

UTOKYO/ICG Training on  
Global Navigation Satellite Systems (GNSS)  
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# GNSS Software and Data Formats

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# Software

## Receiver Configuration and Logging

- U-Center
- Septentrio Rxtools

## Data Processing

- RTKLIB

## MADOCA PPP

- MAD-WIN

# GNSS Sample Data

- StaticData
  - [F9P\\_181215\\_static.ubx](#) : Rover raw observation file
  - [NetR9\\_181215\\_static.binex](#): Base station raw file
  - [BaseStationPosition.txt](#) : Position of base station
  - [PPP.conf](#): RTKLIB configuration file for PPP
  - [PPP\\_correction](#): Correction data for PPP
  
- DynamicData
  - [ECJ02\\_base.ubx](#): Base station raw observation file
  - [F9P\\_dynamic\\_rover.ubx](#): Rover raw observation file
  - [RTK.conf](#): RTKLIB configuration file for RTK
  - [BaseStationPosition.txt](#) : Position of base station

*All these sample data are prepared by researchers at TUMSAT (Tokyo University of Marine Science and Technology)*

# National Marine Electronics Association (NMEA) Format

- NMEA 0183 (National Marine Electronics Association) is format to output measurement data from a sensor in a pre-defined format in ASCII
- Contains GNSS Position, velocity, time, accuracy and satellite information
- Generally output by Rover devices. **Most GNSS Receivers support NMEA output**
- Can be used as a data processing output format.

# NMEA Format

\$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,,\*47

The diagram illustrates the structure of the NMEA message '\$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,,\*47'. Blue arrows point from labels to specific parts of the message: 'Talker ID (GN: GNSS, GP: GPS, GL: GLONASS...)' points to '\$', 'Message Type' points to 'GPGGA', 'Message Contents' points to the comma-separated data fields, and 'Checksum' points to '\*47'.

Different NMEA Message Types contain different types of GNSS information

- **RMC**: 2D Position, Date/Time, Speed, Heading
- **GGA**: 3D Position(Lat/Lon), Time, Fix Quality, DOP, DGPS status
- **GSA**: Active Satellites
- **GSV**: Satellites in view, Azimuth, Elevation, SNR
- **GST**: Estimated accuracy

# Proprietary Receiver Formats

- Most receivers can output RAW data in proprietary binary formats.
- Format depends on receiver module manufacturer.
  - u-blox: UBX
  - Septentrio: SBF
- Contains many additional information
  - GNSS Measurements: Pseudorange, Carrier Phase
  - Navigation messages for computing satellite positions
  - Computed position, satellite positions and signal strengths
- Can be streamed real time or recorded for post-processing
- Data format can be openly available or restricted depending on manufacturer
- Often mixed with NMEA data

