Bernese GNSS Software Version 5.2

Tutorial

Processing Example
Introductory Course
Terminal Session

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Contents

1 Introduction to the Example Campaign

1.1 Stations in the Example Campaign

Data from thirteen European stations of the International GNSS Service (IGS) network and from the EUREF Permanent Network (EPN) were selected for the example campaign. They are listed in Table 1.1. The locations of these stations are given in Figure 1.1. Three of the stations support only Global Positioning System (GPS) whereas all other sites provide data from both GPS and its Russian counterpart Глобальная навигационная спутниковая система: Global Navigation Satellite System (GLONASS).

The observations for these stations are available for four days. Two days in year 2010 (day of year 207 and 208) and two in 2011 (days 205 and 206)[1]. In the terminal sessions you will analyze the data in order to obtain a velocity field based on final products from Center for Orbit Determination in Europe (CODE). For eight of these stations, coordinates and velocities are given in the IGS14 reference frame, an IGS–specific realization of the ITRF2014 (see `${D}/STAT_LOG/IGS14.snx`).

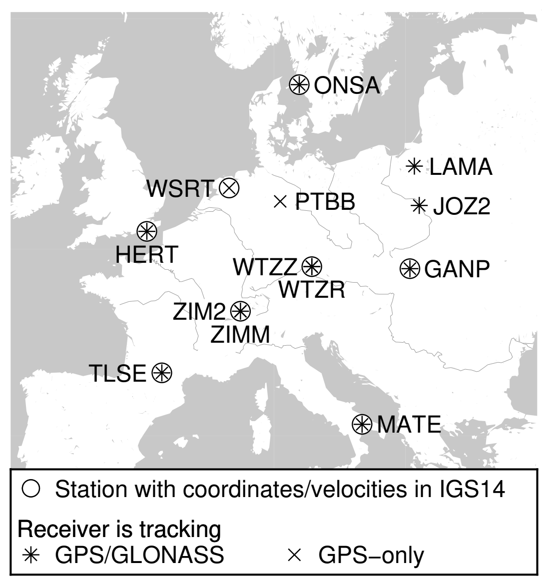


Figure 1.1: Stations used in example campaign

Between these days in 2010 and 2011 the receivers at LAMA, TLSE, and WTZR and the full equipment at WTZZ was changed. The receiver type, the antenna type, and the antenna height are provided in Table 1.1. Notice, that for three antennas (at GANP, WTZR, and ZIM2) values from an individual calibration are available from the EPN processing. For all other antennas only type–specific calibration results from the IGS processing (`${X}/GEN/I14.ATX`) are available. More details are provided in Table 1.2. Only in one case where no calibration of the antenna/radome combination was available (ONSA) the calibration values of the antenna without radome were used instead. With the exception of ONSA even system–specific calibrations for GPS and GLONASS measurements are available.

The distances between occupied locations in the network are between 200 and 1000 km. Two locations (Zimmerwald and Kötzting) are occupied by receiver/antenna pairs defining

[1] A fifth day (day 213 of year 2017) is available to demonstrate the usage of RINEX 3 data and the processing of Galileo observations, see Sections 7.5 and 7.6, respectively. These data are only relevant if you want to follow the examples in these two sections.

Table 1.1: List of stations used for the example campaign including receiver and antenna type as well as the antenna height.

Station name	Location		Receiver type Antenna type	Radome	Antenna height
GANP 11515M001	Ganovce, Slovakia		TRIMBLE NETR8 TRM55971.00	NONE	0.3830 m
HERT 13212M010	Hailsham, United Kingdom		LEICA GRX1200GGPRO LEIAT504GG	NONE	0.0000 m
JOZ2 12204M002	Jozefoslaw, Poland		LEICA GRX1200GGPRO LEIAT504GG	NONE	0.0000 m
LAMA 12209M001	Olsztyn, Poland	2010:	LEICA GRX1200GGPRO LEIAT504GG	LEIS	0.0600 m
		2011:	LEICA GRX1200+GNSS LEIAT504GG	LEIS	0.0600 m
MATE 12734M008	Matera, Italy		LEICA GRX1200GGPRO LEIAT504GG	NONE	0.1010 m
ONSA 10402M004	Onsala, Sweden		JPS E_GGD AOAD/M_B	OSOD	0.9950 m
PTBB 14234M001	Braunschweig, Germany		ASHTECH Z-XII3T ASH700936E	SNOW	0.0562 m
TLSE 10003M009	Toulouse, France	2010:	TRIMBLE NETR5 TRM59800.00	NONE	1.0530 m
		2011:	TRIMBLE NETR9 TRM59800.00	NONE	1.0530 m
WSRT 13506M005	Westerbork, The Netherlands		AOA SNR-12 ACT AOAD/M_T	DUTD	0.3888 m
WTZR 14201M010	Kötzting, Germany	2010:	LEICA GRX1200GGPRO LEIAR25.R3	LEIT	0.0710 m
		2011:	LEICA GRX1200+GNSS LEIAR25.R3	LEIT	0.0710 m
WTZZ 14201M014	Kötzting, Germany	2010:	TPS E_GGD TPSCR3_GGD	CONE	0.2150 m
		2011:	JAVAD TRE_G3TH DELTA LEIAR25.R3	LEIT	0.0450 m
ZIM2 14001M008	Zimmerwald, Switzerland		TRIMBLE NETR5 TRM59800.00	NONE	0.0000 m
ZIMM 14001M004	Zimmerwald, Switzerland		TRIMBLE NETRS TRM29659.00	NONE	0.0000 m

Table 1.2: List of antenna/radome combinations used in the example campaign together with the available antenna calibration values in IGS14 model.

Antenna type		Type of calibration for GPS	for GLONASS	used at stations
AOAD/M_B	OSOD	ADOPTED from NONE	ADOPTED from GPS	ONSA
AOAD/M_T	DUTD	ROBOT	—	WSRT
ASH700936E	SNOW	ROBOT	—	PTBB
LEIAR25.R3	LEIT	ROBOT	ROBOT	WTZR, WTZZ(2011)
LEIAT504GG	NONE	ROBOT	ROBOT	JOZ2, HERT, MATE
LEIAT504GG	LEIS	ROBOT	ROBOT	LAMA
TPSCR3_GGD	CONE	ROBOT	ROBOT	WTZZ(2010)
TRM29659.00	NONE	ROBOT	—	ZIMM
TRM55971.00	NONE	ROBOT	ROBOT	GANP
TRM59800.00	NONE	ROBOT	ROBOT	TLSE, ZIM2

separate stations each: in Zimmerwald, the distance between ZIMM and ZIM2 is only 19 m. In Kötzting, WTZR and WTZZ are separated by less than 2 m — these are short GPS/GLONASS baselines.

The receivers used at the stations MATE, ONSA, PTBB, and WSRT are connected to H-Maser clocks. The receiver type ASHTECH Z-XII3T used at PTBB was specifically developed for time and frequency applications. In 2011 both receivers in Kötzting (WTZR and WTZZ) were connected to the same H–Maser (EFOS 18).

1.2 Directory Structure

The data belonging to this example campaign is included in the distribution of the *Bernese GNSS Software*. Therefore, you may also use this document to generate solutions from the example dataset to train yourself in the use of the *Bernese GNSS Software* outside the environment of the *Bernese Introductory Course*.

There are three areas relevant for the data processing (in the environment of the *Bernese Introductory Course* they are all located in the `${HOME}/GPSDATA` directory):

`${D}`: The `DATAPOOL` area is intended as an interface where all external files can be deposited after their download. It can be used by several processing campaigns.

`${P}`: The `CAMPAIGN52` directory contains all processing campaigns for the Version 5.2 of the *Bernese GNSS Software*. In the *Bernese Introductory Course* environment all groups use `${P}/INTRO`[2] in their `${HOME}` directory.

`${S}`: The `SAVEDISK` area serves as a product database where the result files from different processes/projects can be collected and archived. Before you start processing, only reference files (`*.*_REF`) obtained with the example BPE from the distribution are available here.

[2]The second campaign `${P}/EXM_GAL` is only related to Section 7.6 where the analysis of Galileo measurements is explained.

1.2.1 The DATAPOOL Directory Structure (${D})

Motivation for the DATAPOOL area

The idea of the DATAPOOL area is to store local copies of external files on your filesystem. This offers several advantages compared to downloading the data each time when the processing is started:

- The files are downloaded only once, even if they are used for several campaigns.
- The data download can be organized with a set of scripts running independently from the Bernese GNSS Software environment, scheduled by the expected availability of the external files to download.
- The processing itself becomes independent from the availability of external data sources.

Structure and content of the DATAPOOL area

The DATAPOOL area contains several subdirectories taking into account the different sources of files and their formats:

RINEX :

The data of GNSS stations is provided in Receiver INdependent EXchange format (RINEX) files. The directory contains observation (Hatanaka–compressed) and navigation (GPS and GLONASS) files. These RINEX files are "originary" files that are not changed during the processing.

The RINEX files can be downloaded from international data centers. Project–specific files are copied into this area. If you mix the station lists from different projects, take care about the uniqueness of the four–character IDs of all stations in the RINEX file names.

HOURLY :

The same as the RINEX directory but dedicated to hourly RINEX data used for near real–time applications. Note: not all stations in this example provide hourly RINEX files.

RINEX3 :

The same as the RINEX directory but the data are given in the RINEX 3 format. These files support the description on how to use RINEX 3 data, see Section 7.5 .

LEO :

This directory is intended to host files which are necessary for Low Earth Orbiter (LEO) data processing. RINEX files are stored in the subdirectory RINEX (of the LEO directory). The corresponding attitude files are placed in the subdirectory ATTIT.

These files are needed to run the example BPE on LEO orbit determination (LEOPOD.PCF). They are not used in the example during the *Bernese Introductory Course*.

SLR_NP :

The Satellite Laser Ranging (SLR) data is provided in the quicklook normal point format. The directory contains the normal point files downloaded from the International Laser Ranging Service (ILRS) data centers.

These files are needed to run the example BPE on orbit validation using SLR observations (`SLRVAL.PCF`). They are not used in the example during the *Bernese Introductory Course*.

STAT_LOG :

This directory contains the station information files (e.g., from `ftp://igs.org/pub/station/log`). This information may be complemented by the originary information on the reference frame (e.g., the `IGb08.snx` or `IGS14.snx` from `ftp://igs.org/pub/station/coord`).

Apart from the coordinates and velocities of selected IGS sites, it also contains the history of the used equipment as it has been assumed for the reference frame generation. A comparison with the `igs.snx` file constructed at the IGS Central Bureau (IGSCB) from the site information files may be useful for a verification of the history records.

COD/COM/IGS :

Orbits, Earth orientation parameters (EOP), and satellite clock corrections are basic external information for a GNSS analysis. The source of the files may be the FTP server from CODE (`ftp://ftp.aiub.unibe.ch/CODE` or `http://www.aiub.unibe.ch/download/CODE/`), or the Crustal Dynamics Data Information System FTP server (e.g., for downloading GPS–related IGS products `ftp://cddis.gsfc.nasa.gov/gnss/products` and in `ftp://cddis.gsfc.nasa.gov/glonass/products` for GLONASS–related IGS products). The files are named by the GPS week and the day of the week (apart from files containing information for the entire week, e.g., EOP, or the processing summaries).

The IGS provides GPS and GLONASS orbits only in separate files (`IGS`/`IGL`–series from the final product line) stemming from independent combination procedures with different contributing analysis centers. Nevertheless, they are consistent enough to merge both files together as the first step of the processing as described in Section 7.2 . CODE contributes fully combined multi–GNSS solutions to the IGS final (and rapid as well as ultra–rapid) product line.

When you are going to process Galileo data (see Section 7.6) you will need related orbit, EOP, and satellite clock corrections for these satellites as well. They are not included in the legacy IGS products. For that reason you need products from the Multi-GNSS Extension (MGEX) project of the IGS. CODE's MGEX products are available with the label `COM` at `ftp://ftp.aiub.unibe.ch/CODE_MGEX/CODE` or `ftp://cddis.gsfc.nasa.gov/gnss/products/mgex` .

BSW52 :

In this directory we have placed files containing external input information in Bernese–specific formats. The files are neutral with respect to the data you are going to process. Typical examples are ionosphere maps or differential code biases (DCB) files. These files can be downloaded from `http://www.aiub.unibe.ch/download/CODE/` or `http://www.aiub.unibe.ch/download/BSWUSER52/` areas.

REF52 :

Here we propose to collect files in Bernese format which are useful for several campaigns (e.g., reference frame files: `IGB08_R.CRD`, `IGB08_R.VEL` or `IGS14_R.CRD`, `IGS14_R.VEL`). Typical examples are station coordinate, velocity, and information files (e.g., `EXAMPLE.CRD`, `EXAMPLE.VEL`, `EXAMPLE.STA`, . . . , `EPN.CRD`). All stations of a project are contained in one file but the processing of the project's data may be performed in different campaigns.

MSC :
This directory contains example files for the automated processing with the BPE.

VMF1 :
The grids for the Vienna Mapping Function (VMF1) are located in a separate directory. The files can be downloaded from `http://vmf.geo.tuwien.ac.at/trop_products/GRID/2.5x2/VMF1/VMF1_OP`. They are not used for the examples but it is an indication that for other types of files additional directories may be created.

All files and meta–information related to the 13 stations selected for the example campaign are already in this `DATAPOOL`–area (`${D}`) after installing the *Bernese GNSS Software*. GNSS orbit information is available from CODE (legacy and MGEX) and IGS (directories `${D}/COD`, `${D}/COM` or `${D}/IGS`, respectively).

1.2.2 The Campaign–Directory Structure

Putting data from the DATAPOOL into the campaign

When running an automated processing using the BPE there is a script at the beginning of the process which copies the data from the `DATAPOOL`–area into the campaign. If you are going to process data manually you first have to copy the necessary files into the campaign and decompress them if necessary using standard utilities (`uncompress`, `gunzip`[3], or `CRZ2RNX` for RINEX–files).

Content of the campaign area to process the example

All files needed to process the data according to this tutorial are already copied into the campaign area. If you want to follow the example outside the *Bernese Introductory Course* environment you have to put the following files at the correct places in the campaign directory structure.

```
${P}/INTRO/ATM/   COD10207.ION     COD10208.ION     COD11205.ION     COD11206.ION

${P}/INTRO/BPE/

${P}/INTRO/GRD/   VMF10207.GRD     VMF10208.GRD     VMF11205.GRD     VMF11206.GRD

${P}/INTRO/OBS/

${P}/INTRO/ORB/   COD15941.PRE     COD15942.PRE     COD16460.PRE     COD16461.PRE
                  COD15947.IEP                      COD16467.IEP
                  IGS15941.PRE     IGS15942.PRE     IGS16460.PRE     IGS16461.PRE
                  IGL15941.PRE     IGL15942.PRE     IGL16460.PRE     IGL16461.PRE
                  IGS15947.IEP                      IGS16467.IEP
                  P1C11007.DCB                      P1C11107.DCB
                  P1P21007.DCB                      P1P21107.DCB

${P}/INTRO/ORX/

${P}/INTRO/OUT/   COD15941.CLK     COD15942.CLK     COD16460.CLK     COD16461.CLK
                  IGS15941.CLK     IGS15942.CLK     IGS16460.CLK     IGS16461.CLK

${P}/INTRO/RAW/   GANP2070.10O     GANP2080.10O     GANP2050.11O     GANP2060.11O
                  HERT2070.10O     HERT2080.10O     HERT2050.11O     HERT2060.11O
                  JOZ22070.10O     JOZ22080.10O     JOZ22050.11O     JOZ22060.11O
                  LAMA2070.10O     LAMA2080.10O     LAMA2050.11O     LAMA2060.11O
```

[3] These tools are also available for WINDOWS-platforms, see `www.gzip.org`. Note, that `gunzip` can also be used to uncompress UNIX–compressed files with the extension `.Z`.

	MATE2070.100	MATE2080.100	MATE2050.110	MATE2060.110
	ONSA2070.100	ONSA2080.100	ONSA2050.110	ONSA2060.110
	PTBB2070.100	PTBB2080.100	PTBB2050.110	PTBB2060.110
	TLSE2070.100	TLSE2080.100	TLSE2050.110	TLSE2060.110
	WSRT2070.100	WSRT2080.100	WSRT2050.110	WSRT2060.110
	WTZR2070.100	WTZR2080.100	WTZR2050.110	WTZR2060.110
	WTZZ2070.100	WTZZ2080.100	WTZZ2050.110	WTZZ2060.110
	ZIM22070.100	ZIM22080.100	ZIM22050.110	ZIM22060.110
	ZIMM2070.100	ZIMM2080.100	ZIMM2050.110	ZIMM2060.110
${P}/INTRO/SOL/				
${P}/INTRO/STA/	EXAMPLE.CRD	EXAMPLE.VEL	EXAMPLE.STA	EXAMPLE.ABB
	EXAMPLE.BLQ	EXAMPLE.ATL	EXAMPLE.CLU	EXAMPLE.PLD
	IGB08_R.CRD	IGB08_R.VEL	IGB08.FIX	IGB08.SIG
	IGS14_R.CRD	IGS14_R.VEL	IGS14.PSD	
	IGS14.FIX	IGS14.SIG		
	SESSIONS.SES			

The directory `${P}/INTRO/GEN/` contains copies of the files from the `${X}/GEN` directory, which are used by the processing programs. The files `PCV_Bxx.I08` and `PCV_Bxx.I14`, respectively, are user-specific and the “xx” chars represent your terminal account number. If you want to view these files, please use those in your campaign and not the ones in the `${X}/GEN` directory to prevent potential interferences with your colleagues.

${P}/INTRO/GEN/	CONST.	DATUM.	GPSUTC.	POLOFF.
	RECEIVER.			
	SATELLIT.I08	PCV.I08	PCV_Bxx.I08	I08.ATX
	SATELLIT.I14	PCV.I14	PCV_Bxx.I14	I14.ATX
	SAT_2010.CRX	SAT_2011.CRX		
	IAU2000R06.NUT	IERS2010XY.SUB	OT_FES2004.TID	TIDE2000.TPO
	EGM2014_SMALL.	s1_s2_def_ce.dat		
	SINEX.	SINEX.PPP	SINEX.RNX2SNX	
	IONEX.	IONEX.PPP		

1.2.3 Input Files for the Processing Examples

Atmosphere files `ATM`

The input files in this directory are global ionosphere models in the Bernese format obtained from the IGS processing at CODE. They will be used to support the phase ambiguity resolution with the QIF strategy and to enable the higher order ionosphere (HOI) corrections.

General files `GEN`

These general input files contain information that is neither user– nor campaign–specific. They are accessed by all users, and changes in these files will affect processing for everyone. Consequently, these files are located in the `${X}/GEN` directory. Table 1.3 shows the list of general files necessary for the processing example. It also shows which files need to be updated from time to time by downloading them from the anonymous ftp–server of AIUB (`http://www.aiub.unibe.ch/download/BSWUSER52/GEN`).

Since GPS week 1934 (29 January 2017) the IGS is using the IGS14 reference frame together with the related antenna model (`I14.ATX`). They are available in the related `SATELLIT.I14` and `PCV.I14` files. The predecessor antenna model is related to the IGb08 reference frame and is provided in the `SATELLIT.I08` and `PCV.I08` files. Please check the consistent usage of these files.

Table 1.3: List of general files to be used in the Bernese programs for the processing example.

Filename	Content	Modification	Update from
`CONST.`	All constants used in the *Bernese GNSS Software*	No	BSW aftp
`DATUM.`	Definition of geodetic datum	Introducing new reference ellipsoid	BSW aftp
`GPSUTC.`	Leap seconds	When a new leap second is announced by the IERS	BSW aftp
`POLOFF.`	Pole offset coefficients	Introducing new values from IERS annual report (until 1997)	—
`RECEIVER.`	Receiver information	Introducing new receiver type	BSW aftp
`SATELLIT.I14` or `SATELLIT.I08`	Satellite information file	New launched satellites	BSW aftp
`PCV.I14` or `PCV.I08`	Phase center eccentricities and variations	Introducing new antenna corrections or new antenna/radome combinations	BSW aftp or update with ATX2PCV
`SAT_$Y+0.CRX`	Satellite problems	Satellite maneuvers, bad data, ...	BSW aftp
`IAU2000R06.NUT`	Nutation model coefficients	No	—
`IERS2010XY.SUB`	Subdaily pole model coefficients	No	—
`OT_FES2004.TID`	Ocean tides coefficients	No	—
`TIDE2000.TPO`	Solid Earth tides coefficients	No	—
`EGM2008_SMALL.`	Earth potential coefficients (reduced version, sufficient for GNSS and LEO orbit determination)	No	—
`s1_s2_def_ce.dat`	S1/S2 atmospheric tidal loading coefficients	No	—

`SINEX.`
`SINEX.TRO`
`SINEX.PPP`
`SINEX.RNX2SNX`
	SINEX header information
	
	. . . for the PPP example
	. . . for RNX2SNX example
		Adapt SINEX header for your institution	—

`IONEX.`
 	
`IONEX.PPP`
	IONEX header information
	. . . for the PPP example
		Adapt IONEX header for your institution	—

Each Bernese processing program has its own panel for general files. Make sure that you use the correct files listed in Table 1.3 .

Grid files `GRD`

In this directory the grid files `*.GRD` are collected. To apply, e.g., the VMF1 troposphere model (a priori information from European Centre for Medium-Range Weather Forecasts (ECMWF) and Vienna mapping function) you need a grid with the necessary coefficients.

Orbit files ORB

The precise orbits in the files *.PRE are usually the final products from CODE analysis center containing GPS and GLONASS orbits from a rigorous multi–GNSS analysis. Alternatively also the combined final products from the IGS can be used. They do not contain orbits for the GLONASS satellites. The combined GLONASS satellite orbits from the IGS are available in IGL–files. Both precise orbit files need to be merged for a multi–GNSS analysis.The corresponding EOP are given in weekly files with the extension *.IEP (take care on full consistency with the orbit product).

Furthermore, the directory contains monthly means for the DCB.

Clock RINEX files OUT

The clock RINEX files are located in the OUT–directory. They are consistent with the GNSS orbits and EOP products in the ORB–directory. They contain station and satellite clock corrections with at least 5 minutes sampling — there are also files from the IGS or some of the analysis center (AC)s providing satellite clock corrections with a sampling of 30 seconds .

RINEX files RAW

The raw data are given in RINEX format. The observations *.$YO ($Y is the menu time variable for the two–digit year of the current session) are used for all examples.

Station files STA

The coordinates and velocities of the stations given in the IGS realization of the reference frame ITRF2014 are available in the files IGS14_R.CRD and IGS14_R.VEL . Since the ITRF2014 solution, in addition to the linear station velocities (see VEL) for some stations also corrections for Post Seismic Deformation (PSD) need to apply that are provided in the file IGS14.PSD . The IGS core stations are listed in IGS14.FIX . This file will be used to define the geodetic datum when estimating station coordinates. The files for the previously used IGS realization of the ITRF2008 are available as well: IGB08_R.CRD, IGB08_R.VEL and IGB08.FIX (Note that the PSD corrections are not yet in use). You can browse all these files with a text editor or with the menu ("Menu>Campaign>Edit station files").

For all stations that have unknown coordinates in the IGS14 reference frame a Precise Point Positioning (PPP) using the example BPE (PPP_BAS.PCF) for day 207 of year 2010 has been executed. For our EXAMPLE–project a resulting coordinate file EXAMPLE.CRD has been generated. It contains all IGS core sites (copied from file IGS14_R.CRD) and the PPP results for the remaining stations. The epoch of the coordinates is January 01, 2010 . The corresponding velocity file EXAMPLE.VEL contains the velocities for the core sites (copied from file IGS14_R.VEL) completed by the NNR–NUVEL1A velocities for the other stations. The assignment of stations to tectonic plates is given in the file EXAMPLE.PLD.

To make sure that you process the data in the *Bernese GNSS Software* with correct station information (station name, receiver type, antenna type, antenna height, etc.) the file `EXAMPLE.STA` is used to verify the RINEX header information. The reason to use this file has to be seen in the context that some antenna heights or receiver/antenna types in the RINEX files may not be correct or may be measured to a different antenna reference point. Similarly, the marker (station) names in the RINEX files may differ from the names we want to use in the processing. The antenna types have to correspond to those in the file `${X}/GEN/PCV.I14` in order that the correct phase center offsets and variations are used. The receiver types have to be defined in the `${X}/GEN/RECEIVER.` file to correctly apply the DCB corrections.

For each station name unique four– and two–character abbreviations to construct the names for the Bernese observation files need to be defined in the file `EXAMPLE.ABB`. It was automatically generated by the PPP–example BPE. If you want to process big networks, the baselines need to be divided into clusters to speed up the processing. For that purpose each station has to be assigned to a region by a cluster number in the file `EXAMPLE.CLU`.

The last files to be mentioned in this directory are `EXAMPLE.BLQ` and `EXAMPLE.ATL`. They respectively provide the coefficients for the ocean and atmospheric tidal loading of the stations. They should at least be applied in the final run of GPSEST.

1.2.4 The `SAVEDISK` Directory Structure (`${S}`)

Motivation for the SAVEDISK area

When processing GNSS data, a lot of files from various processing steps will populate your campaign directories. The main result files from the data analysis should be collected in the `SAVEDISK` area. This area is intended as long–term archive for your result files.

Because the result files are stored in the `SAVEDISK` area, you can easily clean up your campaign area without loosing important files. Please keep in mind that the computing performance decreases if you have several thousands of files in a directory.

Structure and content of the SAVEDISK area

We propose to build subdirectories in the `SAVEDISK` area for each of your projects. If these projects collect data over several years, yearly subdirectories are recommended. It is also practical to use further subdirectories like `ATM`, `ORB`, `OUT`, `SOL`, `STA` to distribute the files and to get shorter listings if you are looking for a file.

The `SAVEDISK` area contains after its installation a directory structure according to the description above. Each example BPE is assumed as a project. Therefore, you will find on the top level of the `SAVEDISK` the directories `PPP`, `RNX2SNX`, `CLKDET`, `LEOPOD`, and `SLRVAL` (related to the different example BPEs). There may even be specific directories for different series of solutions in various projects (e.g., `PPP_GAL`, `RNX2SNX_GAL` where also Galileo measurements have been included; see Section 7.6 on how to generate these solutions).

In each of these directories you will find several files ending with `_REF`. They are generated by running the example BPEs on the system at Astronomical Institute of the University of Bern (AIUB). Even if the objectives of this tutorial and of the `RNX2SNX` example BPE are in both cases to process data from a regional network, the results will not be identical since there are some differences in the processing strategies and selected options.

2 Terminal Session: Monday

Today's terminal session is to:
1. *become familiar with the UNIX environment, the menu of the* Bernese GNSS Software, *and the example campaign,*
2. *verify the campaign setup done for you (see sections 2.2 and 2.3, and also the handout for the terminal sessions),*
3. *generate the a priori coordinates for all 4 days using* COOVEL *(see Section 2.5), and*
4. *start to prepare pole and orbit information according to chapter 3.*

2.1 Start the Menu

Start the menu program using the command G[1].

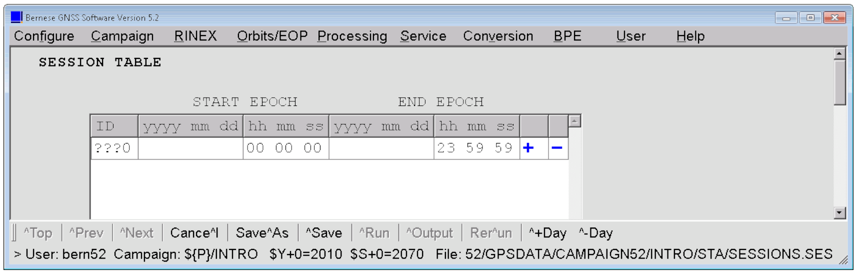
Navigate through the submenus to become familiar with the structure of the menu. Read the general help (available at "Menu>Help>General") to get an overview on the usage of the menu program of the *Bernese GNSS Software*.

For the terminal session in the *Bernese Introductory Course*, the campaign setup has already been done for each user. Please check that the campaign name in the statusbar of the Bernese Menu is set correctly to your campaign (i.e., Campaign ${P}/INTRO) and that the current session is set to the first session (i.e., $Y+0=2010, $S+0=2070). If this is not the case, please contact the staff in the terminal room.

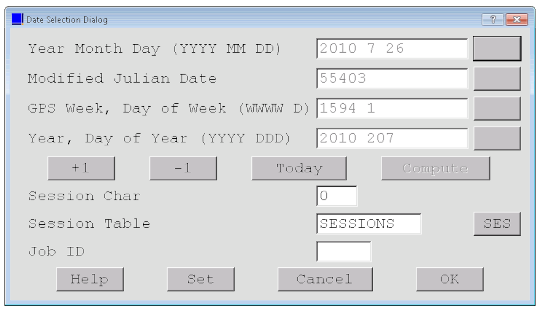
2.2 Select Current Session

Select "Menu>Campaign>Edit session table" to check the session table. It is recommended to use the wildcard string ???0 for the "List of sessions" in panel "SESSION TABLE". The panel below shows the session definition for a typical permanent campaign with 24-hours sessions. The setup of the session table is a very important task when you prepare a campaign. Please read the corresponding online help carefully.

[1] At the exercise terminals the Bernese environment is loaded automatically during login. At home you have to source the file `${X}/EXE/LOADGPS.setvar` on UNIX–platforms either manually or during login.



Save the session table (press the ^Save button) and open the "Date Selection Dialog" in the "Menu>Configure>Set session/compute date" in order to define the current session:



2.3 Campaign Setup

Usually, a new campaign must be added to the campaign list ("Menu>Campaign>Edit list of campaigns") first and select it as the active campaign ("Menu>Campaign>Select active campaign"), before the directory structure can be created ("Menu>Campaign>Create new campaign"). In the *Bernese Introductory Course* environment this should already have been done for your campaign, but please verify that.

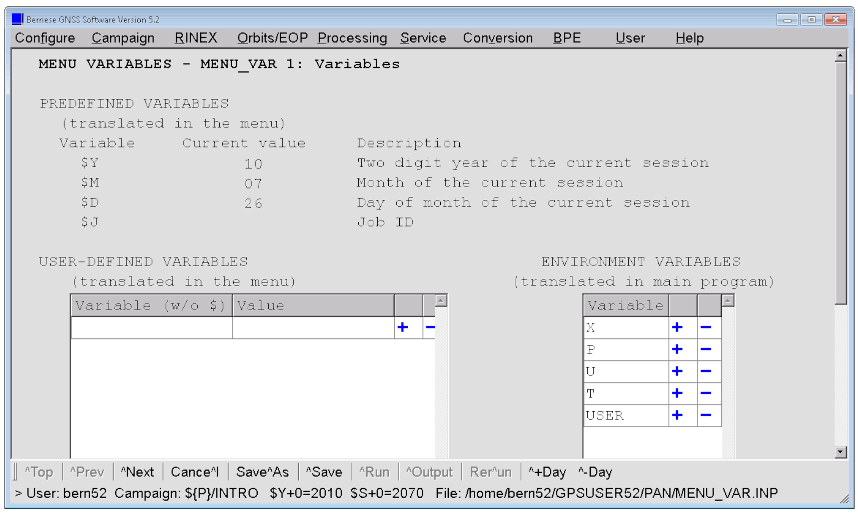
In the *Bernese Introductory Course* environment the selected campaign should be `${P}/INTRO`. In order to become familiar with the campaign structure, you can inspect your campaign directory and inspect the contents using the command line (using *cd* for changing directories and *ls* to create directory listings) or using a filemanager (e.g., midnight commander *mc*).

2.4 Menu Variables

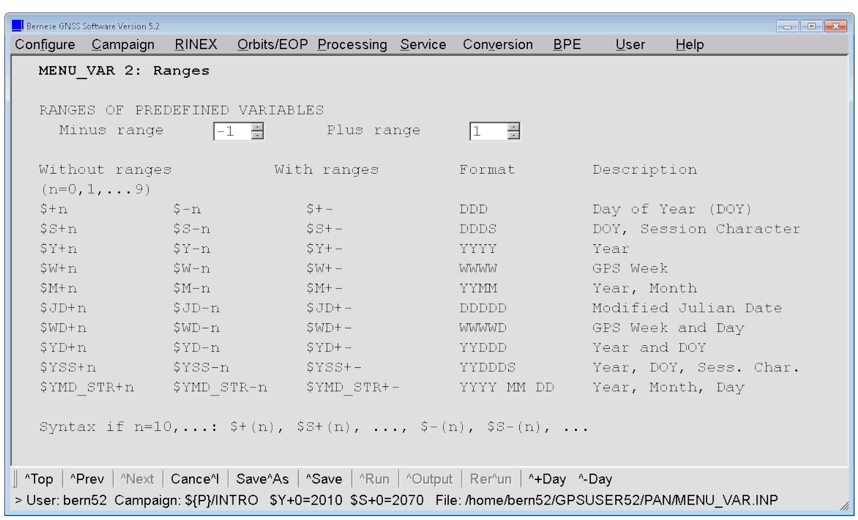
When processing GNSS data, it is often necessary to repeat a program run several times with only slightly different option settings. A typical example would be the processing of several sessions of data. The names of observation files change from session to session because the session number is typically a part of the filename. It would be very cumbersome to repeat all the runs selecting the correct files manually every time. For the BPE an automation is mandatory. For such cases the Bernese menu system provides a powerful tool: the so–called menu variables. The menu variables are defined in the user–specific menu input file `${U}/PAN/MENU_VAR.INP` that is accessible through "Menu

>Configure>Menu variables". Three kinds of menu variables are available: predefined variables (also called menu time variables), user–defined variables, and system environment variables.

The use of system environment variables is necessary to generate the complete path to the files used in the *Bernese GNSS Software*. The campaign data are located in the directory `${P}/INTRO`=`${HOME}/GPSDATA/CAMPAIGN52/INTRO`. The user–dependent files can be found at `${U}`=`${HOME}/GPSUSER52` — note that `${HOME}` may have been already translated into the name of your home–directory. The temporary user files are saved in `${T}`=`/scratch/local/bern52` (change bern52 to your user name). Finally, the campaign–independent files reside in `${X}`=`/home/bswadmin/BERN52/GPS`.



The predefined variables provide a set of time strings assigned to the current session. From the second panel of the menu variables you get an overview on the available variables and their usage:



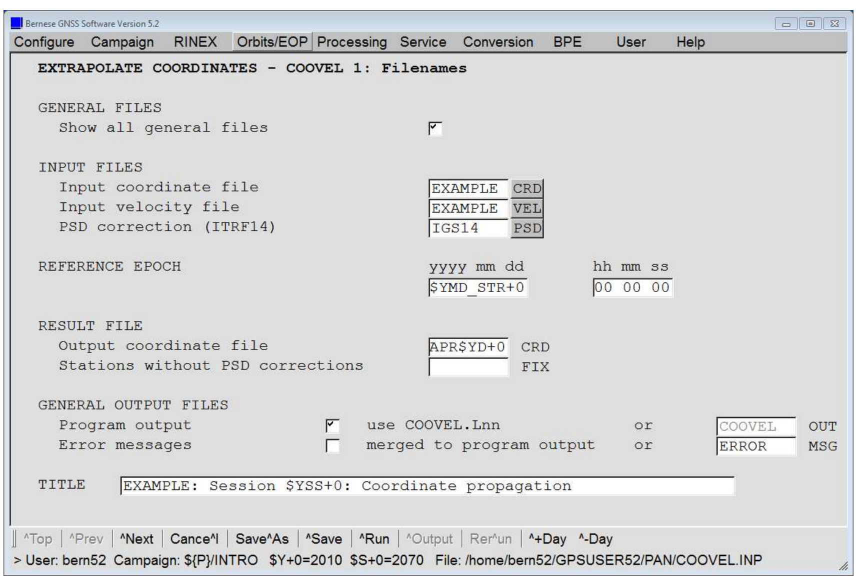
Be aware that the variable `$S+1` refers to the next *session*. Because we are using a session table for daily processing it also corresponds to the next day.

These variables are automatically translated by the menu upon saving the panel or running the program. We recommend to make use of them in the input panels (e.g. for filename specification).

2.5 Generate A Priori Coordinates

As stated before the a priori coordinates generated from the PPP processing example BPE refer to the epoch January 01, 2010 . The first step is to extrapolate the coordinates to the epoch that is currently processed. Starting with ITRF2014 also Post Seismic Deformation (PSD) corrections have to be applied when the epoch of the coordinate sets are changed. They are provided in the input field "PSD corrections (ITRF14)". Of course this feature is also included in the IGS14 frame – the IGS-specific realization of the ITRF2014 . Note that for earlier reference frames (e.g., ITRF2008) this input field has to be empty.

This is the task of the program COOVEL. Open the program input panel in "Menu>Service >Coordinate tools>Extrapolate coordinates":



"Reference epoch: date"	`$YMD_STR+0`	→ 2010 07 26
"Output coordinate file"	`APR$YD+0`	→ `APR10207`
"Title line"	`Session $YSS+0:`	→ `Session 102070:`

Start the program with the `^Run`–button. The program generates an output file `COOVEL.L??` in the directory `${P}/INTRO/OUT`. This file may be browsed using the `^Output`–button or with "Menu>Service>Browse program output". It should look like

```
===============================================================================
Bernese GNSS Software, Version 5.2
-------------------------------------------------------------------------------
Program        : COOVEL
Purpose        : Extrapolate coordinates
-------------------------------------------------------------------------------
Campaign       : ${P}/INTRO
Default session: 2070 year 2010
Date           : 03-Sep-2019 14:42:30
User name      : bern52
===============================================================================


EXAMPLE: Session 102070: Coordinate propagation
-------------------------------------------------------------------------------


INPUT AND OUTPUT FILENAMES
--------------------------

-------------------------------------------------------------------------------
Geodetic datum                 : ${X}/GEN/DATUM.
Input coordinate file          : ${P}/INTRO/STA/EXAMPLE.CRD
Input velocity file            : ${P}/INTRO/STA/EXAMPLE.VEL
Output coordinate file         : ${P}/INTRO/STA/APR10207.CRD
PSD corrections (ITRF14)       : ${P}/INTRO/STA/IGS14.PSD
Stations without PSD corrections:  ---
Program output                 : ${P}/INTRO/OUT/COOVEL.L00
Error message                  : ${U}/WORK/ERROR.MSG
Session table                  : ${P}/INTRO/STA/SESSIONS.SES
-------------------------------------------------------------------------------


REFERENCE EPOCH:         2010-01-01 00:00:00
INTERPOLATION FACTOR:   -0.5639972621492129


-----------------------------------------------------------------
>>> CPU/Real time for pgm "COOVEL": 0:00:00.073 / 0:00:00.072
>>> Program finished successfully
```

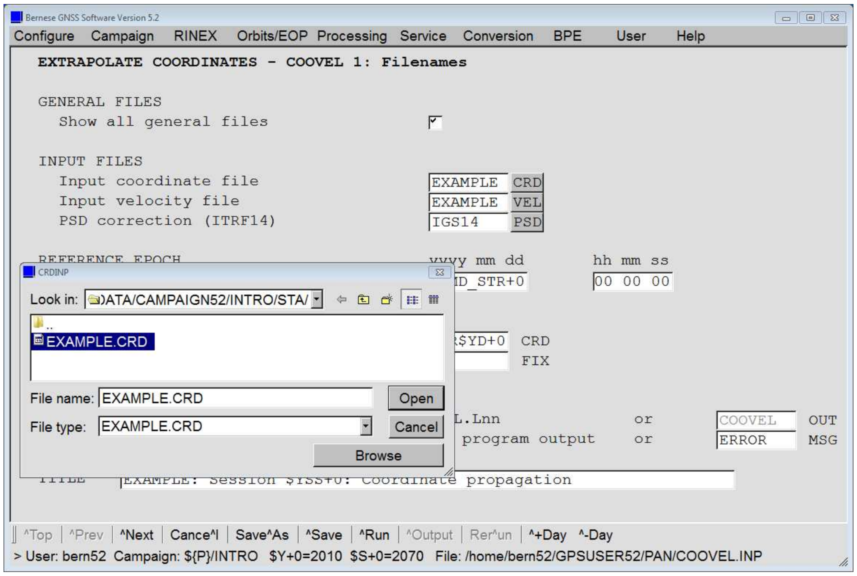
The header area of the program output is standardized for all programs of the *Bernese GNSS Software*, Version 5.2. Furthermore each program has a title line that should characterize the program run. It is printed to the program output and to most of the result files. Many program output files furthermore provide a list of input and output files that have been used or generated.

The last two lines of the above example appear also in each program output of the *Bernese GNSS Software*, Version 5.2. It reports the processing time and the status successful or with error.

The result of the COOVEL run is an a priori coordinate file (`${P}/INTRO/STA/APR10207.CRD`) containing the positions of the sites to be processed for the epoch of the current session (the lines for the other stations are ignored in the processing):

```
EXAMPLE: Session 102070: Coordinate propagation
-------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS14             EPOCH: 2010-07-26 00:00:00

NUM  STATION NAME           X (M)          Y (M)          Z (M)     FLAG

 75  GANP 11515M001    3929181.42149  1455236.82074  4793653.95013    I
 92  HERT 13212M010    4033460.84965    23537.88977  4924318.31452    I
107  JOZ2 12204M002    3664880.48096  1409190.68062  5009618.53020    P
122  LAMA 12209M001    3524522.83273  1329693.71243  5129846.40652    P
136  MATE 12734M008    4641949.45305  1393045.52644  4133287.54704    I
176  ONSA 10402M004    3370658.46071   711877.21784  5349787.00718    I
192  PTBB 14234M001    3844059.87505   709661.40917  5023129.60833    P
236  TLSE 10003M009    4627851.75737   119640.11911  4372993.61061    I
262  WSRT 13506M005    3828735.78447   443305.04516  5064884.77803    I
263  WTZR 14201M010    4075580.45375   931853.89112  4801568.17900    I
264  WTZZ 14201M014    4075579.33655   931853.20686  4801569.08922    P
276  ZIM2 14001M008    4331299.79586   567537.42125  4633133.77671    I
278  ZIMM 14001M004    4331296.98727   567555.97754  4633133.99975    I
```

Have a look at the LOCAL GEODETIC DATUM: in the resulting coordinate file. It is set to IGS14 in this case. If you go back to your input file (e.g., pressing the `Rer^un` button) you may open the dialog to select the "Input coordinate file" by pressing on the button next to the input field. Select now the file `EXAMPLE.CRD` and press the button `Browse` in order to open a window where the selected file is displayed.



Here you can see the LOCAL GEODETIC DATUM: is set to IGS14_0. This difference is the indicator whether the PSD corrections have been applied or not. Coordinate files that indicate that the PSD corrections have not been applied cannot be used for processing GNSS data. At the same time it is protecting you to apply the corrections twice. For that reason the execution of the program COOVEL for applying the PSD corrections is also essential even if none of the stations in your processing (as in our example) is effected by these corrections.

You can repeat all steps for the other three sessions in the example campaign by changing the current session using the `^+Day` or `^-Day` to change a limited number of days (not sessions) or via "Menu>Configure>Set session/compute date". You can then use the `Rer^un` button to restart the program. No options need to be changed because of the consequent use of the menu time variables was made. Even if you are going to process only the first day (207, year 2010) of the example dataset during the terminal sessions, you will need prepared coordinate files for all four days later on Thursday. That's why, this step should be executed for all four days: 207 and 208 of year 2010 as well as 205 and 206 of year 2011.

2.6 Session Goals

At the end of this session, you should have created the following files:

1. *a priori coordinates in your campaign's STA directory: for four sessions* ***APR10207.CRD****,* ***APR10208.CRD****,* ***APR11205.CRD****, and* ***APR11206.CRD***

Until the end of today's terminal session you should start with preparing the pole and orbit information, see Chapter 3.

3 Terminal Session: Pole and Orbit Preparation (Monday/Tuesday)

The terminal session on pole and orbit preparation is to:
1. *generate the pole information file in the Bernese format (POLUPD)*
2. *generate tabular orbit files from CODE precise files (PRETAB)*
3. *generate the Bernese standard orbit files (ORBGEN)*

You should start with these tasks during Monday's terminal sessions and finish the processing during the terminal session on Tuesday.

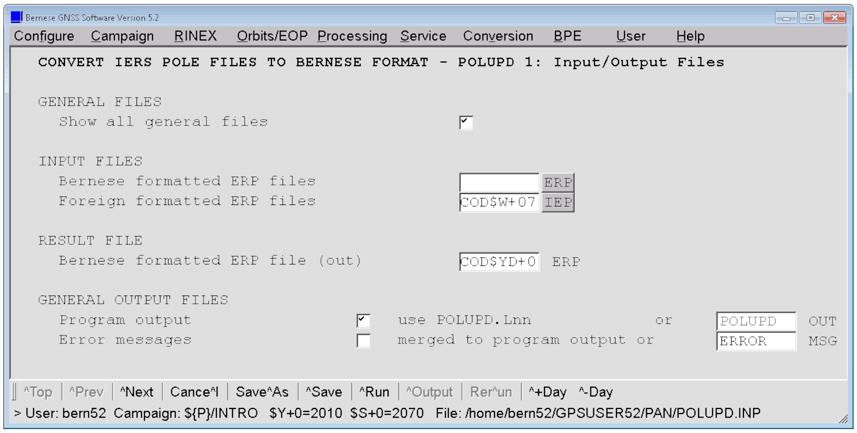
Introductory Remark

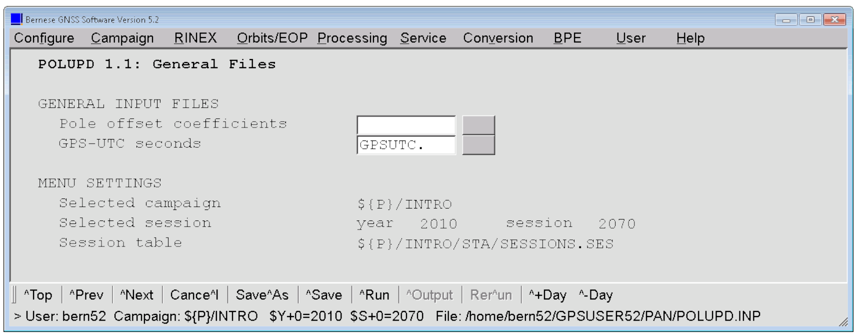
We recommend to use the final or reprocessed products from CODE because they contain consistent orbits for GPS and GLONASS. They also include all active GNSS satellites (even if they are unhealthy or during GPS satellite repositioning events) with the highest possible accuracy thanks to three–day long–arc technology. Due to this choice you will get the best possible consistency between the external products and the software.

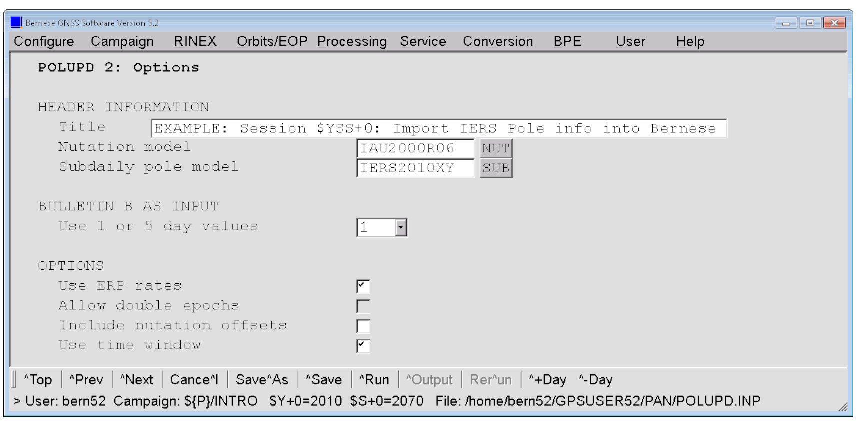
You may alternatively use the products from IGS. Separate product files for GPS and GLONASS orbits exist from independent combination procedures that first need to be merged for a multi–GNSS processing. For most of the applications, merging the precise orbit files is sufficient — a tutorial on the procedure is given in Section 7.2 of this book. On the other hand, the consistency of the orbits can not be as good as that of CODE (or other analysis center) following the strategy of the rigorous combined processing of GPS and GLONASS measurements for orbit determination.

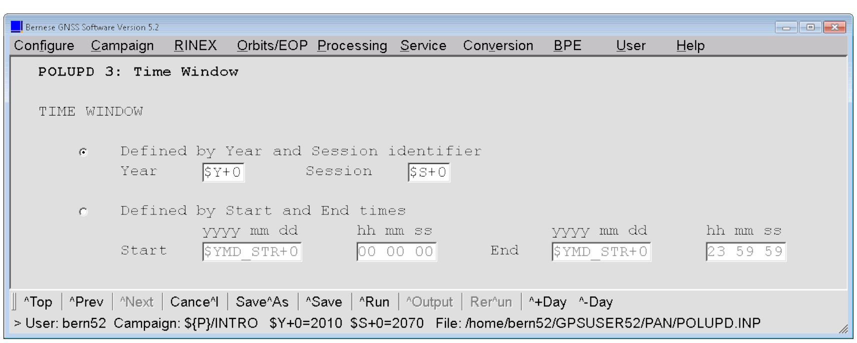
3.1 Prepare Pole Information

Together with the precise orbit files (`PRE`), a consistent set of Earth orientation parameters (`EOP`) is provided in the `ORB` directory. Whereas the orbits are given in daily files the EOP are available in weekly files for the final product series from the CODE analysis center. We have to convert the information from the International Earth Rotation and Reference Systems Service (IERS)/IGS standard format (file extension within the *Bernese GNSS Software* is `IEP`) into the internal Bernese EOP format (file extension within the *Bernese GNSS Software* is `ERP`). This is the task of the program POLUPD ("Menu>Orbits/EOP>Handle EOP files>Convert IERS to Bernese Format") which is also able to update the EOP records of an existing file.


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CONVERT IERS POLE FILES TO BERNESE FORMAT - POLUPD 1: Input/Output Files
GENERAL FILES
Show all general files
INPUT FILES
Bernese formatted ERP files ERP
Foreign formatted ERP files COD$W+07 IEP
RESULT FILE
Bernese formatted ERP file (out) COD$YD+0 ERP
GENERAL OUTPUT FILES
Program output use POLUPD.Lnn or POLUPD OUT
Error messages merged to program output or ERROR MSG
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/POLUPD.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
POLUPD 1.1: General Files
GENERAL INPUT FILES
Pole offset coefficients
GPS-UTC seconds GPSUTC.
MENU SETTINGS
Selected campaign ${P}/INTRO
Selected session year 2010 session 2070
Session table ${P}/INTRO/STA/SESSIONS.SES
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/POLUPD.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
POLUPD 2: Options
HEADER INFORMATION
Title EXAMPLE: Session $YSS+0: Import IERS Pole info into Bernese
Nutation model IAU2000R06 NUT
Subdaily pole model IERS2010XY SUB
BULLETIN B AS INPUT
Use 1 or 5 day values 1
OPTIONS
Use ERP rates
Allow double epochs
Include nutation offsets
Use time window
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/POLUPD.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
POLUPD 3: Time Window
TIME WINDOW
Defined by Year and Session identifier
Year $Y+0 Session $S+0
Defined by Start and End times
yyyy mm dd hh mm ss yyyy mm dd hh mm ss
Start $YMD_STR+0 00 00 00 End $YMD_STR+0 23 59 59
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/POLUPD.INP

The last panel for the program POLUPD is an example for the specification of time windows in the *Bernese GNSS Software*, Version 5.2 . Time windows can be defined by sessions (a single session or a range of sessions). Alternatively, a time window may be specified by a start and an end epoch. By entering either a start or an end epoch you may define only the beginning or the end of the time interval. We refer to the online help for more details.

The messages

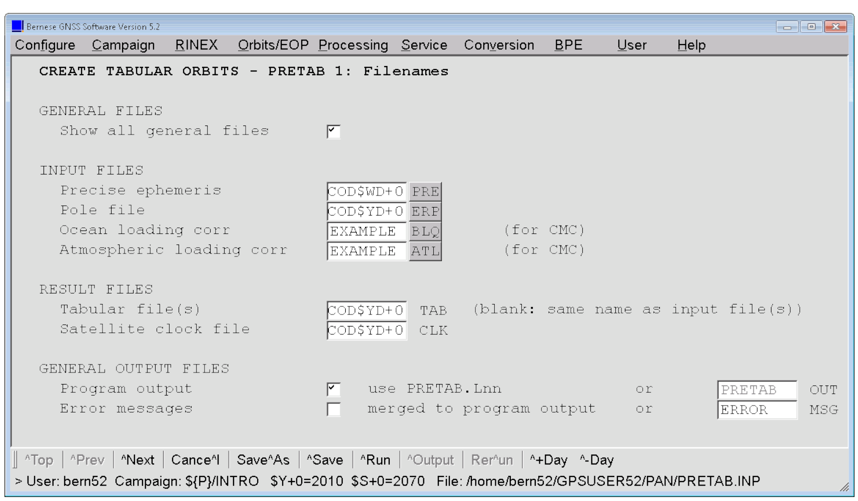
```
### PG POLUPD: NUTATION MODEL NAME NOT EQUAL DEFAULT
              DEFAULT NUTATION MODEL NAME : IAU2000R06
              NUTATION MODEL NAME IN FILE : IAU2000


### PG POLUPD: SUBDAILY POLE MODEL NAME NOT EQUAL DEFAULT
              DEFAULT SUBDAILY POLE MODEL NAME : IERS2010
              SUBDAILY POLE MODEL NAME IN FILE : IERS2000
```

just inform that you have selected the most recent nutation and subdaily pole model whereas the operational solution at CODE was computed using an older model at that time.

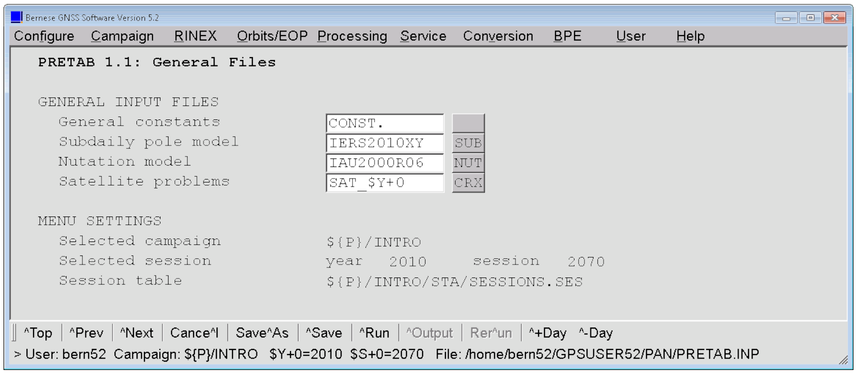
If you do not want to accept this inconsistency you may alternatively use the results from a reprocessing effort (e.g., `http://www.aiub.unibe.ch/download/REPRO_2015/CODE/`).

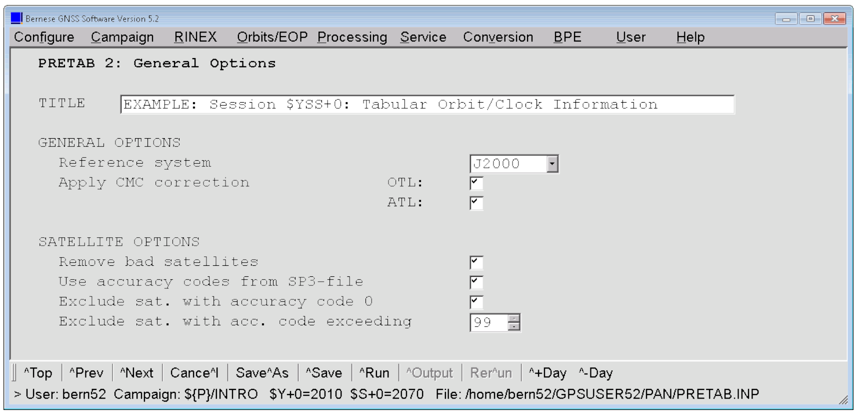
3.2 Generate Orbit Files

In this processing example we use only two programs of the orbit part of the *Bernese GNSS Software*. The first program is called PRETAB and may be accessed using "Menu >Orbits/EOP>Create tabular orbits". The main task of PRETAB is to create tabular orbit files (`TAB`; i.e., to transform the precise orbits from the terrestrial into the celestial reference frame) and to generate a satellite clock file (`CLK`). The clock file will be needed, e.g., in program CODSPP (see Section 4.2.1, to be discussed in the Tuesday's lectures on pre-processing).

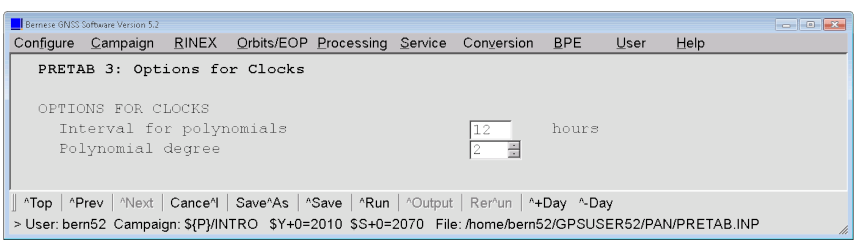


You have to apply the same subdaily pole and nutation models as you have used before when you have generated the Bernese formatted pole file (`COD$YD+0.ERP`).





If you process precise orbits from CODE it is generally not necessary to remove bad satellites. It might become necessary for orbit products from other sources (e.g., from the IGS). Because CODE introduces the correct accuracy code for all its satellites the above settings do not harm the import of satellite orbits from CODE.



Panel "PRETAB 3: Options for Clocks" contains the options for extracting the satellite clock information. The clock values in the precise orbit file are sampled to 15 min. We interpolate with a "Polynomial degree" of 2 with an "Interval for polynomials" of 12 hours. This is good enough for the receiver clock synchronization in CODSPP.

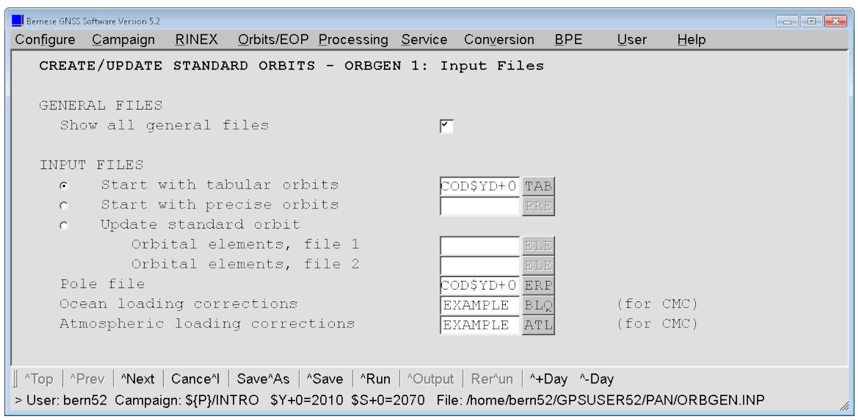
A message like this is expected:

```
### PG PRETAB: SATELLITE CLOCK VALUES MISSING
               SATELLITE  :  101
               FILE NUMBER:    1
               FILE NAME  : ${P}/INTRO/ORB/COD15941.PRE
```

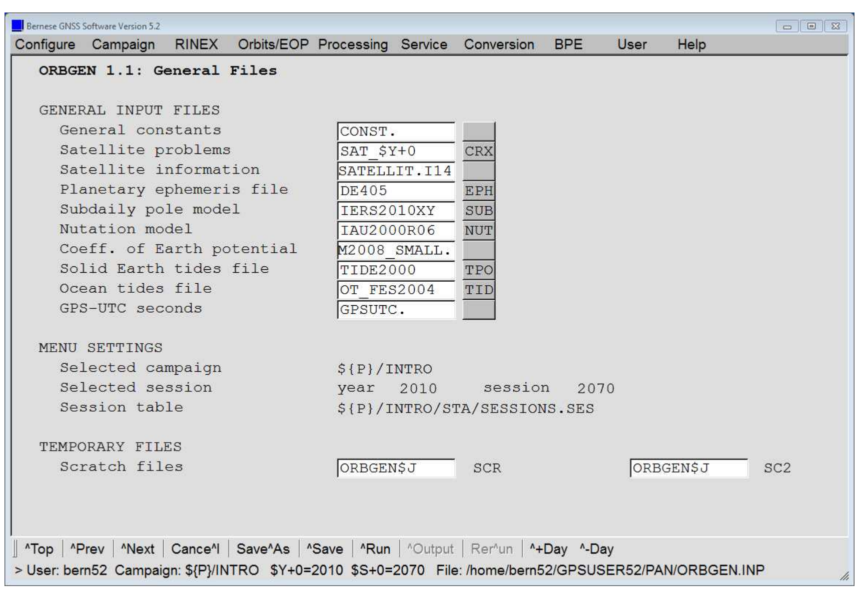
```
### PG PRETAB: SATELLITE CLOCK VALUES MISSING
               SATELLITE  :  102
               FILE NUMBER:    1
               FILE NAME  : ${P}/INTRO/ORB/COD15941.PRE

...
```

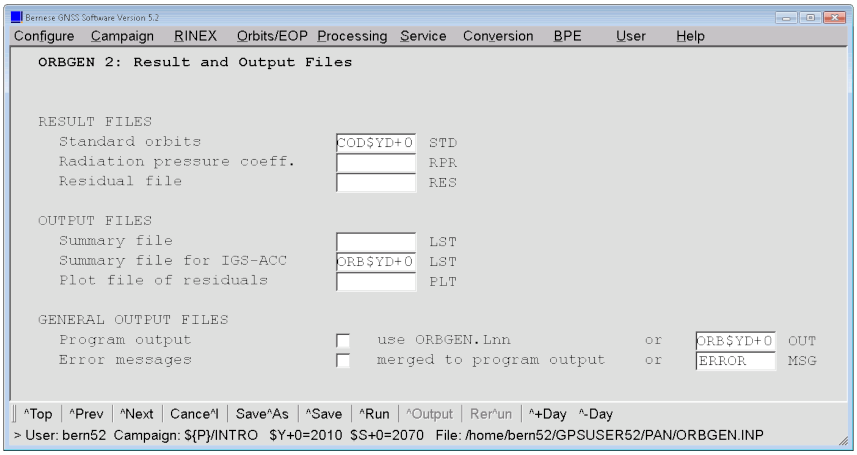
It indicates that the precise orbit files do not contain clock corrections for GLONASS satellites (GLONASS satellite are indicated with satellite number between 100 and 199 within the *Bernese GNSS Software*). Consequently the synchronization of the receiver clocks in CODSPP will only be done based on the GPS satellite clocks.

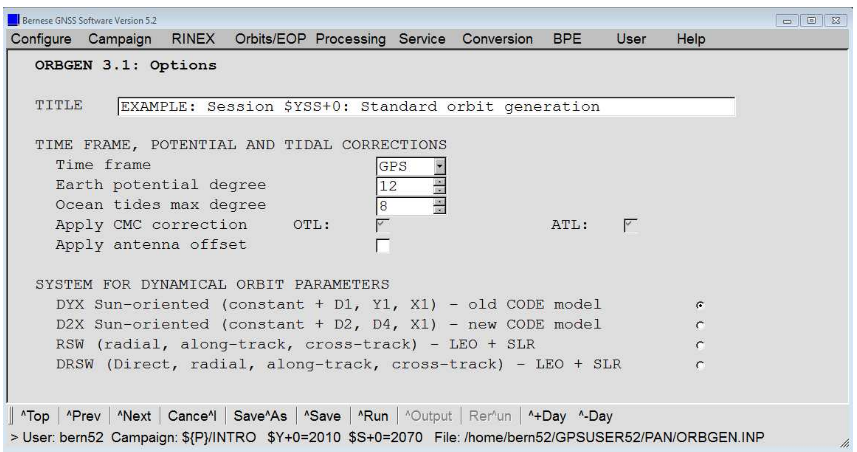
The second program of the orbit part used here is called ORBGEN ("Menu>Orbits/EOP >Create/update standard orbits"). It prepares the so–called standard orbits using the satellite positions in the tabular orbit files as pseudo–observations for a least–squares adjustment.



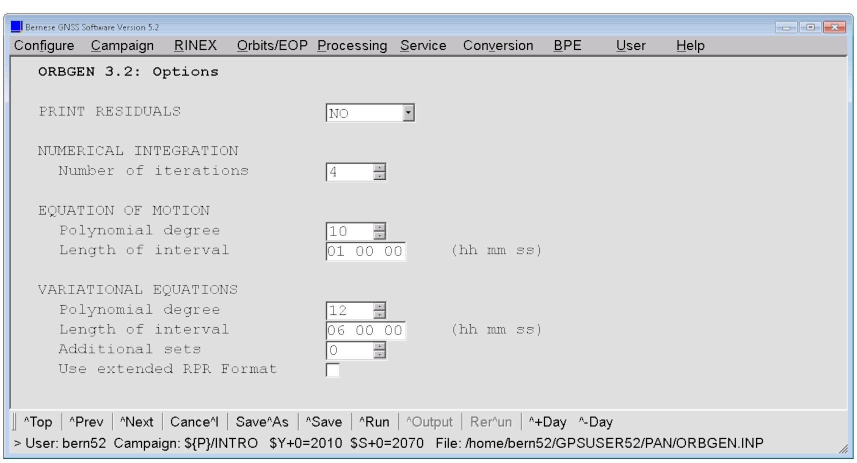
Make sure that the ERP file, the nutation, and the subdaily pole model are the same you have used in PRETAB. It is mandatory to consistently use this triplet of files together with the generated standard orbits for all processing programs (otherwise a warning message is issued).

