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# **Introduction to RTK Data Processing** **How to get centimeter level accuracy?** **Part - 1**

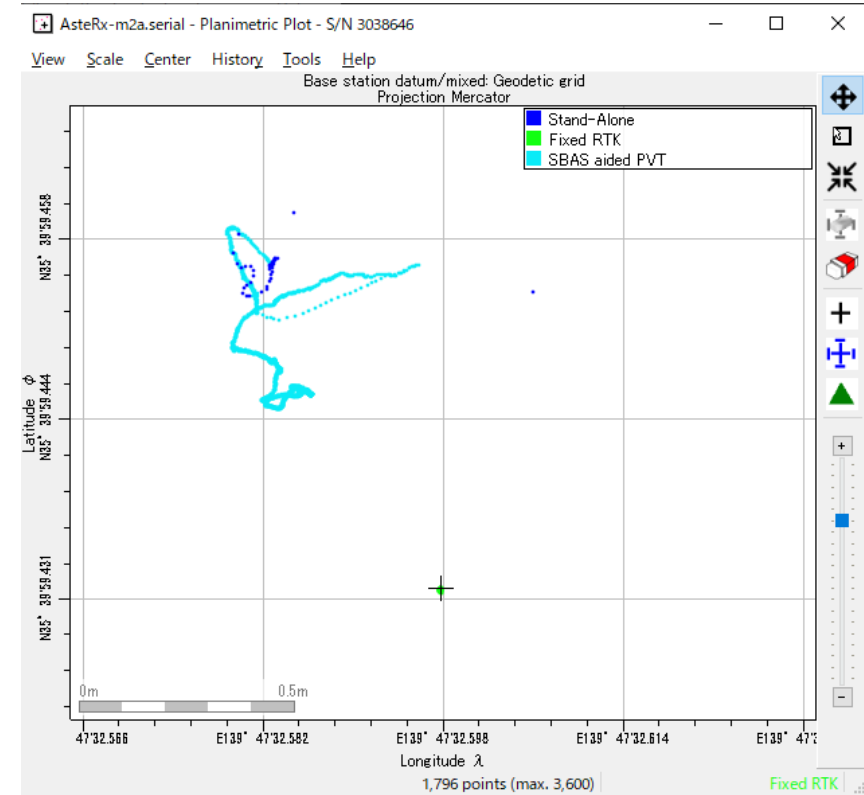
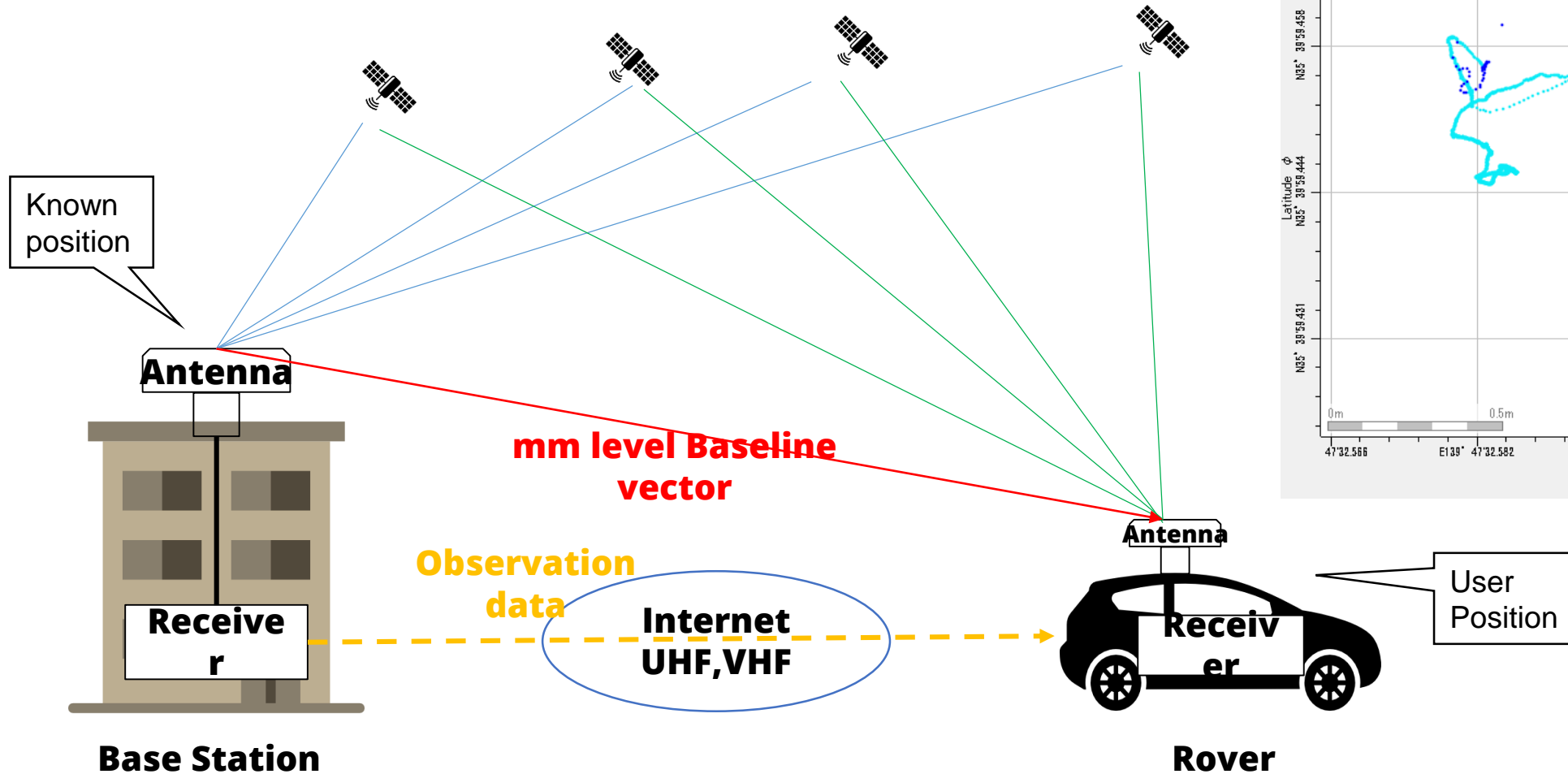
GNSS Data Processing for High-Accuracy Positioning using  
Low-Cost Receiver Systems  
19 – 21 JAN 2021

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Tokyo University of Marine Science and Technology

1. What is RTK
2. RTK applications
3. How to build RTK environment
  1. Base-Station
    1. Receiver and Antenna types
    2. How to setup base-station
  2. Rover Unit
    1. Receiver and Antenna Types
    2. How to setup rover
4. Data Format Conversion for RTK
  1. SBF, UBX, JPX etc. to RINEX
  2. Which version of RINEX shall be used?

# 1. What is RTK

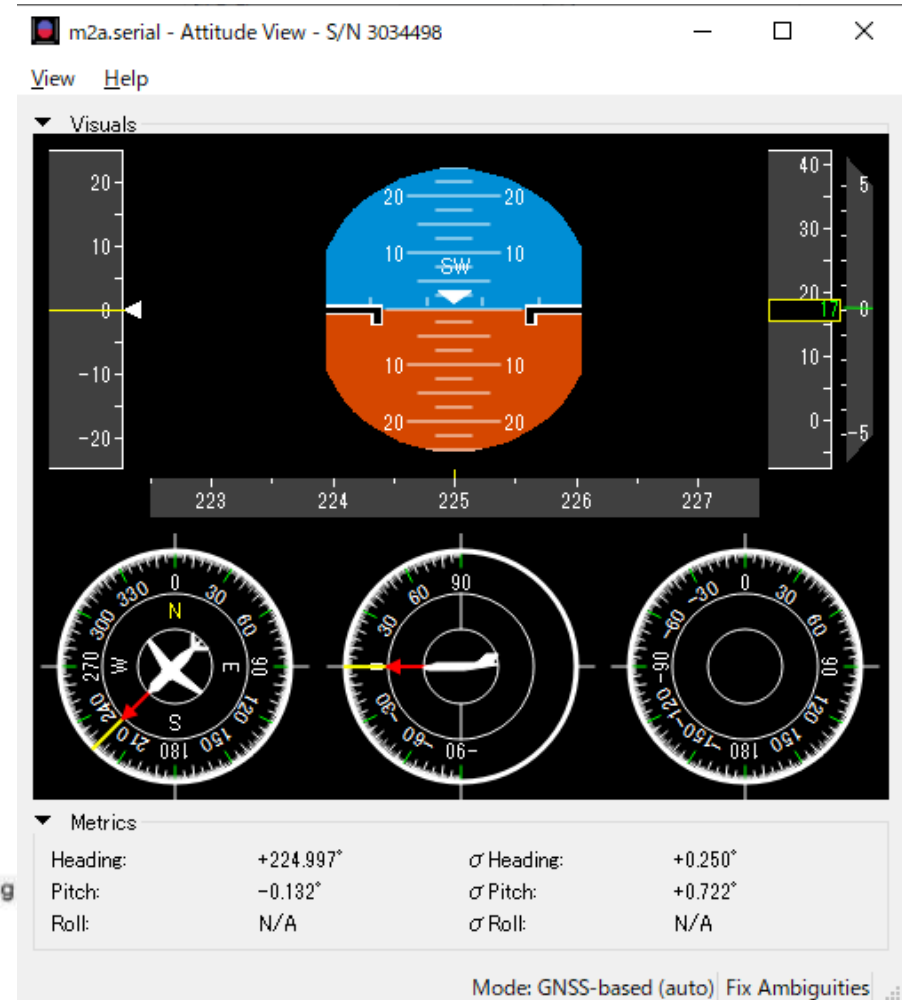
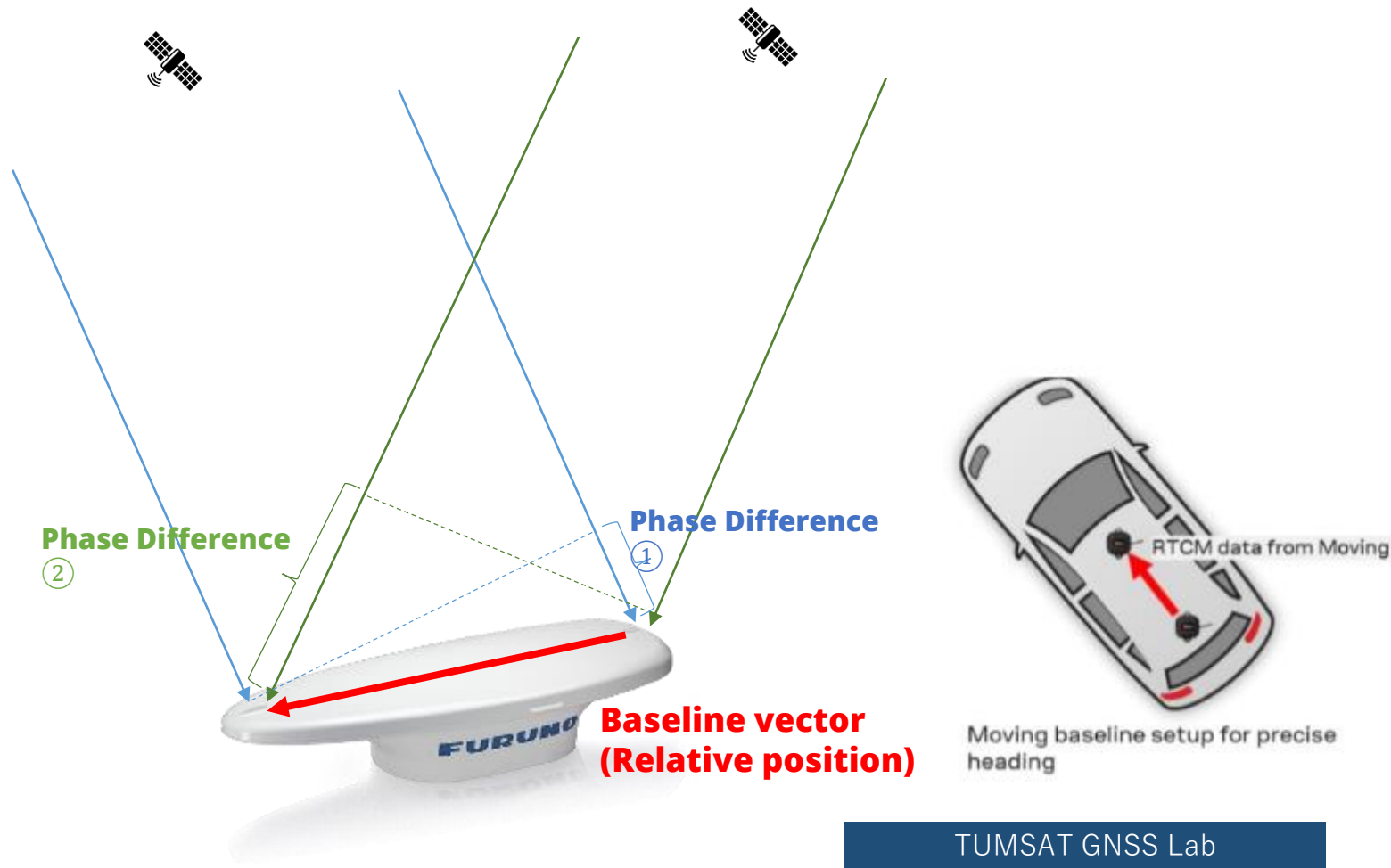
RTK is high accuracy positioning method using "Base Station".



