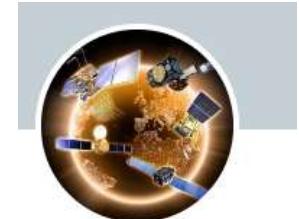


GIS-E5050

Unit 3: GNSS positioning practice

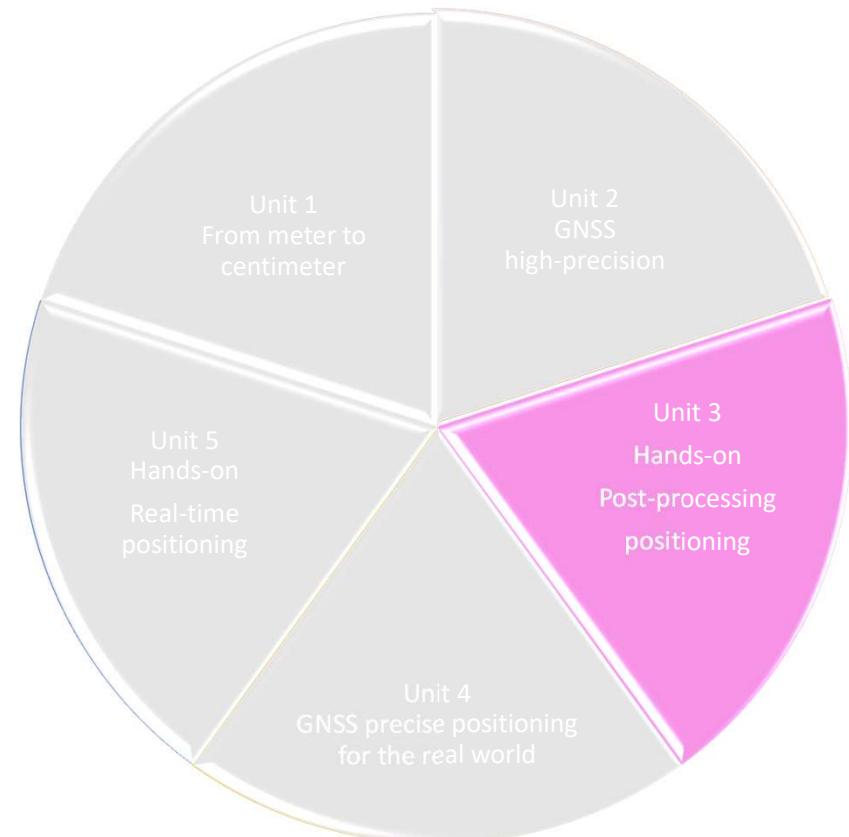
Post-processing hands-on



Octavian Andrei
@coandrei

Module structure

- Preparation
- SPP
- Differential
- Relative
- PPP



Preparation

Tools & data

RTKLIB: the library tool

- **An Open Source Software Package for GNSS Positioning**
 - Has been developed since 2006
 - The latest released version 2.4.2 p13 distributed under BSD license
 - The latest developer version 2.4.3 b34
- **Portable APIs and Useful APIs**
 - "All-in-one" package for Windows with CLI APIs for any environments
 - Many other branches on github

[Overview](#) | [Release Notes](#) | [Support](#) | [Documents](#) | [References](#) | [Porting to BB](#) | [To Do](#) | [Statistics](#) | [SDR Receiver](#)



RTKLIB: An Open Source Program Package for GNSS Positioning

Download

Version	Date	Binary AP Package for Windows	Full Package with Source Programs
0.2.0	2006/12/16	-	rtklib_0.2.0.zip (2.8MB)
1.0.0	2007/01/25	-	rtklib_1.0.0.zip (10.5MB)
1.1.0	2007/03/20	-	rtklib_1.1.0.zip (6.2MB)
2.1.0	2008/07/15	-	rtklib_2.1.0.zip (22.9MB)
2.2.0	2009/01/31	rtklib_2.2.0_bin.zip (10.7MB)	rtklib_2.2.0.zip (23.4MB)
2.2.1	2009/05/17	rtklib_2.2.1_bin.zip (15.3MB)	rtklib_2.2.1.zip (30.6MB)
2.2.2	2009/09/07	rtklib_2.2.2_bin.zip (21.4MB)	rtklib_2.2.2.zip (33.8MB)
2.3.0	2009/12/17	rtklib_2.3.0_bin.zip (26.7MB)	rtklib_2.3.0.zip (35.8MB)
2.4.0	2010/08/08	rtklib_2.4.0_bin.zip (17.4MB)	rtklib_2.4.0.zip (26.5MB)
2.4.1	2011/06/11	rtklib_2.4.1_bin.zip (16.5MB)	rtklib_2.4.1.zip (26.4MB)
2.4.2	2013/04/29	rtklib_2.4.2_bin.zip (30.4MB)	rtklib_2.4.2.zip (55.2MB)

These are just old archives for recording. To download of the newest version, please visit the following GitHub links.

Version	Date	Binary APs for Windows	Source Programs and Data
2.4.2 p13	2018/01/29	GitHub	GitHub
2.4.3 b34	2020/12/29	GitHub	GitHub

The 2.4.2 pXX is the stable version with the newest patches. The 2.4.3 bXX is the development or beta version with experimental implementations.
Please refer the [support information](#) for bug and known problem list.

<http://www.rtklib.com> or
<https://github.com/tomojitakasu/RTKLIB>

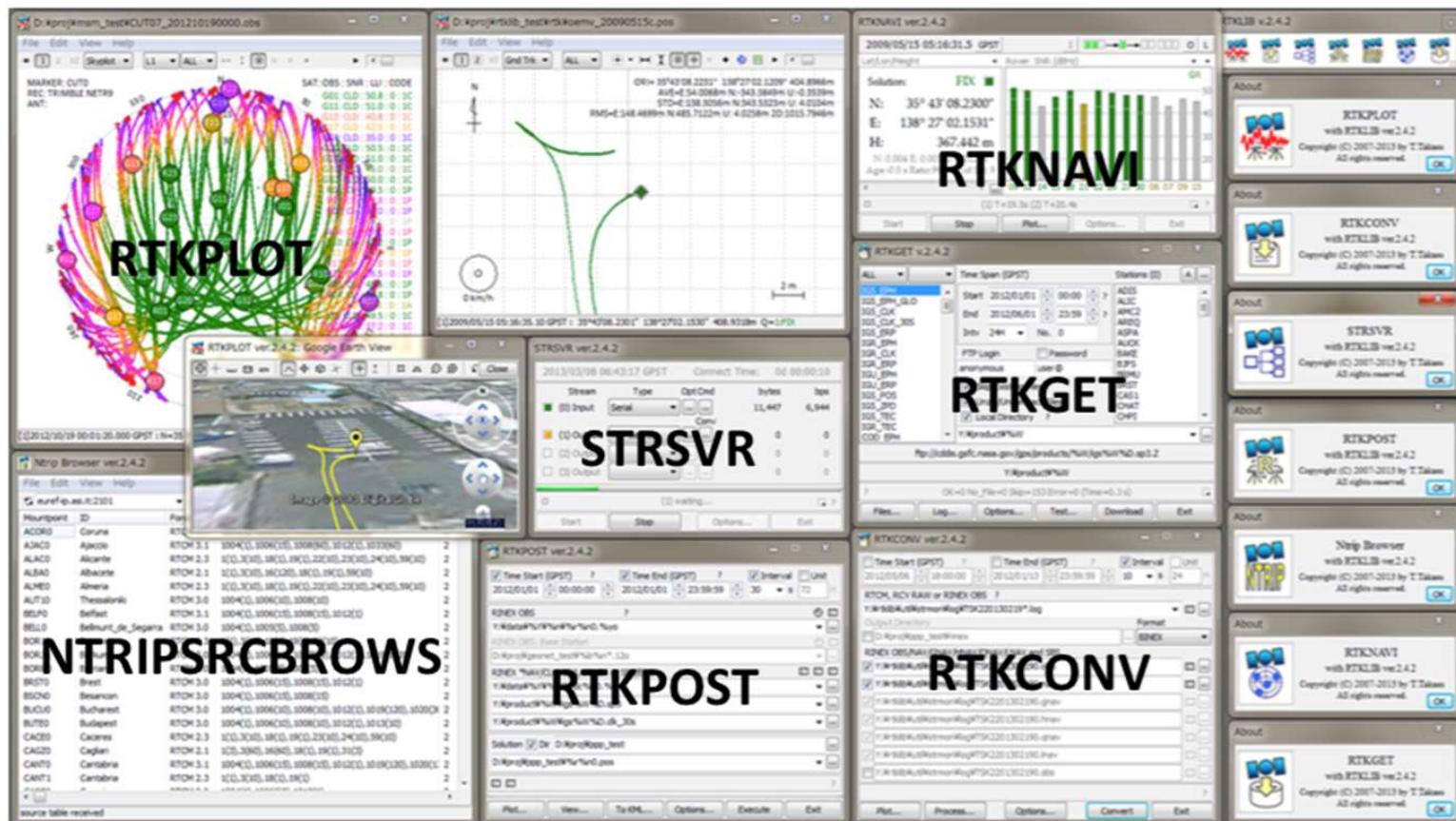
RTKLIB: Features

- Standard & precise positioning
 - ✓ Pseudorange vs. carrier
 - Multiple constellation support
 - GPS, GLONASS, Galileo, BeiDou,
 - QZSS, NavIC, SBAS
 - Real-time and post-processing positioning modes
 - DGPS, SBAS, RTK, NRTK, PPP
 - Static vs. kinematic
 - Fixed vs. moving base



- **Many formats, protocols and receivers**
 - RINEX, SP3, CLK, ANTEX, IONEX, ...
 - BINEX, NMEA, RTCM, NTRIP
 - NovAtel, JAVAD, Hemisphere, SkyTraq, Septentrio, u-blox
 - **Real-time comms**
 - Serial, TCP/IP, NTRIP, file streams

RTKLIB: GUI APs



GIS-E5050: Advanced Geodesy
17.03.2021

Email: octavian.andrei@nls.fi

Twitter: @coandrei

- image
- leaflet
- convbin
- crx2rnx
- gmview_notes
- gzip
- libgcc_s_seh-1.dll
- libgfortran-3.dll
- libiconv-2.dll
- libintl-2.dll
- libopenblas.dll
- libquadmath-0.dll
- LICENSE
- pos2kml
- rnx2rtkp
- rtkconv
- rtkget
- rtklaunch
- rtklib_gmap
- rtknavi
- rtkplot
- rtkplot_gm
- rtkplot_ll
- rtkpost
- srctblbrows
- strsvr
- tar
- teqc
- wget

RTKLIB: CUI APIs

- **RNX2RTKP (rnx2rtkp)**
 - Post-processing Positioning
- **RTKRCV (rtkrcv)**
 - Real-time Positioning
- **CONVBIN (convbin)**
 - RINEX Translator
- **STR2STR (str2str)**
 - Stream Server
- **POS2KML (pos2kml)**
 - Google Earth Converter

A.2 RNX2RTKP

SYNOPSIS

```
rnx2rtkp [option ...] file file [...]
```

DESCRIPTION

Read RINEX OBS/NAV/GNAV/HNAV/CLK, SP3, SBAS message log files and compute receiver (rover) positions and output position solutions.

The first RINEX OBS file shall contain receiver (rover) observations. For the relative mode, the second RINEX OBS file shall contain reference (base station) receiver observations. At least one RINEX NAV/GNAV/HNAV file shall be included in input files. To use SP3 precise ephemeris, specify the path in the files. The extension of the SP3 file shall be **.sp3** or **.eph**. All of the input file paths can include wild-cards (*). To avoid command line deployment of wild-cards, use “...” for paths with wild-cards.

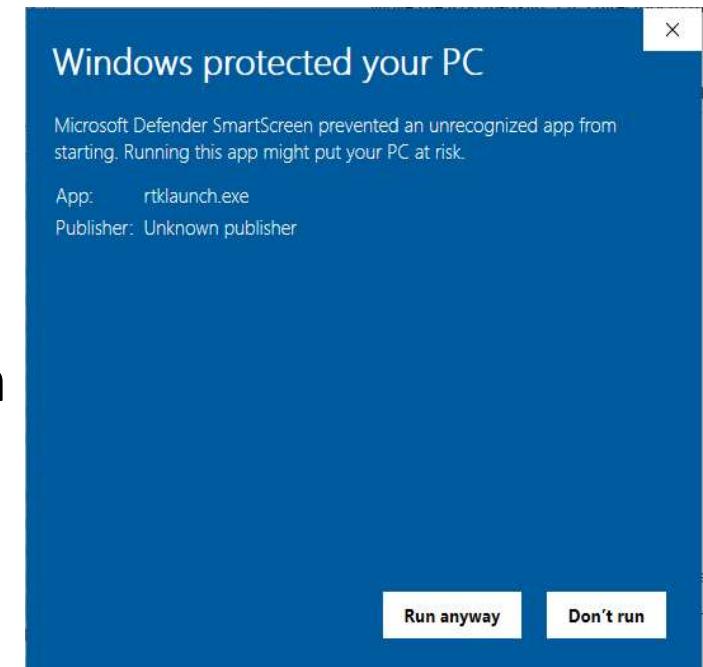
Command line options are as follows ([]:default). With -k option, the processing options are input from the configuration file. In this case, command line options precede options in the configuration file. For the configuration file, refer B.4.

OPTIONS

```
-?      print help
-k file  input options from configuration file [off]
-o file  set output file [stdout]
-ts ds ts start day/time (dssy/m/d tsh:m:s) [obs start time]
-te de te end day/time (dssy/m/d tsh:m:s) [obs end time]
-ti tint time interval (sec) [all]
-p mode   mode (0:single,1:dgps,2:kinematic,3:static,4:moving-base,
           5:fixed,6:ppp-kinematic,7:ppp-static) [2]
-m mask   elevation mask angle (deg) [15]
-f freq   number of frequencies for relative mode (1:L1,2:L1+L2,3:L1+L2+L5) [2]
-v thres validation threshold for integer ambiguity (0.0:no AR) [3.0]
-b       backward solutions [off]
-c       forward/backward combined solutions [off]
-i       instantaneous integer ambiguity resolution [off]
-h       fix and hold for integer ambiguity resolution [off]
-e       output x/y/z-ecef position [latitude/longitude/height]
-a       output e/n/u-baseline [latitude/longitude/height]
```

Word of warning

- The library has no publisher signature. Thus, your Windows machine may complain about it when you want to run any application for the first time.
- The only way to move forward is to choose Run anyway.
- If you feel uncomfortable, then you will be limited to only viewing the demos during the class.



RTKLIB: References

RTKLIB ver. 2.4.2 Manual



April 29, 2013

Contents

1 Overview	1
2 User Requirements	3
2.1 System Requirements	3
2.2 License	4
3 Instructions	5
3.1 Installation and Uninstallation	5
3.2 Real-Time Positioning with RTKNAVI	7
3.3 Configure Input, Output and Log Streams for RTKNAVI	22
3.4 Post-Processing Analysis with RTKPOST	29
3.5 Configure Positioning Options for RTKNAVI and RTKPOST	34
3.6 Convert Receiver Raw Data to RINEX with RTKCONV	50
3.7 View and Plot Solutions with RTKPLOT	55
3.8 View and Plot Observation Data with RTKPLOT	69
3.9 Download GNSS Products and Data with RTKGET	77
3.10 NTRIP Browser	83
3.11 Use CUI APIs of RTKLIB	86
4 Build APIs or Develop User APIs with RTKLIB	87
4.1 Rebuild GUI and CUI APIs on Windows	87
4.2 Build CUI APIs	88
4.3 Develop and Link User APIs with RTKLIB	89
Appendix A CUI Command Reference	90
A.1 RTKRCV	90
A.2 RNX2RTKP	93
A.3 POS2KML	95
A.4 CONVBIN	96
A.5 STR2STR	99

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RTKLIB_2.4.3_b34\doc\manual_2.4.2.pdf

GIS-E5050: Advanced Geodesy
17.03.2021

Email: octavian.andrei@nls.fi

Twitter: @coandrei

RTKLIB: Support Information
update 2021/01/14

Inquiry

First of all, please read again the [manual](#) and the [release notes](#) (refer [RTFM](#) as well.) If they do not solve your problem(s), send the e-mail to the following address. (It may take a long time to receive the answer due to lack of our time for support.)

rtklib_support(a)gpsspp.sakura.ne.jp (replace (a) by @)

Forum

There is no formal support forum but the followings sometimes make discussions on RTKLIB.

[FOSS-GPS — Open Source GPS-related discussion and support](#)
[Geospector GPS-Forum \(formerly kowcon GPS-Forum\) \(in Germany\)](#)
[DIY Drones: The Leading Community for Personal UAVs - GPS](#)
[OpenStreetMapForum-users: Russia \(in Russian\)](#)

Wiki

[OpenStreetMap: RTKLIB](#)

Blog

[rtklibexplorer: Exploring ultra-low cost precision GPS with RTKLIB and Ublox receivers](#)

GitHub

Issues or Pull Requests for the GitHub repository may provide helpful info.
The beta versions of RTKLIB are available as a development branch of the GitHub repository.

