PRIDE PPP-AR II

MANUAL

Multi-GNSS Precise Point Positioning with Ambiguity Resolution

by

PRIDELab

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GNSS Research Center, Wuhan University

Dedicated to those

who are devoted to high-precision GNSS

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1. Overview

1.1 Acknowledgement

PRIDE PPP-AR II originates in Dr. Maorong Ge's efforts on PPP-AR and later developed and improved by Dr. Jianghui Geng's team including Songfeng Yang. It is an open-source software package which is based on many GNSS professionals' collective work in GNSS Research Center, Wuhan University. We would like to thank them (including third parties providing free source code) all for their brilliant contributions to this software.

No proprietary modules are used anymore in the software. We make this package open source with the goal of benefiting those professionals in their early career, and also advocate the geodetic and geophysical applications of PPP-AR. Especially, we hope that this package can contribute to high-precision applications in geosciences such as crustal motion and troposphere sounding studies. The entire open-source project is funded by National Science Foundation of China (No. 41674033 and 41861134009) and is under the auspices of IAG SC 4.4 "GNSS Integrity and Quality Control".

PRIDE PPP-AR II can be downloaded at https://pride.whu.edu.cn and https://github.com/PrideLab/PRIDE-PPPAR. The phase bias products can be accessed at ftp://igs.gnsswhu.cn/pub/whu/phasebias/. Latest updates for Support, Training courses and FAQ can be found at https://pride.whu.edu.cn. The copyright of this package is protected by GNU General Public License (version 3). Relevant publications are

Geng, J., Chen, X., Pan, Y. & Zhao, Q. (2019a). A modified phase clock/bias model to improve PPP ambiguity resolution at Wuhan University. Journal of Geodesy, 93(10), 2053-2067.

Geng, J., Chen, X., Pan, Y., Mao, S., Li, C., Zhou, J., Zhang, K. (2019b) PRIDE PPP-AR: an open-source software for GPS PPP ambiguity resolution. GPS Solutions 23:91 doi:10.1007/s10291-019-0888-1.

1.2 Major features

PRIDE PPP-AR II (Precise Point Positioning with Ambiguity Resolution) aims at post-processing of multi-GNSS data for the science community including geodesy, seismology, photogrammetry, gravimetry, etc. It is an enhanced version of PRIDE PPP-AR I released in 2019. The major features of PRIDE PPP-AR II include

1) GPS, GLONASS, Galileo, BDS-2/3 and QZSS capable;
2) High-rate GNSS data processing of up to 50 Hz;
3) Vienna Mapping Function 1/3 (VMF3) and GPT3 for troposphere modeling;
4) Second-order ionospheric correction;
5) High-dynamic mobile platforms applicable for aerial photogrammetry, ship-borne gravimetry, etc;
6) Receiver clock jump mitigation;
7) A Windows lite-version provided for very early career researchers;
8) Ambiguity-float PPP using data dating back to 1994 when SA was on (see Appendix D);
9) GPS/Galileo/BDS-2/3 PPP-AR in the case of the bias-SINEX format phase biases (ftp://igs.gnsswhu.cn).

1.3 Contact us

You can contact us for **bug reports** and **comments** by sending emails or leave messages on our website.

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For Chinese users, we provide Tencent **QQ Group** service. Group Number: **971523302**. Leave your organization and name when applying for admission.

2. User Requirements

2.1 System Requirements

PRIDE PPP-AR II is composed of CUI APs. The executable binary CUI APs included in the package require Linux environment. All of the codes were written in Fortran. A series of tests are conducted on different operating systems with several gfortran versions. The tests results are listed as below (table 1). Note that you can also try other Linux distribution and Fortran compiler, and tell us if you have any problems.

Fortran compiler needs to be installed before installing PRIDE PPP-AR II.

Table 1 PRIDE PPP-AR II test results in different operating systems.

Platform version	*gfortran version*	*Test result*	*Notes*
Ubuntu14.04.4 (x64)	4.8.4	pass	1. Pre-install ‘gfortran’ before installation; 2. Test result is consistent with the reference
Ubuntu14.04.4 (x32)	4.8.4	pass	1. Pre-install ‘gfortran’ before installation; 2. Test result is consistent with the reference
Ubuntu16.04.11 (x64)	5.4.0	pass	Test result is consistent with the reference
Ubuntu16.04.11 (x32)	5.4.0	pass	Test result is consistent with the reference
Ubuntu18.04 (x64)	7.3.0	pass	1. Pre-install ‘gfortran’ before installation; 2. Test result is consistent with the reference
Ubuntu20.04.4 (x64)	4.8.4	pass	Test result is consistent with the reference

Ubuntu20.04.4 (x32)	4.8.4	pass	Test result is consistent with the reference
Arch Linux (x64)	8.2.1	pass	Test result is consistent with the reference
CentOS 6.5 (x64)	4.4.7	pass	Test result is consistent with the reference
CentOS 7 (x64)	4.8.5	pass	Test result is consistent with the reference
Debian 9.6 (x64)	6.3.0	pass	Test result is consistent with the reference
Debian 8.11 (x64)	4.9.2	pass	1. Pre-install ‘gfortran’ before installation; 2. Test result is consistent with the reference
MacOS 10.14	10.2.0	pass	1. Pre-install ‘gfortran’ before installation; 2. Test result is consistent with the reference

2.2 License

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3. Instructions

3.1 Installation and Validation

Structures of PRIDE PPP-AR II

The structure of PRIDE PPP-AR II is as follow (table 2).

Table 2 PRIDE PPP-AR II structures

PRIDE PPP-AR II		*Instructions*
\bin		**Executable program**
	tedit	Pre-processing RINEX files
	sp3orb	Transform sp3 into self-defined binary file
	lsq	Least squares adjustment
	redig	Residual editing
	arsig	Ambiguity resolution
	get_ctrl	Get configuration parameters
	mergesp3	Merge sp3 (3 files) into one file
	xyz2enu	Convert position of XYZ to ENU
	enucov	Convert covariance of XYZ to ENU
	spp	Standard single point positioning program
\scripts		**Some scripts for efficient data processing**
	pride_pppar.sh	Automatic processing Shell script (Linux)
	pride_pppar_Mac.sh	Automatic processing Shell script (Mac)
\src		**Source programs**
	\header	Header files
	\arsig	Ambiguity resolution
	\lib	Library functions
	\lsq	Least squares adjustment
	\orbit	Sp3orb, mergesp3
	\redig	Residual editing
	\tedit	Pre-processing RINEX files
	\utils	Universal tools
	\spp	Standard single point positioning program
	Makefile	Makefile
\table		**Dependent table files**
	orography_ell	Global terrain file (2.5 degree * 2.5 degree) for VMF1
	orography_ell_1x1	Global terrain file (1 degree * 1 degree) for VMF3
	gpt3_1.grd	External grid file (1 degree * 1 degree) for GPT3
	oceanload	Ocean tidal loading file
	file_name	File names conventions of PRIDE PPP-AR II

install.sh	**Installation script**	
Changelog	**Change log of the software**	
\doc	**Document flag**	
	logo	The logo printed on screen when installing successfully
	Manual	Manual of the software
	Tutorial	Slides for tutorials
\example	**Examples**	
	test.sh	Test script (Linux)
	test_Mac.sh	Test script (Mac)
	\data	Example data
	config_template	Configuration file template
	config_partial	Part of configuration file used to generate the whole configuration file
	\results_ref	Reference results for examples
\win	A Windows lite-version with simple GUI. Sophisticated processing should be done in Linux.	

Installation

Step 1: Make sure you have installed some essential programs in advance.
i.e. **bash, make, gfortran**
Step 2: Run script **./install.sh** to install the program automatically.
(This script executes Makefile to build CUI APs and add CUI APs to system PATH (**~/.PRIDE_PPPAR_BIN/***))
Step 3: **Restart terminal**.

Validation

Step 1: Change directory into **/example**, conduct **./test.sh.**
Step 2: Compare results with reference results (table 3).

The script **./test.sh** in **/example** folder is used to validate the correctness and effectiveness of the installation and execution. Run **./test.sh**, then the examples of PPP and PPP-AR are conducted. The data processing procedure is conducted and some information is printed to the screen. After that, results files are created. Then compare the solution files between results and reference results to make sure the software installation is correct and valid.

Three examples are conducted by script **test.sh**. '**static**' mode denotes that we regard the station as a static station, and estimate only one set of coordinates in the whole observation period. '**kinematic**' denotes that we regard the station as a kinematic station, and estimate one set of coordinates every epoch. '**high-dynamic**' denotes that we use ship-borne gravimetry data, and estimate one set of coordinates every epoch. '**PPP**' means precise point positioning without ambiguity resolution, as we call float solution, while '**PPP-AR**' achieves ambiguity resolution by utilizing phase bias products provided by PRIDELab, together with the open-source program **PRIDE PPP-AR II**. '**PPP-AR LAMBDA**' denotes the ambiguity resolution process is conducted by **LAMBDA** (Least-squares Ambiguity Decorrelation Adjustment) method. The default method is round directly. The one-hour example is conducted by utilizing LAMBDA methods for efficient ambiguity resolution, while the traditional rounding method cannot retrieve ambiguity correctly.

