



Bernese GNSS Software Version 5.4

Tutorial

Processing Example

Introductory Course

Terminal Session

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1 Introduction to the Example Campaign

1.1 Stations in the Example Campaign

Data from seventeen European stations of the International GNSS Service (IGS) network and from the EUREF Permanent Network (EPN) were selected for the example campaign. They are listed in Table 1.1. The locations of these stations are given in Figure 1.1.

The observations for these stations are available for six days. Two days in year 2019 (day of year 044 and 045), two in 2020 (day of year 179 and 180), and two in 2021 (days 095 and 096). The observations are distributed in a mixture of RINEX 2 and RINEX 3 formats with related short and long filenames. Within the campaign area we use a Bernese specific naming convention for observation and navigation RINEX files that is neutral with respect to the original very different filenames. The observation files contain also measurements from different GNSS, indicated in Table 1.1 by the RINEX system characters:

G	GPS	Global Positioning System
R	GLONASS	Russian Global Navigation Satellite System
E	Galileo	European Galileo navigation satellite system
C	BDS	BeiDou Navigation Satellite System
J	QZSS	Quasi-Zenith Satellite System
I	NAVIC	Navigation with Indian Constellation

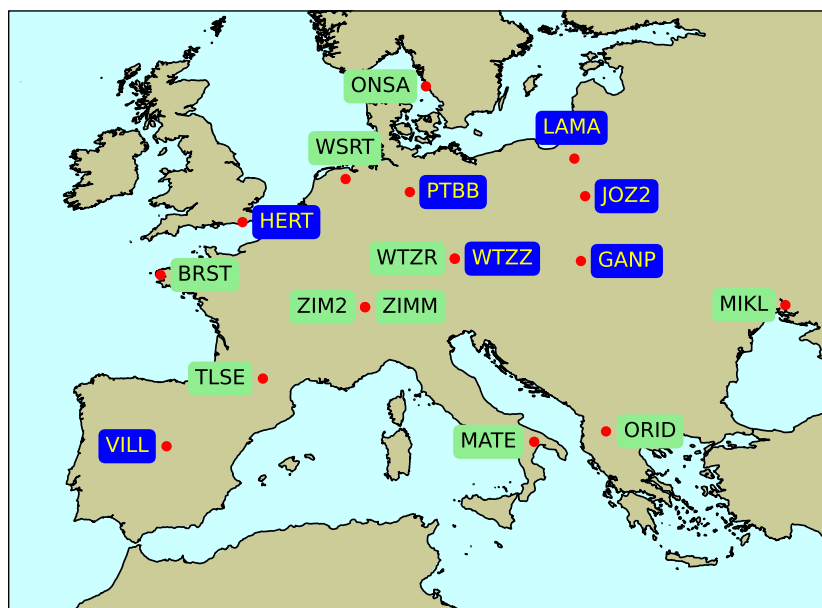


Figure 1.1: Stations used in example campaign (stations indicated by light boxes with coordinates given in the IGS 20 reference frame)

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
BRST00FRA 10004M004	Brest, France	TRIMBLE ALLOY	TRM57971.00	NONE	(GREC) 2.0431 m
GANPOOSVK 11515M001	Ganovce, Slovakia	TRIMBLE ALLOY	TRM59800.00	SCIS	(GRECJI) 0.3830 m
HERTOOGBR 13212M010	Hailsham, United Kingdom	LEICA GRX1200GGPRO	LEIAT504GG	NONE	(GR) 0.0000 m
JOZ200POL 12204M002	Jozefoslaw, Poland	2019: LEICA GRX1200GGPRO	LEIAT504GG	NONE	(GRCJ) 0.0000 m
		2020/21: TRIMBLE NETR9	TRM59800.00	NONE	(GRE) 0.0000 m
LAMA00POL 12209M001	Olsztyn, Poland	LEICA GRX1200+GNSS	LEIAT504GG	LEIS	(GR) 0.0600 m
MATE00ITA 12734M008	Matera, Italy	LEICA GR30	LEIAR20	NONE	(GREC) 0.1010 m
MIKLOOUKR 12335M001	Mykolaiv, Ukraine	LEICA GR10	LEIAR10	NONE	(GRE) 0.0237 m
ONSA00SWE 10402M004	Onsala, Sweden	2019: JAVAD TRE_G3TH	AOAD/M_B	DELTA OSOD	(GR) 0.9950 m
		2020/21: SEPT POLARX5TR	AOAD/M_B	OSOD	(GREC) 0.9950 m
ORID00MKD 15601M001	Ohrid, Republic of North Macedonia	2019: LEICA GRX1200GGPRO	LEIAT504GG	LEIS	(GR) 0.0640 m
		2020/21: LEICA GR30	LEIAR25.R4	LEIT	(GREC) 0.0000 m
PTBB00DEU 14234M001	Braunschweig, Germany	2019: ASHTECH Z-XII3T	ASH700936E	SNOW	(G) 0.0562 m
		2020/21: SEPT POLARX5TR	LEIAR25.R4	LEIT	(GRECI) 0.0590 m
TLSE00FRA 10003M009	Toulouse, France	TRIMBLE NETR9	TRM59800.00	NONE	(GREC) 1.0530 m
VILLO0ESP 13406M001	Villafranca, Spain	2019: SEPT POLARX4	SEPCHOKE_MC	NONE	(GRECI) 0.0937 m
		2020/21: SEPT POLARX5	SEPCHOKE_B3E6	NONE	(GRECI) 0.0937 m
WSRTO0NLD 13506M005	Westerbork, The Netherlands	SEPT POLARX5	AOAD/M_T	DUTD	(GRECJ) 0.3888 m
WTZRO0DEU 14201M010	Kötzing, Germany	LEICA GR50	LEIAR25.R3	LEIT	(GRECI) 0.0710 m
WTZZ00DEU 14201M014	Kötzing, Germany	JAVAD TRE_3	LEIAR25.R3	DELTA LEIT	(GRECI) 0.2840 m
ZIM200CHE 14001M008	Zimmerwald, Switzerland	TRIMBLE NETR9	TRM59800.00	NONE	(GREC) 0.0000 m
ZIMM00CHE 14001M004	Zimmerwald, Switzerland	TRIMBLE NETR9	TRM29659.00	NONE	(G) 0.0000 m

In the terminal sessions you will analyze the data in order to obtain a velocity field based on products computed by Center for Orbit Determination in Europe (CODE) for the IGS repro3 campaign – the contribution to the ITRF 2020. For nine of these stations, coordinates and velocities are given in the IGS 20 reference frame, an IGS-specific realization of the ITRF 2020 (see <https://itrf.ign.fr/en/solutions/ITRF2020>). Even though the scale of the ITRF 2020 has slightly changed with respect to the repro3 series due to the combination with the other space-geodetic techniques, the orbit and Earth orientation parameters (EOP) products can be used together with the IGS 20 reference frame. For Precise Point Positioning (PPP) applications (in particular with the ambiguity resolution) this inconsistency will, however, degrade the results. A related update of the product series is under consideration.

Between the selected days in 2019 and 2020 the receiver in ONSA and the full equipment at stations JOZ2, ORID, PTBB, and VILL was changed. The receiver type, the antenna type, and the antenna height are provided in Table 1.1.

Ideally, consistent (ROBOT) calibrations for each GNSS that should be used. However, those calibrations are not always available. The antenna calibrations available for the example network and related to the IGS20 antenna model are shown in Table 1.2. For station ONSA we have the situation that for the antenna type/radome combination even

Table 1.2: List of antenna/radome combinations used in the example campaign together with the available antenna calibration values in IGS20 model.

Antenna type		Type of calibration	used at stations
AOAD/M_B	OSOD	ADOPTED from NONE for GPS ADOPTED from GPS for other systems	ONSA00SWE
AOAD/M_T	DUTD	ROBOT for GPS and GLO ADOPTED from GPS for other systems	WSRT00NLD
ASH700936E	SNOW	ROBOT for GPS ADOPTED from GPS for other systems	PTBB00DEU (2019)
LEIAR10	NONE	ROBOT for all systems	MIKLOOUKR
LEIAR20	NONE	ROBOT for all systems	MATE00ITA
LEIAR25.R3	LEIT	ROBOT for all systems	WTZR00DEU, WTZZ00DEU
LEIAR25.R4	LEIT	ROBOT for all systems	ORID00MKD (2020/21), PTBB00DEU (2020/21)
LEIAT504GG	LEIS	ROBOT for GPS and GLO ADOPTED from GPS for other systems	LAMA00POL, ORID00MKD (2019)
LEIAT504GG	NONE	ROBOT for all systems	HERT00GBR, JOZ200POL (2019)
SEPCHOKE_B3E6	NONE	ROBOT for all systems	VILL00ESP (2020/21)
SEPCHOKE_MC	NONE	ROBOT for GPS and GLO ADOPTED from GPS for other systems	VILL00ESP (2019)
TRM29659.00	NONE	ROBOT for all systems	ZIMM00CHE
TRM57971.00	NONE	ROBOT for all systems	BRST00FRA
TRM59800.00	NONE	ROBOT for all systems	JOZ200POL (2020/21), TLSE00FRA, ZIM200CHE
TRM59800.00	SCIS	ROBOT for all systems	GANP00SVK

no calibration is available. The values from the same antenna type without radome are used as a proxy.

The distances between occupied locations in the network are between 200 and 1000 km. Two locations (Zimmerwald and Kötzing) are occupied by receiver/antenna pairs defining separate stations each: in Zimmerwald, the distance between ZIMM and ZIM2 is only 19 m. In Kötzing, WTZR and WTZZ are separated by less than 2 m — these are short baselines.

The receivers used at the stations MATE, ONSA, and PTBB are connected to H-Maser clocks, VILL to a Cesium clock. In 2020 and 2021 both receivers in Kötzing (WTZR and WTZZ) were connected to the same H-Maser (EFOS 18); in 2019 WTZZ is running on the internal receiver clock only.

1.2 Directory Structure

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

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

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

`${P}`: The CAMPAIGN54 directory contains all processing campaigns for the Version 5.4 of the *Bernese GNSS Software*. In the *Bernese Introductory Course* environment all groups use `${P}/INTRO` in their `${HOME}` directory.

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

1.2.1 The DATAPPOOL Directory Structure (`${D}`)

Motivation for the DATAPPOOL area

The idea of the DATAPPOOL area is to place local copies of external files somewhere on your filesystem. It has several advantages compared to downloading the data each time when starting the processing:

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

Structure and content of the DATAPOOL area

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

GNSS observation data :

RINEX-directory :

The data of GNSS stations are provided in Receiver INdependent EXchange format (RINEX) format. The directory may contain observation (Hatanaka-compressed) and navigation files. The files in this area may even be UNIX- or gzip-compressed. RINEX file versions 2, 3 or 4 are supported and may be introduced with the related filenaming conventions. If several versions of RINEX files for the same station are available, the script (RNX_COP) decides on the priority.

These RINEX files are “originary” files that are not changed during the processing.

The RINEX files can be downloaded from international data centers. Project-specific files are copied into this area. If you mix the station lists from different projects, it is recommended to keep the four-character IDs of all stations in the RINEX file names unique (even if the remaining characters of the nine-character ID is different). The reason is that a mixture with four-character IDs from files using the RINEX 2 naming convention may lead to unpredictable effects.

HOURLY-directory :

The same as the RINEX directory but dedicated to hourly RINEX data used for near real-time applications.

Note: not all stations in this example provide hourly RINEX files.

GNSS products :

Orbits, EOP, satellite clock corrections and biases are basic external information for a GNSS analysis. We propose to use the ID of the source also to create related subdirectories:

COD – CODE operational final solution, currently containing GPS and GLONASS.

COR – CODE operational rapid solution, containing GPS, GLONASS and Galileo.

CODOR03FIN – CODE contribution to IGS repro3, containing GPS, GLONASS, Galileo.

CODOMGXFIN – CODE experimental Multi-GNSS Extension (MGEX) solution, containing GPS, GLONASS, Galileo, BeiDou, and QZSS.

IGS – combined IGS products from the final series, containing only GPS. GLONASS may be added from separate files (named IGL)

The files are provided at the download area from CODE (<http://www.aiub.unibe.ch/download/CODE/>). Instructions for downloading of combined IGS products as well as selected analysis center results are available at <https://files.igs.org/pub/product/readme.txt>

Note that not all analysis centers/solution series provide clock corrections and consistent bias products.

The files are either named with the GPS-week and the day of the week (apart from files containing information for the entire week, e.g., ERP, or the processing summaries). Alternatively also the new naming convention with long filenames indicating the beginning of the dataset with year, day of year, hour and minute together with the length of the dataset in the file is supported. Unix- or gzip-compressions may be applied to these files.

The IGS provides GPS and GLONASS orbits only in separate files (IGS/IGL-series from the final product line) stemming from independent combination procedures with different contributing analysis centers. Nevertheless, they are consistent enough to merge both files together as the first step of the processing. CODE as well as other analysis centers of the IGS (e.g., ESA or GFZ) contribute fully combined multi-GNSS solutions to the IGS final (and ultra-rapid) product line. The contributions of these groups are already combined GPS/GLONASS orbit files.

BSW54 :

In this directory we have placed files containing external input information in Bernese specific formats. The files are neutral with respect to the data you are going to process. Typically these are ionosphere maps. If the external GNSS product source does not provide biases also Bernese formatted bias files (**OSB**) may be placed here. Please take care on the consistency in this case. These files can be downloaded from <http://www.aiub.unibe.ch/download/CODE/> or <http://www.aiub.unibe.ch/download/BSWUSER54/> areas.

REF54 :

Here we propose to collect files in Bernese format which are useful for several campaigns.

- At first these are the series of files related to the reference frame (e.g., IGB14 or IGS20) that may be updated via the download area <http://www.aiub.unibe.ch/download/BSWUSER54/REF>
- Typically, also the sets of files related to the project-specific station selection are prepared in this area. This allows the usage of these files in various campaigns for data processing. Such files are typically: station coordinates (**CRD**) and velocities (**VEL**), station information (**STA**) and equipment conflict (**CRX**) files, abbreviation (**ABB**), cluster (**CLU**) and tectonic plate (**PLD**) tables, as well as the ocean and atmosphere tidal loading correction tables (**BLQ** and **ATL**, respectively).
- The antenna phase center variation (**PCV**) are expanded according to the used antennas. The supported systems are extracted from the observation selection file (**SEL**). Both are sitting in the campaigns **GEN** directory for processing. If these files are prepared project-specific they can be taken from this **REF54** directory, alternatively one file serving for all projects can be prepared and placed in the **\${CONFIG}** folder.
- The directory is also the source of the **SINEX** and **IONEX** skeleton files to be used to generate the various result files.

LEO-data (e.g., **GRCC** or **GRCD**):

These directories are intended to host files which are necessary for Low Earth Orbiter (LEO) data processing. For each LEO satellite a separate folder is foreseen.

RINEX observation files (version 2 or 3/4) are stored in the subdirectory RINEX (of the LEO directory). The corresponding attitude files are placed in the subdirectory ATTIT.

Both locations can be addressed with PCF variables "V_RNXDIR" and "V_ATTDIR". Also the names of the files in these directories are flexible and can be specified via the variables "V_RNXFIL" and "V_ATTFIL" respectively.

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

SLR_data :

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

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

Miscellaneous directories :

The files in these directories are not necessary for executing the example BPEs as they are provided with the software. They indicate additional files which might be useful when processing your own data with adjusted processing setups.

StationLogs :

This directory contains the site log files (e.g., from <https://files.igs.org/pub/station/log>) providing the information on the equipment history in order to be filled into the station information file to check the header of the RINEX observation files before processing.

VMF3 :

The grids for the Vienna Mapping Function (VMF) (Version 3) are located in a separate directory. They are not used for the examples but it shall indicate that for other types of files other directories may be created.

GFZloading :

Grid files with crustal deformation corrections from the non-tidal loading models as provided by GFZ Potsdam for atmosphere, ocean and hydrology non-tidal loading effects.

All files and meta-information related to the 17 stations selected for the example campaign are already in this DATAPOOL-area (`{D}`) after installing the *Bernese GNSS Software*. GNSS orbit information is available from CODE (legacy, rapid and MGEX) and IGS (directories `{D}/COD`, `{D}/COR`, `{D}/CODOMGXFIN` or `{D}/IGS`, respectively).

1.2.2 The Campaign-Directory Structure

Putting data from the DATAPOOL into the campaign

When running an automated processing using the BPE there is a script at the beginning of the process which copies the data from the DATAPOOL-area into the campaign. If you

are going to process data manually you first have to copy the necessary files into the campaign and decompress them if necessary using standard utilities (`uncompress`, `gunzip`¹, or `CRZ2RNX` for RINEX-files).

Content of the campaign area to process the example

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

#{P}/INTRO/ATM/	HOI_20190440 .ION HOI_20201800 .ION	HOI_20190450 .ION HOI_20210950 .ION	HOI_20201790 .ION HOI_20210960 .ION
#{P}/INTRO/BPE/			
#{P}/INTRO/GEN/	ANTENNA_I14 .PCV OBSERV .SEL	ANTENNA_I20 .PCV SESSIONS .SES	I14 .ATX SINEX_INTRO .SKL I20 .ATX
#{P}/INTRO/GRD/	VMF3_20190440 .GRD VMF3_20201800 .GRD	VMF3_20190450 .GRD VMF3_20210950 .GRD	VMF3_20201790 .GRD VMF3_20210960 .GRD
#{P}/INTRO/OBS/			
#{P}/INTRO/ORB/	COD_20190440 .PRE COD_20190450 .PRE COD_20201790 .PRE COD_20201800 .PRE COD_20210950 .PRE COD_20210960 .PRE IGS_20190440 .PRE IGS_20201800 .PRE IGS_20190440 .IEP IGS_20201800 .IEP IGL_20190440 .PRE IGL_20201800 .PRE BIA_20190440 .OSB BIA_20201800 .OSB	COD_20190440 .IEP COD_20190450 .IEP COD_20201790 .IEP COD_20201800 .IEP COD_20210950 .IEP COD_20210960 .IEP IGS_20190450 .PRE IGS_20210950 .PRE IGS_20190450 .IEP IGS_20210950 .IEP IGL_20190450 .PRE IGL_20210950 .PRE BIA_20190450 .OSB BIA_20210950 .OSB	COD_20201790 .BIA COD_20201800 .BIA COD_20210950 .BIA COD_20210960 .BIA IGS_20201790 .PRE IGS_20210960 .PRE IGS_20201790 .IEP IGS_20210960 .IEP IGL_20201790 .PRE IGL_20210960 .PRE BIA_20201790 .OSB BIA_20210960 .OSB
#{P}/INTRO/ORX/			
#{P}/INTRO/OUT/	COD_20190440 .CLK COD_20201800 .CLK IGS_20190440 .CLK IGS_20201800 .CLK	COD_20190450 .CLK COD_20210950 .CLK IGS_20190450 .CLK IGS_20210950 .CLK	COD_20201790 .CLK COD_20210960 .CLK IGS_20201790 .CLK IGS_20210960 .CLK
#{P}/INTRO/RAW/	BRST00FRA_20190440 .RXO BRST00FRA_20201800 .RXO GANPOOSVK_20190440 .RXO GANPOOSVK_20201800 .RXO HERTOOXYZ_20190440 .RXO HERTOOXYZ_20201800 .RXO JOZ200XYZ_20190440 .RXO JOZ200POL_20201800 .RXO LAMA00XYZ_20190440 .RXO LAMA00XYZ_20201800 .RXO MATE00ITA_20190440 .RXO MATE00ITA_20201800 .RXO MIKLOOUKR_20190440 .RXO MIKLOOUKR_20201800 .RXO ONSA00XYZ_20190440 .RXO ONSA00SWE_20201800 .RXO ORID00XYZ_20190440 .RXO ORID00MKD_20201800 .RXO PTBB00XYZ_20190440 .RXO PTBB00DEU_20201800 .RXO TLSE00FRA_20190440 .RXO TLSE00FRA_20201800 .RXO VILL00ESP_20190440 .RXO VILL00ESP_20201800 .RXO WSRT00NLD_20190440 .RXO WSRT00NLD_20201800 .RXO	BRST00FRA_20190450 .RXO BRST00FRA_20210950 .RXO GANPOOSVK_20190450 .RXO GANPOOSVK_20210950 .RXO HERTOOXYZ_20190450 .RXO HERTOOXYZ_20210950 .RXO JOZ200XYZ_20190450 .RXO JOZ200POL_20210950 .RXO LAMA00XYZ_20190450 .RXO LAMA00XYZ_20210950 .RXO MATE00ITA_20190450 .RXO MATE00ITA_20210950 .RXO MIKLOOUKR_20190450 .RXO MIKLOOUKR_20210950 .RXO ONSA00XYZ_20190450 .RXO ONSA00SWE_20210950 .RXO ORID00XYZ_20190450 .RXO ORID00MKD_20210950 .RXO PTBB00XYZ_20190450 .RXO PTBB00DEU_20210950 .RXO TLSE00FRA_20190450 .RXO TLSE00FRA_20210950 .RXO VILL00ESP_20190450 .RXO VILL00ESP_20210950 .RXO WSRT00NLD_20190450 .RXO WSRT00NLD_20210950 .RXO	BRST00FRA_20201790 .RXO BRST00FRA_20210960 .RXO GANPOOSVK_20201790 .RXO GANPOOSVK_20210960 .RXO HERTOOXYZ_20201790 .RXO HERTOOXYZ_20210960 .RXO JOZ200POL_20201790 .RXO JOZ200POL_20210960 .RXO LAMA00XYZ_20201790 .RXO LAMA00XYZ_20210960 .RXO MATE00ITA_20201790 .RXO MATE00ITA_20210960 .RXO MIKLOOUKR_20201790 .RXO MIKLOOUKR_20210960 .RXO ONSA00SWE_20201790 .RXO ONSA00SWE_20210960 .RXO ORID00MKD_20201790 .RXO ORID00MKD_20210960 .RXO PTBB00DEU_20201790 .RXO PTBB00DEU_20210960 .RXO TLSE00FRA_20201790 .RXO TLSE00FRA_20210960 .RXO VILL00ESP_20201790 .RXO VILL00ESP_20210960 .RXO WSRT00NLD_20201790 .RXO WSRT00NLD_20210960 .RXO

¹These tools are also available for WINDOWS-platforms, see www.gzip.org. Note, that `gunzip` can also be used to uncompress UNIX-compressed files with the extension `.Z`.

	WTZR00DEU_20190440.RXO	WTZR00DEU_20190450.RXO	WTZR00DEU_20201790.RXO
	WTZR00DEU_20201800.RXO		
	WTZZ00DEU_20190440.RXO	WTZZ00DEU_20190450.RXO	WTZZ00DEU_20201790.RXO
	WTZZ00DEU_20201800.RXO	WTZZ00DEU_20210950.RXO	WTZZ00DEU_20210960.RXO
	ZIM200CHE_20190440.RXO	ZIM200CHE_20190450.RXO	ZIM200CHE_20201790.RXO
	ZIM200CHE_20201800.RXO	ZIM200CHE_20210950.RXO	ZIM200CHE_20210960.RXO
	ZIMM00CHE_20190440.RXO	ZIMM00CHE_20190450.RXO	ZIMM00CHE_20201790.RXO
	ZIMM00CHE_20201800.RXO	ZIMM00CHE_20210950.RXO	ZIMM00CHE_20210960.RXO
\${P}/INTRO/SOL/			
\${P}/INTRO/STA/	EXAMPLE.CRD	EXAMPLE.VEL	EXAMPLE.STA
	EXAMPLE.BLQ	EXAMPLE.ATL	EXAMPLE.CLU
	IGB14_R.CRD	IGB14_R.VEL	IGB14.PSD
	IGB14.FIX	IGB14.SIG	
	IGS20_R.CRD	IGS20_R.VEL	IGS20.PSD
	IGS20.FIX	IGS20.SIG	

The directories `${P}/INTRO/MODEL/` and `${P}/INTRO/CONFIG/` contains copies of the files from the `${MODEL}`- and `${CONFIG}`-directories, which are used by the processing programs. If you want to view these files, please use those in your campaign and not the ones in the `${MODEL}`- and `${CONFIG}`-directory to prevent potential interferences with your colleagues.

\${P}/INTRO/MDOEL/	CONST.BSW	EGM2008_SMALL.GRV	IAU2000R06.NUT	IERS2010XY.SUB
	OT_FES2004.TID	s1_s2_def_ce.dat	TIDE2000.TPO	
\${P}/INTRO/CONFIG/	BOXWING.MAC	DATUM.BSW	GPSUTC.BSW	POLOFF.POL
	SAT_2019.CRX	SAT_2020.CRX	SAT_2021.CRX	
	SATELLIT_I14.SAT	SATELLIT_I20.SAT		

1.2.3 Input Files for the Processing Examples

Atmosphere files ATM

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

General files GEN

In this directory campaign-specific configuration files are located:

- **SESSIONS.SES**: Session table
Initial versions for daily and hourly processing are available in `${PAN}`.
- **OBSERV.SEL**: Priority list for selecting the observation/signal types for processing
Initial versions as they are used for the processing at CODE can be downloaded from BSW aftp.
- **ANTENNA_I14.PCV** or **ANTENNA_I20.PCV**: Phase center eccentricities and variations
Updates are needed when introducing new antenna corrections or new antenna/radome combinations. An Initial version can be downloaded from BSW aftp and updated with ATX2PCV.

- **I14.ATX or I20.ATX:** Antenna correction model in ANTenna correction EXchange format (ANTEX)
The corrections are related to IGS 14 and IGS 20, respectively.
- **SINEX header information**
The metadata in the SINEX header has to be adapted to your institution, It is applied to the general SINEX as well as troposphere and bias SINEX.
The skeleton of this file is available at `#{DOC}/EXAMPLE_SINEX.SKL`; versions prepared for the distributed processing examples are copied from `#{D}/REF54` into the campaign:
 - `SINEX.PPP` for PPP example
 - `SINEX.RNX2SNX` for RNX2SNX example
 - `SINEX.IONDET` for IONDET example
- **IONEX header information**
Adapt IONEX header for your institution
The skeleton of this file is available at `#{DOC}/EXAMPLE_IONEX.SKL`; versions prepared for the distributed processing examples are copied from `#{D}/REF54` into the campaign:
 - `IONEX.IONDET` for IONDET example

Grid files GRD

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

Orbit files ORB

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

Furthermore, the directory contains code and phase bias values either in the international Bias SINEX format with the extension `BIA` or the Bernese internal format for Observation-specific signal biasess (OSBs) (extension `OSB`).

Clock RINEX files OUT

The clock RINEX files are located in the `OUT`-directory. They are consistent with the GNSS orbits, EOP, and potentially the phase bias products in the `ORB`-directory. They contain station and satellite clock corrections with at least 5 minutes sampling — there

are also files from the IGS or some of the analysis centers (ACs) providing satellite clock corrections with a sampling of 30 seconds.

RINEX files RAW

The raw data are given in RINEX format. In the Bernese internal naming scheme, we combine the nine character long station identifier with the four digit year and the session. The extension is `RXO` for observation and `RXN` for navigation RINEX files. In case of RINEX2 files, the four characters are just extended by the default naming `00XYZ`.

Station files STA

The coordinates and velocities of the stations given in the IGS realization of the reference frame ITRF2020 are available in the files `IGS20_R.CRD` and `IGS20_R.VEL`. For some stations also corrections for Post Seismic Deformation (PSD) need to be applied that are provided in the file `IGS20.PSD`. The IGS core stations are listed in `IGS20.FIX`. This file will be used to define the geodetic datum when estimating station coordinates. The files for the previously published IGS realization (based on ITRF2014) are available as well: `IGB14_R.CRD`, `IGB14_R.VEL`, `IGB14.PSD` and `IGB14.FIX`. You can browse all these files with a text editor or with the menu ("Menu>Campaign>Edit station files").

For all stations that have unknown coordinates in the IGS20 reference frame a PPP using the example BPE (`PPP.PCF`) for day 044 of year 2019 has been executed. For our `EXAMPLE-project` a resulting coordinate file `EXAMPLE.CRD` has been generated. It contains all IGS core sites (copied from file `IGS20_R.CRD`) and the PPP results for the remaining stations. The epoch of the coordinates is January 01, 2015. The corresponding velocity file `EXAMPLE.VEL` contains the velocities for the core sites (copied from file `IGS20_R.VEL`) completed by the `NNR-NUVEL1A` velocities for the other stations. The assignment of stations to tectonic plates is given in the file `EXAMPLE.PLD`.

To make sure that you process the data in the *Bernese GNSS Software* with correct station information (station name, receiver type, antenna type, antenna height, etc.) the file `EXAMPLE.STA` is used to verify the RINEX header information. The reason to use this file has to be seen in the context that some antenna heights or receiver/antenna types in the RINEX files may not be correct or may be measured to a different antenna reference point. Similarly, the marker (station) names in the RINEX files may differ from the names we want to use in the processing. The antenna types have to correspond to those in the file `#{P}/INTRO/GEN/ANTENNA_I20.PCV` to ensure that the correct phase center offsets and variations are used.

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

Table 1.3: List of global model and configuration files to be used in the Bernese programs for the processing example.Model files located in $\${C}/GLOBAL/MODEL$

Filename	Content	Modification	Update from
CONST.BSW	All constants used in the <i>Bernese GNSS Software</i>	No	BSW aftp
IAU2000R06.NUT	Nutation model coefficients	No	—
IERS2010XY.SUB	Subdaily pole model coefficients	No	—
OT_FES2004.TID	Ocean tides coefficients	No	—
TIDE2000.TPO	Solid Earth tides coefficients	No	—
EGM2008_SMALL.GRV	Earth potential coefficients (reduced version, sufficient for GNSS and LEO orbit determination)	No	—
s1_s2_def_ce.dat	S1/S2 atmospheric tidal loading coefficients	No	—

Configuration files located in $\${C}/GLOBAL/CONFIG$

Filename	Content	Modification	Update from
DATUM.BSW	Definition of geodetic datum	Introducing new reference ellipsoid	BSW aftp
GPSUTC.BSW	Leap seconds	When a new leap second is announced by the IERS	BSW aftp
POLOFF.POL	Pole offset coefficients	Introducing new values from IERS annual report (until 1997)	—
SATELLIT_I14.SAT or SATELLIT_I20.SAT	Satellite information file	New launched satellites	BSW aftp
BOXWING.MAC	Definition of orbit model parameters	New launched satellites	BSW aftp
SAT_\${Y}+0.CRX	Satellite problems	Satellite maneuvers, bad data, ...	BSW aftp

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

Global model and configuration files MODEL and CONFIG

These general model and configuration files contain information that is neither user- nor campaign-specific. They are accessed by all users, and changes in these files will affect processing for everyone. Consequently, these files have a central location in either $\${C}/GLOBAL/MODEL$ or $\${C}/GLOBAL/CONFIG$ directory. Table 1.3 shows the list of these files necessary for the processing example. It also shows which files need to be updated from time to time by downloading them from the anonymous ftp-server of AIUB (<http://www.aiub.unibe.ch/download/BSWUSER54/>).

The antenna corrections have to be applied consistently to the reference frame. Since we are going to use the IGS 20 coordinates and velocities to define the datum for our solution,

the related antenna correction model has to be applied: `IGS20.ATX`. The related values are available in the `SATELLIT_I20.SAT` and `ANTENNA_I20.PCV` files. The first of these two files is located in the central `CONFIG` directory the latter one is contained in the campaign-specific `GEN` directory because it should contain only antenna/radome combinations that are processed in this campaign. Disregarding the two locations it is essential to *use these two files consistently*. For the ITRF 2014 related datum, the files are available as well: `SATELLIT_I14.SAT` and `ANTENNA_I14.PCV`.

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

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

Motivation for the `SAVEDISK` area

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

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

Structure and content of the `SAVEDISK` area

We propose to build subdirectories in the `SAVEDISK` area for each of your projects. If these projects collect data over several years, yearly subdirectories are recommended. It is also practical to use further subdirectories like `ATM`, `ORB`, `OUT`, `SOL`, `STA` to distribute the files and to get shorter listings if you are looking for a file. For reproducibility and documentation of the obtained results it might be a good idea to add the used configuration and model files to a `GEN` directory.

The `SAVEDISK` area contains after its installation a directory structure according to the description above. Each example BPE is assumed as a project. Therefore, you will find on the top level of the `SAVEDISK` the directories `PPP`, `RNS2SNX`, `CLKDET`, `IONDET`, `LEOPOD`, and `SLRVAL` (related to the different example BPEs).

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

1.2.5 Preparing the environment

For the *Bernese Introductory Course* the three data areas are prepared in such a way that the processing of the example data can immediately start. Some of the data are copied from the **DATAPOOL**-area into the **CAMPAIGN**-area and decompressed. An archive file containing the related files is made available that can be installed by

```
cd $D
cd ..
tar -xvzf _where_ever_it_is_/TUTORIAL.tgz
```

(`_where_ever_it_is_` should be replaced by the location of this archive file on your system)

On Windows platforms you have to copy the three subdirectories of the archive to the related locations using the Windows File Explorer.

2 Terminal Session: Monday

Today's terminal session is to:

1. become familiar with the UNIX environment, the menu of the Bernese GNSS Software, and the example campaign,
2. verify the campaign setup done for you (see sections 2.2 and 2.3, and also the handout for the terminal sessions),
3. generate the a priori coordinates for all 6 days using COOVEL (see Section 2.5), and
4. start to prepare pole and orbit information according to chapter 3.

2.1 Start the Menu

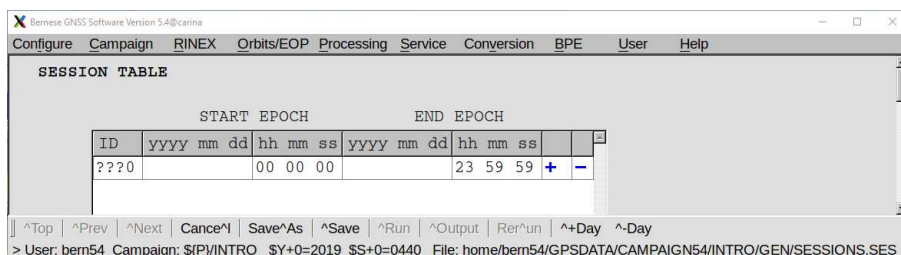
Start the menu program using the command `G`¹.

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

For the terminal session in the *Bernese Introductory Course*, the campaign setup has already been done for each user. Please check that the campaign name in the statusbar of the Bernese Menu is set correctly to your campaign (i.e., Campaign `#{P}/INTRO`) and that the current session is set to the first session (i.e., `#{Y}+0=2019`, `#{S}+0=0440`). If this is not the case, please contact the staff in the terminal room.

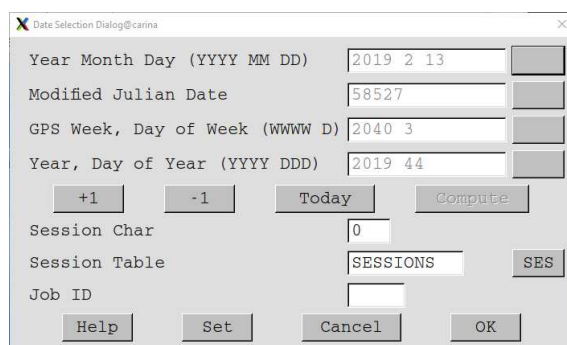
2.2 Select Current Session

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



¹At the exercise terminals the Bernese environment is loaded automatically during login. At home you have to source the file `#{C}/LOADGPS.setvar` on UNIX-platforms either manually or during login.

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



2.3 Campaign Setup

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

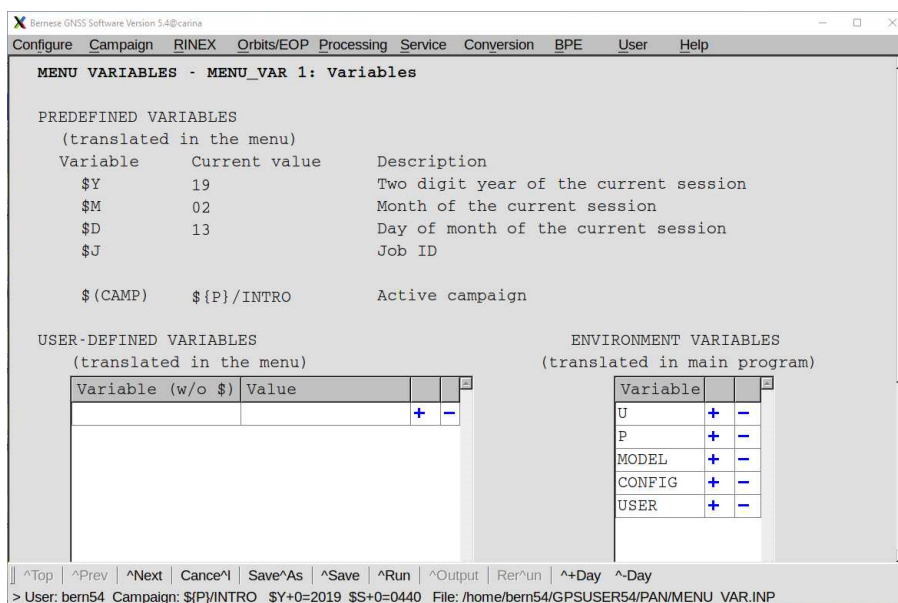
In the *Bernese Introductory Course* environment the selected campaign should be `#{P}/INTRO`. In order to become familiar with the campaign structure, you can inspect your campaign directory and inspect the contents using the command line (using `cd` for changing directories and `ls` to create directory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

2.4 Menu Variables

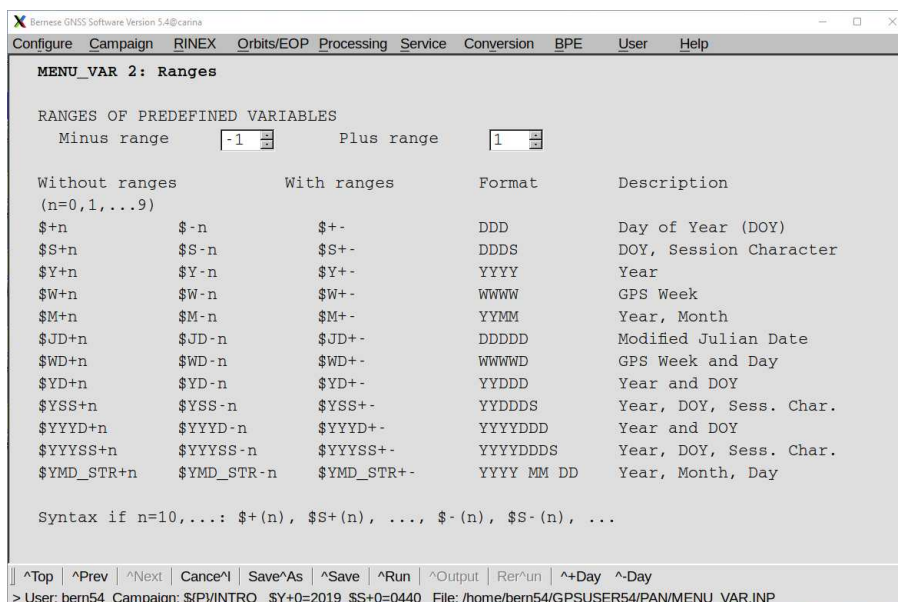
When processing GNSS data, it is often necessary to repeat a program run several times with only slightly different option settings. A typical example would be the processing of several sessions of data. The names of observation files change from session to session because the session number is typically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

The use of system environment variables is necessary to generate the complete path to the files used in the *Bernese GNSS Software*. The campaign data are located in the directory `#{P}/INTRO=#{HOME}/GPSDATA/CAMPAIGN54/INTRO`. The user-dependent files can be found at `#{U}=#{HOME}/GPSUSER54` — note that `#{HOME}` may have been already translated into the name of your home-directory. The temporary user files are

saved in $\${T}=/scratch/local/bern54$ (change `bern54` to your user name). Finally, the campaign-independent model and configuration files reside in $\${MODEL}=\${C}/GLOBAL/MODEL$ and $\${CONFIG}=\${C}/GLOBAL/CONFIG$, respectively.



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



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

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

2.5 Generate A Priori Coordinates

As stated before the a priori coordinates generated from the PPP processing example BPE refer to the epoch January 01, 2015. The first step is to extrapolate the coordinates to the epoch that is currently processed. In the recent ITRF-solutions also Post Seismic Deformation (PSD) corrections have to be applied when the epoch of the coordinate sets are changed. They are provided in the input field "PSD corrections (since ITRF14)". Of course this feature is also included in the IGS 20 frame – the IGS-specific realization of the ITRF 2020.

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

“Reference epoch: date” \$YMD_STR+0 → 2019 02 13
 “Output coordinate file” APR_YYYYSS+0 → APR_20190440
 “Title line” Session \$Y+0-\$S+0: → Session 2019-0440:

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

```

=====
Bernese GNSS Software, Version 5.4
=====
Program       : COOVEL
Purpose       : Extrapolate coordinates
=====
Campaign      : #{P}/INTRO
Default session: 0440 year 2019
Date          : 25-Aug-2024 08:11:53
User name     : bern54
=====

```

```

EXAMPLE: Session 2019-0440: Coordinate propagation
-----

INPUT AND OUTPUT FILENAMES
-----

Geodetic datum           : ${CONFIG}/DATUM.BSW
Input coordinate file     : ${P}/INTRO/STA/EXAMPLE.CRD
Input velocity file       : ${P}/INTRO/STA/EXAMPLE.VEL
Output coordinate file    : ${P}/INTRO/STA/APR_20190440.CRD
Approx. velocities at ref. epoch: ---
PSD corrections (since ITRF14) : ${P}/INTRO/STA/IGS20.PSD
Annual/semiannual corrections (s): ---
Stations without PSD corrections: ---
Program output           : ${P}/INTRO/OUT/COOVEL.L00
Error message            : ${U}/WORK/ERROR.MSG
Session table            : ${P}/INTRO/GEN/SESSIONS.SES
-----

REFERENCE EPOCH:          2015-01-01 00:00:00
INTERPOLATION FACTOR:    -4.1177275838466807
-----

>>> CPU/Real time for pgm "COOVEL": 0:00:00.134 / 0:00:00.135
>>> Program finished successfully

```

The header area of the program output is standardized for all programs of the *Bernese GNSS Software*, Version 5.4. Furthermore each program has a title line that should characterize the program run. It is printed to the program output and to most of the result files. Many program output files furthermore provide a list of input and output files that have been used or generated.

The last two lines of the above example appear also in each program output of the *Bernese GNSS Software*, Version 5.4. It reports the processing time and the status **successful** or **with error**.

The result of the COOVEL run is an a priori coordinate file ($\${P}/INTRO/STA/APR_20190440.CRD$) containing the positions of the sites to be processed for the epoch of the current session (the lines for the other stations are ignored in the processing):

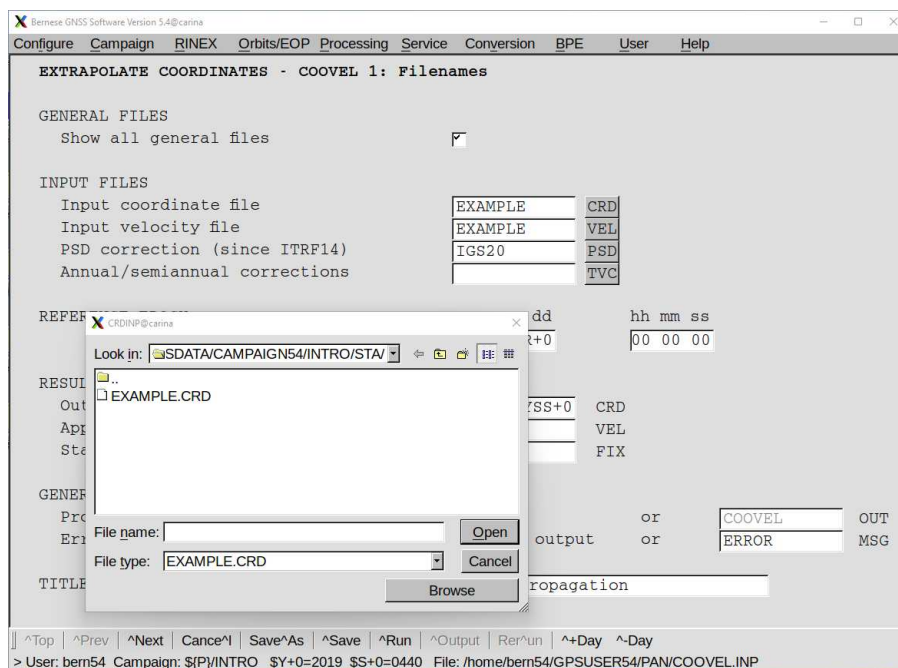
```

EXAMPLE: Session 2019-0440: Coordinate propagation
-----
LOCAL GEODETIC DATUM: IGS20          EPOCH: 2019-02-13 00:00:00
-----
NUM STATION NAME           X (M)           Y (M)           Z (M)           FLAG
SYSTEM
 43 BRST 10004M004          4231162.41765   -332746.42891   4745131.06968   IGS20
104 GANP 11515M001          3929181.30600   1455236.94546   4793653.99294   PPP
122 HERT 13212M010          4033460.75197    23538.05244    4924318.34740   PPP
143 JOZ2 12204M002          3664880.34767   1409190.82194   5009618.55508   PPP
166 LAMA 12209M001          3524522.69472   1329693.85317   5129846.42860   PPP
184 MATE 12734M008          4641949.29729   1393045.69364   4133287.66716   IGS20
198 MIKL 12335M001          3698553.70970   2308676.23252   4639769.62655   IGS20
235 ONSA 10402M004          3370658.33932    711877.34331   5349787.09062   IGS20
236 ORID 15601M001          4498451.47983   1708267.26377   4173591.98565   IGS20
264 PTBB 14234M001          3844059.76112    709661.55883   5023129.64494   PPP
329 TLSE 10003M009          4627851.66234   119640.28843   4372993.71461   IGS20
359 VILL 13406M001          4849833.60409   -335048.75055   4116015.05395   PPP
369 WSRT 13506M005          3828735.65242   443305.18368   5064884.85551   IGS20
370 WTZR 14201M010          4075580.32457    931854.03929   4801568.27077   IGS20
371 WTZZ 14201M014          4075579.21251    931853.36368   4801569.13639   PPP
383 ZIM2 14001M008          4331299.68387    567537.57591   4633133.88020   IGS20
385 ZIMM 14001M004          4331296.87301    567556.13266   4633134.09986   IGS20

```

Have a look at the LOCAL GEODETIC DATUM: in the resulting coordinate file. It is set to IGS20 in this case. If you go back to your input file (e.g., pressing the **Rerun** button)

you may open the dialog to select the "Input coordinate file" by pressing on the button next to the input field. Select now the file EXAMPLE.CRD and press the button **Browse** in order to open a window where the selected file is displayed.



Here you can see the LOCAL GEODETIC DATUM: is set to IGS20_0. This difference is the indicator whether the PSD corrections have been applied or not. Coordinate files indicating that the PSD corrections have not been applied cannot be used for processing GNSS data. At the same time it is protecting you from applying the corrections twice. For that reason the execution of the program COOVEL for applying the PSD corrections is also essential even if none of the stations in your processing (as in our example) is affected by these corrections.

You can repeat all steps for the other sessions in the example campaign by changing the current session using the `^+Day` or `^-Day` to change a limited number of days (not sessions) or via "Menu>Configure>Set session/compute date". You can then use the `Rer^un` button to restart the program. No options need to be changed because of the consequent use of the menu time variables was made. Even if you are going to process only the first day (044, year 2019) of the example dataset during the terminal sessions, you will need prepared coordinate files for all days later on Thursday. That's why, this step should be executed for all six days: 044 and 045 of year 2019, 179 and 180 of year 2020 as well as 095 and 096 of year 2021.

2.6 Session Goals

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

- 1. a priori coordinates in your campaign's STA directory: for six sessions `APR_20190440.CRD`, `APR_20190450.CRD`, `APR_20201790.CRD`, `APR_20201800.CRD`, `APR_20210950.CRD`, and `APR_20210960.CRD`*

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

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

The terminal session on pole and orbit preparation is to:

- 1. generate the pole information file in the Bernese format (POLUPD)*
- 2. generate the Bernese standard orbit files from CODE precise orbit files (ORBGEN)*
- 3. extract satellite clock corrections for receiver clock synchronization (SATCLK2)*
- 4. convert biases from external to internal format (BIA2OSB)*

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

Introductory Remark

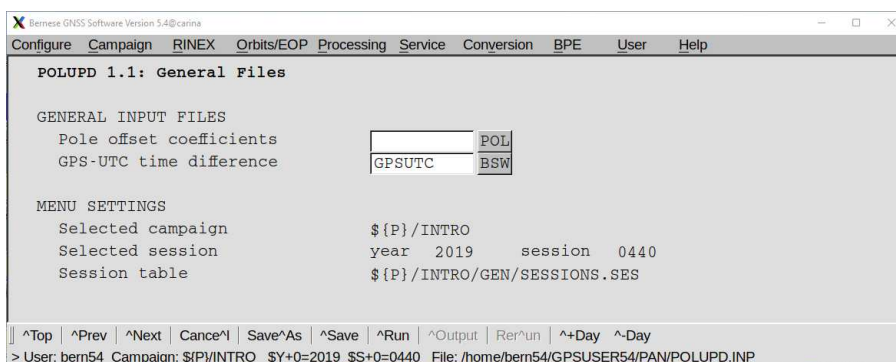
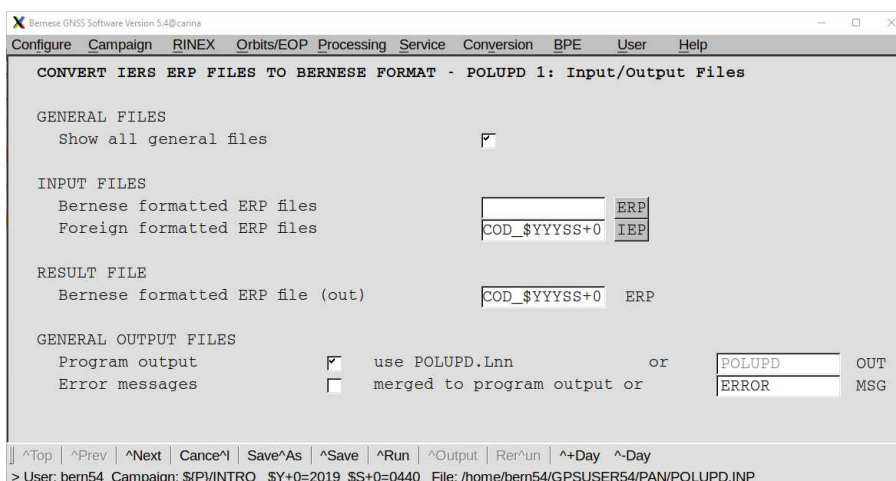
We recommend to use the final or reprocessed products from CODE because they contain consistent orbits for GPS, GLONASS, and Galileo (at least the reprocessing series). Alternatively, the CODE rapid series contains the orbits from all three systems since September 2019. All these series include all active GNSS satellites (even if they are unhealthy or during GPS satellite repositioning events) with the highest possible accuracy thanks to the three-day long-arc technology. Due to this choice you will get the best possible consistency between the external products and the software.

You may alternatively use the products from the IGS. Separate product files for GPS and GLONASS orbits (no combination of Galileo products is executed so far) exist from independent combination procedures that first need to be merged for a multi-GNSS processing. For most of the applications, merging the precise orbit files is sufficient — a tutorial on the procedure is given in Section 7.1 of this book. On the other hand, the consistency of the orbits can not be as good as that of CODE (or other analysis centers) following the strategy of the rigorous combined processing of GPS and GLONASS measurements for orbit determination.

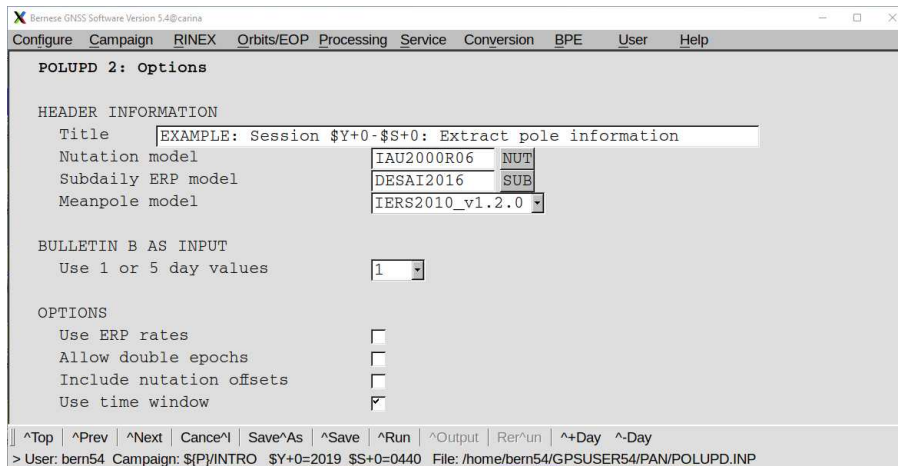
Products for other systems are available in the MGEX solutions provided by CODE and other ACs. Note, that these are experimental products used, e.g., to test various orbit models or antenna calibration sets.

3.1 Prepare Pole Information

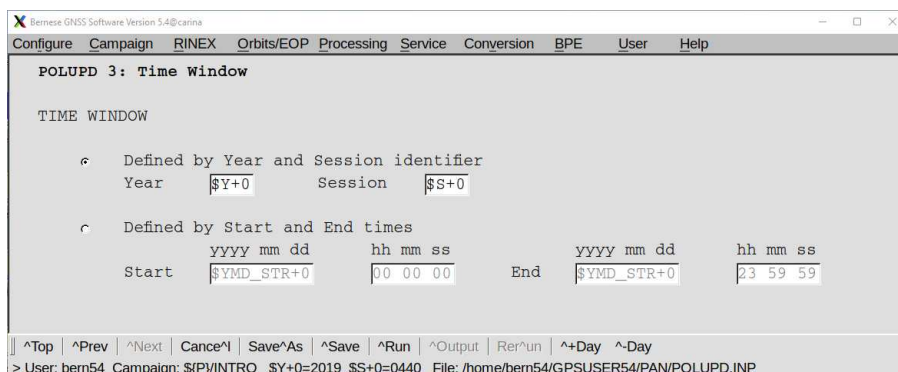
Together with the precise orbit files (PRE), a consistent set of Earth orientation parameters is provided in the ORB directory. Whereas the orbits are given in daily files the EOP may be available in weekly files for some product series (e.g., IGS). We have to convert the information from the International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



Together with the nutation and subdaily pole model also the meanpole model is specified in this panel. They are reported in the resulting Bernese formatted pole file in order to check the consistent use.



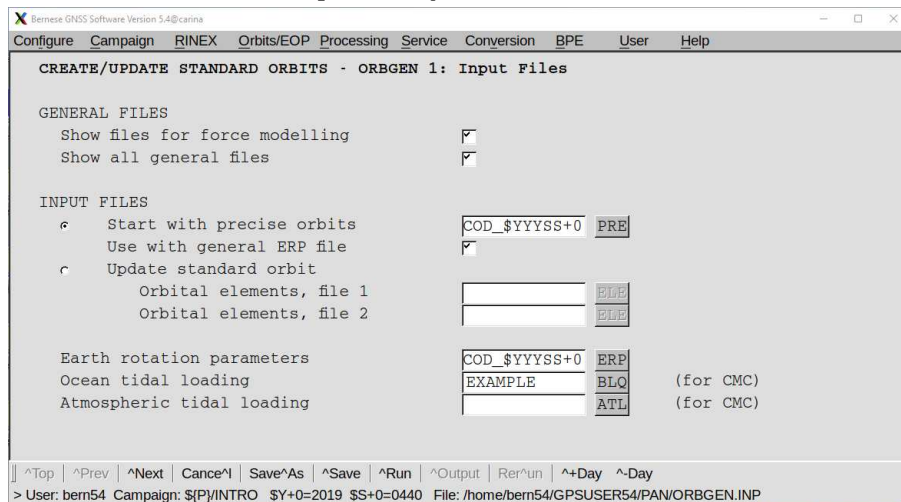
Take care on the option “Meanpole model”. It has to be chosen consistently to the EOPs to be converted. The reprocessing series generated in preparation of ITRF 2020 use IERS2010_v1.2.0. As soon as the ITRF 2020 respective the IGS 20 will be introduced in the operational processing of the IGS this “Meanpole model” has to be used also for the operational products. For earlier operational products the IERS2010XY has to be used. Another important remark is related to option “Use ERP rates”: please check your input “Foreign formatted ERP files” whether they contain the midnight epochs requested to cover the entire period of the session (e.g., in the CODE products). In that case the checkbox should be deactivated. If you have only one record per day at noon in your input “Foreign formatted ERP files” (e.g., in IGS products) the rates from the file should be used, the option has to be activated.



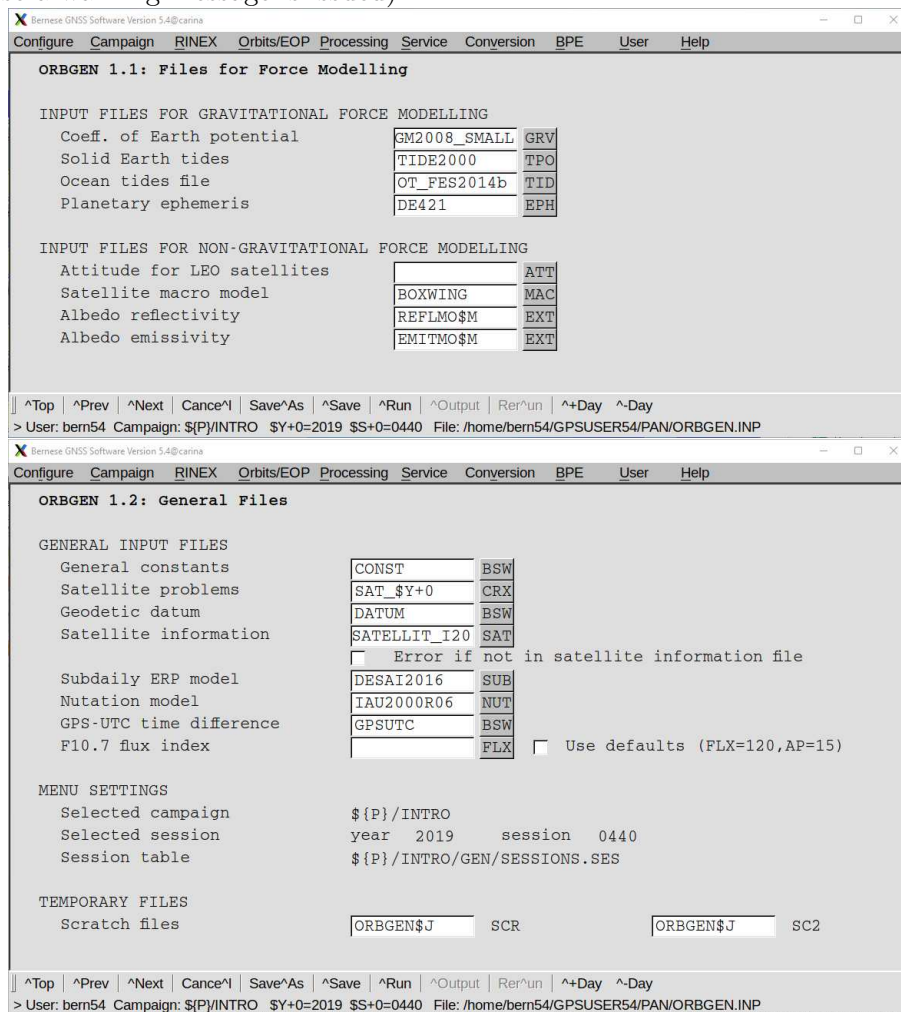
The last panel of the program POLUPD is an example for the specification of time windows in the *Bernese GNSS Software*, Version 5.4. Time windows can be defined by sessions (a single session or a range of sessions). Alternatively, a time window may be specified by a start and an end epoch. By entering either a start or an end epoch you may define only the beginning or the end of the time interval. We refer to the online help for more details.

