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

Talker ID (GN: GNSS, GP: GPS, GL: GLONASS…)

Message Type

Message Contents

Checksum

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

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
AS-ANT3BCAL          NONE                                   ANT # / TYPE
   449569.1885  5636017.8254  2944823.2195                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
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        -504.955          40.750    39389253.193   154571888.980        -377.054
S28  36702013.211   192870457.300        -528.324          47.750    36701995.011   144026507.278        -394.502
G17  21414175.637   112532259.153       -1689.313          47.250
G 3  24059998.552   126436109.957        -379.324          39.750
G11  23791332.429   125024277.314        2951.958          41.750
C 7                                                                  36878523.707   192036398.517        -404.218
G24  23690454.865   124494190.437        1434.931          39.750
S26  37296012.507   195992311.753        -451.695          42.500    37295982.385   146357447.388        -337.235
E21  27420390.229   144095141.986        1804.194          38.250    27420396.208   107603551.307        1347.334
G30  23603455.671   124037040.513       -4096.287          40.500
R10  22996441.158   122583967.377        3391.887          41.250
G 6  20500680.759   107731792.914        1116.599          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

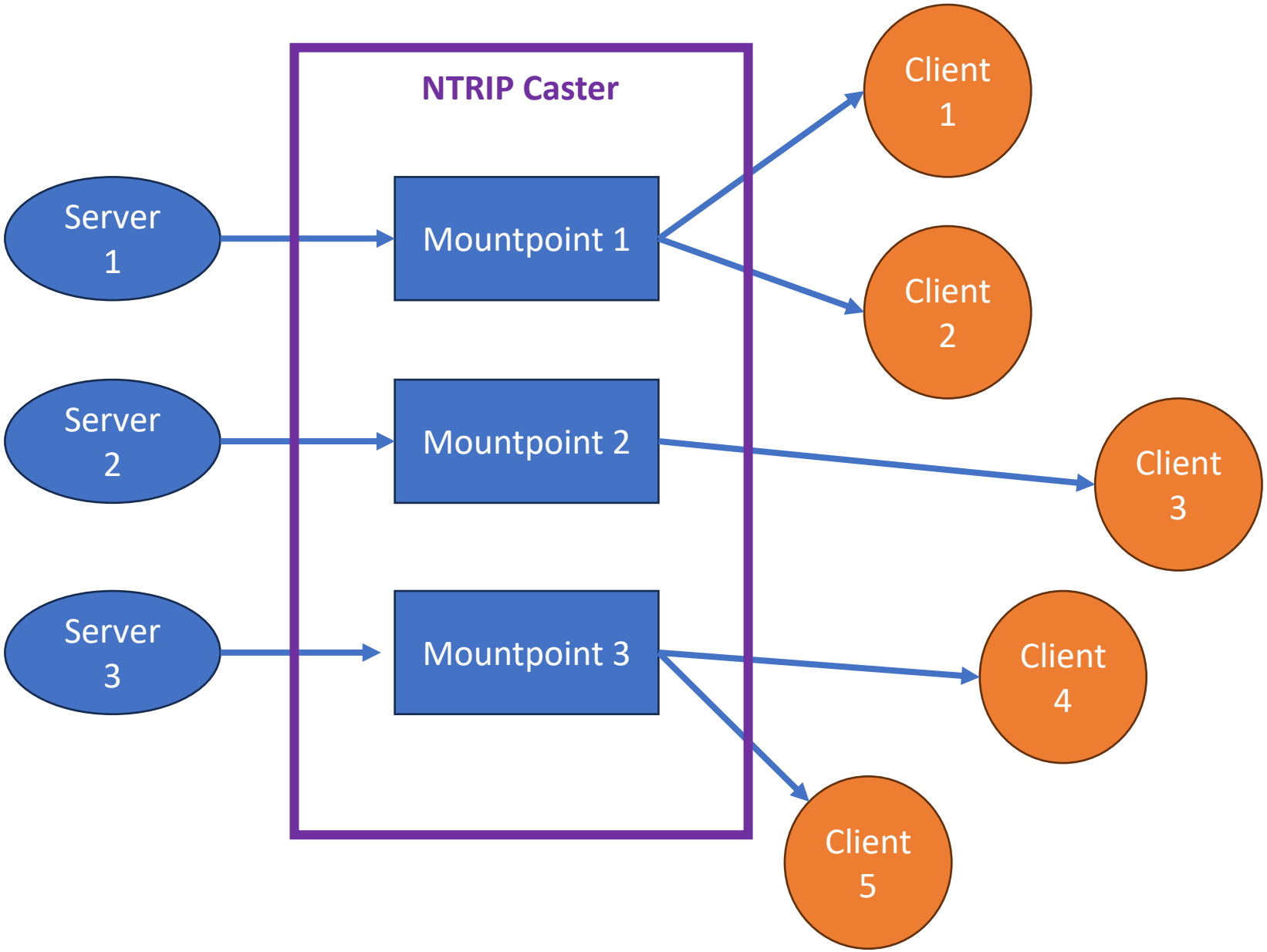
How to distribute correction data from base stations to rovers?

