Bernese GPS Software Version 5.0

Tutorial

Processing Example
Introductory Course
Terminal Session

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Contents

1. Introduction to the Example Campaign

Data from eight European stations of the IGS Network are selected for the example campaign. They are listed in Table 1.1 together with the receiver and antenna type and the antenna height. The locations of these stations are given in Figure 1.1.

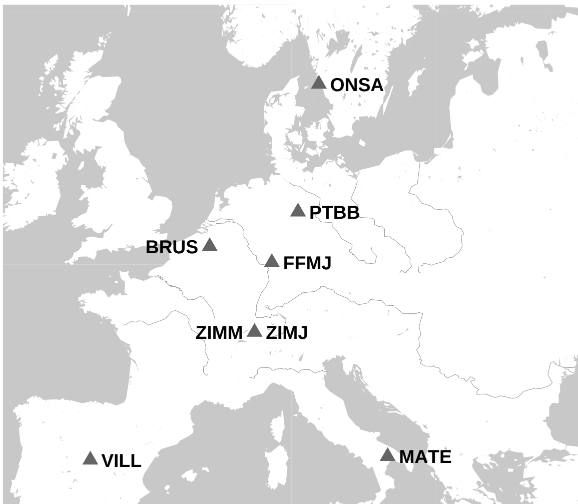


Figure 1.1: Stations used in example campaign

Three of these stations (MATE, ONSA, and VILL) are IGS core sites. This is a set of about 95 IGS stations representing the realization of the reference frame (IGS 00: IGS realization of the ITRF 2000).

Furthermore, two stations (FFMJ and ZIMJ) are equipped with GNSS receivers tracking GPS and GLONASS satellites. The receiver antennas of only two sites (ONSA and PTBB) are equipped with radomes (type OSOD resp. SNOW).

The receivers used at the stations BRUS and PTBB are connected to H-Maser. The receiver type ASHTECH Z-XII3T was developed for time and frequency applications.

The distances between neighboring stations are between 300 and 1200 km. Two GPS receivers in Zimmerwald are included into the example (ZIMM and ZIMJ, distance 14 m).

The observations for these stations are available for four days. Two days in year 2002 (day of year 143 and 144) and two in 2003 (days 138 and 139). In these terminal sessions you will analyze the data in order to obtain a velocity field based on IGS final products.

The data belonging to this example campaign are included in the distribution. Therefore, you may also use this document to repeat the generation of the solution at home to exercise the use of the *Bernese GPS Software*.

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
BRUS 13101M004	Brussels, Belgium	ASHTECH Z-XII3T		
		ASH701945B_M	NONE	3.9702 m
FFMJ 14279M001	Frankfurt (Main), Germany	JPS LEGACY		
		JPSREGANT_SD_E	NONE	0.0000 m
MATE 12734M008	Matera, Italy	TRIMBLE 4000SSI		
		TRM29659.00	NONE	0.1010 m
ONSA 10402M004	Onsala, Sweden	ASHTECH Z-XII3		
		AOAD/M_B	OSOD	0.9950 m
PTBB 14234M001	Braunschweig, Germany	ASHTECH Z-XII3T		
		ASH700936E	SNOW	0.0562 m
VILL 13406M001	Villafranca, Spain	ASHTECH Z-XII3		
		AOAD/M_T	NONE	0.0437 m
ZIMJ 14001M006	Zimmerwald, Switzerland	JPS LEGACY		
		JPSREGANT_SD_E	NONE	0.0770 m
ZIMM 14001M004	Zimmerwald, Switzerland	TRIMBLE 4000SSI		
		TRM29659.00	NONE	0.0000 m

2. Terminal Session: Monday

Today's terminal session is to

- *(1) become familiar with the UNIX environment, the menu of the* Bernese GPS 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 2.6), and*
- *(4) import the observations from the RINEX into the Bernese format for all four days of the example using* RNXOBV3 *(section 2.7).*

2.1 Start the Menu

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

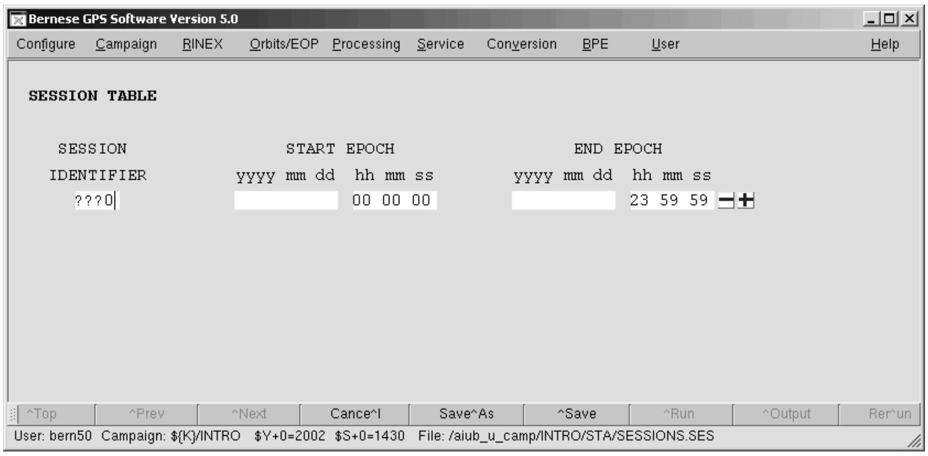
Navigate through the submenus to become familiar with the structure of the menu. Read the general help (available at "Menu>Help>General") to get an overview on the usage of the menu program of the *Bernese GPS Software*.

For the terminal session in the Bernese introduction 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 (refer to the separate handout) and that the current session is set to the first session (i.e. $Y+0=2002, $S+0=1430). If this is not the case, please ask for help.

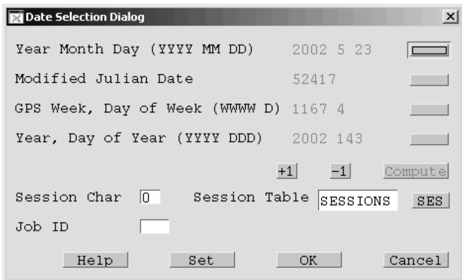
2.2 Select Current Session

Select "Menu>Campaign>Edit session table" to check the session table. It is recommended to use the wildcard string ???0 for the "SESSion identifier" 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 the login. At home you have to source the file `${X}/EXE/LOADGPS.setvar` on UNIX–platforms either manually or during the login.



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



2.3 Campaign Setup

Usually, a new campaign must first be added to the campaign list ("Menu>Campaign>Edit list of campaigns") and set as active campaign ("Menu>Campaign>Select active campaign"), before the directory structure can be created ("Menu>Campaign>Create new campaign". This is already done for your campaign, but you should verify that this is correctly done. In order to become familiar with the campaign structure, you can now visit your campaign directory and inspect the contents using the command line (using *cd* and *ls* for changing directories and creating directory listings, respectively.

You will find the following directories and input data for the processing of the example campaign (note that `${K}/INTRO` is used in this document in place of your individual campaign name):

```
${K}/INTRO/ATM/  COD11674.ION       COD11675.ION       COD12190.ION       COD12191.ION

${K}/INTRO/GEN/  DATUM.
                 IONEX.PPP
                 PHAS_IGS.REL       PHAS_COD.REL
                 RECEIVER.
                 SAT_2002.CRX
                 SAT_2003.CRX
                 SATELLIT.          SATELLIT.I01      SATELLIT.I05
                 SINEX.PPP
                 SINEX.RNX2SNX

${K}/INTRO/OBS/

${K}/INTRO/ORB/  BULLET_A.ERP
                 CODE0205.DCB                          CODE0305.DCB
                 IGS11674.PRE       IGS11675.PRE       IGS12190.PRE       IGS12191.PRE
                 IGS11677.IEP                          IGS12197.IEP
                 P1C10205.DCB                          P1C10305.DCB
                 P1P20205.DCB                          P1P20305.DCB

${K}/INTRO/ORX/  BRUS1430.02O       BRUS1440.02O       BRUS1380.03O       BRUS1390.03O
                 FFMJ1430.02O       FFMJ1440.02O       FFMJ1380.03O       FFMJ1390.03O
                 MATE1430.02O       MATE1440.02O       MATE1380.03O       MATE1390.03O
                 ONSA1430.02O       ONSA1440.02O       ONSA1380.03O       ONSA1390.03O
                 PTBB1430.02O       PTBB1440.02O       PTBB1380.03O       PTBB1390.03O
                 VILL1430.02O       VILL1440.02O       VILL1380.03O       VILL1390.03O
                 ZIMJ1430.02O       ZIMJ1440.02O       ZIMJ1380.03O       ZIMJ1390.03O
                 ZIMM1430.02O       ZIMM1440.02O       ZIMM1380.03O       ZIMM1390.03O
                 BRDC1430.02N       BRDC1440.02N       BRDC1380.03N       BRDC1390.03N
                 IFAG1430.02N       IFAG1440.02N       IFAG1380.03N       IFAG1390.03N
                 MATE1430.02N       MATE1440.02N       MATE1380.03N       MATE1390.03N
                 VILL1430.02N       VILL1440.02N       VILL1380.03N       VILL1390.03N
                 ZIMJ1430.02N       ZIMJ1440.02N       ZIMJ1380.03N       ZIMJ1390.03N

${K}/INTRO/OUT/  IGS11674.CLK       IGS11675.CLK       IGS12190.CLK       IGS12191.CLK

${K}/INTRO/RAW/

${K}/INTRO/SOL/

${K}/INTRO/STA/  EXAMPLE.BLQ
                 EXAMPLE.PLD
                 EXAMPLE.STA
                 IGS_00_R.CRD       IGS_00_R.VEL       IGS_00.FIX
                 SESSIONS.SES

${K}/INTRO/TXT/  COD11677.SUM                          COD12197.SUM
                 IGS11677.SUM                          IGS12197.SUM
```

The directory `${K}/INTRO/GEN/` contains copies of files from the `${X}/GEN` directory, which are actually used by all users. If you want to view these files please use those in your campaign and not in the `${X}/GEN`–directory to prevent interferences with your colleagues. The processing summary files in the directory `${K}/INTRO/TXT/` are just for your information.

In addition you find reference files (`*.*_REF` to compare the solutions obtained with the example BPEs provided in the distribution (`PPP.PCF`, `RNX2SNX.PCF`, `CLKDET.PCF`). The first set (`PPP*`) contains the results from the Precise Point Positioning (`PPP.PCF`). In this course, we assume that this BPE was already successfully executed such that you can start with good a priori coordinates and velocities (files `IGS_00.CRD` and `IGS_00.VEL` in the `STA`–directory) and with a complete list of station abbreviations (file `EXAMPLE.ABB`):

```
${K}/INTRO/ATM/  RIM021430.INX_REF   RIM021440.INX_REF   RIM031380.INX_REF   RIM031390.INX_REF

${K}/INTRO/GEN/

${K}/INTRO/OBS/

${K}/INTRO/ORB/

${K}/INTRO/ORX/

${K}/INTRO/OUT/  PPP021430.PRC_REF   PPP021440.PRC_REF   PPP031380.PRC_REF   PPP031390.PRC_REF
                 PPP021430.CLK_REF   PPP021440.CLK_REF   PPP031380.CLK_REF   PPP031390.CLK_REF
                 PPP021430.OUT_REF   PPP021440.OUT_REF   PPP031380.OUT_REF   PPP031390.OUT_REF

${K}/INTRO/RAW/

${K}/INTRO/SOL/

${K}/INTRO/STA/  EXAMPLE.ABB_REF
                 IGS_00.CRD_REF      IGS_00.VEL_REF
                 PPP021430.CRD_REF   PPP021440.CRD_REF   PPP031380.CRD_REF   PPP031390.CRD_REF
                 REF021430.CRD_REF   REF021440.CRD_REF   REF031380.CRD_REF   REF031390.CRD_REF

${K}/INTRO/TXT/
```

In the terminal session we will more or less follow the example BPE `RNX2SNX.PCF` to compute station coordinates and troposphere parameters for a regional GNSS network. As we will practice the topics of the theoretical morning lessons in these terminal sessions, we will not strictly follow all steps of this example BPE. The reference solutions from this example are:

```
${K}/INTRO/ATM/  F1_021430.TRP_REF   F1_021440.TRP_REF   F1_031380.TRP_REF   F1_031390.TRP_REF

${K}/INTRO/GEN/

${K}/INTRO/OBS/

${K}/INTRO/ORB/

${K}/INTRO/ORX/

${K}/INTRO/OUT/  R2S021430.PRC_REF   R2S021440.PRC_REF   R2S031380.PRC_REF   R2S031390.PRC_REF
                 F1_021430.OUT_REF   F1_021440.OUT_REF   F1_031380.OUT_REF   F1_031390.OUT_REF

${K}/INTRO/RAW/

${K}/INTRO/SOL/  F1_021430.SNX_REF   F1_021440.SNX_REF   F1_031380.SNX_REF   F1_031390.SNX_REF

${K}/INTRO/STA/  F1_021430.CRD_REF   F1_021440.CRD_REF   F1_031380.CRD_REF   F1_031390.CRD_REF

${K}/INTRO/TXT/
```

Another example provided in the distribution concerns the estimation of receiver and satellite clock corrections starting from the broadcast navigation messages (`CLKDET.PCF`). You may use the terminal session on Thursday or Friday to follow this example. The reference result files are:

```
${K}/INTRO/ATM/

${K}/INTRO/GEN/

${K}/INTRO/OBS/

${K}/INTRO/ORB/  TT_021430.CLK_REF   TT_021440.CLK_REF   TT_031380.CLK_REF   TT_031390.CLK_REF

${K}/INTRO/ORX/

${K}/INTRO/OUT/  CLK021430.PRC_REF   CLK021440.PRC_REF   CLK031380.PRC_REF   CLK031390.PRC_REF
                 TT_021430.CLK_REF   TT_021440.CLK_REF   TT_031380.CLK_REF   TT_031390.CLK_REF
                 TTG021430.OUT_REF   TTG021440.OUT_REF   TTG031380.OUT_REF   TTG031390.OUT_REF

${K}/INTRO/RAW/

${K}/INTRO/SOL/

${K}/INTRO/STA/

${K}/INTRO/TXT/
```

2.4 Input Files for the Processing Examples

2.4.1 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 resolve the phase ambiguities using the QIF–strategy (QIF: Quasi–Ionosphere–Free).

2.4.2 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 this files will affect processing for everyone. Consequently, these files are located in the `${X}/GEN` directory. Table 2.1 shows the list of general files necessary for the processing example. It also shows which files need updating from time to time by downloading them from the anonymous ftp–server of AIUB (`http://www.aiub.unibe.ch/download/BSWUSER50/GEN`).

Each Bernese processing program has its own panel for general files. Make sure that you use the correct files listed in Table 2.1 .

Copies of these files are available in your campaign's `GEN`–directory. In order to prevent accidental change of the "live" files in `${X}/GEN`, we recommend that you only inspect/browse the files in your campaign area.

2.4.3 Orbit files ORB

The precise orbits in the files `*.PRE` are the combined final products from the IGS. They do not contain orbits for the GLONASS satellites. The corresponding Earth orientation parameters are given in weekly files with the extension `*.IEP` .

Table 2.1: List of general files to be used in the Bernese programs for the processing example.

Filename	Content	Modification	Download
CONST.	All constants used in the *Bernese GPS Software*	No	BSW aftp
DATUM.	Definition of geodetic datum	Introducing new reference ellipsoid	BSW aftp
RECEIVER.	Receiver information	Introducing new receiver type	BSW aftp
PHAS_COD.REL	Phase center eccentricities and variations including radome codes	Introducing new elevation-dependent corrections New antenna	BSW aftp
SATELLIT.I01	Satellite information file	New launched satellites	BSW aftp
SAT_$Y+0.CRX	Satellite problems	Satellite maneuvers, bad data, ...	BSW aftp
GPSUTC.	Leap seconds	When a new leap second is announced by the IERS	BSW aftp
IAU2000.NUT	Nutation model coefficients	No	—
IERS2000.SUB	Subdaily pole model coefficients	No	— —
POLOFF.	Pole offset coefficients	Introducing new values from IERS annual report (until 1997)	—
JGM3.	Earth potential coefficients	No	—
OT_CSRC.TID	Ocean tides coefficients	No	—
SINEX. SINEX.TRO SINEX.PPP SINEX.RNX2SNX	SINEX header information . . . for the PPP example . . . for the double–diff. example	Adapt SINEX header for your institution	—
IONEX. IONEX.PPP	IONEX header information . . . for the PPP example	Adapt IONEX header for your institution	—

Furthermore, the directory contains monthly means for the differential code biases (DCBs).

2.4.4 RINEX files `ORX`, `OUT`

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. The navigation messages `*.$YN` are only used for the clock determination example.

The clock RINEX files are located in the `OUT`–directory. They are consistent with the IGS orbit and ERP products in the `ORB`–directory. They contain station and satellite clock corrections with 5 min. sampling.

2.4.5 Station files `STA`

The a priori coordinates of the stations in the IGS realization of the reference frame ITRF2000 are available in the file `IGS_00.CRD`. It was generated using the PPP example for day 143 of year 2002. It contains all IGS core sites (copied from file `IGS_00_R.CRD` — the IGS realization of the reference frame ITRF2000) and the PPP results for the remaining stations. The epoch of the coordinates is January 01, 2000. The corresponding velocity file `IGS_00.VEL` contains the velocities for the core sites (copied from file `IGS_00_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`. The file `IGS_00.FIX` contains the list of all IGS core sites. It will be useful to define the geodetic datum when estimating station coordinates. You can browse all these files with a text editor or with the menu ("Menu>Campaign >Edit station files").

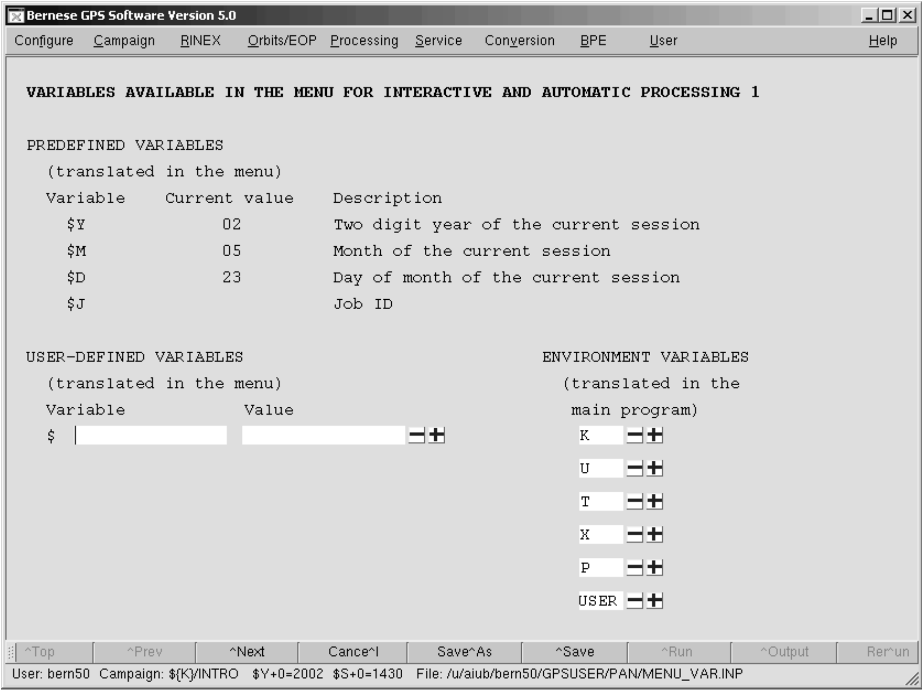
To make sure that you process the data in the *Bernese GPS Software* with correct station information (station name, receiver type, antenna type, antenna height, etc.) the file `EXAMPLE.STA` is used to verify the RINEX header information. The reason to use this file has to be seen in the fact that some 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 `PHAS_COD.REL` in order that the correct phase center offsets and variations are used. The receiver types have to be defined in the `RECEIVER.` file to correctly apply the DCB corrections.

The last file to be mentioned in this list is `EXAMPLE.BLQ`. It provides the coefficients for the ocean tidal loading of the stations to be processed. It has to be applied at least in the final run of GPSEST.

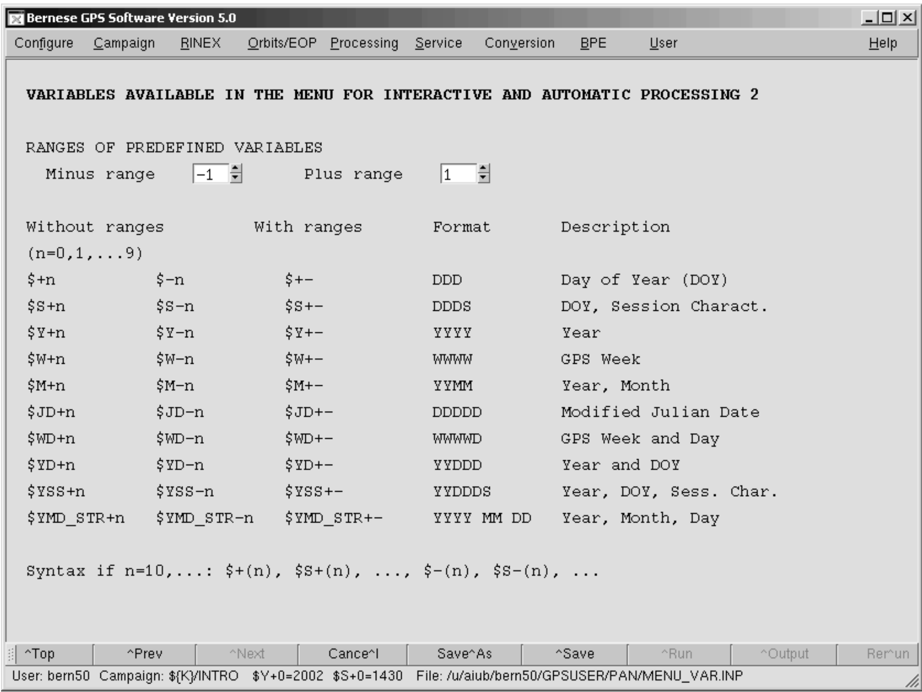
2.5 Menu Variables

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 file name. It would be very cumbersome to repeat all the runs selecting the correct files manually every time. For the BPE an automatization is mandatory. For such cases the Bernese menu system provides a powerful tool — 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 GPS Software*. The campaign data are located in the directory `${K}/INTRO=/aiub_u_camp/INTRO`. The user–dependent files can be found at `${U}=/u/aiub/bern50/GPSUSER` — note, that you will find instead of `bern50` your user name in the path. The temporary user files are saved in `${T}=/scratch/bern50`. Finally, the campaign–independent files reside in `${X}=/aiub_sw/BERN50/GPS`.



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

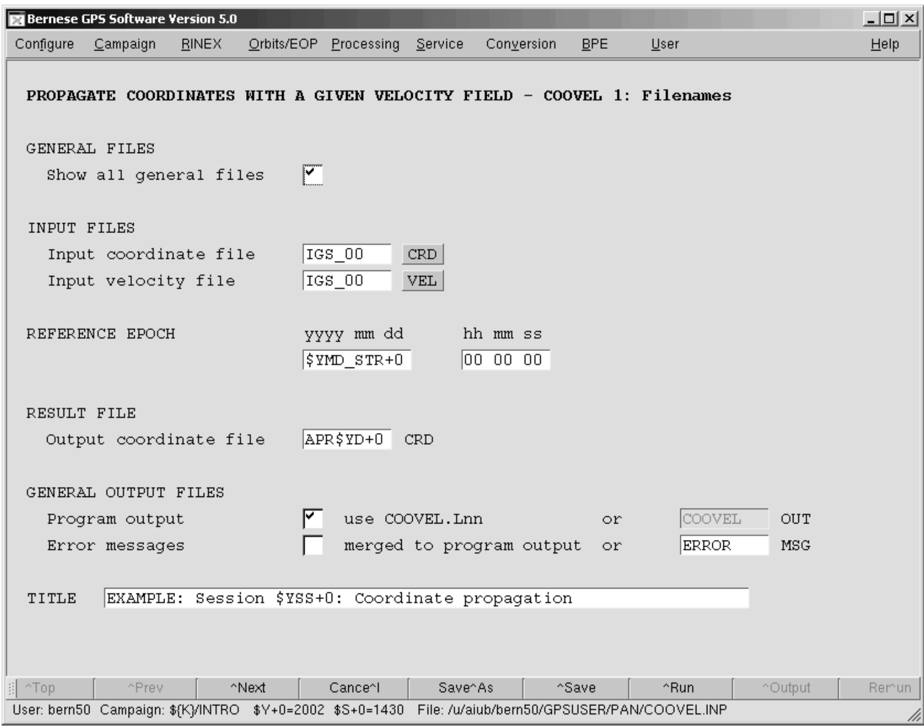


Be aware that the variable `$S+1` refers to the next *session*. Because we are using a session table for a daily processing it also corresponds to the next day.

These variables are automaticall 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).

2.6 Generate A priori Coordinates

As stated before the a priori coordinates generated from the PPP example BPE refer to the epoch January 01, 2000 . The first step is to extrapolate the coordinates to the epoch that is currently processed. The program COOVEL is used for this purpose. Open the program input panel in "Menu>Service>Coordinate tools>Extrapolate coordinates":



"REFERENCE EPOCH"	$YMD_STR+0	→ 2002 05 23
"Output coordinate file"	APR$YD+0	→ APR02143
"TITLE"	Session $YSS+0:	→ Session 021430:

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

```
===============================================================================
Program : coovel                                 Bernese GPS Software Version 5.0
Purpose : Propagation of coordinates with a given velocity field
Campaign: ${K}/INTRO                             Default session: 1430 year 2002
Date    : 13-Feb-2007 11:22                      User name      : bern50
===============================================================================


EXAMPLE: Session 021430: Coordinate propagation
-------------------------------------------------------------------------------



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

-------------------------------------------------------------------------------
Session table             : ${K}/INTRO/STA/SESSIONS.SES
Input coordinate file     : ${K}/INTRO/STA/IGS_00.CRD
Output coordinate file    : ${K}/INTRO/STA/APR02143.CRD
Input velocity file       : ${K}/INTRO/STA/IGS_00.VEL
Program output            : ${K}/INTRO/OUT/COOVEL.L00
Error message             : ${U}/WORK/ERROR.MSG
-------------------------------------------------------------------------------
...
```

The header area of the program output is standardized for all programs of the *Bernese GPS Software*, Version 5.0 . 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 result of the run of COOVEL is an a priori coordinate file (`${K}/INTRO/STA/APR02143.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):

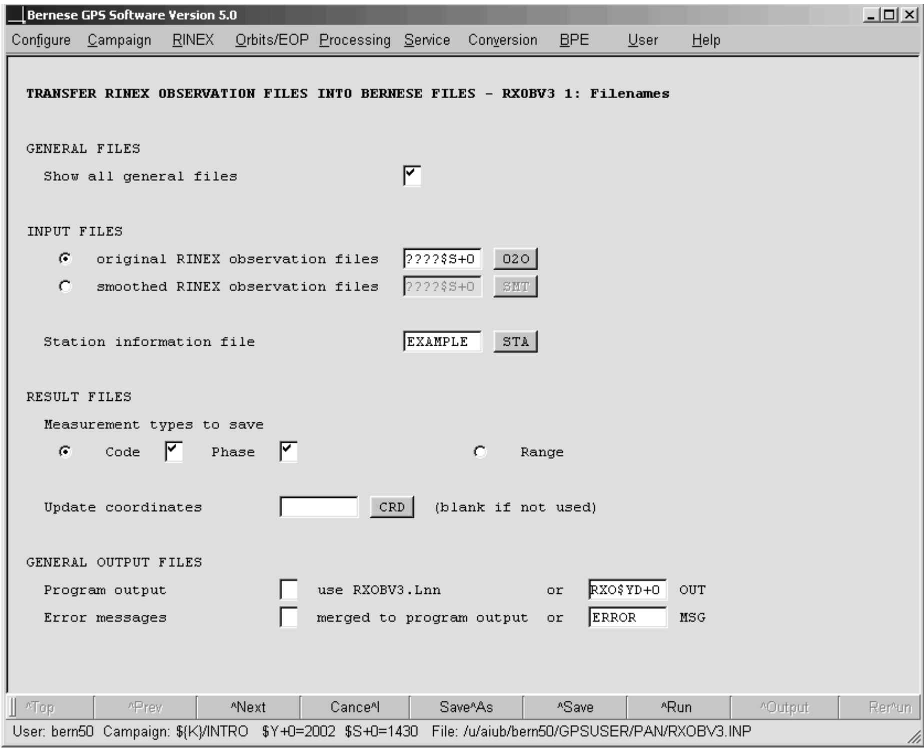
```
IGS00 COORDINATES BASED ON IGS01P37_RS54.SNX                           29-JUN-03
--------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS00            EPOCH: 2002-05-23  0:00:00

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

  6  BRUS 13101M004     4027893.7773    307045.7760   4919475.0809    PPP
 15  FFMJ 14279M001     4053455.9006    617729.6193   4869395.6681    PPP
 36  MATE 12734M008     4641949.6104   1393045.3794   4133287.4177    IGS00
 42  ONSA 10402M004     3370658.5806    711877.1009   5349786.9189    IGS00
 47  PTBB 14234M001     3844059.9795    709661.2696   5023129.5003    PPP
 56  VILL 13406M001     4849833.7343   -335049.0774   4116014.9013    IGS00
 63  ZIMJ 14001M006     4331293.9550    567542.0890   4633135.6788    PPP
 64  ZIMM 14001M004     4331297.0935    567555.8333   4633133.8919    PPP
```

Repeat this step for the other three sessions of the example by changing the current session using "Menu>Configure>Set session/compute date". You can then use the `Rer^un` button to restart the program. No options need to be changed since consequent use of the menu time variables was made.

2.7 Importing the Observations

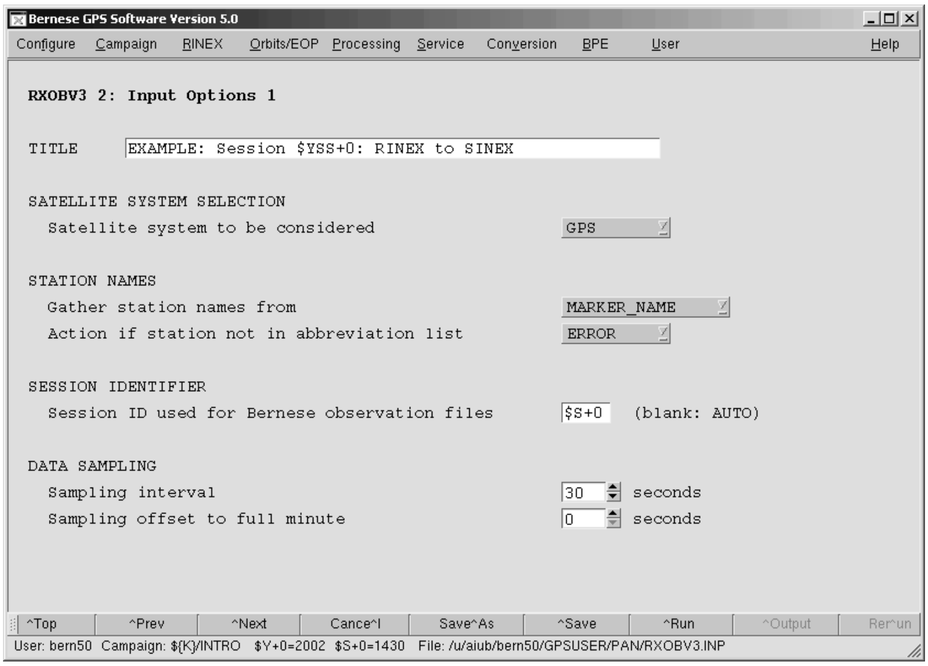
The campaign has now been set up and all necessary files are available. The first part of processing consists of the transfer of the observations from RINEX to Bernese (binary) format. To get an overview of the data availability you may generate a pseudographic from the RINEX observation files using 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). You need to run this program for all 4 sessions of the example.

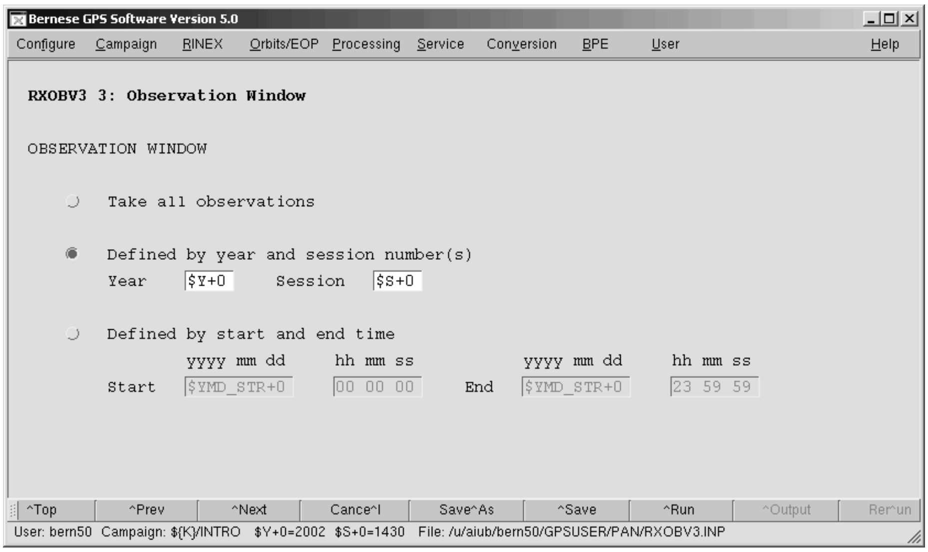


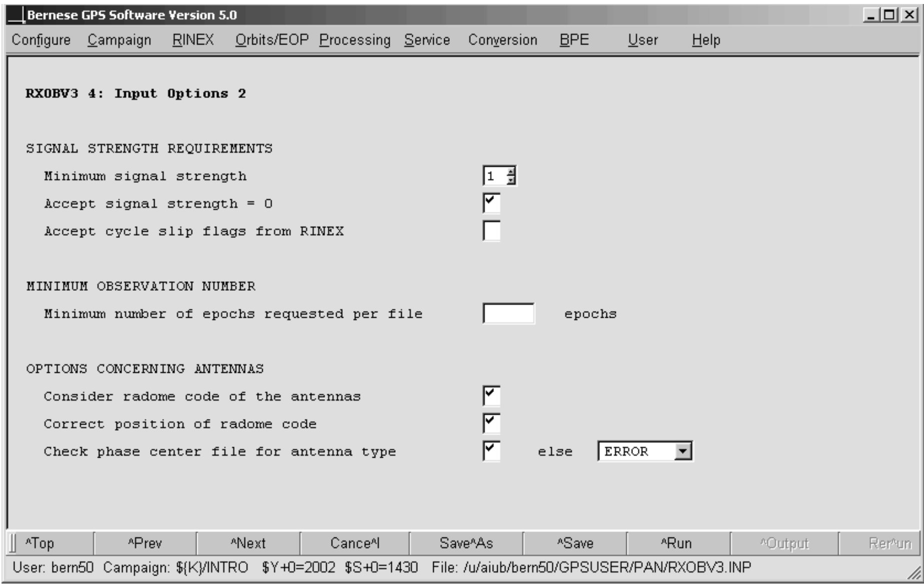
All RINEX observation files fitting `${K}/INTRO/RAW/????1430.02O` are selected automatically by the current entry in the input field "original RINEX observation files". You can verify this by pressing the button just right from this input field (labeled with the file extension `02O`). In the file selection dialogue you will see the list of currently selected files. The RINEX files of the year 2003 are shown if a current session from the year 2003 is selected. In that case the label of the button changes to `03O`.

The next panel specifies the general input files. 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:

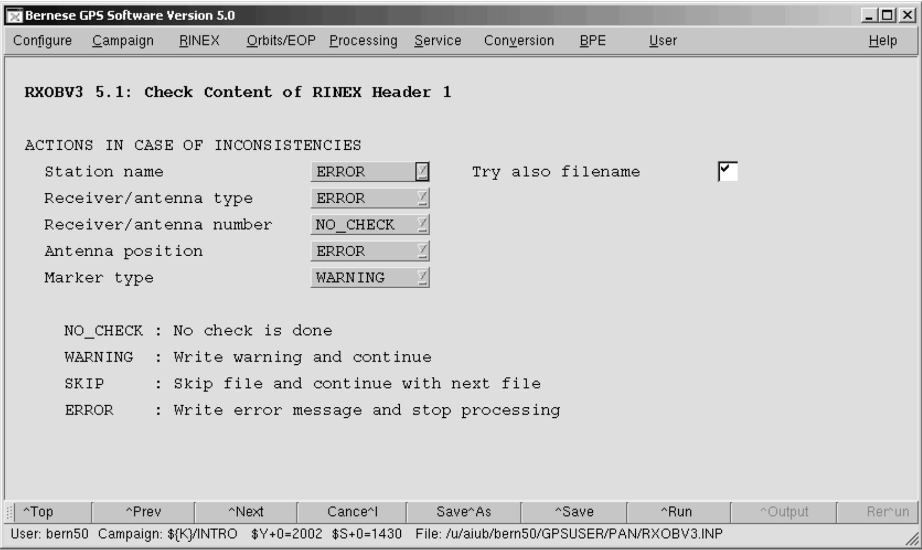


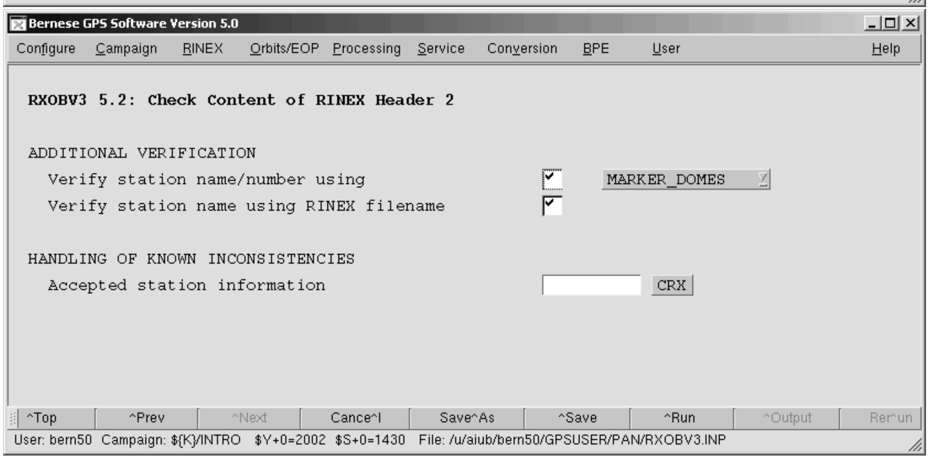
We select GPS for the option "Satellite system to be considered" because the IGS orbits provide only the positions of the GPS satellites.





Two more panels provide options to verify the RINEX header information:





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

A warning message will appear to inform you that the observations to the GLONASS satellites (satellite system R) are removed from the two stations equipped with GNSS receivers.

```
### PG RXOBV3: OBSERVATION DATA FROM OTHER SATELLITE SYSTEM REJECTED
               RINEX FILE NAME: ${K}/INTRO/RAW/FFMJ1430.02O

SR R2RDOR: SATELLITES SKIPPED! SYSTEM: "R"


### PG RXOBV3: OBSERVATION DATA FROM OTHER SATELLITE SYSTEM REJECTED
               RINEX FILE NAME: ${K}/INTRO/RAW/ZIMJ1430.02O
```

The program produces an output file `RXO02143.OUT` in the directory `${K}/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 GPS Software*. In addition some observation statistics are available. In the following section you may check the completeness of the Bernese observation files by the available number of epochs:

```
...
 TABLE OF INPUT AND OUTPUT FILE NAMES:
 ------------------------------------

 Num  Rinex file name                   Bernese code  header  file name   #epo   ...
                                        Bernese code  observ. file name
                                        Bernese phase header  file name   #epo   ...
                                        Bernese phase observ. file name
 ------------------------------------------------------------------------------- ...

   1  ${K}/INTRO/RAW/BRUS1430.02O       ${K}/INTRO/OBS/BRUS1430.CZH       2778   ...
                                        ${K}/INTRO/OBS/BRUS1430.CZO
                                        ${K}/INTRO/OBS/BRUS1430.PZH       2778   ...
                                        ${K}/INTRO/OBS/BRUS1430.PZO

   2  ${K}/INTRO/RAW/FFMJ1430.02O       ${K}/INTRO/OBS/FFMJ1430.CZH       2799   ...
                                        ${K}/INTRO/OBS/FFMJ1430.CZO
                                        ${K}/INTRO/OBS/FFMJ1430.PZH       2799   ...
                                        ${K}/INTRO/OBS/FFMJ1430.PZO

   3  ${K}/INTRO/RAW/MATE1430.02O       ${K}/INTRO/OBS/MATE1430.CZH       2880   ...
                                        ${K}/INTRO/OBS/MATE1430.CZO
                                        ${K}/INTRO/OBS/MATE1430.PZH       2880   ...
                                        ${K}/INTRO/OBS/MATE1430.PZO

 ...
```

If epochs are missing for some RINEX files you may check this with the RINEX observation graphic from the program RNXGRA.

2.8 Daily Goals

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

(1) *a priori coordinates in your campaign's STA directory: file* `APR02143.CRD`, `APR02144.CRD`, *... (for all 4 days)*

(2) *Bernese formatted zero difference observation files in your campaign's OBS directory:*`BRUS1430.CZH`, `BRUS1430.PZH`, `BRUS1430.CZO`, `BRUS1430.PZO`, *... (for all stations).*

These files must be generated for all four days.