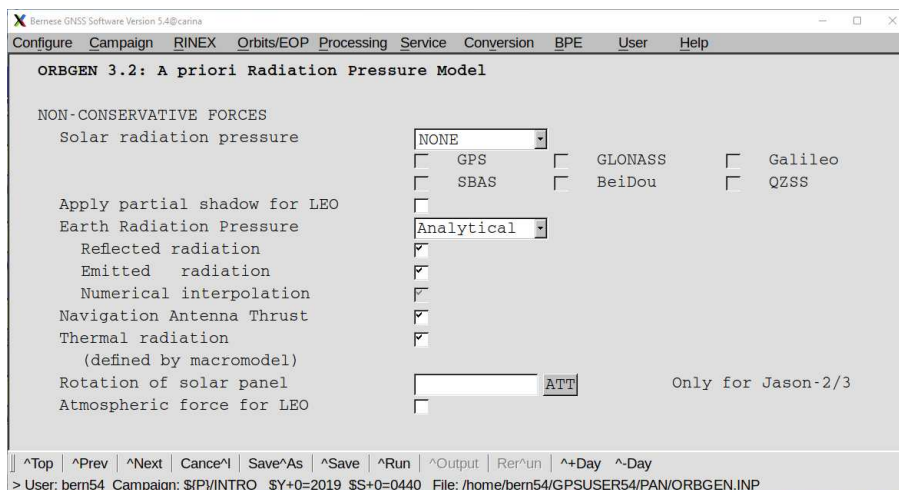
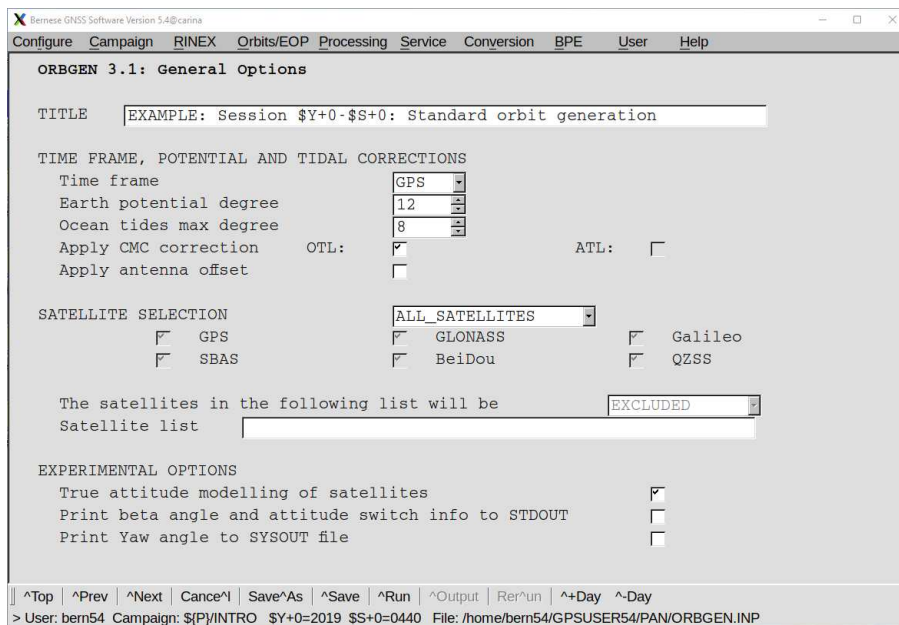
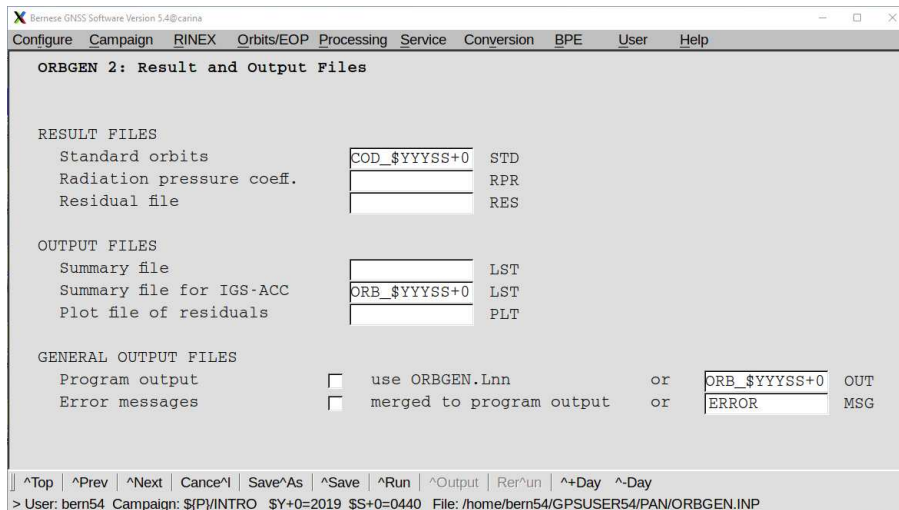
3.2 Generate Orbit Files

In this processing example we use only one program of the orbit part of the *Bernese GNSS Software*, namely ORBGEN ("Menu>Orbits/EOP>Create/update standard orbits"). It prepares the so-called standard orbits using the satellite positions in the precise orbit files as pseudo-observations for a least-squares adjustment.



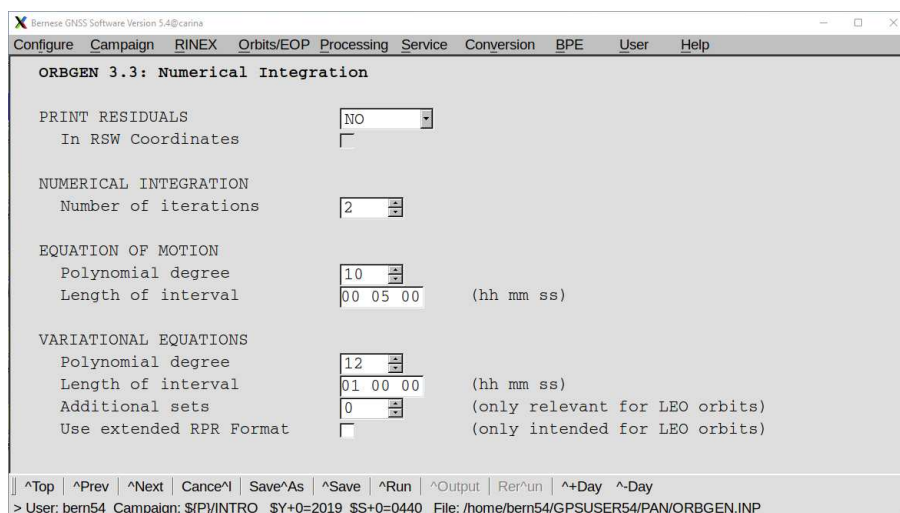
It is mandatory to consistently use the ERP file, the nutation, and the subdaily pole model together with the generated standard orbits in all subsequent processing steps/programs (otherwise a warning message is issued).



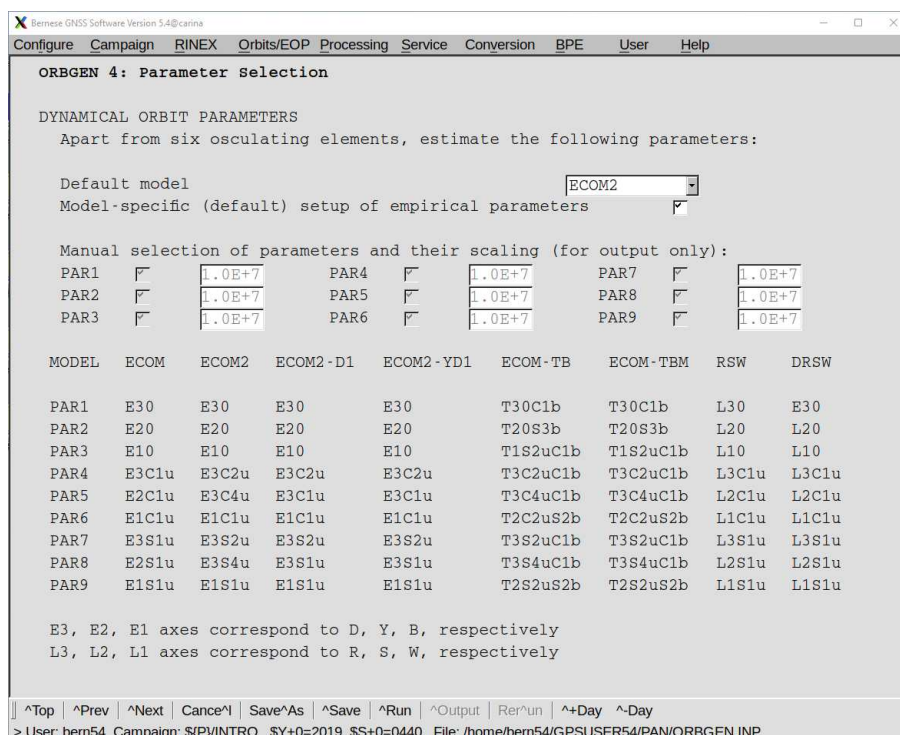


For the options “EQUATION OF MOTION: Length of interval” and “VARIATIONAL EQUATIONS: Length of interval” interval lengths of 00 05 00 and 01 00 00 are sufficient when processing GNSS orbits. Note, that stochastic pulses can only be placed between the integration intervals. When activating the option “Setup of stochastic pulses” later in panel “ORBGEN 5: Stochastic Pulses and Satellite Accuracy Codes” to a specific value (e.g., Orbit midnight) the intervals should allow a realization of this selection.

Shorter intervals will increase of the program run time.

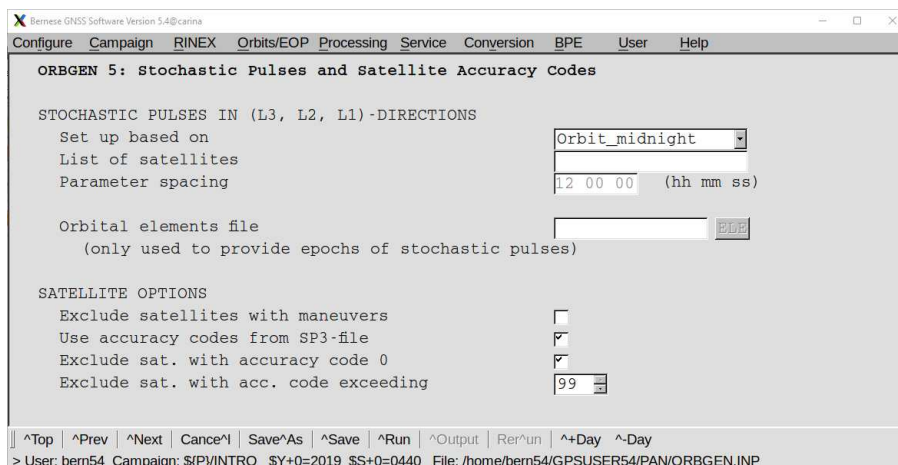


For the option “Number of iterations” 2 is sufficient for most of the cases. You may select a third iteration to check that the output does not change in the additional iteration.

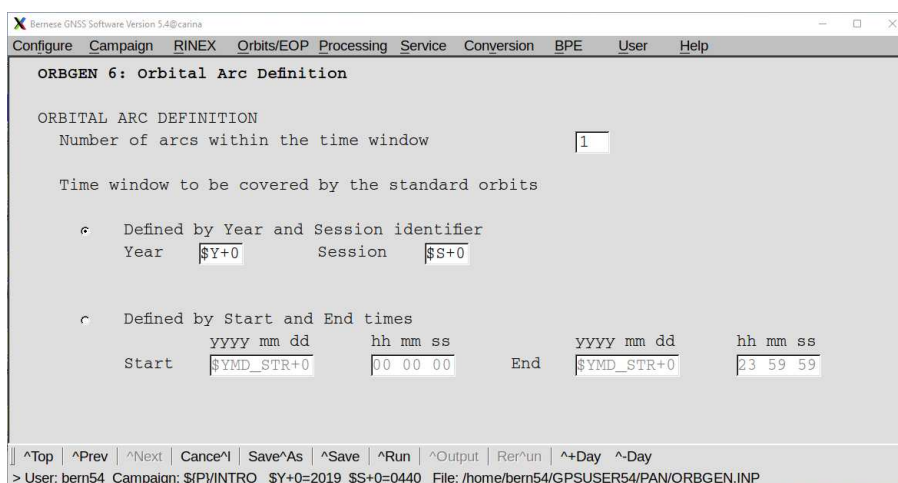


In this panel you see the available orbit models and which of the orbit parameters are used for which component in which coordinate system. We recommend to use the default setup as prepared in the `$(CONFIG)/BOXWING.MAC` (“Satellite macro model” in “ORBGEN 1.1: Files for Force Modelling”).

The stochastic pulses are set in the CODE reprocessing series – used during this exercise session – at Orbit midnight. For the operational final series from CODE this strategy is applied since GPS week 2112, June 2020. For the other products from CODE or other sources we recommend to change the option “Setup of stochastic pulses” to Spacing with 12 00 00 for “Interval for stochastic pulses”.



If you process precise orbits from CODE it is generally not necessary to remove bad satellites, because CODE orbit files contain the correct accuracy codes. It might become necessary for orbit products from other sources (e.g., from the IGS).



The program produces an output file `ORB_2019044.OUT` which should look like

```

...
*****
COMPUTATION OF BERNESE STANDARD ORBITS FROM PRECISE ORBITS      25-AUG-24 08:29
*****
...

-----
LIST OF PRECISE FILES
-----

FILE  PRECISE ORBIT FILENAME          RELATED POLE FILES
-----
  1   ${P}/INTRO/ORB/COD_20190440.PRE  ${P}/INTRO/ORB/COD_20190440.ERP
...

```


Close to the end of the output file you can find the reporting on the orbit model used for each of the satellite according to the “Default model for empirical forces” setup. Most of the GNSS satellites will be represented by the ECOM2 orbit model. Below you find another table that is reporting the parametrization of the selected orbit model.

```

...
-----
USED EMPIRICAL MODELS
-----
EMP MODEL          SATELLITES
-----
EMP: ECOM2          1   2   3   4   5   6   7   8   9  10
EMP: ECOM2          11  12  13  14  15  16  17  18  19  20
EMP: ECOM2          21  22  23  24  25  26  27  28  29  30
EMP: ECOM2          31  32  101 102 103 104 105 107 108 109
EMP: ECOM2          110 111 113 114 115 116 117 118 119 120
EMP: ECOM2          121 122 123 124 126 201 202 203 204 205
EMP: ECOM2          207 208 209 211 212 213 214 215 218 219
EMP: ECOM2          221 224 225 226 227 230 231 233 236
-----

DESCRIPTION OF EMPIRICAL MODELS
-----
MODEL NAME          PAR IDX  PARAMETER LABEL  SHADOW  PAR_SETUP
-----
EMPPAR: ECOM2          1  E30             F        T
EMPPAR: ECOM2          2  E20             F        T
EMPPAR: ECOM2          3  E10             F        T
EMPPAR: ECOM2          4  E3C2u           F        T
EMPPAR: ECOM2          5  E3C4u           F        F
EMPPAR: ECOM2          6  E1C1u           F        T
EMPPAR: ECOM2          7  E3S2u           F        T
EMPPAR: ECOM2          8  E3S4u           F        F
EMPPAR: ECOM2          9  E1S1u           F        T
-----
...

```

Inspecting for instance the program output for day 179 in the year 2020, you will find a series of Galileo satellites represented by the ECOM2-YD1 because of their beta angles (elevation angle of the Sun above the orbital plane) are below the limit 14 degrees. The related definition comes from the BOXWING.MAC file:

```

...
#PARAMETER          VALUE
#*****
MODEL IDENTIFIER    GALILEO-2
PARAMETER DEFAULT   ECOM2
PARAMETER BETA      ECOM2-YD1 14.0
...

```

The most important part of the program output is the quality of the orbit representation by the model defined for the current program run:

```

...
-----
RMS ERRORS AND MAX. RESIDUALS   ARC NUMBER: 1                               ITERATION: 2
-----
SAT  #POS  RMS (M)  QUADRATIC MEAN OF O-C (M)  MAX. RESIDUALS (M)
-----
TOTAL  RADIAL  ALONG  OUT  RADIAL  ALONG  OUT
-----
1    288  0.001  0.001  0.001  0.001  0.001  0.003  0.002  0.003
2    288  0.001  0.001  0.001  0.001  0.001  0.002  0.002  0.003
3    288  0.001  0.001  0.001  0.001  0.001  0.005  0.003  0.001
4    288  0.000  0.000  0.000  0.001  0.000  0.001  0.002  0.001
5    288  0.001  0.001  0.001  0.001  0.001  0.004  0.003  0.001
6    288  0.001  0.001  0.001  0.001  0.001  0.003  0.002  0.003
...
31   288  0.001  0.001  0.000  0.001  0.000  0.001  0.002  0.001
32   288  0.001  0.001  0.001  0.001  0.001  0.002  0.002  0.003

```

101	288	0.001	0.001	0.002	0.001	0.001	0.007	0.004	0.003
102	288	0.001	0.002	0.002	0.001	0.001	0.006	0.004	0.003
103	288	0.001	0.001	0.002	0.001	0.001	0.009	0.004	0.004
...									
124	288	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.004
126	288	0.001	0.001	0.000	0.001	0.000	0.001	0.002	0.001
201	288	0.001	0.001	0.001	0.001	0.001	0.004	0.003	0.004
202	288	0.001	0.001	0.001	0.001	0.001	0.006	0.003	0.004
...									
230	288	0.001	0.001	0.001	0.001	0.001	0.005	0.003	0.004
231	288	0.001	0.001	0.001	0.001	0.001	0.004	0.003	0.004
233	288	0.001	0.001	0.001	0.001	0.001	0.003	0.002	0.004
236	288	0.001	0.001	0.001	0.001	0.001	0.003	0.002	0.004

These should be 1 mm (for older orbits it may also be 3..5 mm) if precise orbits from CODE were used together with the consistent EOP information (the actual RMS errors depend on the quality of the precise orbits, on the pole file used for the transformation between IERS Terrestrial Reference Frame (ITRF) and International Celestial Reference Frame (ICRF), and on the orbit model used in ORBGEN). Comparing the RMS error from the third and the fourth iteration you will see that three iterations are sufficient to produce precise standard orbits for GNSS satellites.

The file `INTRO/OUT/ORB_20190440.LST` summarizes the orbit fit RMS values in one table:

```

EXAMPLE: Session 2019-0440: Standard orbit generation          25-AUG-24 08:29
TIME FROM DAY : 3 GPS WEEK: 2040
      TO   DAY : 4 GPS WEEK: 2040
-----
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:  8 E /  0 M ( 0 EM)
-----
ECL  ..  ..  E.  ..  E.  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
DOY  1  2  3  4  5  6  ...  31  32  101  102  103  ...  124  126  201  202  ...  230  231  233  236
-----
044  1  1  1  1  1  1  ...  1  1  1  2  1  ...  1  1  1  1  ...  1  1  1  1
-----
ALL  1  1  1  1  1  1  ...  1  1  1  2  1  ...  1  1  1  1  ...  1  1  1  1
-----

```

The output shows that 8 satellites are in eclipse (indicated above the satellite number by E for Earth or M for Moon).

A similar file may be generated using the orbit products from IGS (including the EOP information) following the procedure described in Section 7.1. As you can notice the RMS errors are slightly larger. It does not mean that the orbits from CODE are better than the IGS orbits. The orbit model in ORBGEN is just more consistent with the orbit model used at CODE:

```

EXAMPLE: Session 2019-0440: Standard orbit generation          25-AUG-24 13:27
TIME FROM DAY : 3 GPS WEEK: 2040
      TO   DAY : 4 GPS WEEK: 2040
-----
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:  8 E /  0 M ( 0 EM)
-----
ECL  ..  ..  E.  ..  E.  ..  ..  ..  ..  ..  ..  E.  ..  E.  ...  ..  ..  ..  ..  E.  ..  ..  ..  ..
DOY  1  2  3  4  5  6  7  8  9  10  11  12  ...  24  25  26  27  28  29  30  31  32
-----
044  2  2  3  3  3  2  2  3  2  3  2  4  ...  2  3  3  2  4  3  2  1  1
-----
ALL  2  2  3  3  3  2  2  3  2  3  2  4  ...  2  3  3  2  4  3  2  1  1
-----

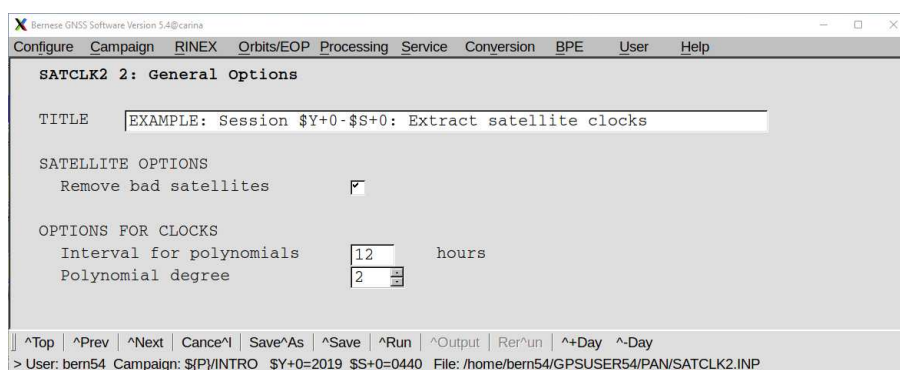
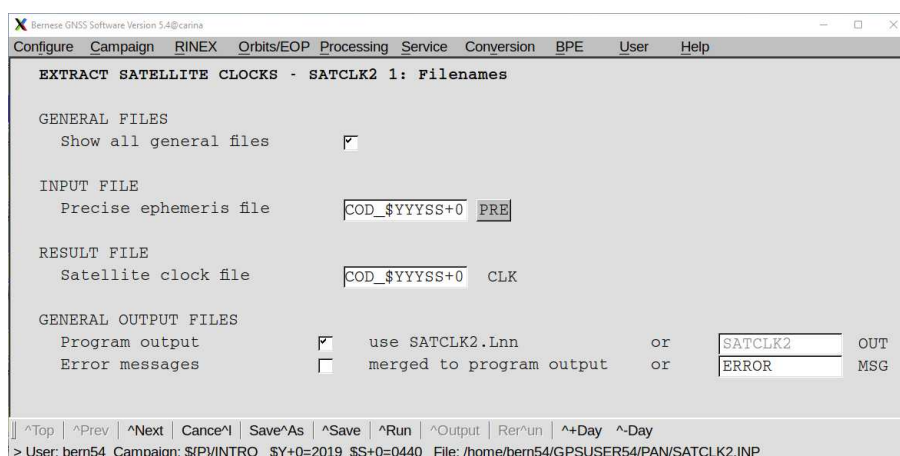
```

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

In the example for day 045 of year 2019 a satellite 76 appears. The GPS-satellite 26 had a repositioning event at 14-Feb-2019 19:47:44 (see `/${CONFIG}/SAT_2019.CRX`). The satellite is introduced in the processing with two independent arcs: one before (number 26) and one after (number 76) the event (you may verify this by the number of epochs available for each of these two satellite arcs).

3.3 Extract satellite clock corrections

As the next step we run SATCLK2 from "Menu>Orbits/EOP>Import satellite clocks>From precise orbit files" in order to generate a satellite clock file (CLK) from the precise orbit file (PRE). The clock file will be needed, e.g., in program CODSPP (see Section 4.2.1, to be discussed in the Tuesday's lectures on pre-processing).



Panel "SATCLK2 2: General Options" 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 [h]" of 12 hours. This is good enough for the receiver clock synchronization in CODSPP.



A message like this is expected:

```

### FN 0_SATCLK2:chkSufficientNbClkValues , PG SATCLK2 (13-Jan-2024 15:46:23)
Satellite clock correction values missing
Minimal number : 3
Number in sample: 0
Satellite      : R26
File name      : ${P}/INTRO/ORB/COD_20190440.PRE

### FN 0_SATCLK2:chkSufficientNbClkValues , PG SATCLK2 (13-Jan-2024 15:46:23)
Satellite clock correction values missing
Minimal number : 3
Number in sample: 0
Satellite      : E01
File name      : ${P}/INTRO/ORB/COD_20190440.PRE

...

```

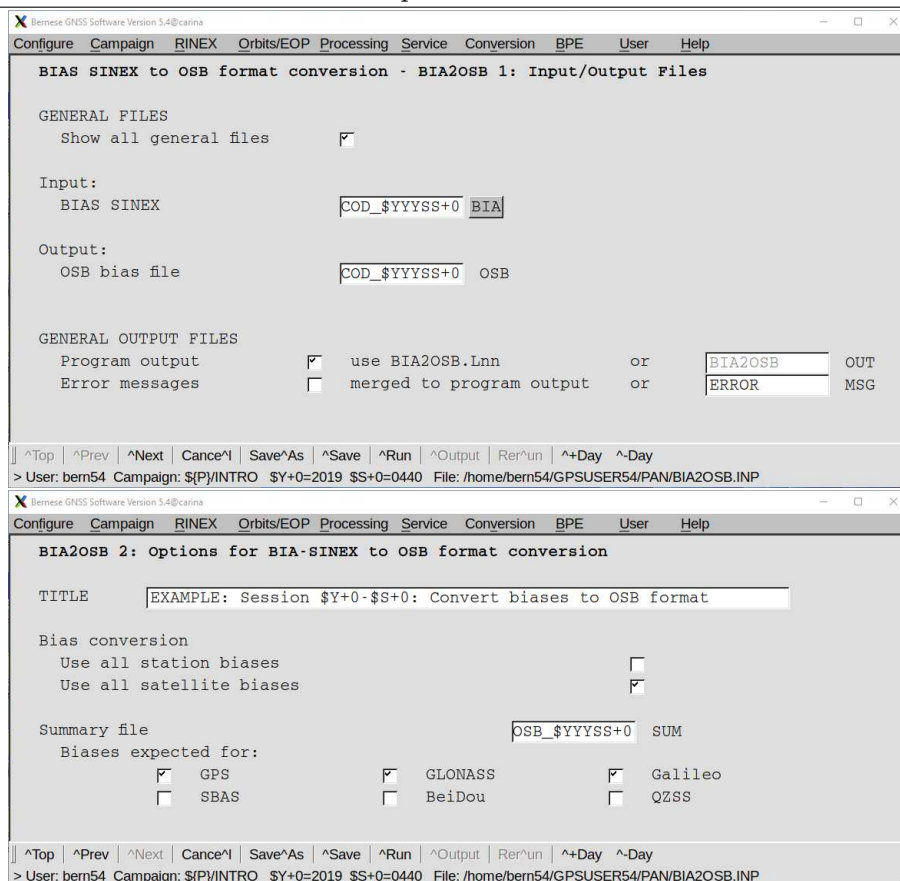
It indicates that the precise orbit files do not contain clock corrections for Galileo satellites. Consequently they are not available for the synchronization of the receiver clocks in CODSP. It does not matter because it is sufficient to do this process based on the GPS satellite clocks only.

3.4 Convert Bias Corrections from Bias SINEX into Bernese bias Format

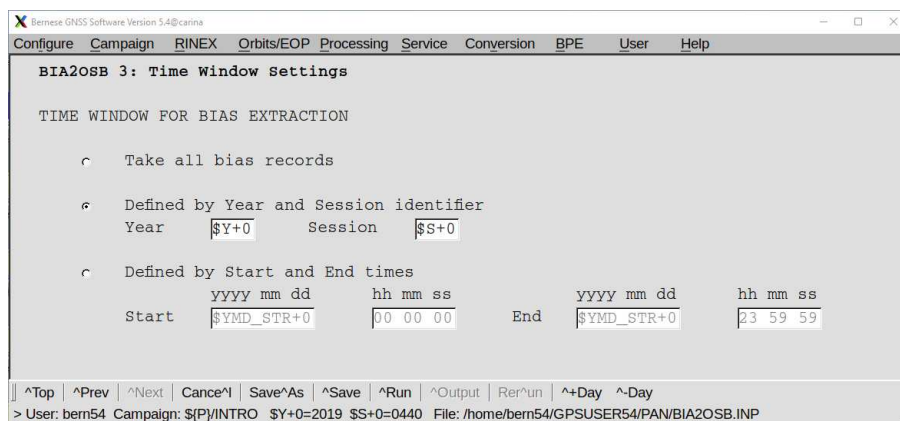
Ideally the clock corrections (either in a separate clock RINEX format or also in a precise orbit file) are provided together with a consistent set of code and potentially phase biases. Biases provided by a different source could potentially be less consistent.

In this context we run BIA2OSB from "Menu>Conversion>BIAS-SINEX to Bernese format". in order to extract biases from international Bias SINEX format file (BIA) into the Bernese formatted file with OSBs (OSB, both files are located in the ORB directory of the campaign).

3 Terminal Session: Pole and Orbit Preparation



We select the current session as the time window in order to extract the expected set of satellites if the input Bias SINEX file contains a longer interval than just the current session (like in our case) and within this interval a satellite change takes place:



If no bias information is provided we can use default code biases from the CODE processing (<http://www.aiub.unibe.ch/download/BSWUSER54/ORB>).

3.5 Session Goals

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

1. Bernese pole file in the campaign's ORB directory: *COD_20190440.ERP*,
2. Bernese standard orbit file in the ORB directory: *COD_20190440.STD*,
3. Bernese satellite clock file in the ORB directory: *COD_20190440.CLK*.
4. Biases in Bernese format file in the ORB directory: *COD_20190440.OSB*.

4 Terminal Session: Tuesday

Today's terminal session is to:

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

4.1 Importing the Observations

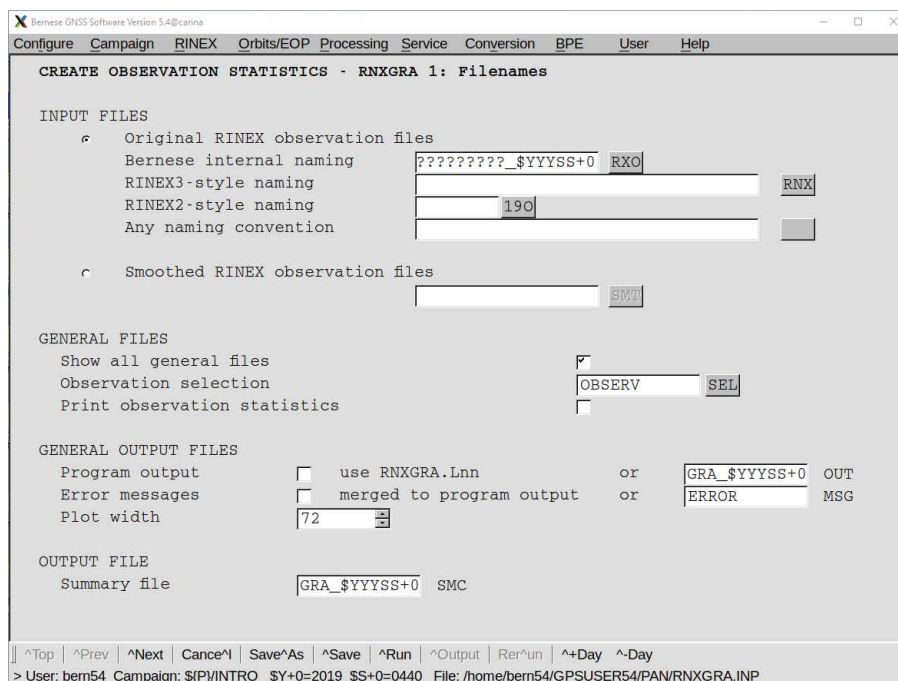
The campaign has been set up and all necessary files are available. The first part of processing consists of the transfer of the observations from RINEX to Bernese (binary) format.

4.1.1 Inventory of the input RINEX files

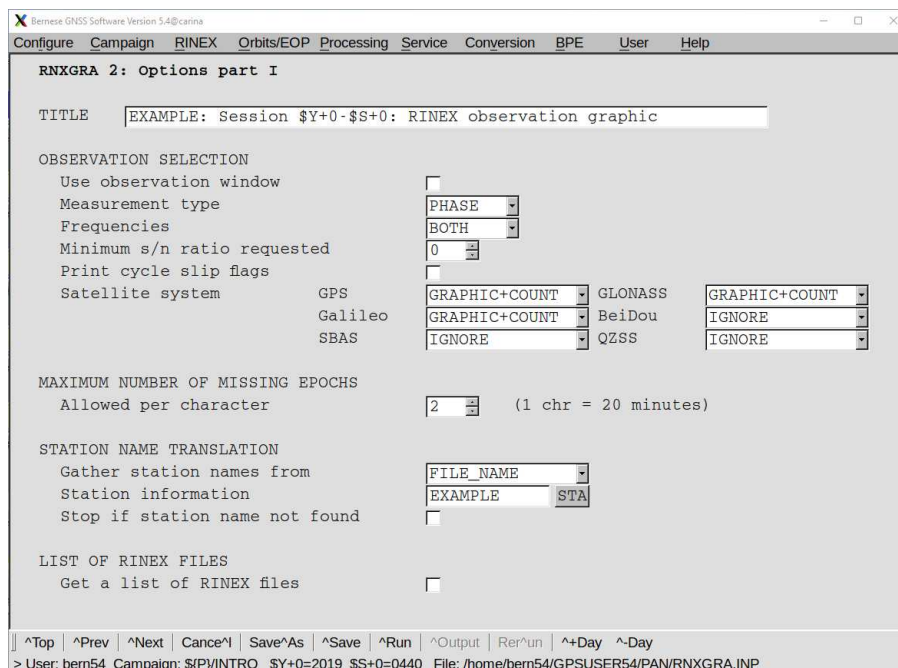
Before starting the data analysis, it is recommended to get an overview of the data availability, completeness, and a first impression on the data quality. For this purpose you may generate a pseudographic from the RINEX observation files using the program RNXGRA in "Menu>RINEX>RINEX utilities>Create observation statistics".

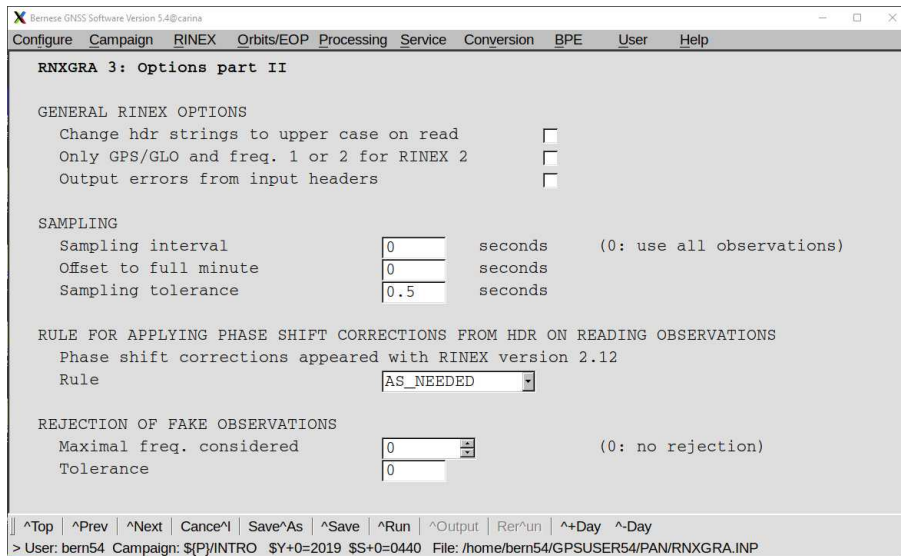
Note that this step is not mandatory and can also be skipped during the tutorial exercise.

You have to select the RINEX observation files for option “Original RINEX observation files”. All three naming schemes of the files are supported by the user interface: “Bernese internal naming”, “RINEX3-style naming”, and “RINEX2-style naming”. If there are files specified in more than one field, they are cumulated.

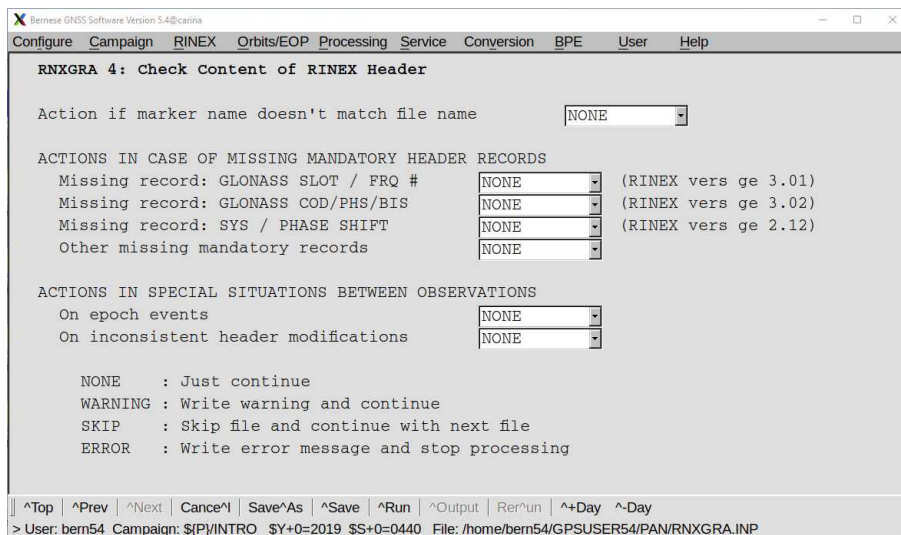


As only GPS, GLONASS, and Galileo satellite orbits are processed in this example, only those systems are selected





All validations are disabled in this step because they can also be carried out when importing the data by the program RXOBV3 described in Section 4.1.2.



From the processing you get a summary in `$(P)/INTRO/OUT/GRA_20190440.SMC`:

```

DATE : 2019-02-13

PHASE OBSERVATIONS
BOTH FREQUENCIES

 1 |*****82 -                11237631 -                -1*
 2 |          -19*****4 -          -37*****51 -
 3 | -17*****41 -                -3221 -
 4 |          -455555577777773 -                111 -
 5 |          -3*****4 -                -125*****82 -
 6 |          -19*****82 -          -138*****81 -
 7 | 1-          -3*****41 -                -16*****3
 8 |*****92 -          -1249****83 -                -17*****
 9 |          -1*****821 -                -2221 -
10 |*****731 -          -5*****41 -                -3*****
...
231 | -366776621 -                -368999*****9999*****99871 -
233 |          -135778899999998874 -          -1189999999998651 -
236 |          -3676632 -                -3789999*****
-----+-----+-----+-----+-----+-----+-----+-----+-----+
 0                                12                                24

NUMBER OF SATELLITES INCLUDED IN DATA FILES: 82

```

The summary reports the number of stations tracking each satellite during a certain period of the day. If more than 9 stations are in view a *-character is written.

The second part shows how many satellites were observed by each station during the course of the day (again the *-character is indicating a number > 9). This part is shown separately for each selected satellite system.

```

DATE : 2019-02-13

PHASE OBSERVATIONS
BOTH FREQUENCIES

SATELLITE SYSTEM: GPS

BRST |*****98798889977788778988899999*9**999999999787998889889****
GANP |9*****9**9999**99989998878*9**9*8889**9*999978887788889999999
HERT |*****9*9**99*8878888887899999**9**99*999799*8888878*89****
JOZ2 |***- *****9*****98**9**997*9*****89*****99898899779899*****
LAMA |9*****9*****9998888*998887679877887*9*99788899998867886776877899**89
MATE |*****9998988998888898889888989*98888*9787778898898899*9
MIKL |*****9*****9**9889*9*****9*9**99***988889889*****9***
ONSA |*****9*****9*****9*8*8*****9*****9989*999*99889*9*****
ORID |*****99*8889887877888**999899**99899*97887888*8888899**
PTBB |67*****9*****88898789*99987868986787799987878999998877777768757899*98
TLSE |*****9*****99**988877796797789*9999*****9*9998999*7799888889****
VILL |9*****99****9**998887888887865687898999878989988899866687687999999
WSRT |---7-----9-----6***999*9*****-----*****889***9*9899*****
WTZR |*****- ****9*****9**989978**88898***9***9**999998*99*7789898*9*****
WTZZ |*****9**89**98898***9***9**999998*9997779898*9*****
ZIM2 |*****9*****9**89*897889*99*9*****999989*998789888989****
ZIMM |9*****99**989*98898986889*9989989*9999998989877798878889***
-----+-----+-----+-----+-----+-----+-----+-----+-----+
0                                     12                                24

```

From this output it can be concluded that station WSRT seems to have some tracking problems in the first half of the day. It is therefore recommended to have a particular look at the results from this station in the different processing steps. In addition, the stations JOZ2 and WTZR show short outages of one hour. This is typically caused by data management issues at the station (related to the extraction of the hourly RINEX files).

Similar tables for the other systems are available as well.

The program output file `#{P}/INTRO/OUT/GRA_20190440.OUT` provides even more detailed information on each individual RINEX file.

4.1.2 Converting the Observations from RINEX into Bernese format

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 in this processing example).

The principle of specifying the input RINEX files is the same as for all RINEX related programs (description see page 36):

The screenshot shows the 'TRANSFER RINEX OBSERVATION FILES TO BERNESE FORMAT - RXOBV3 1: Filenames' dialog box. The interface is organized into several sections:

- INPUT FILES:**
 - Original RINEX observation files: Bernese internal naming (input: ????????_YYYYSS+0, button: RXO), RINEX3-style naming (input: , button: RNX), RINEX2-style naming (input: 190, button:), Any naming convention (input: , button:).
 - Smoothed RINEX observation files: (input: , button: SMT).
- Station information:** (input: EXAMPLE, button: STA).
- GENERAL FILES:**
 - Show all general files:
 - Observation selection: (input: OBSERV, button: SEL)
 - Print observation statistics:
- RESULT FILES:**
 - Measurement types to save: Code , Phase , Range
 - Update coordinates: (input: , button: CRD) (blank if not used)
- GENERAL OUTPUT FILES:**
 - Program output: use RXOBV3.Lnn or (input: RXO_YYYYSS+0, button: OUT)
 - Error messages: merged to program output or (input: ERROR, button: MSG)

The status bar at the bottom indicates: > User: bern54 Campaign: \${P}/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/RXOBV3.INP

The next panel specifies the general input files. The “Satellite information” and “Antenna phase center corrections” files should consistently refer to the used reference frame even if the corrections themselves are not yet needed for the import step.

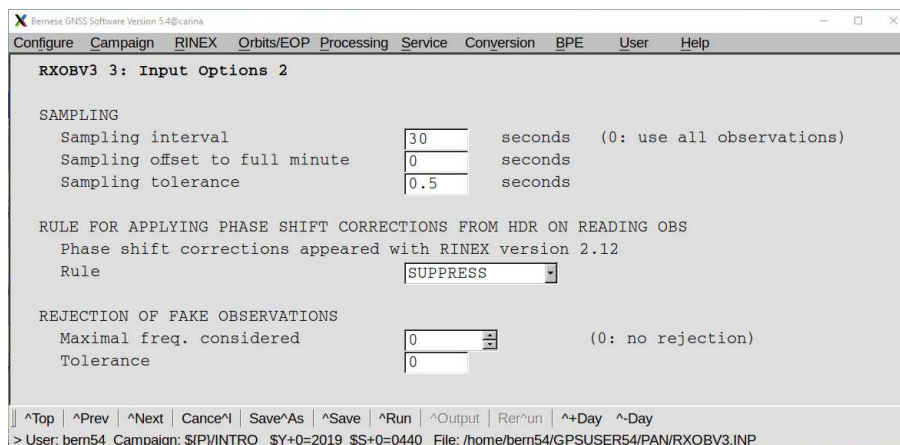
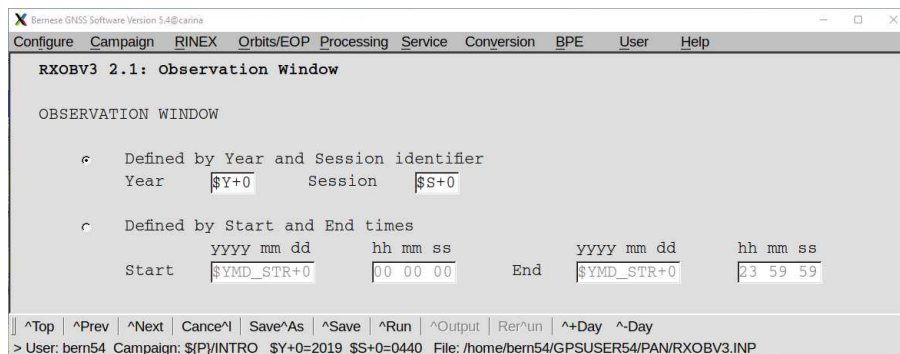
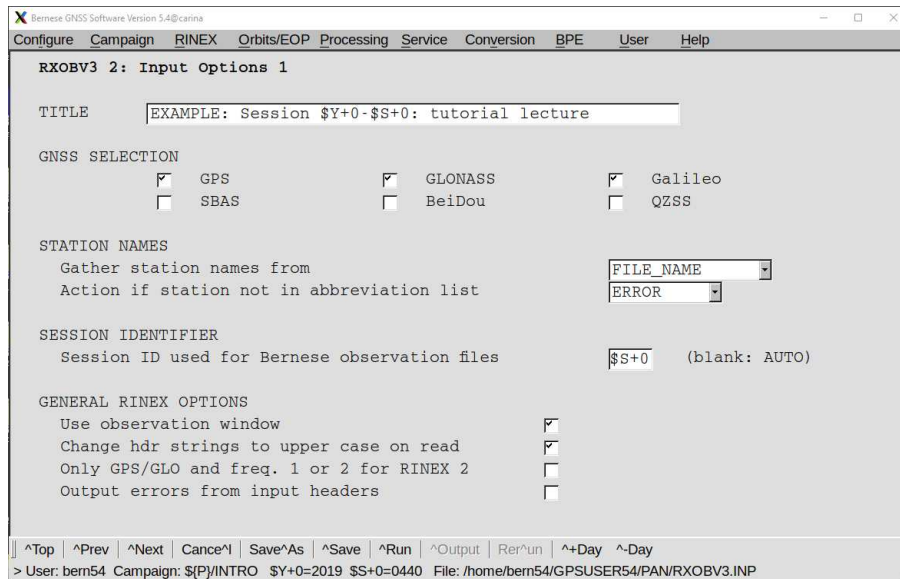
The screenshot shows the 'RXOBV3 1.1: General Files' dialog box. The interface is organized into several sections:

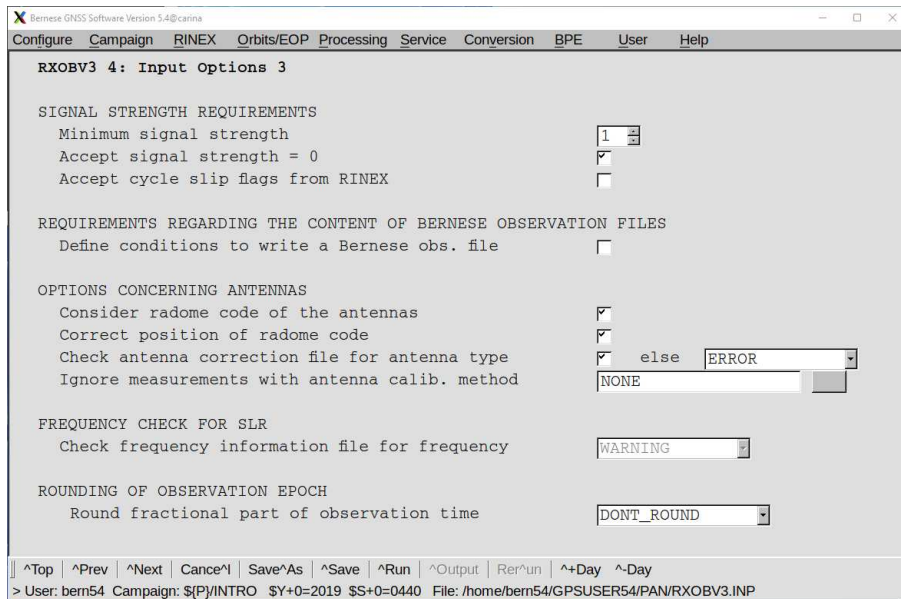
- GENERAL INPUT FILES:**
 - General constants: (input: CONST, button: BSW)
 - Satellite information: (input: SATELLIT_I20, button: SAT)
 - Satellite problems: (input: SAT_\$Y+0, button: CRX)
 - Antenna corrections: (input: ANTENNA_I20, button: PCV)
 - GPS-UTC time difference: (input: GPSUTC, button: BSW)
 - Abbreviation table: (input: EXAMPLE, button: ABB)
 - Frequency information: (input: , button: FRQ)
- MENU SETTINGS:**
 - Selected campaign: \${P}/INTRO
 - Selected session: year 2019 session 0440
 - Session table: \${P}/INTRO/GEN/SESSIONS.SES
- TEMPORARY FILES:**
 - Scratch files: (input: RXOBV3\$J, button: SCR), (input: RXOBV3\$J, button: SC1), (input: RXOBV3\$J, button: SC2)

The status bar at the bottom indicates: > User: bern54 Campaign: \${P}/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/RXOBV3.INP

Other panels allow to select the data to be imported and to specify a few parameters for the Bernese observation header files.

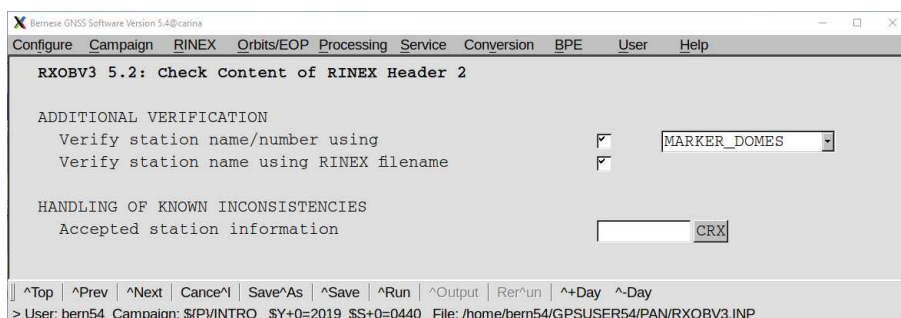
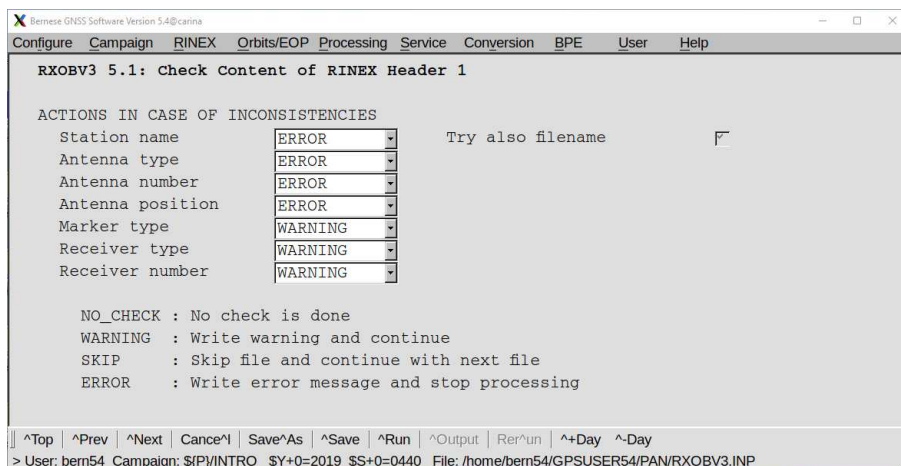
Because the orbits contain only the GPS-, GLONASS, and Galileo-satellites, activate the related checkboxes in the option “GNSS SELECTION”.



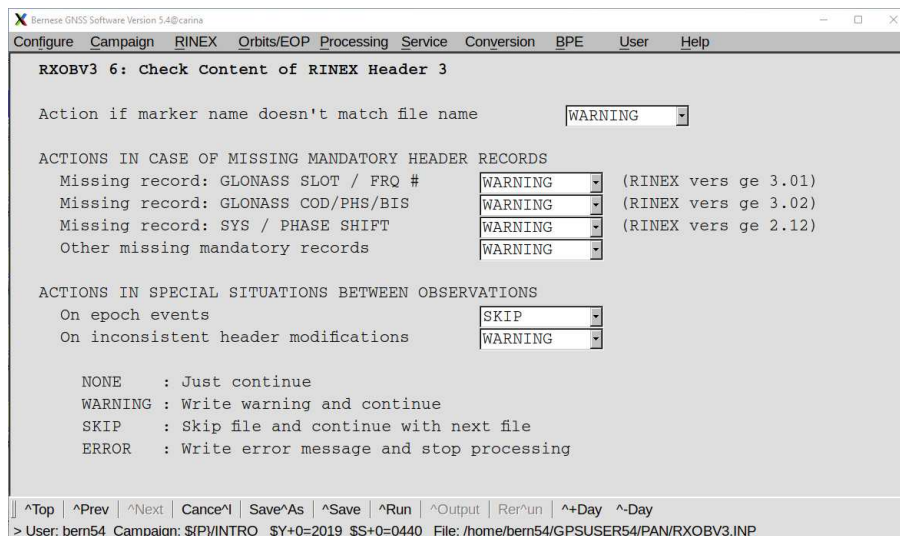


When switching for instance the option “Ignore measurements with antenna calib. method” to ADOPTED from GPS the observations from those GNSS are not imported where no antenna calibration is available for (see Table 1.2). It may also make sense to completely exclude stations where no calibration for the antenna with the specific radome is available (ADOPTED from NONE). In the case of the example dataset this would affect the station ONSA.

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



The last panel allows for checking the compliance of the input RINEX file with the format definition.



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

Various warning messages appear. In an automated processing they are sorted according to a priority and become better readable. In this case they are ordered just by the processing order. Most of them are not critical and do just inform about assumptions made by the program RXOBV3 based on the RINEX format description:

```
### SR SAVMEA: Receiver clock offset in RINEX file found.
It is assumed, that the observations in the
RINEX file are not corrected by applying the
receiver clock offset. Please check the
keyword "RCV CLOCK OFFS APPL" in the RINEX file
header!
RINEX FILENAME: ...RO/RAW/BRST00FRA_20190440.RX0
```

or actions taken on the observations that do not influence the processing results:

```
### SR SAVMEA: JUMP INTRODUCED INTO PHASES
DUE TO FORMAT OVERFLOW
RINEX FILE : ...RO/RAW/HERT00XYZ_20190440.RX0
FREQUENCY : L1
SATELLITE :122
JUMP (CYCLES): 579337875.0
EPOCH :2019-02-13 18:10:00
```

In some cases where there are several (inconsistent) header sequences in the RINEX files containing different information (e.g., related to the APPROX POSITION XYZ record):

```
### SR 0_RNXBASE:wrtHdrEntryChkErrsToLfnErr, PG RXOBV3
Inconsistency between the following two RINEX headers detected:
Filename (header to update):
${P}/INTRO/RAW/JOZ200XYZ_20190440.RX0
Filename (new header):
${P}/INTRO/RAW/JOZ200XYZ_20190440.RX0
Geocentric approx. ant. marker pos. (APPROX POSITION XYZ)
in header to update: '(3.6648784825E+06,1.4091900878E+06,5.0096170459E+06) '
in new header: '(3.6648768963E+06,1.4091892139E+06,5.0096167523E+06) '
```

The amount of these messages may be managed by the setting in panel "RXOBV3 6: Check Content of RINEX Header 3".

More relevant are messages indicating observations were removed due to an entry in the "Satellite problems" file. In the example, station ONSA provides data for the two GLONASS satellites R12 and R06 (satellite system R for GLONASS in RINEX whereas satellite numbers between 100 and 199 are in use within the *Bernese GNSS Software*) which are removed because of an entry in the "Satellite problems" file specified. in panel "RXOBV3 1.1: General Files".

```

### SR SAVMEA: PROBLEM FOR SATELLITE: 112
                INDICATED IN SATCRUX : ${CONFIG}/SAT_2019.CRX
                PROBLEM                : BAD PHASE+CODE
                REQUESTED ACTION        : OBS. REMOVED
                TIME WINDOW             : 2016-11-22 00:00:00 2019-06-19 23:59:59
                IN RINEX FILE           : ...RO/RAW/ONSA00XYZ_20190440.RXO

### SR SAVMEA: PROBLEM FOR SATELLITE: 106
                INDICATED IN SATCRUX : ${CONFIG}/SAT_2019.CRX
                PROBLEM                : BAD PHASE+CODE
                REQUESTED ACTION        : OBS. REMOVED
                TIME WINDOW             : 2018-04-08 00:00:00 2099-12-31 23:59:59
                IN RINEX FILE           : ...RO/RAW/ONSA00XYZ_20190440.RXO

```

The program produces an output file RXO_20190440.OUT in the directory \${P}/INTRO/OUT (resp. corresponding filenames for the other sessions). This file may be browsed using the ^Output button or with "Menu>Service>Browse program output". After echoing the input options, the file provides an overview of the observation intervals), on the station information records in the RINEX observation file header and on the values that are used for the processing in the *Bernese GNSS Software*. In addition some observation statistics are available. In the last section you may check the completeness of the Bernese observation files by the available number of epochs:

TABLE OF INPUT AND OUTPUT FILE NAMES:											
Num	Rinex file name	Bernese code header file	Bernese code observ. file	Bernese phase header file	Bernese phase observ. file	#observ.		#satell.			
						#epo	#C1/P1	#P2	GPS	GLO	GAL
1	...BRST00FRA_20190440.RXO	\${P}/INTRO/OBS/BRST0440.CZH	\${P}/INTRO/OBS/BRST0440.CZO	\${P}/INTRO/OBS/BRST0440.PZH	\${P}/INTRO/OBS/BRST0440.PZO	2880	75780	74934	31	22	24
						2880	75654	74864	31	22	24
						2880	77299	76553	32	22	24
						2880	77040	76362	32	22	24
2	...GANP00SVK_20190440.RXO	\${P}/INTRO/OBS/GANP0440.CZH	\${P}/INTRO/OBS/GANP0440.CZO	\${P}/INTRO/OBS/GANP0440.PZH	\${P}/INTRO/OBS/GANP0440.PZO	2880	52454	51981	31	22	0
						2880	52454	51970	31	22	0
						2880	79238	78472	32	22	24
						2880	78966	78274	32	22	24
3	...HERT00XYZ_20190440.RXO	\${P}/INTRO/OBS/HERT0440.CZH	\${P}/INTRO/OBS/HERT0440.CZO	\${P}/INTRO/OBS/HERT0440.PZH	\${P}/INTRO/OBS/HERT0440.PZO	2880	28964	28819	32	0	0
						2880	28844	28729	32	0	0
						2880	79238	78472	32	22	24
						2880	78966	78274	32	22	24
16	...ZIM200CHE_20190440.RXO	\${P}/INTRO/OBS/ZIM20440.CZH	\${P}/INTRO/OBS/ZIM20440.CZO	\${P}/INTRO/OBS/ZIM20440.PZH	\${P}/INTRO/OBS/ZIM20440.PZO	2880	28964	28819	32	0	0
						2880	28844	28729	32	0	0
						2880	79238	78472	32	22	24
						2880	78966	78274	32	22	24
17	...ZIMM00CHE_20190440.RXO	\${P}/INTRO/OBS/ZIMM0440.CZH	\${P}/INTRO/OBS/ZIMM0440.CZO	\${P}/INTRO/OBS/ZIMM0440.PZH	\${P}/INTRO/OBS/ZIMM0440.PZO	2880	28964	28819	32	0	0
						2880	28844	28729	32	0	0
						2880	79238	78472	32	22	24
						2880	78966	78274	32	22	24

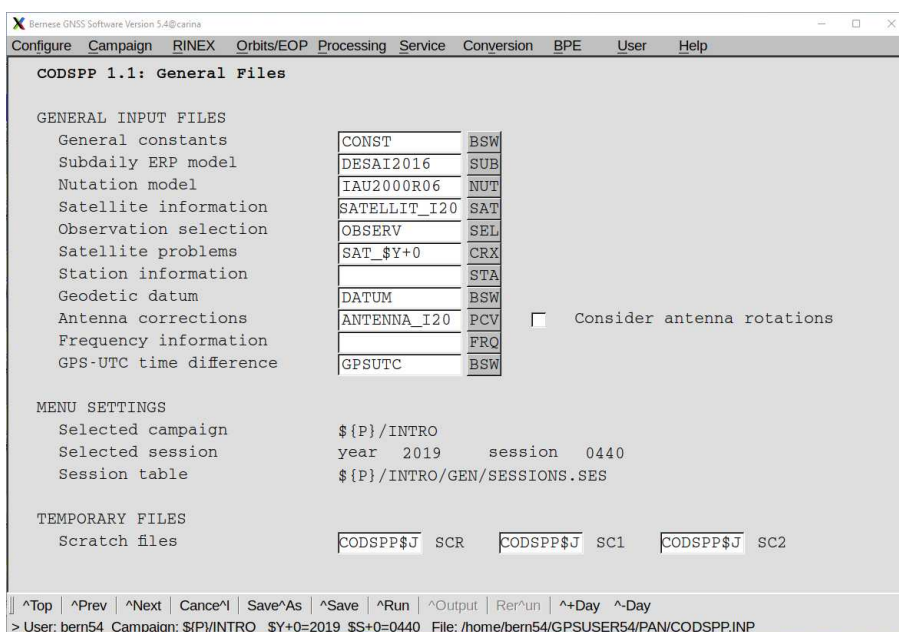
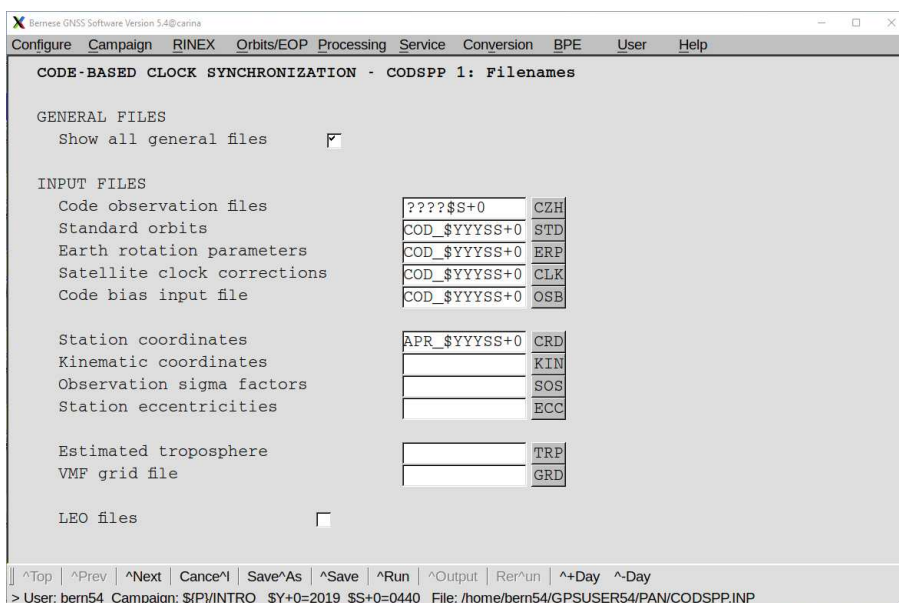
If epochs or satellites are missing for some RINEX files you may check this with the RINEX observation graphic from program RNXGRA ("Menu>RINEX>RINEX utilities>Create observation statistics"). In February 2019 32 GPS, 22 GLONASS, and 24 Galileo satellites were active.