- **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


NTRIP Caster
Server 1
Server 2
Server 3
Mountpoint 1
Mountpoint 2
Mountpoint 3
Client 1
Client 2
Client 3
Client 4
Client 5

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.

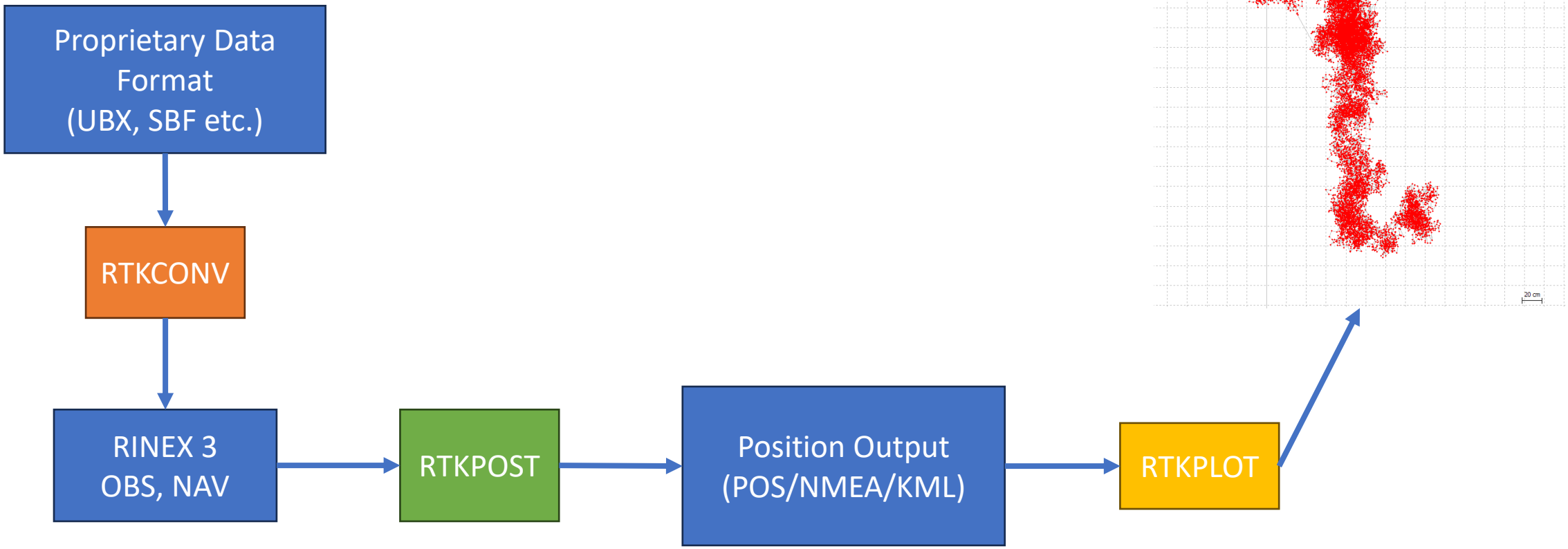
- Contains several windows applications and command line tools for GNSS data collection and processing.