3. Terminal Session: Tuesday

Today's terminal session is to

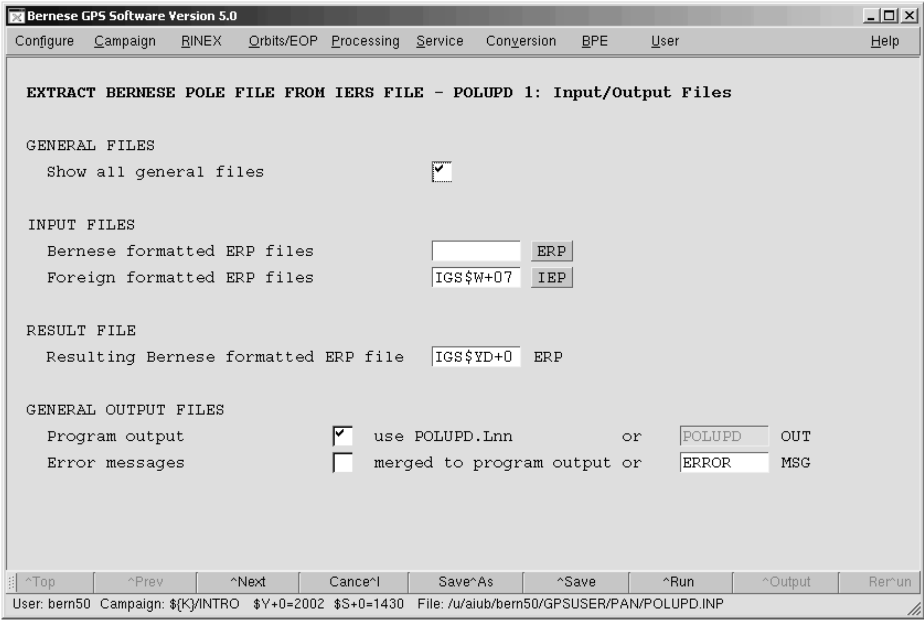
*(1) generate the pole information file in Bernese format (*POLUPD*)*
*(2) generate tabular orbit files from IGS precise files (*PRETAB*)*
*(3) generate Bernese standard orbit files (*ORBGEN*)*
(4) preprocess the Bernese observation files:

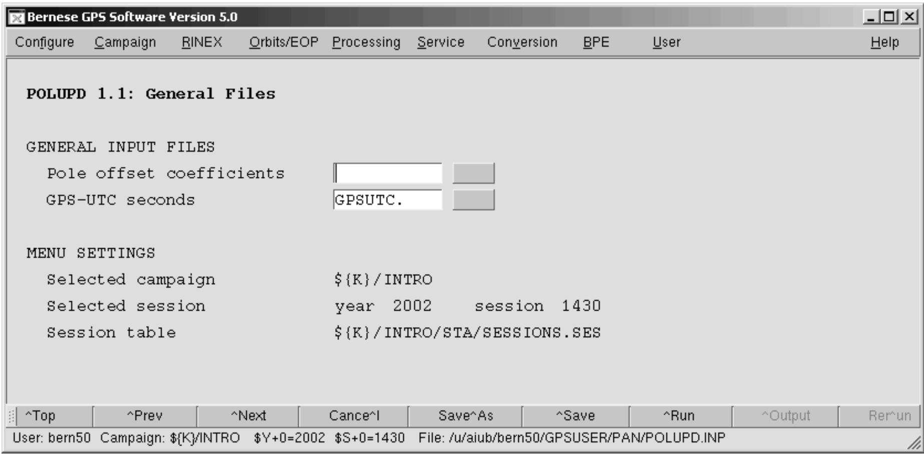
- *receiver clock synchronization (*CODSPP*)*
- *baseline generation (*SNGDIF*)*
- *preprocess baselines (*MAUPRP*)*

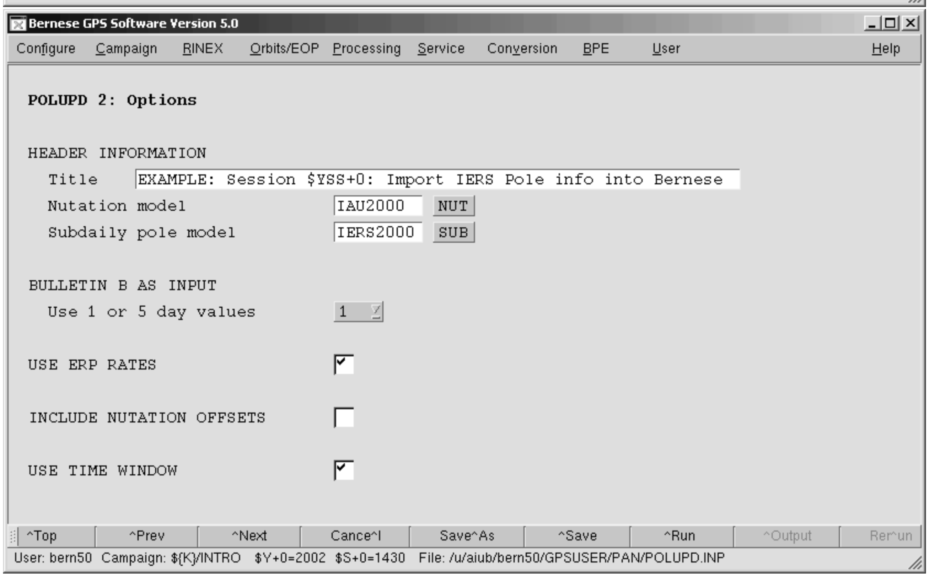
for all four days of the processing example. You can run all programs for one day, and then rerun them for the next day.

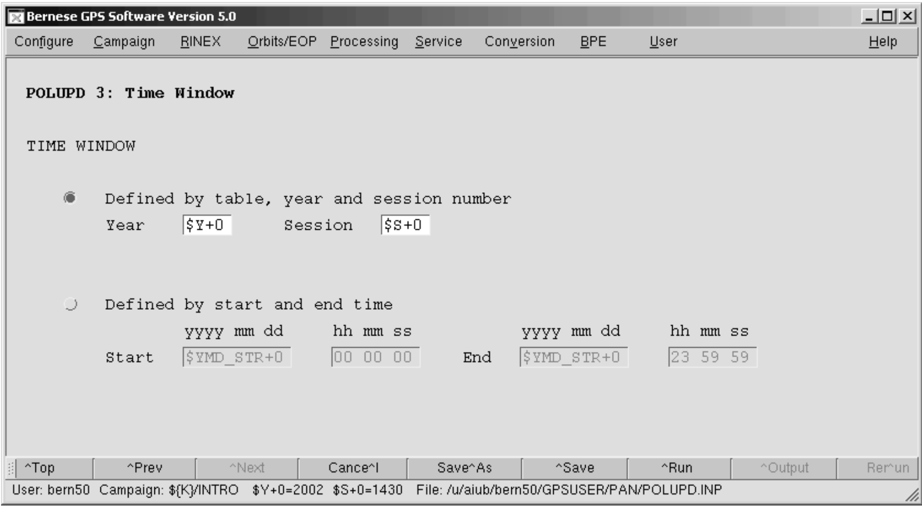
3.1 Prepare Pole Information

Together with the precise orbit files (PRE), a consistent set of Earth orientation information is provided in the ORB–directory. Whereas the orbits are given in daily files the EOPs are available in weekly files for the IGS final product series. We have to convert the information from the IERS/IGS standard format (file extension within the *Bernese GPS Software* is IEP) into the internal Bernese EOP format (file extension within the *Bernese GPS 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 to an existing file.


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
EXTRACT BERNESE POLE FILE FROM IERS FILE - POLUPD 1: Input/Output Files
GENERAL FILES
Show all general files
INPUT FILES
Bernese formatted ERP files
ERP
Foreign formatted ERP files
IGS$W+07
IEP
RESULT FILE
Resulting Bernese formatted ERP file
IGS$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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/POLUPD.INP


Bernese GPS Software Version 5.0
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
${K}/INTRO
Selected session
year 2002 session 1430
Session table
${K}/INTRO/STA/SESSIONS.SES
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/POLUPD.INP


Bernese GPS Software Version 5.0
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
IAU2000
NUT
Subdaily pole model
IERS2000
SUB
BULLETIN B AS INPUT
Use 1 or 5 day values
1
USE ERP RATES
INCLUDE NUTATION OFFSETS
USE TIME WINDOW
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/POLUPD.INP



The last panel for the program POLUPD is an example for the specification of time windows in the *Bernese GPS Software*, Version 5.0 . 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 the user may define only the beginning or the end of the time interval. We refer to the online help for more details.

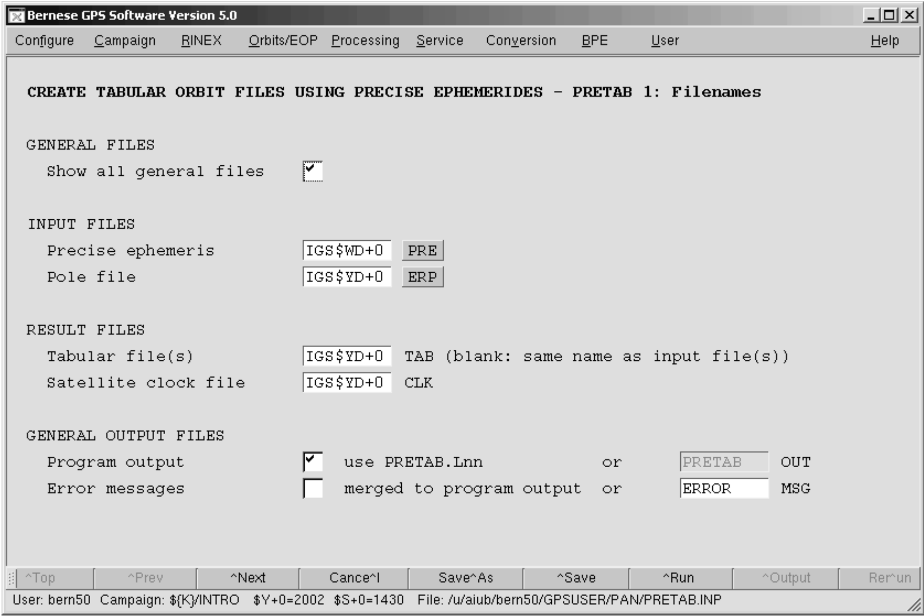
The messages

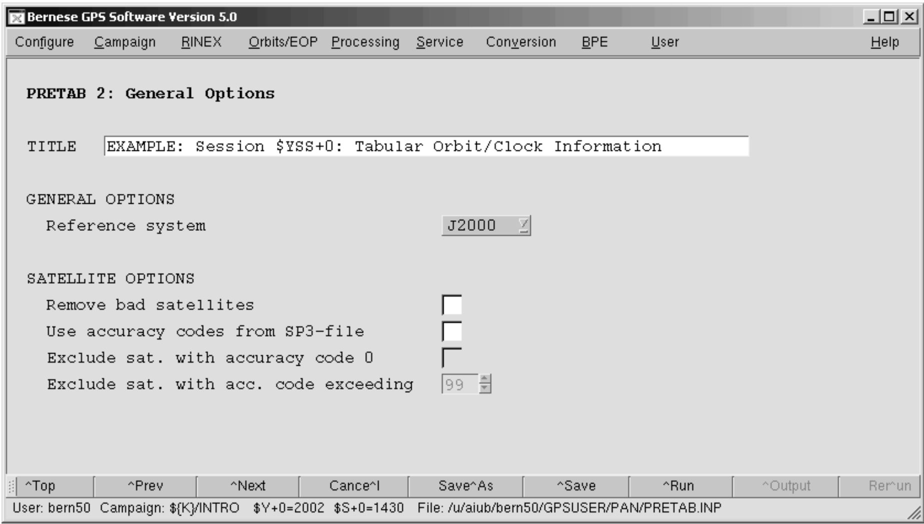
```
### PG POLUPD: NUTATION MODEL NOT SPECIFIED IN INPUT ERP FILE
              USING NUTATION MODEL NAME : IAU2000


### PG POLUPD: SUBDAILY POLE MODEL NOT SPECIFIED IN INPUT ERP FILE
              USING SUBDAILY POLE MODEL NAME : IERS2000
```

just inform you that the subdaily pole and nutation model from the input panel is written to the output file because no Bernese formatted ERP file was used as input.

3.2 Generate Orbit Files

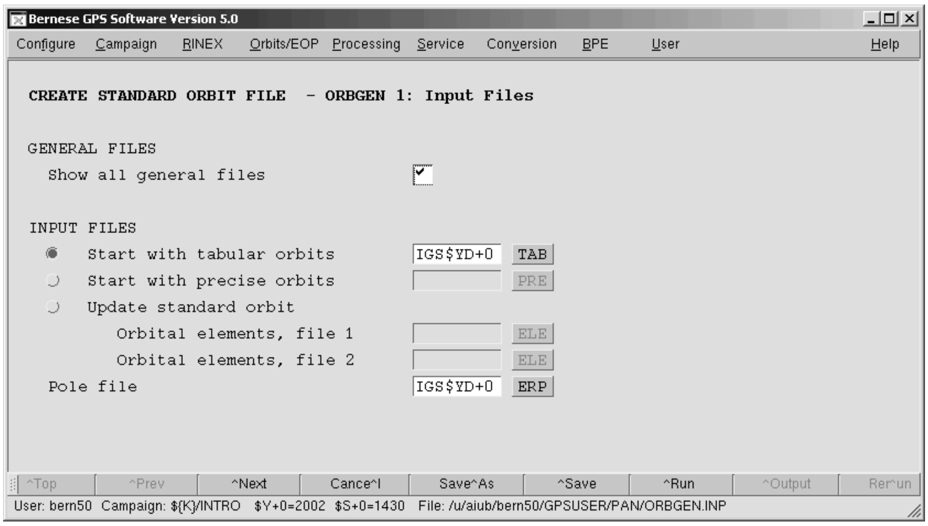
In this processing example we use only two programs of the orbit part of the *Bernese GPS Software*. The first program is called PRETAB and may be accessed using "Menu>Orbits/EOP >Create tabular orbits". The main task of PRETAB is to create tabular orbit files (TAB) (i.e., to transform the precise orbits from the terrestrial into the celestial reference frame) and to generate a satellite clock file (CLK). The clock file will be needed in program CODSPP (see Section 3.3.1) if no broadcast orbits are used.



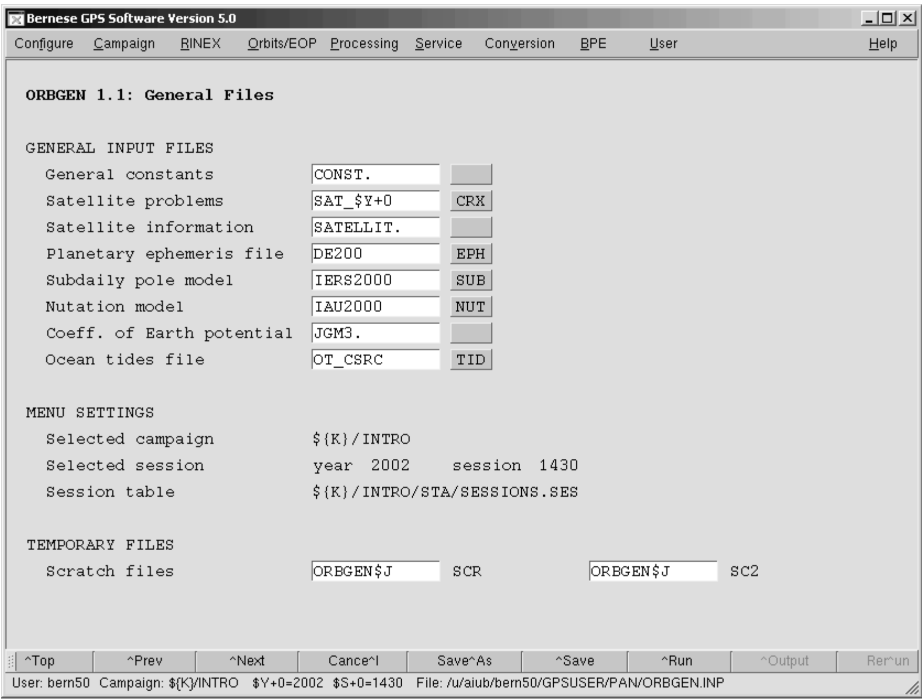


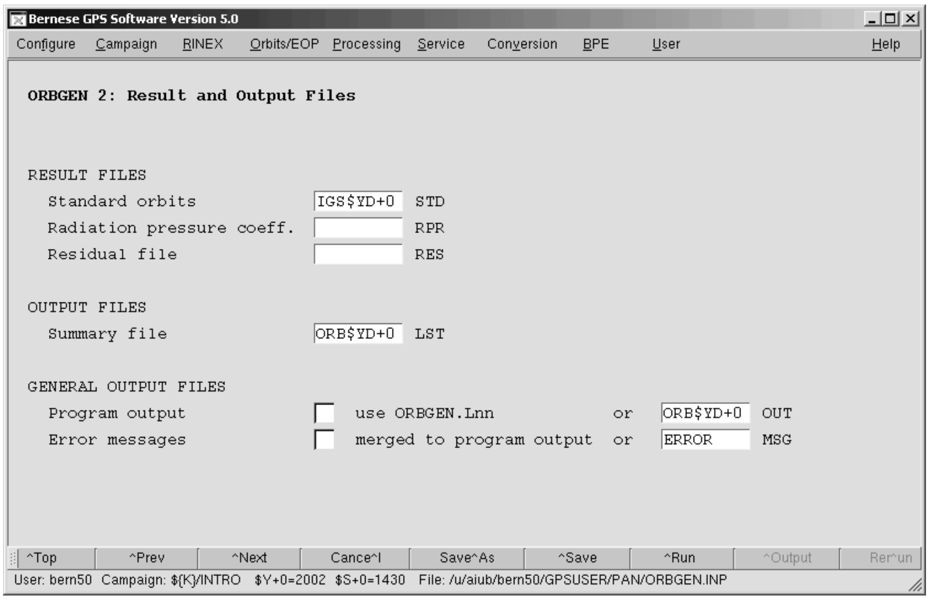
Panel "PRETAB 3: Options for Clocks" contains the options for extracting the satellite clock information. The clock values in the precise orbit file are sampled to 15 min. We interpolate with a "Polynomial degree" of 2 with an "Interval for polynomials" of 12 hours. This is good enough for the receiver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

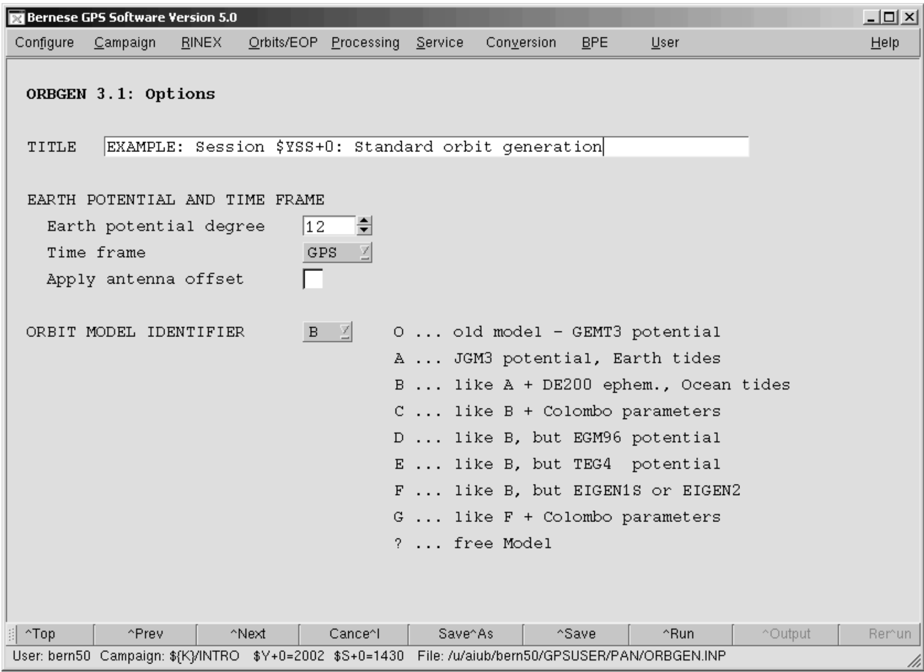
The second program of the orbit part used here is called ORBGEN ("Menu>Orbits/EOP>Create standard orbits"). It prepares the so–called standard orbits using the satellite positions in the tabular orbit files as pseudo–observations for a least–squares adjustment.



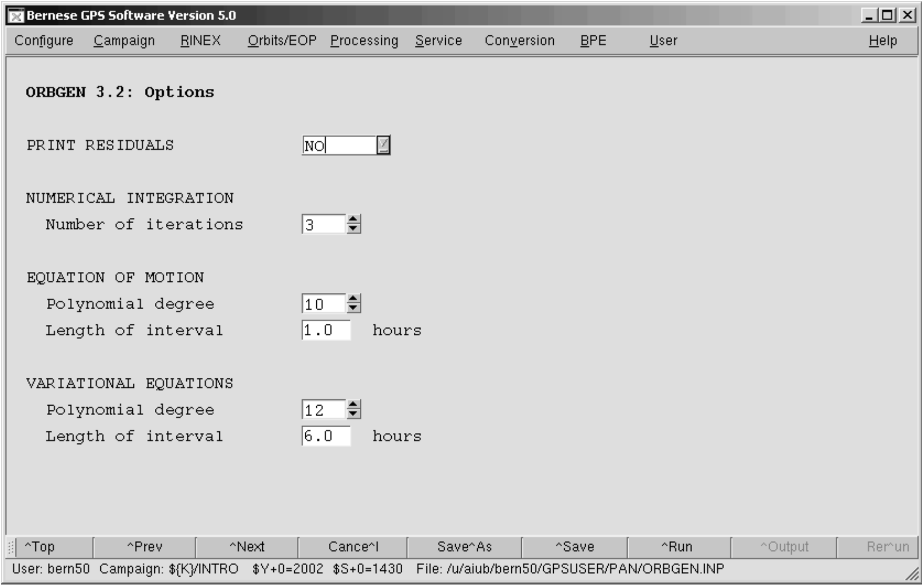
Make sure that the EOP file, the nutation, and the subdaily pole model are the same you have used in PRETAB. It is mandatory to use this triplet of files together with the generated standard orbits for all processing programs.

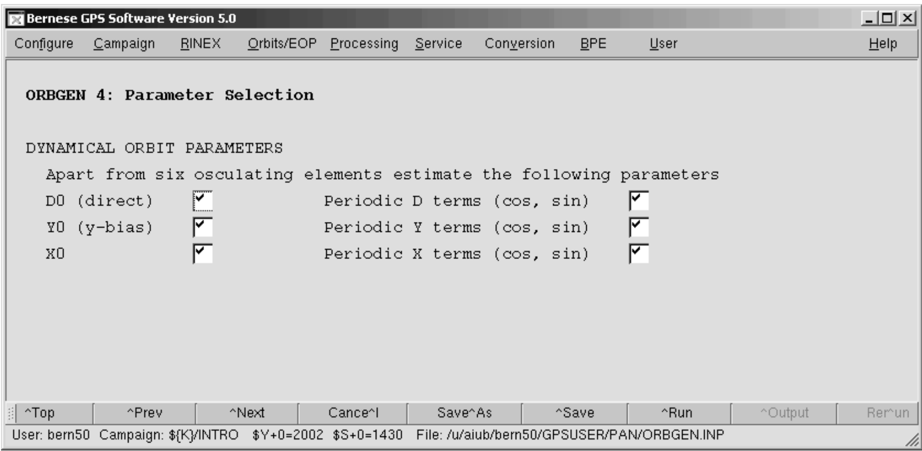


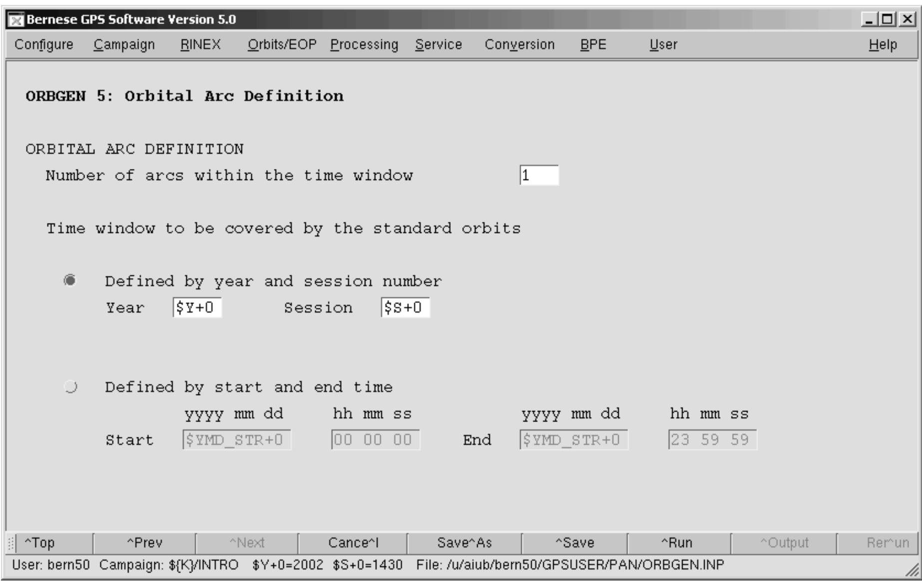




The "ORBIT MODEL IDENTIFIER" is used to check the consistency between input files and options. To generate standard orbits from IGS or CODE products use orbit model B. If the JPL planetary ephemeris (DE200.EPH)is unavailable you may leave the corresponding input field "Planetary ephemeris file" in the panel "ORBGEN 1.1: General Files" empty and set the "ORBIT MODEL IDENTIFIER" to ?.


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ORBGEN 3.2: Options
PRINT RESIDUALS NO
NUMERICAL INTEGRATION
Number of iterations 3
EQUATION OF MOTION
Polynomial degree 10
Length of interval 1.0 hours
VARIATIONAL EQUATIONS
Polynomial degree 12
Length of interval 6.0 hours
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ORBGEN.INP


Bernese GPS Software Version 5.0
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 D terms (cos, sin)
Y0 (y-bias) Periodic Y terms (cos, sin)
X0 Periodic X terms (cos, sin)
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ORBGEN.INP


Bernese GPS Software Version 5.0
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 number
Year $Y+0 Session $S+0
Defined by start and end time
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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ORBGEN.INP

The program produces an output file `ORB02143.OUT` (or corresponding to the other sessions) which should look like

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

 -------------------------------------------------------------------------------
 Session table             : ${K}/INTRO/STA/SESSIONS.SES
 General constants         : ${X}/GEN/CONST.
 Pole file                 : ${K}/INTRO/ORB/IGS02143.ERP
 Subdaily pole model       : ${X}/GEN/IERS2000.SUB
 Nutation model            : ${X}/GEN/IAU2000.NUT
 Coeff. of Earth potential : ${X}/GEN/JGM3.
 Satellite problems        : ${X}/GEN/SAT_2002.CRX
 Satellite information     : ${X}/GEN/SATELLIT.I01
 Planetary ephemeris file  : ${X}/GEN/DE200.EPH
 Ocean tides file          : ${X}/GEN/OT_CSRC.TID
 Orbital elements, file 1  :  ---
 Orbital elements, file 2  :  ---
 Standard orbits           : ${K}/INTRO/ORB/IGS02143.STD
 Radiation pressure coeff. :  ---
 Residual file             :  ---
 Summary file              : ${K}/INTRO/OUT/ORB02143.LST
 Scratch file              : ${U}/WORK/ORBGEN.SCR
 Scratch file              : ${U}/WORK/ORBGEN.SC2
 Program output            : ${K}/INTRO/OUT/ORB02143.OUT
 Error message             : ${U}/WORK/ERROR.MSG
 -------------------------------------------------------------------------------
 ...
 ...
 -------------------------------------------------------------------------------
 RMS ERRORS AND MAX. RESIDUALS   ARC NUMBER:  1                    ITERATION:  2
 -------------------------------------------------------------------------------

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

   1     96     0.01       0.01     0.01   0.01   0.01       0.02   0.02   0.03
   2     96     0.01       0.01     0.01   0.01   0.01       0.04   0.02   0.01
   3     96     0.01       0.01     0.02   0.01   0.01       0.03   0.03   0.02
   4     96     0.01       0.01     0.01   0.01   0.01       0.02   0.02   0.02
...
```

The most important information in the output file are the RMS errors for each satellite. These should not be larger than about 1...2 cm if precise orbits 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 ITRF and ICRF in PRETAB, and on the orbit model used in ORBGEN).[1]

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

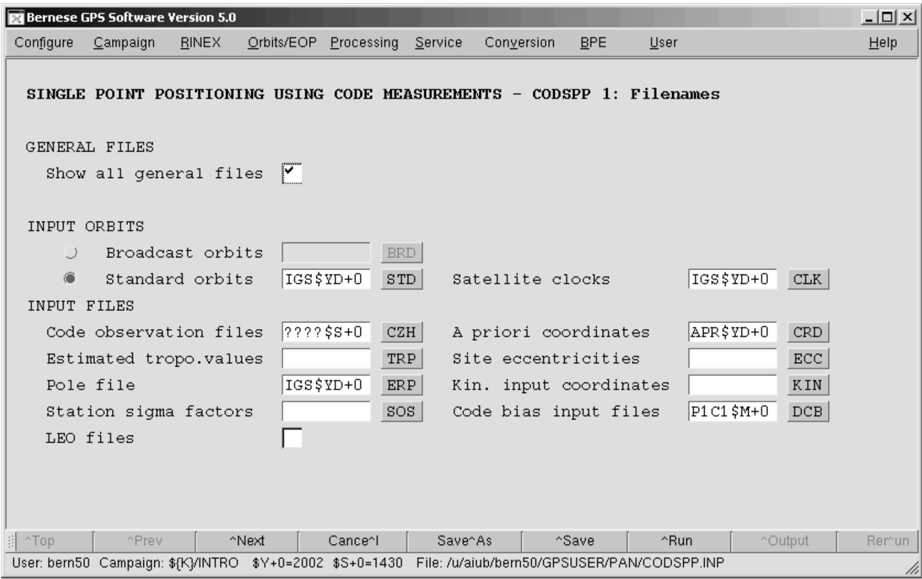
The file `${K}/INTRO/OUT/ORB02143.LST` summarizing the orbit fit rms values may be compared with the corresponding section in the solution reference file `${K}/INTRO/OUT/R2S021430.PRC_REF`.

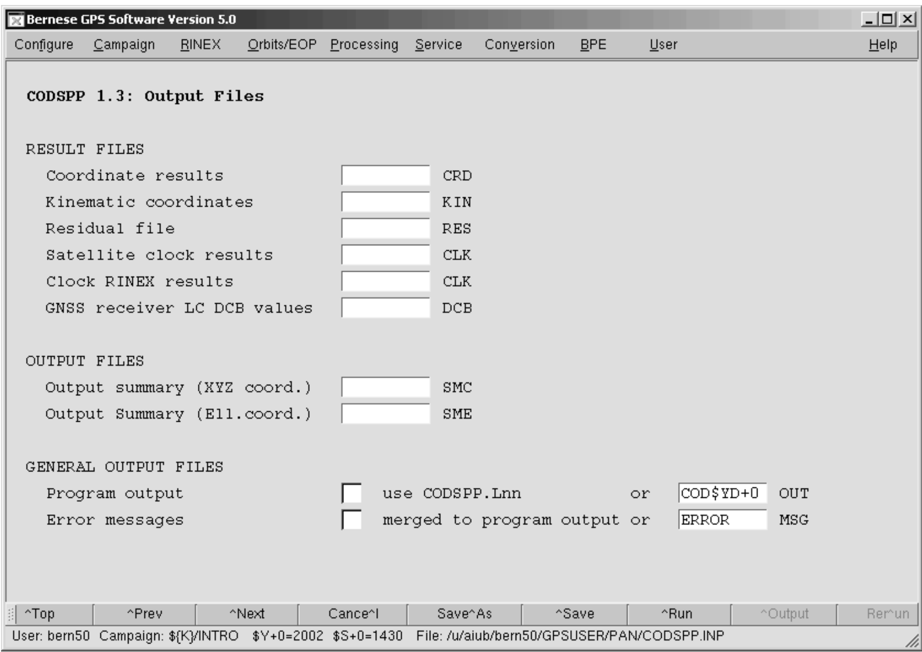
[1] You may check this statement by using the `BULLET_A.ERP` file instead of the `IGS02143.ERP`. *This is only for a test — please, do not use the resulting standard orbit for any further processing!*

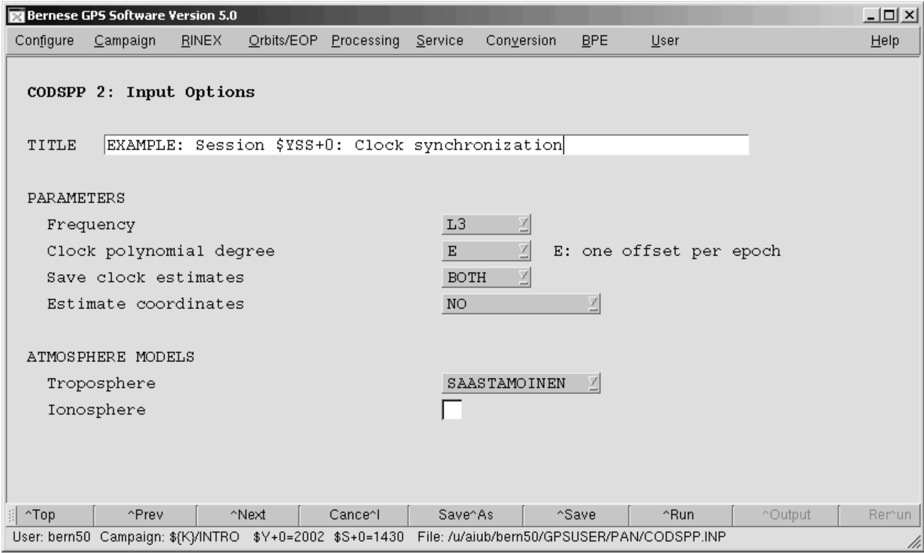
3.3 Data Preprocessing (I)

3.3.1 Receiver Clock Synchronization

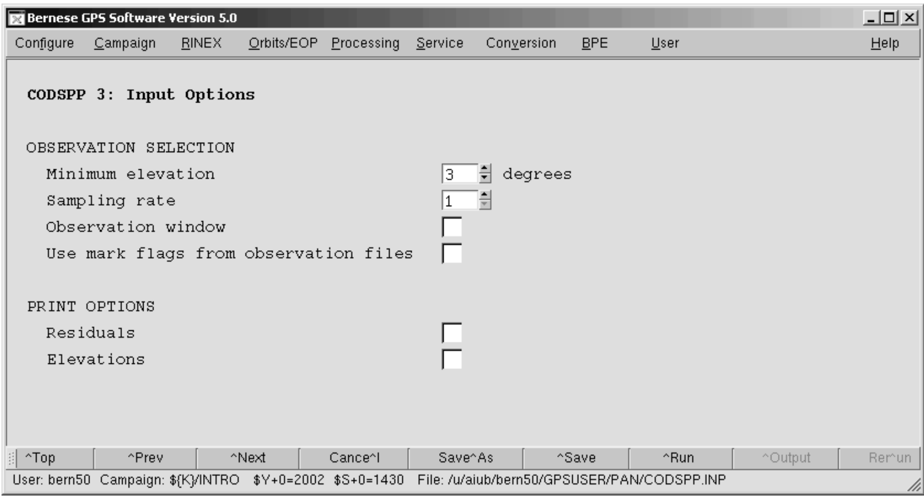
Now we are ready to invoke the processing part of the *Bernese GPS Software*. We have to run three programs for this example. The first program is called CODSPP ("Menu>Processing >Code-based clock synchronization". Its main task is to compute the receiver clock corrections.

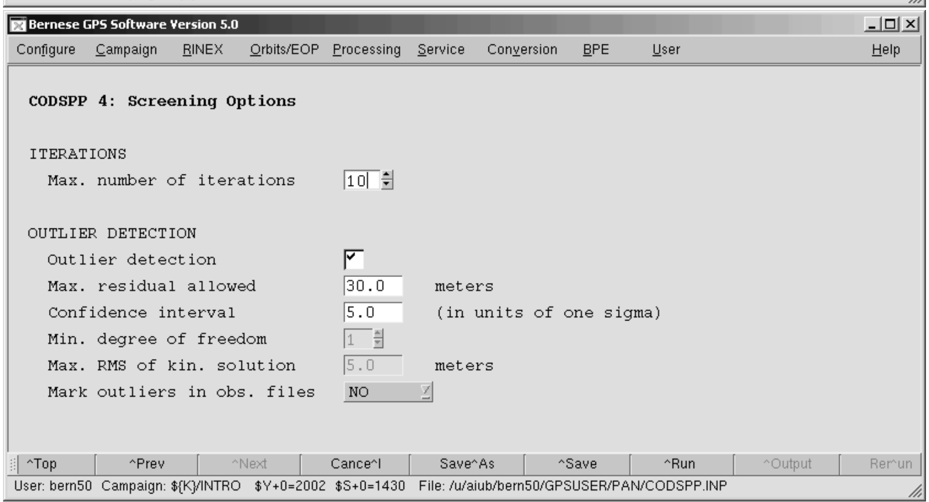






We have already geocentric coordinates of good quality available for the sites from the PPP example BPE. Therefore, the option "Estimate coordinates" may be set to NO. The most important option for this CODSPP run is "Save clock estimates". It has to be set to BOTH.





CODSPP produces the following output:

```
...

STATION:  BRUS 13101M004   FILE:  ${K}/INTRO/OBS/BRUS1430.CZO      RECEIVER UNIT:        0
-------------------------------------------------------------------------------------------
...
...

RESULTS:
--------

OBSERVATIONS IN FILE:     21844
BAD OBSERVATIONS    :         0.15 %
RMS OF UNIT WEIGHT  :         0.97 M
NUMBER OF ITERATIONS:         2
...
...
STATION COORDINATES:
--------------------

LOCAL GEODETIC DATUM:  IGS00

                                  A PRIORI         NEW           NEW- A PRIORI   RMS ERROR
 BRUS 13101M004    X            4027893.78      4027893.78            0.00         0.00
 (MARKER)          Y             307045.78       307045.78            0.00         0.00
                   Z            4919475.08      4919475.08            0.00         0.00

                   HEIGHT           149.66          149.66            0.00         0.00
                   LATITUDE      50 47 52.143    50 47 52.143     0  0  0.000        0.0000
                   LONGITUDE      4 21 33.186     4 21 33.186     0  0  0.000        0.0000



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

OFFSET FOR REFERENCE EPOCH:                0.000000632  SEC


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     :         2

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

   1   2  FFMJ 14279M001    OUT   7  02-05-23 15:47:30  02-05-23 15:47:30     1

   2   4  ONSA 10402M004    OUT   6  02-05-23 17:34:00  02-05-23 17:34:00     1

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

The most important message in the output file is `CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES`. Itindicates that the receiver clock corrections δ_k 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.

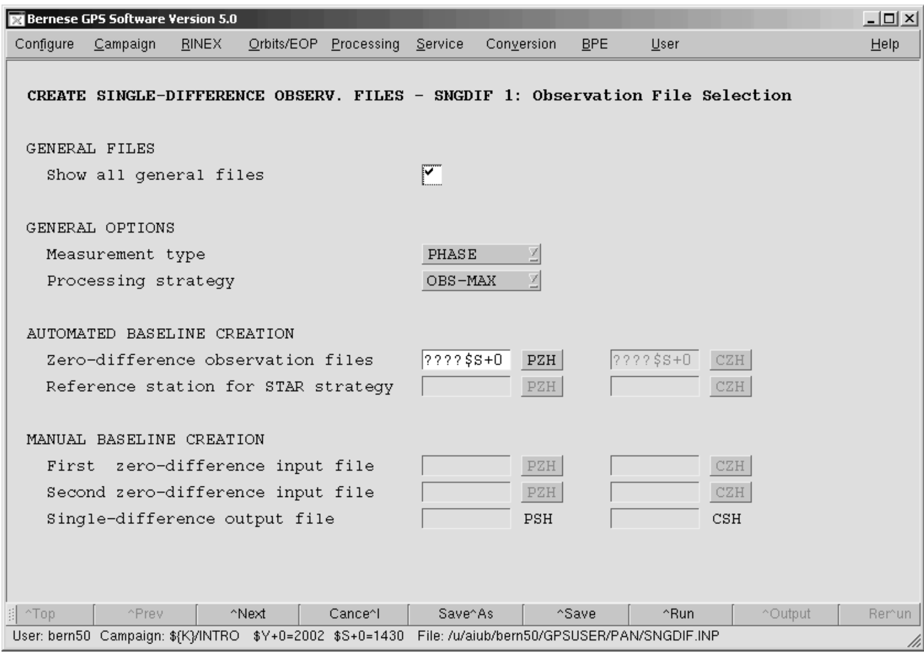
The a posteriori RMS error (for each zero difference file processed) should be checked in the CODSPP output file. A value of about 20–30 m is normal if Selective Availability (SA — artificial degradation of the satellite clock accuracy) is on (before May 2000). Without SA a value of about 3 m is expected 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 δ_k with the necessary accuracy of 1 μs.

