PRIDE PPP-AR II tutorial

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Overview

PRIDE PPP-AR Ⅱ

- GPS, GLONASS, Galileo, BDS-2/3 and QZSS capable
- High-rate GNSS data processing of up to 50Hz
- Vienna Mapping Function 1/3 (VMF3) and GPT3 for troposphere modeling
- Second-order ionospheric correction
- High-dynamic mobile platforms applicable for aerial photogrammetry, ship-borne gravimetry, etc.

Overview

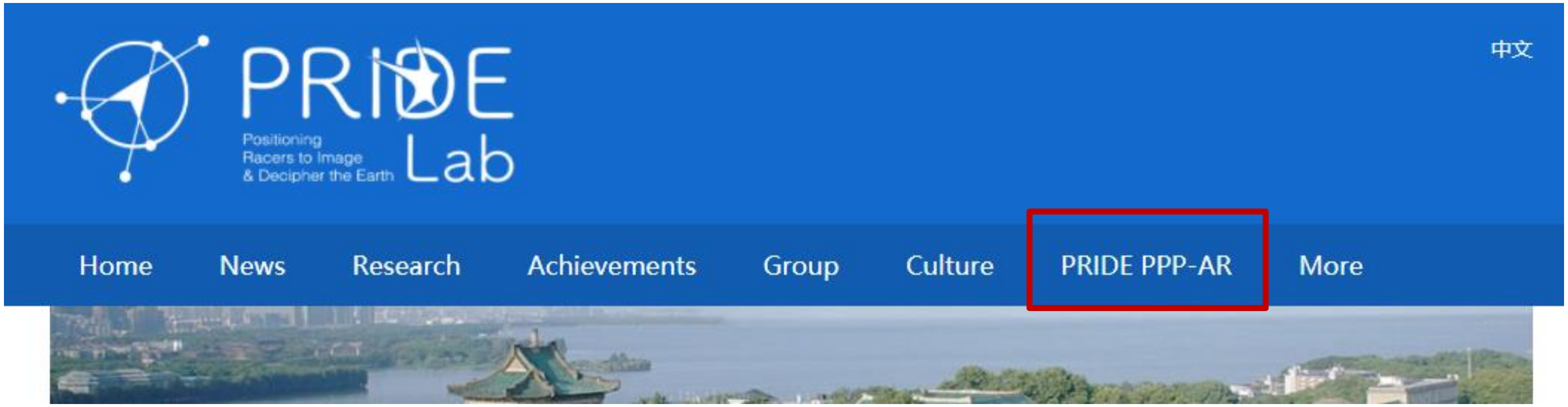
PRIDE PPP-AR II

- Receiver clock jump mitigation
- A Windows lite-version provided for very early career researchers
- Ambiguity-float PPP using data dating back to 1994 when SA was on
- GPS/Galileo/BDS-2/3 PPP-AR in the case of the bias-SINEX format phase biases (ftp: //igs.gnsswhu.cn)

Overview

☐ Download link

- http: //pride.whu.edu.cn/



Overview

The structure of the software package

- \src: source code
- \scripts: script library
- \table: table files
- \bin: executable program
- \doc: manual、logo、tutorial
- \example: examples
- \win: Windows lite-version
- install.sh: installation script
- ChangeLog: description of version change

Overview

- The structure of the software package
  - \src: source code

Subdirectory	Function
\header	Header files
\lib	Library functions
\orbit	sp3orb, mergesp3
\tedit	Pre-processing RINEX files
\redig	Residual editing
\lsq	Least squares adjustment
\arsig	Ambiguity resolution
\utils	Universal tools
\spp	Standard single point positioning
Makefile	Makefile

Overview

- The structure of the software package
  - \scripts: script that facilitates data processing

Subdirectory	Function
pride_pppar.sh	Automatic processing Shell script (Linux)
pride_pppar_Mac.sh	Automatic processing Shell script (Mac)

Overview

- The structure of the software package
  - \table: table files

Subdirectory	Function
oceanload	Ocean tide loading file
gpt3_1.grd	External grid file of meteorological parameters file (1 degree * 1 degree)
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
file_name	File names definition of PRIDE PPP-AR II

Overview

- The structure of the software package
  - \bin: executable program

Subdirectory	Function
get_ctrl	Get configuration parameters
spp	Standard single point positioning program
mergesp3	Merge sp3 (3 files) into one file
sp3orb	Transform sp3 into self-defined binary file
tedit	Pre-processing RINEX files
lsq	Least squares adjustment
redig	Residual editing
arsig	Ambiguity resolution
xyz2enu	Convert position of XYZ to ENU
enucov	Convert covariance of XYZ to ENU

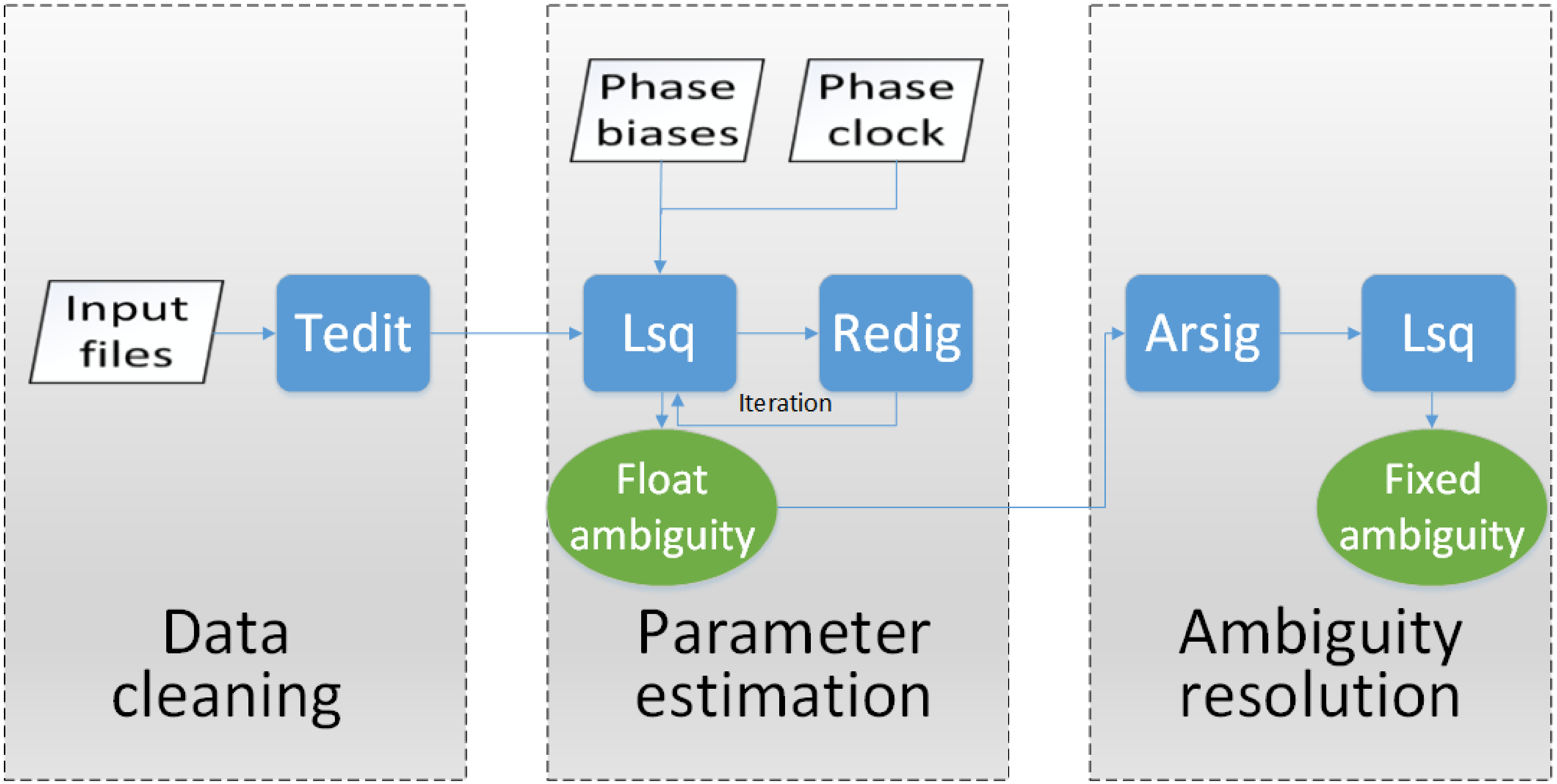
Overview

- The structure of the software package
  - \example: examples

Subdirectory	Function
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

Overview

PRIDE PPP-AR Ⅱ Program architecture



Examples

Installation

- Confirm that bash and gfortran are installed before installation (rename pride_pppar.sh as pride_pppar_Mac.sh for MacOS)
- Run ./install.sh to install the program automatically
- Restart terminal