# 1. What is RTK

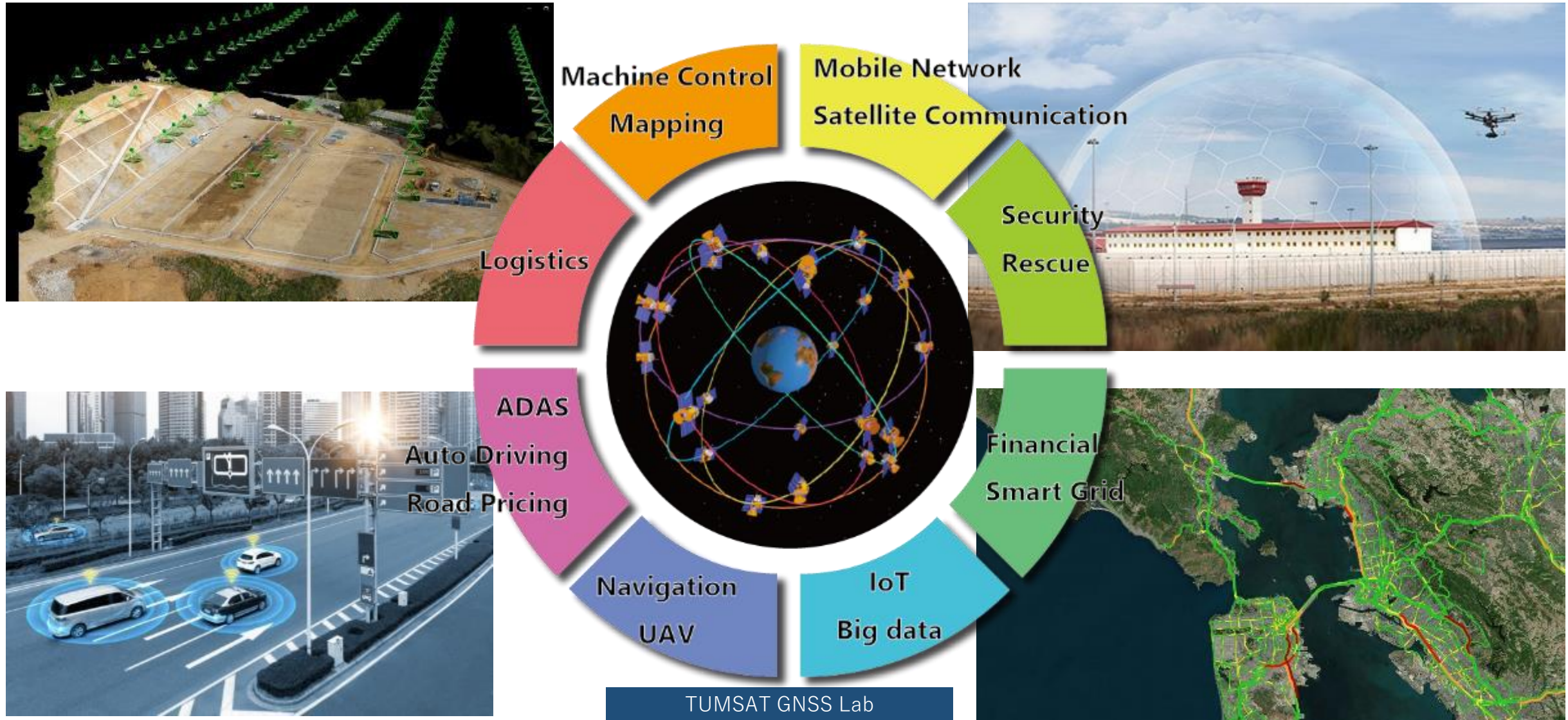
If "Base station" is not fixed → Moving-base RTK

You can get precise relative position, angle between 2 antenna.



## 2. RTK applications

RTK can expand GNSS use field over traditional PNT (Positioning, Navigation, Timing).



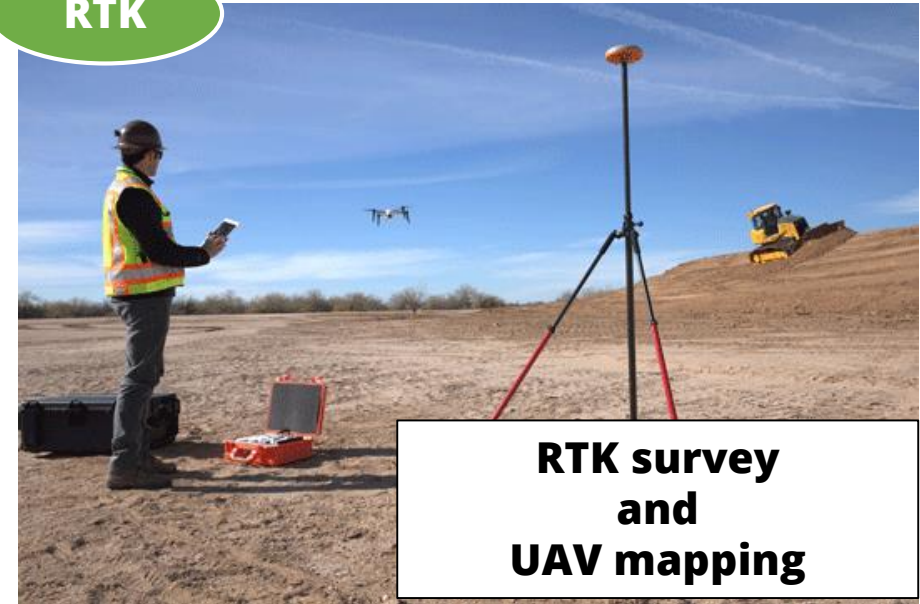
# 2. RTK applications

## ◆ Construction

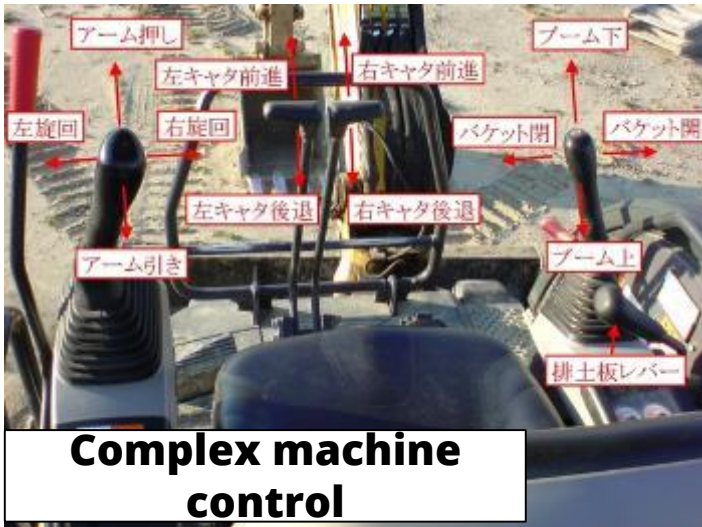


**Traditional optical survey**

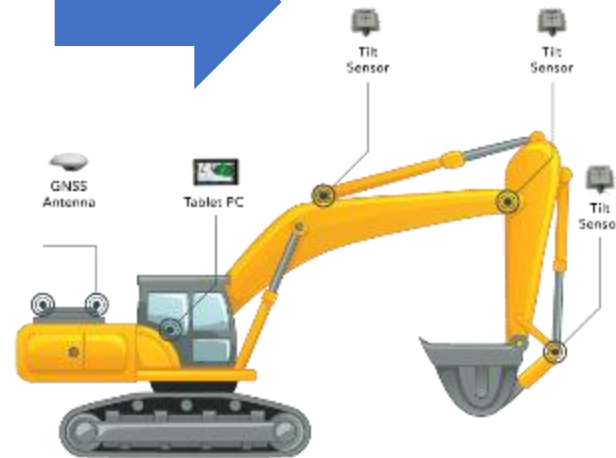
## RTK



**RTK survey and UAV mapping**



**Complex machine control**



TUMSAT GNSS Lab

## RTK Moving-base RTK

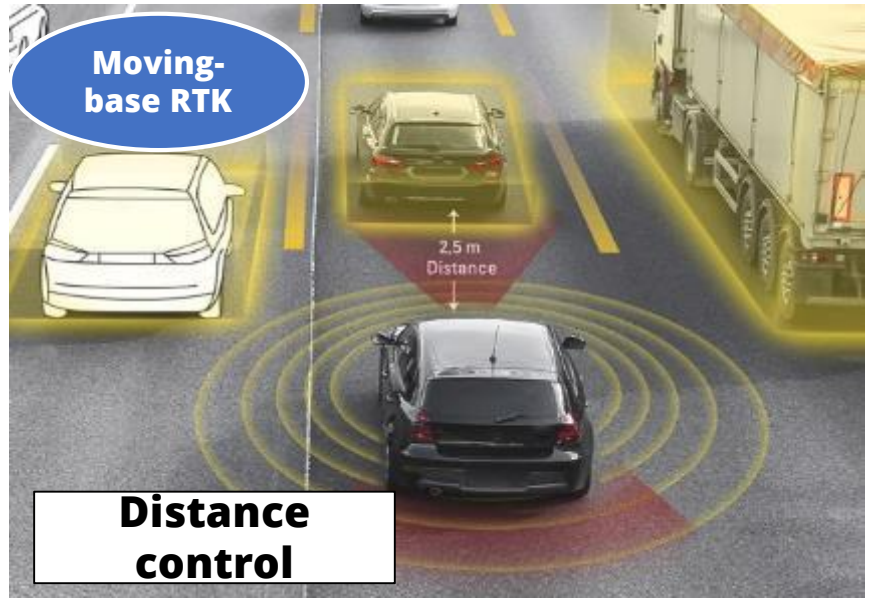
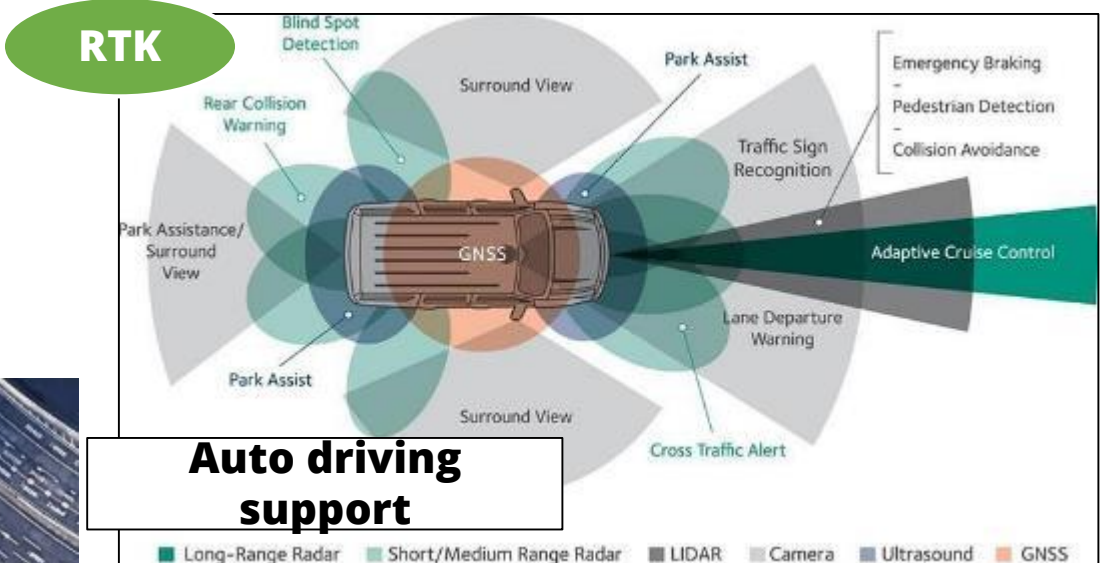


**Machine control using 3D data and Attitude monitoring**

The 3D design data of the job site is being loaded on to the machine control system.

# 2. RTK applications

## ◆ ITS (Intelligent Transportation System)



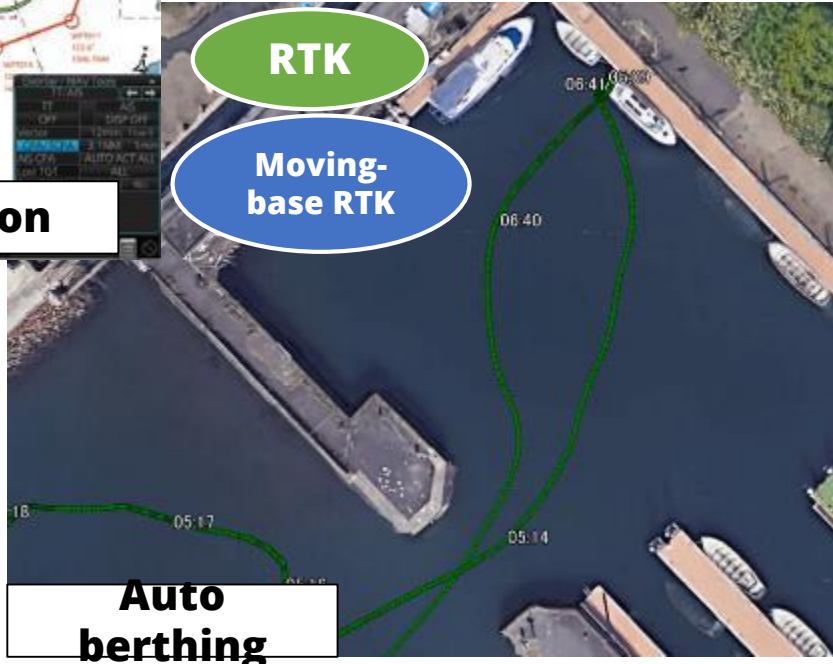
# 2. RTK applications



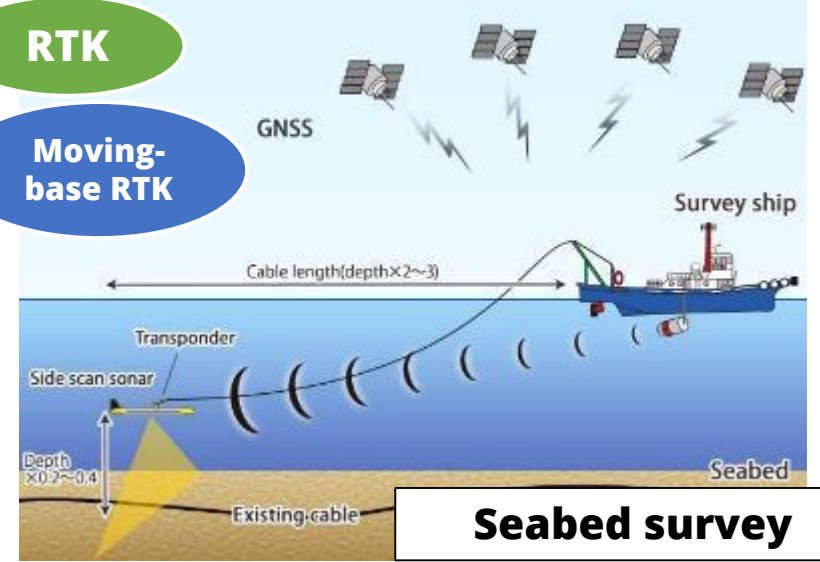
## ◆ Maritime



**Ship navigation**



**Auto berthing**



**Seabed survey**



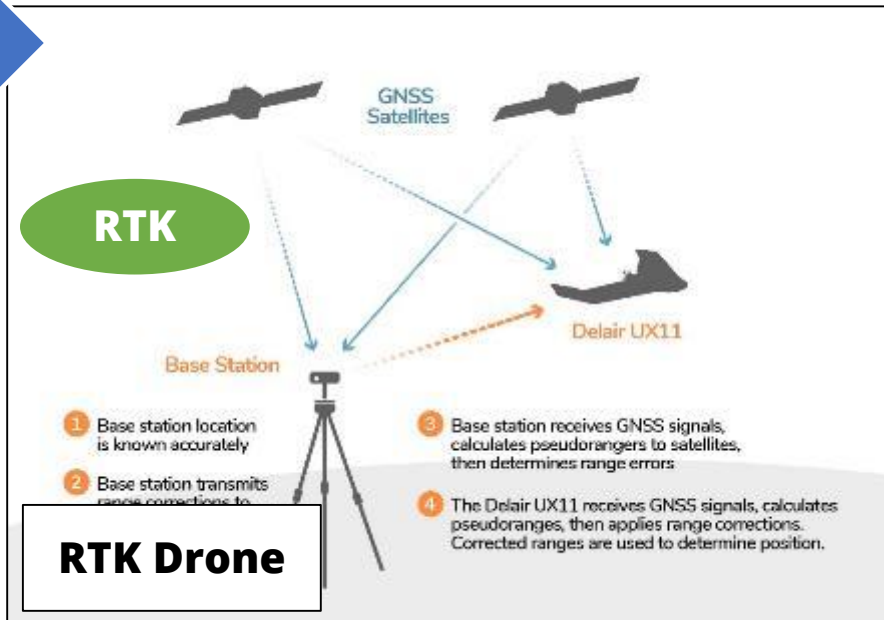
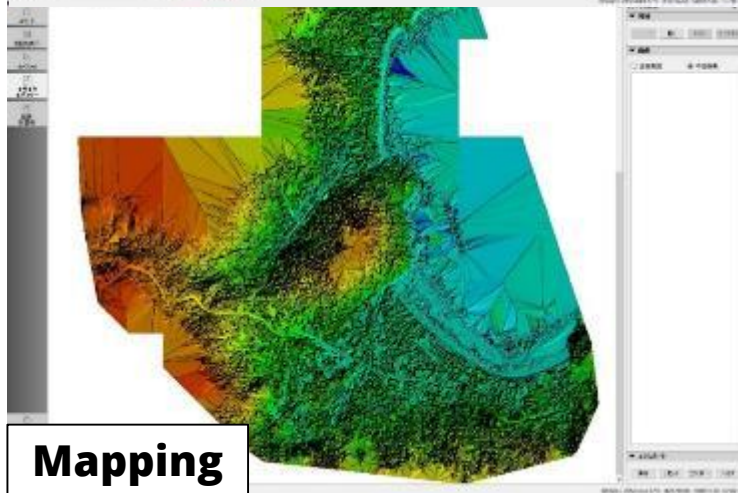
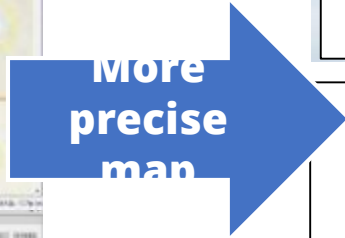
**Drilling, Maritime construction**



