

GPS-TEC analysis application

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Brief features of this application - GPS data analysis

- Ability to batch process the input files (RINEX 2 & 3 formats etc.) for example: all files of the month, year, all stations and all files in directory.
- Gets ephemeris from IGS navigation file, has the ability to download the navigation file automatically if connected to internet; unless it finds the file in the same directory as data.
- Calculates TEC from the observation data of GPS Rinex, Novatel (reads only ID43 records), SCINDA (.scn files) and Leica (for leica formats, file name convention is yet to fix, works with our convention names now).
- Process cycle slips in phase data
- Read satellite biases from DCB IGS code files, if not available calculates them.
- Calculates the receiver bias
- Calculates the inter-channel biases for different satellites in the receiver.
- Plots the vertical TEC values on screen and writes ascii output files (*.CMN & *.STD) in the same directory of data file.

P.S. Complete description of algorithm is included in section 8 (it is brief now, to be improved in next version).

As the software is still in testing/developmental stage, I may recommend the free redistribution of this software when I get to the final version.

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This program was developed from the basic version of Fortran program (rinex_11.for) for RINEX provided by PATRICIA DOHERTY, Boston College, (Revised 02/99 by Pat Doherty)

This readme document is partially updated, will be updated in future to reflect more details.

The updated information may be found from the webpage <http://seemala.blogspot.com/>

List of files (file names) contained in this application (Ver 3.0)

Filename	Description	License	Source
GPS_TEC.exe	TEC analysis software executable	Educational/ Scientific use.	Gopi Seemala, IIG
GPS_TEC.ini	Settings file saved by GPS_TEC.exe	--	Gopi Seemala, IIG
GPS_TEC Readme.txt	This PDF document	Educational/ Scientific use.	Gopi Seemala, IIG
VC_redist.x86.exe	Visual studio run time. One time installation of this executable is required for the program to run.	Microsoft terms of use (may be distributed under excluded license)	Microsoft
mfc140.dll	DLL files from Microsoft, required for the program to run under windows		
msvcp140.odll			
vcruntime140.dll			
WinSCP.exe *	WinSCP is an open source free SFTP client and FTP client for Windows	GNU General Public License	winscp.net
WinSCP.com *	Command line interface for winscp		
Winscp.ini *	configuration file (optional) winscp		
IGS_stations.txt	List of IGS stations in ascii, which contains coordinates incase the Rinex obs. files miss it (optional)	General Public License	Text file created from IGS site.

* These files are required only when you want the program to download navigation and DCB IGS code files automatically from the website.

This application runs on Windows xp, Windows vista, Windows 7 and above versions of operating systems.

1. Installation:

This application doesn't require any installation into program files or registry. You just have to (unzip downloaded file) copy the above files in a folder, in any drive. Mostly the program is self-descriptive. This program runs only on windows operations systems versions windows XP and above.

But, one time installation of visual studio redistributable (32 bit version) is required (as the program is 32 bit for more compatibility), which is downloaded from the following site.
<https://support.microsoft.com/en-in/help/2977003/the-latest-supported-visual-c-downloads>

Note:

The program does not guarantee that the TEC values calculated from RINEX data are perfect; one should verify that the TEC values or any data output from this program are ok and then use them for scientific studies. As the GPS data processing for absolute TEC requires good calculation of the instrumental biases which involves some assumptions that may compromise the actual data quality.

2. Input file/requirements:

This program can process **Rinex observation files, Novatel (reads ID43 type records) binary files, SCINDA (.scn ascii), Leica binary files**; and also it needs **Rinex navigation file** for the observation date (of any station from IGS) to calculate elevation and azimuth angles of the satellites (which are required for vertical TEC calculation). The differential code bias (DCB) files provided by the IGS code website (<ftp://ftp.unibe.ch/aiub/CODE/>) for satellite biases are also required, the program uses them if they are available else it calculates them (not much effective as it allows some room for TEC variability).

Rinex 2.0 file format should be one of

STATddd0.YY<x> where <x> can be o- observation, d- hatanaka compressed observation

STATddd0.YY<x>.Z can be a unix compressed file **OR**

STAT_YYMMDD.YY<x>/.Z may have this year, month, day format in name.

Rinex 3.0 file format should be one of

XXXXMRCCC_K_YYYYDDDHHMM_01D_30S_tt.FFF.gz <.gz compression is optional>

XXXX_YYMMDD_hhmmss.obs (customized, not conforming to rinex 3 file name)

XXXXddd-YYYY-MM-DD.obs (customized, not conforming to rinex 3 file name)

For rinex 3.0 file names and data format details please see <ftp://igs.org/pub/data/format/rinex303.pdf>

Novatel and SCINDA file formats may not work correctly in this present program version 3.0, as couple of code changes may not fully compatible with data formats of Novatel and Scinda binaries. They will be improved in next version, please do not use those files with this Version 3.0

STAT – 4 letter station code

YY – 2 digit year, MM – 2 digit month, DD – 2 digit date, ddd – 3 digit day of the year

hh – hour (UT, 24 hour), mm – minutes, ss – second.