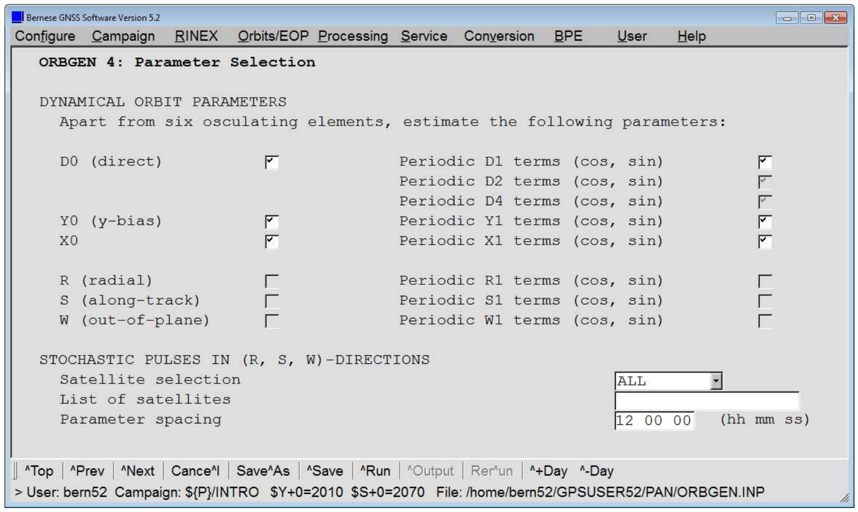


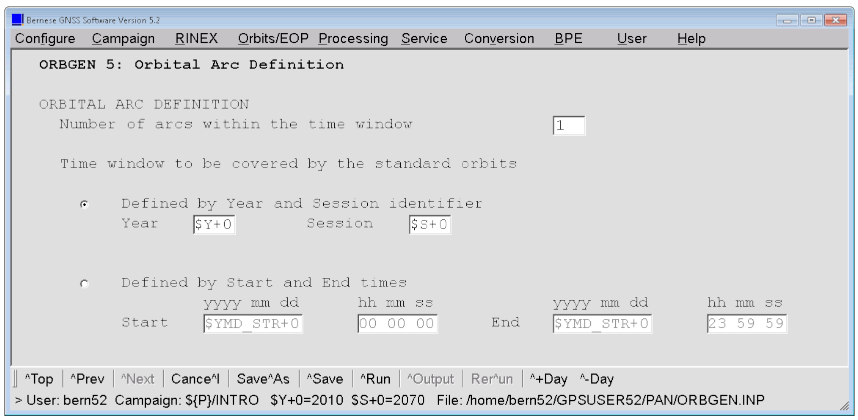




With the beginning of GPS week 1826 (January 4, 2015), the CODE analysis center introduced a new Empirical CODE Orbit Model (new ECOM). Therefore, when using orbits from CODE after January 4, 2015 (or from the CODE's most recent reprocessing effort) you have to choose the new model when importing the orbit files in ORBGEN. This is done by changing the option SYSTEM FOR DYNAMICAL ORBIT PARAMETERS from "System DYX" to "System D2X" in panel 3.1.




Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ORBGEN 4: Parameter Selection
DYNAMICAL ORBIT PARAMETERS
Apart from six osculating elements, estimate the following parameters:
D0 (direct)
Periodic D1 terms (cos, sin)
Periodic D2 terms (cos, sin)
Periodic D4 terms (cos, sin)
Y0 (y-bias)
Periodic Y1 terms (cos, sin)
X0
Periodic X1 terms (cos, sin)
R (radial)
Periodic R1 terms (cos, sin)
S (along-track)
Periodic S1 terms (cos, sin)
W (out-of-plane)
Periodic W1 terms (cos, sin)
STOCHASTIC PULSES IN (R, S, W)-DIRECTIONS
Satellite selection
ALL
List of satellites
Parameter spacing
12 00 00
(hh mm ss)
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/ORBGEN.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ORBGEN 5: Orbital Arc Definition
ORBITAL ARC DEFINITION
Number of arcs within the time window
1
Time window to be covered by the standard orbits
Defined by Year and Session identifier
Year
$Y+0
Session
$S+0
Defined by Start and End times
yyyy mm dd
hh mm ss
Start
$YMD_STR+0
00 00 00
End
$YMD_STR+0
23 59 59
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/ORBGEN.INP

The program produces an output file `ORB10207.OUT` (or corresponding to the other sessions) which should look like

```
...
INPUT AND OUTPUT FILENAMES
--------------------------

-------------------------------------------------------------------------------
General constants               : ${X}/GEN/CONST.
Correction GPS-UTC              : ${X}/GEN/GPSUTC.
Planetary ephemeris file        : ${X}/GEN/DE405.EPH
Coeff. of Earth potential       : ${X}/GEN/EGM2008_SMALL.
Solid Earth tides file          : ${X}/GEN/TIDE2000.TPO
Ocean tides file                : ${X}/GEN/OT_FES2004.TID
Satellite problems              : ${X}/GEN/SAT_2010.CRX
Satellite information           : ${X}/GEN/SATELLIT.I14
Nutation model                  : ${X}/GEN/IAU2000R06.NUT
Subdaily pole model             : ${X}/GEN/IERS2010XY.SUB
Pole file                       : ${P}/INTRO/ORB/COD10207.ERP
Ocean loading corrections       : ${P}/INTRO/STA/EXAMPLE.BLQ
Atmospheric loading corrections : ${P}/INTRO/STA/EXAMPLE.ATL
Orbital elements, file 1        :  ---
Orbital elements, file 2        :  ---
Standard orbits                 : ${P}/INTRO/ORB/COD10207.STD
Radiation pressure coeff.       :  ---
Summary file                    :  ---
Summary file for IGS-ACC        : ${P}/INTRO/OUT/ORB10207.LST
Residual plot file              :  ---
Residual file                   :  ---
Program output                  : ${P}/INTRO/OUT/ORB10207.OUT
Error message                   : ${U}/WORK/ERROR.MSG
Scratch file                    : ${U}/WORK/ORBGEN.SCR
Scratch file                    : ${U}/WORK/ORBGEN.SC2
Session table                   : ${P}/INTRO/STA/SESSIONS.SES
-------------------------------------------------------------------------------

...
```

```
...
-------------------------------------------------------------------------------
RMS ERRORS AND MAX. RESIDUALS   ARC NUMBER:  1                    ITERATION:  4
-------------------------------------------------------------------------------

                          QUADRATIC MEAN OF O-C (M)         MAX. RESIDUALS (M)
SAT   #POS   RMS (M)     TOTAL   RADIAL  ALONG   OUT       RADIAL  ALONG   OUT
---   ----   -------     ---------------------------       --------------------

  1     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
  2     96    0.001      0.001    0.001  0.001  0.001       0.002  0.002  0.002
  3     96    0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.002
  4     96    0.001      0.001    0.001  0.001  0.001       0.001  0.003  0.002
  5     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.003
  6     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
  7     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.003
  8     96    0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.003
  9     96    0.001      0.001    0.001  0.001  0.001       0.002  0.004  0.002
 10     96    0.001      0.001    0.001  0.001  0.001       0.001  0.002  0.002
 11     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
 12     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
 13     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
...
 28     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
 29     96    0.001      0.001    0.001  0.001  0.001       0.002  0.002  0.001
 30     96    0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.002
 31     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
 32     96    0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.002
101     96    0.001      0.001    0.001  0.001  0.001       0.002  0.002  0.002
102     96    0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.003
103     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
104     96    0.001      0.001    0.001  0.001  0.001       0.001  0.003  0.003
105     96    0.001      0.001    0.001  0.001  0.001       0.001  0.003  0.002
107     96    0.001      0.001    0.001  0.001  0.001       0.002  0.002  0.002
...
121     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
122     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002
123     96    0.001      0.001    0.001  0.001  0.001       0.002  0.002  0.002
124     96    0.001      0.001    0.001  0.001  0.001       0.002  0.003  0.002

-------------------------------------------------------------------------------
...
```

The most important information in the output file are the RMS errors for each satellite. These should be 1 mm (for older orbits it may also achieve 3...5 mm) if precise orbits from CODE were used together with the consistent EOP information (the actual RMS errors depend on the quality of the precise orbits, on the pole file used for the transformation between IERS Terrestrial Reference Frame (ITRF) and International Celestial Reference Frame (ICRF) in PRETAB, and on the orbit model used in ORBGEN).

Comparing the RMS error from the third and the fourth iteration you will see that three iterations should already be enough to produce precise standard orbits for GNSS satellites.

The file `${P}/INTRO/OUT/ORB10207.LST` summarizes the orbit fit RMS values in one table:

```
EXAMPLE: Session 102070: Standard orbit generation            12-JAN-18 12:59
TIME FROM DAY : 1 GPS WEEK: 1594
     TO   DAY : 2 GPS WEEK: 1594
-------------------------------------------------------------------------------
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:   5 E /   0 M (  0 EM)
----------------------------- ... --------------------- ... --------------------------- ...
ECL  ..  ..  ..  ..  ..  ..          ..  E.  E.  E.  ..          ..  ..  ..  ..  ..  ..  ..
DOY   1   2   3   4   5   6   ...   12  13  14  15  16   ...   32 101 102 103 104 105 107 ...
----------------------------- ... --------------------- ... --------------------------- ...
207   1   1   1   1   1   1   ...    1   1   1   1   1   ...    1   1   1   1   1   1   1 ...
----------------------------- ... --------------------- ... --------------------------- ...
ALL   1   1   1   1   1   1   ...    1   1   1   1   1   ...    1   1   1   1   1   1   1 ...
----------------------------- ... --------------------- ... --------------------------- ...
```

The output shows that 5 satellites are in eclipse (indicated above the satellite number by E for Earth or M for Moon).

A similar file may be generated using the orbit products from IGS (including the EOP information) following the procedure described in Section 7.2 . As you can notice the RMS errors are slightly higher. It does not mean that the orbits from CODE are better than the IGS orbits. The orbit model in ORBGEN is only more consistent with the orbit model used at CODE:

```
EXAMPLE: Session 102070: Standard orbit generation            12-JAN-18 13:32
TIME FROM DAY : 1 GPS WEEK: 1594
     TO   DAY : 2 GPS WEEK: 1594
-------------------------------------------------------------------------------
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:   5 E /   0 M (  0 EM)
-----------------------------------------------------------------
ECL  ..  ..  ..  ..  ..  ..          ..  E.  E.  E.  ..          ..
DOY   1   2   3   4   5   6   ...   12  13  14  15  16   ...   32
-----------------------------------------------------------------
207   2   2   4   1   2   3   ...    3   3   3   2   3   ...    2
-----------------------------------------------------------------
ALL   2   2   4   1   2   3   ...    3   3   3   2   3   ...    2
-----------------------------------------------------------------
```

(Note the missing GLONASS satellites in the IGS orbit product.)

In the example for day 208 of year 2010 a satellite 75 appears. The GPS–satellite 25 had a repositioning event at 2010–07–27 16:08:03 (see `${X}/GEN/SAT_2010.CRX`). The satellite is introduced in the processing with two independent arcs: one before (number 25) and one after (number 75) the event (you may verify this by the number of epochs available for each of these two satellite arcs).

3.3 Session Goals

At the end of this session, you should have created the following files:

1. *Bernese pole file in the campaign's ORB directory:* `COD10207.ERP`,
2. *Bernese standard orbit file in the ORB directory:* `COD10207.STD`,
3. *Bernese satellite clock file in the ORB directory:* `COD10207.CLK`.

4 Terminal Session: Tuesday

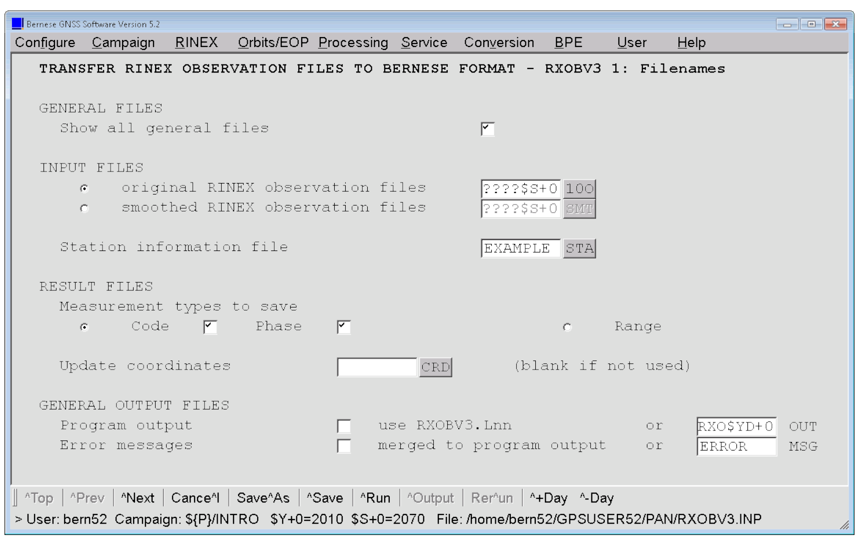
Today's terminal session is to:

1. *import the observations from the RINEX format into the Bernese format using RXOBV3 (section 4.1).*
2. *preprocess the Bernese observation files:*
   - *receiver clock synchronization (CODSPP, section 4.2.1)*
   - *baseline generation (SNGDIF, section 4.2.2)*
   - *preprocess baselines (MAUPRP, section 4.2.3)*

4.1 Importing the Observations

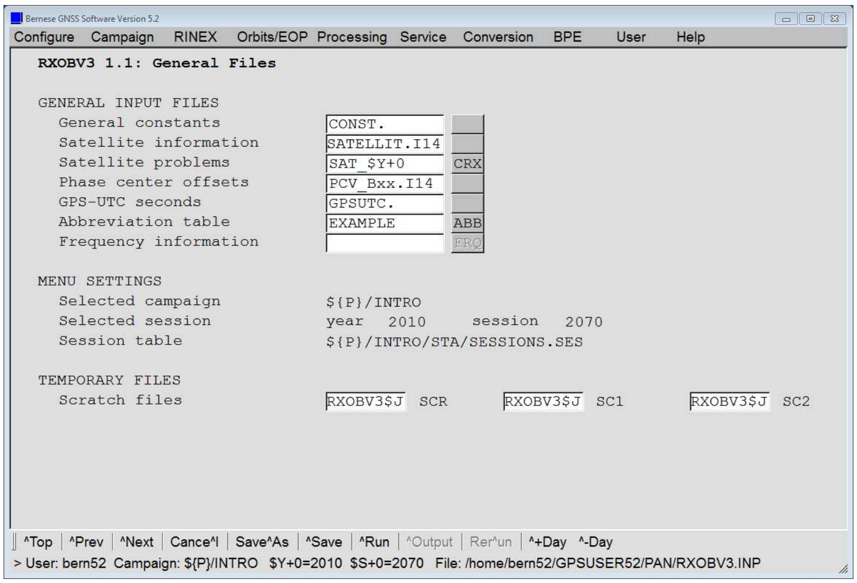
The campaign has been set up and all necessary files are available. The first part of processing consists of the transfer of the observations from RINEX to Bernese (binary) format. To get an overview of the data availability you may generate a pseudographic from the RINEX observation files using the program RNXGRA in "Menu>RINEX>RINEX utilities>Create observation statistics" — this step is not mandatory but it may be useful to get an impression of the tracking performance of the stations before you start the analysis.

Importing the RINEX observation files is the task of the program RXOBV3 in "Menu>RINEX >Import RINEX to Bernese format>Observation files" (we do not use the RINEX navigation files for this processing example).

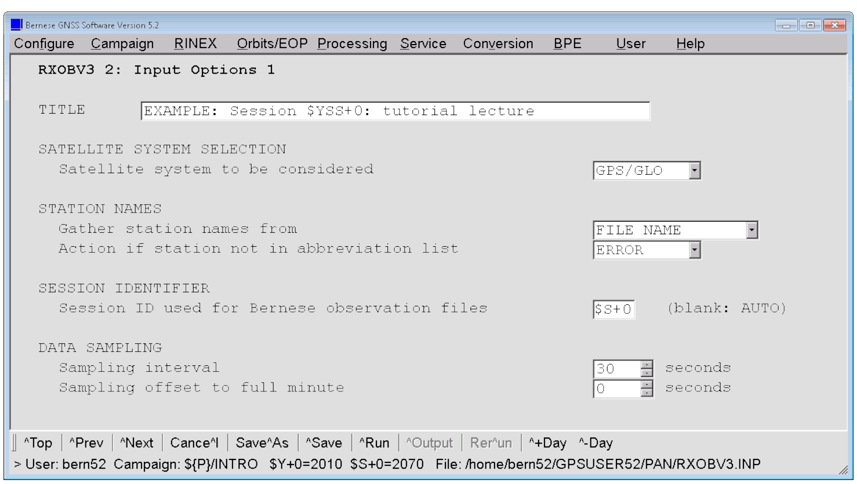


All RINEX observation files fitting the pattern `${P}/INTRO/RAW/????2070.10O` are selected automatically by the current entry in the input field "original RINEX observation files". You can verify this by pressing the button just right from this input field (labeled with the file extension 100). In the file selection dialog you will find the list of currently selected files. The RINEX files of the year 2011 are shown if a current session from the year 2011 is selected. In that case the label of the button changes to 110.

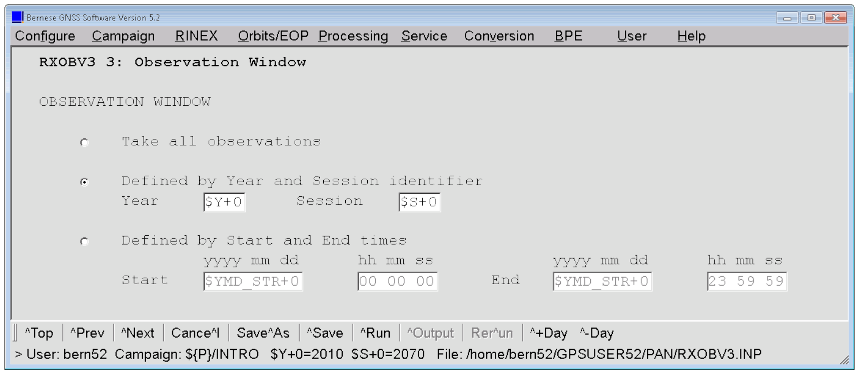
The next panel specifies the general input files. For the tutorial session during the course the phase center offset file has to be changed to a user-specific file (replace the "xx" chars with your user number, e.g.: PCV_Bxx.I14 to PCVB01.I14). Be aware that the file PCV_Bxx.I14 is not part of the distribution. If you are running the tutorial campaign on your own machine you have to use either the PCV.I14 or create a copy of the original file.

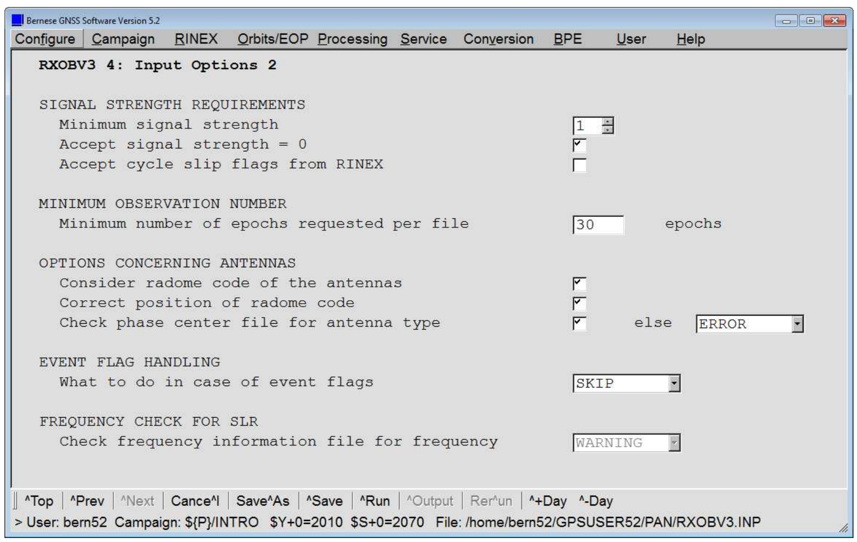


There are three further panels defining the input options for RXOBV3. They allow to select the data to be imported and to specify a few parameters for the Bernese observation header files.

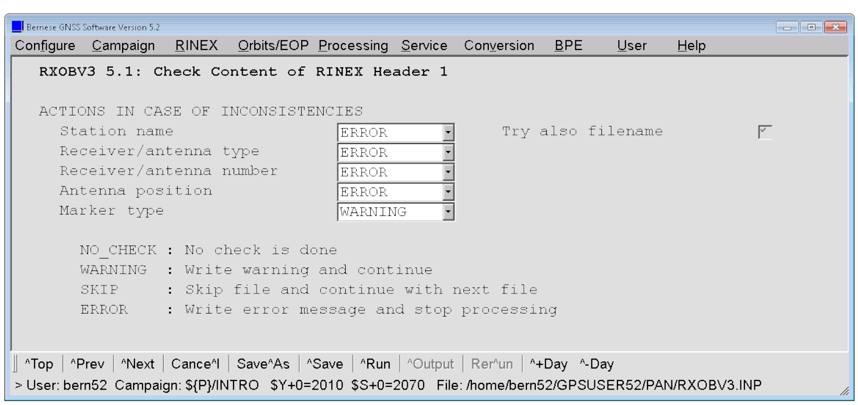


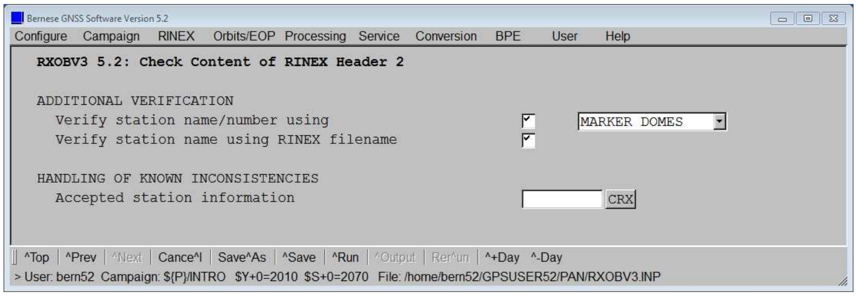
We select GPS/GLO for the option "Satellite system to be considered" to exclude observations from GNSS where no orbits are available.





The next two panels are only displayed, if you specified a station information file in "RXOBV3 1: Filenames". They allow you to configure the RINEX header information verification:





Start the program with the `^Run`–button.

A warning message may appear to inform you that the observations for the GLONASS satellite R09 (satellite system `R` for GLONASS in RINEX whereas satellite numbers between 100 and 199 are in use within the *Bernese GNSS Software*) are removed because of an entry in the "Satellite problems" file provided in panel "RXOBV3 1.1: General Files".

```
### SR SAVMEA: PROBLEM FOR SATELLITE:  109
              INDICATED IN SATCRUX : ${X}/GEN/SAT_2010.CRX
              PROBLEM              : BAD PHASE+CODE
              REQUESTED ACTION     : OBS. REMOVED
              TIME WINDOW          : 2008-05-14 00:00:00  2010-09-30 23:59:59
              IN RINEX FILE        : ${P}/INTRO/RAW/GANP2070.100
```

Messages from SR R2RDOH: TOO MANY COMMENT LINES may appear for some RINEX files but they are not critical.

The program produces an output file `RXO10207.OUT` in the directory `${P}/INTRO/OUT` (resp. corresponding filenames for the other sessions). This file may be browsed using the `^Output` button or with "Menu>Service>Browse program output". After echoing the input options, the file provides an overview of the station information records in the RINEX observation file header and the values that are used for the processing in the *Bernese GNSS Software*. In addition some observation statistics are available. In the last section you may check the completeness of the Bernese observation files by the available number of epochs:

```
...
 TABLE OF INPUT AND OUTPUT FILE NAMES:
 ------------------------------------
                                                                                  #satell.
 Num  Rinex file name                      Bernese code  header  file name   #epo  ... GPS  GLO
                                           Bernese code  observ. file name
                                           Bernese phase header  file name   #epo  ... GPS  GLO
                                           Bernese phase observ. file name
 ---------------------------------------------------------------------------------------------

   1  ${P}/INTRO/RAW/GANP2070.100          ${P}/INTRO/OBS/GANP2070.CZH       2880  ...  30   20
                                           ${P}/INTRO/OBS/GANP2070.CZO
                                           ${P}/INTRO/OBS/GANP2070.PZH       2880  ...  30   20
                                           ${P}/INTRO/OBS/GANP2070.PZO

   2  ${P}/INTRO/RAW/HERT2070.100          ${P}/INTRO/OBS/HERT2070.CZH       2880  ...  31   20
                                           ${P}/INTRO/OBS/HERT2070.CZO
                                           ${P}/INTRO/OBS/HERT2070.PZH       2880  ...  31   20
                                           ${P}/INTRO/OBS/HERT2070.PZO

   3  ${P}/INTRO/RAW/JOZ22070.100          ${P}/INTRO/OBS/JOZ22070.CZH       2880  ...  30   20
                                           ${P}/INTRO/OBS/JOZ22070.CZO
                                           ${P}/INTRO/OBS/JOZ22070.PZH       2880  ...  30   20
                                           ${P}/INTRO/OBS/JOZ22070.PZO

 ...
```

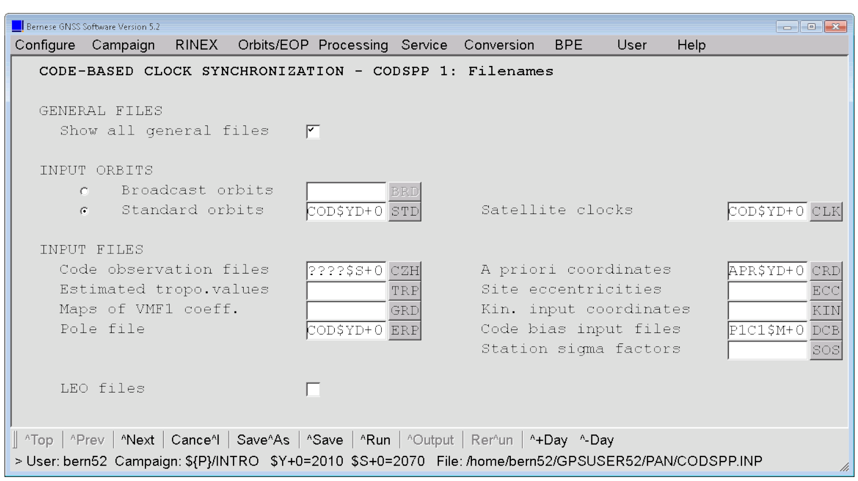
```
  11  ${P}/INTRO/RAW/WTZZ2070.10O      ${P}/INTRO/OBS/WTZZ2070.CZH      2880  ...  32   20
                                       ${P}/INTRO/OBS/WTZZ2070.CZO
                                       ${P}/INTRO/OBS/WTZZ2070.PZH      2880  ...  32   20
                                       ${P}/INTRO/OBS/WTZZ2070.PZO

  12  ${P}/INTRO/RAW/ZIM22070.10O      ${P}/INTRO/OBS/ZIM22070.CZH      2879  ...  32   20
                                       ${P}/INTRO/OBS/ZIM22070.CZO
                                       ${P}/INTRO/OBS/ZIM22070.PZH      2879  ...  32   20
                                       ${P}/INTRO/OBS/ZIM22070.PZO

  13  ${P}/INTRO/RAW/ZIMM2070.10O      ${P}/INTRO/OBS/ZIMM2070.CZH      2879  ...  31    0
                                       ${P}/INTRO/OBS/ZIMM2070.CZO
                                       ${P}/INTRO/OBS/ZIMM2070.PZH      2879  ...  31    0
                                       ${P}/INTRO/OBS/ZIMM2070.PZO


-----------------------------------------------------------------
>>> CPU/Real time for pgm "RXOBV3": 0:00:14.767 / 0:00:14.791
>>> Program finished successfully
```

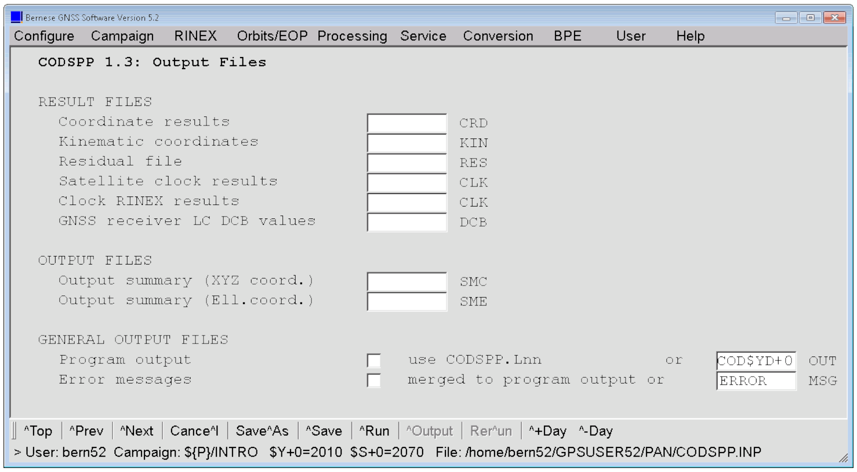
If epochs or satellites are missing for some RINEX files you may check this with the RINEX observation graphic from program RNXGRA ("Menu>RINEX>RINEX utilities>Create observation statistics"). In July 2010 32 GPS and 20 GLONASS satellites were active, where one of the GPS satellites (PRN 01) was unhealthy. For that reason many of the stations did track only 31 out of 32 GPS satellites.

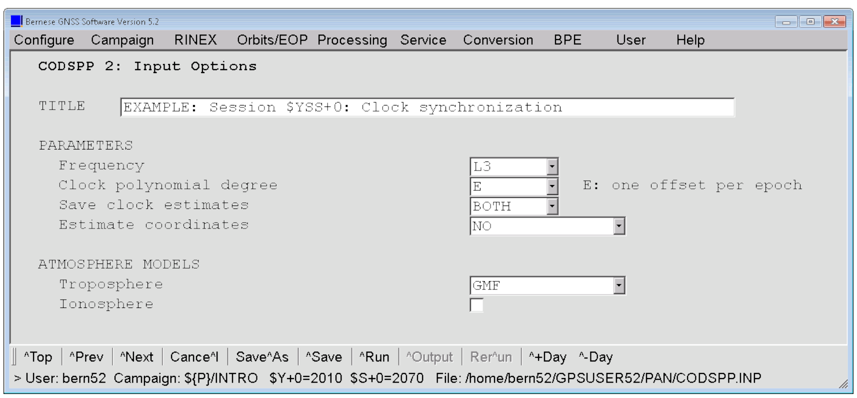
4.2 Data Preprocessing (I)

4.2.1 Receiver Clock Synchronization

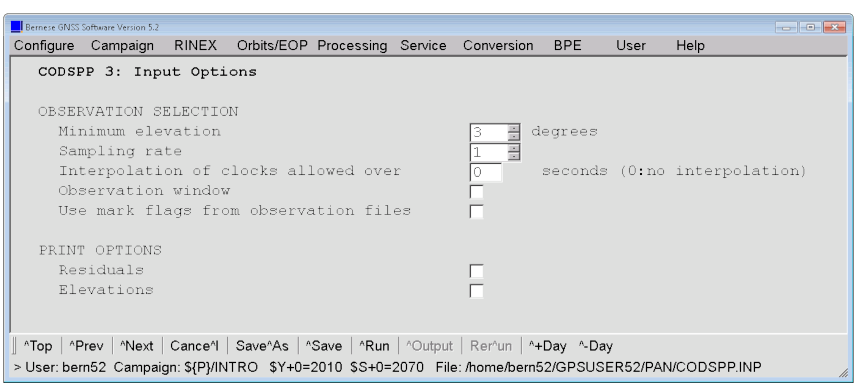
Now we are ready to invoke the processing part of the *Bernese GNSS Software*. We have to run three programs for this example. The first program is called CODSPP ("Menu >Processing>Code-based clock synchronization"). Its main task is to compute the receiver clock corrections.

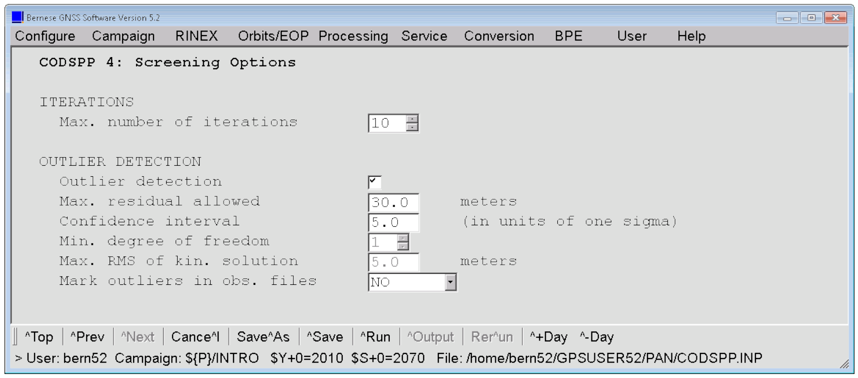






We already have geocentric coordinates of good quality available for the sites from the PPP example BPE. Therefore, the option "Estimate coordinates" may be set to NO. The most important option for this CODSPP run is "Save clock estimates". It has to be set to BOTH.





The warning messages issued by the program CODSPP remind that only GPS satellite clock corrections have been extracted from the precise orbit files. Consequently, the receiver clocks are synchronized with respect to the GPS system time.

CODSPP produces the following output:

```
...
STATION:  GANP 11515M001   FILE:  ${P}/INTRO/OBS/GANP2070.CZO      RECEIVER UNIT:    999999
-------------------------------------------------------------------------------------------


DAY OF YEAR          :   207

                                     FROM                          TO
OBSERVATIONS         :       2010-07-26  00:00: 0.00       2010-07-26  23:59:30.00
REQUESTED WINDOW     :                  --                            --

MEASUREMENT INTERVAL:   30 SEC
SAMPLING RATE        :    1
PROCESSED FREQUENCY :   L3
ELEVATION LIMIT      :    3 DEG

                              TROPOSPHERE                IONOSPHERE
ATMOSPHERE MODELS    :           GMF                        NONE


STATISTICS FOR GPS     SATELLITES:
----------------------------------

SATELLITE NUMBER     :     2     3     4     5     6     7     8     9    10    11 ... TOTAL
OBSERVATIONS IN FILE:  1015   910  1019  1029   838   914   841   832   971   857 ... 27074
USED OBSERVATIONS    :  1015   910  1019  1029   838   914   841   832   971   857 ... 27074
BAD OBSERVATIONS (%):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0 ...   0.0
RMS ERROR (M)        :   0.9   1.1   0.9   1.0   1.0   1.0   1.0   1.2   1.2   0.9 ...   1.0


STATISTICS FOR GLONASS SATELLITES:
----------------------------------

SATELLITE NUMBER     :   101   102   103   104   105   107   108   110   111   113 ... TOTAL
OBSERVATIONS IN FILE:   905   932   935   929  1149  1097   905  1005   991   903 ... 19977
USED OBSERVATIONS    :     0     0     0     0     0     0     0     0     0     0 ...     0
BAD OBSERVATIONS (%):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0 ...   0.0
RMS ERROR (M)        :   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0 ...   0.0


RESULTS:
--------

OBSERVATIONS IN FILE:      47051
USED OBSERVATIONS    :      27074
BAD OBSERVATIONS     :          0.00 %
RMS OF UNIT WEIGHT   :          1.07 M
NUMBER OF ITERATIONS:          2
...
```

You see in this statistic that the GLONASS measurements have not been used (because of the missing GLONASS satellite clock corrections).

```
 ...
STATION COORDINATES:
 --------------------

 LOCAL GEODETIC DATUM:  IGS14

                                  A PRIORI         NEW           NEW- A PRIORI   RMS ERROR
  GANP 11515M001    X             3929181.42      3929181.42           0.00         0.00
  (MARKER)          Y             1455236.82      1455236.82           0.00         0.00
                    Z             4793653.95      4793653.95           0.00         0.00

                    HEIGHT            746.01          746.01           0.00         0.00
                    LATITUDE      49  2  4.971    49  2  4.971     0  0  0.000      0.0000
                    LONGITUDE     20 19 22.574    20 19 22.574     0  0  0.000      0.0000


 CLOCK PARAMETERS:
 -----------------

 OFFSET FOR REFERENCE EPOCH:               -0.000000021  SEC


 GPS/GLONASS SYSTEM DIFFERENCE:  OFFSET    :       0.00 NSEC
                                 RMS ERROR :       0.00 NSEC


 CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES
 ...
```

```
 ...
 *******************************************************************************
 SUMMARY OF BAD OBSERVATIONS
 *******************************************************************************

 MAXIMUM RESIDUAL DIFFERENCE ALLOWED  :     30.00 M
 CONFIDENCE INTERVAL OF F*SIGMA WITH F:      5.00

 NUMBER OF BAD OBSERVATION PIECES     :         3

 NUMB FIL  STATION           TYP SAT       FROM                TO          #EPO
 -------------------------------------------------------------------------------

    1   8  TLSE 10003M009    OUT   1  10-07-26 15:10:00  10-07-26 15:28:30    38
    2   8  TLSE 10003M009    OUT   1  10-07-26 15:32:30  10-07-26 15:33:00     2

    3  12  ZIM2 14001M008    OUT  26  10-07-26 20:08:30  10-07-26 20:08:30     1

 -------------------------------------------------------------------------------




 *******************************************************************************
 GLONASS/GPS TIME OFFSETS
 *******************************************************************************

 FILE  STATION NAME       TIME OFFSET (NS)    RMS ERROR (NS)
 -----------------------------------------------------------

   1   GANP 11515M001     NO RESULTS AVAILABLE
   2   HERT 13212M010     NO RESULTS AVAILABLE
   3   JOZ2 12204M002     NO RESULTS AVAILABLE
   4   LAMA 12209M001     NO RESULTS AVAILABLE
   5   MATE 12734M008     NO RESULTS AVAILABLE
   6   ONSA 10402M004     NO RESULTS AVAILABLE
   7   PTBB 14234M001     NO RESULTS AVAILABLE
   8   TLSE 10003M009     NO RESULTS AVAILABLE
   9   WSRT 13506M005     NO RESULTS AVAILABLE
  10   WTZR 14201M010     NO RESULTS AVAILABLE
  11   WTZZ 14201M014     NO RESULTS AVAILABLE
  12   ZIM2 14001M008     NO RESULTS AVAILABLE
  13   ZIMM 14001M004     NO RESULTS AVAILABLE

 -----------------------------------------------------------

   0   TOTAL                          0.000            0.000
 -----------------------------------------------------------
```

The most important message in the output file is CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES. This indicates that the receiver clock corrections computed by CODSPP are stored in code and phase observation files. After this step we will no longer use the code observations in this example.

The a posteriori RMS error (for each zero difference file processed) should be checked in the CODSPP output file. A value of about 20–30 m is normal if Selective Availability (SA) — artificial degradation of the satellite clock accuracy — is on (before May 2000). Without SA a value of about 3 m is expected if P–code measurements are available (this is the case for the time interval of the processing example). However, much worse code measurements would still be sufficiently accurate to compute the receiver clock corrections with the necessary accuracy of 1 μs .

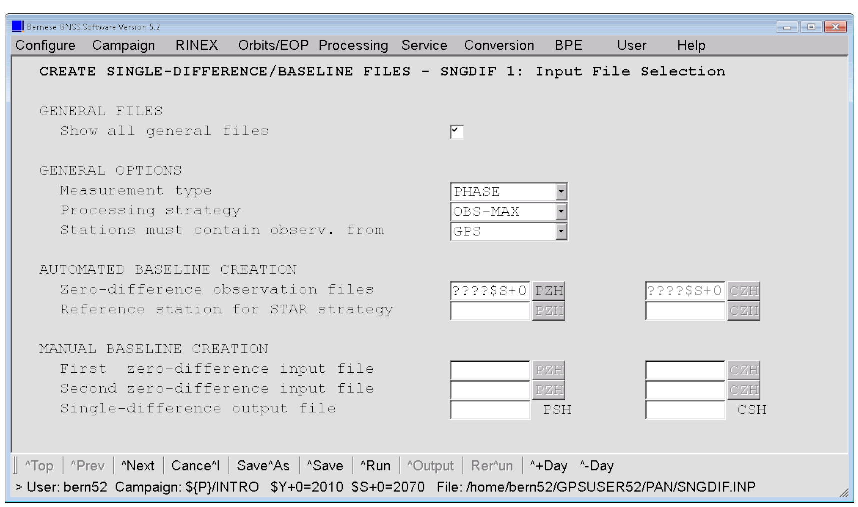
In the section GLONASS/GPS TIME OFFSETS you may only find the inter–system bias (ISB) for each of the receivers as they have been estimated by CODSPP if both, GPS and GLONASS satellite clock corrections were introduced.

You may use the extraction program CODXTR ("Menu>Processing>Program output extraction>Code-based clock synchronization") to generate a short summary from the CODSPP program output:

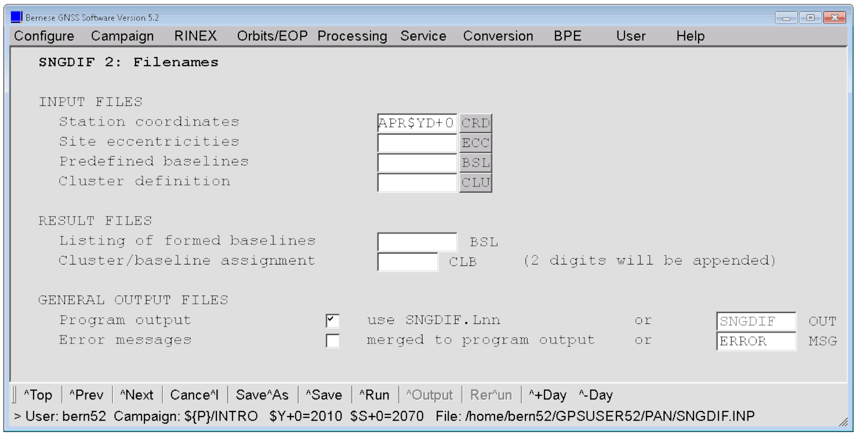
```
 ...

 -------------------------------------------------------------------------------
 File  Input files
 -------------------------------------------------------------------------------
    1  ${P}/INTRO/OUT/COD10207.OUT
 -------------------------------------------------------------------------------



  13 FILES, MAX. RMS:     2.12 M FOR STATION: PTBB 14234M001
            MAX. BAD:     5.26 % FOR STATION: WSRT 13506M005


-----------------------------------------------------------------
>>> CPU/Real time for pgm "CODXTR": 0:00:00.008 / 0:00:00.007
>>> Program finished successfully
```

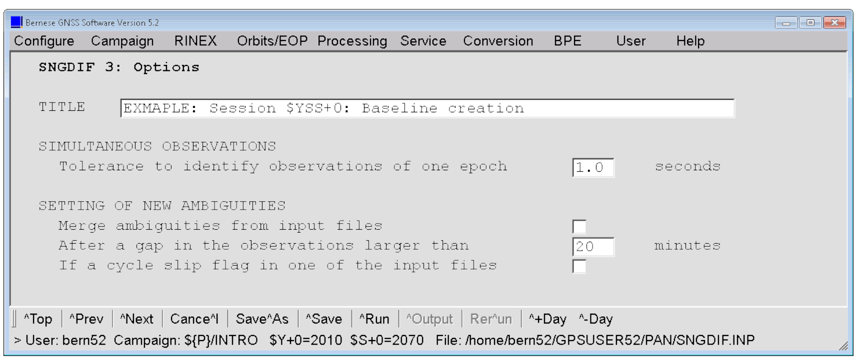
4.2.2 Form Baselines

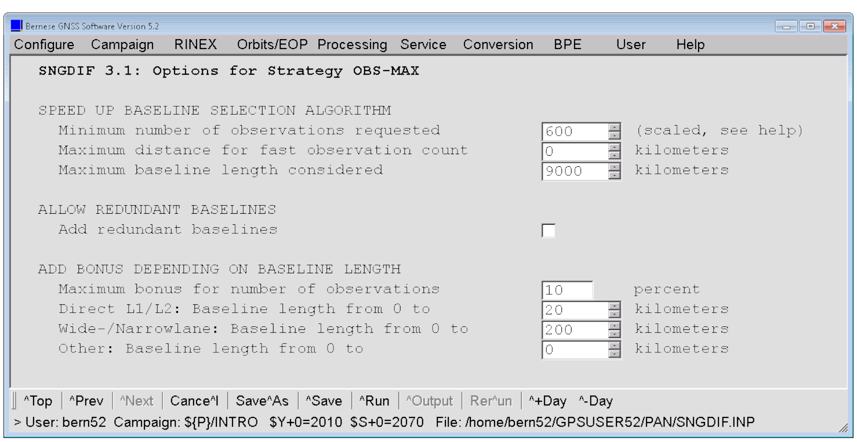
The second preprocessing program is called SNGDIF and may be activated in "Menu >Processing>Create baseline files". SNGDIF creates the single differences and stores them into files. We use the strategy OBS-MAX for PHASE observation files.



To enter GPS in option "Stations must contain observ. from a GNSS" requires that each station included in the baseline creation provides at least GPS measurements. This option can be used to exclude those datasets containing only GLONASS observations.







The output of SNGDIF simply echoes the zero difference files used and the single difference files created. The first table confirms that all stations provide at least data from GPS. For that reason all stations are included in the baseline creation.

```
...

 NUM HEADER FILE NAMES                  STATION NAME    #SAT  SYS    REMARK
------------------------------------------------------------------------------
   1 ${P}/INTRO/OBS/GANP2070.PZH        GANP 11515M001    50  GR     included
   2 ${P}/INTRO/OBS/HERT2070.PZH        HERT 13212M010    51  GR     included
   3 ${P}/INTRO/OBS/JOZ22070.PZH        JOZ2 12204M002    50  GR     included
   4 ${P}/INTRO/OBS/LAMA2070.PZH        LAMA 12209M001    50  GR     included
   5 ${P}/INTRO/OBS/MATE2070.PZH        MATE 12734M008    51  GR     included
   6 ${P}/INTRO/OBS/ONSA2070.PZH        ONSA 10402M004    50  GR     included
   7 ${P}/INTRO/OBS/PTBB2070.PZH        PTBB 14234M001    32  G      included
   8 ${P}/INTRO/OBS/TLSE2070.PZH        TLSE 10003M009    52  GR     included
   9 ${P}/INTRO/OBS/WSRT2070.PZH        WSRT 13506M005    31  G      included
  10 ${P}/INTRO/OBS/WTZR2070.PZH        WTZR 14201M010    51  GR     included
  11 ${P}/INTRO/OBS/WTZZ2070.PZH        WTZZ 14201M014    52  GR     included
  12 ${P}/INTRO/OBS/ZIM22070.PZH        ZIM2 14001M008    52  GR     included
  13 ${P}/INTRO/OBS/ZIMM2070.PZH        ZIMM 14001M004    31  G      included
...
```

The creation of the following 12 baseline files from 13 zero difference observation files is reported:

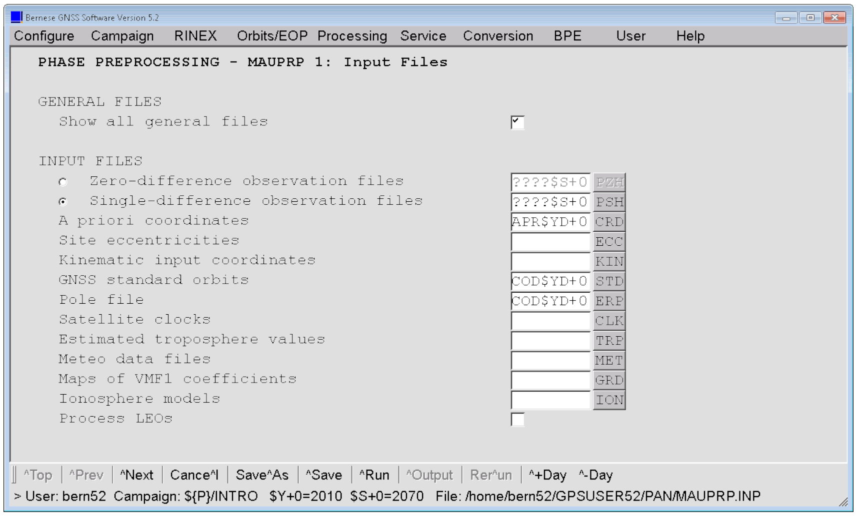
```
SNGDIF: INPUT AND OUTPUT OBSERVATION FILE NAMES
-----------------------------------------------
0-DIF. HEADER FILE NAMES (INPUT) 0-DIF. OBS. FILE NAMES (INPUT)   NUM
******************************** ******************************** ***

${P}/INTRO/OBS/GANP2070.PZH      ${P}/INTRO/OBS/GANP2070.PZO        1
${P}/INTRO/OBS/JOZ22070.PZH      ${P}/INTRO/OBS/JOZ22070.PZO        2
${P}/INTRO/OBS/HERT2070.PZH      ${P}/INTRO/OBS/HERT2070.PZO        3
${P}/INTRO/OBS/ZIM22070.PZH      ${P}/INTRO/OBS/ZIM22070.PZO        4
${P}/INTRO/OBS/JOZ22070.PZH      ${P}/INTRO/OBS/JOZ22070.PZO        5
${P}/INTRO/OBS/LAMA2070.PZH      ${P}/INTRO/OBS/LAMA2070.PZO        6
${P}/INTRO/OBS/JOZ22070.PZH      ${P}/INTRO/OBS/JOZ22070.PZO        7
${P}/INTRO/OBS/ONSA2070.PZH      ${P}/INTRO/OBS/ONSA2070.PZO        8
...
${P}/INTRO/OBS/ZIM22070.PZH      ${P}/INTRO/OBS/ZIM22070.PZO       23
${P}/INTRO/OBS/ZIMM2070.PZH      ${P}/INTRO/OBS/ZIMM2070.PZO       24


1-DIF. HEADER FILE NAMES (OUT)   1-DIF. OBS. FILE NAMES (OUT)     NR1 NR2 STAT.
******************************** ******************************** *** *** *****

${P}/INTRO/OBS/GAJO2070.PSH      ${P}/INTRO/OBS/GAJO2070.PSO        1   2   OK
${P}/INTRO/OBS/HEZI2070.PSH      ${P}/INTRO/OBS/HEZI2070.PSO        3   4   OK
${P}/INTRO/OBS/JOLA2070.PSH      ${P}/INTRO/OBS/JOLA2070.PSO        5   6   OK
${P}/INTRO/OBS/JOON2070.PSH      ${P}/INTRO/OBS/JOON2070.PSO        7   8   OK
...
${P}/INTRO/OBS/ZIZM2070.PSH      ${P}/INTRO/OBS/ZIZM2070.PSO       23  24   OK
```

If the strategy OBS-MAX was selected all possible pairs of zero difference files are listed with the corresponding criterion value. The baselines belonging to the created network configuration are labeled with OK .

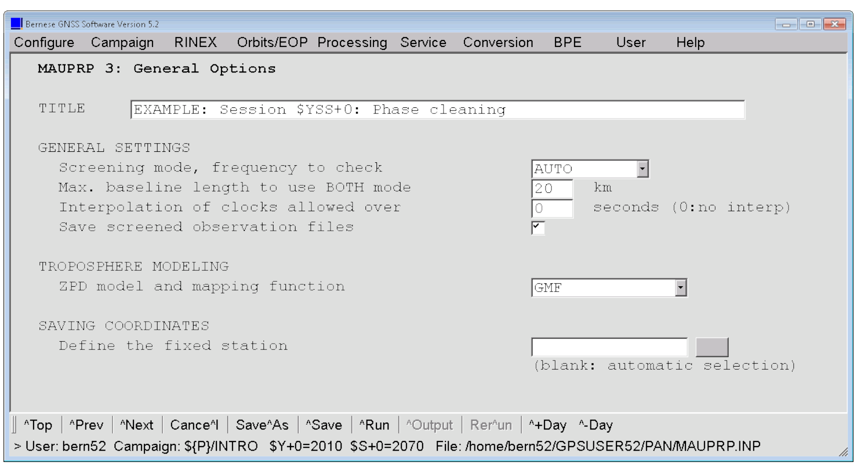
```
   1 GANP 11515M001   - HERT 13212M010   #SAT:  50  CRIT.:   20892
   2 GANP 11515M001   - JOZ2 12204M002   #SAT:  50  CRIT.:   23424  OK
   3 GANP 11515M001   - LAMA 12209M001   #SAT:  50  CRIT.:   22806
   4 GANP 11515M001   - MATE 12734M008   #SAT:  50  CRIT.:   20725
     ...
  21 HERT 13212M010   - WTZZ 14201M014   #SAT:  51  CRIT.:   22697
  22 HERT 13212M010   - ZIM2 14001M008   #SAT:  51  CRIT.:   23219  OK
  23 HERT 13212M010   - ZIMM 14001M004   #SAT:  31  CRIT.:   13051
  24 JOZ2 12204M002   - LAMA 12209M001   #SAT:  50  CRIT.:   24807  OK
  25 JOZ2 12204M002   - MATE 12734M008   #SAT:  50  CRIT.:   20969
  26 JOZ2 12204M002   - ONSA 10402M004   #SAT:  50  CRIT.:   23855  OK
  27 JOZ2 12204M002   - PTBB 14234M001   #SAT:  30  CRIT.:   11243
  28 JOZ2 12204M002   - TLSE 10003M009   #SAT:  50  CRIT.:   21991
  29 JOZ2 12204M002   - WSRT 13506M005   #SAT:  30  CRIT.:   14464  OK
  30 JOZ2 12204M002   - WTZR 14201M010   #SAT:  50  CRIT.:   24390  OK
  31 JOZ2 12204M002   - WTZZ 14201M014   #SAT:  50  CRIT.:   24182
     ...
```

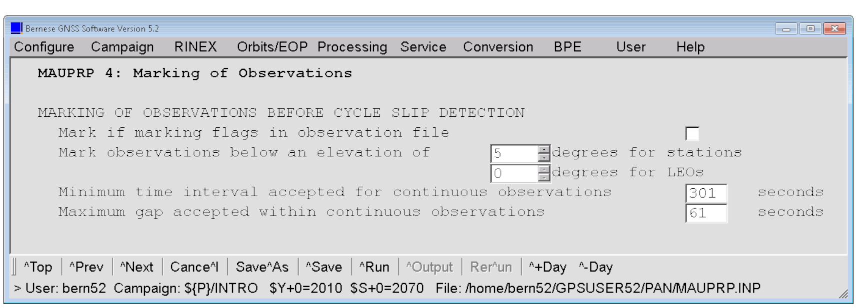
4.2.3 Preprocessing of the Phase Baseline Files

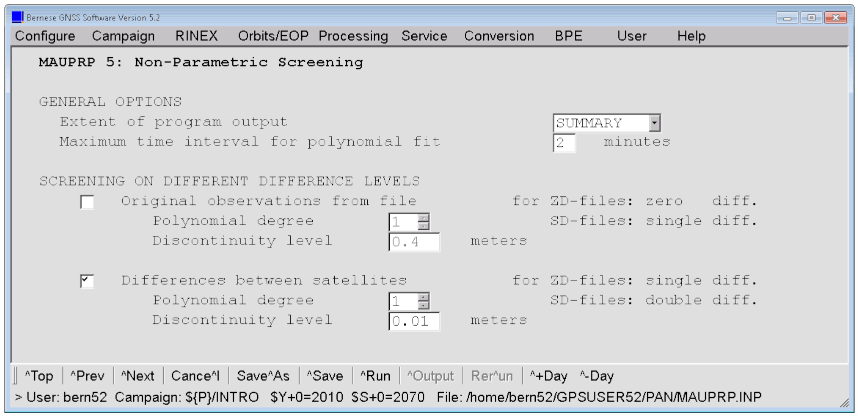
The main task of the program MAUPRP is the cycle–slip detection and correction. It is started using "Menu>Processing>Phase preprocessing".

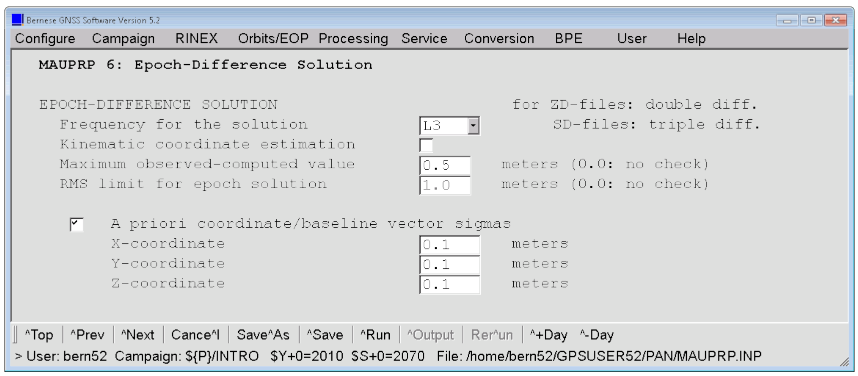


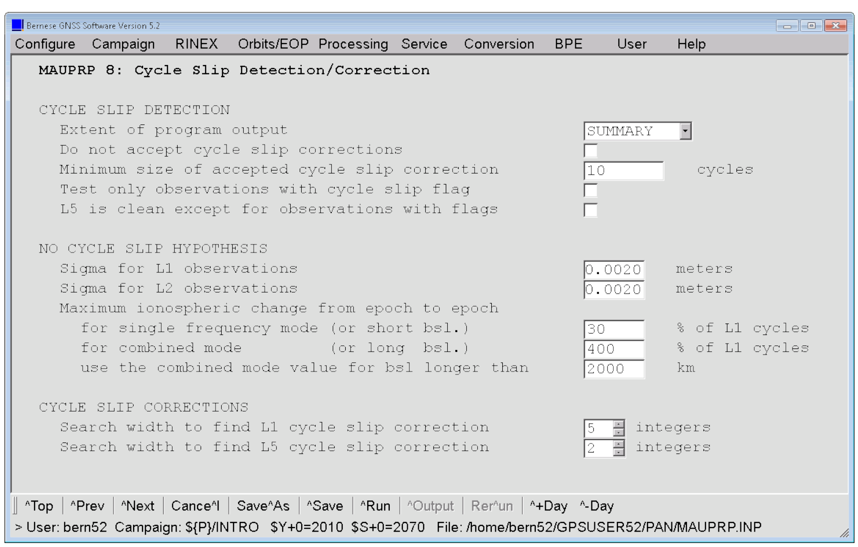
In the next input panel "MAUPRP 2: Output Files" you only need to specify the "Program output", e.g., to MPR$YD+0 .

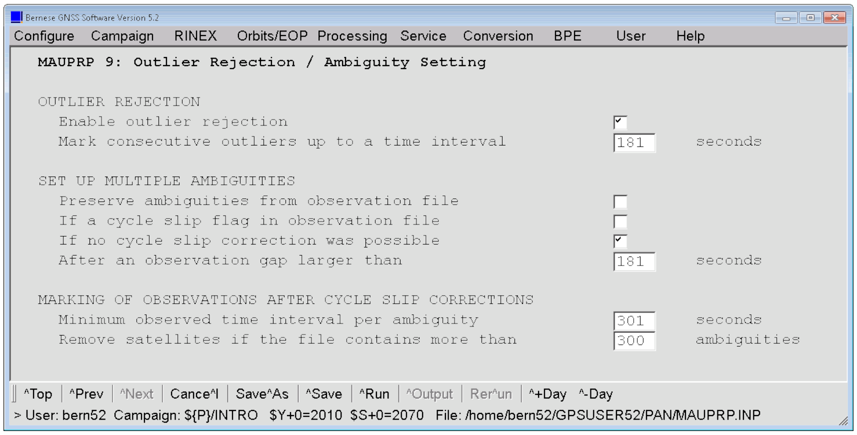





Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 5: Non-Parametric Screening
GENERAL OPTIONS
Extent of program output
SUMMARY
Maximum time interval for polynomial fit
2 minutes
SCREENING ON DIFFERENT DIFFERENCE LEVELS
Original observations from file
for ZD-files: zero diff.
Polynomial degree
1
SD-files: single diff.
Discontinuity level
0.4 meters
Differences between satellites
for ZD-files: single diff.
Polynomial degree
1
SD-files: double diff.
Discontinuity level
0.01 meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/MAUPRP.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 6: Epoch-Difference Solution
EPOCH-DIFFERENCE SOLUTION
for ZD-files: double diff.
Frequency for the solution
L3
SD-files: triple diff.
Kinematic coordinate estimation
Maximum observed-computed value
0.5 meters (0.0: no check)
RMS limit for epoch solution
1.0 meters (0.0: no check)
A priori coordinate/baseline vector sigmas
X-coordinate
0.1 meters
Y-coordinate
0.1 meters
Z-coordinate
0.1 meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/MAUPRP.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 8: Cycle Slip Detection/Correction
CYCLE SLIP DETECTION
Extent of program output
SUMMARY
Do not accept cycle slip corrections
Minimum size of accepted cycle slip correction
10 cycles
Test only observations with cycle slip flag
L5 is clean except for observations with flags
NO CYCLE SLIP HYPOTHESIS
Sigma for L1 observations
0.0020 meters
Sigma for L2 observations
0.0020 meters
Maximum ionospheric change from epoch to epoch
for single frequency mode (or short bsl.)
30 % of L1 cycles
for combined mode (or long bsl.)
400 % of L1 cycles
use the combined mode value for bsl longer than
2000 km
CYCLE SLIP CORRECTIONS
Search width to find L1 cycle slip correction
5 integers
Search width to find L5 cycle slip correction
2 integers
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/MAUPRP.INP



The output of the program MAUPRP is discussed in detail in the lecture session. The software manual contains a detailed description, too.

You can find here the results of the adjustment of the input parameters for the maximum accepted change of the ionosphere from one epoch to the next, which is computed according to the baseline length (AUTO in option "Screening mode, frequency to check", panel "MAUPRP 3: General Options").

```
...
STATION 1: GANP 11515M001          YEAR:  2010            SESSION:  2070
STATION 2: JOZ2 12204M002          DAY :   207            FILE   :     0

BASELINE LENGTH (M) :    344406.641
OBSERVAT. FILE NAME : ${P}/INTRO/OBS/GAJO2070.PSH

BASELINE DEPENDENT OPTIONS:
--------------------------

CHECK FREQUENCIES (L1=1, L2=2, L1&L2=3, L1,L2=4) --> :      3
MAX. IONOS.DIFF. BETW. EPOCHS (o/o OF L1 CYCLES) --> :     94
...
```

The most important item to check is the epoch difference solution:

```
...
-------------------------------------------------------------------------
EPOCH DIFFERENCE SOLUTION
-------------------------------------------------------------------------

FREQUENCY OF EPOCH DIFF. SOLU.:           3
#OBS. USED FOR EPOCH DIFF. SOLU:       42814
RMS OF EPOCH DIFF. SOLUTION (M):       0.012

COORDINATES  NEW-A PRIORI X (M):       0.185 +-       0.021
                          Y (M):       0.032 +-       0.021
                          Z (M):       0.290 +-       0.014

-------------------------------------------------------------------------
...
```

The epoch difference solution is used as the reference for the data screening. For a successful phase preprocessing the RMS OF EPOCH DIFF. SOLUTION has to be below 2 cm. The estimates for the coordinates in the epoch difference solution are expected to be smaller than about 0.5 m.

It should be pointed out that it is not necessary to run the program MAUPRP more than once for each baseline. However, it is mandatory to run MAUPRP again if you (for whatever reason) have to re–create the baselines with program SNGDIF.

You might get some warning messages regarding too large $O - C$ (i.e., observed minus computed) values on certain baselines for certain epochs. The corresponding observations get flagged, and will not disturb the processing.

You can use the extraction program MPRXTR ("Menu>Processing>Program output extraction>Phase preprocessing") to generate a short summary of the MAUPRP output. The file you have specified in "MAUPRP station summary file" looks like this:

```
SUMMARY OF THE MAUPRP OUTPUT FILE
*********************************

SESS FIL OK?  ST1  ST2 L(KM)   #OBS.  RMS    DX    DY    DZ  #SL  #DL  #MA  MAXL3   MIN. SLIP
-----------------------------------------------------------------------------------------------
2070   1 OK   GANP JOZ2  344   42814   12   185    32   290   12  369   72     49         12
2070   2 OK   HERT ZIM2  685   41498   13  -317    11  -329    6  591   95     47         11
2070   3 OK   JOZ2 LAMA  201   43720   11   -12    -4    71   39  826  101     49         11
2070   4 OK   JOZ2 ONSA  830   41462   11  -416  -151  -456    7  609  113     34         11
2070   5 OK   JOZ2 WSRT  981   22358   11  -198   -21  -229    8  413   47     33         11
2070   6 OK   JOZ2 WTZR  663   41785   13  -231   -76  -377   11  641   81     48         11
2070   7 OK   MATE ZIM2 1014   38157   13   471    42   455   64  876  117     49         11
2070   8 OK   PTBB ZIM2  640   20063   12    43    -8   -10   82  242   36     50         13
2070   9 OK   TLSE ZIM2  597   41698   13     8    38   126    6  609   89     47         11
2070  10 OK   WTZR WTZZ    0   43787   12    -9   -13    -4   96  461   65      0          0
2070  11 OK   WTZR ZIM2  476   42211   14   147    11    91    6  974   89     43         13
2070  12 OK   ZIM2 ZIMM    0   23786   13   -16     4   -32   25   88   35      0          0
-----------------------------------------------------------------------------------------------
Tot:  12                 536   43787   14   471    42   455   96  974  117     50          0
```

Note that in the bottom line the maximum values for each column are reported to show the "worst case".

4.3 Daily Goals

At the end of today's session, you should have created the following files:

1. *Bernese formatted zero difference observation files in your campaign's `OBS` directory: `GANP2070.CZH`, `GANP2070.PZH`, `GANP2070.CZO`, `GANP2070.PZO`, ... (for all stations).*
2. *Single difference files (baseline files) in the OBS directory: `GAJO2070.PSH`, `GAJO2070.PSO`, `HEZI2070.PSH`, `HEZI2070.PSO`,... for all baselines,*
3. *you should also have verified the outputs of these programs: ORBGEN, CODSPP, SNGDIF, and MAUPRP*

5 Terminal Session: Wednesday

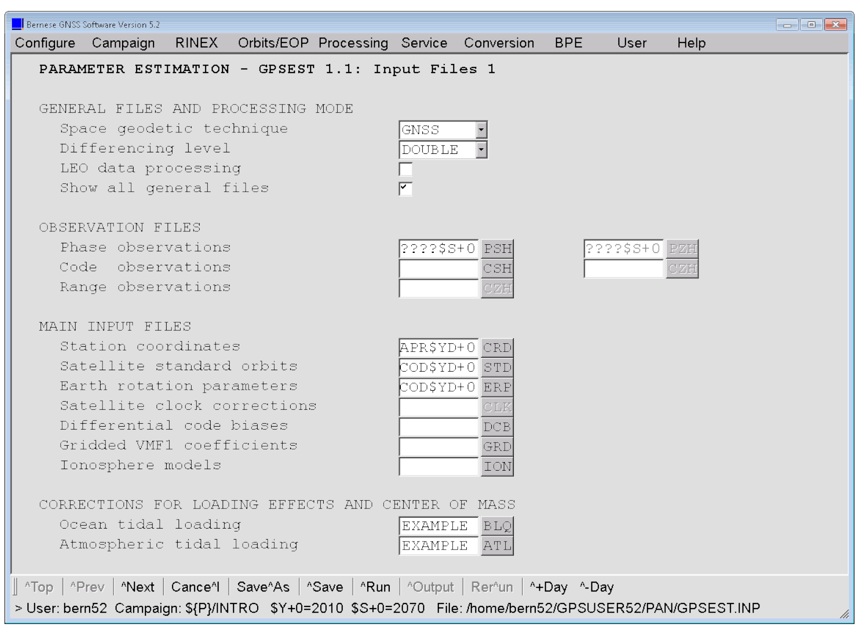
Today's terminal session is to:

1. *perform a residual screening (GPSEST, RESRMS, SATMRK),*
2. *generate a first estimation for coordinates and troposphere parameters (GPSEST),*
3. *resolve the double difference ambiguities (GPSEST).*

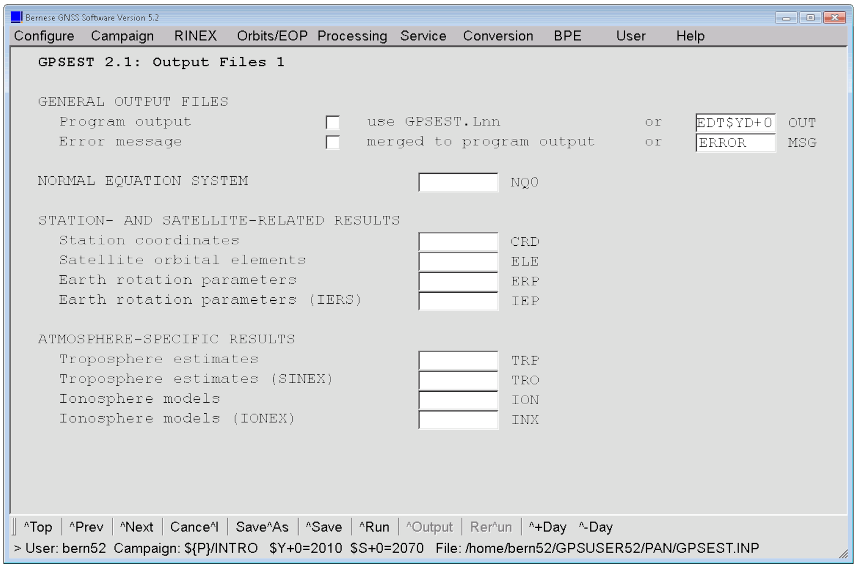
.

