

January 29, 2025

INTRODUCTION OF MALIB OPEN-SOURCE MADOCA-PPP SOFTWARE

Japan Aerospace Exploration Agency (JAXA)
Satellite Navigation Unit
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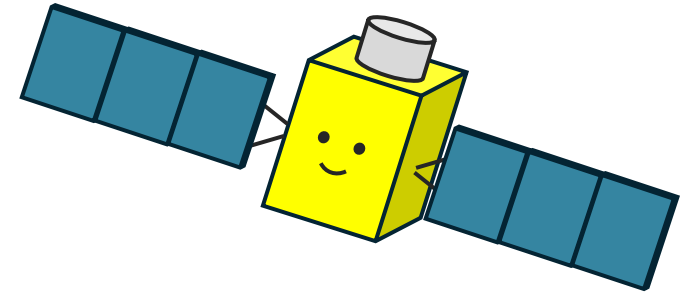
Today's Agenda

Agenda

1. Introduction | What is MALIB and MADOCA-PPP
2. PPP software | RTKLIB and MALIB
3. How to use | Quick setup of MALIB
4. Example | Use case of MALIB

Output

- ✓ Understanding MADOCA PPP fundamentals
- ✓ Installing and operating MALIB software & Executing PPP positioning
- ✓ Exploring real-world applications





1. Transportation

- Intelligent Transport Systems
- Public Transport Monitoring
- Aviation / Drone
- Marine
- Toll Charge



© RESILIENT NAVIGATION and TIMING FORUNDATION

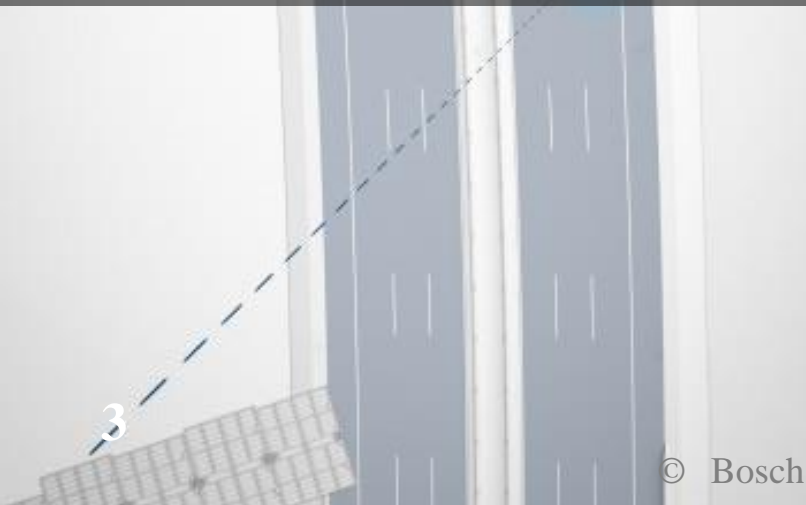
2. Timing Application

- Internet
- Financial Institutes
- Power Grids



4. Precise Agriculture

- Smart track
- Drone



3

© Bosch



3. Logistics

- Management and Monitoring
- Tracking

© septentrio



5. Emergency

- Location beacon
- Tsunami / Earthquake / Landslide

© GALILE GNSS

GNSS Positioning methods

Single

1 receiver
Code range
Precise : ~10 m

Differential GPS

2 receiver (differential)
Code range
Precise : 2-3 m

PPP (MADOCA)

1 receiver
Phase range
Precise :
30 cm~a few cm

Real-Time Kinematic

2 receiver (differential)
Phase range
Precise : a few cm

Easy to handle

Accuracy

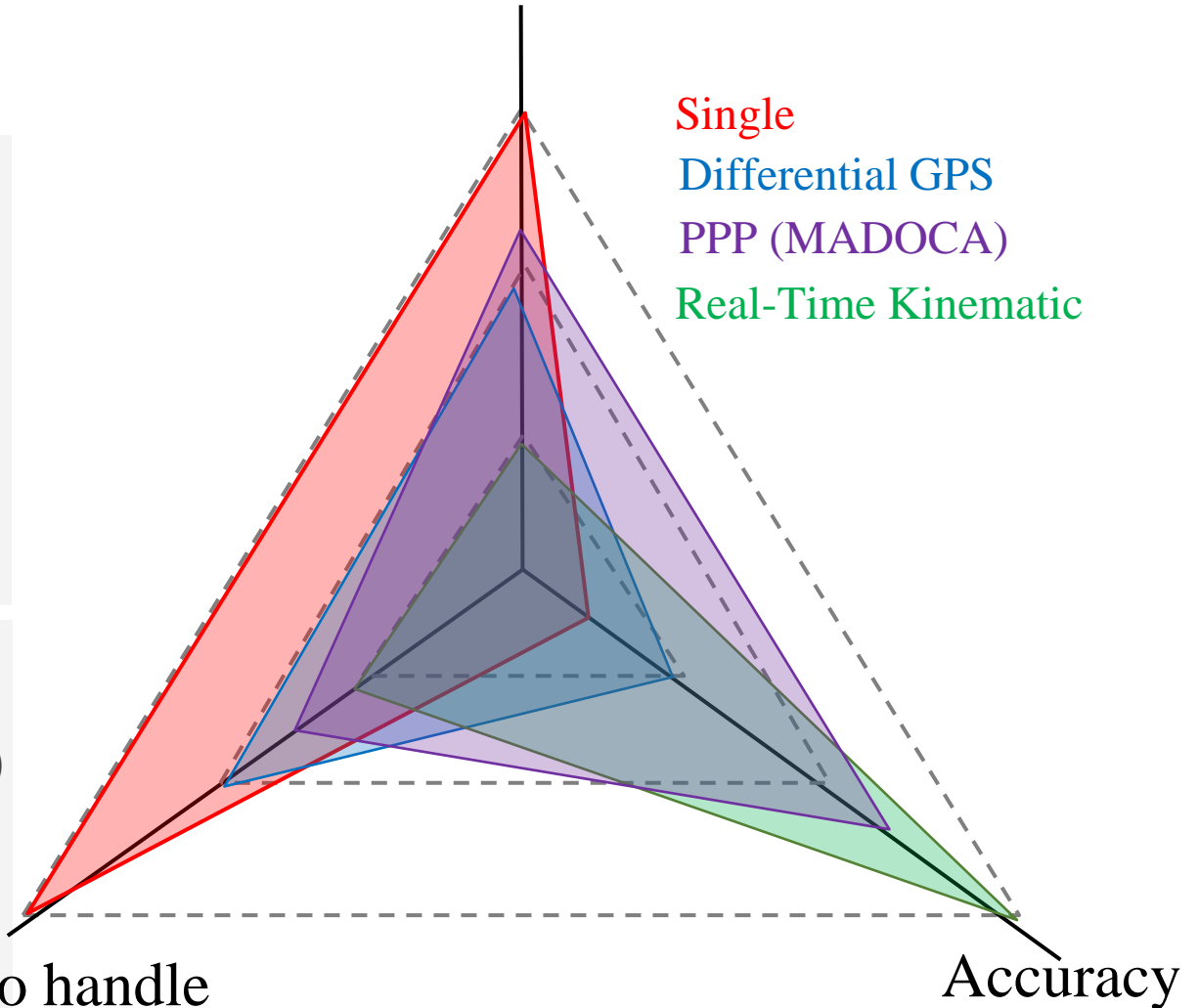
Cost

Single

Differential GPS

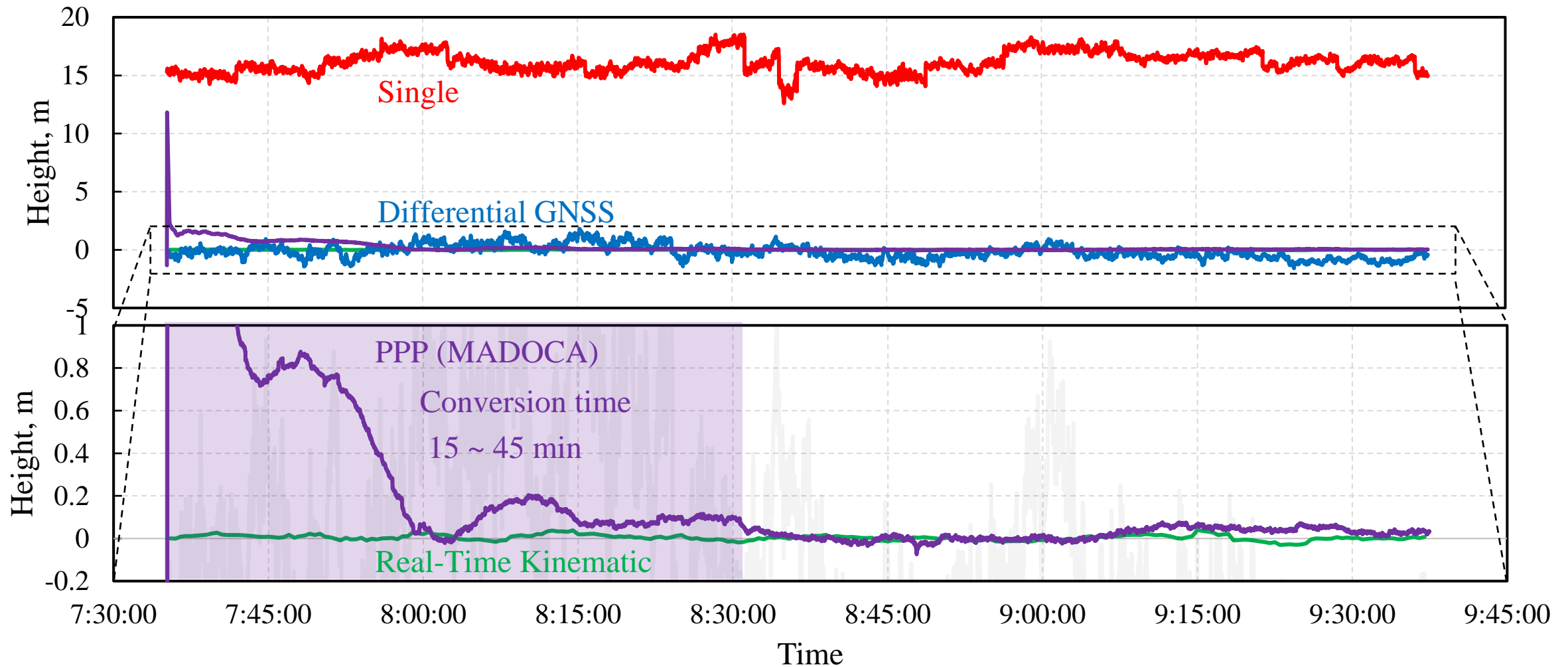
PPP (MADOCA)