- Note: The software will be installed in the ${HOME}/.PRIDE_PPPAR_BIN/

Examples

Validation

- After installation, change directory into /example
- Run ./test.sh (Run ./test_Mac.sh for MacOS)

```
(1) static float
===> CheckExecutables...
===> CheckExecutables done
:: Processing date range: 2020 01 01  <==>  2020 01 01
:: Control file: /home/sfeng/work/pride_pppar_v2.0/example/config.7I08QVnLvi
:: AR switch: N
===> ProcessSingleDay 2020 001...
===> CopyTables...
===> CopyTables done
===> PrepareProducts...
:: Prepare IGS ATX product: igs14_2082.atx ...
:: Prepare IGS ATX product: igs14_2082.atx done
```

Examples

Validation

- Contrast result

Examples	Content
static PPP	Static, PPP Float Solution
static PPP-AR	Static, PPP Ambiguity Resolution
kinematic PPP	Kinematic, PPP Float Solution
kinematic PPP-AR	Kinematic, PPP Ambiguity Resolution
kinematic PPP (1 hour)	Kinematic, PPP Float Solution
kinematic PPP-AR LAMBDA (1 hour)	Kinematic, PPP Ambiguity Resolution with LAMBDA
high-dynamic PPP	High-dynamic, PPP Float Solution

Example: configuration

Project setup

- Project directory is PROJ_DIR, table files in TABLE_DIR
- Data: located in ${PROJ_DIR}/data/2020/001/
- Precision product: located in ${PROJ_DIR}/product/

Data processing flow

1. Open the terminal and enter the ${PROJ_DIR} directory
2. Copy configuration file 'config_template' to ${PROJ_DIR}/config and edit it
3. Run command *'pride_pppar config 20200101 20200101 Y'*
4. After processing, the solution files will be in the ${PROJ_DIR }/2020/001/ directory

Example: configuration

- Precision product

File name	Content
SP3 (satellite orbit)	WUM/COD orbit
ERP (earth rotation parameters)	WUM/COD earth rotation parameters
CLK (satellite clock)	Phase clock ftp: //igs.gnsswhu.cn/pub/whu/phasebias/
BIA (phase bias)	Phase bias ftp: //igs.gnsswhu.cn/pub/whu/phasebias/
DCB (differential code bias)	CODE P1C1 & P2C2 correction
Other	Ionospheric grid file & tropospheric grid file

- Note: The downloaded products are stored in the ${PROJ_DIR}/product/ directory. Change ${HOME}/.PRIDE_PPPAR_BIN/pride_pppar 'USECACHE' to 'YES' to use these files.

Example: configuration

```
## Session config
# User should modify this part configuration to suit their own directory
Interval = 30
Session time    = -YYYY- -MM- -DD- 00 00 00 86360
Rinex directory = /home/username/path-to-data/-YEAR-/-DOY-/
Sp3 directory   = /home/username/path-to-product/product/
Table directory = /home/username/path-to-table/table/
```

- The characters enclosed by'- 'are placeholders and are used in batch scripts
- Interval specifies the data processing sampling rate
- Session time specifies the start time and duration of data processing
- Rinex directory = ${PROJ_DIR}/data/-YEAR-/-DOY-/
- Sp3 directory = ${PROJ_DIR}/product/
- Table directory = ${TABLE_DIR}
- Keep the default values for other parts

PRIDE Lab
Positioning Racers to Image & Decipher the Earth

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Example: configuration

```
## strategies
Strict editting   = YES
Remove bias       = YES
ZTD model         = PWC:60
HTG model         = PWC:720
Iono 2nd          = NO
```

- Strict editing: change to NO if using high-dynamic data with bad quality && default YES denotes strict data editting
- Remove bias: change to NO if AR method is LAMBDA && default YES denotes integer properties
- ZTD model: troposphere estimation
  - PWC: piece-wise constant, 60: 1 hour
  - STO: estimation per epoch
- HTG model: troposphere horizontal gradient
  - PWC && STO
- Iono 2nd: correcting second-order ionospheric delays
  - YES && NO

Example: configuration

```
## ambiguity fixing options
Ambiguity fixing     = ROUNDING
Ambiguity duration   = 600
Cutoff elevation     = 15
Widelane decision    = 0.20 0.15 1000.
Narrowlane decision = 0.15 0.15 1000.
Critical search      = 2 4 1.8 3.0
```

- Ambiguity fixing: change to LAMBDA if AR method is LAMBDA && default FIX denotes integer properties
- Ambiguity duration: common observation time in seconds
- Cutoff elevation: cutoff angles for eligible ambiguities in AR
- Widelane decision:
  - deriation (0.20), sigma (0.15) in WL-cycle
- Narrowlane decision:
  - deriation (0.15), sigma (0.15) in NL-cycle
- Critical search: threshold values in LAMBDA method
  - Ratio value: default 3.0

Example: configuration

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

## Satellite list
+GNSS satellites
*PN
 G01
 G02
# 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
 abmf K  VM1 9000  7 0.20 .020 .005 .002 3.00 .006 10.00 10.00 10.00
-Station used
```

- Users can choose the satellites (G01) and station (abmf) to be used independently
- TP specifies location mode (S/K)
- MAP specifies Tropospheric mapping function (NIE/GMF/VM1/VM3)
- EV specifies cut-off elevation angle
- Keep the default values for other parts

Example 1: configuration with super-high-rate data

◆PRIDE PPP-AR Ⅱ can process super-high-rate data (up to 50 Hz), and the processing strategies should be changed as follows:

- Note that super-high-rate data are often not less than 24 hours
- Interval: change to the real interval, up to 0.02
- Ambiguity fixing: change to LAMBDA to use LAMBDA AR method
- Remove bias: change to NO to use LAMBDA AR method

Example 2: configuration with high-dynamic data

- PRIDE PPP-AR Ⅱ can also process high-dynamic data (such as aerial photogrammetry, ship-borne gravimetry, etc), and the processing strategies should be changed as follows:
  - Note that high-dynamic data are often with bad quality
  - Interval: change to the real interval, up to 0.02
  - Strict editting: change to NO to make loose residuals editor
  - ZTD model: change to STO to estimate per epoch
  - HTG model: change to STO to estimate per epoch
  - Ambiguity fixing: change to LAMBDA to use LAMBDA AR method
  - Remove bias: change to NO to use LAMBDA AR method

Example: Execution steps of the script

PRIDE PPP-AR Ⅱ Work flow

1. Copy table files to project directory ${PROJ_DIR}/2020/001/
2. Download precision products from the FTPs server to ${PROJ_DIR}/product/
3. Station-by-station processing
   1）Prepare the initial coordinates
   2）Data preprocessing
   3）Clean the data according to the residual of post-processing
   4）Parameter estimation（float solution & fixed solution）

Example: Execution steps of the script

Data preprocessing

- Function: detect cycle slips & remove bad observations
- Modul: *spp & tedit*
- Input: RINEX observation file、broadcast ephemeris
- Output: rhd (RINEX health diagnosis) file

Example: Execution steps of the script

Data cleaning

- Function: detect residual cycle slips according to the residual of post-processing & remove bad observations
- Modul: *lsq & redig*
- Input: *lsq* (RINEX observation file, rhd file, all tables & products)

  redig (residual files generated by lsq)
- Output: *lsq* (all estimated parameter files and residual files)

  redig (updated rhd files)

Example: Execution steps of the script

Parameter estimation

- Function: estimate station coordinate & receiver clock & zenith tropospheric delay using final rhd file. If the AR switch is set to 'Y', the ambiguity is fixed.
- Modul: *lsq & arsig*
- Input: *lsq* (RINEX observation file, final rhd file, all tables & products)

  arsig (float ambiguity file generated by *lsq*)
- Output: *lsq* (all estimated parameter files and residual files)

  arsig (integer ambiguity constraint file)

- Note: If the AR switch is set to ‘Y’, the integer ambiguity will be constrained, and lsq will be run again to get a fixed solution; if you select ‘N', you will get a float solution.

Example: Solution Files

- Float ambiguities (amb_2020001_abpo)

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
ABMF	E01	-17.554755	-51.344750	58849.0000000000	58849.2482638889	0.0298	0.0050	47.2
ABMF	E04	0.509143	-5.395267	58849.0000000000	58849.0743055556	0.0526	0.0169	14.3
ABMF	E19	2.345759	-9.496753	58849.0000000000	58849.0739583333	0.0929	0.0163	14.4
ABMF	E21	4.743024	-50.382881	58849.0000000000	58849.1357638889	0.0472	0.0083	31.1
ABMF	E26	-0.805732	-56.359926	58849.0000000000	58849.1527777778	0.0716	0.0086	39.3
ABMF	E33	5.271478	-29.343154	58849.0000000000	58849.3572916667	0.0541	0.0056	40.1
ABMF	C23	8.030809	5.363234	58849.0000000000	58849.0722222222	0.0538	0.0125	29.2
ABMF	C27	10.557816	-31.787956	58849.0000000000	58849.2493055556	0.0705	0.0071	39.1
ABMF	C28	-8.767085	-43.709035	58849.0000000000	58849.0888888889	0.0558	0.0136	29.2
ABMF	C30	-12.991627	-39.716228	58849.0000000000	58849.3920138889	0.0929	0.0053	35.8
ABMF	G22	40.150351	25.903952	58849.0020833333	58849.2350694444	0.0535	0.0111	25.7
ABMF	E31	-3.814974	-12.326350	58849.0086805556	58849.3375000000	0.0533	0.0052	41.0
ABMF	E12	-20.094264	-23.278140	58849.0225694444	58849.4920138889	0.0701	0.0045	36.5
ABMF	G30	15.916349	4.809818	58849.0343750000	58849.2694444444	0.0557	0.0092	31.1
ABMF	G17	-5.771935	1.845451	58849.0569444444	58849.4104166667	0.0549	0.0064	34.3

PRN

ionosphere-free (IF) ambiguity / wide-lane (WL) ambiguity

RMS (IF / WL)

mean elevation angle during the valid time

Example: Solution Files

- Integer ambiguities(con_2020001_abpo)