Rinex navigation file(s) can be obtained from the following websites

<ftp://data-out.unavco.org/pub/rinex/nav/> (program downloads navigation files from this site now)

<ftp://garner.ucsd.edu/pub/nav/>

<https://cddis.nasa.gov/archive/gnss/data/daily> (Earth login is required to access files.)

Select the year, then navigation files are found in directory of day of year.

Differential Code Bias (DCB) files can be obtained from website <ftp://ftp.aiub.unibe.ch/CODE/> select the year, then select files P1C1yymm.DCB.Z and P1P2yymm.DCB.Z (yy – 2 digit year, mm – 2 digit month)

If the files are downloaded manually, you should decompress them. Optionally, if there is internet connection available then the program can download the required Rinex navigation, DCB files from website automatically into the original data observation folder, de-compresses them and uses those files.

The data file can be given as a command line input at the program or *once you run (double click) the program just right click anywhere on the window to open a data file.* Also, you can always drag and drop the data (observational) file into the GPS_TEC.exe icon (Fig. 1) as the input file. If the data is in different directory, create a shortcut of the program by right click on it and select create shortcut . Then you can just copy the shortcut into the data directory, from where you can drag and drop the data files into the shortcut icon.

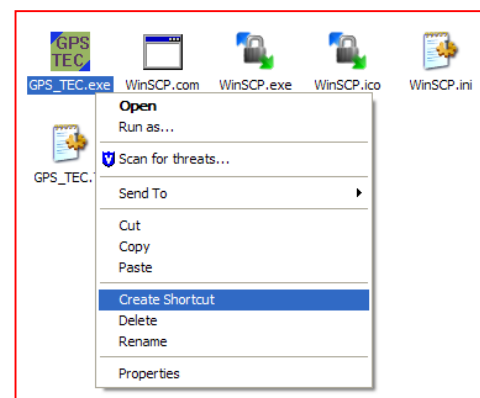


Fig 1. Creating the program shortcut.

2.1 Run it from other programs like Matlab, C, fortran, at command line (silent mode) etc: ("auto" option)

When this option is given, the program processes the command line input file automatically without requiring user action, but still user has chance to see what output types were selected for *5 seconds*. Thus, you will have only *5 seconds* if one wishes to change the settings (but I don't think it is enough time to respond/change settings rather than watch barely).

You can set **auto** mode from command prompt or from a script or program as follows

[Cmd prompt] <path>\GPS_TEC.exe[single space]<observation file with path>[single space]**auto**

d:\> e:\GPS_Gopi\GPS_TEC.exe D:\Gopi\Data\chpi1230.13o **auto**

You can save the file output settings before using the auto mode (you can see section 3), that way you can avoid rushing to change settings while running in auto mode. **Please refer to section 3.4 about saving the option settings before running the program in auto mode.**

The application will close automatically in *1.5 seconds* (just to show result) after the process is completed. That means the application will take *6.5 seconds + time taken to process files* to complete the operation and exit back to the script or your program.

3. Batch processing and file selection options

The screenshot shows the GPS_TEC application interface with the following options:

- Batch processing options:**
 - ☒ This Day only
 - ☐ This Month
 - ☐ This Year
 - ☐ Directory
 - ☐ Is All stations
- Output file path options:**
 - TargetDir: D:\Gopi\GPS_Gopi\
 - ☒ TargetDir Same as data
 - ☐ TargetDir Different
- Output file options:**
 - ☒ CMN file
 - ☒ STD file
 - ☐ Bias file
- Right side controls:**
 - Type: Rinex, 2010-01-01
 - Search: daej0010.10o, Files found # 01
 - Close/Restart to change file(s) to process
 - Browse Dir
 - Save config
 - Start Process

Fig 2. Batch processing and output options of the program

3.1 Batch processing options:

The above (cropped) screen shot that appears after giving the input file to the program, gives an option to selection the following four options for batch processing multiple files, in combination with fifth option (*Is all stations*). These options apply to only one type of files present in the directory, either .z zip files or just RINEX files, etc. but not to combination of different types. The batch option should be repeated for different types of files.

- (1) **This day only**: selecting this option will just process just the entered file, unless “Is all stations” is checked, then the program will process all the files (in that directory) for the present date (of entered file) in that directory.
- (2) **This month**: this option will process the files of the month of the single station (of input file) or all the stations data of the month if “Is all stations” option is checked.
- (3) **This year**: this option will process the files of the entire year of the single station (of input file) or all the stations if “Is all stations” option is checked.
- (4) **This directory**: this option processes all files in the directory (but only of single type) of that station or all stations if the “Is all stations” option is checked.

