MGA Webinar 8th June

How to use free RTK Software?

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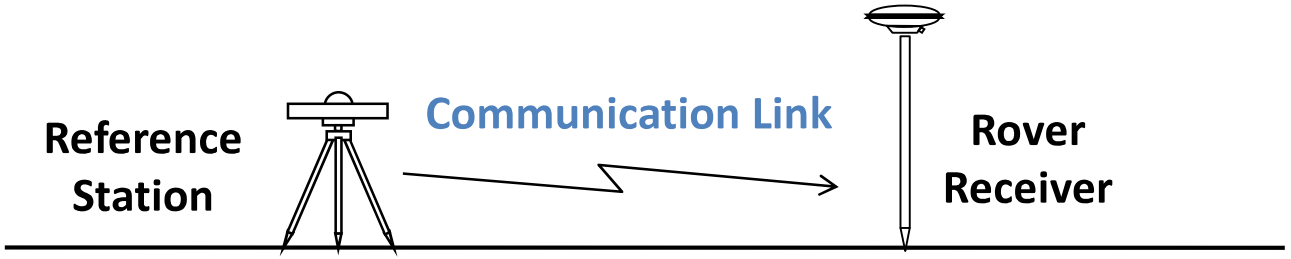
How can we set up RTK by ourselves?

- If you use commercial correction services or via satellites, you don't have to set up. All you need is just rover receiver and maybe software (receiver includes RTK engine).
- If you need to set up base stations by themselves, you can use RTKLIB or if you can prepare Ntrip caster, it is easy for you to conduct. Please contact us if you need any helps.

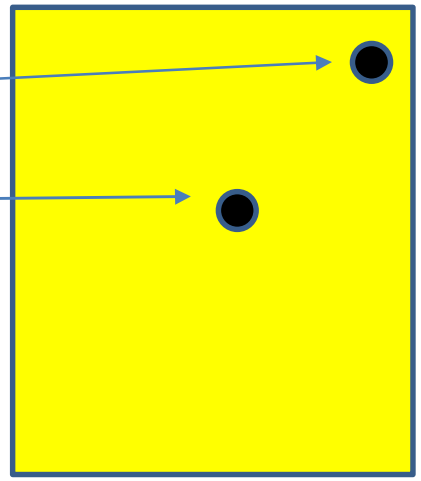
RTK Practice



- Post processing: Observation and Navigation data are required (RINEX).
- Real-Time: Communication link and differential data reception are required (RTCM/NTRIP).

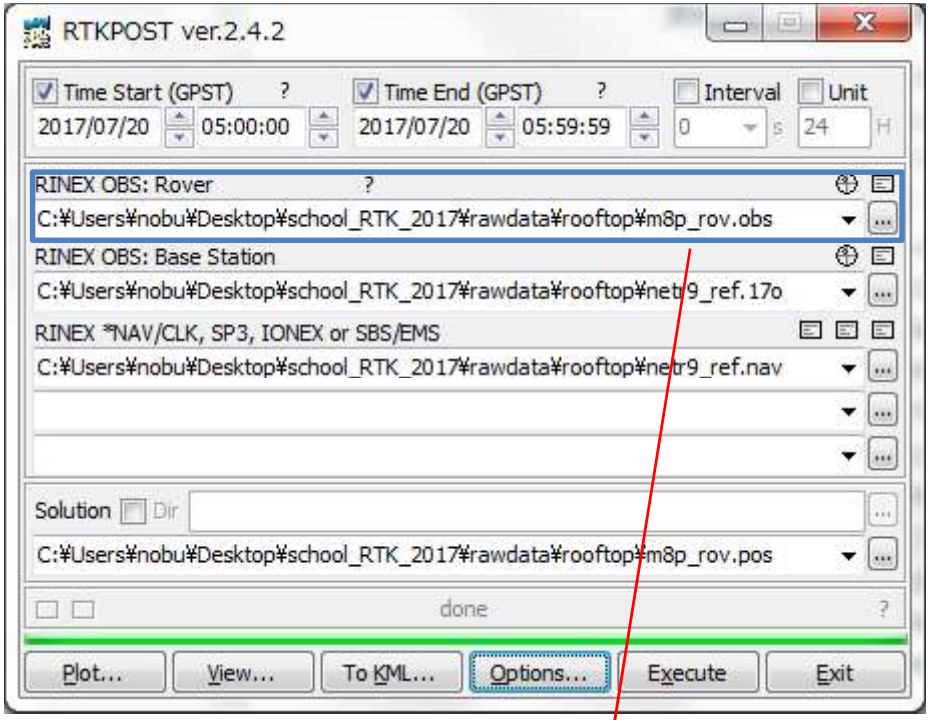
2 receivers were set simultaneously

- Trimble **NetR9** with Trimble antenna
- **u-blox M8P** with YOKOWO antenna

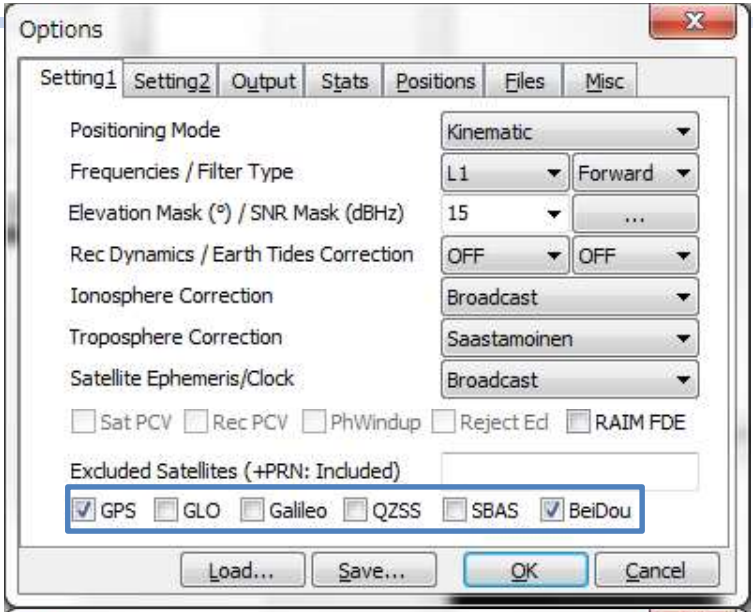


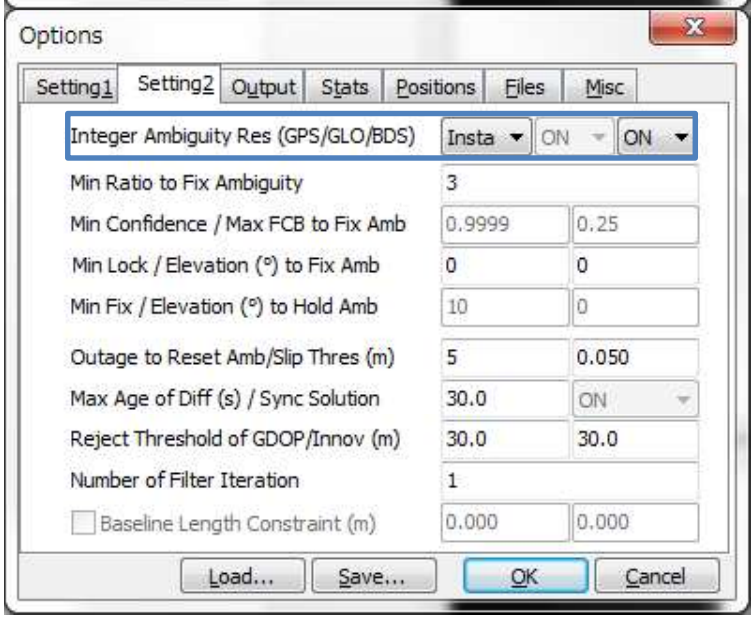
- For the equal comparison, same settings were applied.
- GPS/BEI + Instantaneous.

Similar test using u-blox

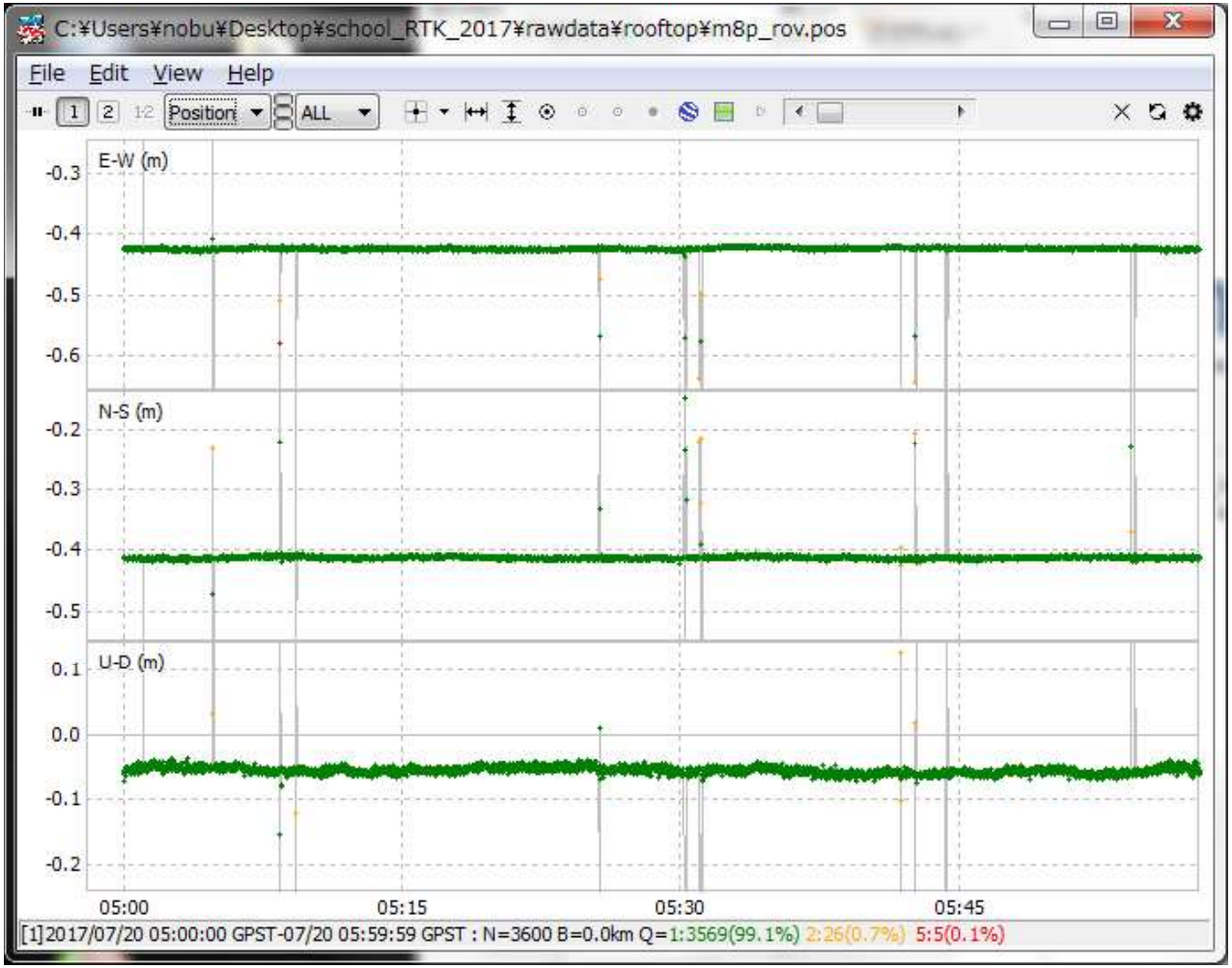


Or, netr9_rov.17o



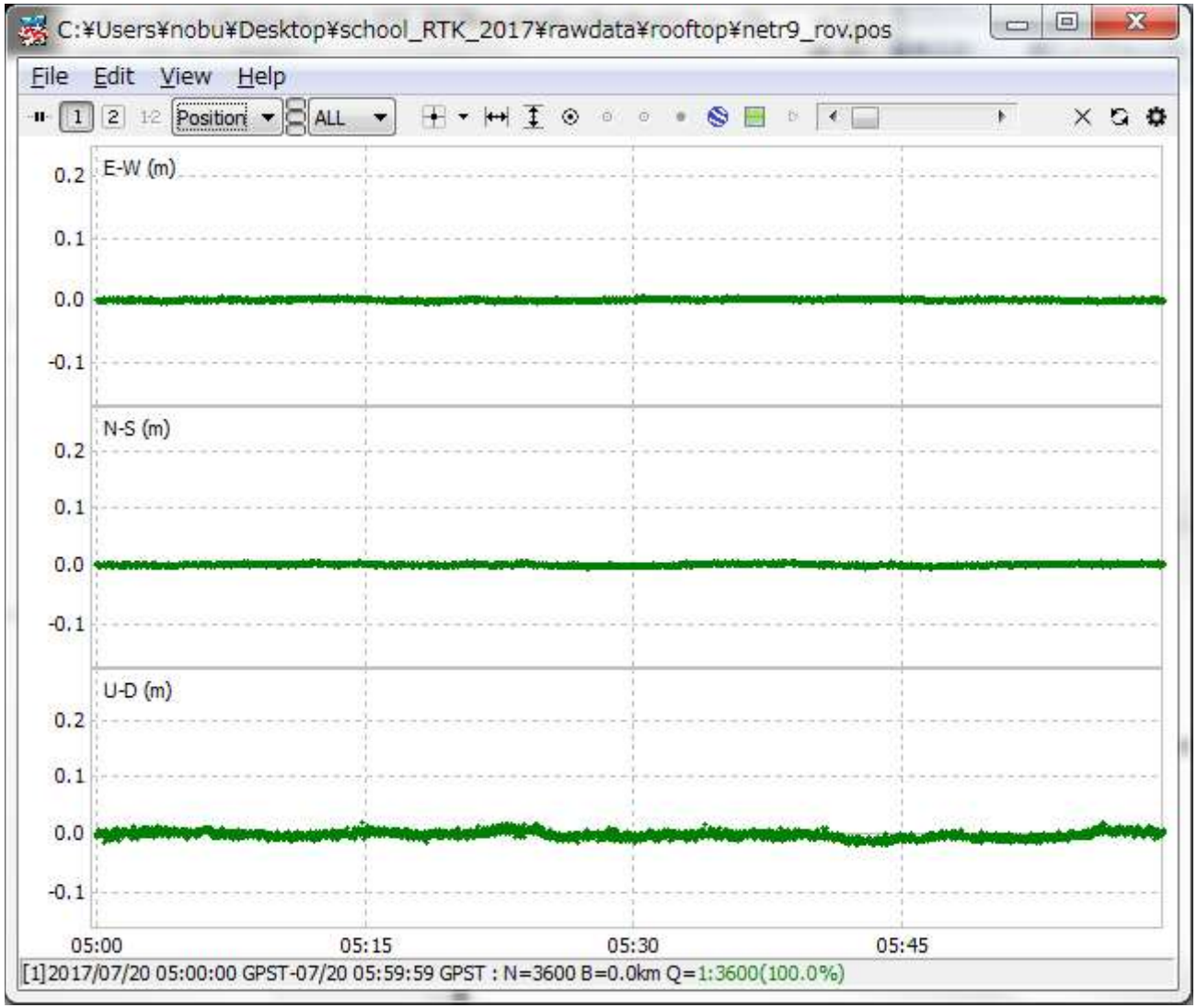


u-blox M8P results



The performance of RTK : M8P is better than M8T
(probably the PLL of M8P is more robust and precise than M8T…)

NetR9 results



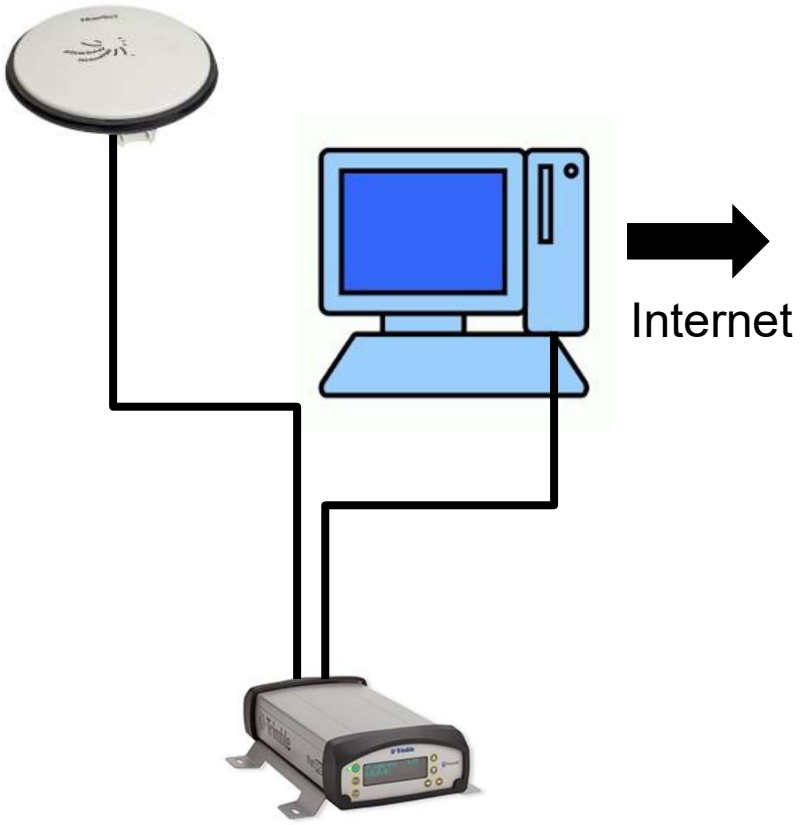
RTKLIB (real-time : RTKNAVI)

- **Connect u-blox M8P**
- **Execute RTKNAVI**
- RTK was valid using NTRIP of base station (NetR9) via the same antenna under perfect condition (GQB).
- GQR was also valid but GLONASS ambiguity resolution is set OFF.