At the end of the RXOBV3 output there is a table of RINEX files rejected during the import for some reasons.

4.2 Data Preprocessing (I)

4.2.1 Receiver Clock Synchronization

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



CODSP 1.3: Output Files

RESULT FILES

Coordinate results	<input type="text"/>	CRD
Kinematic coordinates	<input type="text"/>	KIN
Residual file	<input type="text"/>	RES
Satellite clock results	<input type="text"/>	CLK
Clock RINEX results	<input type="text"/>	CLK

OUTPUT FILES

Output summary (XYZ coord.)	<input type="text"/>	SMC
Output summary (Ell.coord.)	<input type="text"/>	SME

GENERAL OUTPUT FILES

Program output use CODSP.Lnn or OUT

Error messages merged to program output or MSG

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/CODSP.INP

CODSP 2: Input Options

TITLE

GNSS SELECTION FOR COMPUTATION OF SYSTEM TIME DIFFERENCE

<input checked="" type="checkbox"/> GPS	<input type="checkbox"/> GLONASS	<input type="checkbox"/> Galileo
<input type="checkbox"/> SBAS	<input type="checkbox"/> BeiDou	<input type="checkbox"/> QZSS

PARAMETERS

Frequency	<input type="text" value="L3"/>	
Clock polynomial degree	<input type="text" value="E"/>	E: one offset per epoch
Save clock estimates	<input type="text" value="BOTH"/>	
Estimate coordinates	<input type="text" value="NO"/>	

ATMOSPHERE MODELS

Troposphere	<input type="text" value="GPT3"/>
Ionosphere	<input type="checkbox"/>

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/CODSP.INP

We already have geocentric coordinates of good quality available for the sites from the PPP example BPE. Therefore, the option “Estimate coordinates” may be set to NO. The most important option in this CODSP run is “Save clock estimates”. It has to be set to BOTH in order to write the estimated receiver clock corrections into both, the code observation files and the phase observation files.

CODSP 3: Input Options

OBSERVATION SELECTION

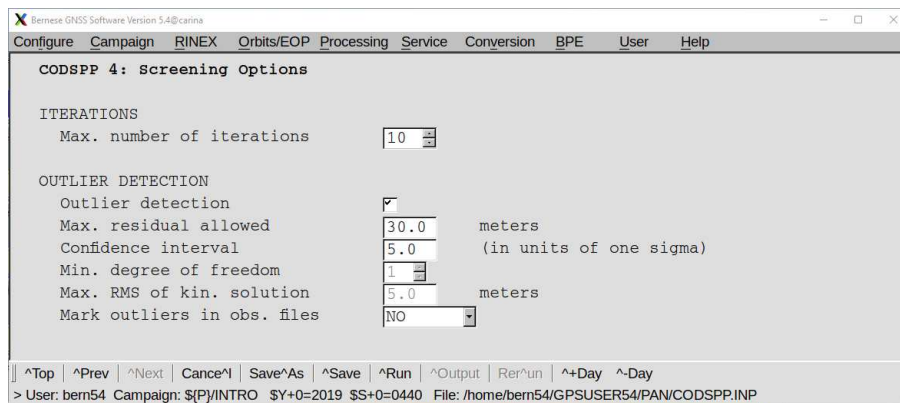
Minimum elevation	<input type="text" value="3"/>	degrees
Sampling interval	<input type="text" value="1"/>	
Interpolation of clocks allowed over	<input type="text" value="0"/>	seconds (0:no interpolation)
Observation window	<input type="checkbox"/>	
Use mark flags from observation files	<input type="checkbox"/>	

PRINT OPTIONS

Residuals	<input type="checkbox"/>
Elevations	<input type="checkbox"/>

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/CODSP.INP



CODSPP produces the following output:

```

...
STATION: BRST 10004M004   FILE:  ${P}/INTRO/OBS/BRST0440.CZ0   RECEIVER UNIT:  999999
-----
DAY OF YEAR      :    44
                   FROM                TO
OBSERVATIONS    :          2019-02-13  00:00: 0.00          2019-02-13  23:59:30.00
REQUESTED WINDOW :          --                --

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

ATMOSPHERE MODELS :          TROPOSPHERE          IONOSPHERE
                   GPT3                          NONE

STATISTICS FOR SATELLITE SYSTEM: GPS
-----
SATELLITE NUMBER :    1    2    3    5    6    7    8    9    10    11 ...  TOTAL
USED OBSERVATIONS :  837 1085 805 903 959 1029 903 765 1047 804 ... 28520
BAD OBSERVATIONS (%):  2.3  2.0  1.0  2.0  0.2  1.5  3.6  0.4  1.8  1.8 ...  1.7
RMS ERROR (M)     :  1.1  1.1  0.9  1.0  1.2  1.0  1.2  1.0  1.0  1.1 ...  1.1

RESULTS:
-----
OBSERVATIONS IN FILE:  29017
USED OBSERVATIONS   :  28520
BAD OBSERVATIONS    :           1.71 %
RMS OF UNIT WEIGHT  :           1.17 M
NUMBER OF ITERATIONS:    2

STATION COORDINATES:
-----
LOCAL GEODETIC DATUM:  IGS20

BRST 10004M004   X          A PRIORI          NEW          NEW- A PRIORI  RMS ERROR
(MARKER)        Y          -332746.43         -332746.43         0.00          0.00
                 Z          4745131.07         4745131.07         0.00          0.00

                 HEIGHT          65.82          65.82          0.00          0.00
                 LATITUDE    48 22 49.784    48 22 49.784    0 0 0.000    0.0000
                 LONGITUDE   - 4 29 47.729  - 4 29 47.729  0 0 0.000    0.0000

CLOCK PARAMETERS:
-----
OFFSET FOR REFERENCE EPOCH:          -0.000000019  SEC

CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES

RECEIVER UNIT    :  999999
REFERENCE EPOCH  :          2019-02-13  00:00: 0.00
...

```

```

...
*****
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      :      28

NUMB FIL  STATION          TYP SAT          FROM          TO          #EPO
-----
  1   2  GANP 11515M001     OUT   4  2019 02 13 04 54 00  2019 02 13 04 54 30    2

  2   8  ONSA 10402M004     OUT  30  2019 02 13 00 16 30  2019 02 13 00 16 30    1
  3   8  ONSA 10402M004     OUT  15  2019 02 13 00 35 30  2019 02 13 00 35 30    1
  4   8  ONSA 10402M004     OUT  17  2019 02 13 01 49 00  2019 02 13 01 49 00    1
  5   8  ONSA 10402M004     OUT  12  2019 02 13 05 17 30  2019 02 13 05 17 30    1
  6   8  ONSA 10402M004     OUT  25  2019 02 13 06 02 00  2019 02 13 06 02 00    1

...
 18  13  WSRT 13506M005     OUT  23  2019 02 13 05 59 30  2019 02 13 05 59 30    1
 19  13  WSRT 13506M005     OUT   6  2019 02 13 06 13 30  2019 02 13 06 14 30    3
 20  13  WSRT 13506M005     OUT   9  2019 02 13 07 31 00  2019 02 13 07 32 00    3
 21  13  WSRT 13506M005     OUT   9  2019 02 13 07 35 30  2019 02 13 07 35 30    1
 22  13  WSRT 13506M005     OUT   9  2019 02 13 08 16 00  2019 02 13 08 16 00    1
 23  13  WSRT 13506M005     OUT  17  2019 02 13 14 14 00  2019 02 13 14 14 30    2
 24  13  WSRT 13506M005     OUT  12  2019 02 13 14 28 30  2019 02 13 14 32 00    8
 25  13  WSRT 13506M005     OUT  32  2019 02 13 14 28 30  2019 02 13 14 32 00    8
 26  13  WSRT 13506M005     OUT  24  2019 02 13 14 29 00  2019 02 13 14 32 00    7
 27  13  WSRT 13506M005     OUT   1  2019 02 13 14 29 00  2019 02 13 14 32 00    7
 28  13  WSRT 13506M005     OUT  24  2019 02 13 14 34 30  2019 02 13 14 35 30    3

-----

>>> CPU/Real time for pgm "CODSPP": 0:01:11.868 / 0:01:11.882
>>> Program finished successfully

```

The most important message in the output file is **CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES**. This indicates that the receiver clock corrections computed by CODSPP are stored in code and phase observation files.

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, even worse code measurements would still be sufficiently accurate to compute the receiver clock corrections with the necessary accuracy of $1 \mu\text{s}$.

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

```

...
-----
File   Input files
-----
  1   ${P}/INTRO/OUT/COD_20190440.OUT
-----

 17 FILES, MAX. RMS:    3.15 M   FOR STATION: ONSA 10402M004
           MAX. BAD:    5.70 %   FOR STATION: MIKL 12335M001
           MAX. OFF:    0.25 MSEC FOR STATION: WTZZ 14201M014

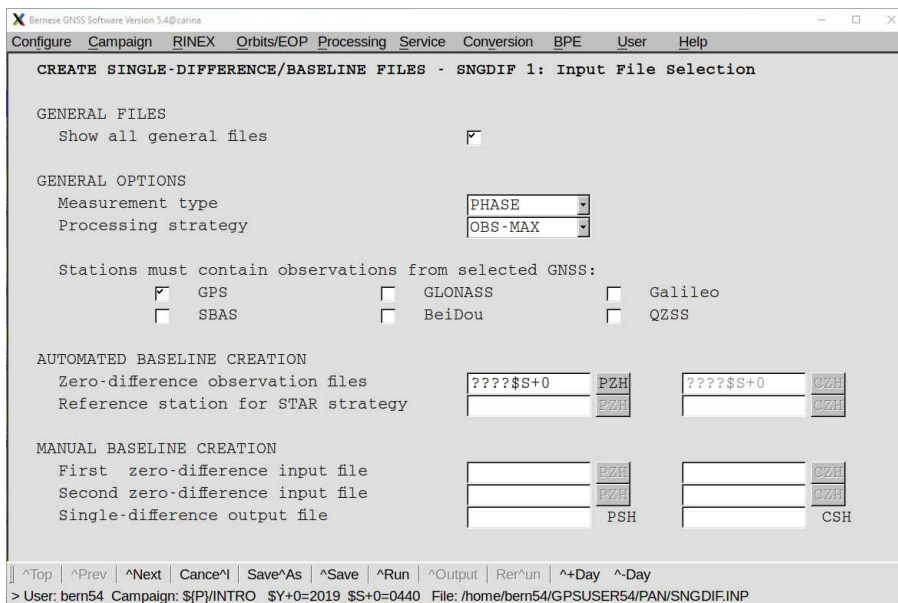
-----

>>> CPU/Real time for pgm "CODXTR": 0:00:00.013 / 0:00:00.013
>>> Program finished successfully

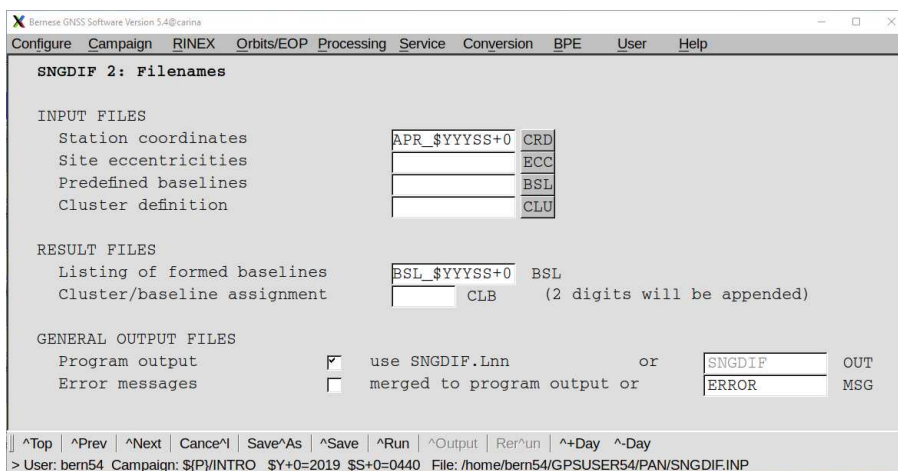
```


4.2.2 Form Baselines

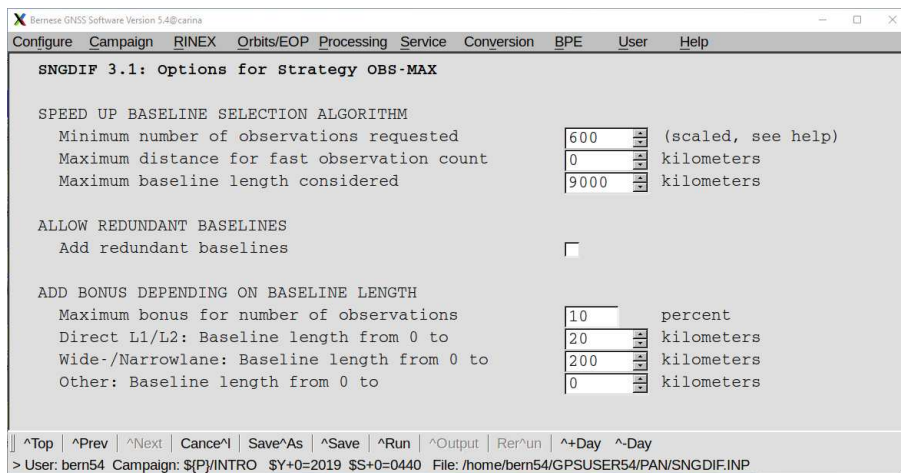
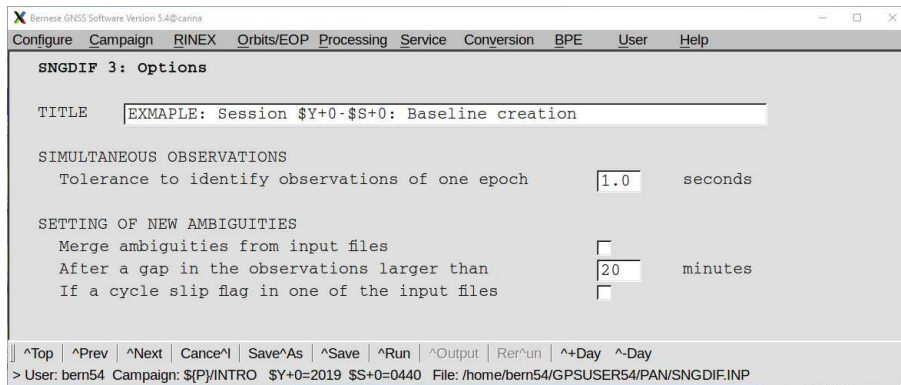
The second preprocessing program is called SNGDIF and may be activated in "Menu >Processing>Create baseline files". SNGDIF creates the single differences and stores them into single-difference observation files. We use the strategy OBS-MAX for PHASE observation files.



By activating the option "Stations must contain observ. from GPS" you demand that stations included in the baseline creation must contain at least GPS measurements. This option can be used to exclude those datasets containing no GPS observations.



The result file specified in option "Listing of formed baselines" stores the selected baseline configuration for further use.



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

```

...
NUM HEADER FILE NAMES          STATION NAME    #SAT  SYS    REMARK
-----
 1 ${P}/INTRO/OBS/BRST0440.PZH  BRST 10004M004   77  GRE    included
 2 ${P}/INTRO/OBS/GANP0440.PZH  GANP 11515M001   78  GRE    included
 3 ${P}/INTRO/OBS/HERT0440.PZH  HERT 13212M010   53  GR     included
 4 ${P}/INTRO/OBS/JOZ20440.PZH  JOZ2 12204M002   53  GR     included
 5 ${P}/INTRO/OBS/LAMA0440.PZH  LAMA 12209M001   53  GR     included
 6 ${P}/INTRO/OBS/MATE0440.PZH  MATE 12734M008   75  GRE    included
 7 ${P}/INTRO/OBS/MIKLO440.PZH  MIKL 12335M001   75  GRE    included
 8 ${P}/INTRO/OBS/ONSA0440.PZH  ONSA 10402M004   54  GR     included
 9 ${P}/INTRO/OBS/ORID0440.PZH  ORID 15601M001   53  GR     included
10 ${P}/INTRO/OBS/PTBB0440.PZH  PTBB 14234M001   32  G      included
11 ${P}/INTRO/OBS/TLSE0440.PZH  TLSE 10003M009   77  GRE    included
12 ${P}/INTRO/OBS/VILLO440.PZH  VILL 13406M001   79  GRE    included
13 ${P}/INTRO/OBS/WSRT0440.PZH  WSRT 13506M005   74  GRE    included
14 ${P}/INTRO/OBS/WTZR0440.PZH  WTZR 14201M010   77  GRE    included
15 ${P}/INTRO/OBS/WTZZ0440.PZH  WTZZ 14201M014   79  GRE    included
16 ${P}/INTRO/OBS/ZIM20440.PZH  ZIM2 14001M008   78  GRE    included
17 ${P}/INTRO/OBS/ZIMM0440.PZH  ZIMM 14001M004   32  G      included
...

```

The creation of the following 16 baseline files from 17 zero difference observation files is reported:

SNGDIF: INPUT AND OUTPUT OBSERVATION FILE NAMES					
-----			-----		
0-DIF. HEADER FILE NAMES (INPUT)	0-DIF. OBS. FILE NAMES (INPUT)	NUM			
*****	*****	***			
#{P}/INTRO/OBS/BRST0440.PZH	#{P}/INTRO/OBS/BRST0440.PZO	1			
#{P}/INTRO/OBS/TLSE0440.PZH	#{P}/INTRO/OBS/TLSE0440.PZO	2			
#{P}/INTRO/OBS/GANP0440.PZH	#{P}/INTRO/OBS/GANP0440.PZO	3			
#{P}/INTRO/OBS/MIKLO440.PZH	#{P}/INTRO/OBS/MIKLO440.PZO	4			
#{P}/INTRO/OBS/GANP0440.PZH	#{P}/INTRO/OBS/GANP0440.PZO	5			
#{P}/INTRO/OBS/WTZZ0440.PZH	#{P}/INTRO/OBS/WTZZ0440.PZO	6			
...					
1-DIF. HEADER FILE NAMES (OUT)	1-DIF. OBS. FILE NAMES (OUT)	NR1	NR2	STAT.	
*****	*****	***	***	*****	
#{P}/INTRO/OBS/BRTLO440.PSH	#{P}/INTRO/OBS/BRTLO440.PSO	1	2	OK	
#{P}/INTRO/OBS/GAMIO440.PSH	#{P}/INTRO/OBS/GAMIO440.PSO	3	4	OK	
#{P}/INTRO/OBS/GAWZO440.PSH	#{P}/INTRO/OBS/GAWZO440.PSO	5	6	OK	
#{P}/INTRO/OBS/HETLO440.PSH	#{P}/INTRO/OBS/HETLO440.PSO	7	8	OK	
#{P}/INTRO/OBS/JOON0440.PSH	#{P}/INTRO/OBS/JOON0440.PSO	9	10	OK	
#{P}/INTRO/OBS/LAON0440.PSH	#{P}/INTRO/OBS/LAON0440.PSO	11	12	OK	
#{P}/INTRO/OBS/MAOR0440.PSH	#{P}/INTRO/OBS/MAOR0440.PSO	13	14	OK	
#{P}/INTRO/OBS/MAZIO440.PSH	#{P}/INTRO/OBS/MAZIO440.PSO	15	16	OK	
#{P}/INTRO/OBS/ONPT0440.PSH	#{P}/INTRO/OBS/ONPT0440.PSO	17	18	OK	
#{P}/INTRO/OBS/ONWZ0440.PSH	#{P}/INTRO/OBS/ONWZ0440.PSO	19	20	OK	
#{P}/INTRO/OBS/TLZIO440.PSH	#{P}/INTRO/OBS/TLZIO440.PSO	21	22	OK	
#{P}/INTRO/OBS/VIWZ0440.PSH	#{P}/INTRO/OBS/VIWZ0440.PSO	23	24	OK	
#{P}/INTRO/OBS/WSWZ0440.PSH	#{P}/INTRO/OBS/WSWZ0440.PSO	25	26	WARNG	
#{P}/INTRO/OBS/WTWZ0440.PSH	#{P}/INTRO/OBS/WTWZ0440.PSO	27	28	OK	
#{P}/INTRO/OBS/WZZIO440.PSH	#{P}/INTRO/OBS/WZZIO440.PSO	29	30	OK	
#{P}/INTRO/OBS/ZIZM0440.PSH	#{P}/INTRO/OBS/ZIZM0440.PSO	31	32	OK	
...					

For the baseline WSWZ (WSRT-WTZZ) it is indicated that warning messages related to this baseline are issued that can be displayed via "Menu>Service>Browse error message":

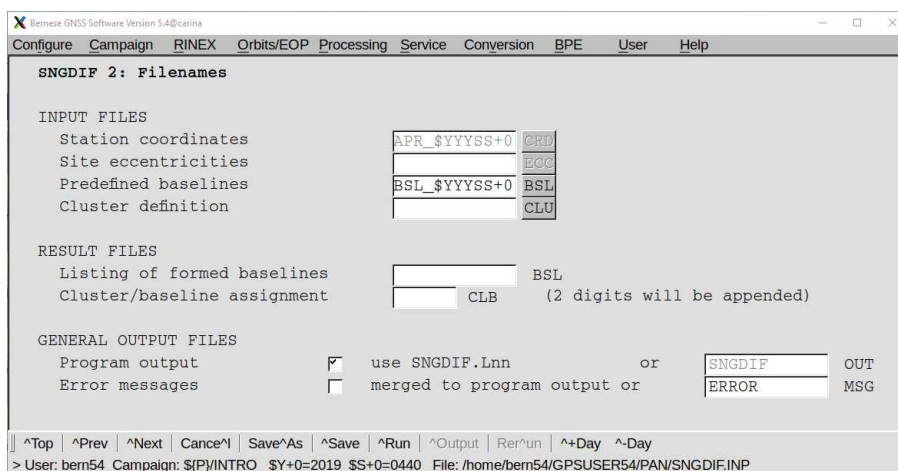
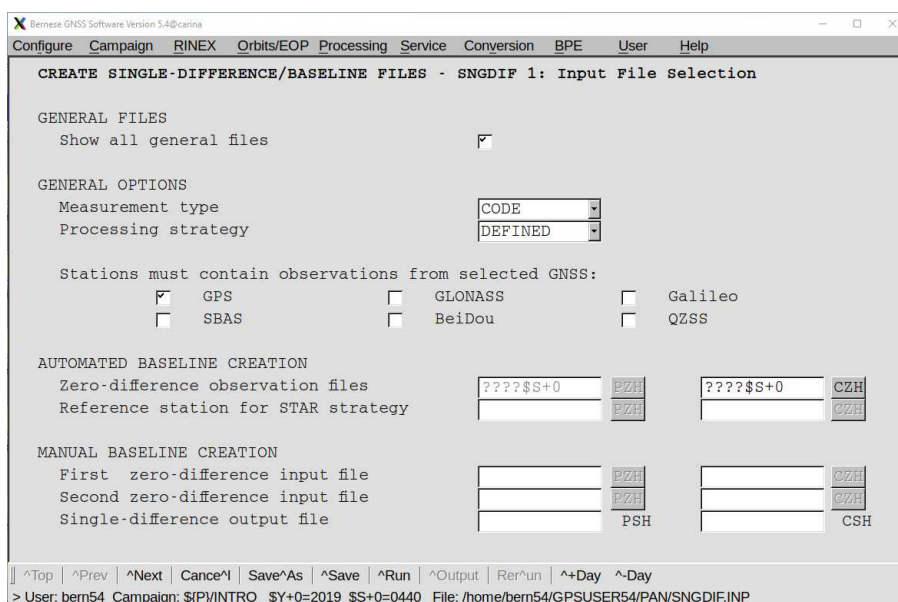
PG SNGDIF: JUMP INTRODUCED TO AVOID FORMAT OVERFLOW
FREQUENCY : 1
SATELLITE : 1
EPOCH NUMBER : 299
JUMP (CYCLES): 872366831.
FILE : #{P}/INTRO/OBS/WSWT0440.PSH
...

These jumps do not influence the obtained results.

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

1	BRST	10004M004	-	GANP	11515M001	#SAT: 77	CRIT.: 32293	
2	BRST	10004M004	-	HERT	13212M010	#SAT: 53	CRIT.: 24582	
3	BRST	10004M004	-	JOZ2	12204M002	#SAT: 53	CRIT.: 22972	
4	BRST	10004M004	-	LAMA	12209M001	#SAT: 53	CRIT.: 22225	
...								
9	BRST	10004M004	-	PTBB	14234M001	#SAT: 31	CRIT.: 11945	
10	BRST	10004M004	-	TLSE	10003M009	#SAT: 77	CRIT.: 35538	OK
11	BRST	10004M004	-	VILL	13406M001	#SAT: 77	CRIT.: 31995	
12	BRST	10004M004	-	WSRT	13506M005	#SAT: 73	CRIT.: 24936	
...								
123	VILL	13406M001	-	WTZR	14201M010	#SAT: 77	CRIT.: 30079	
124	VILL	13406M001	-	WTZZ	14201M014	#SAT: 79	CRIT.: 32284	OK
125	VILL	13406M001	-	ZIM2	14001M008	#SAT: 78	CRIT.: 32108	
126	VILL	13406M001	-	ZIMM	14001M004	#SAT: 32	CRIT.: 12797	
127	WSRT	13506M005	-	WTZR	14201M010	#SAT: 73	CRIT.: 25785	
128	WSRT	13506M005	-	WTZZ	14201M014	#SAT: 74	CRIT.: 26483	OK
129	WSRT	13506M005	-	ZIM2	14001M008	#SAT: 74	CRIT.: 26102	
130	WSRT	13506M005	-	ZIMM	14001M004	#SAT: 32	CRIT.: 10829	
131	WTZR	14201M010	-	WTZZ	14201M014	#SAT: 77	CRIT.: 45323	OK
132	WTZR	14201M010	-	ZIM2	14001M008	#SAT: 77	CRIT.: 36323	
133	WTZR	14201M010	-	ZIMM	14001M004	#SAT: 31	CRIT.: 13183	
134	WTZZ	14201M014	-	ZIM2	14001M008	#SAT: 78	CRIT.: 38261	OK
135	WTZZ	14201M014	-	ZIMM	14001M004	#SAT: 32	CRIT.: 14212	
136	ZIM2	14001M008	-	ZIMM	14001M004	#SAT: 32	CRIT.: 17346	OK

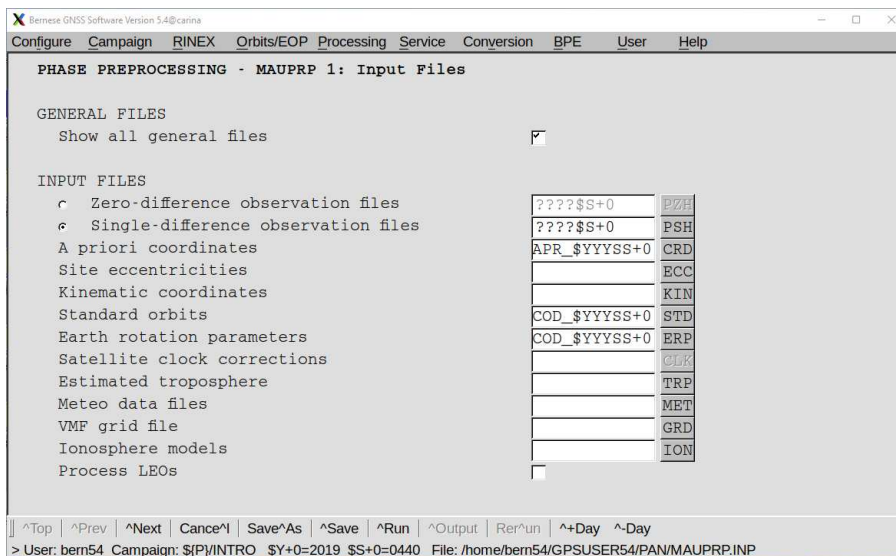
The baseline file stored in option “Listing of formed baselines” can be used for various purposes, e.g., to create code single difference observation files for the same baselines as the corresponding phase files. One application is the ambiguity resolution using the Melbourne-Wübbena linear combination (e.g., in the tomorrow’s terminal session). For this purpose the file is introduced to option “Predefined baselines” when processing code measurements.



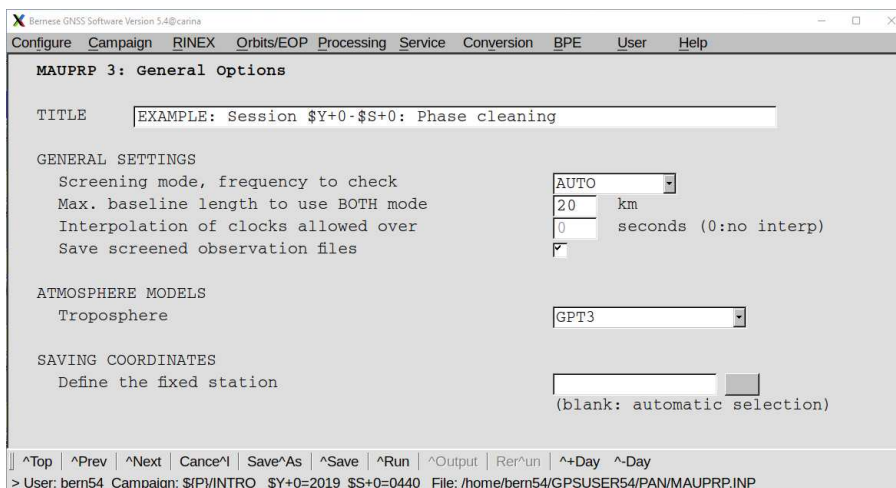
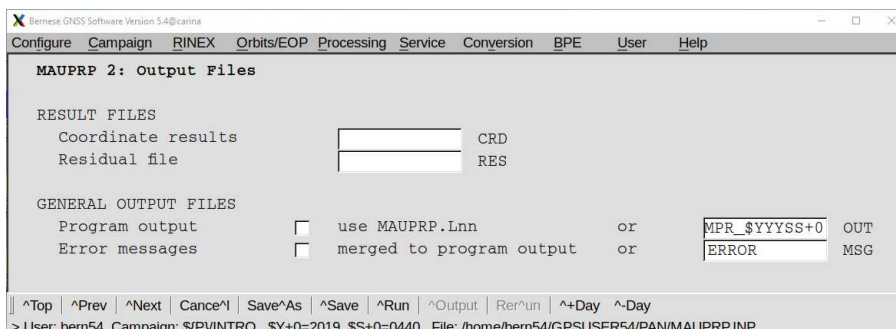
The other options do not matter because we use a predefined baseline configuration.

4.2.3 Preprocessing of the Phase Baseline Files

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



In the next input panel “MAUPRP 2: Output Files” you only need to specify the “Program output”, e.g., to MPR_\$\$YYYYSS+0.



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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 degrees for stations
 degrees for LEOs

Minimum time interval accepted for continuous observations seconds
Maximum gap accepted within continuous observations seconds

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/MAUPRP.INP

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MAUPRP 5: Non-Parametric Screening

GENERAL OPTIONS

Extent of program output

Maximum time interval for polynomial fit minutes

SCREENING ON DIFFERENT DIFFERENCE LEVELS

Original observations from file for ZD-files: zero diff.
Polynomial degree SD-files: single diff.
Discontinuity level meters

Differences between satellites for ZD-files: single diff.
Polynomial degree SD-files: double diff.
Discontinuity level meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/MAUPRP.INP

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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

Kinematic coordinate estimation

Maximum observed-computed value meters (0.0: no check)
RMS limit for epoch diff. solution meters (0.0: no check)
RMS limit for epoch solution meters (0.0: no check)

A priori coordinate/baseline vector sigmas

X-coordinate meters
Y-coordinate meters
Z-coordinate meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/MAUPRP.INP

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MAUPRP 8: Cycle slip Detection/Correction

CYCLE SLIP DETECTION

Extent of program output

Do not accept cycle slip corrections

Minimum size of accepted cycle slip correction cycles

Test only observations with cycle slip flag

L5 is clean except for observations with flags

NO CYCLE SLIP HYPOTHESIS

Sigma for L1 observations meters
Sigma for L2 observations meters

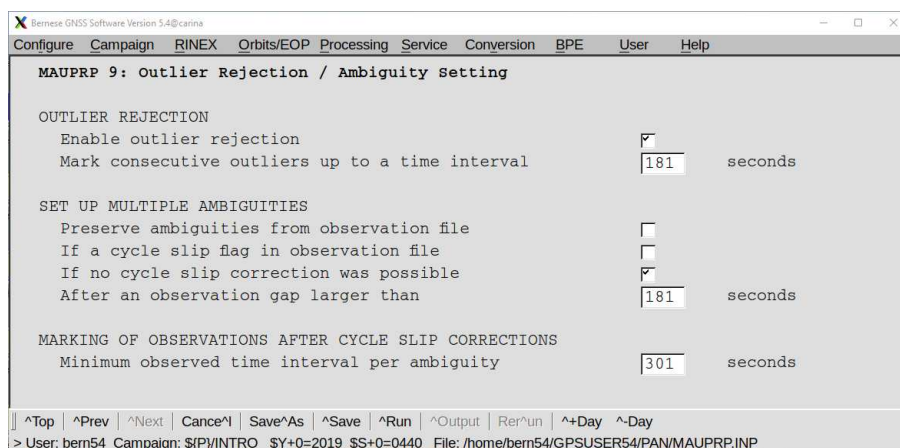
Maximum ionospheric change from epoch to epoch

for single frequency mode (or short bsl.) % of L1 cycles
for combined mode (or long bsl.) % of L1 cycles
use the combined mode value for bsl longer than km

CYCLE SLIP CORRECTIONS

Search width to find L1 cycle slip correction integers
Search width to find L5 cycle slip correction integers

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/MAUPRP.INP



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

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

```

...
STATION 1: BRST 10004M004          YEAR: 2019          SESSION: 0440
STATION 2: TLSE 10003M009          DAY : 44          FILE : 0

REFERENCE EPOCH      : 2019-02-13 00:00:00
SAMPLING INTERVAL   : 30 SEC

BASELINE LENGTH (M) : 707461.879
OBSERVAT. FILE NAME : ${P}/INTRO/OBS/BRTL0440.PSH

BASELINE DEPENDENT OPTIONS:
-----

CHECK FREQUENCIES (L1=1, L2=2, L1&L2=3, L1,L2=4) --> : 3
MAX. IONOS.DIFF. BETW. EPOCHS (o/o OF L1 CYCLES) --> : 161
...

```

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

```

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

FREQUENCY OF EPOCH DIFF. SOLU.:          3
#OBS. USED FOR EPOCH DIFF. SOLU:       60983
RMS OF EPOCH DIFF. SOLUTION (M):       0.013

COORDINATES NEW-A PRIORI X (M):        -0.057 +-      0.018
                                   Y (M):         0.020 +-      0.020
                                   Z (M):        -0.062 +-      0.013
-----
...

```

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

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

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

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

SUMMARY OF THE MAUPRP OUTPUT FILE															

SESS	FIL	OK?	ST1	ST2	L(KM)	#OBS.	RMS	DX	DY	DZ	#SL	#DL	#MA	MAXL3	SLIP
0440	1	OK	BRST	TLSE	707	60983	13	-57	20	-62	9	1522	146	24	11
0440	2	OK	GANP	MIKL	897	59647	11	-96	-31	-171	12	927	108	47	11
0440	3	OK	GANP	WTZZ	544	65887	10	164	7	149	4	873	112	12	31
0440	4	OK	HERT	TLSE	816	42085	12	-192	19	-282	11	1106	117	45	11
0440	5	OK	JOZ2	ONSA	830	43494	13	-19	25	-75	6	1049	129	34	13
0440	6	OK	LAMA	ONSA	674	43514	12	-14	17	-83	35	809	135	42	11
0440	7	OK	MATE	ORID	349	42135	9	2	17	22	29	735	103	44	11
0440	8	OK	MATE	ZIM2	1014	57683	11	214	56	207	24	1390	136	44	11
0440	9	OK	ONSA	PTBB	575	21952	13	120	35	164	63	265	38	50	13
0440	10	OK	ONSA	WTZZ	920	44738	12	180	-3	214	3	717	83	25	11
0440	11	OK	TLSE	ZIM2	597	62587	13	210	-28	203	6	1364	134	43	13
0440	12	OK	VILL	WTZZ	1635	58894	10	237	4	250	5	712	73	16	17
0440	13	OK	WSRT	WTZZ	607	40007	10	-14	24	-40	5	4134	404	49	
12	<<--	AMB													
0440	14	OK	WTZR	WTZZ	0	67195	11	-10	-17	39	4	563	116	0	0
0440	15	OK	WTZZ	ZIM2	476	66640	12	-85	-3	-167	4	1406	105	30	11
0440	16	OK	ZIM2	ZIMM	0	24300	13	19	10	16	7	245	49	0	0

Tot:	16				665	67195	13	237	4	250	63	4134	404	50	0
												+++++	+++++		

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

The indicators show that there is a baseline with exceptionally many AMBIGUITIES and marked observations. This is the baseline containing the station WSRT where data quality issues have already been detected in the RNXGRA summary output.

4.3 Daily Goals

- At the end of today's session, you should have created the following files:*
- Bernese formatted zero difference observation files in your campaign's OBS directory: BRST0440.CZH, BRST0440.PZH, BRST0440.CZO, BRST0440.PZO, ... (for all stations).*
 - Single difference files (baseline files) in the OBS directory: BRTL0440.PSH, BRTL0440.PSO, GAMIO440.PSH, GAMIO440.PSO, ... for all baselines,*
 - you should also have verified the outputs of these programs: ORBGEN, RXOBV3, CODSP, SNGDIF, and MAUPRP*

5 Terminal Session: Wednesday

Today's terminal session is to:

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

5.1 Data Preprocessing (II)

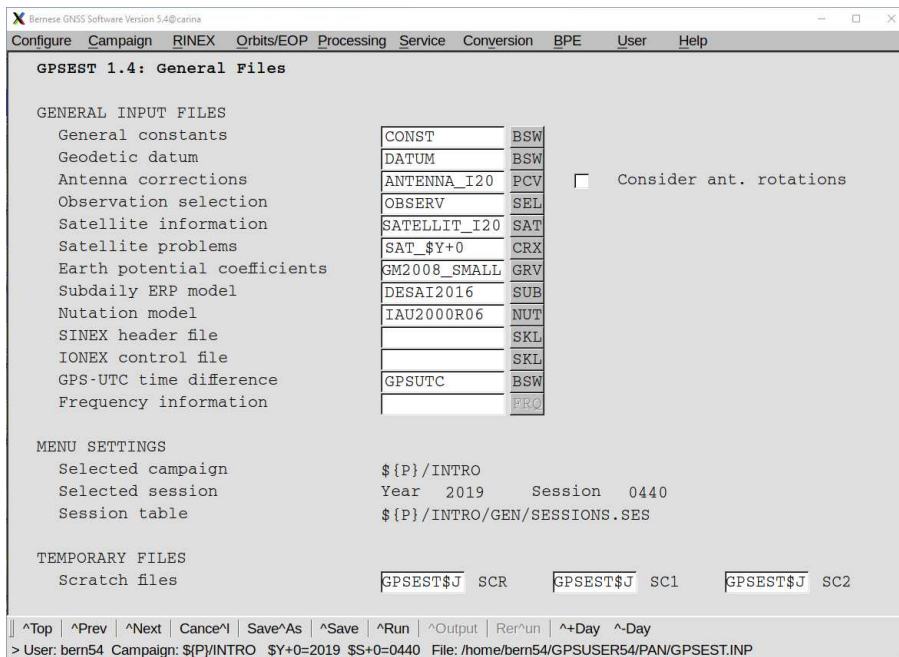
The main parameter estimation based on a least-squares adjustment is the task of program GPSEST. It is a good idea to start GPSEST first in the session mode and to produce a L_3 solution (ionosphere-free linear combination) with real-valued ambiguities. We do not expect any final results from this run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

The screenshot shows the 'PARAMETER ESTIMATION - GPSEST 1.1: Input Files 1' dialog box. The window title is 'Bernese GNSS Software Version 5.4@carina'. The menu bar includes 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The dialog is organized into several sections:

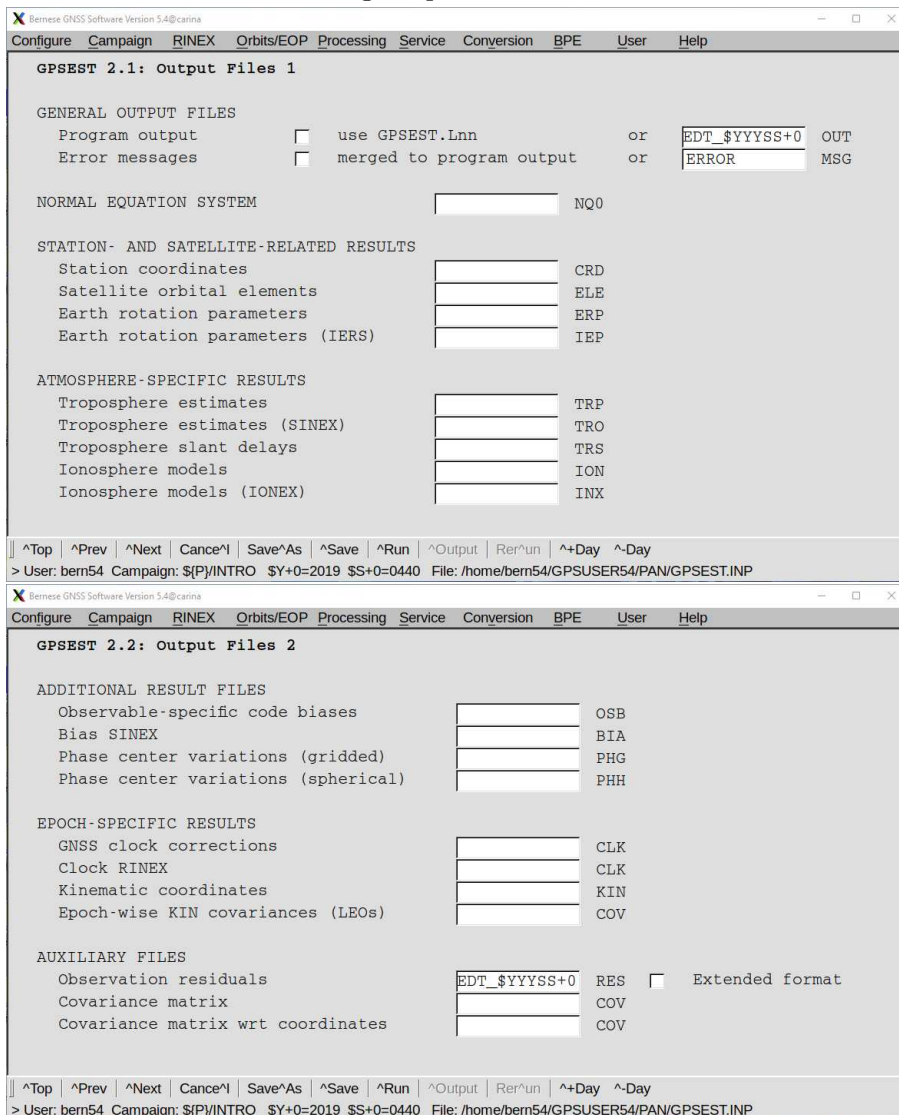
- GENERAL FILES AND PROCESSING MODE:** Space geodetic technique (GNSS), Differencing level (DOUBLE), LEO data processing (unchecked), Show all general files (checked).
- OBSERVATION FILES:** Phase observations (????\$\$+0, PSH), Code observations (CSH), Range observations (RZH).
- MAIN INPUT FILES:** Station coordinates (APR_YYYYSS+0, CRD), Standard orbits (COD_YYYYSS+0, STD), Earth rotation parameters (COD_YYYYSS+0, ERP), Satellite clock corrections (CLK), Observable-specific biases (OSB), VMF grid file (GRD), Ionosphere models (ION). There is a checkbox for 'NL phase biases from CLK' which is unchecked.
- CORRECTIONS FOR LOADING EFFECTS AND CENTER OF MASS:** Ocean tidal loading (EXAMPLE, BLQ), Atmospheric tidal loading (ATL), related error handling (ERROR).

At the bottom, there is a status bar with navigation keys: ^Top, ^Prev, ^Next, ^Cancel, ^Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^Day. The status text reads: > User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$\$+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

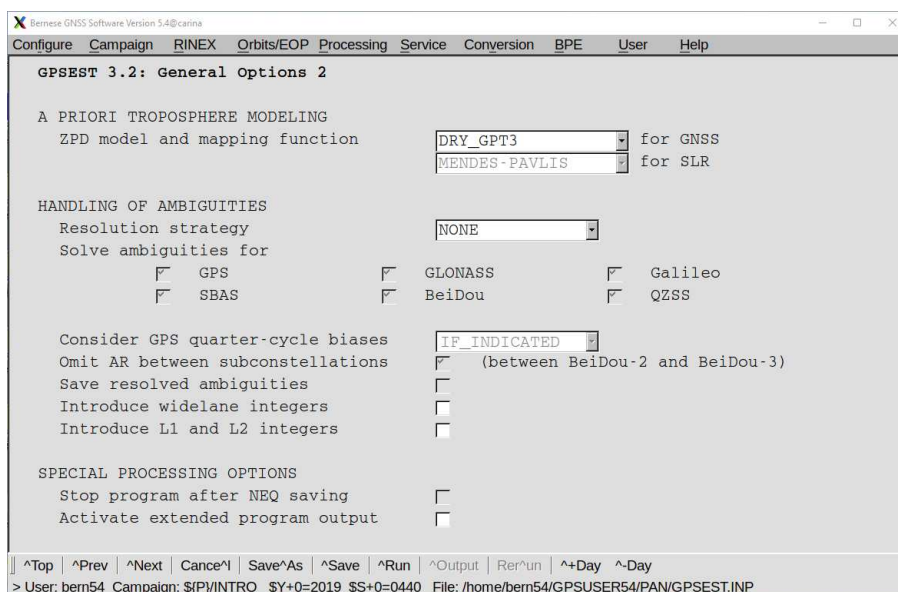
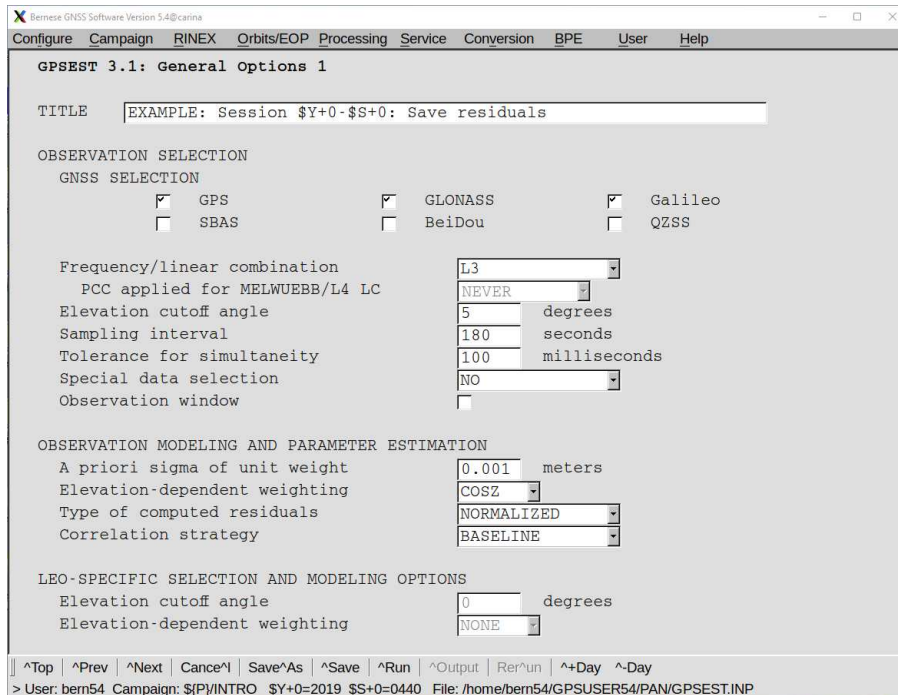
No files are selected in the second input panel. Verify the model and configuration files:



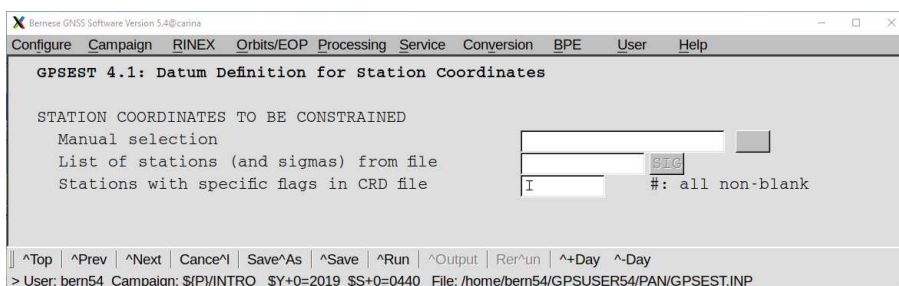
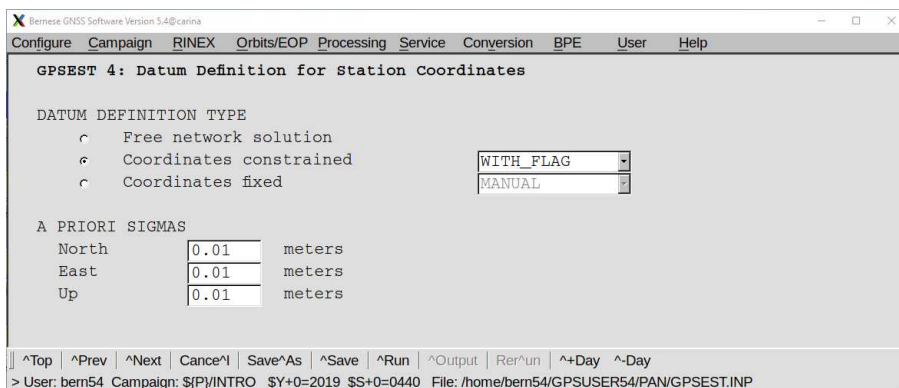
We recommend to select the following output files:



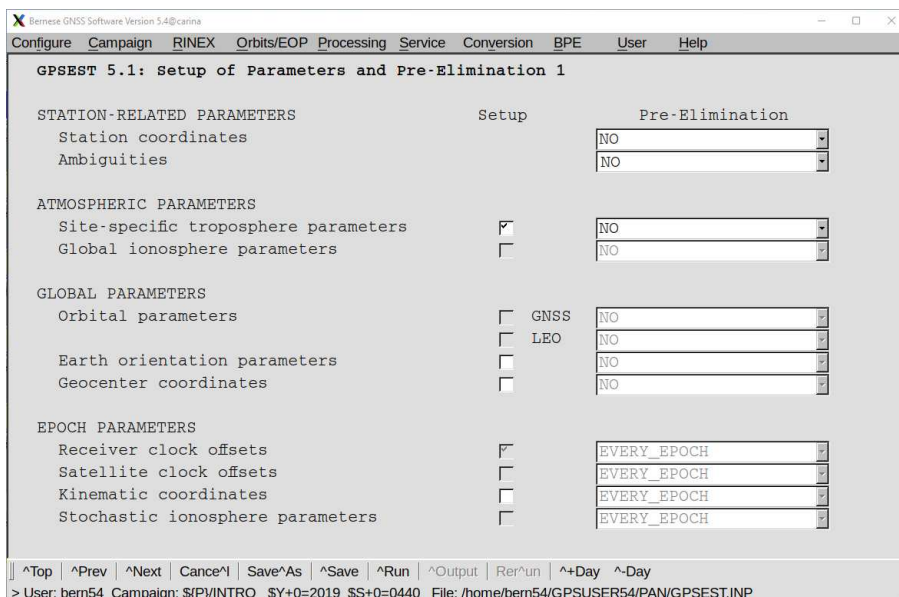
This run is intended to screen the post-fit residuals for outliers. Later on, for the ambiguity resolution, all observations are needed without down-sampling the data. To run the program GPSEST for the network with 17 stations and the observations to more than 75 satellites without reducing the data sampling rate takes easily 10 minutes or more. For that reason we are forced to sample the data, e.g., down to 3 minutes — we will see in the next step how to solve this discrepancy.

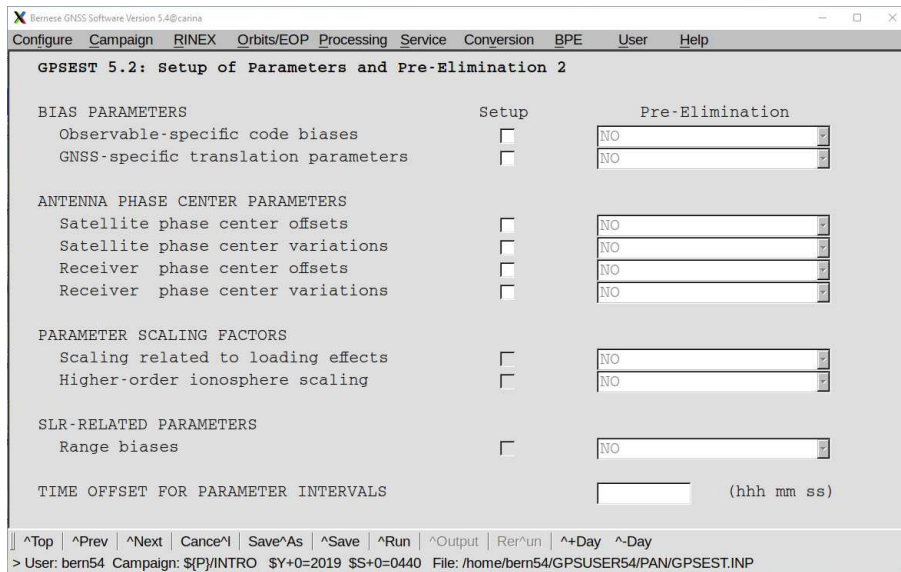


We want to put loose constraints on the station coordinates that are available from the IGS realization of ITRF 2020 reference frame (flag I like IGS20 in the coordinate file).

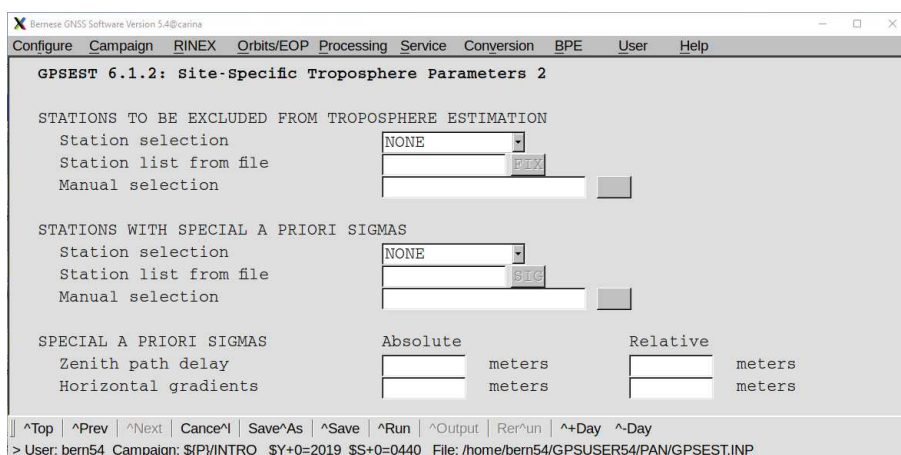
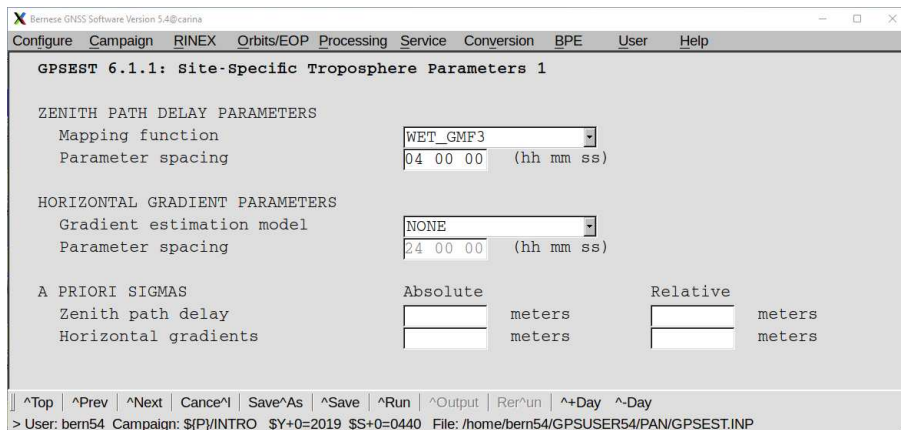


No parameters (not even ambiguity parameters) can be pre-eliminated if residuals should be written into the residual output file:





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



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

```

...
Statistics:
-----
Total number of authentic observations      133349
Total number of pseudo-observations        46

Total number of explicit parameters        2909
Total number of implicit parameters        0

Total number of observations                133395
Total number of adjusted parameters        2909
Degree of freedom (DOF)                   130486

A posteriori RMS of unit weight            0.001041 m
Chi**2/DOF                                1.08

Total number of observation files          16
Total number of unobserved ambiguities    269
Total number of stations                   17
...

```

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

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

```

Station coordinates and velocities:
-----
Sol Station name      Typ Correction  Estimated value  RMS error  A priori value  ... Abb
-----
1 BRST 10004M004      X   0.01152    4231162.42917   0.00303    4231162.41765  ... #CRD
1 BRST 10004M004      Y  -0.00335    -332746.43226   0.00282    -332746.42891  ... #CRD
1 BRST 10004M004      Z   0.00415    4745131.07383   0.00300    4745131.06968  ... #CRD
1 TLSE 10003M009      X   0.00633    4627851.66867   0.00299    4627851.66234  ... #CRD
1 TLSE 10003M009      Y  -0.00418    119640.28425    0.00276    119640.28843   ... #CRD
1 TLSE 10003M009      Z  -0.00281    4372993.71180   0.00295    4372993.71461  ... #CRD
1 GANP 11515M001      X  -0.00393    3929181.30207   0.00302    3929181.30600  ... #CRD
1 GANP 11515M001      Y   0.00394    1455236.94940   0.00278    1455236.94546  ... #CRD
1 GANP 11515M001      Z   0.03959    4793654.03253   0.00296    4793653.99294  ... #CRD
1 MIKL 12335M001      X   0.00239    3698553.71209   0.00305    3698553.70970  ... #CRD
...

Site-specific troposphere parameters:
-----
Station name      Typ      Correction  Estimated value  RMS error  A priori value  ... Abb
-----
BRST 10004M004    U        0.11019        2.42203         0.00081         2.31184         ... #TRP
BRST 10004M004    U        0.09745        2.40934         0.00061         2.31190         ... #TRP
BRST 10004M004    U        0.07787        2.38976         0.00063         2.31188         ... #TRP
BRST 10004M004    U        0.08644        2.39831         0.00063         2.31187         ... #TRP
BRST 10004M004    U        0.08075        2.39261         0.00061         2.31186         ... #TRP
BRST 10004M004    U        0.06701        2.37886         0.00067         2.31185         ... #TRP
BRST 10004M004    U        0.06765        2.37942         0.00098         2.31177         ... #TRP
GANP 11515M001    U        0.04676        2.16866         0.00067         2.12190         ... #TRP
GANP 11515M001    U        0.04605        2.16796         0.00048         2.12192         ... #TRP
GANP 11515M001    U        0.07752        2.19943         0.00045         2.12191         ... #TRP
GANP 11515M001    U        0.08049        2.20239         0.00047         2.12191         ... #TRP
GANP 11515M001    U        0.06357        2.18548         0.00045         2.12190         ... #TRP
GANP 11515M001    U        0.06543        2.18733         0.00049         2.12190         ... #TRP
GANP 11515M001    U        0.06934        2.19121         0.00069         2.12187         ... #TRP
HERT 13212M010    U        0.11227        2.41543         0.00084         2.30316         ... #TRP
HERT 13212M010    U        0.10498        2.40817         0.00066         2.30318         ... #TRP
...