<https://github.com/tomojitataku/RTKLIB>
https://github.com/tomojitataku/RTKLIB/tree/rtklib_2.4.3

Bug and Known Problem List

No.152 Unable to read more than 99 satellites' data in a SP3-d precise ephemeris file (RTKPOST, RNX2RTKP, ver. 2.4.3 b34)

APs can not read SP3-d precise ephemeris if the file contains more than 99 satellites' data.

Due to a bug in RTKLIB/src/preceph.c. Improper decoding of a SP3-d header field causes an error in reading file. It will be fixed in the next release. Wait for the release, or edit the following line and rebuild APs. (2021/01/14)

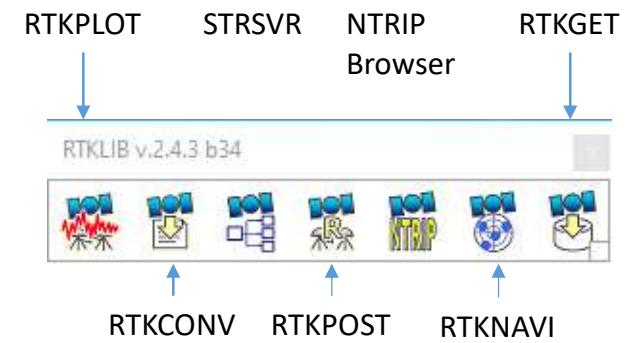
RTKLIB/src/preceph.c L.91 (RTKLIB 2.4.3 b34)

ns=(int)str2num(buff,4,2);

http://www.rtklib.com

Install RTKLIB

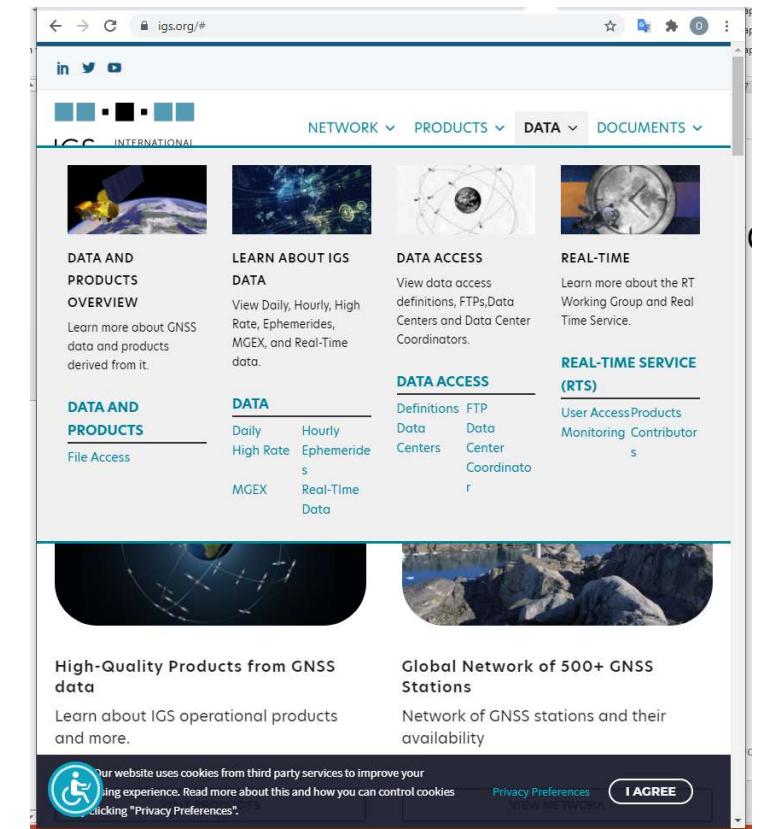
- Fetch **gnss_unit3.zip** archive in MyCourses
- Unzip the archive
- Create a working directory called GIS-E5050 in your **X:** drive
- Copy the content of the unzip archive to this working directory.
- Run **X:\GIS-E5050\RTKLIB_2.4.3_b34\bin\rtklaunch.exe**



Prepare data files: online archives

- **International**

- **International**
 - ✓ <https://www.igs.org/>



- **European**

- **European**
 - ✓ <http://www.epncb.oma.be/>
 - ✓ <http://navigation-office.esa.int>

- **National**

- **National**
 - ✓ <https://finpos.nls.fi/gppweb/rinex>

- ... many more out there

Prepare data files: RTKGET

1. Select the organization

2. Select the data type

3. Select the product

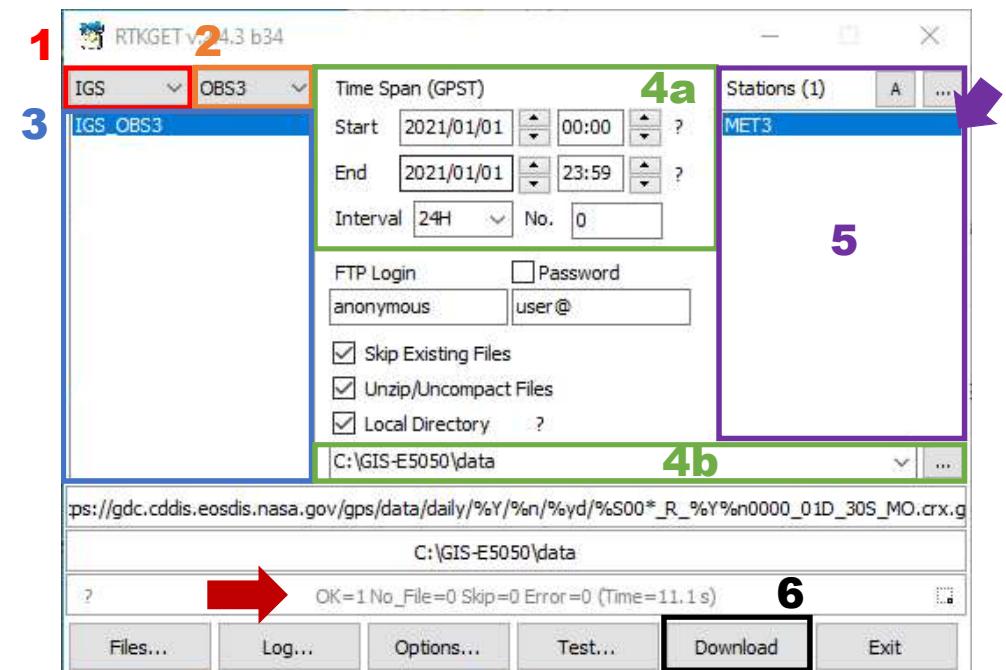
4a. Specify the time span

4b. Specify the location

5. Give the station name

6. Download

7. Verify



Data types

- **OB**Servation
- **AL**Manac
- **NA**Vigation
- Precise **EP**Hemeris
- Precise **CL**o**K**s
- Differential **C**ode **B**iases
- Earth **R**otation **P**arameters
- Antenna Phase Center Offset and Variations
- Ocean Tide Loading¹
- IGS solution
- Global Ionosphere Maps
- Zenith Tropospheric Delay
- ...

¹<http://holt.oso.chalmers.se/loading/>

... and

- For this practice all the necessary files are in the **\data** directory.
- **gnss_unit3.zip** archive in MyCourses (if you have not fetched it already)
- Of course, you are free to explore your own data or other scenarios.

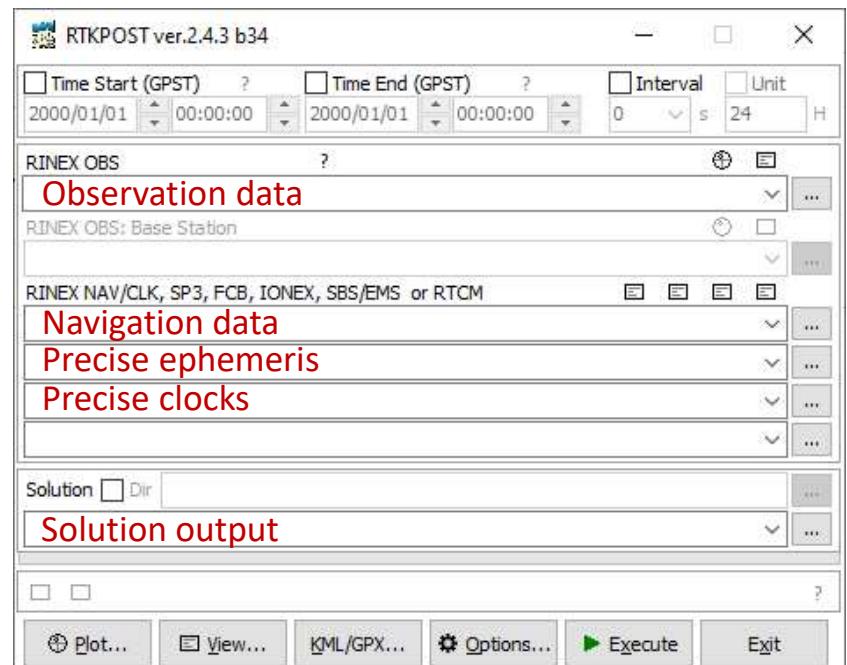


SPP: Standard Point Positioning

Easy, simple and quick

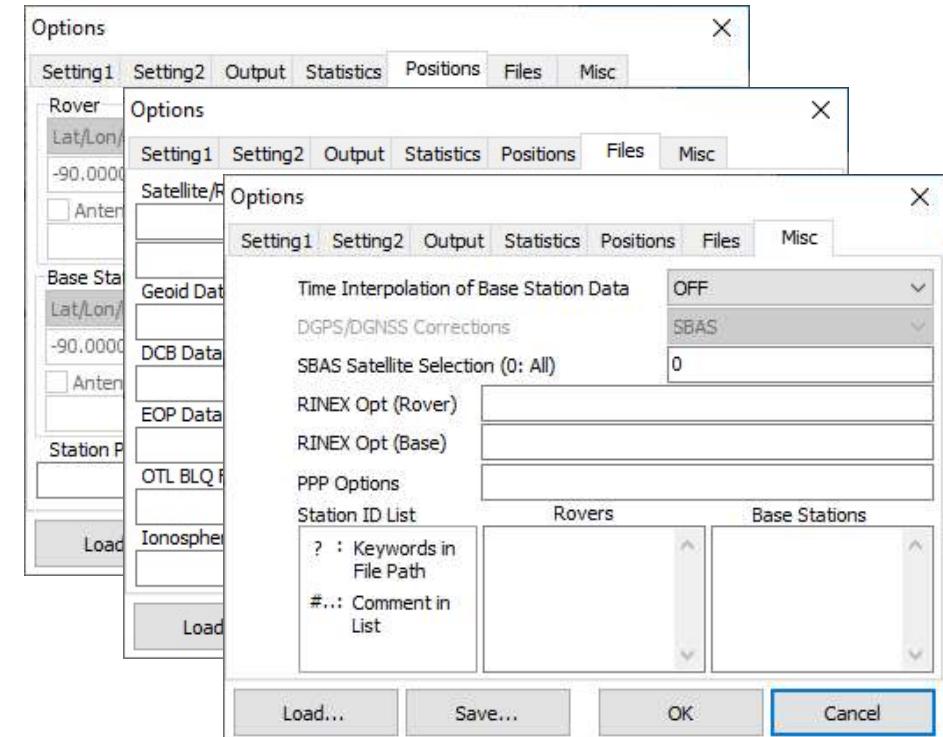
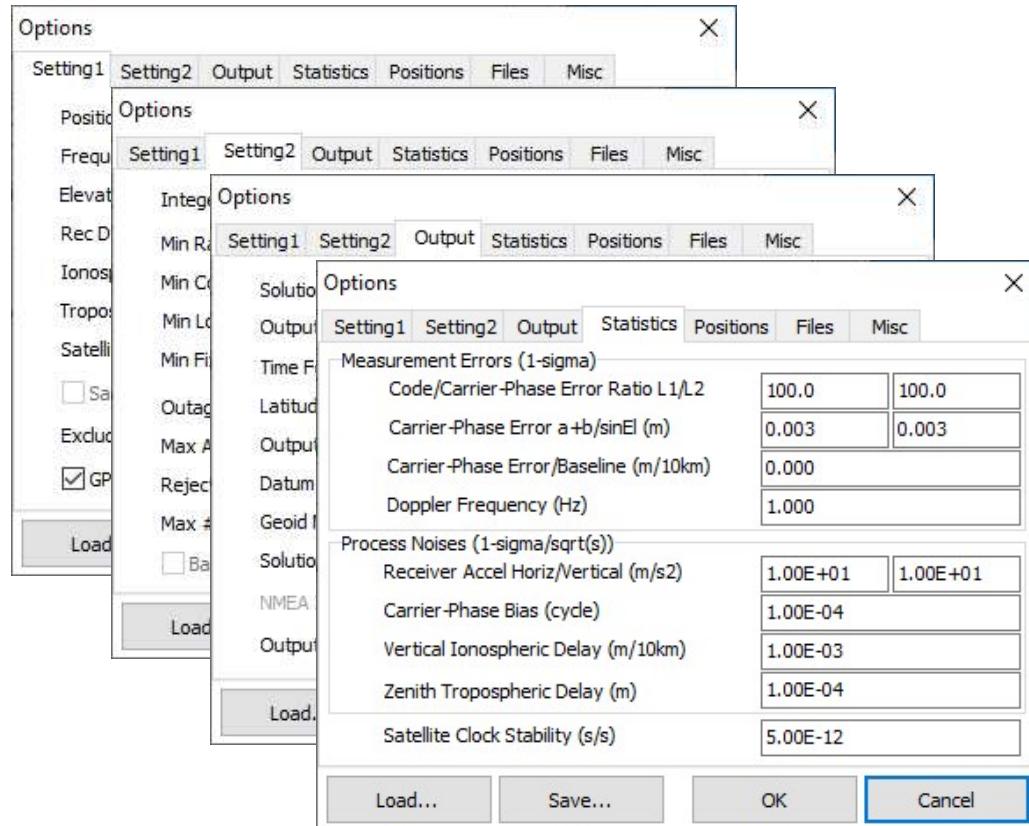
RTKPOST

- to compute the positioning solutions by various positioning modes.
- post-processing analysis.



More details in the manual, section 3.4!

RTKPOST: Options



Notice:

All options can be saved to or loaded from a *.conf file.

SPP @MET300FIN (1/2)

RTKPOST ver.2.4.3 b34

Time Start (GPST) ? Time End (GPST) ? Interval ? Unit ?

RINEX OBS: C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx

RINEX NAV/CLK_SP3_FCB_IOMEX_SRS/EMS or RTCM: C:\GIS-E5050\data\BRDC00IGS_R_20210010000_01D_MN.rnx

Solution Dir: C:\GIS-E5050\results

Output File: C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos

C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos

```
% program : RTKPOST ver.2.4.3 b34
% inp file : C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx
% inp file : C:\GIS-E5050\data\BRDC00IGS_R_20210010000_01D_MN.rnx
% obs start : 2021/01/01 00:00:00.0 GPST (week2138 432000.0s)
% obs end : 2021/01/01 23:59:30.0 GPST (week2138 518370.0s)
% pos mode : Single
% elev mask : 15.0 deg
% ionos opt : Broadcast
% tropo opt : Saastamoinen
% ephemeris : Broadcast
% navi sys : GPS
%
% (lat/lon/height=WG84/ellipsoidal,Q=1:fix,2:float,3:sbas,4:dgps,5:single,6:ppp,ns=#
% GPST           latitude(deg) longitude(deg) height(m) Q ns sdn(m) sc
2021/01/01 00:00:00.000 60.217461770 24.394515650 78.4250 5 9 2.6133 2.
2021/01/01 00:00:30.000 60.217461945 24.394518068 77.5505 5 9 2.6111 2.
2021/01/01 00:01:00.000 60.217459079 24.394515591 77.7466 5 9 2.6088 2.
2021/01/01 00:01:30.000 60.217457266 24.394510122 78.5972 5 9 2.6065 2.
2021/01/01 00:02:00.000 60.217459131 24.394521397 78.6675 5 9 2.6040 2.
2021/01/01 00:02:30.000 60.217460299 24.394517552 78.5669 5 9 2.6015 2.
2021/01/01 00:03:00.000 60.217460934 24.394517080 78.1695 5 9 2.5990 2.
2021/01/01 00:03:30.000 60.217459507 24.394519893 78.3503 5 9 2.5963 2.
2021/01/01 00:04:00.000 60.217459802 24.394511622 77.6523 5 9 2.5936 2.
2021/01/01 00:04:30.000 60.217462875 24.394515399 77.3835 5 9 2.5909 2.
```