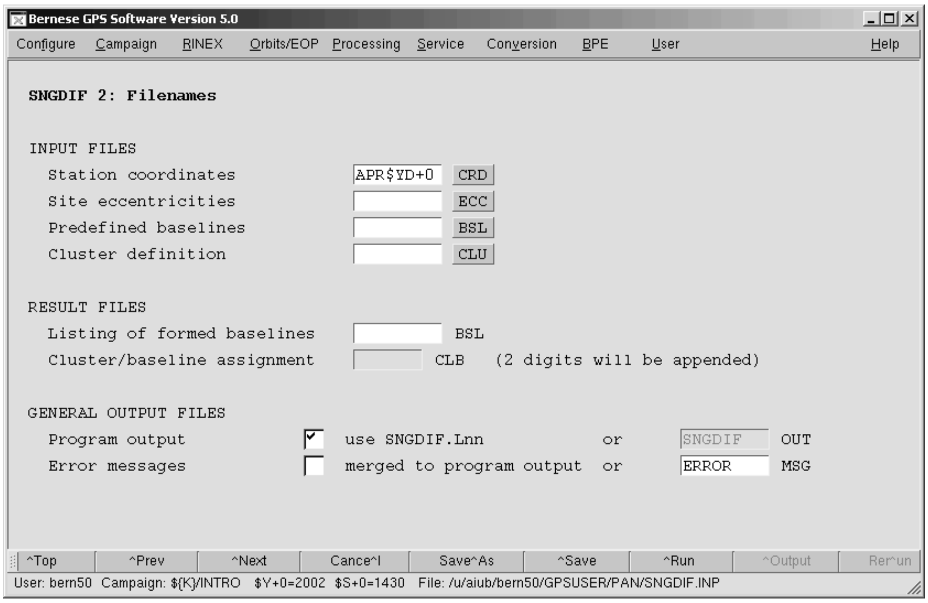
If you get warning messages concerning irregularities, then it is probable that you did not exclude GLONASS in the observation import step. In the GNSS case (GLONASS and GPS) the time offset between the two satellite systems is estimated. The parameter is set up if at least one GNSS observation was found. Because no orbit for GLONASS is available in the standard orbit file, the GLONASS observations are skipped, and therefore no observations for this parameter are available. Because we only process GPS data in this terminal session, you can ignore these warning messages.

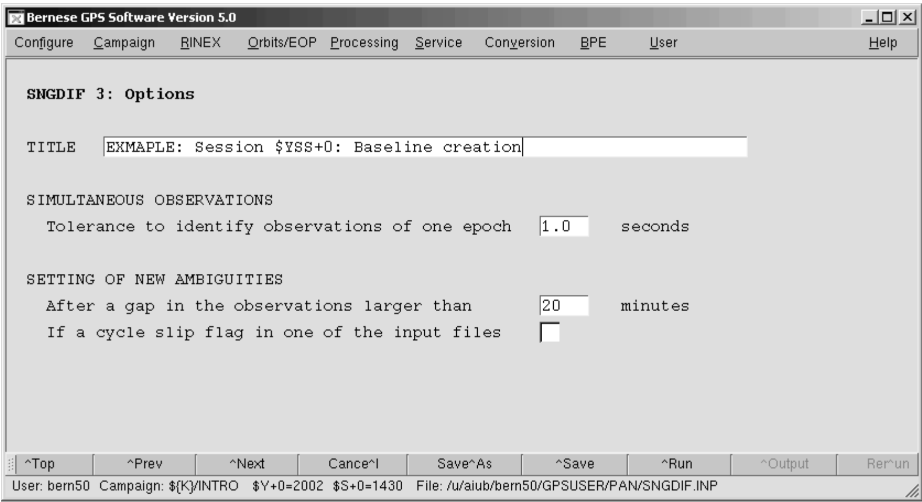
You may use the extraction program CODXTR ("Menu>Processing>Program output extraction>Code-based clock synchronization") to generate a short summary from the CODSPP program output. This summary is included in the solution reference file (`${K}/INTRO/OUT/R2S021430.PRC_REF`).

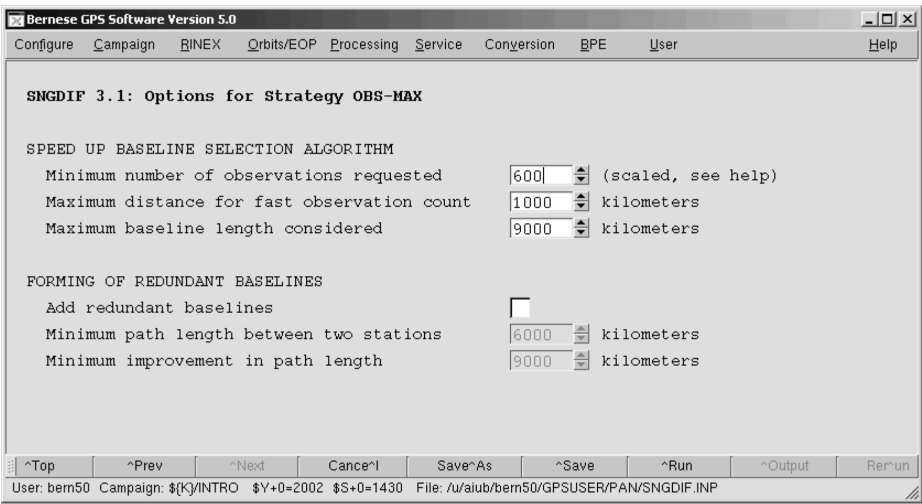
3.3.2 Form Baselines

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




Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
SNGDIF 2: Filenames
INPUT FILES
Station coordinates APR$YD+0 CRD
Site eccentricities ECC
Predefined baselines BSL
Cluster definition CLU
RESULT FILES
Listing of formed baselines BSL
Cluster/baseline assignment CLB (2 digits will be appended)
GENERAL OUTPUT FILES
Program output use SNGDIF.Lnn or SNGDIF OUT
Error messages merged to program output or ERROR MSG
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/SNGDIF.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
SNGDIF 3: Options
TITLE EXMAPLE: Session $YSS+0: Baseline creation
SIMULTANEOUS OBSERVATIONS
Tolerance to identify observations of one epoch 1.0 seconds
SETTING OF NEW AMBIGUITIES
After a gap in the observations larger than 20 minutes
If a cycle slip flag in one of the input files
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/SNGDIF.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
SNGDIF 3.1: Options for Strategy OBS-MAX
SPEED UP BASELINE SELECTION ALGORITHM
Minimum number of observations requested 600 (scaled, see help)
Maximum distance for fast observation count 1000 kilometers
Maximum baseline length considered 9000 kilometers
FORMING OF REDUNDANT BASELINES
Add redundant baselines
Minimum path length between two stations 6000 kilometers
Minimum improvement in path length 9000 kilometers
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/SNGDIF.INP

The output of SNGDIF simply echoes the zero difference files used and the single difference files created. If the strategy OBS-MAX is used the following lines are included:

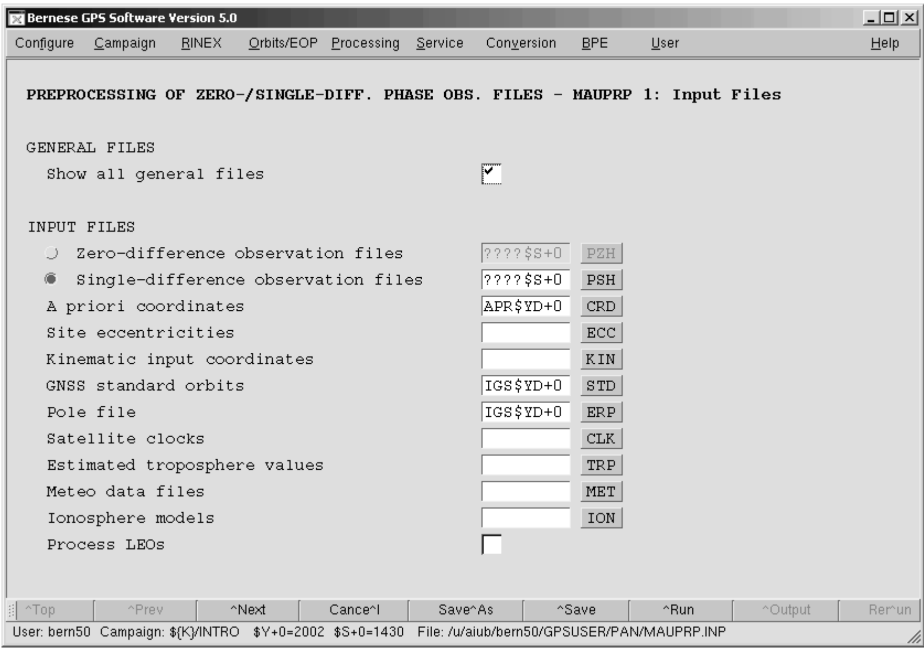
```
  1 BRUS 13101M004   - FFMJ 14279M001   CRIT.:   11280
  2 BRUS 13101M004   - MATE 12734M008   CRIT.:    9694
  3 BRUS 13101M004   - ONSA 10402M004   CRIT.:   11370  OK
  4 BRUS 13101M004   - PTBB 14234M001   CRIT.:   10221
  5 BRUS 13101M004   - VILL 13406M001   CRIT.:   10378
  6 BRUS 13101M004   - ZIMJ 14001M006   CRIT.:    6976
  7 BRUS 13101M004   - ZIMM 14001M004   CRIT.:   11242
  8 FFMJ 14279M001   - MATE 12734M008   CRIT.:   10826  OK
  9 FFMJ 14279M001   - ONSA 10402M004   CRIT.:   12603  OK
 10 FFMJ 14279M001   - PTBB 14234M001   CRIT.:   10252
 11 FFMJ 14279M001   - VILL 13406M001   CRIT.:   10576
 12 FFMJ 14279M001   - ZIMJ 14001M006   CRIT.:    7076  OK
 13 FFMJ 14279M001   - ZIMM 14001M004   CRIT.:   11705  OK
 14 MATE 12734M008   - ONSA 10402M004   CRIT.:   10491
    ...
```

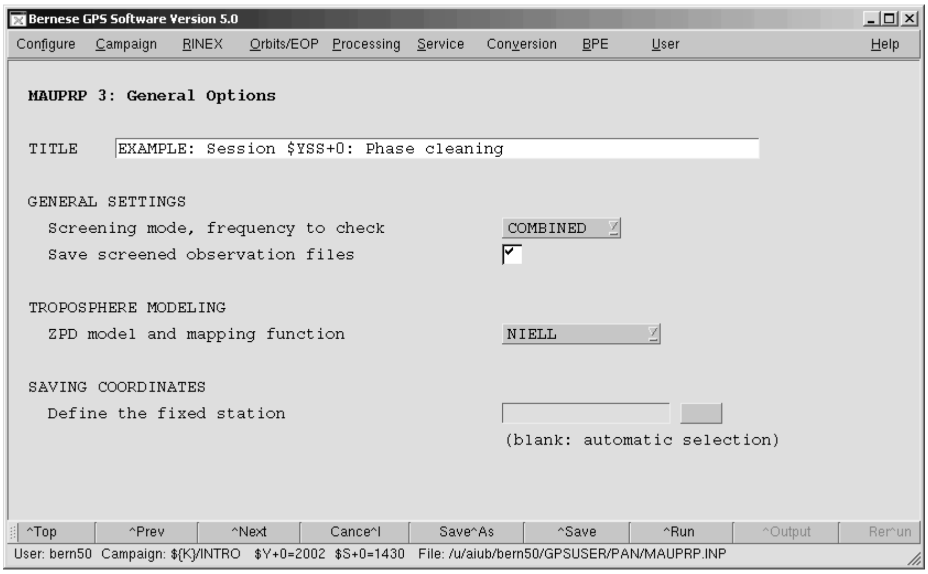
All possible pairs of zero difference files are listed with the corresponding criterion value. The optimal baselines actually created are labeled with "OK".

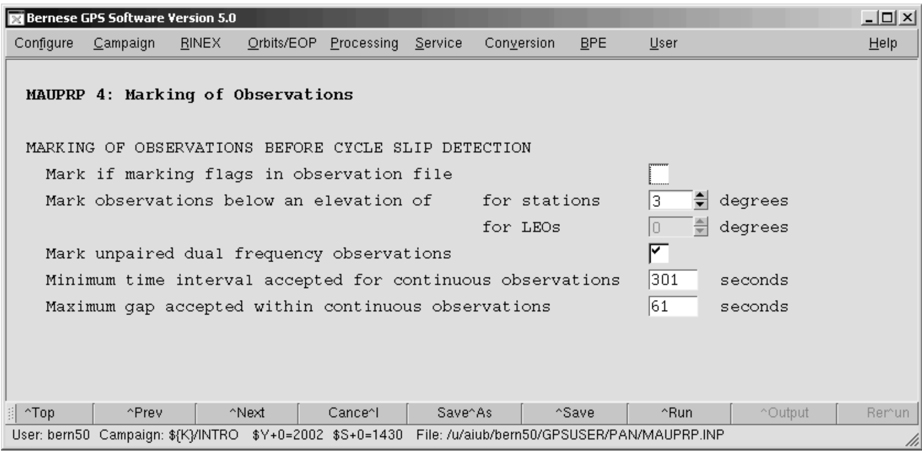
If you introduced GLONASS data you may end up with different baselines than given here, but this will not affect the results.

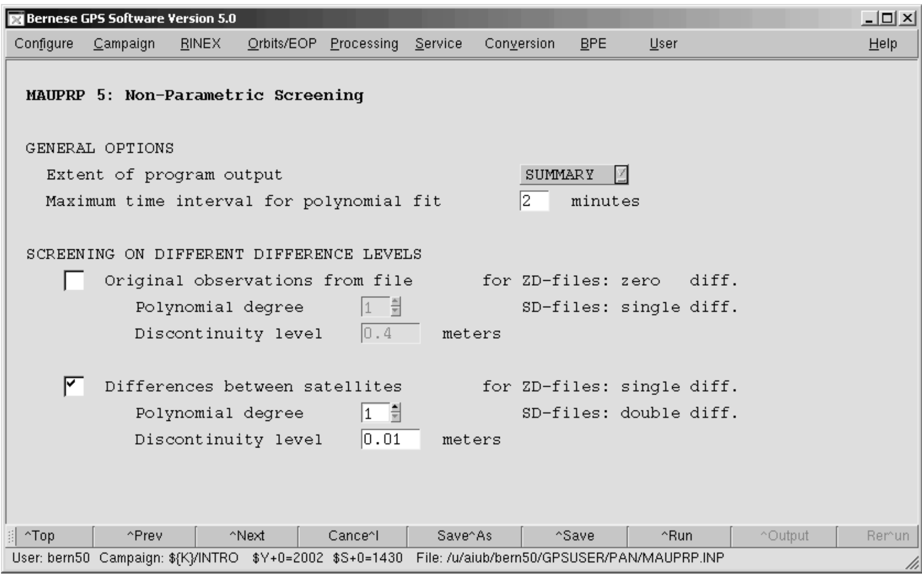
3.3.3 Preprocessing of the Phase Baseline Files

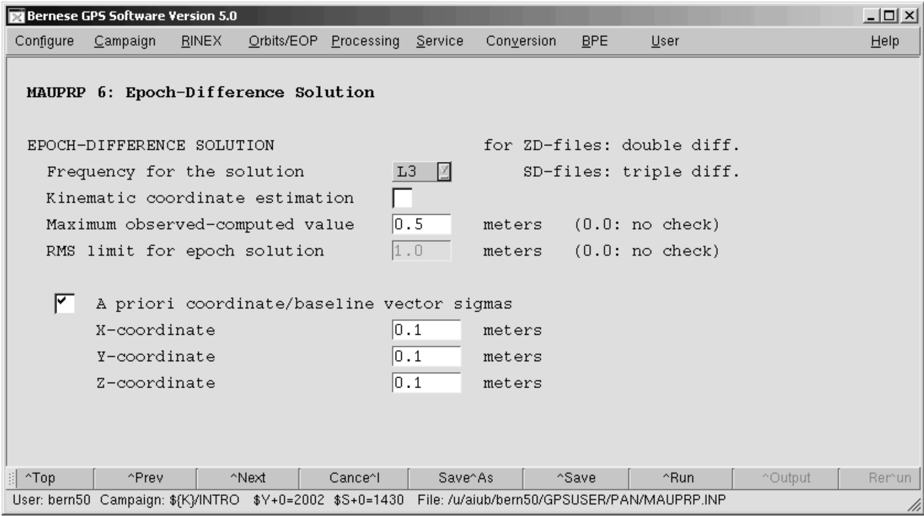
The main task of the program MAUPRP is the cycle–slip screening. It is started using "Menu >Processing>Phase preprocessing".

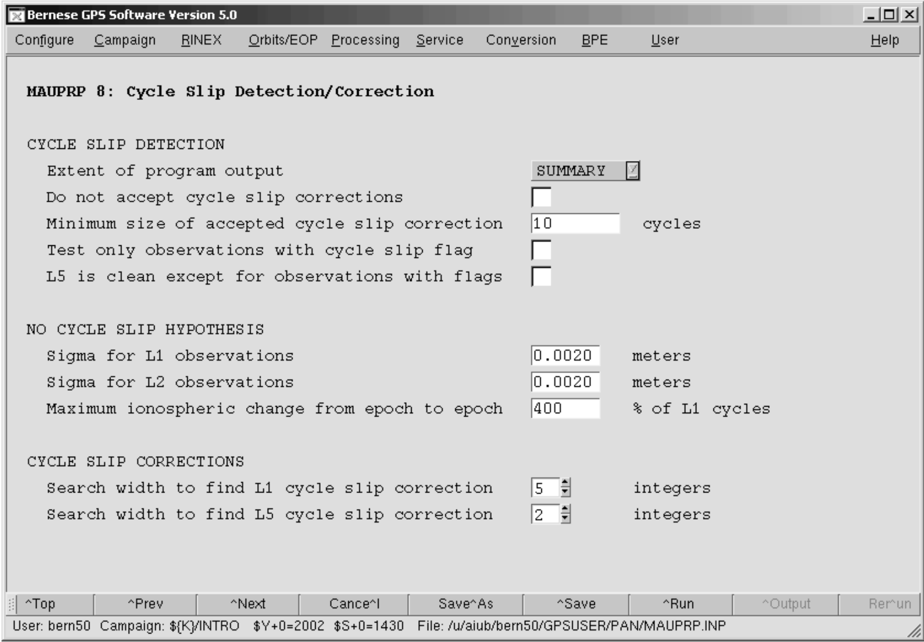


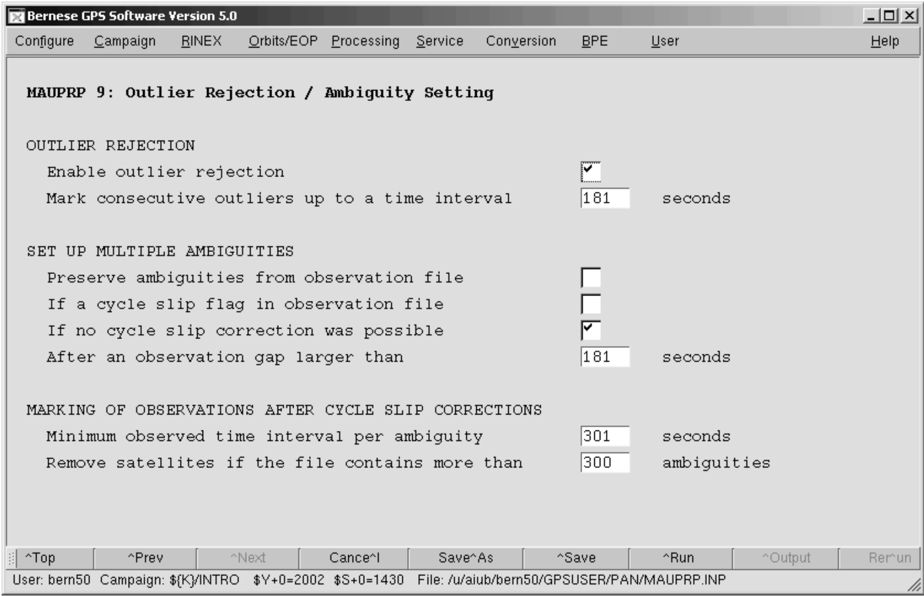

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 3: General Options
TITLE EXAMPLE: Session $YSS+0: Phase cleaning
GENERAL SETTINGS
Screening mode, frequency to check COMBINED
Save screened observation files
TROPOSPHERE MODELING
ZPD model and mapping function NIELL
SAVING COORDINATES
Define the fixed station
(blank: automatic selection)
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/MAUPRP.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 4: Marking of Observations
MARKING OF OBSERVATIONS BEFORE CYCLE SLIP DETECTION
Mark if marking flags in observation file
Mark observations below an elevation of for stations 3 degrees
for LEOs 0 degrees
Mark unpaired dual frequency observations
Minimum time interval accepted for continuous observations 301 seconds
Maximum gap accepted within continuous observations 61 seconds
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/MAUPRP.INP


Bernese GPS Software Version 5.0
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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/MAUPRP.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 6: Epoch-Difference Solution
EPOCH-DIFFERENCE SOLUTION
for ZD-files: double diff.
SD-files: triple diff.
Frequency for the solution L3
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 Cancel ^Save^As ^Save ^Run ^Output Rerun
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/MAUPRP.INP


Bernese GPS Software Version 5.0
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 400 % of L1 cycles
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 Cancel ^Save^As ^Save ^Run ^Output Rerun
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/MAUPRP.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
MAUPRP 9: Outlier Rejection / Ambiguity Setting
OUTLIER REJECTION
Enable outlier rejection
Mark consecutive outliers up to a time interval 181 seconds
SET UP MULTIPLE AMBIGUITIES
Preserve ambiguities from observation file
If a cycle slip flag in observation file
If no cycle slip correction was possible
After an observation gap larger than 181 seconds
MARKING OF OBSERVATIONS AFTER CYCLE SLIP CORRECTIONS
Minimum observed time interval per ambiguity 301 seconds
Remove satellites if the file contains more than 300 ambiguities
^Top ^Prev ^Next Cancel ^Save^As ^Save ^Run ^Output Rerun
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/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. The most important item to check is the epoch difference solution:

```
...
STATION 1: BRUS 13101M004         YEAR:  2002           SESSION:  1430
STATION 2: ONSA 10402M004         DAY :   143           FILE   :     0

BASELINE LENGTH (M) :    883750.408
OBSERVAT. FILE NAME : ${K}/INTRO/OBS/BRON1430.PSH
...
...
------------------------------------------------------------------------
EPOCH DIFFERENCE SOLUTION
------------------------------------------------------------------------

FREQUENCY OF EPOCH DIFF. SOLU.:           3
#OBS. USED FOR EPOCH DIFF. SOLU:       17643
RMS OF EPOCH DIFF. SOLUTION (M):       0.011

COORDINATES  NEW-A PRIORI X (M):       0.145 +-       0.026
                          Y (M):       0.061 +-       0.032
                          Z (M):       0.285 +-       0.020

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

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 values on certain baselines for certain epochs. The corresponding observations get flagged, and will not disturb processing.

You can use the extraction program MPRXTR ("Menu>Processing>Program output extraction>Phase preprocessing") to generate a short summary of the MAUPRP output:

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

SESS FIL OK?  ST1  ST2 L(KM) #OBS.  RMS   DX    DY    DZ   #SL #DL #MA  MAXL3      MIN. SLIP
---------------------------------------------------------------------------------------------
1430   1 OK   BRUS ONSA  884 17643 0.011 0.145 0.061 0.285 131 234  41  0.050             11
1430   2 OK   FFMJ MATE 1220 18002 0.012-0.161 0.030-0.286  36 429  58  0.049            558
1430   3 OK   FFMJ ONSA  840 20430 0.011-0.205 0.021-0.068 101 140  44  0.050             11
1430   4 OK   FFMJ ZIMJ  368 11610 0.011-0.020 0.032-0.071  76 223  24  0.049             11
1430   5 OK   FFMJ ZIMM  368 19563 0.011-0.015-0.015-0.089  46 198  39  0.042          46188
1430   6 OK   PTBB ZIMM  640 17032 0.013-0.018-0.047-0.128  45  96  21  0.049          46188
1430   7 OK   VILL ZIMM 1162 17990 0.012 0.175 0.080 0.199  54 218  30  0.050             17
------------------------------------------------------------------------------------
Tot:   7               783 17467 0.012                    70 220  37
```

This summary file is included in the solution reference file (`${K}/INTRO/OUT/R2S021430.PRC_REF` — the results may be slightly different since the input options were not exactly identical).

3.4 Daily Goals

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

1. *Bernese pole file in the campaign's ORB directory:* `IGS02143.ERP`*,*
2. *Bernese standard orbit file in the ORB directory:* `IGS02143.STD`*,*
3. *Bernese satellite clock files in the ORB directory:* `IGS02143.CLK`*,*
4. *Single difference files (baseline files) in the OBS directory:* `BRON1430.CSH`*,* `BRON1430.PSH`*,* `BRON1430.CSO`*,* `BRON1430.PSO`*,... for all baselines,*
5. *you should also have verified the outputs of these programs:*ORBGEN*,* CODSPP*,* SNGDIF*, and* MAUPRP

Files should be generated for all four days. Simply adapt the session definition for the other days and rerun the programs.

4. Terminal Session: Wednesday

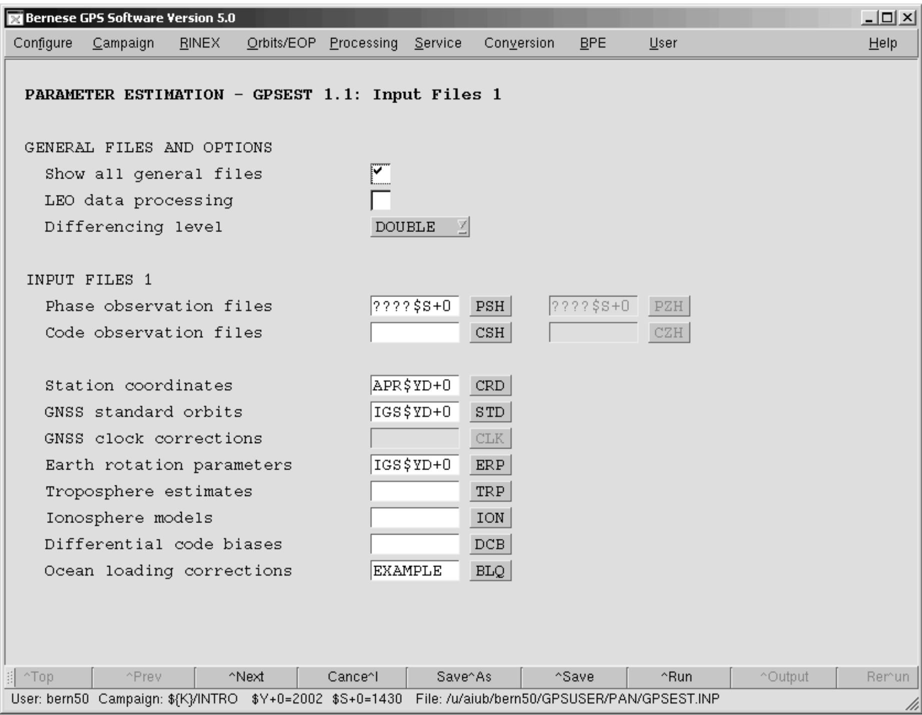
Today's terminal session is to

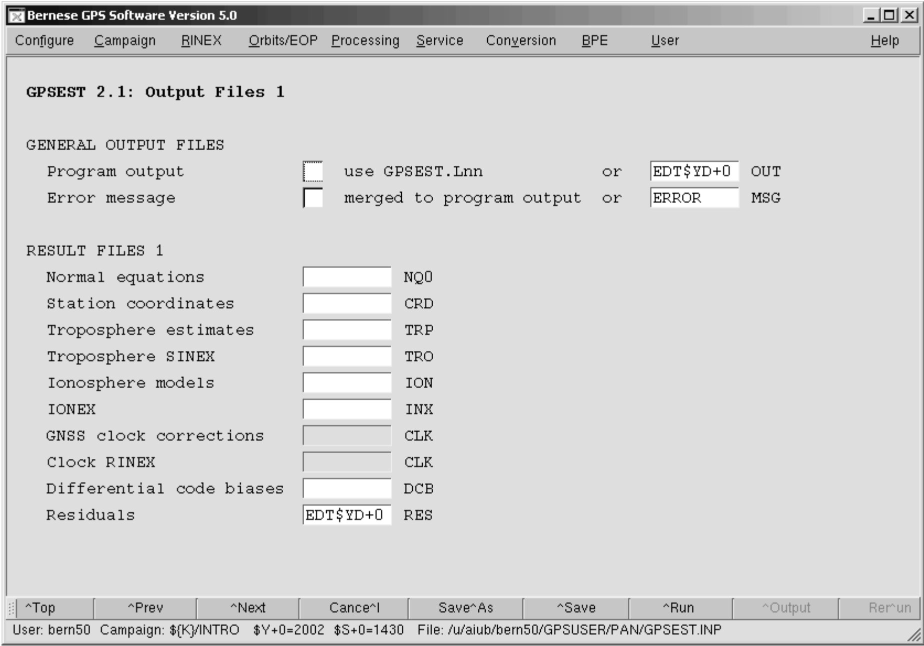
*(1) perform a residual screening (*GPSEST, RESRMS, SATMRK*),*
*(2) generate a first estimation for coordinates and troposphere parameters (*GPSEST*),*
*(3) resolve the double difference ambiguities (*GPSEST*),*

ideally for all four days of the processing example, but at least one session for each year, e.g.: 2002, 143 and 2003, 138. You can run through these steps session by session.

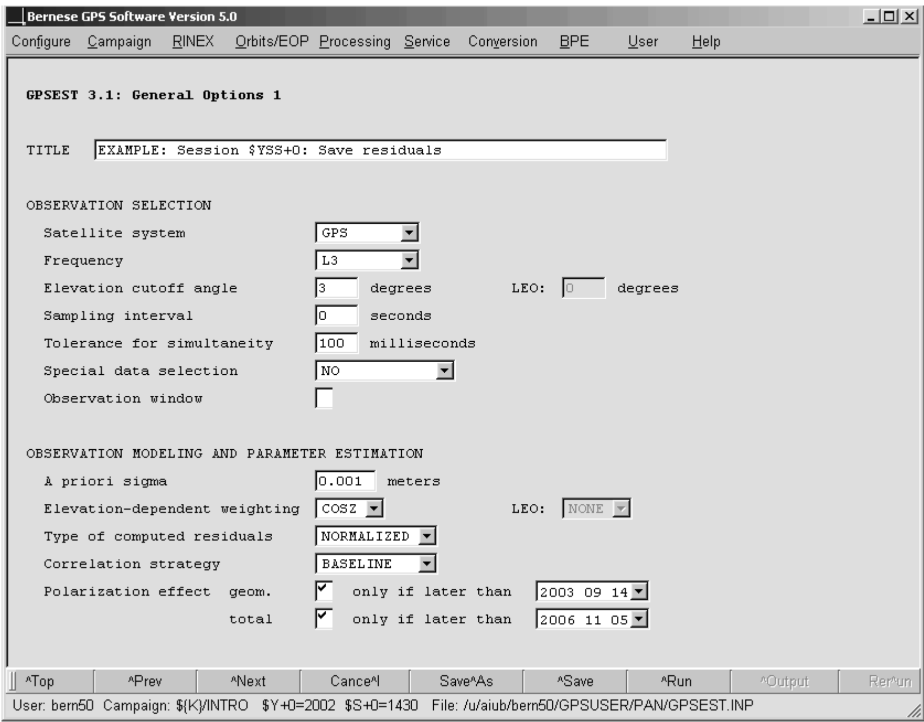
4.1 Data Preprocessing (II)

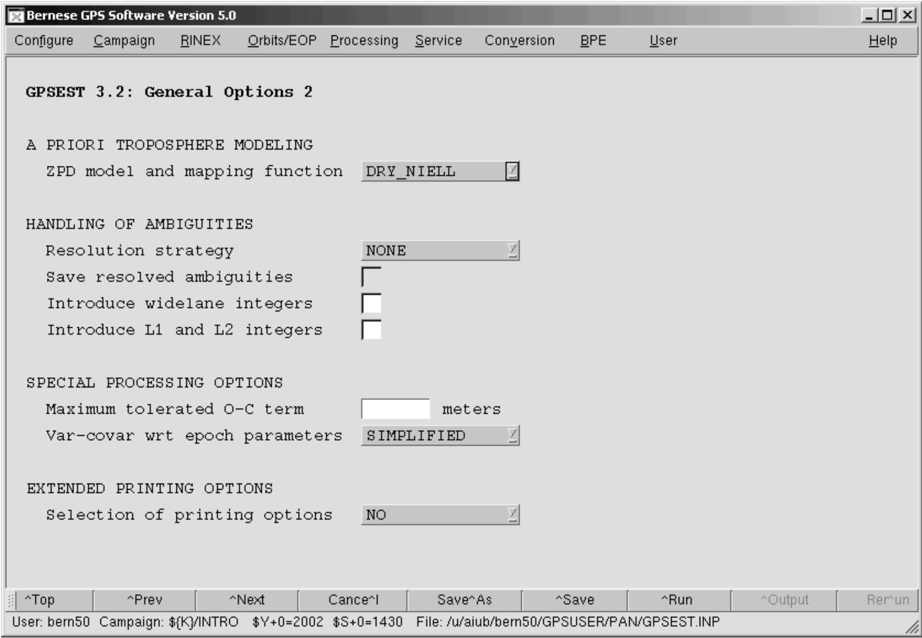
The least–squares adjustment is the task of program GPSEST. It is a good idea to start GPSEST first in the session mode and to produce an ambiguity–free L_3 solution. We do not expect any final results from this run but we want to check the quality of data and save the residuals after the least–squares adjustment. The program is available via "Menu >Processing>Parameter estimation". We use the following options:



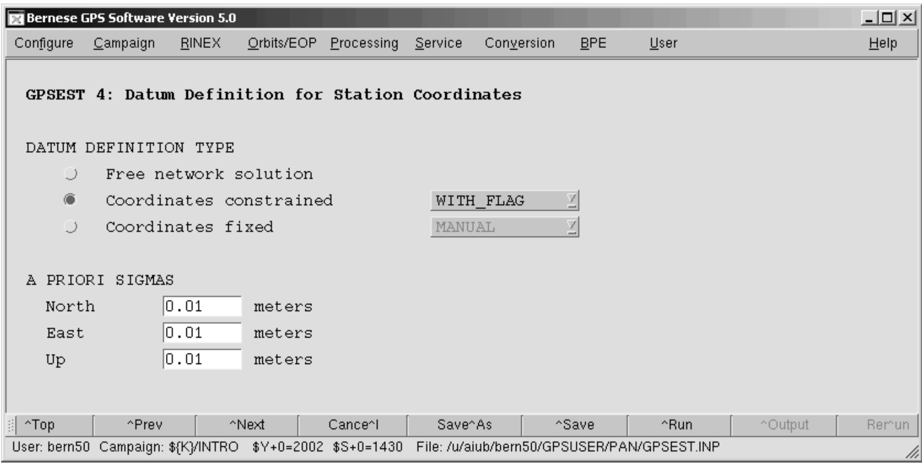


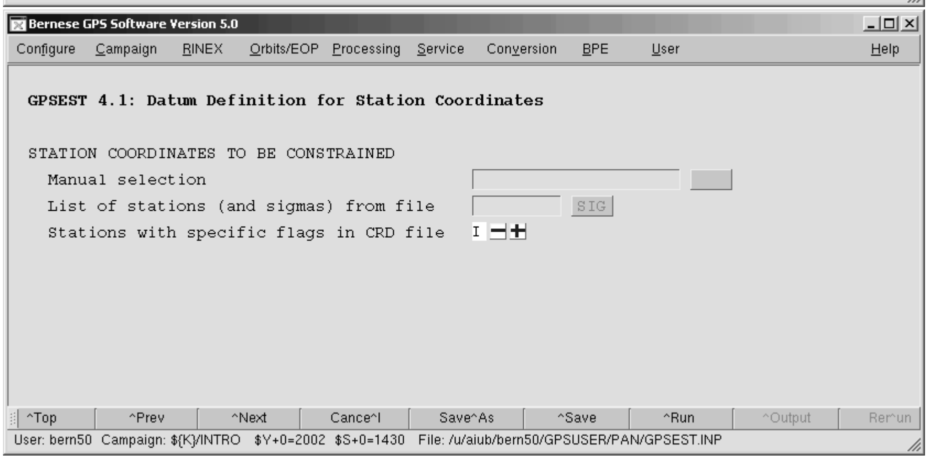
We do not sample the observations in this run. This is important if we want to check *all* observations (we want to use all observations without sampling for the ambiguity resolution). Consequently the program run might be time consuming (about 3 min. CPU time on ubecx).



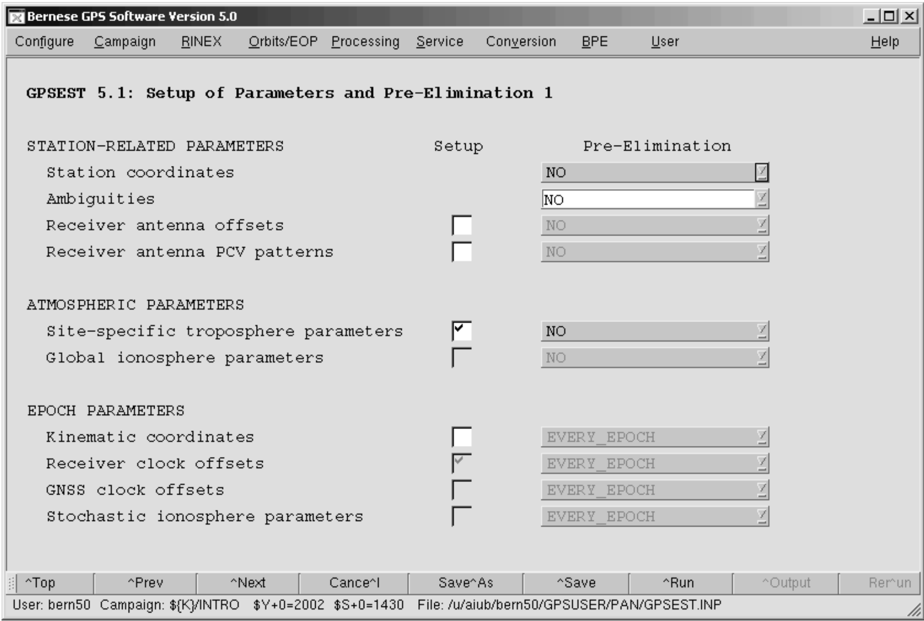


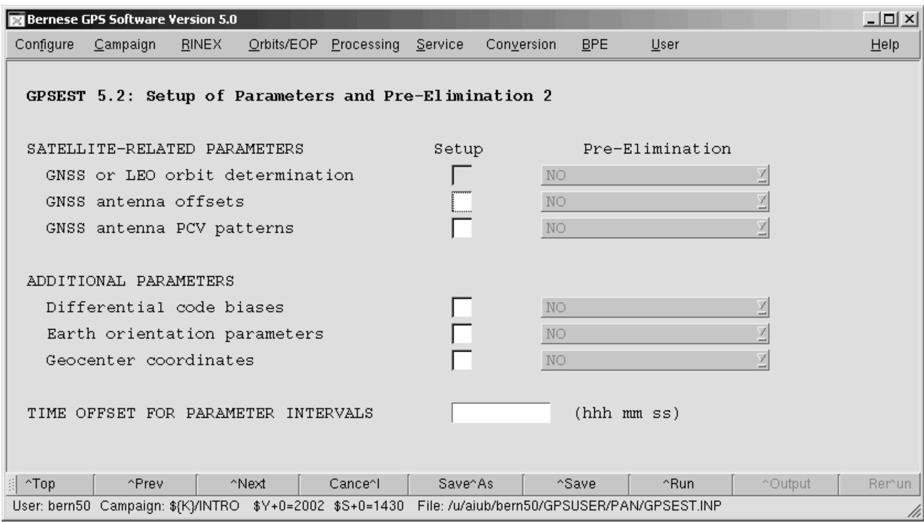
We want to give loose constraints to the station coordinates that are available from the IGS realization of ITRF 2000 reference frame (flag I like IGS00 in the coordinate file).