```


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

After running the program a warning message pops up indicating that the normalization of residuals based on the uncertainty of the estimated parameters (NORMALIZED in option "Type of computed residuals") fails. Some parameters related to the station WSRT (troposphere and ambiguities) show comparable high formal errors. In that case, no normalization of the residuals takes place. They end up as high residuals in the related result file and the related observations will be detected and removed in the subsequent steps.

```

### SR resout: Numerical problems with normalization detected
                for epoch 2019-02-13 01:33:00
                Number of effected observations:      1

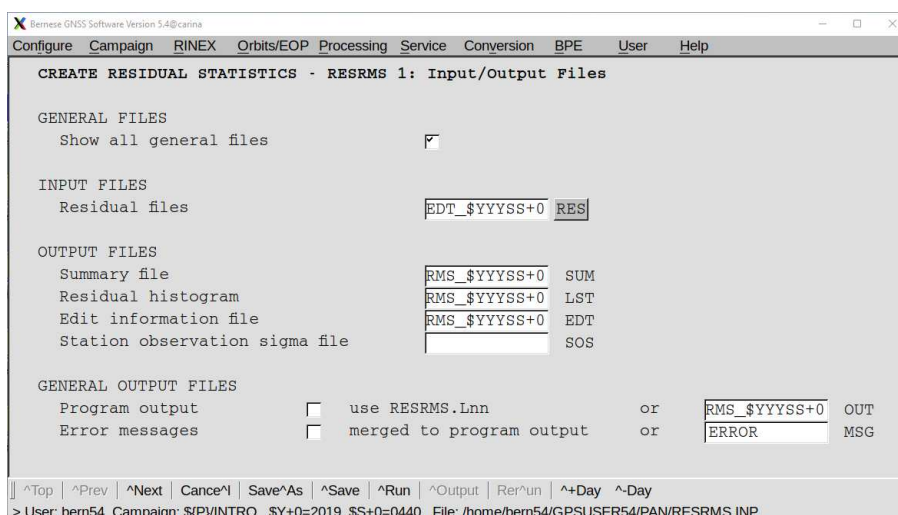
### SR resout: Numerical problems with normalization detected
                for epoch 2019-02-13 23:58:00
                Number of effected observations:      12

...
### SR solcheck:  16 singular element(s) found:
                Num   Type
                ----  -
                2117  S_
                2206  S_
                2225  S_
                2239  S_
                2255  S_
...

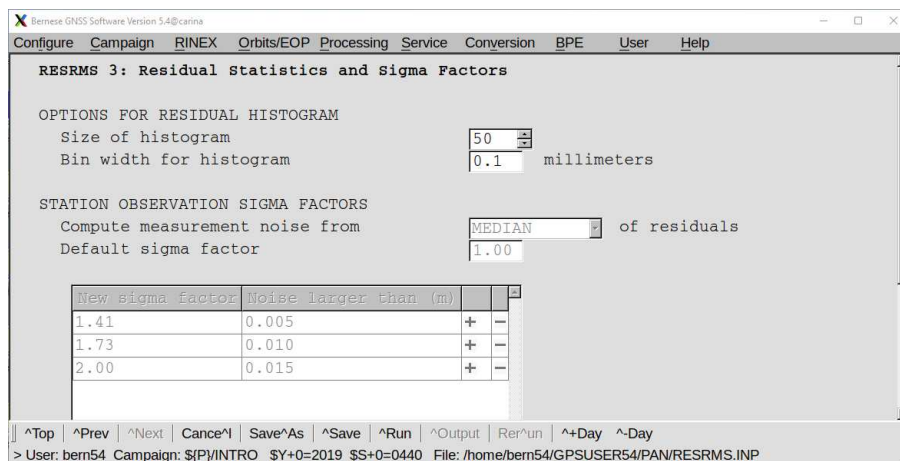
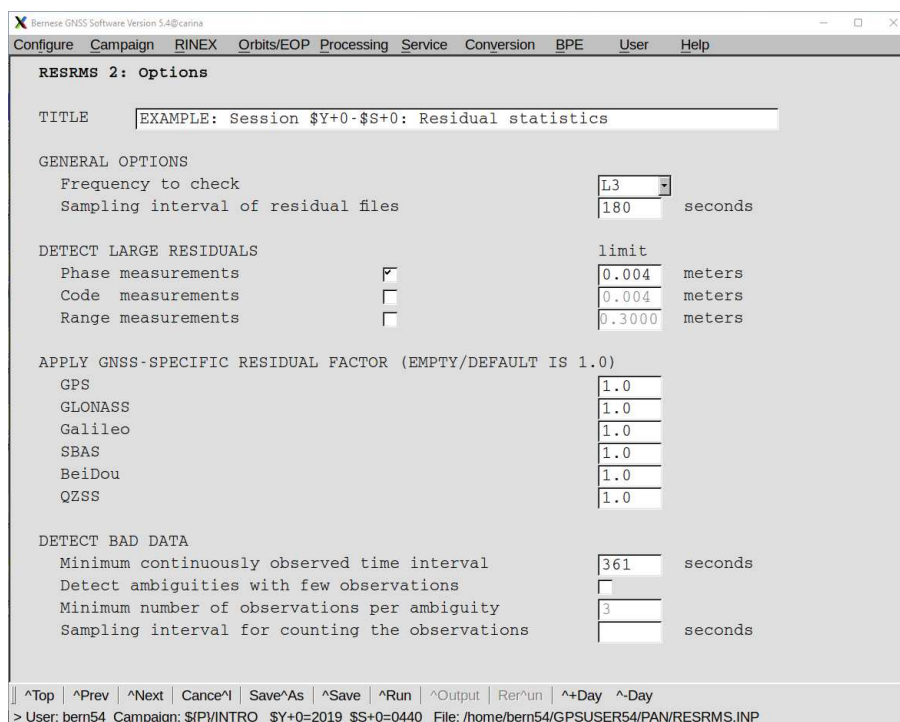
```

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

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



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



The program output of RESRMS ($\{P\}/INTRO/OUT/RMS_2019044.OUT$) provides a nice overview on the data quality.

```

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

```

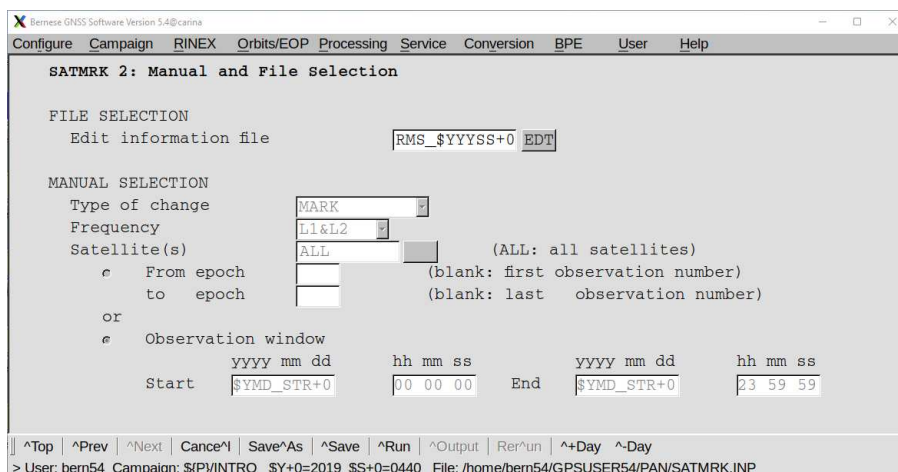
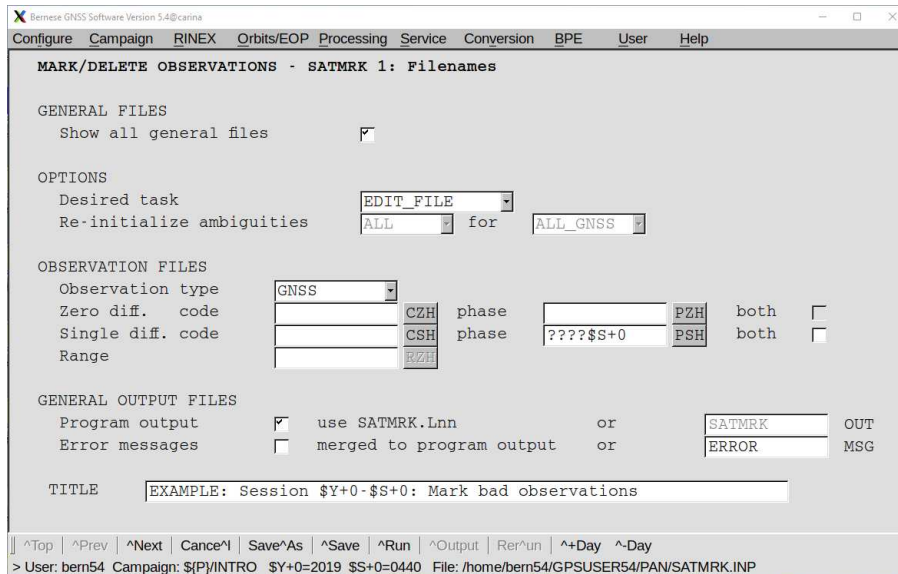
Num	Station 1	Station 2	Total RMS	med.Resi	Sigma	numObs	nSat	nDel	...
1	BRST 10004M004	TLSE 10003M009	1.4	0.7	1.1	10796	77	10	...
2	GANP 11515M001	MIKL 12335M001	1.4	0.7	1.1	10431	75	11	...
3	GANP 11515M001	WTZZ 14201M014	1.2	0.7	0.9	11525	78	1	...
4	HERT 13212M010	TLSE 10003M009	1.1	0.6	1.0	7536	53	7	...
5	JOZ2 12204M002	ONSA 10402M004	1.2	0.7	1.0	7778	53	6	...
6	LAMA 12209M001	ONSA 10402M004	1.1	0.6	1.0	7690	53	7	...
7	MATE 12734M008	ORID 15601M001	1.2	0.6	1.0	7441	53	5	...
8	MATE 12734M008	ZIM2 14001M008	1.3	0.7	1.1	10108	75	12	...
9	ONSA 10402M004	PTBB 14234M001	1.1	0.7	1.0	4163	32	2	...

```

...
NUMBER OF EDIT REQUESTS: 85

```


In addition, files containing a summary table ($\{\text{P}\}/\text{INTRO}/\text{OUT}/\text{RMS_20190440.SUM}$) and a histogram ($\{\text{P}\}/\text{INTRO}/\text{OUT}/\text{RMS_20190440.LST}$) of the residuals are available. The most important result file for the data screening is the "Edit information file" ($\{\text{P}\}/\text{INTRO}/\text{OUT}/\text{RMS_20190440.EDT}$), which may be used by the program SATMRK to mark outliers in the observation files ("Menu>Service>Bernese observation files>Mark/delete observations"):



The program output from SATMRK reports the number of marked observations per base-line:

```

...
SUMMARY OF ACTION IN THE OBS. FILE(S):      $\{P\}/INTRO/OUT/RMS_20190440.EDT
-----

```

Num	Station name 1	Station name 2	Mea- type	Observations			...
				mark	unmark	delete	
1	BRST 10004M004	TLSE 10003M009	P :	238	0	0	...
2	GANP 11515M001	MIKL 12335M001	P :	238	0	0	...
3	GANP 11515M001	WTZZ 14201M014	P :	20	0	0	...
4	HERT 13212M010	TLSE 10003M009	P :	156	0	0	...
5	JOZ2 12204M002	ONSA 10402M004	P :	130	0	0	...
6	LAMA 12209M001	ONSA 10402M004	P :	160	0	0	...
7	MATE 12734M008	ORID 15601M001	P :	86	0	0	...
8	MATE 12734M008	ZIM2 14001M008	P :	262	0	0	...
9	ONSA 10402M004	PTBB 14234M001	P :	70	0	0	...
Total:				1958	0	0	...

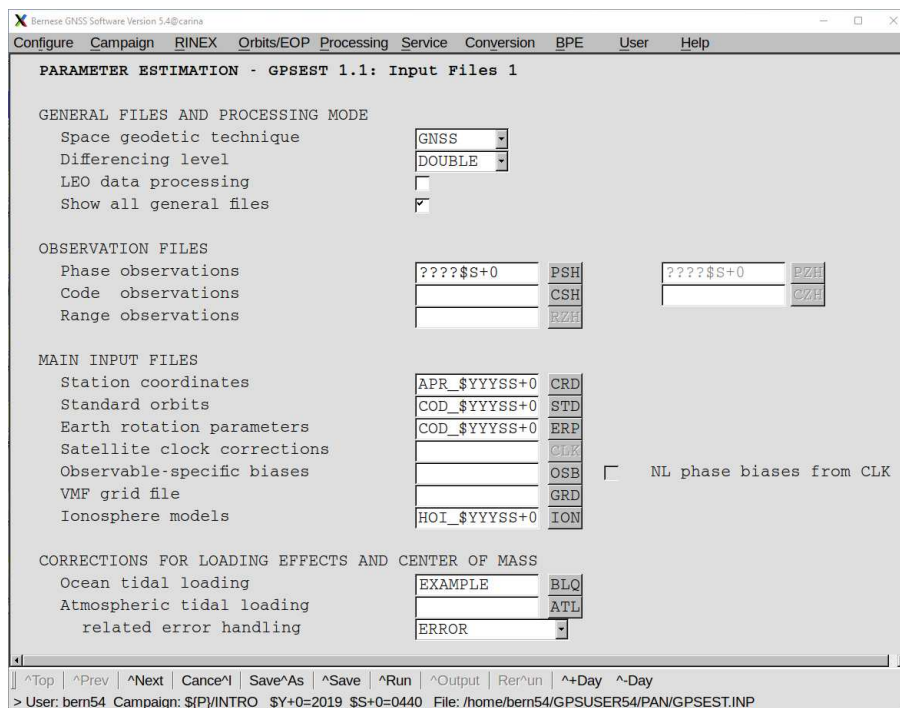
```

-----
...

```

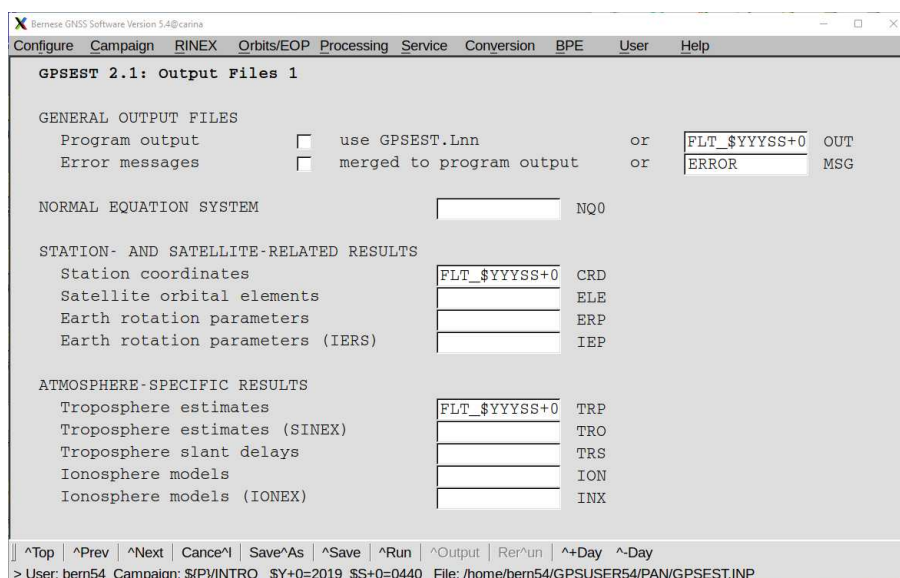
5.2 Produce a First Network Solution

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



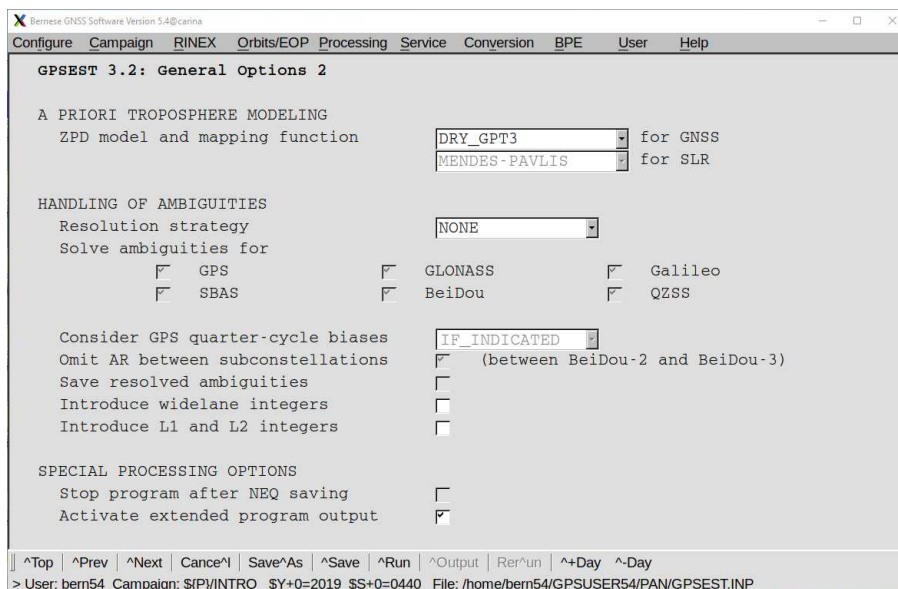
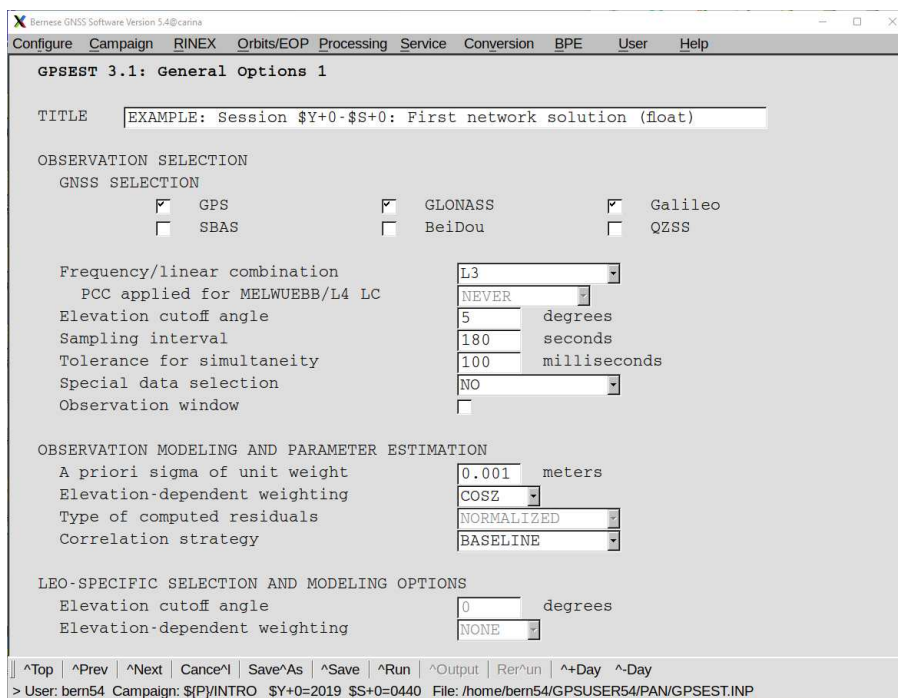
The file in the input field “Ionosphere models” enables the HOI-corrections, which are not considered by the ionosphere-free linear combination.

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



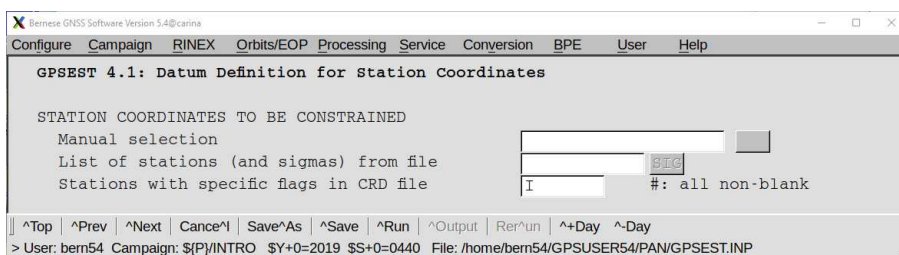
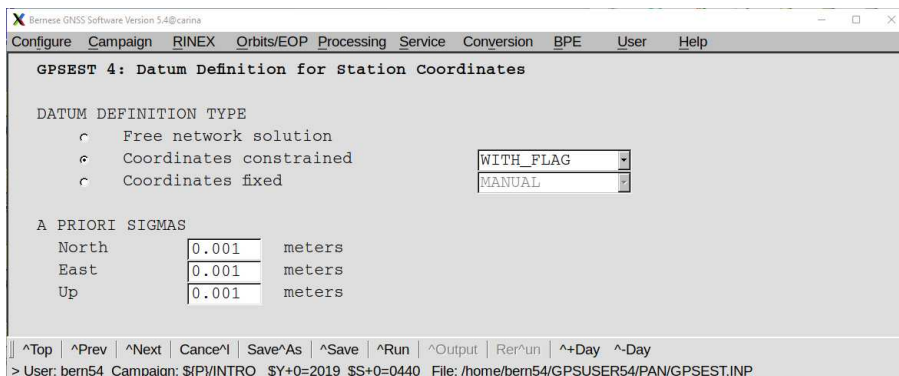
In the subsequent panel you should remove the output filename for the “Residuals” because we do not need the residuals from this run.

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

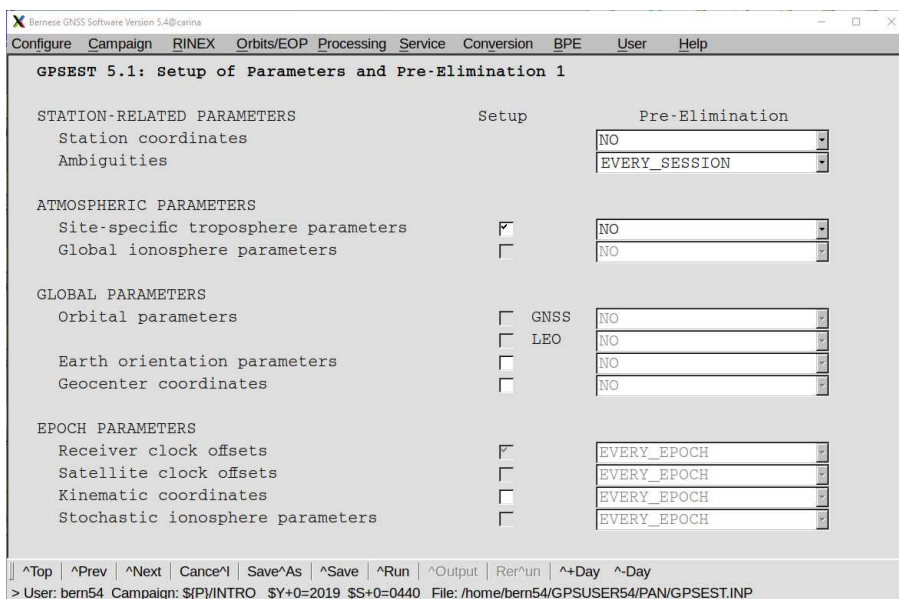


Nevertheless, it might be an interesting idea to enable the option “Activate extended program output”. Two more panels appear where much more information on the data and results can be asked for. In this example we just enable the two options for “Printing: Extended summary concerning coordinates” and “Printing: Extended summary concerning troposphere”. You are invited to discover these options further in order to adjust it to your needs.

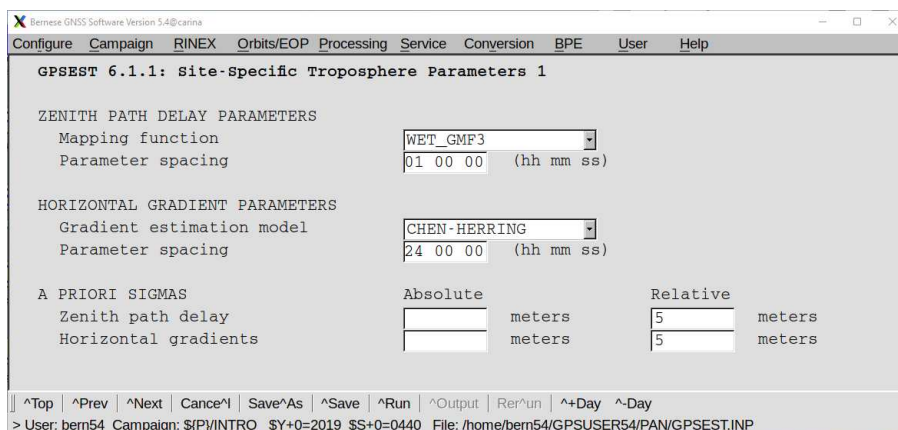
To heavily constrain the coordinates of the IGS core sites is not the best way to realize the geodetic datum for a solution. The program ADDNEQ2 offers more sophisticated options (e.g., minimum constraint solution). Today we will follow this simple approach:



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



The estimation of troposphere parameters is mandatory for a campaign of this type. We increase the number of estimated parameters (e.g., to 24 instead of 6 parameters per station and session). In addition, it is recommended to set up troposphere gradient parameters. In order to avoid a format overflow in the “Troposphere estimates” output file that may happen if a troposphere parameter is estimated based on very few observations concentrated at one end of the interval of parameter validity, a loose relative constraint (e.g., sigmas of 5 meter) may help.



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

```

...
SUMMARY OF RESULTS
-----

Number of parameters:
-----

Parameter type                Adjusted   Expl.    Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities    51        51        0              0  0    0    0
Ambiguities                        2739       0       2739 (bfst)   0  0   40   0
Site-specific troposphere parameters 493       493       0              0  0    0    0
-----
Total number                      3243      544      2699          0  0   40   0

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)
...

```

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

```

...
Statistics:
-----

Total number of authentic observations    133235
Total number of pseudo-observations      30

Total number of explicit parameters      544
Total number of implicit parameters     2699

Total number of observations             133265
Total number of adjusted parameters      3243
Degree of freedom (DOF)                  130022

A posteriori RMS of unit weight          0.000987 m
Chi**2/DOF                              0.97
...

```

Below you find the extended output of the results for coordinates and troposphere parameters at the end of the file that we have asked for in panel "GPSEST 3.2.1.1: Extended Program Output Options":

```

...
Station coordinates and velocities:
-----
Reference epoch: 2019-02-13 11:59:45

Station name      Typ  A priori value  Estimated value  Correction  RMS error  ...
-----
BRST 10004M004   X    4231162.41765  4231162.41830   0.00065    0.00063   ...
                  Y    -332746.42891  -332746.42771   0.00120    0.00056   ...
                  Z    4745131.06968  4745131.07283   0.00315    0.00060   ...
                  U         65.81939      65.82211      0.00272    0.00076   ...
                  N     48.3804957    48.3804957    0.00168    0.00042   ...
                  E     -4.4965914     -4.4965914    0.00125    0.00056   ...
TLSE 10003M009   X    4627851.66234  4627851.66205  -0.00029    0.00051   ...
                  Y    119640.28843   119640.28820  -0.00023    0.00046   ...
                  Z    4372993.71461  4372993.71376  -0.00085    0.00051   ...
                  U         207.18324     207.18244    -0.00080    0.00062   ...
                  N     43.5606968    43.5606968  -0.00041    0.00037   ...
                  E     1.4808939     1.4808938   -0.00022    0.00046   ...
GANP 11515M001   X    3929181.30600  3929181.29822  -0.00778    0.00061   ...
                  Y    1455236.94546  1455236.95378   0.00832    0.00053   ...
                  Z    4793653.99294  4793654.03586   0.04292    0.00063   ...
                  U         746.00460     746.03412    0.02952    0.00078   ...
                  N     49.0347149    49.0347152    0.03144    0.00041   ...
                  E     20.3229395    20.3229396    0.01046    0.00051   ...
MIKL 12335M001   X    3698553.70970  3698553.70973   0.00003    0.00064   ...
                  Y    2308676.23252  2308676.23206  -0.00046    0.00060   ...
                  Z    4639769.62655  4639769.62475  -0.00180    0.00066   ...
                  U         93.92954     93.92808    -0.00146    0.00081   ...
                  N     46.9727862    46.9727862  -0.00107    0.00045   ...
                  E     31.9728450    31.9728450  -0.00040    0.00059   ...
...

```

```

...
Troposphere parameters:
-----
Reference elevation angle of gradient terms : 45.0 degrees
Minimum elevation angle : 5 degrees
Mapping factor at minimum elevation angle : 11.4

Station name      Corrections (m)      RMS errors (m)      ...
                  North   East   Zenith   North   East   Zenith   ...
-----
BRST 10004M004   0.00044  0.00003  0.11297  0.00009  0.00011  0.00150  ...
BRST 10004M004   0.00043  0.00003  0.10486  0.00008  0.00010  0.00105  ...
BRST 10004M004   0.00043  0.00003  0.10191  0.00008  0.00009  0.00113  ...
BRST 10004M004   0.00043  0.00002  0.10370  0.00007  0.00009  0.00108  ...
BRST 10004M004   0.00042  0.00002  0.09834  0.00007  0.00008  0.00104  ...
...
BRST 10004M004   0.00034 -0.00007  0.06907  0.00007  0.00009  0.00106  ...
BRST 10004M004   0.00034 -0.00007  0.06841  0.00008  0.00010  0.00113  ...
BRST 10004M004   0.00034 -0.00008  0.07125  0.00008  0.00011  0.00116  ...
BRST 10004M004   0.00033 -0.00008  0.06842  0.00009  0.00011  0.00212  ...
GANP 11515M001  -0.00001 -0.00088  0.04855  0.00006  0.00006  0.00110  ...
GANP 11515M001  -0.00003 -0.00087  0.04251  0.00006  0.00006  0.00082  ...
GANP 11515M001  -0.00005 -0.00086  0.04326  0.00005  0.00006  0.00081  ...
GANP 11515M001  -0.00007 -0.00085  0.04354  0.00005  0.00005  0.00076  ...
GANP 11515M001  -0.00009 -0.00083  0.04544  0.00005  0.00005  0.00085  ...
GANP 11515M001  -0.00011 -0.00082  0.05617  0.00004  0.00005  0.00073  ...
...

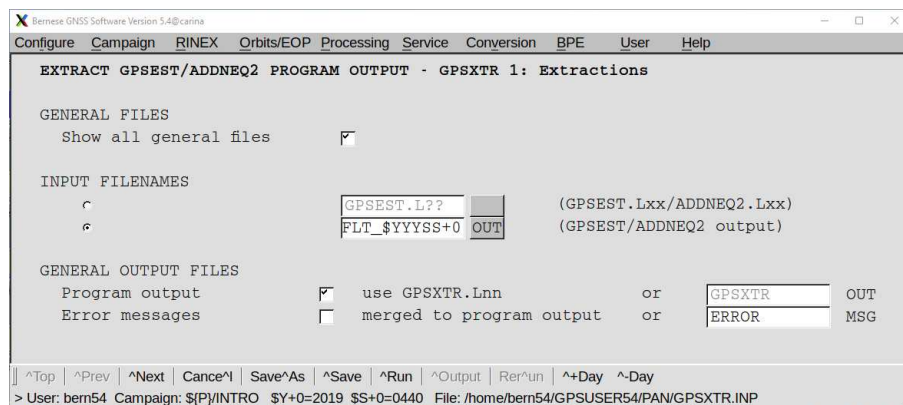
```

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

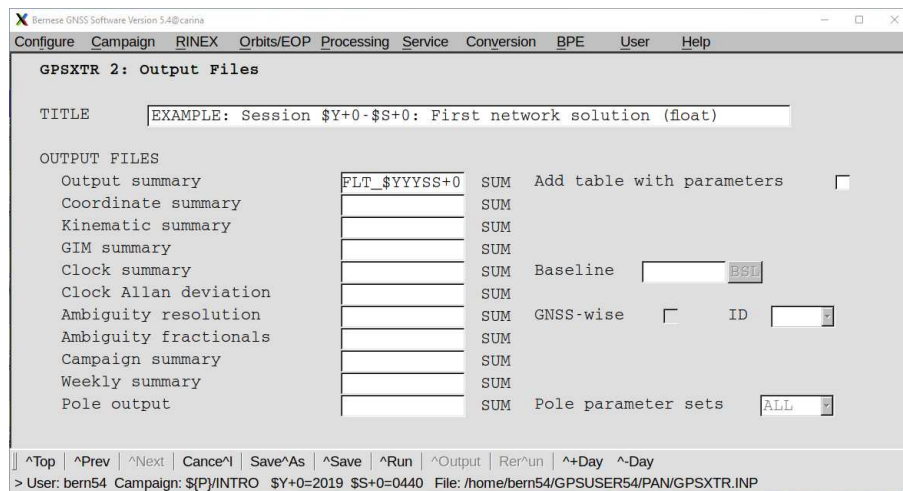
5.2.1 Program Output Extraction

The program output from the program GPSEST is quite long and contains many information that help to identify potential problems in the processing. On the other hand, it would be smart to extract the key parameters into a short summary that can for instance be included in a comprehensive processing protocol. The program GPSXTR (accessible via "Menu>Processing>Program output extraction>Parameter estimation/stacking") provides such a summary.

Select the program output(s) to be analyzed:



and select the name of the summary file



The short extraction from the full program output in `${P}/INTRO/OUT/FLT_20190440.OUT` reads like

```
FLT_20190440.OUT   Rms:  0.99 , # fil.:  16 , # obs.:  133265 , # par.:  3243
(DOY: 2019-044)
```

Also other styles of output are available, check the online help for some examples. Please note, that some summaries only work on specific program output files containing the expected parameter types.

5.3 Ambiguity Resolution

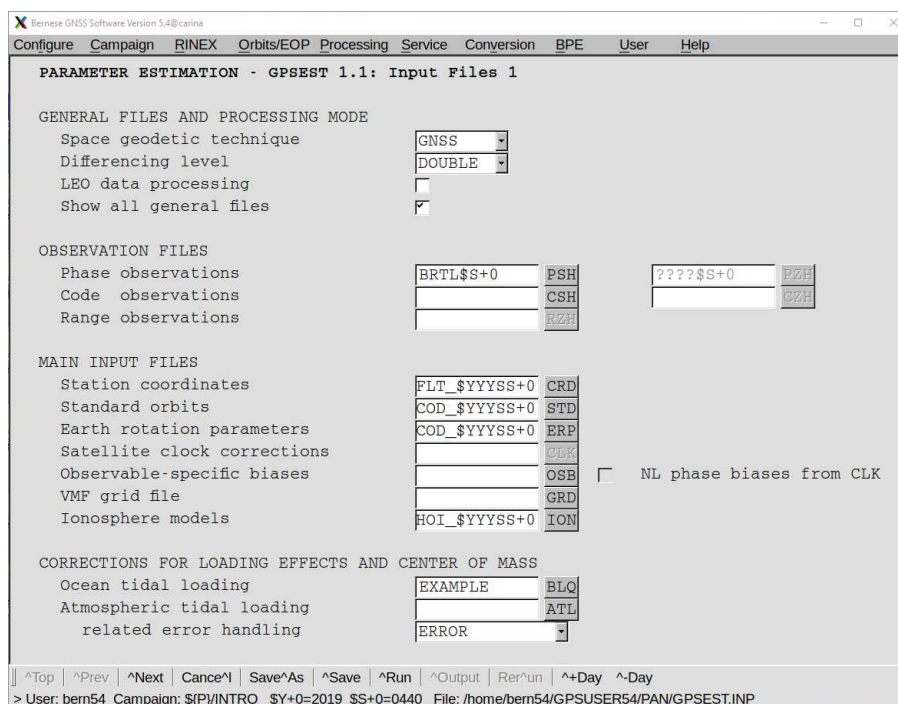
To resolve the ambiguities, we process the baselines separately one by one using the Quasi-Ionosphere-Free (QIF) strategy. This baseline processing mode is necessary because of the tremendous number of parameters. The attempt to resolve the ambiguities in a session solution might require too much CPU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

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

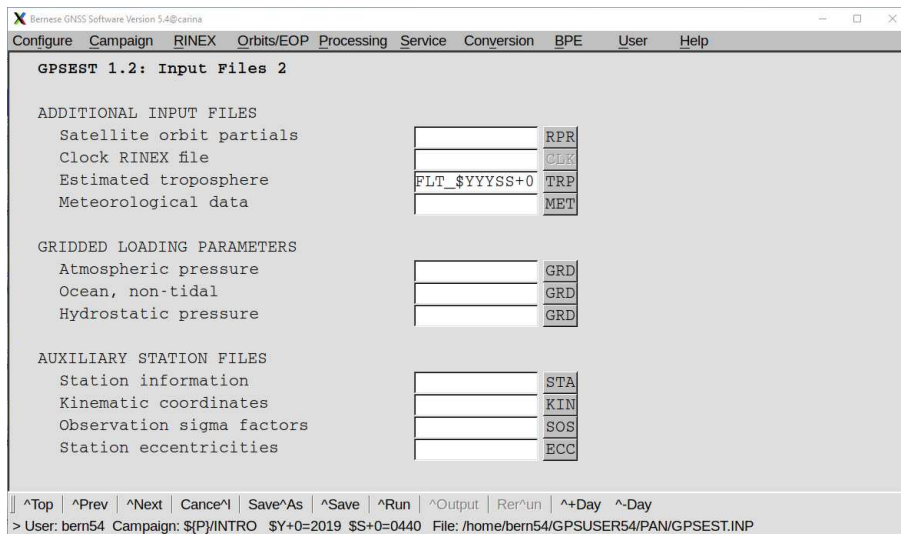
The complete list of baseline observation files of a session (e.g., session 0440 of year 2019) can be generated by listing all phase single-difference header files in the campaign's observation directory of your campaign:

```
bern52@carina:~ > ls ${P}/INTRO/OBS/????0440.PSH
${P}/INTRO/OBS/BRTL0440.PSH
${P}/INTRO/OBS/GAMIO440.PSH
${P}/INTRO/OBS/GAWZO440.PSH
${P}/INTRO/OBS/HETLO440.PSH
${P}/INTRO/OBS/JOON0440.PSH
${P}/INTRO/OBS/LAON0440.PSH
${P}/INTRO/OBS/MAOR0440.PSH
${P}/INTRO/OBS/MAZIO440.PSH
${P}/INTRO/OBS/ONPT0440.PSH
${P}/INTRO/OBS/ONWZ0440.PSH
${P}/INTRO/OBS/TLZIO440.PSH
${P}/INTRO/OBS/VIWZ0440.PSH
${P}/INTRO/OBS/WSWZ0440.PSH
${P}/INTRO/OBS/WTWZ0440.PSH
${P}/INTRO/OBS/WZZIO440.PSH
${P}/INTRO/OBS/ZIZM0440.PSH
```

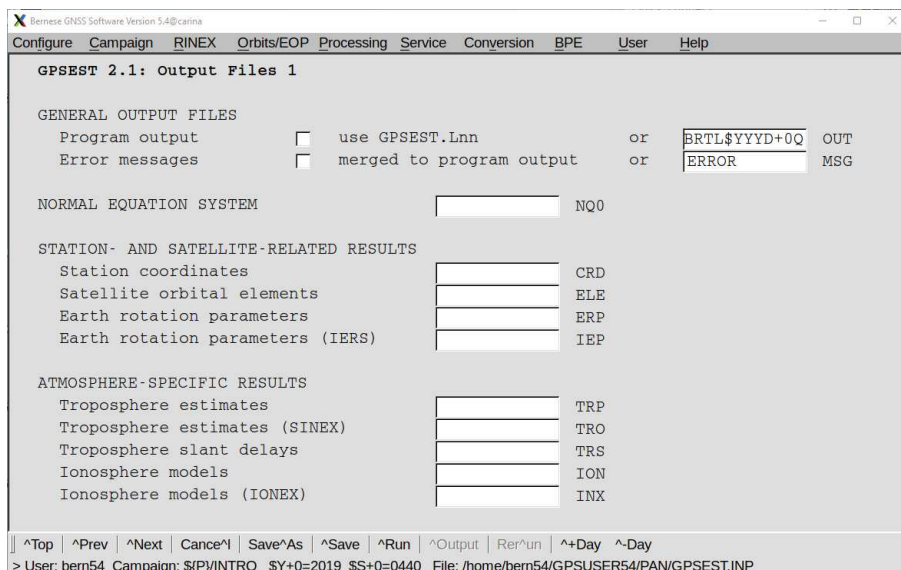
The first baseline for this session is from BRST to TLSE with the observation filename BRTL0440. Using the menu time variables this name is specified as BRTL\$\$+0. The following options are used for the ambiguity resolution step:



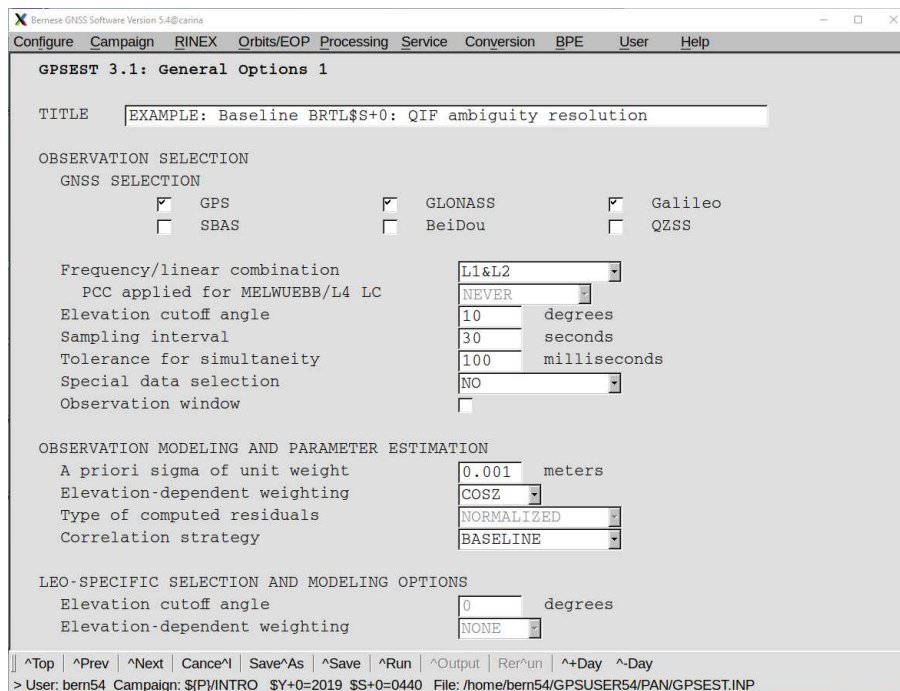
Only one baseline file is selected. Coordinates and troposphere estimates are introduced from the previous first network solution (Section 5.2).



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

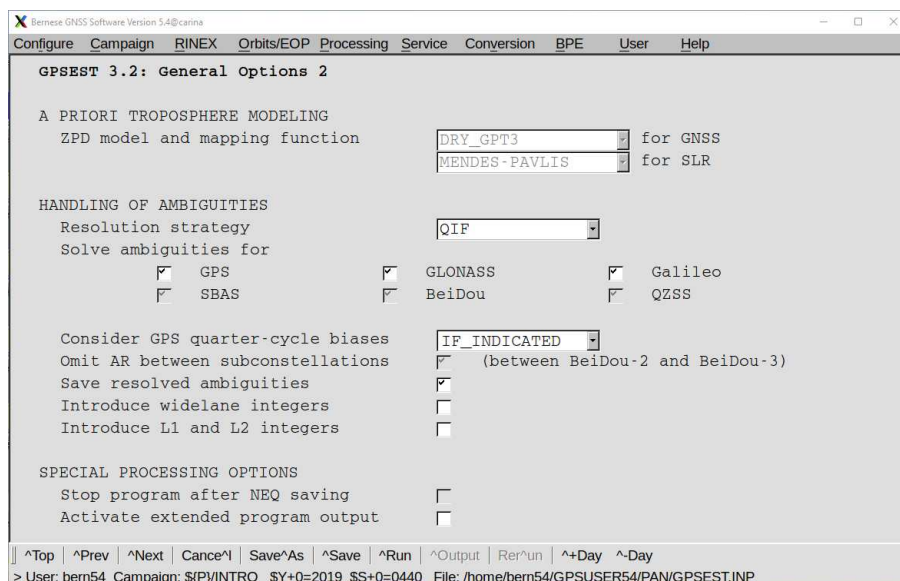


Because the QIF–ambiguity resolution strategy is very sensitive to the formal errors of the ambiguity parameters we have to include all measurements with the full sampling of 30s into the processing.

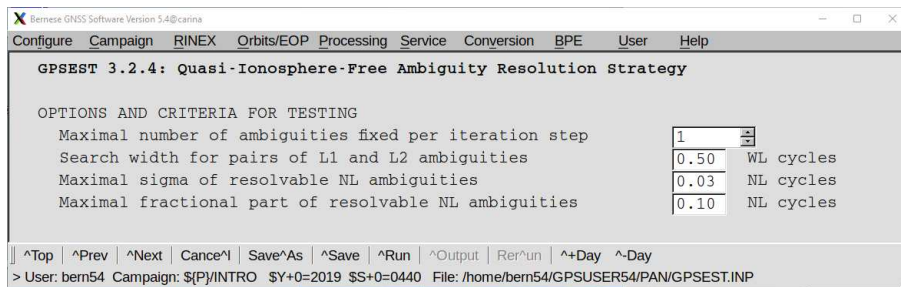


The selection of a “ZPD model and mapping function (GNSS)” is disabled because a troposphere file has been introduced in panel “GPSEST 1.2: Input Files 2”. The program uses the troposphere model from this input file and allows no other selection for consistency reasons.

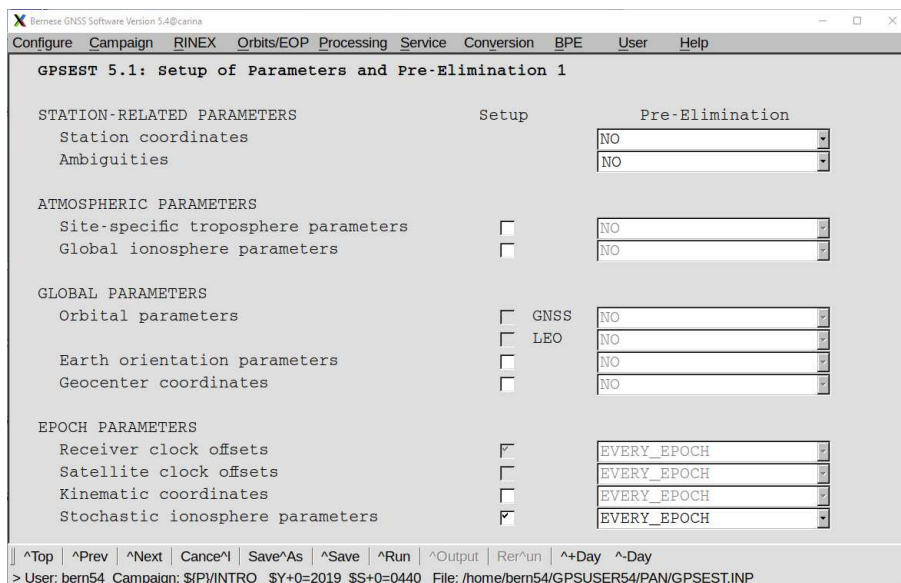
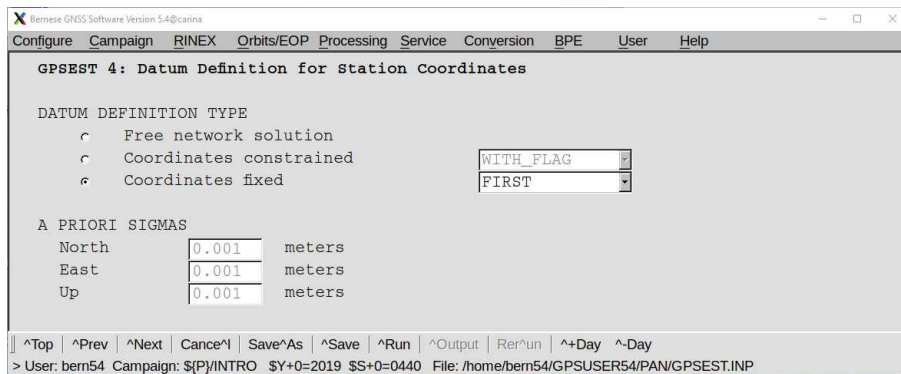
In the subsequent panel the “Resolution strategy” is chosen. Please, do not forget to store the resolved integer ambiguities in your observation file (mark checkbox “Save resolved ambiguities”).



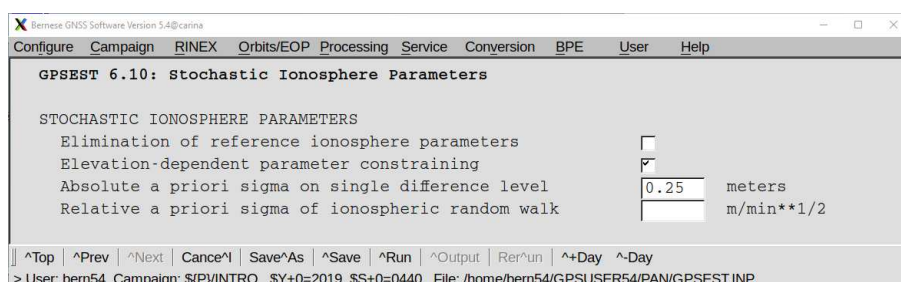
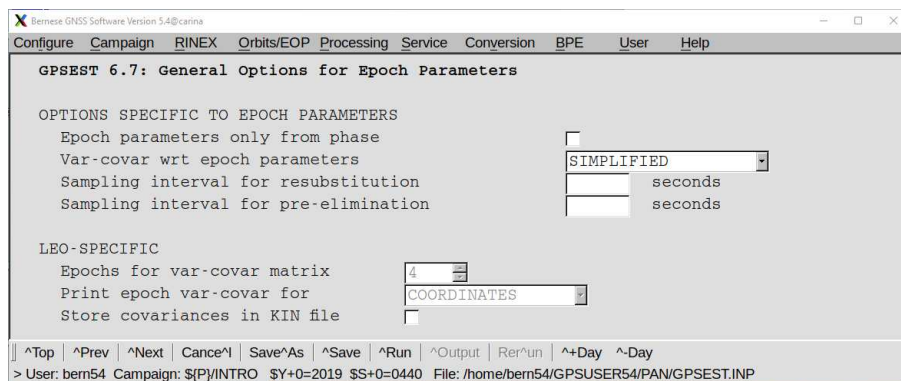
In case of ambiguity resolution including GLONASS, only one ambiguity per iteration can be resolved. The program will adjust the setting automatically issuing a warning message.



Even if we introduce the coordinate solution from the previous network solution from Section 5.2, we fix only the coordinates of the first station and estimate those from the second one with each iteration of ambiguity resolution. In this way, the geometry can react to the resolved ambiguities.



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



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

```

...
SUMMARY OF RESULTS
-----
Number of parameters:
-----
-----
Parameter type                Adjusted   Expl.    Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities      3         3         0              0  0  0  0
Ambiguities                          350       350       0              0  0  0  0
Stochastic ionosphere parameters     59105      0    59105 (epow)  0  0  0  5543
-----
Total number                       59458     353    59105          0  0  0  5543
-----
*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----
Total number of authentic observations      112450
Total number of pseudo-observations         2
...

A posteriori RMS of unit weight            0.001254 m
Chi**2/DOF                                1.57
...

```

```

...
Station coordinates and velocities:
-----
Sol Station name      Typ Correction  Estimated value  RMS error  A priori value ... Abb
-----
 1 TLSE 10003M009      X   -0.00110    4627851.66095   0.00018    4627851.66205 ... #CRD
 1 TLSE 10003M009      Y    0.00010    119640.28830   0.00021    119640.28820 ... #CRD
 1 TLSE 10003M009      Z   -0.00092    4372993.71284   0.00016    4372993.71376 ... #CRD
...
AMBIGUITIES:
-----
                                REFERENCE
AMBI  FILE SAT. S_EPO  L_EPO FRQ WLF CLU  AMBI CLU  AMBIGUITY  RMS  TOTAL AMBIGU.
-----
 1   1   1     1     701  1   1   1  172  217     0.11  0.11    1432776.11
 2   1   1     2830  2880  1   1   2  172  217     3.50  0.85    1432629.50
 3   1   7     720    1326  1   1   4  172  217    -4.27  0.12    2614156.73
 4   1   7    2646    2825  1   1   5  172  217    -1.37  0.47    2614121.63
 5   1   8     1     401  1   1   7  172  217    -1.43  0.13    1201549.57
 6   1   8    2576    2581  1   1   8  172  217    -1.10  3.04    1201598.90
 7   1   8    2588    2880  1   1   9  172  217    -1.75  0.16    1201598.25
 8   1  10     1     240  1   1  10  172  217    -1.94  0.20    -940600.94
 9   1  10    1548    1718  1   1  11  172  217     1.94  0.35    -940558.06
10   1  10    1725    1852  1   1  12  172  217     1.14  0.45    -940553.86
11   1  10    2561    2825  1   1  14  172  217     5.07  0.18    -940673.93
12   1  10    2832    2880  1   1  15  172  217     3.27  0.30    -940674.73
13   1  11     1     606  1   1  16  172  217    -1.69  0.11    2346706.31
14   1  11    2791    2825  1   1  18  172  217    -0.42  0.94    2346725.58
15   1  11    2849    2880  1   1  19  172  217     3.13  0.64    2346724.13
16   1  16     1     78   1   1  20  172  217    -1.69  0.51    -2504795.69
17   1  16    2307    2842  1   1  22  172  217     0.19  0.12    -2504862.81
18   1  16    2849    2880  1   1  23  172  217     3.85  0.55    -2504861.15
19   1  18     1     561  1   1  24  172  217    -1.72  0.12    1349999.28
20   1  18    2689    2842  1   1  25  172  217    -1.60  0.31    1349919.40
21   1  18    2849    2880  1   1  26  172  217     3.24  0.42    1349919.24
22   1  20     1     106  1   1  27  172  217    -1.43  0.45    -139284.43
23   1  20    1424    1432  1   1  29  172  217    -2.66  2.41    -139505.66
24   1  20    1439    1453  1   1  30  172  217     5.89  1.48    -139498.11
25   1  20    1460    1779  1   1  31  172  217    -2.99  0.24    -139500.99
26   1  20    2465    2842  1   1  32  172  217    -0.08  0.16    -139436.08
27   1  20    2849    2880  1   1  33  172  217     3.58  0.56    -139435.42
28   1  22     19     751  1   1  34  172  217     3.07  0.11    -1558169.93
29   1  26    2167    2825  1   1  36  172  217    -3.61  0.11    -3210511.61
30   1  27     1     272  1   1  38  172  217    -1.68  0.16    -899410.68
31   1  27    2411    2825  1   1  39  172  217     1.20  0.13    -899408.80
32   1  27    2832    2880  1   1  40  172  217     3.52  0.26    -899407.48
33   1  30     836    1486  1   1  41  172  217    -1.23  0.12    3572427.77
...

