PPPH

A MATLAB-based Software for Multi-GNSS Precise Point Positioning Analysis

User Manual

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1. Introduction

Over the last decades, Precise Point Positioning (PPP) has become a viable alternative to differential and/or relative positioning techniques which dominates the GNSS community. Even though PPP enables centimeter- or millimeter-level positioning accuracy with only one receiver in the global scale, it still requires a quite long observation period to achieve high positioning accuracy. This period, typically called convergence time, is the main drawback of PPP which restricts its widespread adoption. In recent years, the completion of GLONASS constellation and the emergence of new satellite systems offer considerable opportunity to improve the PPP performance in terms of positioning accuracy and convergence time due to providing additional frequencies and satellite resources. On the other hand, the integration of multi-GNSS observations entails more complex models and algorithms compared with the traditional PPP approach that includes GPS observations only. Considering the limited number of the alternatives, PPPH was developed to benefit the potential advantages of the multi-constellation and multi-frequency GNSS. PPPH is a GNSS analysis software, which can perform multi-GNSS PPP analyses processing GPS, GLONASS, BeiDou, and Galileo observations. Through its user-friendly graphical user interface, PPPH allows users to specify the options, models, and parameters related to PPP process. Furthermore, several analysis tools are provided by PPPH to assess the results obtained.

2. Installation

PPPH was developed in MATLAB environment since its matrix-based structure and built-in graphics are highly suitable for technical computing, programming, and data visualization. PPPH does not entail any toolbox or function except for MATLAB core files. Two steps should be followed to open the graphical user interface (GUI) of PPPH:

(1) add the folder containing the source codes of PPPH into MATLAB search path

(2) type PPPH in MATLAB command line.

The interface of PPPH was developed using the MATLAB App Designer which is a special environment to design and develop the visual components of a user interface. For this reason, MATLAB version 2016a or newer is required for running PPPH. Furthermore, PPPH can be used with no problem in any operating system where MATLAB has been installed, such as Windows, Mac, Unix/Linux, etc.

3. PPPH

PPPH is able to perform multi-GNSS PPP including GPS, GLONASS, Galileo and BeiDou observations. PPPH utilizes undifferenced ionosphere-free multi-GNSS PPP model. PPPH allows specifying options, models, and parameters about PPP processing through its user-friendly interface. Fundamentally, PPPH consists of five main components which are Data Importing, Preprocessing, Modeling, Filtering, and Analyzing (Figure 1). The first four components utilize related models and theory to provide multi-GNSS PPP solutions, while the last one is employed to evaluate and visualize the results. Each component along with its related options is represented by a separate tab in the user interface.

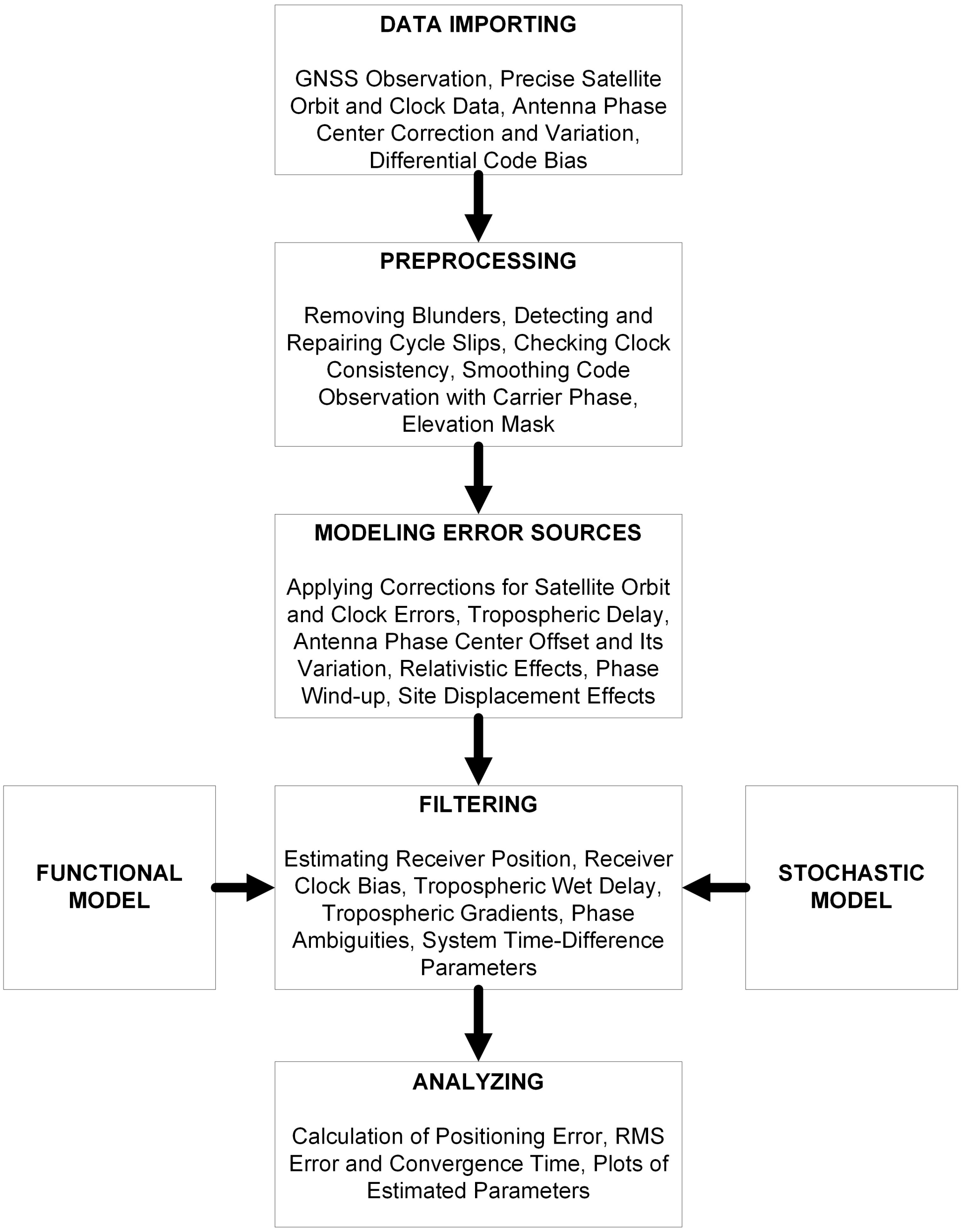


Figure 1: Main components of PPPH.

Figure 2 shows the main window of PPPH. Five fundamental tabs representing the components of the software are located on the top of the main window. Just below, there exist some options concerning about the selected tab. Configuration options, epoch selection tool, and **RUN** button are also located on the bottom. Thanks to configuration options, users are capable of saving their configurations and loading them to use in PPP process whenever they want. The epoch selection section specifies the epoch interval which will be included in the process. In order to initialize PPP process in the software, **RUN** button is clicked. However, importing the related files, such as observation, precise satellite orbit, and clocks, etc. into the software is required before the initialization of PPP process. After the process, PPPH provides an output file that contains estimated parameters for every single epoch. Moreover, the results can be evaluated in terms of positioning accuracy, convergence time, etc. thanks to analyzing tools provided by PPPH.