View & check the solution

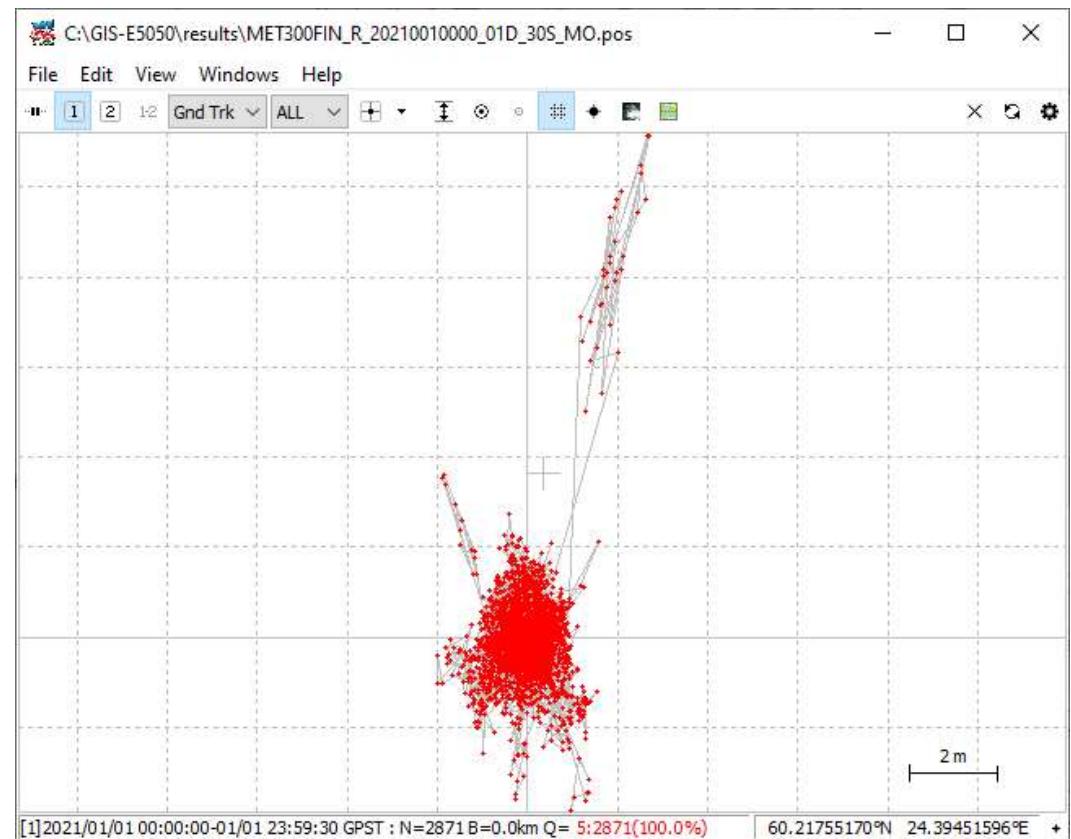
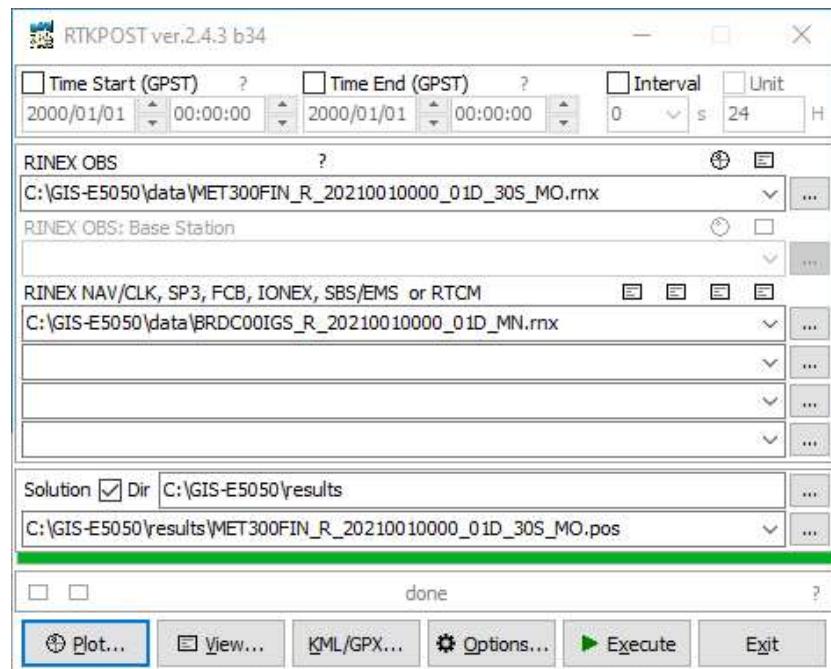
Header

Results

The screenshot shows the RTKPOST software interface. The title bar reads "C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos". The window has tabs for "Header" and "Results". The "Header" tab displays configuration parameters like program version (RTKPOST ver.2.4.3 b34), input files (C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx and C:\GIS-E5050\data\BRDC00IGS_R_20210010000_01D_MN.rnx), observation start (2021/01/01 00:00:00.0 GPST), observation end (2021/01/01 23:59:30.0 GPST), and position mode (Single). The "Results" tab displays a table of GNSS data. The columns include GPST, latitude(deg), longitude(deg), height(m), O, ns, sdn(m), sde(m), sdu(m), sdne(m), sdeu(m), sdun(m), age(s), and ratio. The data shows a series of observations from 2021/01/01 00:00:00.000 to 2021/01/01 00:05:00.000.

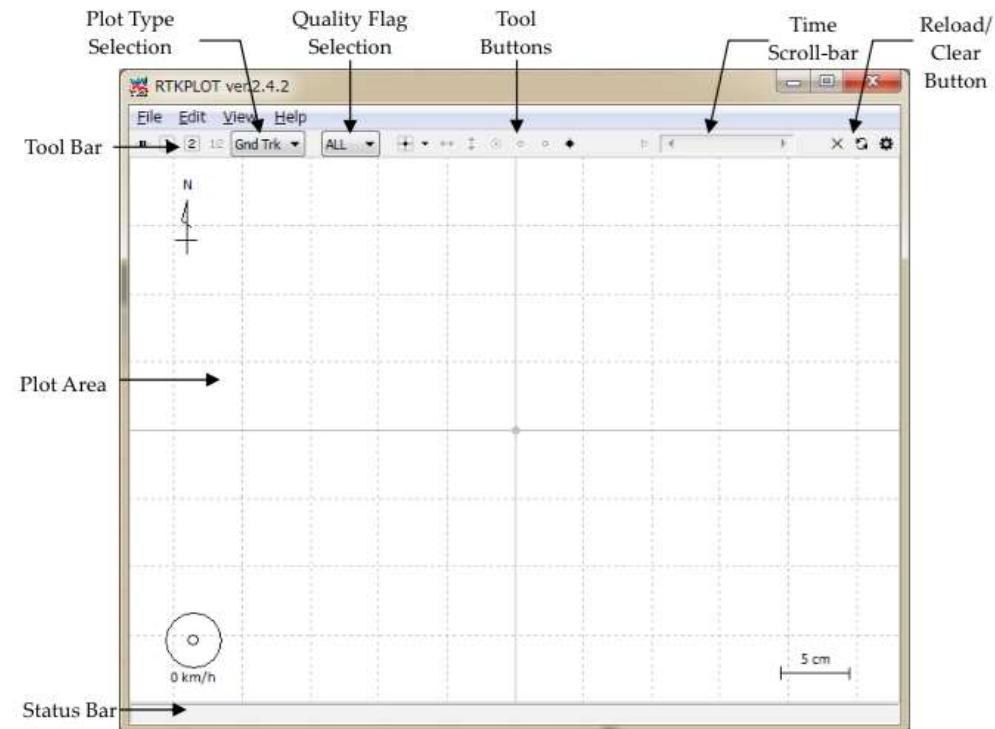
GPST	latitude(deg)	longitude(deg)	height(m)	O	ns	sdn(m)	sde(m)	sdu(m)	sdne(m)	sdeu(m)	sdun(m)	age(s)	ratio
2021/01/01 00:00:00.000	60.217470652	24.394521028	93.9934	5	12	3.5212	3.6891	7.8891	-1.4579	-3.1029	3.3970	0.00	0.0
2021/01/01 00:00:30.000	60.217480177	24.394549584	96.3016	5	13	3.4461	3.5361	7.4366	-1.6899	-3.5029	3.1006	0.00	0.0
2021/01/01 00:01:00.000	60.217479154	24.394546921	97.2046	5	13	3.4436	3.5338	7.4187	-1.6860	-3.4950	3.0863	0.00	0.0
2021/01/01 00:01:30.000	60.217476477	24.394536278	96.8710	5	13	3.4411	3.5314	7.4004	-1.6819	-3.4869	3.0719	0.00	0.0
2021/01/01 00:02:00.000	60.217477612	24.394541281	96.1397	5	13	3.4386	3.5290	7.3819	-1.6778	-3.4785	3.0573	0.00	0.0
2021/01/01 00:02:30.000	60.217481090	24.394531291	96.7731	5	13	3.4361	3.5264	7.3630	-1.6736	-3.4698	3.0425	0.00	0.0
2021/01/01 00:03:00.000	60.217484718	24.394537030	97.4090	5	13	3.4336	3.5238	7.3438	-1.6692	-3.4609	3.0277	0.00	0.0
2021/01/01 00:03:30.000	60.217476515	24.394543765	97.2869	5	13	3.4311	3.5211	7.3244	-1.6648	-3.4518	3.0127	0.00	0.0
2021/01/01 00:04:00.000	60.217476590	24.394538579	96.8219	5	13	3.4286	3.5184	7.3047	-1.6603	-3.4424	2.9975	0.00	0.0
2021/01/01 00:04:30.000	60.217480363	24.394540751	96.8319	5	13	3.4261	3.5155	7.2848	-1.6557	-3.4329	2.9823	0.00	0.0
2021/01/01 00:05:00.000	60.217483597	24.394527113	95.3308	5	13	3.4235	3.5127	7.2646	-1.6510	-3.4231	2.9669	0.00	0.0

SPP @MET300FIN (2/2)



RTKPLOT: at glance

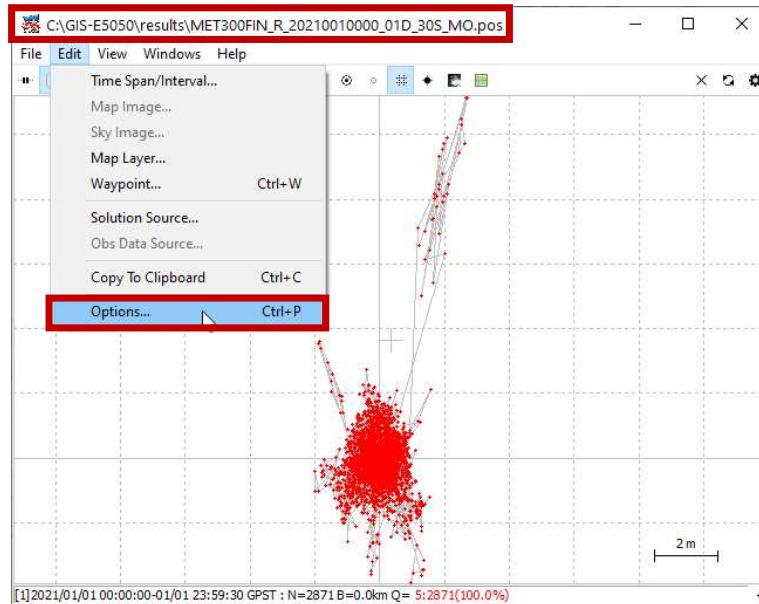
- to view and plot the positioning solutions by RTKPOST and RTKNAVI with graphical user interface.
- Manual located in the doc directory
- X:\GIS-E5050\RTKLIB_2.4.3_b34\doc



More details in the manual, section 3.7 & 3.8!

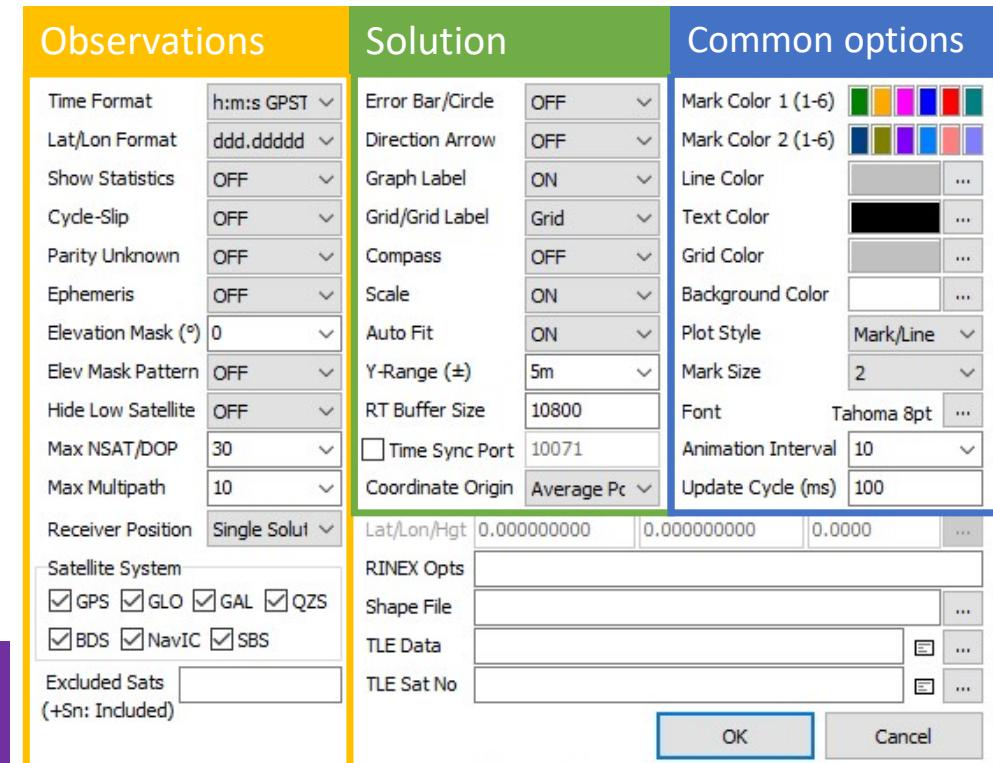
RTKPLOT: accuracy for a known fixed point

Solution file to be explored



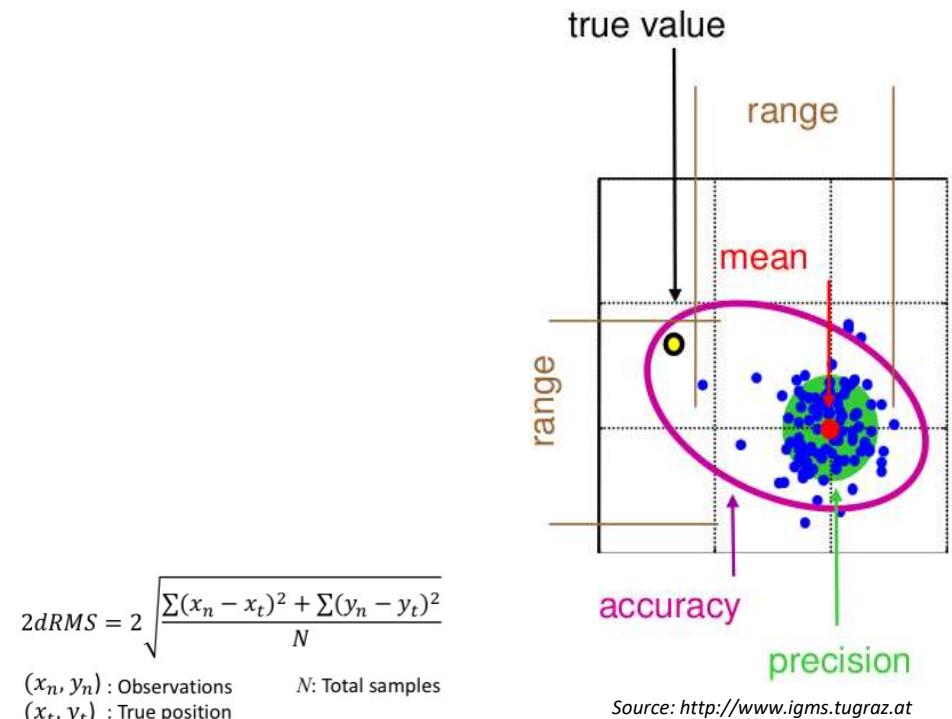
Type Lat/Lon/Hgt for the receiver position in order to compute the statistics with respect to a **true value / ground truth** (e.g., IGS SINEX coordinates).

Be aware that you have to transform the Cartesian coordinates (STAX, STAY, STAZ) into geodetic ellipsoidal coordinates (Lat, Lon, Hgt). Use the proper number of digits.



