tec-suite Documentation

Release v0.7.8

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Nov 07, 2020

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CHAPTER 1

Overview

tec-suite is a tool for reconstruction of the slant total electron content (TEC) value in the ionosphere. It uses data of Global Navigation Satellite Systems such as GPS and GLONASS. To determine TEC value along "receiver-satellite" line-of-sight, **tec-suite** uses phase and pseudorange derived from RINEX files [RNX].

For the moment **tec-suite** supports:

- Navigation systems:
  - GPS
  - GLONASS
  - Galileo
  - Compass/BeiDou
  - GEO (geostationary satellites, part of SBAS)
  - IRNSS
- RINEX versions:
  - v.2 (2.0 - 2.11)
  - v.3 (3.0 - 3.03)
- File types:
  - RINEX observation files
  - Hatanaka-compressed RINEX observation files [CRNX]
  - RINEX navigation files
  - compressed (.Z or .gz) files

CHAPTER 2

Contents

2.1 Installation

Just download and extract **tec-suite** archive wherever you want.

Downloads:

- Windows
- Linux: x86_32 and x86_64
- macOS

2.1.1 Requirements

`crx2rnx` To decompress Hatanaka-compressed RINEX files, **tec-suite** uses crx2rnx.

`gunzip` To unarchive `.z`, `.Z` or `.gz`, files **tec-sutie** uses `gunzip`. If your system is **Linux** or **macOS** you probably have it installed. You can find the **Windows** version at GnuWin site.

Note: **tec-suite** for Windows comes with `crx2rnx` and `gzip` executables. In case of Linux or macOS put `crx2rnx` to a dir where `tecs` could find it, e.g. to the dir which contains `tecs` binary or to any dir in `$PATH` variable.

2.2 Usage

2.2.1 Synopsis

tec-suite is a command line tool. There is an executable named `tecs` (or `tecs.exe`) you should invoke to make work done.

In general, the command line looks like:

```
tecs [-v] [-c config_file] [--save-coordinates]
```

2.2.2 Command line

All the arguments are optional.

-c file Use the given config file instead of `tecs.cfg`.

-v Print the version and exit.

--save-coordinates Save the coordinates of the sites found in `obsDir` into `coordinates.txt`. TEC values are not calculated, the file is saved in a directory which contains configuration file.

2.2.3 Configuration

The configuration file contains a set of variables that affect the `tecs` behaviour. If not set explicitly with `-c file`, `tecs` will look for `tecs.cfg` in the working dir.

The syntax is simple; white-spaces are ignored, the `#` symbol begins comment to the end of the line, blank lines are ignored. All other lines are identified as setting variables, in the form `name = value`. The variable names are case sensitive.

Variables

obsDir *dir [, dir, . . .]* Directory with the RINEX observation files. It can contain a list of the directories separated by a comma.

navDir *dir [, dir, . . .]* Directory with the RINEX navigation files. It can contain a list of the directories separated by a comma.

outDir *dir* Output directory; output files will be saved in it.

outFileMode *mode* Output file format. The only one format available by now, and it is the `text` format (`outFileMode = text`). Output data will be saved in multicolumn text files. The set and the order of data columns are defined by the `recFields` variable.

recFields *'rec format'* Set and order of output file columns. A complete list of the columns ("fields") is given in the *Output file* section.

datetimeFormat *'date format'* Date/time format in output file; see the *Date/time* section for details.

samplingInterval *seconds* Interval in seconds to pick values from an observation file. Values of TEC, azimuth and elevation will be calculated with the interval. In case of `samplingInterval = 0` all the data will be read.

navPriorityGPS $site_1, site_2, \ldots, site_N$ Priority of search of navigation files for GPS. Here, *site* is a 4-symbol code of the station (the first 4 symbols of RINEX file name). First, `tecs` searches for $site_1$ navigation file. If it does not find it, it searches for $site_2$ file and so on to $site_N$. If `tecs` does not find any navigation file from the list, it takes the first available file.

navPriorityGLO $site_1, site_2, \ldots, site_N$ It is an analogue of `navPriorityGPS` for GLONASS.

navPriorityGEO $site_1, site_2, \ldots, site_N$ It is an analogue of `navPriorityGPS` for SBAS.

navIgnoreAbsence [True|False] When `True`, absence of navigation files for all satellite systems besides GLONASS is ignored. The values of elevation and azimuth are not calculated and are written as `0`. Note that for GLONASS the navigation file is required to calculate frequencies.

logLevel (DEBUG|INFO|WARNING|ERROR|CRITICAL) Sets the logging level. `ERROR` is usually enough.