# UBX Raw Data File

StaticData/F9P\_181215\_static.ubx

```
F9P_181215_static.ubx
1 $GNGSA,A,3,09,06,13,16,07,08,,,,,,,,,0.98,0.53,0.82,4*0C
2 $GPGSV,3,1,09,05,15,139,43,10,16,316,40,12,18,163,42,13,31,068,43,1*65
3 $GPGSV,3,2,09,15,64,040,49,20,43,310,46,21,31,256,44,24,82,257,51,1*6E
4 $GPGSV,3,3,09,28,07,036,33,1*55
5 $GPGSV,3,1,09,05,15,139,37,10,16,316,39,12,18,163,39,13,31,068,,6*64
6 $GPGSV,3,2,09,15,64,040,48,20,43,310,,21,31,256,,24,82,257,51,6*6A
7 $GPGSV,3,3,09,28,07,036,,6*52
8 $GLGSV,3,1,10,66,22,109,50,67,63,053,53,68,35,327,52,76,07,028,43,1*70
9 $GLGSV,3,2,10,77,65,053,49,78,53,186,55,79,04,201,34,83,09,272,38,1*76
10 $GLGSV,3,3,10,84,07,324,40,1*43
11 $GLGSV,3,1,09,66,22,109,47,67,63,053,53,68,35,327,50,76,07,028,,3*79
12 $GLGSV,3,2,09,77,65,053,48,78,53,186,53,79,04,201,,83,09,272,40,3*73
13 $GLGSV,3,3,09,84,07,324,43,3*4A
14 $GAGSV,2,1,07,03,35,307,45,05,71,031,47,09,30,098,44,15,13,289,38,7*70
15 $GAGSV,2,2,07,24,60,093,49,25,40,177,45,31,20,040,38,7*4F
16 $GAGSV,2,1,07,03,35,307,51,05,71,031,57,09,30,098,50,15,13,289,,2*7F
17 $GAGSV,2,2,07,24,60,093,55,25,40,177,52,31,20,040,46,2*48
18 $GBGSV,2,1,08,06,61,323,47,07,21,189,39,08,19,215,37,09,37,298,44,1*7F
19 $GBGSV,2,2,08,13,26,239,42,16,54,316,48,20,,46,22,,49,1*75
20 $GBGSV,2,1,06,06,61,323,51,07,21,189,44,08,19,215,43,09,37,298,47,3*7E
21 $GBGSV,2,2,06,13,26,239,43,16,54,316,49,3*74
22 ubSTXNAKpBSklçûKS AiBELDC2CSOHSOHCzHyðETXHTAðöGSOYšAfM ENULFFENULNULôû*ACKSTXBELBELNULENO(ê·éÛtAÏö,,f
23 NULNULôû+ENOSOHACKBELNUL-èhø+dqA`&QzÏÛ-A ÄÄÄNULSTINULNULôû1EOTSOHENOSTINULwfDC1 DEL;raEÛ>*÷6AbUS°DNUL
24 NULNULôû+ENOSOHACKBELNUL%|RS >%GeAbENO`ZÛ0¥AàK&ÄETXDLENULNULôû0EOTSOHENOBELNULDELËË-SItAq3«RGSšA»J-DË
25 ôû4BELSOHENOBELNUL/ätDD`tAPüéUS,k>AWu¥ÄACKFFENULACKôû,BELSOHACKBELNULŽvqÿ1ËpA+ÿ8ÄËSO-A#STX@ÄNULCANNUL
26 NULNULôû(ACKSTXBELBELNULDC4ÿpiùStAAjã.o[šAH;fÄSTXENONULNULôû0EOTSOHENOBELNUL,cSUB3ETX-AEÐ0ùmSOH$Afš
27 ôû&BELSTXBELBELNUL;w²7è[pAUpI8iö•AHDELDC2ÄACK
28 NULENOôû1BELSOHENOBELNUL`òtEOTz°tARíí!ø`>AðG+ÄACKDC4NUL ôû)BELSTXBELSTINULò3 ôÿtA\Gš;V- >A`ATEACKSTINUL
29 ;ZESA>`PJU%;Að³pÄETX STXNULôû/EOTSOHENOBELNULNAKqAw%GèAiDLEšÇxb Ad-NULÄETXDLESTXNULôû1ENOSOHACKSTI
30 STXNULôû+ENOSOHACKBELNULP`"äSTX-AÖ`ðdDC4Ë;ACAN>ETBÄETXBSSTXNULôû+ENOSOHACKBELNULªoADC2úStA-VIÏFS2"
31 ETXNULôû'ACKSTXBELBELNULôËN±éúT*A*StoETB)Y•A,sZÄNULENOETXNULôû%ACKSTXBELBELNUL`·ø1XúpAENOËOTSUBèIw'AJ
32 NAK4ÄACKSTXSTXETXôû/BELSOHENOBELNUL{UCANUè[pAK SOH-íeuAšPäÄACK
33 STXENOôû0BELSOHENOSTINUL-t 3z°tA;ÑDC1A.f•AèkRÄACKDC4STX ôû+BELSTXACKSTINUL¥:DC3GjppAD<,
34 SYN`AÄVHÄACKETXSTXFFôû5BELSOHEOTSTINUL+emèETXHTA;`FFESA"AfðUDNULFFETXNULôû&ACKSTXBELBELNULøxš8fžèAÈ!ç
35 Ìš6`Aii°DACKËOTSTX
36 ôû2BELSOHEOTSTINULDLB%StISOÏxtADELDC1-Óè)•A/ðöÄACKDC3STX
37 ôû(BELSTXBELBELNUL«òxÿ<tA$EMyE~o•A!•+ÄACKÿSTXSTXPF+BELSTXACKBELNUL<+ä×øÿtAääACKÿFF†•AšGS%BACKSI STXE
38 $GNGGA,043532.00,3539.98046,N,13947.53277,E,1,12,0.53,17.7,M,39.4,M,,*78
39 $GNGSA,A,3,12,05,13,15,20,21,24,10,,,,,0.98,0.53,0.82,1*0A
```

NMEA

u-blox Binary Data

# RINEX: Receiver Independent Exchange Format

- Exchange format for raw satellite data among different types of receivers.
- Used to process data from receivers made by different manufacturers
- Contains raw satellite data (Pseudorange, Carrier phase, Doppler, satellite orbits). **No position data.**
- Two types of files in common use
  - Observation File (\*.yyO, \*.obs): Contains measurements
  - Navigation File(\*.yyP, \*.yyN, \*.nav): Contains satellite orbits
- **Frequently used for post-processing GNSS data**