Please check them by yourself after you go back to home.
If you need an information how to set the reference station, please refer to the website (GNSS TUTOR).

http://www.denshi.e.kaiyodai.ac.jp/gnss_tutor/experiment.html

How to connect (my desktop)

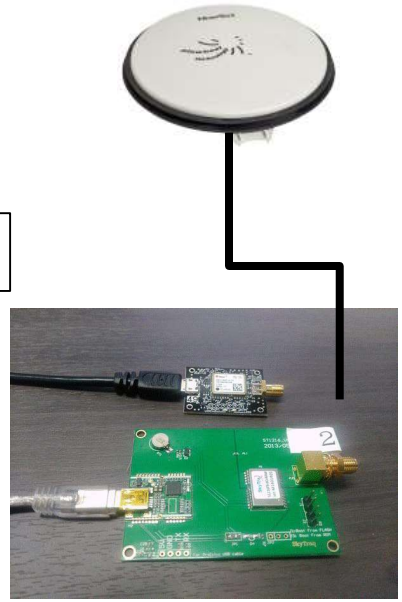


Internet

Base station
(Ntrip server)

u-center / RTKLIB

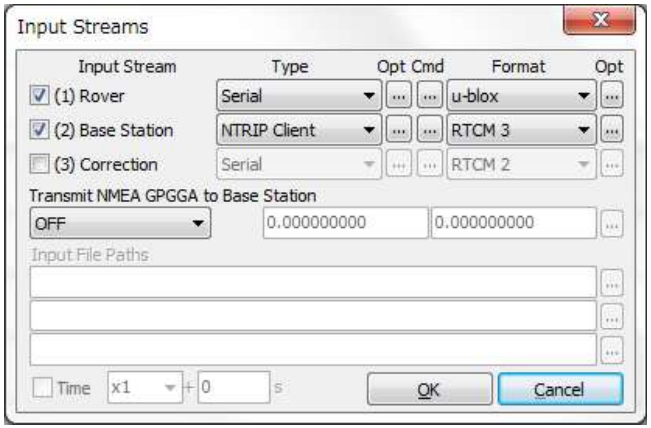
Internet



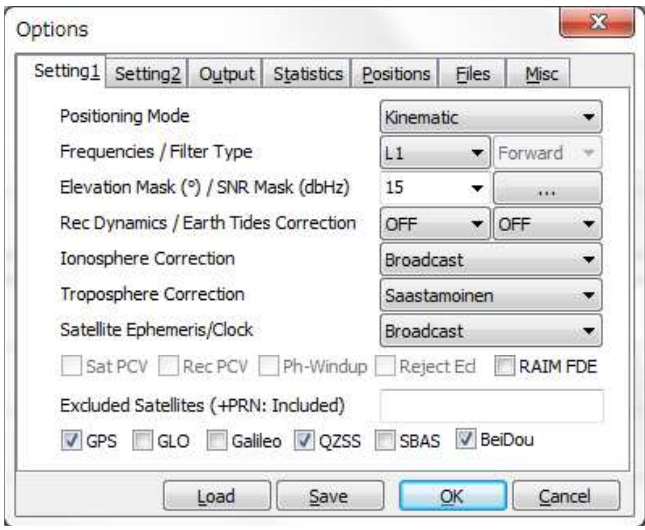
Rover station
Correction data is received via internet
GNSS raw data is received via USB-Serial

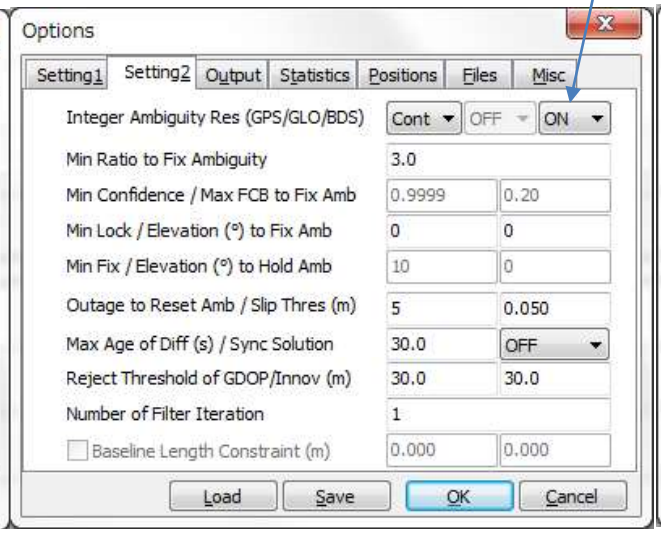
You can switch Desktop to Laptop/Pad/Raspberry Pi

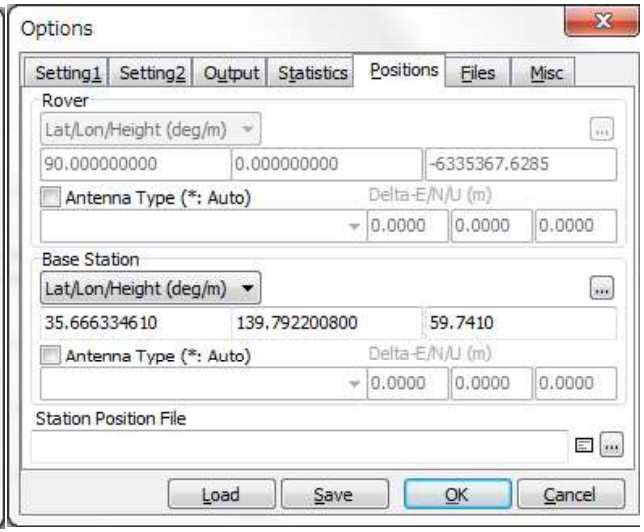
RTKNAVI - Options



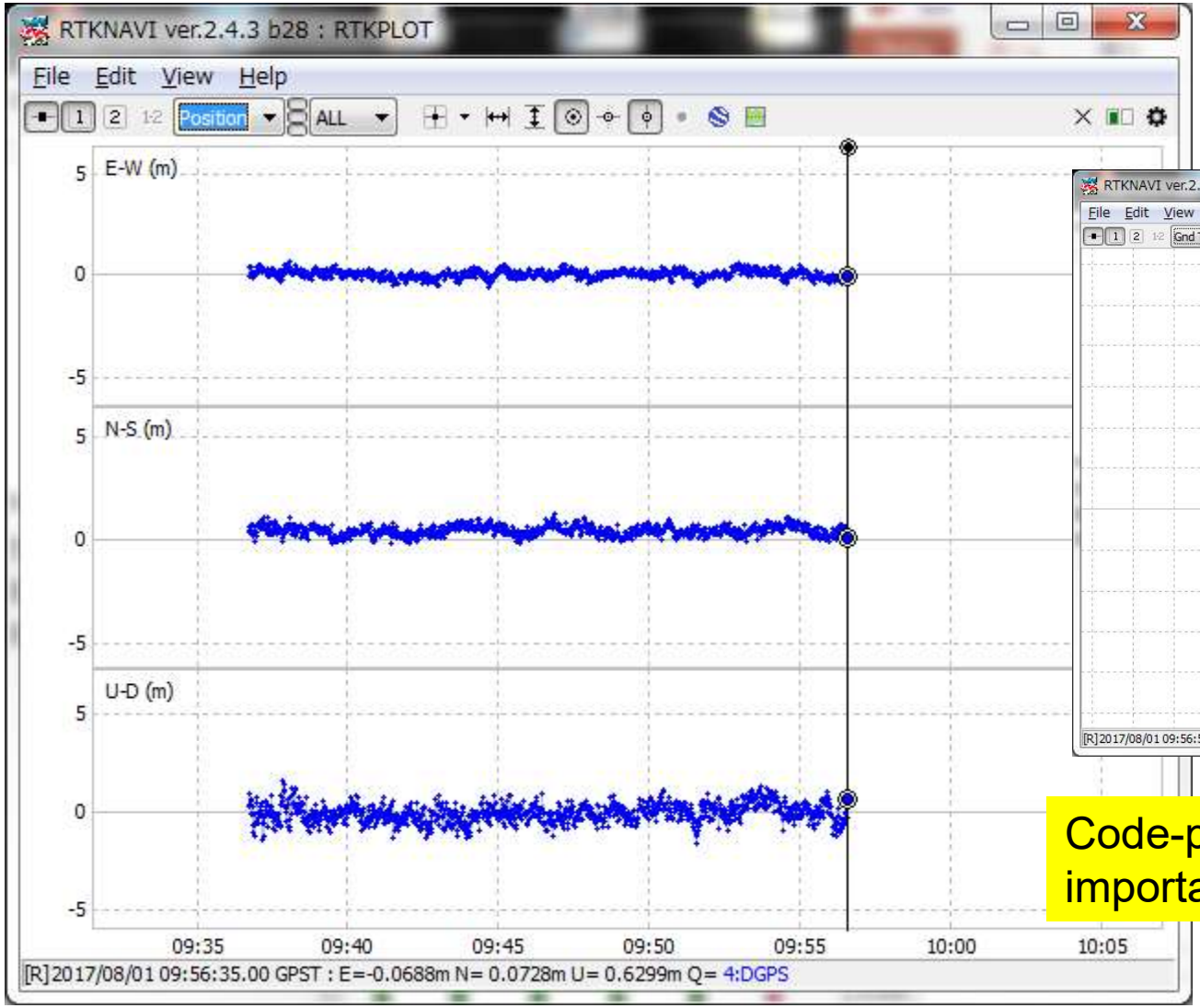
If you set GQR and it doesn't fix, please try it again by changing the setting of Integer Ambiguity Res "OFF".

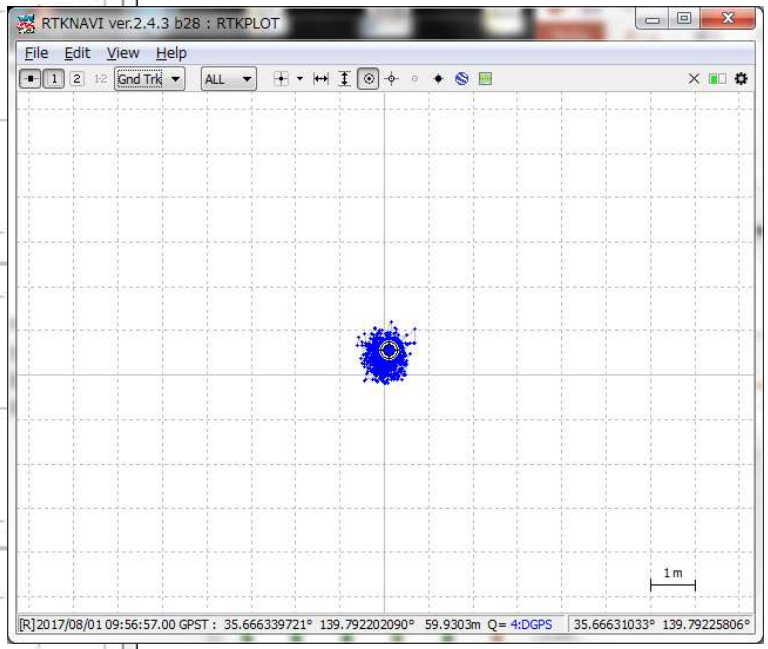




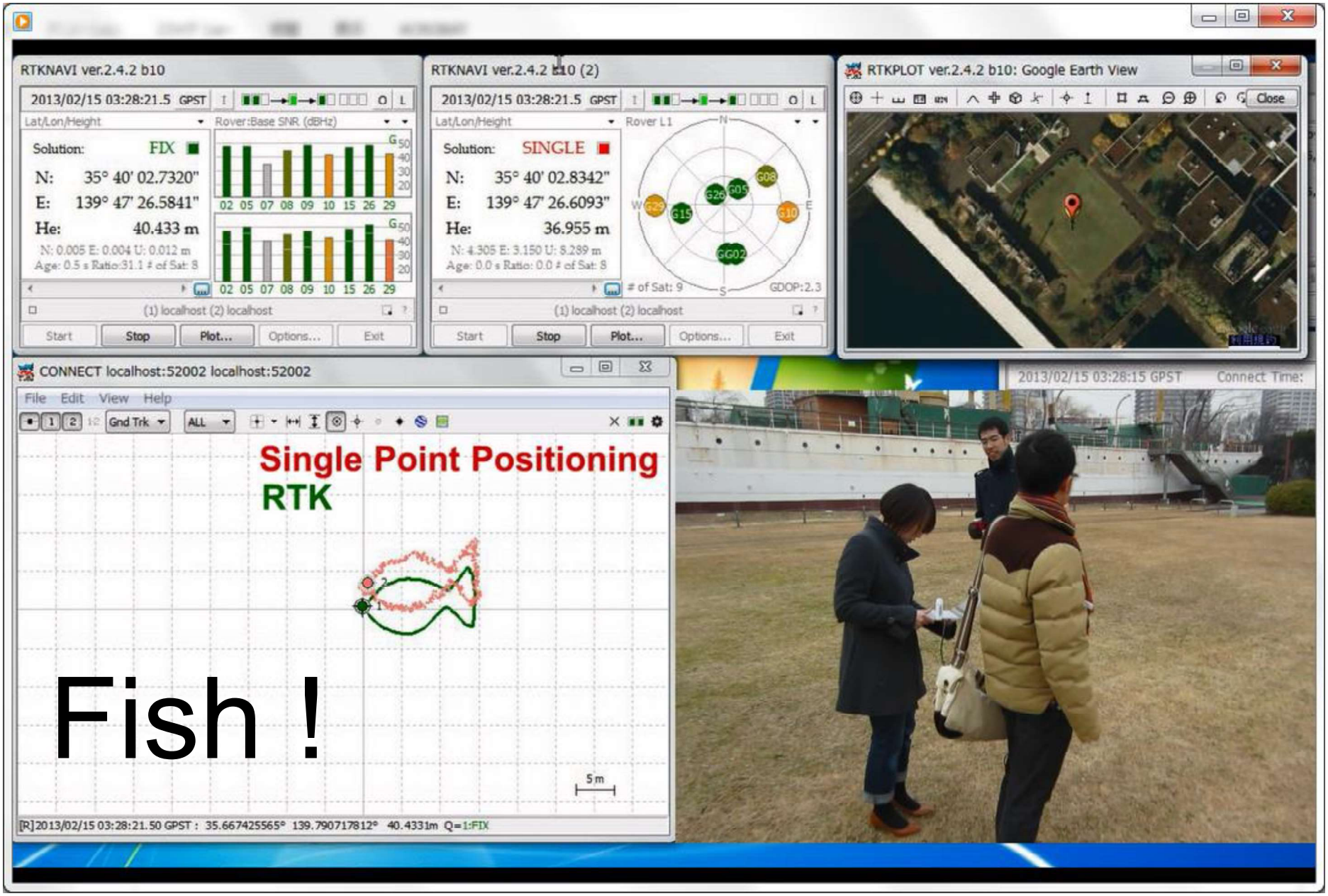


u-blox M8P DGNSS (GB)