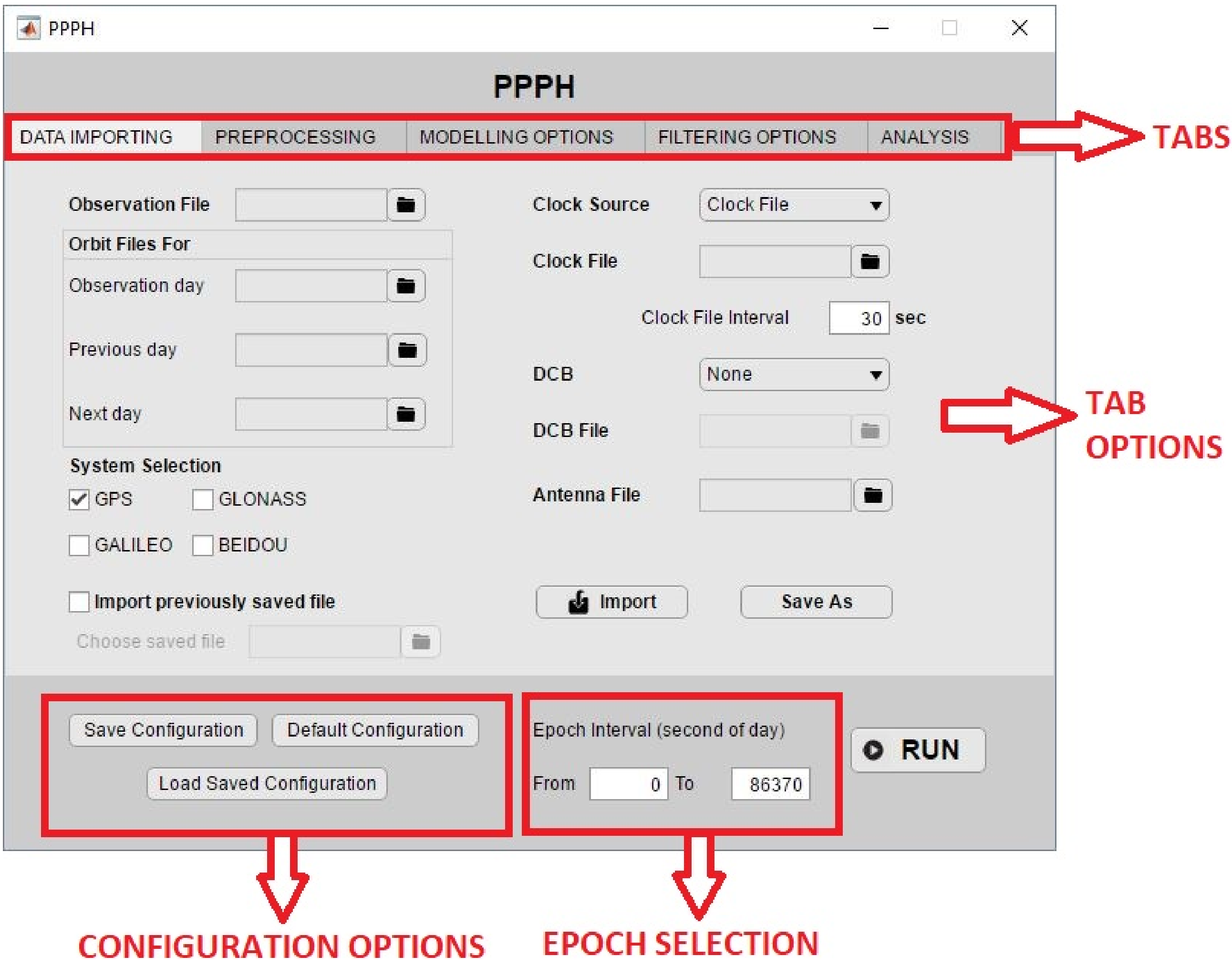


Figure 2: Main window of PPPH.

The explanation of each tab along with its preferences is respectively given below.

3.1. Data Importing

The first component of PPP, that is Data Importing, imports the files containing navigation data which required for performing PPP process into the software format. Before performing PPP process, the whole necessary files, such as observation, satellite orbit, and clock, etc. should be imported into PPPH. There are several file formats designed to exchange data within the GNSS community, e.g. RINEX, SP3, CLK, and ATX. PPPH is able to deal with these standard exchange formats properly. Through Data Importing tab (Figure 3), all the GNSS files can be selected and imported into the software with ease.

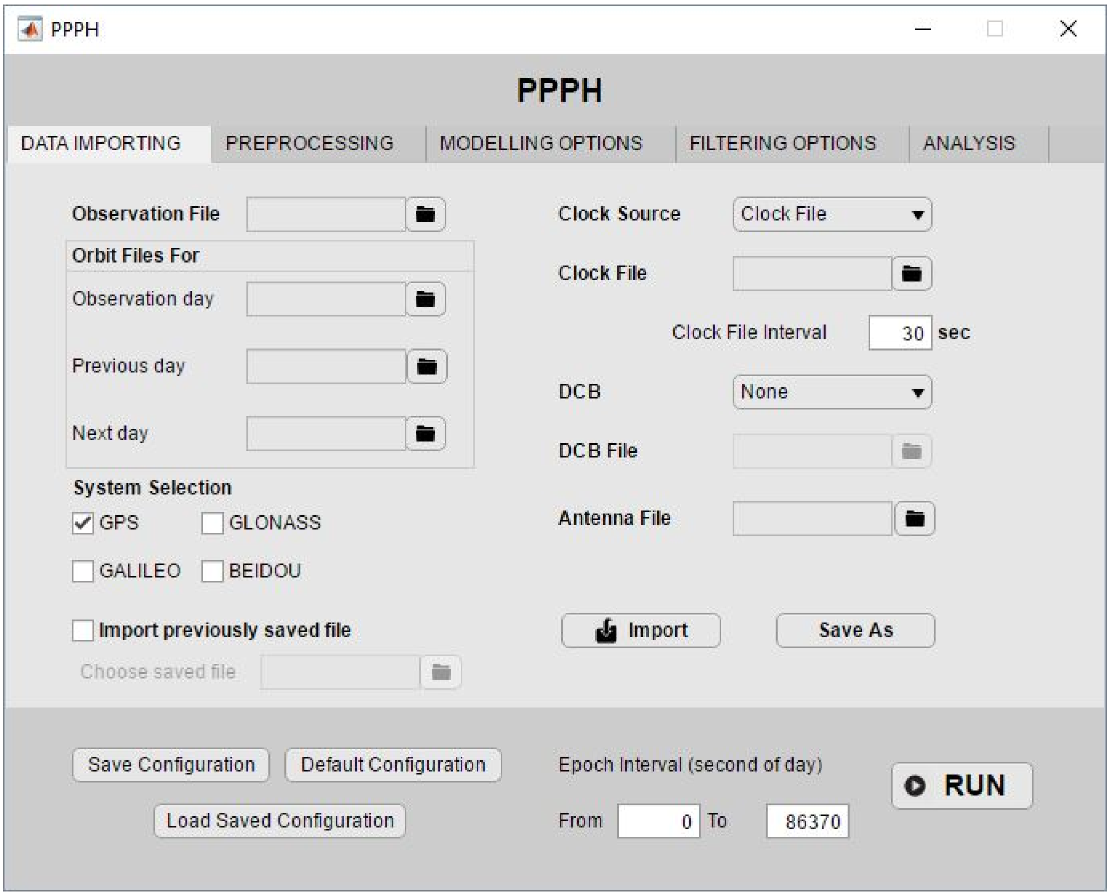


Figure 3: Data Importing Tab of PPPH.

PPPH requires four fundamental data sources to perform PPP process; GNSS observations, satellite orbits, satellite clocks and antenna phase corrections. In addition, differential code biases, as the fifth data source, can be imported into the software depending on the user preference. The whole necessary files should be introduced to PPPH by clicking the selection box to the related field. The comprehensive explanation of Data Importing tab is given below in order of data sources.