Real-Time Kinematic



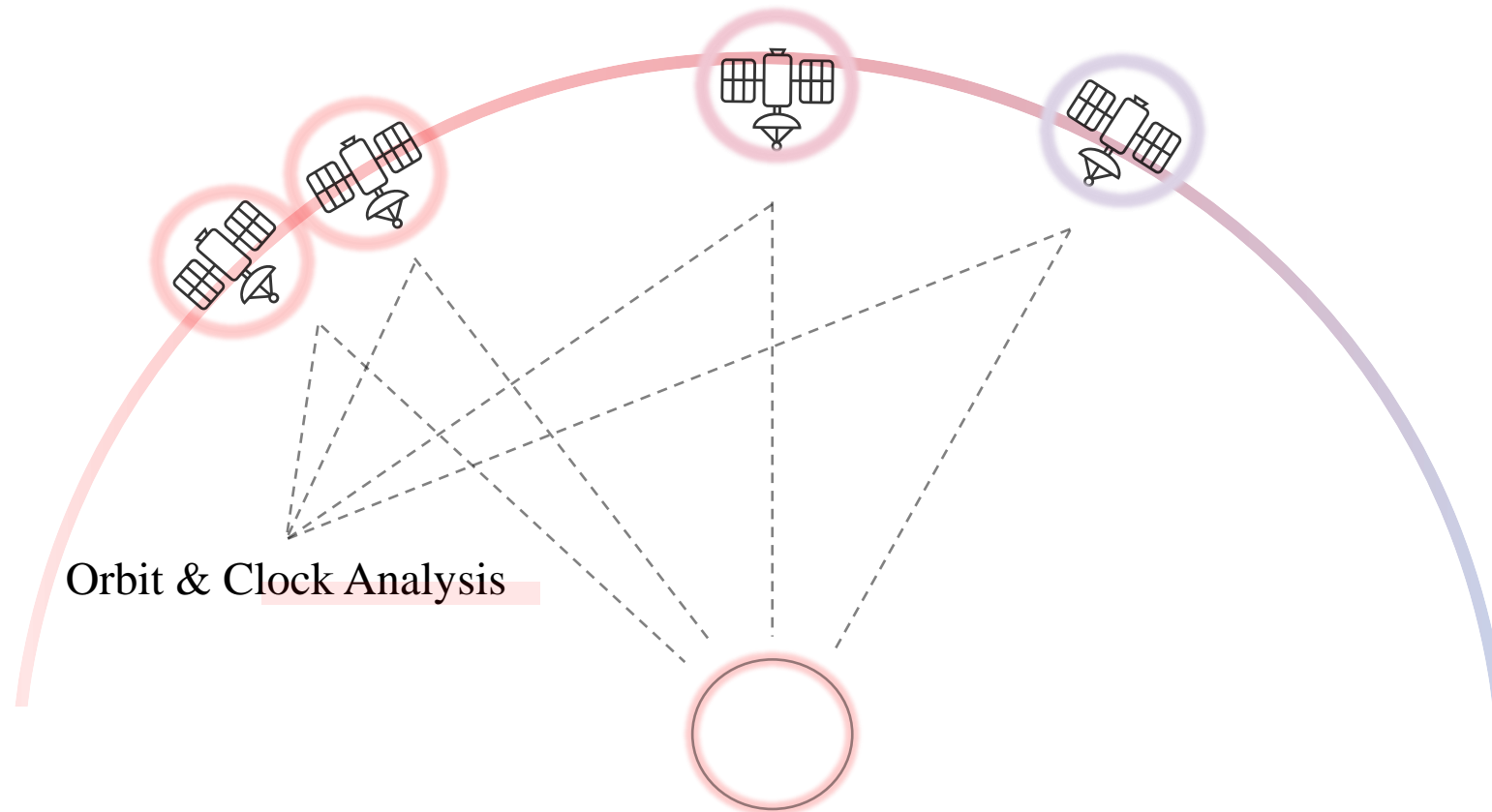
Comparison of GNSS Positioning

Single / Differential GNSS / PPP / RTK



What is MADOCA

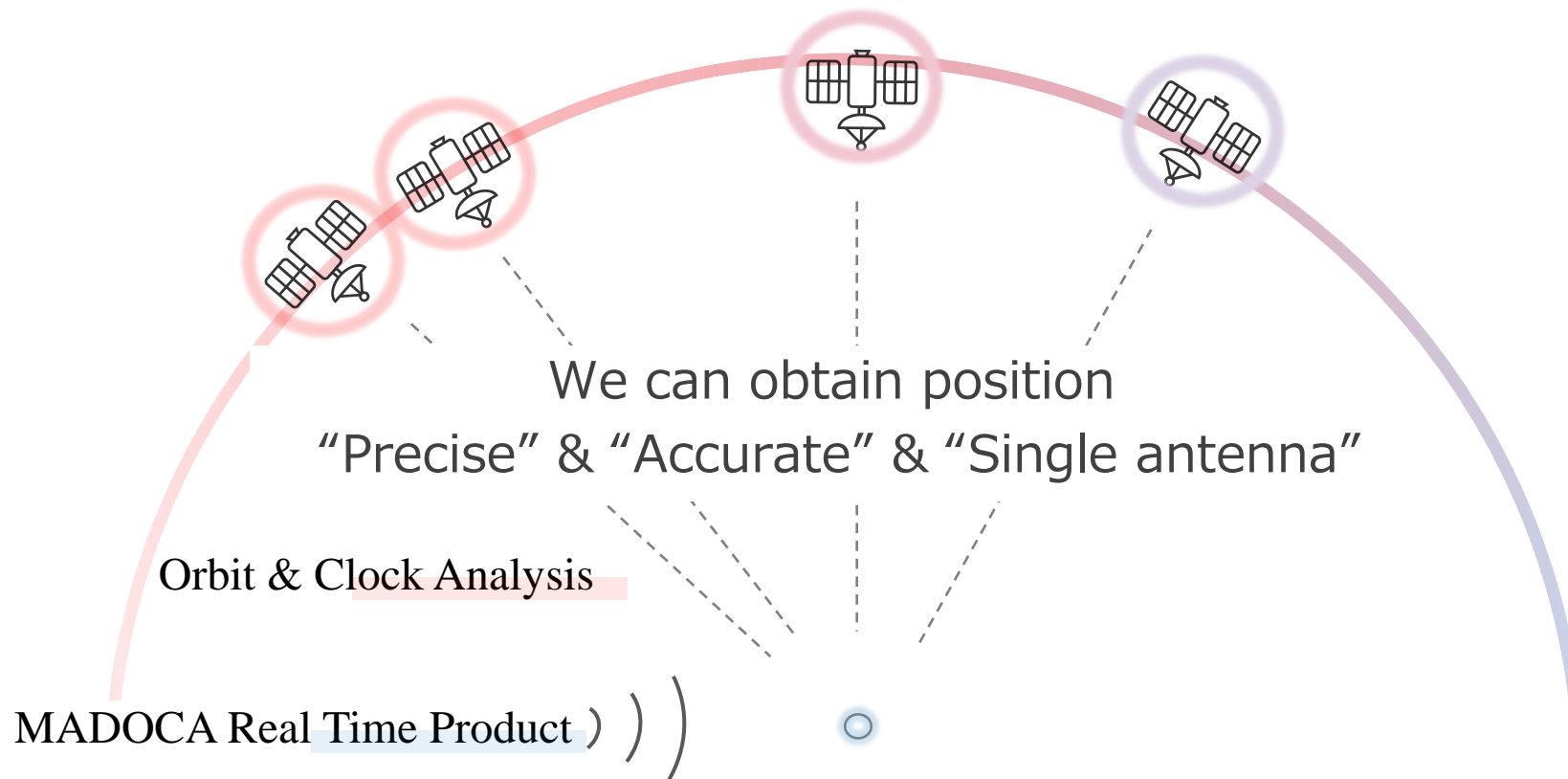
MADOCA : **M**ulti-GNSS **A**dvanced **O**rbit and **C**lock **A**ugmentation



