained in the header section. These labels are mandatory and must appear exactly as given in these descriptions and examples.

The format has been developed to mimic the RINEX v3 in order to maintain as much compatibility as possible. In computer systems allowing variable record lengths the observation records may be kept as short as possible. Trailing blanks can be removed from the records. There is no maximum record length limitation for the observation records.

The actual format descriptions as well as examples are given in the Tables at the end of the paper.

V. THE EXCHANGE OF SCINTEX FILES

It is recommended the following naming convention:

```
ssssdddf.yyT
|   |  | | |
|   |  | | +--    T:    Scintillation and TEC files
|   |  | |
|   |  | +----   yy:    two-digit year
|   |  +------    f:    file sequence number/character within day.
|   |                   daily file: f = 0 (zero)
|   |                   hourly files:
|   |                   a = 1st hour: 00h-01h; b = 2nd hour: 01h-02h;
|   |                         . . .       x = 24th hour: 23h-24h
|   +---------  ddd:    day of the year of first record
+------------- ssss:    4-charcter station name designator
```

For 15-minutes high-rate data (mostly TEC) the following name convention could be used:

```
ssssdddhmm.yyT
|   |  ||  | |
|   |  ||  | +--  T:    Scintillation and TEC files
|   |  ||  +---- yy:    two-digit year
|   |  |+-----   mm:    starting minute within the hour (00,15,30,45)
|   |  +------    h:    character for the n-th hour in the day.
|   |
|   |                   a = 1st hour: 00h-01h; b = 2nd hour: 01h-02h;
|   |                         . . .       x = 24th hour: 23h-24h
|   +---------  ddd:    day of the year of first record
+------------- ssss:    4-charcter station name designator
```

VI. SCINTEX VERSION FEATURES

The data for the scintillation parameters will follow the RINEX v3.01 channel allocation, but tailored to the needs of the ionospheric community.

A. Main observables

The main observable will be on the form of the observation code **tna** consists of three parts:

- **t** : observation type:
  - **W** = S4,
  - **Y** = Sigma phase index,
  - **S** = Signal strength,
  - **V** = S4 correction,
  - **T** = Lock Time,
  - **M** = Code Carrier Divergence (in meters * 10),
  - **N** = Sigma Code Carrier Divergence (in meters * 10),
  - **R** = Standard deviation of Rate change of TEC (ROTI)
  - *A = Ambiguity of the phase observable*
- **n** : band / frequency:
- **a** : attribute:

B. Ionosphere delay observables

Additionally to the **TEC** observable (see Non-frequency dependent data below) the SCINTEX maintains the ionospheric delay as in the RINEX v3. The ionosphere phase delay is expressed in full cycles of the respective satellite system-dependent wavelength as observable. Additionally the

Satellite and Receiver Code Biases can be included (for instance, the Raw Ionospheric delay could be recovered).

It is recommended to use this observable for high accuracy and high frequency ionosphere data. If the receiver raw ionosphere data is used, then the **TEC** observable (see Non-frequency dependent data below) should be used instead.

- **t** : observation type: **I** = Ionosphere phase delay
  J = Satellite Delay Code Biases
  K = Receiver Delay Code Biases
- **n** : band / frequency: 1, 2,...,8
- **a** : attribute: blank

The Satellite and Receiver Delay Code biases are included for high precision applications. It is allowed high sampling of the Satellite and Receiver Delay Code biases that are provided by a model. Since the Code biases are dependent on 2 frequencies this has to be indicated in the header under the **SYS / DCBS COMB**

The ionosphere delay observable has to be included into the list of observables of the respective satellite system. It is recommended one ionosphere delay observable per satellite.

d_ion(f j) = d_ion(fi) · (f i/fj)^2 (accounting for 1st order effects only)
d_ion(fi): Given ionospheric phase correction for frequency fi

If Delay Code biases are included they should be treated as follows:

d_ion_raw(fi)=d_ion(fi)+dcb_sat(fi)+dcb_rec(fi) ;

with,

dcb_xxx(fj)=dcb_xxx(fi) · (f i/fj)^2

Thus, the relation with the 2 fi and fj observables are derived from (see dual frequency observations **SYS / DCBS COMB**):

dcb_sat(fi)= (TR_sat(fi) – TR_sat(fj))/(1-(fi/fj)^2)
dcb_rec(fi)= (TR_rec(fi) – TR_rec(fj))/(1-(fi/fj)^2)
where TR_xxx(fi) are the group delays on frequency fi