Output file

The results are written into multicolumn text files. The name of an output file is formed as follows:

`site_SN_DDD_YY.dat`, where

site - site name, *S* - *satellite system identifier*, *N* - satellite number, *DDD* - day of the year, *YY* - year without century.

The order and the set of the output record fields are set by the `recFields` variable. The `recFields` value is a single quoted string which contains field names separated by a comma. For example,

```
recFields = 'datetime, el, az, tec.l1l2, tec.p1p2'
```

Therefore, it is possible to set the format of an output record so that it contains only desired values. The field names listed in *The TEC fields list* and *The output fields list*.

The following is the list of TEC reconstruction variants, which values can be written into an output file.

Table 1: The TEC fields list

Notation	Meaning
tec.p1p2	TEC value reconstructed using pseudorange P1 and P2 values
tec.c1p2	The same but using C1 and P2 values
tec.c1c2	The same but using C1 and C2 values
tec.c1c5	The same but using C1 and C5 values
tec.c2c5	The same but using C2 and C5 values
tec.c2c6	The same but using C2 and C6 values
tec.c2c7	The same but using C2 and C7 values
tec.c6c7	The same but using C6 and C7 values
tec.l1l2	TEC value reconstructed using phase L1 and L2 values
tec.l1l5	The same but using L1 and L2 values
tec.l2l5	The same but using L2 and L5 values
tec.l2l6	The same but using L2 and L6 values
tec.l2l7	The same but using L2 and L7 values
tec.l6l7	The same but using L6 and L7 values
tec.l1c1	TEC value reconstructed using phase L1 and pseudorange C1 values
tec.l2c2	TEC value reconstructed using phase L2 and pseudorange C2 values

The following is the list of other fields which can be inserted into `recFields` variable.

Table 2: The output fields list

Notation	Meaning
Date and time	
tsn	Time of the observation $t_{sn} = sec/dt$, where sec - number of seconds from
hour	Time of the observation in fractions of an hour.
datetime	Date and time of the observation. You can control date/time string using the
Coordinates	
site.x	Geocentric coordinate X of a receiver.
site.y	Geocentric coordinate Y of a receiver.
site.z	Geocentric coordinate Z of a receiver.
site.l	Geographic longitude L of a receiver.
site.b	Geographic latitude B of a receiver.
site.h	Altitude B of a receiver.
sat.x	Geocentric coordinate X of a satellite.

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Notation	Meaning
sat.y	Geocentric coordinate Y of a satellite.
sat.z	Geocentric coordinate Z of a satellite.
el	Elevation to a satellite.
az	Azimuth to a satellite.
Observable values	
p1	P1 pseudorange value.
p2	P2 pseudorange value.
l1	L1 carrier phase value.
l2	L2 carrier phase value.
l5	L5 carrier phase value.
s1	S1 raw signal strength value.
s2	S2 raw signal strength value.
s5	S5 raw signal strength value.
c1	1 pseudorange value.
c2	2 pseudorange value.
c5	C5 pseudorange value.
p1.lli	P1 Loss of Lock Indicator (LLI) value.
p2.lli	P2 LLI.
l1.lli	L1 LLI.
l2.lli	L2 LLI.
l5.lli	L5 LLI.
s1.lli	S1 LLI.
s2.lli	S2 LLI.
s5.lli	S5 LLI.
c1.lli	C1 LLI.
c2.lli	C2 LLI.
c5.lli	C5 LLI.

Date/time

Using the `datetimeFormat` variable one can set the format of the `datetime` field which will be written into an output file. Note that the `datetime` field should be put into the `recFields` string.

The `datetimeFormat` string can include:

- any printable character;
- date/time codes (according to the standard 1989 version).

For example, `%Y-%m-%d %H:%M:%S` corresponds to `2015-06-23 12:00:00`. The following is the list of codes.