Precision vs. Accuracy

- **Precision** describes the degree of repeatability
 - internal measure of random errors and their effects
- **Accuracy** describes the degree of closeness
 - is a measure of agreement between the observed and the true (correct) value
 - Systematic & non-random errors in addition to random errors



Low precision
High accuracy



High precision
Low accuracy

Further exploration

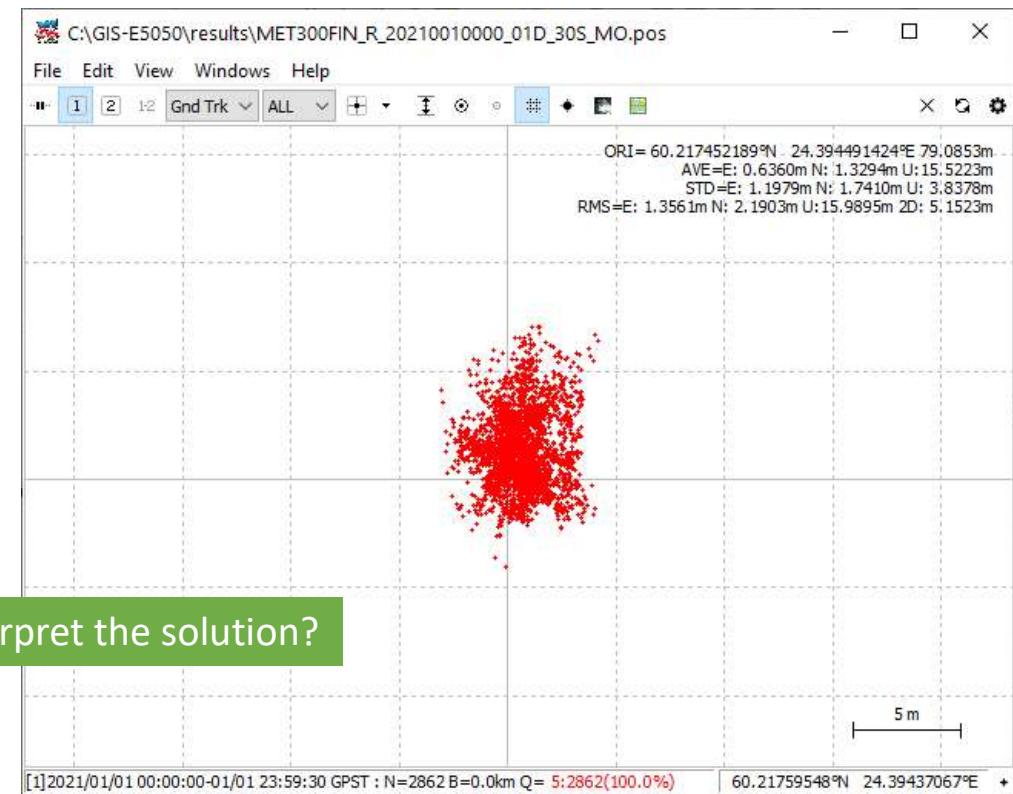
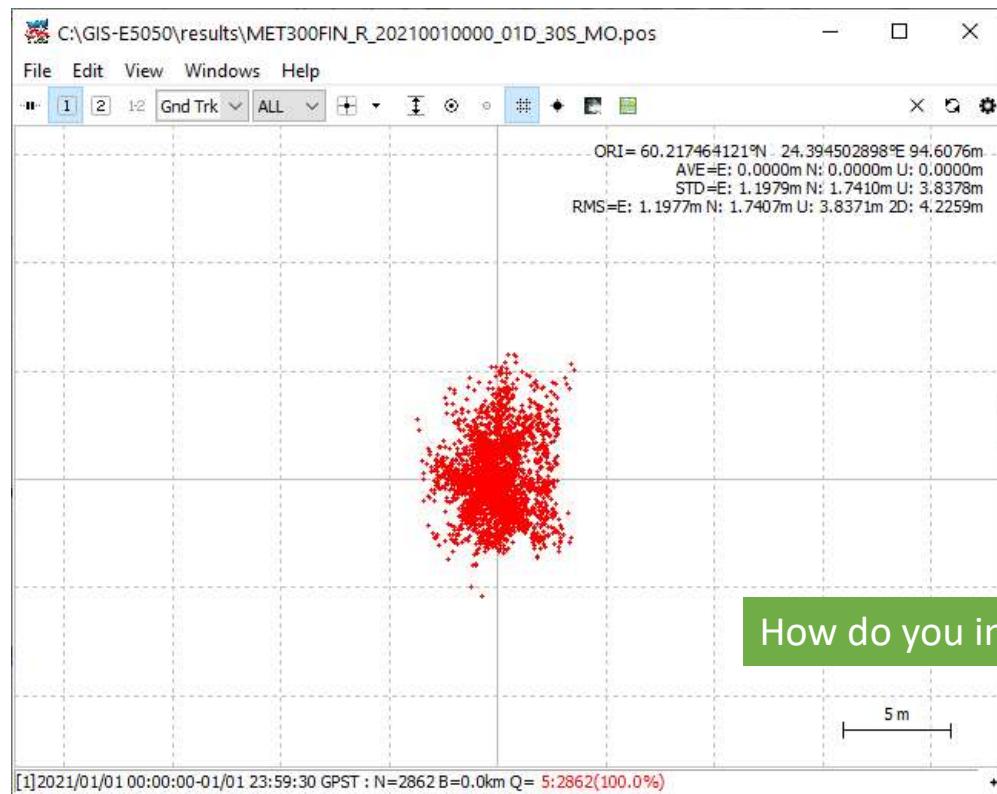
- **Well done!** Now, you are ready to further explore on your own the impact of the atmosphere (iono & tropo) on the single point positioning
- Options->Load... *X:\GIS-E5050\config\spp.conf*
- (a) Type a name for the solution file.
- (b) Run the processing.
- Now, change any parameter of wish
- Repeat (a) and (b)
- Use RTKPLOT to compare any two solutions

Notice:

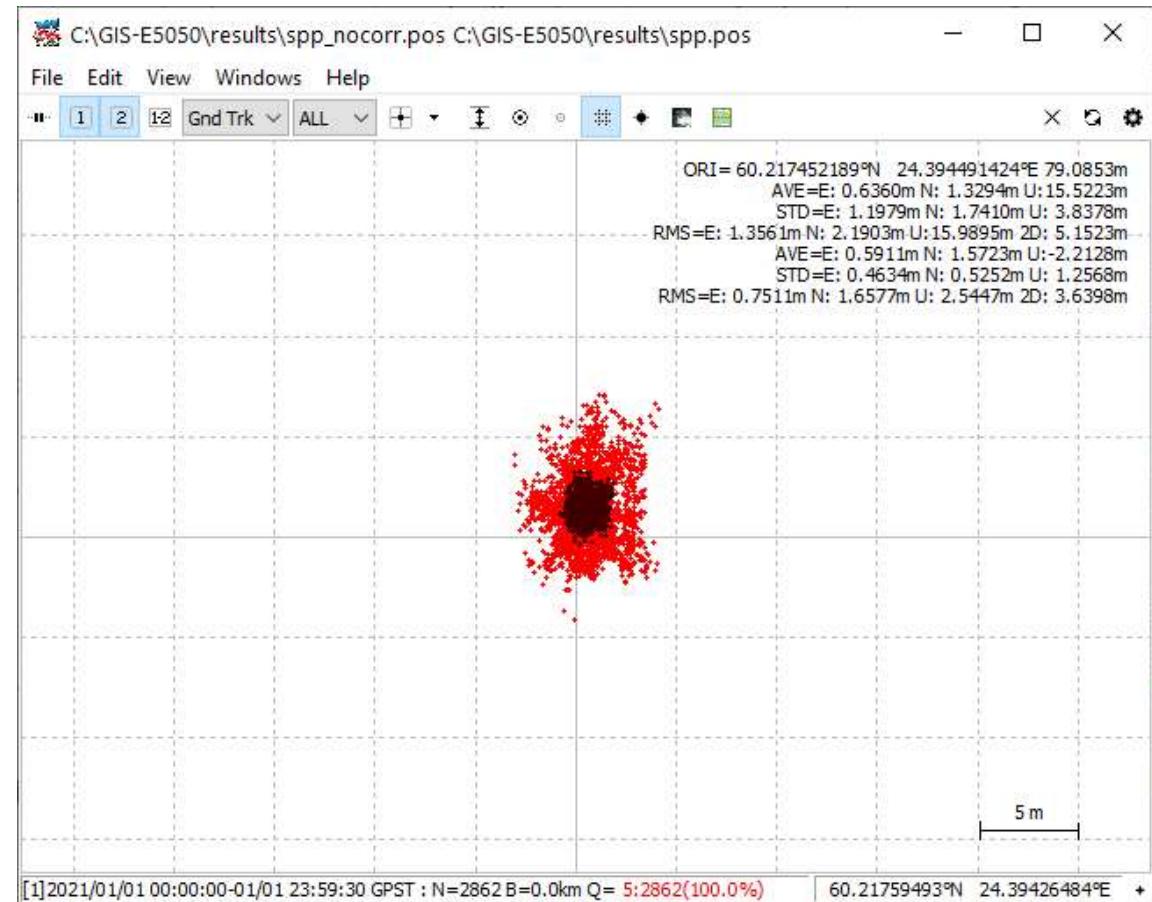
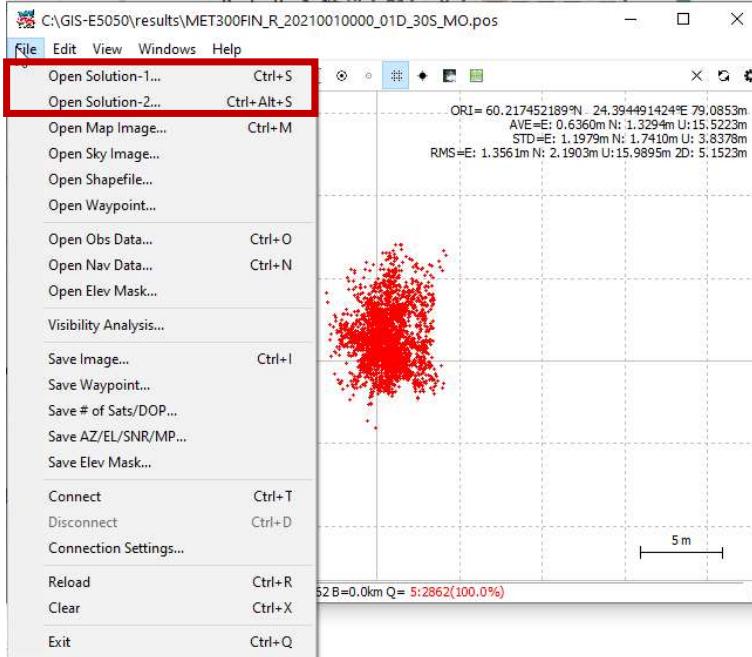
A new run always overwrites the old/existing *pos file.

Demonstration is done in the class.

RTKPLOT: precision vs. accuracy

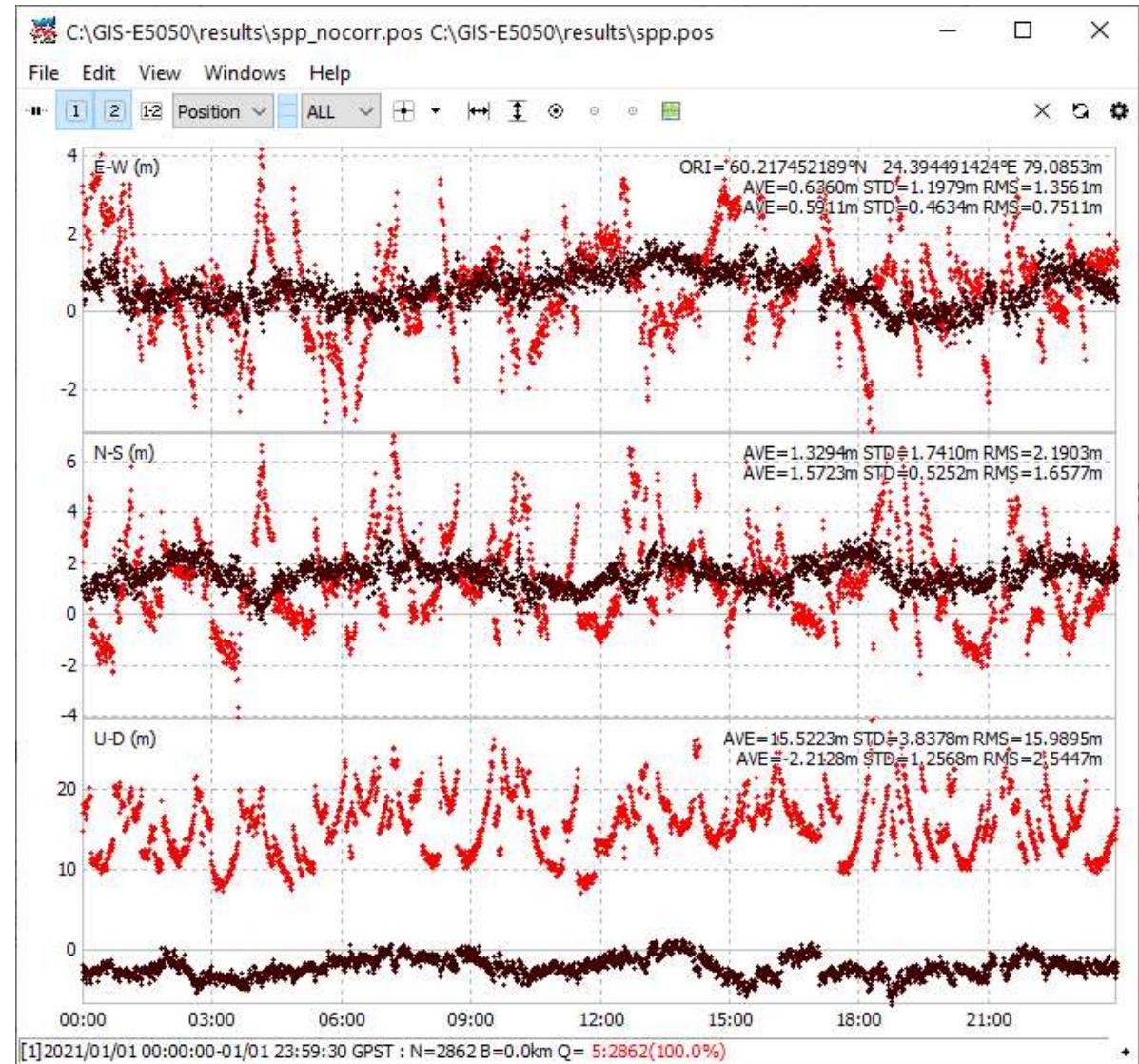


RTKPPLOT: compare two solutions



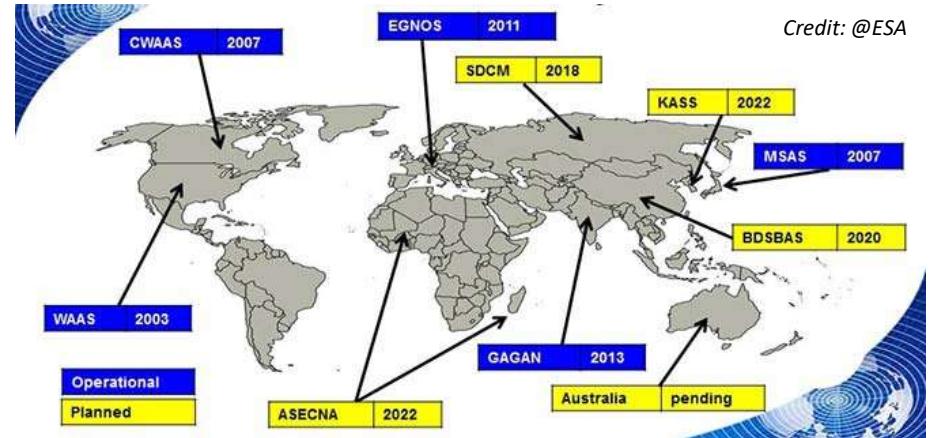
RTKPLOT: solutions over time

- Mark color 2 change to black for more visual contrast
- Feel free to explore other changes
- RTKPLOT saves all changes when exit to a config file saved in the bin directory.



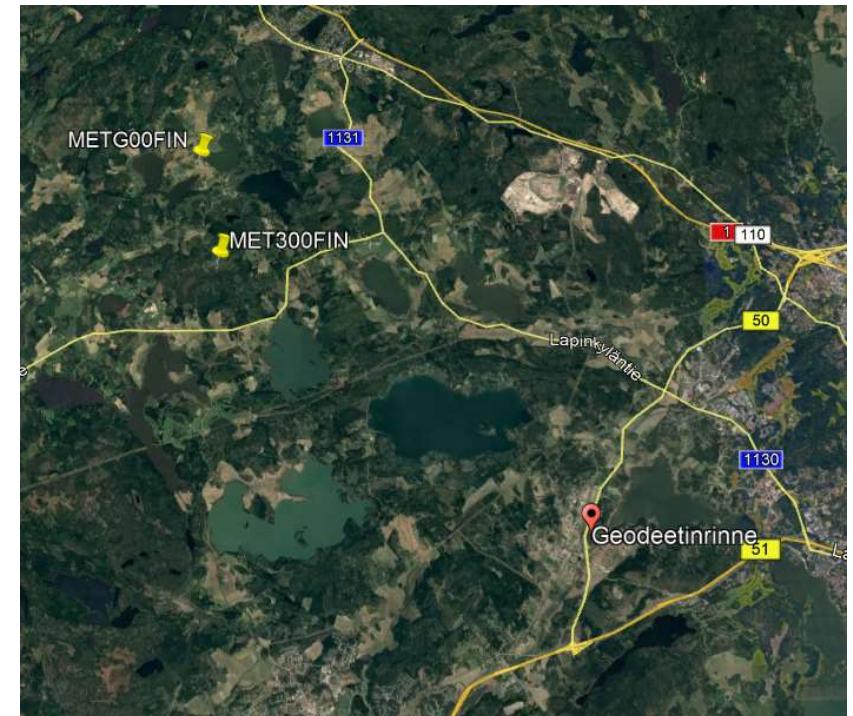
Differential Positioning

Pseudorange/code based DGNSS & SBAS

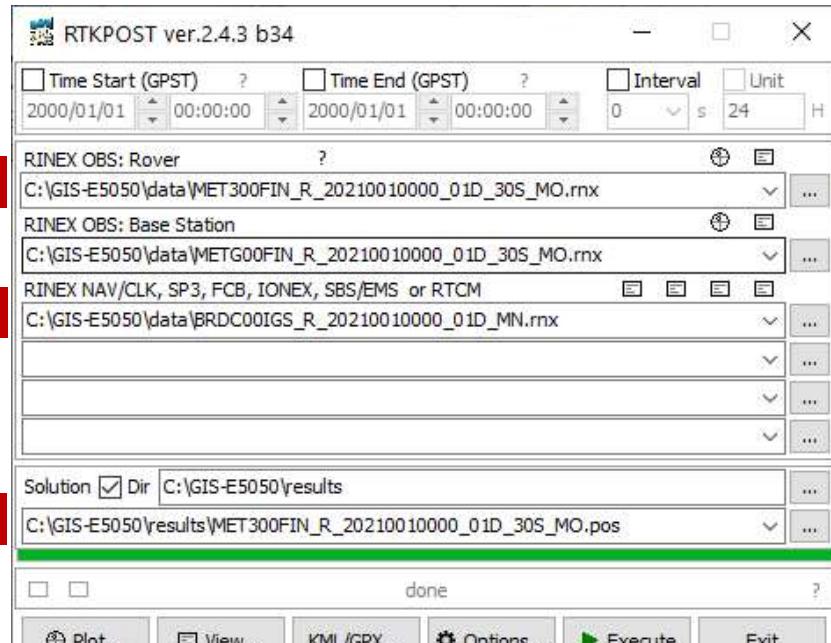


DGNSS: What do you need?