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

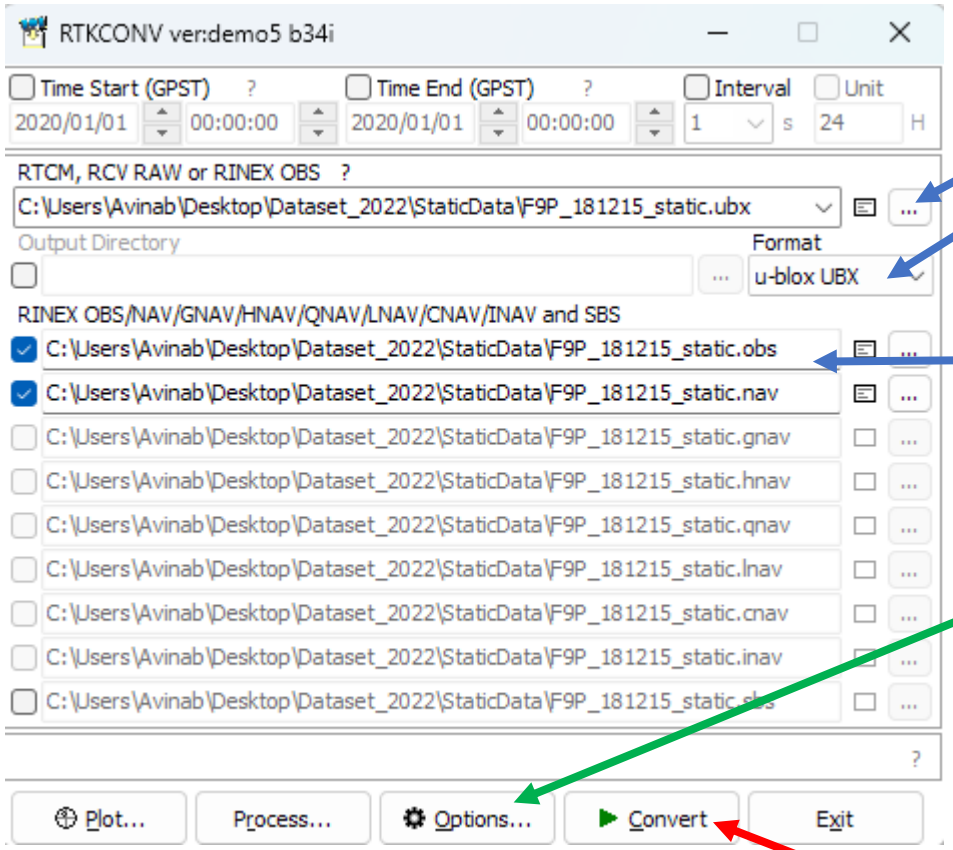
Data Conversion and Processing using RTKLIB