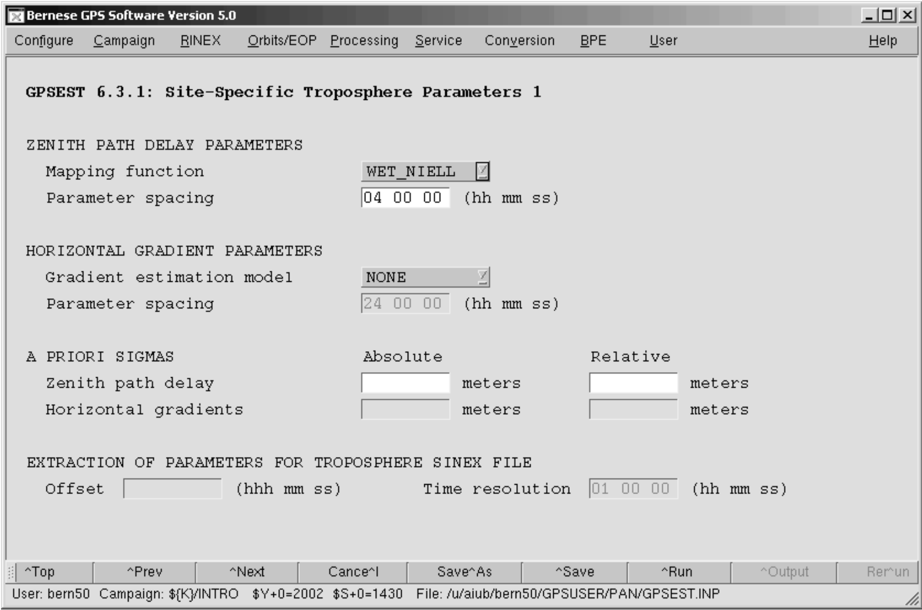


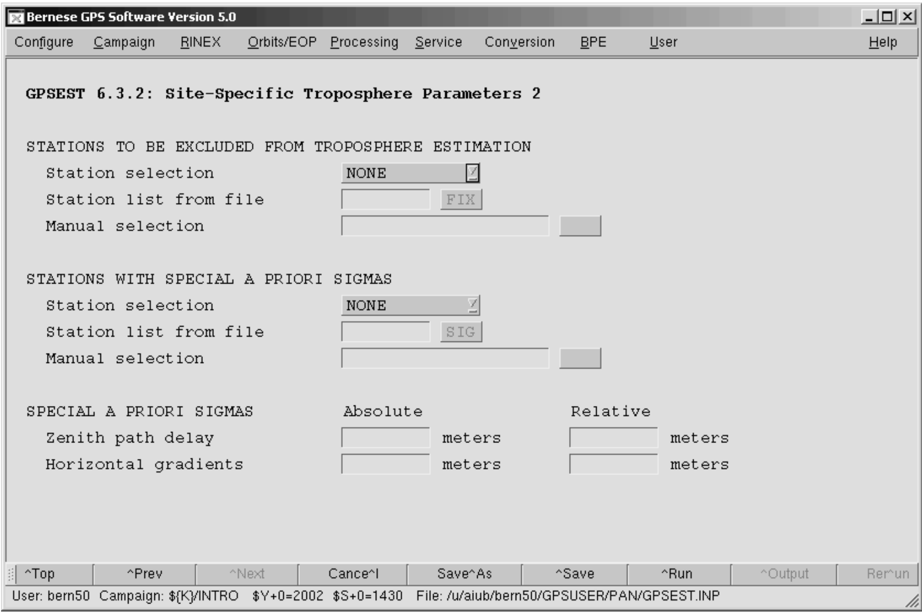
No parameters (not even ambiguity parameters) may be pre–eliminated if residuals should be written into the residual output file:





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



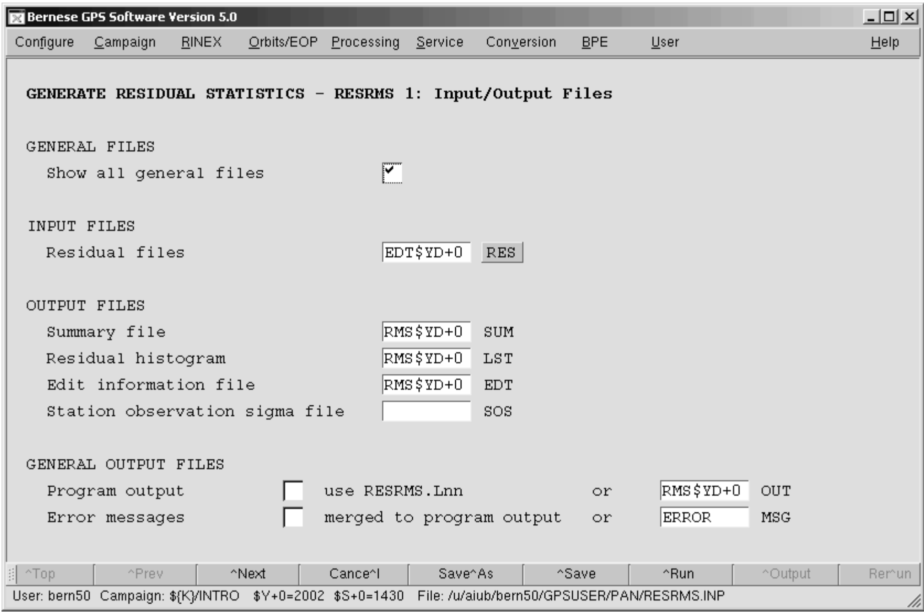


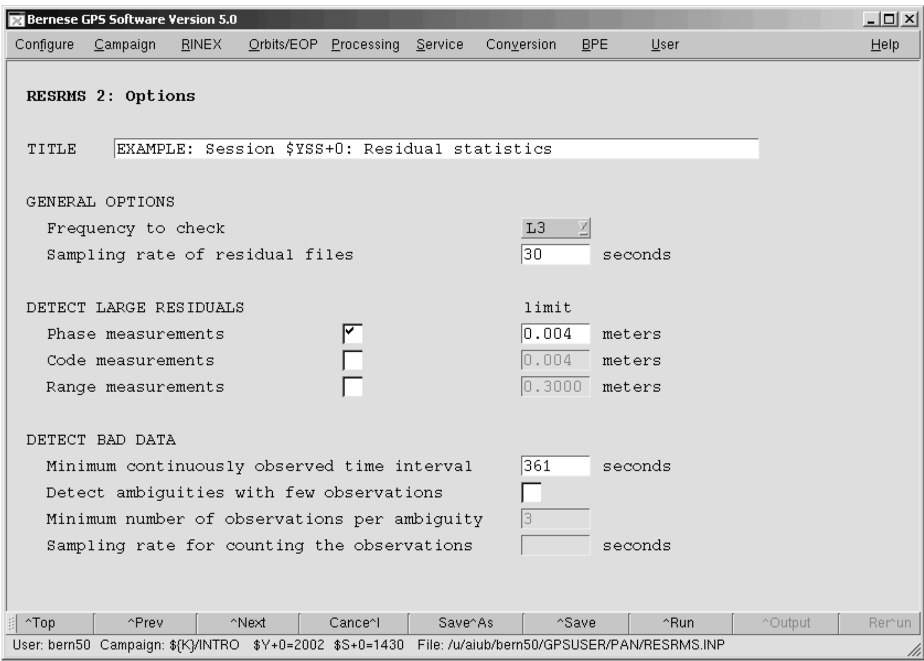
The program output of program GPSEST repeats all important input options, summarizes the input data, and reports the estimated results. An important information in the output file is the a posteriori RMS error:

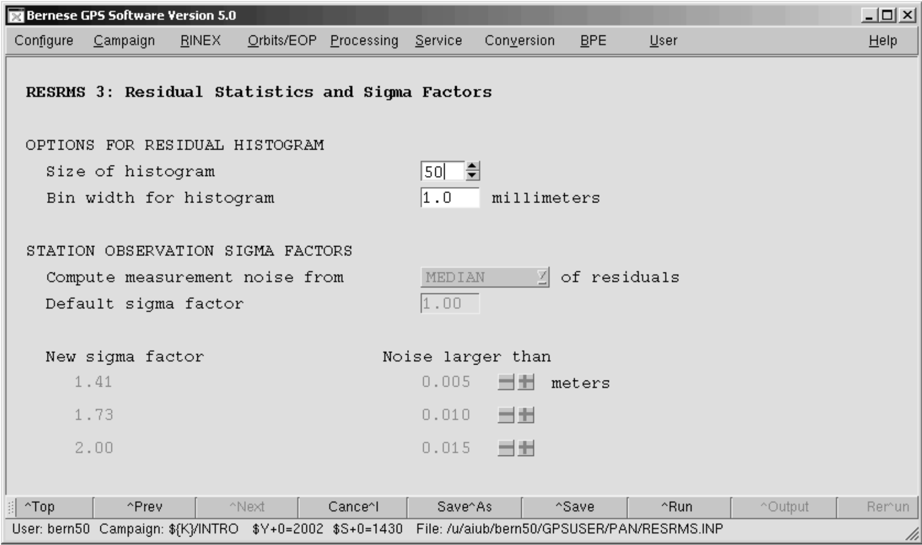
```
A POSTERIORI SIGMA OF UNIT WEIGHT (PART 1):
-------------------------------------------

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

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 pre–processing step (MAUPRP and CODSPP) was not successfully performed.

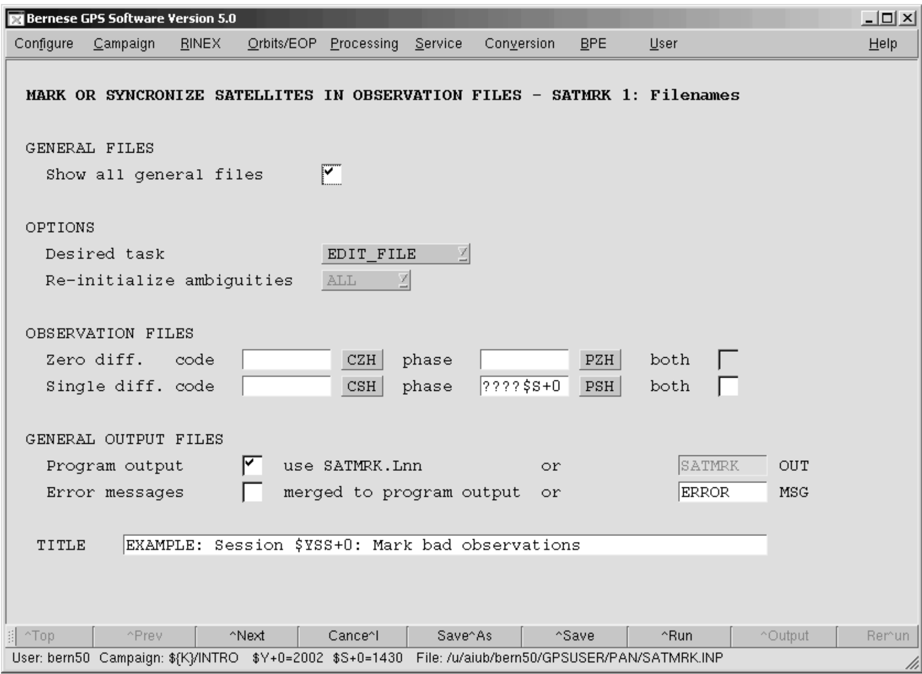
If the residuals have been stored in the binary residual files ("GPSEST 2.1: Output Files 1") it is possible to have a look on the residuals (program REDISP, "Menu>Service>Residual files>Display residual file"). To screen the residuals automatically use the program RESRMS in "Menu>Service >Residual files>Generate residual statistics".

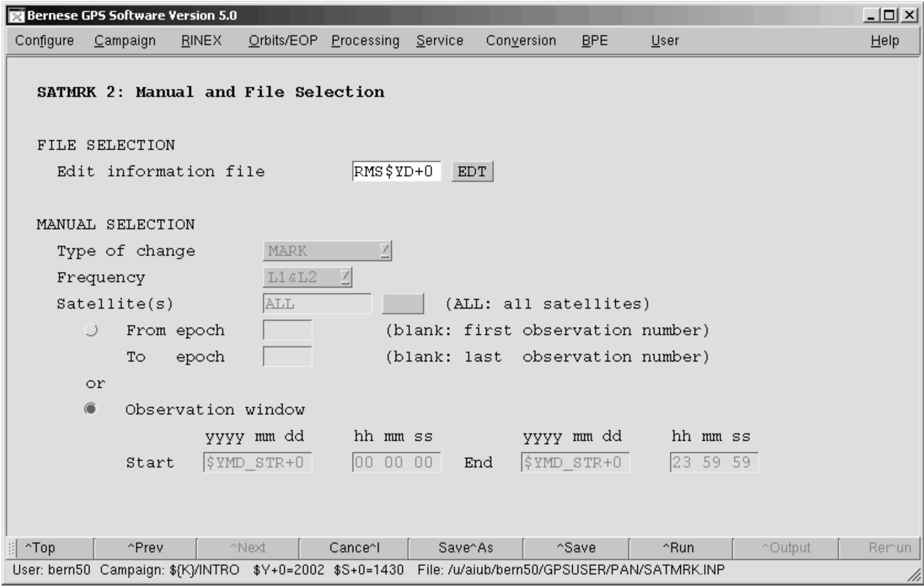






The program output of RESRMS (`${K}/INTRO/OUT/RMS021430.OUT`) provides a nice overview on the data quality. In addition, files containing a summary table (`${K}/INTRO/OUT/RMS02143.SUM` — also included in the reference solution file `${K}/INTRO/OUT/R2S02143.PRC_REF`) — and a histogram (`${K}/INTRO/OUT/RMS02143.LST`) of the residuals are available. The most important result file for the data screening is the "Edit information file" (`${K}/INTRO/OUT/RMS02143.EDT`) which may be used by the program SATMRK to mark outliers ("Menu>Service>Bernese observation files>Mark/delete observations"):

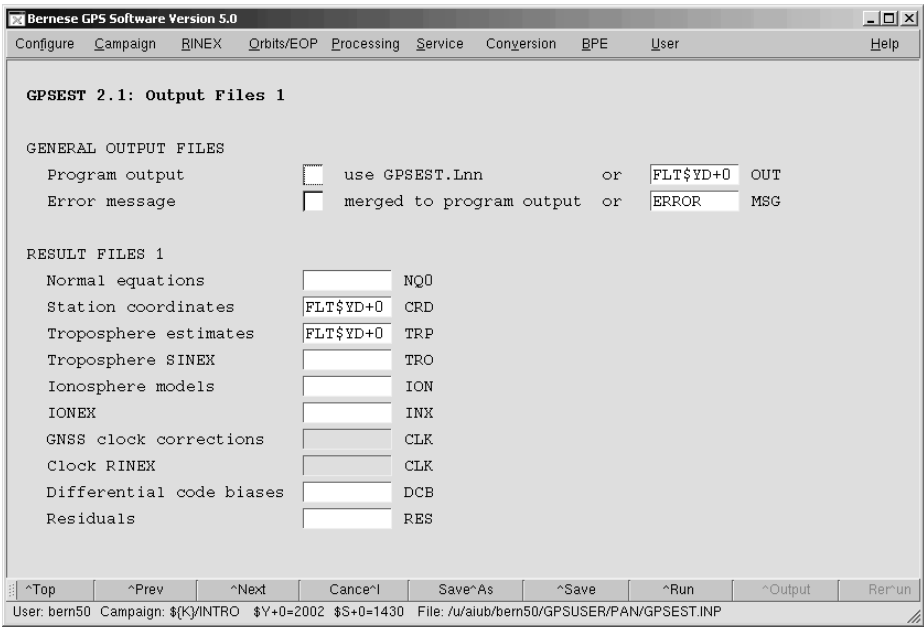




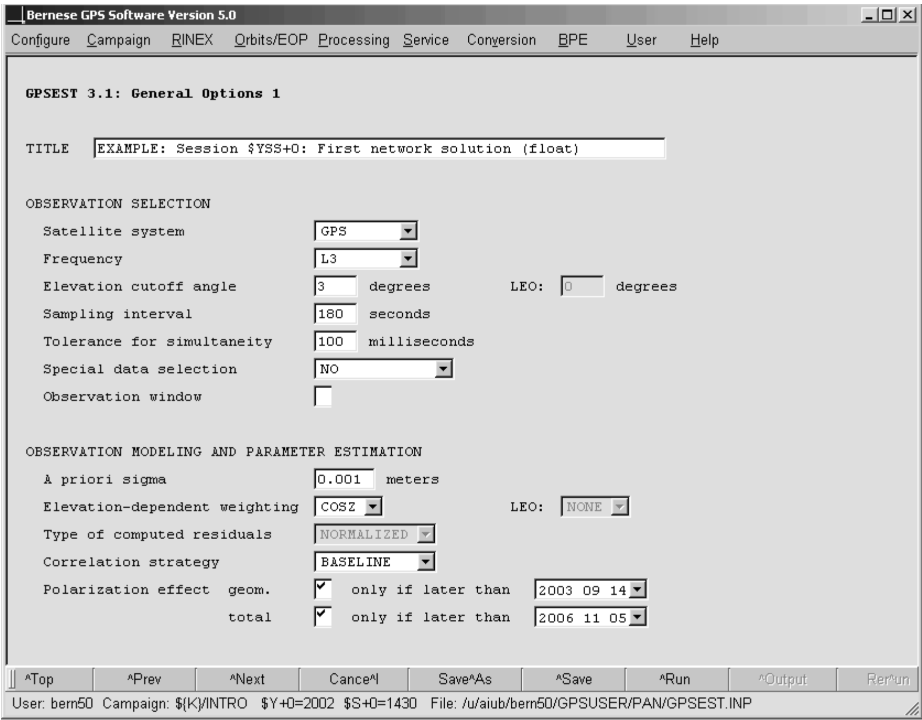
4.2 Make a First Network Solution

After screening the observations for outliers we generate an ionosphere–free (L_3) solution with unresolved ambiguities. The input options are very similar to the previous processing step. There are only a few differences shown in the following:

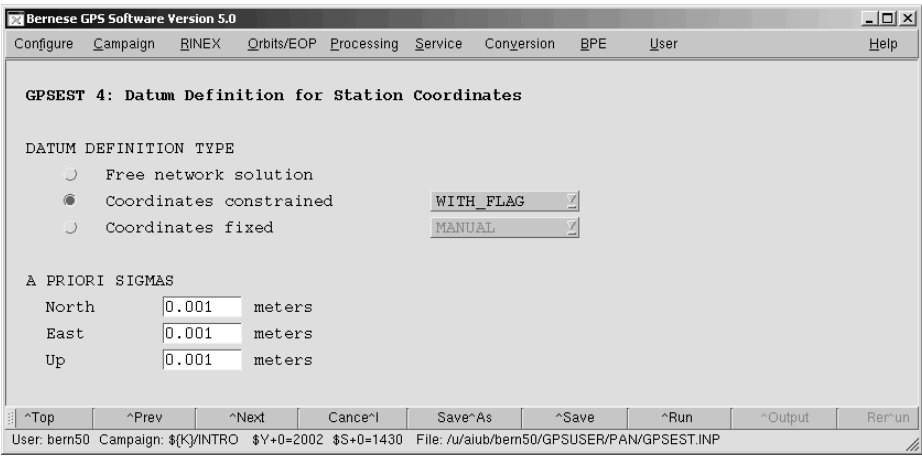
We store the coordinates and troposphere parameters into files to be re–introduced later:



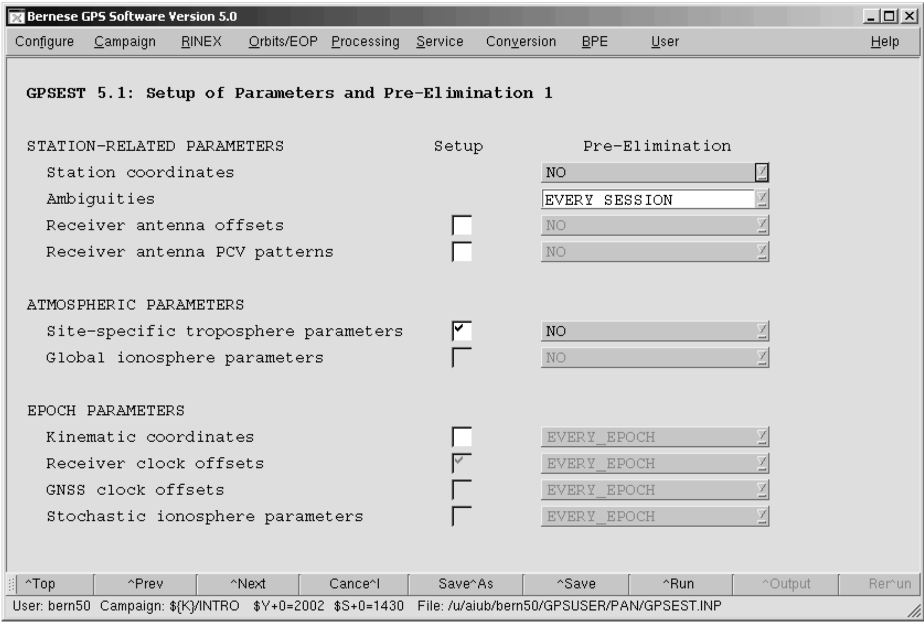
To speed up the processing we increase the sampling rate:



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). This will be the topic of the lecture session tomorrow. 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:



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 parameter and the observations:

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

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

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

STATION COORDINATES                                       24            0                  24     ...
AMBIGUITIES                                              419          419  (BEFORE INV)   451     ...
SITE-SPECIFIC TROPOSPHERE PARAMETERS                      56            0                  56     ...

------------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF PARAMETERS                               499          419                 531     ...
------------------------------------------------------------------------------------------------- ...


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

TYPE         FREQUENCY         FILE              #OBSERVATIONS
------------------------------------------------------------------------------------------------- ...

PHASE           L3              ALL                    20418

------------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF OBSERVATIONS                           20418
------------------------------------------------------------------------------------------------- ...
```

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 ZENITH)

DEGREE OF FREEDOM (DOF)            :     19932
CHI**2/DOF                         :      1.22


STATION COORDINATES:                       ${K}/INTRO/STA/FLT02143.CRD
-------------------

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

  6  BRUS 13101M004   X            4027893.7773       4027893.7804      0.0031      0.0016
                      Y             307045.7760        307045.7753     -0.0007      0.0014
                      Z            4919475.0809       4919475.0800     -0.0009      0.0017

                      HEIGHT            149.6632           149.6644      0.0012      0.0022     ...
                      LATITUDE     50 47 52.143447    50 47 52.143352   -0.0029      0.0009     ...
                      LONGITUDE     4 21 33.186467     4 21 33.186417   -0.0010      0.0014     ...
...
```

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. To check this in detail will be a topic of the terminal session tomorrow.

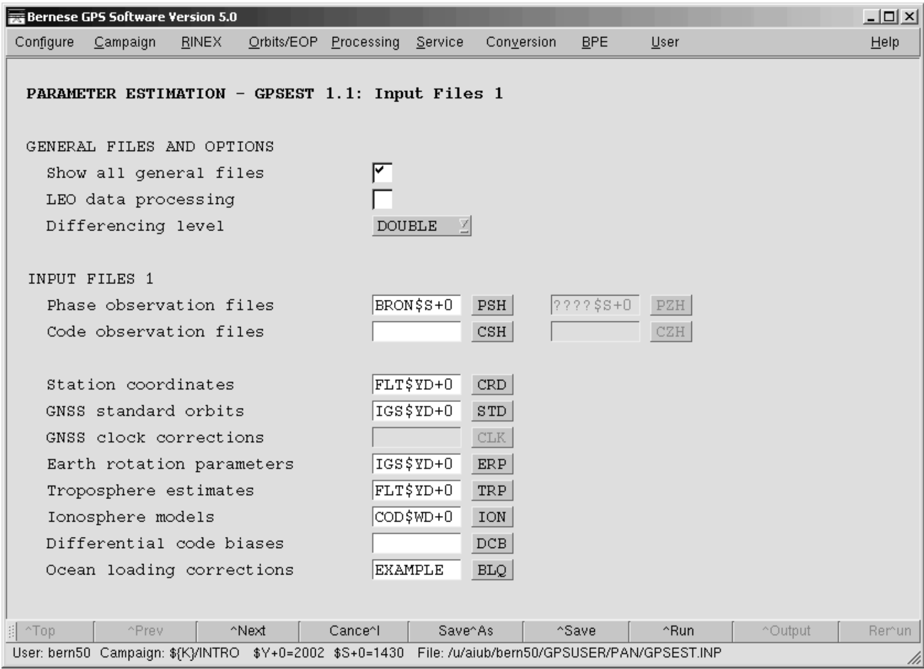
4.3 Ambiguity Resolution (QIF)

To resolve the ambiguities, we process the baselines separately one by one using the QIF (quasi–ionosphere–free) 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. The theoretical background for the ambiguity resolution will be the topic of the lecture session on Thursday morning. Nevertheless you may start the processing "cookbook"–like already today if you have time.

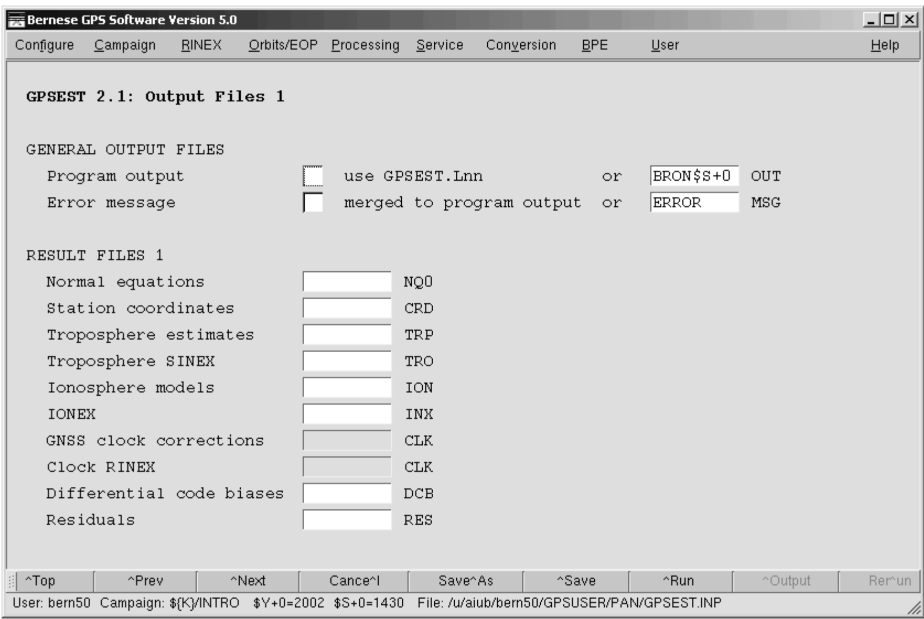
The complete list of baseline observation files of a session (e.g., session 1430 of year 2002) can be generated by listing all phase single-difference header files in the campaign's observation directory of your campaign:

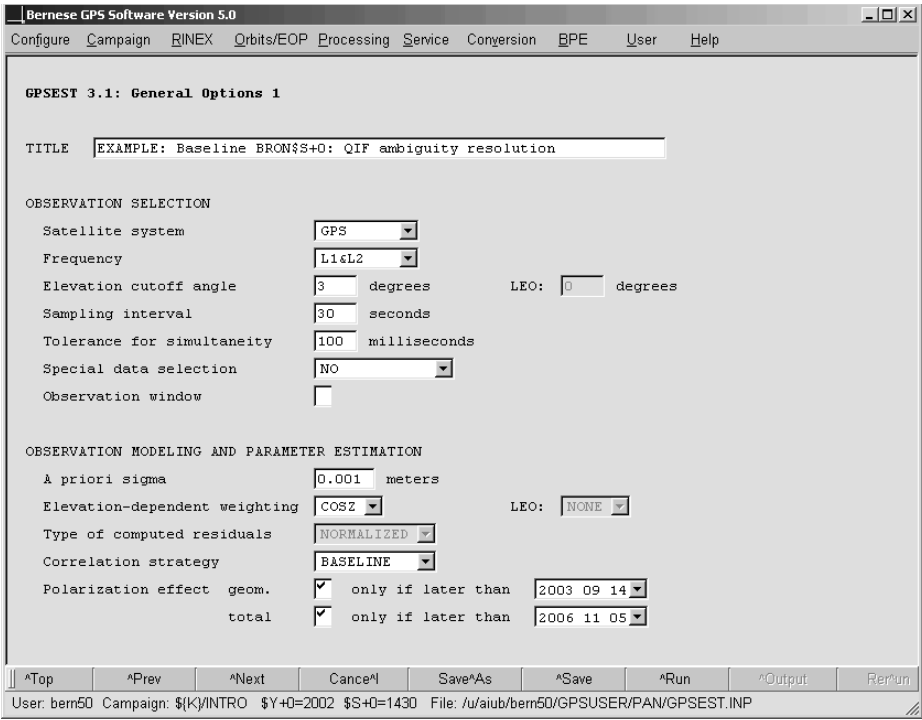
```
> ls ${K}/INTRO/OBS/????1430.PSH
${K}/INTRO/OBS/BRON1430.PSH
${K}/INTRO/OBS/FFMA1430.PSH
${K}/INTRO/OBS/FFON1430.PSH
${K}/INTRO/OBS/FFZI1430.PSH
${K}/INTRO/OBS/FFZM1430.PSH
${K}/INTRO/OBS/PTZM1430.PSH
${K}/INTRO/OBS/VIZM1430.PSH
```

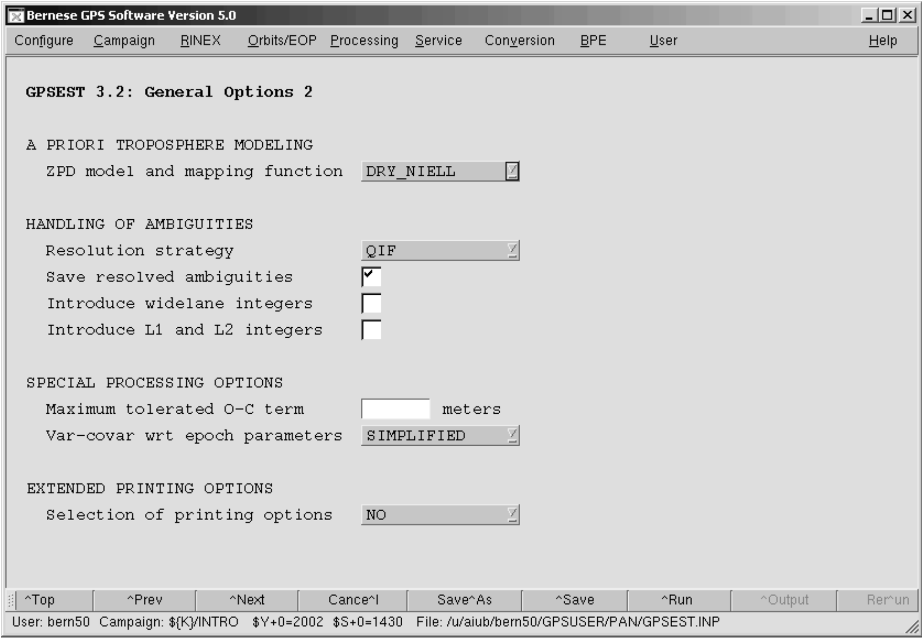
The first baseline for this session is from BRUS to ONSA with the observation filename `BRON1430`. Using the menu time variables this name is specified as `BRON$S+0`. The following options were used for the ambiguity resolution step:

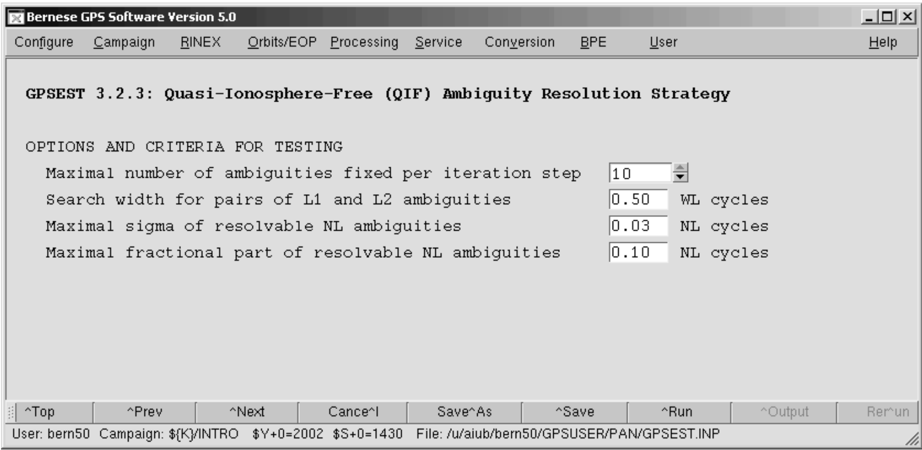


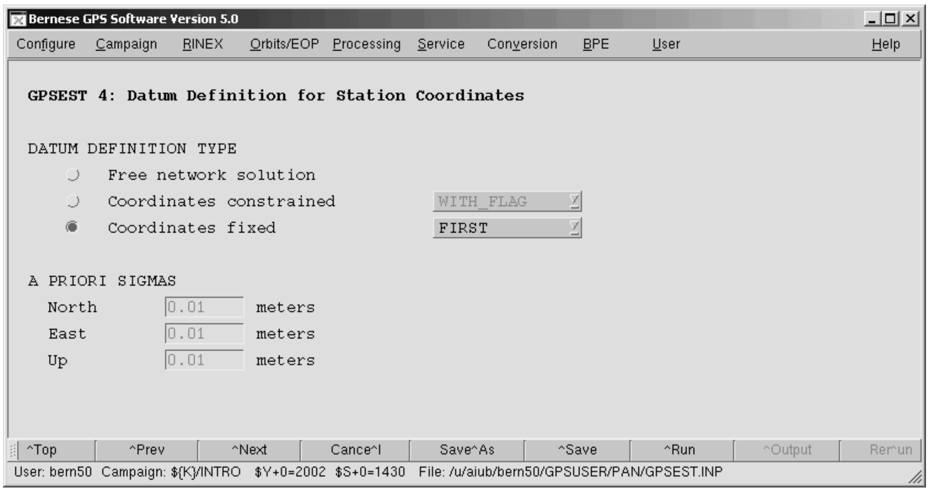
Only one baseline file is input and coordinates and troposphere estimates are introduced from the previous step. Specify a baseline specific output to prevent overwriting in subsequent runs.

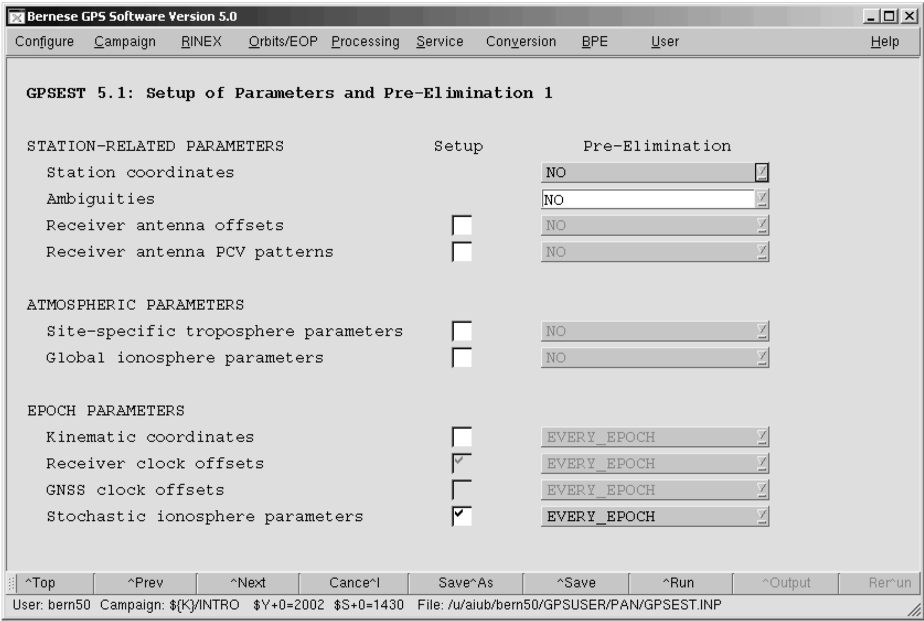


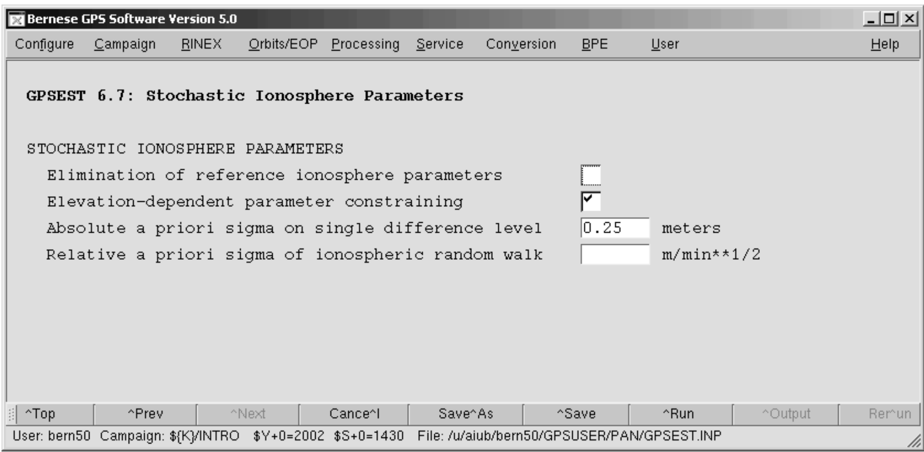

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 3.1: General Options 1
TITLE EXAMPLE: Baseline BRON$S+0: QIF ambiguity resolution
OBSERVATION SELECTION
Satellite system GPS
Frequency L1&L2
Elevation cutoff angle 3 degrees LEO: 0 degrees
Sampling interval 30 seconds
Tolerance for simultaneity 100 milliseconds
Special data selection NO
Observation window
OBSERVATION MODELING AND PARAMETER ESTIMATION
A priori sigma 0.001 meters
Elevation-dependent weighting COSZ LEO: NONE
Type of computed residuals NORMALIZED
Correlation strategy BASELINE
Polarization effect geom. only if later than 2003 09 14
total only if later than 2006 11 05
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 3.2: General Options 2
A PRIORI TROPOSPHERE MODELING
ZPD model and mapping function DRY_NIELL
HANDLING OF AMBIGUITIES
Resolution strategy QIF
Save resolved ambiguities
Introduce widelane integers
Introduce L1 and L2 integers
SPECIAL PROCESSING OPTIONS
Maximum tolerated O-C term meters
Var-covar wrt epoch parameters SIMPLIFIED
EXTENDED PRINTING OPTIONS
Selection of printing options NO
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 3.2.3: Quasi-Ionosphere-Free (QIF) Ambiguity Resolution Strategy
OPTIONS AND CRITERIA FOR TESTING
Maximal number of ambiguities fixed per iteration step 10
Search width for pairs of L1 and L2 ambiguities 0.50 WL cycles
Maximal sigma of resolvable NL ambiguities 0.03 NL cycles
Maximal fractional part of resolvable NL ambiguities 0.10 NL cycles
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 4: Datum Definition for Station Coordinates
DATUM DEFINITION TYPE
Free network solution
Coordinates constrained WITH_FLAG
Coordinates fixed FIRST
A PRIORI SIGMAS
North 0.01 meters
East 0.01 meters
Up 0.01 meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 5.1: Setup of Parameters and Pre-Elimination 1
STATION-RELATED PARAMETERS Setup Pre-Elimination
Station coordinates NO
Ambiguities NO
Receiver antenna offsets NO
Receiver antenna PCV patterns NO
ATMOSPHERIC PARAMETERS
Site-specific troposphere parameters NO
Global ionosphere parameters NO
EPOCH PARAMETERS
Kinematic coordinates EVERY_EPOCH
Receiver clock offsets EVERY_EPOCH
GNSS clock offsets EVERY_EPOCH
Stochastic ionosphere parameters EVERY_EPOCH
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 6.7: Stochastic Ionosphere Parameters
STOCHASTIC IONOSPHERE PARAMETERS
Elimination of reference ionosphere parameters
Elevation-dependent parameter constraining
Absolute a priori sigma on single difference level 0.25 meters
Relative a priori sigma of ionospheric random walk m/min**1/2
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

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                                                120            0                    138     ...
STOCHASTIC IONOSPHERE PARAMETERS                         20578        20578  (EPOCH-WISE)    20578     ...

-------------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF PARAMETERS                               20701        20578                  20719     ...
-------------------------------------------------------------------------------------------------- ...


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

TYPE         FREQUENCY         FILE              #OBSERVATIONS
-------------------------------------------------------------------------------------------------- ...

PHASE           L1              ALL                  17805
PHASE           L2              ALL                  17805

-------------------------------------------------------------------------------------------------- ...
TOTAL NUMBER OF OBSERVATIONS                             35610
-------------------------------------------------------------------------------------------------- ...


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 ZENITH)

DEGREE OF FREEDOM (DOF)            :     17682
CHI**2/DOF                         :      1.58



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

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

 42  ONSA 10402M004   X            3370658.5802       3370658.5804      0.0002      0.0003
                      Y             711877.1002        711877.0999     -0.0003      0.0005
                      Z            5349786.9190       5349786.9195      0.0005      0.0003

                      HEIGHT            45.5659            45.5664      0.0005      0.0004      ...
                      LATITUDE     57 23 43.074626    57 23 43.074633    0.0002      0.0002      ...
                      LONGITUDE    11 55 31.859790    11 55 31.859770   -0.0003      0.0005      ...
...
```

```
...

AMBIGUITIES:
-----------

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

   1    1   18      1  1   1    1  121   25       -1.69   0.72     3181808.31
   2    1   18    803  1   1    2  121   25        0.56   0.27     5312278.56
   3    1   18   1140  1   1    3  122   47        9.10   0.37    21539287.10
   4    1   18   2541  1   1    4  122   47        8.43   0.29     7052711.43
...
 121    1   30      1  1   1   25        --- REFERENCE ---         4265891.
 122    1   13   1688  1   1   47        --- REFERENCE ---         4765818.
...
```

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)
------------------------------------------------------------------------------------------ ...