What is MADOCA-PPP

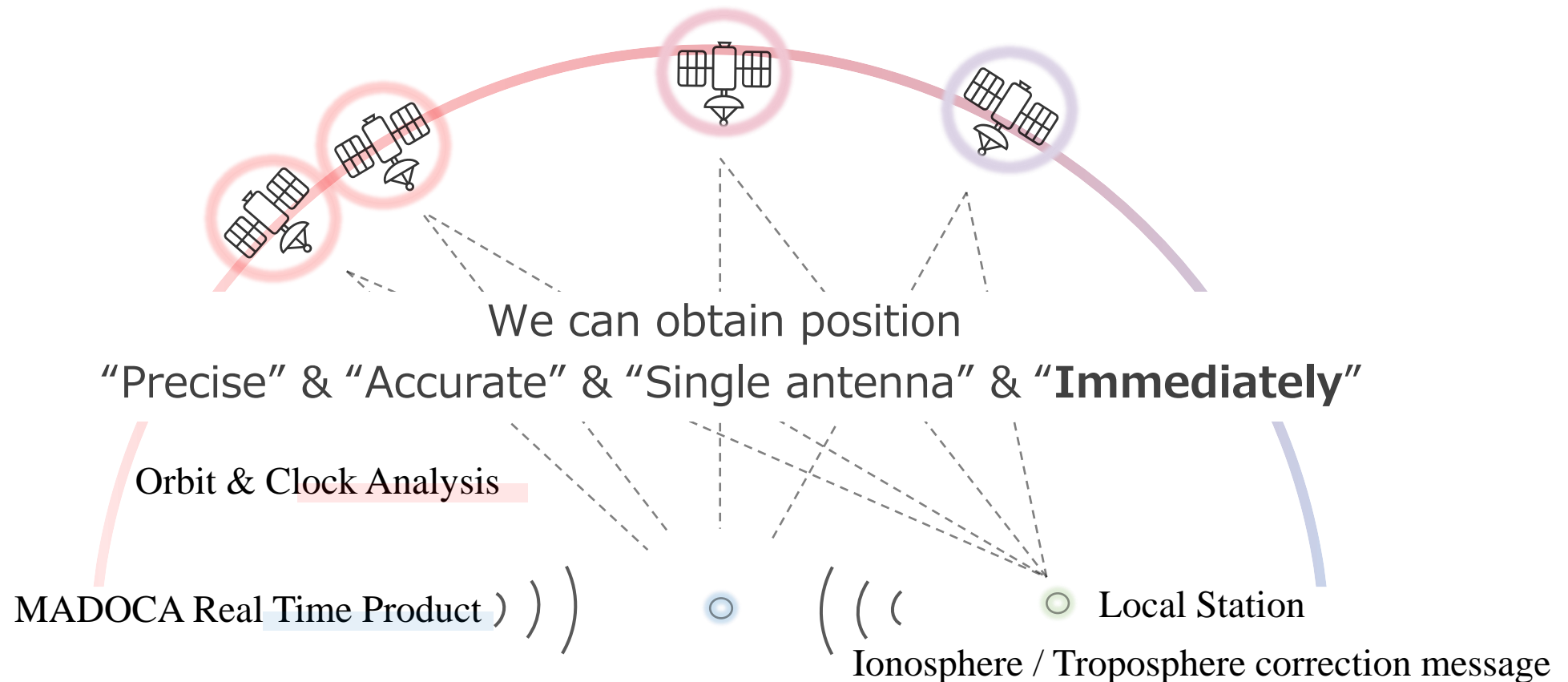
MADOCA : **M**ulti-GNSS **A**dvanced **D**emonstration tool for **O**rbit and **C**lock **A**nalysis

PPP : **P**recise **P**oint **P**ositioning



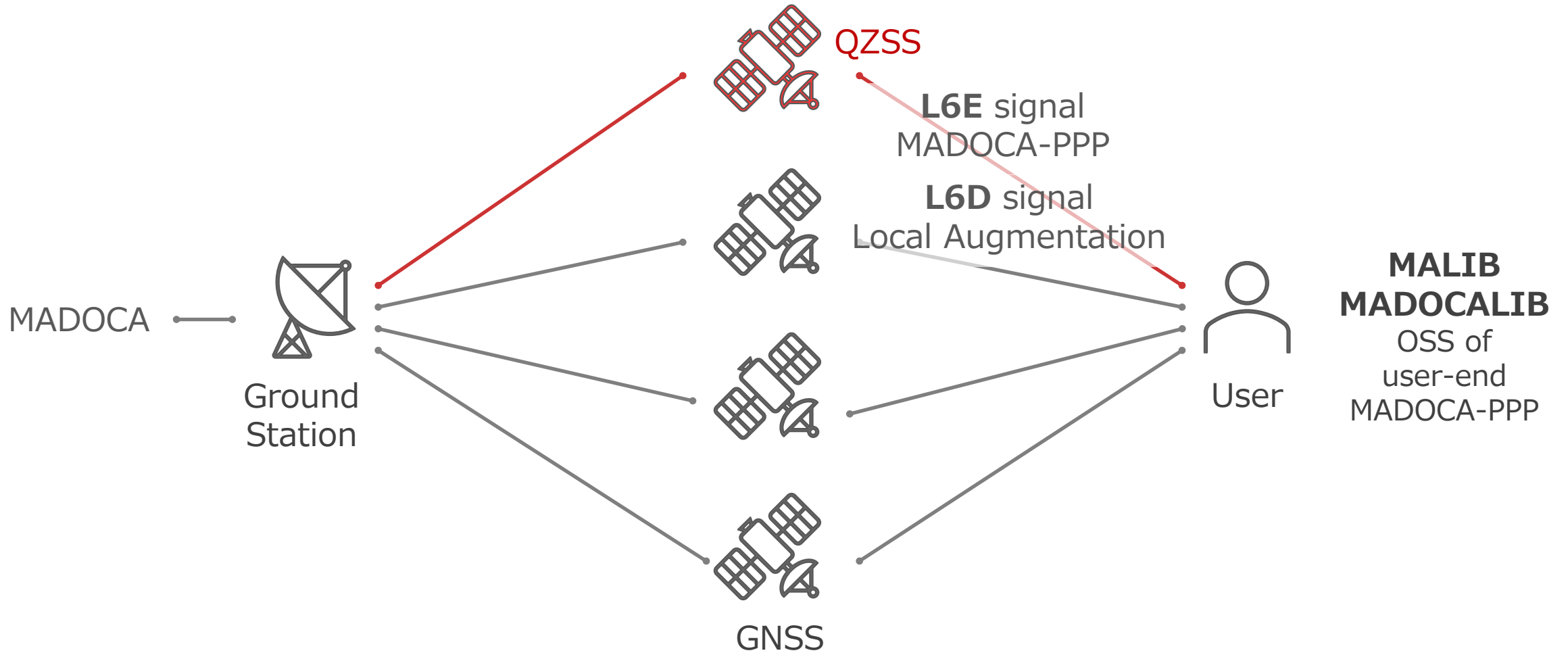
MADOCA-PPP local augmentation

Initial convergence time and **TTFF** (Time To First Fix) can be saved estimating ionosphere/troposphere error by using Local station