Single Point Positioning



Convert RAW to RINEX

Use Data from StaticFiles/F9P_181215_static.ubx



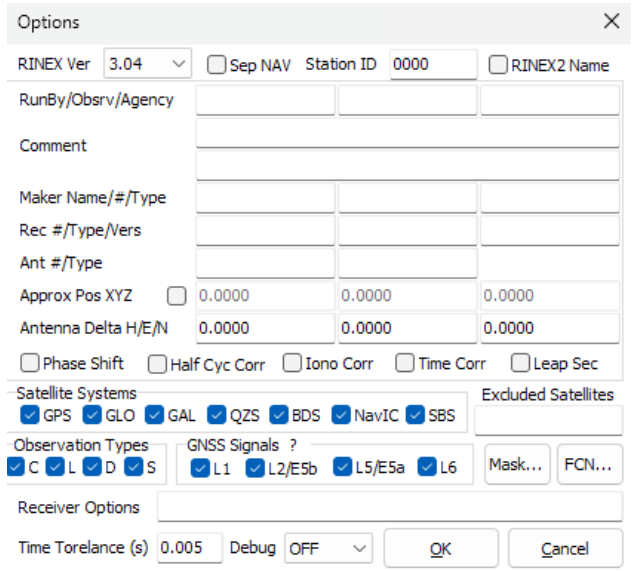
1. Select File

2. Select Format (UBX)

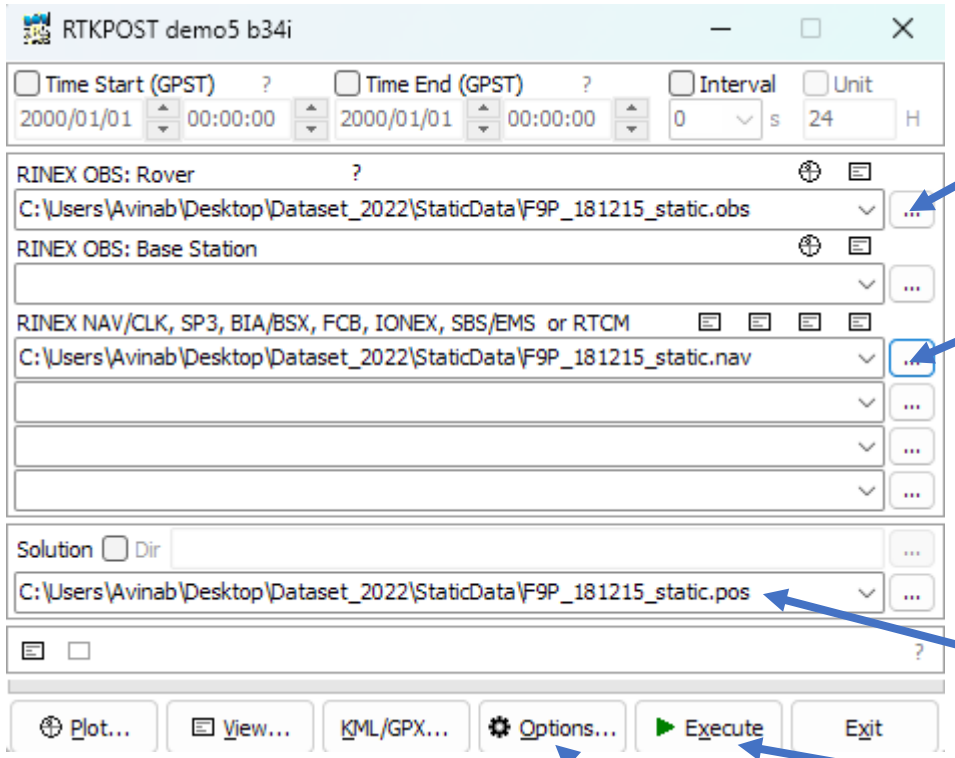
3. Output File Names

4. Conversion Options

5. Start Conversion



Single Point Positioning using RTKPOST



1. Select Rover OBS File