Code-phase accuracy is quite important for RTK performance


RTKNAVI ver.2.4.2 b10
2013/02/15 03:28:21.5 GPST
Lat/Lon/Height
Rover:Base SNR (dBHz)
Solution: FIX
N: 35° 40' 02.7320"
E: 139° 47' 26.5841"
He: 40.433 m
N: 0.005 E: 0.004 U: 0.012 m
Age: 0.5 s Ratio:31.1 # of Sat: 8
02 05 07 08 09 10 15 26 29
(1) localhost (2) localhost
Start
Stop
Plot...
Options...
Exit
RTKNAVI ver.2.4.2 b10 (2)
2013/02/15 03:28:21.5 GPST
Lat/Lon/Height
Rover L1
Solution: SINGLE
N: 35° 40' 02.8342"
E: 139° 47' 26.6093"
He: 36.955 m
N: 4.305 E: 3.150 U: 8.289 m
Age: 0.0 s Ratio: 0.0 # of Sat: 8
# of Sat: 9
GDOP:2.3
(1) localhost (2) localhost
Start
Stop
Plot...
Options...
Exit
RTKPLOT ver.2.4.2 b10: Google Earth View
Close
CONNECT localhost:52002 localhost:52002
File Edit View Help
Gnd Trk
ALL
Single Point Positioning
RTK
Fish !
5 m
[R]2013/02/15 03:28:21.50 GPST : 35.667425565° 139.790717812° 40.4331m Q=1:FIX
2013/02/15 03:28:15 GPST
Connect Time:

Limited Coverage of RTK

- Normally, the coverage of RTK is 10-20km. It strongly depends on the **ionospheric activity**.
- But, the recent commercial RTK engine can cover up to **50-100km**.
- Also, you can use **VRS/FKP correction service**. The commercial company produces real-time correction data (Ntrip) using several base stations.
- **QZSS will provide similar correction data through the L6 signal (inside Japan). It is challenging because message bit-rate is 2Kbps.**

PPP does not have limitation in area

- PPP provides precise orbit and clock of GNSS.
- It means that you have to remove **ionospheric/tropospheric errors** as much as possible. It takes **5-30 minutes** and depends on the ionosphere model you have.
- **QZSS is going to test PPP correction data through the L6 signal. In fact, we have tested it for serval years by JAXA (MADOCA).**

RTKLIB Practice (2)

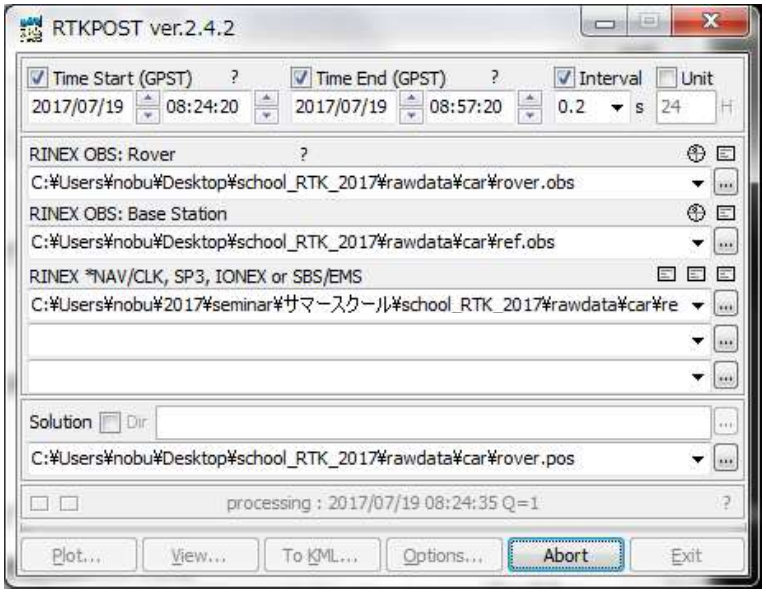
Car data and field test

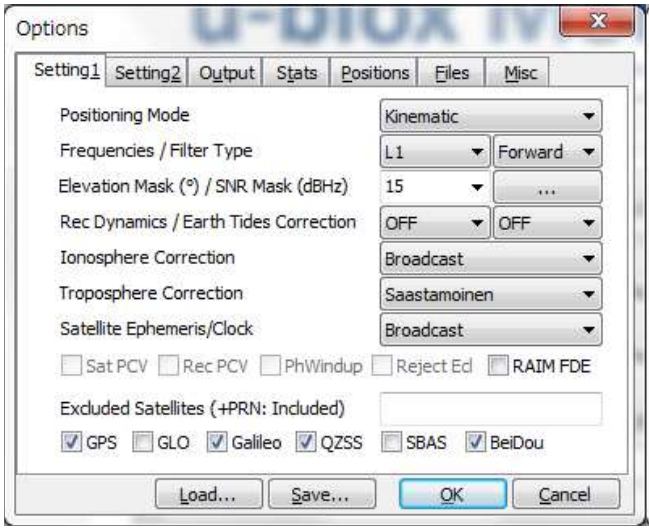
- Car data is post-processed using RTKLIB
- Homework
- RTK field test using u-blox M8P (8 groups)

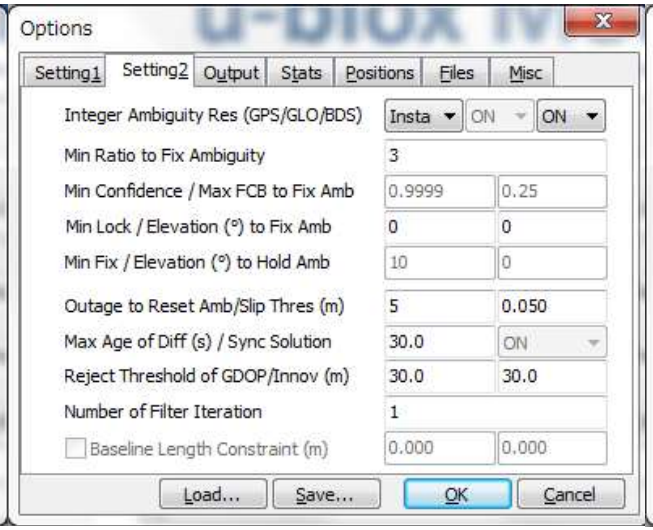
Car data

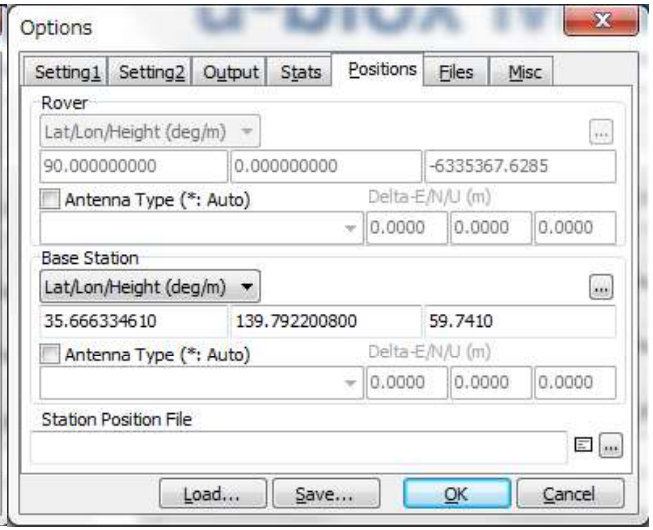
- 2017/7/19　8:24:20 – 8:57:20 (GPST)
- Total 9900 epochs in 5Hz
- Near university campus (normal urban)
- u-blox M8T and Trimble NetR9 for both Rover and reference station
- You can compare these two receivers
- Single-frequency or dual-frequency ?
- What is the best setting ?