Observations Observation File

RINEX (Receiver Independent Exchange Format) is the standard format for GNSS observations. PPPH is able to read and import the observations of GPS, GLONASS, Galileo, and BeiDou given in RINEX 2 or 3 version. Any observation file in RINEX format can be chosen by clicking the selection box situated next to the related field.

PPPH utilizes undifferenced and ionosphere-free multi-GNSS PPP model, which requires dual frequency code pseudorange and carrier phase observations. It is well known that navigation systems provide two different signals at least. However, the types of observation obtained from these navigation signals vary depending on the receiver's model. In PPPH, code pseudorange and carrier phase observations on two different signals are selected in a specific order. In RINEX version 2, C1/P1 and P2 are utilized as the code pseudorange observations, while L1 and L2 are selected to be dual frequency carrier phase observations for GPS and GLONASS. However, C1 and C5 code observations are used in addition to L1 and L5 carrier phase observations for Galileo in this context. As for RINEX version 3, the order of observation selection is given in Table 1

Table 1: Order of observation selection in RINEX version 3.

System	**Code Pseudorange**		**Carrier Phase**	
	1	**2**	**1**	**2**
GPS	C1	C2	L1	L2
Order	PWCSLXYMND			
GLONASS	C1	C2	L1	L2
Order	PC			
GALILEO	C1	C5	L1	L5
Order	BCXAZ	IQX	BCXAZ	IQX
BEIDOU	C1/C2	C7	L1/L2	L7
Order	IQX			

Satellite Orbits Orbit Files For

Standard exchange format for the orbit of GNSS satellite is SP3 (Standard Product # 3). PPPH can read and extract information from the whole orbit files in the SP3 format including the products of IGS and MGEX analysis centers. The computation of satellite orbits is based on 9th degree Lagrange Interpolation, which is a type of polynomial function. Considering that there is not enough orbit data at the beginning and end of the day, PPPH provides additional option to import the orbit files for previous and next day into the software. The import of orbit files for previous and next day reduces the interpolation-induced error, however, it is not obligatory for PPP process. If these files are not selected, PPPH computes the satellite orbits using the orbit file for the observation day only.

Satellite Clocks Clock File

In PPPH, satellite clock corrections can be imported from two different sources. The first option is to use **SP3 file** for obtaining satellite clock corrections. Nevertheless, it is not usually recommended to use satellite clock corrections obtained from the SP3 file for precise GNSS applications due to the long sampling interval. Instead, **CLK file** including high-rate clock data can be used for satellite clock corrections. PPPH can process the CLK file provided by IGS agencies regardless of the sampling rate. The selection of clock source can be done through Clock Source. When clock source option is selected as **Clock File**, clock file box is activated and any CLK file can be selected as the clock source. Still, it is required to specify Clock File Interval in seconds.

Differential Code Biases DCB File

As previously mentioned, PPPH utilizes C1 or P1 as the first code pseudorange observation for forming ionosphere-free linear combination when RINEX version 2 is used. However, observation file does not always include P1 observations depending on receiver's type. In this case, PPPH uses C1 as the first code pseudorange observation automatically. The other option is to use DCB file which includes differential code biases between P1 and C1 observations. Using DCB file, C1 observation can be transformed to P1 observation. If DCB option is selected as **P1-C1**, DCB file produced by IGS agencies, such as CODE, can be imported into the software and used for obtaining P1 observations from C1.

Antenna Phase Correction and Variation Antenna File

Antenna phase center offsets (PCOs) and their variations (PCVs) for satellite and receiver are corrected using ANTEX file which based on IGS absolute antenna model. If there are no PCOs and PCVs for Galileo and BeiDou satellites in the related antenna file, the conventional values are utilized. Similarly, in the absence of receiver's PCO and PCV values for any system, GPS values are employed to correct PCOs and PCVs for these systems.

System Selection

PPPH is able to process GPS, GLONASS, Galileo and BeiDou data. "System Selection" section allows users to select which system will be included for PPP processing. Here, one of the fully operational systems, i.e. GPS and GLONASS, is required to be included in the system selection for performing multi-GNSS PPP.

Import and Save Data

After the selection of all the required files, data can be imported into PPPH by clicking **Import** button. It is the first step for PPP processing and the other steps can be taken only after the data is imported appropriately. On the other hand, users may save their imported data using **Save As** button. Additionally, they can upload previously saved file thanks to **Import Previously Saved File** button.

3.2. Preprocessing

Raw data obtained from the navigation files require a preprocessing step to eliminate gross errors and inconsistencies. After the preprocessing step, the data get completely ready for the filtering process. Preprocessing is composed of the outlier detection, cycle slip detection, and determination of clock inconsistencies. Also, the options of elevation cut-off angle, code smoothing, and processing mode are the part of this step. PPPH accepts user preferences related to this step through the preprocessing section shown in Figure 4.

In Preprocessing tab, Elevation Cut-off Angle can be selected in degrees to mask the satellites whose elevation angle is smaller than the threshold. Additionally, users

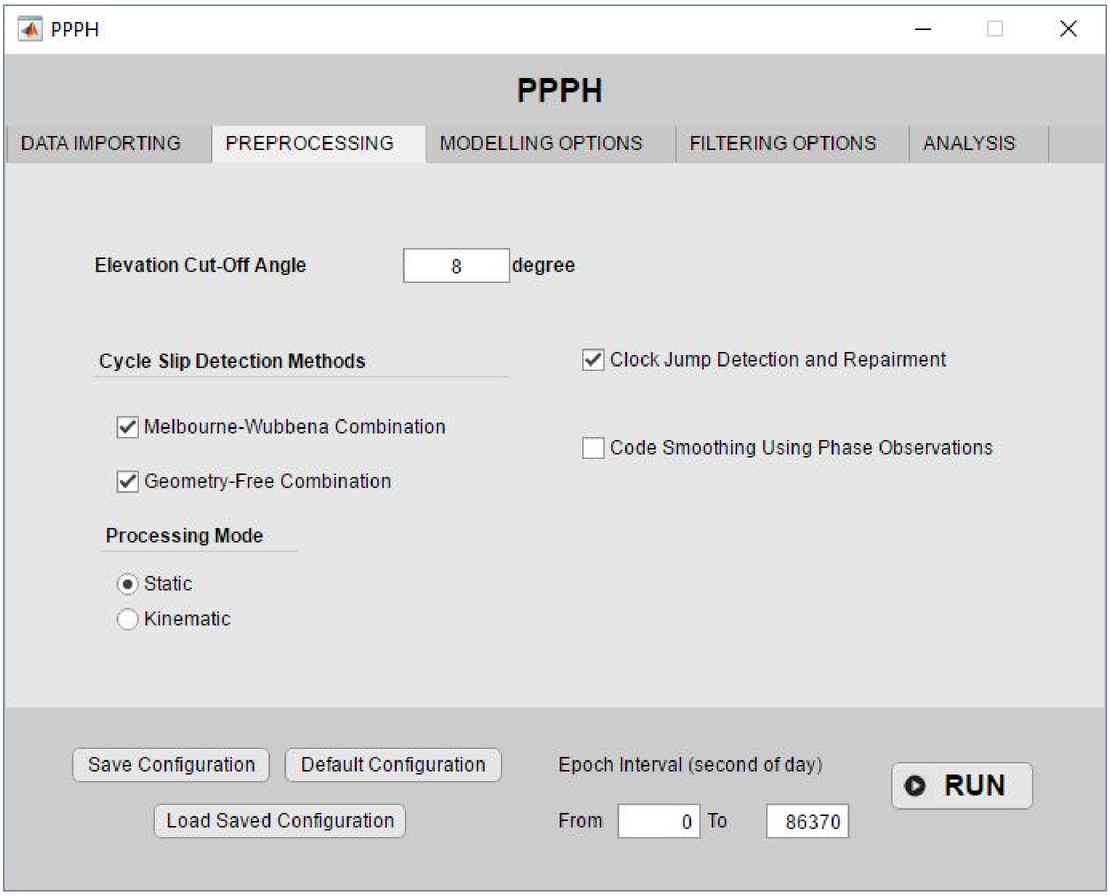


Figure 4: Preprocessing Tab of PPPH.

are able to decide which Cycle Slip Detection Methods will be applied. There are two methods for detecting cycle slips. The first is based on **Melbourne-Wübbena combination**, while the second use **Geometry-free combination**. Similarly, PPPH allows users to determine whether the clock inconsistencies will be checked and the code observations will be smoothed with phase observations. Finally, Processing Mode can be chosen as **Static** or **Kinematic** depending on whether the receiver is moving or not.