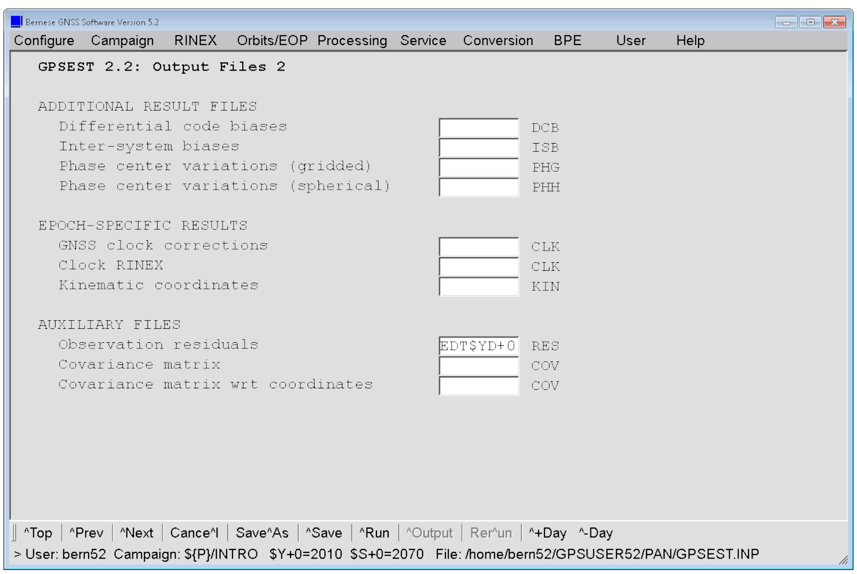
5.1 Data Preprocessing (II)

The main parameter estimation based on a least–squares adjustment is the task of program GPSEST. It is a good idea to start GPSEST first in the session mode and to produce a L_3 solution (ionosphere–free linear combination) with real–valued ambiguities. We do not expect any final results from this run but we want to check the quality of data and save the residuals after the least–squares adjustment. The program is available via "Menu>Processing >Parameter estimation". We use the following options:

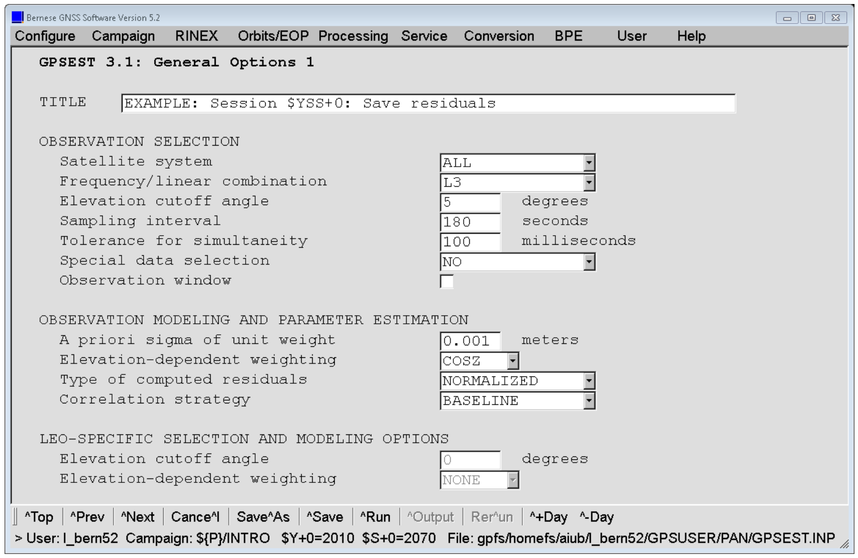


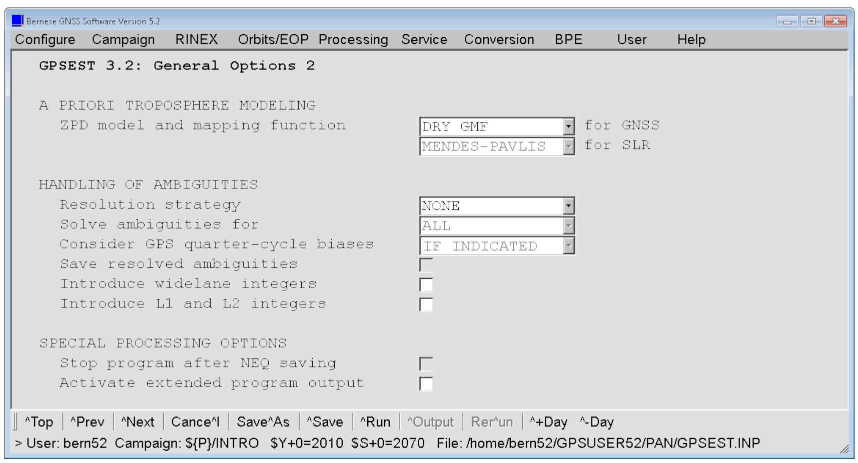
No files are input in the second input panel.



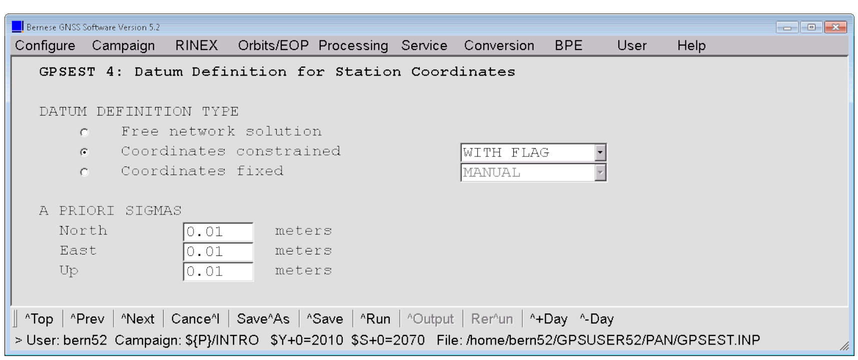


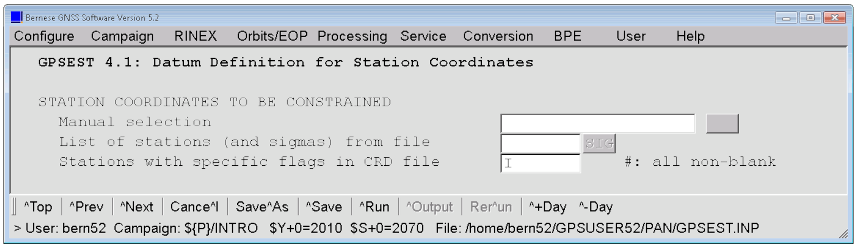
This run is intended to screen the post–fit residuals for outliers. Later on, for the ambiguity resolution, all observations are needed without down–sampling the data. To run the program GPSEST for the network with 13 stations and the observations to more than 50 satellites without reducing the data sampling rate takes easily 10 minutes or more. For that reason we are forced to sample the data, e.g., down to 3 minutes — we will see in the next step how to solve this discrepancy.



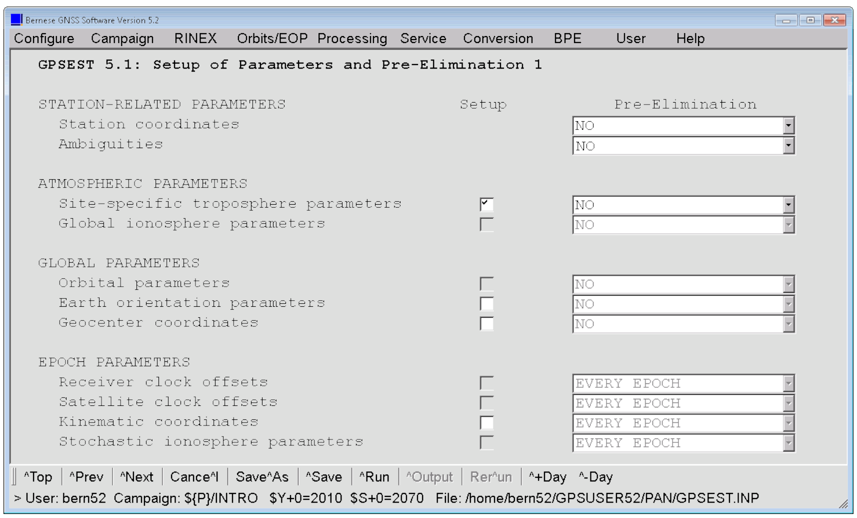


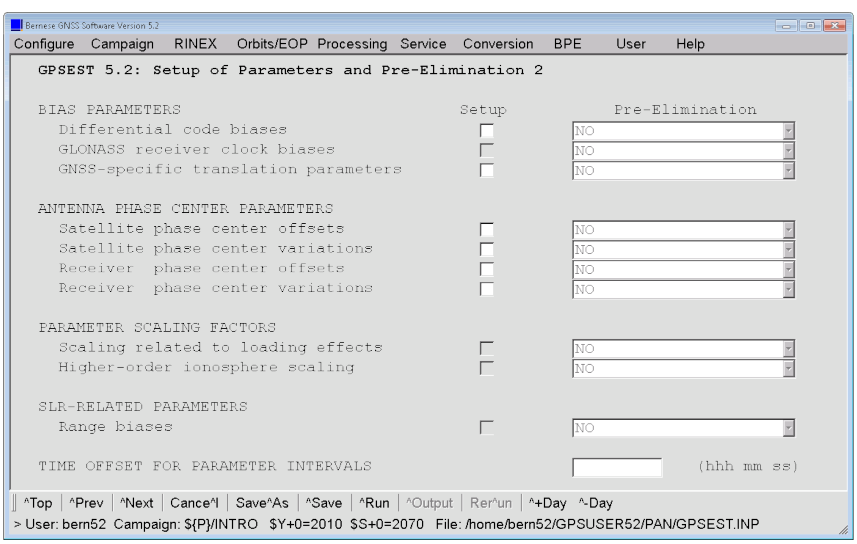
We want to put loose constraints on the station coordinates that are available from the IGS realization of ITRF2014 reference frame (flag `I` like `IGS14` in the coordinate file).



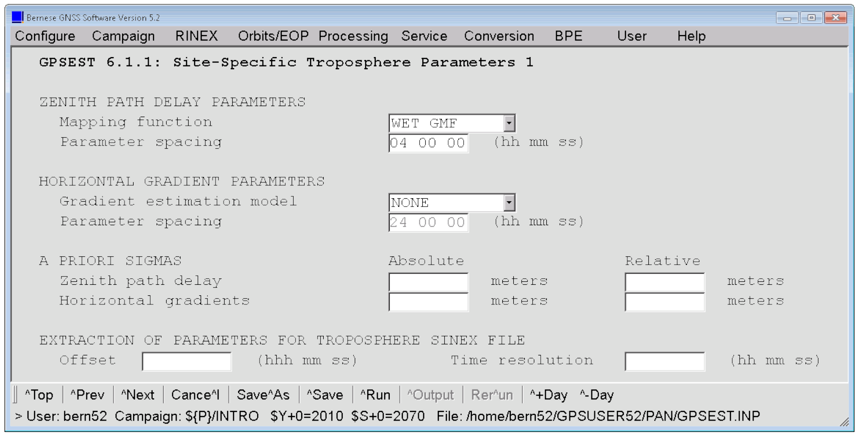


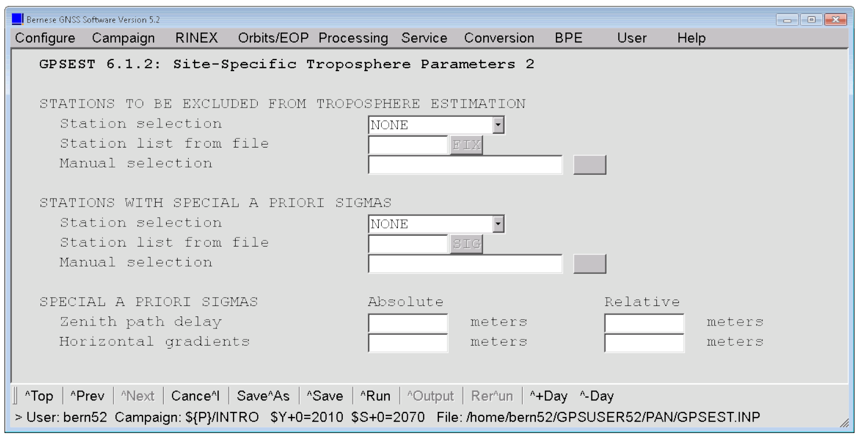
No parameters (not even ambiguity parameters) can be pre–eliminated if residuals should be written into the residual output file:





A 4 hour resolution in time for the troposphere parameters is sufficient for this purpose:





The program output of GPSEST summarizes all important input options, input data, and reports the estimated results. An important information in the output file is the a posteriori RMS error:

```
...

A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0013 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     72462
CHI**2/DOF                         :      1.66

...
```

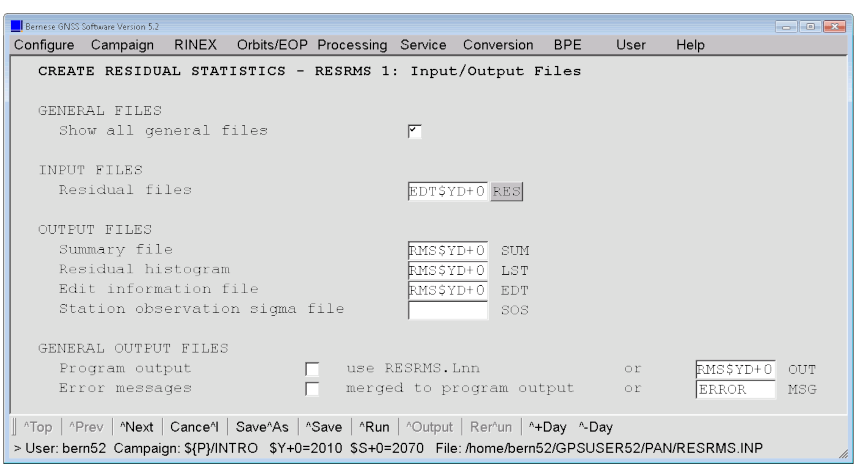
An a posteriori RMS error of about 1.0...1.5 mm is expected if elevation–dependent weighting is used. A significant higher RMS error indicates that either your data stems from low–quality receivers, that the data was collected under extremely bad conditions, or that the preprocessing step (MAUPRP and CODSPP) was not successfully performed.

Below you find the section reporting on coordinate estimation. You should check the improvement for the a priori coordinates. If all stations get approximately the same improvement in the order of decimeters, very likely the datum definition failed. Check that you have really selected datum stations.

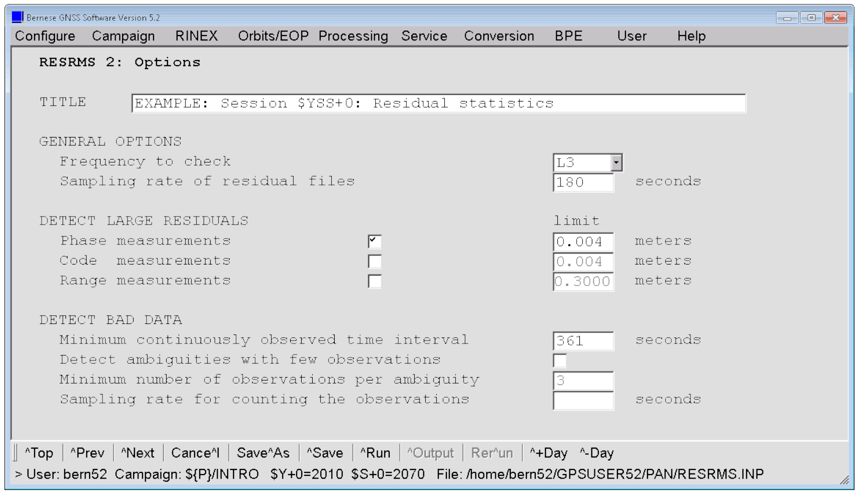
```
 ...
 STATION COORDINATES:                          (NOT SAVED)
 -------------------

 NUM  STATION NAME     PARAMETER    A PRIORI VALUE       NEW VALUE     NEW- A PRIORI  RMS ERROR
 ------------------------------------------------------------------------------------------- ..
  75  GANP 11515M001   X             3929181.4215       3929181.4183      -0.0032       0.0042
                       Y             1455236.8207       1455236.8270       0.0062       0.0041
                       Z             4793653.9501       4793653.9485      -0.0016       0.0042

                       HEIGHT            746.0149           746.0131      -0.0017       0.0044
                       LATITUDE     49  2  4.971296    49  2  4.971282    -0.0004       0.0040
..
                       LONGITUDE    20 19 22.574398    20 19 22.574740     0.0069       0.0041
..
                                                                                               ..
 107  JOZ2 12204M002   X             3664880.4810       3664880.4813       0.0004       0.0042
                       Y             1409190.6806       1409190.6835       0.0029       0.0041
                       Z             5009618.5302       5009618.5337       0.0035       0.0041

                       HEIGHT            152.5315           152.5351       0.0036       0.0043
                       LATITUDE     52  5 52.211587    52  5 52.211621     0.0011       0.0040
..
                       LONGITUDE    21  1 56.470161    21  1 56.470295     0.0025       0.0040
..
                                                                                               ..
  92  HERT 13212M010   X             4033460.8497       4033460.8497       0.0000       0.0042
                       Y               23537.8898         23537.8977       0.0080       0.0041
                       Z             4924318.3145       4924318.3219       0.0074       0.0042

                       HEIGHT             83.3341            83.3399       0.0058       0.0044
                       LATITUDE     50 52  2.929075    50 52  2.929224     0.0046       0.0040
..
                       LONGITUDE     0 20  3.676778     0 20  3.677186     0.0079       0.0040
..
                                                                                               ..
 276  ZIM2 14001M008   X             4331299.7959       4331299.7868      -0.0090       0.0041
                       Y              567537.4213        567537.4272       0.0059       0.0040
                       Z             4633133.7767       4633133.7769       0.0002       0.0041

                       HEIGHT            956.4292           956.4237      -0.0055       0.0042
                       LATITUDE     46 52 37.540239    46 52 37.540436     0.0061       0.0040
..
                       LONGITUDE     7 27 54.115566     7 27 54.115899     0.0070       0.0040
..
                                                                                               ..

...
```

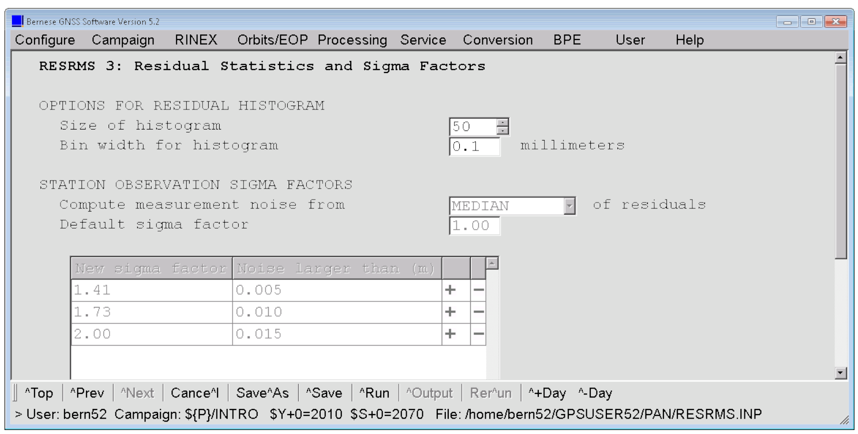
If the residuals have been stored in the binary residual file (specified in "GPSEST 2.2: Output Files 2") it is possible to have a look to the residuals (program REDISP, "Menu>Service>Residual files>Display residual file").

To screen the residuals automatically use the program RESRMS in "Menu>Service>Residual files >Create residual statistics".



The sampling interval you have previously introduced in option "Sampling interval" in program GPSEST has to be repeated here. RESRMS makes the assumption that the observations between two outliers in the sampled residual file are also bad.



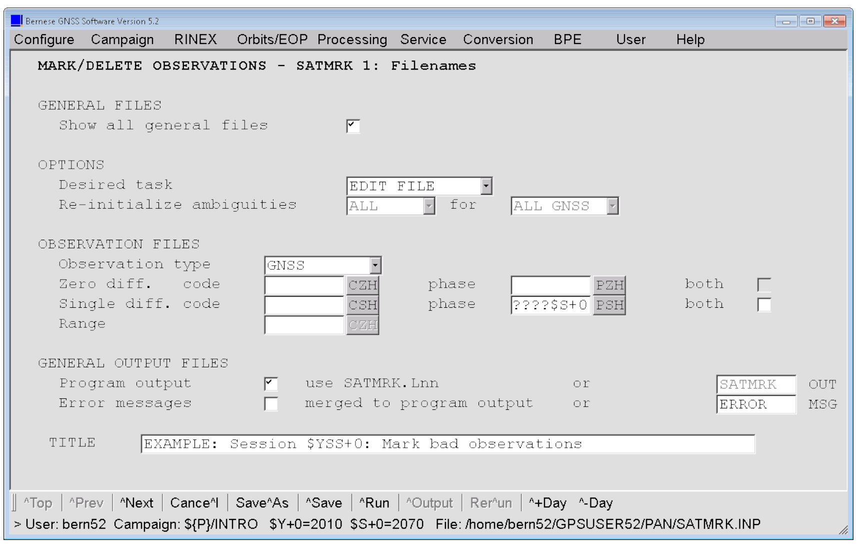


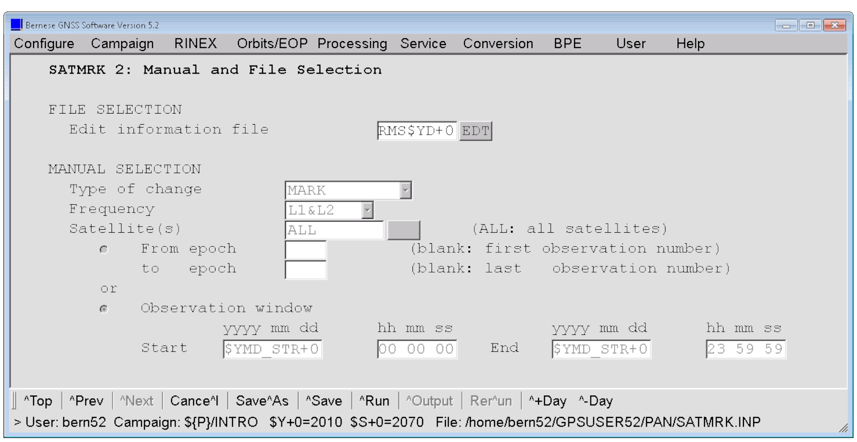
The program output of RESRMS (`${P}/INTRO/OUT/RMS10207.OUT`) provides a nice overview on the data quality.

```
 ...

 FILE INFORMATION AND STATISTIC:
 ------------------------------

 Num   Station 1         Station 2       Total RMS  med.Resi  Sigma  numObs  nSat  nDel ..
 ------------------------------------------------------------------------------------- ..

   1   GANP 11515M001   JOZ2 12204M002          1.4       0.7        1.2    7611    50    16
..
   2   HERT 13212M010   ZIM2 14001M008          1.4       0.8        1.1    7372    51    11
..
   3   JOZ2 12204M002   LAMA 12209M001          1.3       0.7        1.1    7741    50    17
..
   4   JOZ2 12204M002   ONSA 10402M004          1.3       0.7        1.0    7368    50    20
..
   5   JOZ2 12204M002   WSRT 13506M005          1.3       0.8        1.2    4192    30    12
..
   6   JOZ2 12204M002   WTZR 14201M010          1.6       0.8        1.2    7460    50    18
..
   7   MATE 12734M008   ZIM2 14001M008          1.6       0.8        1.2    6788    51    22
..
```

```
   8    PTBB 14234M001   ZIM2 14001M008           1.4         0.8         1.2     3819     32     15
..
   9    TLSE 10003M009   ZIM2 14001M008           1.6         0.8         1.3     7443     52     19
..
  10    WTZR 14201M010   WTZZ 14201M014           1.6         0.7         1.0     7817     51     51
..
  11    WTZR 14201M010   ZIM2 14001M008           1.7         1.0         1.4     7563     51     28
..
  12    ZIM2 14001M008   ZIMM 14001M004           0.9         0.5         0.8     4540     31      1
..
 ------------------------------------------------------------------------------------- ..

 NUMBER OF EDIT REQUESTS:   230
 ...
```

In addition, files containing a summary table (`${P}/INTRO/OUT/RMS10207.SUM`) and a histogram (`${P}/INTRO/OUT/RMS10207.LST`) of the residuals are available. The most important result file for the data screening is the "Edit information file" (`${P}/INTRO/OUT/RMS10207.EDT`), which may be used by the program SATMRK to mark outliers in the observation files ("Menu>Service>Bernese observation files>Mark/delete observations"):





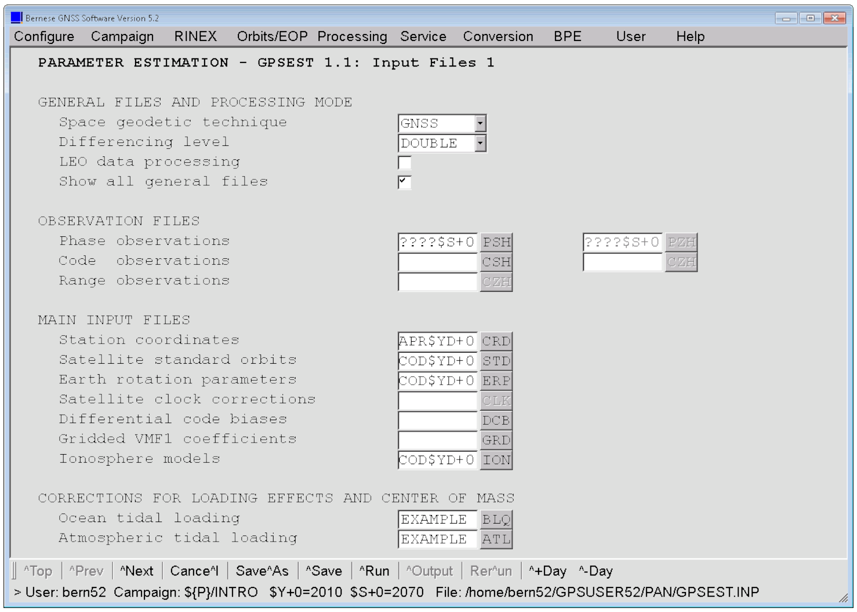
The program output from SATMRK reports the number of marked observations per baseline:

```
 ...
SUMMARY OF ACTION IN THE OBS. FILE(S):      ${P}/INTRO/OUT/RMS10207.EDT
 -----------------------------------
                                                 Mea-        Observations
```

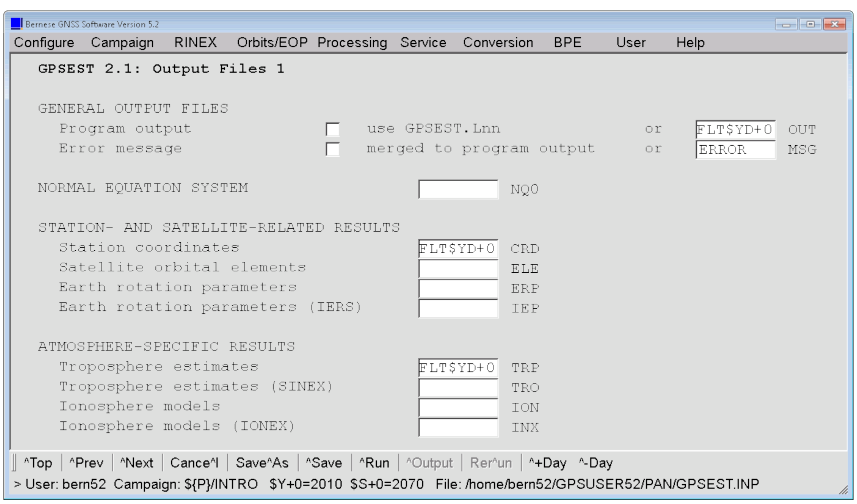
```
  Num  Station name 1        Station name 2      type    mark  unmark  delete ..
 ----------------------------------------------------------------------------- ..
    1  GANP 11515M001        JOZ2 12204M002       P :     420       0       0
..
    2  HERT 13212M010        ZIM2 14001M008       P :     300       0       0
..
    3  JOZ2 12204M002        LAMA 12209M001       P :     422       0       0
..
    4  JOZ2 12204M002        ONSA 10402M004       P :     530       0       0
..
    5  JOZ2 12204M002        WSRT 13506M005       P :     370       0       0
..
    6  JOZ2 12204M002        WTZR 14201M010       P :     526       0       0
..
    7  MATE 12734M008        ZIM2 14001M008       P :     688       0       0
..
    8  PTBB 14234M001        ZIM2 14001M008       P :     326       0       0
..
    9  TLSE 10003M009        ZIM2 14001M008       P :     512       0       0
..
   10  WTZR 14201M010        WTZZ 14201M014       P :    1096       0       0
..
   11  WTZR 14201M010        ZIM2 14001M008       P :     874       0       0
..
   12  ZIM2 14001M008        ZIMM 14001M004       P :      22       0       0
..
 ------------------------------------------------------------------------------ ..
       Total:                                            6086       0       0
..
 ------------------------------------------------------------------------------
                                                                                ..

                                                                                ..
```

5.2 Produce a First Network Solution

After screening the observations for outliers we can generate an ionosphere–free (L_3) solution with unresolved ambiguities. A detailed discussion on the Troposphere/Ionosphere modeling will be given in a dedicated lecture tomorrow. The input options are very similar to the previous preprocessing step. There are only a few differences shown in the following panels:

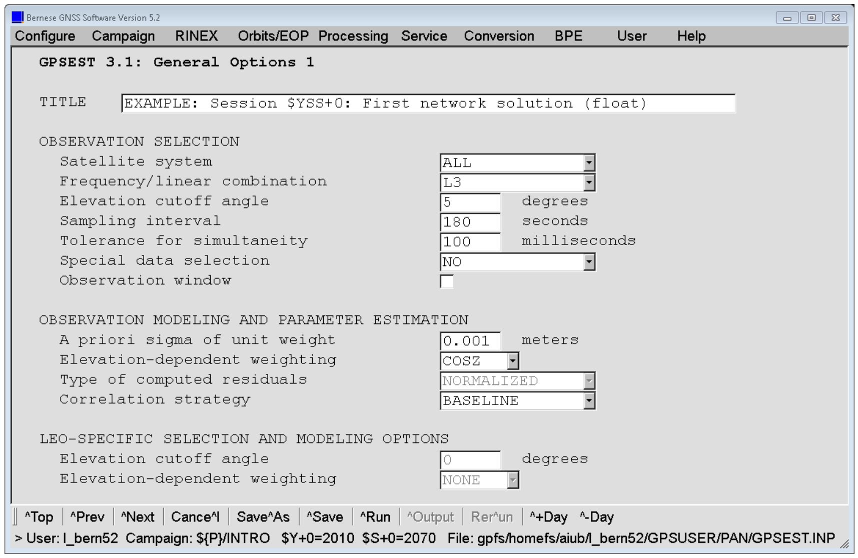


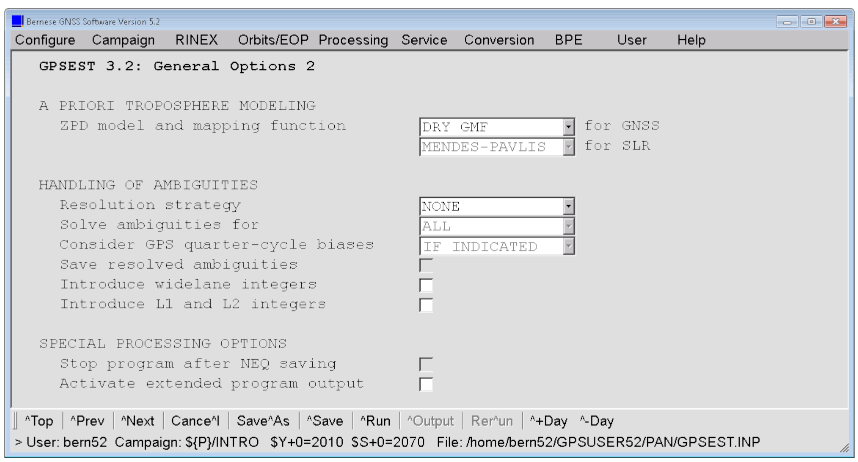
The file in the input field “Ionosphere models” enables the HOI–corrections.
We store the coordinates and troposphere parameters into files to be re–introduced later:



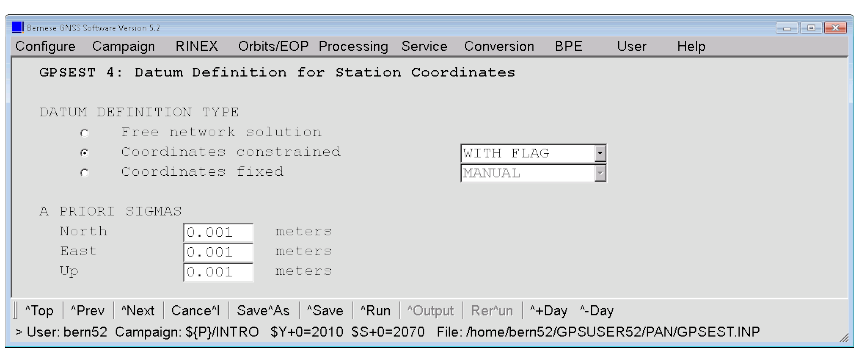
In the subsequent panel you should remove the output filename for the “Residuals” because we do not need the residuals from this run.

The next two panels with the general options for GPSEST remain untouched:

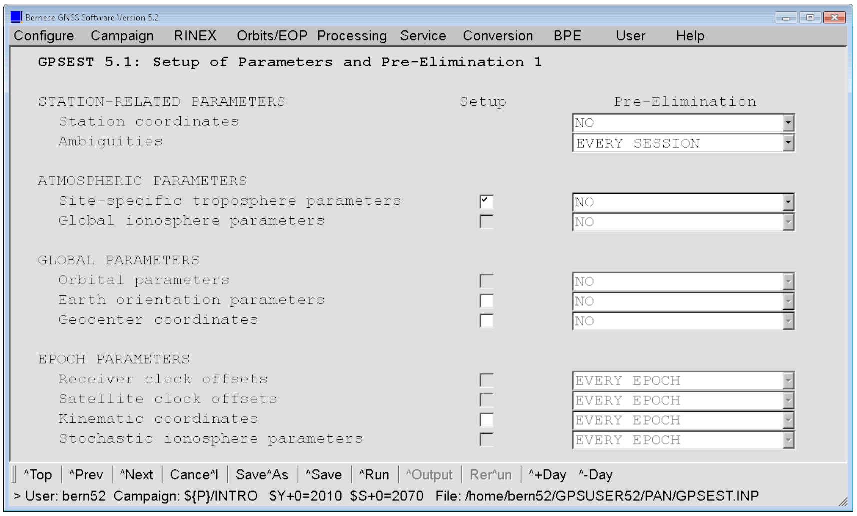




To heavily constrain the coordinates of the IGS core sites is not the best way to realize the geodetic datum for a solution. The program ADDNEQ2 offers more sophisticated options (e.g., minimum constraint solution). Today we will follow this simple approach:

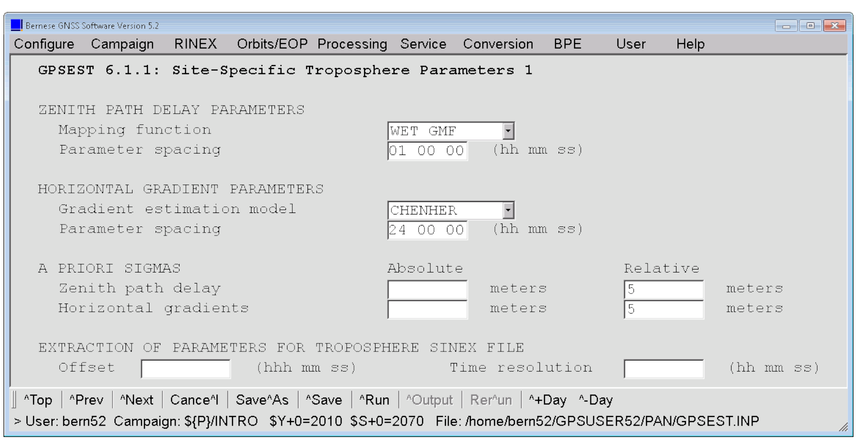


Since we do not store residual files in this run, ambiguity parameters may be pre–eliminated from the normal equation before the parameters are estimated:



The estimation of troposphere parameters is mandatory for a campaign of this type. We increase the number of estimated parameters (e.g., to 24 instead of 6 parameters per station and session). In addition, it is recommended to set up troposphere gradient parameters.

In order to avoid a format overflow in the "Troposphere estimates" output file that may happen if a troposphere parameter is estimated based on very few observations concentrated at one end of the interval of parameter validity, a small relative sigma (e.g., 5 meter) may help.



In the first part of the output generated by program GPSEST, the selected options are echoed. The result part starts with some statistics on the parameters and the observations:

```
 ...

 13. RESULTS (PART 1)
 --------------------

 NUMBER OF PARAMETERS (PART 1):
 -----------------------------

 PARAMETER TYPE                             #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
 ------------------------------------------------------------------------------------------ ...

STATION COORDINATES                              39           0                       39     ...
AMBIGUITIES                                    1369        1369  (BEFORE INV)       1481     ...
SITE-SPECIFIC TROPOSPHERE PARAMETERS            377           0                      377     ...

 ------------------------------------------------------------------------------------------ ...
 TOTAL NUMBER OF PARAMETERS                    1785        1369                     1897     ...
 ------------------------------------------------------------------------------------------ ...


 NUMBER OF OBSERVATIONS (PART 1):
 -------------------------------

 TYPE         FREQUENCY         FILE/PAR     #OBSERVATIONS
 ------------------------------------------------------------------------------------------ ...

 PHASE           L3              ALL             73602

 ------------------------------------------------------------------------------------------ ...
 TOTAL NUMBER OF OBSERVATIONS                        73602
 ------------------------------------------------------------------------------------------ ...
  ...
```

Then the a posteriori RMS error and the results of the initial least–squares adjustment are given

```
 ...

A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
 -----------------------------------------

 A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0011 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

 DEGREE OF FREEDOM (DOF)            :     71834
 CHI**2/DOF                         :      1.28
 ...
```

Below you find the output of the results for coordinates and troposphere parameters:

```
 ...
 STATION COORDINATES:                       ${P}/INTRO/STA/FLT10207.CRD
 -------------------

 NUM  STATION NAME     PARAMETER    A PRIORI VALUE       NEW VALUE     NEW- A PRIORI  RMS ERROR
 ---------------------------------------------------------------------------------------------- ..

  75  GANP 11515M001   X             3929181.4215       3929181.4200      -0.0015       0.0007
                       Y             1455236.8207       1455236.8215       0.0008       0.0007
                       Z             4793653.9501       4793653.9494      -0.0007       0.0008

                       HEIGHT            746.0149           746.0136      -0.0013       0.0009
..
                       LATITUDE     49  2  4.971296    49  2  4.971309     0.0004       0.0005
..
                       LONGITUDE    20 19 22.574398    20 19 22.574460     0.0013       0.0007
..

 107  JOZ2 12204M002   X             3664880.4810       3664880.4789      -0.0021       0.0007
                       Y             1409190.6806       1409190.6787      -0.0019       0.0006
                       Z             5009618.5302       5009618.5326       0.0024       0.0007

                       HEIGHT            152.5315           152.5318       0.0003       0.0008
..
                       LATITUDE     52  5 52.211587    52  5 52.211702     0.0035       0.0005
..
                       LONGITUDE    21  1 56.470161    21  1 56.470106    -0.0010       0.0006
..

  92  HERT 13212M010   X             4033460.8497       4033460.8499       0.0002       0.0007
                       Y               23537.8898         23537.8878      -0.0019       0.0007
```

```
                       Z              4924318.3145       4924318.3167      0.0022       0.0007

                       HEIGHT              83.3341            83.3359      0.0018       0.0009
..
                       LATITUDE     50 52  2.929075    50 52  2.929114     0.0012       0.0005
..
                       LONGITUDE     0 20  3.676778     0 20  3.676679    -0.0019       0.0007
..
 ...
```

```
 ...
 SITE-SPECIFIC TROPOSPHERE PARAMETERS:      ${P}/INTRO/ATM/FLT10207.TRP
 ------------------------------------

 REFERENCE ELEVATION ANGLE OF GRADIENT TERMS :   45.0 DEGREES
 MINIMUM ELEVATION ANGLE                     :    5.0 DEGREES
 MAPPING FACTOR AT MINIMUM ELEVATION ANGLE   :   11.4

                              CORRECTIONS (M)            RMS ERRORS (M)          ...
 REQU. STATION NAME        NORTH    EAST    ZENITH     NORTH    EAST    ZENITH     ...
 --------------------------------------------------------------------------------- ...

    1  GANP 11515M001    -0.00024 -0.00019  0.12103   0.00011  0.00013  0.00226    ...
    2  GANP 11515M001    -0.00021 -0.00015  0.11639   0.00011  0.00012  0.00167    ...
    3  GANP 11515M001    -0.00018 -0.00010  0.11814   0.00010  0.00011  0.00156    ...
    4  GANP 11515M001    -0.00015 -0.00006  0.12171   0.00009  0.00010  0.00160    ...
    5  GANP 11515M001    -0.00012 -0.00001  0.12203   0.00009  0.00010  0.00129    ...
  ...
   24  GANP 11515M001     0.00044  0.00085  0.13680   0.00011  0.00012  0.00181    ...
   25  GANP 11515M001     0.00047  0.00090  0.12869   0.00012  0.00013  0.00224    ...
   26  HERT 13212M010    -0.00142 -0.00190  0.19943   0.00013  0.00015  0.00299    ...
   27  HERT 13212M010    -0.00135 -0.00181  0.19841   0.00012  0.00014  0.00153    ...
   28  HERT 13212M010    -0.00127 -0.00172  0.18943   0.00011  0.00014  0.00187    ...
   29  HERT 13212M010    -0.00120 -0.00163  0.19009   0.00011  0.00013  0.00178    ...
   30  HERT 13212M010    -0.00113 -0.00154  0.19263   0.00010  0.00012  0.00149    ...
  ...
```

Because outliers have been removed in the previous step, the obtained a posteriori RMS error should decrease (at least not increase). If this is not the case, it is likely that the observations and the heavily constrained a priori coordinates are inconsistent.

5.3 Ambiguity Resolution

To resolve the ambiguities, we process the baselines separately one by one using the Quasi–Ionosphere–Free (QIF) strategy. This baseline processing mode is necessary because of the tremendous number of parameters. The attempt to resolve the ambiguities in a session solution might require too much CPU and memory to be feasible (several iterations with inversions of the full normal equation (NEQ) are necessary).

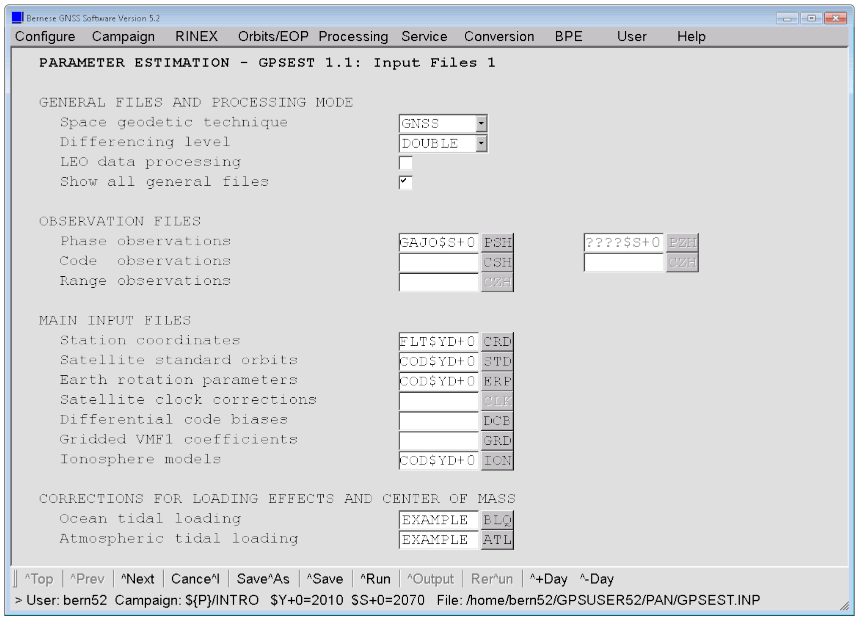
5.3.1 Ambiguity Resolution: Quasi–Ionosphere–Free (QIF)

The complete list of baseline observation files of a session (e.g., session 2070 of year 2010) can be generated by listing all phase single–difference header files in the campaign's observation directory of your campaign:

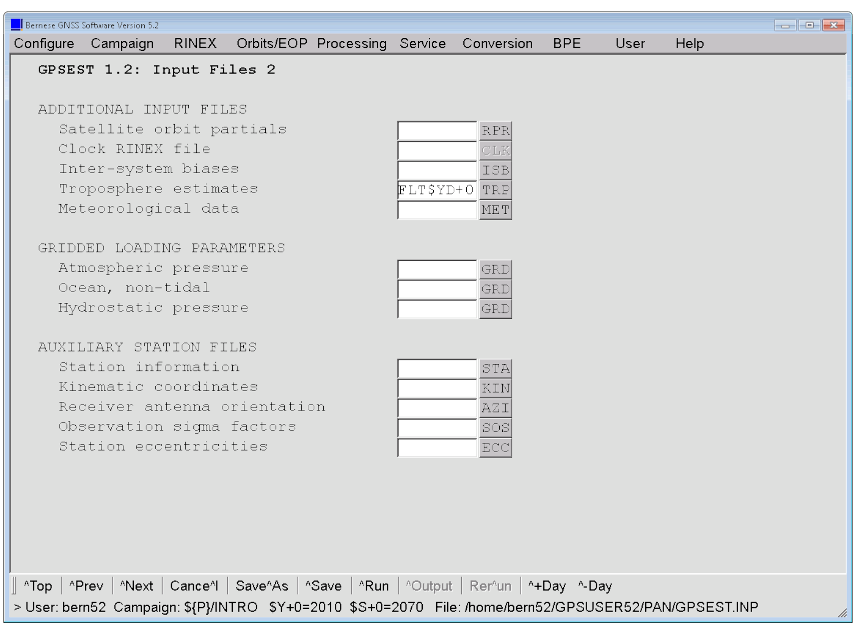
```
bern52@carina:~ > ls ${P}/INTRO/OBS/????2070.PSH
${P}/INTRO/OBS/GAJO2070.PSH
${P}/INTRO/OBS/HEZI2070.PSH
${P}/INTRO/OBS/JOLA2070.PSH
${P}/INTRO/OBS/JOON2070.PSH
${P}/INTRO/OBS/JOWS2070.PSH
${P}/INTRO/OBS/JOWT2070.PSH
${P}/INTRO/OBS/MAZI2070.PSH
${P}/INTRO/OBS/PTZI2070.PSH
${P}/INTRO/OBS/TLZI2070.PSH
```

```
${P}/INTRO/OBS/WTWZ2070.PSH
${P}/INTRO/OBS/WTZI2070.PSH
${P}/INTRO/OBS/ZIZM2070.PSH
```

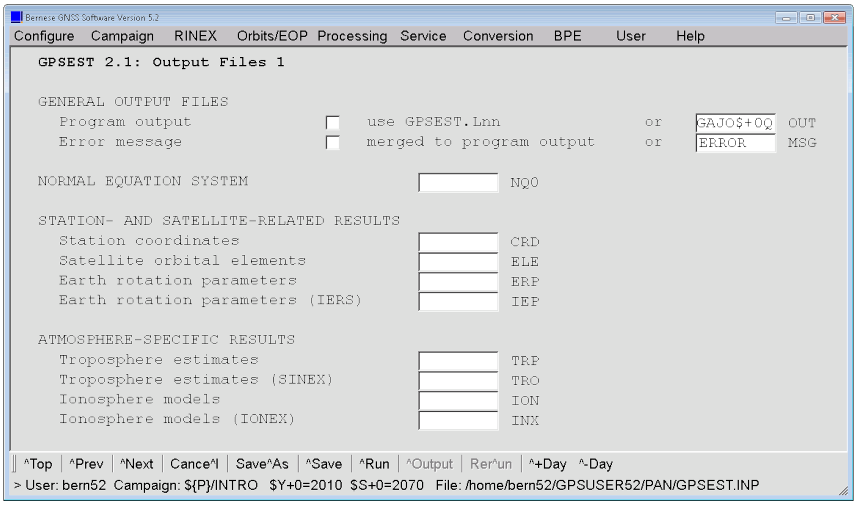
The first baseline for this session is from GANP to JOZ2 with the observation filename `GAJO2070`. Using the menu time variables this name is specified as `GAJO$S+0`. The following options are used for the ambiguity resolution step:



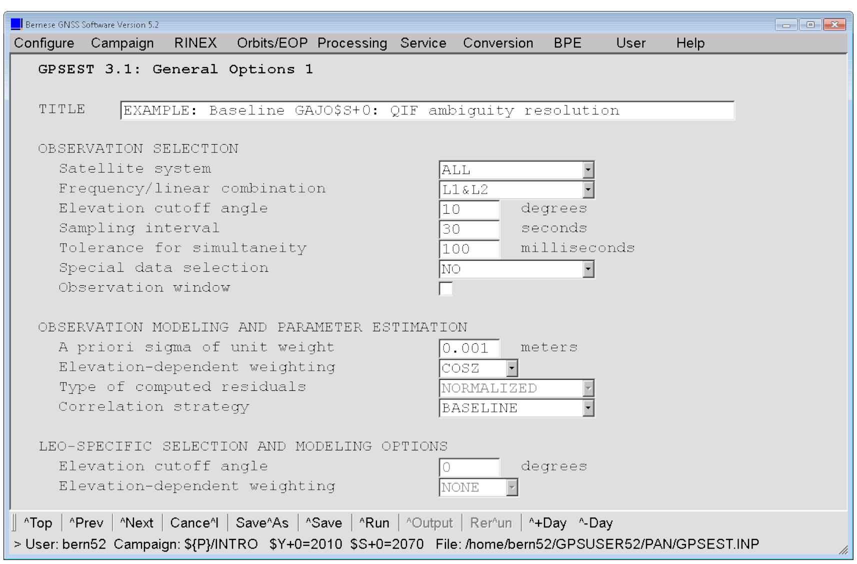
Only one baseline file is selected. Coordinates and troposphere estimates are introduced from the previous first network solution (Section 5.2).



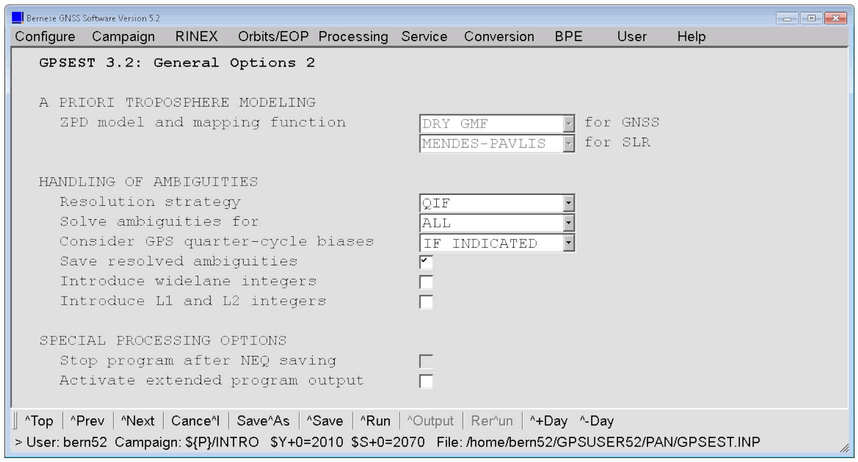
Specify a baseline specific output to prevent overwriting in subsequent runs: `GAJO$+0Q`. The `Q` at the end shall indicate that it is the output from the QIF–strategy.



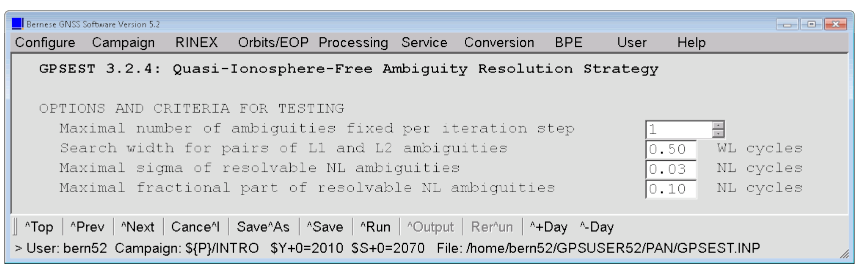
Because the QIF–ambiguity resolution strategy is very sensitive to the formal errors of the ambiguity parameters we have to include all measurements with the full sampling of 30 s into the processing.

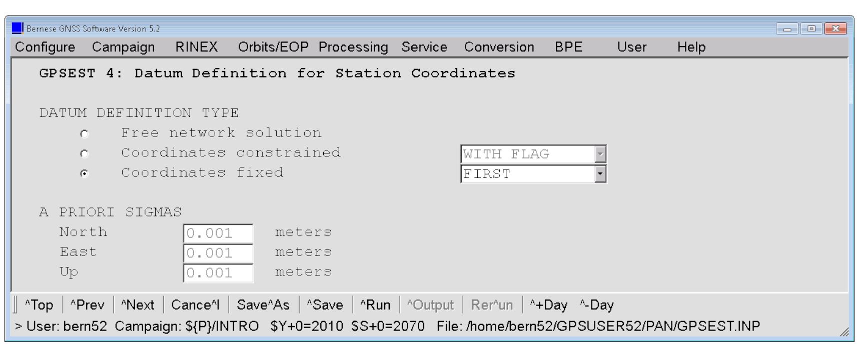


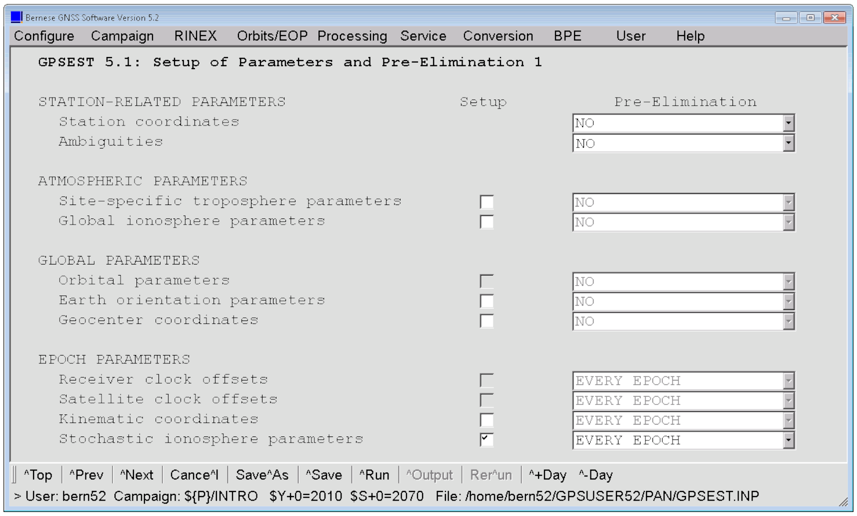
The selection of a "ZPD model and mapping function (GNSS)" is disabled because a troposphere file has been introduced in panel "GPSEST 1.2: Input Files 2". The program uses the troposphere model from this input file and allows no other selection for consistency reasons.
In the subsequent panel the "Resolution strategy" is chosen. Please, do not forget to store the resolved integer ambiguities in your observation file (mark checkbox at "Save resolved ambiguities").



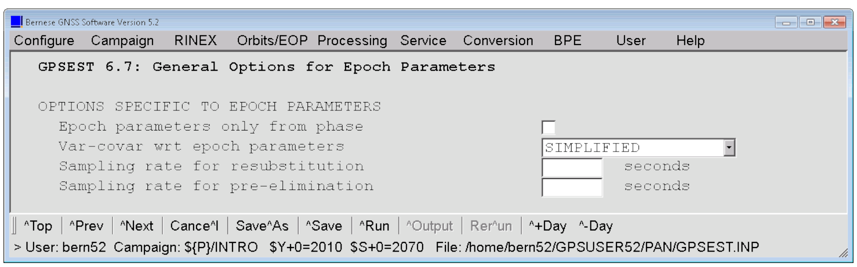
In case of ambiguity resolution including GLONASS, only one ambiguity per iteration can be resolved. The program will adjust the setting automatically issuing a warning message.

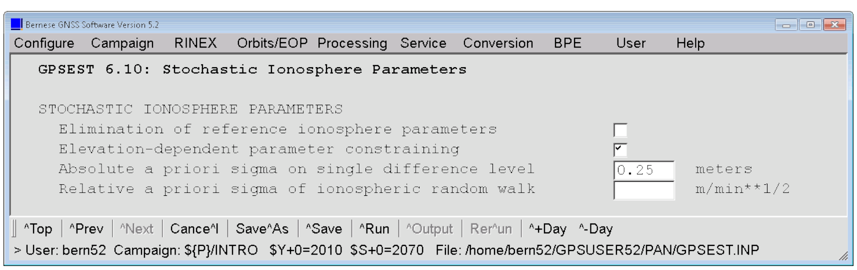






An additional panel with options specific to epoch–parameters is displayed now because the "Parameter Setup: stochastic ionosphere parameters" are pre-eliminated EVERY_EPOCH.





After reporting input options and input data for the current run of GPSEST, the results are presented in two parts. The first part refers to the solution where the ambiguities are estimated as real values whereas the second part reports the results after resolving the ambiguity parameters to integer values. The real–valued estimates for the ambiguities may be found below the STATION COORDINATES section of the program output:

```
...
13. RESULTS (PART 1)
--------------------

NUMBER OF PARAMETERS (PART 1):
------------------------------

PARAMETER TYPE                               #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
-------------------------------------------------------------------------------------------...

STATION COORDINATES                                    3           0                    3   ...
AMBIGUITIES                                          196           0                  242   ...
STOCHASTIC IONOSPHERE PARAMETERS                   40364       40364  (EPOCH-WISE)    45454   ...

-------------------------------------------------------------------------------------------...
TOTAL NUMBER OF PARAMETERS                         40563       40364                  45699   ...
-------------------------------------------------------------------------------------------...


NUMBER OF OBSERVATIONS (PART 1):
--------------------------------

TYPE         FREQUENCY         FILE/PAR     #OBSERVATIONS
-------------------------------------------------------------------------------------------...

PHASE           L1              ALL             37484
PHASE           L2              ALL             37484

-------------------------------------------------------------------------------------------...
TOTAL NUMBER OF OBSERVATIONS                       74968
-------------------------------------------------------------------------------------------...
...
```

```
...
A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
-------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0011 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     34405
CHI**2/DOF                         :      1.18
...
```

```
...
STATION COORDINATES:                           ${P}/INTRO/STA/FLT10207.CRD
-------------------

NUM  STATION NAME     PARAMETER    A PRIORI VALUE       NEW VALUE     NEW- A PRIORI  RMS ERROR
------------------------------------------------------------------------------------------ ..

107  JOZ2 12204M002   X             3664880.4789       3664880.4791      0.0003      0.0002
                      Y             1409190.6787       1409190.6784     -0.0003      0.0002
                      Z             5009618.5326       5009618.5331      0.0005      0.0002

                      HEIGHT            152.5318          152.5323      0.0005      0.0002 ..
                      LATITUDE     52  5 52.211702    52  5 52.211710    0.0002      0.0001 ..
                      LONGITUDE    21  1 56.470106    21  1 56.470086   -0.0004      0.0002 ..
...
```

```
...

AMBIGUITIES:
-----------
                                   REFERENCE
AMBI  FILE SAT. EPOCH FRQ WLF CLU  AMBI CLU    AMBIGUITY   RMS   TOTAL AMBIGU.    DL/L
-------------------------------------------------------------------------------------

   1    1    3   2199  1   1    3    -    -         1.07  21.81     1747244.07
   2    1   11      1  1   1    4    -    -         2.12  21.81     -120949.88
   3    1   11   2613  1   1    6    -    -        -3.84  21.81     -120952.84
   4    1   14      1  1   1    7    -    -         1.74  21.81     -484082.26
   5    1   14   1478  1   1    8    -    -        -0.67  21.81     -484244.67
   6    1   14   2569  1   1    9    -    -         1.17  21.81     -484299.83
   7    1   17      1  1   1   10    -    -         3.38  21.81    -1280029.62
   8    1   17   1111  1   1   11    -    -        -1.90  21.81    -1280192.90
   9    1   19      1  1   1   13    -    -         2.64  21.81     1400087.64
  10    1   19    897  1   1   14    -    -         0.38  21.82     1400165.38
  11    1   19   2337  1   1   15    -    -        -2.80  21.81     1400190.20
  12    1   20      1  1   1   16    -    -         2.31  21.81      757891.31
...
```

If GLONASS data are processed, single–difference (instead of double–difference) ambiguities are resolved and no — REFERENCE — as in case of GPS–only appears.

In the next part of the output the result of the QIF ambiguity resolution algorithm is given:

```
...
AMBIGUITY RESOLUTION:
--------------------

STRATEGY :  QUASI-IONOSPHERE-FREE AMBIGUITY RESOLUTION (QIF)

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:     1
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  89 106   1   94 112   1    -4   -3  -0.03  -0.04   0.009   0.002   0.003   27    9

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:     2
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  18  22   1   82  97   1     0    1   0.09   0.11  -0.022   0.009   0.003   24    6

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:     3
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1   1   3   1   82  97   2    -1   -1  -0.02  -0.03   0.006  -0.002   0.003    3    6

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:     4
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  16  20   1   82  97   3    -4   -2  -0.08  -0.10   0.021  -0.005   0.003   22    6

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:     5
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  11  15   1   82  97   4    -5   -3   0.13   0.18  -0.043  -0.021   0.003   19    6
...
-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:    54
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  70  82   3   71  83   1    -2   -3   0.22   0.31  -0.086  -0.079   0.009  111  111

-----------------------------------------------------------------------------------------
AMBIGUITY RESOLUTION ITERATION:    55
-----------------------------------------------------------------------------------------

                                BEST INT.    CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2   L1   L2    L1     L2     L5      L3    RMS(L3)  SA1  SA2
-----------------------------------------------------------------------------------------

   1  25  29   1   66  77   3     6    5  -0.05  -0.06   0.014   0.001   0.009  105  101
...
```

The individual iteration steps are first described (we specified that only one ambiguity may be resolved within each iteration step — see panel "GPSEST 3.2.4: Quasi-Ionosphere-Free Ambiguity Resolution Strategy"). The following information is listed for each resolved double–difference ambiguity:

`FILE` file number (1 in our case; we process one baseline only),

`AM1` first ambiguity number (single–difference level),

`CL1` corresponding ambiguity cluster,

`#AM1` number of ambiguities belonging to the same cluster,

`AM2, CL2, #AM2`
: similar information for the second ambiguity.

`BEST INT. L1, L2`
: are the integer corrections to the a priori values (a priori values are computed using the a priori coordinates and may be rather inaccurate).

`CORRECTIONS IN CYCLES`
: for carriers L1 and L2 gives the information about the fractional parts of the L_1 and L_2 ambiguities. The CORRECTIONS IN CYCLES L5 and L3 are of greater interest. The value L5 represents the ionosphere–induced bias expressed in L_5 cycles. These values may not be greater than the maximum value specified in panel "GPSEST 3.2.4: Quasi-Ionosphere-Free Ambiguity Resolution Strategy" (option "Search width for pairs of L1 and L2 ambiguities"). RMS(L3) is the criterion according to which the ambiguities are sorted. Ambiguities with L_3 RMS errors larger than the value specified in the program input panel (in our example 0.03) will not be resolved.

`SA1, SA2`
: first and second satellite number related to the ambiguities. Note that in AMBIGUITY RESOLUTION ITERATION: 65 and 66 there are examples for resolving pairs of ambiguities from the same satellite (path–to–path ambiguity resolution) — GLONASS satellites 114, and 119 .

The following table summarizes the results of the ambiguity resolution:

```
 ...
                                                       REFERENCE
 AMBI   FILE SAT. EPOCH FRQ WLF CLU   AMBI CLU    AMBIGUITY    RMS    TOTAL AMBIGU.     DL/L
 ------------------------------------------------------------------------------------------- ...

    1     1     3   2199  1   1    3     -     -           -1              1747242.      0.00000
    2     1    11      1  1   1    4     -     -            1              -120951.      0.00000
    3     1    11   2613  1   1    6     -     -            0              -120949.      0.00000
    4     1    14      1  1   1    7     -     -            5              -484079.      0.00000
    5     1    14   1478  1   1    8     -     -            3              -484241.      0.00000
    6     1    14   2569  1   1    9     -     -            5              -484296.      0.00000
    7     1    17      1  1   1   10     -     -            5             -1280028.      0.00000
    8     1    17   1111  1   1   11     -     -        -1.83  22.57     -1280192.83
    9     1    19      1  1   1   13     -     -            7              1400092.      0.00000
   10     1    19    897  1   1   14     -     -         0.47  22.57      1400165.47
   11     1    19   2337  1   1   15     -     -           -5              1400188.      0.00000
   12     1    20      1  1   1   16     -     -            1               757890.      0.00000
   13     1    20   2770  1   1   17     -     -            6               757842.      0.00000
   14     1    22      1  1   1   18     -     -         1.30  22.59      -893533.70
   15     1    22   1248  1   1   19     -     -            6              -893514.      0.00000
   16     1    22   2254  1   1   20     -     -           -4              -893533.      0.00000
   17     1    24      1  1   1   21     -     -            5               427188.      0.00000
   18     1    24   2196  1   1   22     -     -            0               427032.      0.00000
   19     1    28      1  1   1   23     -     -         1.75  22.60      -394055.25
   20     1    28    782  1   1   24     -     -           -4              -394018.      0.00000
  ...
```

The ambiguities for which an RMS is specified could not be resolved (these ambiguities will be treated as real values by all subsequent program runs). In case of GLONASS, only ambiguities with the same channel number are resolved in Version 5.2 of *Bernese GNSS Software*.