It could also imply that:

d_ion(fi)=d_ion(fi,fj)*1/((fi/fj)^2-1);
where d_ion(fi,fj) := P(fj)-P(fi)

In general, RINEX v3 should be used to exchange GNSS observables. However, SCINTEX allows including the RINEX observables (P and L as observable type) when high rate Ionospheric data is delivered. It is recommended that if the observables are included they should be checked and filtered, and if possible cycle slips should be removed.

Examples:

- W1C: C/A channel S4 derived index
- W5Q: Pilot channel S4 derived index
- Y1P: P channel Sigma Phase derived index

C. Non-frequency dependent data

Most scintillation receivers could provide the slant TEC (sTEC) as an important output. This TEC is supposed to be less accurate than post-process one, but it can give information about the ionosphere directly from the receiver output.

TEC = Slant Total Electron Content (sTEC) from the receiver (could be either Raw or Calibrated; should be specified in the header) **in TEC Units * 1e3**
(1 TEC Unit = 1TECU = 10^{16} e^{-} m^{-2})

d_ion(fi) = 40.3/fi^2 * TEC *1e16 *1e-3 (in meters of signal in fi)

DEC = difference of sTEC from last epoch (t – INTERVAL) **in TEC Units * 1e3**
ELE = Elevation of the satellite in view **in degrees * 1e6**
AZI = Azimuth of satellite in view **in degrees * 1e6**

The values are scaled to fully represent the accuracy if necessary.

D. Band and channel description

System	Freq. Band	Frequency	Channel or Code	Channel ID
GPS	L1	1575.42	C/A	1C
			L1C(M)	1S
			L1C(L)	1L
			L1C(M+L)	1X
			P	1P
			Z-Tracking and similar (AS on)	1W
			Y	1Y
			M	1M
			codeless	1N
	L2	1227.60	C/A	2C
			L1(C/A)+(P2-P1) (semi-codeless)	2D
			L2C (M)	2S
			L2C (L)	2L
			L2C (M+L)	2X
			P	2P
			Z-Tracking and similar (AS on)	2W
			Y	2Y
			M	2M
			codeless	2N
	L5	1176.45	I	5I
			Q	5Q
			I+Q	5X
GLONASS	G1	1602+k*9/16 k=-7...+12	C/A (GLONASS M)	1C
			P	1P
	G2	1246+k*7/16	C/A (GLONASS M)	2C
			P	2P
	G3	1202.025	I	3I
			Q	3Q
			I+Q	3X
Galileo	E1	1575.42	A PRS	1A
			B I/NAV	1B

			OS/CS/SoL	
			C no data	1C
			B+C	1X
			A+B+C	1Z
	E5a	1176.45	I F/NAV OS	5I
			Q no data	5Q
			I+Q	5X
	E5b	1207.140	I F/NAV OS	7I
			Q no data	7Q
			I+Q	7X
	E5 (E5a + E5b)	1191.795	I	8I
			Q	8Q
			I+Q	8X
	E6	1278.75	A PRS	6A
			B C/NAV CS	6B
			C no data	6C
			B+C	6X
			A+B+C	6Z
SBAS	L1	1575.42	C/A	1C
	L5	1176.45	I	5I
			Q	5Q
			I+Q	5X
BDS	B1	1561.098	I	1I
			Q	1Q
			I+Q	1X
	B2	1207.14	I	7I
			Q	7Q
			I+Q	7X
	B3	1268.52	I	6I
			Q	6Q
			I+Q	6X
QZSS	L1	1575.45	C/A	1C
			L1C (D)	1S
			L1C (P)	1L
			L1C (D+P)	1X
			L1-SAIF	1Z
	L2	1227.60	L2C (M)	2S
			L2C (L)	2L
			L2C (M+L)	2X
	L5	1176.45	I	5I
			Q	5Q
			I+Q	5X
	LEX(6)	1278.75	S	6S
			L	6L
			S+L	6X
IRNSS	L5	1176.45	Unknown	5
	S	2492.028	Unknown	9

Unknown tracking mode: In case of unknown tracking mode or channel the attribute **a** can be left blank. However, a mixture of blank and non-blank attributes within the same observation type of the same frequency band and of the same satellite system has to be avoided.