3.3. Modeling

Modeling component of PPPH is responsible for mitigating the influences of error sources on GNSS measurements. PPPH allows selecting which error sources will be corrected through the Modelling Options Tab (Figure 5). The corrections are categorized into four groups in PPPH depending on their effects. Table 2 presents the category of corrections and their handling strategies applied in PPPH. Here, there exists an option for estimating tropospheric gradients. Tropospheric gradients are not corrected with any model actually and they are estimated together with the unknown parameters in filtering. Still, the option for estimating tropospheric gradients is added to the atmosphere category of corrections for the sake of integrity. On the other hand, the option of solid tide correction include both solid Earth tides and ocean loading correction.

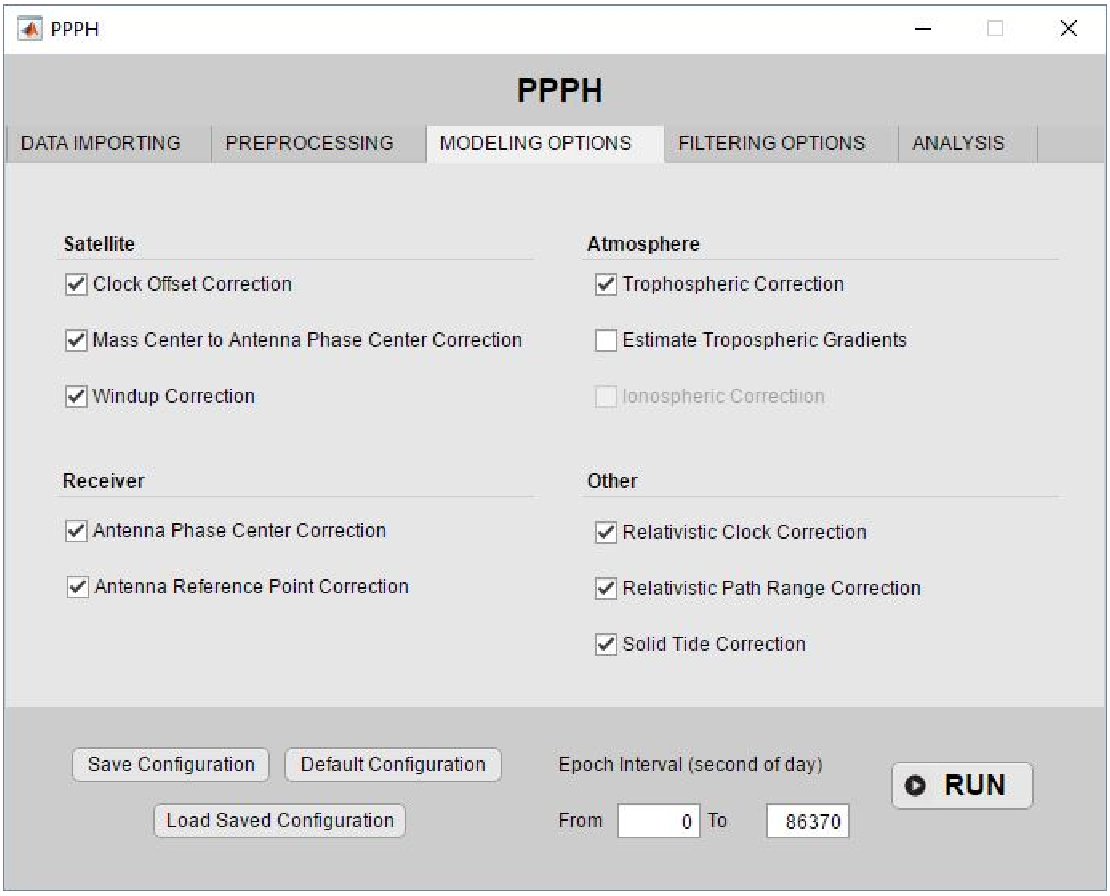


Figure 5: Modeling Options Tab of PPPH.

Table 2: Category of corrections and their handling strategies in PPPH.

Category	Correction	Handling Strategy
Satellite	Clock Offset	From precise ephemeris or clock file
	Antenna Phase Center Offset	From antenna file
	Wind-up	(Wu et al. 1993)
Receiver	Antenna Phase Center Offset	From antenna file
	Antenna Reference Point	From observation file
Atmosphere	Troposphere	(Saastamoinen 1973)
	Tropospheric Gradients	Estimated
	Ionosphere (Not selectable)	Ionosphere-free linear comb.
Other	Relativistic Clock	(Bar-sever et al. 1996)
	Relativistic Path Range	(Kouba 2015)
	Solid Tide	(Petit and Luzum 2010)

3.4. Filtering

PPPH employs the adaptive robust Kalman filtering method, which introduces an equivalent weight matrix to compensate the effect of outliers in observations and also an adaptive factor to balance the contributions of measurement and estimated parameters, in order to estimate the state space vector. The Kalman filter requires the well-defined statistical properties of both unknown parameters and measurements. PPPH enables to specify the options and parameters of the Kalman filter through the Filtering Options Tab (Figure 6).