# RINEX 3 Mixed Observation File

3.03 OBSERVATION DATA M: Mixed										RINEX VERSION / TYPE								
CONVBIN 2.4.3										20230803 115345 UTC PGM / RUN BY / DATE								
log: C:\Users\Avinab\Desktop\KHCE2031.23_\KHCE2031.23_.sbf										COMMENT								
format: Septentrio										COMMENT								
SW_GNSS										COMMENT								
										MARKER NAME								
										MARKER NUMBER								
										MARKER TYPE								
										OBSERVER / AGENCY								
										REC # / TYPE / VERS								
										ANT # / TYPE								
AS-ANT3BCAL NONE										APPROX POSITION XYZ								
449569.1885 5636017.8254 2944823.2195										ANTENNA: DELTA H/E/N								
0.0000 0.0000 0.0000																		
G	16	C1C	L1C	D1C	S1C	C2L	L2L	D2L	S2L	C2W	L2W	D2W	S2W	C5Q	SYS / # / OBS TYPES			
			L5Q	D5Q	S5Q										SYS / # / OBS TYPES			
R	16	C1C	L1C	D1C	S1C	C2C	L2C	D2C	S2C	C2P	L2P	D2P	S2P	C3Q	SYS / # / OBS TYPES			
			L3Q	D3Q	S3Q										SYS / # / OBS TYPES			
E	8	C1C	L1C	D1C	S1C	C5Q	L5Q	D5Q	S5Q						SYS / # / OBS TYPES			
S	8	C1C	L1C	D1C	S1C	C5I	L5I	D5I	S5I						SYS / # / OBS TYPES			
C	8	C2C	L2C	D2C	S2C	C2I	L2I	D2I	S2I						SYS / # / OBS TYPES			
	2023	7	22	0	0	0.0000000				GPS					TIME OF FIRST OBS			
	2023	7	22	5	59	59.0000000				GPS					TIME OF LAST OBS			
G															SYS / PHASE SHIFT			
R															SYS / PHASE SHIFT			
E															SYS / PHASE SHIFT			
S															SYS / PHASE SHIFT			
C															SYS / PHASE SHIFT			
	18	R04	6	R05	1	R06	-4	R07	5	R08	6	R09	-2	R10	-7	R11	0	GLONASS SLOT / FRQ #
		R12	-1	R13	-2	R15	0	R16	-1	R18	-3	R19	3	R20	2	R21	4	GLONASS SLOT / FRQ #
		R22	-3	R23	3													GLONASS SLOT / FRQ #
	C1C	0.000	C1P	0.000	C2C	0.000	C2P	0.000										GLONASS COD/PHS/BIS
										END OF HEADER								
483.417 44.250																		
S30	39389252.514	206992103.641													40.750	39389253.193	154571888.980	-377.054
S28	36702013.211	192870457.300													47.750	36701995.011	144026507.278	-394.502
G17	21414175.637	112532259.153													47.250			
G 3	24059998.552	126436109.957													39.750			
G11	23791332.429	125024277.314													41.750			
C 7																36878523.707	192036398.517	-404.218
G24	23690454.865	124494190.437													39.750			
S26	37296012.507	195992311.753													42.500	37295982.385	146357447.388	-337.235
E21	27420390.229	144095141.986													38.250	27420396.208	107603551.307	1347.334
G30	23603455.671	124037040.513													40.500			
R10	22996441.158	122583967.377													41.250			
G 6	20500680.759	107731792.914													49.000			
C16																40467005.660	210722315.873	-2013.407

# RINEX Navigation File

```
2.11 NAVIGATION DATA GPS (GPS) RINEX VERSION / TYPE
cnvtToRINEX 2.90.0 convertToRINEX OPR 05-Jul-17 03:38 UTC PGM / RUN BY / DATE
----- COMMENT
0.8382D-08 0.2235D-07 -0.5960D-07 -0.1192D-06 ION ALPHA
0.8602D+05 0.6554D+05 -0.1311D+06 -0.4588D+06 ION BETA
-0.931322574615D-09-0.355271367880D-14 405504 1947 DELTA-UTC: A0,A1,T,W
18 LEAP SECONDS
END OF HEADER
32 17 05 01 00 00 0.0-0.400723423809D-03-0.110276232590D-10 0.000000000000D+00
0.370000000000D+02-0.806250000000D+01 0.455840416154D-08-0.192420920137D+01
-0.353902578354D-06 0.111064908560D-02 0.826455652714D-05 0.515371503258D+04
0.864000000000D+05-0.782310962677D-07 0.675647076441D-01-0.838190317154D-07
0.958529124300D+00 0.221156250000D+03-0.265074890978D+01-0.796390315710D-08
-0.389659088008D-09 0.100000000000D+01 0.194700000000D+04 0.000000000000D+00
0.240000000000D+01 0.000000000000D+00 0.465661287308D-09 0.370000000000D+02
0.795120000000D+05 0.400000000000D+01 0.000000000000D+00 0.000000000000D+00
24 17 05 01 00 00 0.0-0.341213308275D-04-0.454747350886D-12 0.000000000000D+00
0.100000000000D+02 0.787812500000D+02 0.459340561950D-08 0.167267059468D+01
0.404566526413D-05 0.564297637902D-02 0.102464109659D-04 0.515370226479D+04
0.864000000000D+05-0.782310962677D-07 0.108986675687D+01 0.484287738800D-07
0.945651423640D+00 0.170906250000D+03 0.490563049326D+00-0.815641117584D-08
-0.128933942045D-09 0.100000000000D+01 0.194700000000D+04 0.000000000000D+00
0.240000000000D+01 0.000000000000D+00 0.279396772385D-08 0.100000000000D+02
0.792180000000D+05 0.400000000000D+01 0.000000000000D+00 0.000000000000D+00
```