E. Satellite system-dependent list of observables

The order of the observations stored per epoch and satellite in the observation records is given by a list of observation codes in a header record. As the types of the observations actually generated by a receiver may heavily depend on the satellite system SCINTEX uses the same solution as in RINEX v3 and requests system-dependent observation code list (header record type **SYS / # / OBS TYPES**).

F. Signal strengths

The raw signal strengths optionally stored as **Sna** observations in the data records should be stored in dbHz if possible. The new SIGNAL STRENGTH UNIT header record can be used to indicate the units of these observations. (This is the preferred option)

G. Observation data records

As the types of the observations and their order within a data record depend on the satellite system, the new format should make it easier for programs as well as human beings to read the data records. Each observation record begins with the satellite number snn, the epoch record starts with special character >. It is now also much easier to synchronize the reading program with the next epoch record in case of a corrupted data file or when streaming observation data. There is no record length limitation.

For the following list of observation types for the six satellite systems G,S,E,R,B,J

```
G   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
S   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
E   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
R   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
B   7 W1I Y1I S1I T1I TEC AZI ELE                          SYS / # / OBS TYPES
J   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
I   7 W5  Y5  S5  T5  TEC AZI ELE                          SYS / # / OBS TYPES
```

the epoch and observation records look as follows *(not real data example)*:

```
> 2011 08 28 21 06  0.0000000  0 09
G09          0.141          0.036        50.000        211.000          3.500   9200000.000  75000000.000
G25          0.121          0.056        43.900        211.000          6.100  55100000.000  45000000.000
S20          0.061          0.066        45.900        321.000          4.000  25200000.000  55000000.000
E19          0.100          0.076        48.000        211.000         11.200   5300000.000  25000000.000
E20          0.541          0.086        43.400        211.000          8.600 245400000.000  35100000.000
R03          0.141          0.022        42.300        213.000         12.700 135700000.000  25900000.000
B01          0.341          0.036        42.700        213.000         12.200 145500000.000  26700000.000
J01          0.141          0.016        41.300        211.000         22.800  45200000.000  10100000.000
I01          0.141          0.016        41.320        211.000         25.800   5200000.000  11100000.000
```

H. Dual frequency observations

In case that the SCINTEX is used to exchange high accuracy TEC information, the **SYS / DCBS COMB** gives valuable and necessary information to know which combination has been used to get the ionosphere phase delay.
The record is allows knowing which observables have been used to compute the ionosphere phase delay. It also records which satellites are using that combination.

Examples:

```
G I 1C2P 1P2P 09 G01 G02 G03 G04 G05 G06 G07 G08 G09
```

The observable I1 for satellites from G01 to G09 has been computed using:
Code: P1C and P2P
Phase: L1P and L2P

```
E I 1C5Q
```

All Galileo satellites uses the same observations for code and phase as follows:
Code: P1C and P5Q
Phase: L1C and L5Q

I. Order of the header records, order of data records

As the record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 3 header are able to decode the header records with formats according to the record descriptor, provided the records have been first read into an internal buffer.
We therefore propose to allow free ordering of the header records, with the following exceptions:

- The **SCINT VERSION / TYPE** record must be the first record in a file
- The **SYS / # / OBS TYPES** record(s) should precede any **SYS / DCBS COMB**.
- The **# OF SATELLITES** record (if present) should be immediately followed by the corresponding number of **PRN / # OF OBS** records. (These records may be handy for documentary purposes, and it is up to the user to include them).
- The **END OF HEADER** of course is the last header in the record

Data records: We explicitly exclude multiple epoch data records with identical time tags (exception: Event records). Epochs have to appear ordered in time.