```
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
```

Constrained satellite single-difference(SD) satellites

SD WL/NL ambiguity

Example: Solution Files

- Kinematic station coordinate (kin_2020001_abpo)

```
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
```

station coordinates (unit: m)

- Note: Run xyz2enu to get the enu value (with the mean of xyz as a reference)

Example: Solution Files

☐ Static station coordinate (pos_2020001_abpo)

```
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
```

- Column 1：station name
- Column 2：reference time (mjd/sod)
- Column 3-5 : coordinates (unit: m)
- Column 6-8 : variance of X/Y/Z
- Column 9-11 : covariance of XY/XZ/YZ
- Column 12 : unit weighted mean errors (unit: m)
- Column 13 : the number of observations used

Example: Solution Files

Receiver clock (rck_2020001_abpo)

```
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
```

- File header: comment
- File body: station name, epoch time, Initial value and correction value of receiver clock

◆ Note: GPS/GLONASS/Galileo/BDS/QZSS estimates the corresponding receiver clock respectively (The file name is rc+g/r/e/c/j)

Example: Solution Files

- Residuals for observation (res_2020001_abpo)

```
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
```

- Epoch time
- Station number、satellite number、phase/pseudorange residual (cycle) and their STDs、data status identification、satellite elevation and azimuth

Example: Solution Files

- RINEX health diagnosis (rhd_2020001_abpo)

```
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
```

- File header: comment
- File body: satellite number、ending time、“AMB” denotes adding new ambiguity parameter、“DEL” denotes the data of the satellite deleted as bad data

Example: Solution Files

Phase residual of single satellite (stt_2020001_abpo)