# 2. RTK applications



## ◆ UAV



# 2. RTK applications

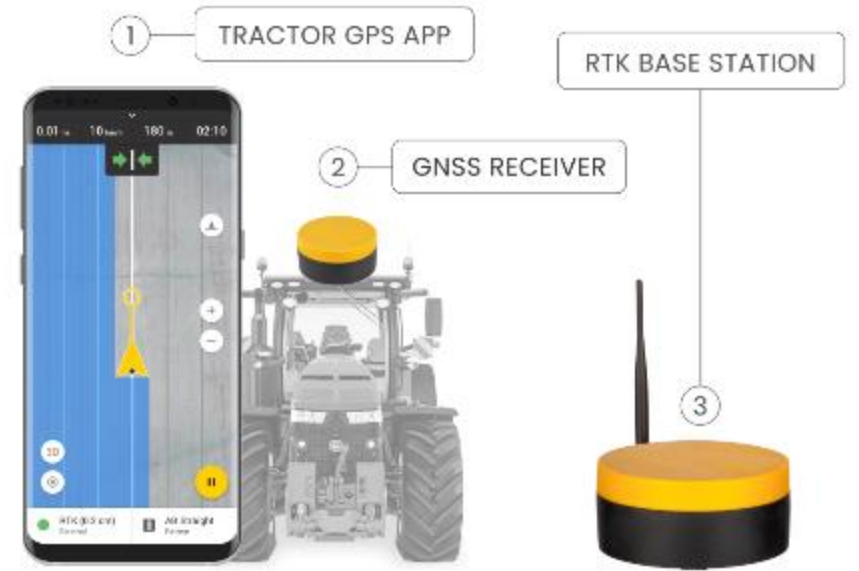
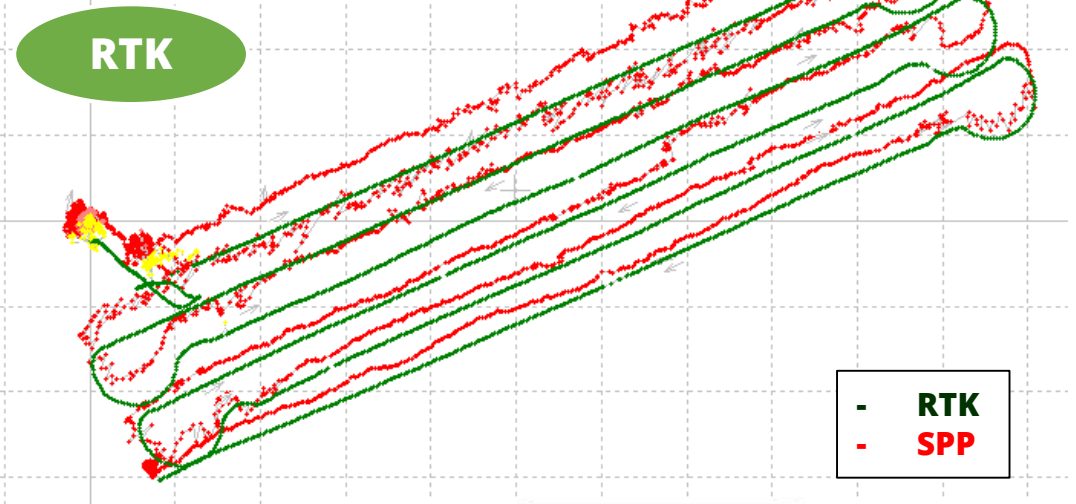


## ◆ Agriculture



Shift to young generation  
Effective working

### Agriculture Machinery Guidance

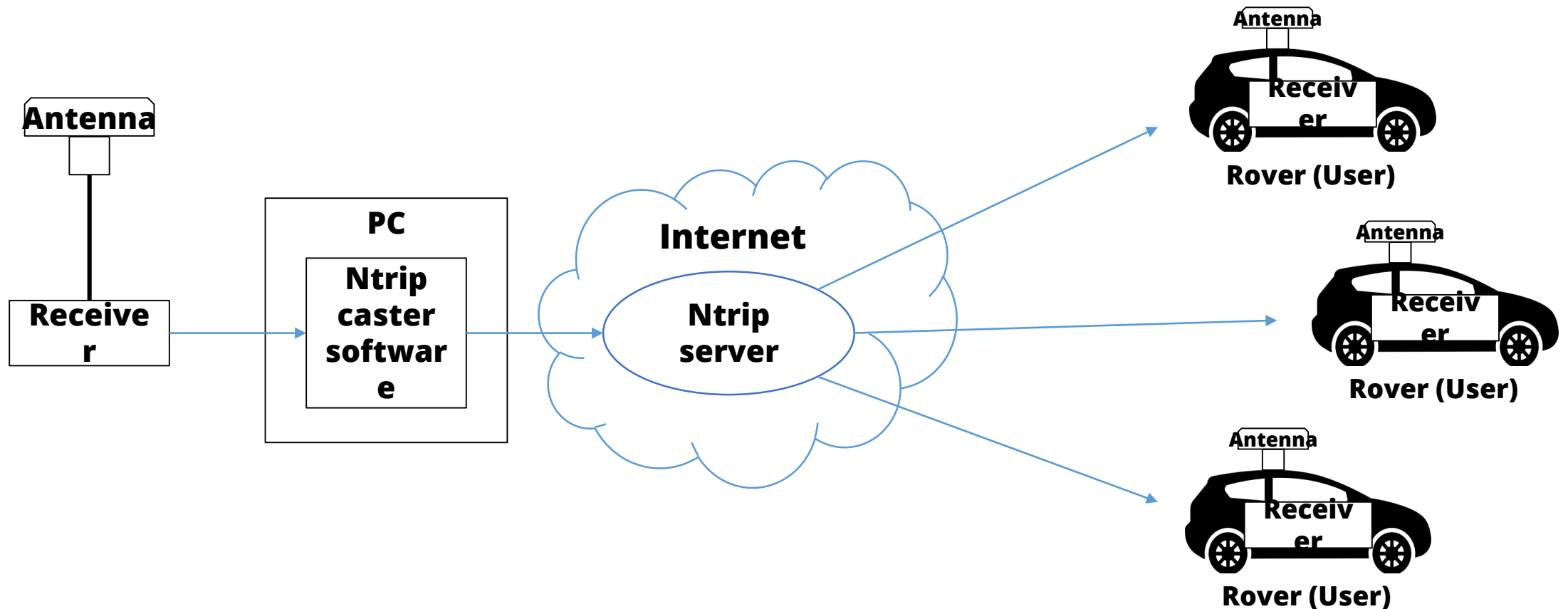


# 3. How to build RTK environment

## ◆ Base station overview

I explain the most common broadcast way using "Ntrip server".

However you can also use VHF/UHF radio, Bluetooth, LAN or cable communication to broadcast base station data.



# 3. How to build RTK environment

## ◆ Base station antenna

Install antenna in open sky & static environment.



**Japanese government base station**



**Our University base station**



**Temporary base station**

# 3. How to build RTK environment

## ◆ Base station receiver selection

The receiver should support raw data output.

- RTCM3

Standard format for RTK. Select base station position and observation message is must.

- Receiver manufacturer format

Binary message.

Input support is depend on the rover receiver.

### RTCM Rev3 Common Message Types

Most common message used for >90% of all RTK applications

1004	Extended L1&L2 GPS RTK Observables for GPS RTK Use, <b>the main msg</b> X
1005	Stationary RTK Reference Station ARP X
1006	Stationary RTK Reference Station ARP plus the Antenna Height X
1007	Antenna Descriptor (msg 1008 (X) is also commonly used) X
1012	Extended L1&L2 GLONASS RTK Observables, <b>the other main msg</b> X

<https://www.use-snip.com/kb/knowledge-base/an-rtcm-message-cheat-sheet/>



CHAPTER 4. CONFIGURING THE ASTERX SB AS A ROVER

### Configure input of differential corrections

The format of the differential corrections output by the Base station should be compatible with what is accepted by the Rover. In the **Corrections Input** window of the **Corrections** menu, you can configure the AsteRx SB to only accept differential corrections of a particular format. The default 'auto' setting will accept correction data format **RTCMv2, RTCMv3 or CMR+**.

### 3.1.5.1 RTCM corrections

RTCM is a binary data protocol for communication of GNSS correction information. The ZED-F9P high precision receiver supports RTCM as specified by RTCM 10403.3, Differential GNSS (Global Navigation Satellite Systems) Services - Version 3 (October 7, 2016).

The RTCM specification is currently at version 3.3 and RTCM version 2 messages are not supported by this standard. Users can download the standard from the RTCM website [here](#).

To modify the RTCM input/output settings, see the configuration section in the u-blox ZED-F9P Interface Description [2].

## 3. How to build RTK environment

### ◆ Base station receiver setting

Change receiver configuration to output RTCM message from USB port.

Here I will show example using u-blox F9P and Septentrio AtseRx-m2a

# 3. How to build RTK environment

## ◆ Base station antenna position

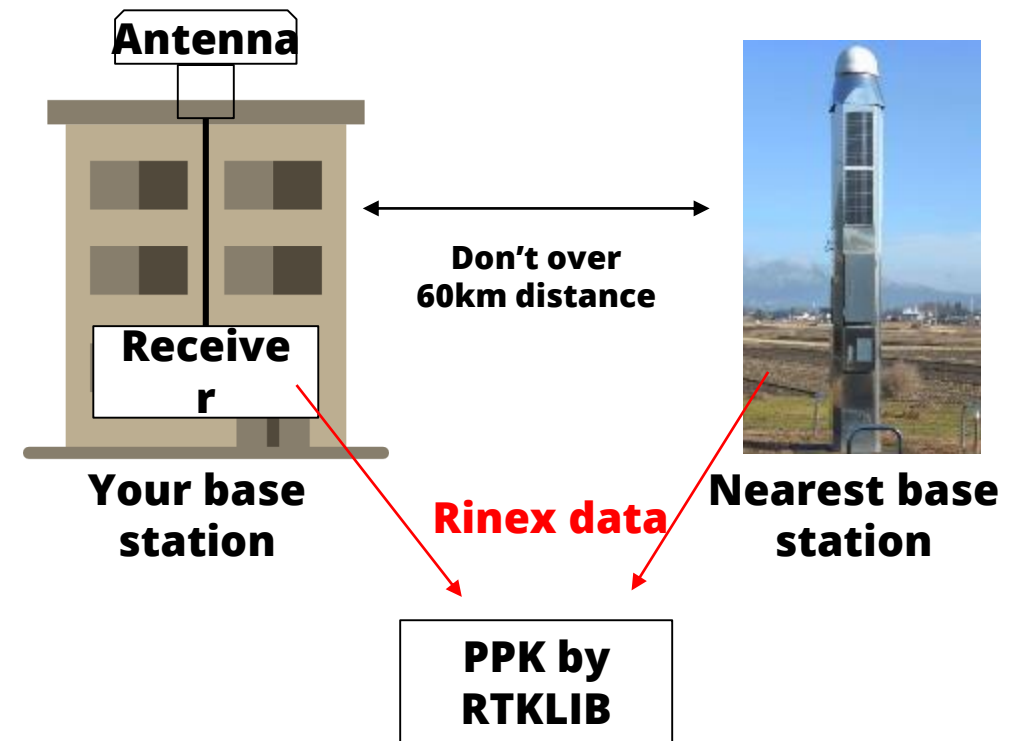
You need to know your base station antenna position with cm level accuracy.

- RTK

If there is another RTK base station near your base, you can calculate by PPK (Post-Process Kinematic).

Free RTK base stations.

- IGS station <http://www.igs.org/network>  
datalink : <ftp://cddis.gsfc.nasa.gov/gnss/data/daily>
- Local CORS <https://www.chcthailand.com/cors-picture>



# 3. How to build RTK environment

## ◆ Base station antenna position

You need to know your base station antenna position with cm level accuracy.