Settings of u-blox M8P

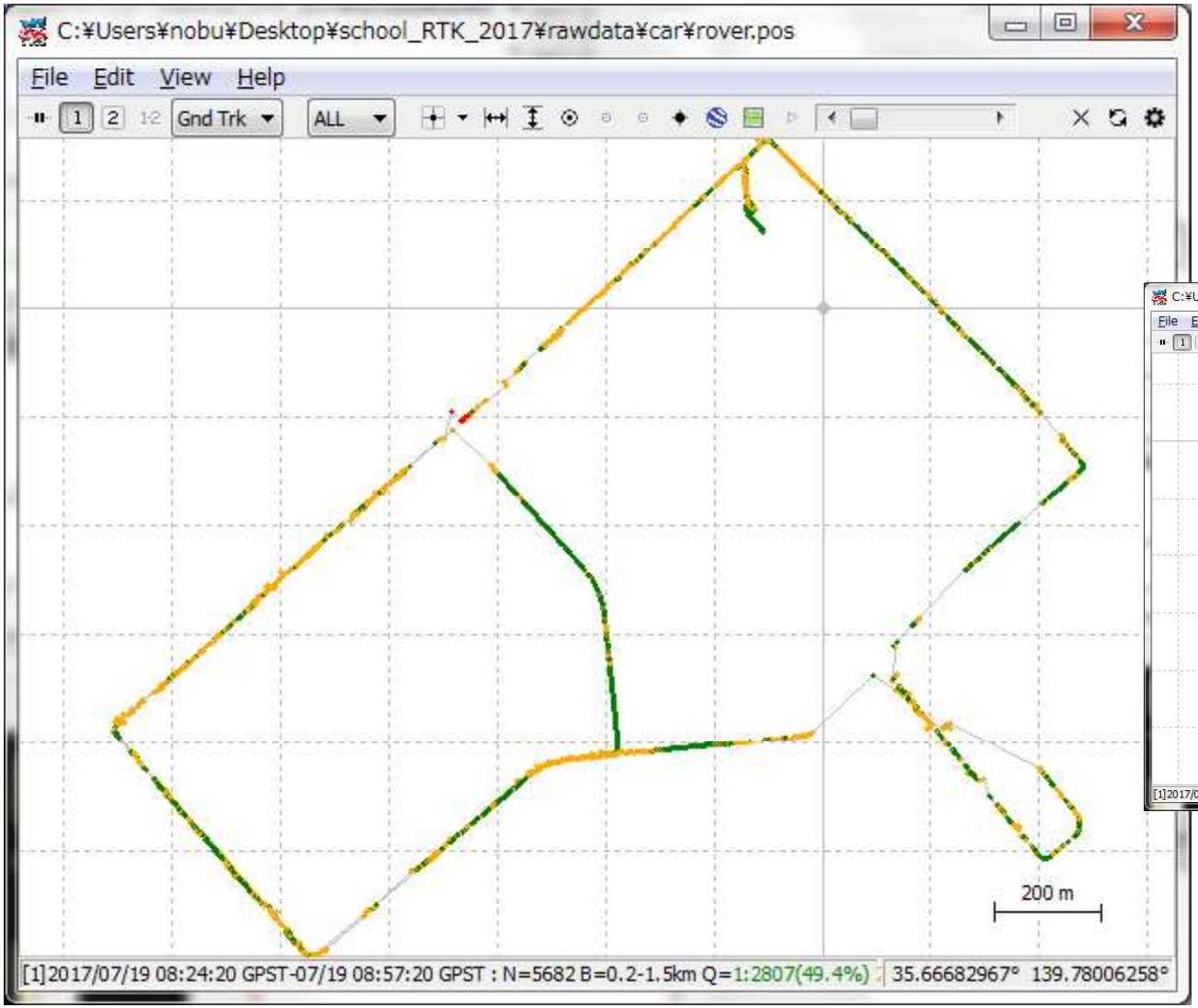


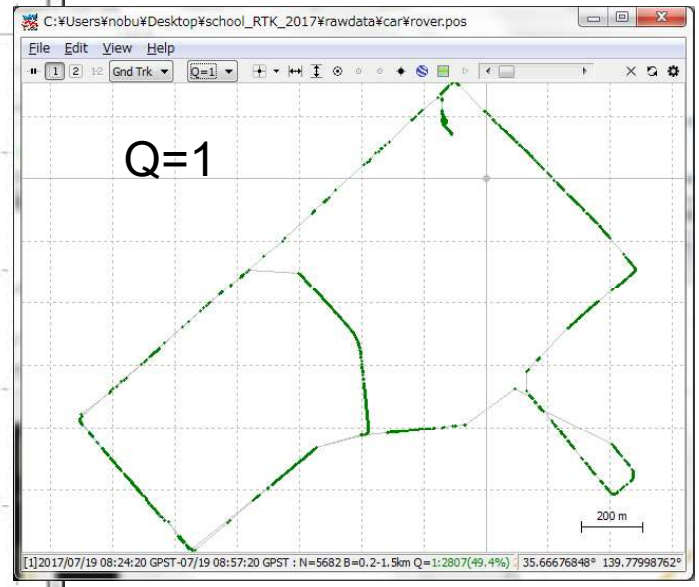




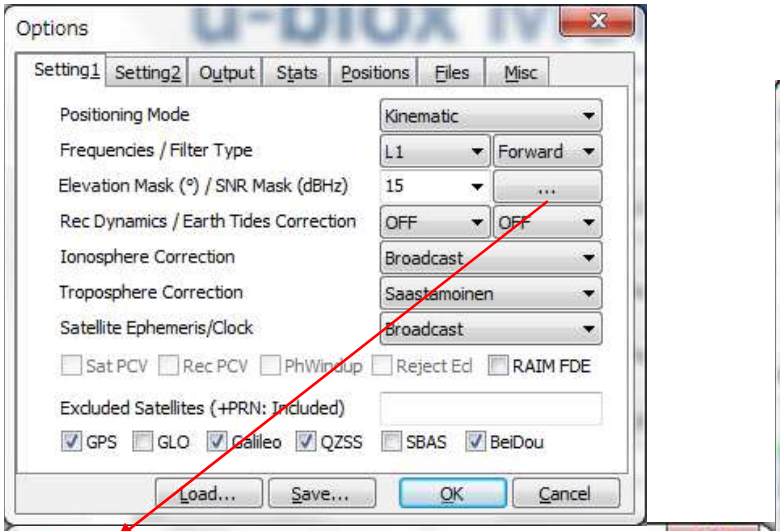


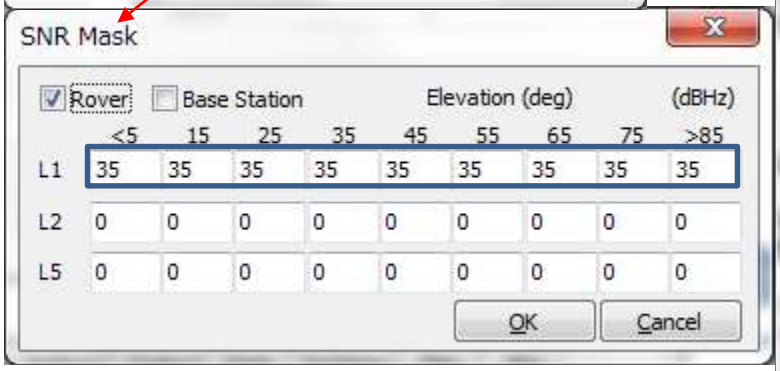
PLOT

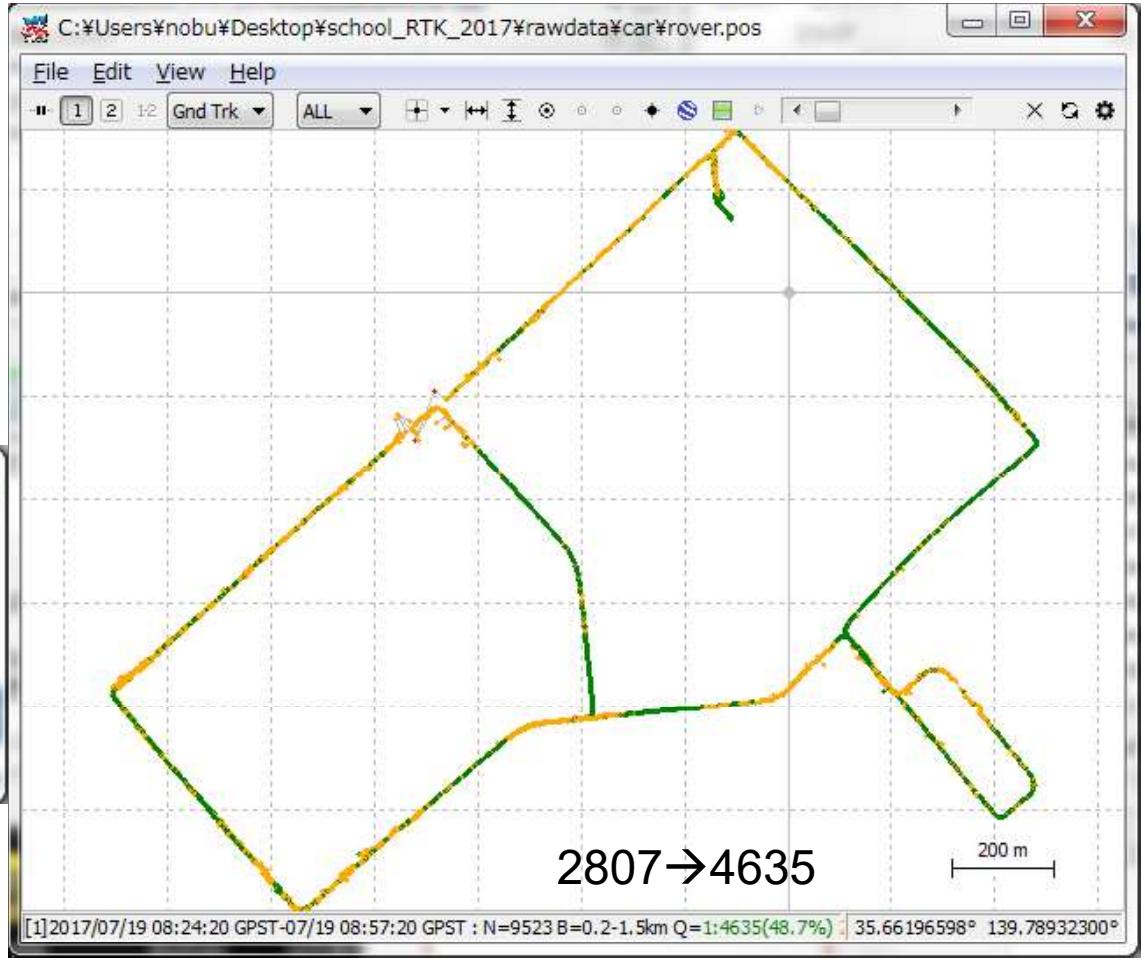

C:¥Users¥nobu¥Desktop¥school_RTK_2017¥rawdata¥car¥rover.pos
File Edit View Help
Gnd Trk
ALL
200 m
[1]2017/07/19 08:24:20 GPST-07/19 08:57:20 GPST : N=5682 B=0.2-1.5km Q=1:2807(49.4%)
35.66682967° 139.78006258°


C:¥Users¥nobu¥Desktop¥school_RTK_2017¥rawdata¥car¥rover.pos
File Edit View Help
Gnd Trk
Q=1
Q=1
200 m
[1]2017/07/19 08:24:20 GPST-07/19 08:57:20 GPST : N=5682 B=0.2-1.5km Q=1:2807(49.4%)
35.66676848° 139.77998762°