Ambiguity resolution has an influence on other parameters. Therefore, the results of the ambiguity–fixed solution are given in Part 2 of the output:

```
...
14. RESULTS (PART 2)
--------------------

NUMBER OF PARAMETERS (PART 2):
-----------------------------

PARAMETER TYPE                                #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
------------------------------------------------------------------------------------------- ...

STATION COORDINATES                                     3           0                     3   ...
AMBIGUITIES                                            66           0                   242   ...
STOCHASTIC IONOSPHERE PARAMETERS                    40364       40364  (EPOCH-WISE)   45454   ...

------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF PARAMETERS                          40433       40364                 45699   ...
------------------------------------------------------------------------------------------- ...


NUMBER OF OBSERVATIONS (PART 2):
-------------------------------

TYPE         FREQUENCY         FILE/PAR          #OBSERVATIONS
------------------------------------------------------------------------------------------- ...

PHASE           L1              ALL                   37484
PHASE           L2              ALL                   37484

------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF OBSERVATIONS                          74968
------------------------------------------------------------------------------------------ ...
 ...
```

```
...
A POSTERIORI SIGMA OF UNIT WEIGHT (PART 2):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0011 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     34535
CHI**2/DOF                         :      1.27
...
```

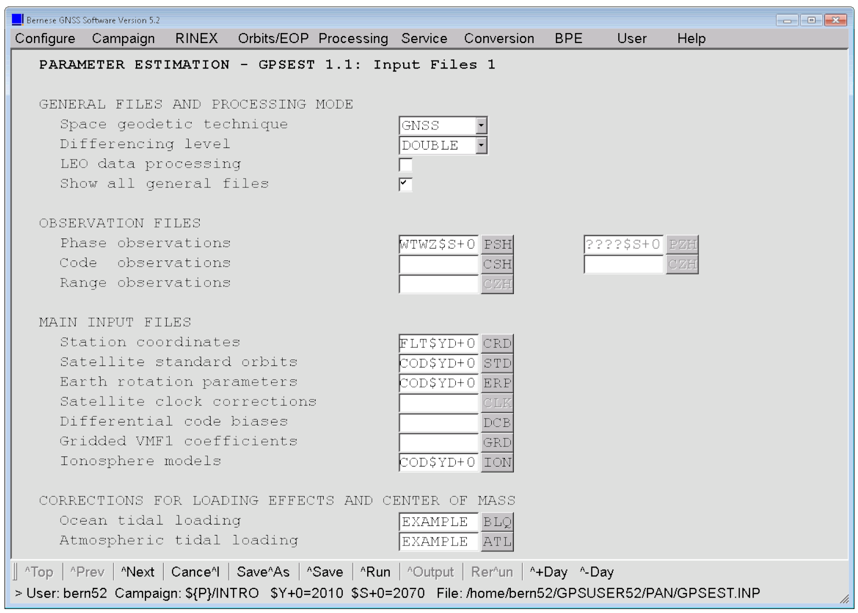
```
...
STATION COORDINATES:                       ${P}/INTRO/STA/FLT10207.CRD
-------------------

NUM  STATION NAME     PARAMETER    A PRIORI VALUE       NEW VALUE     NEW- A PRIORI  RMS ERROR
--------------------------------------------------------------------------------------------- ..

107  JOZ2 12204M002   X             3664880.4789       3664880.4789      0.0000       0.0001
                      Y             1409190.6787       1409190.6780     -0.0007       0.0001
                      Z             5009618.5326       5009618.5333      0.0007       0.0002

                      HEIGHT            152.5318           152.5322      0.0004       0.0002 ..
                      LATITUDE     52  5 52.211702    52  5 52.211720    0.0006       0.0001 ..
                      LONGITUDE    21  1 56.470106    21  1 56.470073   -0.0006       0.0001 ..
...
```

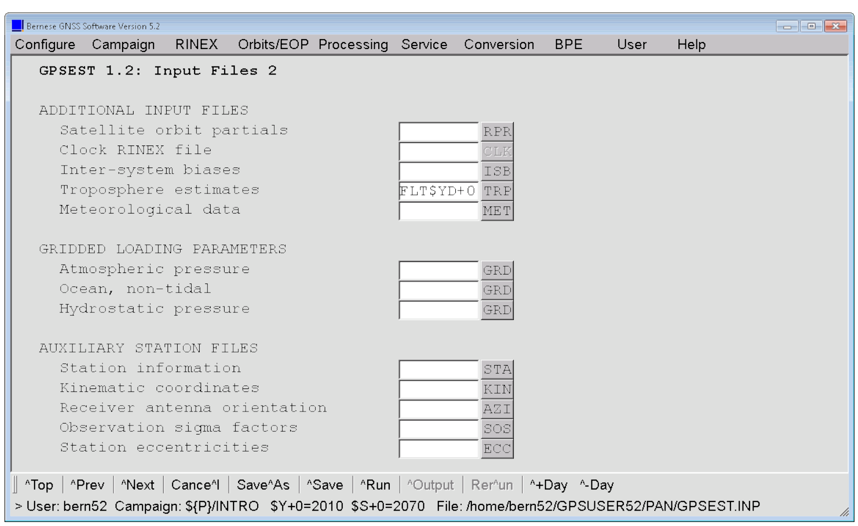
You may see from the output that from a total of 196 ambiguities 130 ambiguities could be resolved (compare part 1 AMBIGUITIES with part 2 AMBIGUITIES). Note that these numbers include reference ambiguities for each GNSS, GLONASS frequency number and frequency.

5.3.2 Ambiguity Resolution: Short Baselines

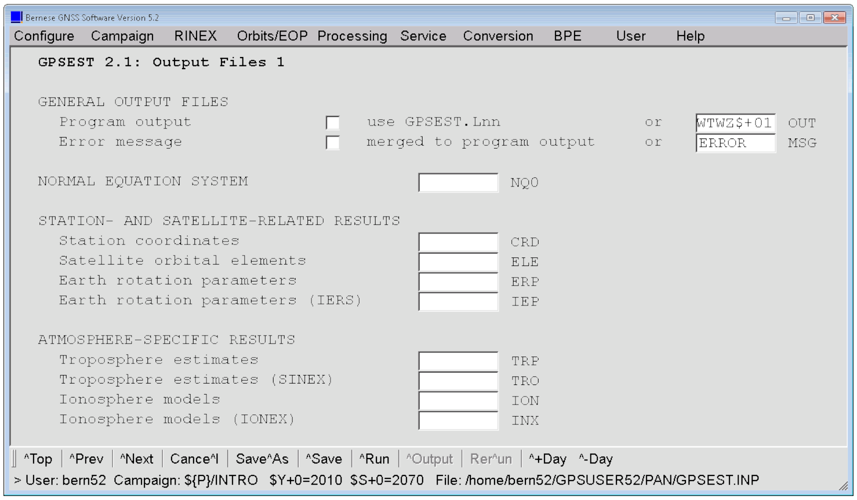
There are two very short baselines in the network where a direct ambiguity resolution for the L_1 and L_2 signal is possible applying the sigma–strategy.

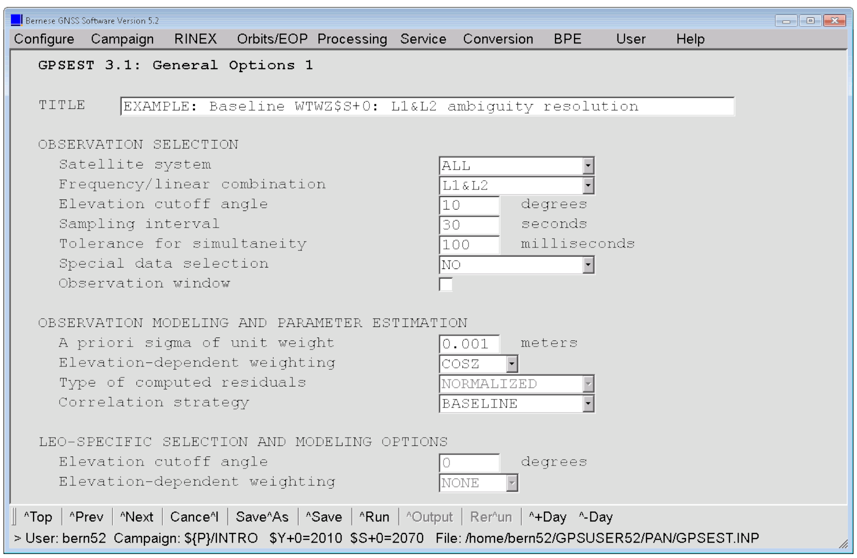
The ultra–short baseline in Kötzting is between WTZR and WTZZ (`WTWZ2070.PSH`). The GPSEST input panels should look like follows:

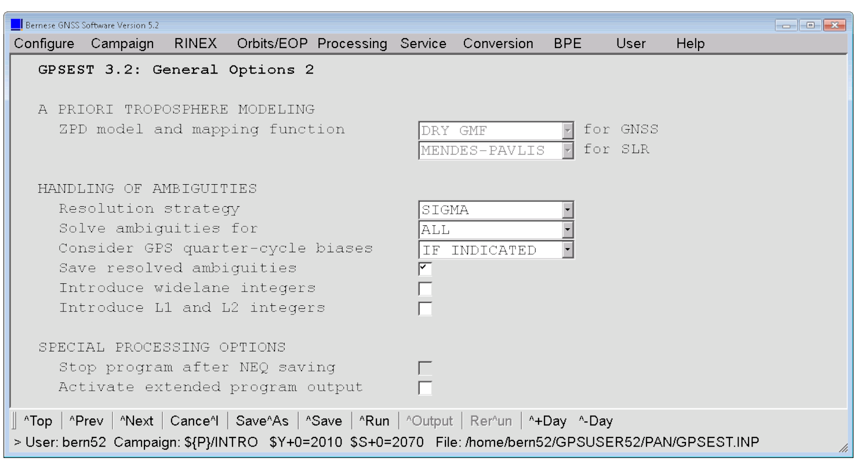


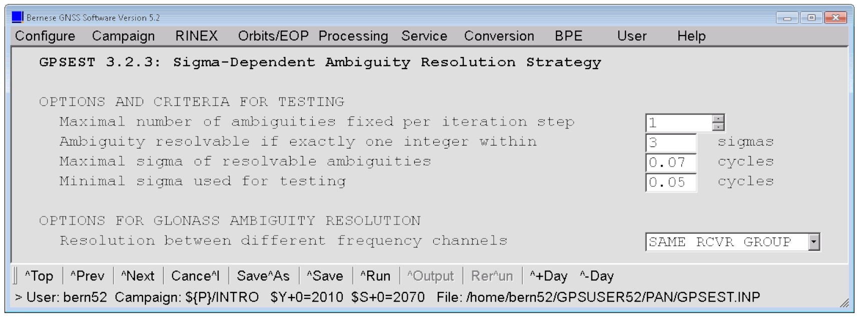


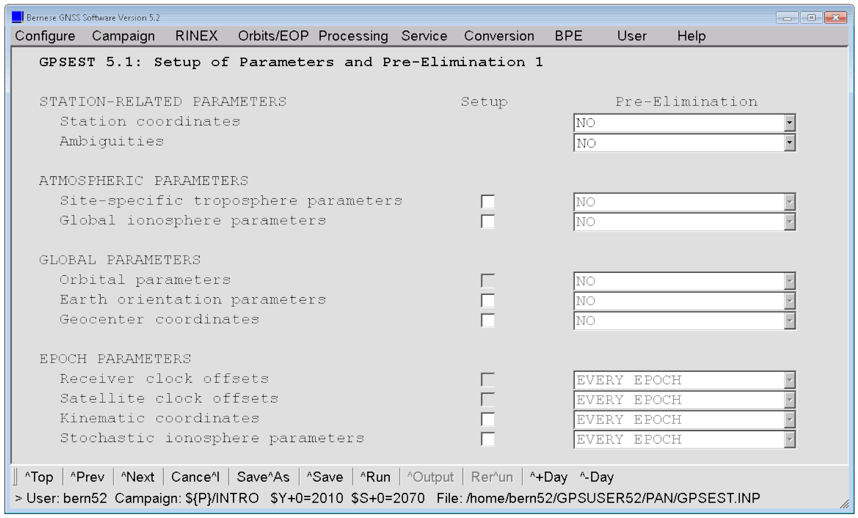
The program output name is again related to the name of the baseline but contains an identifier `1` at the end to distinguish the files from the output files of the QIF–strategy:











The structure of the program output is the same as it has extensively been described in the previous section for the QIF ambiguity resolution strategy. It starts with PART 1 for the solution before the ambiguity resolution. Here are the corresponding parameter statistics:

```
...
13. RESULTS (PART 1)
--------------------

NUMBER OF PARAMETERS (PART 1):
-----------------------------

PARAMETER TYPE                                  #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
------------------------------------------------------------------------------------------ ...

STATION COORDINATES                                       3             0                  3 ...
AMBIGUITIES                                             206             0                232 ...

------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF PARAMETERS                              209             0                235 ...
------------------------------------------------------------------------------------------ ...


NUMBER OF OBSERVATIONS (PART 1):
-------------------------------

TYPE         FREQUENCY         FILE/PAR          #OBSERVATIONS
------------------------------------------------------------------------------------------ ...

PHASE           L1               ALL                  38232
PHASE           L2               ALL                  38232

------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF OBSERVATIONS                          76464
------------------------------------------------------------------------------------------ ...
...
```

```
...

A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
-----------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0012 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     76255
CHI**2/DOF                         :      1.53
...
```

After the ambiguity resolution the same statistics is provided in PART 2:

```
...

14. RESULTS (PART 2)
--------------------

NUMBER OF PARAMETERS (PART 2):
-----------------------------

PARAMETER TYPE                                #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
------------------------------------------------------------------------------------------- ...

STATION COORDINATES                                     3           0                     3   ...
AMBIGUITIES                                            40           0                   232   ...

------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF PARAMETERS                             43           0                   235   ...
------------------------------------------------------------------------------------------- ...
...
```

```
...

A POSTERIORI SIGMA OF UNIT WEIGHT (PART 2):
-----------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0013 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     76421
CHI**2/DOF                         :      1.82
...
```

From the number of ambiguity parameters it can be computed that 166 out of 206 ambiguities from both GPS and GLONASS have been resolved to their integer numbers. Please remind, that at least 4 ambiguity parameters must remain as real values because of one reference ambiguity per GNSS and frequency are needed. Because the two receivers belong to different groups regarding "GLONASS amb. resol. between different frequencies" only the ambiguities between the same frequency numbers have been resolved. In addition, depending on the receiver type, not all ambiguities for GPS are allowed to be resolved too, to prevent problems with the quarter–cycle bias between the L2P and L2C signal (see option "Consider GPS quarter-cycle biases" in panel "GPSEST 3.2: General Options 2" and the lecture on ambiguity resolution).

5.3.3 Ambiguity Resolution: BPE

Admittedly, it is cumbersome to process the baselines "manually" one after the other — you have twelve baselines per session for this small example campaign. On Thursday you will have a lecture on automation of the data processing using the BPE .

In the example BPE `RNX2SNX.PCF` a sequence for the ambiguity resolution is included. For this tutorial lecture a small part of this BPE is extracted into a separate `TUTORIAL.PCF` BPE. The process control file (PCF) is located in the directory `${U}/PCF`. If you are not in the *Bernese Introductory Course* environment, you have to use the `RNX2SNX.PCF` instead of the `TUTORIAL.PCF` and skip the unneeded scripts (a brief description is given in the panel description of the RUNBPE) program.

The PCF consists of three parts: the first part defines the scripts and the option directories where the program's input files are taken from. In addition the waiting conditions are defined to keep the correct order for the execution of the scripts. In the second part, special execution modes are defined, e.g., that the scripts `GNSQIF_P` with PID 132 and `GNSL12_P` with PID 142 may run in parallel for each individual baseline. The preparatory scripts `GNSQIFAP` and `GNSL12AP` define the list of baselines to be processed. The third part defines the so called BPE– or PCF–variables that can be used within the scripts or in the input fields of the menu. A detailed introduction to the BPE will be the topic of a lecture on Thursday.

The `TUTORIAL.PCF` is responsible for the following tasks:

`011 TUT_COP` :
: Copies the files from the previous processing steps of the tutorial to the filenames used in the `RNX2SNX.PCF` example BPE. It uses the PCF– and time variables for that purpose:

  copy file from `../STA/APR${yyddd}.CRD` to `../STA/APR${yyssss}.CRD`
  copy file from `../STA/FLT${yyddd}.CRD` to `../STA/FLT${yyssss}.CRD`
  copy file from `../ATM/FLT${yyddd}.TRP` to `../ATM/FLT${yyssss}.TRP`
  copy file from `../ORB/COD${yyddd}.STD` to `../ORB/COD${yyssss}.STD`
  copy file from `../ORB/COD${yyddd}.ERP` to `../ORB/COD${yyssss}.ERP`

  where `${yyddd}` stands for the two–digit year and the day of year. The new filename contains `${yyssss}` the two–digit year together with the session (in our case day of year plus the zero–character `0`).

  If you are not in the *Bernese Introductory Course* environment, you have to copy these files manually to run the ambiguity resolution sequence of `RNX2SNX.PCF`.

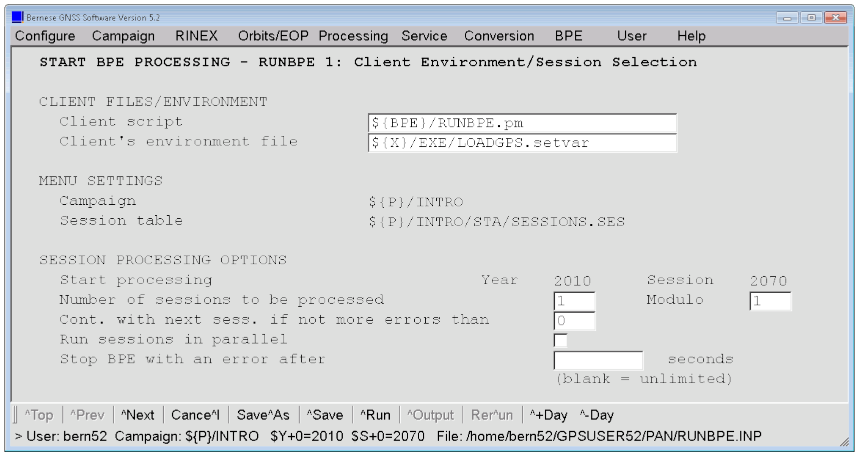
`101 SATMRK` :
: All previously resolved ambiguities are re–initialized to start for all files from unresolved ambiguities (otherwise the interpretation of the statistic of resolved ambiguities may become difficult).

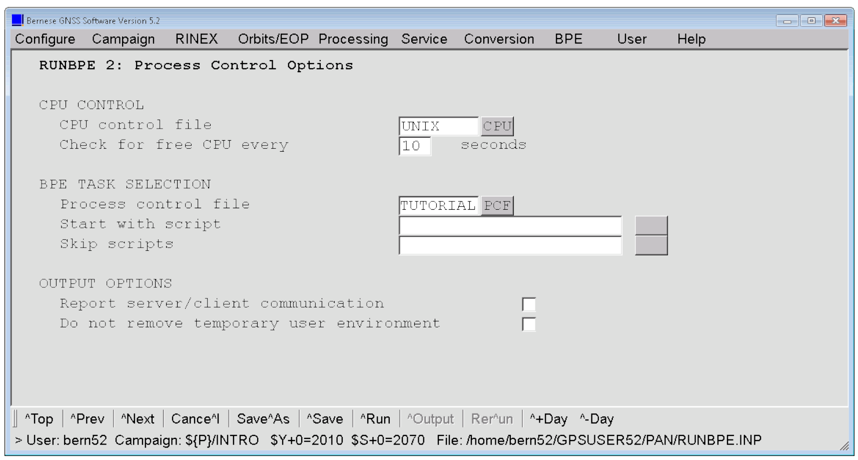
`131 GNSQIFAP` **and** `132 GNSQIF_P` :
: Applies the QIF ambiguity resolution strategy to all baselines of the example in a baseline–by–baseline mode, where several baselines may be processed at the same time in parallel.

`141 GNSL12AP` **and** `142 GNSL12_P` :
: Applies the SIGMA ambiguity resolution strategy directly to the original observations on the L_1 and L_2 frequency for both short baselines in the example network: Kötzting (WTZR and WTZZ) and Zimmerwald (ZIM2 and ZIMM). These scripts also run in a baseline–by–baseline mode, allowing for a parallel processing.

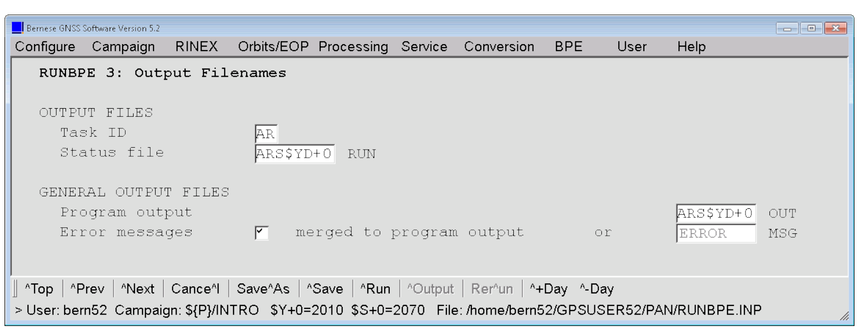
```
#
# ============================================================================
# TUTORIAL.PCF
# ============================================================================
#
# Purpose:       Run the ambiguity resolution for one session in the
#                <<Terminal Session>> of the
#                Bernese Software Introductory Course
#
# ----------------------------------------------------------------------------
#
# Author     :  R. Dach
# Created    :  23-Jan-2012               Last modified: 23-Jan-2012
#
# Changes    :
#
# ============================================================================
#
#
PID SCRIPT   OPT_DIR  CAMPAIGN CPU      P WAIT FOR....
3** 8******* 8******* 8******* 8******* 1 3** 3** 3** 3** 3** 3** 3** 3** 3** 3**
#
# Copy input files
# ----------------
011 TUT_COP  R2S_GEN           ANY      1
#
# Resolve phase ambiguities
# -------------------------
101 SATMRK   R2S_GEN           ANY      1 011
131 GNSQIFAP R2S_QIF           ANY      1 101
132 GNSQIF_P R2S_QIF           ANY      1 131
141 GNSL12AP R2S_L12           ANY      1 132
142 GNSL12_P R2S_L12           ANY      1 141
#
# End of BPE
# ----------
999 DUMMY    NO_OPT            ANY      1 142
#
#
PID USER         PASSWORD PARAM1   PARAM2   PARAM3   PARAM4   PARAM5   PARAM6
..
3** 12********** 8******* 8******* 8******* 8******* 8******* 8******* 8*******..
#
# Resolve phase ambiguities
# -------------------------
131                       $131
132                       PARALLEL $131
141                       $141
142                       PARALLEL $141
#
#
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 16**************
V_A      A priori information                     APR
V_B      Orbit/ERP, DCB, CLK information          COD
V_C      Preliminary (ambiguity-float) results    FLT
V_CRDINF Project related station filenames        EXAMPLE
V_GNSSAR GNSS to be used for ambiguity resolution ALL
V_BL_QIF Maximum baseline length for QIF AR       2000
V_BL_L12 Maximum baseline length for L1&L2 AR     20
V_PCV    Absolute/relative PCV model              I14
V_SATINF Satellite information file               SATELLIT
V_PCVINF PCV information file                     PCV_Bxx
V_SATCRX Satellite problem file                   SAT_$Y+0
V_RECINF Receiver characterization file           RECEIVER.
V_BLQINF BLQ FILE NAME, CMC CORRECTIONS           EXAMPLE
V_ATLINF ATL FILE NAME, CMC CORRECTIONS           EXAMPLE
V_HOIFIL Ionosphere model                         COD$YD+0
#
# DO NOT USE V_D, V_J, V_M, V_Y VARIABLES!
# (they are used already by the menu)
#
```

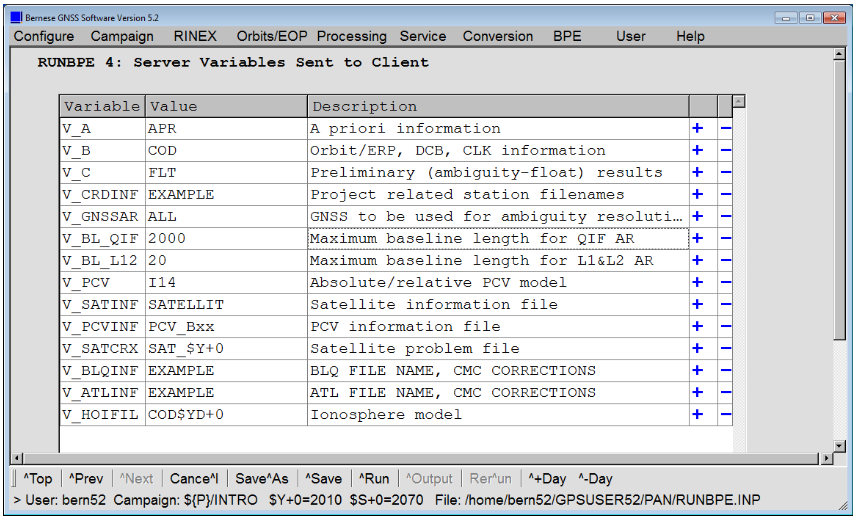
In the *Bernese Introductory Course* environment the `TUTORIAL.PCF` BPE can be started for one session (e.g., day 207 of year 2010) using "Menu>BPE>Start BPE processing":





If you follow the tutorial outside from the environment of the *Bernese Introductory Course* you can select RNX2SNX in option "Process control file" and skip all scripts apart from `PID 401 SATMRK` and the range from `PID 431 GNSQIFAP` to `PID 442 GNSL12_P` (option "Skip scripts").

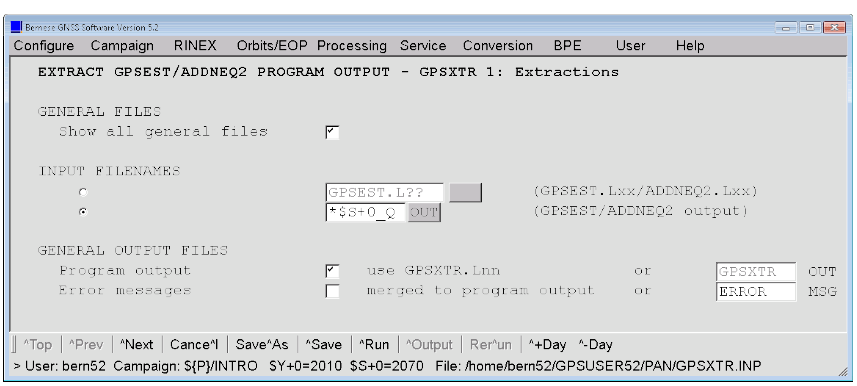




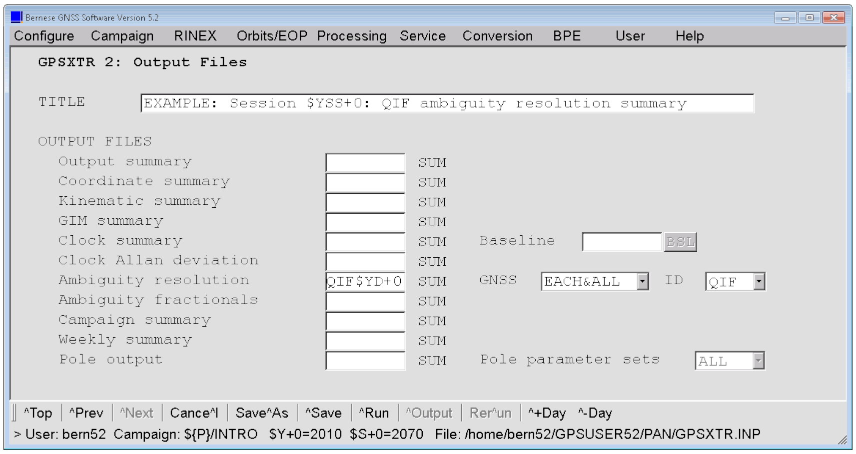
Run the BPE for the current session. If the BPE stops with an error you can inspect the files `ARyyddd0_...PRT` and `ARyyddd0_...LOG` belonging to your current session. They are located in the BPE directory of your campaign. These files notice for instance if an input file is missing. This might be the case if you did not follow the naming convention proposed in the tutorial. In that case you have to copy the file from your naming to the expected one.

5.3.4 Ambiguity Resolution: Summary

For each observation file a corresponding program output file is generated. Using the program GPSXTR ("Menu>Processing>Program output extraction>Parameter estimation/stacking") you can generate a summary of the ambiguity resolution for all baselines of the session:



All program output files related to the QIF ambiguity resolution method have been specified with program output filenames fitting in the shape `${P}/INTRO/OUT/????$S+0_Q.OUT` and can, therefore, easily be selected in the input field "GPSEST/ADDNEQ output files".



The program issues a warning message because only for a global network the evaluation of the ambiguity resolution statistics allow to assess the orbit quality:

```
### SR EXTAMB: ORBIT ACCURACY NOT ESTIMATED
```

This summary (`${P}/INTRO/OUT/QIF10207.SUM`) reports among others how many ambiguities are resolved for each baseline[1]:

```
File      Sta1 Sta2     Length      Before      After     Res  Sys
                         (km)     #Amb  (mm)  #Amb  (mm)  (%)
---------------------------------------------------------------- ...
GAJO2070  GANP JOZ2    344.407    102   1.1    24   1.1   76.5 G     ... #AR_QIF
GAJO2070  GANP JOZ2    344.407     90   1.1    38   1.1   57.8  R    ... #AR_QIF
GAJO2070  GANP JOZ2    344.407    192   1.1    62   1.1   67.7 GR    ... #AR_QIF
HEZI2070  HERT ZIM2    685.151    120   1.1    46   1.1   61.7 G     ... #AR_QIF
HEZI2070  HERT ZIM2    685.151     98   1.1    64   1.1   34.7  R    ... #AR_QIF
HEZI2070  HERT ZIM2    685.151    218   1.1   110   1.1   49.5 GR    ... #AR_QIF
JOLA2070  JOZ2 LAMA    201.183    118   1.0    36   1.0   69.5 G     ... #AR_QIF
JOLA2070  JOZ2 LAMA    201.183     96   1.0    38   1.0   60.4  R    ... #AR_QIF
JOLA2070  JOZ2 LAMA    201.183    214   1.0    74   1.0   65.4 GR    ... #AR_QIF
JOON2070  JOZ2 ONSA    829.775    136   1.0    58   1.1   57.4 G     ... #AR_QIF
JOON2070  JOZ2 ONSA    829.775    104   1.0    68   1.1   34.6  R    ... #AR_QIF
JOON2070  JOZ2 ONSA    829.775    240   1.0   126   1.1   47.5 GR    ... #AR_QIF
JOWS2070  JOZ2 WSRT    981.243    106   1.1    32   1.1   69.8 G     ... #AR_QIF
JOWT2070  JOZ2 WTZR    663.182    104   1.4    28   1.5   73.1 G     ... #AR_QIF
JOWT2070  JOZ2 WTZR    663.182     98   1.4    50   1.5   49.0  R    ... #AR_QIF
JOWT2070  JOZ2 WTZR    663.182    202   1.4    78   1.5   61.4 GR    ... #AR_QIF
MAZI2070  MATE ZIM2   1013.811    122   1.2    54   1.3   55.7 G     ... #AR_QIF
MAZI2070  MATE ZIM2   1013.811     94   1.2    60   1.3   36.2  R    ... #AR_QIF
MAZI2070  MATE ZIM2   1013.811    216   1.2   114   1.3   47.2 GR    ... #AR_QIF
PTZI2070  PTBB ZIM2    640.077    114   1.3    26   1.4   77.2 G     ... #AR_QIF
TLZI2070  TLSE ZIM2    596.848    120   1.3    20   1.3   83.3 G     ... #AR_QIF
TLZI2070  TLSE ZIM2    596.848     90   1.3    58   1.3   35.6  R    ... #AR_QIF
TLZI2070  TLSE ZIM2    596.848    210   1.3    78   1.3   62.9 GR    ... #AR_QIF
WTZI2070  WTZR ZIM2    475.909    116   1.5    44   1.5   62.1 G     ... #AR_QIF
WTZI2070  WTZR ZIM2    475.909     92   1.5    56   1.5   39.1  R    ... #AR_QIF
WTZI2070  WTZR ZIM2    475.909    208   1.5   100   1.5   51.9 GR    ... #AR_QIF
-----------------------------------------------------------------...
Tot:   10              643.159   1158   1.2   368   1.3   68.2 G     ... #AR_QIF
Tot:    8              601.283    762   1.2   432   1.3   43.3  R    ... #AR_QIF
Tot:   10              643.159   1920   1.2   800   1.3   58.3 GR    ... #AR_QIF
```

[1] You may check the impact of introducing the ionosphere model (`COD$YD+0` in "Ionosphere models" of panel "GPSEST 1.1: Input Files 1") by cleaning this input field. Repeat the ambiguity resolution (*without saving the resolved ambiguities into the observation file: unmark option* "Save resolved ambiguities" *in panel* "GPSEST 3.2: General Options 2") and compare the a posteriori RMS and the number of resolved ambiguities.

An analogue statistics can be produced for the short baseline ambiguity resolution. Exchange the entry for the input file selection ("GPSEST/ADDNEQ output files") to catch all files of the shape `${P}/INTRO/OUT/????$S+0_1.OUT`. It is recommended to change also the name of the resulting summary ("Ambiguity res. summary") and the identification string in the summary (e.g., L12 for "Ambiguity resolution: #AR_ID") in panel "GPSXTR 2: Output Files".

```
File      Sta1 Sta2    Length      Before      After    Res  Sys
                        (km)     #Amb (mm)   #Amb (mm)  (%)        ...
---------------------------------------------------------------- ...
WTWZ2070  WTZR WTZZ      0.002    108  1.2     16  1.3  85.2 G     ... #AR_L12
WTWZ2070  WTZR WTZZ      0.002     94  1.2     20  1.3  78.7  R    ... #AR_L12
WTWZ2070  WTZR WTZZ      0.002    202  1.2     36  1.3  82.2 GR    ... #AR_L12
ZIZM2070  ZIM2 ZIMM      0.019    108  1.1      2  1.1  98.1 G     ... #AR_L12
-----------------------------------------------------------------...
Tot:   2                 0.010    216  1.2     18  1.2  91.7 G     ... #AR_L12
Tot:   1                 0.002     94  1.2     20  1.3  78.7  R    ... #AR_L12
Tot:   2                 0.010    310  1.2     38  1.2  87.7 GR    ... #AR_L12
```

The solutions from the BPE are identical to the two manually processed solutions. You can compare the following two files in `${P}/INTRO/OUT` for each strategy (e.g., with `tkdiff`):

		Filenames from
	Manual processing	processed by the BPE
Strategy: QIF:	`GAJO207Q.OUT`	`GAJO2070_Q.OUT`
Strategy: direct L_1/L_2:	`WTWZ2071.OUT`	`WTWZ2070_1.OUT`

If you compare the number of ambiguity parameters in the GPSEST program output with the number of ambiguities in the GPSXTR summary files, the number of reference ambiguities that need to be kept unresolved are considered.

5.4 Daily Goals

At the end of today's session, you should have:

1. *used GPSEST for residual screening, created files: **EDT10207.OUT**, **EDT10207.RES** in your campaign's **OUT** directory,*
2. *screened the residual files from the above run using RESRMS: created files **RMS10207.SUM**, **RMS10207.LST**, **RMS10207.EDT**, and **RMS10207.OUT**,*
3. *used SATMRK to mark the identified outliers,*
4. *used GPSEST for a first coordinate and troposphere estimation, created files: **FLT10207.CRD** and **FLT10207.TRP**,*
5. *used **GPSEST** for QIF ambiguity resolution, created files: **GAJO207Q.OUT**,*
6. *used **GPSEST** for direct SIGMA ambiguity resolution, created files: **WTWZ2071.OUT**,*
7. *apply the ambiguity resolution to all baselines running a BPE,*
8. *used GPSXTR to create a summary of the ambiguity resolution, created file: **QIF10207.SUM***

Proposal for Further Activities

Even if it is not needed for the processing progress of the regional network you may use some time in this terminal session to have a look into the examples for "Epoch Parameter Processing" (sections 7.3 for *Kinematic Positioning* and 7.4 for *Zero Difference Processing for Clock Estimation*). This section also provides some instructions on other topics, e.g., the usage of RINEX 3 observation files in Section 7.5 .

Note that some panels assume the availability of the final solution for regional network processing (`FIN$YD+0`) that will be generated in the terminal session of tomorrow only. You may replace these files by the results from the first network solution before the ambiguity resolution (`FLT$YD+0`) for this exercise.

6 Terminal Session: Thursday

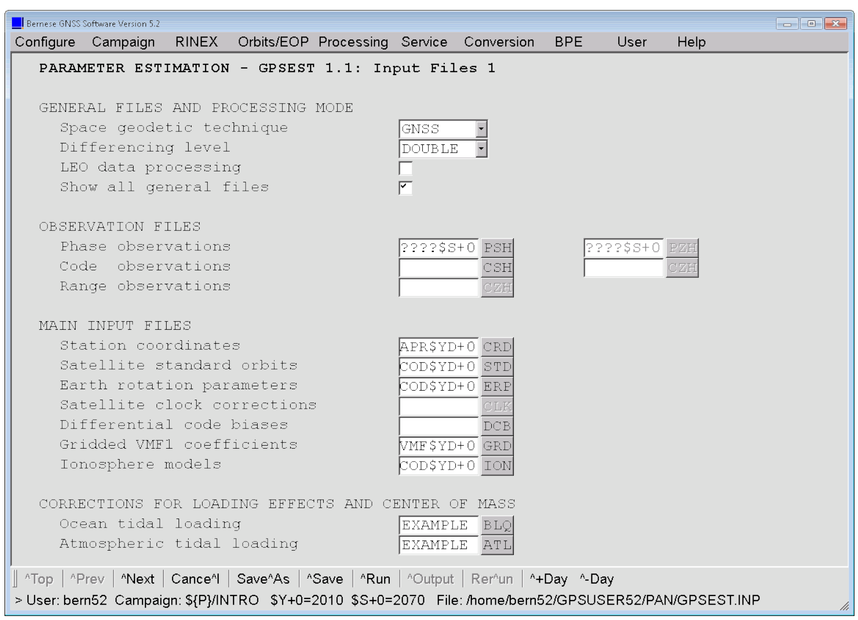
Finish the work of yesterday by resolving the ambiguities for all baselines (day 207 year 2010).
Today's terminal session is to:

1. *compute a final network solution of the day (GPSEST),*
2. *check the coordinates of the fiducial sites (ADDNEQ2, HELMR1),*
3. *check the daily repeatability (COMPAR),*
4. *recompute final solution and generate reduced size normal equation files (ADDNEQ2),*
5. *compute velocities (ADDNEQ2),*

for the current session. Compare the final coordinate results of the daily solutions (which are already processed and available).

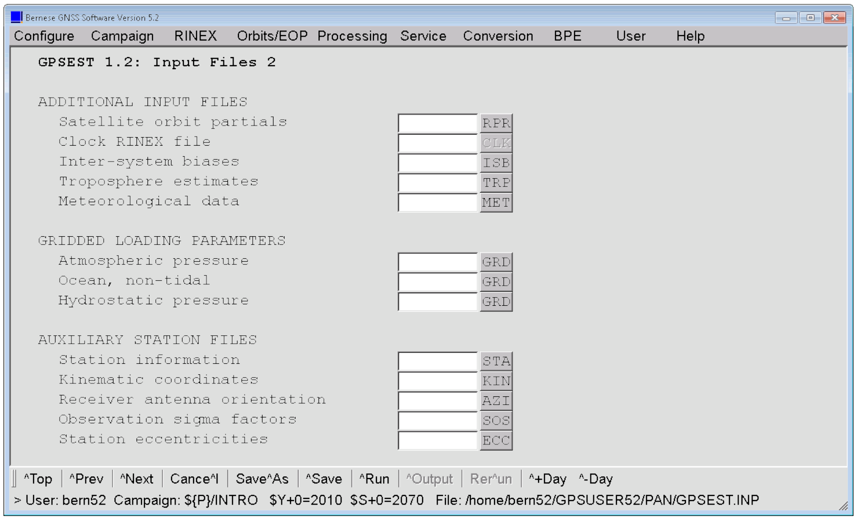
6.1 Final Network Solution

The resolved ambiguities may be introduced from the Bernese observation files into the final network solution. To start the program GPSEST in session mode you have to select all single difference files of the corresponding session. In panel "GPSEST 1.1: Input Files 1":

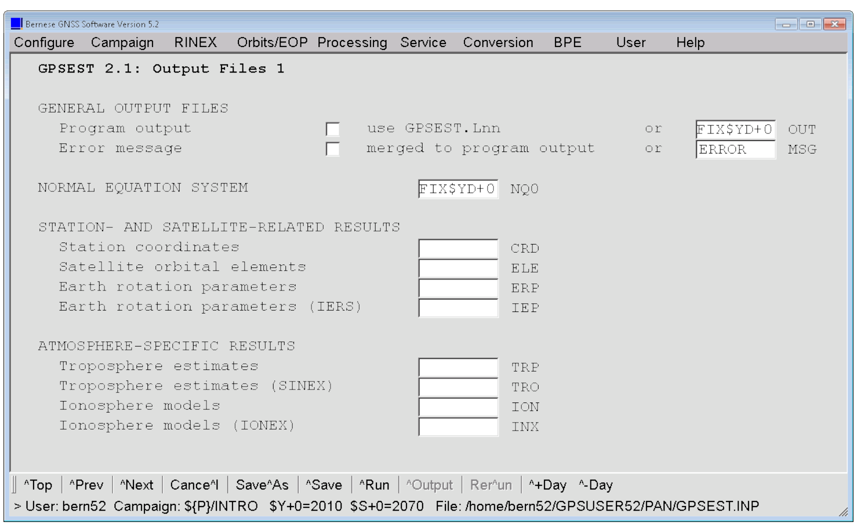


If the grid files for the coefficients of the VMF1 are available (downloaded from `http://vmf.geo.tuwien.ac.at/trop_products/GRID/2.5x2/VMF1/VMF1_OP` and the five grid files of the day are concatenated), we can introduce them into panel "GPSEST 1.1: Input Files 1".

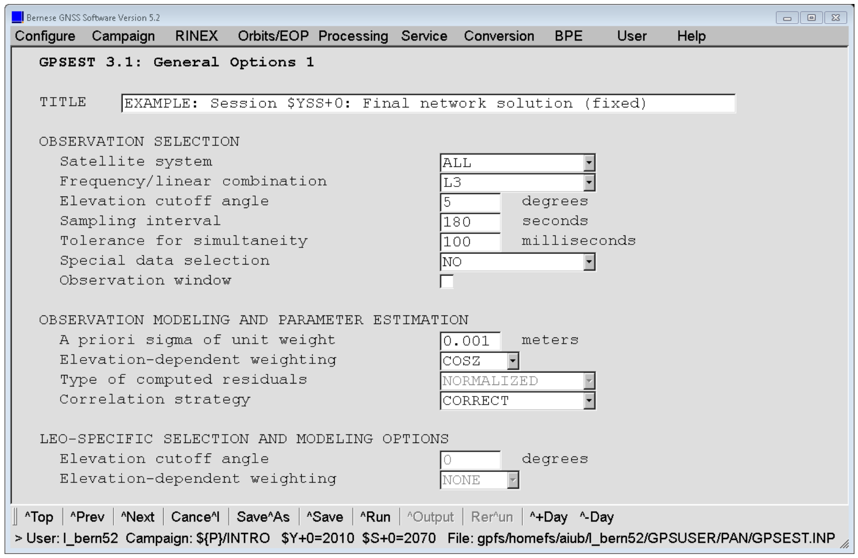
We do not introduce “Troposphere estimates” anymore from the previous solutions.



In panel “GPSEST 2.1: Output Files 1” we request the normal equation file as the only output file.

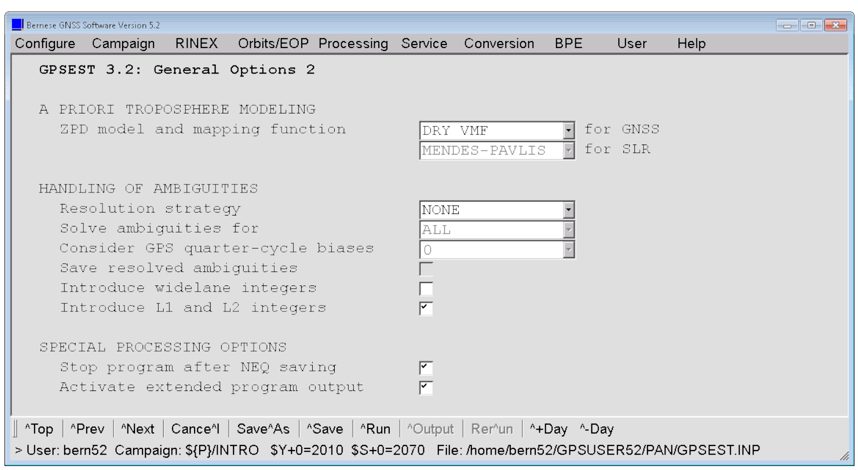


For the final run of GPSEST we consider the correlations between the observations correctly:



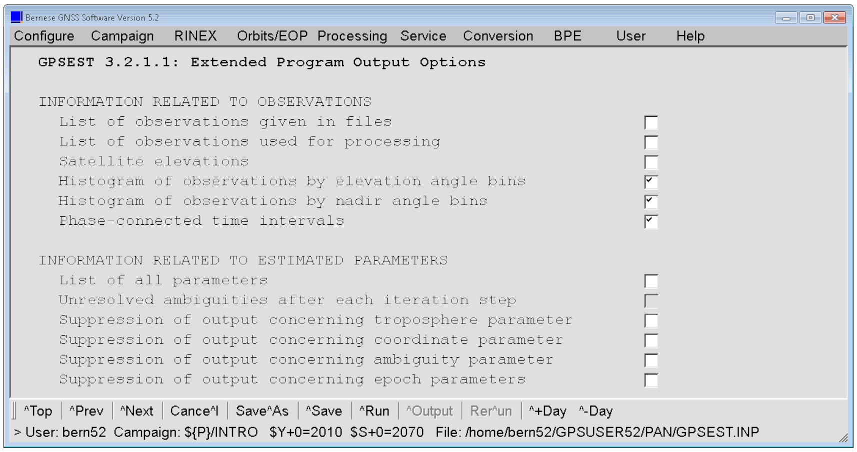
If the VMF1 grid files are available we can switch now from DRY_GMF to DRY_VMF to use the VMF1 instead of the Global Mapping Function (GMF). In the *Bernese Introductory Course* environment these files are available. Remember that you need to specify the grid files with the coefficients in the input field "Gridded VMF1 coefficients" in panel "GPSEST 1.1: Input Files 1".

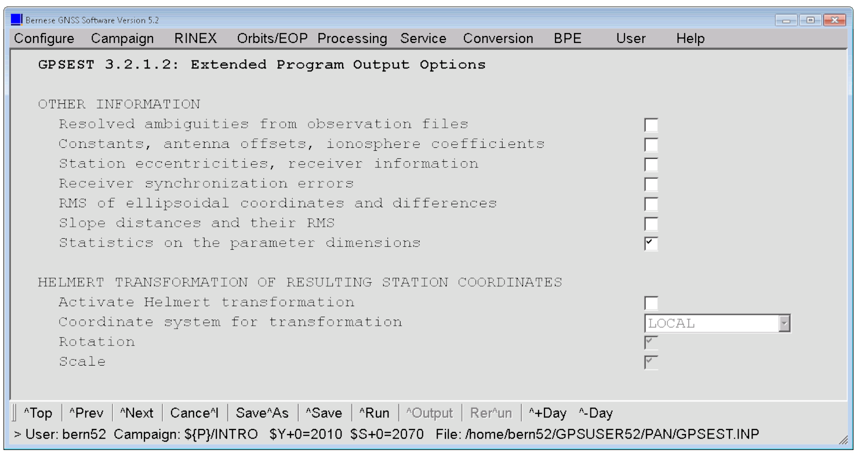
Ambiguities which have been resolved in the previous runs of program GPSEST are introduced as known.



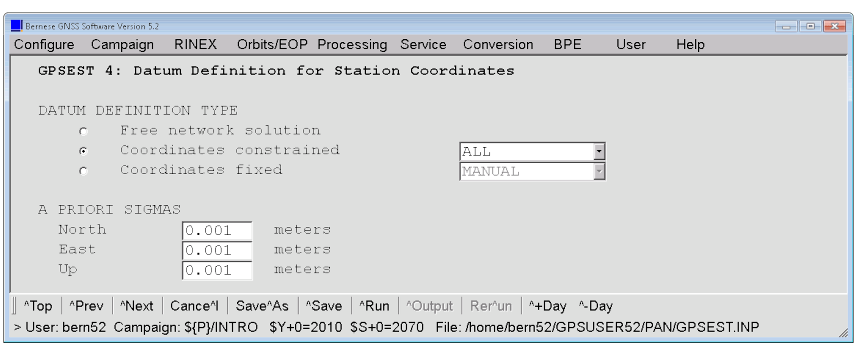
The checkbox in option "Stop program after NEQ saving" reduces the task of GPSEST to setting up the NEQ but not solving it. In particular in case of bigger networks this may save a lot of computing time because the solution for the session will be computed later on by ADDNEQ2 anyhow.

Since this is the final run of GPSEST, it is worthwhile to add some additional information about the observation files into the program output. This is useful if you archive the program output of this run together with the observation files and the resulting normal equation files.

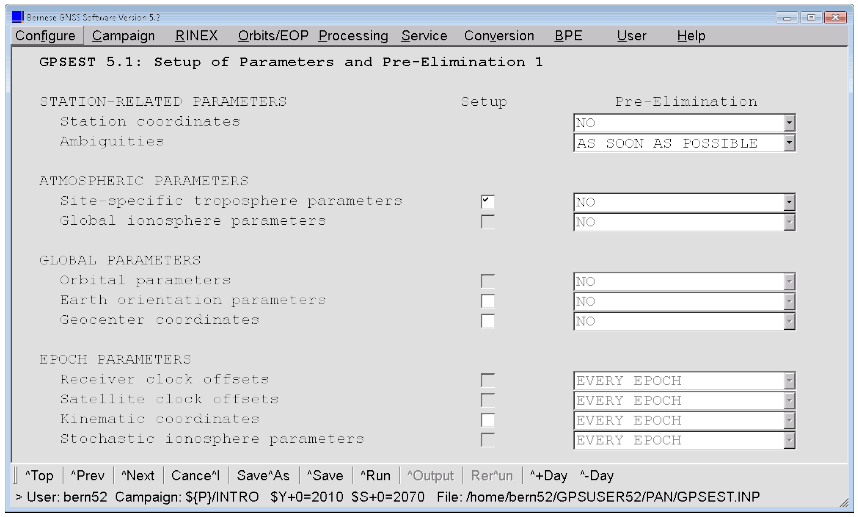




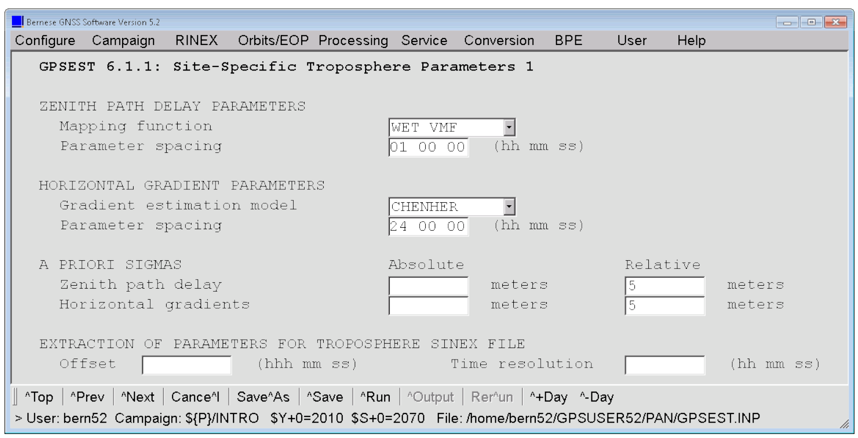
We do not fix any stations on their a priori position, i.e., the coordinates of all stations will be estimated. This retains the flexibility for later changes in the realization of the reference frame (station constraints) with program ADDNEQ2. Because no solution in GPSEST is computed you can select here all types of datum definition apart from "Coordinates fixed" (the normal equations are always stored without any constraints):



The unresolved ambiguities are pre–eliminated. In addition we may setup additional parameters of interest.



The selection of the mapping function has to be consistent with the selection of the troposphere model in "ZPD model and mapping function (GNSS)" in panel "GPSEST 3.2: General Options 2".



The output of the GPSEST contains only the input parameter and ends with the parameter statistics:

```
 13. RESULTS (PART 1)
 --------------------

 NUMBER OF PARAMETERS (PART 1):
 -----------------------------

 PARAMETER TYPE                                #PARAMETERS   #PRE-ELIMINATED        #SET-UP ...
------------------------------------------------------------------------------------------- ...

 STATION COORDINATES                                39            0                     39   ...
 AMBIGUITIES                                       673          673  (BEFORE INV)      785   ...
 SITE-SPECIFIC TROPOSPHERE PARAMETERS              377            0                    377   ...

 ------------------------------------------------------------------------------------------ ...
 TOTAL NUMBER OF PARAMETERS                       1089          673                   1201   ...
 ------------------------------------------------------------------------------------------ ...
```

```
 NUMBER OF OBSERVATIONS (PART 1):
 -------------------------------

 TYPE         FREQUENCY         FILE/PAR          #OBSERVATIONS
 ------------------------------------------------------------------------------------------- ...

 PHASE           L3               ALL                   73602

 ------------------------------------------------------------------------------------------- ...
 TOTAL NUMBER OF OBSERVATIONS                           73602
 ------------------------------------------------------------------------------------------- ...

 SOLUTION SKIPPED...



-----------------------------------------------------------------
>>> CPU/Real time for pgm "GPSEST": 0:00:47.682 / 0:00:47.752
>>> Program finished successfully
```

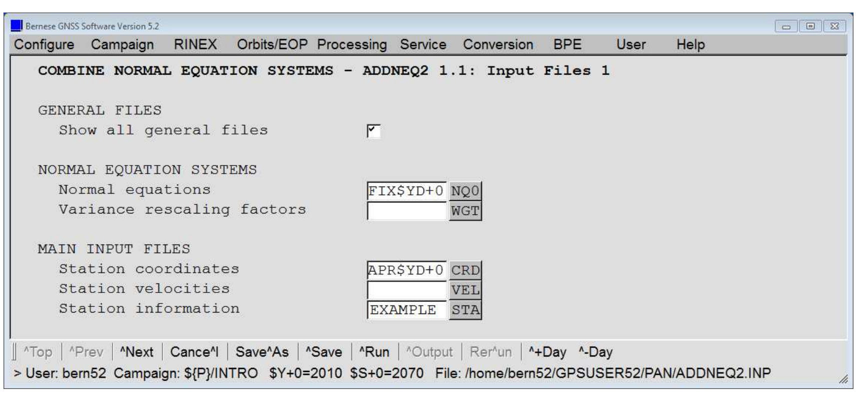
After running GPSEST in session mode the normal equation file FIX10207.NQ0 should be available in the directory ${P}/INTRO/SOL

In the environment of the *Bernese Introductory Course* these files are provided in the archive ${S}/RNX2SNX/2010/SOL/ and ${S}/RNX2SNX/2011/SOL/ respectively. Copy the files of the additional three days into your campaign. Following files should be now available in the directory ${P}/INTRO/SOL

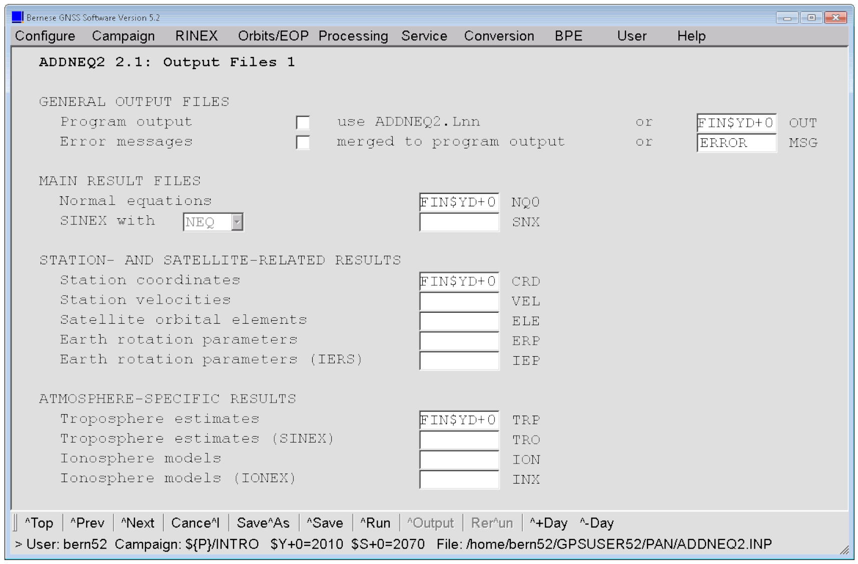
FIX10207.NQ0, FIX10208.NQ0, and
FIX11205.NQ0, FIX11206.NQ0.

6.2 Check the Coordinates of the Fiducial Sites

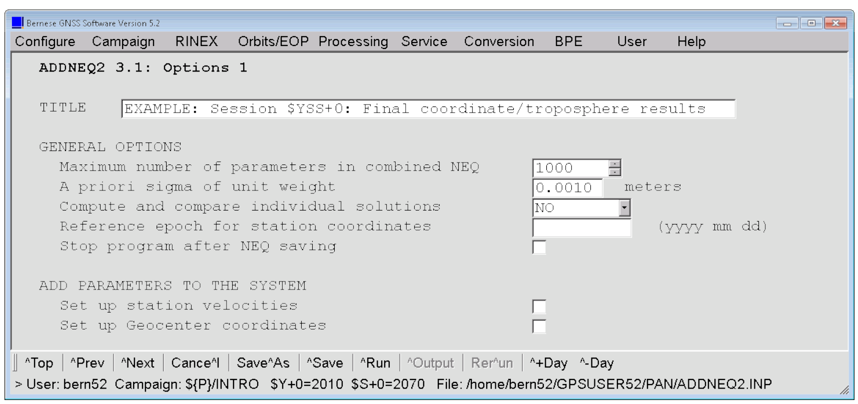
To check the consistency of our network solution with respect to the coordinates available in the IGS14 reference frame we generate a minimum constraint solution for the network using program ADDNEQ2 ("Menu>Processing>Combine normal equation systems") with the following options:

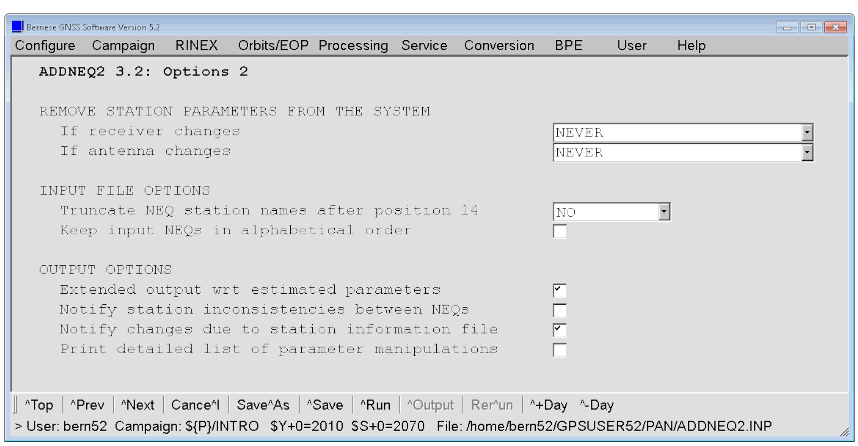


No further input files in the next panel are needed.



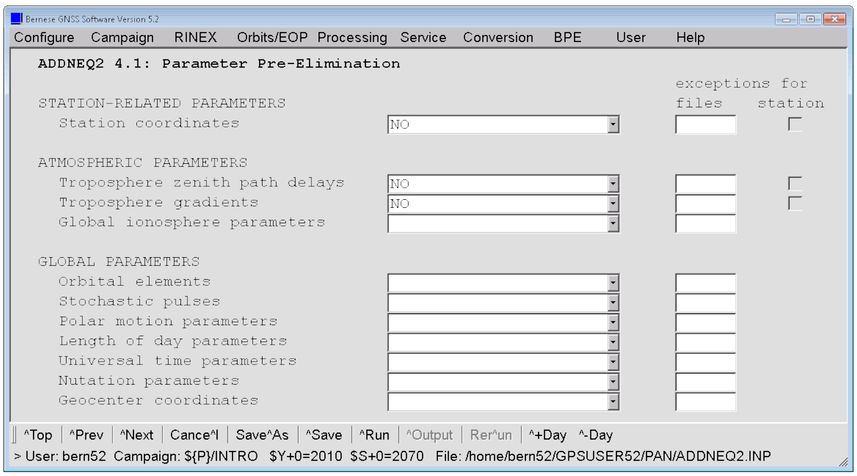
A troposphere SINEX file may be generated in this solution by adding an output filename to the "Troposphere estimates (SINEX)" input field in panel "ADDNEQ2 2.1: Output Files 1".



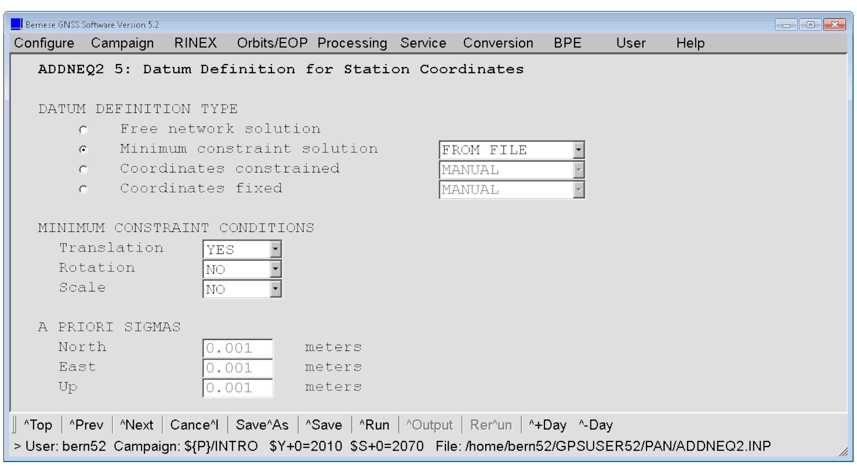


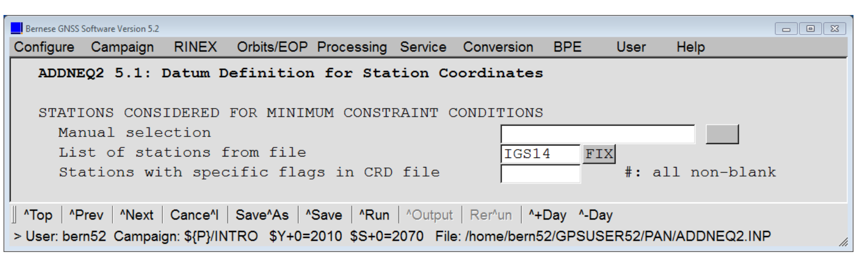
In the following three panels, all parameter types supported by ADDNEQ2 are listed. You may specify whether a parameter shall be pre-eliminated or not. An empty entry means that the parameter is not expected in the input NEQ files.

Please note that an automated preselection is not possible for technical reasons. If a parameter with an empty input field is detected in the input NEQ files, the program will stop with an error. In the opposite case, a warning message is issued.

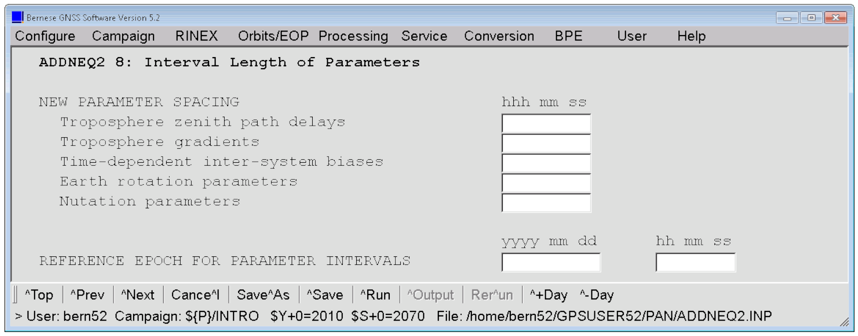


For the validation of the datum stations we choose the "Minimum constraint solution". Because it is a regional network, we only apply the no–translation condition. The other conditions are sufficiently defined by the satellite orbits.

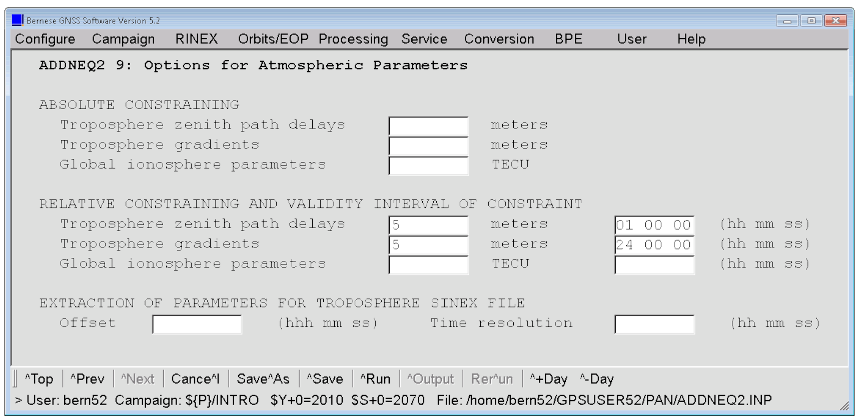




The following panel allows to change the parameter spacing. We do not need this feature at the moment and leave, therefore, all input fields empty.



The relative constraints applied to the vertical troposphere and gradient parameters are so loose that they do not affect the solution. As in GPSEST, they simply prevent a format overflow in the output troposphere file in case of very weakly observed parameters due to gaps in the observation scenario.