```

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

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

```

...
AMBIGUITY RESOLUTION:
-----
STRATEGY : QUASI-IONOSPHERE-FREE AMBIGUITY RESOLUTION (QIF)
-----
AMBIGUITY RESOLUTION ITERATION: 1
-----
                                BEST INT.      CORRECTIONS IN CYCLES
FILE AM1 CL1 #AM1 AM2 CL2 #AM2  L1  L2  L1  L2  L5  L3  RMS(L3) SA1 SA2
-----
 1 154 188 1 175 221 1 -4 0 -0.40 -0.54 0.138 0.007 0.003 211 225

```

```

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

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	66	79	1	156	190	1	3	3	-0.28	-0.38	0.098	0.008	0.003	201	204

```

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

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	79	96	1	93	113	1	-1	1	0.01	0.02	-0.011	-0.021	0.003	226	207

```

-----
...
AMBIGUITY RESOLUTION ITERATION:      15
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	1	1	1	28	34	1	-3	-1	0.03	0.05	-0.015	-0.019	0.004	1	22

```

-----
AMBIGUITY RESOLUTION ITERATION:      16
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	28	34	2	98	118	1	4	3	-0.00	-0.00	0.001	0.000	0.003	22	3

```

-----
...
AMBIGUITY RESOLUTION ITERATION:      48
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	51	62	1	113	136	1	8	5	-0.45	-0.58	0.130	0.004	0.005	114	110

```

-----
AMBIGUITY RESOLUTION ITERATION:      49
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	26	32	1	173	219	12	-8	-8	-0.79	-1.00	0.211	-0.044	0.005	20	25

```

-----
AMBIGUITY RESOLUTION ITERATION:      50
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	44	55	1	101	121	1	1	0	0.78	1.00	-0.217	0.021	0.005	107	103

```

-----
AMBIGUITY RESOLUTION ITERATION:      51
-----

```

FILE	AM1	CL1	#AM1	AM2	CL2	#AM2	BEST INT.		CORRECTIONS IN CYCLES				RMS(L3)	SA1	SA2
							L1	L2	L1	L2	L5	L3			
1	60	73	1	115	138	1	-3	0	0.22	0.27	-0.053	0.033	0.005	123	119

```

-----
...

```

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

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

AM1 first ambiguity number (single-difference level),

CL1 corresponding ambiguity cluster,

#AM1 number of ambiguities belonging to the same cluster,

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

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

CORRECTIONS IN CYCLES

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

SA1, SA2

first and second satellite number related to the ambiguities.

The first ambiguities are resolved for Galileo; with iteration AMBIGUITY RESOLUTION ITERATION: 15 the first GPS satellites follow. In ITERATION: 48, 50 and 51 there are examples for resolving pairs of ambiguities from the satellite using the same frequency. Later there are even examples for path-to-path ambiguity resolution, e.g., ITERATION: 65 or 76, indicated by the same satellite number for SA1 and SA2.

The following table summarizes the results of the ambiguity resolution:

...													
REFERENCE													
AMBI	FILE	SAT.	S_EPO	L_EPO	FRQ	WLF	CLU	AMBI	CLU	AMBIGUITY	RMS	TOTAL AMBIGU.	DL/L
1	1	1	1	701	1	1	1	28	34	-3		1432773.	0.000
2	1	1	2830	2880	1	1	2	173	219	-4		1432622.	0.000
3	1	7	720	1326	1	1	4	126	157	-2		2614159.	0.000
4	1	7	2646	2825	1	1	5	173	219	-11		2614112.	0.000
5	1	8	1	401	1	1	7	125	155	-4		1201547.	0.000
6	1	8	2576	2581	1	1	8	172	217	-3.32	3.14	1201596.68	
7	1	8	2588	2880	1	1	9	173	219	-10		1201590.	0.000
8	1	10	1	240	1	1	10	141	174	2		-940597.	0.000
9	1	10	1548	1718	1	1	11	173	219	-7		-940567.	0.000
10	1	10	1725	1852	1	1	12	172	217	-1.17	0.46	-940556.17	
11	1	10	2561	2825	1	1	14	141	174	9		-940670.	0.000
12	1	10	2832	2880	1	1	15	173	219	-5		-940683.	0.000
13	1	11	1	606	1	1	16	19	24	0		2346708.	0.000
14	1	11	2791	2825	1	1	18	172	217	-2.67	0.97	2346723.33	
15	1	11	2849	2880	1	1	19	173	219	-5		2346716.	0.000
16	1	16	1	78	1	1	20	173	219	-11		-2504805.	0.000

17	1	16	2307	2842	1	1	22	31	39	-1		-2504864.	0.000
18	1	16	2849	2880	1	1	23	143	176	1		-2504864.	0.000
19	1	18	1	561	1	1	24	98	118	-1		1350000.	0.000
20	1	18	2689	2842	1	1	25	36	46	-1		1349920.	0.000
21	1	18	2849	2880	1	1	26	173	219	-5		1349911.	0.000
22	1	20	1	106	1	1	27	143	176	-3		-139286.	0.000
23	1	20	1424	1432	1	1	29	172	217	-4.97	2.49	-139507.97	
24	1	20	1439	1453	1	1	30	172	217	3.57	1.53	-139500.43	
25	1	20	1460	1779	1	1	31	173	219	-12		-139510.	0.000
26	1	20	2465	2842	1	1	32	173	219	-8		-139444.	0.000
27	1	20	2849	2880	1	1	33	143	176	2		-139437.	0.000
28	1	22	19	751	1	1	34	98	118	4		-1558169.	0.000
29	1	26	2167	2825	1	1	36	165	208	-10		-3210518.	0.000
30	1	27	1	272	1	1	38	141	174	2		-899407.	0.000
31	1	27	2411	2825	1	1	39	141	174	5		-899405.	0.000
32	1	27	2832	2880	1	1	40	143	176	1		-899410.	0.000
33	1	30	836	1486	1	1	41	173	219	-10		3572419.	0.000
...													

The ambiguities for which an RMS is specified could not be resolved (these ambiguities will be treated as real values by all subsequent program runs). In case of GLONASS, only ambiguities with the same channel number are resolved in Version 5.4 of *Bernese GNSS Software*.

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

```

...
SUMMARY OF RESULTS
-----

Number of parameters:
-----

-----
Parameter type                Adjusted   Expl.   Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities      3         3         0             0   0   0   0
Ambiguities                          86        84         0             0   2   0   0
Stochastic ionosphere parameters    59105      0    59105 (epow)  0   0   0  5543
-----
Total number                      59194      87    59105             0   0   0  5543

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----

Total number of authentic observations      112450
Total number of pseudo-observations         2

Total number of explicit parameters         89
Total number of implicit parameters        59105

Total number of observations               112452
Total number of adjusted parameters        59194
Degree of freedom (DOF)                   53258

A posteriori RMS of unit weight            0.001298 m
Chi**2/DOF                                1.68

Total number of observation files           1
Total number of unobserved ambiguities     92
Total number of stations                   1

Station coordinates and velocities:
-----

Sol Station name                Typ Correction  Estimated value  RMS error  A priori value ... Abb
-----
1 TLSE 10003M009                X   -0.00063     4627851.66142   0.00014    4627851.66205 ... #CRD
1 TLSE 10003M009                Y    0.00013     119640.28832    0.00007    119640.28819 ... #CRD
1 TLSE 10003M009                Z   -0.00057     4372993.71319   0.00014    4372993.71376 ... #CRD

```


You may see from the output that from a total of 350 ambiguities 266 ambiguities could be resolved (compare part 1 AMBIGUITIES with part 2 AMBIGUITIES). Note that these numbers include reference ambiguities for each GNSS, GLONASS frequency number and frequency.

5.3.2 Ambiguity Resolution: Short Baselines

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

The ultra-short baseline in Kötzing is between WTZR and WTZZ (WTWZ0440.PSH). The GPSEST input panels should look like follows:

PARAMETER ESTIMATION - GPSEST 1.1: Input Files 1

GENERAL FILES AND PROCESSING MODE

Space geodetic technique: GNSS
Differencing level: DOUBLE
LEO data processing:
Show all general files:

OBSERVATION FILES

Phase observations: WTWZ\$\$+0 PSH
Code observations: CSH
Range observations: RZH

MAIN INPUT FILES

Station coordinates: FLT_YYYYSS+0 CRD
Standard orbits: COD_YYYYSS+0 STD
Earth rotation parameters: COD_YYYYSS+0 ERP
Satellite clock corrections: CLK
Observable-specific biases: OSB NL phase biases from CLK
VMF grid file: GRD
Ionosphere models: HOI_YYYYSS+0 ION

CORRECTIONS FOR LOADING EFFECTS AND CENTER OF MASS

Ocean tidal loading: EXAMPLE BLQ
Atmospheric tidal loading: ATL
related error handling: ERROR

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$\$+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials: RPR
Clock RINEX file: CLK
Estimated troposphere: FLT_YYYYSS+0 TRP
Meteorological data: MET

GRIDDED LOADING PARAMETERS

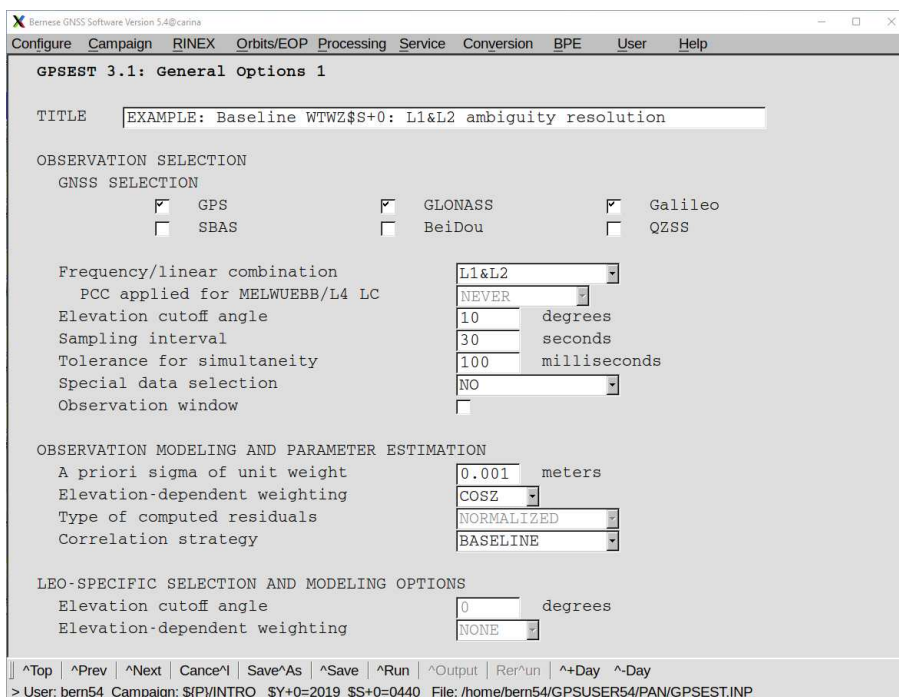
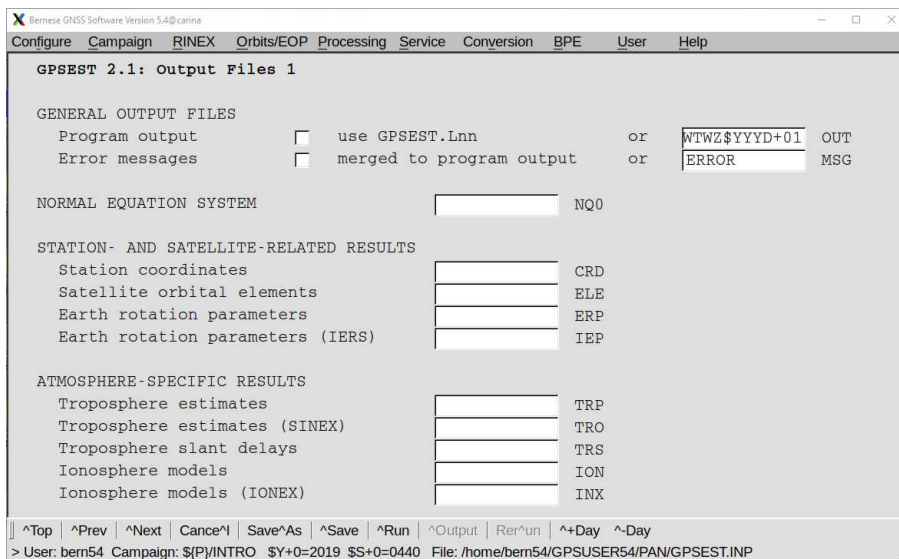
Atmospheric pressure: GRD
Ocean, non-tidal: GRD
Hydrostatic pressure: GRD

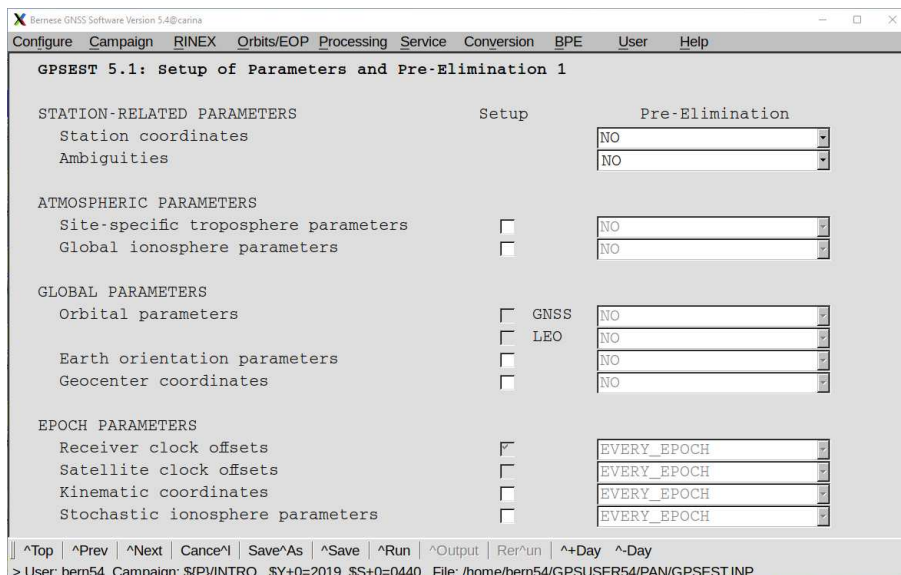
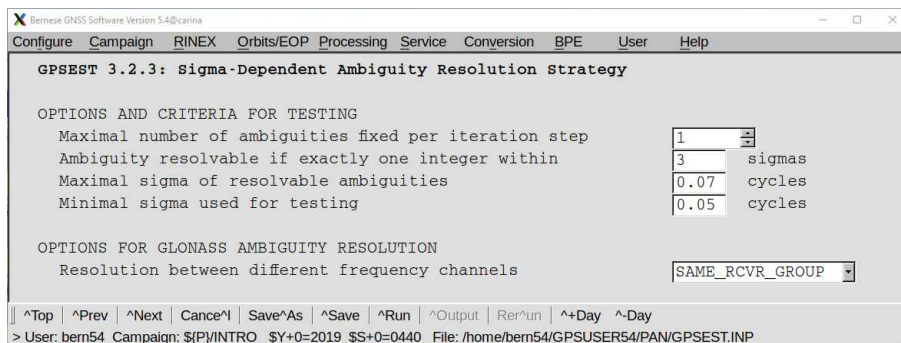
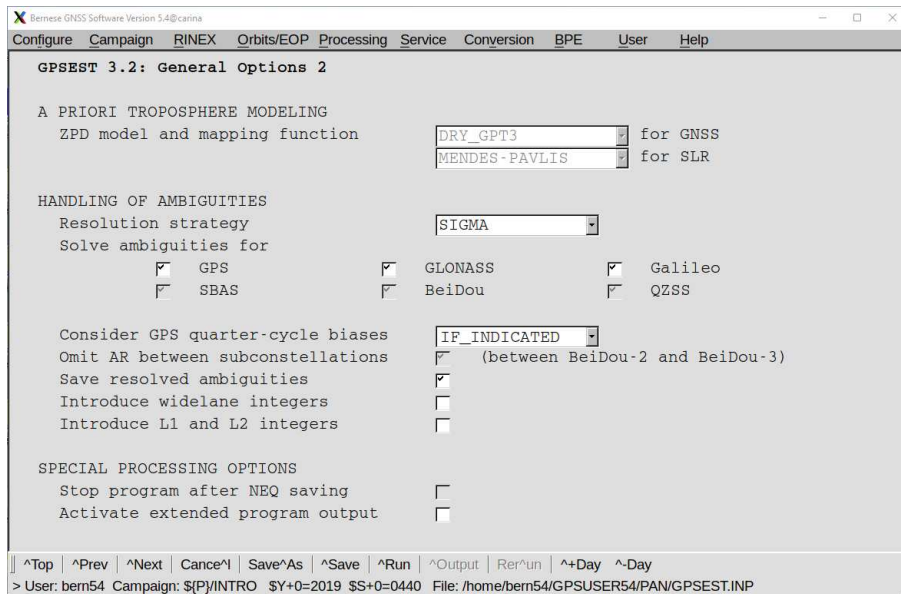
AUXILIARY STATION FILES

Station information: STA
Kinematic coordinates: KIN
Observation sigma factors: SOS
Station eccentricities: ECC

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$\$+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

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





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

```

...
SUMMARY OF RESULTS
-----

Number of parameters:
-----

-----
Parameter type                Adjusted   Expl.   Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities      3         3         0             0  0  0  0
Ambiguities                          344       344         0             0  0  0  0
-----
Total number                       347       347         0             0  0  0  0

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----

Total number of authentic observations      118374
Total number of pseudo-observations         4

Total number of explicit parameters         347
Total number of implicit parameters         0

Total number of observations                118378
Total number of adjusted parameters         347
Degree of freedom (DOF)                    118031

A posteriori RMS of unit weight            0.001128 m
Chi**2/DOF                                 1.27

Total number of observation files           1
Total number of unobserved ambiguities     42
Total number of stations                   1
...

```

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

```

...
SUMMARY OF RESULTS
-----

Number of parameters:
-----

-----
Parameter type                Adjusted   Expl.   Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities      3         3         0             0  0  0  0
Ambiguities                          56        52         0             0  4  0  0
-----
Total number                       59        55         0             0  4  0  0

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----

Total number of authentic observations      118374
Total number of pseudo-observations         4

Total number of explicit parameters         59
Total number of implicit parameters         0

Total number of observations                118378
Total number of adjusted parameters         59
Degree of freedom (DOF)                    118319

A posteriori RMS of unit weight            0.001326 m
Chi**2/DOF                                 1.76

Total number of observation files           1
Total number of unobserved ambiguities     42
Total number of stations                   1
...

```

From the number of ambiguity parameters it can be computed that 288 out of 344 ambiguities from GPS, GLONASS, and Galileo have been resolved to their integer numbers. Please remind, that at least 6 ambiguity parameters must remain real values because one reference ambiguity per GNSS and frequency are needed. For the Code Division Multiple Access (CDMA) systems, GPS and Galileo they are reported as — Reference —. Because the two receivers belong to different groups regarding “GLONASS amb. resol. between different frequencies” only the ambiguities between the same frequency numbers have been resolved. In addition, depending on the receiver type, not all ambiguities for GPS are allowed to be resolved too, to prevent problems with the quarter-cycle bias between the P- and C-code signal (see option “Consider GPS quarter-cycle biases” in panel “GPSEST 3.2: General Options 2” and the lecture on ambiguity resolution).

5.3.3 Ambiguity Resolution: BPE

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

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

The `TUTORIAL.PCF` consists of two parts: the first part defines the scripts and the option directories where the program’s input files are taken from. In addition the CPU-specification and waiting conditions are defined to keep the correct order for the execution of the scripts. The keyword `PARALLEL` indicates a special execution mode for the scripts, e.g., `GNSAMB_P` with PID 412 or `GNSQIF_P` with PID 432. They may run in parallel for each individual baseline. The preparatory scripts, e.g., `GNSAMBAP` or `GNSQIFAP` define the list of baselines to be processed. The second part defines the so called BPE- or PCF-variables that can be used within the scripts or in the input fields of the menu. A detailed introduction to the BPE will be the topic of a lecture on Thursday.

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

401 SATMRK :

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

411 GNSAMBAP and 412 GNSAMB_P :

Applies the `SIGMA` ambiguity resolution strategy using the Melbourne-Wübbena linear combination to all baselines longer than 200 km of the example in a baseline-by-baseline mode, where several baselines may be processed at the same time in parallel.

421 GNSL53AP and 422 GNSL53_P :

Applies the `SIGMA` ambiguity resolution strategy using the wide- and narrow-lane

```

#
# =====
# TUTORIAL.PCF
# =====
#
# Purpose:
# Run the ambiguity resolution for one session in the <<Terminal Session>>
# of the Bernese Software Introductory Course
#
# -----
#
# Author      : R. Dach
# Created     : 27-Aug-2022
#
# Changes    :
#
# =====
#
#
PID  SCRIPT    OPT_DIR  PARAMETERS
#
# Resolve phase ambiguities
# -----
401  SATMRK    R2S_GEN  CPU=ANY
411  GNSAMBAP  R2S_AMB  CPU=ANY; WAIT=401
412  GNSAMB_P  R2S_AMB  CPU=ANY; WAIT=411; PARALLEL=411
421  GNSL53AP  R2S_L53  CPU=ANY; WAIT=412
422  GNSL53_P  R2S_L53  CPU=ANY; WAIT=421; PARALLEL=421
431  GNSQIFAP  R2S_QIF  CPU=ANY; WAIT=422
432  GNSQIF_P  R2S_QIF  CPU=ANY; WAIT=431; PARALLEL=431
441  GNSL12AP  R2S_L12  CPU=ANY; WAIT=432
442  GNSL12_P  R2S_L12  CPU=ANY; WAIT=441; PARALLEL=441
443  AMBXTR    R2S_AMB  CPU=ANY; WAIT=442
#
# End of BPE
# -----
899  DUMMY     NO_OPT   CPU=ANY; WAIT=443
#
#
VARIABLE  DEFAULT  PARAMETERS
#
# General and model files:
# -----
V_SUBMOD = DESAI2016;  DESCRIPTION=Subdaily pole model
V_NUTMOD = IAU2000R06; DESCRIPTION=Nutation model
V_PCV    = I20;        DESCRIPTION=Antenna phase center (PCV) model
V_PCVINF = ANTENNA;    DESCRIPTION=PCV information file
V_SATINF = SATELLIT;   DESCRIPTION=Satellite information file
V_SATCRX = SAT_$Y+0;  DESCRIPTION=Satellite problem file
V_ORB    = COD;        DESCRIPTION=Orbit/ERP, CLK, bias information
#
# Reference frame and station related files:
# -----
V_CRDINF = EXAMPLE;    DESCRIPTION=Merged CRD/VEL filename
V_STAINF = EXAMPLE;    DESCRIPTION=_Station information file
V_BLQINF = EXAMPLE;    DESCRIPTION=_BLQ file name, CMC corrections
V_ATLINF = EXAMPLE;    DESCRIPTION=_ATL file name, CMC corrections
V_HOIFIL = HOI_$$YYS+0; DESCRIPTION=_Ionosphere model for higher order iono
V_OSBFIL = COD_$$YYS+0; DESCRIPTION=_OSB-file with GNSS satellite biases
#
# Data selection:
# -----
#
# Data selection:
# -----
V_OBSSEL = OBSERV;    DESCRIPTION=Observation selection file
V_SATSYS = GRE;       DESCRIPTION=Select the GNSS (max. supported: GRECJ)
#
# Ambiguity resolution:
# -----
V_GNSSAR = GRE;       DESCRIPTION=Select the GNSS for amb. resolu. (GECJ)
V_BL_AMB = 6000;      DESCRIPTION=Maximum baseline length for MW/L3 AR
V_BL_QIF = 2000;      DESCRIPTION=Maximum baseline length for QIF AR
V_BL_L53 = 200;       DESCRIPTION=Maximum baseline length for L5/L3 AR
V_BL_L12 = 20;        DESCRIPTION=Maximum baseline length for L1&L2 AR
#
# Other solution IDs used in the BPE:
# -----
V_APR    = APR;       DESCRIPTION=A priori information
V_FLT    = FLT;       DESCRIPTION=Preliminary (ambiguity-float) results
#
# DO NOT USE V_D, V_J, V_M, V_Y VARIABLES!
# (they are used already by the menu)
#

```

linear combinations to all baselines shorter than 200 km and longer than 20 km. In this example we don't have such a baseline, this section will be skipped automatically.

431 GNSQIFAP and 432 GNSQIF_P :

Applies the QIF ambiguity resolution strategy to all baselines of the example in a baseline-by-baseline mode, where several baselines may be processed at the same time in parallel. The resolved ambiguities from the previous steps are introduced and, consequently the algorithm only applies to the remaining unresolved ambiguities.

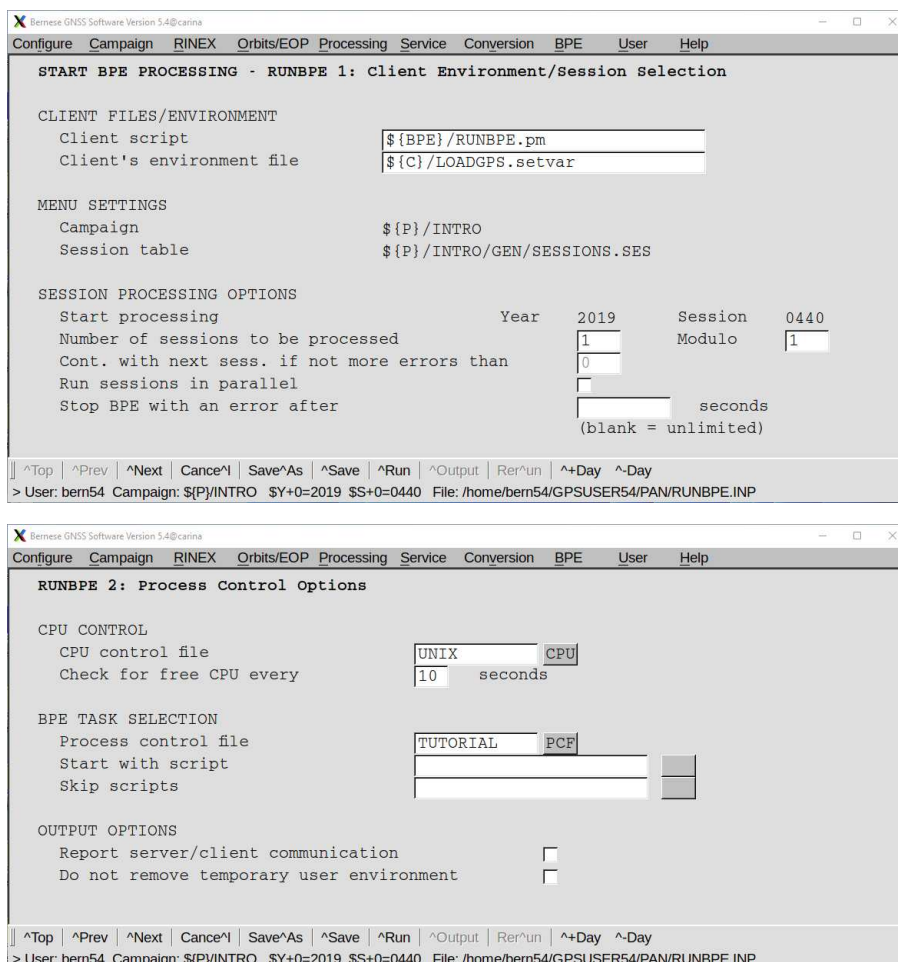
441 GNLS12AP and 442 GNLS12_P :

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

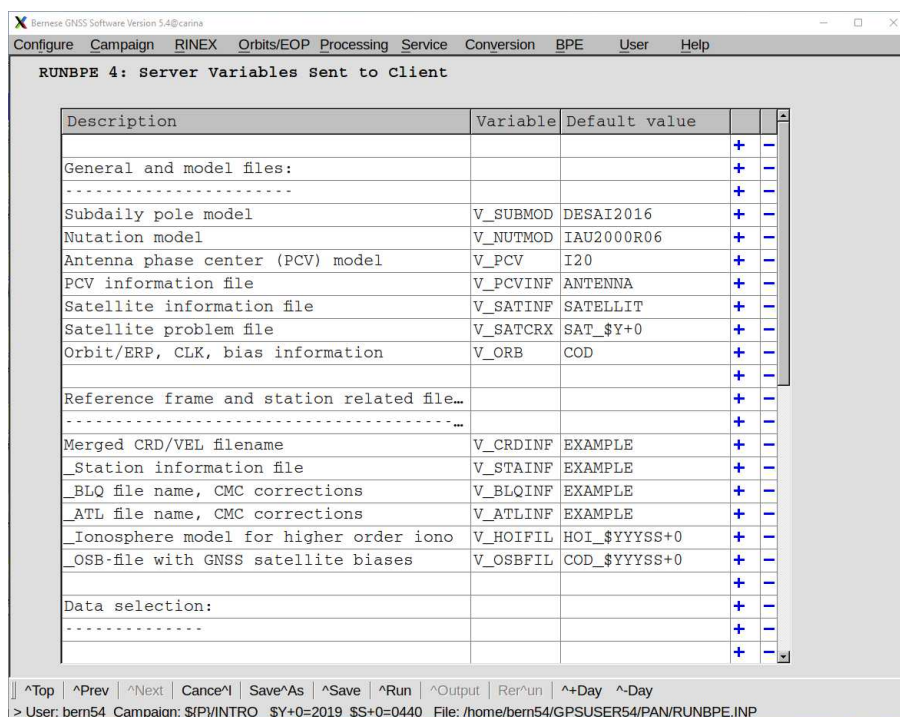
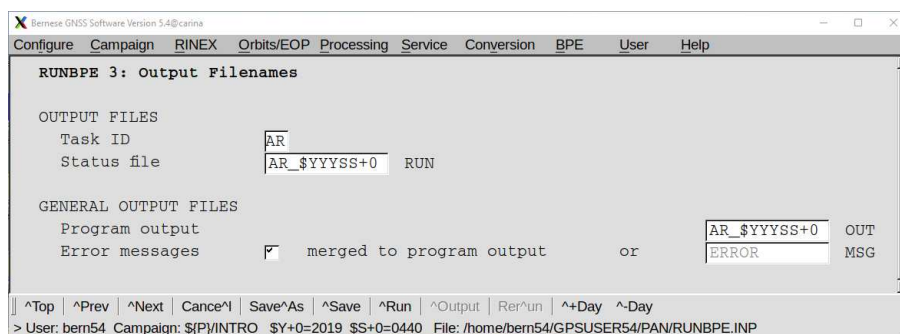
443 AMBXTR :

Creates a series of summary files on the success rate of the ambiguity resolution process in the various steps.

In the *Bernese Introductory Course* environment the TUTORIAL.PCF BPE can be started for one session (e.g., day 044 of year 2019) using "Menu>BPE>Start BPE processing":



If you follow the tutorial outside from the environment of the *Bernese Introductory Course* you can select RNX2SNX in option "Process control file" and skip all scripts apart from the range between PID 401 SATMRK to PID 442 GNLS12_P (option "Skip scripts").

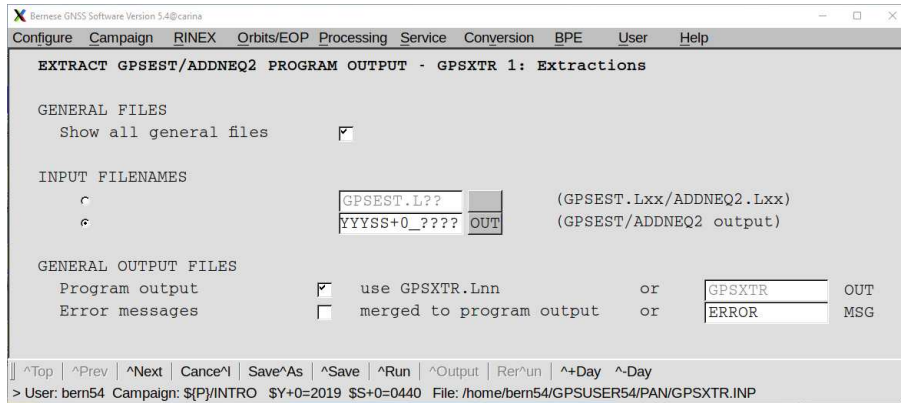


Run the BPE for the current session. If the BPE stops with an error you can inspect the files `${P}/INTRO/BPE/AR190440_...PRT` and `${P}/INTRO/BPE/AR190440_...LOG` belonging to your current session. These files report for instance if an input file is missing. This might be the case if you did not follow the naming convention proposed in the tutorial. In that case you have to copy the file from your naming to the expected one.

5.3.4 Ambiguity Resolution: Summary

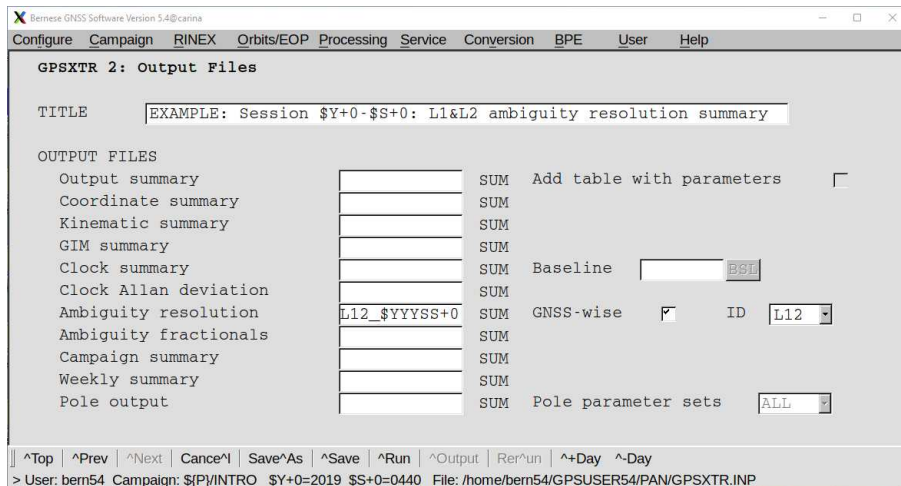
For each observation file a corresponding program output file is generated. To get an overview on the success rate of the various ambiguity resolution steps a one-line summary for each baseline (and optionally for each satellite system) is generated by the BPE in the last step (443 AMBXTR).

The program GPSXTR ("Menu>Processing>Program output extraction>Parameter estimation/stacking") was used in several configurations. Here we have a look at the extraction of the last step of the ambiguity resolution, direct use of the SIGMA-strategy on L_1 and L_2 frequencies (solution indicator L12):



The entry for option “GPSEST/ADDNEQ output files” may be incomplete in the screenshot. It should be L12_YYYYS+0_???? (you may check with bottom right to the input field).

All program output files related to the L12 ambiguity resolution method have been specified with program output filenames fitting in the shape $\${P}/INTRO/OUT/L12_YYYYS+0_????$.OUT and can, therefore, easily be selected in the input field “GPSEST/ADDNEQ output files”.



The resulting protocol in the file $\${P}/INTRO/OUT/L12_20190440.SUM$ looks like:

File	Sta1	Sta2	Length (km)	Before #Amb (mm)	After #Amb (mm)	Res (%)	Sys	...
WTWZ0440	WTZR	WTZZ	0.002	134	1.1	6	1.3	95.5 G ... #AR_L12
WTWZ0440	WTZR	WTZZ	0.002	116	1.1	42	1.3	63.8 R ... #AR_L12
WTWZ0440	WTZR	WTZZ	0.002	90	1.1	0	1.3	100.0 E ... #AR_L12
WTWZ0440	WTZR	WTZZ	0.002	340	1.1	48	1.3	85.9 GRE ... #AR_L12
ZIZM0440	ZIMZ	ZIMM	0.019	112	1.2	4	1.3	96.4 G ... #AR_L12
Tot:	2		0.010	246	1.2	10	1.3	95.9 G ... #AR_L12
Tot:	1		0.002	116	1.1	42	1.3	63.8 R ... #AR_L12
Tot:	1		0.002	90	1.1	0	1.3	100.0 E ... #AR_L12
Tot:	2		0.010	452	1.2	52	1.3	88.5 GRE ... #AR_L12

Legend:

QTR consider GPS quarter cycle : - (not applicable) N (never) A (always)
I (indicated) S (selected)

FRQ GLONASS resolution between freq.: - (not applicable) N (never) A (always)
T (same rcvr. type) M (same rcvr. model)

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

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

Filenames from
 Manual processing processed by the BPE
 Strategy: direct L_1/L_2 : `WTWZ20190441.OUT` `L12_20190440_WTWZ.OUT`

The QIF-based ambiguity resolution in the automated processing started from the resolved ambiguities based on the Melbourne-Wübbena strategy whereas in the manual mode the QIF-strategy was applied to the plain files.

Let's have a look at the complete summary file generated by the script in the BPE available in $\${P}/\text{INTRO}/\text{OUT}/\text{AMB}_20190440.SUM$. The first part is reporting about the wide-lane/narrow-lane ambiguity resolution starting from the Melbourne-Wübbena linear combination:

```

=====
Code-Based Widelane (WL) Ambiguity Resolution (<6000 km)
=====

```

File	Sta1	Sta2	Length (km)	Before		After		Res (%)	Sys	...
				#Amb	(mm)	#Amb	(mm)			
BRTL0440	BRST	TLSE	707.462	69	1.4	15	1.5	78.3	G	... #AR_WL
BRTL0440	BRST	TLSE	707.462	47	1.4	15	1.5	68.1	E	... #AR_WL
BRTL0440	BRST	TLSE	707.462	116	1.4	30	1.5	74.1	G E	... #AR_WL
GAMIO440	GANP	MIKL	897.345	51	0.8	4	0.8	92.2	G	... #AR_WL
GAMIO440	GANP	MIKL	897.345	29	0.8	5	0.8	82.8	E	... #AR_WL
GAMIO440	GANP	MIKL	897.345	80	0.8	9	0.8	88.8	G E	... #AR_WL
GAWZO440	GANP	WTZZ	543.530	56	1.0	9	1.1	83.9	G	... #AR_WL
GAWZO440	GANP	WTZZ	543.530	41	1.0	3	1.1	92.7	E	... #AR_WL
GAWZO440	GANP	WTZZ	543.530	97	1.0	12	1.1	87.6	G E	... #AR_WL
...										...
WSWZO440	WSRT	WTZZ	607.409	142	1.0	95	1.0	33.1	G	... #AR_WL
WSWZO440	WSRT	WTZZ	607.409	20	1.0	10	1.0	50.0	E	... #AR_WL
WSWZO440	WSRT	WTZZ	607.409	162	1.0	105	1.0	35.2	G E	... #AR_WL
WZZIO440	WTZZ	ZIM2	475.909	54	1.1	6	1.2	88.9	G	... #AR_WL
WZZIO440	WTZZ	ZIM2	475.909	38	1.1	3	1.2	92.1	E	... #AR_WL
WZZIO440	WTZZ	ZIM2	475.909	92	1.1	9	1.2	90.2	G E	... #AR_WL
...										...
Tot: 14			760.073	958	1.3	274	1.4	71.4	G	... #AR_WL
Tot: 8			809.713	282	1.1	50	1.2	82.3	E	... #AR_WL
Tot: 14			760.073	1240	1.3	324	1.4	73.9	G E	... #AR_WL

```

=====
Code-Based Narrowlane (NL) Ambiguity Resolution (<6000 km)
=====

```

File	Sta1	Sta2	Length (km)	Before		After		Res (%)	Sys	...
				#Amb	(mm)	#Amb	(mm)			
BRTL0440	BRST	TLSE	707.462	70	1.1	16	1.2	77.1	G	... #AR_NL
BRTL0440	BRST	TLSE	707.462	46	1.1	15	1.2	67.4	E	... #AR_NL
BRTL0440	BRST	TLSE	707.462	116	1.1	31	1.2	73.3	G E	... #AR_NL
GAMIO440	GANP	MIKL	897.345	53	1.1	6	1.1	88.7	G	... #AR_NL
GAMIO440	GANP	MIKL	897.345	37	1.1	14	1.1	62.2	E	... #AR_NL
GAMIO440	GANP	MIKL	897.345	90	1.1	20	1.1	77.8	G E	... #AR_NL
GAWZO440	GANP	WTZZ	543.530	57	0.8	10	1.0	82.5	G	... #AR_NL
GAWZO440	GANP	WTZZ	543.530	40	0.8	2	1.0	95.0	E	... #AR_NL
GAWZO440	GANP	WTZZ	543.530	97	0.8	12	1.0	87.6	G E	... #AR_NL
...										...
WSWZO440	WSRT	WTZZ	607.409	142	1.0	95	1.0	33.1	G	... #AR_WL
WSWZO440	WSRT	WTZZ	607.409	20	1.0	10	1.0	50.0	E	... #AR_WL
WSWZO440	WSRT	WTZZ	607.409	162	1.0	105	1.0	35.2	G E	... #AR_WL
WZZIO440	WTZZ	ZIM2	475.909	55	0.9	6	1.1	89.1	G	... #AR_NL
WZZIO440	WTZZ	ZIM2	475.909	37	0.9	2	1.1	94.6	E	... #AR_NL
WZZIO440	WTZZ	ZIM2	475.909	92	0.9	8	1.1	91.3	G E	... #AR_NL
...										...
Tot: 14			760.073	996	0.9	314	1.0	68.5	G	... #AR_NL
Tot: 8			809.713	307	1.0	80	1.1	73.9	E	... #AR_NL
Tot: 14			760.073	1303	0.9	394	1.0	69.8	G E	... #AR_NL
...										...

In particular for the Melbourne-Wübbena linear combination we observe a higher resolution rate for Galileo than for GPS. The reason is the lower noise level of code measurements

obtained from the Galileo system. GLONASS is not included because it is not supported for the Melbourne-Wübbena linear combination with Version 5.4 of *Bernese GNSS Software*.

The next block of the ambiguity resolution summary is empty because no baselines for the related lengths are available in the example dataset. The next section is related to the QIF-strategy which is only applied to those ambiguities that are not resolved so far. For this reason the ambiguity resolution rate for GPS and Galileo are lower than it might be expected:

```

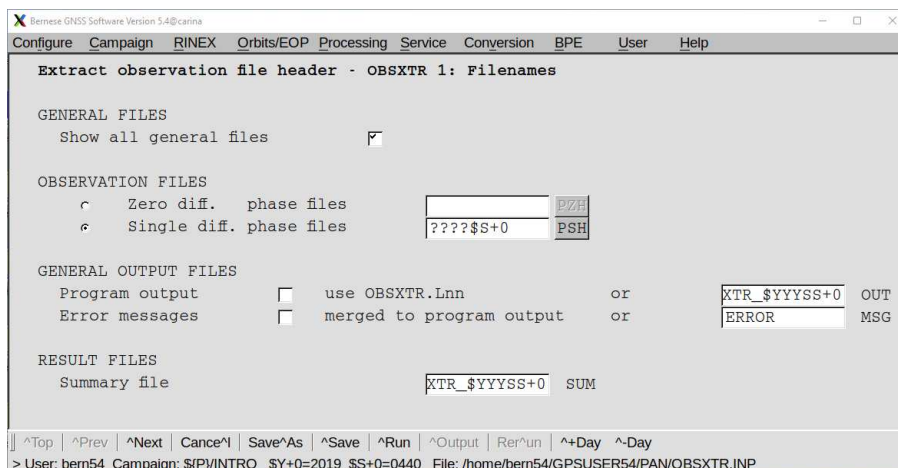
=====
Quasi-Ionosphere-Free (QIF) Ambiguity Resolution (<2000 km)
=====

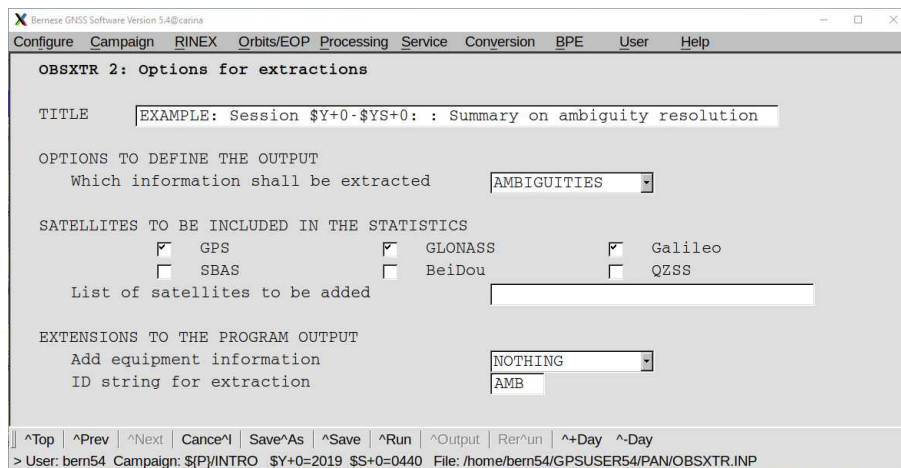
```

File	Sta1	Sta2	Length (km)	Before #Amb (mm)	After #Amb (mm)	Res (%)	Sys	...	
BRTL0440	BRST	TLSE	707.462	30	1.3	28	1.3	6.7 G	... #AR_QIF
BRTL0440	BRST	TLSE	707.462	116	1.3	38	1.3	67.2 R	... #AR_QIF
BRTL0440	BRST	TLSE	707.462	32	1.3	14	1.3	56.2 E	... #AR_QIF
BRTL0440	BRST	TLSE	707.462	178	1.3	80	1.3	55.1 GRE	... #AR_QIF
GAMIO440	GANP	MIKL	897.345	10	1.2	4	1.2	60.0 G	... #AR_QIF
GAMIO440	GANP	MIKL	897.345	98	1.2	40	1.2	59.2 R	... #AR_QIF
GAMIO440	GANP	MIKL	897.345	30	1.2	8	1.2	73.3 E	... #AR_QIF
GAMIO440	GANP	MIKL	897.345	138	1.2	52	1.2	62.3 GRE	... #AR_QIF
GAWZO440	GANP	WTZZ	543.530	20	1.0	14	1.0	30.0 G	... #AR_QIF
GAWZO440	GANP	WTZZ	543.530	102	1.0	36	1.0	64.7 R	... #AR_QIF
GAWZO440	GANP	WTZZ	543.530	6	1.0	4	1.0	33.3 E	... #AR_QIF
GAWZO440	GANP	WTZZ	543.530	128	1.0	54	1.0	57.8 GRE	... #AR_QIF
...									
WSWZO440	WSRT	WTZZ	607.409	246	1.0	166	1.0	32.5 G	... #AR_QIF
WSWZO440	WSRT	WTZZ	607.409	278	1.0	248	1.0	10.8 R	... #AR_QIF
WSWZO440	WSRT	WTZZ	607.409	76	1.0	40	1.0	47.4 E	... #AR_QIF
WSWZO440	WSRT	WTZZ	607.409	600	1.0	454	1.0	24.3 GRE	... #AR_QIF
WZZIO440	WTZZ	ZIM2	475.909	12	1.1	10	1.2	16.7 G	... #AR_QIF
WZZIO440	WTZZ	ZIM2	475.909	96	1.1	30	1.2	68.8 R	... #AR_QIF
WZZIO440	WTZZ	ZIM2	475.909	6	1.1	6	1.2	0.0 E	... #AR_QIF
WZZIO440	WTZZ	ZIM2	475.909	114	1.1	46	1.2	59.6 GRE	... #AR_QIF
Tot: 14			760.073	630	1.1	480	1.1	23.8 G	... #AR_QIF
Tot: 13			774.297	1572	1.1	746	1.1	52.5 R	... #AR_QIF
Tot: 8			809.713	180	1.1	86	1.2	52.2 E	... #AR_QIF
Tot: 14			760.073	2382	1.1	1312	1.1	44.9 GRE	... #AR_QIF

The next section in the ambiguity resolution summary is related to the direct ambiguity resolution applying the SIGMA-strategy directly on the L_1 and L_2 observations for very short baselines. The same summary results as we have obtained above manually.

This multiple-step ambiguity resolution makes it difficult to get an overall overview on the success-rate of the ambiguity resolution. Such an overview can be provided by the program OBSXTR ("Menu>Service>Bernese_observation files>Extract statistics from header file") that evaluates the header of the phase observation files on the relation of resolved ambiguities





The program output and a satellite-wise summary are attached to the ambiguity resolution summary `$(P)/INTRO/OUT/AMB_20190440.SUM` as well:

File	Station 1	Station 2	Sys	numb. sat	ambiguity total	resolution L1	statistics L2	...
1	BRST 10004M004	TLSE 10003M009	GPS	31	70	15 78.6%	15 78.6%	... #AMB
1	BRST 10004M004	TLSE 10003M009	GL0	22	58	19 67.2%	19 67.2%	... #AMB
1	BRST 10004M004	TLSE 10003M009	GAL	24	47	8 83.0%	8 83.0%	... #AMB
1	BRST 10004M004	TLSE 10003M009	tot	77	175	42 76.0%	42 76.0%	... #AMB
2	GANP 11515M001	MIKL 12335M001	GPS	31	53	3 94.3%	3 94.3%	... #AMB
2	GANP 11515M001	MIKL 12335M001	GL0	22	49	20 59.2%	20 59.2%	... #AMB
2	GANP 11515M001	MIKL 12335M001	GAL	22	38	4 89.5%	4 89.5%	... #AMB
2	GANP 11515M001	MIKL 12335M001	tot	75	140	27 80.7%	27 80.7%	... #AMB
3	GANP 11515M001	WTZZ 14201M014	GPS	32	57	8 86.0%	8 86.0%	... #AMB
3	GANP 11515M001	WTZZ 14201M014	GL0	22	51	18 64.7%	18 64.7%	... #AMB
3	GANP 11515M001	WTZZ 14201M014	GAL	24	41	2 95.1%	2 95.1%	... #AMB
3	GANP 11515M001	WTZZ 14201M014	tot	78	149	28 81.2%	28 81.2%	... #AMB
...								
13	WSRT 13506M005	WTZZ 14201M014	GPS	32	177	90 49.2%	90 49.2%	... #AMB
13	WSRT 13506M005	WTZZ 14201M014	GL0	22	141	129 8.5%	129 8.5%	... #AMB
13	WSRT 13506M005	WTZZ 14201M014	GAL	20	49	21 57.1%	21 57.1%	... #AMB
13	WSRT 13506M005	WTZZ 14201M014	tot	74	367	240 34.6%	240 34.6%	... #AMB
14	WTZR 14201M010	WTZZ 14201M014	GPS	31	62	3 95.2%	3 95.2%	... #AMB
14	WTZR 14201M010	WTZZ 14201M014	GL0	22	57	23 59.6%	23 59.6%	... #AMB
14	WTZR 14201M010	WTZZ 14201M014	GAL	24	46	2 95.7%	2 95.7%	... #AMB
14	WTZR 14201M010	WTZZ 14201M014	tot	77	165	28 83.0%	28 83.0%	... #AMB
15	WTZZ 14201M014	ZIM2 14001M008	GPS	32	55	6 89.1%	6 89.1%	... #AMB
15	WTZZ 14201M014	ZIM2 14001M008	GL0	22	48	15 68.8%	15 68.8%	... #AMB
15	WTZZ 14201M014	ZIM2 14001M008	GAL	24	38	3 92.1%	3 92.1%	... #AMB
15	WTZZ 14201M014	ZIM2 14001M008	tot	78	141	24 83.0%	24 83.0%	... #AMB
16	ZIM2 14001M008	ZIMM 14001M004	GPS	32	57	3 94.7%	3 94.7%	... #AMB
16	ZIM2 14001M008	ZIMM 14001M004	tot	32	57	3 94.7%	3 94.7%	... #AMB
16	files do contain		GPS	32	1130	266 76.5%	266 76.5%	...
14	files do contain		GL0	23	846	403 52.4%	403 52.4%	...
9	files do contain		GAL	24	367	47 87.2%	47 87.2%	...
16	files do contain		tot	79	2343	716 69.4%	716 69.4%	...

>>> CPU/Real time for pgm "OBSXTR": 0:00:00.014 / 0:00:00.013								
>>> Program finished successfully								
=====								
Satellite-wise Ambiguity Resolution Statistics								
=====								
PRN	Amb total	L1 & L2 ambiguities solved #/clu rel			L5 ambiguities solved #/clu rel			
1	36	27	7.7	65.2	16	9.6	39.8	
2	41	36	12.2	80.6	29	15.8	66.3	
3	33	21	8.8	56.4	15	11.4	41.5	
4	6	0	0.0	0.0	0	0.0	0.0	
5	35	30	20.2	81.5	24	17.5	64.6	
6	44	34	14.3	71.9	28	16.3	59.7	
...								

27	42	37	16.5	82.8	30	26.1	68.7
28	40	32	18.5	75.7	26	15.0	60.7
29	17	17	28.4	96.5	15	22.1	84.2
30	18	18	18.4	94.6	16	9.3	79.4
31	37	32	10.9	78.6	25	8.9	60.0
32	55	43	18.8	74.0	34	13.6	57.3
101	50	41	3.8	60.3	0	0.0	0.0
102	55	45	3.2	56.4	0	0.0	0.0
103	36	22	3.4	43.1	0	0.0	0.0
104	30	17	4.1	42.9	0	0.0	0.0
105	28	16	3.9	42.3	0	0.0	0.0
107	30	25	3.3	58.3	0	0.0	0.0
...							
122	24	18	3.3	52.3	0	0.0	0.0
123	39	28	3.8	52.7	0	0.0	0.0
124	45	30	4.0	49.9	0	0.0	0.0
126	2	2	2.0	50.0	0	0.0	0.0
201	21	18	18.2	81.0	14	16.0	62.5
202	12	12	26.9	96.3	10	20.3	79.2
203	16	15	15.7	87.8	11	17.5	64.8
204	17	17	29.0	96.5	15	16.4	82.9
...							
226	24	24	7.3	86.3	12	32.1	48.4
227	16	13	13.8	75.4	8	20.4	47.6
230	17	16	36.3	91.5	12	17.6	66.6
231	16	13	9.0	72.2	8	11.0	45.5
233	21	20	14.3	88.6	13	18.1	58.5
236	9	9	24.7	95.9	8	18.8	84.2
-----+-----+-----+-----+-----+-----+-----+-----							
GPS	1130	928	14.5	76.5	732	14.9	60.4
GL0	846	616	3.6	52.4	0	0.0	0.0
GAL	367	342	15.5	87.2	242	20.2	62.7
-----+-----+-----+-----+-----+-----+-----+-----							

Please note, that the program OBSXTR does only evaluate the header of the observation files after the ambiguity resolution, whereas the program GPSXTR inspects the program output files from the specific GPSEST run, in which the ambiguity resolution is executed. Due to this the program GPSXTR has access to more information related to reference ambiguities due to user settings that are considered in the statistics. This detailed information is not available to OBSXTR. As a consequence the statistics provided by these two programs will slightly differ.

5.4 Daily Goals

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

1. used GPSEST for residual screening, created files: *EDT_20190440.OUT*, *EDT_20190440.RES* in your campaign's OUT directory,
2. screened the residual files from the above run using RESRMS: created files *RMS_20190440.SUM*, *RMS_20190440.LST*, *RMS_20190440.EDT*, and *RMS_20190440.OUT*,
3. used SATMRK to mark the identified outliers,
4. used GPSEST for a first coordinate and troposphere estimation, created files: *FLT_20190440.CRD* and *FLT_20190440.TRP*,
5. used GPSEST for QIF ambiguity resolution, created files: *BRTL2019044Q.OUT*,
6. used GPSEST for direct SIGMA ambiguity resolution, created files: *WTWZ20190441.OUT*,
7. apply the ambiguity resolution to all baselines running a BPE,
8. used GPSXTR to create a summary of the ambiguity resolution, created file: *QIF_20190440.SUM* and *L12_20190440.SUM*.

6 Terminal Session: Thursday

Finish the work of yesterday by resolving the ambiguities for all baselines (day 044 year 2019) if not yet done so far.

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 (COMPAR2),*
 - 4. recompute the final solution and generate reduced size normal equation files (ADDNEQ2),*
 - 5. compute velocities (ADDNEQ2),*
- for the current session. Compare the final coordinate results of the daily solutions (which are already processed and available).*

6.1 Final Network Solution

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

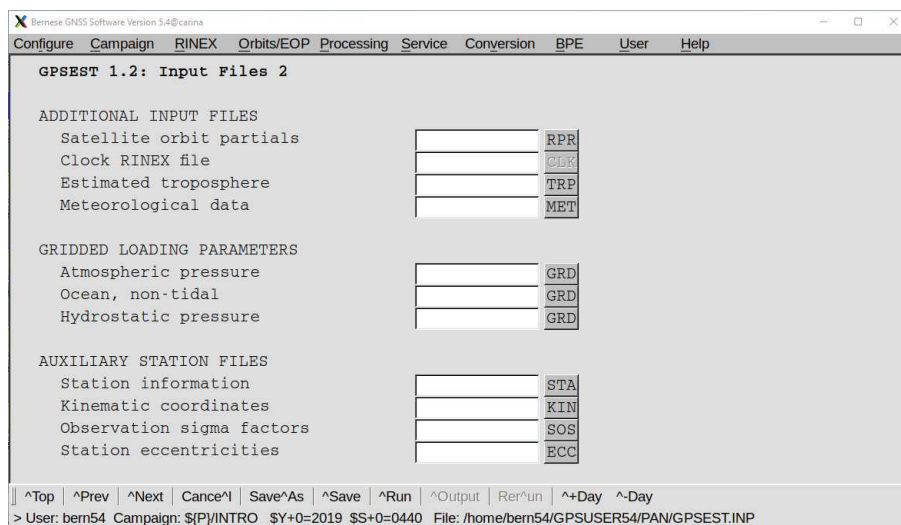
The screenshot shows the 'PARAMETER ESTIMATION - GPSEST 1.1: Input Files 1' window. It has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into four sections:

- GENERAL FILES AND PROCESSING MODE:** Space geodetic technique (GNSS), Differencing level (DOUBLE), LEO data processing (unchecked), Show all general files (checked).
- OBSERVATION FILES:** Phase observations (????\$\$S+0, PSH), Code observations (CSH), Range observations (RZH).
- MAIN INPUT FILES:** Station coordinates (APR_\$\$YYYYSS+0, CRD), Standard orbits (COD_\$\$YYYYSS+0, STD), Earth rotation parameters (COD_\$\$YYYYSS+0, ERP), Satellite clock corrections (CLK, CLK), Observable-specific biases (OSB, NL phase biases from CLK), VMF grid file (VMF3_\$\$YYYYSS+0, GRD), Ionosphere models (HOI_\$\$YYYYSS+0, ION).
- CORRECTIONS FOR LOADING EFFECTS AND CENTER OF MASS:** Ocean tidal loading (EXAMPLE, BLQ), Atmospheric tidal loading (ATL), related error handling (ERROR).

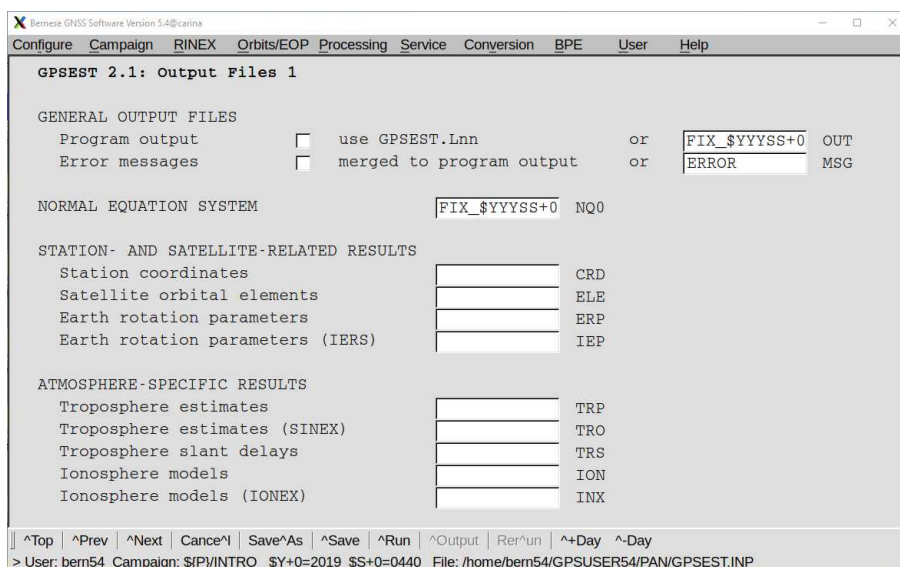
The status bar at the bottom shows: ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day > User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$\$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

If the grid files for the coefficients of the VMF are available (downloaded from https://vmf.geo.tuwien.ac.at/trop_products/GRID/1x1/VMF3/VMF3_OP/ and the five grid files of the day are concatenated), we can introduce VMF3_\$\$YYYYSS+0 into panel "GPSEST 1.1: Input Files 1".

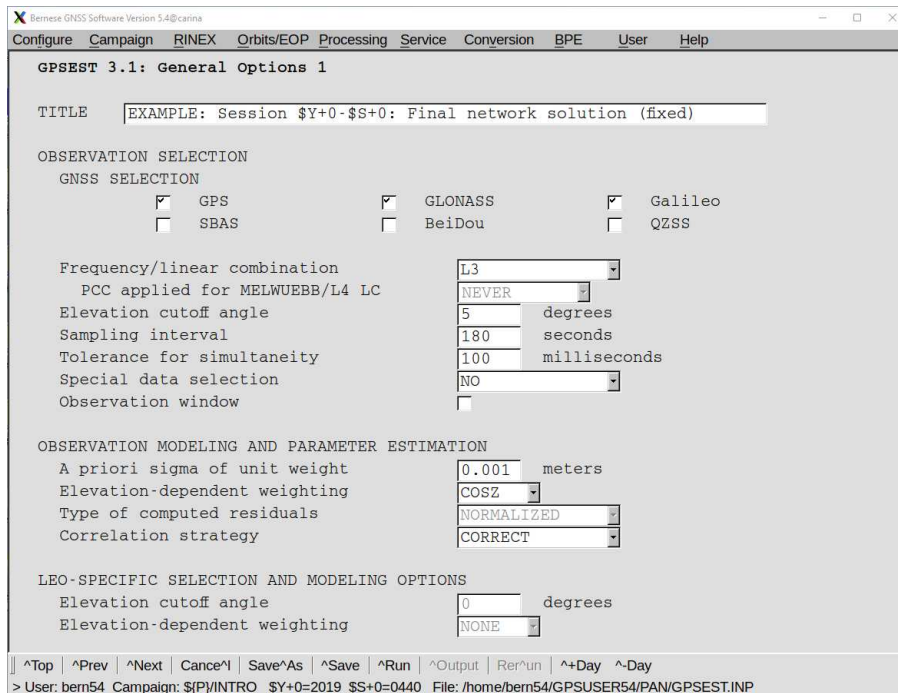
We do not introduce “Estimated troposphere” anymore from the previous solutions.



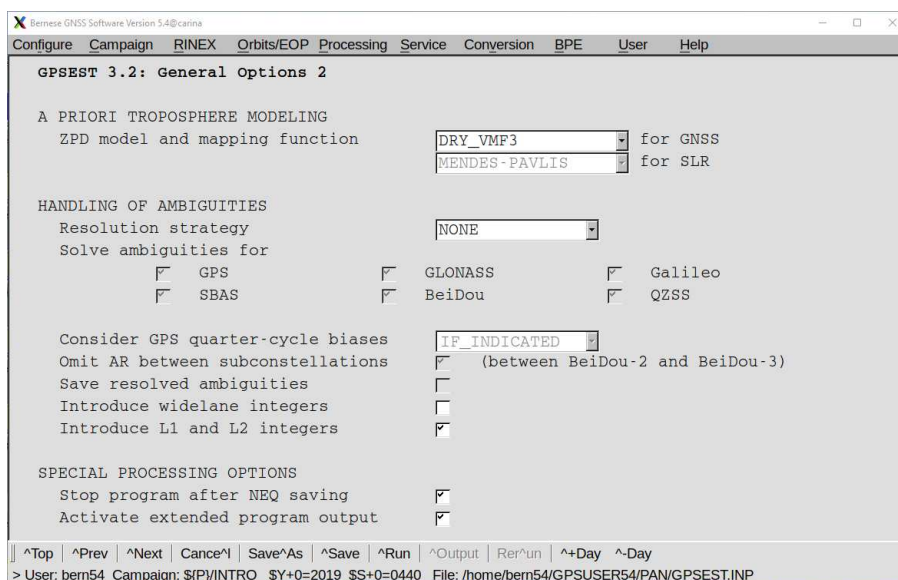
In panel “GPSEST 2.1: Output Files 1” we request the normal equation file as the only output file.



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

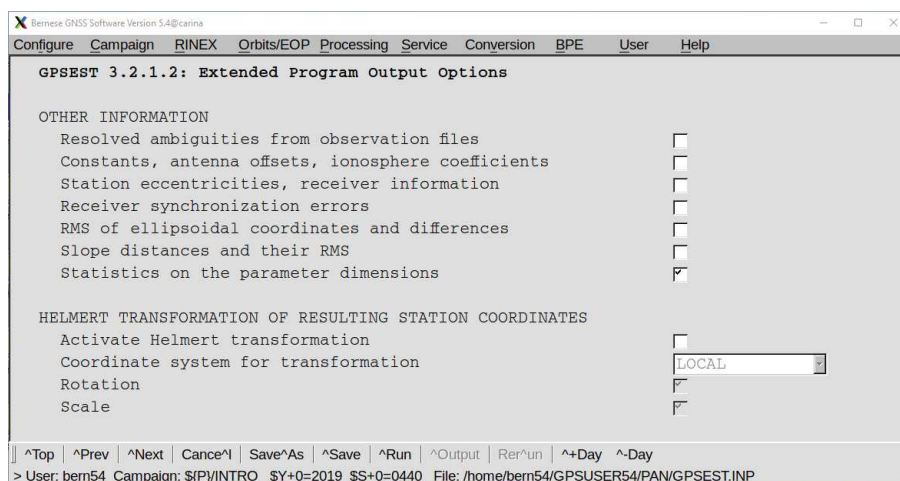
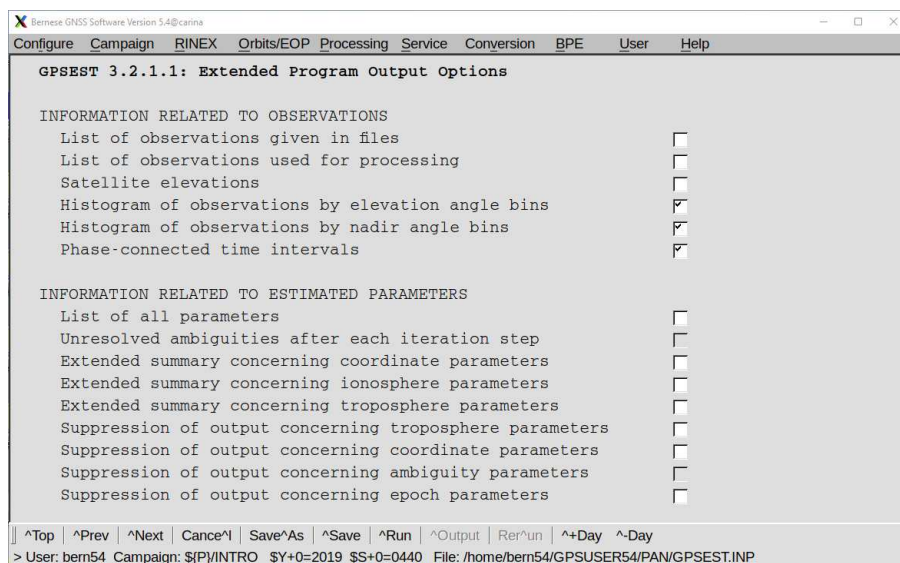


If the VMF grid files are available we can switch now from DRY_GPT3 to DRY_VMF3 to use the VMF instead of the Global Mapping Function (GMF). In the *Bernese Introductory Course* environment these files are available. Remember that you need to specify the grid files with the coefficients in the input field “VMF grid file” in panel “GPSEST 1.1: Input Files 1”. Ambiguities which have been resolved in the previous runs of program GPSEST are introduced as known.

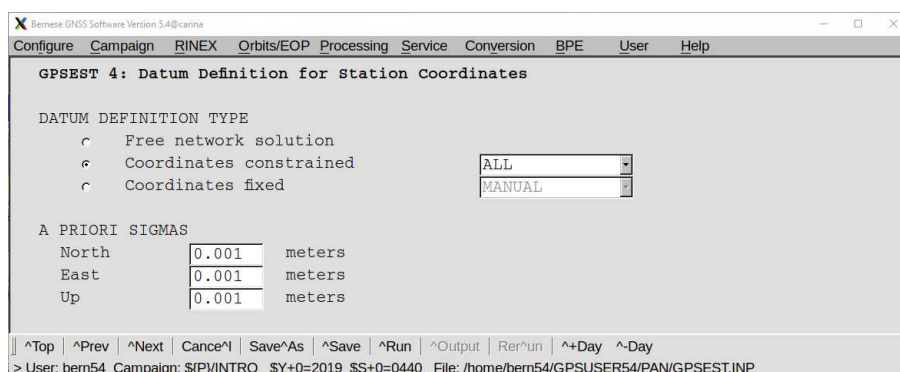


The checkbox in option “Stop program after NEQ saving” reduces the task of GPSEST to setting up the NEQ but not solving it. In particular in case of bigger networks this may save a lot of computing time because the solution for the session will be computed later on by ADDNEQ2 anyhow.

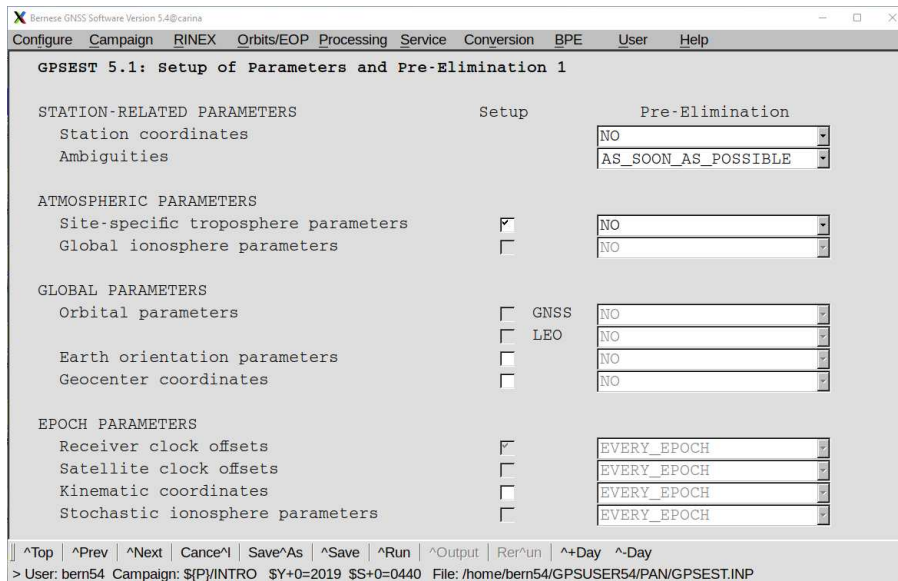
Since this is the final run of GPSEST, it is worthwhile to add some additional information about the observation files into the program output. This is useful if you archive the program output of this run together with the observation files and the resulting normal equation files.



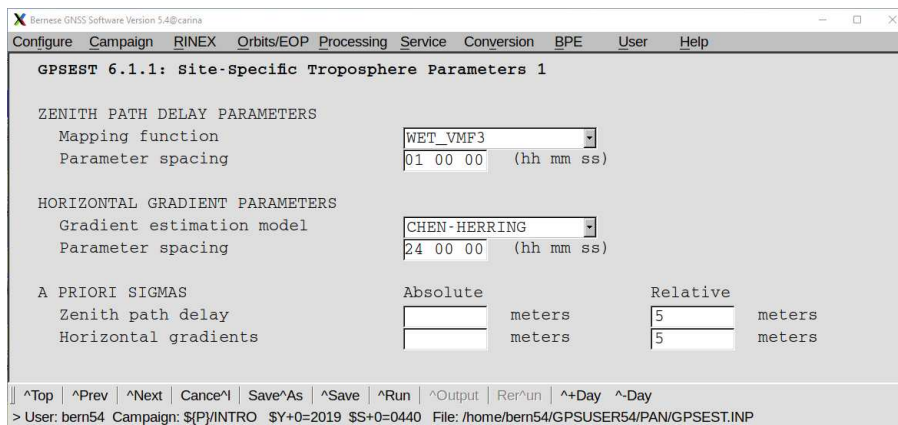
We do not fix any stations on their a priori position, i.e., the coordinates of all stations will be estimated. This retains the flexibility for later changes in the realization of the reference frame (station constraints) with program ADDNEQ2. Because no solution in GPSEST is computed you can select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



The remaining unresolved ambiguities are pre-eliminated. In addition we may set up additional parameters of interest.



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



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