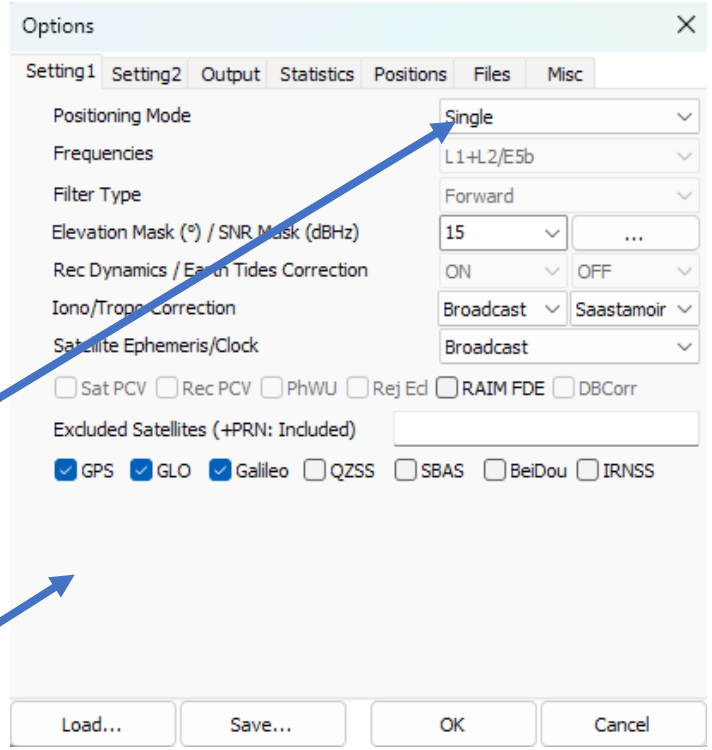
2. Select Rover NAV File

4. Single Positioning Mode

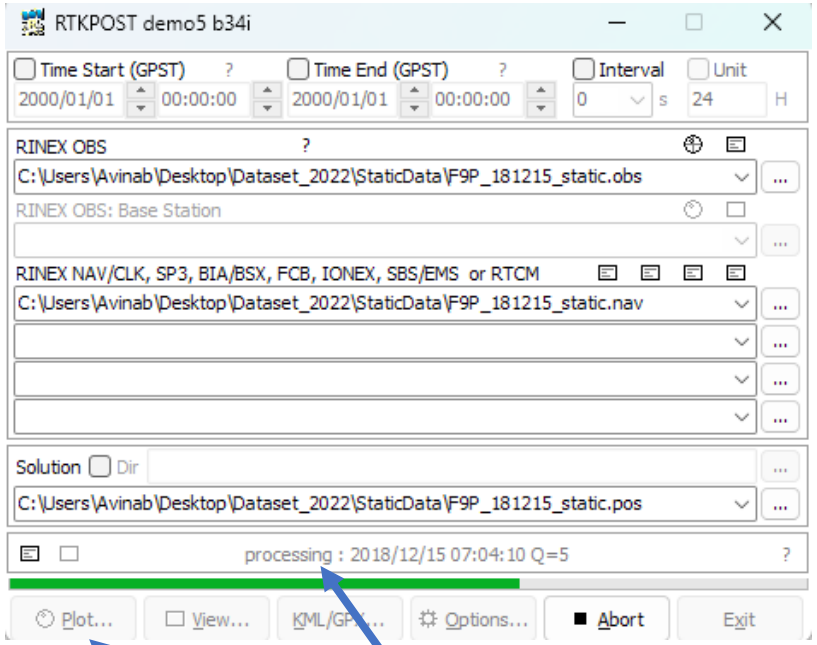
5. Solution Output File

6. Execute

3. Setup Processing Options

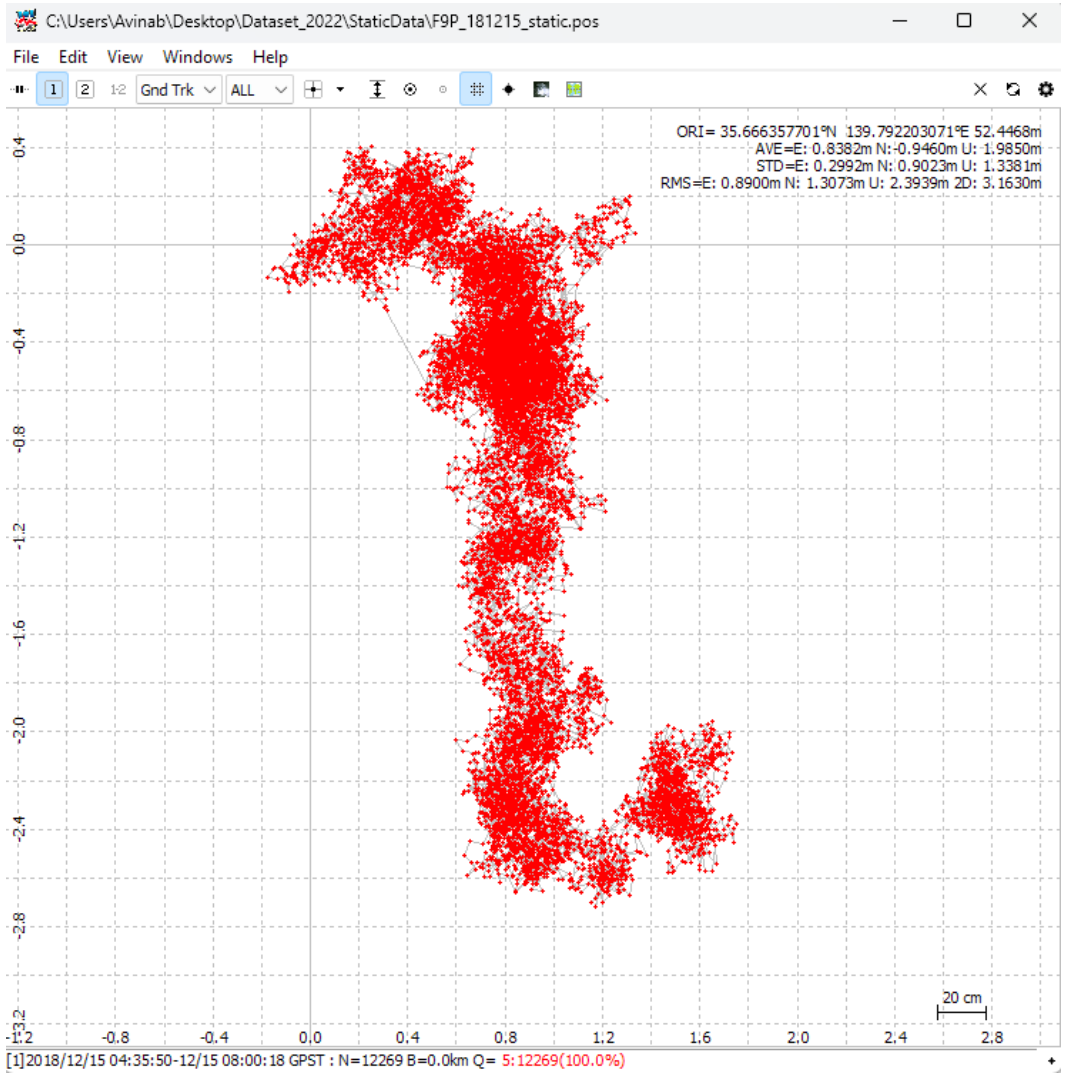


Plotting using RTKPLOT



Processing Status Display

Open results in RTKPLOT



RTKPLOT (20cm Grid)