Table 3 PRIDE PPP-AR II test examples

No.	Examples	Explanation
1	*static PPP*	Static, PPP Float Solution
	static PPP-AR	Static, PPP Ambiguity Resolution
2	*kinematic PPP*	Kinematic, PPP Float Solution
	kinematic PPP-AR	Kinematic, PPP Ambiguity Resolution
3	*kinematic PPP (1 hour)*	Kinematic, PPP Float Solution
	kinematic PPP-AR LAMBDA (1 hour)	Kinematic, PPP Ambiguity Resolution with LAMBDA
4	*high-dynamic PPP*	High-dynamic, PPP Float Solution

3.2 Quick Start

In the folder of script, you can find the Shell script named ***pride_pppar***. Run this script in your work directory as below and then check the results file in the corresponding directory.

& pride_pppar config_template 20200101 20200101 Y/N

config_template denotes session configuration file, and the parameters and formats of these files are described in *Appendix A.2*. ***20200101*** and ***20200101*** denote start time and ending time of data processing, respectively. According to the time format (YYYYMMDD), you can set the processing time as required. Moreover, multi-day data processing is accomplished. The last parameter ***Y/N*** denotes the ambiguity resolution switch, which has two options, ***Y*** or ***N.***

N – PPP Float Solution

Y – PPP Ambiguity Resolution

The automatic processing script ***pride_pppar*** contains the information of processing procedures, you can read the script for details.

PPP

After Installation and validation, let's start PPP data processing! Here we start with an example.

1. The PRIDE PPP-AR II software directory is as below (Fig. 1):

Fig. 1 PRIDE PPP-AR II software directory

2. Create a working folder **/project**, and its subfolder **/data**.
3. Copy RINEX Observation Files and Navigation Files to **/project/data/YEAR/DOY** (/project/data/2020/001, for example).
4. Copy configuration file 'config_template' to **/project** directory.
5. Edit configuration file to set proper processing parameters.
   The specific definition and instruction of some parameters are listed in '*config_template*'.
6. **[Optional choice for stations offshore]** Get Ocean tide loading parameters using the coordinates in **sit.xyz**, according to the website (http://holt.oso.chalmers.se/loading/). Choose the model **FES2004** (Fig. 2), and leave the rest of the options as default.

Fig. 2 Ocean tide model

Then submit a task by add station coordinates as below at the website. When you get the oceanload coefficients through your email, append them to **/table/oceanload** as the original format (Fig. 3).

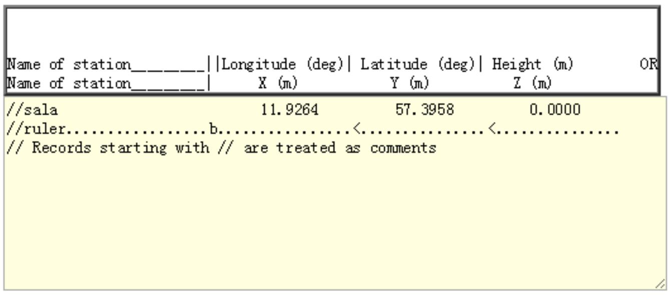


Fig. 3 Submitting the task

7. Change into **/project**, Run the script to start data processing.
   $ pride_pppar config_template 20200101 20200101 N
8. After processing, the solution files will be in the **/project/2020/001** directory.

PPP with Ambiguity Resolution

1. Conduct procedure 1~8 listed above.
2. Change into **/project** directory, run the script to start data processing.
   $ pride_pppar config_template 20200101 20200101 Y
3. After processing, the solution files will be in the **/project/2020/001** directory.

4. Modules of PRIDE PPP-AR II

The modules of PRIDE PPP-AR II software are as below (Fig. 4):

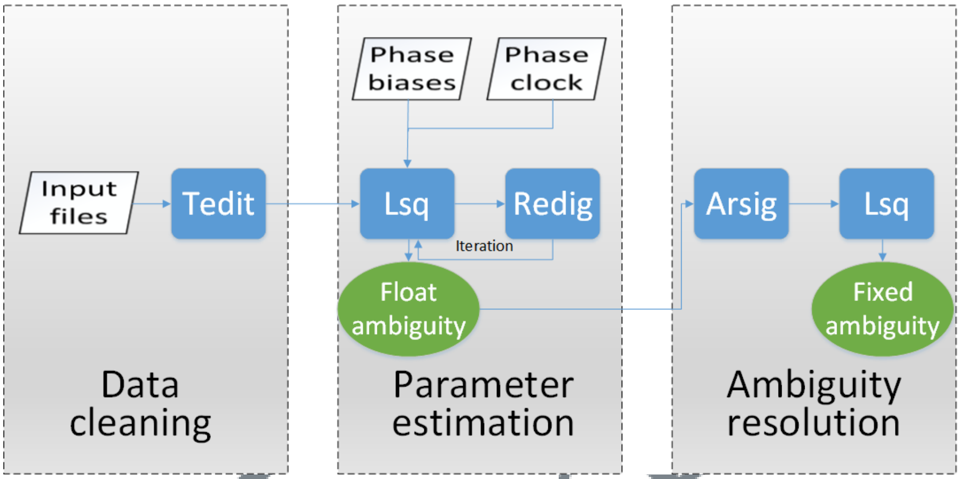


Fig. 4 Module structure of PRIDE PPP-AR II

4.1 Data Preparation

Merge Precise Ephemeris Files with mergesp3

mergesp3 is used to merge three-day SP3 (IGS Standard Product–3) orbit files into one file.

& mergesp3 WUM0MGXFIN_20193650000_01D_15M_ORB.SP3 WUM0MGXFIN_20200010000_01D_15M_ORB.SP3 WUM0MGXFIN_20200020000_01D_15M_ORB.SP3 mer_WUM0MGXFIN_20200010000_01D_15M_ORB.SP3

Input: three SP3/eph files (yesterday, today, tomorrow)

WUM0MGXFIN_20193650000_01D_15M_ORB.SP3 WUM0MGXFIN_20200010000_01D_15M_ORB.SP3 WUM0MGXFIN_20200020000_01D_15M_ORB.SP3

Output: three-day SP3 orbit product result

mer_WUM0MGXFIN_20200010000_01D_15M_ORB.SP3

Prepare Binary Orbit File with sp3orb

sp3orb transforms SP3 orbit files into a self-defined binary format. Then, the software can efficiently access the precise orbit products. In addition, the reference frame is changed from an Earth-fixed system into an inertial system through the ERP files.

& sp3orb WUM0MGXFIN_20200010000_01D_15M_ORB.SP3 -cfg config_template [–erp igserp]

Input:

WUM0MGXFIN_20200010000_01D_15M_ORB.SP3 SP3 orbit file

–cfg config_template session configuration file

[–erp igserp] ERP file

Output:

orb_2020001 Binary format orbit product

The parameters and format of these files are described in ***Appendix A***.

4.2 Data Pre-processing

Pre-processing with tedit

tedit which is based on the pre-processing algorithms by Blewitt (1990)[1] is used to identify bad measurements and cycle slips in a RINEX observation file and generate RINEX health diagnosis files (***rhd***).

For S mode:

& tedit o_file -int 30 -rnxn n_file -xyz $x $y $z -len 86400 -short 1200 -lc_check only -rhd rhd_file -pc_check 300 -elev 7 -time 2020 01 01 00 00 00

For K mode:

& tedit o_file -int 30 -rnxn n_file -len 86400 -time 2020 01 01 00 00 00 –xyz kin_2020001-short 120 -lc_check no –elev 7-rhd rhd_file

Input: files and configuration parameters

o_file	RINEX observation file
-int 30	sampling interval for data editing, Default is 30 seconds
-rnxn n_file	broadcast ephemeris file. If ***-check_lc*** is active or ***-elev*** is on, this file is required
-rhd rhd_file	output ***rhd*** file
-time 2020 01 01 00 00 00	start time for data editing
-len 86400	length of data to be edited. Default is all data in RINEX file
-short 1200	data piece shorter than this value will be removed
-elev 7	cutoff elevation in degree. Default is to use all data
-lc_check yes/no/only	yes = check LC, edit WL and IONO and try to connect WL and IONO no = edit WL and IONO and try to connect WL and IONO observation only= check LC only
-pc_check 300	check PC
-xyz ***$x $y $z***	initial station coordinate

Output: rhd files named rhd_year day of year_station name

rhd_2020001_abmf

[1] Blewitt G. An Automatic Editing Algorithm for GPS Data [J]. Geophysical Research Letters, 1990, 17(3):199-202.

4.3 Data Post-processing

Parameters Estimation with lsq

lsq conducts least squares adjustment. The module ***lsq*** is used to estimate unknown parameters.

& lsq config_template

Input: configuration file

config_template	session configuration file

Output: solution files

-pos/kin	static position / kinematic trajectory
-res	residual information
-ztd	zenith troposphere delay
-htg	horizontal troposphere gradients
-rhd	RINEX health diagnosis
-neq	inversed normal matrix
-amb	ambiguity information
-vmf	Vienna Mapping Function
-tec	Ionosphere grid file
-rcg	receiver clock information for GPS
-rcr	receiver clock information for GLONASS
-rce	receiver clock information for Galileo
-rcc	receiver clock information for BDS-2
-rc3	receiver clock information for BDS-3
-rcj	receiver clock information for QZSS

Residual Edit with redig

Residual editing. ***redig*** is applied to posterior residuals. Once new bad measurements or new cycle slips are identified, run ***lsq*** again. Then, final results can be acquired.