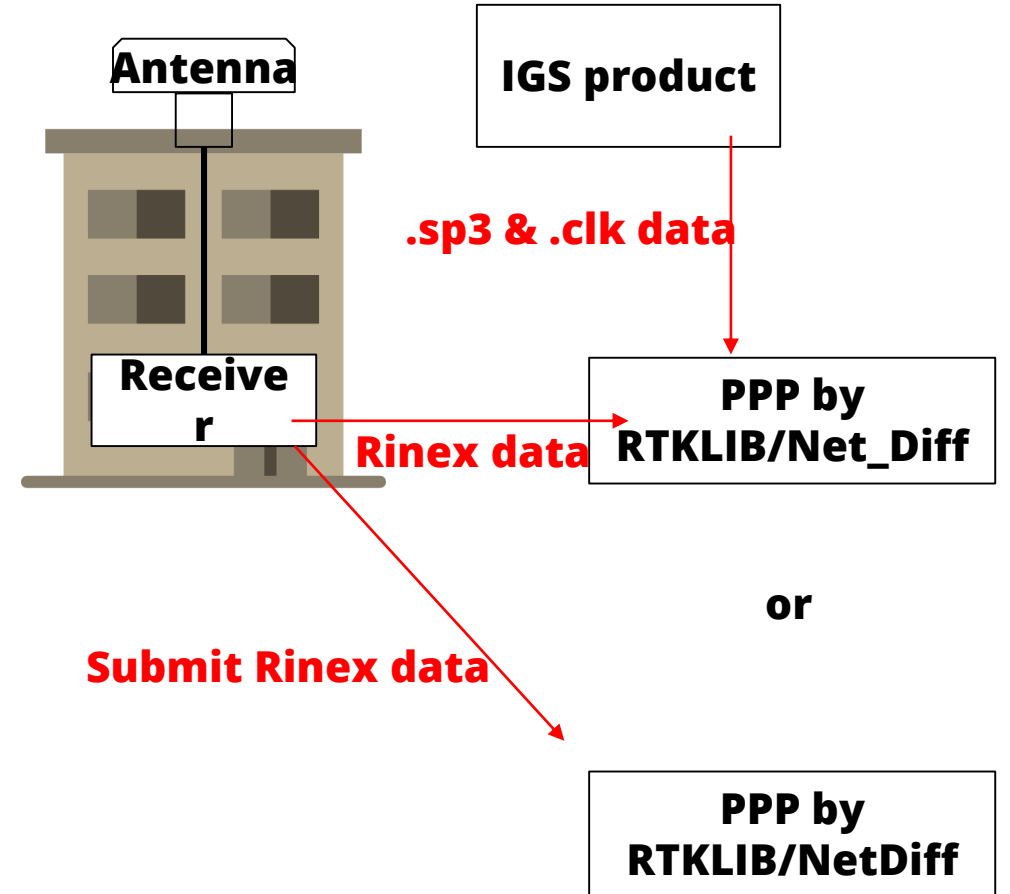
- PPP

If there is no another RTK base station, calculate by PPP.

Free PPP service

- RTKLIB with IGS product (<http://www.rtklib.com/>)
- Net\_Diff with IGS product ([https://github.com/YizeZhang/Net\\_Diff](https://github.com/YizeZhang/Net_Diff))
- Trimble RTX (<https://www.trimblertx.com/UploadForm.aspx>)
- CSRS-PPP (<https://webapp.geod.nrcan.gc.ca/geod/tools-ouils/ppp.php>)
- MADOCA-PPP

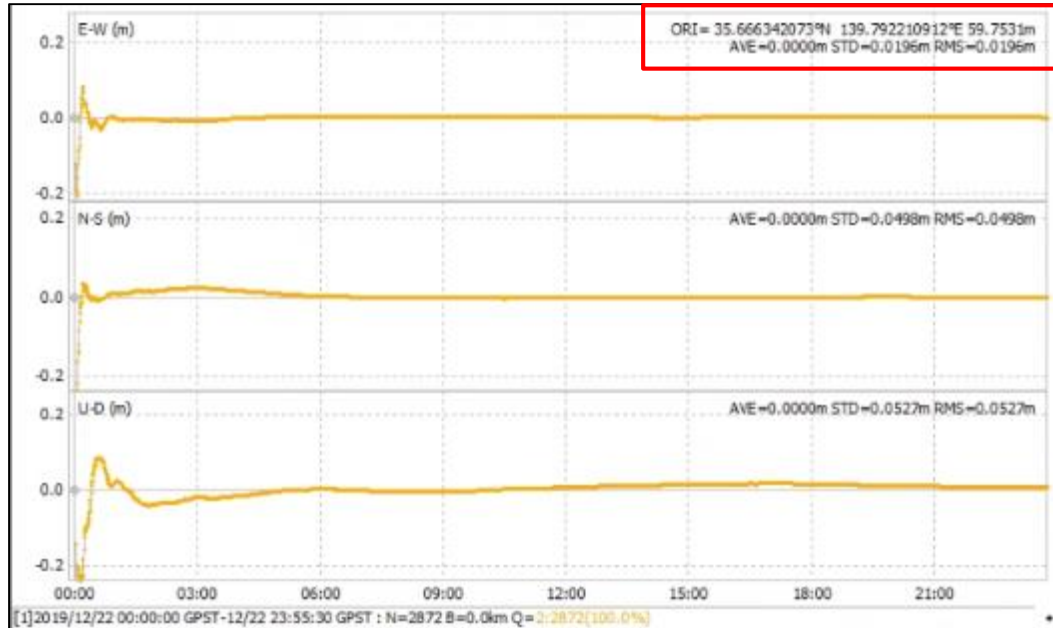
IGS product : ([http://mgex.igs.org/IGS\\_MGEX\\_Products.php](http://mgex.igs.org/IGS_MGEX_Products.php))





# 3. How to build RTK environment

- ◆ Base station antenna position
- Sample of PPP solution



**Net\_Diff + MGEX product**

**Trimble**  
 Post-Processing Service Based on RTX Technology  
 TrimbleRTX.com

Contributor: 1161064@edu.kaiyodai.ac.jp  
 Reference Name: 5301K56165201911030000D.T02  
 Upload Date: 11/05/2019 09:32:44 UTC

Report Time Frame:  
 Start Time: 11/03/2019 00:00:00 UTC  
 End Time: 11/03/2019 23:59:59 UTC  
 Observation File Type(s): T02  
 Observation File(s): 5301K56165201911030000D.T02

Antenna:  
 Name: TRM55971.00 NONE  
 Height: 0.000 m  
 Reference: Bottom of antenna mount

Receiver Name: TRIMBLE NETR9  
 Coordinate Systems: ITRF2014  
 Tectonic Plate: Dzhoksk (Auto-detected)  
 Tectonic Plate Model: MORVEL55  
 Processing Interval: 10 s

**Statistics**

# Total Obs	# Usable Obs	# Used Obs	Percent
81815	8181	8172	99

**Used Satellites**

# Total Satellites:	82
GPS:	G01 G02 G03 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 G32
GLONASS:	R01 R02 R03 R05 R07 R08 R09 R11 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R23 R24
QZSS:	J01 J02 J03
Galileo:	E01 E02 E03 E04 E05 E07 E08 E09 E12 E13 E15 E19 E21 E24 E26 E27 E30 E31 E33 E36
BeiDou:	C06 C07 C08 C09 C10 C11 C12 C13 C14

**Processing Results**

ITRF2014 at Epoch 2010.0			ITRF2014 at Epoch 2019.84		
Coordinate	Value	$\sigma$	Coordinate	Value	$\sigma$
X	-3961904.891 m	0.006 m	X	-3961905.003 m	0.006 m
Y	3348992.800 m	0.006 m	Y	3348992.726 m	0.006 m
Z	3698212.544 m	0.006 m	Z	3698212.805 m	0.006 m
Latitude	35° 39' 58.83700" N	0.003 m	Latitude	35° 39' 58.83146" N	0.003 m
Longitude	139° 47' 31.95195" E	0.004 m	Longitude	139° 47' 31.95911" E	0.004 m
El. Height	59.679 m	0.009 m	El. Height	59.679 m	0.009 m

**Report Information**

Trimble RTX Solution ID: 22163547  
 Solution Type: Static  
 Software Version: 6.1.4.17185  
 Creation Date: 11/05/2019 09:38:09 UTC

**Use this position as your base station position. Trimble RTX service**

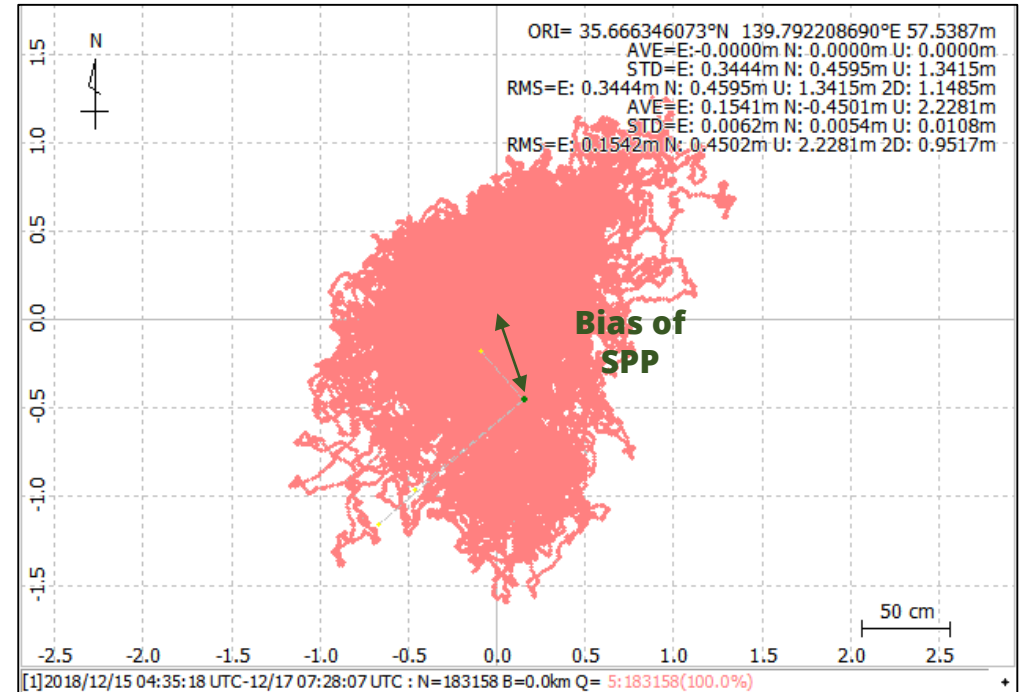
# 3. How to build RTK environment

## ◆ Base station antenna position

Unless there is a special reason, I don't recommend to use optical survey position or SPP average position for the base station position.



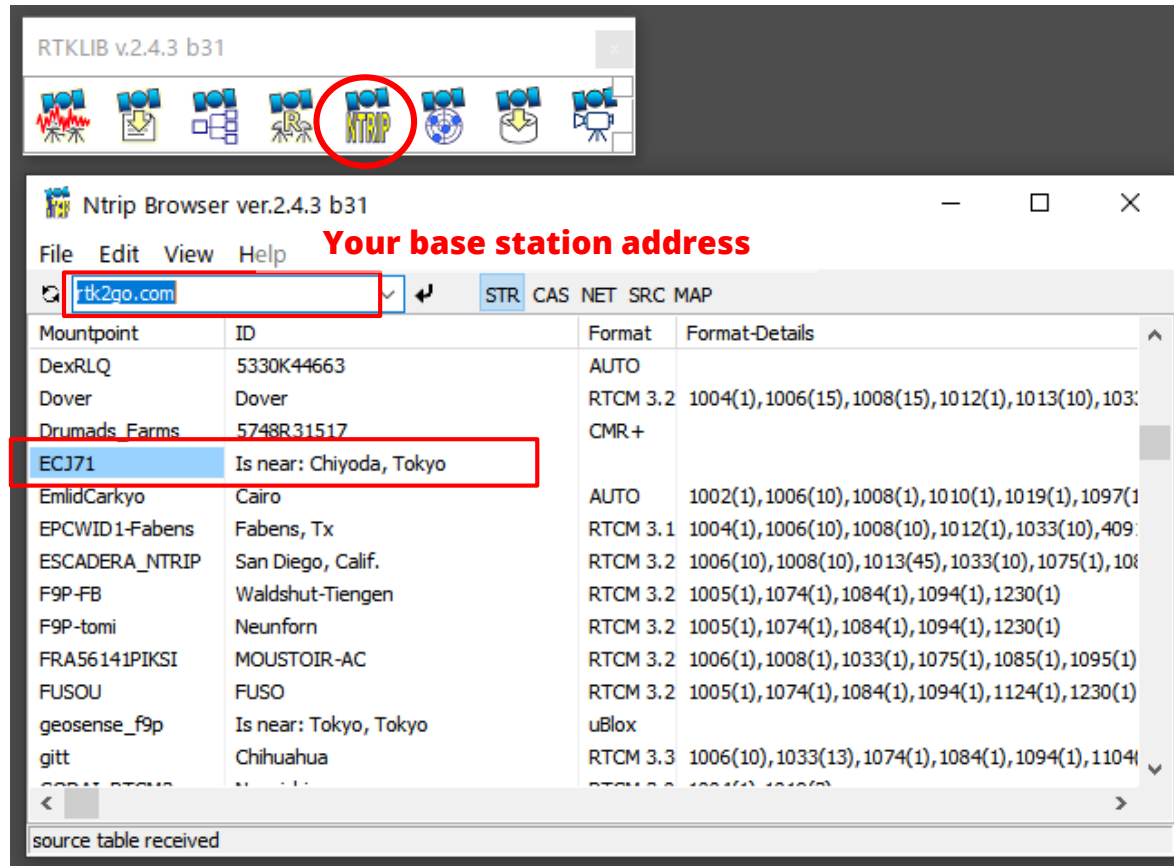
**Local survey coordinate has a gap with GNSS coordinate (ITRF).**



# 3. How to build RTK environment

## ◆ Push out data to Ntrip server

You can check your Mount Point from "NTRIP Browser" in RTKLIB.



# 4. RTK configuration on rover

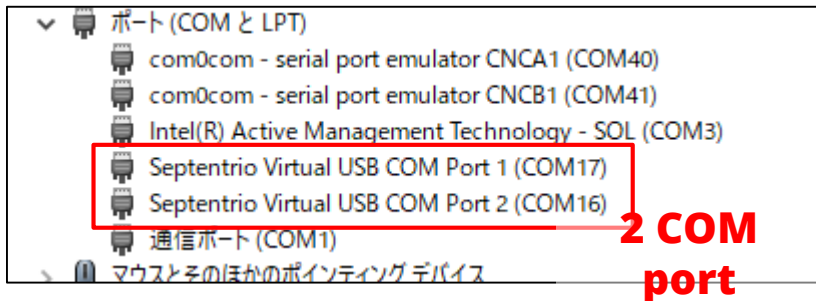
## ◆ RTK (Septentrio with PC)

Use Ntrip client function of "Data Link" in "RxTools"

<https://www.septentrio.com/en/products/software/rxtools>

Download link

<https://www.septentrio.com/en/support/software/rxtools>



**Select base station**

**Input to COM17 port**

Position Information

Geodetic	$\phi$ : N 35° 39'59.43250"	$\sigma_N$	+0.005m
Base station	$\lambda$ : E 139° 47'32.59885"	$\sigma_E$	+0.005m
	h: +59.444m	$\sigma_U$	+0.015m

Satellite Status

Search: Main	4	1G	0R	2E	0C	1S	0J	Track: Main	36	10G	9R	8E	6C	3S	0J
Aux1	14	2G	5R	7E	0C	0S	0J	Aux1	0	0G	0R	0E	0C	0S	0J
Sync: Main	0	0G	0R	0E	0C	0S	0J	PVT: Main	14	6G	5R	0E	3C	0S	0J
Aux1	6	3G	0R	3E	0C	0S	0J	Aux1	0	0G	0R	0E	0C	0S	0J

Receiver Status

Time	RxClock	DOP	PL	RAIM	PVT	Status	Att
GNSS time frame		PDOP: 2.03			Mode: RTK Fixed (0)		
月 30-12-2019		TDOP: 1.37			System: GPS+GLONASS+BeiDou		
07:20:42.000		HDOP: 0.85			Info: CB		
+18s offset to UTC		VDOP: 1.85			Corr Age: 1.00s		

SSRC12 - AsteRx-m2a UAS - SEPT

# 4. RTK configuration on rover

## ◆ RTK (ublox with PC)

Use Ntrip client setting in u-center.