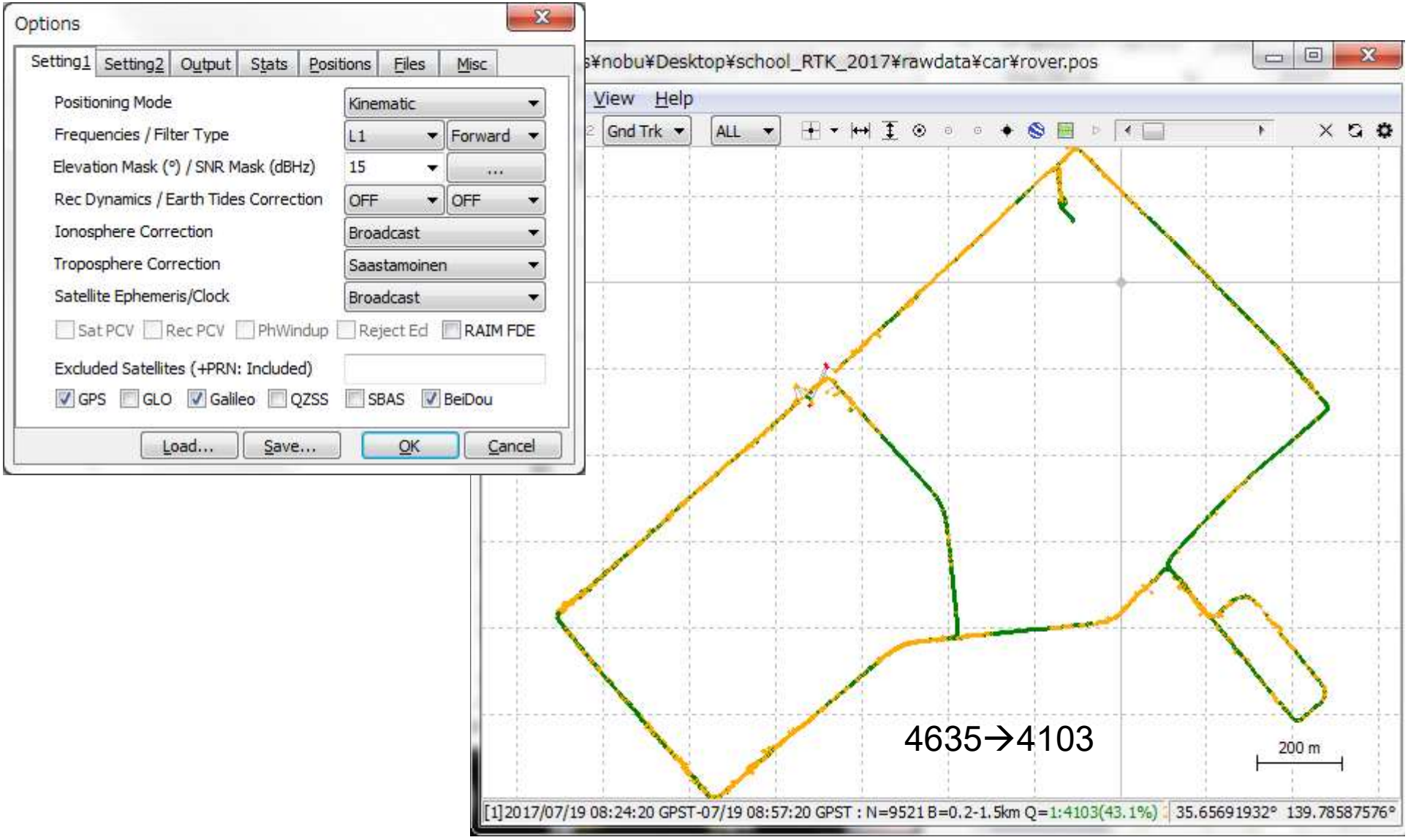
If you set minimum C/N_0 ,



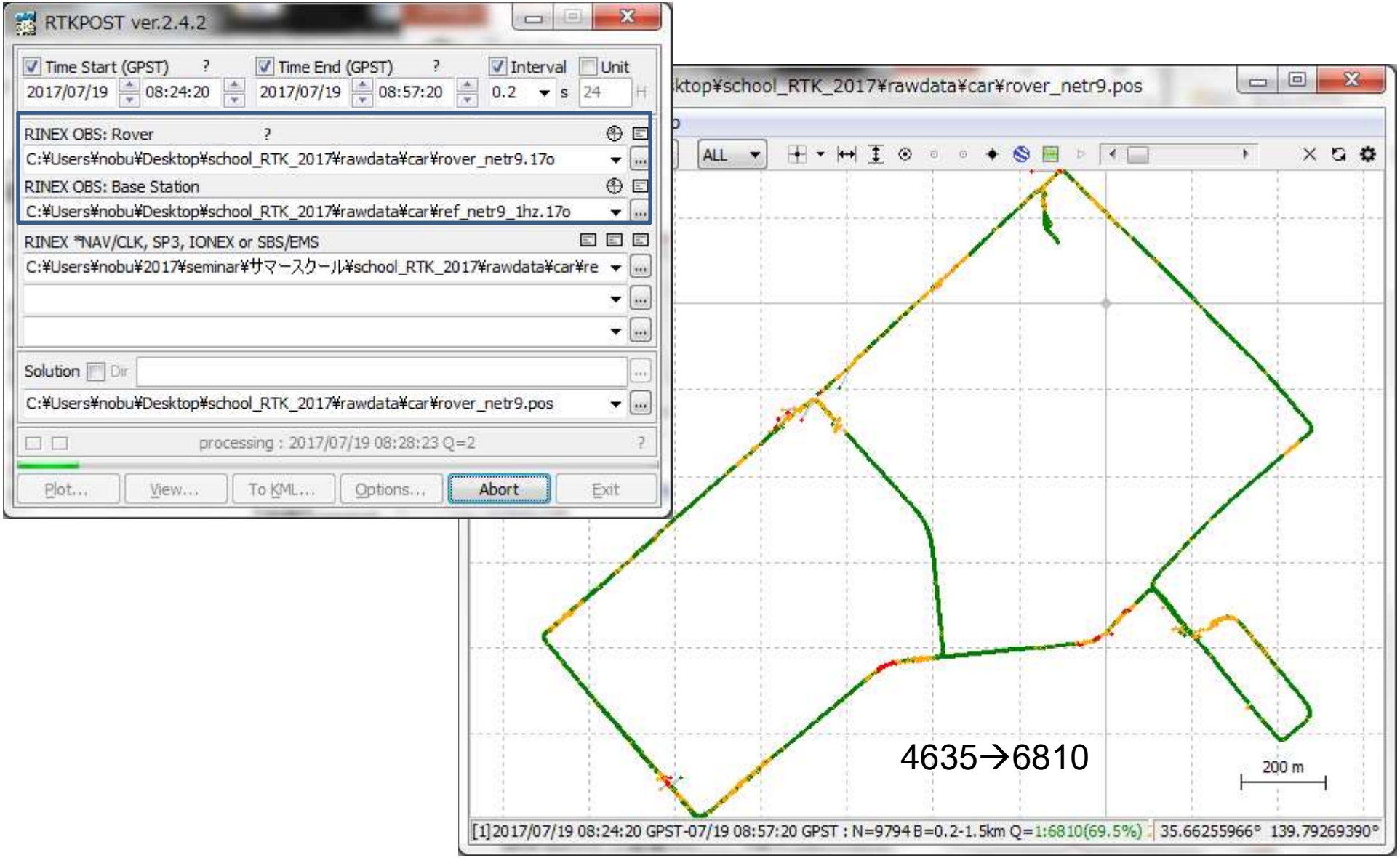




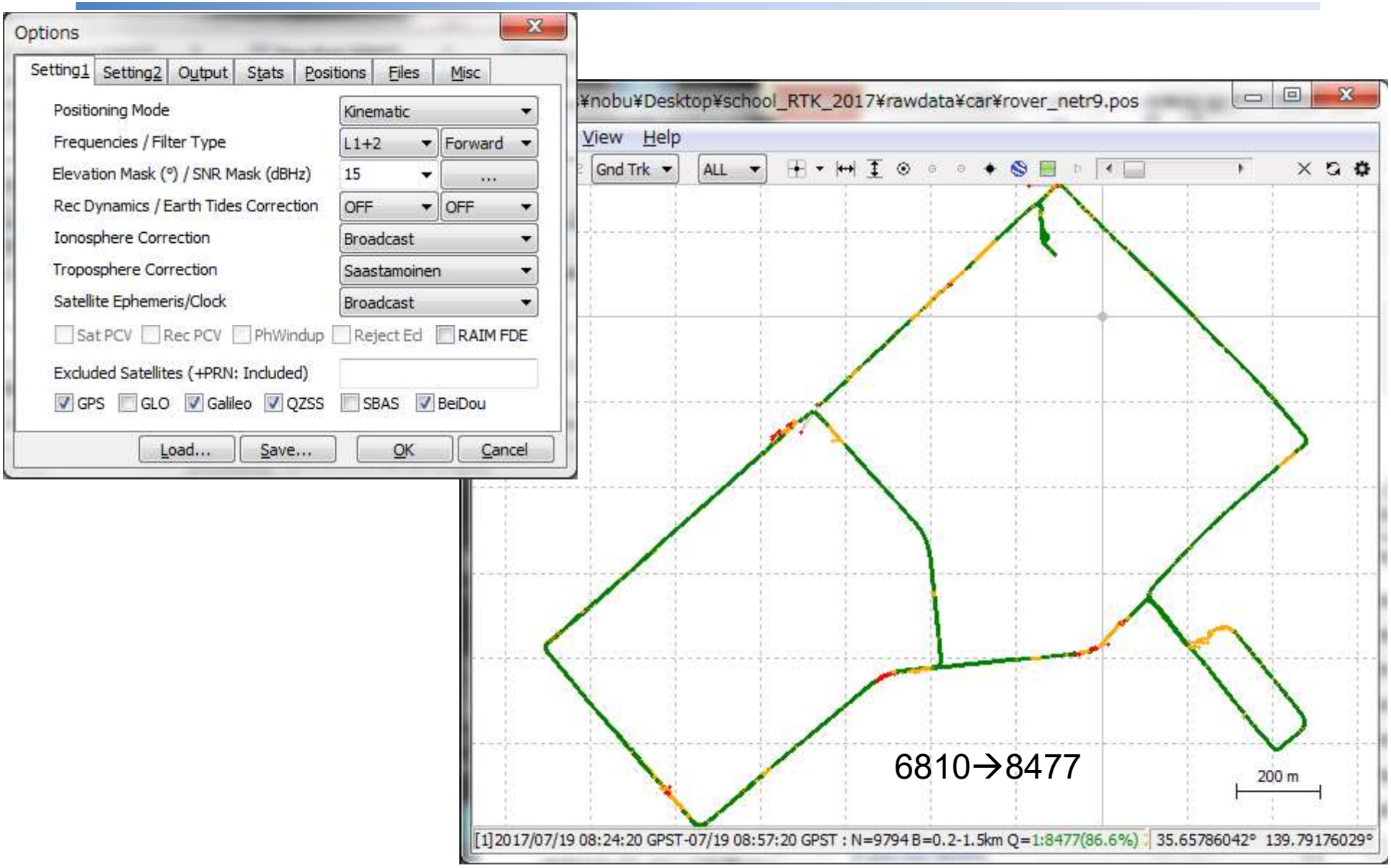
If you remove QZS ,



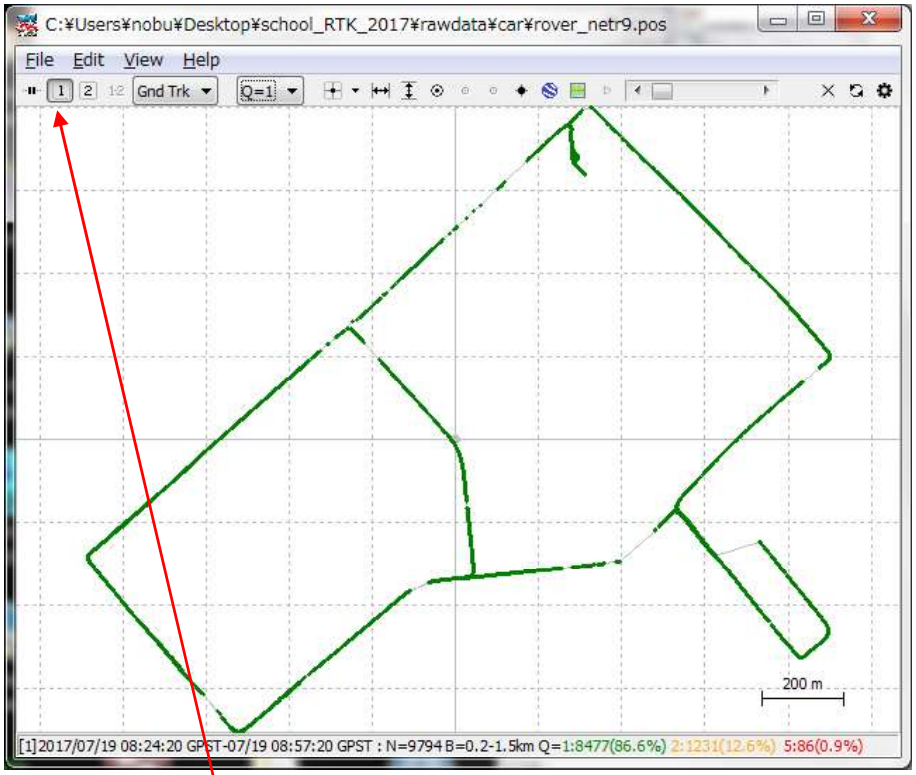
If you use NetR9 ,



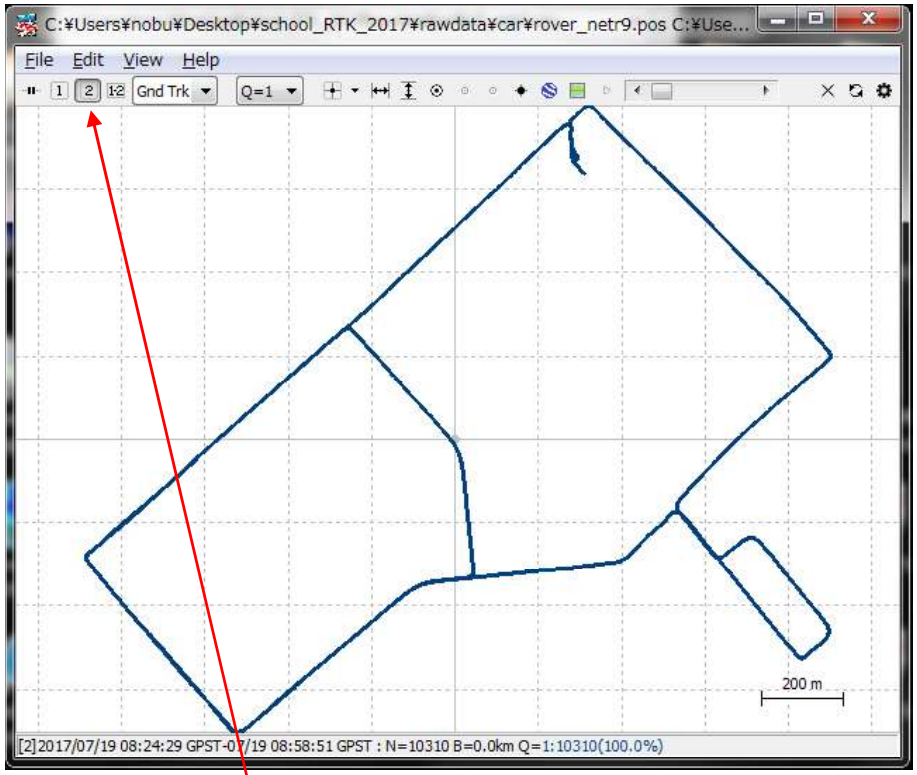
If you use dual-frequency ,



Comparing two POS files (RTKPLOT)



Previous test result

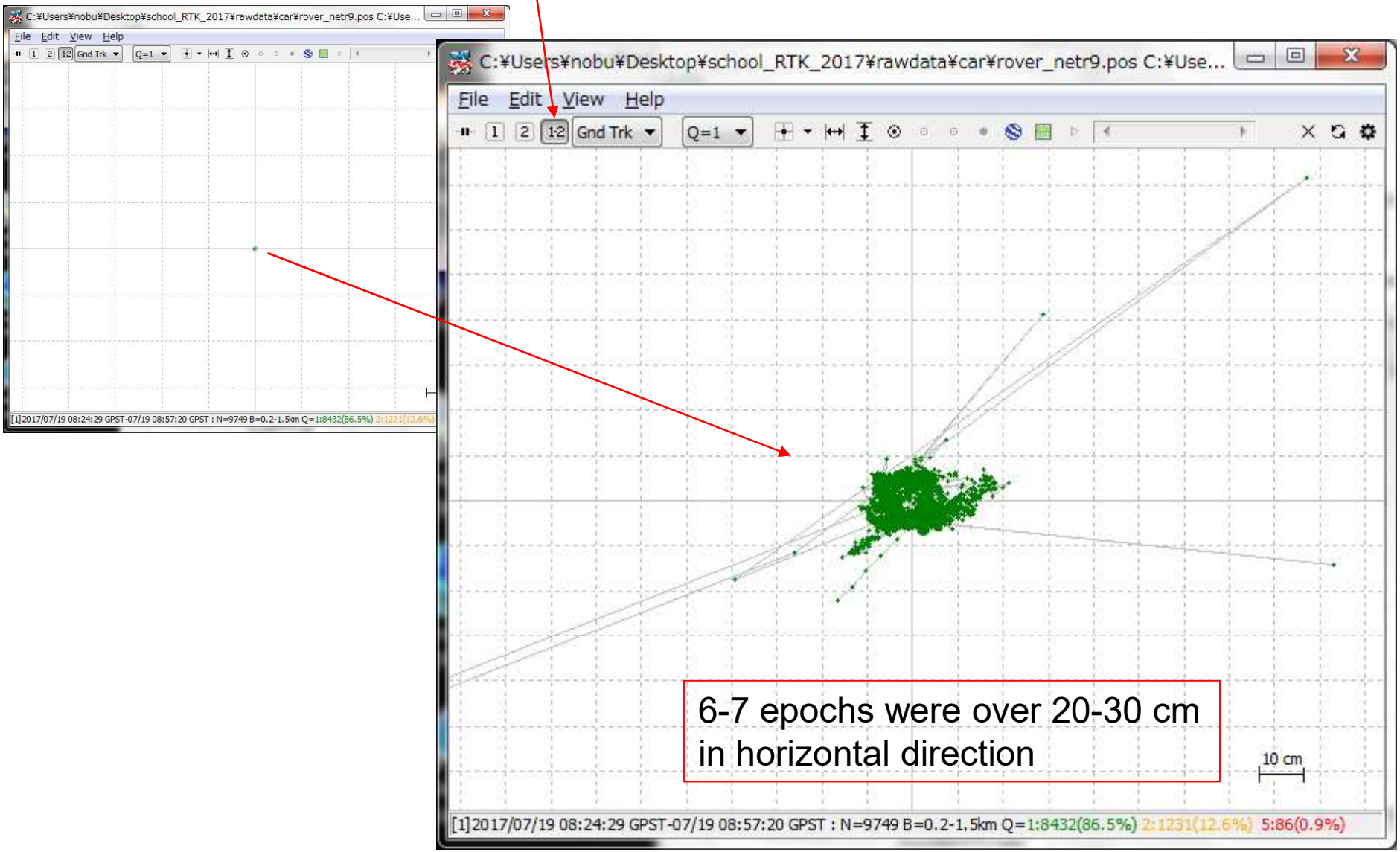


POSLVX result
(Post-processed RTK/IMU/Speed)

Just drug and drop of “poslvx.pos” into RTKPLOT

What happens if you click “1-2” ?

RTKPLOT 1-2


C:¥Users¥nobu¥Desktop¥school_RTK_2017¥rawdata¥car¥rover_netr9.pos C:¥Use...
File Edit View Help
1 2 1-2 Gnd Trk Q=1
6-7 epochs were over 20-30 cm
in horizontal direction
10 cm
[1]2017/07/19 08:24:29 GPST-07/19 08:57:20 GPST : N=9749 B=0.2-1.5km Q=1:8432(86.5%) 2:1231(12.6%) 5:86(0.9%)

Homework

- Please try to find the best setting of RTKLIB using the u-blox data (both ref and rover).
- "Best" means highest number of fixes within 30cm based on POSLVX file.

Simultaneous data is required

You need to prepare the raw-data at base station to include your period at rover.

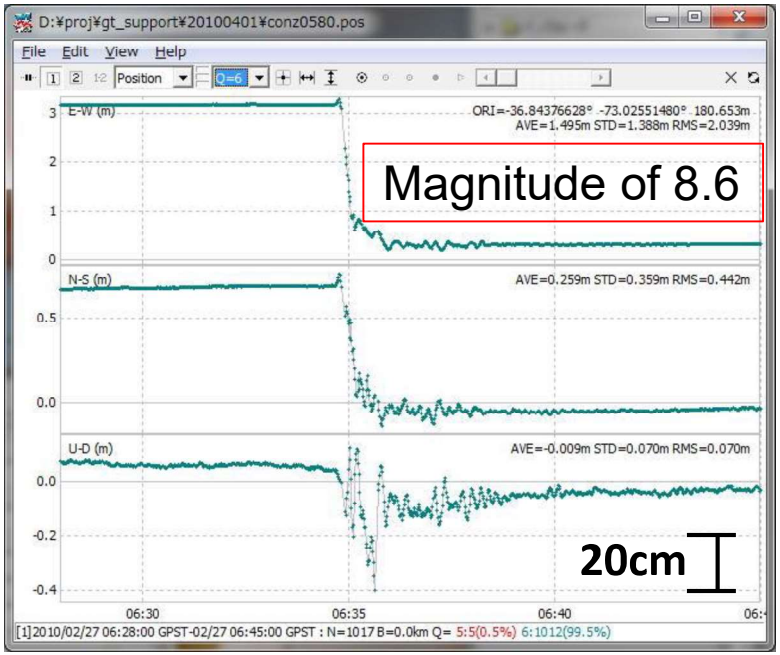
PPP (Precise Point Positioning)

- **Feature**
  - with Single Receiver (No Reference Station)
  - Efficient Analysis for Many Receivers
  - Precise Ephemeris
  - Conventionally Post-Processing
- **Applications**
  - GPS Seismometer
  - GPS Meteorology
  - POD (Precise Orbit Determination) of LEO Satellite
  - Precise Time Transfer

Static PPP vs Kinematic PPP

Kinematic PPP

Station: IGS CONZ (Chile)

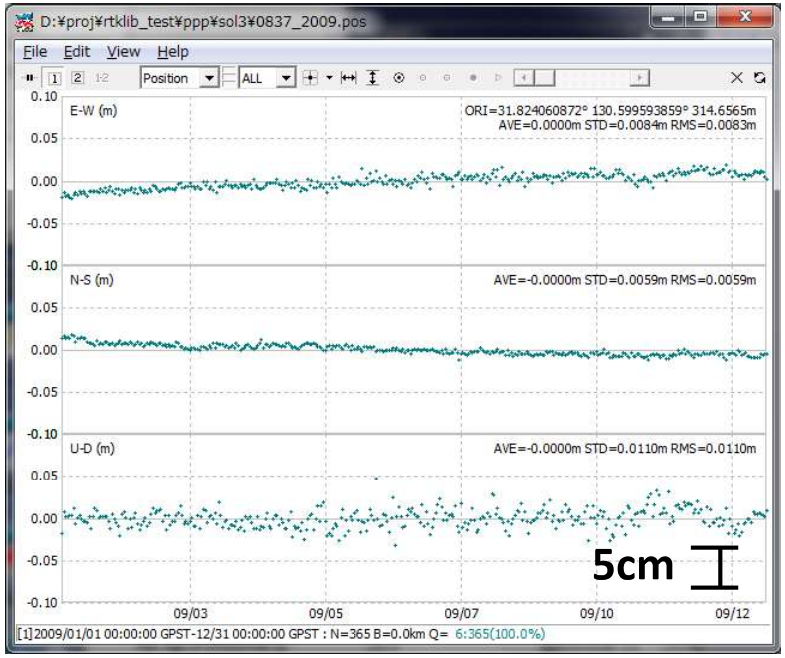


2010/2/27 6:28-6:45 GPST

Interval: 1 s

Static PPP

Station: GEONET 0837



2009/1/1-2009/12/31

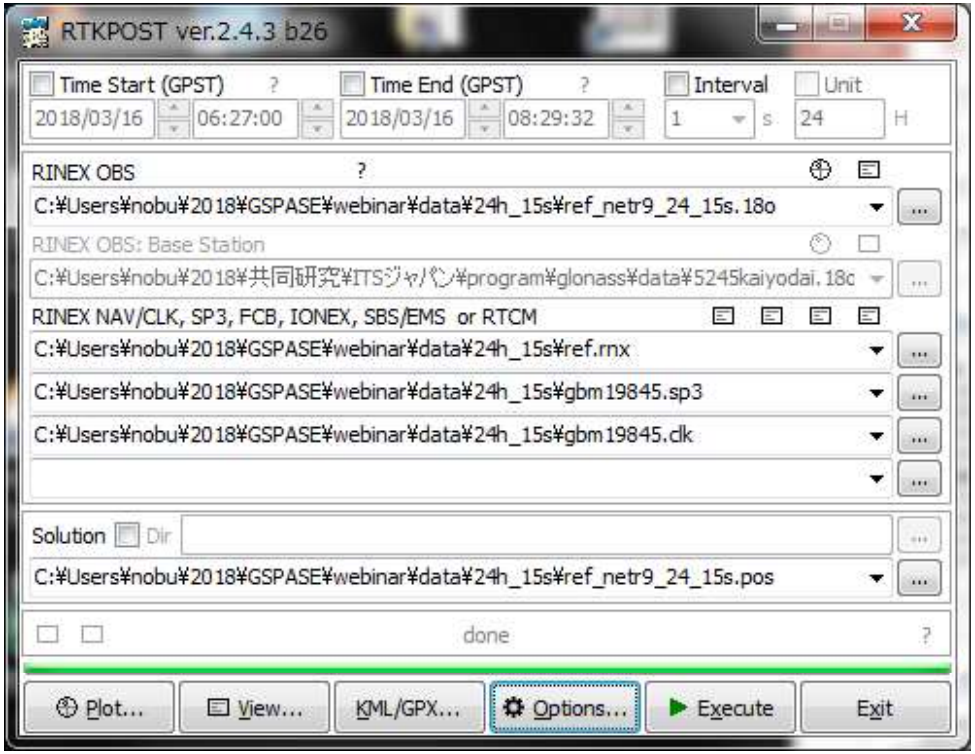
Interval: 1day

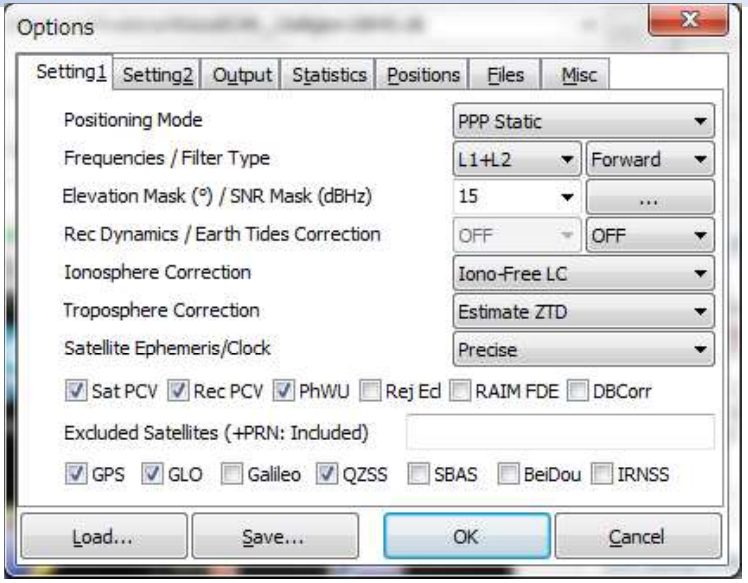
PPP using RTKLIB

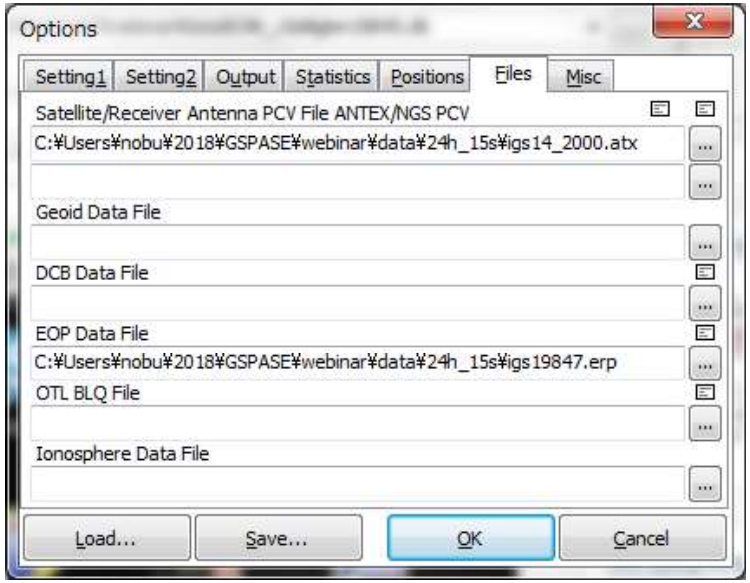
- I will use 24h raw-data/15s interval of NetR9 same as precious test.
- If you need centimeter level, you should use dual-frequency receiver.
- You can download other files required in PPP as follows.