```
+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
```

- RMS of phase residuals (unit: mm) and time series of residuals (unit: mm)

Example: Solution Files

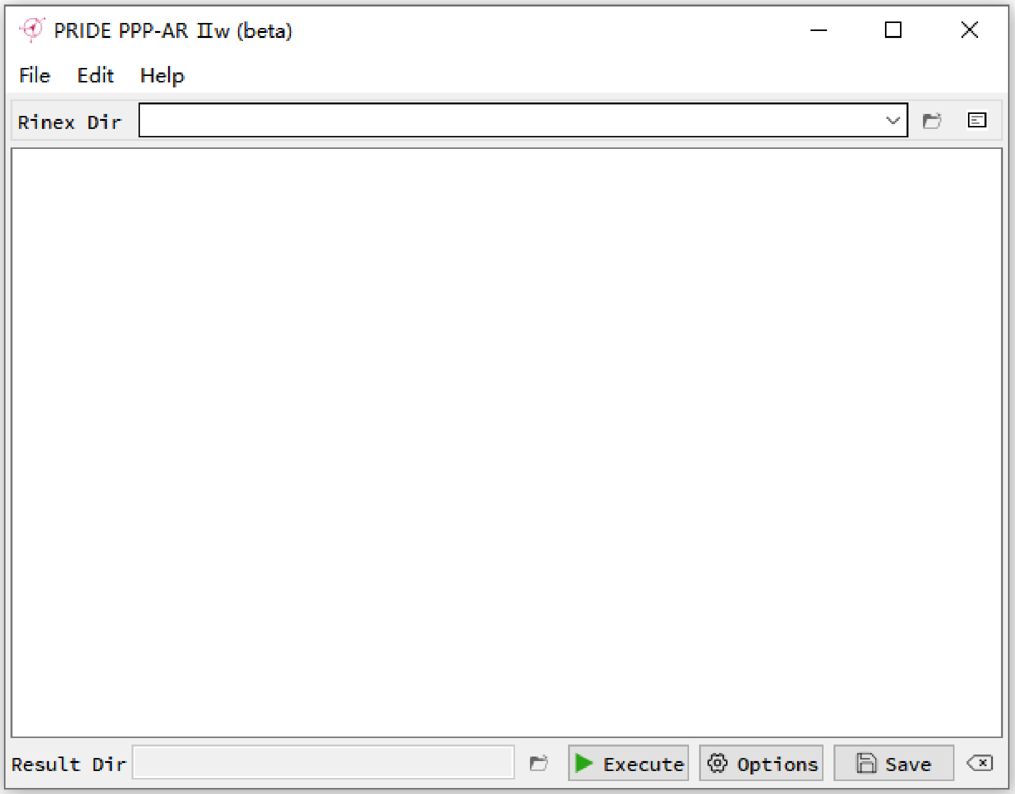
- Zenith tropospheric delay (ztd_2020001_abpo)

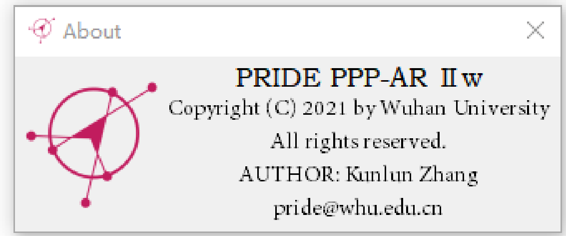
```
Zenith Tropospheric Delay                                   COMMENT
    30.00                                                   INTERVAL
                                                            END OF HEADER
ABMF 2020  1  1  0  0  0.000000   2.311569   0.194287   0.042391
ABMF 2020  1  1  0  0 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
```

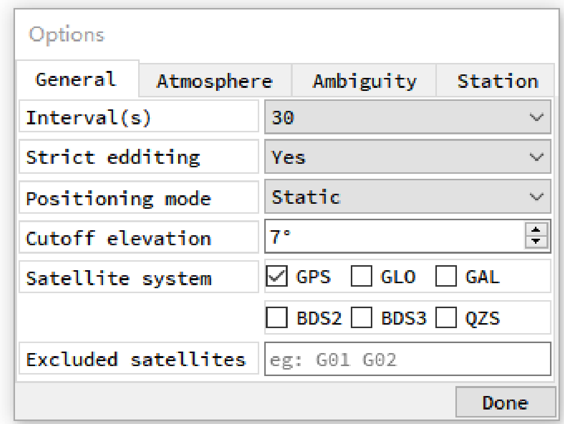
- File header: comment
- File body: epoch time、initial value of dry / wet tropospheric delay、wet tropospheric delay correction

Windows application

The user interface







Windows application

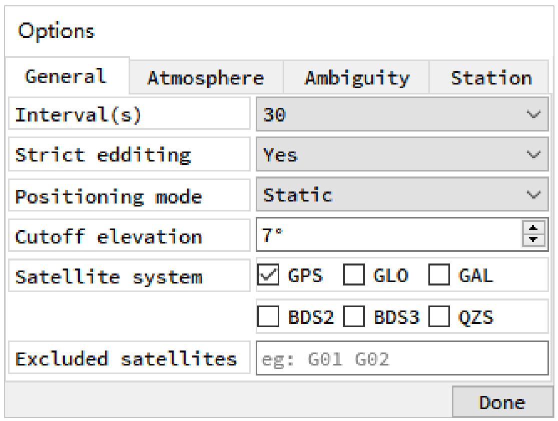
Procedures

1. open rinex dir → choose the directory of observation ;
2. options → customize processing options ;
3. execute → process all files in the directory ;
4. open result dir → view solution files .

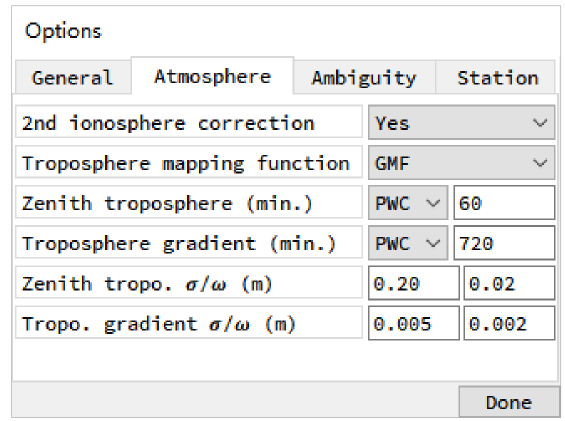
Windows application

Options

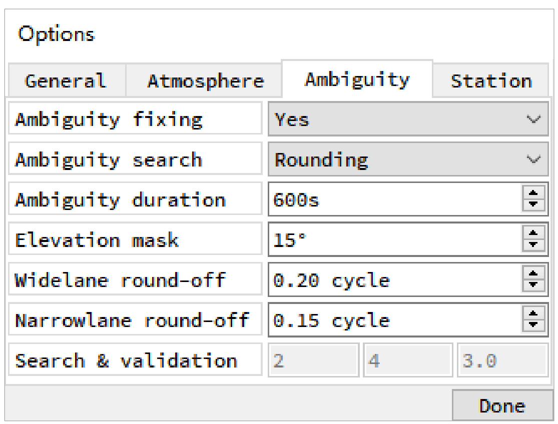
General



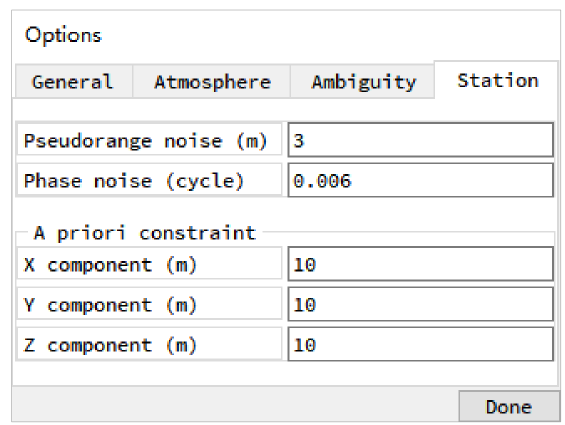
Atmosphere



AR switch



Station



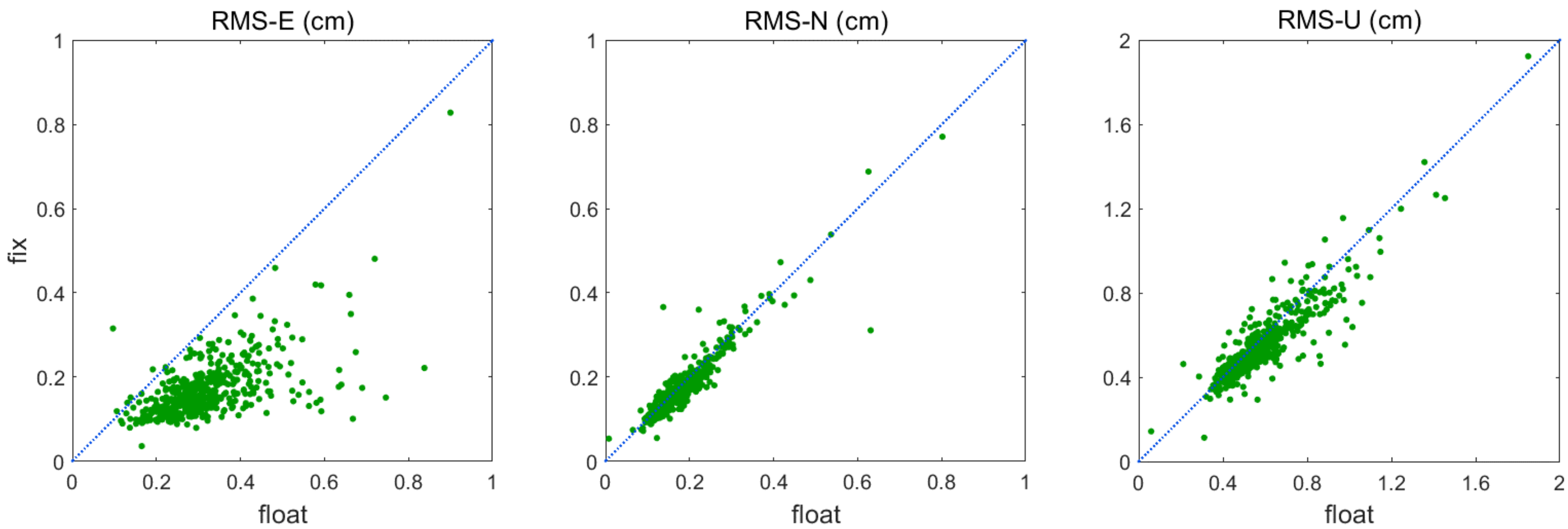