& redig res_2020001 -jmp jump -sht nsht [-hug huge-residual]

Input:

res_2020001	post-fit residuals file
-jmp jump	if difference residuals between adjacent epochs are larger than ***jump***, add a new ambiguity
-sht nsht	validity time of ambiguity shorter than ***nsht*** will be removed
[-hug huge-residual]	residuals larger than this value will be removed

Ambiguity Resolution with arsig

Ambiguity resolution. ***arsig*** aims to retrieve the integer properties of ambiguities to ambiguity-fixed solutions.

& arsig config_template

Input:

config_template session configuration file

Output: solution files with ambiguity resolution

Appendix A. File Specifications

A.1 Table Files

Ocean Tide Loading File (*oceanload*)

In order to obtain ocean tide loading information, you can submit station coordinates to the website (http://holt.oso.chalmers.se/loading/) as required. Then copy the oceanload information to your ocean tide loading file ***oceanload***. The station coordinates in ***sit.xyz*** can be used to calculate ocean tide loading information. The parameters and format of these files are described at the website.

File Name Definition File (*file_name*)

File names of PRIDE PPP-AR II are defined in file ***file_name***. The first column records keyword of output file and following it is the format of file name. In the format, YYYY denotes the year of processing and DDD denotes the day of year. SNAM denotes the station name. For example, "*res_2020001_abmf*" denotes the residual of station abmf in 1st, 2020. The format of ***file_name*** is as below (Fig. 5):

```
amb       amb_-YYYY--DDD-
con       con_-YYYY--DDD-
fcb       fcb_-YYYY--DDD-
htg       htg_-YYYY--DDD-
kin       kin_-YYYY--DDD-
neq       neq_-YYYY--DDD-
orb       orb_-YYYY--DDD-
pos       pos_-YYYY--DDD-
rck       rck_-YYYY--DDD-
res       res_-YYYY--DDD-
rhd       rhd_-YYYY--DDD-_-SNAM-
rnxo      -SNAM--DDD-0.-YY-o
rnxm      -SNAM--DDD-0.-YY-m
rnxn      auto-DDD-0.-YY-n
sck       sck_-YYYY--DDD-
stt       stt_-YYYY--DDD-
ztd       ztd_-YYYY--DDD-
vmf       vmf_-YYYY--DDD-
tec       tec_-YYYY--DDD-
rcg       rcg_-YYYY--DDD-
rcr       rcr_-YYYY--DDD-
rce       rce_-YYYY--DDD-
rcc       rcc_-YYYY--DDD-
rc3       rc3_-YYYY--DDD-
rcj       rcj_-YYYY--DDD-
att       att_-YYYY--DDD-
```

Fig. 5 Format of file_name

Global Terrain File (*orography_ell*)

In order to correct the effect of terrain on the results, the global terrain correction file **orography_ell** which contains coefficients for terrain correction is used, and the grid accuracy is 2.5 degree * 2.5 degree.

Global Terrain File (*orography_ell _1x1*)

The content of another file named **orography_ell_1x1** is similar to **orography_ell**, but the grid precision is 1 degree * 1 degree.

External Grid File (*gpt3_1.grd*)

GPT3_1 is based on a 1 degree * 1 degree external grid file ('gpt3_1.grd') with mean values as well as sine and cosine amplitudes for the annual and semiannual variation of the coefficients.

A.2 Configuration File

configuration file (*config_template*)

The session configuration file (***config_template***) is used to record the processing strategies for ***PRIDE PPP-AR II***. The session configuration file contains processing options, solution options and file options. It is a text file utilizing " **Keyword = Value "** format records for various options. For enumeration values, the selectable value is an enumeration label (NO, YES ...). The texts after **!** in a line are treated as comments.The explanations of the processing parameters are listed below. The content after '#' denotes the explicit explanation of the options.

---*configuration template*---

 # configuration template for PRIDE PPP-AR 2

 # The following options can be kept for all data processing (except for 'Station used' list)
 # For Ambiguity fixing, it can always be 'ROUNDING' in configuration file. Actually, AR is
 # controlled by the command line arguments of pride_pppar.

Session config
 # User should modify this part configuration to suit their own directory
Interval = 30
Session time = -YYYY- -MM- -DD- 00 00 00 86360 ! -YYYY- -MM- -DD- is placeholder for automatic multi-days processing; 3600 for hours solution
Rinex directory = /home/username/path-to-data/-YEAR-/-DOY-/ ! -YEAR- -DOY- is placeholder for automatic multi-days processing
Sp3 directory = /home/username/path-to-product/product/

```
Table directory = /home/username/path-to-table/table/

## strategies
Strict editting        = YES                              ! change to NO if using high-dynamic data with bad quality
Remove bias            = YES                              ! change to NO if AR method is LAMBDA
ZTD model              = PWC:60                           ! troposphere estimation. PWC: piece-wise constant, 60: 1 hour. PWC/STO
HTG model              = PWC:720                          ! troposphere horizontal gradient. PWC/STO
Iono 2nd               = NO                               ! change to YES if correcting higher-order ionospheric delays

## ambiguity fixing options
Ambiguity fixing       = ROUNDING                         ! Ambiguity fixing: ROUNDING/LAMBDA
Ambiguity duration     = 600                              ! common observation time in seconds
Cutoff elevation       = 15                               ! cutoff angles for eligible ambiguities in AR
Widelane decision      = 0.20 0.15 1000.                  ! deriation, sigma in WL-cycle
Narrowlane decision = 0.15 0.15 1000.                     ! deriation, sigma in NL-cycle
Critical search        = 2 4 1.8 3.0

# Insert # at the begining of individual GNSS PRN means not to use this satellite

## Satellite list
+GNSS satellites
*PN
 G01
 G02
 G03
 G04
 G05
 ...
 J05
 J06
 J07
 J08
 J09
 J10
-GNSS satellites

# User can add more station in the following table. Stations will be processed one by one.
# Available positioning mode:   S -- static
#                               K -- kinematic
# Available mapping function:        NIE -- Niell Mapping Function (NMF)
#                                    GMF -- Global Mapping Function
#                                    VM1 -- Vienna Mapping Function (VMF1)
```

 # VM3 -- Vienna Mapping Function (VMF3)
 # Other arguments can be kept.

 # Station list
+Station used
**NAME TP MAP CLKm EV ZTDm PoDm HTGm PoDm RAGm PHSc PoXEm PoYNm PoZHm*

```
 aber S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 abmf S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 abpo S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 acrg S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 adis S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 ...
 zamb S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 zeck S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 zim2 S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 zim3 S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
 zimm S  GMF 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
-Station used
```

-- ***configuration template*** --

A.3 Solution Files

In **PRIDE PPP-AR II**, there are some self-defined solution files, whose formats have been listed in the file ***file_name.***

amb file

The values of float ambiguities are recorded in ***amb*** file. Running ***lsq*** will call ***amb*** file to obtain initial value of ambiguity. An example is shown below (Fig. 6):

```
ABMF G01       2.228929       -24.213358  58849.0000000000  58849.2135416667  0.0410  0.0093  48.1
ABMF G07       5.667315        13.875125  58849.0000000000  58849.2194444444  0.0715  0.0073  41.3
ABMF G08       1.204019       -35.112866  58849.0000000000  58849.1663194444  0.0827  0.0149  31.0
ABMF G09      13.899596         1.802620  58849.0000000000  58849.1211805556  0.1050  0.0207  21.7
ABMF G11      -6.433162       -21.151552  58849.0000000000  58849.2177083333  0.0587  0.0085  47.5
ABMF G16      -2.498858       -38.105137  58849.0000000000  58849.0899305556  0.0829  0.0200  16.3
ABMF G23      13.337554        18.863965  58849.0000000000  58849.0916666667  0.0630  0.0167  23.1
ABMF G26       4.638351       -48.208791  58849.0000000000  58849.0270833333  0.0768  0.0662   9.9
ABMF G27       0.708097       -31.138136  58849.0000000000  58849.0711805556  0.0874  0.0235  22.4
```

Fig. 6 Result file (amb file)

The first column describes the name of station; the second column describes the number of GNSS satellite; the next two columns record the values of ionosphere-free (IF) ambiguity and wide-lane (WL) ambiguity; and then the start time and end time are recorded in the next two columns in order to declare valid time of ambiguity; the following two columns are RMS of IF ambiguity and WL ambiguity, respectively; the last column records corresponding mean elevation angle during the valid time.

con file

Run ***arsig***, ***con*** file will be produced. ***con*** file records the values of integer ambiguity. An example is shown below (Fig. 7):

```
Single-Difference Ambiguity Constraint                          COMMENT
    SD                                                          TYPE OF CONSTRAINT
                                                                END OF HEADER
ABMF G16 G27 2020  1  1  0  0  0.000000 2020  1  1  1 42 30.000000          -7           19   0.000
ABMF C23 C30 2020  1  1  0  0  0.000000 2020  1  1  1 44  0.000000          45         -157   0.000
ABMF C23 C28 2020  1  1  0  0  0.000000 2020  1  1  1 44  0.000000          49         -182   0.000
ABMF C27 C28 2020  1  1  0  0  0.000000 2020  1  1  2  8  0.000000          12          -17   0.000
ABMF G09 G16 2020  1  1  0  0  0.000000 2020  1  1  2  9 30.000000          40         -112   0.000
ABMF G17 G23 2020  1  1  1 22  0.000000 2020  1  1  2 12  0.000000         -17           26   0.000
ABMF G03 G09 2020  1  1  1 50  0.000000 2020  1  1  2 54 30.000000         -18           30   0.000
ABMF E21 E33 2020  1  1  0  0  0.000000 2020  1  1  3 15 30.000000         -21           61   0.000
ABMF E01 E21 2020  1  1  0  0  0.000000 2020  1  1  3 15 30.000000          -1          -36   0.000
ABMF E01 E26 2020  1  1  0  0  0.000000 2020  1  1  3 40  0.000000           5          -44   0.000
ABMF G06 G08 2020  1  1  2 58  0.000000 2020  1  1  3 59 30.000000          33         -105   0.000
ABMF G03 G08 2020  1  1  1 50  0.000000 2020  1  1  3 59 30.000000          19          -78   0.000
ABMF G01 G19 2020  1  1  2 55  0.000000 2020  1  1  5  7 30.000000         -58          120   0.000
ABMF G01 G30 2020  1  1  0 49 30.000000 2020  1  1  5  7 30.000000         -29           78   0.000
```