APPENDIX: SCINTEX FORMAT DEFINITIONS AND EXAMPLES

TABLE A1
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns61-80)	DESCRIPTION	FORMAT
SCINT VERSION / TYPE	- Format version : 0.00 - File type: S for Scintillation Data - Satellite System: G: GPS R: GLONASS E: Galileo S: SBAS payload C: BeiDou J: QZSS I: IRNSS M: Mixed	F9.2,11X, A1,19X, A1,19X
PGM/ RUN BY /DATE	- Name of program creating current file - Name of agency creating current file - Date and time of file creation Format: yyyymmdd hhmmss zone zone: 3-4 char. Code for time zone. UTC recommended LCL if local time with unknown	A20, A20, A20
COMMENT	Comment line(s)	A60 *
MARKER NAME	Name of antenna marker	A60
OBSERVER/AGENCY	Name of the observer / agency	A20,A40
REC # / TYPE / VERS	Receiver number, type, and version	3A20
ANT # / TYPE / VERS	Antenna number and type	3A20
APPROX POSITION XYZ	Geocentric approximate marker position (Units: Meters, System: ITRS recommended)	3F14.4
POSITION LON LAT ALT	Ellipsoidal approximate marker position (Units, degrees and meters, System: WGS84 recommended)	2F14.8, F14.4
SYS/ # / OBS TYPES	- Satellite system code (G/R/E/S/C/J/M) - Number of different observation types for the specified satellite system - Observation descriptors: o Type o Band o Attribute Use continuation line(s) for more than 13 observation descriptors. In mixed files: Repeat for each satellite system. The following observation descriptors are defined in SCINTEX Version 0.xx: **Type:** W = S4 Y = Sigma phase index S = Raw signal strength V = S4 correction T = Lock Time M = Code Carrier Divergence N = Sigma Code Carrier Divergence I = Ionosphere phase delay J = Satellite Code biases K = Receiver Code biases	A1 2X,I3 13(1X,A3) 6X 13(1X,A3)

```
|                    | Band:                                    |            |
|                    |1= L1        (GPS, QZSS, SBAS)            |            |
|                    |   G1        (GLO)                        |            |
|                    |   E2-L1-E1  (GAL)                        |            |
|                    |   B1        (BDS)                        |            |
|                    |2= L2        (GPS, QZSS)                  |            |
|                    |   G2        (GLO)                        |            |
|                    |5= L5        (GPS, QZSS, SBAS, IRNSS)     |            |
|                    |   E5a       (GAL)                        |            |
|                    |6= E6        (GAL)                        |            |
|                    |   LEX       (QZSS)                       |            |
|                    |   B3        (BDS)                        |            |
|                    |7= E5b       (GAL)                        |            |
|                    |   B2        (BDS)                        |            |
|                    |8= E5a+b     (GAL)                        |            |
|                    |9= S         (IRNSS)                      |            |
|                    | Attribute:                               |            |
|                    |P = P code-based   (GPS,GLO)              |            |
|                    |C = C code-based   (SBAS,GPS,GLO, QZSS)   |            |
|                    |D = semi-codeless  (GPS)                  |            |
|                    |Y = Y code-based   (GPS)                  |            |
|                    |M = M code-based   (GPS)                  |            |
|                    |N = codeless       (GPS)                  |            |
|                    |A = A channel      (GAL)                  |            |
|                    |B = B channel      (GAL)                  |            |
|                    |C = C channel      (GAL)                  |            |
|                    |I = I channel      (GPS,GAL, QZSS, BDS)   |            |
|                    |Q = Q channel      (GPS,GAL, QZSS, BDS)   |            |
|                    |S = M channel      (L2C GPS, QZSS)        |            |
|                    |L = L channel      (L2C GPS, QZSS)        |            |
|                    |S = D channel      (GPS, QZSS)            |            |
|                    |L = P channel      (GPS, QZSS)            |            |
|                    |X = B+C channels   (GAL)                  |            |
|                    |I+Q channels       (GPS,GAL, QZSS, BDS)   |            |
|                    |M+L channels       (GPS, QZSS)            |            |
|                    |D+P channels       (GPS, QZSS)            |            |
|                    |W = Z-tracking     (GPS)                  |            |
|                    |Z = A+B+C channels (GAL)                  |            |
|                    |blank : for types I and X (all) or unknown|            |
|                    |tracking mode                             |            |
|                    |All characters in uppercase only!         |            |
|                    |                                          |            |
|                    |Units:                                    |            |
|                    |S4 and S4 correction:   dimensionless     |            |
|                    |Sigma phase index:      radians           |            |
|                    |Lock Time:              seconds           |            |
|                    |CCD and Sigma CCD:      meters    * 1e1   |            |
|                    |SNR:                    receiver-dependent|            |
|                    |Ionosphere:             full cycles       |            |
|                    |DCB satellite/receiver: full cycles       |            |
|                    |TEC and DEC:            TEC Units * 1e3   |            |
|                    |AZI and ELE:            degrees   * 1e6   |            |
|                    |0 <= AZI*1e-6 < 360                       |            |
|                    |0 <= ELE*1e-6 <= 90                       |            |
|                    |                                          |            |