<https://www.u-blox.com/en/product/u-center>

NTRIP client setting

Receiver > NTRIP Client

Select mount point and click "OK".

RTK support is M8P and F9P

The screenshot shows the u-center software interface with the 'Receiver' menu open. A dialog box titled 'NTRIP client settings' is displayed, with the following fields:

- NTRIP caster settings:
  - Address: 153.121.59.53
  - Port: 2101
  - Username: gspase
  - Password: \*\*\*\*\*
- NTRIP stream:
  - Update source table: [X]
  - Request Interval (sec): [ ]
  - NTRIP mount point: ECJ27 (selected)
  - Mount point details: [ ]
  - Use manual position
  - Longitude (deg): 0
  - Latitude (deg): 0
  - Altitude (m): 0
  - Geoid sep. (m): 0

The background interface includes a satellite constellation diagram, a data table with the following values:

Longitude	139.79239585
Latitude	35.66651513
Altitude	59.446 m
Altitude (msl)	19.997 m
TTFF	29.226 s
Fix Mode	3D/DGNSS/FIXED
3D Acc. [m]	0.02
2D Acc. [m]	0.01
PDOP	1.0
HDOP	0.5

Other displays include a compass, a speedometer (0.01 m/s = 0.0 km/h), and a heading indicator (59.446 m).

# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

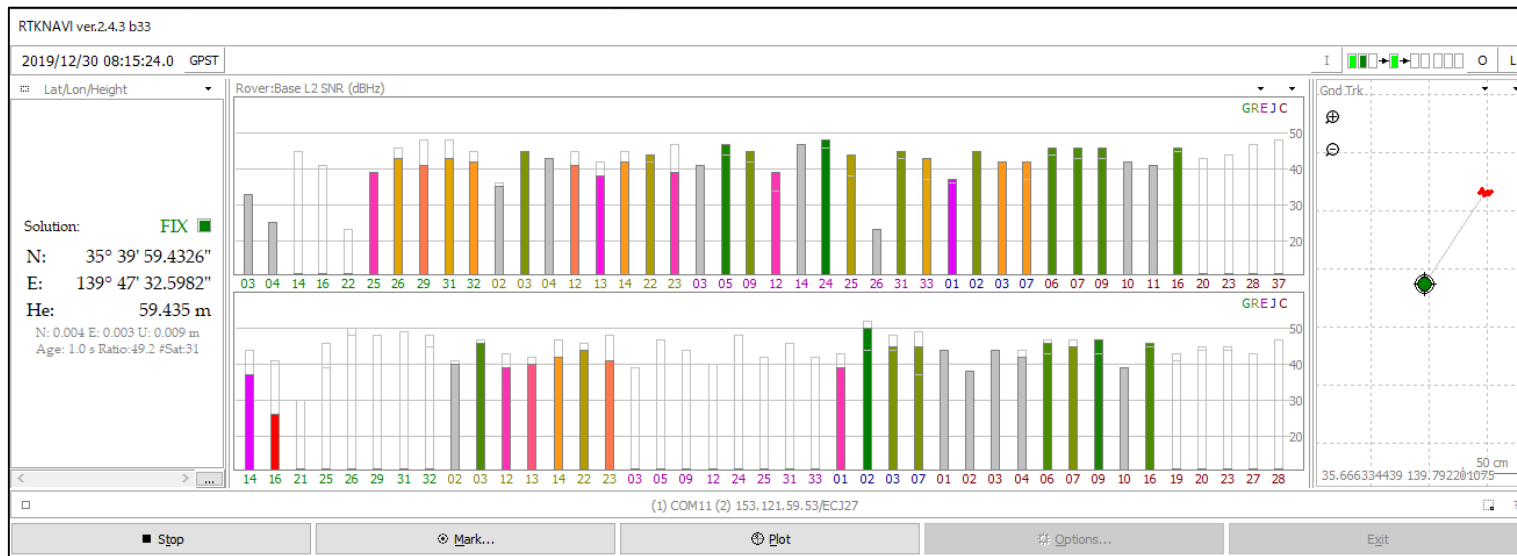
Real time RTK engine that supports many receivers.

To use RTKNAVI, first you should set receiver to output "raw data".

"raw data" means binary observation message include RTCM.

RTKNAVI decodes this "raw data" and calculate RTK solution.

Here, I show the example using u-blox receiver.



- RTCM 2
- RTCM 3
- NovAtel OEM6
- ComNav
- u-blox
- Swift Navigation SB
- Hemisphere
- SkyTraq
- GW10
- Javad
- NVS BINR
- BINEX
- Trimble RT17
- Septentrio
- CMR/CMR +
- TERSUS

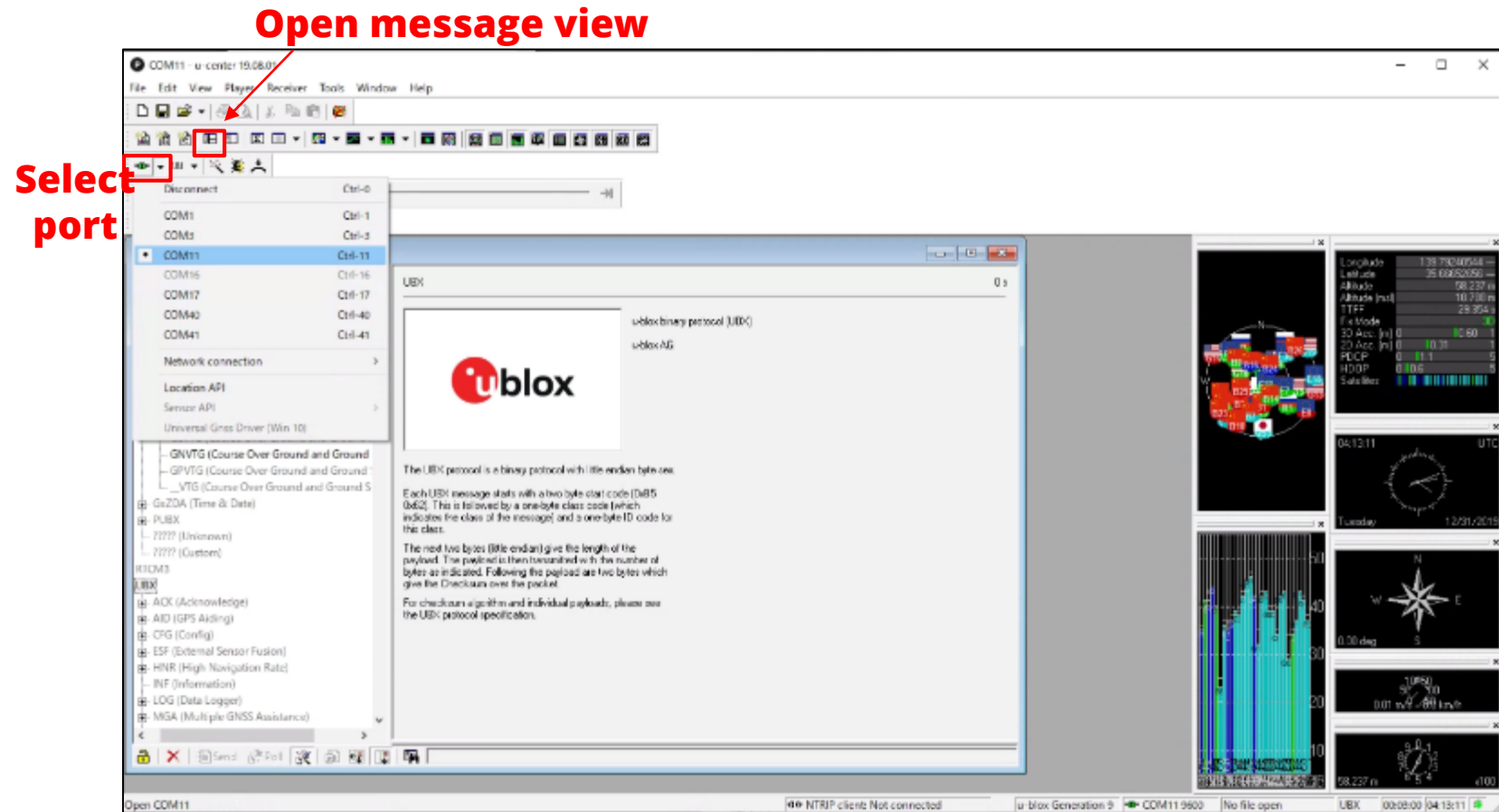
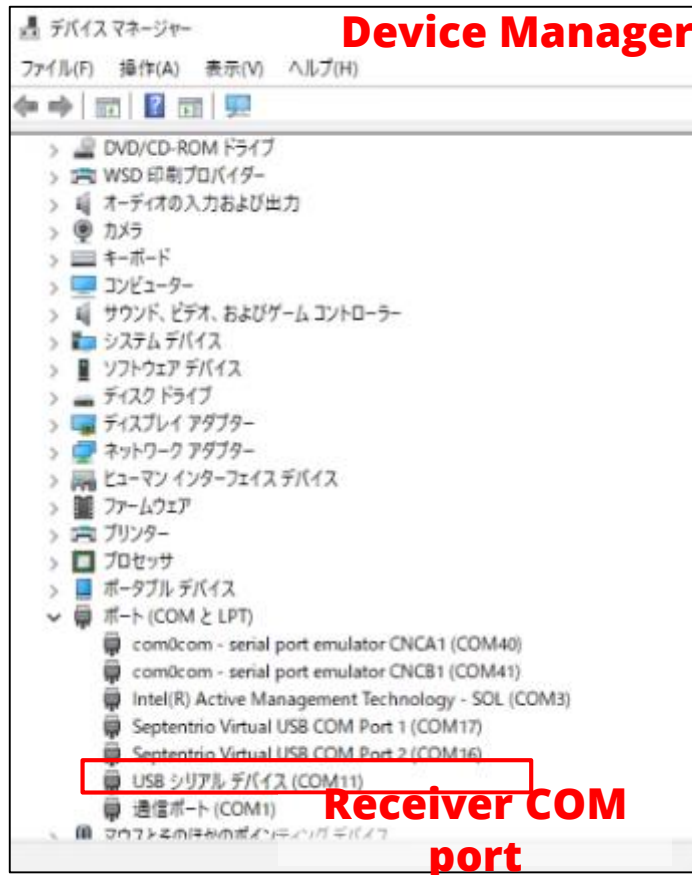
**Supported "raw data" formats**

# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

Receiver configuration on u-center.

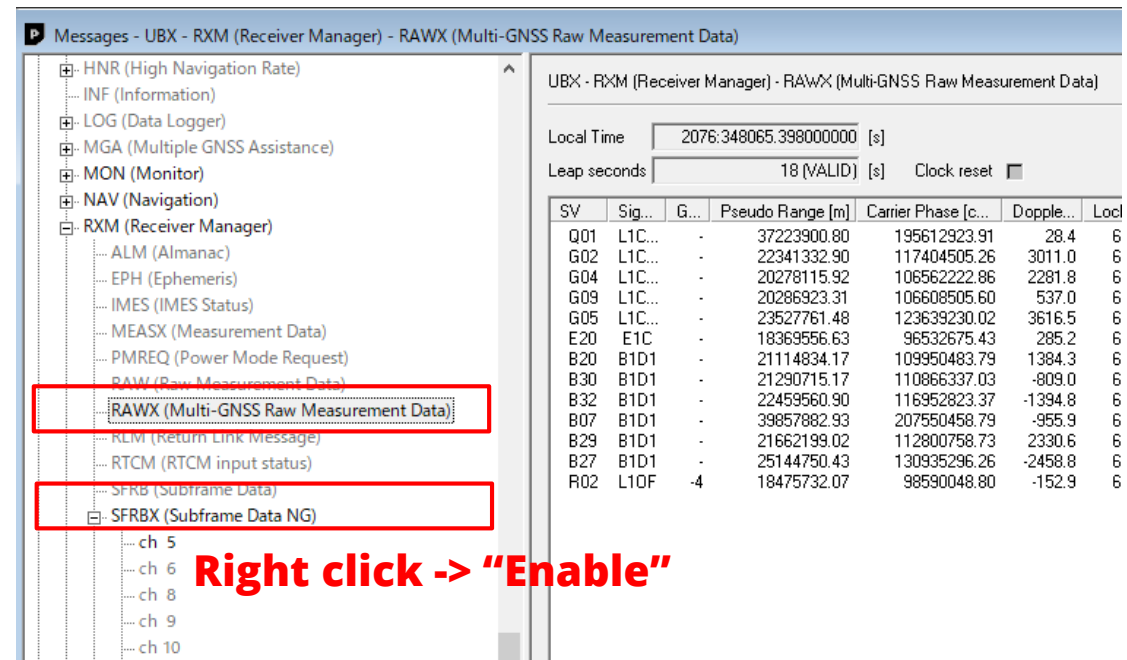
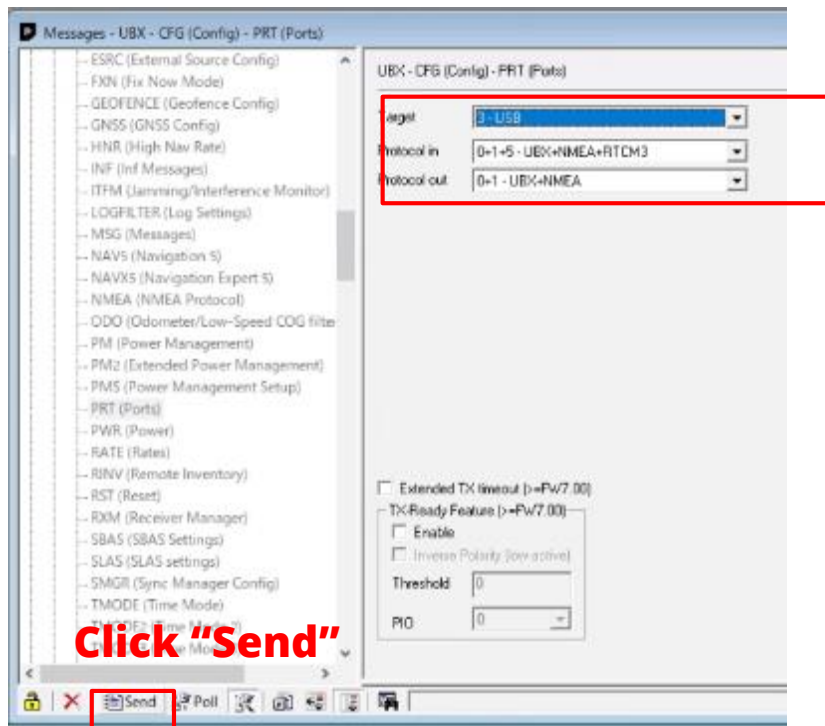
First, select COM port of the receiver and connect. Then open "message view".



# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

Receiver configuration on u-center. Open message view from View>Message View. You need to click "send" after change configuration.