Fig. 7 Result file (con file)

The first three lines, as file header, declare the comment message. The file body records the results of integer ambiguity. The first column is station name and the next two columns record satellites of the single-difference ambiguity constraint. And then it is the start time and end time of ambiguity resolution for these difference satellites. The next two columns denote the values of wide-lane ambiguity and narrow-lane ambiguity, respectively.

kin file

The results of position are recorded in ***kin*** file when using the **K** model (Kinematic Model). The coordinates in this file are recorded epoch by epoch. An example is shown below (Fig. 8):

```
Kinematic Trajectory         abmf                         COMMENT
    30.00                                                 INTERVAL
                                                          END OF HEADER
58849     0.00    2919785.795 -5383744.979  1774604.871
58849    30.00    2919785.795 -5383744.983  1774604.873
58849    60.00    2919785.794 -5383744.981  1774604.876
58849    90.00    2919785.793 -5383744.981  1774604.872
58849   120.00    2919785.798 -5383744.984  1774604.874
58849   150.00    2919785.796 -5383744.979  1774604.872
58849   180.00    2919785.790 -5383744.971  1774604.868
58849   210.00    2919785.791 -5383744.971  1774604.868
58849   240.00    2919785.792 -5383744.972  1774604.867
58849   270.00    2919785.794 -5383744.969  1774604.864
58849   300.00    2919785.795 -5383744.970  1774604.864
58849   330.00    2919785.794 -5383744.973  1774604.870
58849   360.00    2919785.796 -5383744.975  1774604.870
58849   390.00    2919785.796 -5383744.973  1774604.870
58849   420.00    2919785.797 -5383744.974  1774604.870
58849   450.00    2919785.796 -5383744.971  1774604.870
58849   480.00    2919785.794 -5383744.967  1774604.868
58849   510.00    2919785.797 -5383744.972  1774604.870
58849   540.00    2919785.799 -5383744.975  1774604.870
58849   570.00    2919785.796 -5383744.971  1774604.869
58849   600.00    2919785.796 -5383744.972  1774604.871
```

Fig. 8 Kinematic solution file (kin file)

The header recorded the station name, interval and some comment. In the file body, the first two columns record epoch time with MJD and seconds of the day. The following three columns denote the values of coordinates (X, Y, Z) in WGS-84.

pos file

The results of static position are recorded in ***pos*** file using the **S** model (Static Model). Only one coordinate result is recorded as one-day position. An example is shown below (Fig. 9):

```
ABMF  58849.4998   2919785.7889  -5383744.9552   1774604.8574     0.52895575622475E-07     0.14573360746030E-06     0.22942017934127E-07
  -0.74031660494576E-07     0.23278087007773E-07     -0.43545633687323E-07     0.80189911208190E+00          66747
```

Fig. 9 Static position file (pos file)

In this file, the first column shows station name. And then processing time in MJD and "X/Y/Z" coordinates are recorded, respectively. The next columns record the corresponding coordinates' variance and covariance of XY XZ and YZ. Then the column records unit weighted mean errors. The last column records the numbers of observation used for calculating the coordinates.

neq file

This is a binary file which is used to record inversed normal matrix for ambiguity resolution.

rc(g/r/e/c/3/j) file

The results of receiver clock are recorded in ***rcg/r/e/c/3/j*** files. An example is shown below (Fig. 10):

```
Receiver Clock                                              COMMENT
    30.00                                                   INTERVAL
                                                            END OF HEADER
ABMF 2020  1  1  0  0  0.000000    -13726.960102      1.252826
ABMF 2020  1  1  0  0 30.000000    -13726.960102      2.408224
ABMF 2020  1  1  0  1  0.000000    -13726.960102      2.229607
ABMF 2020  1  1  0  1 30.000000    -13726.960102      2.539391
ABMF 2020  1  1  0  2  0.000000    -13726.960102      0.809248
ABMF 2020  1  1  0  2 30.000000    -13726.960102      0.918386
ABMF 2020  1  1  0  3  0.000000    -13726.960102      1.476299
ABMF 2020  1  1  0  3 30.000000    -13726.960102      1.383333
ABMF 2020  1  1  0  4  0.000000    -13726.960102      1.212336
ABMF 2020  1  1  0  4 30.000000    -13726.960102      2.259829
ABMF 2020  1  1  0  5  0.000000    -13726.960102      1.048810
ABMF 2020  1  1  0  5 30.000000    -13726.960102      1.251797
ABMF 2020  1  1  0  6  0.000000    -13726.960102      1.195303
ABMF 2020  1  1  0  6 30.000000    -13726.960102      1.295761
ABMF 2020  1  1  0  7  0.000000    -13726.960102      1.839331
ABMF 2020  1  1  0  7 30.000000    -13726.960102      1.080199
ABMF 2020  1  1  0  8  0.000000    -13726.960102      1.475932
```

Fig. 10 Receiver clock file (rcg file)

The comment and epoch interval are recorded in the part of file header. And in the file body, there are records of station name, epoch time, receiver clock and its STD.

res file

The values of residuals for observation are recorded in ***res*** file. As an output file of ***lsq***, it will be used in ***redig***. An example is shown below (Fig. 11):

```
Residuals                                                      COMMENT
        85                                                     # OF SIT / SAT
     11644    133513                                           # OF UNKNOWN / OBS
     0.779                                                     WEIGHTED SIGMA (CYCLE)
ABMF                                                           STATION LIST
G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 SATELLITE LIST
G16 G17 G18 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 SATELLITE LIST
G31 G32 E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E14 E18 E19 SATELLITE LIST
E21 E24 E25 E26 E27 E30 E31 E33 E36 C01 C02 C03 C04 C05 C06 SATELLITE LIST
C07 C08 C09 C10 C11 C12 C13 C14 C16 C19 C20 C21 C22 C23 C24 SATELLITE LIST
C25 C26 C27 C28 C29 C30 C33 C34 C35 C36                     SATELLITE LIST
     30.00                LCPC                                 INT / OBS TYPE
 2020  1  1  0  0  0.0000000    86280.00                       RES TIME BEG/LEN
 2020  1  1  0  0  0.0000000    86300.00                       CONFIG TIME BEG/LEN
                                                               END OF HEADER
TIM 2020  1  1 23 58  0.0000000  58849  86280.00
  1 83     0.045    -2.678  0.17927954D+04  0.26446719D-03  0  10.349   36.358
  1 79    -0.002     0.061  0.13888889D+05  0.20488425D-02  0  61.629 -134.778
  1 76     0.002    -0.352  0.13888889D+05  0.20488425D-02  0  48.795   92.213
  1 74    -0.005    -0.850  0.13888889D+05  0.20488425D-02  0  53.538   -1.504
  1 65    -0.000     2.308  0.13888889D+05  0.20488425D-02  0  34.701   32.531
  1 51    -0.006     0.301  0.13888889D+05  0.20117601D-02  0  45.287   31.035
  1 50     0.006    -0.045  0.11326529D+05  0.16406107D-02  0  26.842  -32.709
  1 39    -0.008     0.873  0.41025402D+04  0.59423952D-03  0  15.768 -174.501
  1 38    -0.004    -0.660  0.11691089D+05  0.16934160D-02  0  27.306 -121.921
  1 34     0.013     0.128  0.67735938D+04  0.98113289D-03  0  20.437   86.237
  1 31     0.088    -1.404  0.93034336D+03  0.13475719D-03  0   7.435  134.228
```

Fig. 11 Result file (res file)

Some comments have been explained in the part of file header. In the part of file body, the line started with "TIM" records the epoch time of residuals and the next lines record the values of residuals. The first two columns record the station number and the satellite number. And then the values of phase residual (cycle) and pseudorange residual (cycle) are in next two columns. Their STDs are recorded in next two columns, respectively. The next column records the flag of the data to indicate the states of the data. And then, the values of satellite elevation and satellite azimuth are recorded in the next two columns in the unit of angle (°).

rhd file

The results of RINEX health diagnosis are recorded in ***rhd*** file. An example is shown below (Fig. 12):

```
Rinex Health Diagnose     ABMF                             COMMENT
     30.00     30.00                                       INT AMB/DEL
        28       103          1                            AMB MAX/TOT/NEW
     66615     14285        252                            EPO AVA/REM/NEW
                                                           END OF HEADER
TIM 2020  1  1  0  0  0.0000000
G01                           2020  1  1  5  7 30.0000000 AMB
G03                                                       DEL_LOWELEVATION
G07                           2020  1  1  5 16  0.0000000 AMB
G08                           2020  1  1  3 59 30.0000000 AMB
G09                           2020  1  1  2 54 30.0000000 AMB
G11                           2020  1  1  5 13 30.0000000 AMB
G16                           2020  1  1  2  9 30.0000000 AMB
```

Fig. 12 Residual Health Diagnosis file(rhd file)

In the part of file header, the comment "INT AMB/DEL" denotes epoch interval. The comment "AMB

MAX/TOT/NEW" denotes max numbers of ambiguity for epochs, total numbers of ambiguity and newly added ambiguity numbers after posterior residual diagnosis, respectively. The comment "EPO AVA/REM/NEW" denotes available numbers of epochs, deleted numbers of epochs and newly added epoch numbers after posterior residual diagnosis, respectively.