Code	Meaning
%a	Weekday as locale's abbreviated name.
%A	Weekday as locale's full name.
%w	Weekday as a decimal number, where 0 is Sunday and 6 is Saturday.
%d	Day of the month as a zero-padded decimal number.
%b	Month as locale's abbreviated name.
%B	Month as locale's full name.
%m	Month as a zero-padded decimal number.
%y	Year without century as a zero-padded decimal number.
%Y	Year with century as a decimal number.
%H	Hour (24-hour clock) as a zero-padded decimal number.
%I	Hour (12-hour clock) as a zero-padded decimal number.
%p	Locale's equivalent of either AM or PM.
%M	Minute as a zero-padded decimal number.
%S	Second as a zero-padded decimal number.
%f	Microsecond as a decimal number, zero-padded on the left.
%z	UTC offset in the form +HHMM or -HHMM (empty string if the object is naive).
%Z	Time zone name (empty string if the object is naive).
%j	Day of the year as a zero-padded decimal number.
%U	Week number of the year (Sunday as the first day of the week) as a zero padded decimal number. All days in a new year preceding the first Sunday are considered to be in week 0.
%W	Week number of the year (Monday as the first day of the week) as a decimal number. All days in a new year preceding the first Monday are considered to be in week 0.
%c	Locale's appropriate date and time representation.
%x	Locale's appropriate date representation.
%X	Locale's appropriate time representation.
%%	A literal '%' character.

2.3 Moving receiver

Change of site location (i.e. change of the values of geocentric coordinates X, Y, Z during the file reading) is taken into account in the calculation of elevation and azimuth values. Moreover, there is a possibility to set the coordinates for required moments of time. To do that, one should put a file with the values of time and geocentric coordinates corresponding to them into a directory with an observation file. Running into such a file, `tecs` will read the coordinates and changes the values of X, Y and Z for each time moment listed in the file.

2.3.1 File with coordinates

The name of a file with coordinates should correspond to the name of an observation file and has an extension `xyz`. For example,

- `usud0700.11d.Z` and `usud0700.11d.xyz`;
- `usud0700.11o` and `usud0700.11o.xyz`;
- `usud070a00.11o` and `usud070a00.11o.xyz`.

Time stamp is set as `YYYY-MM-DD HH:MM:SS` followed by values of the X, Y and Z (in meters) separated by spaces. The # symbol begins a comment. For example,

```
# Site: USUD
# Datum: IGS08
# datetime, x (meters), y (meters), z (meters)
2011-03-11 05:00:00  -3855263.0771  3427432.6022  3741020.3066
2011-03-11 05:00:30  -3855263.0833  3427432.6068  3741020.3148
2011-03-11 05:01:00  -3855263.0761  3427432.6020  3741020.3089
...
```

2.4 Appendices

2.4.1 Constants

List and meaning of the constants which are used for calculation.

- Conversion of geocentric coordinates into geodesic coordinates:
  - ellipsoid semi-major axis: $6378137, m$;
  - ellipsoid semi-minor axis: $6356752.314245, m$.
- Calculation of elevation and azimuth:
  - Earth's radius: $6371 \cdot 10^3, m$.
- Calculation of geocentric coordinates of the GPS, GLONASS and GEO satellites:
  - Earth's angular velocity: $7.2921151467 \cdot 10^{-5}, rad/s$;
  - Earth's gravitational field constant: $39860044 \cdot 10^7, m^3/s^2$;
  - second zonal harmonic of geopotential expansion into a series of spherical functions: $1082625.7 \cdot 10^{-9}$;
  - ellipsoid semi-major axis: $6378136, m$ (for GLONASS, according to PZ-90).

2.4.2 Satellite system identifiers

The following is the list of the satellites system identifiers according to the RINEX format [RNX]:

- `G` - GPS
- `R` - GLONASS
- `E` - Galileo
- `S` - SBAS
- `C` - BeiDou

2.5 Bibliography

Bibliography

[RNX] The Receiver Independent Exchange Format.

[CRNX] Hatanaka, Y., A Compression Format and Tools for GNSS Observation Data, Bulletin of the GSI, V. 55, pp. 21-30, 2008.