**Enable output of RAWX & SFRBX (UBX-RXM)**

**Setting to output UBX format (UBX-CFG-PRT)**

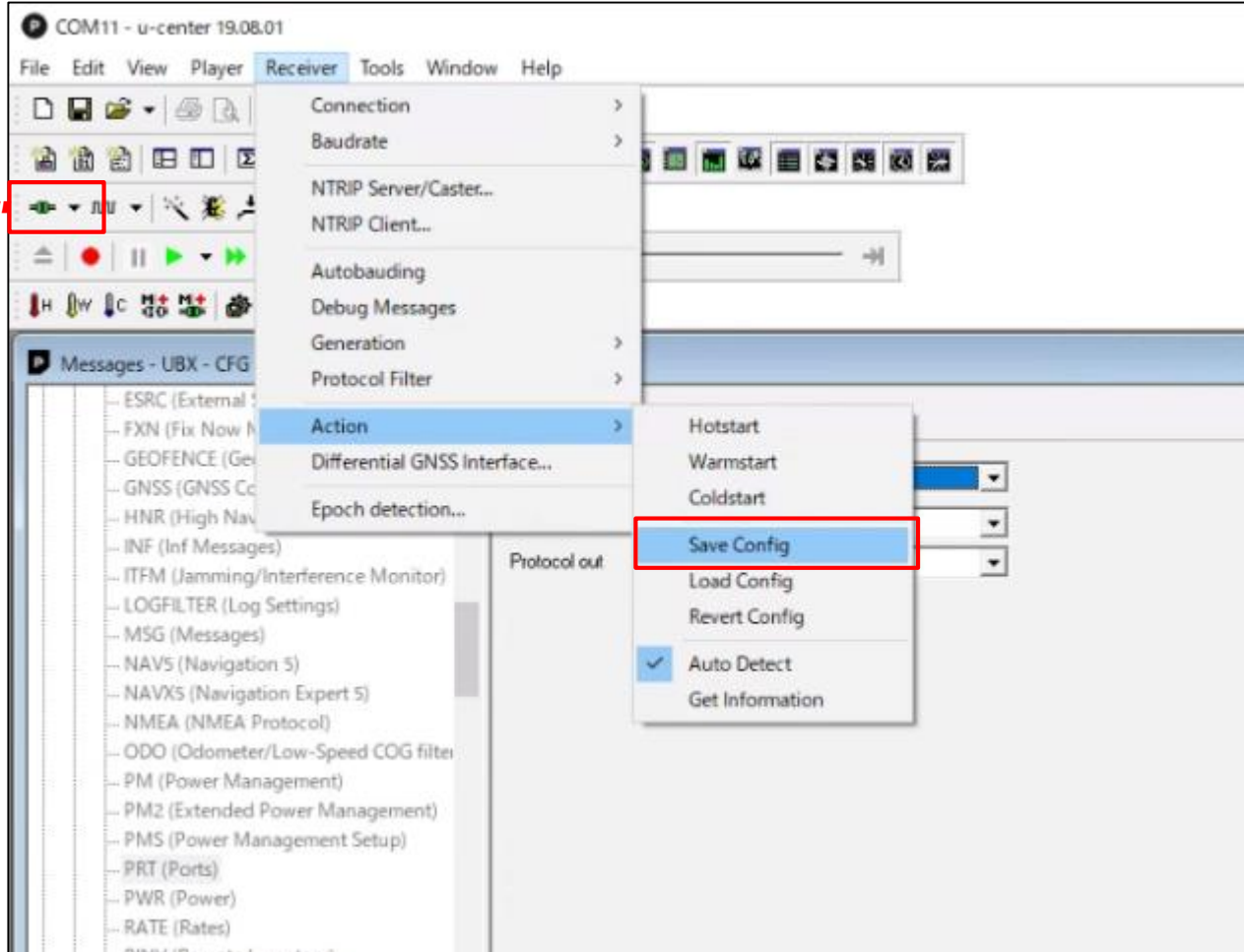


# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

After receiver configuration was completed, save it and disconnect receiver.

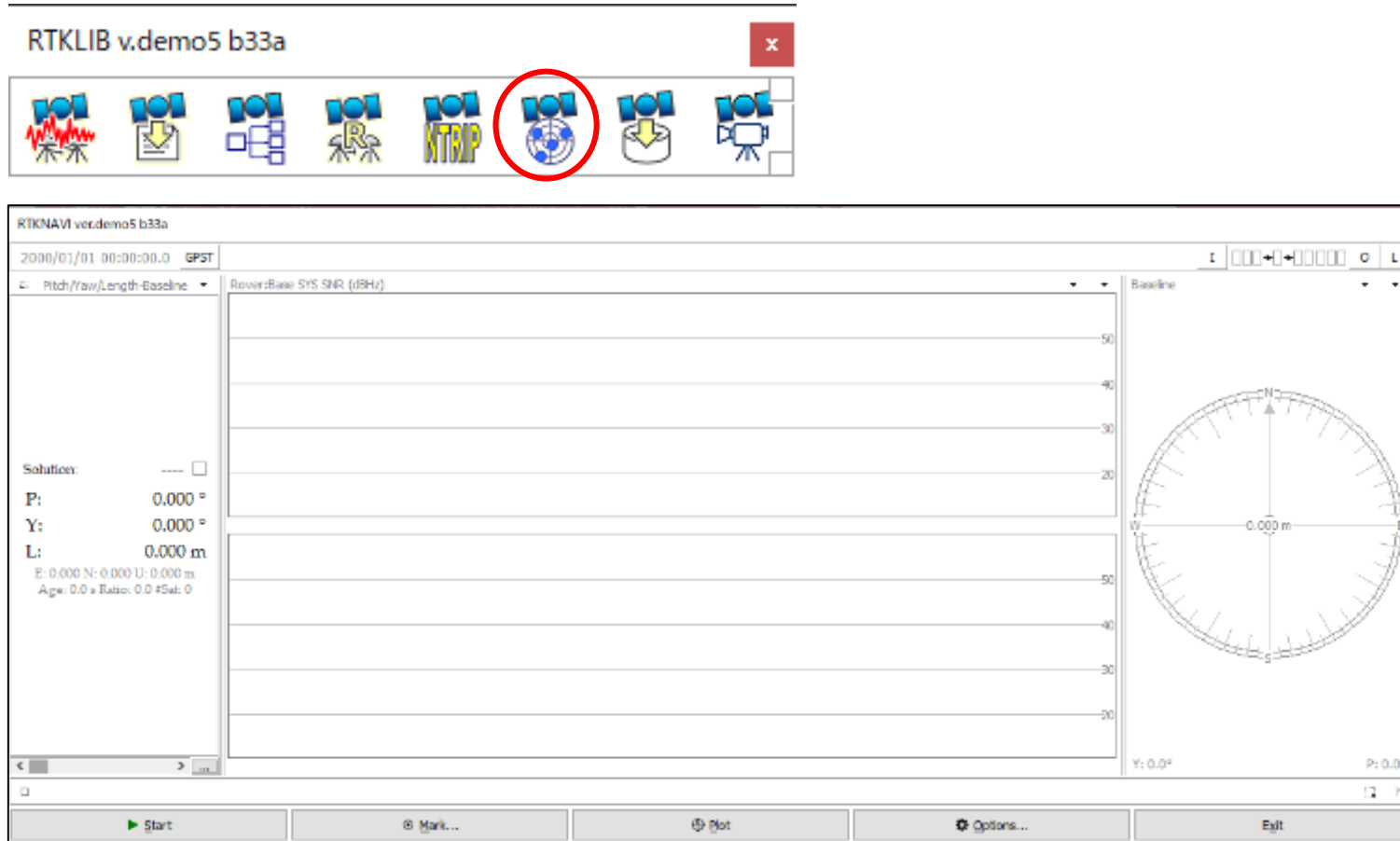
**"Disconnect"**



# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

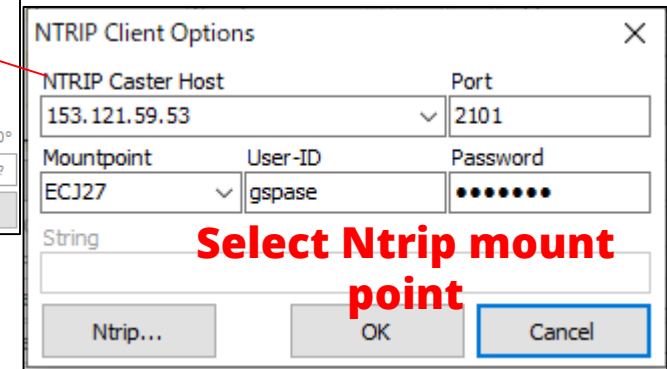
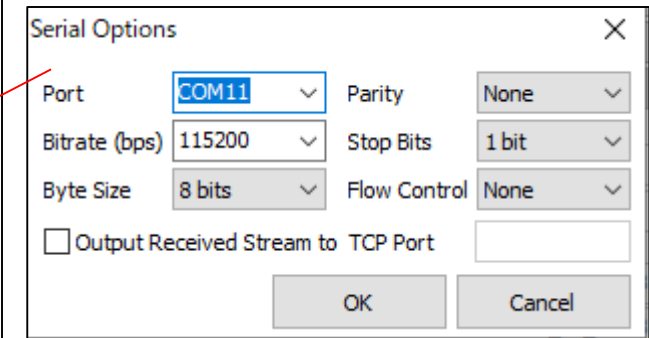
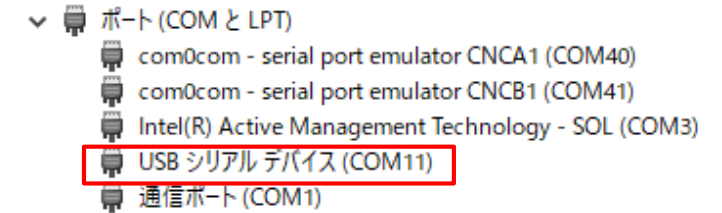
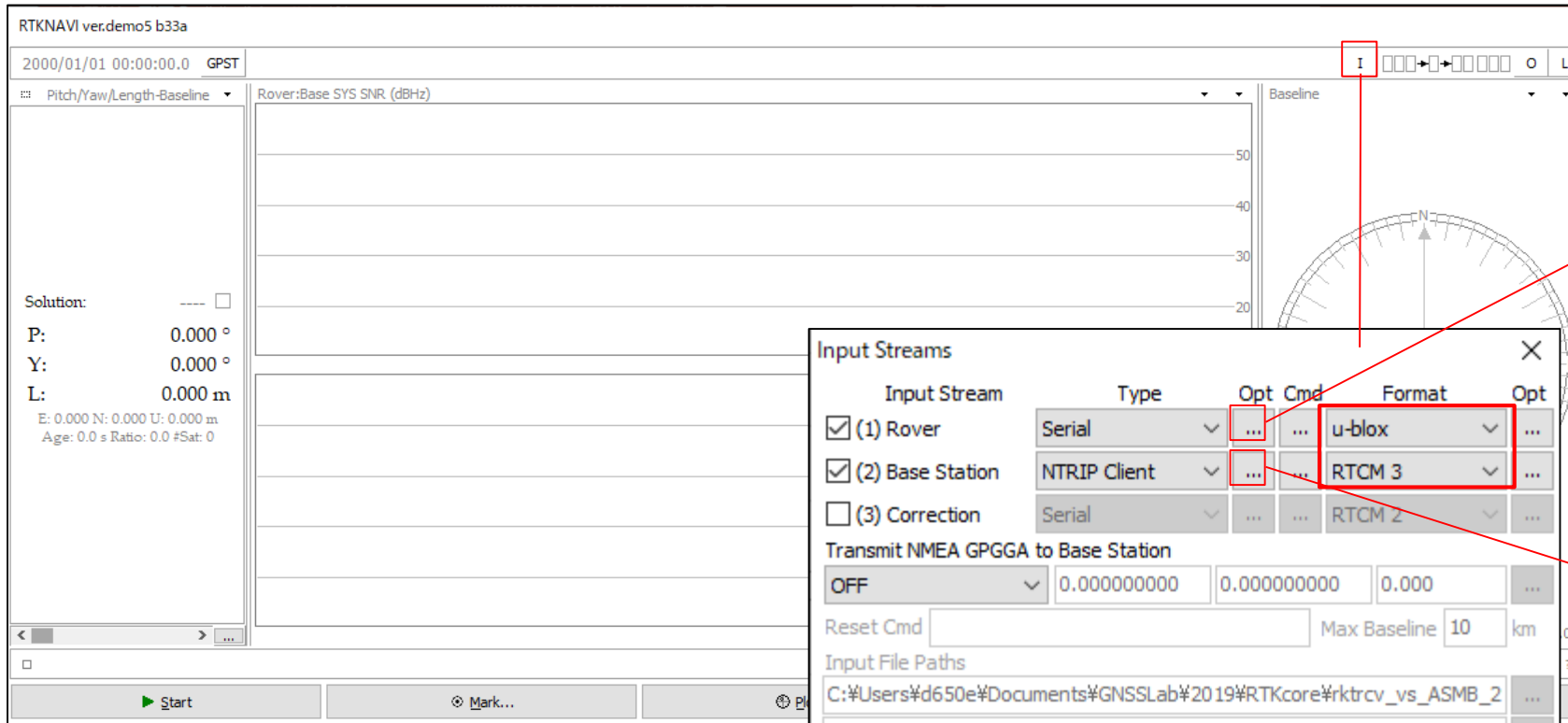
Open RTKNAVI.



# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

Set input stream.