```

SUMMARY OF RESULTS
-----
Number of parameters:
-----

Parameter type                Adjusted   Expl.    Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities    51        51         0              0  0  0  0
Ambiguities                        1105       0       1105 (bfst)    0  0  40  0
Site-specific troposphere parameters  493       493         0              0  0  0  0
-----
Total number                      1609      544      1065           0  0  40  0

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

```

```

Statistics:
-----
Total number of authentic observations      133235
Total number of pseudo-observations         0
Total number of observations                133235

Total number of explicit parameters         544
Total number of implicit parameters        1065
Total number of parameters                 1609

Total number of observation files           16
Total number of stations                   17
Total number of satellites                  0

-----
>>> CPU/Real time for pgm "GPSEST": 0:01:53.835 / 0:01:53.986
>>> Program finished successfully

```

After running GPSEST in session mode the normal equation file `FIX_20190440.NQ0` should be available in the directory `#{P}/INTRO/SOL`.

In the environment of the *Bernese Introductory Course* these files are provided in the archive `#{S}/RNX2SNX/2019/SOL/`, `#{S}/RNX2SNX/2020/SOL/`, and `#{S}/RNX2SNX/2021/SOL/` respectively. Copy the files of the additional five days into your campaign. Following files should be now available in the directory `#{P}/INTRO/SOL`

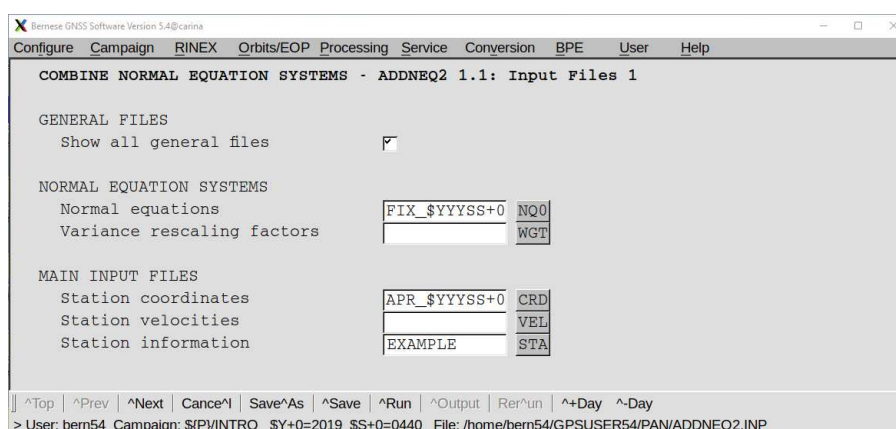
```

FIX_20190440.NQ0,  FIX_20190450.NQ0,
FIX_20201790.NQ0,  FIX_20201800.NQ0,  and
FIX_20210950.NQ0,  FIX_20210960.NQ0.

```

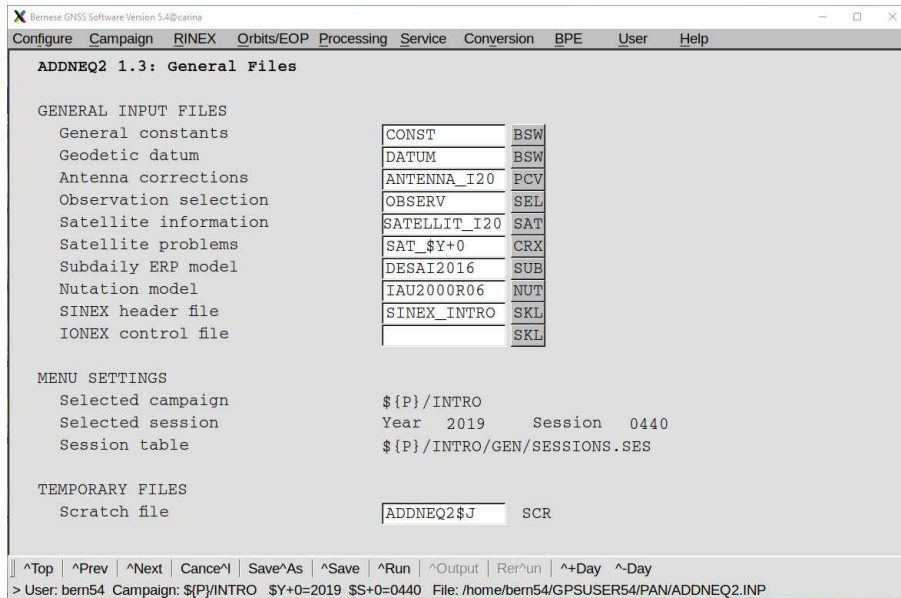
6.2 Check the Coordinates of the Fiducial Sites

To check the consistency of our network solution with respect to the coordinates available in the IGS 20 reference frame we generate a minimum constraint solution for the network using program `ADDNEQ2` ("Menu>Processing>Combine normal equation systems") with the following options:

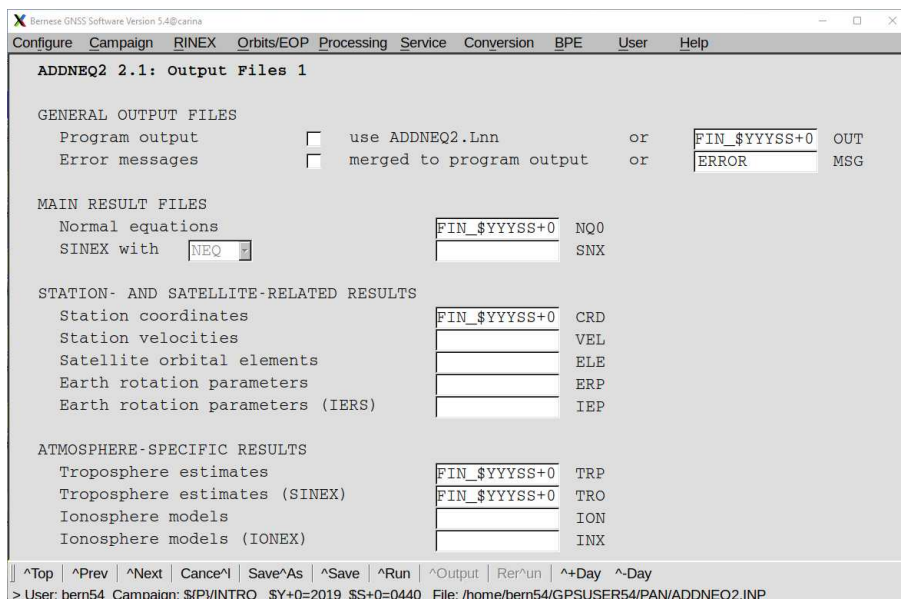


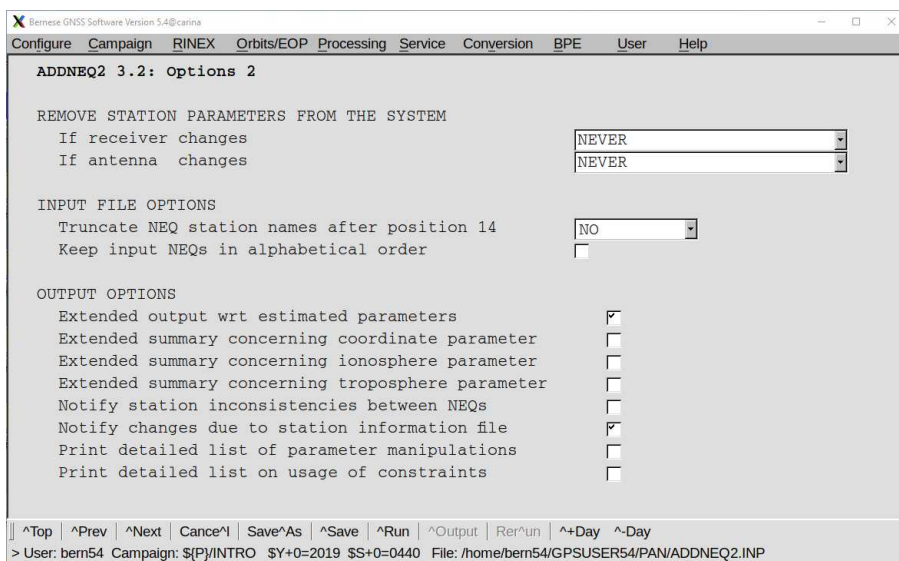
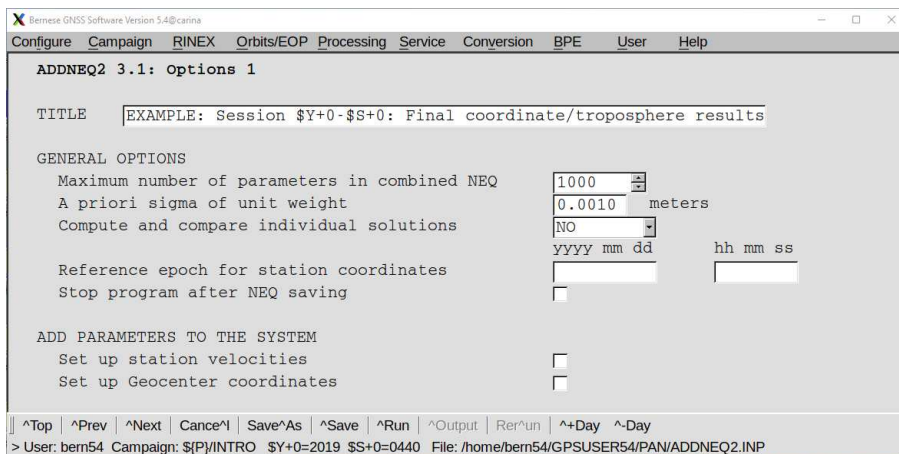
No further input files in the next panel are needed.

If we intend to store a troposphere Solution INdependent EXchange format (SINEX) file to make the troposphere estimates also available in the international format, we need to add the “SINEX header file”. Please adjust the content (in particular the institution and authorship) of this file before using it for your applications.



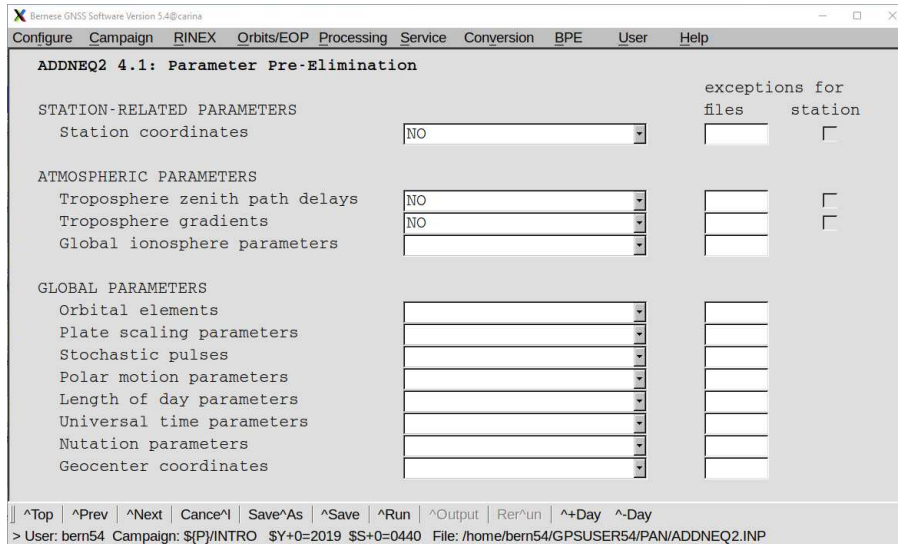
The troposphere estimates are now written in the Bernese internal (option “Troposphere estimates”) and the international format (option “Troposphere estimates (SINEX)”). If there is no need to store both, you may also limit yourself to one of them or even to not store the troposphere results at all.



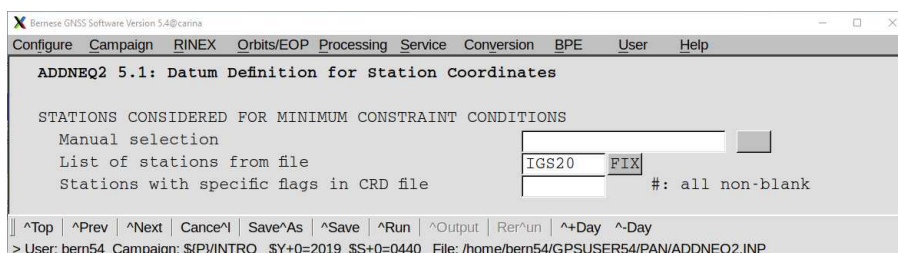
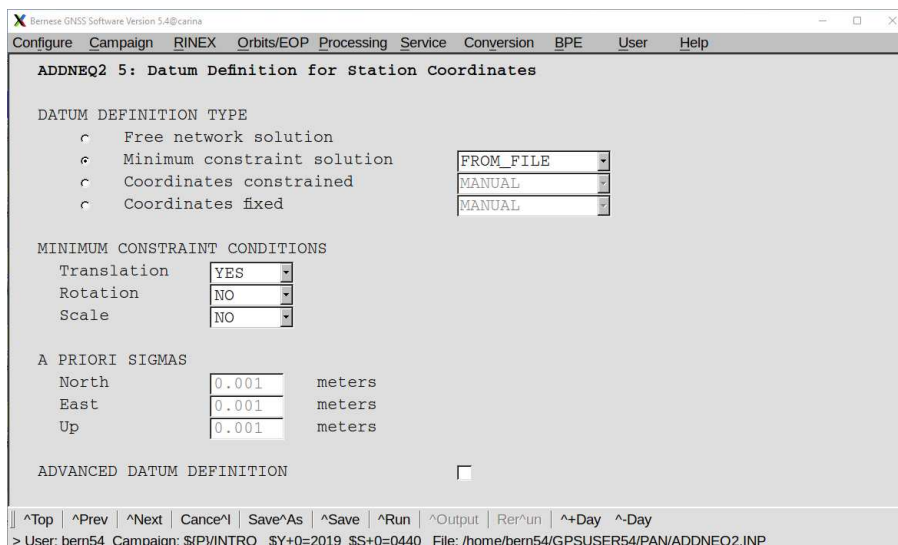


In the following three panels, all parameter types supported by ADDNEQ2 are listed. You may specify whether a parameter shall be pre-eliminated or not. An empty entry means that the parameter is not expected in the input NEQ files.

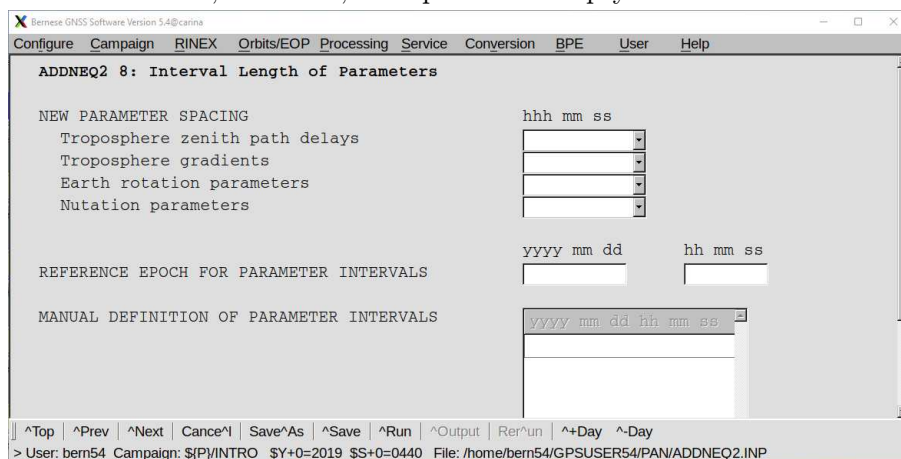
Please note that an automated preselection is not possible for technical reasons. If a parameter with an empty input field is detected in the input NEQ files, the program will stop with an error. In the opposite case, a warning message is issued.



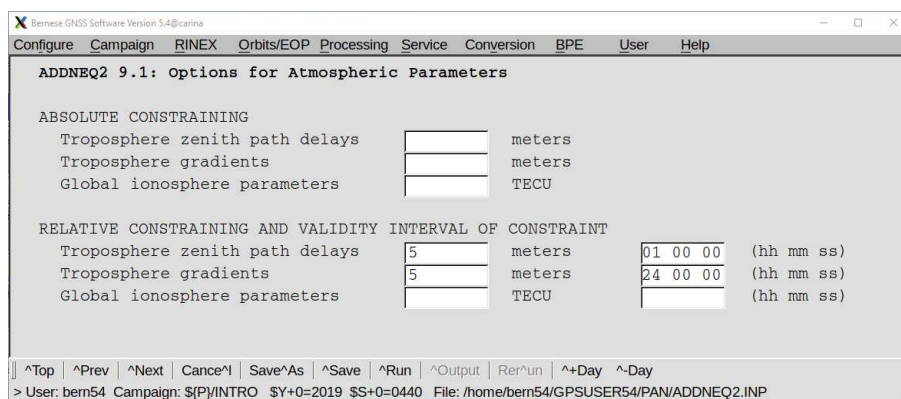
For the validation of the datum stations we choose the “Minimum constraint solution”. Because it is a regional network, we only apply the no-translation condition. The other conditions are sufficiently defined by the satellite orbits.



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

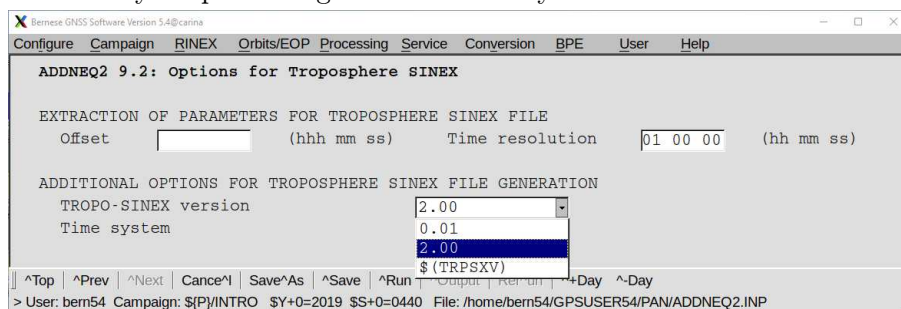


The relative constraints applied to the vertical troposphere and gradient parameters are so loose that they do not affect the solution. As in GPSEST, they simply prevent a format overflow in the output troposphere file in case of very weakly observed parameters due to gaps in the observation scenario.



If you have selected troposphere output in SINEX format you may select the spacing of the sampling of the reported records. Please note that this has no impact on the parametrization of the troposphere parameters.

Furthermore you can decide whether the traditional (0.01) or the latest (2.0) version of the troposphere SINEX format shall be written. In the latter case the nine character station IDs are taken from the related column in PART II of the "Station information" file you have selected in panel "ADDNEQ2 1.1: Input Files 1". Please make sure that you provide for each station in your processing the related entry.



For option "Time system for TROPO-SINEX" we select GPS because the processing takes place in the GPS time system.

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 with the same layout you know already from GPSEST:

```

...
SUMMARY OF RESULTS
-----
Number of parameters:
-----
-----
Parameter type                Adjusted   Expl.    Impl. (elim)*  Del. Ref. Sing. No obs
-----
Station coordinates / velocities      51       51       0              0  0  0  0
Site-specific troposphere parameters  493      493       0              0  0  0  0
-----
Previously pre-eliminated parameters    1065      1065
-----
Total number                       1609      544      1065           0  0  0  0
-----
*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----
Total number of authentic observations      133235
Total number of pseudo-observations         445

Total number of explicit parameters         544
Total number of implicit parameters        1065

Total number of observations                133680
Total number of adjusted parameters        1609
Degree of freedom (DOF)                   132071

A posteriori RMS of unit weight            0.001089 m
Chi**2/DOF                                1.19

Total number of observation files           16
Total number of stations                   17
...

```

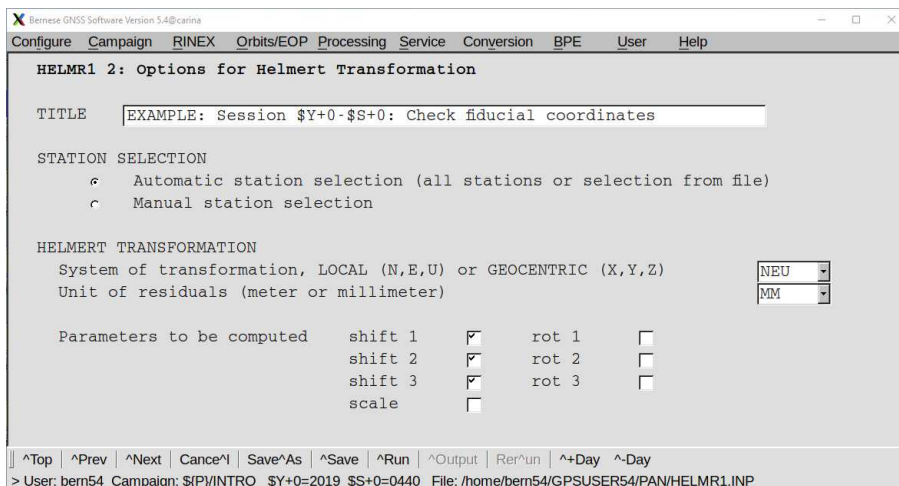
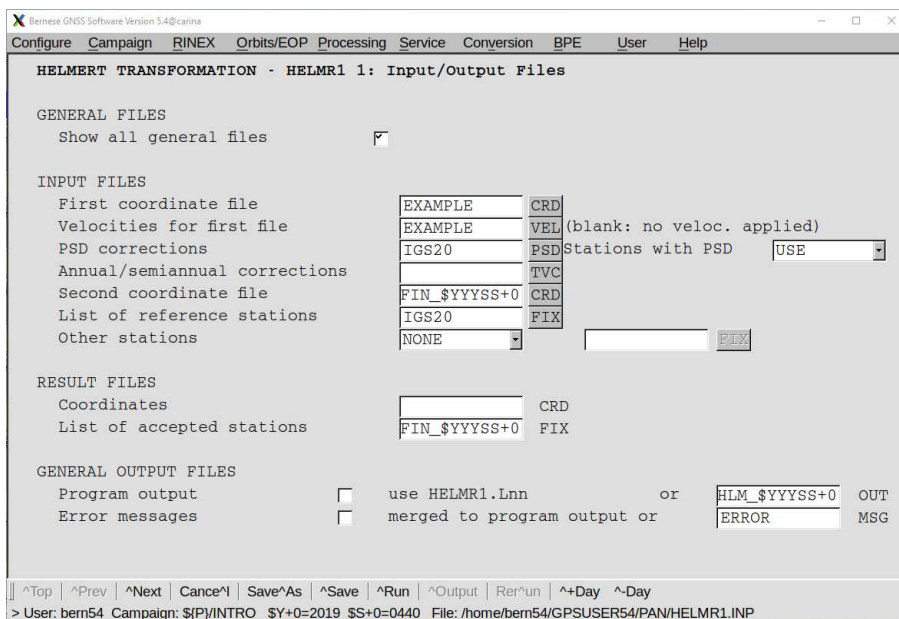
Below this part the program output reports the results of the parameter estimation in the same standardized format for all parameter types as in the program GPSEST:

```

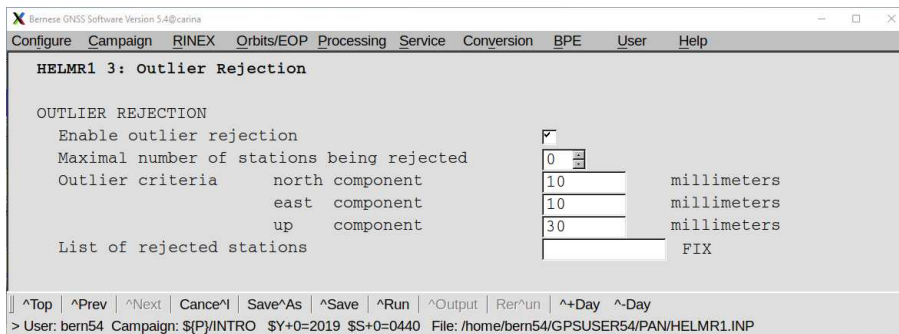
...
Station coordinates and velocities:
-----
Sol Station name              Typ Correction Estimated value RMS error A priori value ... Abb
-----
1 BRST 10004M004             X  0.00152   4231162.41917   0.00047   4231162.41765 ... #CRD
1 BRST 10004M004             Y  0.00316   -332746.42575   0.00015   -332746.42891 ... #CRD
1 BRST 10004M004             Z  0.00309   4745131.07277   0.00047   4745131.06968 ... #CRD
1 GANP 11515M001             X -0.00773   3929181.29827   0.00041   3929181.30600 ... #CRD
1 GANP 11515M001             Y  0.00706   1455236.95252   0.00019   1455236.94546 ... #CRD
1 GANP 11515M001             Z  0.04306   4793654.03600   0.00045   4793653.99294 ... #CRD
1 HERT 13212M010             X -0.01012   4033460.74185   0.00058   4033460.75197 ... #CRD
...
Site-specific troposphere parameters:
-----
Station name                  Typ      Correction Estimated value RMS error A priori value ... Abb
-----
BRST 10004M004               N        0.00009      0.00009   0.00005      0.00000 ... #TRP
BRST 10004M004               E       -0.00001     -0.00001   0.00008      0.00000 ... #TRP
BRST 10004M004               U        0.07659      2.42832   0.00093      2.35173 ... #TRP
BRST 10004M004               U        0.07028      2.42138   0.00067      2.35111 ... #TRP
BRST 10004M004               U        0.06836      2.41885   0.00074      2.35049 ... #TRP
BRST 10004M004               U        0.07018      2.42005   0.00075      2.34987 ... #TRP
...

```

The coordinate solution for the session ($\{\$P\}/INTRO/STA/FIN_20190440.CRD$) may be compared with the a priori coordinates of the IGS core sites. The program HELMR1 ("Menu>Service>Coordinate tools>Helmert transformation") is used for this purpose:



The last panel allows even for an automated quality control and manages a potential update of the list of stations used for the datum definition (option "List of accepted stations" in panel "HELMR1 1: Input/Output Files"):



For our example we get the following output.

```

=====
Bernese GNSS Software, Version 5.4
-----
Program       : HELMR1
Purpose       : Helmert Transformation
-----
Campaign      : ${P}/INTR0
Default session: 0440 year 2019
Date         : 25-Aug-2024 12:17:15
User name    : bern54
=====

EXAMPLE: Session 2019-0440: Check fiducial coordinates
-----

FILE 1: EXAMPLE.CRD: IGS20: coordinate list
FILE 2: FIN_20190440.CRD: EXAMPLE: Session 2019-0440: Final coordinate/troposph

LOCAL GEODETIC DATUM: IGS20
RESIDUALS IN LOCAL SYSTEM (NORTH, EAST, UP)

LIST OF REMOVED STATIONS:
OUTLIER CRITERIA:                10.00    10.00    30.00

-----
| NUM | NAME | FLG | RESIDUALS IN MILLIMETERS | |
-----
| 1 | BRST 10004M004 | I W | -0.51 -2.80 -3.71 | |
| 6 | MATE 12734M008 | I W | -0.35 1.26 0.67 | |
| 7 | MIKL 12335M001 | I W | 1.55 3.48 -0.79 | |
| 8 | ONSA 10402M004 | I W | 1.81 0.43 -9.50 | |
| 9 | ORID 15601M001 | I W | -4.87 1.87 -8.85 | |
| 11 | TLSE 10003M009 | I W | -0.29 -1.44 2.06 | |
| 13 | WSRT 13506M005 | I W | 3.56 -1.23 7.58 | |
| 14 | WTZR 14201M010 | I W | -0.12 0.15 3.26 | |
| 16 | ZIM2 14001M008 | I W | -0.57 -1.20 4.64 | |
| 17 | ZIMM 14001M004 | I W | -0.21 -0.50 4.63 | |
-----
| | RMS / COMPONENT | | 2.18 1.84 5.76 | |
| | IQR | | 2.06 2.49 8.34 | |
| | MEAN | | 0.00 0.00 0.00 | |
| | MEDIAN | | -0.25 -0.18 1.37 | |
| | MIN | | -4.87 -2.80 -9.50 | |
| | MAX | | 3.56 3.48 7.58 | |
-----
OVERALL RMS/IQR/MAX(3D) 3.71 3.07 10.27 ORID ...

| ALL | RMS / COMPONENT | | 2.18 1.84 5.76 | |
| ALL | IQR | | 2.06 2.49 8.34 | |
| ALL | MEAN | | 0.00 0.00 0.00 | |
| ALL | MEDIAN | | -0.25 -0.18 1.37 | |
| ALL | MIN | | -4.87 -2.80 -9.50 | |
| ALL | MAX | | 3.56 3.48 7.58 | |
-----
ALL OVERALL RMS/IQR/MAX(3D) 3.71 3.07 10.27 ORID ...

NUMBER OF PARAMETERS : 3
NUMBER OF STATIONS : 10
NUMBER OF COORDINATES : 30
RMS OF TRANSFORMATION : 3.71 MM

BARYCENTER COORDINATES:
LATITUDE : 47 48 37.88
LONGITUDE : 11 25 53.36
HEIGHT : -64.817 KM

PARAMETERS:

TRANSLATION IN N : 0.02 +- 1.17 MM
TRANSLATION IN E : 0.03 +- 1.17 MM
TRANSLATION IN U : -0.00 +- 1.17 MM

NUMBER OF ITERATIONS : 1

ACCEPTED STATIONS : 10
REJECTED STATIONS : 0
VERIFIED STATIONS : 0

-----
>>> CPU/Real time for pgm "HELMR1": 0:00:00.131 / 0:00:00.131
>>> Program finished successfully

```

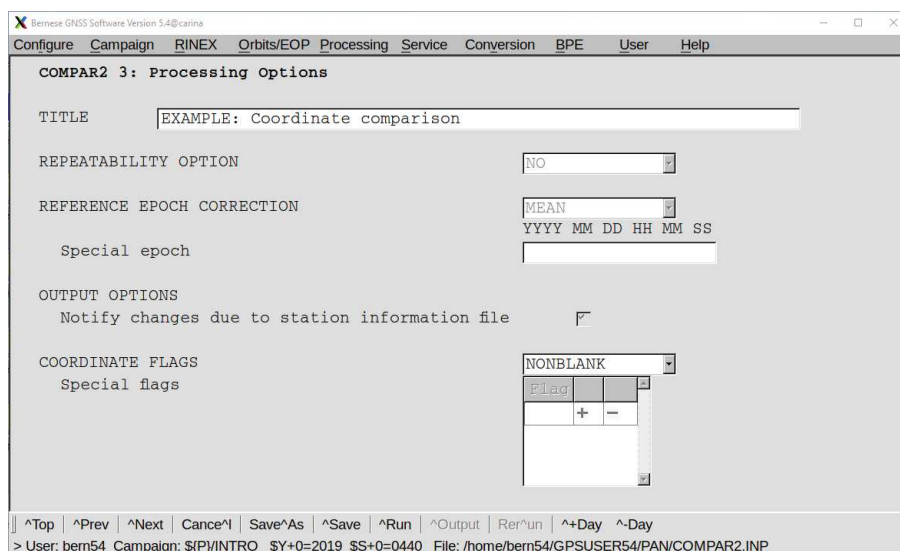
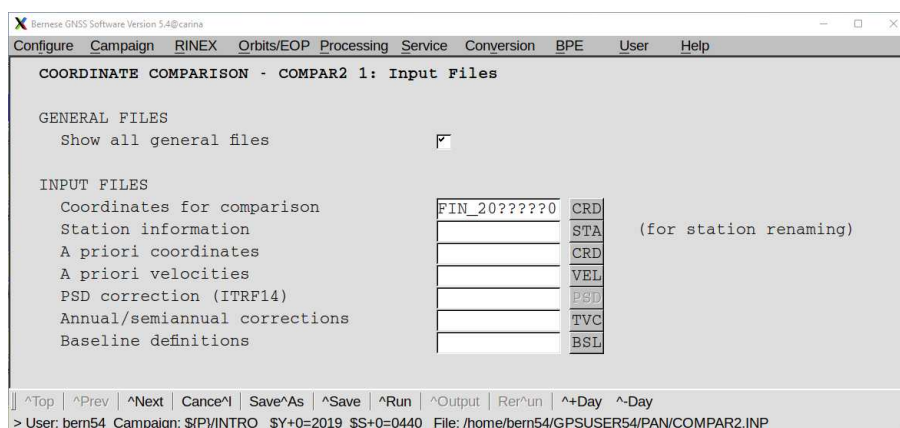
We can conclude that no problems concerning the stations used for the datum definition were detected.

If there were problems, the ADDNEQ2 run needs to be repeated with the problematic station either removed from the file `#{P}/INTRO/STA/IGS20.FIX` (e.g., by using the result file `#{P}/INTRO/STA/FIN_20190440.FIX`) or with manual selection of the stations used for the datum definition in panel “ADDNEQ2 5.1: Datum Definition for Station Coordinates”.

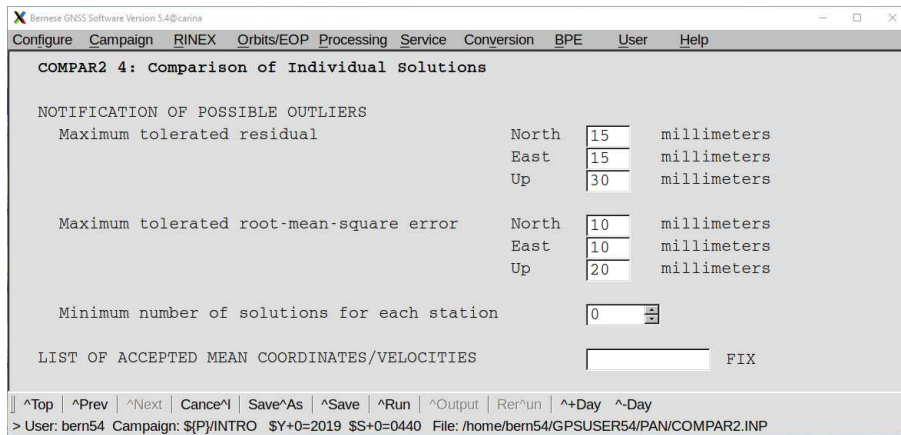
In order to check the repeatability of the coordinate solutions for all six days (or make at least sure to have four days available), repeat the above steps for the remaining days.

6.3 Check the Daily Repeatability

If the minimum constraint solutions of the six sessions are available, the repeatability of the coordinate solutions may be checked using the program COMPAR2 (“Menu>Service >Coordinate tools>Coordinate comparison”).



In the last panel you can define thresholds for detecting stations with exceptionally poor coordinate repeatability.



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

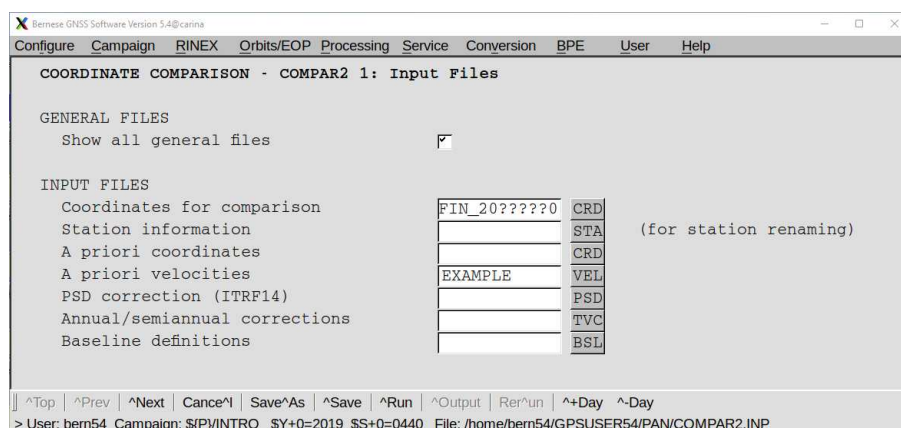
Comparison of individual solutions:									

BRST	10004M004	N	15.82	-18.89	-18.90	3.09	2.39	16.49	15.82
BRST	10004M004	E	14.91	-16.99	-17.54	1.23	1.30	15.85	16.15
BRST	10004M004	U	2.96	4.28	3.07	-0.83	-2.16	-2.96	-1.39
GANP	11515M001	N	12.89	-15.43	-15.25	3.04	1.20	13.32	13.13
GANP	11515M001	E	20.64	-25.62	-25.12	7.31	4.14	19.25	20.03
GANP	11515M001	U	2.42	-0.85	-2.46	-0.94	-1.65	3.80	2.11
HERT	13212M010	N	16.23	-19.80	-19.60	4.40	2.98	15.95	16.07
HERT	13212M010	E	15.93	-17.77	-18.15	-0.08	0.68	17.87	17.45
HERT	13212M010	U	3.03	1.09	-0.74	3.16	3.23	-2.57	-4.16
JOZ2	12204M002	N	13.92	-17.39	-16.58	4.37	2.55	13.55	13.49
JOZ2	12204M002	E	23.96	-29.98	-29.50	9.68	5.63	21.84	22.33
JOZ2	12204M002	U	1.61	-0.89	1.03	2.12	0.43	-0.18	-2.52
LAMA	12209M001	N	14.72	-18.18	-18.12	4.97	3.47	13.78	14.08
LAMA	12209M001	E	20.49	-24.67	-25.36	5.26	4.86	19.77	20.15
LAMA	12209M001	U	3.20	-4.52	-0.67	-1.70	0.72	5.08	1.08
MATE	12734M008	N	18.44	-22.42	-21.77	2.79	4.00	18.66	18.74
MATE	12734M008	E	23.06	-28.00	-27.44	4.78	4.14	23.37	23.16
MATE	12734M008	U	2.94	-2.20	3.30	1.31	-4.75	0.66	1.67
MIKL	12335M001	N	11.88	-14.43	-13.46	1.21	1.69	12.49	12.49
MIKL	12335M001	E	24.78	-30.38	-30.54	7.09	6.45	23.52	23.86
MIKL	12335M001	U	3.27	-3.64	-2.51	-1.61	5.22	1.95	0.59
ONSA	10402M004	N	15.83	-19.33	-19.47	4.89	3.40	15.27	15.24
ONSA	10402M004	E	16.26	-20.05	-19.07	3.30	3.11	15.88	16.83
ONSA	10402M004	U	3.05	-0.79	-3.41	-3.14	0.71	4.30	2.33
ORID	15601M001	N	8.56	-9.69	-9.64	-0.37	0.78	9.19	9.72
ORID	15601M001	E	25.27	-29.92	-31.42	5.09	6.42	24.31	25.52
ORID	15601M001	U	4.17	7.11	2.96	-2.93	-2.79	-3.11	-1.24
PTBB	14234M001	N	18.04	-22.13	-22.32	4.71	5.44	17.11	17.19
PTBB	14234M001	E	18.19	-21.78	-21.37	3.31	2.25	18.81	18.78
PTBB	14234M001	U	2.36	-0.87	-2.09	-2.53	2.74	2.97	-0.22
TLSE	10003M009	N	15.79	-18.79	-19.49	3.60	3.42	15.89	15.37
TLSE	10003M009	E	17.86	-21.38	-21.08	2.91	2.76	18.63	18.16
TLSE	10003M009	U	1.18	-0.16	-0.80	-0.74	-0.36	-0.31	2.37
VILL	13406M001	N	15.17	-18.25	-18.29	2.48	3.66	14.85	15.57
VILL	13406M001	E	16.41	-19.13	-19.52	2.04	2.28	17.02	17.31
VILL	13406M001	U	5.13	7.23	4.71	-4.54	-4.93	0.88	-3.35
WSRT	13506M005	N	16.92	-21.04	-20.57	4.38	4.98	16.96	15.30
WSRT	13506M005	E	16.56	-20.11	-19.77	3.01	3.62	15.75	17.49
WSRT	13506M005	U	5.61	-5.74	-3.92	8.59	5.05	-2.90	-1.09

WTZR	14201M010	N	12.14	-10.37	-10.65	11.09	9.93		
WTZR	14201M010	E	15.86	-13.64	-13.83	14.29	13.18		
WTZR	14201M010	U	2.71	-2.73	-1.54	3.36	0.91		
WTZZ	14201M014	N	15.38	-18.60	-18.58	4.08	2.52	14.68	15.91
WTZZ	14201M014	E	19.81	-23.69	-23.77	4.39	2.84	19.87	20.36
WTZZ	14201M014	U	3.59	-4.47	-4.57	2.30	1.82	3.65	1.27
ZIM2	14001M008	N	15.20	-18.20	-18.03	2.60	2.49	14.68	16.46
ZIM2	14001M008	E	18.99	-23.00	-22.86	4.05	3.93	19.50	18.40
ZIM2	14001M008	U	1.88	-2.03	-2.07	-0.44	0.76	2.69	1.10
ZIMM	14001M004	N	15.74	-18.83	-19.01	3.20	2.94	15.27	16.44
ZIMM	14001M004	E	18.69	-23.03	-22.56	4.43	4.73	18.97	17.47
ZIMM	14001M004	U	2.37	-1.35	-2.59	-0.66	-0.12	4.36	0.37

In the section Notification of detected outliers all stations from the first (in 2019) and last (in 2021) pair of solutions get listed. While interpreting this output, keep in mind that the the six columns refer to different epochs. The difference between these epochs is about one year. Obviously, station velocities need to be estimated (this will be done in the next step described in Section 6.5).

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



You may check the influence on the repeatability on your own. Please be reminded, that for the ITRF 2020 (IGS 20) reference frame the linear station velocities are not sufficient. You may see the effect of the PSD corrections in the repeatability. This is not the case for this example because none of the stations is affected by an earthquake and, therefore, no PSD corrections have to be considered.

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

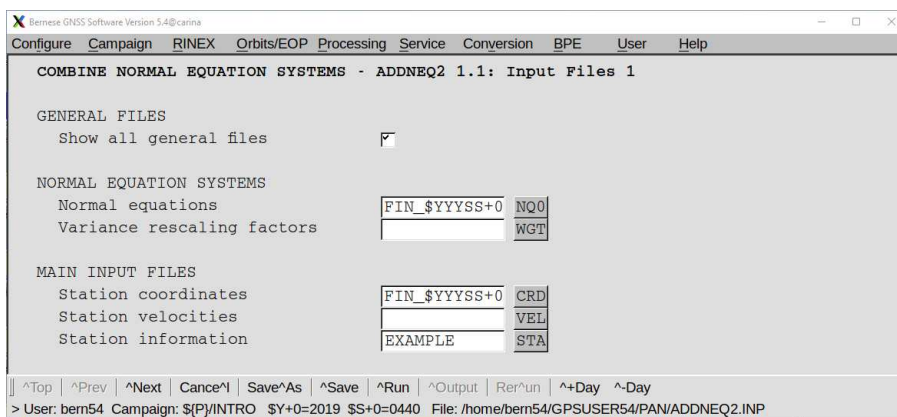
6.4 Compute the Reduced Solution of the Sessions

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

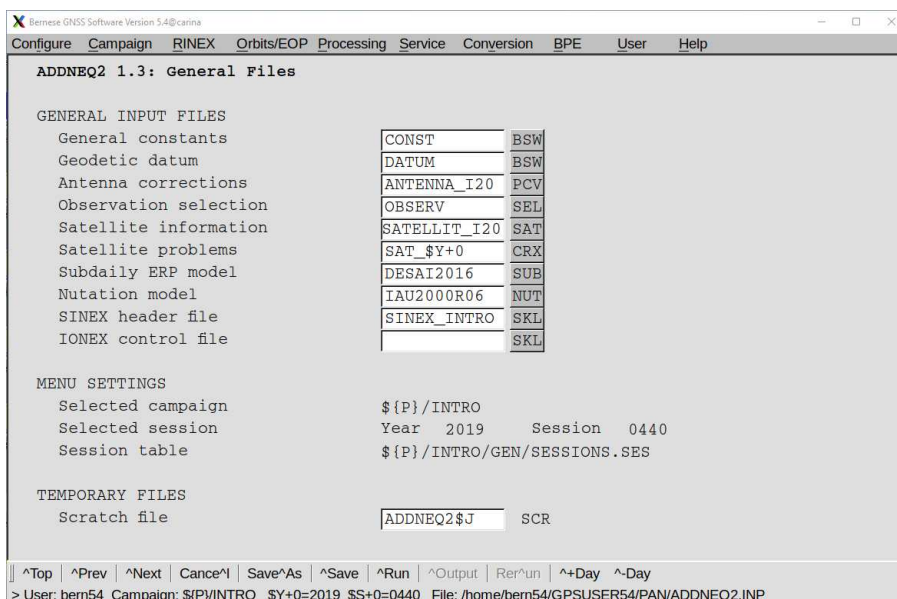
$\{\text{P}\}/\text{INTRO}/\text{SOL}/\text{FIN}_{\$YYYSS+0}.\text{NQ0}$,
 $\{\text{P}\}/\text{INTRO}/\text{STA}/\text{FIN}_{\$YYYSS+0}.\text{CRD}$,
 $\{\text{P}\}/\text{INTRO}/\text{ATM}/\text{FIN}_{\$YYYSS+0}.\text{TRP}$, and potentially
 $\{\text{P}\}/\text{INTRO}/\text{ATM}/\text{FIN}_{\$YYYSS+0}.\text{TRO}$.

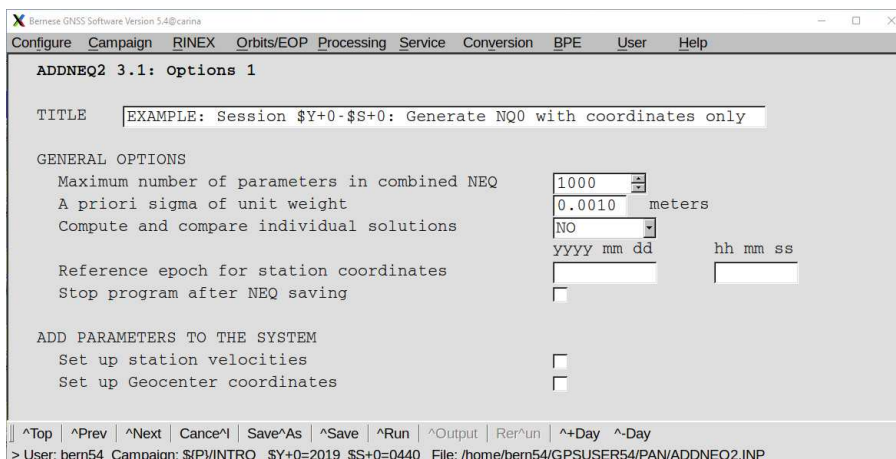
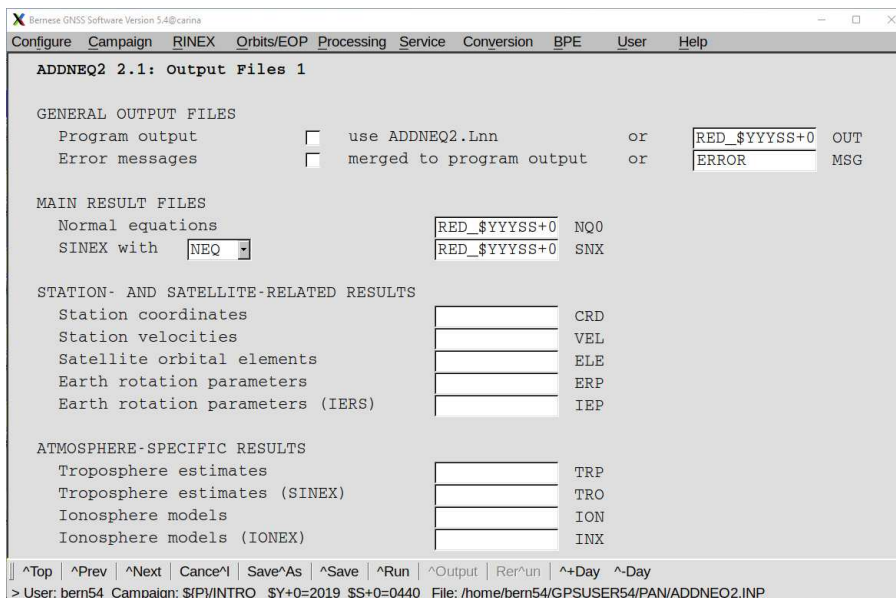
It is preferable for the velocity estimation to have smaller normal equation files containing only the coordinate parameters for each session. In addition, we generate a coordinate SINEX file (in NEQ representation) as the final solution of the day, so the troposphere parameters have to be pre-eliminated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

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

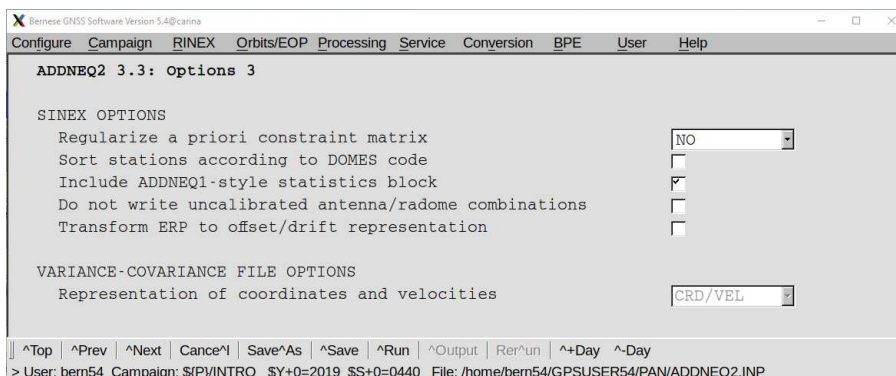


Please note that the output SINEX file includes again the skeleton from $\{\text{P}\}/\text{INTRO}/\text{GEN}/\text{SINEX_INTRO}$ (Copied from $\{\text{D}\}/\text{REF54}$ directory into the campaign) – the same file we used as skeleton for the troposphere SINEX generation.

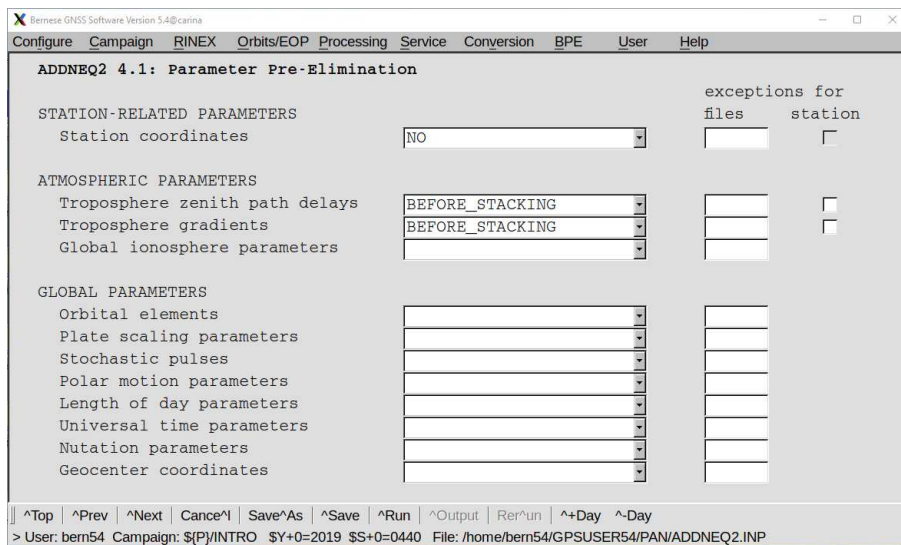




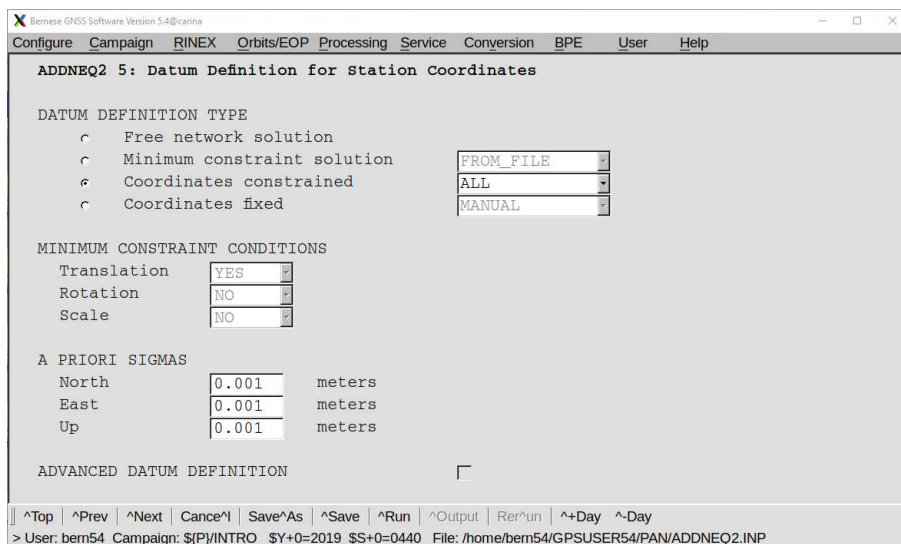
Because you are storing a SINEX file in NEQ representation (see option “Content of SINEX”) no regularization is necessary.



The troposphere parameters are pre-eliminated:



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



The normal equation file ($\{P\}/INTRO/SOL/RED_20190440.NQ0$) 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	Expl.	Impl. (elim)*	Del.	Ref.	Sing.	No obs
Station coordinates / velocities	51	51	0	0	0	0	0
Site-specific troposphere parameters	493	0	493 (bfst)	0	0	0	0
Previously pre-eliminated parameters	1065		1065				
Total number	1609	51	1558	0	0	0	0

```
Statistics:
-----
Total number of authentic observations      133235
Total number of pseudo-observations        493

Total number of explicit parameters         51
Total number of implicit parameters        1558

Total number of observations                133728
Total number of adjusted parameters        1609
Degree of freedom (DOF)                   132119