- **Close** all RTKLIB windows
- **Restart** RTKPOST
- Rover: MET300FIN
- Reference: METG00FIN
- Input data files in *X:\GIS-E5050\data*
- Load *X:\GIS-E5050\config\dgnss.conf*



Differential GPS @MET3:



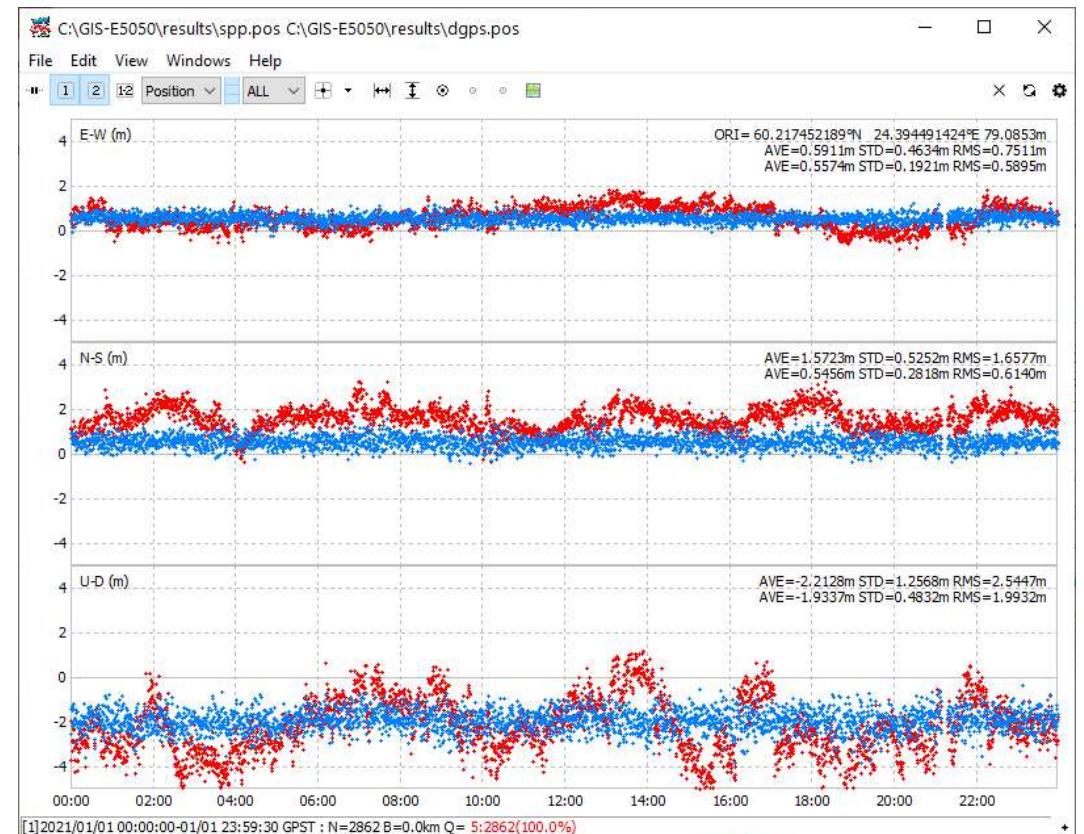
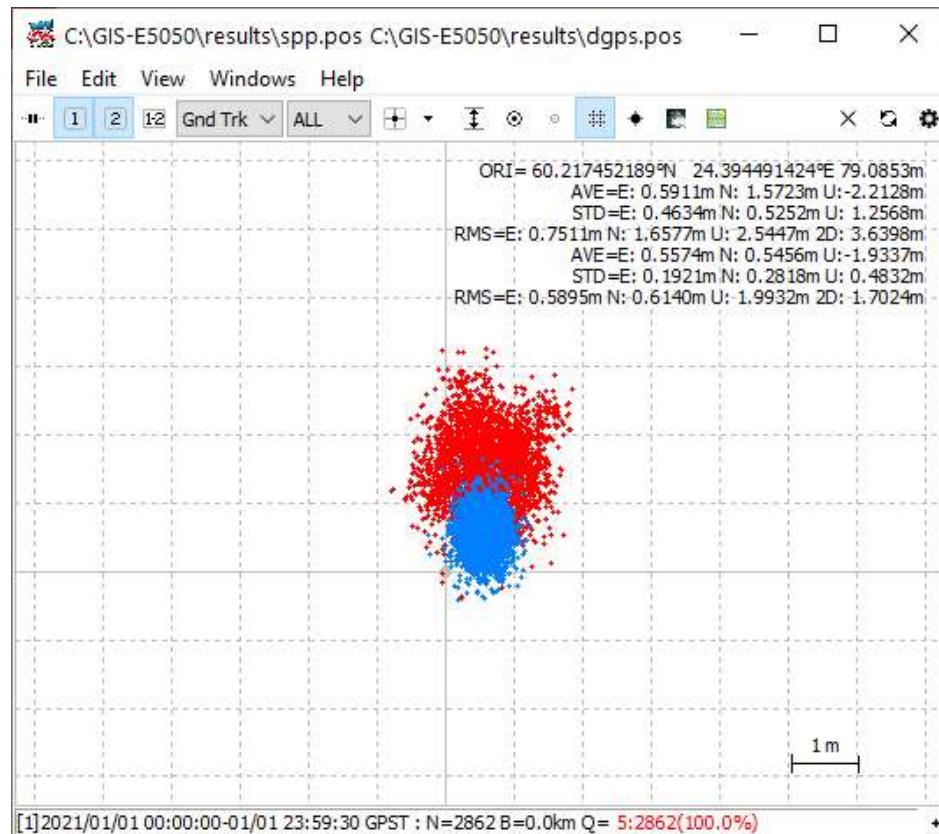
```
C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos
Find Read... Option... Close

% program : RTKPOST ver.2.4.3 b34
% inp file : C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx
% inp file : C:\GIS-E5050\data\METG00FIN_R_20210010000_01D_30S_MO.rnx
% inp file : C:\GIS-E5050\data\BRDC00IGS_R_20210010000_01D_MN.rnx
% obs start : 2021/01/01 00:00:00.0 GPST (week2138 432000.0s)
% obs end : 2021/01/01 23:59:30.0 GPST (week2138 518370.0s)
% pos mode : DGPS
% freqs : L1
% solution : Forward
% elev mask : 5.0 deg
% dynamics : off
% tidecorr : off
% ionos opt : Broadcast
% tropo opt : Saastamoinen
% ephemeris : Broadcast
% navi sys : GPS
% antennal : ( 0.0000 0.0000 0.0000 )
% antenna2 : ( 0.0000 0.0000 0.0000 )
% ref pos : 60.241967371 24.384176738 59.6815

% (lat/lon/height=WGS84/ellipsoidal,Q=1:fix,2:float,3:sbas,4:dgps,5:single,6:ppp,ns=# of satellites)
% GPST latitude(deg) longitude(deg) height(m) Q ns sdn(m) sde(m) sdu(m) sdeu(m) sden(m) sdeun(m) age(s) ratio
2021/01/01 00:00:00.000 60.217453367 24.394498385 77.6475 4 12 0.6934 0.5143 1.3777 -0.2104 -0.3179 0.6214 0.00 0.0
2021/01/01 00:03:00.000 60.217460505 24.394500310 76.5692 4 12 0.6955 0.5147 1.3782 -0.2113 -0.3164 0.6232 0.00 0.0
2021/01/01 00:01:00.000 60.217457850 24.394499954 77.0403 4 12 0.6976 0.5150 1.3786 -0.2121 -0.3148 0.6250 0.00 0.0
2021/01/01 00:01:30.000 60.217456601 24.394490401 76.9052 4 12 0.6997 0.5154 1.3791 -0.2130 -0.3132 0.6268 0.00 0.0
2021/01/01 00:02:00.000 60.217456568 24.394503813 77.6148 4 12 0.7019 0.5157 1.3797 -0.2138 -0.3115 0.6286 0.00 0.0
2021/01/01 00:02:30.000 60.217460775 24.394500991 77.7820 4 12 0.7040 0.5161 1.3802 -0.2146 -0.3097 0.6303 0.00 0.0
2021/01/01 00:03:00.000 60.217458605 24.394501403 77.6467 4 12 0.7062 0.5165 1.3808 -0.2154 -0.3080 0.6321 0.00 0.0
2021/01/01 00:03:30.000 60.217457409 24.394501225 77.9360 4 12 0.7084 0.5169 1.3813 -0.2163 -0.3061 0.6339 0.00 0.0
2021/01/01 00:04:00.000 60.217457090 24.394495074 76.9661 4 12 0.7106 0.5173 1.3820 -0.2171 -0.3042 0.6356 0.00 0.0
2021/01/01 00:04:30.000 60.217456855 24.394501153 77.1523 4 12 0.7128 0.5177 1.3826 -0.2179 -0.3022 0.6374 0.00 0.0
2021/01/01 00:05:00.000 60.217459985 24.394494159 76.1363 4 13 0.7123 0.5142 1.3510 -0.2277 -0.3303 0.6244 0.00 0.0
2021/01/01 00:05:30.000 60.217456089 24.394505585 76.9908 4 13 0.7145 0.5144 1.3502 -0.2290 -0.3301 0.6254 0.00 0.0
2021/01/01 00:06:00.000 60.217458279 24.394503259 76.9458 4 13 0.7166 0.5146 1.3493 -0.2303 -0.3298 0.6264 0.00 0.0
2021/01/01 00:06:30.000 60.217456724 24.394501890 77.2797 4 12 0.7442 0.5148 1.4085 -0.2336 -0.3325 0.6872 0.00 0.0
2021/01/01 00:07:00.000 60.217453397 24.394500477 76.9974 4 12 0.7451 0.5150 1.4045 -0.2349 -0.3323 0.6852 0.00 0.0
2021/01/01 00:07:30.000 60.217456538 24.394500158 77.1674 4 13 0.7231 0.5151 1.3466 -0.2343 -0.3291 0.6294 0.00 0.0
2021/01/01 00:08:00.000 60.217460967 24.394502596 77.6217 4 13 0.7253 0.5153 1.3466 -0.2356 -0.3288 0.6304 0.00 0.0
2021/01/01 00:08:30.000 60.217456882 24.394503172 77.5050 4 13 0.7276 0.5155 1.3452 -0.2370 -0.3286 0.6314 0.00 0.0
```

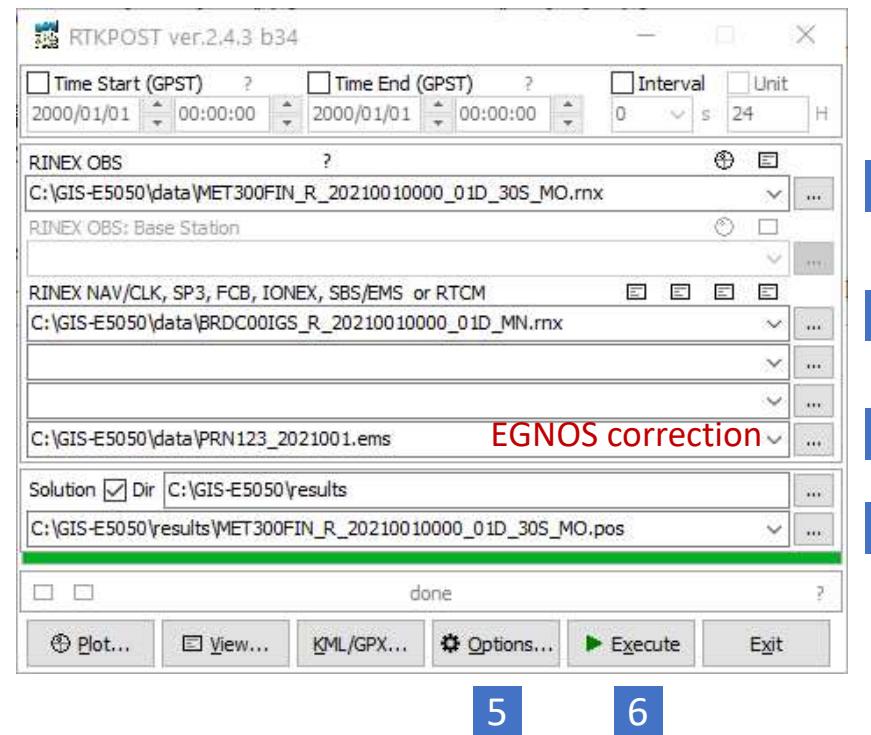
SPP vs. DGPS

What is going on with the Up coordinate?



SBAS: EGNOS positioning

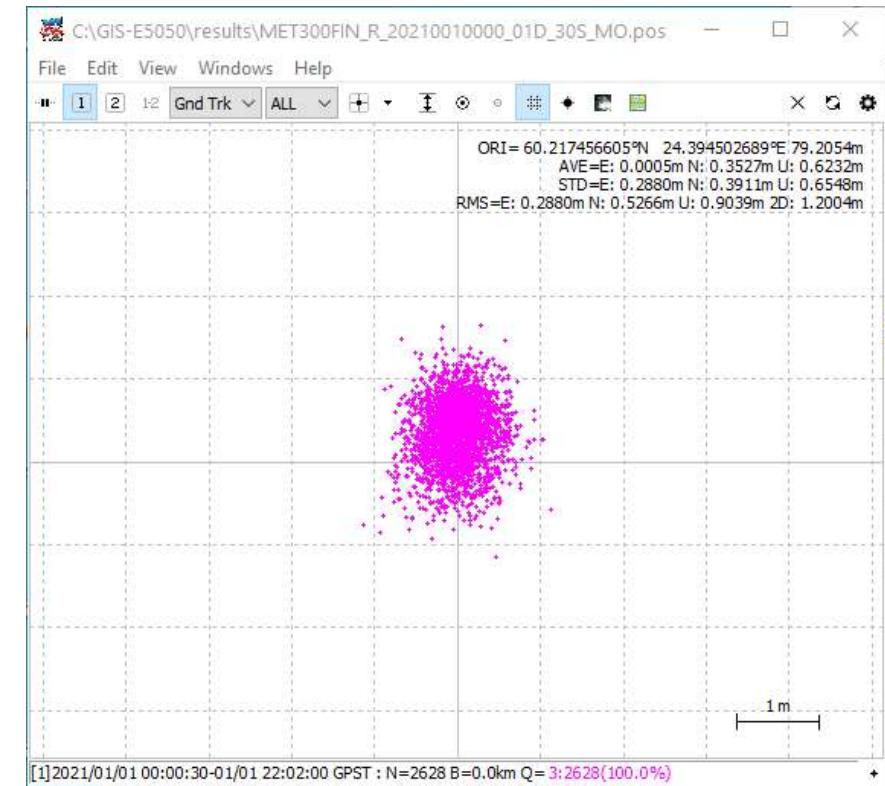
- Close all RTKLIB windows
- Restart RTKPOST
- Input data files in *X:\GIS-E5050\data*
 - Rover: MET3 (obs+nav)
 - Corrections: EGNOS/PRN 123
- Options->Load
X:\GIS-E5050\config\sbas.conf
- Execute