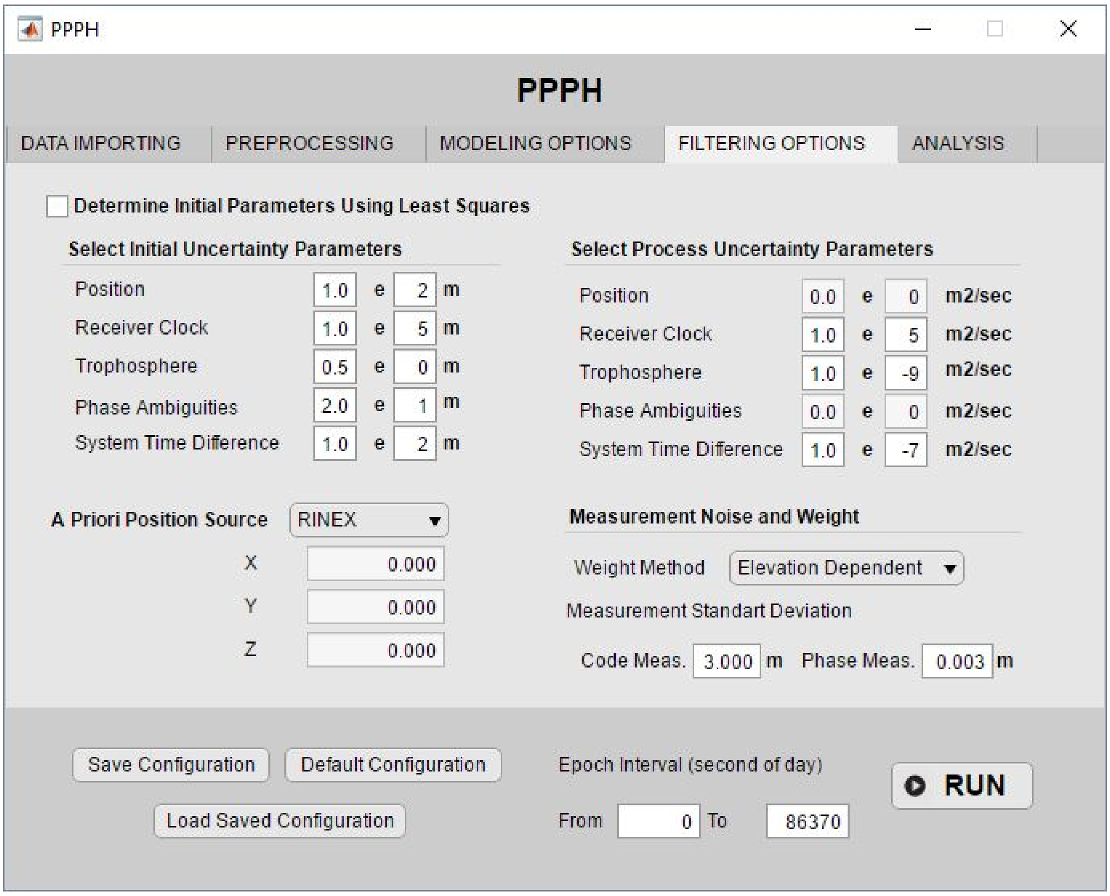


Figure 6: Filtering Options Tab of PPPH.

Initial and process uncertainty parameters for the unknowns can be specified in the Filtering Options Tab of PPPH. The default values for initial and process uncertainties of unknowns are given in Table 3. Furthermore, PPPH provides an additional option to determine the initial uncertainty parameters using the least squares estimation. In this method, the unknown parameters are estimated in the first epoch by the least squares adjustment, and then the estimated parameters and their statistical properties are utilized as the initial parameters for the next epoch.

If A Priori Position Source is selected as **RINEX**, a priori position of the receiver is obtained from the observation file. Additionally, a priori position of the receiver can be specified manually through **Specify** option. Finally, PPPH allows users to determine the measurement noise and weight model. **Code Meas.** and **Phase Meas.** fields enables to specify the noises for code and phase measurements in meters, separately. Also, Weight Method can be selected as **Elevation Dependent** or **Equal**. While **Equal** option assigns equal weights for the measurements, **Elevation Dependent** option determines the weights of measurements depending on the elevation angles of satellites (sin(elv)).

Table 3: Default values for initial and process uncertainties of unknowns.

Component	**Description**	**Initial Uncertainty** (m)	**Process Uncertainty** (m^2/sec)
Position	3D position of the receiver (X, Y, Z)	100	0 for static
Receiver Clock	Clock error of the receiver	$1 \cdot 10^5$	$1 \cdot 10^5$
Troposphere	Wet part of the tropospheric delay	0.5	$1 \cdot 10^{-9}$
Phase Ambiguities	Ambiguity parameters for carrier phase observations	200	0 without cycle slip
System Time Difference	System time difference parameter with respect to GPS time	100	$1 \cdot 10^{-7}$

3.5. Analysis

After PPP processing, PPPH produces an output file which includes the estimated parameters for every single epoch. A statistical calculation tool is also provided to compute the positioning error, root means square (RMS) error and convergence time with respect to a ground truth. Finally, PPPH offers some plotting tools to evaluate the performance of PPP solution. The whole analyses can be made through the Analysis Tab of PPPH indicated in Figure 7 after the PPP process ends.

Thanks to statistical calculation tool, users can compute the positioning error, RMS error and convergence time in the Analysis Tab of PPPH. In order to calculate these statistics, a **Ground Truth** has to be specified in the software. The positioning error is computed as the difference between the related PPP solution and the ground truth at the end of the related process period in the local system (north, east, up). The convergence time was determined as the time when a sub-decimeter 3D positioning accuracy is achieved and subsequently sustained for a period longer than 10 minutes. Finally, RMS error was computed in the local system (north, east, up) for all epochs after the convergence time achieved with respect to the ground truth. The positioning error and RMS error is computed in centimeters (but millimeters can be seen), while the convergence time is determined as epochs.

Figure 8 presents an output file example which is obtained from the software after PPP process. The output file is composed of the estimated parameters for every single epoch. The description of output file is provided in Table 4.

PPPH is able to analyze and evaluate the results obtained from the PPP solution with the aid of its plotting tools. Estimated parameters or statistics calculated from the PPP results can be plotted in the Analysis Tab of PPPH. Additionally, users can determine which epoch will be included in the plot by choosing plot interval in seconds. The plotting options are given in Table 5.

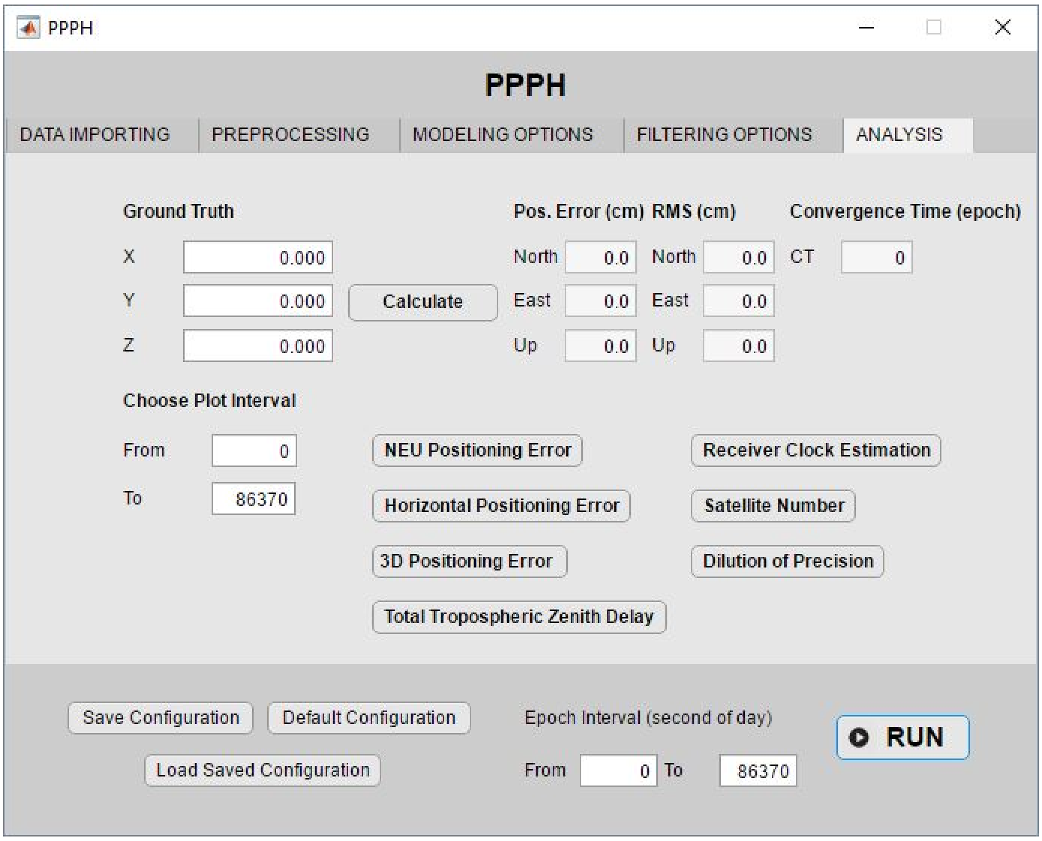


Figure 7: Analysis Tab of PPPH.