In the part of file body, the line started with "TIM" records the time of health diagnosis data. And then next lines record the health diagnosis data. The comment "AMB" denotes adding new ambiguity parameter. The content includes satellite number and ending time. The start time is the time which has been given at the line with "TIM". The comment "DEL" denotes the data of the satellite deleted as bad data.

stt file

The statistic value of phase residuals are recorded in ***stt*** file and you can check this file to obtain the quality of PPP result. An example is shown below (Fig. 13):

```
+RMS OF RESIDUALS---PHASE(MM)
NAME SUMM G01G02G03G04G05G06G07G08G09G10G11G12G13G14G15G16G17G18G19G20G21G22G23G24G25G26G27G28G29G30
ABMF   16  12 10 21  0 10 15 16 15 18 12 12 17 12 14 14 10 10  0 17 21 16 19 13 14 16 19 11 12 15 19
NAME SUMM G01G02G03G04G05G06G07G08G09G10G11G12G13G14G15G16G17G18G19G20G21G22G23G24G25G26G27G28G29G30
-RMS OF RESIDUALS---PHASE(MM)
+TIME SERIES OF RESIDUALS---PHASE(MM)
 ABMF G01G02G03G04G05G06G07G08G09G10G11G12G13G14G15G16G17G18G19G20G21G22G23G24G25G26G27G28G29G30G31G
    1   9               -11  6-15     1              0                    2        4  1
    2  14               -11  5-17     2             -2                   -2       20  2
    3  16               -14  6-17     1             -1                    0       17  0
    4  11               -16  8-16     5             -2                   -2       21  0
    5  14                -6  6-17     4             -1                   -4       11 -1
    6  11                -9 10-13     4             -4                   -5        7  0
    7   9               -18 11-10     5              2               -30 -4      -10  2
    8  10               -18 11-11     7             -2               -25 -5      -14  3
    9   4               -11  9 -6     7             -1               -17 -6      -19  2
   10   2                -3  8 -4     7             -9               -22 -5      -13  3
   11  -1               -11  8 -3     7             -5               -23 -4       -3  4
   12   3               -18  6 -2     5             -5               -16 -2        7  3
   13   6               -16  3 -2     6             -9               -17  1        2  2
   14   9               -12  3 -2     4            -14               -12  1       10  0
   15   6                -6  2  3     3            -17                -6 -1        9 -1
   16   4                -9  1  1     7            -19                -2  2       14  0
   17   8               -13  1 -1    10            -15                -7 -1        3  0
   18   3               -11  3 -1     8            -12               -10  0       -2  1
```

Fig. 13 Result file (stt file)

stt file is composed of RMS of phase residuals(mm) and time series of residuals(mm).

ztd file

The values of zenith tropospheric delay are recorded in ***ztd*** file. An example is shown below (Fig. 14):

```
Zenith Tropospheric Delay                                   COMMENT
    30.00                                                   INTERVAL
                                                            END OF HEADER
ABMF 2020  1  1  0  0  0.000000   2.311569   0.194287   0.042391
ABMF 2020  1  1  0  0 30.000000   2.311595   0.194043   0.042391
ABMF 2020  1  1  0  1  0.000000   2.311595   0.194042   0.042391
ABMF 2020  1  1  0  1 30.000000   2.311595   0.194042   0.042391
ABMF 2020  1  1  0  2  0.000000   2.311595   0.194042   0.042391
ABMF 2020  1  1  0  2 30.000000   2.311595   0.194041   0.042391
ABMF 2020  1  1  0  3  0.000000   2.311595   0.194041   0.042391
ABMF 2020  1  1  0  3 30.000000   2.311595   0.194041   0.042391
ABMF 2020  1  1  0  4  0.000000   2.311595   0.194040   0.042391
ABMF 2020  1  1  0  4 30.000000   2.311595   0.194040   0.042391
ABMF 2020  1  1  0  5  0.000000   2.311595   0.194040   0.042391
ABMF 2020  1  1  0  5 30.000000   2.311595   0.194039   0.042391
ABMF 2020  1  1  0  6  0.000000   2.311595   0.194039   0.042391
ABMF 2020  1  1  0  6 30.000000   2.311595   0.194038   0.042391
ABMF 2020  1  1  0  7  0.000000   2.311595   0.194038   0.042391
ABMF 2020  1  1  0  7 30.000000   2.311595   0.194038   0.042391
```

Fig. 14 Zenith tropospheric delay file (ztd file)

The first column records the station name and the following is the time of epoch. The next two columns record the value of dry tropospheric delay and wet tropospheric delay. The last column records the correction of troposphere.

A.4 Statistical Files

DOP file

The values of DOP (Dilution of Precision) are recorded in ***dop_file*** file. An example is shown below (Fig. 15):

```
DOP(PTG):    58849       0.00       1.2506128      0.6814834      1.4242374
DOP(PTG):    58849      30.00       1.2515942      0.6821264      1.4254068
DOP(PTG):    58849      60.00       1.2525348      0.6827389      1.4265258
DOP(PTG):    58849      90.00       1.2534340      0.6833205      1.4275937
DOP(PTG):    58849     120.00       1.2542914      0.6838709      1.4286099
DOP(PTG):    58849     150.00       1.2551064      0.6843898      1.4295739
DOP(PTG):    58849     180.00       1.1620069      0.6117506      1.3132018
DOP(PTG):    58849     210.00       1.1628831      0.6123683      1.3142648
DOP(PTG):    58849     240.00       1.1637406      0.6129719      1.3153048
DOP(PTG):    58849     270.00       1.1645790      0.6135612      1.3163213
DOP(PTG):    58849     300.00       1.1653982      0.6141359      1.3173139
DOP(PTG):    58849     330.00       1.1661976      0.6146959      1.3182822
DOP(PTG):    58849     360.00       1.1669771      0.6152409      1.3192258
DOP(PTG):    58849     390.00       1.1677362      0.6157707      1.3201445
DOP(PTG):    58849     420.00       1.1684748      0.6162851      1.3210378
DOP(PTG):    58849     450.00       1.1691926      0.6167840      1.3219053
```

Fig. 15 DOP file

The second and third columns record the time of epoch. The next three columns record the values for PDOP, TDOP and GDOP.

satellite number file

The values of satellite number are recorded in ***satnum_file*** file. An example is shown below (Fig. 16):

```
SATNUM:    58849      0.00     19
SATNUM:    58849     30.00     19
SATNUM:    58849     60.00     19
SATNUM:    58849     90.00     19
SATNUM:    58849    120.00     19
SATNUM:    58849    150.00     19
SATNUM:    58849    180.00     20
SATNUM:    58849    210.00     20
SATNUM:    58849    240.00     20
SATNUM:    58849    270.00     20
SATNUM:    58849    300.00     20
SATNUM:    58849    330.00     20
```

Fig. 16 Satellite number file

The second and third columns record the time of epoch. The next column records the values of satellite number.

Appendix B. Phase Bias Products

B.1 Algorithm and Usage

We have implemented the capability to produce phase bias products routinely, which is aiming to facilitate PPP-AR applications. The products are provided in two components:

1) SINEX-BIAS formatted GNSS Fractional Cycle Bias;

2) Ambiguities fixed GNSS satellite clocks.

Along with those products, a counterpart software, called “**PRIDE PPP-AR II**”, is released together. With our phase bias products and software, users can conduct PPP-AR easily and focus on the results analysis. A data processing result is provided below (Fig. 17):

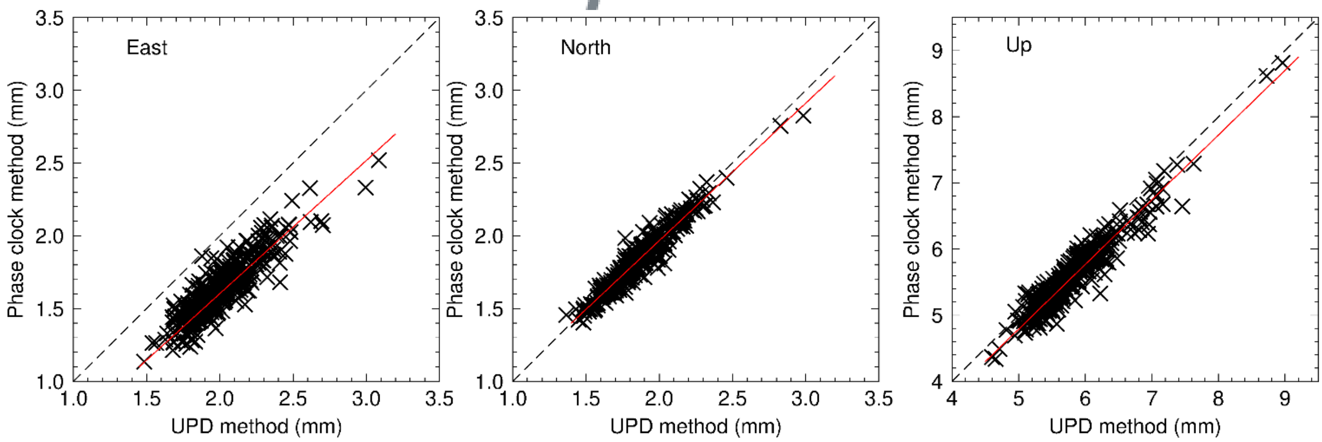


Fig. 17 IGS stations coordinates RMS comparison of two types of PPP-AR solutions, i.e. the widely used UPD method and phase clock method (i.e. with our phase bias products), with respect to the IGS weekly SINEX file solutions in 2016.