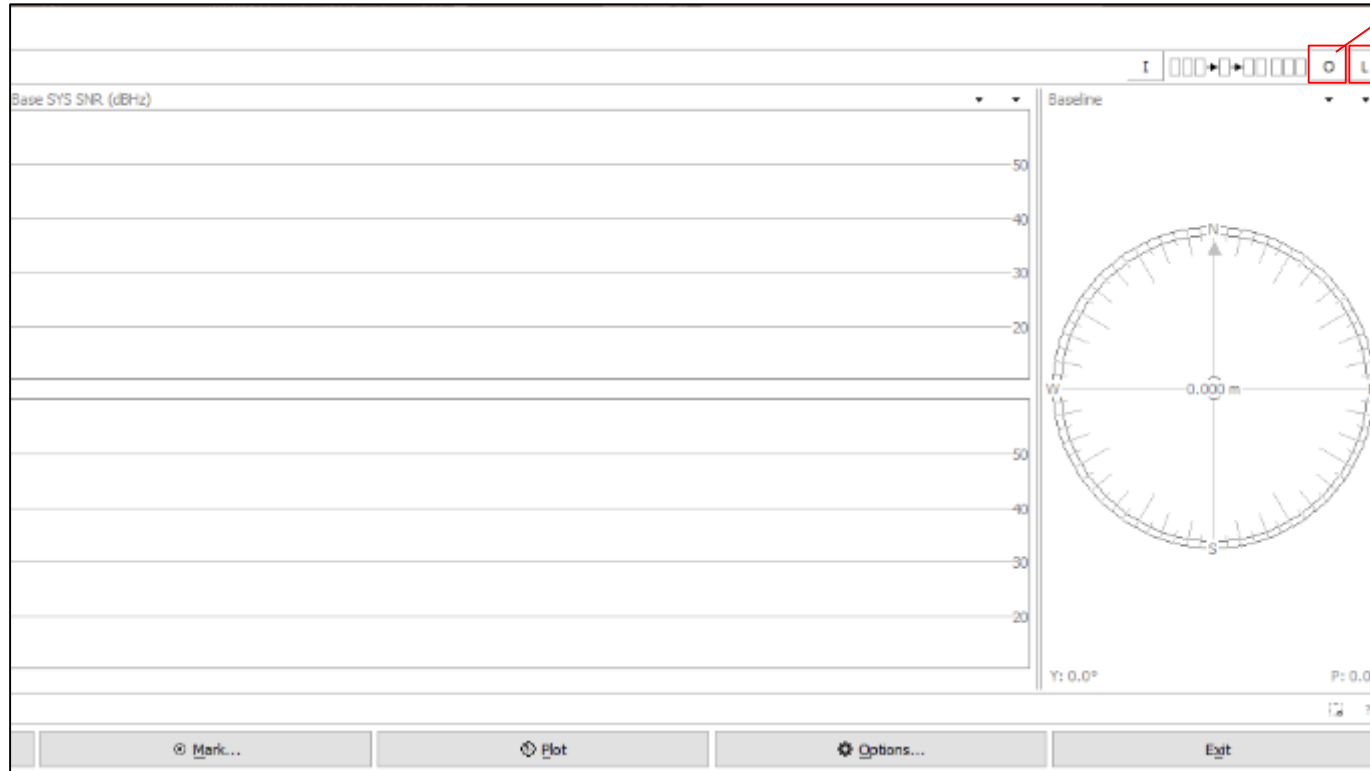


# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

Set output stream & log stream.

**Here the RTK position will be written to the file. Also you can choose other option (TCP, Serial) according to your use case**



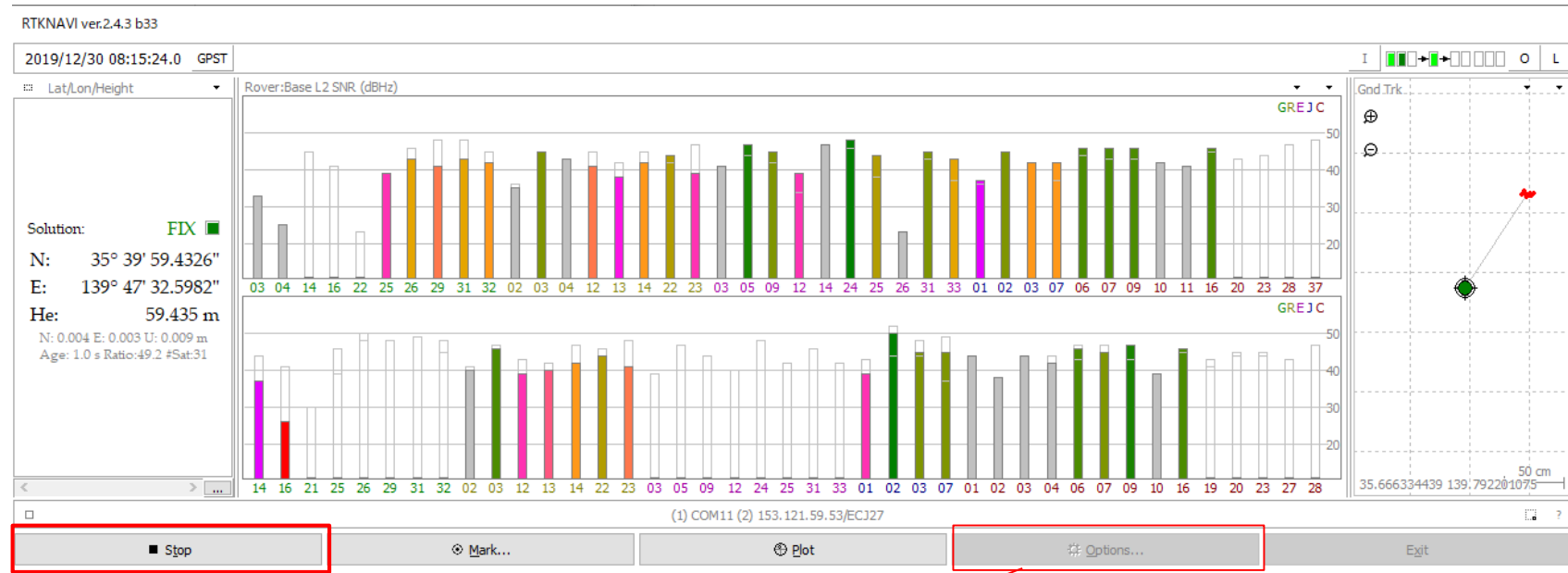
The 'Output Streams' dialog box is shown. It has a table with columns 'Output Stream', 'Type', 'Option', and 'Format'. The first row is checked and shows '(4) Solution 1' with 'File' type and 'Lat/Lon/Height' format. The second row is unchecked and shows '(5) Solution 2' with 'Serial' type and 'Lat/Lon/Height' format. Below the table, there is a text field for 'Output File Paths' containing 'C:\Users\d650e\Desktop\F9P\_RTKNAVI.pos'. At the bottom, there are checkboxes for 'Time-Tag' and 'Swap Intv', a dropdown menu set to 'H', and 'OK' and 'Cancel' buttons.

The 'Log Streams' dialog box is shown. It has a table with columns 'Log Stream', 'Type', and 'Opt'. The first row is checked and shows '(6) Rover' with 'File' type and 'Output Event' option. The second row is checked and shows '(7) Base Station' with 'File' type. The third row is unchecked and shows '(8) Correction' with 'Serial' type. Below the table, there are text fields for 'Log File Paths' containing 'C:\Users\d650e\Desktop\rover.ubx' and 'C:\Users\d650e\Desktop\base.ubx'. At the bottom, there are checkboxes for 'Time-Tag' and 'Swap Intv', a dropdown menu set to 'H', and 'OK' and 'Cancel' buttons.

# 4. RTK configuration on rover

## ◆ RTK (RTKNAVI)

Set option to calculate RTK.  
After option setting, click  
"Start" and then RTK starts.



This screenshot shows the 'Options' dialog box, 'Setting1' tab. The 'Positioning Mode' is set to 'Kinematic'. The 'Excluded Satellites (+PRN: Included)' section has checkboxes for GPS, GLO, Galileo, QZSS, SBAS, BeiDou, and IRNSS, all of which are checked. A red box highlights the 'Kinematic' dropdown menu and the checked satellite options.

This screenshot shows the 'Options' dialog box, 'Setting2' tab. The 'Integer Ambiguity Res (GPS/GLO/BDS)' is set to 'Fix and'. The 'Min Ratio to Fix Ambiguity' is 3.0. The 'Min Confidence / Max FCB to Fix Amb' is 0.9999 / 0.20. The 'Min Lock / Elevation (°) to Fix Amb' is 0 / 0. The 'Min Fix / Elevation (°) to Hold Amb' is 10 / 40. The 'Outage to Reset Amb / Slip Thres (m)' is 5 / 0.050. The 'Max Age of Diff (s) / Sync Solution' is 30.0 / OFF. The 'Reject Threshold of GDOP/Innov (m)' is 30.0 / 30.0. The 'Max # of AR Iter / # of Filter Iter' is 1 / 1. The 'Baseline Length Constraint (m)' is 1.590 / 0.020. A red box highlights the 'Fix and' dropdown menu.

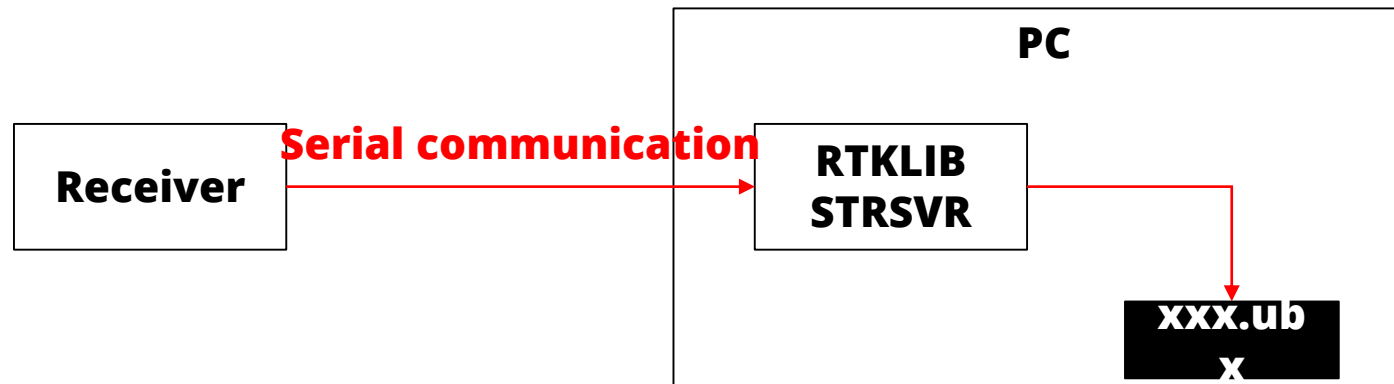
This screenshot shows the 'Options' dialog box, 'Output' tab. The 'Solution Format' is 'Lat/Lon/Height'. The 'Output Header / Output Processing Options' is 'OFF'. The 'Time Format / # of Decimals' is 'hh:mm:ss GPST' / 3. The 'Latitude Longitude Format / Field Separator' is 'ddd.dddddd'. The 'Output Single if Sol Outage / Max Sol Std (m)' is 'ON' / 10. The 'Datum / Height' is 'WGS84' / 'Ellipsoidal'. The 'Geoid Model' is 'Internal'. The 'Solution for Static Mode' is 'All'. The 'NMEA Interval (s) RMC/GGA, GSA/GSV' is 0 / 0. The 'Output Solution Status / Output Debug Trace' is 'OFF' / 'OFF'. A red box highlights the 'Ellipsoidal' dropdown menu.

This screenshot shows the 'Options' dialog box, 'Statistics' tab. The 'Measurement Errors (1-sigma)' section has 'Code/Carrier-Phase Error Ratio L1/L2' set to 600.0 / 600.0, 'Carrier-Phase Error a+b/sinEl (m)' set to 0.003 / 0.003, and 'Carrier-Phase Error/Baseline (m/10km)' set to 0.000. The 'Doppler Frequency (Hz)' is 1.000. The 'Process Noises (1-sigma/sqrt(s))' section has 'Receiver Accel Horiz/Vertical (m/s2)' set to 1.00E+01 / 1.00E+01, 'Carrier-Phase Bias (cycle)' set to 1.00E-04, 'Vertical Ionospheric Delay (m/10km)' set to 1.00E-03, and 'Zenith Tropospheric Delay (m)' set to 1.00E-04. The 'Satellite Clock Stability (s/s)' is 5.00E-12. A red box highlights the '0.003' input field.

This screenshot shows the 'Options' dialog box, 'Positions' tab. The 'Rover' section has 'Lat/Lon/Height (deg/m)' set to 90.000000000 / 0.000000000 / -6335367.6285. The 'Antenna Type (\*: Auto)' is set to 'RTCM Antenna Position'. The 'Base Station' section has 'Lat/Lon/Height (deg/m)' set to 90.000000000 / 0.000000000 / -6335367.6285. The 'Antenna Type (\*: Auto)' is set to 'RTCM Antenna Position'. The 'Station Position File' is empty. A red box highlights the 'RTCM Antenna Position' dropdown menu.

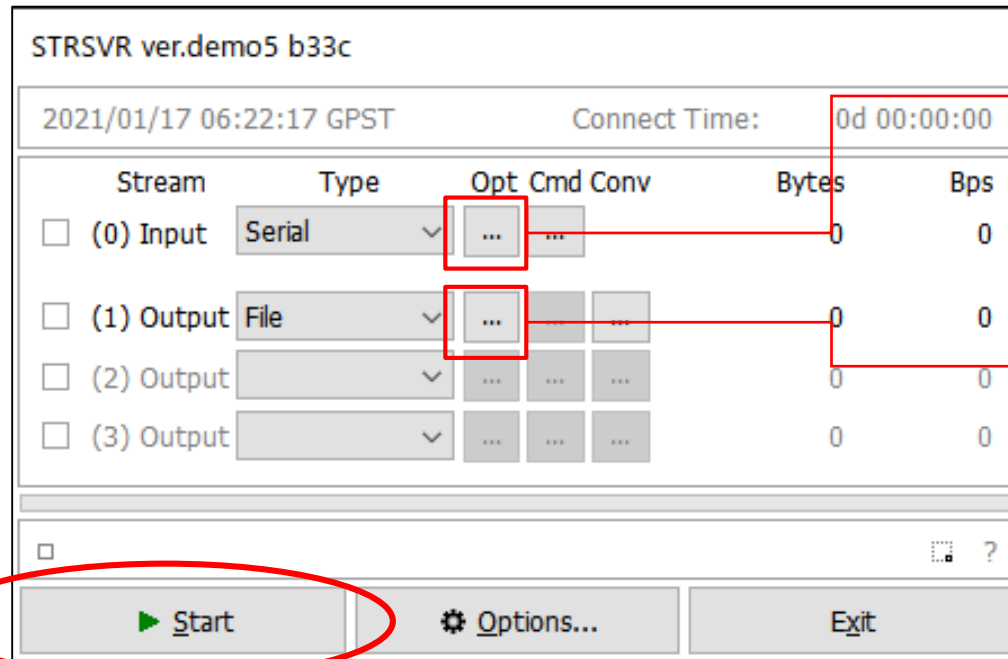
## 5. GNSS raw data recording

- ◆ RTK post processing need GNSS raw data.
- ◆ After change the configuration of the receiver to output raw observation, you need to record it.
- ◆ Most of the receivers output its data stream by serial communication.
- ◆ Easy way to record the data on PC is use RTKLIB.