   1   9   9   1  121  25   1    -2   -1   0.66   0.85  -0.189  -0.005   0.004
   1  26  29   1  121  25   1     1    2   0.08   0.10  -0.020   0.010   0.004
   1  33  38   1  122  47   1     6    9   0.74   0.96  -0.219  -0.035   0.004
   1   6   6   1   18  18   1     3    5   0.11   0.15  -0.034  -0.006   0.004
   1  34  39   1   38  43   1    -5   -5  -0.01  -0.01   0.001  -0.007   0.004
   1  31  35   1   57  65   1    -1   -3   1.09   1.39  -0.305   0.009   0.004
   1  54  62   1  122  47   1    10   12  -0.14  -0.18   0.037  -0.007   0.005
   1  25  28   1  122  47   2    33   44   0.11   0.14  -0.029   0.012   0.005
   1  59  67   1   60  69   1   -11  -13   0.15   0.19  -0.043   0.000   0.005
   1  36  41   1   45  53   1     0   -3  -0.24  -0.32   0.071   0.004   0.005
..
```

First the individual iteration steps are described (we specified that up to ten ambiguities may be resolved within each iteration step — see panel “GPSEST 3.2.3: Quasi-Ionosphere-Free (QIF) 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 3.2.3: QIF Ambiguity Resolution Strategy" (option "Search width of 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.

The results of the ambiguity resolution are summarized in the following table:

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

   1    1   18      1  1   1    1  121   25        -2.06  0.74     3181807.94
   2    1   18    803  1   1    2  121   25            2             5312280.      0.00000
   3    1   18   1140  1   1    3  122   47           11            21539289.      0.00000
   4    1   18   2541  1   1    4  122   47            8             7052711.      0.00000
   5    1   26      1  1   1    5  121   25           -2             2789513.      0.00000
   6    1   26   2316  1   1    6   18   18            3             7998338.      0.00000
   7    1    9      1  1   1    7  121   25           -2              513984.      0.00000
   8    1    9   2580  1   1    8  122   47            8             5465798.      0.00000
   9    1    5      1  1   1    9  121   25           -2             3645130.      0.00000
  10    1    5   2774  1   1   10  122   47            8            11304208.      0.00000
  11    1   21      1  1   1   11  121   25           -1              630972.      0.00000
  12    1   21    875  1   1   12  121   25           -4             2162193.      0.00000
  13    1   21   1140  1   1   13   52   60            0            24351826.      0.00000
  14    1   21   2712  1   1   14   47   55            3             6301871.      0.00000
  15    1   29      1  1   1   15  121   25           -2             2714435.      0.00000
  16    1   29   1191  1   1   16  122   47        17.34  2.16     6067500.34
  17    1   29   1213  1   1   17  122   47        12.88  2.18     6067503.88
  18    1   29   2412  1   1   18   50   58            8             7875520.      0.00000
  19    1    7      1  1   1   19  121   25           -1            -2727952.      0.00000
  20    1    7   1434  1   1   20  122   47        12.15  0.18    -2701064.85
  21    1    7   2657  1   1   21  122   47            5             2332618.      0.00000
  22    1   14     10  1   1   23  121   25           -8            -1371335.      0.00000
  23    1   14   1231  1   1   24  122   47           14             8192805.      0.00000
  24    1    4    191  1   1   27  121   25            1            -2682162.      0.00000
  25    1    4   1650  1   1   28  122   47           33            -4511289.      0.00000
...
```

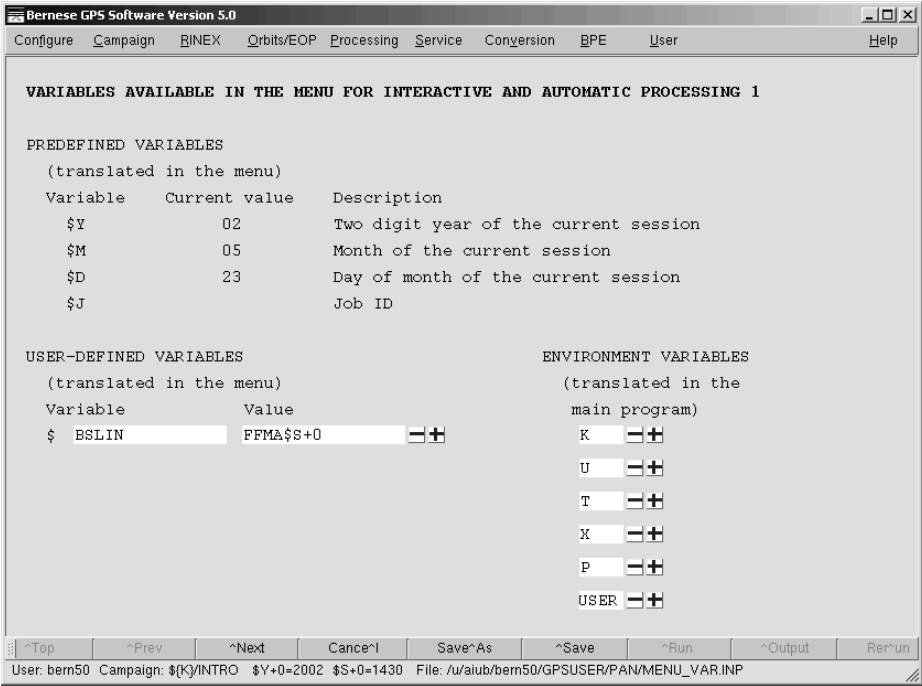
The ambiguities for which a `RMS` is specified could not be resolved (these ambiguities will be treated as real values by all subsequent program runs).

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

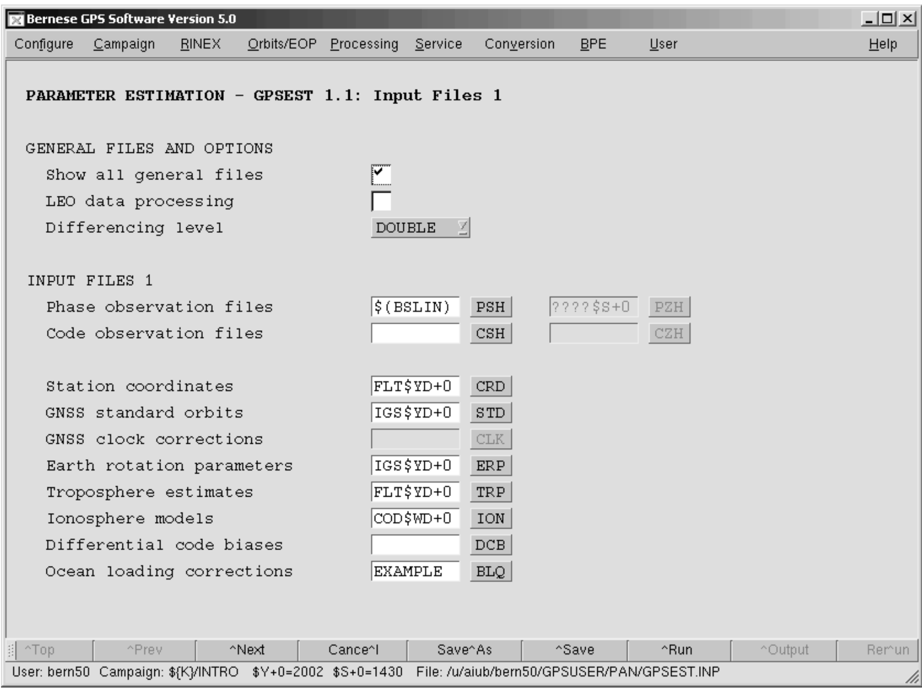
```
...
14. RESULTS (PART 2)
--------------------

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

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

STATION COORDINATES                                         3          0                     3   ...
AMBIGUITIES                                                24          0                   138   ...
STOCHASTIC IONOSPHERE PARAMETERS                        20578      20578  (EPOCH-WISE)    20578   ...

------------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF PARAMETERS                              20605      20578                 20719   ...
------------------------------------------------------------------------------------------------ ...


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

TYPE         FREQUENCY         FILE              #OBSERVATIONS
------------------------------------------------------------------------------------------------ ...

PHASE           L1              ALL                   17805
PHASE           L2              ALL                   17805

------------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF OBSERVATIONS                            35610
------------------------------------------------------------------------------------------------ ...


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 ZENITH)

DEGREE OF FREEDOM (DOF)            :     17778
CHI**2/DOF                         :      1.76



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

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

 42  ONSA 10402M004   X            3370658.5802       3370658.5780     -0.0022      0.0002
                      Y             711877.1002        711877.0976     -0.0026      0.0001
                      Z            5349786.9190       5349786.9177     -0.0013      0.0003

                      HEIGHT            45.5659            45.5634     -0.0025      0.0003      ...
                      LATITUDE     57 23 43.074626    57 23 43.074676   0.0015      0.0002      ...
                      LONGITUDE    11 55 31.859790    11 55 31.859667  -0.0020      0.0001      ...
...
```

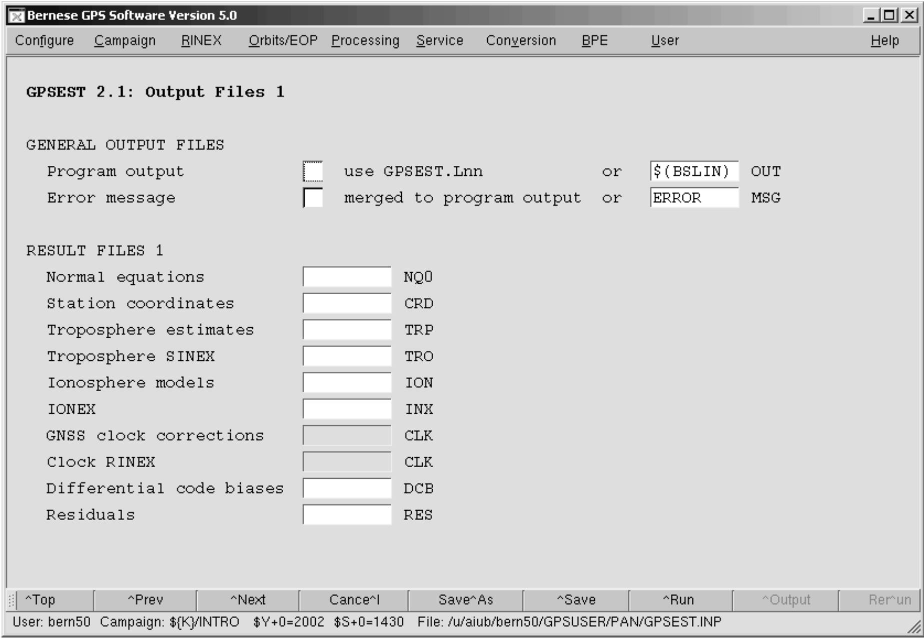
You may see from the output that from a total of 120 ambiguities 96 ambiguities could be resolved (compare part 1 AMBIGUITIES with part 2 AMBIGUITIES).

Admittedly, it is cumbersome to process the baselines "manually" one after the other – you have seven baselines per session for this small example campaign. When we switch the input options from one baseline to the next one we have to change the filename for the baseline in three panels of GPSEST. To avoid this, you may benefit from the semi–automated processing capability of the *Bernese GPS Software*, Version 5.0 : First we define a user variable ("Menu >Configure>Menu variables") containing the name of the baseline we want to process (in that case the second one from the list: FFMJ to MATE with the filename `FFMA1430`):



Now we use the variable `$(BSLIN)` in the three input panels of GPSEST in place of the single difference input filenames:





Bernese GPS Software Version 5.0

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.1: Output Files 1

GENERAL OUTPUT FILES

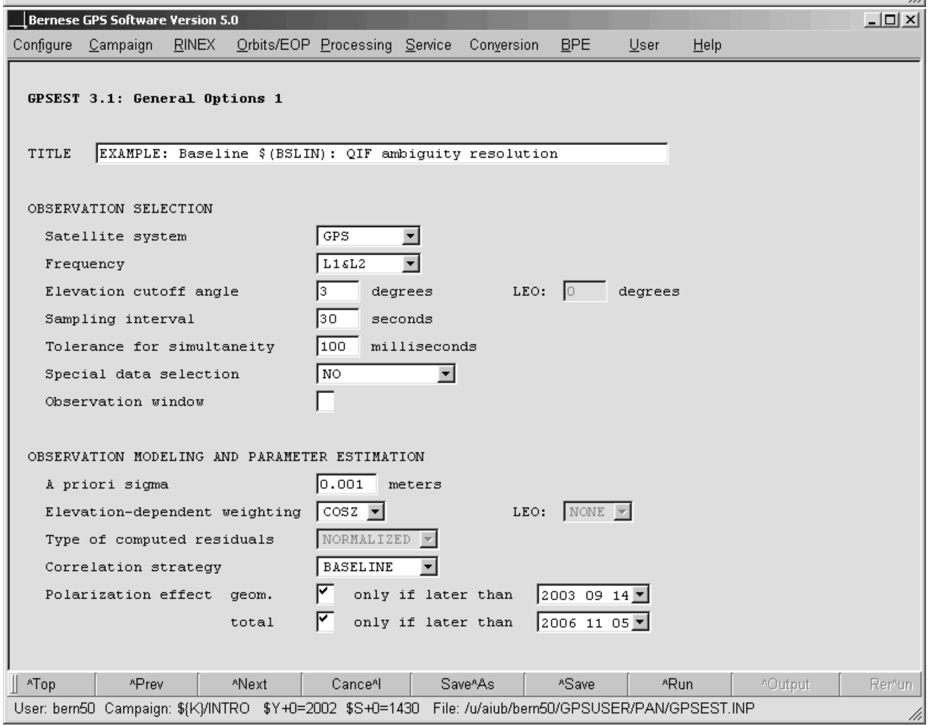
Program output	☐	use GPSEST.Lnn	or	$(BSLIN)	OUT
Error message	☐	merged to program output	or	ERROR	MSG

RESULT FILES 1

Normal equations		NQ0
Station coordinates		CRD
Troposphere estimates		TRP
Troposphere SINEX		TRO
Ionosphere models		ION
IONEX		INX
GNSS clock corrections		CLK
Clock RINEX		CLK
Differential code biases		DCB
Residuals		RES

^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un

User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP



Bernese GPS Software Version 5.0

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.1: General Options 1

TITLE EXAMPLE: Baseline $(BSLIN): QIF ambiguity resolution

OBSERVATION SELECTION

Satellite system	GPS			
Frequency	L1&L2			
Elevation cutoff angle	3	degrees	LEO:	0 degrees
Sampling interval	30	seconds		
Tolerance for simultaneity	100	milliseconds		
Special data selection	NO			
Observation window	☐			

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma	0.001	meters		
Elevation-dependent weighting	COSZ		LEO:	NONE
Type of computed residuals	NORMALIZED			
Correlation strategy	BASELINE			
Polarization effect geom.	☑	only if later than		2003 09 14
total	☑	only if later than		2006 11 05

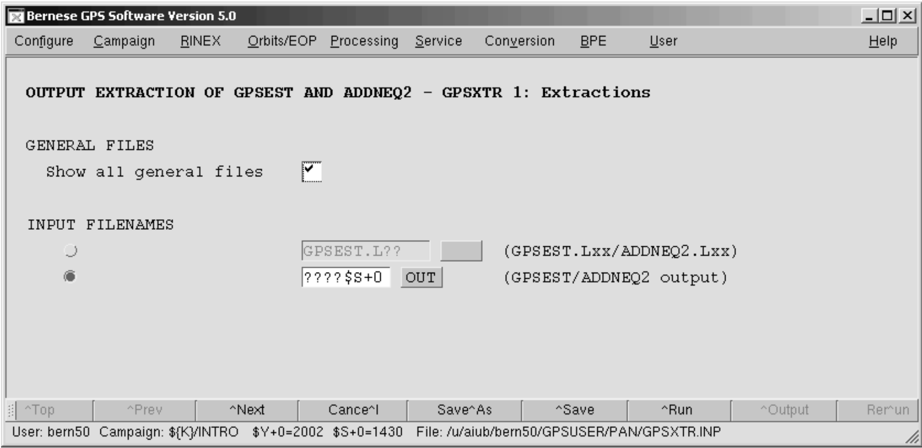
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un

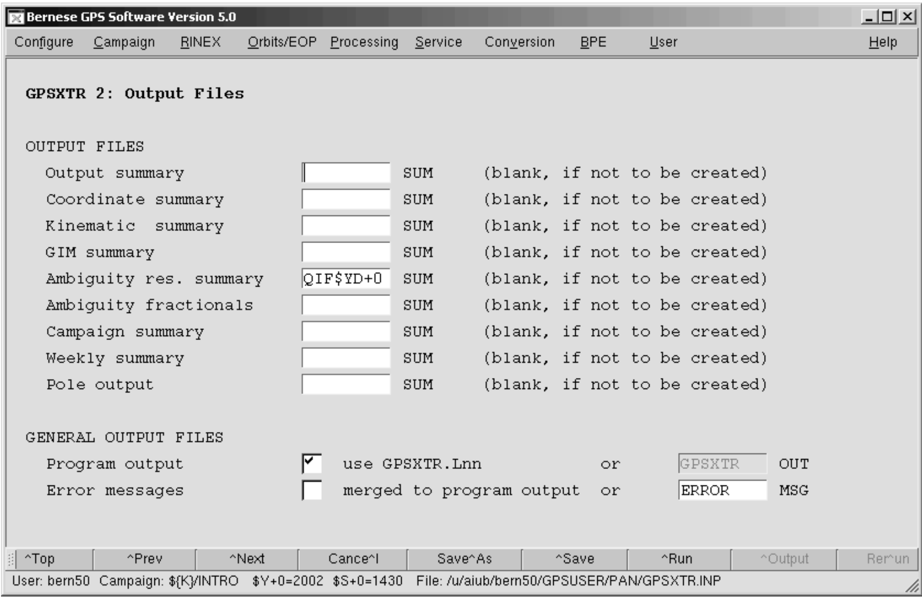
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

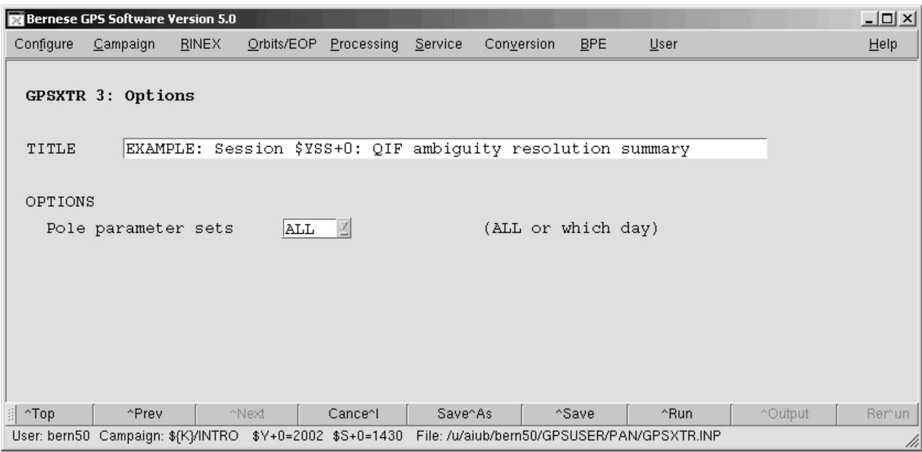
Now, we can easily switch from one baseline to the next by changing the definition of the variable `$(BSLIN)` in the menu variables panel, only. The fields in the input files are updated automatically.

Ambiguity resolution is a typical application for the Bernese Processing Engine (BPE) even if you are going to process the data manually. We have prepared a Perl script that runs GPSEST based on the current settings in the input panels for all baseline observation files in your campaign. The script checks the main settings for the QIF ambiguity resolution. It is required that you have used menu time variables for the filenames in panel "GPSEST 1.1: Input Files 1". The script is started without any parameters by typing `${U}/SCRIPT/qif_all.com`. This script is only available for this course, it is not part of the official distribution of Bernese.

For each observation file a corresponding program output file is generated. Using the program GPSXTR you may generate a summary of the ambiguity resolution for all baselines of the session:







In this summary (`${K}/INTRO/OUT/QIF02143.SUM`) you may easily see how many ambiguities are resolved for each baseline[1]:

```
File       Length   #Amb  RMS0   Max/RMS L5 Amb  Max/RMS L3 Amb   #Amb  RMS0   #Amb Res
           (km)           (mm)   (L5 Cycles)     (L3 Cycles)            (mm)   (%)
--------------------------------------------------------------------------------------
BRON1430    883.8    110   1.2    0.498  0.144    0.096  0.025      16   1.3    85.5
FFMA1430   1220.4    116   1.4    0.487  0.158    0.098  0.028      28   1.5    75.9
FFON1430    840.1    116   1.3    0.474  0.165    0.094  0.025      20   1.4    82.8
FFZI1430    368.1     62   1.2    0.368  0.135    0.089  0.022      10   1.3    83.9
FFZM1430    368.1    116   1.1    0.389  0.122    0.072  0.019      18   1.2    84.5
PTZM1430    640.1     96   1.3    0.489  0.154    0.085  0.021      14   1.4    85.4
VIZM1430   1162.3     96   1.3    0.497  0.166    0.085  0.023      18   1.3    81.2
--------------------------------------------------------------------------------------
Tot:   7    783.3    712   1.3    0.498  0.150    0.098  0.023     124   1.3    82.6
```

This table is a part of the solution reference file (`${K}/INTRO/OUT/R2S02143.PRC_REF`), too.

Additional lines may appear below this table looking like:

```
Estimated Orbit Accuracy:   29.7+-   5.4 mm
Basic Noise of L3 Amb   :    2.2+-   0.2 mm /  0.020 L3 Cycles
```

The orbit accuracy may be estimated when compiling the summary for the ambiguity resolution containing the RMS for the L3 ambiguity estimates from baselines of a global network. In some cases GPSXTR adds these lines also for regional networks. In that case the `Estimated Orbit Accuracy` is not really interpretable.

[1] You may check the impact of introducing the ionosphere model (`COD$WD+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.

4.4 Daily Goals

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

(1) *used* GPSEST *for residual screening, created files:* `EDT02143.OUT`, `EDT02143.RES` *in your campaign's* `OUT` *directory,*
(2) *screened the residual files from the above run using* RESRMS*: created files* `RMS02143.SUM`, `RMS02143.LST`, `RMS02143.EDT`, *and* `RMS02143.OUT`,
(3) *used* SATMRK *to mark the identified outliers,*
(4) *used* GPSEST *for a first coordinate and troposphere estimation, created files:* `FLT02143.CRD` *and* `FLT02143.TRP`,
(5) *used* `GPSEST` *for QIF ambiguity resolution, created files:* `BRON143.OUT`, `FFMA143.OUT`, *etc. for all baselines,*
(6) *used* GPSXTR *to create a summary of the ambiguity resolution, created file:* `QIF02143.SUM`

ideally, files for all sessions should be screened (generation of FLTyyddd files).

5. Terminal Session: Thursday

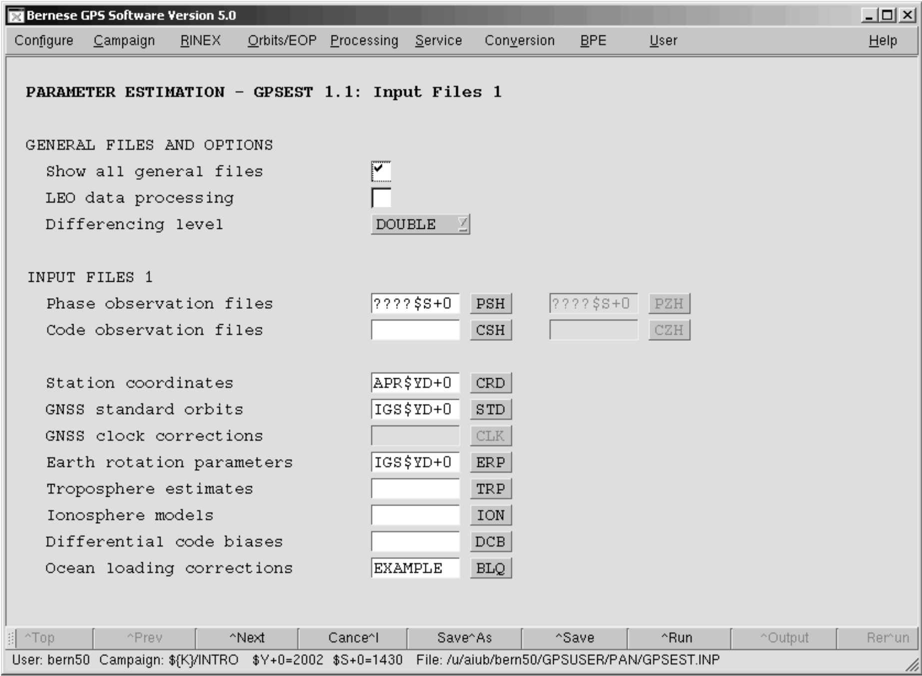
Finish the work of yesterday by resolving the ambiguities for all baselines of all four days. To save time you may do this for one day of each year (e.g. day 143 year 2002, and day 138 year 2003.
Today's terminal session is to:

*(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) (optional) compute velocities (*ADDNEQ2*),*

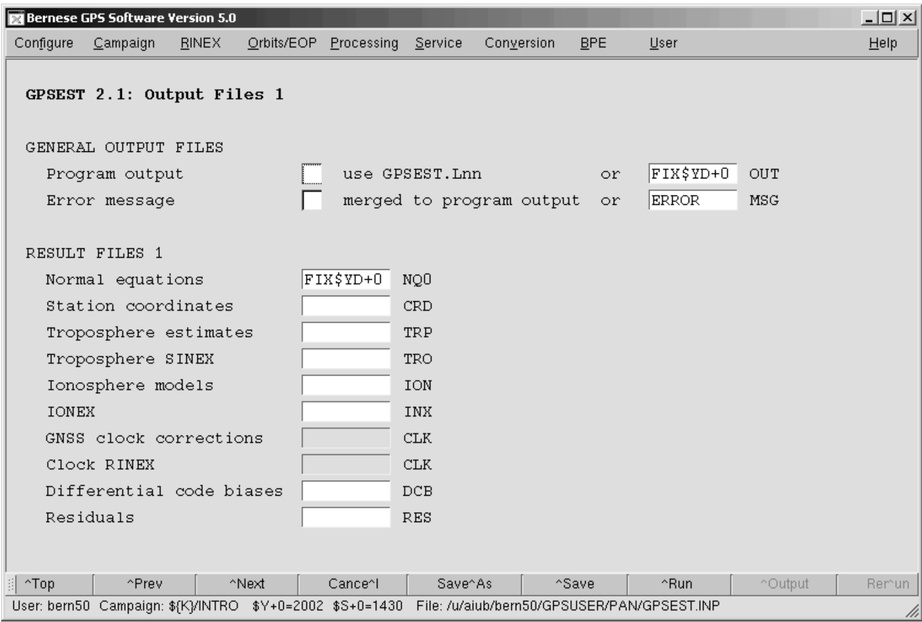
for all four days of the processing example. Compare the final coordinate results of the daily solutions.

5.1 Final Network Solution

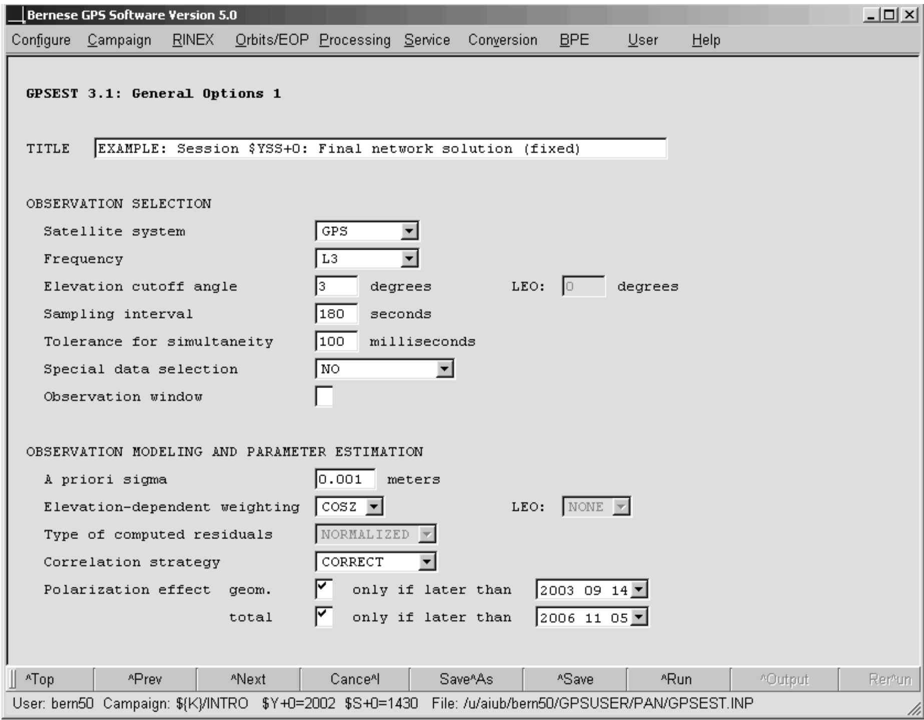
After the loop over all baselines is completed and the ambiguities are resolved you will use the program GPSEST in session mode. In panel "GPSEST 1.1: Input Files 1" you may now select all single difference files of the corresponding session:



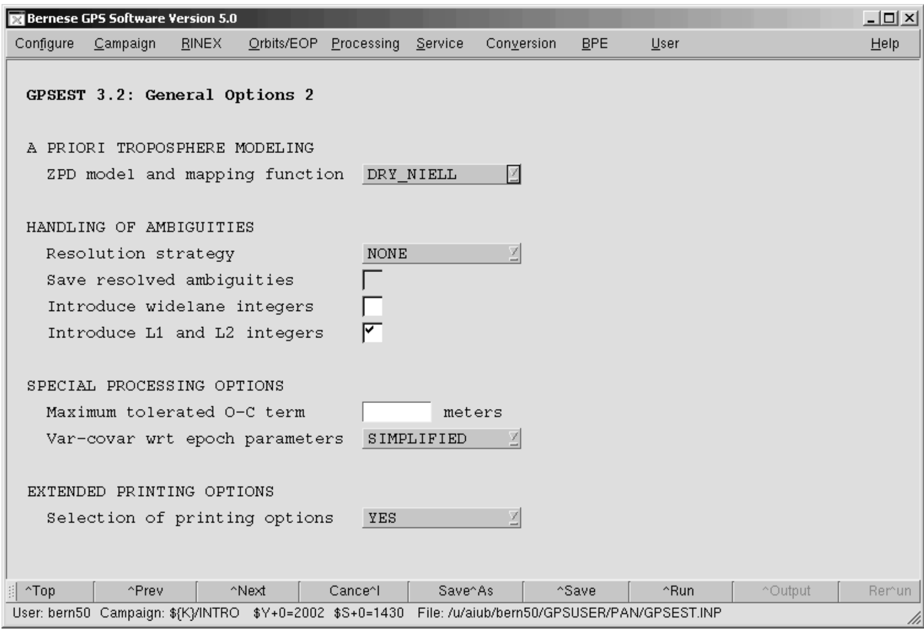
In panel "GPSEST 2.1: Output Files 1" we request the normal equation file as only output file



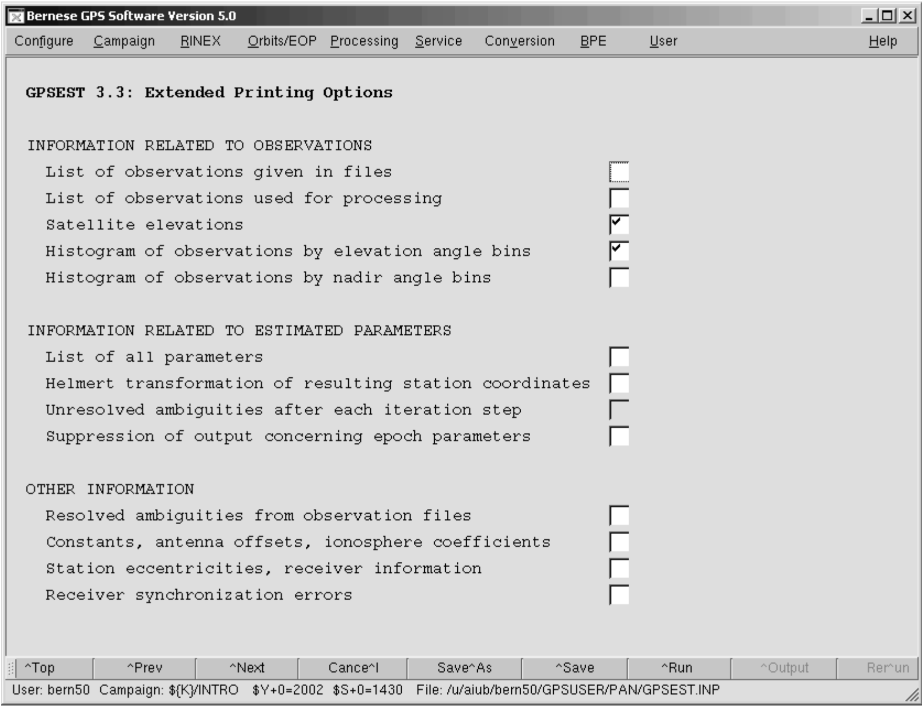
For the final run of GPSEST we consider the correlations between the observations correctly:



Ambiguities which have been resolved in the previous runs of program GPSEST using the QIF strategy are introduced as known:

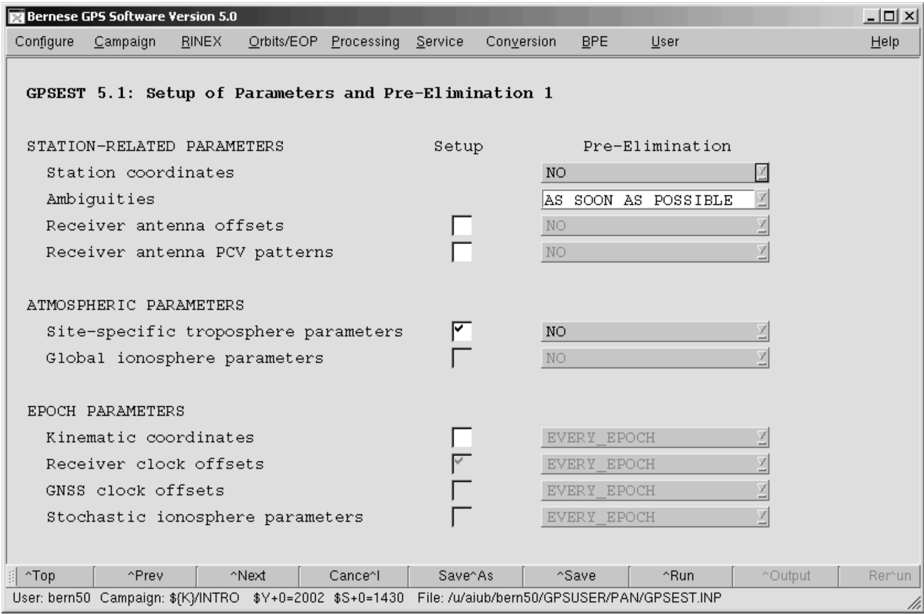


Since this is the final run of GPSEST it is worthwhile to add some more information about the observation files into the program output. This is useful if you archive the program output of this run together with the observation files and the resulting normal equation files.

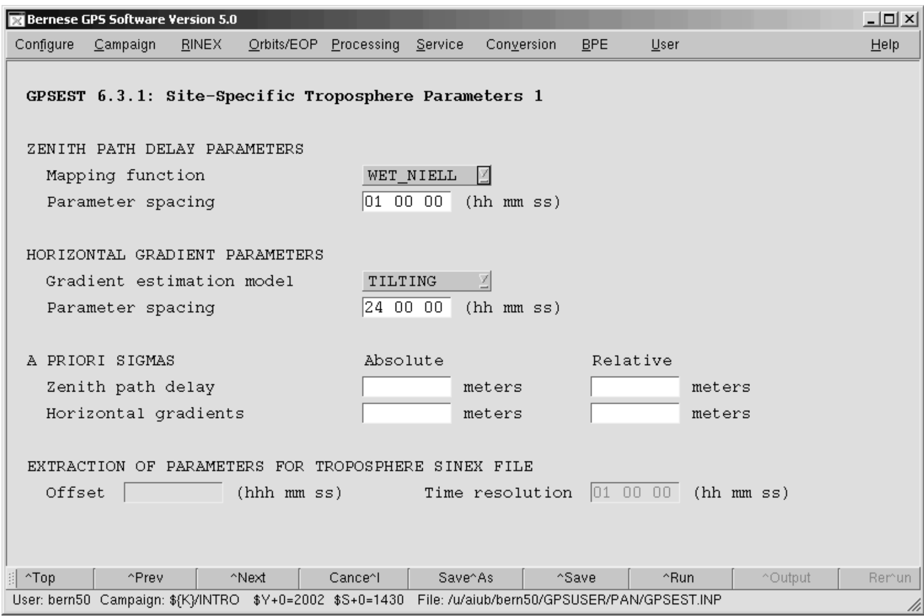


We do not fix any stations on their a priori position, i.e., the coordinates of all stations will be estimated. This retains the flexibility for later changes in the realization of the reference frame (station constraints) with program ADDNEQ2. However, to get already a reasonable solution (also for the station coordinates) from GPSEST we put loose constraints on the coordinates (the normal equations are stored without any constraints):

The unresolved ambiguities are pre–eliminated:



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



The output of a 1-session run of program GPSEST should look like this:

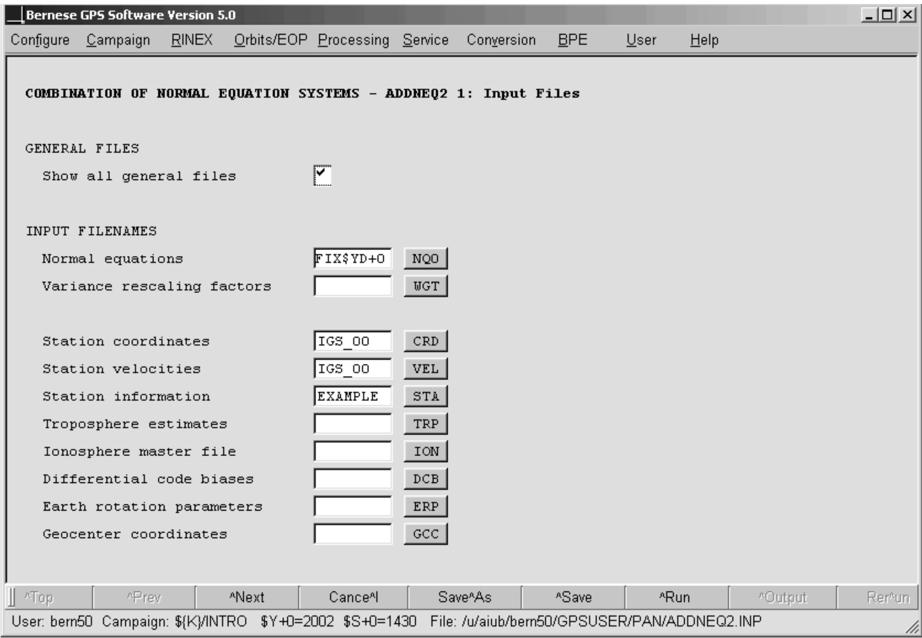
```
...
13. RESULTS (PART 1)
--------------------

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

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

STATION COORDINATES                                        24          0                     24    ...
AMBIGUITIES                                               120        120  (BEFORE INV)      152    ...
SITE-SPECIFIC TROPOSPHERE PARAMETERS                      232          0                    232    ...

------------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF PARAMETERS                                376        120                    408    ...
------------------------------------------------------------------------------------------------ ...


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

TYPE         FREQUENCY         FILE              #OBSERVATIONS
------------------------------------------------------------------------------------------------ ...

PHASE           L3              ALL                    20418

------------------------------------------------------------------------------------------------ ...
TOTAL NUMBER OF OBSERVATIONS                           20418
------------------------------------------------------------------------------------------------ ...


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 ZENITH)

DEGREE OF FREEDOM (DOF)            :     20062
CHI**2/DOF                         :      1.30
...
```

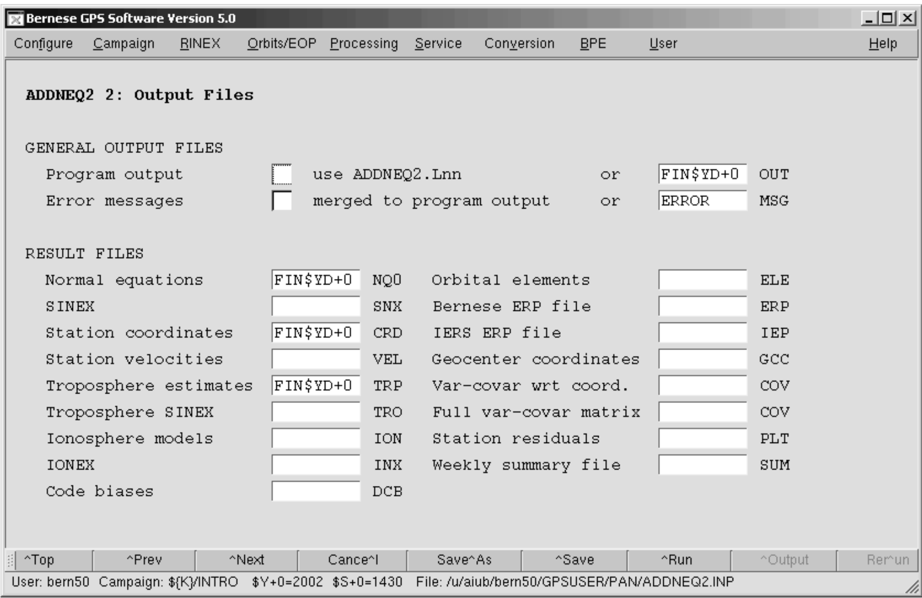
After four runs of GPSEST in session mode the following normal equation files should be available in the directory ${K}/INTRO/SOL

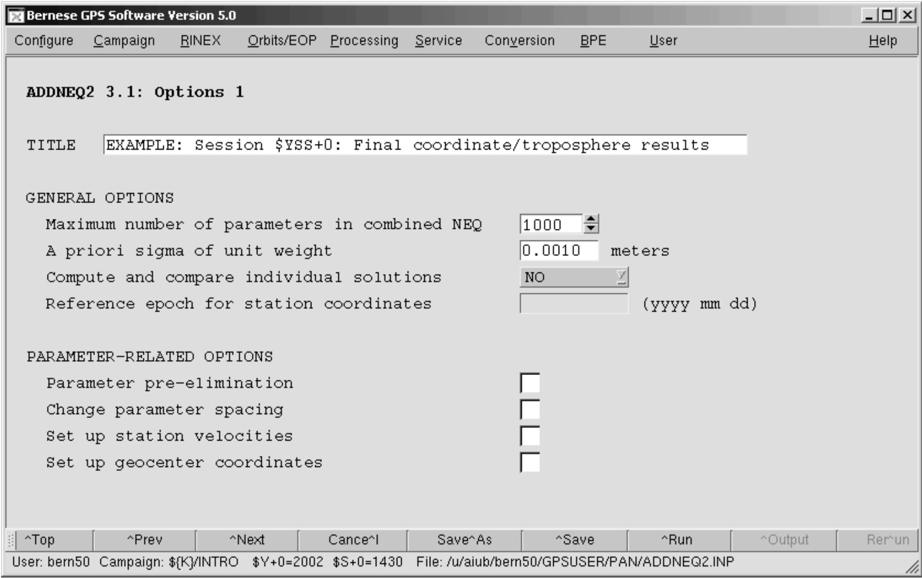
FIX02143.NQ0, FIX02144.NQ0, and
FIX03138.NQ0, FIX03139.NQ0.