The ADDNEQ2 program output starts with some information about the parameters contained in the input NQ0 file(s). The input options for the program run follow. An important part is the statistics for the current ADDNEQ2 solution:

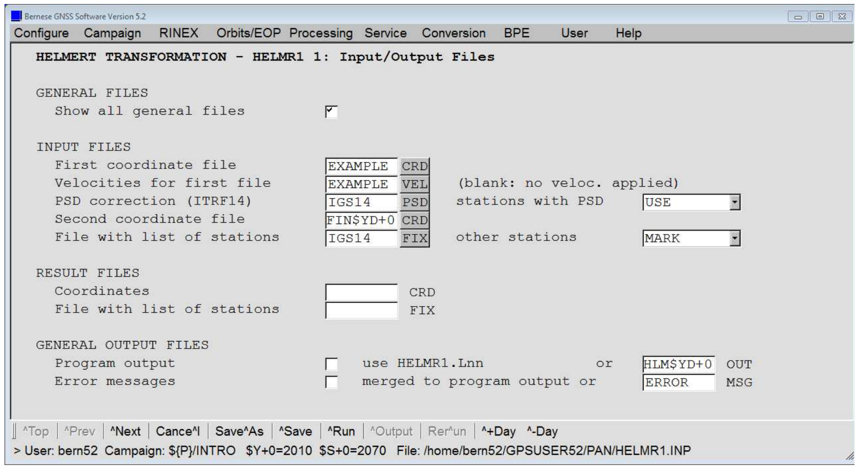
```
...

SUMMARY OF RESULTS
------------------

Number of parameters:
--------------------

Parameter type                                      Adjusted   explicitly / implicitly .. Deleted ...
------------------------------------------------------------------------------------- .. ------- ...
Station coordinates / velocities                          39          39             0          0 ...
Site-specific troposphere parameters                     377         377             0          0 ...
------------------------------------------------------------------------------------- .. ------- ...
Previously pre-eliminated parameters                     656                       656
------------------------------------------------------------------------------------- .. ------- ...
Total number                                            1072         416           656          0
...
```

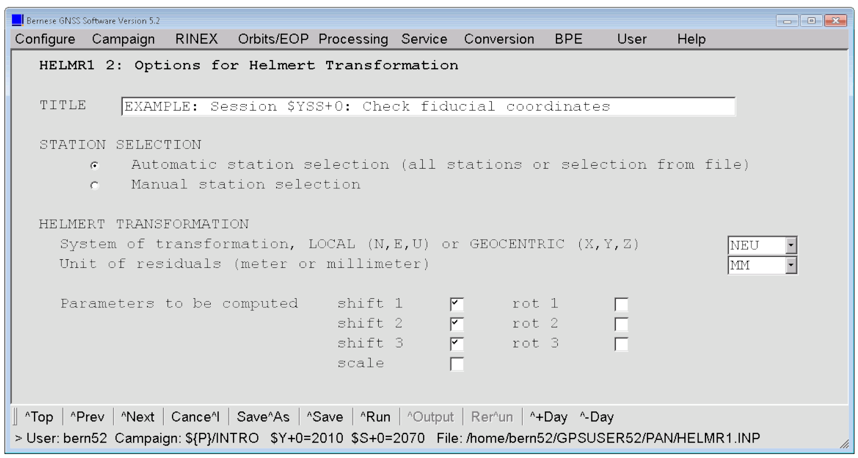
```
...
Statistics:
----------

Total number of authentic observations       73602
Total number of pseudo-observations            341

Total number of explicit parameters            416
Total number of implicit parameters            656

Total number of observations                 73943
Total number of adjusted parameters           1072
Degree of freedom (DOF)                      72871

A posteriori RMS of unit weight            0.00115 m
Chi**2/DOF                                    1.32

Total number of observation files               12
Total number of stations                        13
Total number of satellites                       0
...
```

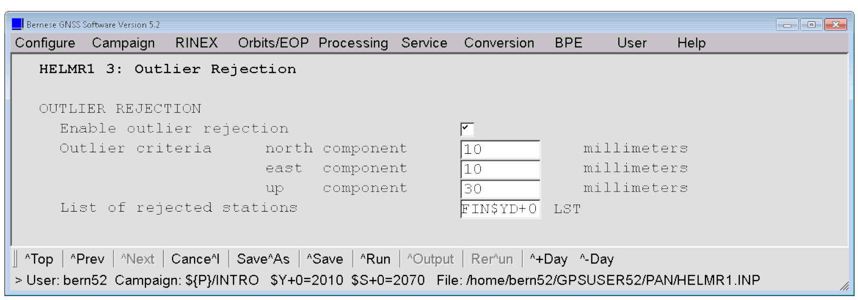
Below this part the program output reports the results of the parameter estimation in a standardized format for all parameter types:

```
...
Station coordinates and velocities:
----------------------------------

Sol Station name         Typ Correction  Estimated value  RMS error   A priori value  ... Abb
------------------------------------------------------------------------------------- ... ----
  1 GANP 11515M001         X   -0.00246    3929181.41903    0.00050    3929181.42149  ... #CRD
  1 GANP 11515M001         Y   -0.00001    1455236.82073    0.00024    1455236.82074  ... #CRD
  1 GANP 11515M001         Z   -0.00240    4793653.94773    0.00059    4793653.95013  ... #CRD
  1 HERT 13212M010         X   -0.00135    4033460.84830    0.00058    4033460.84965  ... #CRD
  1 HERT 13212M010         Y   -0.00158      23537.88819    0.00020      23537.88977  ... #CRD
  1 HERT 13212M010         Z    0.00045    4924318.31497    0.00062    4924318.31452  ... #CRD
  1 JOZ2 12204M002         X   -0.00418    3664880.47678    0.00051    3664880.48096  ... #CRD
  1 JOZ2 12204M002         Y   -0.00372    1409190.67690    0.00025    1409190.68062  ... #CRD
  1 JOZ2 12204M002         Z   -0.00019    5009618.53001    0.00063    5009618.53020  ... #CRD
  1 LAMA 12209M001         X   -0.00759    3524522.82514    0.00055    3524522.83273  ... #CRD
...

Site-specific troposphere parameters:
------------------------------------

Station name         Typ     Correction  Estimated value  RMS error   A priori value  ... Abb
------------------------------------------------------------------------------------- ... ---
GANP 11515M001         N       -0.00035         -0.00035    0.00007          0.00000  ... #TRP
GANP 11515M001         E        0.00011          0.00011    0.00009          0.00000  ... #TRP
GANP 11515M001         U        0.13553          2.24964    0.00135          2.11411  ... #TRP
GANP 11515M001         U        0.13073          2.24507    0.00101          2.11433  ... #TRP
GANP 11515M001         U        0.13286          2.24742    0.00095          2.11456  ... #TRP
GANP 11515M001         U        0.13901          2.25379    0.00097          2.11478  ... #TRP
GANP 11515M001         U        0.13493          2.24993    0.00085          2.11500  ... #TRP
GANP 11515M001         U        0.13519          2.25041    0.00098          2.11522  ... #TRP
GANP 11515M001         U        0.13060          2.24604    0.00095          2.11544  ... #TRP
GANP 11515M001         U        0.13367          2.24951    0.00082          2.11584  ... #TRP
GANP 11515M001         U        0.13178          2.24801    0.00089          2.11623  ... #TRP
GANP 11515M001         U        0.13341          2.25003    0.00085          2.11662  ... #TRP
GANP 11515M001         U        0.13276          2.24977    0.00083          2.11701  ... #TRP
GANP 11515M001         U        0.13687          2.25427    0.00083          2.11740  ... #TRP
GANP 11515M001         U        0.14007          2.25786    0.00077          2.11779  ... #TRP
GANP 11515M001         U        0.14164          2.25973    0.00086          2.11809  ... #TRP
GANP 11515M001         U        0.13776          2.25614    0.00104          2.11838  ... #TRP
GANP 11515M001         U        0.13772          2.25639    0.00096          2.11867  ... #TRP
GANP 11515M001         U        0.13297          2.25194    0.00101          2.11897  ... #TRP
GANP 11515M001         U        0.13823          2.25749    0.00091          2.11926  ... #TRP
GANP 11515M001         U        0.13867          2.25822    0.00088          2.11955  ... #TRP
GANP 11515M001         U        0.13921          2.25881    0.00088          2.11960  ... #TRP
GANP 11515M001         U        0.13899          2.25864    0.00101          2.11965  ... #TRP
GANP 11515M001         U        0.13434          2.25403    0.00102          2.11970  ... #TRP
GANP 11515M001         U        0.14064          2.26039    0.00094          2.11975  ... #TRP
GANP 11515M001         U        0.14075          2.26055    0.00107          2.11980  ... #TRP
GANP 11515M001         N        0.00019          0.00019    0.00007          0.00000  ... #TRP
GANP 11515M001         E        0.00080          0.00080    0.00009          0.00000  ... #TRP
GANP 11515M001         U        0.13904          2.25888    0.00140          2.11985  ... #TRP
HERT 13212M010         N       -0.00105         -0.00105    0.00007          0.00000  ... #TRP
HERT 13212M010         E       -0.00216         -0.00216    0.00010          0.00000  ... #TRP
HERT 13212M010         U        0.20436          2.50827    0.00162          2.30390  ... #TRP
 ...
```

The coordinate solution for the session (`${P}/INTRO/STA/FIN10207.CRD`) may be compared with the a priori coordinates for the IGS core sites. The program HELMR1 ("Menu >Service>Coordinate tools>Helmert transformation") is used for this purpose:







For our example we get the following output. The M–flag for some stations indicates that they are not used to compute the transformation parameters. For these sites, only the residuals are printed to the program output.

```
===============================================================================
Bernese GNSS Software, Version 5.2
-------------------------------------------------------------------------------
Program        : HELMR1
Purpose        : Helmert Transformation
-------------------------------------------------------------------------------
Campaign       : ${P}/INTRO
Default session: 2070 year 2010
Date           : 28-Aug-2017 15:43:08
User name      : bern52
===============================================================================


EXAMPLE: Session 102070: Check fiducial coordinates
-------------------------------------------------------------------------------


FILE 1: EXAMPLE.CRD: IGS14: coordinate list
FILE 2: FIN10207.CRD: EXAMPLE: Session 102070: Final coordinate/troposphere res

LOCAL GEODETIC DATUM: IGS14
RESIDUALS IN LOCAL SYSTEM (NORTH, EAST, UP)



 ---------------------------------------------------------------------
| NUM |      NAME        | FLG |     RESIDUALS IN MILLIMETERS   |   |
 ---------------------------------------------------------------------
|     |                  |     |                                |   |
|  75 | GANP 11515M001   | I W |      -0.24     -0.40      3.40 |   |
|  92 | HERT 13212M010   | I W |      -1.50      1.34      0.71 |   |
| 107 | JOZ2 12204M002   | P A |      -3.44      2.98      3.26 | M |
| 122 | LAMA 12209M001   | P A |      -4.14      1.30      7.27 | M |
| 136 | MATE 12734M008   | I W |       3.61      1.02     -1.72 |   |
| 176 | ONSA 10402M004   | I W |      -0.75     -0.15     -0.64 |   |
| 192 | PTBB 14234M001   | P A |      -3.95      3.14      7.02 | M |
| 236 | TLSE 10003M009   | I W |       2.83     -3.44     -0.06 |   |
| 262 | WSRT 13506M005   | I W |      -0.72     -0.05      0.56 |   |
| 263 | WTZR 14201M010   | I W |       0.52      1.41     -1.24 |   |
| 264 | WTZZ 14201M014   | P A |      -2.77      3.46      1.50 | M |
| 276 | ZIM2 14001M008   | I W |      -4.38     -1.23     -1.83 |   |
| 278 | ZIMM 14001M004   | I W |       0.64      1.49      0.82 |   |
|     |                  |     |                                |   |
 ---------------------------------------------------------------------
|     | RMS / COMPONENT  |     |       2.35      1.60      1.63 |   |
|     | MEAN             |     |       0.00     -0.00     -0.00 |   |
|     | MIN              |     |      -4.38     -3.44     -1.83 |   |
|     | MAX              |     |       3.61      1.49      3.40 |   |
 ---------------------------------------------------------------------


NUMBER OF PARAMETERS  :     3
NUMBER OF COORDINATES :    27
RMS OF TRANSFORMATION :    1.89 MM

BARYCENTER COORDINATES:

LATITUDE              :    48 45 56.82
LONGITUDE             :     9 29 24.71
HEIGHT                :         -37.545 KM


PARAMETERS:

TRANSLATION IN  N     :           0.02     +-  0.63    MM
TRANSLATION IN  E     :           0.03     +-  0.63    MM
TRANSLATION IN  U     :           0.00     +-  0.63    MM


NUMBER OF ITERATIONS  :     1



NO OUTLIER DETECTED



-----------------------------------------------------------------
>>> CPU/Real time for pgm "HELMR1": 0:00:00.076 / 0:00:00.075
>>> Program finished successfully
```

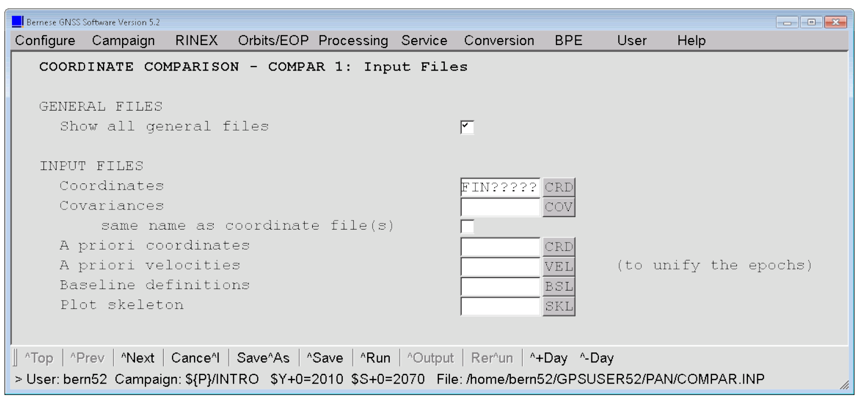
We can conclude that no problems concerning the stations used for the datum definition were detected.

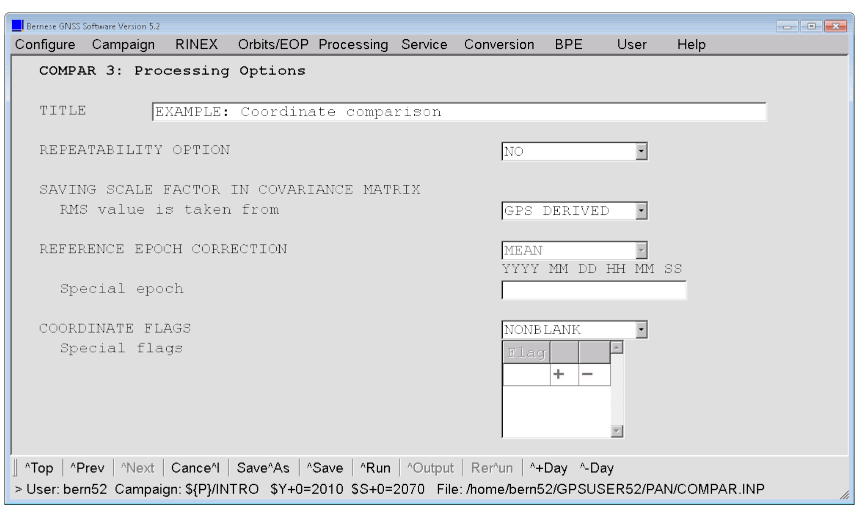
If there were problems, the ADDNEQ2 run needs to be repeated with the problematic station either removed from the file `${P}/INTRO/STA/IGS14.FIX` or with manual selection of the stations used for the datum definition in panel "ADDNEQ2 5.1: Datum Definition for Station Coordinates".

In order to check the repeatability of the coordinate solutions for all 4 days, repeat the above steps for the remaining three days.

6.3 Check the Daily Repeatability

If the minimum constraint solutions of the four sessions are available, the repeatability of the coordinate solutions may be checked using the program COMPAR ("Menu>Service >Coordinate tools>Coordinate comparison").



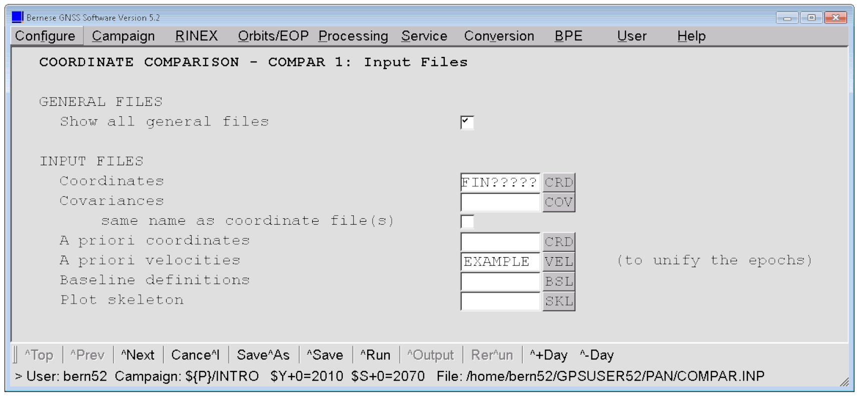


The program computes the arithmetic mean for all station coordinates. The difference of each individual coordinate set to this mean value and the overall RMS are reported in the following section of the program output:

```
NUM  STATION          #FIL C   RMS     1     2     3     4
-----------------------------------------------------------

 75  GANP 11515M001    4  N   8.45  -6.81 -7.81  7.08  7.54
                          E  11.66 -10.03-10.16 10.68  9.50
                          U   2.76   1.58  2.51 -0.36 -3.73

 92  HERT 13212M010    4  N   8.70  -7.38 -7.69  7.61  7.46
                          E   9.56  -8.75 -7.79  8.07  8.47
                          U   3.39  -2.48 -0.29 -2.11  4.88

107  JOZ2 12204M002    4  N   8.11  -6.91 -7.13  7.26  6.78
                          E  12.66 -10.52-11.40 11.18 10.75
                          U   4.40   2.98  4.55 -3.45 -4.08

122  LAMA 12209M001    4  N   8.42  -7.37 -7.19  6.66  7.91
                          E  11.99 -10.50-10.27 10.37 10.40
                          U   3.05   3.42  1.25 -0.97 -3.70

136  MATE 12734M008    4  N  11.57 -10.24 -9.76 10.86  9.15
                          E  14.02 -11.97-12.31 11.85 12.43
                          U   1.58  -0.11 -0.02  1.99 -1.86

176  ONSA 10402M004    4  N   8.22  -7.14 -7.08  6.50  7.72
                          E  10.44  -8.76 -9.31  8.61  9.46
                          U   3.88  -2.34 -3.91  4.70  1.54

192  PTBB 14234M001    4  N   8.91  -6.90 -8.50  7.82  7.58
                          E  11.57  -9.92-10.12  9.75 10.29
                          U   1.11  -1.66  0.43  0.48  0.74

236  TLSE 10003M009    4  N   9.13  -8.60 -7.18  7.67  8.11
                          E  11.50 -10.17 -9.73  9.66 10.24
                          U   2.14  -0.50 -2.65  0.69  2.46

262  WSRT 13506M005    4  N   9.56  -8.18 -8.37  8.64  7.90
                          E  10.00  -8.35 -8.95  8.37  8.94
                          U   2.26   2.45 -0.43 -2.89  0.87

263  WTZR 14201M010    4  N   8.93  -7.86 -7.60  7.59  7.87
                          E  11.55 -10.20 -9.79  9.64 10.35
                          U   2.42   0.47  2.96 -0.56 -2.88

264  WTZZ 14201M014    4  N   8.32  -7.24 -7.17  6.97  7.44
                          E  13.21 -11.43-11.44 10.98 11.89
                          U   1.59  -1.97  1.18  1.40 -0.60

276  ZIM2 14001M008    4  N   9.33  -8.01 -8.14  7.68  8.47
                          E  11.58  -9.93-10.13  9.93 10.13
                          U   0.86  -1.16 -0.04  0.34  0.86

278  ZIMM 14001M004    4  N   9.46  -8.26 -8.11  8.41  7.96
                          E  11.09  -9.63 -9.57  9.73  9.47
                          U   0.53   0.70  0.11 -0.30 -0.51

-----------------------------------------------------------
```

While interpreting this output, keep in mind that the first two columns and the last two columns refer to different epochs (see warning message). The difference between these epochs is about one year. Obviously, station velocities need to be estimated (this will be done in the next step described in Section 6.5).

If reliable velocities for all stations are available they can be introduced:



You may check the influence on the repeatability on your own. Please be reminded, that for the ITRF2014 (IGS14) reference frame the linear station velocities are not sufficient. You may see the effect of the PSD corrections in the repeatablity. This is not the case for this example because none of the stations is affected by an earthquake and, therefore, no PSD corrections have to be considered.

This output may be used for quality assessment. Stations with a problem in one or more sessions can be identified and excluded from the final ADDNEQ2 solution by adding them to section TYPE 003: STATION PROBLEMS in the station information file (`${P}/INTRO/STA/EXAMPLE.STA`). All parameters of these stations will be pre–eliminated before the normal equations are stacked and, therefore, also before the solution is computed.

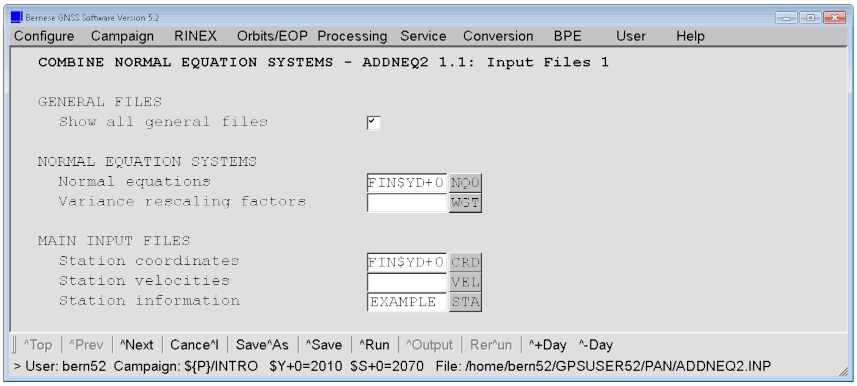
6.4 Compute the Reduced Solution of the Sessions

If one or more stations have to be excluded from the session solution or if the datum definition of the solution is still not acceptable, the final solution of the session has to be re–computed by repeating the ADDNEQ2 in Section 6.2. Finally, the result files for the final solution of the session are:

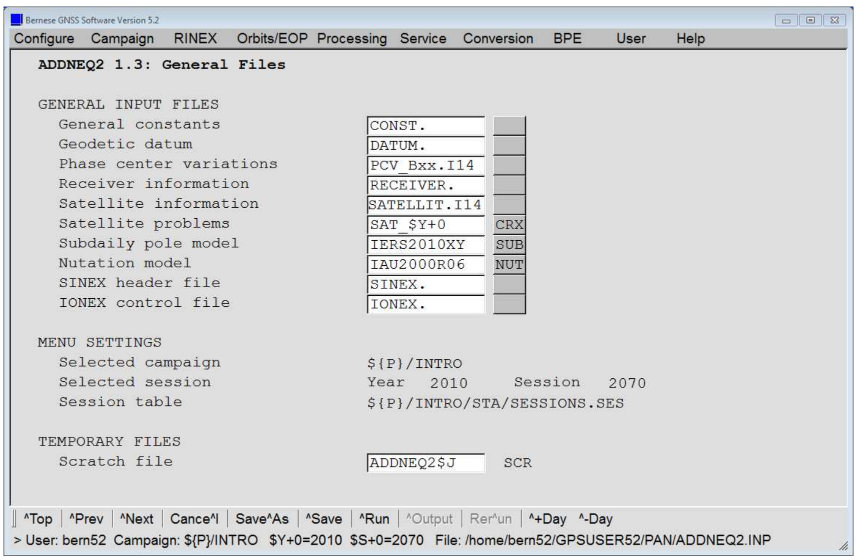
`${P}/INTRO/SOL/FIN$YD+0.NQ0`,
`${P}/INTRO/STA/FIN$YD+0.CRD`, and
`${P}/INTRO/ATM/FIN$YD+0.TRP`.

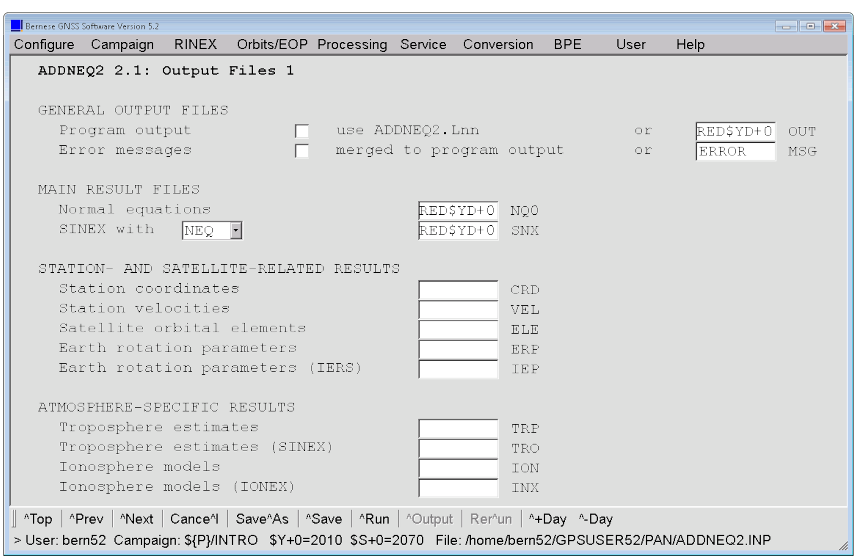
It is preferable for the velocity estimation to have smaller normal equation files containing only the coordinate parameters for each session. In addition, we generate a coordinate Solution INdependent EXchange format (SINEX) file (in NEQ representation) as the final solution of the day, so the troposphere parameters have to be pre–eliminated before the solution is computed. We introduce the station coordinates (`${P}/INTRO/STA/FIN$YD+0.CRD`) obtained with the minimum constraint solution in the previous run of ADDNEQ2 and constrain the solution to these coordinates.

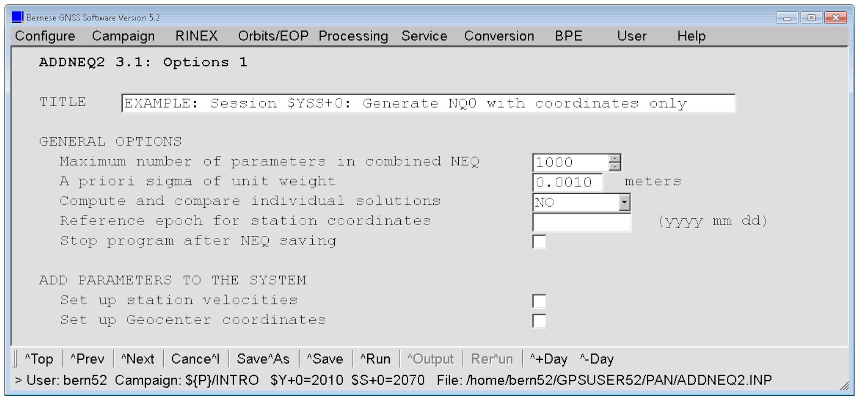
To generate these reduced `NQ0` files and the SINEX file, the execution of ADDNEQ2 has to be repeated with the following changes in the input options:



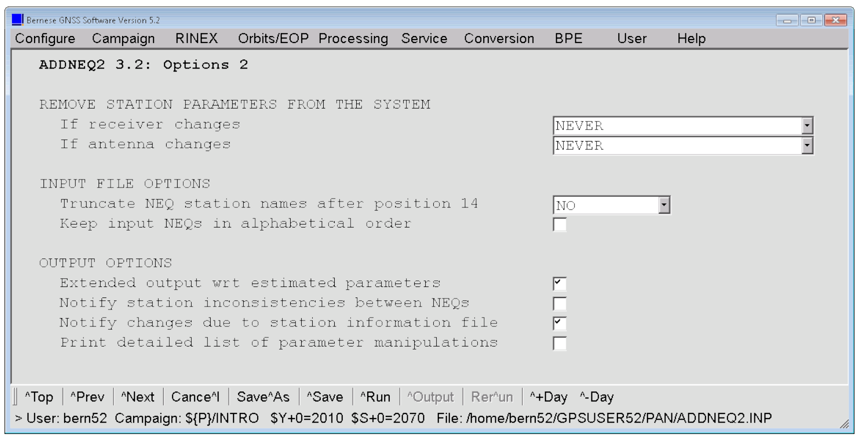
Please note that the output SINEX file includes a skeleton from `${X}/GEN/SINEX.RNX2SNX`. We propose to derive individual SINEX skeletons for different tasks that you can include a specific description how the product has been generated. The skeleton is provided in the input field "SINEX general input file" in panel "ADDNEQ2 1.3: General Files".



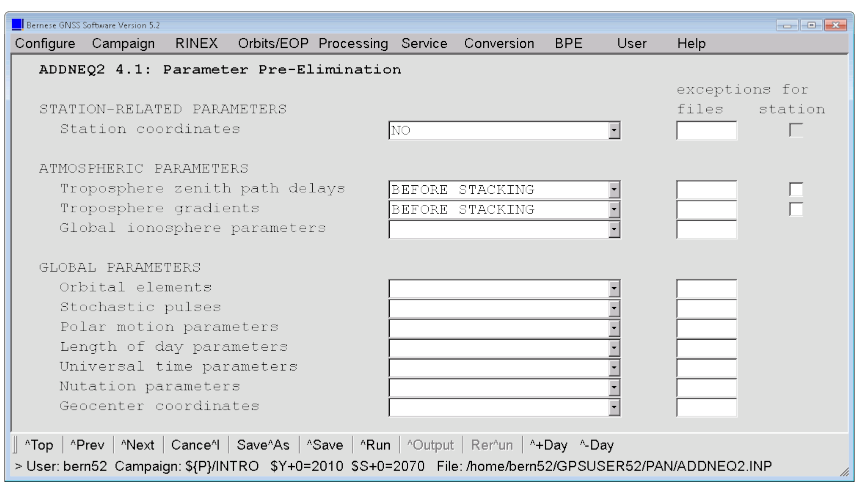




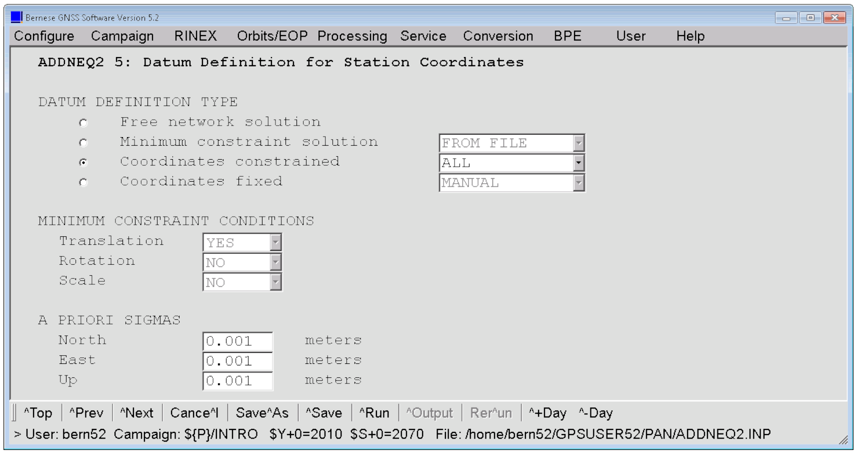
Because you are storing a SINEX file in NEQ representation (see option "Content of SINEX") no regularization is necessary.



The troposphere parameters are pre–eliminated:



To keep the a priori and estimated sets of coordinates in the resulting SINEX file consistent, we introduce the coordinate solution of the session in "Station coordinates" in "ADDNEQ2 1.1: Input Files 1" and constrain all coordinate parameters to these values.



The normal equation file (`${P}/INTRO/SOL/RED10207.NQ0`) contains only the station coordinate parameters. The following section of the program output documents the pre–elimination of the troposphere parameters:

```
...

SUMMARY OF RESULTS
------------------

Number of parameters:
--------------------

Parameter type                                 Adjusted   explicitly / implicitly (pre-elimi ...
------------------------------------------------------------------------------------------- ...
Station coordinates / velocities                     39            39            0            ...
Site-specific troposphere parameters                377             0          377  (before st ...
------------------------------------------------------------------------------------------- ...
Previously pre-eliminated parameters                656                        656
------------------------------------------------------------------------------------------- ...
Total number                                       1072            39         1033            ...
...
```

```
...

Statistics:
----------

Total number of authentic observations       73602
Total number of pseudo-observations            377

Total number of explicit parameters             39
Total number of implicit parameters           1033

Total number of observations                 73979
Total number of adjusted parameters           1072
Degree of freedom (DOF)                      72907

A posteriori RMS of unit weight            0.00115 m
Chi**2/DOF                                    1.32

Total number of observation files               12
Total number of stations                        13
Total number of satellites                       0
...
```

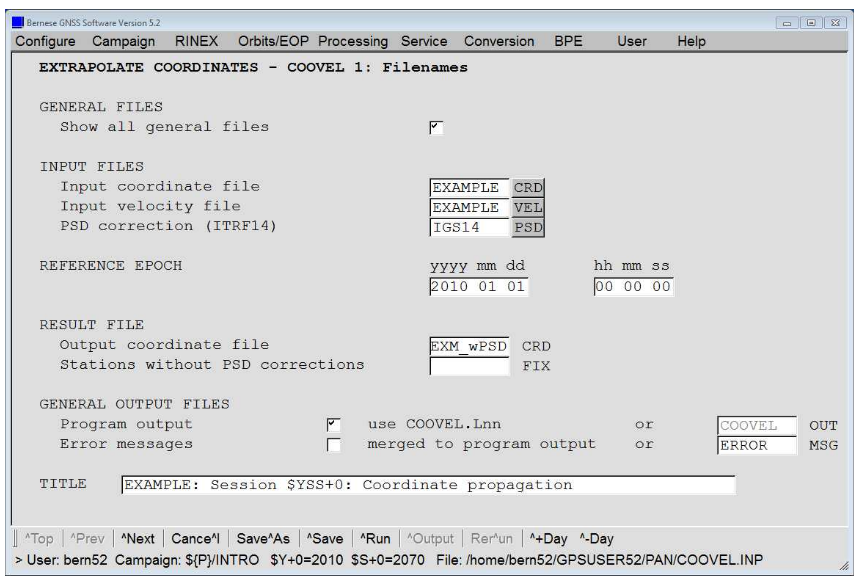
You can also see that the number of explicit parameters in the `NQ0` file was dramatically reduced (from `416` to `39`). This is an advantage for the combination of a big number of normal equation files for the estimation of station velocities.

6.5 Velocity Estimation

6.5.1 Preparation for ITRF2014/IGS14 Velocity Estimation

This section can be skipped if no ITRF2014/IGS14 reference frame is used as geodetic datum.

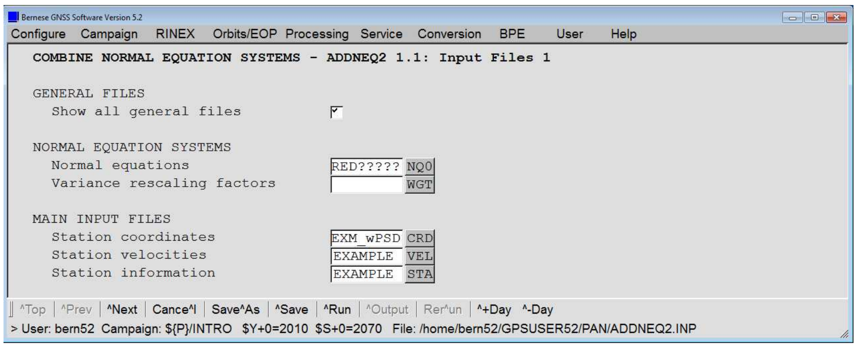
Because of the PSD corrections, the linear station velocity may not represent the actual station velocity and one has to prepare the station coordinate and velocity files before they can be used for the datum definition in the program ADDNEQ2. We have to compute the station coordinates at the reference epoch using the program COOVEL ("Menu>Service >Coordinate tools>Extrapolate coordinates"):

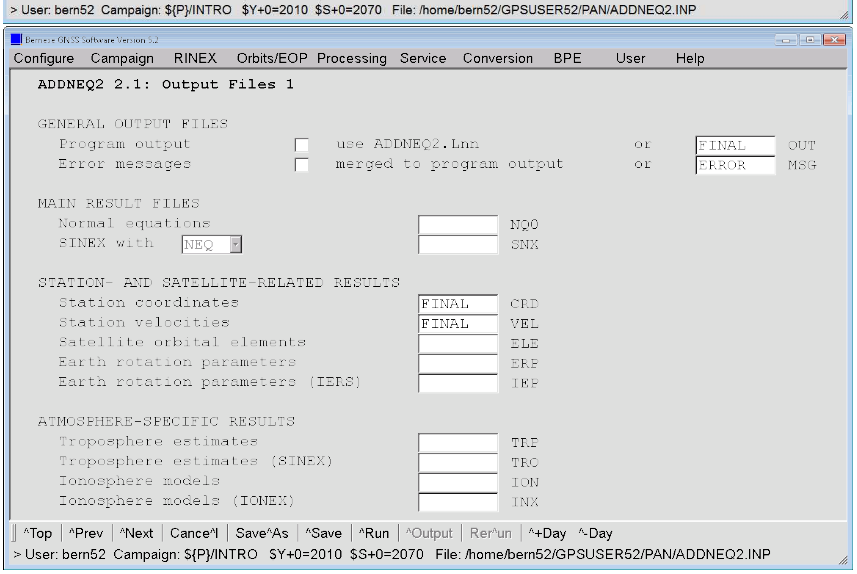


In our example none of the stations that shall be used for the datum definition is related to the PSD corrections. So, you can continue here. If you have another station selection where the PSD corrections become relevant we refer to Section 7.1 for further instructions.

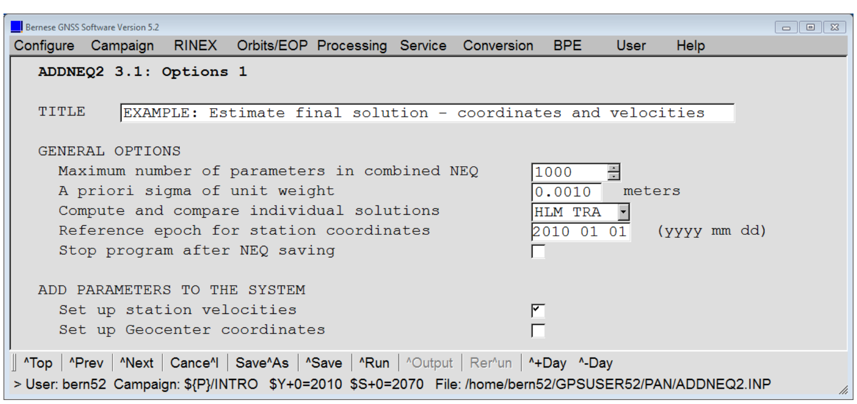
6.5.2 Velocity Estimation Based on NEQ Files

The velocity estimation in program ADDNEQ2 is easy. Introduce the normal equation files containing only the station coordinate parameters. Copy the prepared files for the three additional days (208 year 2010, 205 and 206 year 2011) from `${S}/RNX2SNX/2010/SOL/RED10*NQ0` and `${S}/RNX2SNX/2011/SOL/RED11*NQ0` into `${P}/INTRO/SOL/` directory. The normal equation files have to cover a reasonable time interval to reliably estimate velocities (in this case one year):



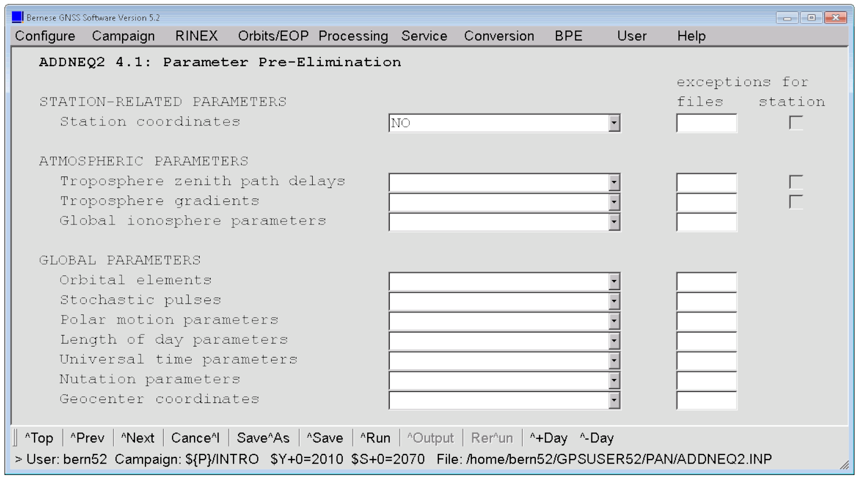


Station velocities are set up by marking the corresponding checkbox:

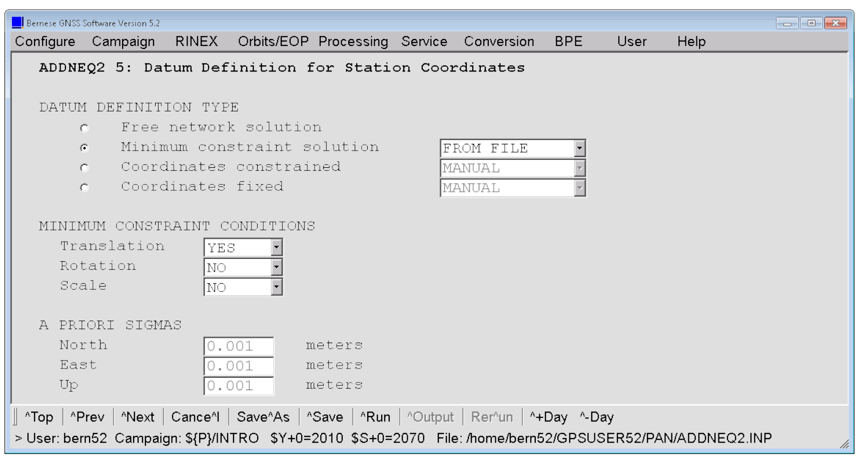


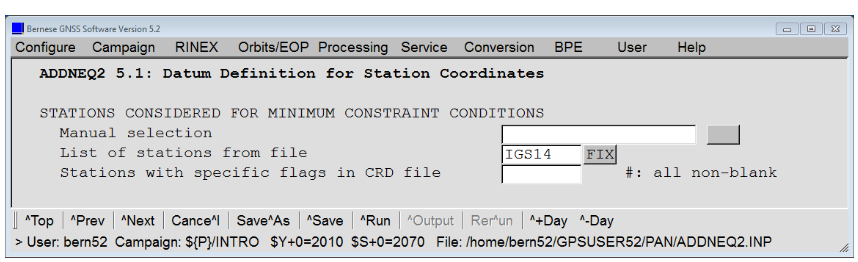
Furthermore, we check the repeatability of the daily solutions after the velocity estimation. The coordinates in the resulting file will refer to the epoch 2010 01 01.

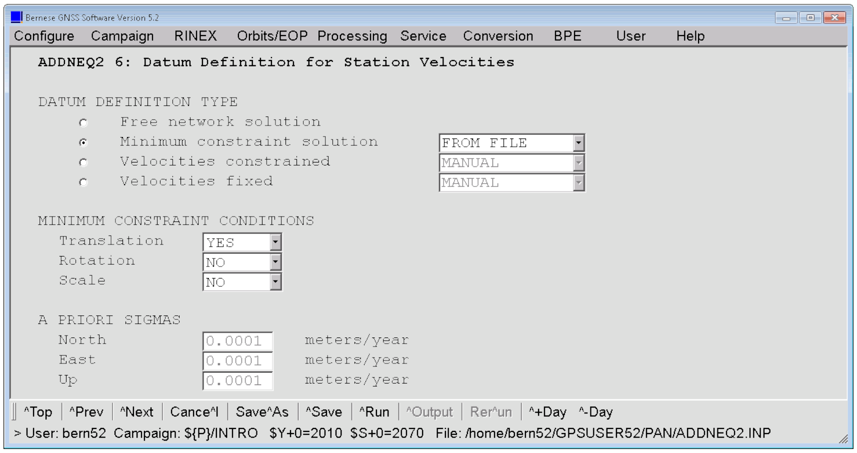
The input NEQ files only contain coordinates:

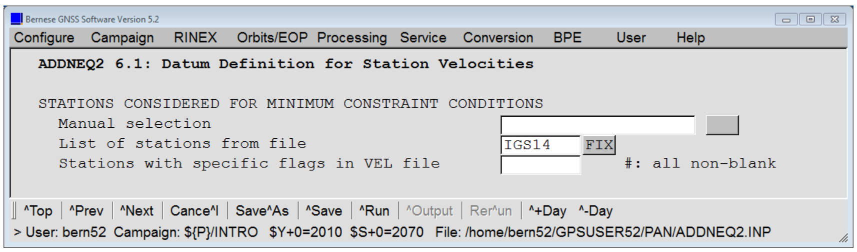


The realization of the geodetic datum is done separately for positions and velocities in the following panels:

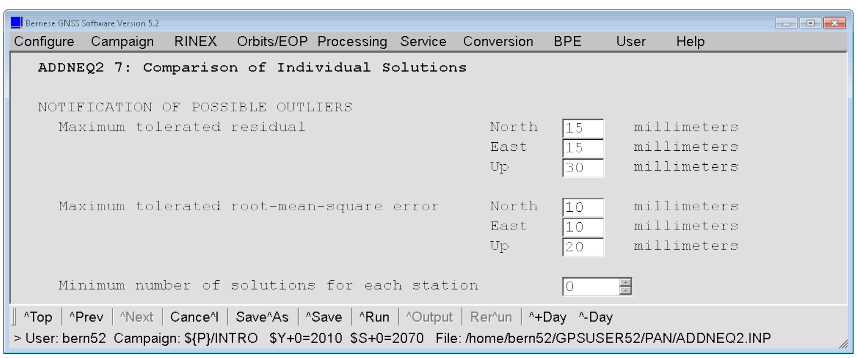








The following panel provides options to detect bad daily solutions based on the repeatability:



After the velocity estimation the repeatability of the coordinate solutions from the individual normal equations look like:

```
...

Statistics of individual solutions:
---------------------------------

                                          #Observations                  #Parameters
File     RMS (m)       DOF  Chi**2/DOF  authentic  / pseudo    explicit  / implicit / singular
------------------------------------------------------------------------------------------------
   1     0.00115     72874        1.32      73940          6         39         1033          0
   2     0.00121     72878        1.46      73861          6         39          950          0
   3     0.00123     75378        1.50      76336          6         39          925          0
   4     0.00122     75405        1.48      76421          6         39          983          0
```

```
 Comparison of individual solutions:
 ----------------------------------

 GANP 11515M001   N    0.40      0.45   -0.46   -0.22    0.17
 GANP 11515M001   E    0.53      0.03   -0.01    0.66   -0.65
 GANP 11515M001   U    1.24     -0.25    0.32    1.58   -1.40

 HERT 13212M010   N    0.12      0.08   -0.10    0.11   -0.13
 HERT 13212M010   E    0.41     -0.48    0.45   -0.20    0.17
 HERT 13212M010   U    3.10     -0.91    0.91   -3.65    3.71

 JOZ2 12204M002   N    0.24      0.06   -0.05    0.28   -0.30
 JOZ2 12204M002   E    0.40      0.41   -0.39    0.28   -0.28
 JOZ2 12204M002   U    0.51     -0.60    0.63    0.11   -0.11

 LAMA 12209M001   N    0.48     -0.14    0.16   -0.57    0.58
 LAMA 12209M001   E    0.14     -0.16    0.16    0.05   -0.04
 LAMA 12209M001   U    1.40      1.27   -1.23    1.15   -1.18

 MATE 12734M008   N    0.74     -0.25    0.25    0.87   -0.87
 MATE 12734M008   E    0.22      0.15   -0.15   -0.23    0.22
 MATE 12734M008   U    1.42      0.12   -0.17    1.80   -1.67

 ONSA 10402M004   N    0.45     -0.09    0.13   -0.53    0.55
 ONSA 10402M004   E    0.37      0.25   -0.24   -0.37    0.39
 ONSA 10402M004   U    1.39      0.98   -0.96    1.40   -1.40

 PTBB 14234M001   N    0.62      0.73   -0.76    0.17   -0.16
 PTBB 14234M001   E    0.20      0.09   -0.09   -0.22    0.23
 PTBB 14234M001   U    0.75     -0.87    0.85   -0.35    0.29

 TLSE 10003M009   N    0.63     -0.77    0.72   -0.21    0.19
 TLSE 10003M009   E    0.27     -0.22    0.18   -0.28    0.26
 TLSE 10003M009   U    1.36      1.31   -1.25   -1.08    1.07

 WSRT 13506M005   N    0.35      0.04   -0.02    0.46   -0.39
 WSRT 13506M005   E    0.32      0.30   -0.29   -0.24    0.28
 WSRT 13506M005   U    2.15      1.65   -1.59   -2.20    1.95

 WTZR 14201M010   N    0.16     -0.18    0.17   -0.09    0.10
 WTZR 14201M010   E    0.31     -0.23    0.22   -0.32    0.30
 WTZR 14201M010   U    1.17     -1.09    1.03    1.01   -0.92

 WTZZ 14201M014   N    0.18     -0.08    0.08   -0.19    0.21
 WTZZ 14201M014   E    0.33     -0.01    0.01   -0.40    0.40
 WTZZ 14201M014   U    1.31     -1.42    1.36    0.80   -0.81

 ZIM2 14001M008   N    0.29      0.03   -0.02   -0.36    0.36
 ZIM2 14001M008   E    0.10      0.11   -0.09   -0.07    0.06
 ZIM2 14001M008   U    0.48     -0.38    0.35   -0.50    0.40

 ZIMM 14001M004   N    0.23     -0.12    0.11    0.25   -0.27
 ZIMM 14001M004   E    0.14     -0.03    0.03    0.14   -0.19
 ZIMM 14001M004   U    0.40      0.47   -0.50   -0.10    0.09


 Variance-covariance scaling factors:
 -----------------------------------

 Parameter type                       Component    Scaling factor wrt RMS /  variance      DOF
 ----------------------------------------------------------------------------------------------
 Station coordinates                  N                               1.39976     1.95932       52
 Station coordinates                  E                               1.31297     1.72389       52
 Station coordinates                  U/vertical                      1.49414     2.23244       52
 Station coordinates                  Horizontal                      1.35706     1.84160      104
 Station coordinates                  All                             1.40424     1.97188      156
 ----------------------------------------------------------------------------------------------
 Total                                                                1.40424     1.97188      156
...
```

Below this table, bad daily solutions according to the settings in panel "ADDNEQ2 7: Comparison of Individual Solutions" are summarized (if there are any). In this example we have no additional section and, therefore, no outliers.

If you compare the velocities obtained for the two sites in Kötzting (WTZR and WTZZ) and Zimmerwald (ZIM2 and ZIMM) you will find small differences:

```
...


Stati Station coordinates and velocities:
---------------------------------
Reference epoch: 2010-01-01 00:00:00

Station name         Typ   A priori value  Estimated value    Correction     RMS error  ...
------------------------------------------------------------------------------------------ ...
...
WTZR 14201M010       VX          -0.01629         -0.01820      -0.00191       0.00050
                     VY           0.01714          0.01648      -0.00066       0.00021
                     VZ           0.00986          0.00751      -0.00235       0.00055

                     VU          -0.00043         -0.00352      -0.00309       0.00071 ...
                     VN           0.01557          0.01555      -0.00002       0.00022 ...
                     VE           0.02034          0.02012      -0.00022       0.00018 ...
...
WTZZ 14201M014       VX          -0.01629         -0.01531       0.00098       0.00054
                     VY           0.01714          0.02011       0.00297       0.00023
                     VZ           0.00986          0.01007       0.00021       0.00059

                     VU          -0.00043          0.00078       0.00121       0.00077 ...
                     VN           0.01557          0.01449      -0.00109       0.00024 ...
                     VE           0.02034          0.02301       0.00267       0.00020 ...

...
...
ZIM2 14001M008       VX          -0.01393         -0.01354       0.00039       0.00050
                     VY           0.01809          0.01860       0.00051       0.00019
                     VZ           0.01169          0.01202       0.00033       0.00052

                     VU           0.00070          0.00125       0.00055       0.00069 ...
                     VN           0.01636          0.01625      -0.00011       0.00022 ...
                     VE           0.01975          0.02020       0.00045       0.00018 ...
...
ZIMM 14001M004       VX          -0.01393         -0.01499      -0.00106       0.00084
                     VY           0.01809          0.01755      -0.00054       0.00028
                     VZ           0.01169          0.01067      -0.00102       0.00081

                     VU           0.00070         -0.00081      -0.00151       0.00113 ...
                     VN           0.01636          0.01648       0.00013       0.00034 ...
                     VE           0.01975          0.01935      -0.00040       0.00026 ...
...
```

You can constrain the velocity estimates for the pairs of receivers at one location in the station information file. Copy the original station information file `${P}/INTRO/STA/EXAMPLE.STA` and add the following lines to part TYPE 004: STATION COORDINATES AND VELOCITIES (ADDNEQ) of this copy.

```
TYPE 004: STATION COORDINATES AND VELOCITIES (ADDNEQ)
----------------------------------------------------
                                         REL. CONSTR. POSITION     RELATIVE CONSTR. VELOCITY
STATION NAME 1        STATION NAME 2   ...  EAST      UP        NORTH     EAST      UP
****************      **************** ...  **.*****  **.*****  **.*****  **.*****  **.*****
WTZR 14201M010        WTZZ 14201M014   ...                       0.00001   0.00001   0.00001
ZIM2 14001M008        ZIMM 14001M004   ...                       0.00001   0.00001   0.00001
```

(Pay attention to the number of blank lines before the next section starts.)

When introducing this information, the program ADDNEQ2 will issue the following message:

```
### SR AOPTNET: You are going to use relative constraints for station
               coordinates/velocities from station info file.
               Please keep in mind that you will NOT constrain the
               estimated results but only the improvements of the
               apriori values.
```

If only the improvements (column Correction) for the velocities are constrained, you must make sure that also the a priori values (column A priori value) for the velocities are identical to obtain (column Estimated value) the same velocities for a group of stations. You can verify this in the input velocity file `${P}/INTRO/STA/EXAMPLE.VEL`:

```
...
263  WTZR 14201M010         -0.01629        0.01714        0.00986    IG14 EURA
264  WTZZ 14201M014         -0.01629        0.01714        0.00986    NNR  EURA
...
276  ZIM2 14001M008         -0.01393        0.01809        0.01169    IG14 EURA
278  ZIMM 14001M004         -0.01393        0.01809        0.01169    IG14 EURA
...
```

If this is not the case, you should unify the a priori values.

The relative constraining of the velocity estimates is confirmed in the section of the input parameters (below the a priori coordinates and velocities) of the ADDNEQ2–program output:

```
 ...

 Relative constraints between stations:
                                                ...  relative constraints for velocities
 Station names                                  ... N (m/year)    E (m/year)    U (m/year)
 ---------------------------------------------- ... -------------------------------------
 WTZR 14201M010        WTZZ 14201M014           ...  0.00001       0.00001       0.00001
 ZIM2 14001M008        ZIMM 14001M004           ...  0.00001       0.00001       0.00001
```

Introducing this modified station information file instead of the original one you will get the following estimates for the station velocities in Kötzting and Zimmerwald:

```
 ...

 Station coordinates and velocities:
 ----------------------------------
 Reference epoch: 2010-01-01 00:00:00

 Station name          Typ   A priori value  Estimated value    Correction     RMS error  ...
 ------------------------------------------------------------------------------------------ ...
 ...

 WTZR 14201M010        VX          -0.01629         -0.01699      -0.00070       0.00039
                       VY           0.01714          0.01806       0.00092       0.00016
                       VZ           0.00986          0.00857      -0.00129       0.00042

                       VU          -0.00043         -0.00172      -0.00129       0.00055  ...
                       VN           0.01557          0.01509      -0.00048       0.00017  ...
                       VE           0.02034          0.02139       0.00105       0.00014  ...
...
 WTZZ 14201M014        VX          -0.01629         -0.01699      -0.00070       0.00039
                       VY           0.01714          0.01807       0.00093       0.00016
                       VZ           0.00986          0.00857      -0.00129       0.00042

                       VU          -0.00043         -0.00172      -0.00128       0.00055  ...
                       VN           0.01557          0.01509      -0.00049       0.00017  ...
                       VE           0.02034          0.02140       0.00106       0.00014  ...
...
```

```
 ...

 ZIM2 14001M008        VX          -0.01393         -0.01414      -0.00021        0.00040
                       VY           0.01809          0.01804      -0.00005        0.00015
                       VZ           0.01169          0.01146      -0.00023        0.00041

                       VU           0.00070          0.00037      -0.00032        0.00055  ...
                       VN           0.01636          0.01635      -0.00000        0.00017  ...
                       VE           0.01975          0.01972      -0.00002        0.00014  ...
...
 ZIMM 14001M004        VX          -0.01393         -0.01414      -0.00021        0.00040
                       VY           0.01809          0.01804      -0.00005        0.00015
                       VZ           0.01169          0.01146      -0.00023        0.00041

                       VU           0.00070          0.00037      -0.00032        0.00055  ...
                       VN           0.01636          0.01635      -0.00000        0.00017  ...
                       VE           0.01975          0.01972      -0.00002        0.00014  ...

 ...
```

The final results are contained in the files `${P}/INTRO/STA/FINAL.CRD`

```
EXAMPLE: Estimate final solution - coordinates and velocities    28-AUG-17 16:03
--------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS14            EPOCH: 2010-01-01 00:00:00

NUM  STATION NAME           X (M)          Y (M)          Z (M)     FLAG

 75  GANP 11515M001    3929181.43126  1455236.81309  4793653.94428    W
 92  HERT 13212M010    4033460.85505    23537.87958  4924318.30931    W
107  JOZ2 12204M002    3664880.49055  1409190.66849  5009618.52923    A
122  LAMA 12209M001    3524522.83658  1329693.70182  5129846.40041    A
136  MATE 12734M008    4641949.46826  1393045.51501  4133287.53776    W
176  ONSA 10402M004    3370658.46734   711877.20881  5349787.00033    W
192  PTBB 14234M001    3844059.87805   709661.39520  5023129.60030    A
236  TLSE 10003M009    4627851.76301   119640.11214  4372993.60102    W
262  WSRT 13506M005    3828735.79223   443305.03608  5064884.77220    W
263  WTZR 14201M010    4075580.46481   931853.87929  4801568.17525    W
264  WTZZ 14201M014    4075579.34558   931853.19399  4801569.08708    A
276  ZIM2 14001M008    4331299.80234   567537.41214  4633133.77514    W
278  ZIMM 14001M004    4331296.99495   567555.96571  4633133.99187    W
```

and `${P}/INTRO/STA/FINAL.VEL`

```
EXAMPLE: Estimate final solution - coordinates and velocities    28-AUG-17 16:03
--------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS14

NUM  STATION NAME           VX (M/Y)       VY (M/Y)       VZ (M/Y)  FLAG   PLATE

 75  GANP 11515M001         -0.02030        0.01400        0.00629    W    EURA
 92  HERT 13212M010         -0.01036        0.01632        0.01150    W    EURA
107  JOZ2 12204M002         -0.02293        0.01468        0.00251    A    EURA
122  LAMA 12209M001         -0.02128        0.01414        0.00466    A    EURA
136  MATE 12734M008         -0.01977        0.01941        0.01507    W    EURA
176  ONSA 10402M004         -0.01249        0.01575        0.01282    W    EURA
192  PTBB 14234M001         -0.01518        0.01748        0.01026    A    EURA
236  TLSE 10003M009         -0.00937        0.01952        0.01347    W    EURA
262  WSRT 13506M005         -0.01652        0.01538        0.00835    W    EURA
263  WTZR 14201M010         -0.01699        0.01806        0.00857    W    EURA
264  WTZZ 14201M014         -0.01699        0.01807        0.00857    A    EURA
276  ZIM2 14001M008         -0.01414        0.01804        0.01145    W    EURA
278  ZIMM 14001M004         -0.01414        0.01804        0.01145    W    EURA
```

6.6 Daily Goals

At the end of today's session, you should have:

1. *used* GPSEST *to compute a final solution of the day, created files:* ***FIX10207.OUT***, ***FIX10207.NQ0*** *(for all sessions),*
2. *checked the coordinates of the fiducial sites using* ADDNEQ2 *and* HELMR1*, created files:* ***FIN10207.CRD***, ***FIN10207.TRP***, ***FIN10207.OUT***, *and* ***HLM10207.OUT***,
3. *used* COMPAR *to check the daily repeatabilities, created file:* ***COMPAR.OUT***,
4. *used* ADDNEQ2 *to create a final session solution, and reduced size NEQs, created files:* ***RED10207.NQ0*** *and* ***RED10207.SNX***,
5. *if possible, used* ADDNEQ2 *for velocity estimation, created files:* ***FINAL.CRD*** *and* ***FINAL.VEL***.

7 Additional Examples

In the previous terminal sessions you have estimated coordinates, velocities, and troposphere parameters. This is the standard application of the *Bernese GNSS Software* for most users.

If you have finished this work or if you want to follow more examples at home, this section of the document provides some suggestions to practice:

- advanced usage of ITRF2014/IGS14
  (see Section 7.1 on page 108),
- generation of a combined GPS/GLONASS orbit from IGS
  (see Section 7.2 on page 114),
- kinematic positioning for a station
  (see Section 7.3 on page 120),
- zero difference processing to estimate clocks
  (see Section 7.4 on page 126),
- inclusion of RINEX 3 data in the processing
  (see Section 7.5 on page 146),
- enabling the processing of Galileo data
  (see Section 7.6 on page 149), and
- simulation of GNSS observations
  (see Section 7.7 on page 157).

Extended Example Dataset

In particular for Sections 7.5 and 7.6 the example dataset has been extended. The same set of stations that have been introduced in Section 1.1 are provided also for day 213 in year 2017 (01 August 2017). For all stations RINEX 2 data are available in the datapool (`${D}/RINEX`). In the (`${D}/RINEX3` directory observations are also given in RINEX 3 format (long filenames) for 7 of them. Six out of these stations provide also Galileo measurements.

An additional campaign (`${P}/EXM_GAL`) in the *Bernese Introductory Course* is defined where these RINEX observation files are copied and extracted into the `RAW` directory. Please note that RINEX 3 file there have the conventional short filename to guarantee the compatibility with the filenaming convention of the Bernese processing programs.

This campaign is prepared to analyze this day. In particular, the orbit product files from CODE are copied into the `ORB` directory. Apart from the `COD` (GPS and GLONASS) also the `COM` products (CODE's five-system solution for IGS MGEX) are available.

7.1 Advanced Aspects in Using ITRF2014/IGS14

The velocity of a station in the ITRF2014/IGS14 is only derived by the sum of the linear velocities and the (non-linear) PSD corrections. On the other hand, for the datum definition of a velocity field the same parametrization for all stations and coordinate components is needed, which means, only linear station velocity parameters may be taken into account.

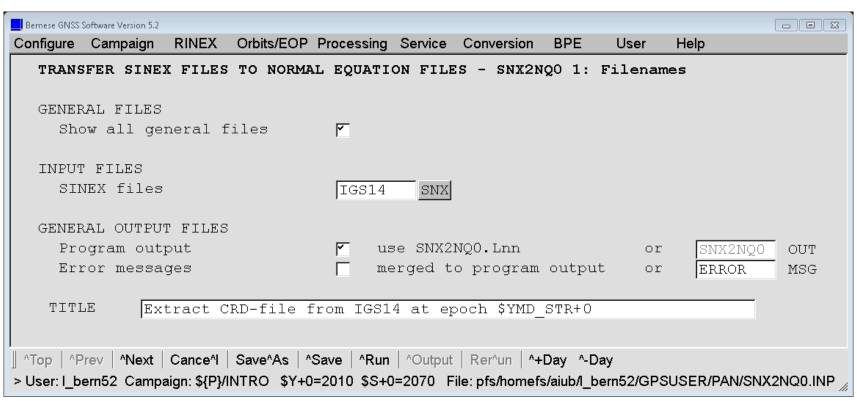
There is of course the option to first subtract the PSD corrections from the coordinates so that only linear velocities remain which can be aligned to the linear velocities from the ITRF2014/IGS14 solution SINEX file. It should be noted that this freezes the empirical PSD corrections that have been computed based on the IGS repro2 campaign. Consequently also GNSS modeling effects from the repro2 solution may be transferred into the new coordinate series, even when computed with a different (better) GNSS observation modeling. In addition the linear velocity field must first be adjusted to the PSD corrections before it can be integrated in the interval of your GNSS solution.

In this section we are discussing potential alternative approaches.

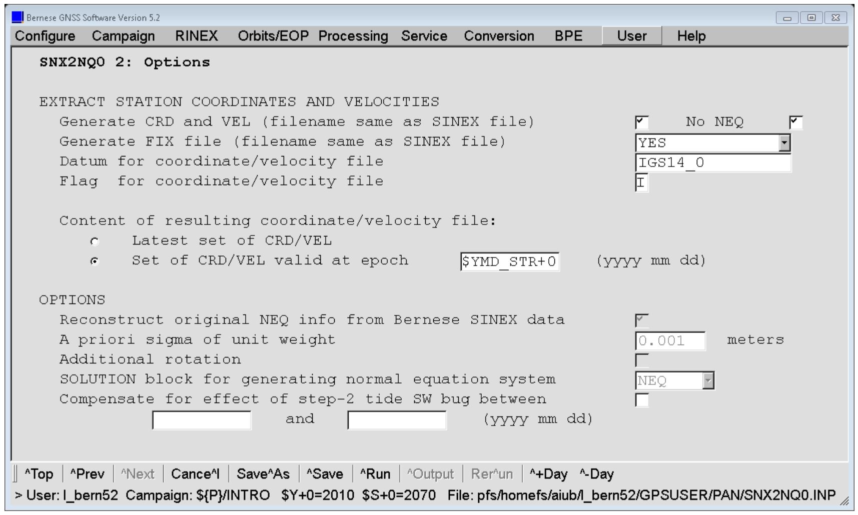
7.1.1 Using ITRF2014/IGS14 Frames for Reprocessing

For reprocessing, the station coordinates for a specific epoch are necessary. This can be done as simply as demonstrated in Section 2.5 of this tutorial.

Nevertheless, it is recommended in case of a reprocessing to not use the `IGS14_R.CRD`, `IGS14_R.VEL`, and `IGS14.FIX` files as they are provided. It is preferable to extract the coordinates and velocities valid for the specific epoch of the session in the reprocessing from the IGS14 SINEX solution file by running the program SNX2NQ0 ("Menu>Conversion >SINEX to normal equations").



In order to follow the example, you have to copy the `IGS14.SNX` from `${D}/STAT_LOG/IGS14.snx` to `${P}/INTRO/SOL/IGS14.SNX` (note that your operating system might be case sensitive).



Note that only the CRD and VEL information must be extracted but no NEQs are needed.