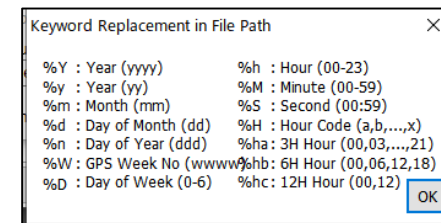
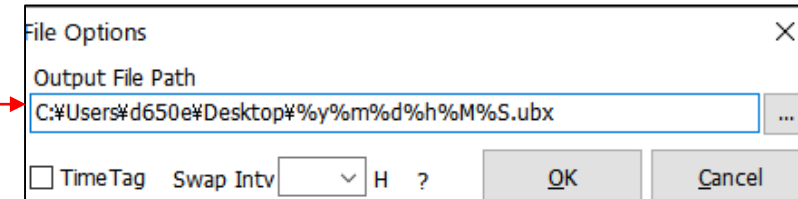
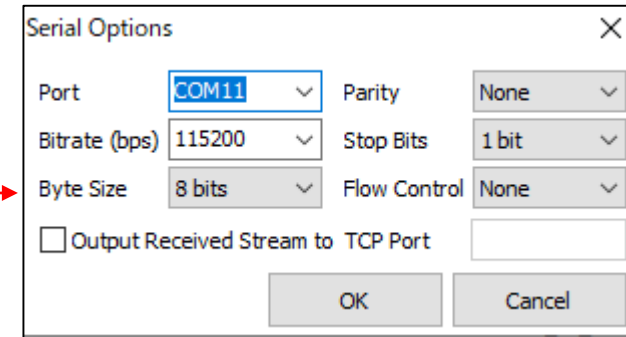
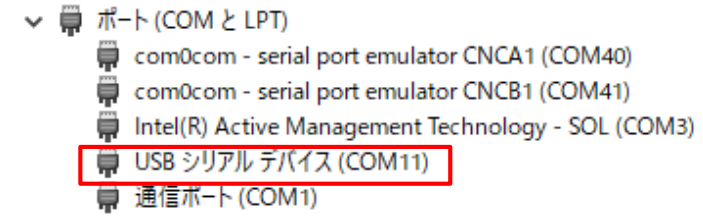


# 5. GNSS raw data recording

## ◆ Data recording (STRSVR)



**Start recording**



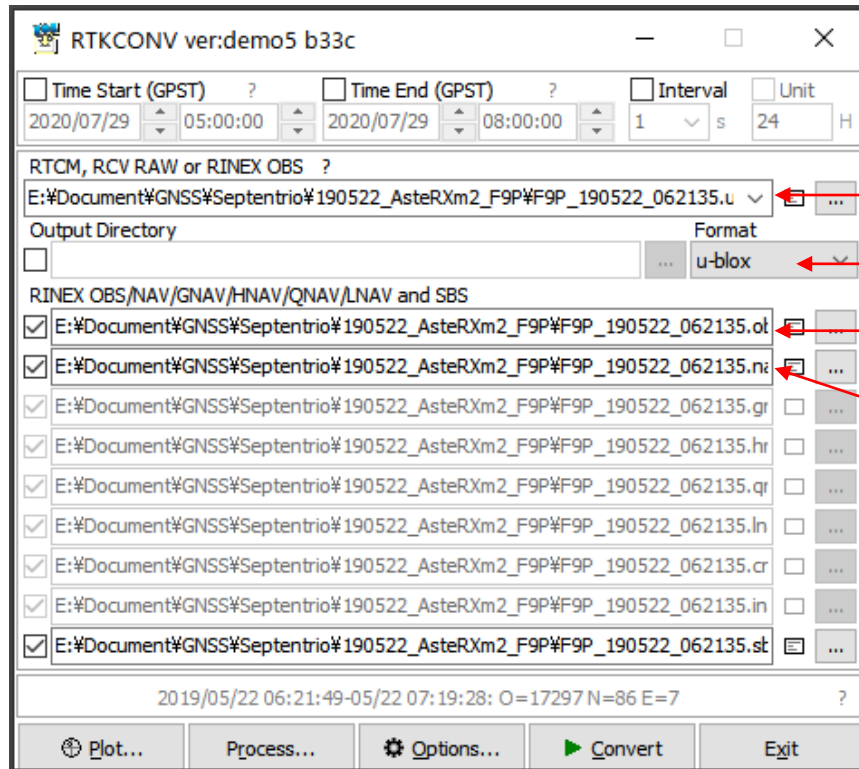
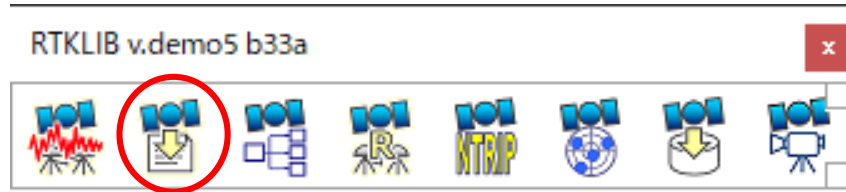
**File name Tips**





# 6. GNSS raw data convert

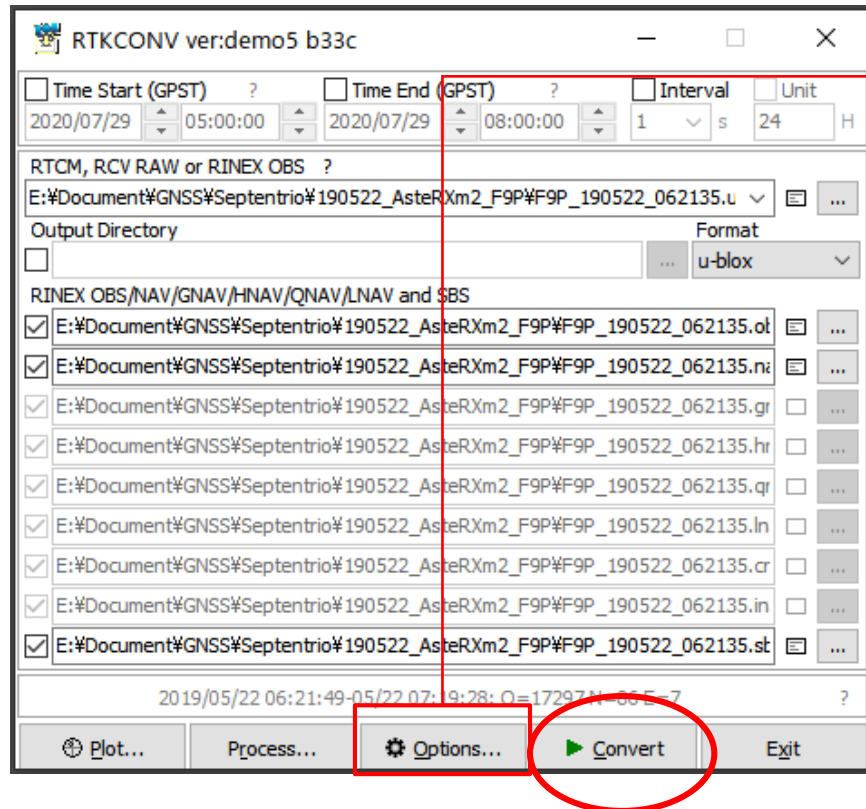
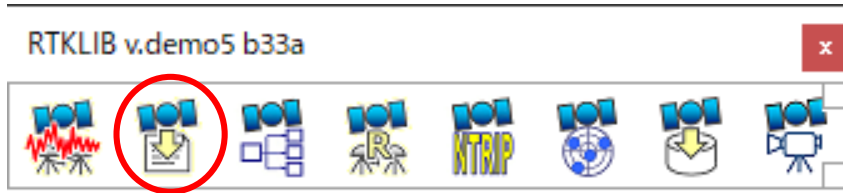
## ◆ Data conversion (RTKCONV)



**GNSS raw data**  
**Select receiver manufacturer**  
**.obs is observation file with RINEX format**  
**.nav is ephemeris file with RINEX format**

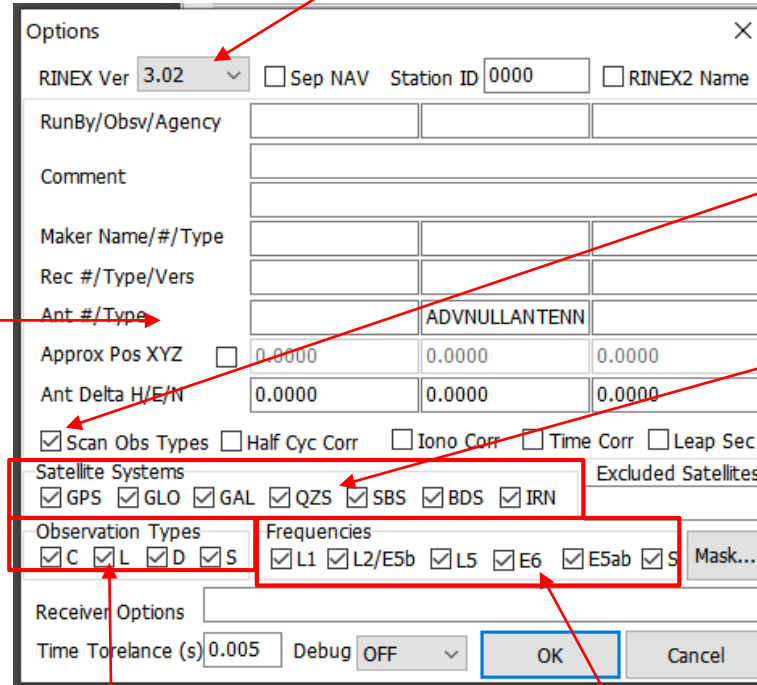
# 6. GNSS raw data convert

## ◆ Data conversion (RTKCONV)



**Start conversion**

**Output RINEX version.  
Recommend upper  
3.02**



**Recommend check  
"Scan Obs Types"**

**Satellite  
constellations you  
want to output**




**Recommend check  
all  
C: Code range  
L: Carrier phase  
D: Doppler shift  
S: SNR**

**GNSS frequencies you want to use  
Recommend check all for general  
purpose**

## 6. GNSS raw data convert

### ◆Data conversion (RTKCONV)

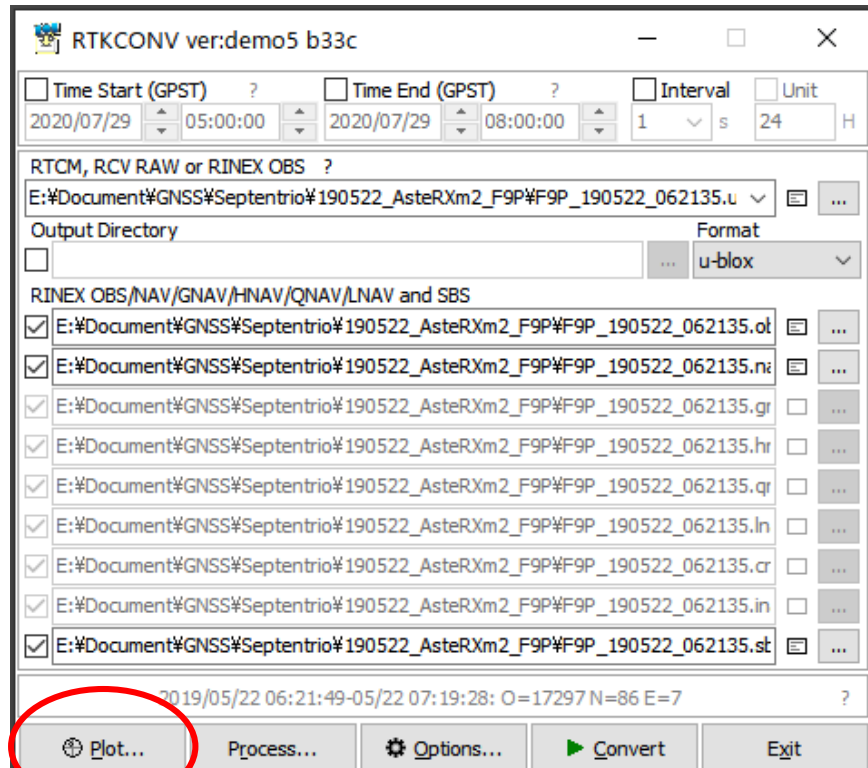
After conversion you can find .obs file and .nav file which can open with text editor.

<input type="checkbox"/> 名前	更新日時	種類	サイズ
 F9P_190522_062135.nav	2021/01/17 15:55	NAV ファイル	45 KB
 F9P_190522_062135.obs	2021/01/17 15:55	OBS ファイル	77,984 KB
 F9P_190522_062135.ubx	2019/05/22 16:36	u-blox Log File	61,031 KB

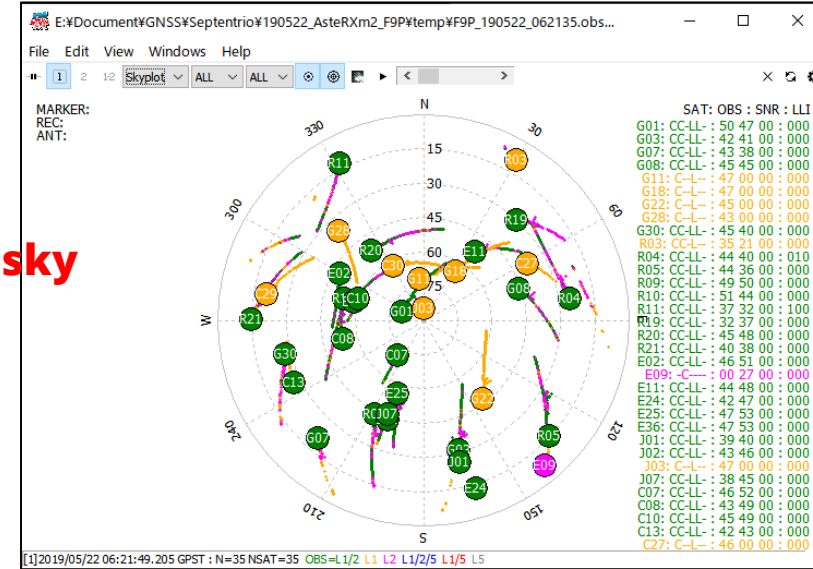
# 6. GNSS raw data convert

## ◆ Data conversion (RTKCONV)

You can also check RINEX format data graphically by RTKPLOT.



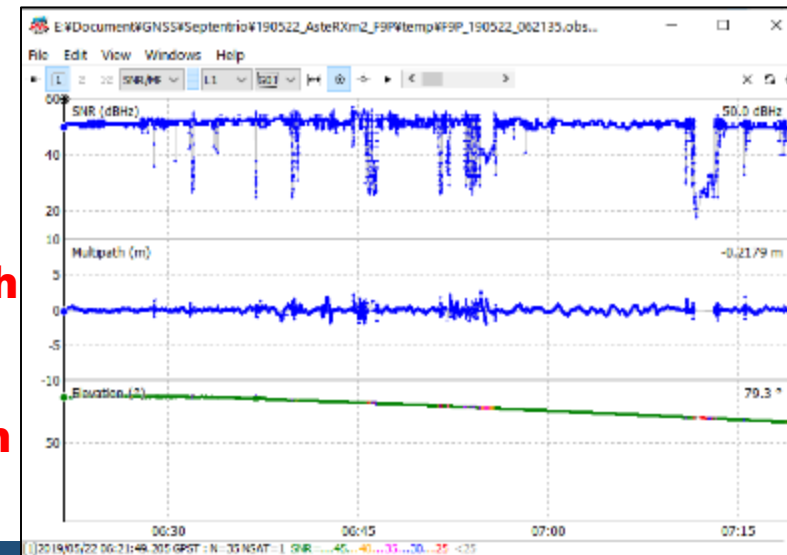
Satellite sky plot



SNR

Multipath

Elevation



## 7. Useful web sites

- ◆ Useful web sites for your RTK experiment
- [http://www.denshi.e.kaiyodai.ac.jp/gnss\\_tutor/base\\_station.html](http://www.denshi.e.kaiyodai.ac.jp/gnss_tutor/base_station.html)
- <https://home.csis.u-tokyo.ac.jp/~dinesh/>
- <http://www.rtklib.com/>