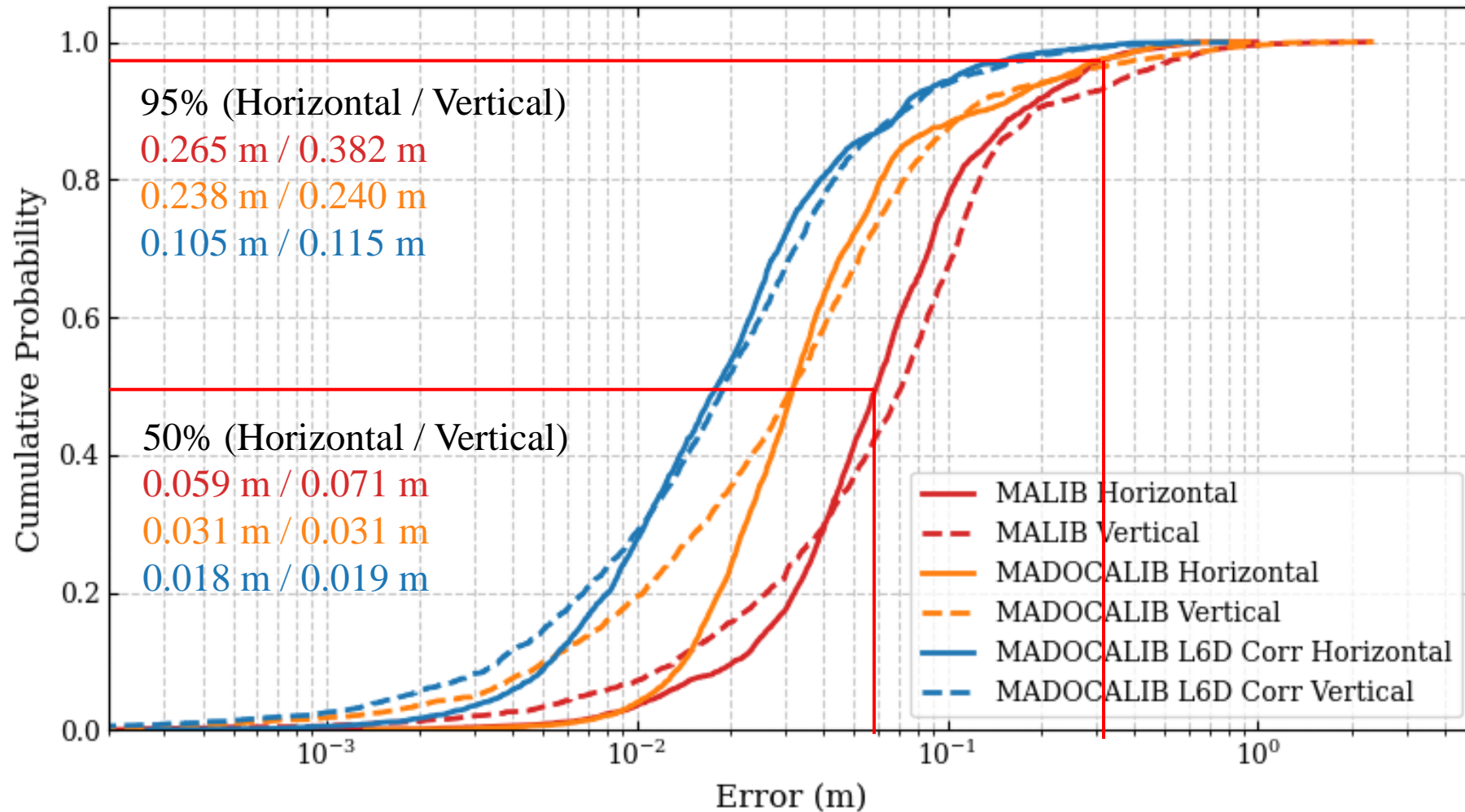
Overview of MADOCA & MALIB

MALIB : User-end MADOCA-PPP software



Error Distribution of MALIB / MADOCALIB

CAO MADOCALIB Sample data (Tsukuba-2, 24 hour (divided 1 hour & execute), Open-sky)



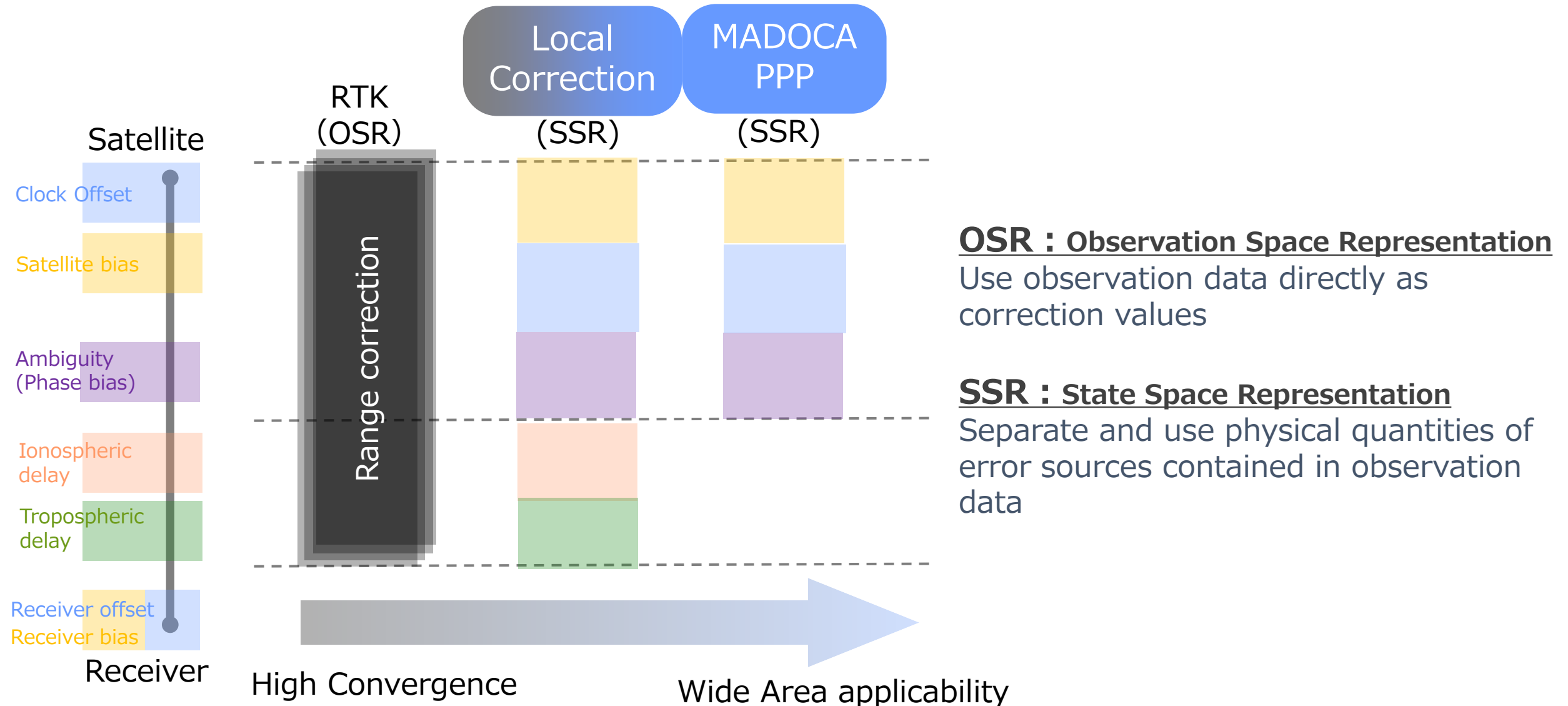
QZSS Signals

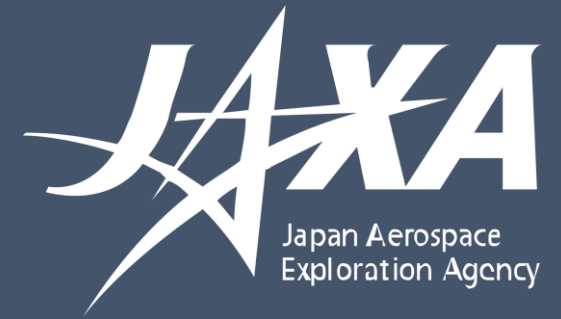
Service name		Signal Name	Center Frequency [MHz]	QZSS							
				QZS -1	QZS -2	QZS -3	QZS -4	QZS -1R	QZS -5	QZS -6	QZS -7
				QZO		GEO	QZO			GEO	準静止軌道
Positioning service	Positioning Service	L1C/A	1575.42	○	○	○	○	*1	*2	*2	*2
		L1C/B		—	—	—	—	*1	○	○	○
		L1C		○	○	○	○	○	○	○	○
		L2C	1227.6	○	○	○	○	○	—	—	—
		L5	1176.45	○	○	○	○	○	○	○	○
Augmentation service	Sub-meter Level Augmentation Service (SLAS)	L1S	1575.42	○	○	○	○	○	—	—	—
	Centimeter Level Augmentation Service (CLAS)	L6D	1278.75	○	○	○	○	○	—	—	—
	High-Precision Positioning Service (MADOCA-PPP)	L6D		—	—	—	—	—	○	○	○
		L6E		—	○	○	○	○	○	○	○
Other services	Disaster & Crisis Management Report (DC-Report)	L1S	1575.42	○	○	○	○	○	—	—	—
	SBAS Transmission	L1Sb		—	—	○	—	—	—	○	○
	Technology Verification	L5S	1176.45	—	○	○	○	○	—	○	○
	Health Monitoring (Q-ANPI)	S-Band	2000	—	—	○	—	—	—	—	○

Mitigation strategies of PPP error sources

Effect	Magnitude	Domain	Mitigation Strategy	Residual error
Ionosphere	10 m	Range	IFLC / STEC	mm
Troposphere	Few m	Range	Modeling	dm mm
Relativity	10 m	Range	Modeling	mm
Satellite antenna PCO/PCV	m cm	Position; range	Modeling	mm
Solid earth tide	20 cm	Position	Modeling	mm
Phase windup	10 cm	Range	Modeling	mm
Ocean loading	5 cm	Position	Modeling	mm
Satellite orbits/clocks	Few cm	Position; range	Modeling	mm
Pseudorange multipath and noise	1-3 m	Range	Filtering	dm mm
Receiver antenna PCO/PCV	cm mm	Position; range	Modeling	mm

Carrier Phase Positioning | Correction





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PPP SOFTWARE : RTKLIB & MALIB

PPP Correction service

System	Service	Satellite	Status	Data Rate	Format
QZSS CLAS	Nationwide PPP-RTK	IGSO/GEO	Operational (2018-)	2,000 bps	Compact SSR
QZSS MADOCA	Regional PPP	IGSO/GEO	Operational (2023-)	2,000 bps	Compact SSR
GALILEO HAS	Global PPP	MEO	Operational (2023-)	500 bps	Base on Compact SSR
BeiDou PPP	Regional PPP	GEO	Operational (2020-)	500 bps	SSR (PPP-B2b1 ICD)
SouthPAN PVS	Regional PPP	GEO	Development (2023-)	250 bps	Under definition
GLONASS PPP	Regional PPP	GEO	Concept (2030-)	4,000 bps	RTCM SSR

PPP/PPP-RTK open formats: Overview, comparison, and proposal for an interoperable message, Rui Hirokawa, et. al. First published: 15 December 2021 <https://doi.org/10.1002/navi.452>

PPP | Open-Source Software

	Developer	Stars	Fork	Watch	License	Last update
RTKLIB	Tomoji Takasu	2.5k	297	1.6k	BSD-2.0	4 years ago
GSILIB	GSI	-	-	-	BSD-2.0 GPL v3	2022/08/30
MALIB	JAXA	25	0	1	BSD-2.0	2024/09/30
MADOCALIB	CAO	28	2	11	BSD-2.0	2024/08/23
CLASLIB	CAO	15	2	11	BSD-2.0	2024/06/27
PRIDE	Wuhan University	257	35	101	GPL-3.0	2024/10/04
Ginan	Geoscience Australia Contributor : 8	226	108	29	Apache v2	2024/10/12
GipsyX	NASA JPL	-	-	-	-	2024/09/04
PPP-WIZARD	CNES	-	-	-	-	2024/07/12
CSRS-PPP	NRCan	-	-	-	-	2022/11/27
PPPLib	Chao Chen	29	2	66	-	4 years ago

What is RTKLIB ?