Table 4: Description of standard output file of PPPH.

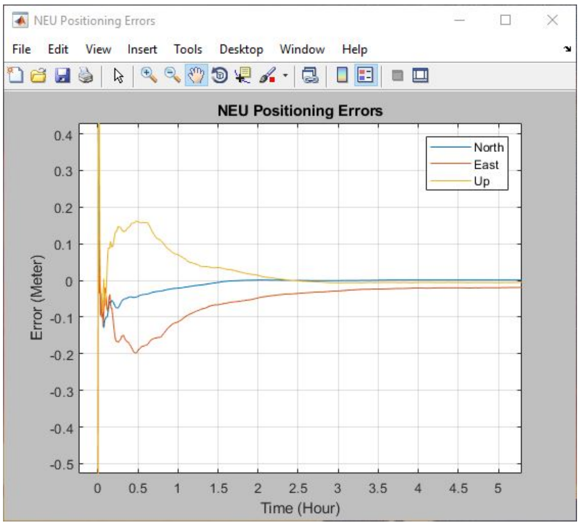
Column	Description	Format
Year	Year of the observation day	%4d
DOY	Day of the year	%3d
SOD	Second of the day	%5d
X	X coordinate of the station in ECEF coordinate system	%13.3f
Y	Y coordinate of the station in ECEF coordinate system	%13.3f
Z	Z coordinate of the station in ECEF coordinate system	%13.3f
DT	Receiver clock error	%10.3f
TH	Hydrostatic part of tropospheric delay	%7.3f
TW	Wet part of tropospheric delay	%7.3f
TH	Tropospheric zenith total delay	%7.3f
TGN	North horizontal gradient	%7.4f
TGE	East horizontal gradient	%7.4f
SDR	GLONASS system time difference parameter with respect to GPS time	%7.3f
SDE	Galileo system time difference parameter with respect to GPS time	%7.3f
SDC	BeiDou system time difference parameter with respect to GPS time	%7.3f

Table 5: Plotting tools provided by PPPH.

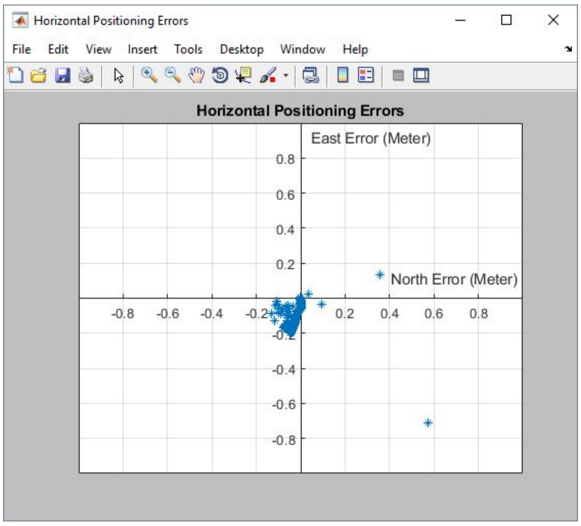
Plotting tools	**Description**
NEU Positioning Error	Plots the positioning error in north, east and up directions, separately.
Horizontal Positioning Error	Plots the positioning error in north and east directions.
3D Positioning Error	Plots total positioning error (three dimensions)
Tropospheric Zenith Total Delay	Plots total tropospheric zenith delay at the station
Receiver Clock Estimation	Plots the receiver clock error estimated
Satellite Number	Plots the satellite numbers
Dilution of Precision	Plots GDOP, PDOP and TDOP, separately.

Year	DOY	SOD	(X)	(Y)	(Z)	(DT)	(TH)	(TW)	(TT)	(TGN)	(TGE)	(SDR)	(SDE)	(SDC)
2017	309	0	4121946.579	2652185.829	4069022.385	0.389	2.068	0.001	2.069	0.0000	0.0000	5.660	-7.591	20.003
2017	309	30	4121948.615	2652188.147	4069024.582	1.700	2.068	0.067	2.136	-0.0000	0.0000	5.330	-7.143	20.789
2017	309	60	4121948.708	2652188.006	4069024.243	1.818	2.068	0.097	2.166	-0.0000	0.0000	5.062	-7.384	21.253
2017	309	90	4121948.456	2652187.915	4069023.944	1.000	2.068	0.102	2.171	-0.0000	0.0000	4.845	-7.614	21.655
2017	309	120	4121948.483	2652187.789	4069023.807	0.806	2.068	0.135	2.203	-0.0000	0.0000	4.735	-7.699	21.841
2017	309	150	4121948.437	2652187.818	4069023.799	1.061	2.068	0.142	2.211	-0.0000	0.0000	4.663	-7.744	22.058
2017	309	180	4121948.465	2652187.772	4069023.762	0.570	2.068	0.132	2.201	-0.0000	0.0000	4.601	-7.796	22.181
2017	309	210	4121948.448	2652187.790	4069023.728	1.457	2.068	0.123	2.191	-0.0000	0.0000	4.556	-7.826	22.322
2017	309	240	4121948.531	2652187.784	4069023.739	0.894	2.068	0.102	2.170	-0.0000	0.0000	4.516	-7.851	22.388
2017	309	270	4121948.538	2652187.837	4069023.755	2.541	2.068	0.090	2.159	-0.0000	0.0000	4.491	-7.858	22.492
2017	309	300	4121948.477	2652187.850	4069023.740	2.895	2.068	0.095	2.164	-0.0000	0.0000	4.469	-7.873	22.585
2017	309	330	4121948.442	2652187.853	4069023.725	3.276	2.068	0.098	2.166	-0.0000	0.0000	4.448	-7.887	22.655
2017	309	360	4121948.462	2652187.849	4069023.743	2.612	2.068	0.097	2.165	-0.0000	0.0000	4.431	-7.896	22.690
2017	309	390	4121948.494	2652187.841	4069023.764	2.759	2.068	0.095	2.164	-0.0000	0.0000	4.417	-7.905	22.713
2017	309	420	4121948.540	2652187.844	4069023.797	2.627	2.068	0.089	2.157	-0.0000	0.0000	4.408	-7.909	22.734
2017	309	450	4121948.562	2652187.853	4069023.830	2.700	2.068	0.083	2.151	-0.0000	0.0000	4.401	-7.913	22.764
2017	309	480	4121948.555	2652187.871	4069023.848	2.635	2.068	0.082	2.150	0.0000	0.0000	4.395	-7.914	22.808
2017	309	510	4121948.536	2652187.883	4069023.858	2.830	2.068	0.081	2.149	0.0000	0.0000	4.392	-7.918	22.853
2017	309	540	4121948.528	2652187.887	4069023.863	2.684	2.068	0.080	2.148	0.0000	0.0000	4.390	-7.921	22.888
2017	309	570	4121948.553	2652187.876	4069023.874	2.680	2.068	0.076	2.145	0.0000	0.0000	4.387	-7.924	22.903
2017	309	600	4121948.556	2652187.860	4069023.868	2.754	2.068	0.076	2.144	0.0000	0.0000	4.387	-7.931	22.922
2017	309	630	4121948.546	2652187.855	4069023.868	2.924	2.068	0.075	2.144	0.0000	-0.0000	4.387	-7.935	22.949
2017	309	660	4121948.559	2652187.841	4069023.867	2.866	2.068	0.074	2.142	0.0000	-0.0000	4.386	-7.939	22.961
2017	309	690	4121948.571	2652187.831	4069023.868	2.699	2.068	0.071	2.140	0.0000	0.0000	4.386	-7.944	22.974
2017	309	720	4121948.593	2652187.821	4069023.873	2.917	2.068	0.068	2.137	0.0000	0.0000	4.388	-7.948	22.981
2017	309	750	4121948.610	2652187.814	4069023.877	3.202	2.068	0.065	2.133	0.0000	0.0000	4.387	-7.952	22.991
2017	309	780	4121948.626	2652187.808	4069023.880	2.814	2.068	0.062	2.130	0.0000	0.0000	4.388	-7.955	23.001
2017	309	810	4121948.634	2652187.804	4069023.881	2.933	2.068	0.062	2.130	0.0000	0.0000	4.386	-7.956	23.014
2017	309	840	4121948.636	2652187.804	4069023.880	3.102	2.068	0.062	2.131	0.0000	0.0000	4.386	-7.956	23.030
2017	309	870	4121948.639	2652187.805	4069023.882	3.290	2.068	0.063	2.131	0.0000	0.0000	4.385	-7.955	23.044
2017	309	900	4121948.644	2652187.808	4069023.887	3.478	2.068	0.063	2.131	0.0000	0.0000	4.385	-7.954	23.056
2017	309	930	4121948.645	2652187.807	4069023.889	4.908	2.068	0.063	2.132	0.0000	0.0000	4.388	-7.953	23.067
2017	309	960	4121948.640	2652187.808	4069023.890	2.687	2.068	0.065	2.133	0.0000	0.0000	4.389	-7.951	23.082
2017	309	990	4121948.638	2652187.808	4069023.893	2.587	2.068	0.066	2.134	0.0000	0.0000	4.391	-7.950	23.094