PRN123

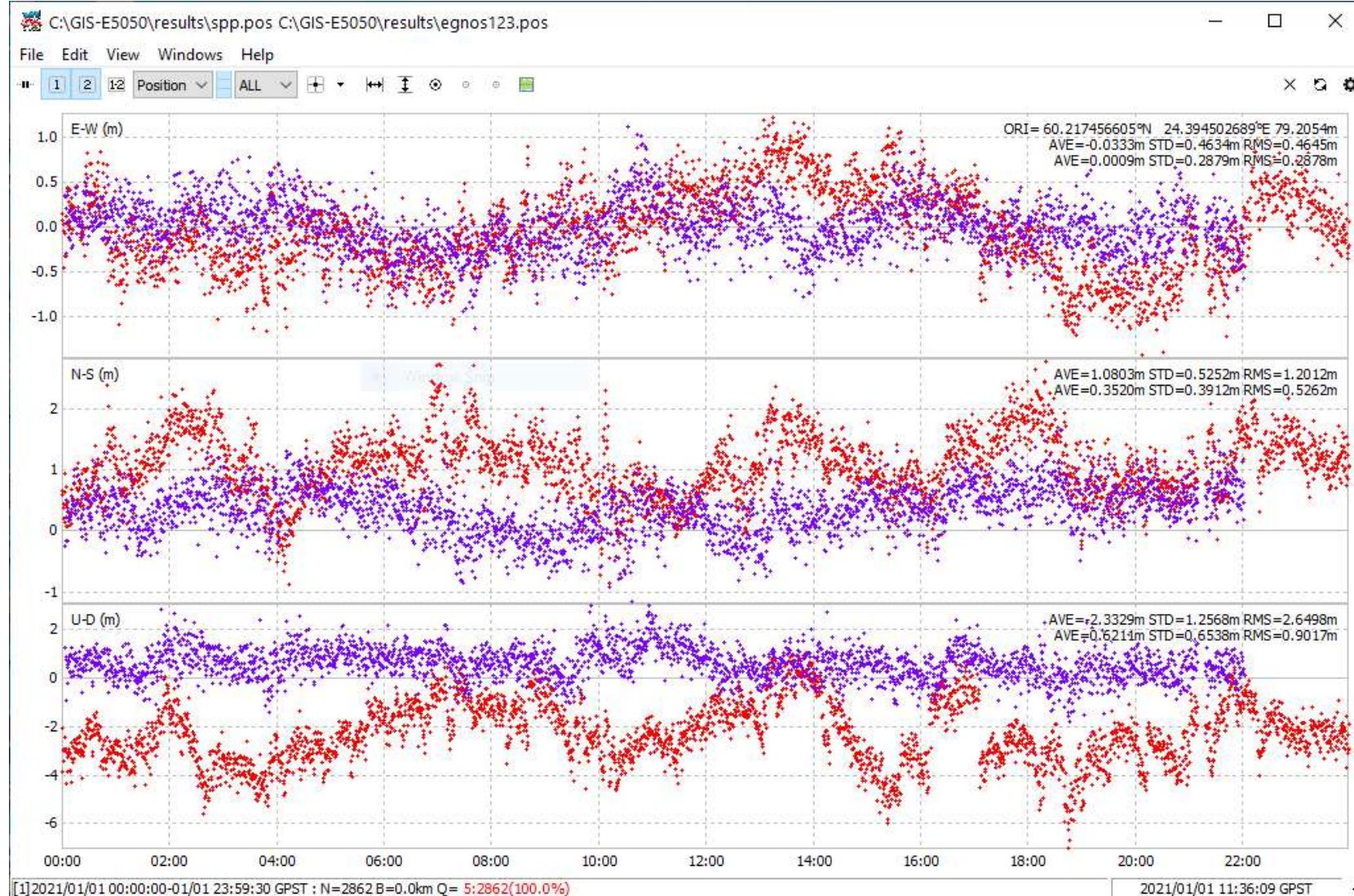
C:\GIS-E5050\results\MET300FIN_R_2021010000_01D_30S_MO.pos

```
% program : RTKPOST ver.2.4.3 b34
% inp file : C:\GIS-E5050\data\MET300FIN_R_2021010000_01D_30S_MO.rnx
% inp file : C:\GIS-E5050\data\BRDC001GS_R_2021010000_01D_MN.rnx
% inp file : C:\GIS-E5050\data\PRN123_2021001.ems
% obs start: 2021/01/01 00:00:00.0 GPST (week2138 432000.0s)
% obs end: 2021/01/01 23:59:30.0 GPST (week2138 518370.0s)
% pos mode : Single
% elev mask : 5.0 deg
% ionos opt : SBAS
% tropo opt : SBAS
% ephemeris : Broadcast+SBAS
% navi sys : GPS
%
% (lat/ion/height=WGS84/ellipsoidal,Q=1:fix,2:float,3:sbas,4:dgps,5:single,6:ppp,ns=# of satellites)
% GPST      latitude(deg) longitude(deg) height(m) Q ns sdn(m) sde(m) sdu(m) sdne(m) sdeu(m) sdun(m) age(s) ratio
2021/01/01 00:00:30.000 60.217465094 24.394503127 80.7590 3 10 0.9605 0.8471 1.9759 -0.4985 -0.8048 1.0797 0.00 0.0
2021/01/01 00:01:00.000 60.217461980 24.394503683 81.0942 3 9 1.0891 0.8718 1.9906 -0.5905 -0.8563 1.1510 0.00 0.0
2021/01/01 00:01:30.000 60.217462981 24.394491483 81.3243 3 9 1.1024 0.8736 2.0130 -0.5972 -0.8574 1.1660 0.00 0.0
2021/01/01 00:02:00.000 60.217461011 24.394500825 80.7173 3 9 1.1071 0.8834 1.9885 -0.5990 -0.8701 1.1168 0.00 0.0
2021/01/01 00:02:30.000 60.217461737 24.394493504 80.2556 3 11 0.7905 0.8109 1.5295 -0.3510 -0.7295 0.6216 0.00 0.0
2021/01/01 00:03:00.000 60.217463790 24.394503464 80.3938 3 12 0.7750 0.7140 1.4853 -0.3282 -0.6649 0.6077 0.00 0.0
2021/01/01 00:03:30.000 60.217454358 24.394508182 80.4674 3 12 0.7833 0.7032 1.4987 -0.3397 -0.6526 0.6268 0.00 0.0
2021/01/01 00:04:00.000 60.217455138 24.394503596 79.9833 3 12 0.7775 0.6991 1.4747 -0.3396 -0.6484 0.6132 0.00 0.0
2021/01/01 00:04:30.000 60.217458554 24.394506457 80.0724 3 12 0.7752 0.7013 1.4940 -0.3343 -0.6562 0.6373 0.00 0.0
2021/01/01 00:05:00.000 60.217461213 24.394497386 78.3041 3 12 0.7689 0.6970 1.4705 -0.3336 -0.6523 0.6251 0.00 0.0
2021/01/01 00:05:30.000 60.217455204 24.394509244 78.9912 3 12 0.7887 0.7202 1.5100 -0.3140 -0.6836 0.6188 0.00 0.0
2021/01/01 00:06:00.000 60.217459387 24.394509819 79.7538 3 12 0.7810 0.6997 1.4778 -0.3251 -0.6607 0.6140 0.00 0.0
2021/01/01 00:06:30.000 60.217460074 24.394503590 79.6550 3 12 0.7919 0.7037 1.5007 -0.3283 -0.6655 0.6274 0.00 0.0
2021/01/01 00:07:00.000 60.217458051 24.394500484 80.0906 3 12 0.7859 0.6988 1.4783 -0.3287 -0.6611 0.6173 0.00 0.0
2021/01/01 00:07:30.000 60.217458668 24.394502115 79.8449 3 12 0.7970 0.7029 1.5014 -0.3320 -0.6658 0.6310 0.00 0.0
2021/01/01 00:08:00.000 60.217458481 24.394505570 79.9401 3 12 0.7913 0.6980 1.4796 -0.3325 -0.6616 0.6216 0.00 0.0
2021/01/01 00:08:30.000 60.217458287 24.394506177 80.2044 3 12 0.7935 0.6791 1.4840 -0.3022 -0.6334 0.6126 0.00 0.0
2021/01/01 00:09:00.000 60.217458888 24.39450101 79.4162 3 12 0.7971 0.6973 1.4818 -0.3366 -0.6620 0.6271 0.00 0.0
2021/01/01 00:09:30.000 60.217458546 24.394503829 79.5041 3 12 0.8087 0.7016 1.5054 -0.3403 -0.6666 0.6415 0.00 0.0
2021/01/01 00:10:00.000 60.217459728 24.394498389 80.1070 3 12 0.7929 0.6716 1.4583 -0.3154 -0.6403 0.6046 0.00 0.0
```



SPS VS. SBAS

What is going on
with the Up
coordinate?



Further exploration

- **Congratulations!** Now, you are able to improve the positioning solution using differential correction data
 - from a **ground base station** (i.e. pseudorange corrections)
 - from a **GEO satellite** (i.e. orbit, clock, atmospheric corrections)
- Try also the correction data from the other two EGNOS satellites (PRN126 & PRN136)

How all these solutions compare to each other?

Precise Positioning

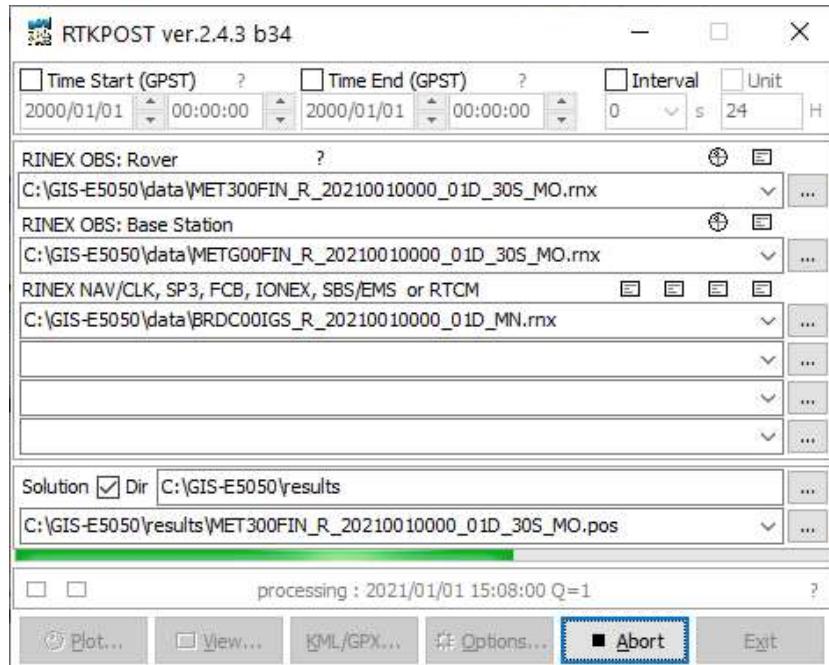
Carrier phase-based: relative (PPK/RTK) & point (PPP) positioning

Post-Processed Kinematic (PPK)

Relative positioning: What do we need?

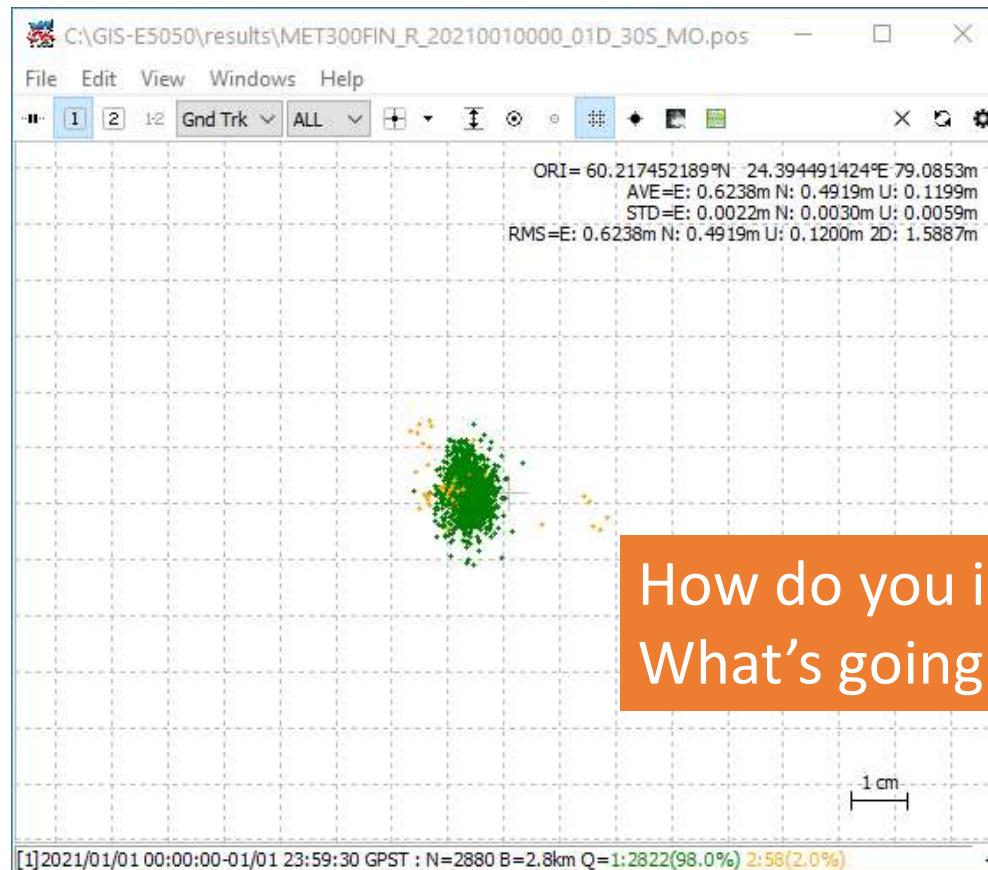
- Close all RTKLIB windows
- Restart RTKPOST
- Rover: MET300FIN (obs+nav)
- Base: METG00FIN (obs)
- Same epoch rate
- Common satellites
- Input data files in *X:\GIS-E5050\data*
- Options->Load *X:\GIS-E5050\config\ppk.conf*

How does the solution look like?