The image displays a collage of screenshots from various RTKLIB software applications, illustrating their interfaces and data processing capabilities. The applications shown include:

- RTKPLLOT ver.2.4.2:** Displays a 3D visualization of satellite orbits and ground stations, with a Google Earth view inset.
- RTKNAV ver.2.4.2:** Shows a 2D plot of satellite trajectories and provides real-time position data (N: 35° 43' 08.2300", E: 138° 27' 02.1531", H: 367.442 m).
- RTKGET ver.2.4.2:** Displays a list of stations and their coordinates, along with a table of stream data.
- RTKCONV ver.2.4.2:** Shows the conversion of raw data files into RINEX format, with a table of input and output files.
- STRSVR ver.2.4.2:** Displays a table of stream data, including station ID, type, and data rates.
- Ntrip Browser ver.2.4.2:** Shows a list of Ntrip stations and their coordinates.

Stream	Type	Opt Cond	bytes	bps
(0) Input	Serial		11,447	6,944
(1) Output	TCP Server	Conv	0	0
(2) Output			0	0
(3) Output			0	0

Station ID	Station Name	RTM	Time Start (GPST)	Time End (GPST)	Interval	Unit
ACOR0	Coruna	RTM 3.1	3004(1), 3006(15), 3008(60), 3012(1), 3033(60)		2	
AJAC0	Ajaccio	RTM 3.1	3(1), 3(30), 38(1), 39(1), 22(30), 23(30), 24(30), 59(30)		2	
ALAC0	Alicante	RTM 2.1	3(1), 3(30), 38(1), 39(1), 22(30), 23(30), 24(30), 59(30)		2	
ALBA0	Albacete	RTM 2.1	3(1), 3(30), 38(1), 39(1), 22(30), 23(30), 24(30), 59(30)		2	
ALME0	Almeria	RTM 2.3	3(1), 3(30), 38(1), 39(1), 22(30), 23(30), 24(30), 59(30)		2	
AUT30	Thessaloniki	RTM 3.0	3004(1), 3006(30), 3008(30)		2	
BELF0	Belfast	RTM 3.1	3004(1), 3006(15), 3008(15), 3012(1)		2	
BELL0	bellmunt_de_Segarra	RTM 3.0	3004(1), 3005(3), 3008(3)		2	
BOR10	Boroviec	RTM 2.3	3(1), 3(30), 38(1), 39(1), 22(30)		2	
BOR11	Borkum	RTM 3.0	3004(1), 3006(30), 3007(30), 3012(1), 3019, 3030		2	
BORR0	Borriana	RTM 3.0	3004(1), 3005(15), 3008(15)		2	
BRST0	Brest	RTM 3.0	3004(1), 3006(15), 3008(15), 3012(1)		2	
BSCW0	Besancon	RTM 3.0	3004(1), 3006(15), 3008(15)		2	
BUJU0	Budapest	RTM 3.0	3004(1), 3006(30), 3008(30), 3012(1), 3019(120), 3020(1)		2	
BUTE0	Budapest	RTM 3.0	3004(1), 3006(30), 3008(30), 3012(1), 3013(30)		2	
CACE0	Caoceres	RTM 2.1	3(1), 3(30), 38(1), 39(1), 22(30), 23(30), 24(30), 59(30)		2	
CAGZ0	Cagliari	RTM 2.3	3(1), 3(60), 36(60), 38(1), 39(1), 3(1)		2	
CANT0	Cantabria	RTM 3.1	3004(1), 3006(15), 3008(15), 3012(1), 3019(120), 3020(1)		2	
CANT1	Cantabria	RTM 2.3	3(1), 3(30), 38(1), 39(1)		2	

MALIB Open-Source Software released !!!

<https://www.satnavi.jaxa.jp/ja/news/2024/10/04/9950/index.html>

<https://github.com/JAXA-SNU/MALIB>

This branch is 132 commits ahead of, 69 commits behind [tomoyukitakasu/RTKLIB-master](#)

JAXA-SNU	MALIB ver. 1.0.0	139e150 · 3 weeks ago
app/consapp	MALIB ver. 1.0.0	
bin	MALIB ver. 1.0.0	
data	MALIB ver. 1.0.0	
doc	MALIB ver. 1.0.0	
lib/mkl	MALIB ver. 1.0.0	
src	MALIB ver. 1.0.0	
test	RTKLIB 3.4.1-3.4	

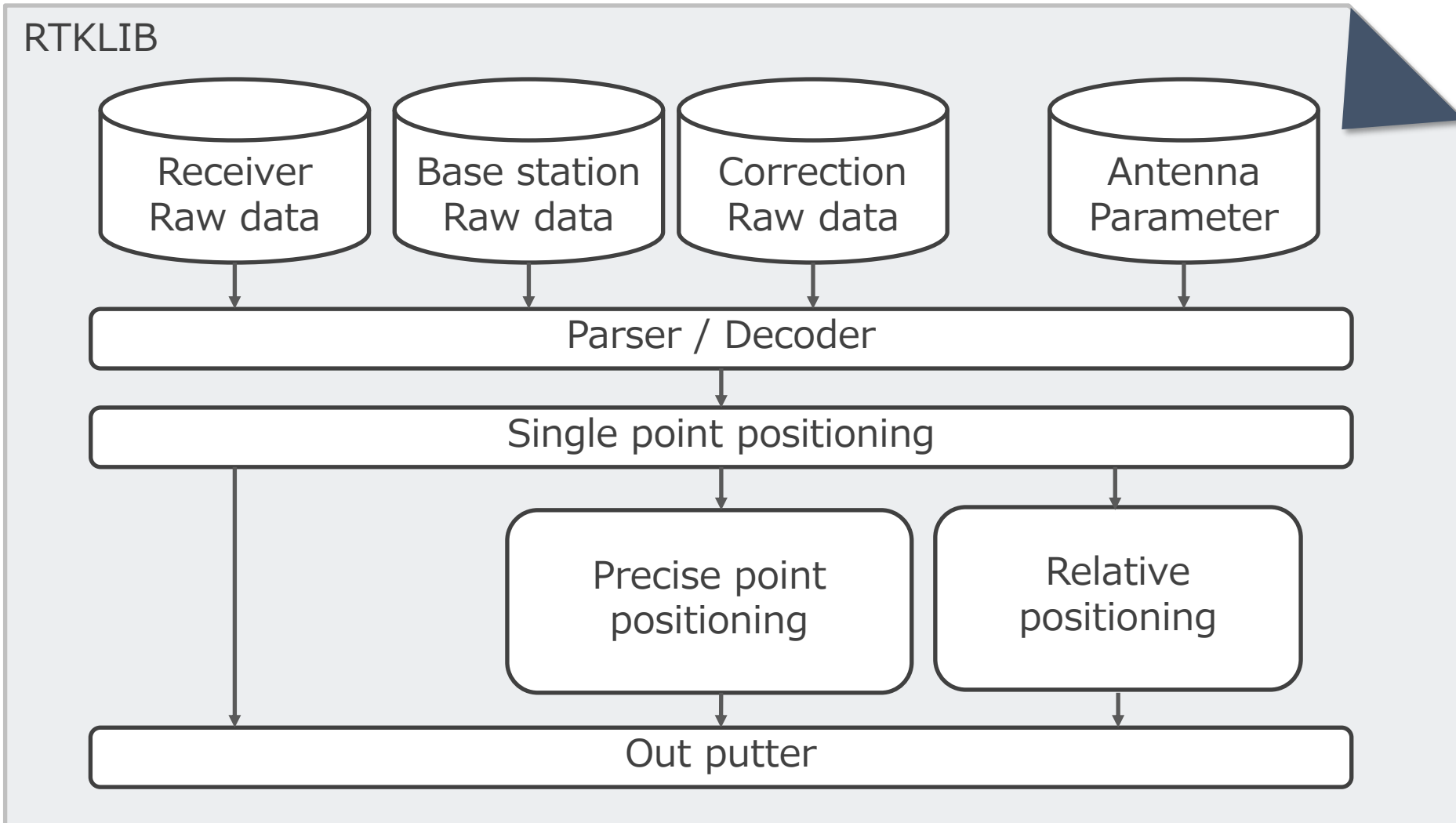
更新情報 2024.10.04 (金)