# RTCM : Radio Technical Commission for Maritime Services

- An internationally accepted data transmission standard for base-station data transmission
- The standards are defined and maintained by RTCM SC-104.
- Provides **GNSS Raw Data** in compressed format that can be used as **DGPS or RTK Corrections**
- Output by GNSS Base stations, must be transmitted to rover device in real-time for RTK.

# RTCM 3 Message Types

- MT 1-100 : Experimental Messages
- MT 1001 –1230 : GNSS Messages
- MT 4001 –4095 : Proprietary Messages

## RTCM 3.0 Messages

- GPS L1 MT: 1001, 1002
- GPS L1/L2 MT: 1003, 1004
- GLONASS L1 MT: 1009, 1010
- GLONASS L1/L2 MT: 1011, 1012
- Station Coordinates MT: 1005,1006
- Antenna Description MT: 1007,1008

## RTCM 3.2 Multi Signal Messages

- Developed to support new constellations and frequencies
- MSM1 to MSM7 messages defined to provide different levels of raw data

## Commonly used MSM messages

- MSM1: Pseudorange DGNSS
- MSM4: RTK
- MSM5: Full RINEX data
- MSM7: Full RINEX data with extended resolution

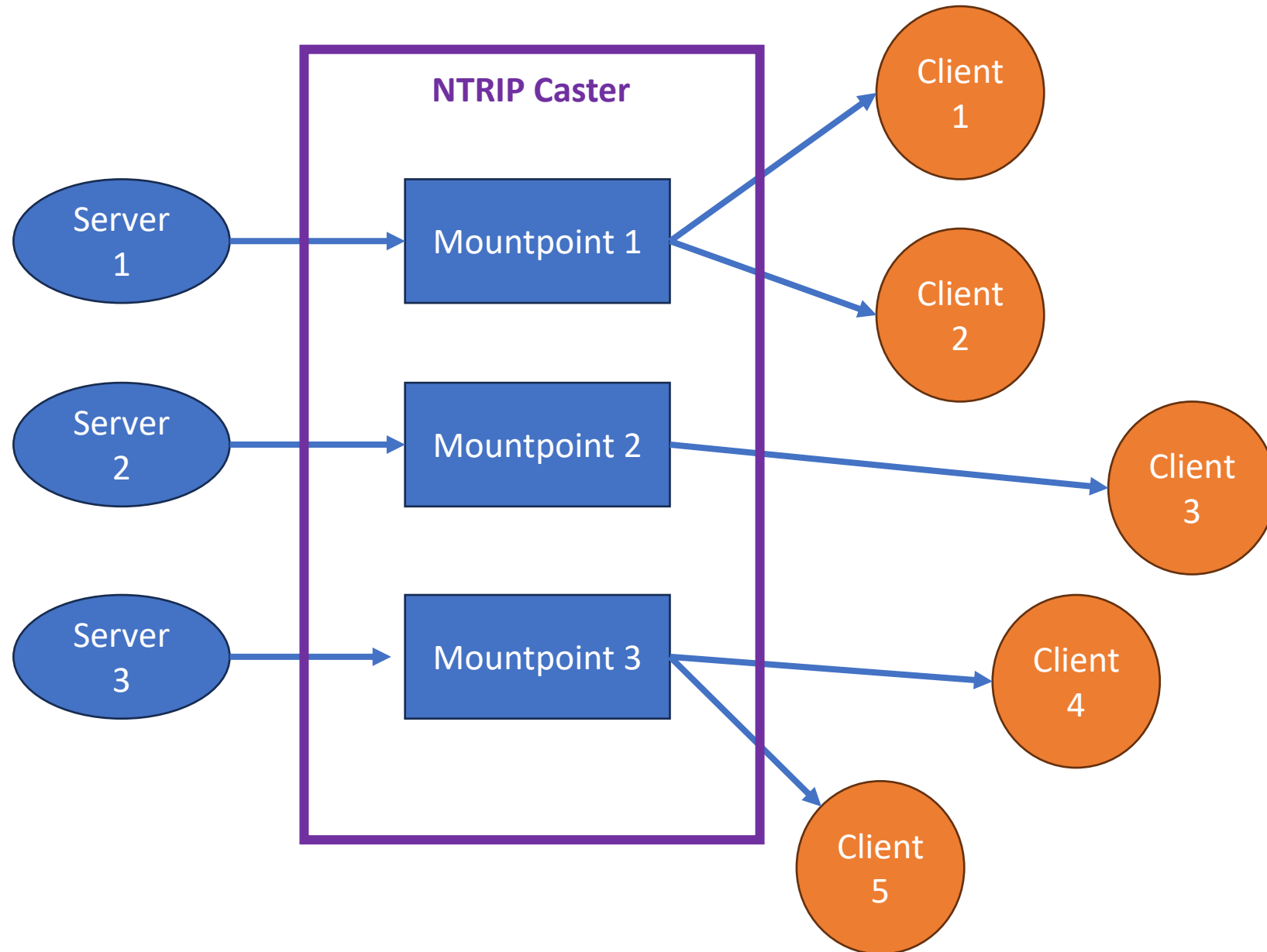
MSM may not be supported by all receivers.