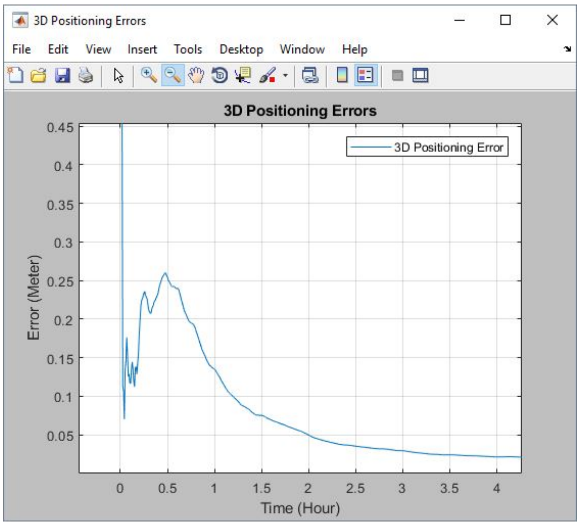
Figure 8: An output file example obtained from PPPH.



(a) NEU positioning error.

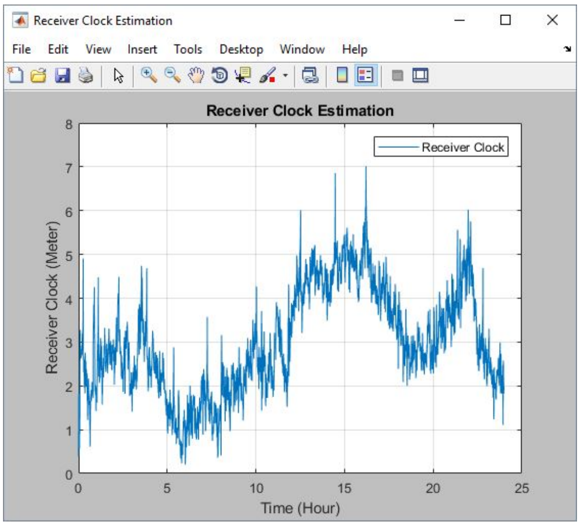


(b) Horizontal positioning error.

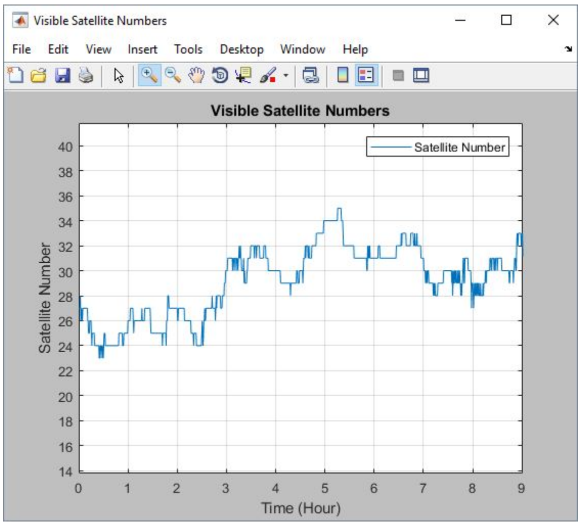


(c) 3D positioning error.

(d) Tropospheric zenith total delay.



(e) Receiver clock estimation.



(f) Visible satellite number.

Figure 9: Examples of the plots generated by PPPH.

4. PPP Processing with Function m-files in PPPH

PPPH enables to perform multi-GNSS PPP with its user-friendly GUI. At the same time, it is possible to perform multi-GNSS PPP without using the GUI. In PPPH, a MATLAB function m-file, named ppph_complete, is provided to execute the full PPP process including the whole functionalities of GUI. Thanks to complete function m-file, it may become much easier to perform multi-station and multi-day solution. The description of the function is presented below.

Usage:

```
[xs] = ppph_complete(files, options)
```

Inputs: The function requires two data inputs which defined as structure arrays. Inputs are explained as follows:

Variable		Format	Description	Extension	Condition
files.	rinex	character	Name of the observation file	*.**o, *.rnx	Obligatory
	orbit	character	Name of the precise ephemeris for observation day	*.sp3	Obligatory
	orbitb	character	Name of the precise ephemeris for previous day	*.sp3	Optional
	orbita	character	Name of the precise ephemeris for next day	*.sp3	Optional
	anten	character	Name of the antenna file	*.atx	Obligatory
	clock	character	Name of the clock product file	*.clk*	Optional
	dcb	character	Name of the differential code bias file	*.DCB	Optional

Variable		Format	Description	Value	Condition
options.	system.gps	integer	GPS system selection	0 or 1	Obligatory
	system.glo	integer	GLONASS system selection	0 or 1	Obligatory
	system.gal	integer	Galileo system selection	0 or 1	Obligatory
	system.bds	integer	BeiDou system selection	0 or 1	Obligatory
	clock	character	Definition of the clock source	*Clock File or Sp3 File*	Obligatory
	clck_int	integer	Sample interval of the clock file	user-defined (in seconds)	Obligatory
	dcb	integer	DCB file selection	0 or 1	Obligatory (requires for dcb file)
	elvangle	integer	Elevation cut-off angle	user-defined (in degree)	Obligatory
	CsMw	integer	Selection of cycle slip detection using Melbourne-Wübbena comb.	0 or 1	Obligatory
	CsGf	integer	Selection of cycle slip detection using Geometry-free comb.	0 or 1	Obligatory
	clkjump	integer	Selection of clock jump detection	0 or 1	Obligatory
	codsmth	integer	Selection of code smoothing with phase	0 or 1	Obligatory
	ProMod	integer	Selection of processing mode	0 (kinematic) 1 (static)	Obligatory
	SatClk	integer	Selection of satellite clock correction	0 or 1	Obligatory
	SatAPC	integer	Selection of satellite antenna phase center correction	0 or 1	Obligatory
	SatWind	integer	Selection of satellite wind-up correction	0 or 1	Obligatory
	RecAPC	integer	Selection of receiver antenna phase center correction	0 or 1	Obligatory
	RecARP	integer	Selection of receiver antenna reference point correction	0 or 1	Obligatory
	AtmTrop	integer	Selection of tropospheric correction	0 or 1	Obligatory
	TroGrad	integer	Selection of tropospheric gradients estimation	0 or 1	Obligatory
	RelClk	integer	Selection of relativistic clock correction	0 or 1	Obligatory
	RelPath	integer	Selection of relativistic path correction	0 or 1	Obligatory
	Solid	integer	Selection of solid tides correction	0 or 1	Obligatory