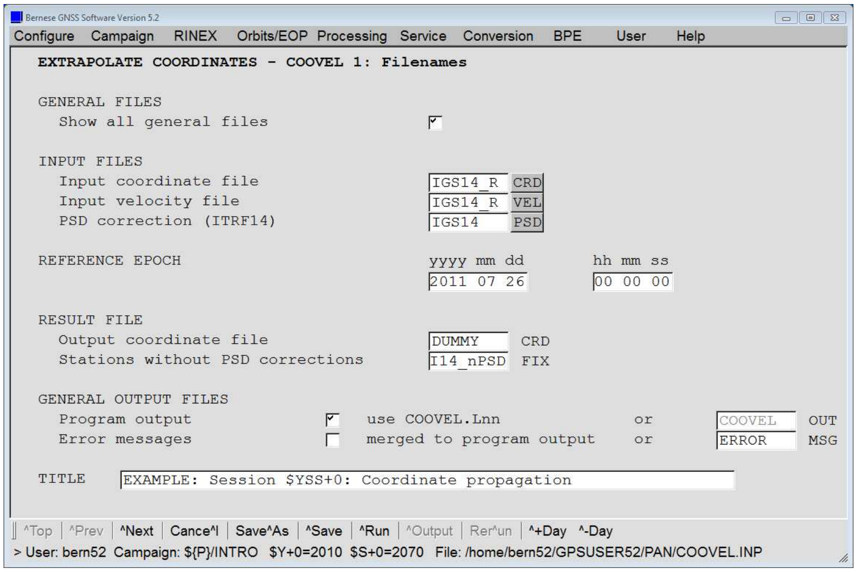
The following three files should now be available:
`${P}/INTRO/STA/IGS14.CRD`,
`${P}/INTRO/STA/IGS14.VEL`, and
`${P}/INTRO/STA/IGS14.FIX`.

The datum identifier in the coordinate files should be IGS14_0 in order to apply the PSD corrections when executing the program COOVEL. Because the files only contain those stations where coordinates and velocities are given in the IGS14 solution for the given epoch, the remaining stations for your project need to be added using the program program CRDMERGE ("Menu>Service>Coordinate tools>Merge coordinate/velocity files").

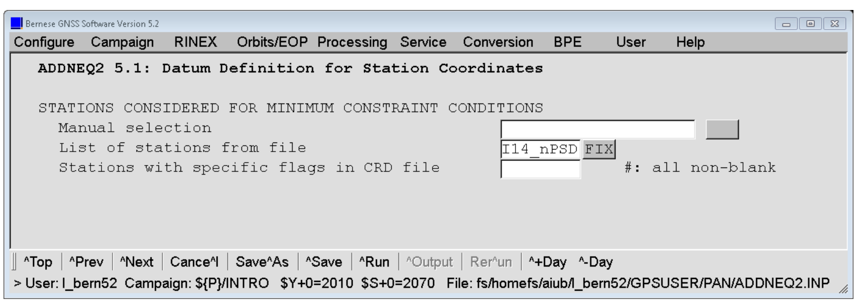
7.1.2 Ignoring Stations with PSD Corrections for Datum Definition

You may simply follow the approach from previous ITRF solutions by limiting yourself to those stations for the datum definition where no PSD corrections are given in the IGS14 solution. As long as this limited number of stations is sufficient for your application you can follow this simple approach as it was demonstrated in Section 6.5 of this tutorial.

In order to get a list of stations where no PSD corrections are applied the pogram COOVEL offers an option "Stations without PSD corrections".



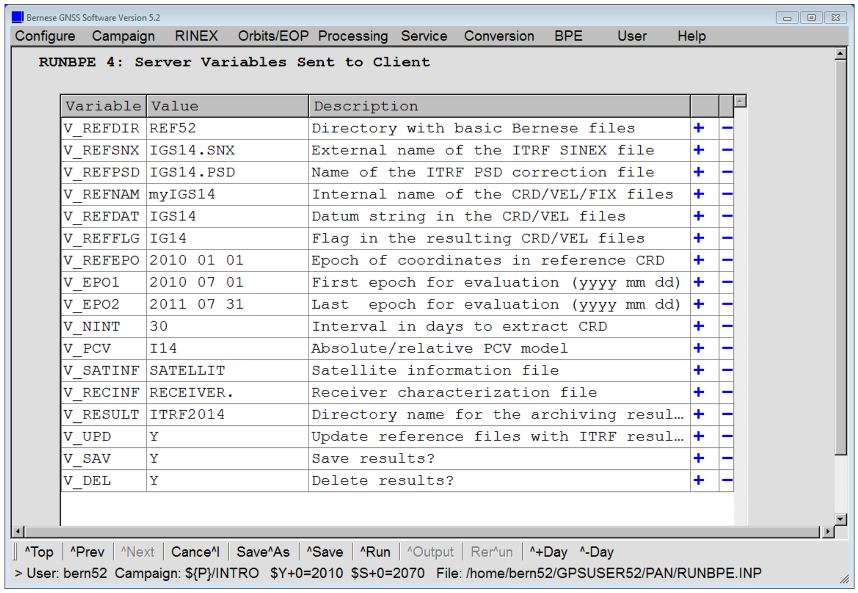
You may enter the last epoch of interest (e.g., day 206 of year 2011, the last day of the example dataset). The resulting file `${P}/INTRO/STA/I14_nPSD.FIX` contains a list of stations where no PSD corrections were given. This file can be used as the list of available set of stations that may be used for the datum definition in program ADDNEQ2:



Use the analogue setting for the datum definition for the station velocities in panel "ADDNEQ2 6.1: Datum Definition for Station Velocities".

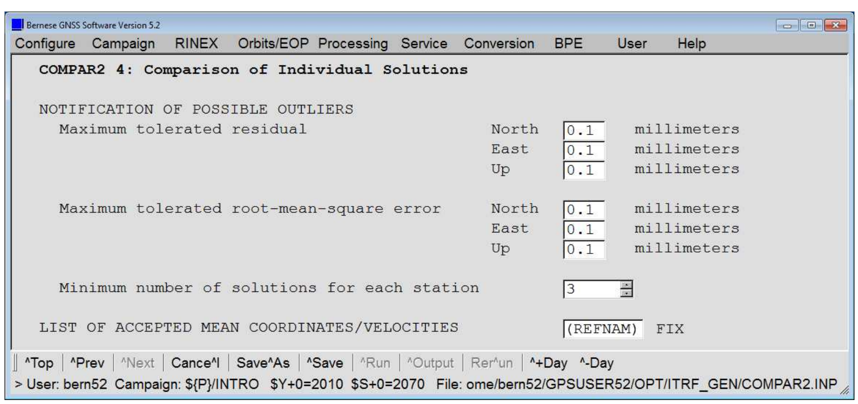
7.1.3 Recovering a Linear Velocity Field for a Certain Interval

If you cannot continue in the simple way as in this example by simply ignoring all stations with PSD corrections for the datum definition, a dedicated BPE named `${U}/PCF/ITRF.PCF` (description in `${U}/PCF/ITRF.README`) is provided with the software. It may be started with "Menu>BPE>Start BPE processing". In the second panel "RUNBPE 2: Process Control Options" the ITRF.PCF is specified for "Process control file". The most interesting is the last panel:



The BPE copies the files `IGS14.SNX` (given in V_REFSNX) and `IGS14.PSD` (given in V_REFPSD) from `${D}/REF52` into the campaign. It extracts the coordinates and velocities into Bernese formatted files where the datum identifier IGS14 (see variable V_REFDAT) is used. Starting from the epoch 2010 07 01 (see V_EPO1) this extraction is repeated every 30 days (see V_NINT) until epoch 2011 07 31 (see V_EPO2) is exceeded. The start and end date should cover the data interval that shall be used for the velocity estimation (in our case from day 207 in year 2010 to day 206 in year 2011).

In this way, 10 coordinate files are extracted. The coordinates are fitted by a linear model in script COMPAR2 (PID 212) expecting that the fit during the interval is better than the thresholds given in the last panel of the related program input file:



(The panel is obtained via "Menu>BPE>Edit PCF program input files" after selecting PID 121: COMPAR2 .)

For most of the stations the residuals in the program output file `${P}/INTRO/OUT/myIGS14.OUT` (where `myIGS14` is again related to the variable V_REFNAM) are zero. Deviations from zero may have two reasons:

- the PSD corrections are close to a linear model with station AREQ as an example where the earthquake from 2001 has only a marginal deviation from a linear station velocity

```
AREQ 42202M005   N    0.03       0.07    0.03    0.01   -0.01   -0.03   -0.03   -0.04
                                -0.03   -0.03   -0.02   -0.01    0.02    0.03    0.05
AREQ 42202M005   E    0.05       0.08    0.05    0.01   -0.02   -0.03   -0.05   -0.05
                                -0.05   -0.04   -0.03   -0.01    0.00    0.04    0.09
AREQ 42202M005   U    0.01      -0.02   -0.01   -0.00    0.01    0.01    0.01    0.01
                                 0.01    0.01    0.00    0.00   -0.00   -0.01   -0.02
```

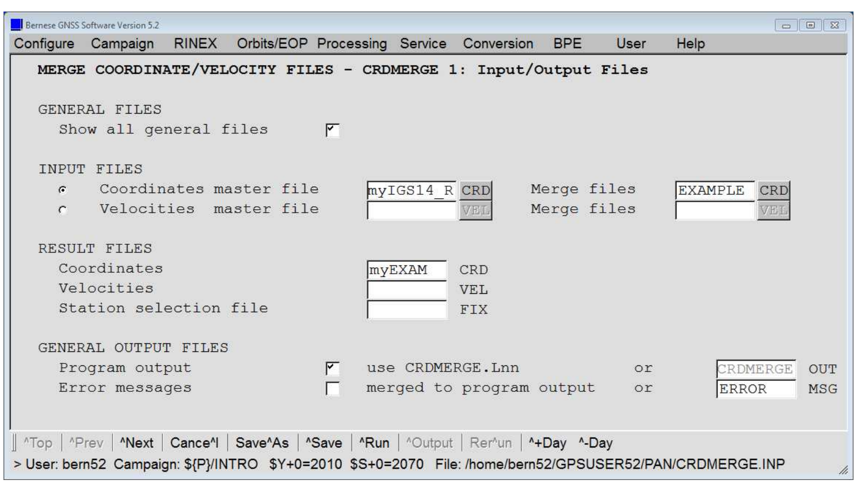
- the `IGS14.SNX` contains discontinuities like in the example for station WUHN at day 082 of year 2011

```
WUHN 21602M001   N    0.11       0.12    0.08    0.04   -0.00   -0.05   -0.09   -0.13
                                -0.17   -0.21    0.16    0.12    0.08    0.04    0.00
WUHN 21602M001   E    1.09       1.13    0.73    0.35   -0.04   -0.44   -0.82   -1.21
                                -1.61   -1.99    1.56    1.17    0.77    0.39    0.01
WUHN 21602M001   U    4.19      -4.34   -2.84   -1.33    0.17    1.67    3.17    4.67
                                 6.18    7.68   -6.01   -4.51   -3.01   -1.50   -0.00
```

(Note that discontinuities can be managed according to the description in Section 10.3.5 of the *Bernese GNSS Software* user manual. The station information file may be added in panel "COMPAR2 1: Input Files", PID 121 .)

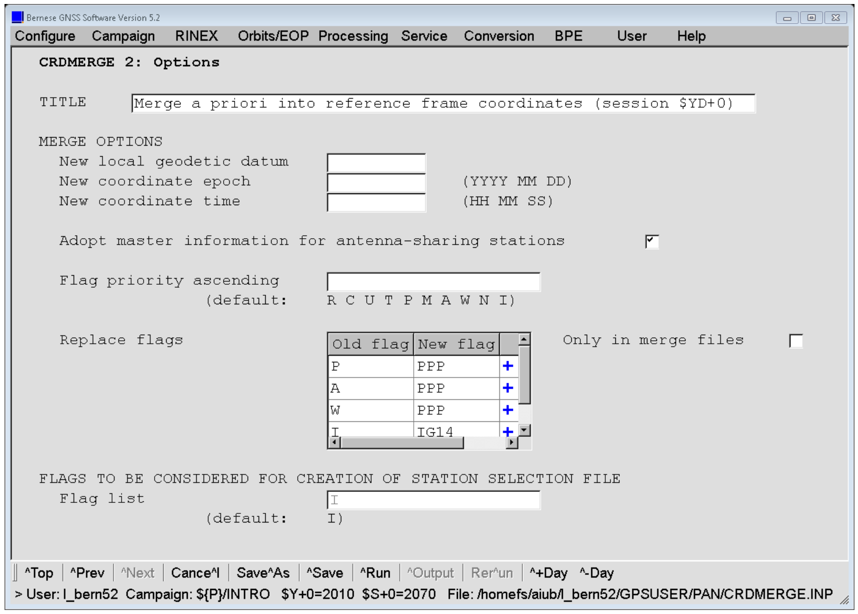
At the end of the procedure three files are obtained that contain only those stations for which the thresholds defined above were not exceeded: `myIGS14_R.CRD`, `myIGS14_R.VEL`, and `myIGS14.FIX` (where `myIGS14` is defined by the variable V_REFNAM). These files may either be copied to `${D}/REF52` (take care not to overwrite files from other projects) and may be used for variable V_REFINF in other example BPEs.

For the interactive use they should be merged with the stations from you project using the program CRDMERGE:



If is of course essential that all coordinate files (`myIGS14_R.CRD` and `EXAMPLE.CRD`) refer to the same epoch.

Activating the option "Synchronize stations with same DOMES number" is in particular helpful in cases of antenna sharing stations, where not all of the receiver/antenna combinations are included in the reference frame file `myIGS14_R.CRD`.



Note that this option requires the IGS-related station naming convention with the 4-character ID and the domes number.
Repeat the program to merge also the velocity files.

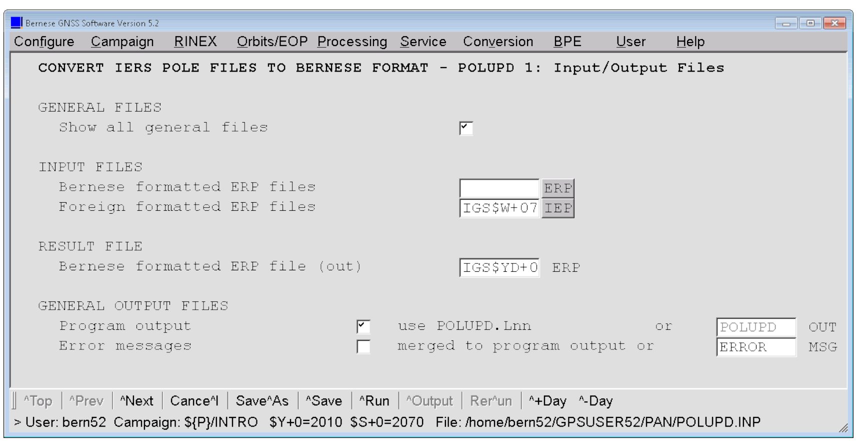
7.2 Preparing Combined GPS and GLONASS IGS–Orbits

In this section the differences to the standard procedure using CODE products containing GPS and GLONASS orbits with respect to IGS products are demonstrated. The IGS uses independent combination procedures for GPS and GLONASS orbits resulting in two sets of precise orbit files. That's why the orbits for the two GNSS first need to be merged.

In contrast, CODE (and other AC) uses a rigorous combined multi–GNSS processing scheme, hence producing a single precise orbit file.

7.2.1 Prepare Pole Information

For the IGS precise orbit files (`PRE`) the consistent EOP need to be available in the `ORB` directory (which is the case in the *Bernese Introductory Course* environment). As for the use of CODE products in Section 3.1, the EOP information has to be converted from the IERS/IGS standard format (file extension within the *Bernese GNSS Software* is `IEP`) to the internal Bernese EOP format (file extension within the *Bernese GNSS Software* is `ERP`). This is the task of the program POLUPD ("Menu>Orbits/EOP>Handle EOP files>Convert IERS to Bernese Format"). Simply specify IGS–related filenames — other settings are analogous to Section 3.1 .



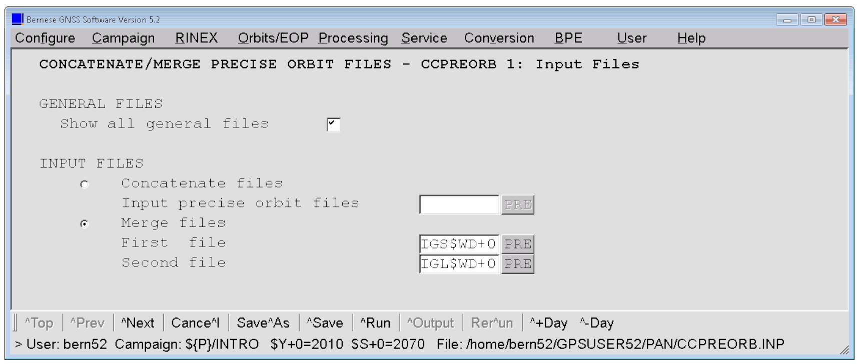
The messages

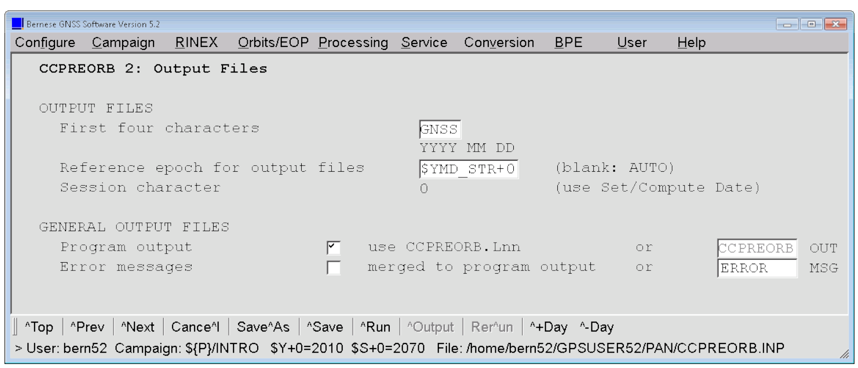
```
### PG POLUPD: NUTATION MODEL NOT SPECIFIED IN INPUT ERP FILE
              USING NUTATION MODEL NAME : IAU2000R06

### PG POLUPD: SUBDAILY POLE MODEL NOT SPECIFIED IN INPUT ERP FILE
              USING SUBDAILY POLE MODEL NAME : IERS2010
```

just inform you that the nutation and subdaily pole models from the files in the input panel are written to the output file because no Bernese formatted ERP file was used as input. This is different to importing the EOP from CODE products because here the information on the nutation and sub daily pole model is also available in the international format (with the extension `IEP`).

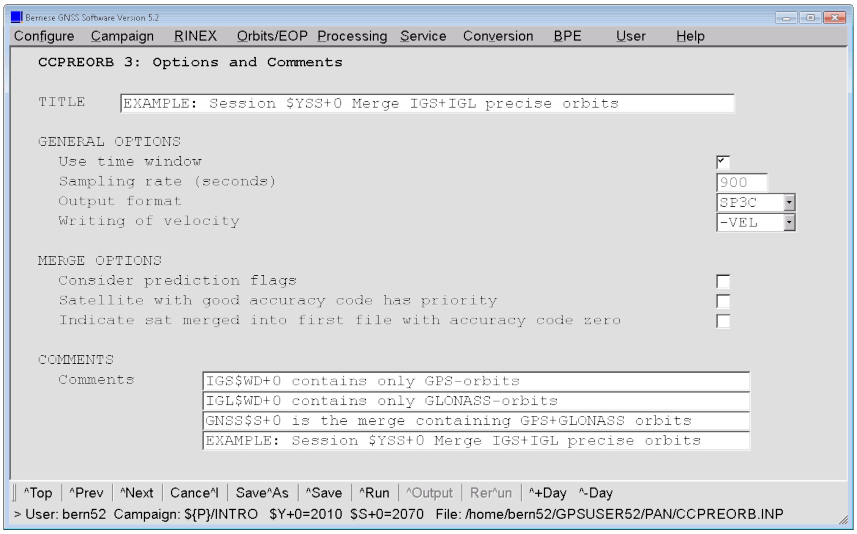
7.2.2 Merging Precise Orbit Files

Before we can prepare the orbits from the IGS for a combined GPS+GLONASS processing we need to merge the two separate files `IGS15941.PRE` and `IGL15941.PRE`. This is the task of the program CCPREORB ("Menu>Orbits/EOP>Concatenate/merge precise orbit files"):





The resulting filename consists of the solution identifier ("First four characters") and the session of the first epoch (if "Reference epoch for output files" is empty). The reference epoch may also be specified by the user as the above example shows. Using the input options from above panel we expect the result file named as `${P}/INTO/ORB/GNSS2070.PRE`.

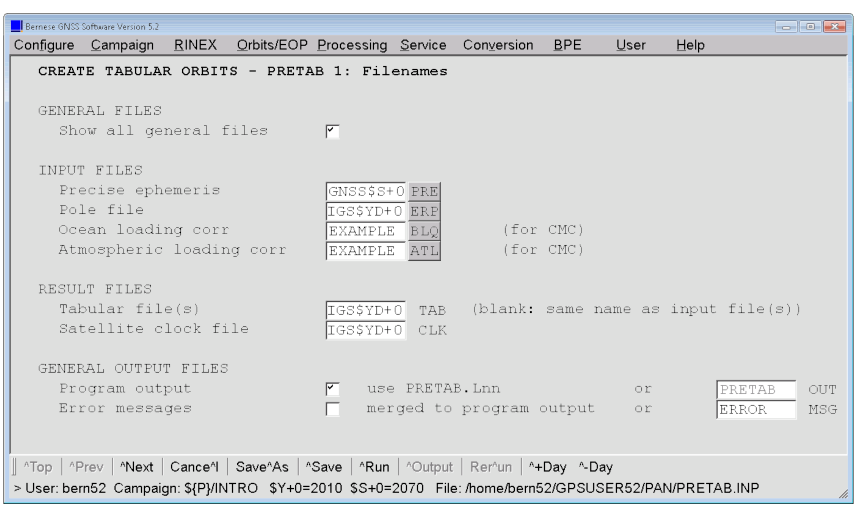


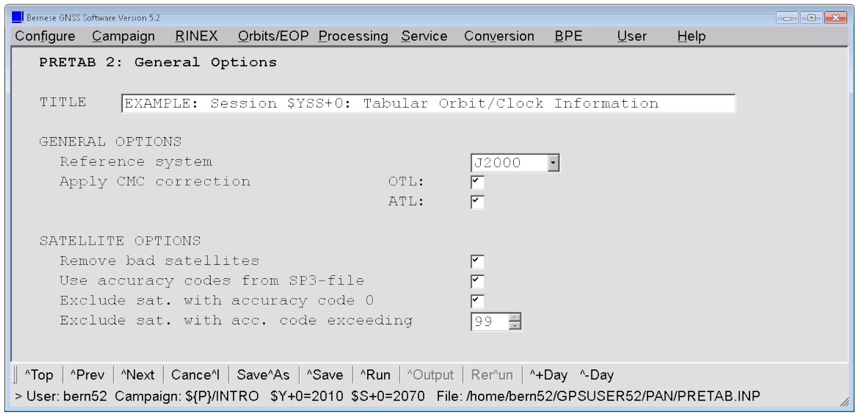
In the next panel you may specify the time window for which the satellite positions shall be included in the resulting precise orbit file.

7.2.3 Generating Standard Orbit Files

The subsequent steps to create the so–called standard orbit files from precise orbit files are again analogue to the standard procedure using CODE products as detailed in Section 3.2 .

The first step is the conversion into tabular orbit files (`TAB`) using the program PRETAB ("Menu>Orbits/EOP>Create tabular orbits"). The merged GPS/GLONASS precise orbit file is chosen as input and IGS–related output files are recommended.





It is important to enable the option "Exclude sat. with accuracy code 0" if you process orbits that are not provided by CODE (label "COD").

The precise GLONASS orbit files from the IGS contain the GLONASS broadcast clock information (instead of no clock corrections for GLONASS as in the CODE product files). This leads to two differences with respect to the use of the standard products from CODE:

- The messages on missing GLONASS satellites clocks are not displayed (at least not for all GLONASS satellites).
- Because the Bernese GNSS satellite clock files contain also clock corrections for the GLONASS satellites, the program CODSPP may compute the inter–system bias between IGSF–time scale (GPS satellite clocks in the IGS final product files) and GLONASS broadcast time system.

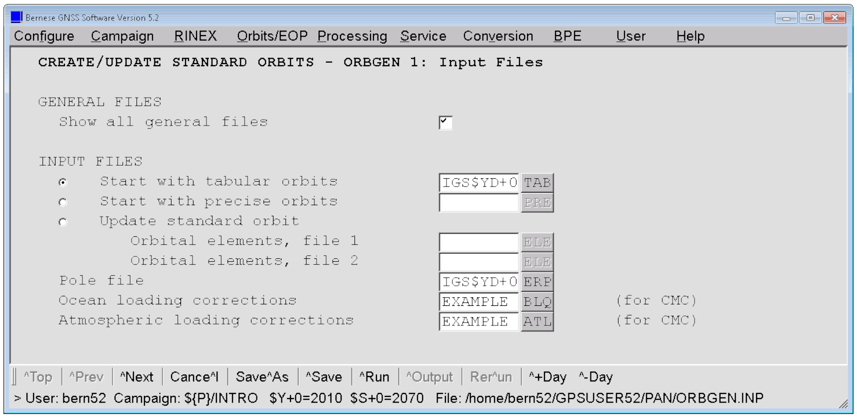
Both differences have no impact on the obtained results.

For some days a message like this may appear:

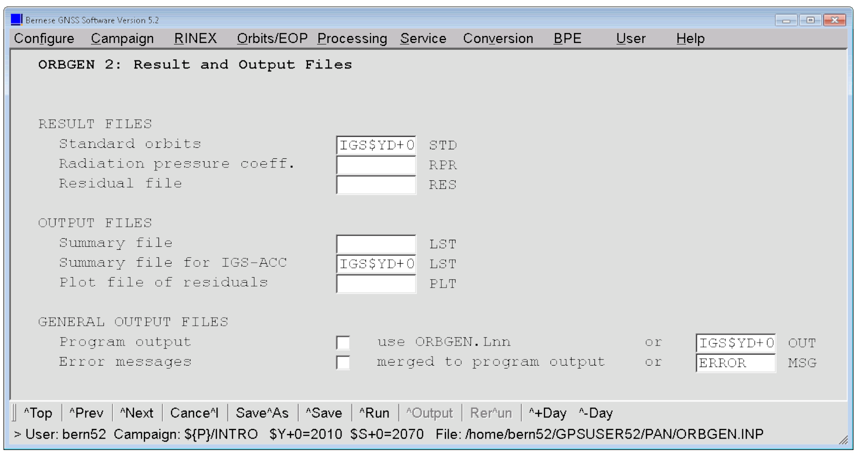
```
### PG PRETAB: SATELLITE CLOCK VALUES MISSING
              SATELLITE  :    1
              FILE NUMBER:    1
              FILE NAME  : ${P}/INTRO/ORB/GNSS2080.PRE
```

It reports that for a specific satellite no clock information is provided in the IGS files. As long as this message lists only a limited number of satellites, the synchronization of the receiver clocks in CODSPP is still possible with the remaining satellites. It is therefore not critical.

To generate the standard orbits (extension STD) from the tabular orbits the program ORBGEN ("Menu>Orbits/EOP>Create/update standard orbits") has to be used. Introduce the IGS–related tabular orbit file together with the consistent ERP file (as well as the consistent nutation, and the subdaily pole model in panel "ORBGEN 1.1: General Files"):



The name of the resulting orbit file should also be related to IGS:



The other options can be used as given in Section 3.2. The resulting program output is expected to look like

```
...
-------------------------------------------------------------------------------
RMS ERRORS AND MAX. RESIDUALS   ARC NUMBER:  1                    ITERATION:  4
-------------------------------------------------------------------------------

                          QUADRATIC MEAN OF O-C (M)         MAX. RESIDUALS (M)
SAT   #POS   RMS (M)     TOTAL   RADIAL  ALONG   OUT       RADIAL  ALONG   OUT
---   ----   -------     ----------------------------      --------------------

  1    96     0.002      0.002    0.001  0.001  0.003       0.004  0.004  0.007
  2    96     0.002      0.002    0.002  0.001  0.002       0.003  0.004  0.005
  3    96     0.004      0.004    0.004  0.003  0.004       0.009  0.006  0.007
  4    96     0.001      0.001    0.001  0.001  0.001       0.003  0.003  0.003
  5    96     0.002      0.002    0.002  0.001  0.002       0.004  0.005  0.010
  6    96     0.003      0.003    0.003  0.003  0.004       0.008  0.006  0.007
  7    96     0.002      0.002    0.002  0.002  0.002       0.005  0.005  0.004
  8    96     0.002      0.002    0.001  0.001  0.002       0.003  0.003  0.006
  9    96     0.002      0.002    0.002  0.001  0.003       0.003  0.003  0.006
 10    96     0.002      0.002    0.002  0.002  0.003       0.005  0.005  0.005
 11    96     0.002      0.002    0.001  0.001  0.002       0.004  0.003  0.007
 12    96     0.003      0.003    0.003  0.002  0.003       0.007  0.005  0.006
 13    96     0.003      0.003    0.003  0.002  0.003       0.013  0.007  0.006
 14    96     0.003      0.003    0.004  0.003  0.002       0.011  0.006  0.009
 15    96     0.002      0.002    0.002  0.002  0.002       0.008  0.004  0.005
 16    96     0.004      0.003    0.004  0.003  0.004       0.007  0.008  0.008
 17    96     0.002      0.002    0.002  0.002  0.002       0.006  0.005  0.007
 18    96     0.003      0.002    0.003  0.002  0.003       0.006  0.004  0.007
 19    96     0.002      0.002    0.002  0.002  0.003       0.005  0.004  0.005
 20    96     0.002      0.002    0.002  0.001  0.003       0.004  0.004  0.006
 21    96     0.002      0.002    0.001  0.001  0.003       0.003  0.002  0.006
 22    96     0.003      0.003    0.003  0.002  0.003       0.005  0.005  0.006
 23    96     0.003      0.003    0.003  0.002  0.003       0.011  0.006  0.005
```

```
  24      96     0.001        0.001     0.001  0.001  0.002        0.003  0.002  0.005
  25      96     0.002        0.002     0.001  0.001  0.003        0.003  0.003  0.007
  26      96     0.004        0.004     0.005  0.003  0.003        0.011  0.006  0.005
  27      96     0.002        0.002     0.002  0.001  0.003        0.003  0.003  0.006
  28      96     0.002        0.002     0.002  0.002  0.002        0.004  0.005  0.007
  29      96     0.003        0.003     0.003  0.003  0.003        0.005  0.006  0.007
  30      96     0.002        0.002     0.002  0.002  0.002        0.006  0.005  0.005
  31      96     0.002        0.002     0.002  0.002  0.003        0.005  0.005  0.009
  32      96     0.002        0.002     0.002  0.001  0.003        0.005  0.003  0.006
 101      96     0.002        0.002     0.002  0.002  0.002        0.006  0.004  0.007
 102      96     0.002        0.002     0.002  0.002  0.002        0.006  0.005  0.005
 103      96     0.002        0.002     0.002  0.002  0.002        0.005  0.006  0.006
 104      96     0.002        0.001     0.002  0.001  0.002        0.005  0.003  0.004
 105      96     0.001        0.001     0.001  0.001  0.002        0.003  0.007  0.004
 107      96     0.002        0.002     0.001  0.001  0.002        0.003  0.007  0.005
 108      96     0.002        0.002     0.002  0.001  0.002        0.004  0.003  0.004
 110      96     0.002        0.002     0.001  0.001  0.003        0.007  0.003  0.005
 111      96     0.001        0.001     0.001  0.001  0.002        0.003  0.010  0.006
 113      96     0.002        0.002     0.002  0.001  0.002        0.004  0.005  0.005
 114      96     0.002        0.002     0.002  0.002  0.002        0.005  0.012  0.004
 115      96     0.002        0.002     0.002  0.001  0.002        0.004  0.008  0.005
 117      96     0.002        0.002     0.003  0.002  0.002        0.010  0.009  0.003
 118      96     0.002        0.002     0.002  0.001  0.002        0.004  0.006  0.006
 119      96     0.003        0.002     0.002  0.002  0.003        0.005  0.006  0.006
 120      96     0.002        0.002     0.002  0.001  0.003        0.004  0.004  0.006
 121      96     0.002        0.002     0.002  0.002  0.003        0.006  0.004  0.014
 122      96     0.002        0.002     0.002  0.002  0.002        0.004  0.006  0.004
 123      96     0.002        0.001     0.001  0.001  0.002        0.003  0.004  0.004
 124      96     0.002        0.002     0.001  0.002  0.001        0.003  0.017  0.003

 -------------------------------------------------------------------------------
 ...
```

The RMS error for the orbit fit for precise IGS orbits should be below 5 mm (for older orbits it may also achieve 10. . . 15 mm).

The file ${P}/INTRO/OUT/IGS10207.LST contains the same results as displayed on page 27 but contains also the GLONASS satellite orbits:

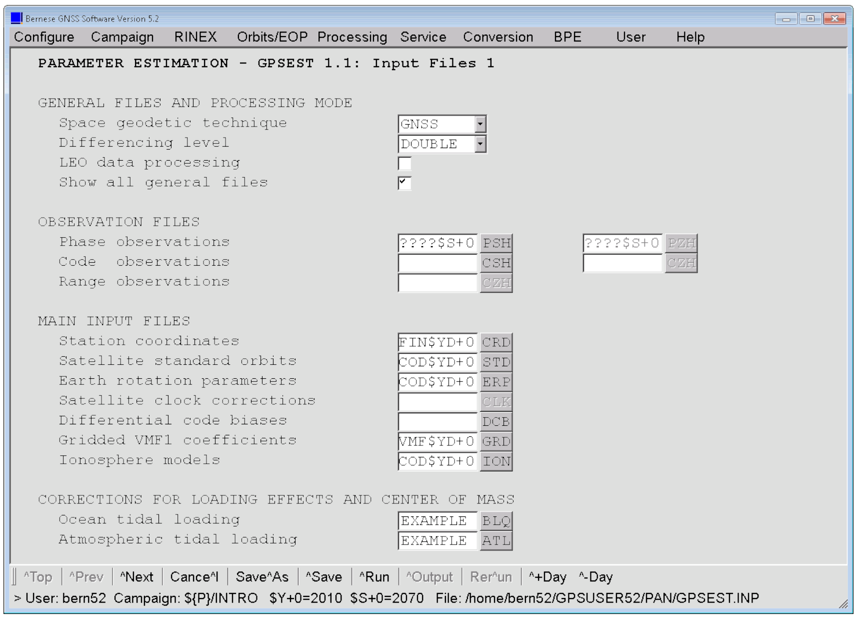
```
EXAMPLE: Session 102070: Standard orbit generation               28-AUG-17 13:32
TIME FROM DAY : 1 GPS WEEK: 1594
     TO   DAY : 2 GPS WEEK: 1594
-------------------------------------------------------------------------------
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:   5
--------------------------- ... -------------------- ... ---------------------------- ...
ECL  ..  ..  ..  ..  ..  ..      ..  E.  E.  E.  ..       ..  ..  ..  ..  ..  ..  ..
DOY   1   2   3   4   5   6 ...  12  13  14  15  16  ...  32 101 102 103 104 105 107  ...
--------------------------- ... -------------------- ... ---------------------------- ...
207   2   2   4   1   2   3 ...   3   3   3   2   3  ...   2   2   2   2   1   1   2  ...
--------------------------- ... -------------------- ... ---------------------------- ...
ALL   2   2   4   1   2   3 ...   3   3   3   2   3  ...   2   2   2   2   1   1   2  ...
--------------------------- ... -------------------- ... ---------------------------- ...
```

If you want to use these orbit files in the processing programs, you simply have to replace the CODE–related by the IGS–related filenames for the standard orbit and EOP files.

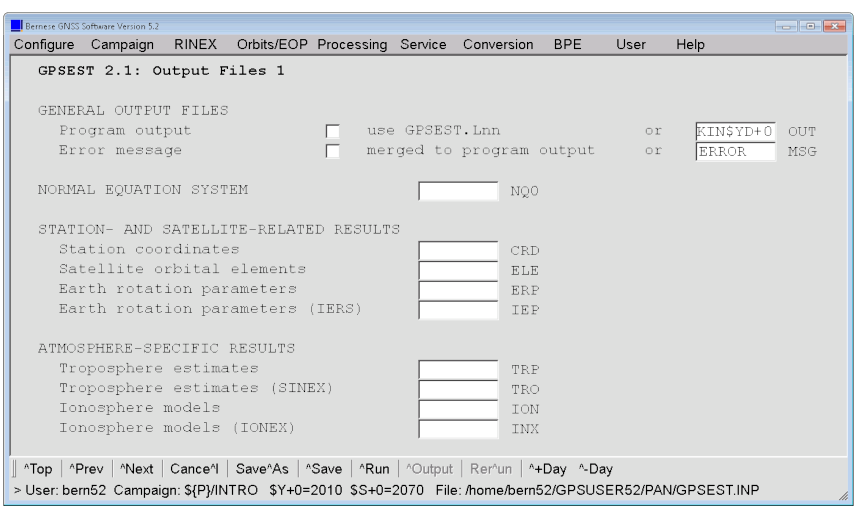
7.3 Kinematic Positioning

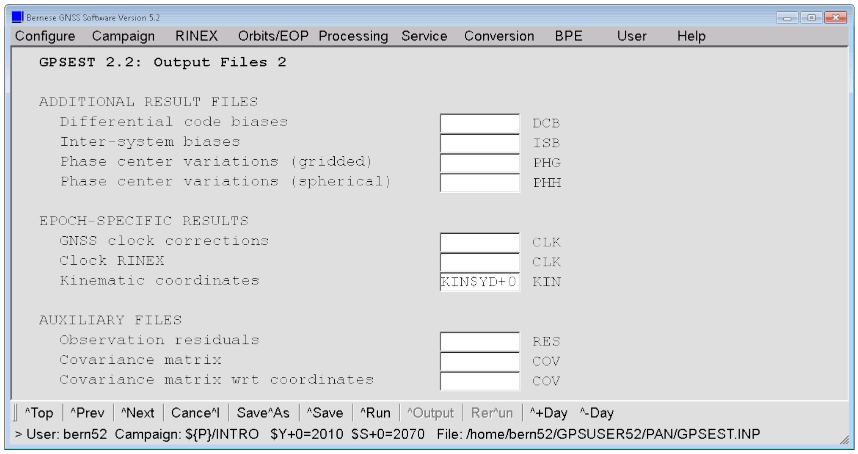
7.3.1 Estimating Kinematic Positions in a Double–Difference Solution

The example campaign contains no really roving stations. You can, however, define one of them to be kinematic (e.g., station GANP). Introduce the coordinates from the final solution (`${P}/INTRO/STA/FIN10207.CRD`) for all other sites.

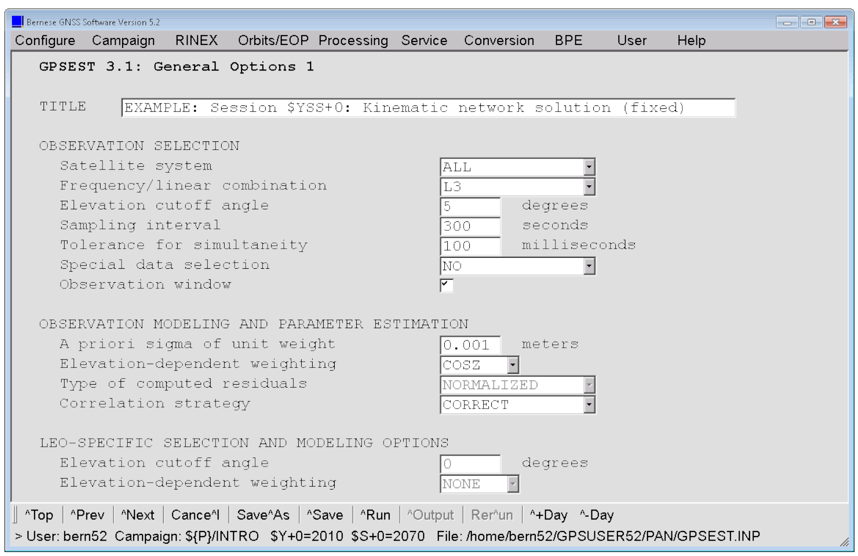


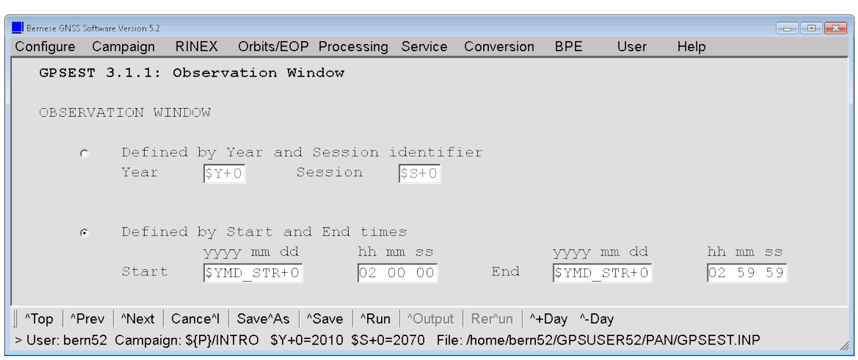
Remove the name of the resulting "Normal equations" file in panel "GPSEST 2.1: Output Files 1" if there is any entry in this input field. Store the kinematic coordinates in an output file ("Kinematic coordinates" in panel "GPSEST 2.2: Output Files 2").



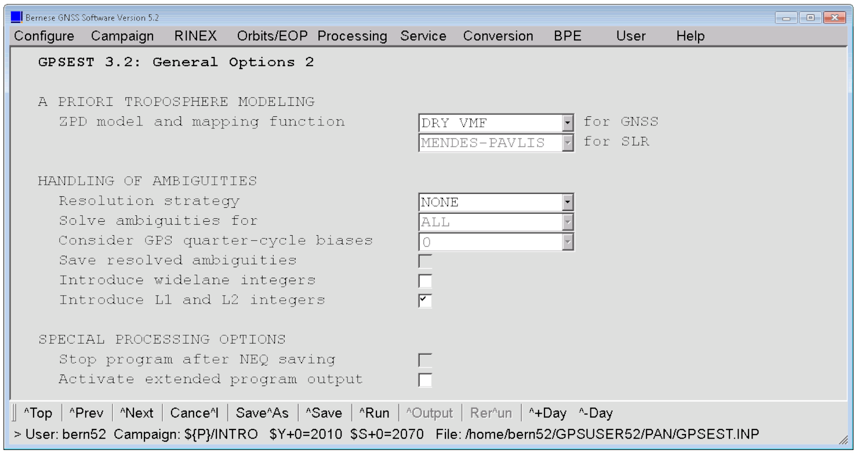


Because the number of parameters for the kinematic positioning may become very large, we select only a short data interval of one hour for this kinematic positioning:

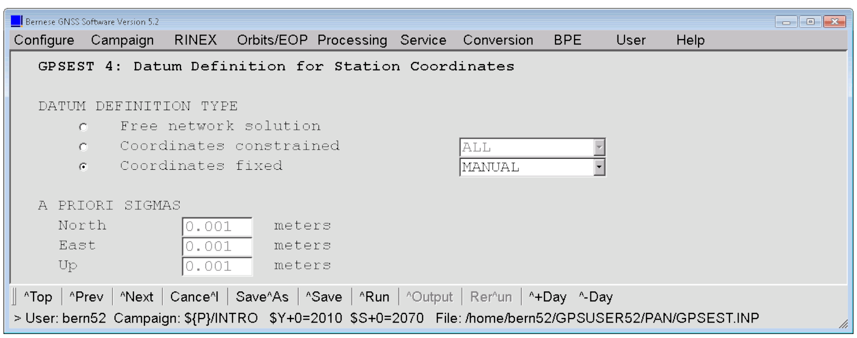


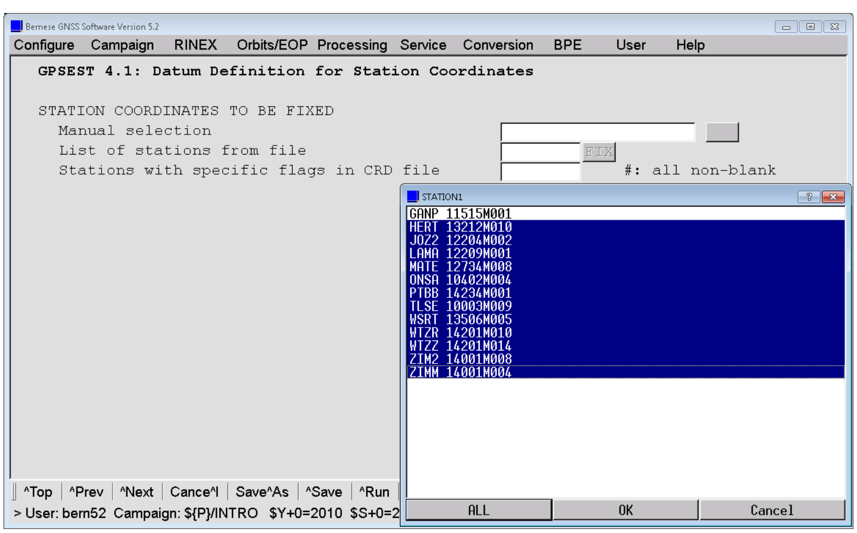


The option "Enable extended program output" may be disabled now:

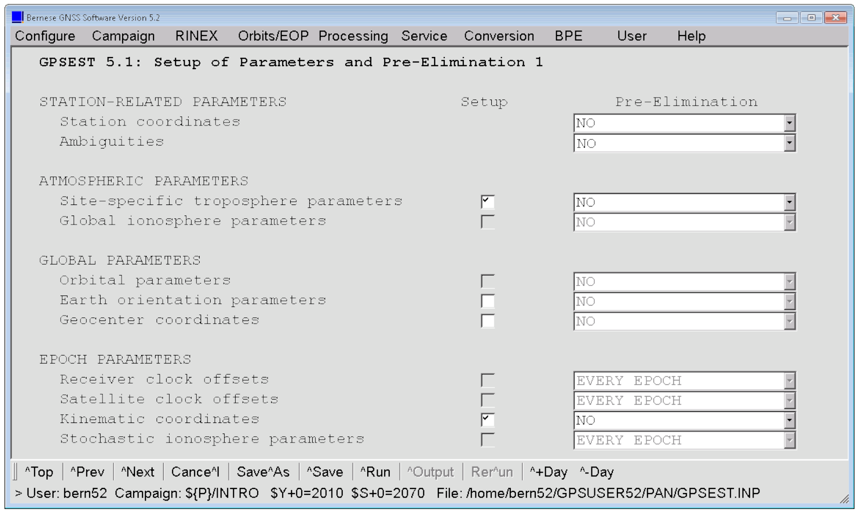


Fix all station coordinates apart from GANP in the panels "GPSEST 4: Datum Definition for Station Coordinates" (choose MANUAL in panel "GPSEST 4: Datum Definition for Station Coordinates" and select all stations except GANP in panel "GPSEST 4.2").

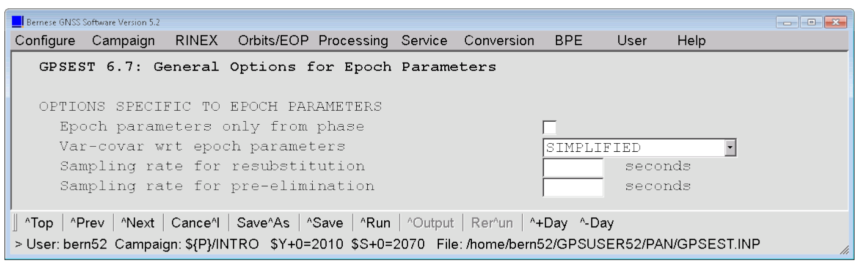




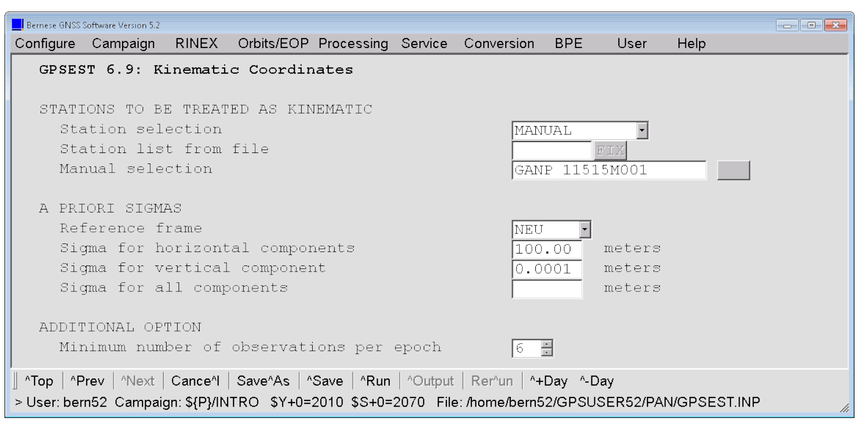
Enable the kinematic coordinates option without any pre–elimination in a first run:



An additional panel for options related to epoch parameters is displayed where you can accept the default values:



Let us assume only horizontal movements for this site:

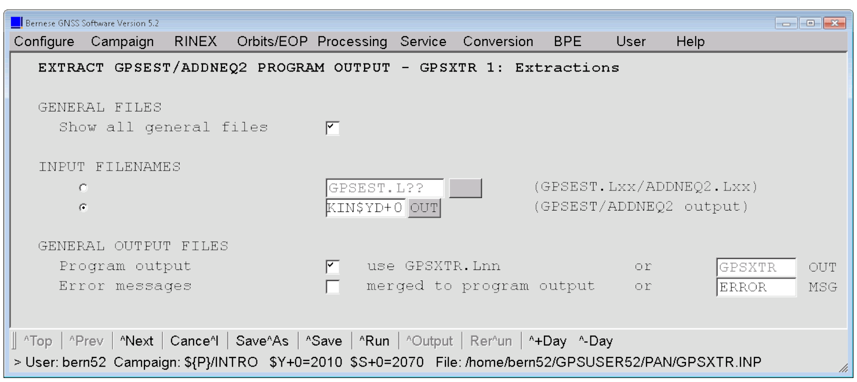


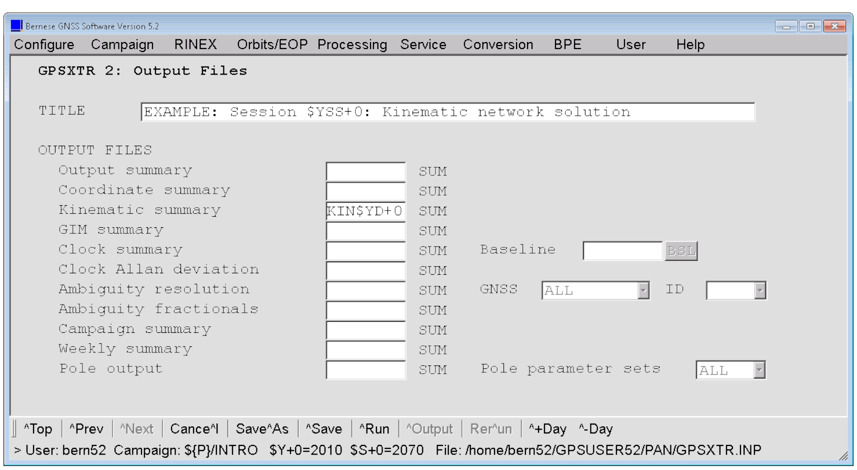
7.3.2 Extracting the Program Output from a Kinematic Positioning

As expected you will get only small estimates for the kinematic coordinates since GANP was not moving:

```
KINEMATIC COORDINATES:                     ${P}/INTRO/STA/KIN10207.KIN
---------------------

 EPO: EPOCHS SINCE  2010-07-26 02:00:00  (SAMPLING   300 SEC)

                                              CORRECTION AND RMS IN METER             ...
 EPO   EPOCH(MJD)     #OBS STA         LATITUDE          LONGITUDE             HEIGHT    ...
-------------------------------------------------------------------------------------...

       GANP 11515M001              49  2  4.971302    20 19 22.574439         746.0115
   1   55403.083333   15   GANP   -0.0048 +- 0.004   -0.0035 +- 0.004    0.0000 +- 0.000 ...
   2   55403.086806   14   GANP    0.0049 +- 0.004   -0.0045 +- 0.004    0.0000 +- 0.000 ...
   3   55403.090278   14   GANP    0.0019 +- 0.004   -0.0003 +- 0.004   -0.0000 +- 0.000 ...
   4   55403.093750   14   GANP    0.0007 +- 0.004    0.0015 +- 0.004   -0.0000 +- 0.000 ...
   5   55403.097222   13   GANP   -0.0024 +- 0.004    0.0016 +- 0.004    0.0000 +- 0.000 ...
   6   55403.100694   13   GANP   -0.0045 +- 0.004    0.0034 +- 0.004    0.0000 +- 0.000 ...
   7   55403.104167   13   GANP   -0.0031 +- 0.004    0.0026 +- 0.004    0.0000 +- 0.000 ...
   8   55403.107639   13   GANP    0.0012 +- 0.005    0.0041 +- 0.004   -0.0000 +- 0.000 ...
   9   55403.111111   14   GANP   -0.0062 +- 0.005    0.0022 +- 0.004    0.0000 +- 0.000 ...
  10   55403.114583   14   GANP   -0.0028 +- 0.005    0.0034 +- 0.005    0.0000 +- 0.000 ...
  11   55403.118056   14   GANP   -0.0009 +- 0.005    0.0023 +- 0.005    0.0000 +- 0.000 ...
  12   55403.121528   13   GANP   -0.0049 +- 0.005   -0.0014 +- 0.005   -0.0000 +- 0.000 ...
```

With the program GPSXTR ("Menu>Processing>Program output extraction>Parameter estimation/stacking") a comprehensive summary of the estimates for the kinematic solution can be extracted:





The resulting summary file looks like:

```
 ------------------------------------------------------------------------------
*XEPO              12            0            12
*INI           0.0000       0.0000        0.0000
*EST           0.0000       0.0000        0.0000
*DIFXYZ        0.0000       0.0000        0.0000
*DIFNEU       -0.0017       0.0009        0.0000
------------------------------------------------------------------------------
  EPOCH            DN           DE            DU
      1       -0.0048      -0.0035        0.0000
      2        0.0049      -0.0045        0.0000
      3        0.0019      -0.0003       -0.0000
      4        0.0007       0.0015       -0.0000
      5       -0.0024       0.0016        0.0000
      6       -0.0045       0.0034        0.0000
      7       -0.0031       0.0026        0.0000
      8        0.0012       0.0041       -0.0000
      9       -0.0062       0.0022        0.0000
     10       -0.0028       0.0034        0.0000
     11       -0.0009       0.0023        0.0000
     12       -0.0049      -0.0014       -0.0000
------------------------------------------------------------------------------
*AVG          -0.0017       0.0009        0.0000
*SIG           0.0036       0.0028        0.0000
*RMS           0.0033       0.0028        0.0000
*RMSTC         0.0011
------------------------------------------------------------------------------
 STATION: GANP
 PARAMS :     96     12      0    509 (AMB, CRD, CLK, TOT)
 OBSERV :      0   1592   1592
```

The different components of the summary are described in the online help.

7.3.3 Further suggestions

- Introduce the result file with kinematic coordinates as an input file for another run of GPSEST. If the estimates become zero it is a confirmation that the file was correctly considered as the a priori kinematic positions for the station GANP.
- Use the pre–elimination EVERY_EPOCH for the "Kinematic coordinates" (they are back–substituted by the program in order to get a solution also for those parameters). Compare the results with the first solution.
- Switch the "Var-covar wrt epoch parameters" in panel "GPSEST 6.7: General Options for Epoch Parameters" from SIMPLIFIED to CORRECT. Compare the results again with the first solution.
- Compute kinematic coordinates for the full day using the epoch–wise pre–elimination and back–substitution algorithm. To save computing power we recommend to sample the data to 300 s.
- Repeat the kinematic solution considering only one of the two GNSS at the time (choose either GPS or GLONASS in option "Satellite system" of panel "GPSEST 3.1: General Options 1").

7.4 Zero Difference Processing for Clock Estimation

For the clock estimation we have to use code and phase data together. The data is analyzed at zero difference level.

7.4.1 Preprocessing

There are two ways for preprocessing zero difference observations in the *Bernese GNSS Software*, Version 5.2 available:

- *Precise satellite clocks are available* for all satellites with the same sampling as the RINEX observations to be processed (typically 30 s):

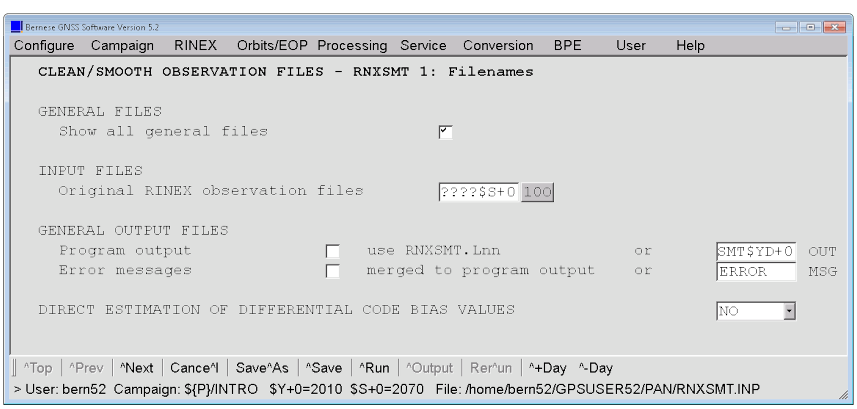
  1. RNXSMT to screen and smooth code measurements based on a consistency check between the code and phase observations
  2. RXOBV3 to import the screened smoothed code together with the original phase data into Bernese observation file format
  3. CODSPP to synchronize receiver clocks with respect to the GNSS system time
  4. MAUPRP to screen the phase measurements
  5. GPSEST, RESRMS, SATMRK to screen residuals from a zero difference network solution

- *Precise satellite clocks are* not *available*:

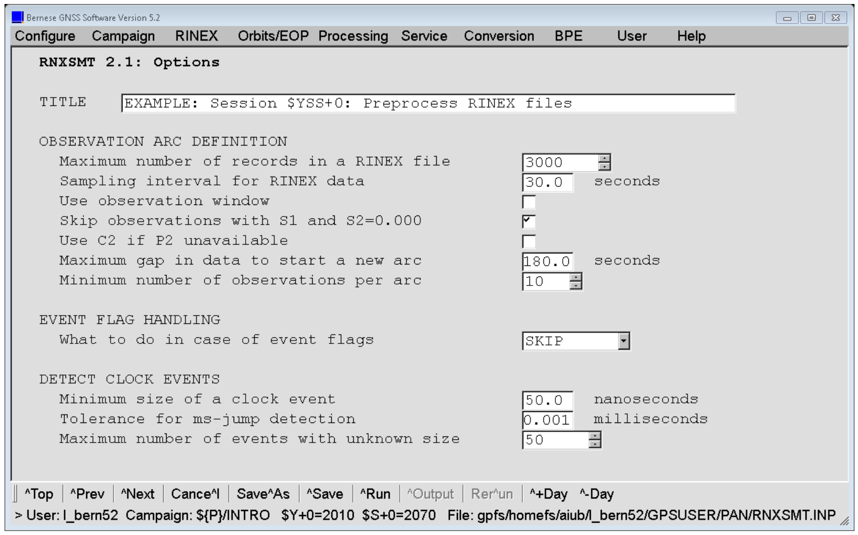
  1. RNXSMT to screen phase and code measurements based on a consistency check; smooth the code observations
  2. RXOBV3 to import the screened phase and smoothed code data into Bernese observation file format
  3. CODSPP to synchronize receiver clocks with respect to the GNSS system time
  4. GPSEST, RESRMS, SATMRK to screen residuals from a zero difference network solution iteratively with a decreasing threshold

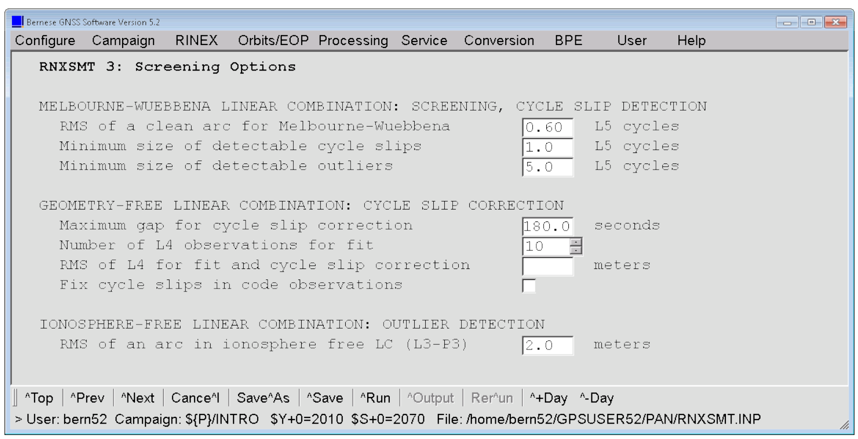
In this text book we follow the second approach.

The preprocessing of zero difference data starts with program RNXSMT, available from "Menu>RINEX>RINEX utilities>Clean/smooth observation files". In the first panel select all RINEX files of the active session:

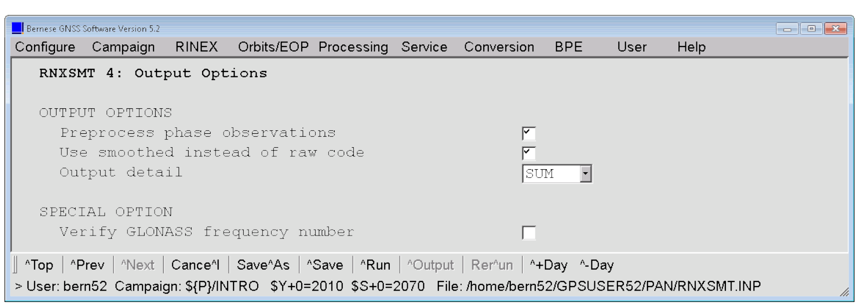


The default input options perform well in most cases:





In the last panel you decide whether or not to "Preprocess phase observations" by checking or unchecking the box:

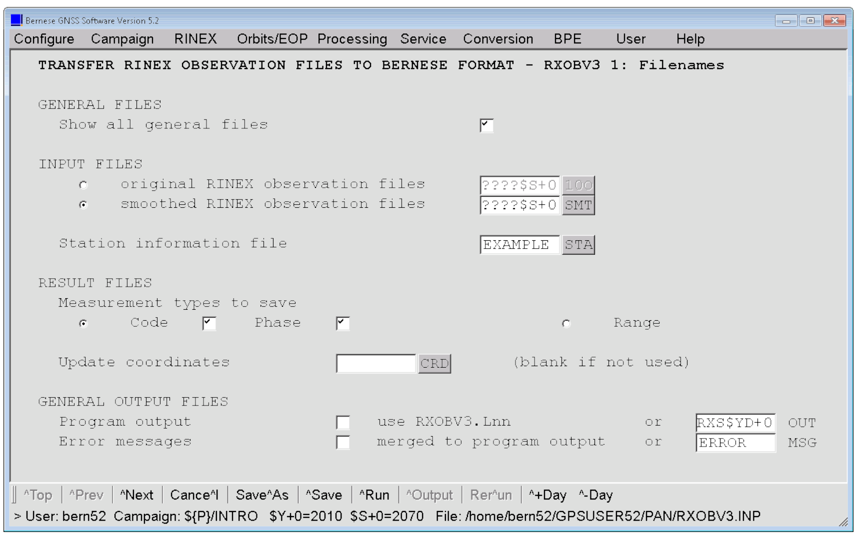


The resulting smoothed RINEX files look like usual RINEX files but the line

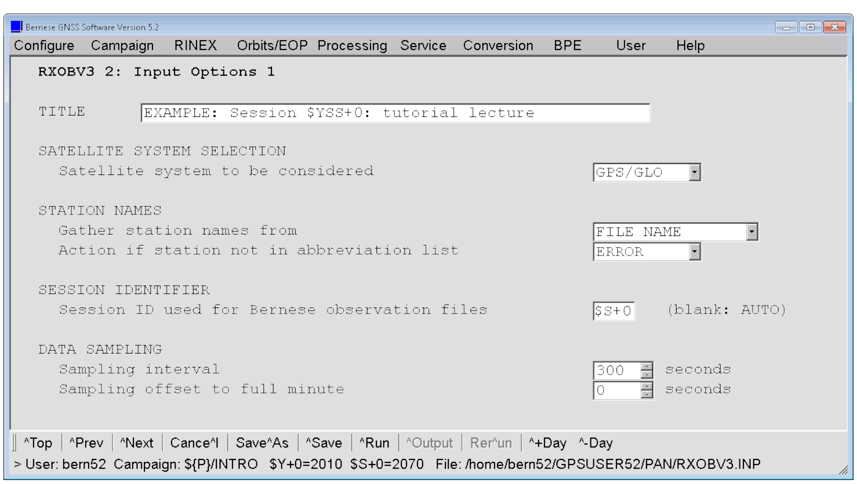
```
### PG RNXSMT: RINEX FILE CHANGED                          COMMENT
```

indicates that the numbers in the file result from RNXSMT. The S/N indicators have the following meaning:
"1" considered by RNXSMT as bad data
"5" data have only been copied from the original file by RNXSMT
"9" considered by RNXSMT as good data
The cycle slip flags in a smoothed RINEX file indicate the epochs/satellites where new ambiguities are needed according to the evaluation of RNXSMT.

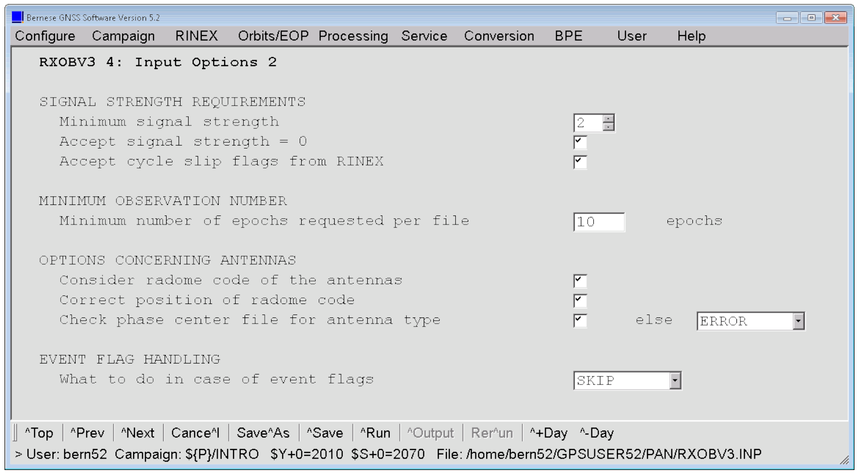
In order to import the smoothed RINEX observation files into the Bernese format you have to select them in the first input panel of program RXOBV3 (note that you will overwrite your zero difference observation files from the previous processing example by doing this):



If you have preprocessed the phase measurements already in RNXSMT you can resample the observations already in RXOBV3: set the "Sampling interval" in panel "RXOBV3 2: Input Options 1", e.g., to 300 seconds.