The products generation strategies are listed as follows:

1. Phase biases are obtained from the globally distributed IGS network stations;
2. PPP-AR is complemented with the same network using the phase bias product above;
3. Satellite clocks are re-estimated with holding the fixed ambiguities and correcting phase biases.

Currently, the products from 2006 onwards can be publicly accessible from the WHU ftp (ftp://igs.gnsswhu.cn/pub/whu/phasebias/) and the software can be download from the homepage of PRIDELab (https://pride.whu.edu.cn).

For more information, please refer to the attached 2018 IGS Report: Phase bias product and open-source software for undifferenced ambiguity resolution at Wuhan University.

B.2 Product Usage

In order to keep homogeneity with phase clocks and phase bias products, users should use CODE/WUM final products (except the satellite clock) while using our phase clock and phase bias products to achieve ambiguity resolution with PRIDE PPP-AR II. The usage of phase bias product is similar to DCB (Differencial Code Bias). You can simply subtract the phase biases from the original observations equations for correction. The procedures of ambiguity resolution are as follow:

1) Before realizing PPP float solution with ionosphere free (IF) combination, phase biases in L1C, L2W, C1W and C2W measurements (take GPS as an example) should be corrected. Note that our phase biases only target L1C, L2W, C1W and C2W observations, so users need to remove DCB with other biases products;

$$\tilde{\Phi}_{true} = \Phi_{observed} - B \qquad (1)$$

Where $\tilde{\Phi}_{ture}$ denotes true (or unbiased) observation; $\Phi_{observed}$ denotes original observation; B denotes phase biases (L1C, L2W, C1W and C2W).

2) Estimate wide-lane ambiguity and realize float PPP;

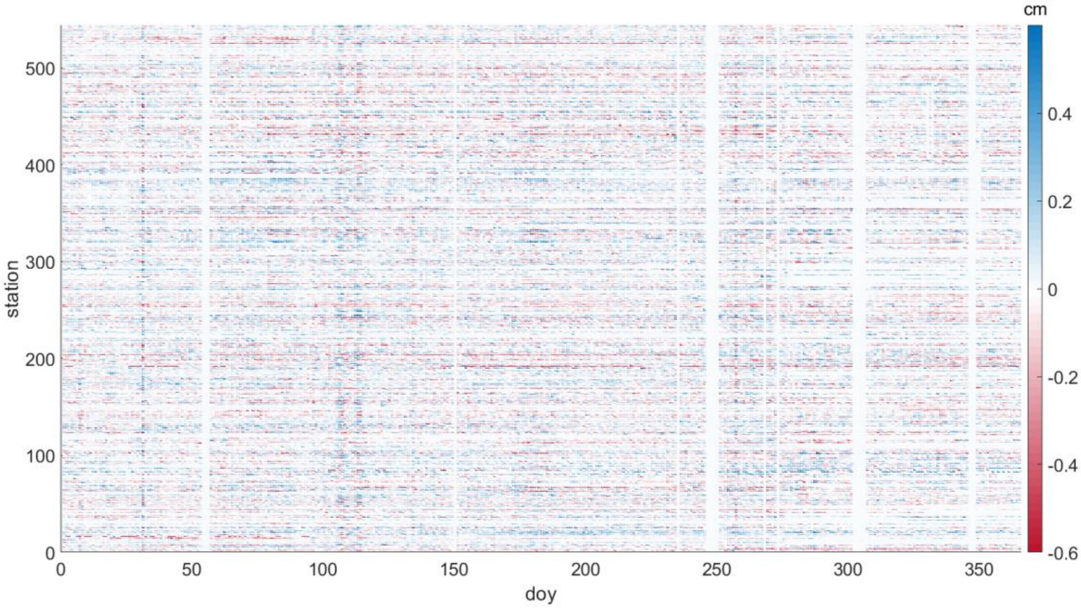
3) Fix wide-lane ambiguities and narrow-lane ambiguities without any biases correction;

4) Calculate IF ambiguities values with the fixed wide-lane ambiguities and narrow-lane ambiguities, then achieve PPP ambiguity resolution.

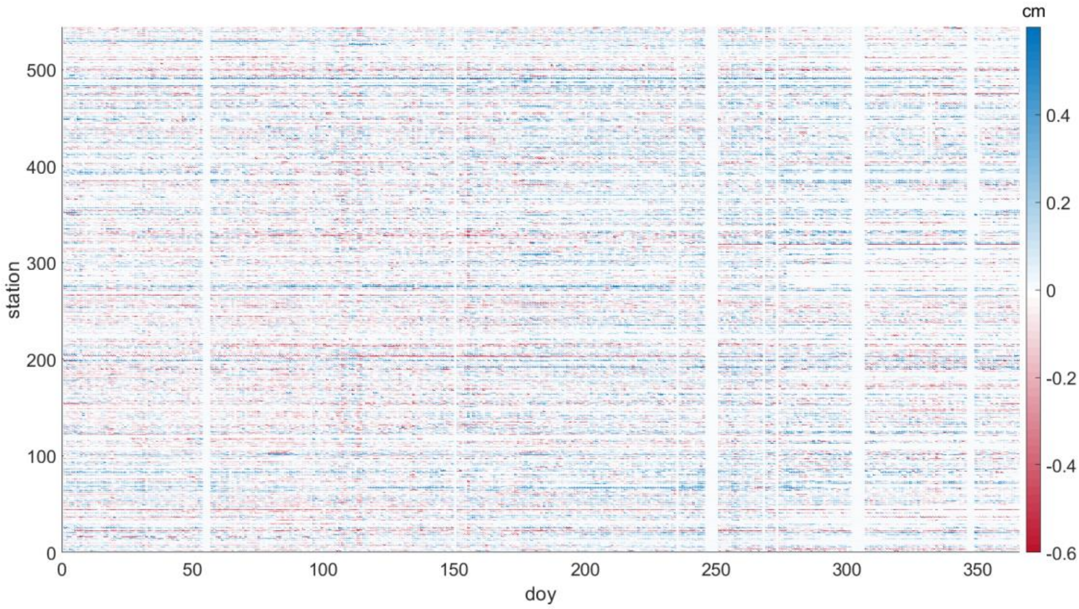
Appendix C. Typical examples

C.1 Daily solutions

Utilizing the phase bias products we released, we test a series of IGS static stations in 2020. Then we compare the static PPP-AR results with IGS SINEX solutions. The figures listed below (Fig. 18) record the difference between our solutions and IGS SINEX solutions in east/north/up directions, respectively. The X axis, which denotes day of year, ranges from 1 to 366. The Y axis denotes different stations. The color map, which ranges from blue to red, represents the difference value in the unit of centimeter.



cm
0.4
0.2
0
-0.2
-0.4
-0.6
station
500
400
300
200
100
0
50
150
250
350
doy



cm
0.4
0.2
0
-0.2
-0.4
-0.6
station
500
400
300
200
100
0
50
150
250
350
doy

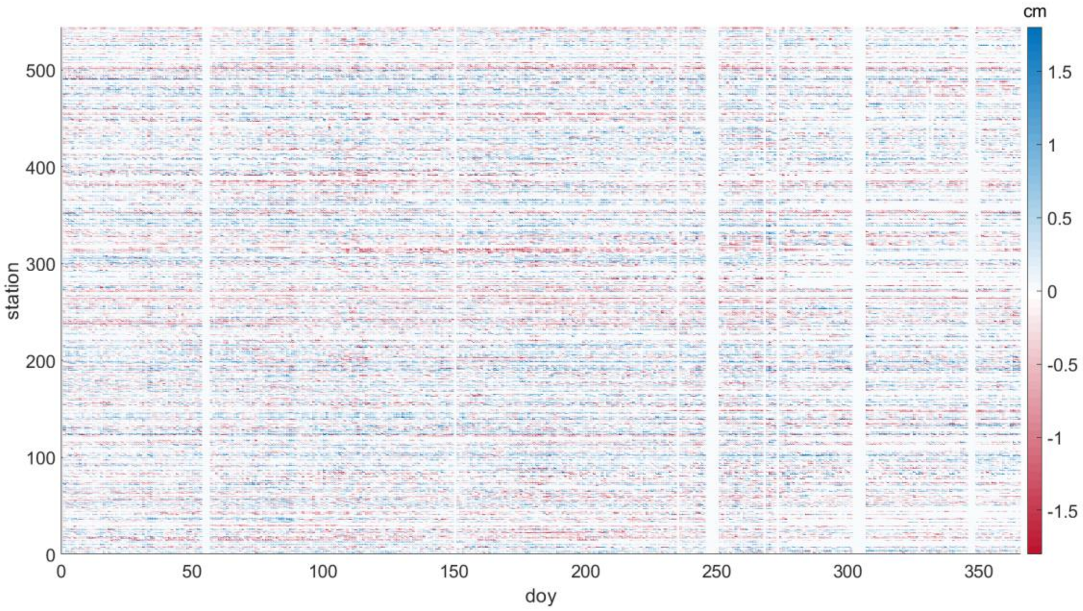


Fig. 18 Difference between PRIDE PPP-AR II solution and IGS SINEX solution of various stations.