# NTRIP

*How to distribute correction data from base stations to rovers?*

- **Networked Transport of RTCM via Internet Protocol**
- A protocol used to distribute GNSS data streams, commonly used to distribute corrections in RTCM format.
- Contains three components
  - Caster: Internet server that receives data and broadcasts to clients
  - Client: User who takes and applies correction to get high accuracy positioning (RTK Rover)
  - Server: Base station/CORS receiver that generates and transmits corrections to the caster.
- A caster can have many mountpoints.
- Each mountpoint has one base station (server) and multiple rovers (clients).

# NTRIP



# Accessing Data from NTRIP Caster

## NTRIP Clients

- GNSS receivers with built-in cellular device (SIM Card)
- Computer Programs (RTKLIB, u-center, MAD-WIN)
- Mobile Applications: RTKDROID, MADROID, SW Maps...
- RTK Drone Remote Controllers

## What you need

- **Caster Address**: Domain name or IP Address
- **Caster Port**: Usually 2101
- **Mount Point Name**
- **Username and Password**

# RTKLIB: Introduction

- RTKLIB is an open source program package for standard and precise positioning with GNSS.
- Contains several windows applications and command line tools for GNSS data collection and processing.

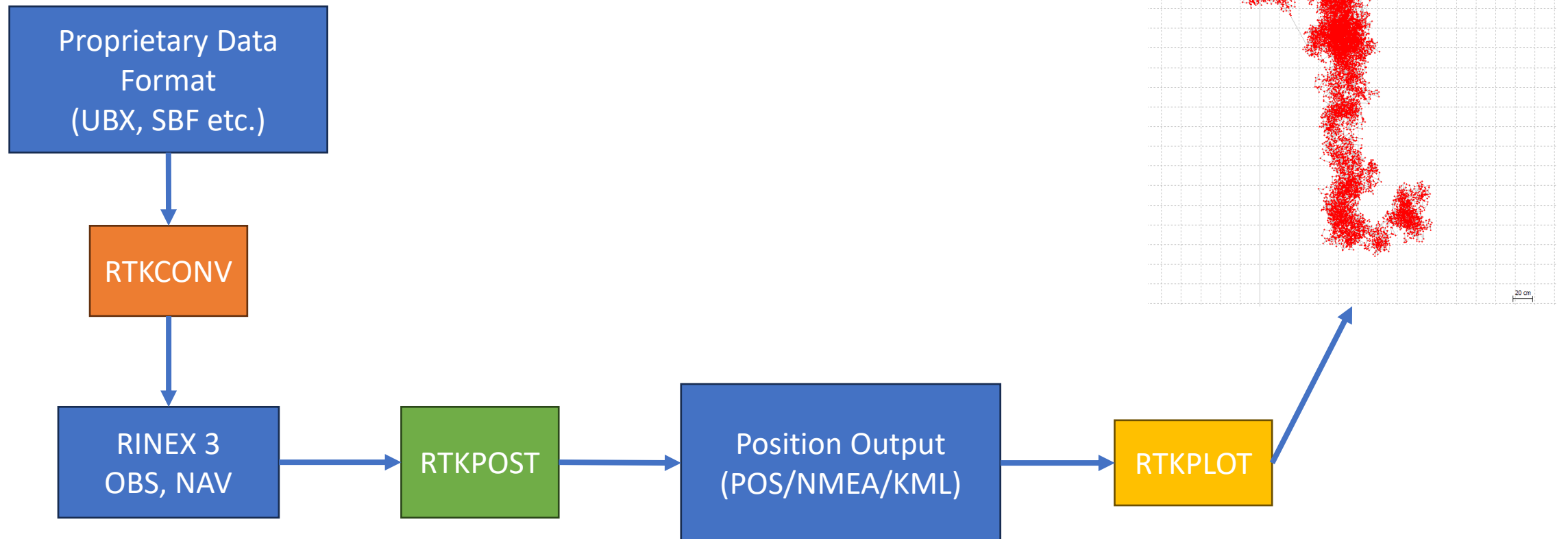
## Useful tools:

- [strsvr.exe](#): communication server, connect to receivers/NTRIP and log/retransmit data
- [rtkconv.exe](#): Convert proprietary receiver raw data to RINEX
- [rtkpost.exe](#): Post-process GNSS data
- [rtknavi.exe](#): Real time processing of GNSS data (RTK)
- [rtkplot.exe](#): Plotting and visualization tool



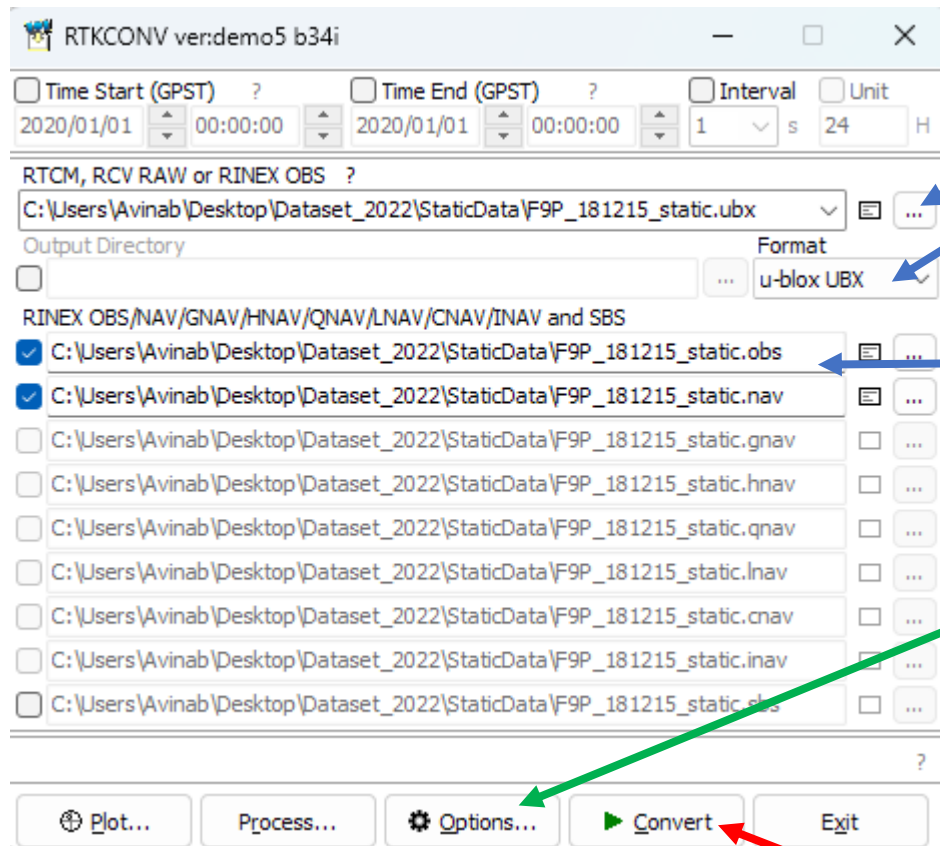
# Data Conversion and Processing using RTKLIB

## Single Point Positioning



# Convert RAW to RINEX

Use Data from [StaticFiles/F9P\\_181215\\_static.ubx](#)