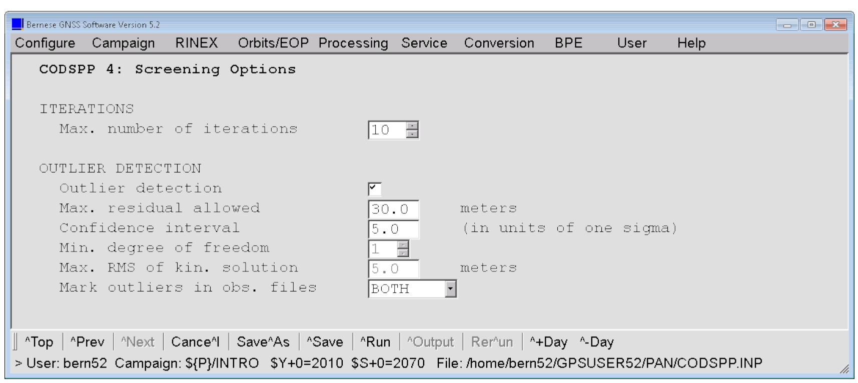
Furthermore, you have to consider the "SIGNAL STRENGTH REQUIREMENTS" for smoothed RINEX files (see above):



After importing the data into the Bernese format you have to repeat the receiver clock synchronization with program CODSPP. The options are identical to the settings in Section 4.2.1. The only difference is the option "Mark outliers in obs. files" in the last input panel: depending on your preprocessing chain it is recommended to select:

BOTH if you have screened phase and code data in RNXSMT, because it is assumed that the corresponding phase measurement is also bad if a problematic code data record has passed RNXSMT.

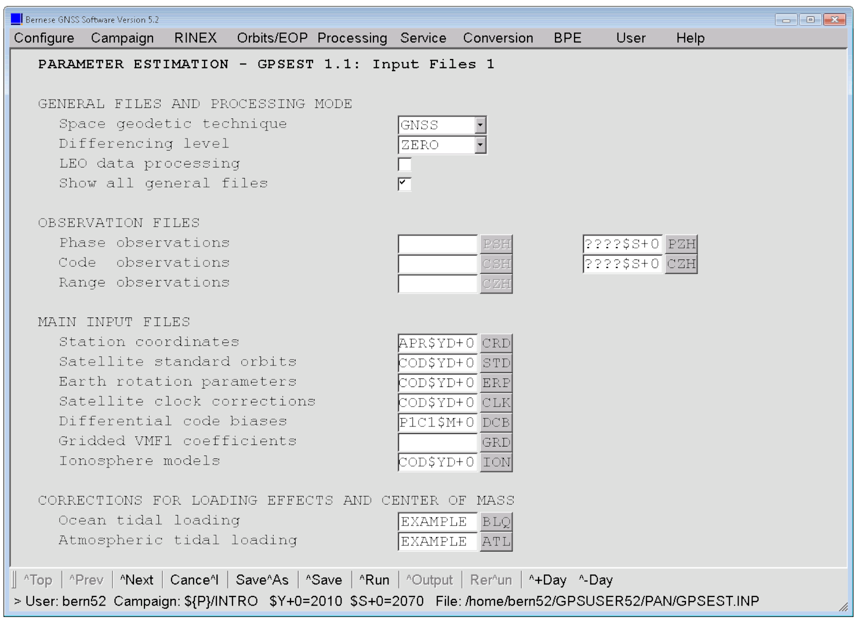
CODE if you have used RNXSMT to only screen and smooth code observations so far. From problems in the code data cannot be deduced the quality of the corresponding phase measurements.



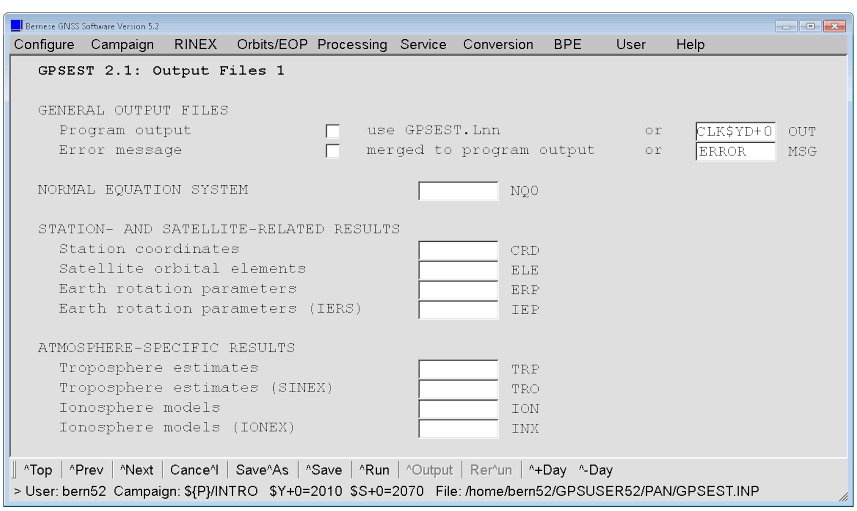
If you have not yet cleaned the phase observations in RNXSMT (approach with precise high–rate clocks available), you have to run MAUPRP now ("Menu>Processing>Phase preprocessing"). For this purpose, you need precise satellite clock corrections for all satellites and with the full sampling of 30 seconds (or even higher). Select "Zero-difference observation files" instead of "Single-difference observation files" and introduce a consistent set of "GNSS standard orbits", "Pole file", and "Satellite clocks" in panel "MAUPRP 1: Input Files". An additional panel "MAUPRP 7: Clock Events" will be displayed (see online help for further details). It is recommended to disable the cycle slip corrections by checking the box for option "Do not accept cycle slip corrections" in panel "MAUPRP 8: Cycle Slip Detection/Correction". All other settings can remain as described in Section 4.2.3: You may skip this step if you have preprocessed the phase data already in RNXSMT.

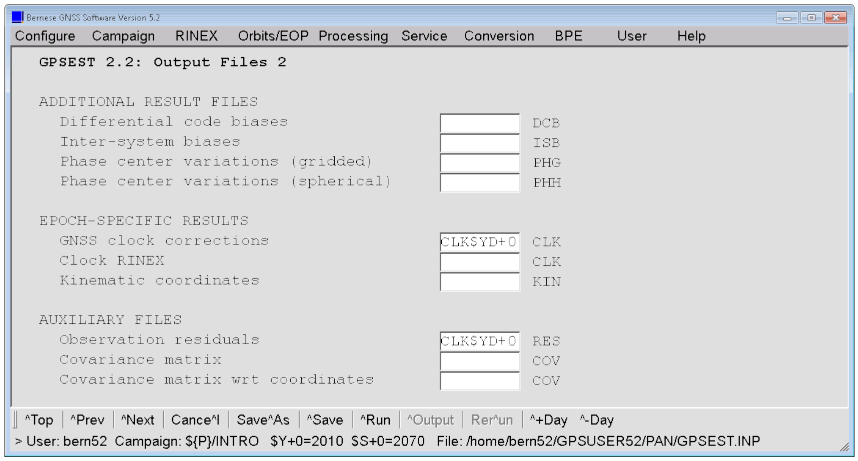
7.4.2 Residual Screening

Now you are ready to run GPSEST ("Menu>Processing>Parameter estimation") in the zero difference mode to store residuals for screening. You also have to include a DCB file when processing code observations.

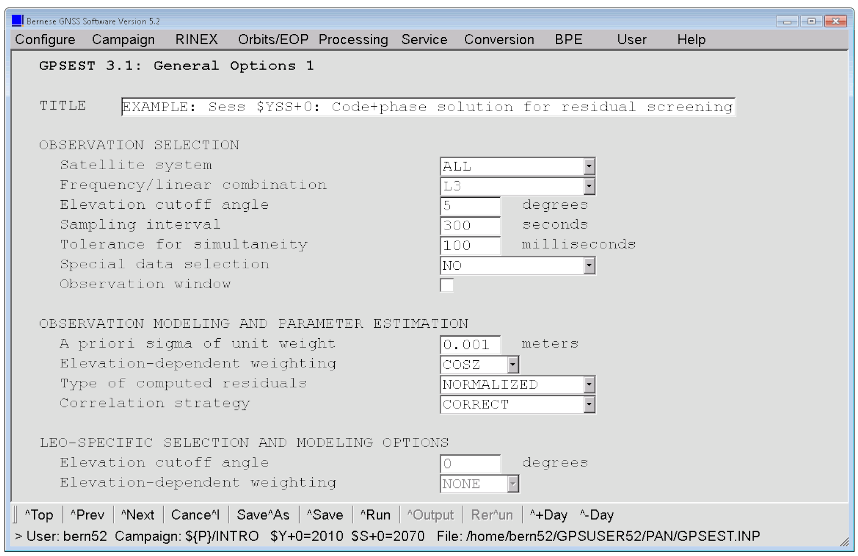


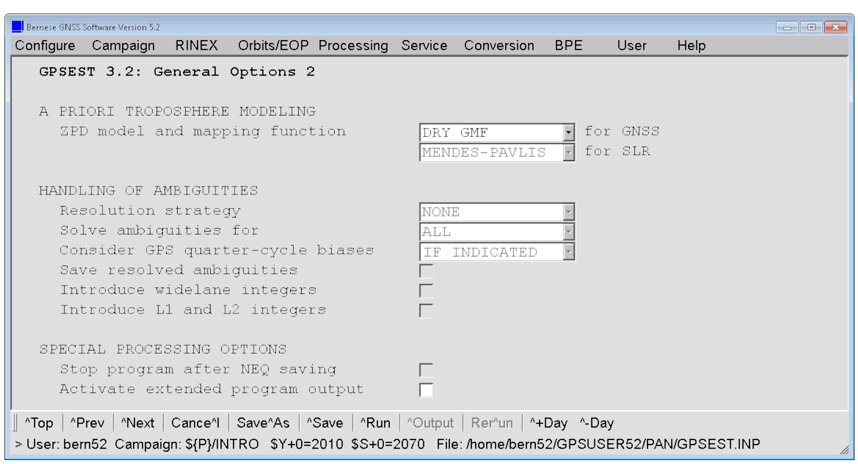
In the subsequent two panels, the output files for residuals and clock estimates are specified:



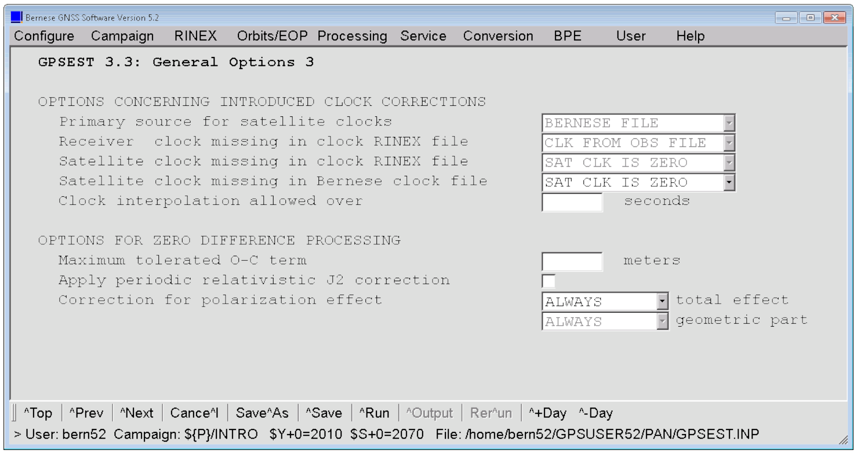


Take care to specify "Correlation strategy" with CORRECT and to store NORMALIZED residuals

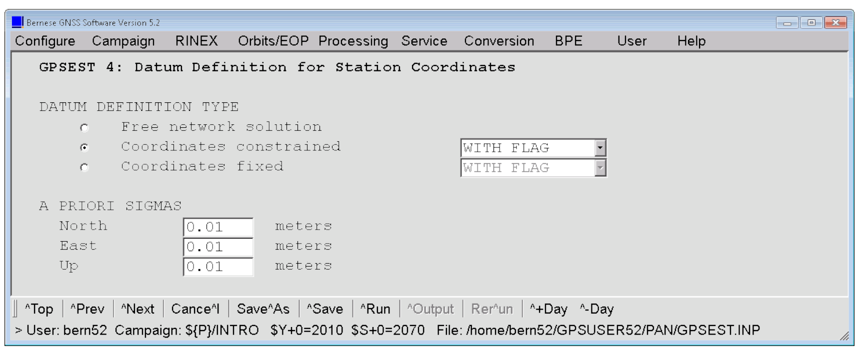


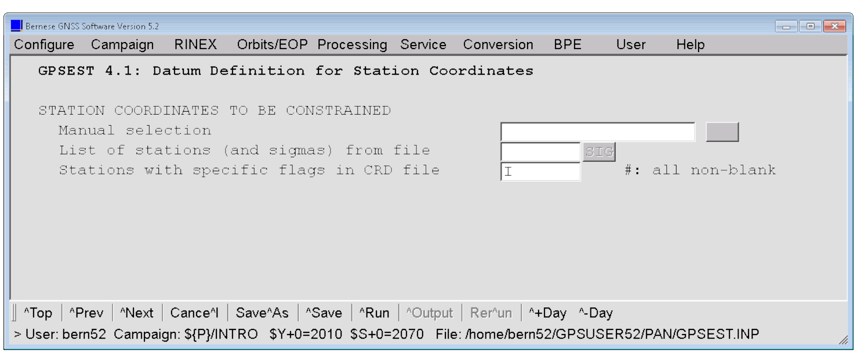


The options in the following panel are only relevant to zero difference processing. They define, e.g., the source clocks used as a priori for satellites and receivers if more than one potential source is available:

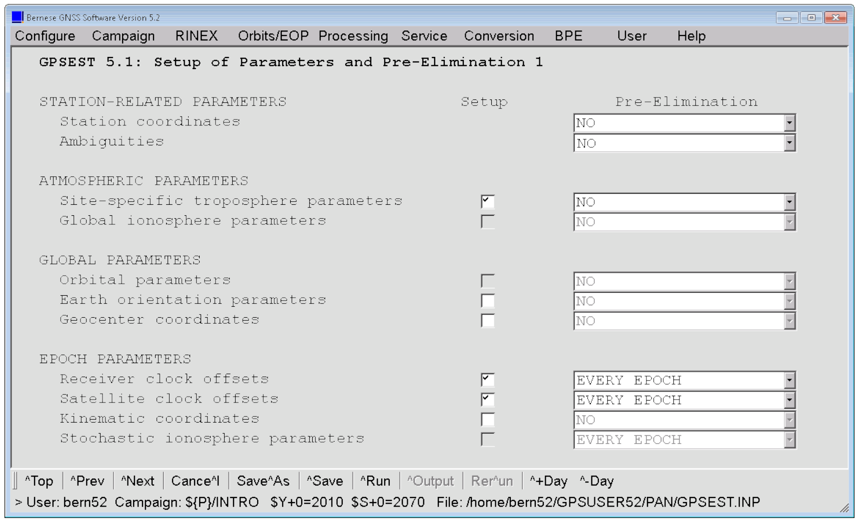


The datum definition shall be consider according to the information in the a priori coordinate file given in panel "GPSEST 1.1: Input Files 1":

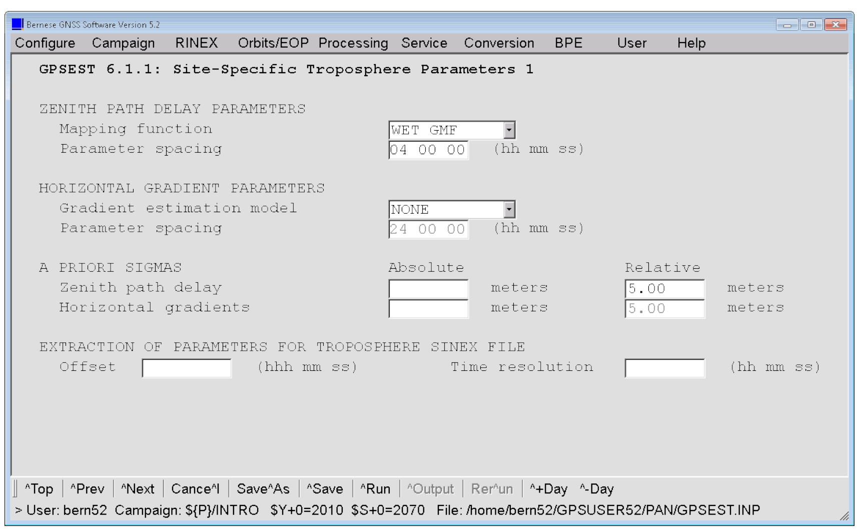




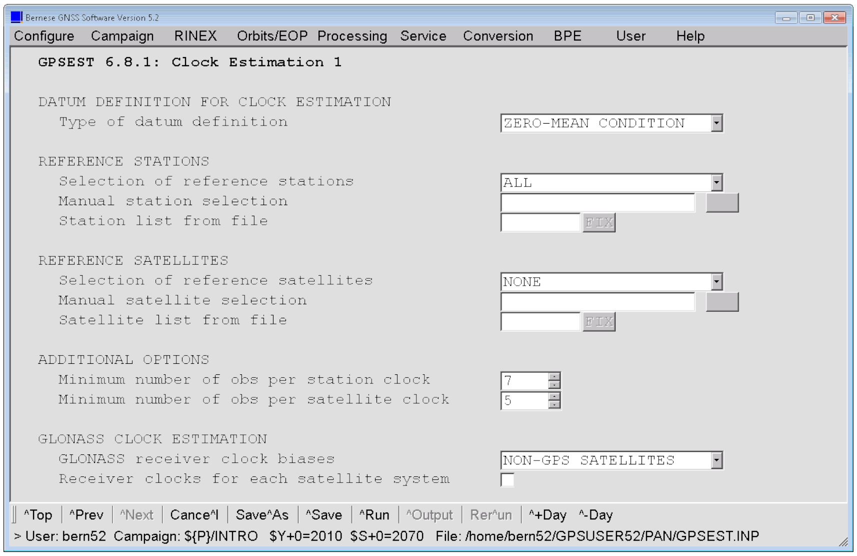
Clock parameters are setup and pre–eliminated EVERY_EPOCH:



For the residual screening, a reduced set of troposphere parameters can be estimated:



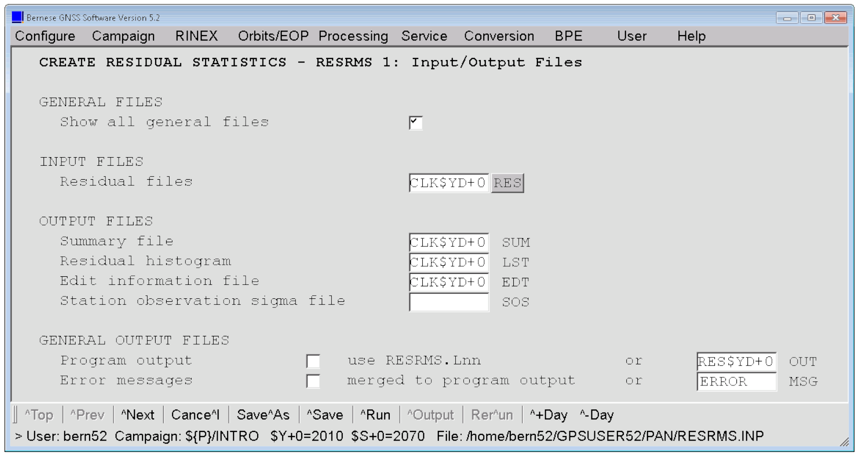
The following panel asks for the options regarding the clock estimation. If you include GLONASS you need to choose "Rclk.off: Parameter setup" different from NONE. See online help for additional information.

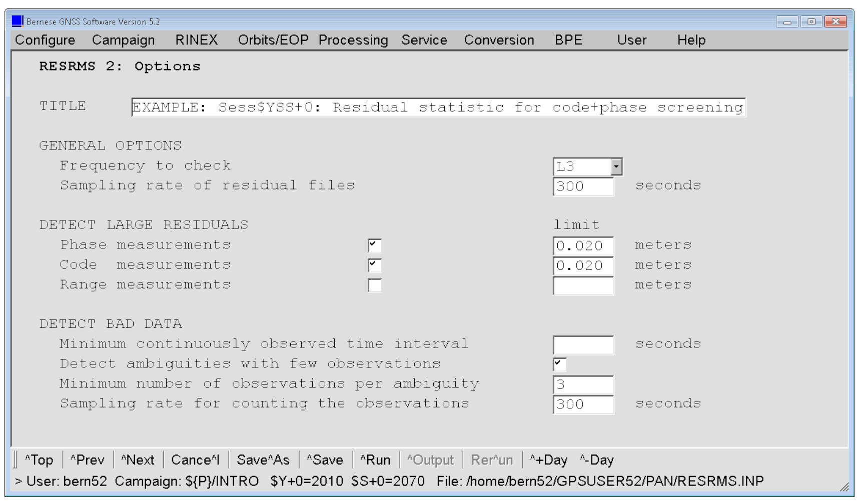


The program output file should report the clock parameters:

```
...
 13. RESULTS (PART 1)
--------------------

NUMBER OF PARAMETERS (PART 1):
-----------------------------

PARAMETER TYPE                              #PARAMETERS   #PRE-ELIMINATED        #SET-UP  ...
------------------------------------------------------------------------------------------ ...


STATION COORDINATES                              39           0                      39   ...
RECEIVER CLOCK BIASES / TIME BIASES             200           0                     200   ...
AMBIGUITIES                                    1375           0                    1442   ...
SITE-SPECIFIC TROPOSPHERE PARAMETERS             91           0                      91   ...
EPOCH WISE STATION CLOCKS                      3739        3739  (EPOCH-WISE)      3744   ...
EPOCH WISE SATELLITE CLOCKS                    5842        5842  (EPOCH-WISE)      6059   ...

------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF PARAMETERS                    11286        9581                   11575   ...
------------------------------------------------------------------------------------------ ...


NUMBER OF OBSERVATIONS (PART 1):
-------------------------------

TYPE         FREQUENCY         FILE/PAR          #OBSERVATIONS
------------------------------------------------------------------------------------------ ...

PHASE           L3               ALL                    54384
CODE            L3               ALL                    54393

------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF OBSERVATIONS                                108777
------------------------------------------------------------------------------------------ ...


A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0015 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     97491
CHI**2/DOF                         :      2.38
...
```

The residuals are stored in the file `${P}/INTRO/OUT/CLK02143.RES`. Use program RESRMS ("Menu>Service>Residual files>Create residual statistics") to screen for outliers bigger than 2 cm for code and phase data (remember that code residuals are scaled to phase residuals — 2 cm in the input field correspond to a 2 m threshold for code residuals):

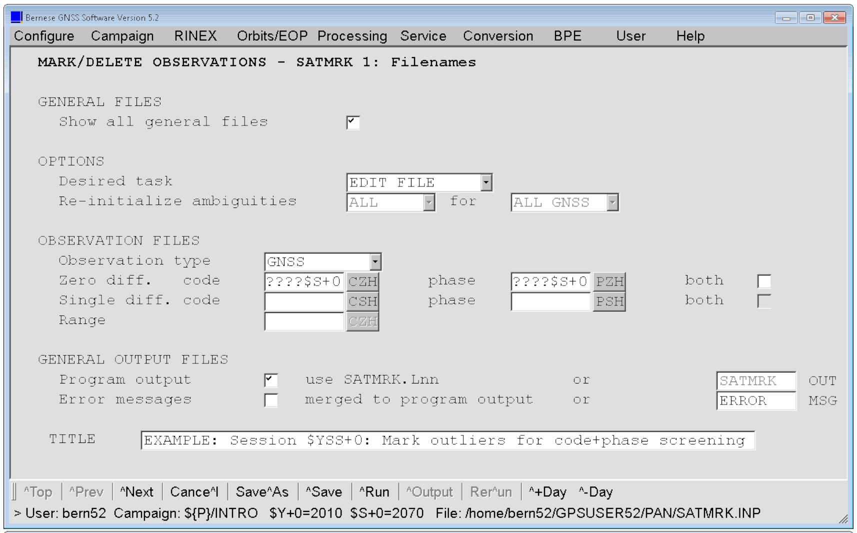


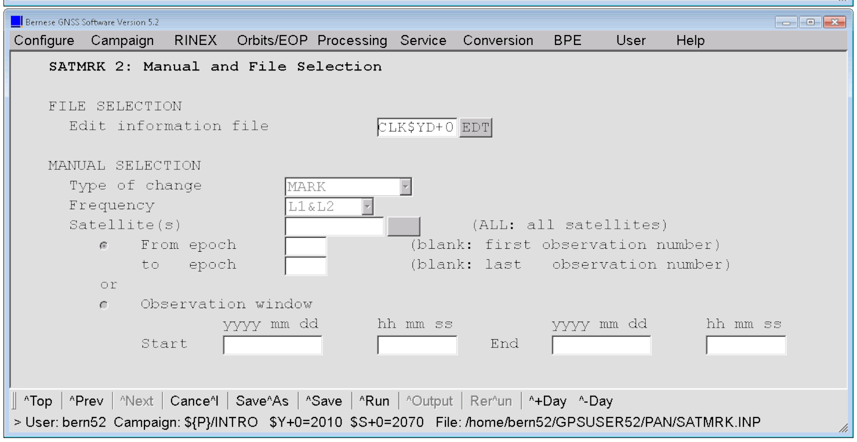


The statistics in the program output file clearly indicates some stations with problematic obervations:

```
FILE INFORMATION AND STATISTIC:
------------------------------

Num   Station 1       ... Total RMS   med.Resi      Sigma  numObs  nSat  nDel  ObsTyp ..
-----------------------------------------------------------------------------------------..

  1   GANP 11515M001  ...      1.3        0.7         1.1    4682    50     1  PHASE  ..
  2   HERT 13212M010  ...      2.0        0.7         1.0    4716    51     3  PHASE  ..
  3   JOZ2 12204M002  ...      2.0        0.8         1.1    4805    50     2  PHASE  ..
  4   LAMA 12209M001  ...      1.3        0.6         0.9    4786    50     1  PHASE  ..
  5   MATE 12734M008  ...      3.6        0.8         1.2    4324    51     9  PHASE  ..
  6   ONSA 10402M004  ...      2.4        0.7         1.0    4624    50     1  PHASE  ..
  7   PTBB 14234M001  ...      1.7        0.9         1.3    2155    32     1  PHASE  ..
...
 14   GANP 11515M001  ...      0.4        0.1         0.3    4683    50     0  CODE   ..
 15   HERT 13212M010  ...      0.3        0.1         0.2    4718    51     0  CODE   ..
 16   JOZ2 12204M002  ...      0.3        0.1         0.2    4806    50     0  CODE   ..
 17   LAMA 12209M001  ...      0.2        0.1         0.2    4788    50     0  CODE   ..
 18   MATE 12734M008  ...      0.3        0.1         0.2    4325    51     0  CODE   ..
 19   ONSA 10402M004  ...      0.3        0.1         0.2    4624    50     0  CODE   ..
 20   PTBB 14234M001  ...      0.5        0.2         0.3    2155    32     0  CODE   ..
...
```

Mark the corresponding code and phase zero difference observations using program SATMRK ("Menu>Service>Bernese observation files>Mark/delete observations":





If you inspect the program output you will notice that only 354 observations have been removed from all observation files.

Repeat the GPSEST–run and store again the residuals.

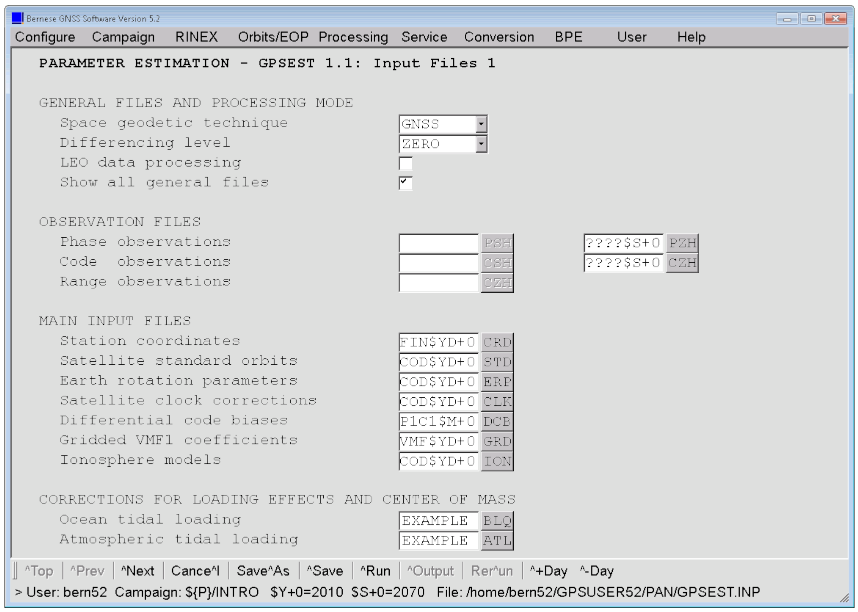
```
...
A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0009 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :     97420
CHI**2/DOF                         :      0.79
...
```

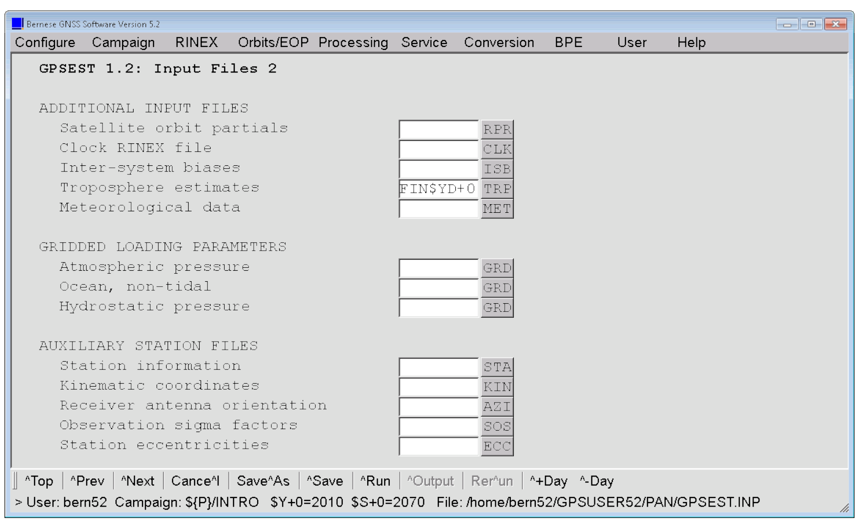
In the second iteration we screen for residuals bigger than 6 mm in RESRMS and mark these observations with SATMRK, too.

If you have done the screening of phase observations in MAUPRP instead of RNXSMT you can skip the first iteration and you only need to run once through the residual screening procedure (sequence of GPSEST, RESRMS, SATMRK) using the final threshold for the residuals of 6 mm .

7.4.3 Generate Clock Solutions

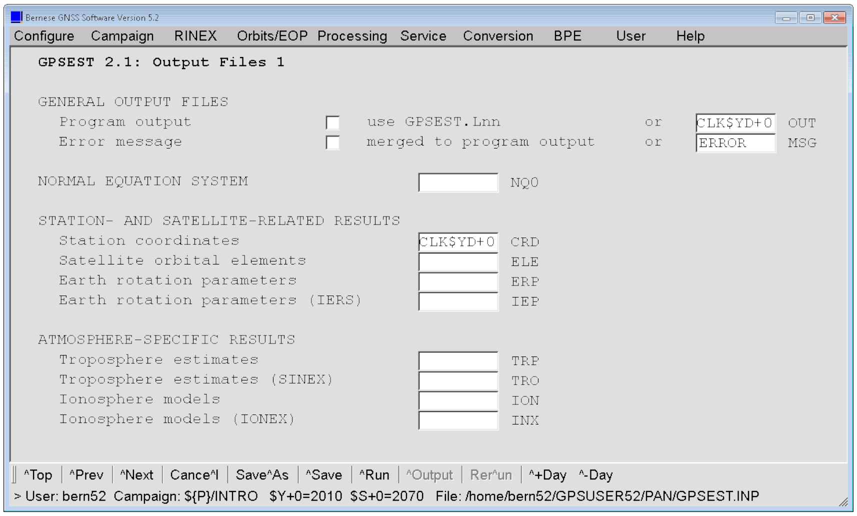
Repeat the run of GPSEST with the clean observation files to get the definitive clock estimates. You may introduce the estimated coordinates and troposphere parameters[1] from the final double–difference solution for the session (e.g., `FIN$YD+0`). You also have to include a DCB file when processing code observations.



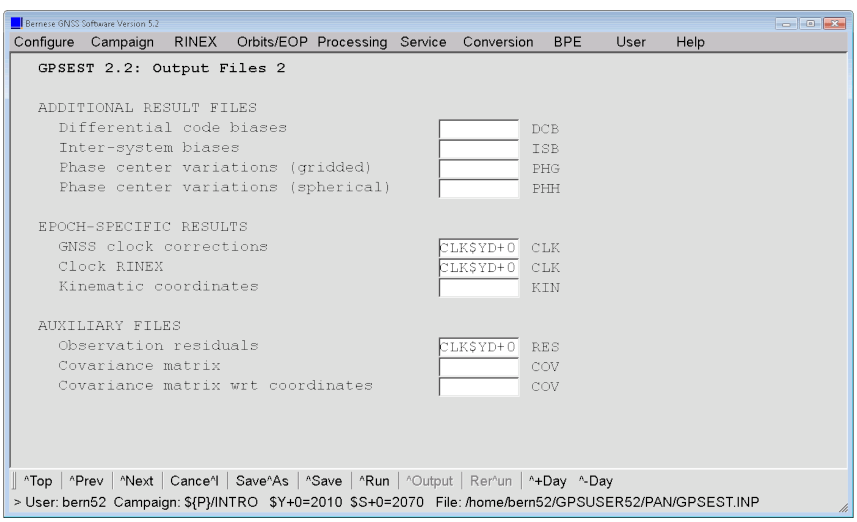


[1] If you introduce a troposphere result file based on VMF1, you also need to introduce the same "Gridded VMF1 coefficients" in panel "GPSEST 1.1: Input Files 1" as you have used to generate the "Troposphere estimates".

Store also the coordinate results that correspond to the clock estimates.

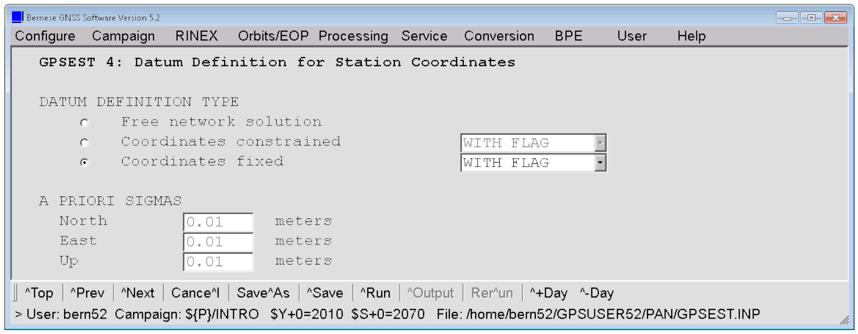


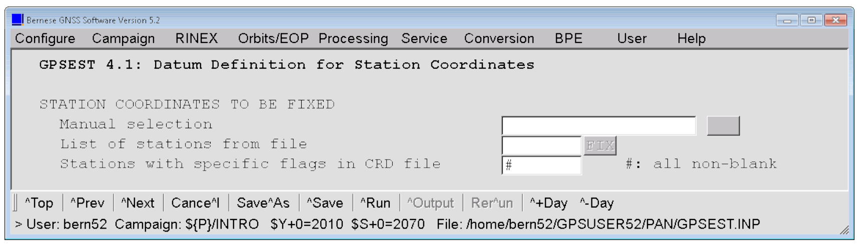
In the final run the clock results for satellites and receivers shall be stored in a "Clock RINEX" result file in panel "GPSEST 2.2: Output Files 2".



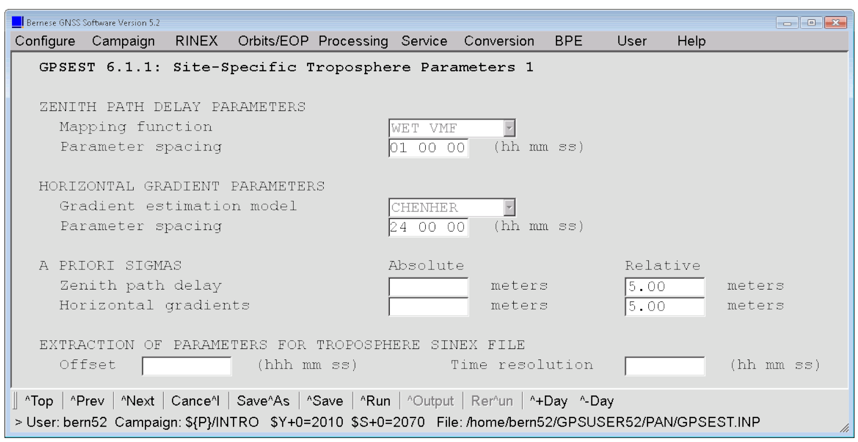
The input field for "ZPD model and mapping function (GNSS)" in panel "GPSEST 3.2: General Options 2" is inactive because a file with "Troposphere estimates" is introduced. The same troposphere model is used in this program run.

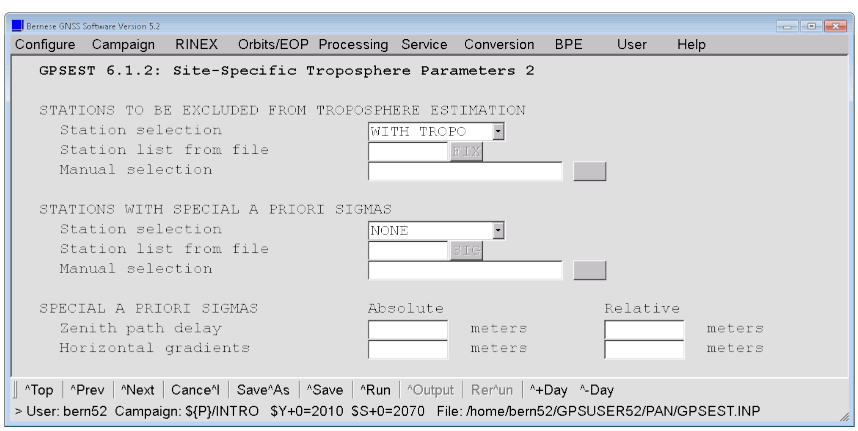
The datum definition shall be reconsidered when introducing a solution for the coordinates:



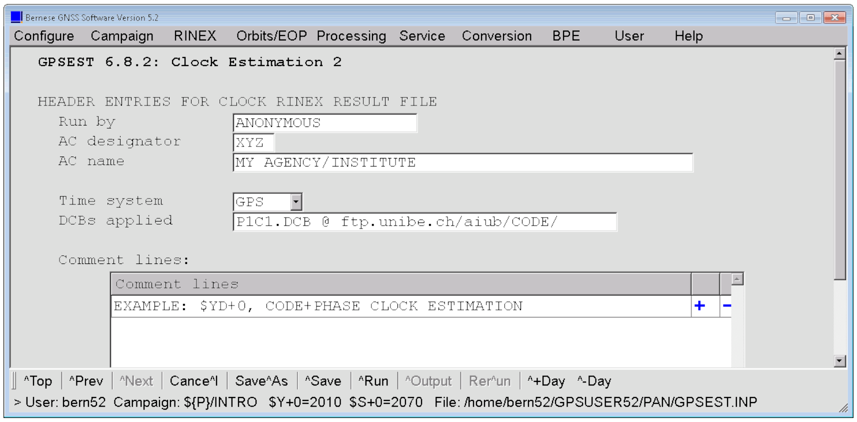


The sampling of troposphere parameters for those stations where you cannot introduce a complete set of estimates in the file from “Troposphere estimates” given in panel “GPSEST 1.2: Input Files 2” shall be identical with those in the input file:





If you have selected a "Clock RINEX" result file in panel "GPSEST 2.2: Output Files 2" you are asked for the header information. Please replace the placeholders by the information for your institution and give a description for your results.




```
...
NUMBER OF PARAMETERS (PART 1):
-----------------------------

PARAMETER TYPE                                #PARAMETERS   #PRE-ELIMINATED        #SET-UP  ...
------------------------------------------------------------------------------------------  ...
RECEIVER CLOCK BIASES / TIME BIASES                 200            0                   200  ...
AMBIGUITIES                                        1320            0                  1442  ...
EPOCH WISE STATION CLOCKS                          3739         3739  (EPOCH-WISE)    3744  ...
EPOCH WISE SATELLITE CLOCKS                        5842         5842  (EPOCH-WISE)    6059  ...
------------------------------------------------------------------------------------------  ...
TOTAL NUMBER OF PARAMETERS                        11101         9581                 11445  ...
------------------------------------------------------------------------------------------  ...


NUMBER OF OBSERVATIONS (PART 1):
-------------------------------

TYPE          FREQUENCY          FILE/PAR          #OBSERVATIONS
-----------------------------------------------------------------------------------------  ...

PHASE            L3               ALL                    54188
CODE             L3               ALL                    54390

----------------------------------------------------------------------------------------  ...
TOTAL NUMBER OF OBSERVATIONS                             108578
----------------------------------------------------------------------------------------  ...


A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :     0.0008 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :      97477
CHI**2/DOF                         :       0.64
...
```

The estimated inter–frequency biases caused by different hardware delays in the receiver for each GLONASS satellite due to the individual frequency are reported in the following section in the program output:

```
...

RECEIVER CLOCKS / TIME BIASES:
----------------------------

REQUEST  STATION NAME        OFFSET (USEC)  RMS (NSEC)
---------------------------------------------------------------------------------------------

    1    GANP 11515M001        0.000000        ---        0.000000        ---       SAT GPS
    1    GANP 11515M001        0.000000     -0.244906     -0.244906      0.134      SAT 101
    1    GANP 11515M001        0.000000     -0.251354     -0.251354      0.144      SAT 102
    1    GANP 11515M001        0.000000     -0.236973     -0.236973      0.153      SAT 103
    1    GANP 11515M001        0.000000     -0.229242     -0.229242      0.150      SAT 104
    1    GANP 11515M001        0.000000     -0.243824     -0.243824      0.128      SAT 105
    1    GANP 11515M001        0.000000     -0.241614     -0.241614      0.118      SAT 107
    1    GANP 11515M001        0.000000     -0.226128     -0.226128      0.131      SAT 108
    1    GANP 11515M001        0.000000     -0.250173     -0.250173      0.129      SAT 110
    1    GANP 11515M001        0.000000     -0.248057     -0.248057      0.129      SAT 111
    1    GANP 11515M001        0.000000     -0.249851     -0.249851      0.131      SAT 113
    1    GANP 11515M001        0.000000     -0.250245     -0.250245      0.130      SAT 114
    1    GANP 11515M001        0.000000     -0.245288     -0.245288      0.128      SAT 115
    1    GANP 11515M001        0.000000     -0.243093     -0.243093      0.132      SAT 117
    1    GANP 11515M001        0.000000     -0.249622     -0.249622      0.131      SAT 118
    1    GANP 11515M001        0.000000     -0.244722     -0.244722      0.131      SAT 119
    1    GANP 11515M001        0.000000     -0.243063     -0.243063      0.125      SAT 120
    1    GANP 11515M001        0.000000     -0.242501     -0.242501      0.113      SAT 121
    1    GANP 11515M001        0.000000     -0.250258     -0.250258      0.127      SAT 122
    1    GANP 11515M001        0.000000     -0.242287     -0.242287      0.149      SAT 123
    1    GANP 11515M001        0.000000     -0.242737     -0.242737      0.140      SAT 124
    2    HERT 13212M010        0.000000        ---        0.000000        ---       SAT GPS
    2    HERT 13212M010        0.000000      0.065866      0.065866      0.131      SAT 101
    2    HERT 13212M010        0.000000      0.069644      0.069644      0.135      SAT 102
...
```

The report of the clock estimates looks like:

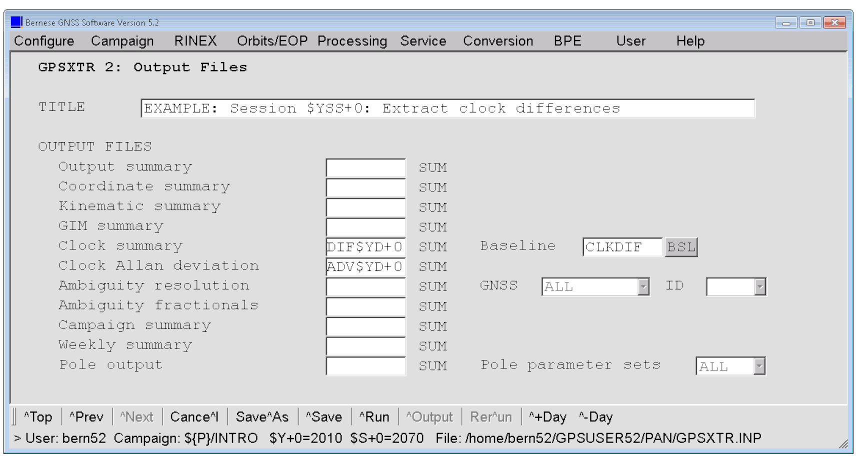
```
...

EPOCH WISE STATION CLOCKS:                 ${P}/INTRO/OUT/CLK10207.CLK
-------------------------
                                          STATION CLOCK VALUES (USEC)
TYPE  STAT   EPOCH(MJD)        A PRIORI    CORRECTION         TOTAL   RMS(NSEC)  #OBS    STAT.
---------------------------------------------------------------------------------------------

  23     1   55403.000000     -0.021330      0.000009     -0.021321      0.003   34 R  # GANP
  23     2   55403.000000     -0.002644     -0.000817     -0.003462      0.003   29 R  # HERT
  23     3   55403.000000      0.001614     -0.000189      0.001424      0.003   35 R  # JOZ2
  23     4   55403.000000     -0.000525      0.000184     -0.000340      0.003   35 R  # LAMA
  23     5   55403.000000     -0.028072      0.001137     -0.026935      0.003   30 R  # MATE
  23     6   55403.000000    -31.022254     -0.000121    -31.022376      0.003   30 R  # ONSA
  23     7   55403.000000      0.528750      0.000326      0.529076      0.005   11 R  # PTBB
  23     8   55403.000000     -0.035458     -0.000356     -0.035814      0.003   28 R  # TLSE
  23     9   55403.000000      0.138215      0.000294      0.138509      0.004   20 R  # WSRT
  23    10   55403.000000     -0.008899     -0.000339     -0.009237      0.003   33 R  # WTZR
  23    11   55403.000000   -219.055034      0.000212   -219.054822      0.004   18 R  # WTZZ
  23    12   55403.000000     -0.031458     -0.000164     -0.031623      0.003   30 R  # ZIM2
  23    13   55403.000000      0.028115     -0.000175      0.027940      0.004   18 R  # ZIMM
  23     1   55403.003472     -0.022433      0.000071     -0.022362      0.003   34 R  # GANP
  23     2   55403.003472     -0.001060     -0.000899     -0.001959      0.003   29 R  # HERT
  23     3   55403.003472      0.001511     -0.000144      0.001367      0.003   34 R  # JOZ2
...

EPOCH WISE SATELLITE CLOCKS:               ${P}/INTRO/ORB/CLK10207.CLK
---------------------------
                                        SATELLITE CLOCK VALUES (USEC)
TYPE   SAT   EPOCH(MJD)        A PRIORI    CORRECTION         TOTAL   RMS(NSEC)   #OBS
-----------------------------------------------------------------------------------------

  24     3   55403.000000    586.451514     -0.000519    586.450995       0.013    15
  24     6   55403.000000    559.025665      0.001482    559.027147       4.082     1 *
  24     9   55403.000000     20.468252      0.007644     20.475896       7.717     1 *
  24    11   55403.000000    -78.075202      0.000795    -78.074407       0.002    26
  24    14   55403.000000     71.688147      0.000893     71.689041       0.003    26
  24    17   55403.000000    163.652097      0.000782    163.652879       0.010    22
  24    19   55403.000000    -52.512921      0.000589    -52.512332       0.003    26
  24    20   55403.000000     52.929104      0.000155     52.929259       0.004    26
  24    22   55403.000000    166.687820      0.002045    166.689865       0.014    12
  24    24   55403.000000    307.451136      0.000259    307.451395       0.007    25
  24    28   55403.000000     -9.425636      0.000221     -9.425414       0.007    22
  24    31   55403.000000    -21.952063      0.000419    -21.951644       0.084     2 *
  24    32   55403.000000    -46.318216      0.000435    -46.317781       0.003    26
```

```
   24   104   55403.000000       0.000000     -79.261456     -79.261456        7.795     1 *
   24   105   55403.000000       0.000000    -153.329680    -153.329680        0.004    18
   24   107   55403.000000       0.000000    -292.762903    -292.762903        0.011    18
   24   113   55403.000000       0.000000    -276.613710    -276.613710        0.023     9
   24   114   55403.000000       0.000000    -168.479768    -168.479768        0.010    15
   24   115   55403.000000       0.000000      23.463583      23.463583        0.028     6
   24   120   55403.000000       0.000000     -73.657604     -73.657604        0.004    18
   24   121   55403.000000       0.000000    -200.315946    -200.315946        0.003    18
   24   122   55403.000000       0.000000     -10.570479     -10.570479        0.006    18
   24     3   55403.003472     586.452934      -0.001054     586.451879        0.015    13
   24     6   55403.003472     559.021364       0.001878     559.023242        4.987     1 *
   24     9   55403.003472      20.469100      -0.000804      20.468296        5.760     1 *
   24    11   55403.003472     -78.075981       0.000704     -78.075277        0.002    26
 ...
```

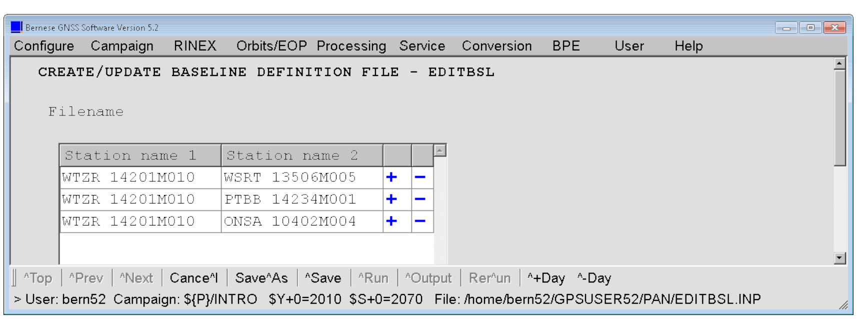
The "∗"–character indicates satellites where the satellite clock correction has been computed from a limited number of stations.

Because this section can become very long, it can also be skipped in the GPSEST program output by checking the box "Printing: Suppression of output concerning epoch parameters" in panel "GPSEST 3.2.1.1: Extended Program Output Options" (enabled only if the checkbox "Enable extended program output" in panel "GPSEST 3.2: General Options 2" is checked).

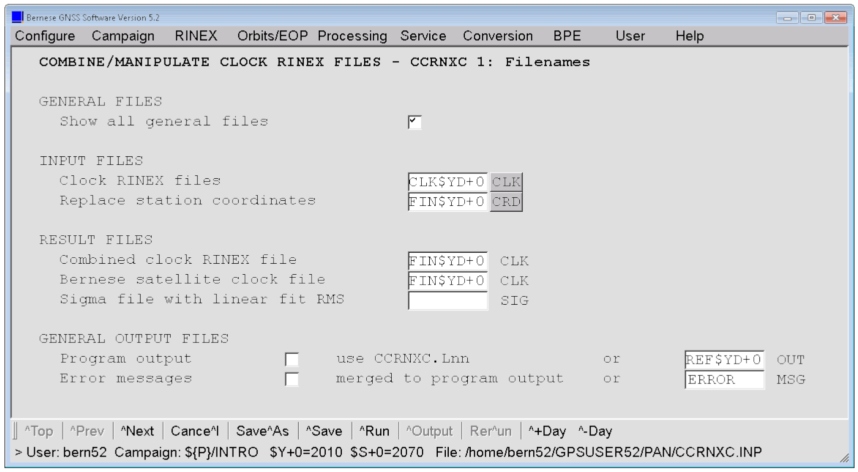
Differences of clocks and Allan deviations for differences of clocks can be extracted from the GPSEST program output by the program GPSXTR ("Menu>Processing>Program output extraction >Parameter estimation/stacking"). The pair of clocks (receiver or satellites) are defined by a baseline file (extension BSL).

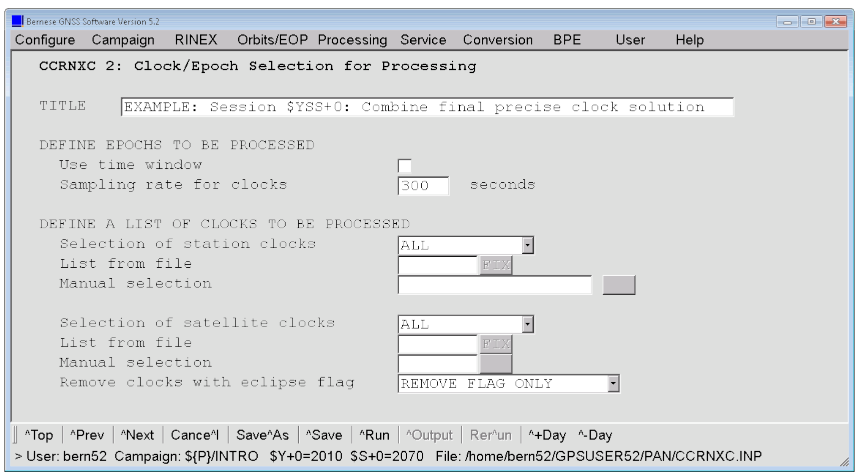


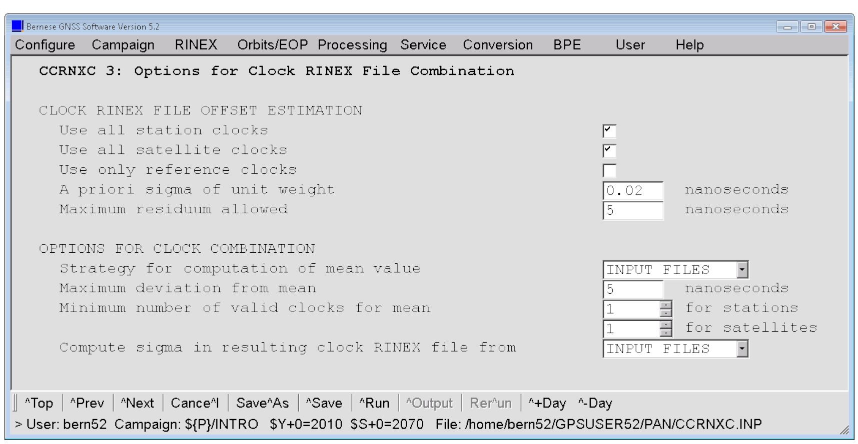
The baseline file might, e.g., be generated via the "Menu>Campaign>Edit station files>Baseline definition file":

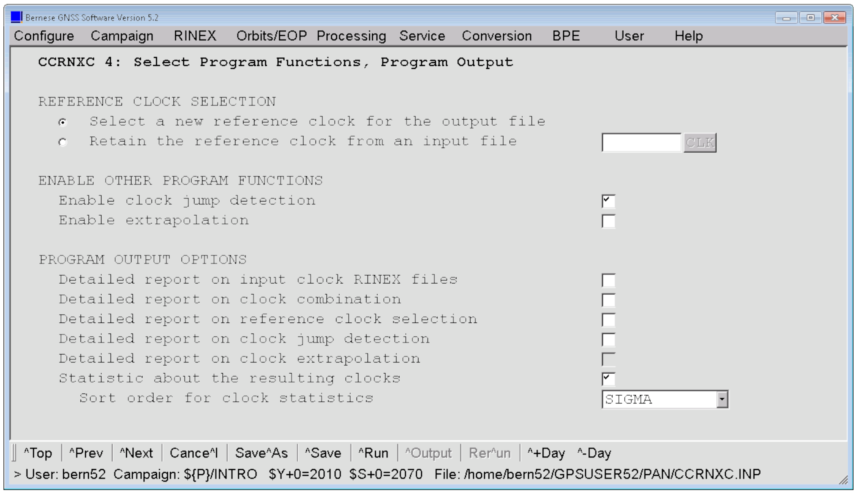


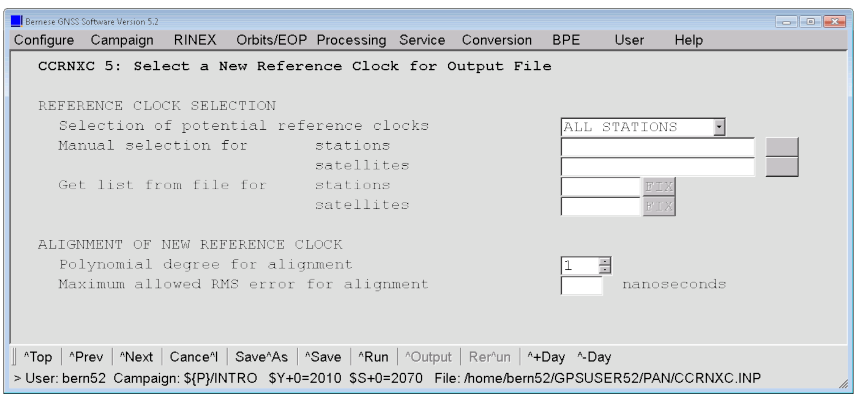
The clock solution is finalized by selecting the reference clock using program CCRNXC ("Menu>Service>Clock tools>Combine/manipulate clock RINEX files"):

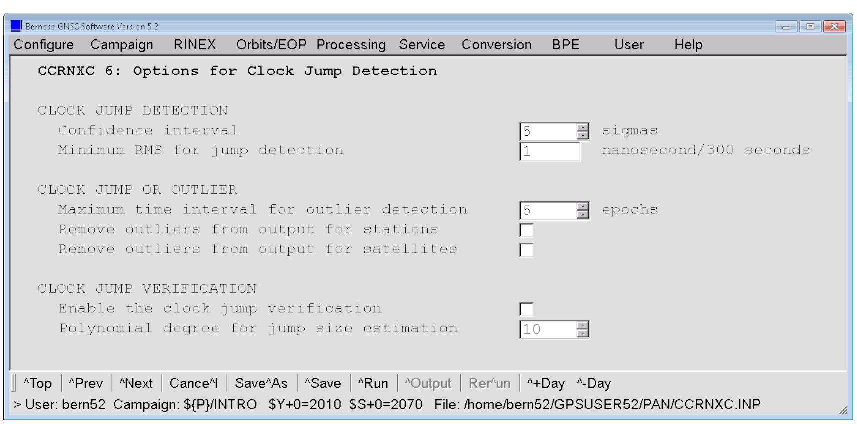







Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CCRNXC 4: Select Program Functions, Program Output
REFERENCE CLOCK SELECTION
Select a new reference clock for the output file
Retain the reference clock from an input file
CLK
ENABLE OTHER PROGRAM FUNCTIONS
Enable clock jump detection
Enable extrapolation
PROGRAM OUTPUT OPTIONS
Detailed report on input clock RINEX files
Detailed report on clock combination
Detailed report on reference clock selection
Detailed report on clock jump detection
Detailed report on clock extrapolation
Statistic about the resulting clocks
Sort order for clock statistics
SIGMA
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/CCRNXC.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CCRNXC 5: Select a New Reference Clock for Output File
REFERENCE CLOCK SELECTION
Selection of potential reference clocks
ALL STATIONS
Manual selection for stations
satellites
Get list from file for stations
satellites
FIX
FIX
ALIGNMENT OF NEW REFERENCE CLOCK
Polynomial degree for alignment
1
Maximum allowed RMS error for alignment
nanoseconds
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/CCRNXC.INP


Bernese GNSS Software Version 5.2
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CCRNXC 6: Options for Clock Jump Detection
CLOCK JUMP DETECTION
Confidence interval
5
sigmas
Minimum RMS for jump detection
1
nanosecond/300 seconds
CLOCK JUMP OR OUTLIER
Maximum time interval for outlier detection
5
epochs
Remove outliers from output for stations
Remove outliers from output for satellites
CLOCK JUMP VERIFICATION
Enable the clock jump verification
Polynomial degree for jump size estimation
10
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern52 Campaign: ${P}/INTRO $Y+0=2010 $S+0=2070 File: /home/bern52/GPSUSER52/PAN/CCRNXC.INP

The table at the end of the program output provides an overview of the clock quality:

```
...

REFERENCE CLOCK SELECTION FOR OUTPUT FILE
----------------------------------------

Selected reference station:     WTZR 14201M010
...

STATISTICS ON THE CLOCKS IN THE OUTPUT FILE
------------------------------------------
                         # per file         rms of poly. fit (ns)
Clock name               out    001         n = 0    n = 1    n = 2
-------------------------------------------------------------------
WTZR 14201M010           288    288         1.472    0.000    0.000
WSRT 13506M005           288    288         4.520    0.030    0.030
MATE 12734M008           288    288        29.164    0.054    0.052
PTBB 14234M001           288    288         0.397    0.058    0.043
ONSA 10402M004           284    284         5.626    0.081    0.076
LAMA 12209M001           288    288         2.928    2.933    2.932
JOZ2 12204M002           288    288         3.062    3.067    3.069
HERT 13212M010           288    288         3.316    3.322    3.328
ZIMM 14001M004           288    288         4.277    4.091    3.833
TLSE 10003M009           288    288         5.174    4.892    4.734
ZIM2 14001M008           287    287         5.297    5.021    4.712
GANP 11515M001           288    288         6.752    6.689    6.629
WTZZ 14201M014           288    288       0.3E+06  0.3E+06  0.3E+06
G01                       59     59        21.055    0.132    0.133
G02                      113    113        53.429    0.138    0.122
G18                      111    111        42.222    0.159    0.160
G29                       93     93        40.762    0.163    0.136
G20                       83     83        14.263    0.176    0.176
G07                      105    105         3.172    0.187    0.139
G11                       87     87        89.783    0.196    0.194
G19                      103    103        91.484    0.196    0.135
G25                       83     83        32.984    0.208    0.064
G23                       98     98        32.857    0.221    0.115
G13                       86     86        10.754    0.224    0.171
G12                       86     86        38.001    0.230    0.155
G15                      102    102       104.651    0.230    0.203
G14                      111    111       111.497    0.240    0.234
G16                      108    108        87.317    0.243    0.240
G31                      113    113        71.214    0.268    0.165
G22                      110    110        14.917    0.272    0.244
G21                      102    102        45.128    0.292    0.254
G05                      111    111        65.889    0.357    0.310
G06                       93     93       248.950    0.371    0.341
R02                       98     98        44.930    0.371    0.271
R13                      103    103        22.467    0.371    0.341
R04                       99     99         4.500    0.407    0.380
G32                       87     87       300.001    0.425    0.257
R05                      124    124        19.774    0.573    0.499
R19                      100    100        20.046    0.592    0.318
...
```

7.4.4 Further Suggestions

- Switch the "Var-covar wrt epoch parameters" in panel "GPSEST 6.7: General Options for Epoch Parameters" from SIMPLIFIED to CORRECT.
- Compute a PPP for one of the stations in the zero difference network solution. Compare the coordinates and clocks from the PPP with the results from the network solution. Exchange the orbits, EOP, and satellite clock corrections from your solution by products from other sources (e.g., CODE or IGS).
- Use the PPP approach to screen the residuals of the Bernese zero difference observation files. This has to be done station by station. Make sure that you use a consistent set of orbits, EOP, and satellite clocks (e.g., IGS final products or CODE final solution).

7.5 Using RINEX 3 Data

The campaign `${P}/EXM_GAL` in the *Bernese Introductory Course* environment contains some RINEX 3 files in order to follow the example in this section.

7.5.1 Basic Principles

To accommodate for the various GNSS, RINEX 3 format was adapted for additional observation types. However, Version 5.2 of the *Bernese GNSS Software* is still limited to dual-frequency processing, so we need to select two frequencies for the processing. For each frequency, then, different observation types may be selected according to the availability and a priority list given in a file (e.g, `${X}/GEN/OBS.SEL`):

```
GNSS observation selection for Bernese GNSS Software Version 5.2     21-Aug-2012
--------------------------------------------------------------------------------

Format version:  1.00

Receiver type         S/S  O/F  RINEX observation codes and their priority
********************  ***  ***  *** *** *** *** *** *** *** *** *** *** *** ***

DEFAULT               G    L1   L1P L1W L1C     L1X
                      G    L2   L2P L2W L2C L2D L2X
                      G    C1   C1P C1W C1C     C1X
                      G    C2   C2P C2W C2C C2D C2X
                      R    L1   L1P     L1C     L1X
                      R    L2   L2P     L2C     L2X
                      R    C1   C1P     C1C     C1X
                      R    C2   C2P     C2C     C2X

SIMULA                G    L1   L1W
                      G    L2   L2W
                      G    C1   C1W
                      G    C2   C2W
                      R    L1   L1W
                      R    L2   L2W
                      R    C1   L1W
                      R    C2   L2W
```

Make sure that the observation types from your RINEX 3 observation files are contained in this priority list. If an observation type is not listed it is not considered by the program RNXSMT.

This selection is performed by the program RNXSMT where the priority list is specified in option "Receiver-specific observation type priority" (panel "RNXSMT 1.1: General Files"). The resulting smoothed RINEX file (extension `SMT`) contains a special section in its comment lines reporting the original observation types according to the RINEX 3 convention:

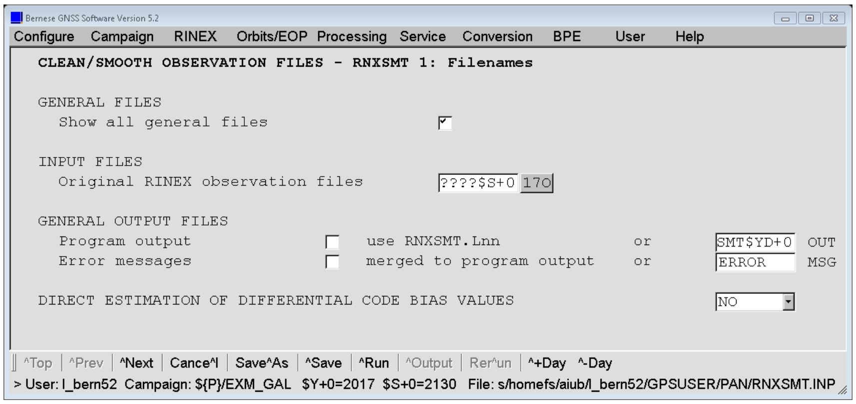
```
  ### PG RNXSMT: RINEX FILE CHANGED                                 COMMENT
GEOS:  1 G   1 C1C C2W L1C L2W                                      COMMENT
GEOS:  2 G   2 C1C C2W L1C L2W                                      COMMENT
GEOS:  3 G   3 C1C C2W L1C L2W                                      COMMENT
GEOS:  4 G   4 C1C C2W L1C L2W                                      COMMENT
GEOS:  5 G   5 C1C C2W L1C L2W                                      COMMENT
...
GEOS: 51 R121 C1P C2P L1P L2P                                       COMMENT
GEOS: 52 R122 C1P C2P L1P L2P                                       COMMENT
GEOS: 53 R123 C1P C2P L1P L2P                                       COMMENT
GEOS: 54 R124 C1P C2P L1P L2P                                       COMMENT
```

When importing these files into the binary Bernese observation file format using the program RXOBV3, this information is kept in the header section. This information will be used in future versions of *Bernese GNSS Software* to manage the observation type identification.