items	website
Precise ephemeris	ftp://cddis.nasa.gov/gps/products/mgex/1984/
Precise clock	ftp://cddis.nasa.gov/gps/products/mgex/1984/
Satellite antenna information	ftp://igs.org/pub/station/general/
erp file	ftp://cddis.nasa.gov/gps/products/mgex/1984/

PPP static setting

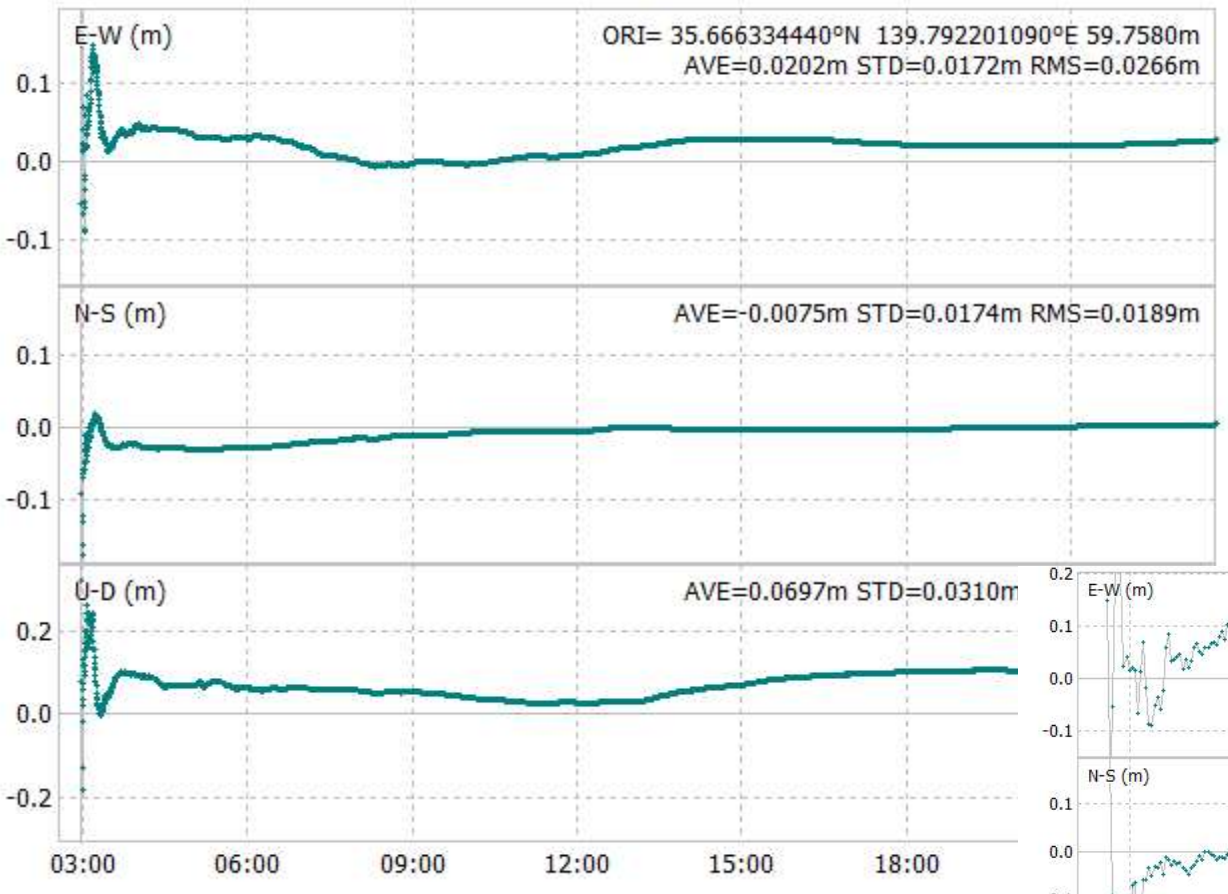




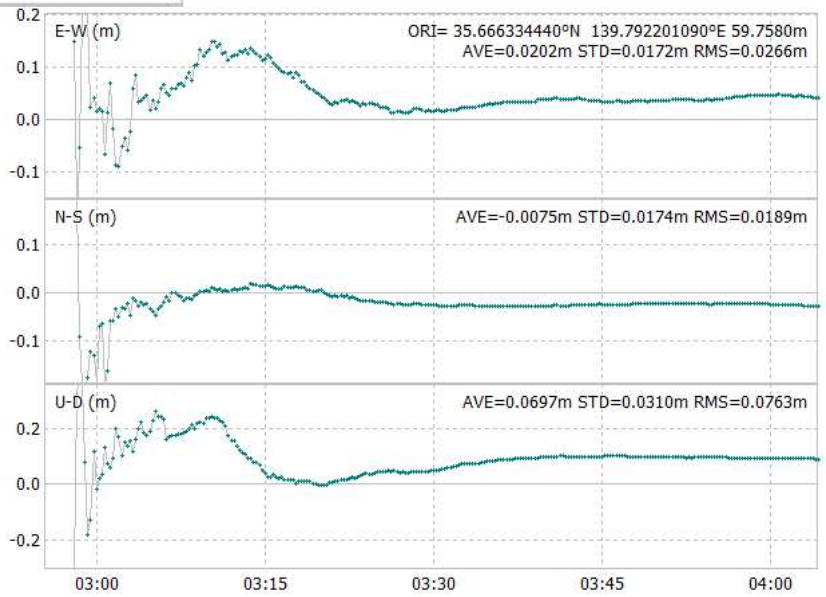


PPP static results

(0,0,0) are the RTK fixed solutions based on F3/GEONET in GSI.

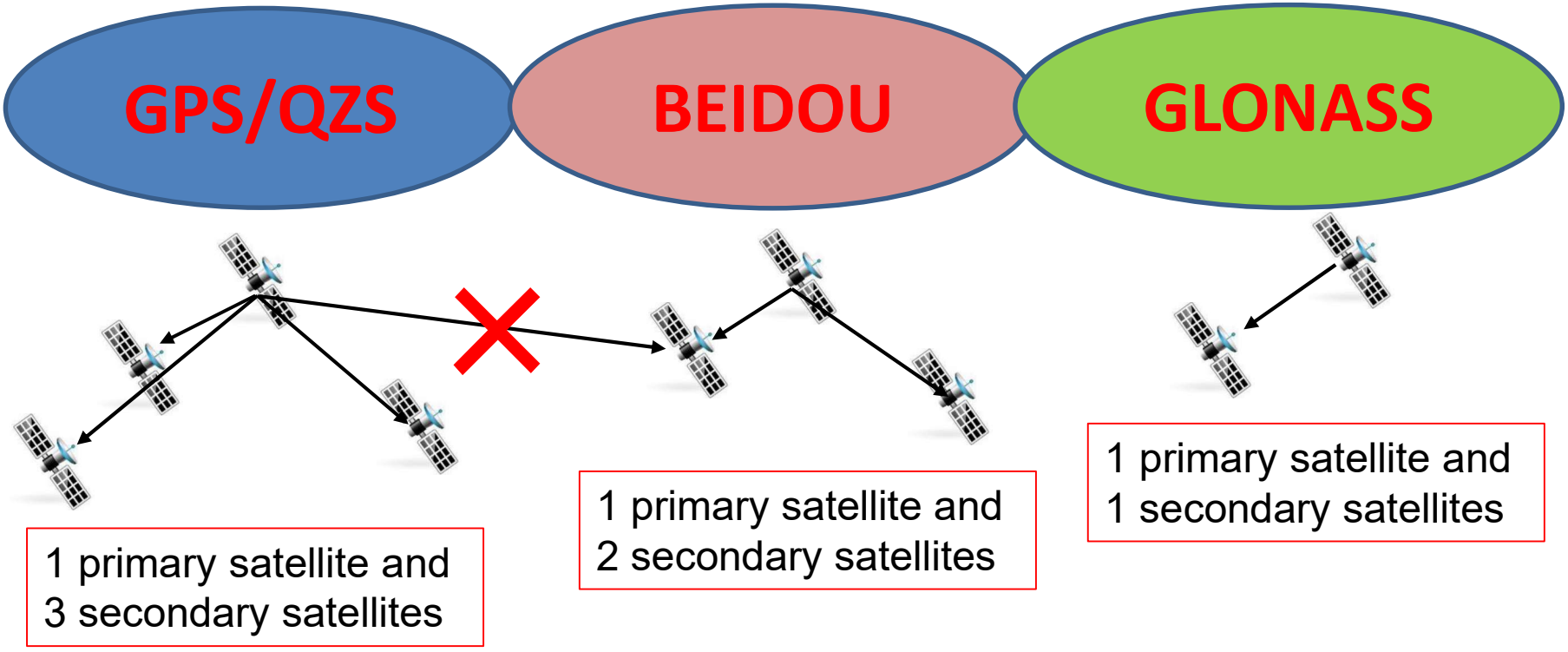


First 1 hour results



Past important questions

Multi-GNSS RTK



In total, 3+2+1=6 ambiguities have to be resolved.
But, we actually need 9 satellites !
It also can be applied in RTKLIB

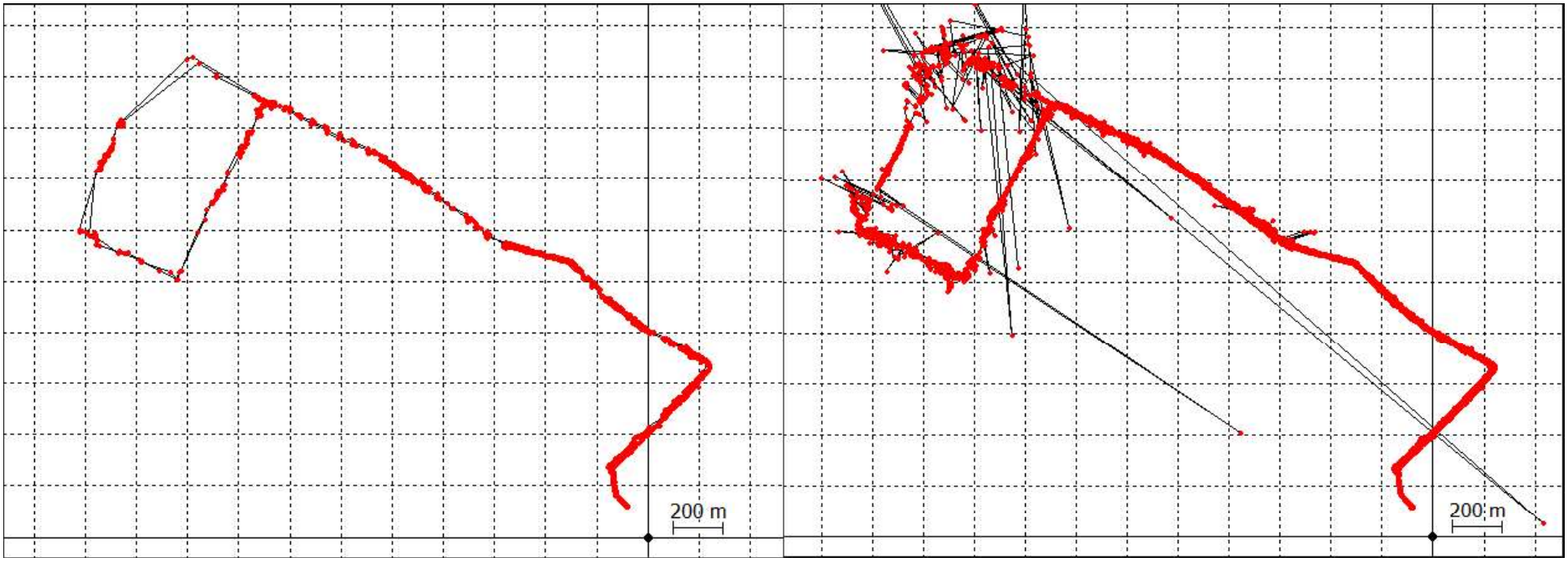
Required satellite number for reliable RTK

- We have to discuss the number of ambiguities because LAMBDA method strongly depends on the number of ambiguities. With more satellites, the reliability of AR increases.

Receiver	environment	Required
Dual-frequency	Open sky	5
	Urban	10
Single-frequency	Open sky	10
	Urban	20

There is a contradiction because the number of usable satellites in urban areas is sure to decrease compared with open sky areas…

Why is the availability of dense-urban areas so bad ?

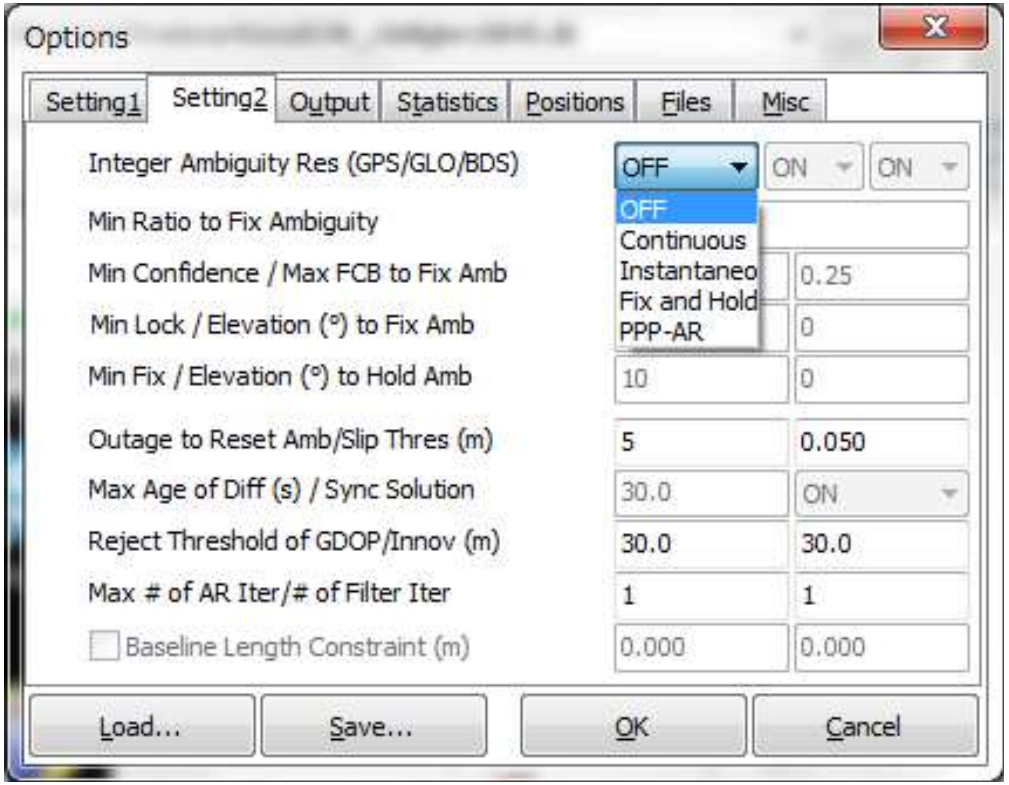


4196 epochs → 11493 epochs

Single positioning in the center of Tokyo
GPS+QZS+BEIDOU in 2016

What is the difference between two results ?
Same raw data (ublox M8T) is used !!!

What is the best mode in RTK ?
Or what do these modes mean ?



Please remember that RTKLIB is not designed for the purpose of navigation under **dense-urban areas** although it can be used even in the raw-data obtained in urban areas.