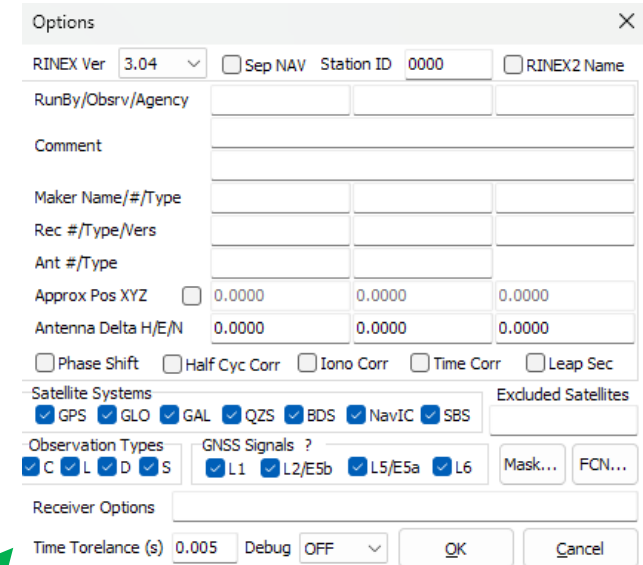
1. Select File

2. Select Format (UBX)

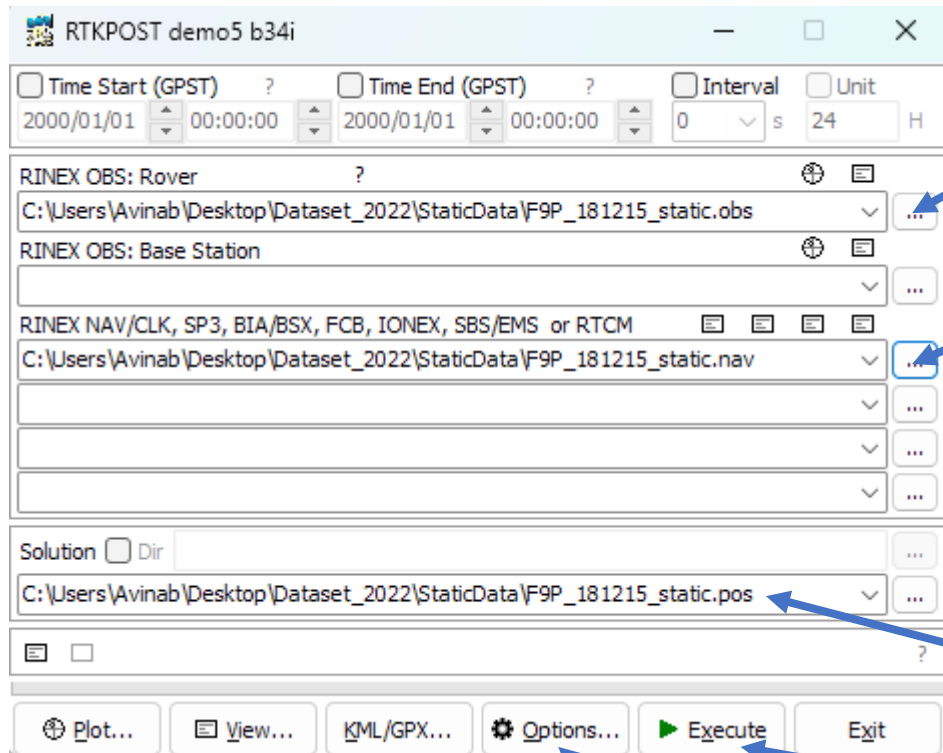
3. Output File Names

4. Conversion Options

5. Start Conversion



# Single Point Positioning using RTKPOST



1. Select Rover OBS File

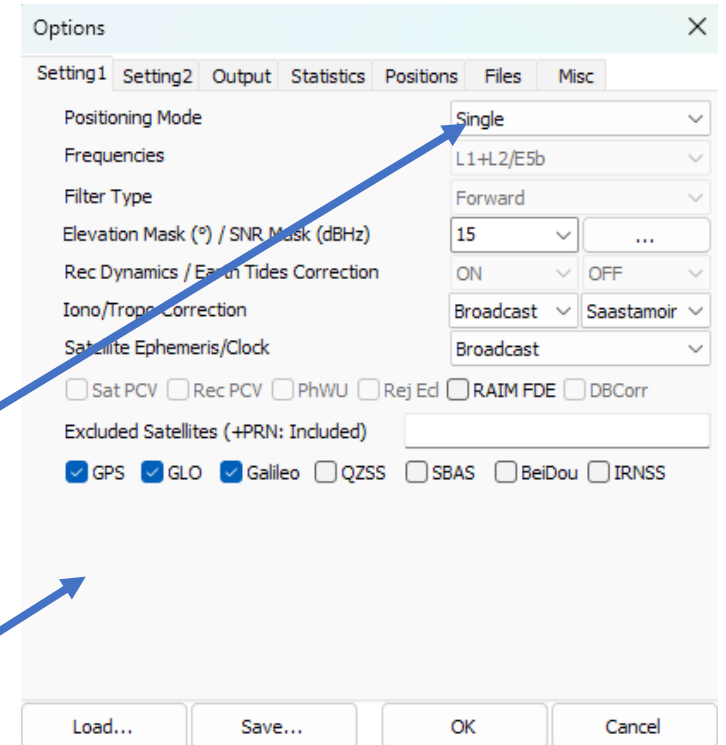