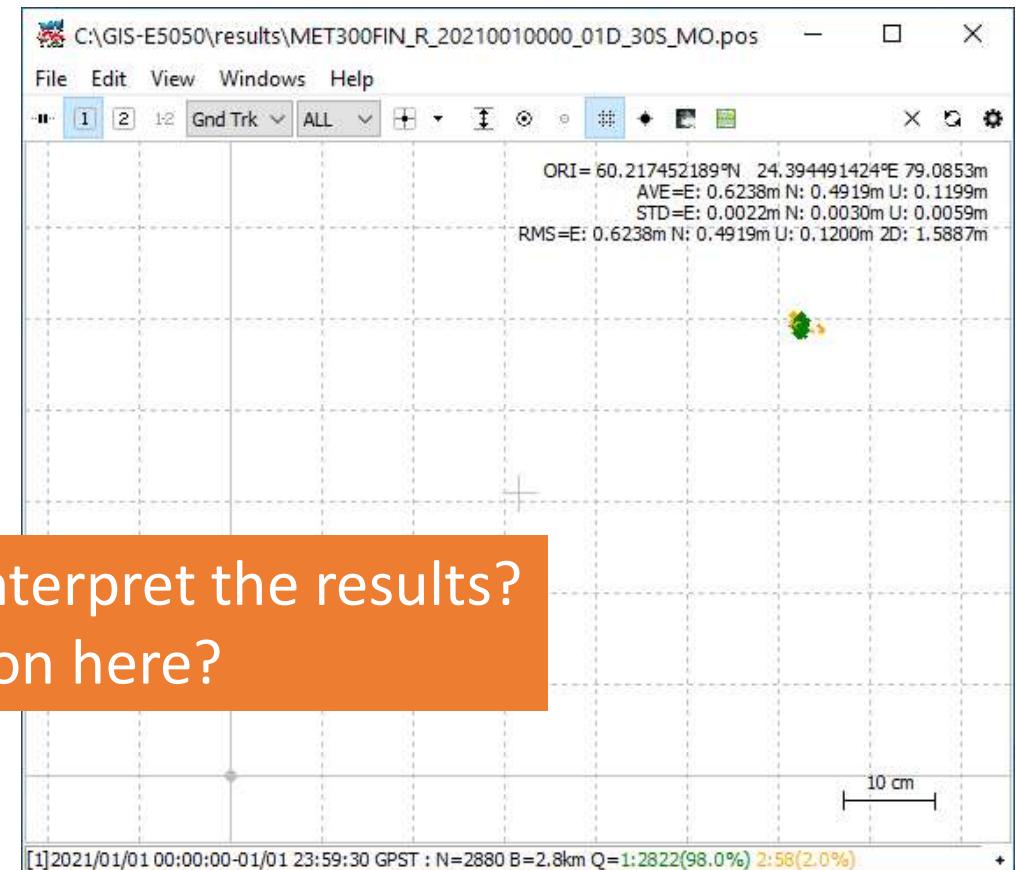
C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos														
% program	:	RTKPOST	ver.2.4.3	b34										
% inp file	:	C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx												
% inp file	:	C:\GIS-E5050\data\METG00FIN_R_20210010000_01D_30S_MO.rnx												
% obs start	:	2021/01/01 00:00:00.0	GPST	(week2139 432000.0s)										
% obs end	:	2021/01/01 23:59:30.0	GPST	(week2138 518370.0s)										
% pos mode	:	Kinematic												
% freqs	:	L1+2												
% solution	:	Forward												
% elev mask	:	10.0 deg												
% dynamics	:	off												
% tidecorr	:	off												
% ionos opt	:	Broadcast												
% tropo opt	:	Saastamoinen												
% ephemeris	:	Broadcast												
% navi sys	:	GPS												
% amb res	:	Continuous												
% val thres	:	3.0												
% antennal	:	JAVRINGANT_DM	SCIS	(0.0000 0.0000 0.0000)										
% antennal2	:	TRMS9800.00	SCIS	(0.0020 0.0046 2.0352)										
% ref pos	:	60.241967752	24.384177954	59.6964										
%														
% (lat/lon/height=WGS84/ellipsoidal,Q=1:fix,2:float,3:sbas,4:dgps,5:single,6:ppp,ns=# of satellites)														
% GPSI		latitude(deg)	longitude(deg)	height(m)	Q	ns	sdn(m)	sde(m)	sdu(m)	sde(m)	sdeu(m)	sdun(m)	age(s)	ratio
2021/01/01 00:00:00.000	60.217456617	24.394502684	79.2023	1	11	0.0053	0.0036	0.0107	-0.0014	-0.0023	0.0050	0.00	17.6	
2021/01/01 00:30:00.000	60.217456605	24.394502706	79.2016	1	11	0.0054	0.0036	0.0107	-0.0013	-0.0022	0.0049	0.00	15.9	
2021/01/01 00:01:00.000	60.217456601	24.394502703	79.2005	1	11	0.0055	0.0030	0.0107	-0.0020	-0.0017	0.0047	0.00	19.1	
2021/01/01 00:01:30.000	60.217456574	24.394502690	79.1995	1	11	0.0055	0.0042	0.0106	-0.0020	-0.0025	0.0050	0.00	24.7	
2021/01/01 00:02:00.000	60.217456572	24.394502659	79.2017	1	11	0.0052	0.0033	0.0106	-0.0007	-0.0018	0.0049	0.00	35.4	
2021/01/01 00:02:30.000	60.217456536	24.394502661	79.1962	1	11	0.0055	0.0042	0.0106	-0.0017	-0.0022	0.0048	0.00	40.4	
2021/01/01 00:03:00.000	60.217456552	24.394502679	79.1959	1	11	0.0053	0.0042	0.0105	-0.0011	-0.0026	0.0050	0.00	46.4	
2021/01/01 00:03:30.000	60.217456555	24.394502680	79.2002	1	11	0.0054	0.0040	0.0106	-0.0009	-0.0024	0.0048	0.00	53.9	
2021/01/01 00:04:00.000	60.217456584	24.394502703	79.1971	1	11	0.0052	0.0042	0.0105	0.0007	-0.0025	0.0049	0.00	65.1	
2021/01/01 00:04:30.000	60.217456581	24.394502770	79.2000	1	10	0.0056	0.0032	0.0107	-0.0022	-0.0021	0.0050	0.00	85.4	
2021/01/01 00:05:00.000	60.217456607	24.394502739	79.2003	1	10	0.0055	0.0044	0.0108	-0.0013	-0.0022	0.0049	0.00	77.9	
2021/01/01 00:05:30.000	60.217456611	24.394502726	79.2028	1	10	0.0056	0.0036	0.0107	-0.0019	-0.0011	0.0047	0.00	69.5	
2021/01/01 00:06:00.000	60.217456594	24.394502668	79.2034	1	10	0.0051	0.0030	0.0108	-0.0022	0.0003	0.0047	0.00	61.2	
2021/01/01 00:06:30.000	60.217456574	24.394502724	79.2011	1	10	0.0054	0.0047	0.0108	0.0014	-0.0026	0.0047	0.00	56.8	
2021/01/01 00:07:00.000	60.217456594	24.394502702	79.1974	1	10	0.0053	0.0042	0.0107	-0.0015	-0.0019	0.0047	0.00	54.8	
2021/01/01 00:07:30.000	60.217456561	24.394502703	79.1958	1	10	0.0053	0.0042	0.0107	-0.0006	-0.0020	0.0048	0.00	55.3	
2021/01/01 00:08:00.000	60.217456563	24.394502699	79.1869	1	10	0.0056	0.0034	0.0106	-0.0019	0.0004	0.0047	0.00	60.8	
2021/01/01 00:08:30.000	60.217456572	24.394502630	79.1880	1	10	0.0053	0.0029	0.0106	-0.0022	-0.0008	0.0047	0.00	65.4	
2021/01/01 00:09:00.000	60.217456563	24.394502631	79.1852	1	10	0.0056	0.0034	0.0106	-0.0003	-0.0019	0.0047	0.00	64.4	
2021/01/01 00:09:30.000	60.217456567	24.394502682	79.1905	1	10	0.0051	0.0038	0.0106	-0.0022	-0.0018	0.0045	0.00	67.7	
2021/01/01 00:10:00.000	60.217456555	24.394502681	79.1943	1	10	0.0054	0.0032	0.0105	-0.0021	-0.0010	0.0047	0.00	74.6	

MET3-METG (1/3)



GIS-E5050: Advanced Geodesy
17.03.2021

How do you interpret the results?
What's going on here?

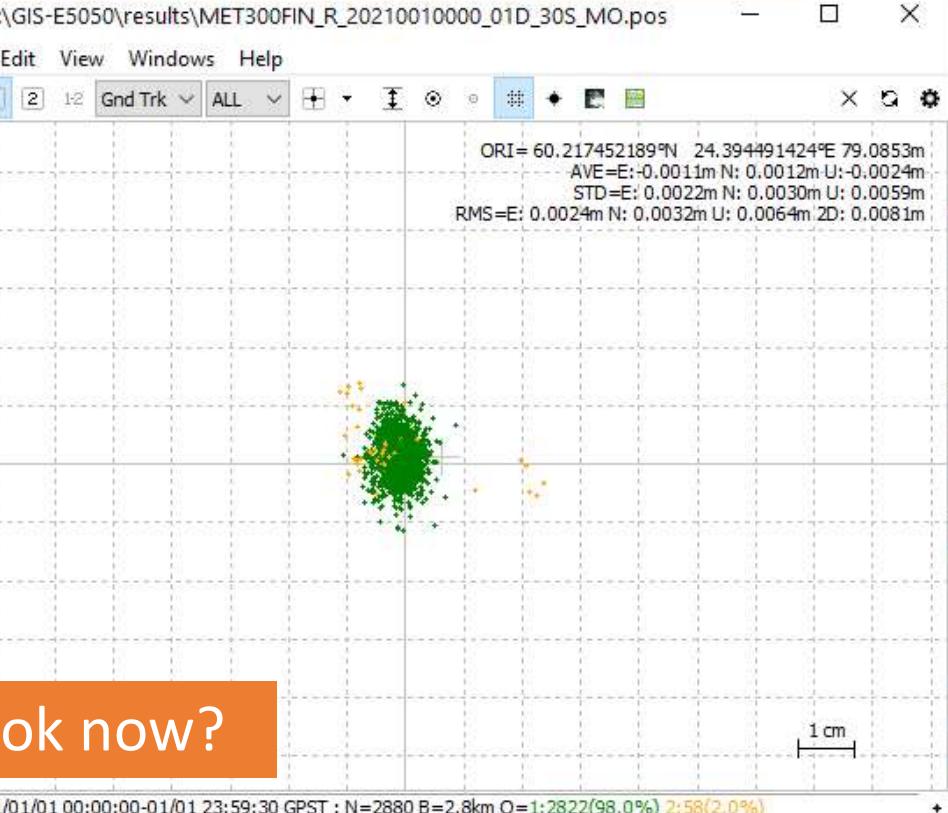


Email: octavian.andrei@nls.fi

Twitter: @coandrei

MET3-METG (2/3): EUREF-FIN version

- Go to *Options->Positions*
- Change the base station reference coordinates
 - X=2890652.9299
 - Y=1310295.2579
 - Z=5513958.6080
- Run the processing again

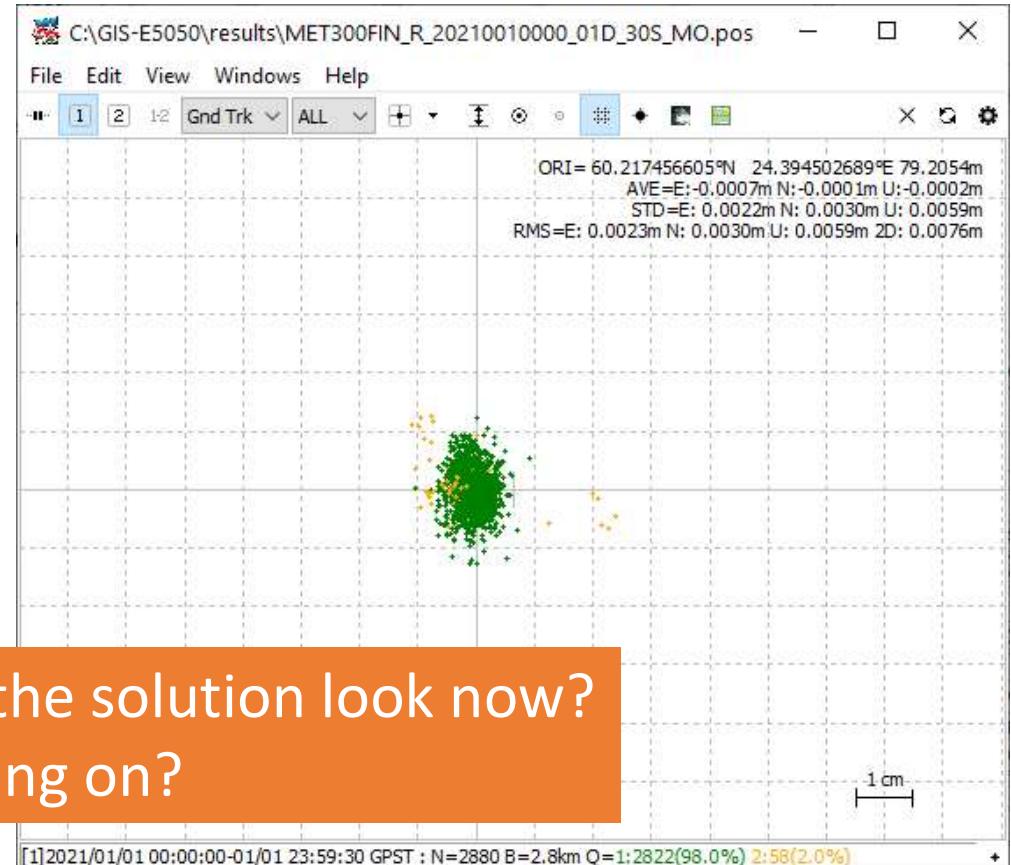


How does the solution look now?

MET3-METG (3/3): ITRF2014 version

- Go to *Options->Load...*
X:\GIS-E5050\config\rtk.conf
- Run the processing again
- Choose *Plot->Edit->Options*
- Change the ground truth to:
 - Lat=60.217456605
 - Lon=24.394502689
 - Hgt=79.2054
- Press OK

How does the solution look now?
What is going on?



Further exploration

- **Congratulations!** Now, you are now able to compute precise relative positions with respect to a known base/reference station.
- Feel free to explore what happens when other setting parameters are changed, such as:
 - frequency number,
 - filter type,
 - elevation mask,
 - precise orbits,
 - multiple constellations,
 - ambiguity resolution method, etc.

Could you further improve the ambiguity resolution percentage?

Further exploration (cont')

- **Repeat** the process for other baselines, such as
 - MET3-MPAS (~30 km)
 - MET3-OLK2 (~191 km)
 - MET3-ROM2 (~530 km)
 - MET3-KEV2 (~1000 km)
 - OLOS-AAKE (~30 km)
- Check the NLS data access slides to fetch / download the additional files.

Do you see any effect?

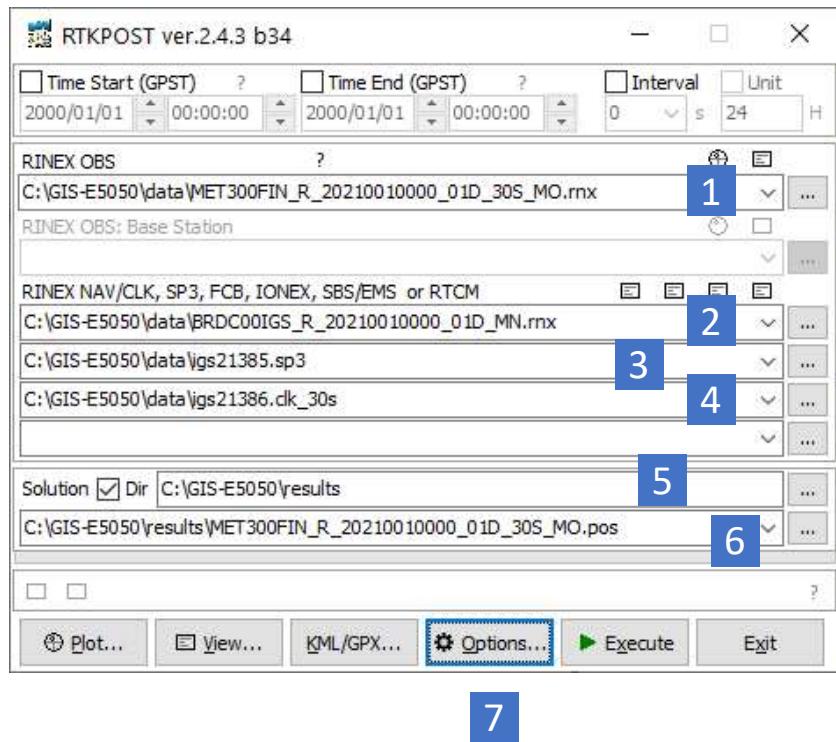
PPP (Optional)

This is rather advanced stuff ...

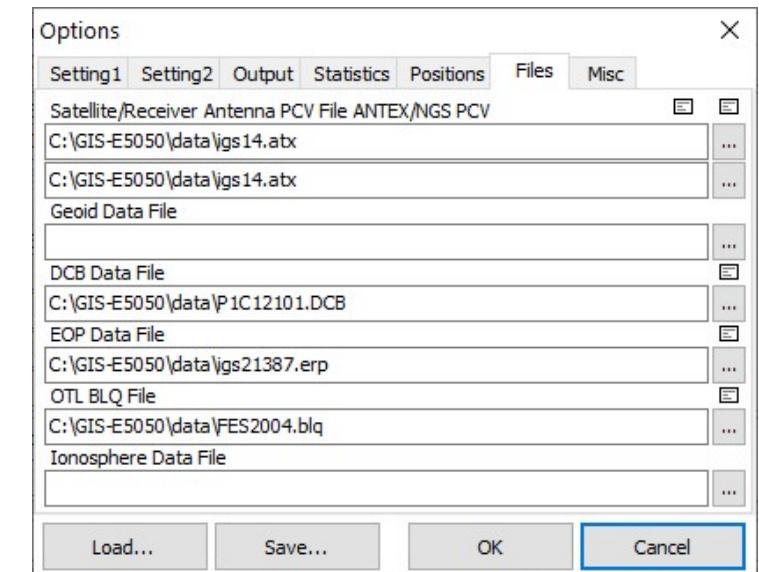
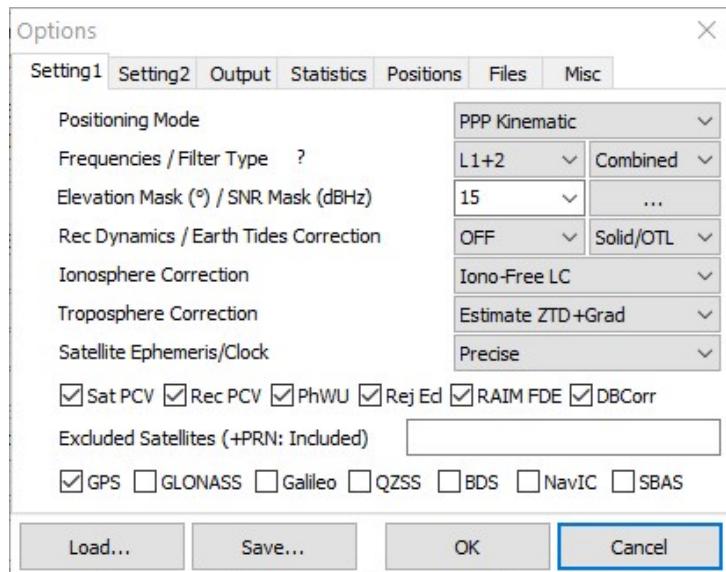
What do we need?