Software application: Daily solutions

- ambiguity fixing rates (unit: %)
  - Observation period: 2020
  - Observation data: IGS global station（about 500 stations）
  - Constellation type: GPS/Galileo/BEIDOU

	Wind-lane	Narrow-lane
GPS	92.7	95.8
Galileo	98.0	95.5
BEIDOU	90.5	77.5

Software application: Daily solutions

- RMS of position errors comparison (unit: cm, using helmert transformation)



RMSs decrease significantly after ambiguities fixed in the east direction, but the improvements of accuracy are low in the north and up directions

Software application: Daily solutions

- RMS statistics (unit: cm)

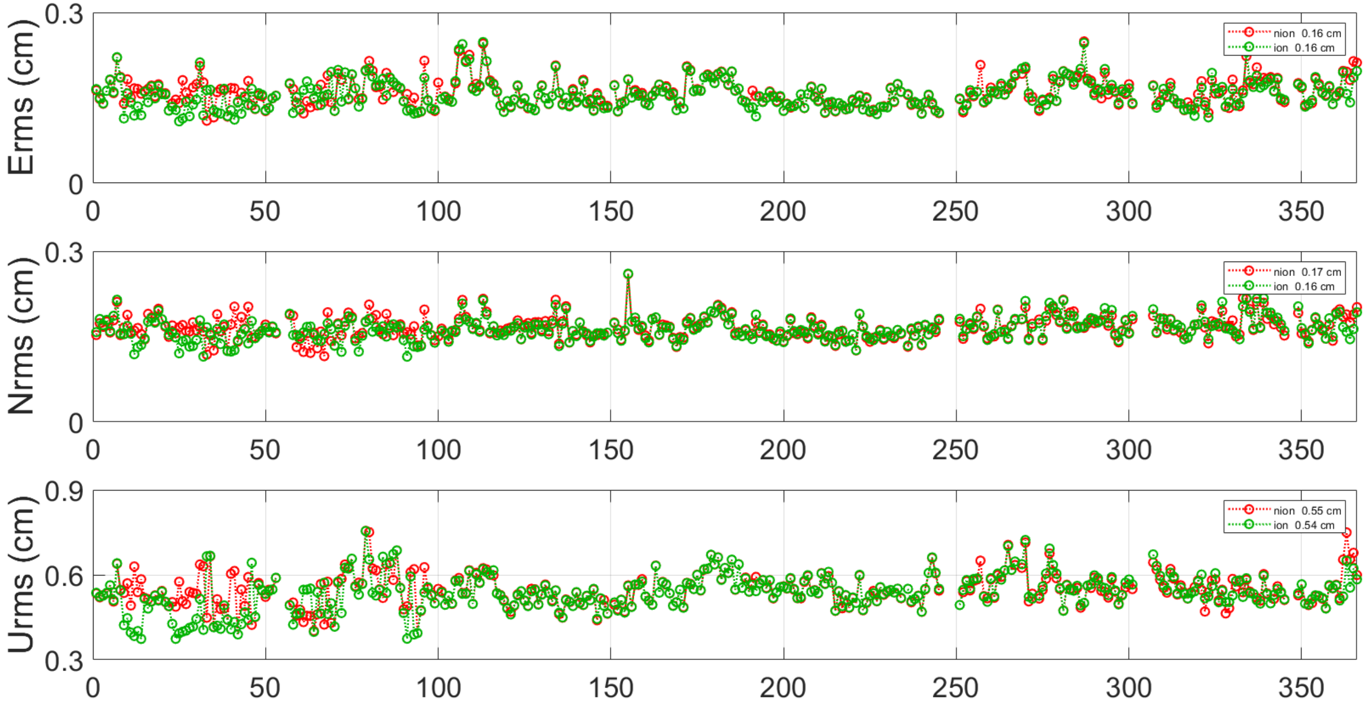
	RMS-E	RMS-N	RMS-U	RMS-3D
Gx-float	0.35	0.18	0.60	0.72
Gx-fix	**0.16**	**0.16**	**0.54**	**0.58**
xE-float	0.40	0.30	0.96	1.08
xE-fix	**0.27**	**0.29**	**0.94**	**1.02**
GE-float	0.32	0.19	0.61	0.72
GE-fix	**0.17**	**0.18**	**0.57**	**0.62**
GEC-float	0.33	0.19	0.61	0.72
GEC-fix	**0.18**	**0.19**	**0.57**	**0.63**

1. GPS only precise point positioning can achieve the highest accuracy of daily solutions

2. The RMSs of multi-GNSS precise point positioning are higher because of the incomplete models and low-precision orbits

Software application: Atmosphere research

- Positioning performance before and after higher-order ionospheric corrections

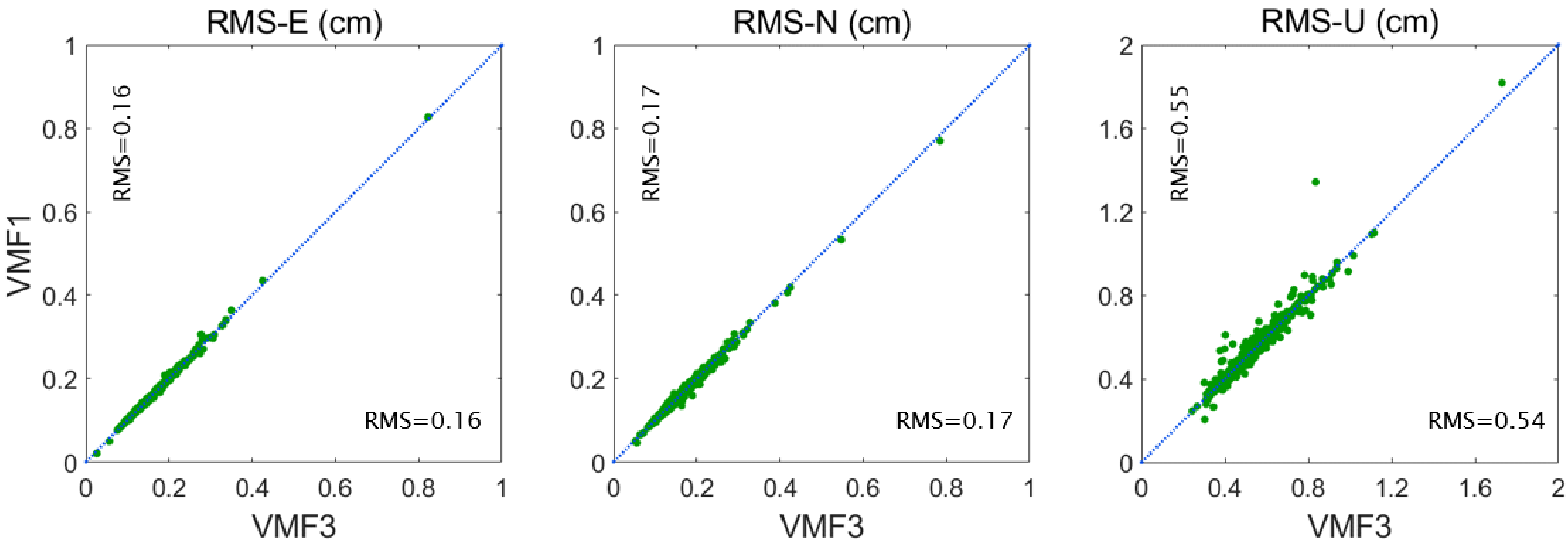