C.2 Super-high-rate (50 Hz) data

PRIDE PPP-AR II can still process super-high-rate data, up to 50 Hz. Then we test HLFY station (1300 kilometers away from epicenter), to presenting the 2011 earthquake of the Pacific coast of Tōhoku occurred in Japan at 05:46:24 (UTC) on March 11, 2011 with a magnitude of MW 9.0. As shown in Fig. 19, the black box shows the evident horizontal vibration, about 10 centimeters.

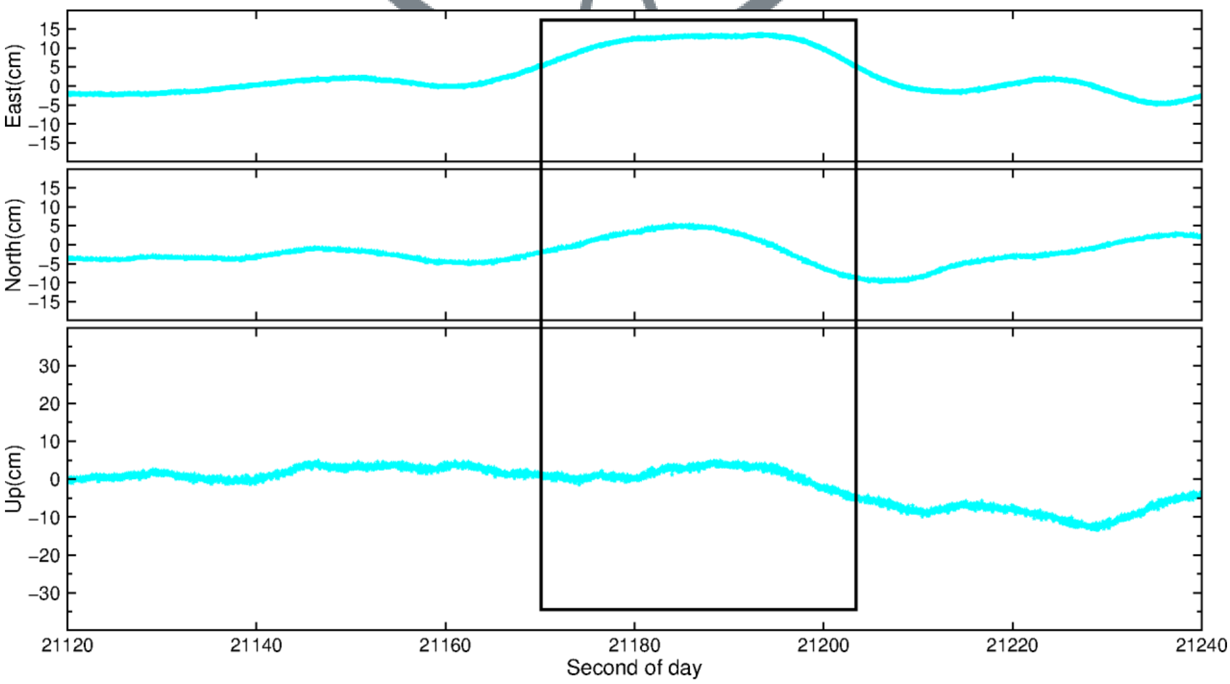


Fig. 19 Time series of super-high-rate kinematic solutions (cm) in east, north, and up components at station HLFY

on March 11, 2011

C.3 High-dynamic mobile platforms

In an aerial photogrammetry experiment, high-dynamic PPP has been realized. The observation period is on November 27, 2017 and lasting about 5 hours. The sampling rate is 0.5 seconds. The trajectory of the aircraft is shown in Fig. 20. And we use relative positioning solutions of WayPoint software (a commercial positioning software) as the reference solutions, whose maximum baseline length is up to 170 kilometers. As shown in Fig. 21, In the airborne experiment with less shielding, the positioning accuracy is basically the same with that of commercial software. Besides, fixed ambiguity can also significantly improve the positioning accuracy in high-dynamic data solutions.

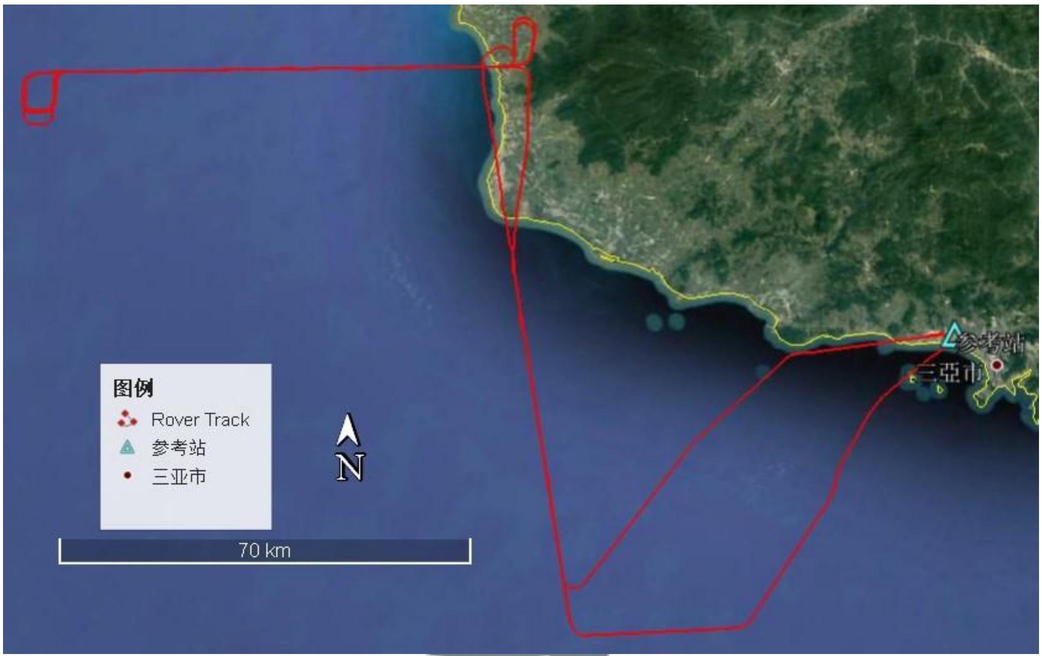


Fig. 20 Trajectory of the aircraft in high-dynamic aerial photogrammetry experiment

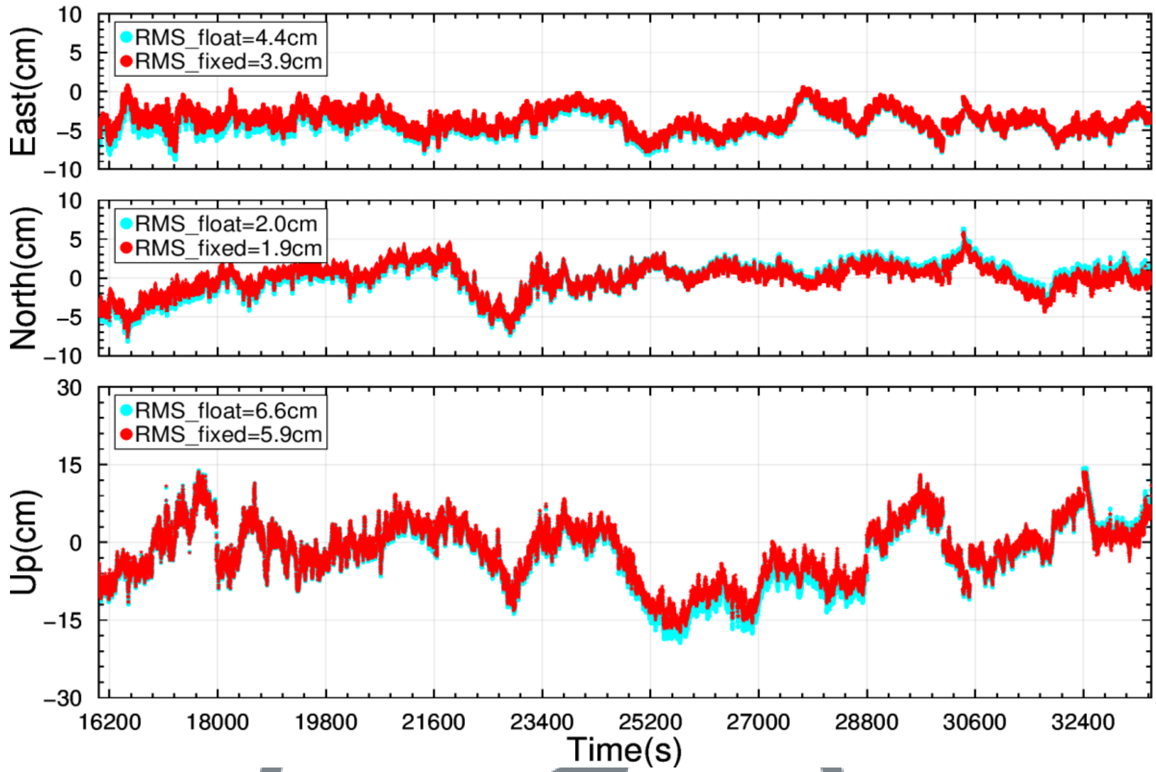


Fig. 21 Location differences between PRIDE PPP-AR II and WayPoint software

Appendix D. GPS data processing when SA is on

GPS data when SA is on have low-precision broadcast ephemeris, so the usage of broadcast ephemeris in these period should be cautious. In order to process these GPS data for users easily, we have set some configurations in ***"tedit"*** module to avoid obtaining satellite clock corrections from broadcast ephemeris. Besides, users should change the **"Strict editting"** mode from **"YES"** to **"NO"** in ***"config_file"***. Then users should change the script ***"pride_pppar.sh"*** as follows:

1. Change the ways of **precise satellite clock** download;
2. Similarly, change the ways of **precise satellite orbit** download;
3. Besides, change the ways of **earth rotation parameters** download;
4. Note that **earth rotation parameters** need continuous 3-day files to merge.