MALIB：高精度測位補強サービス「MADOCA-PPP」のユーザー測位ソフトウェア公開

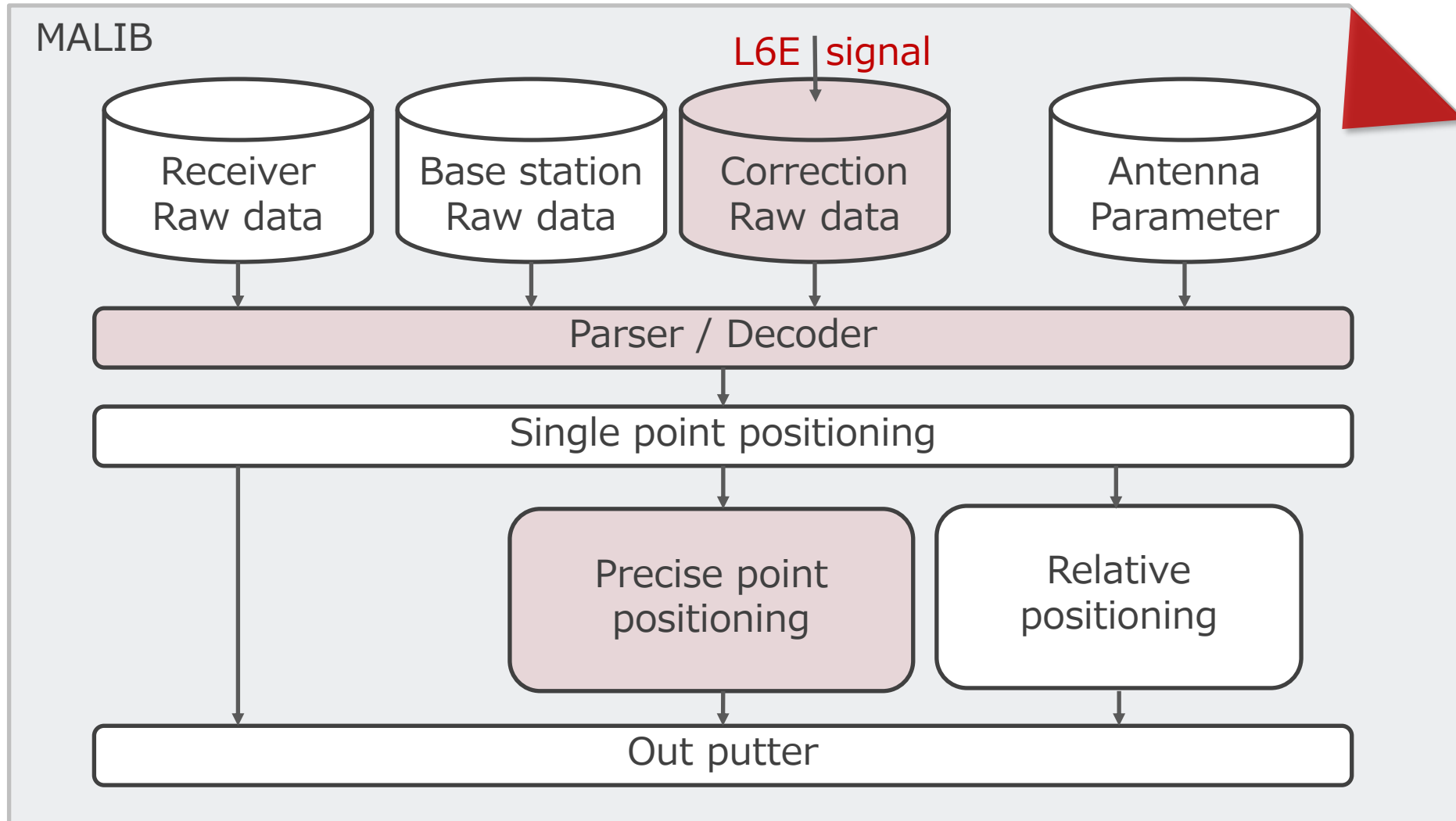
高精度測位補強サービス「MADOCA-PPP」のユーザー測位ソフトウェア公開

高精度測位補強サービス（MADOCA-PPP）を用いた単独高精度測位のプログラムパッケージを広く用いられているRTKLIBにMADOCA-PPPによる高精度測位機能を追加しました。リアルタイム・テストデータ・ソースコードをGitHubにて公開しました。

RTKLIB | GNSS Open-Source Software



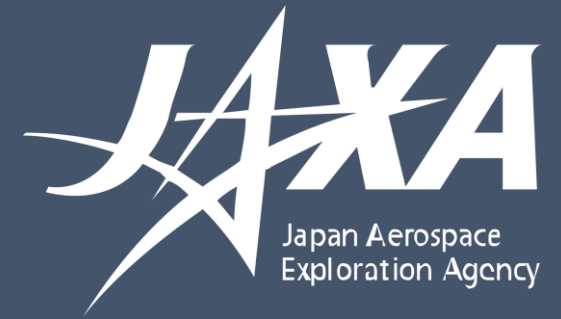
MALIB | MADOCA-PPP Open-Source Software



MALIB | MADOCA-PPP Open-Source Software

Key features

- Decode **Various L6E data** format (e.g. .ubx / .sbf / .msj)
- Applicable **Multi-GNSS** (GPS / GLONASS / GALILEO / QZSS)
- PPP & **PPP-AR**
- **Real Time** & Post process positioning
- Base on **RTKLIB 2.4.3 b34**
- Select Frequency depends on the GNSS satellites



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HOW TO INSTALL MALIB

MALIB Public

forked from

Pin Watch 0 Forks 1 Star 25

How to install MALIB on your system



<https://github.com/JAXA-SNU/MALIB>

main

This branch is

JAXA-SNU

File	Commit	Time
app/console	1.0.0	3 weeks ago
bin	1.0.0	3 weeks ago
data	1.0.0	3 weeks ago
doc	1.0.0	3 weeks ago
lib/mal	MALIB ver. 1.0.0	3 weeks ago
src	MALIB ver. 1.0.0	3 weeks ago
test	RTKLIB 3.4.3.1.34	4 weeks ago

Go to file

Code

Contribute

Sync fork

About

No description, website, or topics provided.

- Readme
- View license
- Activity
- 25 stars
- 0 watching
- 1 fork

Releases

4 tags

[Create a new release](#)

Packages

Functions of RTKLIB

Linux

- rtkrcv : Real-time positioning (console)
- rnx2rtkp : Post process (console)
- str2str : Stream server (console)
- convbin : Binary to RINEX converter (console)
- pos2kml : Google Earth KML converter (console)

Windows

- rtkconv : Binary to RINEX converter (GUI)
- srctblbrows : Ntrip source table browser (GUI)
- rtknavi : Real-time positioning (GUI)
- rtkplot : Plot position & observation data (GUI)
- rtkpost : Post process (GUI)
- strsvr : Stream server (GUI)

Functions of MALIB

Linux

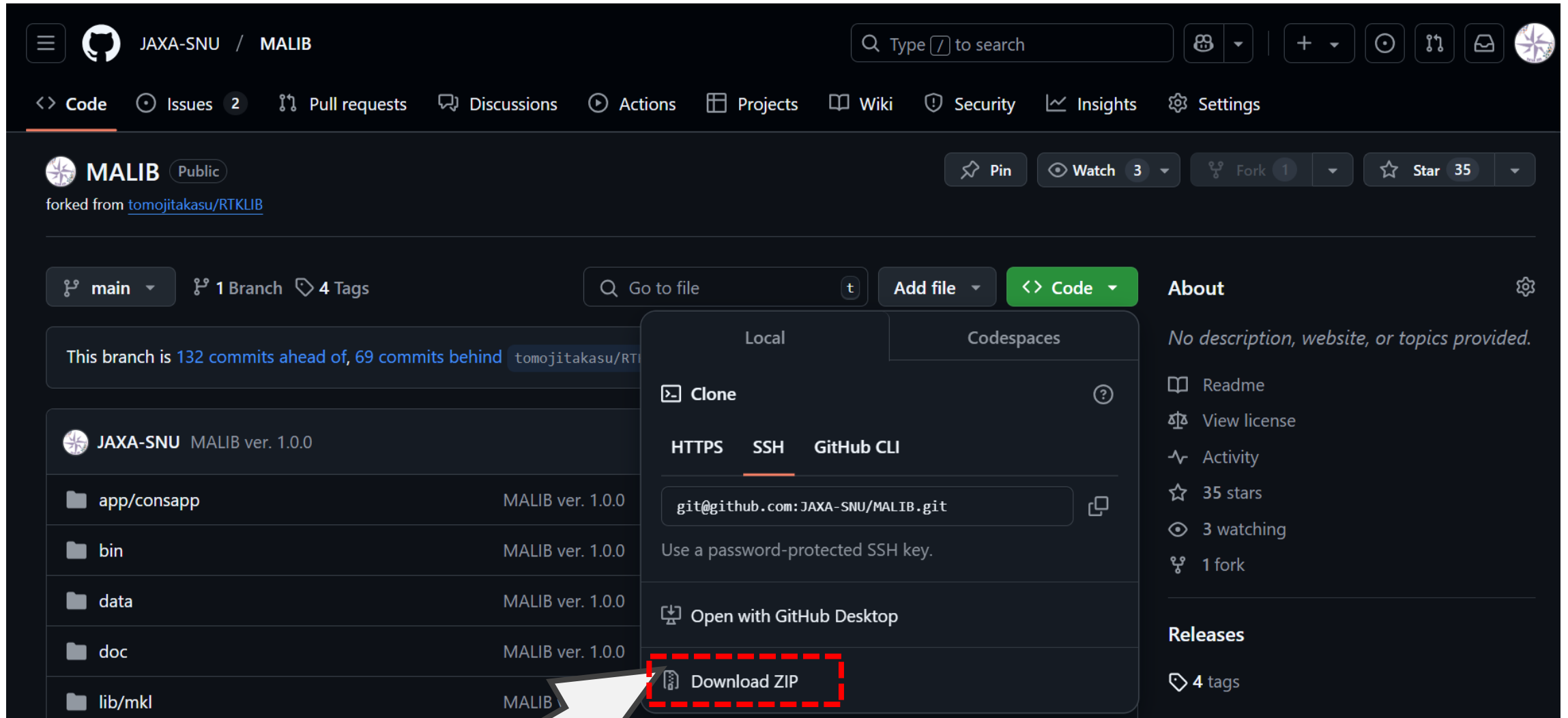
- **rtkrcv** : **Real-time positioning** (console)
- **rnx2rtkp** : **Post process** (console)
- str2str : Stream server (console)
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- rtkconv : Binary to RINEX converter (GUI)
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- rtknavi : Real-time positioning (GUI)
- rtkplot : Plot position & observation data (GUI)
- rtkpost : Post process (GUI)
- strsvr : Stream server (GUI)