1. After the correction in the higher-order ionosphere, there are improvements of 0.1 mm in the north and up directions

2. 2020 is not an active period of ionosphere, so the improvements are not obvious

Software application: Atmosphere research

- Positioning comparison between VMF1 and VMF3 models

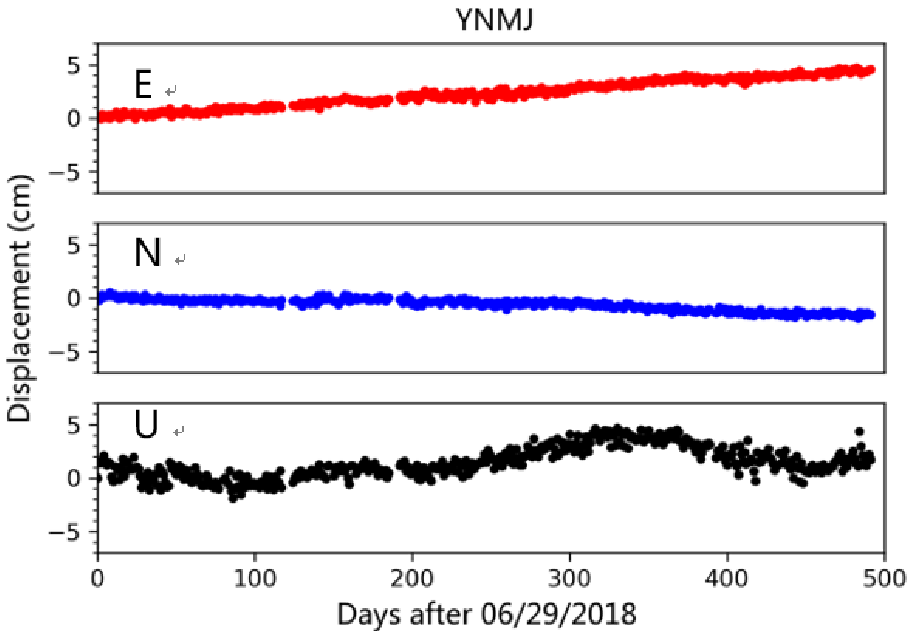


1. Based on the average RMSs in 2020, compared with VMF1, the VMF3 model improves the accuracy of 0.1 mm in the up direction

2. From the point of view of single station, some stations use VMF3 model to get better positioning performance

Software application: Time series analysis

- Time series diagram of YNMJ station's location from 2018 to 2019

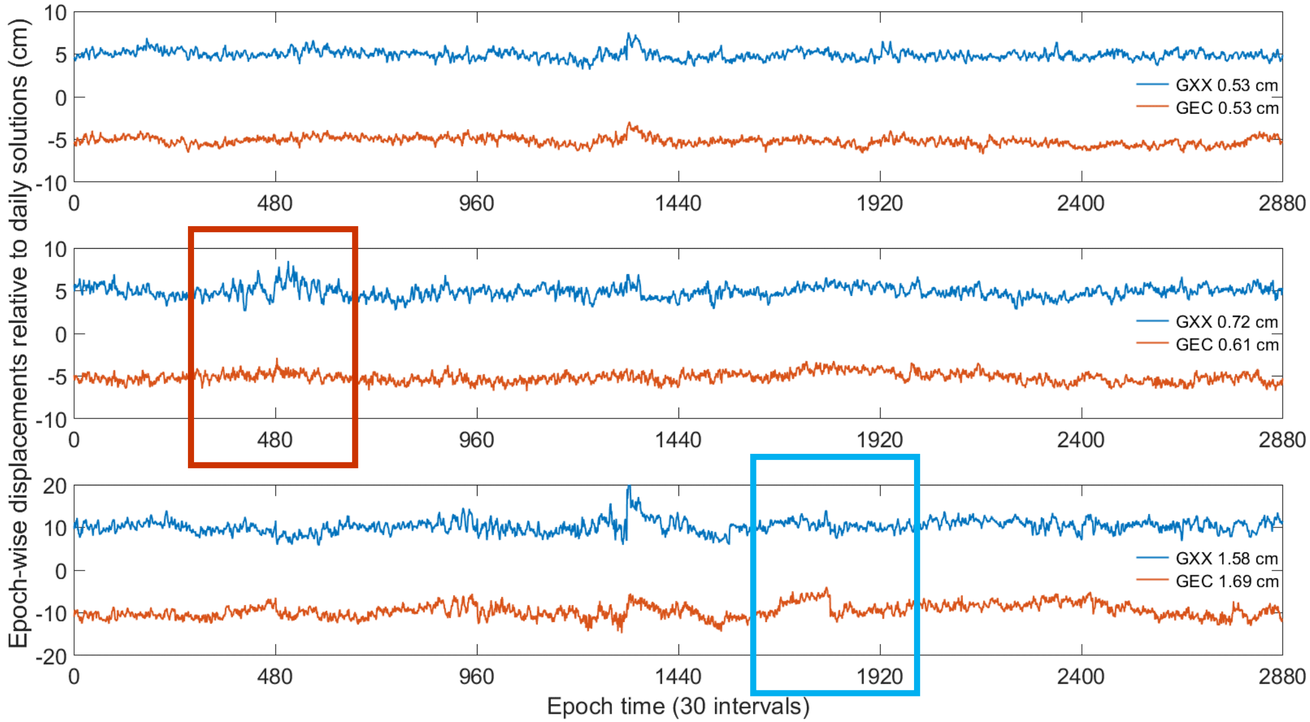


1. In the horizontal direction, the movement of the station in the east and south directions is approximately linear, reflecting the characteristics of tectonic movement

2. In the vertical direction, the movement of the station has obvious seasonal trend, and the annual fluctuation can reach up to 3cm

Software application: Kinematic solutions of IGS station

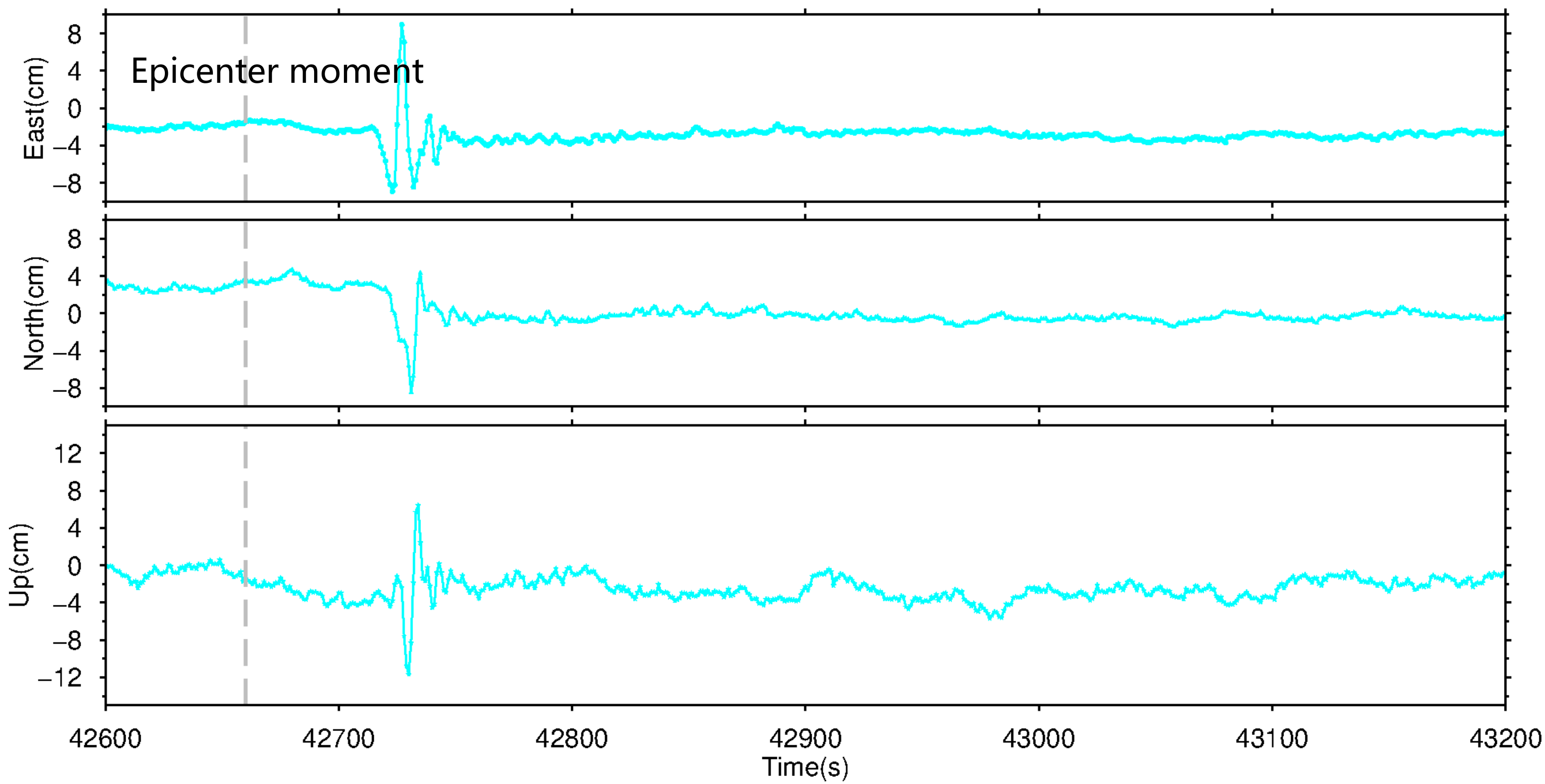
- RMS of positioning errors of ARUC station (January 1, 2020)



1. Red box: the kinematic positioning time series of multi-GNSS are more stable
2. Blue box: The jump of multi-GNSS solutions are caused by the low-precision BEIDOU orbits and models

Software application: Earthquake monitoring