As an example, we select precise satellite clock/orbit/ERP repro2 products of JPL to process GPS data when SA is on. We test an IGS station (ALBH) in 1995. The figure listed below (Fig. 22) records the position time series in east/north/up directions, respectively. The X axis, which denotes day of year, ranges from 1 to 365. The Y axis denotes changes of positions.

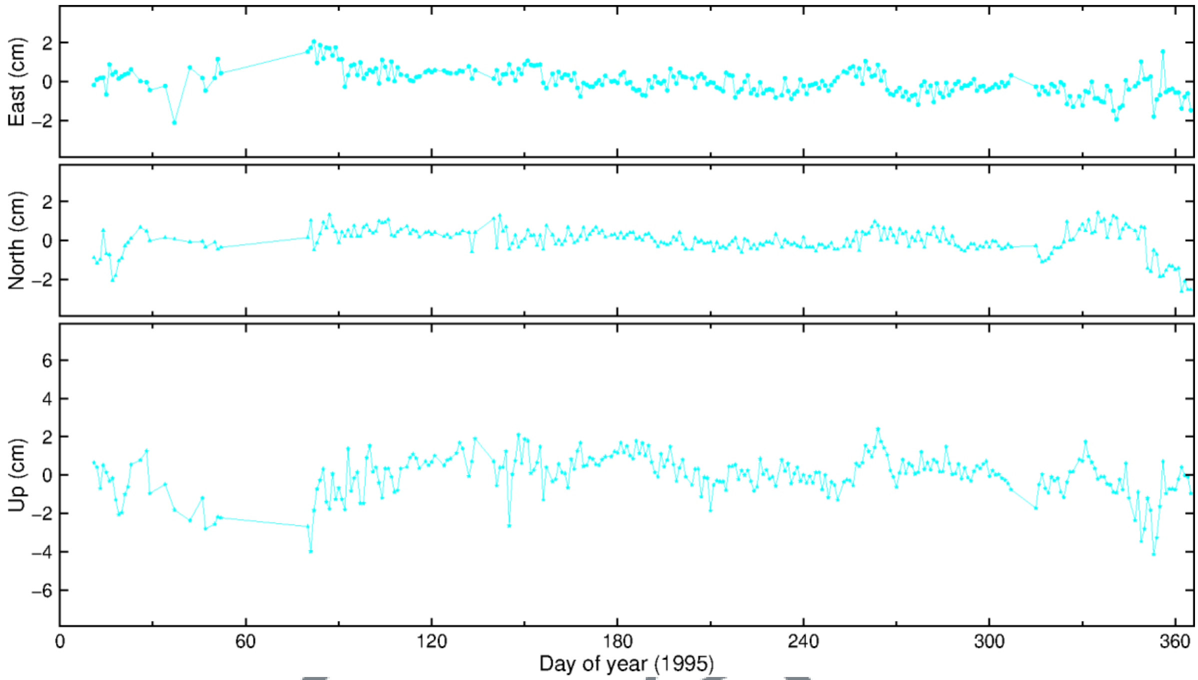


Fig. 22 Position time series at station ALBH in 1995

Appendix E. Windows lite-version

E.1 The main interface of program

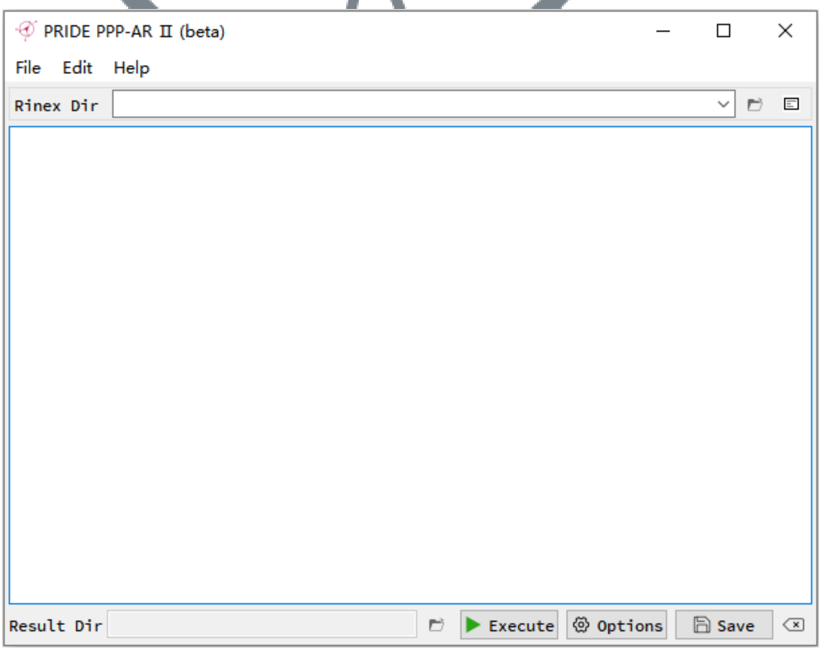


Fig. 23 The user interface

PRIDE_PPPAR_WIN compiles source code of PRIDE PPP-AR II under Windows environment, and calls the generated executable program to realize precise point positioning with ambiguity resolution, and achieves the same function as Linux version basically (shown in Fig. 23).

E.2 Procedures

1) menu bar　: File→Open Rinex Dir, choose the directory of observation;
2) menu bar　: Edit→Options, customize processing options;
3) user interface: Execute, process all observation files in the directory;
4) user interface: Open Results Dir, view solution files.

E.3 Options

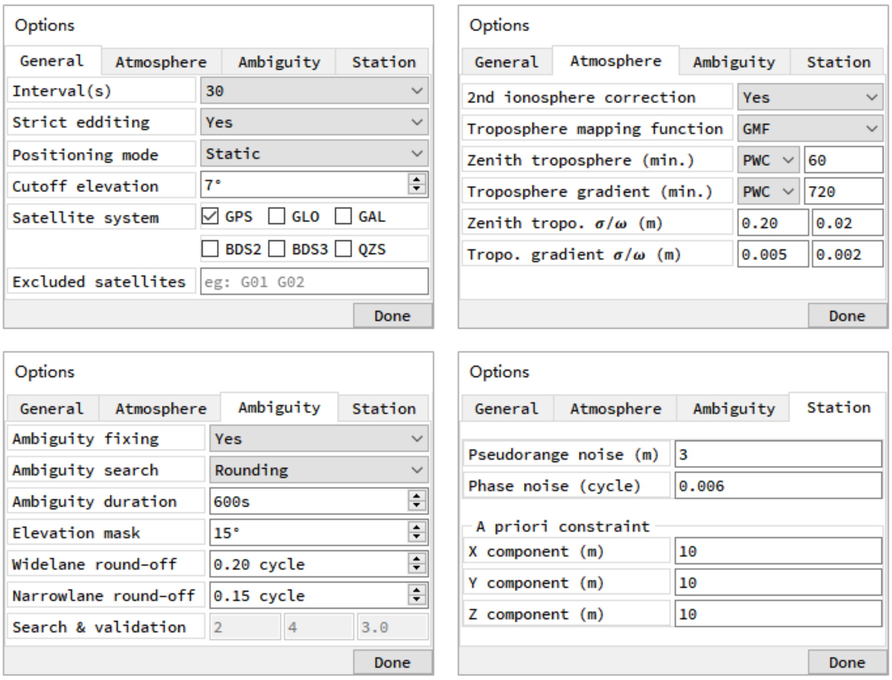


Fig. 24 Primary processing options

1) General　: data sampling interval, editing mode, positioning mode, cutoff elevation, satellite system;

2) Atmosphere　: two-second ionospheric correction, troposphere mapping function, estimation strategy of troposphere delays, the priori constraint and process noise of zenith troposphere delay and troposphere gradient;

3) Ambiguity　: ambiguity search method, the minimum arc length of ambiguities, cutoff angles for eligible ambiguities, round-off criterion for wide-lane/narrow-lane ambiguities, maximum number of ambiguities to be removed, minimum number of ambiguities to be saved, Ratio;

4) Station　: a priori constraint of pseudorange and carrier phase, a priori constraint of initial position.