Install MALIB

<https://github.com/JAXA-SNU/MALIB>



The screenshot shows the GitHub repository page for MALIB. The repository is public and forked from tomojitakasu/RTKLIB. The main branch is selected, and the repository is 132 commits ahead of, 69 commits behind the upstream repository. The repository contains several folders: app/consapp, bin, data, doc, and lib/mkl. The 'Code' dropdown menu is open, showing options for cloning the repository using HTTPS, SSH, or GitHub CLI, and an option to open with GitHub Desktop. The 'Download ZIP' option is highlighted with a red dashed box and a white arrow pointing to it.

Click & Download or `git clone git@github.com:JAXA-SNU/MALIB.git`

Folder structure of MALIB



The screenshot shows the file browser of a GitHub repository for 'MALIB ver. 1.0.0'. The repository is owned by 'JAXA-SNU' and has 132 commits. The file list includes folders for application, binaries, data, documentation, MKL libraries, source code, tests, and utilities, along with configuration files like .gitattributes, .gitignore, LICENSE.txt, and README.md.

Item	Version	Last Commit
app/consapp	MALIB ver. 1.0.0	4 months ago
bin	MALIB ver. 1.0.0	4 months ago
data	MALIB ver. 1.0.0	4 months ago
doc	MALIB ver. 1.0.0	4 months ago
lib/mkl	MALIB ver. 1.0.0	4 months ago
src	MALIB ver. 1.0.0	4 months ago
test	RTKLIB 2.4.3 b34	5 years ago
util	RTKLIB 2.4.3 b34	5 years ago
.gitattributes	RTKLIB 2.4.2	12 years ago
.gitignore	RTKLIB 2.4.3 b34	5 years ago
LICENSE.txt	MALIB ver. 1.0.0	4 months ago
readme.md	MALIB ver. 1.0.0	4 months ago

Application

Binary file of executable

Data folder

Document folder

Library of MKL

Source code of MALIB

Test code

Utility file

rtkrcv | real-time processing application

- step. 0 | clone GitHub link or download zip file from GitHub
git clone <https://github.com/JAXA-SNU/MALIB.git>
cd MALIB
- step. 1 | Unzip test data
tar -zxvf ./data/MALIB_OSS_data.tar.gz -C ./
- step. 2 | Compile rtkrcv
cd ./app/consapp/rtkrcv/gcc/
make clean
make
make install
cd ../../../../..

rtkrcv | real-time processing application

- step. 3 | Execute rtkrcv (replay processing)
./bin/rtkrcv -o ./bin/rtkrcv.conf

Tips

usage: rtkrcv [-s][-p port][-d dev][-o file][-w pwd][-r level][-t level][-sta sta]

options

-s	start RTK server on program startup
-p port	port number for telnet console
-m port	port number for monitor stream
-d dev	terminal device for console
-o file	processing options file
-w pwd	login password for remote console ("": no password)
-r level	output solution status file (0:off,1:states,2:residuals)
-t level	debug trace level (0:off,1-5:on)
-sta sta	station name for receiver dcb
-v -ver	print version
-rst	ds ts start day/time (ds=y/m/d ts=h:m:s) [raw/rtcm data start time]

rtkrcv | real-time processing application

- step. 4 | Execute rtkrcv (replay processing)
./bin/rtkrcv -o ./bin/rtkrcv.conf

Tips

```
** rtkrcv ver.1.0.0 console (h:help) **
rtkrcv> start
rtk server start
rtkrcv> sol
2024/08/22 10:59:49.0 (PPP ) N:36.06873342 E:140.12835085 H: 114.218
2024/08/22 10:59:50.0 (PPP ) N:36.06873356 E:140.12835072 H: 114.239
2024/08/22 10:59:51.0 (PPP ) N:36.06873409 E:140.12834980 H: 114.198

rtkrcv> stat
Parameter           : Value
malib version       : 1.0.0
rtk server thread   : -544123328
rtk server state    : run
...
```

rtkrcv | real-time processing configuration file

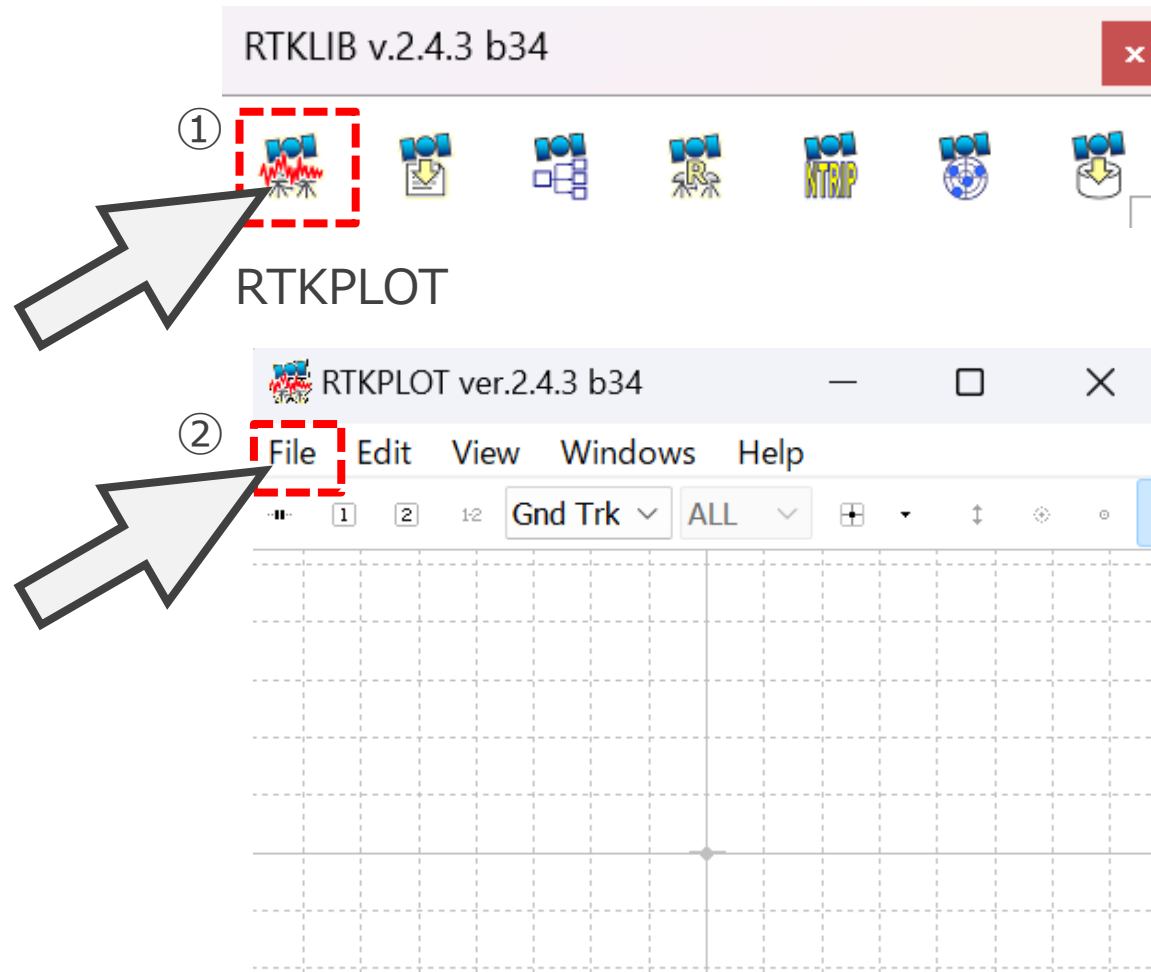
- # Input stream type (0:off,1:serial,2:file,3:tcpsvr,4:tcpcli,7:ntripcli,8:ftp,9:http)
- inpstr1-type =ntripcli
- inpstr2-type =off
- inpstr3-type =ntripcli

- # Input stream path
- inpstr1-path =[user[:passwd]]@addr:port/mntpnt
- inpstr2-path =
- inpstr3-path =[user[:passwd]]@addr:port/mntpnt