|                    | The sequence of the observations in the  |            |
|                    | observation records has to correspond to |            |
|                    | the sequence of the types in this record |            |
|                    | of the respective satellite system.      |            |
+--------------------+------------------------------------------+------------+
|SIGNAL STRENGHT UNIT| Unit of the carrier to noise ratio       | A20,40X    |*
|                    | observables Snn (if present)             |            |
|                    | DBHZ: s/N given in dbHz                  |            |
+--------------------+------------------------------------------+------------+
|INTERVAL            | Observation interval in seconds          |   F10.3    |
+--------------------+------------------------------------------+------------+
|SYS / DCBS COMB     | Channels used to perform the ionospheric |            |*
|                    | combination.                             |            |
|                    | - Satellite system (G/R/E/S/C/J)         |   A1,1X    |
|                    | - Ionosphere phase delay (I)             |   A1,1X    |
```

```
|                    | - 1st frequency observation              |   I1A1,    |
|                    |   - Code Band        (1,2..8)            |            |
|                    |   - Code Attribute   (P,A..X, blank)     |            |
|                    | - 2nd frequency observation              |   I1A1,    |
|                    |   - Code Band                            |            |
|                    |   - Code Attribute                       |            |
|                    | Additionally the phase observations can  |            |
|                    | be specified if different from Code ones |   1X,      |
|                    | Otherwise leave 4 additional blanks      |  (4X or    |
|                    | - 1st frequency observation              |   I1A1,    |
|                    |   - Phase Band       (1,2..8)            |            |
|                    |   - Phase Attribute  (P,A..X, blank)     |            |
|                    | - 2nd frequency observation              |   I1A1,)   |
|                    |   - Phase Band                           |            |
|                    |   - Phase Attribute                      |            |
|                    | - Number of satellites involved 0        |   1X,I2.2, |
|                    | or blank: All                            |            |
|                    |    - List of satellites                  | 11(1X,A3)  |
|                    | Use continuation line(s) for more than 11| 18X,       |
|                    | satellites                               | 11(1X,A3)  |
|                    | Repeat record for each Ionosphere phase  |            |
|                    | delay                                    |            |
+--------------------+------------------------------------------+------------+
|# OF SATELLITES     | Number of satellites, for which          |    I6      |*
|                    | observations are stored in the file      |            |
+--------------------+------------------------------------------+------------+
|PRN / # OF OBS      | Satellite numbers, number of observations|    3X      |*
|                    | for each observation type indicated      |  A1,I2.2   |
|                    | in the SYS/ # / OBS TYPES record         |   9I6      |
|                    |                                          |            |
|                    | If more than 9 observations types:       |   6X,9I6   |
|                    | Use continuation line(s)                 |            |
|                    | In order to avoid format overflows, 99999|            |
|                    | indicates >= 99999 observations.         |            |
|                    | This record is (these records are)       |            |
|                    | repeated for each satellite present in   |            |
|                    | the data file.                           |            |
+--------------------+------------------------------------------+------------+
|TIME OF FIRST OBS   | - Time of first observation record       | 5I6,F13.7, |
|                    |  (4-digit- year, month, day, hour, min   |            |
|                    |   sec)                                   |            |
|                    |  Time system:                            |            |
|                    |     - GPS (=GPS time system)             |   5X,A3    |
|                    |     - GLO (=UTC time system)             |            |
|                    |     - GAL (=Galileo System Time)         |            |
|                    |     - QZS (= QZSS time system)           |            |
|                    |     - BDT (=BDS Time system)             |            |
|                    | Compulsory in mixed GNSS files Defaults: |            |
|                    |     GPS for pure GPS files               |            |
|                    |     GLO for pure GLONASS files           |            |
|                    |     GAL for pure Galileo files           |            |
|                    |     QZS for pure QZSS files              |            |
|                    |     BDT for pure BDS files               |            |
+--------------------+------------------------------------------+------------+
|TIME OF LAST OBS    | - Time of first observation record       | 5I6,F13.7, |*
|                    |  (4-digit- year, month, day, hour, min   |            |
|                    |   sec)                                   |            |
|                    | -Time system: Same value as TIME OF      |   5X,A3    |
|                    | FIRST OBS record                         |            |
+--------------------+------------------------------------------+------------+
|END OF HEADER       | Last record in the header section        |    60X     |
+--------------------+------------------------------------------+------------+
Records marked with * are optional
```