Variable		Format	Description	Value	Condition
	InMethod	integer	Selection of initial parameters method	0 (manually) or 1 (least squares)	Obligatory
	*IntPos, IntPos2	integer	Initial uncertainty parameters for position components	user-defined (in meters)	Optional (requires for In-Method = 0)
	*IntClk, IntClk2	integer	Initial uncertainty parameters for receiver clock	user-defined (in meters)	Optional (requires for In-Method = 0)
	*IntTrop, IntTrop2	integer	Initial uncertainty parameters for tropospheric delay	user-defined (in meters)	Optional (requires for In-Method = 0)
	*IntSTD, IntSTD2	integer	Initial uncertainty parameters for system time difference parameters	user-defined (in meters)	Optional (requires for In-Method = 0)
options.	*NosPos, NosPos2	integer	Process uncertainty parameters for position components	user-defined (in m^2/sec)	Obligatory
	*NosClk, NosClk2	integer	Process uncertainty parameters for position components	user-defined (in m^2/sec)	Obligatory
	*NosTrop, NosTrop2	integer	Process uncertainty parameters for tropospheric delay	user-defined (in m^2/sec)	Obligatory
	*NosSTD, NosSTD2	integer	Process uncertainty parameters for system time difference parameters	user-defined (in m^2/sec)	Obligatory
	ApMethod	character	Selection of a priori position	RINEX or Specify	Obligatory
	WeMethod	character	Observation weighting method	Elevation-Dependent or Equal	Obligatory
	CodeStd	float	Standard deviation of code observations	user-defined (in meters)	Obligatory
	PhaseStd	float	Standard deviation of phase observations	user-defined (in meters)	Obligatory
	from	integer	First epoch for processing	user-defined (in seconds)	Obligatory
	to	integer	Last epoch for processing	user-defined (in seconds)	Obligatory

Uncertainty parameters are given by $x \cdot 10^n$. The first parameter indicates x, while the second represents n. For example, $IntPos \cdot 10^{IntPos2}$

5. Example

In order to ensure that users have installed and run the software correctly, we present an example of PPP processing in this section. 24-hr observation data collected at ISTA station on 10 July 2017 were obtained from IGS data server. Since ISTA is one of the MGEX stations equipped with the multi-GNSS receivers, the observation file contains GPS, GLONASS, Galileo and BeiDou satellites. The observation data were processed using PPPH software in static mode with two different ways; (1) including GPS satellites only, (2) including GPS, GLONASS, Galileo and BeiDou satellites. The precise orbit and clock products provided by GFZ (German Research Centre for Geosciences) were utilized for all systems for the sake of consistency. The processing options and parameters were set as the defaults in PPPH. The whole files required for conducting PPP process in addition to the output files are presented within the *Example* folder of the software package and also provided below.

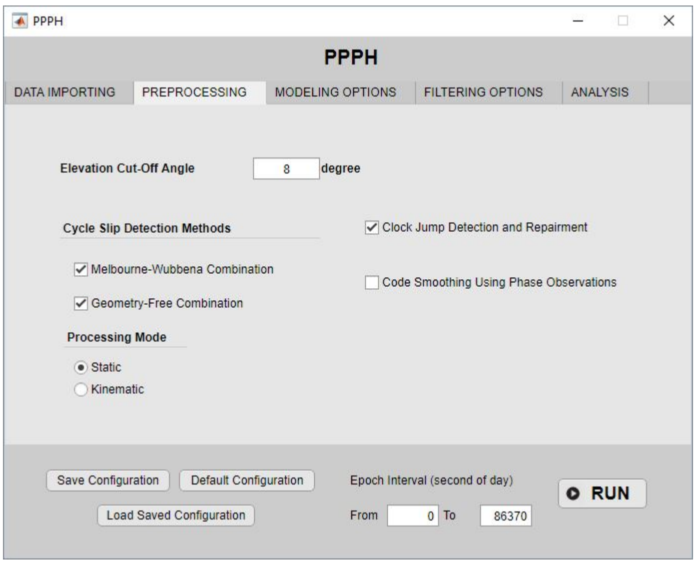
Files

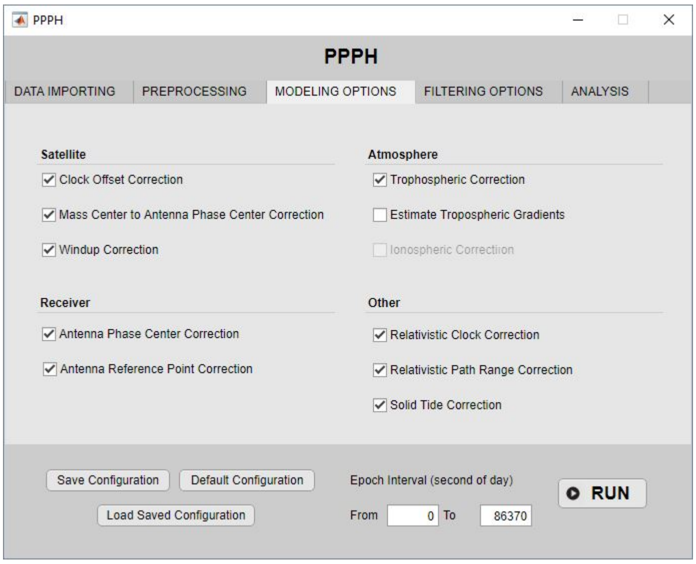
File	Name
Observation	ISTA00TUR_R_20171910000_01D_30S_MO.00o
Orbit	gbm19570.sp3, gbm19571.sp3, gbm19572.sp3
Clock	gbm19571.clk
Antenna	igs14_1935.atx

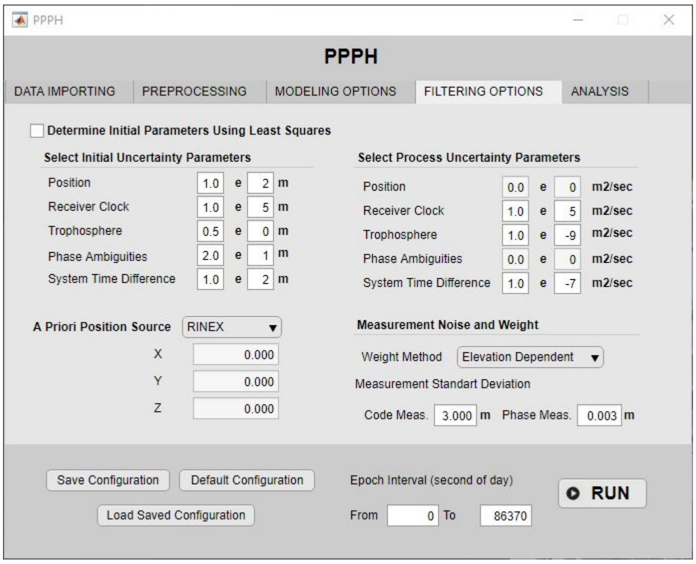
Outputs

Processing Mode	Output File
GPS-Only	out_gpsonly.txt
Multi-GNSS	out_multi-gnss.txt

Options







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