2. Select Rover NAV File

4. Single Positioning Mode

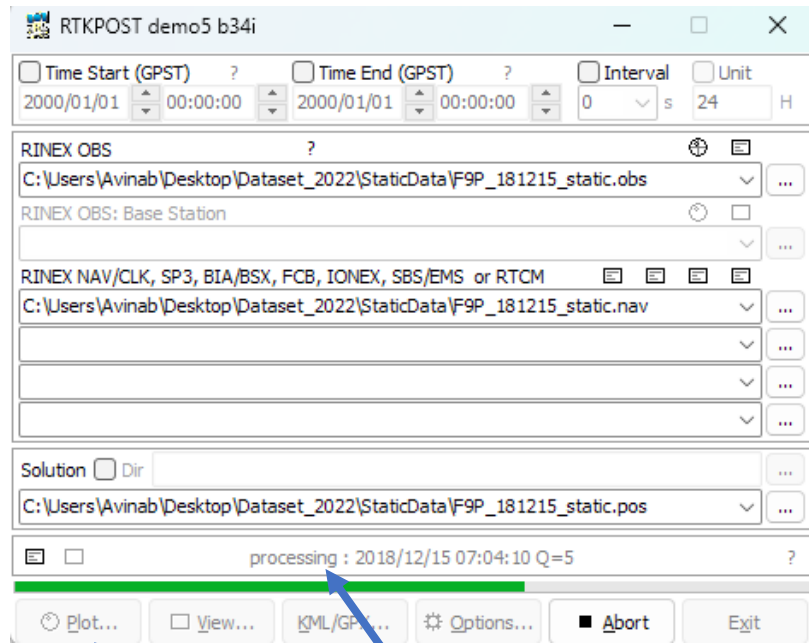
5. Solution Output File

6. Execute

3. Setup Processing Options

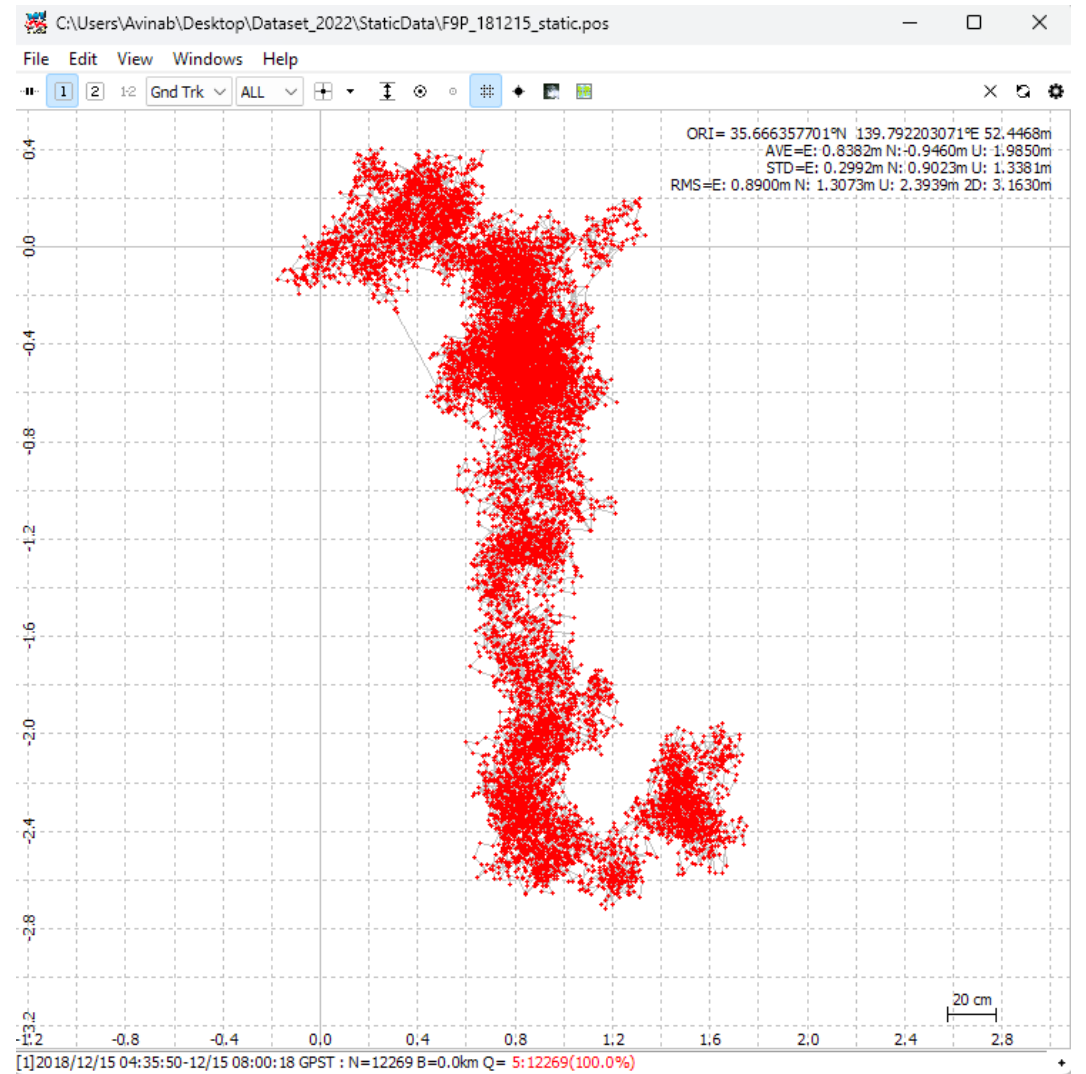


# Plotting using RTKPLOT



Processing Status Display

Open results in RTKPLOT



RTKPLOT (20cm Grid)