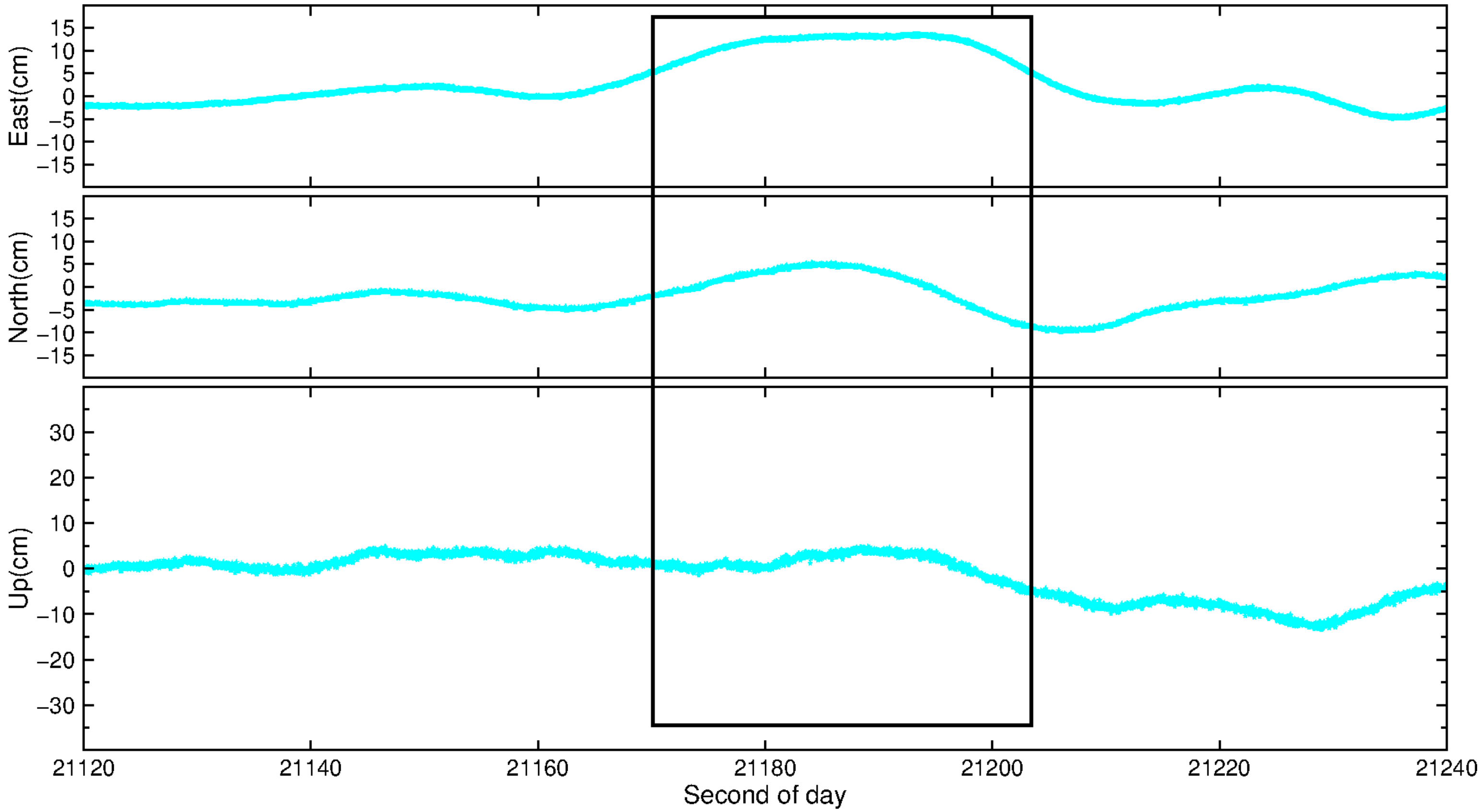
- IKAR station (Oct.30th zozecanisos earthquake)



Software application: Super-high-rate data

- 50-Hz data processing

(The 2011 earthquake of the Pacific coast of Tōhoku)

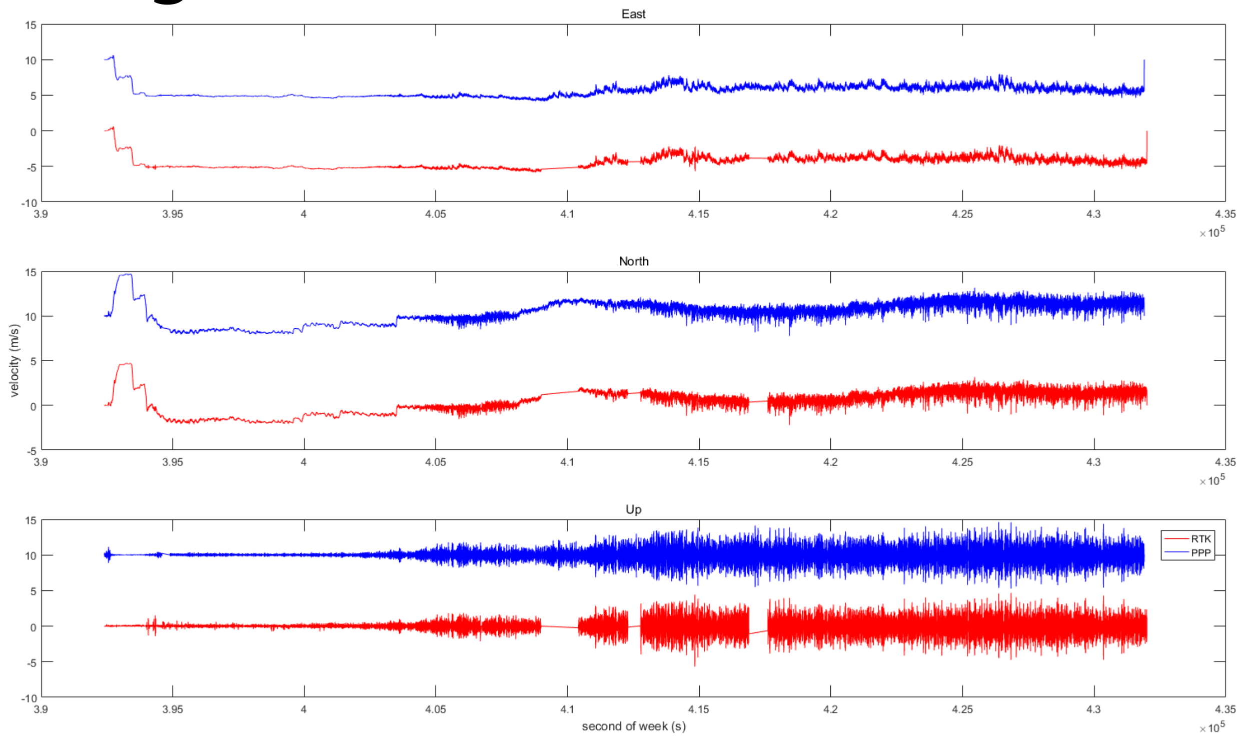


Software application: Shipborne marine gravity survey

- Sampling rate: 1s
- Observation period: 0:00-24:00 on August 25, 2016
- Constellation type: GPS/GLONASS/GALILEO
- Maximum baseline length of relative positioning: 115 km

Software application: Shipborne marine gravity survey

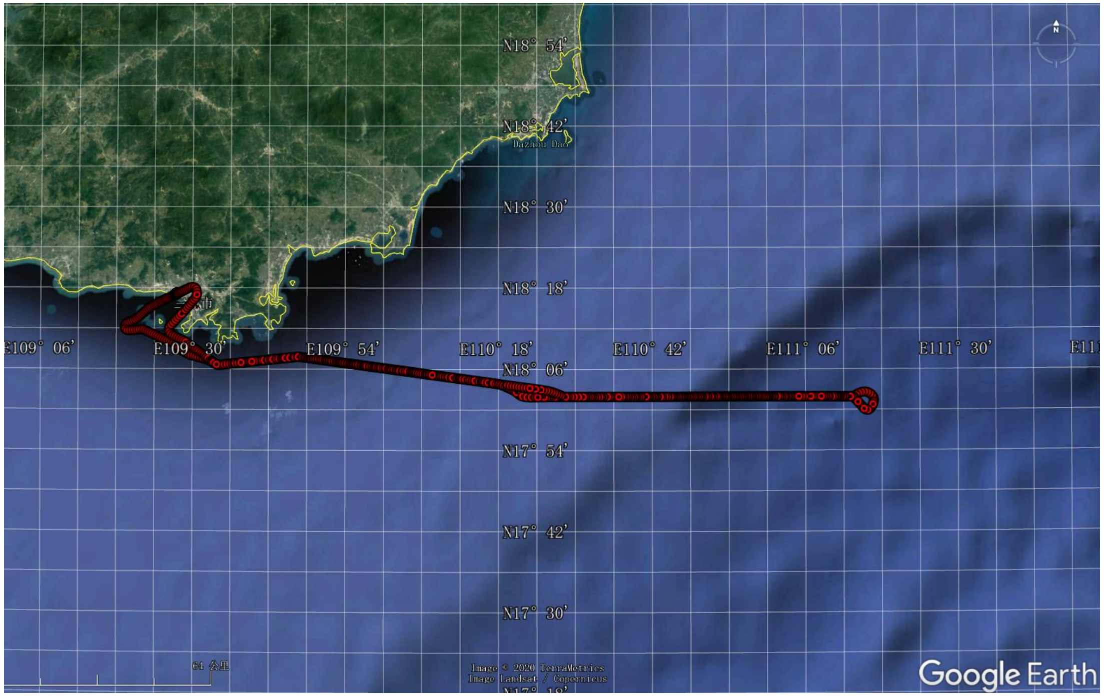
- Speed comparison between PPP and relative positioning (RTKLIB software)



The relative positioning depends on the observation of the reference station (The reference station has only GPS observations and data interruption)

Software application: Airborne gravimetry

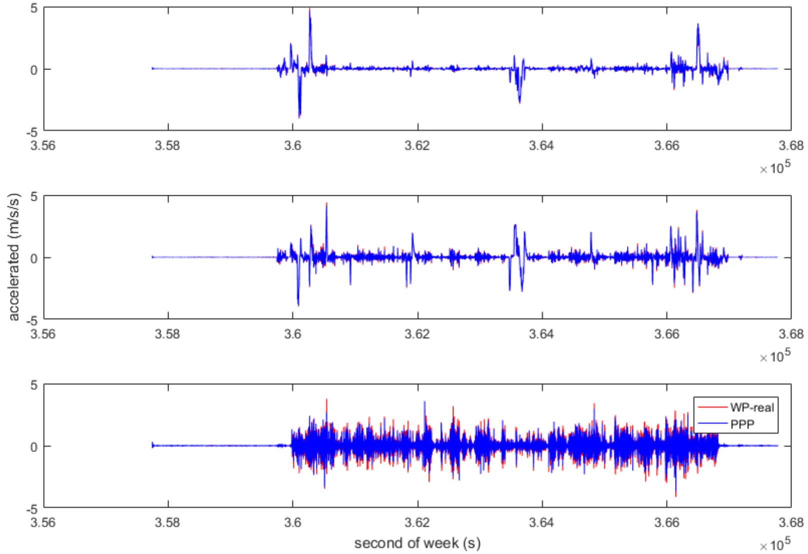
- Sampling rate: 0.5s
- Observation period: 3:20-6:09 on November 5, 2016
- Constellation type: GPS
- Maximum baseline length of relative positioning: 220 km



Software application: Airborne gravimetry

Differences of gravity acceleration between PPP and relative positioning (WayPoint software)

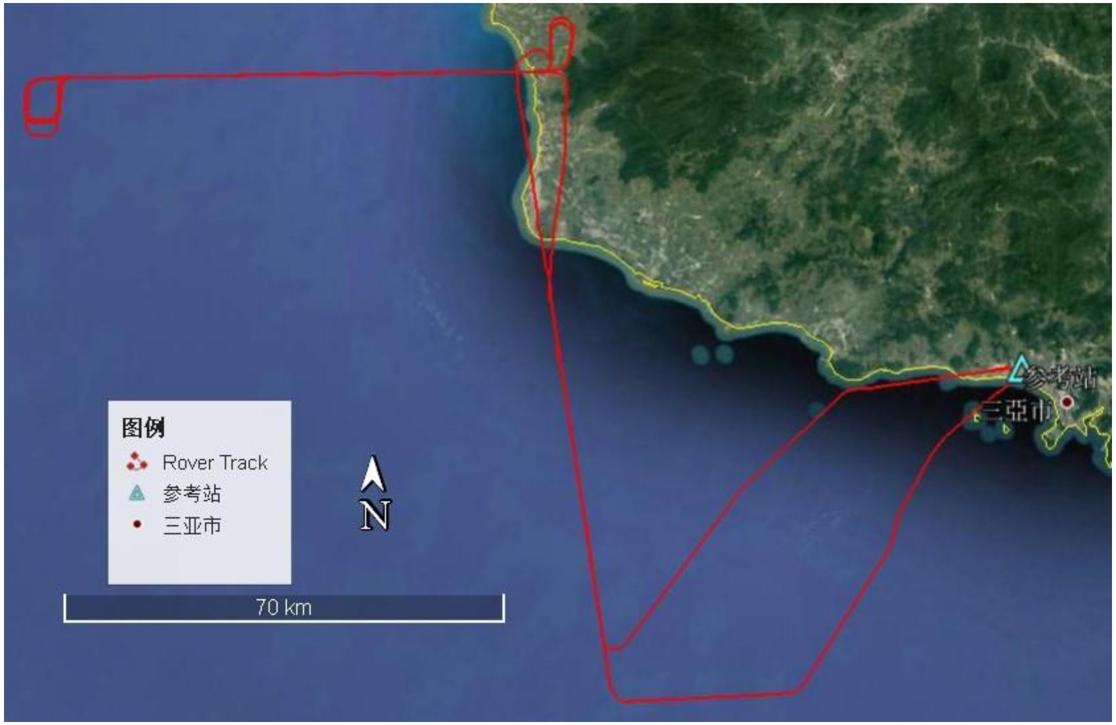
- WP-real: Acceleration of gravity from WayPoint software
- PPP: Acceleration of gravity from PRIDE PPP-AR II software



1. Relative positioning depends on the length of baseline, and the errors of long baseline solutions are large