Answer is actually difficult…

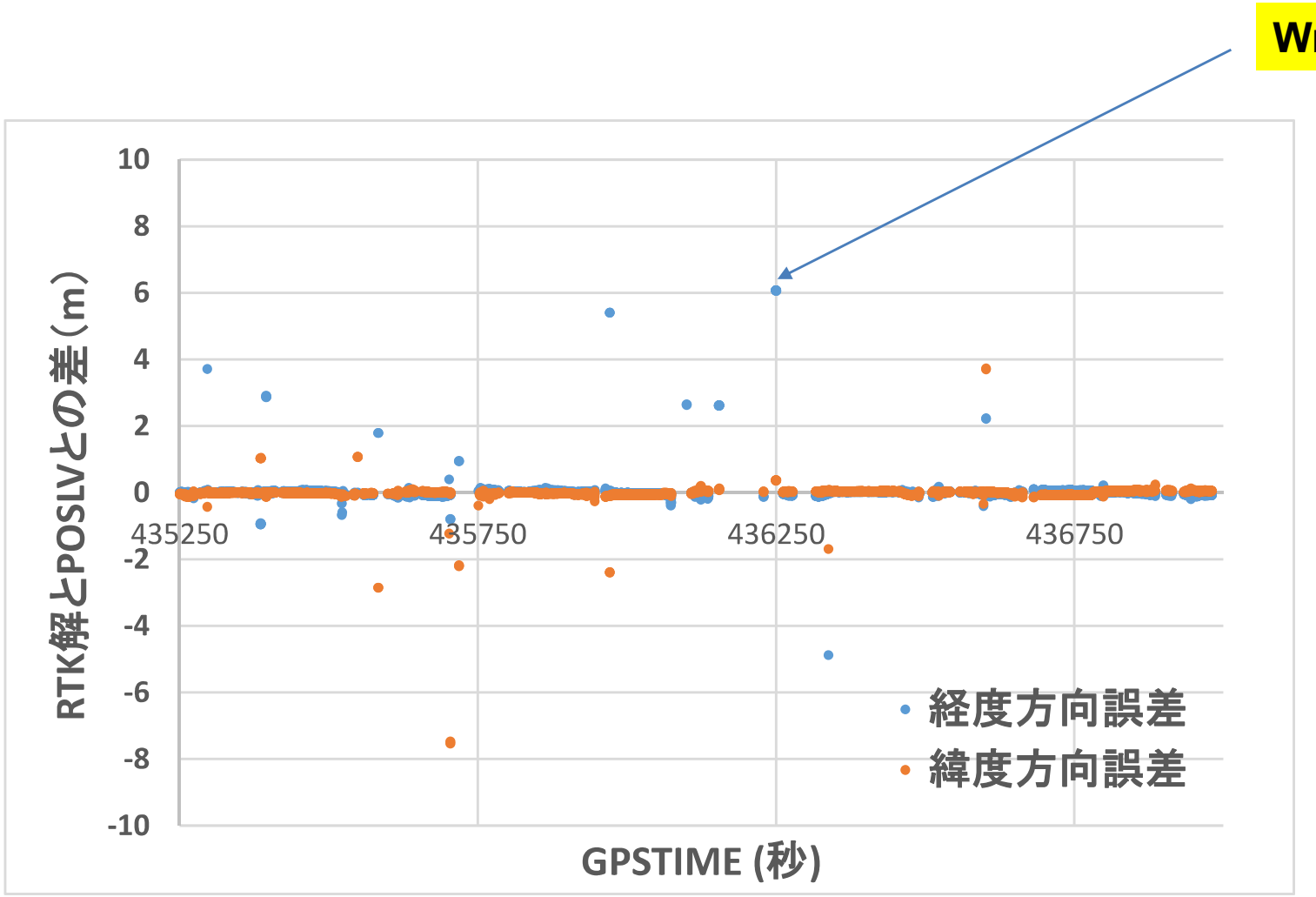
- Mr. Takasu developed those modes based on his own ideas. It means that there is no reference paper.
- I can say that “LAMBDA + Ratio test” are always used in RTK (kinematic).
- Each mode has each characteristics.

Kinematic modes	explanation
Instantaneous	Only single epoch observation data is used to resolve ambiguities
Continuous	Kalman Filter is used.
FIX and HOLD	Once the reliable correct ambiguities are resolved, those ambiguities information are retained.

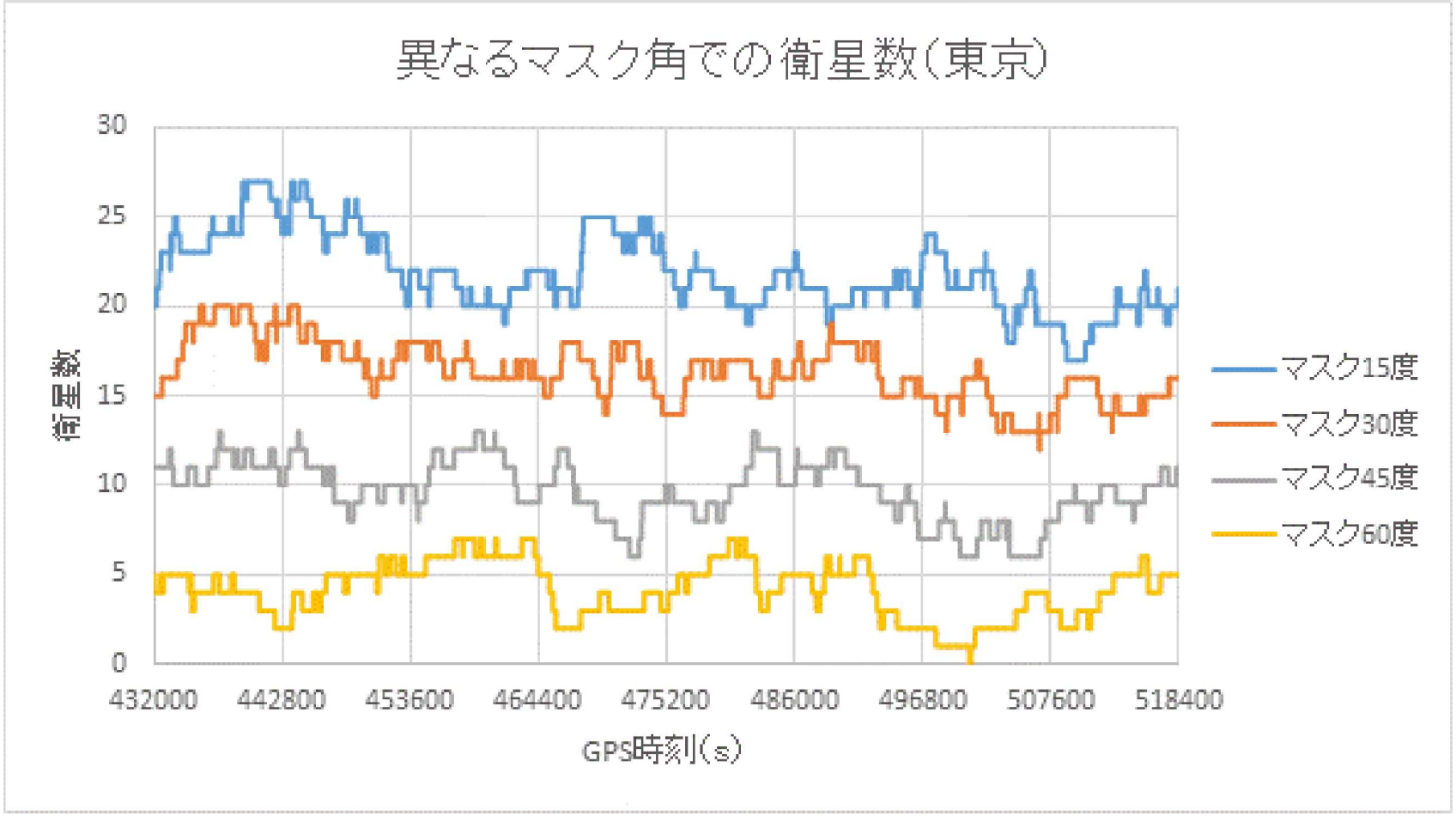
Suitable test environment

Kinematic modes	Suitable test environment
Instantaneous	The accuracy of float solutions is like DGNSS. In the case of open sky condition, instantaneous mode should be OK. You can see the real performance of your receiver because if the accuracy of code-phase is not so good, you can't obtain the better RTK results.
Continuous	The accuracy of float solutions will be better as time passes without cycle slips. If you have many overpasses (which means cycle-slips), the RTK performance is similar to the instantaneous mode. Open sky and semi-urban: continuous > instantaneous Urban : continuous = instantaneous (maybe)
FIX and HOLD	The accuracy of float solutions will be same as continuous mode. The only difference is reliable correct ambiguities are retained. If these ambiguities are not correct, you will see wrong fixed solutions for a several time (be careful). Open sky and semi-urban: hold > continuous > instantaneous Urban : hold = continuous = instantaneous (maybe)

You need a reference system to evaluate RTK test results



RTK performance differs with the time



Any questions ?

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Actual Steps of RTK

- After this summer school, please check the followings regarding the process of RTK to deepen your understanding !

1. Generating “double difference”
2. Finding “integer ambiguities”
3. Baseline processing

1. DD (Double Difference)

$$\Phi_{ub}^{ij} \equiv \lambda((\phi_u^i - \phi_b^i) - (\phi_u^j - \phi_b^j))$$
$$= \rho_{ub}^{ij} + c(dt_{ub}^{ij} - dT_{ub}^{ij}) - I_{ub}^{ij} + T_{ub}^{ij} + \lambda N_{ub}^{ij} + d_{ub}^{ij} + \varepsilon_\Phi$$
$$= \rho_{ub}^{ij} - I_{ub}^{ij} + T_{ub}^{ij} + \lambda N_{ub}^{ij} + d_{ub}^{ij} + \varepsilon_\Phi$$

Without reference station,
it is impossible to remove “receiver And satellite clock error” completely !
Generate new observation
which means double difference.

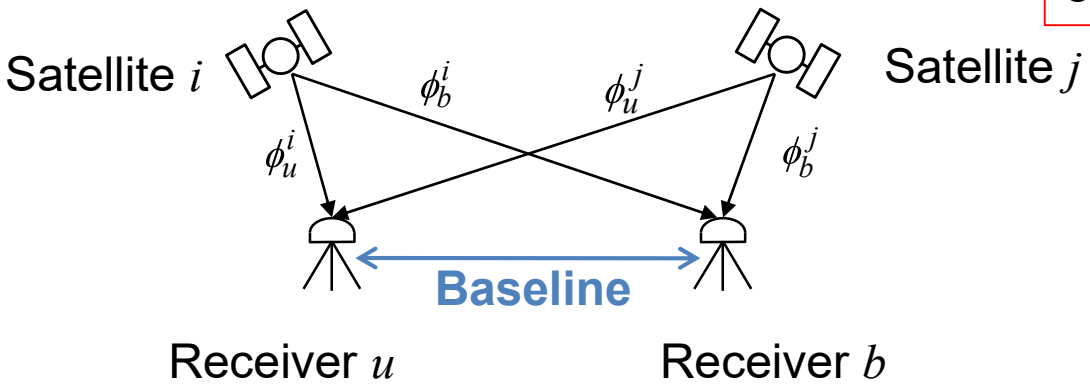
$$dt_{ub}^{ij} = dt_u^{ij} - dt_b^{ij} = 0, \quad dT_{ub}^{ij} = dT_{ub}^{i} - dT_{ub}^{j} \approx 0$$

$$B_{ub}^{ij} = (\phi_{u,0} - \phi_0^i + N_u^i) - (\phi_{b,0} - \phi_0^i + N_b^i) - (\phi_{u,0} - \phi_0^j + N_u^j) + (\phi_{b,0} - \phi_0^j + N_b^j) = N_{ub}^{ij}$$

(short Baseline and same antenna type)

$$I_{ub}^{ij} = I_{ub}^{i} - I_{ub}^{j} \approx 0, T_{ub}^{ij} = T_{ub}^{i} - T_{ub}^{j} \approx 0, d_{ub}^{ij} = d_{ub}^{i} - d_{ub}^{j} \approx 0$$

Why do we say the baseline limitation of RTK ?
(10-100 km or more)
It strongly depends on each RTK engine !



Memo for Misra & Enge:
http://gpspp.sakura.ne.jp/diary200608.htm

2. Integer Ambiguity Resolution

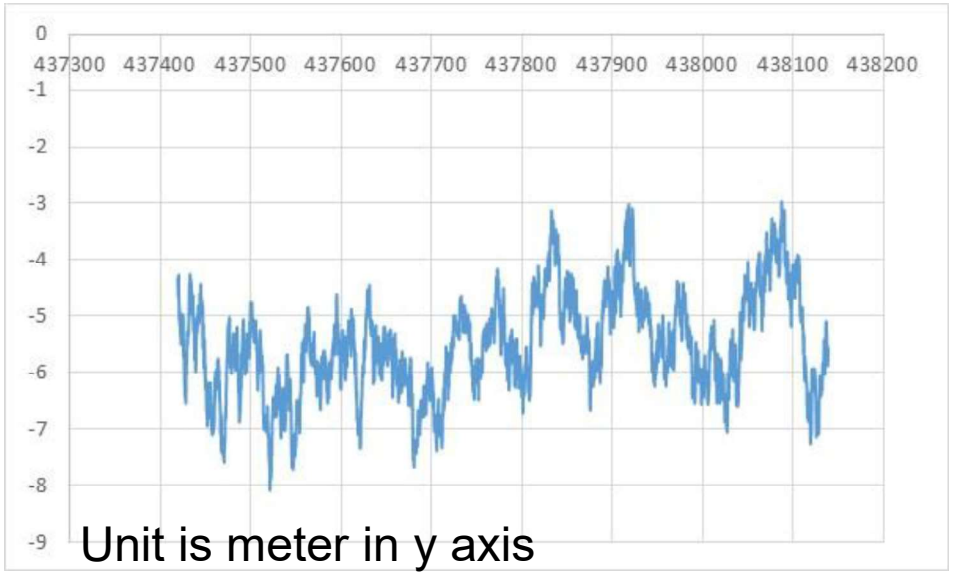
$$P_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + \varepsilon_{p,rov\_ref}^{sv1\_sv2}$$

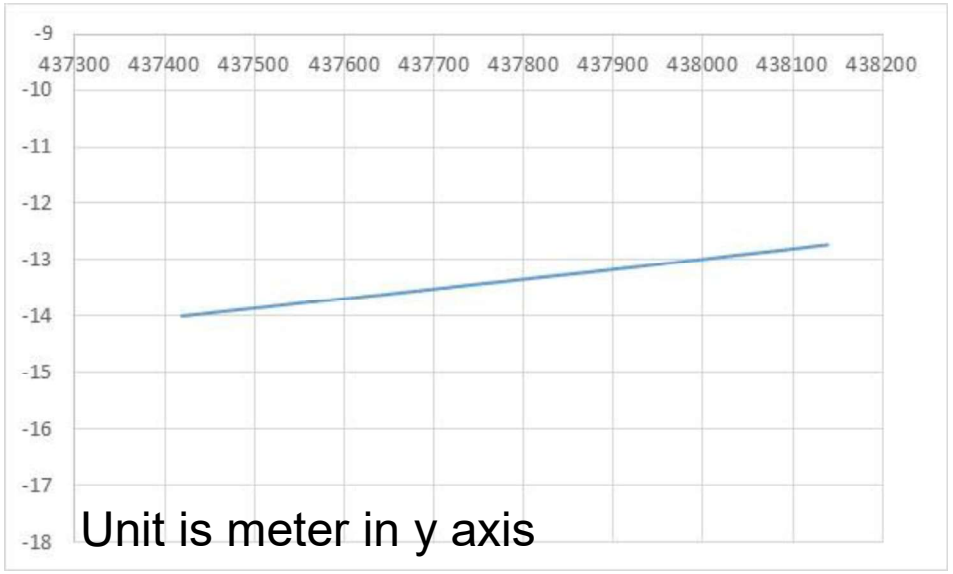
$$\phi_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + N_{rov\_ref}^{sv1\_sv2} + \varepsilon_{\phi,rov\_ref}^{sv1\_sv2}$$