- # Input stream format (0:rtcm2,1:rtcm3,2:oem4,3:oem3,4:ubx,5:ss2,6:hemis,7:skytraq,8:sp3)
- inpstr1-format =rtcm3
- inpstr2-format =
- inpstr3-format =rtcm3

rtkrcv | real-time processing application

- step. 4 | plot data (e.g. RTKPLOT in RTKLIB)



rnx2rtkp | post processing application

- step. 0 | clone GitHub link or download zip file from GitHub
git clone <https://github.com/JAXA-SNU/MALIB.git>
cd MALIB
- step. 1 | Unzip test data
tar -zxvf ./data/MALIB_OSS_data.tar.gz -C ./
- step. 2 | Compile rnx2rtkp
cd ./app/consapp/rnx2rtkp/gcc/
make clean
make
make install
cd ../../../../..

rnx2rtkp | post processing application

- step. 3 | Execute rnx2rtkp

Execute file

./bin/rnx2rtkp ¥

Config file

> -k ./bin/rnx2rtkp.conf ¥

Observation

> ./data/MALIB_OSS_data_obsnav_240822-1100.obs ¥

Navigation

> ./data/MALIB_OSS_data_obsnav_240822-1100.nav ¥

L6E MADOCA

> ./data/2024235L.209.l6¥

Output file

> -o ./data/out/rnx2rtkp_test.pos

rnx2rtkp | post processing application

- step. 3 | Execute rnx2rtkp

```
./bin/rnx2rtkp ¥
```

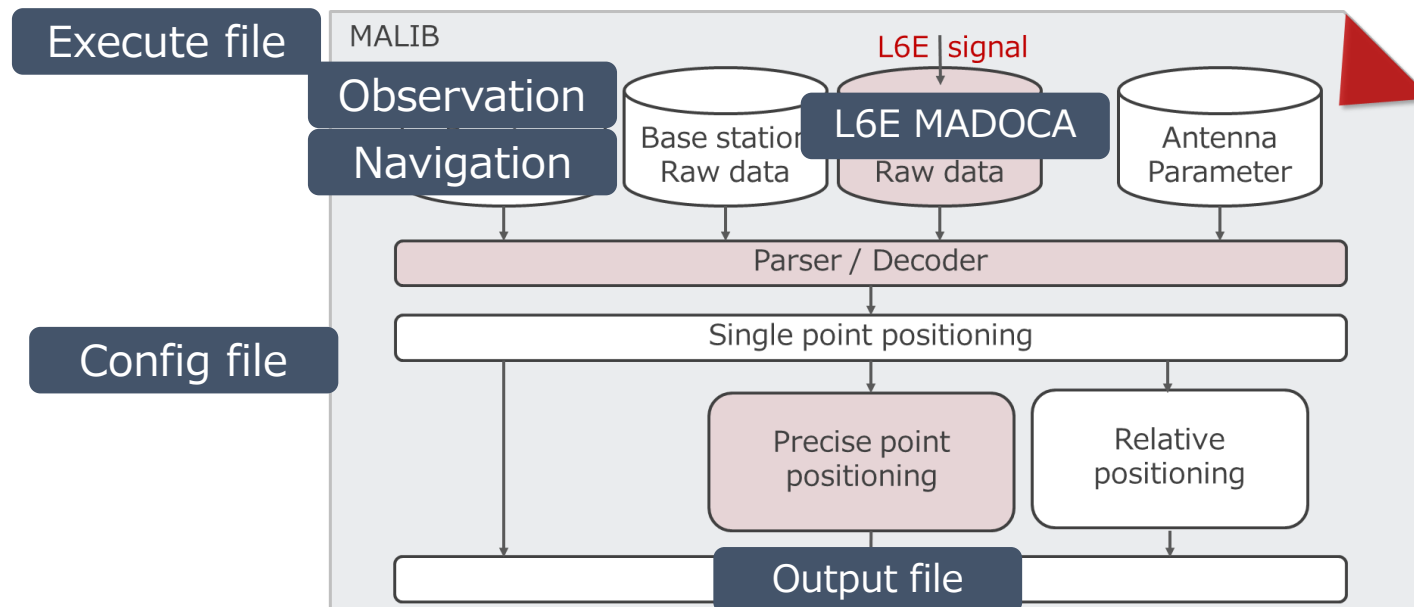
```
> -k ./bin/rnx2rtkp.conf ¥
```

```
> ./data/MALIB_OSS_data_obsnav_240822-1100.obs ¥
```

```
> ./data/MALIB_OSS_data_obsnav_240822-1100.nav ¥
```

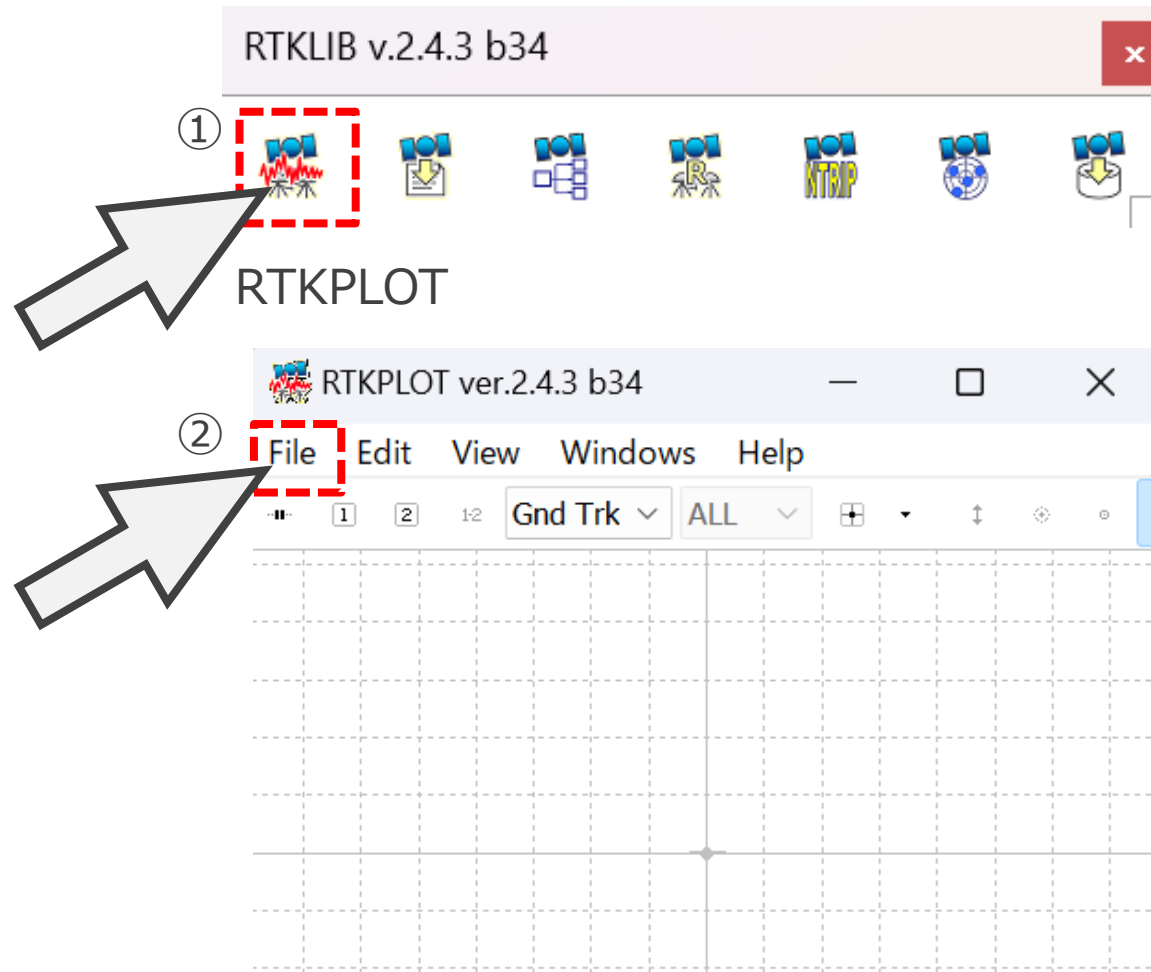
```
> ./data/2024235L.209.l6¥
```

```
> -o ./data/out/rnx2rtkp_test.pos
```



rnx2rtkp | post processing application

- step. 4 | plot data (e.g. RTKPLOT in RTKLIB)



Summary | MALIB & MADOCA-PPP

MALIB Features

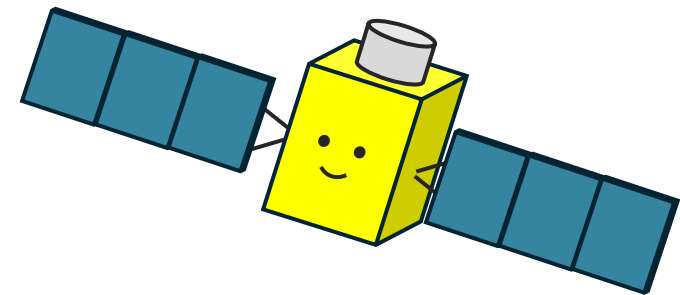
- **Open-source PPP** software based on RTKLIB 2.4.3
- **Multi-GNSS** capability and various L6E signal receiver processing
- **Real-time** & post-processing support
- GitHub: github.com/JAXA-SNU/MALIB

Applications

- Autonomous vehicles (YADOCAR-i)
- Low-cost GNSS receivers (micro computer w/MALIB)
- Integration example with other sensors

Future Development

- Ongoing improvements and updates
- Community contributions welcome
- Let's expanding application areas together



THANK YOU