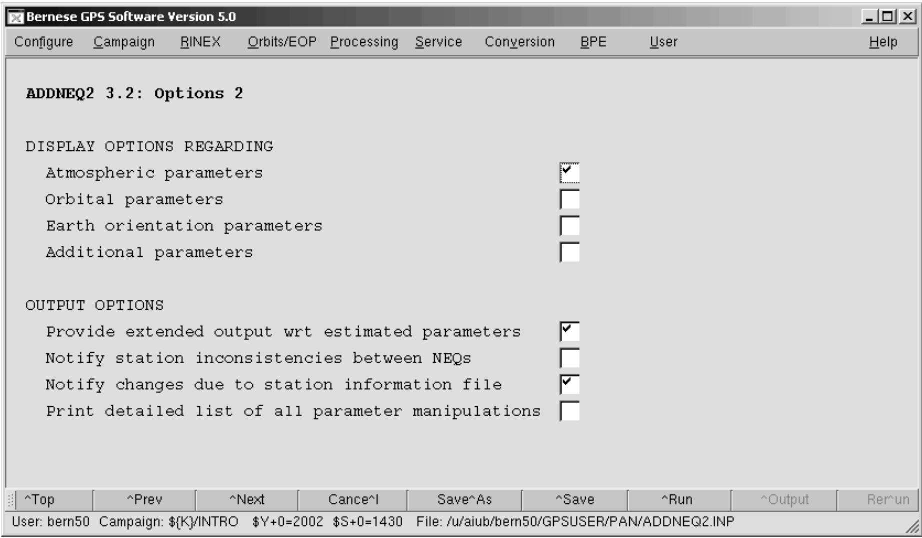
5.2 Check the Coordinates of the Fiducial Sites

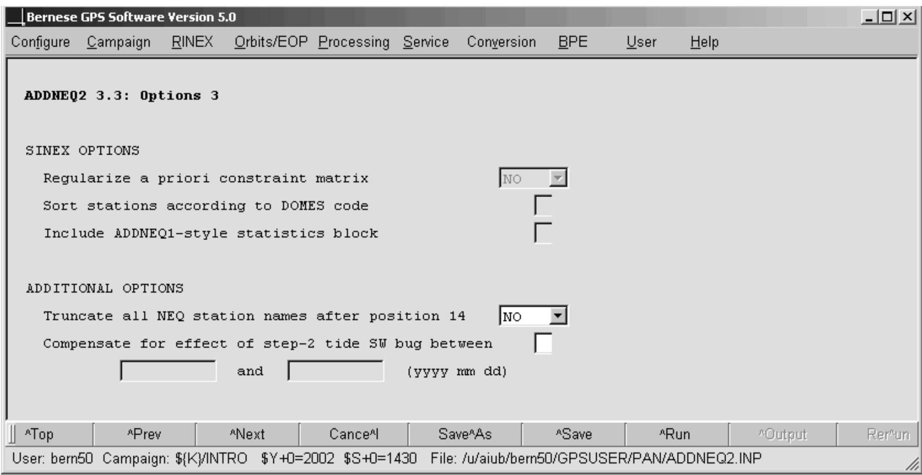
To check the consistency of our data with the coordinates of the IGS core sites we generate a minimum constraint solution for the network using program ADDNEQ2 ("Menu>Processing >Normal equation stacking") with the following options:

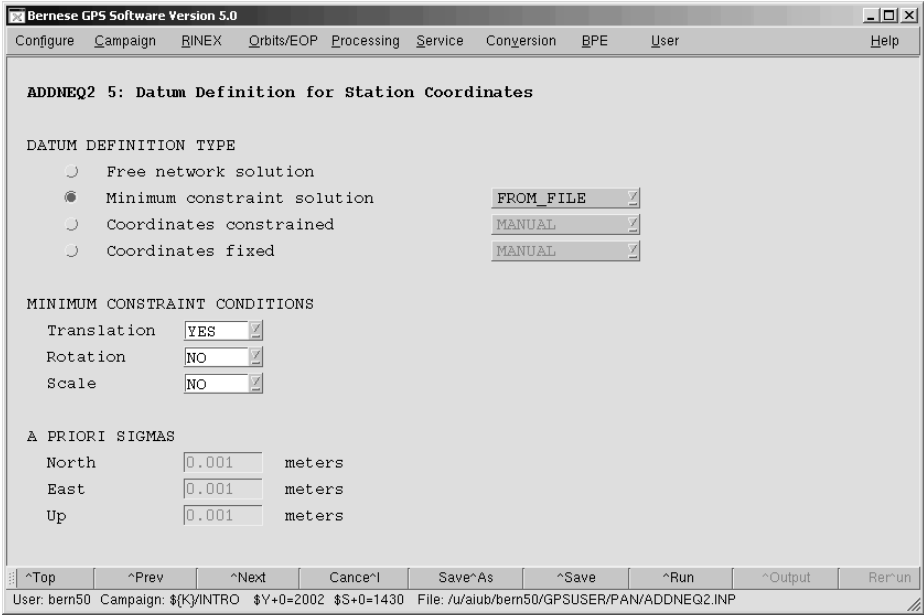


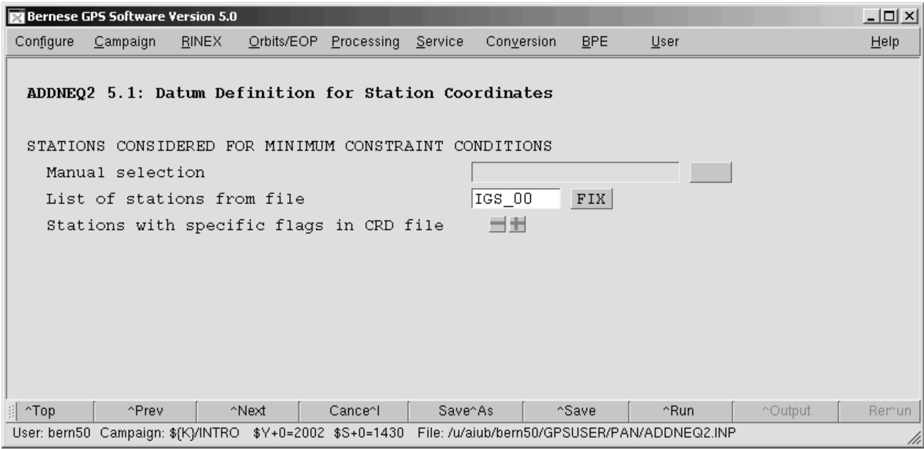


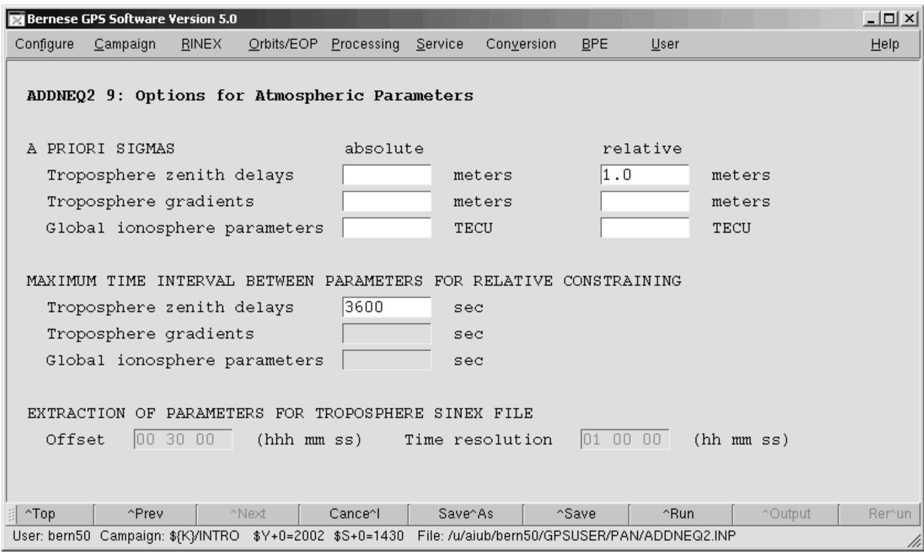

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 3.1: Options 1
TITLE EXAMPLE: Session $YSS+0: Final coordinate/troposphere results
GENERAL OPTIONS
Maximum number of parameters in combined NEQ 1000
A priori sigma of unit weight 0.0010 meters
Compute and compare individual solutions NO
Reference epoch for station coordinates (yyyy mm dd)
PARAMETER-RELATED OPTIONS
Parameter pre-elimination
Change parameter spacing
Set up station velocities
Set up geocenter coordinates
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 3.2: Options 2
DISPLAY OPTIONS REGARDING
Atmospheric parameters
Orbital parameters
Earth orientation parameters
Additional parameters
OUTPUT OPTIONS
Provide extended output wrt estimated parameters
Notify station inconsistencies between NEQs
Notify changes due to station information file
Print detailed list of all parameter manipulations
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 3.3: Options 3
SINEX OPTIONS
Regularize a priori constraint matrix NO
Sort stations according to DOMES code
Include ADDNEQ1-style statistics block
ADDITIONAL OPTIONS
Truncate all NEQ station names after position 14 NO
Compensate for effect of step-2 tide SW bug between
and (yyyy mm dd)
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 5: Datum Definition for Station Coordinates
DATUM DEFINITION TYPE
Free network solution
Minimum constraint solution
FROM_FILE
Coordinates constrained
MANUAL
Coordinates fixed
MANUAL
MINIMUM CONSTRAINT CONDITIONS
Translation
YES
Rotation
NO
Scale
NO
A PRIORI SIGMAS
North
0.001
meters
East
0.001
meters
Up
0.001
meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 5.1: Datum Definition for Station Coordinates
STATIONS CONSIDERED FOR MINIMUM CONSTRAINT CONDITIONS
Manual selection
List of stations from file
IGS_00
FIX
Stations with specific flags in CRD file
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 9: Options for Atmospheric Parameters
A PRIORI SIGMAS
absolute
relative
Troposphere zenith delays
meters
1.0
meters
Troposphere gradients
meters
meters
Global ionosphere parameters
TECU
TECU
MAXIMUM TIME INTERVAL BETWEEN PARAMETERS FOR RELATIVE CONSTRAINING
Troposphere zenith delays
3600
sec
Troposphere gradients
sec
Global ionosphere parameters
sec
EXTRACTION OF PARAMETERS FOR TROPOSPHERE SINEX FILE
Offset
00 30 00
(hhh mm ss)
Time resolution
01 00 00
(hh mm ss)
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP

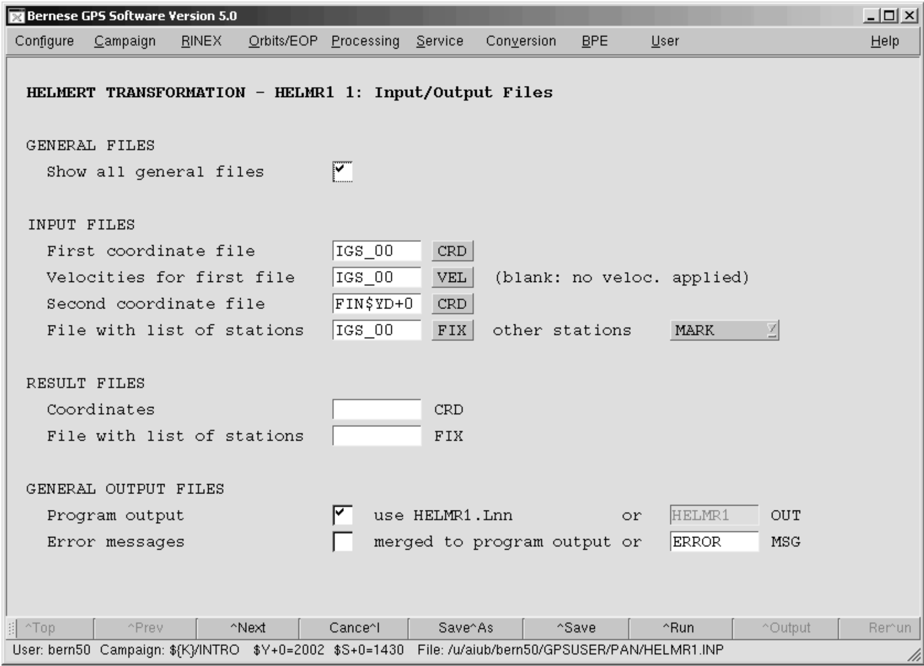
The ADDNEQ2 program output starts with some information about the parameters contained in the input NQ0–file(s). The input options for the program run follow. An important part is the statistics for the current ADDNEQ2 solution:

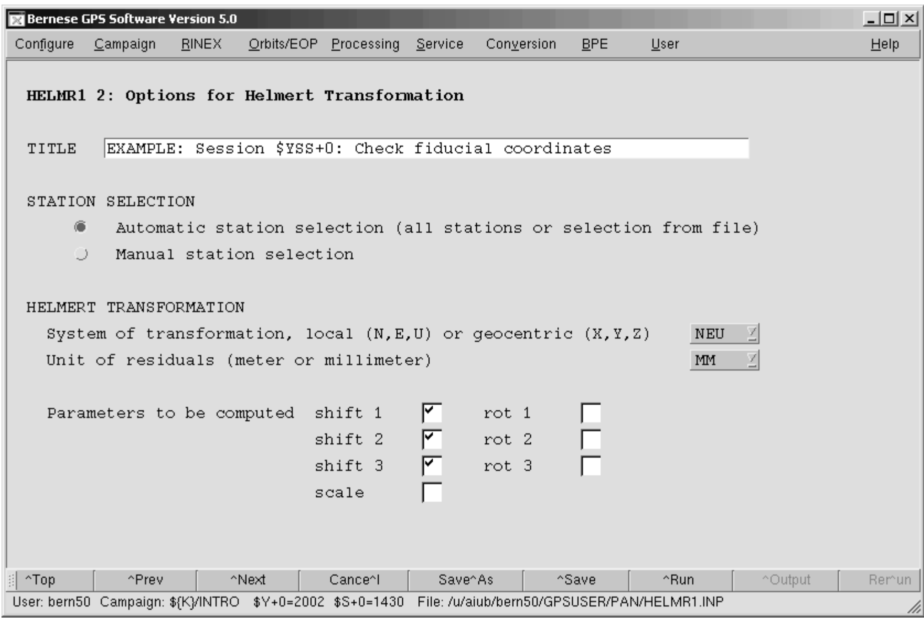
```
...
SUMMARY OF RESULTS
------------------

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

Parameter type                              Adjusted   explicitly / implicitly (pre-eliminated) ...
------------------------------------------------------------------------------------------------ ...
Station coordinates / velocities                  24           24            0                  ...
Site-specific troposphere parameters             223          223            0                  ...
------------------------------------------------------------------------------------------------ ...
Previously pre-eliminated parameters             109                       109
------------------------------------------------------------------------------------------------ ...
Total number                                     356          247          109                  ...


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

Total number of explicit parameters            247
Total number of implicit parameters            109

Total number of adjusted parameters            356
Total number of observations                 20418
Degree of freedom (DOF)                      20062

A posteriori RMS of unit weight            0.00114 m
Chi**2/DOF                                    1.30
...
```

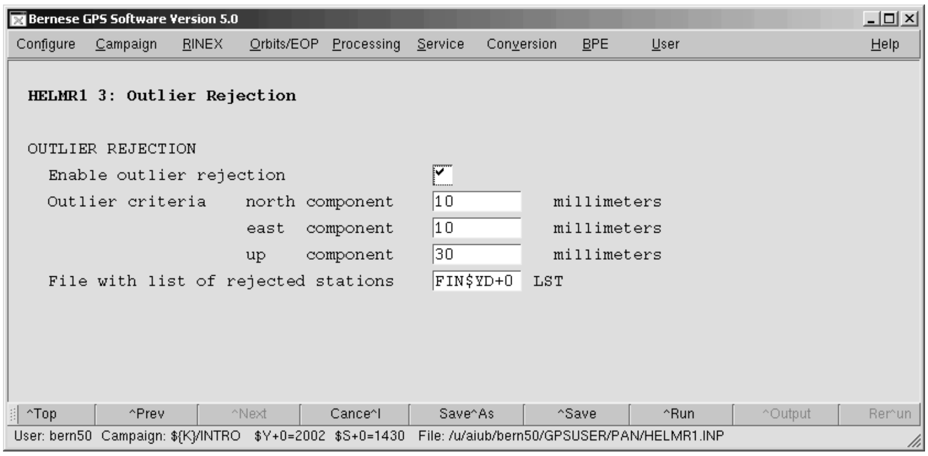
Below this part the program output reports the results of the parameter estimation in a standard format for all parameter types:

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

Sol Station name         Typ Correction Estimated value  RMS error  A priori value   Unit    ...
-------------------------------------------------------------------------------------------- ...
  1 BRUS 13101M004         X     0.0141     4027893.7914     0.0011     4027893.7773 meters  ...
  1 BRUS 13101M004         Y     0.0051      307045.7812     0.0004      307045.7761 meters  ...
  1 BRUS 13101M004         Z     0.0059     4919475.0868     0.0013     4919475.0809 meters  ...
  1 FFMJ 14279M001         X     0.0141     4053455.9147     0.0009     4053455.9006 meters  ...
    ...

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

Station name         Typ     Correction Estimated value  RMS error  A priori value   Unit    ...
-------------------------------------------------------------------------------------------- ...
BRUS 13101M004         N        -0.0001          -0.0001     0.0001           0.0000 meters  ...
BRUS 13101M004         E         0.0006           0.0006     0.0001           0.0000 meters  ...
BRUS 13101M004         U         0.1278           2.3945     0.0024           2.2667 meters  ...
...
```

The coordinate solution for the session (`${K}/INTRO/STA/FIN02143.CRD`) may be compared with the a priori coordinates for the IGS core sites. The program HELMR1 ("Menu>Service >Coordinate tools>Helmert transformation") may be 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. Only the residuals for those sites are printed to the program output.

```
===============================================================================
Program : HELMR1                                 Bernese GPS Software Version 5.0
Purpose : Helmert Transformation
Campaign: ${K}/INTRO                             Default session: 1430 year 2002
Date    : 13-Feb-2007 14:49                      User name      : bern50
===============================================================================


EXAMPLE: Session 021430: Check fiducial coordinates
-------------------------------------------------------------------------------


FILE 1: IGS00 COORDINATES BASED ON IGS01P37_RS54.SNX
FILE 2: EXAMPLE: Session 021430: Final coordinate/troposphere results

LOCAL GEODETIC DATUM: IGS00
RESIDUALS IN LOCAL SYSTEM (NORTH, EAST, UP)



---------------------------------------------------------------------
| NUM |      NAME        | FLG |     RESIDUALS IN MILLIMETERS   |   |
---------------------------------------------------------------------
|     |                  |     |                                |   |
|   6 | BRUS 13101M004   | P A |      6.5      -9.9     -14.6 | M |
|  15 | FFMJ 14279M001   | P A |      7.2      -2.4     -12.3 | M |
|  36 | MATE 12734M008   | I W |      0.3       2.0      -6.3 |   |
|  42 | ONSA 10402M004   | I W |      0.5      -0.0      -6.0 |   |
|  47 | PTBB 14234M001   | P A |      4.4      -4.7     -22.4 | M |
|  56 | VILL 13406M001   | I W |     -0.8      -1.9      12.3 |   |
|  63 | ZIMJ 14001M006   | P A |      6.9      -4.9     -20.3 | M |
|  64 | ZIMM 14001M004   | P A |      6.0      -4.2     -12.1 | M |
|     |                  |     |                                |   |
---------------------------------------------------------------------
|     | RMS / COMPONENT  |     |      0.7       2.0      10.6 |   |
---------------------------------------------------------------------
...
```

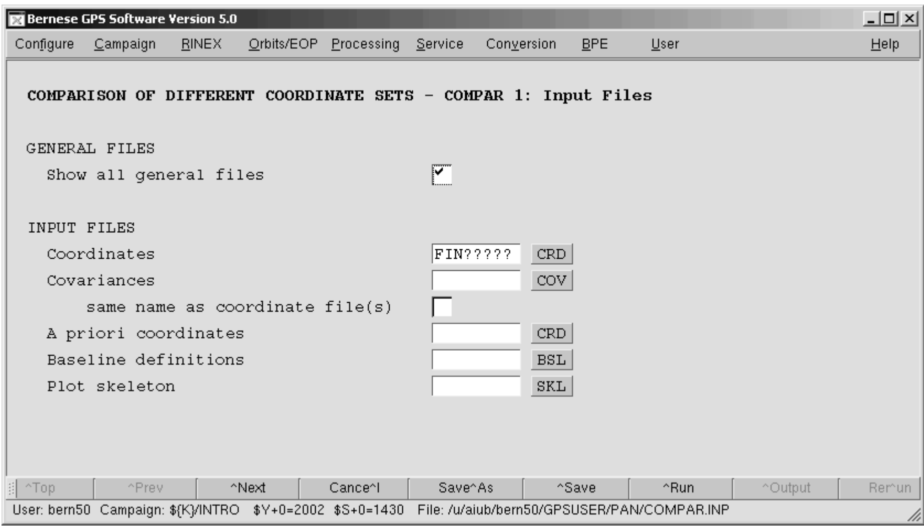
```
...
NUMBER OF PARAMETERS  :     3
NUMBER OF COORDINATES :     9
RMS OF TRANSFORMATION :     6.3 MM

BARYCENTER COORDINATES:

LATITUDE              :    46 31 17.52
LONGITUDE             :     7 50  4.94
HEIGHT                :         -99.634 KM


PARAMETERS:

TRANSLATION IN  N     :          0.0     +-  3.6    MM
TRANSLATION IN  E     :         -0.0     +-  3.6    MM
TRANSLATION IN  U     :         -0.0     +-  3.6    MM


NUMBER OF ITERATIONS  :     1



NO OUTLIER DETECTED
```

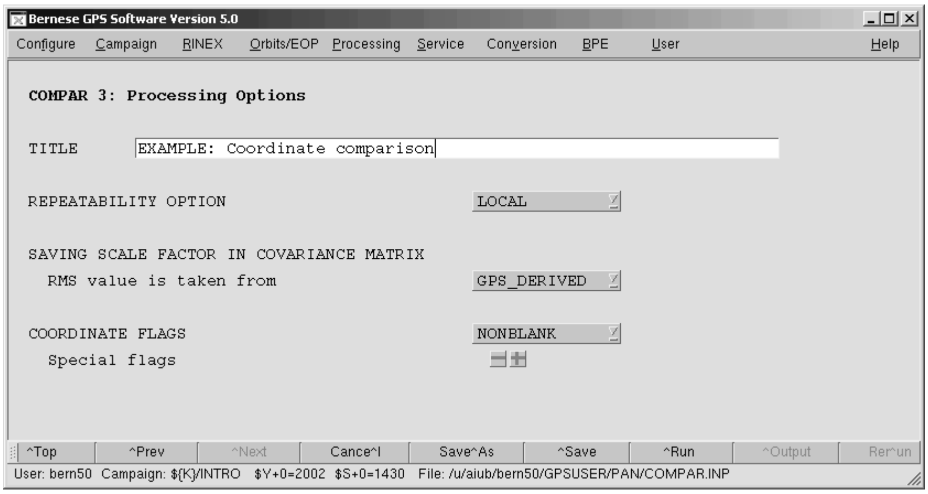
We can conclude that no problems concerning the stations used for the datum definition were detected.

If there were problems, the ADDNEQ2–run needs to be repeated with the problematic station either removed from the file `${K}/INTRO/STA/IGS_00.FIX` or with manual selection of the stations used for the datum definition in panel "ADDNEQ2 5.1: Datum Definition for Station Coordinates".

5.3 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 is reported in the following section of the program output:

```
NUM  STATION         #FIL C   RMS     1     2     3     4
---------------------------------------------------------
  6  BRUS 13101M004    4  N   11.6  -10.5  -9.4   8.9  11.1
                          E   10.7   -9.8  -8.6   9.5   8.9
                          U    4.1    2.9   2.5   0.6  -6.0

 15  FFMJ 14279M001    4  N    7.2   -6.5  -6.0   5.8   6.7
                          E   10.3   -8.9  -8.8   8.8   9.0
                          U    2.1   -0.2  -2.8   2.2   0.8

 36  MATE 12734M008    4  N   10.6   -8.2 -10.2   9.5   8.8
                          E   13.3  -12.2 -10.8  10.7  12.3
                          U    2.5    3.6  -1.4  -2.0  -0.2

 42  ONSA 10402M004    4  N    7.3   -6.2  -6.4   6.3   6.3
                          E   10.2   -9.2  -8.6   8.7   9.1
                          U    2.2   -3.2   1.1   1.6   0.5

 47  PTBB 14234M001    4  N    9.0   -7.5  -8.1   6.6   8.9
                          E   11.3  -10.2  -9.4   9.6  10.0
                          U    3.1    2.1   2.9  -1.2  -3.8

 56  VILL 13406M001    4  N    9.1   -8.2  -7.5   7.4   8.2
                          E   11.6   -9.2 -10.7  11.1   8.8
                          U    0.6   -0.3   1.0  -0.3  -0.3

 63  ZIMJ 14001M006    4  N    9.3   -7.6  -8.5   8.3   7.8
                          E   11.1   -9.9  -9.2   9.4   9.8
                          U    2.1    2.3  -0.4   0.8  -2.7

 64  ZIMM 14001M004    4  N    9.1   -7.4  -8.4   8.1   7.6
                          E   11.4  -10.0  -9.9   9.8  10.0
                          U    2.0    0.9  -2.5   2.0  -0.4
```

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 considered (this will be done in the next step, Section 5.5).

This output may be used to identify problematic daily solutions for individual sessions. They may be excluded from the final ADDNEQ2–solution by listing them in section `TYPE 3: STATION PROBLEMS` in the station information file (`${K}/INTRO/STA/EXAMPLE.STA`). All parameters of this station will be pre–eliminated before the normal equations are stacked and, therefore, also before the solution is computed.

5.4 Compute the Final Solution of the Session

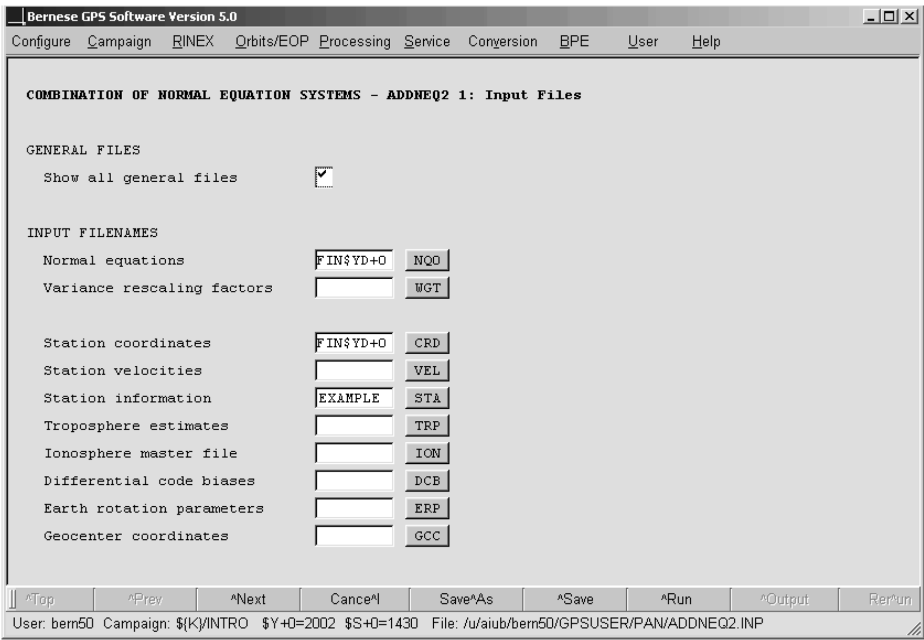
If one or more stations have to be excluded from the session solution or if the datum definition of the solution is still not acceptable, the final solution of the session has to be re–computed. Repeat the execution of ADDNEQ2 corresponding to Section 5.2. Finally, the result files for the final solution of the session are:

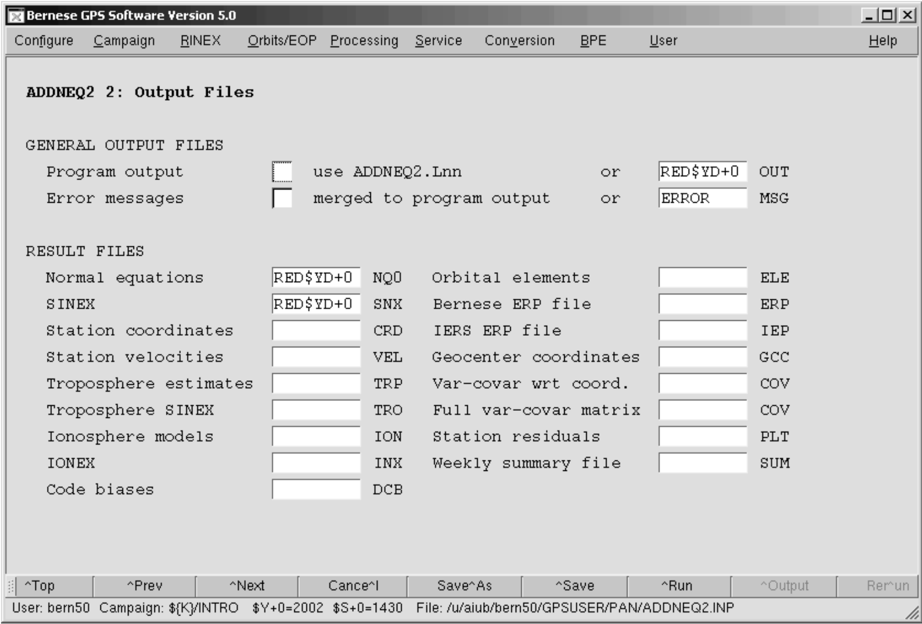
`${K}/INTRO/SOL/FIN$YD+0.NQ0`,
`${K}/INTRO/STA/FIN$YD+0.CRD`, and
`${K}/INTRO/ATM/FIN$YD+0.TRP`.

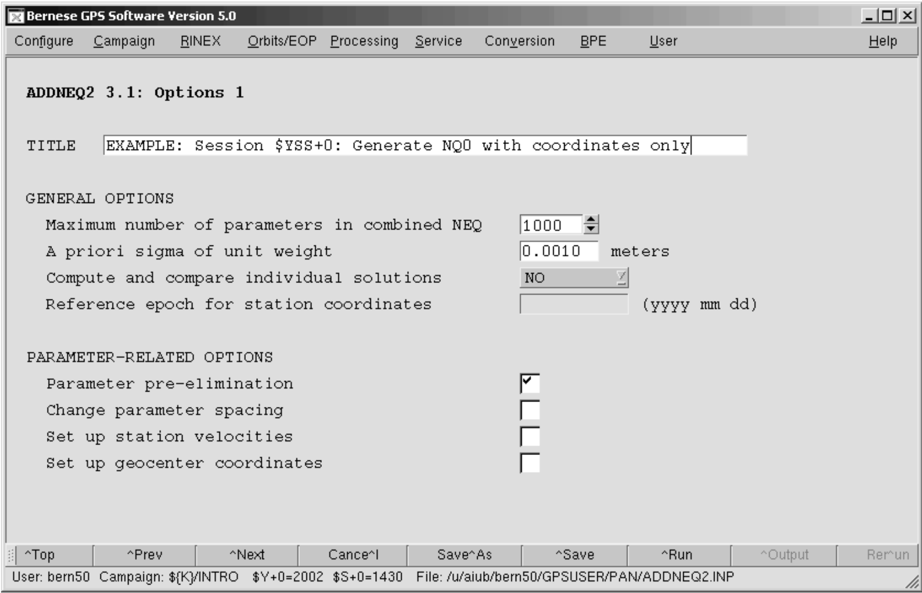
A troposphere SINEX file may be generated in the final solution by adding an output filename to the "Troposphere SINEX" input field in panel "ADDNEQ2 2: Output Files".

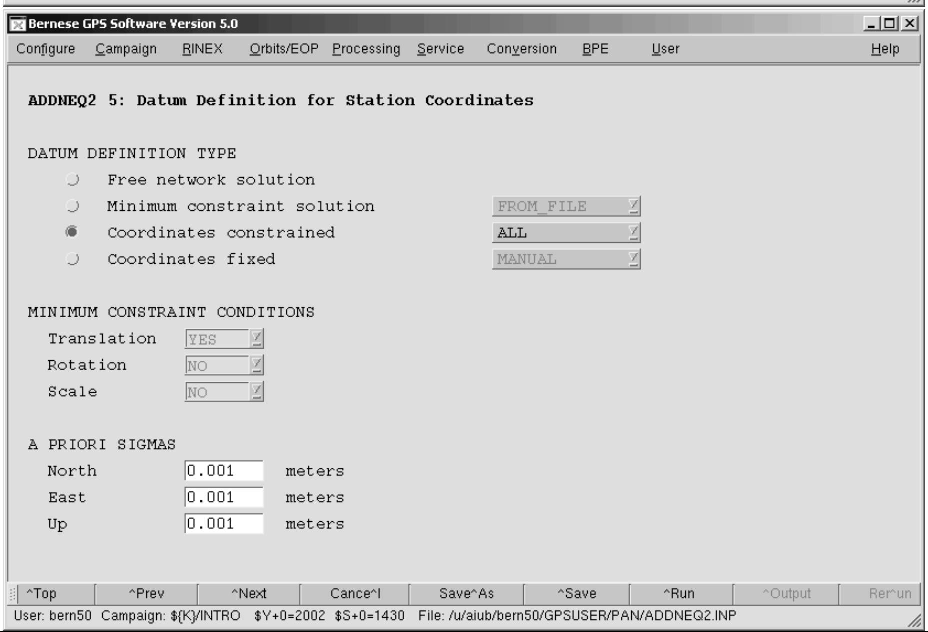
It is preferable for the velocity estimation to have smaller normal equation files containing only the coordinate parameters for each session. In addition, in order to generate a coordinate SINEX file as the final solution of the day, the troposphere parameters have to be pre–eliminated before the solution is computed. To avoid singularities when writing the SINEX file all station coordinates have to be constrained. We introduce the station coordinates (`${K}/INTRO/STA/FIN$YD+0.CRD`) obtained with the minimum constraint solution in the previous run of ADDNEQ2 and constrain the solution to these coordinates.

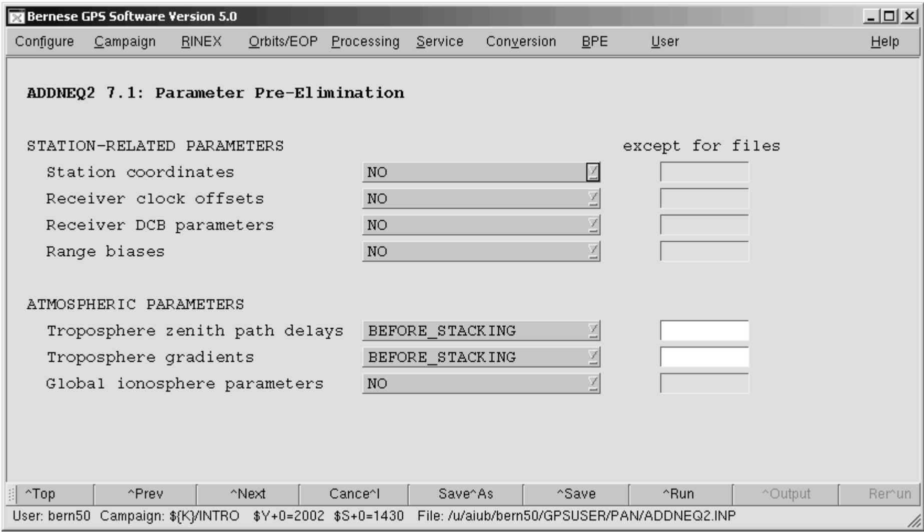
To generate these reduced `NQ0`–files and the SINEX–file the execution of ADDNEQ2 has to be repeated with the following changes in the input options:




Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 2: Output Files
GENERAL OUTPUT FILES
Program output use ADDNEQ2.Lnn or RED$YD+0 OUT
Error messages merged to program output or ERROR MSG
RESULT FILES
Normal equations RED$YD+0 NQ0
SINEX RED$YD+0 SNX
Station coordinates CRD
Station velocities VEL
Troposphere estimates TRP
Troposphere SINEX TRO
Ionosphere models ION
IONEX INX
Code biases DCB
Orbital elements ELE
Bernese ERP file ERP
IERS ERP file IEP
Geocenter coordinates GCC
Var-covar wrt coord. COV
Full var-covar matrix COV
Station residuals PLT
Weekly summary file SUM
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 3.1: Options 1
TITLE EXAMPLE: Session $YSS+0: Generate NQ0 with coordinates only
GENERAL OPTIONS
Maximum number of parameters in combined NEQ 1000
A priori sigma of unit weight 0.0010 meters
Compute and compare individual solutions NO
Reference epoch for station coordinates (yyyy mm dd)
PARAMETER-RELATED OPTIONS
Parameter pre-elimination
Change parameter spacing
Set up station velocities
Set up geocenter coordinates
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 5: Datum Definition for Station Coordinates
DATUM DEFINITION TYPE
Free network solution
Minimum constraint solution FROM_FILE
Coordinates constrained ALL
Coordinates fixed MANUAL
MINIMUM CONSTRAINT CONDITIONS
Translation YES
Rotation NO
Scale NO
A PRIORI SIGMAS
North 0.001 meters
East 0.001 meters
Up 0.001 meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP



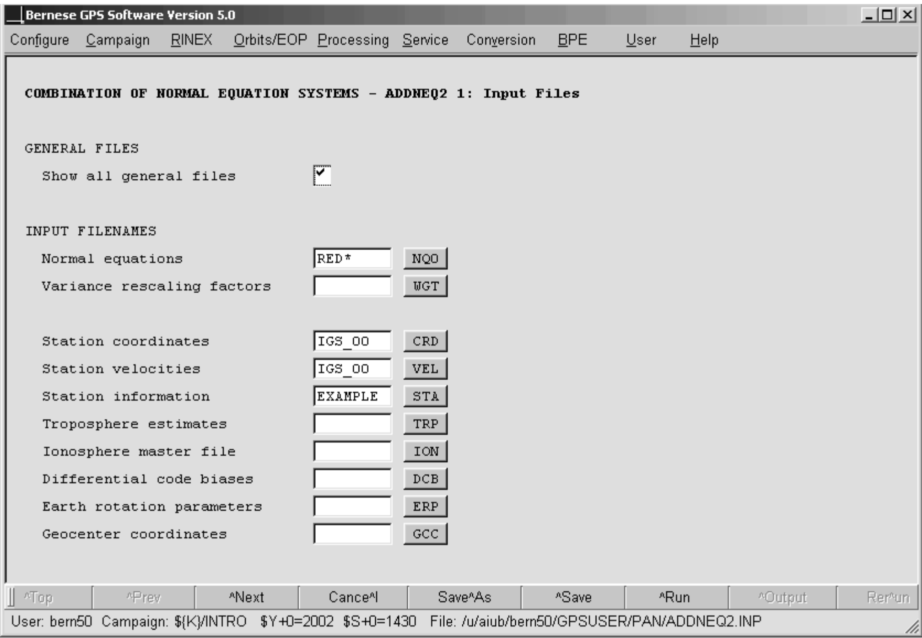
The normal equation file (`${K}/INTRO/SOL/RED02143.NQ0`) contains only the station coordinate parameters. The following section of the program output documents the pre–elimination of the troposphere parameters:

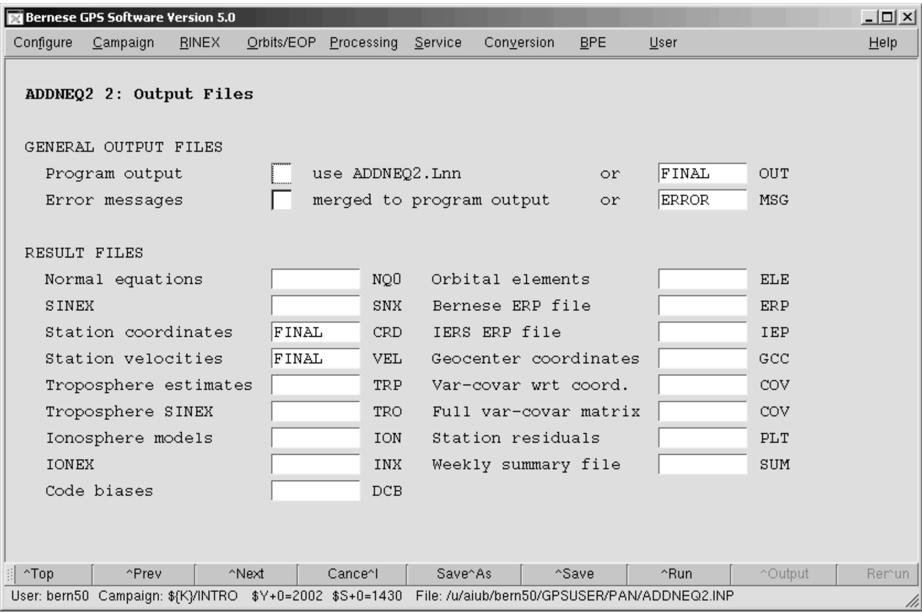
```
...
SUMMARY OF RESULTS
------------------

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

Parameter type                                  Adjusted   explicitly / implicitly (pre-eliminated) ...
---------------------------------------------------------------------------------------------------- ...
Station coordinates / velocities                     24           24            0                    ...
Site-specific troposphere parameters                223            0          223  (before stacking)...
---------------------------------------------------------------------------------------------------- ...
Previously pre-eliminated parameters                109                       109
---------------------------------------------------------------------------------------------------- ...
Total number                                        356           24          332                    ...