TABLE A2

GNSS OBSERVATION DATA FILE – DATA RECORD DESCRIPTION

DESCRIPTION	FORMAT
- Record identifier : >	A1
- Epoch	
- year (4 digits):	1X,I4
- month, day, hour, min (two digits)	4(1X,I2.2),
- sec	F11.7,
- Epoch flag	2X,I1,
0: OK	
1: power failure between previous and current epoch	
>1: Special event	
- Number of satellites observed in current epoch	I3,
- (reserved)	6X,
- Receiver clock offset (seconds, optional)	F15.2,
Epoch flag = 0 or 1: OBSERVATION records follow	
- Satellite number	A1,I2.2,
- Observation - repeat within record for each observation	m(F14.3)
This record is repeated for each satellite having been observed in the current epoch. The record length is given by the number of observation types for this satellite.	
Observations: For definition see text.	
Missing observations are written as 0.0 or blanks.	
--> Special events are fully compatible with RINEX v3.0 Listed the most common ones in SCINTEX	
- Epoch flag 2 - 5: EVENT: Special records may follow	[2X,I1]
- 4: header information follows	
- "Number of satellites" contains number of special records to follow. 0 if no special records follow.	[I3]
- Maximum number of records: 999	
For events without significant epoch the epoch fields in the EPOCH RECORD can be left blank	

Example SCINTEX file for GPS and Galileo:

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|0-
     0.00           SCINTILLATION DATA  M                  SCINT VERSION / TYPE
scintex_sept_v1     ESA                 20140401 153912 LCL 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
  344.88314896   21.01074126    11567.5697                 POSITION LON LAT ALT
E  18 W1C V1C Y1C S1C T1C M1C N1C W7Q V7Q Y7Q S7Q T7Q M7Q   SYS / # / OBS TYPES
      N7Q TEC DEC ELE AZI                                  SYS / # / OBS TYPES
G   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
S   7 W1C Y1C S1C T1C TEC AZI ELE                          SYS / # / OBS TYPES
E I 1C7Q                                                   SYS / DCBS COMB
   60.000                                                  INTERVAL
  2011     8    28    21    06    0.0000000     GPS        TIME OF FIRST OBS
  2011     8    28    21    59   59.0000000     GPS        TIME OF LAST OBS
   10                                                      # OF SATELLITES
                                                           END OF HEADER
> 2011 08 28 21 06  0.0000000  0 01
E19         0.041         0.036         0.000        48.900        11.000         0.000
0.000         0.037         0.038         0.000        48.500        11.000         0.019
0.019         0.000         0.000         0.000         0.000
> 2011 08 28 21 07  0.0000000  0 06
E19         0.041         0.040         0.000        48.000        71.000      -307.520
409.090         0.037         0.039         0.000        48.300        71.000
0.018         0.129        -8.000    885261.000  13000000.000  57000000.000
E11         0.045         0.036         0.000        48.800        17.000         1.520
0.730         0.033         0.035         0.000        49.200        17.000         0.016
0.040         0.000         0.000  60000000.000 291000000.000
E08         0.040         0.039         0.000        48.200        26.000        -0.020
0.330         0.035         0.038         0.000        48.500        26.000         0.006
0.024         0.000         0.000         0.000         0.000
G09         0.141         0.036        50.000       211.000         3.500   9200000.000
75000000.000
G25         0.121         0.056        43.900       211.000         6.100  55100000.000
45000000.000
S20         0.061         0.066        45.900       321.000         4.000  25200000.000
55000000.000
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