3.2 Output File path options:

These options give the user a control to change the location of where the output files can be saved! Saving the output files in a different directory other than the input path may be useful for multiple files.

- (1) **TargetDir same as data**: The input file path is the default path for the output files to be written when this option is selected.
- (2) **TargetDir Different**: the output files can be saved to a different directory by selecting this option and then browsing the destination folder using the “Browse Dir” command button, once the folder is selected it shows the new path in the textbox above the path options.

3.3 Output File options:

These options give the user a control to decide which output files to write to the destination path selected (click to put a tick for selection).

- (1) **CMN file**: selecting this option will write the calculated TEC ascii file (format as described in the following section 5) with extension .cmn in the destination directory.
- (2) **STD file**: this option will write the diurnal average TEC ascii file in the destination directory (see the following section for more details).
- (3) **Bias file**: this option will save an ascii file containing the satellite and receiver bias values (in TEC units) that were applied while processing the RINEX file.
- (4) **TEC 24 Hrs Image**: an image of 24 hour TEC plot for all prns will be saved when this option is selected.
- (5) **TEC PRN images**: selecting this option will save TEC plots individual PRN plots (a maximum of four files) as png images.
- (6) **(UN)/Bias TEC image**: this option will save TEC plots before and after receiver & satellite biases are removed, as shown in the application (see screenshot in section 6).

Note: the program will not write any output files if no option is selected.

3.4 “Save config” button:

Once you have selected all the required options and if you want these options to be saved for later use, you can press this button to save all the selected options. Next time the when the program will run, it will load these saved options (that are saved in *GPS_TEC.ini* file).

3.5 “Start process” button:

By pressing this button, the program will now start processing the given input(s) and the selected output files will be written to the output directory.

4. Receiver Bias Calculations:

The slant (STEC) calculated from phase & group TEC which is polluted with the receiver & satellite biases. Hence, desired slant $TEC = STEC + B_{Rx} + B_{Rich} + B_{sat}$

where B_{Rx} , B_{Rich} , B_{sat} are receiver bias, receiver inter-channel bias and satellite biases.

P.S. In the next version (I am hoping to upload by next month) will have more detail and complete process of the program will be explained with equations. Please check <http://seemala.blogspot.com/>

5. Format of generated TEC output file (*.CMN)

This ascii output file is in 10 columns separated by a tab, which is created in the same folder as data with file name "STATddd-YYY-MM-DD.CMN".

Data file contains the header of 3 lines as shown below

Line 1: `Station_name, Country` (OR)

Line 1a: `Unknown_station, "path\filename"` (written if the station & country are not available)

Line 2: `Latitude(deg) Longitude(deg) Altitude(m)`

Line 3: `Jdatet Time PRN Az Ele Lat Lon Stec Vtec S4`

(Line 3 is short description of data columns)

Jdatet Modified Julian date with fraction of day as time (next column [time in UT] may be preferred to Julian date as it is easier to interpret)

Time time in UT (it is in decimals, means $\text{hrs} + \frac{\text{minutes}}{60} + \frac{\text{Secs}}{3600}$, to convert back take integer as hours and multiply the fraction part with 60 & 3600 to get minutes & seconds respectively)

Az azimuth of the satellite in degrees.

Ele elevation of the satellite in degrees.

Lat, Lon sub-ionospheric pierce point latitude & longitude at 350 Km altitude.

Stec, Vtec slant and vertical TEC values respectively.

S4 S4 index where available (when using LISN formats). -99.000 indicates no data (such as in Rinex observation data). For Novatel format this will be implemented shortly.

All the columns are separated by tab.

6. Format of the mean TEC output (*.std)

This ascii output file is in 4 columns separated by a tab, which is created in the same folder as data with same file name except the extension changes to ".std"