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

Total number of explicit parameters              24
Total number of implicit parameters             332

Total number of adjusted parameters             356
Total number of observations                  20418
Degree of freedom (DOF)                       20062

A posteriori RMS of unit weight             0.00114 m
Chi**2/DOF                                     1.30
...
```

You can also see that the number of parameters in the `NQ0`–file was dramatically reduced. This is an advantage for the combination of a big number of normal equation files for the estimation of station velocities.

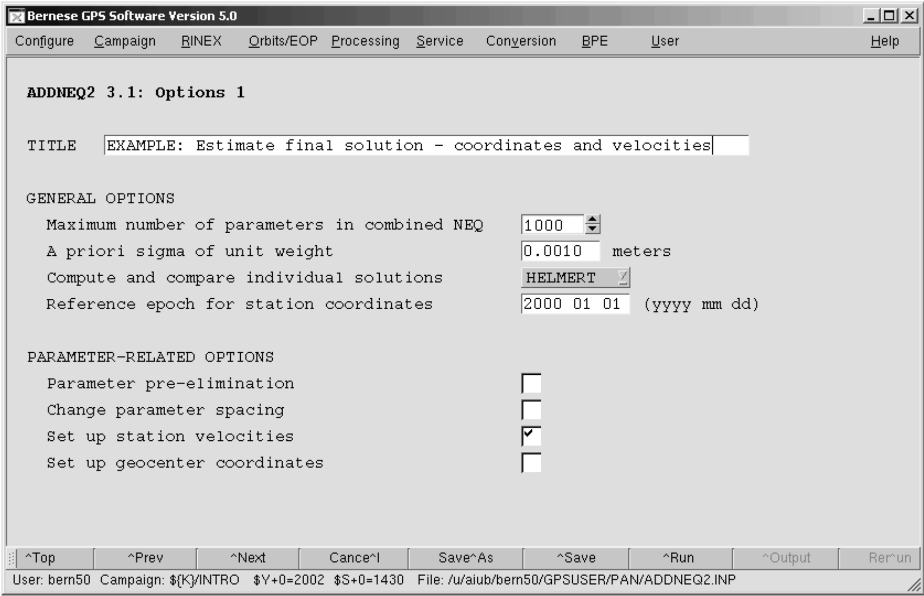
5.5 Velocity Estimation

The velocity estimation in program ADDNEQ2 is easy. Introduce the normal equation files containing only the station coordinate parameters. The normal equation files have to cover a reasonable time interval to reliably estimate velocities (in this case one year):

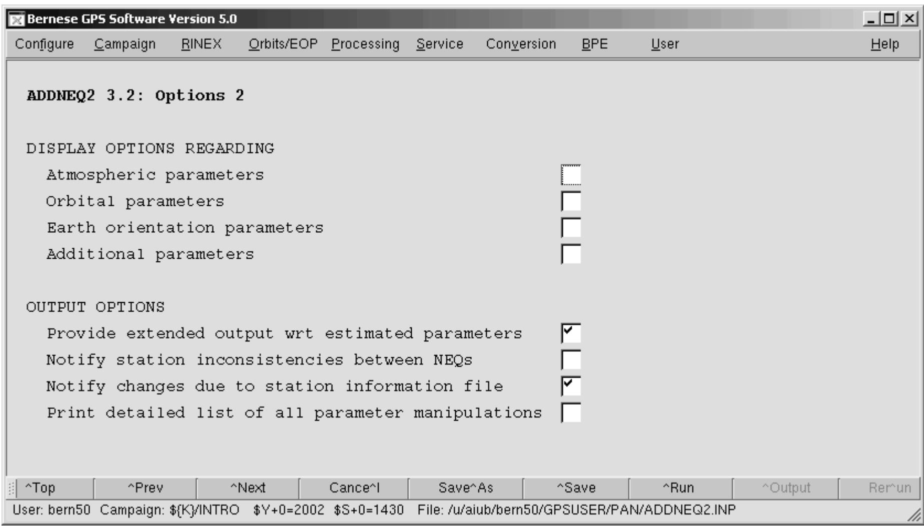




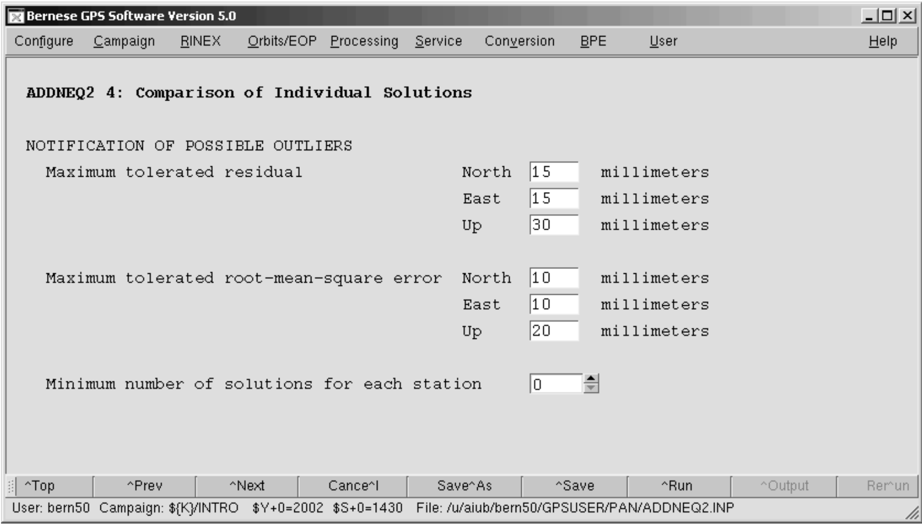
Station velocities are set up by marking the checkbox:



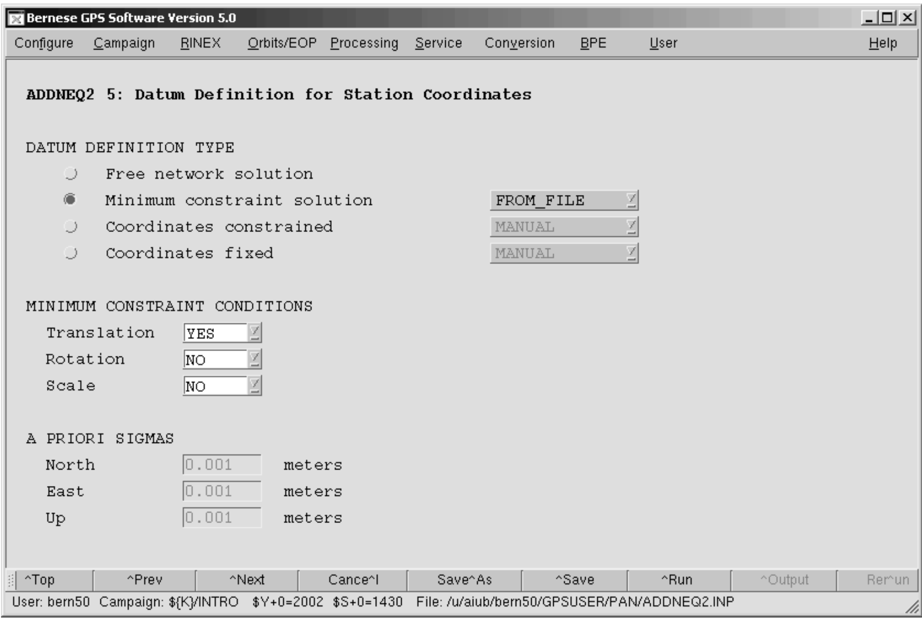
Furthermore we check the repeatability of the daily solutions after the velocity estimation. The coordinates in the resulting file will refer to the epoch 2000 01 01.

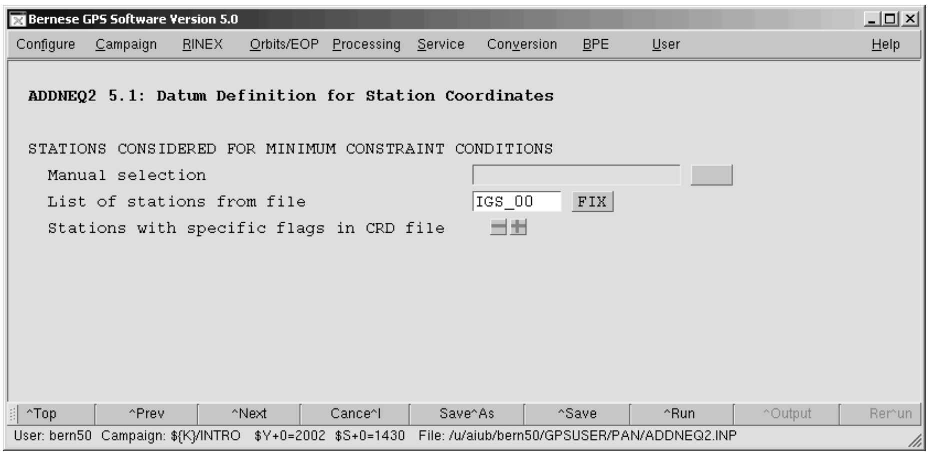


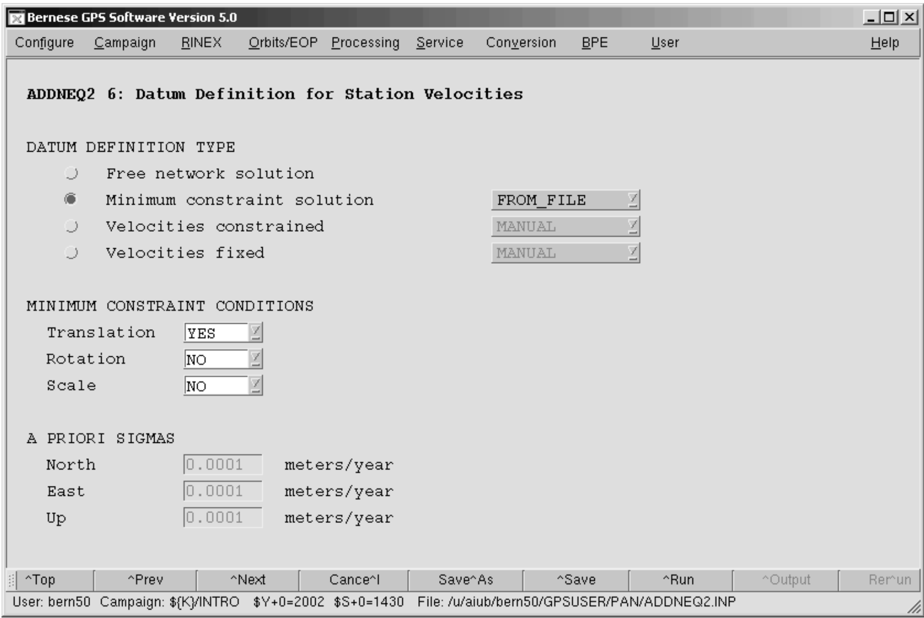
The following panel provides options to detect bad daily solutions based on the repeatability:

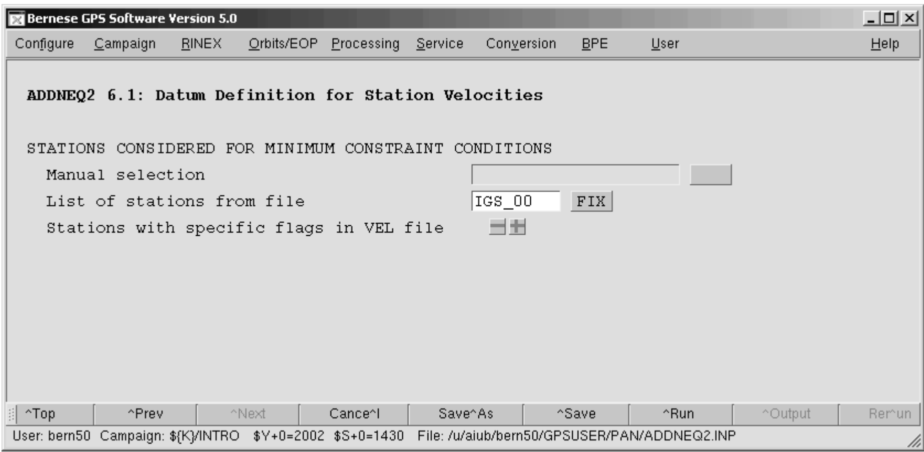


The realization of the geodetic datum is done for positions and velocities separately in the following panels:




Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 5.1: Datum Definition for Station Coordinates
STATIONS CONSIDERED FOR MINIMUM CONSTRAINT CONDITIONS
Manual selection
List of stations from file
IGS_00
FIX
Stations with specific flags in CRD file
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 6: Datum Definition for Station Velocities
DATUM DEFINITION TYPE
Free network solution
Minimum constraint solution
FROM_FILE
Velocities constrained
MANUAL
Velocities fixed
MANUAL
MINIMUM CONSTRAINT CONDITIONS
Translation
YES
Rotation
NO
Scale
NO
A PRIORI SIGMAS
North
0.0001
meters/year
East
0.0001
meters/year
Up
0.0001
meters/year
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
ADDNEQ2 6.1: Datum Definition for Station Velocities
STATIONS CONSIDERED FOR MINIMUM CONSTRAINT CONDITIONS
Manual selection
List of stations from file
IGS_00
FIX
Stations with specific flags in VEL file
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/ADDNEQ2.INP

After the velocity estimation the repeatability of the coordinates solutions from the individual normal equations looks like:

```
...
Comparison of Individual Solutions:
----------------------------------

BRUS N    0.59     -0.47    0.47   -0.56    0.52
BRUS E    0.31     -0.29    0.36    0.20   -0.18
BRUS U    1.53      0.62   -0.58    1.80   -1.75

FFMJ N    0.27     -0.32    0.34    0.00    0.02
FFMJ E    0.26      0.33   -0.32    0.01    0.00
FFMJ U    0.95      0.99   -1.14   -0.48    0.44

MATE N    0.03      0.02    0.01    0.04    0.01
MATE E    0.58     -0.32    0.35   -0.64    0.60
MATE U    0.63     -0.61    0.72   -0.35    0.42

ONSA N    0.76      0.19   -0.27    0.90   -0.90
ONSA E    0.38      0.23   -0.25    0.40   -0.39
ONSA U    1.34     -1.04    1.30   -1.10    1.19

PTBB N    0.55      0.29   -0.32   -0.60    0.60
PTBB E    0.16      0.12   -0.11    0.17   -0.16
PTBB U    0.32     -0.49    0.27    0.01   -0.05

VILL N    0.54     -0.33    0.28   -0.60    0.56
VILL E    0.31      0.05   -0.10    0.36   -0.39
VILL U    1.13     -0.90    1.00   -0.98    1.04

ZIMJ N    0.43      0.36   -0.16    0.47   -0.43
ZIMJ E    0.23     -0.19    0.12   -0.23    0.23
ZIMJ U    0.83      0.60   -0.56    0.77   -0.89

ZIMM N    0.44      0.25   -0.34    0.43   -0.46
ZIMM E    0.17      0.17   -0.13   -0.13    0.15
ZIMM U    0.81      0.83   -1.01    0.34   -0.40
```

Below this table all bad daily solutions according to the settings in panel "ADDNEQ2 4: Comparison of Individual Solutions" are summarized. if bad daily solution are detected. In that case we have no additional section and, therefore, no outliers.

If you compare the velocities obtained for the two GPS receivers in Zimmerwald (ZIMJ and ZIMM) you will find small differences:

```
...
Station coordinates and velocities:
----------------------------------
Reference epoch: 2000-01-01 00:00:00

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

ZIMJ 14001M006        VX          -0.0129           -0.0156       -0.0027      0.0011
                      VY           0.0182            0.0175       -0.0007      0.0004
                      VZ           0.0098            0.0099        0.0001      0.0011

                      VU           0.0000           -0.0018       -0.0019      0.0015      ...
                      VN           0.0143            0.0164        0.0021      0.0004      ...
                      VE           0.0197            0.0194       -0.0003      0.0003      ...
...

ZIMM 14001M004        VX          -0.0129           -0.0131       -0.0002      0.0010
                      VY           0.0182            0.0185        0.0003      0.0004
                      VZ           0.0098            0.0120        0.0022      0.0011

                      VU           0.0000            0.0015        0.0015      0.0014      ...
                      VN           0.0143            0.0159        0.0016      0.0004      ...
                      VE           0.0197            0.0201        0.0004      0.0003      ...
...
```

You may constrain the velocity estimates for a pair of sites in the station information file. Copy the original station information file `${K}/INTRO/STA/EXAMPLE.STA` and add the following line to this copy

```
TYPE 004: STATION COORDINATES AND VELOCITIES (ADDNEQ)
-----------------------------------------------------
                                            RELATIVE CONSTR. POSITION     RELATIVE CONSTR. VELOCITY
STATION NAME 1        STATION NAME 2        NORTH     EAST      UP        NORTH     EAST      UP
****************      ****************      **.*****  **.*****  **.*****  **.*****  **.*****  **.*****
ZIMM 14001M004        ZIMJ 14001M006                                       0.00001   0.00001   0.00001
```

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

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

```
...
Station coordinates and velocities:
----------------------------------
Reference epoch: 2000-01-01 00:00:00

Station name          Typ     A priori value    Estimated value  Correction   RMS error      ...
---------------------------------------------------------------------------------------------  ...
...
ZIMJ 14001M006        VX           -0.0129            -0.0143       -0.0014      0.0009
                      VY            0.0182             0.0181       -0.0001      0.0003
                      VZ            0.0098             0.0110        0.0012      0.0009

                      VU            0.0000            -0.0000       -0.0001      0.0012      ...
                      VN            0.0143             0.0162        0.0019      0.0003      ...
                      VE            0.0197             0.0198        0.0001      0.0003      ...
...
ZIMM 14001M004        VX           -0.0129            -0.0143       -0.0014      0.0009
                      VY            0.0182             0.0181       -0.0001      0.0003
                      VZ            0.0098             0.0110        0.0012      0.0009

                      VU            0.0000            -0.0000       -0.0001      0.0012      ...
                      VN            0.0143             0.0162        0.0019      0.0003      ...
                      VE            0.0197             0.0198        0.0001      0.0003      ...
...
```

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

```
EXAMPLE: Estimate final solution - coordinates and velocities    13-FEB-07 14:59
--------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS00             EPOCH: 2000-01-01  0:00:00

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

  6  BRUS 13101M004     4027893.8398    307045.7403   4919475.0665    A
 15  FFMJ 14279M001     4053455.9388    617729.5767   4869395.6460    A
 36  MATE 12734M008     4641949.6604   1393045.3349   4133287.3899    W
 42  ONSA 10402M004     3370658.6174    711877.0633   5349786.9038    W
 47  PTBB 14234M001     3844060.0446    709661.2309   5023129.5007    A
 56  VILL 13406M001     4849833.7491   -335049.1265   4116014.8656    W
 63  ZIMJ 14001M006     4331294.0075    567542.0461   4633135.6607    A
 64  ZIMM 14001M004     4331297.1406    567555.7889   4633133.8693    A
```

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

```
EXAMPLE: Estimate final solution - coordinates and velocities    13-FEB-07 14:59
--------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS00

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

  6  BRUS 13101M004          -0.0205         0.0173         0.0086    A    EURA
 15  FFMJ 14279M001          -0.0105         0.0167         0.0104    A    EURA
 36  MATE 12734M008          -0.0199         0.0184         0.0126    W    EURA
 42  ONSA 10402M004          -0.0130         0.0156         0.0088    W    EURA
 47  PTBB 14234M001          -0.0190         0.0167         0.0056    A    EURA
 56  VILL 13406M001          -0.0096         0.0208         0.0114    W    EURA
 63  ZIMJ 14001M006          -0.0143         0.0181         0.0110    A    EURA
 64  ZIMM 14001M004          -0.0143         0.0181         0.0110    A    EURA
```

5.6 Daily Goals

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

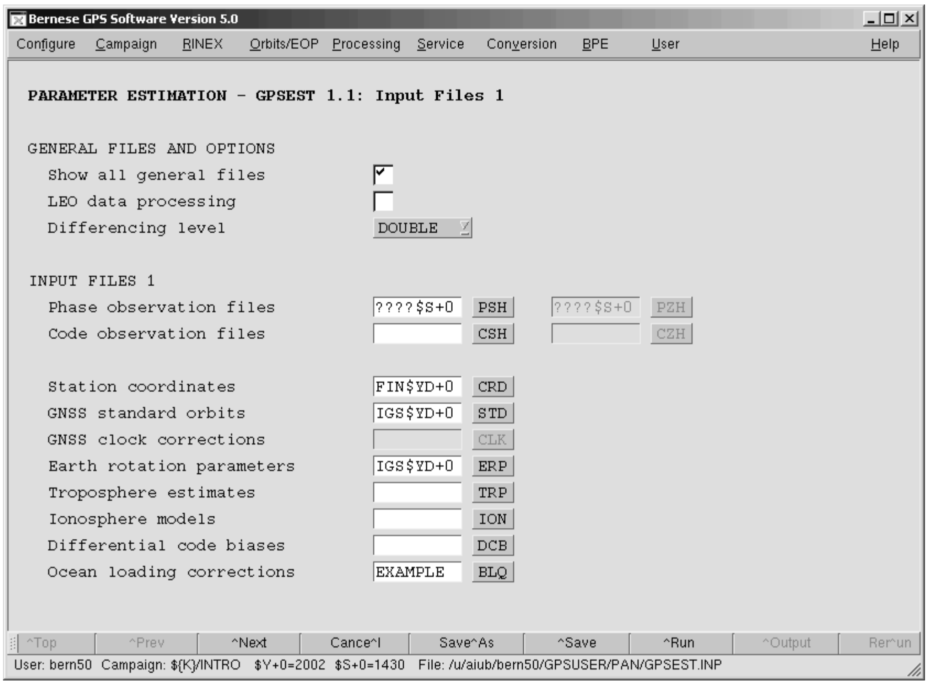
(1) *used* GPSEST *to compute a final solution of the day, created files:* `FIX02143.OUT`, `FIX02143.NQ0` *(for all sessions),*
(2) *checked the coordinates of the fiducial sites using* ADDNEQ2 *and* HELMR1*, created files:* `FIN02143.CRD`,`FIN02143.TRP`, `FIN02143.OUT`, *and* `HELMR1.OUT`,
(3) *used* COMPAR *to check the daily repeatabilities, created file* `COMPAR.OUT`,
(4) *used* ADDNEQ2 *to create a final session solution, and reduced size NQ0s, created file:* `RED02143.NQ0` *and* `RED02143.SNX`,
(5) *if possible, used* ADDNEQ2 *for velocity estimation, created files:* `FINAL.CRD` *and* `FINAL.VEL`.

6. Terminal Session: Friday

> *In the previous terminal sessions you have estimated coordinates, velocities, and troposphere parameters. This is the standard application of the* Bernese GPS Software *for most users.*
> *If you have finished this work you may compute some special solutions today according to your interest. This document provides some suggestions to practice:*
> - *kinematic positioning for a station,*
> - *zero–difference processing to estimate clocks, or*
> - *use of the Bernese Processing Engine.*

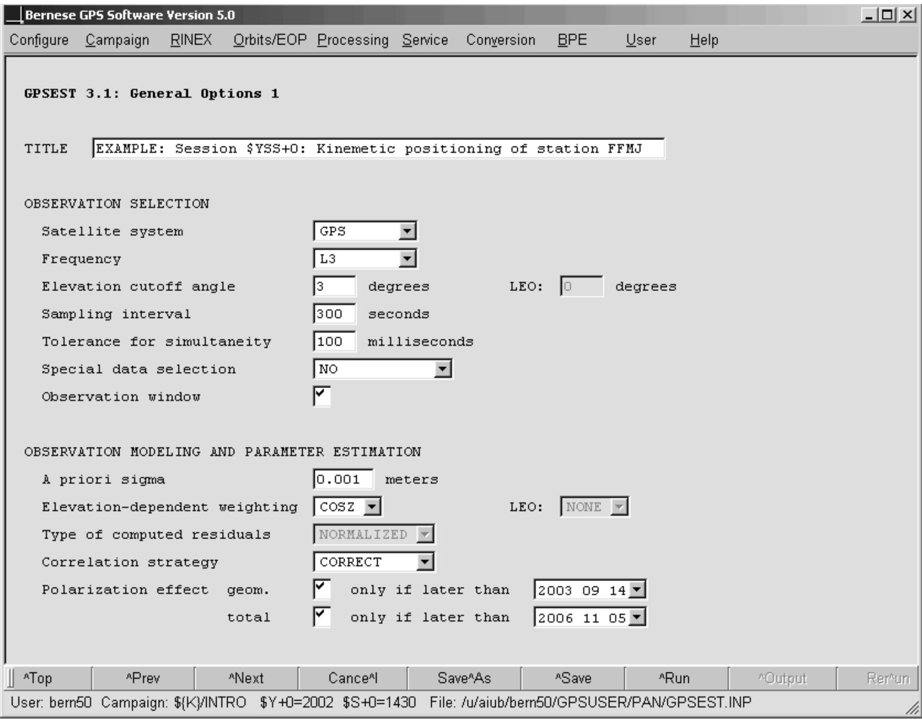
6.1 Kinematic Positioning

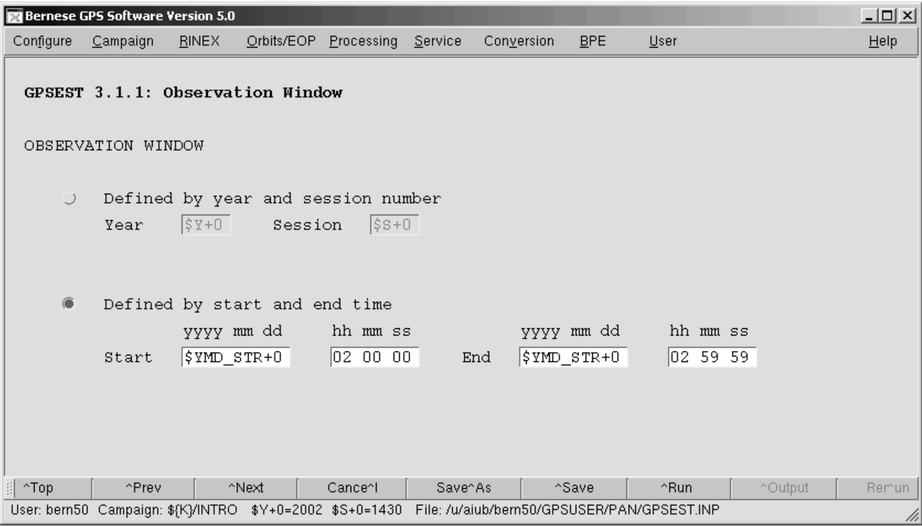
The example campaign contains no really roving stations. You can, however, define one of them to be kinematic (e.g., station FFMJ). Introduce the coordinates from the final solution (`${K}/INTRO/STA/FIN02143.CRD`) for all other sites.



Store the kinematic coordinates in an output file ("Kinematic coordinates" in panel "GPSEST 2.2: Output Files 2").

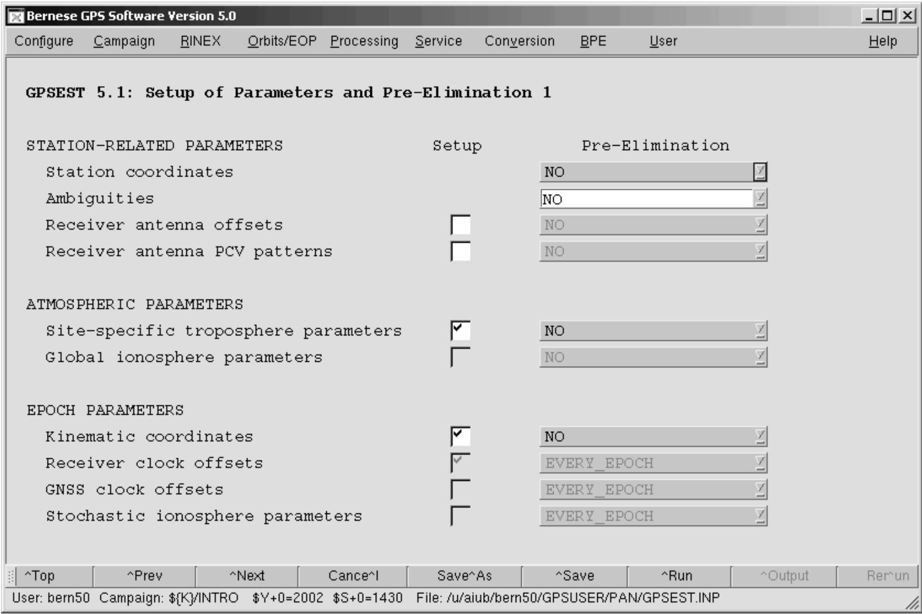
Because the number of parameters for the kinematic positioning may become very large we select only a short data interval for this kinematic positioning:



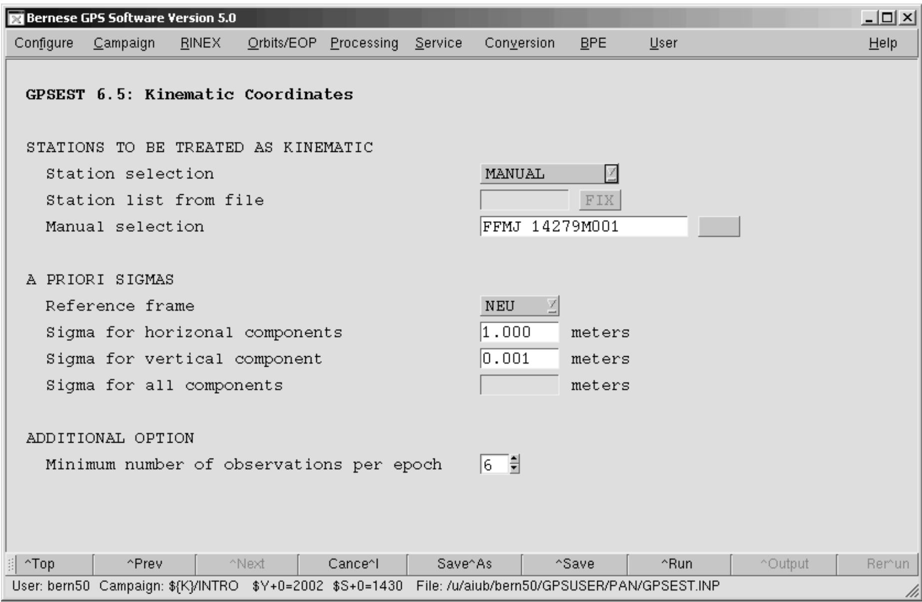


Fix all station coordinates apart from FFMJ in the panels "Datum Definitions for Stations" (choose MANUAL in panel "GPSEST 4" and select all stations except FFMJ in panel "GPSEST 4.2").

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



Let us assume only horizontal movements for this site:



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

```
KINEMATIC COORDINATES:                    ${K}/INTRO/STA/KIN02143.KIN
---------------------

 EPO: EPOCHS SINCE  2002-05-23 02:00:00  (SAMPLING   300 SEC)