A posteriori RMS of unit weight            0.001089 m
Chi**2/DOF                                 1.19

Total number of observation files          16
Total number of stations                   17
...
```

You can also see that the number of explicit parameters in the NQ0 file was dramatically reduced (from 544 to 51). This is an advantage for the combination of a big number of normal equation files for the estimation of station velocities.

6.5 Velocity Estimation

6.5.1 Preparation for ITRF 2020/IGS 20 Velocity Estimation

This section can be skipped if no ITRF 2020/IGS 20 reference frame is used as geodetic datum.

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

EXTRAPOLATE COORDINATES - COOVEL 1: Filenames

GENERAL FILES
 Show all general files

INPUT FILES
 Input coordinate file CRD
 Input velocity file VEL
 PSD correction (since ITRF14) PSD
 Annual/semiannual corrections TVC

REFERENCE EPOCH
 yyyy mm dd hh mm ss

RESULT FILE
 Output coordinate file CRD
 Approx. velocities at ref. epoch VEL
 Stations without PSD corrections FIX

GENERAL OUTPUT FILES
 Program output use COOVEL.Lnn or OUT
 Error messages merged to program output or MSG

TITLE

> User: bern54 Campaign: \${P}/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/COOVEL.INP

In our example none of the stations that shall be used for the datum definition is related to the PSD corrections. So, you can continue here. If you have another station selection where the PSD corrections become relevant the distributed BPE $\{U\}$ /PCF/ITRF.PCF may be helpful. In the related README file you will find further instructions. It can be accessed via "Menu>Help>Readme" (Section Example BPE).

6.5.2 Velocity Estimation Based on NEQ Files

The velocity estimation in program ADDNEQ2 is easy. Introduce the normal equation files containing only the station coordinate parameters. Independent from your success in following the example so far, you may copy the prepared files for all days (044/045 year 2019, 179/180 year 2020, and 095/096 year 2021) from $\{S\}$ /RNX2SNX/2019/SOL/RED_2019*NQ0, $\{S\}$ /RNX2SNX/2020/SOL/RED_2020*NQ0, and $\{S\}$ /RNX2SNX/2021/SOL/RED_2021*NQ0 into the $\{P\}$ /INTRO/SOL/ directory. The normal equation files have to cover a reasonable time interval to reliably estimate velocities (in this case about two years):

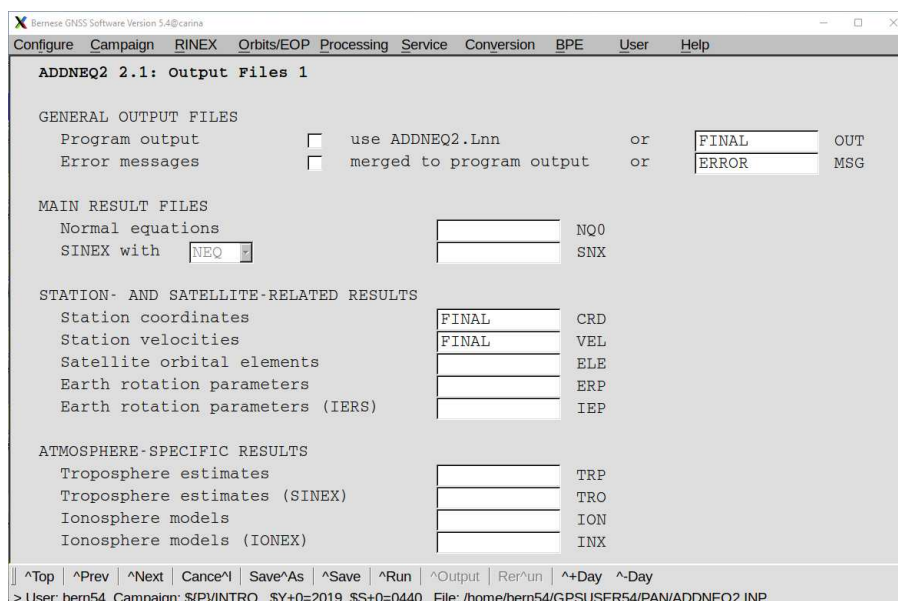
COMBINE NORMAL EQUATION SYSTEMS - ADDNEQ2 1.1: Input Files 1

GENERAL FILES
 Show all general files

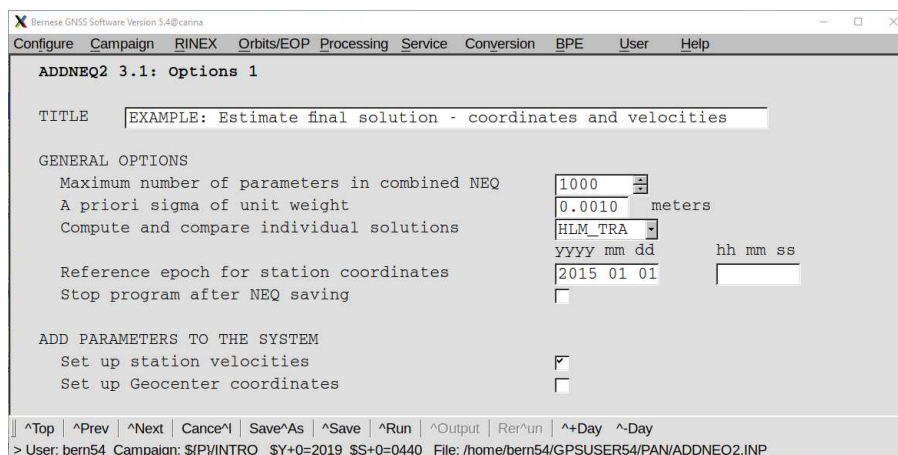
NORMAL EQUATION SYSTEMS
 Normal equations NQ0
 Variance rescaling factors WGT

MAIN INPUT FILES
 Station coordinates CRD
 Station velocities VEL
 Station information STA

> User: bern54 Campaign: \${P}/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/ADDNEQ2.INP

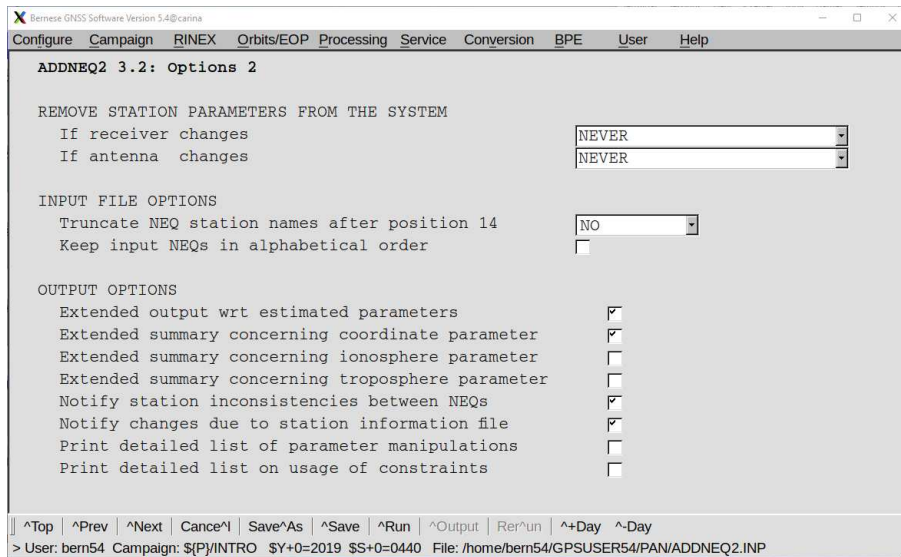


Station velocities are set up by marking the corresponding checkbox:

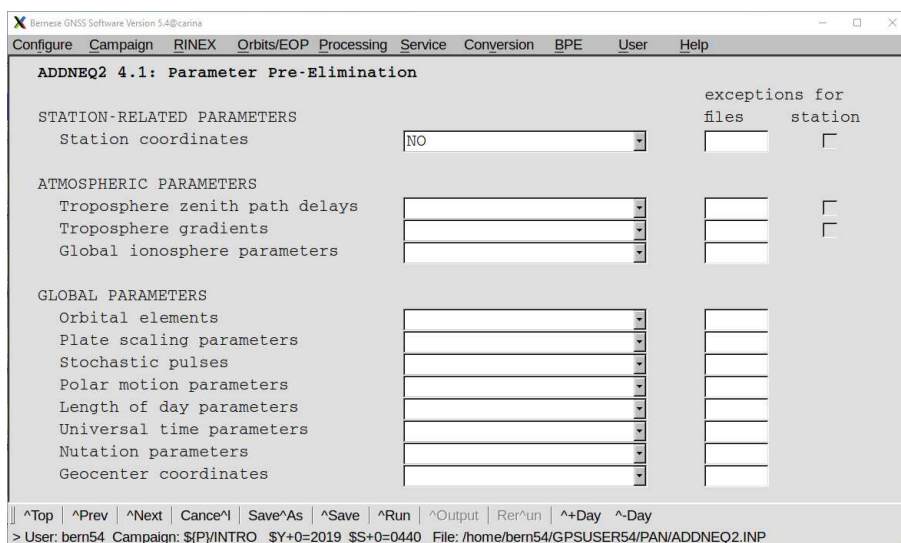


Furthermore, we check the repeatability of the daily solutions after the velocity estimation. The coordinates in the resulting file will refer to the epoch 2015 01 01.

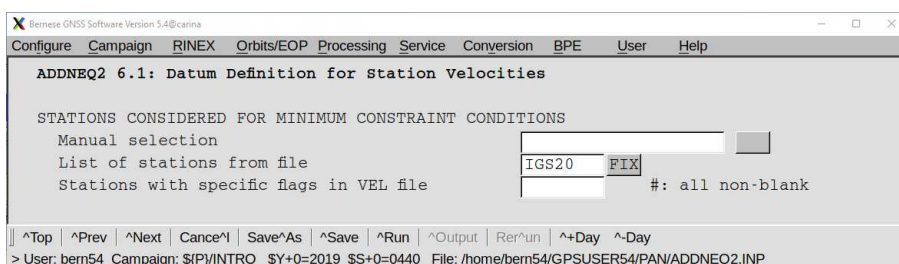
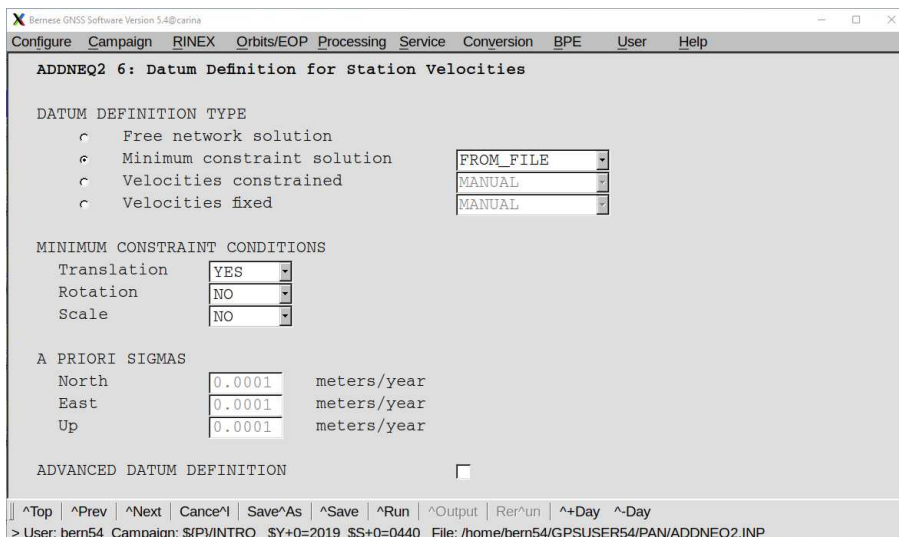
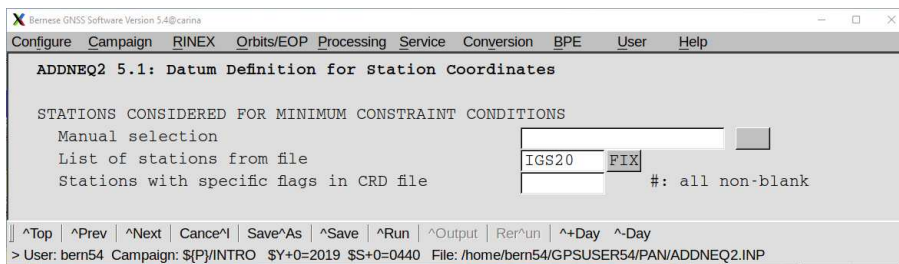
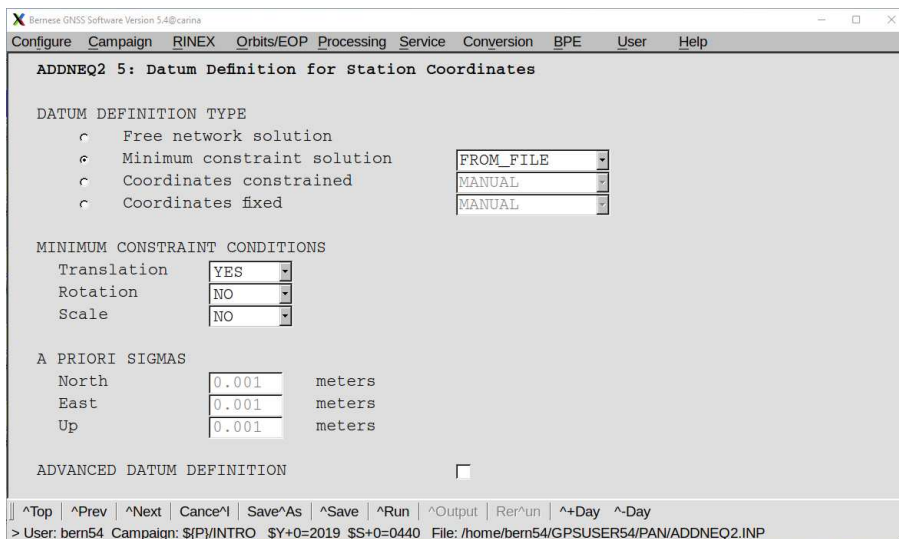
This panel is important for stations where an equipment change has taken place during the interval covered by this solution.



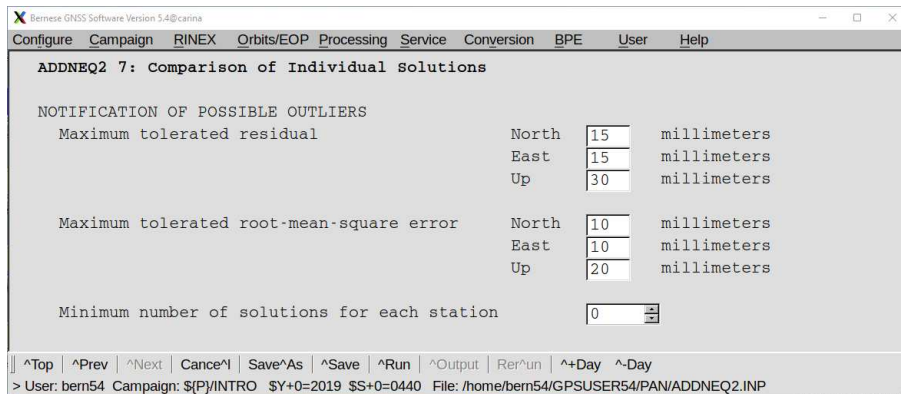
The input NEQ files only contain coordinates:



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



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



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

```

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

```

File	RMS (m)	DOF	Chi**2/DOF	#Observations		#Parameters		
				authentic	/ pseudo	explicit	/ implicit	/ singular
1	0.00109	132071	1.19	133677	3	51	1558	0
2	0.00106	134591	1.13	136030	3	51	1391	0
3	0.00148	147487	2.19	148986	3	51	1451	0
4	0.00145	147425	2.09	148917	3	51	1444	0
5	0.00110	138483	1.22	139733	3	48	1205	0
6	0.00111	136210	1.23	137543	3	48	1288	0

```

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

```

BRST 10004M004	N	0.69	0.38	0.24	-0.67	-0.91	0.94	0.11
BRST 10004M004	E	1.34	0.84	0.26	-1.89	-1.51	0.87	1.25
BRST 10004M004	U	1.21	0.66	-0.44	0.16	-1.58	-1.03	1.76
GANP 11515M001	N	0.82	0.28	0.34	-0.06	-1.59	0.69	0.37
GANP 11515M001	E	1.41	-0.66	-0.27	2.75	0.12	-1.16	-0.71
GANP 11515M001	U	1.24	1.29	-0.23	-0.88	-1.88	1.13	0.61
HERT 13212M010	N	0.31	-0.03	0.03	0.52	-0.45	-0.01	-0.09
HERT 13212M010	E	2.28	1.21	0.78	-3.48	-2.35	1.95	1.55
HERT 13212M010	U	2.97	-0.46	-2.19	3.88	3.57	-2.18	-2.56
JOZ2 12204M002	N	0.57	-0.53	0.15	1.00	-0.49	-0.05	-0.30
JOZ2 12204M002	E	2.41	-1.58	-1.22	4.34	0.83	-1.73	-1.57
JOZ2 12204M002	U	1.64	-2.05	-0.04	2.51	0.56	-0.40	-1.57
LAMA 12209M001	N	0.78	-0.26	-0.34	1.45	0.28	-0.62	-0.54
LAMA 12209M001	E	0.66	0.09	-0.70	0.71	0.86	-0.51	-0.46
LAMA 12209M001	U	1.77	-1.52	2.40	-1.79	0.37	1.81	-1.02
MATE 12734M008	N	0.72	0.01	0.54	-1.38	0.11	0.37	0.48
MATE 12734M008	E	0.33	-0.10	0.35	-0.26	-0.41	0.42	-0.05
MATE 12734M008	U	2.99	-2.30	3.31	1.87	-4.54	-0.13	2.08
MIKL 12335M001	N	1.05	0.07	0.95	-1.59	-0.91	0.81	0.77
MIKL 12335M001	E	1.21	-0.37	-0.66	1.55	1.52	-0.93	-1.09
MIKL 12335M001	U	2.50	-1.21	0.01	-1.50	5.12	-0.70	-0.93
ONSA 10402M004	N	0.56	-0.09	-0.38	1.07	0.00	-0.14	-0.51
ONSA 10402M004	E	0.40	-0.35	0.55	-0.29	-0.00	-0.33	0.44
ONSA 10402M004	U	1.82	2.19	-0.34	-3.04	0.52	1.34	0.55
ORID 15601M001	N	1.50	0.92	0.88	-2.44	-1.00	0.84	1.42
ORID 15601M001	E	0.91	0.60	-1.02	-0.45	1.41	-0.75	0.12
ORID 15601M001	U	2.14	2.53	-1.50	-1.67	-1.85	-0.25	2.83
PTBB 14234M001	N	0.96	-0.71	-1.04	0.37	1.50	-0.48	-0.64
PTBB 14234M001	E	0.84	0.67	1.01	-0.55	-1.15	0.57	0.38
PTBB 14234M001	U	1.73	0.32	-0.82	-2.35	2.58	1.00	-0.99

TLSE	10003M009	N	0.32	0.45	-0.37	-0.14	0.08	0.24	-0.32
TLSE	10003M009	E	0.63	0.13	0.37	-0.89	-0.67	0.71	0.22
TLSE	10003M009	U	1.28	0.34	-0.19	-0.44	-0.51	-1.91	1.99
VILL	13406M001	N	0.60	0.23	0.07	-1.03	0.55	-0.10	0.64
VILL	13406M001	E	0.89	0.59	0.14	-1.34	-0.80	0.57	0.92
VILL	13406M001	U	3.11	2.49	0.09	-3.13	-4.01	3.92	0.91
WSRT	13506M005	N	0.98	-0.44	-0.11	0.35	1.38	0.34	-1.57
WSRT	13506M005	E	0.63	-0.12	0.16	-0.59	0.45	-0.83	0.83
WSRT	13506M005	U	5.50	-3.56	-1.65	8.68	4.80	-5.54	-2.54
WTZR	14201M010	N	0.37	0.27	-0.14	0.34	-0.46		
WTZR	14201M010	E	0.29	0.11	-0.16	0.39	-0.24		
WTZR	14201M010	U	1.91	0.02	1.29	-0.24	-3.04		
WTZZ	14201M014	N	0.52	0.15	0.03	0.44	-0.75	-0.42	0.65
WTZZ	14201M014	E	0.51	0.24	0.08	0.08	-0.99	0.17	0.48
WTZZ	14201M014	U	1.39	-0.51	-0.52	2.14	1.31	-0.45	-1.64
ZIM2	14001M008	N	0.87	0.31	0.36	-1.00	-0.73	-0.27	1.39
ZIM2	14001M008	E	0.41	-0.08	-0.01	-0.02	0.29	0.57	-0.64
ZIM2	14001M008	U	0.30	-0.01	0.05	-0.28	0.53	0.12	-0.26
ZIMM	14001M004	N	0.50	0.32	0.00	-0.54	-0.41	-0.25	0.80
ZIMM	14001M004	E	0.83	-0.47	-0.07	0.45	1.17	0.38	-1.24
ZIMM	14001M004	U	1.03	0.81	-0.33	-0.45	-0.31	1.78	-1.01
Variance-covariance scaling factors:									

Parameter type				Component		Scaling factor wrt RMS /	variance		DOF

Station coordinates				N		3.19994	10.23965		100
Station coordinates				E		5.23587	27.41430		100
Station coordinates				U/vertical		2.69282	7.25129		100
Station coordinates				Horizontal		4.33901	18.82697		200
Station coordinates				All		3.86890	14.96841		300

Total						3.86890	14.96841		300
...									

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

Directly below the Solution Statistics potential changes of the equipment are reported that might influence the velocity estimation. In our example, four stations are affected:

Station inconsistencies:									

Station		First obs. epoch		Last obs. epoch		Receiver type		Antenna type	..

JOZ2	12204M002	2019-02-13 00:00:00		2019-02-14 23:59:30		LEICA GRX1200GGPRO		LEIAT504GG	..
JOZ2	12204M002	2020-06-27 00:00:00		2021-04-06 23:59:30		TRIMBLE NETR9		TRM59800.00	..
ONSA	10402M004	2019-02-13 00:00:00		2019-02-14 23:59:30		JAVAD TRE_G3TH DELTA		AOAD/M_B	..
ONSA	10402M004	2020-06-27 00:00:00		2021-04-06 23:59:30		SEPT POLARX5TR		AOAD/M_B	..
ORID	15601M001	2019-02-13 00:00:00		2019-02-14 23:59:30		LEICA GRX1200GGPRO		LEIAT504GG	..
ORID	15601M001	2020-06-27 00:00:00		2021-04-06 23:59:30		LEICA GR30		LEIAR25.R4	..
PTBB	14234M001	2019-02-13 00:00:00		2019-02-14 23:59:30		ASHTech Z-XII3T		ASH700936E	..
PTBB	14234M001	2020-06-27 00:00:00		2021-04-06 23:59:30		SEPT POLARX5TR		LEIAR25.R4	..
VILL	13406M001	2019-02-13 00:00:00		2019-02-14 23:59:30		SEPT POLARX4		SEPCHOKE_MC	..
VILL	13406M001	2020-06-27 00:00:00		2021-04-06 23:59:30		SEPT POLARX5		SEPCHOKE_B3E6	..
...									

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

```

...
Station coordinates and velocities:
-----
Reference epoch: 2015-01-01 00:00:00
Station name      Typ  A priori value  Estimated value  Correction  RMS error  ...
-----
...
WTZR 14201M010   VX   -0.01593      -0.01259        0.00334      0.00028
                  VY    0.01721       0.01765        0.00044      0.00012
                  VZ    0.01006       0.01349        0.00343      0.00031
...
                  VU   -0.00004       0.00475        0.00479      0.00040 ...
                  VN    0.01543       0.01514       -0.00029      0.00013 ...
                  VE    0.02033       0.02001       -0.00032      0.00010 ...
...
WTZZ 14201M014   VX   -0.01593      -0.01425        0.00168      0.00020
                  VY    0.01721       0.01772        0.00051      0.00009
                  VZ    0.01006       0.01274        0.00268      0.00022
...
                  VU   -0.00004       0.00313        0.00317      0.00029 ...
                  VN    0.01543       0.01585        0.00043      0.00009 ...
                  VE    0.02033       0.02045        0.00012      0.00007 ...
...
ZIM2 14001M008   VX   -0.01378      -0.01285        0.00093      0.00020
                  VY    0.01810       0.01806       -0.00004      0.00008
                  VZ    0.01164       0.01180        0.00016      0.00021
...
                  VU    0.00076       0.00150        0.00074      0.00027 ...
                  VN    0.01621       0.01565       -0.00056      0.00009 ...
                  VE    0.01974       0.01957       -0.00016      0.00007 ...
...
ZIMM 14001M004   VX   -0.01378      -0.01317        0.00061      0.00031
                  VY    0.01810       0.01769       -0.00041      0.00011
                  VZ    0.01164       0.01223        0.00059      0.00031
...
                  VU    0.00076       0.00158        0.00081      0.00042 ...
                  VN    0.01621       0.01621       -0.00000      0.00014 ...
                  VE    0.01974       0.01925       -0.00049      0.00010 ...
...

```

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

```

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

```

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

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

```

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

```

If only the improvements (column Correction) for the velocities are constrained, you must make sure that also the a priori values (column A priori value) for the velocities are identical to obtain (column Estimated value) the same velocities for a group of stations.

You can verify this in the input velocity file $\${P}\}/\text{INTRO}/\text{STA}/\text{EXAMPLE.VEL}$:

...
370 WTZR 14201M010 -0.01593 0.01721 0.01006 IG20 EURA
371 WTZZ 14201M014 -0.01593 0.01721 0.01006 NNR EURA
...
383 ZIM2 14001M008 -0.01378 0.01810 0.01164 IG20 EURA
385 ZIMM 14001M004 -0.01378 0.01810 0.01164 IG20 EURA
...

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

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

...
Relative constraints between stations:
Station names

WTZR 14201M010 WTZZ 14201M014
ZIM2 14001M008 ZIMM 14001M004

... relative constraints for velocities
... N (m/year) E (m/year) U (m/year)

... 0.00001 0.00001 0.00001
... 0.00001 0.00001 0.00001

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

...
Station coordinates and velocities:

Reference epoch: 2010-01-01 00:00:00
Station name Typ A priori value Estimated value Correction RMS error ...

...
WTZR 14201M010 VX -0.01593 -0.01371 0.00222 0.00016
VY 0.01721 0.01768 0.00047 0.00007
VZ 0.01006 0.01301 0.00295 0.00018
VU -0.00004 0.00367 0.00371 0.00023 ...
VN 0.01543 0.01564 0.00021 0.00008 ...
VE 0.02033 0.02029 -0.00004 0.00006 ...
...
WTZZ 14201M014 VX -0.01593 -0.01371 0.00222 0.00016
VY 0.01721 0.01768 0.00047 0.00007
VZ 0.01006 0.01301 0.00295 0.00018
VU -0.00004 0.00367 0.00371 0.00023 ...
VN 0.01543 0.01564 0.00022 0.00007 ...
VE 0.02033 0.02029 -0.00004 0.00006 ...
...
ZIM2 14001M008 VX -0.01378 -0.01282 0.00096 0.00016
VY 0.01810 0.01793 -0.00017 0.00006
VZ 0.01164 0.01199 0.00035 0.00016
VU 0.00076 0.00165 0.00089 0.00021 ...
VN 0.01621 0.01577 -0.00044 0.00007 ...
VE 0.01974 0.01945 -0.00029 0.00005 ...
...
ZIMM 14001M004 VX -0.01378 -0.01283 0.00095 0.00016
VY 0.01810 0.01793 -0.00017 0.00006
VZ 0.01164 0.01199 0.00035 0.00016
VU 0.00076 0.00165 0.00089 0.00021 ...
VN 0.01621 0.01578 -0.00044 0.00007 ...
VE 0.01974 0.01945 -0.00029 0.00006 ...
...

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

```

EXAMPLE: Estimate final solution - coordinates and velocities      25-AUG-24 13:15
-----
LOCAL GEODETIC DATUM: IGS20                      EPOCH: 2015-01-01 00:00:00
-----
NUM  STATION NAME          X (M)          Y (M)          Z (M)          FLAG
SYSTEM
43   BRST 10004M004        4231162.47225  -332746.49379  4745131.03711  W    GRE
104  GANP 11515M001        3929181.36192  1455236.88349  4793653.99376  A    GRE
122  HERT 13212M010        4033460.79936   23537.97229   4924318.35814  A    GR
143  JOZ2 12204M002        3664880.40508  1409190.73252  5009618.56140  A    GRE
166  LAMA 12209M001        3524522.74513  1329693.77173  5129846.42522  A    GR
184  MATE 12734M008        4641949.37575  1393045.61381  4133287.60971  W    GRE
198  MIKL 12335M001        3698553.79490  2308676.15755  4639769.58706  W    GRE
235  ONSA 10402M004        3370658.41003   711877.28746  5349787.05074  W    GRE
236  ORID 15601M001        4498451.55313  1708267.17399  4173591.97667  W    GRE
264  PTBB 14234M001        3844059.81627   709661.47882  5023129.63893  A    GRE
329  TLSE 10003M009        4627851.70708   119640.21486  4372993.66293  W    GRE
359  WILL 13406M001        4849833.62038  -335048.82494  4116015.07867  A    GRE
369  WSRT 13506M005        3828735.71201  443305.12099  5064884.80165  W    GRE
370  WTZR 14201M010        4075580.37965   931853.96581  4801568.21512  W    GRE
371  WTZZ 14201M014        4075579.25913   931853.28127  4801569.12265  A    GRE
383  ZIM2 14001M008        4331299.73306   567537.50277  4633133.82752  W    GRE
385  ZIMM 14001M004        4331296.92163   567556.05878  4633134.04681  W    G

```

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

```

EXAMPLE: Estimate final solution - coordinates and velocities      25-AUG-24 13:15
-----
LOCAL GEODETIC DATUM: IGS20
-----
NUM  STATION NAME          VX (M/Y)          VY (M/Y)          VZ (M/Y)          FLAG  PLATE
43   BRST 10004M004        -0.01299          0.01632          0.00849          W    EURA
104  GANP 11515M001        -0.01571          0.01686          0.00999          A    EURA
122  HERT 13212M010        -0.01396          0.01617          0.00945          A    EURA
143  JOZ2 12204M002        -0.01978          0.01848          0.00802          A    EURA
166  LAMA 12209M001        -0.01757          0.01594          0.01087          A    EURA
184  MATE 12734M008        -0.01881          0.01920          0.01427          W    EURA
198  MIKL 12335M001        -0.02004          0.01765          0.00970          W    EURA
235  ONSA 10402M004        -0.01569          0.01385          0.01068          W    EURA
236  ORID 15601M001        -0.01745          0.02122          0.00401          W    EURA
264  PTBB 14234M001        -0.01707          0.01619          0.01194          A    EURA
329  TLSE 10003M009        -0.01135          0.01810          0.01211          W    EURA
359  WILL 13406M001        -0.01205          0.01769          0.00916          A    EURA
369  WSRT 13506M005        -0.01474          0.01548          0.01191          W    EURA
370  WTZR 14201M010        -0.01371          0.01768          0.01301          W    EURA
371  WTZZ 14201M014        -0.01371          0.01768          0.01301          A    EURA
383  ZIM2 14001M008        -0.01282          0.01793          0.01199          W    EURA
385  ZIMM 14001M004        -0.01283          0.01793          0.01199          W    EURA

```

6.6 Daily Goals

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

1. used *GPSEST* to compute a final solution of the day, created files: *FIX_20190440.OUT*, *FIX_20190440.NQ0*,
2. checked the coordinates of the fiducial sites using *ADDNEQ2* and *HELMR1*, created files: *FIN_20190440.CRD*, *FIN_20190440.TRP*, optionally also *FIN_20190440.TRO*, *FIN_20190440.OUT*, and *HLM_20190440.OUT* – these results should be available for all sessions,
3. used *COMPAR2* to check the daily repeatabilities, created file: *COMPAR.OUT*,
4. used *ADDNEQ2* to create a final session solution, and reduced size *NEQs*, created files: *RED_20190440.NQ0* and *RED_20190440.SNX*,
5. if possible, used *ADDNEQ2* for velocity estimation, created files: *FINAL.CRD* and *FINAL.VEL*.

7 Additional Examples

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

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

- generation of a combined GPS/GLONASS orbit from IGS legacy product series (see Section 7.1 on page 126),
- kinematic positioning for a station (see Section 7.2 on page 132), and
- simulation of GNSS observations (see Section 7.3 on page 139).

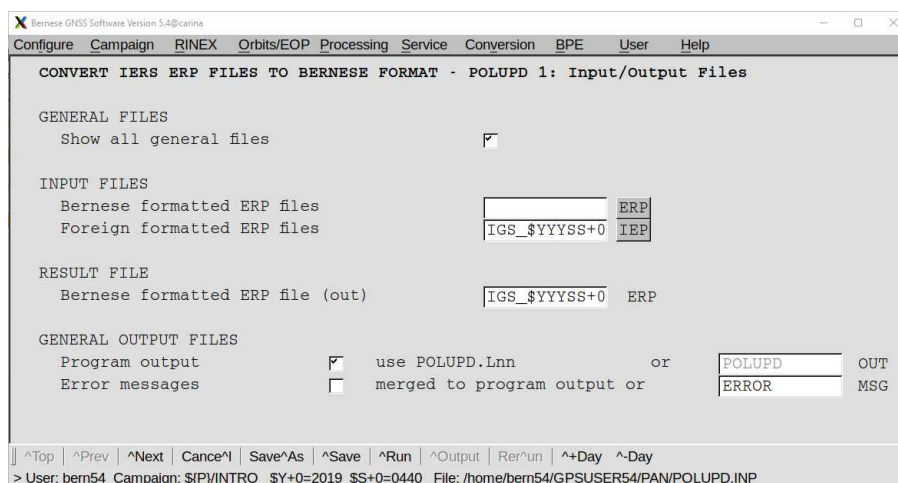
7.1 Preparing Combined GPS and GLONASS legacy IGS–Orbits

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

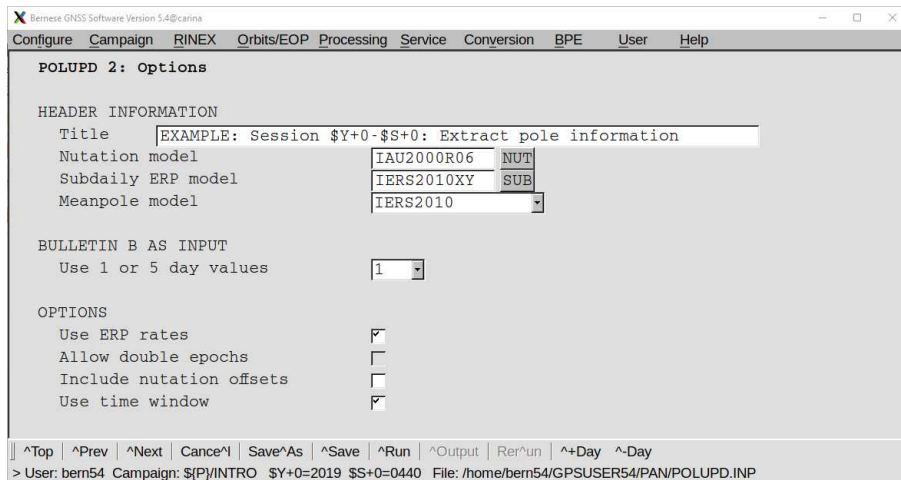
In contrast, CODE (and other AC) uses a rigorous combined multi–GNSS processing scheme, hence producing a single precise orbit file.

7.1.1 Prepare Pole Information

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



Because the input “Foreign formatted ERP files” is generated using the modelling of the operational processing within the IGS in that time for the “Subdaily ERP model” as well as the “Meanpole model” we have to switch it back to maintain the compatibility:



Because the IGS “Foreign formatted ERP files” contain only the noon epoch we have to enable the checkbox for option “Use ERP rates” in order to cover the full interval of the session in the resulting “Bernese formatted ERP file (out)”.

The messages

```

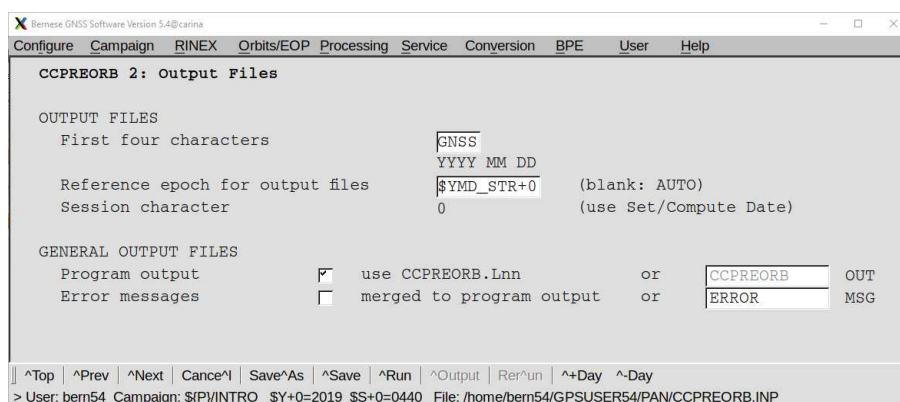
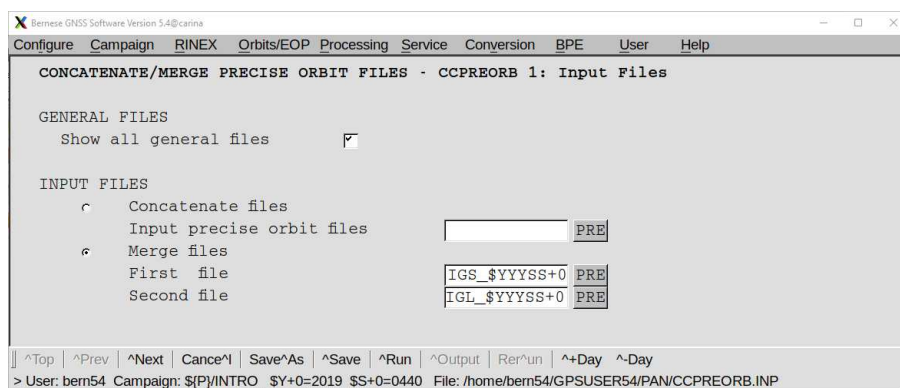
### PG POLUPD: NUTATION MODEL NOT SPECIFIED IN INPUT ERP FILE
                USING NUTATION MODEL NAME : IAU2000R06

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

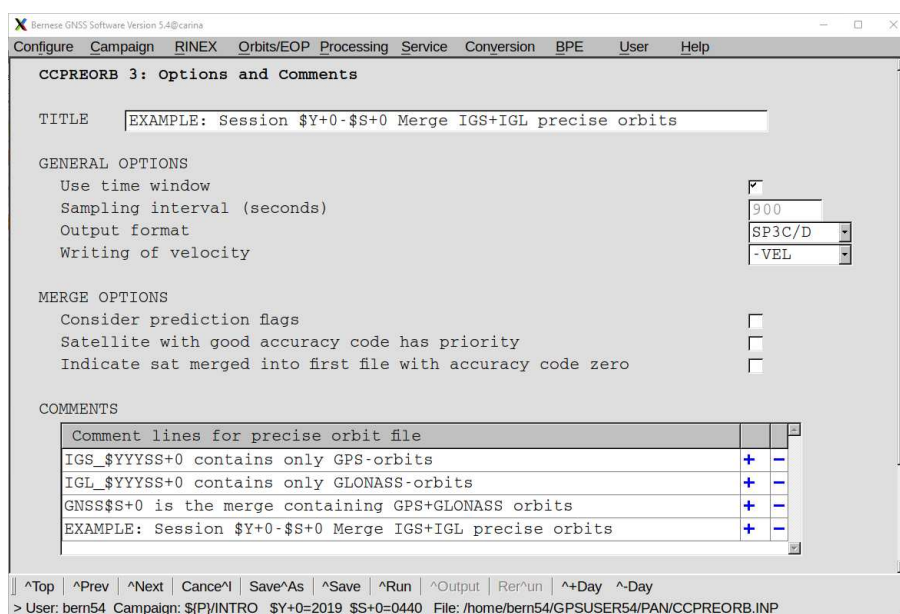
just inform you that the nutation and subdaily pole models from the files in the input panel are written to the output file because no Bernese formatted ERP file was used as input. This is different to importing the EOP from CODE products because here the information on the nutation and sub daily pole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

7.1.2 Merging Precise Orbit Files

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



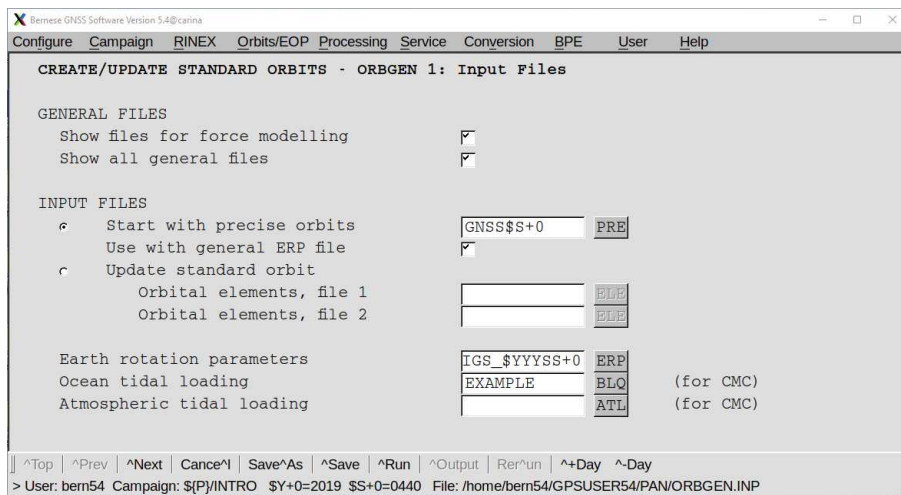
The resulting filename consists of the solution identifier (“First four characters”) and the session of the first epoch (if “Reference epoch for output files” is empty). The reference epoch may also be specified by the user as the above example shows. Using the input options from above panel we expect the result file named as $\${P}/INTRO/ORB/GNSS0440.PRE$.



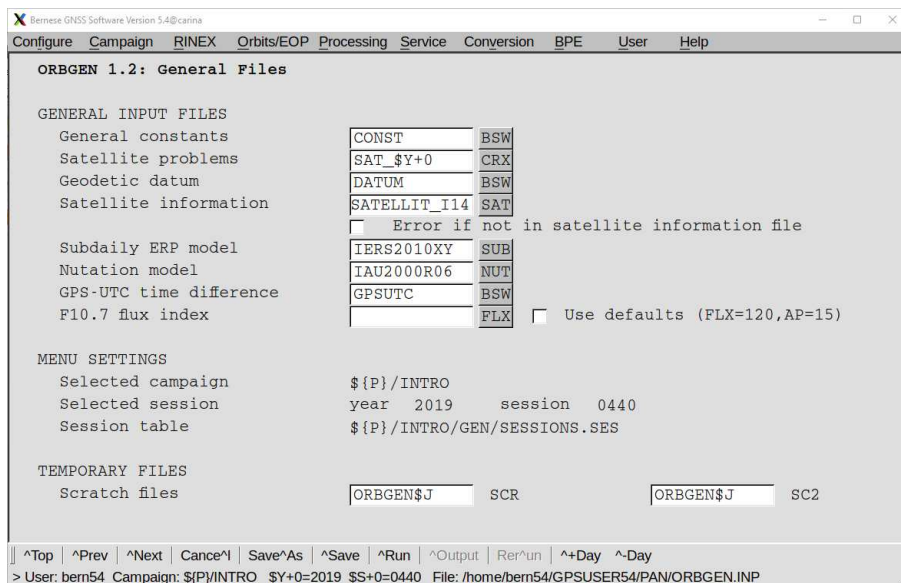
In the next panel you may specify the time window for which the satellite positions shall be included in the resulting precise orbit file.

7.1.3 Generating Standard Orbit Files

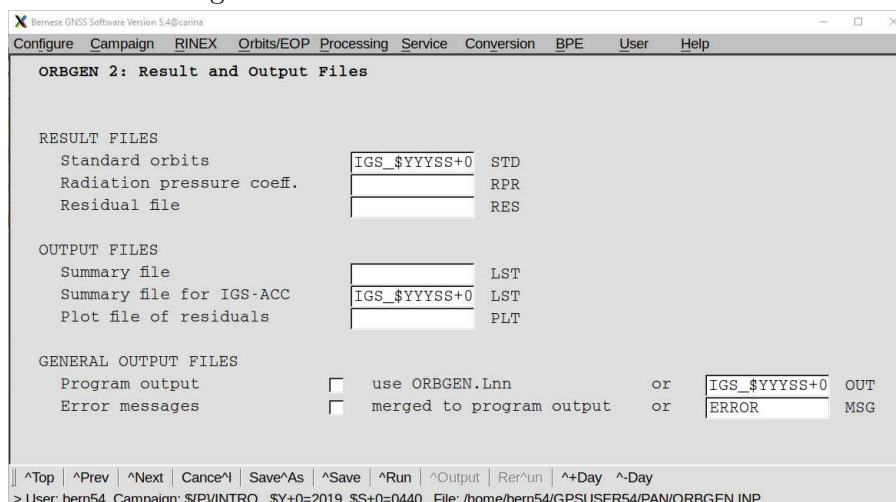
To generate the standard orbits (extension STD) from the merged precise orbits the program ORBGEN ("Menu>Orbits/EOP>Create/update standard orbits") has to be used. Introduce the merged IGS-related precise orbit file together with the consistent ERP file:



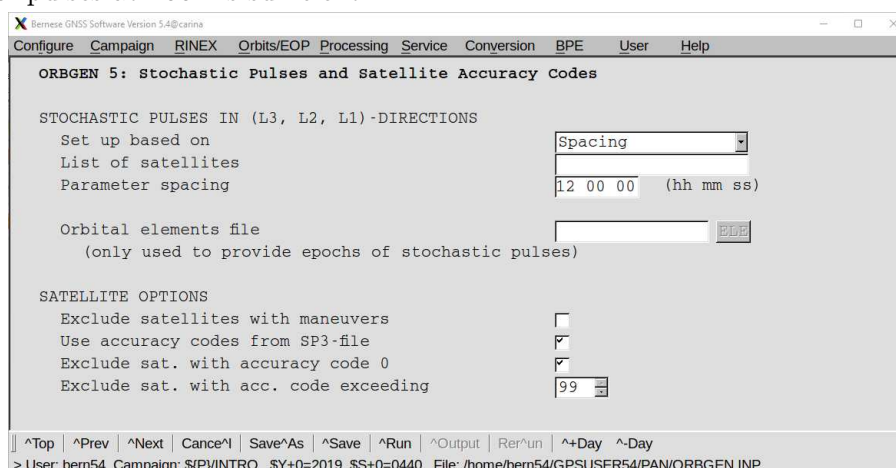
Adjust the entries for the “Satellite information” (including the correct antenna model based on IGS 14) and the “Subdaily ERP model” to be consistent to the introduced “Earth rotation parameters” file:



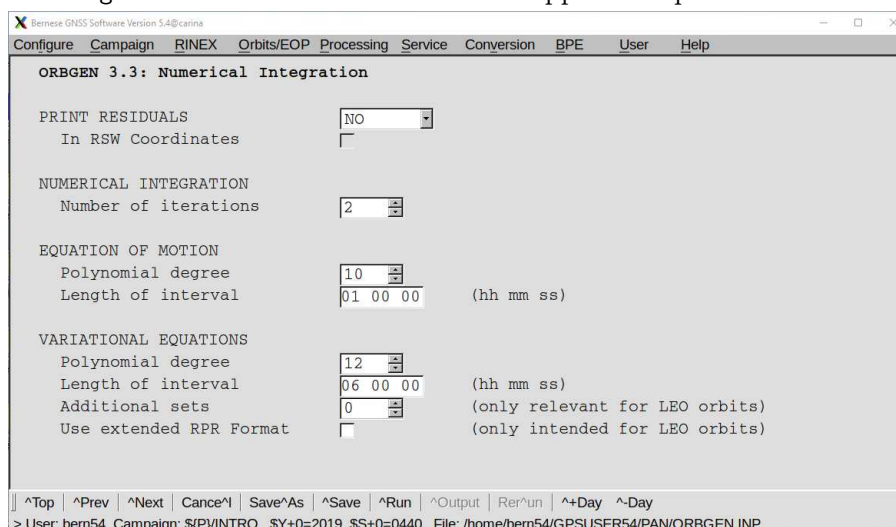
The name of the resulting orbit file should also be related to IGS:



In the general case it is preferable to setup the pulses just in an equidistant spacing by changing option “Setup of stochastic pulses” to Spacing. The interval in “Interval for stochastic pulses” is recommended to be relatively short in order to obtain a “reasonable” representation of the introduced positions in the precise orbit file. In case of IGS orbits one set of pulses at noon is sufficient.



Now you should go back to panel “ORBGEN 3.3: Numerical Integration” and increase the values for options “EQUATION OF MOTION: Length of interval” and “VARIATIONAL EQUATIONS: Length of interval”. We don’t need to support the pulses at uneven epoch.



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

```

...
-----
RMS ERRORS AND MAX. RESIDUALS      ARC NUMBER: 1                      ITERATION: 2
-----
SAT   #POS   RMS (M)      QUADRATIC MEAN OF O-C (M)      MAX. RESIDUALS (M)
      -----      -----      -----
      TOTAL   RADIAL  ALONG   OUT      RADIAL  ALONG   OUT
-----
  1    96    0.002      0.002   0.002   0.002   0.001      0.006   0.005   0.003
  2    96    0.002      0.002   0.002   0.002   0.001      0.008   0.005   0.004
  3    96    0.003      0.003   0.004   0.002   0.003      0.013   0.007   0.006
  4    96    0.004      0.003   0.005   0.003   0.002      0.011   0.007   0.009
  5    96    0.003      0.003   0.005   0.002   0.001      0.020   0.007   0.002
  6    96    0.002      0.002   0.002   0.002   0.002      0.005   0.004   0.004
  7    96    0.002      0.002   0.001   0.001   0.002      0.003   0.003   0.005
  8    96    0.003      0.003   0.003   0.003   0.002      0.006   0.007   0.004
  9    96    0.002      0.002   0.002   0.001   0.002      0.003   0.003   0.004
 10    96    0.003      0.003   0.004   0.002   0.002      0.015   0.006   0.005
 11    96    0.003      0.002   0.003   0.003   0.002      0.006   0.007   0.004
 12    96    0.004      0.004   0.005   0.003   0.002      0.018   0.007   0.005
 13    96    0.001      0.001   0.001   0.001   0.001      0.003   0.003   0.005
...
 28    96    0.005      0.004   0.007   0.003   0.002      0.031   0.007   0.007
 29    96    0.003      0.003   0.004   0.003   0.002      0.007   0.008   0.003
 30    96    0.002      0.002   0.003   0.002   0.002      0.005   0.004   0.004
 31    96    0.001      0.001   0.001   0.001   0.001      0.003   0.003   0.003
 32    96    0.001      0.001   0.001   0.001   0.001      0.003   0.004   0.003
101    96    0.007      0.007   0.010   0.006   0.003      0.018   0.013   0.007
102    96    0.003      0.003   0.004   0.002   0.002      0.019   0.006   0.009
103    96    0.005      0.005   0.008   0.003   0.002      0.014   0.010   0.008
104    96    0.006      0.006   0.009   0.004   0.003      0.015   0.019   0.006
105    96    0.005      0.005   0.007   0.003   0.003      0.012   0.013   0.006
107    96    0.006      0.006   0.009   0.004   0.003      0.017   0.016   0.006
108    96    0.005      0.005   0.008   0.003   0.002      0.013   0.010   0.005
109    96    0.004      0.004   0.006   0.003   0.003      0.012   0.012   0.009
...
120    96    0.003      0.003   0.003   0.002   0.004      0.007   0.007   0.016
121    96    0.004      0.004   0.005   0.002   0.003      0.009   0.008   0.009
122    96    0.004      0.004   0.006   0.002   0.003      0.014   0.007   0.006
123    96    0.004      0.004   0.005   0.002   0.003      0.010   0.005   0.009
124    96    0.003      0.003   0.002   0.001   0.004      0.004   0.004   0.014
126    96    0.007      0.006   0.007   0.006   0.007      0.013   0.011   0.013
-----
...

```

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

The file `INTRO/OUT/IGS_2019044.LST` contains the same results as displayed on page 31 but contains also the GLONASS satellite orbits:

```

EXAMPLE: Session 2019-0440: Standard orbit generation      25-AUG-24 13:27
TIME FROM DAY : 3 GPS WEEK: 2040
      TO DAY : 4 GPS WEEK: 2040
-----
ORBIT REPEATABILITY FROM A 1-DAY FIT THROUGH DAILY ORBIT SOLUTIONS (MM)
# ECLIPSING SATELLITES:  8 E /  0 M ( 0 EM)
-----
ECL  ..  ..  E.  ..  E.  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..  ..
DOY  1  2  3  4  5  6  7  8  ...  31  32  101  102  103  104  105  107  ...  122  123  124  126
-----
044  2  2  3  3  3  2  2  3  ...  1  1  7  3  5  6  5  6  ...  4  4  3  6
-----
ALL  2  2  3  3  3  2  2  3  ...  1  1  7  3  5  6  5  6  ...  4  4  3  6
-----

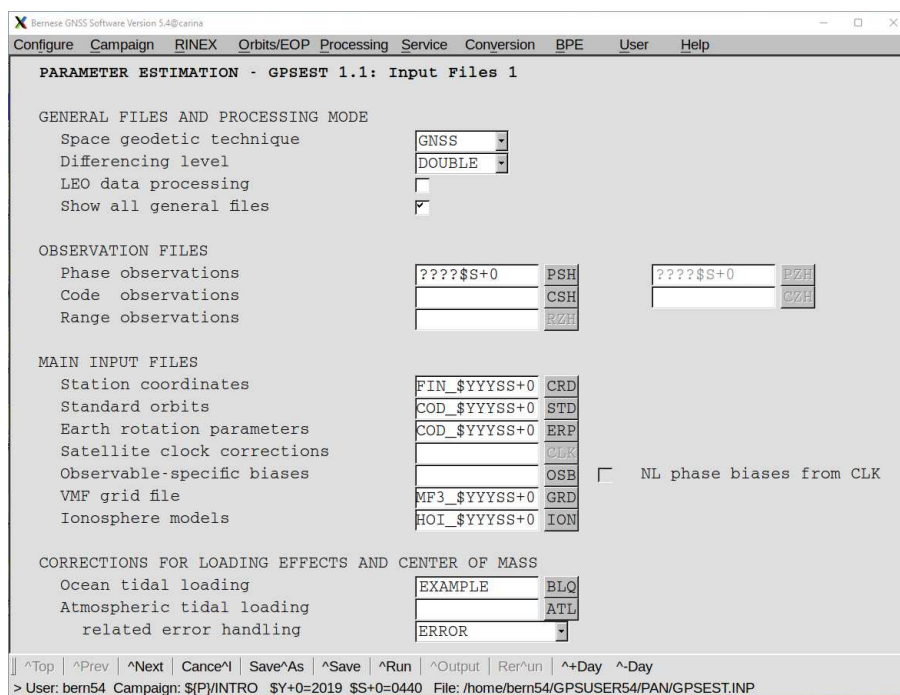
```

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

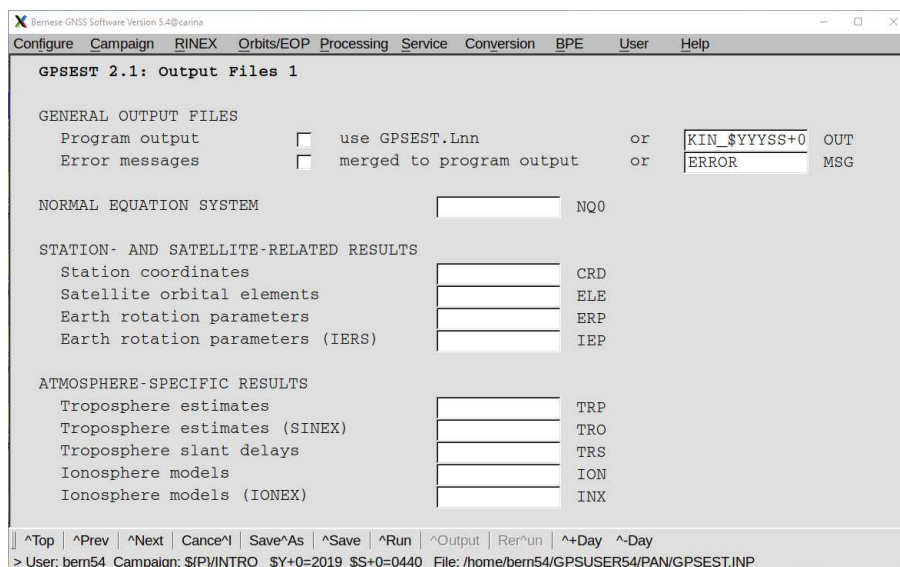
7.2 Kinematic Positioning

7.2.1 Estimating Kinematic Positions in a Double-Difference Solution

The example campaign contains no really roving stations. You can, however, define one of them to be kinematic (e.g., station GANP). Introduce the coordinates from the final solution ($\{\$P\}/\text{INTRO}/\text{STA}/\text{FIN}_20190440.\text{CRD}$) for all other sites.