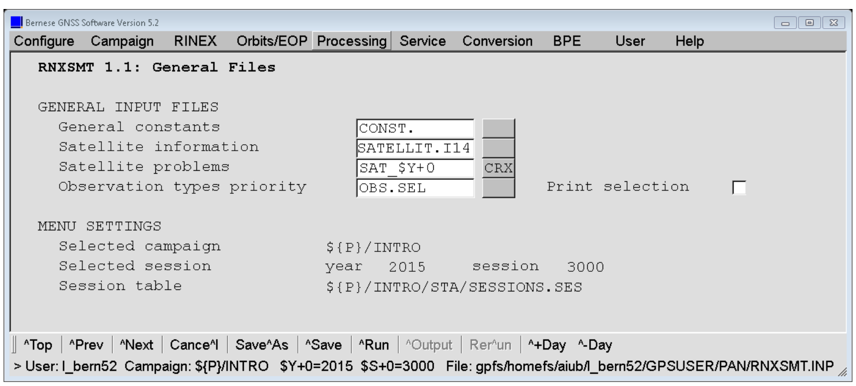
This mechanism requires to start with program RNXSMT whenever RINEX 3 files should be imported into *Bernese GNSS Software*, Version 5.2 .

7.5.2 RINEX 3 Handling in RNXSMT

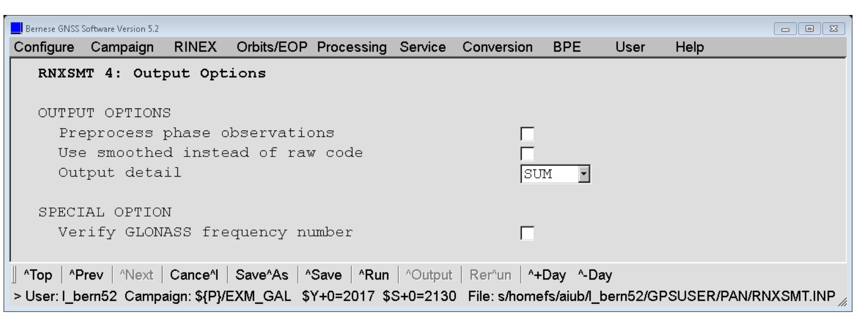
In the first panel of RMXSMT the "Original RINEX observation files" are selected. Observation files in RINEX 2 and RINEX 3 format can be processed together in one program run. For that reason the potential long names of RINEX 3 files need to be converted to the conventional names of the RINEX 2 format.



In order to import RINEX 3 formatted files, a priority list need to be specified in "Receiver-specific observation type priority":



In the last panel of RNXSMT you can select whether phase and/or code measurements shall be preprocessed. If both checkboxes are deactivated the original observations from the input RINEX files are simply copied into the smoothed RINEX files.



7.5.3 RINEX 3 Handling in the Example BPEs

Since the release from 2016-Jan-08 of Version 5.2 , the BPE examples distributed with the *Bernese GNSS Software* contain four variables related to the selection of RINEX files to be processed:

- V_OBSSEL to select the stations to be processed (see more information in the README-files of the BPEs),
- V_RNXDIR location of the observation files in RINEX 2 format,
- V_RX3DIR location of the observation files in RINEX 3 format, and
- V_OBSINF name of the "Receiver-specific observation type priority" file to be used in the program RNXSMT if RINEX 3 formatted observation files are used.

In the default setup the third section of the process control files considers only RINEX 2 formatted observation files:

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_RNXDIR Directory with the RINEX2 files          RINEX
V_RX3DIR Directory with the RINEX3 files
..
V_OBSINF RINEX 3 observation typ selection        OBS.SEL
...
```

To accept also observation files in RINEX 3 format for processing, the corresponding directory need to be specified in V_RX3DIR :

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_RNXDIR Directory with the RINEX2 files          RINEX
V_RX3DIR Directory with the RINEX3 files          RINEX3
..
V_OBSINF RINEX 3 observation typ selection        OBS.SEL
...
```

The user script RNX_COP copies the observation files with the following priority from the datapool into the campaign area:

1. RINEX 3 files with long names; generated by the receiver
2. RINEX 3 files with long names; generated from a stream
3. RINEX 3 files with long names; source unknown
4. RINEX 3 files with short names; source unknown
5. RINEX 2 files with short names

As soon as a RINEX 3 observation file is found, the variable designed for the "Receiver-specific observation type priority" becomes relevant. Make sure that for your own BPEs the program RNXSMT is the first program that accesses the RINEX observation files.

7.6 Processing Galileo Observations

Orbit and observation files containing Galileo are provided for one day (doy 213 of year 2017) in the campaign `${P}/EXM_GAL` in the *Bernese Introductory Course* environment.

7.6.1 Galileo Satellite-Related Metadata

Since 29 January 2017, the IGS is using the antenna corrections related to the IGS realization of the ITRF2014. The `igs14.atx` published by the IGS contains also corrections for the Galileo satellite antennas. Galileo meta data are contained in the satellite information file (`${X}/GEN/SATELLIT.I14`) as well as the antenna phase center correction file (`${X}/GEN/PCV.I14`) published at `http://www.aiub.unibe.ch/download/BSWUSER52/GEN` or distributed with the software.

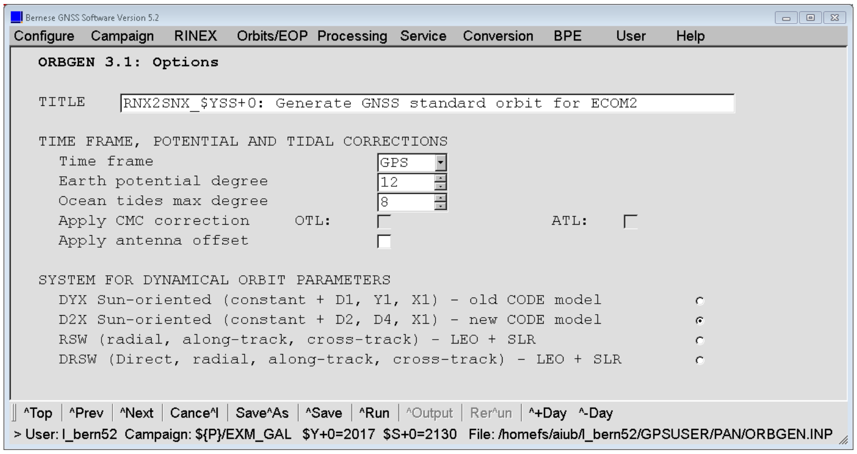
These antenna corrections have been estimated under the assumption that the Galileo L_1/L_5 ground antenna phase center corrections are identical with GPS L_1/L_2. This assumption has been taken because dedicated Galileo calibrations are not yet available for most antennas. The processing of Galileo observations follows the same scheme and is, therefore, consistent.

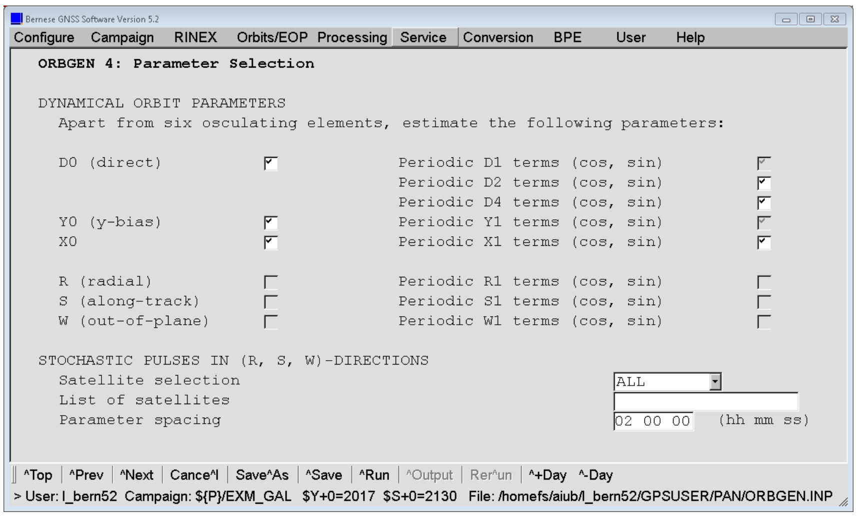
7.6.2 Preparing the Orbit and Clock Products

The orbit products that shall be used need also to contain Galileo orbits and satellite clock corrections (in particular for a PPP processing). Since this information is not contained in the IGS legacy products, it is necessary to introduce products from the MGEX project of the IGS. In this context for instance CODE provides a dedicated multi-GNSS solution (the solution label `COM` is used for this purpose). The products can be downloaded from `http://www.aiub.unibe.ch/download/CODE_MGEX/CODE` and should be made available in the datapool area `${D}/COM` for the use with the BPE.

The orbit files have to be prepared as described in Section 3. Apart from the different filenaming (`COM` instead of `COD`) it should be considered that the EOP files are given in daily instead of weekly files. Consequently, you need to specify `COM$WD+0` instead of `COD$W+07` to the field "Foreign formatted ERP files" in panel "POLUPD 1: Input/Output Files".

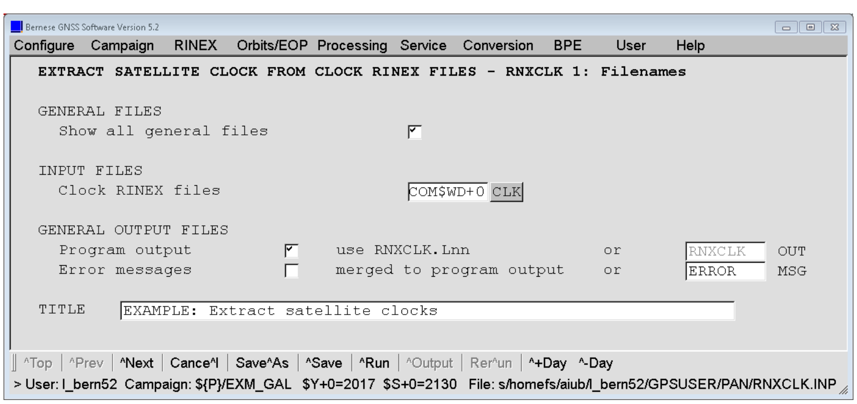
Since the beginning of the year 2014, the MGEX-related products generated by CODE are based on the updated Empirical CODE Orbit Model (ECOM) containing the twice-per-revolution term in the D-component (pointing from the satellite to the Sun). In order to correctly integrate these orbits with the program ORBGEN of Version 5.2 of *Bernese GNSS Software* you should consider the remarks in the section on *Orbit Modeling at CODE Analysis Center and Compatibility with Version 5.2* on page 119 of the user manual. It means in particular that the orbit model in the program ORBGEN should be adjusted as follows:





Even if orbits from more than GPS, GLONASS, and Galileo (as supported by Version 5.2 of *Bernese GNSS Software*) are contained in the orbit products, ORBGEN selects only those where records in the satellite information file are available.

If you plan to do a PPP processing you may directly extract the satellite clock corrections from the clock RINEX file using the program RNXCLK ("Menu>RINEX>RINEX utilities>Extract satellite clock"):



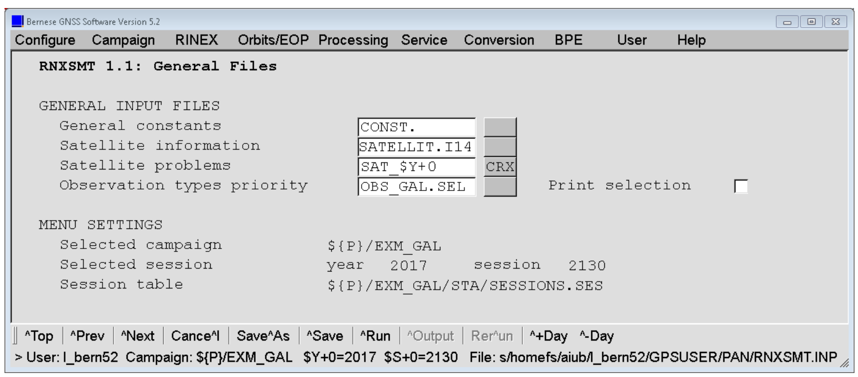
The result file will have the same name as the input file but will be located in the `ORB` directory of the campaign.

7.6.3 Observation Selection

Galileo measurements should only be provided in RINEX 3 format. Basically the instructions from Section 7.5 apply. It is only necessary to extend the observation type priority file by the Galileo-related measurement types. An example (`${X}/GEN/OBS_GAL.SEL`) is provided together with the *Bernese GNSS Software*:

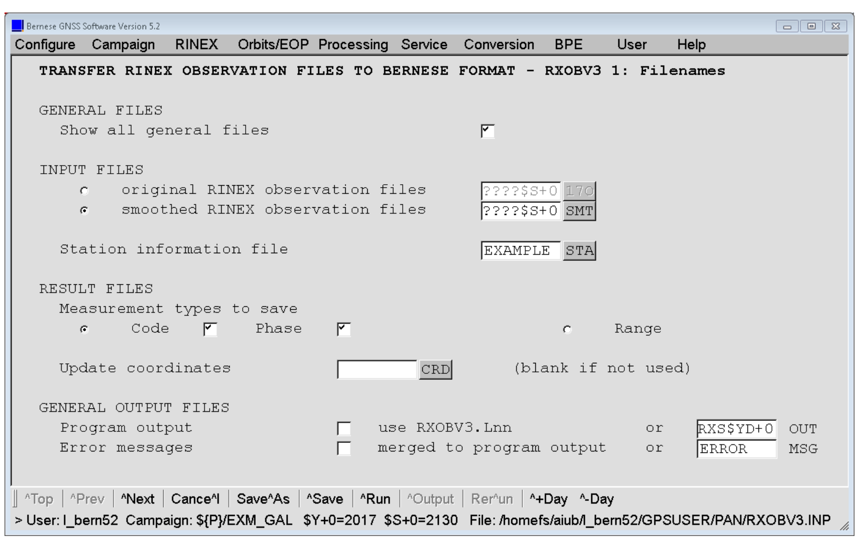
```
Receiver type         S/S  O/F  RINEX observation codes and their priority
********************  ***  ***  *** *** *** *** *** *** *** *** *** *** *** ***

DEFAULT               G    L1   L1P L1W L1C     L1X
                      G    L2   L2P L2W L2C L2D L2X
                      G    C1   C1P C1W C1C     C1X
                      G    C2   C2P C2W C2C C2D C2X
                      R    L1   L1P     L1C     L1X
                      R    L2   L2P     L2C     L2X
                      R    C1   C1P     C1C     C1X
                      R    C2   C2P     C2C     C2X
                      E    L1   L1C     L1X
                      E    L2   L5Q L5I L5X
                      E    C1   C1C     C1X
                      E    C2   C5Q C5I C5X
...
```

This file needs to be specified in the option "Receiver-specific observation type priority" for the program RNXSMT:

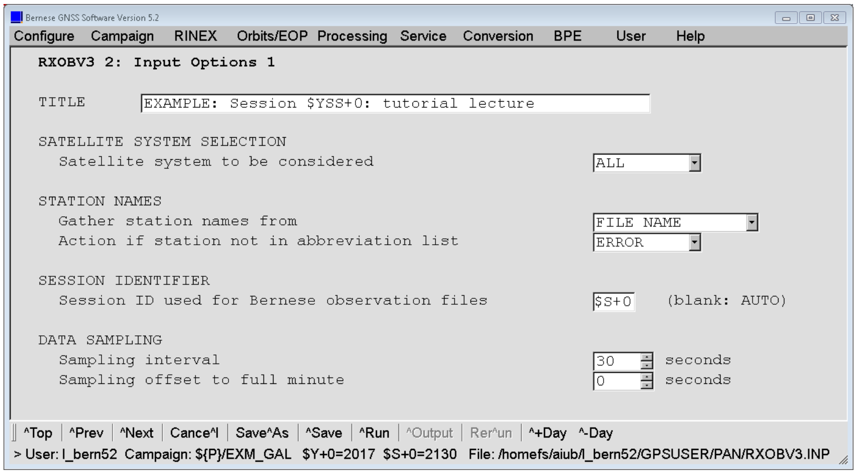


All the other settings may be taken as shown in Section 7.5.2 .

The `SMT` files have now to be imported into the the Bernese internal observation file format using the program RXOBV3:



Since the observation type priority file acts as a filter, only observations for the systems listed in this file have been passed the program RNXSMT. For that reason the `SMT`-files contain only observations from the selected satellite systems. No further filtering is needed when importing the observations into the Bernese observation file format. Therefore, ALL satellite systems can selected in option "Satellite system to be considered":



Please take care on the settings in the section "SIGNAL STRENGTH REQUIREMENTS" in panel "RXOBV3 4: Input Options 2" (see Section 7.4.1).

7.6.4 Processing the Example Including Galileo

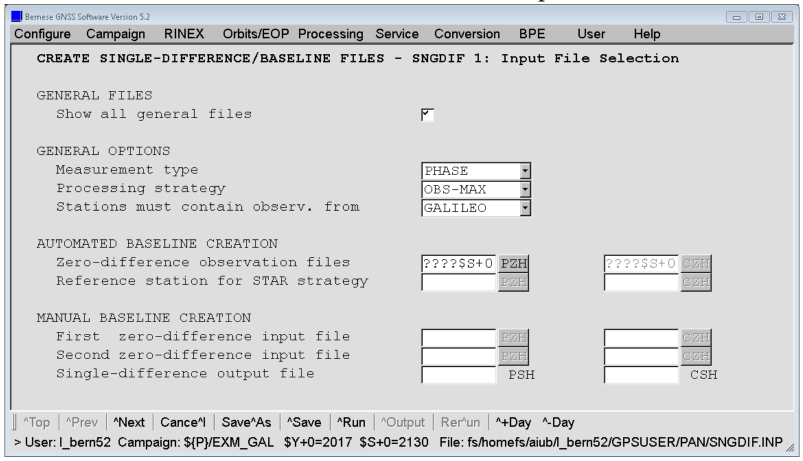
At this point you can continue the processing for a regional network as described in this tutorial from Section 4.2 (page 33) onwards in order to generate a double difference network solution including Galileo. You need only to take care that you use the `COM` instead of `COD` orbit products and the the selection of the GNSS to be processed does not exclude Galileo (ALL for "Satellite system").

Forcing the Usage of Galileo Data in a Double-Difference Solution

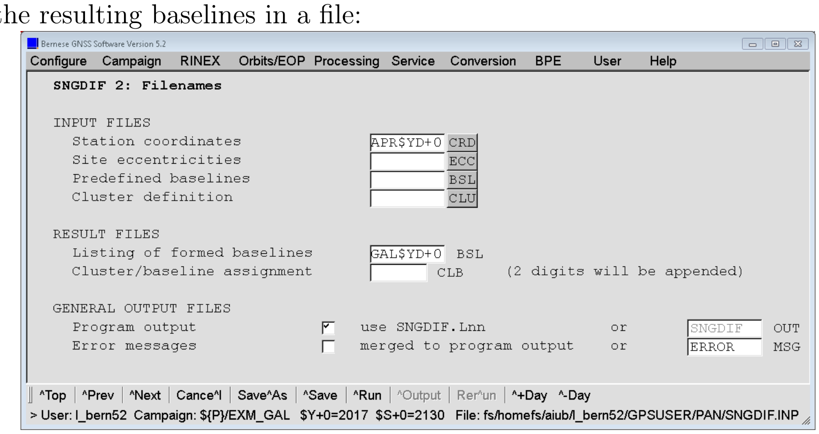
In order to optimize the baseline creation for the usage of Galileo data the following procedure can be established. It is in particular useful if orbits for these satellites shall be estimated and/or the network of the Galileo tracking stations is so sparse that these measurements are not sufficiently available.

Step 1:

Create first a set of baselines from those stations that provide Galileo measurements:

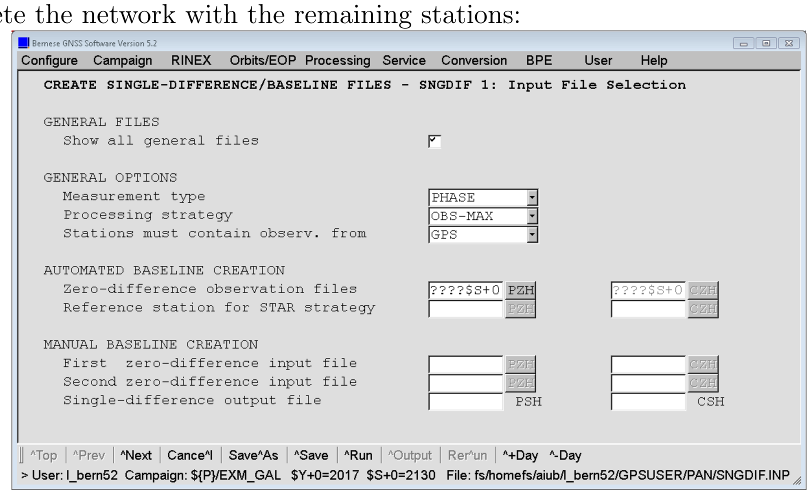


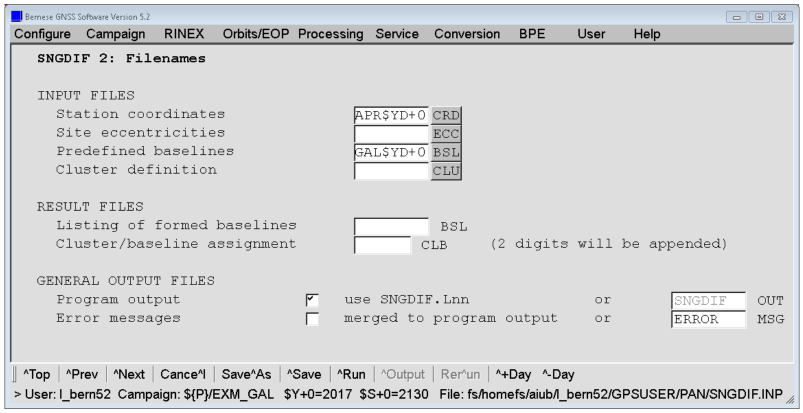
Store the resulting baselines in a file:



Step 2:

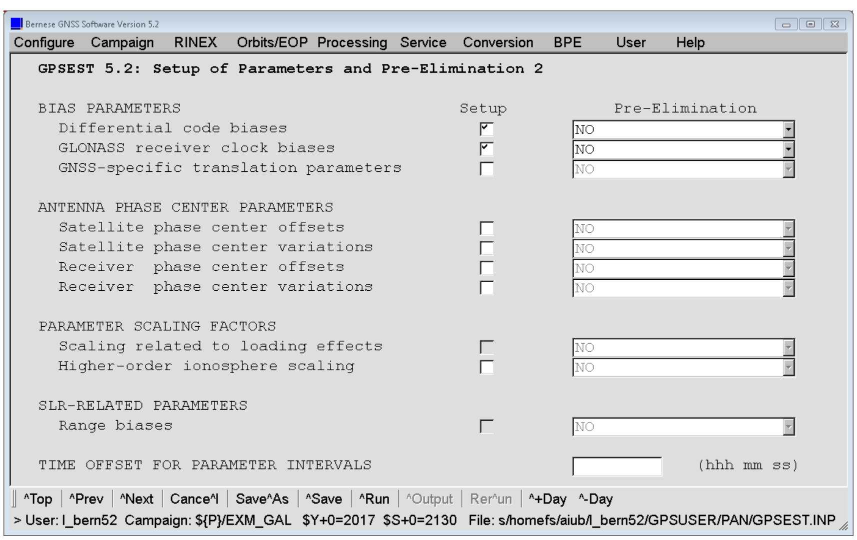
Complete the network with the remaining stations:



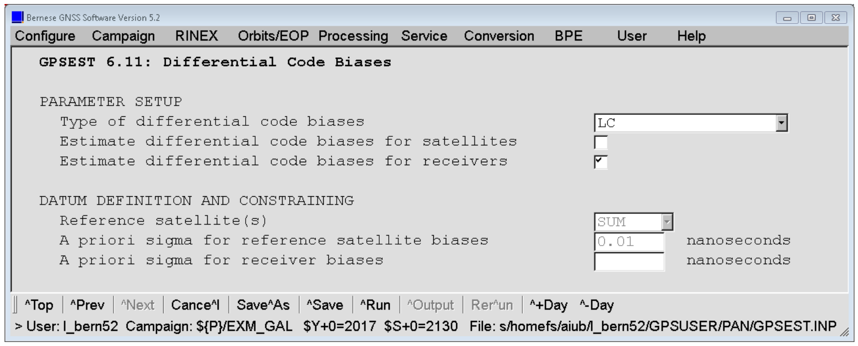


Using Galileo in a Zero-Difference Solution

Within the receivers an ISB between the Galileo and GPS pseudorange signals is expected as it is the case between GPS and GLONASS. Because all Galileo satellites are using the same frequencies only one bias parameter per station needs to be added. In order to setup this bias parameter the option "Differential code biases" needs to be enabled:



As the "Type of differential code biases" LC for the receivers needs to be selected if the ionosphere-free linear combination L_3 is processed:



Unfortunately, this bias parameter cannot be combined with bias parameters from the type P1-C1 or P1-C1_MULTIPLIER. The related biases for GPS need to be introduced as a priori values in "Observable-specifc biases" in panel "GPSEST 1.1: Input Files 1" and cannot be reestimated at the same time. If P1-C1_MULTIPLIER is selected, GPSEST automatically switches to LC if GPS and Galileo observations are processed together.

In case of the geometry-free linear combination L_4 the $P1 - P2$ bias needs to be specified. Here the necessary Galileo-related bias is set up automatically.

Apart from these modifications, the analysis of the zero-difference network as described in Section 7.4 is possible including Galileo observations.

7.6.5 Adapting the Example BPEs

The PPP (`PPP_BAS.PCF` and `PPP_DEMO.PCF`) as well as the double-difference network (`RNX2SNX.PCF`) processing example BPEs can be switched for processing Galileo observations by changing a few BPE server variables:

- Allow the import of Galileo observations from the RINEX observation files by changing

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_SATSYS Select the GNSS (GPS, GPS/GLO)           GPS/GLO
...
```

  to

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_SATSYS Select the GNSS (GPS, GPS/GLO)           ALL
...
```

  The value of this variable is introduced into the option "Satellite system to be considered" in program RXOBV3 in order to select the GNSS for importing the measurements into the Bernese formatted binary files.

- Another set of changes in the BPE variables is related to the usage of RINEX 3 measurements, which is disabled in the default version:

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_RNXDIR Directory with the RINEX2 files          RINEX
V_RX3DIR Directory with the RINEX3 files
..
V_OBSINF RINEX 3 observation typ selection        OBS.SEL
...
```

According to Section 7.5 they are enabled by:

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_RNXDIR Directory with the RINEX2 files          RINEX
V_RX3DIR Directory with the RINEX3 files          RINEX3
..
V_OBSINF RINEX 3 observation typ selection        OBS_GAL.SEL
...
```

- Finally, the orbit products that shall be used need also to contain Galileo orbits and satellite clock corrections by choosing `COM` instead of `COD` products by changing

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_B      Orbit/ERP, DCB, CLK information          COD
...
```

to

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_B      Orbit/ERP, DCB, CLK information          COM
...
```

It is obvious that the products need to be available in the datapool (`${D}/COM`).

- It might be useful to deposit the results from the Galileo processing in a separate folder in the savedisk archive. You may adapt the BPE variable `V_RESULT` accordingly:

```
VARIABLE DESCRIPTION                              DEFAULT
8******* 40************************************** 30****************************
...
V_RESULT Directory name for the RNX2SNX results   RNX2SNX_GAL
...
```

For zero-difference processing, the ISB between the three involved GNSS in the receivers need to be taken into account. In Section 7.4 this is demonstrated between GPS and GLONASS by enabling the "GLONASS receiver clock biases" in panel "GPSEST 5.2: Setup of Parameters and Pre-Elimination 2". To add the ISB for Galileo as well, one additional bias parameter is needed per receiver (because, as GPS, Galileo uses the same frequency for all satellites). This additional bias is enabled automatically by the user script `TIMEST_P` in conjunction with the program GPSEST. The program switches the "Type of differential code biases" from P1-C1_MULTIPLIER to LC as soon as Galileo data are available. This mechanism allows the PPP example BPEs to use Galileo data. In the case of the zero-difference network processing example (`CLKDET.PCF`) this would require a reorganization of the bias-handling. For that reason this example BPE does not support the analysis of Galileo data at the current status.

7.7 Simulation of GNSS Observations

The *Bernese GNSS Software* provides the simulation tool GPSSIM ("Menu>Service>Generate simulated observation data"). It generates synthetic GNSS (i.e., GPS and GLONASS) observations for terrestrial static or kinematic stations as well as for LEO. Code and phase zero difference observation files can be created based on an observation scenario defined by

- GNSS satellite geometry given by a standard orbit and
- a set of receivers with positions from a coordinate file, kinematic positions, or a LEO standard orbit file.

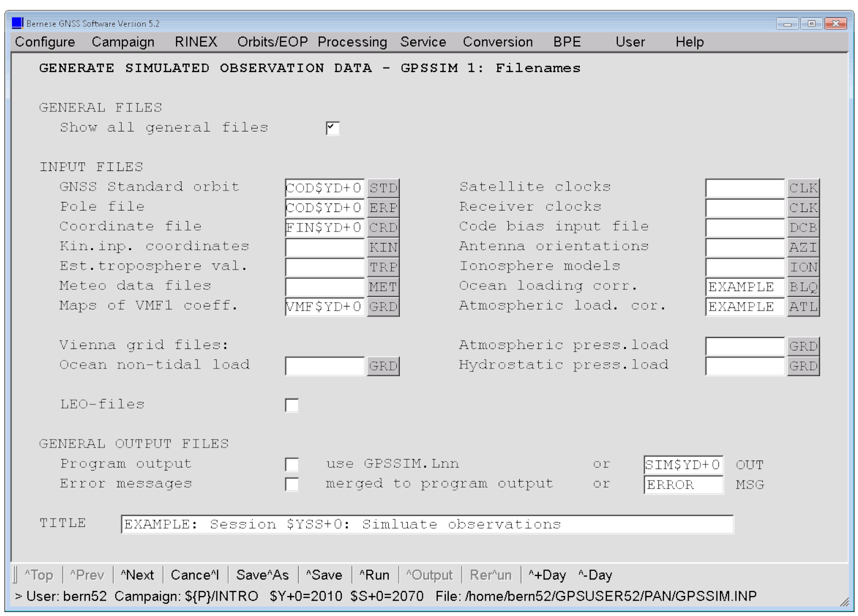
7.7.1 Simulation of GNSS Observations

It is important that you remove all previously existing observation files for this session from the `OBS` directory of your campaign before your start to simulate observations. Otherwise you run into the danger of mixing your current set of simulated observations with other measurements:

```
bern52@carina:~ > rm ${P}/INTRO/OBS/????2070.CZ?
bern52@carina:~ > rm ${P}/INTRO/OBS/????2070.PZ?
```

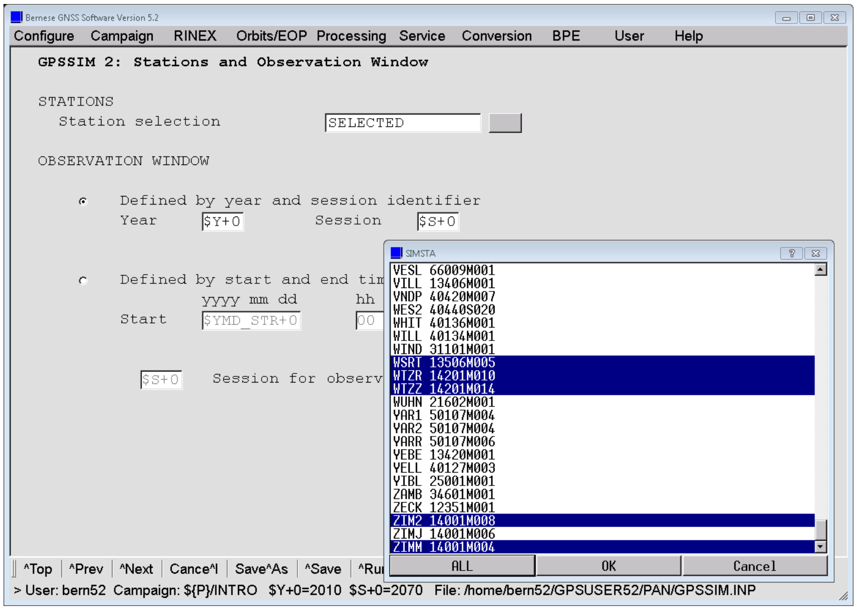
Please keep in mind that the observation files from your previous work in this campaign are lost due to this command. If you still need them, please copy them away.

The input files for the generation of synthetic GNSS observations with program GPSSIM ("Menu>Service>Generate simulated observation data") are defined in the first input panel:

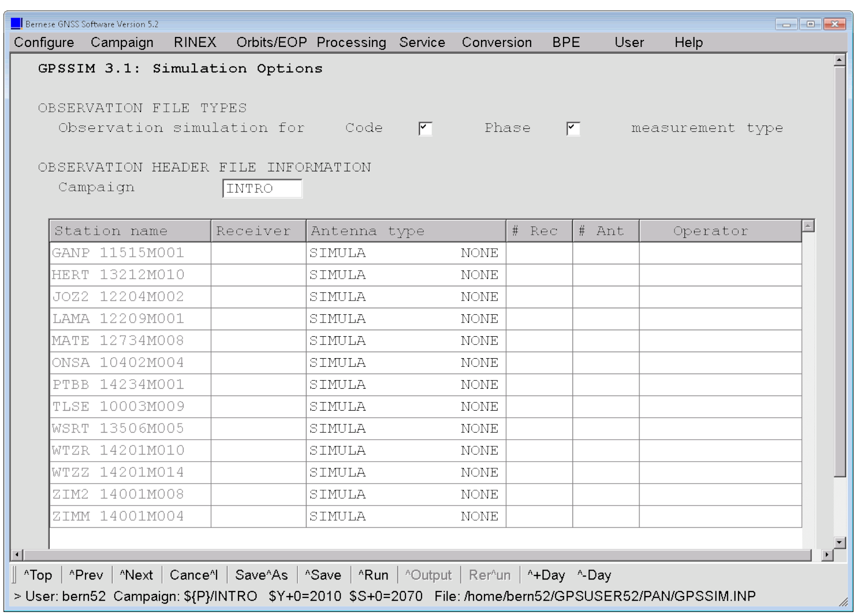


Select `EXAMPLE.ABB` in option "Abbreviation table" in the next panel "GPSSIM 1.1: General Files".

In the second panel, the interval for data simulation is defined and the list of stations selected from all sites in the input "Coordinate file":



The meta data for each station is specified in this panel:



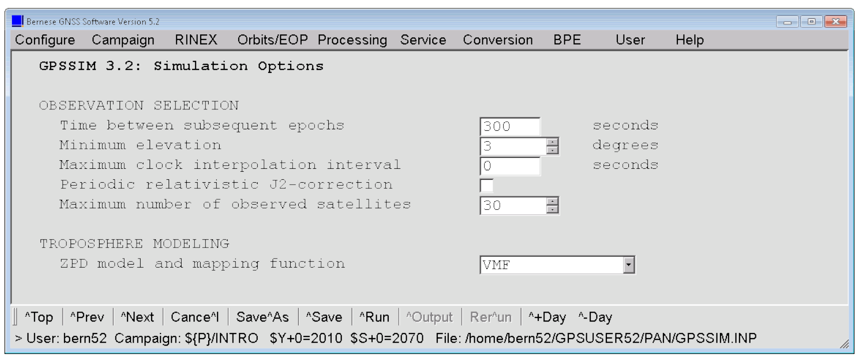
The "Receiver" for each station must start with SIMULA to indicate that this is a simulated station. In the input field you may only extend this string by a user input. Note that the receiver and antenna types you are defining here must be registered in the "Receiver information" and "Phase center eccentricities" files given in panel "GPSSIM 1.1: General Files".

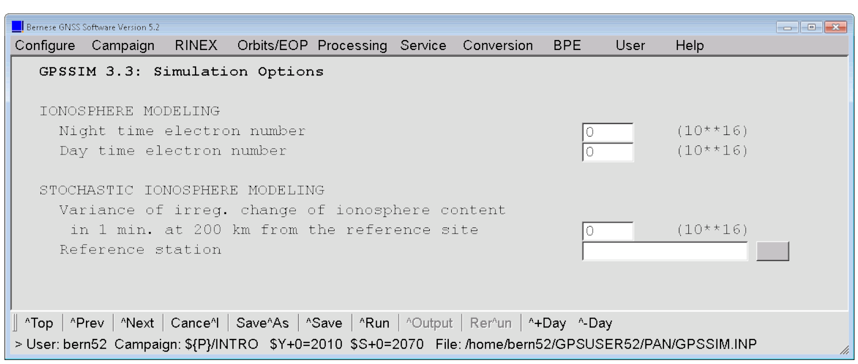
Please check the completeness for each involved GNSS which is not defined by the receiver type connected to the antenna but by the list of satellites in the "GNSS Standard orbit". If you would use the real antenna names for the stations as they are given in Tab. 1.1 GPSSIM would fail and issue a message like

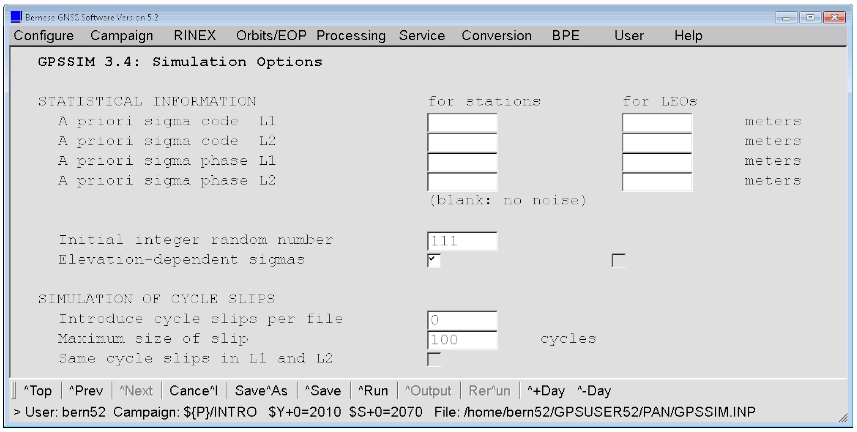
```
*** SR SEARCH_OFF: No offset values found for
                   satellite system R of
                   Antenna: ASH700936E      SNOW
                   Number:         0
```

which indicates deficiencies that need to be fixed manually or with the support of the program ATX2PCV ("Menu>Conversion>ANTEX to Bernese format"). In that case you need to define some antenna phase center corrections for this antenna type for GLONASS. If there is no need for any other antenna naming convention it is proposed to use the antenna name SIMULA with radome type NONE what seems to be sufficient for most of the simulation purposes.

In the subsequent panels some basic characteristics, assumptions on the ionospheric conditions, and the noise level are introduced. Even cycle slips may be simulated.



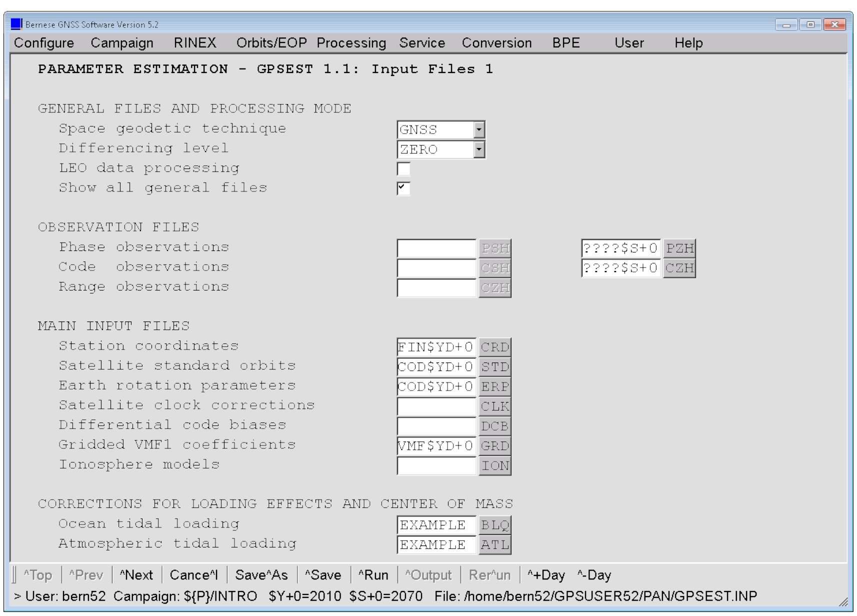


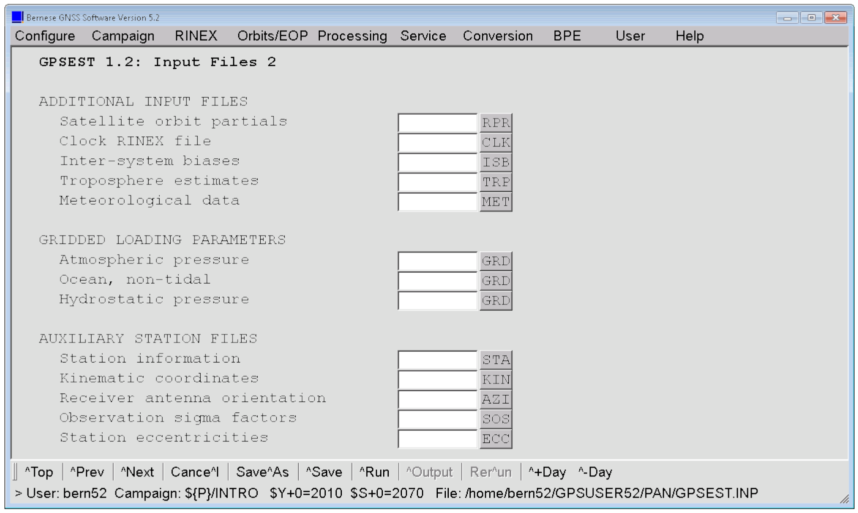


The observations are generated without noise to check the consistency with the processing program in the subsequent sections.

7.7.2 Zero Difference Solution from Simulated GNSS Observations

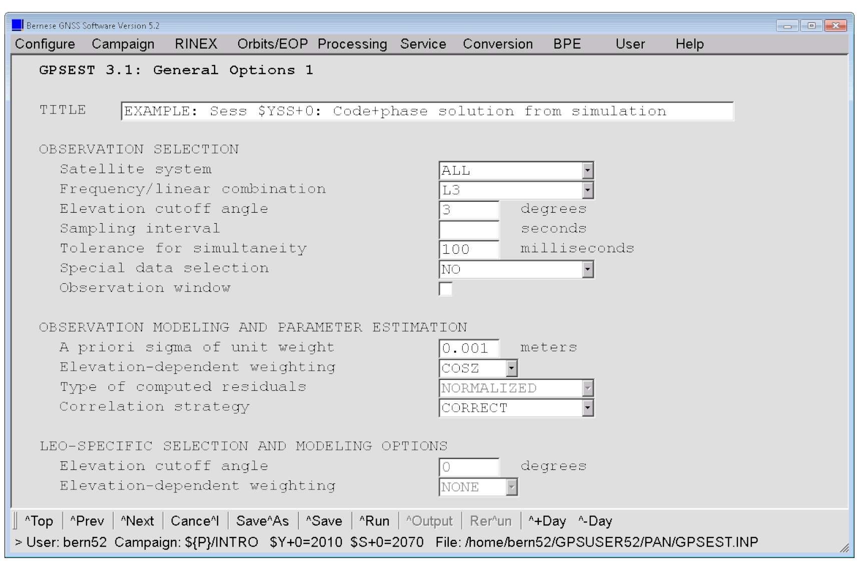
The simulated observations can directly be introduced in program GPSEST for an analysis on zero difference level (if you have not simulated cycle slips). Please pay attention to the consistency of all input files:

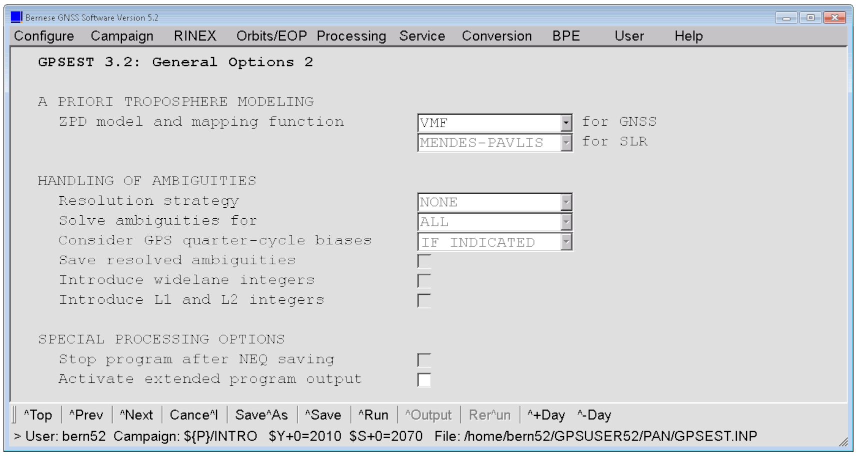




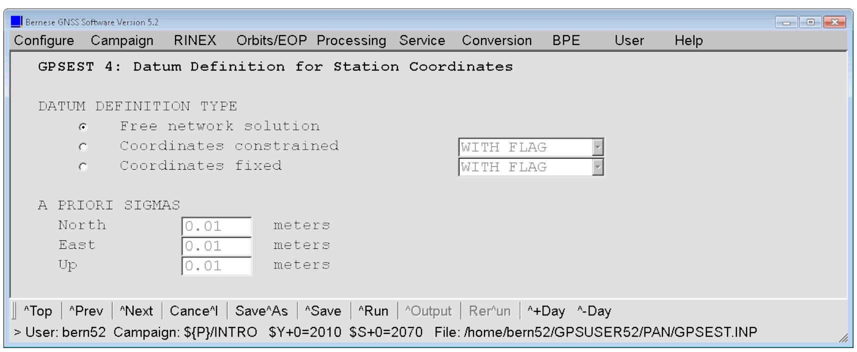
Result files can be specified to compare the results with the inputs for GPSSIM. A residual file might also be useful.

The processing models also have to be consistent with the simulation or to contain well defined differences which are the subject of your investigation:

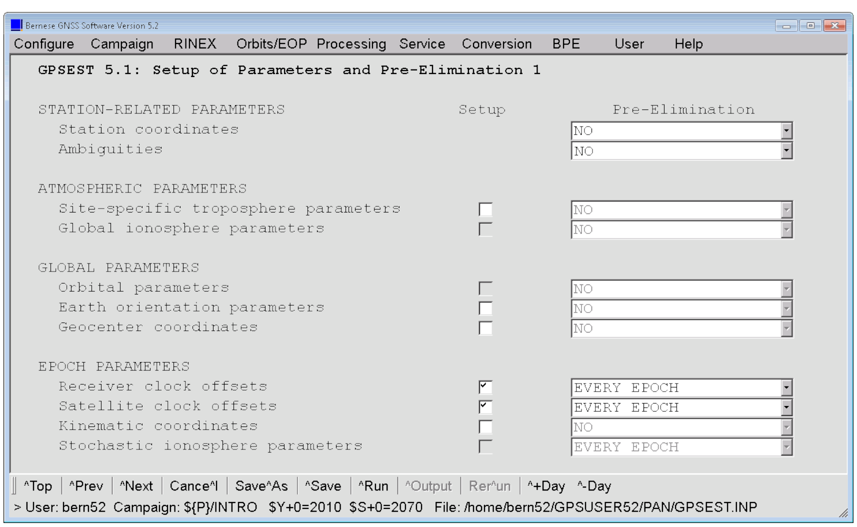


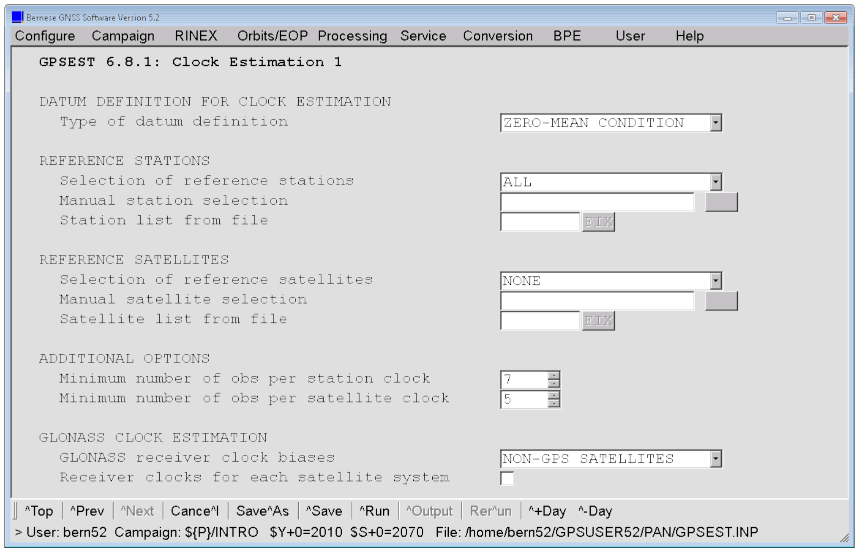


No constraints for datum definition are needed because these are noise–free simulated data:



Only the receiver and satellite clocks are estimated:





The resulting program output file looks like the usual output from GPSEST but with perfect observations without any noise:

```
...

13. RESULTS (PART 1)
--------------------

NUMBER OF PARAMETERS (PART 1):
-----------------------------

PARAMETER TYPE                                #PARAMETERS   #PRE-ELIMINATED        #SET-UP  ...
--------------------------------------------------------------------------------------------- ...

STATION COORDINATES                                    39             0                     39    ...
RECEIVER CLOCK BIASES / TIME BIASES                   260             0                    260    ...
AMBIGUITIES                                          1529             0                   1529    ...
EPOCH WISE STATION CLOCKS                            3744          3744   (EPOCH-WISE)      3744    ...
EPOCH WISE SATELLITE CLOCKS                          6302          6302   (EPOCH-WISE)      6302    ...

--------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF PARAMETERS                          11874         10046                    11874    ...
--------------------------------------------------------------------------------------------- ...


NUMBER OF OBSERVATIONS (PART 1):
-------------------------------

TYPE          FREQUENCY         FILE/PAR          #OBSERVATIONS
--------------------------------------------------------------------------------------------- ...

PHASE            L3               ALL                   68024
CODE             L3               ALL                   68024

--------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF OBSERVATIONS                           136048
--------------------------------------------------------------------------------------------- ...


A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :    0.0000 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE AT ...

DEGREE OF FREEDOM (DOF)            :    124174
CHI**2/DOF                         :      0.00
...
```

No improvements for the station coordinates and other parameters are expected:

```
...
STATION COORDINATES:                          (NOT SAVED)
-------------------

NUM  STATION NAME     PARAMETER    A PRIORI VALUE       NEW VALUE     NEW- A PRIORI  RMS ERROR
------------------------------------------------------------------------------------------ ..

 75  GANP 11515M001   X             3929181.4190       3929181.4190      0.0000      0.0000
                      Y             1455236.8207       1455236.8207      0.0000      0.0000
                      Z             4793653.9477       4793653.9477      0.0000      0.0000

                      HEIGHT            746.0115           746.0115      0.0000      0.0000 ..
                      LATITUDE     49  2  4.971302    49  2  4.971302    0.0000      0.0000 ..
                      LONGITUDE    20 19 22.574439    20 19 22.574439    0.0000      0.0000 ..
   ...
```

The inter–system and inter–frequency biases have been assumed to be zero during the simulation (what is equivalent to any other constant number):

```
...

RECEIVER CLOCKS / TIME BIASES:
-----------------------------

REQUEST  STATION NAME        OFFSET (USEC)  RMS (NSEC)
----------------------------------------------------------------------------------------------

    1    GANP 11515M001        0.000000        ---         0.000000        ---         SAT GPS
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 101
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 102
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 103
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 104
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 105
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 107
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 108
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 110
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 111
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 113
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 114
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 115
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 117
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 118
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 119
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 120
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 121
    1    GANP 11515M001        0.000000     -0.000000     -0.000000       0.000        SAT 122
    1    GANP 11515M001        0.000000      0.000000      0.000000       0.000        SAT 123
...
```

The same holds for the epoch–wise clocks.

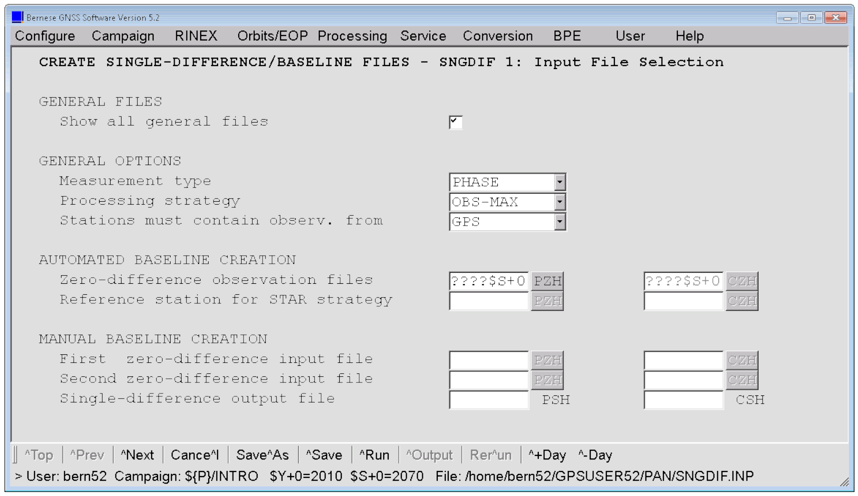
The residuals in the optional residual output file of such a dataset is well below the 1 μm level.

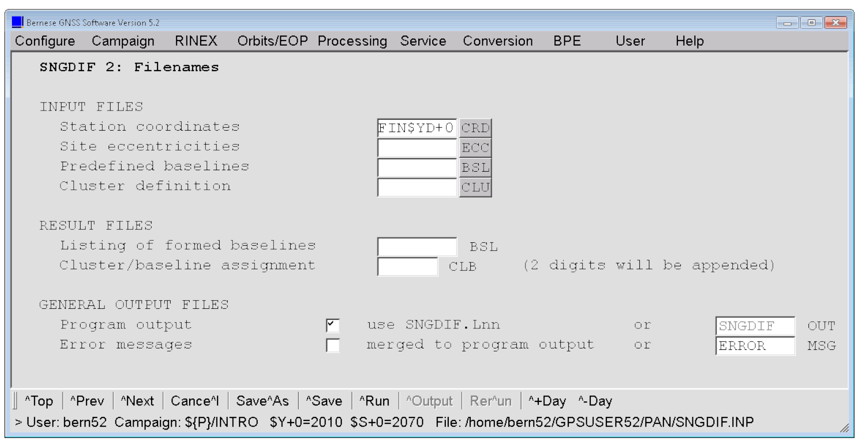
7.7.3 Double–Difference Solution from Simulated GNSS Observations

As in the beginning of the simulation, you should make sure that no other baseline observation files for the current session exist in the `OBS`–directory of your campaign to prevent any interferences and mixtures of simulated measurements with other ones.

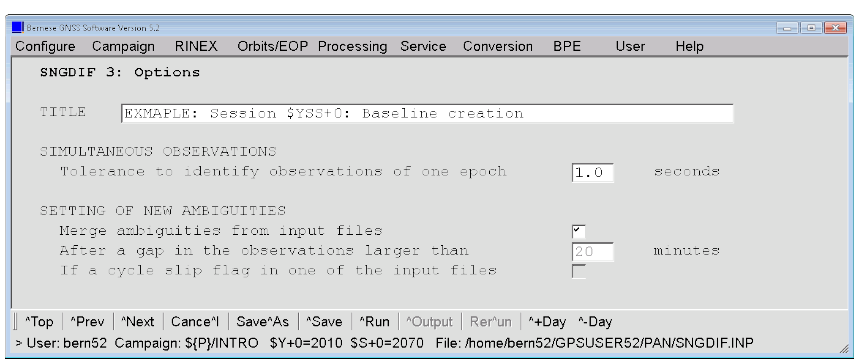
```
bern52@carina:~ > rm ${P}/INTRO/OBS/????2070.PS?
```

The simulated measurements can also be processed in the double–difference mode. In that case you have to start with forming baselines using the program SNGDIF ("Menu>Processing >Create baseline files") in nearly the same shape as in Section 4.2.2 for real observations:

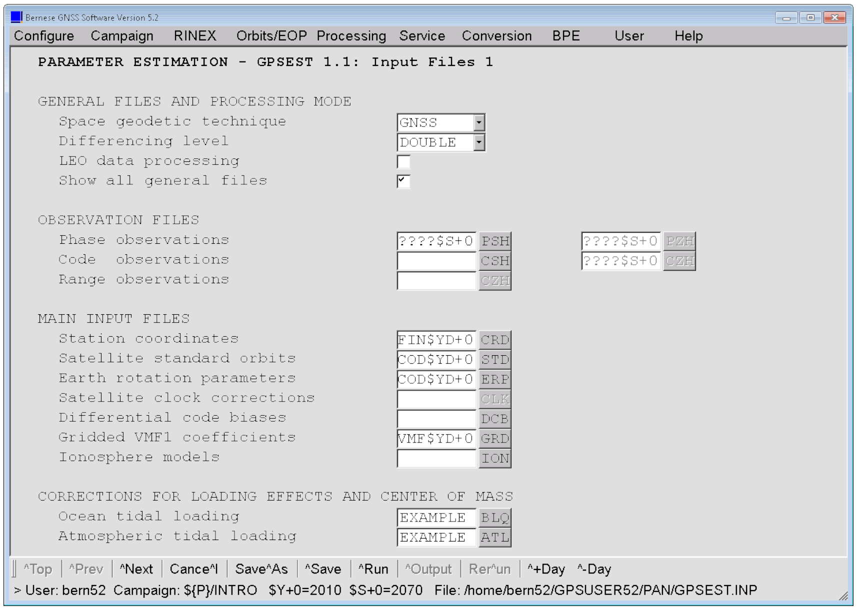


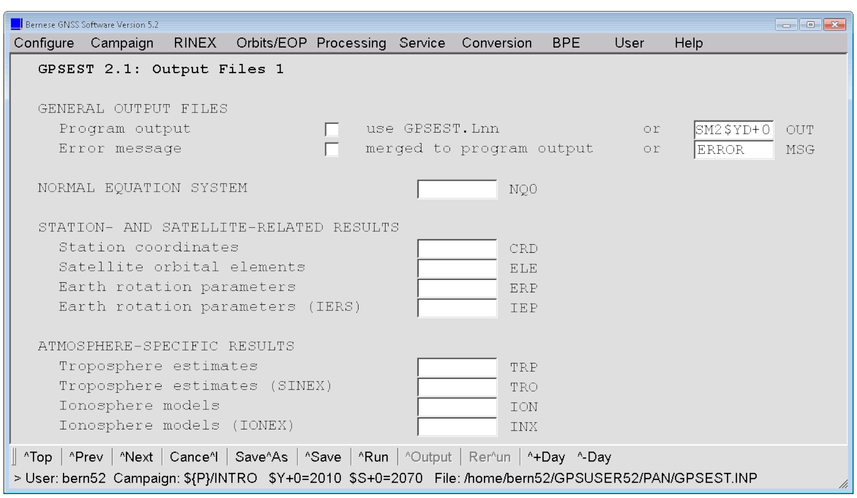


The main difference is that you should also keep all ambiguities from the zero difference in the baseline observation files, what is managed by checking the box for option "Merge ambiguities from input files":

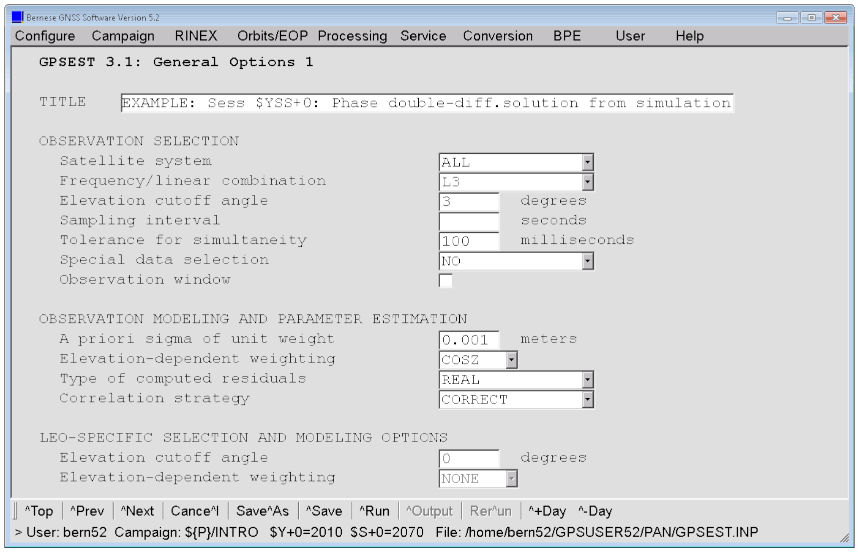


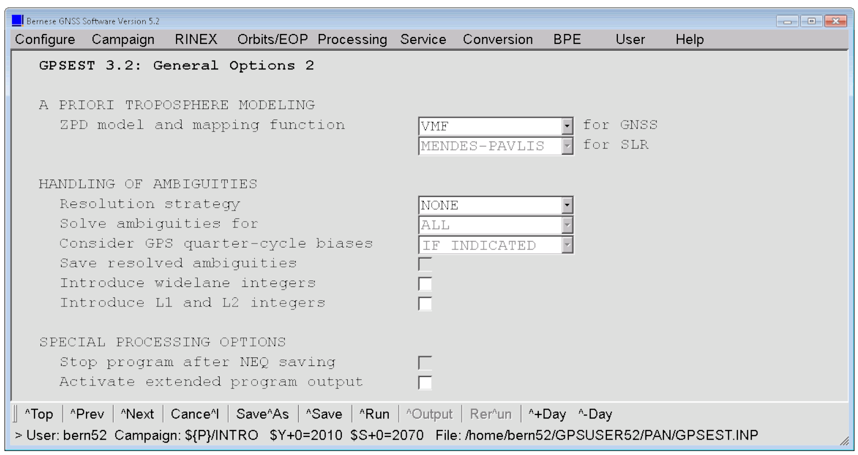
The resulting baseline files from simulated observations can now be analyzed with program GPSEST:



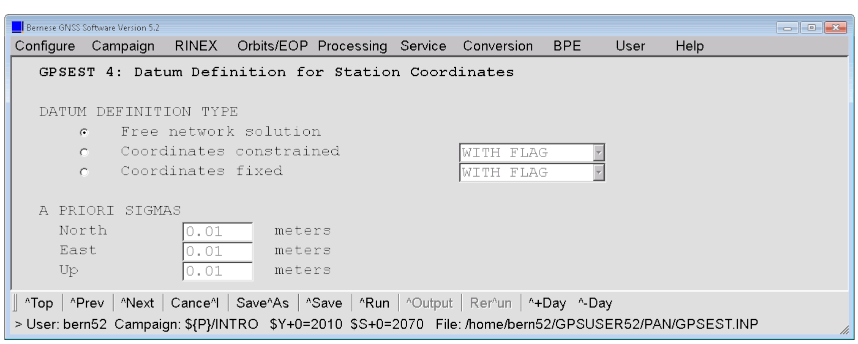


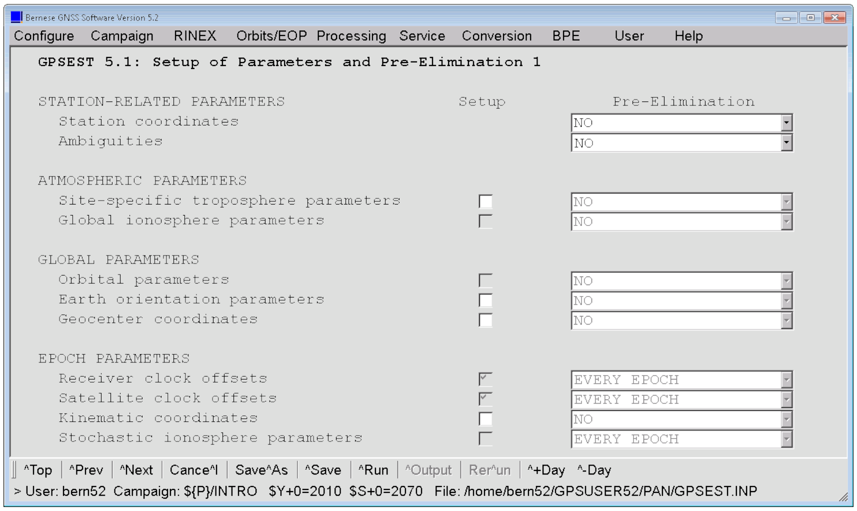
The models are selected to be fully consistent with the simulation:





No other parameters than station coordinates and ambiguities are estimated:





The results are analogue to the zero difference case previously described:

```
...
A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
------------------------------------------

A POSTERIORI SIGMA OF UNIT WEIGHT  :     0.0000 M  (SIGMA OF ONE-WAY L1 PHASE OBSERVABLE ...

DEGREE OF FREEDOM (DOF)            :      56179
CHI**2/DOF                         :       0.00
...
```

The ambiguities are set up in a way that the correct resolution for all ambiguities is zero in any case. This is an easy way to verify ambiguity resolution strategies.

7.7.4 Final Remarks

There are many opportunities to use this simulation tool. It depends on your needs and the concrete target of the simulation study to define the experiment. As it was just demonstrated the full consistency between the processing and the simulation programs is guaranteed by the *Bernese GNSS Software*.

The big advantage of a simulation is that the correct solution is known a priori. On the other hand, you have to keep in mind that the simulated data can only contain effects included in the simulation model. If a receiver for instance introduces a significant variation of the inter–system bias between GPS and GLONASS data — an effect that is not considered in the simulation model — the influence of such an effect on the results cannot be evaluated by the simulation.