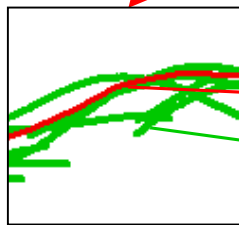
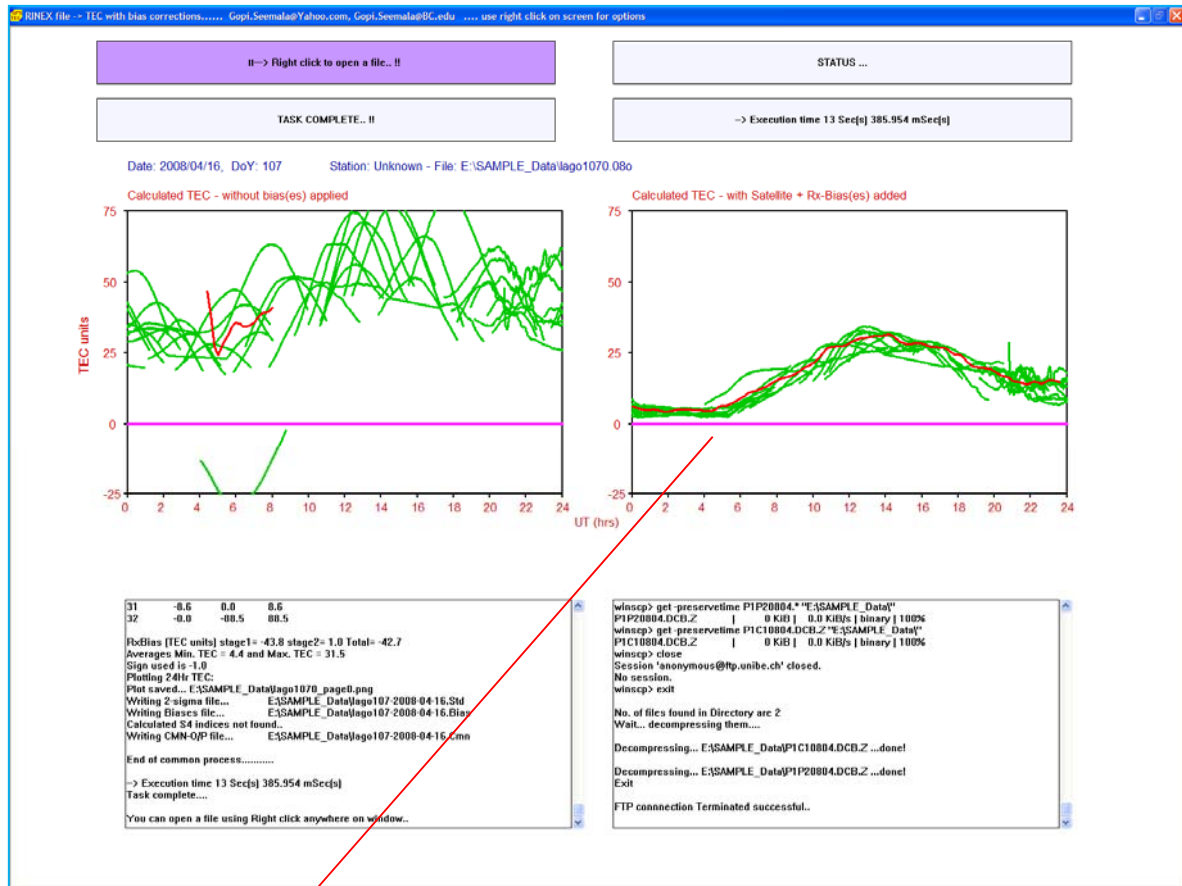
Column 1: Universal Time (in decimals, as described above)

Column 2: mean (2 sigma iterated) TEC, "-" (minus sign or hipen) indicates no data.

Column 3: standard deviation of TEC (at second iteration), "-" indicates no data.

Column 4: Latitude of the station

6. Screenshot of the program



- Red line** – Average (2 sigma iterated) TEC over all PRNs (output file: *.std)
- Green line** – vertical TEC from individual PRNs, here data presented is **above 20 deg elevation** angles (output file: *.cmn, it contains all elevation angles)

7. Known bugs:

1. Problem with Navigation file read:

Bug: Program keeps reading the *Navigation file* for an infinite time or it hangs:

Sometimes this may happen when you use the observation and *navigation files* respectively generated by your GPS receiver or from a source *other than from IGS website*. I have taken care to avoid this problem in most cases, but still it may happen in some cases.

Solution: This may be due to the incorrect format of the navigation file, so *please remove your navigation file* (or you can save it to another location, *move the file with name “*.<yy>n” to another folder instead, <yy> is the two digit year*), then *the program will automatically download navigation file from the IGS site*. Now the program should process everything as usual with the downloaded navigation file.

Also please send me the navigation file & observation file which resulted in error if possible, so that I can correct it.

2. Bias correction problems:

Calculating a correct receiver bias is always an unsolved problem. Most of the files were processed fine with proper (acceptable) bias corrections, but sometimes the TEC output figure doesn't look so good or completely like unbiased TEC because of incorrect calculation of receiver biases.

Solution: I am still working to improve the algorithm to handle this kind of situations, but any of your advice is most welcome.

3. Program hangs:

Bug: sometimes the input RINEX file(s) either observation or navigation file may not follow the RINEX specific format and this may result in hanging or no response from the program. Please try closing the program and run it; if this doesn't solve you may send those respective files to me so that I can look into the problem.

8. Feedback

In case if program didn't work on some data, send me the text copied from the text box of the program along with the sample data file that didn't work; I shall try to correct that.

email: Gopi.Seemala@Yahoo.com or Gopi.Seemala@Gmail.com