- Close all RTKLIB windows
- Restart RTKPOST
 - Rover: MET300FIN (obs+nav)
 - Precise orbits & clocks: igs*.sp3, igs*.clk
 - Few other additional files (*.atx, *.erp, *.dcb)
- Input data files in *X:\GIS-E5050\data*
- Options->Load *X:\GIS-E5050\config\ppp.conf*

Main input & output



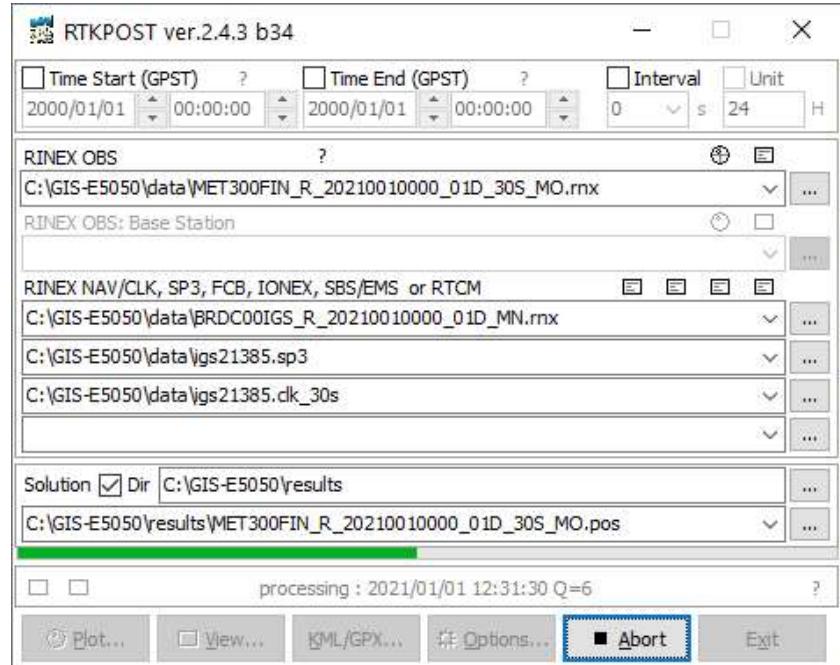
Processing settings



Settings are read from the configuration file.

Settings are read from the configuration file.
Adjust the paths if you have not followed exactly the guidelines.

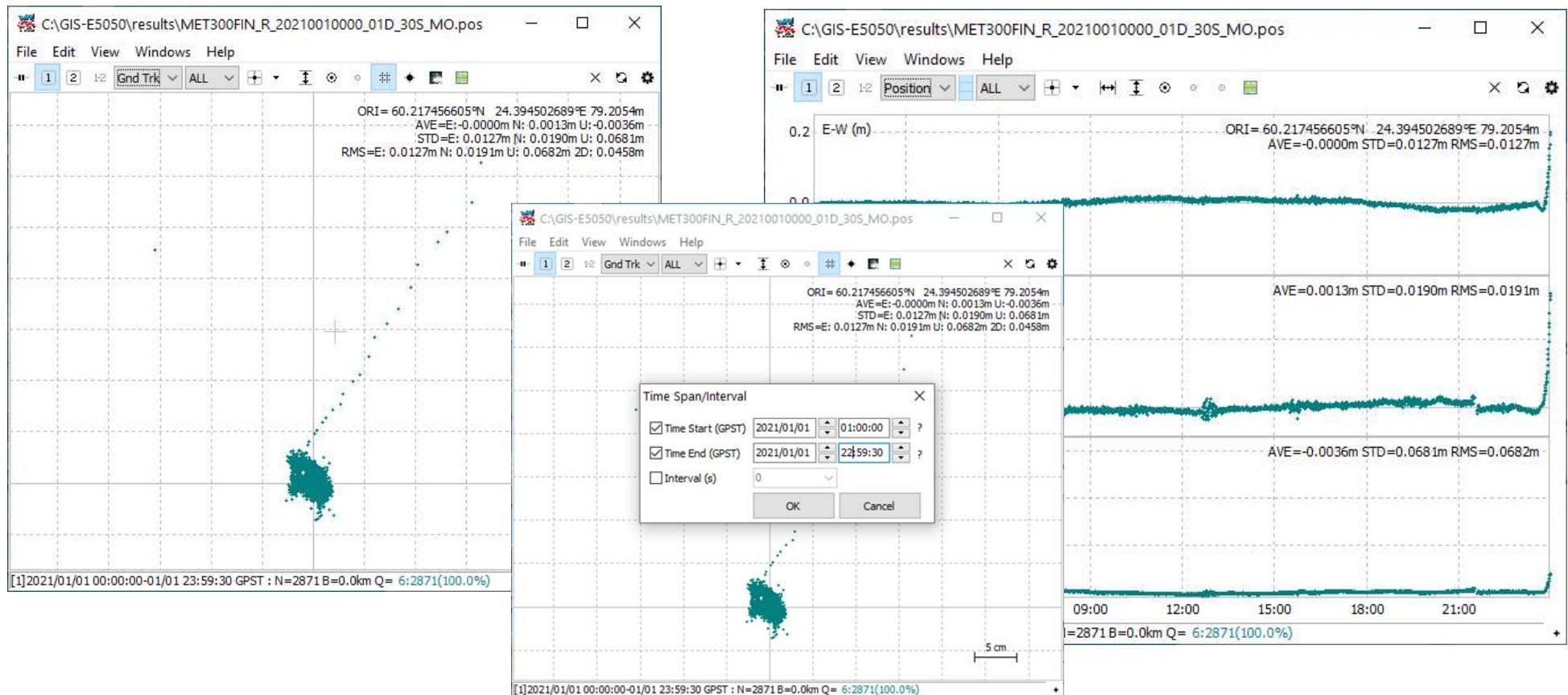
Execute



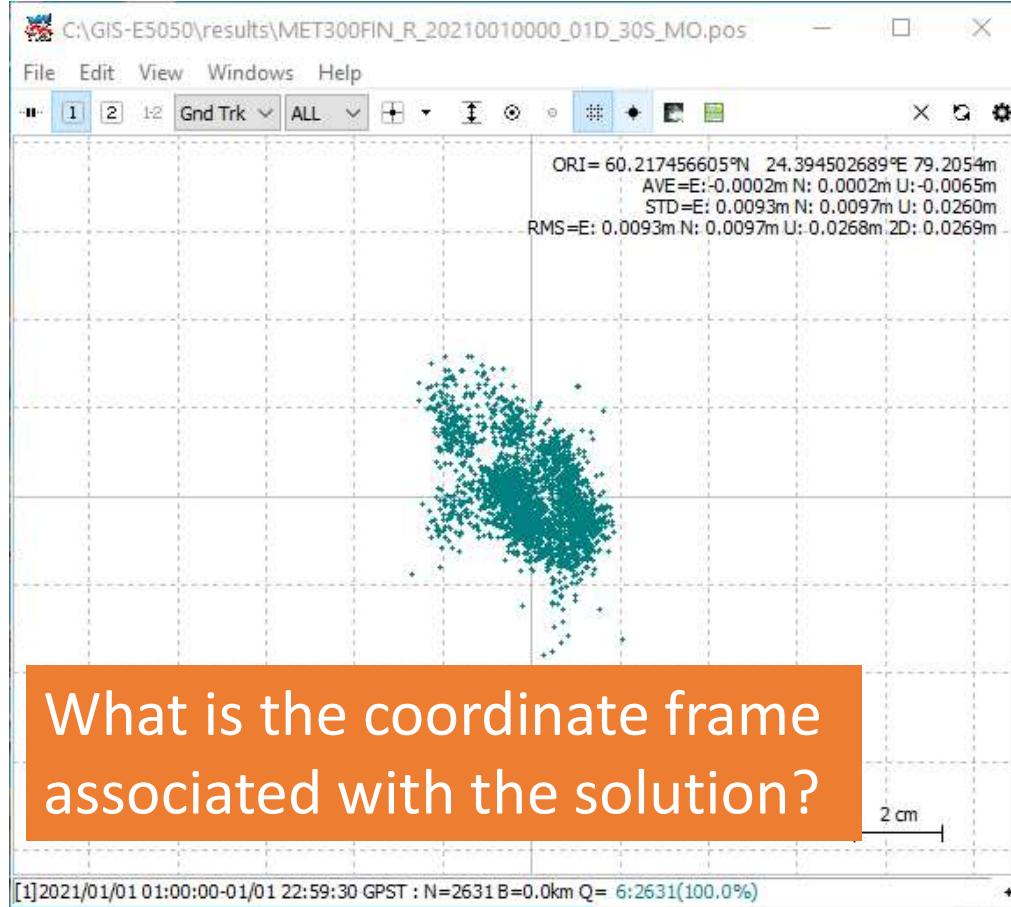
```
C:\GIS-E5050\results\MET300FIN_R_20210010000_01D_30S_MO.pos
Find Close Read... Option...

% program : RTKPOST ver.2.4.3 b34
% inp file : C:\GIS-E5050\data\MET300FIN_R_20210010000_01D_30S_MO.rnx
% inp file : C:\GIS-E5050\data\BRDC00IGS_R_20210010000_01D_MN.rnx
% inp file : C:\GIS-E5050\data\jgs21385.sp3
% inp file : C:\GIS-E5050\data\jgs21385.clk_30s
% obs start : 2021/01/01 00:00:00.0 GPST (week2138 432000.0s)
% obs end : 2021/01/01 23:59:30.0 GPST (week2138 518370.0s)
% pos mode : PPP Kinematic
% solution : Combined
% elev mask : 15.0 deg
% dynamics : off
% tidecorr : on
% tropo opt : Estimate ZTD+Grad
% ephemeris : Precise
% navi sys : GPS
% antenna : JAVRINGANT_DM SCIS ( 0.0000 0.0000 0.0000)
%
% (lat/lon/height=WGS84/ellipsoidal,Q=l:fix,2:floating,3:shab,4:dgps,5:single,6:ppp,ns=# of satellites)
% GPST      latitude(deg) longitude(deg) height(m) Q ns sdn(m) sde(m) sdu(m) sdeu(m) sdne(m) sdeu(m) sdun(m) age(s) ratio
2021/01/01 00:00:00.000 60.217458646 24.394499901 82.4433 6 8 1.2118 0.7949 2.5024 -0.3588 -0.3355 0.8096 0.00 0.0
2021/01/01 00:00:30.000 60.217456644 24.394502612 79.2197 6 8 0.0257 0.0208 0.0563 0.0052 -0.0086 0.0214 0.00 0.0
2021/01/01 00:01:00.000 60.217456616 24.394502580 79.2197 6 8 0.0259 0.0210 0.0564 0.0055 -0.0075 0.0215 0.00 0.0
2021/01/01 00:01:30.000 60.217456565 24.394502565 79.2256 6 8 0.0260 0.0210 0.0566 0.0055 -0.0079 0.0220 0.00 0.0
2021/01/01 00:02:00.000 60.217456574 24.394502565 79.2228 6 8 0.0261 0.0211 0.0566 0.0056 -0.0078 0.0219 0.00 0.0
2021/01/01 00:02:30.000 60.217456558 24.394502620 79.2209 6 8 0.0261 0.0209 0.0565 0.0051 -0.0081 0.0218 0.00 0.0
2021/01/01 00:03:00.000 60.217456649 24.394502557 79.2212 6 8 0.0260 0.0209 0.0561 0.0051 -0.0080 0.0216 0.00 0.0
2021/01/01 00:03:30.000 60.217456603 24.394502600 79.2236 6 8 0.0260 0.0210 0.0560 0.0051 -0.0078 0.0213 0.00 0.0
2021/01/01 00:04:00.000 60.217456529 24.394502594 79.2184 6 8 0.0258 0.0211 0.0558 0.0046 -0.0078 0.0211 0.00 0.0
2021/01/01 00:04:30.000 60.217456601 24.394502573 79.2125 6 8 0.0258 0.0210 0.0555 0.0038 -0.0081 0.0208 0.00 0.0
2021/01/01 00:05:00.000 60.217456607 24.394502601 79.2217 6 8 0.0263 0.0213 0.0569 0.0024 -0.0089 0.0210 0.00 0.0
2021/01/01 00:05:30.000 60.217456601 24.394502630 79.2181 6 8 0.0256 0.0211 0.0551 0.0043 -0.0082 0.0205 0.00 0.0
2021/01/01 00:06:00.000 60.217456604 24.394502578 79.2224 6 8 0.0256 0.0209 0.0549 0.0035 -0.0083 0.0203 0.00 0.0
2021/01/01 00:06:30.000 60.217456566 24.394502604 79.2228 6 8 0.0257 0.0209 0.0547 0.0032 -0.0086 0.0204 0.00 0.0
2021/01/01 00:07:00.000 60.217456616 24.394502659 79.2199 6 8 0.0256 0.0210 0.0547 0.0030 -0.0085 0.0201 0.00 0.0
2021/01/01 00:07:30.000 60.217456548 24.394502530 79.2233 6 8 0.0256 0.0210 0.0545 0.0028 -0.0081 0.0201 0.00 0.0
2021/01/01 00:08:00.000 60.217456587 24.394502612 79.2134 6 8 0.0256 0.0209 0.0543 0.0025 -0.0083 0.0200 0.00 0.0
2021/01/01 00:08:30.000 60.217456620 24.394502603 79.2178 6 8 0.0256 0.0211 0.0542 0.0027 -0.0085 0.0198 0.00 0.0
2021/01/01 00:09:00.000 60.217456575 24.394502613 79.2266 6 8 0.0256 0.0210 0.0541 0.0028 -0.0084 0.0197 0.00 0.0
2021/01/01 00:09:30.000 60.217456633 24.394502652 79.2203 6 8 0.0256 0.0210 0.0540 0.0012 -0.0085 0.0198 0.00 0.0
2021/01/01 00:10:00.000 60.217456543 24.394502613 79.2200 6 8 0.0263 0.0213 0.0554 -0.0023 -0.0087 0.0201 0.00 0.0
```

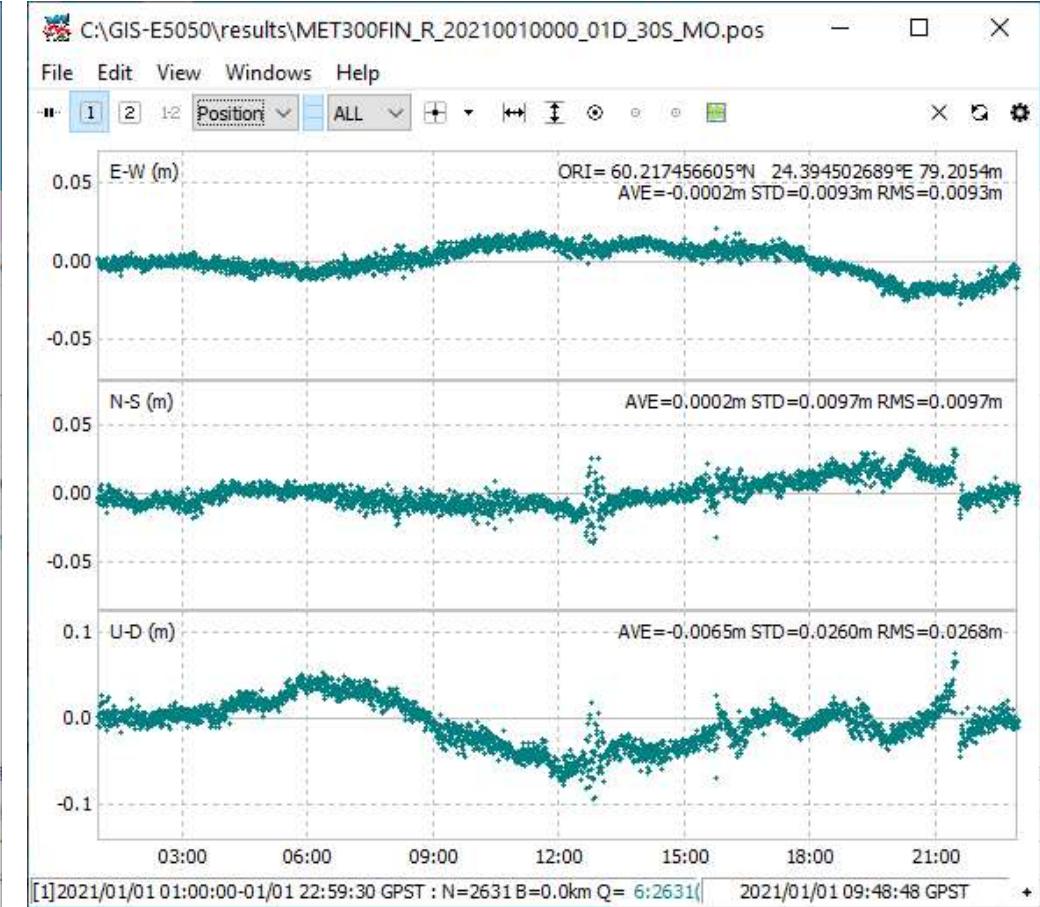
Initial results & trimming



Final solution



What is the coordinate frame associated with the solution?



Further exploration

- **Congratulations!** Now, you are now able to compute point positioning with high precision & accuracy.
 - PPP requires careful & fine tuning to handle different error sources
- **Change** different setting parameters and see for yourself the impact
 - IGS final product covers only GPS constellation
 - \data directory contains similar product files from CODE & ESA. These files include other constellations, such as Galileo, GLONASS, BeiDou.
- **Produce** multi-constellation solution using COD* & ESA* files.

What is the impact on the solution?

Next session

- We are going to do some of these things in **real-time!**
 - RTK
 - NRTK (VRS)
 - More PPP (perhaps ... we shall see how we manage time)
- **NOTE:** To try RT-PPP one needs access to the necessary correction data streams. IGS RTS streams require additional user registration at <https://register.rtcm-ntrip.org/cgi-bin/registration.cgi>

Internet
connection
is needed!