2. PPP does not depend on the reference station, and the calculated gravity acceleration noise are smaller

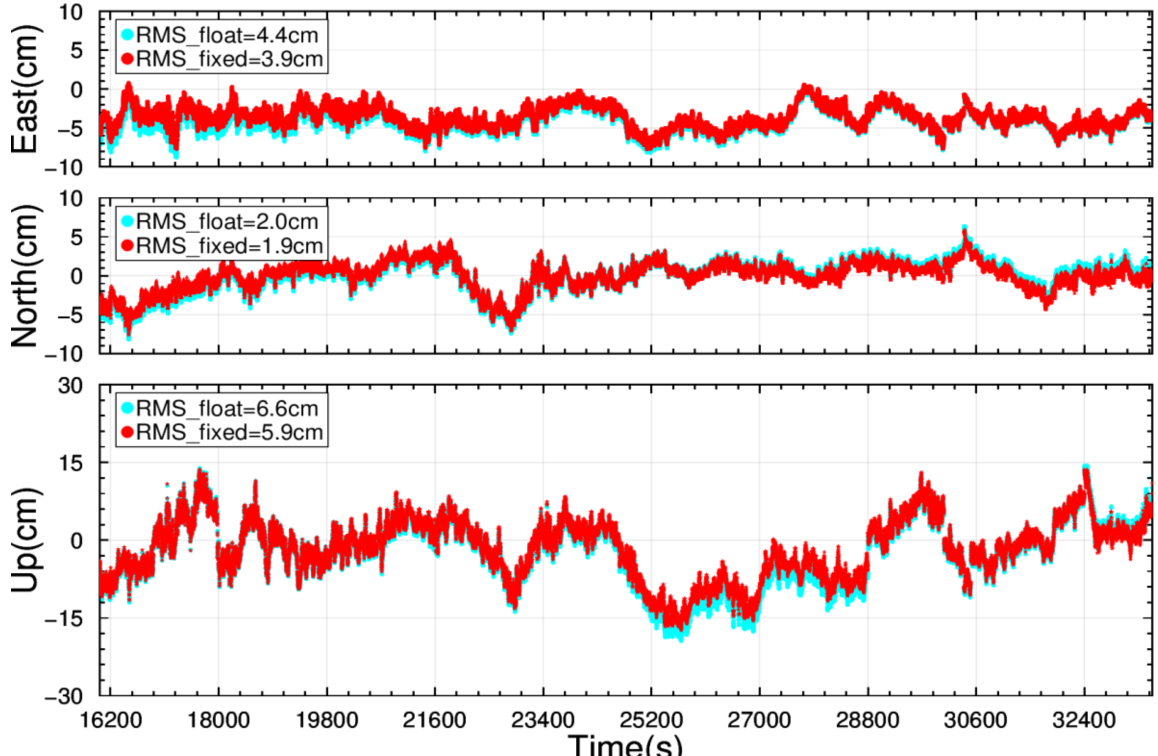
Software application: Aerial photogrammetry

- Sampling rate: 0.5s
- Observation period: 4:27-9:18 on November 27, 2017
- Constellation type: GPS
- Maximum baseline length of relative positioning: 170 km



Software application: Aerial photogrammetry

- Position differences between PPP and WayPoint software



1. In the airborne experiment with less shielding, the positioning accuracy is basically the same with that of commercial software

2. Fixed ambiguities can also significantly improve the positioning accuracy in high-dynamic solutions

Learn more

- Geng J, Chen X, Pan Y, Mao S, Li C, Zhou J and Zhang K (2019) PRIDE PPP-AR: an open-source software for GPS PPP ambiguity resolution. GPS Solut. 23(4).
- Geng J, Chen X, Pan Y and Zhao Q (2019) A modified phase clock/bias model to improve PPP ambiguity resolution at Wuhan University. J. Geod. 93(10): 2053-2067
- Pan Y, Geng J, Liu K, Chen X and Fang R (2020) Evalutaion of rapid phase clock/bias products for PPP ambiguity resolution and its application to the M7.1 2019 Ridgecrest, California earthquake. Adv Space Res. https://doi.org/10.1016/j.asr.2020.02.016

Contact us

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THANK YOU !