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

       FFMJ 14279M001             50  5 26.079483     8 39 53.878597         178.1970
   1   52417.083333   21   FFMJ   -0.0297 +- 0.011   -0.0170 +- 0.007   -0.0001 +- 0.001         ...
   2   52417.086806   21   FFMJ   -0.0147 +- 0.009   -0.0047 +- 0.006   -0.0000 +- 0.001         ...
   3   52417.090278   22   FFMJ   -0.0040 +- 0.009   -0.0058 +- 0.006    0.0002 +- 0.001         ...
   4   52417.093750   23   FFMJ   -0.0020 +- 0.010   -0.0054 +- 0.007   -0.0001 +- 0.001         ...
   5   52417.097222   23   FFMJ   -0.0048 +- 0.012   -0.0014 +- 0.009   -0.0000 +- 0.001         ...
```

Further suggestions:

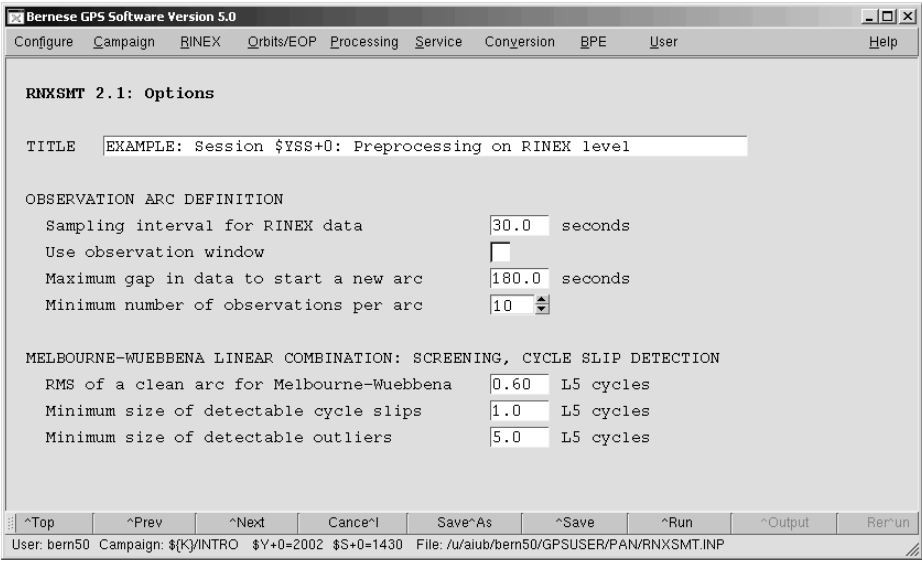
- Introduce the result file with kinematic coordinates as an input file for another run of GPSEST. If the estimates become zero it is a confirmation that the file was correctly considered as the a priori kinematic positions for the station FFMJ.
- Use the pre–elimination EVERY_EPOCH for the "Kinematic coordinates" (they are back–substituded 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 3.2: General Options 2" 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.
- You may also run the pre–processing programs CODSPP and MAUPRP for "kinematic stations".

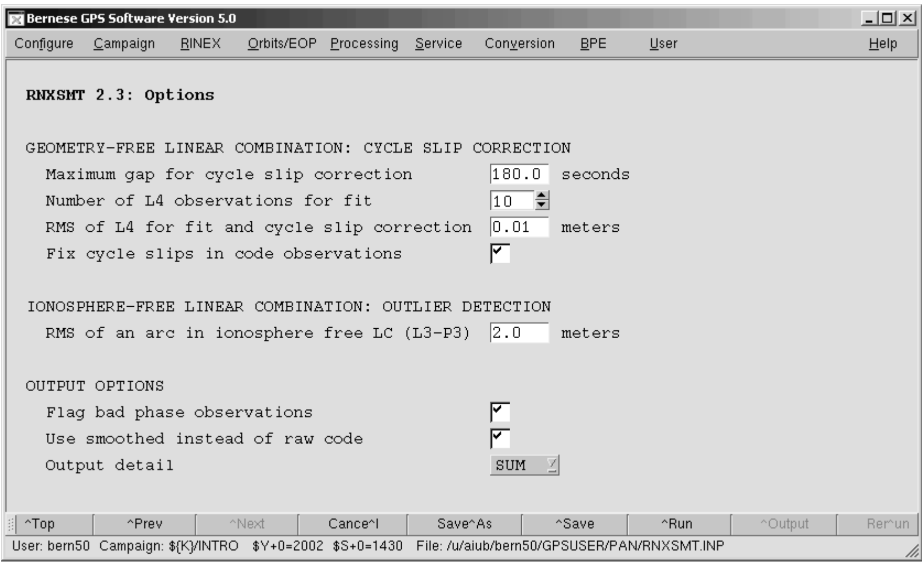
In addition you may use the *Bernese GPS Software* with zero–difference observations to obtain kinematic positions. Smoothed code, phase–only, or combined code and phase solutions are possible. Consult the following section on clock estimation for the preprocessing of zero–difference data. Compare the results you generate with the different observation types to get an impression on the accuracy that can be obtained.

6.2 Clock Estimation

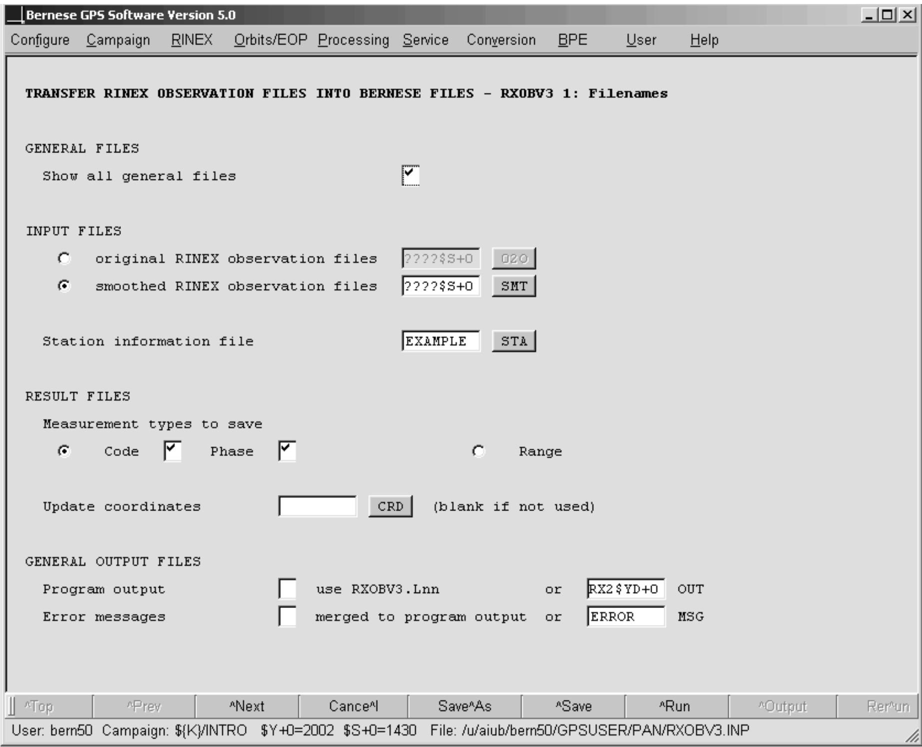
For the clock estimation we have to use code and phase data together. The data are analyzed at zero–difference level.

The preprocessing for zero–difference data starts with program RNXSMT, available in "Menu >RINEX>RINEX utilities>Clean/smooth observation files". In the first panel select all RINEX files of a session. The default input options perform well in most cases:



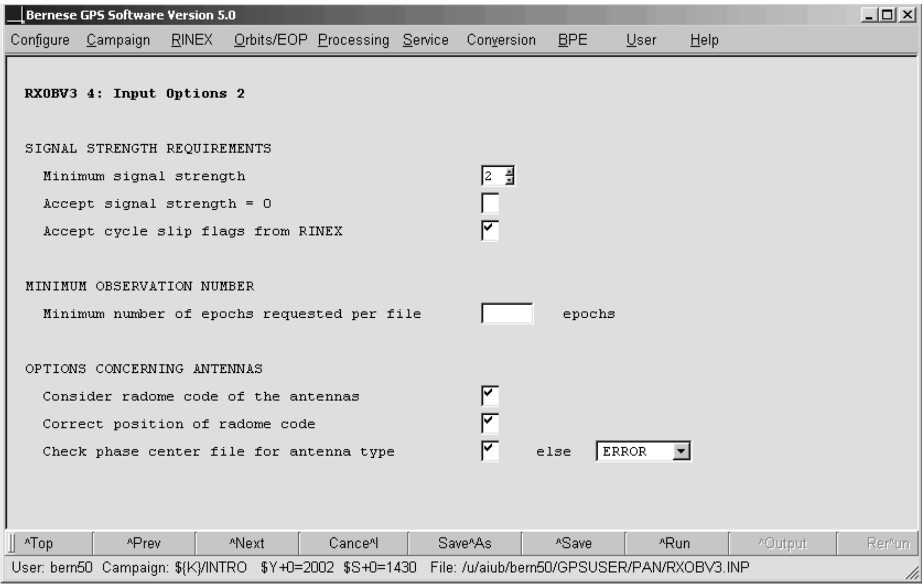


In order to import the smoothed RINEX observation files into the Bernese format you have to select them in the first input panel of program RXOBV3 (note that you will overwrite your zero–difference observation files from the previous processing example by doing this):



Because we want to compute clock values with a sampling of 5 min. only in GPSEST you can resample the observations already in RXOBV3: set the "Sampling interval" in panel "RXOBV3 2: Input Options 1" to 300 seconds.

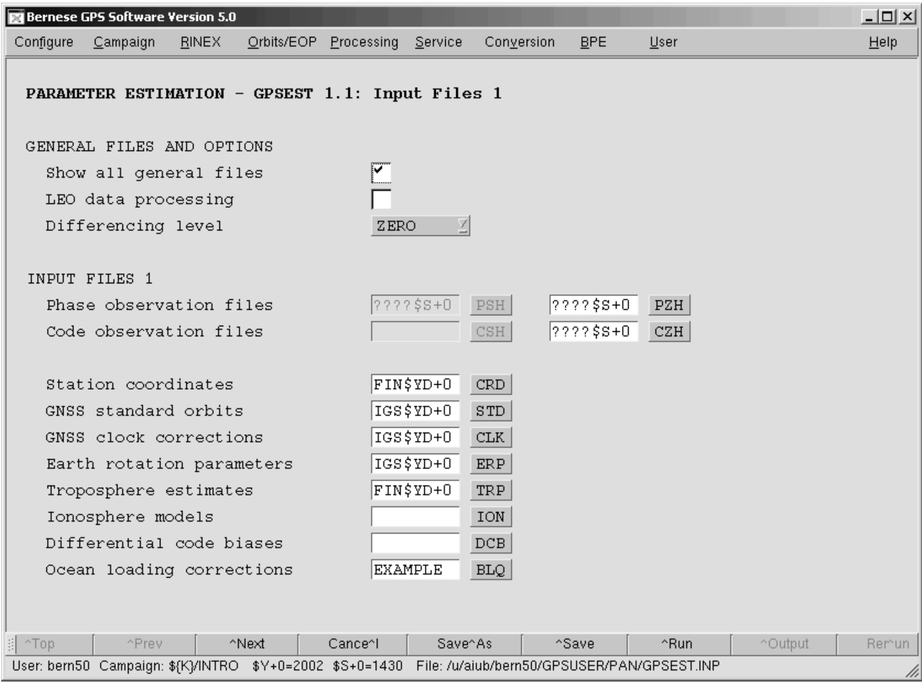
Furthermore you have to consider the "SIGNAL STRENGTH REQUIREMENTS" for smoothed RINEX files (see online help):

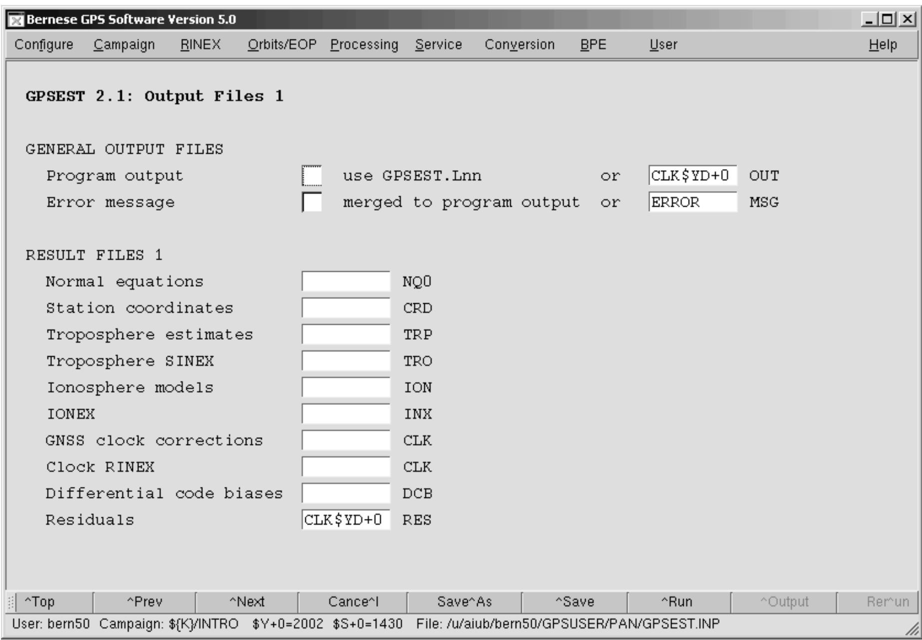


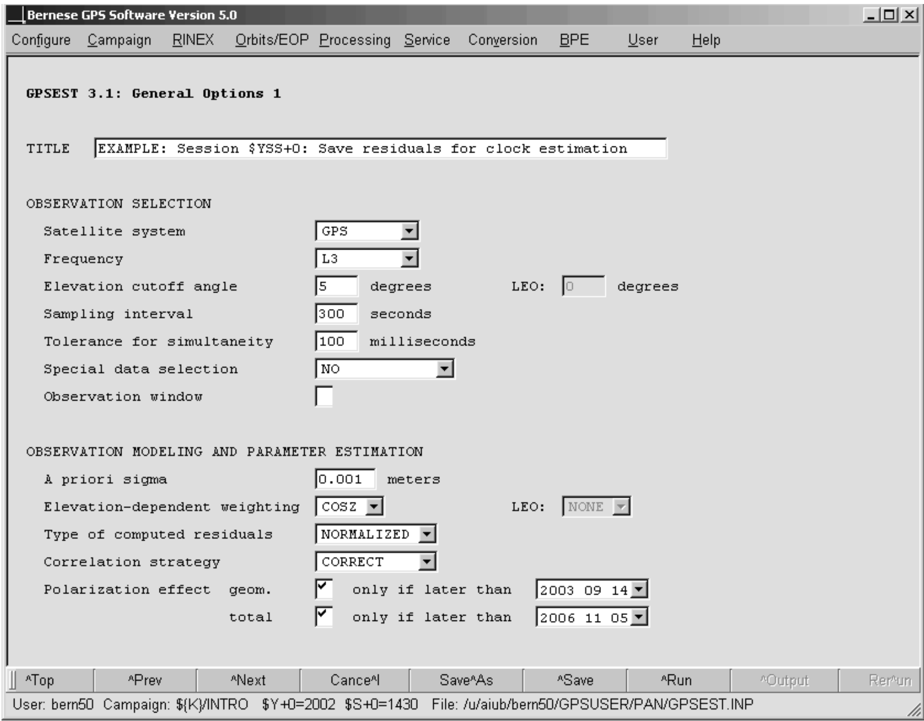
After importing the data into the Bernese format you have to repeat the receiver clock synchronization with program CODSPP. The options are identical to the settings in Section 3.3.1. The only difference is that we select CODE for the option "Mark outliers in obs.

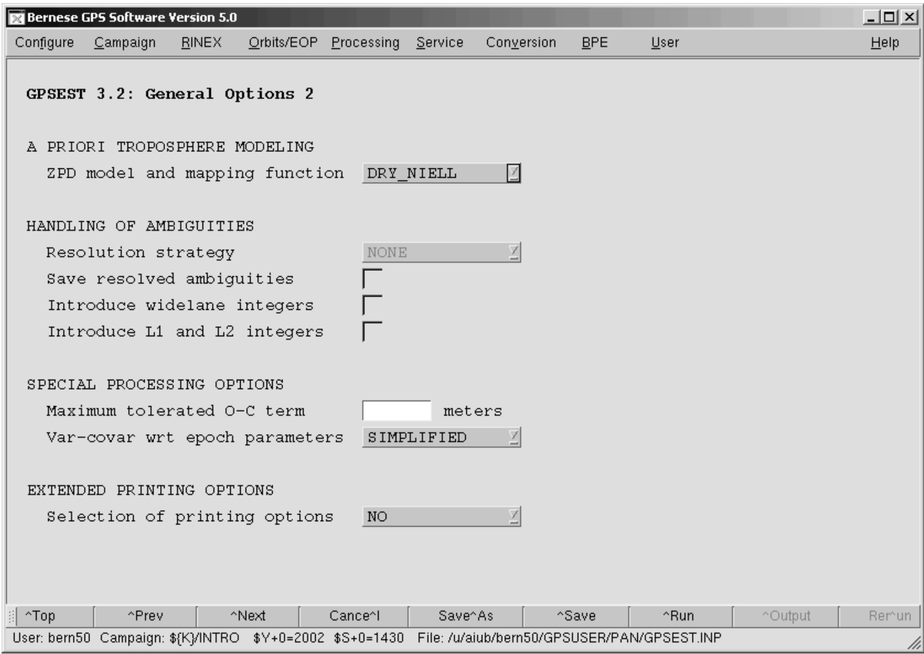
files" in the last input panel. In this way very bad code observations are excluded from the parameter estimation in program GPSEST.

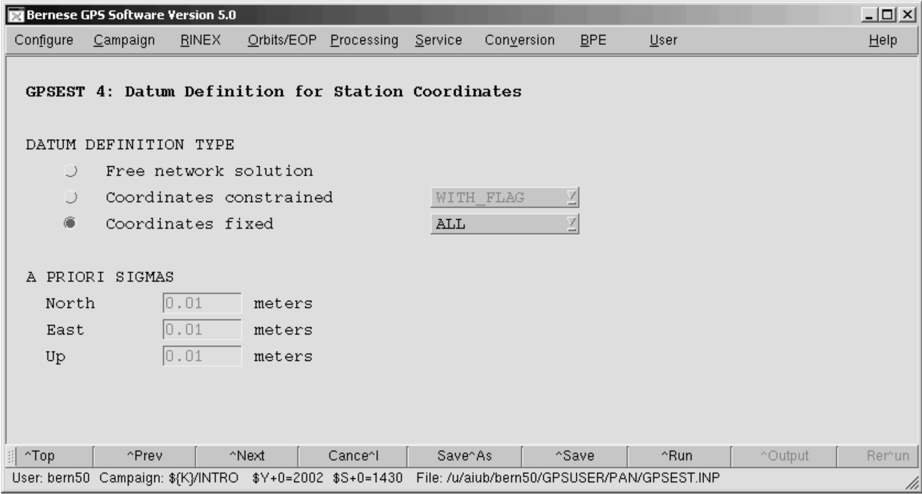
Now you are ready to run GPSEST in the zero–difference mode. Introduce the estimated coordinates and troposphere parameters from the final solution you have computed for the session:

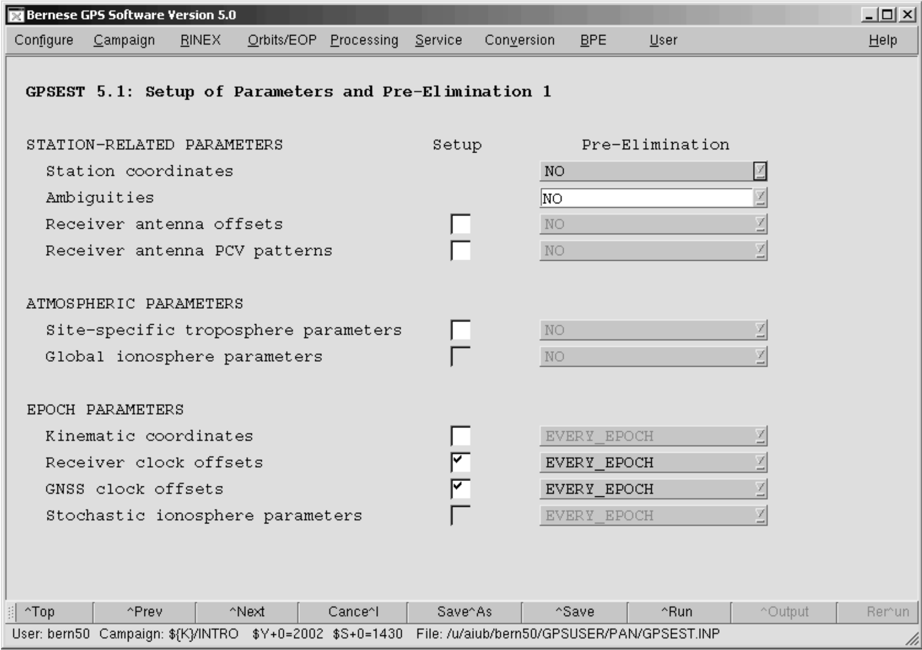


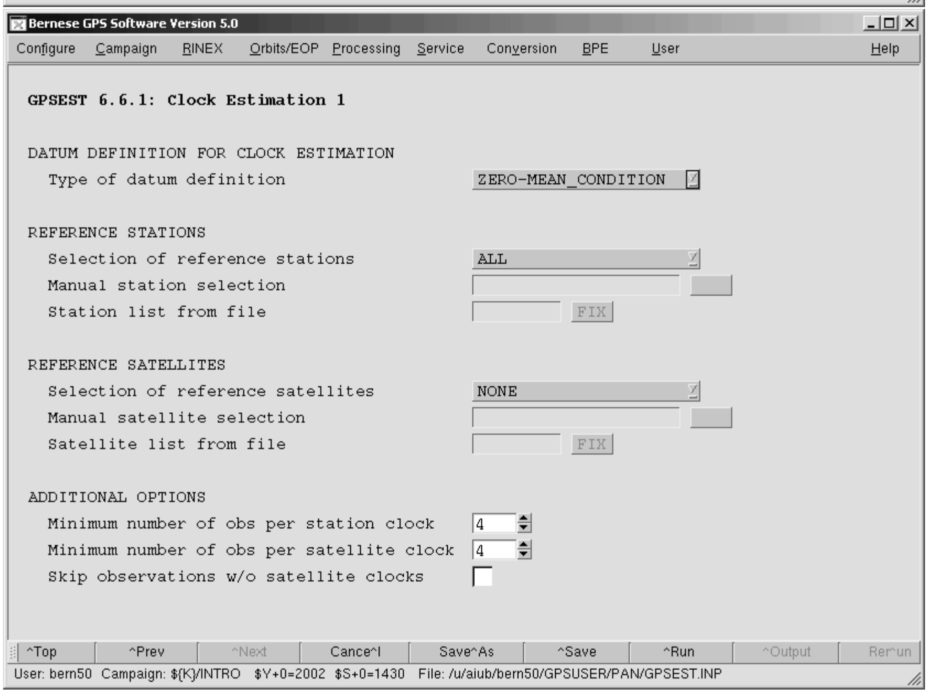



Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 3.1: General Options 1
TITLE
EXAMPLE: Session $YSS+0: Save residuals for clock estimation
OBSERVATION SELECTION
Satellite system
GPS
Frequency
L3
Elevation cutoff angle
5
degrees
LEO:
0
degrees
Sampling interval
300
seconds
Tolerance for simultaneity
100
milliseconds
Special data selection
NO
Observation window
OBSERVATION MODELING AND PARAMETER ESTIMATION
A priori sigma
0.001
meters
Elevation-dependent weighting
COSZ
LEO:
NONE
Type of computed residuals
NORMALIZED
Correlation strategy
CORRECT
Polarization effect geom.
only if later than
2003 09 14
total
only if later than
2006 11 05
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

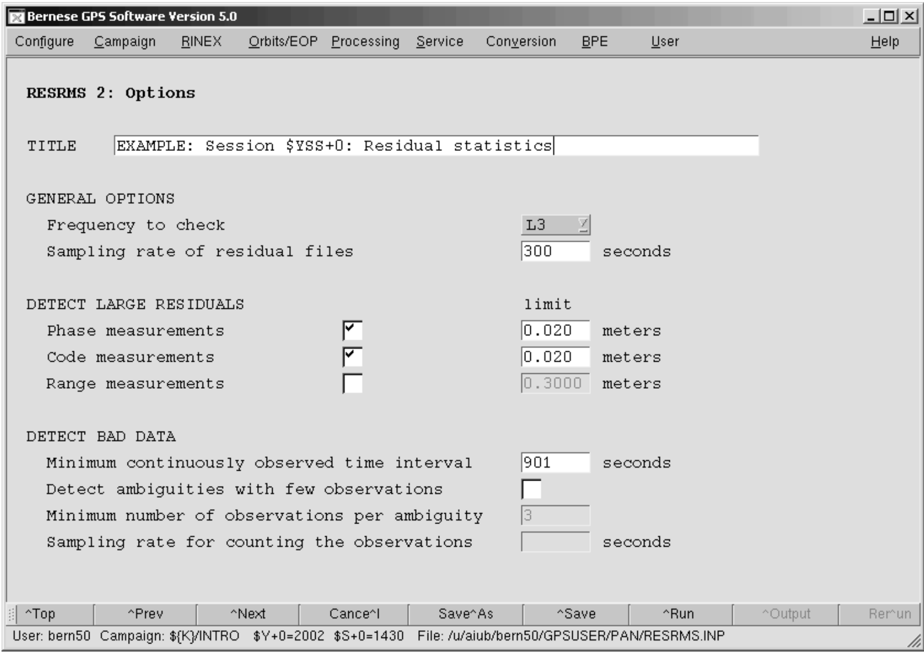

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 3.2: General Options 2
A PRIORI TROPOSPHERE MODELING
ZPD model and mapping function
DRY_NIELL
HANDLING OF AMBIGUITIES
Resolution strategy
NONE
Save resolved ambiguities
Introduce widelane integers
Introduce L1 and L2 integers
SPECIAL PROCESSING OPTIONS
Maximum tolerated O-C term
meters
Var-covar wrt epoch parameters
SIMPLIFIED
EXTENDED PRINTING OPTIONS
Selection of printing options
NO
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 4: Datum Definition for Station Coordinates
DATUM DEFINITION TYPE
Free network solution
Coordinates constrained
WITH_FLAG
Coordinates fixed
ALL
A PRIORI SIGMAS
North 0.01 meters
East 0.01 meters
Up 0.01 meters
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

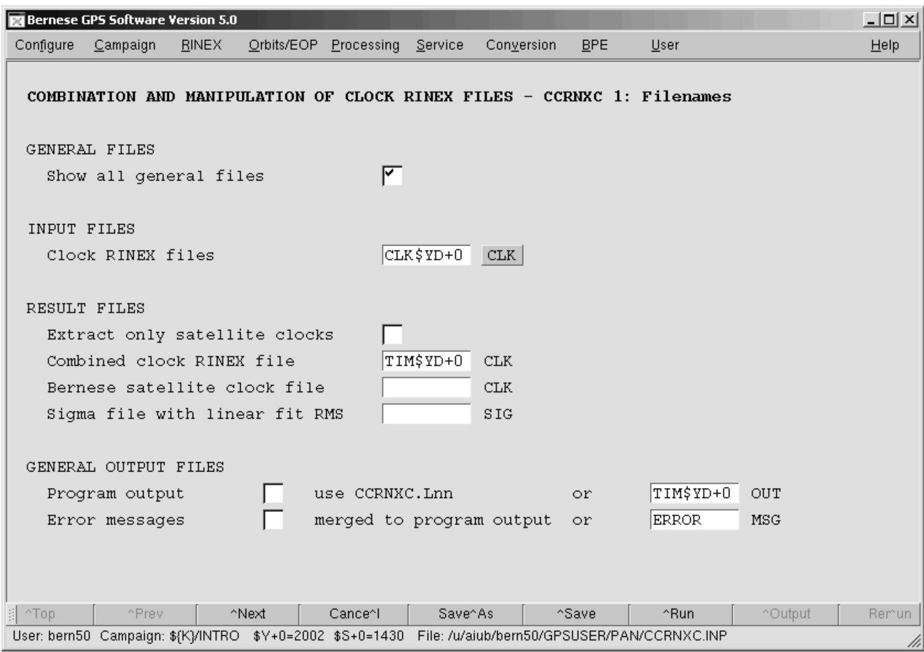

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 5.1: Setup of Parameters and Pre-Elimination 1
STATION-RELATED PARAMETERS Setup Pre-Elimination
Station coordinates NO
Ambiguities NO
Receiver antenna offsets NO
Receiver antenna PCV patterns NO
ATMOSPHERIC PARAMETERS
Site-specific troposphere parameters NO
Global ionosphere parameters NO
EPOCH PARAMETERS
Kinematic coordinates EVERY_EPOCH
Receiver clock offsets EVERY_EPOCH
GNSS clock offsets EVERY_EPOCH
Stochastic ionosphere parameters EVERY_EPOCH
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

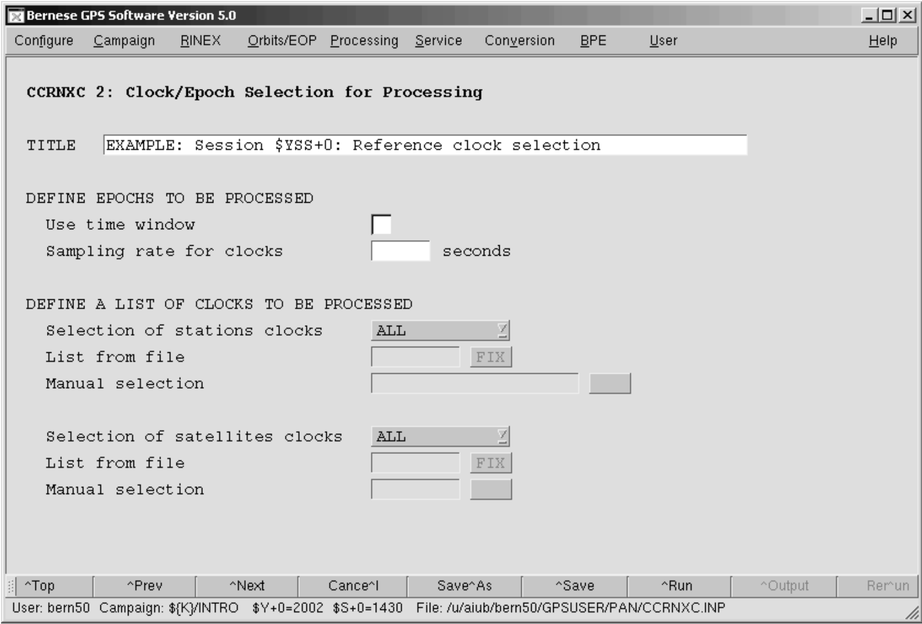

Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
GPSEST 6.6.1: Clock Estimation 1
DATUM DEFINITION FOR CLOCK ESTIMATION
Type of datum definition ZERO-MEAN_CONDITION
REFERENCE STATIONS
Selection of reference stations ALL
Manual station selection
Station list from file FIX
REFERENCE SATELLITES
Selection of reference satellites NONE
Manual satellite selection
Satellite list from file FIX
ADDITIONAL OPTIONS
Minimum number of obs per station clock 4
Minimum number of obs per satellite clock 4
Skip observations w/o satellite clocks
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/GPSEST.INP

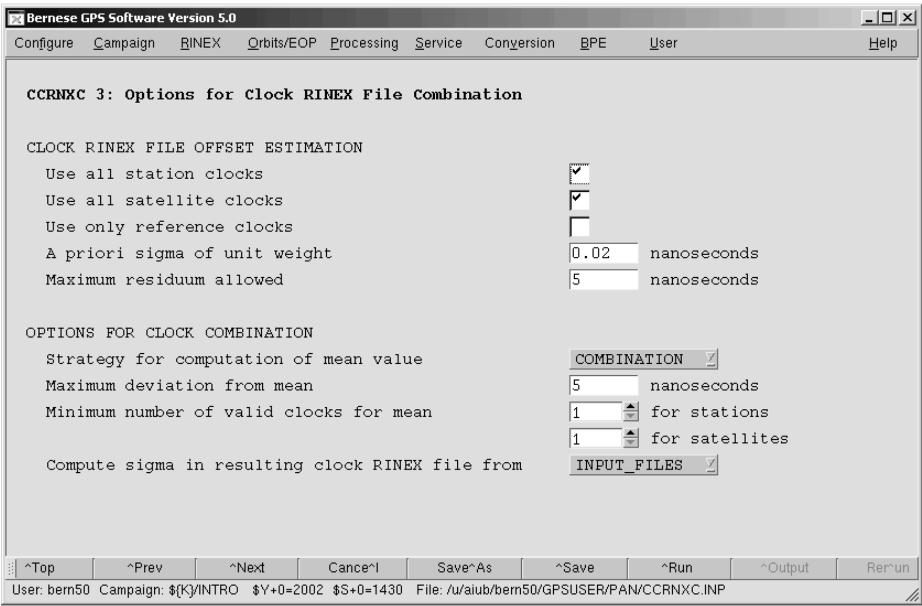
The residuals are stored in the file `${K}/INTRO/OUT/CLK02143.RES`. Use program RESRMS to screen for outliers bigger than 2 cm for code and phase data (remember that code residuals are scaled to phase residuals — 2 cm in the input field correspond to a 2 m threshold for code residuals):

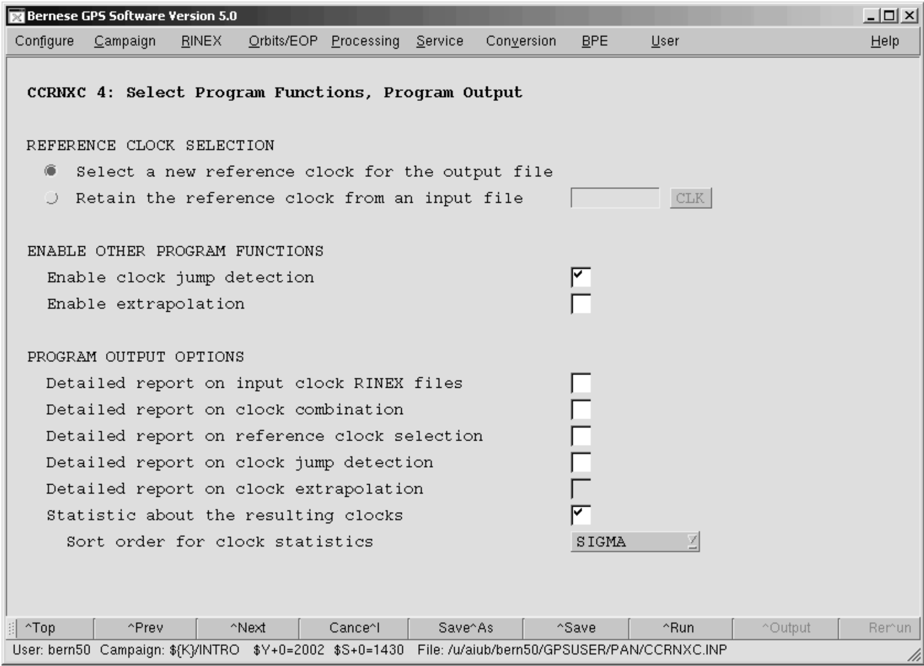


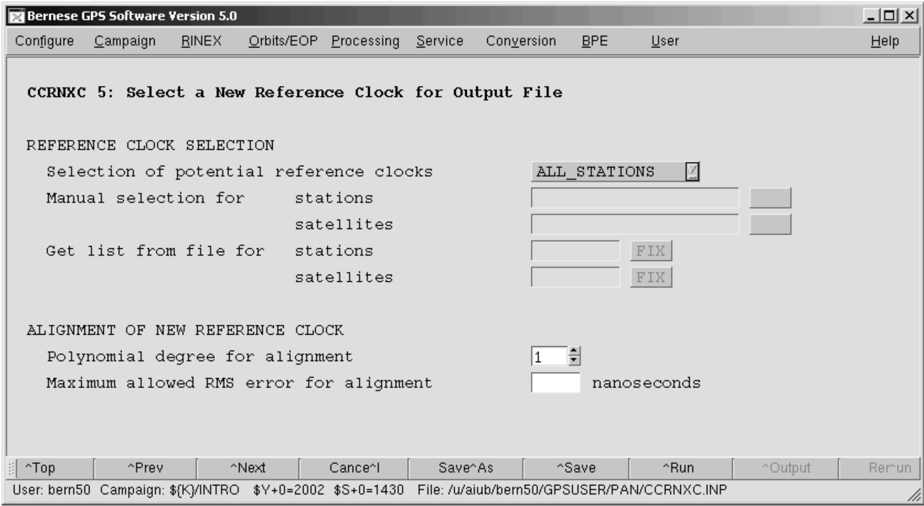
Mark the corresponding observations using program SATMRK and repeat the GPSEST–run. In the second iteration we screen for residuals bigger than 6 mm in RESRMS and mark these observations with SATMRK, too. Repeat the run of GPSEST a third time to get the definitive clock estimates. Specify a "Clock RINEX" file (e.g., CLK$YD+0) in the panel "GPSEST 2.1: Output Files 1".
The clock solution is finalized by selecting the reference clock using program CCRNXC ("Menu >RINEX>RINEX utilities>Combine/manipulate clock data"):

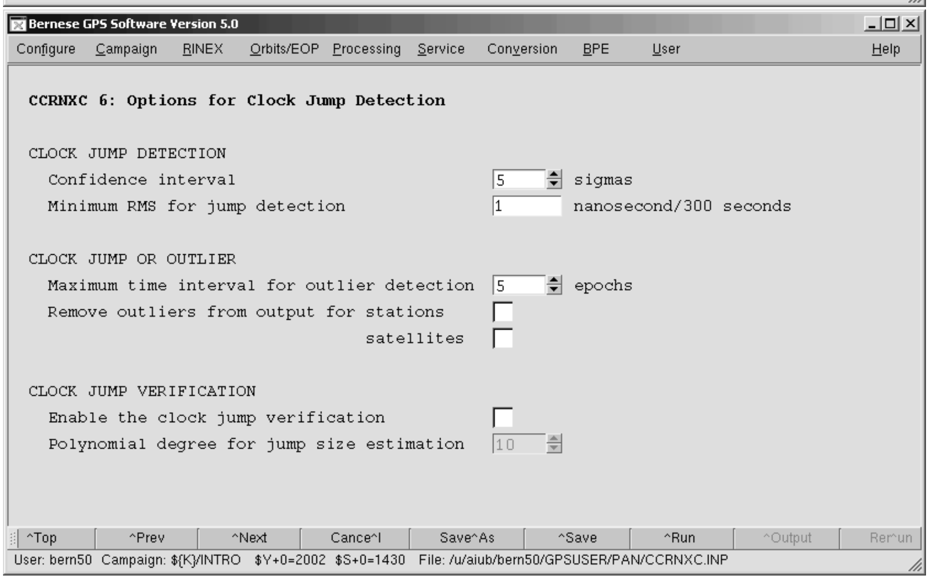



Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CCRNXC 2: Clock/Epoch Selection for Processing
TITLE
EXAMPLE: Session $YSS+0: Reference clock selection
DEFINE EPOCHS TO BE PROCESSED
Use time window
Sampling rate for clocks
seconds
DEFINE A LIST OF CLOCKS TO BE PROCESSED
Selection of stations clocks
ALL
List from file
FIX
Manual selection
Selection of satellites clocks
ALL
List from file
FIX
Manual selection
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/CCRNXC.INP


Bernese GPS Software Version 5.0
Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help
CCRNXC 3: Options for Clock RINEX File Combination
CLOCK RINEX FILE OFFSET ESTIMATION
Use all station clocks
Use all satellite clocks
Use only reference clocks
A priori sigma of unit weight
0.02
nanoseconds
Maximum residuum allowed
5
nanoseconds
OPTIONS FOR CLOCK COMBINATION
Strategy for computation of mean value
COMBINATION
Maximum deviation from mean
5
nanoseconds
Minimum number of valid clocks for mean
1
for stations
1
for satellites
Compute sigma in resulting clock RINEX file from
INPUT_FILES
^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/CCRNXC.INP


Bernese GPS Software Version 5.0
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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/CCRNXC.INP


Bernese GPS Software Version 5.0
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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/PAN/CCRNXC.INP


Bernese GPS Software Version 5.0
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
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
User: bern50 Campaign: ${K}/INTRO $Y+0=2002 $S+0=1430 File: /u/aiub/bern50/GPSUSER/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:     MATE 12734M008
...

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
-------------------------------------------------------------------
MATE 12734M008           288    288        57.543    0.000    0.000
ONSA 10402M004           288    288        36.041    0.100    0.093
PTBB 14234M001           288    288         1.222    0.138    0.072
BRUS 13101M004           278    278         2.497    1.600    1.358
VILL 13406M001           288    288        24.142   23.310   18.686
FFMJ 14279M001           281    281       0.3E+06  0.3E+06  0.3E+06
ZIMJ 14001M006           169    169       0.3E+06  0.3E+06  0.3E+06
ZIMM 14001M004           288    288       0.3E+06  0.3E+06  0.3E+06
G20                       80     80        19.792    0.161    0.161
G14                      106    106        52.600    0.183    0.154
...
```

Further suggestions:

- 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., final IGS products or final CODE solution).
- Switch the "Var–covar wrt epoch parameters" in panel "GPSEST 3.2: General Options 2" from SIMPLIFIED to CORRECT.
- Make a PPP for one of the stations included in the network and compare the obtained clock corrections with the estimates from the network solution generated before. You may either use the IGS clocks (extract the satellite clocks from the clock RINEX files in the OUT–directory of your campaign using the program CCRNXC) or the satellite clock estimates from your network solution (specify a "Bernese satellite clock file" in the "RESULT FILES" section of the panel "CCRNXC 1: Filenames").

6.3 Bernese Processing Engine

It is possible to run one of the example BPEs provided with the distribution. They are installed in your user environment and the data are available, too. In detail these are:

(1) PPP.PCF — Precise Point Positioning

(2) RNX2SNX.PCF — Generate a SINEX file starting with GNSS RINEX observation files

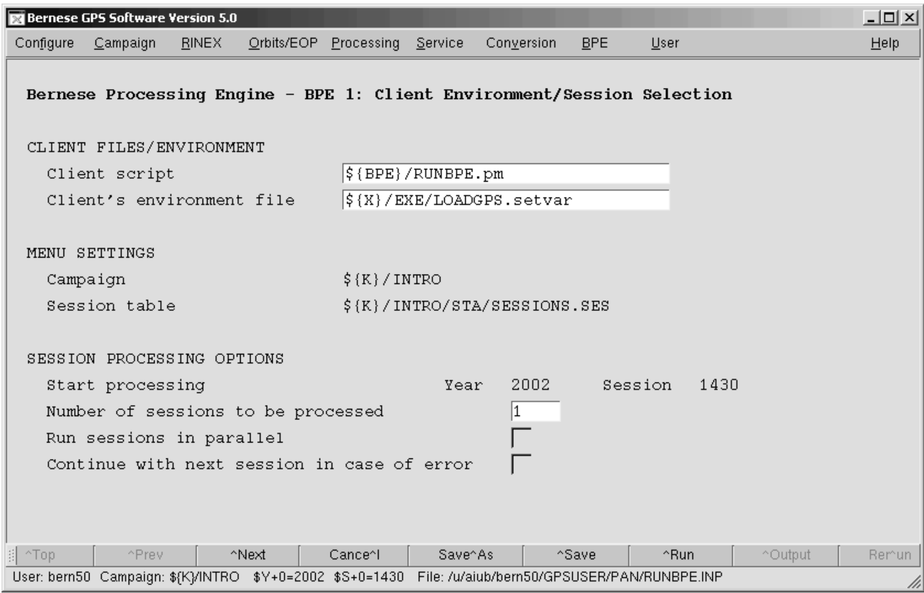
(3) CLKDET.PCF — Estimate station and satellite clocks

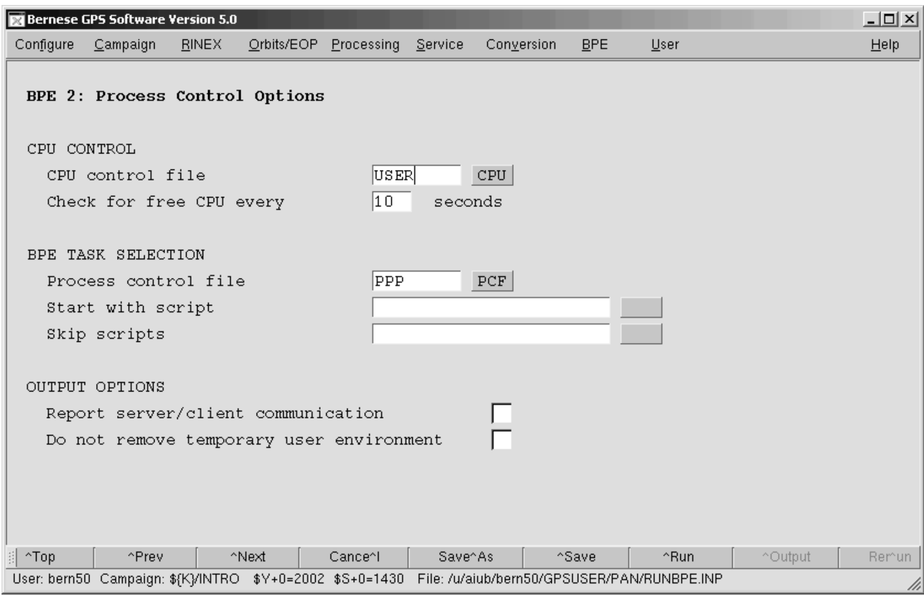
The reference files for the solution are also available in your campaign directories.

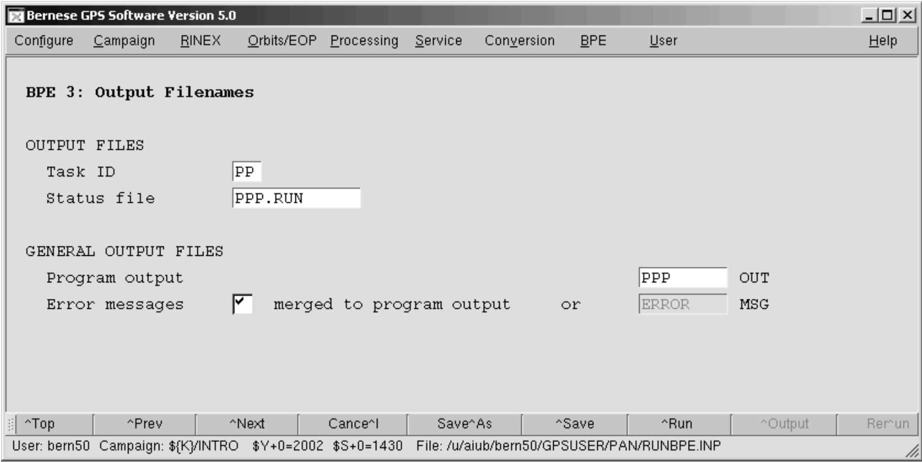
Be aware that some of the files you have generated in the previous terminal sessions may be overwritten.

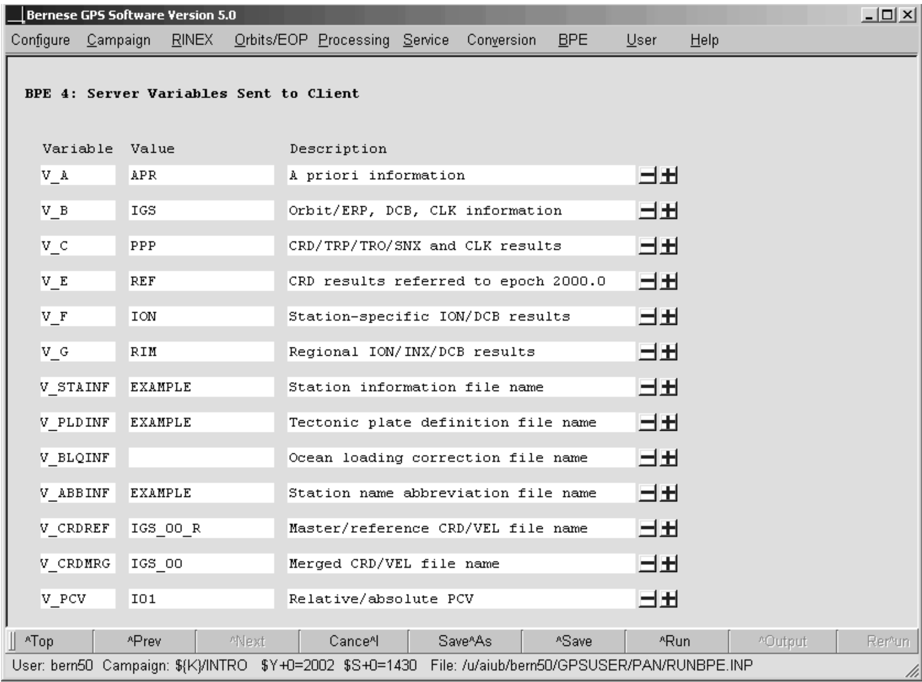
Even if it is simple to run a BPE: please, do not run all BPEs for all sessions. First it is rather boring to look at the screen with a BPE running and, secondly, we like to avoid to overload the CPUs. Running one example for one session with the BPE should be enough to get the BPE output files.

Select first the session for which you want to run the BPE (e.g., day 143 of year 2002). To start the BPE use "Menu>BPE>Start BPE process":









In addition we suggest to become familiar with the structure and the functionality of the BPE in this terminal session, e.g.,

- by reading the header information of the PCF files,
- by viewing the user scripts of the example BPE that can be used as modules for your own BPE at home, or
- by studying the BPE output files.