- Once you can resolve **integer N** in carrier phase double difference, you get accurate position about 1 cm.
- It can be imagine that the pseudo-range (code) accuracy is quite important.
- Code-phase is noisy (1 m-) but absolute distance
- Carrier-phase is accurate but includes integer ambiguity

3. Test results on the rooftop

- double difference of 10 m baseline-

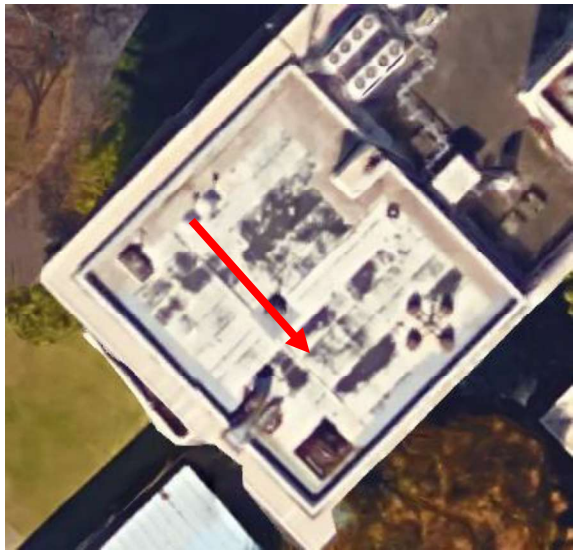




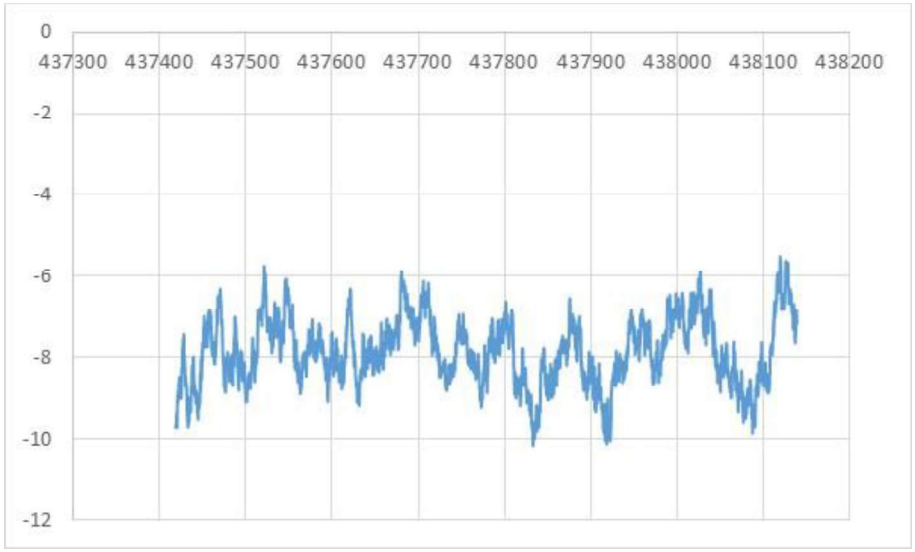
1. Reference satellite GPS PRN 16
   and target satellite is GPS PRN 8
2. Which is code-phase double difference ?
3. If you subtract from right to left, what happen ?

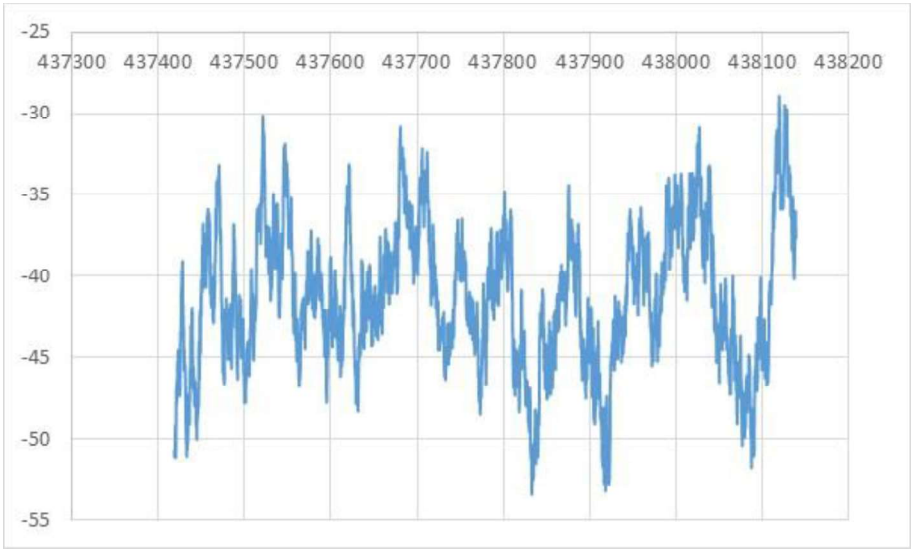
$$P_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + \varepsilon_{p,rov\_ref}^{sv1\_sv2}$$

$$\phi_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + N_{rov\_ref}^{sv1\_sv2} + \varepsilon_{\phi,rov\_ref}^{sv1\_sv2}$$



4. (Carrier DD) - (Code DD)





The unit is meter

Divided by wavelength
0.19029 m… (L1)

The unit is cycle

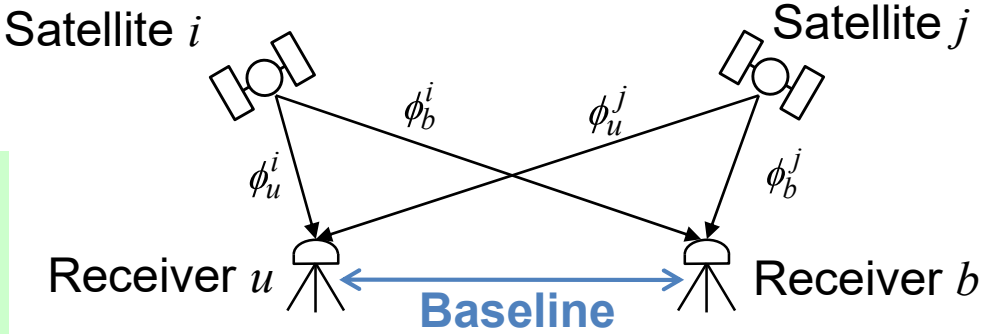
Probably, we guess the integer ambiguity between PRN16 and PRN8 is about - 40 ?
In fact, the average of this right results was - 41.3

5. What is the correct ambiguity ?

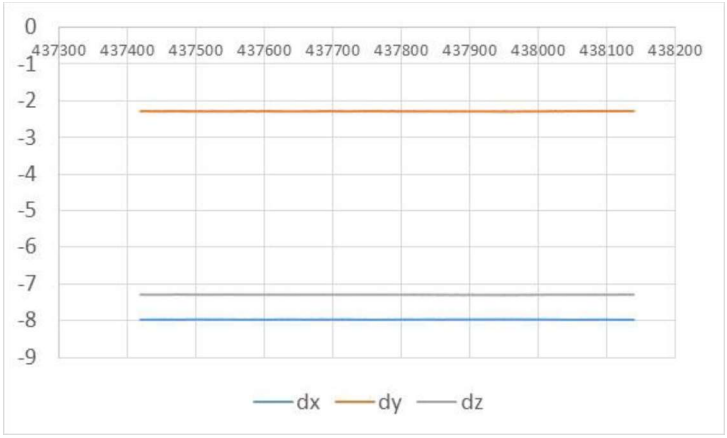
- "Integer least square method" tells us "– 42" in a single epoch !
- If you know the 3 or more ambiguities, you can estimate the user position with the level of carrier phase because only 3 unknowns remains.
- Then, (dx, dy, dz) can be estimated and finally,
- (X_user, Y_user, Z_user) = (X, Y, Z) + (dx, dy, dz)

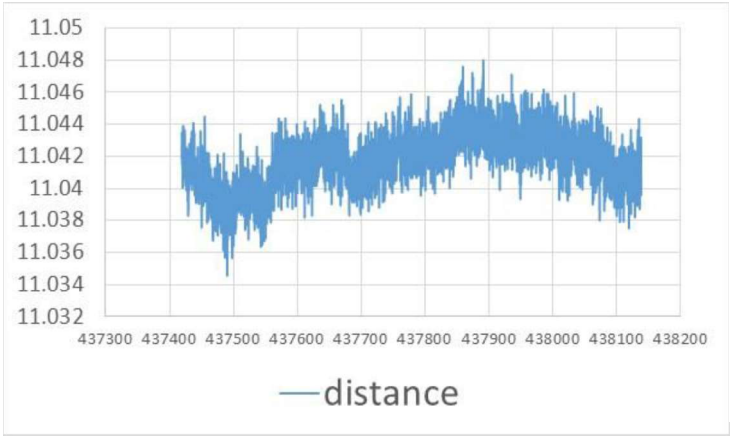
$$P_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + \varepsilon_{p,rov\_ref}^{sv1\_sv2}$$

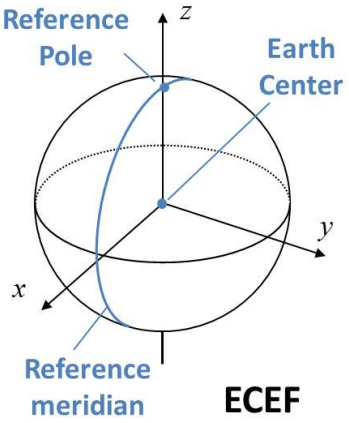
$$\phi_{rov\_ref}^{sv1\_sv2} = r_{rov\_ref}^{sv1\_sv2} + N_{rov\_ref}^{sv1\_sv2} + \varepsilon_{\phi,rov\_ref}^{sv1\_sv2}$$

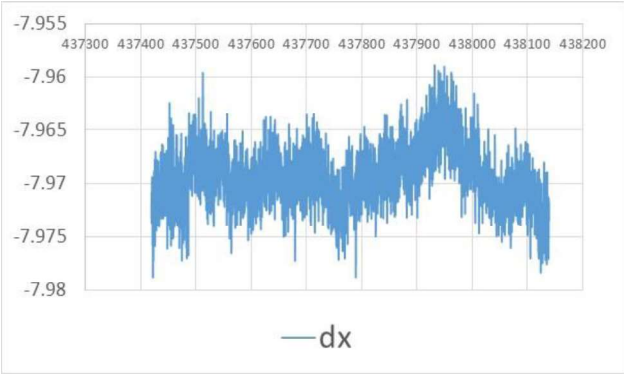


6. Test results (dx, dy, dz)

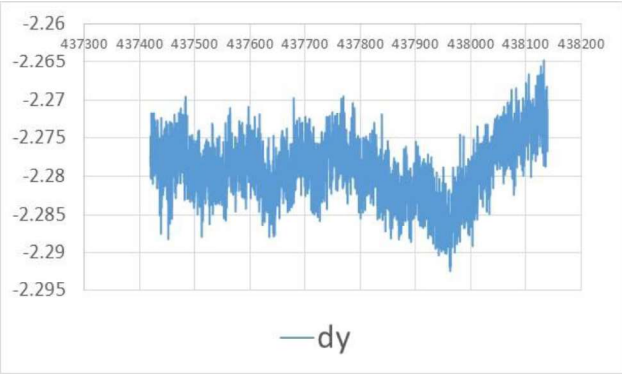




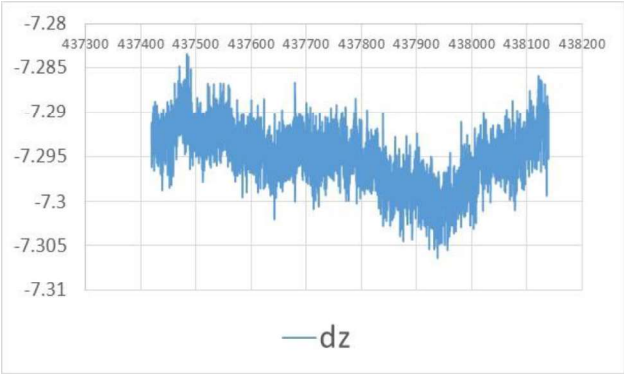




Std. = 2.8 mm

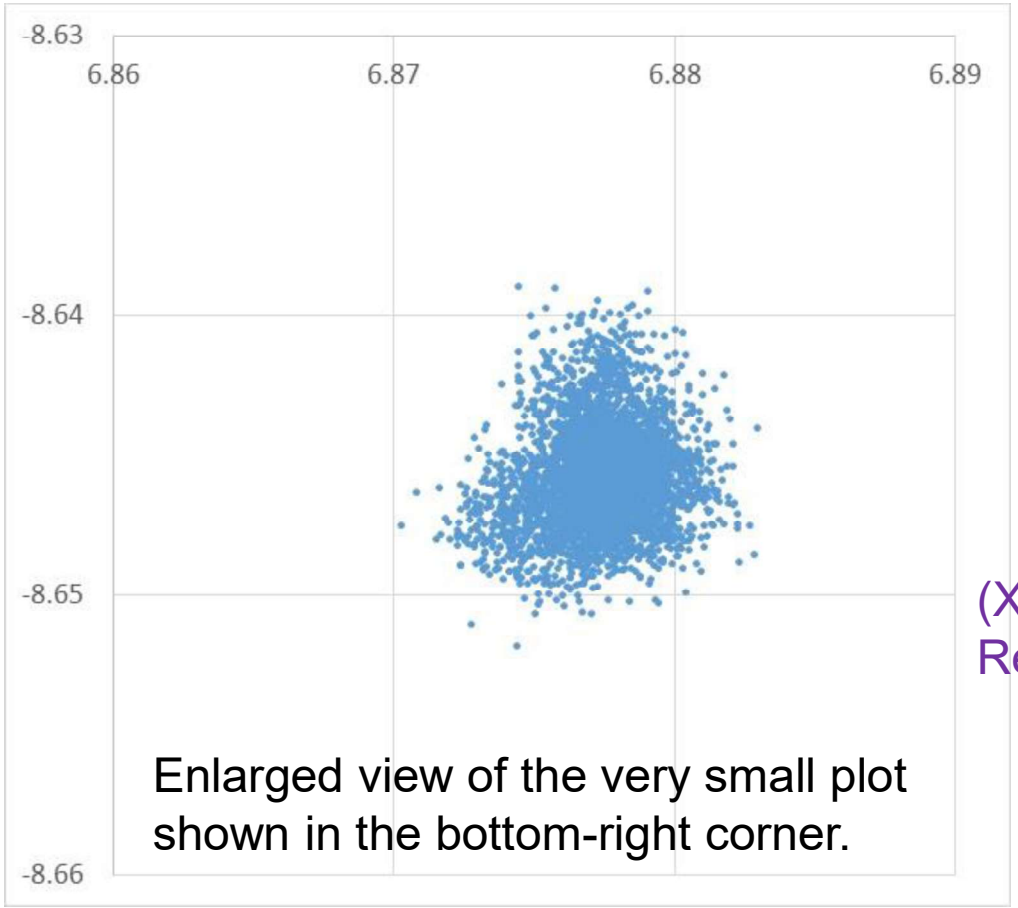


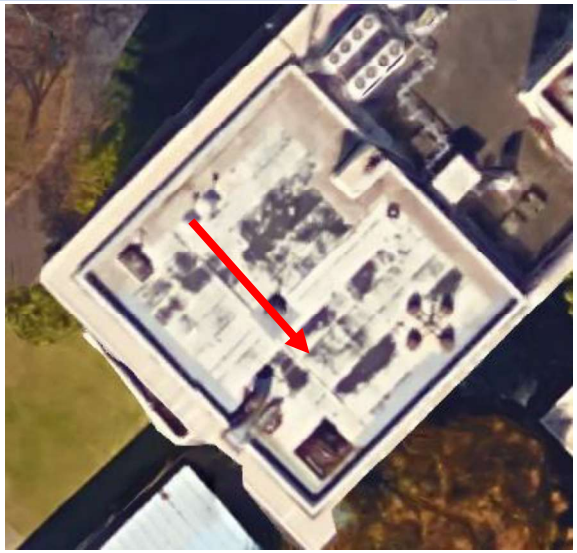
Std. = 4.0 mm



Std. = 3.4 mm

7. Convert to horizontal positions





(X, Y, Z)
Reference sta.

(X_user, Y_user, Z_user)

I am repeating myself, RTK tells you only dx, dy, dz.
You have to decide the precise reference positions !