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



GPSEST 2.2: Output Files 2

ADDITIONAL RESULT FILES

Observable-specific code biases	<input type="text"/>	OSB
Bias SINEX	<input type="text"/>	BIA
Phase center variations (gridded)	<input type="text"/>	PHG
Phase center variations (spherical)	<input type="text"/>	PHH

EPOCH-SPECIFIC RESULTS

GNSS clock corrections	<input type="text"/>	CLK
Clock RINEX	<input type="text"/>	CLK
Kinematic coordinates	<input type="text" value="KIN_YYYYSS+0"/>	KIN
Epoch-wise KIN covariances (LEOs)	<input type="text"/>	COV

AUXILIARY FILES

Observation residuals	<input type="text"/>	RES	<input type="checkbox"/> Extended format
Covariance matrix	<input type="text"/>	COV	
Covariance matrix wrt coordinates	<input type="text"/>	COV	

^Top | ^Prev | ^Next | Cance^N | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^-Day
 > User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

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

GPSEST 3.1: General Options 1

TITLE

OBSERVATION SELECTION

GNSS SELECTION

<input checked="" type="checkbox"/> GPS	<input checked="" type="checkbox"/> GLONASS	<input checked="" type="checkbox"/> Galileo
<input type="checkbox"/> SBAS	<input type="checkbox"/> BeiDou	<input type="checkbox"/> QZSS

Frequency/linear combination

PCC applied for MELWUEBB/L4 LC

Elevation cutoff angle degrees

Sampling interval seconds

Tolerance for simultaneity milliseconds

Special data selection

Observation window

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma of unit weight meters

Elevation-dependent weighting

Type of computed residuals

Correlation strategy

LEO-SPECIFIC SELECTION AND MODELING OPTIONS

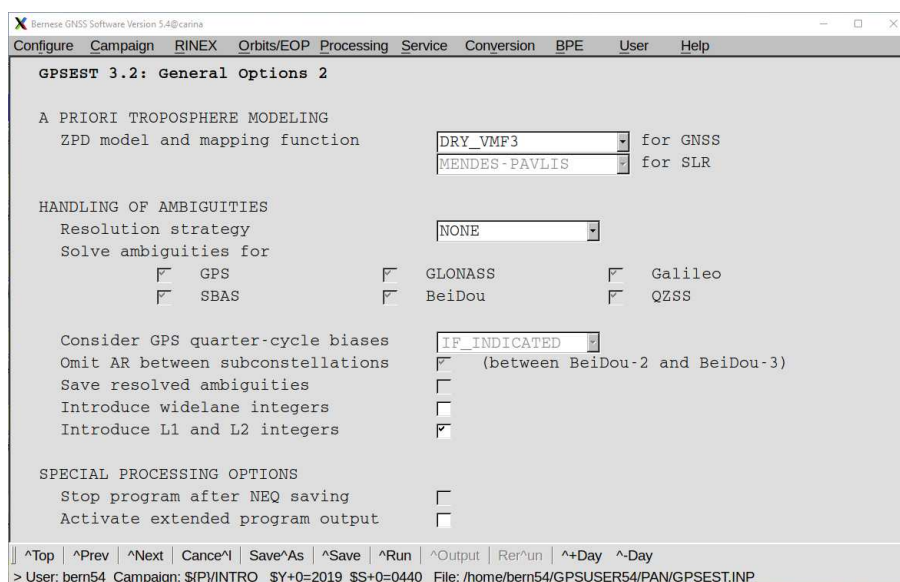
Elevation cutoff angle degrees

Elevation-dependent weighting

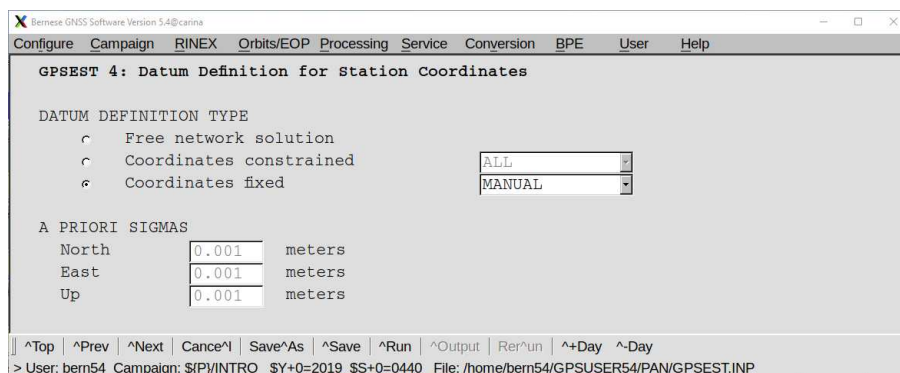
^Top | ^Prev | ^Next | Cance^N | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^-Day
 > User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

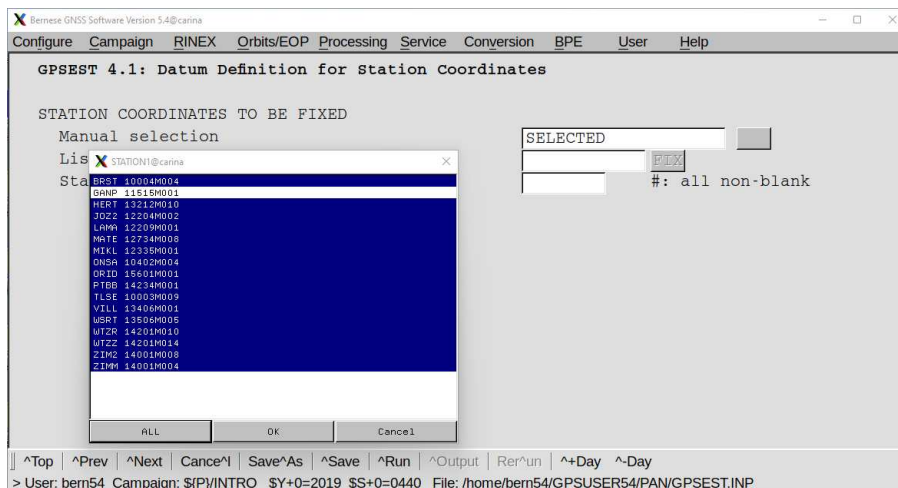


The option “Activate extended program output” may be disabled now:

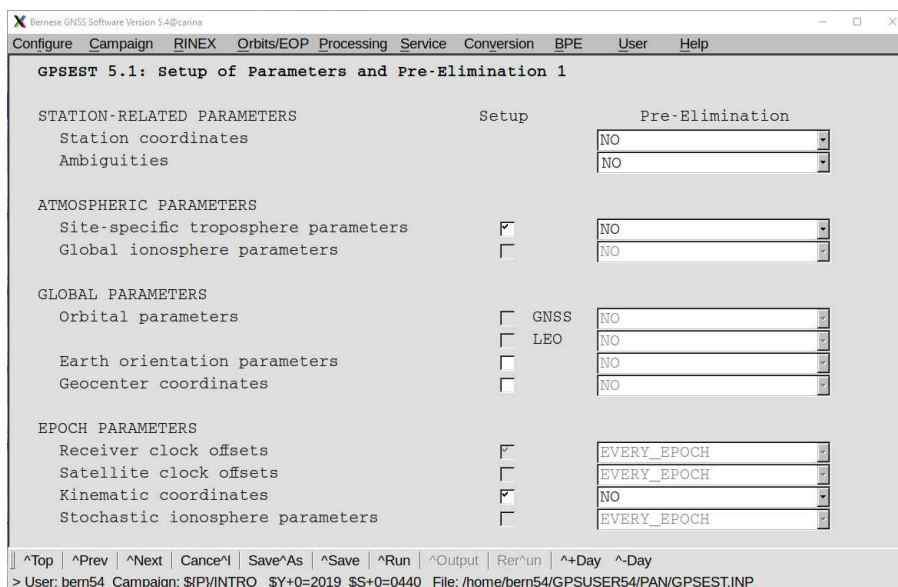


Fix all station coordinates apart from GANP in the panels “GPSEST 4: Datum Definition for Station Coordinates” (choose MANUAL in panel “GPSEST 4: Datum Definition for Station Coordinates”) and select all stations except GANP in panel “GPSEST 4.2”).

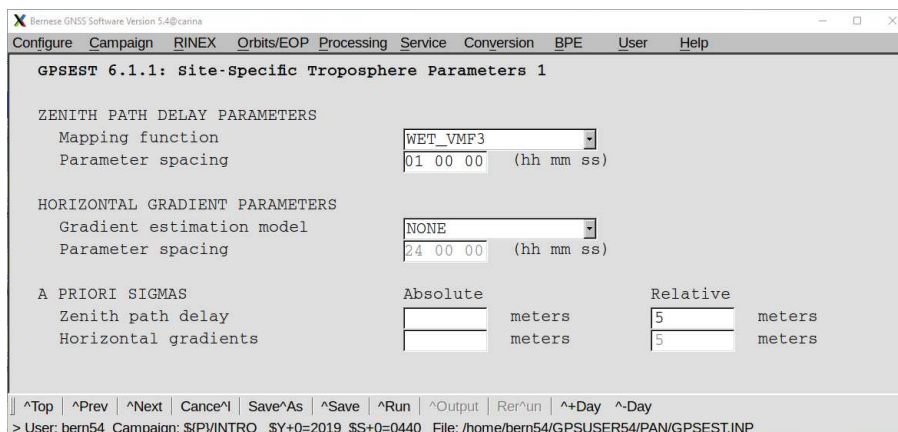




Enable the kinematic coordinates option without any pre-elimination in a first run:

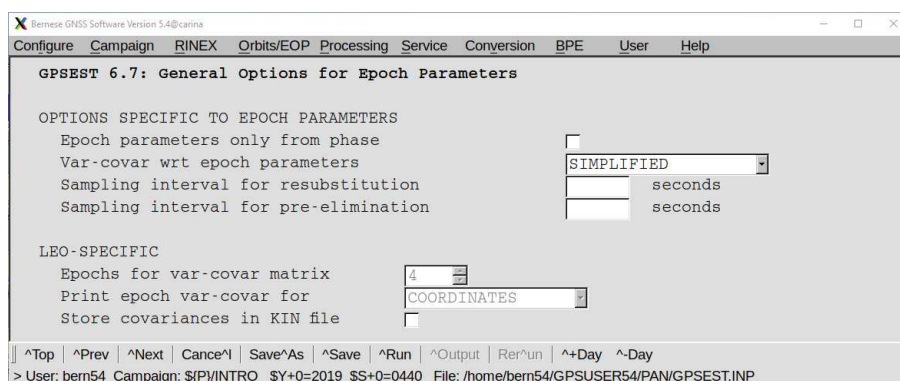


Because of the short analysis interval of only one hour we disable the estimation of troposphere gradients:

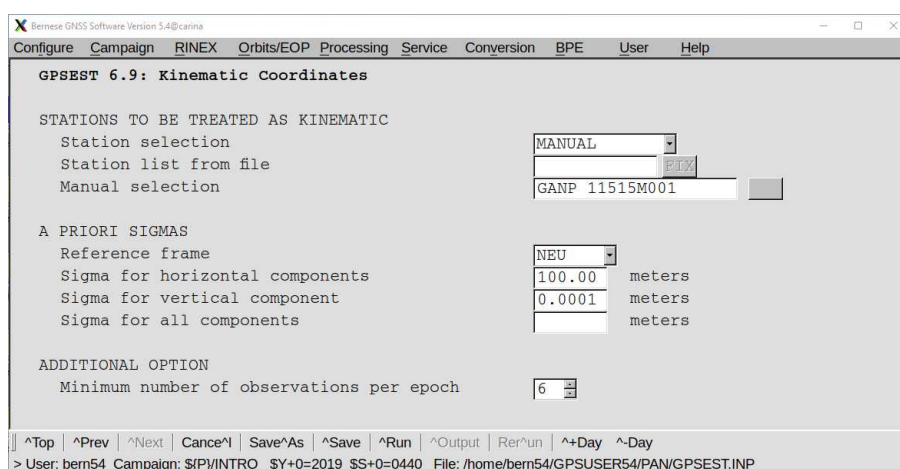


7 Additional Examples

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



Let us assume only horizontal movements for this site:



7.2.2 Extracting the Program Output from a Kinematic Positioning

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

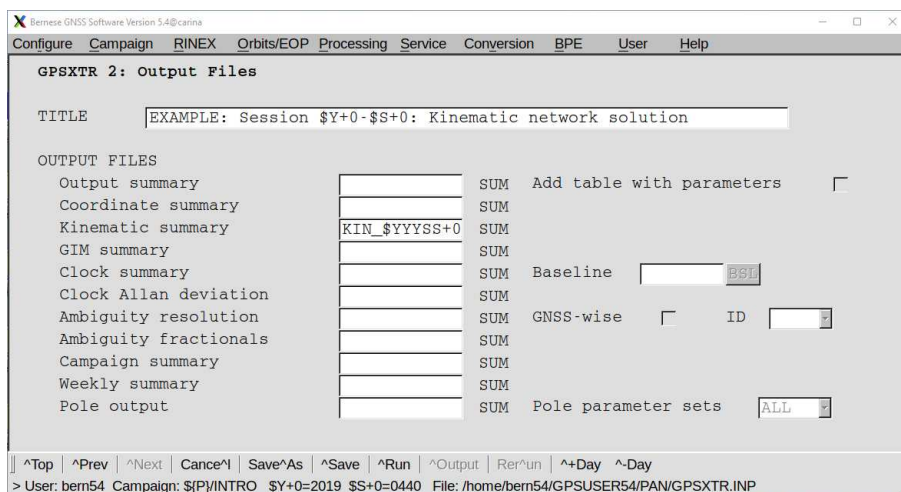
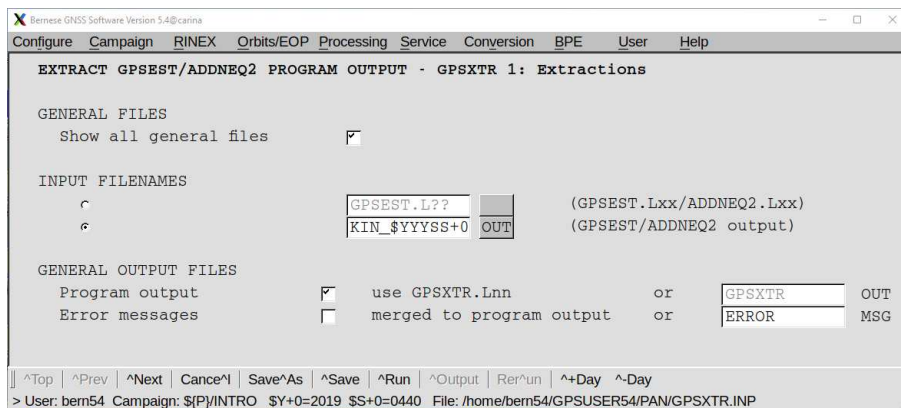
```

Kinematic coordinates:
-----

```

Station name	Typ	Obs	Correction	Estimated value	RMS error	...	From	Num	Abb
GANP 11515M001	X	41	0.00446	3929181.30273	0.00244	...	2019-02-13 18:00:00	35	#KIN
GANP 11515M001	Y	41	0.00241	1455236.95493	0.00260	...	2019-02-13 18:00:00	36	#KIN
GANP 11515M001	Z	41	-0.00436	4793654.03164	0.00211	...	2019-02-13 18:00:00	37	#KIN
GANP 11515M001	X	40	-0.00286	3929181.29541	0.00243	...	2019-02-13 18:05:00	38	#KIN
GANP 11515M001	Y	40	0.00213	1455236.95465	0.00260	...	2019-02-13 18:05:00	39	#KIN
GANP 11515M001	Z	40	0.00169	4793654.03769	0.00209	...	2019-02-13 18:05:00	40	#KIN
GANP 11515M001	X	40	0.00041	3929181.29868	0.00241	...	2019-02-13 18:10:00	41	#KIN
GANP 11515M001	Y	40	0.00002	1455236.95254	0.00262	...	2019-02-13 18:10:00	42	#KIN
GANP 11515M001	Z	40	-0.00034	4793654.03666	0.00206	...	2019-02-13 18:10:00	43	#KIN
GANP 11515M001	X	39	0.00052	3929181.29879	0.00242	...	2019-02-13 18:15:00	44	#KIN
GANP 11515M001	Y	39	0.00205	1455236.95457	0.00260	...	2019-02-13 18:15:00	45	#KIN
GANP 11515M001	Z	39	-0.00104	4793654.03496	0.00206	...	2019-02-13 18:15:00	46	#KIN
GANP 11515M001	X	40	-0.00091	3929181.29736	0.00240	...	2019-02-13 18:20:00	47	#KIN
GANP 11515M001	Y	40	0.00061	1455236.95313	0.00260	...	2019-02-13 18:20:00	48	#KIN
GANP 11515M001	Z	40	0.00056	4793654.03656	0.00204	...	2019-02-13 18:20:00	49	#KIN
GANP 11515M001	X	39	-0.00237	3929181.29590	0.00241	...	2019-02-13 18:25:00	50	#KIN
GANP 11515M001	Y	39	0.00097	1455236.95349	0.00263	...	2019-02-13 18:25:00	51	#KIN
GANP 11515M001	Z	39	0.00164	4793654.03764	0.00203	...	2019-02-13 18:25:00	52	#KIN
GANP 11515M001	X	38	-0.00241	3929181.29586	0.00241	...	2019-02-13 18:30:00	53	#KIN
GANP 11515M001	Y	38	-0.00101	1455236.95151	0.00264	...	2019-02-13 18:30:00	54	#KIN
GANP 11515M001	Z	38	0.00226	4793654.03826	0.00203	...	2019-02-13 18:30:00	55	#KIN
...									

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



The resulting summary file looks like:

*STATION	GANP 11515M001		
*XEPO	12		
*INI	3929181.2983	1455236.9525	4793654.0360
*EST	0.0000	0.0000	0.0000
*DIFXYZ	0.0006	0.0005	-0.0006
*DIFNEU	-0.0010	0.0002	-0.0000

EPOCH	DN	DE	DU
58527.75000	-0.0066	0.0007	-0.0000
58527.75347	0.0026	0.0030	0.0000
58527.75694	-0.0005	-0.0001	-0.0000
58527.76042	-0.0016	0.0017	0.0000
58527.76389	0.0009	0.0009	0.0000
58527.76736	0.0025	0.0017	0.0000
58527.77083	0.0035	-0.0001	-0.0000
58527.77431	-0.0026	0.0014	0.0000
58527.77778	-0.0035	-0.0018	-0.0000
58527.78125	-0.0042	0.0032	0.0000
58527.78472	-0.0004	-0.0033	-0.0000
58527.78819	-0.0017	-0.0045	-0.0000

*AVG	-0.0010	0.0002	-0.0000
*SIG	0.0030	0.0024	0.0000
*RMS	0.0031	0.0023	0.0000
*RMSTC	0.0011		

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

7.2.3 Further suggestions

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

7.3 Simulation of GNSS Observations

The *Bernese GNSS Software* provides the simulation tool GPSSIM ("Menu>Service>Generate simulated observation data"). It generates synthetic GNSS (i.e., GPS, GLONASS, Galileo, BDS, and QZSS) observations for terrestrial static or kinematic stations as well as for LEOs. Code and phase zero difference observation files can be created based on an observation scenario defined by

- GNSS satellite geometry given by a standard orbit and
- a set of receivers with positions from a coordinate file, kinematic positions, or a LEO standard orbit file.

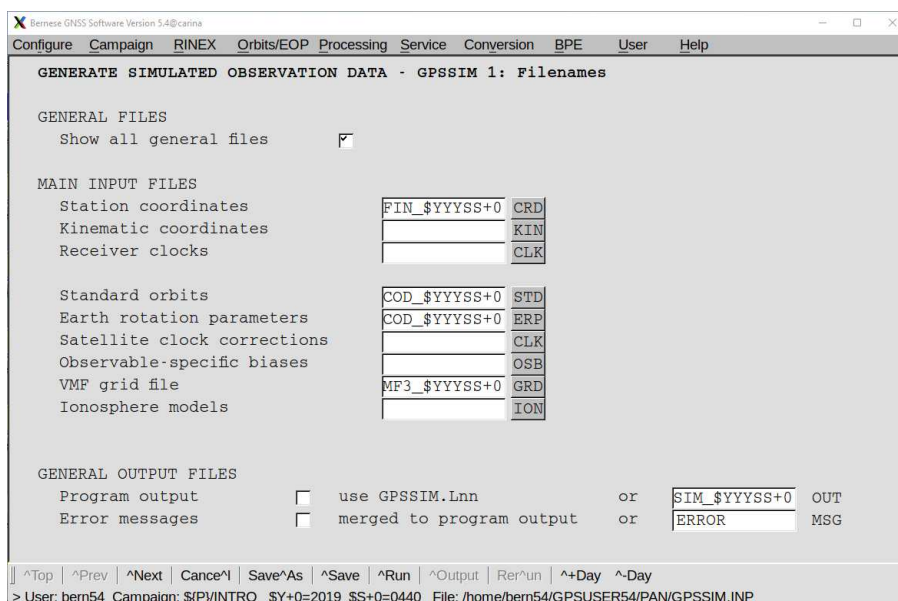
7.3.1 Simulation of GNSS Observations

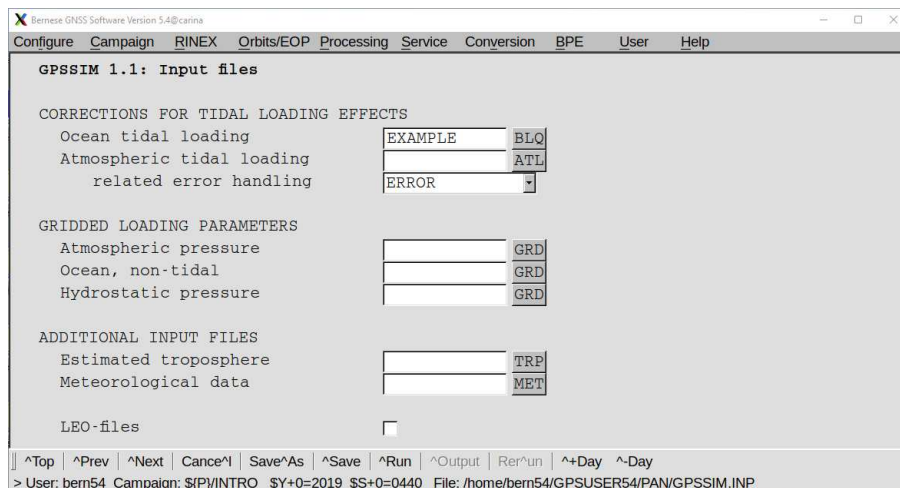
It is important that you remove all previously existing observation files for this session from the OBS directory of your campaign before you start to simulate observations. Otherwise you run into the danger of mixing your current set of simulated observations with other measurements:

```
bern54@carina:~ > rm ${P}/INTRO/OBS/????0440.CZ?
bern54@carina:~ > rm ${P}/INTRO/OBS/????0440.PZ?
```

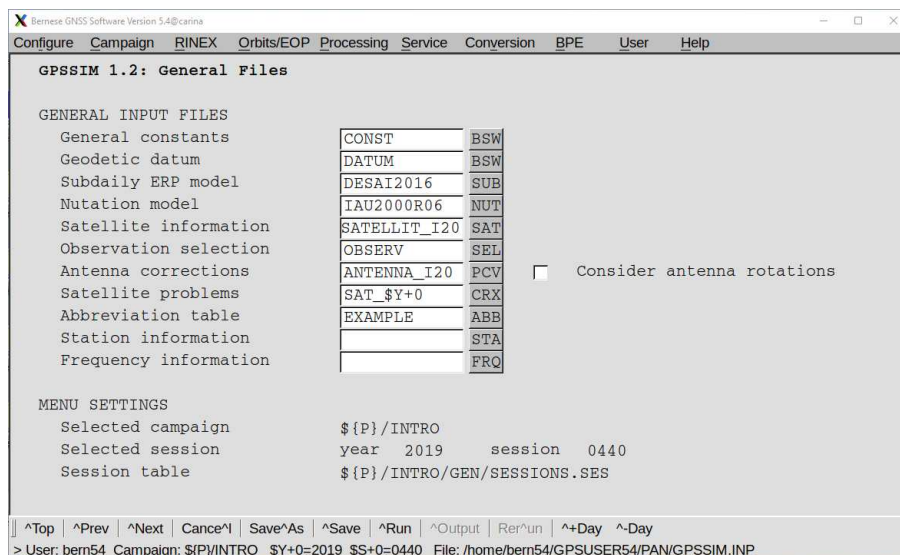
Please keep in mind that the observation files from your previous work in this campaign are lost due to this command. If you still need them, please copy them away.

The input files for the generation of synthetic GNSS observations with program GPSSIM ("Menu>Service>Generate simulated observation data") are defined in the first input panel:

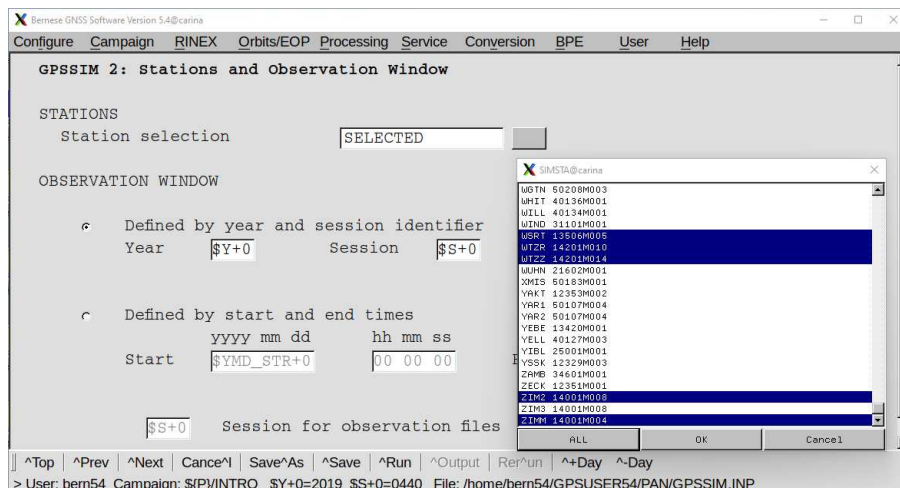




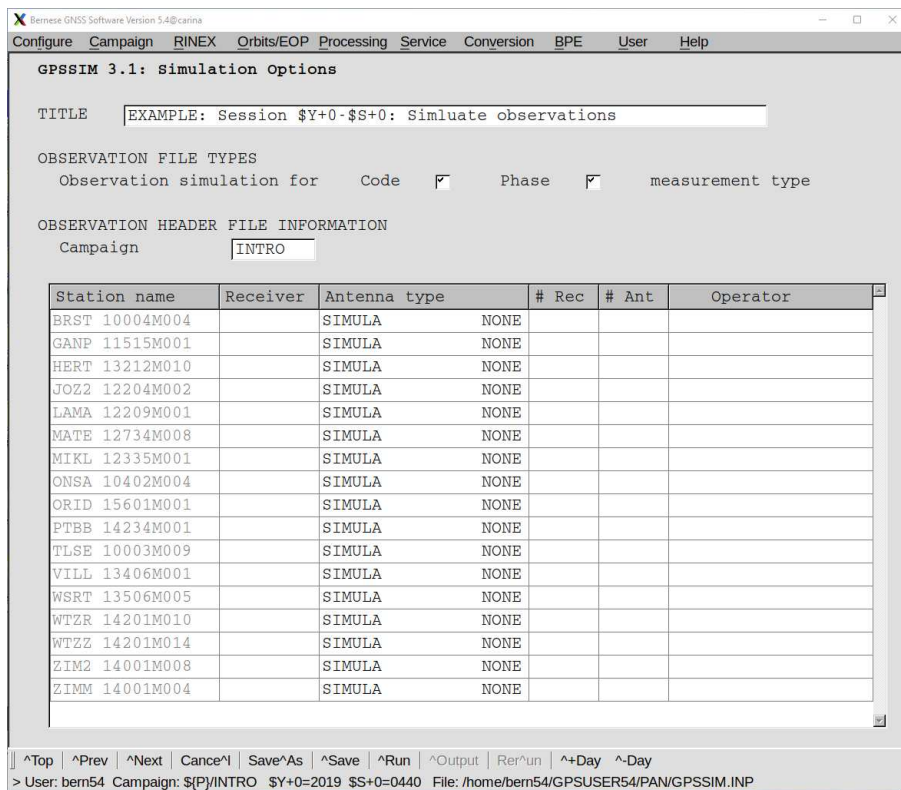
Select EXAMPLE.ABB in option “Abbreviation table”. Take care on the consistency for the other entries



In the next panel, the interval for data simulation is defined and the list of stations selected from all sites in the input “Coordinate file”:



The meta data for each station is specified in this panel:



The “Receiver” for each station must start with `SIMULA` to indicate that this is a simulated station. In the input field you may only extend this string by a user input.

The selection of the systems for the simulation is given by the content of your standard orbit file. The signal types used for the two frequencies for each of these GNSS are given in the “Observation selection” file also defined in panel “GPSSIM 1.2: General Files”:

```

...
Receiver type          S/S  O/F  RINEX observation codes and their priority
*****
...
SIMULA                 G    L1   1P
                      G    L2   2P
                      G    C1   1P
                      G    C2   2P
                      R    L1   1P
                      R    L2   2P
                      R    C1   1P
                      R    C2   2P
                      E    L1   1C
                      E    L2   5Q
                      E    C1   1C
                      E    C2   5Q
...

```

Note that each of these frequencies needs a corresponding antenna correction in the “Antenna corrections” file given in panel “GPSSIM 1.2: General Files”. The simplest definition for this application is:

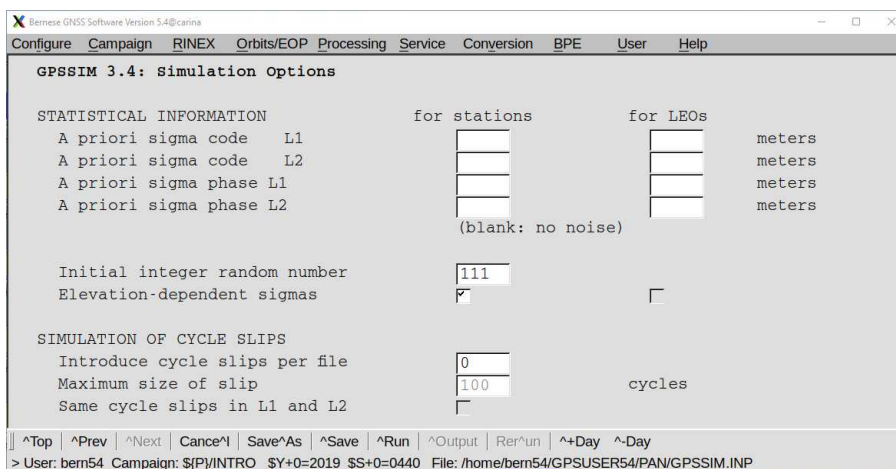
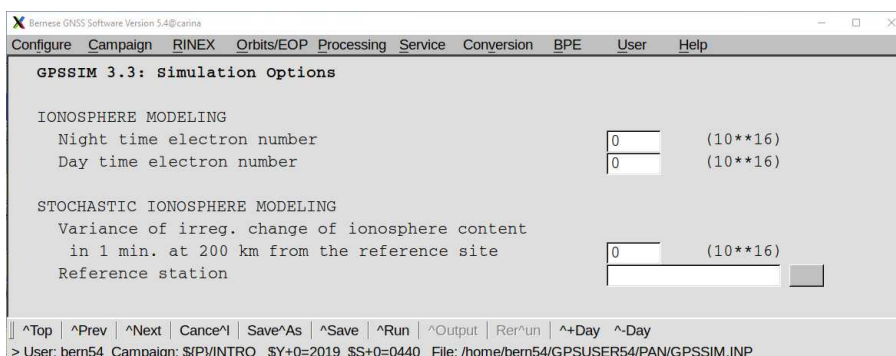
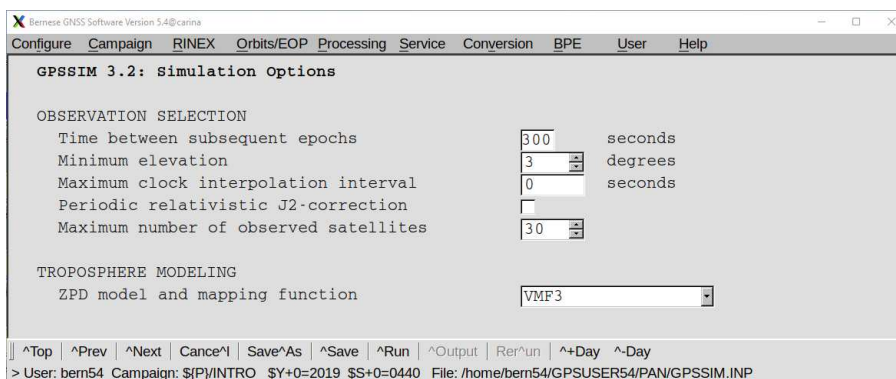
```

...
ANTENNA/RADOME TYPE  NUMBER SYS FRQ TYP D(0) D(Z) D(A) M(Z) SINEX ...
*****
SIMULA               NONE      0  G   2   0   0   0   0   90
                      R   2   0   0   0   0   0   90
                      E   2   0   0   0   0   0   90
...

```


	NORTH MM	EAST MM	UP MM	FACTOR
	*****.**	*****.**	*****.**	*****.
G01 0	0.00	0.00	0.00	0.100E+01
G02 0	0.00	0.00	0.00	0.100E+01
R01 0	0.00	0.00	0.00	0.100E+01
R02 0	0.00	0.00	0.00	0.100E+01
E01 0	0.00	0.00	0.00	0.100E+01
E05 0	0.00	0.00	0.00	0.100E+01
...				

In the subsequent panels some basic characteristics, assumptions on the ionospheric conditions, and the noise level are introduced. Even cycle slips may be simulated.



The observations are generated without noise to check the consistency with the processing program in the subsequent sections.

7.3.2 Zero Difference Solution from Simulated GNSS Observations

The simulated observations can directly be introduced in program GPSEST for an analysis on zero difference level (if you have not simulated cycle slips). Please pay attention to the consistency of all input files with respect to the simulation:

PARAMETER ESTIMATION - GPSEST 1.1: Input Files 1

GENERAL FILES AND PROCESSING MODE

Space geodetic technique: GNSS

Differencing level: ZERO

LEO data processing:

Show all general files:

OBSERVATION FILES

Phase observations: PBH P???\$S+0 PZH

Code observations: CBH P???\$S+0 CZH

Range observations: RBH

MAIN INPUT FILES

Station coordinates: PIN_YYYYSS+0 CRD

Standard orbits: COD_YYYYSS+0 STD

Earth rotation parameters: COD_YYYYSS+0 ERP

Satellite clock corrections: CLK

Observable-specific biases: OSB NL phase biases from CLK

VMF grid file: MF3_YYYYSS+0 GRD

Ionosphere models: ION

CORRECTIONS FOR LOADING EFFECTS AND CENTER OF MASS

Ocean tidal loading: EXAMPLE BLQ

Atmospheric tidal loading: ATL

related error handling: ERROR

^Top | ^Prev | ^Next | Cancel | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^Day

> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials: RPR

Clock RINEX file: CLK

Estimated troposphere: TRP

Meteorological data: MET

GRIDDED LOADING PARAMETERS

Atmospheric pressure: GRD

Ocean, non-tidal: GRD

Hydrostatic pressure: GRD

AUXILIARY STATION FILES

Station information: STA

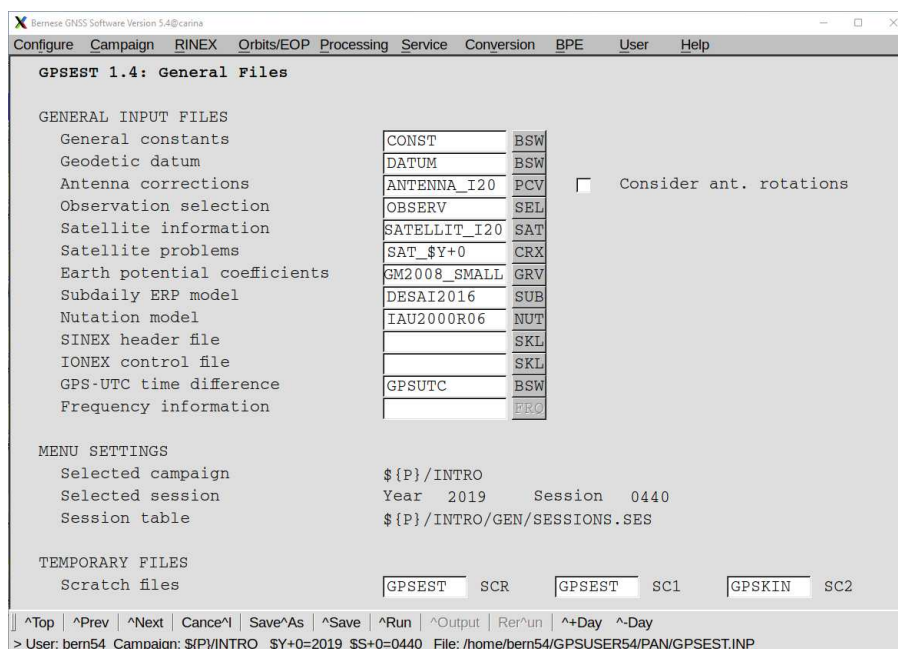
Kinematic coordinates: KIN

Observation sigma factors: SOS

Station eccentricities: ECC

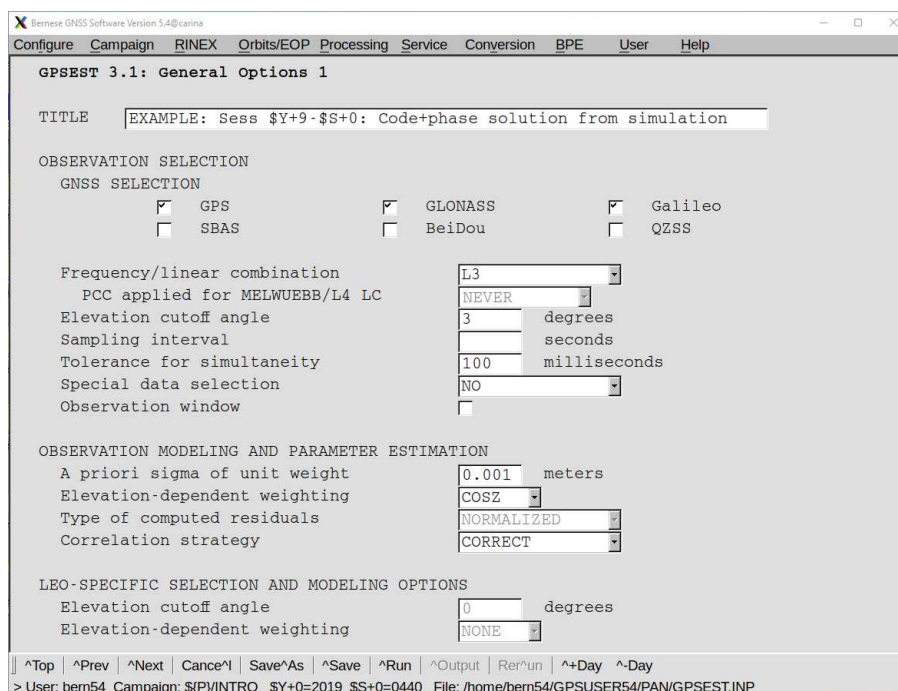
^Top | ^Prev | ^Next | Cancel | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^Day

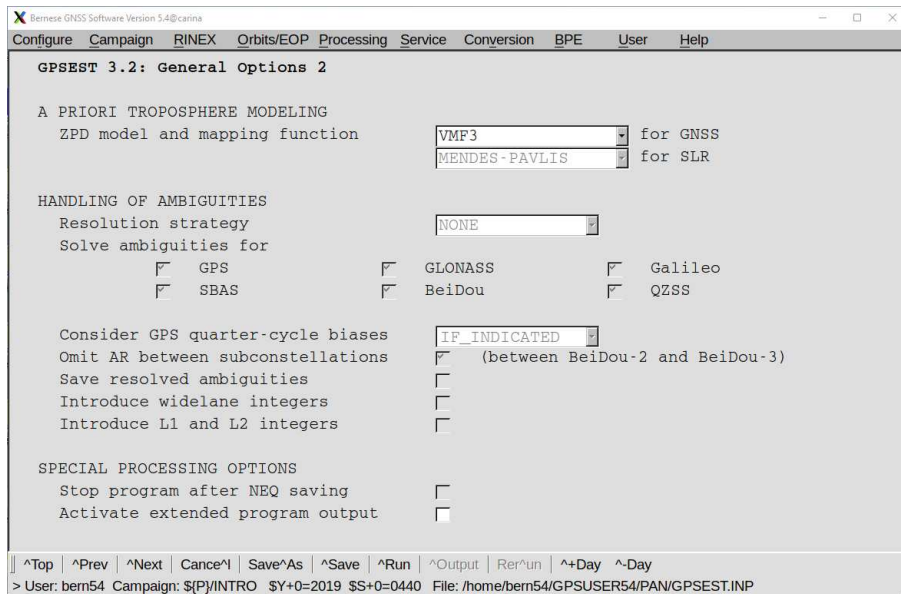
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP



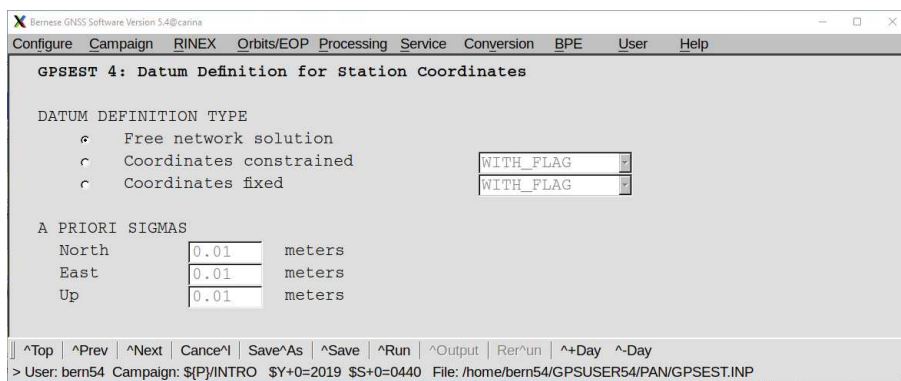
Result files can be specified to compare the results with the inputs for GPSSIM. A residual file might also be useful.

The processing models also have to be consistent with the simulation or to contain well defined differences which are the subject of your investigation:

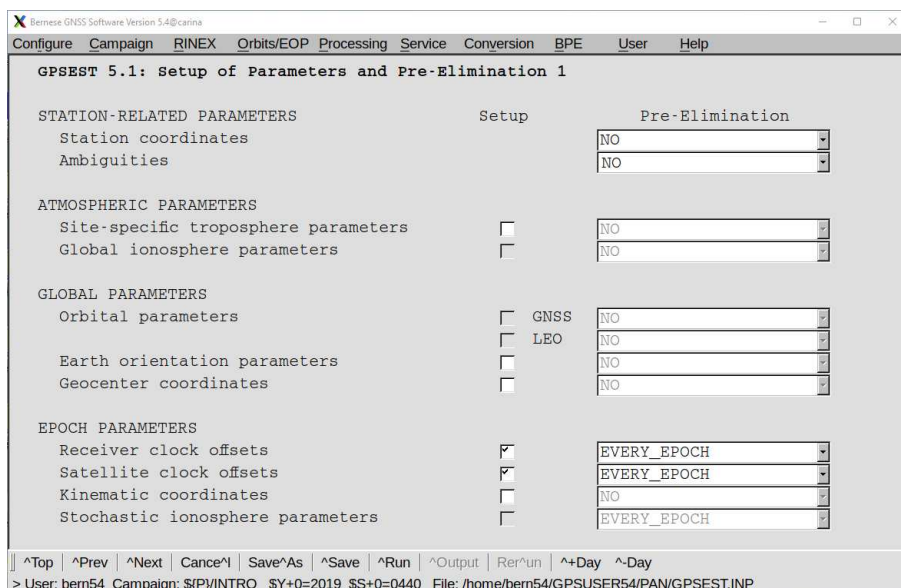


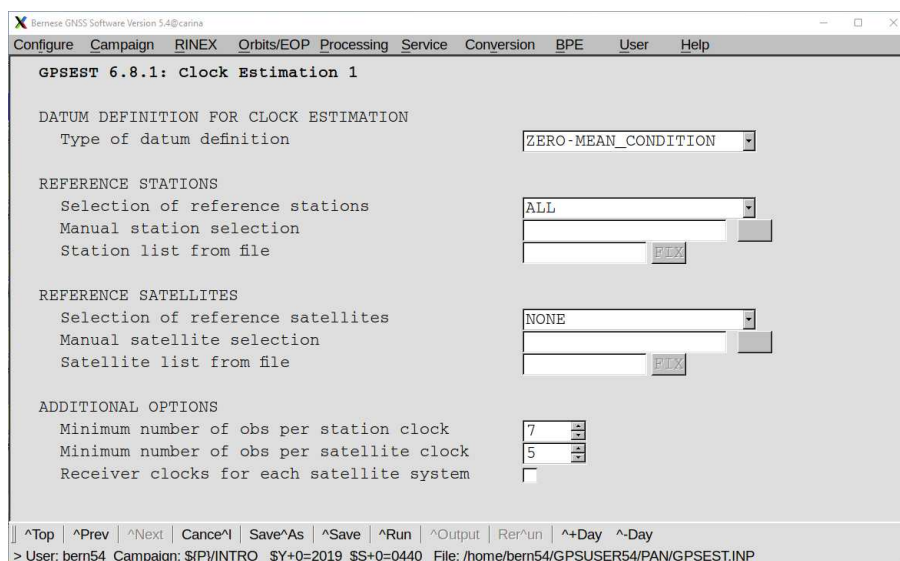


No constraints for datum definition are needed because these are noise-free simulated data:



Only the receiver and satellite clocks are estimated:





The resulting program output file looks like the usual output from GPSEST but with perfect observations without any noise:

```

...
SUMMARY OF RESULTS
-----
Number of parameters:
-----

```

Parameter type	Adjusted	Expl.	Impl. (elim)*	Del.	Ref.	Sing.	No obs
Station coordinates / velocities	51	51	0	0	0	0	0
Ambiguities	2925	2925	0	0	0	0	0
Epochwise receiver clocks	4896	0	4896 (epow)	0	0	0	0
Epochwise satellite clocks	10076	0	10076 (epow)	0	0	0	0
Total number	17948	2976	14972	0	0	0	0

```

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking (afst),
epoch-wise (epow), after inversion (afin)

Statistics:
-----
Total number of authentic observations      270132
Total number of pseudo-observations        0

Total number of explicit parameters        2976
Total number of implicit parameters        14972

Total number of observations                270132
Total number of adjusted parameters        17948
Degree of freedom (DOF)                    252184

A posteriori RMS of unit weight            0.000000 m
Chi**2/DOF                                 0.00

Total number of observation files          34
Total number of stations                   17
...

```

No improvements for the station coordinates and other parameters are expected:

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

Sol	Station name	Typ	Correction	Estimated value	RMS error	A priori value	...	Abb
1	BRST 10004M004	X	-0.00000	4231162.41917	0.00000	4231162.41917	...	#CRD
1	BRST 10004M004	Y	0.00000	-332746.42575	0.00000	-332746.42575	...	#CRD
1	BRST 10004M004	Z	-0.00000	4745131.07277	0.00000	4745131.07277	...	#CRD
1	GANP 11515M001	X	-0.00000	3929181.29827	0.00000	3929181.29827	...	#CRD
1	GANP 11515M001	Y	0.00000	1455236.95252	0.00000	1455236.95252	...	#CRD
1	GANP 11515M001	Z	-0.00000	4793654.03600	0.00000	4793654.03600	...	#CRD
1	HERT 13212M010	X	-0.00000	4033460.74185	0.00000	4033460.74185	...	#CRD
1	HERT 13212M010	Y	0.00000	23538.04010	0.00000	23538.04010	...	#CRD

The inter-system and inter-frequency biases have been assumed to be zero during the simulation (what is equivalent to any other constant number):

```
...
Epochwise station clocks:
-----
```

Station name	#obs	Correction	Estimated value	RMS error	...	From	Abb
BRST 10004M004	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
GANP 11515M001	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
HERT 13212M010	60 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
JOZ2 12204M002	56 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
LAMA 12209M001	58 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
MATE 12734M008	60 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
MIKL 12335M001	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
ONSA 10402M004	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
ORID 15601M001	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
PTBB 14234M001	60 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
TLSE 10003M009	60 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
VILL 13406M001	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
WSRT 13506M005	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
WTZR 14201M010	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
WTZZ 14201M014	60 R	-0.00000	-0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
ZIM2 14001M008	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK
ZIMM 14001M004	60 R	0.00000	0.00000	0.00000	...	2019-02-13 00:00:00	#RCK

```
...
```

The same holds for the epoch-wise clocks.

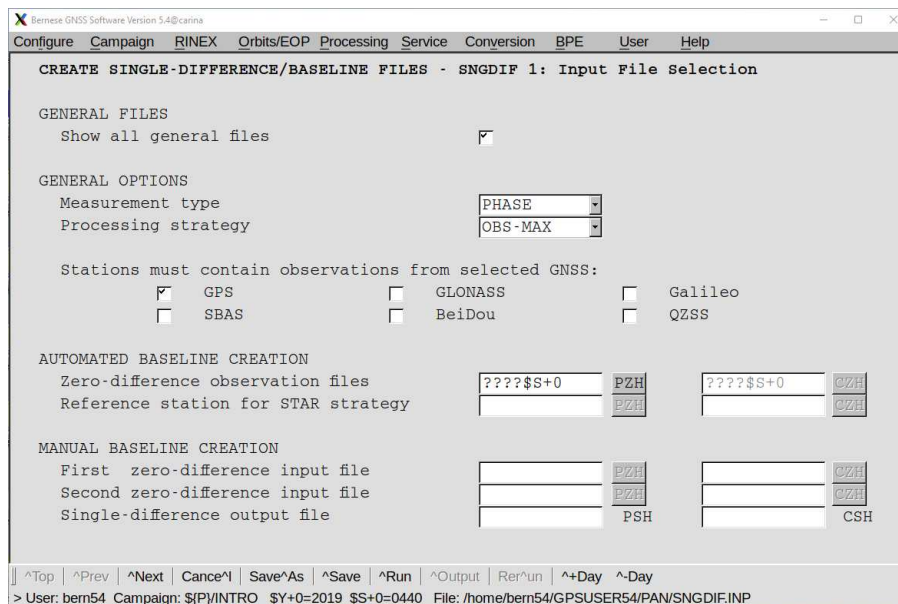
The residuals in the optional residual output file of such a dataset are well below the $1\ \mu\text{m}$ level.

7.3.3 Double-Difference Solution from Simulated GNSS Observations

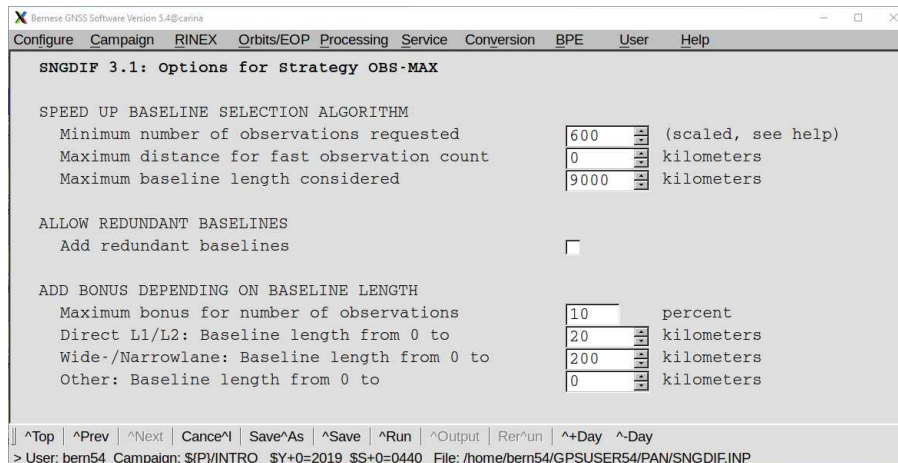
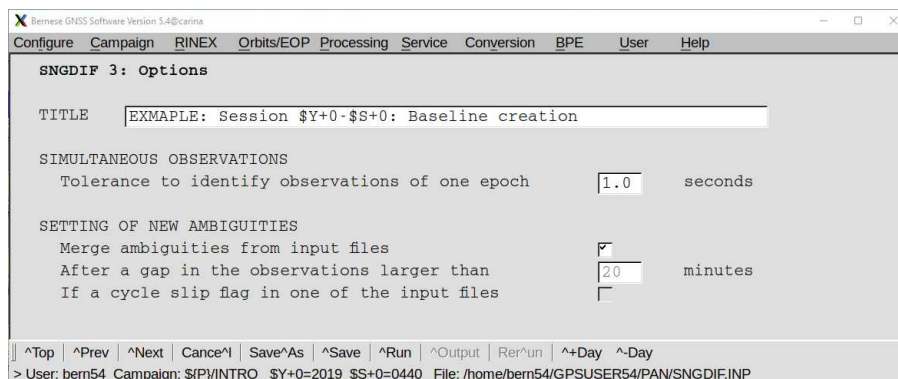
As in the beginning of the simulation, you should make sure that no other baseline observation files for the current session exist in the `OBS`-directory of your campaign to prevent any interferences and mixtures of simulated measurements with other ones.

```
bern54@carina:~ > rm ${P}/INTRO/OBS/????0440.PS?
```

The simulated measurements can also be processed in the double-difference mode. In that case you have to start with forming baselines using the program SNGDIF ("Menu>Processing >Create baseline files") in nearly the same way as in Section 4.2.2 for real observations:



The main difference is that you should also keep all ambiguities from the zero difference in the baseline observation files, what is managed by checking the box for option "Merge ambiguities from input files":



The resulting baseline files from simulated observations can now be analyzed with program GPSEST:

PARAMETER ESTIMATION - GPSEST 1.1: Input Files 1

GENERAL FILES AND PROCESSING MODE

Space geodetic technique: GNSS
Differencing level: DOUBLE
LEO data processing:
Show all general files:

OBSERVATION FILES

Phase observations: ????\$S+0 PSH
Code observations: CSH
Range observations: RZH

MAIN INPUT FILES

Station coordinates: PIN_YYYYSS+0 CRD
Standard orbits: COD_YYYYSS+0 STD
Earth rotation parameters: COD_YYYYSS+0 ERP
Satellite clock corrections: CLK
Observable-specific biases: OSB NL phase biases from CLK
VMF grid file: MF3_YYYYSS+0 GRD
Ionosphere models: ION

CORRECTIONS FOR LOADING EFFECTS AND CENTER OF MASS

Ocean tidal loading: EXAMPLE BLQ
Atmospheric tidal loading: ATL
related error handling: ERROR

GPSEST 2.1: Output Files 1

GENERAL OUTPUT FILES

Program output: use GPSEST.Lnn or SM2_YYYYSS+0 OUT
Error messages: merged to program output or ERROR MSG

NORMAL EQUATION SYSTEM: NQ0

STATION- AND SATELLITE-RELATED RESULTS

Station coordinates: CRD
Satellite orbital elements: ELE
Earth rotation parameters: ERP
Earth rotation parameters (IERS): IEP

ATMOSPHERE-SPECIFIC RESULTS

Troposphere estimates: TRP
Troposphere estimates (SINEX): TRO
Troposphere slant delays: TRS
Ionosphere models: ION
Ionosphere models (IONEX): INX

GPSEST 2.2: Output Files 2

ADDITIONAL RESULT FILES

Observable-specific code biases: OSB
Bias SINEX: BIA
Phase center variations (gridded): PHG
Phase center variations (spherical): PHH

EPOCH-SPECIFIC RESULTS

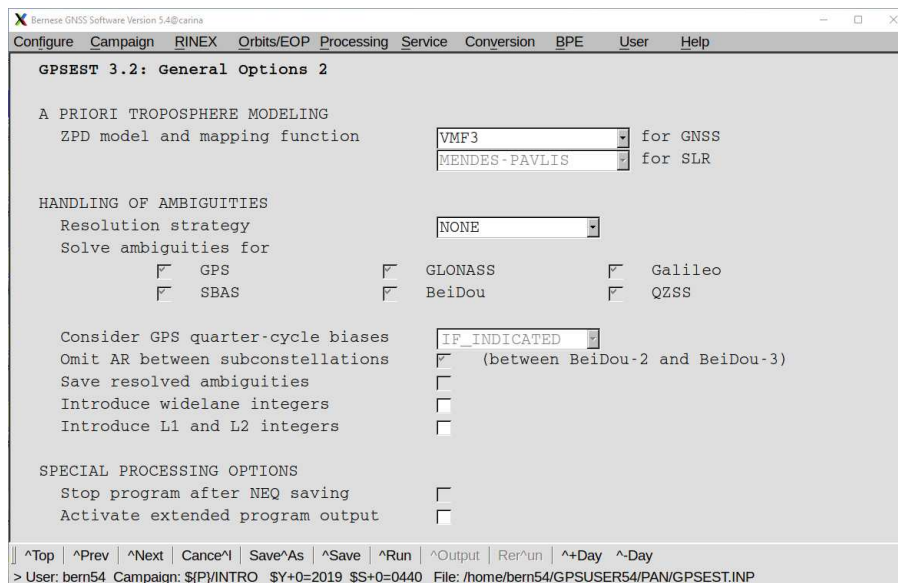
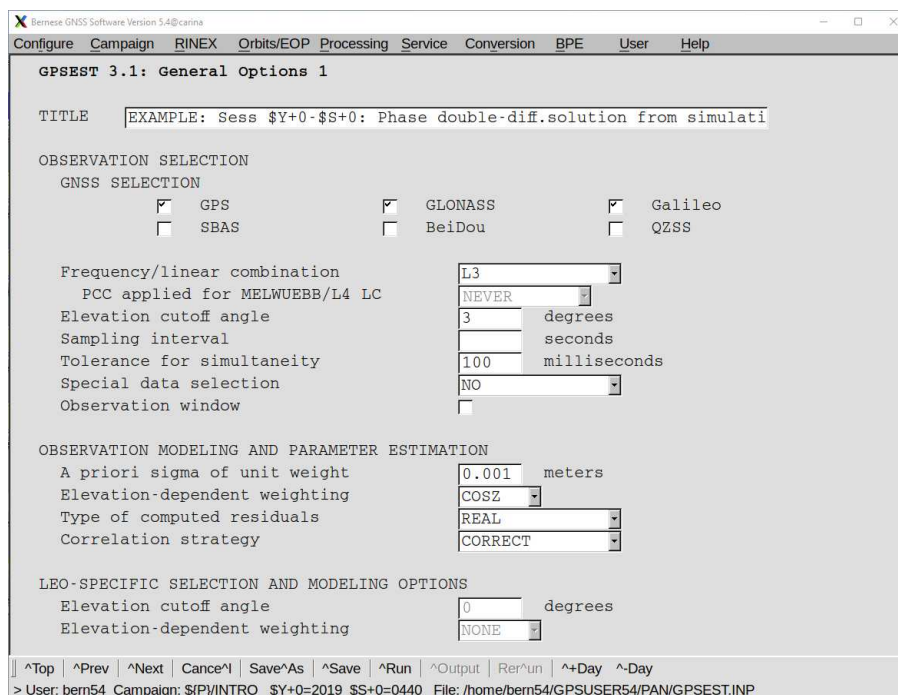
GNSS clock corrections: CLK
Clock RINEX: CLK
Kinematic coordinates: KIN
Epoch-wise KIN covariances (LEOs): COV

AUXILIARY FILES

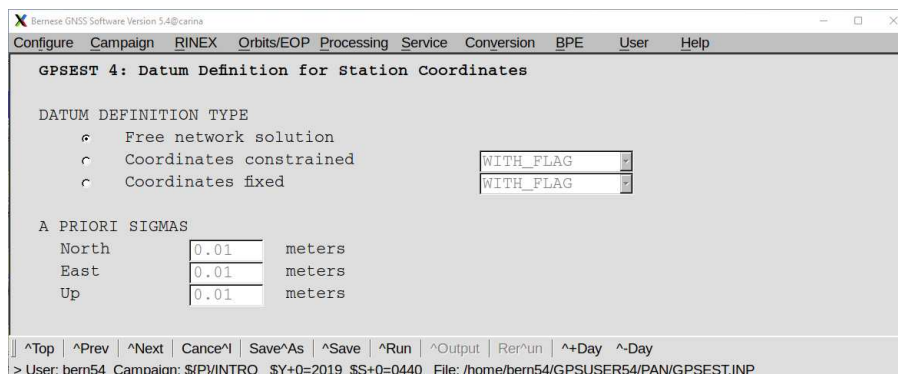
Observation residuals: SM2_YYYYSS+0 RES Extended format
Covariance matrix: COV
Covariance matrix wrt coordinates: COV

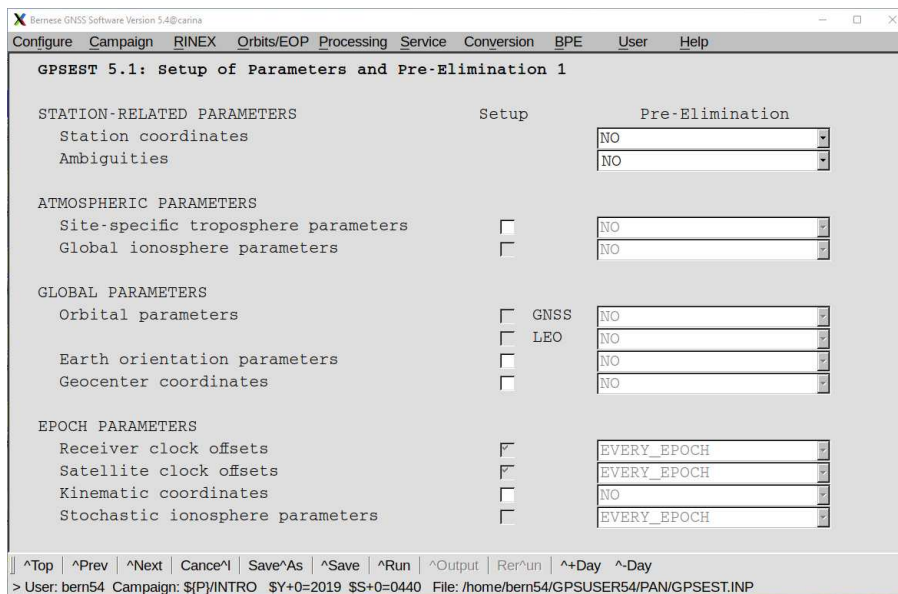
^Top | ^Prev | ^Next | Cance^N | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^-Day
> User: bern54 Campaign: \$(P)/INTRO \$Y+0=2019 \$S+0=0440 File: /home/bern54/GPSUSER54/PAN/GPSEST.INP

The models are selected to be fully consistent with the simulation:



No other parameters than station coordinates and ambiguities are estimated:





The results are analogue to the zero difference case previously described:

```

...
Statistics:
-----
Total number of authentic observations      118515
Total number of pseudo-observations        16

Total number of explicit parameters        2763
Total number of implicit parameters        0

Total number of observations               118531
Total number of adjusted parameters        2763
Degree of freedom (DOF)                   115768

A posteriori RMS of unit weight            0.000000 m
Chi**2/DOF                                0.00

Total number of observation files          16
Total number of stations                   17
...

```

The ambiguities are set up in a way that the correct resolution for all ambiguities is zero in any case. This is an easy way to verify ambiguity resolution strategies.

7.3.4 Final Remarks

There are many opportunities to use this simulation tool. It depends on your needs and the concrete target of the simulation study to define the experiment. As it was just demonstrated the full consistency between the processing and the simulation programs is guaranteed by the *Bernese GNSS Software*.

The big advantage of a simulation is that the correct solution is known a priori. On the other hand, you have to keep in mind that the simulated data can only contain effects included in the simulation model. If a receiver for instance introduces a significant variation of the inter-system bias between GPS and GLONASS data – an effect that is not considered in the simulation model – the influence of such an effect on the results cannot be evaluated by the simulation.

